Assessing impacts of climate extremes on the terrestrial carbon cycle

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with contributions from

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I. Introduction

- *Terrestrial ecosystems play a crucial role in the Earth System as:*
  - biogeochemical reactors
  - direct interface to the atmosphere
  - mediator of GHGs …

- *Impacts of climate extremes on terrestrial ecosystems:*
  - may feedback to the climate system

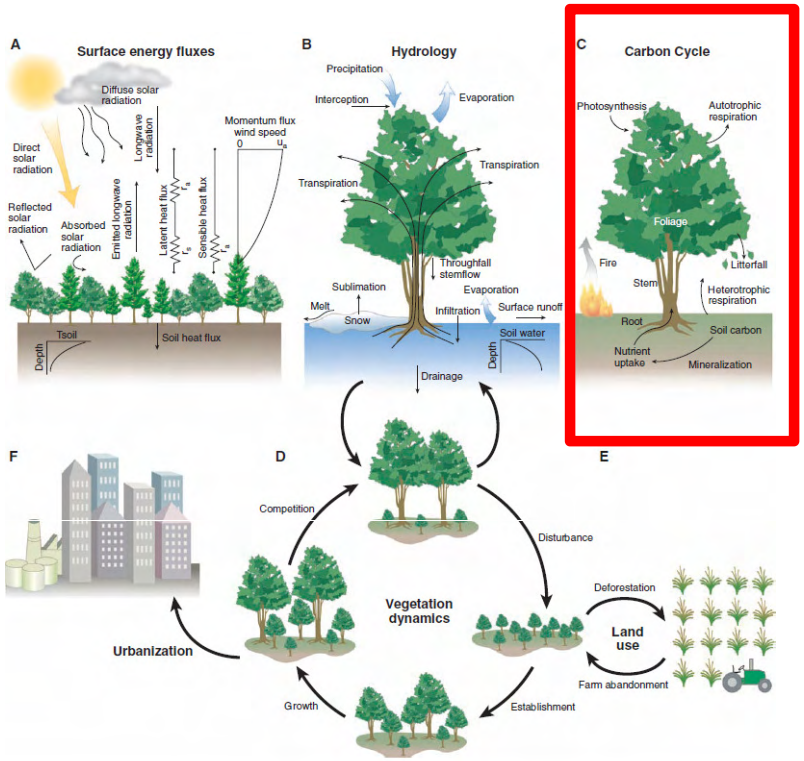


Fig. 2. The current generation of climate models treats the biosphere and atmosphere as a coupled system. Land surface parameterizations represent the biogeophysics, biogeochemistry, and biogeography of terrestrial ecosystems. **(A)** Surface energy fluxes and **(B)** the hydrologic cycle. These are the core biogeophysical processes. Many models also include **(C)** the carbon cycle and **(D)** vegetation dynamics so that plant ecosystems respond to climate change. Some models also include **(E)** land use and **(F)** urbanization to represent human alteration of the biosphere.

Bonan (2008) Science: 320, 1444

I. Introduction

Terminology:

GPP = total CO_2 uptake (via photosynthesis)

TER = Σ natural CO_2 losses

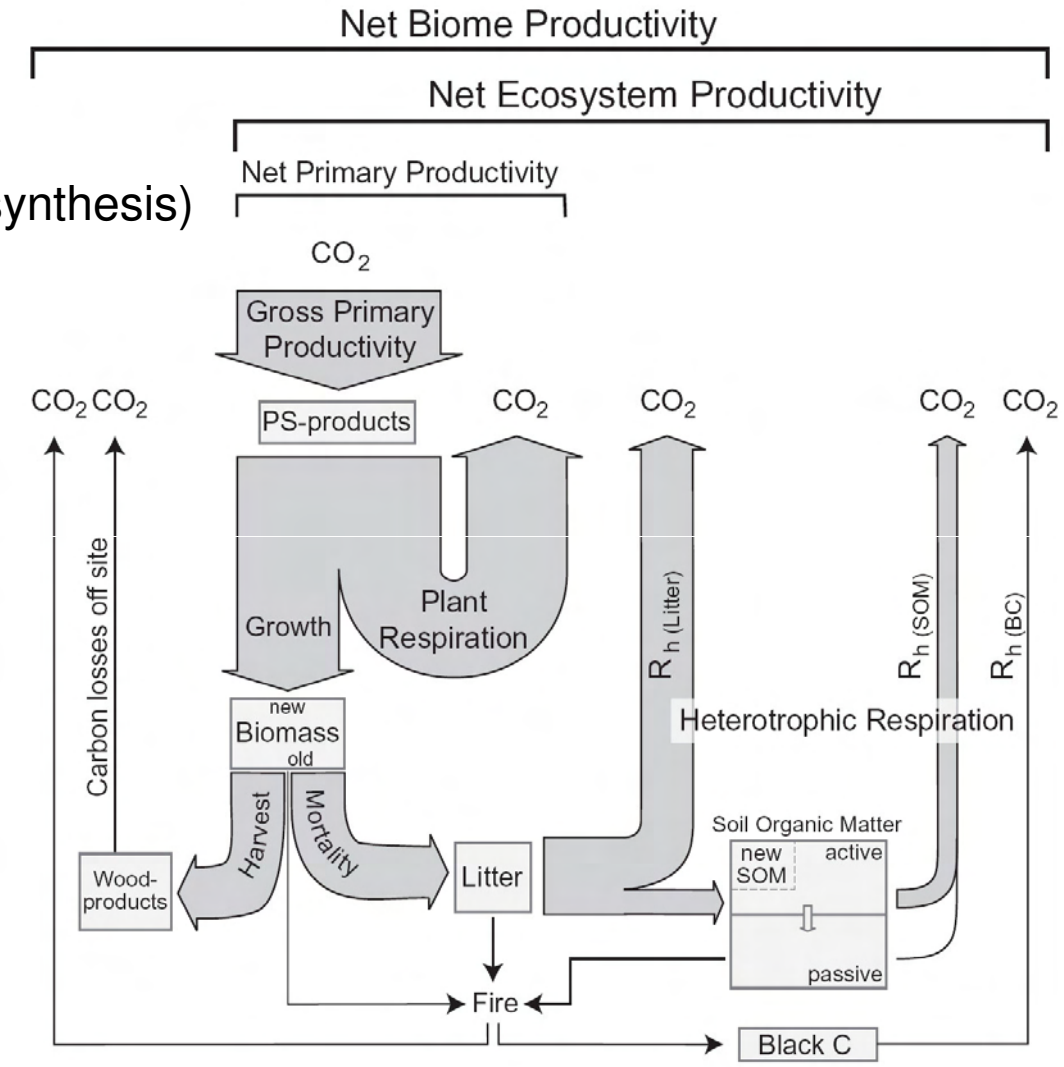
NEE = NEP (net balance)

NEE = GPP - TER

Sign convention CO_2 fluxes:

