



HAL
open science

The role of paleogeography in Asian monsoon evolution: a review and new insights from climate modelling

D. Tardif, A.-C. Sarr, F. Fluteau, W. Banfield, C. T. Bolton, Y. Donnadieu,
Guillaume Dupont-Nivet, M. Kaya, J.-B. Ladant, G. Le Hir, et al.

► To cite this version:

D. Tardif, A.-C. Sarr, F. Fluteau, W. Banfield, C. T. Bolton, et al.. The role of paleogeography in Asian monsoon evolution: a review and new insights from climate modelling. *Earth-Science Reviews*, 2023, 243, pp.104464. 10.1016/j.earscirev.2023.104464 . hal-04125728v2

HAL Id: hal-04125728

<https://hal.science/hal-04125728v2>

Submitted on 23 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0
International License

Asynchronous apparition of the Asian monsoons features since the late Eocene and associated paleogeographic and climatic drivers

D. Tardif^{1,2}, A-C. Sarr¹, F. Fluteau², W. Banfield¹, C. Bolton¹, Y. Donnadieu¹, G. Dupont-Nivet^{3,4}, M. Kaya¹, J-B. Ladant⁵, G. Le Hir², A. Licht¹, Q. Pillot¹, F. Poblete⁶, P. Sepulchre⁵, A. Toumoulin¹

¹Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

²Université Paris Cité, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France

³Géosciences Rennes, UMR CNRS 6118, Univ Rennes, Rennes, France

⁴Institute of Geosciences, Potsdam University, Potsdam, Germany

⁵Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université

Paris-Saclay, 91191 Gif-sur-Yvette, France

⁶Departamento de Geología, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Chile

Key Points:

- Asian monsoons modern characteristics appeared sequentially during the Cenozoic, driven by distinct paleogeographic and climatic forcings.
- Model results depict seasonal precipitation in parts of Southern and Eastern Asia since the Paleogene.
- The Paratethys Sea retreat and the Arabian Platform emergence, by greatly increasing continentality, are instrumental for the development of surface temperature gradients between Asia and the Indian Ocean which reinforces the advection of moist air towards Asia in summer.
- Iran-Zagros and East African landforms contribute to channel and enhance the Somali Jet that brings moisture to Southeastern Asia in summer, while the Himalayan-Tibetan plateau uplift induces heavy orographic precipitation.
- Mongolian landforms uplift is the main driver for the Siberian high pressure settlement in winter. It results in a broad reinforcement of East Asian Monsoon precipitation seasonality, as it strongly reduces winter precipitation. It also induces aridification of current Gobi desert region.
- Tian Shan and Pamir uplifts, by intercepting and deviating westerly moisture flux, concur to force the summer northern Jet Stream migration in Tibet and Eastern China. This triggers local orographic precipitation, increased winter precipitation in India (weaker South Asian Monsoon), and increased summer precipitation in North-eastern China (stronger East Asian monsoon). It enhances global aridification of Gobi, Taklamakan and Northeastern Tibet regions.

Corresponding author: Delphine Tardif, delphine.tardif@hotmail.fr

Corresponding author: Anta-Clarisse Sarr, anta.clarisse.sarr@gmail.com

Abstract

Modern Asian monsoons are triggered by complex interactions between the atmosphere, Asian and African orography and the surrounding oceans, resulting in a highly seasonal climate characterized by typical regional features. Although long considered as a Neogene phenomenon, recent evidence for monsoon-like seasonality as early as in the Paleogene Greenhouse, has come to challenge this paradigm. The occurrence of monsoons in a climatic and paleogeographic context very different from the present-day question our understanding of the drivers underpinning this peculiar atmospheric phenomenon, in particular with regards to its dependence to paleogeography. In this study, we take advantage of the wealth of new studies to tentatively draw an up-to-date portrait of the Asian tectonic and paleoenvironmental evolution through the Cenozoic and of the questions that remain to be answered. We then simulate the evolution of the Asian monsoon subsystems by investigating seasonal trends of 20 paleoclimate simulations spanning the late Eocene to latest Miocene (40-6 Ma). At odds with the traditional view of a monsoonal evolution driven mainly by the Himalayan-Tibetan uplift, this study confirms the findings of previous works stating the importance of peripheral landforms on the different Asian monsoons subsystems. Eastern African and Anatolian-Iranian topography, as well as the Arabian Peninsula emergence all concur to shape the South Asian summer Monsoon. Additionally, we suggest that continentality, together with Mongolia, Tian Shan and Pamir orographic evolution, and $p\text{CO}_2$ decrease, played important parts in the settlement of the East Asian Monsoon and in the aridification of inland Asia.

1 Introduction

The South and East Asian monsoons are highly seasonal climatic phenomena, that today conditions the livelihood of billions of people. During summer, moisture-loaded winds blowing from the Indian Ocean (Fig. 1) trigger important nutrients-rich upwellings and lead to heavy precipitation over Southeastern Asia, allowing for widespread agriculture and fisheries. In winter, the reversal in wind direction induces advection of cold, dry and dust-loaded air masses from Siberia over Eastern and Southern Asia (Fig. 1). The spectacular extension and intensity of the Asian monsoons, combined to the highly dynamic tectonic context of the region, have triggered a lot of interest from the scientific community, in order to understand potential links between orography, land-sea distribution, global climate and the monsoon.

While monsoons have long been viewed as an atmospheric phenomenon intimately intertwined with the Himalayan-Tibetan plateau uplift history (Molnar et al., 1993; Zhisheng et al., 2001; Tada et al., 2016; X. Liu, Guo, et al., 2015) and rooted in the Neogene, first with records of strong upwellings initiating in the Arabian Sea at ~ 8 Ma (Kroon et al., 1991), then with evidence for massive dust deposition in the Chinese Loess Plateau since ~ 22 Ma (Guo et al., 2002), a wealth of recent studies has come to challenge this paradigm. Indeed, aeolian dust deposits in the Xining basin (northeastern China, see Fig. 1 for localities mentioned in the text), as well as paleoflora and isotopic measurement in fossils indicating a seasonal climate in Myanmar (Licht et al., 2014) and in the Yunnan region (South China) (Sorrel et al., 2017; Fang et al., 2021; Zheng et al., 2022) have been interpreted as pieces of evidence for an active monsoon as early as in the late Eocene. Proposing a monsoonal onset in the Paleogene, in a warmer, ice-free climate, during the early stage of the Tibetan plateau uplift and with much lower continentality due to higher sea level and to the presence of the Paratethys Sea in the west (see the late Eocene paleogeography in Fig. 3a), radically questions our understanding of the forcings of the monsoons.

Climate modeling provides a unique opportunity to understand the part played by each potential forcing on the resulting climate. Overall, such studies, and independently of the model used (complexity, resolution) or the simulation protocol (i.e., derived from modern geography or with realistic paleogeography), have tended to highlight that paleogeography

87 out-compete global $p\text{CO}_2$ variations or far-field ice-sheets effects when it comes to the SAM
88 and EAM settlement and intensification over multi-million years time scales (Farnsworth
89 et al., 2019; J.-Y. Lee et al., 2015; Zoura et al., 2019; Roe et al., 2016; Thomson et al.,
90 2021). In a second time, sensitivity experiments of increasing complexity and precision,
91 have helped disentangle the effect of the Himalaya-Tibet (and its sub units) uplift from
92 that of peripheral landforms uplifts, such as the Tian Shan ranges, the Iranian-Anatolian
93 orogen, eastern African domes, Mongolia landforms (H. Tang et al., 2013; Acosta & Huber,
94 2020; R. Zhang et al., 2017), and from the effect of land-sea distribution changes (Fluteau
95 et al., 1999; Z. Zhang et al., 2007). While modeling studies provide mechanistic basis to
96 apprehend potential leverages for monsoon and aridity modulation, it remains paramount to
97 dispose of robust constraints on the paleogeography and paleoclimate evolution, and on the
98 relative chronology of these events. The past decades have been rich in both modeling and
99 field studies, for example with marine cores that were extended back to the late Paleogene
100 (W. Ding et al., 2021; S. Ali et al., 2021; Betzler et al., 2016; Beasley et al., 2021), and
101 increased coverage in well-dated paleoclimate indicators, which offer new constraints on
102 Cenozoic tectonic and paleoclimate.

103 In this contribution, and building upon previous work (Sarr et al., 2022; Tardif et al.,
104 2020; Barbolini et al., 2020), we aim at providing a comprehensive picture of large-scale wind
105 circulation, precipitation seasonality and aridity evolution in continental Asia from the late
106 Eocene to the late Miocene, using realistic paleoclimate simulations. In the following parts,
107 we first describe in more depth the Asian monsoon subsystems characteristics (section 2),
108 and propose an up-to-date overview of the Asian monsoon history as understood through
109 proxy and models studies, and of remaining outstanding issues (section 3, Fig. 2). The main
110 paleogeographic events that affected the regions surrounding the Indian Ocean together
111 with continental Asia during the Cenozoic are presented (section 4), along with the past
112 continental configurations that have been used (Fig.3). Other boundary conditions and
113 simulations spin-up are then introduced, as well as criteria retained to track the Asian
114 monsoons evolution throughout the different simulations (section 5). Our results are then
115 presented and discussed in the light of actual knowledge.

116 2 Modern Asian Monsoon subsystems characteristics

117 The Asian monsoon is subdivided into two regional subsystems: the South Asian
118 Monsoon, spreading roughly from Pakistan to Myanmar, and the East Asian Monsoon, from
119 Myanmar to Japan. We hereafter refer to them as SAM and EAM respectively, SASM and
120 EASM are used for the summer monsoon season while SAWM and EAWM refer to the winter
121 monsoon season. These regional monsoons present specific climatic characteristics and have
122 long been studied by distinct communities, although regions situated in the Southeastern
123 Asian Peninsula can present mixed attributes of both subsystems and may be referred to
124 as "transition area" in the literature (R. Spicer et al., 2017).

125 2.1 Summer season

126 The SASM is associated with intense orographic precipitation over the Himalayan
127 foothills as well as over smaller mountains ranges like the Ghats in western India and the
128 Indo-Burman Ranges in Myanmar (Fig. SI 14 a,b). In these regions, summer precipitation
129 account for nearly 80% of the total annual precipitation and are responsible for massive fresh-
130 water discharge in the Bay of Bengal, *via* the Ganga, Brahmaputra and Ayeyarwady Rivers
131 and in the Arabian Sea *via* the Indus River. Precipitation is supplied by moisture-loaded
132 air masses from the Inter Tropical Convergence Zone (ITCZ), which is steered towards the
133 Asian continent during summer, as a consequence of the wide low pressure belt develop-
134 ing from Arabia to eastern China (Fig. SI 14 d). This typical pressure pattern is driven
135 by the establishment of a surface temperature gradient between the Indian Ocean and the
136 overheated Asian continent and the Arabian Peninsula (up to 40°C, Fig. SI 14 d).

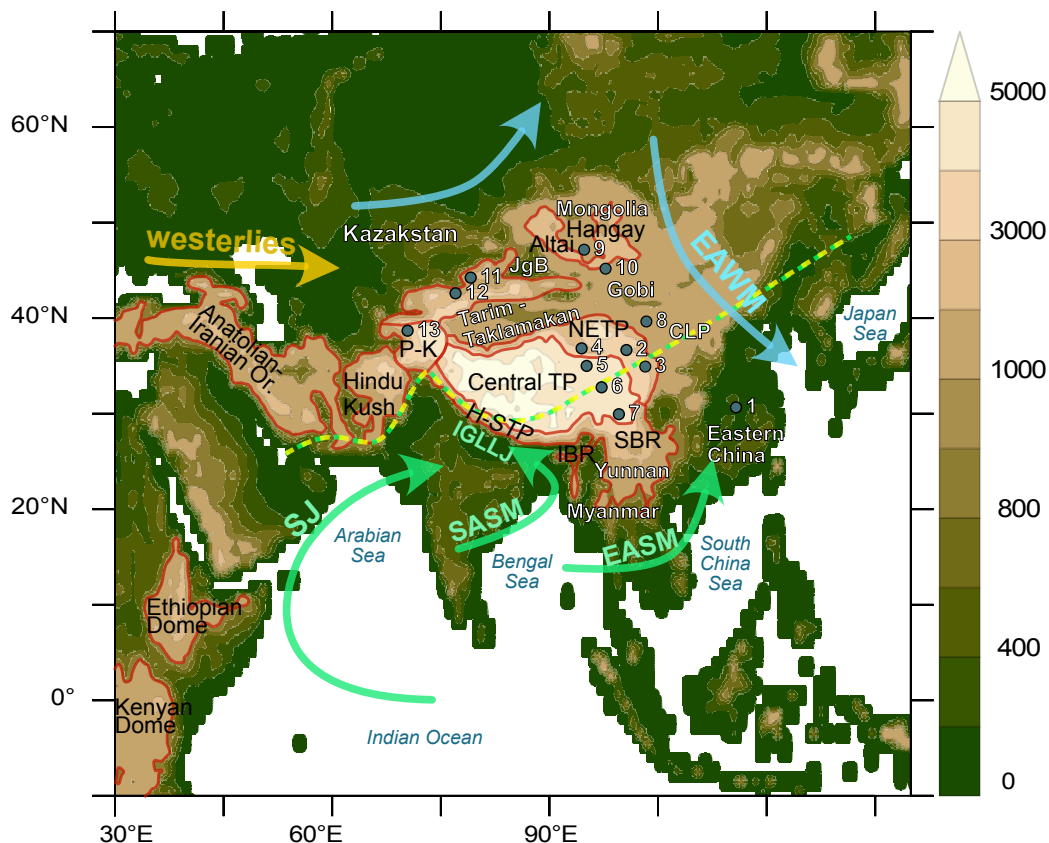


Figure 1. Modern geography and topography (in m), with main seasonal winds: Westerlies (yellow arrow), East Asian Winter monsoon (blue arrow) and Summer monsoons (green arrows) ; Somali Jet (SJ), Indo-Gangetic-Low Level Jet (IGLLJ). Dotted green/yellow line indicate the modern limit between the westerlies and the monsoonal regions. Main landforms units (in black) and main geographical regions (in white) mentioned in the text, with the following abbreviations: H-STP - Himalayas and Southern Tibetan Plateau, NETP - Northeastern Tibetan Plateau, IBR - Indo Burman Ranges, SBR - Sino Burman Ranges, ML - Mongolian Landforms, CLP - Chinese Loess Plateau, JgB - Junggar Basin. Smaller basins and localities mentioned in the text are numbered as follow: (1) Jiangnan B., (2) Xining B., (3) Linzhou B., (4) Qaidam, (5) Hoh Xil B., (6) Nangqian B., (7) Markam B., (8) Bayanhot B., (9) Valley of Lakes, (10) Taatsin Gol, (11) Ili B., (12) Issyk Kul B., (13) Tajik B.

137 Characteristic low-level wind patterns are associated with the SASM, represented by
 138 the Findlater Jet (Findlater, 1969) (or Somali Jet (H.-H. Wei & Bordoni, 2016)), which
 139 crosses the equator alongshore East Africa and blows towards the Indian subcontinent (Fig.
 140 SI 14 d). This powerful trans-equatorial jet triggers strong surface oceanic currents, flowing
 141 up the East African and Arabian coasts, then circumventing India from West to East. These
 142 currents generate strong upwellings in the Arabian Sea and the Bay of Bengal (Schott & Mc-
 143 Creary, 2001), favoring broad phytoplankton productivity blooms from July to September
 144 (Lévy et al., 2007). Over the Bay of Bengal, the Somali Jet splits into two distinct branches
 145 (Fig. SI 14 d), one pursuing its northeastern flow towards southeastern and eastern Asia
 146 (from Myanmar to China), and the Indo-Gangetic Low Level Jet (Acosta & Huber, 2017),
 147 bifurcating towards northwestern India and the Himalayan foothills.

148 The EASM is characterized by a band of strong convective precipitation stretching
 149 from Myanmar to Japan along eastern China, also called the Meiyu-Bayu front. This high-
 150 precipitation zone is fed by warm moist air, advected from the Bay of Bengal and nearby
 151 Indo-Pacific Warm Pool (IPWP) (Fig. SI 14 d). The Meiyu-Bayu front results from the
 152 ascension of these moist winds over the Jet Stream in the subtropics (Kong et al., 2017;
 153 Molnar et al., 2010; Sampe & Xie, 2010). The progressive northward migration of the front
 154 during spring and early summer is likely influenced by the seasonal displacement of the
 155 Jet Stream relative to the Tibetan Plateau (TP): it is located south of the TP at $\sim 25^\circ\text{N}$ in
 156 winter, and progressively migrates to its northern edge in summer. The EASM, observed up
 157 to $\sim 40^\circ\text{N}$, is an extra-tropical phenomenon, and is therefore regularly questioned as being
 158 a "real" monsoon (Molnar et al., 2010; R. A. Spicer et al., 2016).

159 2.2 Winter season

160 Boreal winter is marked by a generally dry climate over most of the Asian continent.
 161 North of $\sim 20^\circ\text{N}$, Eastern Asia is swept by northwestern winds bringing cold air and dusts
 162 from inland Asia, while south of $\sim 20^\circ\text{N}$, northeastern winds carry moisture from the Pacific
 163 Warm Pool, leading to monsoonal precipitation over Indonesia and northern Australia (Fig.
 164 SI 14 f). The Indian subcontinent experiences a more complex wind pattern, as the westerly
 165 winds in the North are channeled by the Zagros and Himalaya-Tibetan orography and then
 166 deviated into northeasterly winds over the Arabian Sea, towards the eastern African coast
 167 (Fig. SI 14 f). These peculiar winds lead to the formation of upwellings in the Bay of Bengal
 168 and the Arabian Sea, allowing phytoplankton productivity blooms to occur in winter as well
 169 (Lévy et al., 2007). This typical winter wind circulation (Fig. SI 14 f) is controlled by the
 170 pressure gradients forming between the Siberian High and the surrounding Aleutian Low
 171 (over the North Pacific) to the East and the low pressure center settled over the Maritime
 172 Continent to the South (L. Wang & Chen, 2014). The spectacular extent and strength of
 173 the Siberian High in boreal winter is a consequence of a strong radiative cooling of the lower
 174 troposphere over snow-covered Asia (Jeong et al., 2011; Cohen et al., 2001; Jhun & Lee,
 175 2004).

176 2.3 Summary: what traces leave the monsoons ?

177 Asian climate is under the crossed influence of the dry East Asian winter monsoon and
 178 of three moisture sources, the westerlies and the East and South Asian summer monsoon
 179 (Fig. 1). Nowadays, the boundary between regions receiving most of their annual precipita-
 180 tion via the monsoons or via the westerlies is clearly bounded by the Himalayas in the South,
 181 while it fluctuates in the East over China (Chen et al., 2021), crossing Eastern Tibet and
 182 the Chinese Loess Plateau (Fig. 1). This boundary however likely evolved in the past, espe-
 183 cially during the Paleogene when the orography and land-sea distribution were substantially
 184 different from today (no Himalayas, less extent Tibetan Plateau, presence of the Paratethys
 185 epicontinental Sea until the EOT) (X. Liu, Guo, et al., 2015) (see section 4). Tracking the
 186 monsoons back in time can be done thanks to a variety of paleoclimatic archives recording
 187 either their winds (intensity, direction) or precipitation (amount, seasonality) (P. Wang et
 188 al., 2005; Zhisheng et al., 2015; Tada et al., 2016). Markers of aridification on the other
 189 hand, such as increased proportion of xerophytic or halophytic plants or aeolian deposits
 190 (dusts, loesses) in the fossil record are often interpreted as evidence for the presence of a
 191 winter monsoon. The next section depicts the evolution of the Asian climate throughout
 192 the Cenozoic based on these different paleoclimate indicators.

193 3 Increasingly old testimonies of paleo-monsoons through times

194 The classical view for the Asian paleoenvironment evolution throughout the Cenozoic
 195 usually proposes a transition from a Paleogene "zonal climatic pattern" to a Neogene "mon-
 196 soonal climatic pattern" (Guo et al., 2008; X. Sun & Wang, 2005; Jia et al., 2003). The

197 zonal pattern is described as a widespread arid to semi-arid band stretching across China
198 and bracketed in its southern and northern borders by two humid belts, while the mon-
199 soonal pattern hosts a core of pronounced aridity in inland Asia, surrounded by monsoonal
200 (seasonally wet) climate on its southern and eastern edges. This view is mostly based on
201 paleoclimate indicators compilations (pollen, fossils and lithological arguments, e.g. from
202 Boucot et al. (2013)) used to infer either humid conditions (coal, indicators of forested en-
203 vironments, large mammals, etc.) or arid ones (evaporites, desert and shrub environment,
204 etc.). Recent evidence for highly seasonal climate in India, Myanmar and China as early
205 as in the Eocene, at least 20 Myr earlier than previously thought, nevertheless challenge
206 this paradigm. This section aims at presenting in the most comprehensive way the broad
207 paleoenvironmental changes inferred from paleoclimate indicators in Asia from the Eocene
208 to the early Pliocene, which are tentatively gathered in Fig. 2 (upper part). Localities and
209 basins mentioned throughout the text are localized in Fig. 1.

210 **3.1 Eocene to Oligocene paleoenvironment evolution**

211 *3.1.1 A progressive increase in summer monsoon indices from the Eocene* 212 *to the Oligocene*

213 Oldest testimonies of strongly seasonal precipitation in Southern Asia come from early
214 Eocene floras situated in northwestern India (Shukla et al., 2014; Bhatia, Khan, et al., 2021)
215 and from mid-late Eocene (40 Ma) floras and isotopic measurements in freshwater gastropod
216 shells and mammals tooth enamel found in Myanmar (Licht et al., 2014; H. Huang et
217 al., 2021). Both regions were however located further South at their respective period of
218 deposition (between the equator and $\sim 10^\circ\text{N}$, Shukla et al. (2014); Westerweel et al. (2019))
219 and their seasonality is therefore mainly interpreted within the scope of a pronounced ITCZ
220 seasonal migration rather than monsoonal climate.

221 Further east, in the Yunnan region (Southwestern China), today submitted to a mix-
222 ture of Southern and Eastern Asian summer monsoon, a shift from arid/semi-arid to humid
223 environment is recorded during the late Eocene and interpreted as the onset of the Asian
224 monsoon at that time (Sorrel et al., 2017; Fang et al., 2021; Zheng et al., 2022). Such cli-
225 mate transition is inferred by the presence of coal layers, a change in the pollen record from
226 xerophytic to mixed forest, change in lithology interpreted as lake and swamps expansion,
227 together with the presence of fossils of freshwater fishes, gastropods and large mammals.
228 While the precise date for this paleoenvironmental change is still debated between ~ 41 Ma
229 (Fang et al., 2021), ~ 36 Ma (Zheng et al., 2022) and ~ 35.5 Ma (Sorrel et al., 2017), it never-
230 theless predates the Eocene-Oligocene Transition (~ 34 Ma). Proposed driving mechanisms
231 to explain this regional climate shift usually involve either the crossing of a Tibetan Plateau
232 elevation threshold (Zheng et al., 2022), a response to the Paratethys Sea retreat in the
233 west, that would have allowed the penetration of more moisture from the east (Fang et al.,
234 2021), or a response to the global climate cooling initiated after the Middle Eocene Climate
235 Optimum (MECO) and subsequent sea surface temperature patterns reorganization (Sorrel
236 et al., 2017).

237 Signs for the presence of an Eocene East Asian summer monsoon are also debated.
238 In eastern China, Eocene paleovegetation mostly point to warm, humid and weakly sea-
239 sonal evergreen forested environments on the coast (R. A. Spicer et al., 2016; X. Ma et al.,
240 2012; Pound & Salzmann, 2017), except for northeastern middle-late Eocene Chinese floras
241 retrieved from the coal deposits of the Huadian basin, that already seem to indicate adapta-
242 tion to highly seasonal climate (Meng et al., 2018). Further inland, toward the eastern edge
243 of the TP, these paleoenvironments gradually translate into sub-humid and/or seasonally
244 dry conditions, as attested by various basin displaying alternating mudstone and evaporite
245 deposits (D. Wang et al., 2013; Abels et al., 2011). Highly resolved deposits from the
246 Jiangnan basin, spanning the mid Eocene to early Oligocene (~ 40 -34 Ma), together with
247 modeling studies (Tardif et al., 2021), have shown that the penetration of moisture into east-

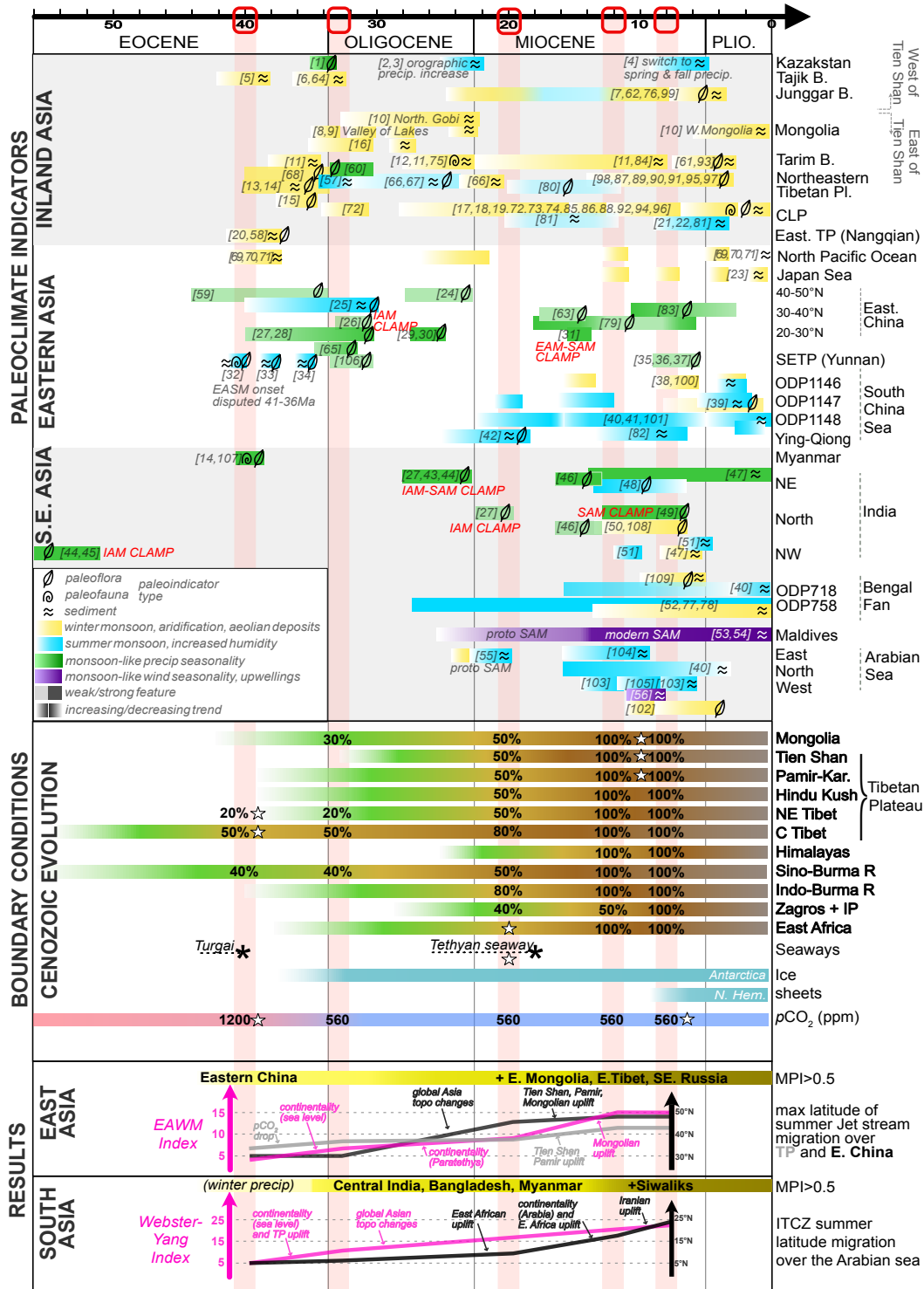


Figure 2. upper Paleoclimate tendencies recorded in inland, eastern and southern Asia. Bibliographic references in brackets are listed in SI Table 3 ; center Evolution of main landforms, seaways, ice sheets and pCO₂ during the Cenozoic overlain with values used in our reference simulations (elevations expressed in % of modern). White stars indicate parameters that were tested with sensitivity experiments ; bottom Overview of the main monsoon indicators evolution obtained in this study. We used the following abbreviations: NETP (SETP) - Northeastern (Southeastern) Tibetan Plateau, CLP - Chinese Loess Plateau.

ern China in the late Eocene was likely strongly modulated by orbital forcing. This may indicate that this Paleogene wet/dry zonal climatic pattern previously introduced (Guo et al., 2008; X. Sun & Wang, 2005) was already periodically disturbed in the late Eocene, and may have prefigured a more stable and widespread monsoon-like precipitation seasonality settlement in the Oligocene.

Indeed, after the global cooling and aridification occurring at the Eocene-Oligocene Transition, pieces of evidence for monsoon-like precipitation seasonality of variable intensity become more widespread in floras from both China (X. Ma et al., 2012; Herman et al., 2017; Vornlocher et al., 2021; J. Ren et al., 2021; Miao, 2013; Ling et al., 2021; S. Li et al., 2018; C. Huang & Hinnov, 2019; H. Tang et al., 2020) and India (Bhatia, Khan, et al., 2021; R. Spicer et al., 2017; Srivastava et al., 2012). Additionally, oceanographic records from adjacent seas (Bay of Bengal and South China Sea) that were recently extended back to the late Paleogene, have been used to track the SAM and EAM evolution from the middle Oligocene onward. Drilling from the Ying-Qiong Basin in the South China Sea, spanning the late Oligocene to early Miocene (25-18 Ma), record an increase in terrigenous organic matter influx, together with increased tropical-subtropical angiosperm pollen proportion, which are interpreted as signs of increasing East Asian summer monsoon during this period (W. Ding et al., 2021). In the Bay of Bengal (ODP 758), measurements of clays radiogenic isotopic composition, indicating undisturbed weathering patterns over the last 27 Ma, are interpreted as signs of stable South Asian summer monsoon activity since at least the late Oligocene (S. Ali et al., 2021).

3.1.2 Late Eocene aridification in response to the Paratethys Sea retreat and global climate cooling

Markers of arid to sub-humid climate are already widespread in inland Asia in the Eocene with, for example, many sites displaying pollen assemblages characteristics of steppe-desert environments such as in the Xining, Hoh Xil, Qaidam and Tarim basins (Q. Yuan et al., 2020; Miao, Wu, et al., 2016; X. Ma et al., 2012). During the mid-late Eocene (~40-34 Ma), inland Asia records an evolution toward drier conditions, as suggested by increased proportions of xerophytic plants such as *Nitraria* and *Ephedra* in Xining, Hoh Xil, Qaidam (Northeastern Tibet), Nangqian (central-eastern Tibet) and Tarim basins (Q. Yuan et al., 2020; Barbolini et al., 2020; Hoorn et al., 2012; Miao, Wu, et al., 2016), $\delta^{18}\text{O}$ measurements from ostracod shells in the Tarim basin (Bougeois et al., 2018), clumped isotopes from pedogenic carbonates in the Xining basin (Page et al., 2019), compound-specific hydrogen isotope analyses ($\delta^2\text{H}$) applied to sedimentary leaf wax *n-alkanes* in the Qaidam basin (Wu et al., 2021) and by lipid biomarkers and compound-specific carbon isotopic compositions from bulk sediments in the Nangqian basin (J. Wei et al., 2022). The presence of detrital material attributed to Asian dusts is also recorded in sediments from Central North Pacific (GPC3 and ODP site 1215) since ~40 Ma (Pettke et al., 2002; D. Rea et al., 1985; Ziegler et al., 2007).

This late Eocene aridification stage is mostly interpreted as resulting from the reduced westerly moisture input during the two successive Paratethys Sea regression phases from the Tarim and the Tajik basins, recorded between ~41-37 Ma (Carrapa et al., 2015; J. Sun et al., 2020, 2022; Bougeois et al., 2018; Bosboom et al., 2014b; Kaya et al., 2019). Highly resolved sediment deposits, such as those of the Xining basin (northeastern Tibet) display good correlation between wetter evaporite layers and Paratethys Sea transgressions phases into the Tajik and Tarim basins, and between arid mudstone intervals and regression phases. This confirms the key role played by the westerlies and the Paratethys Sea as a major moisture source for inland Asia in the Eocene, even over long distances (Meijer et al., 2019; Bosboom et al., 2014a). Additionally, a strong obliquity cyclicity is imprinted on the Xining evaporite/mudflat layers in the late Eocene (40-34 Ma), coeval with the appearance of loess-like dusts in the mudflat phases (Meijer et al., 2021; Licht et al., 2014). This hints a marked influence of high latitudes dynamics, such as incipient ice-sheets at the poles (Abels et al.,

2011; Xiao et al., 2010) and variations in the Siberian High intensity (Meijer et al., 2021),
on inland Asian climate at that time.

3.1.3 *Oligocene climate fluctuations and inception of major modern Asian deserts*

The Oligocene evolution of inland Asian climate appears both regionally and timely contrasted. In the early Oligocene, a few sites situated within the westerly moisture region tend to show increased humidity trends, recorded by $\delta^{18}\text{O}$ isotopic measurements in pedogenic carbonates (Kent-Corson et al., 2009) in the Tarim and western Qaidam basins together with $\delta^2\text{H}$ measurements in leaf waxes (Wu et al., 2021) and leaf fossil CLAMP analysis suggesting wet environment with weak (not monsoonal) precipitation seasonality (Song et al., 2020) from western Qaidam. On the other hand, many testimonies for drier climate are reported within the eastern Asian monsoon domain by $\delta^{18}\text{O}$ isotopic measurement in pedogenic carbonates from the eastern Qaidam basin (Y. Sun et al., 2020; Kent-Corson et al., 2009), Lanzhou basin in the Chinese Loess plateau area (B. Li et al., 2016), together with CLAMP analysis on fossil leaves advocating for an increased (and monsoon-like) precipitation seasonality in Lanzhou (Miao, 2013), and Markam basin in southeastern TP (T. Su, Spicer, et al., 2019), in agreement with records of increased monsoon-like precipitation seasonality in Eastern China introduced in the previous section. Interpretations nevertheless diverge and suggest that this aridification trend may indicate either weakened East Asian summer monsoon precipitation due to global cooling after the EOT (Wu et al., 2021), increased winter aridity due to the final Paratethys Sea retreat, global sea level fall after the EOT and/or global cooling (Miao, 2013; B. Li et al., 2016), or be due to TP uplift (T. Su, Spicer, et al., 2019).

In the Taatsin Gol region, at the southern edge of the Hangay Dome and extreme north of the modern Gobi desert, isotope measurement from pedogenic carbonates indicate aridification since the early Oligocene (Caves Rugenstein et al., 2014). Finer resolved records reveal several bursts of aridification at ~ 34 - 33 , ~ 31 , ~ 28 and ~ 23 (Baldermann et al., 2021) and the presence of loess as soon as ~ 34 Ma (J. Sun & Windley, 2015). Proposed mechanisms for such aridification involve increased continentality due to land-sea distribution fluctuations at 34 Ma (J. Sun & Windley, 2015) and an early Hangay Dome uplift that would have acted as a barrier to moisture advection from Siberia to Mongolia as soon as the Oligocene (Caves Rugenstein et al., 2014). Better resolved records however highlight the good correlation in time between ice sheets expansion phases and these aridification pulses, and therefore propose that large scale climate fluctuations at that time were the main drivers of Mongolia hydrologic dynamics (Baldermann et al., 2021). Further south, in the Bayanhot basin (southern Gobi), two bursts of aridification inferred from environmental magnetic, mineralogical and geochemical study at ~ 31 and ~ 28 Ma seem to further confirm the influence of high latitude ice sheet fluctuation on Mongolian Oligocene climate (Wasiljeff et al., 2022).

In the mid to late Oligocene, massive eolian dust deposits are reported in three major sites: in the Chinese loess plateau in Northeastern Tibet starting at ~ 29 Ma (Garzzone et al., 2005; Qiang et al., 2011) (see (Meijer et al., 2021) for a full review), in the Tarim Basin (hosting today the Taklamakan desert) at ~ 27 - 22 Ma (Zheng et al., 2015) and in the Junggar basin at ~ 24 Ma (J. Sun et al., 2010). Aridification is also inferred from $\delta^{18}\text{O}$ isotopic measurements from ostracods and pedogenic carbonates from the Tarim basin at ~ 25 Ma (Bougeois et al., 2018; Kent-Corson et al., 2009) and from isotopic records in stromatolites from the Junggar basin loosely dated in the early Miocene (W. Yang et al., 2019). This second step of aridification is coeval with $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ isotopic measurements from pedogenic carbonates suggesting increased orographic precipitation in the Issyk Kul and Ili basins, both situated on the western side of the Tian Shan ranges (Hellwig et al., 2018; Macaulay et al., 2016). Collectively, these observations are interpreted as the sign that the Tian Shan-Pamir uplift had reached an elevation threshold that would have started

shielding the Tarim and Junggar basins from westerlies moisture input, thus favoring their aridification (Bougeois et al., 2018; W. Yang et al., 2019).

This late Oligocene to early Miocene aridification phase seems to be recorded by several oceanic drillings, for example in Central North Pacific, with an increase in dust mass accumulation rate recorded at ~ 25 Ma by (drilling site GPC3) (D. K. Rea, 1994; Pettke et al., 2002) and at ~ 22 Ma (ODP site 1215) (Ziegler et al., 2007). These drillings are however situated far from the Asian coast and underwent important plate motion throughout the Cenozoic, making it difficult to disentangle variations due to inland Asia climate changes, possible global atmospheric/oceanic circulation patterns changes, and variations in the recorded signal due to plate motion. The presence of a proto winter monsoon wind circulation is also suggested by increased proportion of dusts, inferred from magnetic susceptibility measurement in the Maldives (IODP sites U1467, U1468) at ~ 24 Ma (Betzler et al., 2016), and by an increase in water column mixing and ventilation evidenced by a reduction in $\Delta \delta^{13}\text{C}$, increase in bulk sediment Mn/Fe and Mn/Ti and foraminiferal Mn/Ca in the eastern Arabian Sea (Beasley et al., 2021).

3.2 Strengthening of summer and winter monsoon patterns in the Neogene

3.2.1 *An East-West gradation in Miocene South Asian summer monsoon variations and the expansion of grassland*

Despite a better coverage in both continental and marine records in the Neogene, substantially diverging interpretations remain regarding the evolution of the monsoons winds and precipitation seasonality, especially during the late Miocene. Precipitation proxies from the South Asian Monsoon domain allow to highlight an East-West gradation in climate evolution throughout the Miocene, recorded in the Siwaliks deposits of the Himalayan foreland basin. In northeasternmost India (Arunachal Pradesh), modern-like monsoon precipitation seasonality is inferred from plant macrofossils since the middle Miocene (13 Ma) and displays little variation in intensity when compared to early Pleistocene fossils from the same locality (Khan et al., 2014). Further west, plant macrofossils and pollen from Darjeeling, Nepal, northwestern India and Pakistan show a progressive replacement of middle Miocene evergreen forests by deciduous forests in the late Miocene, and finally a massive expansion of grassland in the latest Miocene (Hoorn et al., 2000; Bhatia et al., 2022; Bhatia, Srivastava, et al., 2021; Srivastava et al., 2018). This late Miocene floristic change is also accompanied by several shifts in $\delta^{13}\text{C}$ toward more positive values, recorded between 10.5 and 6 Ma by isotopic measurements in pedogenic carbonates and organic matter and lipid biomarkers in the Central Siwaliks (Nepal) (Quade et al., 1995; Neupane et al., 2020; Dettman et al., 2001), and in the Western Siwaliks (northwestern India and Pakistan) (Sanyal et al., 2004; Vögeli et al., 2017; Quade & Cerling, 1995). Similar trends are also recorded in nearby marine basins by isotopic measurements from bulk sediments and leaf wax, pollen and macrofossils at ~ 8 -7 Ma in the Arabian Sea (ODP 722 and IODP U1457) (Feakins et al., 2020; Y. Huang et al., 2007) and at ~ 7 -6 Ma in the Bengal fan (Polissar et al., 2021).

This marked carbon isotope excursion is observed in other localities of the globe and testify of an important ecological change, characterized by the replacement of plants using the C3 photosynthetic pathway by grasslands using the C4 photosynthetic pathway (Cerling et al., 1993; Tauxe & Feakins, 2020; Edwards et al., 2010). Recent re-calibration of these Asian continental carbon isotope records and comparison to other available records allow to show that C4 expansion occurred at distinct times: ~ 10 Ma in Africa, ~ 8 Ma in Pakistan, ~ 7 Ma in peninsular India, ~ 6 Ma in Nepal and later during the Pliocene in Australia and South America (Tauxe & Feakins, 2020). Although a late Miocene $p\text{CO}_2$ drawdown was initially proposed as the main driver for the C3/C4 transition, such distinct timing in ecological turnover over the globe is assumed to reflect the multiplicity of forcing factors at play in this major biome reorganization. In the Siwaliks, this East-West climate gradation likely reflects the crossing of a precipitation threshold somewhere in Nepal (Central Siwa-

403 liks), with northwestern India, Nepal and Pakistan experiencing drier winters and overall
 404 aridification in the late Miocene compared to the more stably humid northeastern Indian re-
 405 gion. The C4 grasslands expansion would thus possibly result from a combination of $p\text{CO}_2$
 406 decrease, reduced moisture advection from the westerlies in this region, Tibetan Plateau
 407 and Himalayas uplift and to more frequent forest fire that would have favored grasses over
 408 trees (Sanyal et al., 2004; Vögeli et al., 2017; Quade & Cerling, 1995; Srivastava et al., 2018;
 409 Tauxe & Feakins, 2020; Polissar et al., 2021; Feakins et al., 2020).

410 Precipitation proxies recovered from marine drillings offer contrasting information. In
 411 the central Bay of Bengal (ODP site 758), relatively undisturbed isotopic composition of
 412 clays issued from silicate weathering since the Oligocene (~ 27 Ma) are interpreted as signs
 413 of a stable South Asian summer monsoon presence since that time (S. Ali et al., 2021).
 414 On the other hand, chemical weathering (CIA, K/Al ratio) and sediment accumulation
 415 rates from both the Indus Fan and the Bay of Bengal recording the physical erosion of the
 416 Himalayas and southern Tibet, suggest that SASM precipitation reached a maxima in the
 417 middle Miocene (~ 10 -16 Ma) before declining between ~ 8 -3 Ma (P. Clift et al., 2008). This
 418 decline was primarily interpreted as reflecting a weakened SASM precipitation (P. Clift et
 419 al., 2008), although other studies based on similar proxies from the Bay of Bengal argue it
 420 may rather reflect an intensification of the winter monsoon (S. Ali et al., 2021), possibly
 421 coupled to a weakening of the South Asian summer monsoon (J. Lee et al., 2020), which
 422 seem in better agreement with continental proxies, and with marine records from the South
 423 China Sea (Wan et al., 2010) (developed in the next section).

424 Wind proxies retrieved from the Arabian Sea and the Bengal Fan pointing to the
 425 presence of seasonal wind reversal (hence of a winter monsoon) since the middle Miocene
 426 seem to corroborate this explanation, although some aspects of the SAM wind circulation
 427 evolution remain debated. In the Arabian Sea, the appearance of *Globigerina Bulloides*
 428 in the sediments had initially been used to infer an intensification (or an onset) of the
 429 South Asian summer monsoon wind circulation at ~ 8 Ma (Kroon et al., 1991), based on
 430 the assumption that stronger SASM winds would translate into stronger upwelling activity.
 431 Those records have since then been extended back in time (Bialik et al., 2020; Zhuang et al.,
 432 2017; Gupta et al., 2015) and combined with analysis of current-controlled drift sediments
 433 and geochemical tracers from the Maldives archipelago (Betzler et al., 2016). These new
 434 studies now point to a settlement of a "proto" South Asian monsoon wind circulation since
 435 the late Oligocene (~ 25 Ma), and of its reinforcement in the middle Miocene (~ 13 -10 Ma)
 436 (Betzler et al., 2016; Zhuang et al., 2017; Bialik et al., 2020) and possibly also in the late
 437 Miocene (~ 8 -7 Ma) (Gupta et al., 2015). Nevertheless, increasing number of studies based
 438 on marine records from both the Arabian Sea and the Bengal Fan do not observe this latest
 439 Miocene (8-7 Ma) SASM peak (Bolton et al., 2021; Tripathi et al., 2017; Betzler et al., 2016;
 440 Y. Huang et al., 2007). Strong SAM wind circulation since at least 10 Ma is also supported
 441 by clay mineralogy, detrital isotopes, export productivity and sediments accumulation from
 442 records in the southern Bay of Bengal (IODP 1443) (Bolton et al., 2021; J. Lee et al., 2020))
 443 and the eastern Arabian Sea (IODP 1456) (Tripathi et al., 2017)).

444 3.2.2 *EASM in the Neogene*

445 Summer precipitation typical of the East Asian summer monsoon is assumed to occur
 446 throughout the Neogene (22-3 Ma), as attested by sediments exported to the South China
 447 Sea, such as weathering indices (P. Clift et al., 2008), $\delta^{13}\text{C}$ measurements in black carbon
 448 (Jia et al., 2003), pollen, biomarkers, kerogen composition and clay mineralogy (W. Ding et
 449 al., 2021). On land, $\delta^{18}\text{O}$ from paleosol carbonates in the CLP (Suarez et al., 2011) and most
 450 Chinese floras, studied with Coexistence Approach, CLAMP or Bayesian method applied
 451 to pollen, point to summer precipitation comparable to modern amounts (Q. Wang et al.,
 452 2021; Yao et al., 2011; Xing et al., 2012; Hui et al., 2021; B. Wang et al., 2021; Q.-g. Sun et
 453 al., 2002). Most of those studies nevertheless suggest wetter winters due to weaker winter
 454 monsoon until the latest Miocene, with a few exceptions, such as the mid-Miocene floras

455 from the Zhangpu biota in southeastern China characteristic of megathermal seasonal forest
 456 which CLAMP signature showing affinities with EAM and SAM floras (B. Wang et al., 2021).
 457 The variations in EASM intensity throughout the Miocene remain controversial in both
 458 continental and marine deposits, but two intensification peaks usually emerge, tentatively
 459 linked to the Middle Miocene Climatic Optimum (~17-14 Ma) and to the Miocene-Pliocene
 460 boundary (~8-5 Ma).

461 The middle Miocene EASM peak is inferred from sediments from the South China Sea
 462 by chemical weathering proxies at 15-12 Ma (P. Clift et al., 2008), and $\delta^{13}\text{C}$ in black carbon
 463 (Jia et al., 2003), although the latter rather point to a step-wise intensification of EASM in
 464 the course of the Neogene (at ca. 20, 15, 10, 6 and 2 Ma). On land, characterization of iron
 465 oxides from the Chinese Loess Plateau suggest an EASM peak at 16-14 Ma (H. Zhao et al.,
 466 2020). The proportion of *Fupingopollenites*, an extinct palynomorph supposed to be highly
 467 dependent on summer moisture, has also been used in an extensive compilation spanning
 468 available Miocene Chinese pollen records and point to an important penetration of EASM
 469 moisture, up to the eastern Qaidam basin, during the MMCO, before retreating to the East
 470 in the rest of the Neogene (Miao, Song, et al., 2016).

471 A substantial increase in EASM strength is also robustly suggested by many lines of
 472 evidence in the late Miocene to Pliocene, although with notable variations in onset timing
 473 (10-4 Ma). In the South China Sea, it is inferred from $\delta^{18}\text{O}$ and Mg/Ca derived temper-
 474 ature records of surface and sub-surface water (IODP U1501) (C. Yang et al., 2021), clay
 475 minerals, grain size, major and trace elements analysis from terrigenous sediments (ODP
 476 1146) (Wan et al., 2007, 2010) and by black carbon $\delta^{13}\text{C}$ (Jia et al., 2003). In China, this
 477 EASM intensification is recorded through mineralogical, chemical and magnetic analysis of
 478 sedimentary deposits in the Chinese Loess Plateau (Ao et al., 2016, 2021; H. Zhao et al.,
 479 2020), and by pollen from the Tianshui (Hui et al., 2021) and the Weihe Basin (L. Zhao
 480 et al., 2020). The forcing factors responsible for these EASM intensification peaks remain
 481 debated, but are usually attributed to global warming (Ao et al., 2021; H. Wang et al.,
 482 2019) and/or to Neogene TP uplift phases (Hui et al., 2021; X. Ren et al., 2020; H. Zhao
 483 et al., 2020). Although EASM and EAWM evolution show few correlation during most of
 484 Cenozoic, this late Miocene EASM increase is notably accompanied with EAWM increase
 485 (described in next section).

486 **3.2.3 Miocene to Pliocene aridification pulses in response to regional up-** 487 **lifts**

488 Throughout the Miocene, dust deposition continues in the Chinese Loess Plateau (Guo
 489 et al., 2002; Meijer et al., 2021), Tarim-Taklamakan (Kent-Corson et al., 2009; Zheng et
 490 al., 2015; Heermance et al., 2018) and Junggar basins (J. Sun et al., 2010). In parallel
 491 with previously mentioned indices for an increased EASM during the MMCO (~17-14 Ma)
 492 (P. Clift et al., 2008; Jia et al., 2003; H. Zhao et al., 2020), a warmer and less arid climate
 493 interval is suggested by pollen showing relatively lower proportion of xerophytic taxa in the
 494 Junggar (J. Sun et al., 2010) and Qaidam basins (Miao et al., 2011). After the MMCO,
 495 a pronounced step-wise aridification is recorded in most of inland Asia until the Miocene-
 496 Pliocene boundary (Lu et al., 2010; Lu & Guo, 2014; Z.-H. Tang & Ding, 2013). Here again,
 497 the timing for aridification steps varies with the region and is usually tentatively explained
 498 by a combination of global cooling, ice-sheet expansion and multiple regional uplift episodes
 499 occurring at that time.

500 In the eastern part of inland Asia, encompassing the Chinese Loess Plateau, central
 501 China and northeastern Tibetan Plateau, this aridification is attributed to northeastern TP
 502 uplift (Miao et al., 2012), Altai mountains uplift (Caves Rugenstein et al., 2014) and/or late
 503 Miocene cooling (Lu et al., 2010; Lu & Guo, 2014; Peng et al., 2016). Such aridification is
 504 supported by overwhelming evidences, such as pollen and biomarkers documenting a step-
 505 wise transition from sub-humid to arid environment starting at ~15 Ma (J. Liu et al., 2016;

506 Miao et al., 2011; Jiang & Ding, 2008; Peng et al., 2016), massive grasses expansion at
 507 \sim 11-7 Ma (Suarez et al., 2011; Barbolini et al., 2020; Y. Ma et al., 2005; L. Zhao et al.,
 508 2020; H. Wang et al., 2019), widespread eolian deposition at \sim 8-7 Ma (X. Ma & Jiang, 2015;
 509 Guo et al., 2002; Qiang et al., 2011; B. Li et al., 2016; Jiang et al., 2017), increased $\delta^{18}\text{O}$
 510 of pedogenic carbonates and terrestrial mammals tooth enamel at \sim 14-13 and \sim 7-5 Ma
 511 (B. Li et al., 2016; Kent-Corson et al., 2009; Wu et al., 2021; W. Liu et al., 2014; Y. Sun et
 512 al., 2020; Kaakinen et al., 2006; Y. Wang & Deng, 2005), *n*-alkanes analysis from Qaidam
 513 sediments since 13 Ma (Z. Liu et al., 2014) and dominance of cold-aridiphilous mollusks
 514 proportion in the CLP from 7-5 Ma (F. Li et al., 2008).

