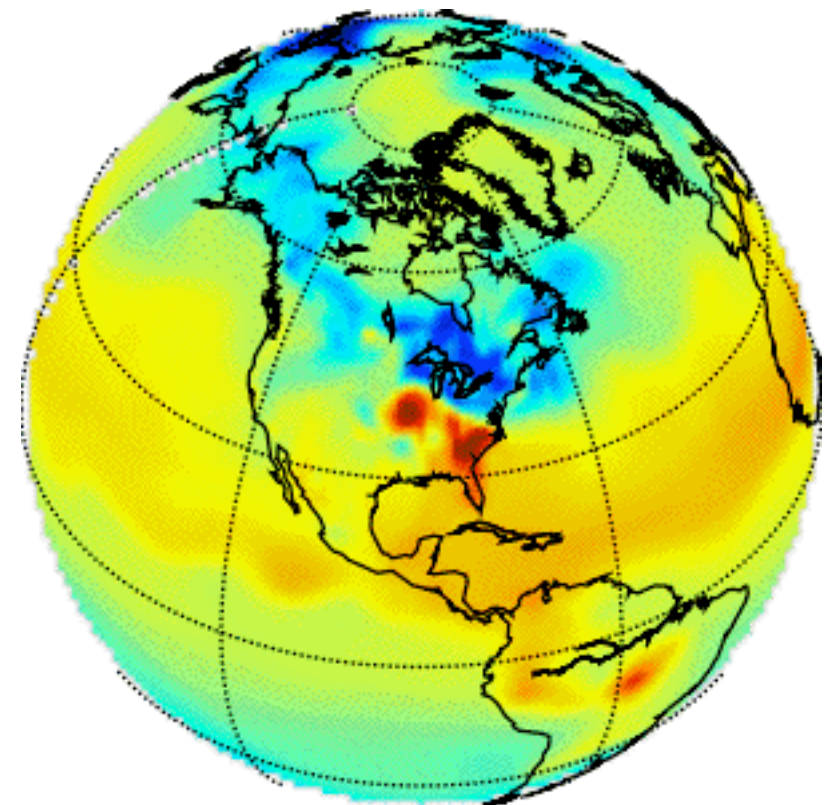
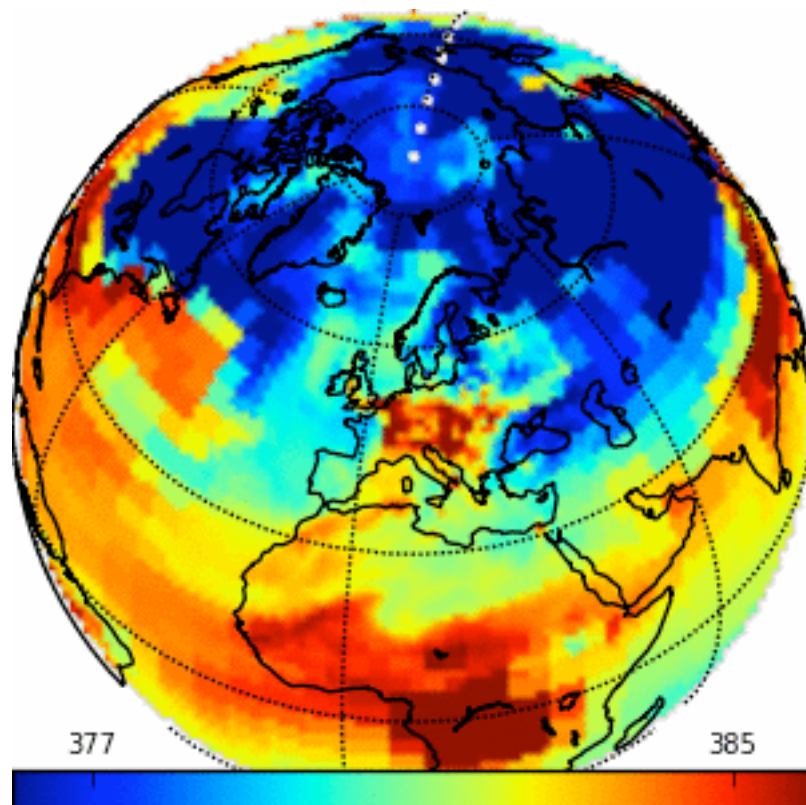


CarbonTracker: monitoren van veranderingen in de terrestrische koolstofcyclus

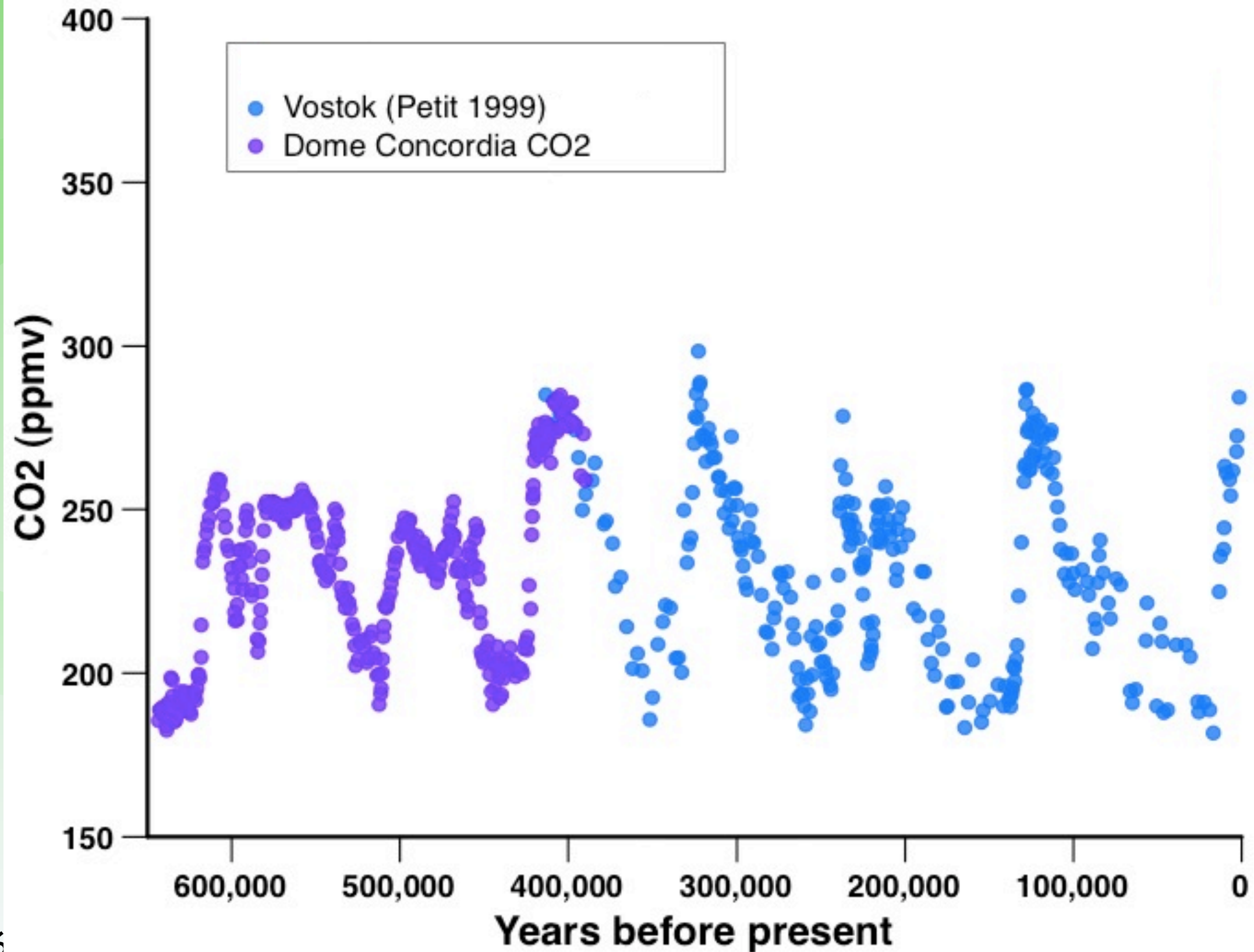
Wouter Peters
& MAQ staf



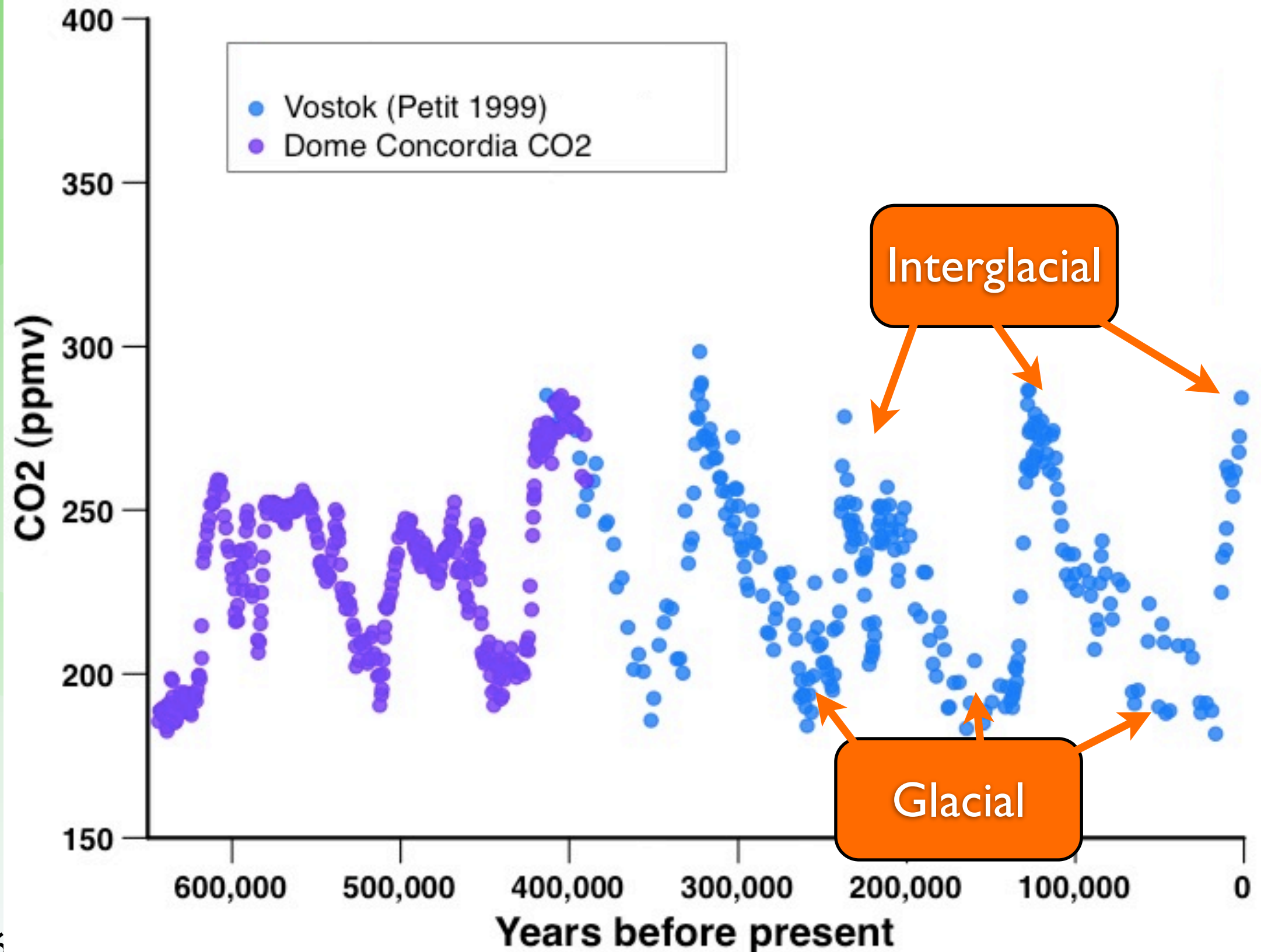
Inhoud

- **De koolstofcyclus in perspectief**
- **Monitoren van de koolstofcyclus**
- **Resultaten van 7 jaar “Carbon Tracking”**

