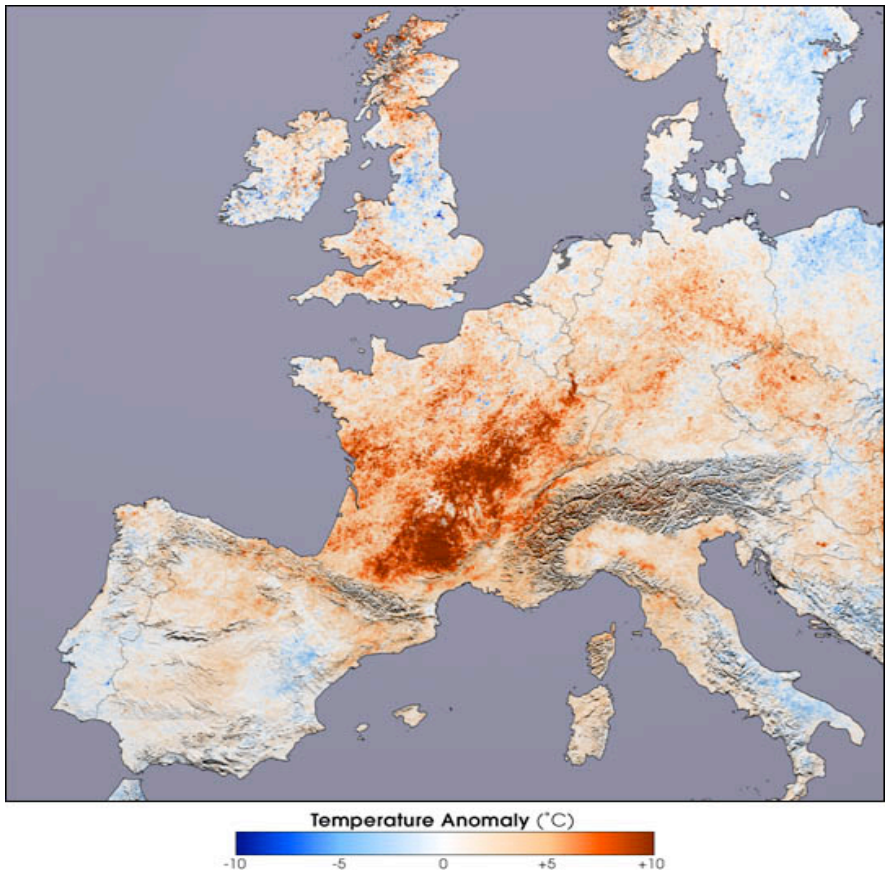
Europe-wide reduction in primary productivity caused by the heat and drought in 2003

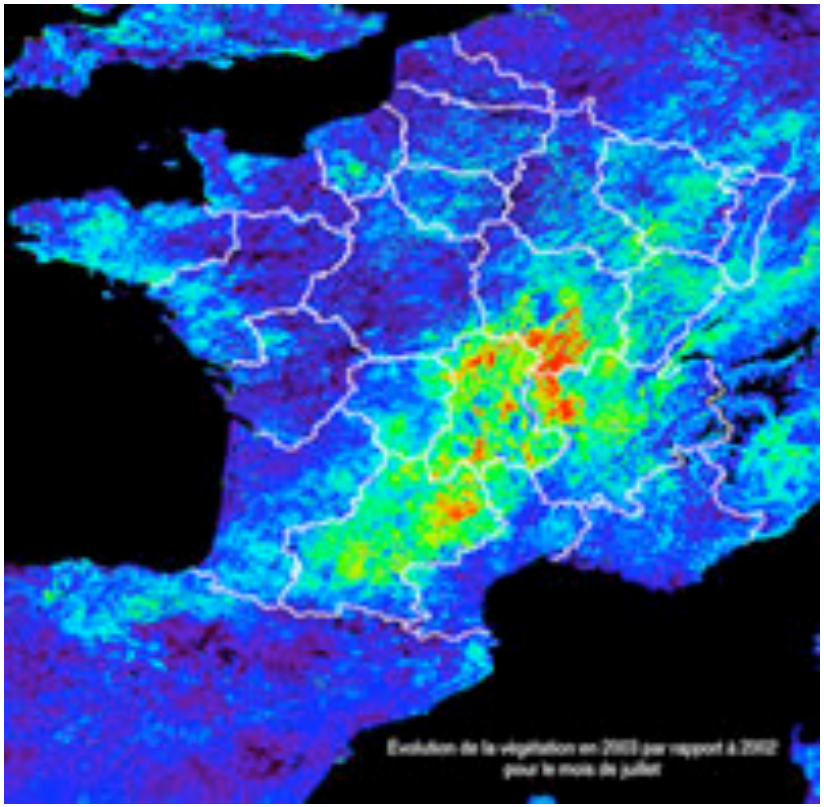
Ph. Ciais , M. Reichstein, N. Viovy

A. Granier , J. Ogée , V. Allard , M. Aubinet , Chr. Bernhofer , A. Carrara , F. Chevallier , T. Conway, N. De Noblet , A. Friend , T. Grünwald , B. Heinesch , G. Inoue, P. Keronen, A. Knohl, D. Loustau , G. Manca , T. Machida, G. Matteucci , F. Miglietta , J.M. Ourcival , K. Pilegaard , P. Peylin, S. Rambal , P. Rayner, G. Seufert , J.-F. Soussana , M.-J. Sanz ,

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

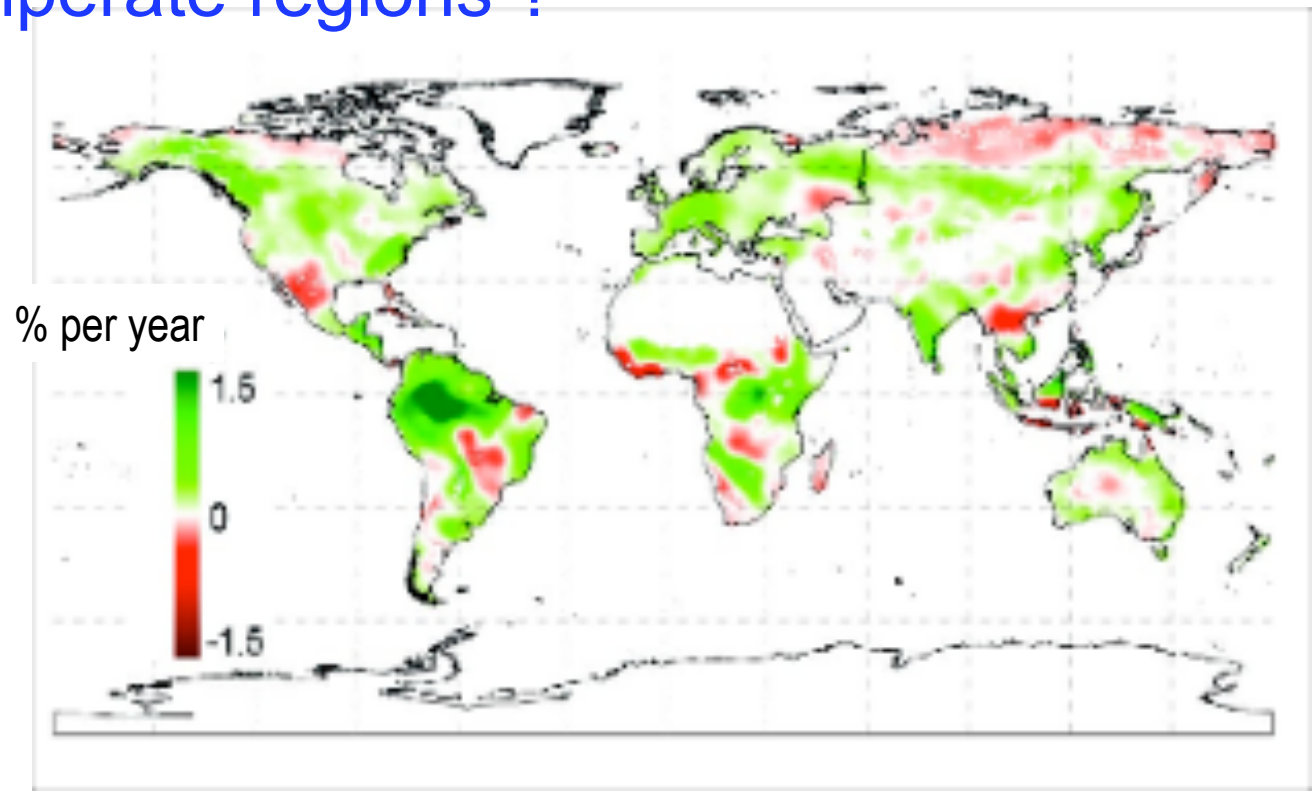
Linking the 2003 European heatwave with carbon observations





Will the greening trends continue with more frequent climate extremes ?

Can positive carbon-climate feedbacks come from temperate regions ?

