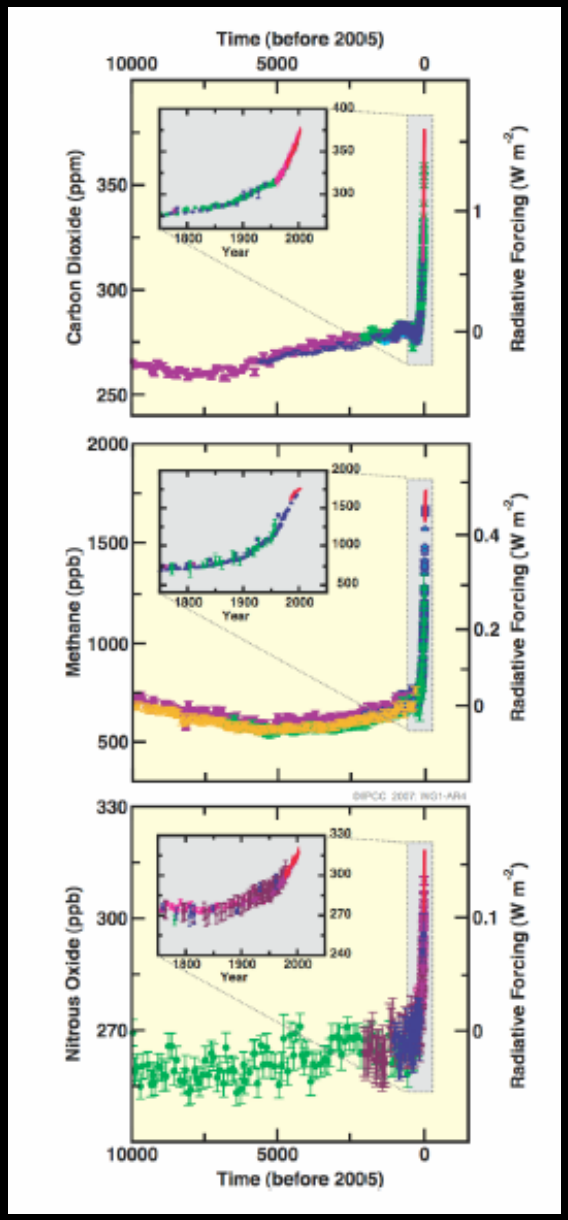
Questions:

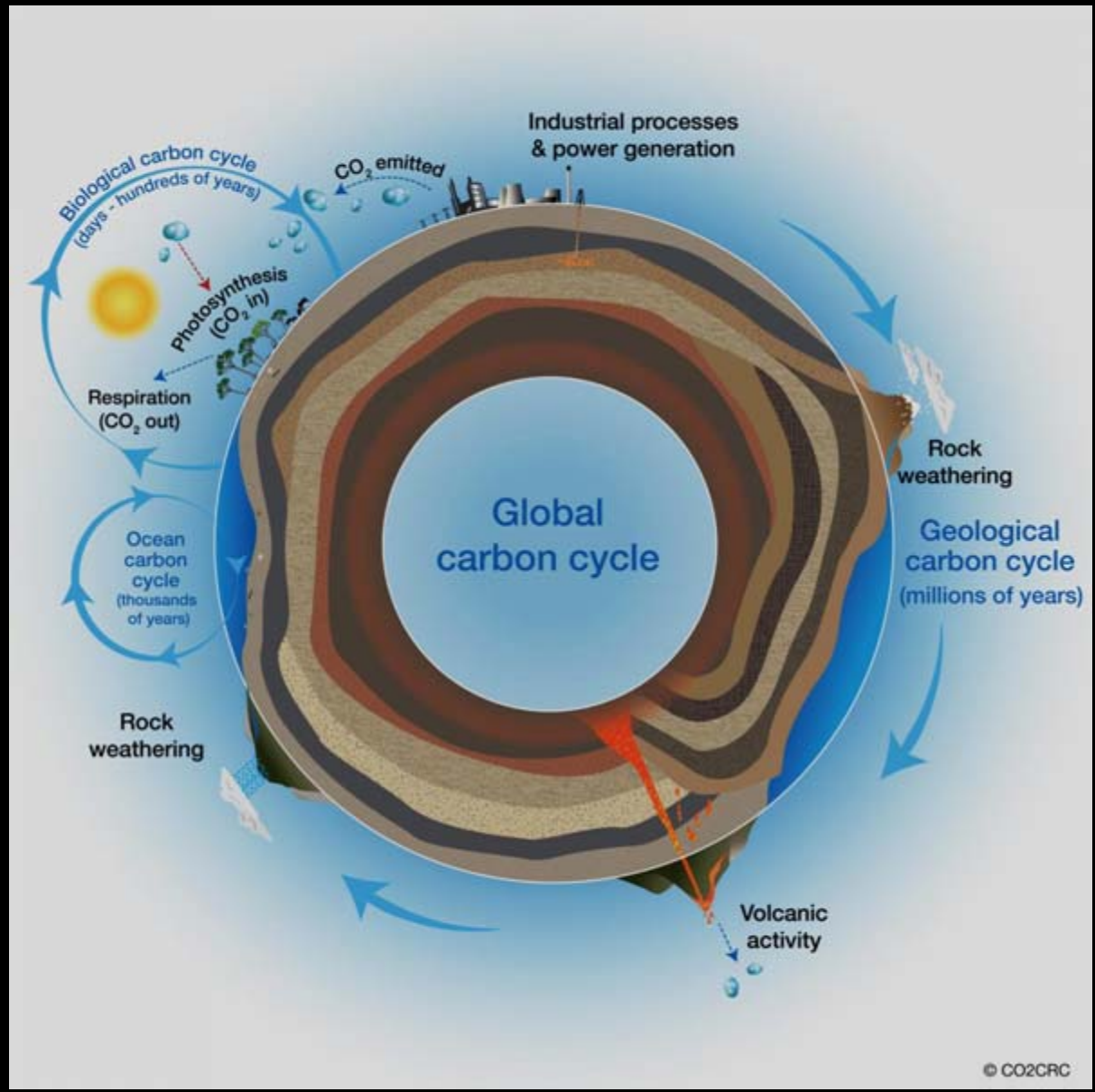
- What are the natural processes regulating the increase of CO_2 during the fossil-fuel era ?

- What do the observations tell us about these processes ?

