12.810 Dynamics of the Atmosphere

General circulation of the atmosphere

Spinup of the general circulation in an idealized model

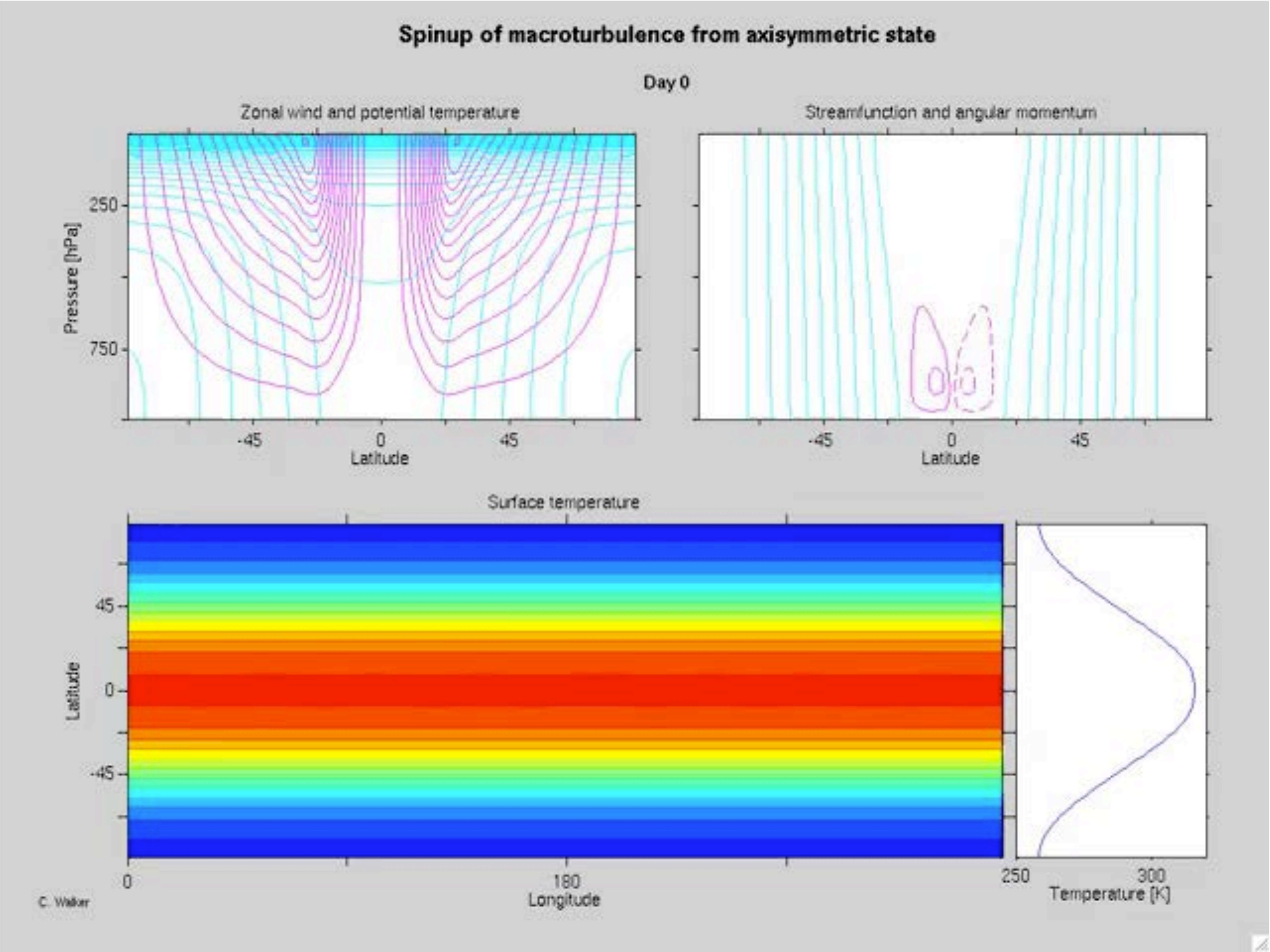
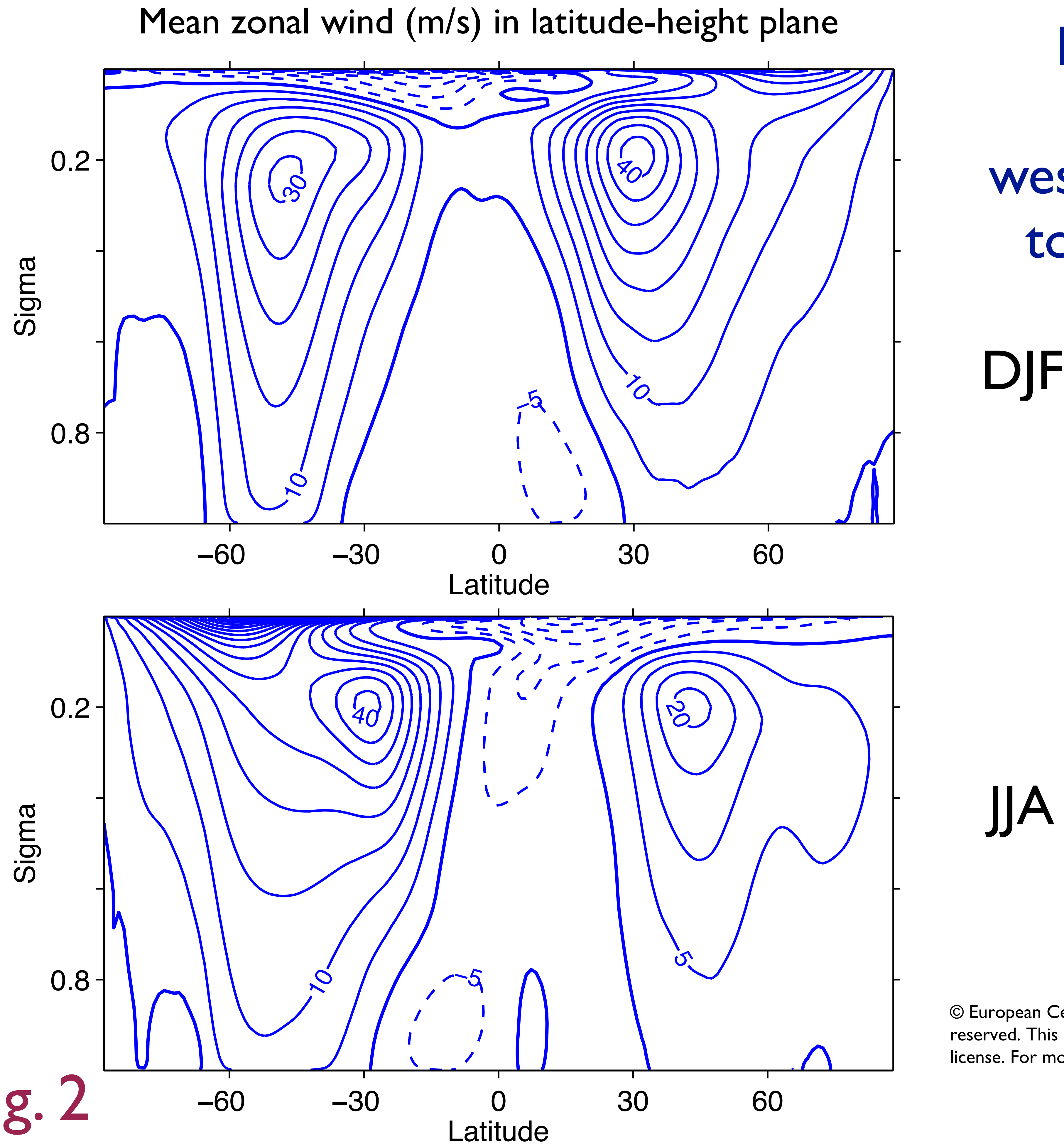


Fig. 1



Midlatitude jets with surface westerlies in addition to subtropical jets

Fig. 2

Both Hadley and Ferrel cells

Eulerian mean meridional streamfunction (10^{10} kg s^{-1})

