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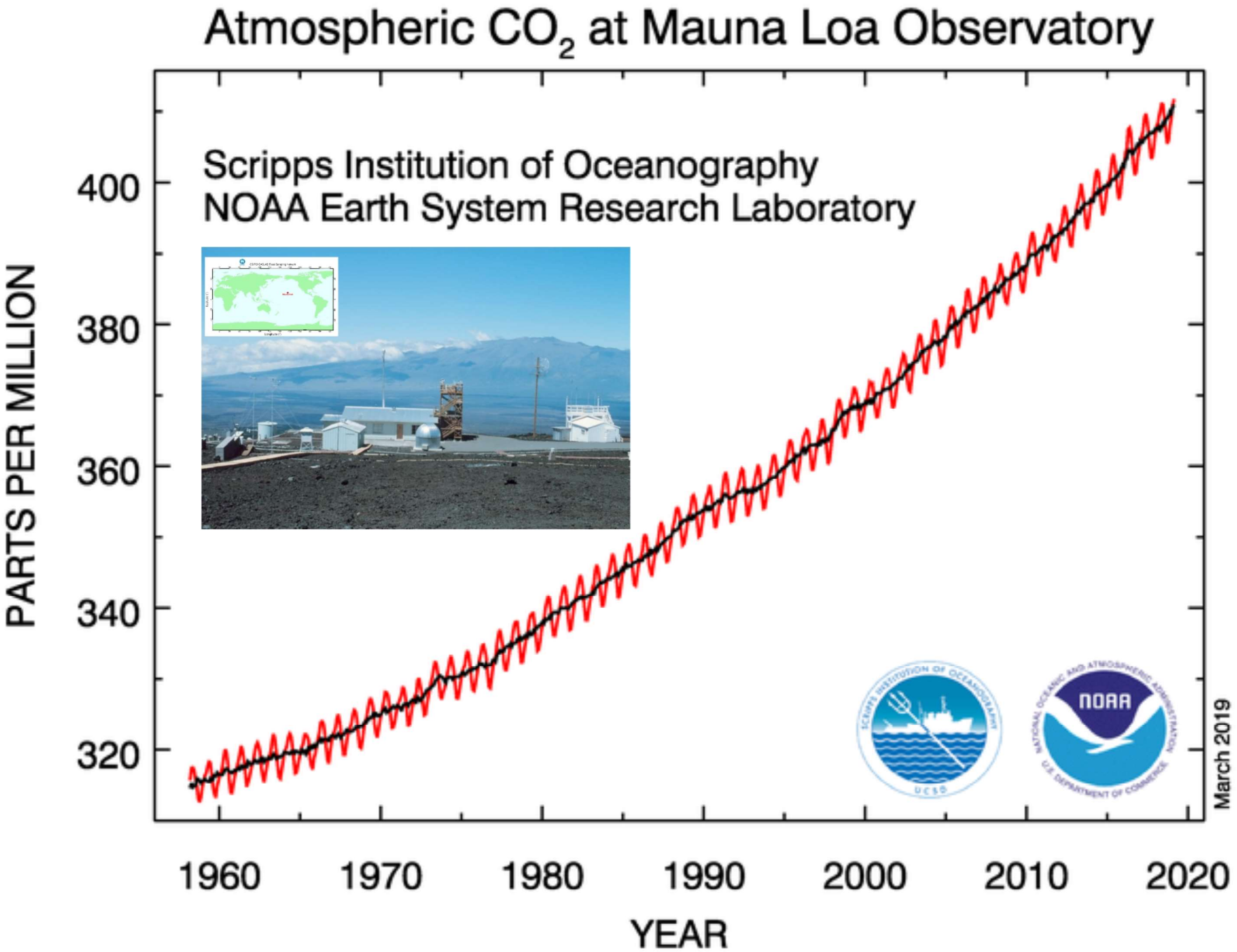
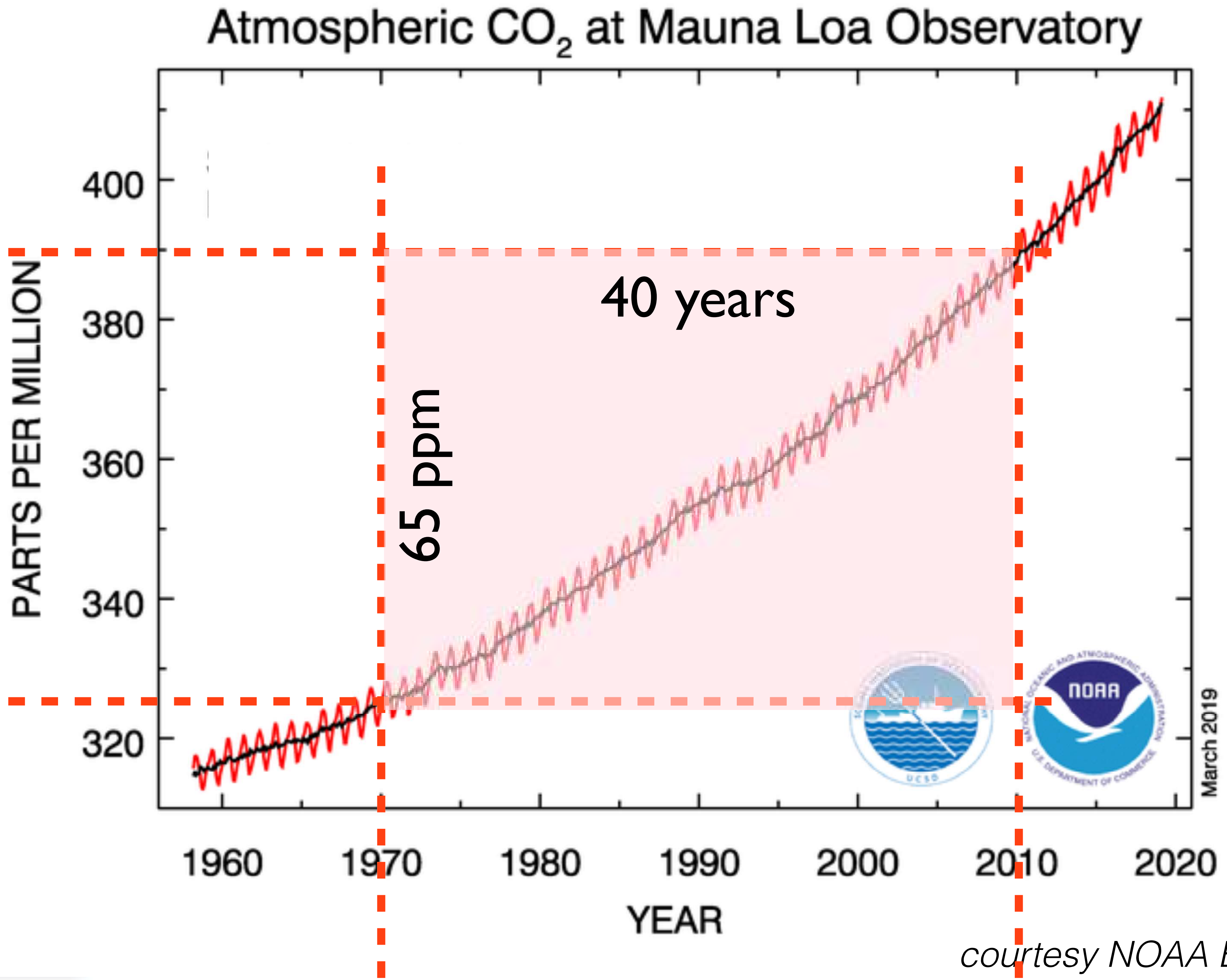
Interactions between the carbon cycle and climate from local to global scales

Wouter Peters
&
Carbon cycle group @ Wageningen
Stable Isotope group @ Groningen

university of groningen

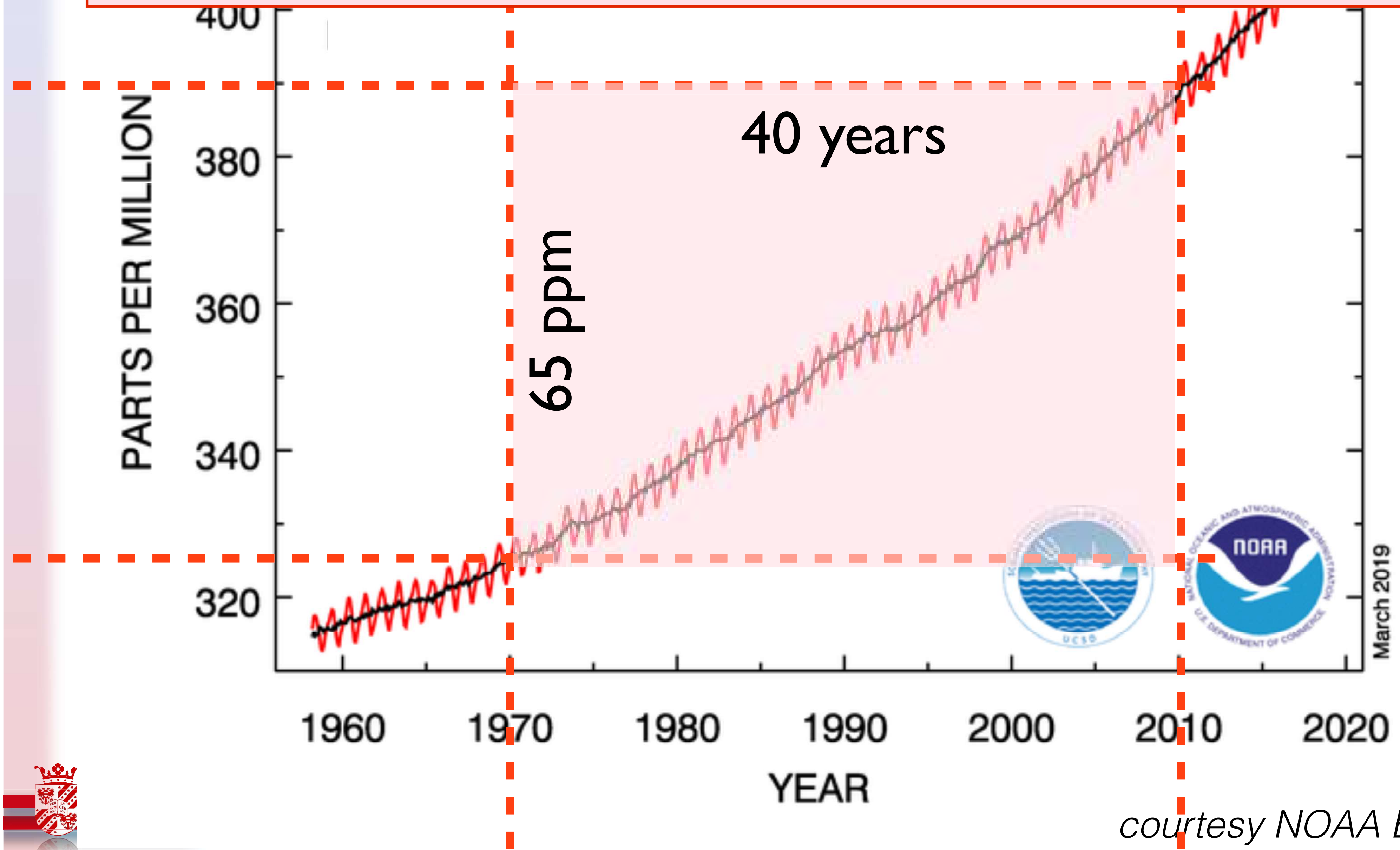


courtesy NOAA ESRL



courtesy NOAA ESRL

$$\frac{\Delta[CO_2]}{\Delta t} = F_{\text{fossil}} + F_{\text{fire}} + F_{\text{ocean}} + F_{\text{biosphere}}$$

