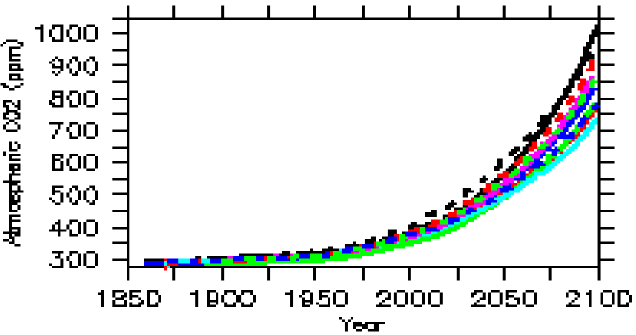
ENSO, Drought and the Changing Carbon Cycle

Ning Zeng

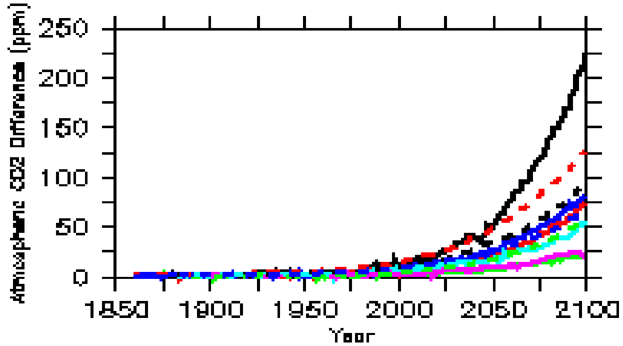
Dept. Atmospheric and Oceanic Science and
Earth System Science Interdisciplinary Center
University of Maryland

Contributors: M. Heimann, A. Mariotti, C. Roedenbeck, P Wetzel, E. Maier-Reimer
H. Qian, R. Iacono, E. Munoz

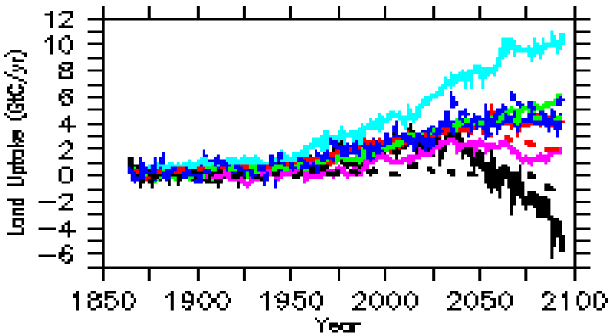
CO2



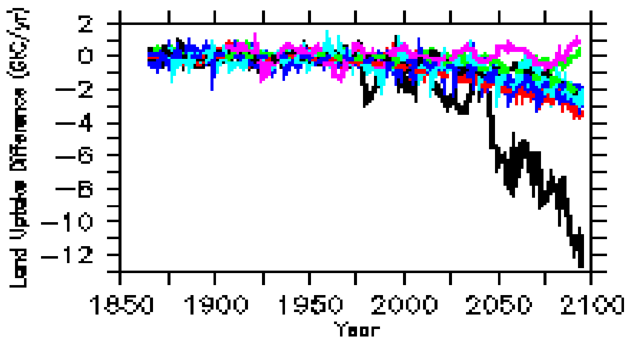
ΔCO2 from climate feedback



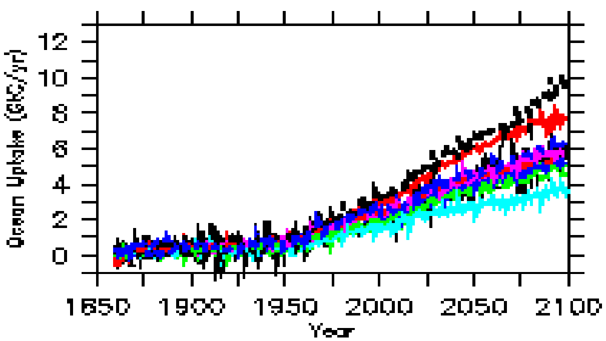
Land uptake



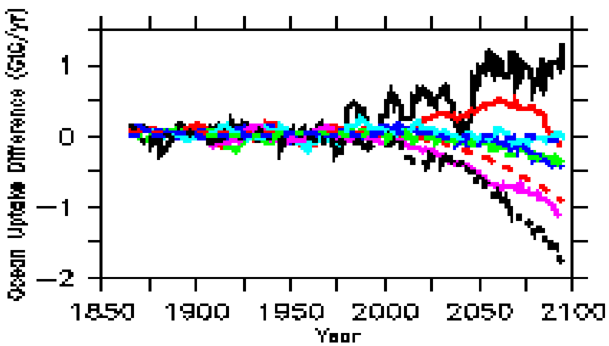
Δ Land uptake



Ocean uptake



Δ Ocean uptake



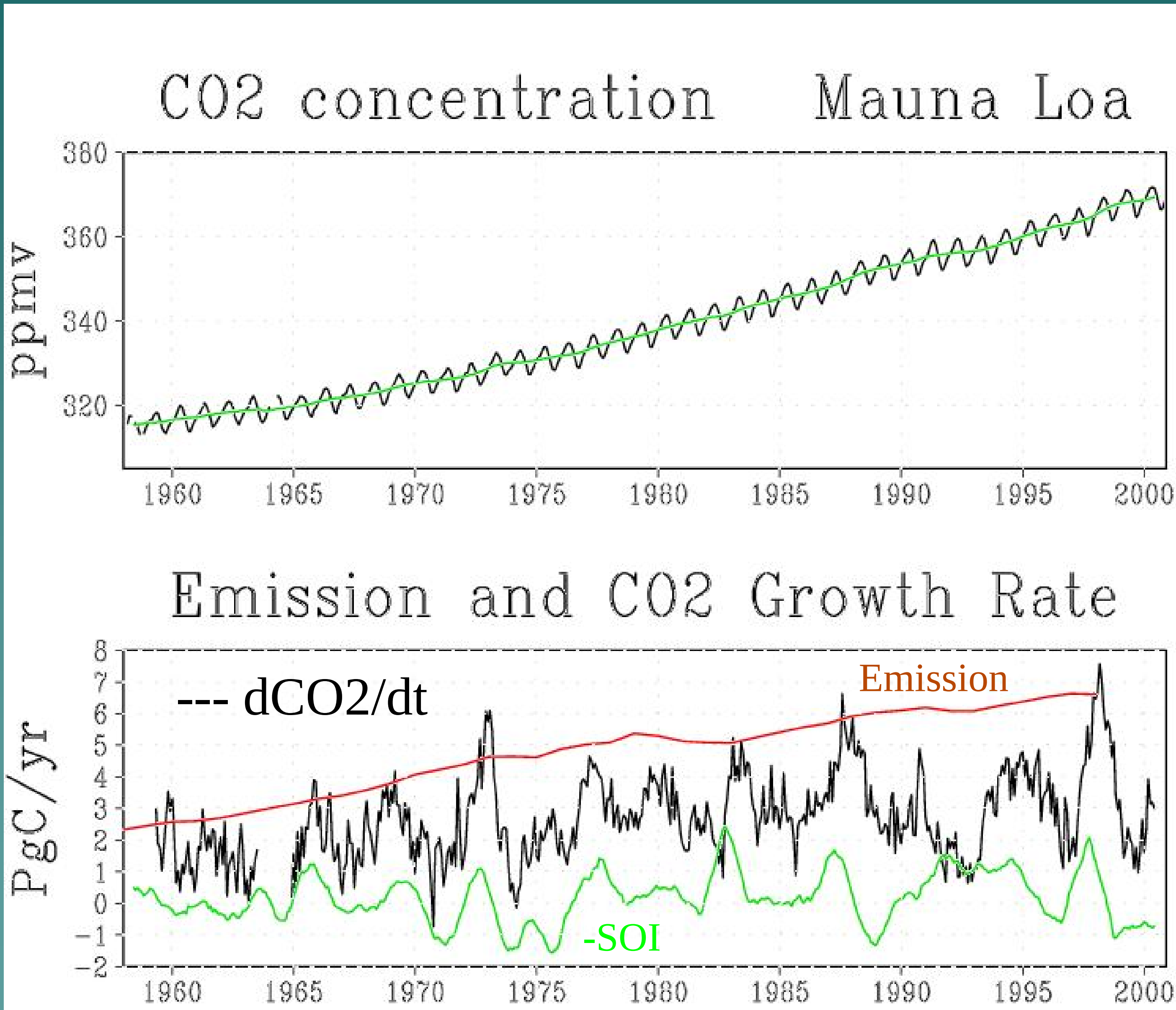
Friedlingstein et al., J. Climate in press

Enhanced global warming from carbon-climate interaction:
the C4MIP results

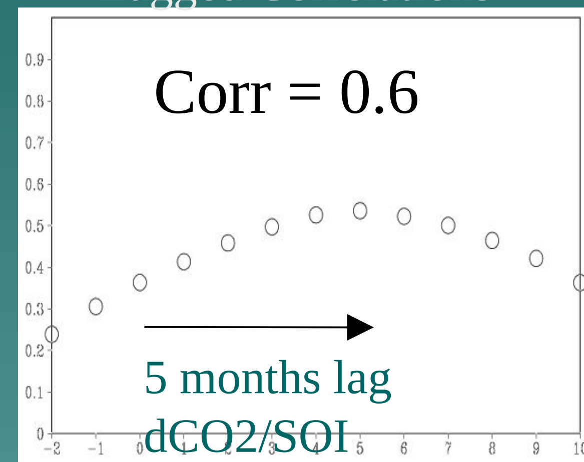
--- UMD Earth System Model (CABO)