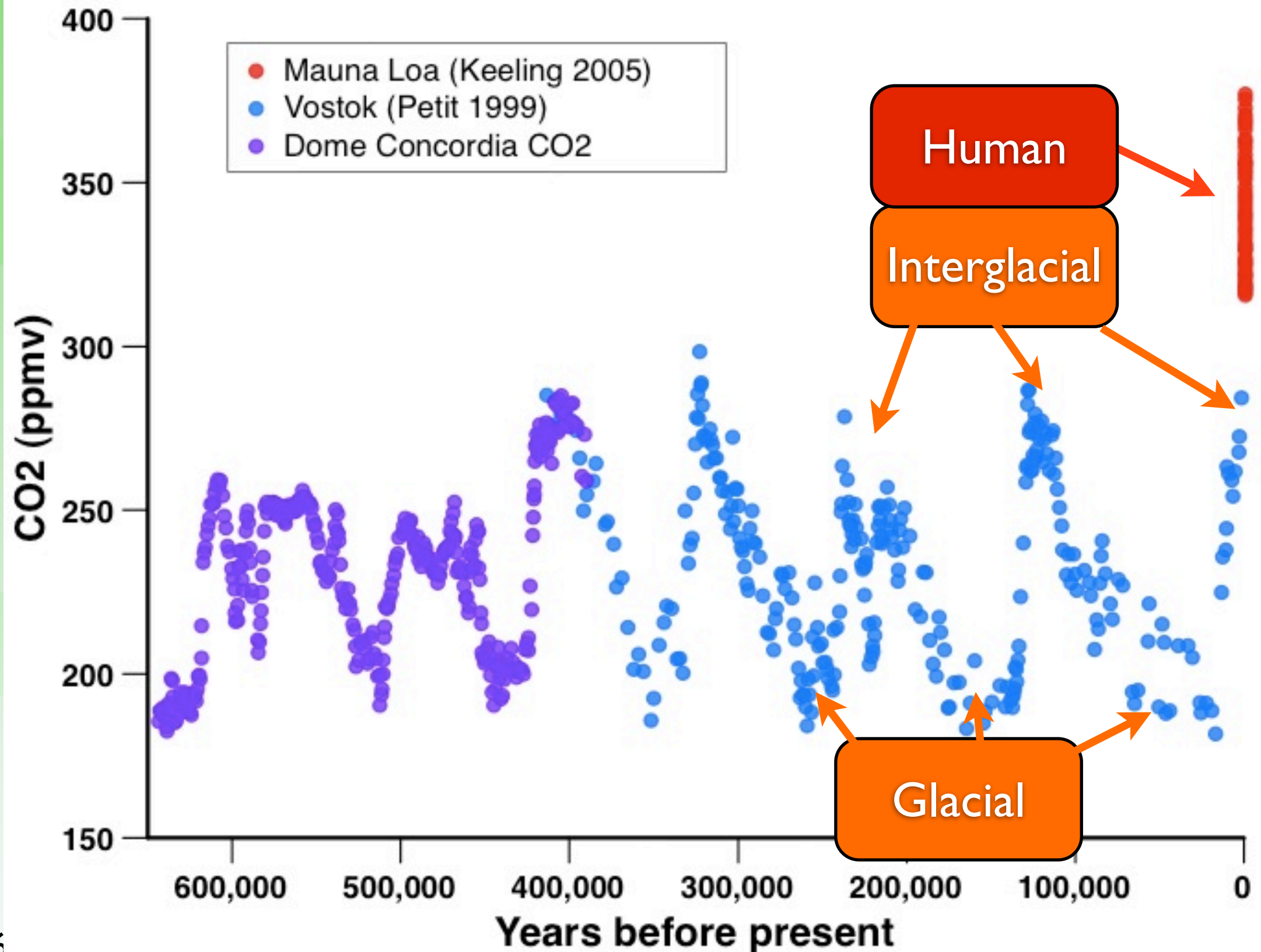
Natuurlijke koolstofcyclus



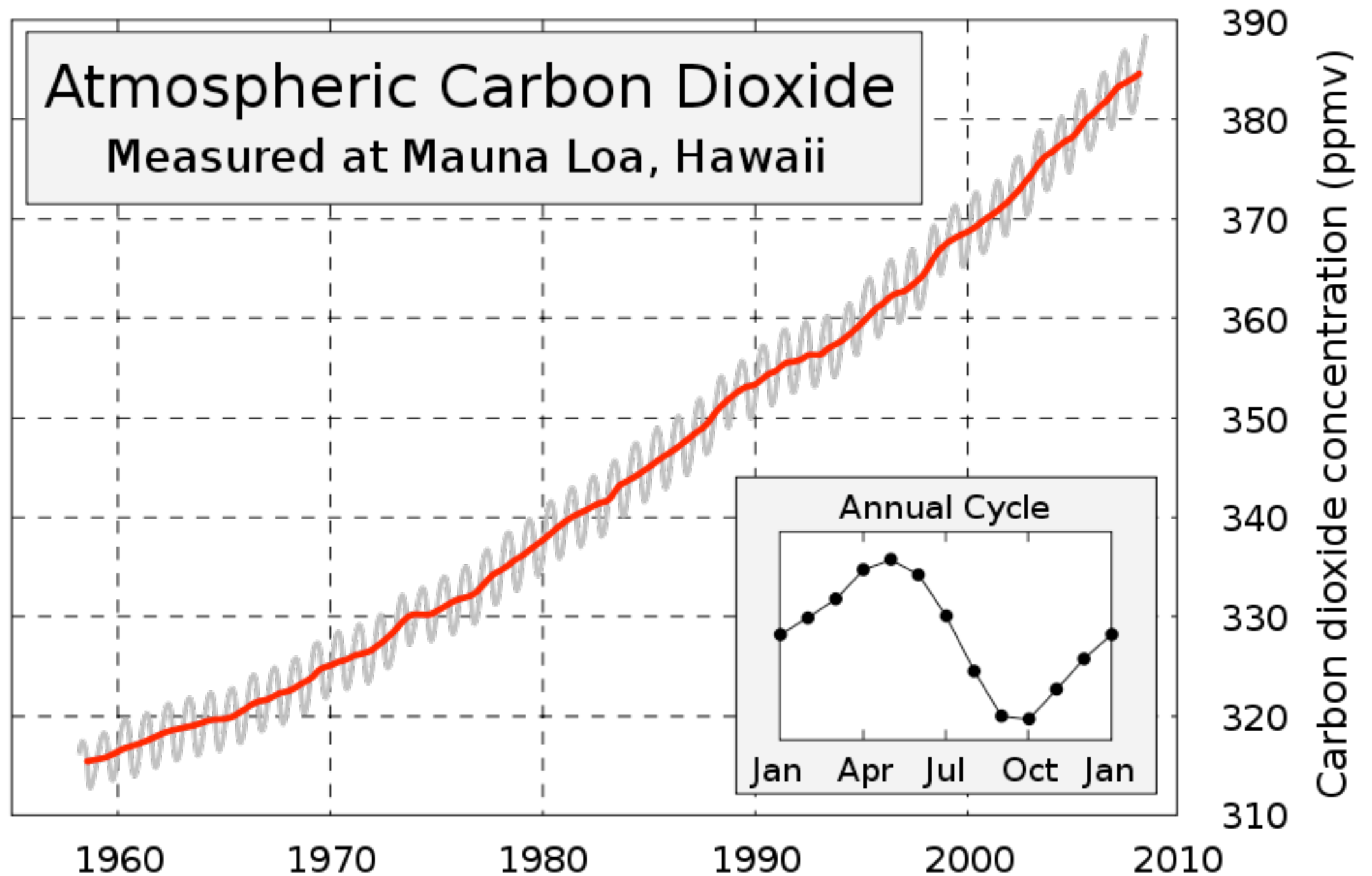
Natuurlijke koolstofcyclus



Natuurlijke koolstofcyclus



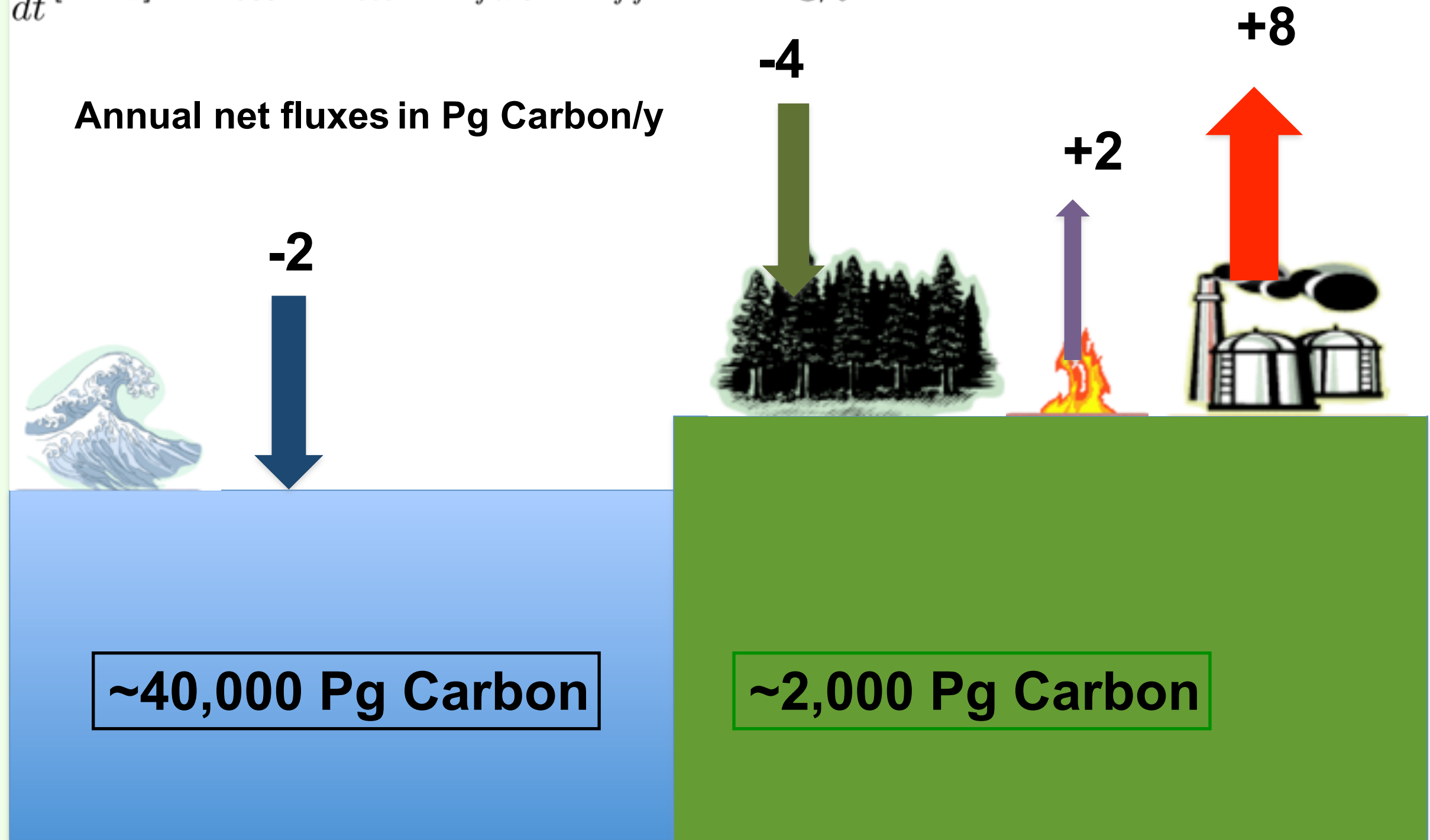
~~Natuurlijke~~ koolstofcyclus



Global Carbon Cycle

$$\frac{d}{dt}[CO_2] = F_{oce} + F_{bio} + F_{fire} + F_{ff} = +4 \text{ Pg/y}$$

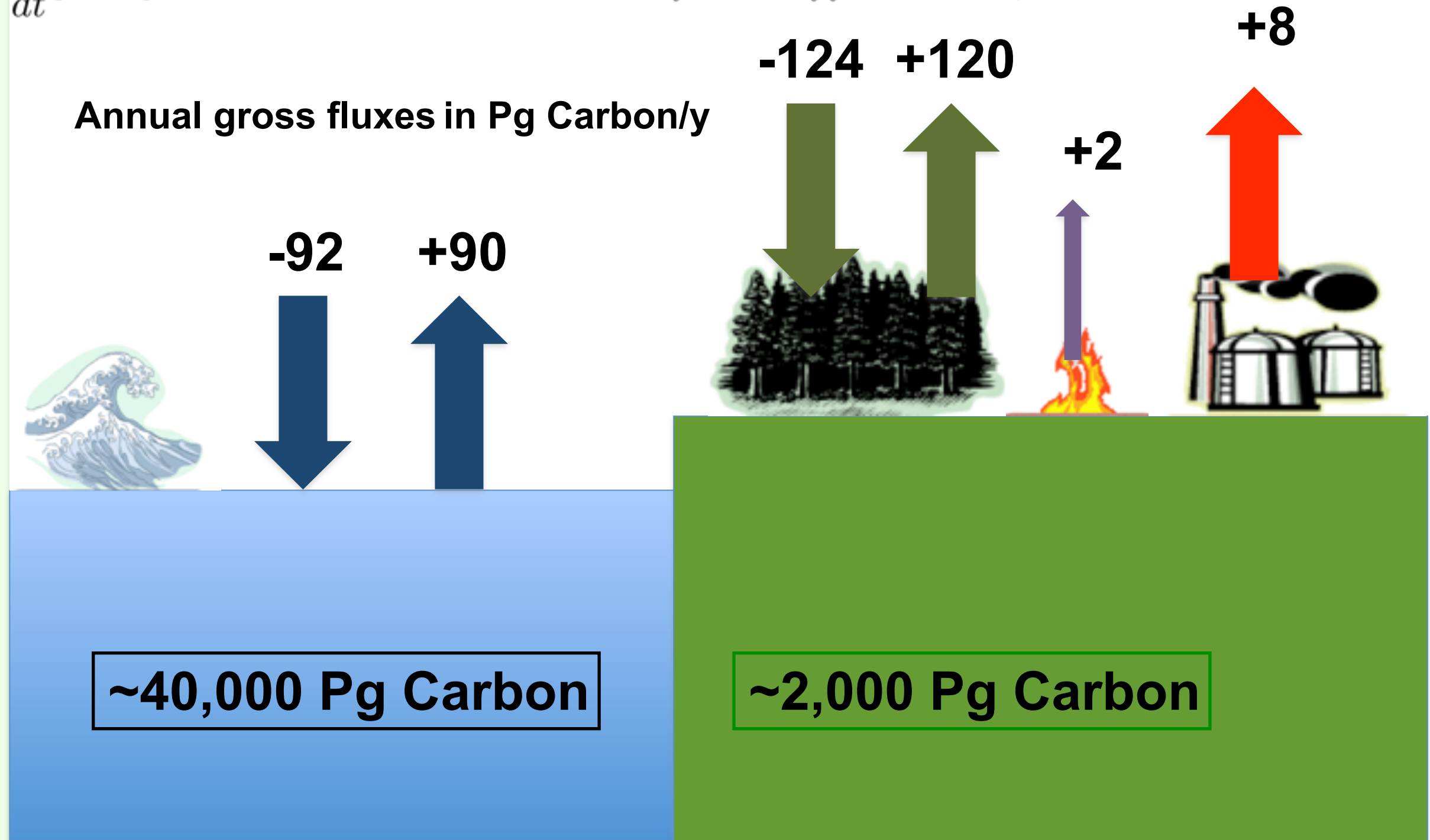
Annual net fluxes in Pg Carbon/y



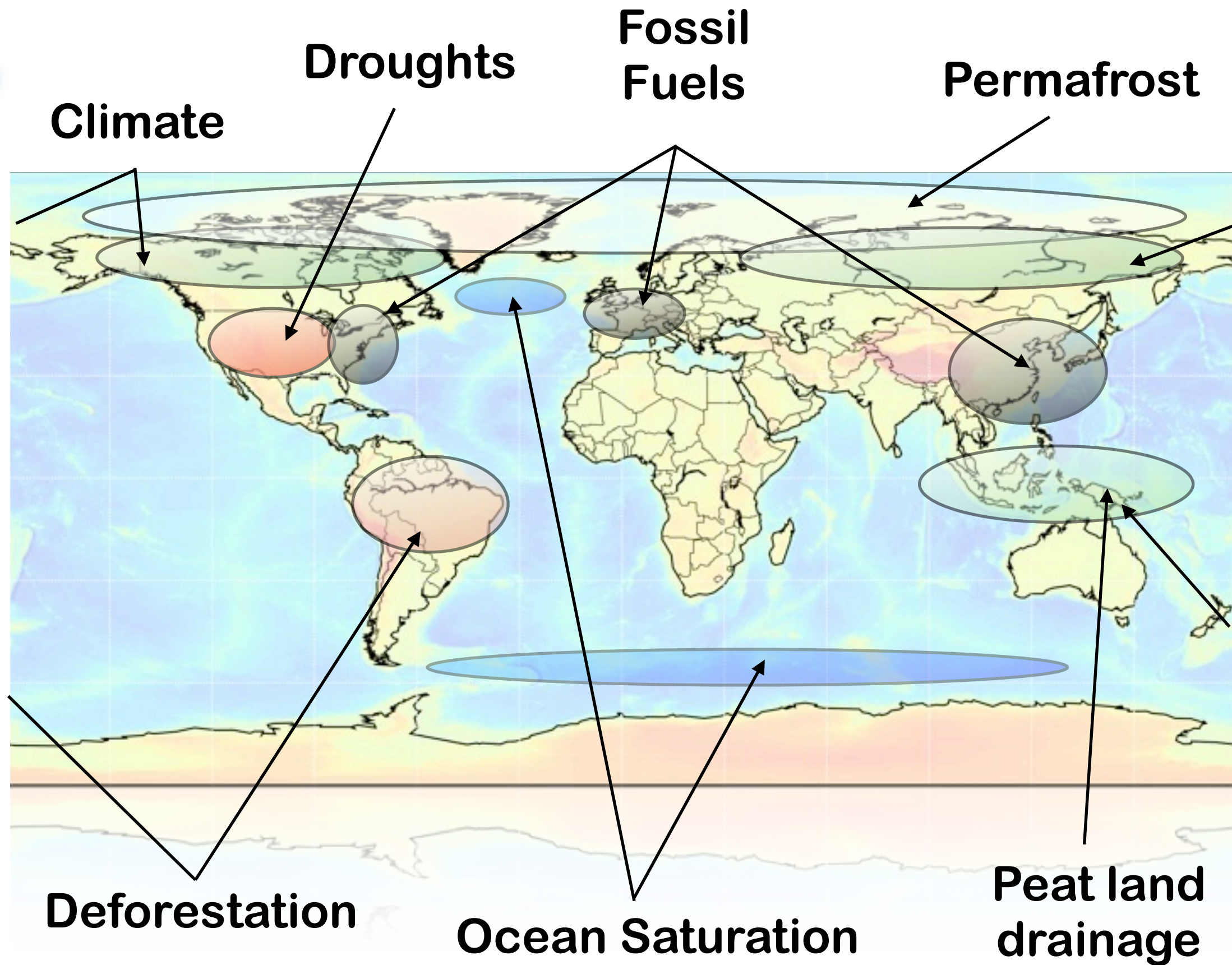
Global Carbon Cycle

$$\frac{d}{dt}[CO_2] = F_{ao} + F_{oa} + F_{ab} + F_{ba} + F_{fire} + F_{ff} = +4 \text{ Pg/y}$$

Annual gross fluxes in Pg Carbon/y

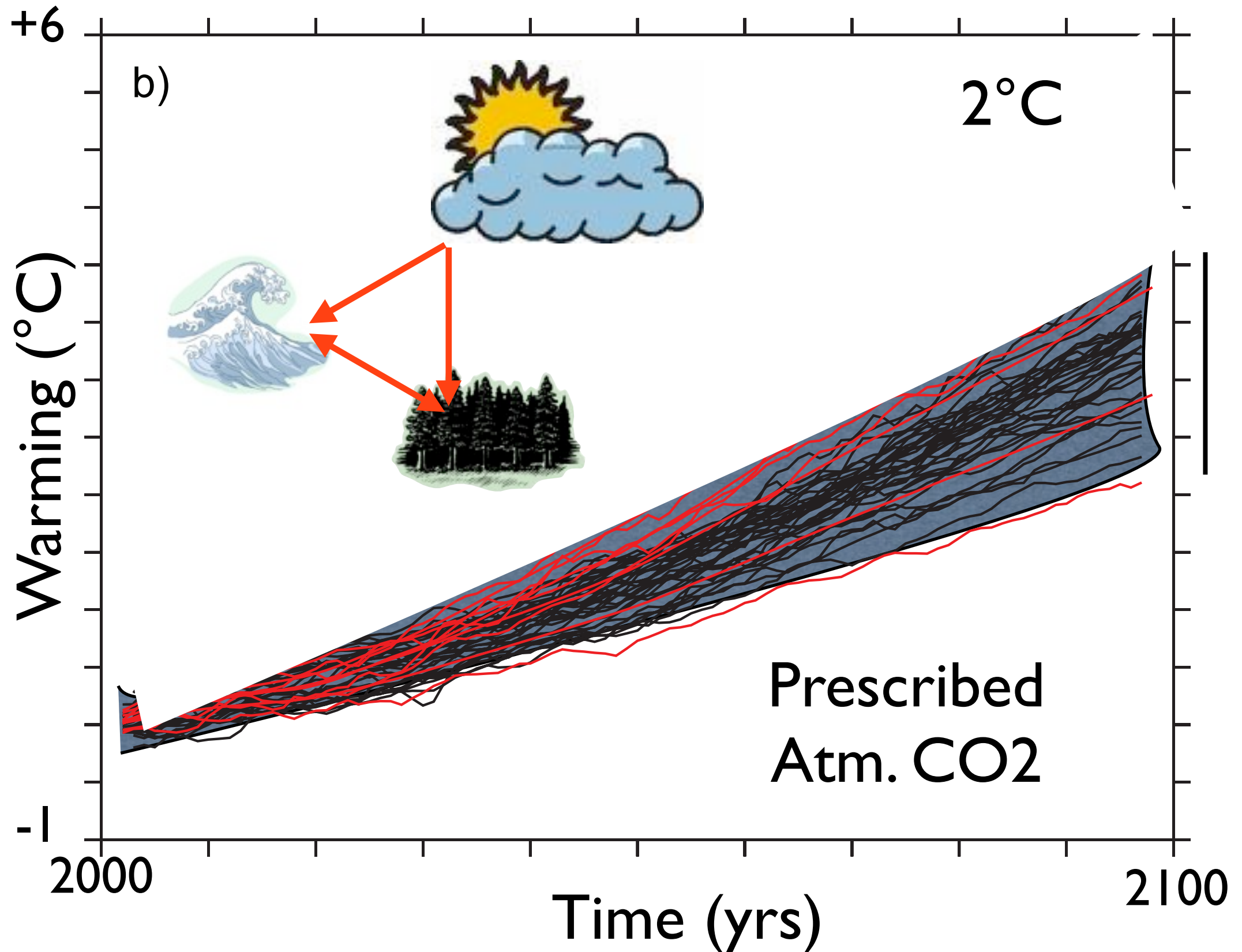


**Non
steady-
state**



Climate–Carbon Cycle Feedback Analysis: Results from the C⁴MIP Model Intercomparison

