Vulnerability of Primary Production to Climate Extremes
Lessons from the 2003 heatwave in Europe

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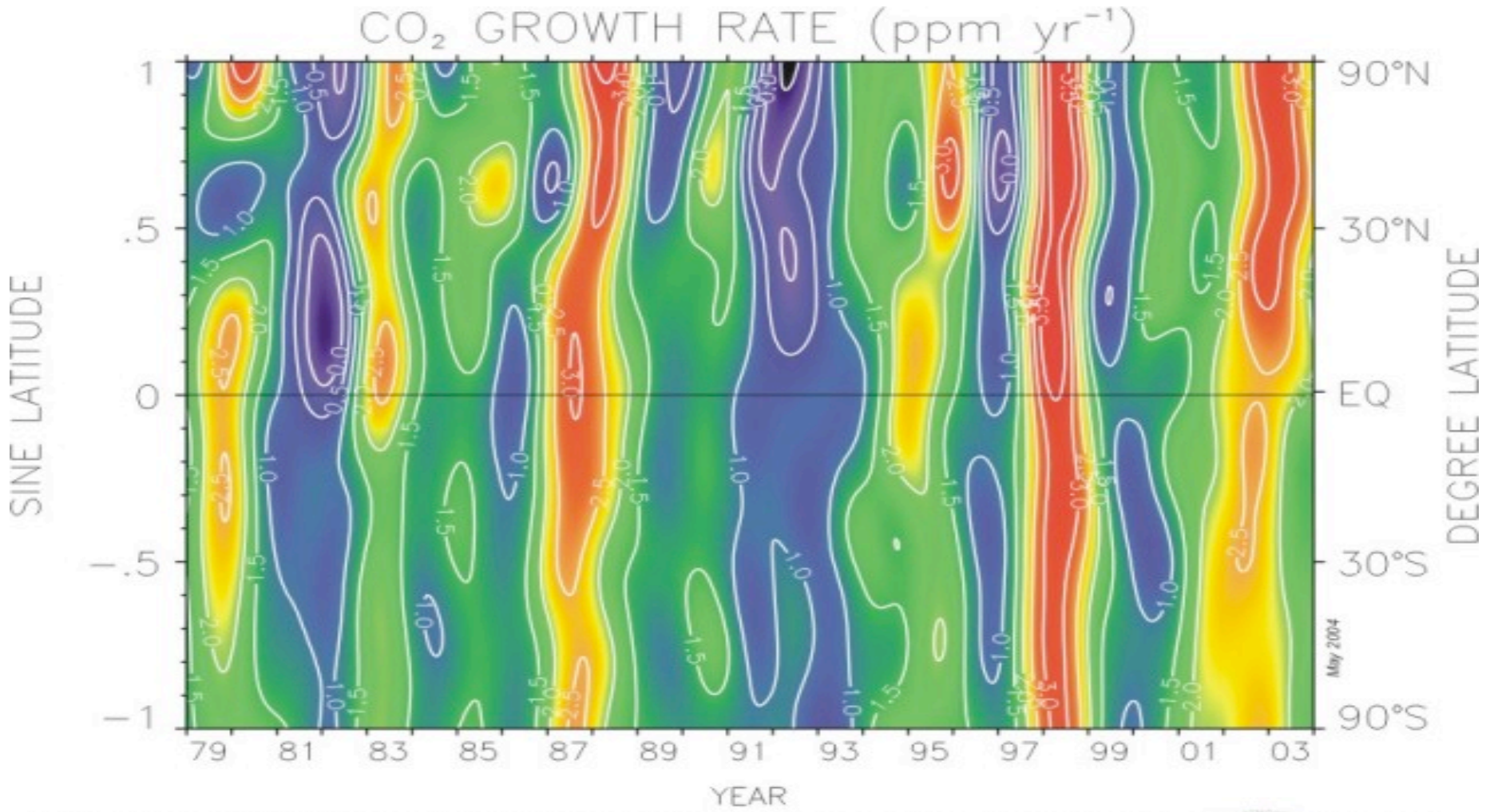
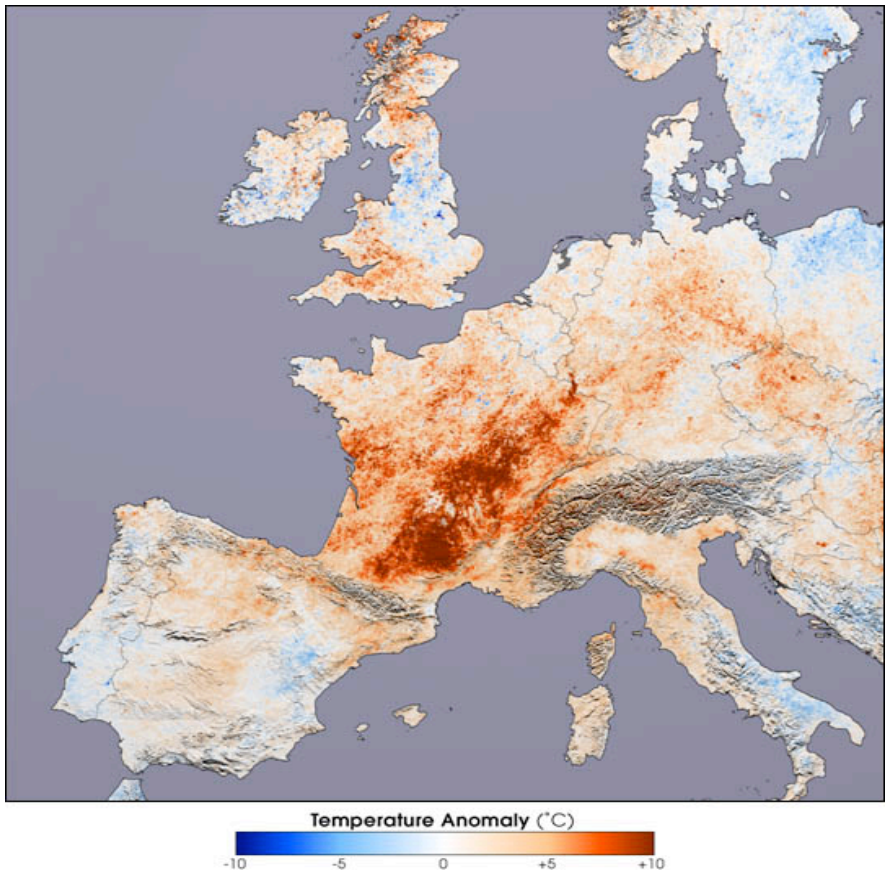
E.D. Schulze , T. Vesala, and R. Valentini

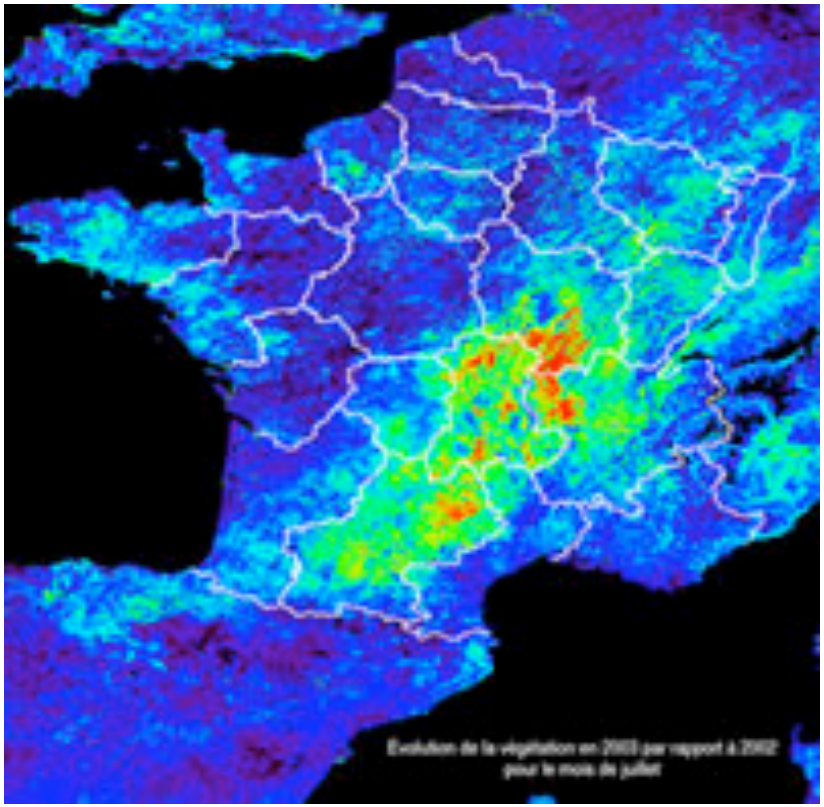
Interannual variations in CO_2 growth rate



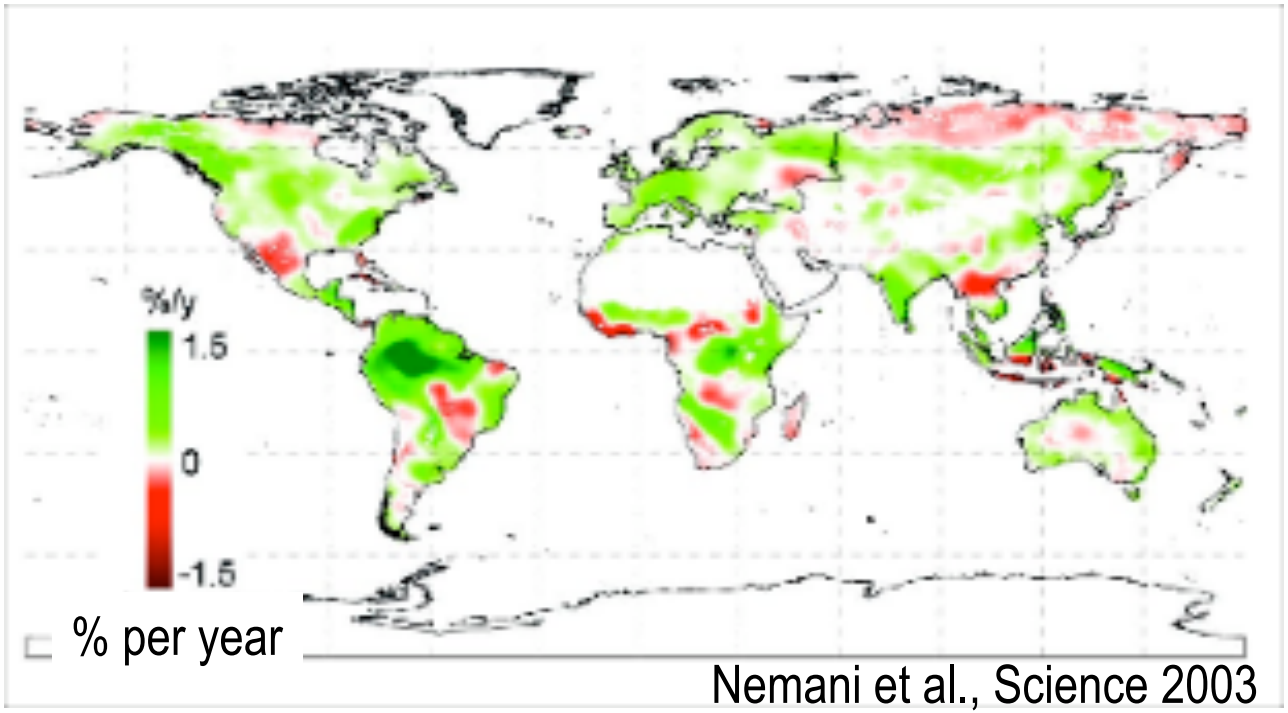
Contour plot showing the temporal and spatial variations in the atmospheric increases of carbon dioxide. The cooler colors (green, blue, violet) represent periods of lower than average growth rates and the warmer colors (yellow, orange, red) represent high growth rate periods. The plot is derived from measurements of thousands of samples collected at the CMDL cooperative air sampling network sites. The variations in the growth rate of this climatically important gas are due to interannual variations in the imbalance between sources and sinks, and also to variations in atmospheric transport. Principal investigator: Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6681 (thomas.j.conway@noaa.gov, http://www.cmdl.noaa.gov/ccgg).

