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1 Global patterns of biomass burning during the last glacial period

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6

7 **Sedimentary charcoal records covering part of the last glacial period were**
8 **synthesized to analyse the response of global biomass burning to rapid climate**
9 **changes during the so-called Dansgaard-Oeschger “cycles”.**

10

11 The Global Palaeofire Working Group

12 (http://www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeo

13 fire_WG) has updated a database over 700 individual sedimentary charcoal records

14 worldwide (GCD_V2: Daniau et al., in prep). This database provides a powerful tool

15 for studying changes of biomass burning at global and regional scale (Power et al.,

16 2008; Power et al., in press). A focused study of fire records covering the last glacial

17 period (73.5-14.7 ka) allows examination of the response of biomass burning to the

18 rapid climate changes (within 10-200 years) of large magnitude that occur during

19 Dansgaard-Oeschger (D-O) cycle. D-O cycles are characterized in Greenland by a

20 marked warming followed by a cooling. D-O warming event refers here to the initial

21 rapid warming (Sánchez-Goñi and Harrison, in press). The Greenland Interstadial

22 (GI) corresponds to the D-O warming event followed by a first slow phase of cooling.

23 GI end by a precipitous cooling (refers here as D-O cooling event). Greenland Stadial

24 (GS) correspond to the final slow phase of cooling.

25

26

27 **Methodology**

28 Sixty-seven sites (11 marine and 56 terrestrial, Figure 1) which have records for some

29 part of the last glacial period were extracted from the database and used to analyse

30 changes in global biomass burning (Daniau et al., in press). Those records present a

31 broad range of quantification methods and units. For the majority, charcoal counts are

32 expressed as concentration/influx of number of particles or area measurements made

33 on pollen slide or using image analysis. Few records were studied using chemical
34 assay such as total organic fraction and black carbon concentration, or expressed as
35 Charcoal/Pollen ratio and percentage dry weight. The data were therefore
36 standardized to facilitate comparisons between sites and through time. Original
37 charcoal data (abundance or concentration) were transformed and rescaled to obtain a
38 common mean and variance for all sites, and detrended to remove orbital time-scale
39 variability. A Superposed- Epoch Analysis (SEA) was performed on the detrended
40 charcoal data to examine the pattern of fire around the time of key events, aligning the
41 charcoal deviations on the ages of the D-O warming and D-O cooling events (Figure
42 2). When the SEA summary curves fall outside a confidence band determined by
43 Monte Carlo methods, a significant or systematic response of the variable to some
44 externally determined event is inferred.

45

46 **Fire and temperature**

47 Figure 2 illustrates SEAs for the NGRIP oxygen-isotope data and for the global
48 composite-curve of charcoal data to illustrate the nature of the abrupt climate changes
49 and the response of global biomass burning to the abrupt warming at the beginning of
50 the Greenland Interstadials (GI) and the most rapid interval of cooling that delimits
51 the beginning of Greenland Stadials (GS). A general increase in charcoal levels
52 during warming (Fig. 2A and B) and a decrease in charcoal levels during cooling
53 (Fig. 2C and D) suggest a strong correlation between biomass burning and
54 temperature. Biomass burning increases rapidly during D-O warming events, and
55 reaches a peak at nearly the same time as temperature. In contrast, biomass burning
56 decreases significantly at the onset of the GS and then returns to “background” levels
57 while temperatures remain low (Figs. 2C and D). The response of biomass burning to
58 the warming events is not the simple inverse of the response to cooling, suggesting a
59 nonlinear relationship between biomass burning and climate. The association between
60 rapid warming and increases in biomass burning seen during the glacial period has
61 also been observed during the last deglaciation at the termination of the Younger
62 Dryas chronozone (Marlon et al., 2009).