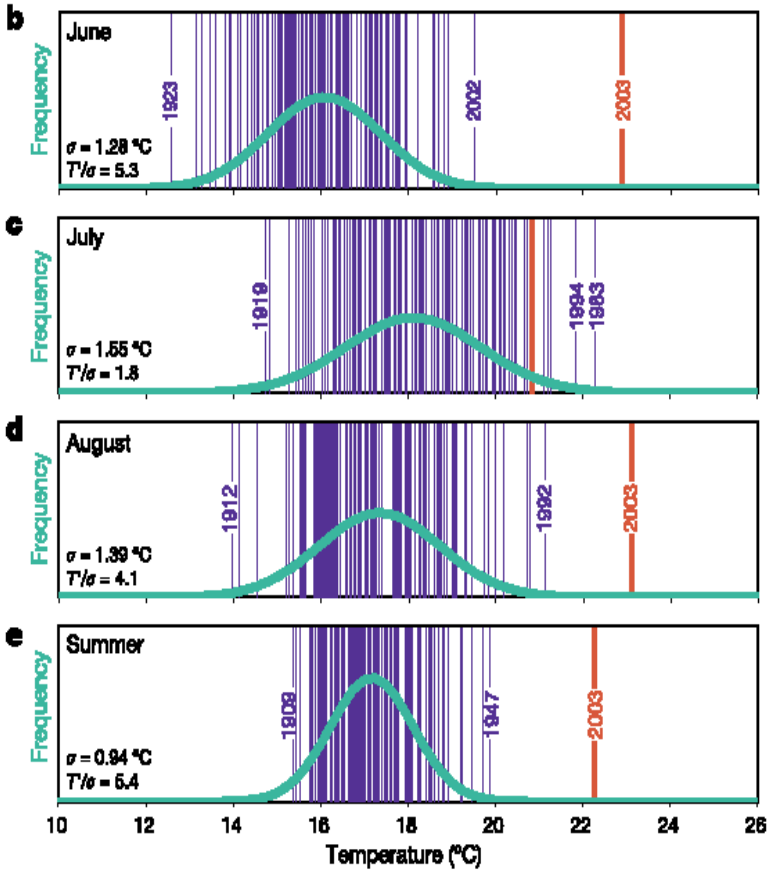


Secular increase in primary productivity from satellite NDVI over the past 20 years

Nemani et al., Science 2003

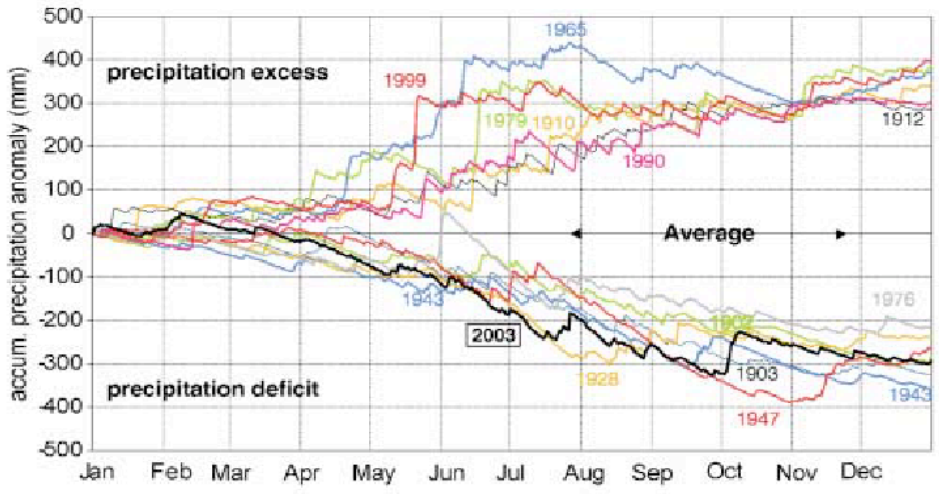
Europe-wide climate Spell : heat & drought

Historical temperature records in Switzerland

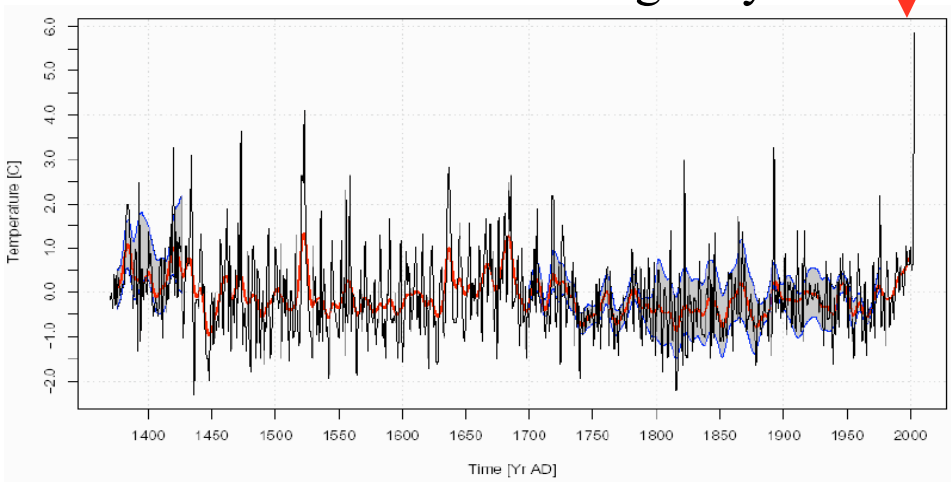


Shär et al., Nature 2003

Precipitation history in Bavaria



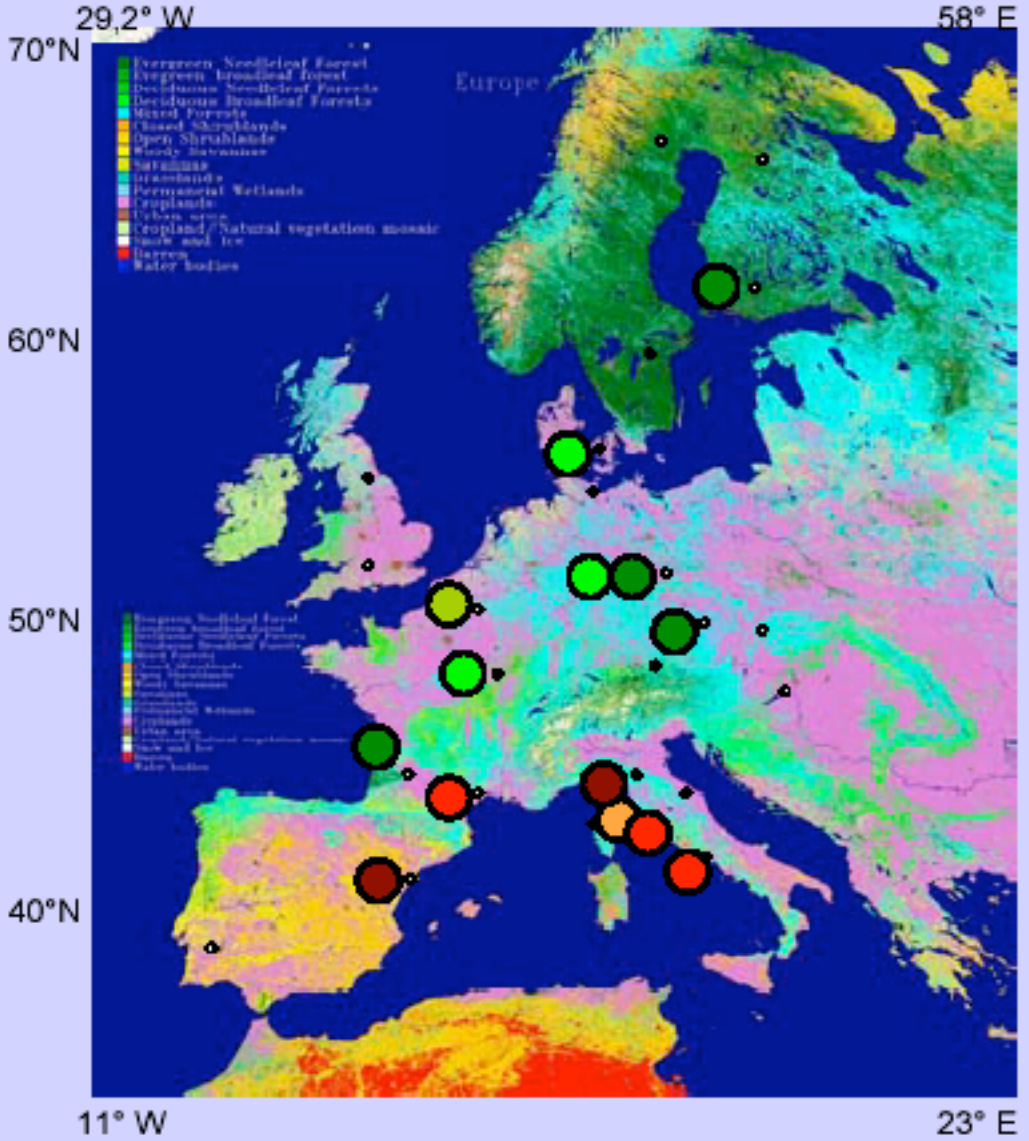
Summer temperature reconstruction from harvest dates in Burgundy