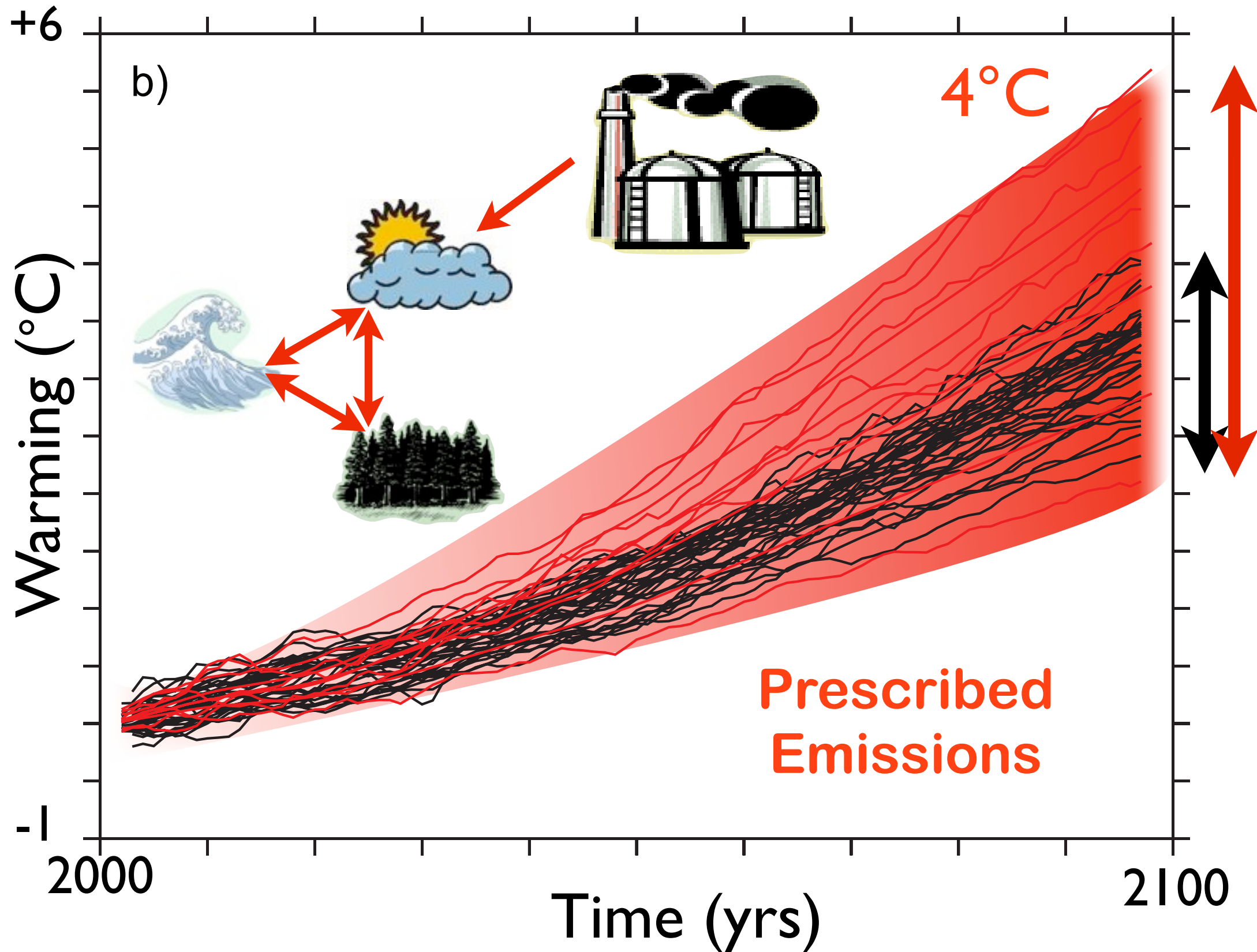
P. FRIEDLINGSTEIN,^a P. COX,^b R. BETTS,^c L. BOPP,^a W. VON BLOH,^d V. BROVKIN,^d P. CADULE,^e



A key
 uncertainty
 in climate

Climate–Carbon Cycle Feedback Analysis: Results from the C⁴MIP Model Intercomparison

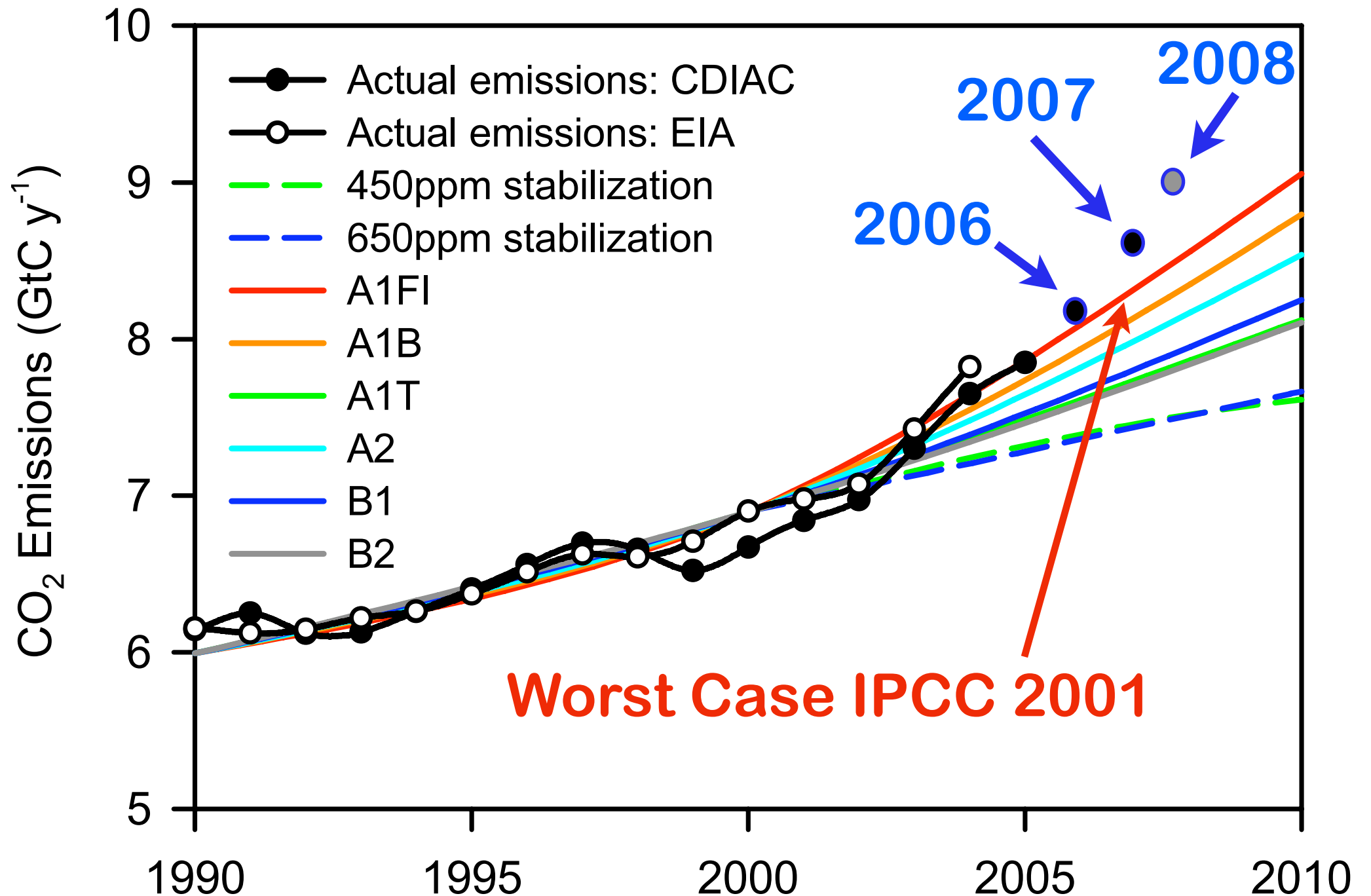
P. FRIEDLINGSTEIN,^a P. COX,^b R. BETTS,^c L. BOPP,^a W. VON BLOH,^d V. BROVKIN,^d P. CADULE,^e



A key
uncertainty
in climate

Global and regional drivers of accelerating CO₂ emissions

Michael R. Raupach^{*†}, Gregg Marland[‡], Philippe Ciais[§], Corinne Le Quéré^{¶||}, Josep G. Canadell^{*}, Gernot Klepper^{**}, and Christopher B. Field^{††}



Emission
scenarios

Saturation of the Southern Ocean CO₂ 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 Heimann¹

CLIMATE CHANGE

Illuminating the Modern Dance of Climate and CO₂

Peter Cox¹ and Chris Jones²

High sensitivity of peat decomposition to climate change through water-table feedback

TAKESHI ISE^{1*}, ALLISON L. DUNN², STEVEN C. WOFSY³ AND PAUL R. MOORCROFT⁴

REVIEW ARTICLE

Global nitrogen deposition and carbon sinks

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

Shilong Piao¹, Philippe Ciais¹, Pierre Friedlingstein¹, Philippe Peylin², Markus Reichstein³, Sebastiaan Luyssaert⁴, Hank Margolis⁵, Jingyun Fang⁶, Alan Barr⁷, Anping Chen⁸, Achim Grelle⁹, David Y. Hollinger¹⁰, Tuomas Laurila¹¹, Anders Lindroth¹², Andrew D. Richardson¹³ & Timo Vesala¹⁴

PROGRESS ARTICLE

Carbon accumulation in European forests

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. Crummer¹, Hanna Lee¹, James O. Sickman² & T. E. Osterkamp³

Searching out the sinks

Martin Heimann

ATMOSPHERIC SCIENCE

Himalaya—Carbon Sink or Source?

Jerome Gaillardet¹ and Albert Galy²

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO₂

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 Denning¹³

CARBON CYCLE

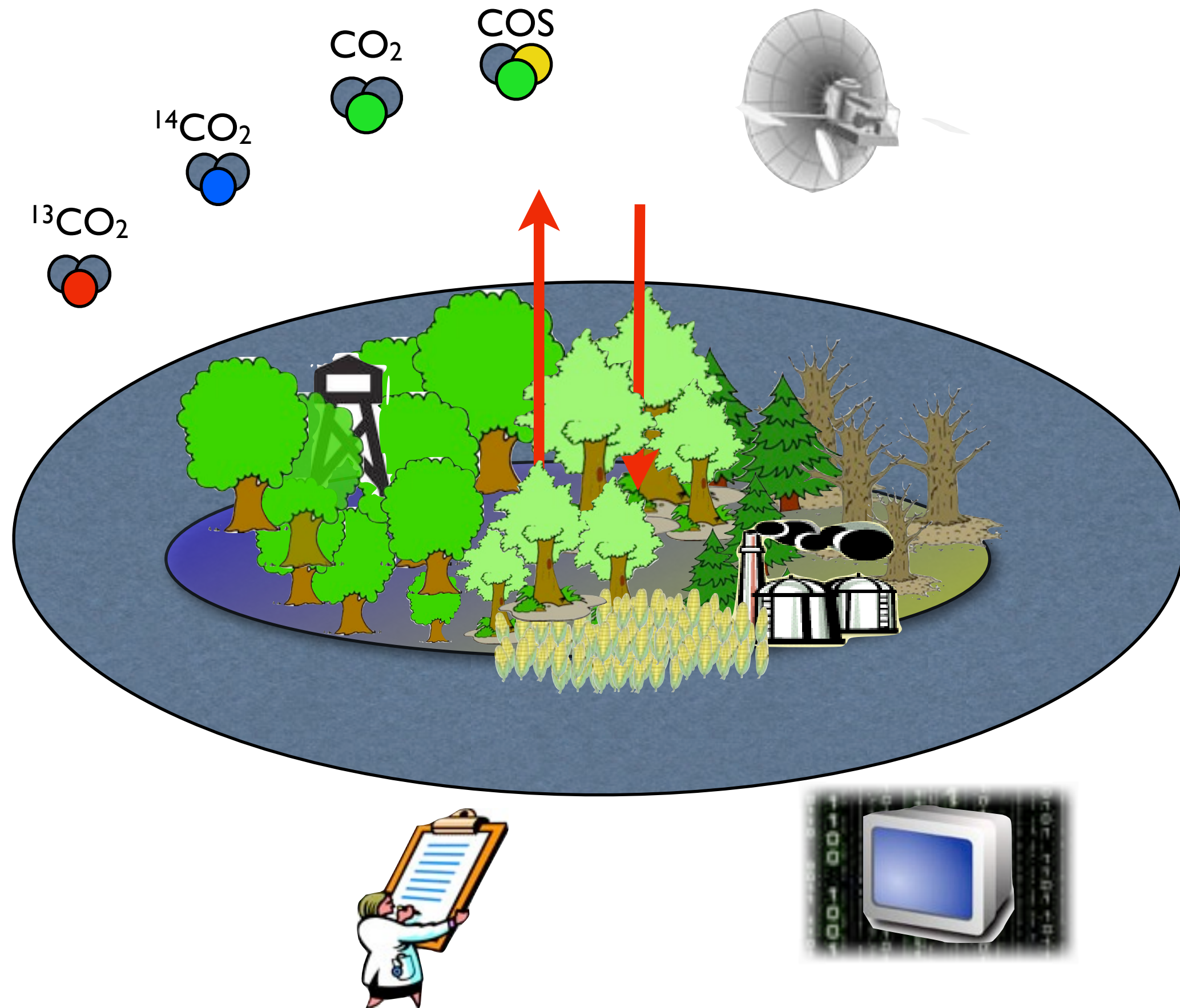
Sources, sinks and seasons

John B. Miller

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

John A. Arnone III¹, Paul S. J. Verburg¹, Dale W. Johnson², Jessica D. Larsen¹, Richard L. Jasoni¹, Annmarie J. Lucchesi¹, Candace M. Batts¹, Christopher von Nagy¹, William G. Coulombe¹, David E. Schorran¹, Paul E. Buck¹, Bobby H. Braswell³, James S. Coleman⁴, Rebecca A. Sherry⁵, Linda L. Wallace⁵, Yiqi Luo⁵ & David S. Schimel⁶

