Atmospheric Heat Transport Estimations Based on Satellite and Assimilation Data

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Outline

- Introduction: energy cycle for climate
- climate heat balance
- interact with water cycle
- previous efforts: observation & assimilation
- Energy balance: TOA, sfc, atm.
  - radiation & turbulence $\leftrightarrow$ precipitation
  - land surface fluxes
  - Global, zonal and regional annual means
  - energy & water balance
- Summary

Introduction

- Energy imbalance: a fundamental process:
  related directly to climate sensitivity and ocean heat storage
- Entwined with water cycles – E and P
- Observations + assimilations:

global/large scale balances, variability,
atmospheric & ocean heat transports
lack: land/cold regions, light rains
errors: divergence calculation, model errors

Estimation Approaches

- Land surface fluxes: assimilations

  heat storage (S), Bowen ratio

$$Rnet = LH + SH + S \qquad (1)$$

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

  - negligible land horizontal heat transport
  - forced by surface net radiative fluxes

- Net radiation: satellite observations

  TOA, surface, within atmosphere

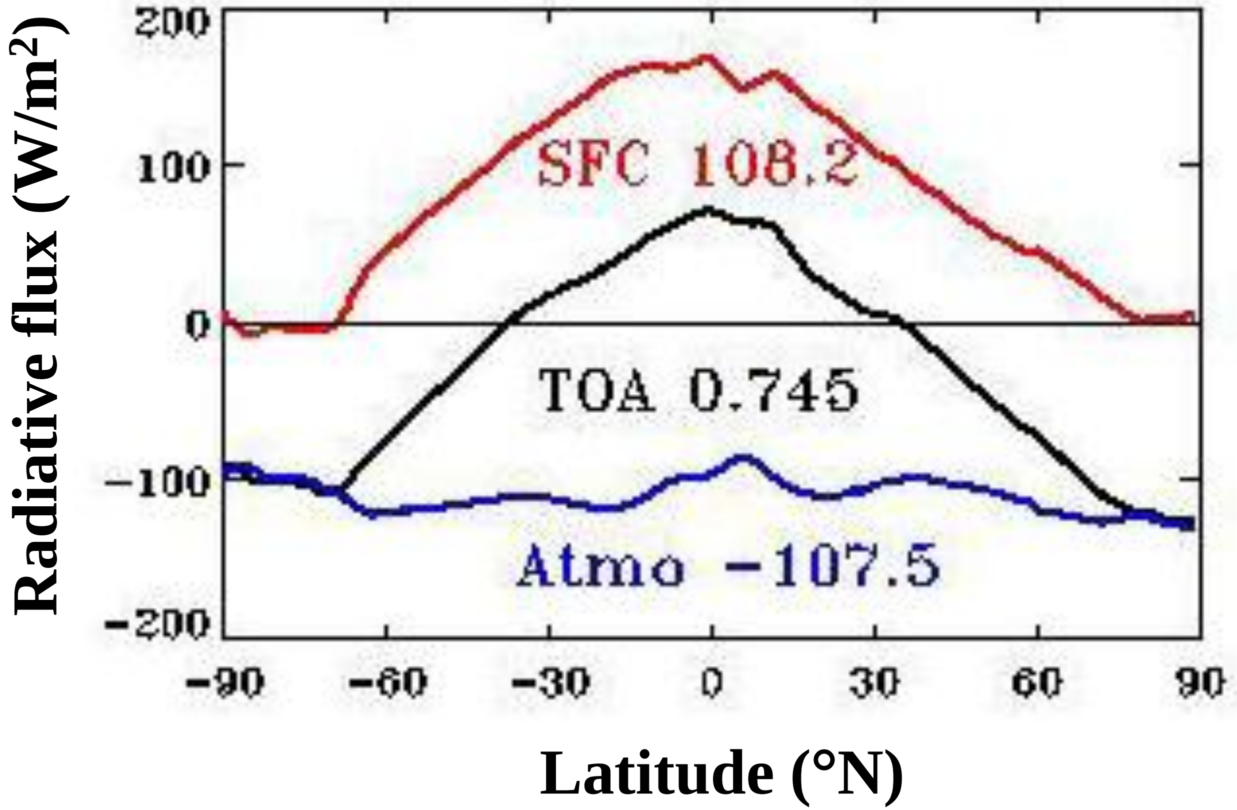
Estimation Approaches

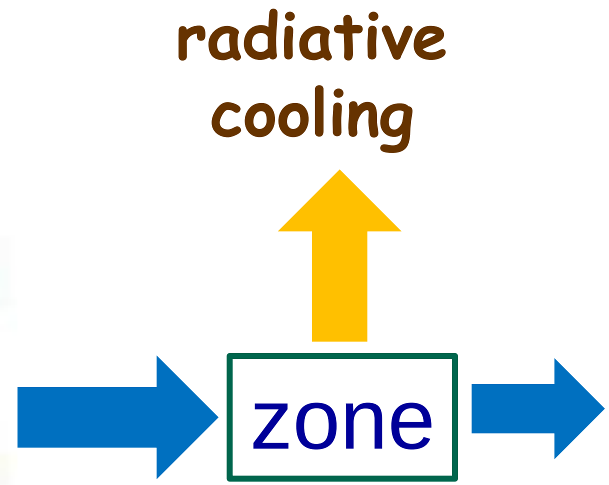
- Atmospheric heat flux transports:
  Moist static energy:
  sensible heat, latent heat, geopotential energy