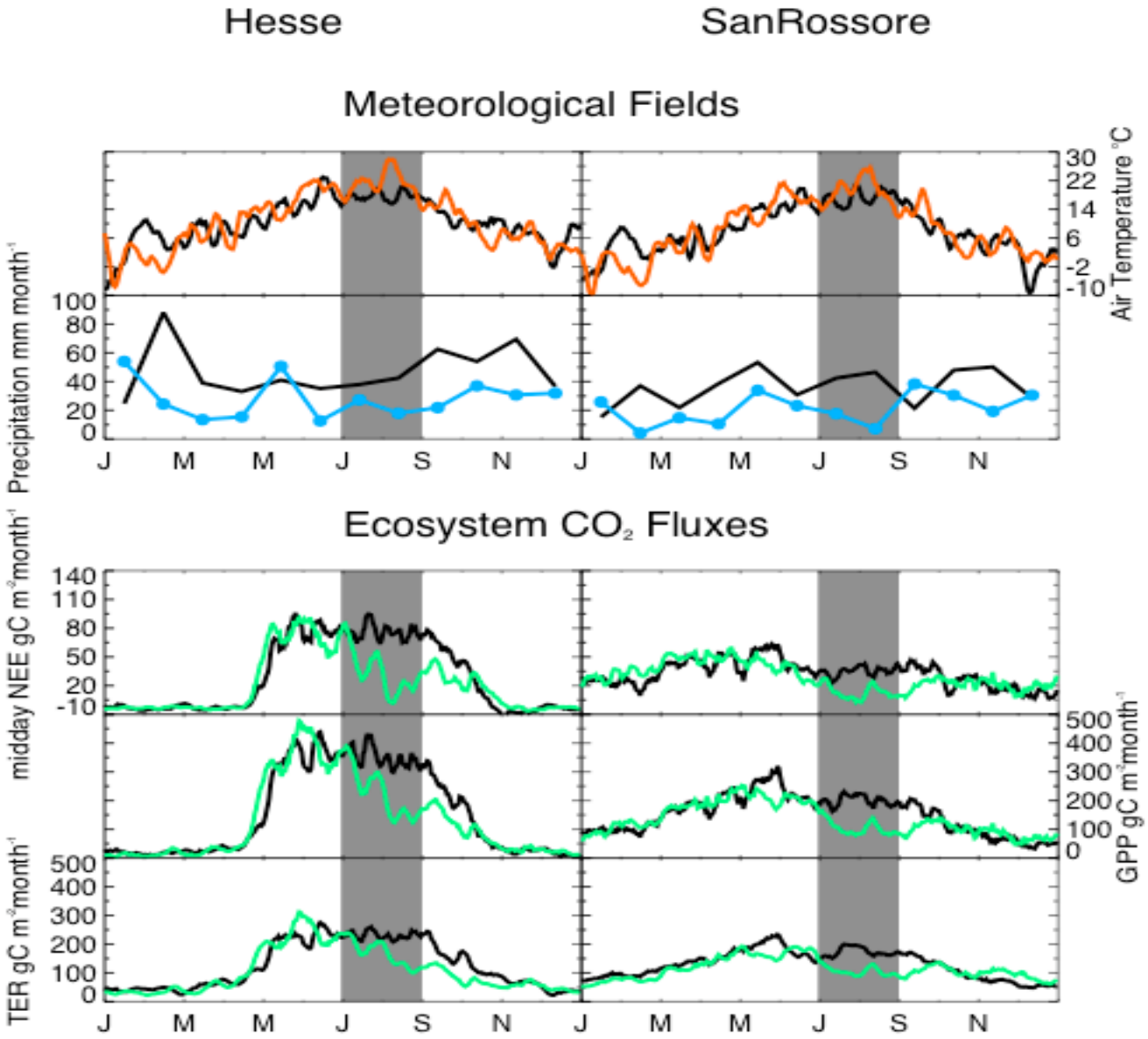
Chuine et al., Nature, 2003

THE EDDY COVARIANCE SITES ON A MODIS LANDCOVER CLASSIFICATION MAP

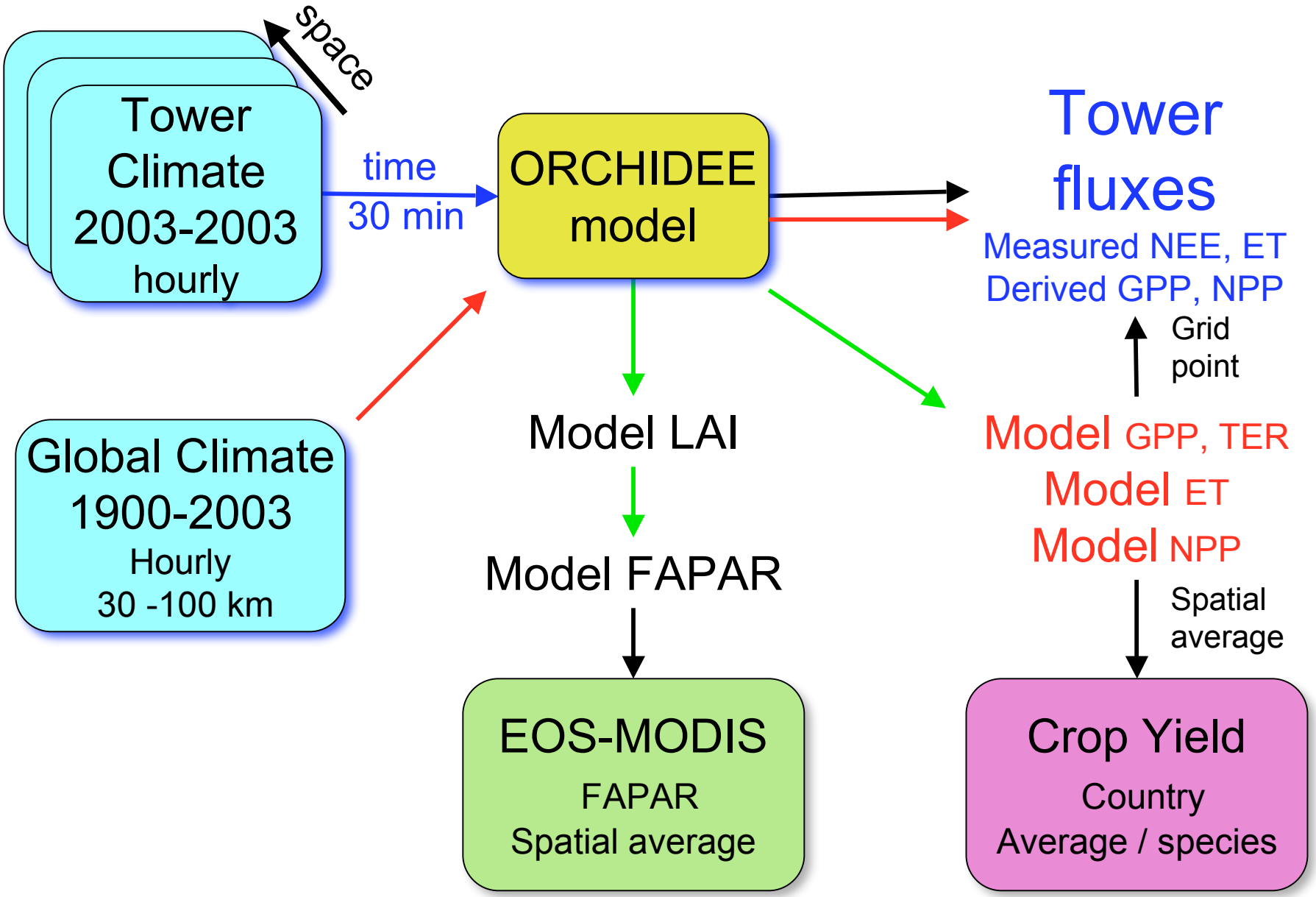
Sites used in this study include: **Deciduous broadleaf forests**; Soroe, Hainich, Hesse **Evergreen needle leaf forests**; Hyytiala, Tharandt, Bray Mediterranean **needle-leaf** and **broad-leaf** forests and **macchia:** Puéchabon, San Rossore, Pianosa, Roccares-pampani, El Saler, Castelporziano



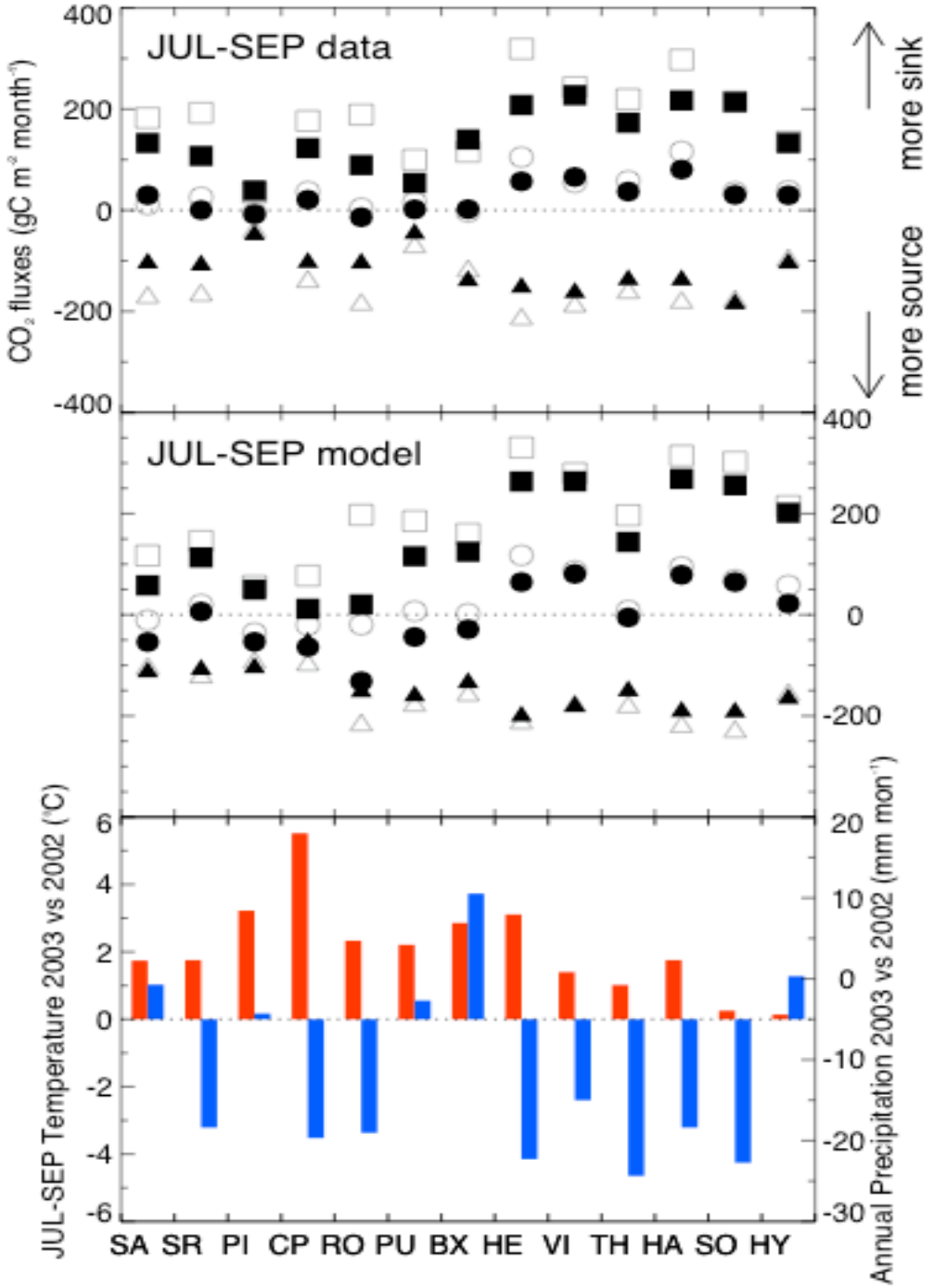
Temperate and Mediterranean forests show reduced, GPP, TER, NEE