- What are the coupling mechanisms between climate and terrestrial carbon fluxes ?

Fossil-fuel Era: Natural Processes Regulating the Increase of CO_2

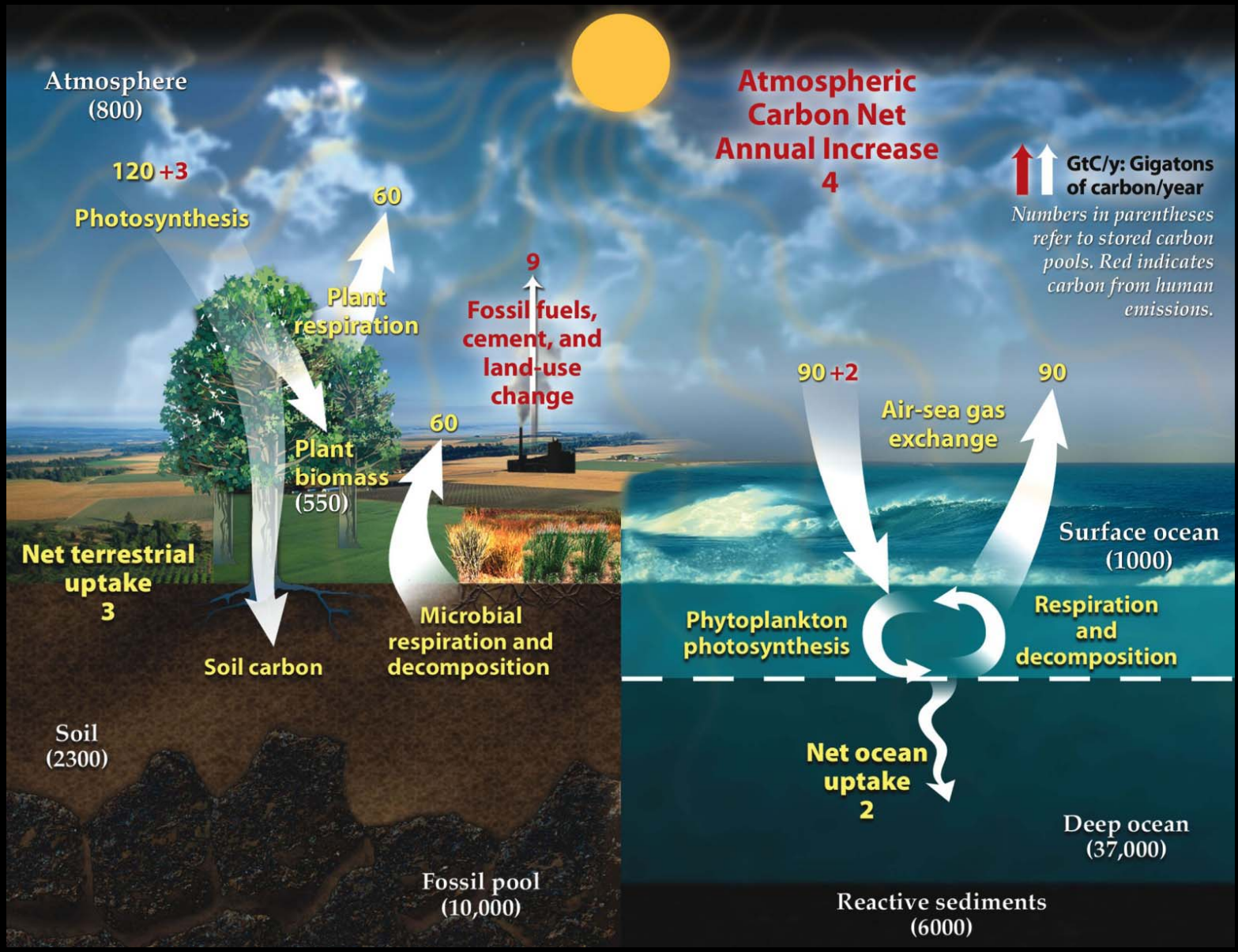




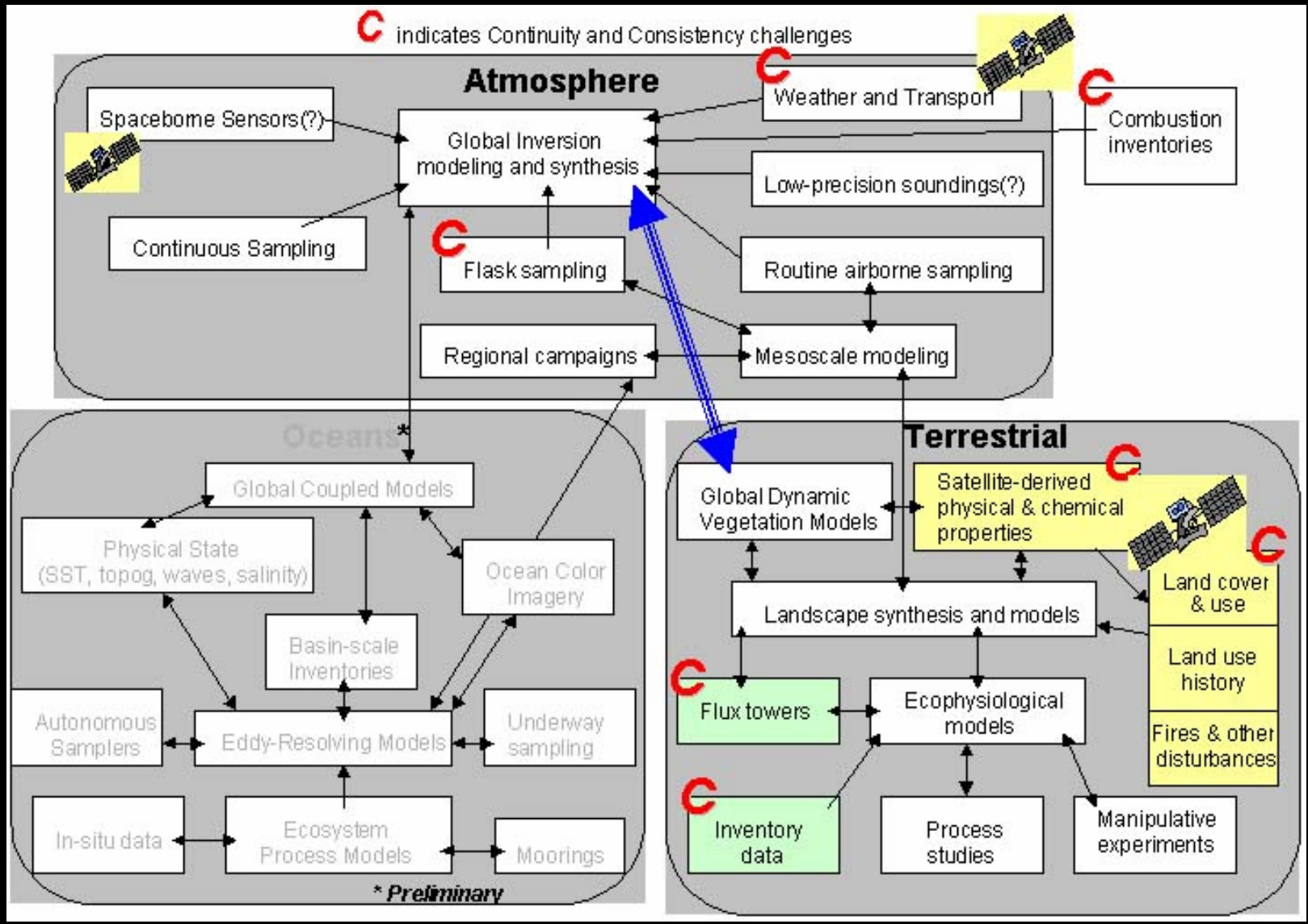
Fossil-fuel Era: Natural Processes Regulating the Increase of CO_2