Linking with bottom up observations
The 2003 European heatwave



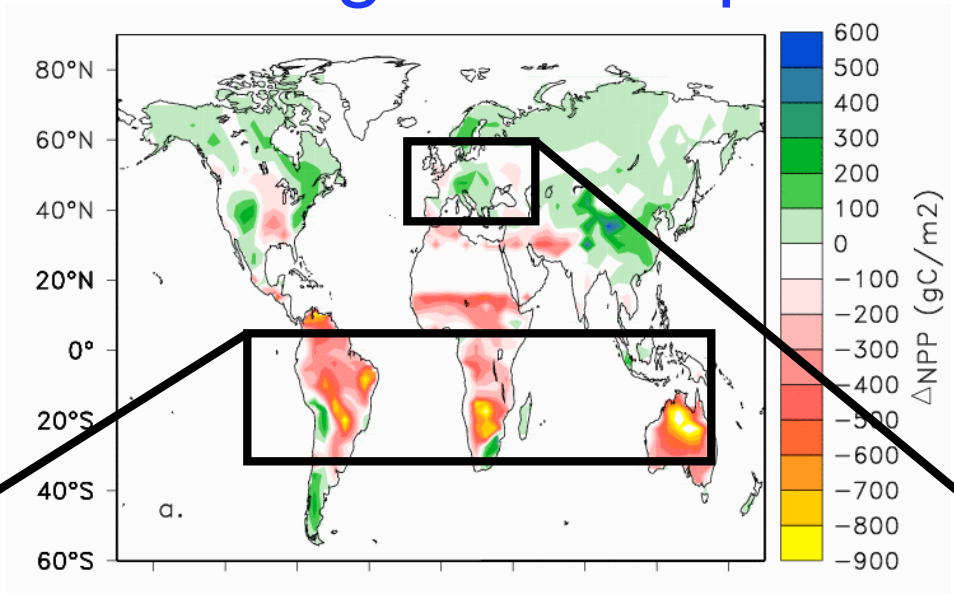


Will the greening continue with more frequent climate extremes?

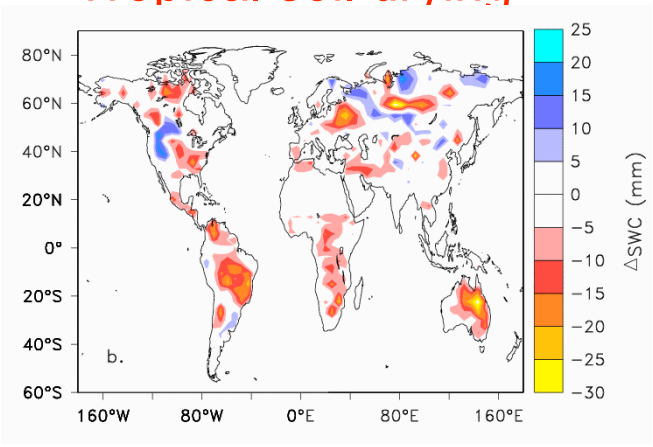


Secular increase in primary productivity from satellite NDVI over the past years

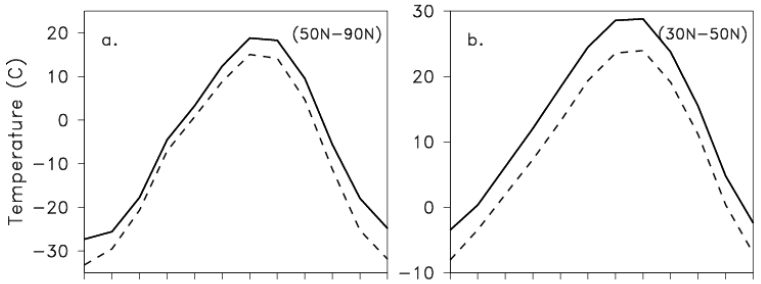
Coupled Climate-Carbon models Predict an Increase in NPP and in carbon storage in Temperate Regions



Tropical soil drying



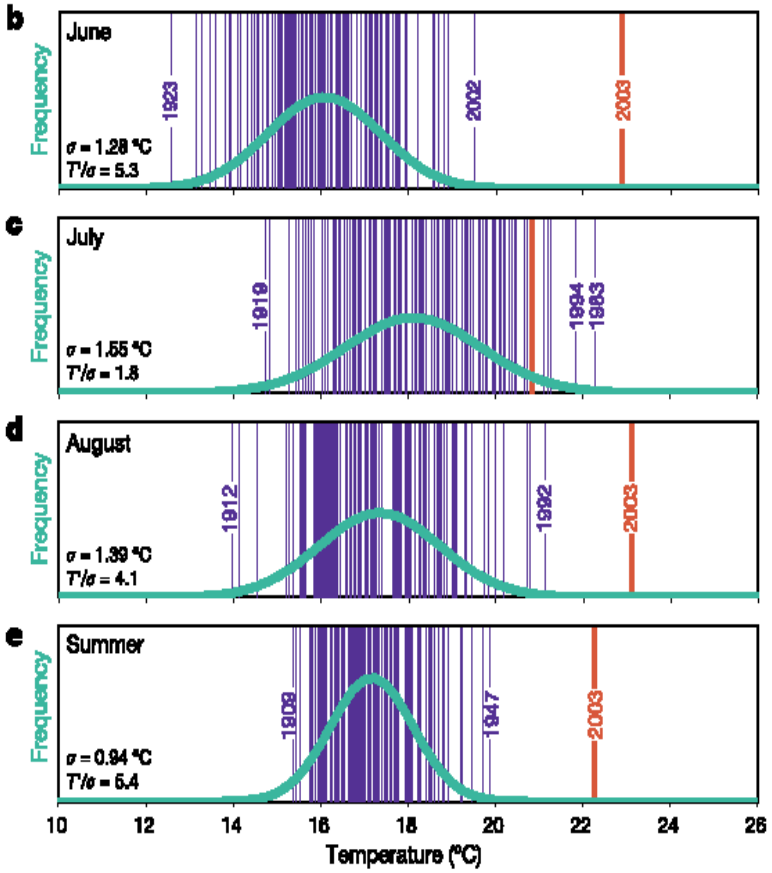
Longer growing seasons



Berthelot et al., GBC 2003

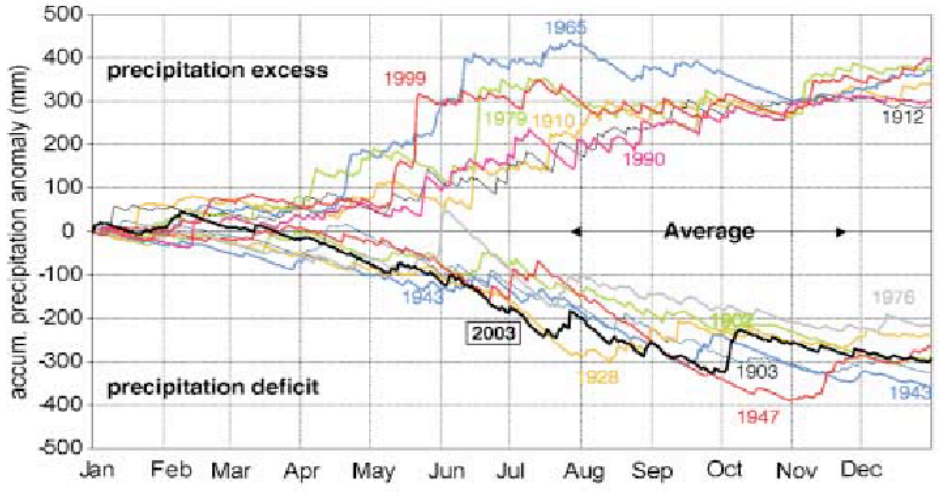
See also Cox et al., Nature 2001

Historical temperature records in Switzerland

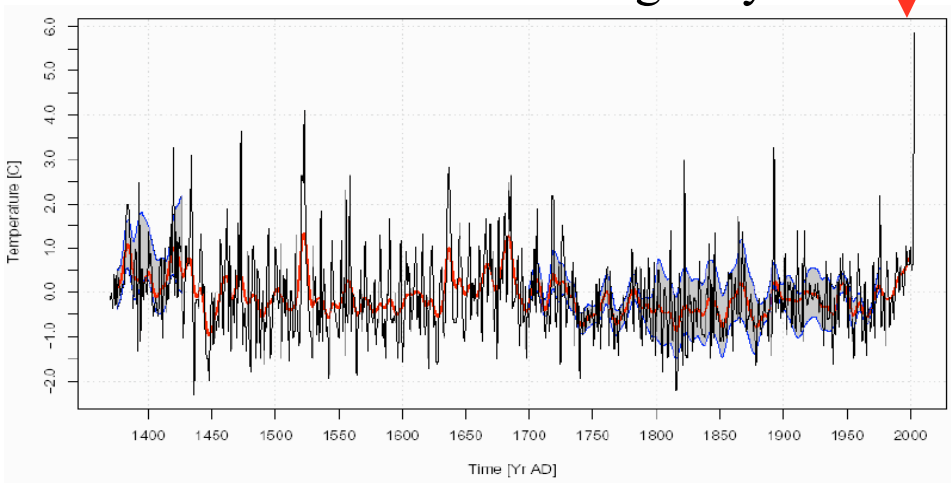


Shär et al., Nature 2003

Precipitation history in Bavaria



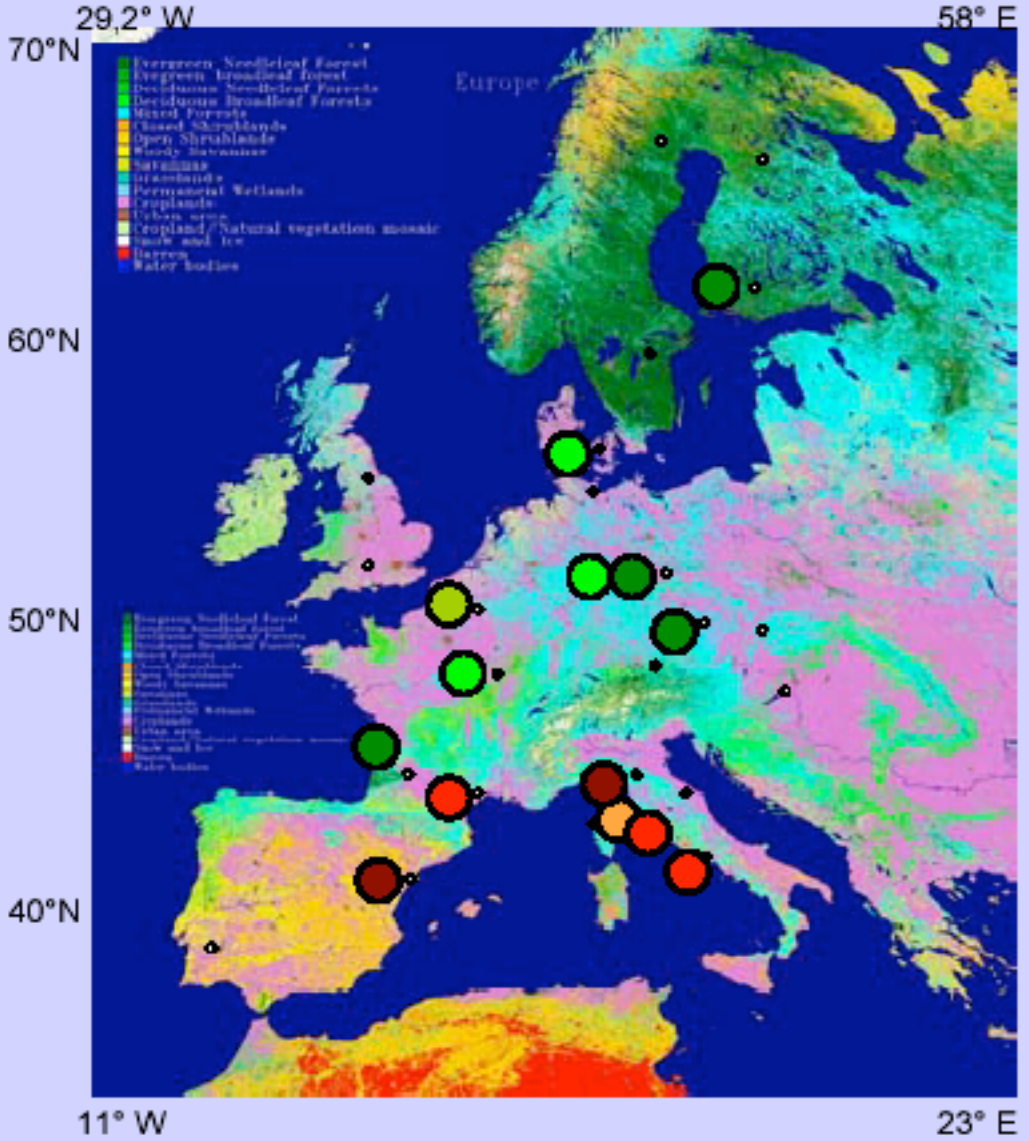
Summer temperature reconstruction from harvest dates in Burgundy