63

64 **Fire regime and fuel**

65 Changes in charcoal concentration have been described from two marine records off

66 the European margin and interpreted as changes in biomass burning caused by
67 variations in fuel availability during D-O “cycles” (Daniau et al., 2007; Daniau et al.,
68 2009). Recent syntheses of the glacial vegetation history of Europe, Japan and
69 adjacent parts of the Asian mainland, North America and the tropical regions of South
70 America and Africa (Fletcher et al., in press; Takahara et al., in press; Jiménez-
71 Moreno et al., in press; Hessler et al., in press) suggest that these rapid climate
72 changes had an impact on vegetation globally. Warmings are generally accompanied
73 by shifts from open vegetation to forest or increases in tree abundance. The similarity
74 of variations in global levels of fire and regional vegetation patterns suggest that
75 climate-driven changes in vegetation and biomass productivity (fuel) caused changes
76 in global biomass burning during the last glacial period. During the D-O warming
77 events and GI, increased productivity led to increased fuel availability and promoted
78 fire. Conversely, decreased fire in response to rapid cooling was a consequence of
79 reduced fuel loads from lower productivity. Increase in biomass burning to levels
80 similar to pre-cooling fire regimes during GS may be caused by temperature-driven
81 forest die-back, which would create conditions for increased fire.

82

83

84 **Conclusion and outlook**

85 This effort to synthesise charcoal records from the last glacial period allows us to
86 explore changes in global fire regimes during a period of high millennial-scale
87 climate variability. Biomass burning at the global scale apparently responded rapidly
88 to variations in temperature, as recorded in the Greenland ice core. Increases in
89 biomass burning were synchronous with warming whereas decreases in burning
90 followed by a return of fire to previous levels accompanied cooling. Changes in
91 vegetation productivity and fuel availability may explain the inferred variations in
92 biomass burning during D-O cycles.

93 Additional fire records however are needed to derive statistically robust results at a
94 regional scale and better examine fire and climate interactions. Global biomass
95 burning responds to temperature variation, but we also seek to explore the control of
96 seasonality of temperature and precipitation on fire, playing a role in shaping the
97 vegetation (type of biomes, abundance of fuel) but also on the flammability of fuel.
98 We intend to extend the database by adding worldwide long and high-resolution
99 marine and terrestrial charcoal records, in particular from poorly documented North

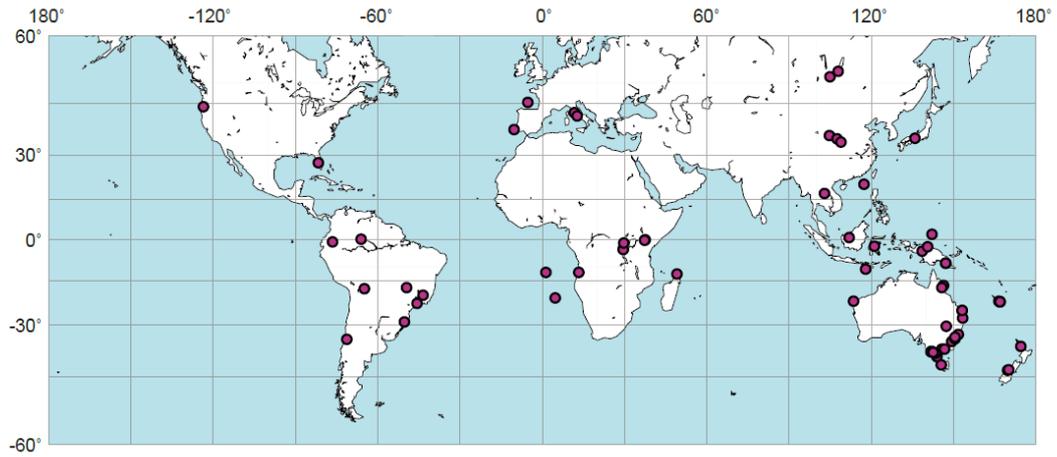
100 America, Africa and a large part of Eurasia. There is a great potential for the use of
101 long marine records to document regional fire where terrestrial records are not
102 available. Characterisation of the role of temperature and precipitation on fire would
103 benefit from the close comparison between fire and well-documented high resolution
104 changes in vegetation during D-O rapid climate changes. This could be done in
105 particular in Europe where these rapid changes lead to an alternation between steppe-
106 like environments and different forest biomes.