	Negative feedbacks	Positive feedbacks
Ocean	• Marine ecosystem (phytoplankton) • Ocean uptake • Exchange of surface-deep sea water • Carbonate and silicate sedimentation	• Acidification • Warming induced die off, decay and CO_2 emission
Land	• CO_2 Fertilization of terrestrial vegetation and N deposition • Soil respiration decrease • Albedo change (land use change, warming induced drought)	• Land use change induced carbon emission • Warming induced soil carbon storage • Drought (as warming) induced vegetation decline
Atmosphere	• CO_2 concentration?	

Fossil-fuel Era: Natural Processes Regulating the Increase of CO_2



What Do the Observations Tell Us About These Processes



http://www.fao.org/docrep/005/AC667E/ac667e04.htm

What Do the Observations Tell Us About These Processes

Ocean CO_2 flux

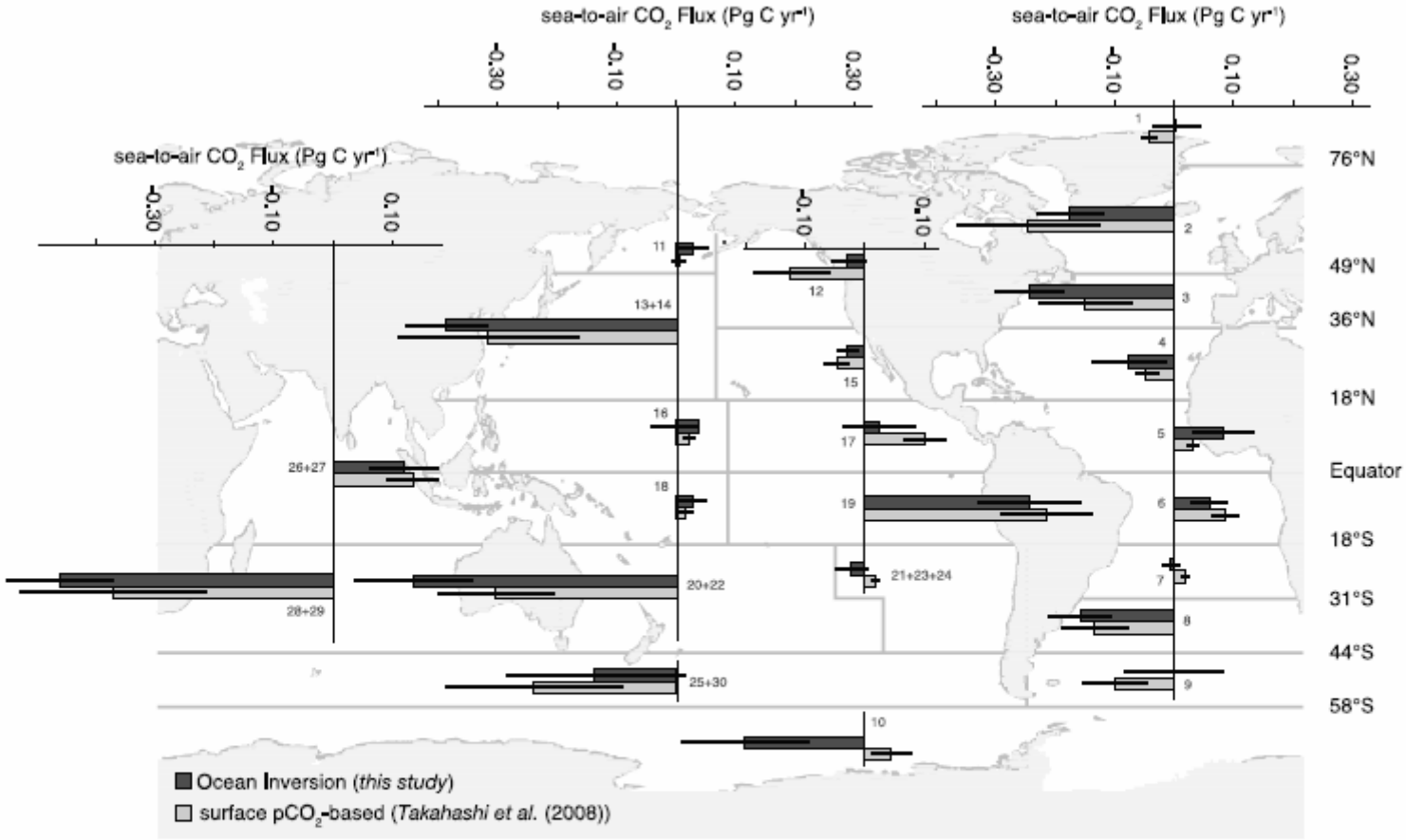


Figure 2. Comparison of the ocean inversion estimate of the contemporary sea-to-air CO_2 flux with that based on the pCO_2 climatology of *Takahashi et al.* [2008] for each of the 23 regions resolved by the ocean inversion. The zero-line crossing of each flux estimate indicates the region that this flux belongs to. Small gray numbers indicate the region number (see Table S1 for the region name). Positive fluxes indicate outgassing.