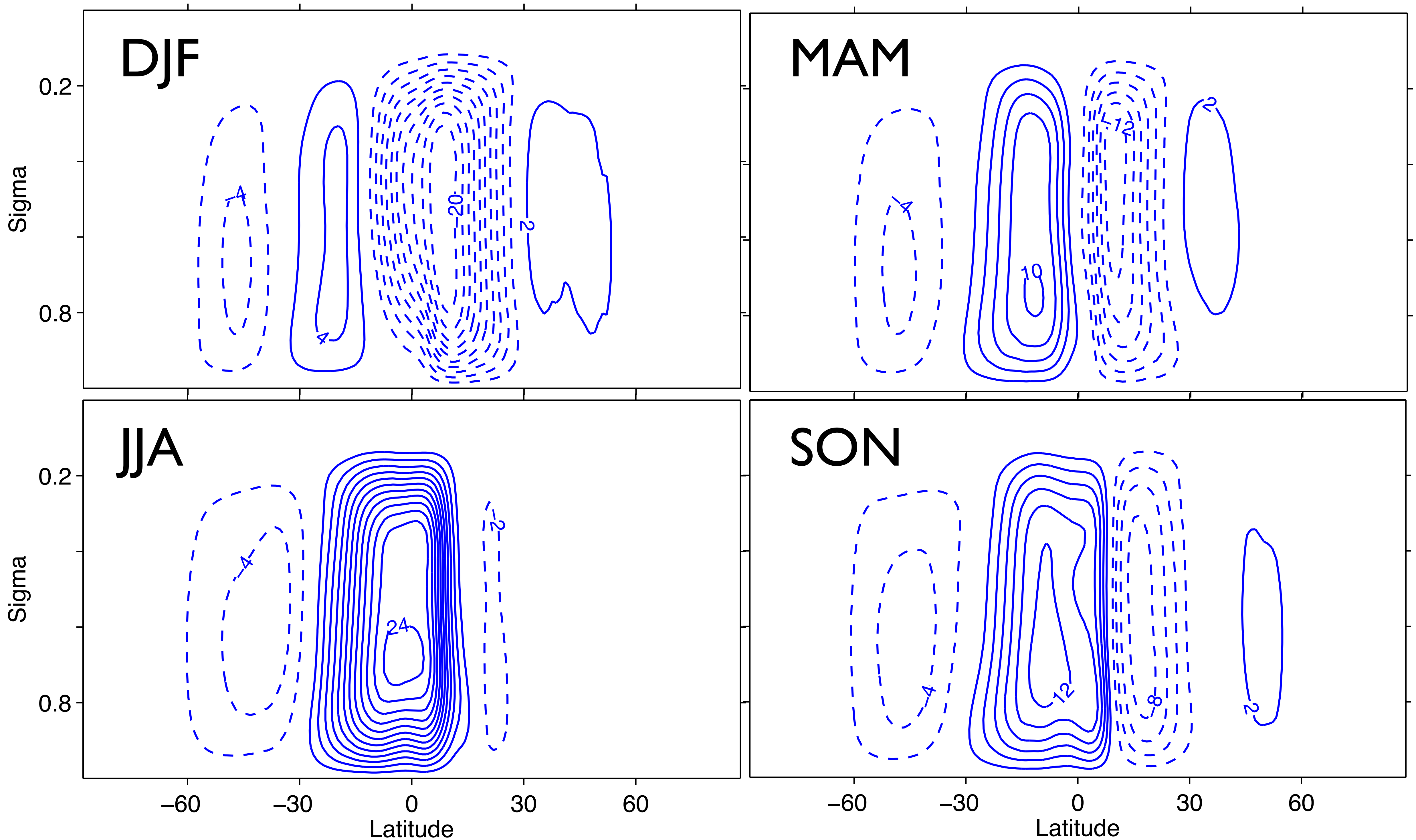


Fig. 3

General circulation of the atmosphere: subtopics

1. The impact of eddies: Midlatitude surface westerlies and the Ferrel cells

2. Circulation in isentropic coordinates and transport of tracers

Eddy meridional heat flux: poleward in both hemispheres

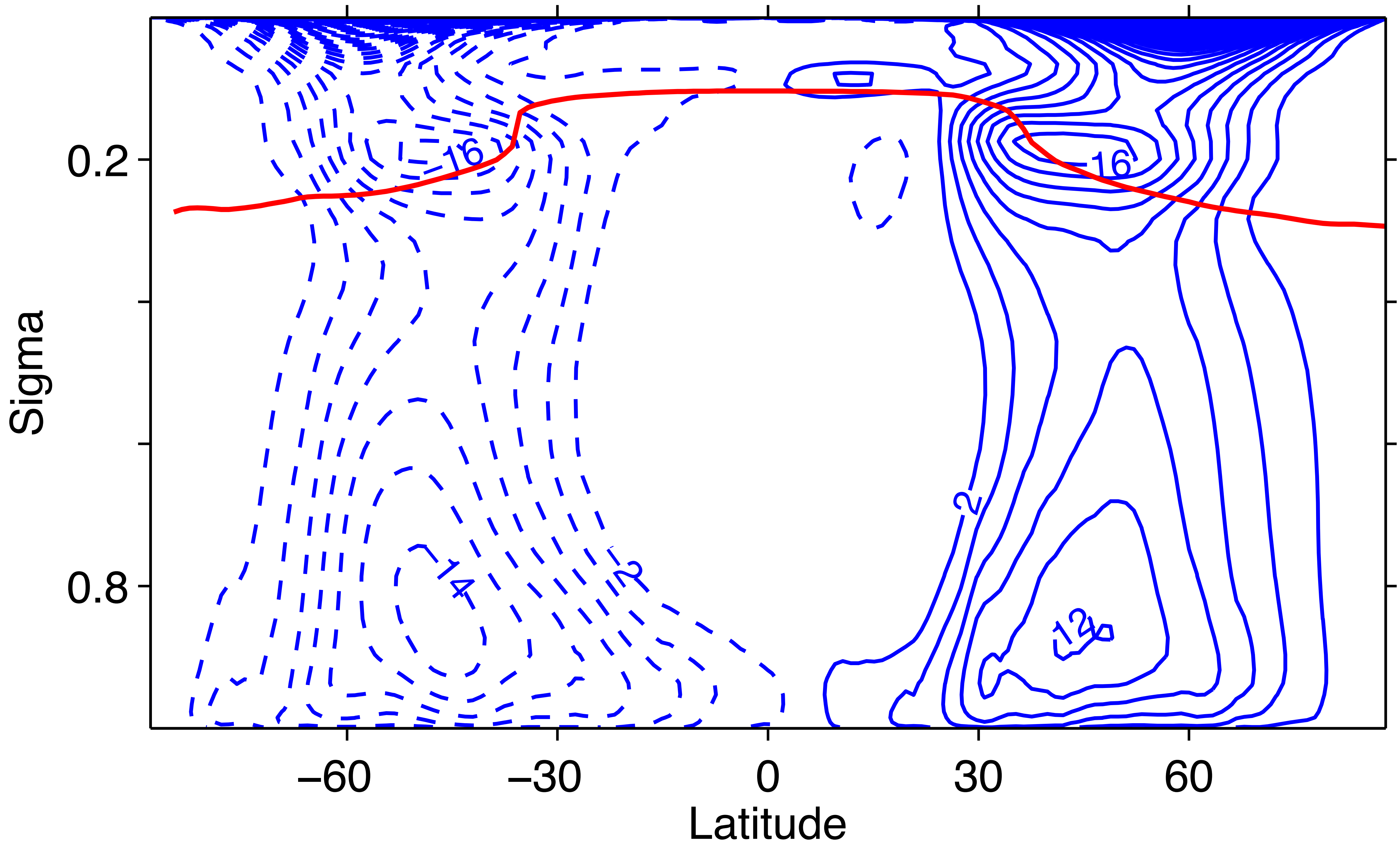
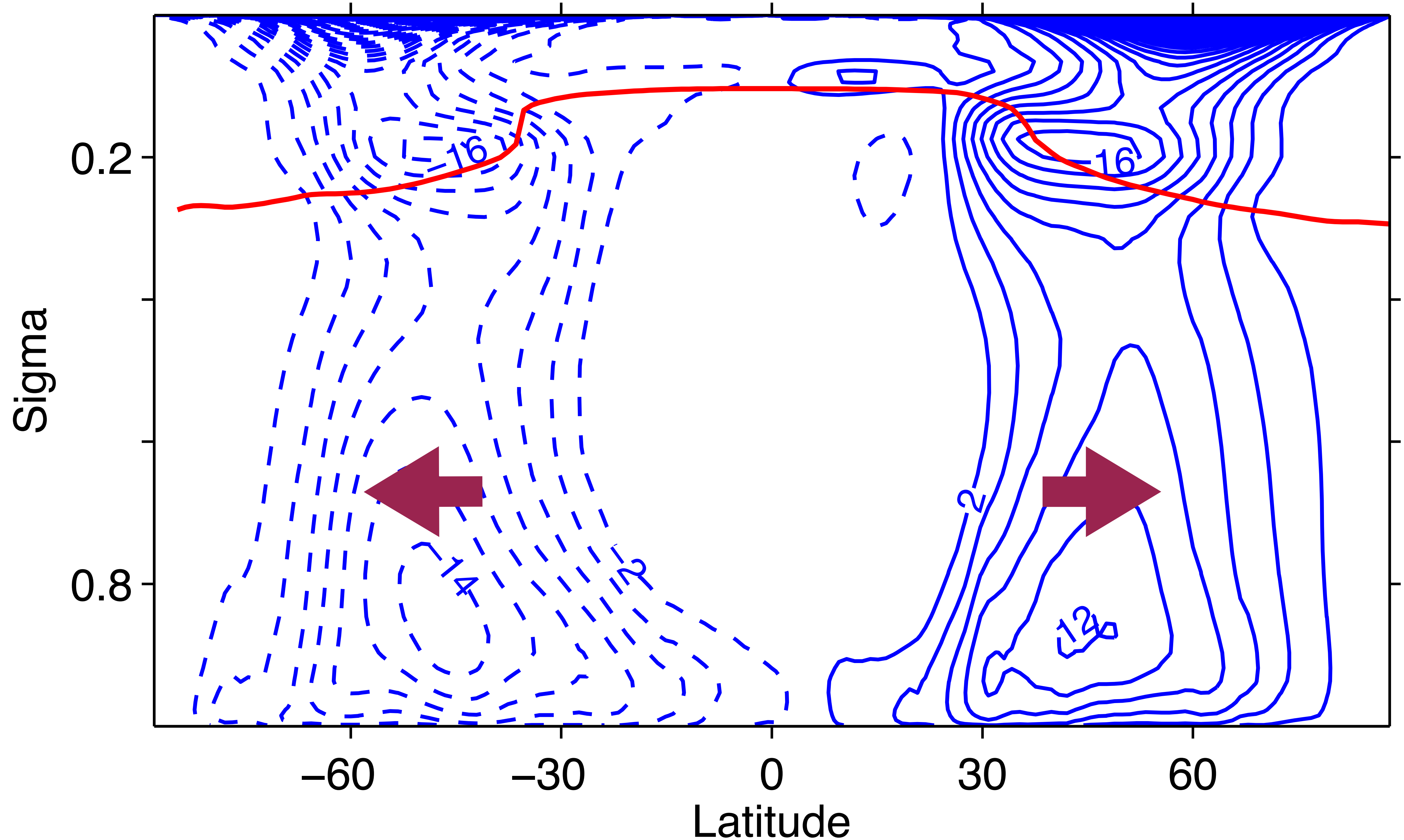