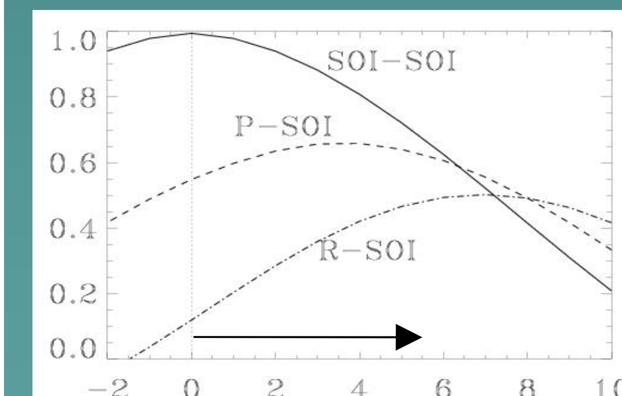
Large differences in land response:
interannual variability as a testbed

Atmospheric CO2 Variability 1958-2000

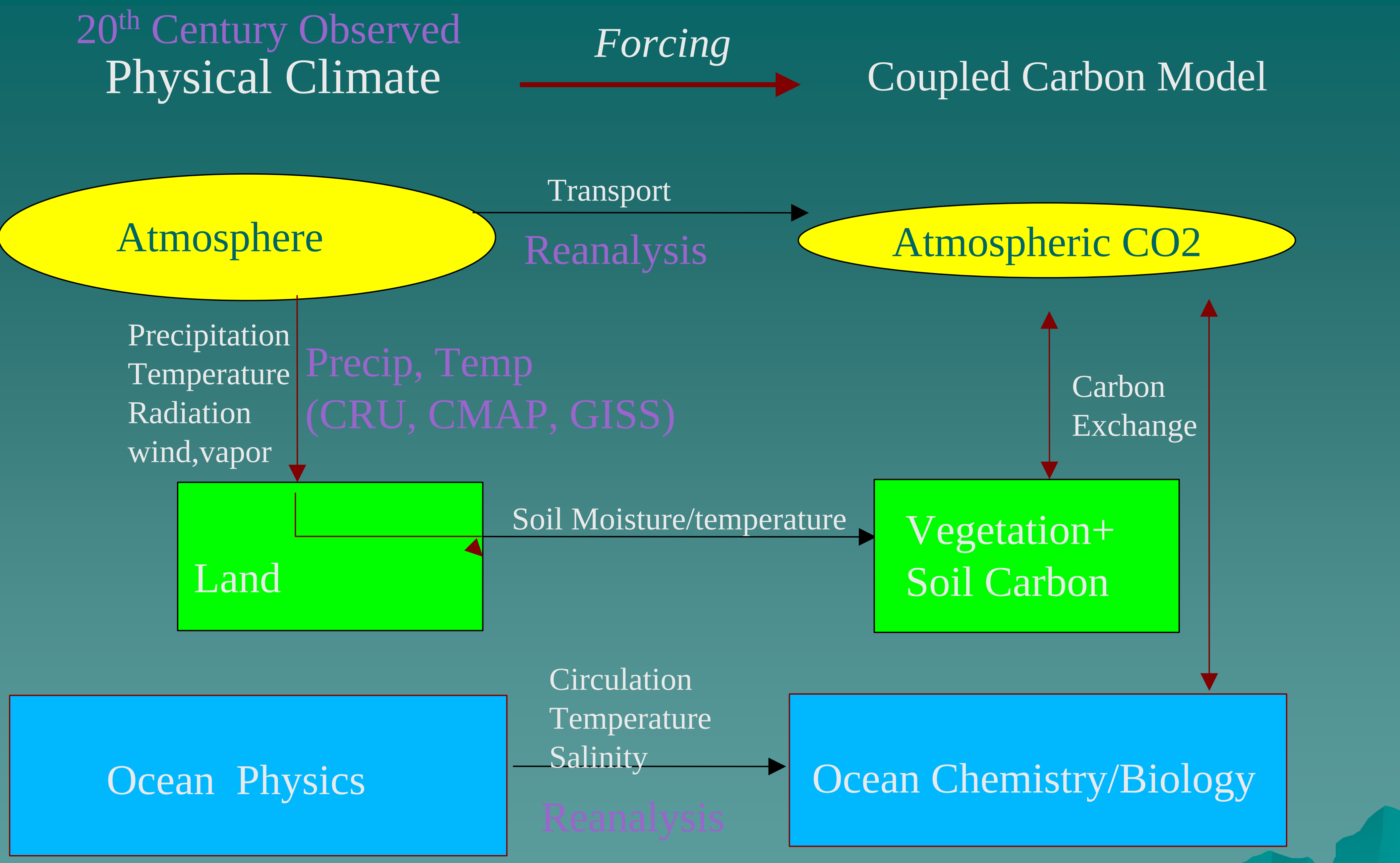


Lagged Correlations



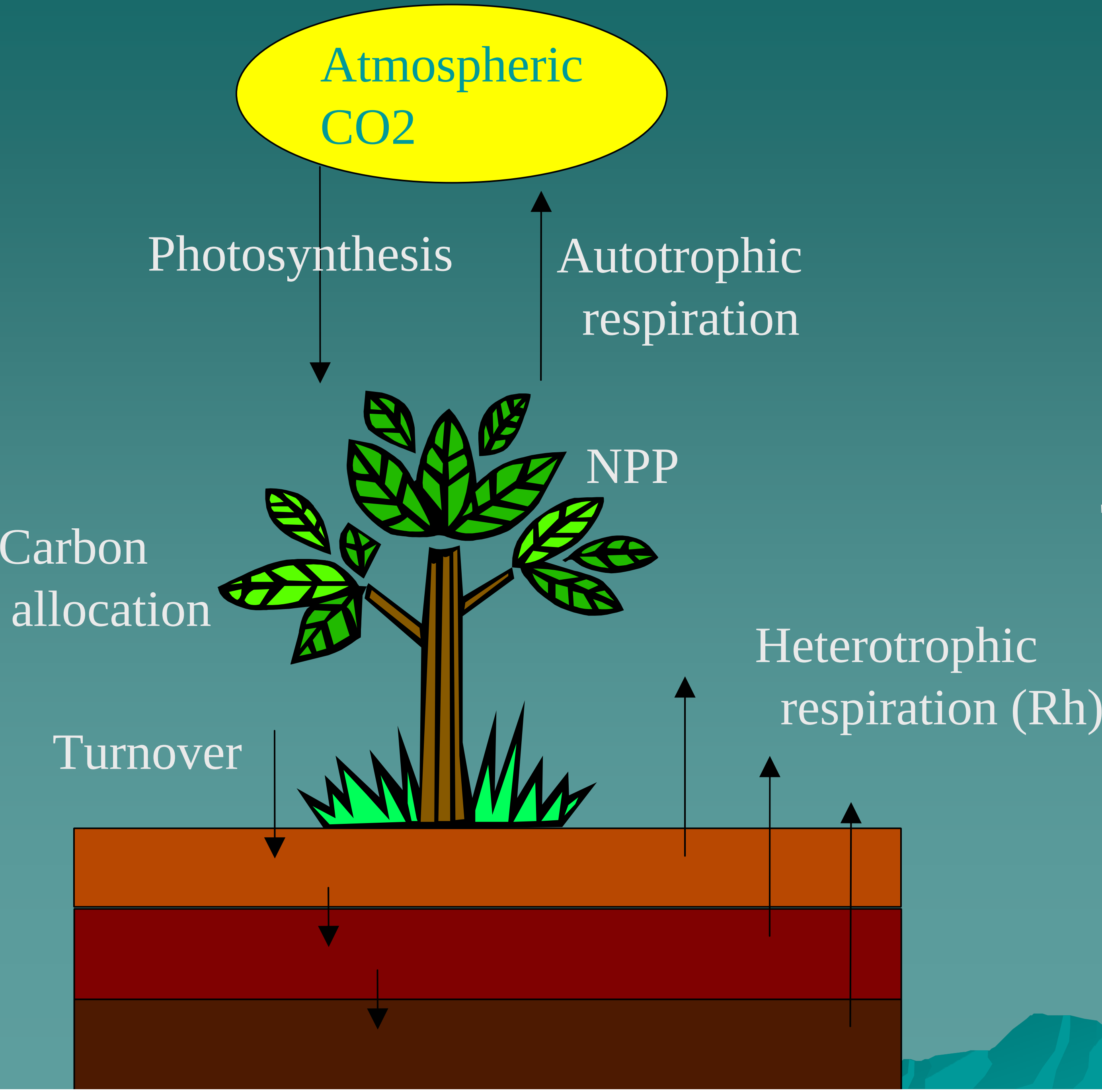


3-6 months lag
Hydrology/SOI



Goal: To understand the changing carbon cycle in the 20th Century

The VEgetation-Global Atmosphere-Soil Model (VEGAS)



4 **Plant Functional Types**:

- Broadleaf tree
- Needleleaf tree
- C3 Grass (cold)
- C4 Grass (warm)

3 Vegetation carbon pools:

- Leaf
- Root
- Wood

3 Soil carbon pools:

- Fast
- Intermediate
- Slow

VEGAS II

Photosynthesis:

Light (PAR, LAI, Height), soil moisture, temperature, CO2

Respiration:

Temperature, soil moisture, lower soil pools slower decay

Competition:

Net growth, shading => fractional cover

Fire:

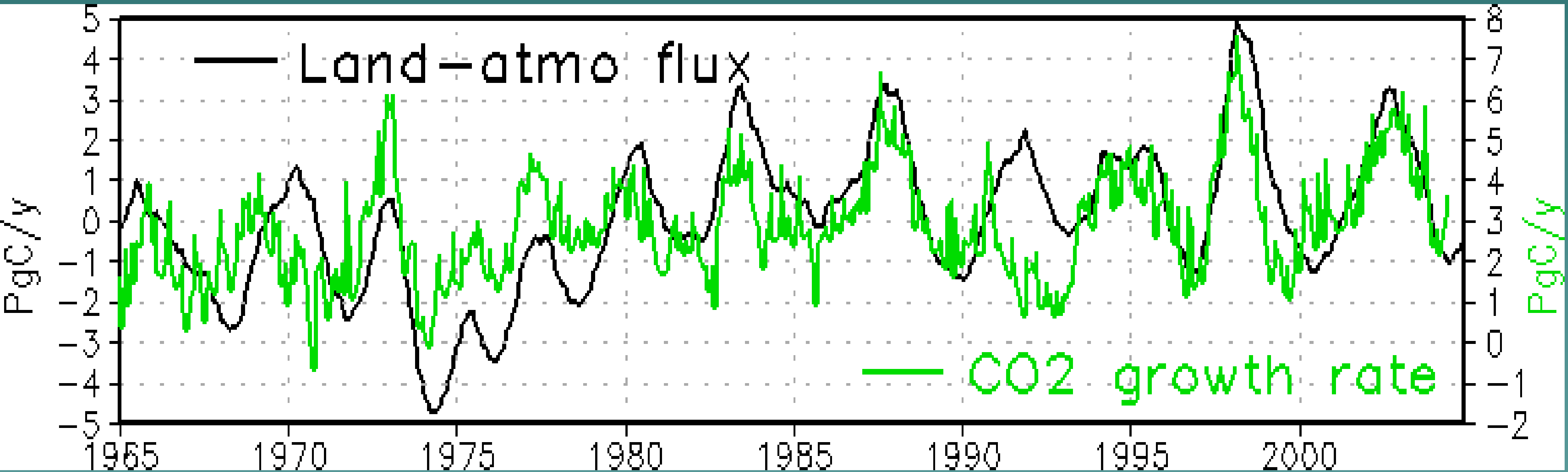
moisture, fuel load, PFT dependent resistance

Wetland/CH4:

moisture, topography gradient

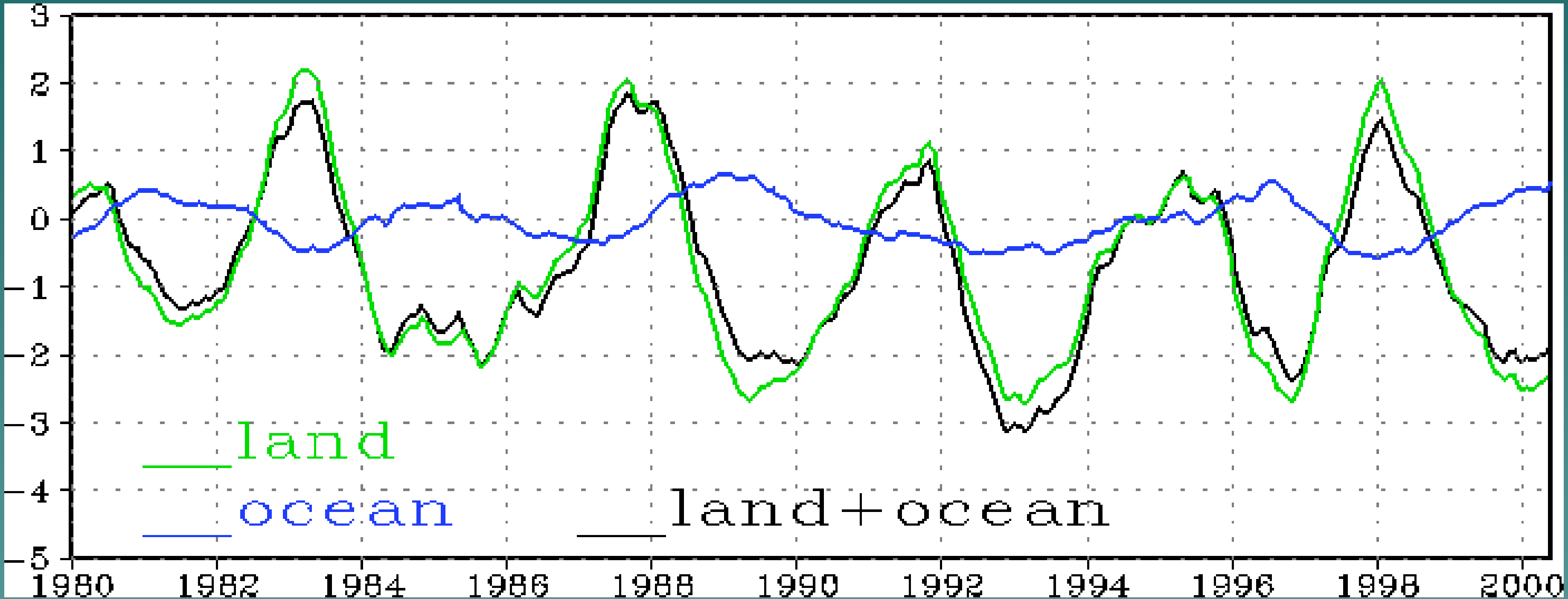
Mechanisms of Interannual Variability I

Modeled land-atmo flux vs. MLO CO2 growth rate



Terrestrial carbon model forced by observed climate variability

Land vs. ocean fluxes

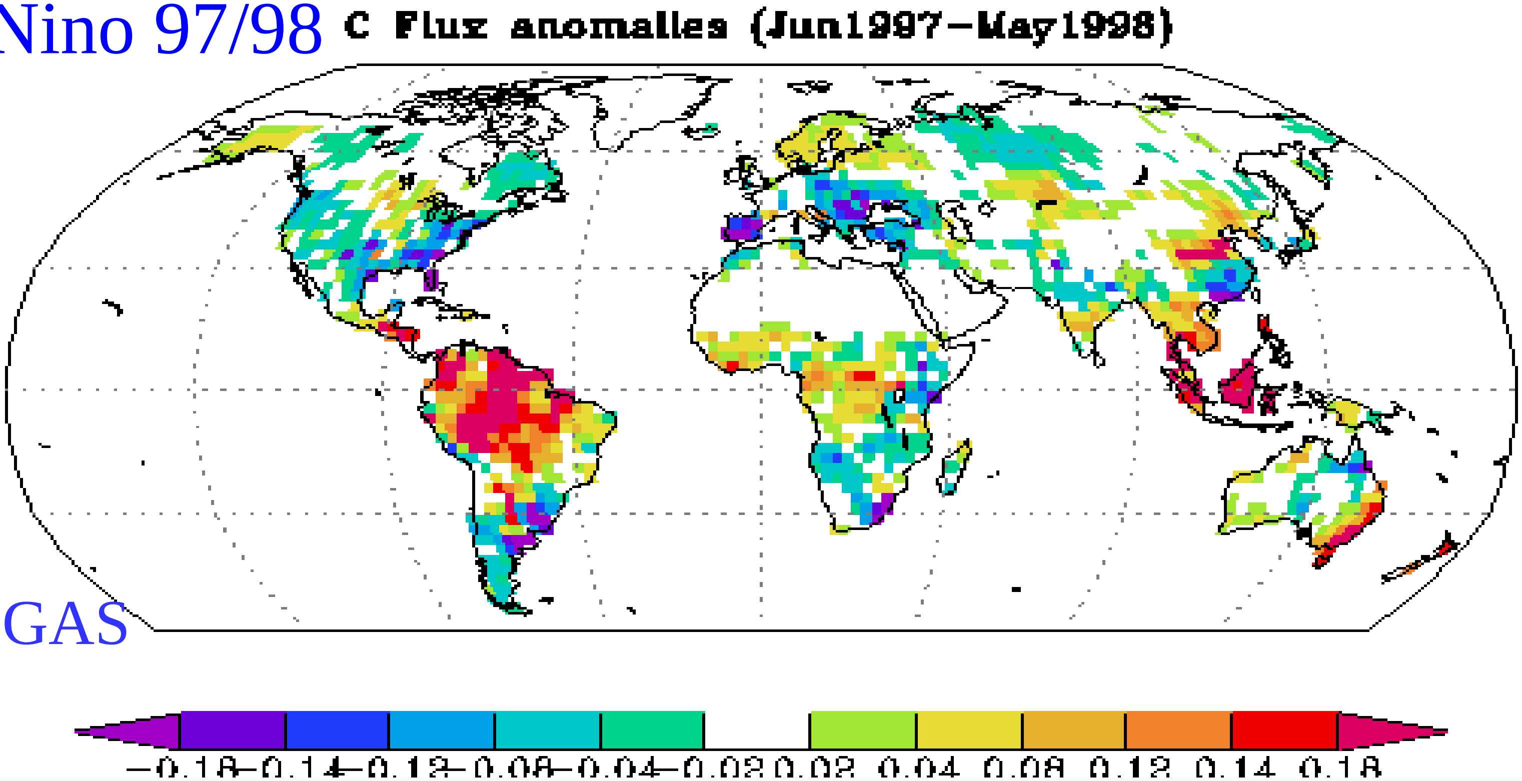


Land: VEGAS
Ocean: HAMOCC

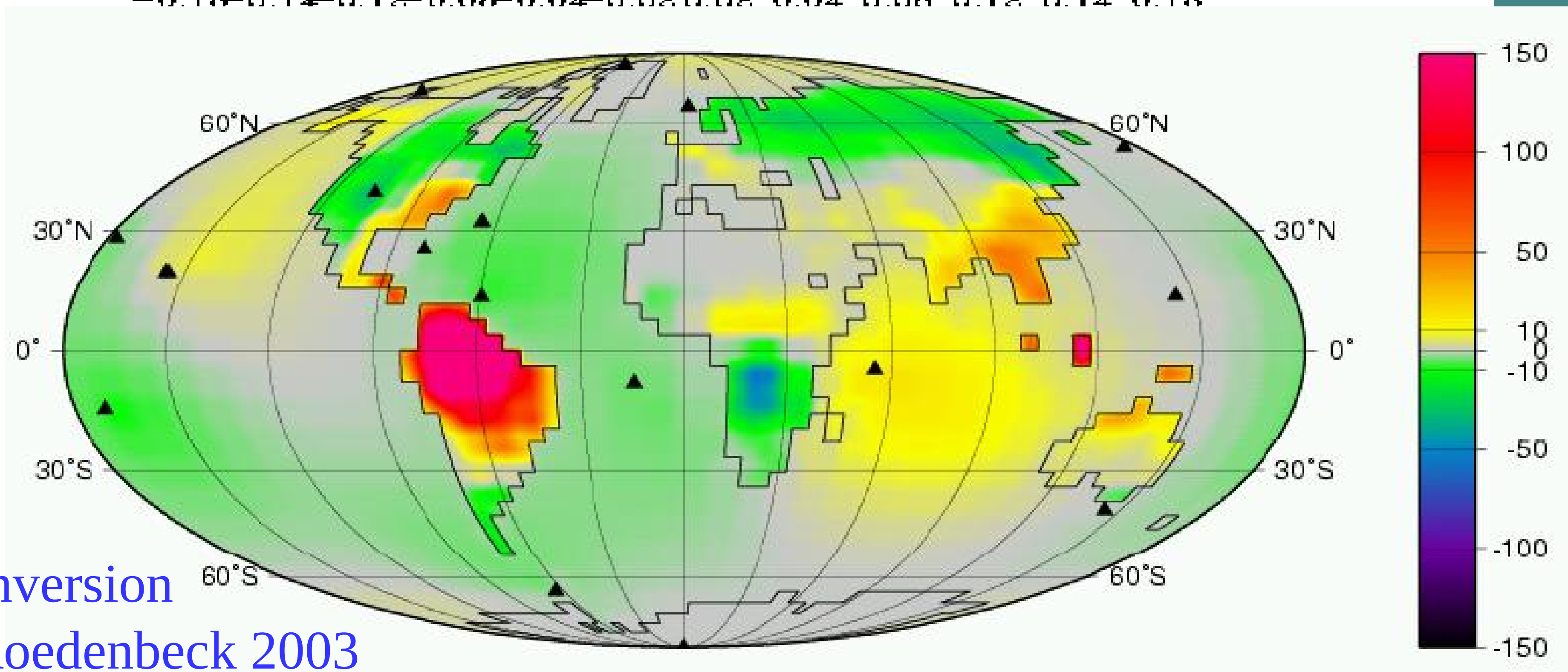