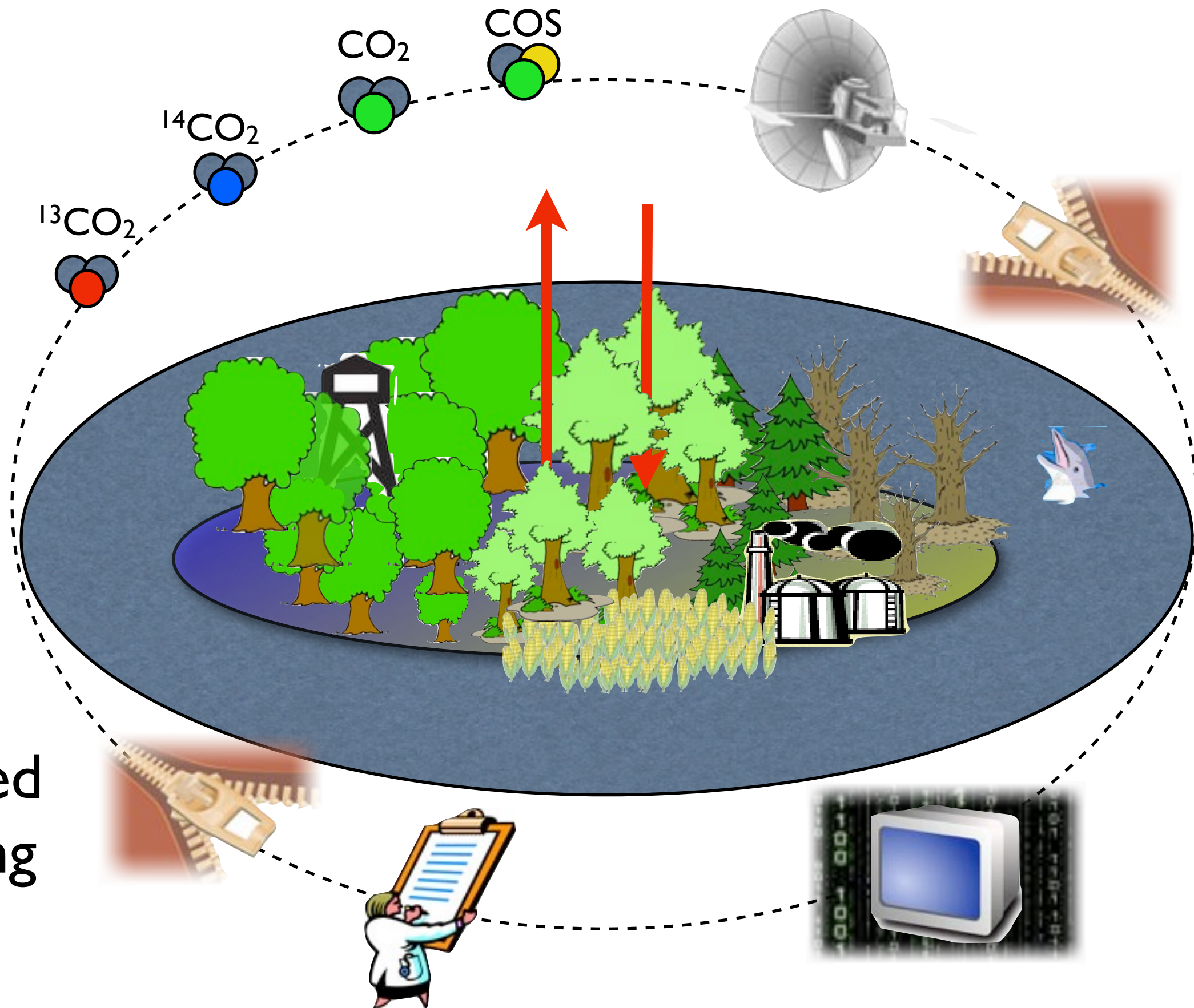
Monitoren van de koolstof cyclus



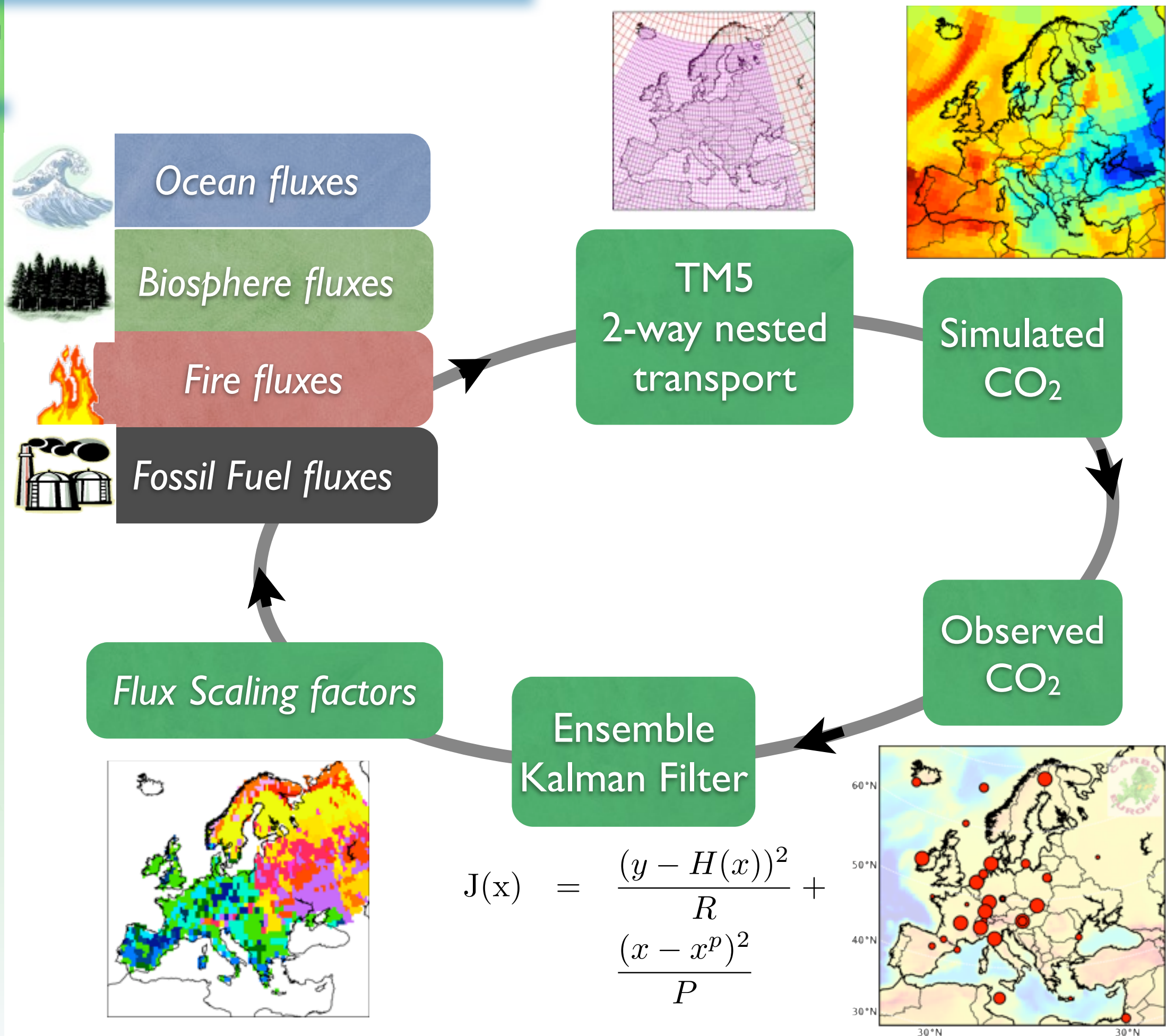
Monitoren van de koolstof cyclus

Integrated
observing
system

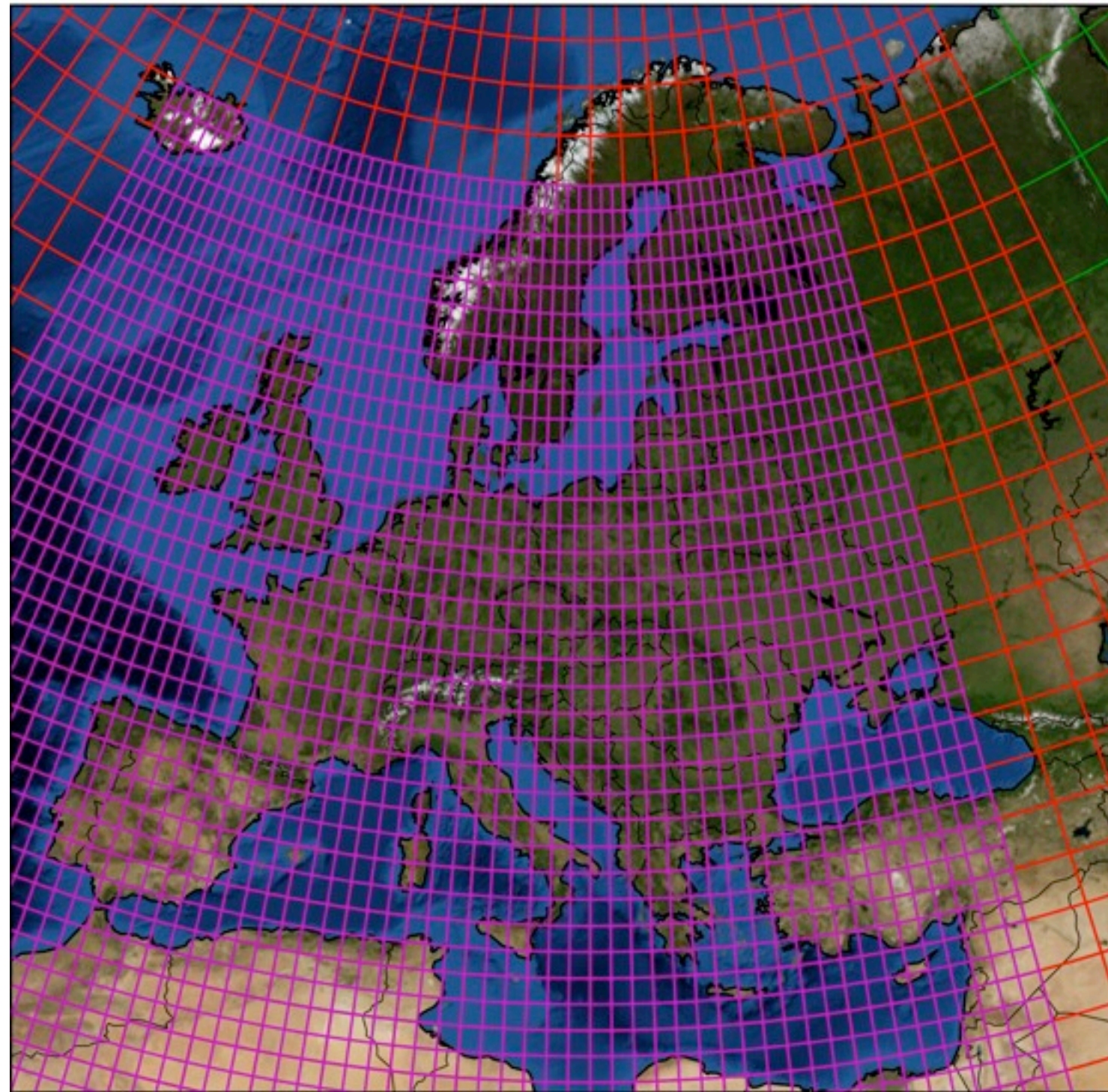
NVBM, 6/11/09



CT Europe system

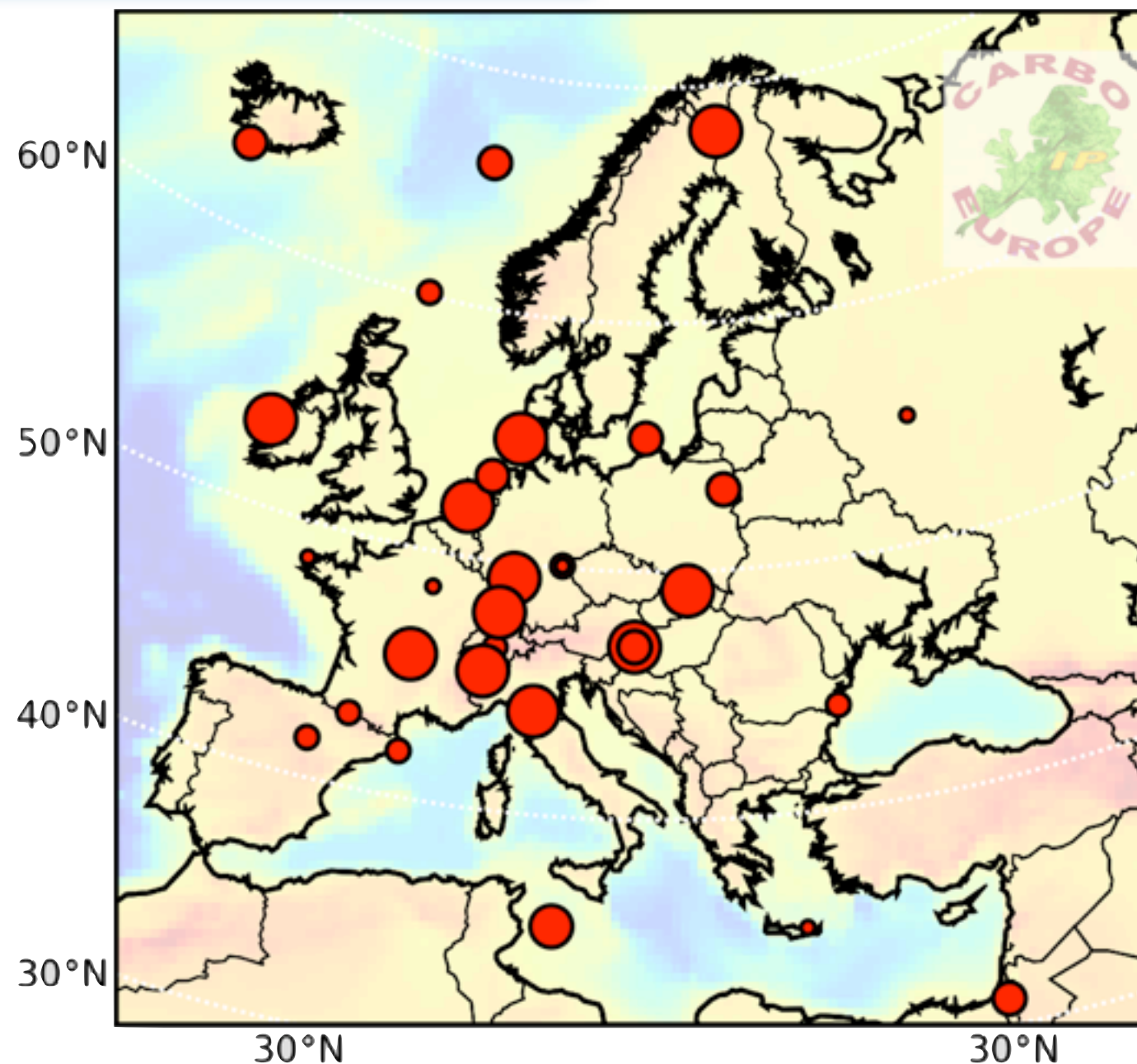


CT Europe system



**TM5 2-way nested transport
glb6x4, eur3x2, eur1x1, 25/34 levels
ECMWF 3-hourly meteo**

CT Europe system



Observed CO₂

- 17 European continuous sites (1 obs per day)
- 19 European flask sites (~1 obs per week)
- >23,000 European observations
- >60,000 total observations

Resultaten van 7 jaar “Carbon Tracking”

- De Europese koolstofbalans
- Interjaarlijkse variabiliteit
- De rol van het klimaat
- Isotopen

Global Change Biology (2009), doi: 10.1111/j.1365-2486.2009.02078.x

Seven years of recent European net terrestrial carbon dioxide exchange constrained by atmospheric observations

An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker

NVBM, 6/11/09

nature
geoscience

FOCUS | PROGRESS ARTICLE

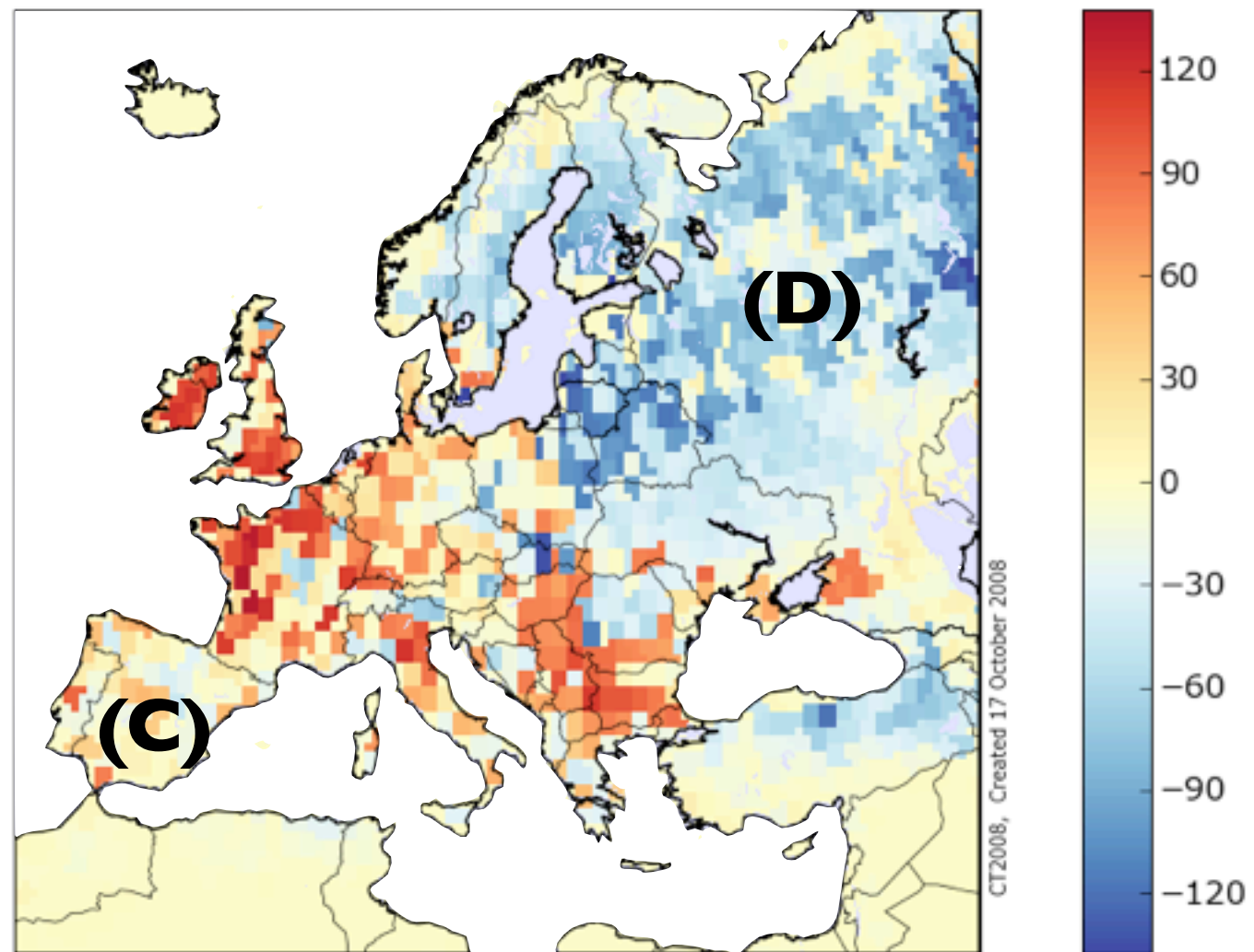
PUBLISHED ONLINE: XX DECEMBER 2009 | DOI: 10.1038/NNGEO686

Importance of methane and nitrous oxide for Europe's terrestrial greenhouse-gas balance