Fig. 4

Zonal and time mean of $v'\theta'\cos(\text{lat})$ in $\mathrm{ms^{-1}K}$

Red line indicates the tropopause

Eddy meridional heat flux: poleward in both hemispheres

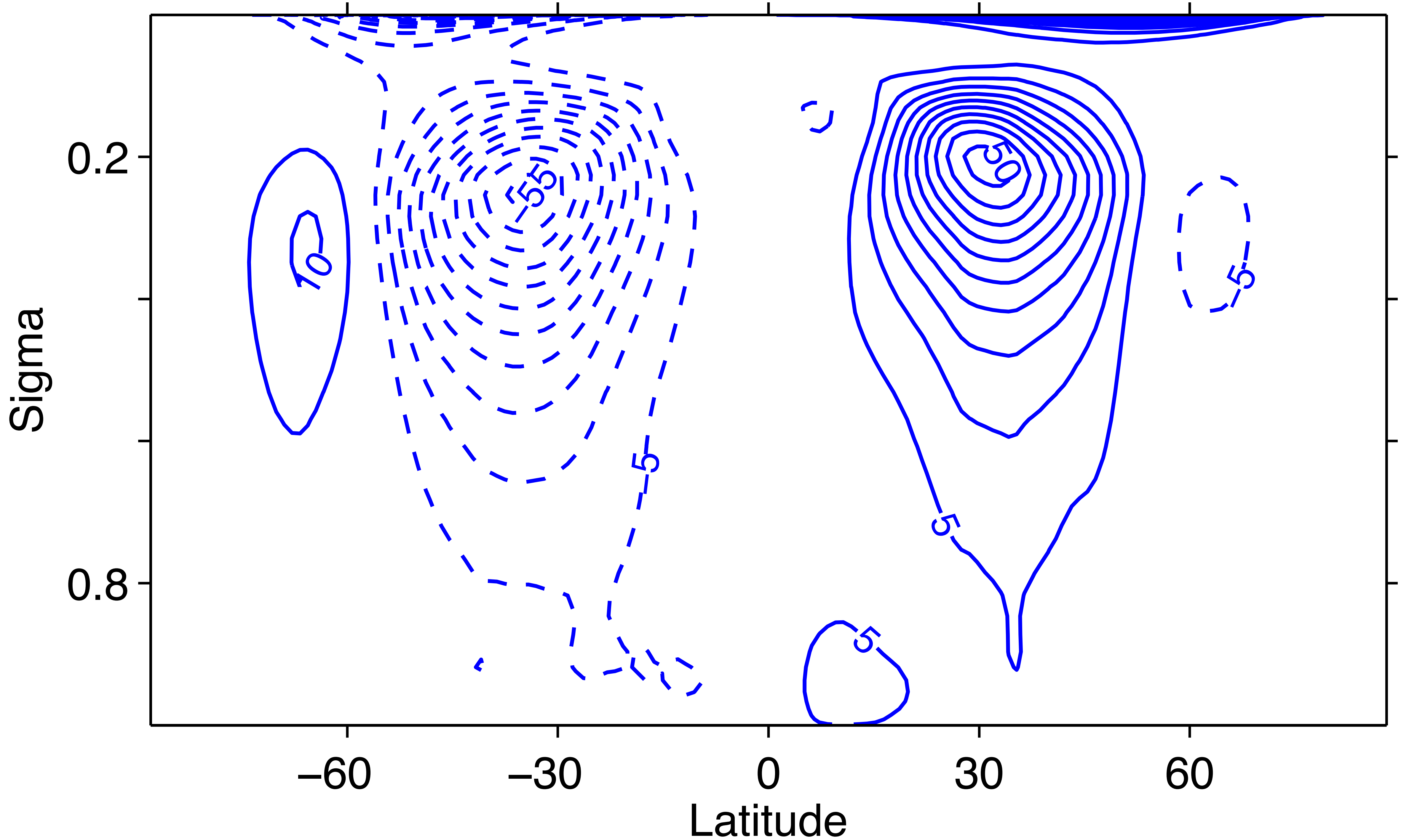


Zonal and time mean of $v'\theta'\cos(\text{lat})$ in ms^{-1}K

Red line indicates the tropopause

Fig. 4

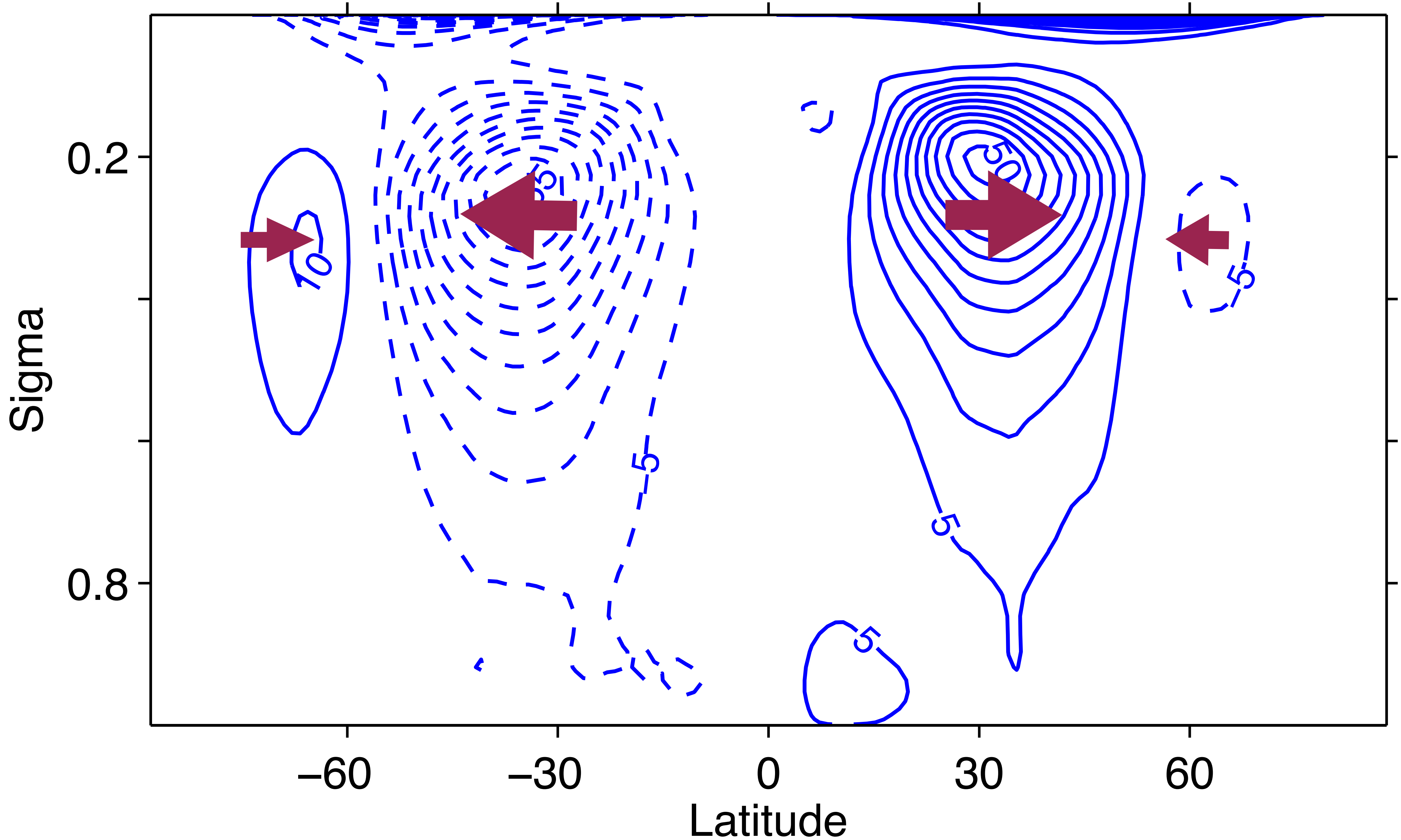
Eddy momentum flux: mostly poleward and converges at midlatitudes