  Kinetic energy: air movements

- Assuming no horizontal net radiation transports in large/long-term scales & no horizontal heat transports over land

Net radiation
(annual mean)

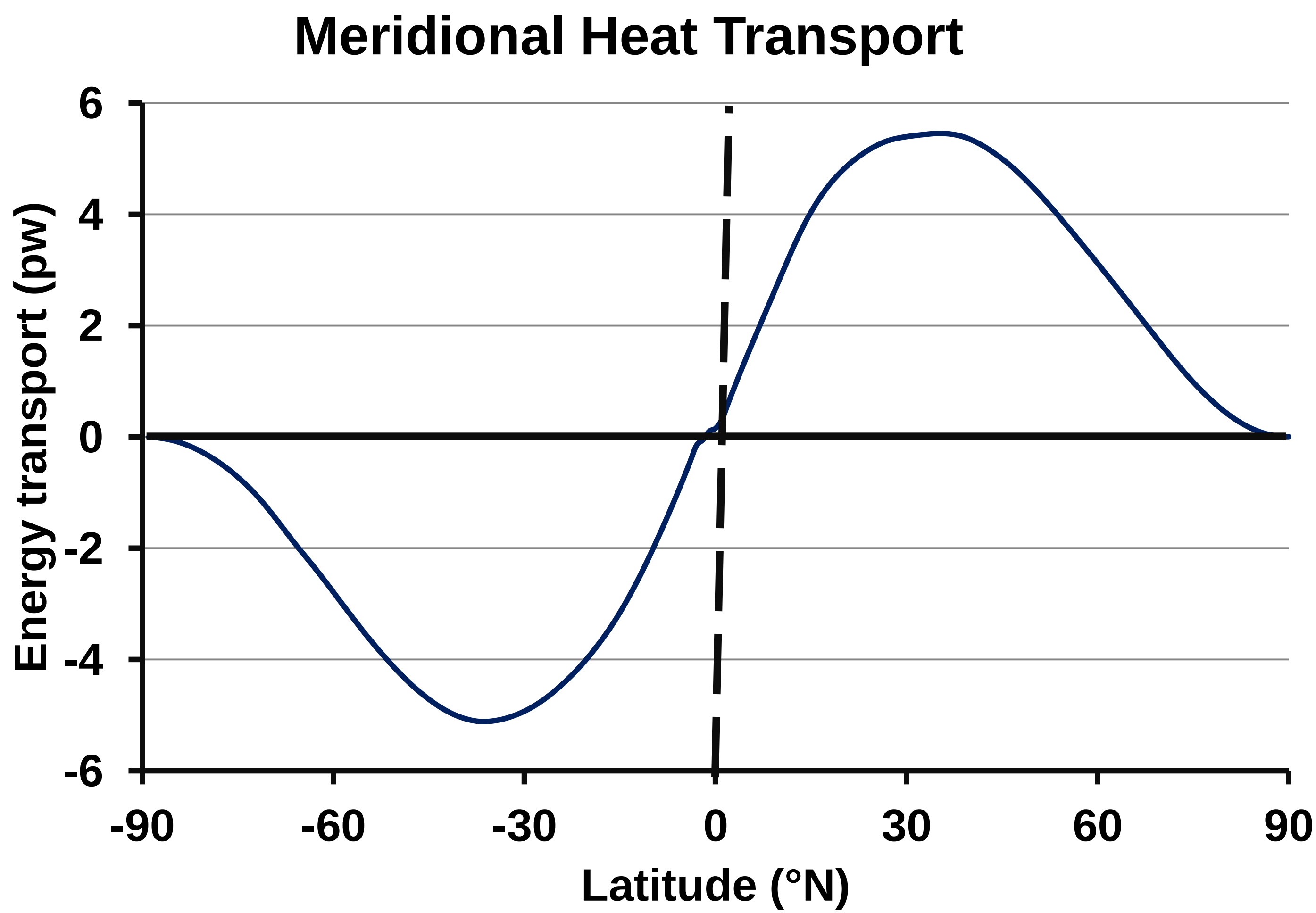




Local heat balance: latent & sensible heat, transport

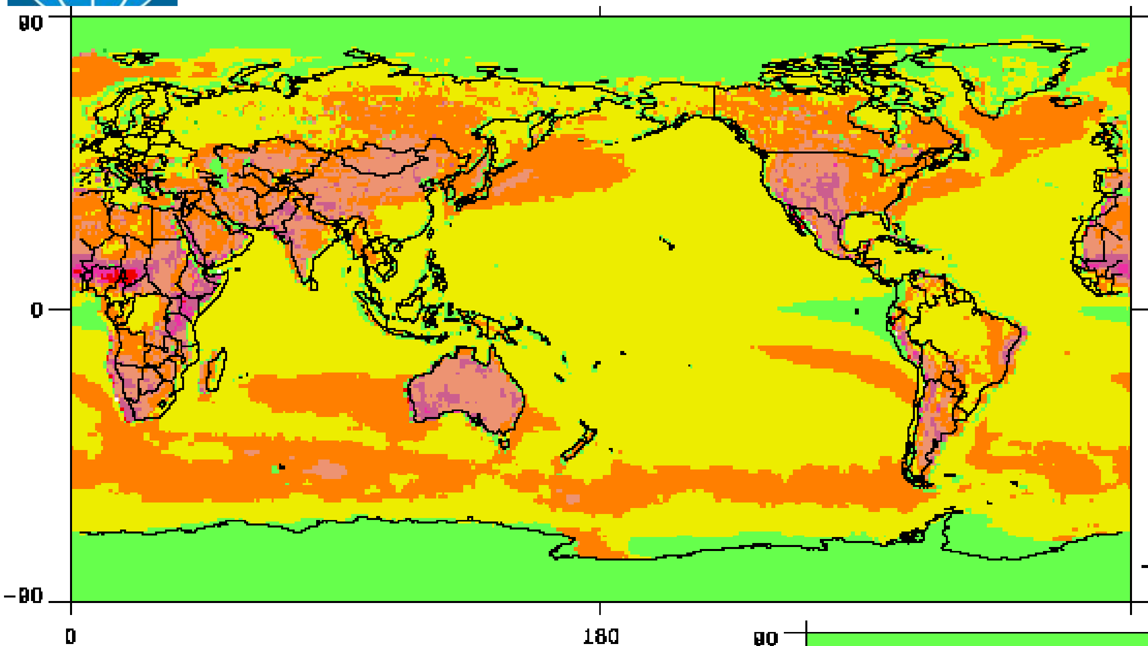
zonal heat transports: heat balance from TOAnet radiation