[–] *removal from atmosphere*

[+] *Release to atmosphere*

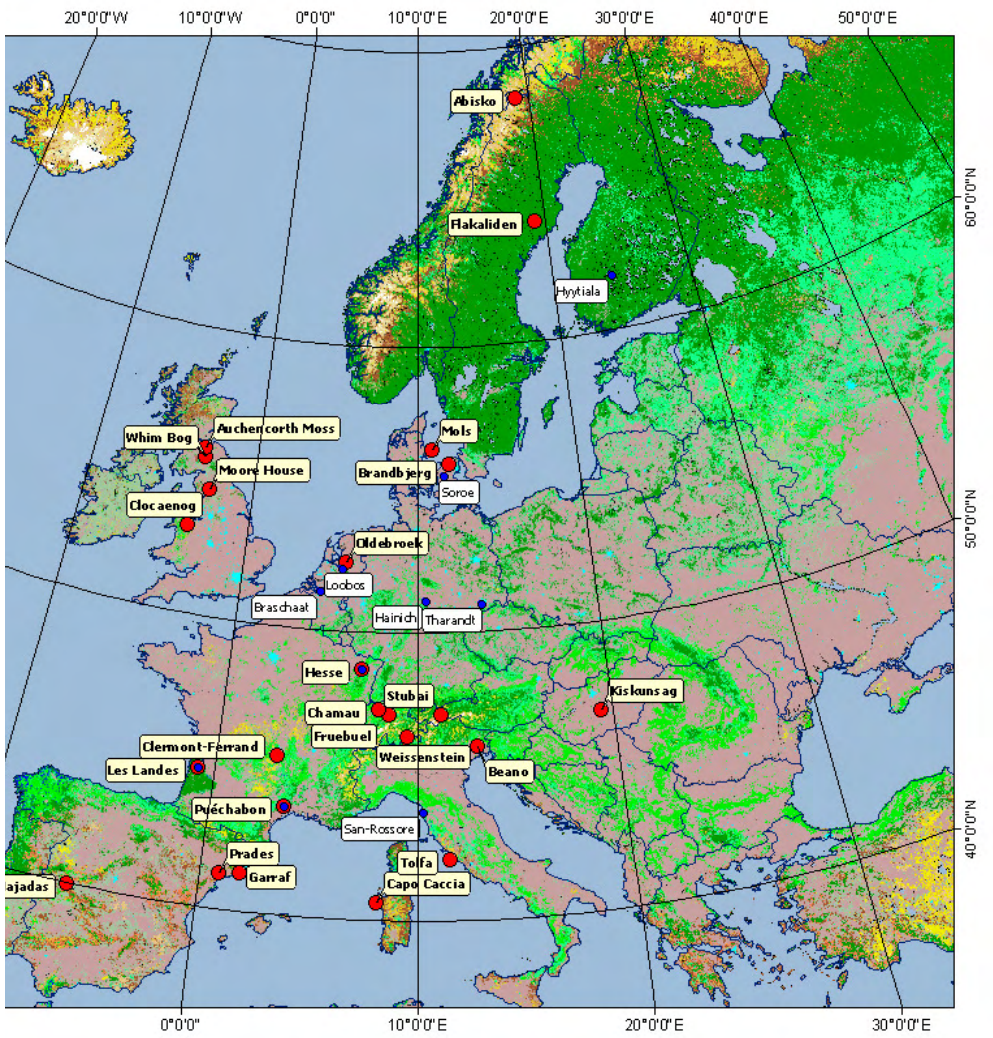


Schulze, ED (2000) Science: 289, 2058

II. Project: CARBO-Extreme

The terrestrial C-cycle under Climate Variability and Extremes – a Pan-European synthesis

European Terrestrial Carbon Cycle – *State of the Art*



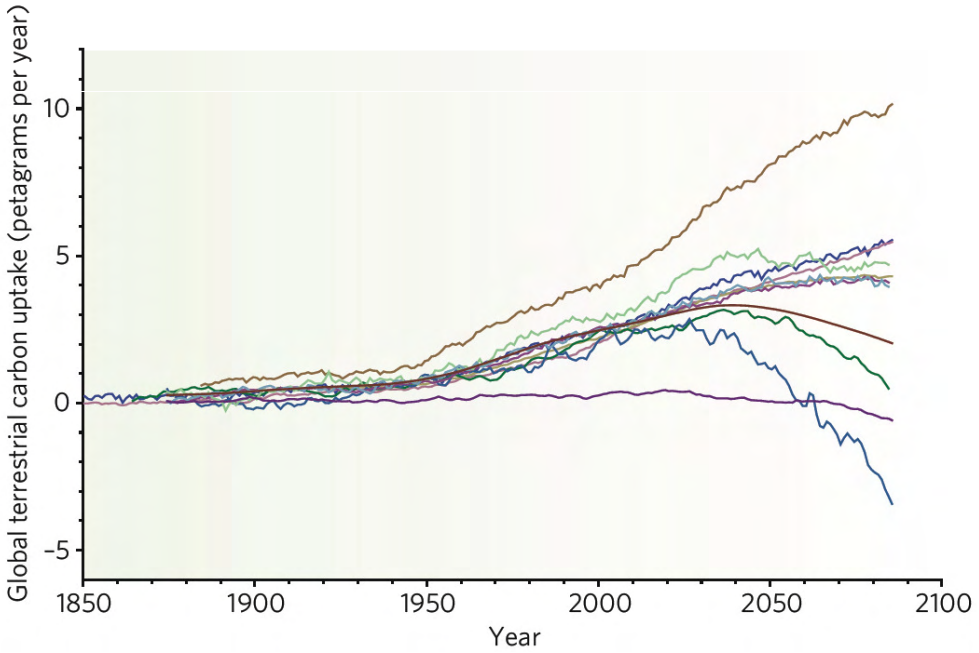
(CARBOEUROPE-IP project)

ariability/extremes on carbon cycle?

ttp://www.carbo-extreme.eu

III. Problem

- *Understanding ecosystem functioning is complicated:*
  - processes act from **seconds to millennia**
  - couplings are often **non-linear,**
  - ecosystems have **memory**
  - **coupling** to other subsystems (hydrosphere, anthroposphere) is manifold



Coupled Carbon Cycle Climate Model Inter-comparisons …

Friedlingstein et al. (2006) J. Climate 19,3337.

III. Problem

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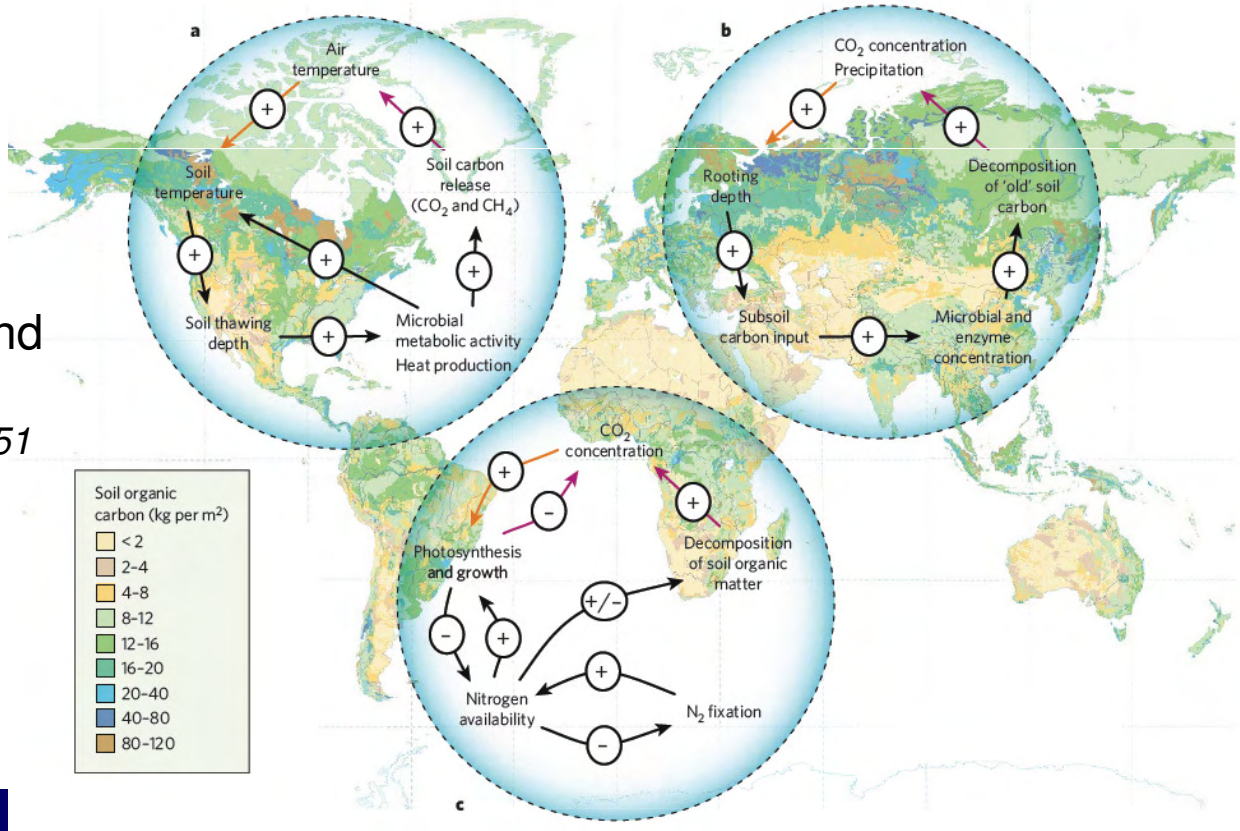
Ecosystem carbon dynamics and climate feedbacks
Heimann & Reichstein (2008) Nature: 451