Land contributes to most of the interannual variability, with significant contribution from ocean

Modeling results supported by in-situ data and inversion

El Nino 97/98



VEGAS



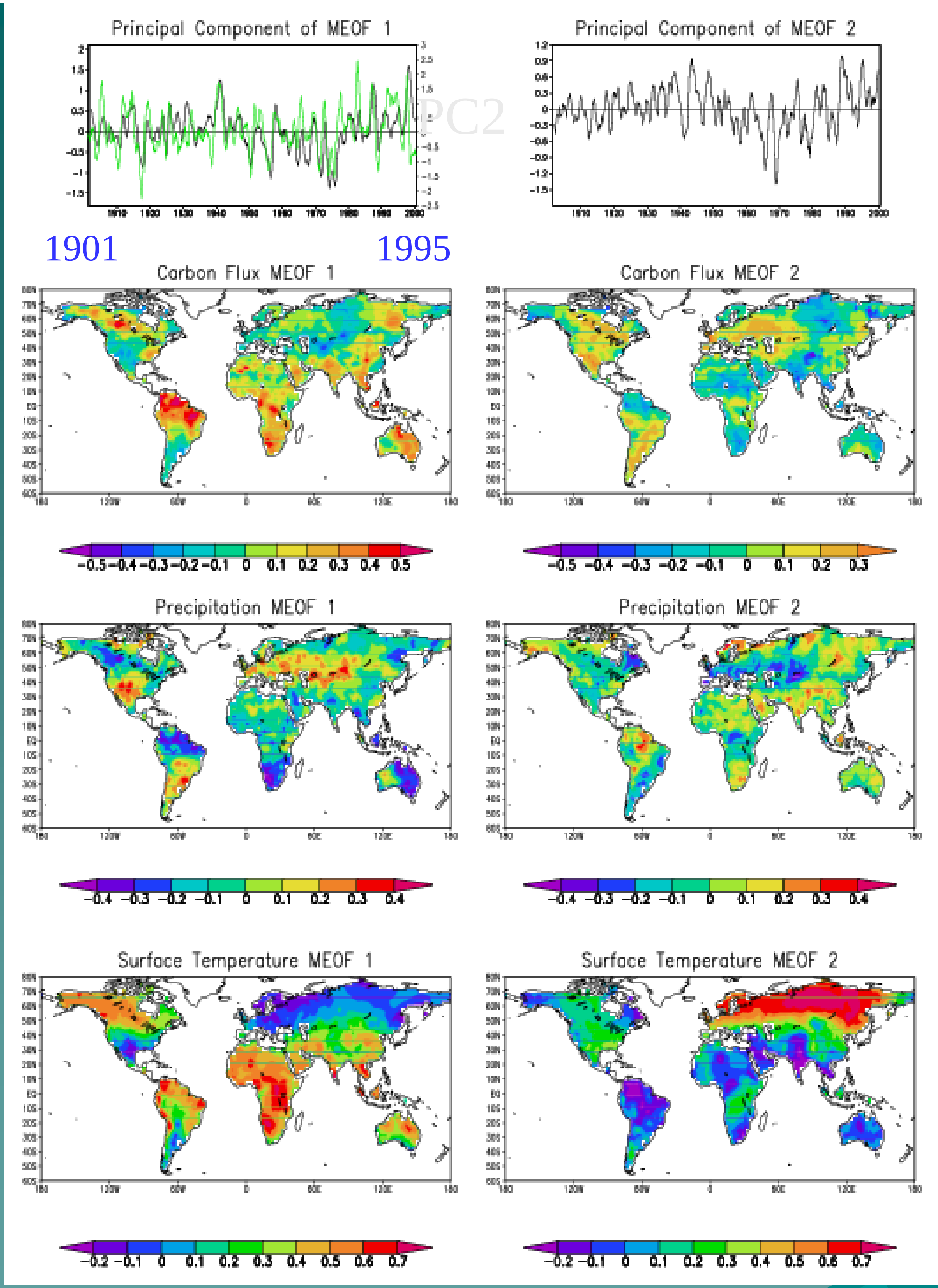
Inversion
Roedenbeck 2003

PC1

C flux

Precip

Temp



Spatial patterns from multi-variate EOF analysis

Tropics during El Nino

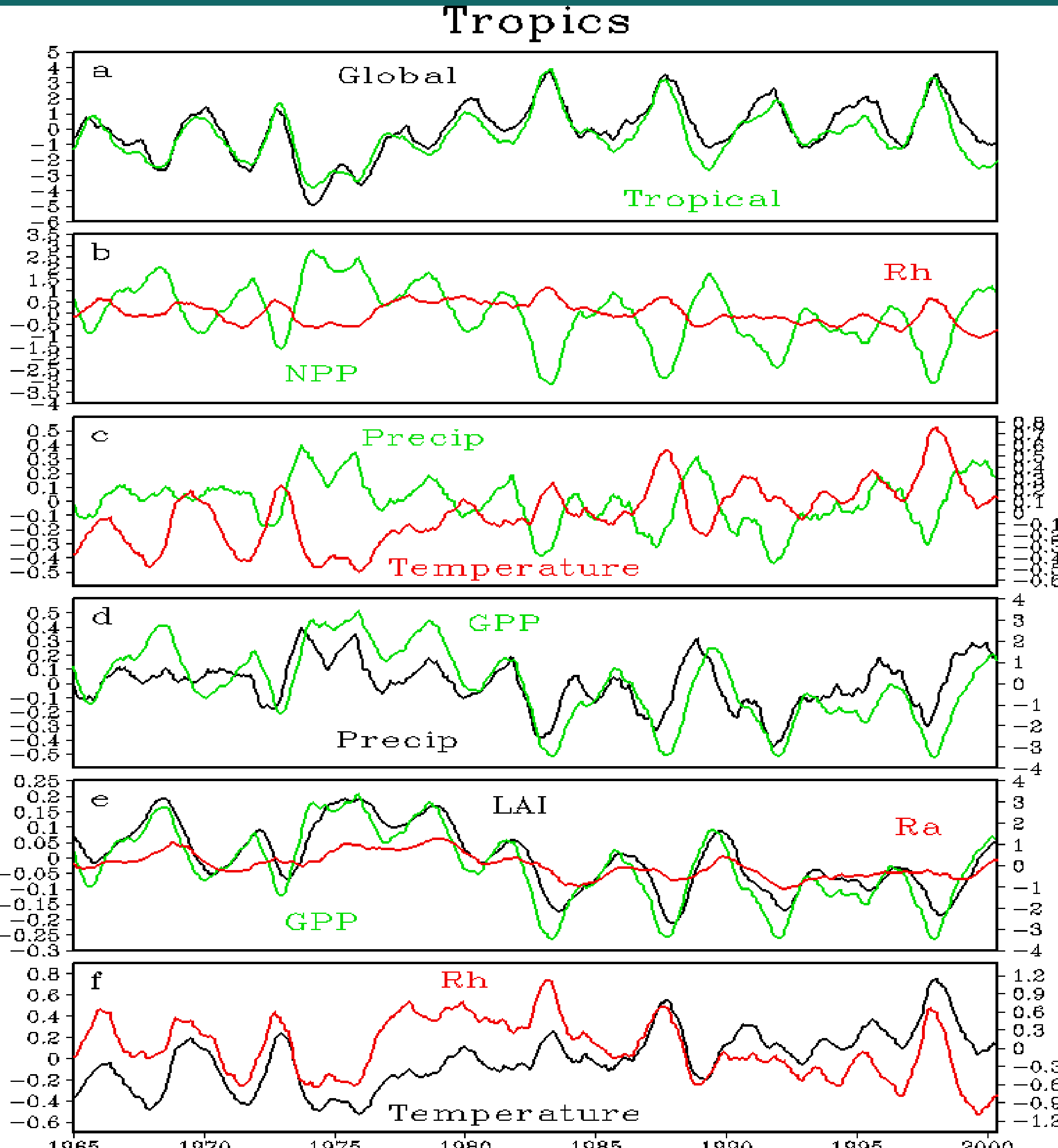
1) Drier and warmer conditions coexist at tropical locations

