



Detecting together what cannot be seen alone: the ICOS infrastructure. Introductory lecture to the European Research Course on Atmosphere

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DETECTING TOGETHER WHAT YOU CANNOT SEE ALONE: THE ICOS INFRASTRUCTURE.

Denis Loustau
Virginie Moreaux



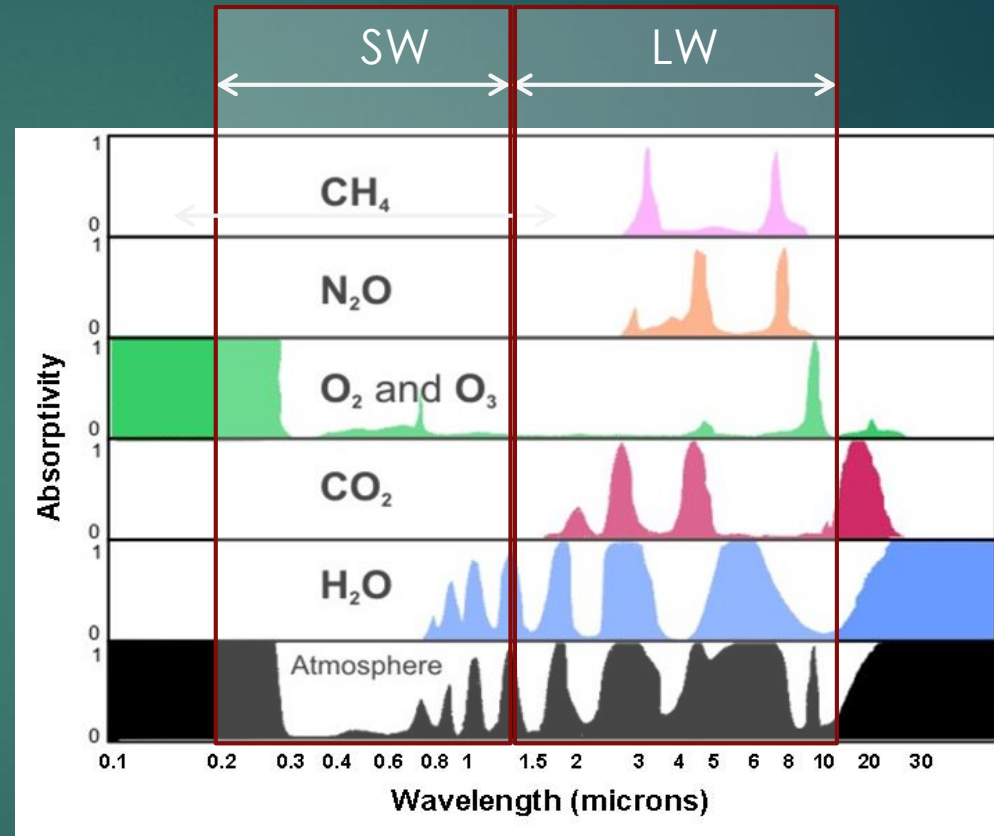
DETECTING TOGETHER WHAT YOU CANNOT SEE ALONE: THE ICOS STATION NETWORK CASE.

1. Short- and long term changes in the atmospheric GreenHouseGases
2. Observation of GHG: the ICOS infrastructure
3. Seeing the unseen ?

PART 1.

Changes in atmospheric
greenhouse gases

- 70-75% of SW (solar) radiation passes through the atmosphere
- 15-30% of the earth LW radiation escapes from the top of the atmosphere
- The LW trapped by GHG heats the lower troposphere by $\sim +18^{\circ}\text{C}$

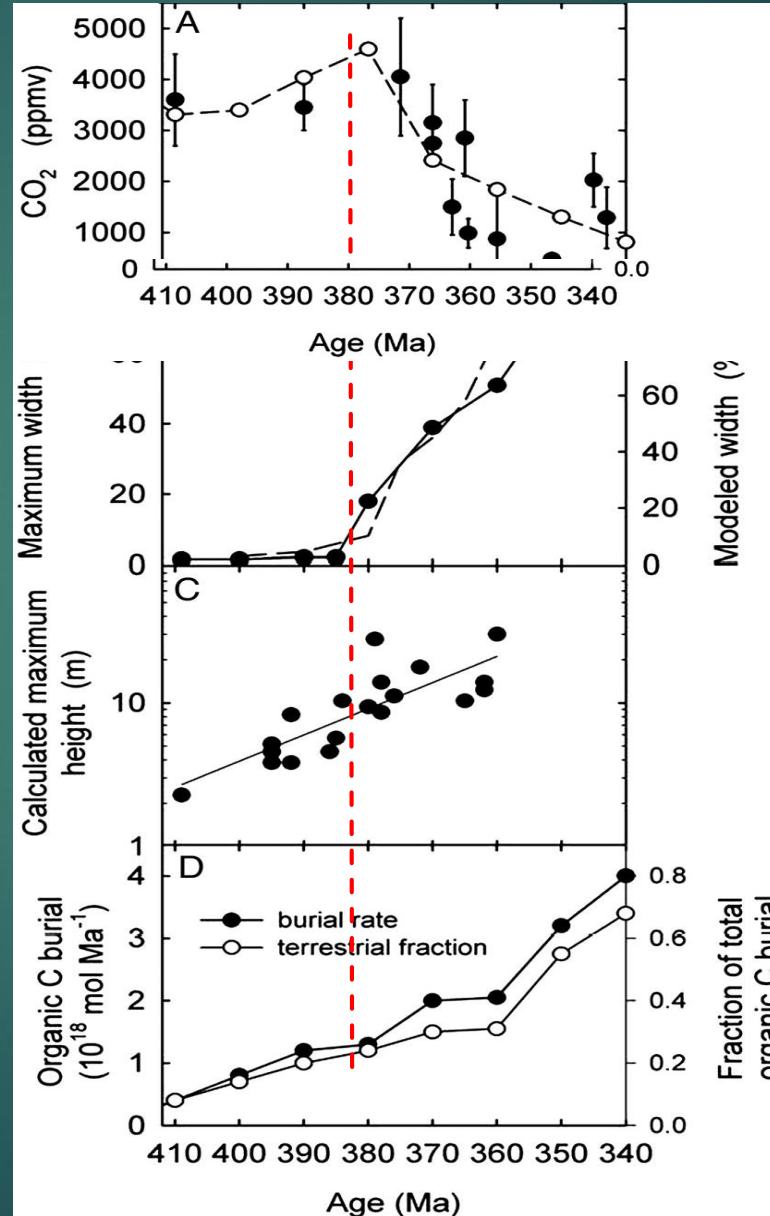


Part1. Concise history of the GHG atmospheric concentration:

Link with land colonisation

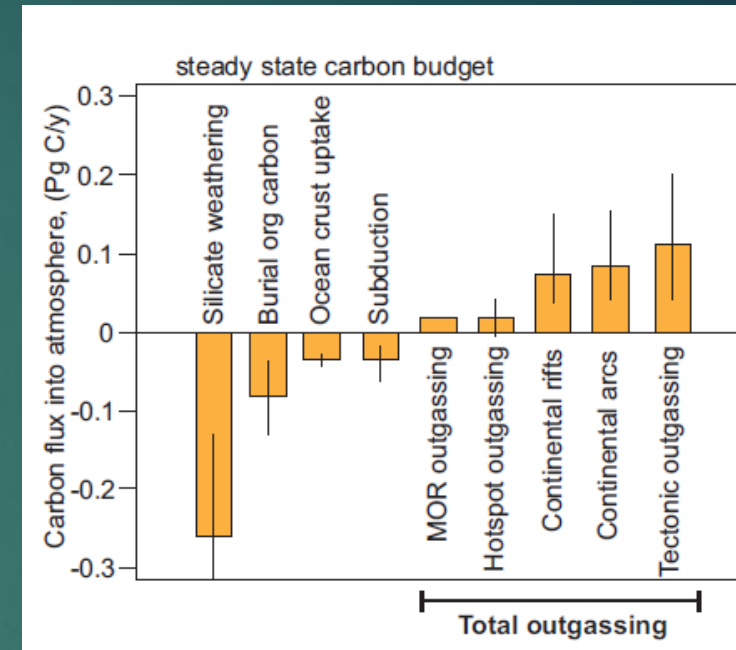
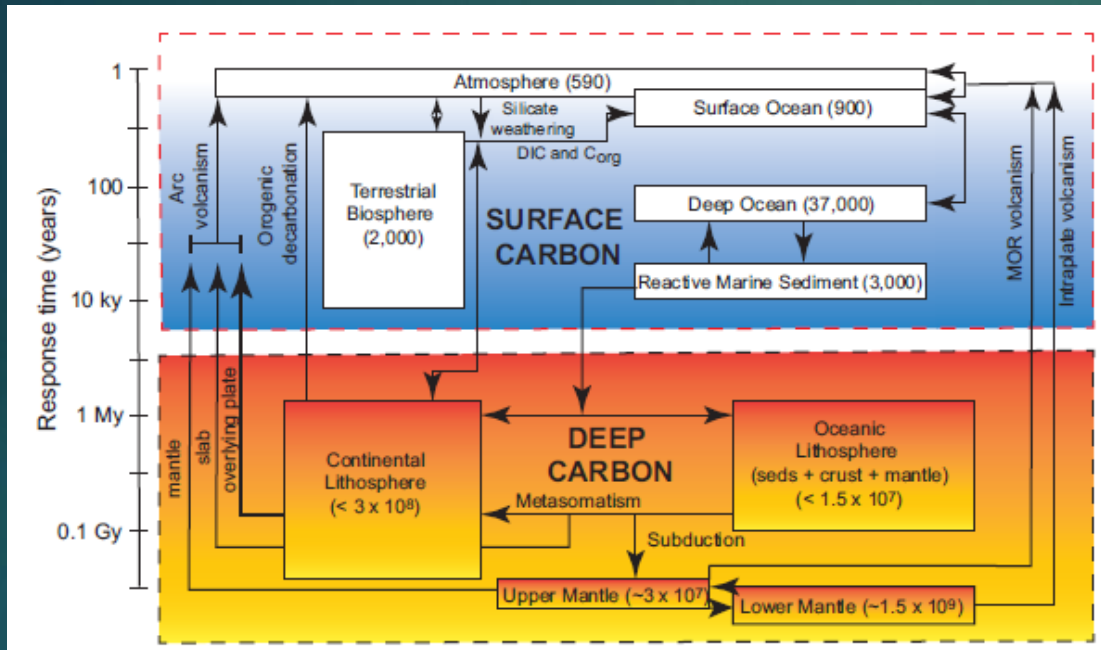
- CO₂ atmospheric concentration →
- Conductive plant tissues (tracheids) →
- Wood (lignin), leaves →
- Trees (coniferous) →
- Soil →

Beerling D J , Berner R A
PNAS 2005;102:1302-1305
©2005 by National Academy of Sciences



Part 1.

The control of the GHG concentration : long term processes ($10^6 - 10^8$ yrs)

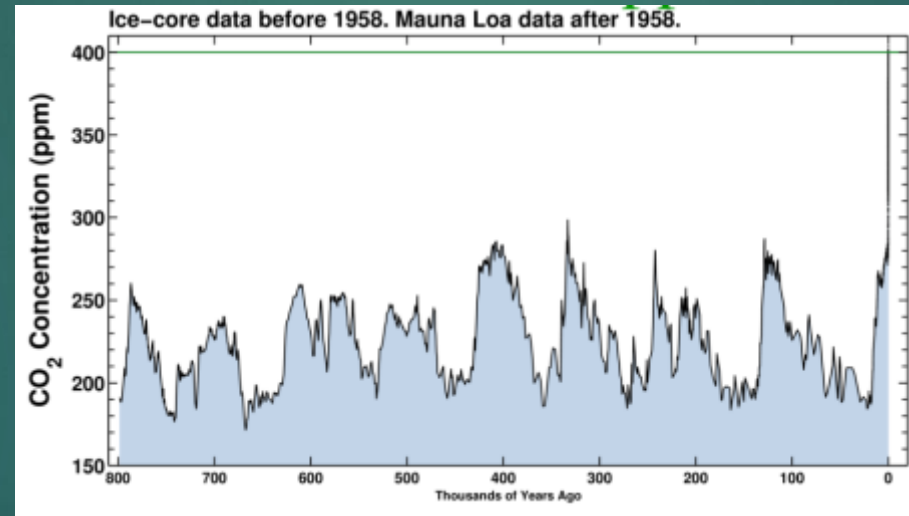


- Atmospheric carbon is $\sim 3 \times 10^{-7}$ of earth carbon and 1,3% of surface carbon

Suarez et al. 2019. *Elements*, Vol. 15, pp. 301–306

- Atmospheric carbon content is controlled ultimately by the balance between sources and sinks

Part 1. Atmospheric carbon, past 800 000 years.