515 The western part of inland Asia, comprising the Tarim and Junggar basins and several
 516 sites in eastern Kazakhstan, which all add to the body of evidence indicating mid to late
 517 Miocene aridification, as shown by increased xerophytic and grasses pollen proportions at
 518 \sim 7-5 Ma (J. Sun et al., 2010; J. Sun & Zhang, 2008; Z. Zhang & Sun, 2011; Barbolini et
 519 al., 2020; J. Sun et al., 2008), massive eolian deposition in the western Tarim at \sim 12-7 Ma
 520 (Heermance et al., 2018) and permanent drying of lakes in the eastern Tarim at \sim 5 Ma
 521 (W. Liu et al., 2014). The pedogenic carbonates $\delta^{18}\text{O}$ record of these regions nevertheless
 522 offers diverging pattern evolution, that have been tentatively explained by their location
 523 with respect to the Tian Shan and Altai mountains (Caves Rugenstein et al., 2017). Regions
 524 today lying upwind of the Tian Shan and Altai mountains, such as the Issyk Kul (Macaulay
 525 et al., 2016), Junggar (Charreau et al., 2012) and Zaysan basins (Caves Rugenstein et
 526 al., 2017) show a decline in $\delta^{18}\text{O}$ between 10-5 Ma (varying from \sim 1.5 to 4 ‰) which
 527 was interpreted as a change in precipitation seasonality following the uplift of the Altai
 528 Mountains (Caves Rugenstein et al., 2017). On the other hand, increased $\delta^{18}\text{O}$ values since
 529 \sim 15 Ma and peaking at \sim 7-5 Ma in the Tarim basin, situated downwind of the Tian Shan
 530 ranges display trends similar as those of the Qaidam basin (Kent-Corson et al., 2009), which
 531 are interpreted as indicating aridification at that time.

532 EAWM intensification peaks are also recorded offshore at \sim 15-12, \sim 8-5 and \sim 3 Ma,
 533 in usually good coherence with continental data. In the South China Sea, it is suggested
 534 by increased black carbon concentration and accumulation (whose transportation to the
 535 Sea would be favored by stronger winter winds) (Jia et al., 2003), planktic and benthic
 536 $\delta^{18}\text{O}$ records and mixed layer temperature (A. Holbourn et al., 2021; A. E. Holbourn et al.,
 537 2018), clay mineralogy and grain size analysis (Wan et al., 2007), and by indices of decreased
 538 chemical weathering (G. Wei et al., 2006). In the Sea of Japan, clay mineral assemblage
 539 and isotopic analysis of silicate fraction covering the last 15 Ma suggests a stepwise drying
 540 of Central Asia suggested at 12, 8 and 3.5 Ma (Shen et al., 2017). In the North Pacific,
 541 an increase in Asian dusts proportion is recorded at \sim 10 and \sim 4 Ma (D. Rea et al., 1985;
 542 Pettke et al., 2002). Last, brutal onset of SAM wind seasonality (and therefore occurrence
 543 of winter monsoon reversed winds) is inferred at \sim 12 Ma in the Maldives (Betzler et al.,
 544 2016) and in the eastern Arabian Sea (X. Yang et al., 2020).

545 3.3 Assessing forcings and mechanisms through climate models

546 3.3.1 SAM forcings assessed by modeling experiments derived from mod- 547 ern geography

548 Major forcings proposed to explain multi-million year monsoon variability are global
 549 climate variations, changes in topography and changes in land-sea distribution. Attributing
 550 a specific change to one or several of these forcings is nevertheless complicated by the
 551 fact that they may vary at the same time, produce non-linear responses with potentially
 552 antagonizing effects and because they are sometimes poorly dated or quantified. Modeling
 553 experiments, first derived from modern geographies and boundary conditions, have helped
 554 better understanding the role played by these different forcings in shaping the regional
 555 monsoons.

556 The Tibetan Plateau has long been seen as instrumental in driving the South Asian
 557 monsoon circulation and precipitation, its elevated heated surface acting as a "heat pump"
 558 driving the convergence of the surrounding air masses (Kutzbach et al., 1993; Zou et al.,
 559 2019; Molnar et al., 1993). It seems now that it is rather the physical barrier created by
 560 the landform (the Himalayas or the Tibetan Plateau) that is essential to induce abundant
 561 orographic precipitation over northern India, through steering and lifting of moist air masses
 562 (Abbott et al., 2016; Boos & Kuang, 2010; Acosta & Huber, 2020). The condensation
 563 of moisture in these ascending air masses leads to important latent heat release in the
 564 high troposphere over northern India, which acts as a positive feedback sustaining summer
 565 convection and precipitation in South Asia (He, 2017). The large-scale monsoon circulation
 566 seasonal reversal resulting in the initial advection of these moist air masses over Asia in late
 567 spring and early summer, on the other hand, is essentially driven by surface ocean-continent
 568 temperature gradients and resulting pressure patterns (Acosta & Huber, 2020; Merlis et al.,
 569 2013).

570 Smaller orographic features were also shown to play a critical role in shaping and
 571 strengthen the South Asian monsoon. By channeling the Somali Jet and insulating it from
 572 the subtropical dry westerly flow, the Anatolian-Iranian landform were shown to greatly con-
 573 tribute to enhance moisture transport towards India and Eastern Asia (Acosta & Huber,
 574 2020; He, 2017; H. Tang et al., 2013). The Eastern African highlands, positioned on the way
 575 of the ITCZ flow, are critical in shaping both African and South Asian climate (Bannon,
 576 1979; Rodwell & Hoskins, 1995; Sepulchre et al., 2006). Recent studies have specifically
 577 demonstrated that Eastern African highlands presence contribute greatly to strengthen and
 578 concentrate the Somali Jet, but that their absence would result, quite counter-intuitively,
 579 into higher summer precipitation over SAM region, due to increased advection directly from
 580 the ocean to the continent (H.-H. Wei & Bordoni, 2016; Chakraborty et al., 2009). This last
 581 aspect hints that strong upwellings, due to strong atmospheric circulation, may not correlate
 582 with strong precipitation on land. The effect of the Pamirs, Tian Shan and northeastern
 583 TP uplifts on SAM remains unclear. When these uplift together with Mongolian landforms,
 584 H. Tang et al. (2013) simulate increased moisture advection to eastern China but decreased
 585 precipitation over India, while the opposite effect is obtained when not modifying (mod-
 586 ern) Mongolian topography (R. Zhang et al., 2017). Apart from differences coming from
 587 the model and boundary conditions, this likely points to the complex interactions existing
 588 between the SAM and EAM regional monsoons.

589 ***3.3.2 EAM forcings assessed by modeling experiments derived from mod-*** 590 ***ern geography***

591 In contrast with the modest effect it has on the SAM, the Tibetan Plateau uplift is
 592 instrumental for the EASM, as the heating of the Plateau, induces a cyclonic circulation
 593 anomaly promoting advection of moist air masses towards Eastern Asia (Z. Zhang et al.,
 594 2007; H. Tang et al., 2013; R. Zhang et al., 2017). Additionally, simulations testing the
 595 effects of increased Asian continentality (to mirror a global sea level fall or the retreat of
 596 the Paratethys Sea, for example), have shown that it results in amplified summer moisture
 597 convergence from the Indian Ocean towards Asia, due to changes in surface temperature
 598 gradients deepening the continental low pressure belt (Z. Zhang et al., 2007).

599 Although smaller than the HTP complex, the Pamir, Tian Shan and Mongolian land-
 600 forms are adequately situated in latitude to interfere both dynamically and thermally with
 601 planetary-scale atmospheric circulation. Their uplift was shown to enhance the aridity in
 602 inland Asia (actual Gobi and Taklimakan deserts), as it reinforces the EAWM circulation
 603 patterns (X. Liu & Yin, 2002; X. Liu, Sun, et al., 2015; Baldwin & Vecchi, 2016; Sato,
 604 2009). By creating a cold pool and deviating the westerlies towards northern Siberia, the
 605 Mongolian orography has been proposed to be responsible for the Jet Stream northward
 606 migration in summer and intensity in winter (White et al., 2017; Shi et al., 2015; Sha et al.,
 607 2020), and for most of the Siberian High location and intensity (Sha et al., 2015).

608 **3.3.3 Modeling experiments derived from paleo boundary conditions**

609 Modeling studies based on modern geographies are nevertheless limited in to what
 610 extent they allow to understand past changes, especially for periods where very different
 611 geographies and climate prevailed. Paleoclimate simulations, using sets of realistic (as much
 612 as possible) paleo-boundary conditions are however rarer. Indeed, they usually imply high
 613 computational cost, and require important background knowledge on past constraints (pa-
 614 leogeography, CO₂, solar constant, ice-sheets volume).

615 More specifically, paleoclimate modeling has confirmed that increasing Asian conti-
 616 nentality during the Oligocene and the Miocene, mirroring either the Paratethys Sea retreat
 617 and/or global eustatic sea level fall, was a key leverage of increased moisture advection
 618 toward Asia in summer (Fluteau et al., 1999; Ramstein et al., 1997; Z. Zhang et al., 2014;
 619 Sarr et al., 2022). In Oligocene conditions, the uplift of the peripheral Tian Shan, Pamir
 620 and northeastern portions of the TP was also shown to promote inland Asian aridity, when
 621 compared to the sole uplift of the "core" Tibetan plateau (R. Zhang et al., 2017). In late
 622 Eocene conditions, the latitude of the Tibetan Plateau was also shown to impact signif-
 623 icantly and non-linearly East Asian climate: with a TP uplifting in the tropics ($\sim 11^\circ\text{N}$)
 624 inducing precipitation on the reliefs but aridification in most of China, while a TP uplifting
 625 at its modern latitude ($\sim 26^\circ\text{N}$) would increase moisture advection to eastern China and
 626 aridification of inland Asia (R. Zhang et al., 2018).

627 Although paleoclimate studies offer contrasted views regarding Eocene climate, some
 628 suggesting the presence of monsoons at that time (Huber, 2003) and others not (Tardif et
 629 al., 2020; Z. Zhang et al., 2012; R. Zhang et al., 2018), this divergence is most likely due to
 630 the very different paleogeographic reconstructions that were used. Indeed, as many features
 631 of the Eocene paleogeography remain highly controversial (height of the incipient Tibetan
 632 topography, shape of Indo-Asian collision zone, height of peripheral landforms, land-sea
 633 distribution, etc.), the geographic reconstructions may diverge widely from one study to
 634 another. Paleoclimate modeling have nevertheless allowed to emphasize the prevalence of
 635 geography impact on climate, rather than $p\text{CO}_2$ variations or far-field ice-sheets effects
 636 when it comes to the SAM and EAM settlement and intensification over long time scales
 637 (Farnsworth et al., 2019; Thomson et al., 2021). Collectively, these information rather
 638 reinforce the need for good paleogeographic constraints, and for more sensitivity experiments
 639 in paleo context, which we aim at doing in the present contribution.

640 **3.4 Summary: a diachronous settlement of SAM and EAM seasonal fea-** 641 **tures, potential forcings and mechanisms and remaining uncertainties**

642 The past decade have brought plenty of new analysis based on fossil material, both
 643 onshore and offshore. The history of SAM, EASM and EAWM settlement and intensification
 644 now clearly seem to have been diachronous and its evolution tightly linked to land-sea mask,
 645 topography and global climate evolution over long time scales. Some questions nevertheless
 646 remain to be answered.

647 First, it is unclear whether Paleogene records of highly seasonal precipitations at low
 648 latitudes ($< 20^\circ\text{N}$) do describe an actual monsoon, given that no wind proxies can be pro-
 649 vided at this period, and that Eocene paleoclimate studies propose widely diverging scenar-
 650 ios. CLAMP (Climate Leaf Analysis Multivariate Program) paleobotanical analysis (Feng
 651 & Poulsen, 2016; Wolfe, 1993; Jacques, Su, et al., 2011) have brought interesting insight
 652 on this point. Generally, they show that, although strong precipitation seasonality was
 653 likely present since the Paleogene in broad parts of Southeastern Asia (Bhatia, Khan, et
 654 al., 2021; R. Spicer et al., 2017; Herman et al., 2017), these floras did not yet developed
 655 the characteristics of plants growing today in modern SAM or EAM regions until the mid-
 656 dle Miocene (~ 13 Ma) (R. Spicer et al., 2017; Bhatia, Srivastava, et al., 2021). Instead,
 657 Paleogene Asian floras display a signature typical of the regions today dominated by the
 658 ITCZ seasonal migrations (referred to as Indonesian-Australian monsoon, or IAM in Fig-

659 ure 2). The reorganization from an ITCZ dominated to a monsoonal wind circulation may
 660 have initiated in the Oligocene (~ 28 -23 Ma), according to fossils from northeastern India
 661 displaying a mixture of SAM and IAM leaf signatures (R. Spicer et al., 2017). These typical
 662 monsoonal signatures likely emerged from a combination of both biotic and abiotic factors,
 663 although CLAMP method is unable to disentangle the forcings responsible for these spe-
 664 cific signatures. They however add to the body of evidence suggesting that precipitation
 665 seasonality and typical monsoonal wind circulation may have been decoupled in the past.

666 Second, although modeling studies have started to explore localized landforms effect
 667 in paleo context, there is plenty of room for improvement. For example, many of these
 668 landforms have been tested collectively (eg. Tian Shan and Mongolia uplifting together),
 669 and analyzed within the scope of a single time period. Significant hypotheses remain to
 670 be tested in a paleo context, such as identifying the leverage for a Siberian High pressure
 671 development, and its actual impact on inland Asian aridity. Indeed, the presence of loess-
 672 like deposits since the Eocene, that were tentatively explained by the presence of an active
 673 Siberian High at that time (Meijer et al., 2021; Licht et al., 2014), question its actual
 674 dependence to the presence of Tian Shan and/or Mongolian orogens, which are usually dated
 675 later in the Oligocene to late Miocene. In addition, the notion of threshold elevation is a key
 676 point to tackle, as strongly non-linear responses of climate circulation with respect to this
 677 parameter are expected. These considerations highlight the need for a finer understanding of
 678 the actual drivers of today's regional Asian monsoons. Given the demonstrated prevalence
 679 of geography in shaping the Asian Monsoons, an accurate representation of its evolution is
 680 therefore paramount to study their history over long time-scales.

681 4 Cenozoic paleogeography evolution

682 Simulations in this study have been performed with Eocene, Oligocene and Miocene
 683 paleogeographic configurations from previous studies (Poblete et al., 2021; Tardif et al.,
 684 2020; Sarr et al., 2022; Barbolini et al., 2020), which are coherent with geological history.
 685 The Eocene and the early Miocene paleogeographic configurations are from Poblete et al.
 686 (2021); Tardif et al. (2020) reconstruction at 40 and 20 Ma. The early Oligocene geography
 687 is based on the Eocene geography with an homogeneous sea level drop of 70 meters to
 688 account for sea level changes related to Antarctic ice-sheet building during the Eocene-
 689 Oligocene transition (Miller et al., 2020). The mid and late Miocene geographies are based
 690 on the PRISM4 (Dowsett et al., 2016) reconstruction used in PlioMIP2 (Haywood et al.,
 691 2020) with modifications to include a southward shift of the Australian continent and an
 692 emerged Sunda Shelf (see Sarr et al. (2022) for details). We in addition performed sensitivity
 693 experiments to test the impact of specific topographic features on different characteristics
 694 of the Asian monsoons.

695 In this section, we provide an overview of the main landmarks and persistent uncer-
 696 tainties regarding the paleogeography evolution during the Cenozoic in our region of interest
 697 (see Fig. 2). The paleogeographic configurations used in our simulations are introduced, for
 698 each of these key regions (Fig. 3 and Table 1).

699 4.1 Asia

700 4.1.1 Indo-Asia collision and land-sea distribution uncertainties

701 The initiation of the Indo-Asian collision, marking the closure of the Neotethys Ocean
 702 (J. R. Ali & Aitchison, 2008; Chatterjee et al., 2013), is dated around ~ 50 Ma (C. Wang
 703 et al., 2014; D. J. J. van Hinsbergen et al., 2012; Dupont-Nivet et al., 2010; Jagoutz et
 704 al., 2015; Lippert et al., 2014; W. Huang et al., 2015), or alternately around ~ 58 Ma
 705 (D. J. van Hinsbergen et al., 2019; Ingalls et al., 2016), via sedimentology and paleomagnetic
 706 evidence. The morphology of the *Greater India* portion (i.e. northern India) before collision
 707 remains unclear. Depending on the collision scenario considered (see Kapp and DeCelles

Table 1. List of reference simulations (in bold) and sensitivity experiments used in this study. Abbreviations stand for East Antarctic Ice Sheet (EAIS), Antarctic Ice Sheet (AIS) and Greenland + Antarctic Ice Sheet (G+AIS). The last column explains the relationship between the different paleogeographic configurations, and therefore define the anomalies that can be tested (e.g. the effect of a lowered TP will be studied through the "LEo2_TP - LEo2_TPlow" difference, while the effect of $p\text{CO}_2$ halving in the Eocene is obtained with the "LEo1_REF - LEo1_2X". Likewise, all paleogeography sensitivity experiment from the Middle to late Miocene will be compared to the "LMio_smallT" simulation.

Simulation	$p\text{CO}_2$	Ice sheets	Paleogeography
LEo1_REF	1120	-	from (Tardif et al., 2020)
LEo2_TP	1120	-	from (Poblete et al., 2021)
LEo2_TPlow	1120	-	from LEo2_TP, with TP lowered to 800 m
LEo2_TPhigh	1120	-	from LEo2_TP, with TP raised to 4500 m
LEo2_TPsouth	1120	-	from LEo2_TP, with TP shifted to the South (Poblete et al., 2021)
LEo2_BengalSea	1120	-	from LEo2_TP, with a Bengal Sea (Poblete et al., 2021)
LEo1_2X	560	-	from LEo1_REF, with $p\text{CO}_2$ halved to 560 ppm
EOli_REF	560	AIS	from LEo1_REF, with 70m sea level drop
EMio_REF	560	EAIS	from (Poblete et al., 2021)
EMio_TetSw	560	EAIS	from EMio_REF, with open Tethyan Seaway (120 m depth)
EMio_EAfr	560	EAIS	from EMio_REF, with modern East African landforms
MMio_REF	560	AIS	from (Sarr et al., 2022)
LMio_smallT	560	AIS	from MMio_REF, with a reduced Paratethys
LMio_noAr	560	AIS	from LMio_smallT, with immersed Arabia
LMio_noM	560	AIS	from LMio_smallT, with Mongolia lowered to 800 m
LMio_noTS	560	AIS	from LMio_smallT, with Tian Shan lowered to 800 m
LMio_noTSM	560	AIS	from LMio_smallT, with TienShan + Mongolia lowered to 800 m
LMio_noTSP	560	AIS	from LMio_smallT, with TienShan + Pamir lowered to 800 m
LMio_REF	560	G+AIS	from (Sarr et al., 2022)
LMio_1.5X	420	G+AIS	from LMio_REF with $p\text{CO}_2$ lowered to 420 ppm

(2019); Poblete et al. (2021) for a review), *Greater India* is represented as fully emerged (Ingalls et al., 2016; C. Wang et al., 2014), or partially flooded until the middle-late Eocene (D. J. J. van Hinsbergen et al., 2012; D. J. van Hinsbergen et al., 2019; W. Huang et al., 2015). From the Eocene onward, India's progressive migration to the North, indentation into the Asian continent and counterclockwise rotation (Molnar et al., 2010) triggered widespread orography changes in Asia, which are summarized below. The most salient of these events is of course the Tibetan Plateau and Himalayas uplift, and the spreading of deformation and uplift to peripheral terranes.

4.1.2 Himalayas-Tibetan Plateau uplift history

The early uplift history of the Tibetan Plateau is highly debated. Oxygen isotopic paleoaltimetry studies suggest that the Gangdese (Southern TP, Lhasa terrane) and Qiangtang mountains (Central TP) are already as high as ~ 4000 - 5000 m during the early Eocene (Rowley & Currie, 2006; L. Ding et al., 2014; Xu et al., 2013; Xiong et al., 2020; C. Wang et al., 2014). The robustness of this method is however questioned by isotope-enabled climate models demonstrating that other factors than elevation affect the $\delta^{18}\text{O}$ precipitation signature, such as the air masses provenance, climate change, or water recycling (Poulsen & Jeffery, 2011; Botsyun et al., 2016). Considering these additional factors, a revised Ti-

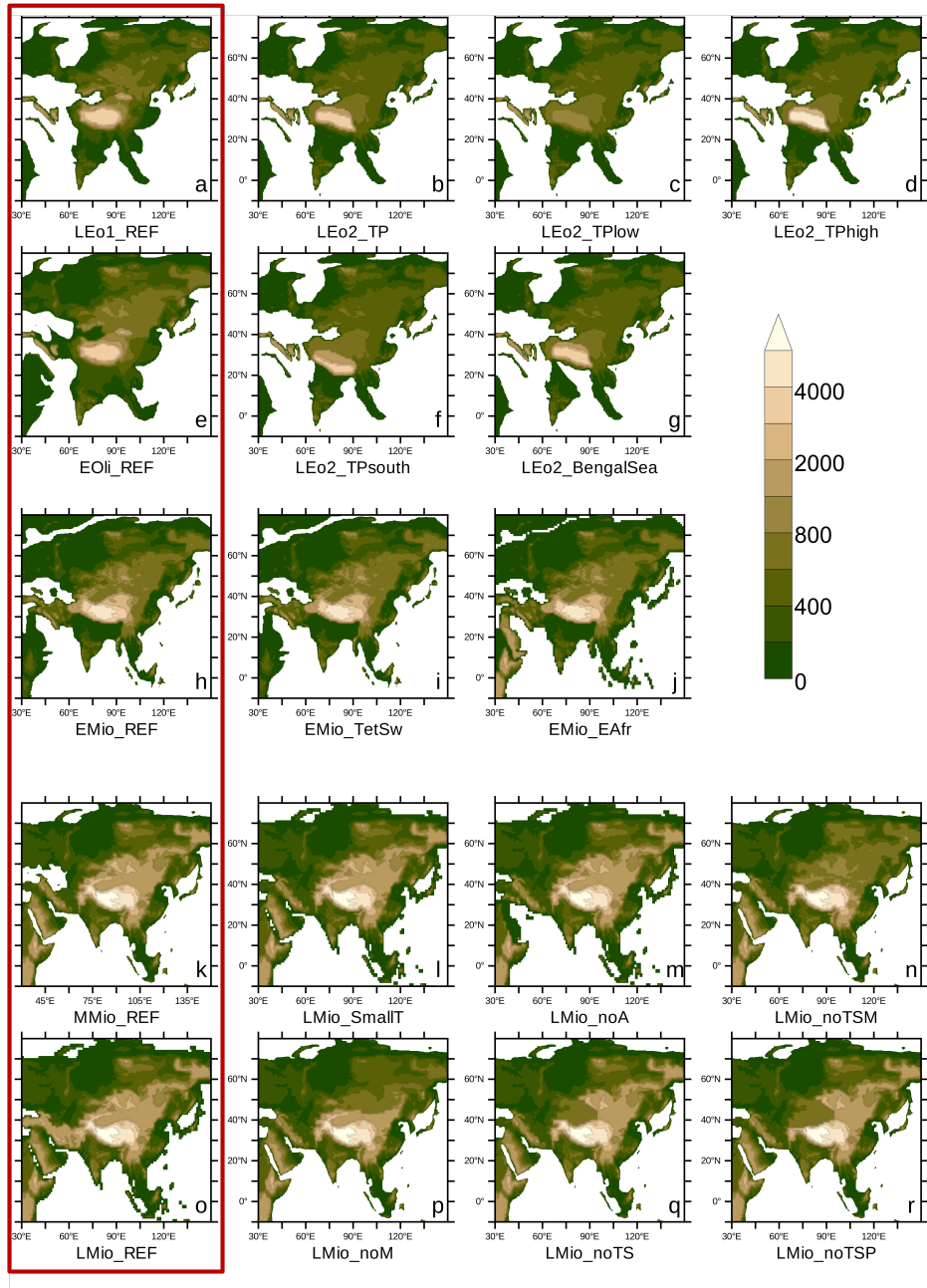


Figure 3. paleogeographic configurations used in this study. (a,e,h,k,o) Reference paleogeographic configurations for the late Eocene (~40 Ma), early Oligocene (~34 Ma), early (~20 Ma), mid (~12 Ma) and late Miocene (~8 Ma) are aligned in the first column (red box). Alternative configurations used for sensitivity tests are also presented, for the late Eocene (b,c,d,f,g), the early Miocene (i,j) and the mid to late Miocene (l,m,n,p,q,r)

betan Plateau paleo-elevation, most likely inferior to ~ 3000 m in the Oligocene, is suggested (Botsyun et al., 2019). The presence of frost-intolerant fossil flora assemblage in Central TP in the middle Eocene (T. Su et al., 2020) and late Oligocene (T. Su, Farnsworth, et al., 2019), as well as clumped isotope measures (Xiong et al., 2022), advocating for a subtropical climate in this region, seems incompatible with a TP exceeding 4000 m. Therefore, a more complex morphology for this proto-TP, with the presence of a low-elevated (~ 1500 m) valley dividing the almost fully uplifted (~ 3000 - 4000 m) Lhasa and Qiangtang terranes until the late Oligocene has been proposed (T. Su, Farnsworth, et al., 2019; Xiong et al., 2020; R. Spicer et al., 2020; Xiong et al., 2022).

In the periphery of the proto-TP, data collected from different basins offer contradictory information. In southeastern Tibet, at the extremity of the Qiangtang terrane, T. Su, Spicer, et al. (2019) use paleo-elevation calculated from the CLAMP method to suggest that the Markam Basin was already high in the late Eocene (~ 3000 m) and could have reached its modern elevation (~ 3900 m) by the earliest Oligocene. Alternately, paleo-elevation based on oxygen isotopic measurements of the nearby Jianchuan Basin (belonging to the Qiangtang terrane as well) could have not exceeded ~ 1200 m in the late Eocene (Gourbet et al., 2017). The northern TP is proposed to remain relatively low (maximum ~ 2000 m) in the Eocene before uplifting in the Oligocene or the early Miocene, based on $\delta^{18}\text{O}$ measurements from the Hoh Xil Basin (Cyr et al., 2005; C. Wang et al., 2014). An early uplift of the northeastern TP is however suggested as early as the late Eocene by increased coniferous pollen proportion in the Xining Basin (Hoorn et al., 2012), although cooling and Paratethys Sea retreat were also shown to promote coniferous trees expansion in this region (Barbolini et al., 2020).

The history of the TP build-up from the Miocene onward is less controversial. The Central TP would have reached modern elevation by the early Miocene, while the northern TP uplift is completed by the late Miocene (C. Wang et al., 2014). Stratigraphy and detrital zircon analysis indicate that the western TP (Pamir-Karakoram-Hindu Kush) may have underwent several phases of uplift between the mid Eocene to latest Miocene (Bershaw et al., 2012; L. Li et al., 2021; Blayney et al., 2016; Carrapa et al., 2015). Finally, the Himalayas start uplifting in the early Miocene (~ 20 Ma) and reach their modern elevation by the mid-late Miocene (~ 15 Ma) (Gébelin et al., 2013; L. Ding et al., 2017; Xu et al., 2018; C. Wang et al., 2014; Webb et al., 2017).

4.1.3 *Inland Asia and Myanmar mountain building*

Asian terranes located in the vicinity of the HTP complex are impacted by the Indo-Asian collision. In Myanmar, the Sino and Indo-Burman Ranges have distinct uplift histories. Indo-Burma ranges build-up in a three-step process in the late Eocene, at the Oligo-Miocene boundary and Pliocene respectively (Najman et al., 2020; Morley, 2018; Maurin & Rangin, 2009; Westerweel et al., 2020; Licht et al., 2018), as a result of the progressive indentation of the Burma block into the Eastern Himalayan collision zone. The Sino-Burman Ranges inherited old landforms from previous collisions between Indochina and Sibumasu terranes (Metcalf, 2013) and experienced major uplift in the mid-late Miocene (~ 13 - 9 Ma) (Cook & Royden, 2008; Clark et al., 2005), as a result of the Tibetan crustal flow eastward propagation.

North of the Tibetan Plateau, the collision propagated through reactivated pre-existing tectonic structures and triggered the uplift of the inland Asia orogenic belt: the Tian Shan and the Mongolian (Altai, Hangay and Sayan) landforms (Jolivet et al., 2010). The southwestern and Central Tian Shan uplift initiation is very loosely constrained, either in the middle to late Miocene (~ 15 Ma, (Käbner et al., 2016)), late Oligocene to early Miocene (~ 25 Ma, (Bande et al., 2017; Macaulay et al., 2016, 2014)), or in the Eocene-Oligocene (D. Liu et al., 2017; Tapponnier & Molnar, 1979). The northeastern Tian Shan, together with the Sayan and Altai regions (in western Mongolia), likely remained quiescent until the

late Miocene (Bullen et al., 2003; Caves Rügenstein et al., 2017). After a global pulse of uplift at the latest Miocene (~ 8 Ma) for the whole Tian Shan, Sayan and Altai mountains (W. Yuan et al., 2006; Caves Rügenstein et al., 2017; Charreau et al., 2005), regional landforms would have reached their full elevation after a last Pliocene uplift phase (~ 5 -3 Ma, (Bullen et al., 2003; Caves Rügenstein et al., 2014; De Grave et al., 2007, 2009; Jolivet et al., 2007; Vassallo et al., 2007)). The Hangay Dome uplift (in central Mongolia) began in the mid-Oligocene (Caves Rügenstein et al., 2014; Cunningham, 2001), but the date of completion of the uplift remains debated, either in the mid-Miocene (~ 13 Ma, (Smith et al., 2016)), or the Pliocene (~ 3 Ma, (Yarmolyuk et al., 2008)).

4.1.4 Evolution of Asia in our reference paleogeographic configurations and sensitivity experiments performed

Our late Eocene reference paleogeography (**LEo1_REF**, ~ 40 Ma, Fig. 3 a), previously introduced in (Tardif et al., 2020), displays a fully emerged *Greater India* and a TP elevation set to ~ 3000 m. Considering the persistent controversy surrounding the extension of India and the TP morphology at that time, other configurations are tested to better understand the sensitivity of our results to these features. **LEo2_TP** (Fig. 3 b) is an alternative late Eocene paleogeography, with a slightly different Tibetan Plateau shape (obtained with the "double collision model" in Poblete et al. (2021)), from which we derived sensitivity tests with a lowered Tibetan Plateau (~ 800 m, **LEo2_TPlow**, Fig. 3 c) and a high Tibetan Plateau (~ 4500 , **LEo2_TPhigh**, Fig. 3 d). Two additional tests are performed, with a Tibetan Plateau translated more to the South (**LEo2_TPsouth**, Fig. 3 f), obtained with the collision model from Jagoutz et al. (2015) and the presence of a remaining Bengal Sea (**LEo2_sea**, Fig. 3g), obtained with the collision model from D. J. J. van Hinsbergen et al. (2012); D. J. van Hinsbergen et al. (2019).

The early Oligocene simulation (**EOLI_REF**, ~ 33 Ma, previously introduced in Barbolini et al. (2020)), is designed to represent the Asian climatic state right after the Eocene-Oligocene Transition (Fig. 3 e). We use the same late Eocene paleogeography from **LEo1_REF**, in which the sea level is lowered by 70 m to account for an ice sheet over Antarctica with a modern extent (it is an end-member scenario). This leads to important changes in terms of land-sea distribution, principally in the Paratethys Sea region, detailed in section 4.2.3.

The early Miocene paleogeography (**EMio_REF**, ~ 20 Ma, Fig. 3 h) (previously introduced in Sarr et al. (2022) and Burls et al. (2021), from Poblete et al. (2021)) displays an Indian subcontinent translated 5° further north compared to the Eocene, and an uplifted Central TP close to its present elevation (~ 5000 m), while western and northeastern TP portions are lower (~ 2000 -3000 m). In the middle (**MMio_REF**, ~ 12 Ma, Fig. 3 k) and late Miocene (**LMio_REF**, ~ 8 Ma, Fig. 3 o) paleogeographic configurations, the Himalayas and Tibetan Plateau have reached their present day configuration, along with the peripheral landforms in Myanmar and inland Asia (Fig. 3). Sensitivity tests are performed on inland Asian landforms, lowering to ~ 800 m the elevation of Mongolia (**LMio_noM**, Fig. 3 p), the Tian Shan (**LMio_noTS**, Fig. 3 q), both Mongolia and Tian Shan (**LMio_noTSM**, Fig. 3 n), and finally, the Tian Shan and Pamir (**LMio_noTSP**, Fig. 3 r).

4.2 The Peri-Tethys region evolution under the complex interplay of tectonics and global sea level changes

Throughout the Cenozoic, global sea level fluctuations in an active tectonic convergence context have led to a profound paleogeographic reorganization and a general increase in continentality of the regions encompassing the Mediterranean Sea, Middle East and inland Asia. We resume here the main paleogeography changes (in terms of sea connections between Indian, Atlantic and Arctic Oceans).

825 **4.2.1 Retreat of the Paratethys Sea and closure of the Neotethys Ocean**

826 During the Paleocene-Eocene, Eurasia is largely flooded by the proto-Paratethys, an
 827 epicontinental sea connected to the Arctic Ocean *via* the Turgai Strait and to the Neotethys
 828 Ocean (Meulenkamp & Sissingh, 2003; Golonka, 2009). Paleoenvironmental analysis suggest
 829 a maximal extension of the proto-Paratethys Sea reaching the Tajik and Tarim Basins, in
 830 inland Asia, at the Paleocene-Eocene transition (~56 Ma), followed by a long-term westward
 831 retreat, punctuated by marine transgressions of decreasing magnitude (Kaya et al., 2019;
 832 Bosboom et al., 2014b, 2017; Carrapa et al., 2015). In Central Asia, the shrinkage of the
 833 proto-Paratethys Sea during the Eocene is attributed to far-field effect of the Indo-Asia
 834 collision and to the early indentation of the Pamir and TP, leading to the progressive basins
 835 infilling with sediments (Kaya et al., 2019; Carrapa et al., 2015). The build-up of the
 836 Antarctic ice-sheet initiated in the late Eocene, resulted in a sea-level drop that culminated
 837 at the EOT (~33.5 Ma, sea-level fall estimated at ~70 m by Miller et al. (2020)), which
 838 drastically reduced the extent of the Paratethys and favored its isolation (Kaya et al., 2019;
 839 Bosboom et al., 2014b, 2017). Water exchanges between the Paratethys and global oceans
 840 are progressively restricted, as attested by $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ of foraminifera shells diverging
 841 increasingly from global oceanic signals at that time (Ozsvárt et al., 2016). The Paratethys
 842 Sea is fully isolated from the Mediterranean Sea at ~12 Ma, with the final uplift of the
 843 Dinarides belt (Harzhauser & Piller, 2007). A connection with the Mediterranean Sea is
 844 restored between 6.9–6.1 Ma when the Aegean region subsides during the latest Miocene
 845 (Krijgsman et al., 2020).

846 The Tethyan Seaway (or Mesopotamian Seaway) which connected Indian and Atlantic
 847 Oceans remained fully open before the Miocene (Straume et al., 2020). ϵNd data suggest
 848 that it became strongly restricted around ~22 Ma (Bialik et al., 2019), with intermittent
 849 periods of closure, as attested by evidence of mammal exchanges between Eurasia and
 850 Africa through the Gomphotherium landbridge (Rögl, 1999; Harzhauser & Piller, 2007).
 851 The Tethyan Seaway permanently closed at ~14 Ma (Bialik et al., 2019), due to combined
 852 effect of Arabian-Eurasian plates collision and glacio-eustatic sea level fall associated with
 853 the cooling following the Mid-Miocene Climatic Optimum (MMCO).

854 **4.2.2 Middle-East: Eastern Anatolian-Iranian Plateau and Zagros Moun-** 855 **tains**

856 The Middle-East experienced multiple changes in land-sea distribution and topogra-
 857 phy, forced by the collision of the Arabian plate with Eurasia, which drove the uplift of
 858 the Zagros mountains and of the Iranian Plateau. The exact timing of the Arabia-Eurasia
 859 collision in eastern Anatolia remains highly debated with estimated date ranging from the
 860 Eocene-Oligocene (Karaođlan et al., 2016; Darin et al., 2018; McQuarrie & Hinsbergen,
 861 2013; Pirouz et al., 2017), the early Miocene (Okay et al., 2010; Gülyüz et al., 2020), to
 862 the late Miocene (H. Su & Zhou, 2020; Z. Zhang et al., 2017). Most studies however pro-
 863 pose an early Miocene age (~20 Ma) for the hard collision related to the arrival of thick
 864 Arabian crust along the Bitilis suture zone (Okay et al., 2010; Cavazza et al., 2018; Gülyüz
 865 et al., 2020). After the collision, the Zagros orogen built up during three successive pulses
 866 occurring within the last ~20 Ma (Agard et al., 2011; Mouthereau, 2011).

867 The Alborz mountains uplift (northwest of the Zagros) is dated during the middle
 868 Miocene (~17.5–13 Ma), according to sediments stable isotopic signatures (Ballato et al.,
 869 2010, 2015) and may have continued until the latest Miocene (Mouthereau et al., 2012).
 870 A Miocene age for the commencement of the eastern Anatolian Plateau growth has been
 871 estimated based on the youngest marine unit of the eastern Anatolian Plateau (~17 Ma)
 872 (Gülyüz et al., 2020) and apatite fission-track data (18–13 Ma) (Okay et al., 2010; Karaođlan
 873 et al., 2016). Stratigraphic evidence suggest a rise due to crustal shortening and thickening
 874 occurring between 15 and 12 Ma (Mouthereau et al., 2012). Numerical simulations suggest
 875 a buildup of the Plateau within ~15–20 Ma after the continental collision, likely sustained

876 by slab break-off, mantle flow disruption and associated changes in dynamic topography,
 877 followed by isostatic adjustment (François et al., 2014). With this mechanism, the modern
 878 elevation (~ 1500 m.a.s.l) is only reached during the late Miocene ($\sim 7-10$ Ma).

879 **4.2.3 Evolution of the Peri-Tethys region in our reference paleogeographic** 880 **configurations and sensitivity experiments performed**

881 Our paleogeographic reference configurations are consistent with the geological history
 882 of the Paratethys Sea demise and with uplift phases in the region. In our late Eocene
 883 geography (**LEo1_REF**, Fig. 3 a) the proto-Paratethys Sea fills the Tarim Basin ; it is still
 884 connected to the Neotethys and Indian Oceans, but not to the Arctic, as the Turgai Strait
 885 is already closed. In the Oligocene reconstruction (**EOLI_REF**, Fig. 3 e), the 70 m sea
 886 level drop (Miller et al., 2020)) leads to the emergence of continental portions in Arabia and
 887 North-Africa, and to the drying of the Tarim Basin and lowlands north of the Turgai Strait,
 888 which all conspire to increase greatly Asian continentality. The former shallow connection
 889 between the Paratethys and the Tethys ceases in the Pamir-Zagros region at that time. In
 890 the early Miocene geography (**EMio_REF**, Fig. 3 h), an emerged land-bridge interrupts
 891 the Tethyan seaway that previously connected the Mediterranean Sea and the Indian Ocean,
 892 but shallow sea persists at the location of the present-day Arabian Peninsula. Given the
 893 uncertainty surrounding the precise closure time of the seaway, an alternative early Miocene
 894 configuration is also tested, with a 120 m deep Tethyan seaway (**EMio_TetSw**, Fig. 3 i).
 895 In the middle Miocene reference simulation (**MMio_REF**, Fig. 3 k), the Iranian Plateau
 896 and Zagros mountains are halfway uplifted (~ 1000 m) compared to present-day and the
 897 Paratethys extends up to 60° E. By the late Miocene (**LMio_REF**, Fig. 3 o), the Paratethys
 898 is strongly reduced and the Iranian landforms have reached their modern elevation. An
 899 intermediate reconstruction is proposed, testing the impact of the Paratethys retreat only,
 900 in the mid-late Miocene (**LMio_smallT**, Fig. 3 l). Note that LMio_smallT is the mid-late
 901 Miocene paleogeography to which all others late and middle Miocene simulations can be
 902 compared to, to single out the effect of regional changes.

903 **4.3 East Africa and Arabian Peninsula evolution**

904 While much attention has been paid to the Eastern African topography evolution in the
 905 Neogene due to its implication on early hominins development, its history fits in a broader
 906 paleogeographic context rooted in the late Eocene to early Oligocene times (see Couvreur
 907 et al. (2021); Guillocheau et al. (2018) for a synthesis). Landforms in East Africa (Kenyan
 908 and Ethiopian plateaux) developed during the late Cenozoic, triggered by a combination
 909 of tectonics, basaltic flooding, and large wave-length deformation related to the African
 910 superswell activity (Moucha & Forte, 2011; Faccenna et al., 2019; Roberts et al., 2012).
 911 Uplift in the Ethiopian region would have began during the Eocene, with doming event
 912 sustained by dynamic topography (Roberts et al., 2012; Faccenna et al., 2019) that then
 913 propagates to Kenya during the middle Miocene. In the early Oligocene, basaltic flooding
 914 in Ethiopia would have contributed to the formation of these large-scale elevated features
 915 (Sembroni et al., 2016). Rifting initiated during the middle Miocene, with main uplift of
 916 rift shoulders (Wichura et al., 2015). Overall, past elevations in the course of the Cenozoic
 917 are poorly constrained in East Africa, but modern elevations were most likely reached by
 918 the late Miocene to early Pliocene (Couvreur et al., 2021).

919 **4.3.1 Arabian Peninsula**

920 The Arabian Peninsula records successive marine and freshwater environments from
 921 the early Oligocene to the late Miocene, as attested by paleo-ichtthyofaunas (Otero &
 922 Gayet, 2001). Before the Neogene, the Arabian plate is assumed to be flat and low ele-
 923 vated (Daradich et al., 2003), making it particularly sensitive to sea-level changes. It is
 924 therefore largely submerged during the Eocene, and its southwestern part becomes par-

925 tially emerged after the sea-level fall at EOT (Barrier et al., 2018). During the Miocene,
 926 the Arabian plate is tilted when transiting over the East-Africa mantle plume (Vicente de
 927 Gouveia et al., 2018), leading to the uplift of the Red sea margin, and the flooding of its
 928 northeastern corner, due to mantle convective drawdown (Daradich et al., 2003; Moucha
 929 & Forte, 2011). This mechanism favored temporary transgression phases in the subdued
 930 northeastern region in early Miocene times (Barrier et al., 2018), until its full emergence in
 931 the late Miocene, possibly favored by global sea-level fall after the MMCT (Golonka, 2009;
 932 Harzhauser & Piller, 2007; Miller et al., 2020).

933 *4.3.2 Evolution of East Africa and Arabia in our reference paleogeographic* 934 *configurations and sensitivity experiments*

935 Our reference paleogeographic configurations (Fig. 3 a,e,h,k,o) display a low East
 936 Africa during the Eocene-Oligocene, which rises to ~ 750 -1,000 m in the early Miocene and
 937 a modern-like elevation in the mid and late Miocene reconstructions. Given the large uncer-
 938 tainties on east African topography precise elevation, we perform a sensitivity experiment on
 939 an early Miocene paleogeography, with fully uplifted east African landforms (**EMio_EAfr**,
 940 Fig. 3 j). Additionally, a mid-late Miocene configuration displaying an almost fully flooded
 941 Arabian Peninsula is tested (**LMio_noAr**, Fig. 3 m), to account for its high sensitivity to
 942 sea level fluctuations at that period.

943 **5 Materials and Methods**

944 **5.1 IPSL-CM5A2 model**

945 We performed the simulations with the IPSL-CM5A2 Earth System Model (Sepulchre
 946 et al., 2020), an updated version of the IPSL-CM5A model (Dufresne et al., 2013) suitable
 947 for deep-time paleoclimate simulations. It is composed of the atmospheric model LMDz5A
 948 (Hourdin et al., 2013), the land surface and vegetation model ORCHIDEE (Krinner et al.,
 949 2005) and the oceanic model NEMO (v3.6) (Madec, 2016) that also includes the LIM2
 950 model (Fichefet & Maqueda, 1997) for sea-ice. OASIS coupler ensures synchronization
 951 between the different model components (Valcke et al., 2006). Atmospheric component
 952 has a nominal horizontal resolution of 96x95 grid points (3.75° in longitude by 1.9°
 953 in latitude) with 39 irregularly distributed vertical levels from the surface to 40 km high.
 954 The land surface ORCHIDEE model is coupled with LMDZ5a and redirects runoff water
 955 toward the ocean. The vegetation cover is represented through 11 Plant Functional Types
 956 (PFTs), including one describing bare soil. NEMO uses a tripolar grid, with two poles in
 957 the Northern hemisphere to avoid singularity (Madec & Imbard, 1996). It has a resolution
 958 of 2° by 2° refined at 0.5° in the equatorial region, with 31 vertical levels, whose thickness
 959 span from 10 meters near the surface to 500 meters in the deep ocean. Full description of
 960 IPSL-CM5A2 can be found in Sepulchre et al. (2020); Dufresne et al. (2013).

961 IPSL-CM5A2 has been previously used for paleoclimatic simulations of the Miocene
 962 (Burls et al., 2021; Sarr et al., 2022) and the Eocene (Toumoulin et al., 2020; Tardif
 963 et al., 2020; Barbolini et al., 2020; Tardif et al., 2021; Toumoulin et al., 2022). The ability
 964 of the model to simulate the modern Asian climate was previously assessed (Sepulchre et
 965 al., 2020; Tardif et al., 2020) and a comparison with observations is provided (SI, Fig. 15).
 966 While general atmospheric circulation patterns are well reproduced, IPSL-CM5A2 overall
 967 underestimates precipitation amounts and delays inland monsoonal precipitation onset by
 968 about a month, a feature shared with IPSL-CM5A version (Sepulchre et al., 2020; Valdes
 969 et al., 2017).

970 **5.2 Experiments design**

971 The boundary conditions are summarized in Table 1. Experiments at Late Eocene
 972 are considered ice-free, as $p\text{CO}_2$ is above the threshold for permanent Antarctic glaciation

973 (Ladant et al., 2014; DeConto & Pollard, 2003). Unipolar glaciation, with Antarctic ice-
 974 sheet only, is used for the Oligocene and early Miocene and both Greenland and Antarctic
 975 ice-sheets are accounted for in the late Miocene (Bierman et al., 2016) configurations. CO₂
 976 concentration varies from 1,120 ppm for the late Eocene to 560 ppm in the late Miocene
 977 (Table 1) Foster et al. (2017); Rae et al. (2021), while other greenhouse gases are kept at
 978 preindustrial values. Given the persistent uncertainties regarding precise $p\text{CO}_2$ concentra-
 979 tion during the Cenozoic, we performed two additional sensitivity tests on this parameter,
 980 in the late Eocene (**LEo1_2X**, 560 ppm), and in the late Miocene (**LMio_1.5X**, 420 ppm).
 981 The solar constant was adjusted according to Gough (1981) and set to 1360.19 W.m⁻² for
 982 late Eocene and early Oligocene simulations, to 1362.92 W.m⁻² for early Miocene simu-
 983 lations and to 1364.30 W.m⁻² for late and middle Miocene simulations. Although orbital
 984 variations are known to impact monsoonal circulation (Zhisheng et al., 2015; P. Wang et
 985 al., 2005; Tardif et al., 2021), we prescribed a modern-like configuration to focus on the
 986 impact of paleogeography on the monsoon system. Considering the lack of congruent global
 987 vegetation reconstruction over the Cenozoic, the same PFT map was used throughout the
 988 experiments, prescribing latitudinal bands of idealized vegetation cover based on modern
 989 distribution, as done in previous studies (Tardif et al., 2020; Laugié et al., 2020). The
 990 reference experiments have been run for 3000 years and deep ocean layers reached quasi-
 991 equilibrium after ~ 2000 years of integration. Sensitivity experiments were restarted from
 992 there reference experiments an run for 300 to 500 years until reaching stable sea surface
 993 temperatures. Model outputs are averaged over the last 50 years.

994 5.3 Monsoon metrics

995 The evolution of Asian monsoons back in time is assessed through specific markers
 996 that are characteristic of the present-day phenomenon. We favored SAM and EAM features
 997 offering means of comparison with paleoclimate records, which typically involve precipitation
 998 amounts, seasonality and wind direction and strength. Several features of the monsoons,
 999 however, are not recorded by proxies, or in a very indirect way. This is for example the case
 1000 of the pressure patterns, and of all mid-to-high tropospheric features associated with the
 1001 modern monsoons. In that aspect, numerical simulations are a valuable tool to grasp the
 1002 full signature of eventual paleo-monsoons.

1003 For both SAM and EAM, we evaluated the evolution of precipitation seasonality using
 1004 the Monsoon Precipitation Index (MPI) (B. Wang & Ding, 2008), expressed as follow:

$$\text{MPI} = \frac{\text{Seasonal range of precipitation}}{\text{Mean annual precipitation}}$$

1005 where the seasonal range of precipitation is the difference between May to September
 1006 (MJJAS) precipitation minus November to March (NDJFM) precipitation. Regional oc-
 1007 currence of a monsoon-like seasonality is considered providing a seasonal range superior to
 1008 300 mm and a majority of precipitation falling during the extended summer season (MPI
 1009 > 0.5). This criteria has the benefit of not being exclusive (with or without monsoon), as
 1010 it proposes a discrete metric for seasonality amplitude (from 0 to 1). It also imposes the
 1011 wet season to be in summer, as in the present-day monsoon region, as opposed to other
 1012 existing precipitation metrics (such as the ratio of the 3 wettest month over the 3 driest
 1013 month precipitation, commonly used in paleobotanic studies), which enables us to test the
 1014 presence of modern-like climate patterns.

1015 The wind patterns, described through their shape and strength, are the second funda-
 1016 mental characteristic observed. The latitudinal migration of the Somali Jet is tracked over
 1017 the Arabian sea (Fluteau et al., 1999). The wind shear between low and high troposphere
 1018 over India, that describes the vigor of the SASM zonal circulation and its inclusion in the
 1019 Walker circulation, is calculated through the Webster-Yang Index ($U_{850}-U_{200}$, calculated in
 1020 an area from 0°:20°N to 40°E:110°E) (Webster et al., 1998). The positive thermal anomaly

1021 observed at 200-300 hPa over northern India in summer has additionally been used as a
 1022 marker of the deep convection characterizing the modern SASM (Boos & Kuang, 2010;
 1023 Acosta & Huber, 2020). This feature is due to the important latent heat release provoked
 1024 by the condensation of moisture in convecting air masses and in air masses ascending on the
 1025 southern flank of the Himalayas, which heat the high troposphere (see Fig. 14 c). Fewer
 1026 criteria exist to formally describe the EAM. In addition to the precipitation seasonality de-
 1027 scribed through the Monsoon Precipitation Index, we tracked the EASM via the description
 1028 of the latitudinal displacement of the Jet Stream with respect to Tibetan and inland Asia
 1029 landforms, and the surface wind patterns that constitute the Meiyu-Bayu front at present-
 1030 day. The EAWM is tracked principally through the evolution of temperature and pressure
 1031 gradients, leading to the Siberian High formation in winter, and of its associated wind pat-
 1032 terns. Here we used the EAWM index defined by L. Wang and Chen (2014) that accounts for
 1033 both the North-South (Siberia-Maritime continent) and West-East (Siberia-North Pacific)
 1034 pressure gradients and is expressed as follow:

$$I_{\text{EAWM}} = (2 \times \text{SLP}_{\text{S}} - \text{SLP}_{\text{NP}} - \text{SLP}_{\text{MC}}) / 2$$

1035 where SLP_{S} , SLP_{NP} and SLP_{MC} is the area-averaged Sea Level Pressure (SLP) over
 1036 Siberia (40°:60°N, 70°:120°E), North Pacific (30°:50°N, 140°E:170°W) and the Maritime con-
 1037 tinent (20°S:10°N, 110°:160°E), respectively.

1038 6 Results

1039 We present the results obtained for the five reference simulations as well as for the
 1040 different sensitivity numerical experiments, first for the South Asian Monsoon, then for the
 1041 East Asian Monsoon domain. Main outcomes in terms of seasonal winds and precipitations
 1042 are qualitatively summed up in Table 6.

1043 6.1 South Asian summer monsoon controlled by the orography surround- 1044 ing the Indian Ocean

1045 6.1.1 *Spatial and seasonal precipitation patterns evolution*

1046 In the late Eocene a wide arid region (< 500 mm/yr) spreads from northern India
 1047 to north of the proto-Tibet (Fig. 4 a). High mean annual precipitation amounts (> 3000
 1048 mm/yr) are simulated over equatorial regions, in southern India and southeastern Asia.
 1049 There is no monsoon-like seasonality according to the MPI index in India, because the
 1050 rainy season in this region occurs in winter (as previously described in Tardif et al. (2020)).
 1051 The precipitation pattern evolves from the early Oligocene onward, with the progressive
 1052 translation of the arid region to Arabia and Northern Africa (Fig. 4 e,i,m,q). This in
 1053 turn allows the penetration of rainfall in summer in South-Eastern Asia, and the onset
 1054 of a monsoon-like seasonality in this region, as well as a reinforcement of monsoon-like
 1055 seasonality in Eastern Asia.