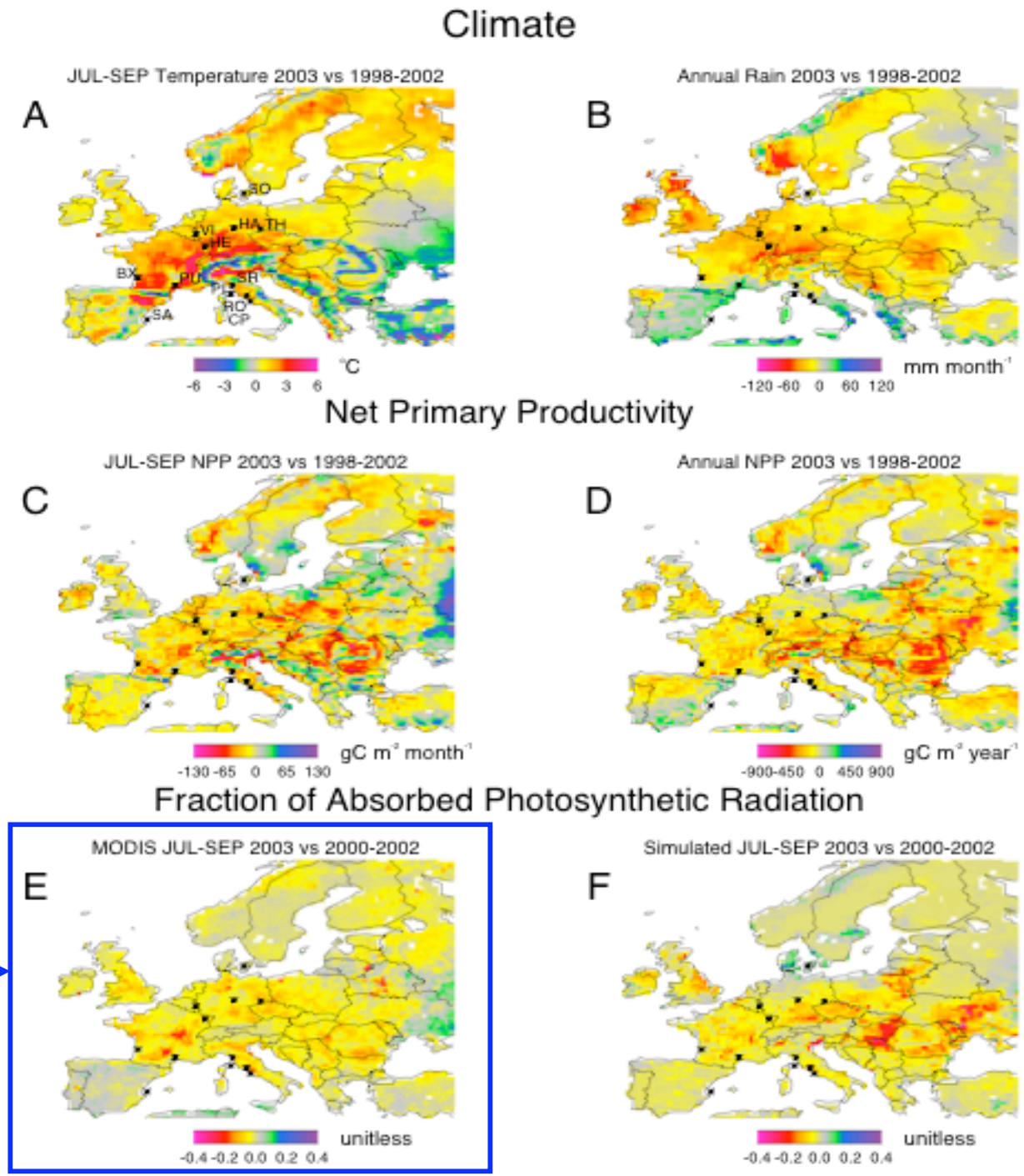
modelling system



Climate, and carbon fluxes in summer 2002 vs. summer 2003

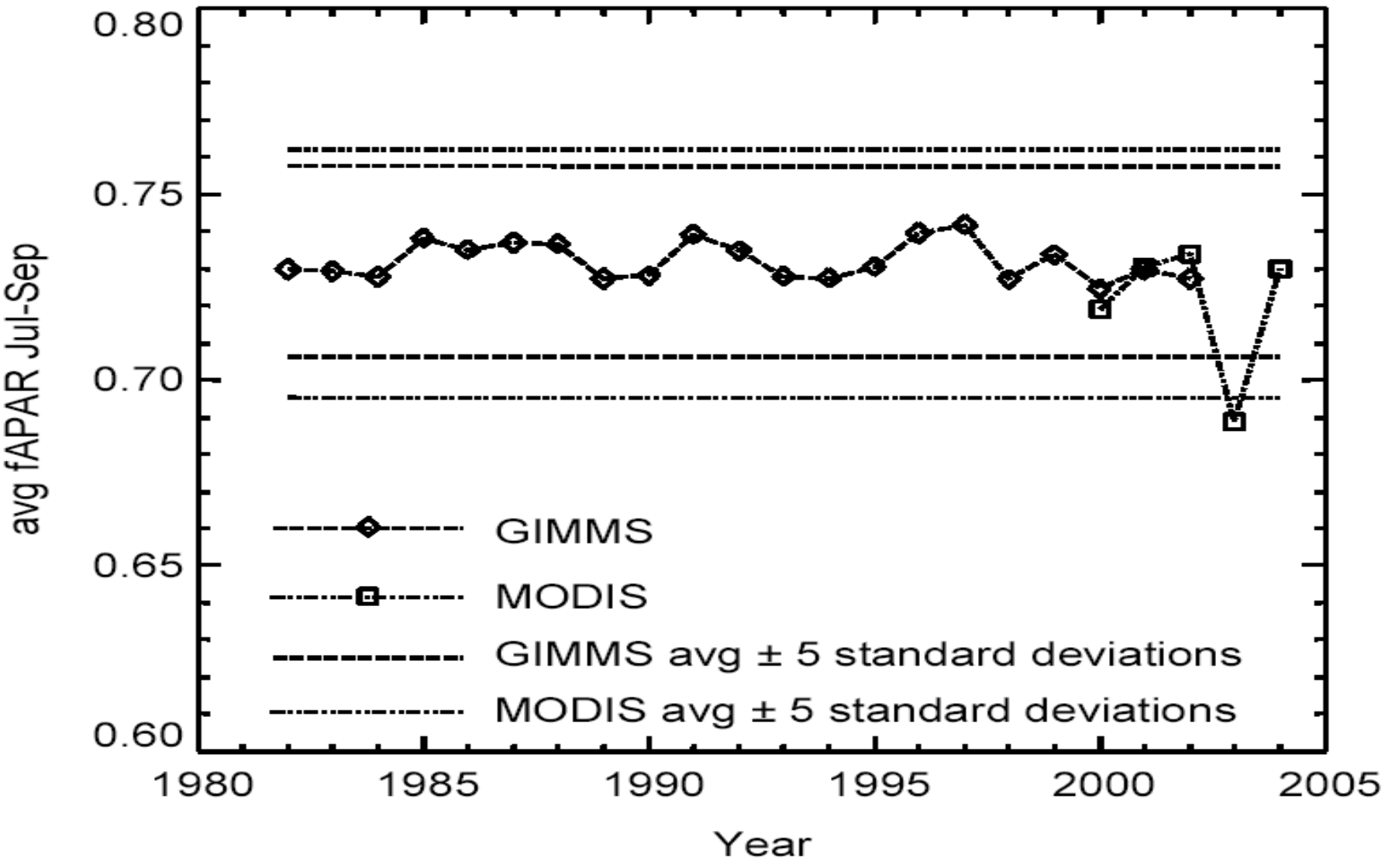


Abnormal Climate and Modelled Productivity in 2003

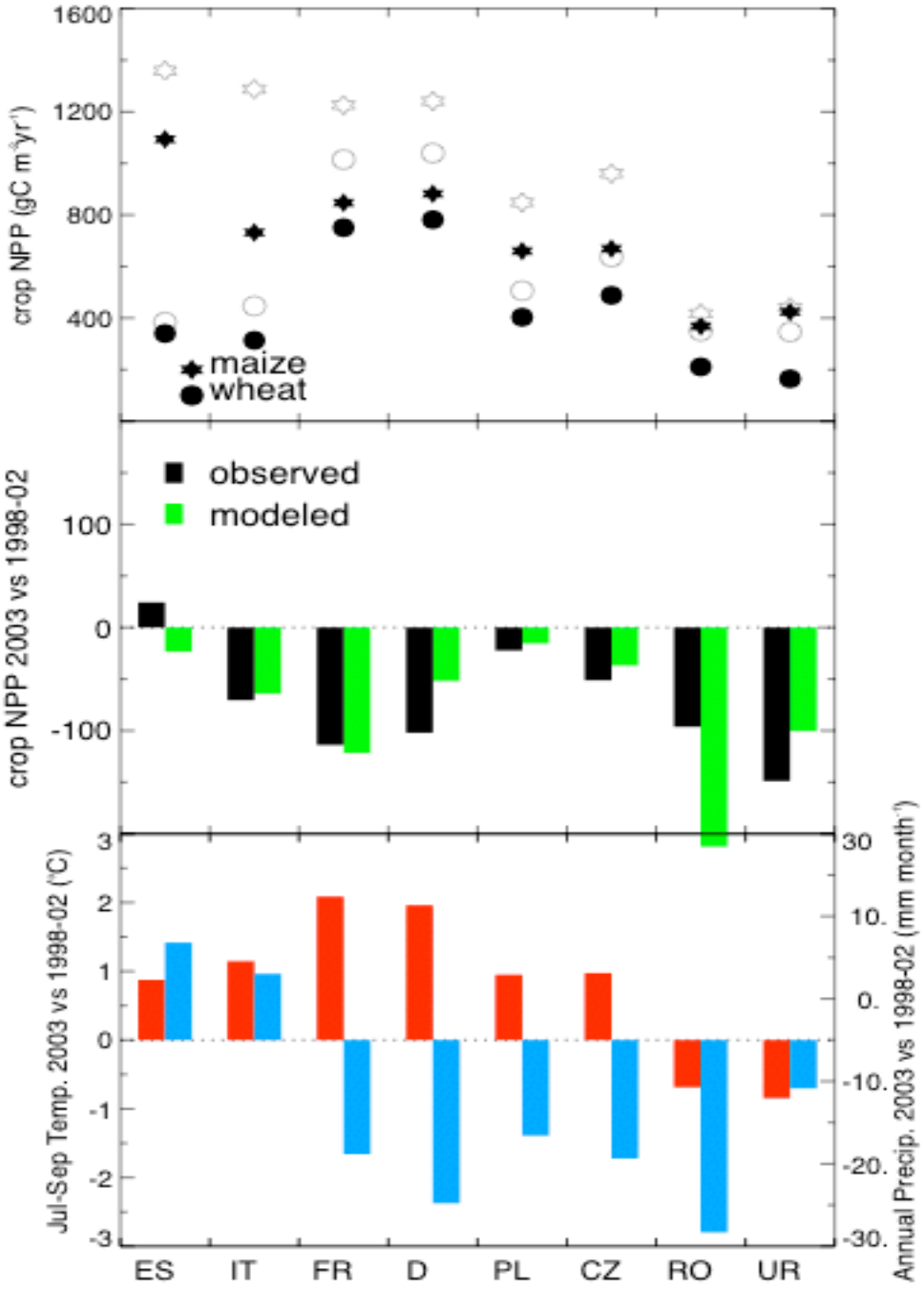


EOS-MODIS FAPAR anomaly