III. Problem

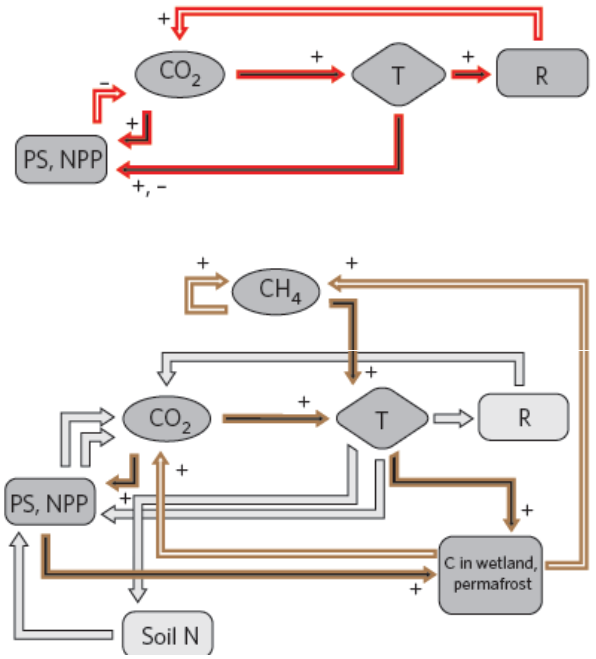
Most of the “likely” or “very likely” changes in the climate system are affecting land-surface processes:

- *less frequent cold nights,*
- *increased frequency of hot extremes*
- *etc…*

… are tightly linked to the controls of the terrestrial carbon cycle.

… and may even indirectly enhanced /dampened by the C-cylce climate feedback

Typical feedbacks



Arneth et al. (2010) Nature Geoscience, 3, 552

III. Problem

Cutout of the ``Essential Climate Variables'' (GCOS)

Terrestrial surface obs. (max. 30 yr, nice but not what we really need!)

- Albedo,
- Land cover,
- FAPAR,
- Leaf area index,
- Active fires,
- Soil moisture,
- …

Direct observations of fluxes ~ acupuncture

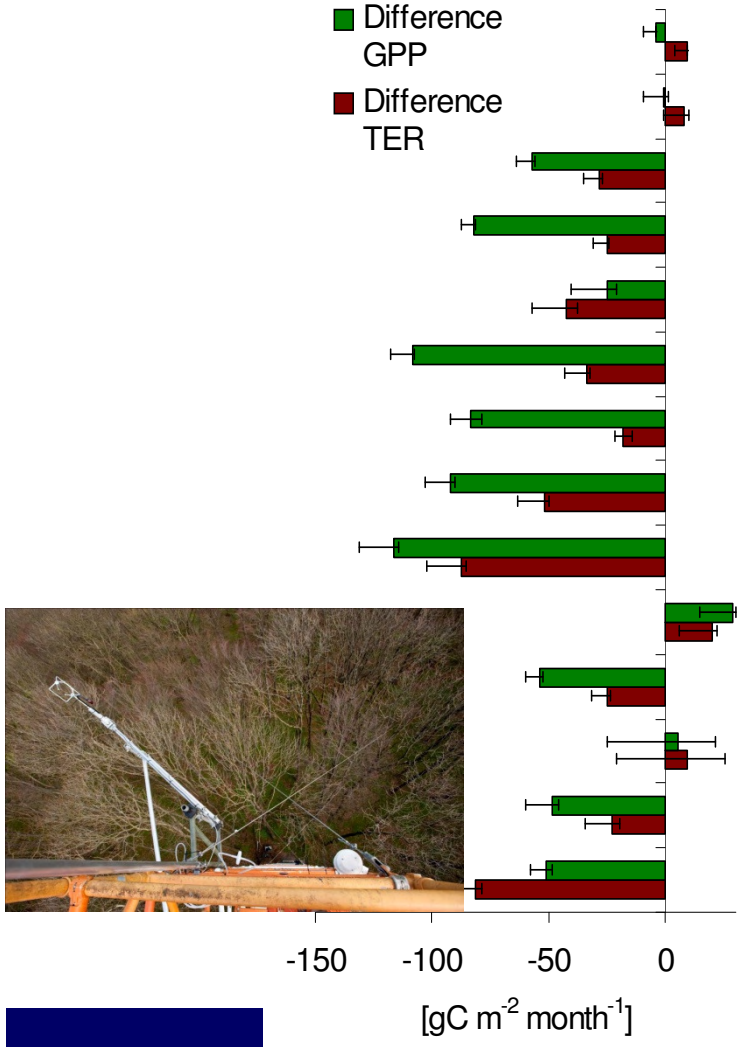
- Point measurements of CO_2, H, LH fluxes
- Local inventories
- Tree rings

Hydrometeorological observations (up to ~100 yr)