107

108

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112



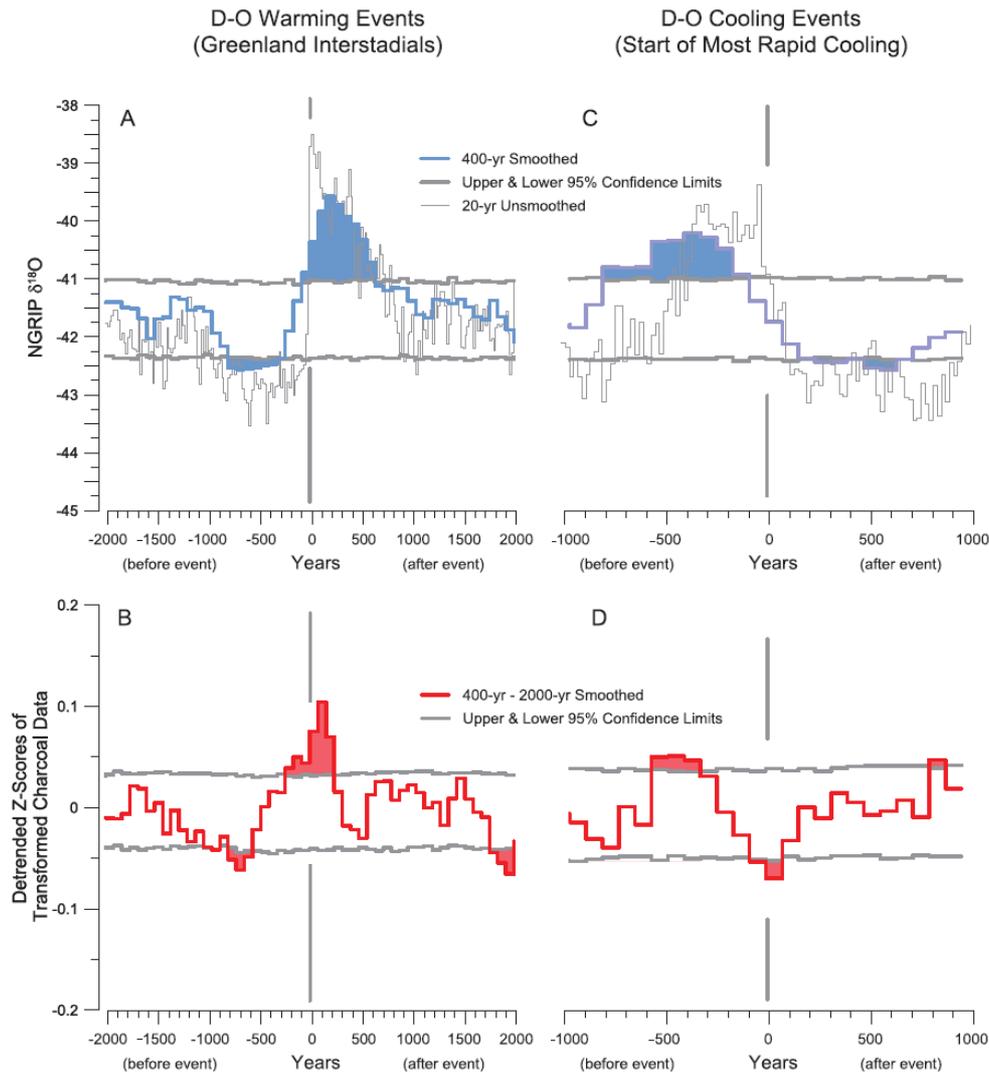
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115 **Figure 1:**

116 Location of marine and terrestrial sites with charcoal records covering all or part of
117 the last glacial period. Figure modified from Danialu et al., in press.

118



119

120 **Figure 2:**

121 Superposed Epoch Analysis (SEA) composites illustrating changes in biomass
 122 burning associated with D-O warming event (A and B) and D-O cooling event (C and
 123 D) with x-axis corresponding to time (before event on the left (negative values) and
 124 after event on the right (positive values)). The NGRIP $\delta^{18}\text{O}$ SEA composite record for
 125 the D-O cycles is shown for comparison. The NGRIP oxygen-isotope data (Wolff et
 126 al., in press) were summarized using 20-year-wide bins (the resolution of the data),
 127 and also using the same 80-year-wide bins used for charcoal data, for comparison
 128 with the SEA of the charcoal data. The confidence intervals are given by Monte-
 129 Carlo simulation using the timing of the 20 D-O warming events and 19 D-O cooling
 130 events. Figure modified from Daniau et al., in press.

