Global Budgeting

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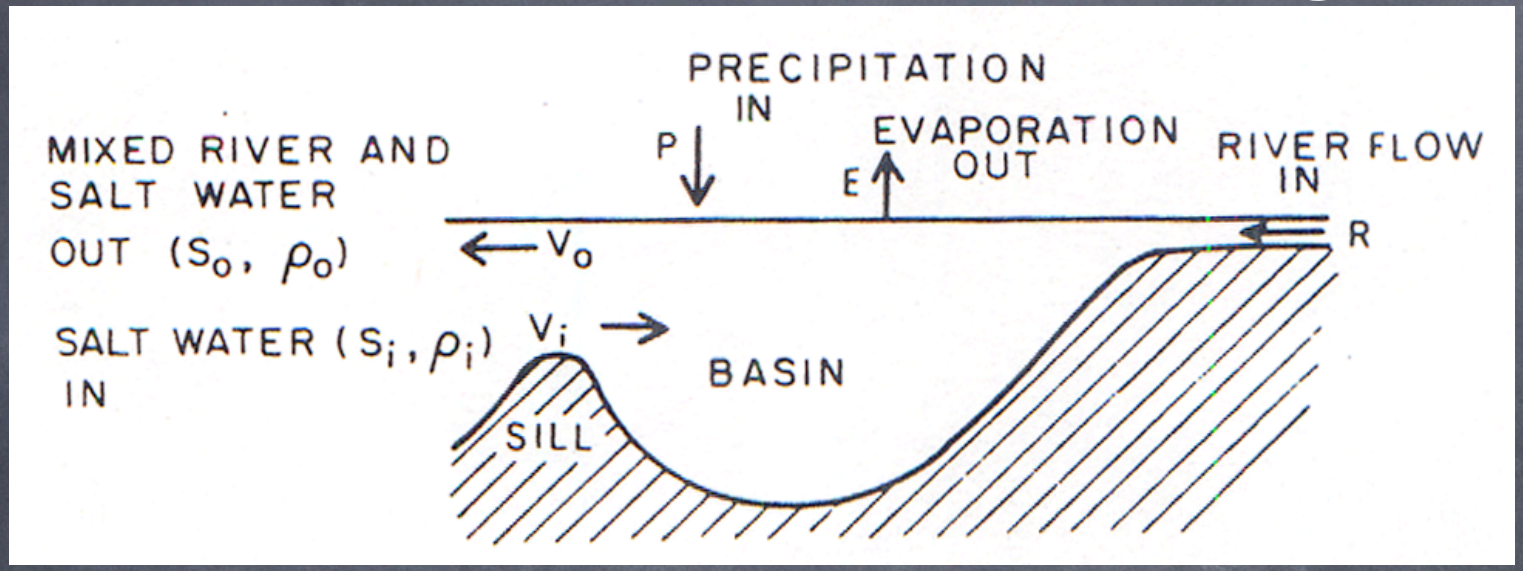
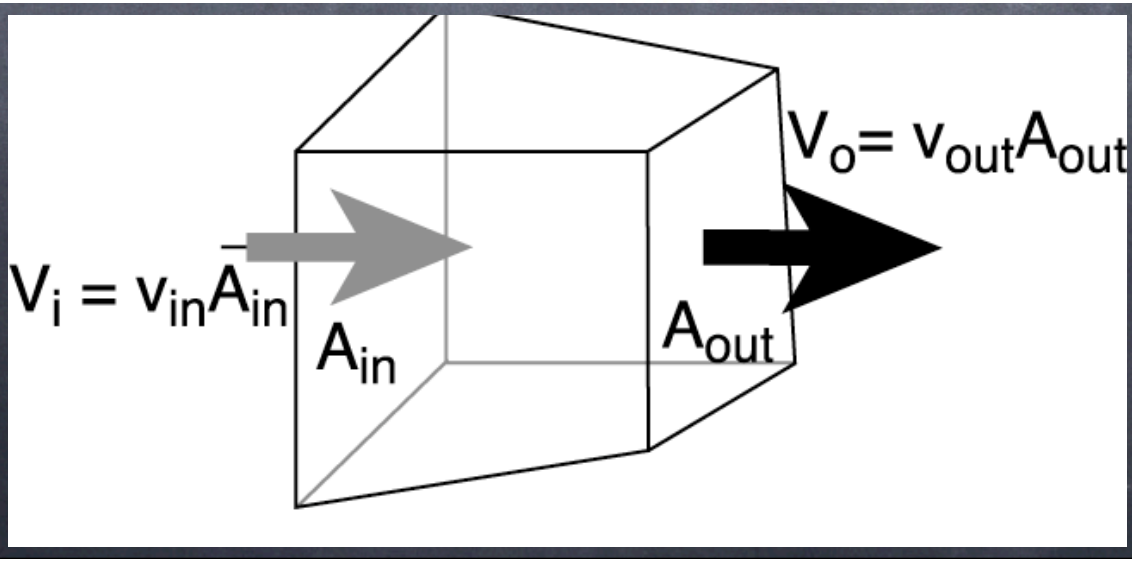
ATOC 5051

The Story So Far:

- We have discussed conservation of Volume, Salt, Energy, and seen some of the equations
- We have seen how potential temperature compensates for pressure/temperature connection, allowing potential temperature to take the role of Entropy/Energy conservation
- We have seen how in estuarine flow, integrating the budgets over a fixed volume leads to manageable equations.