(Gruber *et al.*, 2009)

What Do the Observations Tell Us About These Processes

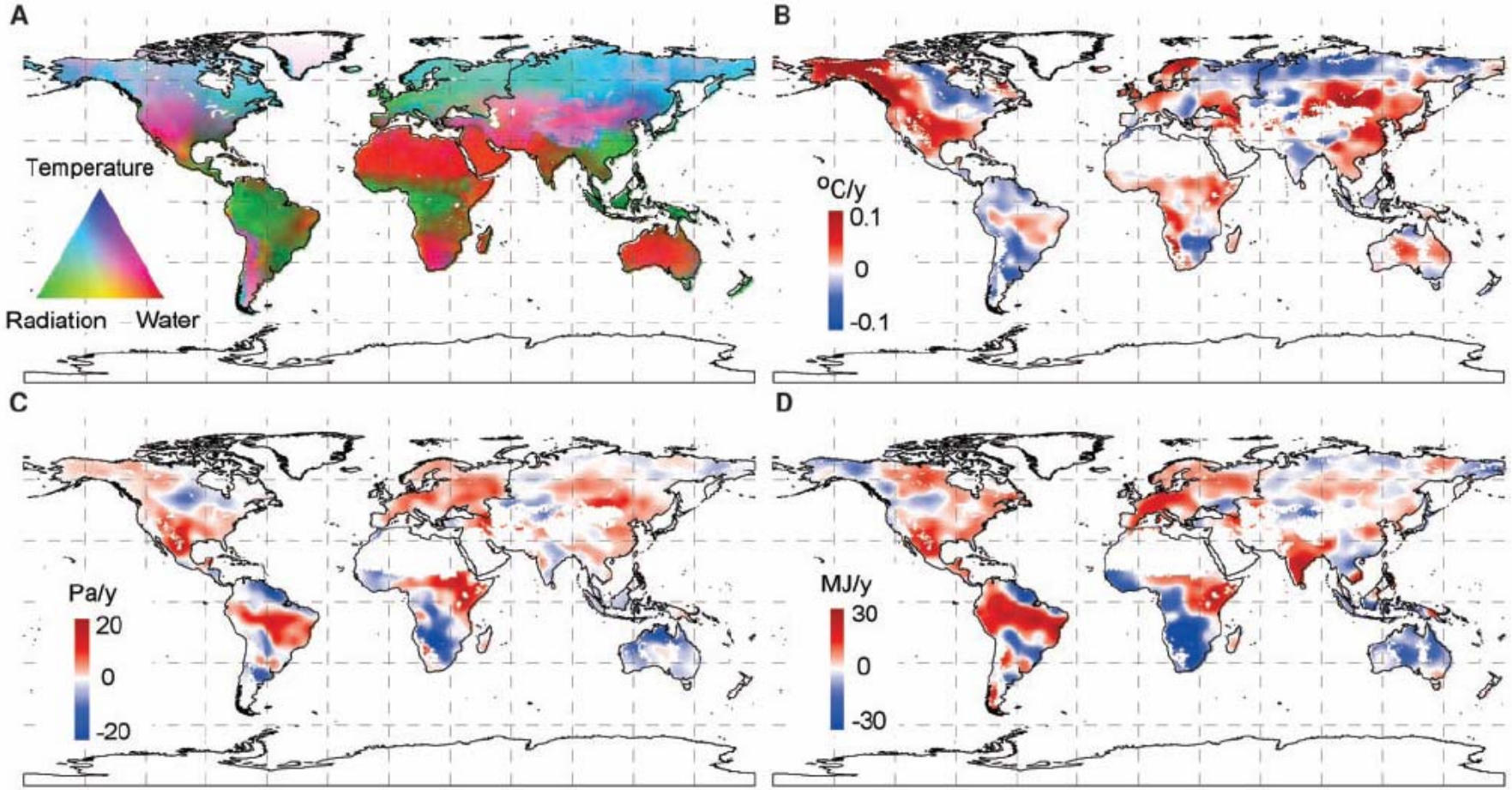
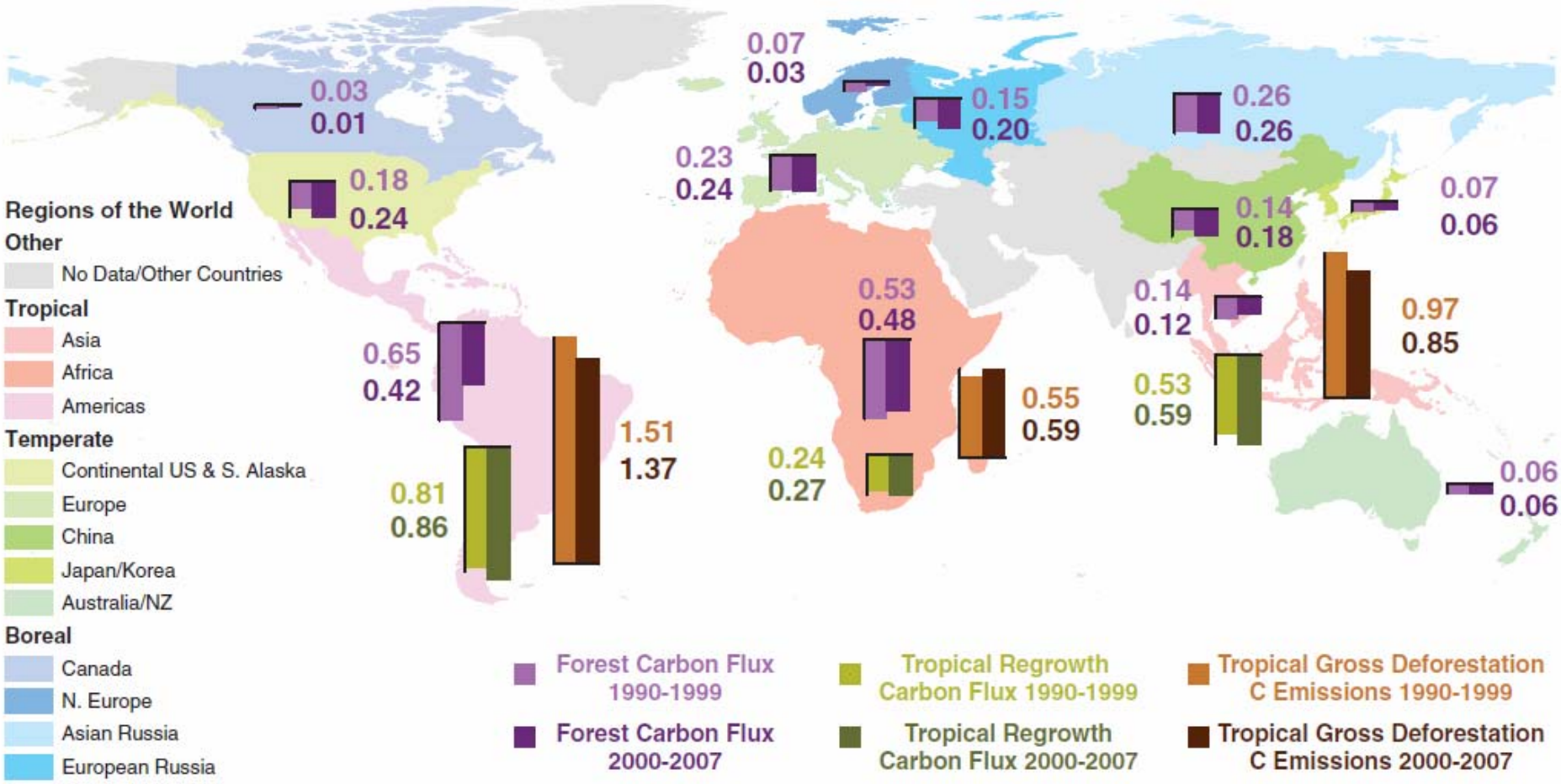


