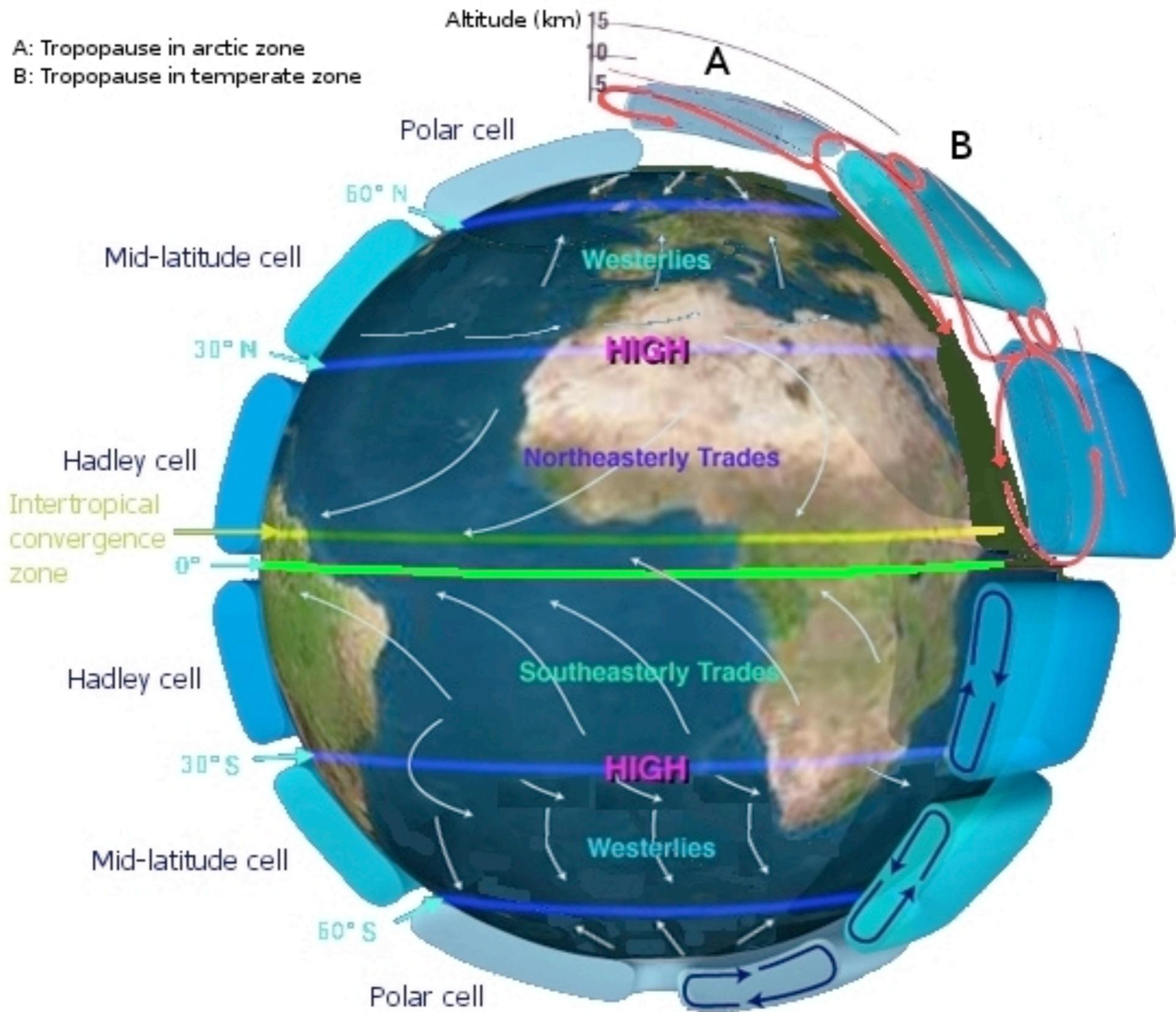