Poleward Heat Transport

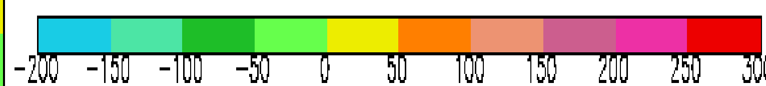


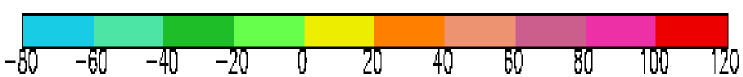
other heat forms than radiation from atmosphere & ocean

sfc turbulent fluxes

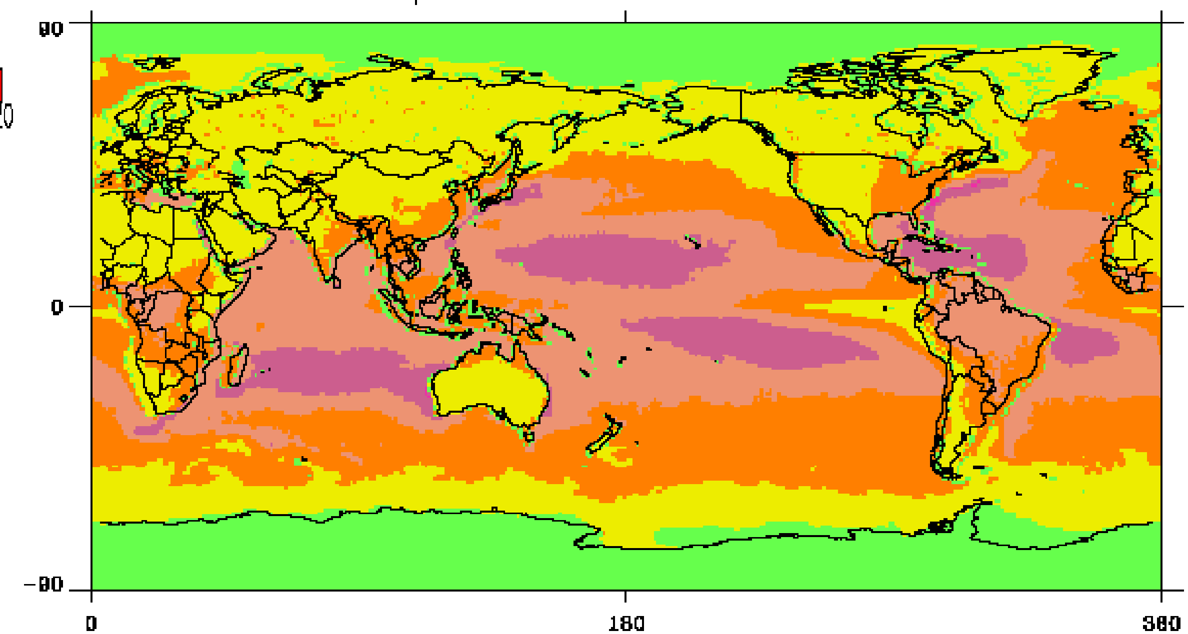


latent heat



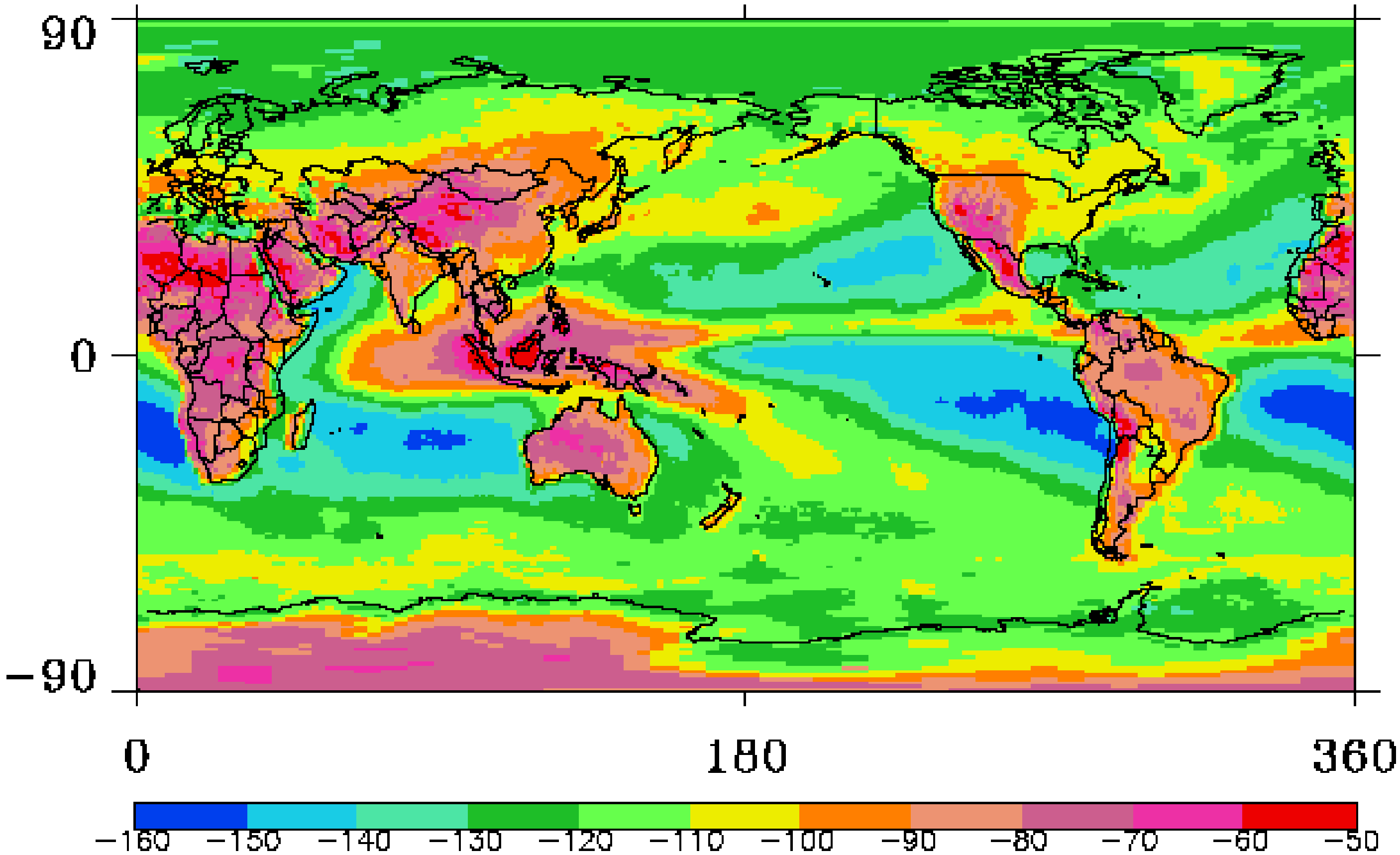


sensible heat



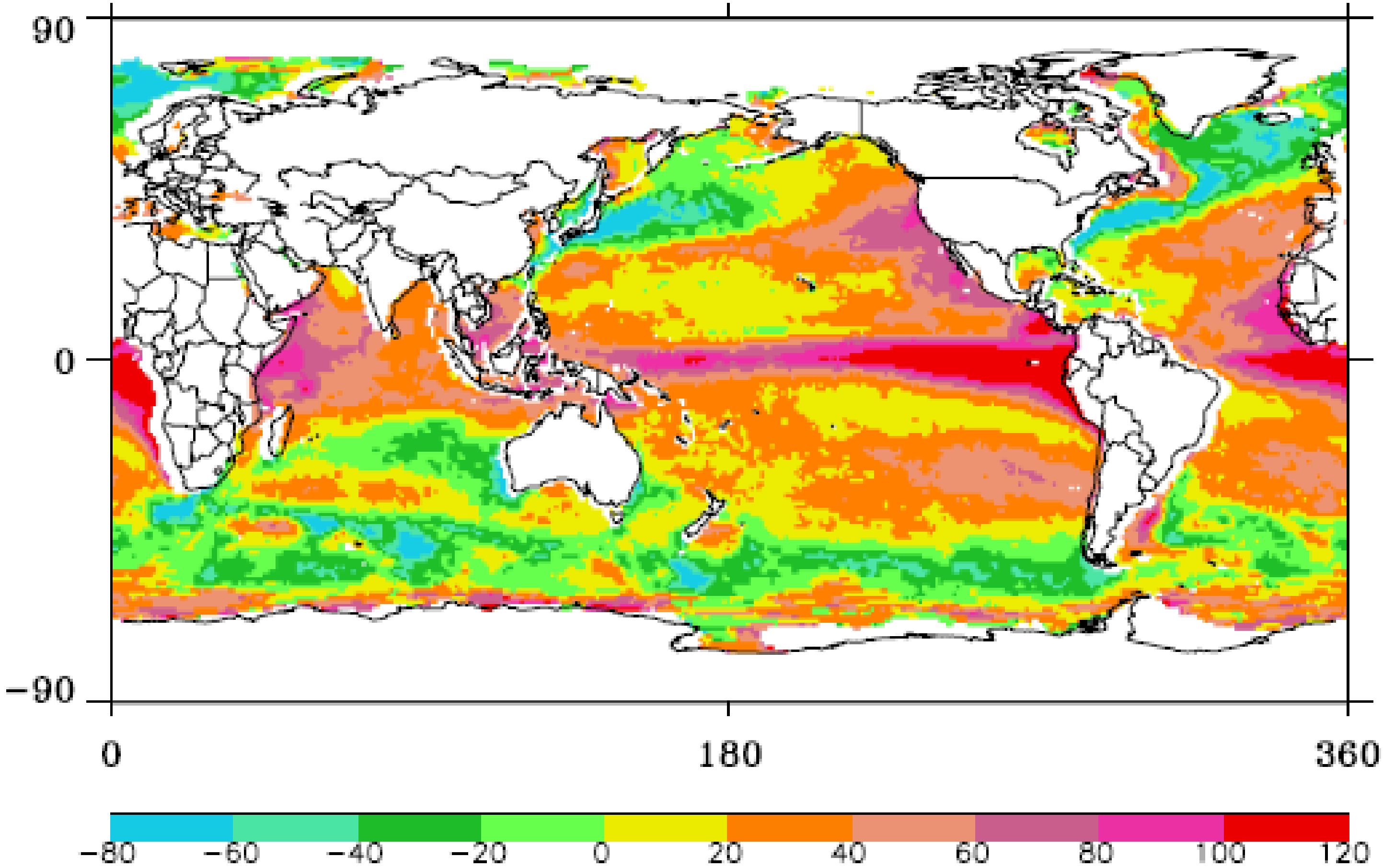
Annual Mean

Atmos. Net Radiation



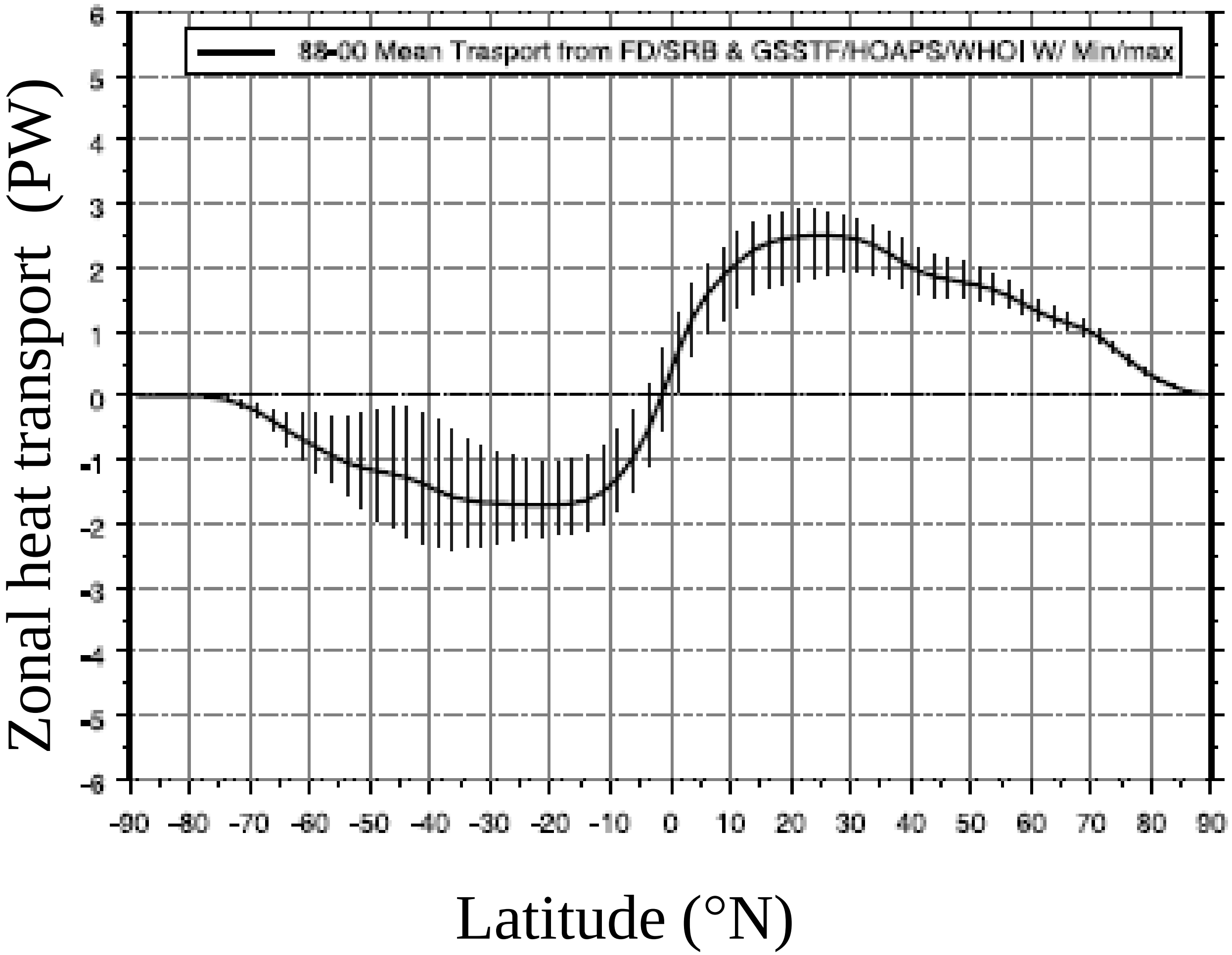
Annual Mean

Ocean surface heat budget



Annual mean sea surface heat budget (W/m^2).
Positive values indicate that oceans gain heat from the atmosphere.
Assuming minimal vertical heat transports, large horizontal heat transports can be seen here.