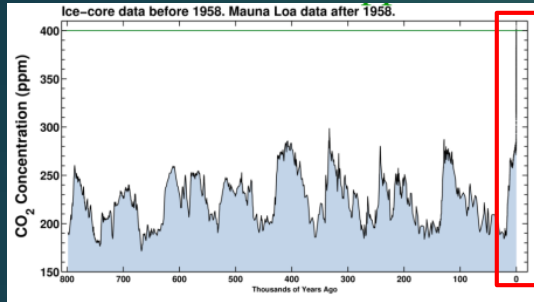


800.000 years

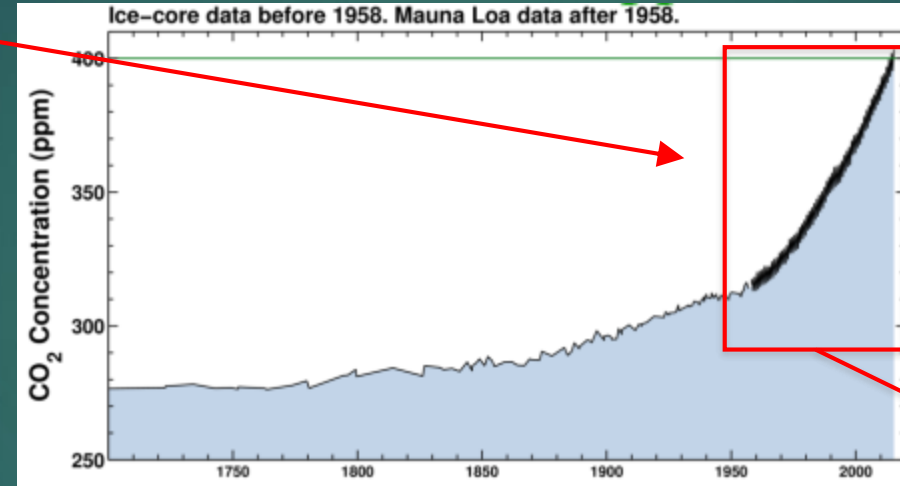
[CO₂] varied from 180 to 290 ppmv
in response to glaciations episodes



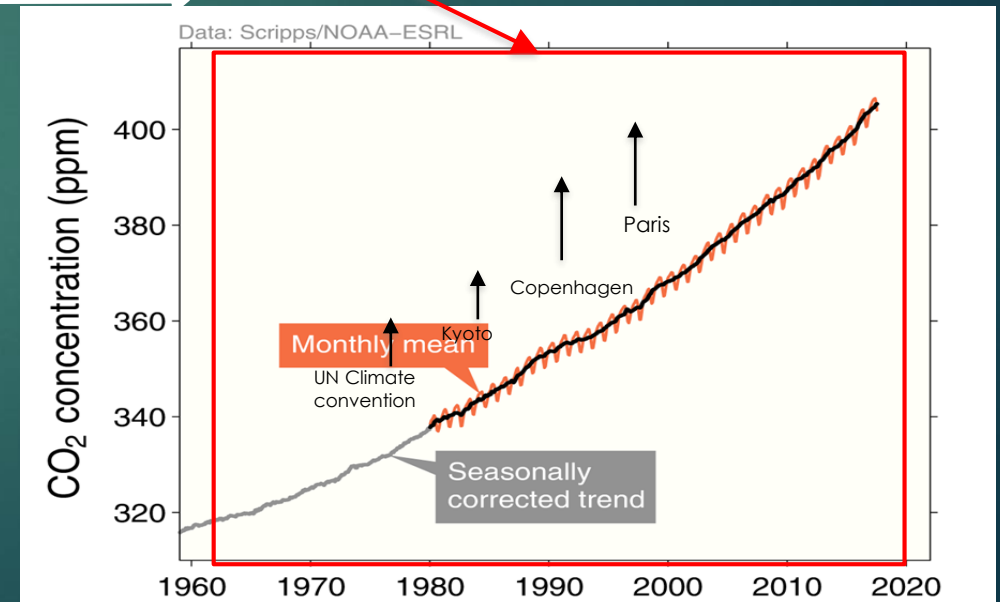
Part 1. Recent changes in the atmosphere GHG content



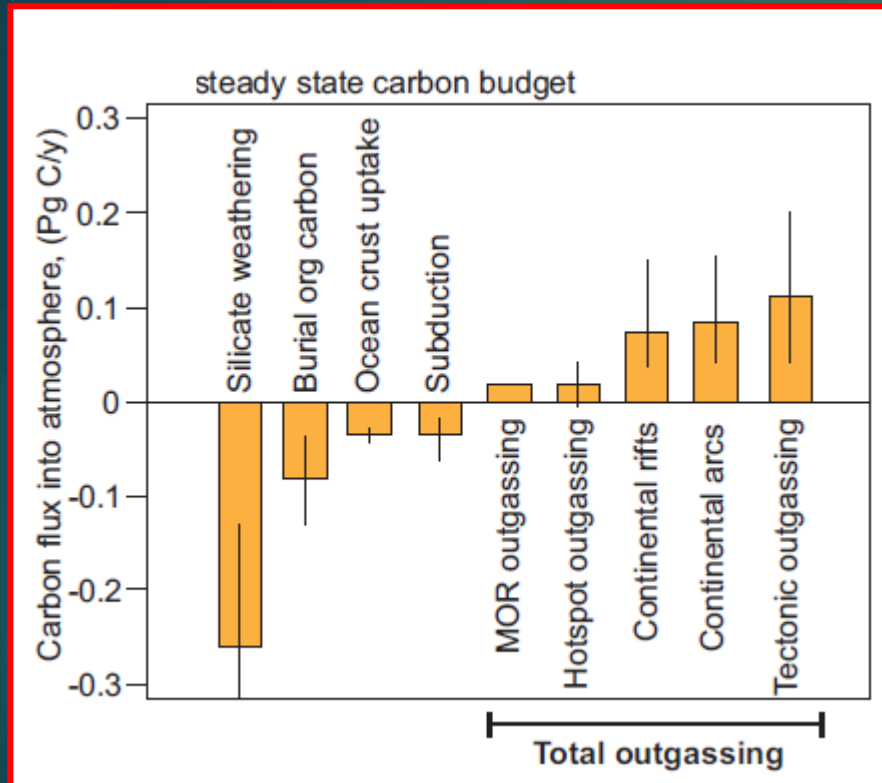
800.000 years



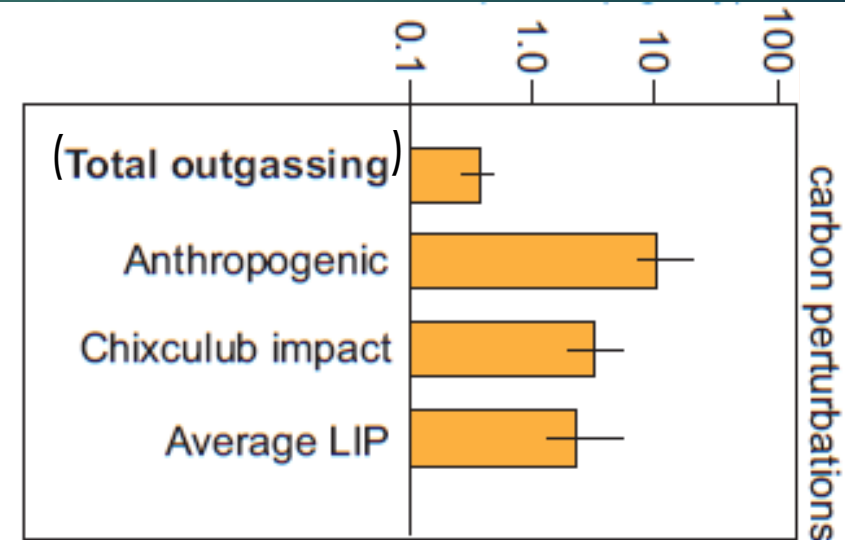
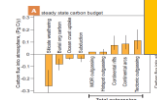
315 years



1. The anthropocene



Fossil fuel
emission
(2010)

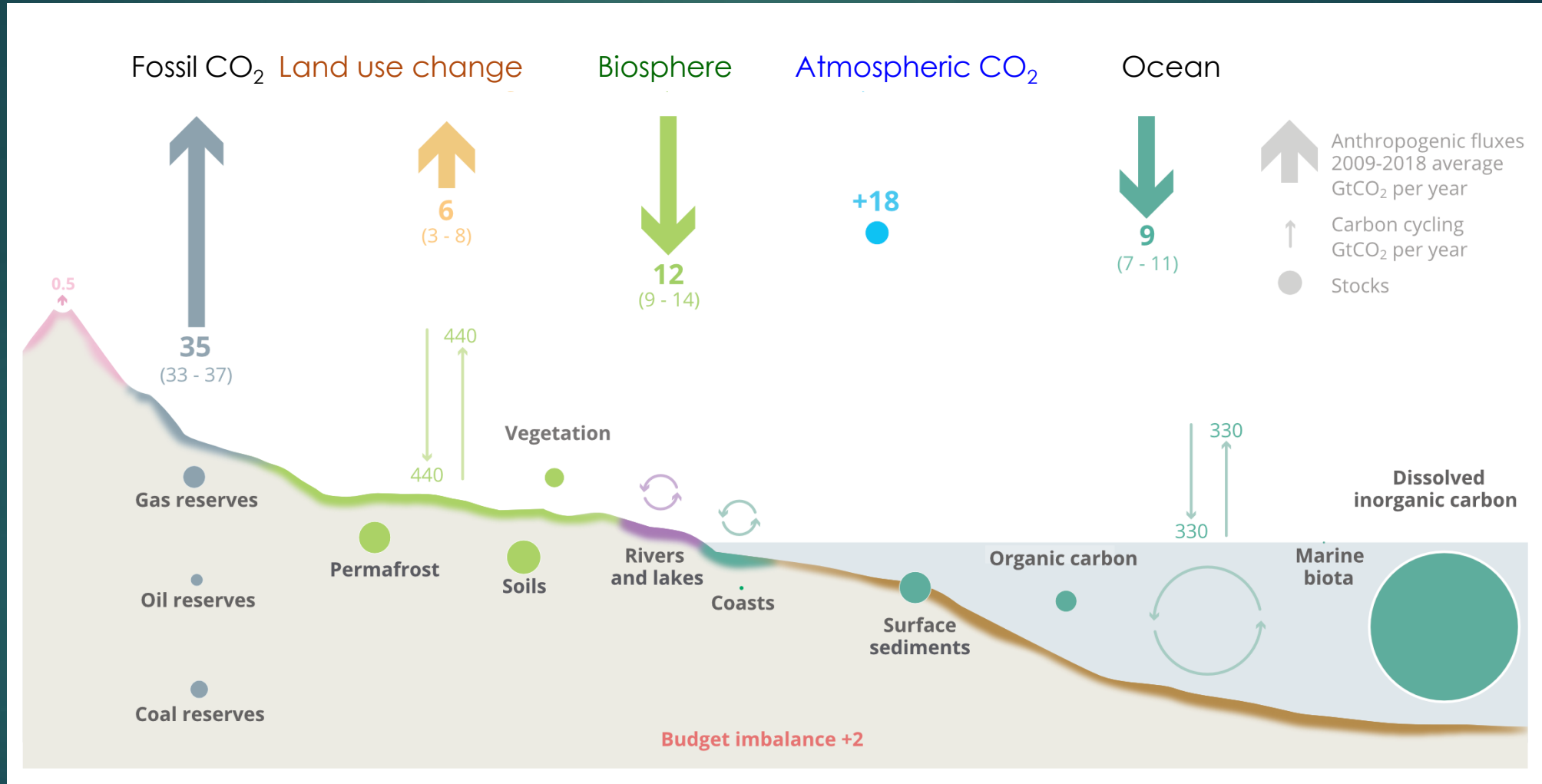


Disturbances in the carbon flux into the atmosphere (PgC.yr-1).

- Anthropogenic are fossil C emissions
- Chicxulub refers to the end-Cretaceous asteroid impact having led to mass extinction
- LIP to the large igneous provinces.

(Kawaragi 2009, Lee et al. 2019, Black and Gibson 2019).

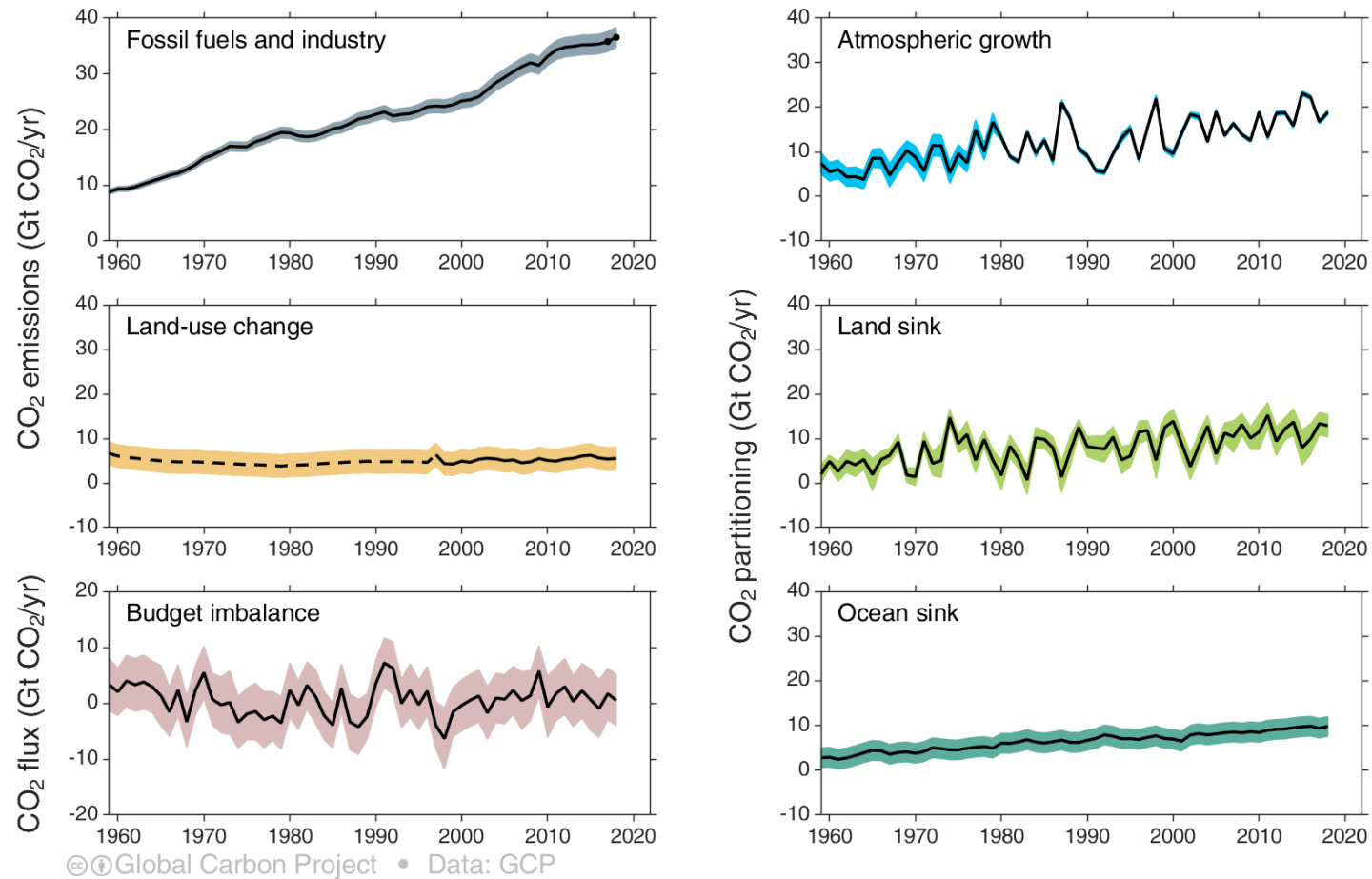
Part 1. The surface carbon cycle 2019



The budget imbalance is the difference between the estimated emissions and sinks.
Source: [CDIAC](#); [NOAA-ESRL](#); [Friedlingstein et al 2019](#); [Ciais et al. 2013](#); [Global Carbon Budget 2019](#)