1+) Drier and warmer across much of tropical land during El Nino

2) Less precip
   => Less growth (lower NPP) and more fire
   => Less C uptake

Higher T
   => more respiration (higher Rh)
   => more C release

Why CO2 correlates so well with ENSO: A ‘conspiracy’ theory



Tropics during El Nino

Precipitation decrease

Temperature increase

Out of phase

NPP decrease

Rh increase

Additive

Land-atmo flux (Rh-NPP) increase

+

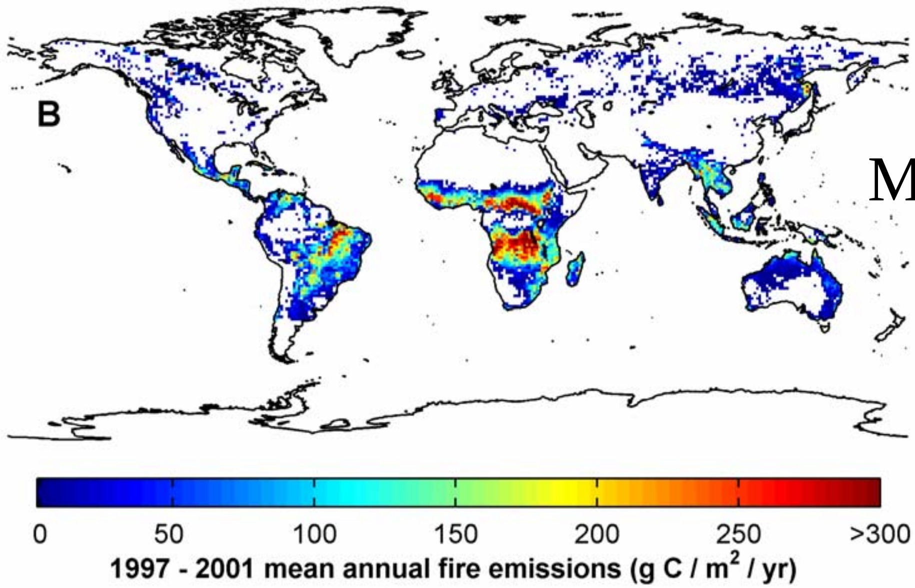
Spatially coherent climate anomalies

Large land-atmo C flux

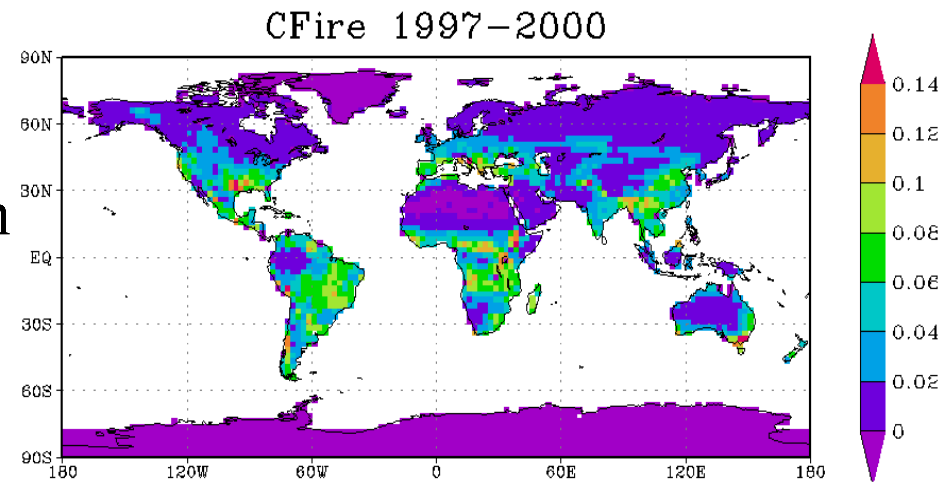
Fire carbon flux during 1997-98 El Nino

CASA

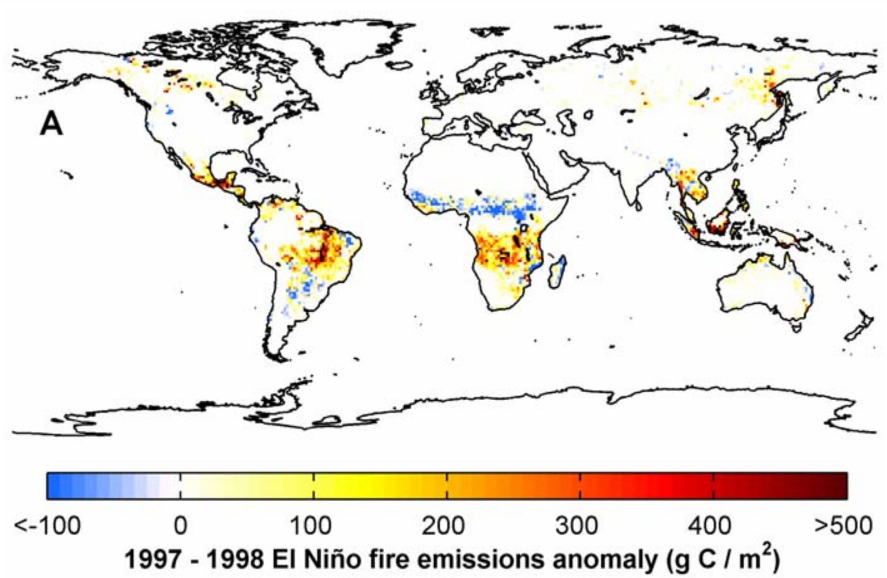
VEGAS

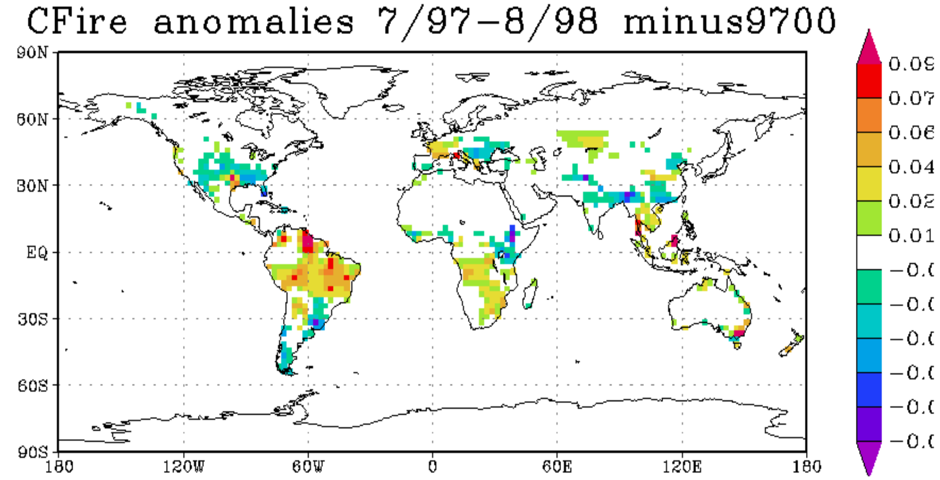


Mean



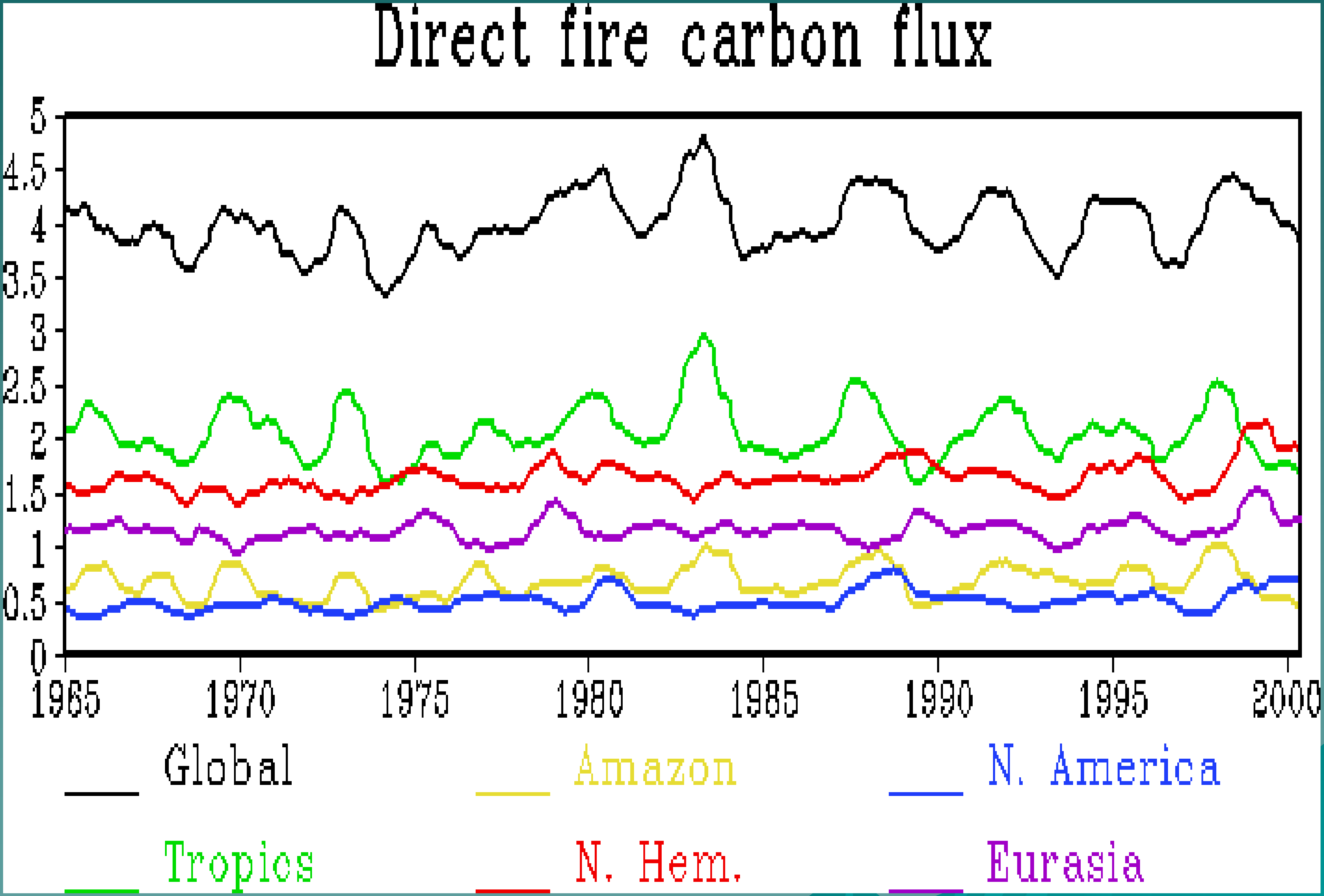
1997-98 El Nino Anomalies



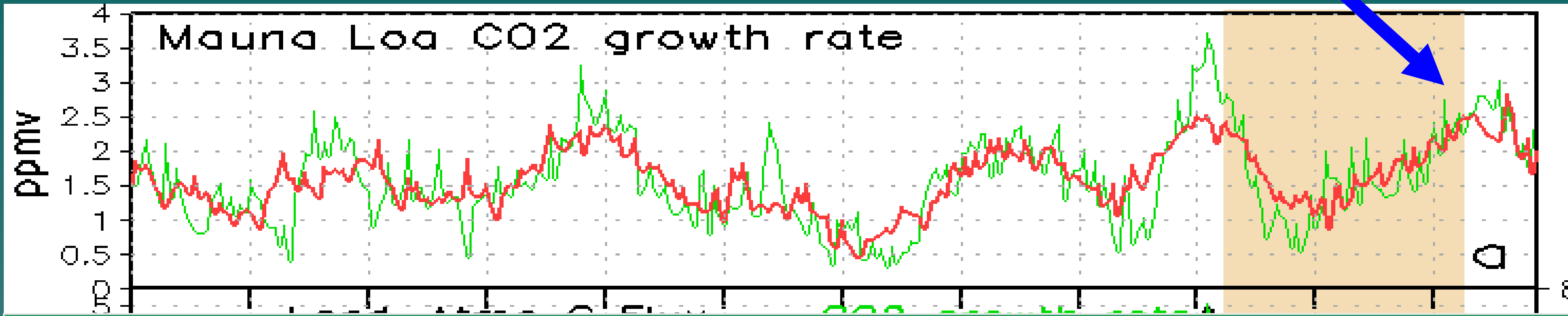


Input: satellite fire counts, climate

Input: climate only


Direct fire carbon flux
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1965
1970
1975
1980
1985
1990
1995
2000
Global
Amazon
N. America
Tropics
N. Hem.
Eurasia