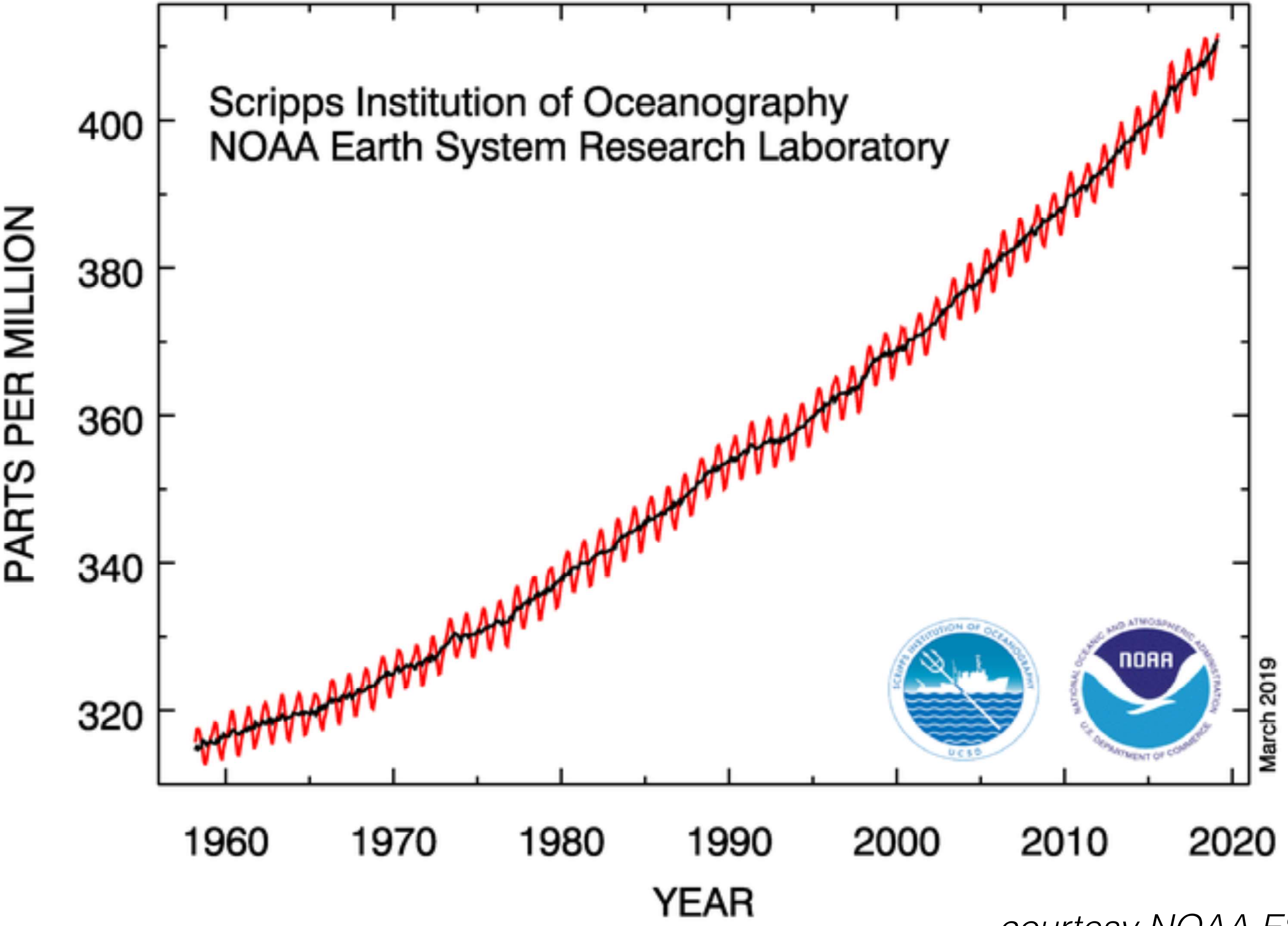


courtesy NOAA ESRL

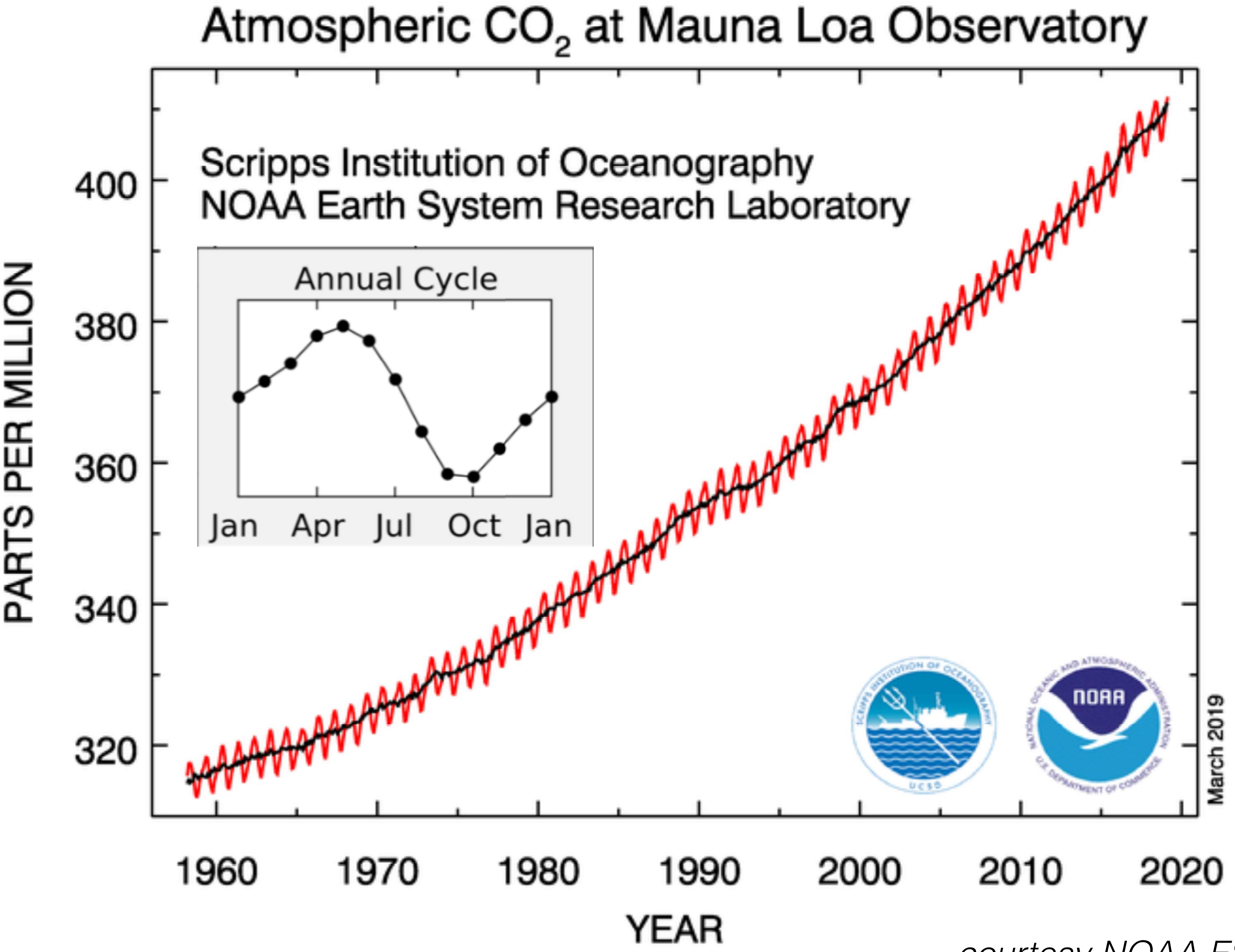
The carbon cycle

Tans et al., 1990: 1.4 PgC/yr ocean, 2.0 PgC/yr land
Keeling et al., 1996: 1.7 PgC/yr ocean, 2.0 PgC/yr land
Gurney et al., 2002: 1.7 PgC/yr ocean, 1.5 PgC/yr land
Watson and Orr, 2003: 2.4 PgC/yr ocean, ...
Rödenbeck et al., 2003: 2.1 PgC/yr ocean, 1.2 PgC/yr land
Jacobson et al., 2007: 2.1 PgC/yr ocean, 1.1 PgC/yr land
Takahashi et al., 2008: 1.9 PgC/yr ocean, ...
Peters et al., 2010: 2.2 PgC/yr ocean, 1.7 PgC/yr land
Pan et al., 2011: 2.3 PgC/yr ocean, 2.3 PgC/yr land
Peylin et al., 2013: 2.2 PgC/yr ocean, 1.3 PgC/yr land
LeQuere et al., 2013: 2.6 PgC/yr ocean, 1.8 PgC/yr land
Peters et al., 2014: 2.3 PgC/yr ocean, 1.6 PgC/yr land
LeQuere et al., 2018: 2.4 PgC/yr ocean, 1.7 PgC/yr land