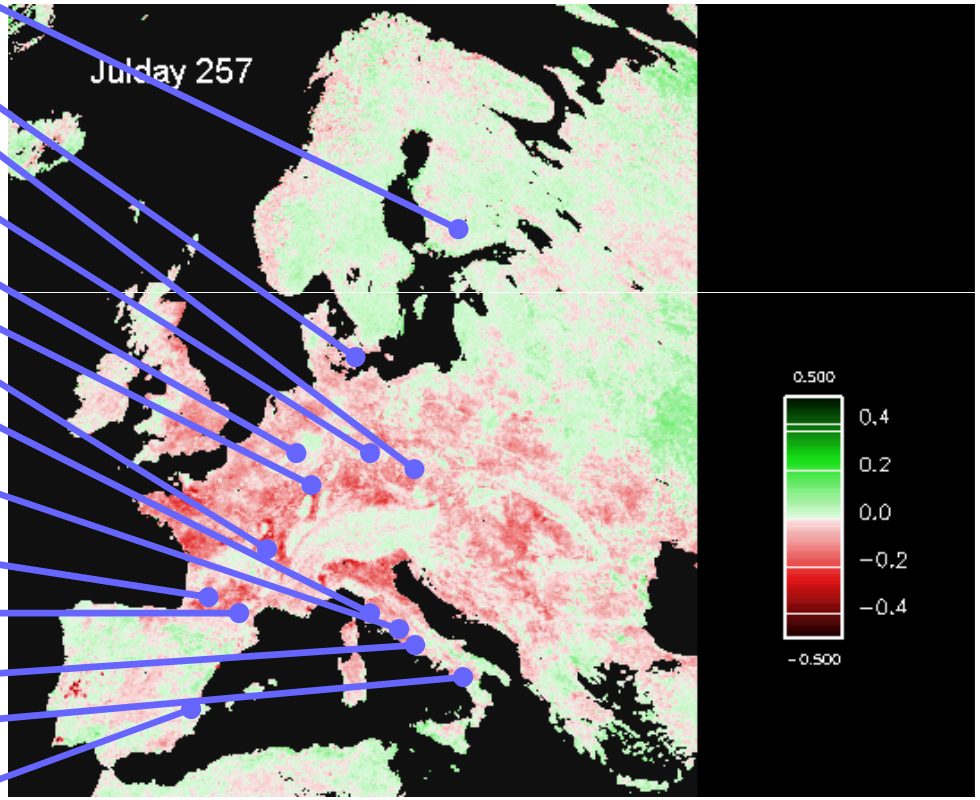
- Air temperature
- Precipitation
- Surface radiation budget
- Wind speed and direction
- Water vapor
- River discharge,
- Water use, Ground water, Lake levels,
- Snow cover,
- Glaciers and ice caps …

IV. Data

Eddy covariance GPP & TER reduction Jul-Sep 2003

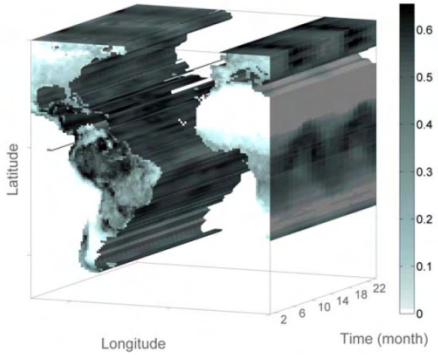


FAPAR anomaly 2003 from MODIS (unitless)

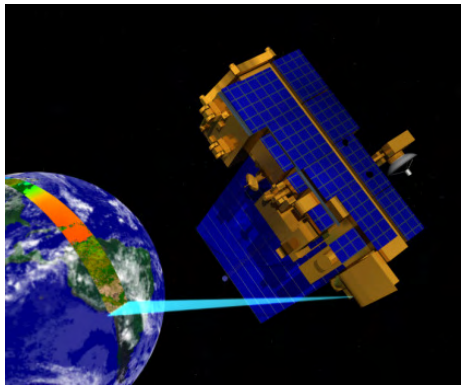


Ciais et al. (2005) Nature: 437, 529-533

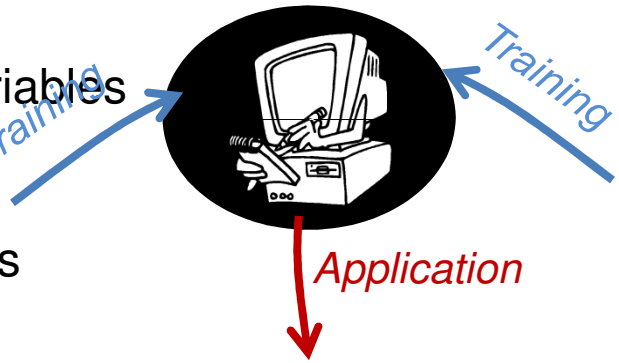
IV. Data



The same gridded explanatory variables

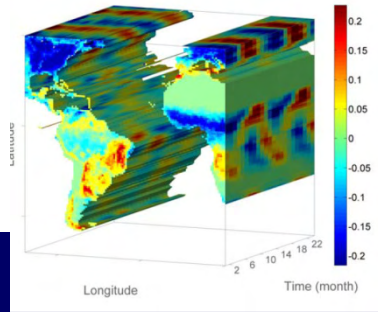


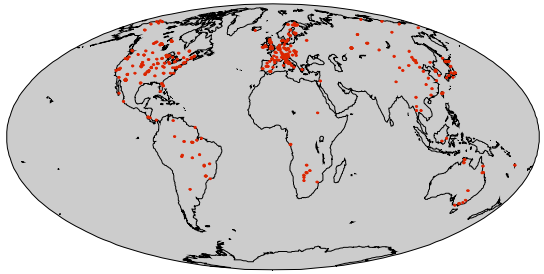
Site-level explanatory variables
- Meteorology
- Vegetation type
- Remote sensing indices