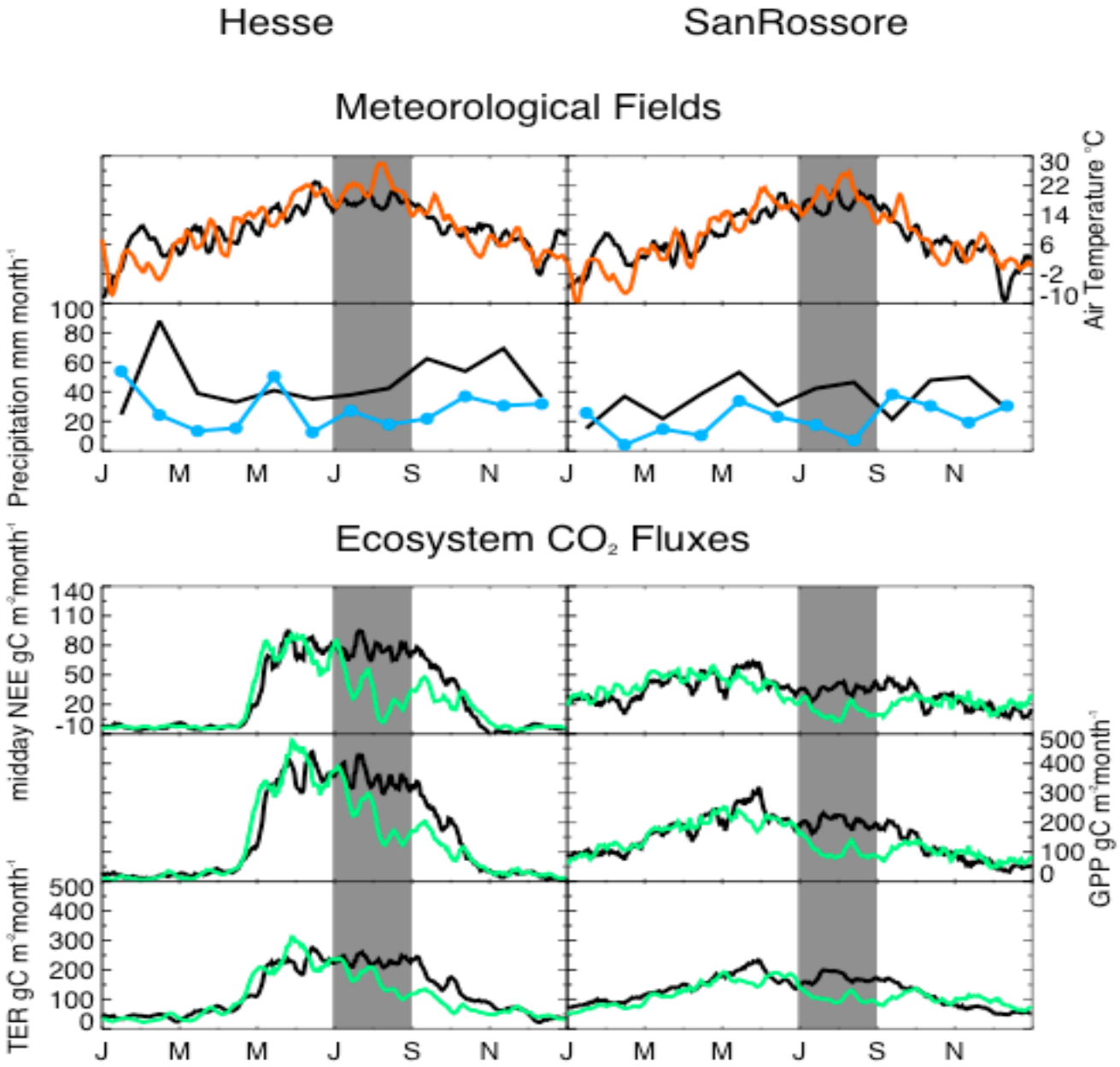
Chuine et al., Nature, 2003

THE EDDY COVARIANCE SITES ON A MODIS LANDCOVER CLASSIFICATION MAP

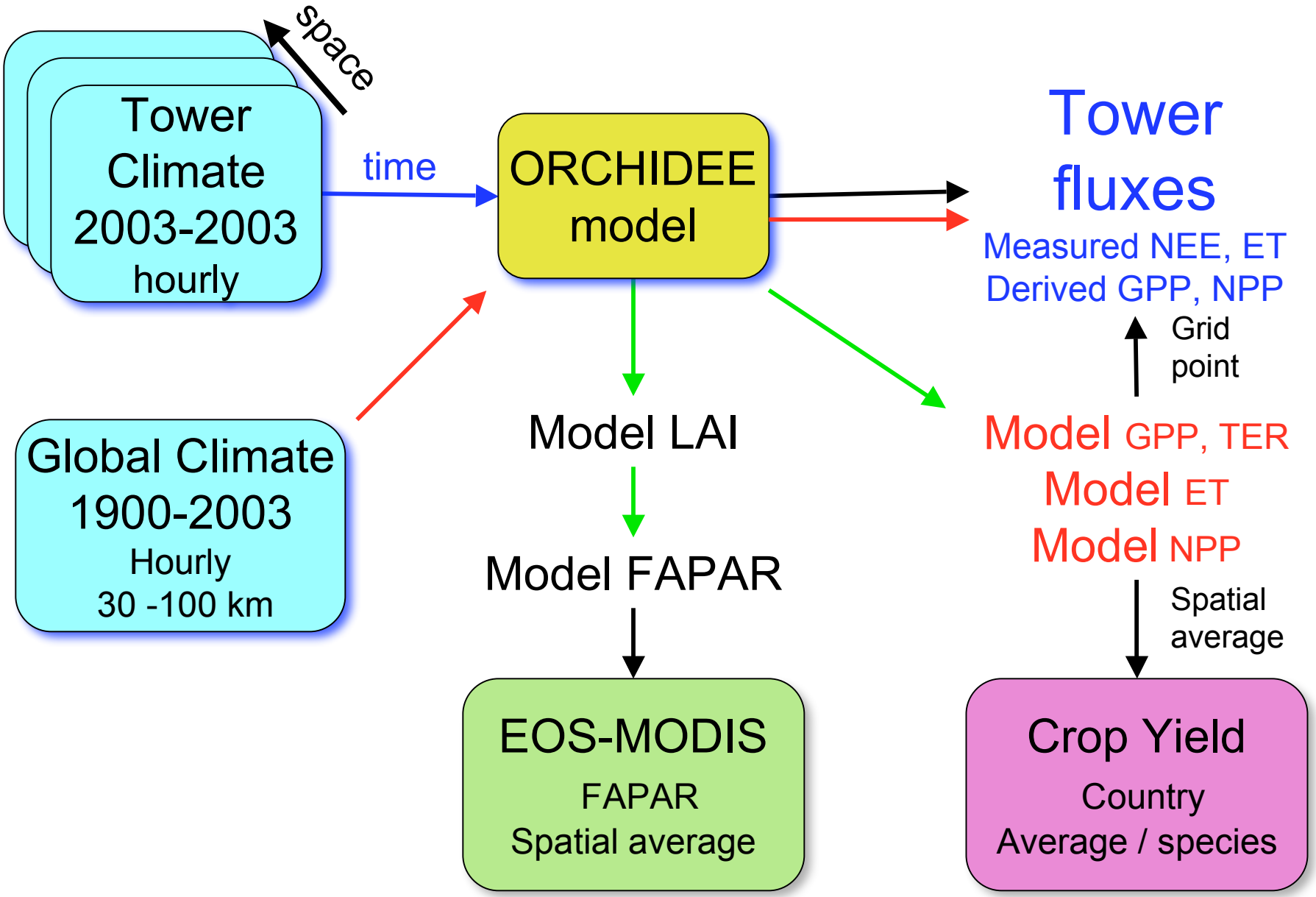
Sites used in this study include: **Deciduous broadleaf forests**; Soroe, Hainich, Hesse **Evergreen needle leaf forests**; Hyytiala, Tharandt, Bray Mediterranean **needle-leaf** and **broad-leaf** forests and **macchia:** Puéchabon, San Rossore, Pianosa, Roccares-pampani, El Saler, Castelporziano