1056 In the course of the Miocene, as India drifts northward, its southern tip receives less
 1057 precipitation (~ 1500 mm/yr in the late Miocene, Fig. 4 q), and the intensity and extent of
 1058 highly seasonal precipitation increases greatly over southern and eastern Asia (red dotted
 1059 regions in Fig. 4 e,i,m,q). Orographic precipitation over the southern flank of the Himalayas
 1060 initiate by the mid Miocene simulation (~ 900 mm/yr, Fig. 4 m), and further increase in the
 1061 late Miocene ($\sim 1200 - 1500$ mm/yr, Fig. 4 q). These changes in precipitation patterns in
 1062 both space and time are triggered by a profound reorganization of surface pressure patterns
 1063 and winds throughout the Cenozoic.

Overview of the effect simulated in each region. Abbreviations stand for Transition Area (TA), cardinal directions (E, W, S, N), Basins mentioned in Fig. 1 (eg. Tadjik E)

	SAM				EAM				Inland Asia	
	Precipitation		Winds	Seasonality	Precipitation		Winds	Seasonality	Winter	Summer
	Winter	Summer			Winter	Summer				
No TP (LEo)	~	++			+	--	~	+	~	~
High TP uplift (LEo)	~	+	~		++					~
TP South (LEo)	-	+			+				~	~
Bengal Sea (LEo)	+	++	-		+				+	+
CO2 decrease (EOT)	--	++	+	(TA)	~		~	+	+	+
CO2 and sea level fall (EOT)	---	+++	+	(TA, North. India)	--	++	+	(E)	--	+
East Africa uplift (EMio)	+	++	-	(India) + (TA, Himalaya)	+	+++ (Somali Jet)	+	+	+	-
Paratethys retreat (LMio)	~	++	+		+	++	+	+(SW)	--	~
Arabian peninsula emergence (LMio)	+	+	~		-	+	+	~	-	-
Iranian uplift (LMio)	--	++	+++		-	+++ (Somali Jet)	+		+	++
Mongolia uplift (LMio)	~	~	+		---		~	+++ (NW)	+	++(orog.) -- (Gobi, Takl., TS, Tjk)
TienShan uplift (LMio)	+	~	-		-		~	+	+(orog.) -- (Gobi Takl.)	+(orog.)
TienShan+Mongolia a uplift (LMio)	+	~	+		---		~	+++ (NW)	+(orog.) -(Gobi)	+(orog.) -(Takl, Tjk.)
TienShan+Pamir uplift (LMio)	+	+	--		~	+	~	+(SW)	+(orog.) -(Gobi, Takl.)	++(orog.) -(Tjk)

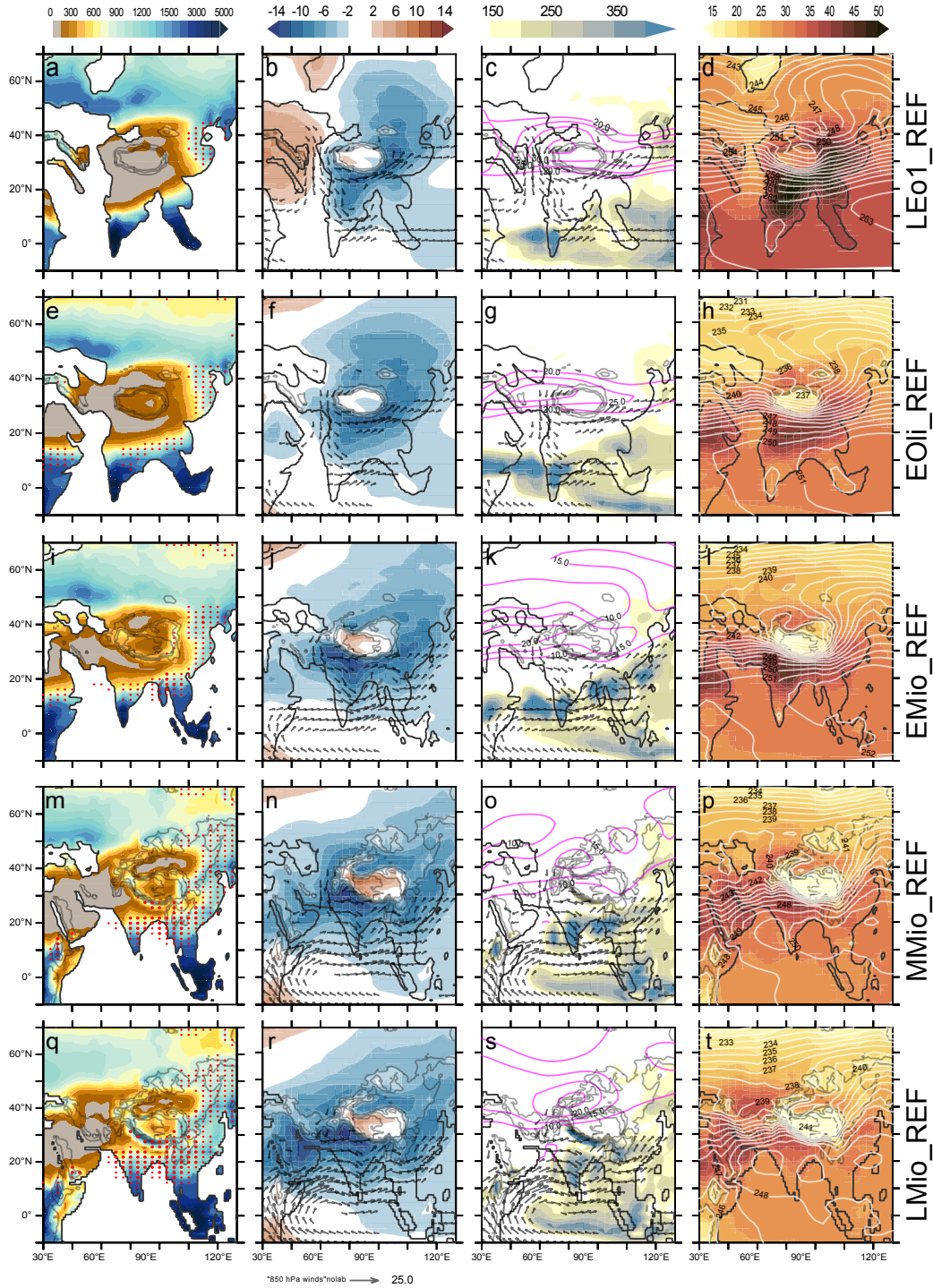


Figure 4. Evolution of the summer monsoon diagnostics since the Eocene. **First column:** Mean Annual Precipitation (shading, mm/yr) overlain with regions where the Monsoon Precipitation Index is over 0.5 (thin red dots) and 0.75 (thick red dots); **Second column:** June-August (JJA) normalized Sea Level Pressure (SLP) anomaly defined as the difference between summer SLP and mean annual SLP (shading, hPa) and 850 hPa winds over 4 m/s (vectors); **Third column:** August Jet Stream speed (magenta contour, maximal zonal wind velocity in the mid to high troposphere, in m/s), August monthly precipitation amounts (shading, mm/month) and 850 hPa winds over 4 m/s (vectors) ; **Fourth column:** JJA mean temperature at 2m (shading, Celsius) and 300 hPa atmospheric temperature (white contour, Kelvin). On all captions, topography is overlain in gray contour each 1000 m.

1064 **6.1.2 Summer pressure and wind patterns reorganization**

1065 The summer (June to August, JJA) sea level pressure (SLP) patterns in Eurasia in
 1066 the late Eocene experiment (Fig. 4 b) contrast strongly with the modern ones (Fig. 14 d).
 1067 While a low-pressure center driven by extreme summer temperature forms over southeastern
 1068 Asia (up to 50°C over *Greater India*, Fig. 4 d), the Paratethys Sea and Neotethys Ocean are
 1069 the locus of a wide high pressure cell (Fig. 4 b). This induces low tropospheric anticyclonic
 1070 wind patterns, that counteract potential moisture advection from the Indian Ocean towards
 1071 South Asian regions. From the early Oligocene onward, the Paratethys Sea and Neotethys
 1072 shrinkage increase the Eurasian continentality and emerging landforms, such as Anatolia
 1073 and Arabia, become the locus of high summer temperature (35-45°C, Fig. 4 l,p,t). This
 1074 leads to the progressive widening of the South Asian low-pressure belt, while the Neotethyan
 1075 anticyclone gradually regresses westward (Fig. 4 f,j,n,r). This low pressure cell reaches its
 1076 modern-like extent in the mid Miocene simulation (Fig. 4 n), but only attains its current
 1077 values (~14 hPa over Arabia and northern India) by the late Miocene (Fig. 4 r).

1078 Mirroring this progressive strengthening and widening of the summer low-pressure
 1079 belt over South Asia and Arabia, humidity-loaded air masses are gradually advected from
 1080 the Indian Ocean towards the continent over the Cenozoic. A weak cross equatorial flow
 1081 (<4 m/s against ~25 m/s today), confined to low latitudes (<10°N, Fig. 5 a, simulations
 1082 LEo1_REF and EOli_REF) is simulated over the Arabian Sea in the late Eocene and early
 1083 Oligocene experiments (Fig. 4 b,f). A proto-Somali Jet, mostly zonal and confined to
 1084 low latitudes (<11°N) is simulated in the early Miocene simulation (Fig. 5 b, simulation
 1085 EMio_REF). From the mid Miocene onward, and following the reinforcement of the Asian
 1086 low-pressure belt, the now fully-formed Somali Jet increases in strength and migrates further
 1087 north over the Arabian Sea (~18-24°N) (Fig. 4 n,r and Fig. 5 b, simulations MMio_REF
 1088 and LMio_REF).

1089 The simulated tropospheric circulation above southern Asia deeply evolves since the
 1090 Late Eocene, as exemplified by the calculation of the Webster-Yang Index. This index
 1091 doubles between the late Eocene and the early Oligocene (from ~5 to 11 m/s, Fig. 5 c,
 1092 reference simulations LEo1_REF and EOli_REF), and keeps increasing through the Miocene
 1093 (from ~16 to 21 m/s, Fig. 5 d, simulations EMio_REF, MMio_REF and LMio_REF). Finally,
 1094 while heating of the high troposphere (~300 hPa) due to deep convection is observed in most
 1095 experiments (Fig. 4 d,h,l,p,t), its settlement over Northern India is only reached by the mid
 1096 Miocene experiment, following the increase in summer convective precipitation in this region
 1097 driven by orographic lifting.

1098 **6.1.3 Limited effect of $p\text{CO}_2$ drawdown and Tibetan Plateau changes on** 1099 **South Asian summer monsoon evolution**

1100 The non-linearity in the response of the Somali Jet through time calls for a more
 1101 thorough analysis of the different forcing at stakes between each of these simulations. In
 1102 this section, we take advantage of our different alternative paleogeography reconstructions
 1103 and $p\text{CO}_2$ to attribute the simulated changes to their respective underlying drivers. Overall,
 1104 the SASM presents a low sensitivity to $p\text{CO}_2$ changes, when compared to paleogeographic
 1105 forcings. This is true for the late Eocene experiments, where a change from 1120 ppm to 560
 1106 ppm only induces minimal variations in the WYI (Webster-Yang Index) strength, summer
 1107 northward ITCZ migration (difference between experiments LEo1.2X and LEo1_REF in
 1108 Fig. 5 a,c), or monsoon-like seasonality extension (Fig. 7 f). This is also the case for the
 1109 late Miocene experiments, with a switch from 560 ppm to 420 ppm (difference between
 1110 experiments LMio.1.5X and LMio_REF in Fig. 5 b,d).

1111 The paleogeography of *Greater India* and Tibetan regions have been recurrently pro-
 1112 posed as a driver of monsoon onset or intensification (R. Zhang et al., 2012; Yu et al., 2018;
 1113 Molnar et al., 1993). While alternative TP configuration lead to slightly different results
 1114 (detailed below), their impact on the SASM large-scale wind circulation remains limited in

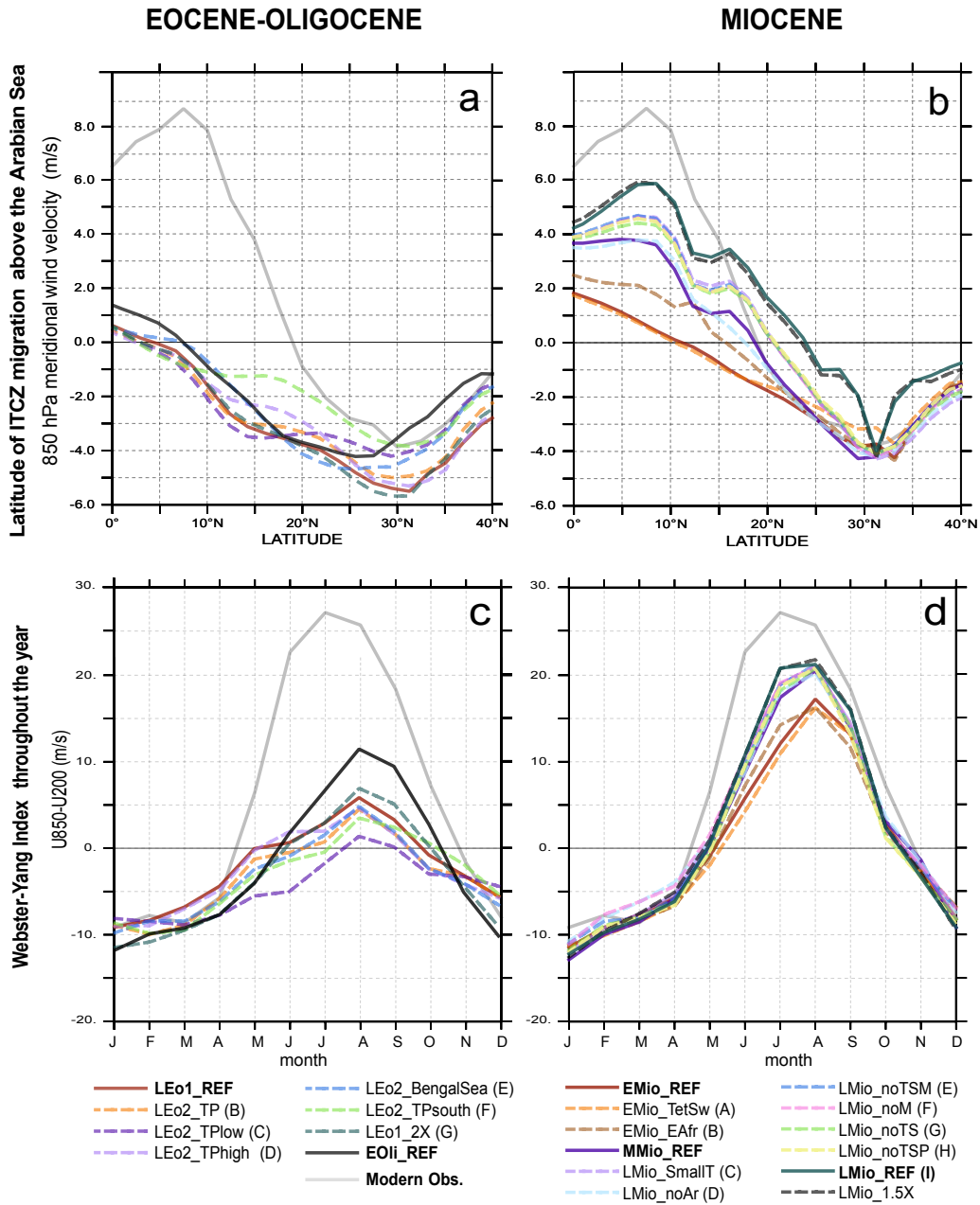


Figure 5. Estimation of the South Asian monsoon strength evolution in all the simulations via: (a,b) the calculation of the summer (JJA) cross-equatorial flow latitude over the Arabian Sea, after Fluteau et al. (1999) and (c,d) the calculation of the Webster-Yang Index (850 hPa minus 200 hPa zonal wind velocity, in the region 0:20 °N ; 40:110 °E, after Webster and Yang (1992)). For better readability, the experiments are split into Eocene-Oligocene (a,c) and Miocene (b,d) simulations. Reference simulations are highlighted in bold characters and full lines, while sensitivity tests are in dotted lines.

our simulations (Fig. 5 a,c and Fig. 6). In the late Eocene, increasing TP elevation strengthens the zonal wind shear over India (3000 m, WYI = \sim 6 m/s, for experiment LEO2_TP, Fig. 5 c), when compared to Eocene experiment with low topography in the region (800 m, WYI = 1 m/s, LEO2_TPlow). Additionally, the magnitude of the WYI gradually increases with the TP latitude, with values spanning from 3 m/s when its southern edge is at \sim 20°N (LEO2_TPsouth), 4 m/s (southern edge at \sim 25°N in LEO2_TP), to finally 6 m/s (southern edge at \sim 30°N, experiment LEO1_REF). The sea inlet that flooded the northern *Greater India* during the late Eocene, as sometimes suggested in the literature (D. J. J. van Hinsbergen et al., 2012; D. J. van Hinsbergen et al., 2019), limits the northward migration of the ITCZ in summer (from \sim 7 to 3°N between experiments LEO2_BengalSea and LEO2_TP, Fig. 5 c). It also produce a decrease in year-round precipitation, especially in South and inland Asia (Fig. 6 m,n,o).

6.1.4 *Continentality increase and East African and Iranian uplifts as major drivers of the South Asian summer monsoon*

The changes induced by the Tibetan plateau uplift or by its latitudinal location on the South Asian climate are however out-competed by far by the effects of other paleogeography changes, namely a global sea-level fall, reflecting the Antarctica glaciation at the EOT and the uplift of peripheral terranes (Fig. 5). Indeed, the increase in continentality driven by the sea level fall, together with the $p\text{CO}_2$ halving, induces a colder and drier winter (Fig. 7 g) as well as hotter and wetter summer (Fig. 7 h), which results into a monsoon-like seasonality signal stretching over Southeastern Asia (Fig. 7 i). It also translates into a doubling of the WYI (from 6 to 11 m/s between experiments EOLI_REF and LEO1_REF, Fig. 5 c) and a strong reorganization of summer Jet Stream behavior (see dedicated section below).

Likewise, increasing continentality during the Miocene appears to be the key leverage for inducing a more pronounced migration of the ITCZ over the Arabian Sea (from 18 to 21°N in more continental case, Fig. 5 b), as well as a slight increase of the WYI (Fig. 5 d). This is achieved either with the emergence of the Arabian platform (Fig. 8 g,h,i), or with the narrowing of the Neotethys Ocean and the shrinkage of the Paratethys Sea (Fig. 8 d,e,f). In both cases, the amplification of the summer low pressure belt results into increased moisture advection from the Arabian Sea, and therefore increased summer precipitation in SAM and EAM domains. The overall precipitation seasonality increase is however not homogeneous, because of contrasted effects on the winter season precipitation. Our results point that the Arabian platform emergence, by amplifying the winter Siberian high pressure would dry Eastern Asia and southeastern Tibet, which would increase precipitation seasonality in parts of SAM but mostly in EAM domain (Fig. 8 d,f). The retreat of the Paratethys Sea, on the other hand, would mostly increase precipitation seasonality in the South Asian monsoon domain (Fig. 8 i). Moreover, a clear dichotomy emerges between Central Asia, that becomes drier after the Paratethys Sea retreat, and all surrounding regions that become wetter (Fig. 8 i).

Additionally, the successive buildup of both East African (difference between experiments EMio_EAfr-EMio_REF) and Iran-Zagros landforms (difference between experiments LMio_REF-LMio_smallT) is critical for the amplification of the ITCZ migration and strengthening of SAM. Each uplift triggers a \sim 4-5° northward migration of the ITCZ over the Arabian Sea in summer, as well as a slight increase in July WYI (Fig. 5 b,d). The uplift of East African landforms under Early Miocene conditions reinforces the Somali Jet and brings moisture to Iran-Zagros and SAM domain in summer (Fig. 9 e), which results in intensification of monsoon-like seasonality on the Himalayan foothills and in Southeastern Asia (mainly Myanmar, Fig. 9 f). Iran-Zagros landforms final uplift under late Miocene conditions promotes winter aridity and summer precipitation in SAM domain through a strong strengthening of the Somali Jet, resulting in a reinforced monsoon-like seasonality (Fig. 9 j,k,l). By preventing the advection of westerly mid-latitudes winds to lower latitudes, it channels this humidity towards inland Asia in summer, thus reducing the aridity

1167 of the region. On the other hand, and although being sometimes put forward as a plausible
 1168 event contributing to modification of monsoon strength during the Miocene (Bialik et al.,
 1169 2019, 2020; Rögl, 1997; J. Sun et al., 2021), the mechanical effect of the Tethyan seaway
 1170 closure, without strong modification of land extension in the Arabian Peninsula region, re-
 1171 mains limited in our experiments (+1 m/s for the WYI between experiments EMio_REF
 1172 and EMio_TetSw in Fig. 5 d).

1173 **6.2 The Eastern Asian monsoon under the crossed influence of Asian orog-** 1174 **raphy, continentality and $p\text{CO}_2$**

1175 **6.2.1 EASM: precipitation patterns and summer Jet Stream position evo-** 1176 **lution**

1177 As opposed to the South Asian region, monsoon-like precipitation seasonality is simu-
 1178 lated in Eastern Asia in all reference experiments, although it remains initially confined to
 1179 Northeastern China in the Eocene (Fig. 4 a). As this region of monsoon-like precipitation
 1180 regime expands to southeastern and inland China throughout the Cenozoic and reaches
 1181 modern-like extension in the mid Miocene experiment, the Paleogene broad zonal arid band
 1182 retreats from China (Fig. 4 m). Today, precipitation in eastern China are triggered by the
 1183 penetration of the Meiyu-Bayu front as it follows the migration of the Jet Stream north of
 1184 the Tibetan Plateau during summer (Kong et al., 2017). In our simulations, the summer Jet
 1185 Stream (approximated through the location of maximum zonal wind velocity in the tropo-
 1186 sphere in August), transits above the proto-Tibetan Plateau and Eastern China in a strong
 1187 zonal flux in the Eocene and Oligocene experiments (up to 30-35 m/s centered at $\sim 30^\circ\text{N}$
 1188 Fig. 4 c,g). It then weakens (10-20 m/s) and progressively migrates north of the Plateau in
 1189 the Miocene experiments (Fig. 4 k,o,s). The Jet also loses its very zonal configuration and
 1190 undulates towards Japan. This relocation of the Jet Stream is accompanied by increased
 1191 precipitation in eastern China, southeastern Siberia and Japan, reaching 200-300 mm in
 1192 August (Fig. 4 k,o,s), and locally accounting for up to 25% of the annual precipitation in
 1193 this sole month. These results suggest that the Jet Stream seasonal displacement indeed
 1194 amplifies the EASM rainy season, although seasonal precipitation have been observed in
 1195 this region in Late Eocene experiments.

1196 **6.2.2 Summer Jet Stream migration and associated EASM precipitation** 1197 **driven by $p\text{CO}_2$ decrease at the EOT and the Northern TP, Tian** 1198 **Shan, Pamir and Mongolian uplift in the Miocene**

1199 To identify the drivers responsible for the Jet Stream seasonal migration about the
 1200 Tibetan Plateau, we here again take advantage of the available sensitivity experiments. All
 1201 1120 ppm (or 4X) late Eocene simulations display a behavior of the Jet opposite to its
 1202 modern counterpart, with a northward migration in winter, and a southward migration in
 1203 summer, below or over the proto-Central TP (Fig. 10 a). This tendency remains relatively
 1204 undisturbed with alternative TP configurations (Fig. 10 a and Fig. 6 e,h,k,n). The $p\text{CO}_2$
 1205 halving in the Eocene-Oligocene reverses this tendency (LEo1_2X and EOLI_REF, compared
 1206 to LEo1_REF). It induces a migration northward of the Tibetan landform in late summer
 1207 to early fall (Fig. 10 a and Fig. 7 e,h), and an important decrease in winter zonal speed
 1208 ($\sim 50\text{m/s}$ against $\sim 70\text{ m/s}$ in other Eocene simulations, Fig. 10 a and Fig. SI 21 a to h).
 1209 This migration is however restricted to the TP region, and the Jet Stream remains at low
 1210 latitude over eastern Asia ($\sim 35^\circ\text{N}$, Fig. 10 b and Fig. SI 19), with few summer precipitation
 1211 (100-150 mm/month).

1212 All subsequent Miocene simulations display an important latitudinal migration of the
 1213 Jet along the year, both in the TP region (Fig. 10 c,e), and over eastern Asia (Fig. 10
 1214 d,f). The northward migration of the Jet is comparable between early Oligocene and early
 1215 Miocene experiments (up to $\sim 38\text{-}40^\circ\text{N}$ in September), despite a higher Central Tibet (from
 1216 3000 to 4000 m) and a wider Tibetan landform, due to the incipient uplift of Northeastern

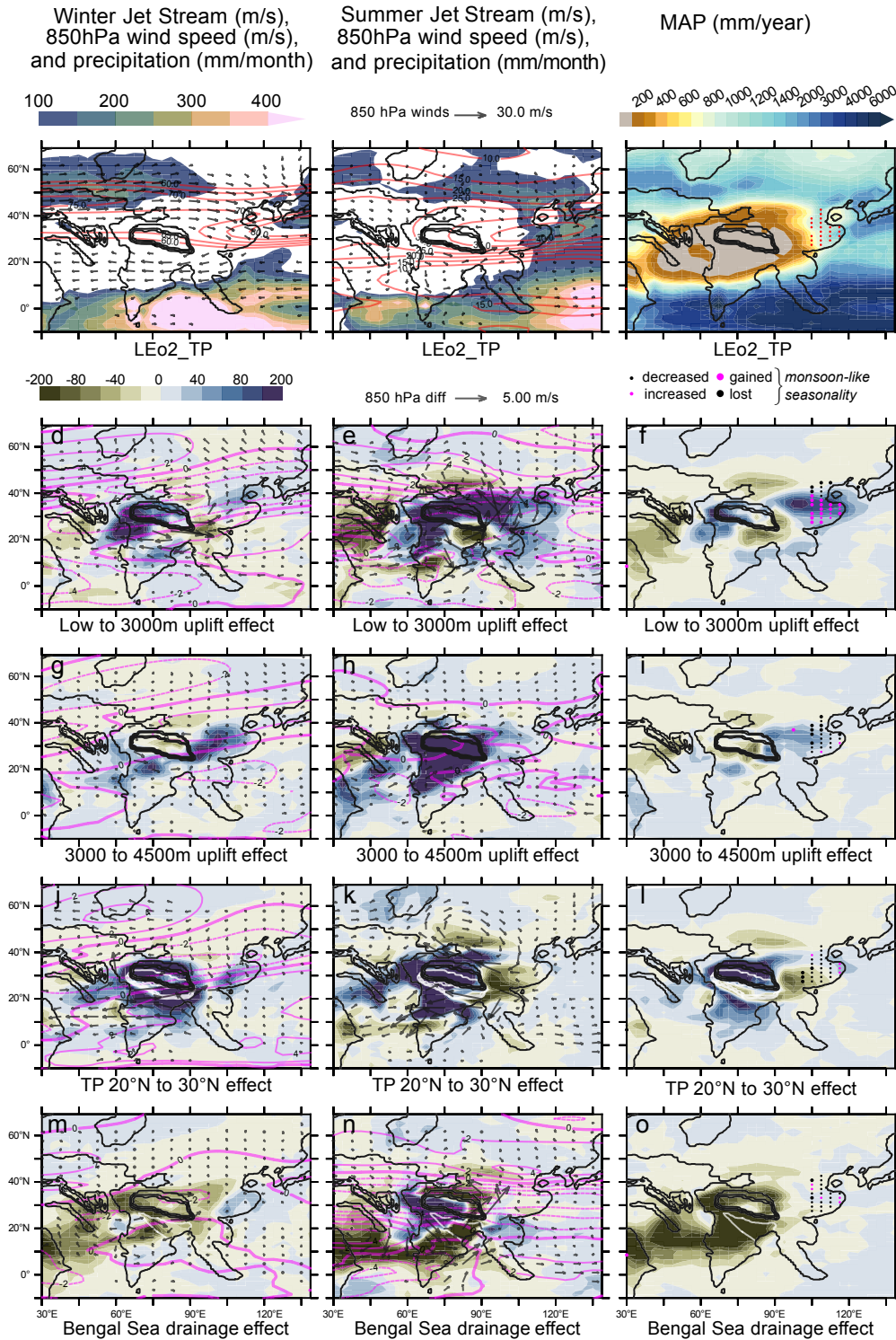


Figure 6. Sensitivity to the Tibetan configurations on Eocene climate: (a,d,g,j,m) winter precipitation (shading), 850 hPa winds (vectors), jet stream speed (contour) ; (b,e,h,k,n) on summer precipitation (shading), 850 hPa winds (vectors), jet stream speed (contour); (c,f,i,l,o) mean annual precipitation (shading) and monsoon-like seasonality according to the MPI index (red dots). Sensitivity tests are compared to the simulation LEO2_TP (a,b,c) and anomalies (d to o) are expressed as "test minus LEO2_TP", except for the "lowered TP effect" which is "LEO2_TP minus LEO2_TPflat"). Precipitation anomalies (shading) are expressed in % and normalized by the averaged precipitation of both simulations (therefore, a change from or to zero mm/year accounts for +/- 200%). In (f,i,l,o): four types of seasonality changes induced by uplift are displayed (e.g. regions showing a decrease of monsoon-like seasonality after lowering the TP are in small black dots) ; white and black topographic contours indicate the LEO2_TP and test topography.

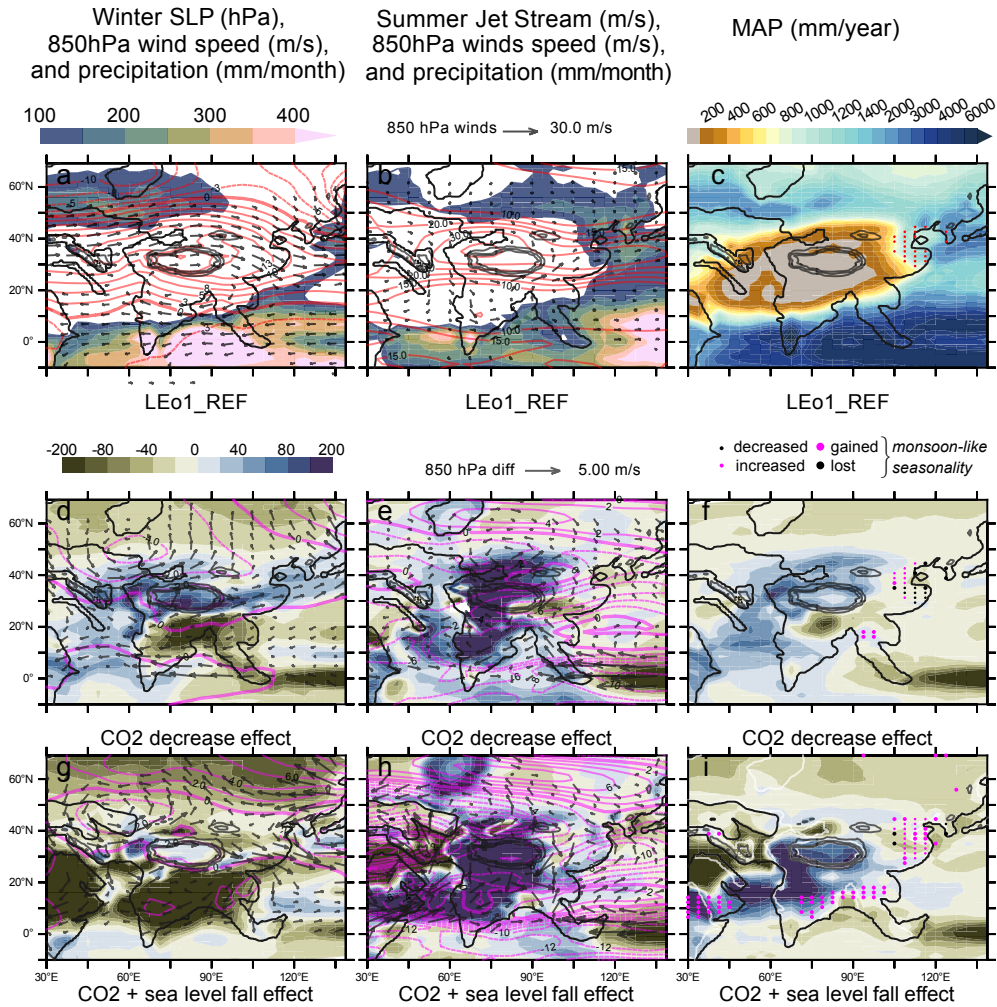


Figure 7. Influence of the $p\text{CO}_2$ decrease and sea level drop at the EOT on: (a,d,g) winter precipitation (shading), 850 hPa winds (vectors), Sea Level Pressure (contour) ; (b,e,h) on summer precipitation (shading), 850 hPa wind (vectors), jet stream speed (contour); (c,f,i) mean annual precipitation (shading) and monsoon-like seasonality according to the MPI index (red dots). Sensitivity tests are compared to the simulation LEO1_REF (a,b,c) and anomalies (d to i) are expressed in order to highlight the impact of the test (i.e. test-LEO1_REF). Precipitation anomalies (shading) are expressed in % and normalized by the averaged precipitation of both simulations (therefore, a change from or to zero mm/year accounts for +/- 200%). In (f,i): four types of seasonality changes induced by uplift are displayed (e.g. regions switching from no monsoon to monsoon-like seasonality after the sea level fall and $p\text{CO}_2$ decrease in thick magenta dots) ; white topographic contours indicate the LEO1_REF contour.

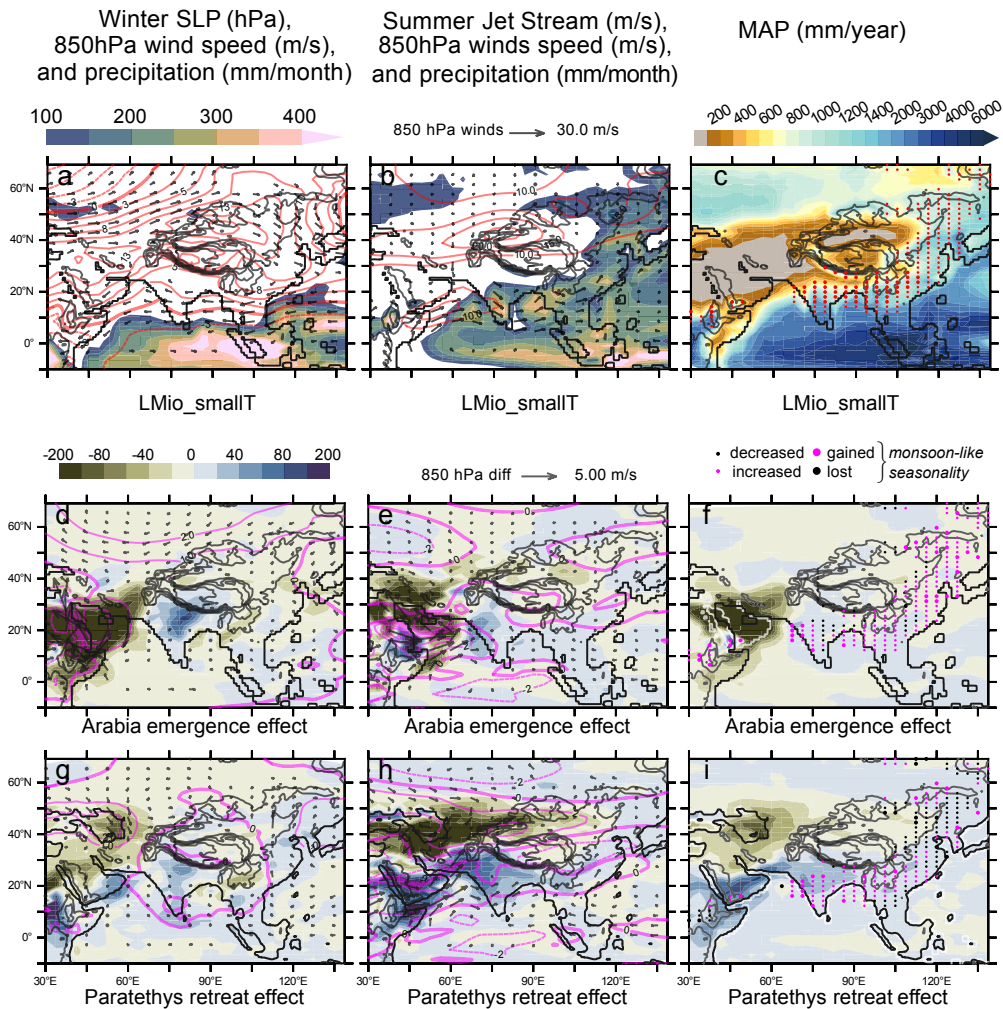


Figure 8. Influence of continentality increase in a Mid-late Miocene context on: (a,d,g) winter precipitation (shading), 850 hPa winds (vectors), Sea Level Pressure (contour) ; (b,e,h) on summer precipitation (shading), 850 hPa winds (vectors), jet stream speed (contour); (c,f,i) and on mean annual precipitation (shading) and monsoon-like seasonality according to the MPI index (red dots). Sensitivity tests are compared to the simulation LMio_smallT (a,b,c) and anomalies (d to i) are expressed in order to highlight the impact of the continentality increase (i.e. LMio_smallT-test). Precipitation anomalies (shading) are expressed in % and normalized by the averaged precipitation of both simulations (therefore, a change from or to zero mm/year accounts for +/- 200%). In (f,i): four types of seasonality changes induced by continentality are displayed (e.g. regions switching from no monsoon to monsoon-like seasonality after continentality increase in thick magenta dots) ; white topographic contours indicate the test simulation.

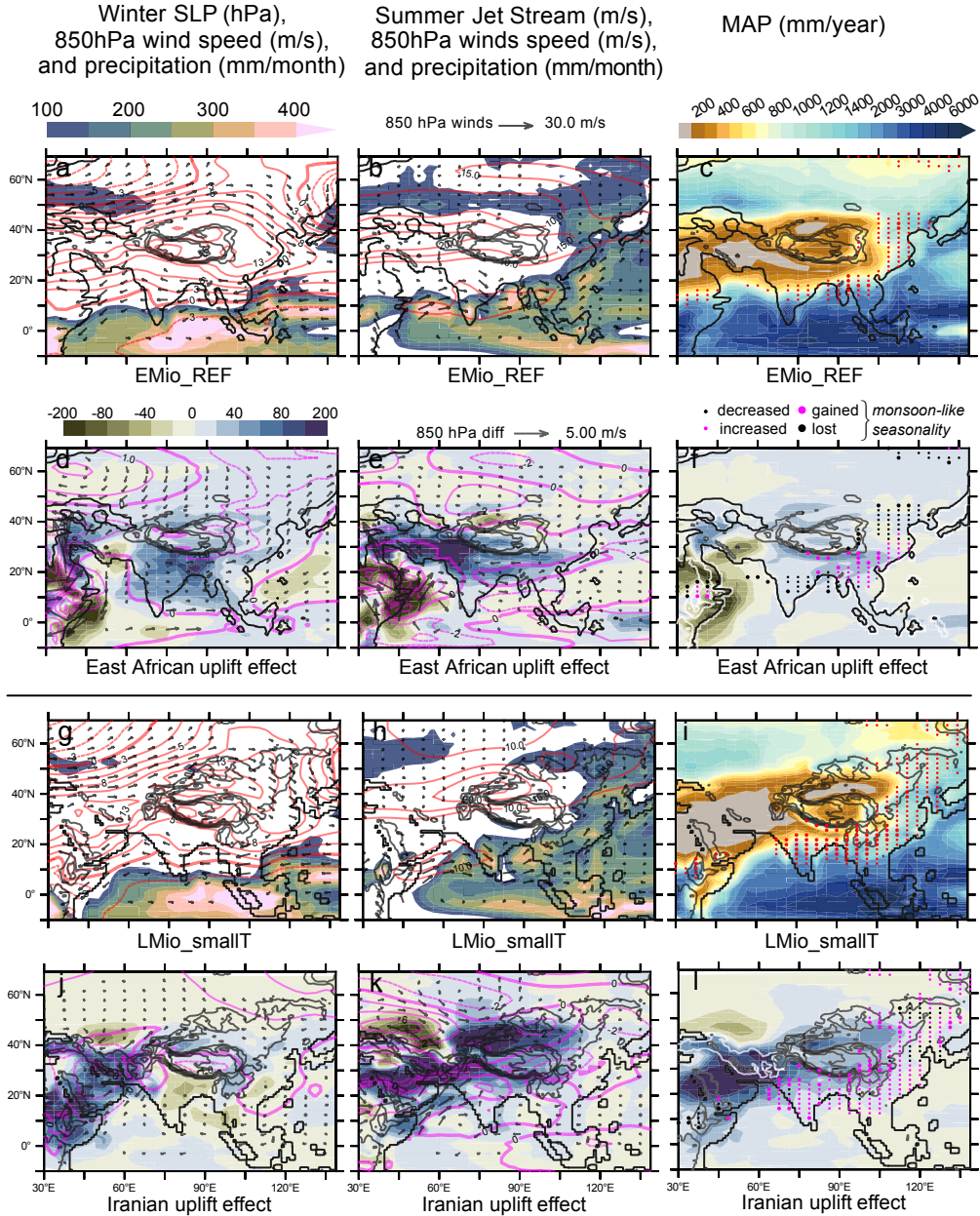


Figure 9. Influence of the East African uplift in the Early Miocene (a to f) and of Iran-Zagros uplift in the late Miocene (g to l) on: (a,d,g,j) winter precipitation (shading), 850 hPa winds (vectors), Sea Level Pressure (contour) ; (b,e,h,k) on summer precipitation (shading), 850 hPa winds (vectors), jet stream speed (contour); (c,f,i,l) and mean annual precipitation (shading) and monsoon-like seasonality according to the MPI index (red dots). East African (Iran-Zagros) uplift is compared to the simulation EMio_REF (LMio_SmallT) (a,b,c and g,h,i) and anomalies (d,e,f and j,k,l) are expressed in order to highlight the impact of uplift (i.e. EMio_EAfr-EMio_REF and LMio_REF-LMio_smallT respectively). Precipitation anomalies (shading) are expressed in % and normalized by the averaged precipitation of both simulations (therefore, a change from or to zero mm/year accounts for +/- 200%). In (f,i): four types of seasonality changes induced by continentality are displayed (e.g. regions switching from no monsoon to monsoon-like seasonality after continentality increase in thick magenta dots) ; white topographic contours indicate the uplifted area.

1217 and Northwestern TP portions in the early Miocene simulation (the Tian Shan is ~ 1000 m
 1218 and the NE Tibet ~ 2000 m high). We therefore suggest that the Jet Stream latitudinal mi-
 1219 gration is primarily triggered by $p\text{CO}_2$ drawdown, and resulting tropospheric temperature
 1220 gradients, and that a significant threshold is crossed at the Greenhouse-Icehouse transi-
 1221 tion (EOT, ~ 34 Ma). In contrast, the subsequent variations in the Jet Stream latitudinal
 1222 migration in the course of the Miocene, appear to be mainly driven by topography changes.

1223 The opening of the Tethyan seaway in the early Miocene (comparing EMio_REF and
 1224 EMio_TetSw), the Iran-Zagros landform uplift (comparing LMio_SmallT and LMio_REF),
 1225 or a $p\text{CO}_2$ decrease (comparing LMio_REF and LMio_1.5X) in the late Miocene do not
 1226 appear to trigger important variations in the Jet Stream migration (Fig. 10 c to f). Other
 1227 experiments, on the other hand, induce notable variations in response to localized uplift
 1228 of specific landforms, especially in the mid-late Miocene. Sensitivity experiments removing
 1229 either Mongolia, Tian Shan, or a combination of both, or Tian Shan and Pamir show that
 1230 these landforms all contribute to amplify the northward migration of the Jet in summer,
 1231 both in the TP region and in Eastern Asia (from $39\text{--}41^\circ\text{N}$ in LMio_noTS, LMio_noTSP,
 1232 LMio_noTSM and LMio_noM to 43°N in MMio_REF and LMio_REF, Fig. 10 e and Fig.
 1233 11 h,k,n). This is especially marked in the experiment removing specifically the Tian Shan
 1234 orogen, which results in the Jet staying above the TP, without passing its northern edge (Fig.
 1235 11 h,k,n). We therefore propose that the final uplifts of the Tian Shan, and in a lesser way
 1236 of the Pamir (from ~ 1000 m in the early Miocene to ~ 3000 m in the mid and late Miocene
 1237 experiments) and Mongolian mountains (from ~ 500 m in the early Miocene to ~ 1500 m in
 1238 the mid and late Miocene experiments) are critical to deviate the Jet northward in summer
 1239 (Fig. 11 e,h,k,n and Fig. SI 19 o to r). This relocation of the Jet Stream in summer induces
 1240 orographic precipitation on the uplifted landforms, aridification of the regions standing to
 1241 the west (-20 to -60% of summer precipitation in eastern Kazakhstan and Uzbekistan) and
 1242 increased precipitation in Eastern Mongolia ($+20$ to 60%). This translates into increased
 1243 monsoon-like seasonality in Northeastern Asia (magenta dots in Fig. 11 f,i,l,o).

1244 **6.2.3 East Asian winter monsoon: the Siberian High genesis**

1245 Modern EAWM is characterized by cold and dry climate, together with northwesterly
 1246 low tropospheric winds above 20°N and northeasterly winds below 20°N . This peculiar atmo-
 1247 spheric circulation is driven by the strong pressure gradients settling between the Siberian
 1248 High anticyclone, the Aleutian Low and the Maritime Continent Low (L. Wang & Chen,
 1249 2014; T. Ma & Chen, 2021). Our results suggest strong changes in surface temperature
 1250 gradients throughout the experiments, that induce an important remodeling of associated
 1251 pressure and wind patterns (Fig. 12 and Fig. 13). In our Eocene experiment, a high-pressure
 1252 band centered around 30°N is simulated, but it remains mainly zonal, following large-scale
 1253 Hadley winter descending branch driven by latitudinal surface temperature gradients (Fig.
 1254 12 b). Indeed, the temperature difference between Tibetan region ($\sim 10^\circ\text{C}$) (located below
 1255 the high pressure cell) and neighboring North Pacific Ocean ($\sim 30^\circ\text{C}$) remains relatively low
 1256 ($\sim 20^\circ\text{C}$, Fig. 12 a), when compared to modern temperature difference at the same season
 1257 ($\sim 40^\circ\text{C}$, Fig. 14). As a result, no significant pressure difference is simulated between the
 1258 Asian continent and the North Pacific in the Eocene and the calculated EAWM index is
 1259 low (< 5 , Fig. 13), reflecting only the North-South pressure gradient between Asia and the
 1260 Maritime Continent.

1261 The extent of the Asian high pressure zone increases gradually in the early Oligocene
 1262 and early Miocene experiments (Fig. 12 d,f), but its modern-like Siberian High shape is only
 1263 simulated in the mid and late Miocene experiments, when its center relocates over Siberia
 1264 ($\sim 40\text{--}60^\circ\text{N}$, Fig. 12 h,j). Additionally, the North Pacific low relocates 10° to the south
 1265 from the early Oligocene simulation onward and steadily decreases until the late Miocene
 1266 (from over ~ 14 to 10 hPa anomaly). All these changes conspire to increase progressively
 1267 both North-South and East-West pressure gradients, and therefore the global EAWM in-
 1268 dex, which reaches maximal values in the mid and late Miocene experiments (~ 15 , Fig.

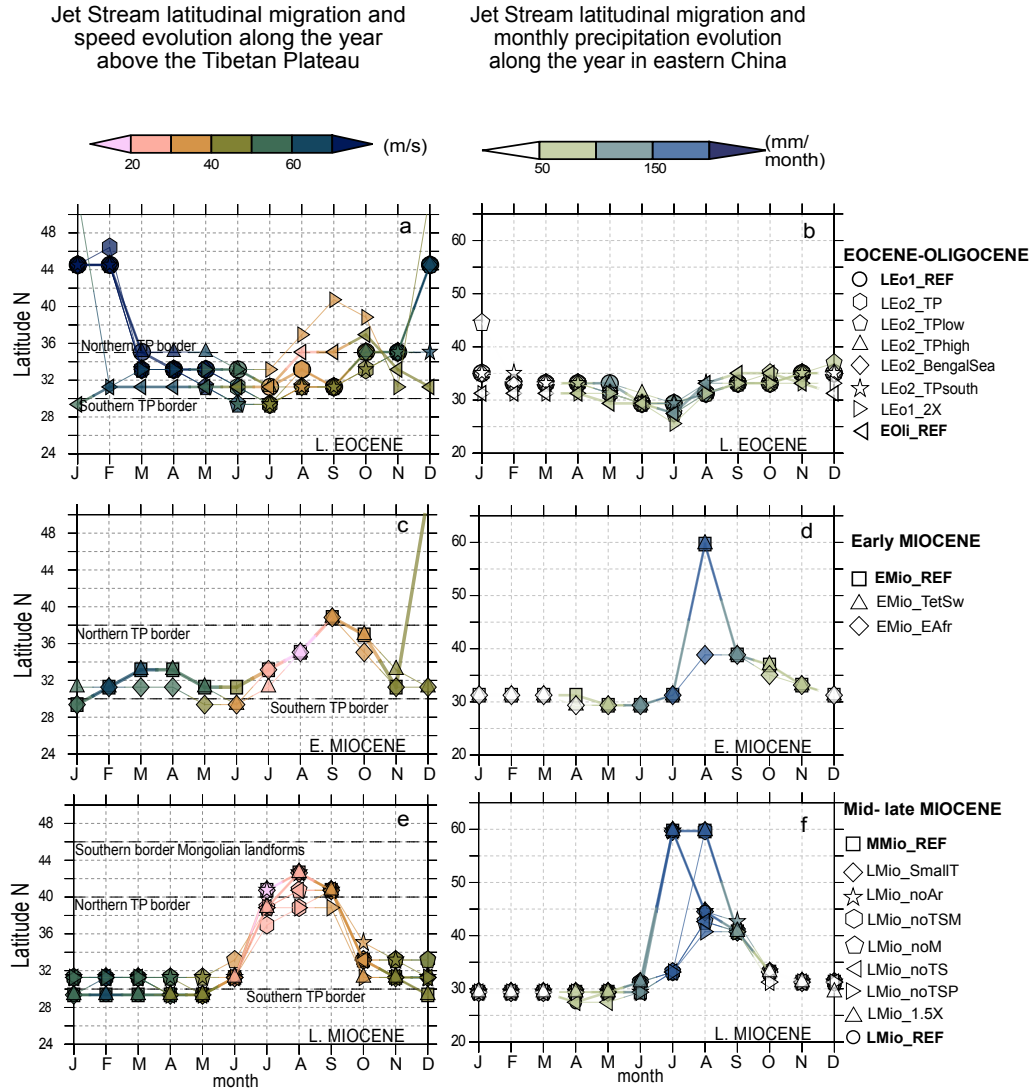


Figure 10. Jet Stream behavior along the year over the Tibetan Plateau and eastern China for all sensitivity experiments, divided into (**up**) Late Eocene, (**mid**) early Miocene and (**bottom**) mid to late Miocene. (**left**) Jet Stream latitudinal migration and speed (shading) evolution along the year in the Tibetan region (averaged over 80:90°E). Mean latitudes of the northern and southern bounds of the Himalaya-Tibet and Mongolian landforms are indicated. (**right**) Jet Stream latitudinal position and precipitation (shading) amounts along the year in East Asia (averaged over 100:120°E).

1269 13). Following this reorganization in pressure patterns simulated during the Cenozoic, low
 1270 tropospheric winds transiting over China display a progressive change in orientation. While
 1271 their zonal component remains important in the Paleogene and early Miocene experiments
 1272 (Fig. 12 b,d), the development of the Siberian High triggers a marked increase in their
 1273 meridional component in the mid and late Miocene experiments (Fig. 12 h,j).