Target variable: ecosystem-atmosphere flux

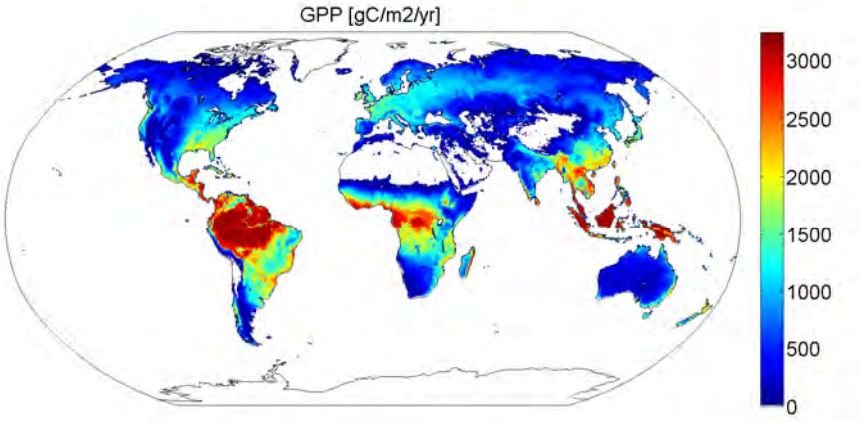
Gridded target variable



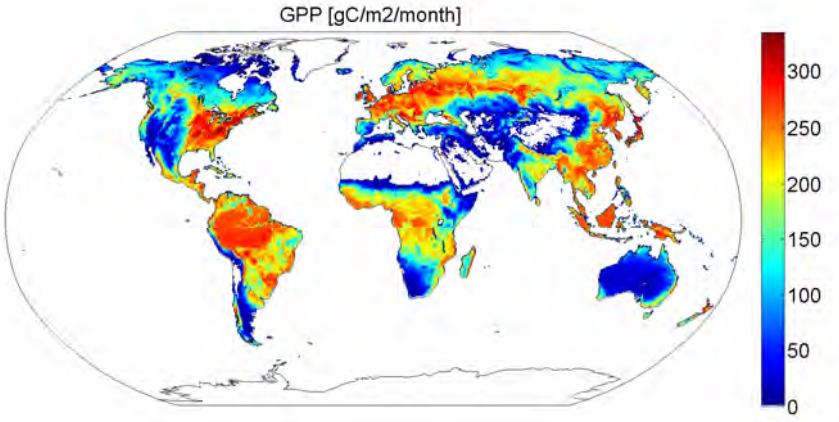


IV. Data

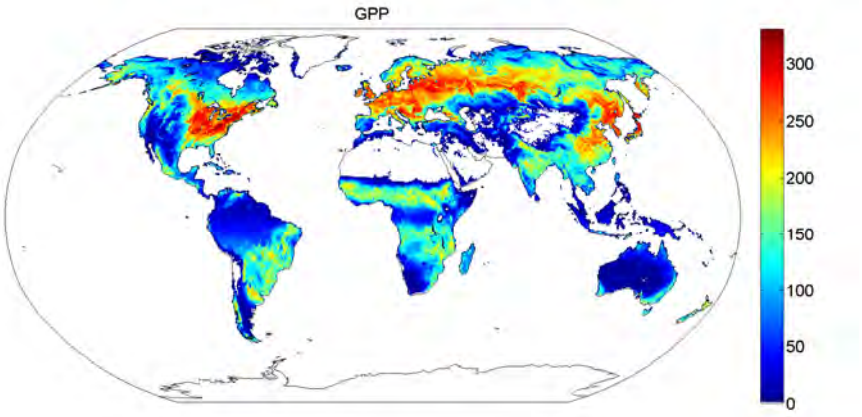
Mean annual



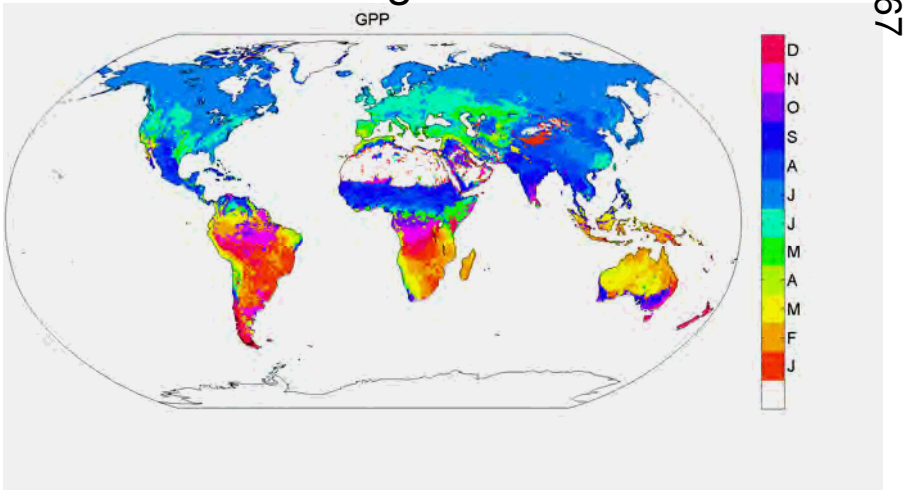
Max of seasonal cycle



Amplitude of seasonal cycle



Month of largest C flux

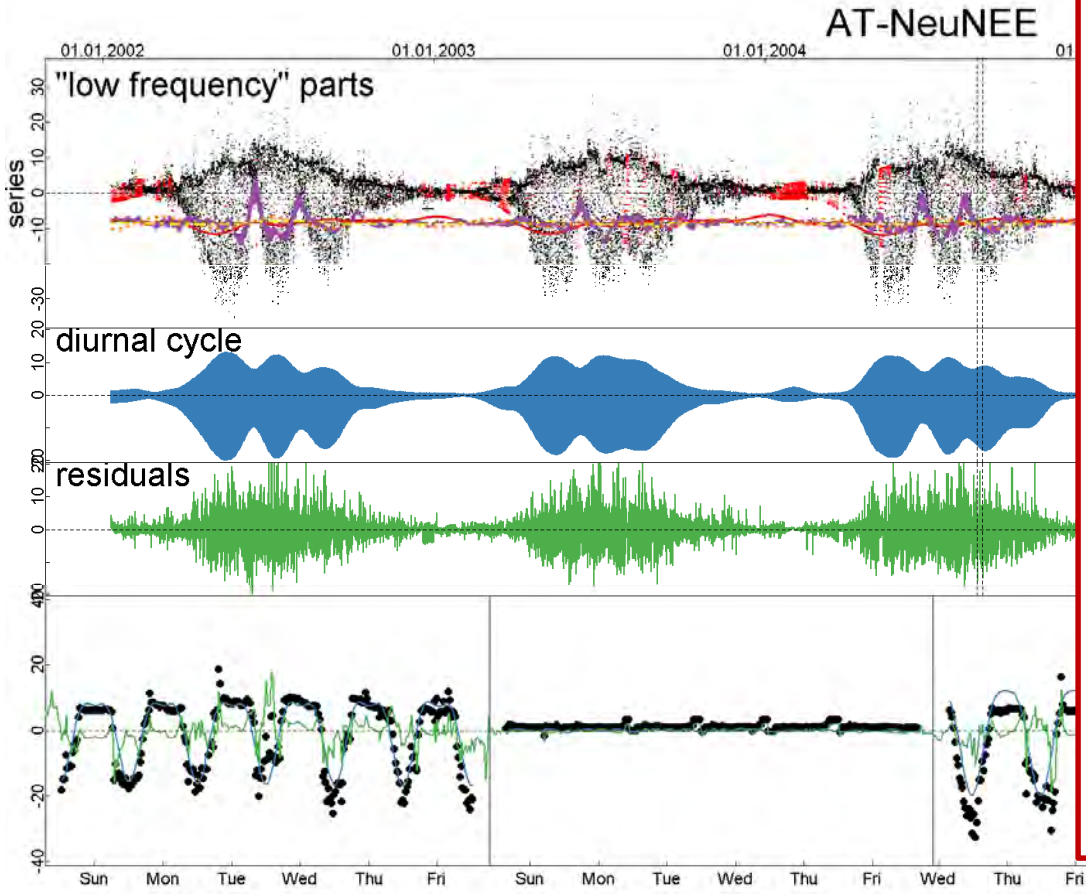


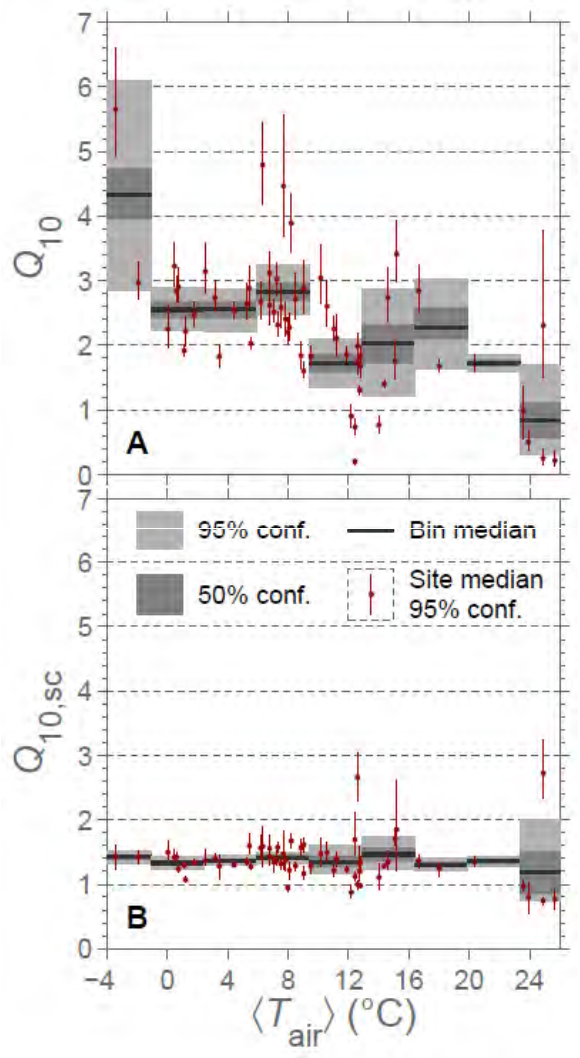
Jung et al. (2009) Biogeosciences: 6
Beer et al. (2010) Science: 329
Jung et al. (2010) Nature: 467