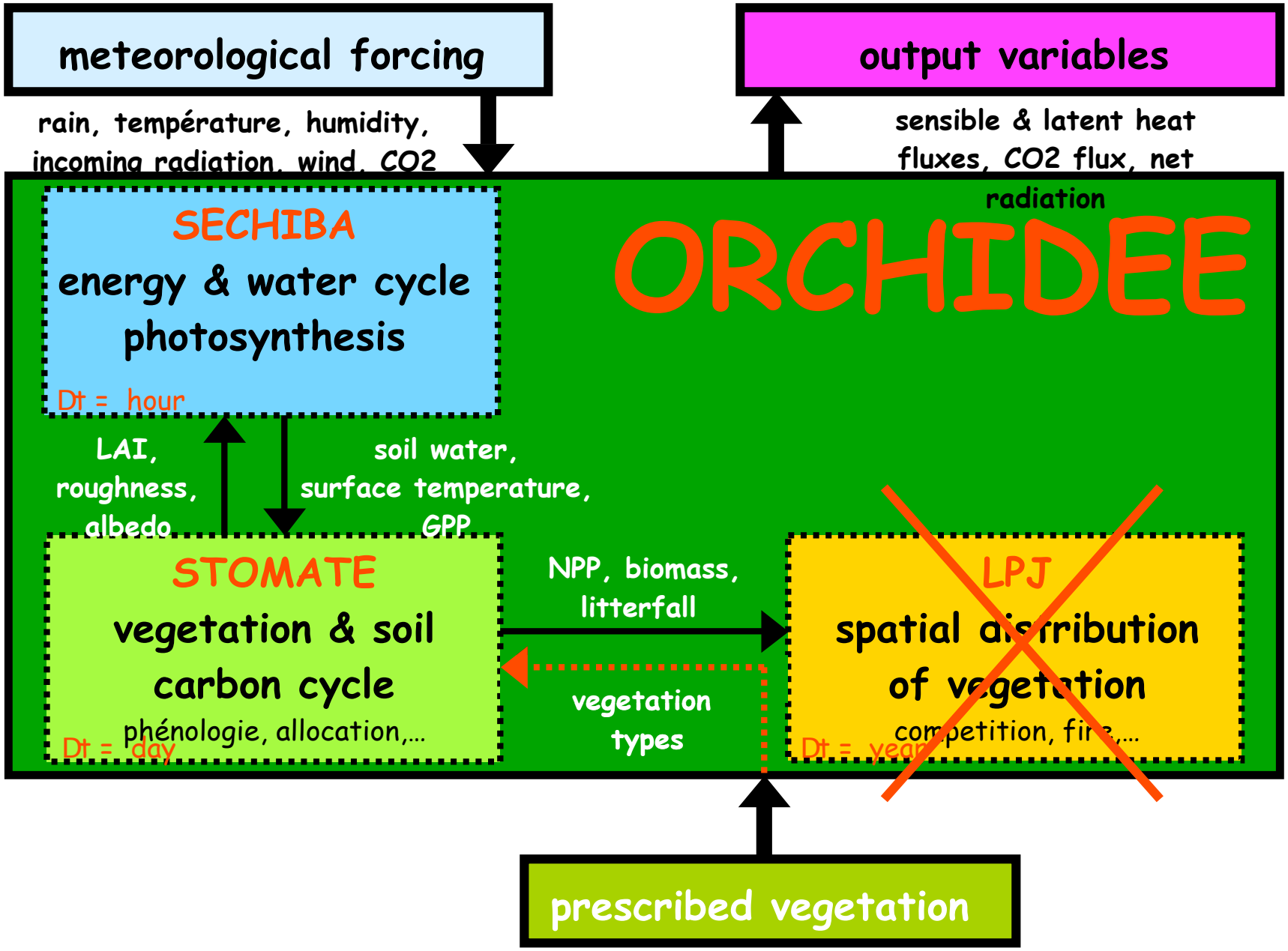
Temperate and Mediterranean forests



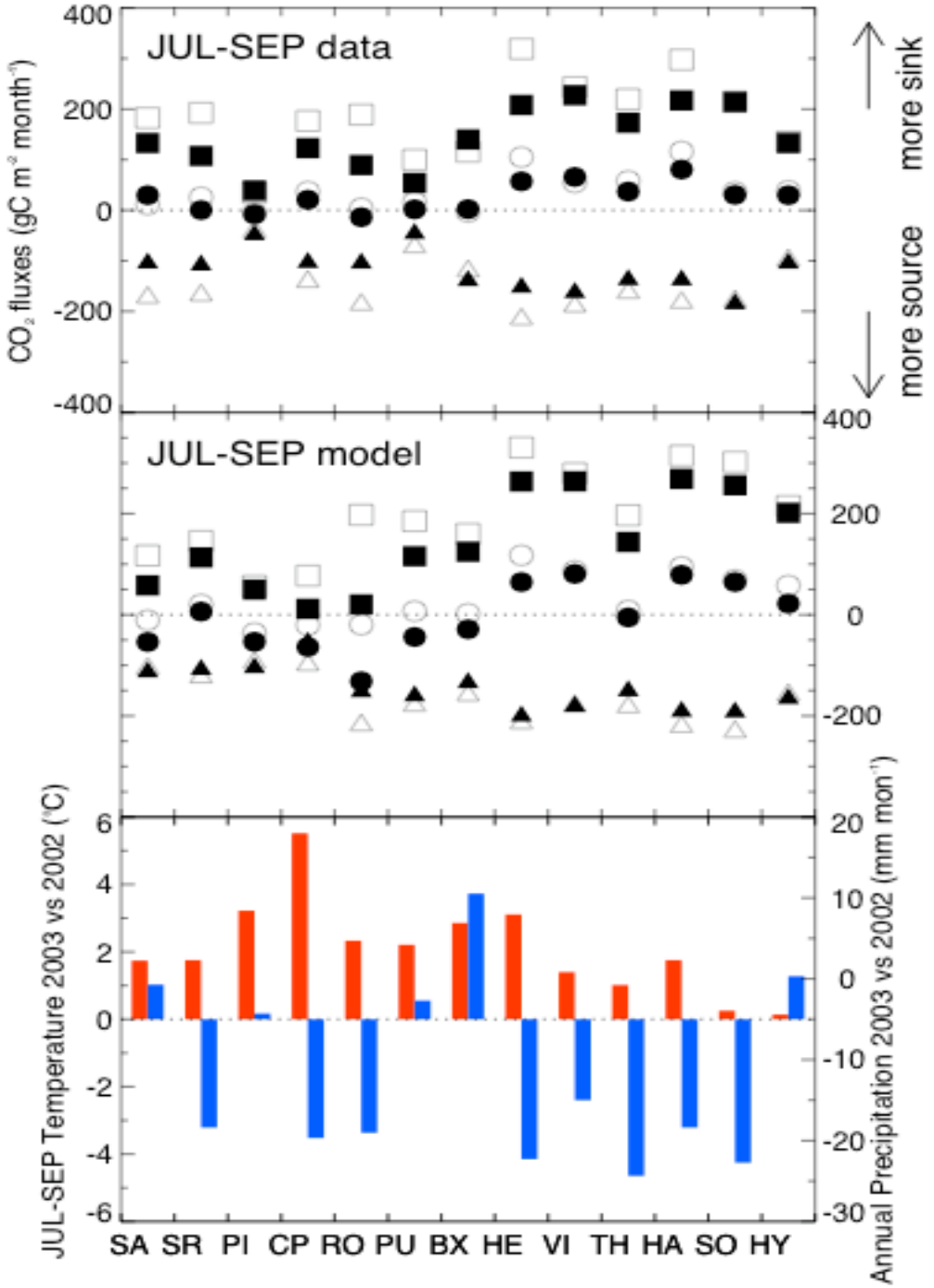
2003 modelling system



Global biospheric model ORCHIDEE

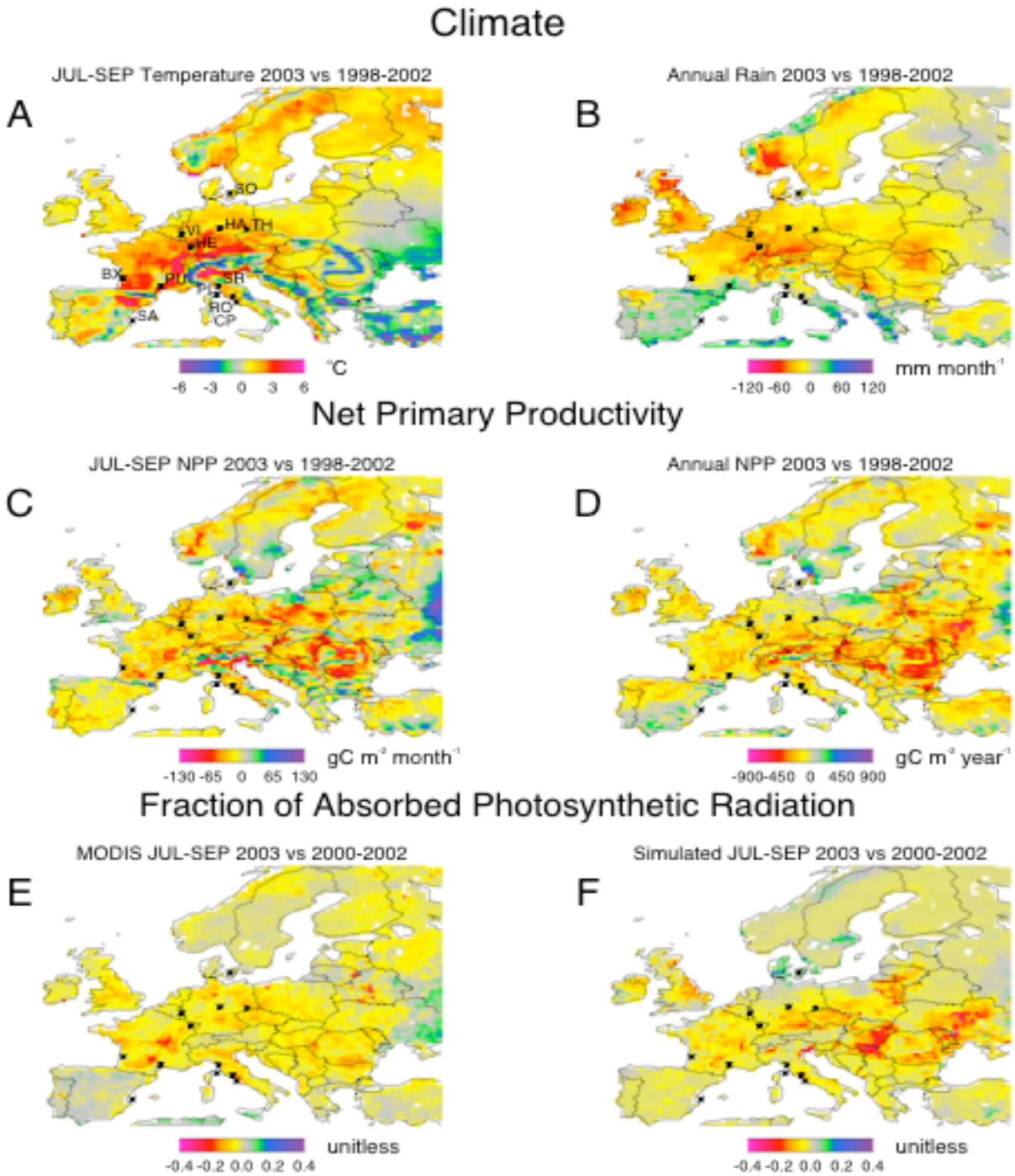


Comparing gross and net fluxes during summer 2002 and 2003



Abnormal Climate and Productivity in 2003