Recent Anomalous growth in CO2

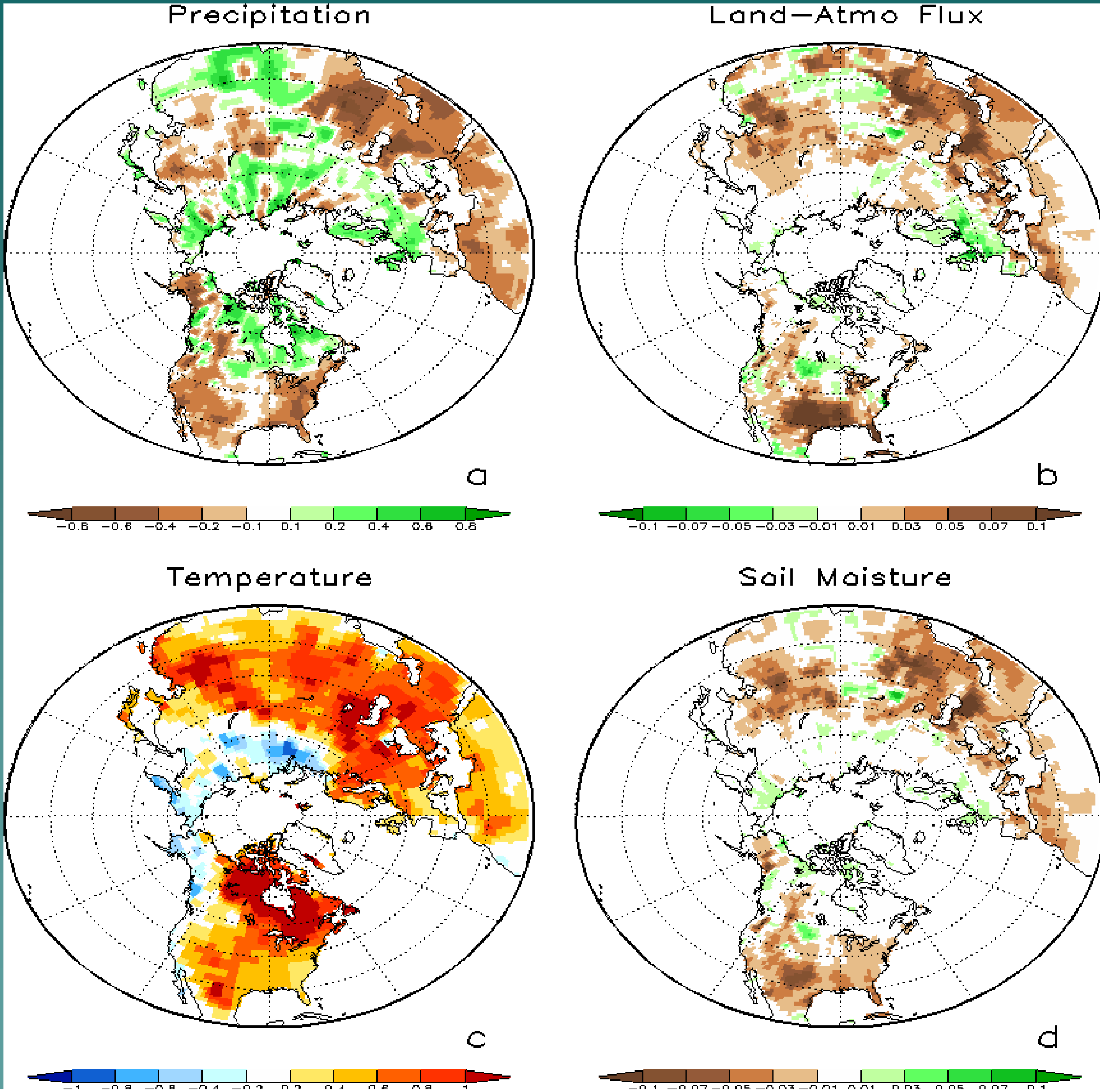


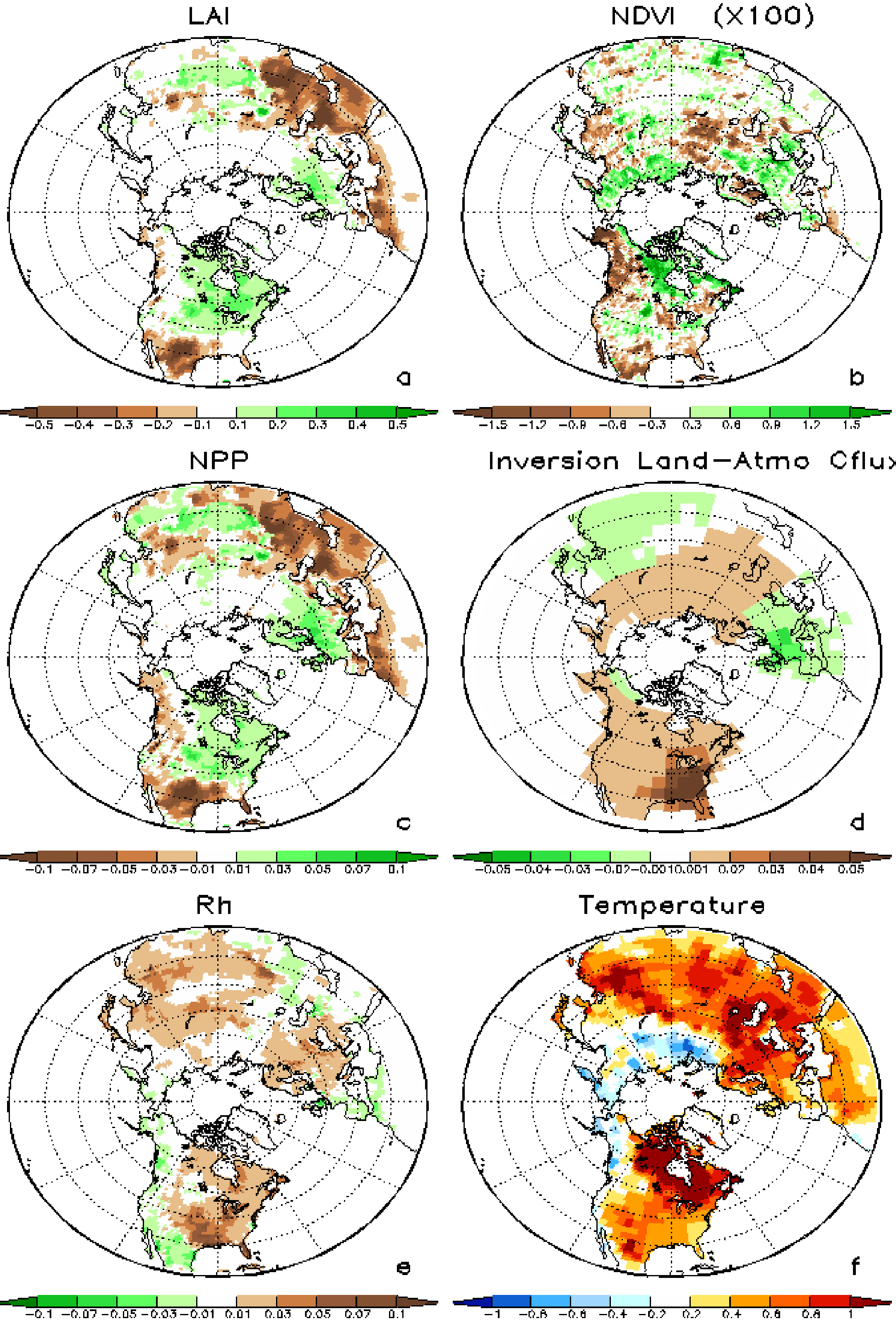
1980 2003

Proposed explanations:

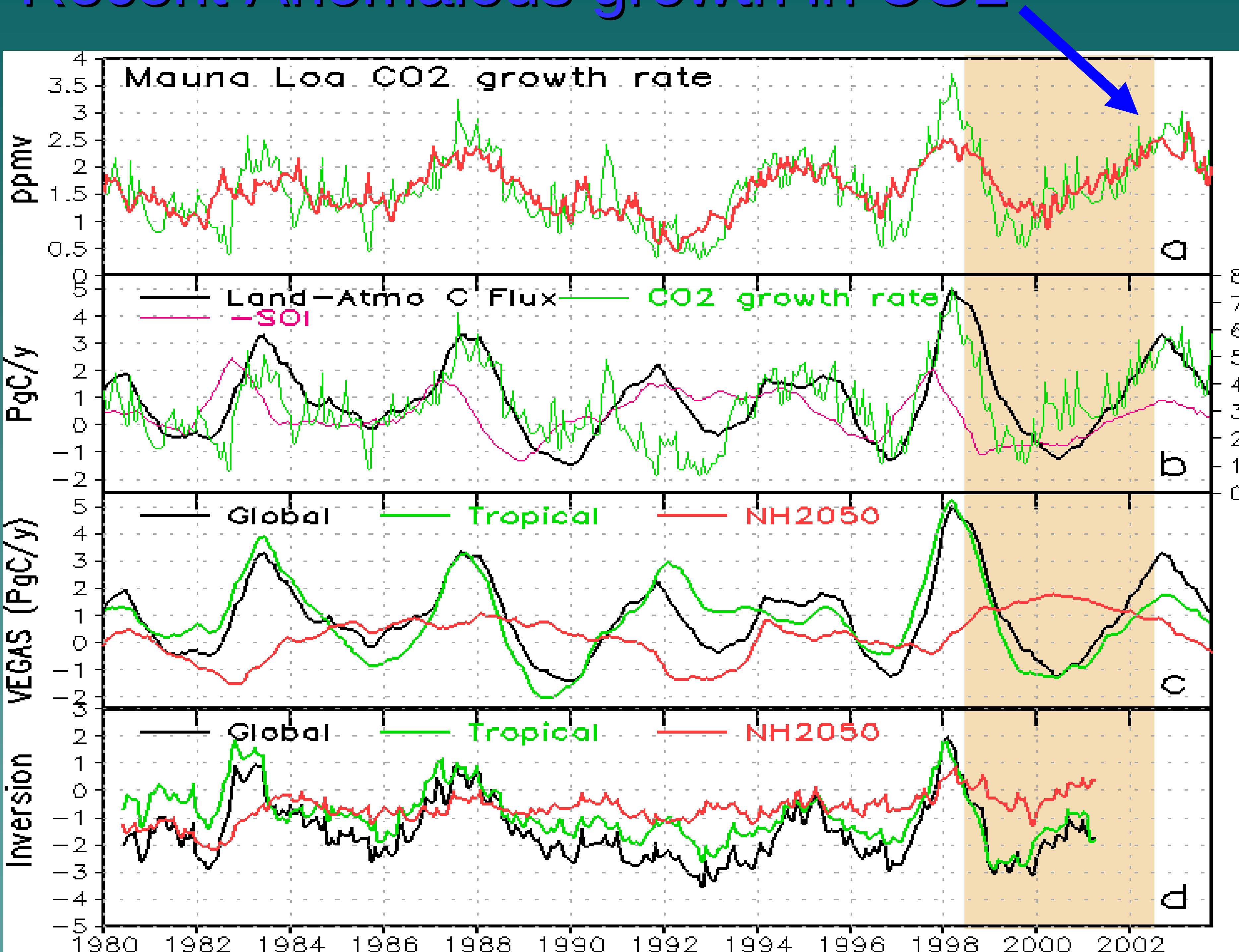
1. Fire in Siberia, North America, and other places
2. Accelerated carbon emission from China, India
3. Mid-latitude drought

Mid-latitude Drought: 1998-2002

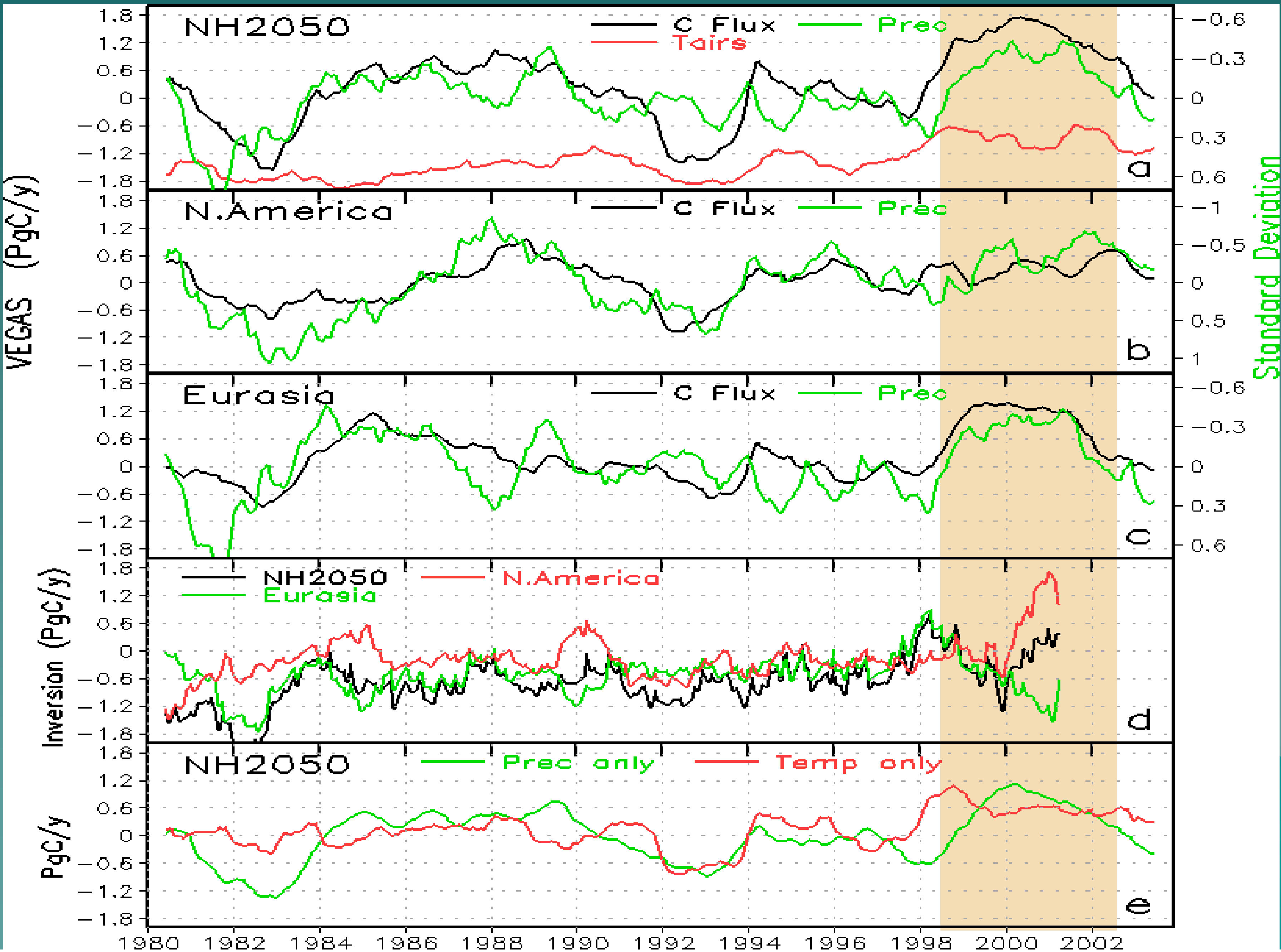



LAI
NDVI (X100)
a
b
−0.5 −0.4 −0.3 −0.2 −0.1 0.1 0.2 0.3 0.4 0.5
−1.5 −1.2 −0.9 −0.6 −0.3 0.3 0.6 0.9 1.2 1.5
NPP
Inversion Land−Atmo Cflux
c
d
−0.1 −0.07 −0.05 −0.03 −0.01 0.01 0.03 0.05 0.07 0.1
−0.05 −0.04 −0.03 −0.02 −0.001 0.001 0.02 0.03 0.04 0.05
Rh
Temperature
e
f
−0.1 −0.07 −0.05 −0.03 −0.01 0.01 0.03 0.05 0.07 0.1
−1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8 1