Zonal and time mean of u′v′cos(lat) in m²/s²

Fig. 5

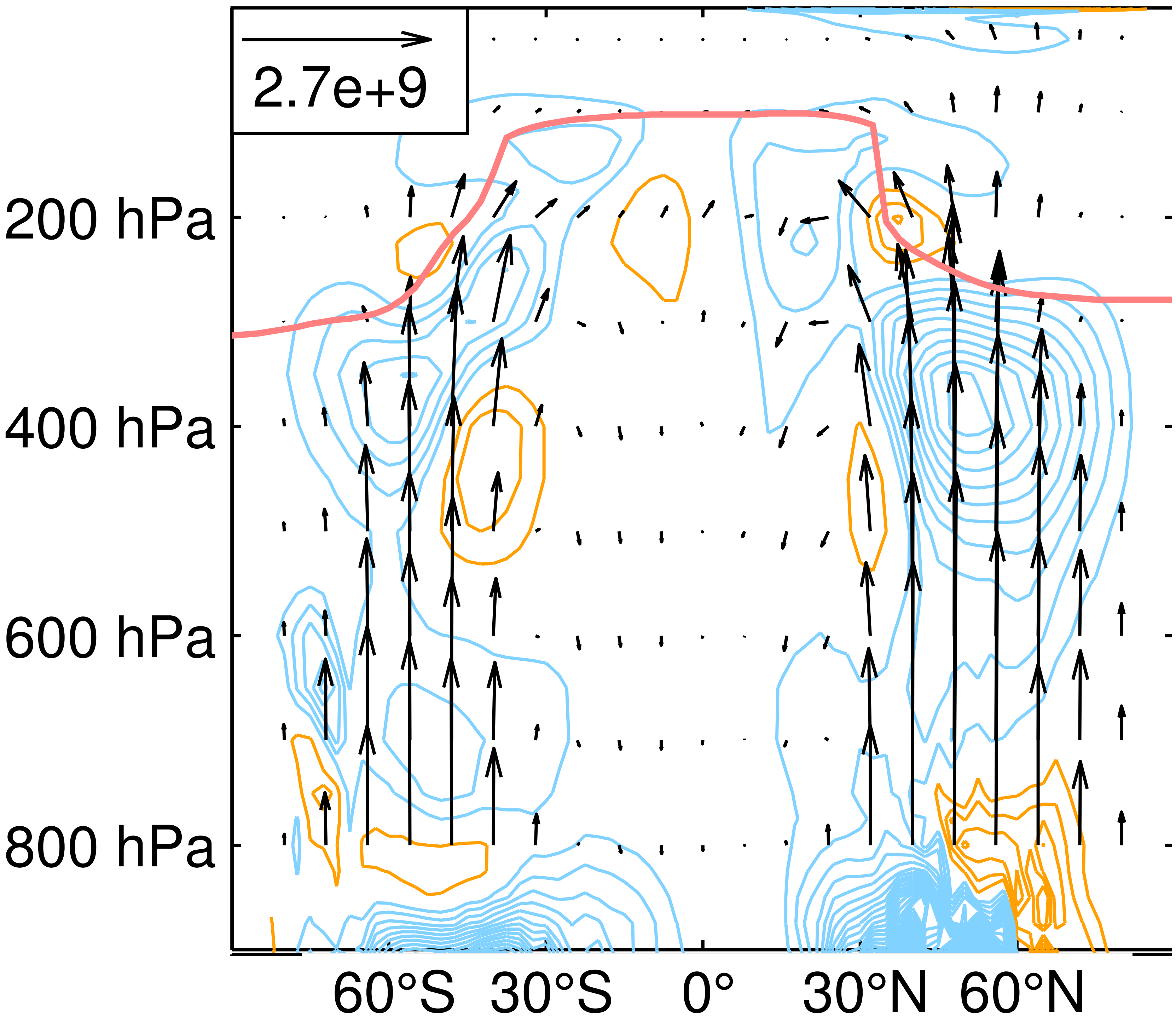
Eddy momentum flux: mostly poleward and converges at midlatitudes



Zonal and time mean of $u'v'\cos(\text{lat})$ in m^2/s^2

Fig. 5

Eliassen-Palm fluxes: upwards and then equatorward



EP fluxes (arrows); orange is divergence, blue is convergence

The reference arrow has units m^3s^{-2}. The contour interval is 75 m^2s^{-2}.