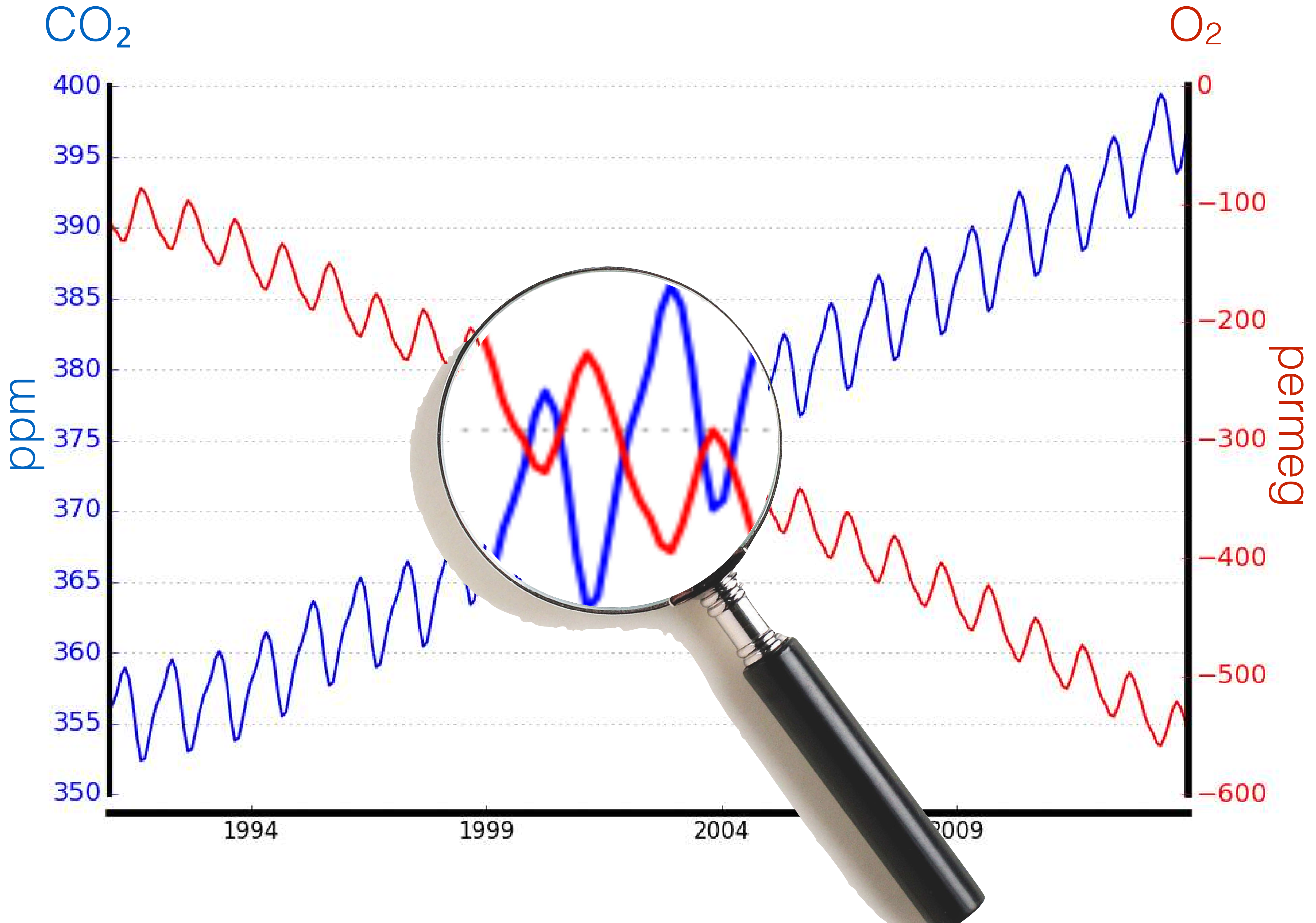
Atmospheric CO_2 at Mauna Loa Observatory

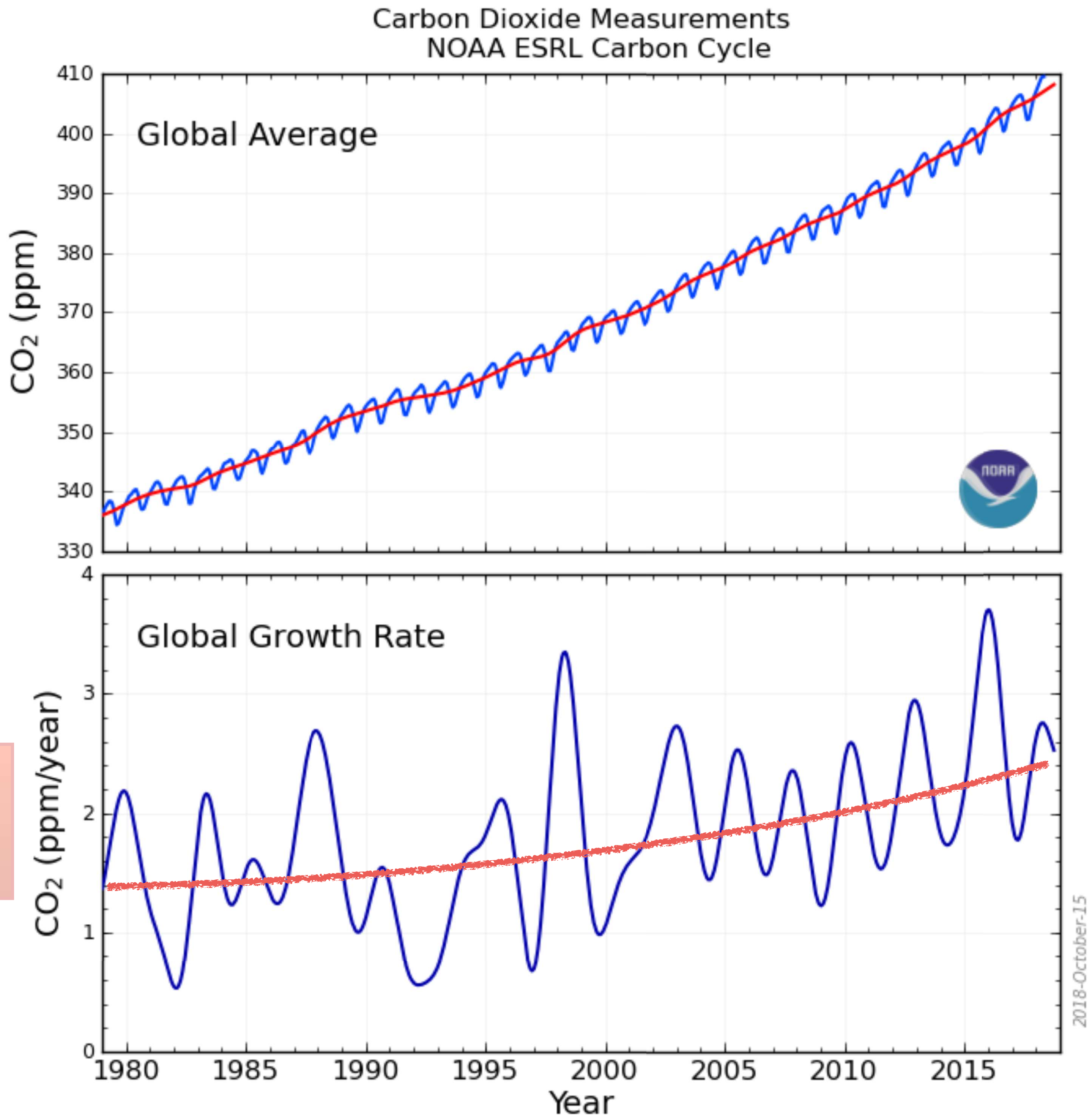


courtesy NOAA ESRL



courtesy NOAA ESRL

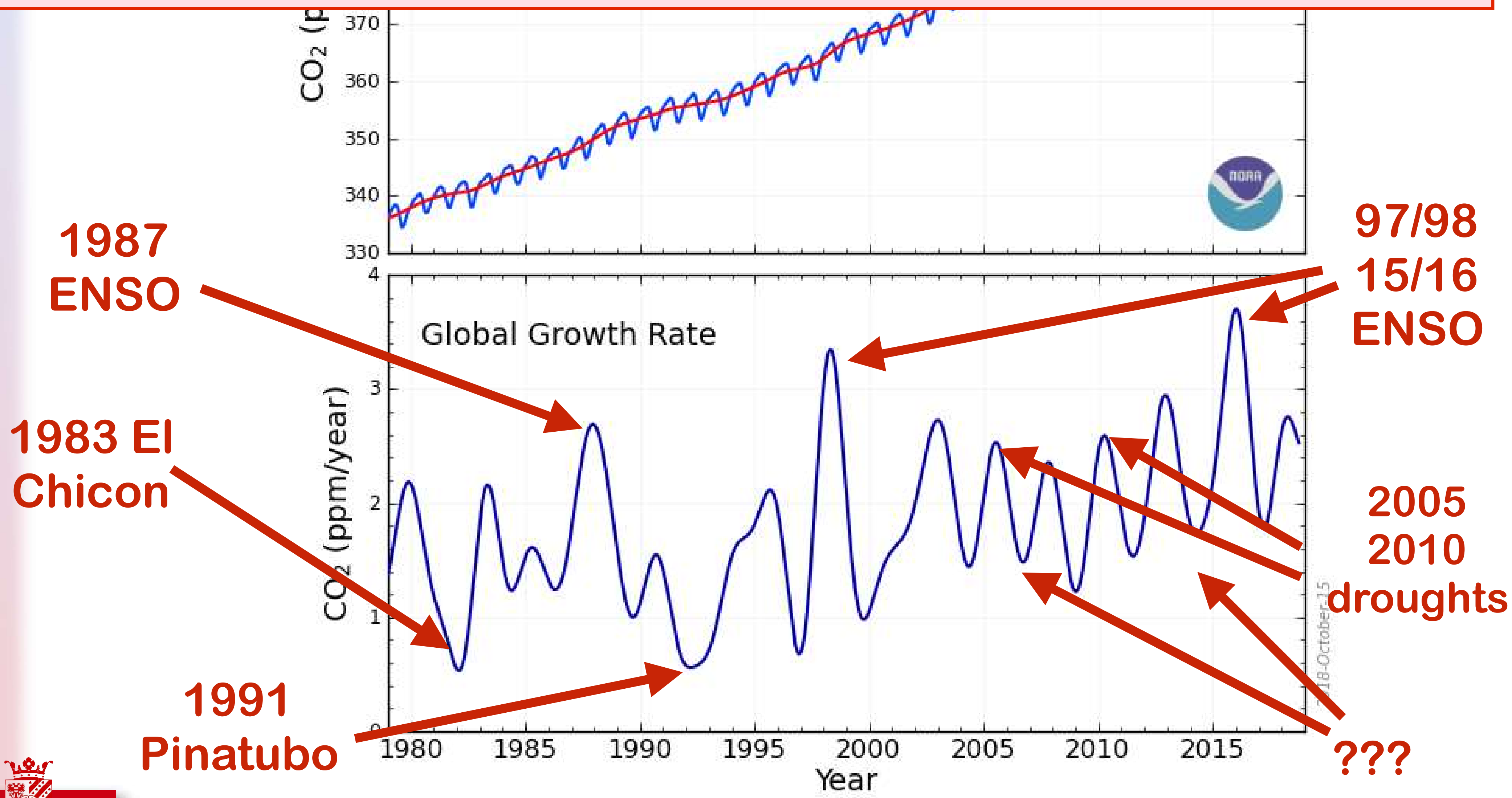

CO₂
O₂
ppm
permeg
400
395
390
385
380
375
370
365
360
355
350
0
−100
−200
−300
−400
−500
−600
1994
1999
2004
2009