Fig. 1. (A) Geographic distribution of potential climatic constraints to plant growth derived from long-term climate statistics. (B to D) Recent climatic changes, estimated from reanalysis data from 1982 to 1999, in the growing season average temperature (B), vapor pressure deficit (VPD) (C), and solar radiation (D). Reductions in VPD are indicative of increased water availability (C). The growing season is defined as those months with 1982 to 1999 average air temperatures above 0°C.

What Do the Observations Tell Us About These Processes

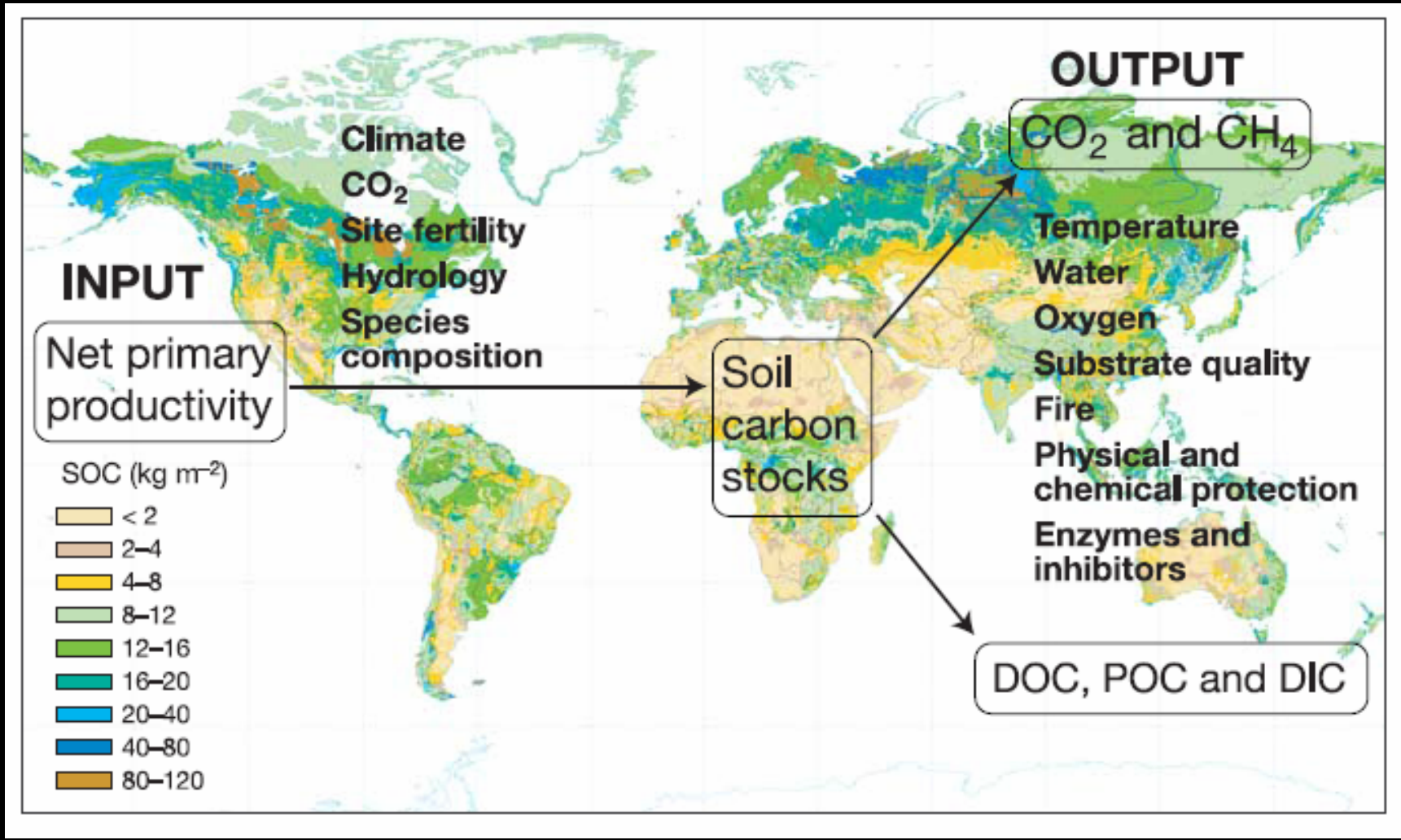
Carbon sinks and sources (Pg C /year) in the world's forests.



(Pan et al., 2011)

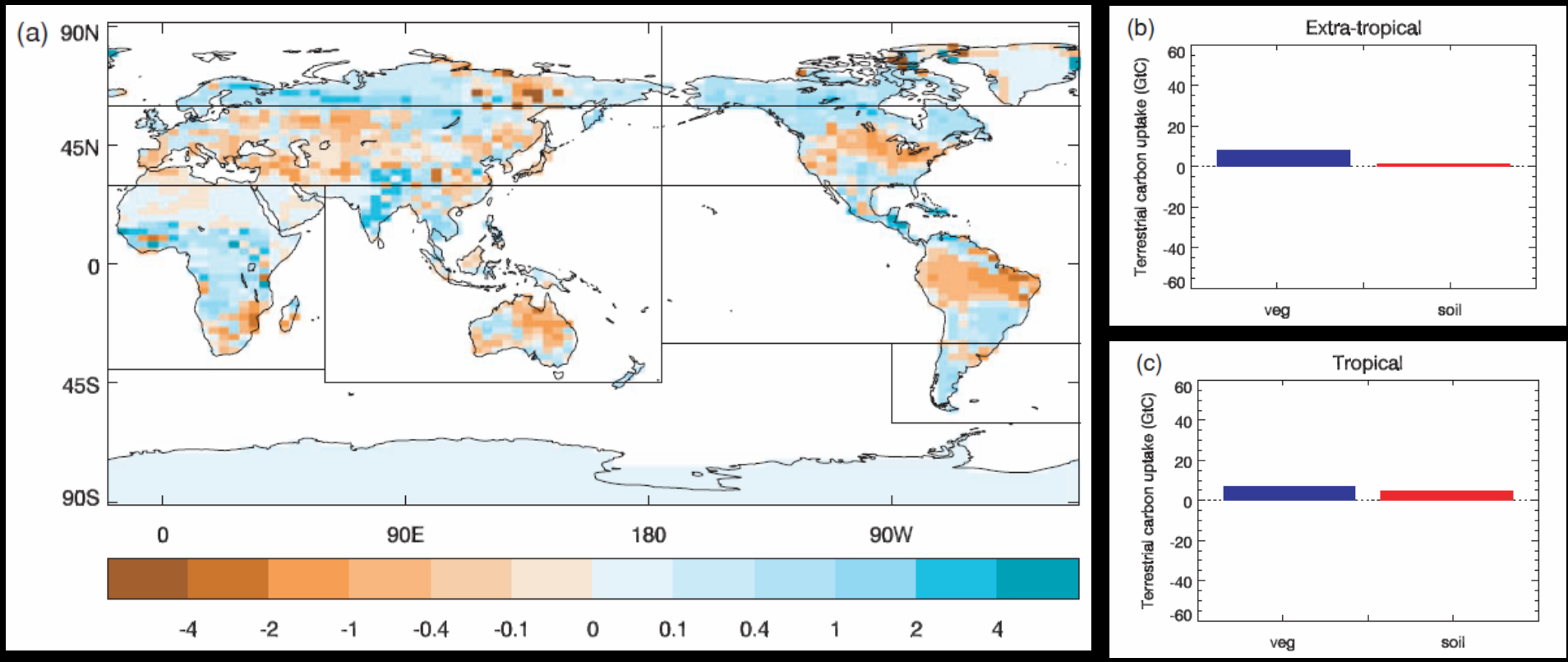
What Do the Observations Tell Us About These Processes

Soil carbon stocks



(Davidson et al., 2006)

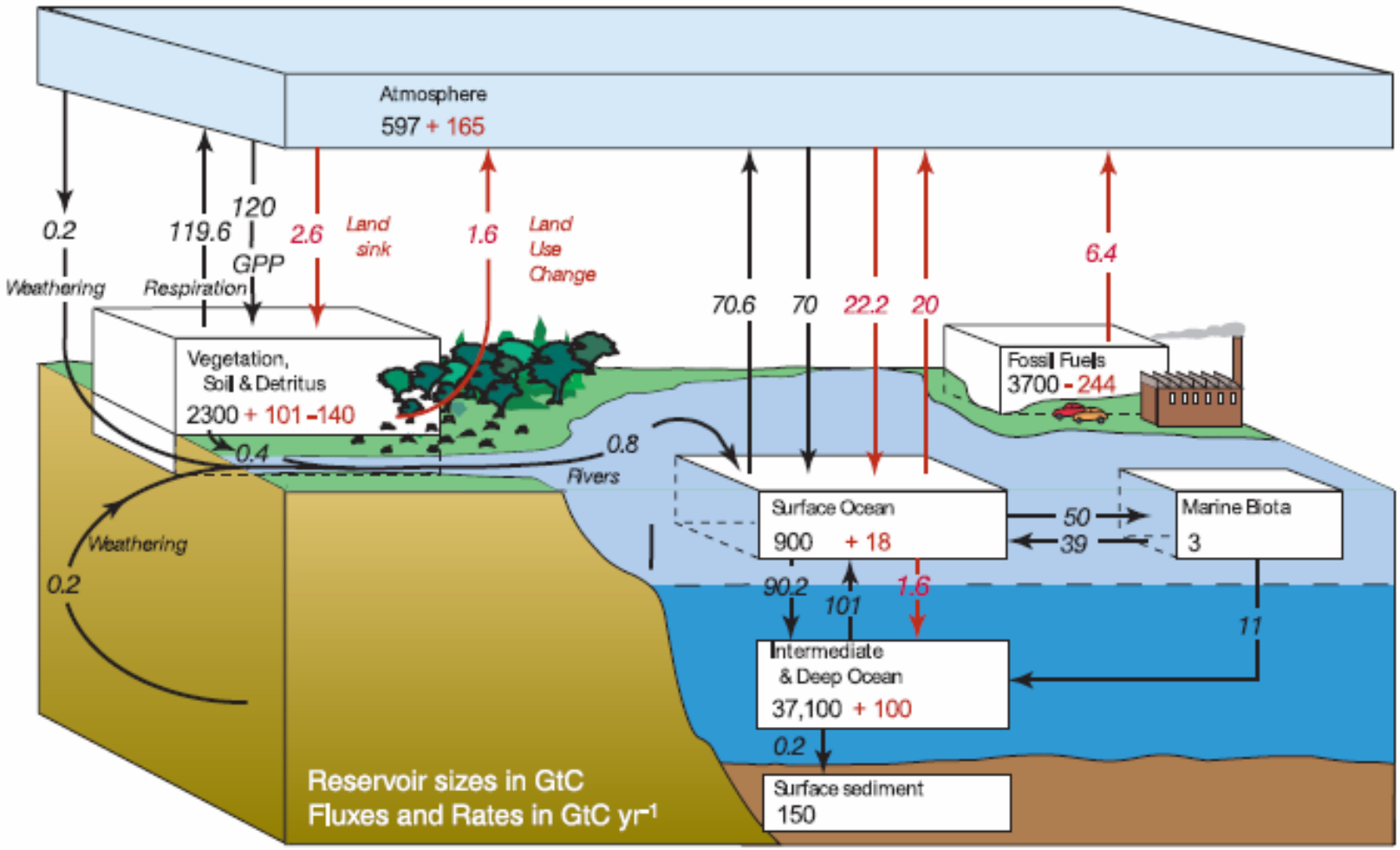
What Do the Observations Tell Us About These Processes



Terrestrial carbon uptake in 100 yr following emissions reductions in 2012.

(Jones et al., 2010)

What Do the Observations Tell Us About These Processes



IPCC， 2007

Climate and Terrestrial Carbon Fluxes Coupling Mechanisms

- Climate: heat or cold, wetness or dryness, calm or storm, clearness or cloudiness
  - Rising temperature
  - Precipitation pattern change
  - Radiation and cloudiness pattern change
  - Seasonality change?
  - Extreme climate events?
- Terrestrial Carbon Fluxes → Terrestrial carbon storage
  - Vegetation
    - in short time scale: photosynthesis –respiration–growth:
      - CO2 fertilization, N deposition, WUE, biomass distribution, growing season length
    - Long time scale: biome composition change
  - Soil and detritus carbon storage
    - soil respiration: Q 10
    - peatlands, wetlands and permafrost
  - Ice sheet, etc.

Climate and Terrestrial Carbon Fluxes Coupling Mechanisms

If temperature rise

Carbon uptake increase

Output increase

Vegetation

- photosynthesis vs. respiration → growth increase
- Longer growing season
- NPP increase

- Drought (as warming) induced vegetation decline
- Warming induced die off, decay and CO2 emission

Albedo ?

Soil

- Larger litter input

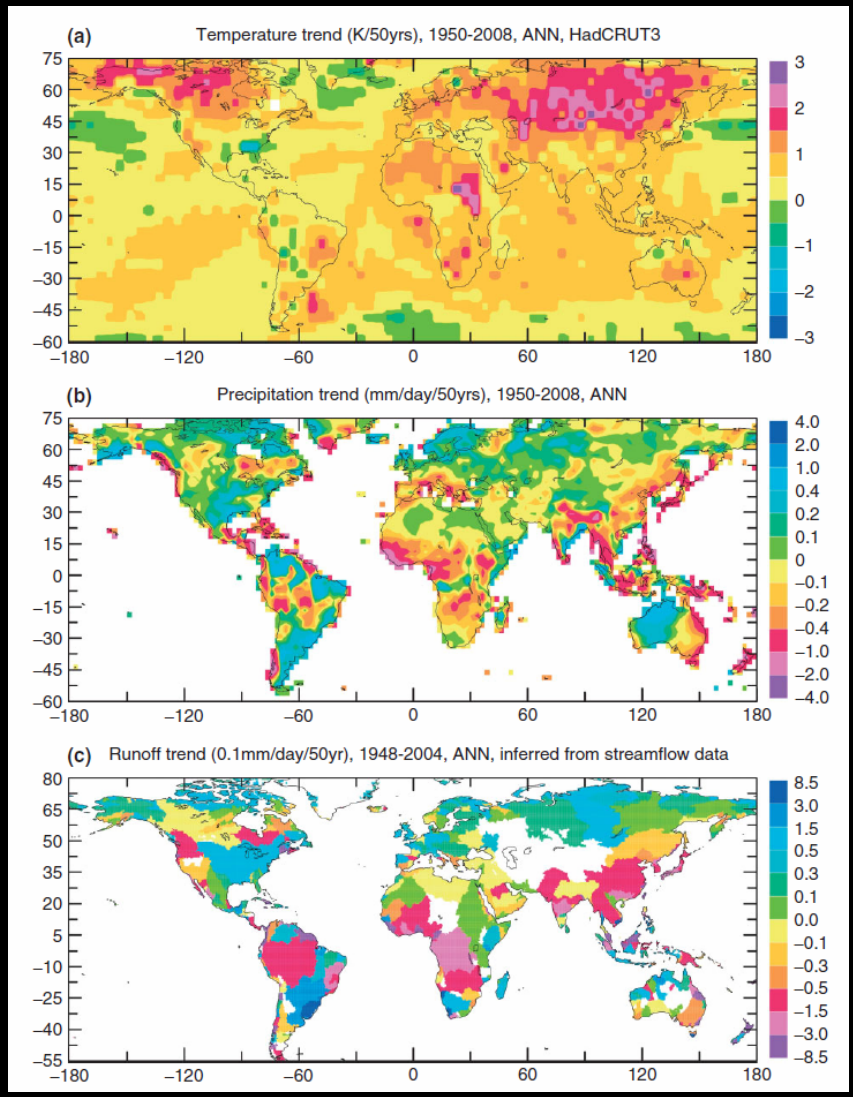
- Higher respiration and decomposition rate
- Peatlands and permafrost carbon loss; wetlands carbon loss under warming induced drought

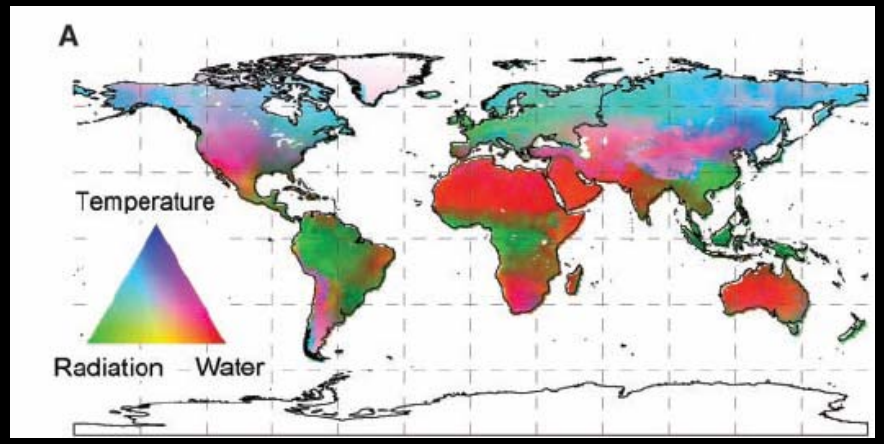
Ice sheet

- Higher CO2 uptake for high altitude

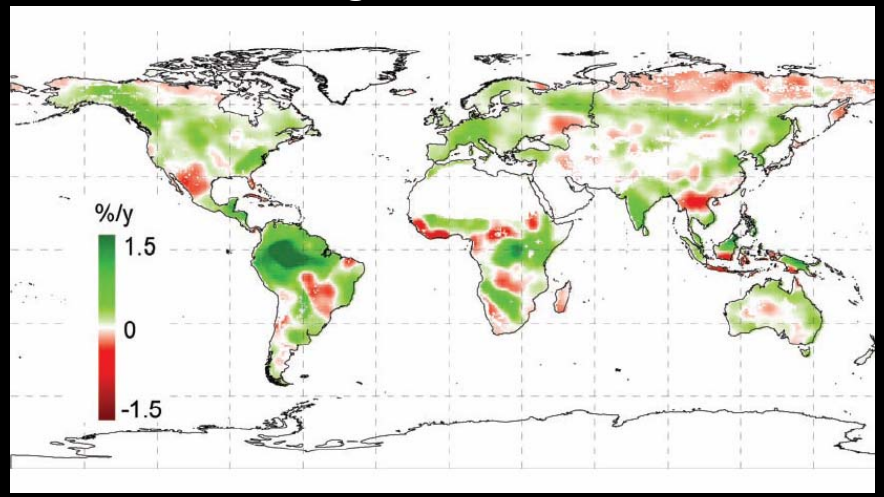
- Ice melt--CO_2 emission
- Albedo decrease

Climate and Terrestrial Carbon Fluxes Coupling Mechanisms





potential climatic constraints to plant growth derived from long-term climate statistics



NPP trend from 1982-1999 (Nemani et al.,2003)

Climate and Terrestrial Carbon Fluxes Coupling Mechanisms

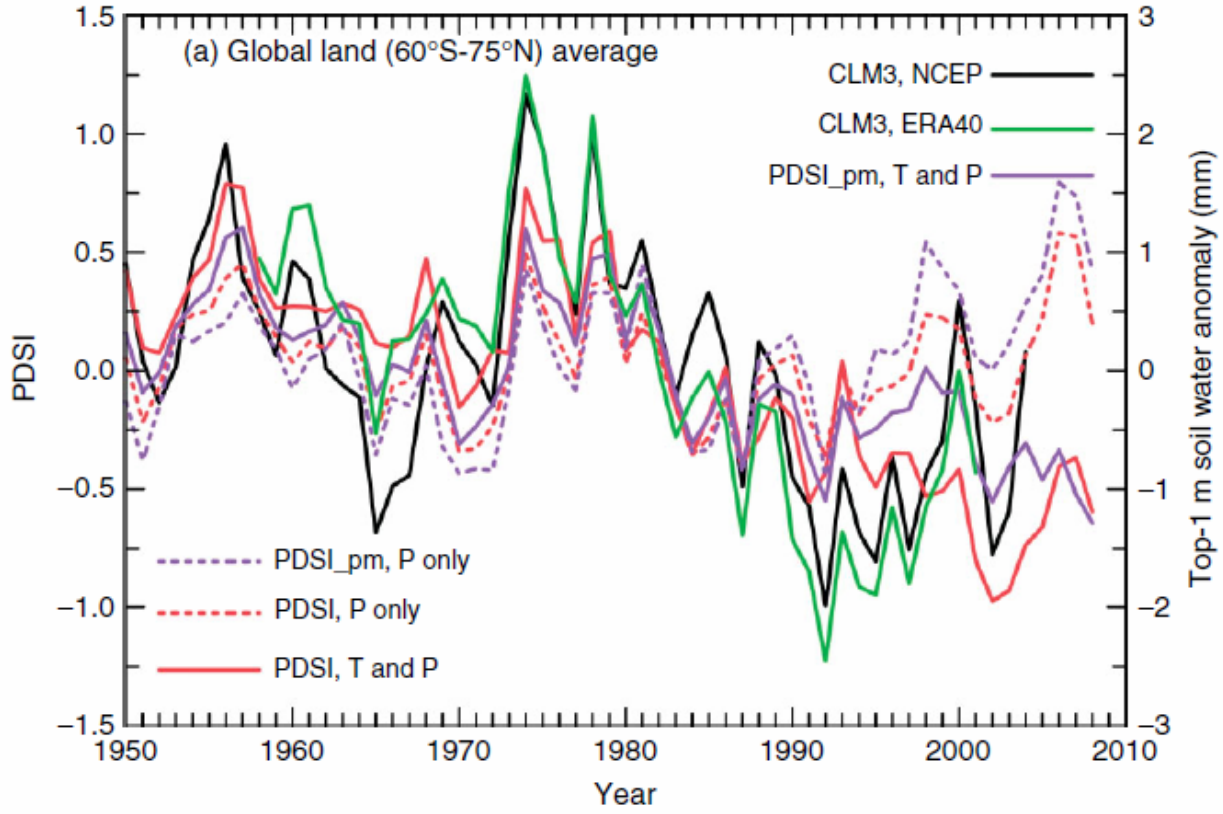


FIGURE 8 | Global land (60°S–75°N) averaged annual time series of top 1 m soil moisture anomaly (mm) simulated by a land surface model (CLM3) forced with observation-based estimates of monthly temperature, precipitation, and solar radiation with intra-monthly variations from the NCEP-NCAR (black) and ERA-40 (green) reanalysis (see Ref 29 for details), compared with the similarly averaged PDSI time series computed with both observed temperature and precipitation (red solid line for PDSI with Thornthwaite PE and magenta for PDSI with Penman-Monteith PE) and precipitation only (i.e., no temperature changes, dashed lines). Results for averages over 40°S–40°N land areas are very similar. The SC-PDSI_pm is similar to the PDSI_pm.