1274 This profound atmospheric circulation reorganization is driven by temperature gradient
 1275 changes, and mainly due to progressive cooling of the Tibetan, Mongolian and Siberian
 1276 regions, as illustrated by the $\sim 22^\circ$ shift southward of the 0°C isotherm between the late
 1277 Eocene and the late Miocene simulations (Fig. 12 a,i). Several factors may be responsible

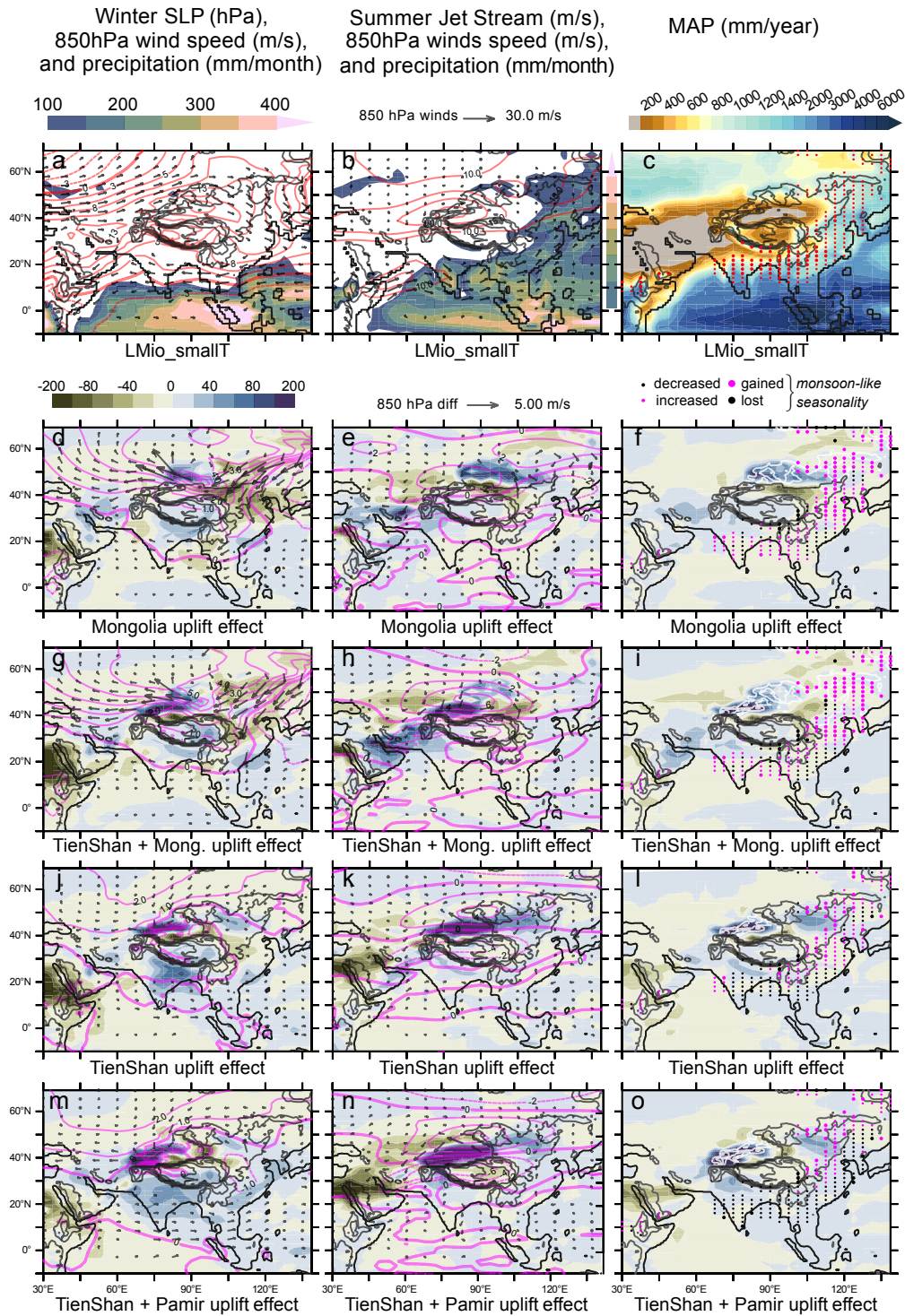


Figure 11. Influence of Mongolia, Tian Shan and Pamir regional uplifts on (a,d,g,j,m) winter precipitation (shading), 850 hPa winds (vectors), Sea Level Pressure (contour) ; (b,e,h,k,n) on summer precipitation (shading), 850 hPa wind (vectors), jet stream speed (contour); (c,f,i,l,o) mean annual precipitation (shading) and monsoon-like seasonality according to the MPI index (red dots). Sensitivity tests are compared to the simulation LMio_smallT (a,b,c) and anomalies (d to o) are expressed in order to highlight the impact of the uplift (i.e. LMio_smallT-test). Precipitation anomalies (shading) are expressed in % and normalized by the averaged precipitation of both simulations (therefore, a change from or to zero mm/year accounts for +/- 200%). In (f,i,l,o): four types of seasonality changes induced by uplift are displayed (e.g. regions switching from no monsoon to monsoon-like seasonality after uplift in thick magenta dots) ; white topographic contours indicate the landforms that were added.

1278 for this important winter cooling, such as the $p\text{CO}_2$ drawdown, local topography changes
1279 or increased continentality.

1280 **6.2.4 Siberian High inception driven mainly by Mongolia uplift in the** 1281 **Miocene and its impact on precipitation seasonality**

1282 The Eocene sensitivity experiments display a stable zonal high pressure pattern at mid
1283 latitudes (Fig. SI 18 a to g), with weak response to changing Tibetan orography or $p\text{CO}_2$
1284 values (Fig. 13). Likewise, our Miocene sensitivity experiments allow to highlight that the
1285 winter pressure patterns in Asia (comprising the Siberian High, the North Pacific Low and
1286 the Maritime Continent Low) are not impacted by African or Iran-Zagros landforms uplifts,
1287 the Arabian platform configuration, the Paratethys extent, or a $p\text{CO}_2$ drop from 560 to 420
1288 ppm (Fig. 13 and Fig. SI 18 i to n and s,t).

1289 On the other hand, sensitivity experiments reveal the impact of the Mongolian land-
1290 form uplift in the mid-late Miocene (either Mongolia alone, or both Tian Shan and Mongo-
1291 lia). Indeed, their settlement induces a strengthening of both the Siberian High (up to ~ 6
1292 hPa, Fig. 11 d,g) and the North Pacific low, resulting in a reinforcement of the East-West
1293 and North-South pressure gradients, and ultimately of the EAWM index (from ~ 8 to ~ 15 ,
1294 Fig. 13). Mongolian (and/or Tian Shan and/or Pamir) uplift also results in increased pre-
1295 cipitation localized over the landforms (Fig. 11 d to o), despite the overall dryness of inland
1296 Asia region (SI Fig. 16). As Mongolian uplift deviates the winter westerlies flux northward,
1297 Eastern China is swept by colder and drier winds coming from Siberia, which translates into
1298 a marked decrease in winter precipitation (up to 80% decrease, Fig. 11 d). The uplift of
1299 Tian Shan landforms, alone or together with the Pamir, has a lower impact on the global
1300 winter pressure patterns (Fig. 13), but nonetheless provokes an almost complete drying on
1301 its eastern flanks (modern Gobi and Taklimakan deserts), as it acts as an orographic barrier
1302 to westerly moisture flux (Fig. 11 g,j,m).

1303 These changes on winter wind circulation and precipitation amounts, combined to
1304 those observed in summer and described above, produce contrasted responses in terms of
1305 monsoon-like precipitation seasonality. As the Mongolian uplift generates a mixed response
1306 on summer precipitation in eastern China (Fig. 11 e,h), but dries consistently the region in
1307 winter (Fig. 11 d,g), it induces important spreading of new regions displaying monsoon-like
1308 precipitation seasonality in eastern China (thick magenta dots in Fig. 11 f,i). At the oppo-
1309 site, Tian Shan and Pamir uplift, let alone the important year-round increase in orographic
1310 precipitation, triggers overall increased winter precipitation amounts in Southeastern Asia
1311 (Fig. 11 j,m), which leads to widespread reduction of precipitation seasonality in the SAM
1312 domain (Fig. 11 l,o).

1313 **7 Discussion**

1314 A long-standing debate opposes the effect of continentality against orography regarding
1315 the Asian climate evolution (Prell & Kutzbach, 1992; Kutzbach et al., 1993; Ramstein et
1316 al., 1997; Fluteau et al., 1999; Z. Zhang et al., 2007; Roe et al., 2016; Zoura et al., 2019;
1317 R. Zhang et al., 2021). Our results hint that these two features most likely impacted different
1318 climatic characteristics of the Asian Monsoons and all concurred to the settlement of current
1319 Asian climate (see Table 6 for a sum-up of the main effects of each forcing on monsoonal
1320 features). In the following sections we put our main findings in perspective with available
1321 paleoclimatic indicators and previous modeling work.

1322 **7.1 A possible inception of monsoons in the Paleogene: which dependence** 1323 **to $p\text{CO}_2$, Tibetan paleogeography and continentality ?**

1324 Our late Eocene set of simulations follows a previous study, in which we introduced
1325 the results from LEo1_REF, displaying no monsoon circulation, and discussed a possible dry

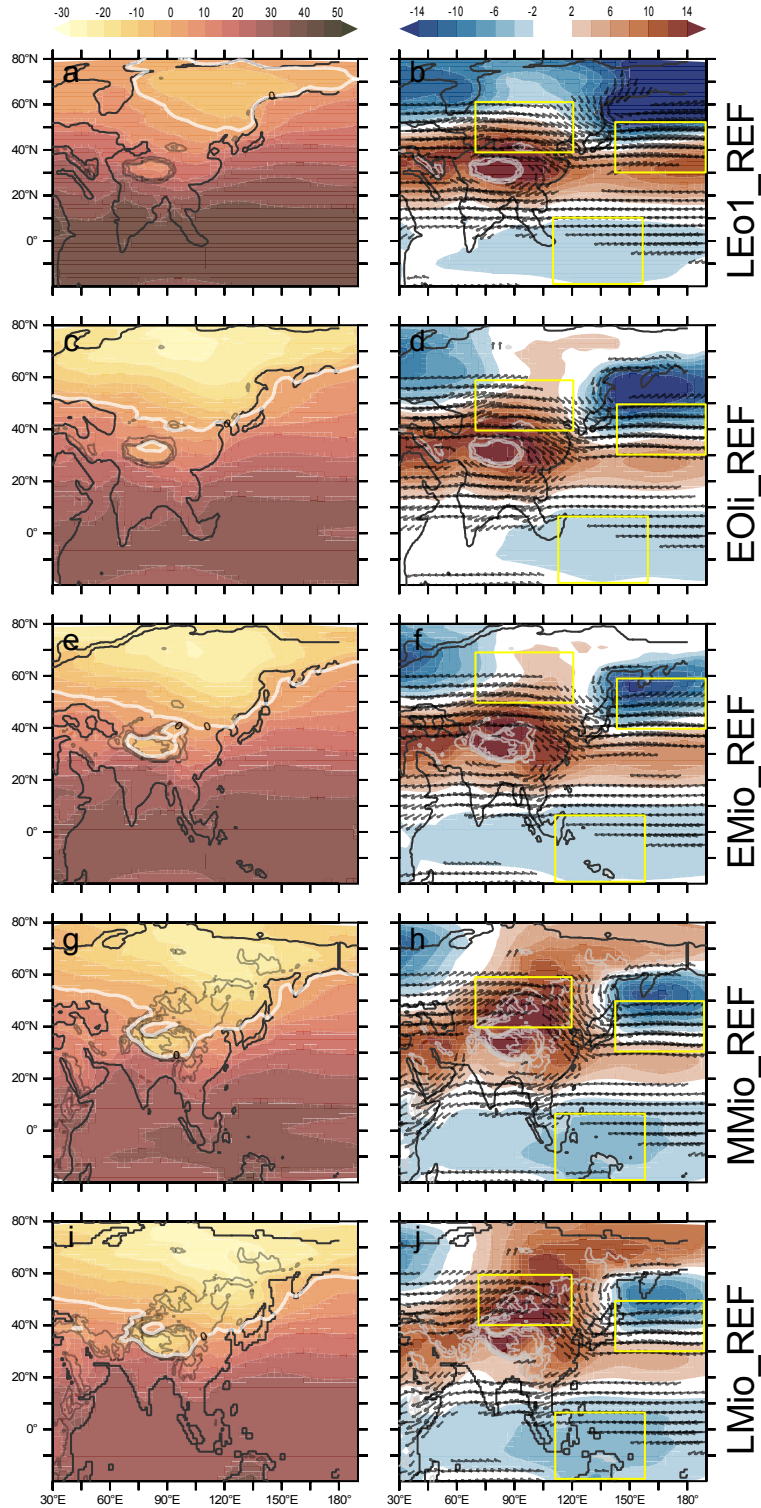


Figure 12. Evolution of the winter monsoon diagnostics throughout the Cenozoic. **Left column:** December-February (DJF) mean 2m temperature (shading, Celsius), overlain with a white contour line marking the 0°C isotherm ; **Right column:** DJF normalized Sea Level Pressure anomaly (shading, hPa) and 850 hPa winds above 4 m/s (vectors). In all captions, topography is overlain in gray contour each 1000 m. Yellow boxes indicate the regions over which are calculated the sea level pressure gradients from the East Asian Winter Monsoon Index, presented in section 5.3

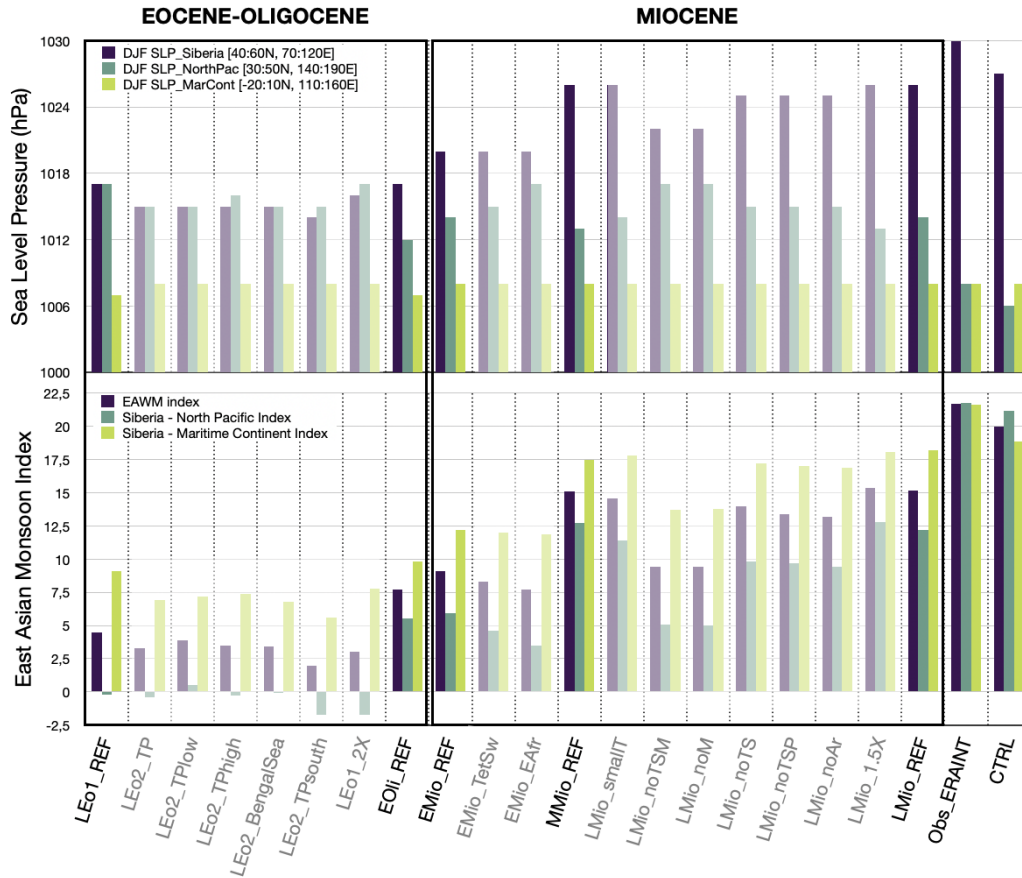


Figure 13. Upper panel: Winter (DJF) Sea Level Pressure (hPa) evolution over Siberia, North Pacific and the Maritime Continent ; lower panel: Evolution of the East Asian Winter Monsoon index (purple) and of the East-West and North-South regional indexes throughout the different reference and sensitivity experiments, after (L. Wang & Chen, 2014).

1326 bias in our simulations, when comparing our results to several proxy localities indicating
 1327 significantly wetter environments (Tardif et al., 2020). Indeed, while markers of arid to sub-
 1328 arid climate are widespread for the late Eocene for example in Northeastern TP (J. X. Li
 1329 et al., 2018; Meijer et al., 2019), Tajikistan (Carrapa et al., 2015) or on the Tarim Basin
 1330 shores (Bougeois et al., 2018), our Eocene experiment fails to render the wetter climate
 1331 inferred from fossil paleoflora and paleofauna in Northern India (Saxena & Trivedi, 2009)
 1332 and Tibet (T. Su et al., 2020; Sorrel et al., 2017). Asian overall aridity in this reference
 1333 Eocene simulation was interpreted as resulting from the hot surface temperatures simulated
 1334 in the region, together with strong mid-tropospheric subsidence that inhibits deep convection
 1335 and condensation, especially over Northern India (Tardif et al., 2020). Nevertheless, much
 1336 wetter and closer to monsoon-like summer climate patterns were simulated in both EAM and
 1337 SAM domains for the late Eocene with the same model and paleogeography, but with orbital
 1338 configurations inducing summer solar maxima (Tardif et al., 2021). This potential orbitally-
 1339 paced wet/dry climate dichotomy is, at least qualitatively, in agreement with stratigraphic
 1340 and paleobotanic evidence from Eastern China (C. Huang & Hinnov, 2019; Tong et al.,
 1341 2002). Another hypothesis for this mismatch was an eventual sensitivity of the simulated
 1342 climate to Asian paleogeography which, as introduced before, is still highly debated for this
 1343 period.

1344 *7.1.1 Late Eocene climate sensitivity to alternative paleogeographic config-* 1345 *urations: persistent mismatch with paleoclimate indicators in SAM* 1346 *domain*

1347 In this study, we explored the Asian climate sensitivity to different late Eocene Tibetan
 1348 configurations, which aimed at reflecting the main theories regarding the paleogeography at
 1349 that time. We also evaluated the effect of decreased $p\text{CO}_2$ values (1120 to 560 ppm). Our
 1350 results reveal that the arid pattern previously described shows low sensitivity to the Tibetan
 1351 Plateau configuration or to a reduced $p\text{CO}_2$, and is only disturbed by the presence of a
 1352 Bengal Sea (LEo2_BengalSea), which lowers the surface temperatures and slightly enhances
 1353 precipitation in this region (Fig. SI 16 f). This tendency is however opposite to similar
 1354 modeling studies comparing an early and a late Eocene paleogeography, and which suggest
 1355 increased precipitation after the drainage of this Bengal Sea (X. Li et al., 2017, 2018).
 1356 Comparing these different simulations is nevertheless hampered by the significant difference
 1357 between other boundary conditions that were used. Collectively, these results rather points
 1358 to the high sensitivity of late Eocene climate to surface temperature gradients, at least with
 1359 the IPSL-CM5A2 model, which is further emphasized by the changes induced by the sea
 1360 level fall tested in our Oligocene simulation and presented in the next section.

1361 The EAM region displays higher sensitivity to the paleogeography changes that were
 1362 tested. We simulate that an uplift in the Tibetan region (compared to a low ~ 800 m TP
 1363 in LEo2_TPLow) would result into an onset or increase in EAM monsoon-like precipitation
 1364 seasonality due to increased summer precipitation (up to 50, Fig. 6e, Fig. SI 16 b,c,d),
 1365 in agreement with previous modeling works (R. Zhang et al., 2018, 2017, 2021; Z. Zhang
 1366 et al., 2007; X. Liu & Yin, 2002; X. Li et al., 2017; Farnsworth et al., 2019; Thomson et
 1367 al., 2021). Likewise, the decreased EAM intensity and increased inland Asian aridity due
 1368 to the northern migration of the TP (its southern edge translating from ~ 20 to 30°N) is
 1369 coherent with previous study testing the impact of the latitudinal position of the incipient
 1370 TP (R. Zhang et al., 2017).

1371 *7.1.2 Imprint of the Eocene-Oligocene transition on summer monsoon and* 1372 *inland Asia aridification*

1373 Paleoclimatic indicators from inland Asia suggest increased precipitation seasonality
 1374 in EAM and SAM domains, wetter conditions localized in the Tarim and western Qaidam
 1375 basins and overall aridification everywhere else in inland Asia (described in section 3.1.3).
 1376 This aridification was attributed either to global cooling at the EOT (J. Sun et al., 2015;

1377 X. Li et al., 2017), to the Paratethys Sea retreat (Barbolini et al., 2020; Z. Zhang et al.,
 1378 2007), or both (J. Sun & Windley, 2015). Our sensitivity experiment testing the effect
 1379 of cooling alone (LEo1.2X) seems to better render wetter conditions in the Tarim-Qaidam
 1380 region and global drying in the Yunnan region (Fig. 7 f). Taking into account the EOT
 1381 global sea level drop in addition to global cooling (EOli_REF) on the other hand, better
 1382 simulates the monsoon-like precipitation seasonality suggested by paleofloras in both EAM
 1383 (Vornlocher et al., 2021; R. Spicer et al., 2017; J. Ren et al., 2021; J. Huang et al., 2022;
 1384 Herman et al., 2017; Ling et al., 2021) and SAM domains (R. Spicer et al., 2017; Srivastava
 1385 et al., 2012), as well as precipitation amounts in Kazakhstan (Averyanova et al., 2021).
 1386 Although the comparison to existing modeling studies is limited by the many additional
 1387 parameters that may vary from our experiments (ice sheets, $p\text{CO}_2$, etc.), those which
 1388 explicitly tested the effect of the Paratethys Sea retreat (R. Zhang et al., 2021; Z. Zhang et
 1389 al., 2007), tend to simulate similar SAM and EAM precipitation seasonality increase. Our
 1390 Oligocene experiment however still underestimates precipitation over Tibet (Deng et al.,
 1391 2021; Song et al., 2020) and does not simulate the drying trend indicated by proxies in the
 1392 Tajik and Junggar basins as well as in the Gobi region after the EOT (J. Sun & Windley,
 1393 2015; Baldermann et al., 2021; J. Sun et al., 2015, 2020), although simulated Oligocene
 1394 mean annual precipitation remain very low in these regions. We suggest this mismatch may
 1395 be due to the shape of the proto-Tibetan orogen or paleoshorelines used in LEo1_REF and
 1396 EOli_REF, as all of these locations stand very close to the boundary between regions that
 1397 became indeed drier (Fig. 7). To further explore the impact of land-sea distribution change,
 1398 the Miocene experiments offer additional input.

1399 *7.1.3 Continentality increase as a potential driver of Paleogene wintertime* 1400 *climate variability*

1401 The precocious observation of loess deposits in northeastern Tibet at 40 Ma was inter-
 1402 preted as resulting from the periodical inception (or reinforcement) of the Siberian High
 1403 in winter due to enhanced continentality after the Paratethys Sea retreat (Meijer et al.,
 1404 2021). Other loess deposits are reported during the Oligocene in the Chinese Loess Plateau
 1405 and Mongolia, apparently coeval with periods of cooling and ice-sheets expansion (J. Sun &
 1406 Windley, 2015; Wasiljeff et al., 2022). These discoveries question the presence of a Siberian
 1407 High in the Paleogene, of its role in dust transport and accumulation, and of its forcing
 1408 factors. Indeed, most modeling studies so far focused on the link between regional uplift
 1409 and enhanced Siberian High and winter monsoon circulation rather than on the influence
 1410 of continentality or global climate cooling. Our results suggest that both increased conti-
 1411 nentality and regional uplift have concurred to the progressive inception of modern Siberian
 1412 High, while $p\text{CO}_2$ fall had apparently little impact on its intensity (Fig. 13).

1413 Oligocene global sea level fall increases winter sea level pressure by ~ 2 to 4 hPa over
 1414 Siberia (Fig. 7 g) and induces the southward expansion of the North Pacific Aleutian
 1415 low, which altogether increase the pressure gradient between those two regions. Similar
 1416 trend is obtained, although in a lower magnitude, with our simulation testing the effect
 1417 of the Arabian platform emergence, while the final retreat of the Paratethys Sea tested in
 1418 Miocene configuration does not trigger changes (Fig. 13). A modern-like Siberian High with
 1419 typical EAWM wind patterns is however not simulated until our middle and late Miocene
 1420 simulations, when the current Tian Shan and Mongolian landforms are set to their present
 1421 elevations. Collectively, these results suggest that continentality increase may have induced
 1422 changes in wintertime pressure gradients and atmospheric circulation mostly before the
 1423 uplift of Tian Shan and Mongolian landforms, but would have had a decreasing importance
 1424 afterwards.

1425 We also acknowledge that the Mongolian and Tian Shan uplifting history was likely
 1426 more complex than depicted here, with signs of early uplift in the Hangay region as soon
 1427 as the Oligocene. Performing additional experiments allowing to test the role of an up-
 1428 lifted Hangay dome in an Oligocene configuration should allow us to evaluate the potential

1429 presence of a Siberian High at that time. This may help interpreting precocious loess-like de-
 1430 posits observed at that time in the Chinese Loess Plateau and Mongolia (J. Sun & Windley,
 1431 2015; Wasiljeff et al., 2022). The presence loess-like deposits in the Xining Basin at ~ 40 Ma
 1432 however, seems too old to be attributed to the development of the modern Siberian High,
 1433 if its full development is conditional to uplift of the Mongolian and Tian Shan landforms.
 1434 This discrepancy suggest that additional mechanisms for dust transport over long distances
 1435 should be explored for this period, although testing this hypothesis would require further
 1436 investigation, likely with daily to hourly wind speed outputs (Aoki et al., 2005).

1437 **7.2 Peripheral landforms critical role in monsoon seasonal feature settle-** 1438 **ment in the Miocene**

1439 ***7.2.1 Tian Shan, Pamir and Mongolia: small mountains, strong effect***

1440 The role played by Mongolian landform uplift in the inception of the Siberian High is
 1441 one of the most salient outcomes of these experiments. Previous modeling works based on
 1442 modern geography that have tested the effect of Mongolia uplift (Sha et al., 2015; Shi et al.,
 1443 2015; Yu et al., 2018) reproduce the same tendencies we have presented, namely a strong
 1444 increase of the winter sea level pressure over Siberia and typical deflation of the westerly flow
 1445 towards northern latitudes resulting in a pronounced drying of Eastern Asia and EAWM
 1446 amplification (Fig. 11 d). Other studies simulate increased EASM precipitation and wind
 1447 circulation, although they incorporate Tian Shan uplift together with Mongolia (Yu et al.,
 1448 2018; R. Zhang et al., 2012; H. Tang et al., 2013; Zhisheng et al., 2001), which remains
 1449 coherent with our findings testing the uplift of both features (Fig. 11 h). Paleoclimate
 1450 simulations using more realistic paleogeographic reconstructions (Eocene or Oligocene) tend
 1451 to confirm such tendencies, although the effect of Mongolian landforms was not explicitly
 1452 tested. Generally, we can observe that when a modern-like Mongolia was prescribed, the
 1453 simulated winds and precipitation were close to modern-like EAWM (Licht et al., 2014;
 1454 X. Li et al., 2017), while it is not the case with a reduced Mongolia elevation (Huber &
 1455 Goldner, 2012).

1456 The effect of the Tian Shan ranges uplift on Asian climate is less conspicuous and
 1457 seems also more sensitive to the degree of uplift of other surrounding landforms (such as
 1458 the Pamir-Karakoram, the Hindu Kush or Iran-Zagros), likely owing to its lower latitude.
 1459 While a rigorous comparison between our results and previous studies is hampered by too
 1460 many diverging boundary conditions, all tend to point that the Tian Shan uplift would
 1461 have i) increased yearly orographic precipitation on the ranges, ii) decreased it in the Tarim
 1462 Basin located in their rain shadow and in inland Asia mid latitudes and iii) reinforced the
 1463 EAM through increased summer precipitation (Fig. 11 m,n,o) (Baldwin & Vecchi, 2016;
 1464 H. Tang et al., 2013; Yu et al., 2018; R. Zhang et al., 2017). The key role played by the
 1465 Tian Shan ranges, together with the Pamirs and Mongolian landforms in triggering the Jet
 1466 Stream northward migration in summer (Fig. 19e,f and Fig. 9e,h,k,n), as suggested by
 1467 previous modeling works derived from modern geography (Sha et al., 2020; Shi et al., 2015),
 1468 likely contributes to increase the EAM. Nevertheless, substantial differences are noted with
 1469 other modeling studies, especially regarding the effect on SAM domain: where we simulate
 1470 a weakening of SAM seasonality due to increased winter precipitation, opposite trend is
 1471 simulated in studies where the Iran-Zagros and Hindu Kush are fully uplifted and prevent
 1472 the westerly flux to bring moisture to India (Baldwin & Vecchi, 2016; H. Tang et al., 2013;
 1473 Yu et al., 2018; R. Zhang et al., 2017; X. Wang et al., 2020).

1474 ***7.2.2 East Africa and Zagros-Anatolia: the Far West uplifts and SAM*** 1475 ***evolution***

1476 Our set of simulation highlight in addition that paleogeographic evolution in the Middle
 1477 Eastern and East African regions have been important for the Neogene evolution of the
 1478 SASM as they strongly contributed to the settlement of modern-like atmospheric circulation

1479 as discussed by Sarr et al. (2022). The presence of intermediate to high elevation topography
1480 in East Africa in the early Miocene is for example crucial for the "early" bending of the
1481 Somali Jet, before the closure of the West Tethys seaway and settlement of Iran-Zagros
1482 topography with modern-like elevation (Fig. 9).

1483 Increasing elevation in the East African region is also responsible, in our simulations
1484 for increasing SAWM precipitation (Fig. 9), which contrast with previous studies that sim-
1485 ulate reduced SASM precipitation instead (H.-H. Wei & Bordoni, 2016; Chakraborty et al.,
1486 2009) as topography would block the advection of moisture from equatorial Africa towards
1487 India. We hypothesize that such difference may come from these studies using present-day
1488 paleogeography, and/or unchanged fixed SSTs for all the experiments, thereby neglecting
1489 the potential effect of the East Africa uplift on Indian Ocean SSTs and SST gradients. These
1490 studies however critically highlight that a reinforced Somali Jet may not be systematically
1491 correlated with increased SAM precipitation, although this genetic relationship is commonly
1492 found in the literature. Alongside, increasing land exposure in the Arabian platform region
1493 in the middle Miocene, the uplift of the Iran-Zagros topography strongly reinforces the So-
1494 mali Jet speed and northward migration, together with the summer precipitation amounts
1495 (Fig. 5, Fig. 9), as previously suggested by (R. Zhang et al., 2017; Acosta & Huber, 2020;
1496 H. Tang et al., 2013).

1497 Given their respective impact in the SAM, knowledge of the evolution of those western
1498 topographies, although seldom taken into account, is critical to interpret paleoenvironmental
1499 indicators. This is especially true for inland Asia and northwestern India regions, because
1500 of their key location with respect to the westerlies flux. Westerlies may indeed be deviated
1501 either to the North or the South depending on the Zagros-Iran and Tian Shan respective
1502 elevation. Indication of increased SAM precipitation during the Miocene (X. Yang et al.,
1503 2020) could for example be, at least partly due to Zagros-Iran uplift, as geological evidences
1504 indicate that the high topography settled at that time (Austermann et al., 2017; François
1505 et al., 2014).

1506 **7.3 Miocene continentality increase as an amplifier of SAM, EAM and** 1507 **inland aridity**

1508 The northward motion of the ITCZ over the Arabian Sea and the stronger SASM
1509 precipitation in response to continentality increase in the Miocene is a feature clearly sim-
1510 ulated in our experiments, and which is obtained with either the Paratethys Sea retreat or
1511 the Arabian peninsula emergence (Fig. 8 e,h). The role of the Paratethys Sea retreat as
1512 a vector of amplified summer low sea level pressure zone and resulting moisture advection
1513 via strengthened Somali Jet is well established by modeling experiments (Ramstein et al.,
1514 1997; Fluteau et al., 1999; R. Zhang et al., 2021; Z. Zhang et al., 2007). The Paratethys Sea
1515 retreat also drastically dries the "westerly corridor" (centered around 40°N, Fig. 8 h) which
1516 overall results in increased inland Asian aridity and moderately increases EAM seasonality,
1517 north and south of this latitudinal band (Fig. 8 i). These patterns are mostly coherent with
1518 those obtained by previous modeling studies (R. Zhang et al., 2021; Z. Zhang et al., 2007),
1519 although here again, important differences in the paleogeography and type of model that
1520 were used prevent a rigorous comparison.

1521 On the other hand, the effect of increased land exposure in the Arabian peninsula
1522 region on Asian climate was, to our knowledge, significantly less explored by modeling
1523 studies and is never mentioned as a potential forcing by field work. In most modeling
1524 studies, the region usually evolves together with the global paleogeography, without being
1525 specifically tested. We putatively attribute this to the lack of constraints and data in this
1526 region. Given the shallowness and extension of the Arabian peninsula (~3 million square
1527 meters, roughly comparable to India area), it is very likely that the episodes of partial or
1528 complete flooding that it witnessed from the Oligocene to the late Miocene (Barrier et al.,
1529 2018; Otero & Gayet, 2001) may have had great consequences on atmospheric circulation

1530 patterns. Our results show that increased peninsula exposure reinforces the Somali Jet
 1531 in summer and enhances summer precipitation in SAM and EAM domains (Fig. 8 e).
 1532 Additionally, it drives the onset of upwelling in the Arabian Sea (see Sarr et al. (2022),
 1533 with the same set of simulations), which are traditionally used as proxies indicating the
 1534 establishment of a monsoon regime in South Asia. These findings imply that a proto-Somali
 1535 Jet and intense summer precipitation settled before the emergence the Arabian peninsula in
 1536 the middle Miocene, and therefore before the recording of upwelling in the Arabian Sea. In
 1537 any cases, the onset of upwellings in the Arabian Sea was likely decorrelated from potential
 1538 Miocene uplifts events in the Himalaya-Tibet region (Sarr et al., 2022).

1539 **7.4 Persistent uncertainties and directions for further works**

1540 Our study demonstrates the key role played by land-sea distribution and by all to-
 1541 pographic features surrounding the Indian Ocean in shaping the modern SAM, EAM and
 1542 inland Asia aridity. Nevertheless, additional work is required from both modeling and the
 1543 field research to help refine our understanding of the complex mechanisms at play through-
 1544 out the Cenozoic in Asia.

1545 **7.4.1 *Opposite effect and thresholds crossings: the need for improved rel- 1546 ative and absolute timing and elevation constraints on uplift events***

1547 Overall, our results highlight the strong crossed influence of the various sub-geographical
 1548 units on resulting monsoons and therefore the conceptual limitations of performing tests
 1549 based on modern geographies or assuming homogeneous Asian orography uplift in the course
 1550 of time to evaluate past monsoon evolution. In that aspect, it is not surprising that most
 1551 of such studies simulate somehow modern-like summer and winter monsoons when keeping
 1552 uplifted African, Mongolian and Iranian landforms, as well as an emerged Arabia (Roe et
 1553 al., 2016; Zoura et al., 2019; Acosta & Huber, 2020).

1554 The need to better constrain the evolution in time, elevation and shape of the various
 1555 Asian, East African and Anatolian landforms, appears paramount, in order to refine our
 1556 understanding of Cenozoic paleoclimate evolution. Our results also suggest that some pa-
 1557 leogeographic events may have had contrary influences on either SAM or EAM, although
 1558 we might picture them as roughly coeval. This is for example the case of the Tien-Shan
 1559 and Pamir uplifts that weaken SAM seasonality, while Mongolian and Iran-Zagros uplifts,
 1560 together with continentality strengthen it. Here, we chose to perform our mid-late Miocene
 1561 sensitivity tests based on a halfway uplifted Iran-Zagros orogen (LMio_SmallT), but it is
 1562 likely that we may obtain different results if testing the uplift on Mongolia (for example) in a
 1563 paleogeography with an already fully uplifted Iran-Zagros topography. Refining the relative
 1564 chronology of these various paleogeographic events is therefore critical to better interpret
 1565 the variations in monsoon intensity recorded by the proxies. Additionally, paleoelevation
 1566 thresholds are likely to be critical for constraining the Asian climate evolution, due to in-
 1567 teractions of the topography with either low level (e.g. the summer monsoon winds) or mid
 1568 tropospheric (e.g. the Jet Stream) air masses (X. Liu & Yin, 2002; X. Wang et al., 2020;
 1569 Zhisheng et al., 2001; Prell & Kutzbach, 1992).

1570 **7.4.2 *Land-sea distribution and gateway closure***

1571 A more precise view of land-sea distribution and regional seaways evolution is also
 1572 paramount. Indeed, they influence the surface temperature gradients, and therefore con-
 1573 dition sea level pressure patterns, low tropospheric circulation as well as oceanic surface
 1574 circulation. Although our results point to a minimal effect of the mechanical closure of the
 1575 Tethyan Seaway on regional results, other features need to be tested. For example, a better
 1576 understanding of the Indonesian Gateway and Indonesian throughflow evolution would be
 1577 of great interest, as they control part of Indo-Pacific Warm Pool SSTs distribution (Cane
 1578 & Molnar, 2001). While the final step of the gateway constriction likely occurs during

1579 the Pliocene (Auer et al., 2019), its paleobathymetric and geometric configuration remains
1580 however largely undocumented between 17-3.5 Ma, due to difficulties in reconstructing the
1581 complex configuration of the region (Kuhnt et al., 2004). Although no major tectonic deforma-
1582 tion is supposed to have occurred during this period, the shallow depth of the gateway
1583 likely made it sensitive to middle Miocene sea level fluctuations (Sosdian & Lear, 2020),
1584 with possible impact the Eastern Indian and Western Pacific oceans surface temperatures
1585 and therefore on SST gradients.

1586 8 Conclusions

1587 In this study, we took advantage of the rich discoveries that have allowed to extend
1588 the fossil record to the Paleogene in Asia, as well as the consolidation of the understanding
1589 of the physical concepts underpinning the monsoons brought by modeling studies. Overall,
1590 we simulate an intensification of all considered monsoon metrics throughout the Cenozoic,
1591 in response to specific forcings. We find that, in agreement with paleoclimate indicators,
1592 modern-like monsoons, in terms of atmospheric circulation, seasonality and precipitation
1593 amounts, likely exist since at least the mid-late Miocene. We however show that high
1594 seasonality in precipitation may have existed since the Paleogene in both SAM and EAM
1595 domains, before the settlement of modern atmospheric circulation patterns. In agreement
1596 with previous studies, our results highlight the rather limited effect of $p\text{CO}_2$ when compared
1597 to paleogeographic changes, with the notable exception of the effect of the $p\text{CO}_2$ drawdown
1598 at the EOT on the Jet Stream latitudinal migration over the year in the Tibetan region.

1599 First, although the exact shape and extent of coastal shallow environments remain
1600 poorly constrained, our results strongly hint that any variations in the land-sea distribution,
1601 whether due to tectonic activity, or sea level fluctuations, would have strongly impacted the
1602 Asian climate. Many episodes of increased continentality are documented in the course of the
1603 Cenozoic, including the regional regressions of the Paratethys epicontinental Sea, periodical
1604 exposure of the Arabian platform due to sea level fluctuations, and global sea level fall
1605 at the Eocene Oligocene Transition. All of these events likely favored the enhancement of
1606 summer moisture penetration into Asia, by promoting the extension of the wide subtropical
1607 low pressure belt and thus amplifying the seasonal latitudinal migration of the ITCZ on
1608 land.

1609 Second, while the HTP complex was recurrently put forward as the leading mech-
1610 anism in Asian climate evolution, our results rather points toward a shared responsibility
1611 between all landforms surrounding the modern Indian Ocean. We also stress the fact that all
1612 paleogeographic features do not bear the same importance on SASM, EASM or EAWM re-
1613 spectively. The Tibetan Plateau uplift likely favored the onset of monsoon-like precipitation
1614 seasonality in eastern Asia in the Eocene, by promoting the advection of moist air masses
1615 in summer, and by partially shielding the region from westerly moisture input in winter.
1616 The Miocene Eastern African and Iran-Zagros uplift were critical to intensify and redirect
1617 the Somali Jet towards the Indian subcontinent, and thus develop the modern-like South
1618 Asian monsoon summer circulation and amplify moisture advection to Asia in summer.
1619 Additionally, Iranian-Anatolian uplift, by blocking moisture advection from the westerlies
1620 to lower latitudes likely contributed enhance winter aridity in most of Southeastern Asia.
1621 The Himalaya-Tibet complex then conditions the SASM precipitation distribution over the
1622 South Asian region, triggers heavy orographic precipitation and upper atmosphere heating
1623 over northern India.

1624 We show that the uplift of the Tian Shan and the Mongolian mountains was key for
1625 the settlement of the winter Siberian high pressure cell, and resulting aridification of inland
1626 and eastern Asia in winter. The summer Jet Stream migration northward of the Tibetan
1627 Plateau was likely amplified in the mid-late Miocene, as the Pamir and Tian Shan landforms
1628 approached their modern elevation and contributed to its channeling toward higher latitudes.
1629 This relocation of the Jet Stream amplifies the penetration of moist air masses over eastern

1630 China, thus contributing to increase the EAM precipitation seasonality. Overall, our results,
1631 in agreement with available paleoclimate indicators and most previous modeling studies,
1632 show the fundamentally polygenetic history of monsoonal evolution, suggesting that the very
1633 concept of a "monsoon onset" is inappropriate. We also stress the need for more accurate
1634 constrains regarding paleoshorelines evolutions, relative timing of uplift and landforms paleo-
1635 elevations in order to propose better global climate evolution scenarios.

1636 Acronyms

1637 **ITCZ** Inter Tropical Convergence Zone
1638 **SASM** South Asian Summer Monsoon
1639 **EASM** East Asian Summer Monsoon
1640 **EAWM** East Asian Winter Monsoon
1641 **HTP** Himalaya-Tibetan Plateau
1642 **IGLLJ** Indo-Gangetic Low Level Jet
1643 **MMCO** Mid Miocene Climatic Optimum
1644 **EOT** Eocene Oligocene Transition

1645 Acknowledgments

1646 The scientific colour maps (<https://www.fabiocrameri.ch/colourmaps/>) (Crameri, 2021)
1647 used in most of the Figures prevent visual distortion of the data and exclusion of read-
1648 ers with colourvision deficiencies (Crameri et al., 2020). D.T., G.L.H., F.F., A.T., Y.D.,
1649 P.S., J-B.L. and A-C.S. were granted access to the HPC resources of TGCC under the allo-
1650 cations 2018-A0050107601, 2018-A0030102212, 2019-A0070107601, 2019-A0050102212 and
1651 2020-A0090107601 made by GENCI. Y.D. acknowledges support from ANR AMOR (ANR-
1652 16-CE31-0020). Most of the Figures were done using NOAA pyferret within Jupyter note-
1653 books, thanks to the ferretmagic add-on developed at LSCE by Patrick Brockmann. Ferret
1654 is a product of NOAA's Pacific Marine Environmental Laboratory. Information is available
1655 at <http://ferret.pmel.noaa.gov/Ferret> (last access: 1 Jan 2022; NOAA's Pacific Marine En-
1656 vironmental Laboratory, 2020), distributed under the Open Source Definition. The Jupyter
1657 notebook is an open-source web application. The paleogeographic configurations from F.P.
1658 were produced using the paleoenvironment online application (<https://map.paleoenvironment.eu/>).
1659 Other reconstructions were obtained with NetCDF editor online tools developed by the Pale-
1660 oclimate modelling group at CEREGE laboratory ([https://paleoclim-cnrs.github.io/documentation-
1661 processing/IPSL_Boundary_Conditions/](https://paleoclim-cnrs.github.io/documentation-processing/IPSL_Boundary_Conditions/)).

1662

References

1663

Abbott, A. N., Haley, B. A., Tripathi, A. K., & Frank, M. (2016, April). Constraints on ocean circulation at the Paleocene–Eocene Thermal Maximum from neodymium isotopes. *Climate of the Past*, *12*(4), 837–847. Retrieved 2017-10-09, from <http://www.clim-past.net/12/837/2016/> doi: 10.5194/cp-12-837-2016

1664

1665

1666

Abels, H. A., Dupont-Nivet, G., Xiao, G., Bosboom, R., & Krijgsman, W. (2011, January). Step-wise change of Asian interior climate preceding the Eocene–Oligocene Transition (EOT). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *299*(3-4), 399–412. Retrieved 2017-10-09, from <http://linkinghub.elsevier.com/retrieve/pii/S0031018210007042> doi: 10.1016/j.palaeo.2010.11.028

1667

1668

1669

1670

1671

Acosta, R. P., & Huber, M. (2017). The neglected Indo-Gangetic Plains low-level jet and its importance for moisture transport and precipitation during the peak summer monsoon. *Geophysical Research Letters*, *44*(16), 8601–8610. Retrieved 2021-03-08, from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017GL074440> (_eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2017GL074440>) doi: <https://doi.org/10.1002/2017GL074440>

1672

1673

1674

1675

1676

1677

Acosta, R. P., & Huber, M. (2020, February). Competing Topographic Mechanisms for the Summer Indo-Asian Monsoon. *Geophysical Research Letters*, *47*(3). Retrieved 2020-06-19, from <https://onlinelibrary.wiley.com/doi/abs/10.1029/2019GL085112> doi: 10.1029/2019GL085112

1678

1679

1680

1681

Agard, P., Omrani, J., Jolivet, L., Whitechurch, H., Vrielynck, B., Spakman, W., ... Wortel, R. (2011, November). Zagros orogeny: a subduction-dominated process. *Geological Magazine*, *148*(5-6), 692–725. Retrieved 2017-10-09, from <http://www.journals.cambridge.org/abstract.S001675681100046X> doi: 10.1017/S001675681100046X

1682

1683

1684

1685

Ali, J. R., & Aitchison, J. C. (2008, June). Gondwana to Asia: Plate tectonics, paleogeography and the biological connectivity of the Indian sub-continent from the Middle Jurassic through latest Eocene (166–35 Ma). *Earth-Science Reviews*, *88*(3-4), 145–166. Retrieved 2020-10-14, from <https://linkinghub.elsevier.com/retrieve/pii/S0012825208000196> doi: 10.1016/j.earscirev.2008.01.007

1686

1687

1688

1689

1690

Ali, S., Hathorne, E. C., & Frank, M. (2021). Persistent Provenance of South Asian Monsoon-Induced Silicate Weathering Over the Past 27 Million Years. *Paleoceanography and Paleoclimatology*, *36*(3), e2020PA003909. Retrieved 2022-05-02, from <https://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003909> (_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA003909>) doi: 10.1029/2020PA003909

1691

1692

1693

1694

1695

1696

Ao, H., Roberts, A. P., Dekkers, M. J., Liu, X., Rohling, E. J., Shi, Z., ... Zhao, X. (2016, June). Late Miocene–Pliocene Asian monsoon intensification linked to Antarctic ice-sheet growth. *Earth and Planetary Science Letters*, *444*, 75–87. Retrieved 2022-05-03, from <https://linkinghub.elsevier.com/retrieve/pii/S0012821X16301157> doi: 10.1016/j.epsl.2016.03.028

1697

1698

1699

1700

1701

Ao, H., Rohling, E. J., Zhang, R., Roberts, A. P., Holbourn, A. E., Ladant, J.-B., ... An, Z. (2021, November). Global warming-induced Asian hydrological climate transition across the Miocene–Pliocene boundary. *Nature Communications*, *12*(1), 6935. Retrieved 2022-05-03, from <http://www.nature.com/articles/s41467-021-27054-5> (Number: 1 Publisher: Nature Publishing Group) doi: 10.1038/s41467-021-27054-5

1702

1703

1704

1705

1706

Aoki, I., Kurosaki, Y., Osada, R., Sato, T., & Kimura, F. (2005). Dust storms generated by mesoscale cold fronts in the Tarim Basin, Northwest China. *Geophysical Research Letters*, *32*(6). Retrieved 2022-02-21, from <http://onlinelibrary.wiley.com/doi/abs/10.1029/2004GL021776> (_eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2004GL021776>) doi: 10.1029/2004GL021776

1707

1708

1709

1710

1711

1712

Auer, G., Vleeschouwer, D. D., Smith, R. A., Bogus, K., Groeneveld, J., Grunert, P., ... Henderiks, J. (2019). Timing and Pacing of Indonesian Throughflow Restriction and Its Connection to Late Pliocene Climate Shifts. *Paleoceanography and Paleoclimatology*, *34*(4), 635–657. Retrieved 2021-09-02, from <http://>

1713

1714

1715

1716

- 1717 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018PA003512 (eprint:
1718 https://onlinelibrary.wiley.com/doi/pdf/10.1029/2018PA003512) doi: 10.1029/
1719 2018PA003512
- 1720 Austermann, J., Mitrovica, J. X., Huybers, P., & Rovere, A. (2017, July). Detection of
1721 a dynamic topography signal in last interglacial sea-level records. *Science Advances*,
1722 3(7), e1700457. Retrieved 2021-04-07, from [https://advances.sciencemag.org/
1723 content/3/7/e1700457](https://advances.sciencemag.org/content/3/7/e1700457) (Publisher: American Association for the Advancement of
1724 Science Section: Research Article) doi: 10.1126/sciadv.1700457
- 1725 Averyanova, A., Tarasevich, V., Popova, S., Utescher, T., Li, S.-F., Mosbrugger, V., & Xing,
1726 Y. (2021, February). Rupelian Kazakhstan floras in the context of early Oligocene
1727 climate and vegetation in Central Asia. *Terra Nova*, 33. doi: 10.1111/ter.12523
- 1728 Baldermann, A., Wasser, O., Abdullayev, E., Bernasconi, S., Löhr, S., Wemmer, K., ...
1729 Richoz, S. (2021, September). Palaeo-environmental evolution of Central Asia during
1730 the Cenozoic: new insights from the continental sedimentary archive of the Valley
1731 of Lakes (Mongolia). *Climate of the Past*, 17(5), 1955–1972. Retrieved 2022-03-09,
1732 from <https://cp.copernicus.org/articles/17/1955/2021/> doi: 10.5194/cp-17-
1733 -1955-2021
- 1734 Baldwin, J., & Vecchi, G. (2016, August). Influence of the Tian Shan on Arid Ex-
1735 tratropical Asia. *Journal of Climate*, 29(16), 5741–5762. Retrieved 2021-09-
1736 23, from [https://journals.ametsoc.org/view/journals/clim/29/16/jcli-d-15-
1737 -0490.1.xml](https://journals.ametsoc.org/view/journals/clim/29/16/jcli-d-15-0490.1.xml) (Publisher: American Meteorological Society Section: Journal of Cli-
1738 mate) doi: 10.1175/JCLI-D-15-0490.1
- 1739 Ballato, P., Landgraf, A., Schildgen, T. F., Stockli, D. F., Fox, M., Ghassemi, M. R.,
1740 ... Strecker, M. R. (2015, September). The growth of a mountain belt forced
1741 by base-level fall: Tectonics and surface processes during the evolution of the Al-
1742 borz Mountains, N Iran. *Earth and Planetary Science Letters*, 425, 204–218. Re-
1743 trieved 2021-03-10, from [https://www.sciencedirect.com/science/article/pii/
1744 S0012821X15003490](https://www.sciencedirect.com/science/article/pii/S0012821X15003490) doi: 10.1016/j.epsl.2015.05.051
- 1745 Ballato, P., Mulch, A., Landgraf, A., Strecker, M. R., Dalconi, M. C., Friedrich, A., &
1746 Tabatabaei, S. H. (2010, November). Middle to late Miocene Middle Eastern climate
1747 from stable oxygen and carbon isotope data, southern Alborz mountains, N Iran. *Earth
1748 and Planetary Science Letters*, 300(1), 125–138. Retrieved 2021-04-07, from [https://
1749 www.sciencedirect.com/science/article/pii/S0012821X10006308](https://www.sciencedirect.com/science/article/pii/S0012821X10006308) doi: 10.1016/
1750 j.epsl.2010.09.043
- 1751 Bande, A., Sobel, E. R., Mikolaichuk, A., Schmidt, A., & Stockli, D. F. (2017). Ex-
1752 humation history of the western Kyrgyz Tien Shan: Implications for intramontane
1753 basin formation. *Tectonics*, 36(1), 163–180. Retrieved 2021-03-26, from [http://
1754 agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2016TC004284](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2016TC004284) (eprint:
1755 <https://onlinelibrary.wiley.com/doi/pdf/10.1002/2016TC004284>) doi: [https://doi
1756 .org/10.1002/2016TC004284](https://doi.org/10.1002/2016TC004284)
- 1757 Bannon, P. R. (1979, November). On the Dynamics of the East African Jet. I: Simu-
1758 lation of Mean Conditions for July. *Journal of the Atmospheric Sciences*, 36(11),
1759 2139–2152. Retrieved 2019-07-05, from [http://journals.ametsoc.org/doi/abs/
1760 10.1175/1520-0469%281979%29036%3C2139%3AOTDOTE%3E2.0.CO%3B2](http://journals.ametsoc.org/doi/abs/10.1175/1520-0469%281979%29036%3C2139%3AOTDOTE%3E2.0.CO%3B2) doi: 10.1175/
1761 1520-0469(1979)036(2139:OTDOTE)2.0.CO;2
- 1762 Barbolini, N., Woutersen, A., Dupont-Nivet, G., Silvestro, D., Tardif, D., Coster, P. M. C.,
1763 ... Hoorn, C. (2020). Cenozoic evolution of the steppe-desert biome in Central
1764 Asia. *Science Advances*, 6(41), eabb8227. Retrieved 2022-05-03, from [https://www
1765 .science.org/doi/10.1126/sciadv.abb8227](https://www.science.org/doi/10.1126/sciadv.abb8227) (Publisher: American Association for
1766 the Advancement of Science) doi: 10.1126/sciadv.abb8227
- 1767 Barrier, , Vrielynck, B., & Brunet-Lourdin, M.-F. (2018). *Paleotectonic Reconstruction
1768 of the Central Tethyan Realm: Tectono-Sedimentary-Palinspastic Maps from Late
1769 Permian to Pliocene: Atlas of 20 Maps.*
- 1770 Beasley, C., Kender, S., Giosan, L., Bolton, C. T., Anand, P., Leng, M. J.,
1771 ... Littler, K. (2021). Evidence of a South Asian Proto-Monsoon Dur-