$$\frac{d[CO_2]}{dt}(t)$$

courtesy NOAA ESRL

$$\frac{d[CO_2]}{dt}(t) \quad = \quad F_{fossil}(t) + F_{fire}(t) + F_{ocean}(t) + F_{biosphere}(t)$$



courtesy NOAA ESRL

Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

Corinne Le Quéré,[1,2,3]* Christian Rödenbeck,[1] Erik T. Buitenhuis,[1,2] Thomas J. Conway,[4] Ray Langenfelds,[5] Antony Gomez,[6] Casper Labuschagne,[7] Michel Ramonet,[8] Takakiyo Nakazawa,[9] Nicolas Metzl,[10] Nathan Gillett,[11] Martin Heimann[1]

The effect of permafrost thaw on old carbon release and net carbon exchange from tundra

Edward A. G. Schuur[1]*, Jason G. Vogel[1]*, Kathryn G. Crummer[1], Hanna Lee[1], James O. Sickman[2] & T. E. Osterkamp[3]

CLIMATE CHANGE

Illuminating the Modern Dance of Climate and CO_2

Peter Cox[1] and Chris Jones[2]

Searching out the sinks

Increased water-use efficiency and reduced CO_2 uptake by plants during droughts at a continental scale

ATMOSPHERIC SCIENCE

Himalaya—Carbon Sink or Source?

Jerome Gaillardet[1] and Albert Galy[2]

The carbon balance of terrestrial ecosystems in China

Shilong Piao[1], Jingyun Fang[1], Philippe Ciais[2], Philippe Peylin[3], Yao Huang[4], Stephen Sitch[5] & Tao Wang[1]

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO_2

Britton B. Stephens,[1]* Kevin R. Gurney,[2] Pieter P. Tans,[3] Colm Sweeney,[3] Wouter Peters,[3] Lori Bruhwiler,[3] Philippe Ciais,[4] Michel Ramonet,[4] Philippe Bousquet,[4] Takakiyo Nakazawa,[5] Shuji Aoki,[5] Toshinobu Machida,[6] Gen Inoue,[7] Nikolay Vinnichenko,[8]† Jon Lloyd,[9] Armin Jordan,[10] Martin Heimann,[10] Olga Shibistova,[11] Ray L. Langenfelds,[12] L. Paul Steele,[12] Roger J. Francey,[12] A. Scott Denning[13]

REVIEW ARTICLE

Global nitrogen deposition and carbon sinks

CARBON CYCLE

Sources, sinks and seasons

John B. Miller

Net carbon dioxide losses of northern ecosystems in response to autumn warming

Shilong Piao[1], Philippe Ciais[1], Pierre Friedlingstein[1], Philippe Peylin[2], Markus Reichs
Hank Margolis[5], Jingyun Fang[6], Alan Barr[7], Anping Chen[8], Achim Grelle[9], David Y. H
Anders Lindroth[12], Andrew D. Richardson[13] & Timo Vesala[14]

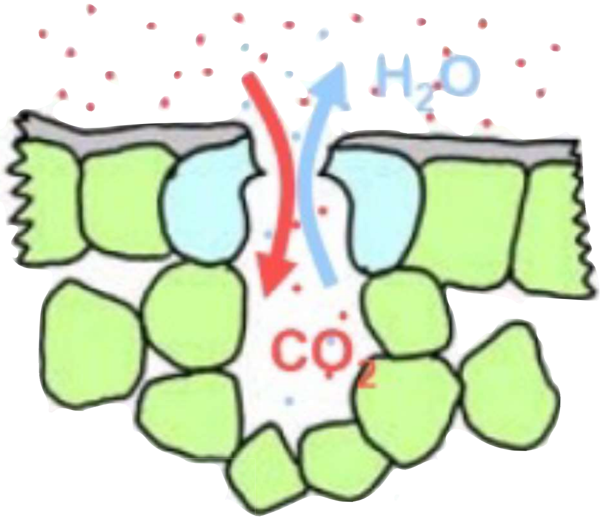
Prolonged suppression of ecosystem carbon dioxide uptake after an anomalously warm year

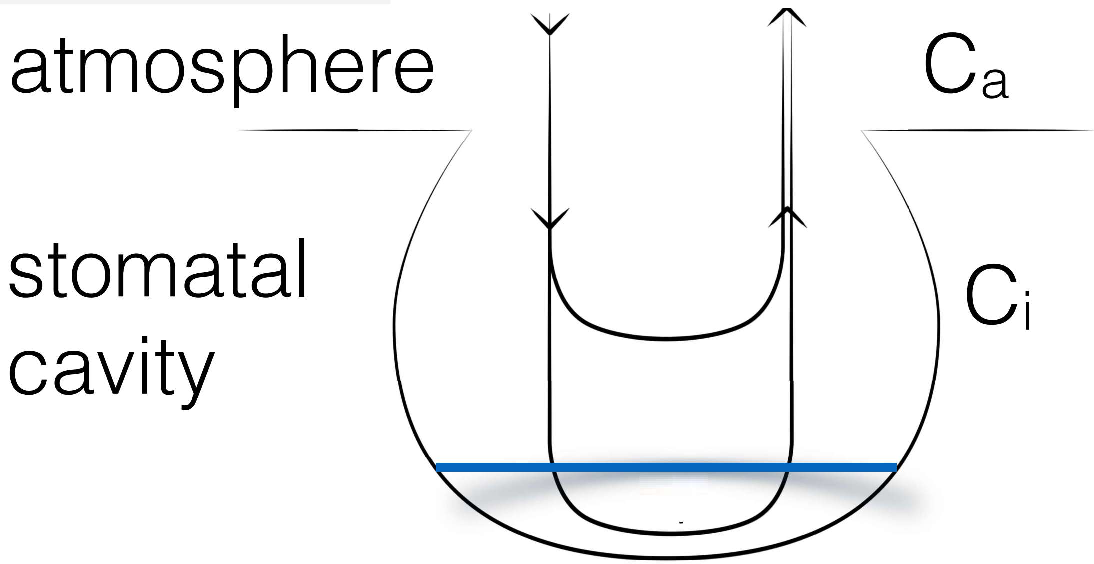
A. Arnone III[1], Paul S. J. Verburg[1], Dale W. Johnson[2], Jessica D. Larsen[1], Richard L. Jasoni[1],
arie J. Lucchesi[1], Candace M. Batts[1], Christopher von Nagy[1], William G. Coulombe[1], David E. Schorran[1],
. Buck[1], Bobby H. Braswell[3], James S. Coleman[4], Rebecca A. Sherry[5], Linda L. Wallace[5], Yiqi Luo[5]
vid S. Schimel[6]