Red line is the tropopause. Based on ERA-interim DJF 1980-2013. (*Dwyer & O'Gorman, 2017)*

Fig. 6

E-P fluxes and their divergence in baroclinic lifecycle

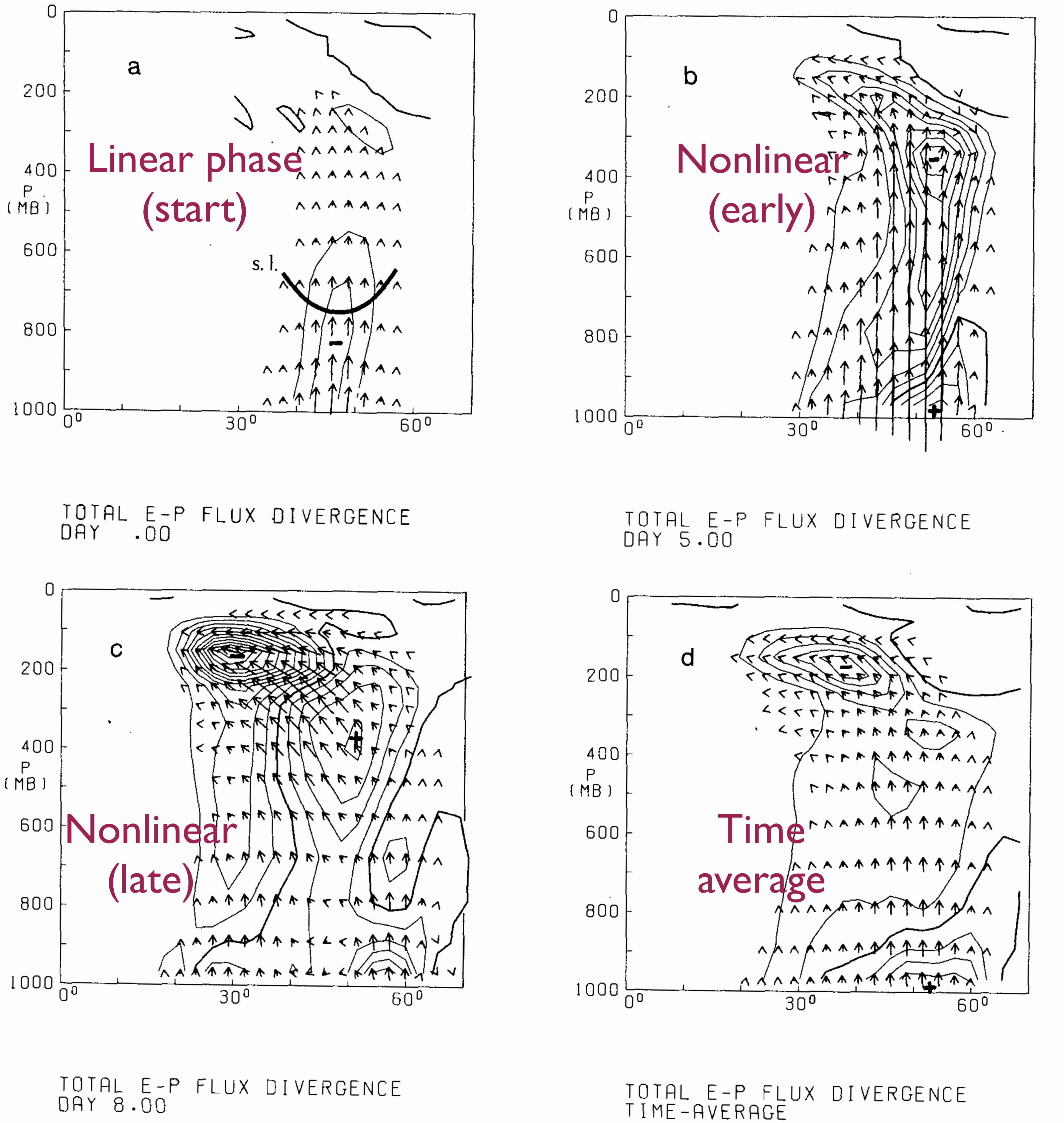
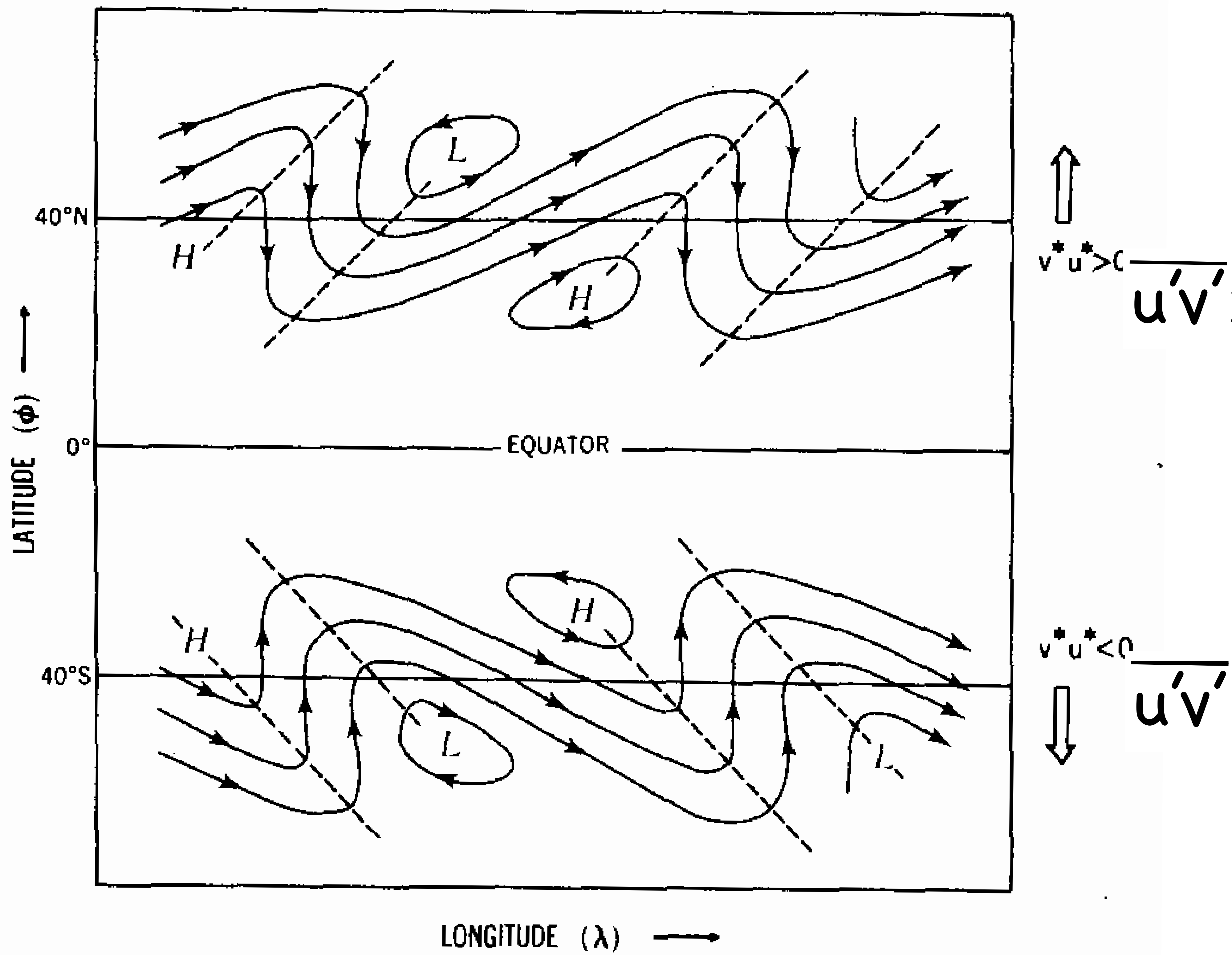


FIG. 3. (a) Eliassen-Palm cross section for a linear, growing baroclinic instability on a realistic mean state [the first case studied in Simmons and Hoskins (1980); (b), (c) cross sections for two stages in the life cycle of the same disturbance after it goes nonlinear; (d) time-averaged cross section for the life cycle. The contour interval is 4×10^{15} m^3 for (b) and (c), and 1.5×10^{15} m^3 for (d). The arrow scales are the same in all three, and such that the distance occupied by 10° of latitude represents a value 12.5×10^{15} m^3 of $\hat{F}_{(\varphi)}$, and that occupied by 100 mb represents a value 7150×10^{15} m^3 mb, or 715×10^{15} m^3 kPa, of $\hat{F}_{(p)}$.

Fig. 7

Edmon et al 1980

Tilts in Rossby waves leads to poleward flux of eastward momentum



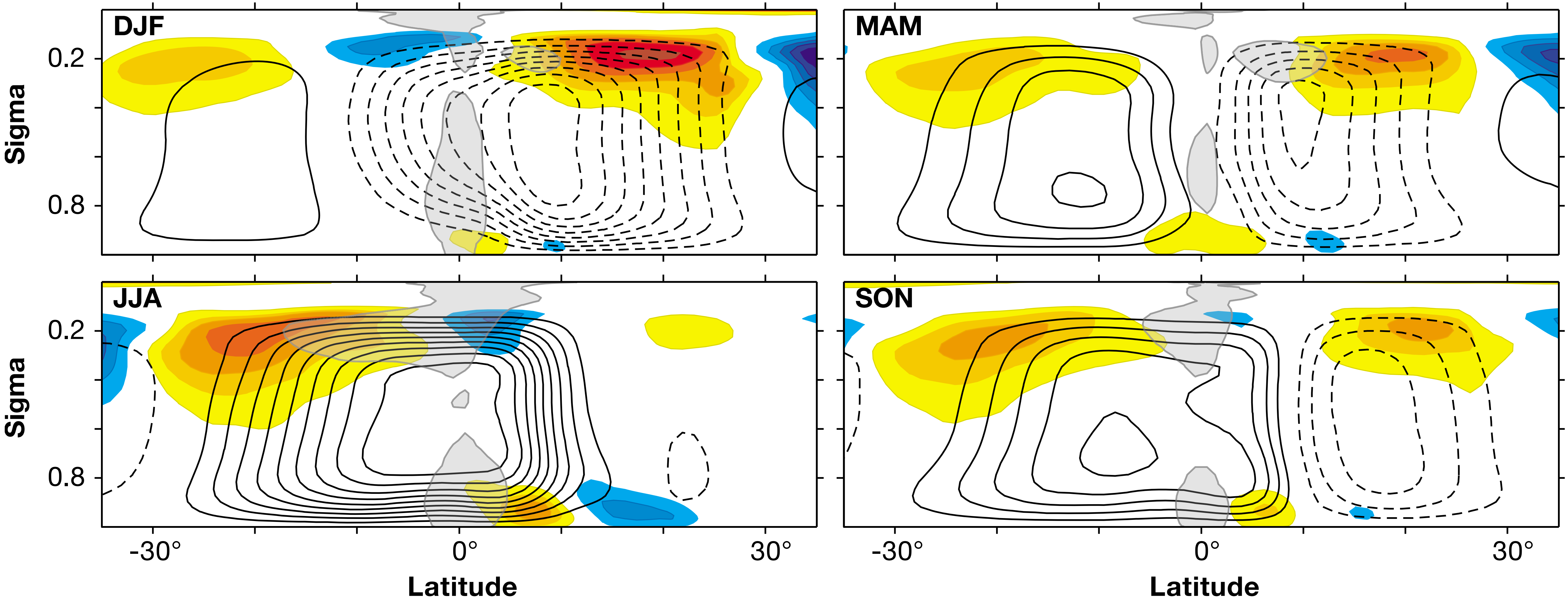
$\overline{u'v'}>0$

$\overline{u'v'}<0$

Fig. 8

Oort, 1989

Eddy momentum fluxes also affect the Hadley cells



Colors: eddy momentum flux divergence (red positive)

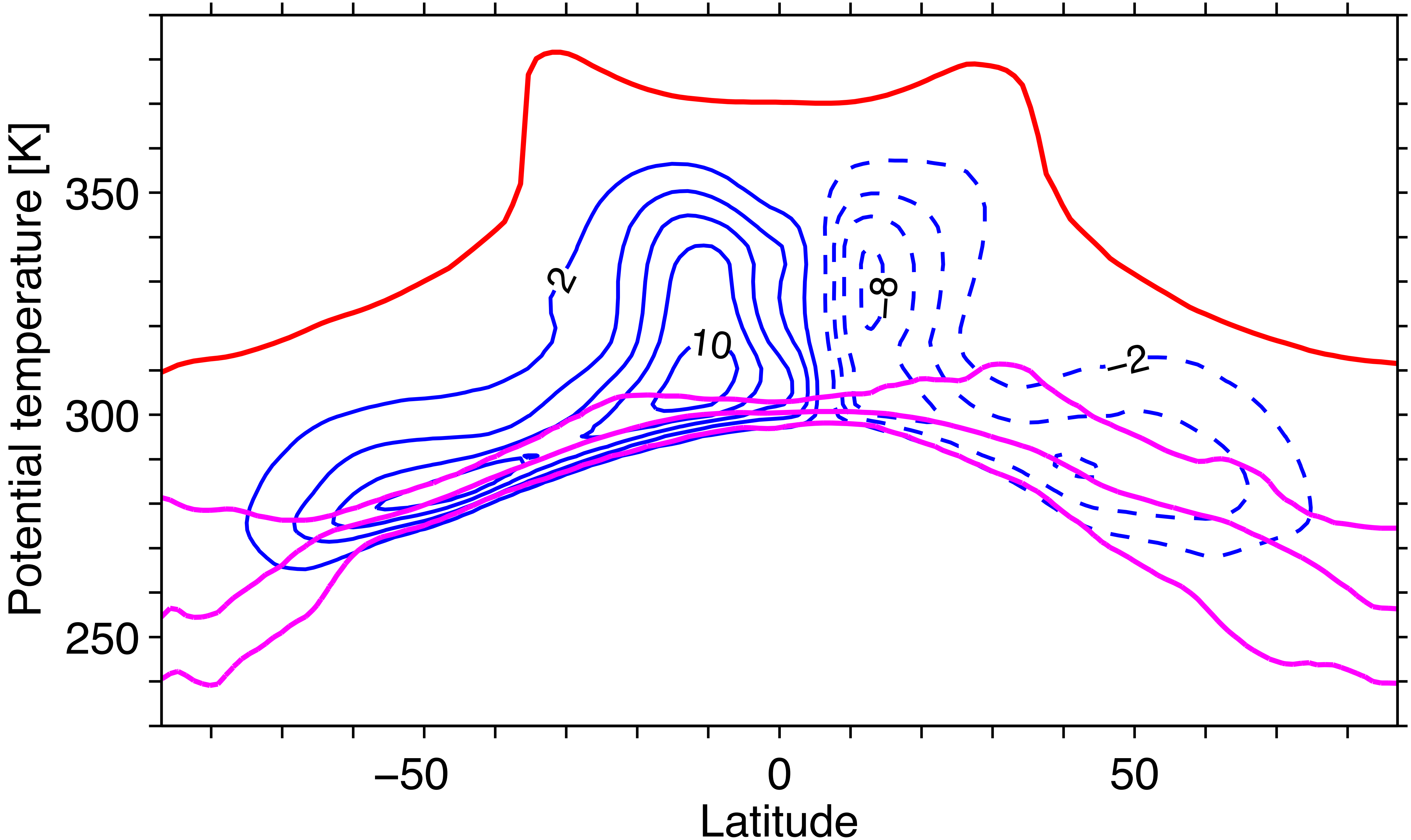
Lines: Eulerian meridional streamfunction

Gray shading: Eddy momentum fluxes not as important in zonal momentum balance in this region

Fig. 9

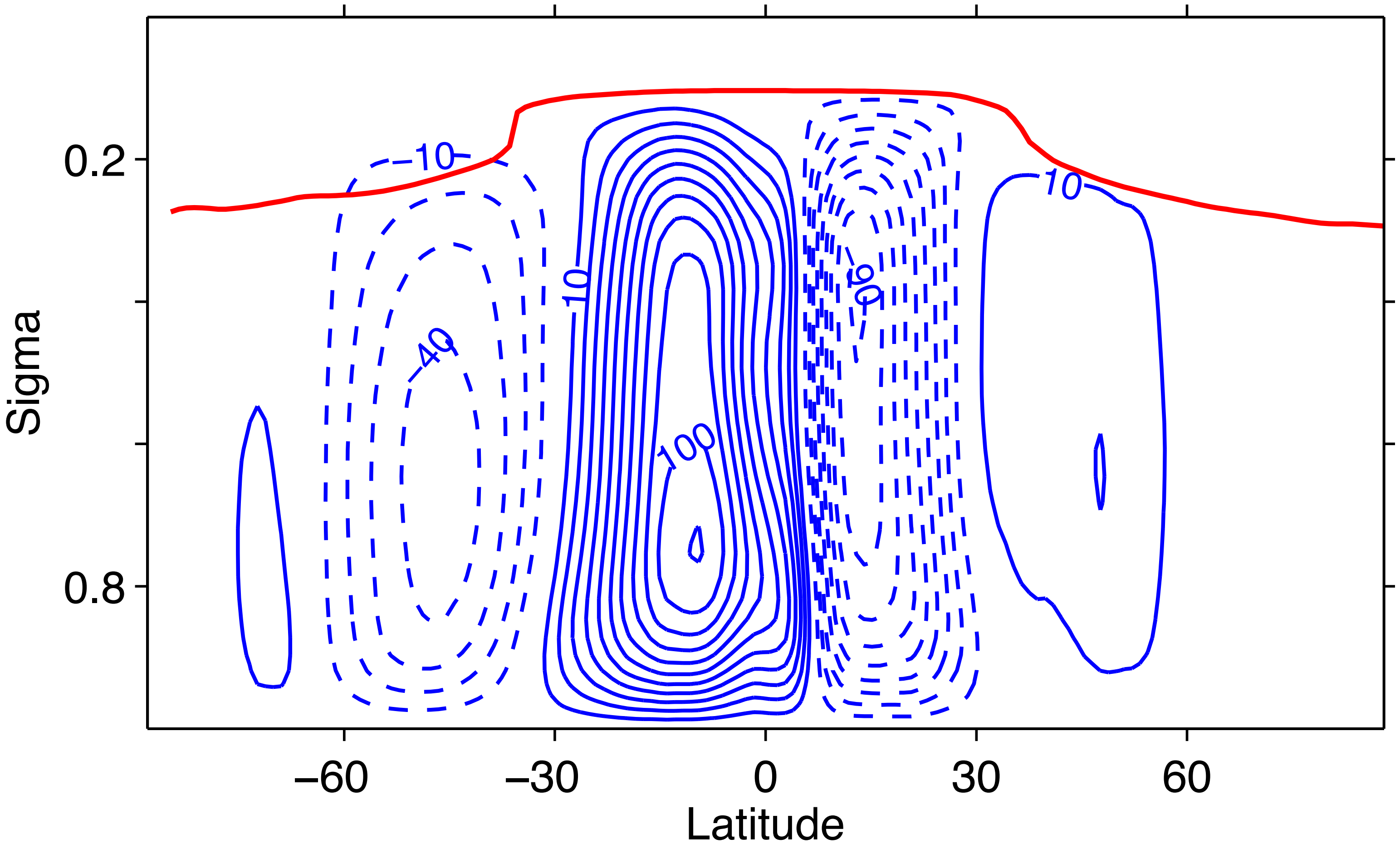
Schneider et al, Rev. Geophysics, 2010

Dry-isentropic mean meridional streamfunction (10^{10} kg s^{-1})

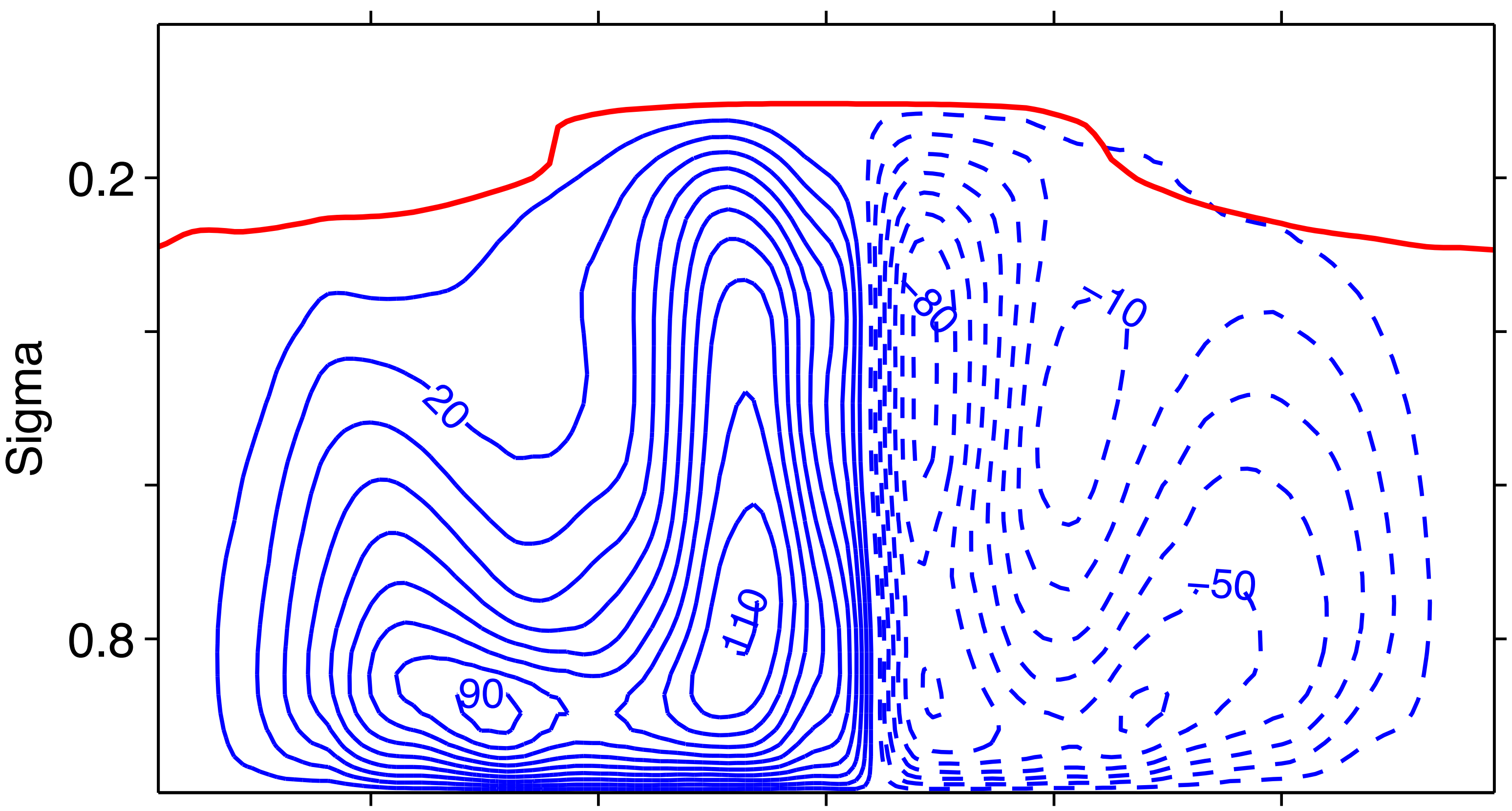


Red: Tropopause
Magenta: 10, 50, 90 percentiles of surface potential temperature distribution