Model verification with EOS-MODIS FAPAR



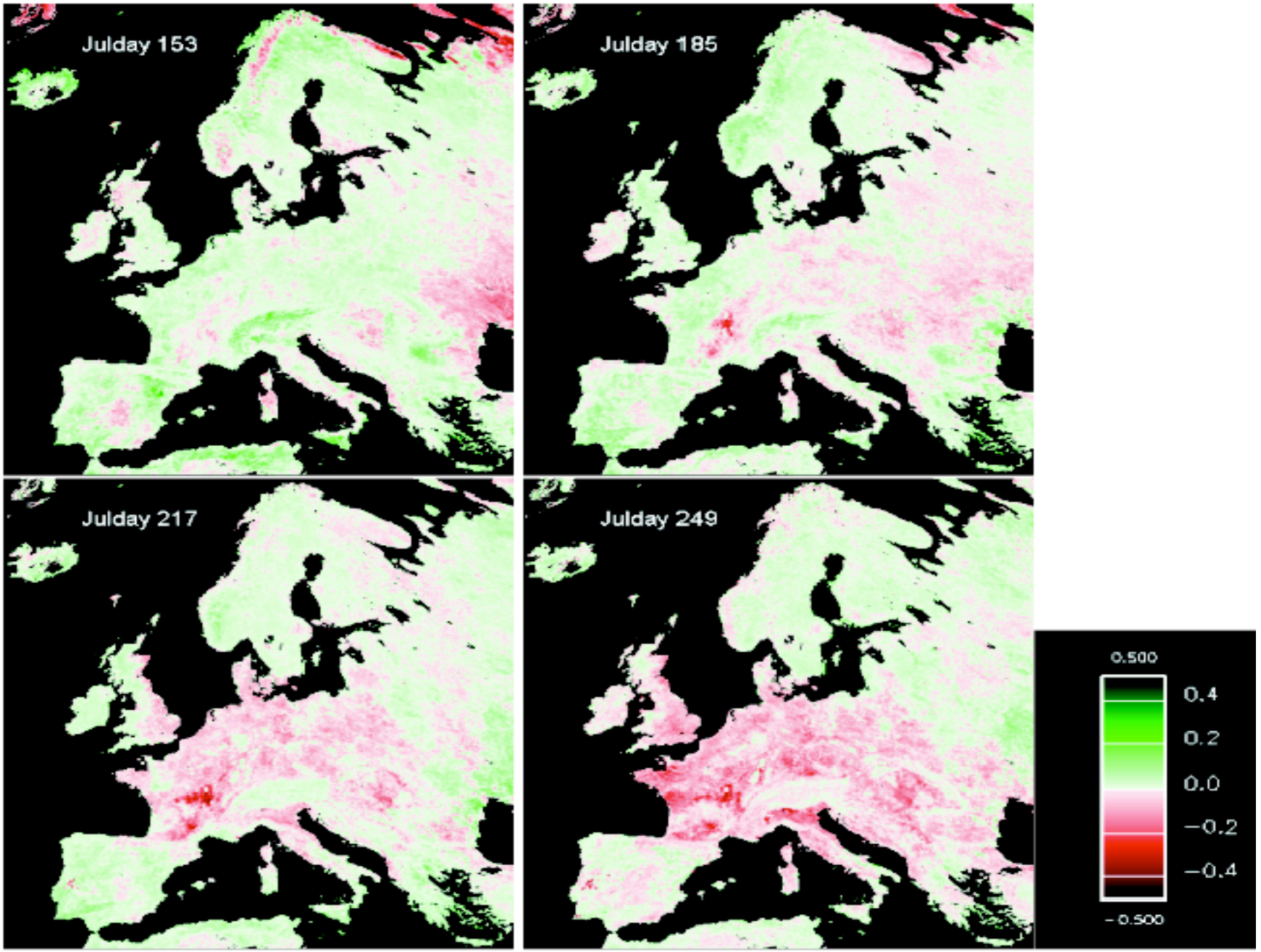
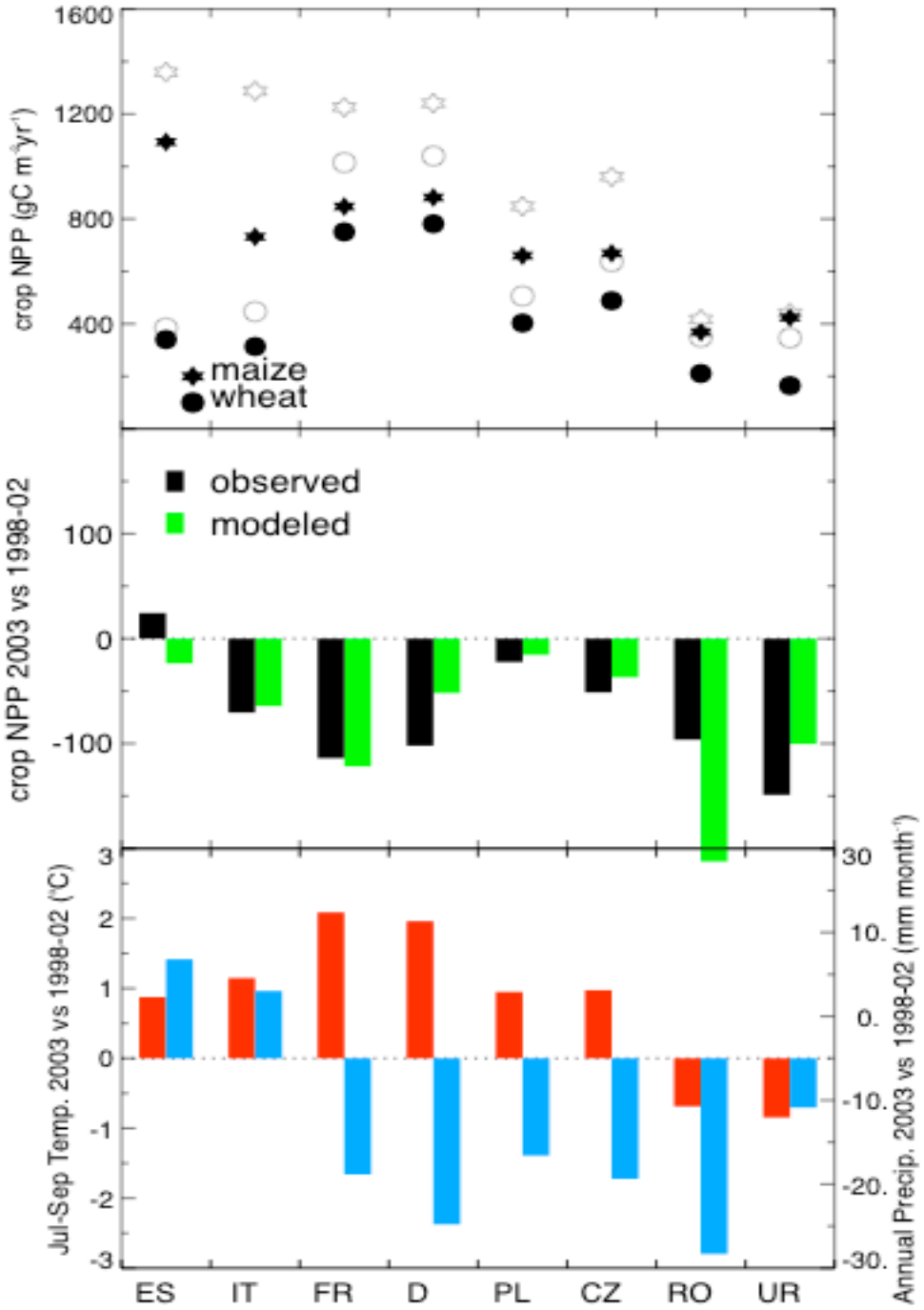
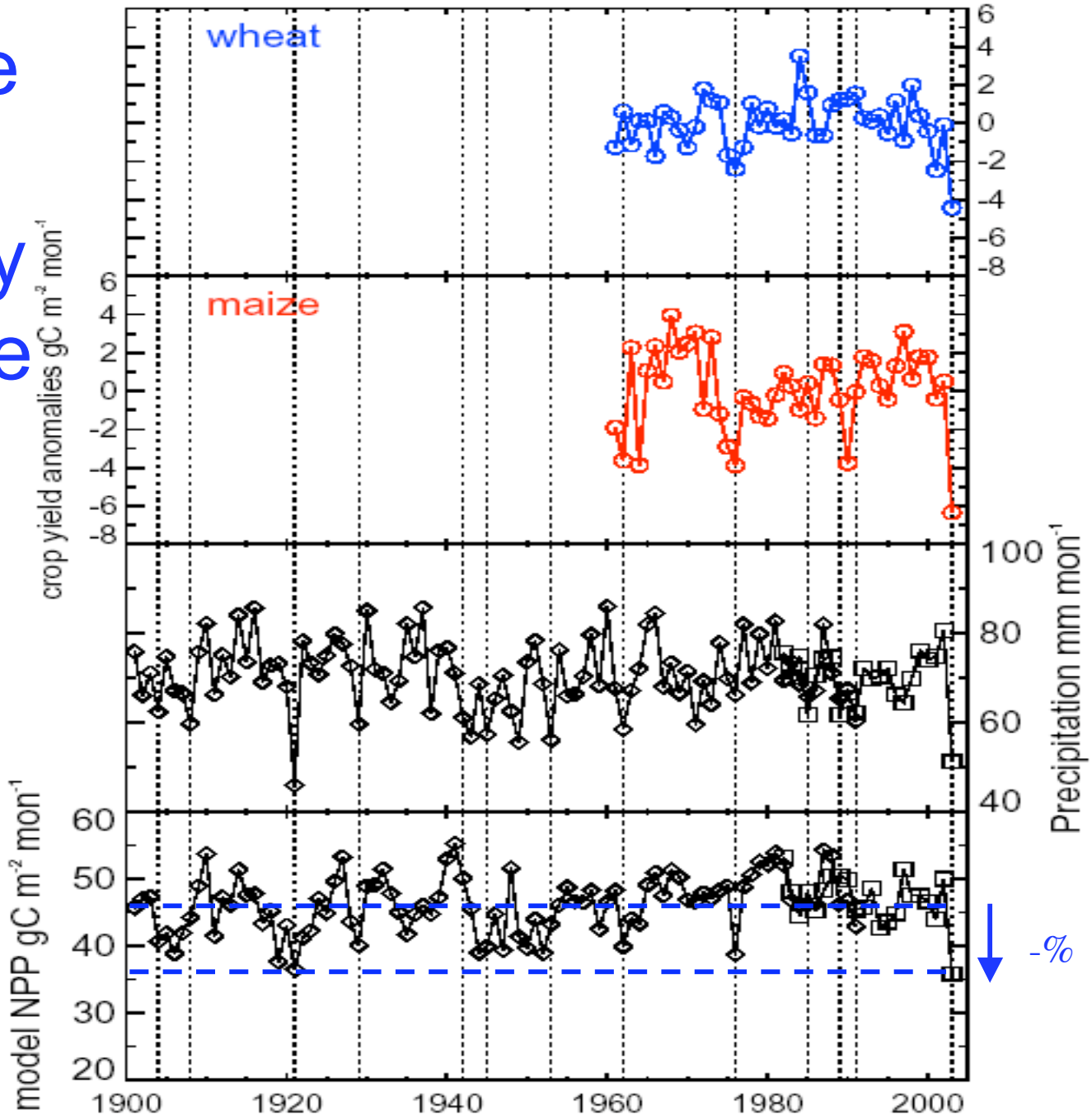


Fig. 1: Temporal development of the spatial pattern of the fAPAR anomaly during 2003

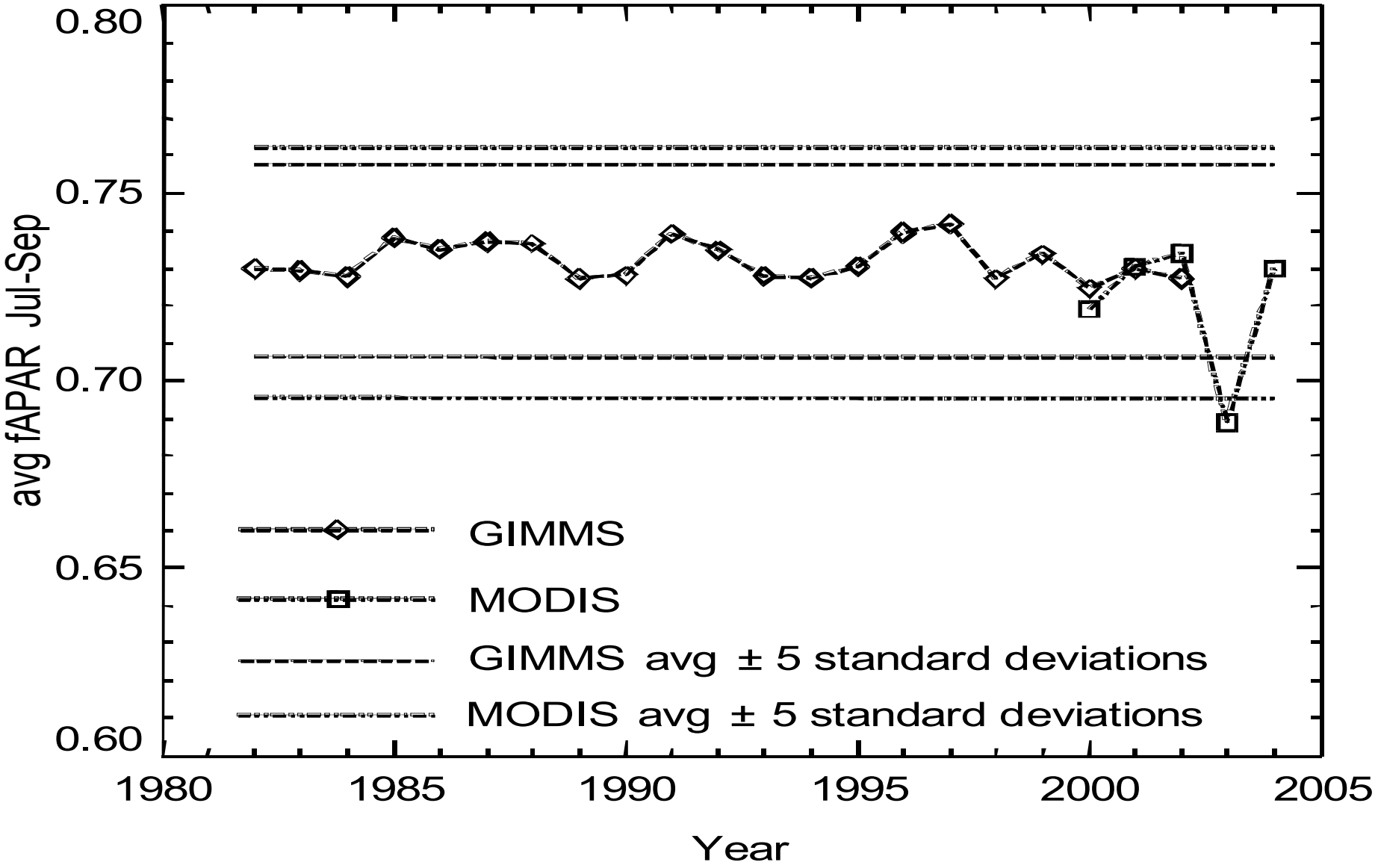
Verification against crops yield national data