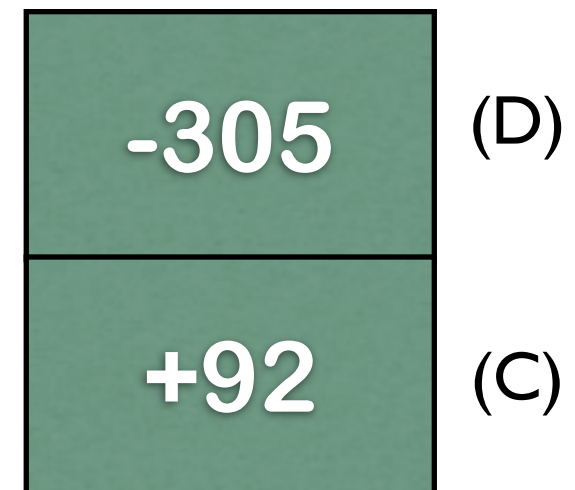
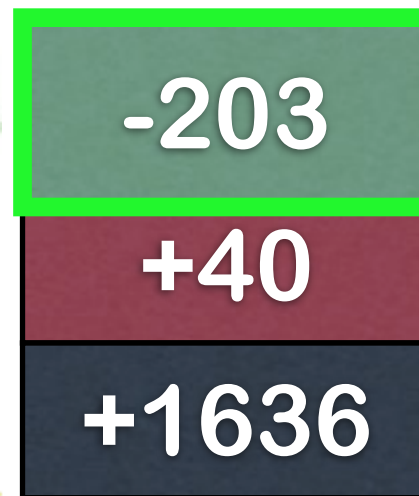
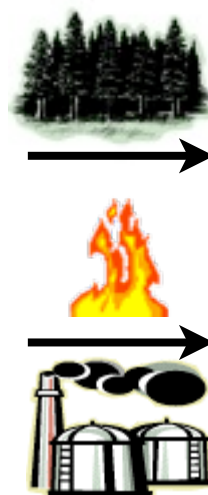
natural fluxes only!

Results

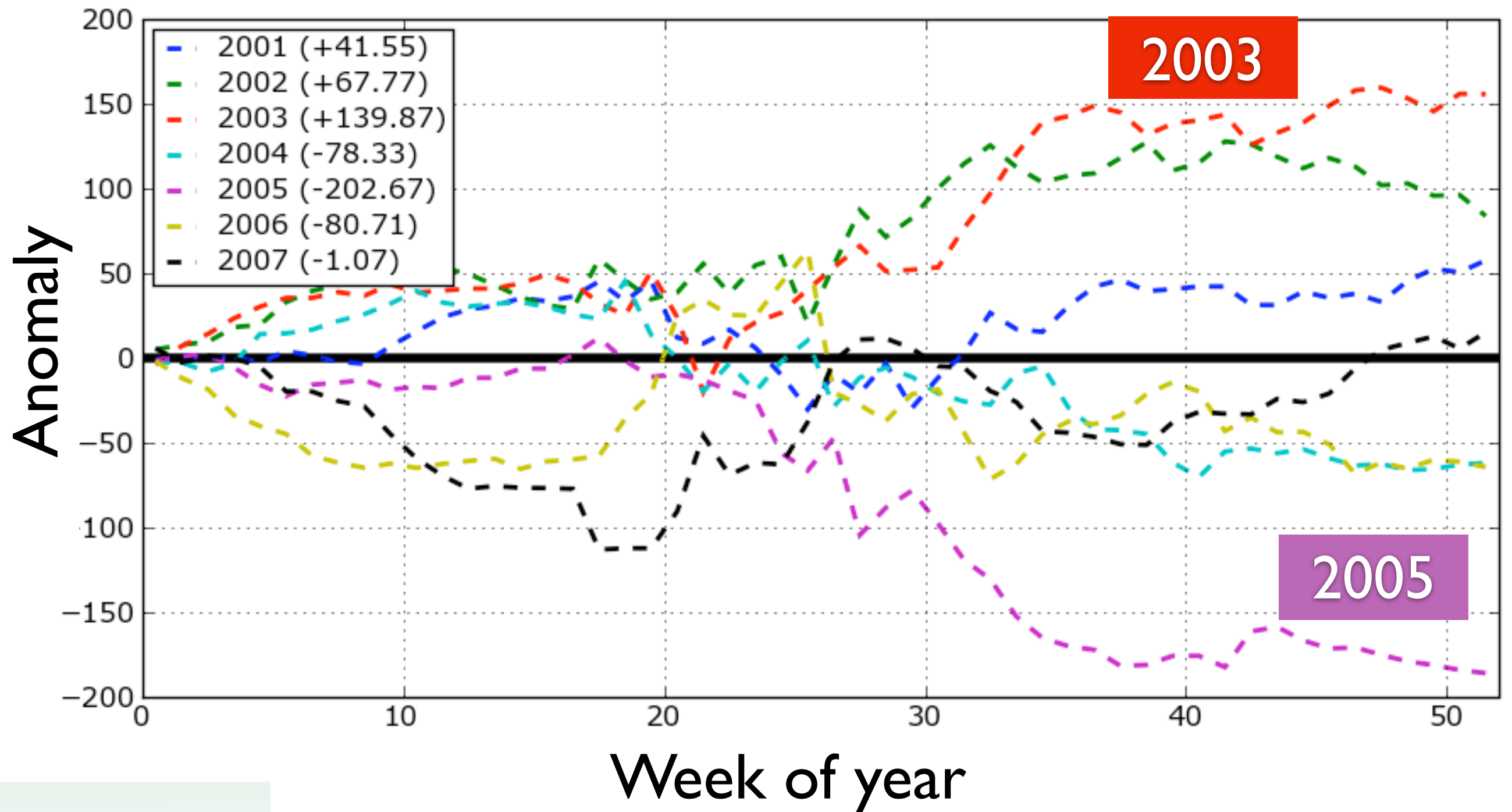
mean of 2001-2007



Total:
+1473 TgC/
yr (release)



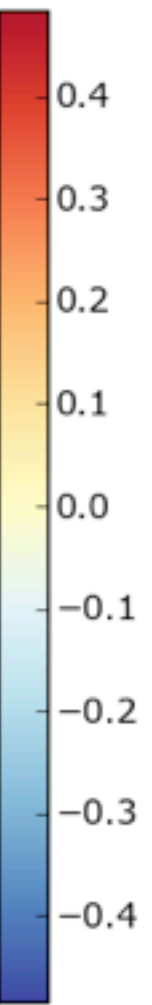
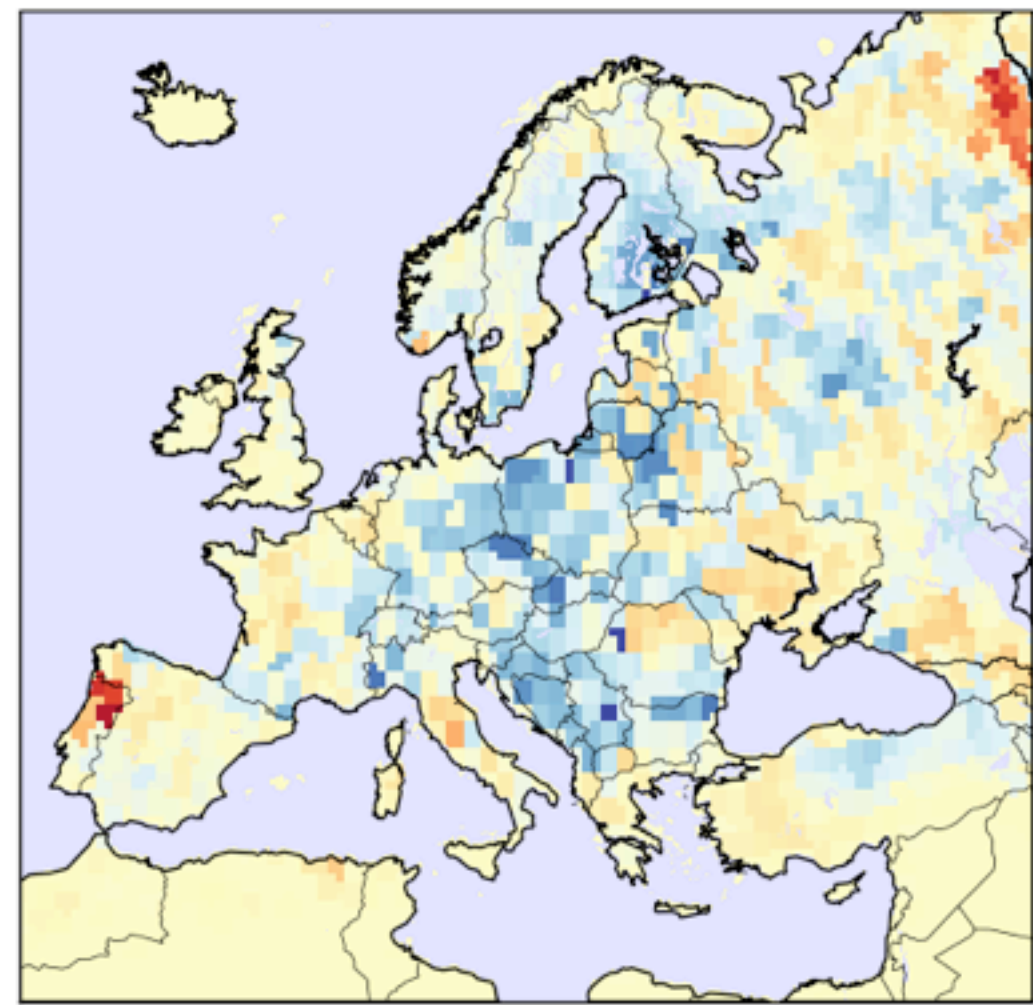
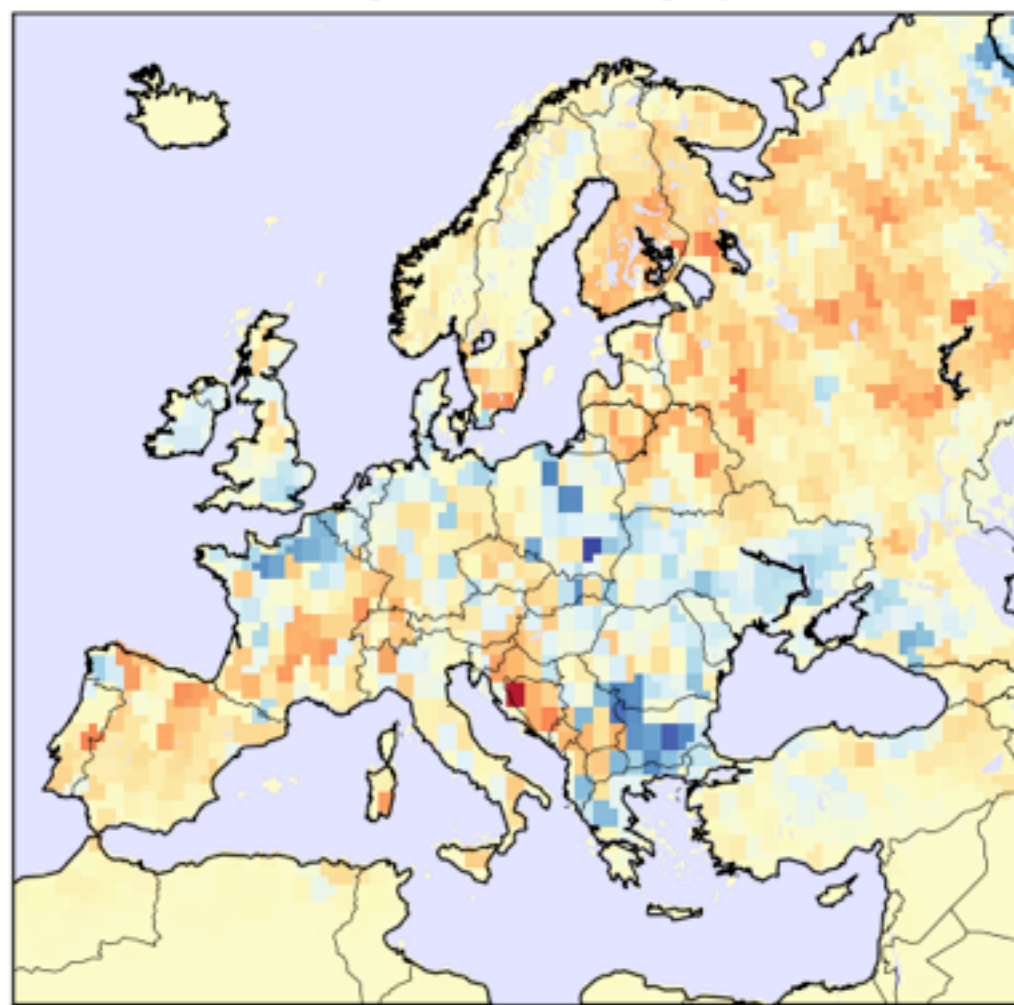
Interannual Variability



Carbon anomaly relative to 2001-2007 mean

June-July-August 2003

June-July-August 2005

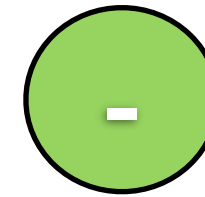
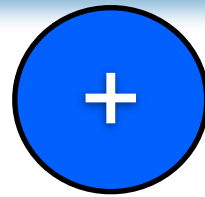


1st guess:
 optimized:

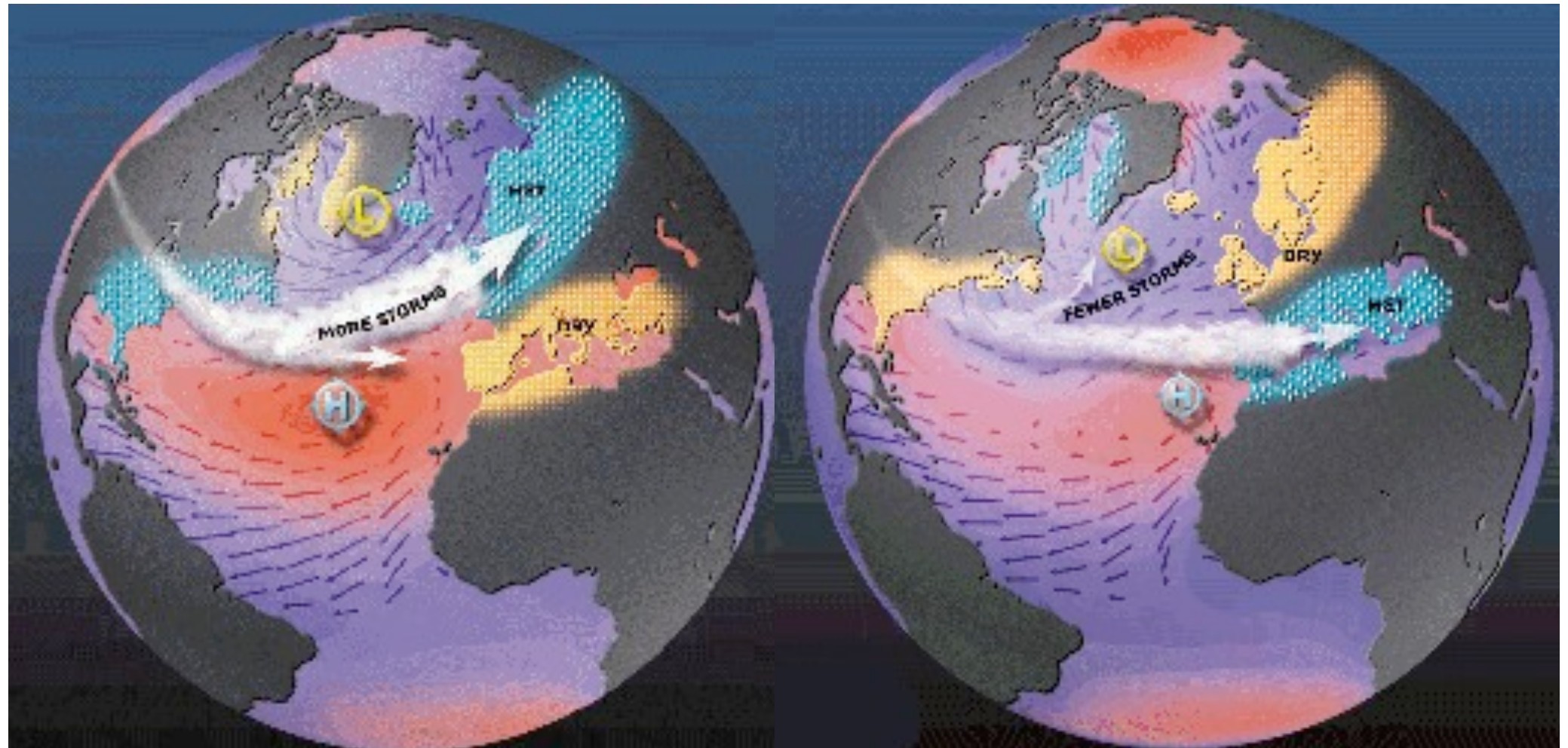
+271 TgC/yr
 +233 TgC/yr

-109 TgC/yr
 -574 TgC/yr

kgC/m²/yr



NAO



Positive Phase:

- ▶ Stronger Azores H
- ▶ Stronger Iceland L
- ▶ High P gradient
- ▶ More westerly storms
- ▶ Moisture goes North

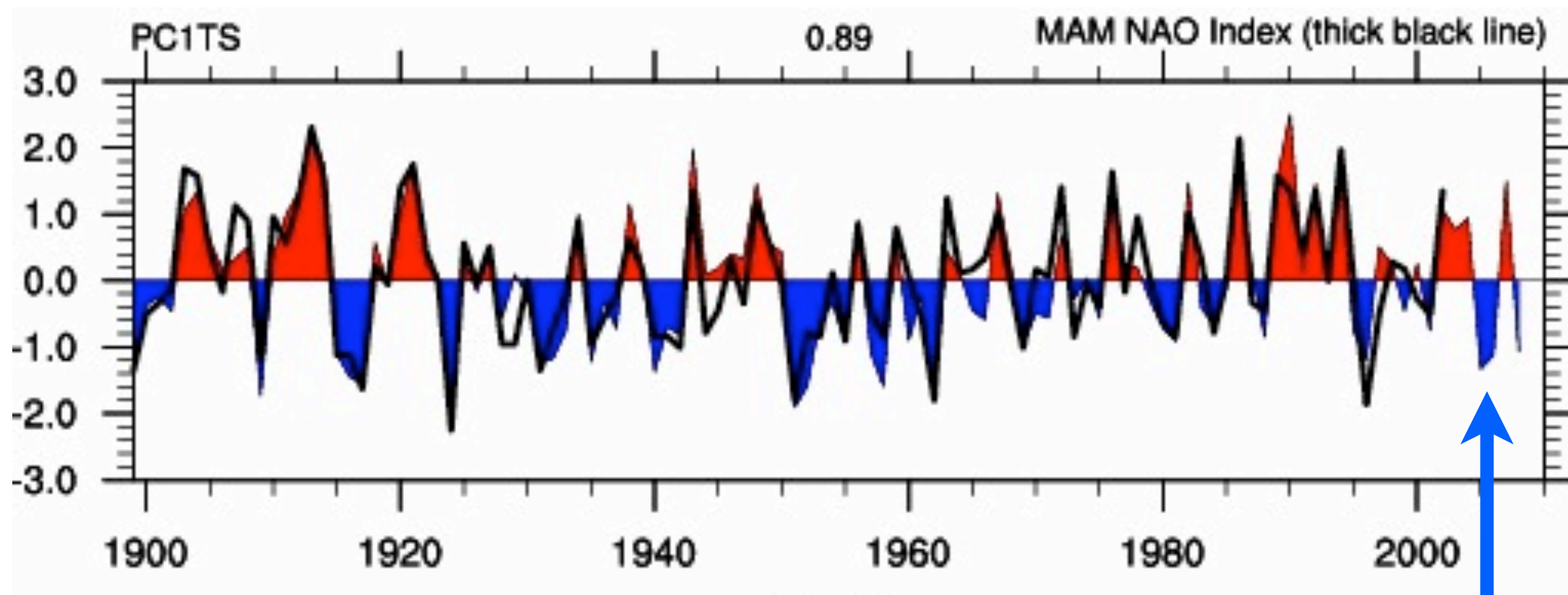
Negative Phase:

- ▶ Weaker Azores H
- ▶ Weaker Iceland L
- ▶ Low P gradient
- ▶ Fewer westerly storms
- ▶ Moisture goes South

NAO index 1995-2008

bars = March-April-May avg

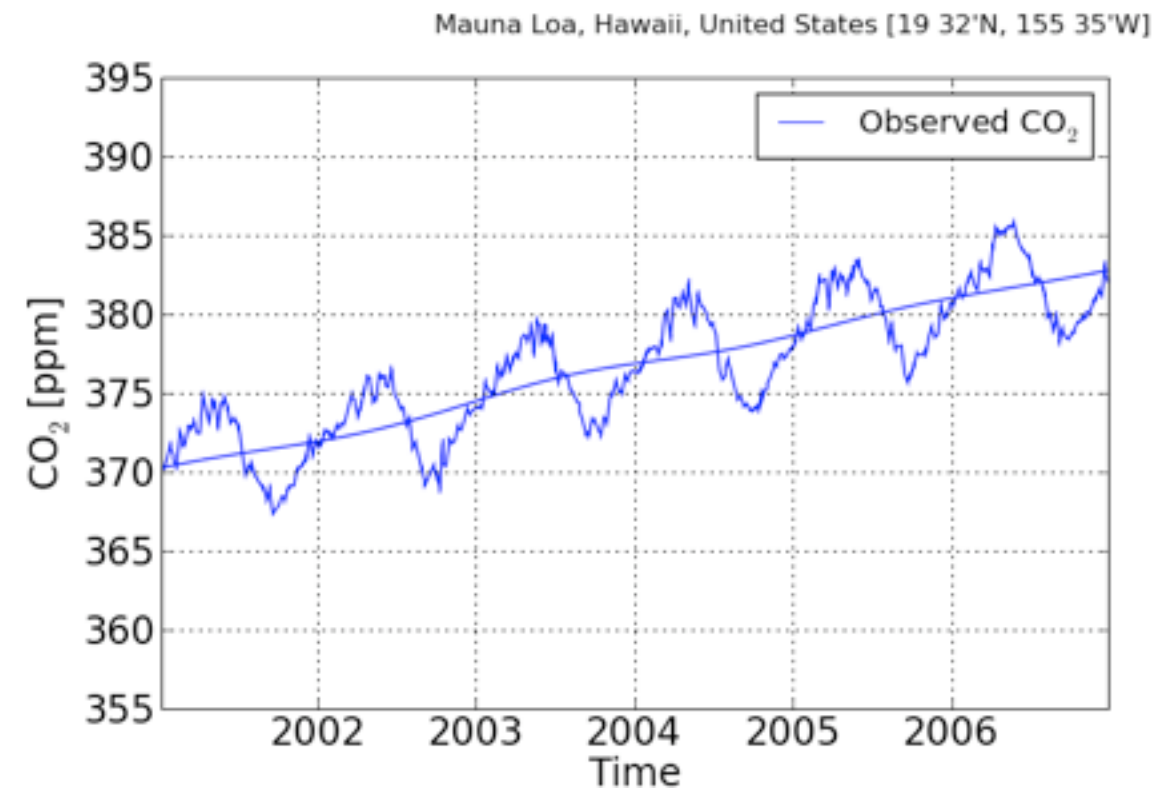
NAO



source: Dr J. Hurrell (NCAR)

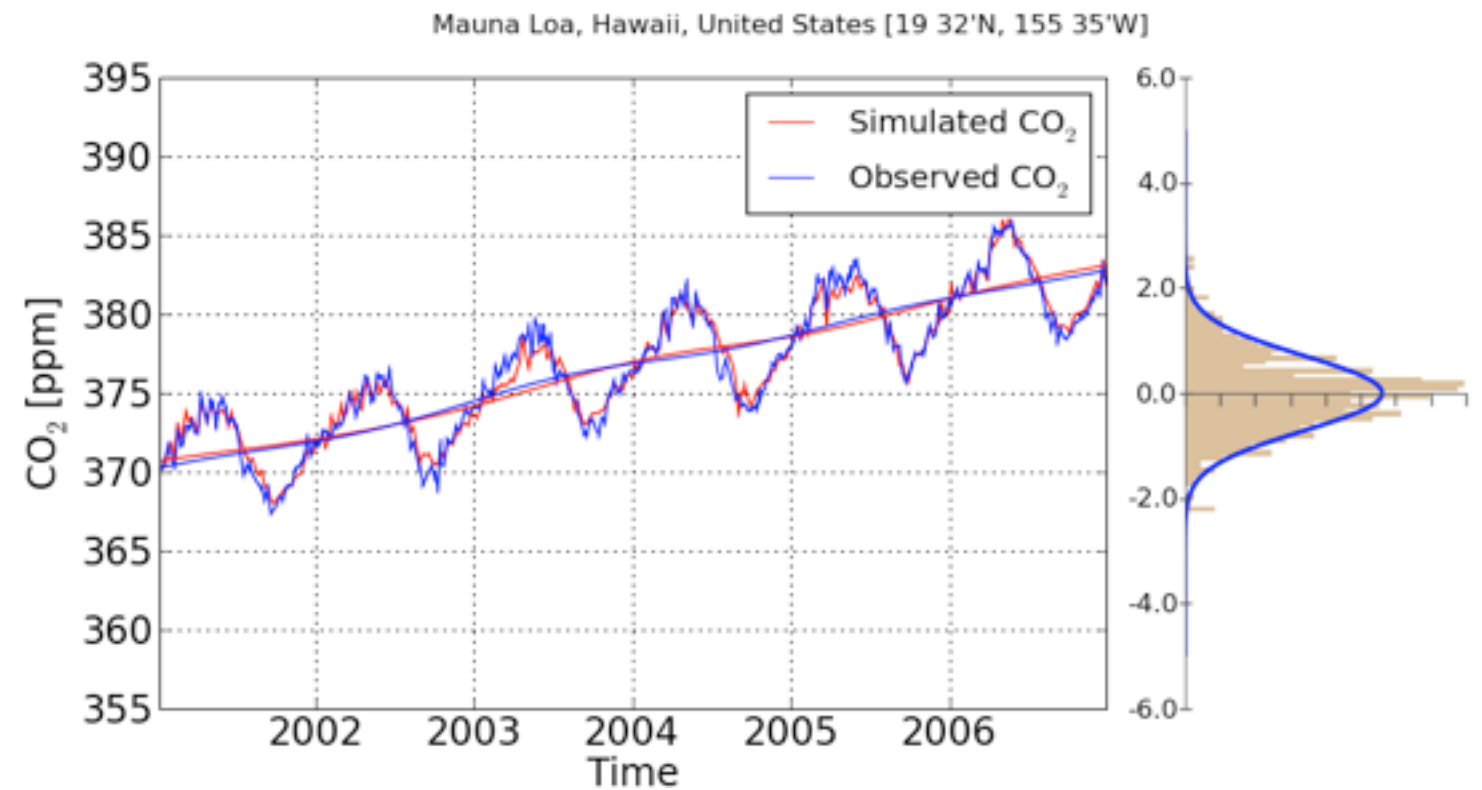
Carbon cycle, climate, and tracer transport links with NAO partly established. Soil moisture effect also expected (but not analyzed yet?)

Forward simulations with CO₂ and ¹³CO₂ in TM5



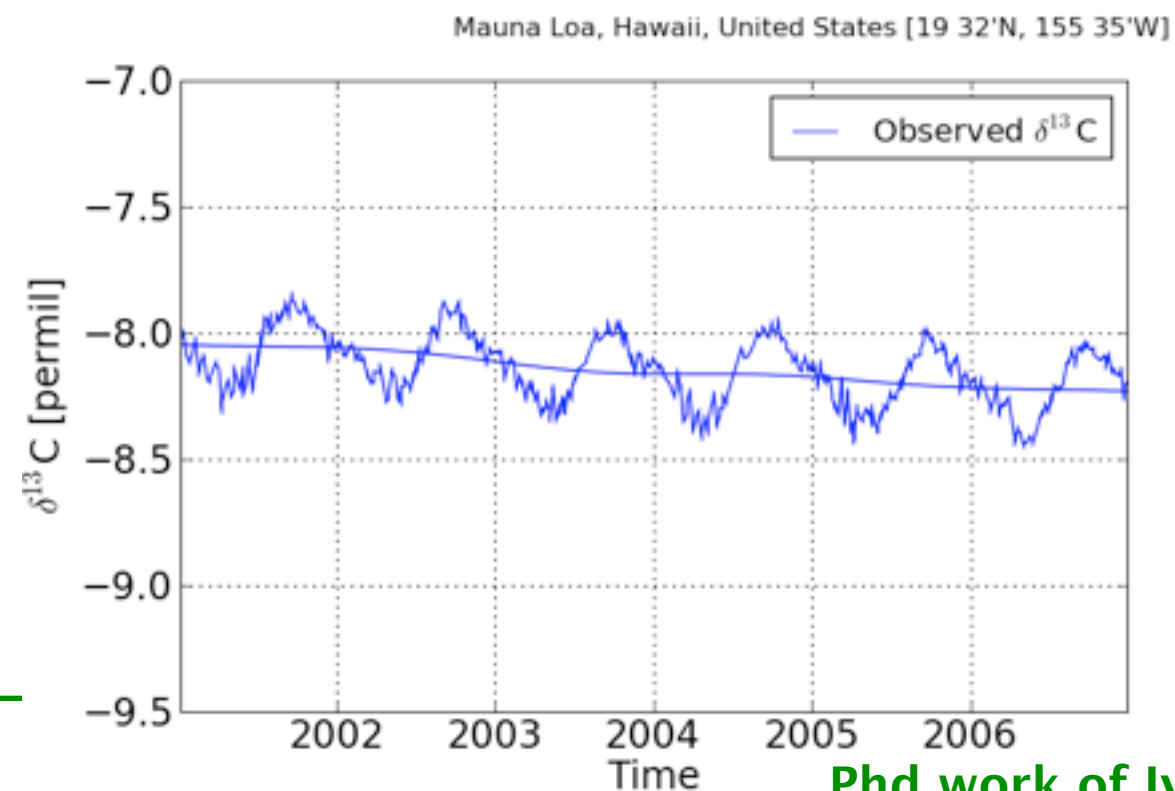
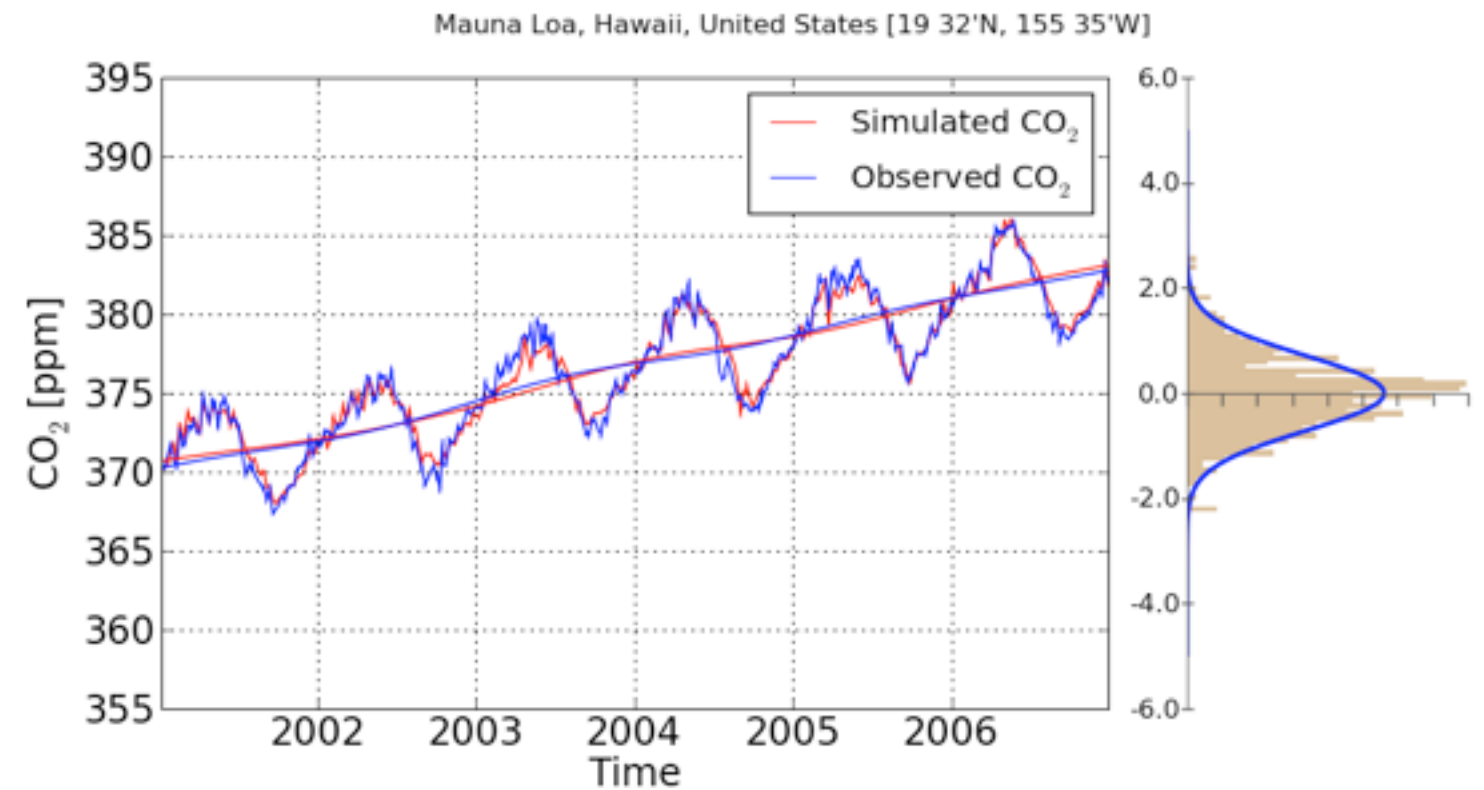
Forward simulations with CO₂ and ¹³CO₂ in TM5