Recent changes in the surface carbon budget

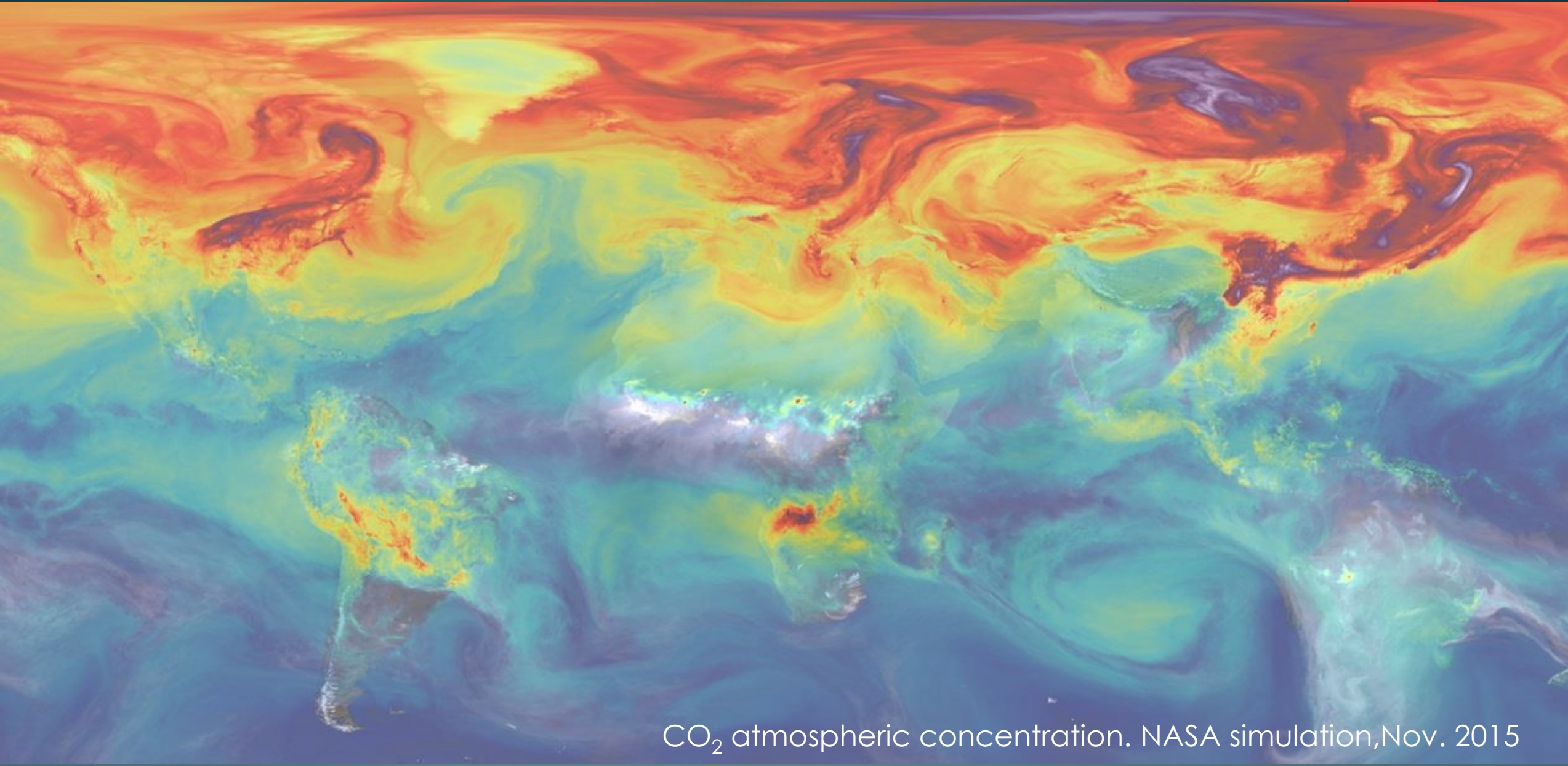
The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO₂ in the atmosphere



The budget imbalance is the total emissions minus the estimated growth in the atmosphere, land and ocean. It reflects the limits of our understanding of the carbon cycle.

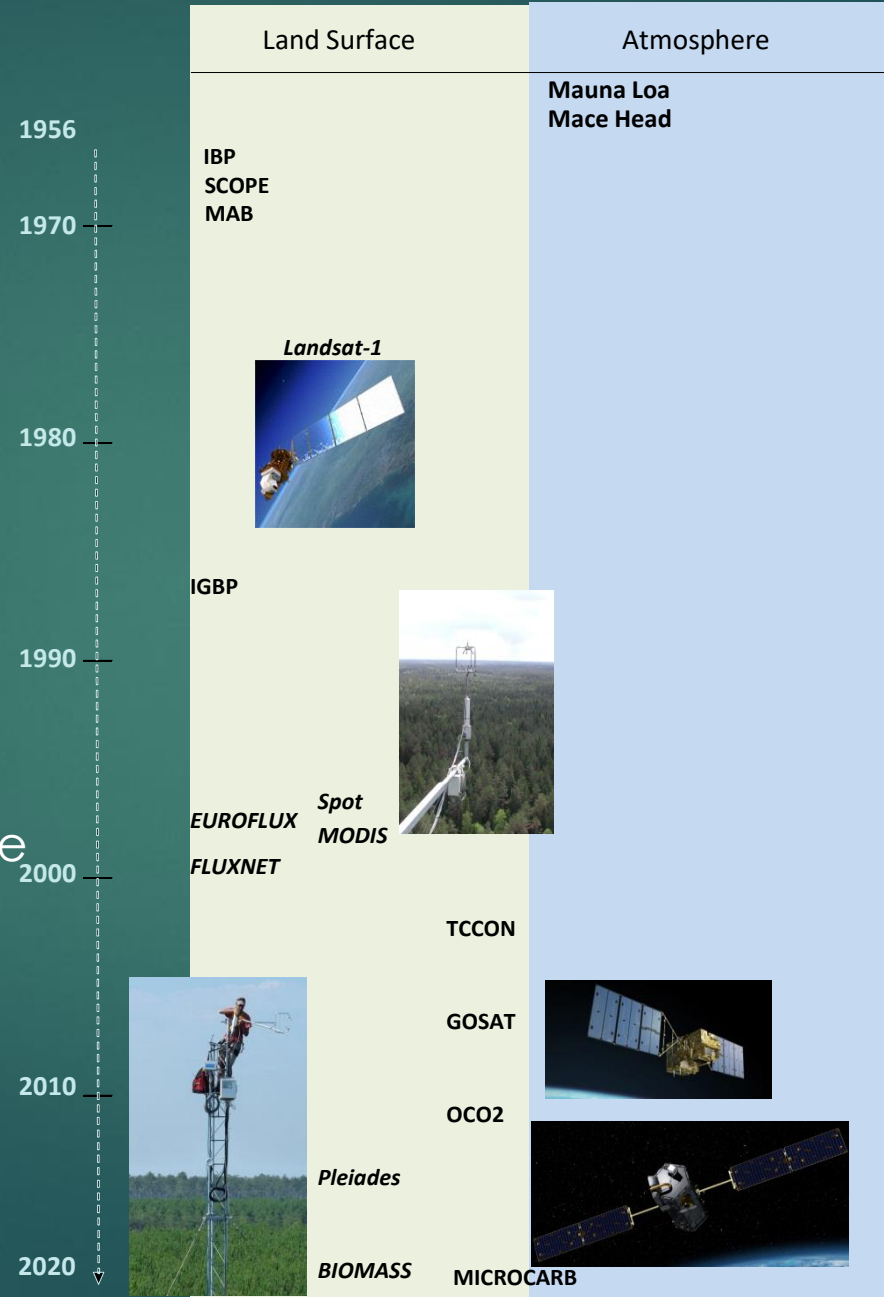
Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton and Nassikas 2017](#); [Hansis et al 2015](#); [Friedlingstein et al 2019](#); [Global Carbon Budget 2019](#)

Part 2. Observe and monitor atmospheric GHG



Part 2. Observing the Greenhouse gases

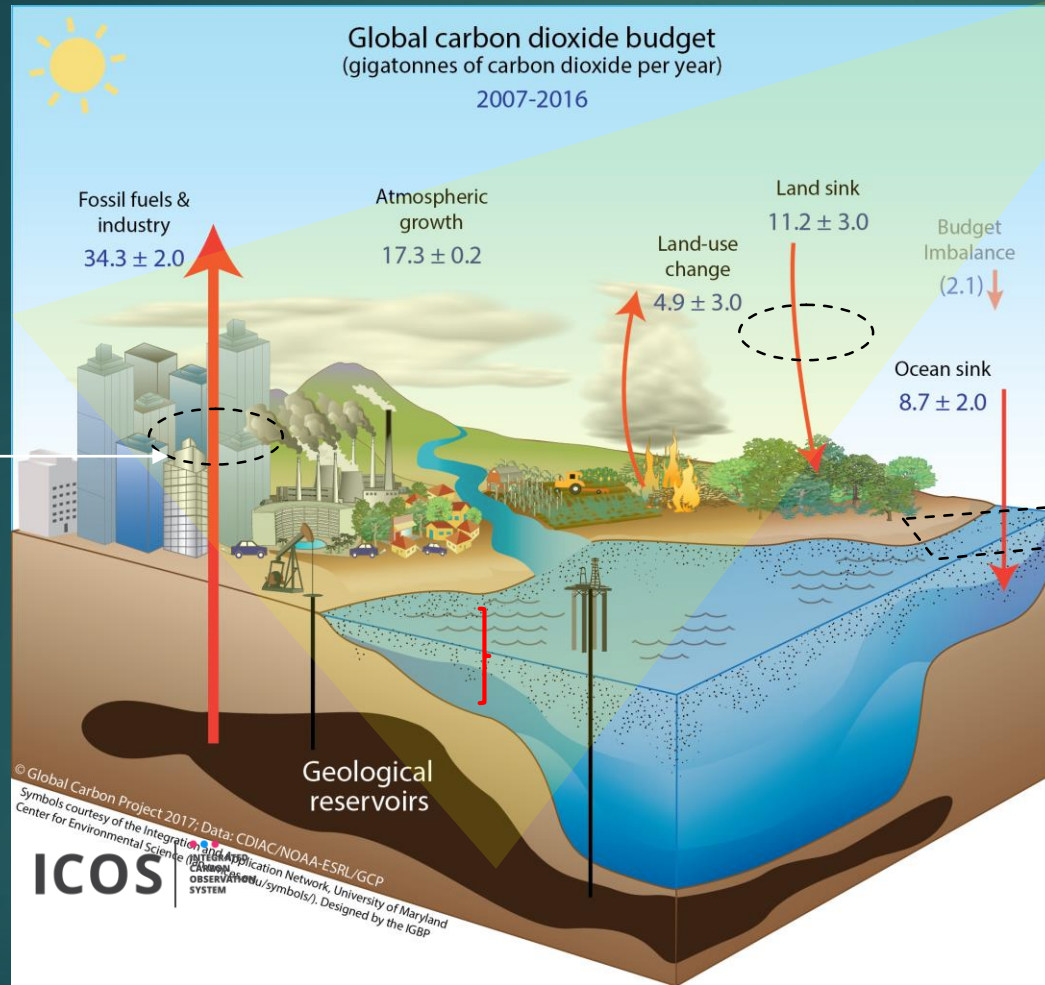
- J. Fourier 1824, J. Tyndall 1861
- 1st atmospheric long term observatory
- Carbon and biomass inventories.
- 1st carbon balance of the atmosphere
- 1st CO₂ flux measurements
- 1st global monitoring of land atmosphere CO₂ exchange (*Fluxnet*)
- **ICOS Launching**



There is a missing sink !

1st assessment of surface carbon budget

Part 2. The GHG cycle observation. The ICOS strategy



Atmosphere:

Data for regional/global inversion modelling
remote and in situ

Land surface:

Local observations (EC tower); Flux and stock

Ocean surface: observations of Ocean – Atmosphere flux

Fossil C

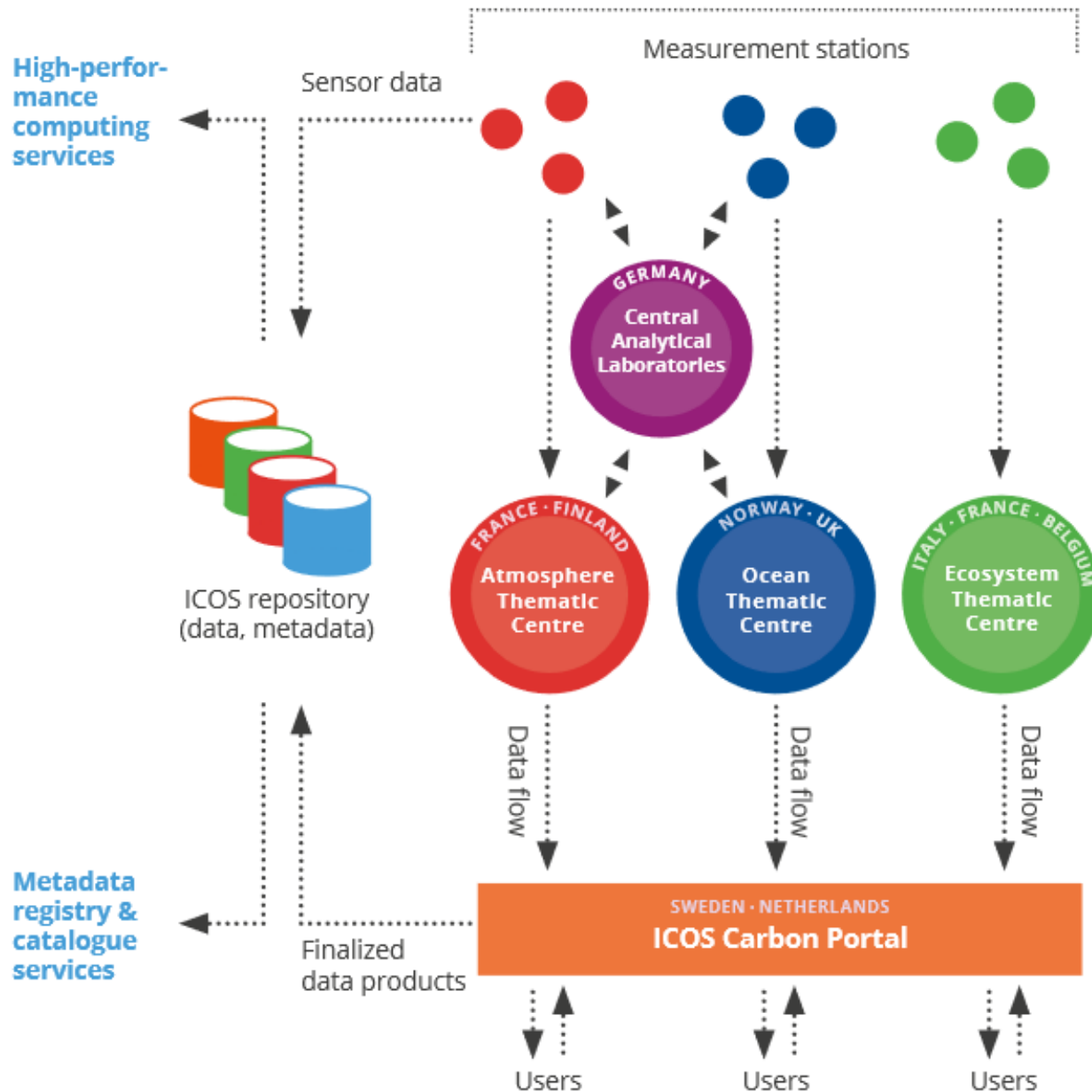
Country inventory
Bookkeeping models

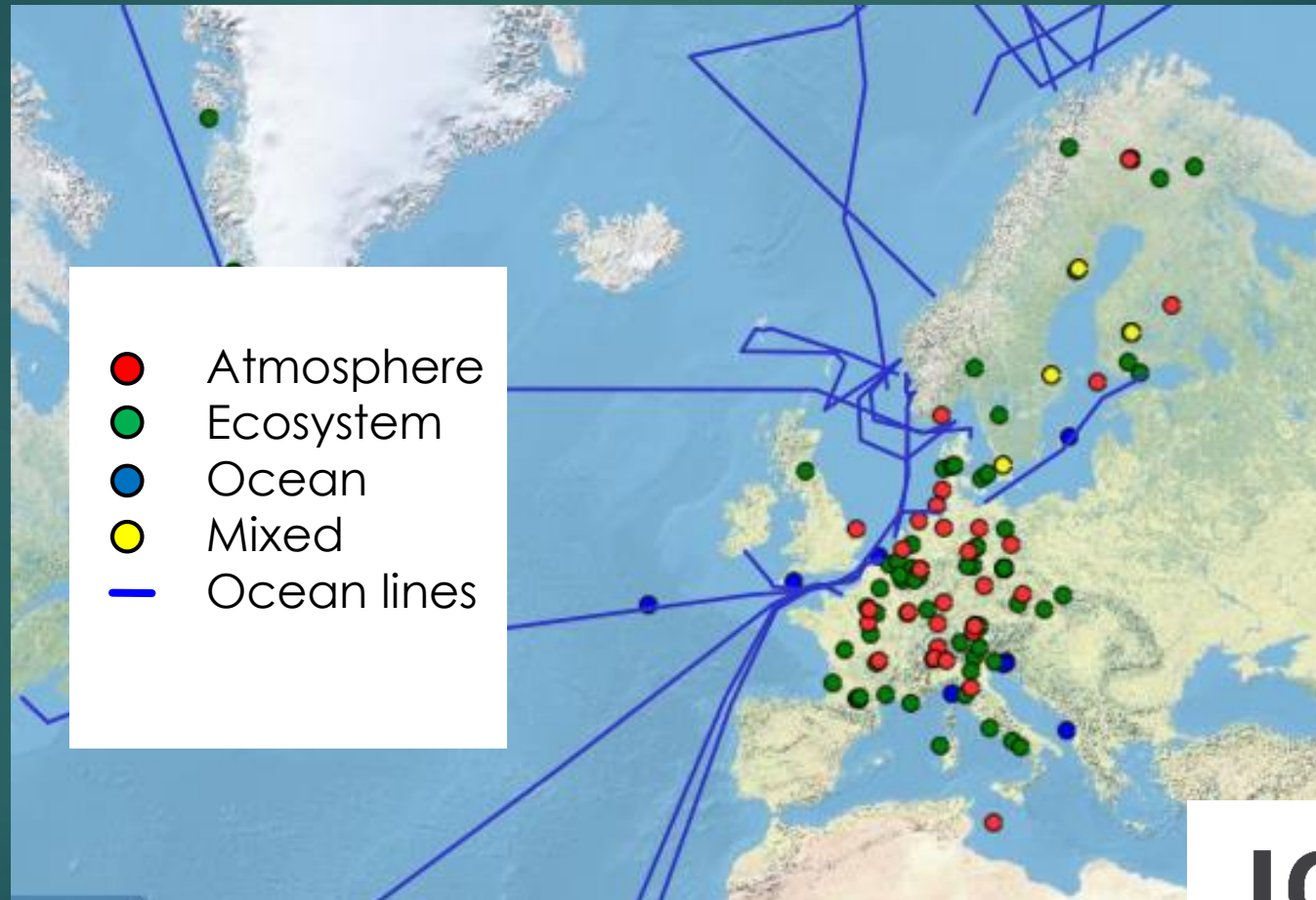
(<https://www.icos-ri.eu/>)

- ▶ Launched in 2013 as a distributed RI., expected lifetime 20 years
- ▶ Head Office in Helsinki, D.G. W. Kutsch
- ▶ 13 countries, ~500 scientists,
- ▶ Networks of 120 stations in Atmosphere, Ocean and Land surface.
- ▶ Open free access, central data delivery through the Carbon Portal @

<https://www.icos-cp.eu/>







ICOS

INTEGRATED
CARBON
OBSERVATION
SYSTEM

ATC. LSCE, Saclay.

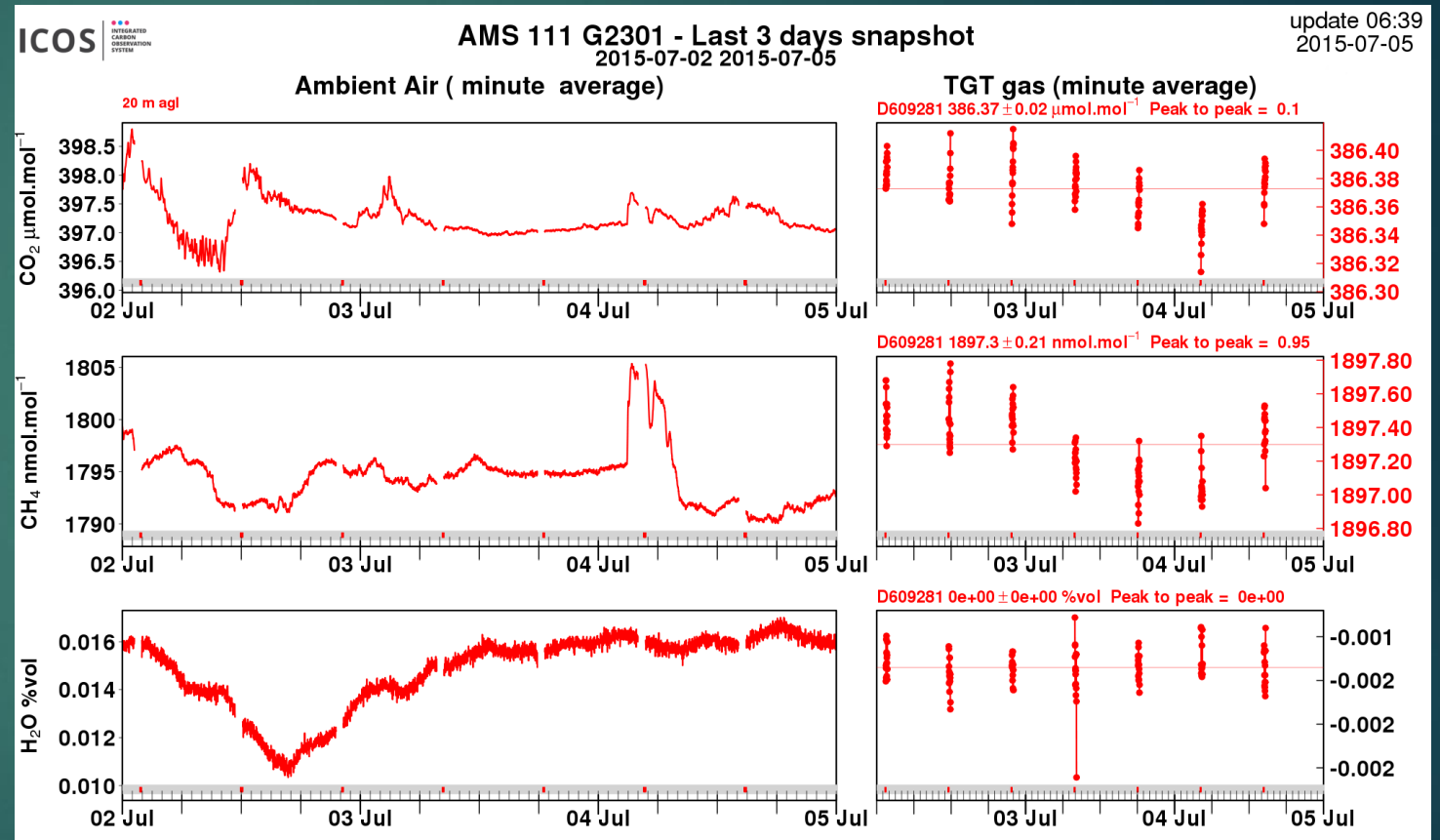
- Organisation and operation of the workflow of atmospheric data (30 stations)
- New instruments qualifications
- New techniques development
- Support of ICOS development in the Atmospheric domain
- Mobile lab



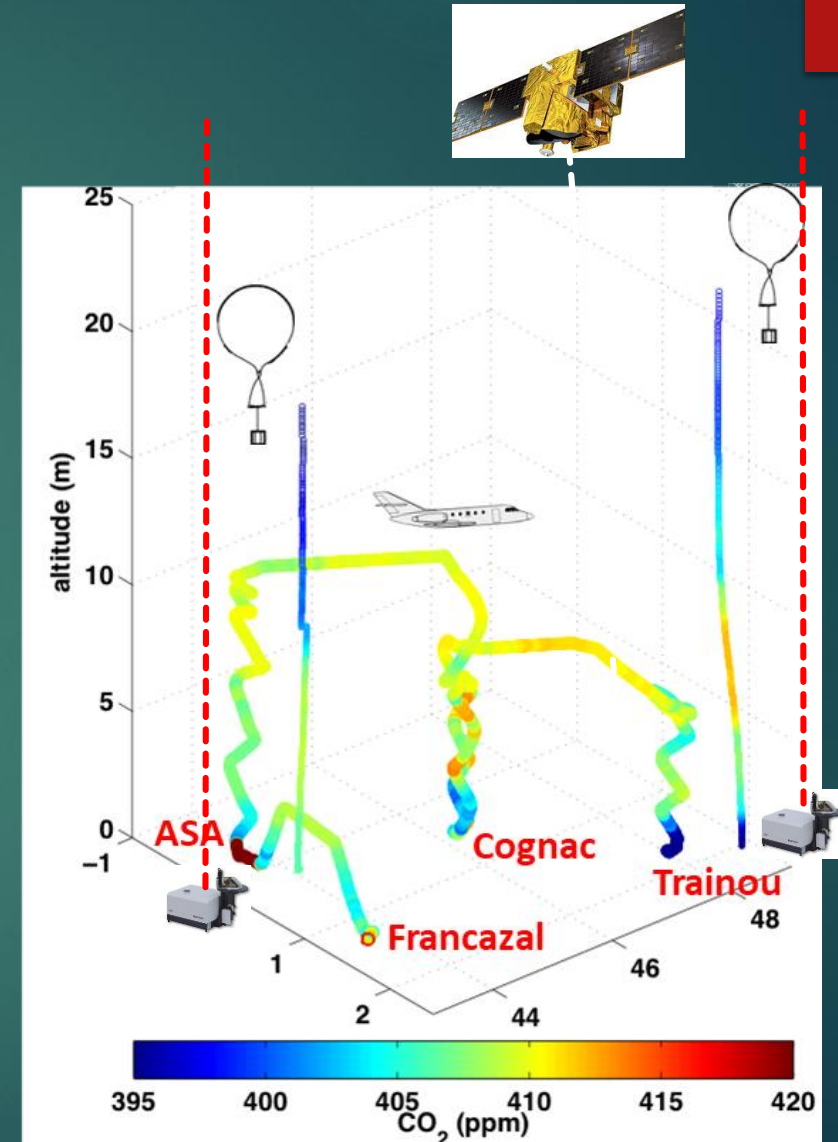
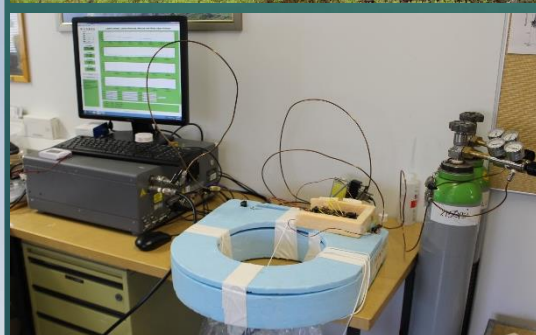
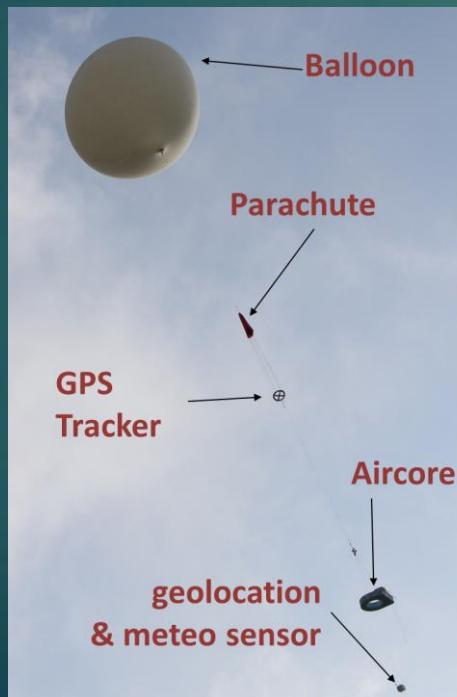
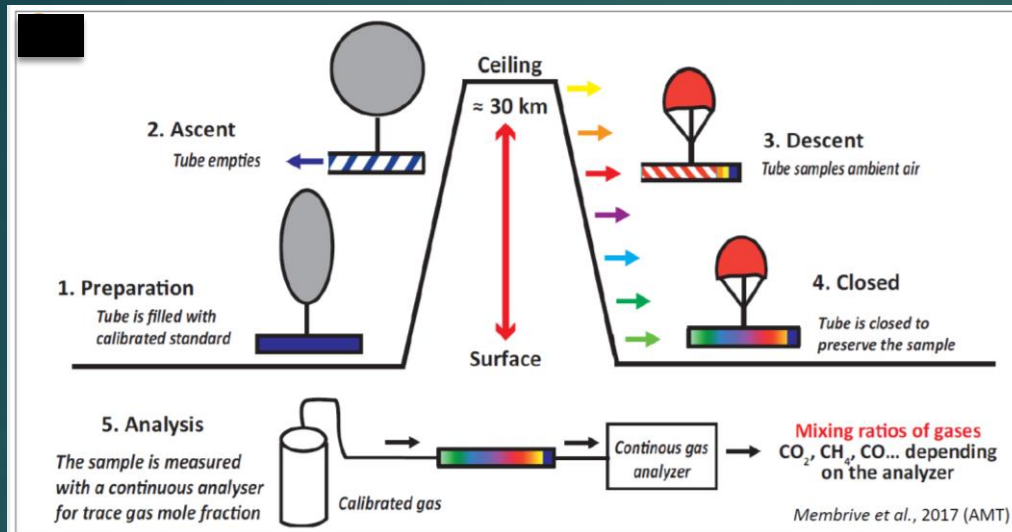
Part 2.