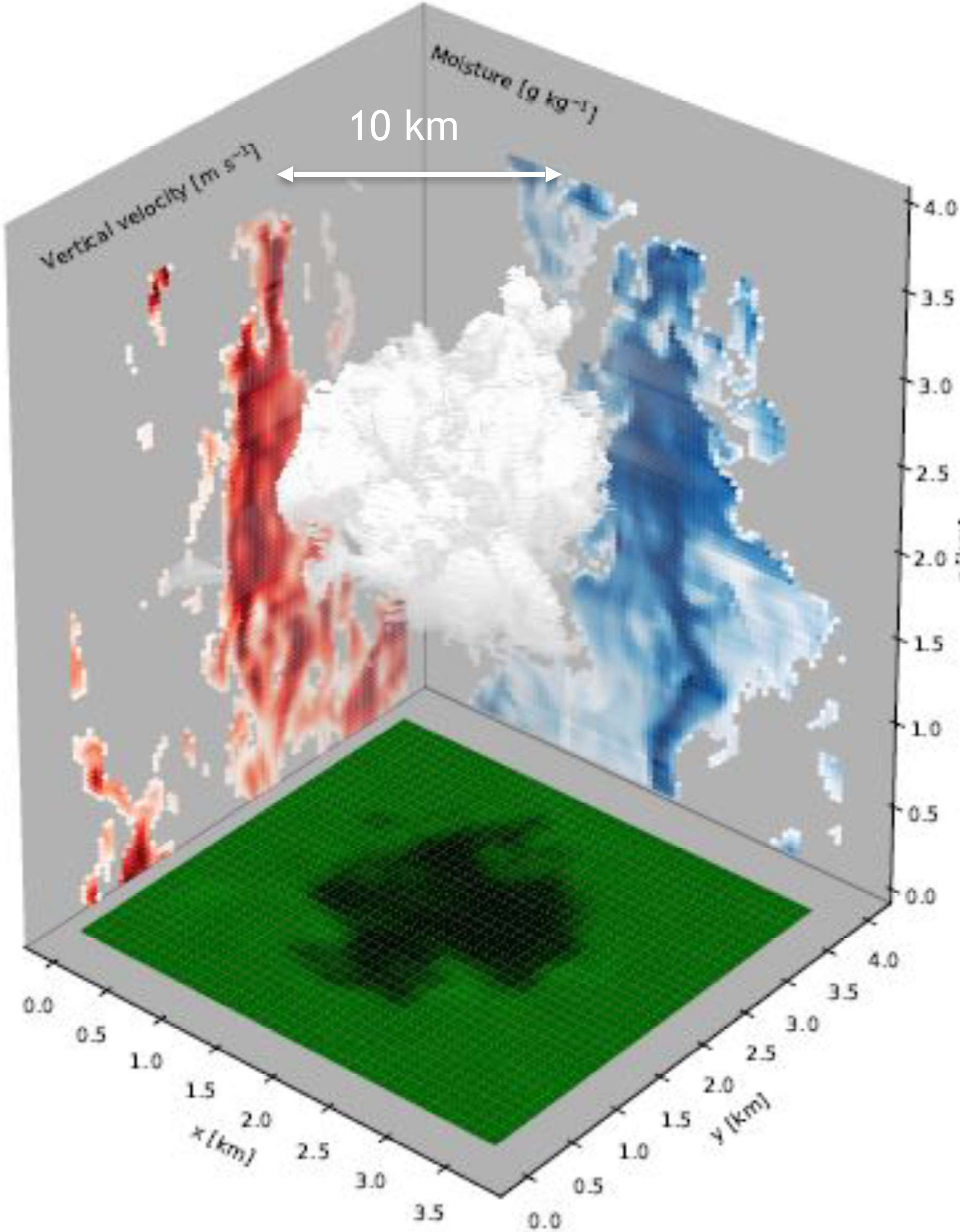
PROGRESS ARTICLE

Carbon accumulation in European forests

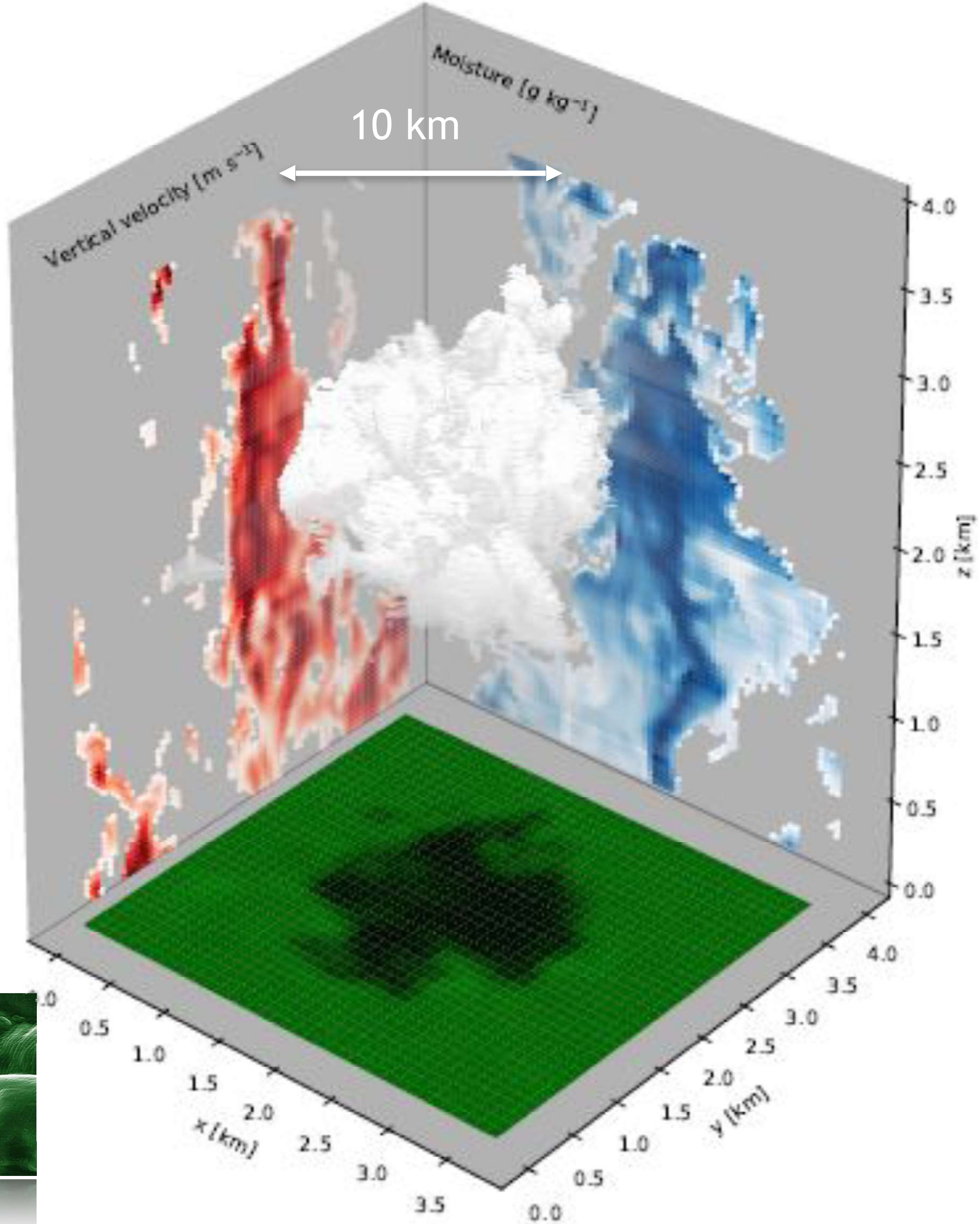
Plant Stomata

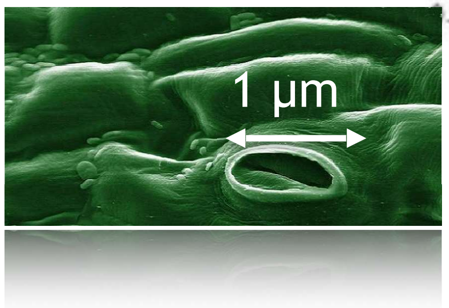






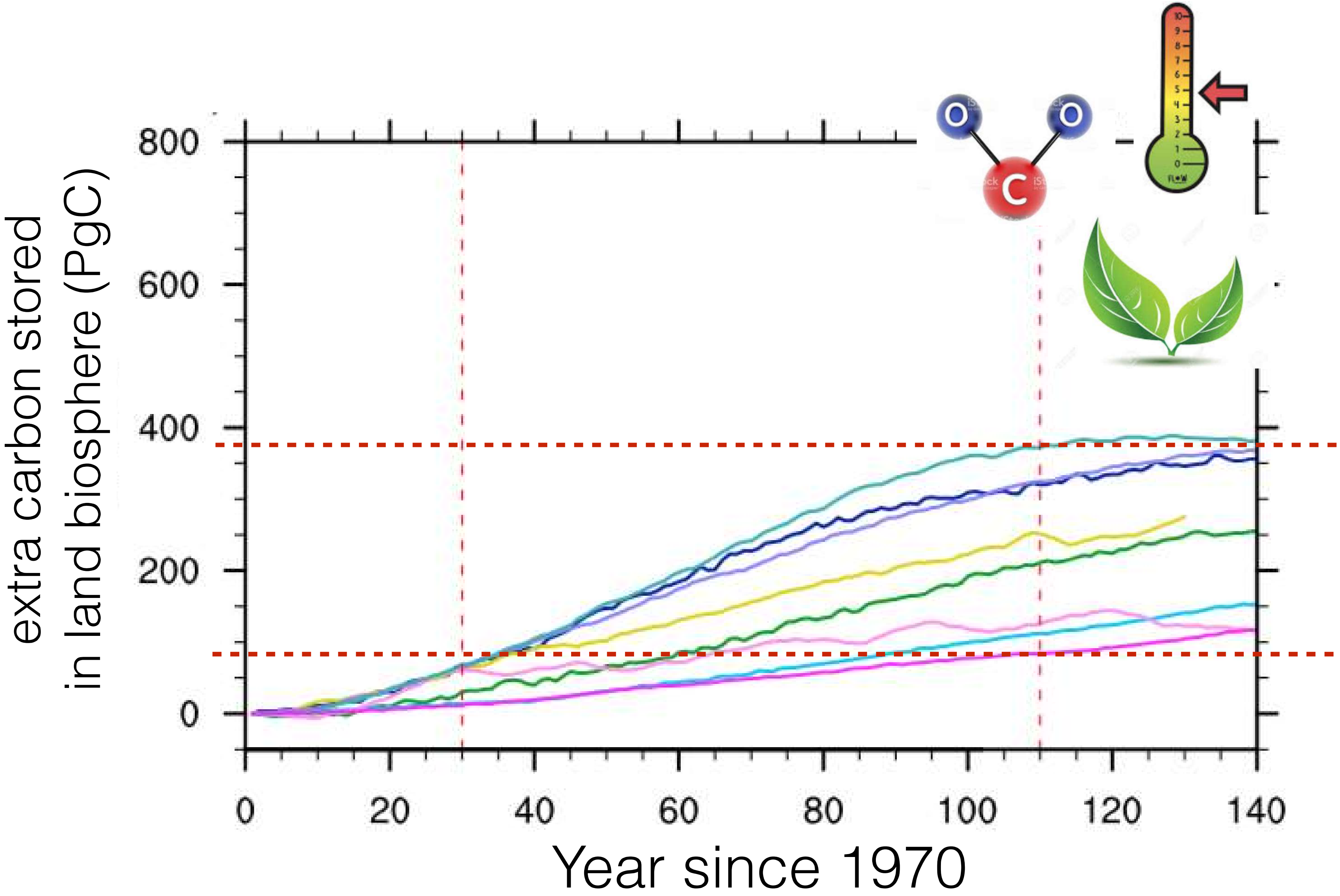
courtesy Jordi Vila and Martin Sikma





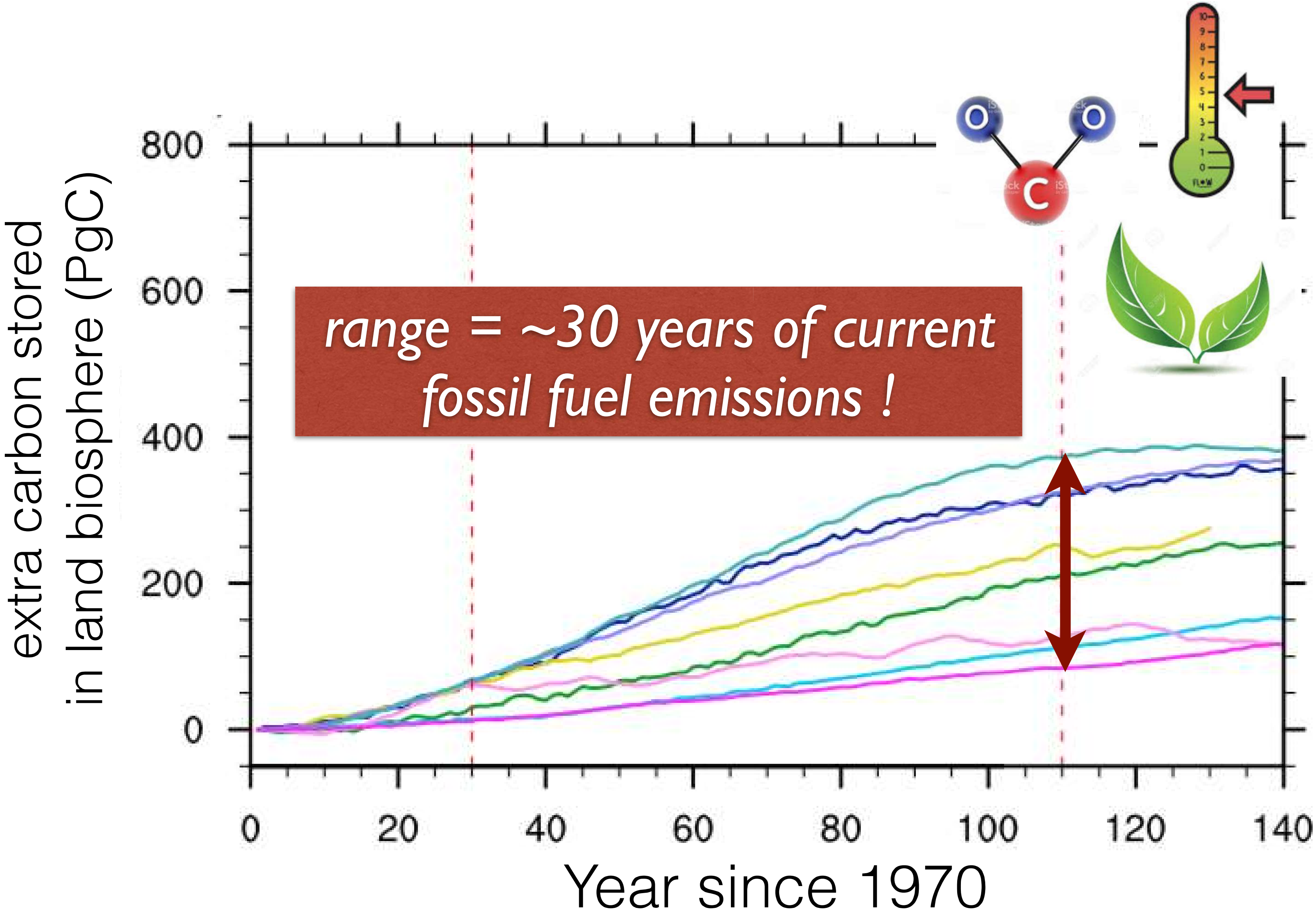
courtesy Jordi Vila and Martin Sikma

Climate models



Wenzel et al., (2014)