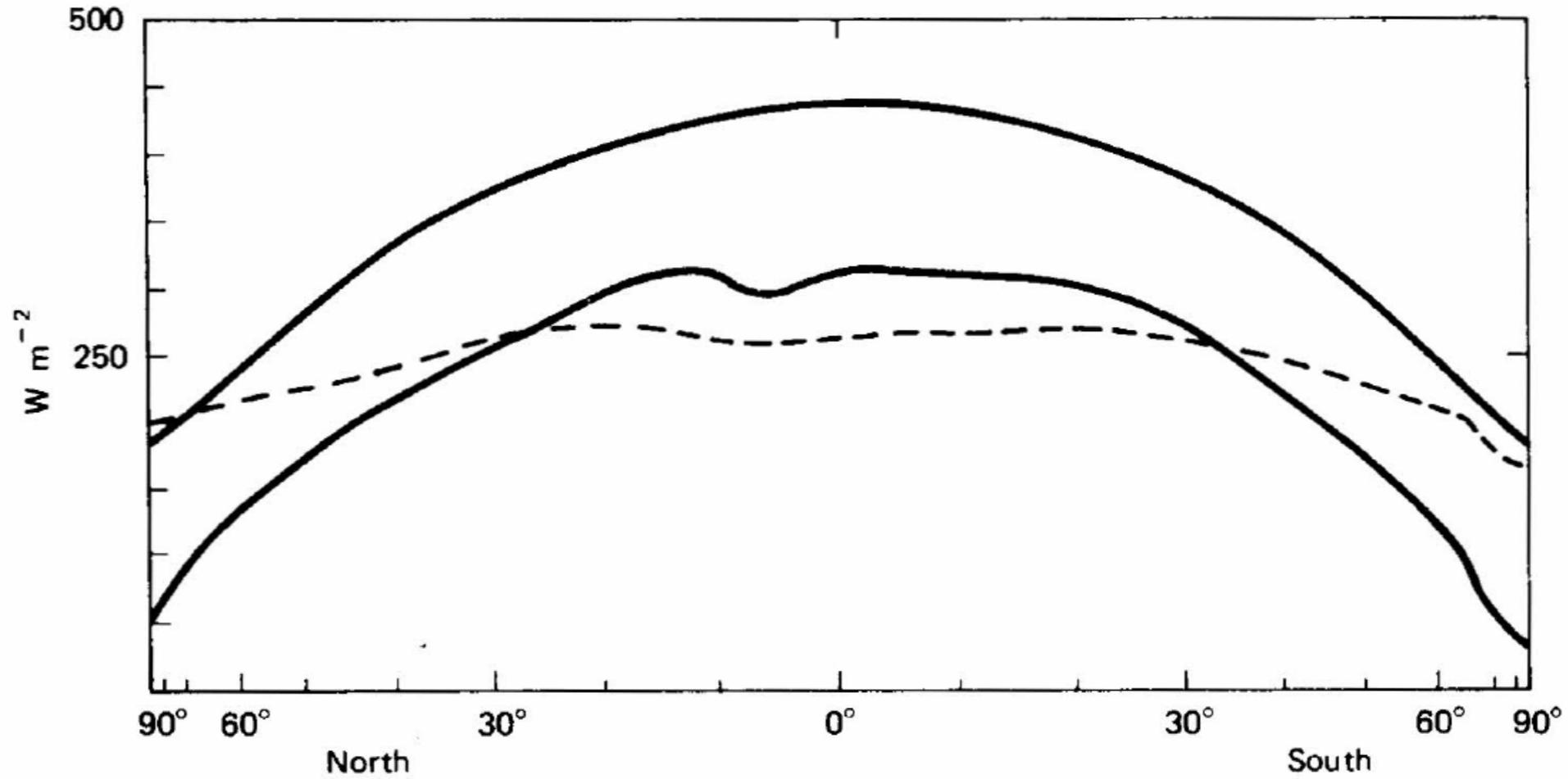