- 1772 ing the Oligocene-Miocene Transition. *Paleoceanography and Paleocli-*
 1773 *matology*, 36(9), e2021PA004278. Retrieved 2022-05-03, from [https://](https://onlinelibrary.wiley.com/doi/abs/10.1029/2021PA004278)
 1774 onlinelibrary.wiley.com/doi/abs/10.1029/2021PA004278 (eprint:
 1775 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2021PA004278>) doi: 10.1029/
 1776 2021PA004278
- 1777 Bershaw, J., Garziona, C. N., Schoenbohm, L., Gehrels, G., & Tao, L. (2012, January).
 1778 Cenozoic evolution of the Pamir plateau based on stratigraphy, zircon provenance,
 1779 and stable isotopes of foreland basin sediments at Oyttag (Wuyitake) in the Tarim
 1780 Basin (west China). *Journal of Asian Earth Sciences*, 44, 136–148. Retrieved 2017-
 1781 10-09, from <http://linkinghub.elsevier.com/retrieve/pii/S1367912011001878>
 1782 doi: 10.1016/j.jseaes.2011.04.020
- 1783 Betzler, C., Eberli, G. P., Kroon, D., Wright, J. D., Swart, P. K., Nath, B. N., ... Young,
 1784 J. R. (2016, July). The abrupt onset of the modern South Asian Monsoon winds.
 1785 *Scientific Reports*, 6(1), 29838. Retrieved 2022-05-03, from [http://www.nature.com/](http://www.nature.com/articles/srep29838)
 1786 [articles/srep29838](http://www.nature.com/articles/srep29838) (Number: 1 Publisher: Nature Publishing Group) doi: 10
 1787 .1038/srep29838
- 1788 Betzler, C., Eberli, G. P., Lüdmann, T., Reolid, J., Kroon, D., Reijmer, J. J. G., ... Yao,
 1789 Z. (2018, January). Refinement of Miocene sea level and monsoon events from the
 1790 sedimentary archive of the Maldives (Indian Ocean). *Progress in Earth and Planetary*
 1791 *Science*, 5(1), 5. Retrieved 2021-03-17, from [https://doi.org/10.1186/s40645-018-](https://doi.org/10.1186/s40645-018-0165-x)
 1792 [0165-x](https://doi.org/10.1186/s40645-018-0165-x) doi: 10.1186/s40645-018-0165-x
- 1793 Bhatia, H., Khan, M. A., Srivastava, G., Hazra, T., Spicer, R., Hazra, M., ... Roy, K. (2021,
 1794 May). Late Cretaceous–Paleogene Indian monsoon climate vis-à-vis movement of the
 1795 Indian plate, and the birth of the South Asian Monsoon. *Gondwana Research*, 93,
 1796 89–100. Retrieved 2022-05-03, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S1342937X21000289)
 1797 [pii/S1342937X21000289](https://linkinghub.elsevier.com/retrieve/pii/S1342937X21000289) doi: 10.1016/j.jgr.2021.01.010
- 1798 Bhatia, H., Srivastava, G., Adhikari, P., Tao, S., Utescher, T., Paudyal, K. N., &
 1799 Mehrotra, R. C. (2022, April). Asian monsoon and vegetation shift: evidence
 1800 from the Siwalik succession of India. *Geological Magazine*, 1–18. Retrieved 2022-
 1801 05-02, from [http://www.cambridge.org/core/journals/geological-magazine/](http://www.cambridge.org/core/journals/geological-magazine/article/asian-monsoon-and-vegetation-shift-evidence-from-the-siwalik-succesion-of-india/C11DD05BB2C70B0BA4ED7930A80219D2)
 1802 [article/asian-monsoon-and-vegetation-shift-evidence-from-the-siwalik](http://www.cambridge.org/core/journals/geological-magazine/article/asian-monsoon-and-vegetation-shift-evidence-from-the-siwalik-succesion-of-india/C11DD05BB2C70B0BA4ED7930A80219D2)
 1803 [-succesion-of-india/C11DD05BB2C70B0BA4ED7930A80219D2](http://www.cambridge.org/core/journals/geological-magazine/article/asian-monsoon-and-vegetation-shift-evidence-from-the-siwalik-succesion-of-india/C11DD05BB2C70B0BA4ED7930A80219D2) (Publisher: Cam-
 1804 bridge University Press) doi: 10.1017/S0016756822000243
- 1805 Bhatia, H., Srivastava, G., Spicer, R., Farnsworth, A., Spicer, T., Mehrotra, R., ... Valdes,
 1806 P. (2021, January). Leaf physiognomy records the Miocene intensification of the South
 1807 Asia Monsoon. *Global and Planetary Change*, 196, 103365. Retrieved 2022-05-03,
 1808 from <https://linkinghub.elsevier.com/retrieve/pii/S0921818120302563> doi:
 1809 10.1016/j.gloplacha.2020.103365
- 1810 Bialik, O. M., Auer, G., Ogawa, N. O., Kroon, D., Waldmann, N. D., & Ohkouchi, N.
 1811 (2020). Monsoons, Upwelling, and the Deoxygenation of the Northwestern Indian
 1812 Ocean in Response to Middle to Late Miocene Global Climatic Shifts. *Paleoceanogra-*
 1813 *phy and Paleoclimatology*, 35(2), e2019PA003762. Retrieved 2021-03-17, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019PA003762)
 1814 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019PA003762 (eprint:
 1815 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2019PA003762>) doi: [https://doi](https://doi.org/10.1029/2019PA003762)
 1816 [.org/10.1029/2019PA003762](https://doi.org/10.1029/2019PA003762)
- 1817 Bialik, O. M., Frank, M., Betzler, C., Zammit, R., & Waldmann, N. D. (2019, June).
 1818 Two-step closure of the Miocene Indian Ocean Gateway to the Mediterranean. *Sci-*
 1819 *entific Reports*, 9(1), 8842. Retrieved 2021-03-09, from [https://www.nature.com/](https://www.nature.com/articles/s41598-019-45308-7)
 1820 [articles/s41598-019-45308-7](https://www.nature.com/articles/s41598-019-45308-7) (Number: 1 Publisher: Nature Publishing Group)
 1821 doi: 10.1038/s41598-019-45308-7
- 1822 Bierman, P. R., Shakun, J. D., Corbett, L. B., Zimmerman, S. R., & Rood, D. H.
 1823 (2016, December). A persistent and dynamic East Greenland Ice Sheet over the
 1824 past 7.5 million years. *Nature*, 540(7632), 256–260. Retrieved 2021-06-21, from
 1825 <http://www.nature.com/articles/nature20147> (Bandiera_abtest: a Cg_type: Na-
 1826 ture Research Journals Number: 7632 Primary_atype: Research Publisher: Nature

- 1827 Publishing Group Subject_term: Cryospheric science;Nuclear chemistry;Palaeoclimate
 1828 Subject_term_id: cryospheric-science;nuclear-chemistry;palaeoclimate) doi: 10.1038/
 1829 nature20147
- 1830 Blayney, T., Najman, Y., Dupont-Nivet, G., Carter, A., Millar, I., Garzanti, E., ... Vezzoli,
 1831 G. (2016, October). Indentation of the Pamirs with respect to the northern margin
 1832 of Tibet: Constraints from the Tarim basin sedimentary record: INDENTATION OF
 1833 THE PAMIRS. *Tectonics*, *35*(10), 2345–2369. Retrieved 2017-10-09, from [http://](http://doi.wiley.com/10.1002/2016TC004222)
 1834 doi.wiley.com/10.1002/2016TC004222 doi: 10.1002/2016TC004222
- 1835 Bolton, C. T., Gray, E., Kuhnt, W., Holbourn, A. E., Lübbbers, J., Grant, K., ... Andersen,
 1836 N. (2021, June). *Secular and orbital-scale variability of equatorial Indian Ocean*
 1837 *summer monsoon winds during the late Miocene* (preprint). Ocean Dynamics/Marine
 1838 Archives/Milankovitch. Retrieved 2021-09-07, from [https://cp.copernicus.org/](https://cp.copernicus.org/preprints/cp-2021-77/)
 1839 [preprints/cp-2021-77/](https://cp-2021-77/) doi: 10.5194/cp-2021-77
- 1840 Bolton, C. T., Gray, E., Kuhnt, W., Holbourn, A. E., Lübbbers, J., Grant, K., ... Andersen,
 1841 N. (2022, April). Secular and orbital-scale variability of equatorial Indian Ocean
 1842 summer monsoon winds during the late Miocene. *Climate of the Past*, *18*(4), 713–738.
 1843 Retrieved 2022-06-02, from <https://cp.copernicus.org/articles/18/713/2022/>
 1844 [doi: 10.5194/cp-18-713-2022](https://cp.copernicus.org/articles/18/713/2022/)
- 1845 Boos, W. R., & Kuang, Z. (2010, January). Dominant control of the South Asian monsoon by
 1846 orographic insulation versus plateau heating. *Nature*, *463*(7278), 218–222. Retrieved
 1847 2017-10-09, from <http://www.nature.com/doi/10.1038/nature08707> doi:
 1848 10.1038/nature08707
- 1849 Bosboom, R., Dupont-Nivet, G., Grothe, A., Brinkhuis, H., Villa, G., Mandic, O., ...
 1850 Krijgsman, W. (2014a, October). Linking Tarim Basin sea retreat (west China) and
 1851 Asian aridification in the late Eocene. *Basin Research*, *26*(5), 621–640. Retrieved 2017-
 1852 10-09, from <http://doi.wiley.com/10.1111/bre.12054> doi: 10.1111/bre.12054
- 1853 Bosboom, R., Dupont-Nivet, G., Grothe, A., Brinkhuis, H., Villa, G., Mandic, O., ... Guo,
 1854 Z. (2014b, June). Timing, cause and impact of the late Eocene stepwise sea retreat
 1855 from the Tarim Basin (west China). *Palaeogeography, Palaeoclimatology, Palaeoecol-*
 1856 *ogy*, *403*, 101–118. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/](http://linkinghub.elsevier.com/retrieve/pii/S0031018214001709)
 1857 [retrieve/pii/S0031018214001709](http://linkinghub.elsevier.com/retrieve/pii/S0031018214001709) doi: 10.1016/j.palaeo.2014.03.035
- 1858 Bosboom, R., Mandic, O., Dupont-Nivet, G., Proust, J.-N., Ormukov, C., & Aminov, J.
 1859 (2017). Late Eocene palaeogeography of the proto-Paratethys Sea in Central Asia
 1860 (NW China, southern Kyrgyzstan and SW Tajikistan). *Geological Society, Lon-*
 1861 *don, Special Publications*, *427*(1), 565–588. Retrieved 2019-11-22, from [http://](http://sp.lyellcollection.org/lookup/doi/10.1144/SP427.11)
 1862 sp.lyellcollection.org/lookup/doi/10.1144/SP427.11 doi: 10.1144/SP427.11
- 1863 Botsyun, S., Sepulchre, P., Donnadieu, Y., Risi, C., Licht, A., & Caves Rugenstein,
 1864 J. K. (2019, March). Revised paleoaltimetry data show low Tibetan Plateau el-
 1865 evation during the Eocene. *Science*, *363*(6430), eaaq1436. Retrieved 2019-07-23,
 1866 from <http://www.sciencemag.org/lookup/doi/10.1126/science.aaq1436> doi:
 1867 10.1126/science.aaq1436
- 1868 Botsyun, S., Sepulchre, P., Risi, C., & Donnadieu, Y. (2016, June). Impacts of Tibetan
 1869 Plateau uplift on atmospheric dynamics and associated precipitation ¹⁸O. *Climate of*
 1870 *the Past*, *12*(6), 1401–1420. Retrieved 2017-10-09, from [http://www.clim-past.net/](http://www.clim-past.net/12/1401/2016/)
 1871 [12/1401/2016/](http://www.clim-past.net/12/1401/2016/) doi: 10.5194/cp-12-1401-2016
- 1872 Boucot, A. J., Xu, C., Scotese, C. R., & Morley, R. J. (2013). *Phanerozoic Paleoclimate: An*
 1873 *Atlas of Lithologic Indicators of Climate*. Tulsa, Oklahoma, U.S.A.: SEPM (Society for
 1874 Sedimentary Geology). Retrieved 2019-11-04, from [https://pubs.geoscienceworld](https://pubs.geoscienceworld.org/books/book/1966/)
 1875 [.org/books/book/1966/](https://pubs.geoscienceworld.org/books/book/1966/) doi: 10.2110/sepmsp.11
- 1876 Bougeois, L., Dupont-Nivet, G., de Rafélis, M., Tindall, J. C., Proust, J.-N., Reichart,
 1877 G.-J., ... Ormukov, C. (2018, March). Asian monsoons and aridification response
 1878 to Paleogene sea retreat and Neogene westerly shielding indicated by seasonality in
 1879 Paratethys oysters. *Earth and Planetary Science Letters*, *485*, 99–110. Retrieved 2018-
 1880 04-03, from <http://linkinghub.elsevier.com/retrieve/pii/S0012821X17307483>
 1881 [doi: 10.1016/j.epsl.2017.12.036](http://linkinghub.elsevier.com/retrieve/pii/S0012821X17307483)

- 1882 Bullen, M., Burbank, D., & Garver, J. (2003, March). Building the Northern Tien Shan: In-
 1883 tegrated Thermal, Structural, and Topographic Constraints. *The Journal of Geology*,
 1884 *111*(2), 149–165. Retrieved 2021-03-26, from [https://www.journals.uchicago.edu/](https://www.journals.uchicago.edu/doi/10.1086/345840)
 1885 [doi/10.1086/345840](https://www.journals.uchicago.edu/doi/10.1086/345840) doi: 10.1086/345840
- 1886 Burls, N. J., Bradshaw, C. D., Boer, A. M. D., Herold, N., Huber, M., Pound,
 1887 M., ... Zhang, Z. (2021). Simulating Miocene Warmth: Insights From
 1888 an Opportunistic Multi-Model Ensemble (MioMIP1). *Paleoceanography and Pa-*
 1889 *leoclimatology*, *36*(5), e2020PA004054. Retrieved 2021-06-21, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020PA004054)
 1890 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020PA004054 (eprint:
 1891 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA004054>) doi: 10.1029/
 1892 2020PA004054
- 1893 Cane, M. A., & Molnar, P. (2001, May). Closing of the Indonesian seaway as a
 1894 precursor to east African aridification around 3–4 million years ago. *Nature*,
 1895 *411*(6834), 157–162. Retrieved 2021-09-09, from [http://www.nature.com/articles/](http://www.nature.com/articles/35075500)
 1896 [35075500](http://www.nature.com/articles/35075500) (Bandiera_abtest: a Cg_type: Nature Research Journals Number: 6834 Pri-
 1897 mary_atype: Research Publisher: Nature Publishing Group) doi: 10.1038/35075500
- 1898 Carrapa, B., DeCelles, P. G., Wang, X., Clementz, M. T., Mancin, N., Stoica, M., ... Chen,
 1899 F. (2015, August). Tectono-climatic implications of Eocene Paratethys regression in
 1900 the Tajik basin of central Asia. *Earth and Planetary Science Letters*, *424*, 168–178. Re-
 1901 trieved 2022-03-21, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0012821X15003325)
 1902 [S0012821X15003325](https://www.sciencedirect.com/science/article/pii/S0012821X15003325) doi: 10.1016/j.epsl.2015.05.034
- 1903 Cavazza, W., Cattò, S., Zattin, M., Okay, A. I., & Reiners, P. (2018, August). Ther-
 1904 mochronology of the Miocene Arabia-Eurasia collision zone of southeastern Turkey.
 1905 *Geosphere*, *14*(5), 2277–2293. Retrieved 2022-03-04, from [https://doi.org/10](https://doi.org/10.1130/GES01637.1)
 1906 [.1130/GES01637.1](https://doi.org/10.1130/GES01637.1) doi: 10.1130/GES01637.1
- 1907 Caves Rugenstein, J., Bayshashov, B., Zhamangara, A., Ritch, A., Ibarra, D., Mix, H.,
 1908 ... Chamberlain, C. (2017, February). Late Miocene Uplift of the Tian Shan and
 1909 Altai and Reorganization of Central Asia Climate. *GSA Today*, *27*. doi: 10.1130/
 1910 GSATG305A.1
- 1911 Caves Rugenstein, J., Sjostrom, D., Mix, H., Winnick, M., & Chamberlain, C. (2014,
 1912 September). Aridification of Central Asia and Uplift of the Altai and Hangay Moun-
 1913 tains, Mongolia: Stable Isotope Evidence. *American Journal of Science*, *314*, 1171–
 1914 1201. doi: 10.2475/08.2014.01]
- 1915 Cerling, T. E., Wang, Y., & Quade, J. (1993). Expansion of C4 ecosystems as an indicator
 1916 of global ecological change in the late Miocene. *Nature*, *361*(6410), 344–345.
- 1917 Chakraborty, A., Nanjundiah, R. S., & Srinivasan, J. (2009). Impact of African
 1918 orography and the Indian summer monsoon on the low-level Somali jet. *In-*
 1919 *ternational Journal of Climatology*, *29*(7), 983–992. Retrieved 2022-06-28,
 1920 from <http://onlinelibrary.wiley.com/doi/abs/10.1002/joc.1720> (eprint:
 1921 <https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/joc.1720>) doi: 10.1002/joc
 1922 .1720
- 1923 Charreau, J., Chen, Y., Gilder, S., Dominguez, S., Avouac, J.-P., Sen, S., ... Wang,
 1924 W.-M. (2005, January). Magnetostratigraphy and rock magnetism of the Neogene
 1925 Kuitun He section (northwest China): implications for Late Cenozoic uplift of the
 1926 Tianshan mountains. *Earth and Planetary Science Letters*, *230*(1), 177–192. Re-
 1927 trieved 2021-03-29, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0012821X04006739)
 1928 [S0012821X04006739](https://www.sciencedirect.com/science/article/pii/S0012821X04006739) doi: 10.1016/j.epsl.2004.11.002
- 1929 Charreau, J., Kent-Corson, M. L., Barrier, L., Augier, R., Ritts, B. D., Chen, Y.,
 1930 ... Guilmette, C. (2012, August). A high-resolution stable isotopic record from
 1931 the Junggar Basin (NW China): Implications for the paleotopographic evolution
 1932 of the Tianshan Mountains. *Earth and Planetary Science Letters*, *341–344*, 158–
 1933 169. Retrieved 2022-06-17, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S0012821X12002622)
 1934 [pii/S0012821X12002622](https://linkinghub.elsevier.com/retrieve/pii/S0012821X12002622) doi: 10.1016/j.epsl.2012.05.033
- 1935 Chatterjee, S., Goswami, A., & Scotese, C. R. (2013, January). The longest voy-
 1936 age: Tectonic, magmatic, and paleoclimatic evolution of the Indian plate during

- 1937 its northward flight from Gondwana to Asia. *Gondwana Research*, 23(1), 238–
 1938 267. Retrieved 2020-10-14, from [https://linkinghub.elsevier.com/retrieve/
 1939 pii/S1342937X12002390](https://linkinghub.elsevier.com/retrieve/pii/S1342937X12002390) doi: 10.1016/j.gr.2012.07.001
- 1940 Chen, J., Huang, W., Feng, S., Zhang, Q., Kuang, X., Chen, J., & Chen, F. (2021). The
 1941 modulation of westerlies-monsoon interaction on climate over the monsoon bound-
 1942 ary zone in East Asia. *International Journal of Climatology*, 41(S1), E3049–E3064.
 1943 Retrieved 2022-05-16, from [http://onlinelibrary.wiley.com/doi/abs/10.1002/
 1944 joc.6903](http://onlinelibrary.wiley.com/doi/abs/10.1002/joc.6903) (eprint: <https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/joc.6903>)
 1945 doi: 10.1002/joc.6903
- 1946 Clark, M., House, M., Royden, L., Whipple, K., Burchfiel, B., Zhang, X., & Tang, W. (2005,
 1947 June). Late Cenozoic uplift of southeastern Tibet. *Geology*, 33(6), 525–528. Retrieved
 1948 2022-03-03, from <https://doi.org/10.1130/G21265.1> doi: 10.1130/G21265.1
- 1949 Clift, P., Hodges, K., Heslop, Hannigan, R., Hoang, L., & Calves, G. (2008, November).
 1950 Correlation of Himalayan exhumation rates and Asia monsoon intensity. *Nature Geo-
 1951 science*, 1, doi:10.1038/ngeo351. doi: 10.1038/ngeo351
- 1952 Clift, P. D. (2020, June). Asian monsoon dynamics and sediment transport in SE
 1953 Asia. *Journal of Asian Earth Sciences*, 195, 104352. Retrieved 2022-05-02, from
 1954 <https://linkinghub.elsevier.com/retrieve/pii/S1367912020301334> doi: 10
 1955 .1016/j.jseaes.2020.104352
- 1956 Cohen, J., Saito, K., & Entekhabi, D. (2001, January). The role of the Siberian high in
 1957 northern hemisphere climate variability. *Geophysical Research Letters*, 28(2), 299–302.
 1958 Retrieved 2020-06-20, from <http://doi.wiley.com/10.1029/2000GL011927> doi:
 1959 10.1029/2000GL011927
- 1960 Cook, K. L., & Royden, L. H. (2008). The role of crustal strength varia-
 1961 tions in shaping orogenic plateaus, with application to Tibet. *Journal of Geo-
 1962 physical Research: Solid Earth*, 113(B8). Retrieved 2021-03-29, from [http://
 1963 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2007JB005457](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2007JB005457) (eprint:
 1964 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2007JB005457>) doi: [https://doi
 1965 .org/10.1029/2007JB005457](https://doi.org/10.1029/2007JB005457)
- 1966 Couvreur, T. L. P., Dauby, G., Blach-Overgaard, A., Deblauwe, V., Dessein, S., Drois-
 1967 sart, V., ... Sepulchre, P. (2021). Tectonics, climate and the diversification of
 1968 the tropical African terrestrial flora and fauna. *Biological Reviews*, 96(1), 16–51.
 1969 Retrieved 2021-03-09, from [https://onlinelibrary.wiley.com/doi/abs/10.1111/
 1970 brv.12644](https://onlinelibrary.wiley.com/doi/abs/10.1111/brv.12644) (eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/brv.12644>)
 1971 doi: <https://doi.org/10.1111/brv.12644>
- 1972 Crameri, F. (2021, February). *Scientific colour maps*. Zenodo. Retrieved 2021-04-15,
 1973 from <https://zenodo.org/record/4491293> (Language: eng) doi: 10.5281/zenodo
 1974 .4491293
- 1975 Crameri, F., Shephard, G. E., & Heron, P. J. (2020, October). The misuse of colour
 1976 in science communication. *Nature Communications*, 11(1), 5444. Retrieved 2021-
 1977 04-15, from <http://www.nature.com/articles/s41467-020-19160-7> (Number: 1
 1978 Publisher: Nature Publishing Group) doi: 10.1038/s41467-020-19160-7
- 1979 Cunningham, W. D. (2001, February). Cenozoic normal faulting and regional doming in the
 1980 southern Hangay region, Central Mongolia: implications for the origin of the Baikal
 1981 rift province. *Tectonophysics*, 331(4), 389–411. Retrieved 2021-03-26, from [https://
 1982 www.sciencedirect.com/science/article/pii/S0040195100002286](https://www.sciencedirect.com/science/article/pii/S0040195100002286) doi: 10.1016/
 1983 S0040-1951(00)00228-6
- 1984 Cyr, A., Currie, B., & Rowley, D. (2005, September). Geochemical Evaluation of
 1985 Fenghuoshan Group Lacustrine Carbonates, North-Central Tibet: Implications for
 1986 the Paleoaerometry of the Eocene Tibetan Plateau. *The Journal of Geology*, 113(5),
 1987 517–533. Retrieved 2021-03-29, from [https://www.journals.uchicago.edu/doi/
 1988 10.1086/431907](https://www.journals.uchicago.edu/doi/10.1086/431907) doi: 10.1086/431907
- 1989 Daradich, A., Mitrovica, J. X., Pysklywec, R. N., Willett, S. D., & Forte, A. M. (2003).
 1990 Mantle flow, dynamic topography, and rift-flank uplift of Arabia. *Geology*, 31(10),
 1991 901–904.

- 1992 Darin, M. H., Umhoefer, P. J., & Thomson, S. N. (2018). Rapid Late Eocene
1993 Exhumation of the Sivas Basin (Central Anatolia) Driven by Initial Arabia-
1994 Eurasia Collision. *Tectonics*, *37*(10), 3805–3833. Retrieved 2022-03-04, from
1995 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2017TC004954> (eprint:
1996 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2017TC004954>) doi: 10
1997 .1029/2017TC004954
- 1998 DeConto, R. M., & Pollard, D. (2003, September). A coupled climate–ice sheet mod-
1999 eling approach to the Early Cenozoic history of the Antarctic ice sheet. *Palaeo-*
2000 *geography, Palaeoclimatology, Palaeoecology*, *198*(1-2), 39–52. Retrieved 2018-01-08,
2001 from <http://linkinghub.elsevier.com/retrieve/pii/S0031018203003936> doi:
2002 10.1016/S0031-0182(03)00393-6
- 2003 De Grave, J., Buslov, M. M., & Van den haute, P. (2007, February). Distant effects
2004 of India–Eurasia convergence and Mesozoic intracontinental deformation in Central
2005 Asia: Constraints from apatite fission-track thermochronology. *Journal of Asian Earth*
2006 *Sciences*, *29*(2), 188–204. Retrieved 2021-03-26, from [https://www.sciencedirect](https://www.sciencedirect.com/science/article/pii/S136791200600071X)
2007 [.com/science/article/pii/S136791200600071X](https://www.sciencedirect.com/science/article/pii/S136791200600071X) doi: 10.1016/j.jseas.2006.03.001
- 2008 De Grave, J., Buslov, M. M., Van Den Haute, P., Metcalf, J., Dehandschutter, B., &
2009 McWilliams, M. O. (2009). Multi-method chronometry of the Teletskoye graben and
2010 its basement, Siberian Altai Mountains: new insights on its thermo-tectonic evolution.
2011 *Geological Society, London, Special Publications*, *324*(1), 237–259. Retrieved 2021-04-
2012 20, from <http://sp.lyellcollection.org/lookup/doi/10.1144/SP324.17> doi:
2013 10.1144/SP324.17
- 2014 Deng, T., Wu, F., Wang, S., Su, T., & Zhou, Z. (2021, April). Major turnover of biotas
2015 across the Oligocene/Miocene boundary on the Tibetan Plateau. *Palaeogeography,*
2016 *Palaeoclimatology, Palaeoecology*, *567*, 110241. Retrieved 2022-03-22, from [https://](https://www.sciencedirect.com/science/article/pii/S0031018221000262)
2017 www.sciencedirect.com/science/article/pii/S0031018221000262 doi: 10.1016/
2018 j.palaeo.2021.110241
- 2019 Dettman, D. L., Kohn, M. J., Quade, J., Ryerson, F., Ojha, T. P., & Hamidullah, S. (2001,
2020 January). Seasonal stable isotope evidence for a strong Asian monsoon throughout
2021 the past 10.7 m.y. *Geology*, *29*(1), 31–34. Retrieved 2022-05-30, from [https://](https://doi.org/10.1130/0091-7613(2001)029<0031:SSIEFA>2.0.CO;2)
2022 [doi.org/10.1130/0091-7613\(2001\)029<0031:SSIEFA>2.0.CO;2](https://doi.org/10.1130/0091-7613(2001)029<0031:SSIEFA>2.0.CO;2) doi: 10.1130/0091-
2023 -7613(2001)029(0031:SSIEFA)2.0.CO;2
- 2024 Ding, L., Spicer, R., Yang, J., Xu, Q., Cai, F., Li, S., ... Mehrotra, R. (2017, March).
2025 Quantifying the rise of the Himalaya orogen and implications for the South Asian
2026 monsoon. *Geology*, *45*(3), 215–218. Retrieved 2017-10-09, from [https://pubs](https://pubs.geoscienceworld.org/geology/article/45/3/215-218/195254)
2027 [.geoscienceworld.org/geology/article/45/3/215-218/195254](https://pubs.geoscienceworld.org/geology/article/45/3/215-218/195254) doi: 10.1130/
2028 G38583.1
- 2029 Ding, L., Xu, Q., Yue, Y., Wang, H., Cai, F., & Li, S. (2014, April). The Andean-
2030 type Gangdese Mountains: Paleoelevation record from the Paleocene–Eocene Linzhou
2031 Basin. *Earth and Planetary Science Letters*, *392*, 250–264. Retrieved 2017-10-09,
2032 from <http://linkinghub.elsevier.com/retrieve/pii/S0012821X14000612> doi:
2033 10.1016/j.epsl.2014.01.045
- 2034 Ding, W., Hou, D., Gan, J., Wu, P., Zhang, M., & George, S. C. (2021, April).
2035 Palaeovegetation variation in response to the late Oligocene-early Miocene East
2036 Asian summer monsoon in the Ying-Qiong Basin, South China Sea. *Palaeogeog-*
2037 *raphy, Palaeoclimatology, Palaeoecology*, *567*, 110205. Retrieved 2022-05-03, from
2038 <https://linkinghub.elsevier.com/retrieve/pii/S0031018220306532> doi: 10
2039 .1016/j.palaeo.2020.110205
- 2040 Ding, Z., Huang, G., Liu, F., Wu, R., & Wang, P. (2021, June). Responses of global mon-
2041 soon and seasonal cycle of precipitation to precession and obliquity forcing. *Climate*
2042 *Dynamics*, *56*. doi: 10.1007/s00382-021-05663-6
- 2043 Dowsett, H., Dolan, A., Rowley, D., Moucha, R., Forte, A. M., Mitrovica, J. X., ... Hay-
2044 wood, A. (2016, July). The PRISM4 (mid-Piacenzian) paleoenvironmental reconstruc-
2045 tion. *Climate of the Past*, *12*(7), 1519–1538. Retrieved 2022-04-15, from [https://](https://cp.copernicus.org/articles/12/1519/2016/)
2046 cp.copernicus.org/articles/12/1519/2016/ doi: 10.5194/cp-12-1519-2016

- 2047 Dufresne, J.-L., Foujols, M.-A., Denvil, S., Caubel, A., Marti, O., Aumont, O., ... Vuichard,
2048 N. (2013, May). Climate change projections using the IPSL-CM5 Earth System
2049 Model: from CMIP3 to CMIP5. *Climate Dynamics*, *40*(9-10), 2123–2165. Retrieved
2050 2019-11-22, from <http://link.springer.com/10.1007/s00382-012-1636-1> doi:
2051 10.1007/s00382-012-1636-1
- 2052 Dupont-Nivet, G., Lippert, P. C., Van Hinsbergen, D. J., Meijers, M. J., & Kapp, P.
2053 (2010, September). Palaeolatitude and age of the Indo-Asia collision: palaeomagnetic
2054 constraints: Palaeolatitude and age of the Indo-Asia collision. *Geophysical Journal*
2055 *International*, *182*(3), 1189–1198. Retrieved 2019-10-21, from [https://academic](https://academic.oup.com/gji/article-lookup/doi/10.1111/j.1365-246X.2010.04697.x)
2056 [.oup.com/gji/article-lookup/doi/10.1111/j.1365-246X.2010.04697.x](https://academic.oup.com/gji/article-lookup/doi/10.1111/j.1365-246X.2010.04697.x) doi:
2057 10.1111/j.1365-246X.2010.04697.x
- 2058 Edwards, E. J., Osborne, C. P., Strömberg, C. A. E., Smith, S. A., C4 GRASSES
2059 CONSORTIUM, Bond, W. J., ... Tipple, B. (2010, April). The Origins of C4
2060 Grasslands: Integrating Evolutionary and Ecosystem Science. *Science*, *328*(5978),
2061 587–591. Retrieved 2022-06-08, from [http://www.science.org/doi/full/10.1126/](http://www.science.org/doi/full/10.1126/science.1177216)
2062 [science.1177216](http://www.science.org/doi/full/10.1126/science.1177216) (Publisher: American Association for the Advancement of Science)
2063 doi: 10.1126/science.1177216
- 2064 Faccenna, C., Glišović, P., Forte, A., Becker, T. W., Garzanti, E., Sembroni, A., & Gvirtz-
2065 man, Z. (2019, December). Role of dynamic topography in sustaining the Nile River
2066 over 30 million years. *Nature Geoscience*, *12*(12), 1012–1017. Retrieved 2021-03-10,
2067 from <http://www.nature.com/articles/s41561-019-0472-x> (Number: 12 Pub-
2068 lisher: Nature Publishing Group) doi: 10.1038/s41561-019-0472-x
- 2069 Fang, X., Yan, M., Zhang, W., Nie, J., Han, W., Wu, F., ... Yang, Y. (2021, Novem-
2070 ber). Paleogeography control of Indian monsoon intensification and expansion at
2071 41 Ma. *Science Bulletin*, *66*(22), 2320–2328. Retrieved 2022-05-02, from [https://](https://linkinghub.elsevier.com/retrieve/pii/S2095927321005041)
2072 linkinghub.elsevier.com/retrieve/pii/S2095927321005041 doi: 10.1016/j.scib
2073 .2021.07.023
- 2074 Farnsworth, A., Lunt, D. J., Robinson, S. A., Valdes, P. J., Roberts, W. H. G., Clift,
2075 P. D., ... Pancost, R. D. (2019, October). Past East Asian monsoon evolution
2076 controlled by paleogeography, not CO₂. *Science Advances*, *5*(10), eaax1697. Retrieved
2077 2019-11-04, from [http://advances.sciencemag.org/lookup/doi/10.1126/sciadv](http://advances.sciencemag.org/lookup/doi/10.1126/sciadv.aax1697)
2078 [.aax1697](http://advances.sciencemag.org/lookup/doi/10.1126/sciadv.aax1697) doi: 10.1126/sciadv.aax1697
- 2079 Feakins, S. J., Liddy, H. M., Tauxe, L., Galy, V., Feng, X., Tierney, J. E., ... Warny,
2080 S. (2020). Miocene C4 Grassland Expansion as Recorded by the Indus Fan. *Paleo-*
2081 *ceanography and Paleoclimatology*, *35*(6), e2020PA003856. Retrieved 2022-06-07, from
2082 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003856> (eprint:
2083 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA003856>) doi: 10
2084 .1029/2020PA003856
- 2085 Feng, R., & Poulsen, C. J. (2016, February). Refinement of Eocene lapse rates, fossil-
2086 leaf altimetry, and North American Cordilleran surface elevation estimates. *Earth*
2087 *and Planetary Science Letters*, *436*, 130–141. Retrieved 2020-03-23, from [https://](https://linkinghub.elsevier.com/retrieve/pii/S0012821X15007852)
2088 linkinghub.elsevier.com/retrieve/pii/S0012821X15007852 doi: 10.1016/j.epsl
2089 .2015.12.022
- 2090 Fichefet, T., & Maqueda, M. A. M. (1997). Sensitivity of a global sea ice model to the
2091 treatment of ice thermodynamics and dynamics. *Journal of Geophysical Research:*
2092 *Oceans*, *102*(C6), 12609–12646.
- 2093 Findlater, J. (1969, April). A major low-level air current near the Indian Ocean during the
2094 northern summer. *Quarterly Journal of the Royal Meteorological Society*, *95*(404),
2095 362–380. Retrieved 2021-09-02, from [https://onlinelibrary.wiley.com/doi/10](https://onlinelibrary.wiley.com/doi/10.1002/qj.49709540409)
2096 [.1002/qj.49709540409](https://onlinelibrary.wiley.com/doi/10.1002/qj.49709540409) doi: 10.1002/qj.49709540409
- 2097 Fluteau, F., Ramstein, G., & Besse, J. (1999, May). Simulating the evolution of the
2098 Asian and African monsoons during the past 30 Myr using an atmospheric general
2099 circulation model. *Journal of Geophysical Research: Atmospheres*, *104*(D10), 11995–
2100 12018. Retrieved 2019-05-10, from <http://doi.wiley.com/10.1029/1999JD900048>
2101 doi: 10.1029/1999JD900048

- 2102 Foster, G. L., Royer, D. L., & Lunt, D. J. (2017, April). Future climate forcing potentially without precedent in the last 420 million years. *Nature Communications*, 8(1).
 2103 Retrieved 2020-05-28, from <http://www.nature.com/articles/ncomms14845> doi:
 2104 10.1038/ncomms14845
- 2106 François, T., Burov, E., Agard, P., & Meyer, B. (2014). Buildup of a dynamically supported
 2107 orogenic plateau: Numerical modeling of the Zagros/Central Iran case study. *Geo-*
 2108 *chemistry, Geophysics, Geosystems*, 15(6), 2632–2654. Retrieved 2021-03-09, from
 2109 <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2013GC005223>
 2110 (_eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2013GC005223>)
 2111 doi: <https://doi.org/10.1002/2013GC005223>
- 2112 Garzione, C. N., Ikari, M. J., & Basu, A. R. (2005, September). Source of Oligocene
 2113 to Pliocene sedimentary rocks in the Linxia basin in northeastern Tibet from Nd
 2114 isotopes: Implications for tectonic forcing of climate. *GSA Bulletin*, 117(9-10), 1156–
 2115 1166. Retrieved 2021-09-07, from <https://doi.org/10.1130/B25743.1> doi: 10.
 2116 .1130/B25743.1
- 2117 Golonka, J. (2009). Phanerozoic paleoenvironment and paleolithofacies maps : Cenozoic.
 2118 *Geologia / Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, T. 35, z.*
 2119 *4*, 507–587. Retrieved 2021-04-06, from [http://yadda.icm.edu.pl/yadda/element/](http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-AGHM-0011-0001)
 2120 [bwmeta1.element.baztech-article-AGHM-0011-0001](http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-AGHM-0011-0001)
- 2121 Gough, D. O. (1981). Solar Interior Structure and Luminosity Variations. In V. Domingo
 2122 (Ed.), *Physics of Solar Variations* (pp. 21–34). Dordrecht: Springer Netherlands.
 2123 Retrieved 2019-10-03, from [http://link.springer.com/10.1007/978-94-010-9633](http://link.springer.com/10.1007/978-94-010-9633-1_4)
 2124 [-1_4](http://link.springer.com/10.1007/978-94-010-9633-1_4) doi: 10.1007/978-94-010-9633-1_4
- 2125 Gourbet, L., Leloup, P. H., Paquette, J.-L., Sorrel, P., Maheo, G., Wang, G., ... Shen, T.
 2126 (2017, March). Reappraisal of the Jianchuan Cenozoic basin stratigraphy and its impli-
 2127 cations on the SE Tibetan plateau evolution. *Tectonophysics*, 700-701, 162–179. Re-
 2128 trieved 2021-03-29, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0040195117300537)
 2129 [S0040195117300537](https://www.sciencedirect.com/science/article/pii/S0040195117300537) doi: 10.1016/j.tecto.2017.02.007
- 2130 Guillocheau, F., Simon, B., Baby, G., Bessin, P., Robin, C., & Dauteuil, O. (2018, January).
 2131 Planation surfaces as a record of mantle dynamics: The case example of Africa. *Gond-*
 2132 *wana Research*, 53, 82–98. Retrieved 2021-04-07, from [https://www.sciencedirect](https://www.sciencedirect.com/science/article/pii/S1342937X17302496)
 2133 [.com/science/article/pii/S1342937X17302496](https://www.sciencedirect.com/science/article/pii/S1342937X17302496) doi: 10.1016/j.gr.2017.05.015
- 2134 Guo, Z. T., Ruddiman, W. F., Hao, Q. Z., Wu, H. B., Qiao, Y. S., Zhu, R. X., ... Liu,
 2135 T. S. (2002, March). Onset of Asian desertification by 22 Myr ago inferred from
 2136 loess deposits in China. *Nature*, 416(6877), 159–163. Retrieved 2020-04-24, from
 2137 <http://www.nature.com/articles/416159a> doi: 10.1038/416159a
- 2138 Guo, Z. T., Sun, B., Zhang, Z. S., Peng, S. Z., Xiao, G. Q., Ge, J. Y., ... Liu, J. F. (2008).
 2139 A major reorganization of Asian climate by the early Miocene. *Climate of the Past*,
 2140 4(3), 153–174.
- 2141 Gupta, A. K., Yuvaraja, A., Prakasam, M., Clemens, S. C., & Velu, A. (2015, Novem-
 2142 ber). Evolution of the South Asian monsoon wind system since the late Middle
 2143 Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 438, 160–167. Re-
 2144 trieved 2021-09-07, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018215004332)
 2145 [S0031018215004332](https://www.sciencedirect.com/science/article/pii/S0031018215004332) doi: 10.1016/j.palaeo.2015.08.006
- 2146 Gébelin, A., Mulch, A., Teyssier, C., Jessup, M. J., Law, R. D., & Brunel, M.
 2147 (2013, July). The Miocene elevation of Mount Everest. *Geology*, 41(7), 799–
 2148 802. Retrieved 2017-10-09, from [http://pubs.geoscienceworld.org/geology/](http://pubs.geoscienceworld.org/geology/article/41/7/799/131318/The-Miocene-elevation-of-Mount-Everest)
 2149 [article/41/7/799/131318/The-Miocene-elevation-of-Mount-Everest](http://pubs.geoscienceworld.org/geology/article/41/7/799/131318/The-Miocene-elevation-of-Mount-Everest) doi: 10.
 2150 .1130/G34331.1
- 2151 Gülyüz, E., Durak, H., Özkaptan, M., & Krijgsman, W. (2020, January). Paleomagnetic
 2152 constraints on the early Miocene closure of the southern Neo-Tethys (Van region; East
 2153 Anatolia): Inferences for the timing of Eurasia-Arabia collision. *Global and Planetary*
 2154 *Change*, 185, 103089. Retrieved 2022-03-04, from [https://www.sciencedirect.com/](https://www.sciencedirect.com/science/article/pii/S0921818119305740)
 2155 [science/article/pii/S0921818119305740](https://www.sciencedirect.com/science/article/pii/S0921818119305740) doi: 10.1016/j.gloplacha.2019.103089
- 2156 Harzhauser, M., & Piller, W. E. (2007, September). Benchmark data of a changing sea

- 2157 — Palaeogeography, Palaeobiogeography and events in the Central Paratethys during
 2158 the Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 253(1), 8–31. Re-
 2159 trieved 2021-04-01, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018207001927)
 2160 [S0031018207001927](https://www.sciencedirect.com/science/article/pii/S0031018207001927) doi: 10.1016/j.palaeo.2007.03.031
- 2161 Haywood, A. M., Tindall, J. C., Dowsett, H. J., Dolan, A. M., Foley, K. M., Hunter, S. J., ...
 2162 Lunt, D. J. (2020, November). The Pliocene Model Intercomparison Project Phase 2:
 2163 large-scale climate features and climate sensitivity. *Climate of the Past*, 16(6), 2095–
 2164 2123. Retrieved 2021-03-09, from [https://cp.copernicus.org/articles/16/2095/](https://cp.copernicus.org/articles/16/2095/2020/)
 2165 [2020/](https://cp.copernicus.org/articles/16/2095/2020/) (Publisher: Copernicus GmbH) doi: <https://doi.org/10.5194/cp-16-2095-2020>
- 2166 He, B. (2017, May). Influences of elevated heating effect by the Himalaya on the changes
 2167 in Asian summer monsoon. *Theoretical and Applied Climatology*, 128(3-4), 905–917.
 2168 Retrieved 2017-10-09, from [http://link.springer.com/10.1007/s00704-016-1746-](http://link.springer.com/10.1007/s00704-016-1746-5)
 2169 [-5](http://link.springer.com/10.1007/s00704-016-1746-5) doi: 10.1007/s00704-016-1746-5
- 2170 Heermance, R., Pearson, J., Moe, A., Langtao, L., Jianhong, X., Chen, J., ... Bogue,
 2171 S. (2018, September). Erg deposition and development of the ancestral Taklimakan
 2172 Desert (western China) between 12.2 and 7.0 Ma. *Geology*, 46. doi: 10.1130/G45085.1
- 2173 Hellwig, A., Voigt, S., Mulch, A., Frisch, K., Bartenstein, A., Pross, J., ...
 2174 Voigt, T. (2018). Late Oligocene to early Miocene humidity change
 2175 recorded in terrestrial sequences in the Ili Basin (south-eastern Kazakhstan,
 2176 Central Asia). *Sedimentology*, 65(2), 517–539. Retrieved 2022-03-22,
 2177 from <http://onlinelibrary.wiley.com/doi/abs/10.1111/sed.12390> (_eprint:
 2178 <https://onlinelibrary.wiley.com/doi/pdf/10.1111/sed.12390>) doi: 10.1111/sed.12390
- 2179 Herman, A. B., Spicer, R. A., Aleksandrova, G. N., Yang, J., Kodrul, T. M., Maslova,
 2180 N. P., ... Jin, J.-H. (2017, August). Eocene–early Oligocene climate and veg-
 2181 etation change in southern China: Evidence from the Maoming Basin. *Palaeo-*
 2182 *geography, Palaeoclimatology, Palaeoecology*, 479, 126–137. Retrieved 2017-10-09,
 2183 from <http://linkinghub.elsevier.com/retrieve/pii/S0031018217300664> doi:
 2184 [10.1016/j.palaeo.2017.04.023](http://linkinghub.elsevier.com/retrieve/pii/S0031018217300664)
- 2185 Holbourn, A., Kuhnt, W., Clemens, S. C., & Heslop, D. (2021). A 12 Myr Miocene Record
 2186 of East Asian Monsoon Variability From the South China Sea. *Paleoceanography*
 2187 *and Paleoclimatology*, 36(7), e2021PA004267. Retrieved 2021-09-08, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021PA004267)
 2188 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021PA004267 (_eprint:
 2189 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2021PA004267>) doi: 10.1029/
 2190 [2021PA004267](https://onlinelibrary.wiley.com/doi/pdf/10.1029/2021PA004267)
- 2191 Holbourn, A. E., Kuhnt, W., Clemens, S. C., Kochhann, K. G. D., Jöhnck, J., Lübbers, J.,
 2192 & Andersen, N. (2018, December). Late Miocene climate cooling and intensification
 2193 of southeast Asian winter monsoon. *Nature Communications*, 9(1). Retrieved 2020-
 2194 10-09, from <http://www.nature.com/articles/s41467-018-03950-1> doi: 10.1038/
 2195 [s41467-018-03950-1](http://www.nature.com/articles/s41467-018-03950-1)
- 2196 Hoorn, C., Ohja, T., & Quade, J. (2000, November). Palynological evidence for veg-
 2197 etation development and climatic change in the Sub-Himalayan Zone (Neogene,
 2198 Central Nepal). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 163(3-4), 133–
 2199 161. Retrieved 2022-06-07, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S0031018200001498)
 2200 [pii/S0031018200001498](https://linkinghub.elsevier.com/retrieve/pii/S0031018200001498) doi: 10.1016/S0031-0182(00)00149-8
- 2201 Hoorn, C., Straathof, J., Abels, H. A., Xu, Y., Utescher, T., & Dupont-Nivet, G. (2012, Au-
 2202 gust). A late Eocene palynological record of climate change and Tibetan Plateau uplift
 2203 (Xining Basin, China). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 344-345,
 2204 16–38. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/retrieve/](http://linkinghub.elsevier.com/retrieve/pii/S0031018212002775)
 2205 [pii/S0031018212002775](http://linkinghub.elsevier.com/retrieve/pii/S0031018212002775) doi: 10.1016/j.palaeo.2012.05.011
- 2206 Hourdin, F., Foujols, M.-A., Codron, F., Guemas, V., Dufresne, J.-L., Bony, S., ... Bopp,
 2207 L. (2013, May). Impact of the LMDZ atmospheric grid configuration on the climate
 2208 and sensitivity of the IPSL-CM5A coupled model. *Climate Dynamics*, 40(9-10), 2167–
 2209 2192. Retrieved 2018-06-05, from [http://link.springer.com/10.1007/s00382-012-](http://link.springer.com/10.1007/s00382-012-1411-3)
 2210 [-1411-3](http://link.springer.com/10.1007/s00382-012-1411-3) doi: 10.1007/s00382-012-1411-3
- 2211 Huang, C., & Hinnov, L. (2019, December). Astronomically forced climate evolution in a