Climate models



Wenzel et al., (2014)

Observations

ASICA

Observations

- fingerprinting processes -

CO_2 : net ecosystem exchange

CO : combustion of fuels and biomass

COS : GPP and stomatal conductance

$\delta^{13}C$: C_i/C_a, water-use efficiency

$\Delta^{17}O$: leaf-atmosphere exchange

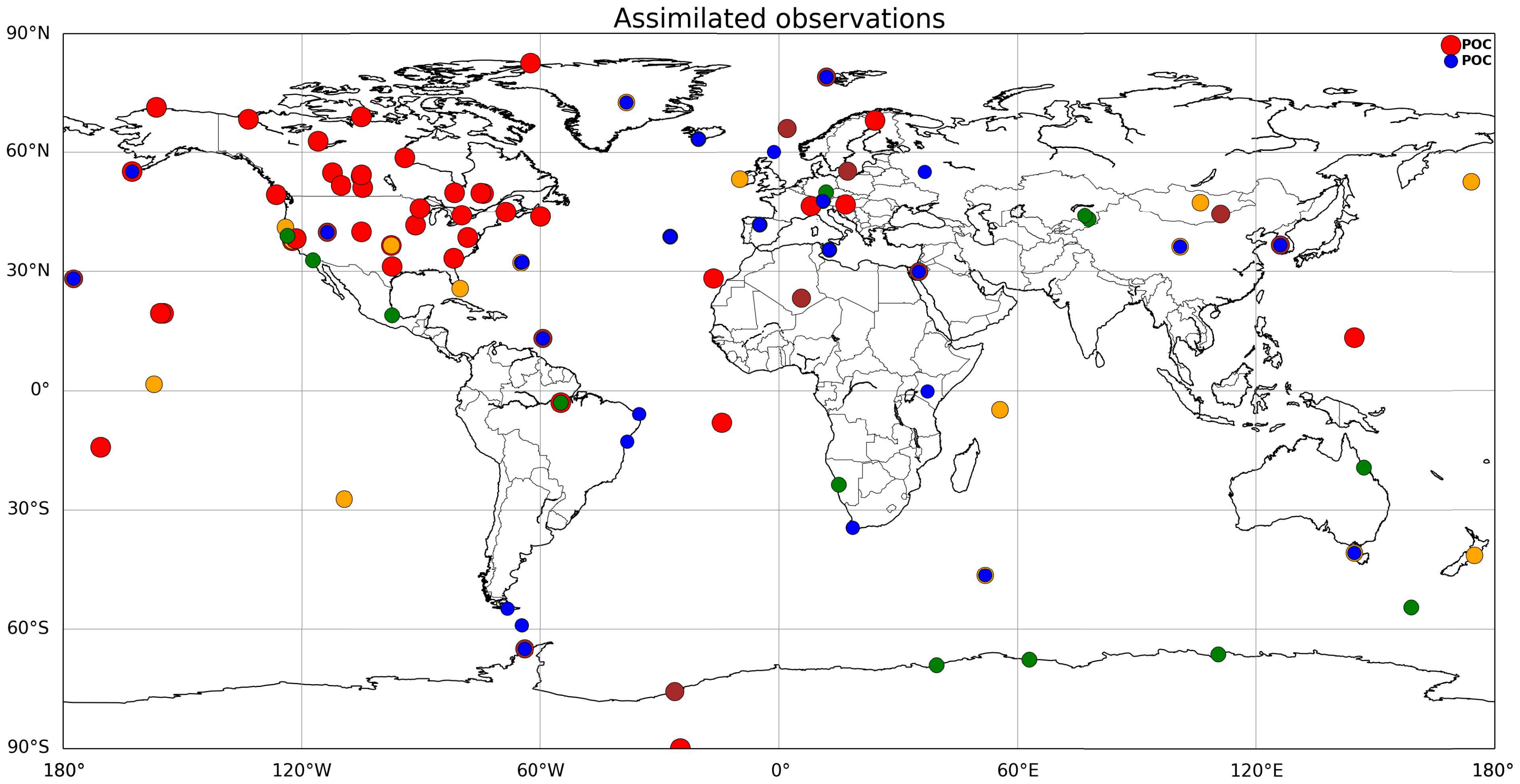
$\Delta^{14}C$: fossil fuel emissions, carbon-age