V. Concepts under development

Analyzing the records at **different time scales** o

- Half hourly data *(CO_2 fluxes)*
- *Yiou et al. (2000) Physica D: 142,*
- *Golyandina et al. (2004), Chapman & Hall, ..*

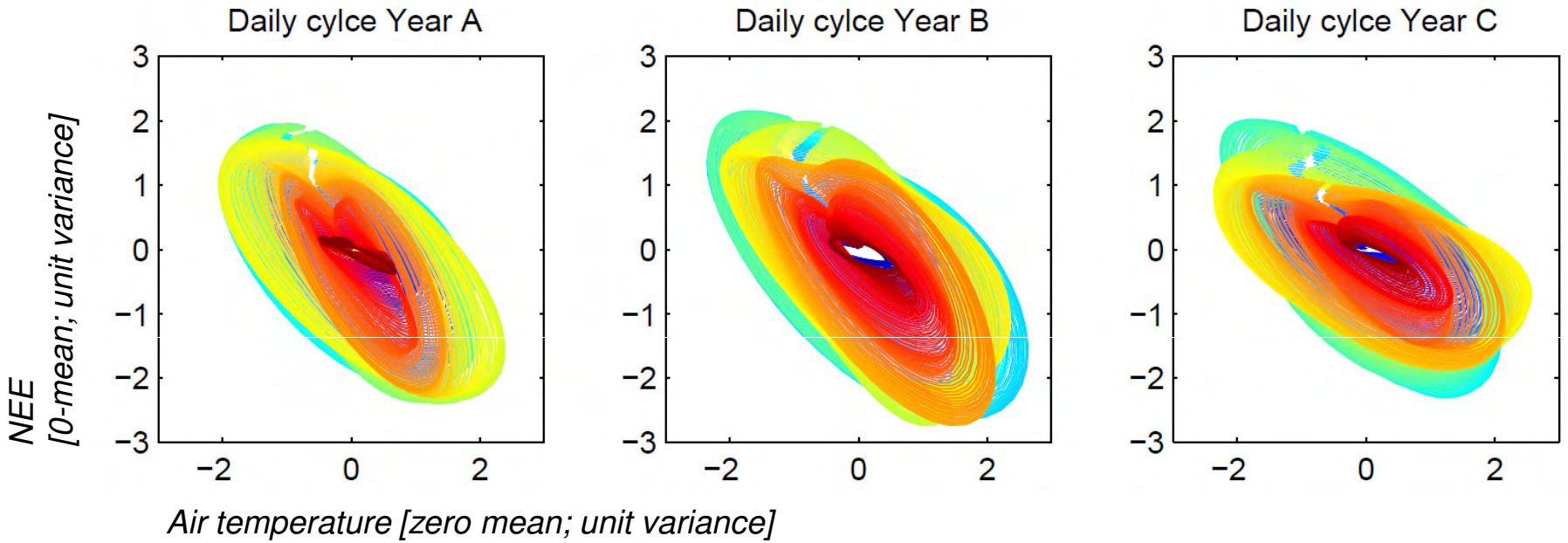




Mahecha et al. (2010) Science: 329

V. Concepts under development

Towards **motion patterns**… (daily cycle only aims at understanding “fast” dynamics)



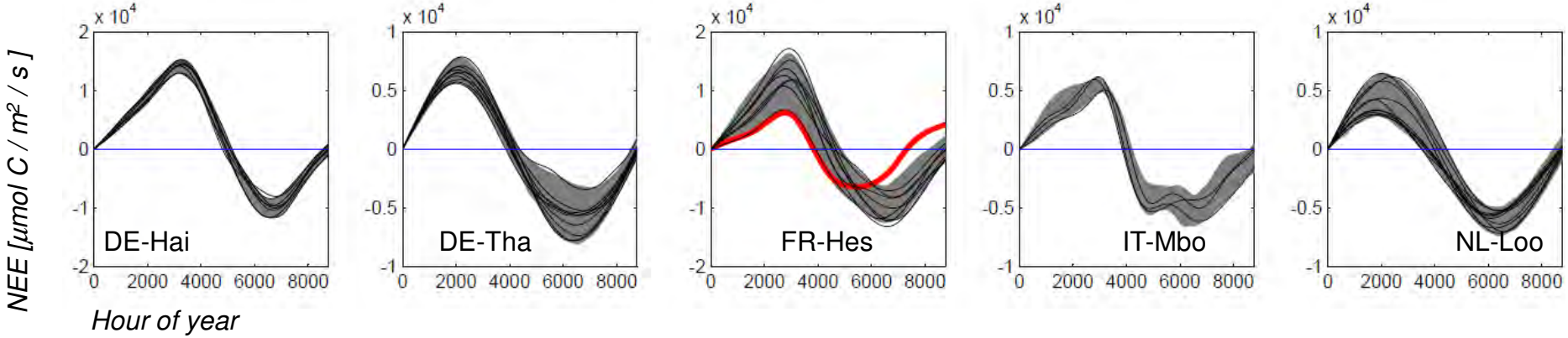
→ (time localized) detection of anomalies in a trajectory... ?? If so…

→ how to define the expected trajectory ***f*(meteo., state of ecosys)**

→ how many dimensions do we have to scrutinize?

V. Concepts under development

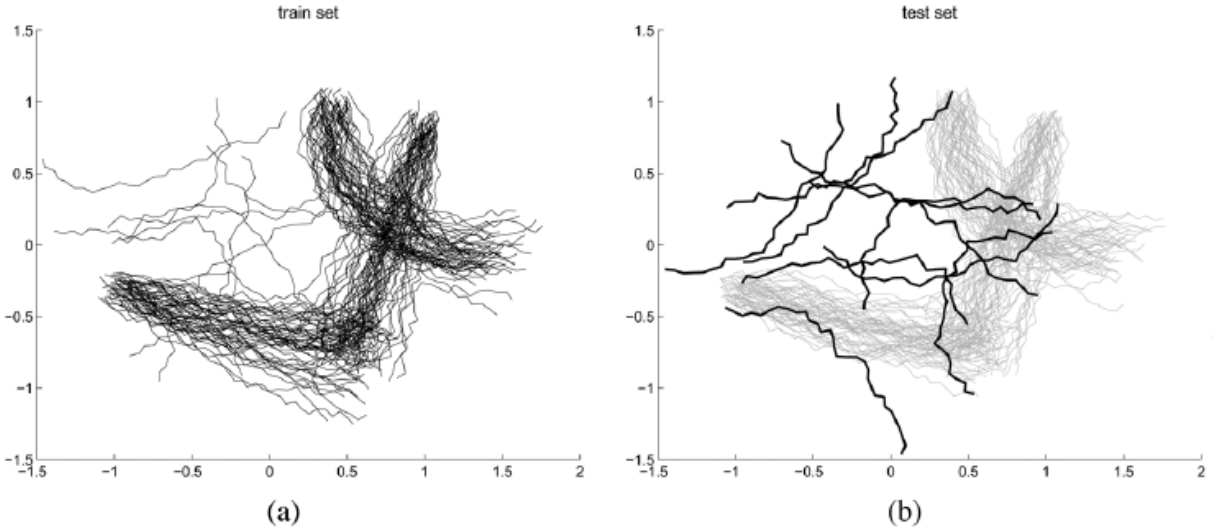
Towards **typical annual trajectories** … (annual cycle + intra-monthly variability only)