- 2212 saline lake record of the middle Eocene to Oligocene, Jiangnan Basin, China. *Earth*
 2213 *and Planetary Science Letters*, 528, 115846. Retrieved 2020-09-07, from [https://](https://linkinghub.elsevier.com/retrieve/pii/S0012821X19305382)
 2214 linkinghub.elsevier.com/retrieve/pii/S0012821X19305382 doi: 10.1016/j.epsl
 2215 .2019.115846
- 2216 Huang, H., Pérez-Pinedo, D., Morley, R. J., Dupont-Nivet, G., Philip, A., Win, Z., ...
 2217 Hoorn, C. (2021, August). At a crossroads: The late Eocene flora of central
 2218 Myanmar owes its composition to plate collision and tropical climate. *Review of*
 2219 *Palaeobotany and Palynology*, 291, 104441. Retrieved 2022-06-22, from [https://](https://www.sciencedirect.com/science/article/pii/S0034666721000658)
 2220 www.sciencedirect.com/science/article/pii/S0034666721000658 doi: 10.1016/
 2221 j.revpalbo.2021.104441
- 2222 Huang, J., Spicer, R. A., Li, S.-F., Liu, J., Do, T. V., Nguyen, H. B., ... Su, T. (2022,
 2223 May). Long-term floristic and climatic stability of northern Indochina: Evidence from
 2224 the Oligocene Ha Long flora, Vietnam. *Palaeogeography, Palaeoclimatology, Palaeoe-*
 2225 *ecology*, 593, 110930. Retrieved 2022-03-22, from [https://www.sciencedirect.com/](https://www.sciencedirect.com/science/article/pii/S0031018222001006)
 2226 [science/article/pii/S0031018222001006](https://www.sciencedirect.com/science/article/pii/S0031018222001006) doi: 10.1016/j.palaeo.2022.110930
- 2227 Huang, W., Dupont-Nivet, G., Lippert, P. C., van Hinsbergen, D. J. J., Dekkers, M. J.,
 2228 Waldrip, R., ... Kapp, P. (2015, March). What was the Paleogene latitude of the
 2229 Lhasa terrane? A reassessment of the geochronology and paleomagnetism of Linz-
 2230 izong volcanic rocks (Linzhou basin, Tibet). *Tectonics*, 34(3), 594–622. Retrieved
 2231 2017-10-09, from <http://doi.wiley.com/10.1002/2014TC003787> doi: 10.1002/
 2232 2014TC003787
- 2233 Huang, Y., Clemens, S., Liu, W., Wang, Y., & Prell, W. (2007, June). Large-scale hydro-
 2234 logical change drove the late Miocene C4 plant expansion in the Himalayan foreland
 2235 and Arabian Peninsula. *Geology*, 35. doi: 10.1130/G23666A.1
- 2236 Huber, M. (2003, February). Eocene El Niño: Evidence for Robust Tropical Dynamics in
 2237 the "Hothouse". *Science*, 299(5608), 877–881. Retrieved 2020-04-15, from [https://](https://www.sciencemag.org/lookup/doi/10.1126/science.1078766)
 2238 www.sciencemag.org/lookup/doi/10.1126/science.1078766 doi: 10.1126/science
 2239 .1078766
- 2240 Huber, M., & Goldner, A. (2012, January). Eocene monsoons. *Journal of Asian Earth*
 2241 *Sciences*, 44, 3–23. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/](http://linkinghub.elsevier.com/retrieve/pii/S1367912011003725)
 2242 [retrieve/pii/S1367912011003725](http://linkinghub.elsevier.com/retrieve/pii/S1367912011003725) doi: 10.1016/j.jseas.2011.09.014
- 2243 Hui, Z., Zhou, X., Chevalier, M., Wei, X., Pan, Y., & Chen, Y. (2021, Au-
 2244 gust). Miocene East Asia summer monsoon precipitation variability and its possi-
 2245 ble driving forces. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 110609. Re-
 2246 trieved 2021-09-22, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018221003941)
 2247 [S0031018221003941](https://www.sciencedirect.com/science/article/pii/S0031018221003941) doi: 10.1016/j.palaeo.2021.110609
- 2248 Ingalls, M., Rowley, D. B., Currie, B., & Colman, A. S. (2016, November). Large-scale sub-
 2249 duction of continental crust implied by India–Asia mass-balance calculation. *Nature*
 2250 *Geoscience*, 9(11), 848–853. Retrieved 2020-10-16, from [http://www.nature.com/](http://www.nature.com/articles/ngeo2806)
 2251 [articles/ngeo2806](http://www.nature.com/articles/ngeo2806) (Number: 11 Publisher: Nature Publishing Group) doi:
 2252 10.1038/ngeo2806
- 2253 Jacques, F. M., Guo, S.-X., Su, T., Xing, Y.-W., Huang, Y.-J., Liu, Y.-S. C., ... Zhou, Z.-K.
 2254 (2011, May). Quantitative reconstruction of the Late Miocene monsoon climates of
 2255 southwest China: A case study of the Lincang flora from Yunnan Province. *Palaeo-*
 2256 *geography, Palaeoclimatology, Palaeoecology*, 304(3-4), 318–327. Retrieved 2022-05-03,
 2257 from <https://linkinghub.elsevier.com/retrieve/pii/S0031018210002233> doi:
 2258 10.1016/j.palaeo.2010.04.014
- 2259 Jacques, F. M., Su, T., Spicer, R. A., Xing, Y., Huang, Y., Wang, W., & Zhou, Z. (2011,
 2260 March). Leaf physiognomy and climate: Are monsoon systems different? *Global and*
 2261 *Planetary Change*, 76(1-2), 56–62. Retrieved 2022-05-06, from [https://linkinghub](https://linkinghub.elsevier.com/retrieve/pii/S0921818110002560)
 2262 [.elsevier.com/retrieve/pii/S0921818110002560](https://linkinghub.elsevier.com/retrieve/pii/S0921818110002560) doi: 10.1016/j.gloplacha.2010
 2263 .11.009
- 2264 Jagoutz, O., Royden, L., Holt, A. F., & Becker, T. W. (2015, June). Anomalously fast con-
 2265 vergence of India and Eurasia caused by double subduction. *Nature Geoscience*, 8(6),
 2266 475–478. Retrieved 2019-11-22, from <http://www.nature.com/articles/ngeo2418>

- doi: 10.1038/ngeo2418
- 2267
2268 Jeong, J.-H., Ou, T., Linderholm, H. W., Kim, B.-M., Kim, S.-J., Kug, J.-S., & Chen, D.
2269 (2011, December). Recent recovery of the Siberian High intensity: RECOVERY OF
2270 THE SIBERIAN HIGH INTENSITY. *Journal of Geophysical Research: Atmospheres*,
2271 *116*(D23), n/a–n/a. Retrieved 2020-06-20, from [http://doi.wiley.com/10.1029/](http://doi.wiley.com/10.1029/2011JD015904)
2272 [2011JD015904](http://doi.wiley.com/10.1029/2011JD015904) doi: 10.1029/2011JD015904
- 2273 Jhun, J.-G., & Lee, E.-J. (2004, February). A New East Asian Winter Monsoon Index and
2274 Associated Characteristics of the Winter Monsoon. *Journal of Climate*, *17*(4), 711–
2275 726. Retrieved 2021-11-10, from [https://journals.ametsoc.org/view/journals/](https://journals.ametsoc.org/view/journals/clim/17/4/1520-0442_2004_017_0711_aneawm_2.0.co_2.xml)
2276 [clim/17/4/1520-0442_2004_017_0711_aneawm_2.0.co_2.xml](https://journals.ametsoc.org/view/journals/clim/17/4/1520-0442_2004_017_0711_aneawm_2.0.co_2.xml) (Publisher: American
2277 Meteorological Society Section: Journal of Climate) doi: 10.1175/1520-0442(2004)
2278 017<0711:ANEAWM>2.0.CO;2
- 2279 Jia, G., Peng, P., Zhao, Q., & Jian, Z. (2003, December). Changes in terrestrial ecosystem
2280 since 30 Ma in East Asia: Stable isotope evidence from black carbon in the South China
2281 Sea. *Geology*, *31*(12), 1093–1096. Retrieved 2022-05-02, from [https://doi.org/](https://doi.org/10.1130/G19992.1)
2282 [10.1130/G19992.1](https://doi.org/10.1130/G19992.1) doi: 10.1130/G19992.1
- 2283 Jiang, H., & Ding, Z. (2008, July). A 20 Ma pollen record of East-Asian summer monsoon
2284 evolution from Guyuan, Ningxia, China. *Palaeogeography, Palaeoclimatology, Palaeoecology*,
2285 *265*(1-2), 30–38. Retrieved 2022-06-14, from [https://linkinghub.elsevier](https://linkinghub.elsevier.com/retrieve/pii/S0031018208002629)
2286 [.com/retrieve/pii/S0031018208002629](https://linkinghub.elsevier.com/retrieve/pii/S0031018208002629) doi: 10.1016/j.palaeo.2008.04.016
- 2287 Jiang, H., Wan, S., Ma, X., Zhong, N., & Zhao, D. (2017, October). End-member modeling
2288 of the grain-size record of Sikouzi fine sediments in Ningxia (China) and implica-
2289 tions for temperature control of Neogene evolution of East Asian winter monsoon.
2290 *PLOS ONE*, *12*(10), e0186153. Retrieved 2022-06-14, from [https://dx.plos.org/](https://dx.plos.org/10.1371/journal.pone.0186153)
2291 [10.1371/journal.pone.0186153](https://dx.plos.org/10.1371/journal.pone.0186153) doi: 10.1371/journal.pone.0186153
- 2292 Jolivet, M., Dominguez, S., Charreau, J., Chen, Y., Li, Y., & Wang, Q. (2010). Mesozoic and
2293 Cenozoic tectonic history of the central Chinese Tian Shan: Reactivated tectonic struc-
2294 tures and active deformation. *Tectonics*, *29*(6). Retrieved 2021-03-29, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2010TC002712)
2295 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2010TC002712 (eprint:
2296 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2010TC002712>) doi: [https://doi](https://doi.org/10.1029/2010TC002712)
2297 [.org/10.1029/2010TC002712](https://doi.org/10.1029/2010TC002712)
- 2298 Jolivet, M., Ritz, J.-F., Vassallo, R., Larroque, C., Braucher, R., Todbileg, M., ...
2299 Arzhanikov, S. (2007, October). Mongolian summits: An uplifted, flat, old
2300 but still preserved erosion surface. *Geology*, *35*(10), 871–874. Retrieved 2021-03-
2301 29, from [http://pubs.geoscienceworld.org/gsa/geology/article/35/10/871/](http://pubs.geoscienceworld.org/gsa/geology/article/35/10/871/129664/Mongolian-summits-An-uplifted-flat-old-but-still)
2302 [129664/Mongolian-summits-An-uplifted-flat-old-but-still](http://pubs.geoscienceworld.org/gsa/geology/article/35/10/871/129664/Mongolian-summits-An-uplifted-flat-old-but-still) (Publisher: Geo-
2303 ScienceWorld) doi: 10.1130/G23758A.1
- 2304 Kaakinen, A., Sonninen, E., & Lunkka, J. P. (2006, August). Stable isotope record in
2305 paleosol carbonates from the Chinese Loess Plateau: Implications for late Neogene
2306 paleoclimate and paleovegetation. *Palaeogeography, Palaeoclimatology, Palaeoecology*,
2307 *237*(2-4), 359–369. Retrieved 2022-06-16, from [https://linkinghub.elsevier.com/](https://linkinghub.elsevier.com/retrieve/pii/S0031018205007315)
2308 [retrieve/pii/S0031018205007315](https://linkinghub.elsevier.com/retrieve/pii/S0031018205007315) doi: 10.1016/j.palaeo.2005.12.011
- 2309 Kapp, P., & DeCelles, P. G. (2019, March). Mesozoic–Cenozoic geological evolution of the
2310 Himalayan–Tibetan orogen and working tectonic hypotheses. *American Journal of*
2311 *Science*, *319*(3), 159–254. Retrieved 2019-11-15, from [http://www.ajsonline.org/](http://www.ajsonline.org/lookup/doi/10.2475/03.2019.01)
2312 [lookup/doi/10.2475/03.2019.01](http://www.ajsonline.org/lookup/doi/10.2475/03.2019.01) doi: 10.2475/03.2019.01
- 2313 Karaođlan, F., Parlak, O., Hejl, E., Neubauer, F., & Klötzli, U. (2016, May). The tempo-
2314 ral evolution of the active margin along the Southeast Anatolian Orogenic Belt (SE
2315 Turkey): Evidence from U–Pb, Ar–Ar and fission track chronology. *Gondwana Re-*
2316 *search*, *33*, 190–208. Retrieved 2022-03-04, from [https://www.sciencedirect.com/](https://www.sciencedirect.com/science/article/pii/S1342937X16000599)
2317 [science/article/pii/S1342937X16000599](https://www.sciencedirect.com/science/article/pii/S1342937X16000599) doi: 10.1016/j.gr.2015.12.011
- 2318 Kaya, M. Y., Dupont-Nivet, G., Proust, J., Roperch, P., Bougeois, L., Meijer, N., ...
2319 Zhaojie, G. (2019, June). Paleogene evolution and demise of the proto-Paratethys
2320 Sea in Central Asia (Tarim and Tajik basins): Role of intensified tectonic activity at
2321 ca. 41 Ma. *Basin Research*, *31*(3), 461–486. Retrieved 2019-11-22, from <https://>

- 2322 onlinelibrary.wiley.com/doi/abs/10.1111/bre.12330 doi: 10.1111/bre.12330
 2323 Kent-Corson, M. L., Ritts, B. D., Zhuang, G., Bovet, P. M., Graham, S. A., &
 2324 Page Chamberlain, C. (2009, May). Stable isotopic constraints on the tectonic, to-
 2325 pographic, and climatic evolution of the northern margin of the Tibetan Plateau.
 2326 *Earth and Planetary Science Letters*, *282*(1-4), 158–166. Retrieved 2017-10-09,
 2327 from <http://linkinghub.elsevier.com/retrieve/pii/S0012821X0900154X> doi:
 2328 10.1016/j.epsl.2009.03.011
- 2329 Khan, M. A., Spicer, R. A., Bera, S., Ghosh, R., Yang, J., Spicer, T. E. V., ... Grote,
 2330 P. J. (2014, February). Miocene to Pleistocene floras and climate of the Eastern
 2331 Himalayan Siwaliks, and new palaeoelevation estimates for the Namling–Oiyug Basin,
 2332 Tibet. *Global and Planetary Change*, *113*, 1–10. Retrieved 2022-05-02, from [https://](https://www.sciencedirect.com/science/article/pii/S0921818113002749)
 2333 www.sciencedirect.com/science/article/pii/S0921818113002749 doi: 10.1016/
 2334 j.gloplacha.2013.12.003
- 2335 Kong, W., Swenson, L. M., & Chiang, J. C. H. (2017, May). Seasonal Transitions and
 2336 the Westerly Jet in the Holocene East Asian Summer Monsoon. *Journal of Climate*,
 2337 *30*(9), 3343–3365. Retrieved 2020-03-04, from [http://journals.ametsoc.org/doi/](http://journals.ametsoc.org/doi/10.1175/JCLI-D-16-0087.1)
 2338 [10.1175/JCLI-D-16-0087.1](http://journals.ametsoc.org/doi/10.1175/JCLI-D-16-0087.1) doi: 10.1175/JCLI-D-16-0087.1
- 2339 Krijgsman, W., Palcu, D. V., Andreetto, F., Stoica, M., & Mandic, O. (2020, Novem-
 2340 ber). Changing seas in the late Miocene Northern Aegean: A Paratethyan ap-
 2341 proach to Mediterranean basin evolution. *Earth-Science Reviews*, *210*, 103386.
 2342 Retrieved 2022-02-04, from [https://linkinghub.elsevier.com/retrieve/pii/](https://linkinghub.elsevier.com/retrieve/pii/S0012825220304323)
 2343 [S0012825220304323](https://linkinghub.elsevier.com/retrieve/pii/S0012825220304323) doi: 10.1016/j.earscirev.2020.103386
- 2344 Krinner, G., Viovy, N., de Noblet-Ducoudré, N., Ogée, J., Polcher, J., Friedlingstein, P.,
 2345 ... Prentice, I. C. (2005, March). A dynamic global vegetation model for studies
 2346 of the coupled atmosphere-biosphere system: DVGM FOR COUPLED CLIMATE
 2347 STUDIES. *Global Biogeochemical Cycles*, *19*(1). Retrieved 2018-10-22, from [http://](http://doi.wiley.com/10.1029/2003GB002199)
 2348 doi.wiley.com/10.1029/2003GB002199 doi: 10.1029/2003GB002199
- 2349 Kroon, D., Steens, T., & Troelstra, S. R. (1991). Onset of monsoonal related upwelling in
 2350 the western Arabian sea as revealed by planktonic foraminifers. In *Proceedings of the*
 2351 *ocean drilling program, scientific results* (Vol. 11).
- 2352 Kuhnt, W., Holbourn, A., Hall, R., Zuvela, M., & Käse, R. (2004). Neogene history of the In-
 2353 donesian Throughflow. In P. Clift, W. Kuhnt, P. Wang, & D. Hayes (Eds.), *Geophysical*
 2354 *Monograph Series* (Vol. 149, pp. 299–320). Washington, D. C.: American Geophys-
 2355 ical Union. Retrieved 2021-09-02, from [https://onlinelibrary.wiley.com/doi/](https://onlinelibrary.wiley.com/doi/10.1029/149GM16)
 2356 [10.1029/149GM16](https://onlinelibrary.wiley.com/doi/10.1029/149GM16) doi: 10.1029/149GM16
- 2357 Kutzbach, J. E., Prell, W. L., & Ruddiman, W. F. (1993, March). Sensitivity of Eurasian
 2358 Climate to Surface Uplift of the Tibetan Plateau. *The Journal of Geology*, *101*(2),
 2359 177–190. Retrieved 2020-05-11, from [https://www.journals.uchicago.edu/doi/](https://www.journals.uchicago.edu/doi/10.1086/648215)
 2360 [10.1086/648215](https://www.journals.uchicago.edu/doi/10.1086/648215) doi: 10.1086/648215
- 2361 Käßner, A., Ratschbacher, L., Jonckheere, R., Enkelmann, E., Khan, J., Sonntag, B.-L., ...
 2362 Oimahmadov, I. (2016). Cenozoic intracontinental deformation and exhumation at
 2363 the northwestern tip of the India-Asia collision—southwestern Tian Shan, Tajikistan,
 2364 and Kyrgyzstan. *Tectonics*, *35*(9), 2171–2194. Retrieved 2021-03-26, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015TC003897)
 2365 agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015TC003897 (eprint:
 2366 <https://onlinelibrary.wiley.com/doi/pdf/10.1002/2015TC003897>) doi: [https://doi](https://doi.org/10.1002/2015TC003897)
 2367 [.org/10.1002/2015TC003897](https://doi.org/10.1002/2015TC003897)
- 2368 Ladant, J.-B., Donnadiou, Y., Lefebvre, V., & Dumas, C. (2014, August). The respec-
 2369 tive role of atmospheric carbon dioxide and orbital parameters on ice sheet evolution
 2370 at the Eocene-Oligocene transition: Ice sheet evolution at the EOT. *Paleoceanogra-*
 2371 *phy*, *29*(8), 810–823. Retrieved 2019-05-10, from [http://doi.wiley.com/10.1002/](http://doi.wiley.com/10.1002/2013PA002593)
 2372 [2013PA002593](http://doi.wiley.com/10.1002/2013PA002593) doi: 10.1002/2013PA002593
- 2373 Laugié, M., Donnadiou, Y., Ladant, J.-B., Green, J. A. M., Bopp, L., & Raison, F.
 2374 (2020, June). Stripping back the modern to reveal the Cenomanian–Turonian cli-
 2375 mate and temperature gradient underneath. *Climate of the Past*, *16*(3), 953–971.
 2376 Retrieved 2021-03-09, from <https://cp.copernicus.org/articles/16/953/2020/>

- (Publisher: Copernicus GmbH) doi: <https://doi.org/10.5194/cp-16-953-2020>
- 2377 Lee, J., Kim, S., Lee, J. I., Cho, H. G., Phillips, S. C., & Khim, B.-K. (2020, January).
 2378 Monsoon-influenced variation of clay mineral compositions and detrital Nd-Sr isotopes
 2379 in the western Andaman Sea (IODP Site U1447) since the late Miocene. *Palaeo-*
 2380 *geography, Palaeoclimatology, Palaeoecology*, *538*, 109339. Retrieved 2022-06-02,
 2381 from <https://linkinghub.elsevier.com/retrieve/pii/S0031018219303773> doi:
 2382 10.1016/j.palaeo.2019.109339
- 2384 Lee, J.-Y., Wang, B., Seo, K.-H., Ha, K.-J., Kitoh, A., & Liu, J. (2015, August). Effects of
 2385 mountain uplift on global monsoon precipitation. *Asia-Pacific Journal of Atmospheric*
 2386 *Sciences*, *51*(3), 275–290. Retrieved 2017-10-09, from [http://link.springer.com/](http://link.springer.com/10.1007/s13143-015-0077-2)
 2387 [10.1007/s13143-015-0077-2](http://link.springer.com/10.1007/s13143-015-0077-2) doi: 10.1007/s13143-015-0077-2
- 2388 Li, B., Sun, D., Wang, X., Zhang, Y., Hu, W., Wang, F., ... Liang, B. (2016, Au-
 2389 gust). 18O and 13C records from a Cenozoic sedimentary sequence in the Lanzhou
 2390 Basin, Northwestern China: Implications for palaeoenvironmental and palaeoecolog-
 2391 ical changes. *Journal of Asian Earth Sciences*, *125*, 22–36. Retrieved 2022-05-12,
 2392 from <https://linkinghub.elsevier.com/retrieve/pii/S1367912016301249> doi:
 2393 10.1016/j.jseaes.2016.05.010
- 2394 Li, F., Rousseau, D.-D., Wu, N., Hao, Q., & Pei, Y. (2008, October). Late Neogene
 2395 evolution of the East Asian monsoon revealed by terrestrial mollusk record in Western
 2396 Chinese Loess Plateau: From winter to summer dominated sub-regime. *Earth and*
 2397 *Planetary Science Letters*, *274*(3-4), 439–447. Retrieved 2022-06-16, from [https://](https://linkinghub.elsevier.com/retrieve/pii/S0012821X08004986)
 2398 linkinghub.elsevier.com/retrieve/pii/S0012821X08004986 doi: 10.1016/j.epsl
 2399 .2008.07.038
- 2400 Li, J. X., Yue, L. P., Roberts, A. P., Hirt, A. M., Pan, F., Guo, L., ... Liu, Q. S. (2018,
 2401 August). Global cooling and enhanced Eocene Asian mid-latitude interior aridity.
 2402 *Nature Communications*, *9*(1), 3026. Retrieved 2022-03-21, from [http://www.nature](http://www.nature.com/articles/s41467-018-05415-x)
 2403 [.com/articles/s41467-018-05415-x](http://www.nature.com/articles/s41467-018-05415-x) (Number: 1 Publisher: Nature Publishing
 2404 Group) doi: 10.1038/s41467-018-05415-x
- 2405 Li, L., Dupont-Nivet, G., Najman, Y., Kaya, M., Meijer, N., Poujol, M., & Aminov, J.
 2406 (2021). Middle to late Miocene growth of the North Pamir. *Basin Research*, *n/a*(n/a).
 2407 Retrieved 2021-11-09, from [http://onlinelibrary.wiley.com/doi/abs/10.1111/](http://onlinelibrary.wiley.com/doi/abs/10.1111/bre.12629)
 2408 [bre.12629](http://onlinelibrary.wiley.com/doi/abs/10.1111/bre.12629) (eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/bre.12629>) doi:
 2409 10.1111/bre.12629
- 2410 Li, S., Xing, Y., Valdes, P. J., Huang, Y., Su, T., Farnsworth, A., ... Zhou, Z. (2018,
 2411 September). Oligocene climate signals and forcings in Eurasia revealed by plant macro-
 2412 fossil and modelling results. *Gondwana Research*, *61*, 115–127. Retrieved 2019-10-18,
 2413 from <https://linkinghub.elsevier.com/retrieve/pii/S1342937X18301473> doi:
 2414 10.1016/j.gr.2018.04.015
- 2415 Li, X., Zhang, R., Zhang, Z., & Yan, Q. (2017, October). What enhanced the aridity in
 2416 Eocene Asian inland: Global cooling or early Tibetan Plateau uplift? *Palaeogeography,*
 2417 *Palaeoclimatology, Palaeoecology*. Retrieved 2018-01-16, from [http://linkinghub](http://linkinghub.elsevier.com/retrieve/pii/S0031018217306922)
 2418 [.elsevier.com/retrieve/pii/S0031018217306922](http://linkinghub.elsevier.com/retrieve/pii/S0031018217306922) doi: 10.1016/j.palaeo.2017.10
 2419 .029
- 2420 Li, X., Zhang, R., Zhang, Z., & Yan, Q. (2018, January). Do climate simulations support
 2421 the existence of East Asian monsoon climate in the Late Eocene? *Palaeogeography,*
 2422 *Palaeoclimatology, Palaeoecology*. Retrieved 2018-06-12, from [http://linkinghub](http://linkinghub.elsevier.com/retrieve/pii/S0031018217313123)
 2423 [.elsevier.com/retrieve/pii/S0031018217313123](http://linkinghub.elsevier.com/retrieve/pii/S0031018217313123) doi: 10.1016/j.palaeo.2017.12
 2424 .037
- 2425 Licht, A., Dupont-Nivet, G., Win, Z., Swe, H. H., Kaythi, M., Roperch, P., ... Sein, K.
 2426 (2018, November). Paleogene evolution of the Burmese forearc basin and implications
 2427 for the history of India-Asia convergence. *GSA Bulletin*, *131*(5-6), 730–748. Retrieved
 2428 2021-03-29, from <https://doi.org/10.1130/B35002.1> doi: 10.1130/B35002.1
- 2429 Licht, A., van Cappelle, M., Abels, H. A., Ladant, J.-B., Trahucho-Alexandre, J., France-
 2430 Lanord, C., ... Jaeger, J.-J. (2014, September). Asian monsoons in a late Eocene
 2431 greenhouse world. *Nature*, *513*(7519), 501–506. Retrieved 2017-10-09, from <http://>

- 2432 www.nature.com/doi/10.1038/nature13704 doi: 10.1038/nature13704
- 2433 Ling, C.-C., Ma, F.-J., Dong, J.-L., Zhou, G.-H., Wang, Q.-J., & Sun, B.-N. (2021, Oc-
2434 tober). A mid-altitude area in southwestern China experienced a humid subtropical
2435 climate with subtle monsoon signatures during the early Oligocene: Evidence from the
2436 Ningming flora of Guangxi. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *579*,
2437 110601. Retrieved 2022-05-03, from [https://linkinghub.elsevier.com/retrieve/
2438 pii/S0031018221003862](https://linkinghub.elsevier.com/retrieve/pii/S0031018221003862) doi: 10.1016/j.palaeo.2021.110601
- 2439 Lippert, P. C., Van Hinsbergen, D. J., & Dupont-Nivet, G. (2014). Early Cretaceous to
2440 present latitude of the central proto-Tibetan Plateau: A paleomagnetic synthesis with
2441 implications for Cenozoic tectonics, paleogeography, and climate of Asia. *Geological
2442 Society of America Special Papers*, *507*, 1–21.
- 2443 Liu, D., Li, H., Sun, Z., Cao, Y., Wang, L., Pan, J., ... Ye, X. (2017, August). Cenozoic
2444 episodic uplift and kinematic evolution between the Pamir and Southwestern Tien
2445 Shan. *Tectonophysics*, *712-713*, 438–454. Retrieved 2021-03-26, from [https://www
2446 .sciencedirect.com/science/article/pii/S004019511730255X](https://www.sciencedirect.com/science/article/pii/S004019511730255X) doi: 10.1016/j
2447 .tecto.2017.06.009
- 2448 Liu, J., Li, J., Song, C., Yu, H., Peng, T., Hui, Z., & Ye, X. (2016, July). Palynological
2449 evidence for late Miocene stepwise aridification on the northeastern Tibetan Plateau.
2450 *Climate of the Past*, *12*, 1473–1484. doi: 10.5194/cp-12-1473-2016
- 2451 Liu, W., Liu, Z., An, Z., Sun, J., Chang, H., Wang, N., ... Wang, H. (2014, Novem-
2452 ber). Late Miocene episodic lakes in the arid Tarim Basin, western China. *Proceed-
2453 ings of the National Academy of Sciences*, *111*(46), 16292–16296. Retrieved 2022-06-
2454 17, from <https://www.pnas.org/doi/full/10.1073/pnas.1410890111> (Publisher:
2455 Proceedings of the National Academy of Sciences) doi: 10.1073/pnas.1410890111
- 2456 Liu, X., Guo, Q., Guo, Z., Yin, J., Dong, B., & Smith, R. (2015, October). Where were the
2457 monsoon regions and arid zones in Asia prior to the Tibetan Plateau uplift? *National
2458 Science Review*, *2*, nww068. doi: 10.1093/nsr/nww068
- 2459 Liu, X., Sun, H., Miao, Y., Dong, B., & Yin, Z.-Y. (2015, May). Impacts of uplift of
2460 northern Tibetan Plateau and formation of Asian inland deserts on regional climate
2461 and environment. *Quaternary Science Reviews*, *116*, 1–14. Retrieved 2022-06-22,
2462 from <https://linkinghub.elsevier.com/retrieve/pii/S0277379115001171> doi:
2463 10.1016/j.quascirev.2015.03.010
- 2464 Liu, X., & Yin, Z.-Y. (2002, July). Sensitivity of East Asian monsoon climate to the uplift
2465 of the Tibetan Plateau. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *183*(3),
2466 223–245. Retrieved 2021-04-14, from [https://www.sciencedirect.com/science/
2467 article/pii/S0031018201004886](https://www.sciencedirect.com/science/article/pii/S0031018201004886) doi: 10.1016/S0031-0182(01)00488-6
- 2468 Liu, Z., Zhang, K., Sun, Y., Liu, W., Liu, Y. C., & Quan, C. (2014). Cenozoic Environ-
2469 mental Changes in the Northern Qaidam Basin Inferred from n-alkane Records. *Acta
2470 Geologica Sinica - English Edition*, *88*(5), 1547–1555. Retrieved 2022-06-17, from
2471 <http://onlinelibrary.wiley.com/doi/abs/10.1111/1755-6724.12317> (eprint:
2472 <https://onlinelibrary.wiley.com/doi/pdf/10.1111/1755-6724.12317>) doi: 10.1111/1755
2473 -6724.12317
- 2474 Lu, H., & Guo, Z. (2014, January). Evolution of the monsoon and dry climate in East Asia
2475 during late Cenozoic: A review. *Science China Earth Sciences*, *57*(1), 70–79. Retrieved
2476 2017-10-09, from <http://link.springer.com/10.1007/s11430-013-4790-3> doi:
2477 10.1007/s11430-013-4790-3
- 2478 Lu, H., Wang, X., & li, l. (2010, August). Aeolian sediment evidence that global cooling has
2479 driven late Cenozoic stepwise aridification in Central Asia. *Geological Society London
2480 Special Publications*, *342*, 29–44. doi: 10.1144/SP342.4
- 2481 Lévy, M., Shankar, D., André, J.-M., Shenoi, S. S. C., Durand, F., & de Boyer Montégut, C.
2482 (2007, December). Basin-wide seasonal evolution of the Indian Ocean’s phytoplankton
2483 blooms. *Journal of Geophysical Research*, *112*(C12). Retrieved 2020-07-30, from
2484 <http://doi.wiley.com/10.1029/2007JC004090> doi: 10.1029/2007JC004090
- 2485 Ma, T., & Chen, W. (2021). Climate variability of the East Asian winter mon-
2486 soon and associated extratropical–tropical interaction: a review. *Annals of*

- 2487 *the New York Academy of Sciences*, 1504(1), 44–62. Retrieved 2022-03-25,
 2488 from <http://onlinelibrary.wiley.com/doi/abs/10.1111/nyas.14620> (eprint:
 2489 <https://nyaspubs.onlinelibrary.wiley.com/doi/pdf/10.1111/nyas.14620>) doi: 10.1111/
 2490 nyas.14620
- 2491 Ma, X., & Jiang, H. (2015, June). Combined tectonics and climate forcing for the widespread
 2492 aeolian dust accumulation in the Chinese Loess Plateau since the early late Miocene.
 2493 *International Geology Review*, 57, 1861–1876. doi: 10.1080/00206814.2015.1027305
- 2494 Ma, X., Jiang, H., Cheng, J., & Xu, H. (2012, September). Spatiotemporal evolution
 2495 of Paleogene palynoflora in China and its implication for development of the ex-
 2496 tensional basins in East China. *Review of Palaeobotany and Palynology*, 184, 24–
 2497 35. Retrieved 2019-02-10, from [https://linkinghub.elsevier.com/retrieve/pii/
 2498 S0034666712001935](https://linkinghub.elsevier.com/retrieve/pii/S0034666712001935) doi: 10.1016/j.revpalbo.2012.07.013
- 2499 Ma, Y., Fang, X., Li, J., Wu, F., & Zhang, J. (2005, May). The vegetation and cli-
 2500 mate change during Neocene and Early Quaternary in Jiuxi Basin, China. *Sci-
 2501 ence in China Series D: Earth Sciences*, 48(5), 676. Retrieved 2022-06-16, from
 2502 <http://link.springer.com/10.1360/03yd0110> doi: 10.1360/03yd0110
- 2503 Macaulay, E. A., Sobel, E. R., Mikolaichuk, A., Kohn, B., & Stuart, F. M.
 2504 (2014). Cenozoic deformation and exhumation history of the Central Kyr-
 2505 gyz Tien Shan. *Tectonics*, 33(2), 135–165. Retrieved 2022-03-22, from
 2506 <http://onlinelibrary.wiley.com/doi/abs/10.1002/2013TC003376> (eprint:
 2507 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2013TC003376>) doi: 10
 2508 .1002/2013TC003376
- 2509 Macaulay, E. A., Sobel, E. R., Mikolaichuk, A., Wack, M., Gilder, S. A., Mulch, A., ...
 2510 Apayarov, F. (2016). The sedimentary record of the Issyk Kul basin, Kyrgyzstan:
 2511 climatic and tectonic inferences. *Basin Research*, 28(1), 57–80. Retrieved 2022-03-22,
 2512 from <http://onlinelibrary.wiley.com/doi/abs/10.1111/bre.12098> (eprint:
 2513 <https://onlinelibrary.wiley.com/doi/pdf/10.1111/bre.12098>) doi: 10.1111/bre.12098
- 2514 Madec, G. (2016). NEMO ocean engine. *Note du P^ole de modélisation de l'Institut
 2515 Pierre-Simon Laplace*(27), 396.
- 2516 Madec, G., & Imbard, M. (1996, May). A global ocean mesh to overcome the North
 2517 Pole singularity. *Climate Dynamics*, 12(6), 381–388. Retrieved 2021-03-09, from
 2518 <https://doi.org/10.1007/BF00211684> doi: 10.1007/BF00211684
- 2519 Maurin, T., & Rangin, C. (2009). Structure and kinematics of the Indo-Burmese Wedge: Re-
 2520 cent and fast growth of the outer wedge. *Tectonics*, 28(2). Retrieved 2021-03-29, from
 2521 <http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2008TC002276>
 2522 (eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2008TC002276>) doi:
 2523 <https://doi.org/10.1029/2008TC002276>
- 2524 McQuarrie, N., & Hinsbergen, D. J. J. v. (2013, March). Retrodeforming-
 2525 ing the Arabia-Eurasia collision zone: Age of collision versus magnitude of
 2526 continental subduction. *Geology*, 41(3), 315–318. Retrieved 2021-04-06,
 2527 from [http://pubs.geoscienceworld.org/gsa/geology/article-abstract/41/3/
 2528 315/131120/Retrodeforming-the-Arabia-Eurasia-collision-zone](http://pubs.geoscienceworld.org/gsa/geology/article-abstract/41/3/315/131120/Retrodeforming-the-Arabia-Eurasia-collision-zone) (Publisher:
 2529 GeoScienceWorld) doi: 10.1130/G33591.1
- 2530 Meijer, N., Dupont-Nivet, G., Abels, H. A., Kaya, M. Y., Licht, A., Xiao, M., ... Guo,
 2531 Z. (2019, March). Central Asian moisture modulated by proto-Paratethys Sea in-
 2532 cursions since the early Eocene. *Earth and Planetary Science Letters*, 510, 73–
 2533 84. Retrieved 2019-04-25, from [https://linkinghub.elsevier.com/retrieve/pii/
 2534 S0012821X19300019](https://linkinghub.elsevier.com/retrieve/pii/S0012821X19300019) doi: 10.1016/j.epsl.2018.12.031
- 2535 Meijer, N., Dupont-Nivet, G., Barbolini, N., Woutersen, A., Rohrmann, A., Yang, Z., ...
 2536 Nowaczyk, N. (2021, February). Loess-Like Dust Appearance at 40 Ma in Central
 2537 China. *Paleoceanography and Paleoclimatology*, 36. doi: 10.1029/2020PA003993
- 2538 Meng, Q.-t., Bruch, A. A., Sun, G., Liu, Z.-j., Hu, F., & Sun, P.-c. (2018, December). Quan-
 2539 titative reconstruction of Middle and Late Eocene paleoclimate based on palynological
 2540 records from the Huadian Basin, northeastern China: Evidence for monsoonal influ-
 2541 ence on oil shale formation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 510,

- 2542 63–77. Retrieved 2020-07-10, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S0031018217304741)
 2543 [pii/S0031018217304741](https://linkinghub.elsevier.com/retrieve/pii/S0031018217304741) doi: 10.1016/j.palaeo.2017.11.036
- 2544 Merlis, T. M., Schneider, T., Bordoni, S., & Eisenman, I. (2013, Febru-
 2545 ary). Hadley Circulation Response to Orbital Precession. Part II: Subtrop-
 2546 ical Continent. *Journal of Climate*, *26*(3), 754–771. Retrieved 2020-09-
 2547 07, from [https://journals.ametsoc.org/jcli/article/26/3/754/33493/Hadley](https://journals.ametsoc.org/jcli/article/26/3/754/33493/Hadley-Circulation-Response-to-Orbital-Precession)
 2548 [-Circulation-Response-to-Orbital-Precession](https://journals.ametsoc.org/jcli/article/26/3/754/33493/Hadley-Circulation-Response-to-Orbital-Precession) (Publisher: American Meteorolo-
 2549 gical Society) doi: 10.1175/JCLI-D-12-00149.1
- 2550 Metcalfe, I. (2013, April). Gondwana dispersion and Asian accretion: Tectonic and palaeo-
 2551 geographic evolution of eastern Tethys. *Journal of Asian Earth Sciences*, *66*, 1–
 2552 33. Retrieved 2020-10-14, from [https://linkinghub.elsevier.com/retrieve/pii/](https://linkinghub.elsevier.com/retrieve/pii/S1367912012005779)
 2553 [S1367912012005779](https://linkinghub.elsevier.com/retrieve/pii/S1367912012005779) doi: 10.1016/j.jseaes.2012.12.020
- 2554 Meulenkamp, J. E., & Sissingh, W. (2003, July). Tertiary palaeogeography and
 2555 tectonostratigraphic evolution of the Northern and Southern Peri-Tethys platforms
 2556 and the intermediate domains of the African–Eurasian convergent plate boundary
 2557 zone. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *196*(1), 209–228. Re-
 2558 trieved 2021-04-06, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018203003195)
 2559 [S0031018203003195](https://www.sciencedirect.com/science/article/pii/S0031018203003195) doi: 10.1016/S0031-0182(03)00319-5
- 2560 Miao, Y. (2013, August). Late Cenozoic continuous aridification in the western Qaidam
 2561 Basin: evidence from sporopollen records.
- 2562 Miao, Y., Fang, X., Herrmann, M., Wu, F., Zhang, Y., & Liu, D. (2011, January). Miocene
 2563 pollen record of KC-1 core in the Qaidam Basin, NE Tibetan Plateau and implications
 2564 for evolution of the East Asian monsoon. *Palaeogeography, Palaeoclimatology, Palaeoe-*
 2565 *cology*, *299*(1-2), 30–38. Retrieved 2022-05-04, from [https://linkinghub.elsevier](https://linkinghub.elsevier.com/retrieve/pii/S0031018210006425)
 2566 [.com/retrieve/pii/S0031018210006425](https://linkinghub.elsevier.com/retrieve/pii/S0031018210006425) doi: 10.1016/j.palaeo.2010.10.026
- 2567 Miao, Y., Herrmann, M., Wu, F., Yan, X., & Yang, S. (2012, May). What controlled
 2568 Mid–Late Miocene long-term aridification in Central Asia? — Global cooling or
 2569 Tibetan Plateau uplift: A review. *Earth-Science Reviews*, *112*(3), 155–172. Re-
 2570 trieved 2022-03-22, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0012825212000141)
 2571 [S0012825212000141](https://www.sciencedirect.com/science/article/pii/S0012825212000141) doi: 10.1016/j.earscirev.2012.02.003
- 2572 Miao, Y., Song, C., Fang, X., Meng, Q., Zhang, P., Wu, F., & Yan, X. (2016, January).
 2573 Late Cenozoic genus Fupingopollenites development and its implications for the Asian
 2574 summer monsoon evolution. *Gondwana Research*, *29*(1), 320–333. Retrieved 2017-
 2575 10-09, from <http://linkinghub.elsevier.com/retrieve/pii/S1342937X15000040>
 2576 doi: 10.1016/j.gr.2014.12.007
- 2577 Miao, Y., Wu, F., Chang, H., Fang, X., Deng, T., Sun, J., & Jin, C. (2016, March). A
 2578 Late-Eocene palynological record from the Hoh Xil Basin, northern Tibetan Plateau,
 2579 and its implications for stratigraphic age, paleoclimate and paleoelevation. *Gondwana*
 2580 *Research*, *31*, 241–252. Retrieved 2017-10-09, from [http://linkinghub.elsevier](http://linkinghub.elsevier.com/retrieve/pii/S1342937X15000374)
 2581 [.com/retrieve/pii/S1342937X15000374](http://linkinghub.elsevier.com/retrieve/pii/S1342937X15000374) doi: 10.1016/j.gr.2015.01.007
- 2582 Miller, K. G., Browning, J. V., Schmelz, W. J., Kopp, R. E., Mountain, G. S., & Wright, J. D.
 2583 (2020, May). Cenozoic sea-level and cryospheric evolution from deep-sea geochemical
 2584 and continental margin records. *Science Advances*, *6*(20), eaaz1346. Retrieved 2021-
 2585 03-09, from <https://advances.sciencemag.org/content/6/20/eaaz1346> (Pub-
 2586 lisher: American Association for the Advancement of Science Section: Review) doi:
 2587 10.1126/sciadv.aaz1346
- 2588 Molnar, P., Boos, W. R., & Battisti, D. S. (2010, April). Orographic Controls on Climate
 2589 and Paleoclimate of Asia: Thermal and Mechanical Roles for the Tibetan Plateau.
 2590 *Annual Review of Earth and Planetary Sciences*, *38*(1), 77–102. Retrieved 2018-
 2591 03-09, from [http://www.annualreviews.org/doi/10.1146/annurev-earth-040809-](http://www.annualreviews.org/doi/10.1146/annurev-earth-040809-152456)
 2592 [-152456](http://www.annualreviews.org/doi/10.1146/annurev-earth-040809-152456) doi: 10.1146/annurev-earth-040809-152456
- 2593 Molnar, P., England, P., & Martinod, J. (1993). Mantle dynamics, uplift of the Tibetan
 2594 Plateau, and the Indian Monsoon. *Reviews of Geophysics*, *31*(4), 357. Retrieved 2020-
 2595 07-27, from <http://doi.wiley.com/10.1029/93RG02030> doi: 10.1029/93RG02030
- 2596 Morley, R. J. (2018, July). Assembly and division of the South and South-East Asian

- 2597 flora in relation to tectonics and climate change. *Journal of Tropical Ecology*,
 2598 34(4), 209–234. Retrieved 2022-06-23, from [https://www.cambridge.org/core/](https://www.cambridge.org/core/product/identifier/S0266467418000202/type/journal_article)
 2599 [product/identifier/S0266467418000202/type/journal_article](https://www.cambridge.org/core/product/identifier/S0266467418000202/type/journal_article) doi: 10.1017/
 2600 S0266467418000202
- 2601 Moucha, R., & Forte, A. M. (2011, October). Changes in African topography driven
 2602 by mantle convection. *Nature Geoscience*, 4(10), 707–712. Retrieved 2021-04-07,
 2603 from <http://www.nature.com/articles/ngeo1235> (Number: 10 Publisher: Nature
 2604 Publishing Group) doi: 10.1038/ngeo1235
- 2605 Mouthereau, F. (2011, November). Timing of uplift in the Zagros belt/Iranian plateau and
 2606 accommodation of late Cenozoic Arabia–Eurasia convergence. *Geological Magazine*,
 2607 148(5-6), 726–738. Retrieved 2020-06-22, from [https://www.cambridge.org/core/](https://www.cambridge.org/core/product/identifier/S0016756811000306/type/journal_article)
 2608 [product/identifier/S0016756811000306/type/journal_article](https://www.cambridge.org/core/product/identifier/S0016756811000306/type/journal_article) doi: 10.1017/
 2609 S0016756811000306
- 2610 Mouthereau, F., Lacombe, O., & Vergés, J. (2012, April). Building the Zagros collisional
 2611 orogen: Timing, strain distribution and the dynamics of Arabia/Eurasia plate con-
 2612 vergence. *Tectonophysics*, 532-535, 27–60. Retrieved 2021-09-15, from [https://](https://www.sciencedirect.com/science/article/pii/S0040195112000509)
 2613 www.sciencedirect.com/science/article/pii/S0040195112000509 doi: 10.1016/
 2614 j.tecto.2012.01.022
- 2615 Najman, Y., Sobel, E. R., Millar, I., Stockli, D. F., Govin, G., Lisker, F., ... Kahn, A.
 2616 (2020, January). The exhumation of the Indo-Burman Ranges, Myanmar. *Earth*
 2617 *and Planetary Science Letters*, 530, 115948. Retrieved 2021-03-29, from [https://](https://www.sciencedirect.com/science/article/pii/S0012821X19306405)
 2618 www.sciencedirect.com/science/article/pii/S0012821X19306405 doi: 10.1016/
 2619 j.epsl.2019.115948
- 2620 Neupane, P. C., Gani, M. R., Gani, N. D., & Huang, Y. (2020). Neogene vegeta-
 2621 tion shift in the Nepalese Siwalik, Himalayas: A compound-specific isotopic study
 2622 of lipid biomarkers. *The Depositional Record*, 6(1), 192–202. Retrieved 2022-06-
 2623 07, from <http://onlinelibrary.wiley.com/doi/abs/10.1002/dep2.91> (eprint:
 2624 <https://onlinelibrary.wiley.com/doi/pdf/10.1002/dep2.91>) doi: 10.1002/dep2.91
- 2625 Okay, A. I., Zattin, M., & Cavazza, W. (2010, January). Apatite fission-track data for the
 2626 Miocene Arabia-Eurasia collision. *Geology*, 38(1), 35–38. Retrieved 2022-03-04, from
 2627 <https://doi.org/10.1130/G30234.1> doi: 10.1130/G30234.1
- 2628 Otero, O., & Gayet, M. (2001, January). Palaeoichthyofaunas from the Lower Oligocene
 2629 and Miocene of the Arabian Plate: palaeoecological and palaeobiogeographical im-
 2630 plications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 165(1), 141–169. Re-
 2631 trieved 2021-04-06, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018200001589)
 2632 [S0031018200001589](https://www.sciencedirect.com/science/article/pii/S0031018200001589) doi: 10.1016/S0031-0182(00)00158-9
- 2633 Ozsvárt, P., Kocsis, L., Nyerges, A., Györi, O., & Pálffy, J. (2016, October). The
 2634 Eocene-Oligocene climate transition in the Central Paratethys. *Palaeogeography,*
 2635 *Palaeoclimatology, Palaeoecology*, 459, 471–487. Retrieved 2021-04-01, from [https://](https://www.sciencedirect.com/science/article/pii/S0031018216302899)
 2636 www.sciencedirect.com/science/article/pii/S0031018216302899 doi: 10.1016/
 2637 j.palaeo.2016.07.034
- 2638 Page, M., Licht, A., Dupont-Nivet, G., Meijer, N., Barbolini, N., Hoorn, C., ... Guo, Z.
 2639 (2019, March). Synchronous cooling and decline in monsoonal rainfall in northeastern
 2640 Tibet during the fall into the Oligocene icehouse. *Geology*, 47(3), 203–206. Retrieved
 2641 2020-01-21, from [https://pubs.geoscienceworld.org/gsa/geology/article/47/](https://pubs.geoscienceworld.org/gsa/geology/article/47/3/203/568396/Synchronous-cooling-and-decline-in-monsoonal)
 2642 [3/203/568396/Synchronous-cooling-and-decline-in-monsoonal](https://pubs.geoscienceworld.org/gsa/geology/article/47/3/203/568396/Synchronous-cooling-and-decline-in-monsoonal) doi: 10.1130/
 2643 G45480.1
- 2644 Peng, T., Li, J., Song, C., Guo, B., Liu, J., Zhao, Z., & Zhang, J. (2016, April).
 2645 An integrated biomarker perspective on Neogene–Quaternary climatic evolution in
 2646 NE Tibetan Plateau: Implications for the Asian aridification. *Quaternary Interna-*
 2647 *tional*, 399, 174–182. Retrieved 2022-06-09, from [https://www.sciencedirect.com/](https://www.sciencedirect.com/science/article/pii/S104061821500422X)
 2648 [science/article/pii/S104061821500422X](https://www.sciencedirect.com/science/article/pii/S104061821500422X) doi: 10.1016/j.quaint.2015.04.020
- 2649 Pettke, T., Halliday, A. N., & Rea, D. K. (2002). Cenozoic evolution of Asian climate
 2650 and sources of Pacific seawater Pb and Nd derived from eolian dust of sediment
 2651 core LL44-GPC3. *Paleoceanography*, 17(3), 3–1–3–13. Retrieved 2022-03-25, from

- 2652 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2001PA000673> (_eprint:
2653 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2001PA000673>) doi: 10
2654 .1029/2001PA000673
- 2655 Pirouz, M., Avouac, J.-P., Hassanzadeh, J., Kirschvink, J. L., & Bahroudi, A. (2017,
2656 November). Early Neogene foreland of the Zagros, implications for the initial closure
2657 of the Neo-Tethys and kinematics of crustal shortening. *Earth and Planetary Science
2658 Letters*, *477*, 168–182. Retrieved 2020-10-20, from [https://linkinghub.elsevier
2659 .com/retrieve/pii/S0012821X17304302](https://linkinghub.elsevier.com/retrieve/pii/S0012821X17304302) doi: 10.1016/j.epsl.2017.07.046
- 2660 Poblete, F., Dupont-Nivet, G., Licht, A., van Hinsbergen, D. J. J., Roperch, P., Miha-
2661 lynuk, M. G., ... Baatsen, M. L. J. (2021, March). Towards interactive global
2662 paleogeographic maps, new reconstructions at 60, 40 and 20Ma. *Earth-Science Re-
2663 views*, *214*, 103508. Retrieved 2021-04-07, from [https://www.sciencedirect.com/
2664 science/article/pii/S0012825221000076](https://www.sciencedirect.com/science/article/pii/S0012825221000076) doi: 10.1016/j.earscirev.2021.103508
- 2665 Polissar, P. J., Uno, K. T., Phelps, S. R., Karp, A. T., Freeman, K. H., &
2666 Pensky, J. L. (2021). Hydrologic Changes Drove the Late Miocene Expan-
2667 sion of C4 Grasslands on the Northern Indian Subcontinent. *Paleoceanogra-
2668 phy and Paleoclimatology*, *36*(4), e2020PA004108. Retrieved 2022-06-07, from
2669 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA004108> (_eprint:
2670 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA004108>) doi: 10
2671 .1029/2020PA004108
- 2672 Poulsen, C. J., & Jeffery, M. L. (2011, June). Climate change imprint-
2673 ing on stable isotopic compositions of high-elevation meteoric water cloaks
2674 past surface elevations of major orogens. *Geology*, *39*(6), 595–598. Re-
2675 trieved 2022-04-11, from [http://pubs.geoscienceworld.org/geology/article/
2676 39/6/595/130636/Climate-change-imprinting-on-stable-isotopic](http://pubs.geoscienceworld.org/geology/article/39/6/595/130636/Climate-change-imprinting-on-stable-isotopic) doi: 10
2677 .1130/G32052.1
- 2678 Pound, M. J., & Salzmann, U. (2017, February). Heterogeneity in global vegetation and ter-
2679 restrial climate change during the late Eocene to early Oligocene transition. *Scientific
2680 Reports*, *7*, 43386. Retrieved 2017-11-23, from [http://www.nature.com/articles/
2681 srep43386](http://www.nature.com/articles/srep43386) doi: 10.1038/srep43386
- 2682 Prell, W. L., & Kutzbach, J. E. (1992). Sensitivity of the Indian monsoon to forcing
2683 parameters and implications for its evolution. *Nature*, *360*(6405), 647–652.
- 2684 Qiang, X., An, Z., Song, Y., Chang, H., Sun, Y., Liu, W., ... Ai, L. (2011, January).
2685 New eolian red clay sequence on the western Chinese Loess Plateau linked to onset of
2686 Asian desertification about 25 Ma ago. *Science China Earth Sciences*, *54*(1), 136–144.
2687 Retrieved 2017-10-09, from [http://link.springer.com/10.1007/s11430-010-4126-
2688 -5](http://link.springer.com/10.1007/s11430-010-4126-5) doi: 10.1007/s11430-010-4126-5
- 2689 Quade, J., Cater, J. M., Ojha, T. P., Adam, J., & Mark Harrison, T. (1995, De-
2690 cember). Late Miocene environmental change in Nepal and the northern In-
2691 dian subcontinent: Stable isotopic evidence from paleosols. *Geological Society of
2692 America Bulletin*, *107*(12), 1381–1397. Retrieved 2022-05-30, from [https://pubs
2693 .geoscienceworld.org/gsabulletin/article/107/12/1381-1397/182993](https://pubs.geoscienceworld.org/gsabulletin/article/107/12/1381-1397/182993) doi:
2694 10.1130/0016-7606(1995)107<1381:LMECIN>2.3.CO;2
- 2695 Quade, J., & Cerling, T. E. (1995, May). Expansion of C4 grasses in the Late
2696 Miocene of Northern Pakistan: evidence from stable isotopes in paleosols. *Palaeo-
2697 geography, Palaeoclimatology, Palaeoecology*, *115*(1-4), 91–116. Retrieved 2022-05-30,
2698 from <https://linkinghub.elsevier.com/retrieve/pii/003101829400108K> doi:
2699 10.1016/0031-0182(94)00108-K
- 2700 Rae, J. W., Zhang, Y. G., Liu, X., Foster, G. L., Stoll, H. M., & Whiteford, R. D.
2701 (2021, May). Atmospheric CO₂ over the Past 66 Million Years from Marine
2702 Archives. *Annual Review of Earth and Planetary Sciences*, *49*(1), 609–641. Re-
2703 trieved 2021-06-01, from [https://www.annualreviews.org/doi/10.1146/annurev
2704 -earth-082420-063026](https://www.annualreviews.org/doi/10.1146/annurev-earth-082420-063026) doi: 10.1146/annurev-earth-082420-063026
- 2705 Ramstein, G., Fluteau, F., Besse, J., & Joussaume, S. (1997, April). Effect of orogeny,
2706 plate motion and land-sea distribution on Eurasian climate change over the past