# Fluid dynamics of climate

## Lecture I: Atmospheric Circulation





**Fig. 1.1.** The radiation balance of the earth. The upper solid curve shows the average flux of solar energy reaching the outer atmosphere. The lower solid curve shows the average amount of solar energy absorbed; the dashed line shows the average amount of outgoing radiation. The lower curves are average values from satellite measurements between June 1974 and February 1978, and are taken from Volume 2 of Winston *et al.* (1979). Values are in watts per square meter. The horizontal scale is such that the spacing between latitudes is proportional to the area of the earth's surface between them, i.e., is linear in the sine of the latitude.

## (Journal of Climate)

## Estimates of Meridional Atmosphere and Ocean Heat Transports

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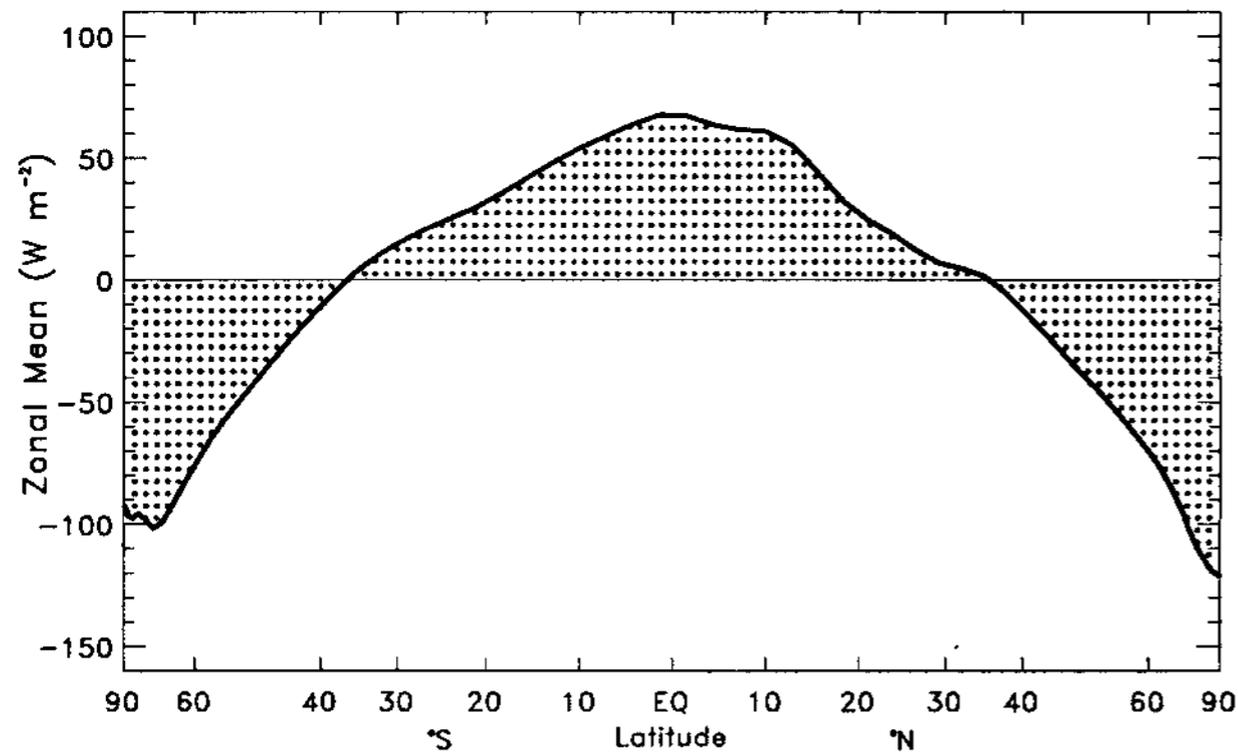


FIG. 1. TOA annualized ERBE zonal mean net radiation ( $\text{W m}^{-2}$ ) for Feb 1985–Apr 1989.