O_2 : fossil fuel sources, ocean exchange

Observations

- reanalysis of fluxes -

●: N<250 ●: N<500 ●: N<750 ●: N<1000 ●: N>1000

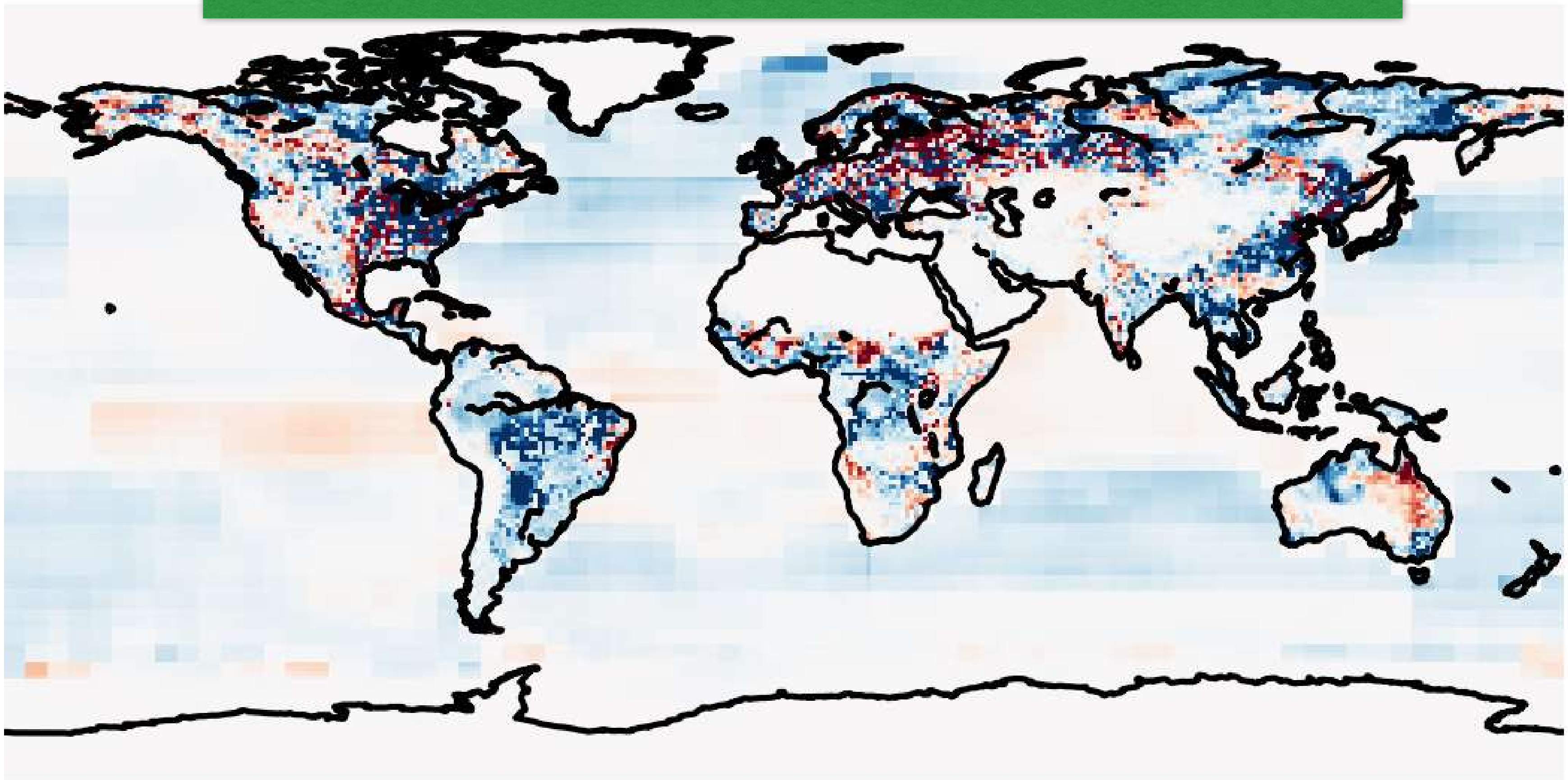


CarbonTracker Europe
© Wageningen University

Assimilation of Observations

- reanalysis of fluxes -

CarbonTracker land and ocean carbon exchange for 2017
www.carbontracker.eu



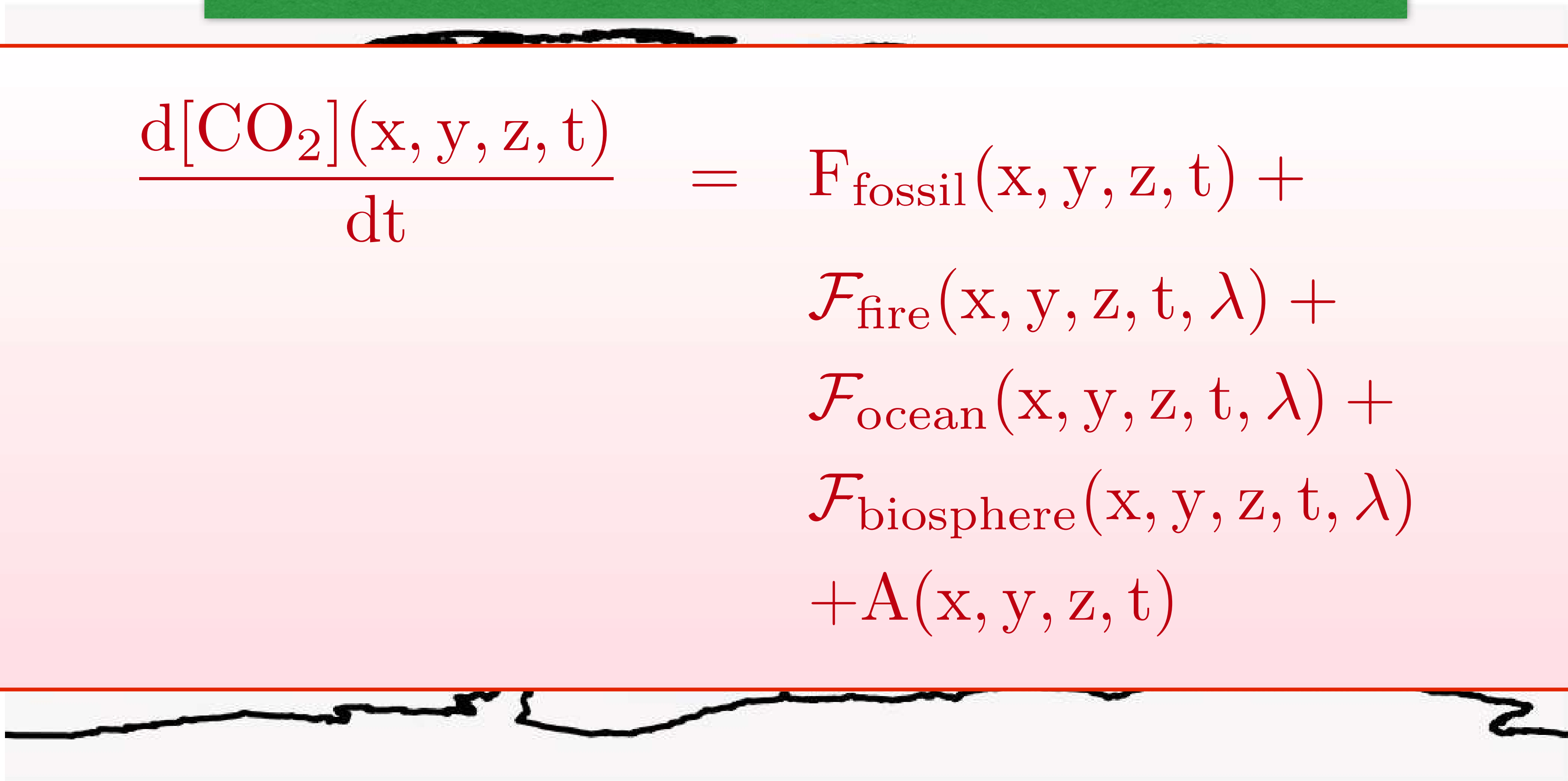
uptake

release

Assimilation of Observations

- reanalysis of fluxes -

CarbonTracker land and ocean carbon exchange for 2017
www.carbontracker.eu

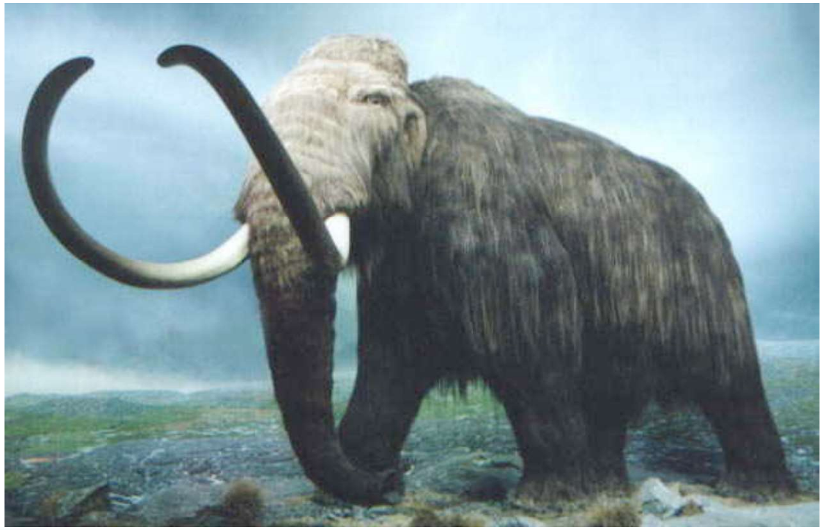


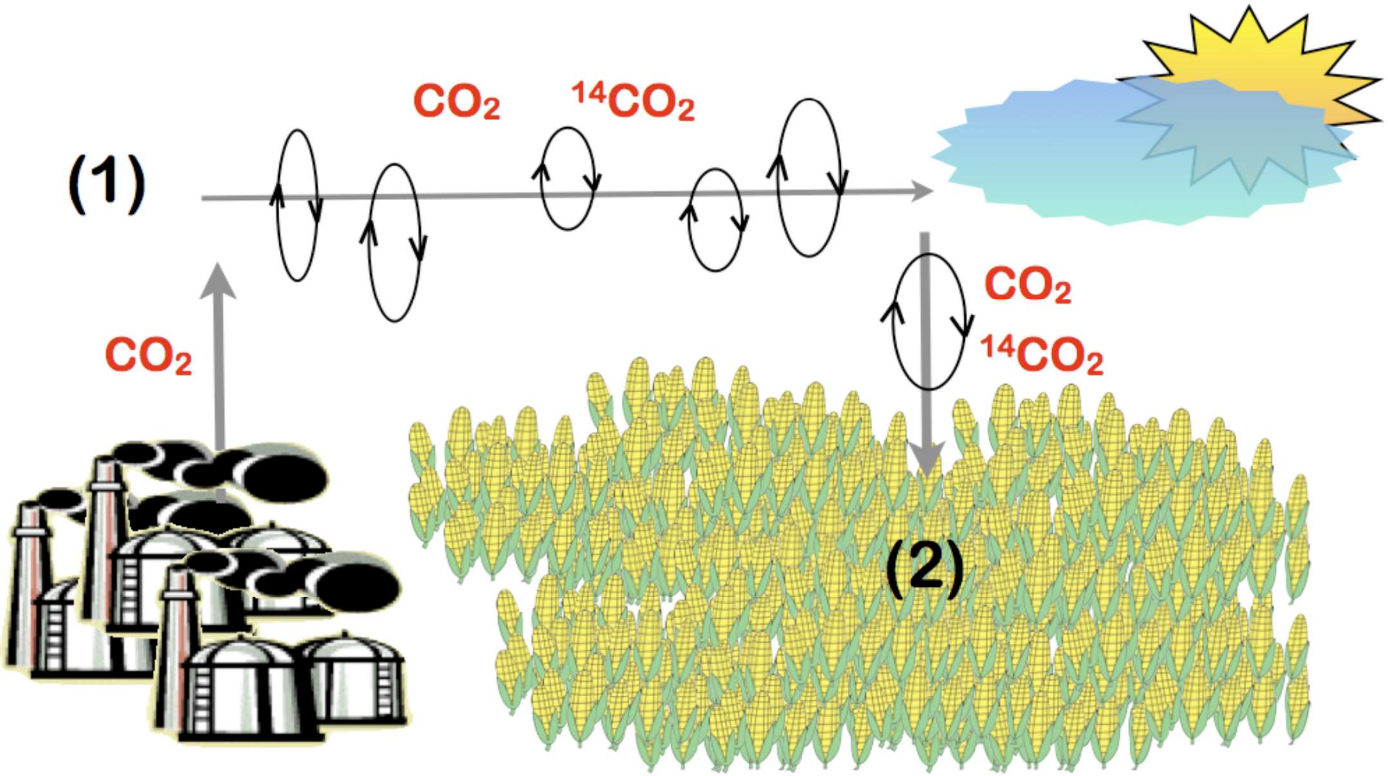
$$\frac{d[CO_2](x,y,z,t)}{dt} = F_{\mathrm{fossil}}(x,y,z,t) + \mathcal{F}_{\mathrm{fire}}(x,y,z,t,\lambda) + \mathcal{F}_{\mathrm{ocean}}(x,y,z,t,\lambda) + \mathcal{F}_{\mathrm{biosphere}}(x,y,z,t,\lambda) + A(x,y,z,t)$$