2003 is the largest productivity crash of the past 100 years

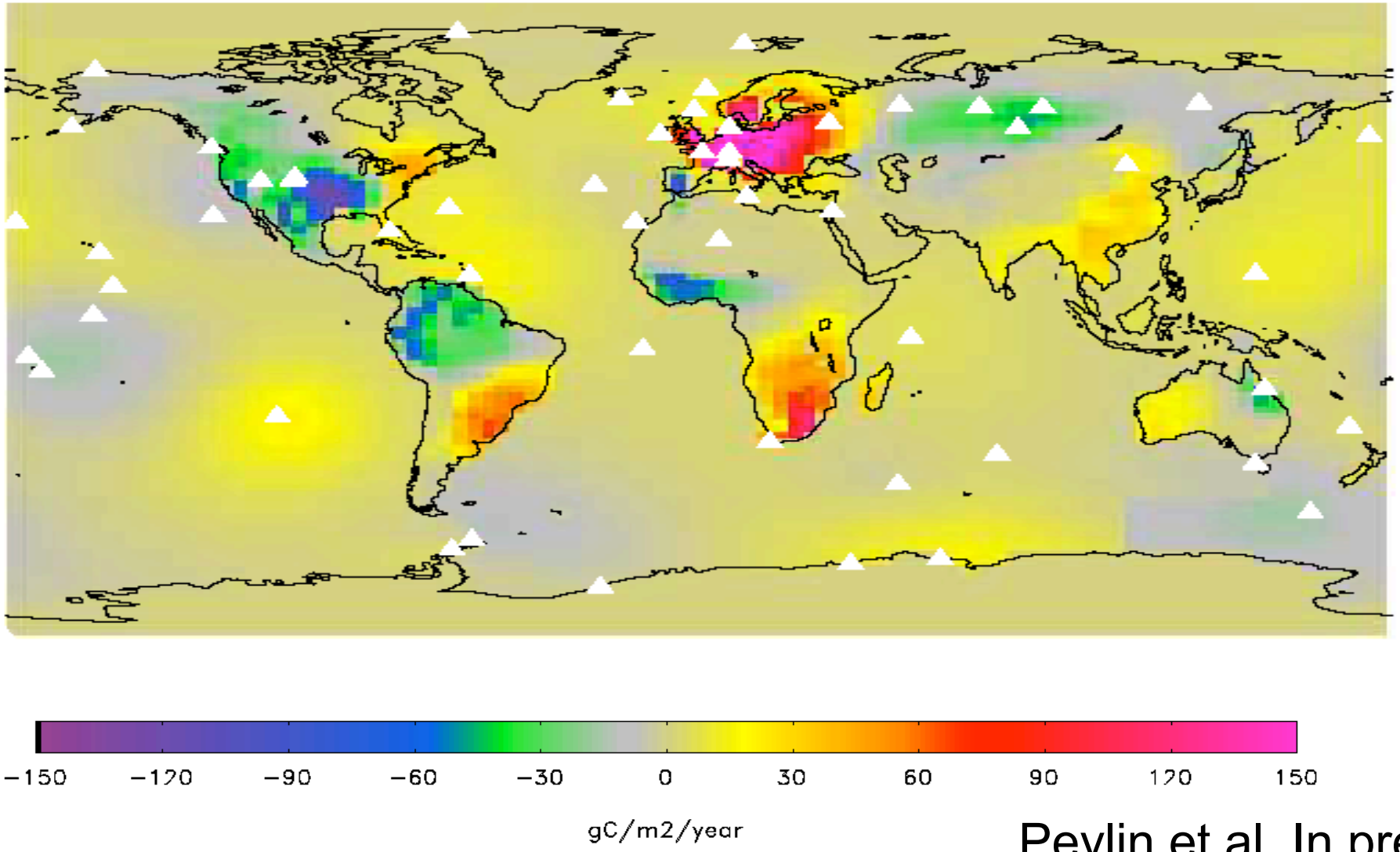


How abnormal is 2003 ?



Independent inversion estimate

Inversion / stations / interannual winds / resolved on each model grid point



Peylin et al. In prep

- Uniquely dense eddy covariance network to map climate-carbon-water interactions at the regional level
- Severe drop of transpiration and GPP
- Respiration tailed off with the GPP drop rather than increasing with temperature ; forests became net CO2 sources to the atmosphere in summer !
- Anomalous source of 0.5 PgC y^{-1}, undoing years of mean sink, enough to explain 50% of the global CO2 growth rate anomaly

Processes

Soil water content variation model and observations indicate large water stress at all sites in 2003 with Root Extractable Water REW < 0.

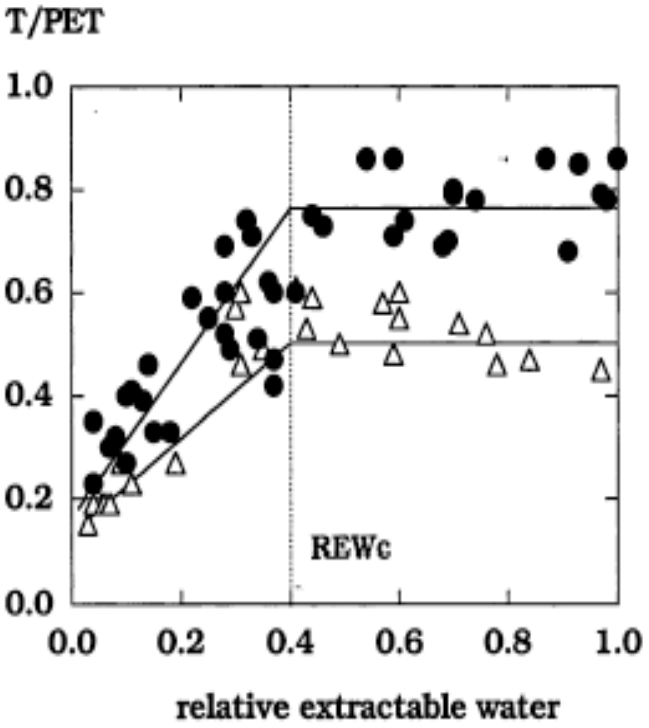
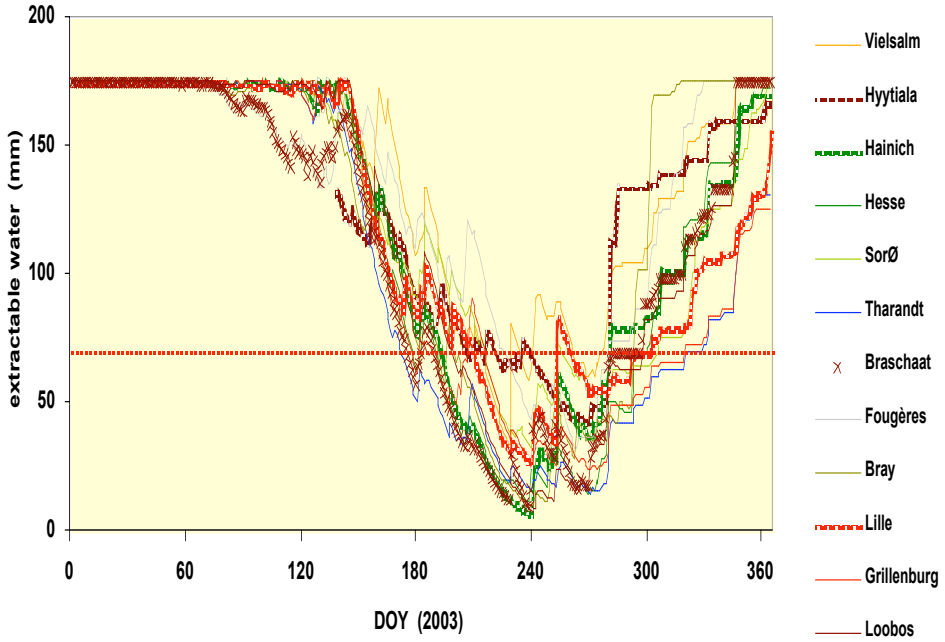
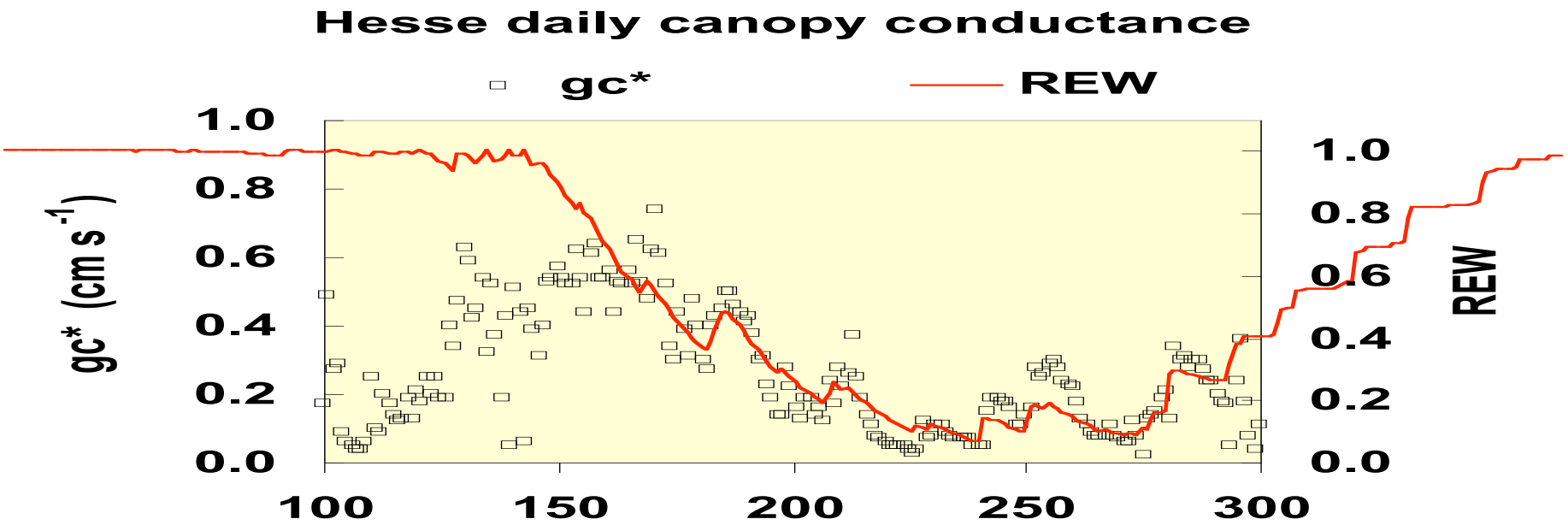


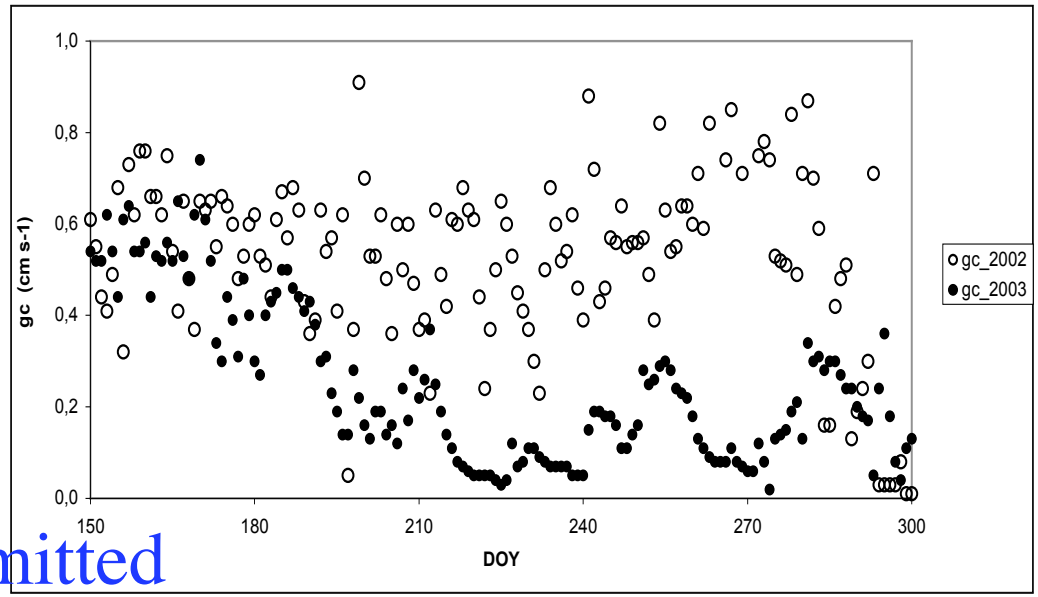
Fig. 2. Ratio T/PET calculated from sap flow measurements in an oak stand as a function of relative extractable water (REW) calculated from neutron probe measurements (from Bréda and Granier, 1996). Two data sets are reported: LAI = 6 m^2 m^{-2} (black circles) and LAI = 4.5 m^2 m^{-2} (open triangles). The dotted line shows the critical REW (REW_c).



Breda et al.