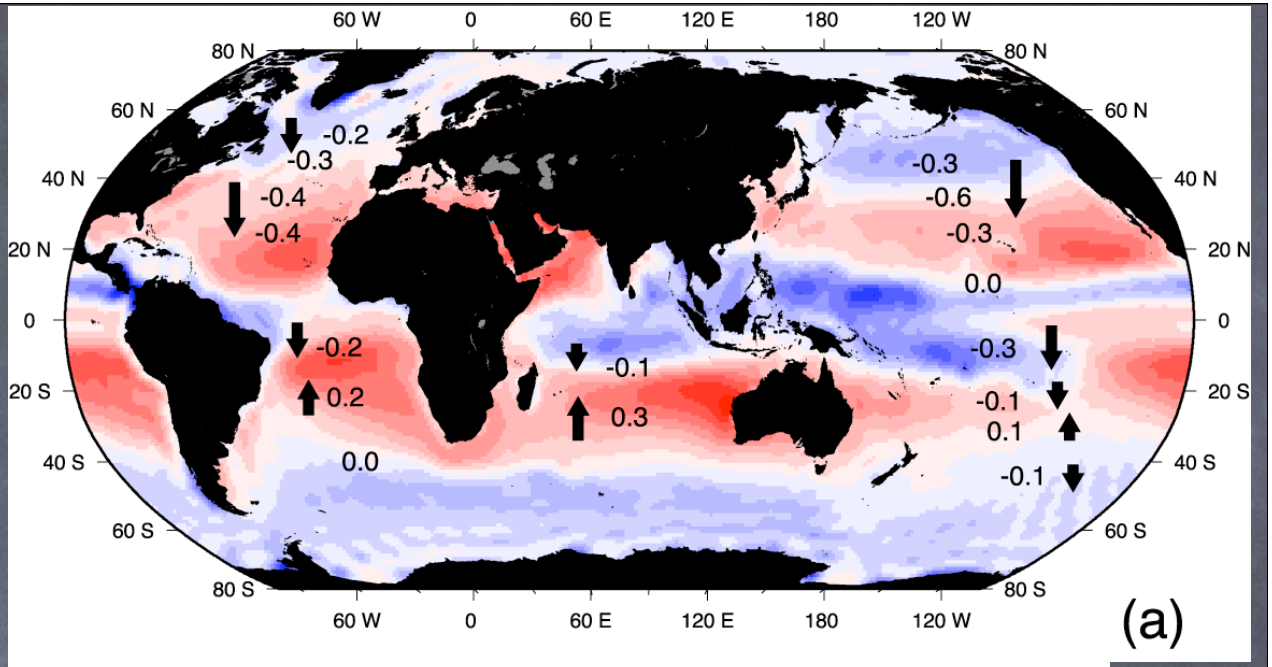
From Estuary to Budget

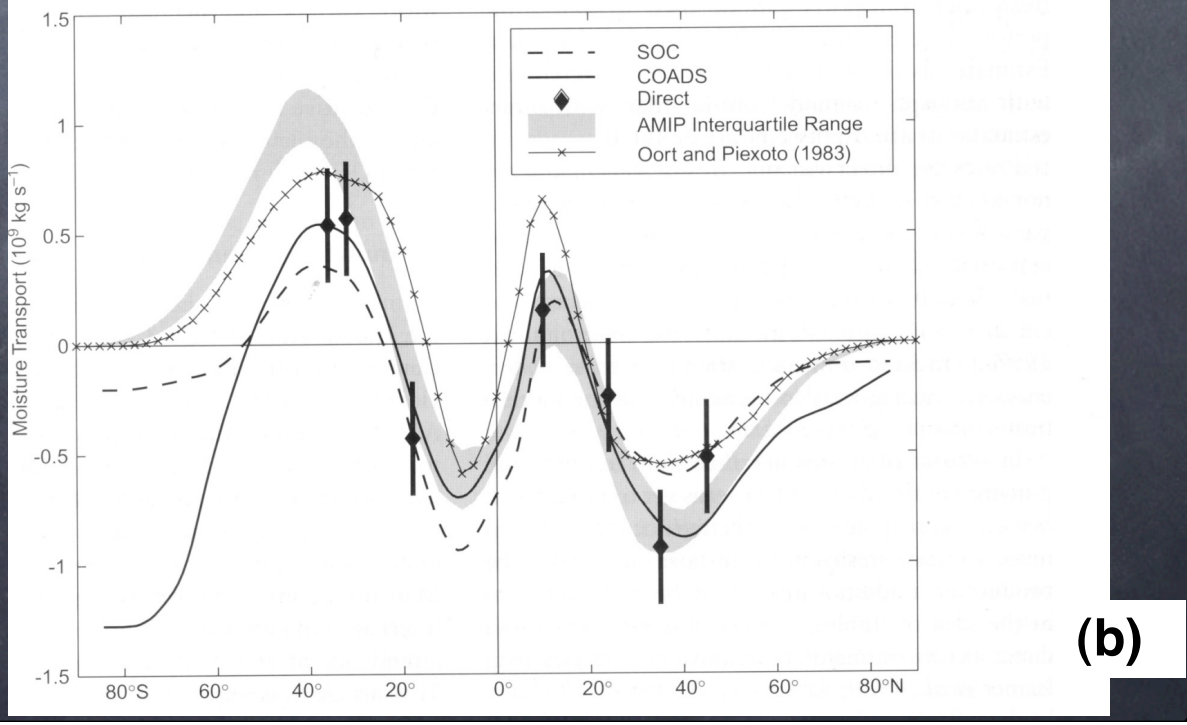




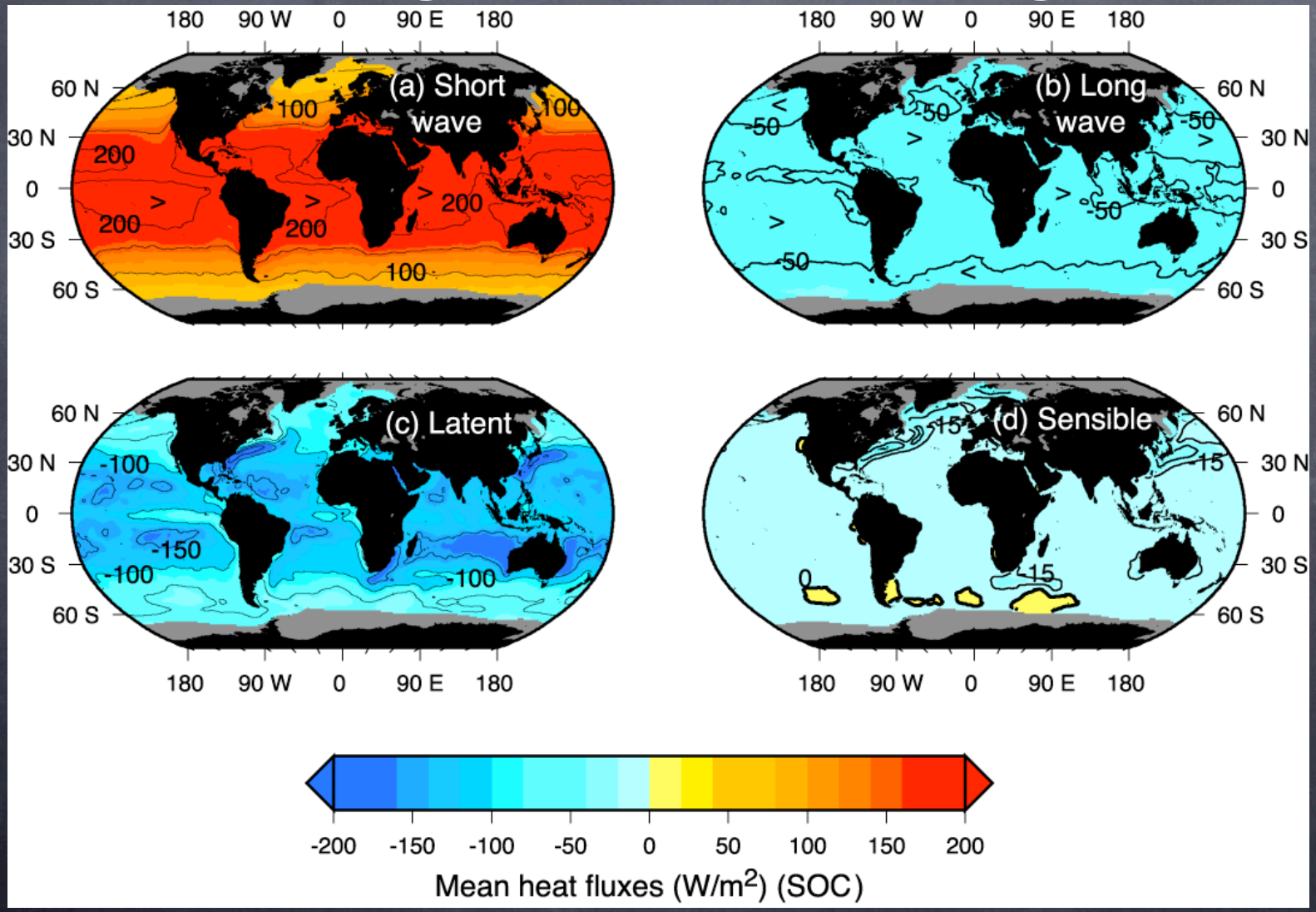
Volume Budget

Consistent with Salinity

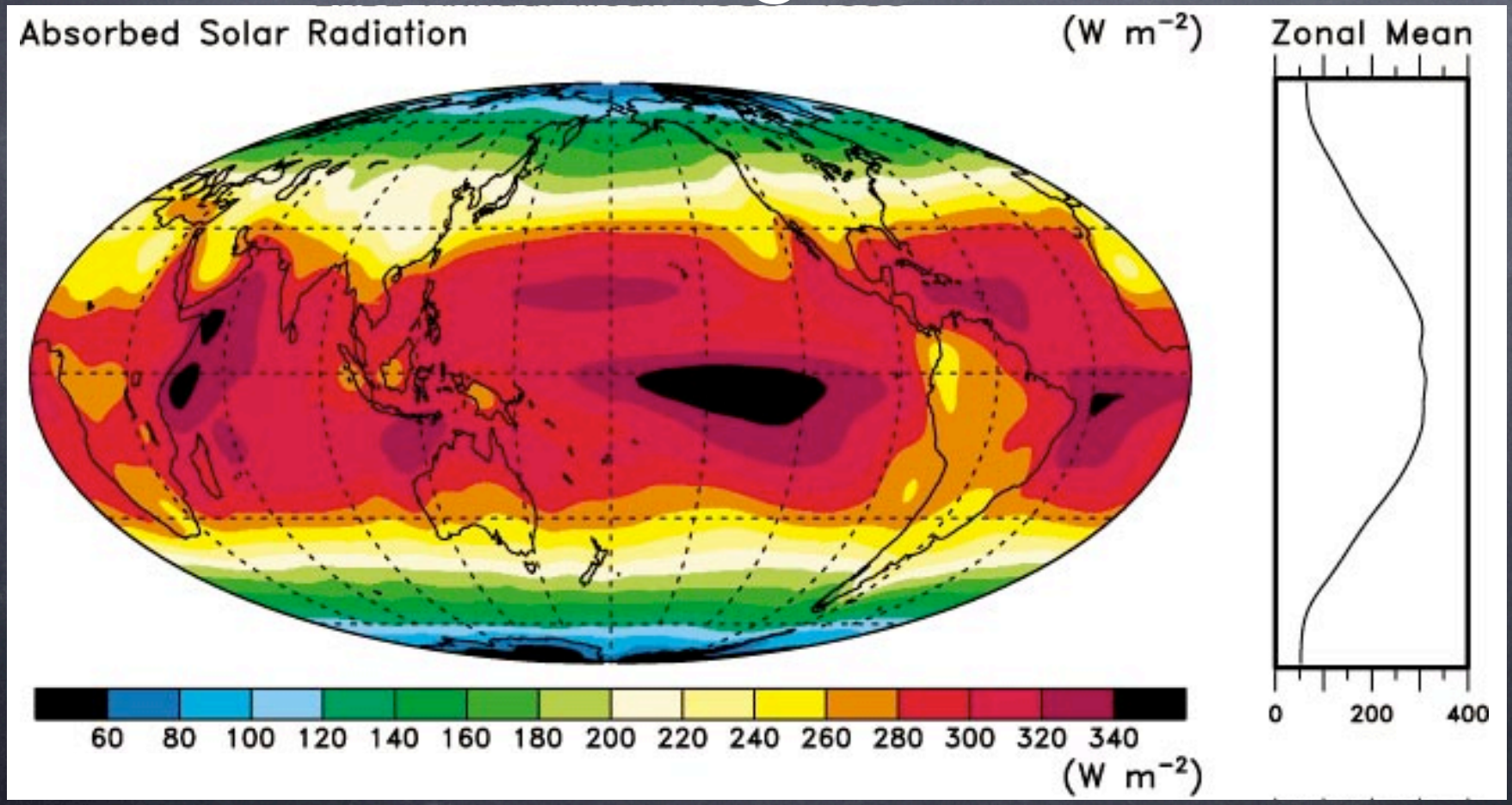




Energy/Heat Budget

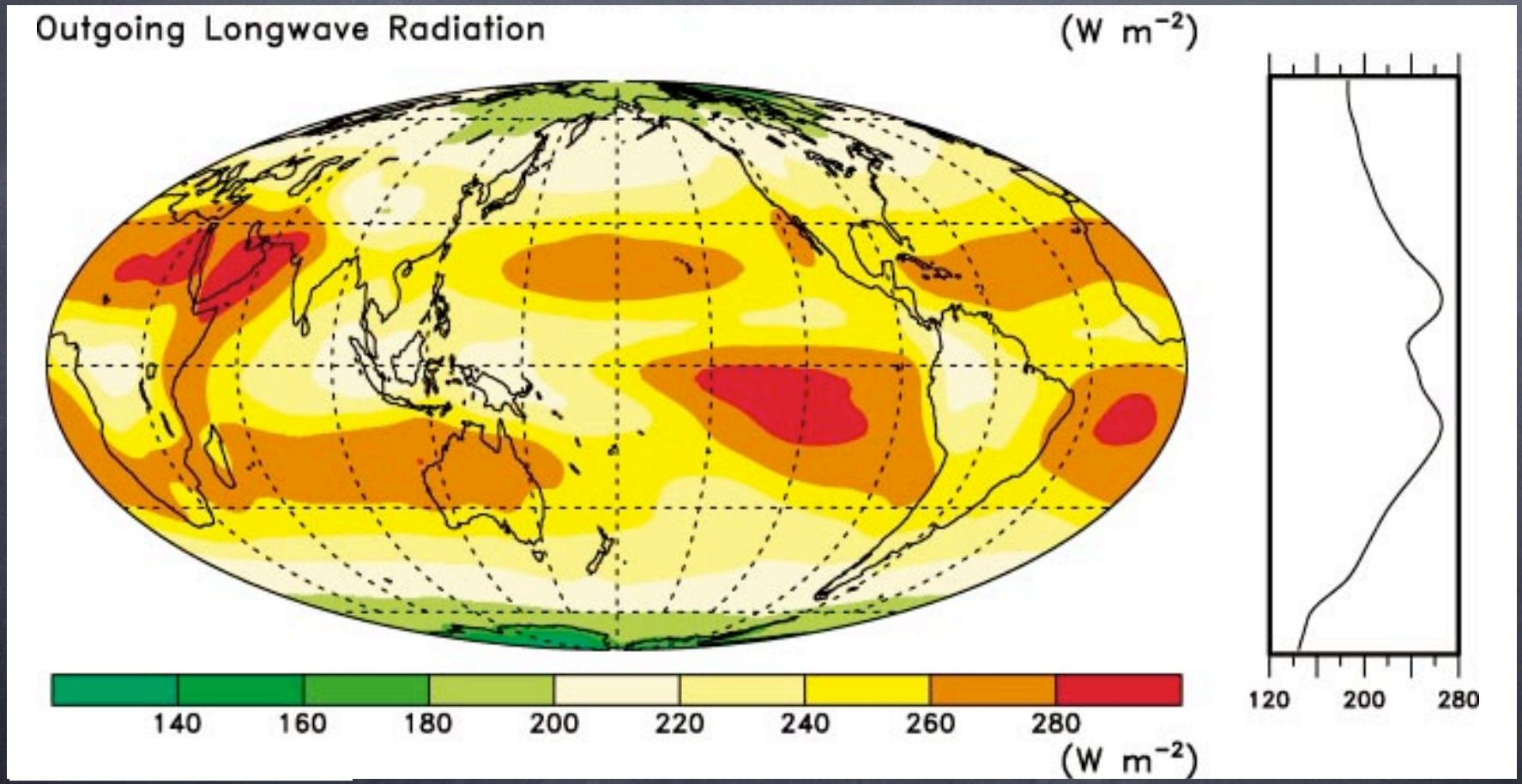


How do we get this?
1) Incoming to Atm.



Trenberth & Stepaniak 03

2) Outgoing from Atm.



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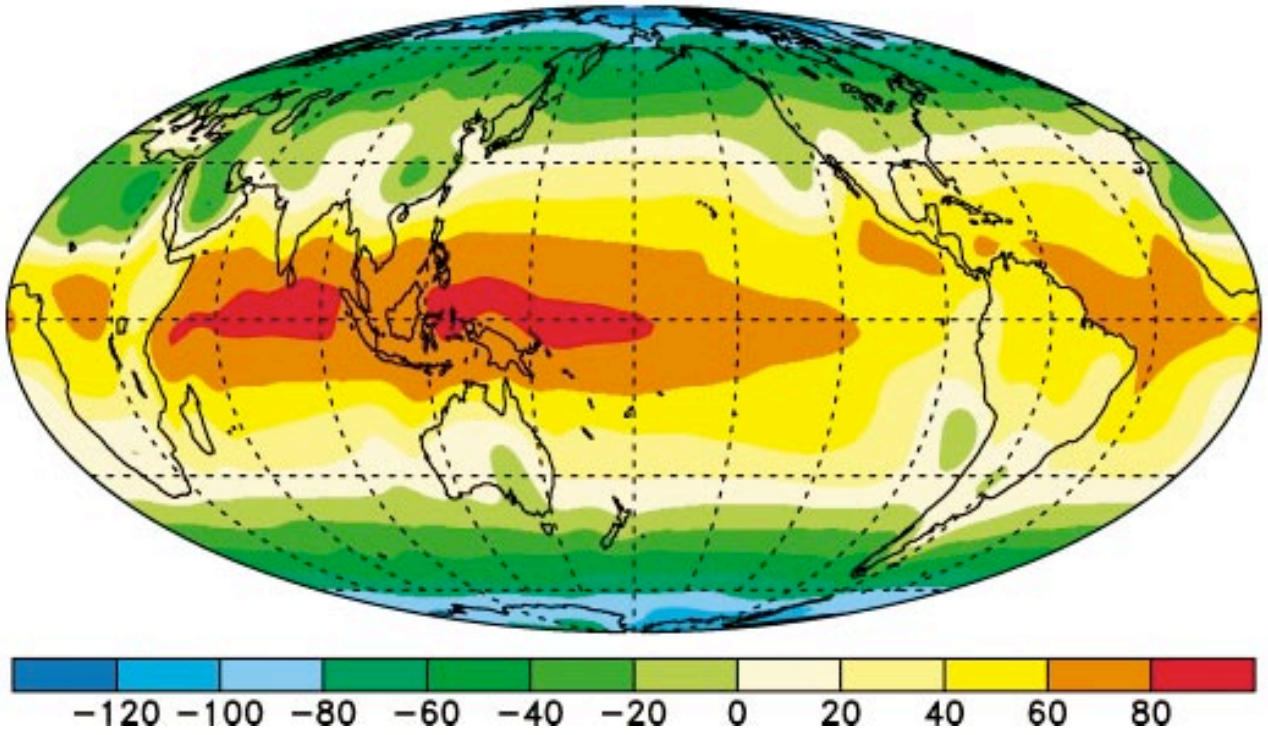
3) Net to Atm.



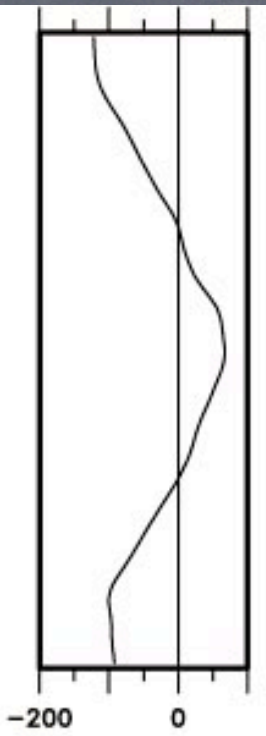


FIG. 2. Annualized mean TOA ERBE measurements for the period Feb 1985–Apr 1989 for the ASR, OLR, and net in W m^{-2}. The color key is under each plot and the contour interval is 20 W m^{-2}. Zonal mean profile panels are given at right.

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Account for Atm. Transport w/ Reanalysis

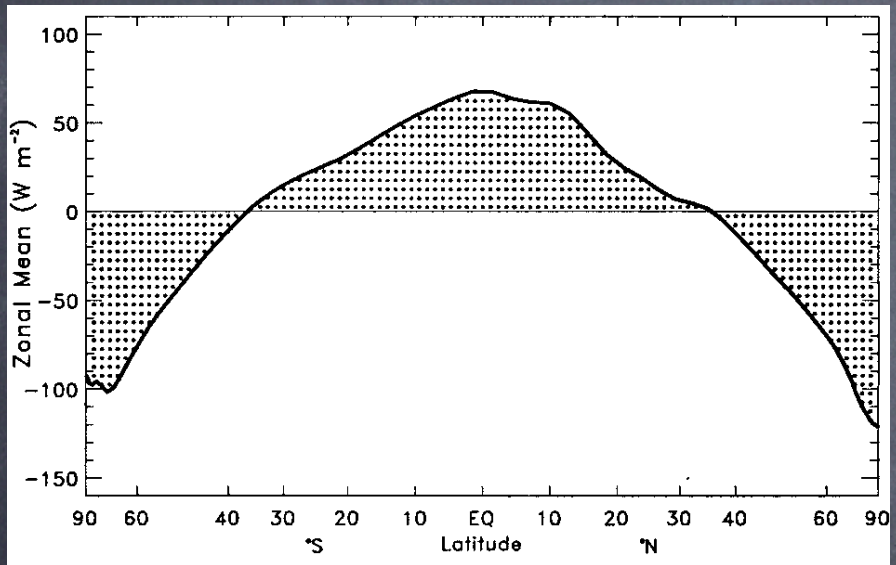


FIG. 1. TOA annualized ERBE zonal mean net radiation (W m^{-2}) for Feb 1985–Apr 1989.

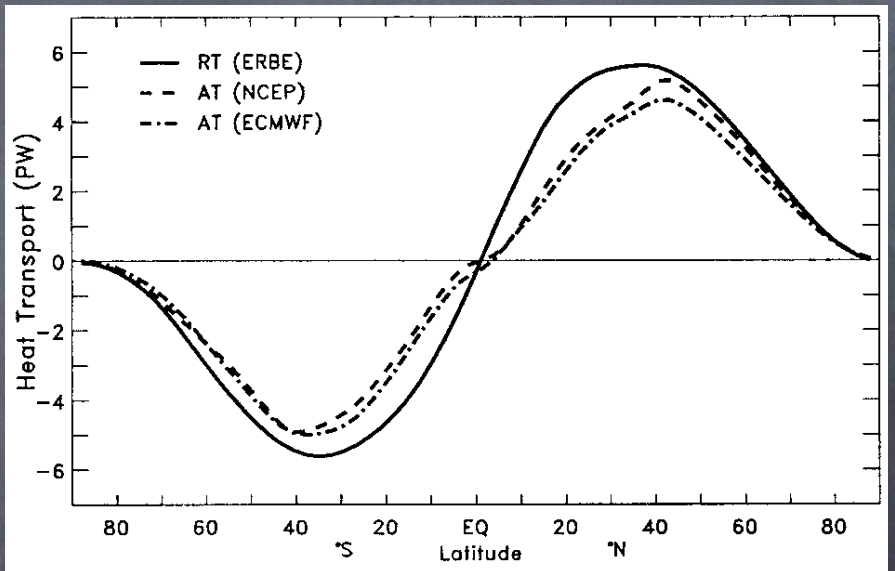


FIG. 2. The required total heat transport from the TOA radiation RT is given along with the estimates of the total atmospheric transport AT from NCEP and ECMWF reanalyses (PW).

Trenberth & Caron 01

What's Left is Ocean (Trenberth & Caron, 01)

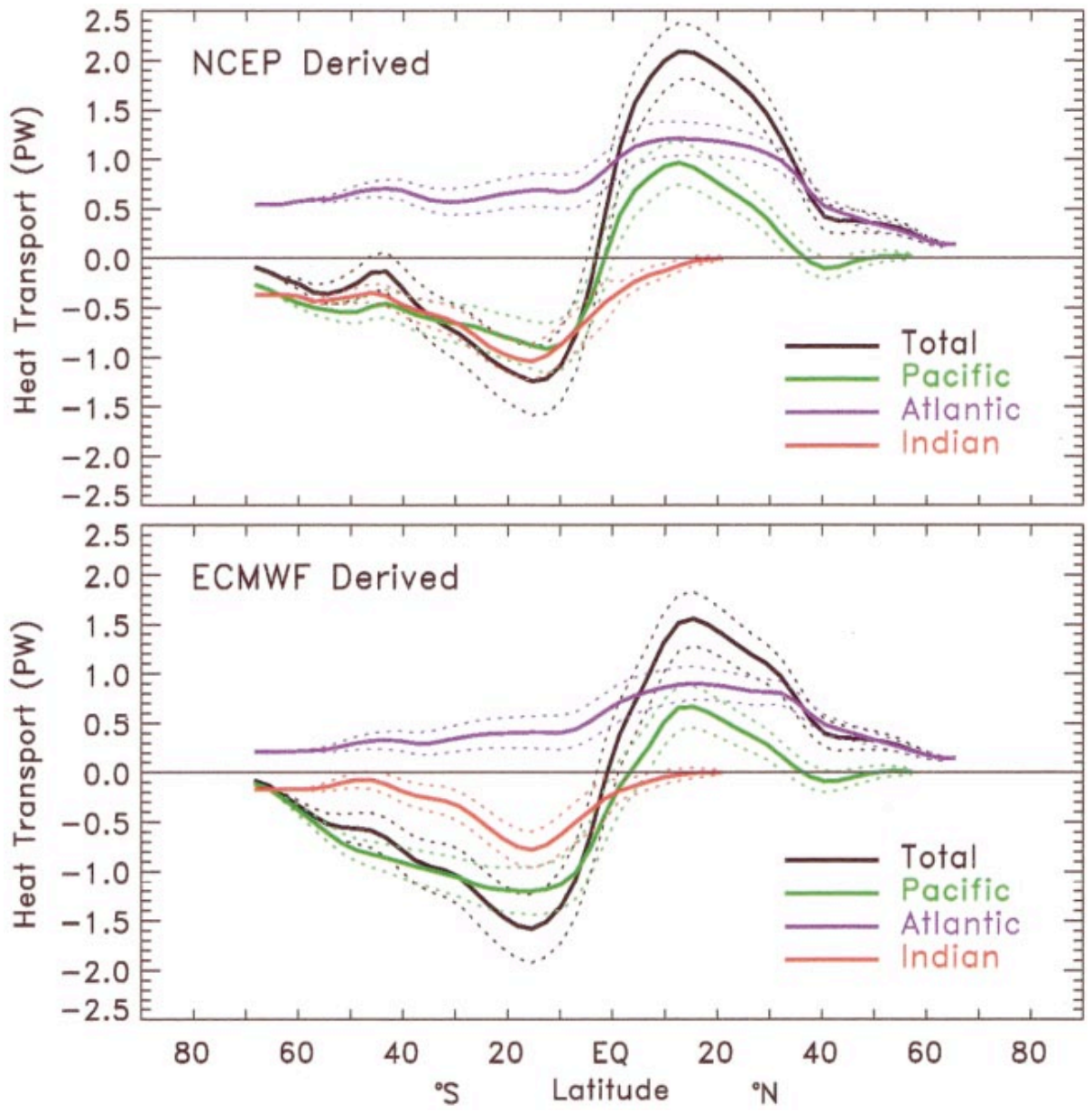
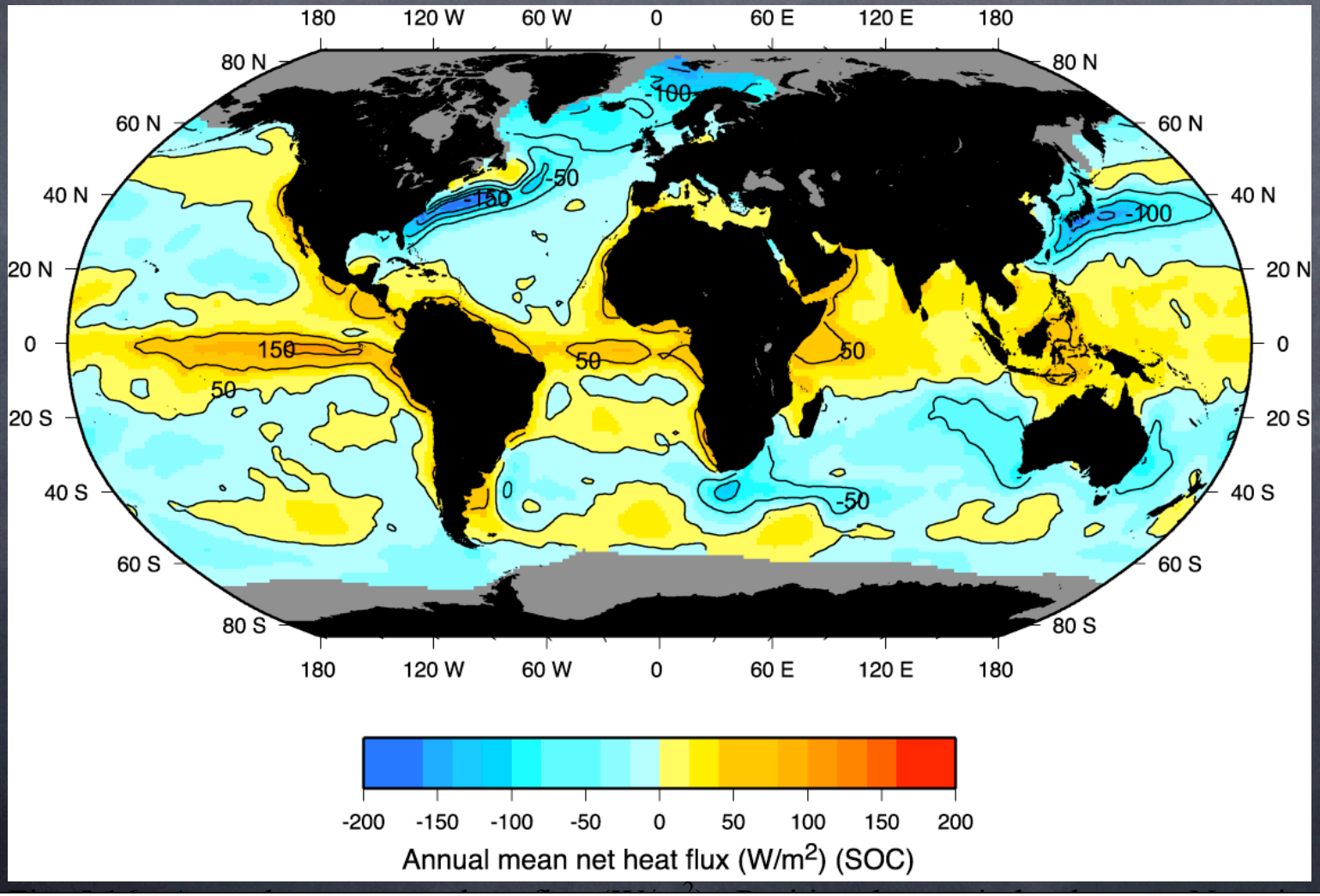
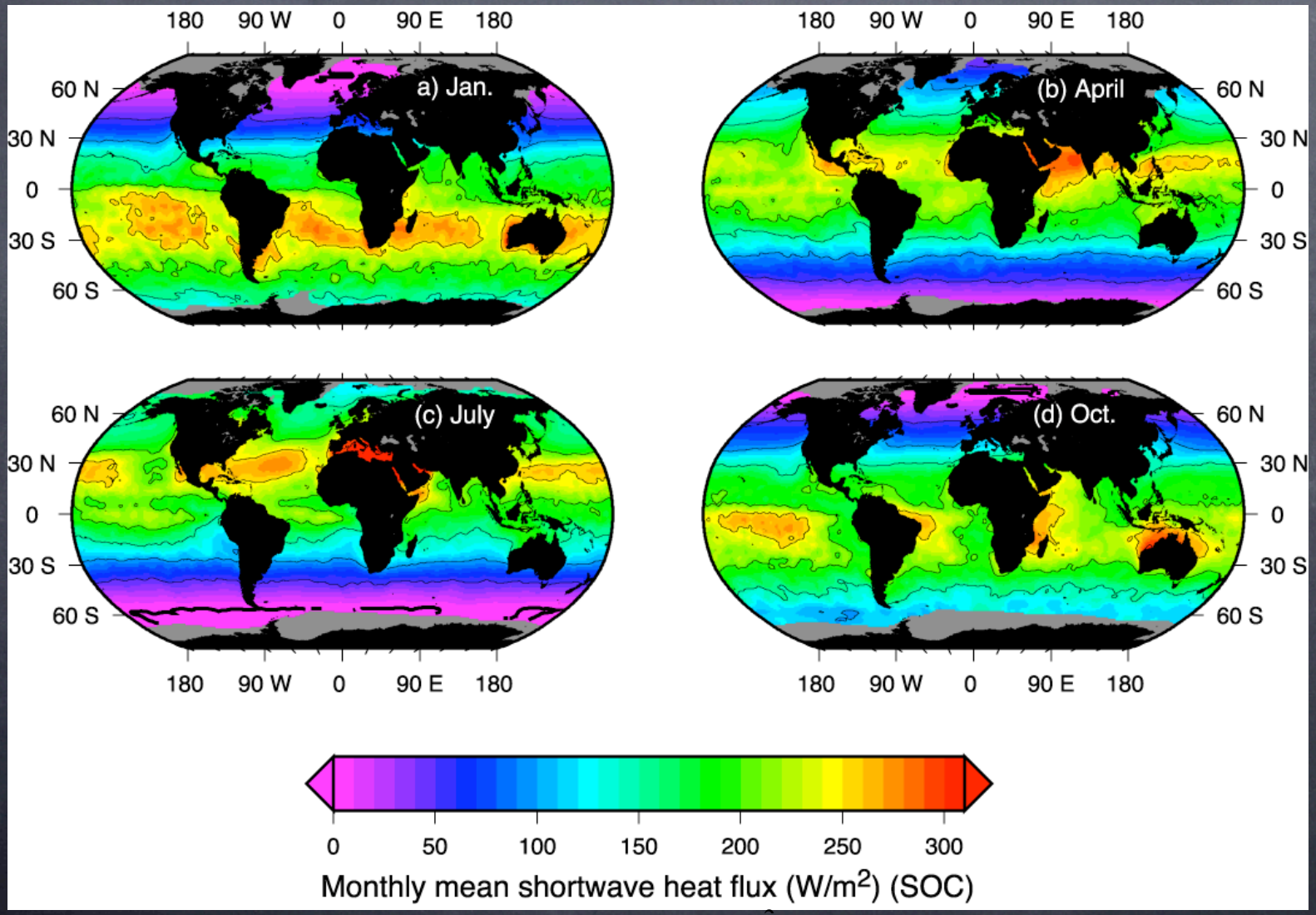


FIG. 5. Implied zonal annual mean ocean heat transports based upon the surface fluxes for Feb 1985–Apr 1989 for the total, Atlantic, Indian, and Pacific basins for NCEP and ECMWF atmospheric fields (PW). The 1 std err bars are indicated by the dashed curves.

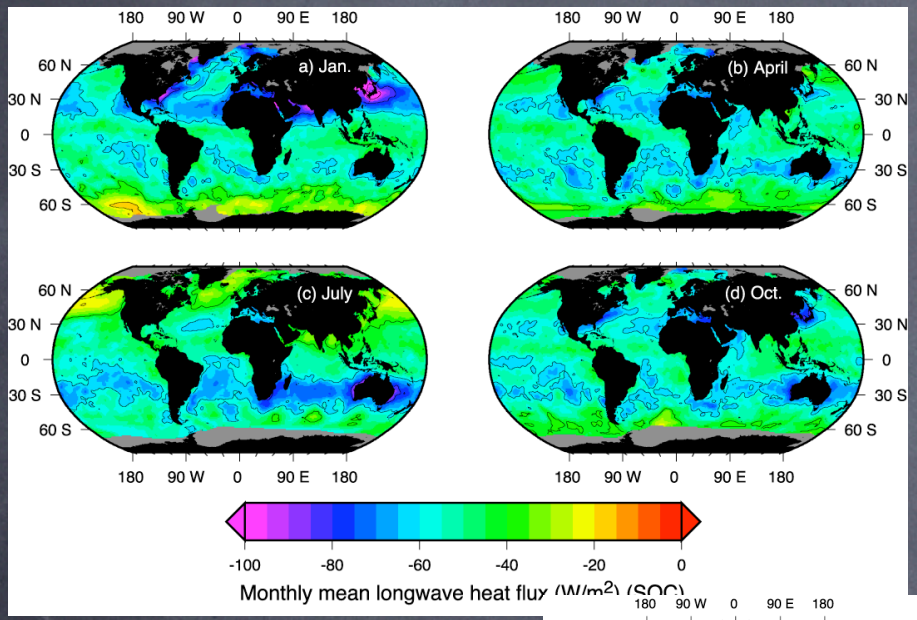
Alternatively, Total Flux Can be mapped from Ocean Obs



Beware! Seasonal Variability



Longwave & Latent vary, too



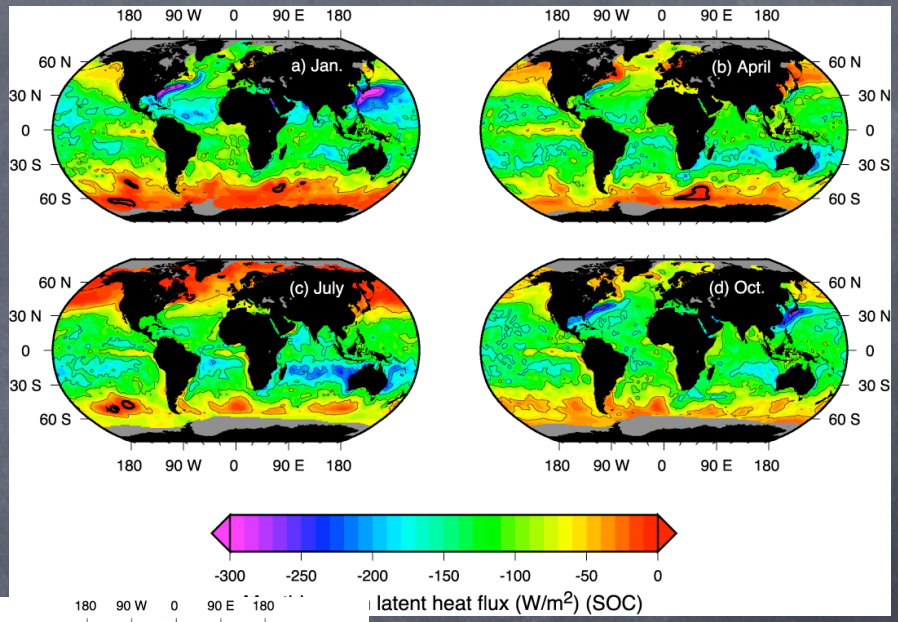
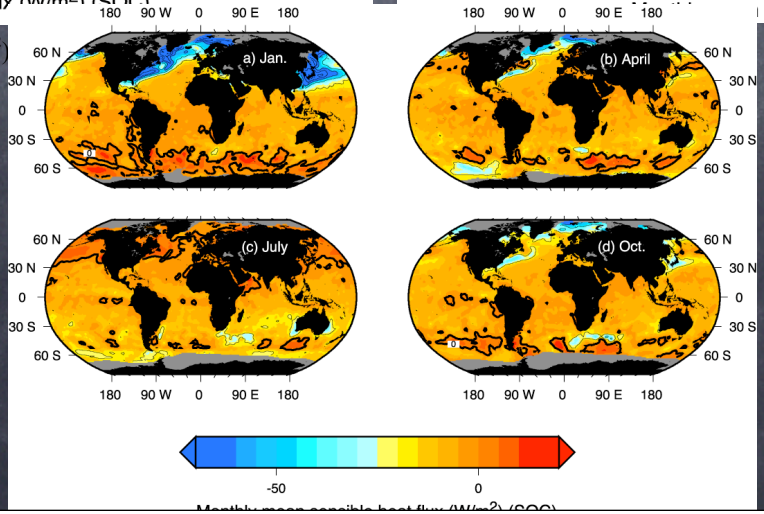
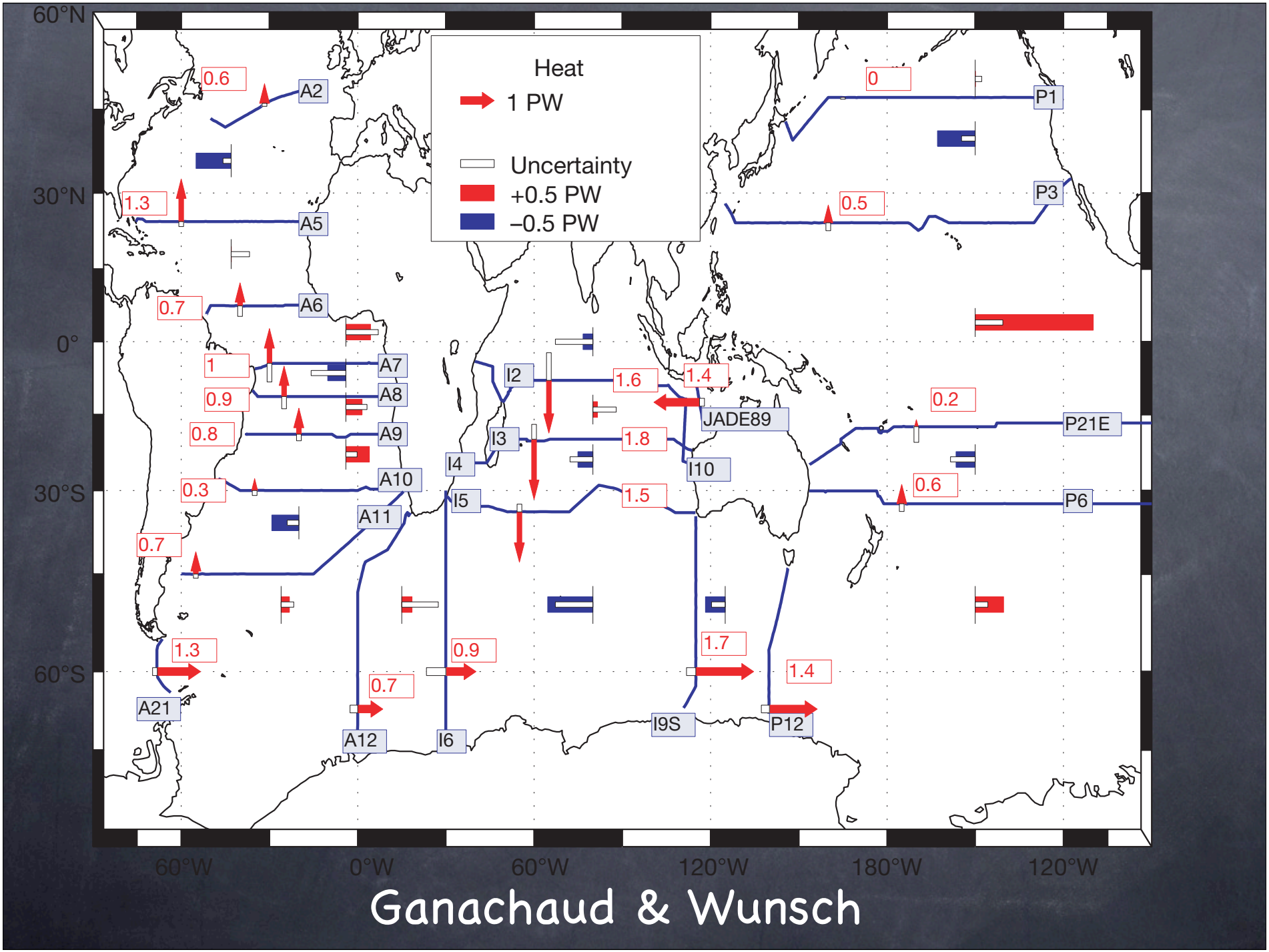


Fig. 5.20 Monthly mean longwave heat flux (W/m^2) Wm^{-2} from Grist and Josey (2003).





Ganachaud & Wunsch

But, It doesn't sum up to nothing! There are internal fluxes of heat Estimated with 'Inverse Methods'

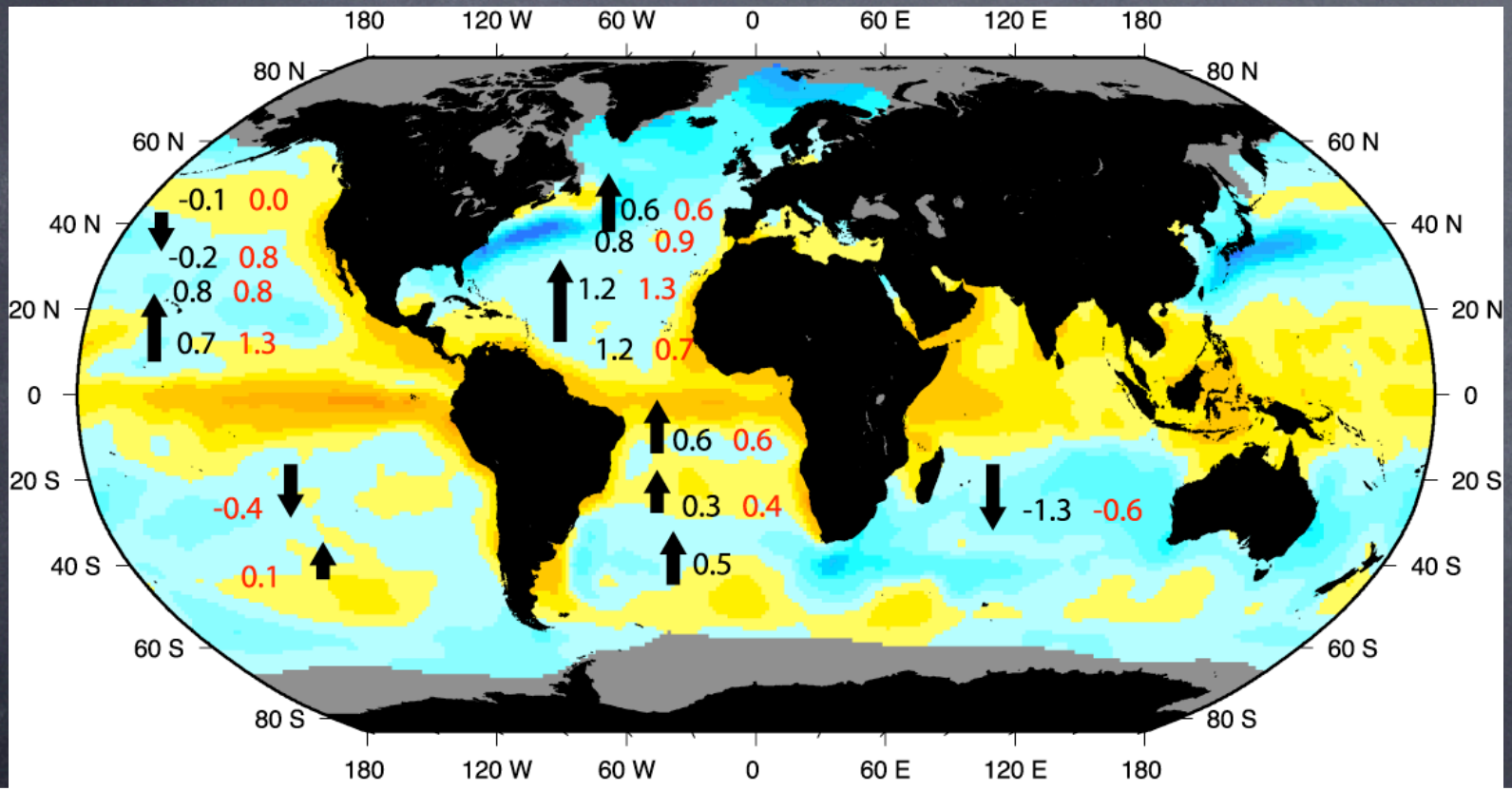
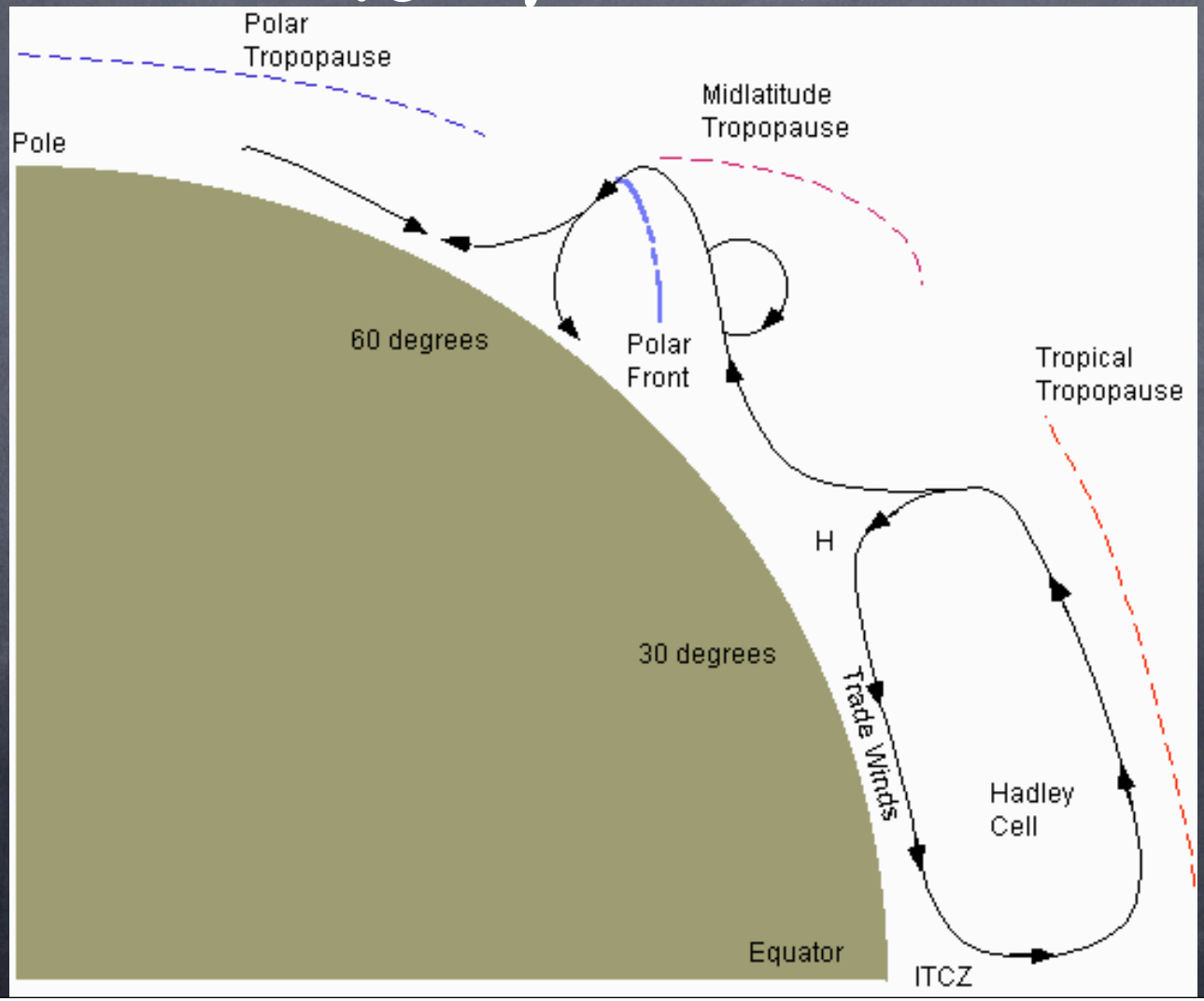


Fig. 5.23. Net south-north heat transports (PW) from direct estimates, superimposed on the map of annual average heat flux (Fig. 5.10). Black: estimates from "inverse models" from many sources (summaries in Bryden and Imawaki, 2001; Talley, 2003). Red: Talley (2003). Positive transports are northward.