Poleward Ocean Heat Transport



Zhang et al. JGR 2002

Heat transports by dynamics & thermodynamics

- Atmospheric heat flux transports:

  moist static energy

  $Em = CpT + Lq + gz$

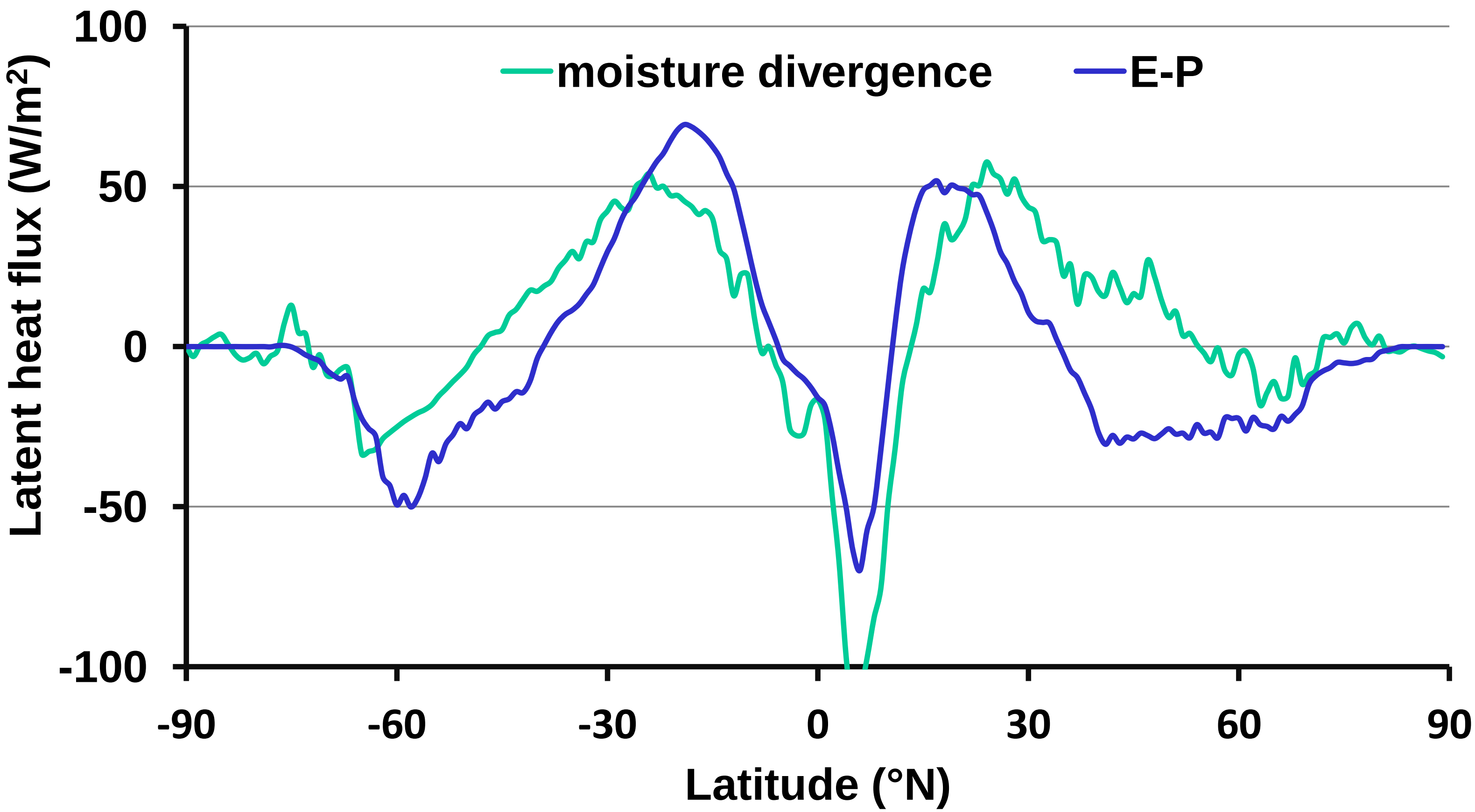
  Kinetic energy

  $Ek = ||\vec{V}||^2/2$ for unit mass