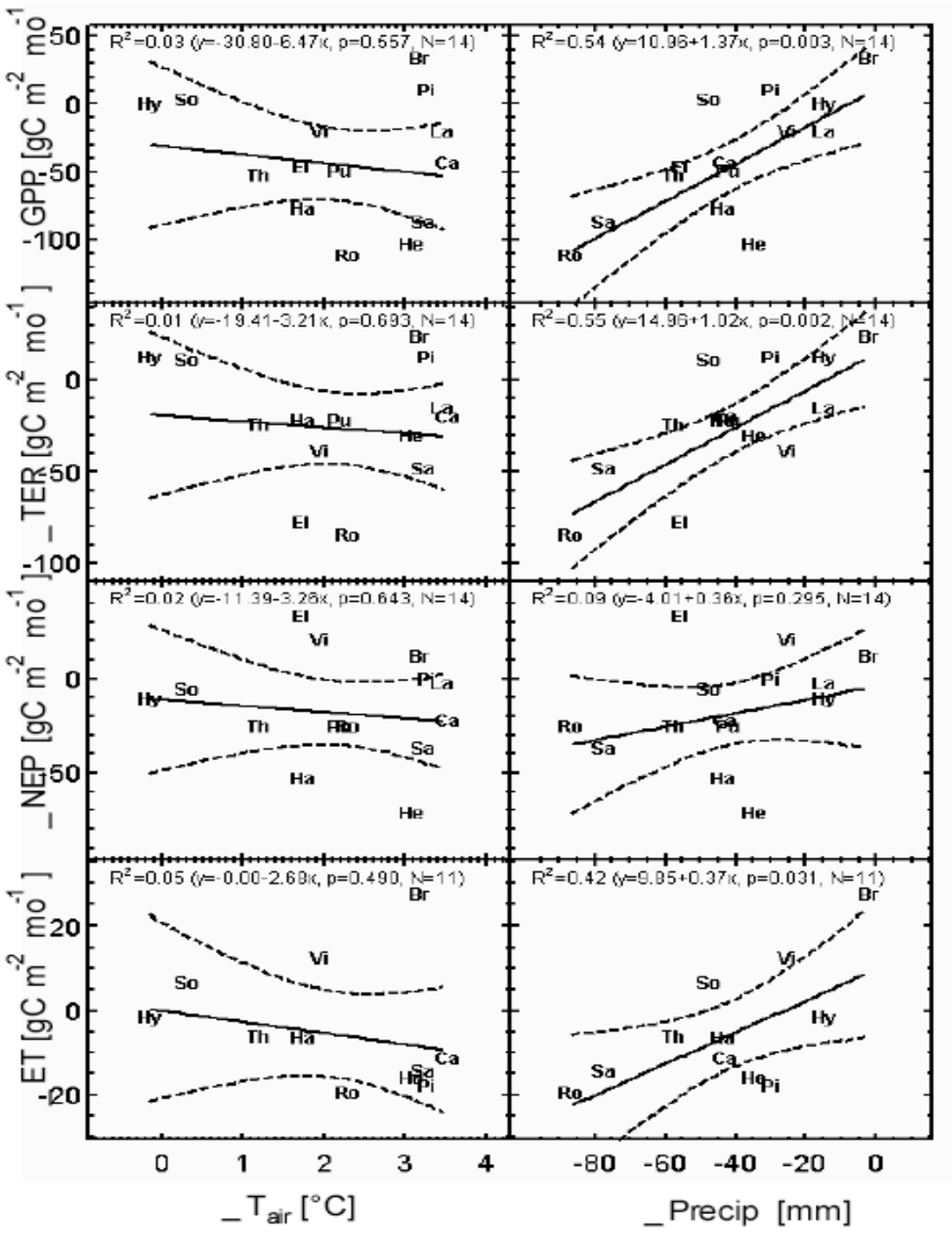
water-stress controls on stomatal conductance



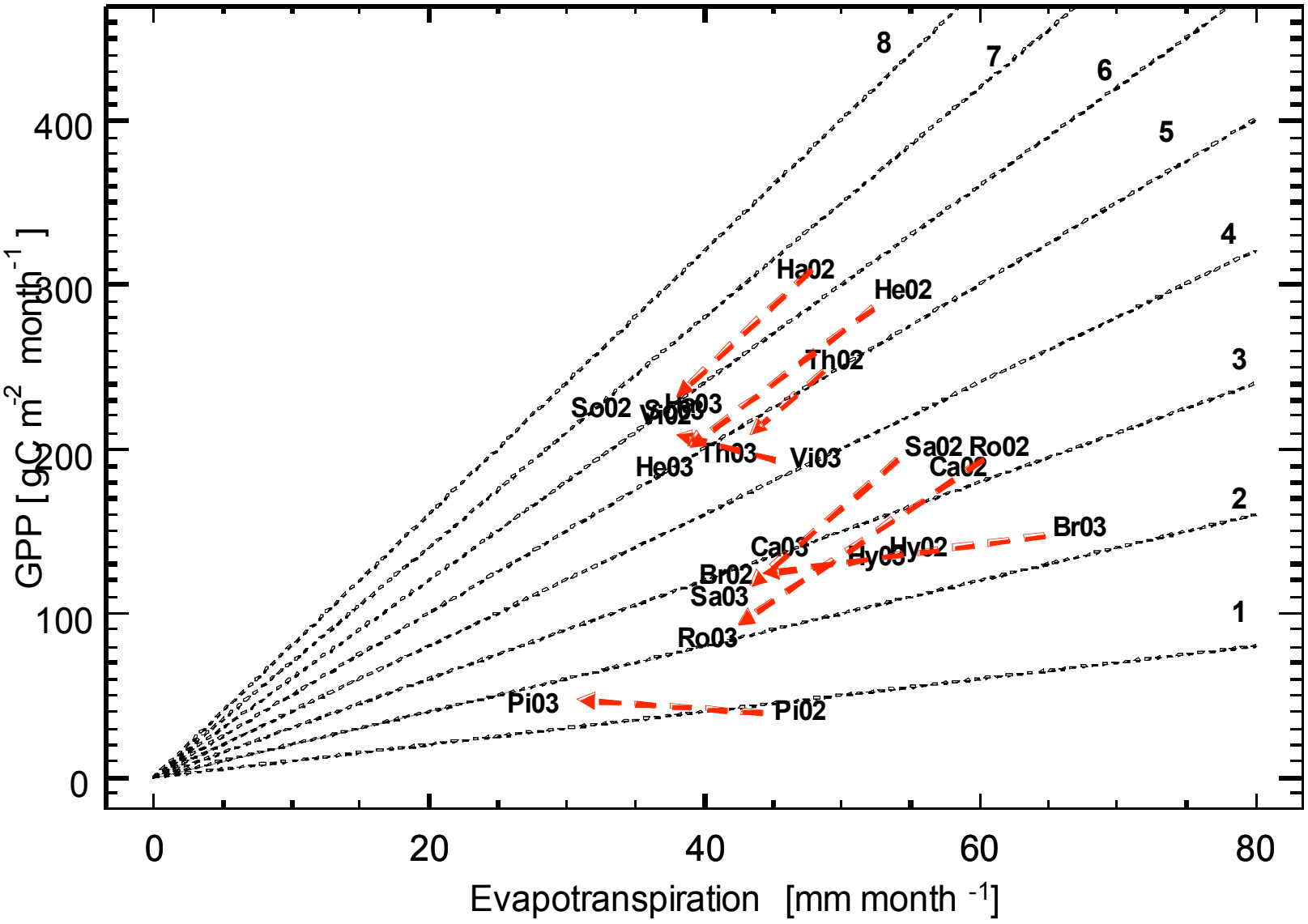


Granier et al. submitted

Response of ecosystem fluxes to high temperatures and precipitation deficits

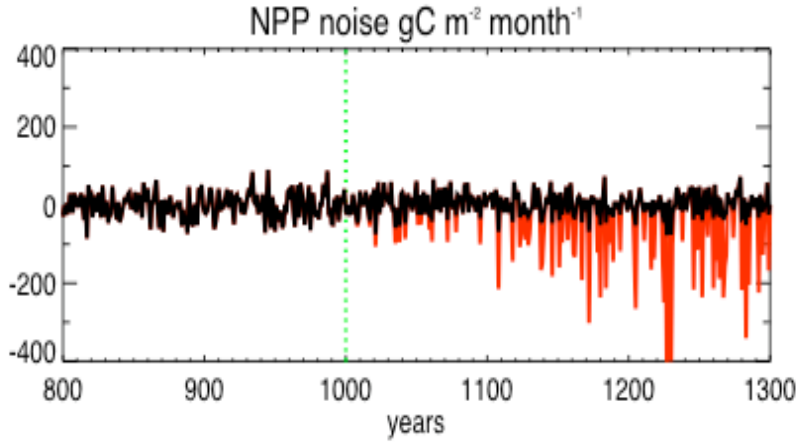


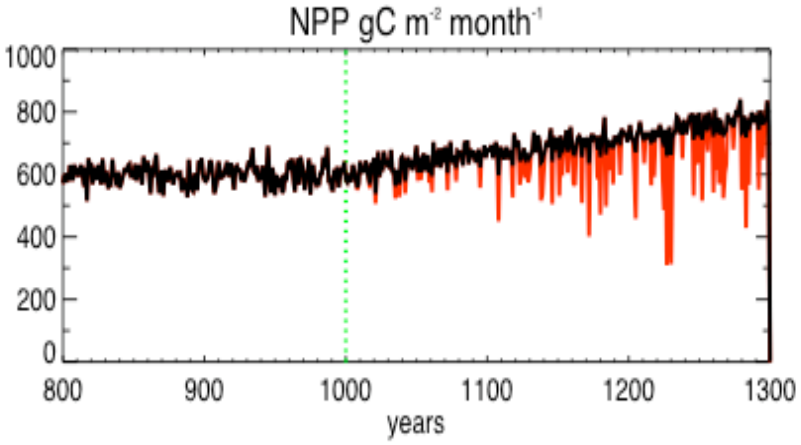
No Changes in water use efficiency

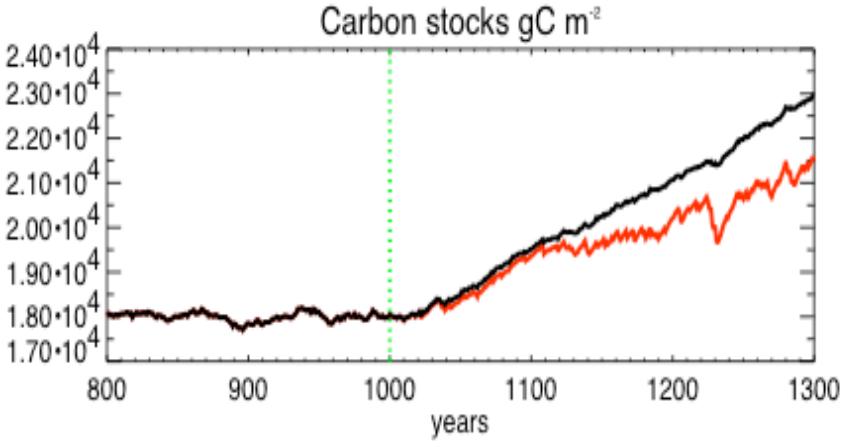


- Unprecedented decrease in NPP during the past century
- No intrinsic change in water use efficiency
- Delayed impact on carbon balance may be extended over several years via mortality, insect attacks, tree damage