In-situ atmosphere measurements

<https://stilt.icos-cp.eu/viewer/>



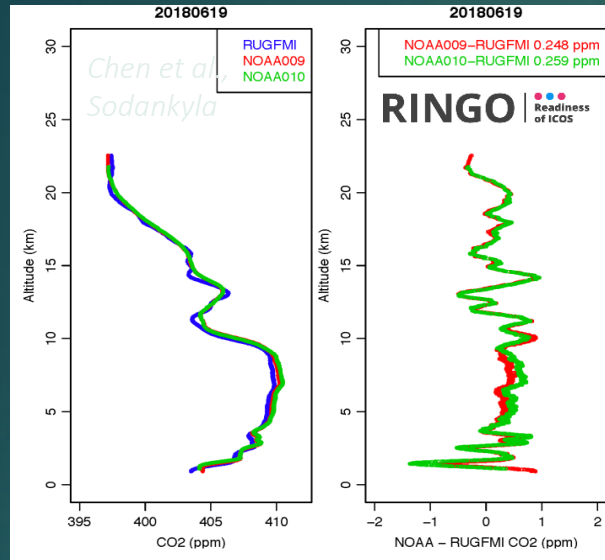
Part 2. Aircores: vertical sampling of the atmosphere



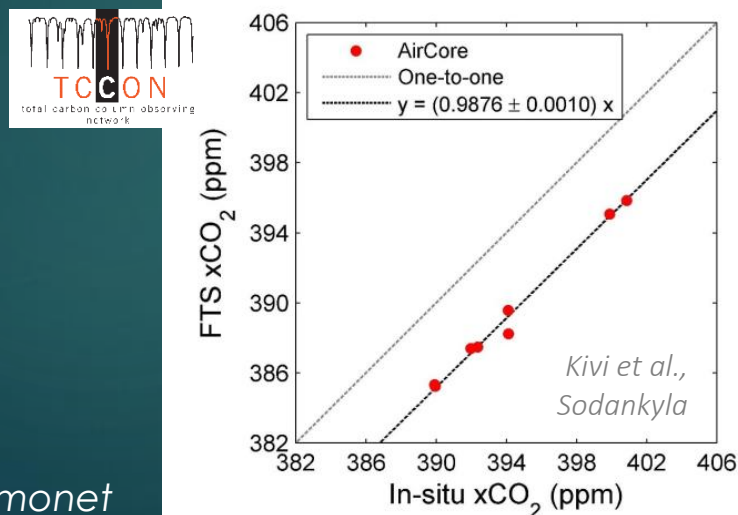
24 mai 2018
Crevoisier et al.

Courtesy L.
Rivier, M.
Ramonet

Quality control Intercomparison

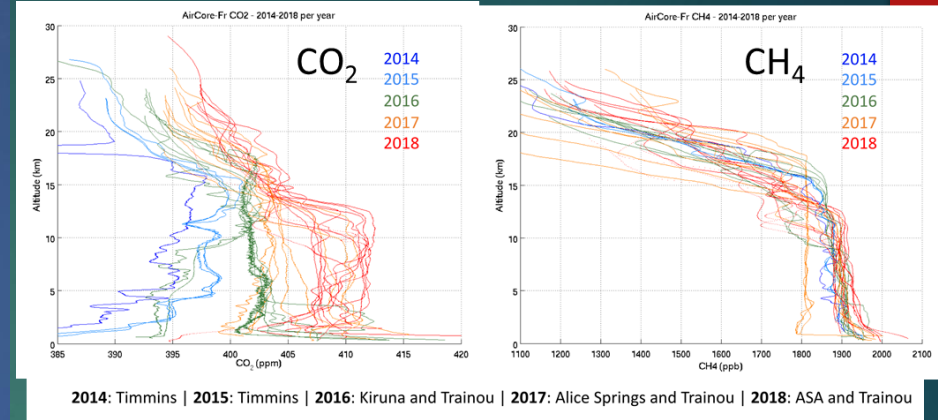


Calibration of TCCON

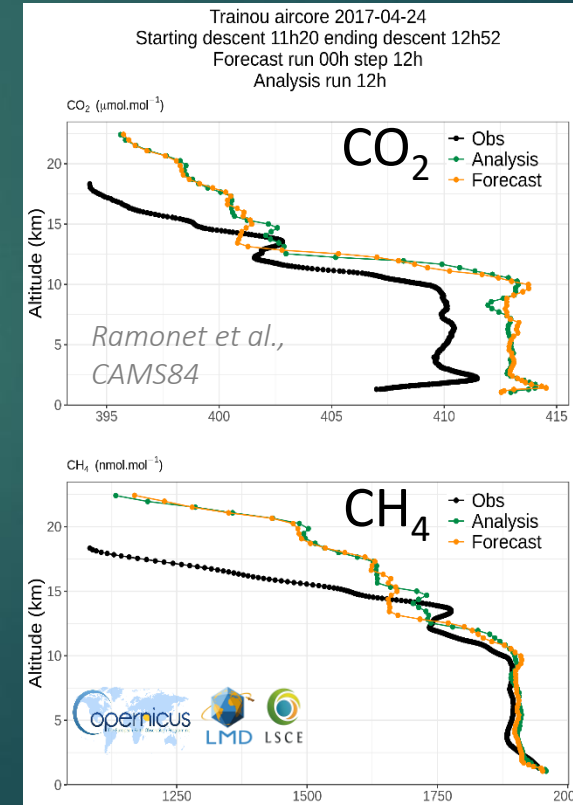


AIRCORE

Long term monitoring



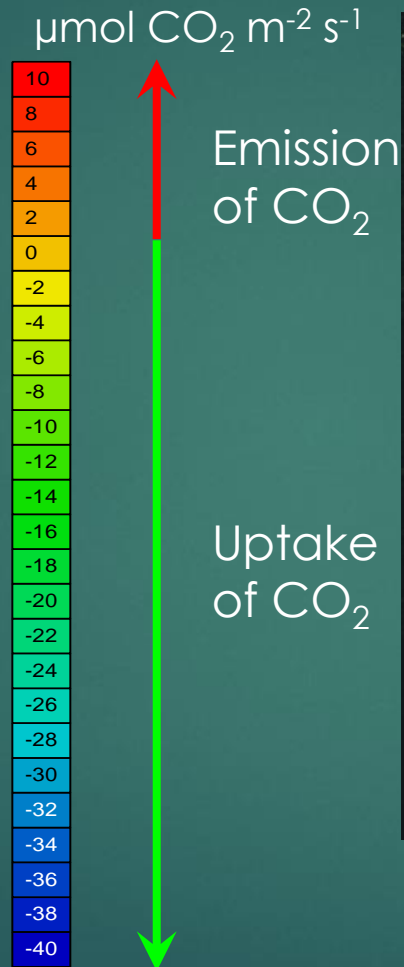
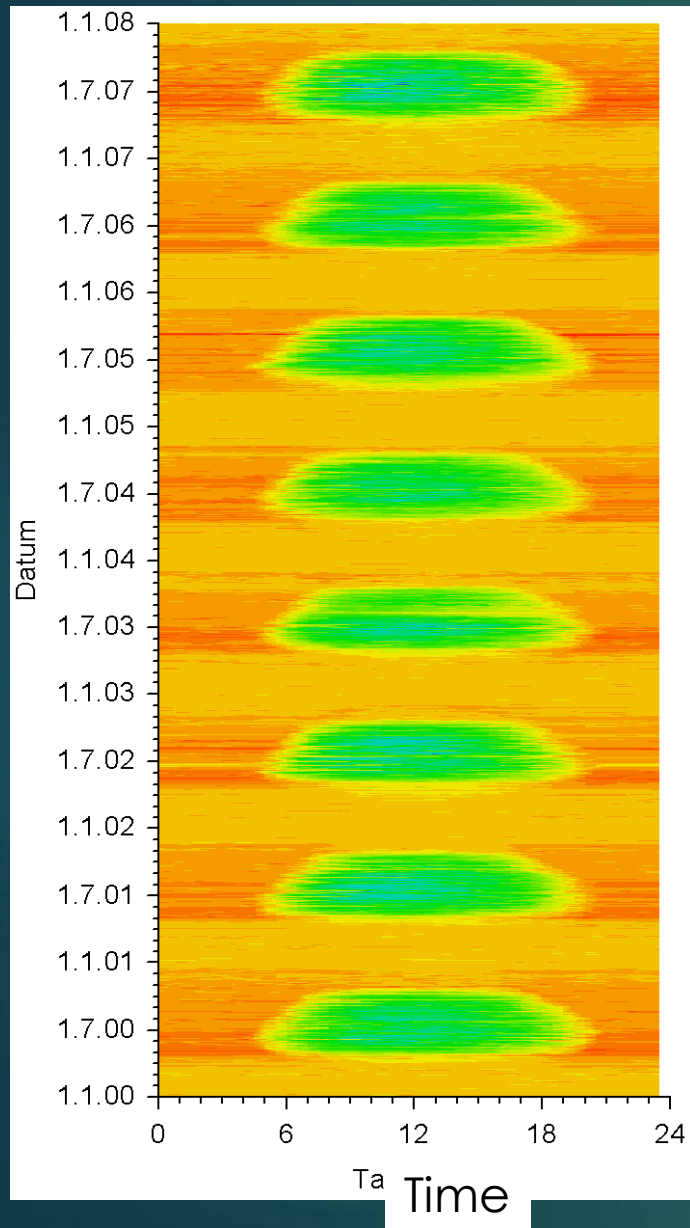
Model & satellite validations



In-situ atmosphere measurements – Global Atmosphere Watch



Part 2. In-situ ecosystem measurements



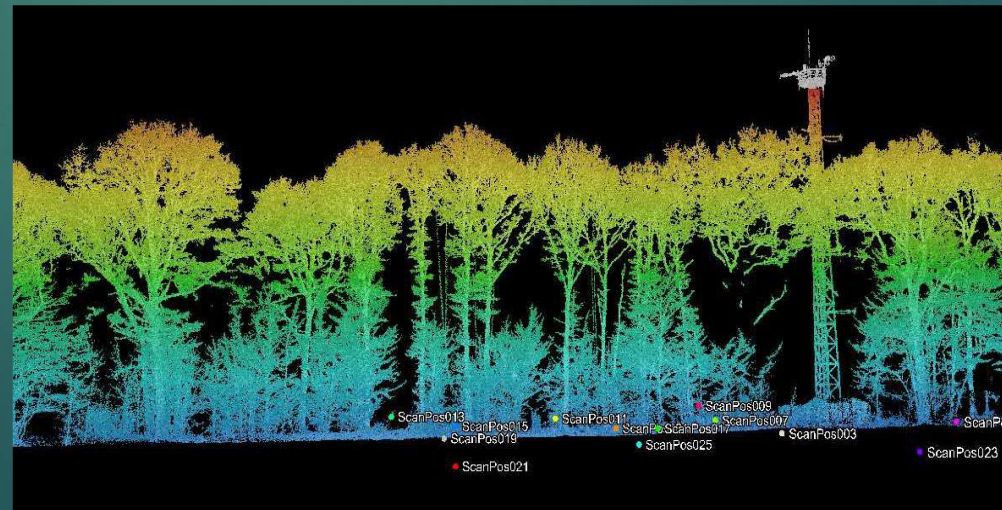
ICOS Scares project – Konsta Punkka

ICOS

INTEGRATED
CARBON
OBSERVATION
SYSTEM

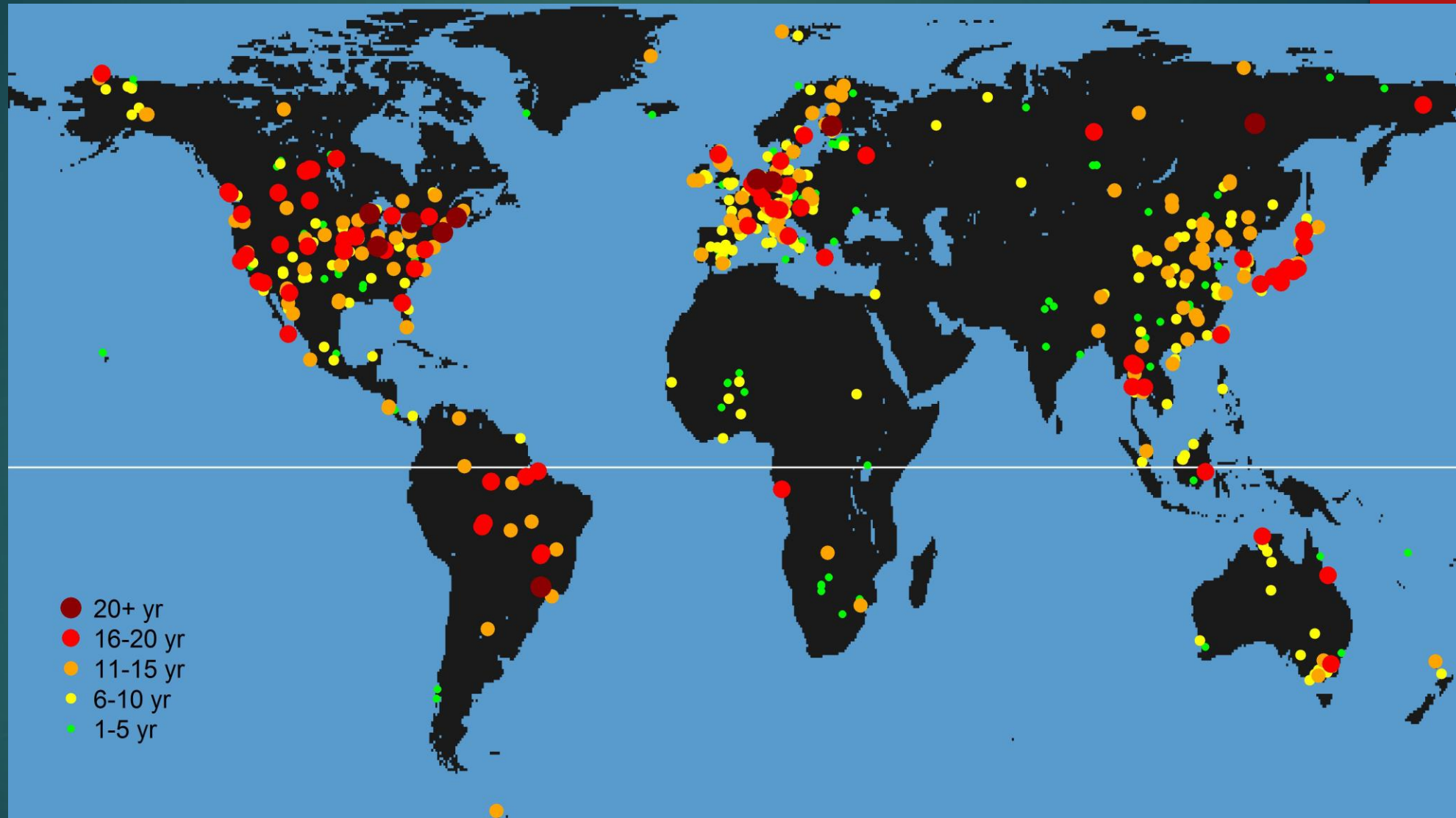
ETC. Viterbo-Bordeaux-Antwerpen

- Organisation and operation of the workflow of ecosystem data (40 → 70 stations)
- New instruments qualifications
- New techniques development
- Soil and plant archiving
- Community support