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133 **Five references to be included in the article:**

- 134 Daniau, A.-L., Harrison, S. P. and Bartlein, P. J., in press: Fire regimes during the
135 Last Glacial, *Quaternary Science Reviews*,
136 doi:10.1016/j.quascirev.2009.11.008.
- 137 Marlon, J. R., Bartlein, P. J., Walsh, M. K., Harrison, S. P., Brown, K. J., Edwards,
138 M. E., Higuera, P. E., Power, M. J., Anderson, R. S., Briles, C., Brunelle, A.,
139 Carcaillet, C., Daniels, M., Hu, F. S., Lavoie, M., Long, C., Minckley, T.,
140 Richard, P. J. H., Scott, A. C., Shafer, D. S., Tinner, W., Umbanhowar Jr., C.
141 E. and Whitlock, C., 2009. Wildfire responses to abrupt climate change in
142 North America, *Proceedings of the National Academy of Sciences* **106** (8):
143 2519-2524 doi: 10.1073/pnas.0808212106.
- 144 Power, M. J., Marlon, J. R., Bartlein, P. J., Harrison, S. P., in press. Fire History and
145 the Global Charcoal Database: a new tool for hypothesis testing and data
146 exploration, *Palaeogeography, Palaeoclimatology, Palaeoecology*,
147 doi:10.1016/j.palaeo.2009.09.014.
- 148 Sánchez-Goñi, M. F. and Harrison, S. P., in press. Millennial-scale climate variability
149 and vegetation changes during the last glacial: concepts and terminology,
150 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.11.014.
- 151 Wolff, E. W., Chappellaz, J., Blunier, T., Rasmussen, S. O. and Svensson, A., in
152 press. Millennial-scale variability during the last glacial: The ice core record,
153 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.10.013.

154

155 **All References**

- 156 Daniau, A.-L., Harrison, S. P. and Bartlein, P. J., in press: Fire regimes during the
157 Last Glacial, *Quaternary Science Reviews*,
158 doi:10.1016/j.quascirev.2009.11.008.
- 159 Daniau, A.-L., Sánchez-Goñi, M. F., Beaufort, L., Laggoun-Defarge, F., Loutre, M.-
160 F. and Duprat, J., 2007: Dansgaard-Oeschger climatic variability revealed by
161 fire emissions in southwestern Iberia, *Quaternary Science Reviews* **26**: 1369-
162 1383.
- 163 Daniau, A.-L., Sánchez-Goñi, M. F. and Duprat, J., 2009. Last glacial fire regime
164 variability in western France inferred from microcharcoal preserved in core
165 MD04-2845, Bay of Biscay, *Quaternary Research* **71** (3): 385-396.
- 166 Fletcher, W. J., Sánchez Goñi, M. F., Allen, J. R. M., Cheddadi, R., Combourieu-
167 Nebout, N., Huntley, B., Lawson, I., Londeix, L., Magri, D., Margari, V.,
168 Müller, U. C., Naughton, F., Novenko, E., Roucoux, K. and Tzedakis, P. C., in
169 press. Millennial-scale variability during the last glacial in vegetation records
170 from Europe. *Quaternary Science Reviews*,
171 doi:10.1016/j.quascirev.2009.11.015.
- 172 Hessler, I., Dupont, L., Bonnefille, R., Behling, H., González, C., Helmens, K. F.,
173 Hooghiemstra, H., Lebamba, J., Ledru, M.-P., Lézine, A.-M., Maley, J.,
174 Marret, F. and Vincens, A., in press. Millennial-scale changes in vegetation
175 records from tropical Africa and South America during the last glacial.
176 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.11.029.
- 177 Jiménez-Moreno, G., Anderson, R. S., Desprat, S., Grigg, L. D., Grimm, E. C.,
178 Heusser, L. E., Jacobs, B. F., López-Martínez, C., Whitlock, C. L. and
179 Willard, D. A., in press. Millennial-scale variability during the last glacial in

180 vegetation records from North America. *Quaternary Science Reviews*,
181 doi:10.1016/j.quascirev.2009.12.013.