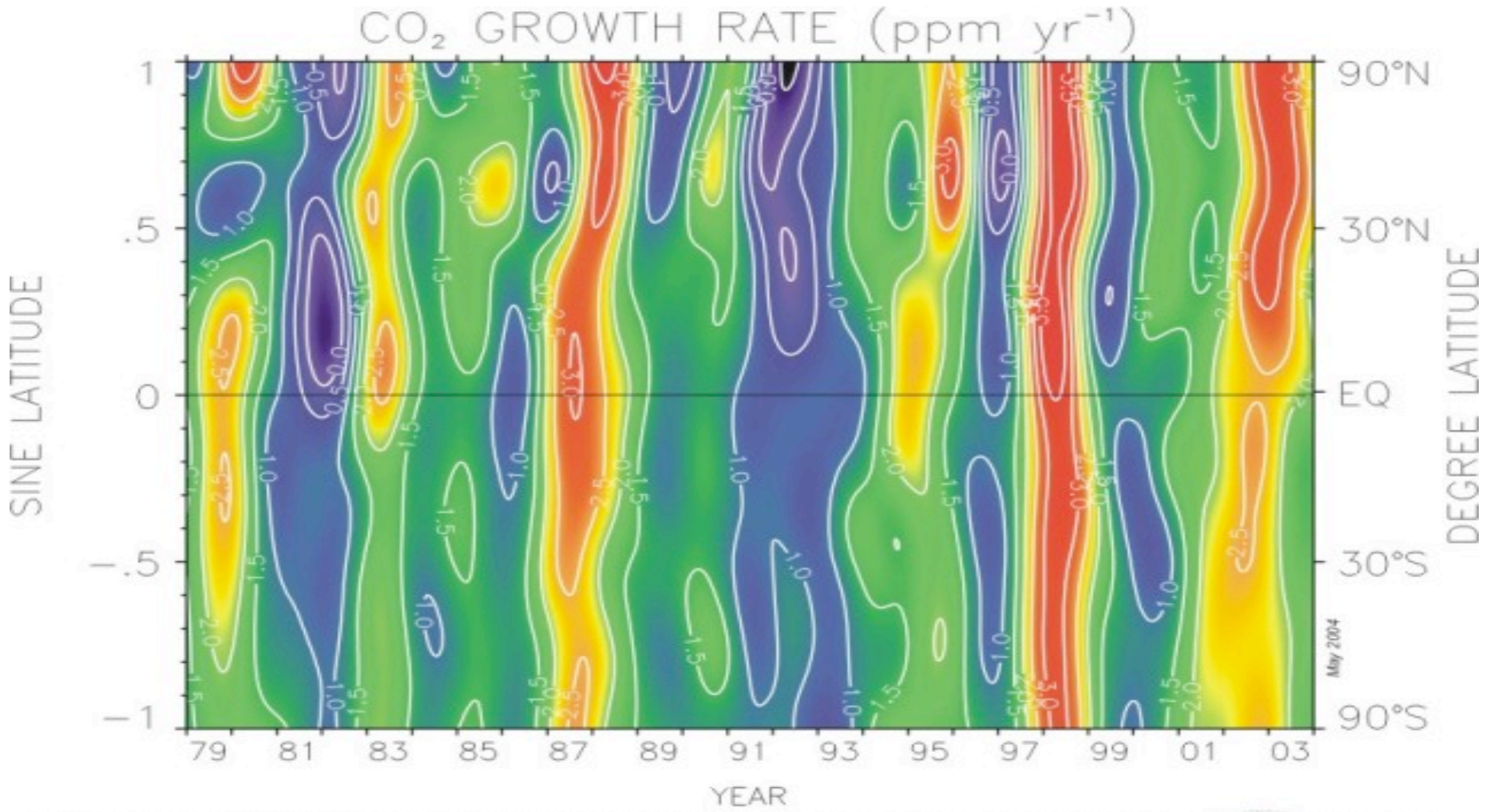
How abnormal is 2003 ?



Verification against crops yield national data



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).

Atmosphere-based inversion estimate

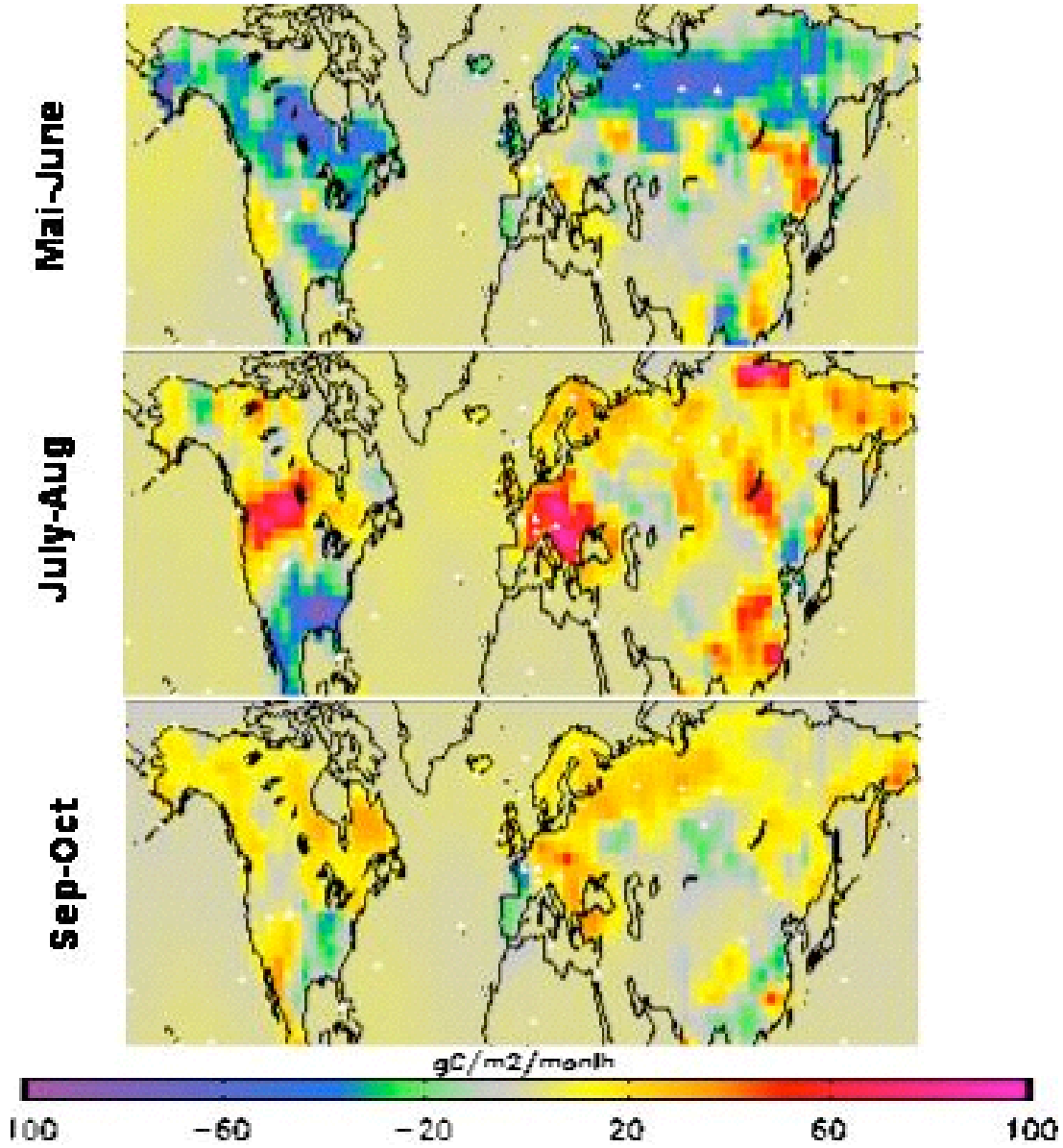
70 sites
Grid based inversion
(3.5 x 2.5°)