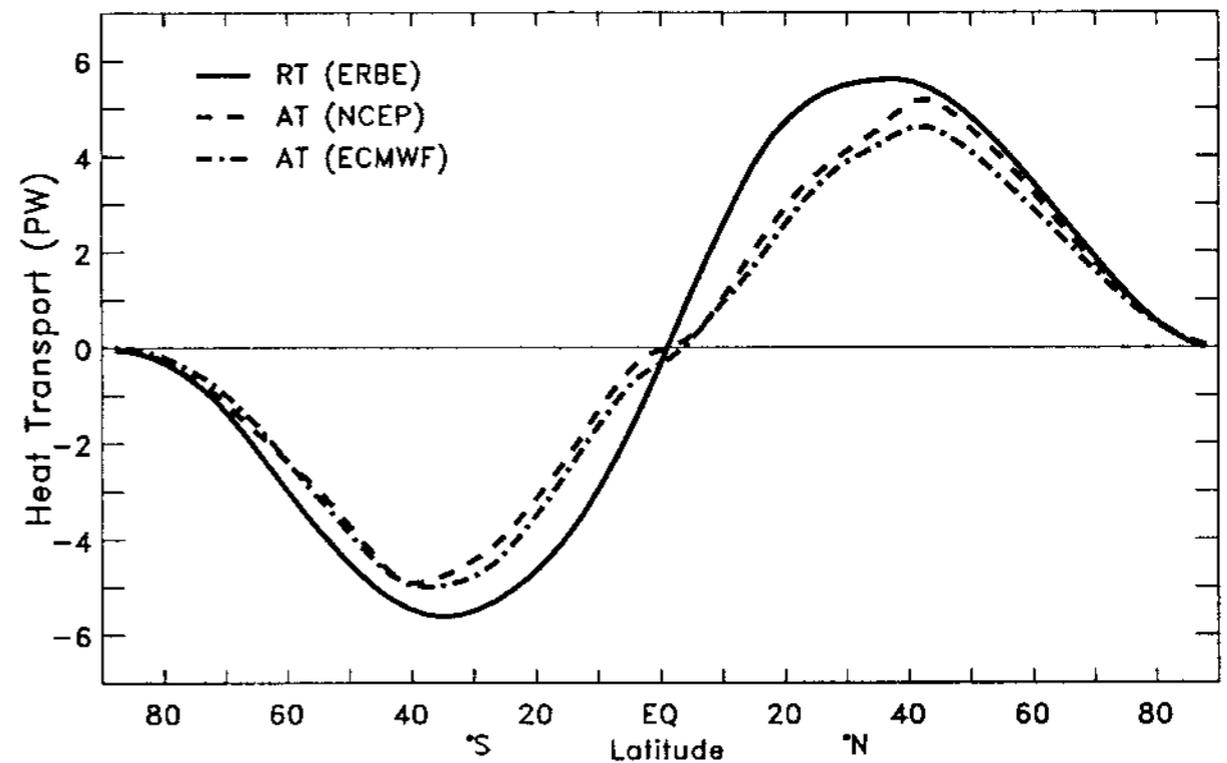
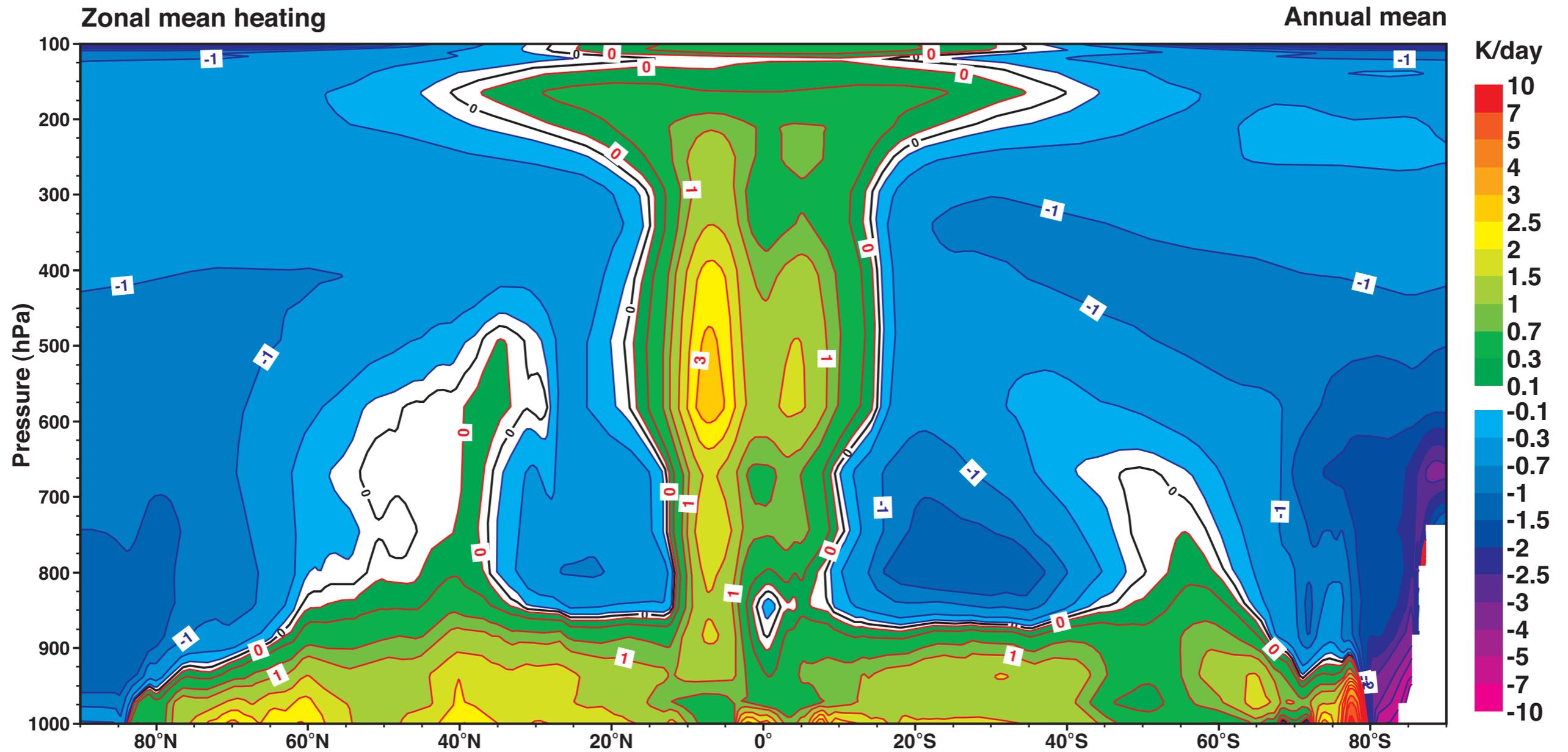


FIG. 2. The required total heat transport from the TOA radiation RT is given along with the estimates of the total atmospheric transport AT from NCEP and ECMWF reanalyses (PW).



From ECMWF numerical weather prediction model

# Meridional heat transport by the atmosphere and the ocean: analysis of FGGE data

By KOOITI MASUDA, Geophysical Institute, University of Tokyo, Yayoi, Bunkyo-ku, Tokyo 113, Japan