182 Marlon, J. R., Bartlein, P. J., Walsh, M. K., Harrison, S. P., Brown, K. J., Edwards,
183 M. E., Higuera, P. E., Power, M. J., Anderson, R. S., Briles, C., Brunelle, A.,
184 Carcaillet, C., Daniels, M., Hu, F. S., Lavoie, M., Long, C., Minckley, T.,
185 Richard, P. J. H., Scott, A. C., Shafer, D. S., Tinner, W., Umbanhowar Jr., C.
186 E. and Whitlock, C., 2009. Wildfire responses to abrupt climate change in
187 North America, *Proceedings of the National Academy of Sciences* **106** (8):
188 2519-2524 doi: 10.1073/pnas.0808212106.

189 Power, M. J., Marlon, J., Ortiz, N., Bartlein, P. J., Harrison, S. P., Mayle, F. E.,
190 Ballouche, A., Bradshaw, R. H. W., Carcaillet, C., Cordova, C., Mooney, S.,
191 Moreno, P. I., Prentice, I. C., Thonicke, K., Tinner, W., Whitlock, C., Zhang,
192 Y., Zhao, Y., Ali, A. A., Anderson, R. S., Beer, R., Behling, H., Briles, C.,
193 Brown, K. J., Brunelle, A., Bush, M., Camill, P., Chu, G. Q., Clark, J.,
194 Colombaroli, D., Connor, S., Daniau, A.-L., Daniels, M., Dodson, J., Doughty,
195 E., Edwards, M. E., Finsinger, W., Foster, D., Frechette, J., Gaillard, M.-J.,
196 Gavin, D. G., Gobet, E., Haberle, S., Hallett, D. J., Higuera, P. E., Hope, G.,
197 Horn, S., Inoue, J., Kaltenreider, P., Kennedy, L., Kong, Z. C., Larsen, C.,
198 Long, C. J., Lynch, J. A., Lynch, E. A., McGlone, M., Meeks, S., Mensing, S.,
199 Meyer, G., Minckley, T., Mohr, J., Nelson, D. M., New, J., Newnham, R.,
200 Noti, R., Oswald, W., Pierce, J., Richard, P. J. H., Rowe, C., Sanchez Goñi,
201 M. F., Shuman, B. J., Takahara, H., Toney, J., Turney, C., Urrego-Sanchez, D.
202 H., Umbanhowar, C., Vandergoes, M., Vanniere, B., Vescovi, E., Walsh, M.,
203 Wang, X., Williams, N., Wilmschurst, J. and Zhang, J. H., 2008. Changes in
204 fire regimes since the Last Glacial Maximum: an assessment based on a global
205 synthesis and analysis of charcoal data, *Climate Dynamics* **30**: 887-907.

206 Power, M. J., Marlon, J. R., Bartlein, P. J., Harrison, S. P., in press. Fire History and
207 the Global Charcoal Database: a new tool for hypothesis testing and data
208 exploration, *Palaeogeography, Palaeoclimatology, Palaeoecology*,
209 doi:10.1016/j.palaeo.2009.09.014.

210 Sánchez-Goñi, M. F. and Harrison, S. P., in press. Millennial-scale climate variability
211 and vegetation changes during the last glacial: concepts and terminology,
212 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.11.014.

213 Steffensen, J. P., Andersen, K. K., Bigler, M., Clausen, H. B., Dahl-Jensen, D.,
214 Fischer, H., Goto-Azuma, K., Hansson, M., Johnsen, S. J., Jouzel, J., Masson-
215 Delmotte, V., Popp, T., Rasmussen, S. O., Röthlisberger, R., Ruth, U.,
216 Stauffer, B., Siggaard-Andersen, M.-L., Sveinbjörnsdóttir, A.-E., Svensson,
217 A., and White, J. W. C., 2008. High-Resolution Greenland Ice Core Data Show
218 Abrupt Climate Change Happens in Few Years, *Nature* **321**: 680-684.

219 Takahara, H., Igarashi, Y., Hayashi, R., Kumon, F., Liew, P.-M., Yamamoto, M.,
220 Kawai, S., Oba, T., Irino, T., in press. Millennial-scale variability in
221 vegetation records from the East Asian Islands: Taiwan, Japan and Sakhalin,
222 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.11.026.

223 Wolff, E. W., Chappellaz, J., Blunier, T., Rasmussen, S. O. and Svensson, A., in
224 press. Millennial-scale variability during the last glacial: The ice core record,
225 *Quaternary Science Reviews*, doi:10.1016/j.quascirev.2009.10.013.

226
227