LMDZ model

Interannual winds

Spatial correlations

Anomalies vs. mean
97-03



See Peylin et al. Poster
also Patra, Roedenbeck…

Processes

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

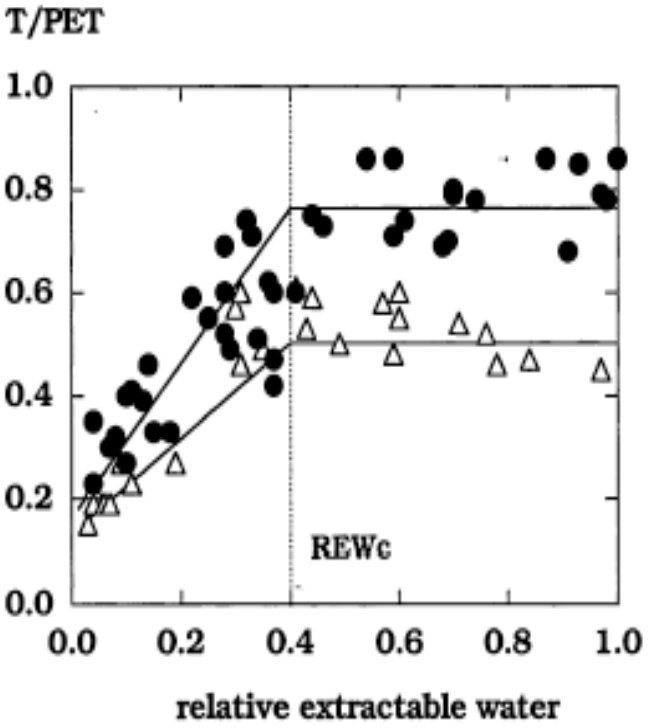
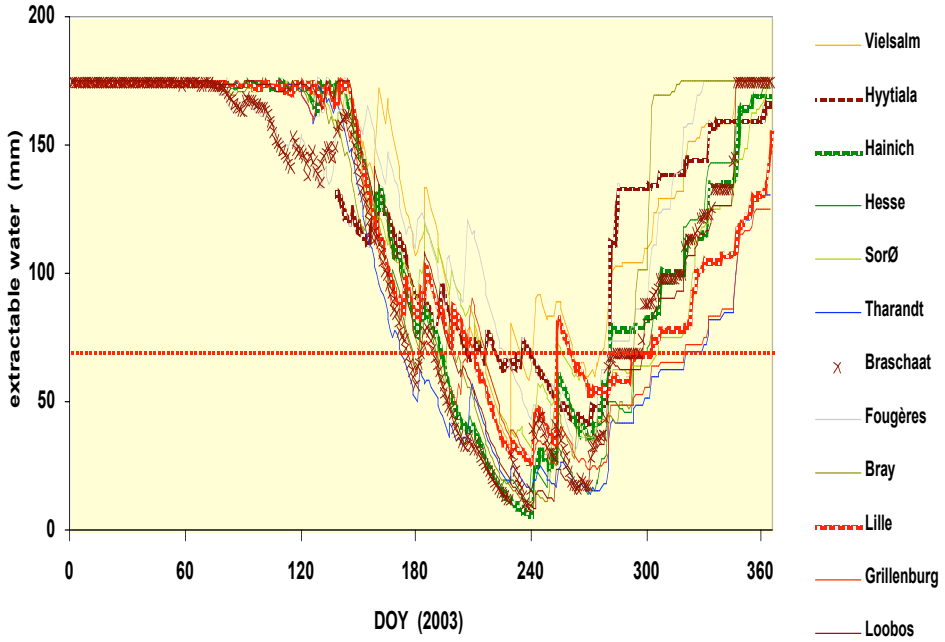
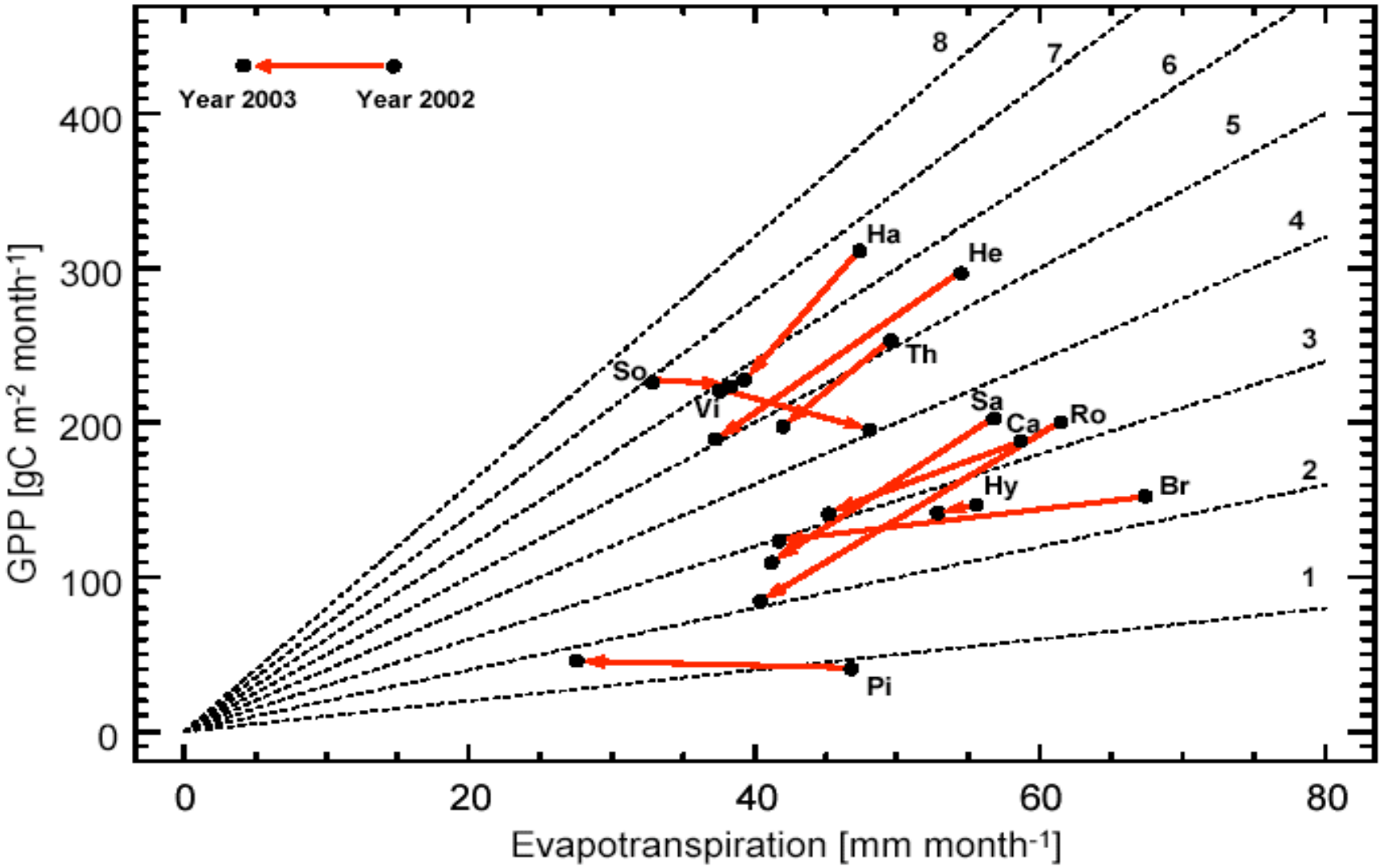


Fig. 2. Ratio T/PET calculated from sap flow measurements in an oak stand as a function of relative extractable water (REW) calculated from neutron probe measurements (from Bréda and Granier, 1996). Two data sets are reported: LAI = 6 m^2 m^{-2} (black circles) and LAI = 4.5 m^2 m^{-2} (open triangles).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