- Atmospheric CO₂ is well simulated by the optimized CarbonTracker fluxes



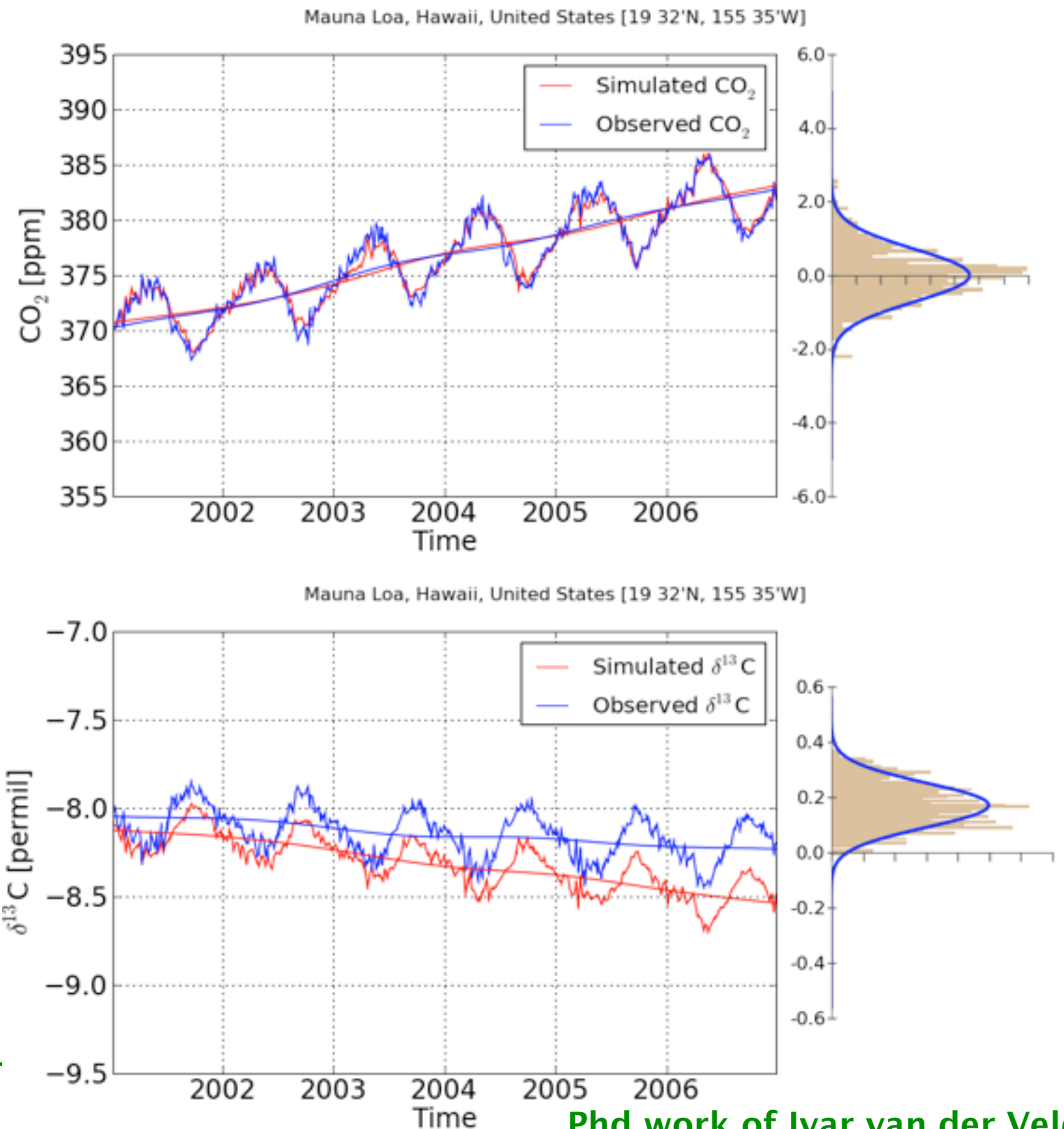
Forward simulations with CO₂ and ¹³CO₂ in TM5

- Atmospheric CO₂ is well simulated by the optimized CarbonTracker fluxes



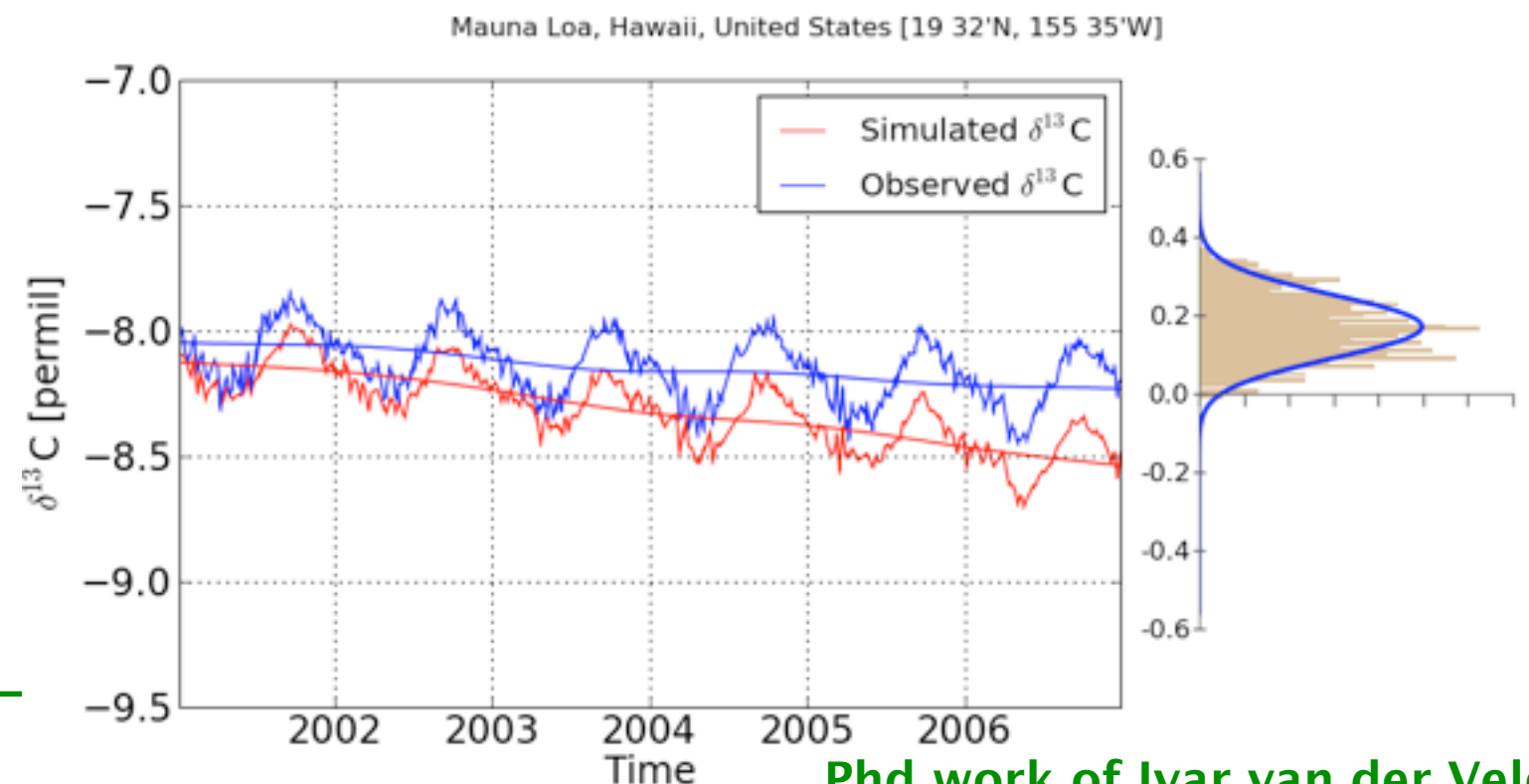
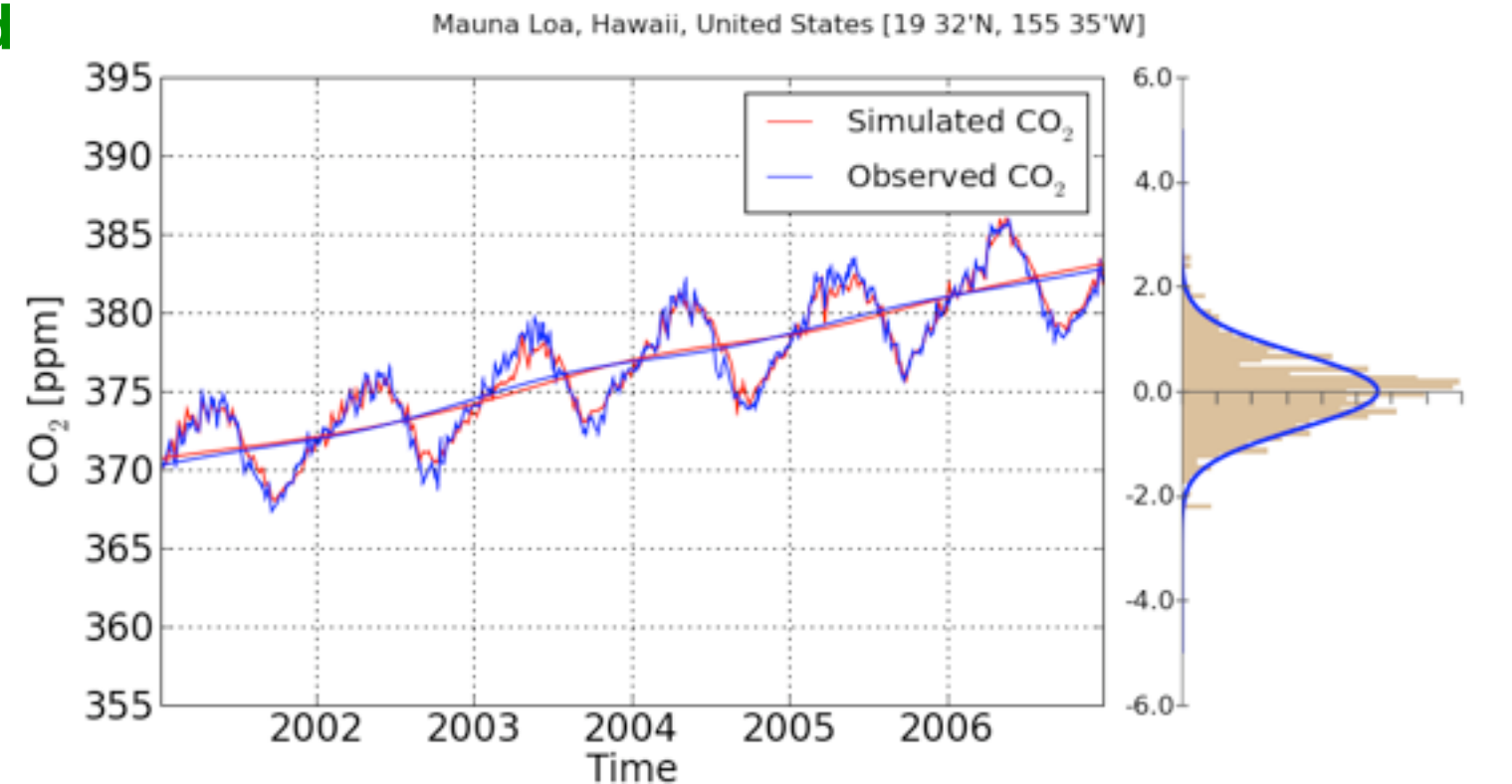
Forward simulations with CO₂ and ¹³CO₂ in TM5

- Atmospheric CO₂ is well simulated by the optimized CarbonTracker fluxes
- Downward trend of $\delta^{13}\text{C}$ is overestimated, possible culprits:



Forward simulations with CO₂ and ¹³CO₂ in TM5

- Atmospheric CO₂ is well simulated by the optimized CarbonTracker fluxes
- Downward trend of $\delta^{13}\text{C}$ is overestimated, possible culprits:
 - Lack of biospheric CO₂ uptake (1 Pg/y), hence an overestimate of other fluxes
 - Underestimate of ocean/land carbon residence time (25%)



Samenvatting

- **Belangrijke vragen in de koolstofcyclus zijn vooralsnog onbeantwoord**
- **MAQ ontwikkelt een pionier systeem voor “integrated monitoring”**
- **De koppeling met weer, klimaat, en de land-atmosfeer grens is erg sterk**
- **Er zijn leuke mogelijkheden voor studenten om mee te werken!**

Meer Info

<http://www.carbontracker.eu>

<http://carbontracker.noaa.gov>

<http://maq.wur.nl>



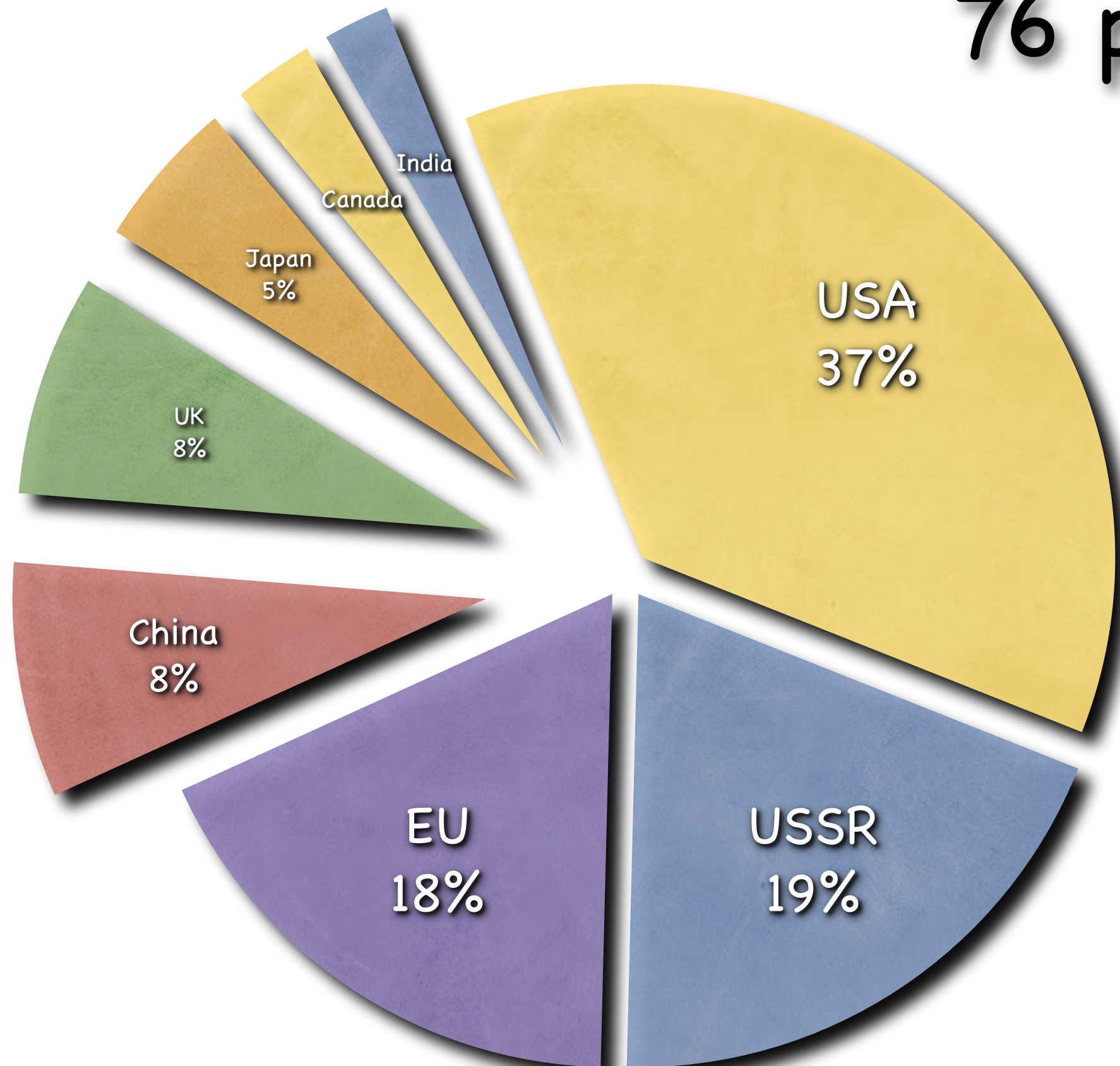
CarbonTracker

MAQ + Wouter + Peters

Where does all the carbon go?