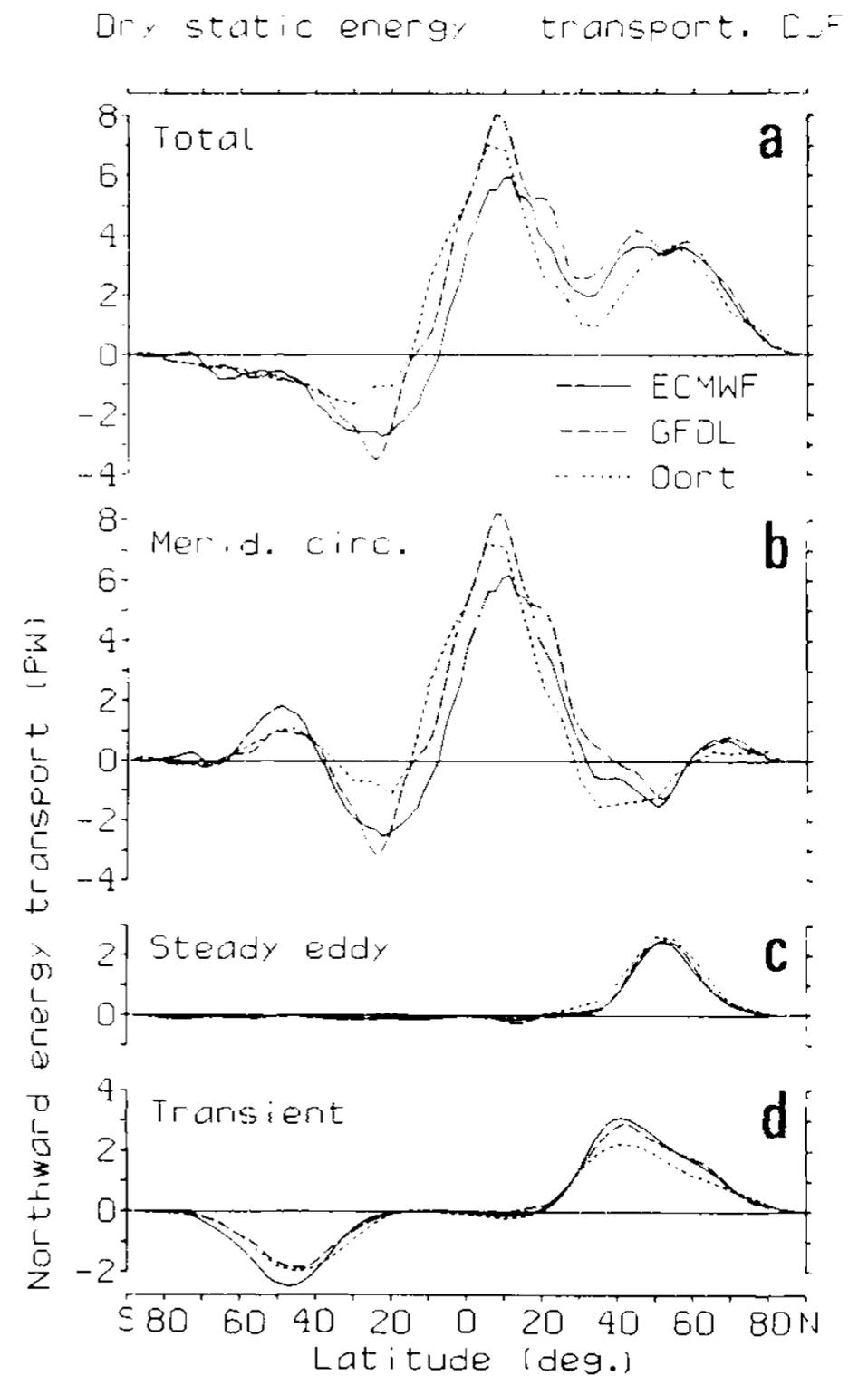
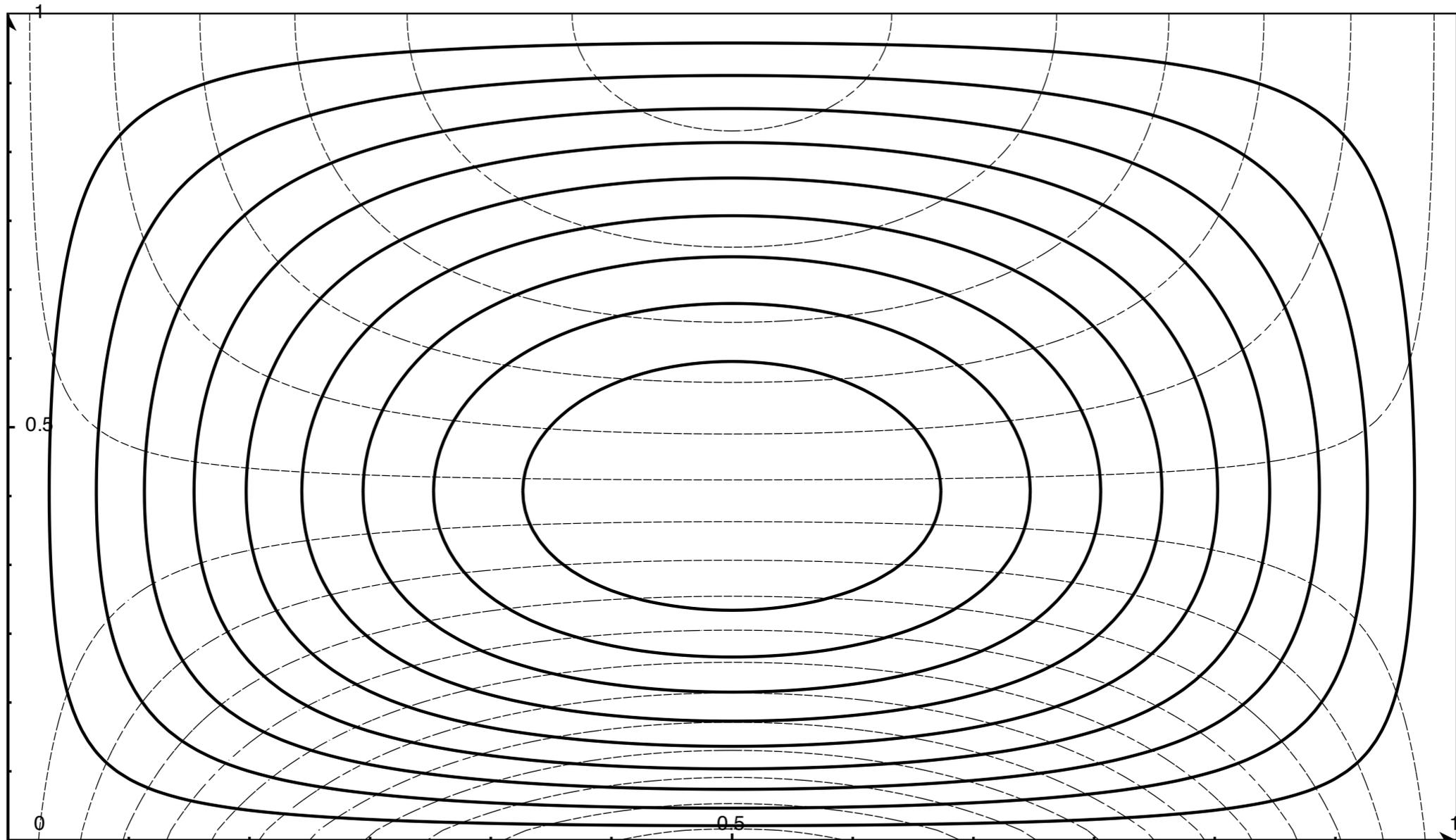
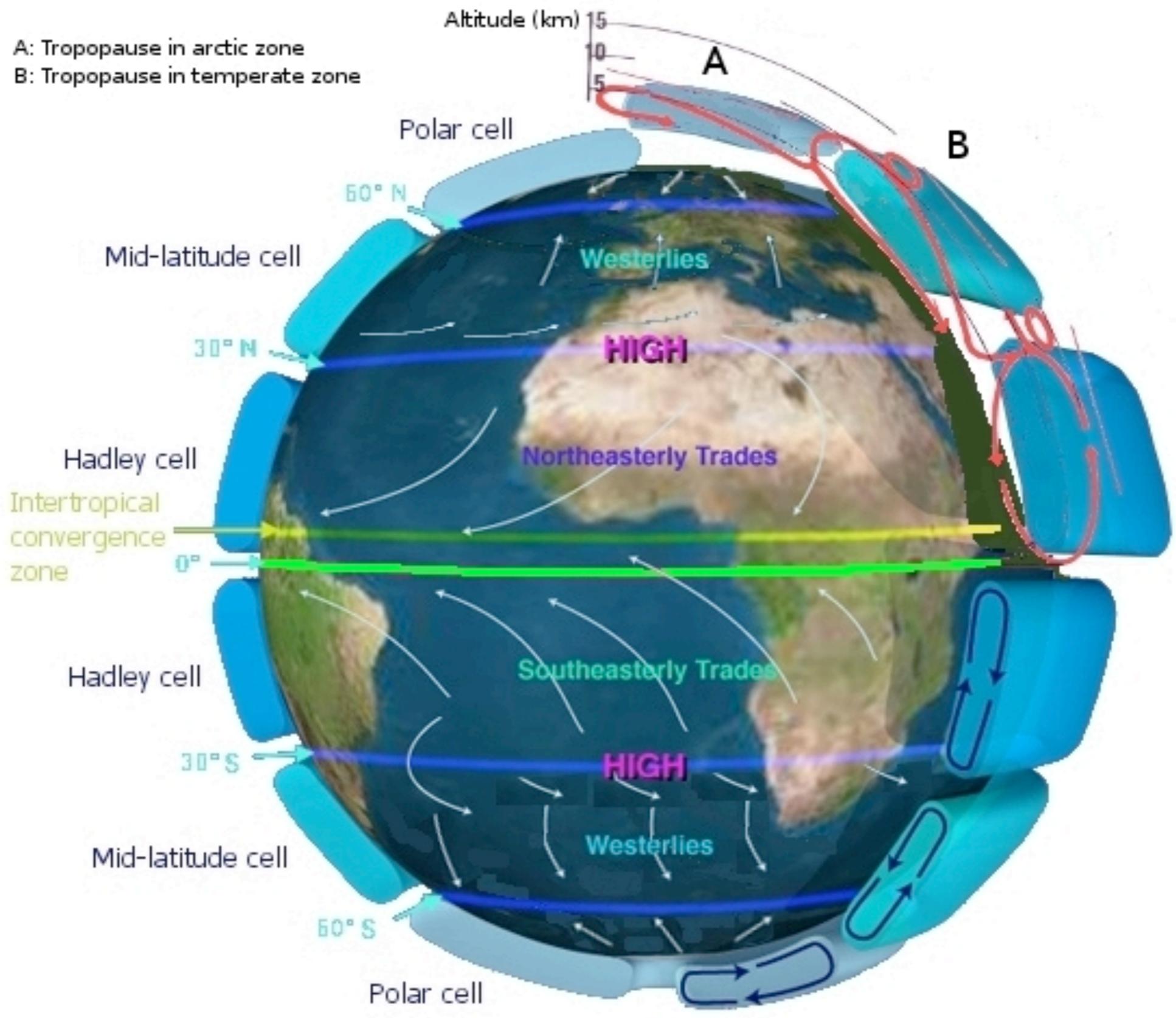


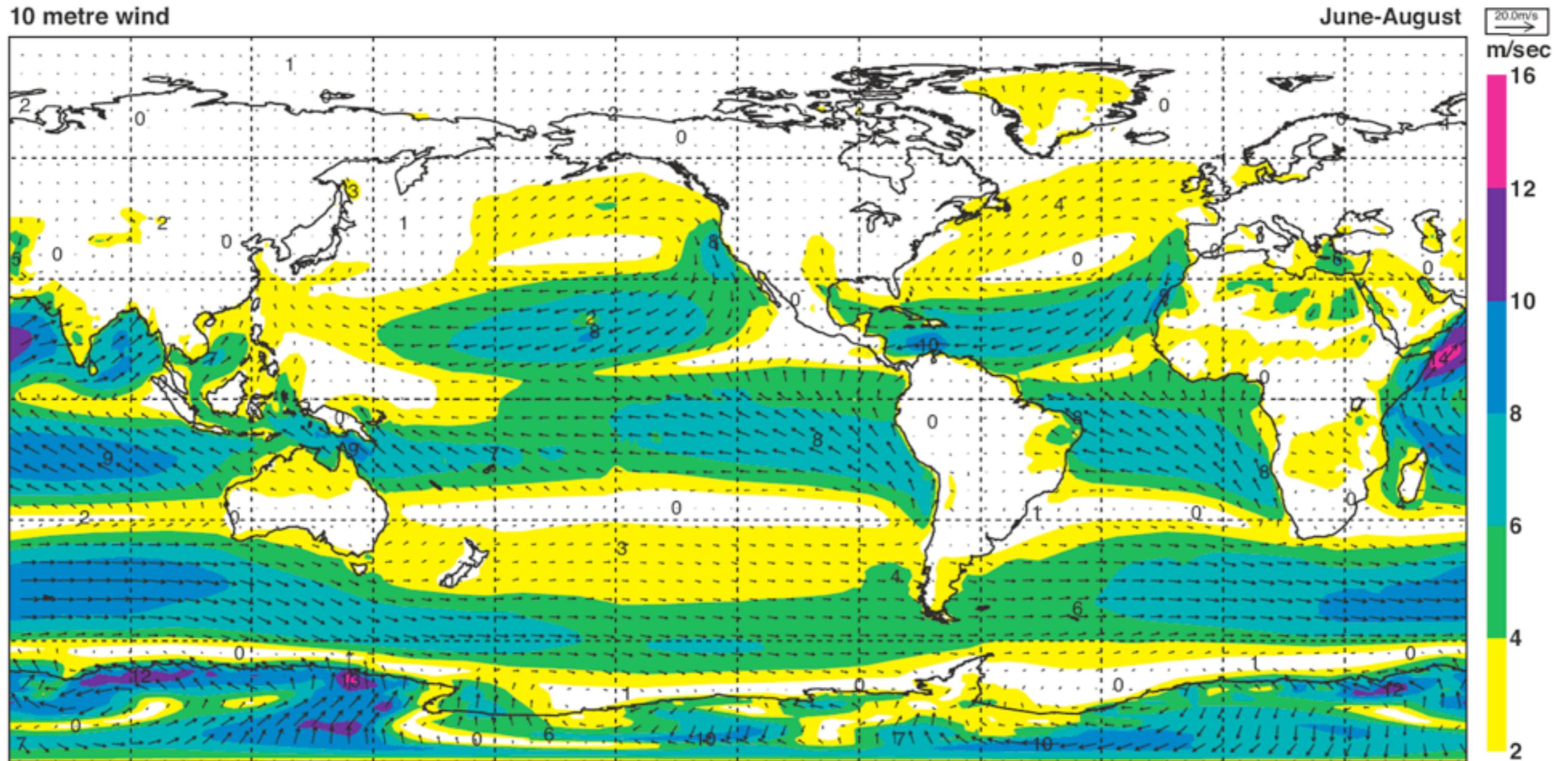
Fig. 3. Northward transport of dry static energy during DJF (December-January-February) in PW. (a) Total transport; (b) transport by the mean meridional circulation; (c) transport by stationary eddies; (d) Transport by transient eddies. For all panels, the solid lines show the results obtained from ECMWF data, the dashed lines from GFDL data, and the dotted lines from Oort's (1983) statistics.