  $\Delta E = \nabla \bullet E\vec{V}$ in zonal or regional scale

- Mostly for Lq term

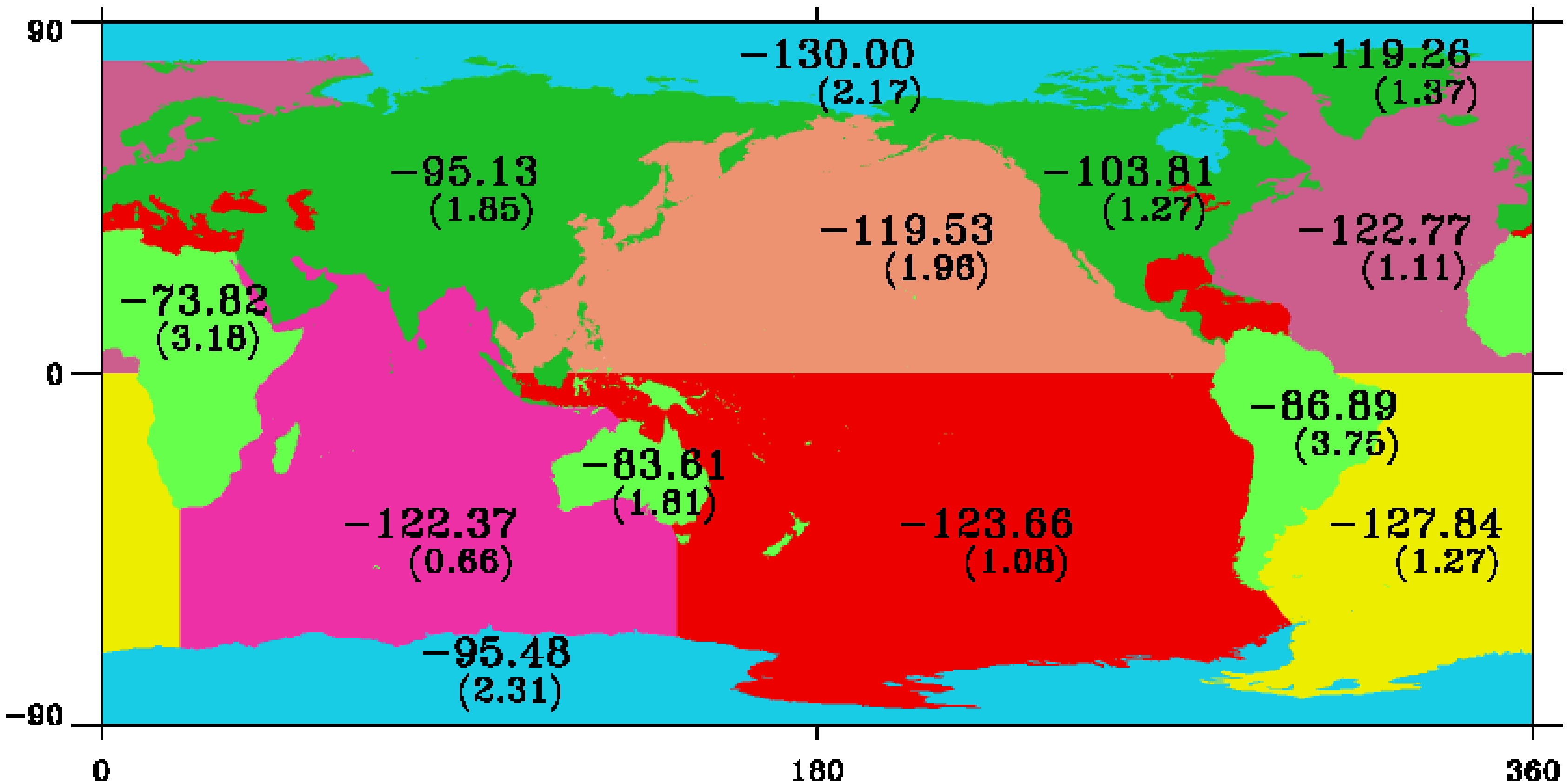
Zonal latent heat divergence



ITCZ: very weak winds
& potential large divergence errors

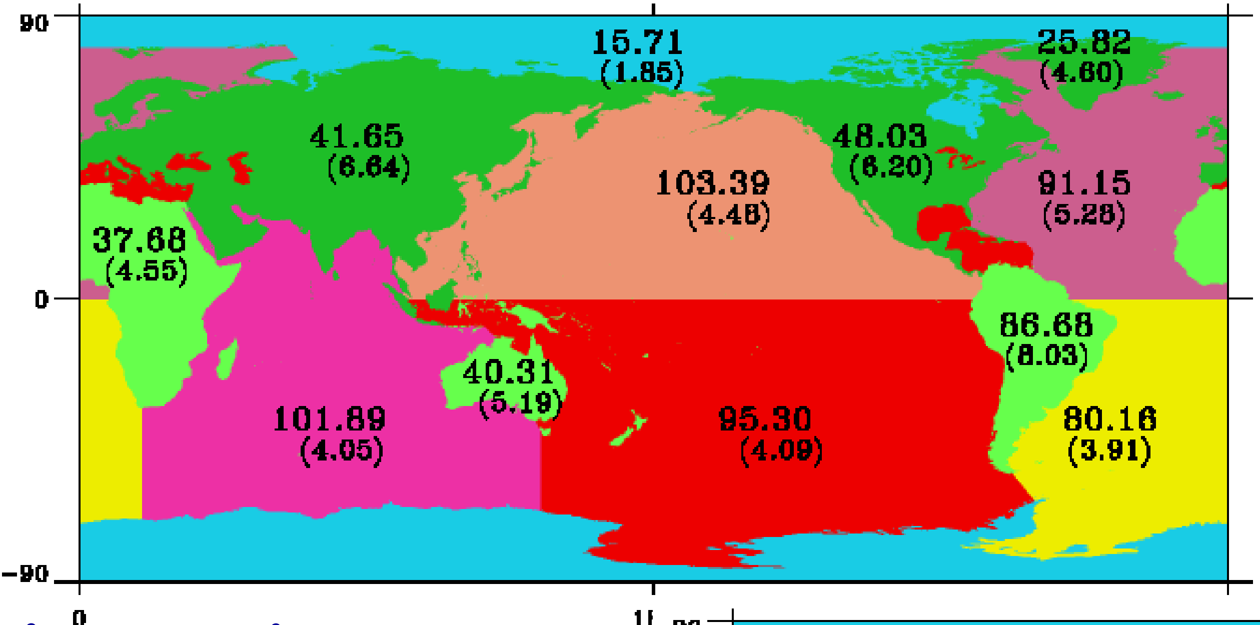
Regional Atmos. Net Radiation

(-113 ± 0.97 W/m^2)