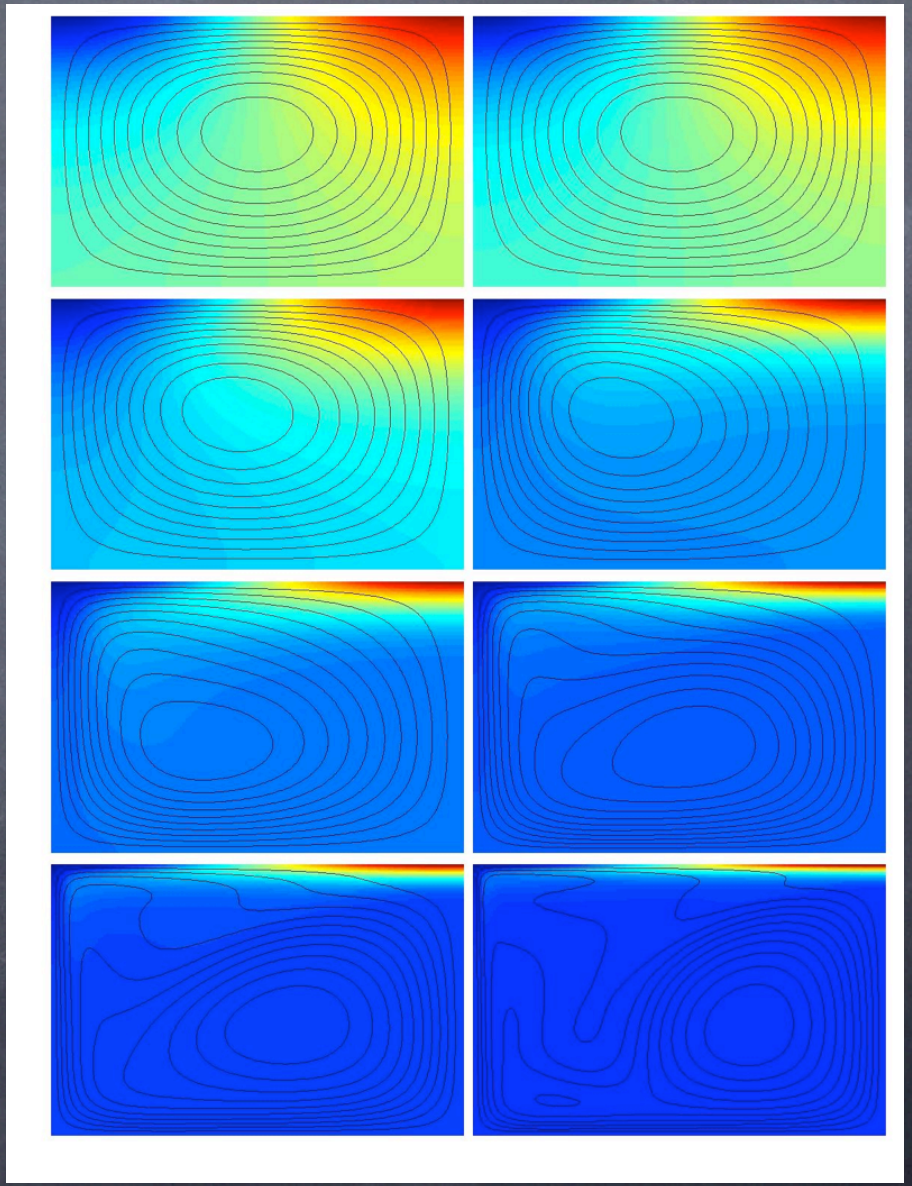
Atmosphere Heated from below/within…



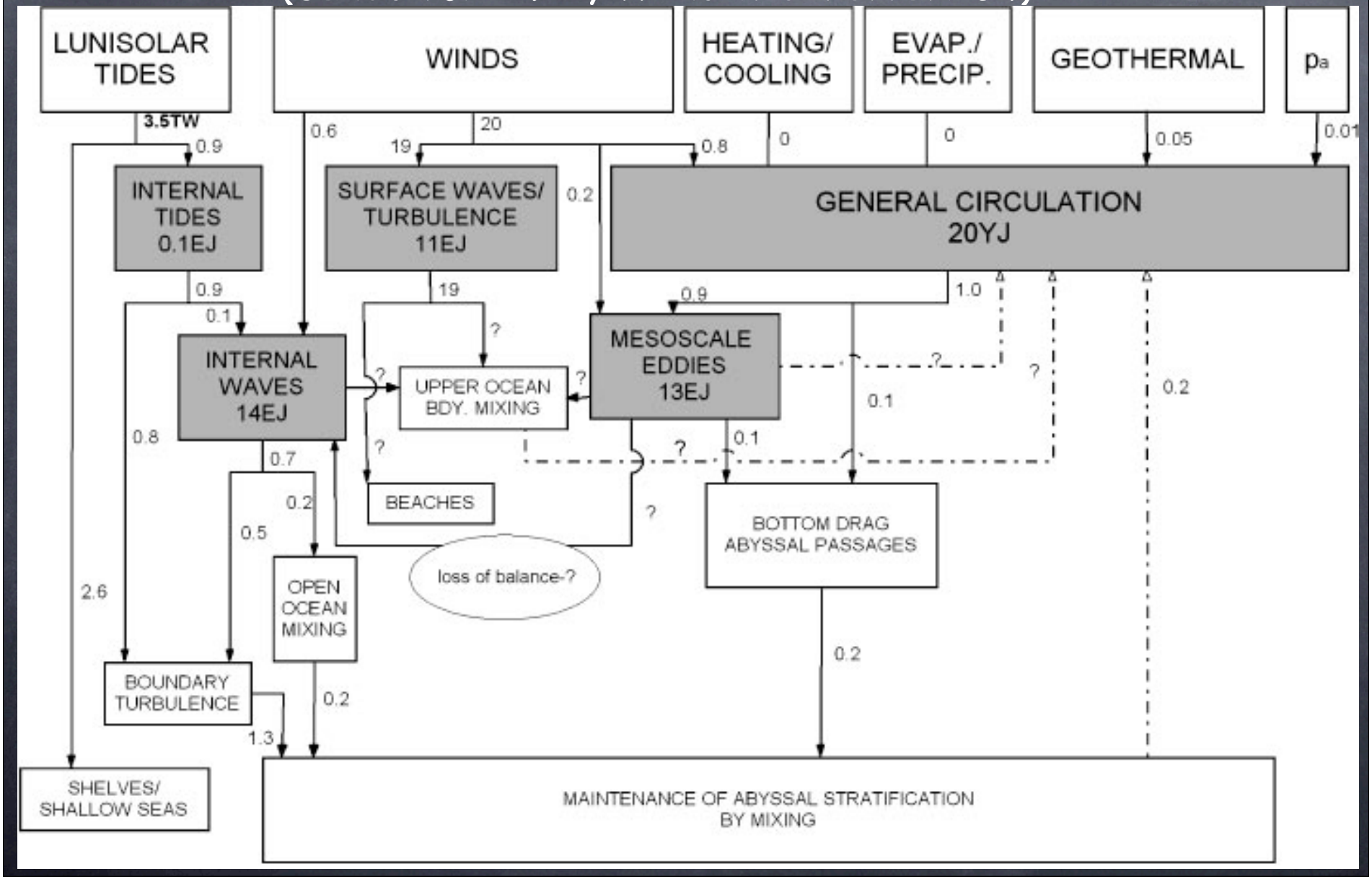
Ocean Heated & cooled at top

Image Courtesy:
N. Balmforth

Diffusivity (Rayleigh #):
Decreasing (increasing)
as you go down.