- Ho to define the trajectory? Short monitoring period → ***IAAFT***
- Extremes climate conditions translate into the balance **depending on the ecosystem type**
- Different pathways are thinkable … even **the "no impact" scenario**

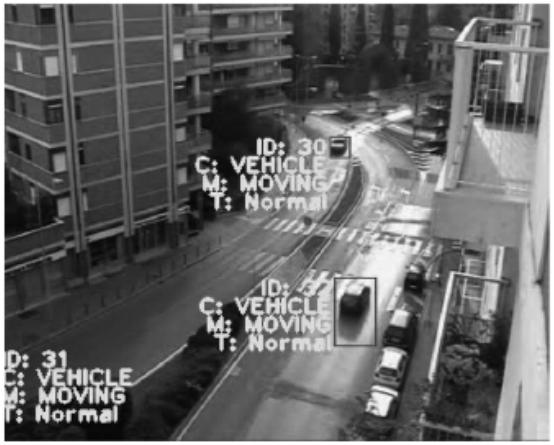
cf. also: POSTER 32:
Wu, Ibrom et al. *Effect of climate variability and anomalies on the long term C dynamics in a temperate deciduous forest.*

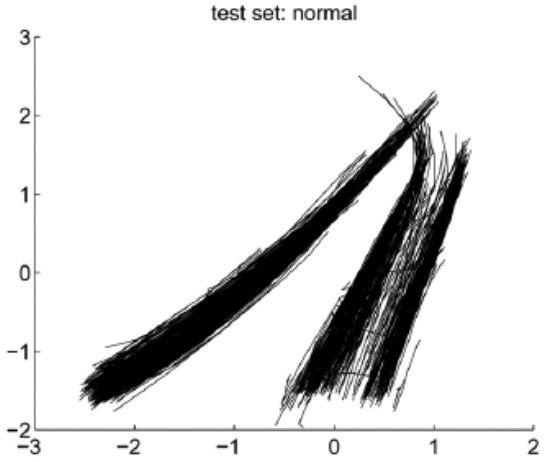
V. Concepts under development

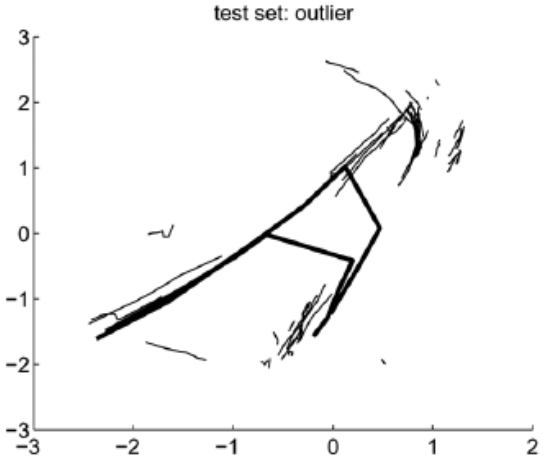


Other sources of inspiration… ?

Picarielle et al. 2008: Trajectory-Based Anomalous Event Detection.
IEEE Transactions on Circuits and Systems for Video Technology, 18, 1544-1554







VI. Perspective

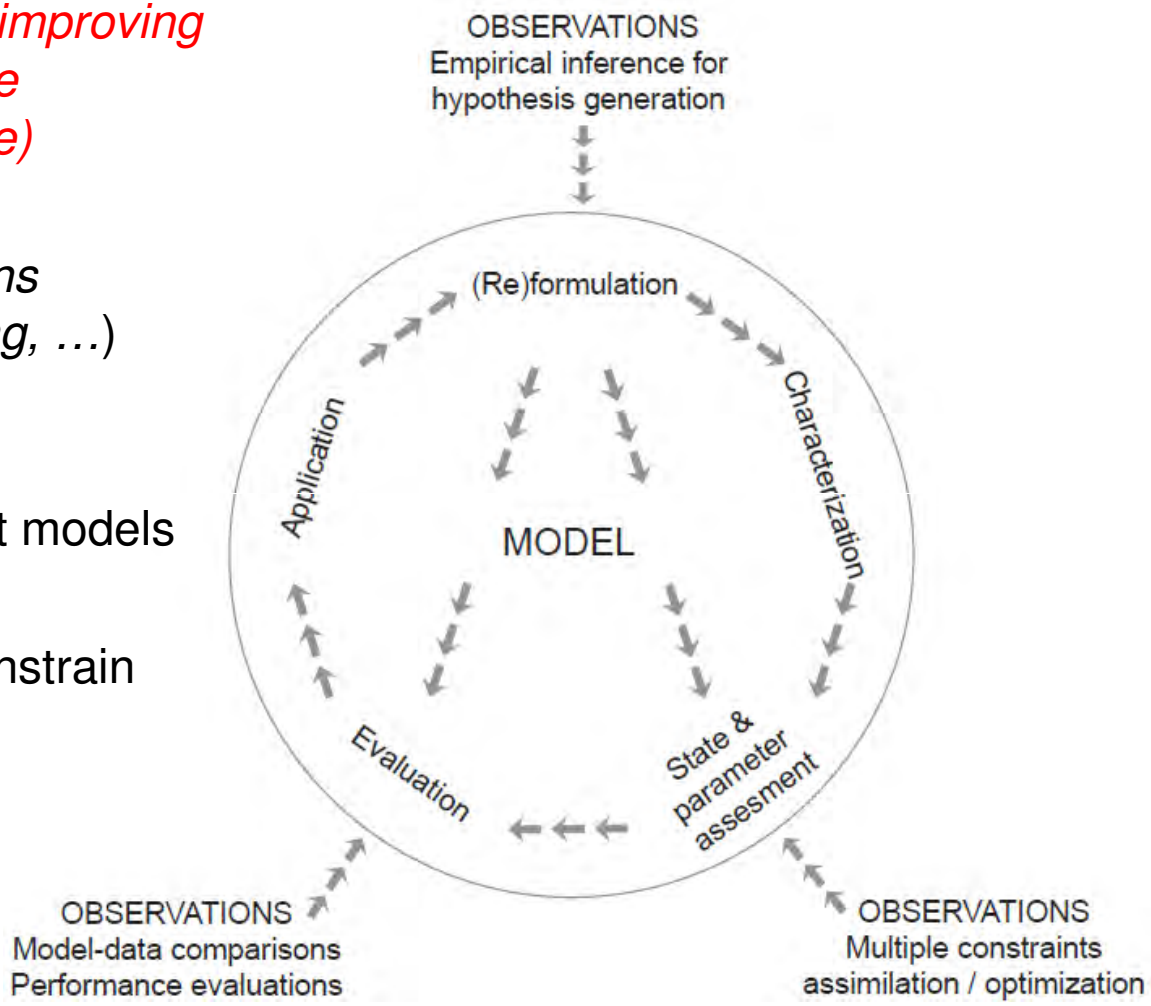
"what are you doing, data mining or science?"