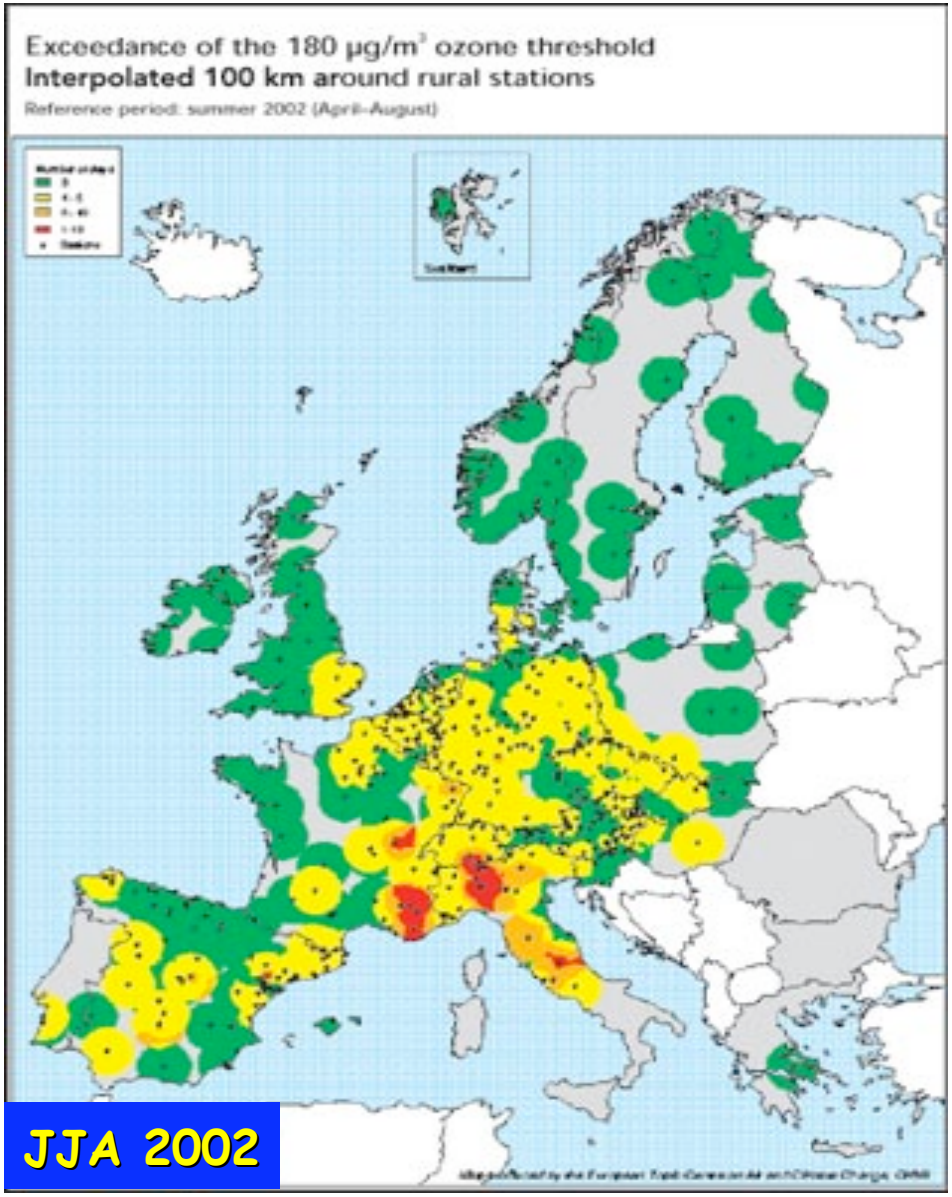


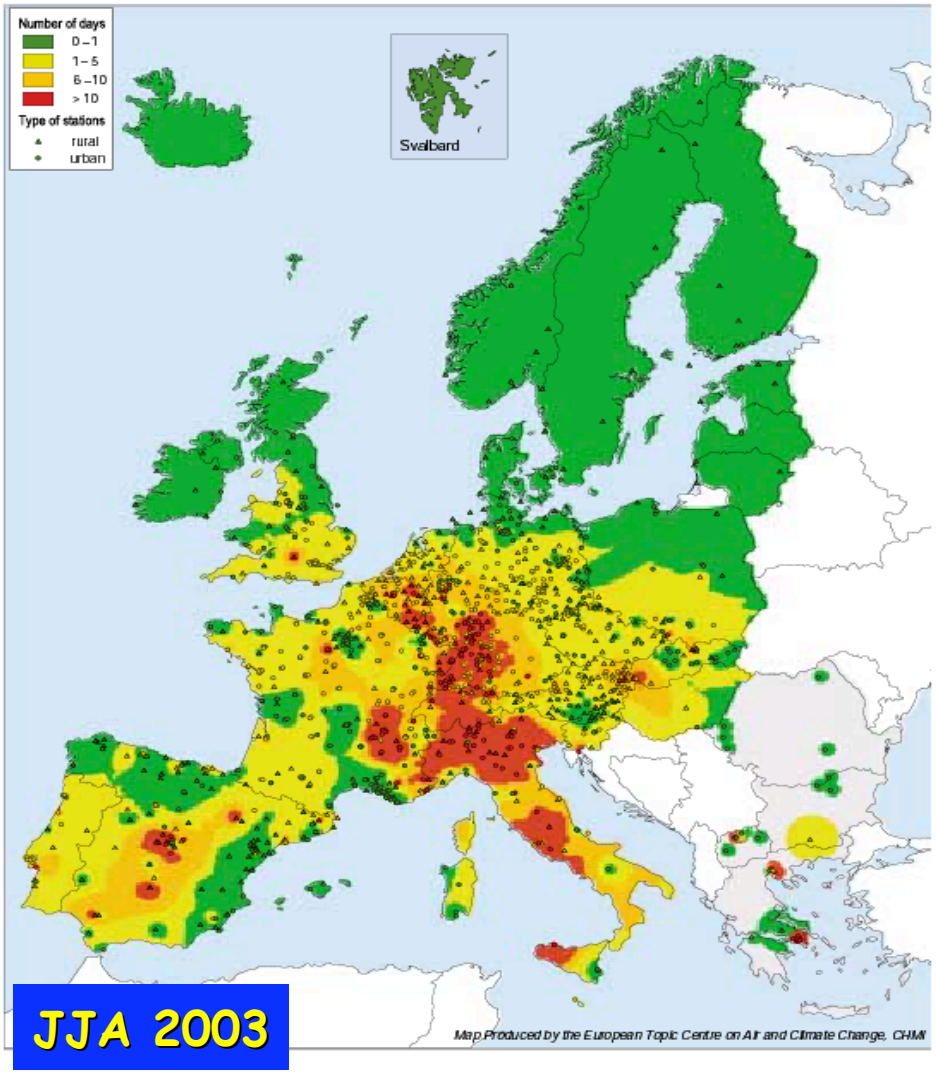
Breda et al. 2004

Small Changes in water use efficiency

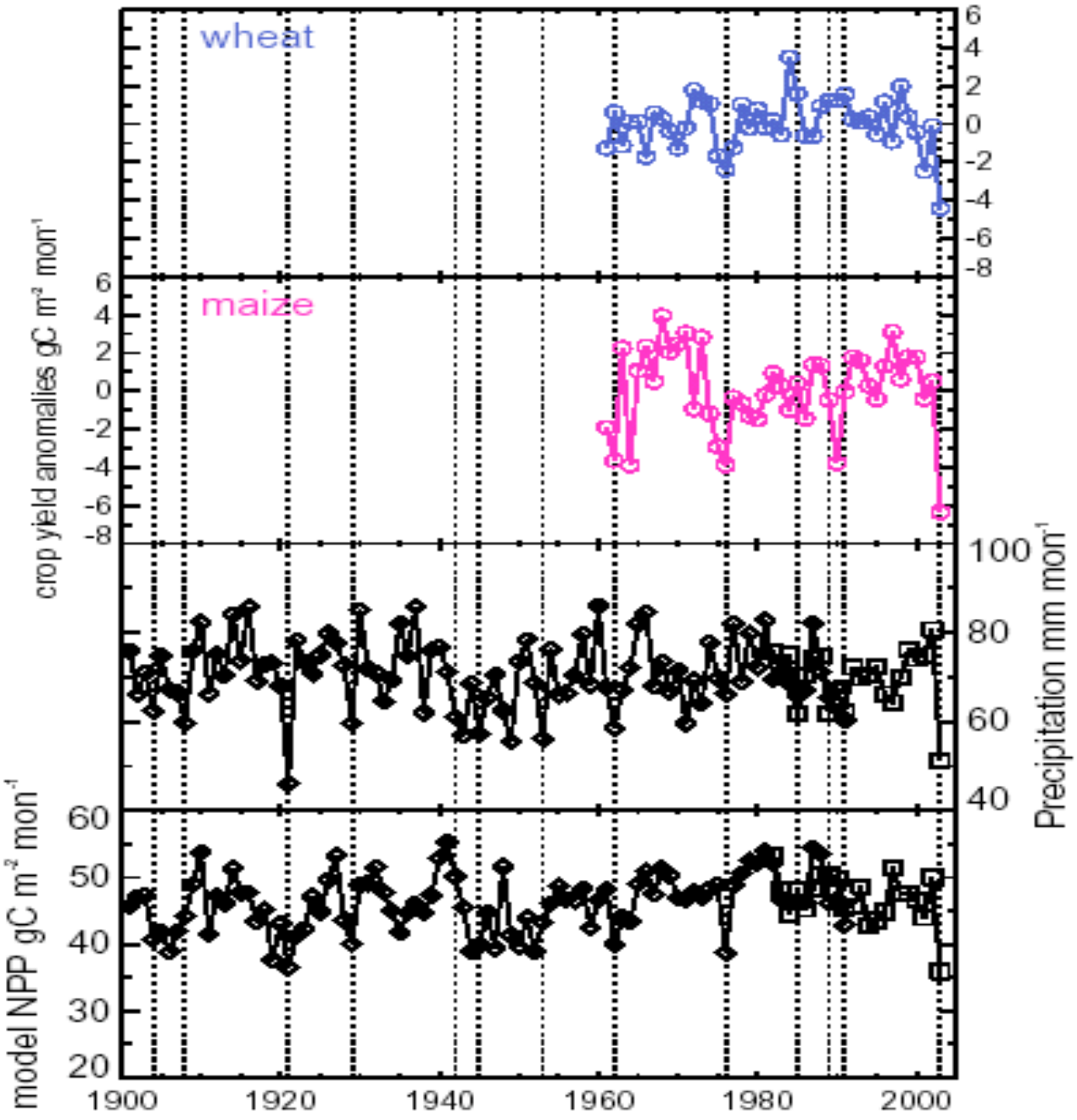


Effects of high ozone exposure





Carbon crashes in the recent past



Conclusions (1)

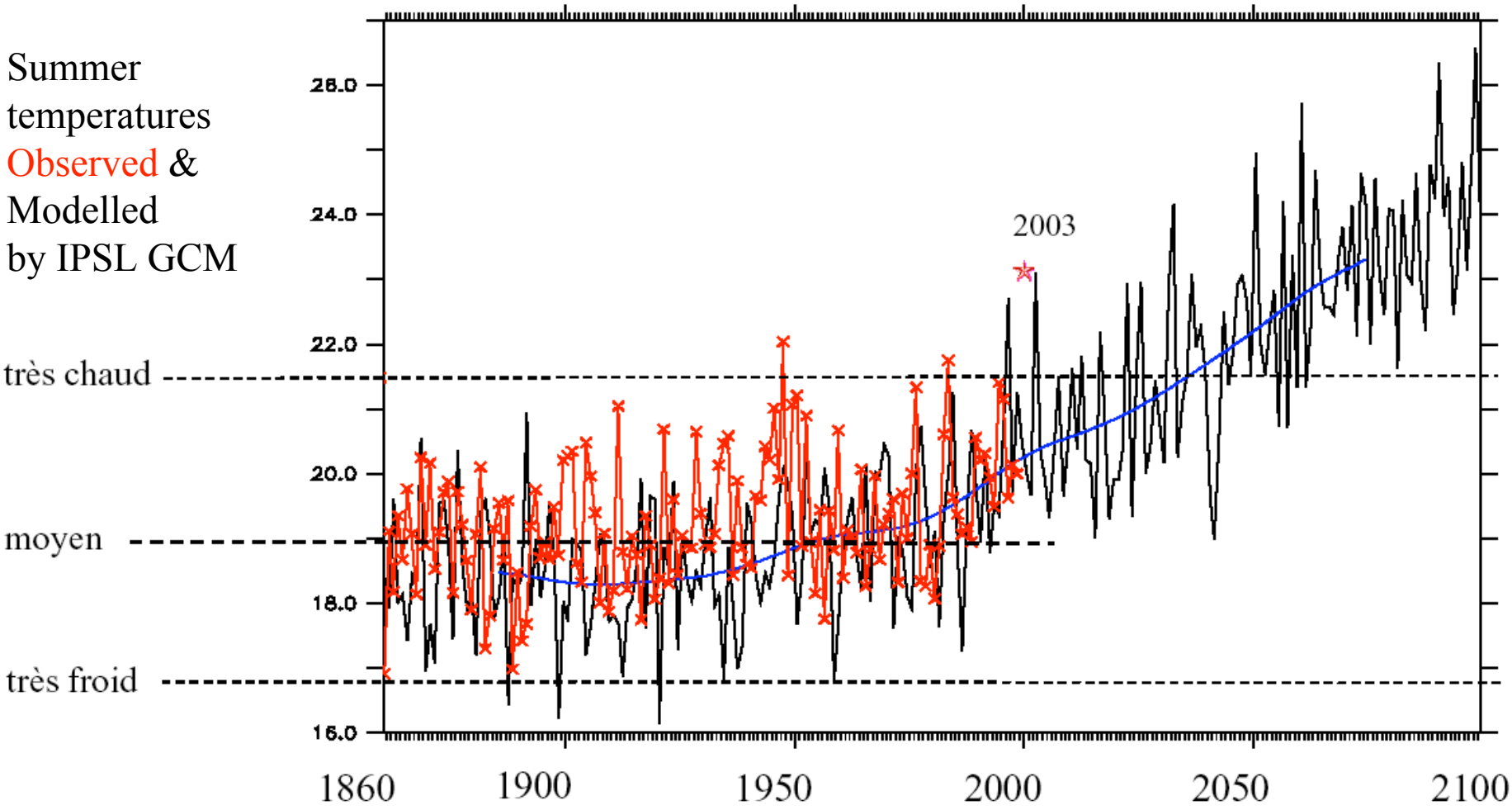
- Uniquely dense eddy covariance network to understand climate-carbon-water interactions at the sub-continental level
- Severe drop of transpiration and GPP
- Respiration tailed off with GPP drop rather than increased with warming
- forests became net CO_2 sources to the atmosphere in July-Aug !
- Anomalous source of 0.5 PgC y^{-1}, undoing years of mean sink, enough to explain 50% of the global CO_2 growth rate anomaly during 2003

Conclusions (2)

- In the future, adverse impacts of climate extremes may cancel out the benefits of moderate climate change
- Forest productivity may be durably reduced if extremes become more frequent
- In the long run, conifer forest may be more adapted to future climate conditions in Europe
- And so large uncertainties !