Vulnerability of carbon stocks to climate extremes







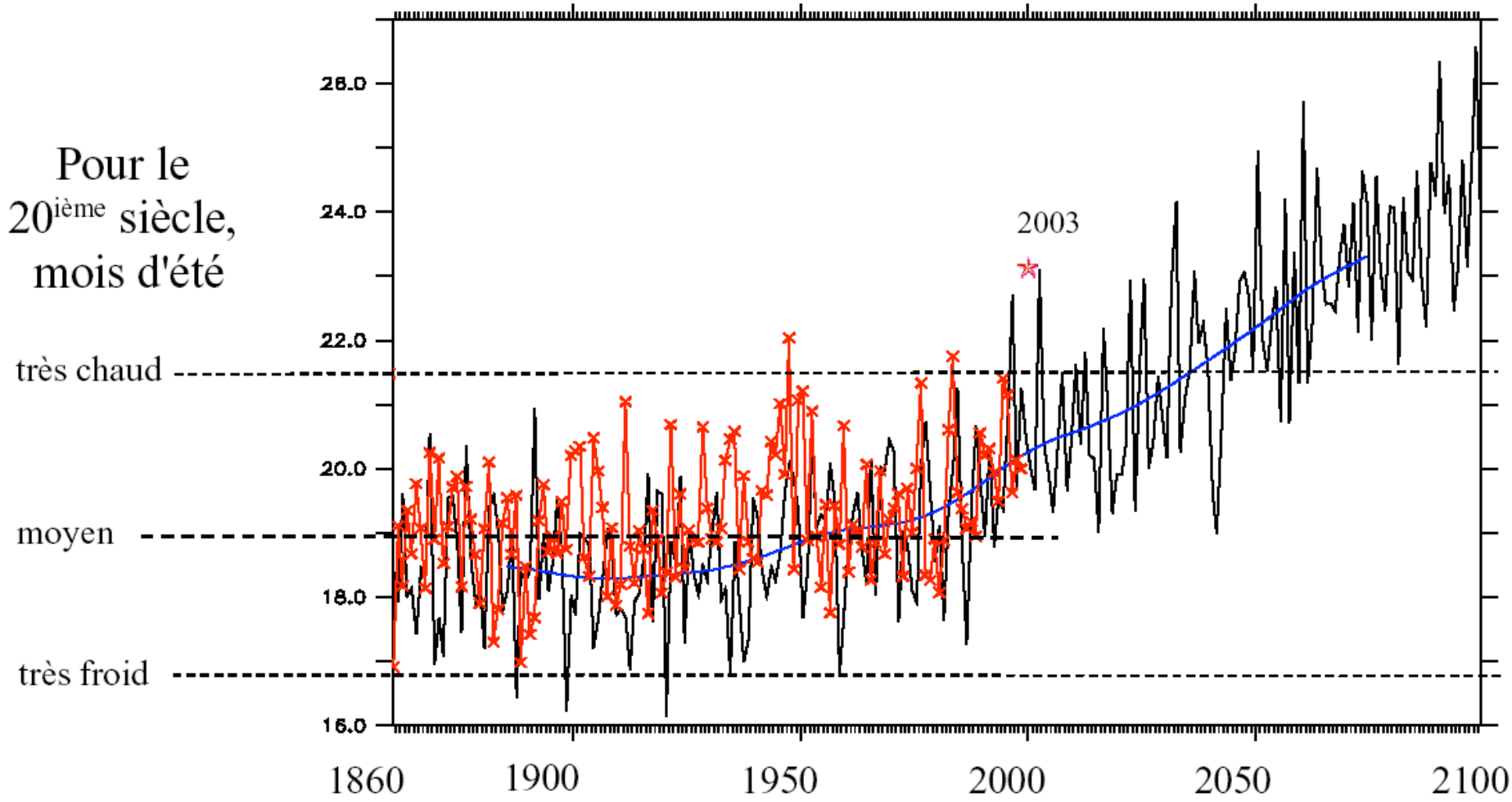
Rainfall Variability, Carbon Cycling, and Plant Species Diversity in a Mesic Grassland

Alan K. Knapp,[1]* Philip A. Fay,[1] John M. Blair,[1] Scott L. Collins,[1,2]
Melinda D. Smith,[3] Jonathan D. Carlisle,[1]
Christopher W. Harper,[1] Brett T. Danner,[1] Michelle S. Lett,[1]
James K. McCarron[1]

Ecosystem responses to increased variability in rainfall, a prediction of general circulation models, were assessed in native grassland by reducing storm frequency and increasing rainfall quantity per storm during a 4-year experiment. More extreme rainfall patterns, without concurrent changes in total rainfall quantity, increased temporal variability in soil moisture and plant species diversity. However, carbon cycling processes such as soil CO_2 flux, CO_2 uptake by the dominant grasses, and aboveground net primary productivity (ANPP) were reduced, and ANPP was more responsive to soil moisture variability than to mean soil water content. Our results show that projected increases in rainfall variability can rapidly alter key carbon cycling processes and plant community composition, independent of changes in total precipitation.

Evolution de la température moyenne en été en France de 1860 à 2100

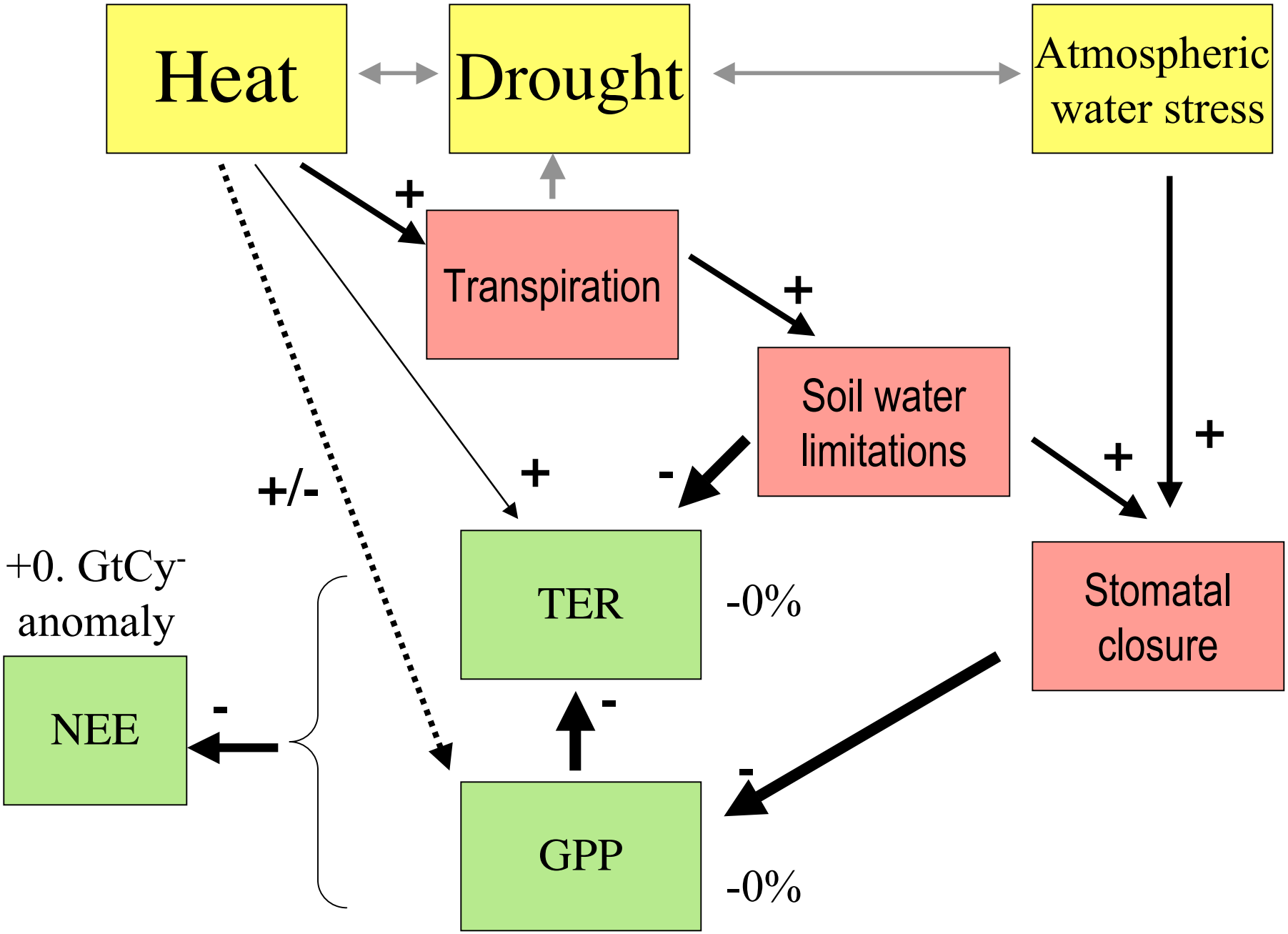
(modèle de l'IPSL, scenario SRES A2, sans aérosols)



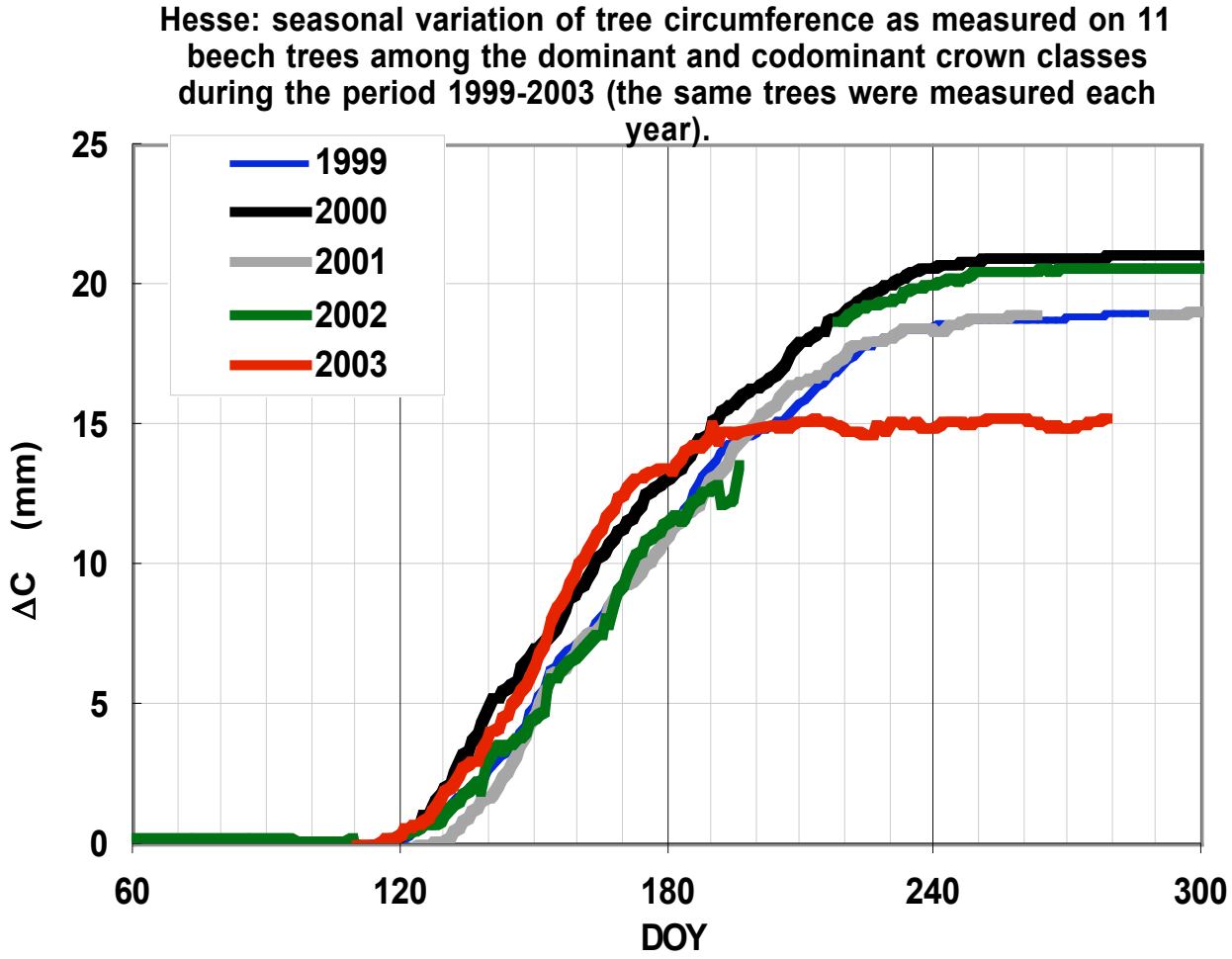
Source: IPSL 2001

Take home

- In the future, adverse impacts of climate extremes may cancel out any benefits of moderate climate change
- European temperate productivity may be durably reduced if extremes become more frequents
- In the long run, conifer forest may be more adapted to European future climate conditions


Heat
Drought
Atmospheric water stress
Transpiration
Soil water limitations
+
+
+
+
+
+
-
+/-
TER
-0%
Stomatal closure
+0. GtCy- anomaly
NEE
-
-
-
GPP
-0%

Independent tree ring verification



A. Granier pers. Comm

GPP modelled vs measured anomaly