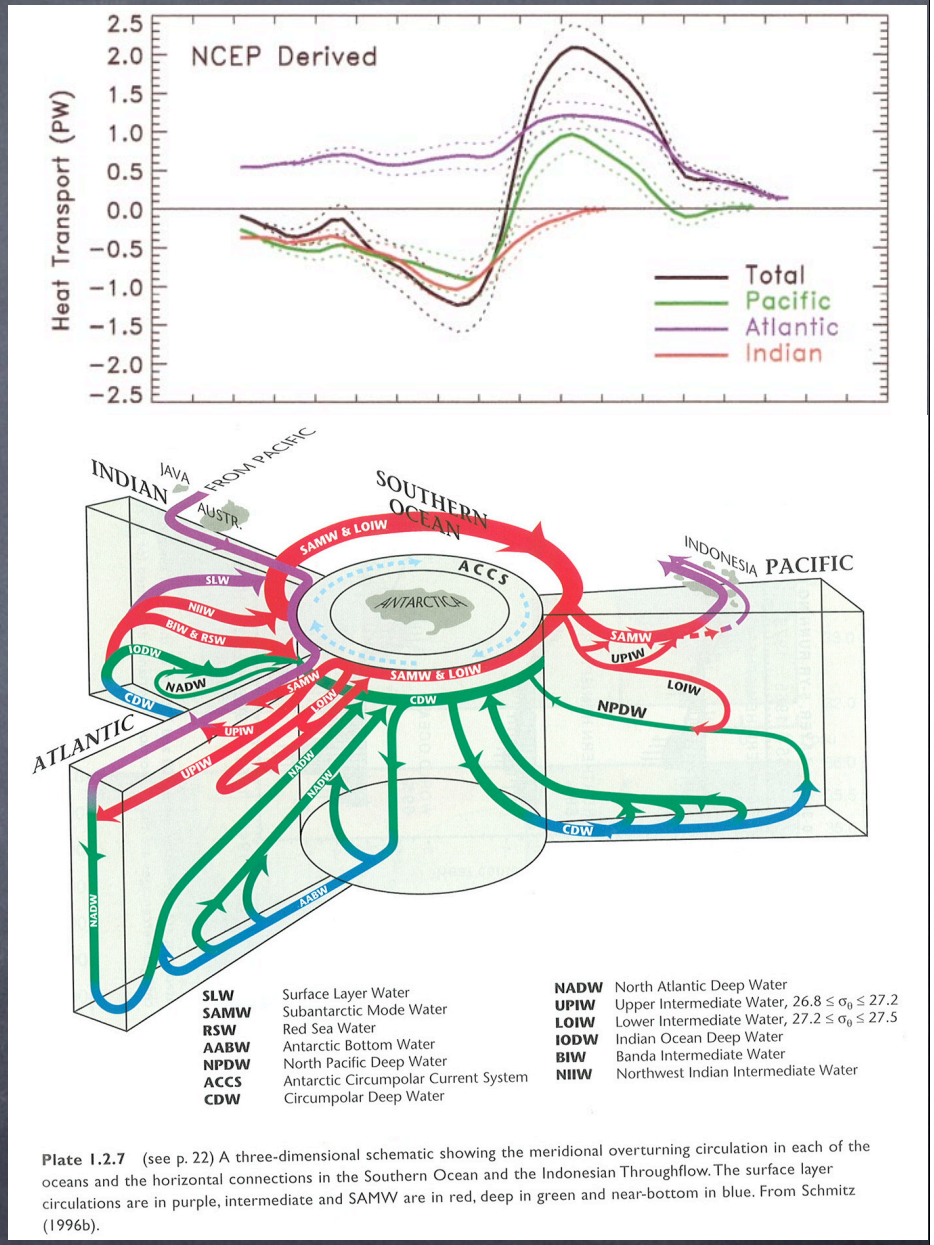


Ocean Transports Heat,
But Atmosphere is Heat Engine that Drives the system
(Sandstrom 1916, Wunsch & Ferrari 04)



Thermohaline or Meridional Overturning Circulation:

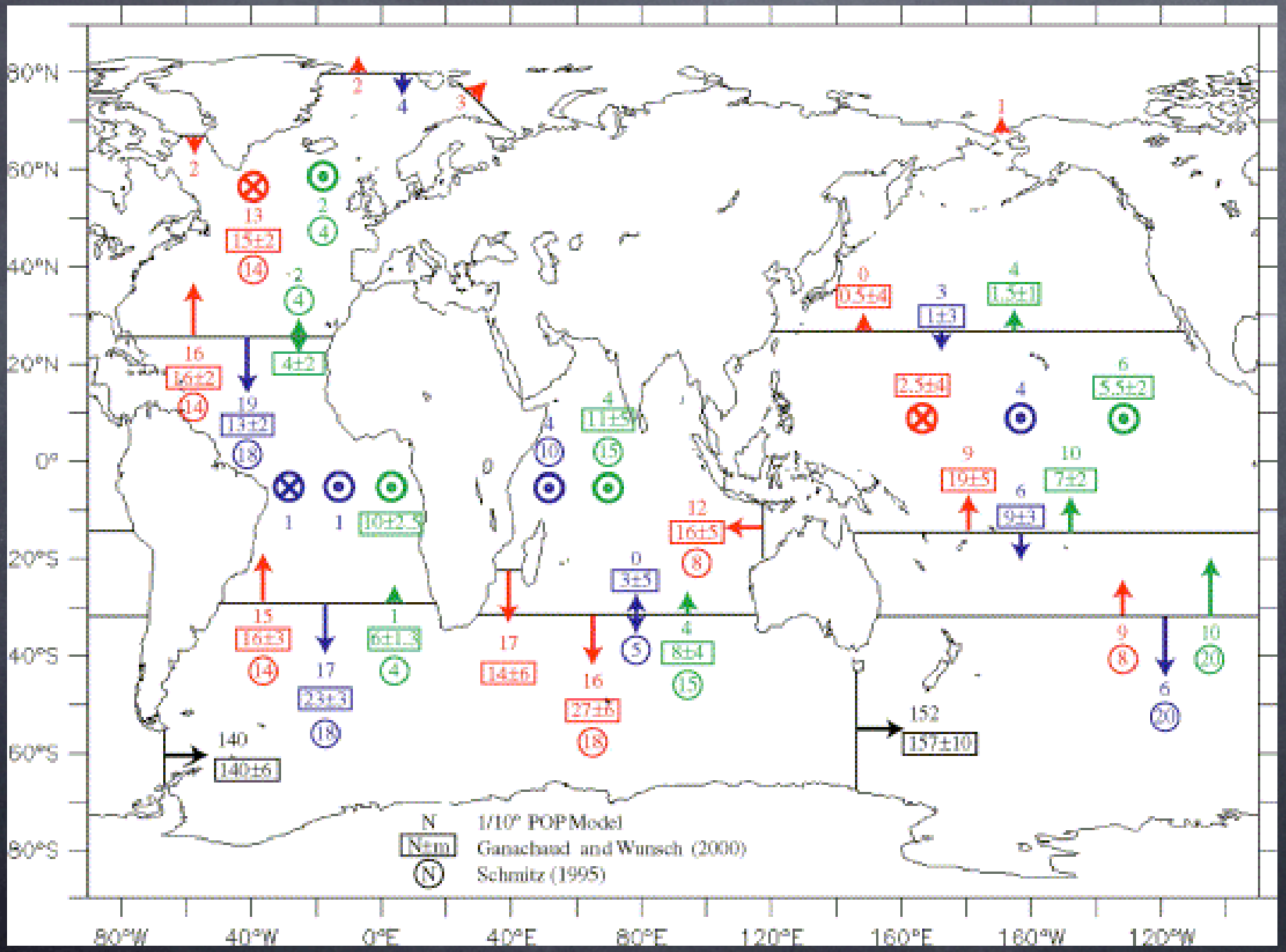
- A bit like a conveyor belt, because energy is externally supplied (Winds & Tides)
- However, what's on the conveyor affects how the conveyor moves
- Heating and cooling at the surface affect how/what is tranported.
- This is what we are after now...



SLW	Surface Layer Water	**NADW**	North Atlantic Deep Water
SAMW	Subantarctic Mode Water	**UPIW**	Upper Intermediate Water, $26.8 \le \sigma_0 \le 27.2$
RSW	Red Sea Water	**LOIW**	Lower Intermediate Water, $27.2 \le \sigma_0 \le 27.5$
AABW	Antarctic Bottom Water	**IODW**	Indian Ocean Deep Water
NPDW	North Pacific Deep Water	**BIW**	Banda Intermediate Water
ACCS	Antarctic Circumpolar Current System	**NIIW**	Northwest Indian Intermediate Water
CDW	Circumpolar Deep Water		

Plate 1.2.7 (see p. 22) A three-dimensional schematic showing the meridional overturning circulation in each of the oceans and the horizontal connections in the Southern Ocean and the Indonesian Throughflow. The surface layer circulations are in purple, intermediate and SAMW are in red, deep in green and near-bottom in blue. From Schmitz (1996b).

Volume Transports/Transform



Different Ways To Consider Flow...

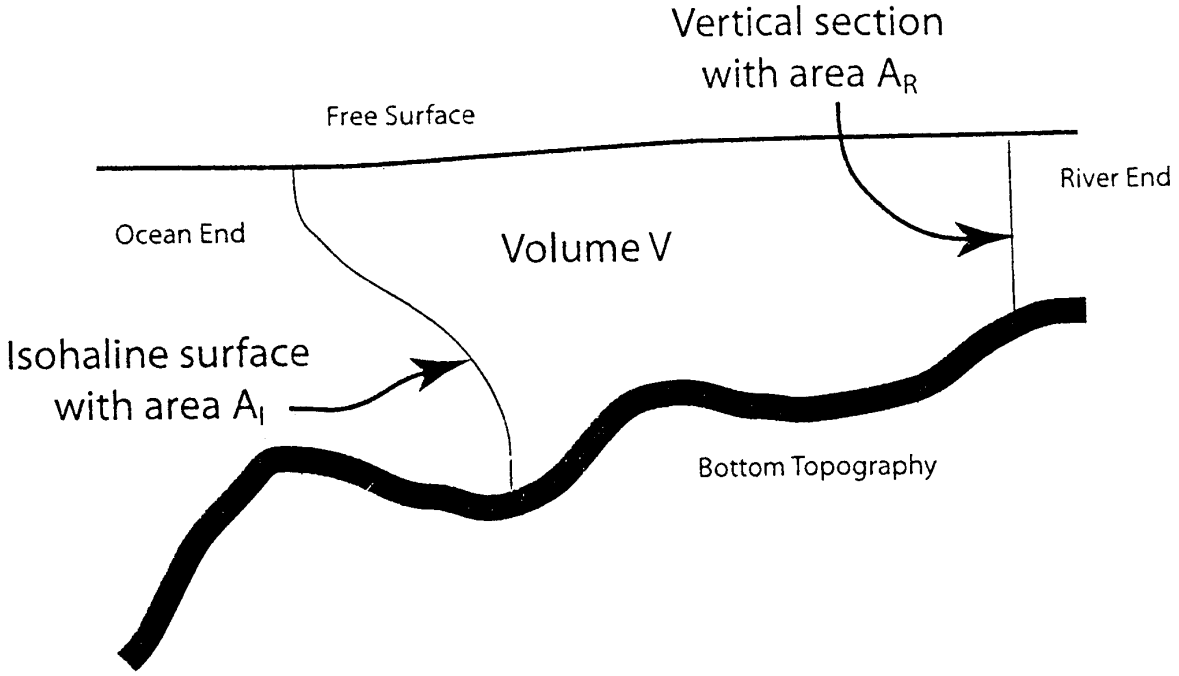


Figure 1. Definition sketch of the estuarine volume V, whose seaward end is defined by the moving, curved, isohaline surface with area A_I. The landward end of the volume is defined by the stationary, vertical plane with area A_R.