- 2707 30 million years. *Nature*, 386(6627), 788–795. Retrieved 2017-12-05, from <http://www.nature.com/doi/10.1038/386788a0> doi: 10.1038/386788a0
- 2708
- 2709 Rea, D., Leinen, M., & Janecek, T. (1985, March). Geologic Approach to the Long-Term
2710 History of Atmospheric Circulation. *Science (New York, N.Y.)*, 227, 721–5. doi:
2711 10.1126/science.227.4688.721
- 2712 Rea, D. K. (1994). The paleoclimatic record provided by eolian deposition in the deep
2713 sea: The geologic history of wind. *Reviews of Geophysics*, 32(2), 159–195. Retrieved
2714 2022-05-16, from <http://onlinelibrary.wiley.com/doi/abs/10.1029/93RG03257>
2715 (_eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/93RG03257>) doi:
2716 10.1029/93RG03257
- 2717 Ren, J., Schubert, B. A., Lukens, W. E., & Quan, C. (2021, September). Low oxy-
2718 gen isotope values of fossil cellulose indicate an intense monsoon in East Asia dur-
2719 ing the late Oligocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 577,
2720 110556. Retrieved 2022-02-22, from [https://linkinghub.elsevier.com/retrieve/
2721 pii/S0031018221003412](https://linkinghub.elsevier.com/retrieve/pii/S0031018221003412) doi: 10.1016/j.palaeo.2021.110556
- 2722 Ren, X., Nie, J., Saylor, J. E., Wang, X., Liu, F., & Horton, B. K. (2020). Temperature Con-
2723 trol on Silicate Weathering Intensity and Evolution of the Neogene East Asian Summer
2724 Monsoon. *Geophysical Research Letters*, 47(15), e2020GL088808. Retrieved 2022-
2725 06-09, from <http://onlinelibrary.wiley.com/doi/abs/10.1029/2020GL088808>
2726 (_eprint: <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020GL088808>)
2727 doi: 10.1029/2020GL088808
- 2728 Roberts, E. M., Stevens, N. J., O’Connor, P. M., Dirks, P. H. G. M., Gottfried, M. D.,
2729 Clyde, W. C., . . . Hemming, S. (2012, April). Initiation of the western branch of the
2730 East African Rift coeval with the eastern branch. *Nature Geoscience*, 5(4), 289–294.
2731 Retrieved 2021-04-07, from <http://www.nature.com/articles/ngeo1432> (Number:
2732 4 Publisher: Nature Publishing Group) doi: 10.1038/ngeo1432
- 2733 Rodwell, M. J., & Hoskins, B. J. (1995, May). A Model of the Asian Summer Monsoon.Part
2734 II: Cross-Equatorial Flow and PV Behavior. *Journal of the Atmospheric Sciences*,
2735 52(9), 1341–1356. Retrieved 2019-07-05, from [http://journals.ametsoc.org/doi/
2736 abs/10.1175/1520-0469%281995%29052%3C1341%3AAMOTAS%3E2.0.CO%3B2](http://journals.ametsoc.org/doi/abs/10.1175/1520-0469%281995%29052%3C1341%3AAMOTAS%3E2.0.CO%3B2) doi: 10
2737 .1175/1520-0469(1995)052(1341:AMOTAS)2.0.CO;2
- 2738 Roe, G. H., Ding, Q., Battisti, D. S., Molnar, P., Clark, M. K., & Garziona, C. N. (2016,
2739 May). A modeling study of the response of Asian summertime climate to the largest
2740 geologic forcings of the past 50 Ma: geological controls on Asian climate. *Journal of
2741 Geophysical Research: Atmospheres*, 121(10), 5453–5470. Retrieved 2018-01-11, from
2742 <http://doi.wiley.com/10.1002/2015JD024370> doi: 10.1002/2015JD024370
- 2743 Rowley, D. B., & Currie, B. S. (2006, February). Palaeo-altimetry of the late Eocene
2744 to Miocene Lunpola basin, central Tibet. *Nature*, 439(7077), 677–681. Retrieved
2745 2020-10-17, from <https://www.nature.com/articles/nature04506> (Number: 7077
2746 Publisher: Nature Publishing Group) doi: 10.1038/nature04506
- 2747 Rögl, F. (1997). Palaeogeographic Considerations for Mediterranean and Paratethys Sea-
2748 ways (Oligocene to Miocene). *Annalen des Naturhistorischen Museums in Wien. Se-
2749 rie A für Mineralogie und Petrographie, Geologie und Paläontologie, Anthropologie
2750 und Prähistorie*, 99, 279–310. Retrieved 2021-03-09, from [http://www.jstor.org/
2751 stable/41702129](http://www.jstor.org/stable/41702129) (Publisher: Naturhistorisches Museum)
- 2752 Rögl, F. (1999). MEDITERRANEAN AND PARATETHYS. FACTS AND HY-
2753 POTHESES OF AN OLIGOCENE TO MIOCENE PALEOGEOGRAPHY (SHORT
2754 OVERVIEW). *Geologica carpathica*, 50(4), 339–349.
- 2755 Sampe, T., & Xie, S.-P. (2010, January). Large-Scale Dynamics of the Meiyu-Baiu Rain-
2756 band: Environmental Forcing by the Westerly Jet*. *Journal of Climate*, 23(1), 113–
2757 134. Retrieved 2020-07-25, from [https://journals.ametsoc.org/jcli/article/
2758 23/1/113/32279/LargeScale-Dynamics-of-the-MeiyuBaiu-Rainband](https://journals.ametsoc.org/jcli/article/23/1/113/32279/LargeScale-Dynamics-of-the-MeiyuBaiu-Rainband) doi: 10
2759 .1175/2009JCLI3128.1
- 2760 Sanyal, P., Bhattacharya, S., Kumar, R., Ghosh, S., & Sangode, S. (2004, March).
2761 Mio–Pliocene monsoonal record from Himalayan foreland basin (Indian Siwalik) and

- its relation to vegetational change. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 205, 23–41. doi: 10.1016/j.palaeo.2003.11.013
- Sarr, A.-C., Donnadieu, Y., Bolton, C. T., Ladant, J.-B., Licht, A., Fluteau, F., . . . Dupont-Nivet, G. (2022, April). Neogene South Asian monsoon rainfall and wind histories diverged due to topographic effects. *Nature Geoscience*, 1–6. Retrieved 2022-04-12, from <http://www.nature.com/articles/s41561-022-00919-0> (Publisher: Nature Publishing Group) doi: 10.1038/s41561-022-00919-0
- Sato, T. (2009, February). Influences of subtropical jet and Tibetan Plateau on precipitation pattern in Asia: Insights from regional climate modeling. *Quaternary International*, 194(1-2), 148–158. Retrieved 2022-06-27, from <https://linkinghub.elsevier.com/retrieve/pii/S1040618208002176> doi: 10.1016/j.quaint.2008.07.008
- Saxena, R. K., & Trivedi, G. K. (2009). Palynological investigation of the Kopili Formation (Late Eocene) in North Cachar Hills, Assam, India. , 25.
- Schott, F. A., & McCreary, J. P. (2001, January). The monsoon circulation of the Indian Ocean. *Progress in Oceanography*, 51(1), 1–123. Retrieved 2020-07-23, from <https://linkinghub.elsevier.com/retrieve/pii/S0079661101000830> doi: 10.1016/S0079-6611(01)00083-0
- Sembroni, A., Faccenna, C., Becker, T. W., Molin, P., & Abebe, B. (2016). Long-term, deep-mantle support of the Ethiopia-Yemen Plateau. *Tectonics*, 35(2), 469–488. Retrieved 2021-09-02, from <http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015TC004000> (_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/2015TC004000>) doi: 10.1002/2015TC004000
- Sepulchre, P., Caubel, A., Ladant, J.-B., Bopp, L., Boucher, O., Braconnot, P., . . . Tardif, D. (2020, July). IPSL-CM5A2 – an Earth system model designed for multi-millennial climate simulations. *Geoscientific Model Development*, 13(7), 3011–3053. Retrieved 2020-11-27, from <https://gmd.copernicus.org/articles/13/3011/2020/> doi: 10.5194/gmd-13-3011-2020
- Sepulchre, P., Ramstein, G., Fluteau, F., Schuster, M., Tiercelin, J.-J., & Brunet, M. (2006, September). Tectonic Uplift and Eastern Africa Aridification. *Science*, 313(5792), 1419–1423. Retrieved 2020-06-22, from <https://www.sciencemag.org/lookup/doi/10.1126/science.1129158> doi: 10.1126/science.1129158
- Sha, Y., Ren, X., Shi, Z., Zhou, P., Li, X., & Liu, X. (2020, April). Influence of the Tibetan Plateau and its northern margins on the mid-latitude Westerly Jet over Central Asia in summer. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 544, 109611. Retrieved 2022-06-27, from <https://linkinghub.elsevier.com/retrieve/pii/S0031018219306819> doi: 10.1016/j.palaeo.2020.109611
- Sha, Y., Shi, Z., Liu, X., & An, Z. (2015). Distinct impacts of the Mongolian and Tibetan Plateaus on the evolution of the East Asian monsoon. *Journal of Geophysical Research: Atmospheres*, 120(10), 4764–4782. Retrieved 2021-04-19, from <http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2014JD022880> (_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/2014JD022880>) doi: <https://doi.org/10.1002/2014JD022880>
- Shen, X., Wan, S., France-Lanord, C., Clift, P. D., Tada, R., Révillon, S., . . . Li, A. (2017, September). History of Asian eolian input to the Sea of Japan since 15 Ma: Links to Tibetan uplift or global cooling? *Earth and Planetary Science Letters*, 474, 296–308. Retrieved 2017-10-09, from <http://linkinghub.elsevier.com/retrieve/pii/S0012821X17303771> doi: 10.1016/j.epsl.2017.06.053
- Shi, Z., Liu, X., Liu, Y., Sha, Y., & Xu, T. (2015). Impact of Mongolian Plateau versus Tibetan Plateau on the westerly jet over North Pacific Ocean. *Climate Dynamics*, 44(11-12), 3067–3076. (ISBN: 0930-7575 Publisher: Springer)
- Shukla, A., Mehrotra, R. C., Spicer, R. A., Spicer, T. E., & Kumar, M. (2014, October). Cool equatorial terrestrial temperatures and the South Asian monsoon in the Early Eocene: Evidence from the Gurha Mine, Rajasthan, India. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 412, 187–198. Retrieved 2017-10-09,

- 2817 from <http://linkinghub.elsevier.com/retrieve/pii/S003101821400399X> doi:
2818 10.1016/j.palaeo.2014.08.004
- 2819 Smith, S. G., Wegmann, K. W., Ancuta, L. D., Gosse, J. C., & Hopkins, C. E. (2016,
2820 August). Paleotopography and erosion rates in the central Hangay Dome, Mongo-
2821 lia: Landscape evolution since the mid-Miocene. *Journal of Asian Earth Sciences*,
2822 *125*, 37–57. Retrieved 2021-03-29, from [https://www.sciencedirect.com/science/
2823 article/pii/S1367912016301274](https://www.sciencedirect.com/science/article/pii/S1367912016301274) doi: 10.1016/j.jseaes.2016.05.013
- 2824 Song, B., Spicer, R. A., Zhang, K., Ji, J., Farnsworth, A., Hughes, A. C., ... Shi, G.
2825 (2020, May). Qaidam Basin leaf fossils show northeastern Tibet was high, wet and
2826 cool in the early Oligocene. *Earth and Planetary Science Letters*, *537*, 116175. Re-
2827 trieved 2021-05-27, from [https://www.sciencedirect.com/science/article/pii/
2828 S0012821X20301187](https://www.sciencedirect.com/science/article/pii/S0012821X20301187) doi: 10.1016/j.epsl.2020.116175
- 2829 Sorrel, P., Eymard, I., Leloup, P.-H., Maheo, G., Olivier, N., Sterb, M., ... Replumaz, A.
2830 (2017, December). Wet tropical climate in SE Tibet during the Late Eocene. *Scien-
2831 tific Reports*, *7*(1). Retrieved 2018-04-03, from [http://www.nature.com/articles/
2832 s41598-017-07766-9](http://www.nature.com/articles/s41598-017-07766-9) doi: 10.1038/s41598-017-07766-9
- 2833 Sosdian, S. M., & Lear, C. H. (2020). Initiation of the Western Pacific
2834 Warm Pool at the Middle Miocene Climate Transition? *Paleoceanogra-
2835 phy and Paleoclimatology*, *35*(12), e2020PA003920. Retrieved 2021-09-20, from
2836 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003920> (eprint:
2837 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA003920>) doi: 10.1029/
2838 2020PA003920
- 2839 Spicer, R., Su, T., Valdes, P. J., Farnsworth, A., Wu, F.-X., Shi, G., ... Zhou, Z. (2020,
2840 May). Why ‘the uplift of the Tibetan Plateau’ is a myth? *National Science Review*,
2841 *19*. Retrieved 2020-11-27, from [https://academic.oup.com/nsr/advance-article/
2842 doi/10.1093/nsr/nwaa091/5829861](https://academic.oup.com/nsr/advance-article/doi/10.1093/nsr/nwaa091/5829861) doi: 10.1093/nsr/nwaa091
- 2843 Spicer, R., Yang, J., Herman, A., Kodrul, T., Aleksandrova, G., Maslova, N., ... Jin, J.-
2844 H. (2017, September). Paleogene monsoons across India and South China: Drivers of
2845 biotic change. *Gondwana Research*, *49*, 350–363. Retrieved 2022-05-03, from [https://
2846 linkinghub.elsevier.com/retrieve/pii/S1342937X16304385](https://linkinghub.elsevier.com/retrieve/pii/S1342937X16304385) doi: 10.1016/j.gr
2847 .2017.06.006
- 2848 Spicer, R. A., Yang, J., Herman, A. B., Kodrul, T., Maslova, N., Spicer, T. E., ... Jin,
2849 J. (2016, September). Asian Eocene monsoons as revealed by leaf architectural sig-
2850 natures. *Earth and Planetary Science Letters*, *449*, 61–68. Retrieved 2017-10-09,
2851 from <http://linkinghub.elsevier.com/retrieve/pii/S0012821X16302618> doi:
2852 10.1016/j.epsl.2016.05.036
- 2853 Srivastava, G., Paudyal, K. N., Utescher, T., & Mehrotra, R. (2018, February). Miocene
2854 vegetation shift and climate change: Evidence from the Siwalik of Nepal. *Global and
2855 Planetary Change*, *161*, 108–120. Retrieved 2022-05-30, from [https://linkinghub
2856 .elsevier.com/retrieve/pii/S092181811730317X](https://linkinghub.elsevier.com/retrieve/pii/S092181811730317X) doi: 10.1016/j.gloplacha.2017
2857 .12.001
- 2858 Srivastava, G., Spicer, R. A., Spicer, T. E., Yang, J., Kumar, M., Mehrotra, R., & Mehro-
2859 tra, N. (2012, July). Megafloora and palaeoclimate of a Late Oligocene tropical
2860 delta, Makum Coalfield, Assam: Evidence for the early development of the South
2861 Asia Monsoon. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *342-343*, 130–
2862 142. Retrieved 2018-06-22, from [http://linkinghub.elsevier.com/retrieve/pii/
2863 S0031018212002532](http://linkinghub.elsevier.com/retrieve/pii/S0031018212002532) doi: 10.1016/j.palaeo.2012.05.002
- 2864 Straume, E. O., Gaina, C., Medvedev, S., & Nisancioglu, K. H. (2020, October). Global
2865 Cenozoic Paleobathymetry with a focus on the Northern Hemisphere Oceanic Gate-
2866 ways. *Gondwana Research*, *86*, 126–143. Retrieved 2021-04-08, from [https://
2867 www.sciencedirect.com/science/article/pii/S1342937X20301659](https://www.sciencedirect.com/science/article/pii/S1342937X20301659) doi: 10.1016/
2868 j.gr.2020.05.011
- 2869 Su, H., & Zhou, J. (2020, June). Timing of Arabia-Eurasia collision: Constraints
2870 from restoration of crustal-scale cross-sections. *Journal of Structural Geology*, *135*,
2871 104041. Retrieved 2022-03-04, from <https://www.sciencedirect.com/science/>

- 2872 article/pii/S0191814119304456 doi: 10.1016/j.jsg.2020.104041
- 2873 Su, T., Farnsworth, A., Spicer, R., & Huang, J. (2019). No high Tibetan Plateau until the
2874 Neogene. *Science Advances*, 9.
- 2875 Su, T., Spicer, R. A., Li, S.-H., Xu, H., Huang, J., Sherlock, S., ... Zhou, Z.-K. (2019, May).
2876 Uplift, climate and biotic changes at the Eocene–Oligocene transition in south-eastern
2877 Tibet. *National Science Review*, 6(3), 495–504. Retrieved 2019-10-24, from [https://](https://academic.oup.com/nsr/article/6/3/495/5036537)
2878 academic.oup.com/nsr/article/6/3/495/5036537 doi: 10.1093/nsr/nwy062
- 2879 Su, T., Spicer, R. A., Wu, F.-X., Farnsworth, A., Huang, J., Del Rio, C., ... Zhou,
2880 Z.-K. (2020, December). A Middle Eocene lowland humid subtropical “Shangri-
2881 La” ecosystem in central Tibet. *Proceedings of the National Academy of Sciences*,
2882 117(52), 32989–32995. Retrieved 2021-02-01, from [http://www.pnas.org/lookup/](http://www.pnas.org/lookup/doi/10.1073/pnas.2012647117)
2883 [doi/10.1073/pnas.2012647117](http://www.pnas.org/lookup/doi/10.1073/pnas.2012647117) doi: 10.1073/pnas.2012647117
- 2884 Suarez, M. B., Passey, B. H., & Kaakinen, A. (2011, December). Paleosol carbonate
2885 multiple isotopologue signature of active East Asian summer monsoons during the
2886 late Miocene and Pliocene. *Geology*, 39(12), 1151–1154. Retrieved 2022-06-09,
2887 from [http://pubs.geoscienceworld.org/geology/article/39/12/1151/130458/](http://pubs.geoscienceworld.org/geology/article/39/12/1151/130458/Paleosol-carbonate-multiple-isotopologue-signature)
2888 [Paleosol-carbonate-multiple-isotopologue-signature](http://pubs.geoscienceworld.org/geology/article/39/12/1151/130458/Paleosol-carbonate-multiple-isotopologue-signature) doi: 10.1130/G32350.1
- 2889 Sun, J., Liu, W., Guo, Z., Qi, L., & Zhang, Z. (2022, April). Enhanced aridifi-
2890 cation across the Eocene/Oligocene transition evidenced by geochemical record in
2891 the Tajik Basin, Central Asia. *Global and Planetary Change*, 211, 103789. Re-
2892 trieved 2022-03-22, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S092181812200056X)
2893 [S092181812200056X](https://www.sciencedirect.com/science/article/pii/S092181812200056X) doi: 10.1016/j.gloplacha.2022.103789
- 2894 Sun, J., Ni, X., Bi, S., Wu, W., Ye, J., Meng, J., & Windley, B. F. (2015, May). Syn-
2895 chronous turnover of flora, fauna and climate at the Eocene–Oligocene Boundary in
2896 Asia. *Scientific Reports*, 4(1). Retrieved 2020-02-03, from [http://www.nature.com/](http://www.nature.com/articles/srep07463)
2897 [articles/srep07463](http://www.nature.com/articles/srep07463) doi: 10.1038/srep07463
- 2898 Sun, J., Sheykh, M., Ahmadi, N., Cao, M., Zhang, Z., Tian, S., ... Talebian, M.
2899 (2021, February). Permanent closure of the Tethyan Seaway in the northwest-
2900 ern Iranian Plateau driven by cyclic sea-level fluctuations in the late Middle
2901 Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 564, 110172. Re-
2902 trieved 2021-05-03, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0031018220306209)
2903 [S0031018220306209](https://www.sciencedirect.com/science/article/pii/S0031018220306209) doi: 10.1016/j.palaeo.2020.110172
- 2904 Sun, J., & Windley, B. (2015, October). Onset of aridification by 34 Ma across the Eocene-
2905 Oligocene transition in Central Asia. *Geology*, 43, G37165.1. doi: 10.1130/G37165.1
- 2906 Sun, J., Ye, J., Wu, W., Ni, X., Bi, S., Zhang, Z., ... Meng, J. (2010, June). Late
2907 Oligocene–Miocene mid-latitude aridification and wind patterns in the Asian interior.
2908 *Geology*, 38(6), 515–518. Retrieved 2022-04-06, from [https://doi.org/10.1130/](https://doi.org/10.1130/G30776.1)
2909 [G30776.1](https://doi.org/10.1130/G30776.1) doi: 10.1130/G30776.1
- 2910 Sun, J., Zhang, L., Deng, C., & Zhu, R. (2008, May). Evidence for enhanced aridity in
2911 the Tarim Basin of China since 5.3Ma. *Quaternary Science Reviews*, 27(9-10), 1012–
2912 1023. Retrieved 2022-06-16, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S0277379108000310)
2913 [pii/S0277379108000310](https://linkinghub.elsevier.com/retrieve/pii/S0277379108000310) doi: 10.1016/j.quascirev.2008.01.011
- 2914 Sun, J., & Zhang, Z. (2008, November). Palynological evidence for the Mid-Miocene Cli-
2915 matic Optimum recorded in Cenozoic sediments of the Tian Shan Range, northwest-
2916 ern China. *Global and Planetary Change*, 64(1-2), 53–68. Retrieved 2022-05-04,
2917 from <https://linkinghub.elsevier.com/retrieve/pii/S0921818108001045> doi:
2918 [10.1016/j.gloplacha.2008.09.001](https://linkinghub.elsevier.com/retrieve/pii/S0921818108001045)
- 2919 Sun, J., Zhang, Z., Cao, M., Windley, B. F., Tian, S., Sha, J., ... Oimahmadov, I.
2920 (2020, May). Timing of seawater retreat from proto-Paratethys, sedimentary provenance,
2921 and tectonic rotations in the late Eocene-early Oligocene in the Tajik Basin,
2922 Central Asia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 545, 109657. Re-
2923 trieved 2020-11-02, from [http://www.sciencedirect.com/science/article/pii/](http://www.sciencedirect.com/science/article/pii/S0031018220301024)
2924 [S0031018220301024](http://www.sciencedirect.com/science/article/pii/S0031018220301024) doi: 10.1016/j.palaeo.2020.109657
- 2925 Sun, Q.-g., Collinson, M. E., Li, C.-S., Wang, Y.-f., & Beerling, D. J. (2002). Quantitative
2926 reconstruction of palaeoclimate from the Middle Miocene Shanwang flora, eastern

- 2927 China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 15. doi: 10.1016/S0031
2928 -0182(01)00433-3
- 2929 Sun, X., & Wang, P. (2005, July). How old is the Asian monsoon system?—Palaeobotanical
2930 records from China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 222(3-4),
2931 181–222. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/retrieve/
2932 pii/S0031018205001203](http://linkinghub.elsevier.com/retrieve/pii/S0031018205001203) doi: 10.1016/j.palaeo.2005.03.005
- 2933 Sun, Y., Liu, J., Liang, Y., Ji, J., Liu, W., Aitchison, J. C., ... Liu, Z. (2020, September).
2934 Cenozoic moisture fluctuations on the northeastern Tibetan Plateau and association
2935 with global climatic conditions. *Journal of Asian Earth Sciences*, 200, 104490. Re-
2936 trieved 2022-05-12, from [https://www.sciencedirect.com/science/article/pii/
2937 S1367912020302832](https://www.sciencedirect.com/science/article/pii/S1367912020302832) doi: 10.1016/j.jseaes.2020.104490
- 2938 Tada, R., Zheng, H., & Clift, P. D. (2016, December). Evolution and variability of the Asian
2939 monsoon and its potential linkage with uplift of the Himalaya and Tibetan Plateau.
2940 *Progress in Earth and Planetary Science*, 3(1). Retrieved 2017-10-09, from [http://
2941 www.progearthplanetsci.com/content/3/1/4](http://www.progearthplanetsci.com/content/3/1/4) doi: 10.1186/s40645-016-0080-y
- 2942 Tang, H., Li, S.-F., Su, T., Spicer, R. A., Zhang, S.-T., Li, S.-H., ... Zhou, Z.-K. (2020,
2943 December). Early Oligocene vegetation and climate of southwestern China inferred
2944 from palynology. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 560, 109988. Re-
2945 trieved 2022-03-11, from [https://www.sciencedirect.com/science/article/pii/
2946 S0031018220304338](https://www.sciencedirect.com/science/article/pii/S0031018220304338) doi: 10.1016/j.palaeo.2020.109988
- 2947 Tang, H., Micheels, A., Eronen, J. T., Ahrens, B., & Fortelius, M. (2013, March). Asyn-
2948 chronous responses of East Asian and Indian summer monsoons to mountain uplift
2949 shown by regional climate modelling experiments. *Climate Dynamics*, 40(5), 1531–
2950 1549. Retrieved 2022-06-28, from <https://doi.org/10.1007/s00382-012-1603-x>
2951 doi: 10.1007/s00382-012-1603-x
- 2952 Tang, Z.-H., & Ding, Z.-L. (2013, December). A palynological insight into the Miocene arid-
2953 ification in the Eurasian interior. *Palaeoworld*, 22(3-4), 77–85. Retrieved 2022-06-23,
2954 from <https://linkinghub.elsevier.com/retrieve/pii/S1871174X13000073> doi:
2955 10.1016/j.palwor.2013.05.001
- 2956 Tapponnier, P., & Molnar, P. (1979). Active faulting and cenozoic tectonics of
2957 the Tien Shan, Mongolia, and Baykal Regions. *Journal of Geophysical Re-
2958 search: Solid Earth*, 84(B7), 3425–3459. Retrieved 2021-03-26, from [http://
2959 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/JB084iB07p03425](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/JB084iB07p03425) (eprint:
2960 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/JB084iB07p03425>) doi: [https://doi
2961 .org/10.1029/JB084iB07p03425](https://doi.org/10.1029/JB084iB07p03425)
- 2962 Tardif, D., Fluteau, F., Donnadiou, Y., Le Hir, G., Ladant, J.-B., Sepulchre, P., ... Dupont-
2963 Nivet, G. (2020, May). The origin of Asian monsoons: a modelling perspective.
2964 *Climate of the Past*, 16(3), 847–865. Retrieved 2020-05-08, from [https://www.clim-
2965 -past.net/16/847/2020/](https://www.clim-past.net/16/847/2020/) doi: 10.5194/cp-16-847-2020
- 2966 Tardif, D., Toumoulin, A., Fluteau, F., Donnadiou, Y., Le Hir, G., Barbolini, N., ...
2967 Dupont-Nivet, G. (2021, October). Orbital variations as a major driver of climate
2968 and biome distribution during the greenhouse to icehouse transition. *Science Ad-
2969 vances*, 7(43), eabh2819. Retrieved 2021-10-25, from [https://www.science.org/
2970 doi/10.1126/sciadv.abh2819](https://www.science.org/doi/10.1126/sciadv.abh2819) doi: 10.1126/sciadv.abh2819
- 2971 Tauxe, L., & Feakins, S. J. (2020). A Reassessment of the Chronostratig-
2972 raphy of Late Miocene C3–C4 Transitions. *Paleoceanography and Paleo-
2973 climatology*, 35(7), e2020PA003857. Retrieved 2022-06-07, from [http://
2974 onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003857](http://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003857) (eprint:
2975 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA003857>) doi:
2976 10.1029/2020PA003857
- 2977 Thomson, J. R., Holden, P. B., Anand, P., Edwards, N. R., Porchier, C. A., & Harris,
2978 N. B. W. (2021, June). Tectonic and climatic drivers of Asian monsoon evolu-
2979 tion. *Nature Communications*, 12(1), 4022. Retrieved 2021-10-05, from [http://www
2980 .nature.com/articles/s41467-021-24244-z](http://www.nature.com/articles/s41467-021-24244-z) (Bandiera_abtest: a Cc_license_type:
2981 cc_by Cg_type: Nature Research Journals Number: 1 Primary_atype: Research Pub-

- 2982 publisher: Nature Publishing Group Subject_term: Climate change;Palaeoclimate Sub-
 2983 ject_term_id: climate-change;palaeoclimate) doi: 10.1038/s41467-021-24244-z
- 2984 Tong, G., Liu, Z., Zheng, M., & Wang, W. (2002, September). Primary Study on Quanti-
 2985 tative Reconstruction of Middle Late Eocene Climate in Jiangnan Basin. *Journal of*
 2986 *Earth Science*, 13(3). Retrieved 2020-09-07, from [http://en.earth-science.net/](http://en.earth-science.net/en/article/id/128)
 2987 [en/article/id/128](http://en.earth-science.net/en/article/id/128) (Publisher: Journal of Earth Science)
- 2988 Toumoulin, A., Donnadieu, Y., Ladant, J., Batenburg, S. J., Poblete, F., & Dupont-Nivet,
 2989 G. (2020, August). Quantifying the Effect of the Drake Passage Opening on the
 2990 Eocene Ocean. *Paleoceanography and Paleoclimatology*, 35(8). Retrieved 2020-08-13,
 2991 from <https://onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003889> doi: 10
 2992 .1029/2020PA003889
- 2993 Toumoulin, A., Tardif, D., Donnadieu, Y., Licht, A., Ladant, J.-B., Kunzmann, L., &
 2994 Dupont-Nivet, G. (2022, February). Evolution of continental temperature season-
 2995 ality from the Eocene greenhouse to the Oligocene icehouse –a model–data compar-
 2996 ison. *Climate of the Past*, 18(2), 341–362. Retrieved 2022-02-28, from [https://](https://cp.copernicus.org/articles/18/341/2022/)
 2997 cp.copernicus.org/articles/18/341/2022/ (Publisher: Copernicus GmbH) doi:
 2998 10.5194/cp-18-341-2022
- 2999 Tripathi, S., Tiwari, M., Lee, J., & Khim, B.-K. (2017, February). First evidence of
 3000 denitrification vis-à-vis monsoon in the Arabian Sea since Late Miocene. *Scien-*
 3001 *tific Reports*, 7(1), 43056. Retrieved 2022-06-02, from [http://www.nature.com/](http://www.nature.com/articles/srep43056)
 3002 [articles/srep43056](http://www.nature.com/articles/srep43056) (Number: 1 Publisher: Nature Publishing Group) doi:
 3003 10.1038/srep43056
- 3004 Valcke, S., Budich, R., Carter, M., Guilyardi, E., Lautenschlager, M., Redler, R., &
 3005 Steenman-Clark, L. (2006). The PRISM software framework and the OASIS cou-
 3006 pler. *Annual BMRC Modelling Workshop 'The Australian Community Climate and*
 3007 *Earth System Simulator (ACCESS)-challenges and opportunities'*, 10.
- 3008 Valdes, P. J., Armstrong, E., Badger, M. P. S., Bradshaw, C. D., Bragg, F., Crucifix, M., ...
 3009 Williams, J. H. T. (2017, October). The BRIDGE HadCM3 family of climate models:
 3010 HadCM3@Bristol v1.0. *Geoscientific Model Development*, 10(10), 3715–3743. Re-
 3011 trieved 2019-11-07, from <https://www.geosci-model-dev.net/10/3715/2017/> doi:
 3012 10.5194/gmd-10-3715-2017
- 3013 van Hinsbergen, D. J., Lippert, P. C., Li, S., Huang, W., Advokaat, E. L., & Spakman,
 3014 W. (2019, June). Reconstructing Greater India: Paleogeographic, kinematic, and
 3015 geodynamic perspectives. *Tectonophysics*, 760, 69–94. Retrieved 2020-10-15, from
 3016 <https://linkinghub.elsevier.com/retrieve/pii/S0040195118301331> doi: 10
 3017 .1016/j.tecto.2018.04.006
- 3018 van Hinsbergen, D. J. J., Lippert, P. C., Dupont-Nivet, G., McQuarrie, N., Doubrovine,
 3019 P. V., Spakman, W., & Torsvik, T. H. (2012, May). Greater India Basin hypothesis
 3020 and a two-stage Cenozoic collision between India and Asia. *Proceedings of the National*
 3021 *Academy of Sciences*, 109(20), 7659–7664. Retrieved from [http://www.pnas.org/](http://www.pnas.org/content/109/20/7659.abstract)
 3022 [content/109/20/7659.abstract](http://www.pnas.org/content/109/20/7659.abstract) doi: 10.1073/pnas.1117262109
- 3023 Vassallo, R., Jolivet, M., Ritz, J. F., Braucher, R., Larroque, C., Sue, C., ... Javkhlanbold,
 3024 D. (2007, July). Uplift age and rates of the Gurvan Bogd system (Gobi-Altay) by ap-
 3025 atite fission track analysis. *Earth and Planetary Science Letters*, 259(3), 333–346. Re-
 3026 trieved 2021-04-20, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0012821X07002853)
 3027 [S0012821X07002853](https://www.sciencedirect.com/science/article/pii/S0012821X07002853) doi: 10.1016/j.epsl.2007.04.047
- 3028 Vicente de Gouveia, S., Besse, J., Frizon de Lamotte, D., Greff-Lefftz, M., Lescanne, M.,
 3029 Gueydan, F., & Leparmentier, F. (2018, April). Evidence of hotspot paths below
 3030 Arabia and the Horn of Africa and consequences on the Red Sea opening. *Earth*
 3031 *and Planetary Science Letters*, 487, 210–220. Retrieved 2021-10-13, from [https://](https://www.sciencedirect.com/science/article/pii/S0012821X18300487)
 3032 www.sciencedirect.com/science/article/pii/S0012821X18300487 doi: 10.1016/
 3033 j.epsl.2018.01.030
- 3034 Vornlocher, J., Lukens, W., Schubert, B., & Quan, C. (2021, April). Late Oligocene
 3035 Precipitation Seasonality in East Asia Based on 13 C Profiles in Fossil Wood. *Paleo-*
 3036 *ceanography and Paleoclimatology*, 36. doi: 10.1029/2021PA004229

- 3037 Vögeli, N., Najman, Y., van der Beek, P., Huyghe, P., Wynn, P. M., Govin, G., ... Sachse,
3038 D. (2017, August). Lateral variations in vegetation in the Himalaya since the Miocene
3039 and implications for climate evolution. *Earth and Planetary Science Letters*, *471*, 1–
3040 9. Retrieved 2022-05-02, from [https://www.sciencedirect.com/science/article/
3041 pii/S0012821X17302315](https://www.sciencedirect.com/science/article/pii/S0012821X17302315) doi: 10.1016/j.epsl.2017.04.037
- 3042 Wan, S., Clift, P., Li, A., Li, T., & Yin, X. (2010, August). Geochemical records in the
3043 South China Sea: Implications for East Asian summer monsoon evolution over the last
3044 20 Ma. *Geological Society, London, Special Publications*, *342*. doi: 10.1144/SP342.14
- 3045 Wan, S., Li, A., Clift, P. D., & Stuu, J.-B. W. (2007, October). Development of the East
3046 Asian monsoon: Mineralogical and sedimentologic records in the northern South China
3047 Sea since 20 Ma. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *254*(3-4), 561–
3048 582. Retrieved 2022-05-03, from [https://linkinghub.elsevier.com/retrieve/
3049 pii/S0031018207003963](https://linkinghub.elsevier.com/retrieve/pii/S0031018207003963) doi: 10.1016/j.palaeo.2007.07.009
- 3050 Wang, B., & Ding, Q. (2008, March). Global monsoon: Dominant mode of annual
3051 variation in the tropics. *Dynamics of Atmospheres and Oceans*, *44*(3-4), 165–
3052 183. Retrieved 2019-05-16, from [https://linkinghub.elsevier.com/retrieve/
3053 pii/S0377026508000055](https://linkinghub.elsevier.com/retrieve/pii/S0377026508000055) doi: 10.1016/j.dynatmoce.2007.05.002
- 3054 Wang, B., Shi, G., Xu, C., Spicer, R. A., Perrichot, V., Schmidt, A. R., ... Engel, M. S.
3055 (2021). The mid-Miocene Zhangpu biota reveals an outstandingly rich rainforest
3056 biome in East Asia. *Science Advances*, *7*(18), eabg0625. Retrieved 2022-05-03,
3057 from <https://www.science.org/doi/full/10.1126/sciadv.abg0625> (Publisher:
3058 American Association for the Advancement of Science) doi: 10.1126/sciadv.abg0625
- 3059 Wang, C., Dai, J., Zhao, X., Li, Y., Graham, S. A., He, D., ... Meng, J. (2014, May).
3060 Outward-growth of the Tibetan Plateau during the Cenozoic: A review. *Tectono-
3061 physics*, *621*, 1–43. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/
3062 retrieve/pii/S0040195114000729](http://linkinghub.elsevier.com/retrieve/pii/S0040195114000729) doi: 10.1016/j.tecto.2014.01.036
- 3063 Wang, D., Lu, S., Han, S., Sun, X., & Quan, C. (2013, January). Eocene prevalence of
3064 monsoon-like climate over eastern China reflected by hydrological dynamics. *Journal of
3065 Asian Earth Sciences*, *62*, 776–787. Retrieved 2022-05-04, from [https://linkinghub
3066 .elsevier.com/retrieve/pii/S1367912012005184](https://linkinghub.elsevier.com/retrieve/pii/S1367912012005184) doi: 10.1016/j.jseaes.2012.11
3067 .032
- 3068 Wang, H., Lu, H., Zhao, L., Zhang, H., Lei, F., & Wang, Y. (2019, November).
3069 Asian monsoon rainfall variation during the Pliocene forced by global tempera-
3070 ture change. *Nature Communications*, *10*(1), 5272. Retrieved 2022-06-09, from
3071 <https://www.nature.com/articles/s41467-019-13338-4> (Number: 1 Publisher:
3072 Nature Publishing Group) doi: 10.1038/s41467-019-13338-4
- 3073 Wang, L., & Chen, W. (2014, March). An Intensity Index for the East Asian
3074 Winter Monsoon. *Journal of Climate*, *27*(6), 2361–2374. Retrieved 2021-10-
3075 13, from [https://journals.ametsoc.org/view/journals/clim/27/6/jcli-d-13
3076 -00086.1.xml](https://journals.ametsoc.org/view/journals/clim/27/6/jcli-d-13-00086.1.xml) (Publisher: American Meteorological Society Section: Journal of
3077 Climate) doi: 10.1175/JCLI-D-13-00086.1
- 3078 Wang, P., Clemens, S., Beaufort, L., Braconnot, P., Ganssen, G., Jian, Z., ... Sarn-
3079 thein, M. (2005, March). Evolution and variability of the Asian monsoon system:
3080 state of the art and outstanding issues. *Quaternary Science Reviews*, *24*(5-6), 595–
3081 629. Retrieved 2020-10-11, from [https://linkinghub.elsevier.com/retrieve/
3082 pii/S0277379104002975](https://linkinghub.elsevier.com/retrieve/pii/S0277379104002975) doi: 10.1016/j.quascirev.2004.10.002
- 3083 Wang, Q., Li, Y., Ferguson, D. K., Mo, W.-B., & Yang, N. (2021, July). An equable
3084 subtropical climate throughout China in the Miocene based on palaeofloral evi-
3085 dence. *Earth-Science Reviews*, *218*, 103649. Retrieved 2022-05-03, from [https://
3086 www.sciencedirect.com/science/article/pii/S0012825221001501](https://www.sciencedirect.com/science/article/pii/S0012825221001501) doi: 10.1016/
3087 j.earscirev.2021.103649
- 3088 Wang, X., Carrapa, B., Sun, Y., Dettman, D. L., Chapman, J. B., Caves Rügenstein,
3089 J. K., ... Chen, F. (2020, July). The role of the westerlies and orography in
3090 Asian hydroclimate since the late Oligocene. *Geology*, *48*(7), 728–732. Retrieved
3091 2020-10-11, from <https://pubs.geoscienceworld.org/gsa/geology/article/48/>

- 3092 7/728/584578/The-role-of-the-westerlies-and-orography-in-Asian doi: 10
 3093 .1130/G47400.1
- 3094 Wang, Y., & Deng, T. (2005, July). A 25 m.y. isotopic record of paleodiet and environmental
 3095 change from fossil mammals and paleosols from the NE margin of the Tibetan Plateau.
 3096 *Earth and Planetary Science Letters*, *236*(1-2), 322–338. Retrieved 2022-06-16, from
 3097 <https://linkinghub.elsevier.com/retrieve/pii/S0012821X0500316X> doi: 10
 3098 .1016/j.epsl.2005.05.006
- 3099 Wasiljeff, J., Salminen, J. M., Stenman, J., Zhang, Z., & Kaakinen, A. (2022, April).
 3100 Oligocene moisture variations as evidenced by an aeolian dust sequence in Inner Mon-
 3101 golia, China. *Scientific Reports*, *12*. doi: 10.1038/s41598-022-09362-y
- 3102 Webb, A. A. G., Guo, H., Clift, P. D., Husson, L., Müller, T., Costantino, D., ... Wang,
 3103 Q. (2017, April). The Himalaya in 3D: Slab dynamics controlled mountain building
 3104 and monsoon intensification. *Lithosphere*, *9*(4), 637–651. Retrieved 2022-06-07, from
 3105 <https://doi.org/10.1130/L636.1> doi: 10.1130/L636.1
- 3106 Webster, P. J., Magaña, V. O., Palmer, T. N., Shukla, J., Tomas, R. A., Yanai, M., &
 3107 Yasunari, T. (1998, June). Monsoons: Processes, predictability, and the prospects
 3108 for prediction. *Journal of Geophysical Research: Oceans*, *103*(C7), 14451–14510. Re-
 3109 trieved 2020-06-19, from <http://doi.wiley.com/10.1029/97JC02719> doi: 10.1029/
 3110 97JC02719
- 3111 Webster, P. J., & Yang, S. (1992, July). Monsoon and Enso: Selectively Interactive Systems.
 3112 *Quarterly Journal of the Royal Meteorological Society*, *118*(507), 877–926. Retrieved
 3113 2019-07-05, from <http://doi.wiley.com/10.1002/qj.49711850705> doi: 10.1002/
 3114 qj.49711850705
- 3115 Wei, G., Li, X.-H., Liu, Y., Shao, L., & Liang, X. (2006). Geochemical
 3116 record of chemical weathering and monsoon climate change since the early
 3117 Miocene in the South China Sea. *Paleoceanography*, *21*(4). Retrieved 2022-
 3118 05-03, from <https://onlinelibrary.wiley.com/doi/abs/10.1029/2006PA001300>
 3119 (_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2006PA001300>) doi: 10
 3120 .1029/2006PA001300
- 3121 Wei, H.-H., & Bordoni, S. (2016, August). On the Role of the African Topography in
 3122 the South Asian Monsoon. *Journal of the Atmospheric Sciences*, *73*(8), 3197–3212.
 3123 Retrieved 2019-11-15, from [http://journals.ametsoc.org/doi/10.1175/JAS-D-15-
 3124 -0182.1](http://journals.ametsoc.org/doi/10.1175/JAS-D-15-0182.1) doi: 10.1175/JAS-D-15-0182.1
- 3125 Wei, J., Wang, Y., Wang, G., Wei, Z., Wei, H., Zhang, T., ... Li, L. (2022, April).
 3126 Biomarker Records From Eocene Lacustrine Sequence in the Eastern Tibet Plateau
 3127 and Its Implication for Organic Matter Sources. *Frontiers in Earth Science*, *10*,
 3128 849041. doi: 10.3389/feart.2022.849041
- 3129 Westerweel, J., Licht, A., Cogné, N., Roperch, P., Dupont-Nivet, G., Thi, M. K., ...
 3130 Aung, D. W. (2020). Burma Terrane Collision and Northward Indentation in
 3131 the Eastern Himalayas Recorded in the Eocene-Miocene Chindwin Basin (Myan-
 3132 mar). *Tectonics*, *39*(10), e2020TC006413. Retrieved 2021-03-29, from [http://
 3133 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020TC006413](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020TC006413) (_eprint:
 3134 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2020TC006413>) doi: [https://doi
 3135 .org/10.1029/2020TC006413](https://doi.org/10.1029/2020TC006413)
- 3136 Westerweel, J., Roperch, P., Licht, A., Dupont-Nivet, G., Win, Z., Poblete, F., ... Aung,
 3137 D. W. (2019, October). Burma Terrane part of the Trans-Tethyan arc during collision
 3138 with India according to palaeomagnetic data. *Nature Geoscience*, *12*(10), 863–868.
 3139 Retrieved 2019-10-17, from <http://www.nature.com/articles/s41561-019-0443-2>
 3140 doi: 10.1038/s41561-019-0443-2
- 3141 White, R. H., Battisti, D. S., & Roe, G. H. (2017). Mongolian Mountains Matter Most:
 3142 Impacts of the Latitude and Height of Asian Orography on Pacific Wintertime Atmo-
 3143 spheric Circulation. *JOURNAL OF CLIMATE*, *30*, 18.
- 3144 Wichura, H., Jacobs, L. L., Lin, A., Polcyn, M. J., Manthi, F. K., Winkler, D. A., ...
 3145 Clemens, M. (2015, March). A 17-My-old whale constrains onset of uplift and
 3146 climate change in east Africa. *Proceedings of the National Academy of Sciences*,

- 3147 112(13), 3910–3915. Retrieved 2021-04-07, from [http://www.pnas.org/content/](http://www.pnas.org/content/112/13/3910)
 3148 112/13/3910 (Publisher: National Academy of Sciences Section: Physical Sciences)
 3149 doi: 10.1073/pnas.1421502112
- 3150 Wolfe, J. (1993). A method of obtaining climatic parameters from leaf assemblages. *US*
 3151 *Government Printing Office*.(2040-2041).
- 3152 Wu, M., Zhuang, G., Hou, M., & Liu, Z. (2021, July). Expanded lacustrine sedimentation
 3153 in the Qaidam Basin on the northern Tibetan Plateau: Manifestation of climatic
 3154 wetting during the Oligocene icehouse. *Earth and Planetary Science Letters*, 565,
 3155 116935. Retrieved 2022-05-04, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S0012821X21001941)
 3156 [pii/S0012821X21001941](https://linkinghub.elsevier.com/retrieve/pii/S0012821X21001941) doi: 10.1016/j.epsl.2021.116935
- 3157 Xia, K., Su, T., Liu, Y.-S. C., Xing, Y.-W., Jacques, F. M., & Zhou, Z.-K. (2009,
 3158 May). Quantitative climate reconstructions of the late Miocene Xiaolongtan megafloora
 3159 from Yunnan, southwest China. *Palaeogeography, Palaeoclimatology, Palaeoecology*,
 3160 276(1-4), 80–86. Retrieved 2022-03-22, from [https://linkinghub.elsevier.com/](https://linkinghub.elsevier.com/retrieve/pii/S0031018209000819)
 3161 [retrieve/pii/S0031018209000819](https://linkinghub.elsevier.com/retrieve/pii/S0031018209000819) doi: 10.1016/j.palaeo.2009.02.024
- 3162 Xiao, G. Q., Abels, H. A., Yao, Z. Q., Dupont-Nivet, G., & Hilgen, F. J. (2010, July). Asian
 3163 aridification linked to the first step of the Eocene-Oligocene climate Transition (EOT)
 3164 in obliquity-dominated terrestrial records (Xining Basin, China). *Climate of the Past*,
 3165 6(4), 501–513. Retrieved 2017-10-09, from <http://www.clim-past.net/6/501/2010/>
 3166 doi: 10.5194/cp-6-501-2010
- 3167 Xing, Y., Utescher, T., Jacques, F. M., Su, T., Liu, Y. C., Huang, Y., & Zhou, Z.
 3168 (2012, November). Paleoclimatic estimation reveals a weak winter monsoon in south-
 3169 western China during the late Miocene: Evidence from plant macrofossils. *Palaeo-*
 3170 *geography, Palaeoclimatology, Palaeoecology*, 358-360, 19–26. Retrieved 2022-05-04,
 3171 from <https://linkinghub.elsevier.com/retrieve/pii/S0031018212004129> doi:
 3172 10.1016/j.palaeo.2012.07.011
- 3173 Xiong, Z., Ding, L., Spicer, R. A., Farnsworth, A., Wang, X., Valdes, P. J., ... Yue, Y. (2020,
 3174 August). The early Eocene rise of the Gonjo Basin, SE Tibet: From low desert to
 3175 high forest. *Earth and Planetary Science Letters*, 543, 116312. Retrieved 2020-10-12,
 3176 from <https://linkinghub.elsevier.com/retrieve/pii/S0012821X20302569> doi:
 3177 10.1016/j.epsl.2020.116312
- 3178 Xiong, Z., Liu, X., Ding, L., Farnsworth, A., Spicer, R. A., Xu, Q., ... Yue, Y. (2022).
 3179 The rise and demise of the Paleogene Central Tibetan Valley. *Science Advances*,
 3180 8(6), eabj0944. Retrieved 2022-02-10, from [http://www.science.org/doi/10.1126/](http://www.science.org/doi/10.1126/sciadv.abj0944)
 3181 [sciadv.abj0944](http://www.science.org/doi/10.1126/sciadv.abj0944) (Publisher: American Association for the Advancement of Science)
 3182 doi: 10.1126/sciadv.abj0944
- 3183 Xu, Q., Ding, L., Spicer, R. A., Liu, X., Li, S., & Wang, H. (2018, February). Stable iso-
 3184 topes reveal southward growth of the Himalayan-Tibetan Plateau since the Paleocene.
 3185 *Gondwana Research*, 54, 50–61. Retrieved 2020-10-20, from [https://linkinghub](https://linkinghub.elsevier.com/retrieve/pii/S1342937X17303295)
 3186 [.elsevier.com/retrieve/pii/S1342937X17303295](https://linkinghub.elsevier.com/retrieve/pii/S1342937X17303295) doi: 10.1016/j.gr.2017.10.005
- 3187 Xu, Q., Ding, L., Zhang, L., Cai, F., Lai, Q., Yang, D., & Liu-Zeng, J. (2013, January).
 3188 Paleogene high elevations in the Qiangtang Terrane, central Tibetan Plateau. *Earth*
 3189 *and Planetary Science Letters*, 362, 31–42. Retrieved 2020-10-17, from [http://www](http://www.sciencedirect.com/science/article/pii/S0012821X1200684X)
 3190 [.sciencedirect.com/science/article/pii/S0012821X1200684X](http://www.sciencedirect.com/science/article/pii/S0012821X1200684X) doi: 10.1016/j
 3191 [.epsl.2012.11.058](http://www.sciencedirect.com/science/article/pii/S0012821X1200684X)
- 3192 Yang, C., Dang, H., Zhou, X., Zhang, H., Wang, X., Wang, Y., ... Jian, Z. (2021, April).
 3193 Upper ocean hydrographic changes in response to the evolution of the East Asian
 3194 monsoon in the northern South China Sea during the middle to late Miocene. *Global*
 3195 *and Planetary Change*, 201, 103478. doi: 10.1016/j.gloplacha.2021.103478
- 3196 Yang, W., Zuo, R., Wang, X., Song, Y., Jiang, Z., Luo, Q., ... Zhang, Z. (2019, Janu-
 3197 ary). Sensitivity of lacustrine stromatolites to Cenozoic tectonic and climatic forcing
 3198 in the southern Junggar Basin, NW China: New insights from mineralogical, stable
 3199 and clumped isotope compositions. *Palaeogeography, Palaeoclimatology, Palaeoecol-*
 3200 *ogy*, 514, 109–123. Retrieved 2022-06-17, from [https://linkinghub.elsevier.com/](https://linkinghub.elsevier.com/retrieve/pii/S0031018218303985)
 3201 [retrieve/pii/S0031018218303985](https://linkinghub.elsevier.com/retrieve/pii/S0031018218303985) doi: 10.1016/j.palaeo.2018.10.011