Learning from observations for improving models (~our hypotheses on the functioning of the terr. biosphere)

1. Empirical inference (*patterns extraction, machine learning, …*)

2. Performance evaluations: observations (patterns) test models

3. Observations (patterns) constrain processes responses



Preliminary conclusions …

(1) A framework to quantify the impacts may differ from the detection issue (trajectory concepts…)

(2) New techniques need to consider short monitoring periods

(3) Extreme events translate or not into anomalies of the C cycle (different pathways are thinkable)

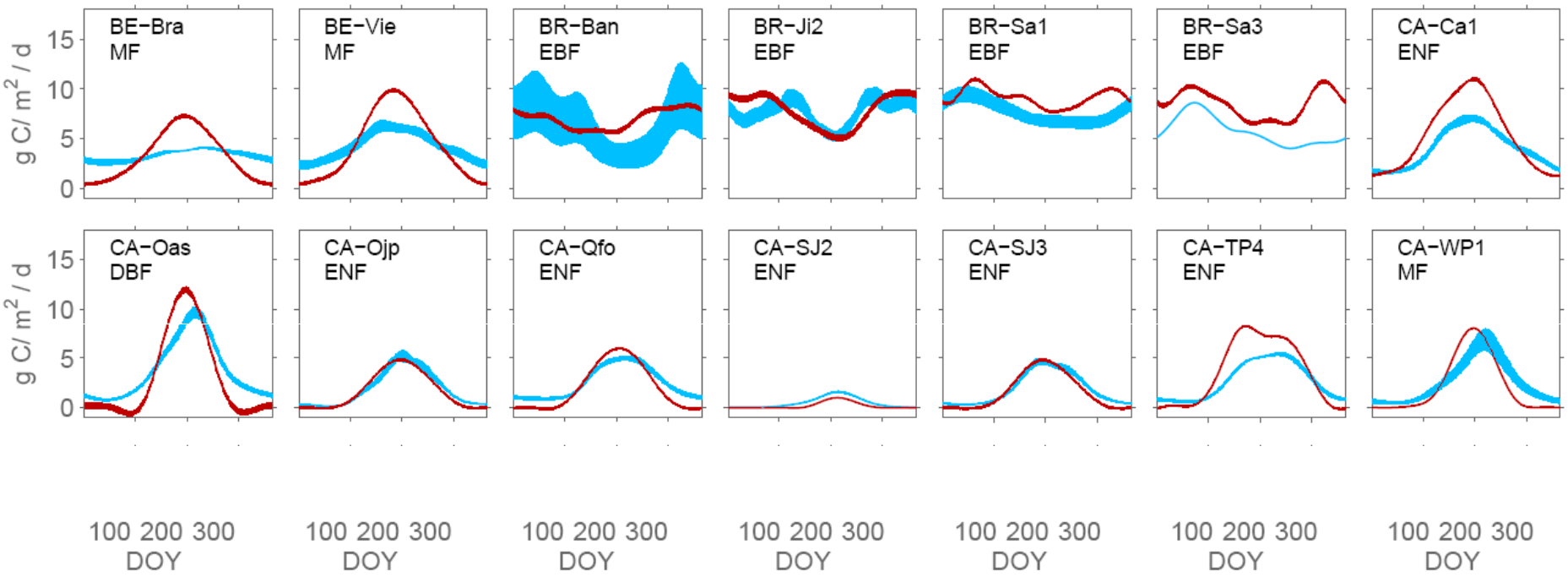
(4) Impacts may differ depending on the time scale

(5) Extremes impact C cycling depending on the type of ecosystem and “state of the biosphere” (timing, phenostate, life-cylce, …)

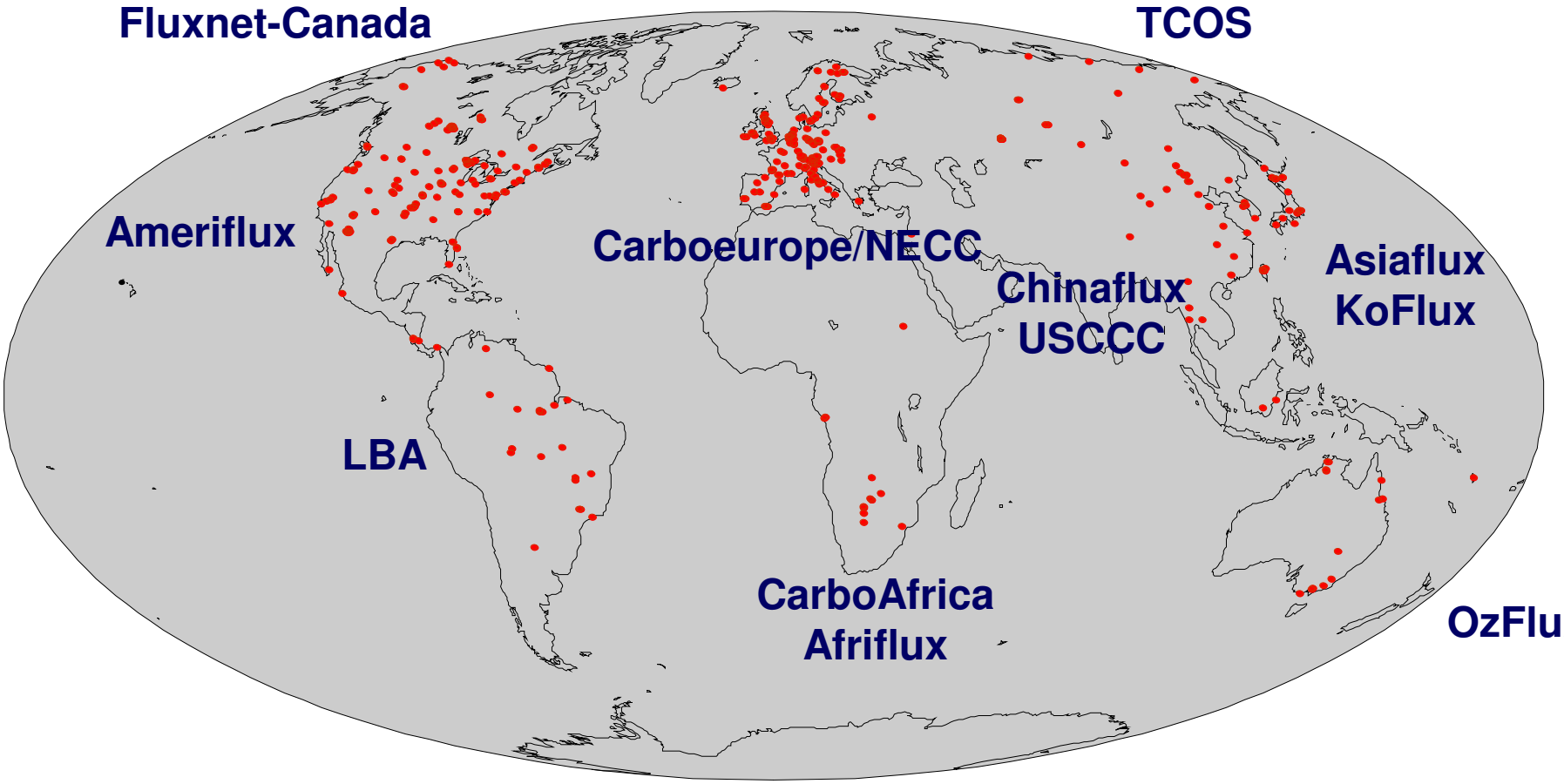
THANK YOU

V. Concepts under development

Basal respiration and low freq. Gross Primary Productivity (GPP)



IV. Data



AfriFlux ChinaFLUX OzFlux Australian and New Zealand flux Research and Monitoring USCCC NECC Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate System