



Satellite observations of global and regional energy budgets

Bing Lin¹, P. Stackhouse¹, N. Loeb¹,
C.A. Schlosser², M. Rodell³, T.F. Fan⁴

¹NASA Langley Research Center, Hampton, VA

²Massachusetts Institute of Technology, Cambridge, MA

³NASA Goddard Space Flight Center, Greenbelt, MD

⁴SSAI, Hampton, VA

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Outline



- **Introduction: EC for climate studies**
 - climate heat balance
 - interact with water cycle
 - historical results: blended data
- **Energy balance of the atmosphere**
 - uncertainties in current sat. data sets
 - land surface fluxes
 - global and regional annual means
 - decadal variations
- **Summary**



Introduction



- Energy balance: fundamental physical process of the climate system.
- Entwined with water cycles.
- Reanalyses: potentially large errors, mass corrections needed;
obtain: heat transports, global/large scale balances, interannual variability
- Observations: radiation, oceanic turbulent heat fluxes, rain latent heat
lack: turbulent fluxes over land

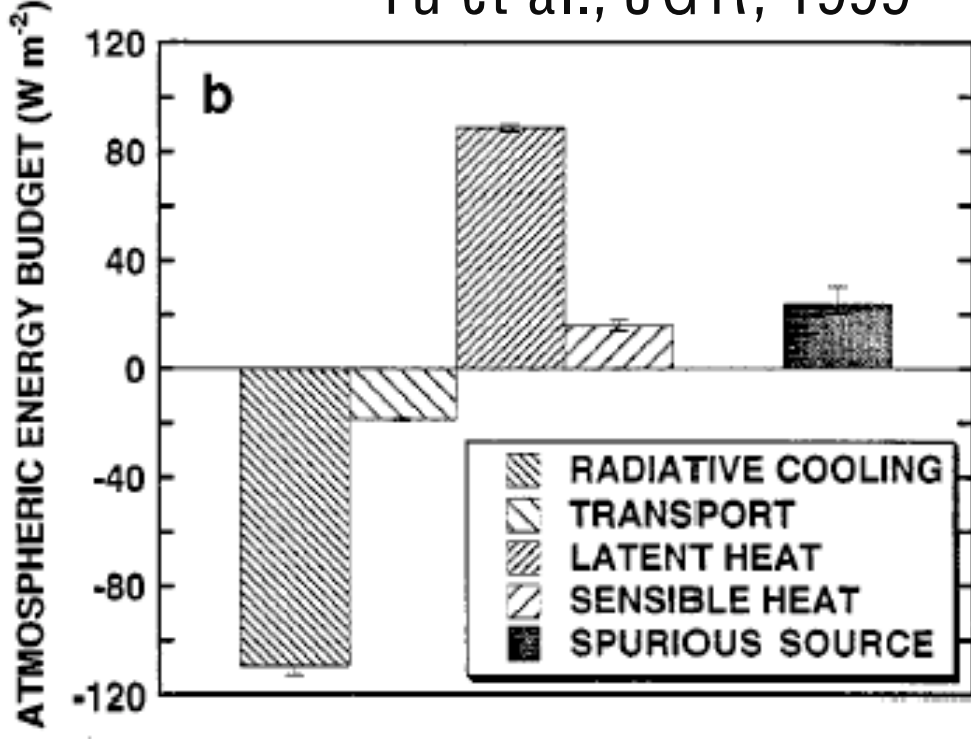
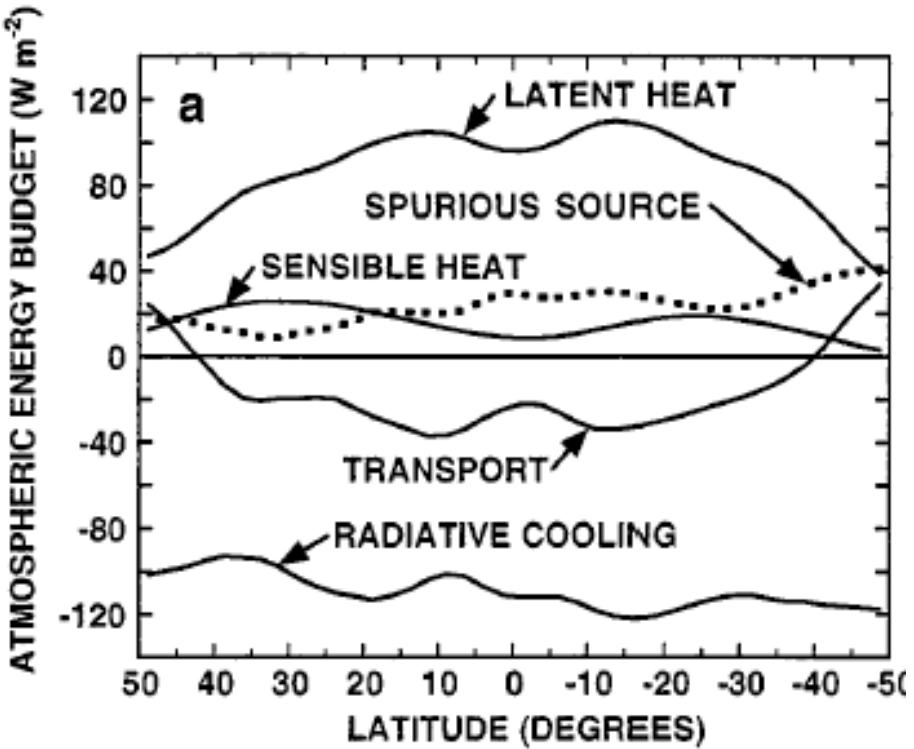


Historical results



• Blended data: satellite radiation, in-situ & assimilation turbulent fluxes $\rightarrow -20 \text{ W/m}^2$
 systematic errors \rightarrow insufficient SW absorption!

Yu et al., JGR, 1999





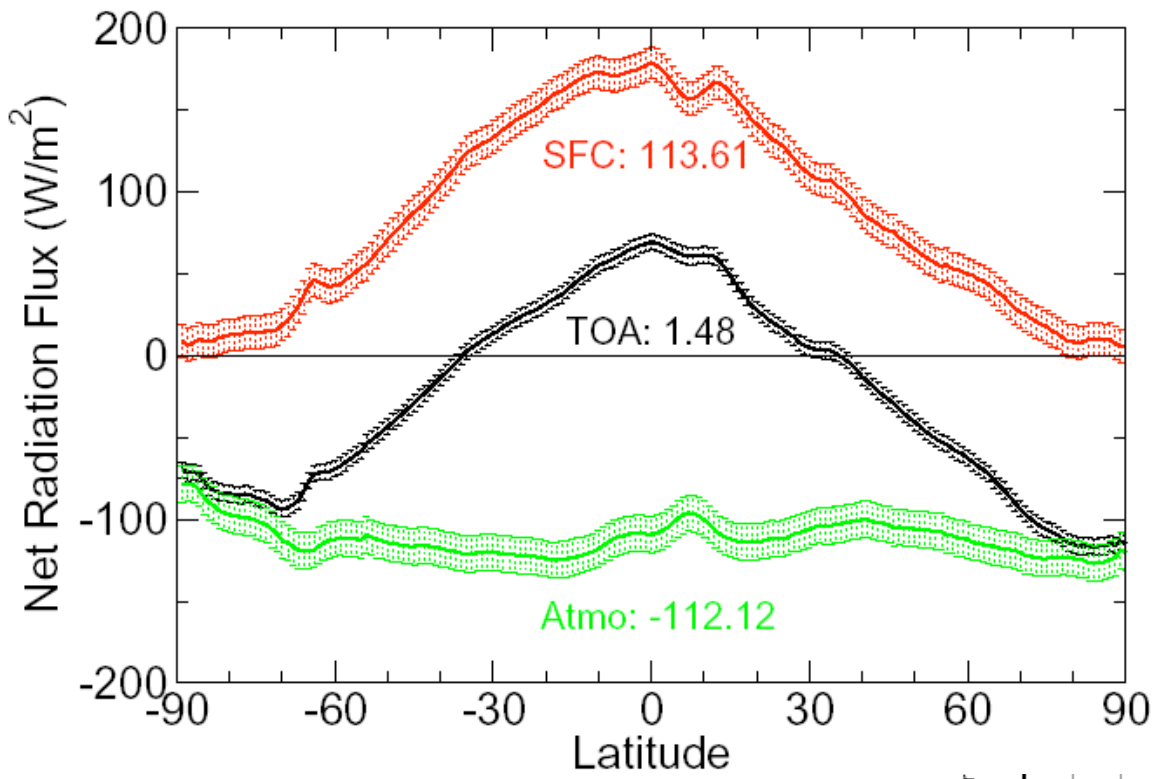
Heat budget (1988-2004)



- Radiation:
TOA & sfc -- CERES, SRB, ISCCP-FD
bias errors: $\sim 10 \text{ W/m}^2$
- Sea surface turbulent fluxes: RSS,
GSSTF, HOAPS
bias errors: $\sim 7 \text{ W/m}^2$ overall < 17 W/m^2
- Precipitation: GPCP
atmospheric latent heat balance
annual mean errors: 5% or $\sim 4 \text{ W/m}^2$



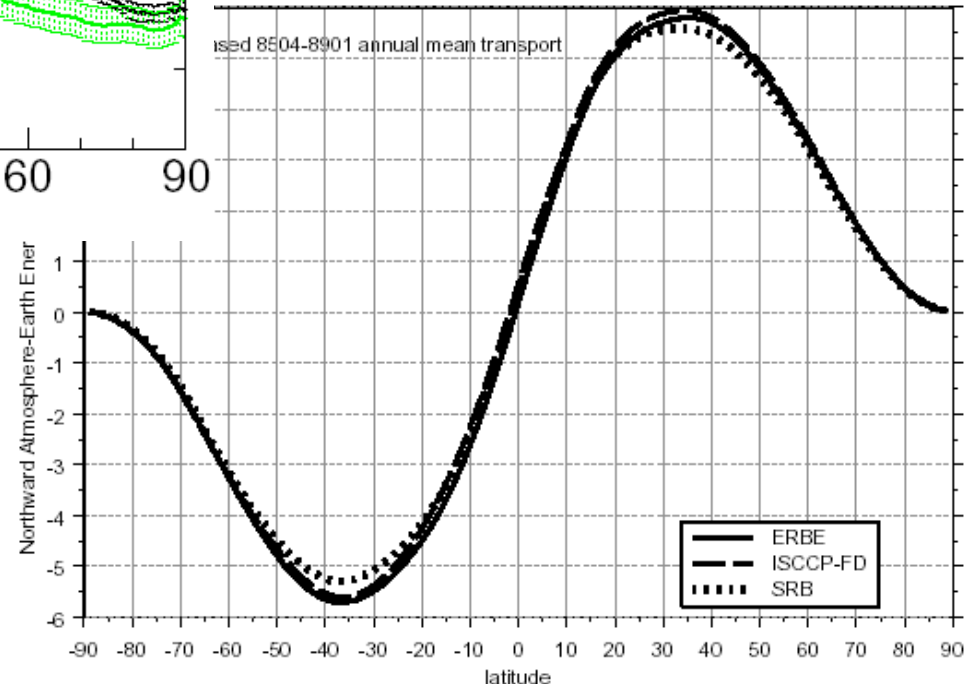
annual zonal mean radiation



zonal heat transport:
the integral of
TOA net radiation.

Lin et al.
JGR 2008

Zhang et al.
JGR, 2007

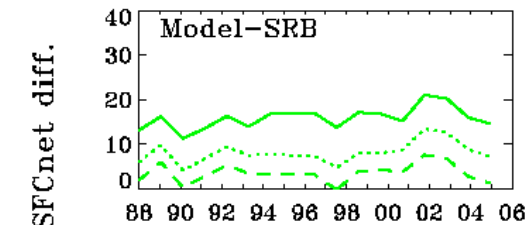
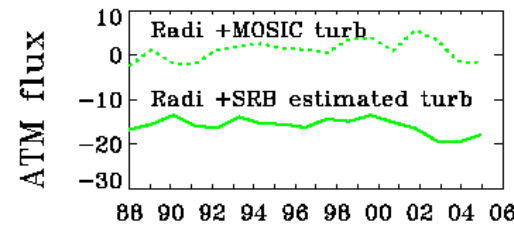
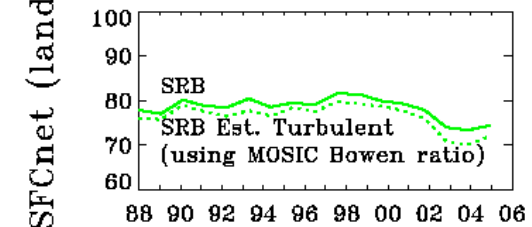
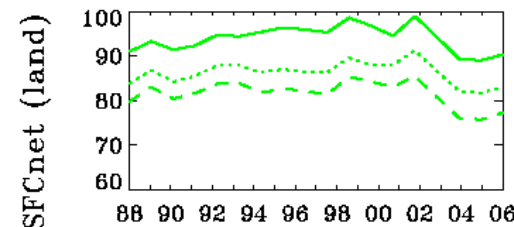
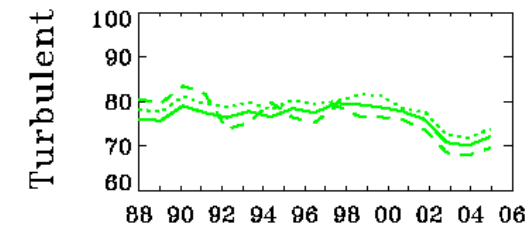
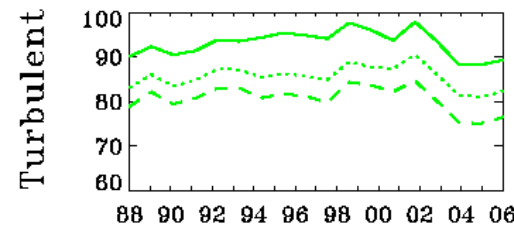
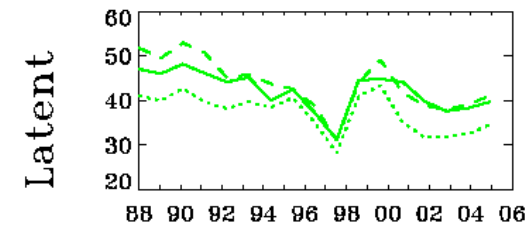
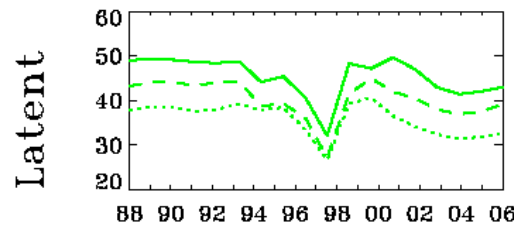
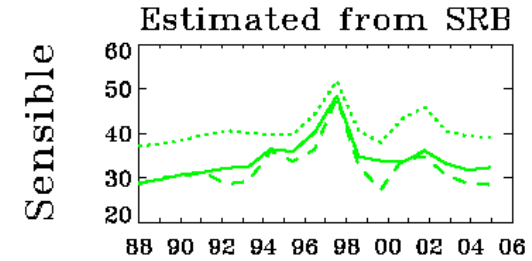
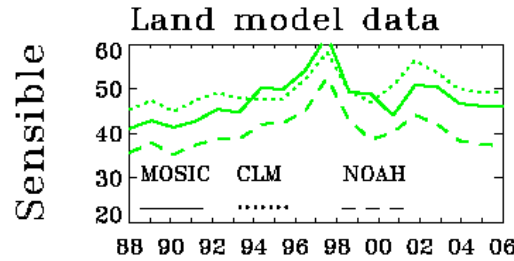




Land surface fluxes



differences among models are about 15 W/m^2 : all larger than sfc radiation estimates.





Land heat budget

- Land surface fluxes: GLDAS/Noah
heat storage (S), Bowen ratio,
- Observations: SRB

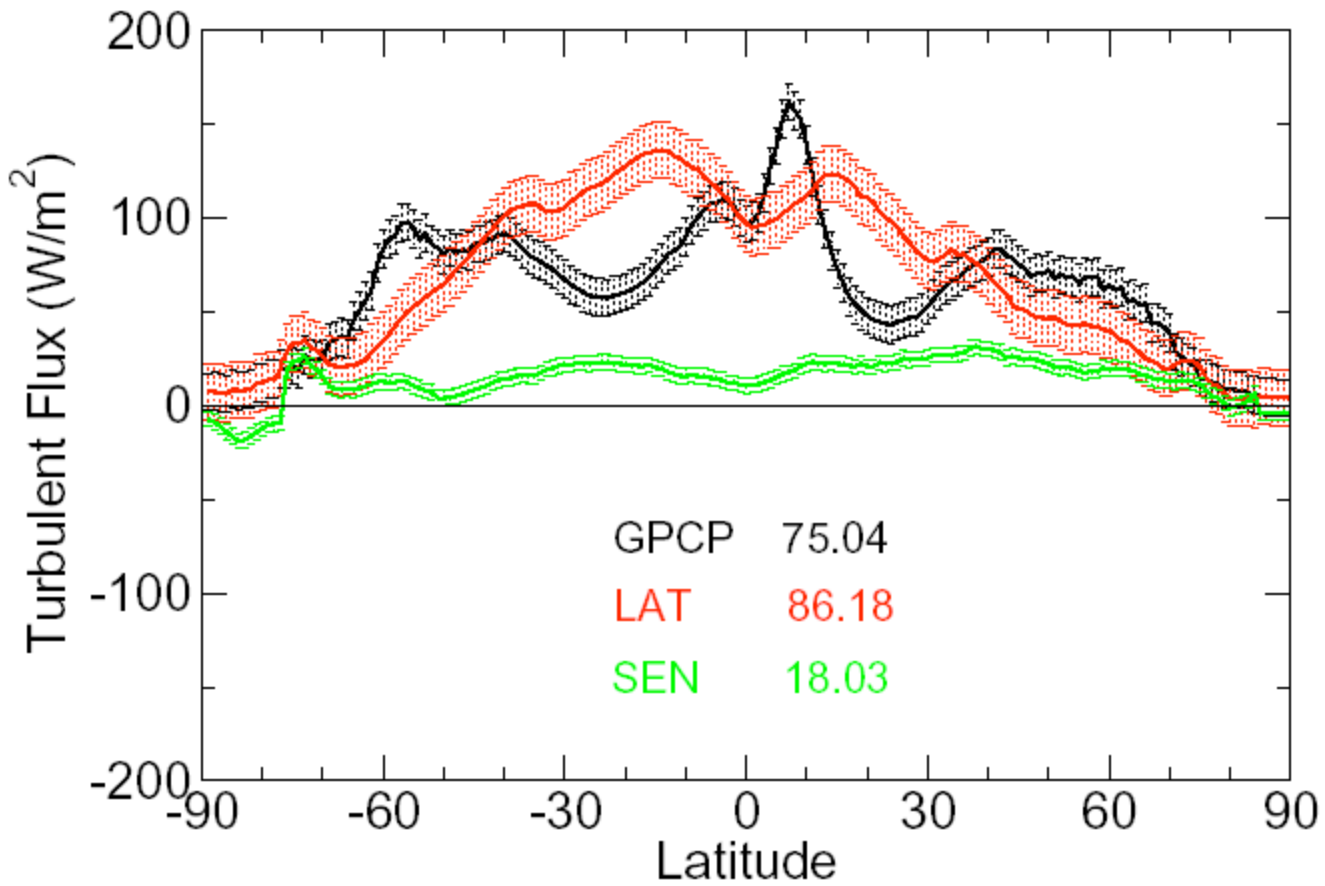
$$R_{net} = LH + SH + S \quad (1)$$

$$B = LH / (LH + SH) \quad (2)$$

- negligible horizontal heat transport
- forced by surface net radiative fluxes in daily to monthly time scale



Annual mean turbulence

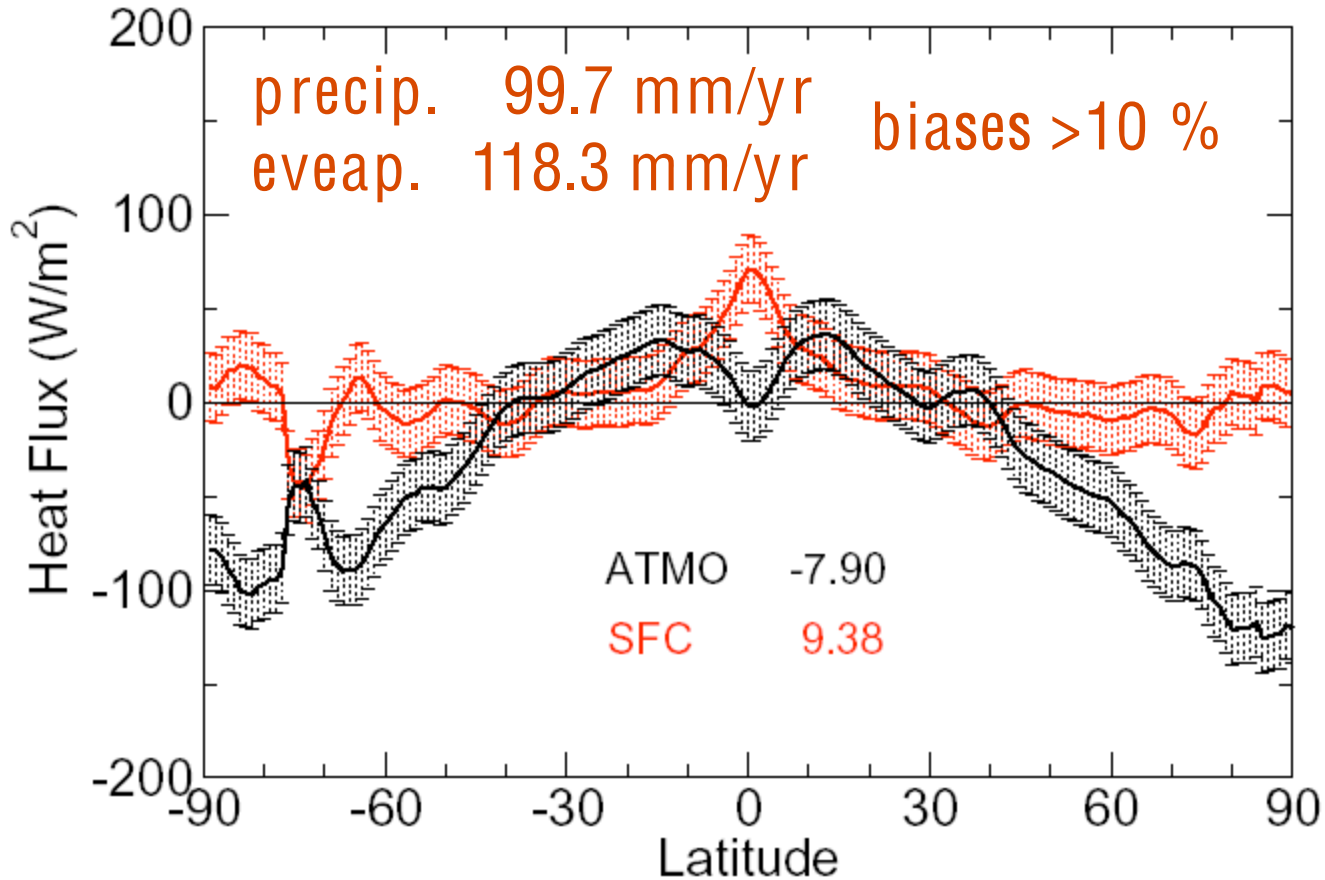


Year:
2000

water budget $\sim 11 \text{ W/m}^2$: within uncertainties of these flux retrievals
GPCP: no snow and drizzle precipitation



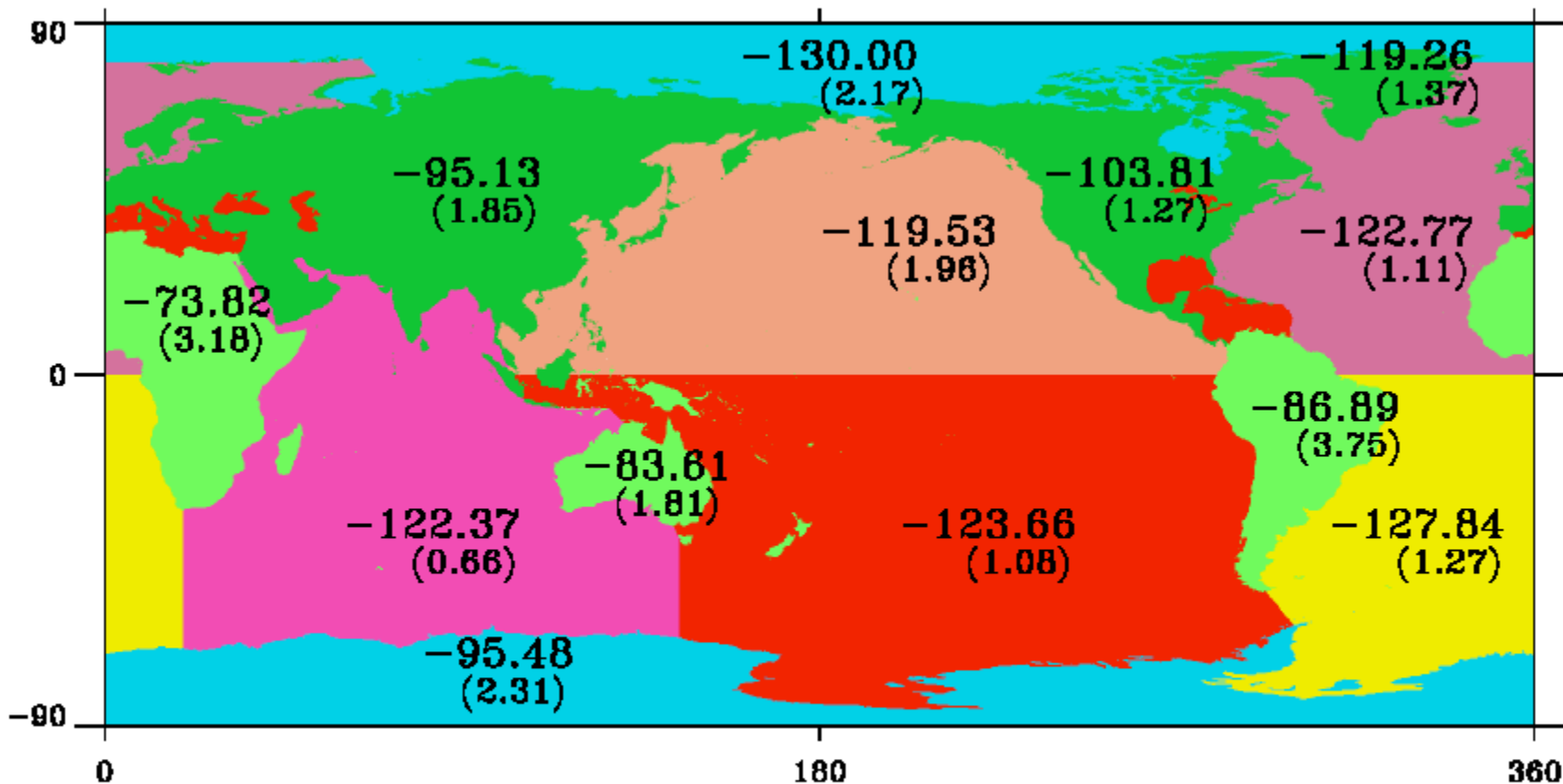
Annual mean balance



Total budget < 17 W/m²: within uncertainties of these flux retrievals, also maybe similar to the magnitude of the errors in water cycle.

Regional atmospheric net radiation

($-113 \pm 0.97 \text{ W/m}^2$; 1988 ~ 2004)



Mediterranean -120.35
(1.50)

Caribbean -125.61
(1.57)

Black Sea -110.43
(2.07)



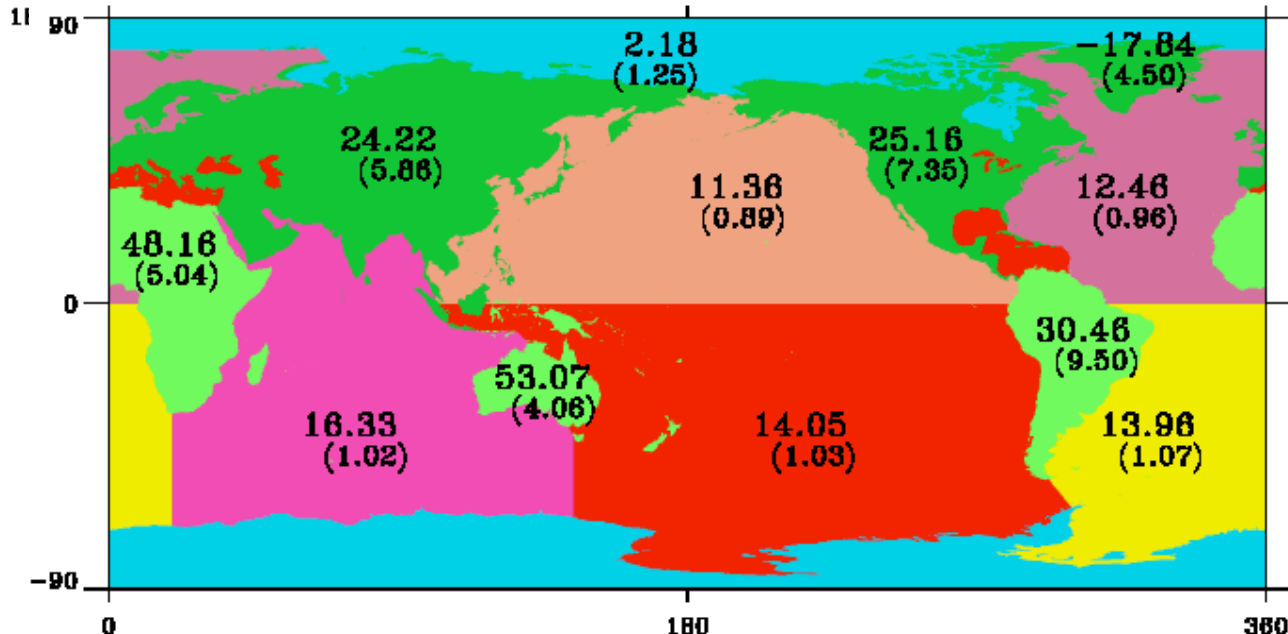
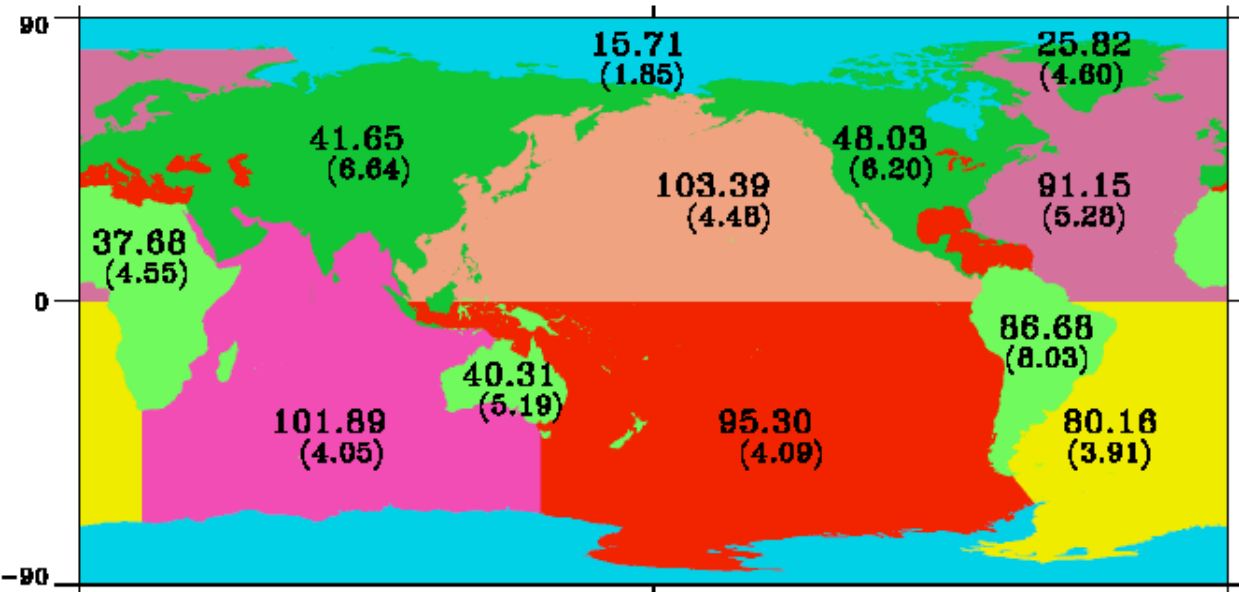
sfc turbulent fluxes



Ocean: HOAPS
Land: Noah

sensible heat
($18 \pm 1.9 \text{ W/m}^2$)

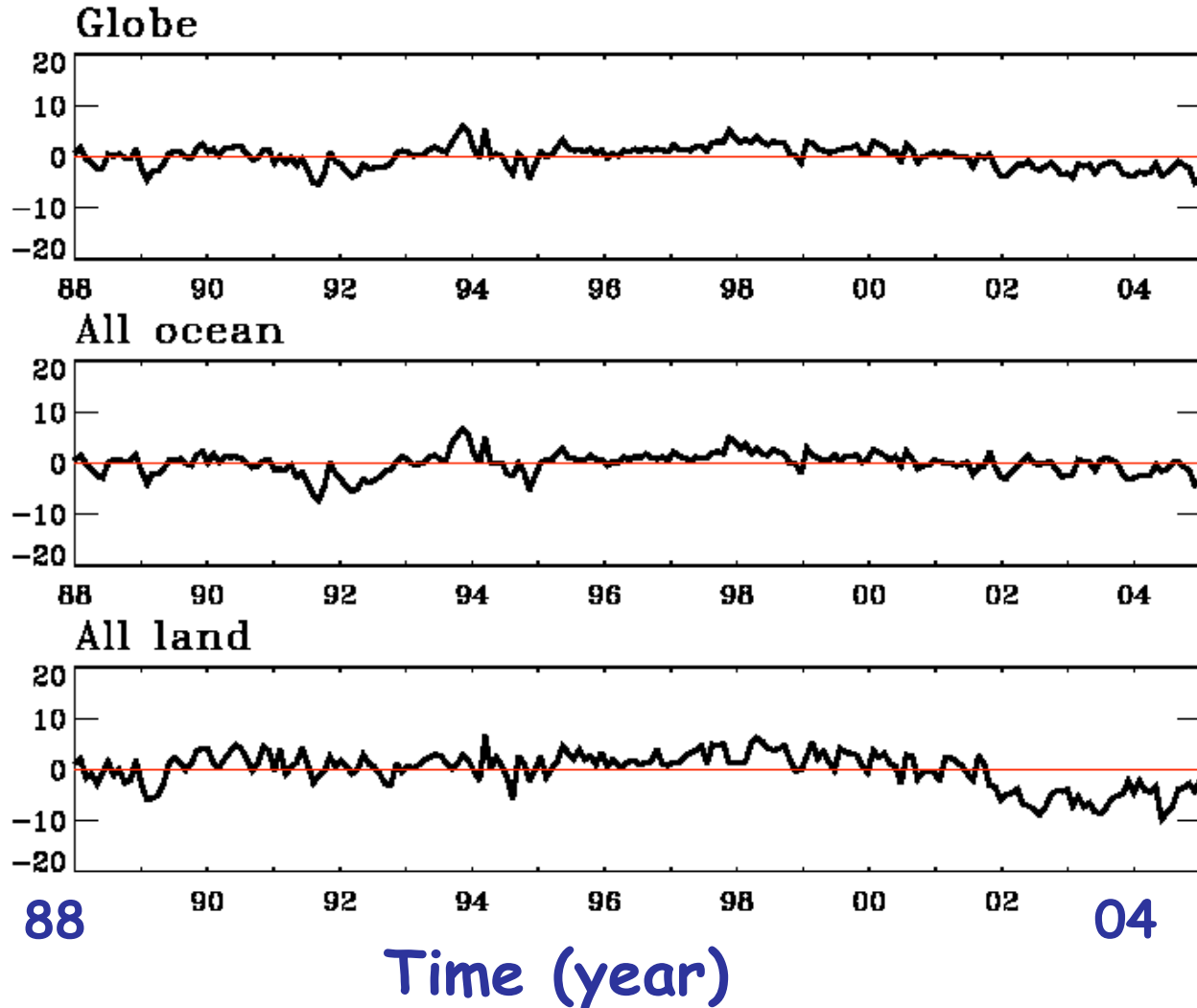
latent heat
($82.2 \pm 2.5 \text{ W/m}^2$)





global surface net radiation anomaly (W/m^2)

no significant trends



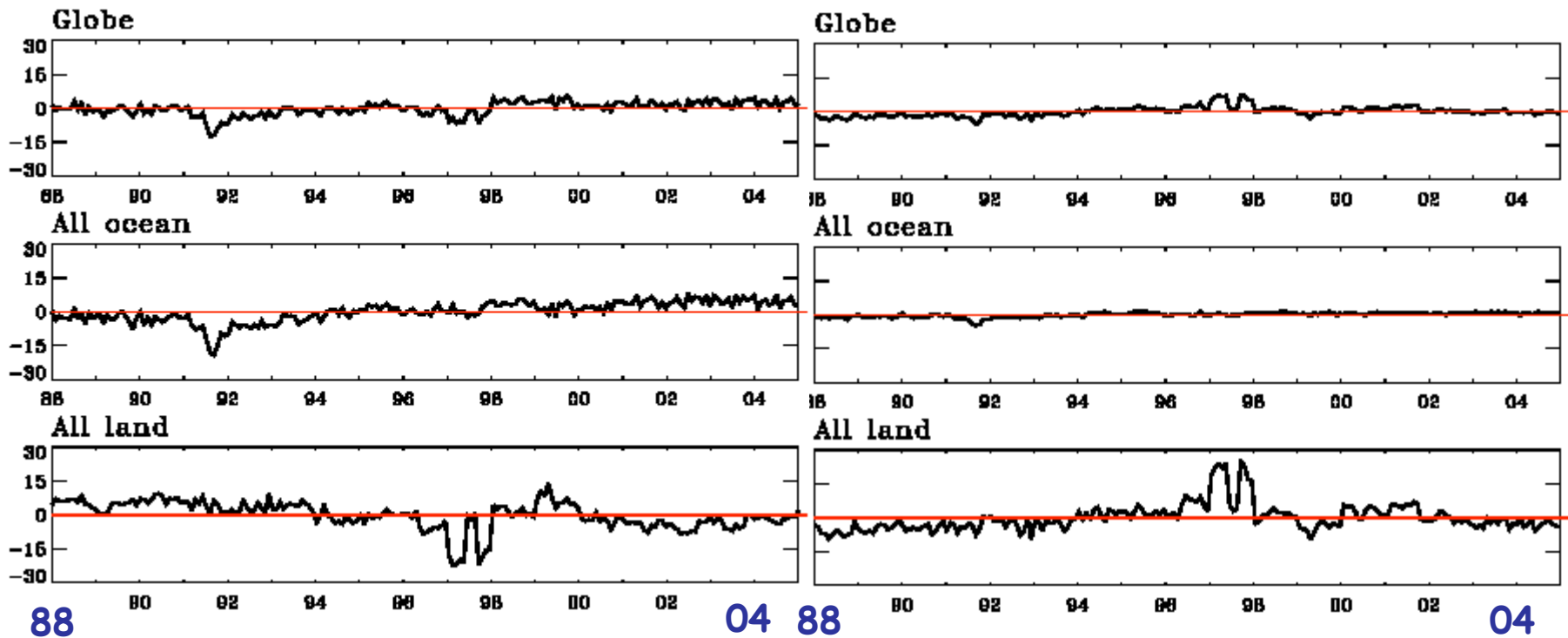


global surface turbulent flux anomaly (W/m^2)



latent heat

sensible heat



Time (year)



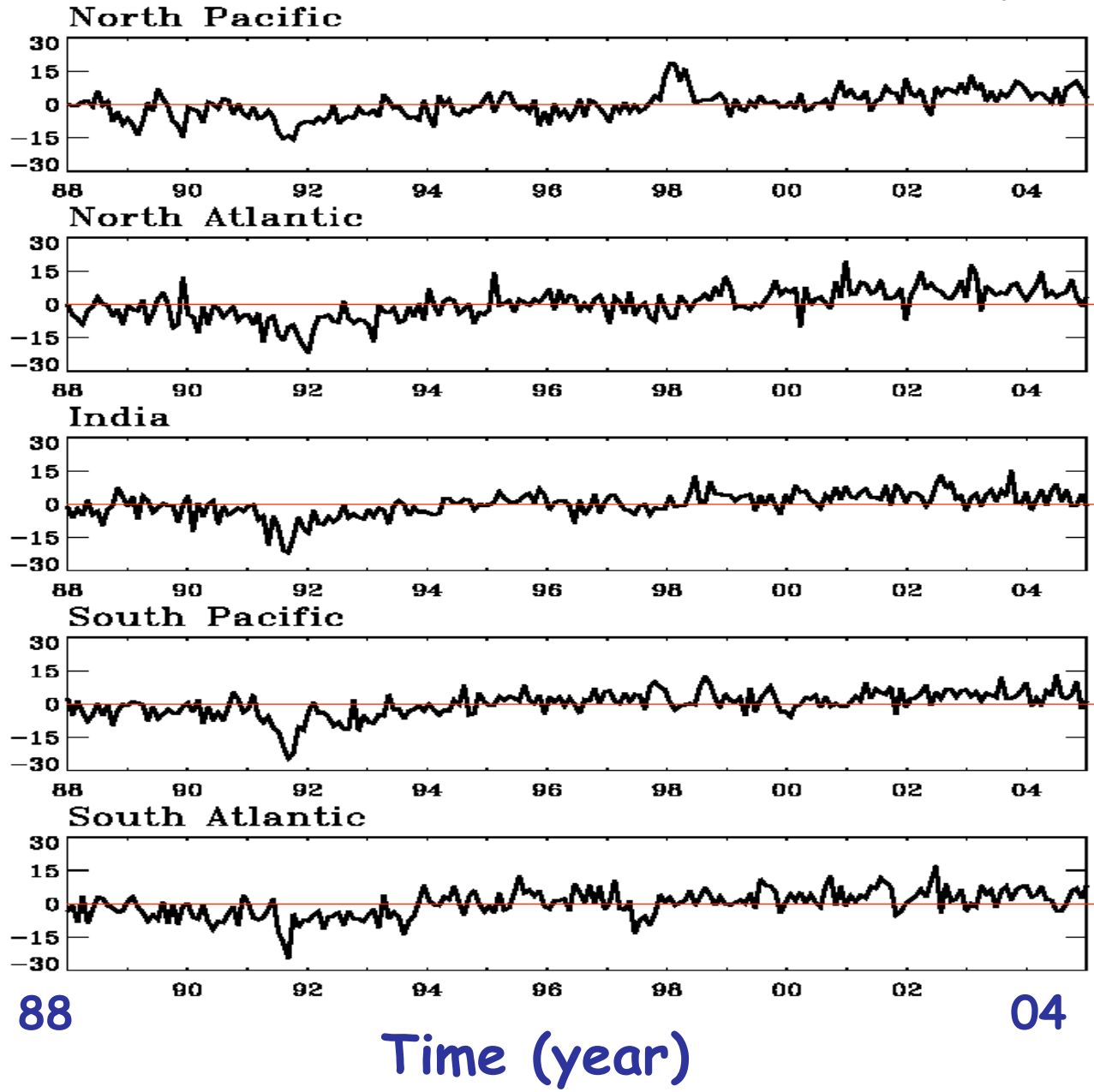
regional oceanic LH anomaly



clear time dependence

LH flux (w/m^2)

similar as global data



88

04

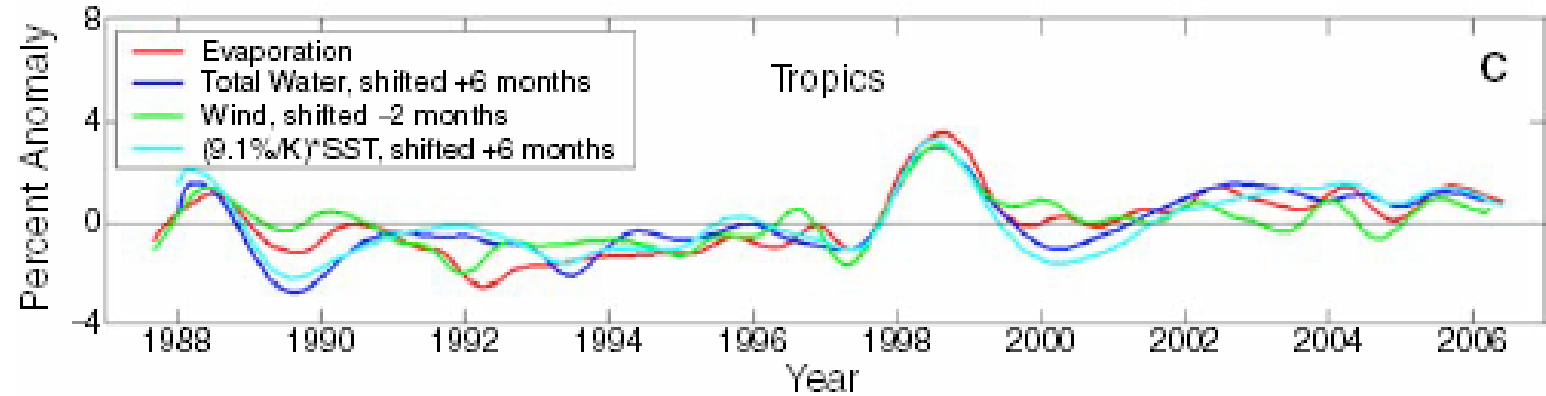
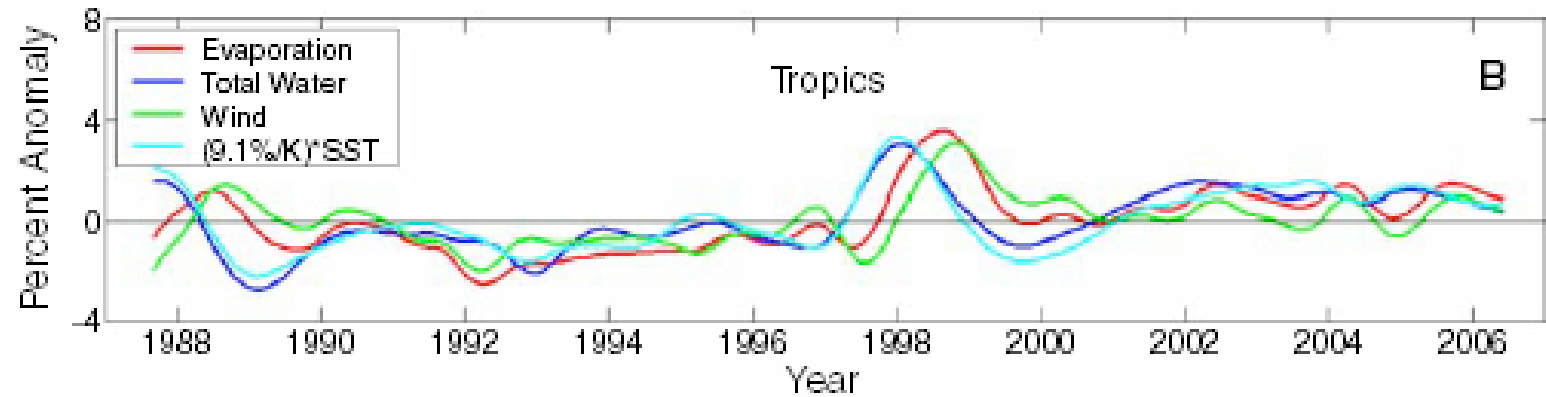
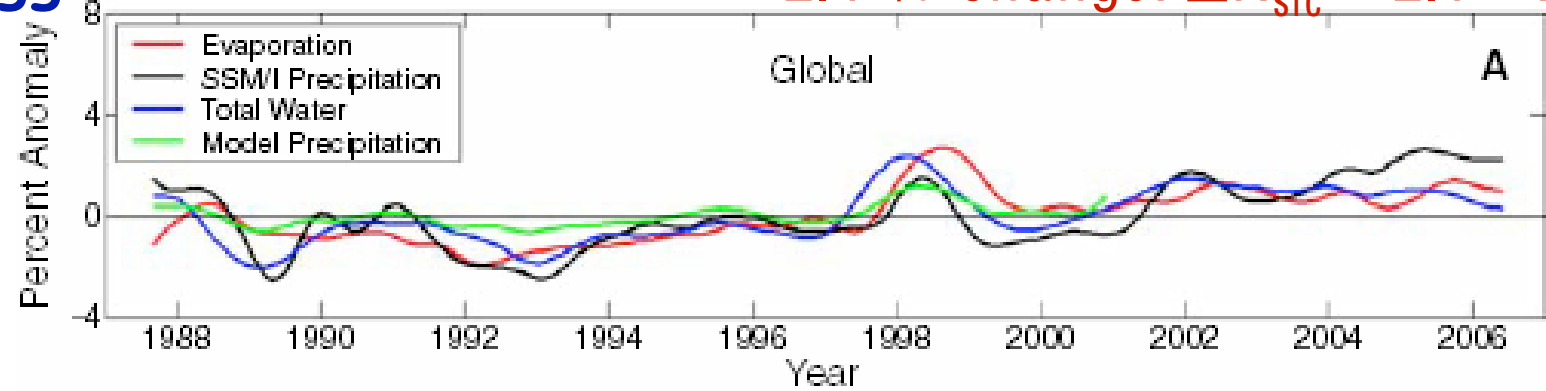
Time (year)



another aspect: water



bigger than radiation obs. 2.4 % change: $\Delta R_{sfc} = 2.1 \sim 2.7 \text{ W/m}^2$



Wentz
at al.,
Science
2007

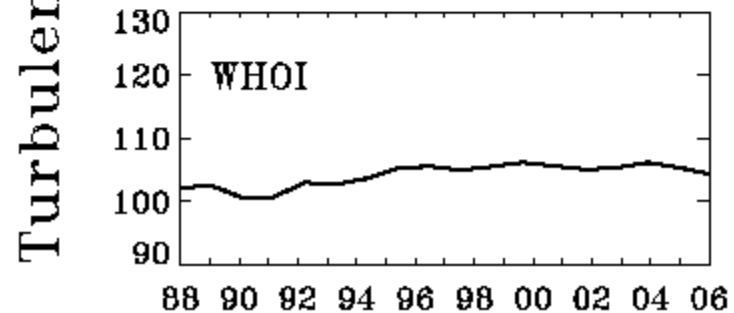
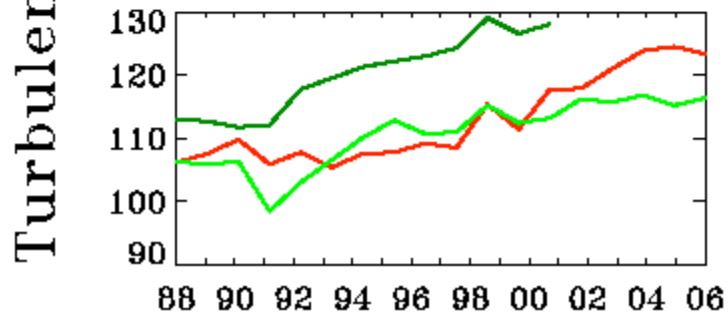
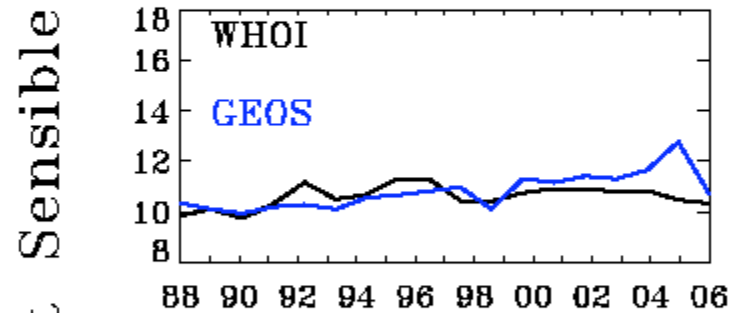
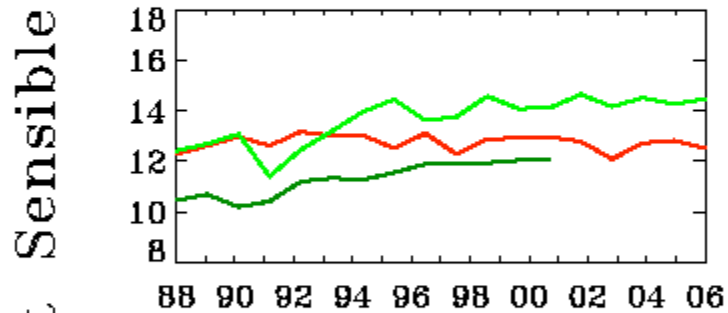
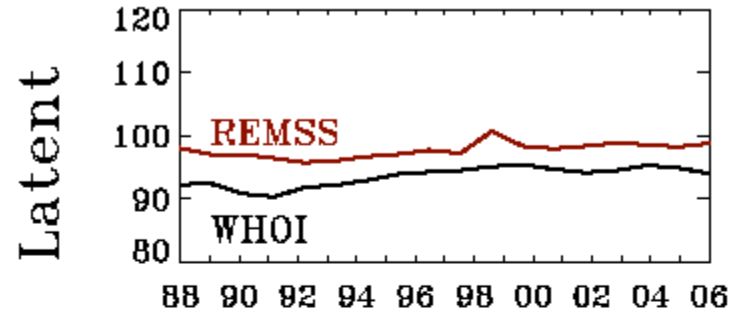
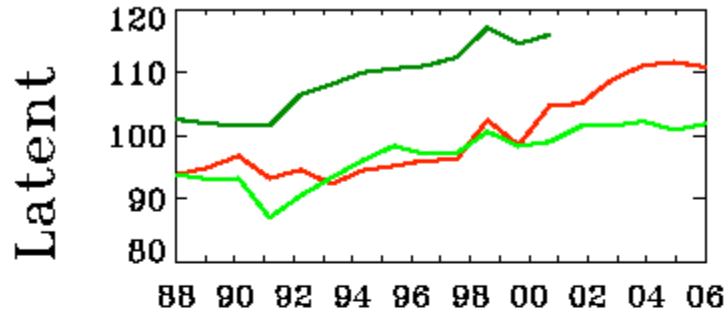


more turbulent measurements



large biases & spurious trends: SSM/I calibration

GSSTF OFURO HOAPS GEOS REMSS WHOI





Summary



- Although satellites can provide invaluable estimates of major EC components over global oceans, there are still some gaps in global EC observations, especially for land surface and cold region processes.
- The errors in annual atmospheric energy balance are within the systematic error range of combined sfc radiative and turbulent fluxes. Progress in satellite observations of sfc radiation and sea surface turbulent fluxes significantly reduces observational uncertainties.



Summary (conti.)



- Systematic errors in annual mean atmospheric budgets are not small. More work on sfc radiation and turbulent fluxes are needed.
- Due to uncertainties in the satellite data sets of decadal sfc radiation, evaporation and precipitation, there are certain differences among global energy data sets. Long-term measurements and inter-calibration of different sensors on different spacecraft are critical in detecting trends even for single component.

Reconciliation is really needed!

Acknowledgements



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