Mediterranean −120.35 (1.50) Caribbean −125.61 (1.57) Black Sea −110.43 (2.07)

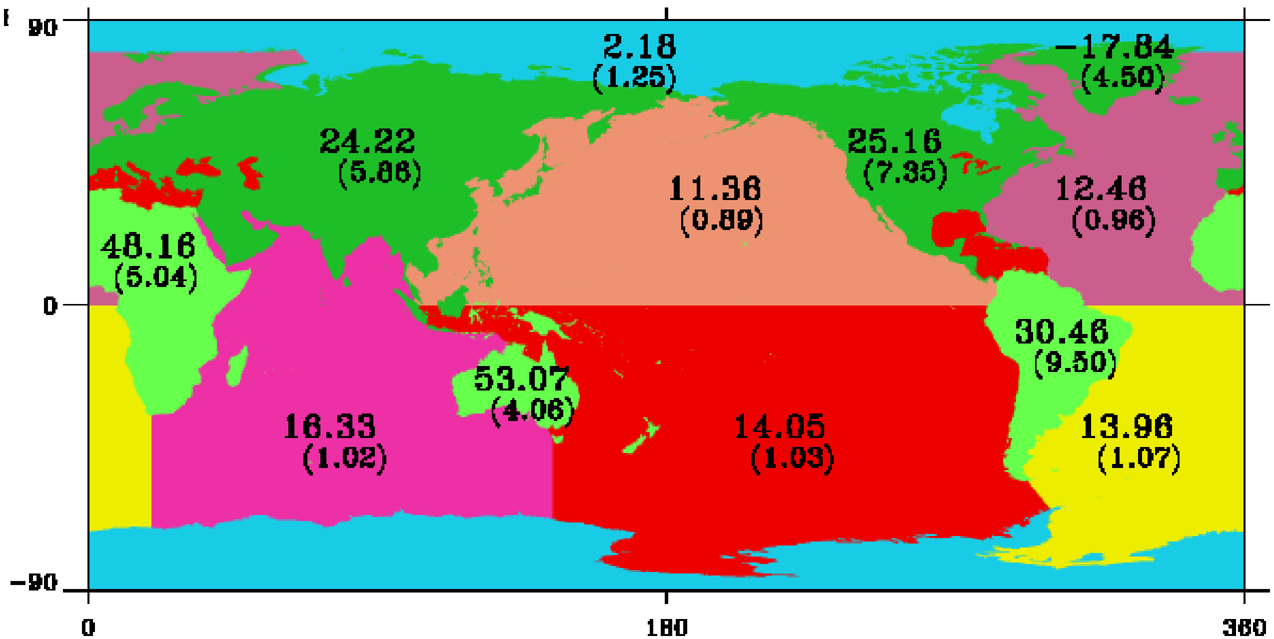
sfc turbulent fluxes



Ocean: HOAPS
Land: GLDAS

sensible heat
(18 ± 1.9 W/m²)

latent heat
(82.2 ± 2.5 W/m²)



Regionaal radiative and other heat fluxes (W/m²)

	TOA	SFC	ATMO	Latent	Sensi ble	Atmo + Lat + Sen	E-P	Moist div
N_Pacific	28.4	136.2	-107.8	108.7	12.1	13.0	0.12	
S_Pacific	8.9	123.3	-114.5	99.2	14.7	-0.5	19.50	
N_Atlantic	1.0	113.1	-112.1	97.2	13.4	-1.4	17.97	
S_Atlantic	-7.0	111.0	-118.1	84.1	14.9	-19.0	25.64	
India	12.6	125.6	-112.9	105.9	17.0	10.0	24.54	
Ocean	7.8	120.9	-113.0	100.5	14.4	1.9	18.75	
S_America	32.6	119.3	-86.7	72.3	40.3	25.9	-58.74	-44.5
Africa	17.8	99.2	-81.4	41.9	80.1	40.6	-13.57	-37.3
Australia	15.3	104.9	-89.6	32.0	68.5	10.9	-24.36	-61.5
Eurasia	-30.4	65.8	-96.2	26.4	37.7	-32.1	-29.54	-15.9
N_America	-36.1	68.5	-104.6	30.8	35.3	-37.5	-27.84	-24.5
Land	-17.9	74.9	-92.8	36.7	49.0	-7.1	-24.91	
Globe	0.745	108.2	-107.5	82.8	28.2	3.5	5.12	

EBAF, HOAPS, Princeton (latent),
MOSIC (sensible), and GMAO (div) 2001-2005

Summary

- Satellite observations and assimilation results provide certain insights for the global heat transports. However, certain heat fluxes and transports may not be available, especially those for cold region processes.
- The errors in annual global energy balance are within the systematic error range of radiation estimations. Progress in satellite observations of radiation and sea surface turbulent fluxes significantly reduces the uncertainties in annual mean energy budgets.

Summary (conti.)

- Zonal total poleward heat transports vary from -6PW to +6PW with peak values around 30° to 35° latitudes. The errors and uncertainties are limited by the accuracy of current satellite TOA observations.

- Although certain differences among global satellite estimates of oceanic heat transports exist, the larger errors are among atmospheric heat transports. Analysis finds general agreements of zonal & regional latent heat transport between E-P and water vapor transports. Moisture divergence is the key in estimations.

Thank You!