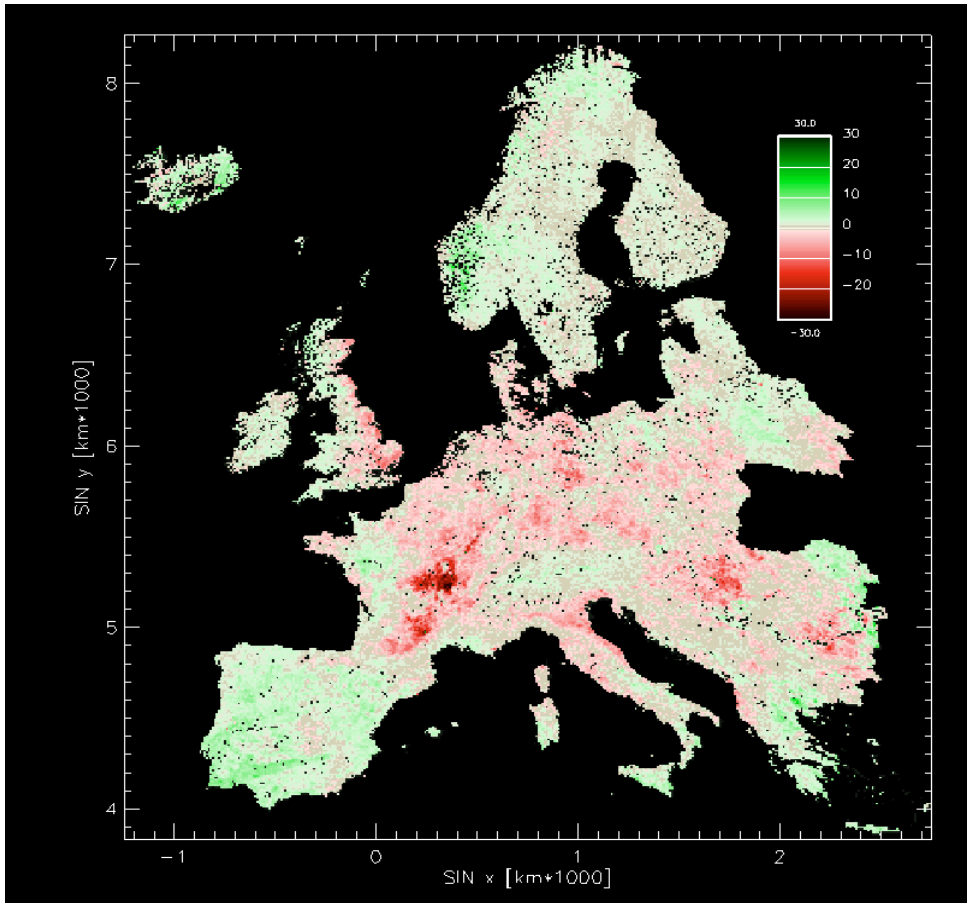
Implications for the future

Summer temperatures Observed & Modelled by IPSL GCM

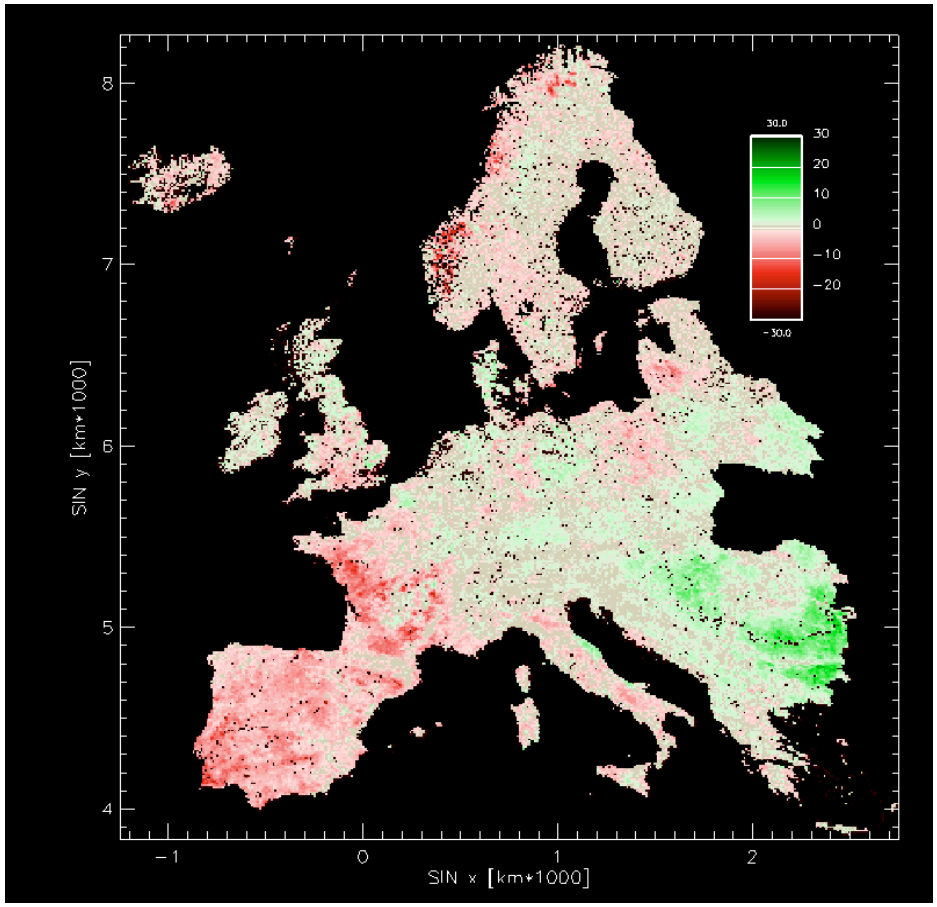


FPAR anomalies & recent droughts

2003



2005



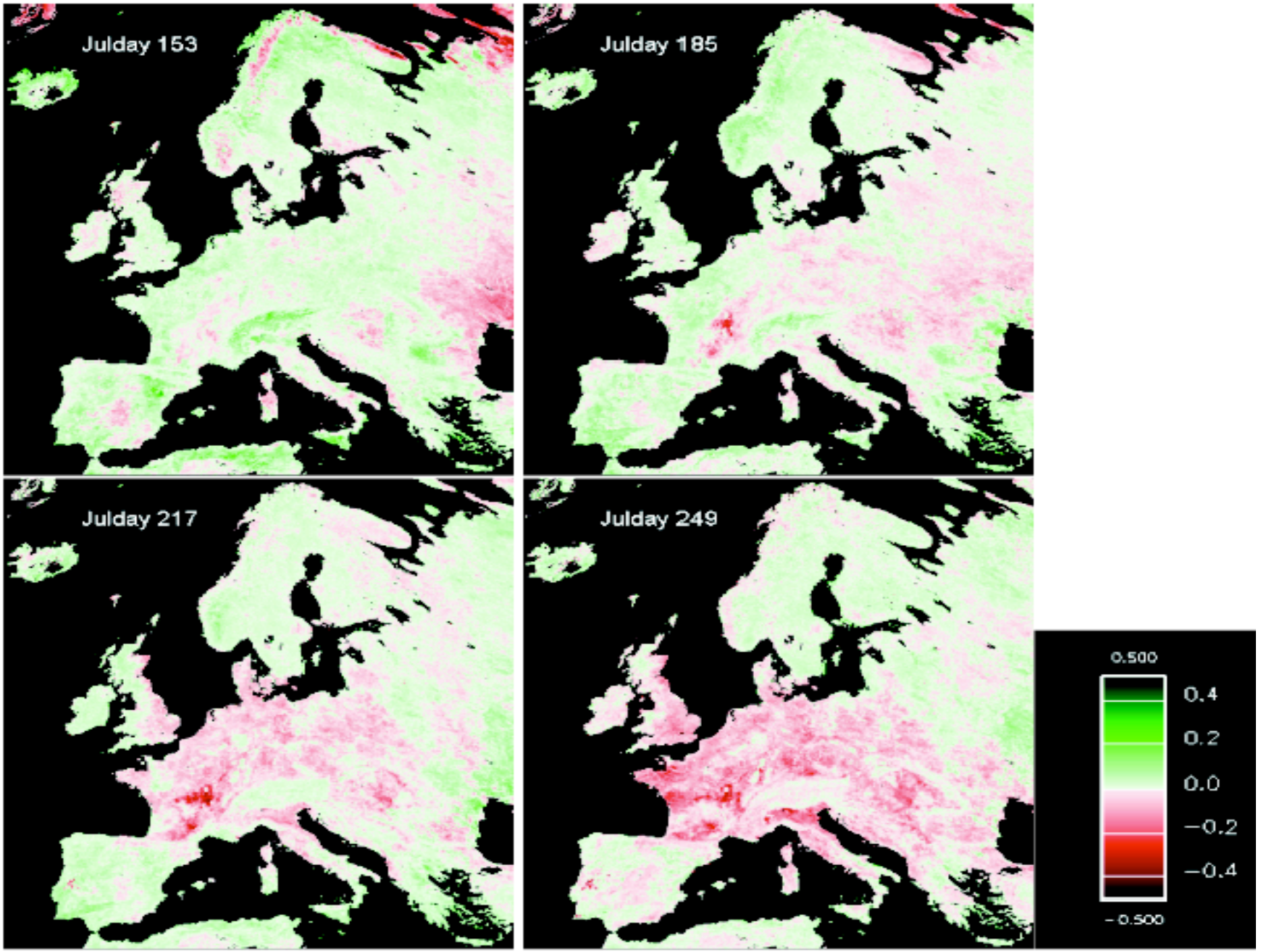


Fig. 1: Temporal development of the spatial pattern of the fAPAR anomaly during 2003