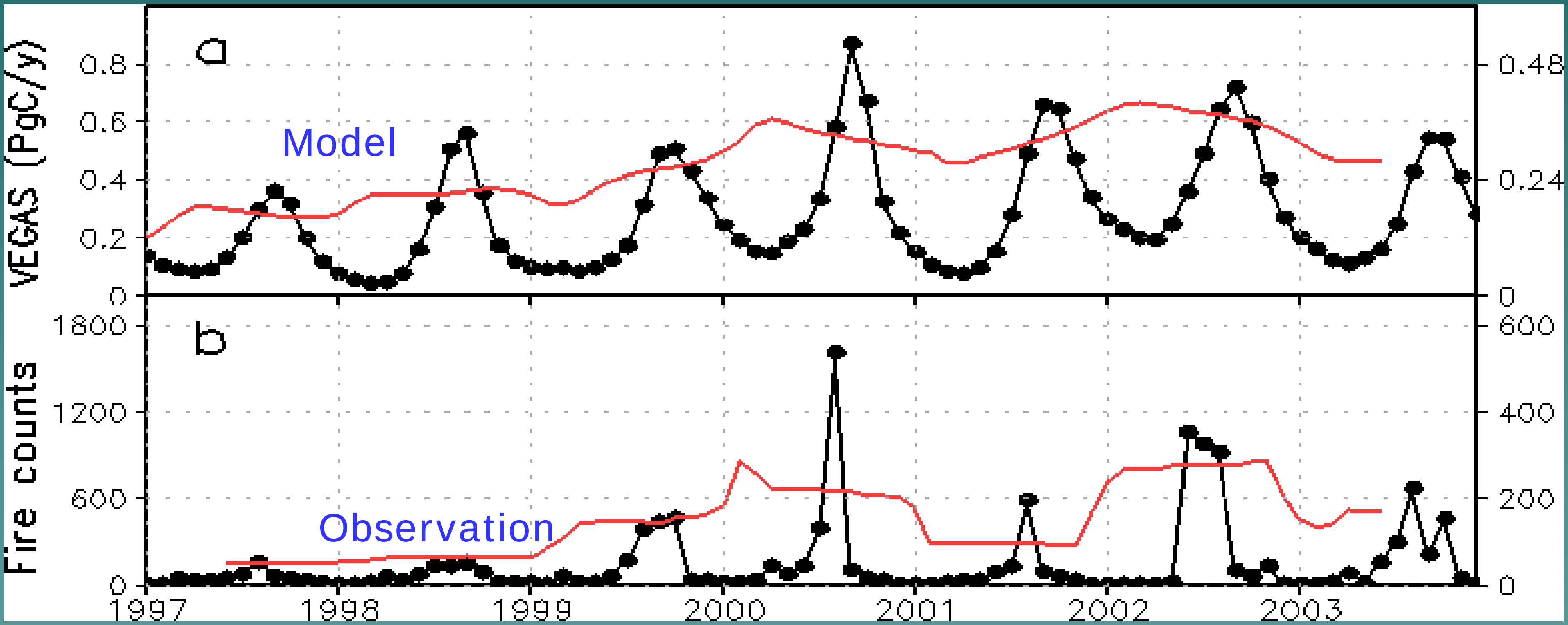
Recent Anomalous growth in CO2



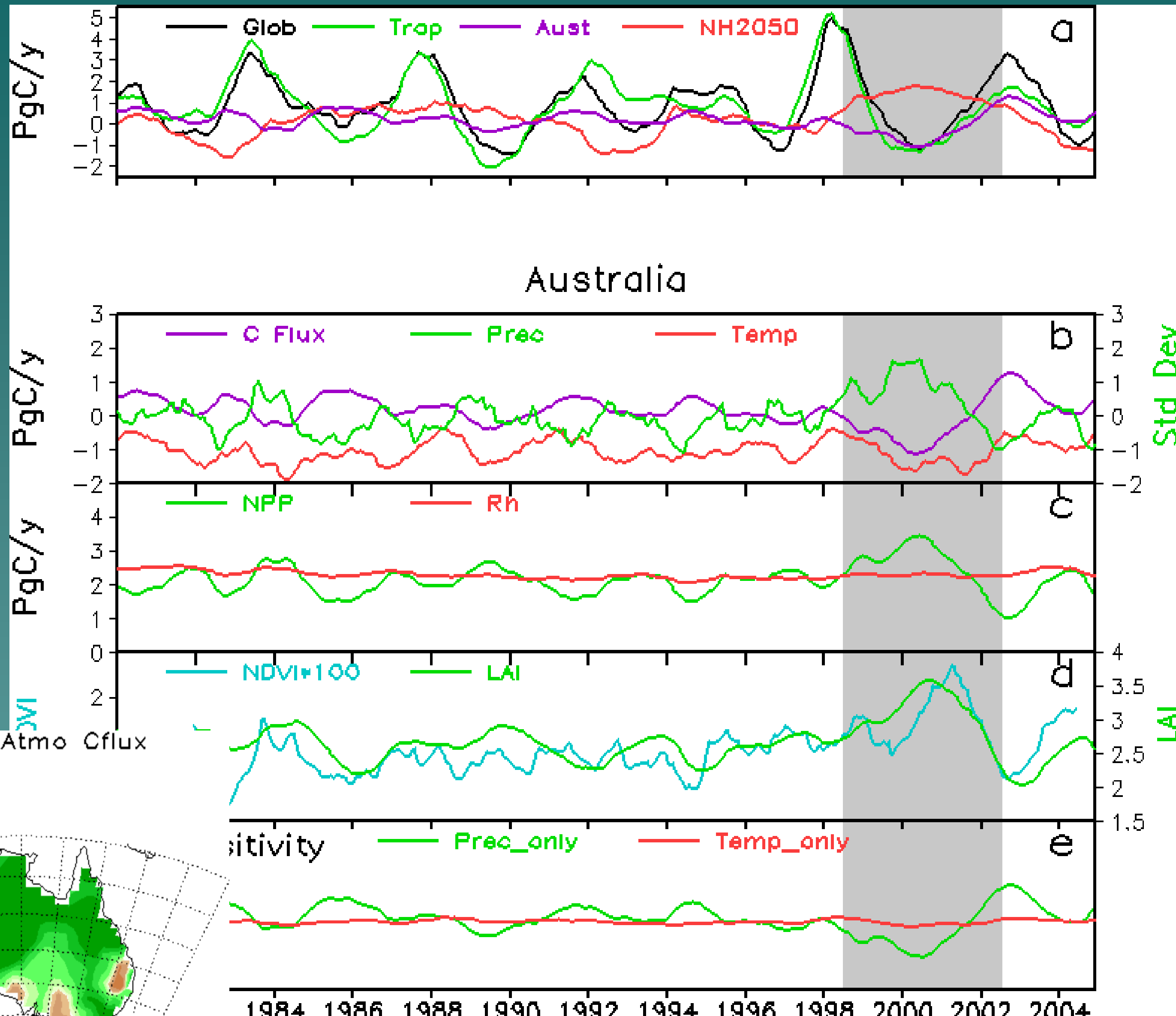
Drying or Warming?

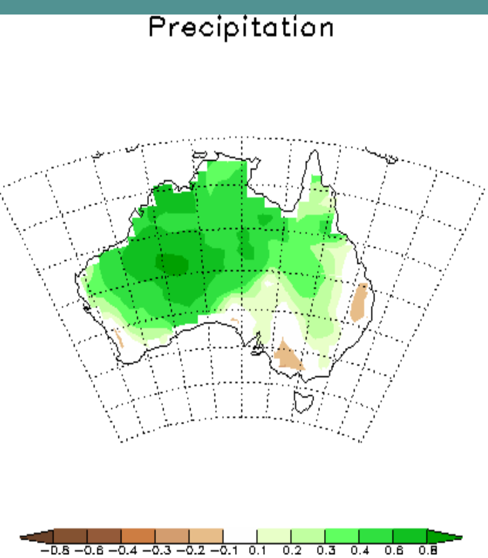


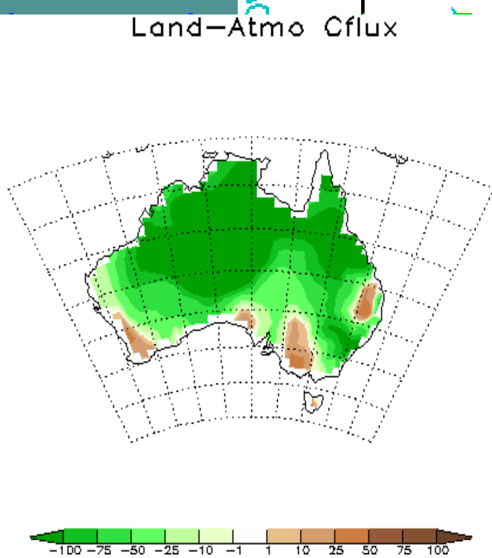
Fire in the US:
Natural vs anthropogenic factors



What happened in Australia 1998-2002 ?







Conclusions

- Drought is the major source of CO_2 variability, whether it's tropical (ENSO) or midlatitude.
- The high correlation between CO_2 and ENSO is mainly due to a 'conspiracy' between climate anomalies and plant/soil physiology.
  - This conspiracy makes it difficult to narrow down the relative roles of NPP, Rh, and fire based on observations alone, yet models do not agree.
- Recent anomalously large CO_2 growth can be explained by a (so far) unusual midlatitude drought, a possible glimpse into a warmer world
- Understanding the mechanisms and processes underlying such interactions provides crucial insight into the fate of anthropogenic CO_2 and the degree of future climate change