uptake

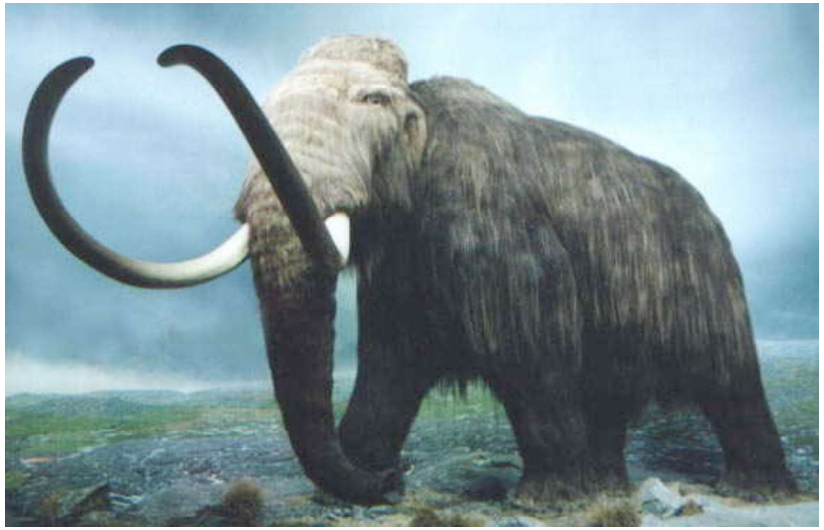
release

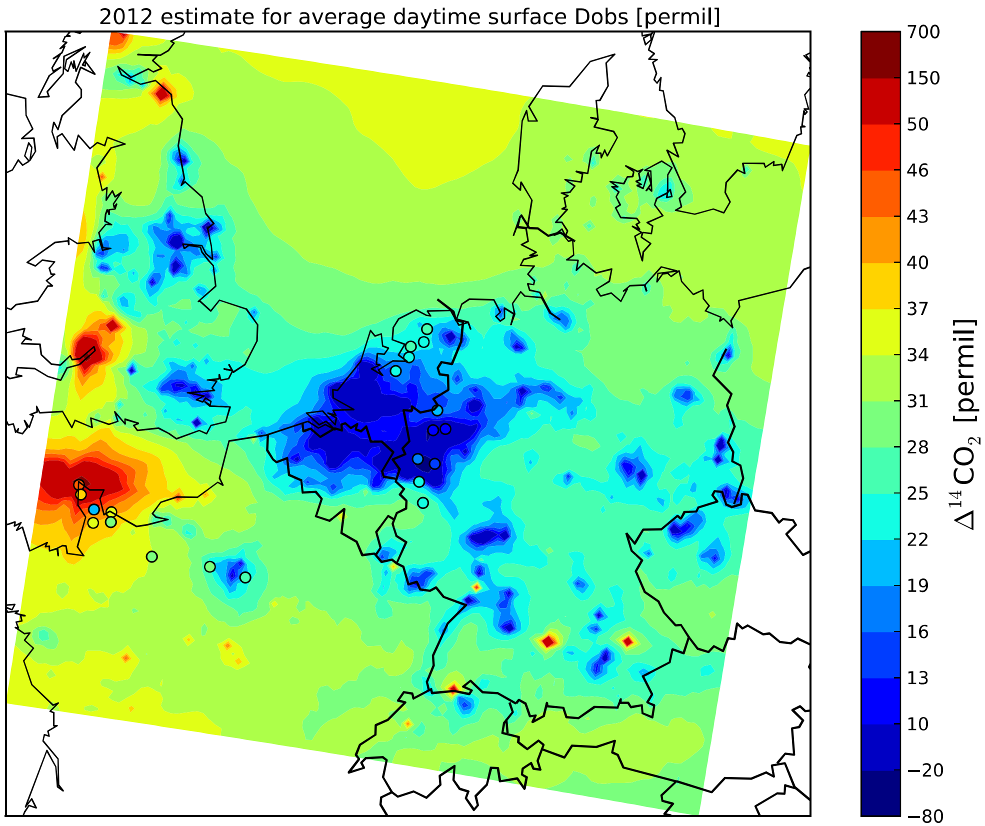
European Research Council

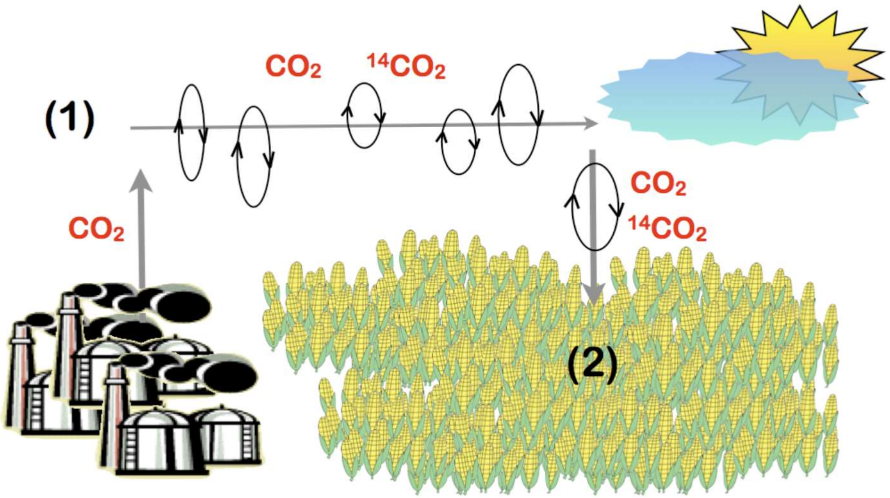


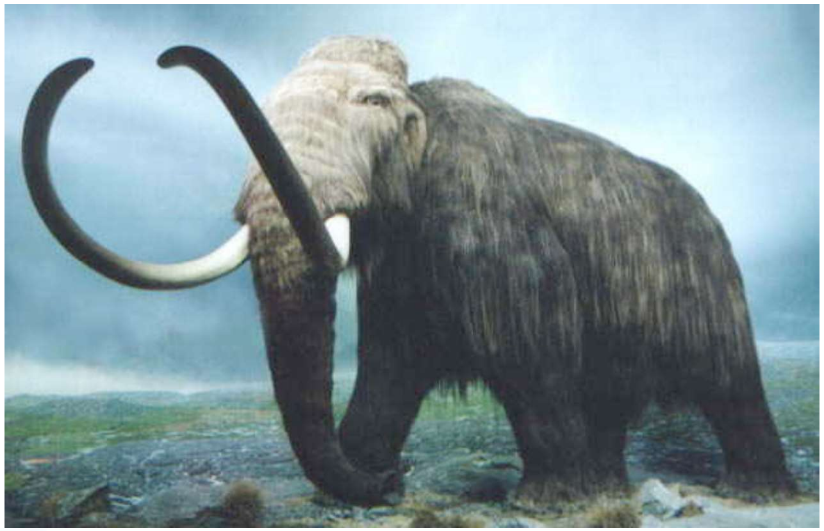


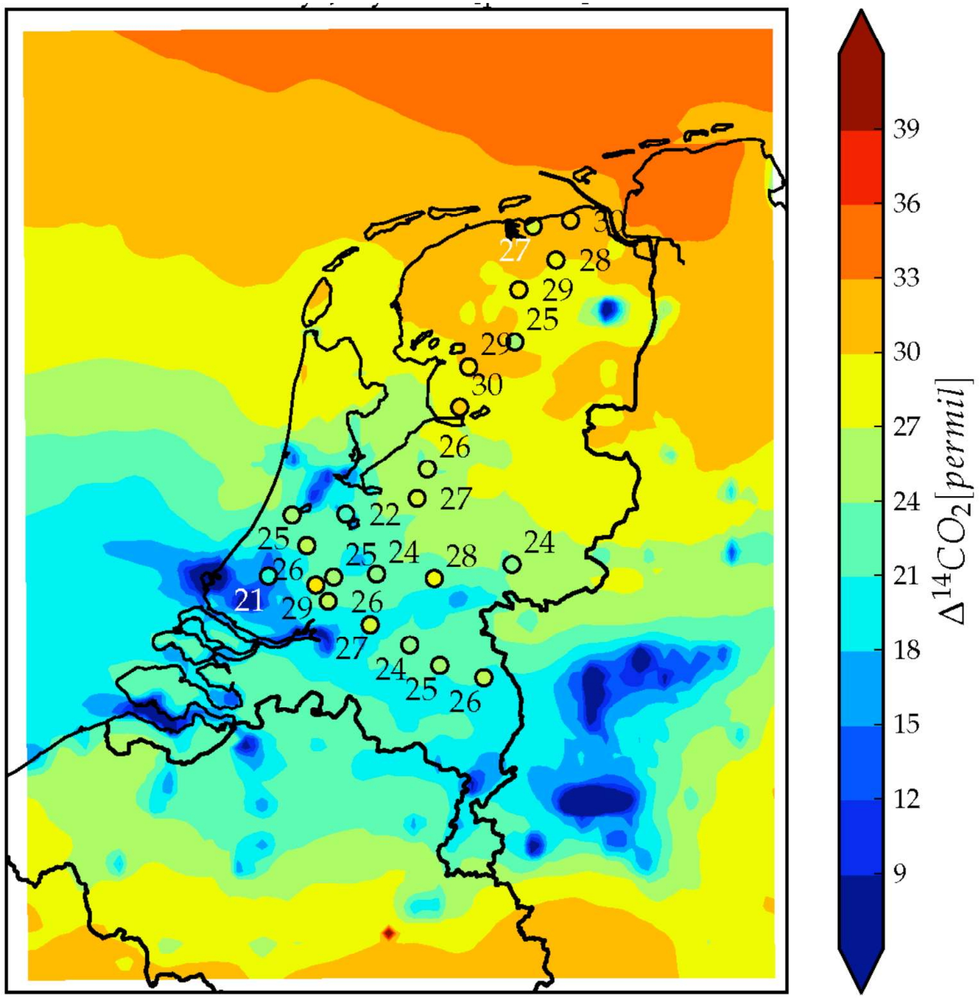
CO_2
$^{14}CO_2$
(1)
CO_2
CO_2
$^{14}CO_2$
(2)











courtesy Denica Bozhinova and H Meijer

Summary

- Carbon-climate interactions play across a range of scales
- Feedbacks, heterogeneous landscape, and slow changes in system complicate forecasts
- Vegetation plays a key role in shaping future global CO_2 trajectory…
- …but also in local balances of water, energy, radiation, and clouds
  - *=> weather, food production, energy transition*
- Observation networks covering climate time scales, and multi-species for fingerprinting are key to make progress