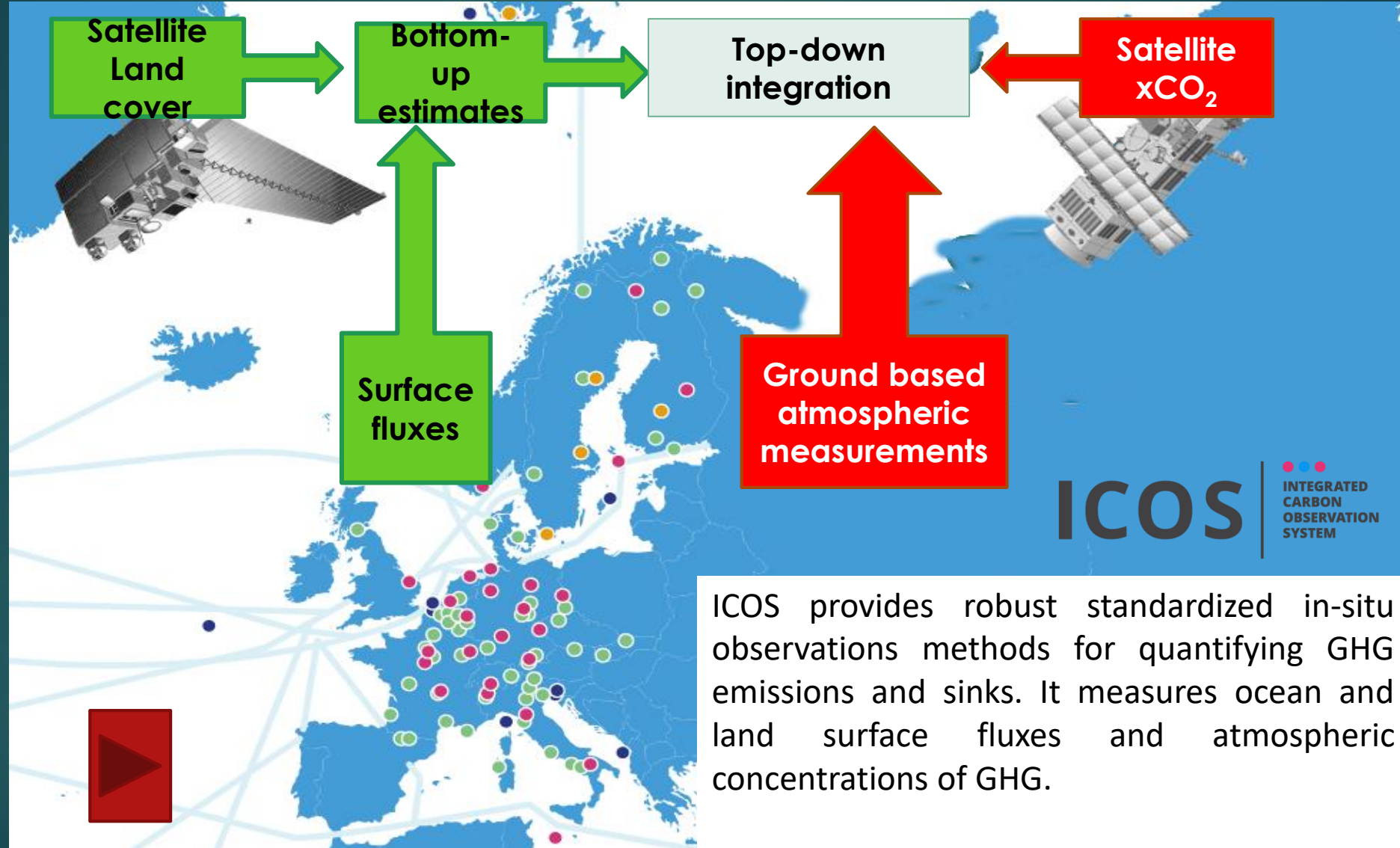
Courtesy B. Gielen, U. Antwerpen.

Part 2. In-situ ecosystem measurements - FLUXNET



Part 2.

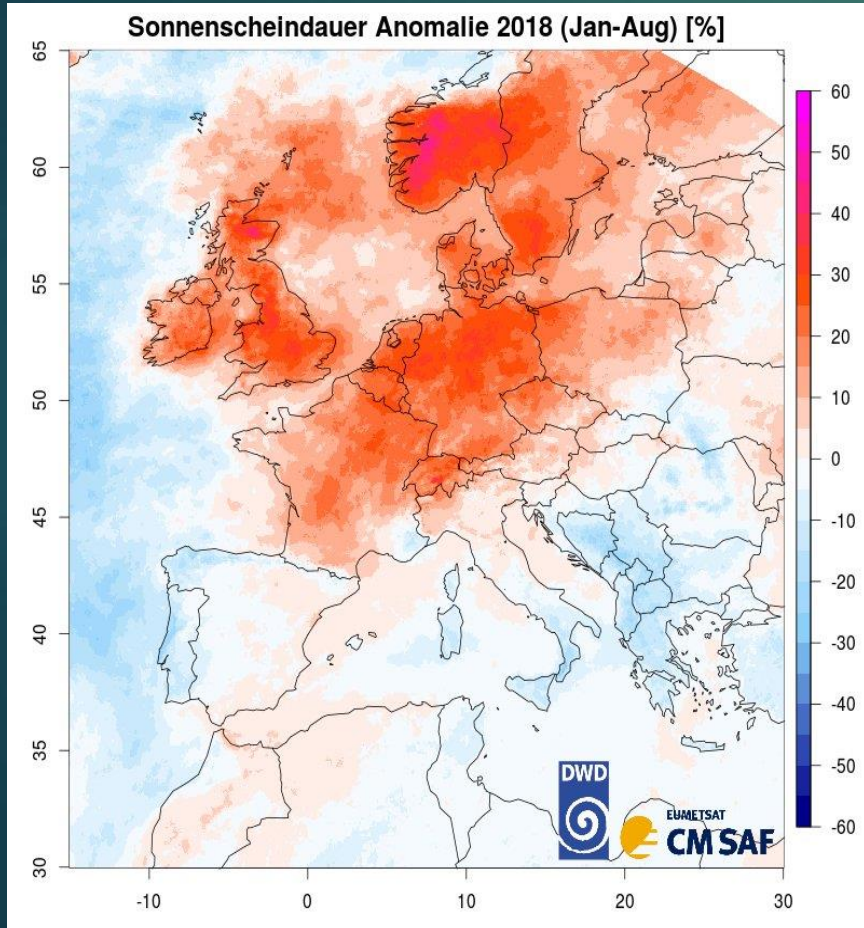
The ICOS data integration



ICOS outcome: the 2018 drought case 3

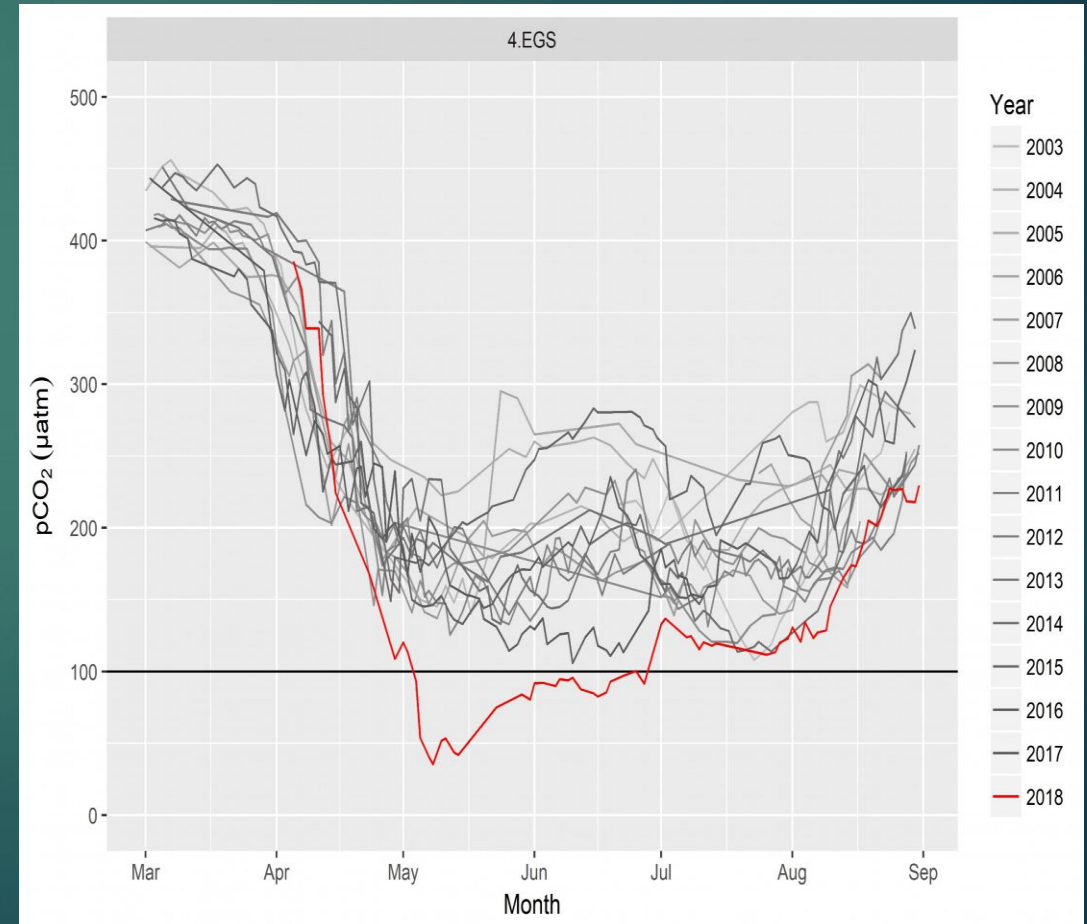
Special issue with 21 papers in Phil. Trans. Roy. Soc.

Sunshine hour anomaly (Jan-Aug) (%)