- 3202 Yang, X., Groeneveld, J., Jian, Z., Steinke, S., & Giosan, L. (2020). Middle
3203 Miocene Intensification of South Asian Monsoonal Rainfall. *Paleoceanography and*
3204 *Paleoclimatology*, *35*(12), e2020PA003853. Retrieved 2021-03-17, from [http://](http://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003853)
3205 agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020PA003853 (eprint:
3206 <https://onlinelibrary.wiley.com/doi/pdf/10.1029/2020PA003853>) doi: [https://doi](https://doi.org/10.1029/2020PA003853)
3207 [.org/10.1029/2020PA003853](https://doi.org/10.1029/2020PA003853)
- 3208 Yao, Y.-F., Bruch, A. A., Mosbrugger, V., & Li, C.-S. (2011, May). Quantitative re-
3209 construction of Miocene climate patterns and evolution in Southern China based
3210 on plant fossils. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *304*(3-4), 291–
3211 307. Retrieved 2022-05-06, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S003101821000221X)
3212 [pii/S003101821000221X](https://linkinghub.elsevier.com/retrieve/pii/S003101821000221X) doi: 10.1016/j.palaeo.2010.04.012
- 3213 Yarmolyuk, V. V., Kudryashova, E. A., Kozlovsky, A. M., & Lebedev, V. A. (2008, October).
3214 Late Cenozoic volcanism of Khangai (Central Mongolia): Evidence for recent orogeny
3215 in Central Asia. *Doklady Earth Sciences*, *422*(1), 1032–1036. Retrieved 2021-03-
3216 29, from <http://link.springer.com/10.1134/S1028334X08070064> doi: 10.1134/
3217 [S1028334X08070064](http://link.springer.com/10.1134/S1028334X08070064)
- 3218 Yu, E., Zhang, R., Jiang, D., Ramstein, G., Zhang, Z., & Sun, J. (2018, October). High-
3219 resolution simulation of Asian monsoon response to regional uplift of the Tibetan
3220 Plateau with regional climate model nested with global climate model. *Global and*
3221 *Planetary Change*, *169*, 34–47. Retrieved 2021-09-24, from [https://linkinghub](https://linkinghub.elsevier.com/retrieve/pii/S0921818118300407)
3222 [.elsevier.com/retrieve/pii/S0921818118300407](https://linkinghub.elsevier.com/retrieve/pii/S0921818118300407) doi: 10.1016/j.gloplacha.2018
3223 [.07.002](https://linkinghub.elsevier.com/retrieve/pii/S0921818118300407)
- 3224 Yuan, Q., Barbolini, N., Ashworth, L., Rydin, C., Gao, D.-L., Shan, F.-S., ... Vajda, V.
3225 (2021, July). Palaeoenvironmental changes in Eocene Tibetan lake systems traced by
3226 geochemistry, sedimentology and palynofacies. *Journal of Asian Earth Sciences*, *214*,
3227 104778. Retrieved 2022-05-04, from [https://linkinghub.elsevier.com/retrieve/](https://linkinghub.elsevier.com/retrieve/pii/S1367912021001164)
3228 [pii/S1367912021001164](https://linkinghub.elsevier.com/retrieve/pii/S1367912021001164) doi: 10.1016/j.jseas.2021.104778
- 3229 Yuan, Q., Barbolini, N., Rydin, C., Gao, D.-L., Wei, H.-C., Fan, Q.-S., ... Vajda, V. (2020,
3230 November). Aridification signatures from fossil pollen indicate a drying climate in
3231 east-central Tibet during the late Eocene. *Climate of the Past*, *16*(6), 2255–2273.
3232 Retrieved 2022-05-04, from <https://cp.copernicus.org/articles/16/2255/2020/>
3233 [doi: 10.5194/cp-16-2255-2020](https://cp.copernicus.org/articles/16/2255/2020/)
- 3234 Yuan, W., Carter, A., Dong, J., Bao, Z., An, Y., & Guo, Z. (2006, January). Meso-
3235 zoic–Tertiary exhumation history of the Altai Mountains, northern Xinjiang, China:
3236 New constraints from apatite fission track data. *Tectonophysics*, *412*(3), 183–193. Re-
3237 trieved 2021-03-26, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S004019510500449X)
3238 [S004019510500449X](https://www.sciencedirect.com/science/article/pii/S004019510500449X) doi: 10.1016/j.tecto.2005.09.007
- 3239 Zhang, R., Jiang, D., Liu, X., & Tian, Z. (2012, December). Modeling the climate effects of
3240 different subregional uplifts within the Himalaya-Tibetan Plateau on Asian summer
3241 monsoon evolution. *Chinese Science Bulletin*, *57*(35), 4617–4626. Retrieved 2017-10-
3242 09, from <http://link.springer.com/10.1007/s11434-012-5284-y> doi: 10.1007/
3243 [s11434-012-5284-y](http://link.springer.com/10.1007/s11434-012-5284-y)
- 3244 Zhang, R., Jiang, D., Ramstein, G., Zhang, Z., Lippert, P. C., & Yu, E. (2018, February).
3245 Changes in Tibetan Plateau latitude as an important factor for understanding East
3246 Asian climate since the Eocene: A modeling study. *Earth and Planetary Science*
3247 *Letters*, *484*, 295–308. Retrieved 2018-01-16, from [http://linkinghub.elsevier](http://linkinghub.elsevier.com/retrieve/pii/S0012821X1730746X)
3248 [.com/retrieve/pii/S0012821X1730746X](http://linkinghub.elsevier.com/retrieve/pii/S0012821X1730746X) doi: 10.1016/j.epsl.2017.12.034
- 3249 Zhang, R., Jiang, D., & Zhang, Z. (2017, December). Effects of the uplifts of the main and
3250 marginal Tibetan Plateau on the Asian climate under modern and ~30 Ma boundary
3251 conditions. *Palaeogeography, Palaeoclimatology, Palaeoecology*. Retrieved 2018-01-16,
3252 from <http://linkinghub.elsevier.com/retrieve/pii/S0031018217308866> doi:
3253 [10.1016/j.palaeo.2017.12.022](http://linkinghub.elsevier.com/retrieve/pii/S0031018217308866)
- 3254 Zhang, R., Jiang, D., Zhang, Z., & Zhang, C. (2021). Effects of Ti-
3255 betan Plateau Growth, Paratethys Sea Retreat and Global Cooling on
3256 the East Asian Climate by the Early Miocene. *Geochemistry, Geo-*

- 3257 *physics, Geosystems*, 22(6), e2021GC009655. Retrieved 2021-09-24, from
 3258 <http://onlinelibrary.wiley.com/doi/abs/10.1029/2021GC009655> (eprint:
 3259 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2021GC009655>) doi: 10
 3260 .1029/2021GC009655
- 3261 Zhang, Z., Flatøy, F., Wang, H., Bethke, I., Bentsen, M., & Guo, Z. (2012, January). Early
 3262 Eocene Asian climate dominated by desert and steppe with limited monsoons. *Journal*
 3263 *of Asian Earth Sciences*, 44, 24–35. Retrieved 2017-10-09, from [http://linkinghub](http://linkinghub.elsevier.com/retrieve/pii/S1367912011002148)
 3264 [.elsevier.com/retrieve/pii/S1367912011002148](http://linkinghub.elsevier.com/retrieve/pii/S1367912011002148) doi: 10.1016/j.jseas.2011.05
 3265 .013
- 3266 Zhang, Z., Ramstein, G., Schuster, M., Li, C., Contoux, C., & Yan, Q. (2014, Septem-
 3267 ber). Aridification of the Sahara desert caused by Tethys Sea shrinkage during the
 3268 Late Miocene. *Nature*, 513(7518), 401–404. Retrieved 2019-09-06, from [http://](http://www.nature.com/articles/nature13705)
 3269 www.nature.com/articles/nature13705 doi: 10.1038/nature13705
- 3270 Zhang, Z., & Sun, J. (2011, January). Palynological evidence for Neogene environ-
 3271 mental change in the foreland basin of the southern Tianshan range, north-west-
 3272 ern China. *Global and Planetary Change*, 75(1-2), 56–66. Retrieved 2022-05-04,
 3273 from <https://linkinghub.elsevier.com/retrieve/pii/S0921818110002304> doi:
 3274 10.1016/j.gloplacha.2010.10.006
- 3275 Zhang, Z., Wang, H., Guo, Z., & Jiang, D. (2007, March). What triggers the transi-
 3276 tion of palaeoenvironmental patterns in China, the Tibetan Plateau uplift or the
 3277 Paratethys Sea retreat? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 245(3-4),
 3278 317–331. Retrieved 2017-10-09, from [http://linkinghub.elsevier.com/retrieve/](http://linkinghub.elsevier.com/retrieve/pii/S0031018206004469)
 3279 [pii/S0031018206004469](http://linkinghub.elsevier.com/retrieve/pii/S0031018206004469) doi: 10.1016/j.palaeo.2006.08.003
- 3280 Zhang, Z., Xiao, W., Majidifard, M. R., Zhu, R., Wan, B., Ao, S., ... Esmaili, R. (2017,
 3281 June). Detrital zircon provenance analysis in the Zagros Orogen, SW Iran: impli-
 3282 cations for the amalgamation history of the Neo-Tethys. *International Journal of*
 3283 *Earth Sciences*, 106(4), 1223–1238. Retrieved 2022-03-04, from [https://doi.org/](https://doi.org/10.1007/s00531-016-1314-3)
 3284 [10.1007/s00531-016-1314-3](https://doi.org/10.1007/s00531-016-1314-3) doi: 10.1007/s00531-016-1314-3
- 3285 Zhao, H., Qiang, X., Xu, X., & Sun, Y. (2020, April). Iron oxide characteris-
 3286 tics of the Chinese loess-red clay sequences and their implications for the evo-
 3287 lution of the East Asian summer monsoon since the Late Oligocene. *Palaeo-*
 3288 *geography, Palaeoclimatology, Palaeoecology*, 543, 109604. Retrieved 2022-06-09,
 3289 from <https://linkinghub.elsevier.com/retrieve/pii/S0031018219308995> doi:
 3290 10.1016/j.palaeo.2020.109604
- 3291 Zhao, L., Lu, H., Wang, H., Meadows, M., Ma, C., Tang, L., ... Zhang, H. (2020, Octo-
 3292 ber). Vegetation dynamics in response to evolution of the Asian Monsoon in a warm
 3293 world: Pollen evidence from the Weihe Basin, central China. *Global and Planetary*
 3294 *Change*, 193, 103269. Retrieved 2022-06-09, from [https://linkinghub.elsevier](https://linkinghub.elsevier.com/retrieve/pii/S0921818120301600)
 3295 [.com/retrieve/pii/S0921818120301600](https://linkinghub.elsevier.com/retrieve/pii/S0921818120301600) doi: 10.1016/j.gloplacha.2020.103269
- 3296 Zheng, H., Wei, X., Tada, R., Clift, P. D., Wang, B., Jourdan, F., ... He, M. (2015,
 3297 June). Late Oligocene–early Miocene birth of the Taklimakan Desert. *Proceedings*
 3298 *of the National Academy of Sciences*, 112(25), 7662–7667. Retrieved 2022-02-11,
 3299 from <http://www.pnas.org/lookup/doi/10.1073/pnas.1424487112> doi: 10.1073/
 3300 pnas.1424487112
- 3301 Zheng, H., Yang, Q., Cao, S., Clift, P. D., He, M., Kano, A., ... Jourdan, F. (2022,
 3302 December). From desert to monsoon: irreversible climatic transition at ~ 36 Ma
 3303 in southeastern Tibetan Plateau. *Progress in Earth and Planetary Science*, 9(1),
 3304 12. Retrieved 2022-05-02, from [https://progearthplanetsci.springeropen.com/](https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-022-00470-x)
 3305 [articles/10.1186/s40645-022-00470-x](https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-022-00470-x) doi: 10.1186/s40645-022-00470-x
- 3306 Zhisheng, A., Guoxiong, W., Jianping, L., Youbin, S., Yimin, L., Weijian, Z., ... Juan,
 3307 F. (2015, May). Global Monsoon Dynamics and Climate Change. *Annual Review of*
 3308 *Earth and Planetary Sciences*, 43(1), 29–77. Retrieved 2017-10-09, from [http://www](http://www.annualreviews.org/doi/10.1146/annurev-earth-060313-054623)
 3309 [.annualreviews.org/doi/10.1146/annurev-earth-060313-054623](http://www.annualreviews.org/doi/10.1146/annurev-earth-060313-054623) doi: 10.1146/
 3310 annurev-earth-060313-054623
- 3311 Zhisheng, A., Kutzbach, J. E., Prell, W. L., & Porter, S. C. (2001, May). Evolution of Asian

3312 monsoons and phased uplift of the Himalaya–Tibetan plateau since Late Miocene
3313 times. *Nature*, *411*(6833), 62–66. Retrieved 2021-09-16, from [http://www.nature](http://www.nature.com/articles/35075035)
3314 [.com/articles/35075035](http://www.nature.com/articles/35075035) (Bandiera_abtest: a Cg_type: Nature Research Journals
3315 Number: 6833 Primary_atype: Research Publisher: Nature Publishing Group) doi:
3316 10.1038/35075035

3317 Zhuang, G., Pagani, M., & Zhang, Y. G. (2017, July). Monsoonal upwelling in the western
3318 Arabian Sea since the middle Miocene. *Geology*, *45*(7), 655–658. Retrieved 2022-05-02,
3319 from <https://doi.org/10.1130/G39013.1> doi: 10.1130/G39013.1

3320 Ziegler, C. L., Murray, R. W., Hovan, S. A., & Rea, D. K. (2007, February). Re-
3321 solving eolian, volcanogenic, and authigenic components in pelagic sediment from
3322 the Pacific Ocean. *Earth and Planetary Science Letters*, *254*(3), 416–432. Re-
3323 trieved 2022-03-25, from [https://www.sciencedirect.com/science/article/pii/](https://www.sciencedirect.com/science/article/pii/S0012821X06008661)
3324 [S0012821X06008661](https://www.sciencedirect.com/science/article/pii/S0012821X06008661) doi: 10.1016/j.epsl.2006.11.049

3325 Zoura, D., Hill, D., Dolan, A., Hunter, S., Tang, Z., & Haywood, A. (2019, August). Atmo-
3326 spheric carbon dioxide, ice sheet and topographic constraints on palaeo moisture avail-
3327 ability in Asia. *Earth and Planetary Science Letters*, *519*, 12–27. Retrieved 2019-09-12,
3328 from <https://linkinghub.elsevier.com/retrieve/pii/S0012821X19302390> doi:
3329 10.1016/j.epsl.2019.04.035

9 Supplementary

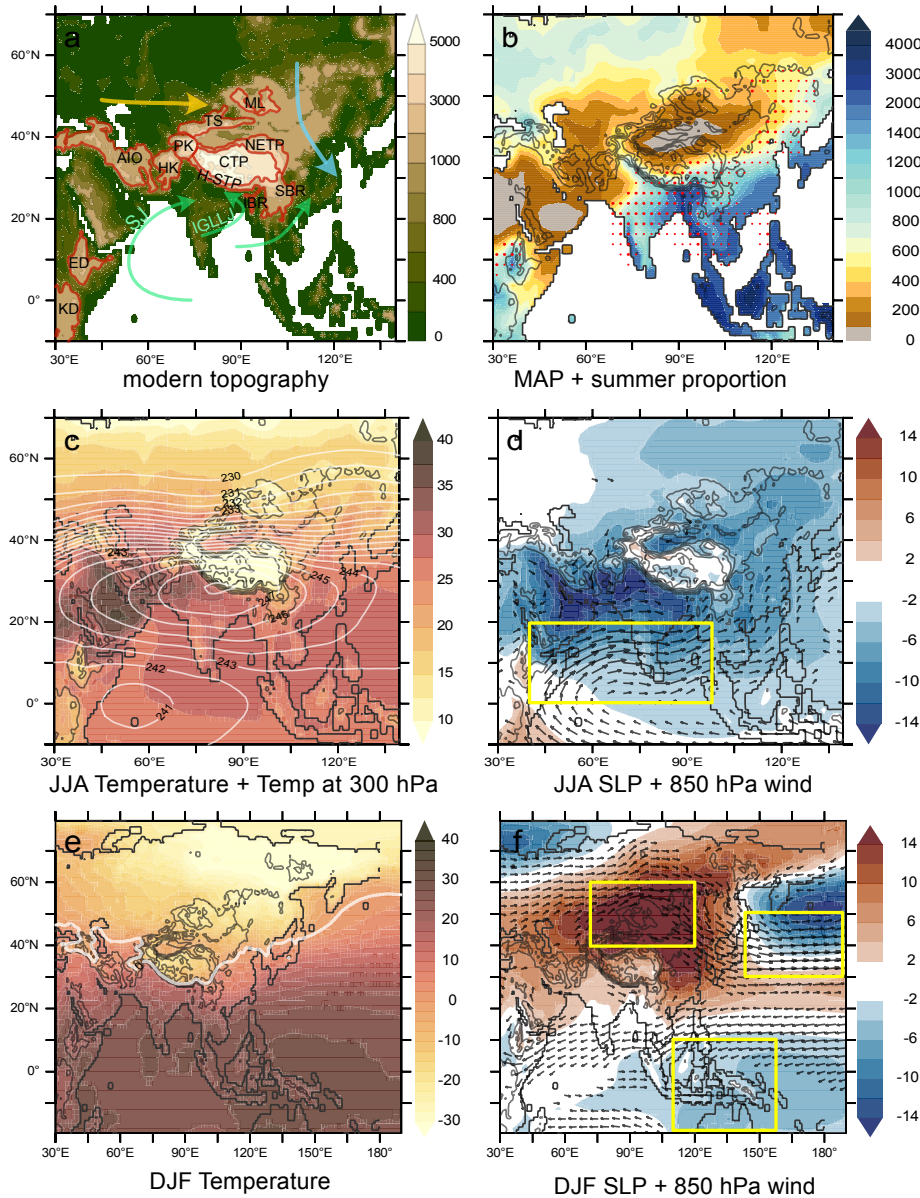


Figure 14. South Asian orography and main seasonal characteristics of South and East Asian Monsoons subsystems from observations and reanalysis. (a) Modern geography and topography (in m), with main seasonal winds: Westerlies (yellow arrow), Winter monsoon (blue arrow) and Summer monsoon (green arrows); Somali Jet (SJ), Indo-Gangetic-Low Level Jet (IGLLJ) and main geographic units mentioned in Section 4 highlighted: KD - Kenyan Dome, ED - Ethiopian Dome, AIO - Anatolian and Iranian orogens, PK - Pamir-Karakoram, HK - Hindu Kush, CTP - Central Tibetan Plateau, H-STP - Himalayas and Southern Tibetan Plateau, NETP - North-eastern TP, TS - Tian Shan, IBR - Indo Burman Ranges, SBR - Sino Burman Ranges, ML - Mongolian Landforms.; (b) Mean Annual Precipitation (shading, mm/yr), and regions where the Monsoon Precipitation Index is over 0.5 (thin red dots) and 0.75 (thick red dots). The Monsoon Precipitation Index is defined in the Monsoon Metrics section 5.3; (c) JJA mean 2m temperature (shading, Celsius) and 300 hPa atmospheric temperature (white contour, Kelvin); (d) JJA normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds (vectors over 4m/s). Yellow box highlight the region of calculation of the Webster-Yang Index, defined in the Monsoon Metrics section 5.3; (e) DJF mean 2m temperature (shading, Celsius); (f) DJF normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds (vectors over 4m/s). Yellow boxes highlight the regions of calculation of the Eastern Asian Monsoon Index, defined in the Monsoon Metrics section. In all captions, topography (each 1000 m) is in gray contour. Precipitation for 1979-2021 from the Global Precipitation Climatology Project (GPCP) (Pendergrass, Angeline, Wang, Jian-Jian National Center for Atmospheric Research Staff (Eds). Last modified 06 Nov 2020. "The Climate Data Guide: GPCP (Monthly): Global Precipitation Climatology Project." Retrieved from

	Reference
1	(Averyanova et al., 2021)
2	(Hellwig et al., 2018)
3	(Macaulay et al., 2016)
4	(Caves Rugenstein et al., 2017)
5	(Carrapa et al., 2015)
6	(J. Sun et al., 2022)
7	(J. Sun et al., 2010)
8	(J. Sun & Windley, 2015)
9	(Baldermann et al., 2021)
10	(Caves Rugenstein et al., 2014)
11	(Kent-Corson et al., 2009)
12	(Zheng et al., 2015)
13	(Meijer et al., 2021)
14	(Licht et al., 2014)
15	(Wasiljeff et al., 2022)
16	(Hoorn et al., 2012)
17	(X. Ma & Jiang, 2015)
18	(Guo et al., 2002)
19	(Guo et al., 2008)
20	(Q. Yuan et al., 2020)
21	(Ao et al., 2016)
22	(Ao et al., 2021)
23	(Shen et al., 2017)
24	(S. Li et al., 2018)
25	(C. Huang & Hinnov, 2019)
26	(Ling et al., 2021)
27	(R. Spicer et al., 2017)
28	(Herman et al., 2017)
29	(Vornlocher et al., 2021)
30	(J. Ren et al., 2021)
31	(Q. Wang et al., 2021)
32	(Fang et al., 2021)
33	(Zheng et al., 2022)
34	(Sorrel et al., 2017)
35	(Jacques, Guo, et al., 2011)
36	(Xia et al., 2009)
37	(Xing et al., 2012)
38	(Wan et al., 2007)
39	(Jia et al., 2003)
40	(P. Clift et al., 2008)
41	(P. D. Clift, 2020)
42	(Z. Ding et al., 2021)
43	(Srivastava et al., 2012)
44	(Bhatia, Khan, et al., 2021)
45	(Shukla et al., 2014)
46	(Khan et al., 2014)
47	(Vögeli et al., 2017)
48	(Bhatia et al., 2022)
49	(Bhatia, Srivastava, et al., 2021)
50	(Srivastava et al., 2018)
51	(Sanyal et al., 2004)
52	(S. Ali et al., 2021)
53	(Betzler et al., 2016)
54	(Betzler et al., 2018)
55	(Beasley et al., 2021)
56	(Zhuang et al., 2017)
57	(Page et al., 2019)
58	(Q. Yuan et al., 2021)
59	(Meng et al., 2018)

Table 2. List of references used in Figure 2 for paleoclimate indicators compilation

	Reference (suite)
60	(Miao, 2013)
61	(Z. Zhang & Sun, 2011)
62	(J. Sun & Zhang, 2008)
63	(Q.-g. Sun et al., 2002)
64	(J. Sun et al., 2020)
65	(T. Su, Spicer, et al., 2019)
66	(Wu et al., 2021)
67	(Song et al., 2020)
68	(Miao, Wu, et al., 2016)
69	(D. Rea et al., 1985)
70	(Pettke et al., 2002)
71	(Ziegler et al., 2007)
72	(B. Li et al., 2016)
73	(Garziona et al., 2005)
74	(Qiang et al., 2011)
75	(Bougeois et al., 2018)
76	(W. Yang et al., 2019)
77	(J. Lee et al., 2020)
78	(Bolton et al., 2022)
79	(Hui et al., 2021)
80	(Miao, Song, et al., 2016)
81	(H. Zhao et al., 2020)
82	(C. Yang et al., 2021)
83	(L. Zhao et al., 2020)
84	(Heermance et al., 2018)
85	(J. Liu et al., 2016)
86	(Jiang & Ding, 2008)
87	(Peng et al., 2016)
88	(Suarez et al., 2011)
89	(Barbolini et al., 2020)
90	(Y. Ma et al., 2005)
91	(H. Wang et al., 2019)
92	(Jiang et al., 2017)
93	(W. Liu et al., 2014)
94	(Kaakinen et al., 2006)
95	(Y. Wang & Deng, 2005)
96	(F. Li et al., 2008)
97	(Z. Liu et al., 2014)
98	(Miao et al., 2011)
99	(Charreau et al., 2012)
100	(A. E. Holbourn et al., 2018)
101	(G. Wei et al., 2006)
102	(Y. Huang et al., 2007)
103	(Gupta et al., 2015)
104	(X. Yang et al., 2020)
105	(Bialik et al., 2020)
106	(H. Tang et al., 2020)
107	(H. Huang et al., 2021)
108	(Hoorn et al., 2000)
109	(Polissar et al., 2021)

Table 3. (suite) List of references used in Figure 2 for paleoclimate indicators compilation

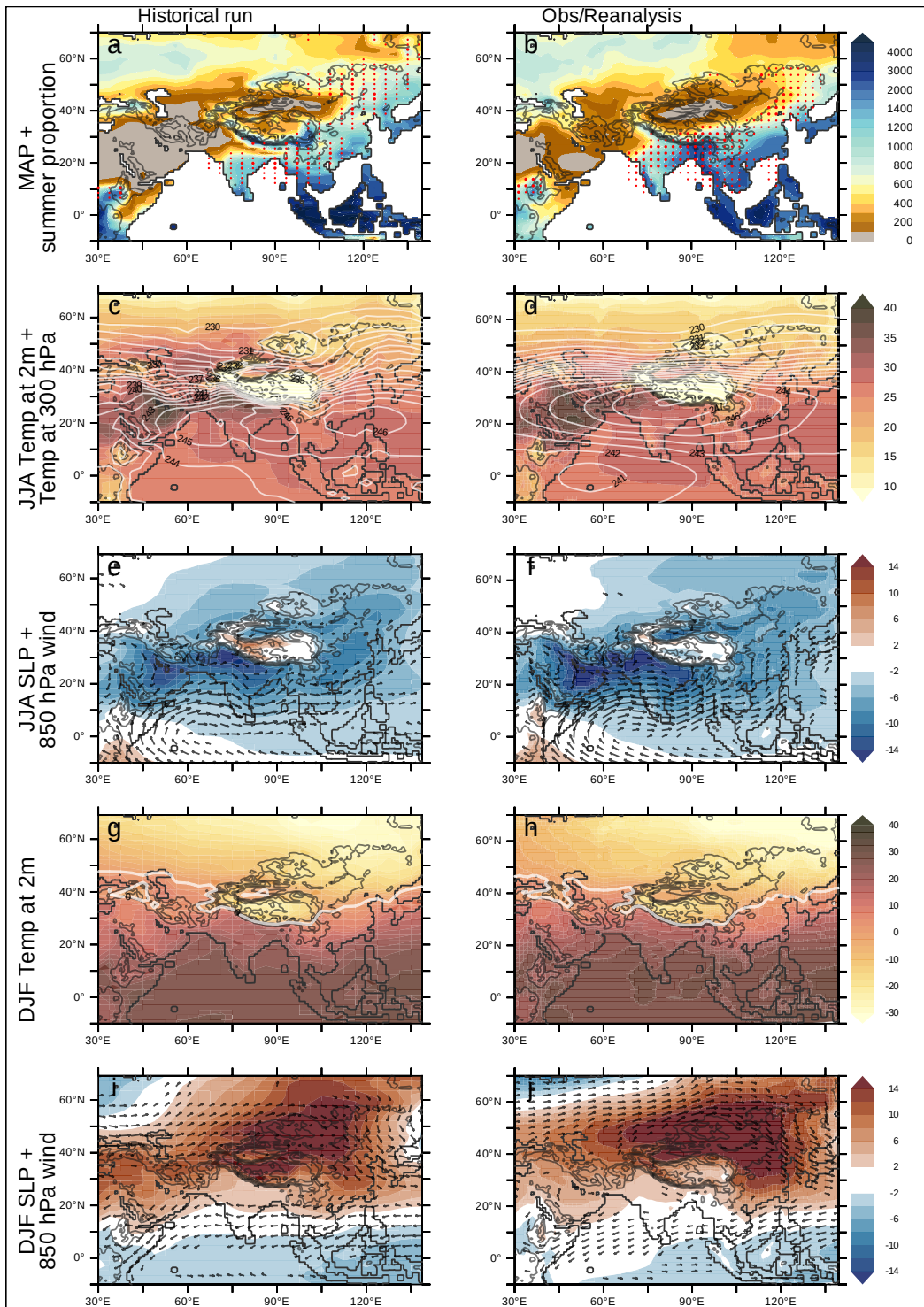


Figure 15. Comparison of monsoon diagnostics obtained in our control historical simulation (**Left column**) with modern observations and reanalysis (**Right column**). (**a,b**) Mean Annual Precipitations (shading, mm/yr), and regions where the Monsoon Precipitation Index is over 0.5 (thin red dots) and 0.75 (thick red dots) ; (**c,d**) JJA mean 2m temperature (shading, Celsius) and 300 hPa atmospheric temperature (white contour, Kelvin) ; (**e,f**) JJA normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds (vectors over 4m/s); (**g,h**) DJF mean 2m temperature (shading, Celsius) ; (**i,j**) DJF normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds (vectors over 4m/s). In all captions, topography in gray contour, each 1000 m. On the right column, precipitation are from GPCP, pressure and 300hPa temperature from ERAINT, 850hPa winds and surface temperature from ERA40.

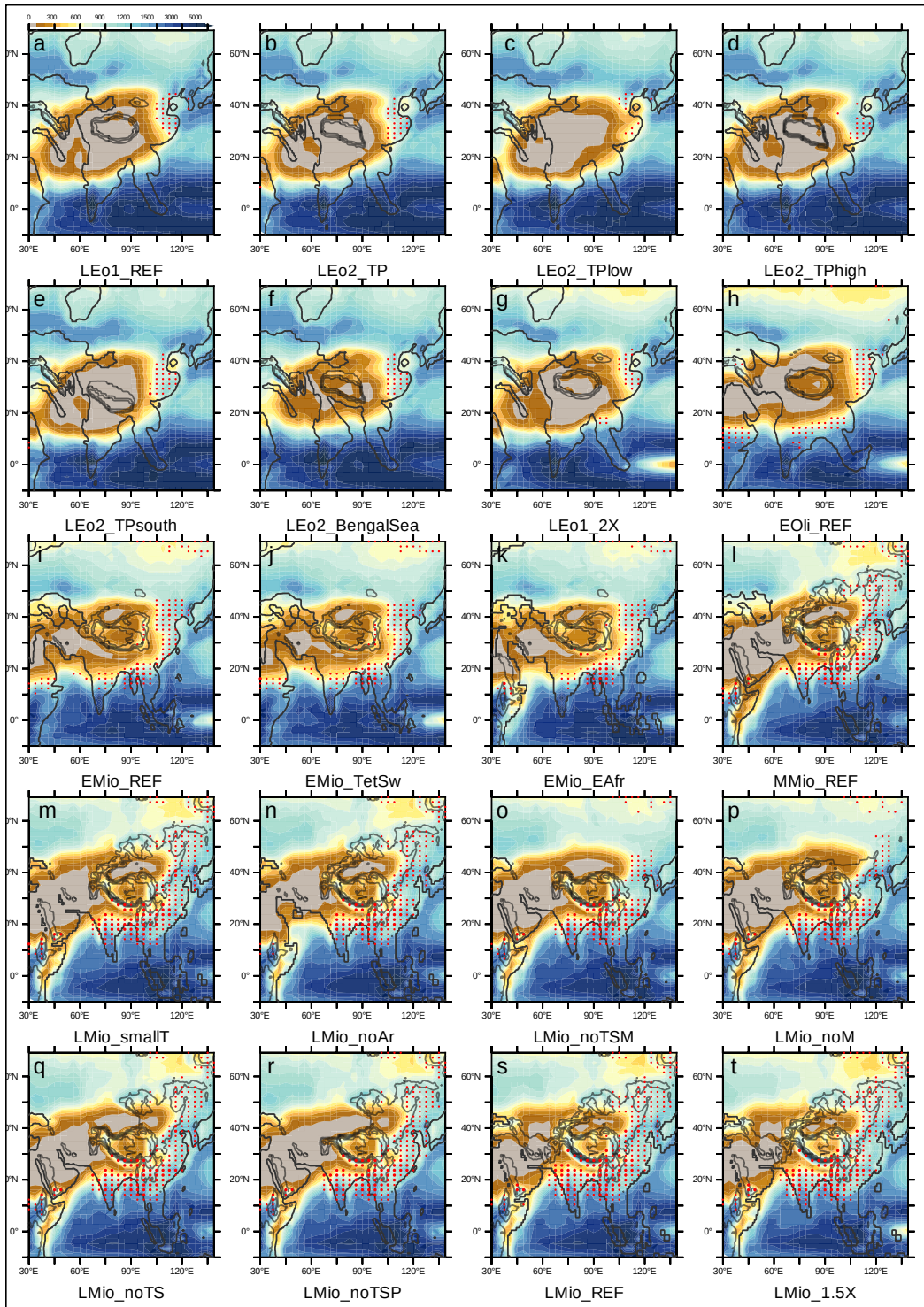


Figure 16. Mean Annual Precipitation (shading, mm/yr), overlain with regions where the Monsoon Precipitation Index (B. Wang & Ding, 2008) is over 0.5 (thin red dots) and 0.75 (thick red dots), for all reference and sensitivity experiments.

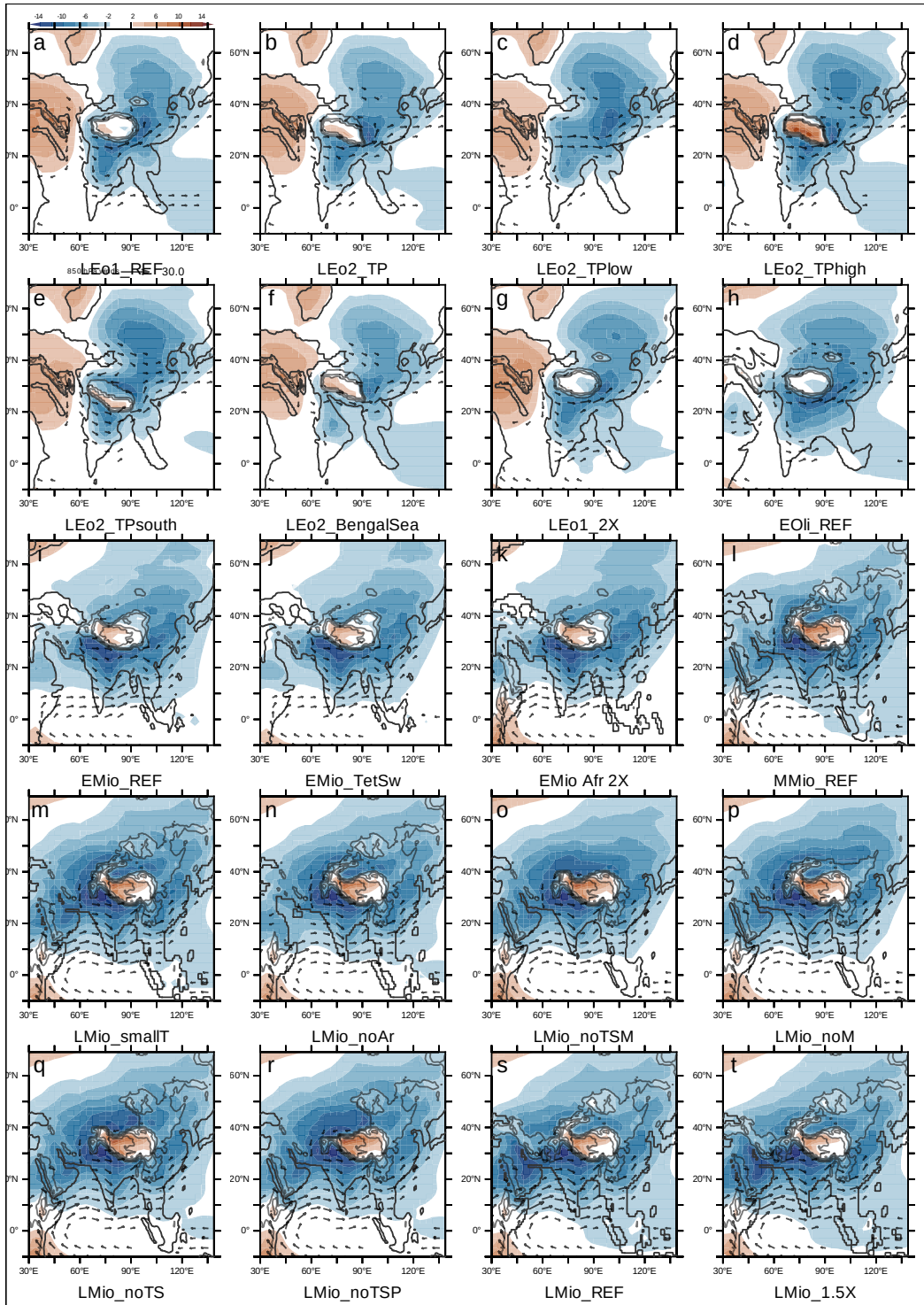


Figure 17. June-August (JJA) normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds over 4 m/s (vectors), for all reference and sensitivity experiments.

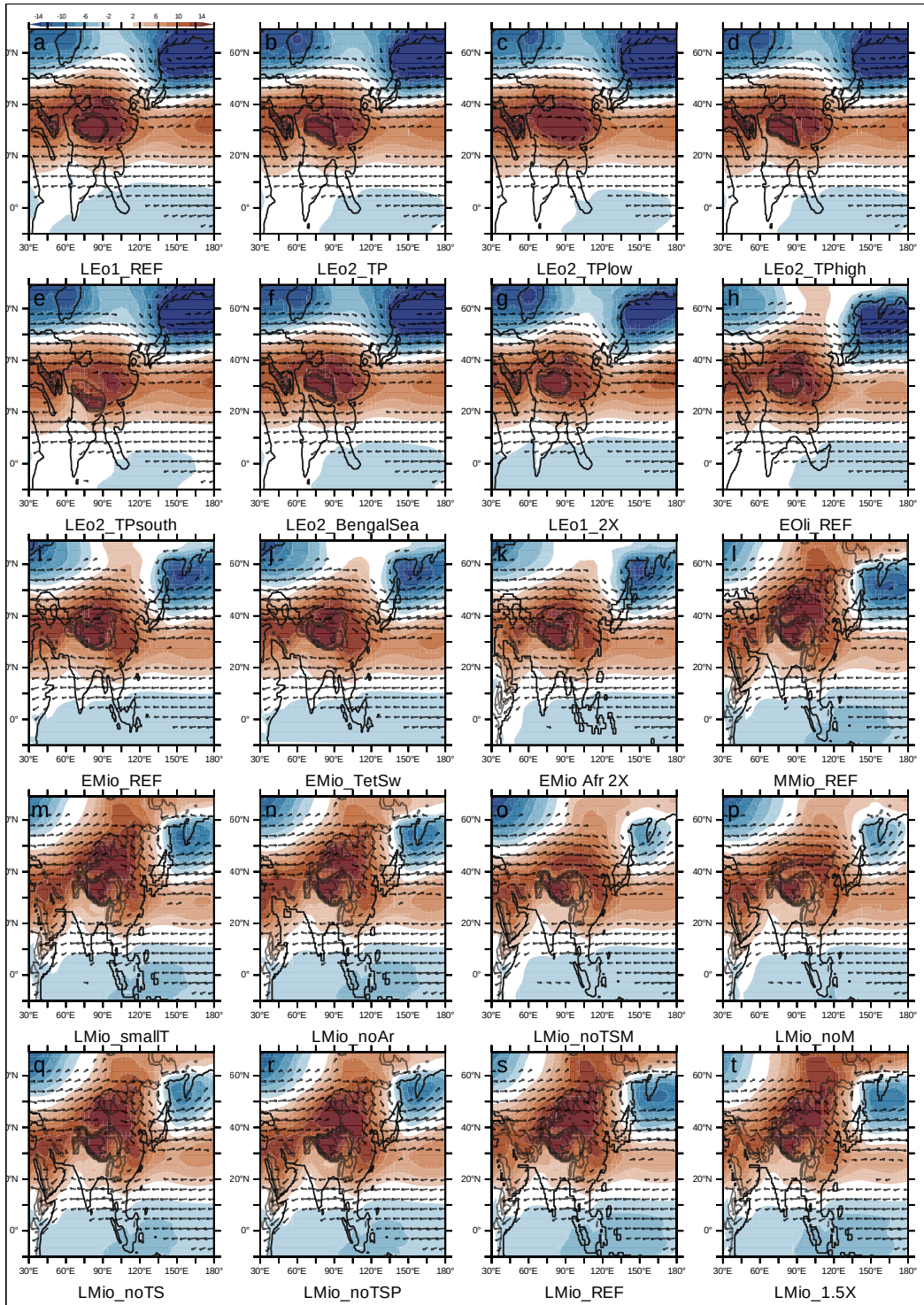


Figure 18. December-February (DJF) normalized Sea Level Pressure anomalies (shading, hPa) and 850 hPa winds over 4 m/s (vectors), for all reference and sensitivity experiments.

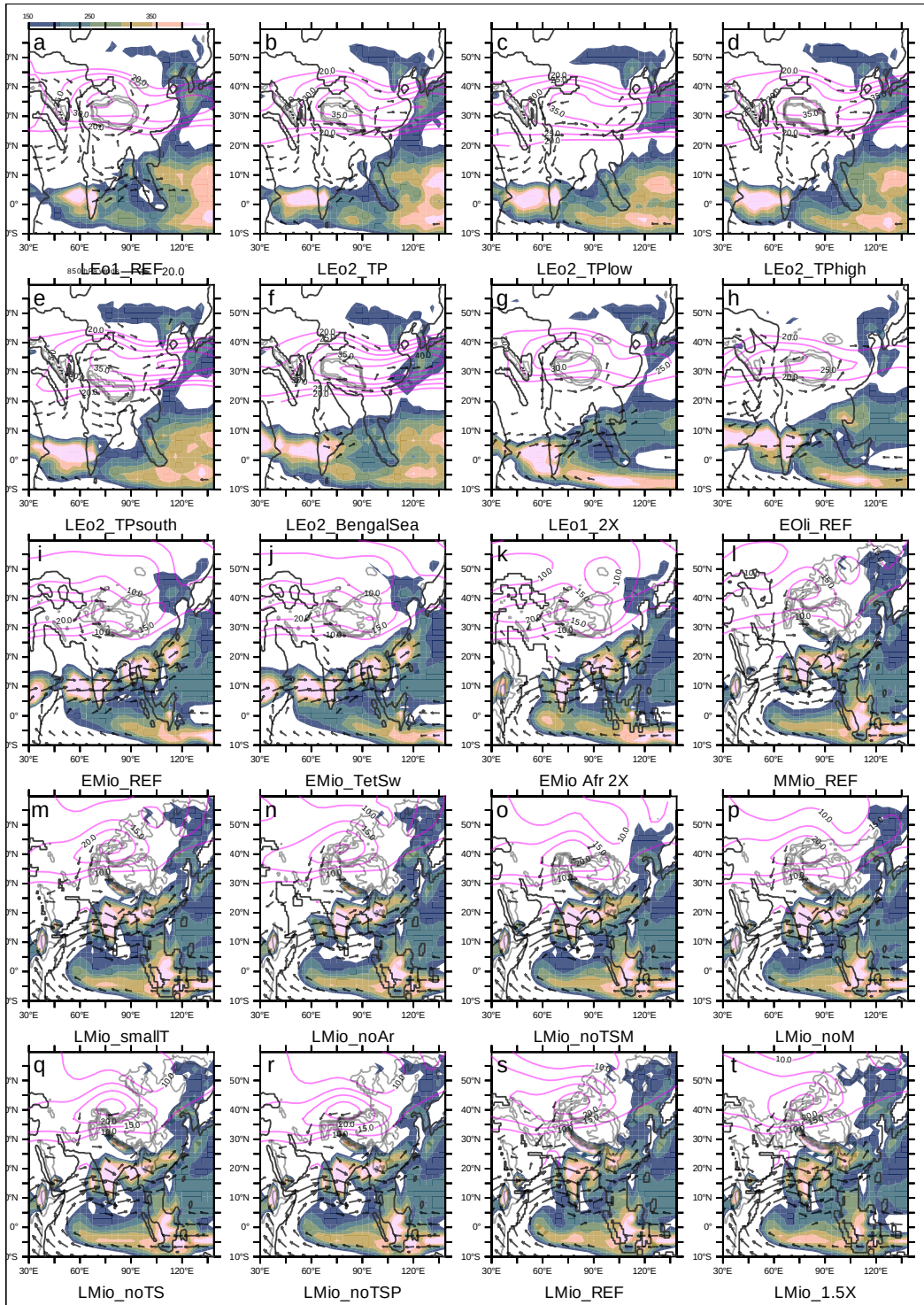


Figure 19. Jet Stream velocity and localization over Asia in August (purple outline), for all sensitivity experiments and precipitation for the month of August (shading, mm/month).

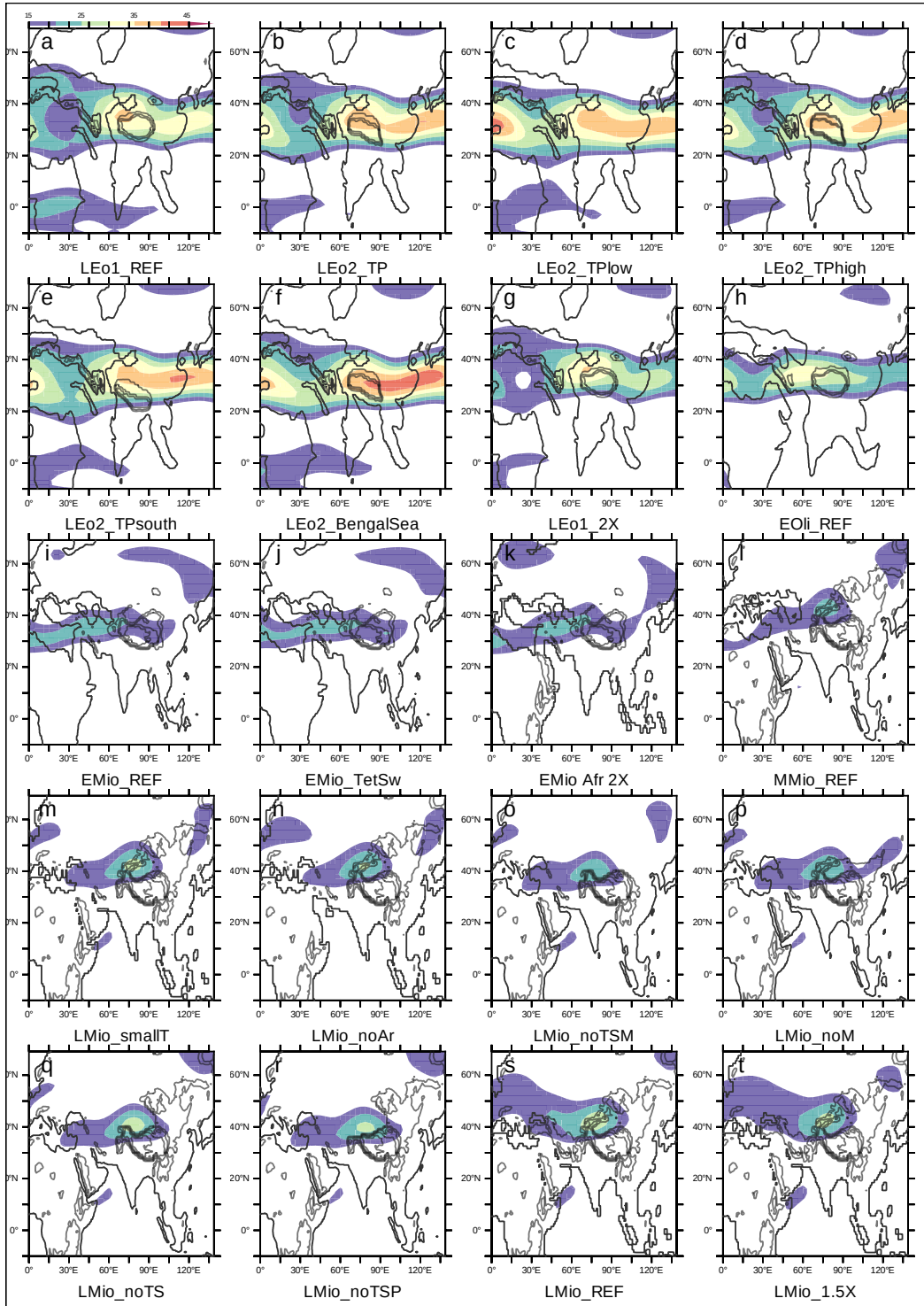


Figure 20. Jet Stream August velocity and localization over Asia, for all sensitivity experiments.

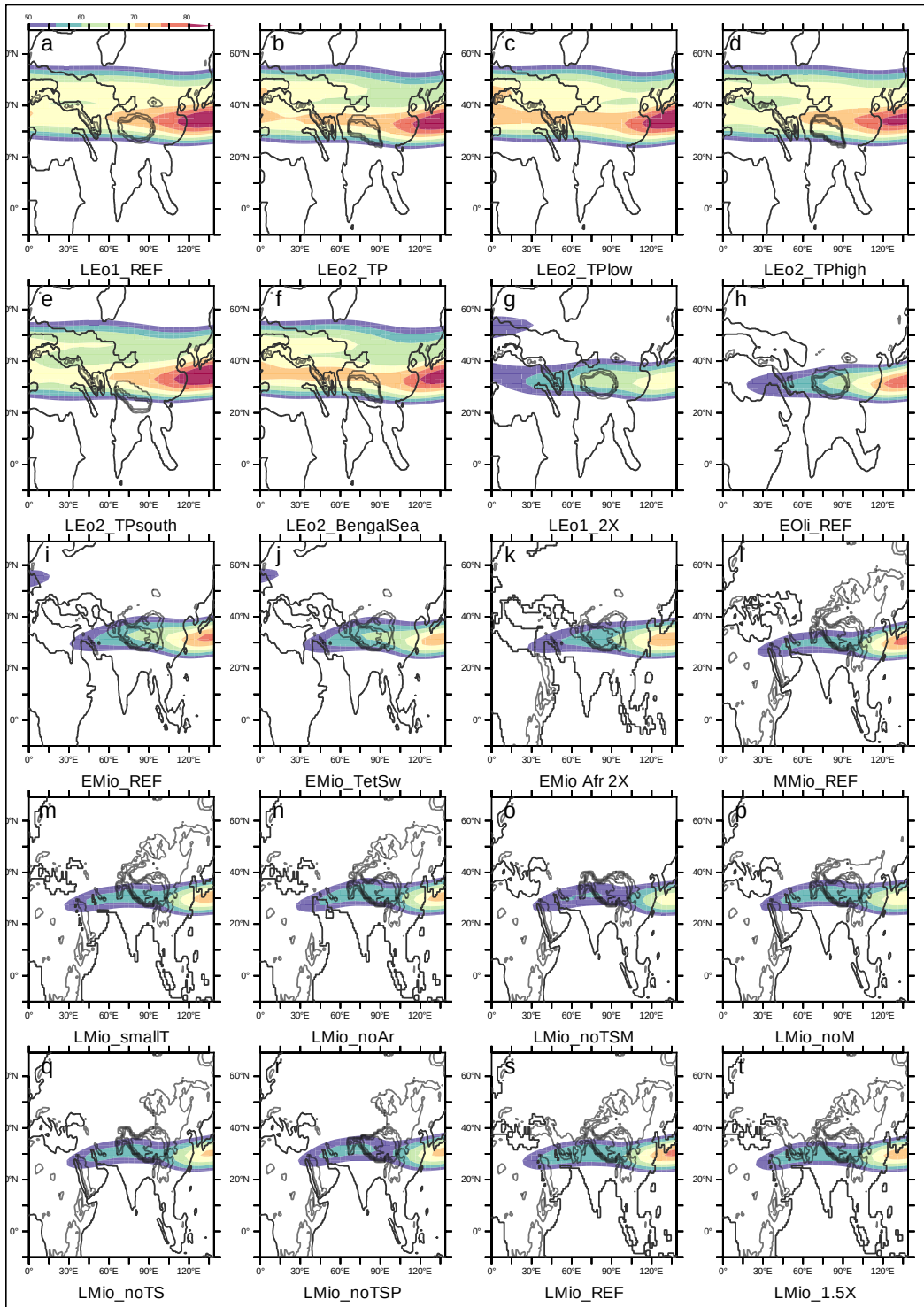


Figure 21. Jet Stream April velocity and localization over Asia, for all sensitivity experiments.