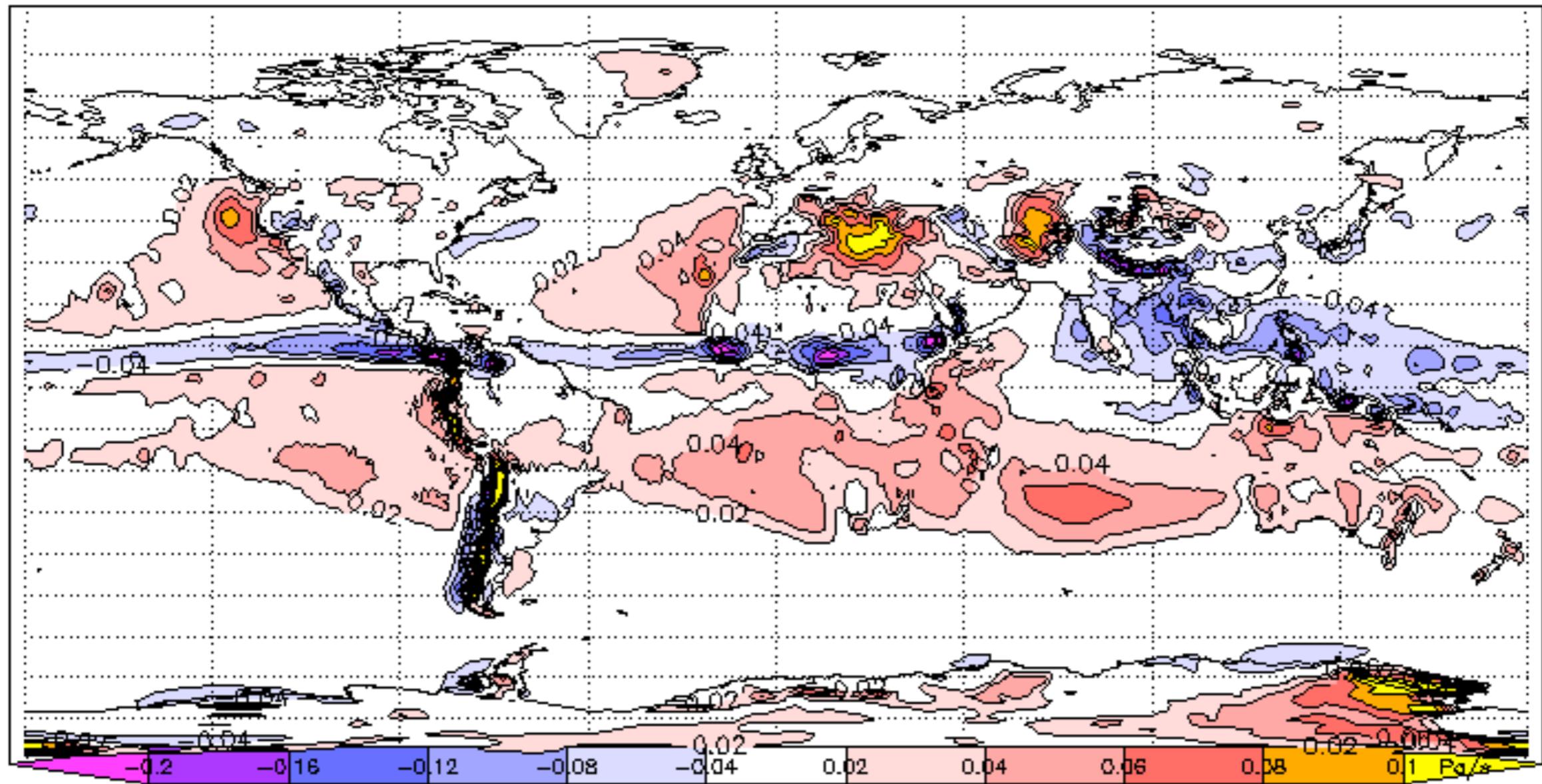
**Meridional streamfunction (solid) and zonal flow (dashed) from an analytical model of the Hadley cell**



# Surface winds



*Kallberg et al. 1995 (ERA-40 reanalysis)*



Vertical velocity at 500hPa (Pa/s)  
Blue = up, Red = down