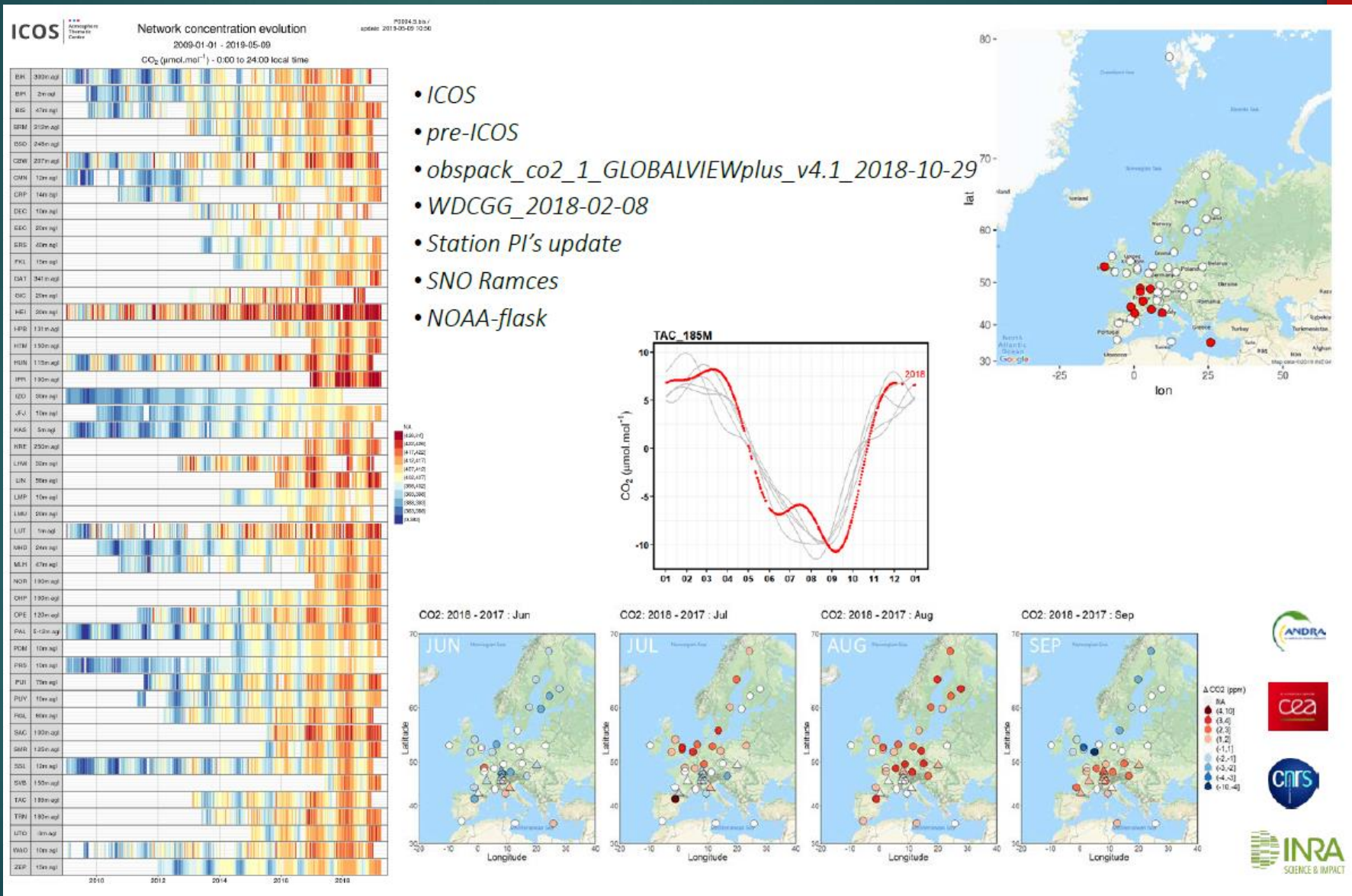


Baltic Sea 2018

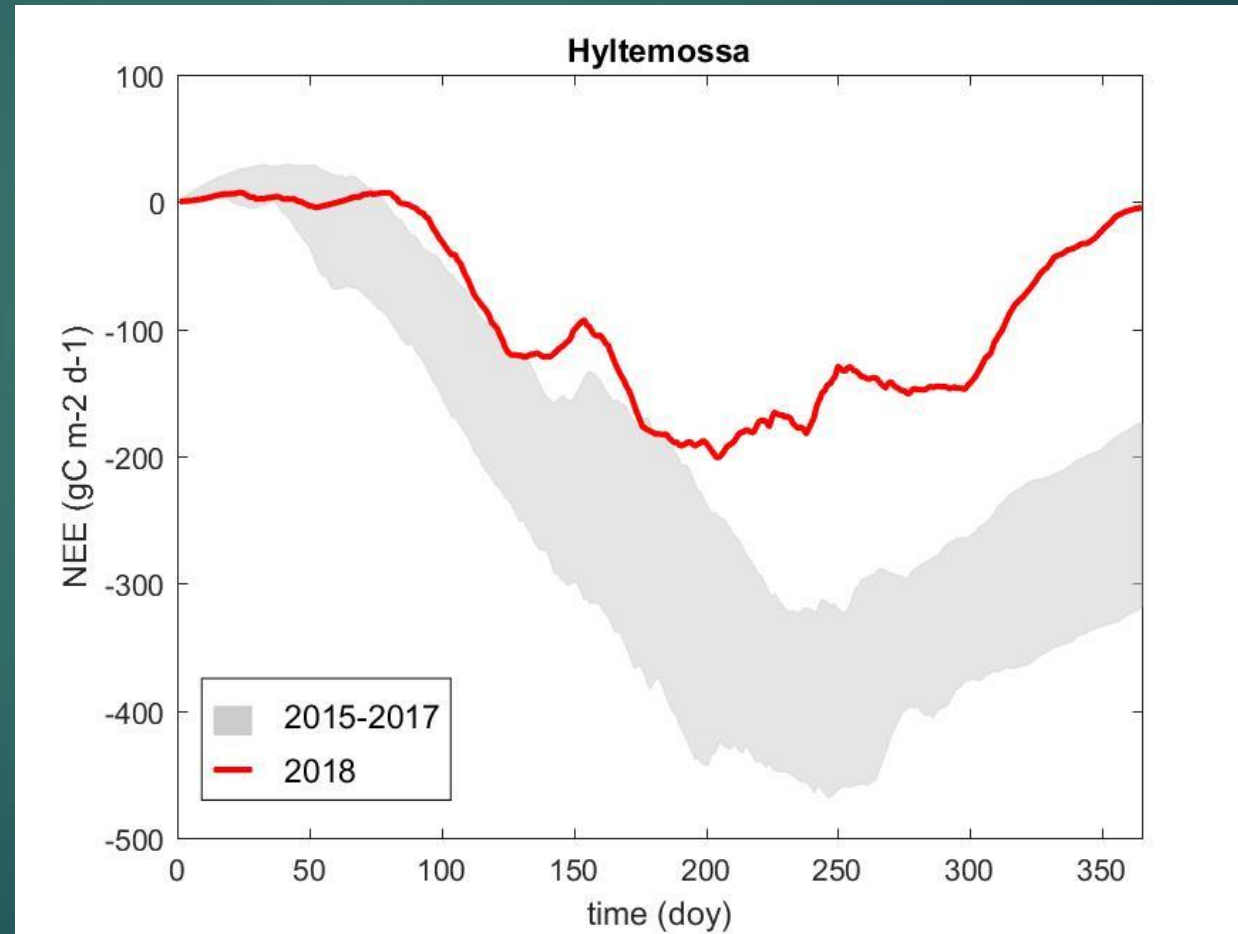
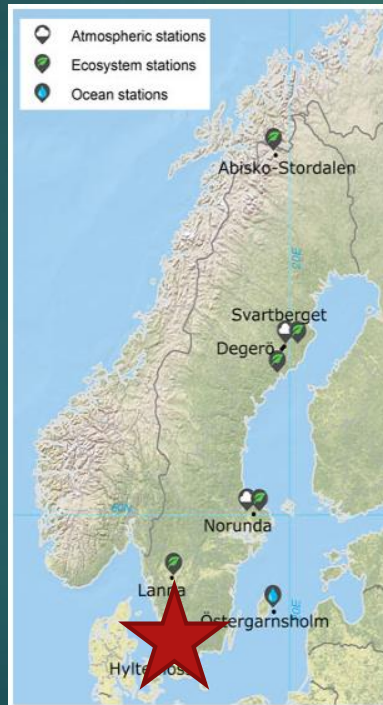
(Slide by Gregor Rehder, IOW)



[CO₂] air seasonal cycles



Ecosystems: example forest site, south Sweden



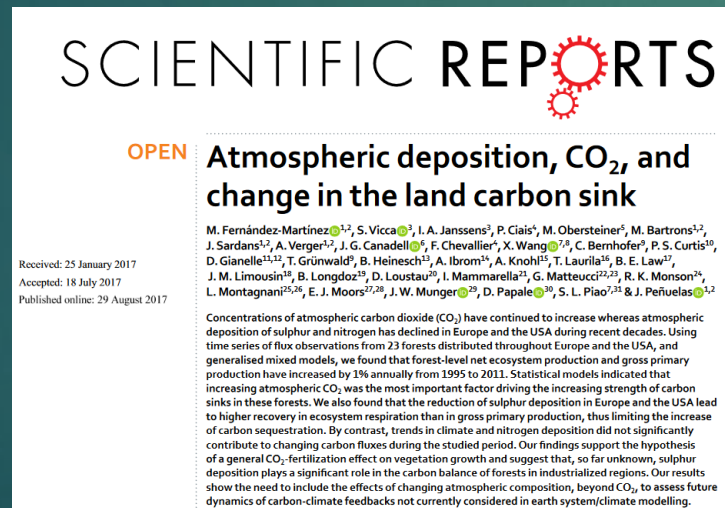
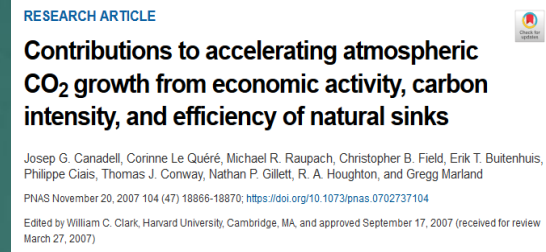
Part 3.

How could we see the unseen ?

- GHG exchange with land surface is changing continuously in response to :
 - CO₂ concentration,
 - Climate,
 - Ozone, nitrogen & sulfur deposition,
 - Management...

- Effects are :
 - Non-linear, accumulative or transient
 - Interacting:
 - ⇒ antagonistic (CO₂ × O₃),
 - ⇒ synergistic (CO₂ × N, T × VPD)
 - Heterogeneous in temporal and spatial domains

Are we able to observe and understand the temporal variations in land surface GHG?

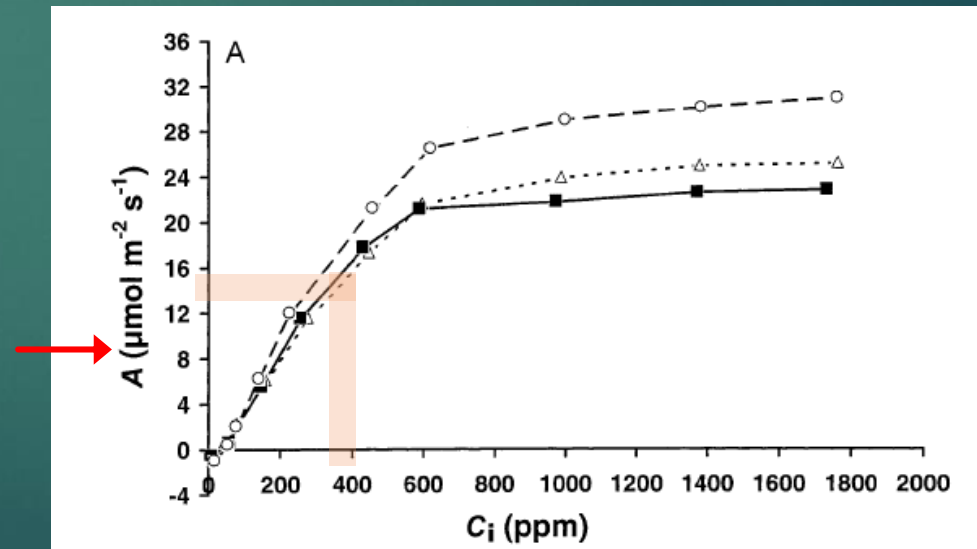


The CO₂ case

Well documented temporal evolution since 1958 ([see previous slides](#))

Well-known effect on CO₂ uptake at leaf and plant level:

The [CO₂]_a change from 1995 to 2015, (+ 40 ppm) enhances leaf photosynthesis (A) by 12-15%



Response of pine needle assimilation to CO₂.

Porté & Loustau
1998, Tree Physiol.

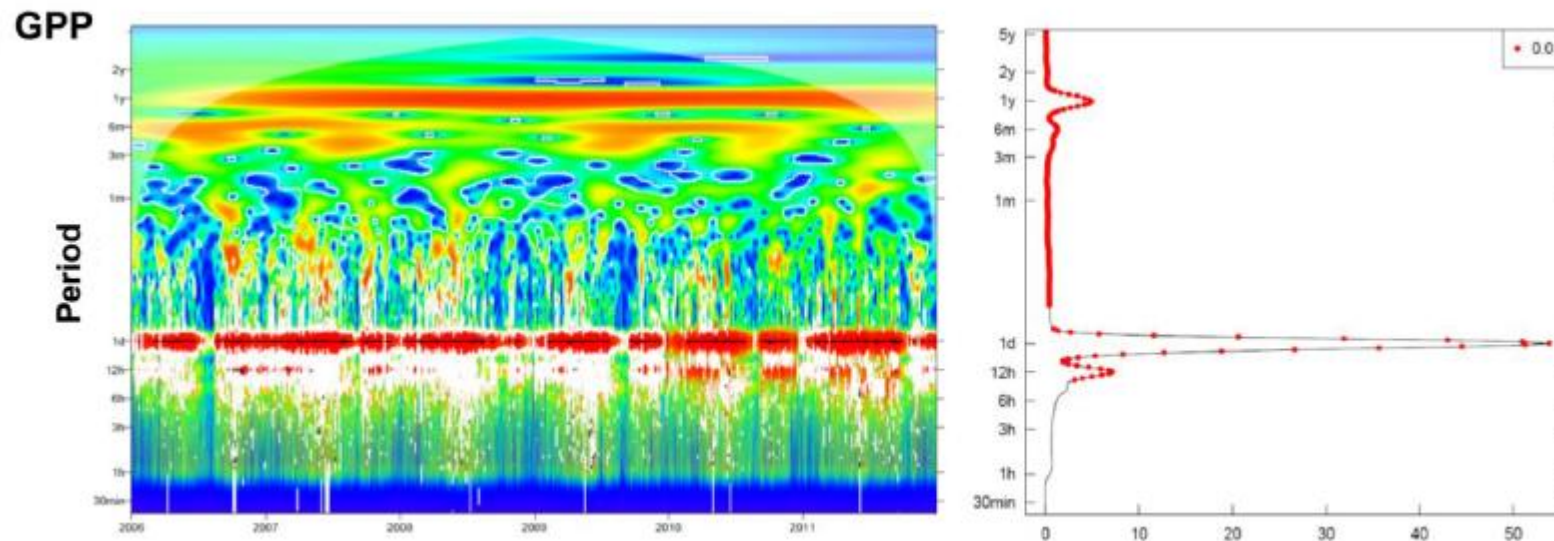
The CO₂ case

What to observe ?

→ Gross CO₂ uptake by land surface, GPP

At which resolution / scale ?

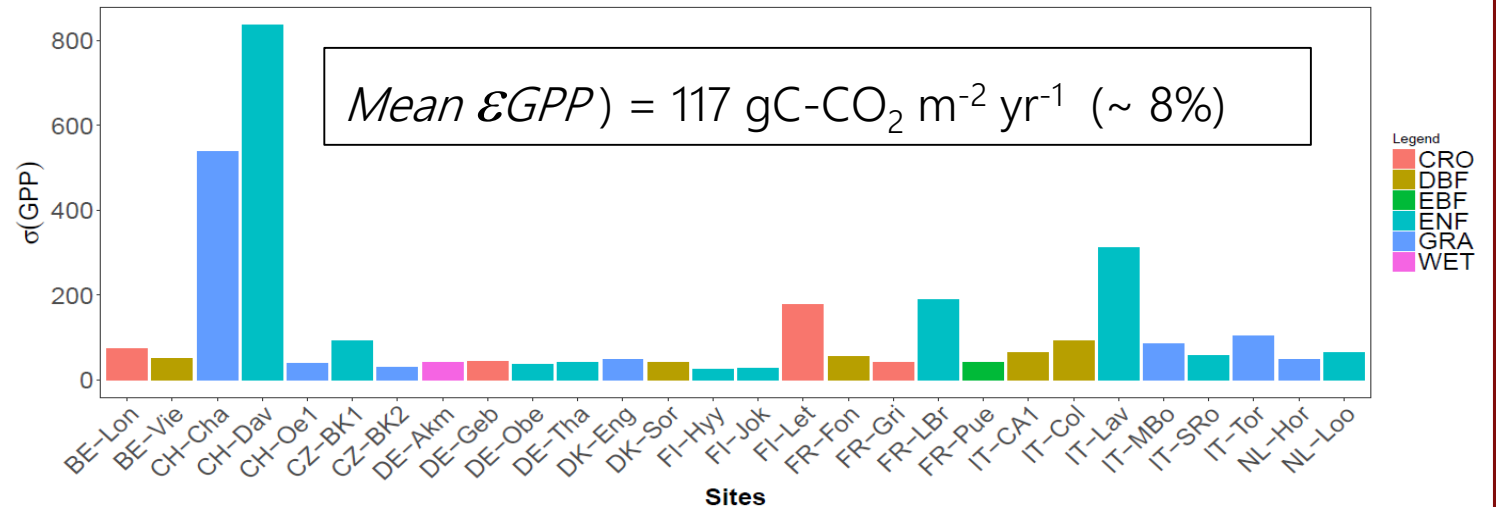
→ Instantaneous values (hour) and temporal integrals (year)



Power spectrum of *GPP* at the Puechabon forest site 2006-2011.