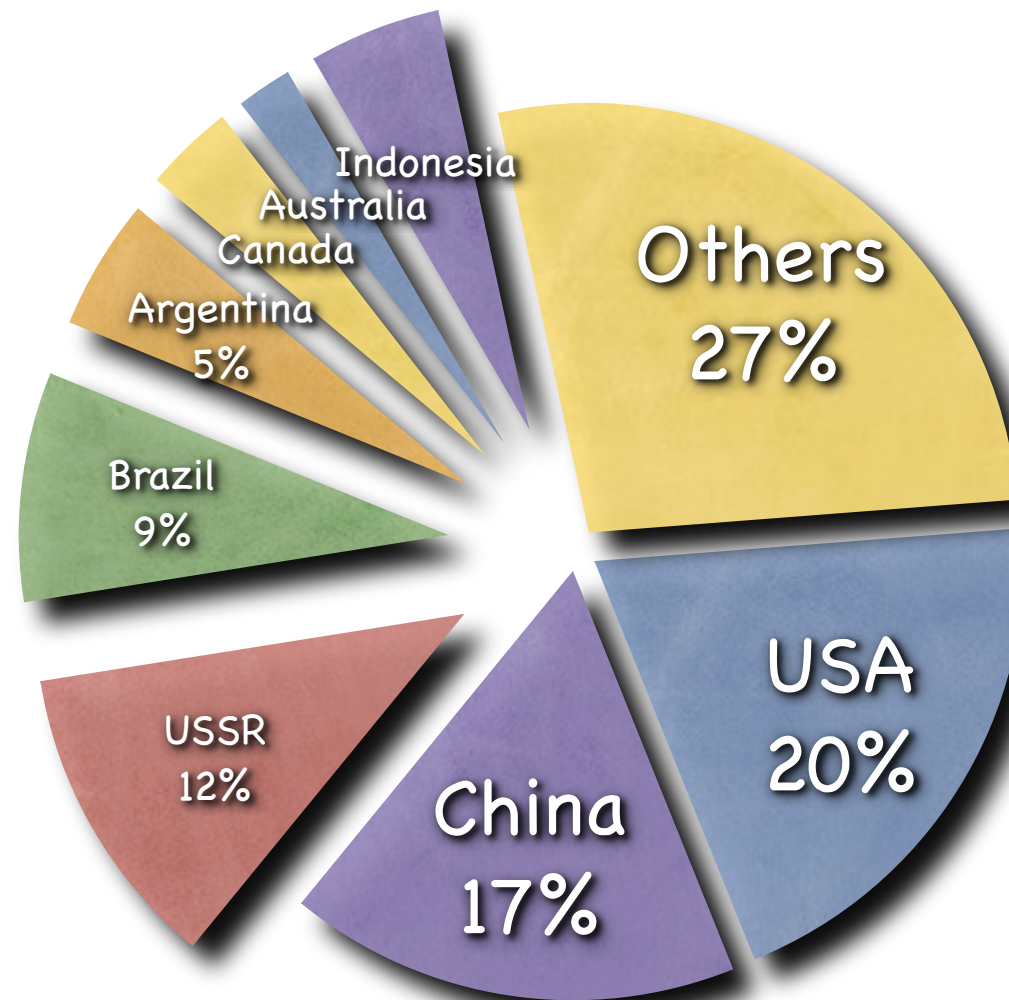
(1) Burning of fossil fuels

76 ppm



(2) Changes in land-use (deforestation)

24 ppm

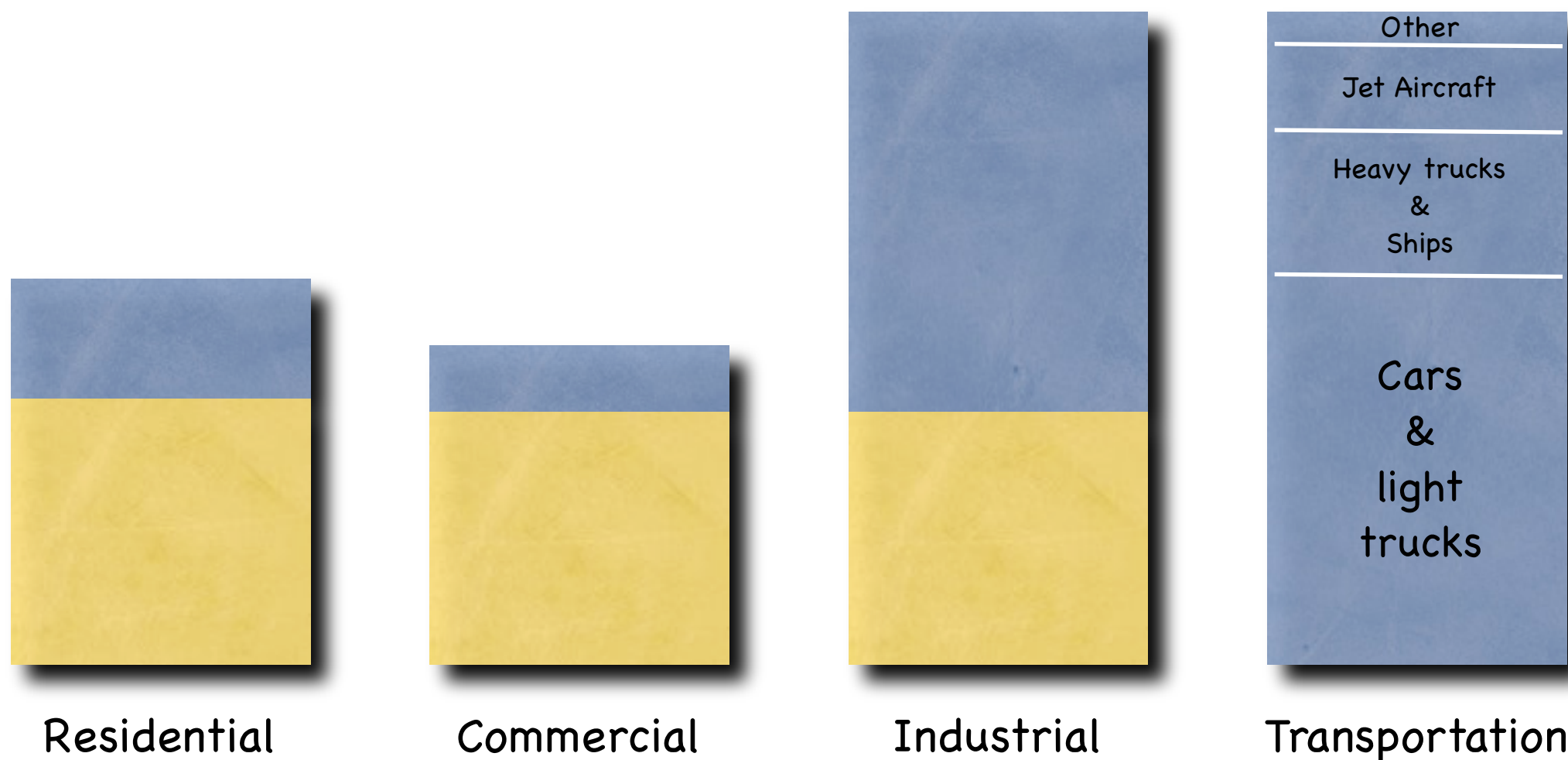


Industry \approx Transport Commercial \approx Residential

■ Electricity Generation ■ Direct Burning

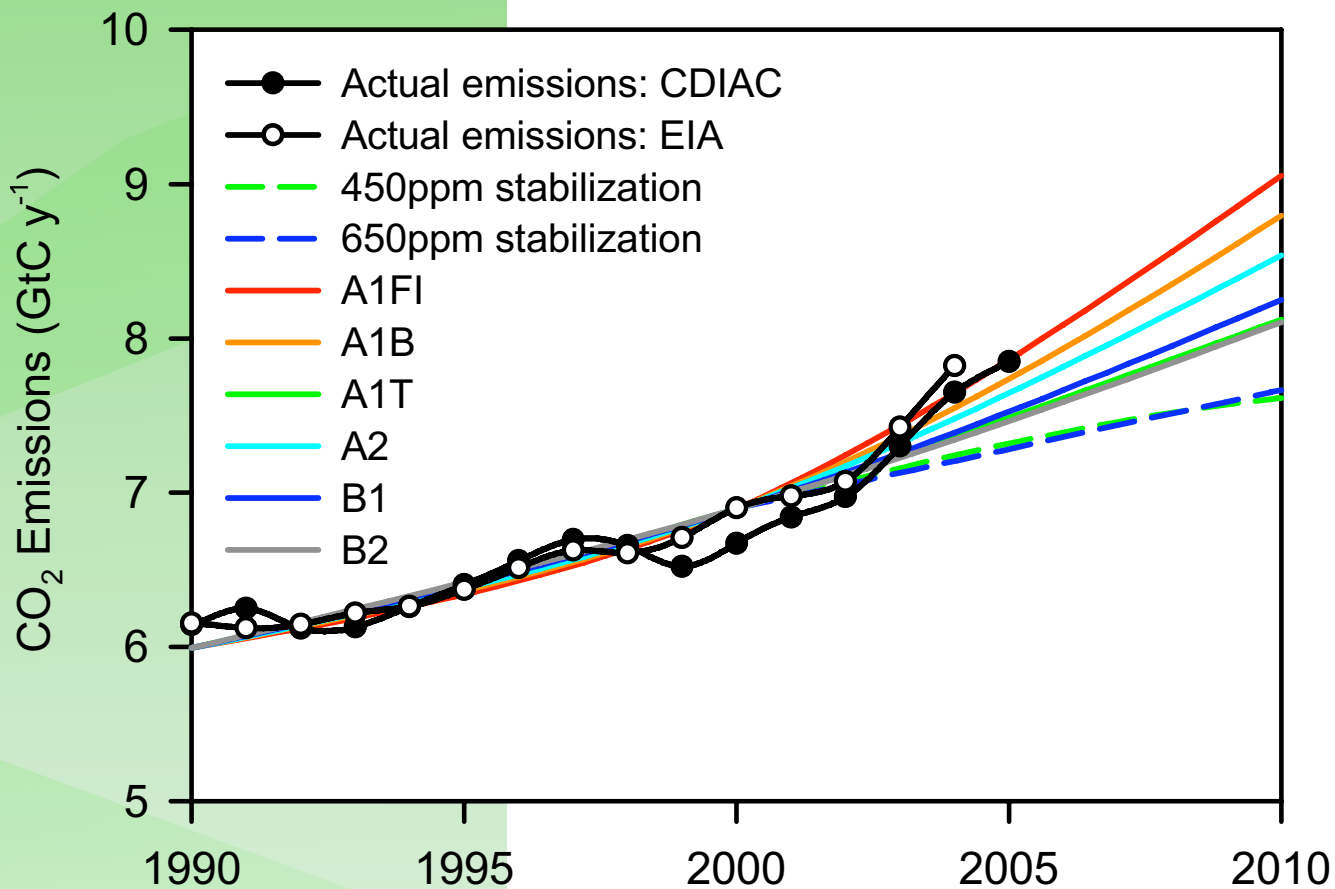
UNITS!!

500
375
250
125
0

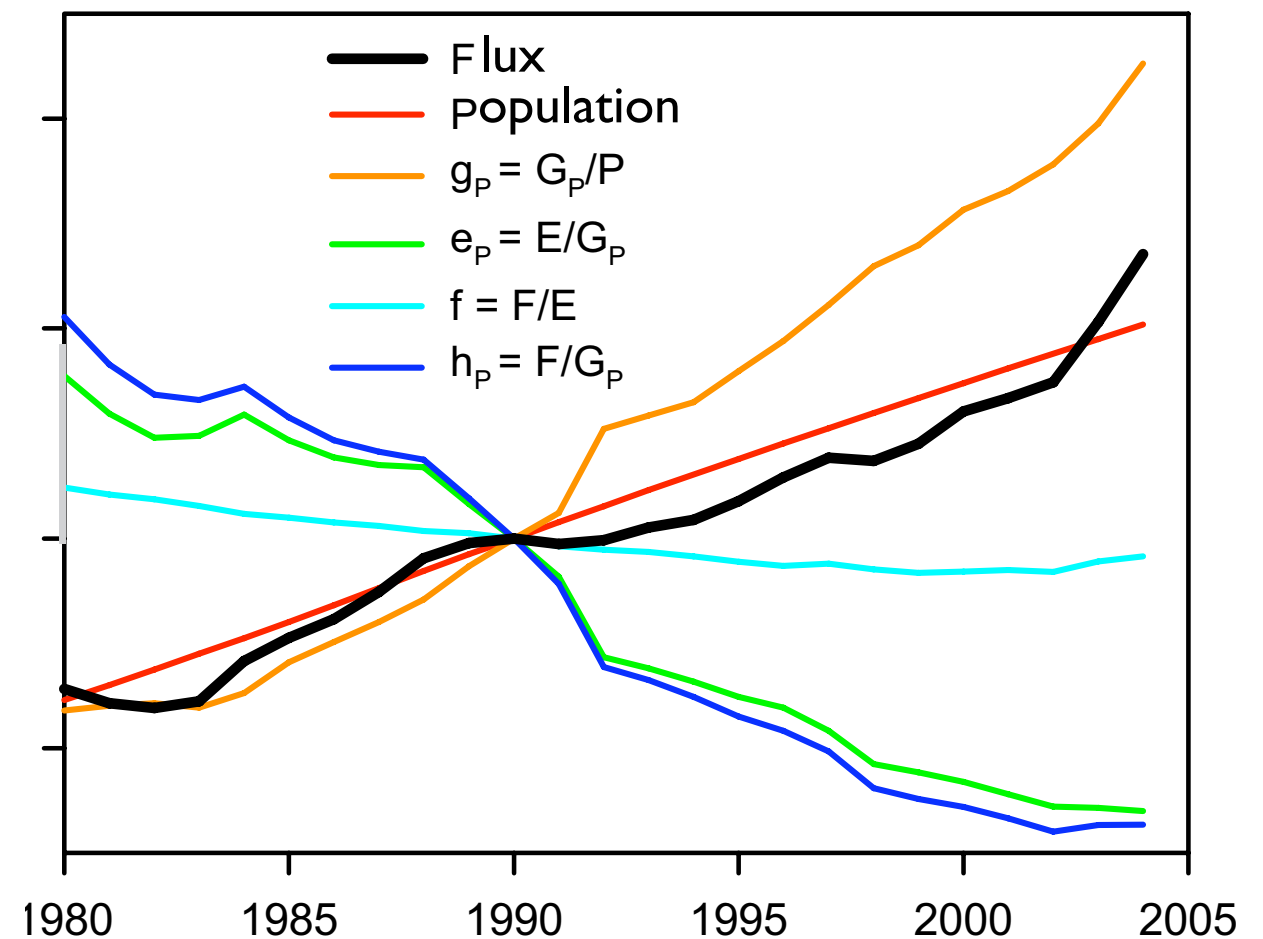


Global and regional drivers of accelerating CO₂ emissions

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f = carbon intensity of energy
 h_p = carbon intensity of GDP
 e_p = energy intensity of GDP



Population growth and GDP growth outpace innovations!

Atmosphere

CO₂ flux (PgCO₂/y)

