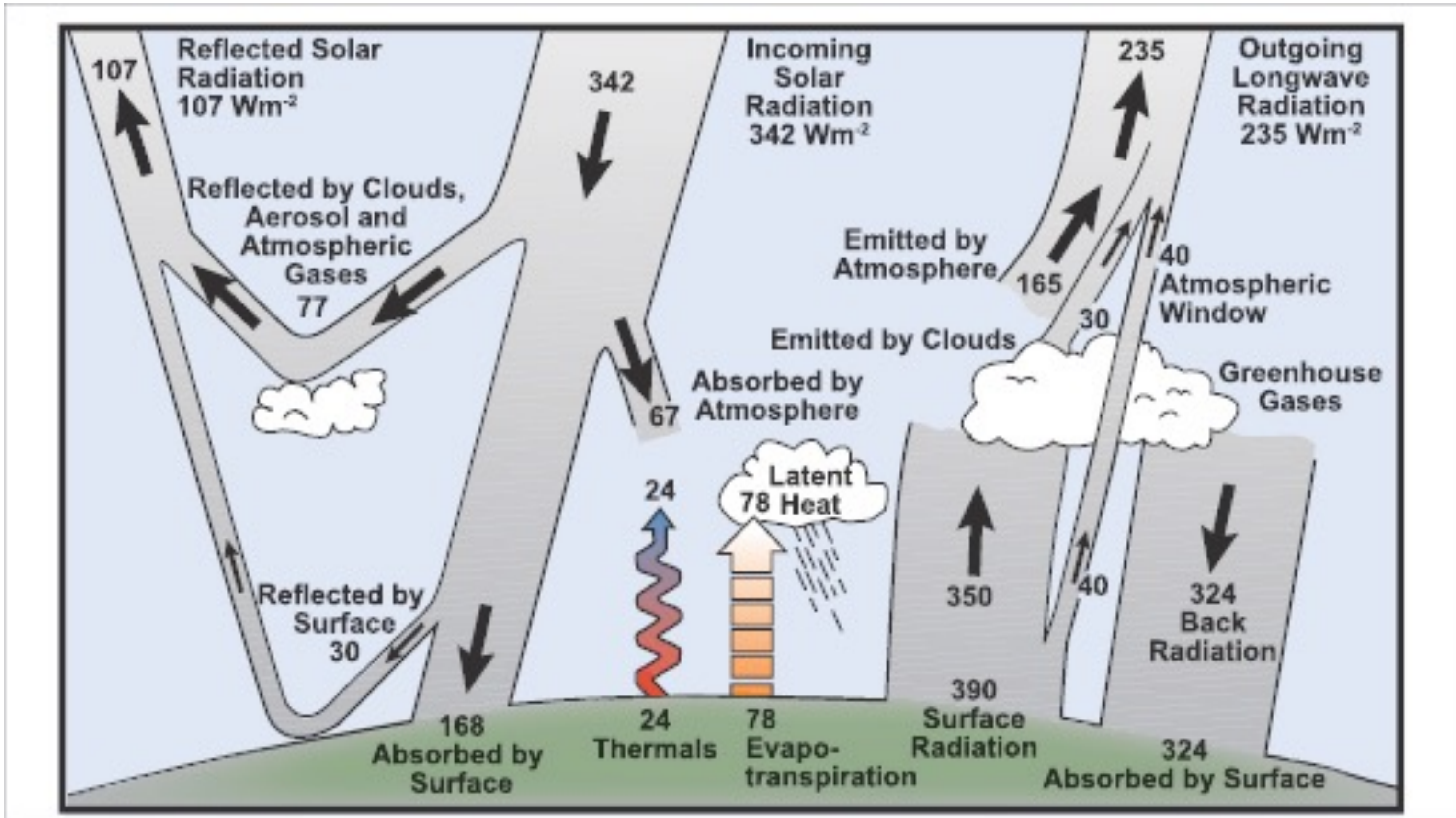
Air-Sea Heat Fluxes

$$Q_{net} = Q_{sw} - Q_{lw} - Q_{lat} - Q_{sen}$$

see Cronin et al 2019

Global mean radiation budget



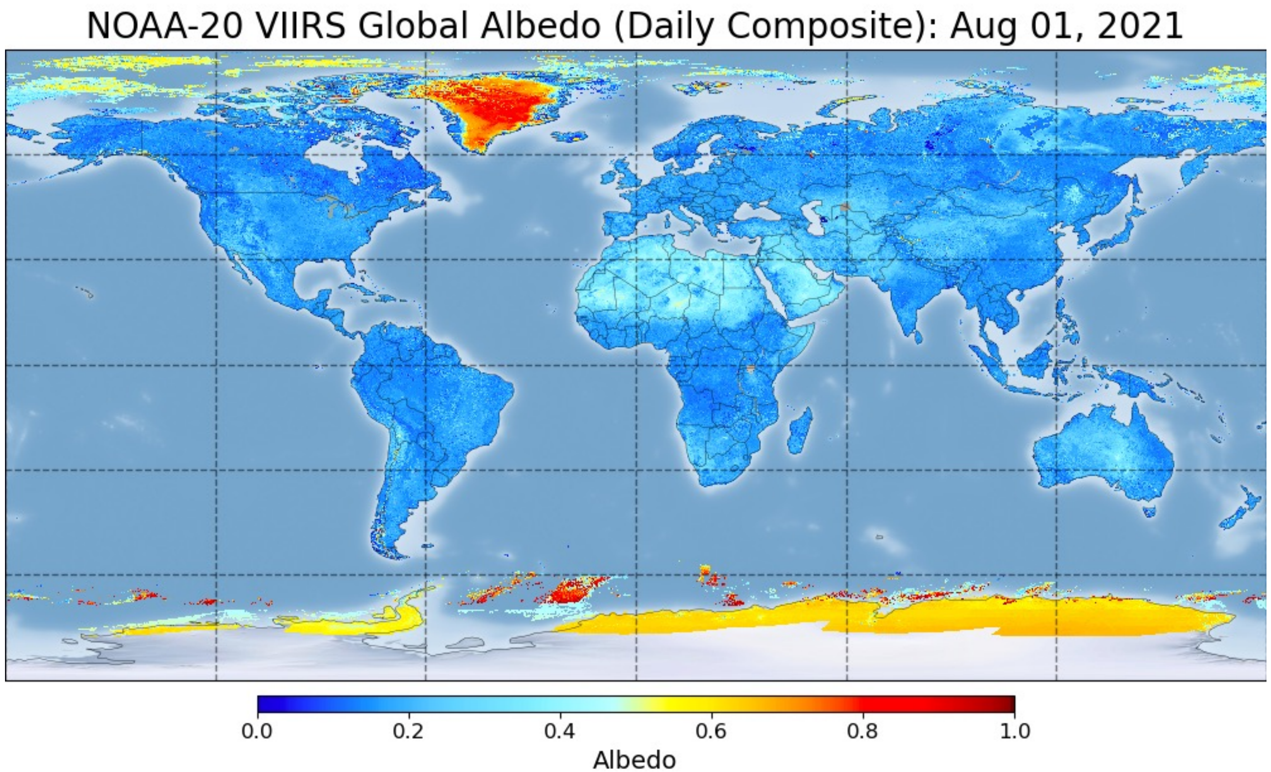
IPCC, AR4

Incoming shortwave radiation
always adds heat (av. rate ~ 175 Wm^{-2})

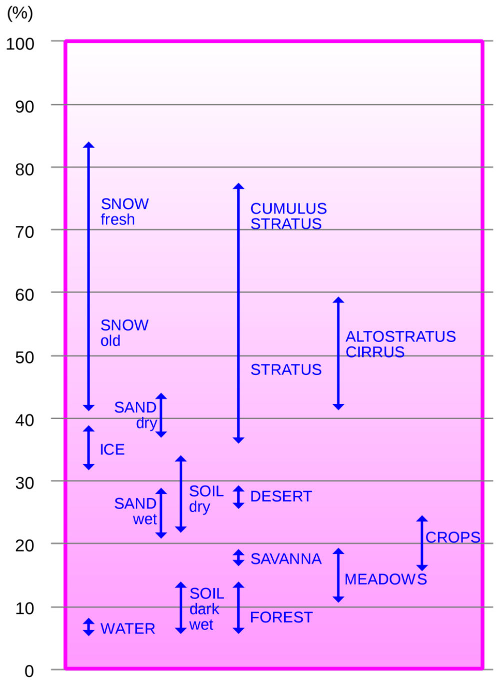
Simple parameterization:

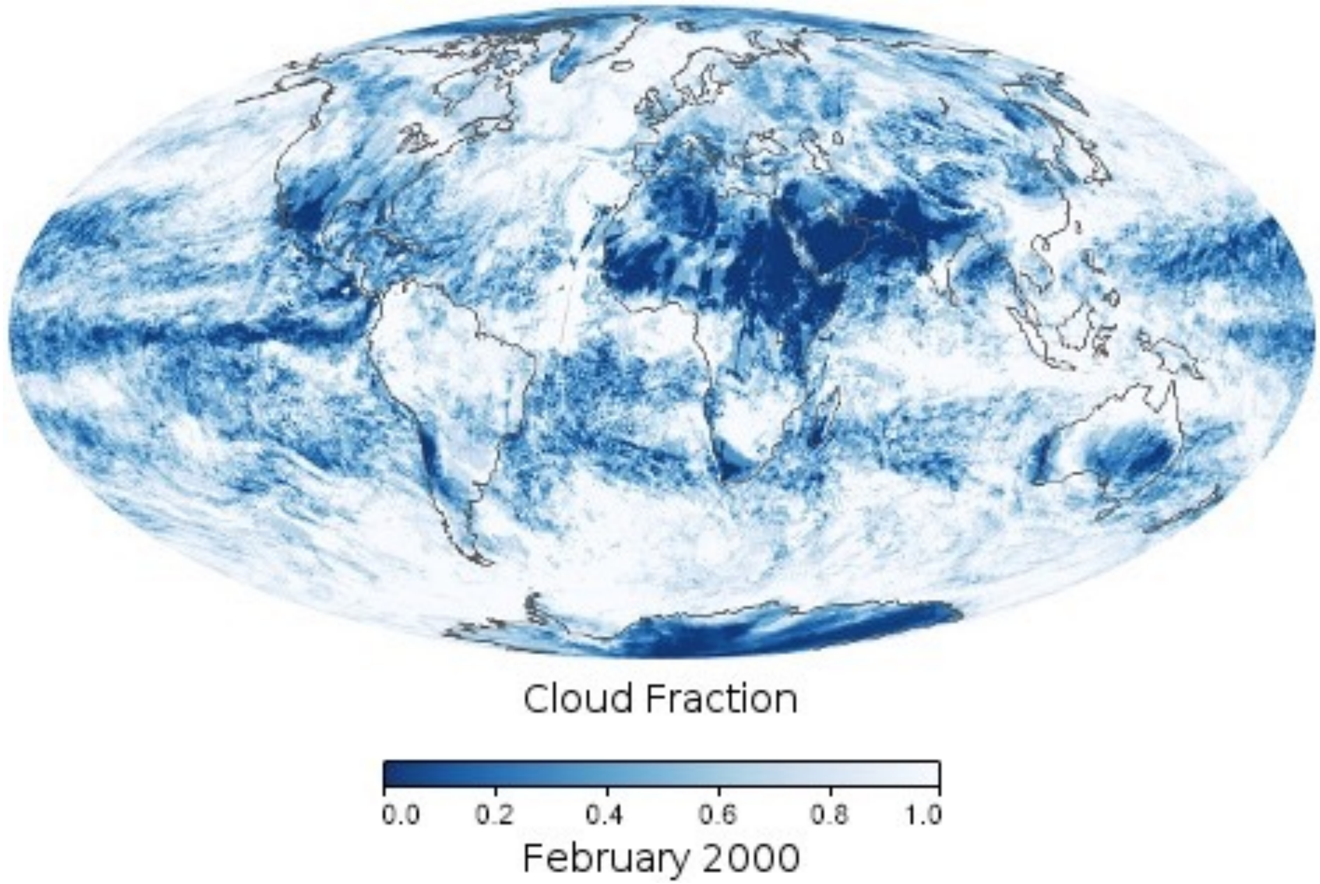
$$Q_I = Q_{I_0}(1 - \alpha_s)(1 - 0.7n_c)$$

Q_{I0}	incoming radiation under cloudless conditions, a function of sun's position
n_c	fraction of sky covered by cloud
α_S	surface albedo. Depends on angle of incidence and spectral distribution of solar radiation, and ocean surface texture.


NOAA-20 VIIRS Global Albedo (Daily Composite): Aug 01, 2021
0.0
0.2
0.4
0.6
0.8
1.0
Albedo

Wikipedia


(%)
100
90
80
70
60
50
40
30
20
10
0
SNOW fresh
CUMULUS STRATUS
SNOW old
ALTOSTRATUS CIRRUS
STRATUS
SAND dry
ICE
SOIL dry
DESERT
SAND wet
CROPS
SAVANNA
MEADOWS
SOIL dark wet
FOREST
WATER



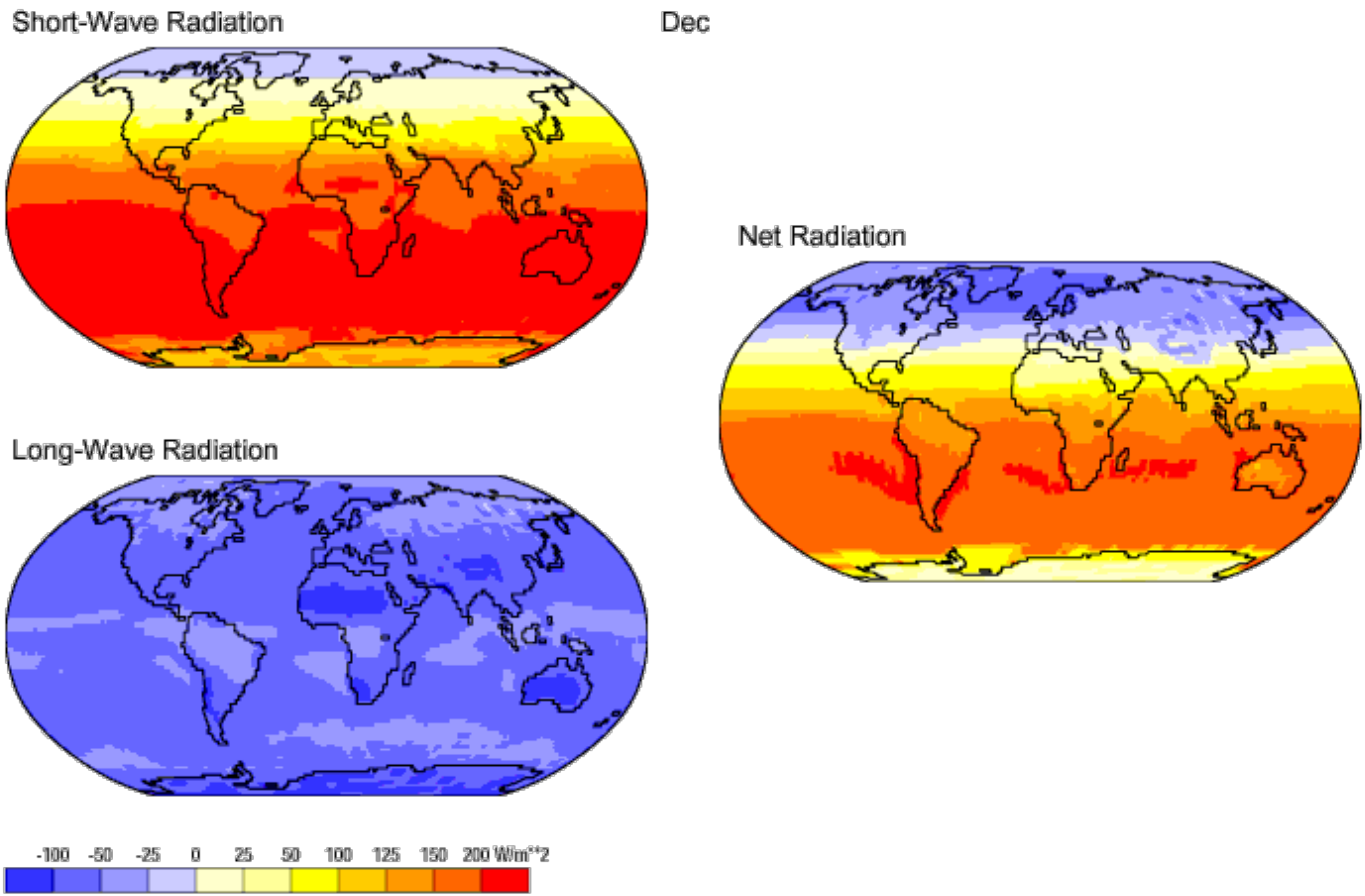
NASA (MODIS)

Longwave radiation
removes heat (av. Rate ~ 65 Wm^{-2})

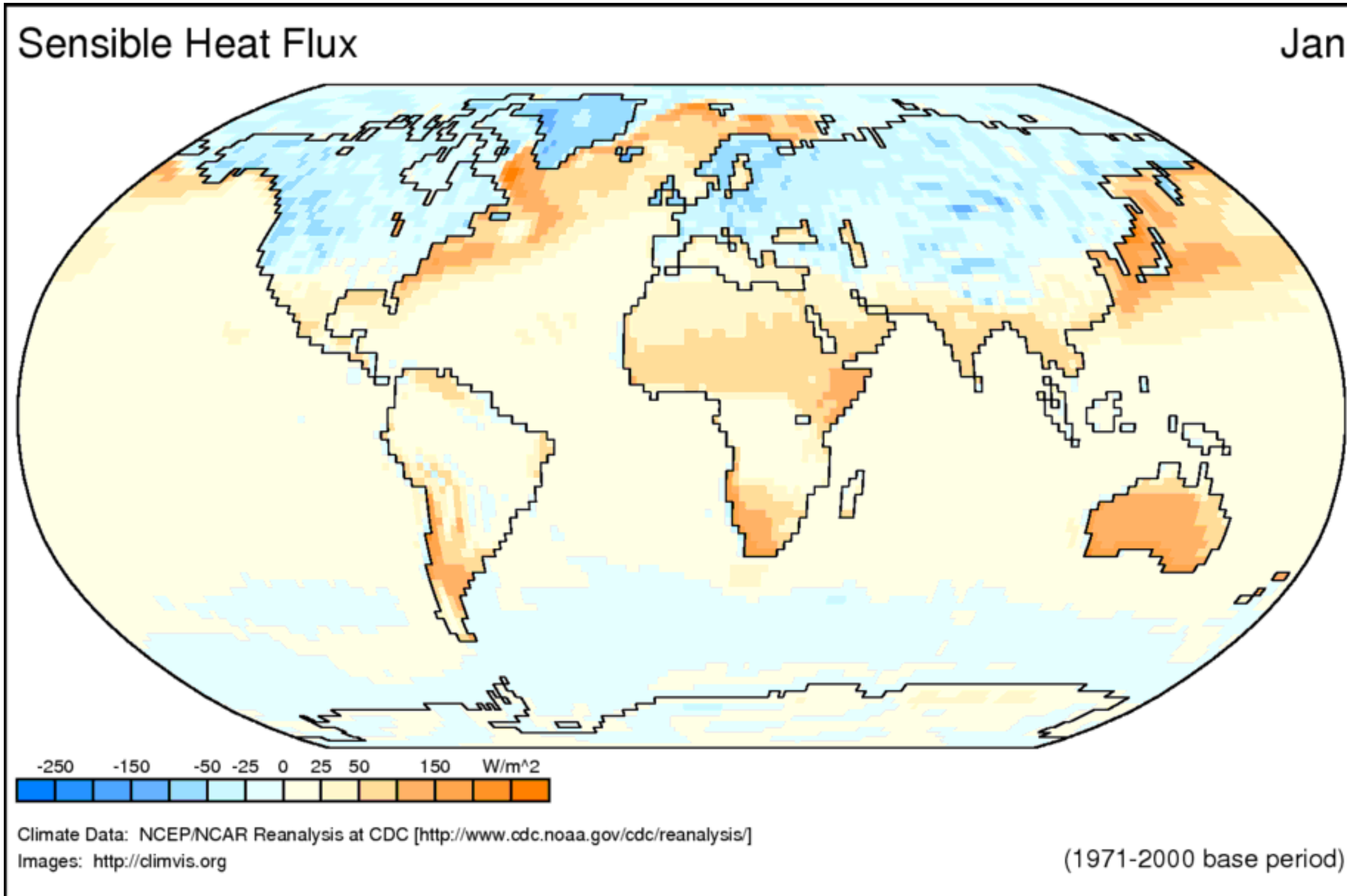
Simple parameterization:

$$Q_B = 0.985\sigma T^4(0.39 - 0.05\sqrt{e_a})(1 - 0.6n_c^2)$$

e_a vapor pressure of water in atmosphere at standard height.

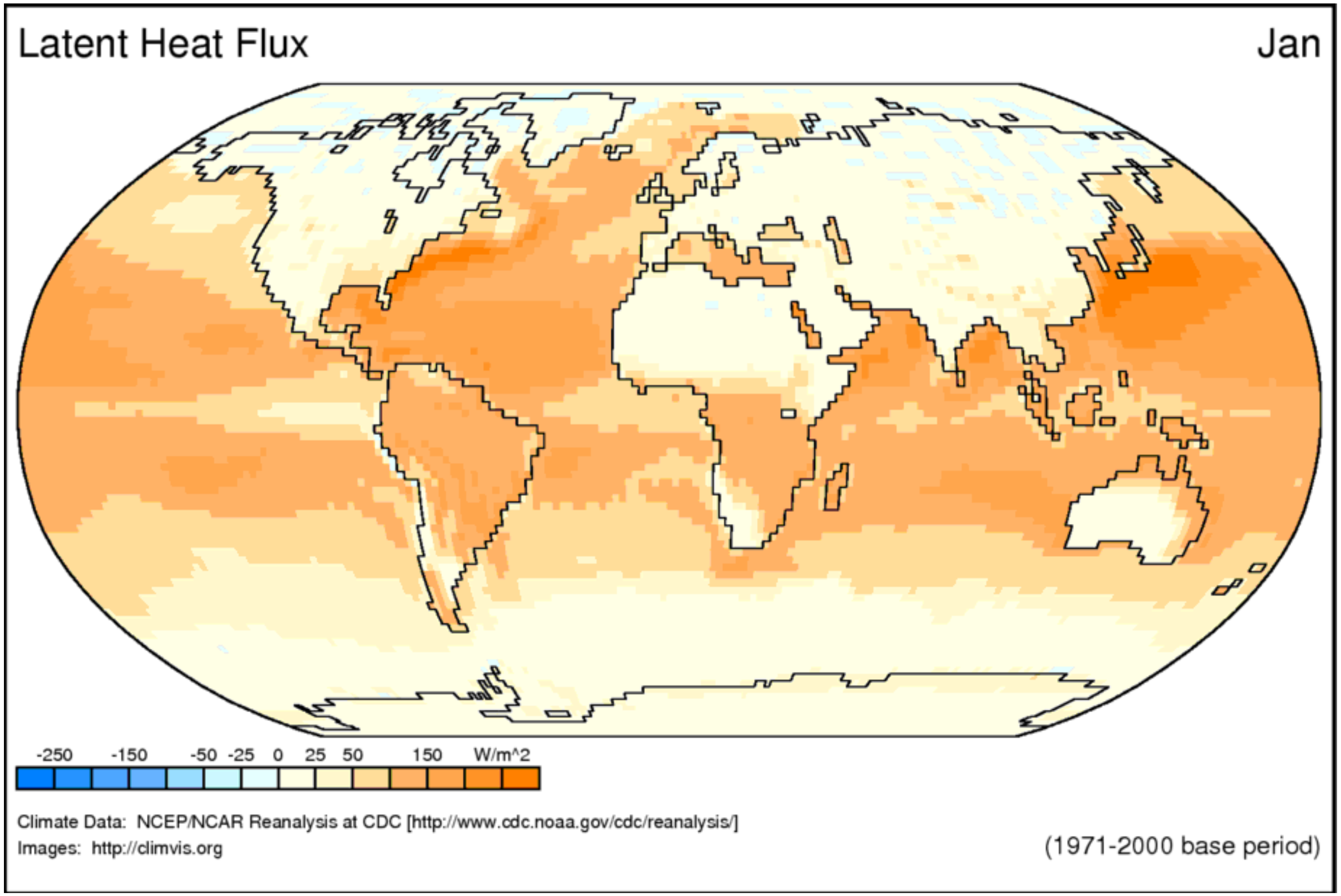


Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000



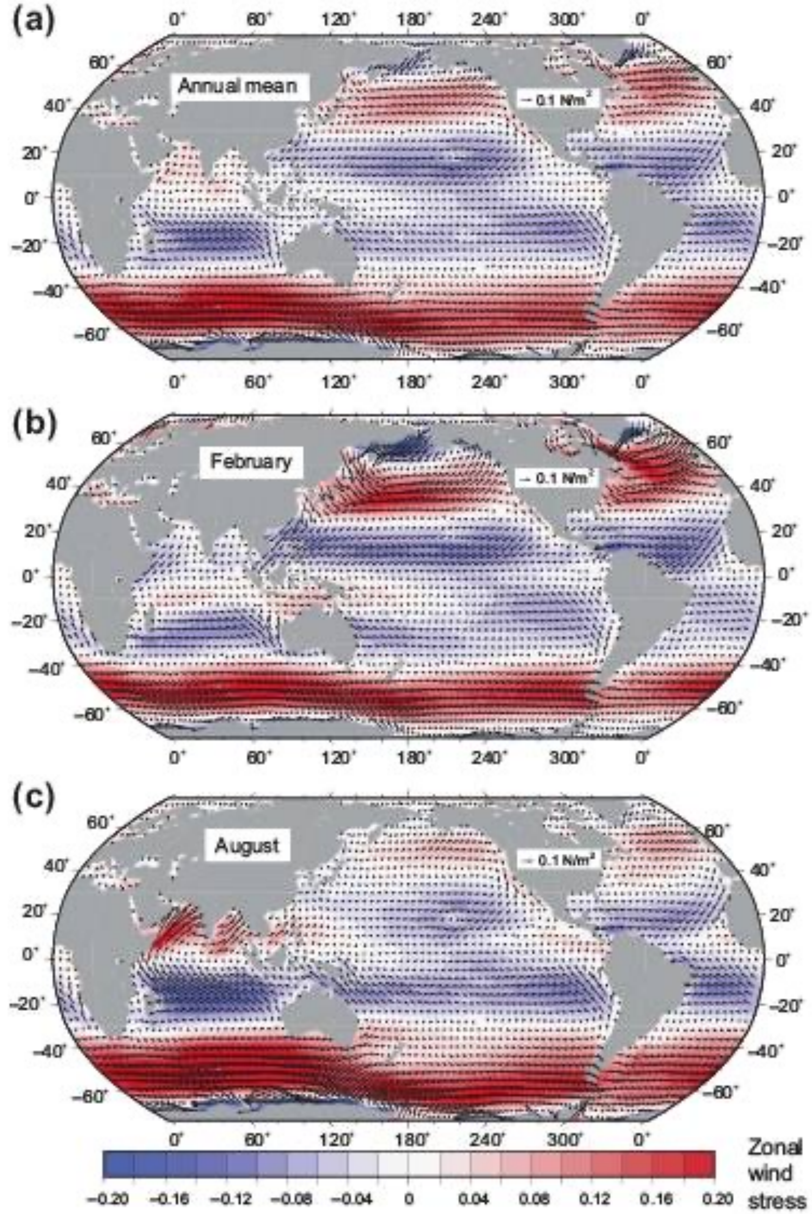
$$Q_s = \rho_a c_p C_h |U_{10}| (T_s - T_a)$$

c_p specific heat of air, C_h heat transfer coefficient



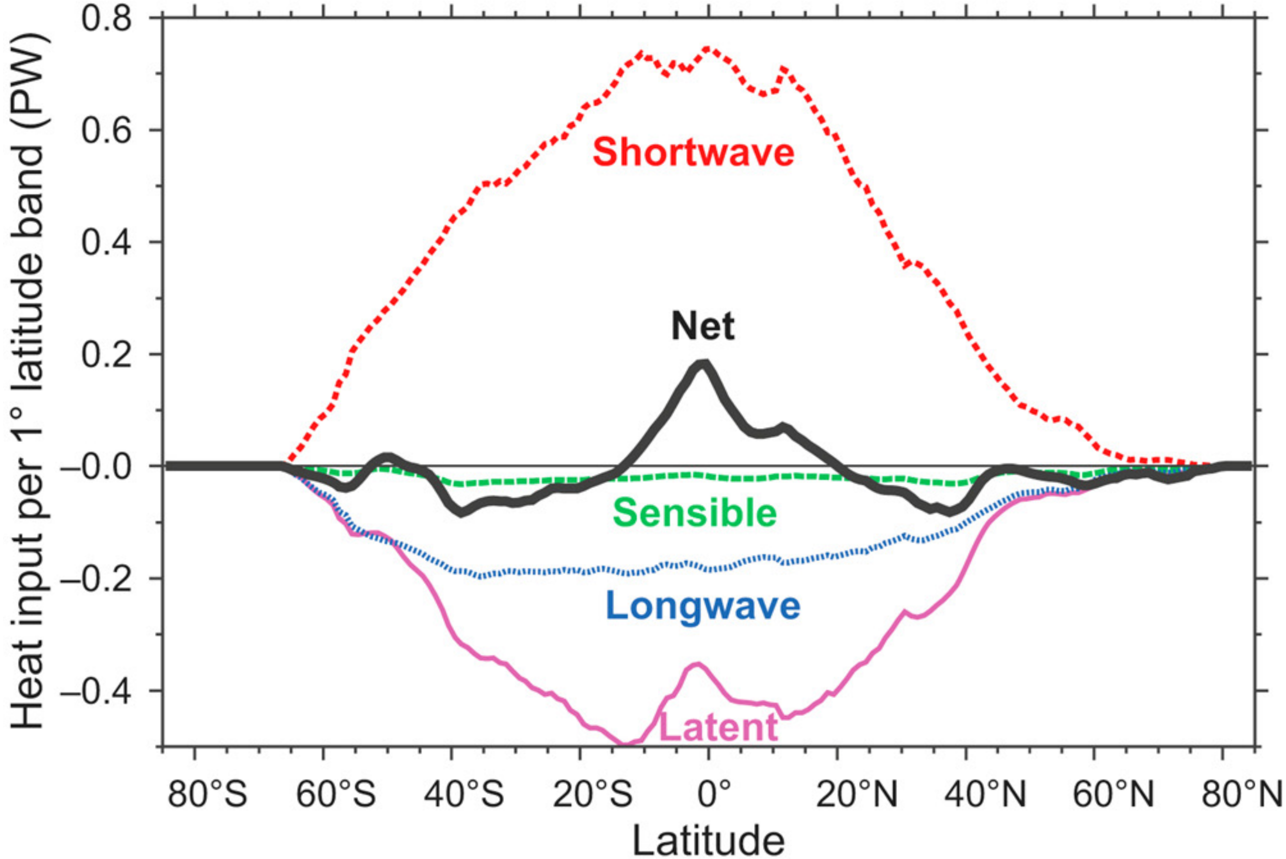
$$Q_L = L_v E \qquad\qquad E = \rho_a C_E |U_{10}| (q_s - q_a)$$

L_v latent heat of evaporation, q_s saturation humidity at SST, q_a specific humidity at 10m



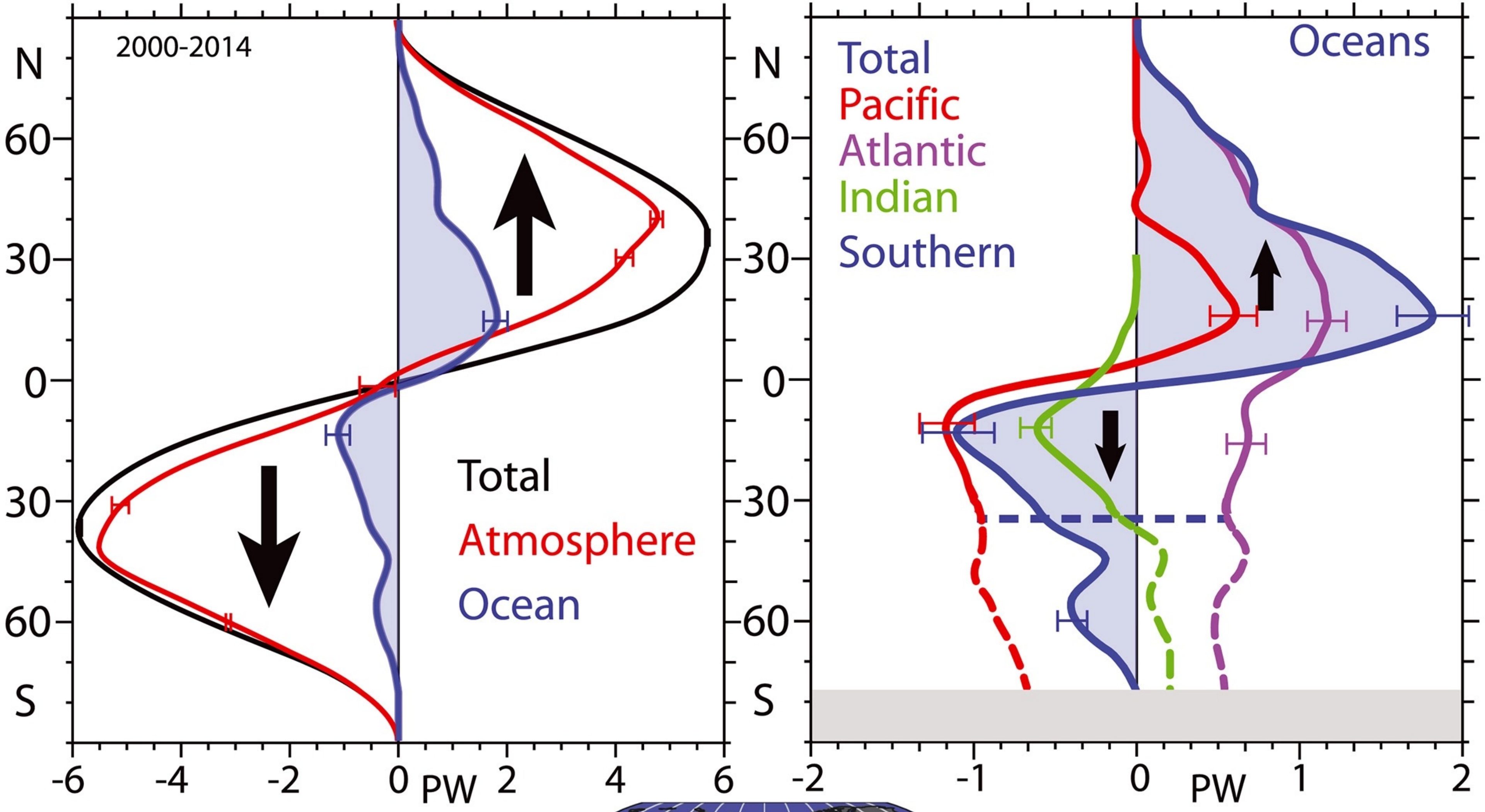
Talley et al, 2011

Annual mean fluxes with latitude

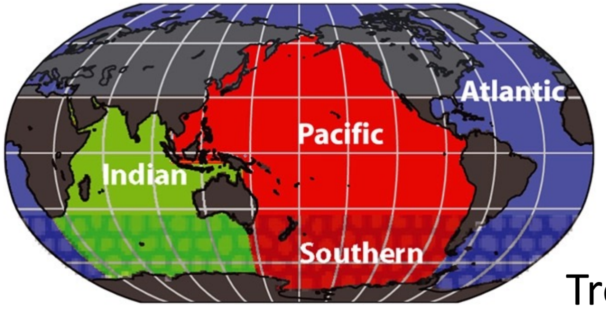


Talley et al, 2011

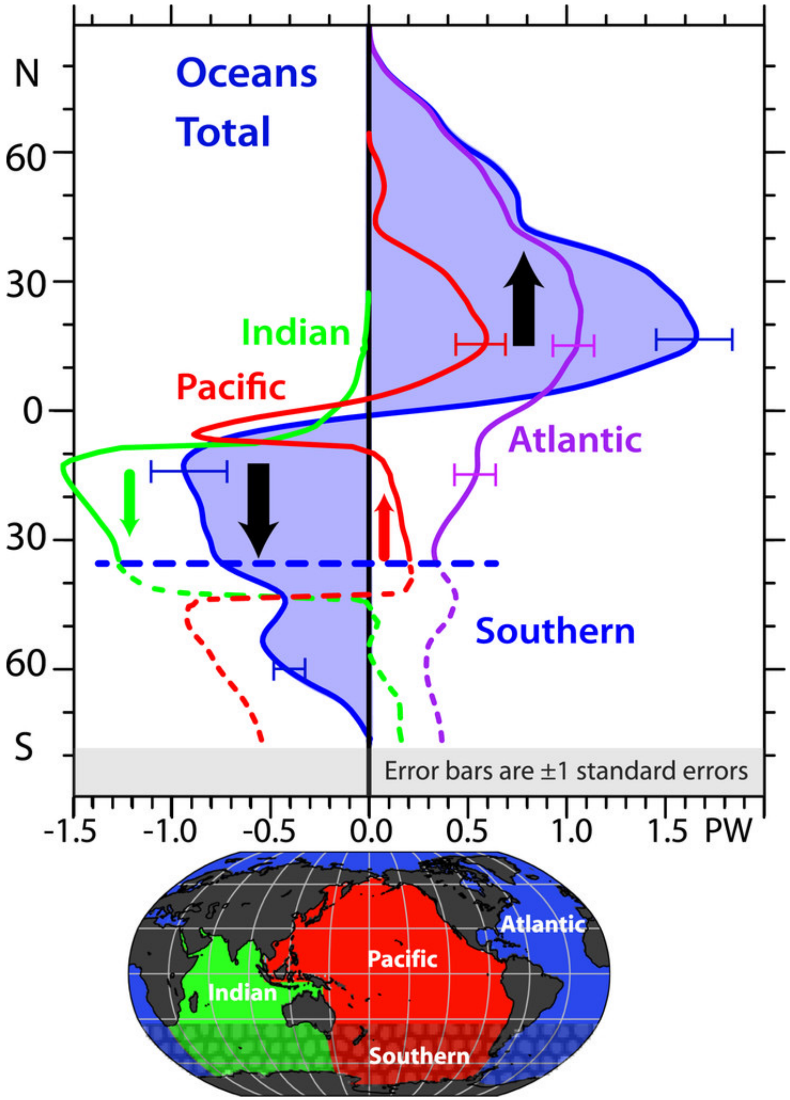
Annual mean northward energy transports



Error bars are ±1 standard errors



Trenberth and Fasullo GRL 2017



Taking ITF into account
Trenberth and Zhang JC 2019

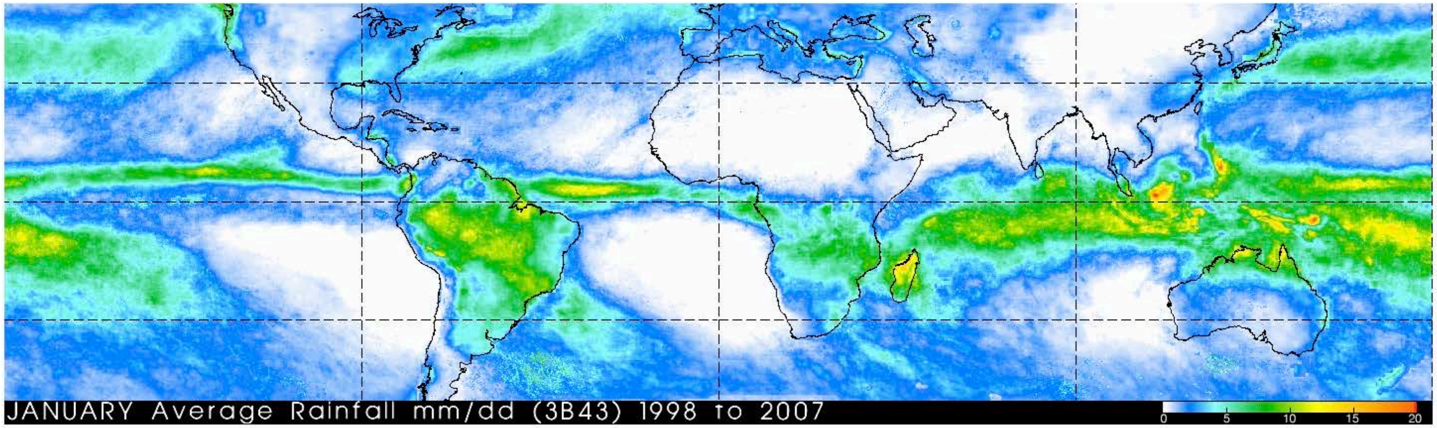
Heat budget

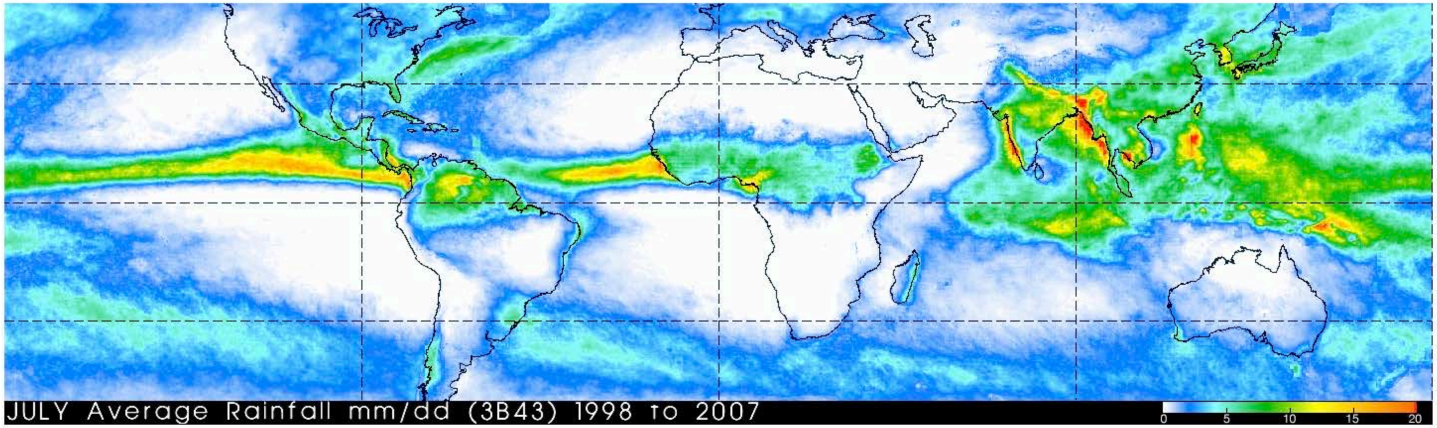
$$\left\langle \frac{\partial T}{\partial t} \right\rangle = \frac{1}{h}\left[\frac{1}{\rho c_p}(Q_{net} - q_{-h}) - \left(\kappa_z \frac{\partial T}{\partial z}\right)\Big|_{z=-h}\right] - \langle \mathrm{adv} \rangle \; + \langle \mathrm{lat\ diff} \rangle$$

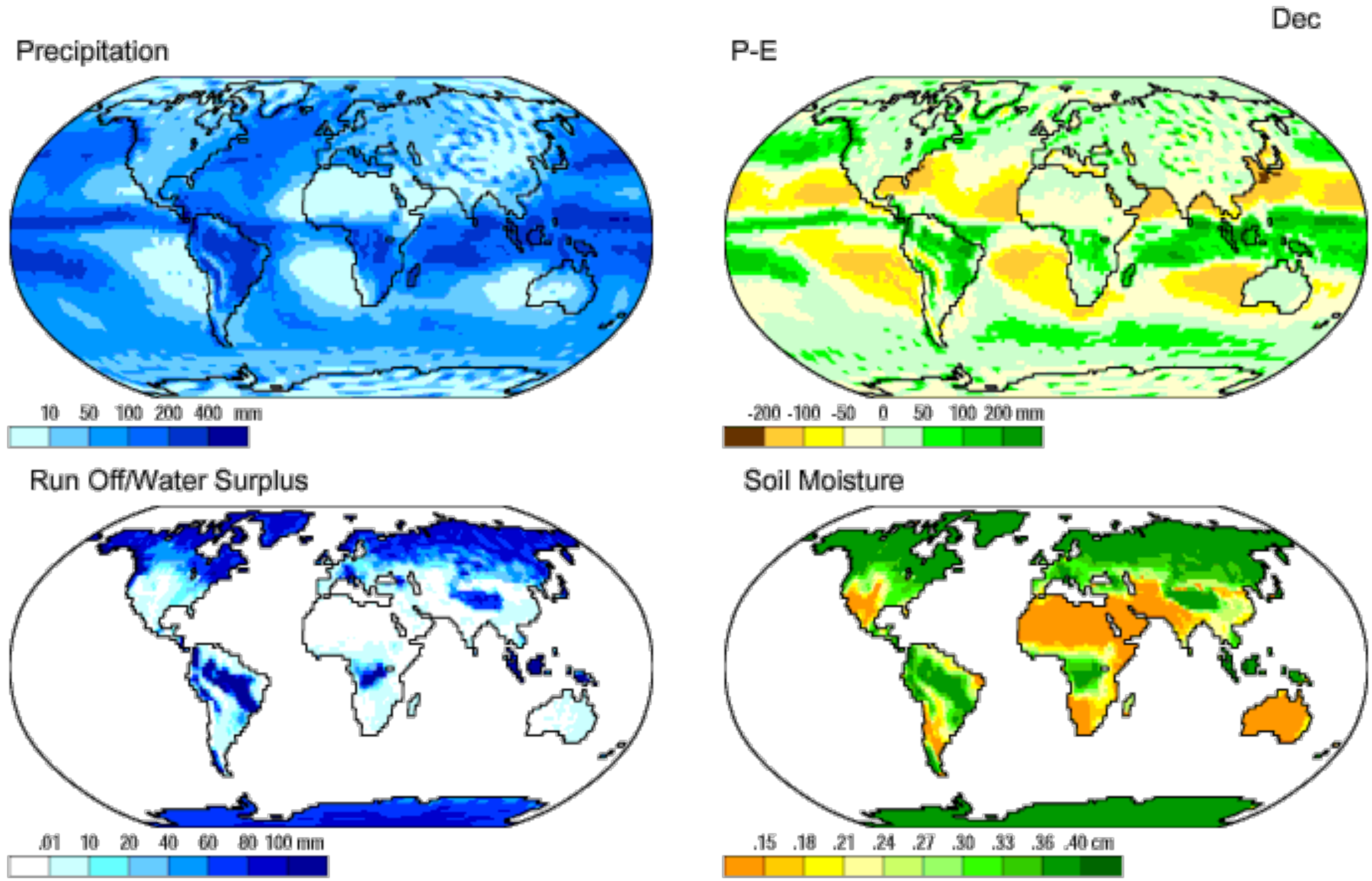
$$\langle \; \rangle = \frac{1}{h}\int_{-h}^{0} dz$$

Salt
(fresh water flux)

Precipitation: TRMM





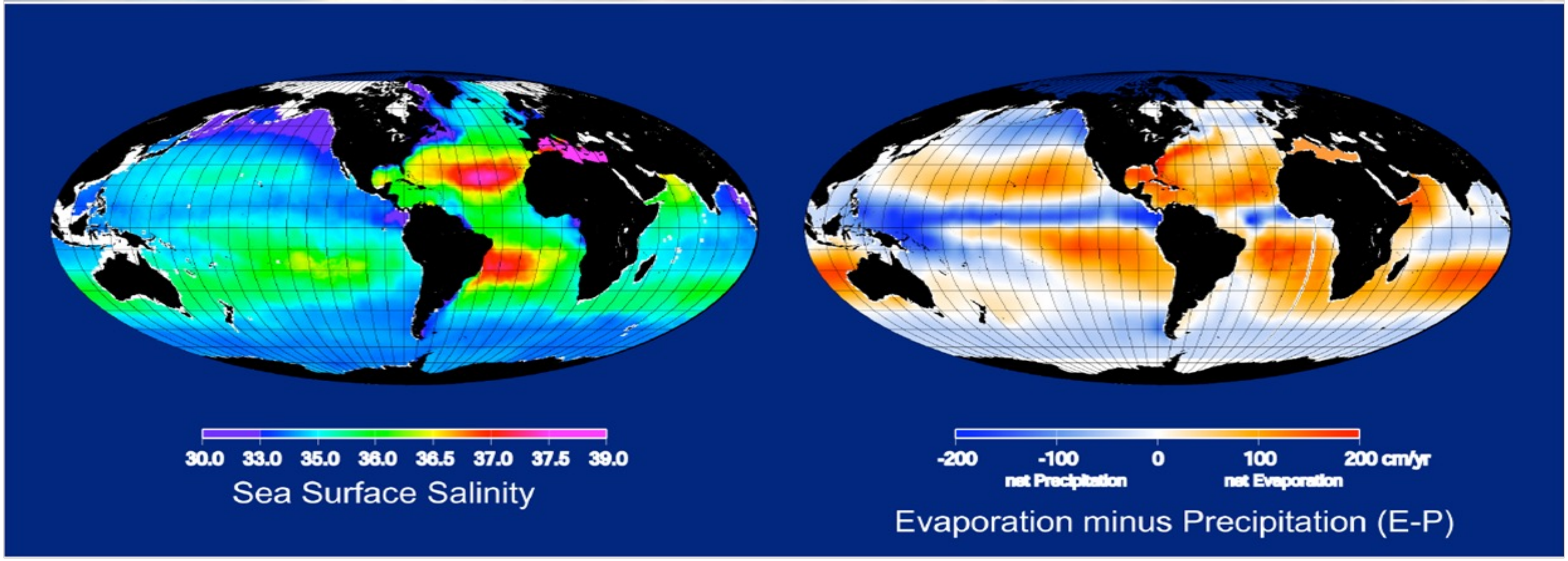


Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Salt budget

$$\left\langle \frac{\partial S}{\partial t} \right\rangle = \frac{1}{h} \left[S_{ref}(E - P) - \left(\kappa_z \frac{\partial S}{\partial z} \right) \Bigg|_{z=-h} \right] - \langle \mathrm{adv} \rangle \ + \langle \mathrm{lat\ diff} \rangle$$

Surface salinity distributions are closely tied to E-P patterns



http://www.salinityremotesensing.ifremer.fr