1st step . Assessment of the uncertainty in GPP measurements $\varepsilon(GPP)$

- u^* filtering,
- Random uncertainty
 - Instrument noise
 - Covariance sampling error

 $\sigma(GPP)$ (gC m⁻² y⁻¹)Error in gross CO₂ uptake (GPP) at the pre ICOS stations

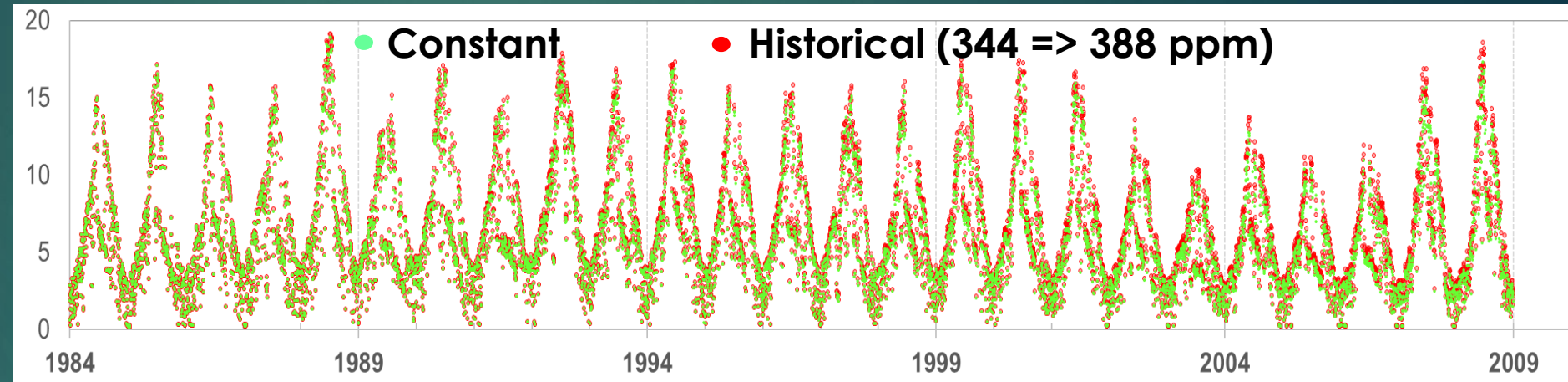
Part 3.

Can we see the unseen ?

2nd step. Expected magnitude of [CO₂] impact on *GPP*: model results

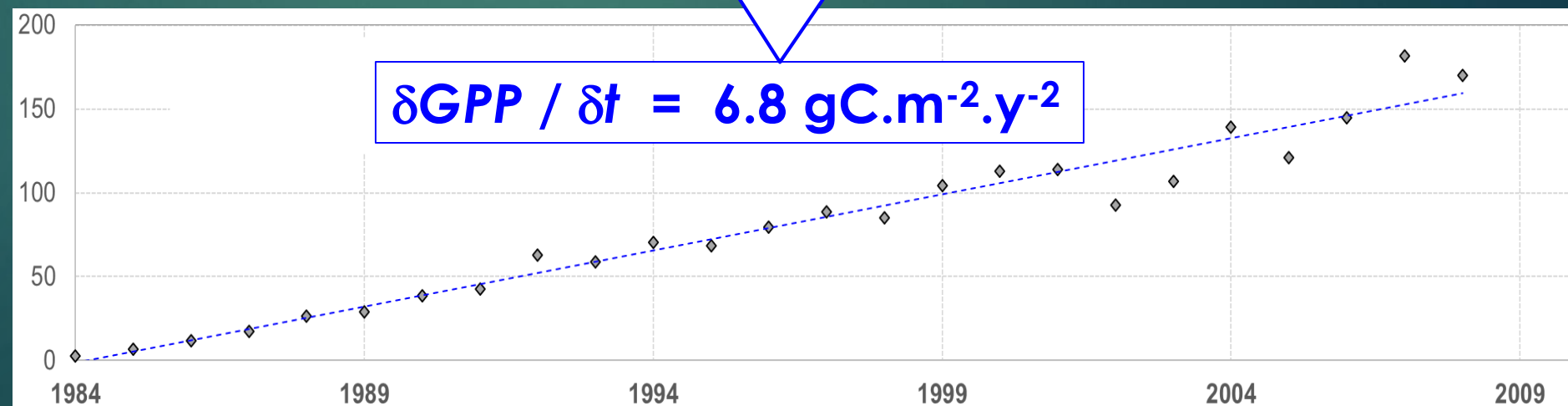
30yr old coniferous forest – Gross CO₂ uptake (*GPP*)

Daily *GPP*
(gC.m⁻² d⁻¹)



Annual drift
 δGPP
(Hist – Const)

(gC.m⁻² y⁻²)



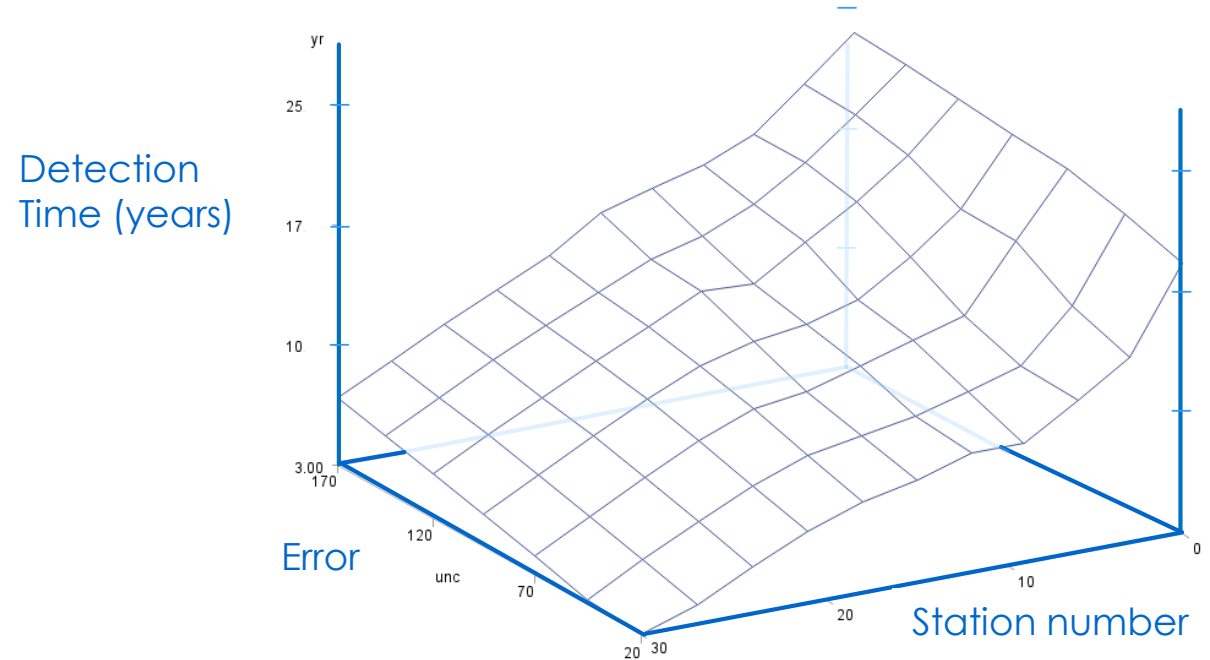
3rd step . Modelling the sensitivity of station network to the [CO₂] drift

→ Simple regression model applied to an ensemble of 2500 virtual networks

→ GPP modelled as :

$$\frac{\partial(GPP)}{\partial t} \times t + \beta (IAV) + \mathcal{N}(\overline{GPP}, \varepsilon(GPP))$$

(IAV being the natural residual variability.)



Detection threshold surface for $\delta y / \delta t = 0,015$

The plotted area delimits the duration and size needed for detecting a temporal trend in $\delta GPP / \delta t = - 1,5\% \text{ yr}^{-1}$ ($p=0,05$).

Part 3.

Can we see the unseen ?

4th step. Designing an optimal ecosystem network 2020-2050

- Projection of expected changes in Ecosystem drivers along 2020-2040

Temperature ↗

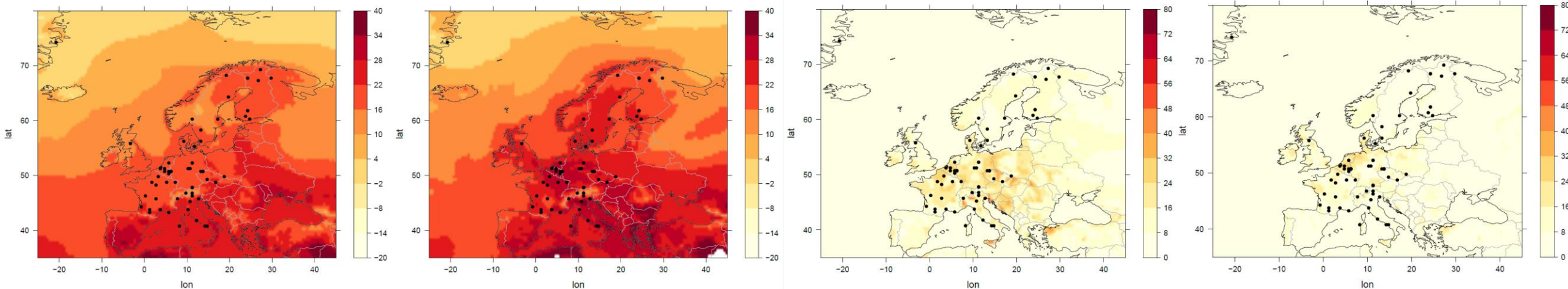
O₃ dry deposition ↘

15/07/1995

15/07/2045, RCP4.5

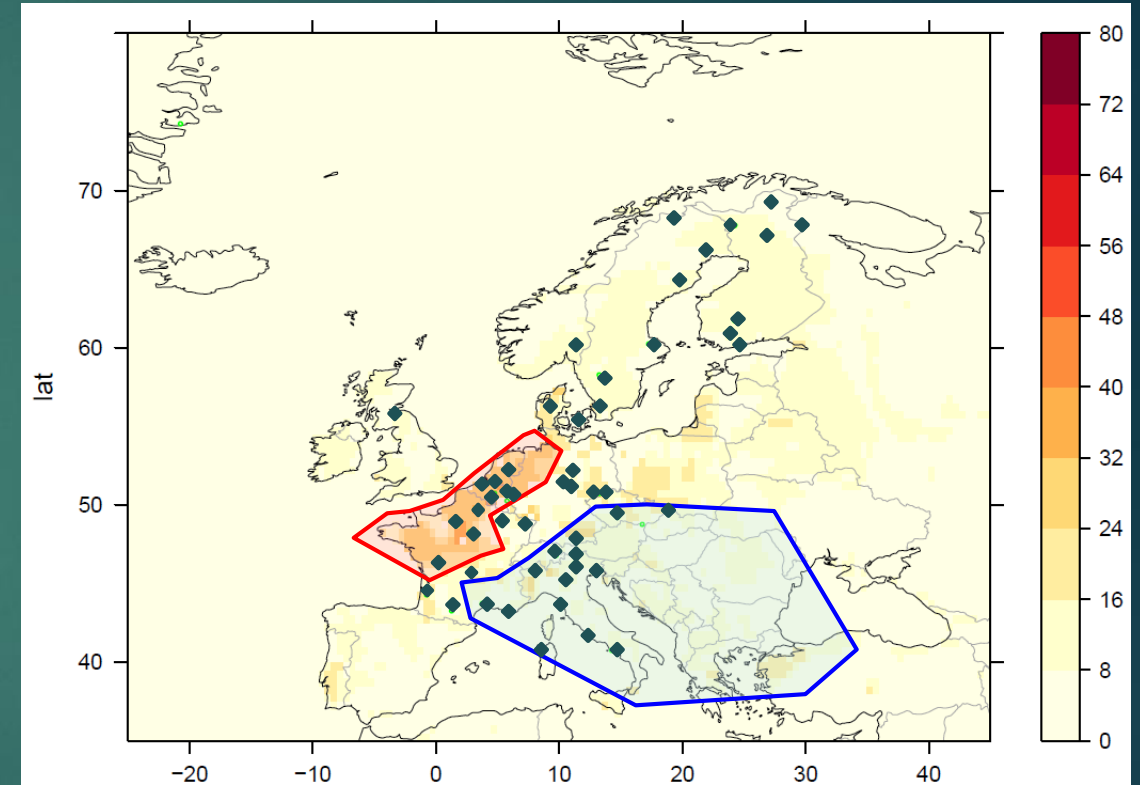
15/07/1995

15/07/2045



4th step. Designing an optimal ecosystem network 2020-2050

- Partitioning Europe among homogenous eco(iso)zones
= Subdomains where changes in O_2 , N, CO_2 and climate are homogenous. Ex.:
 - O_3 ecozones:
 - no change**, n = 22 stations
 - enhanced**, n = 10 stations
 - decreased**, n = 12 stations
- Ensure the completeness and coverage of relevant variables in each subdomain



2035 anomaly of O_x deposition over Europe.
Simulation by the MOCAGE météo France model
B. Josse et al. 2019.

The black hole observation lesson

nature [Subscribe](#)

NEWS · 10 APRIL 2019

Black hole pictured for first time – in spectacular detail

The Event Horizon Telescope’s global network of radio dishes has produced the first-ever direct image of a black hole and its event horizon.

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Katie Bouman: The woman behind the first black hole image

11 April 2019 [f](#) [p](#) [t](#) [m](#) [Share](#)



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SPACE + SCIENCE

This is the first photo of a black hole

By [Ashley Strickland](#), CNN

Updated 1640 GMT (0040 HKT) April 10, 2019

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The first black hole image: what can we really see?

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Last week scientists produced the first image of a black hole, shining a light on one of the universe’s great mysteries

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La première photo d’un trou noir publiée par un consortium scientifique international

L’image montre le trou noir supermassif de M87, une galaxie elliptique géante située à 53 millions d’années-lumière de la Terre.

Par Pierre Barthélémy · Publié le 10 avril 2019 à 15h16 · Mis à jour le 11 avril 2019 à 08h58

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The first picture of a black hole opens a new era of astrophysics

The supermassive beast lies in a galaxy called M87 more than 50 million light-years away

The black hole observation lesson

To see the unseen, let's be standardised, synchronised, accurate and multiple,





And get fun !!

Thank you for attention

Most illustrations were taken from ICOS presentations available at ICOS web pages and French ICOS web Site and were cooked by:

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Werner Kutsch (DG ICOS RI)

Alex Vermeulen (Carbon Portal, ICOS-RI)

Philippe Ciais (LSCE, IPSL, ICOS-France)

Léonard Rivier (LSCE, IPSL, ICOS-France)

Benjamin Pfeil, ICOS-OCEAN

Armin Jordan, Heidelberg University, ICOS-CAL