Fig. 10

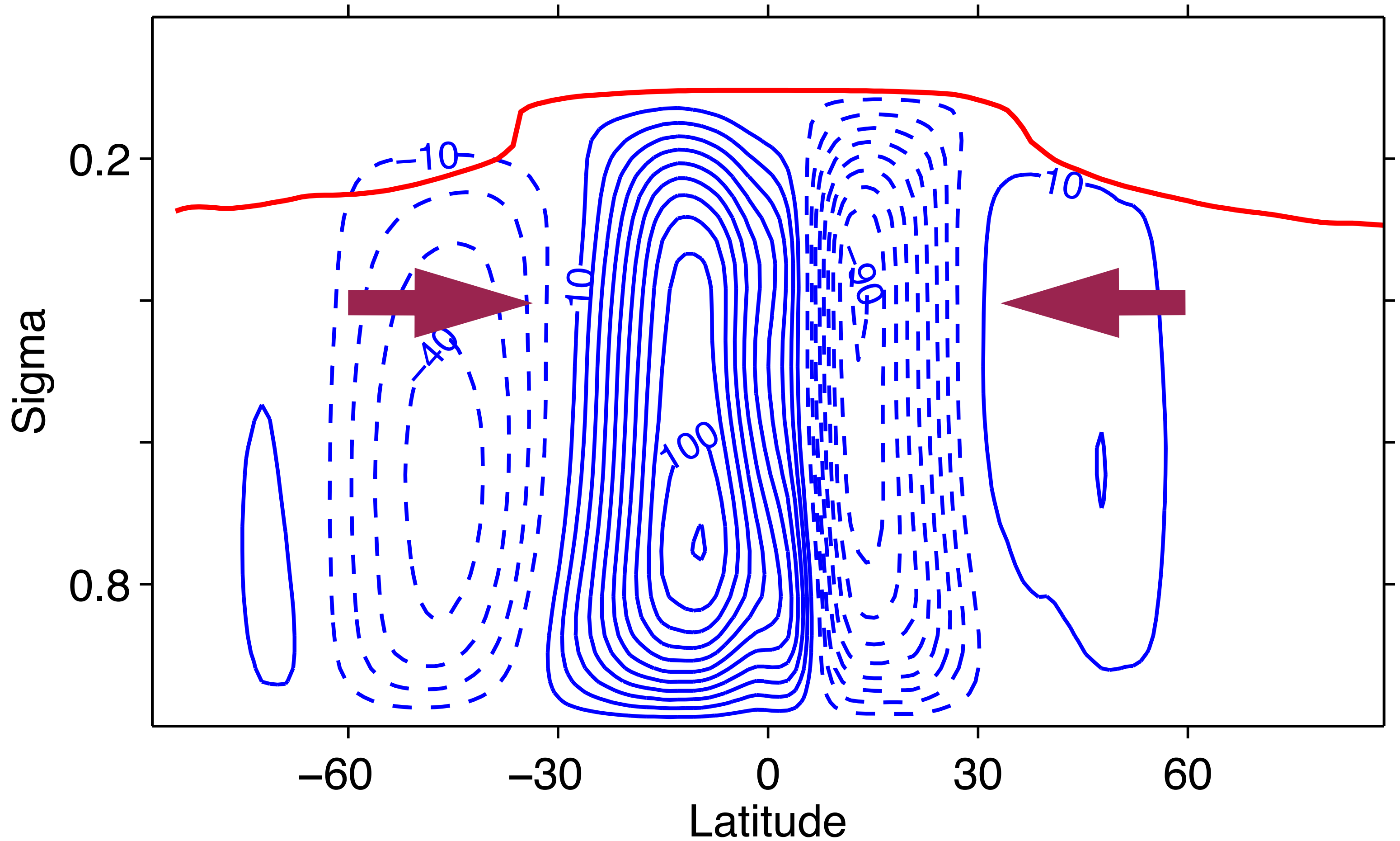


Eulerian-mean (i.e. calculated in sigma coordinates) circulation (10^9 kg s^{-1})

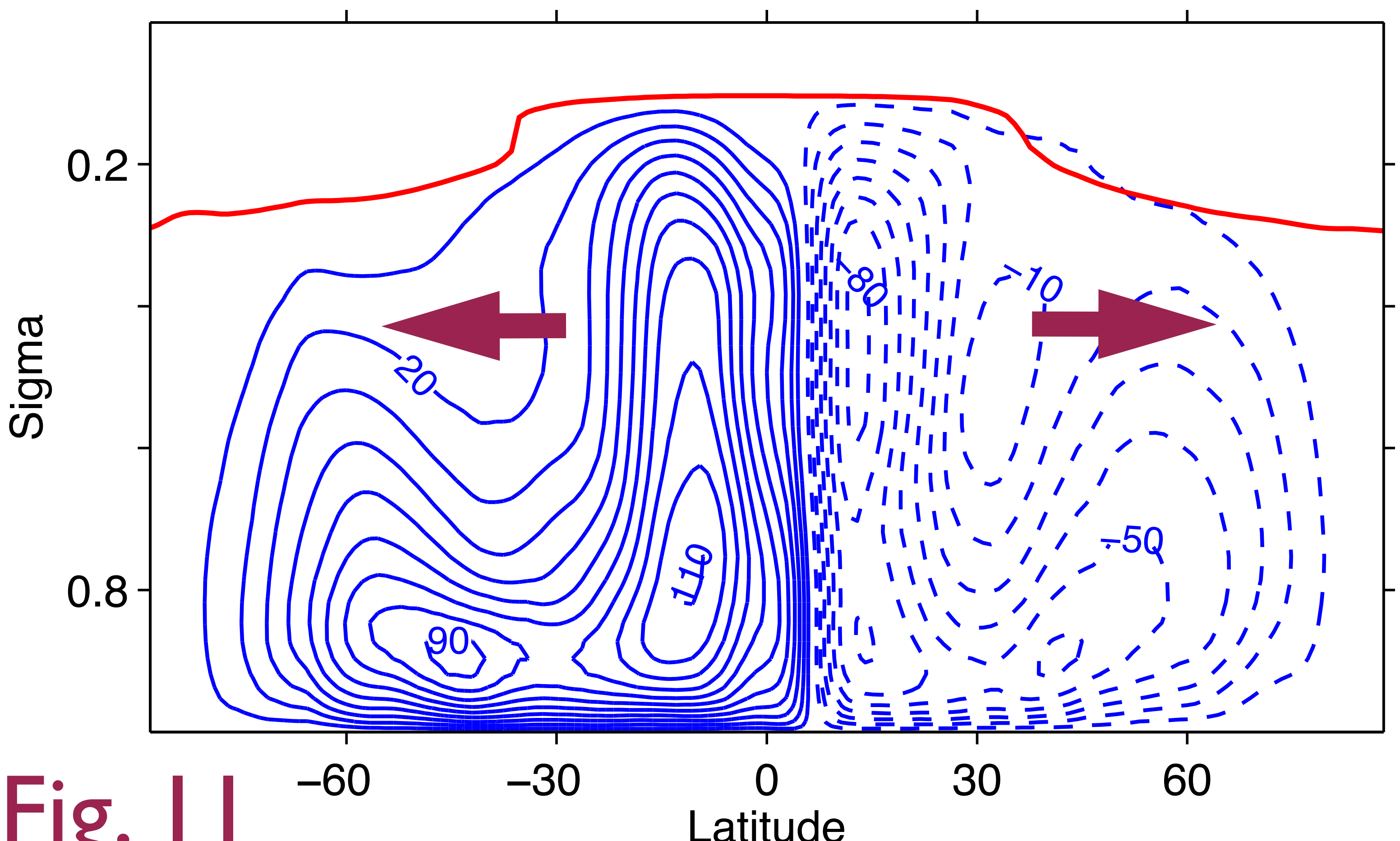


Dry isentropic circulation interpolated to sigma coordinates (10^9 kg s^{-1})

Fig. 11



Eulerian-mean (i.e. calculated in sigma coordinates) circulation (10^9 kg s^{-1})

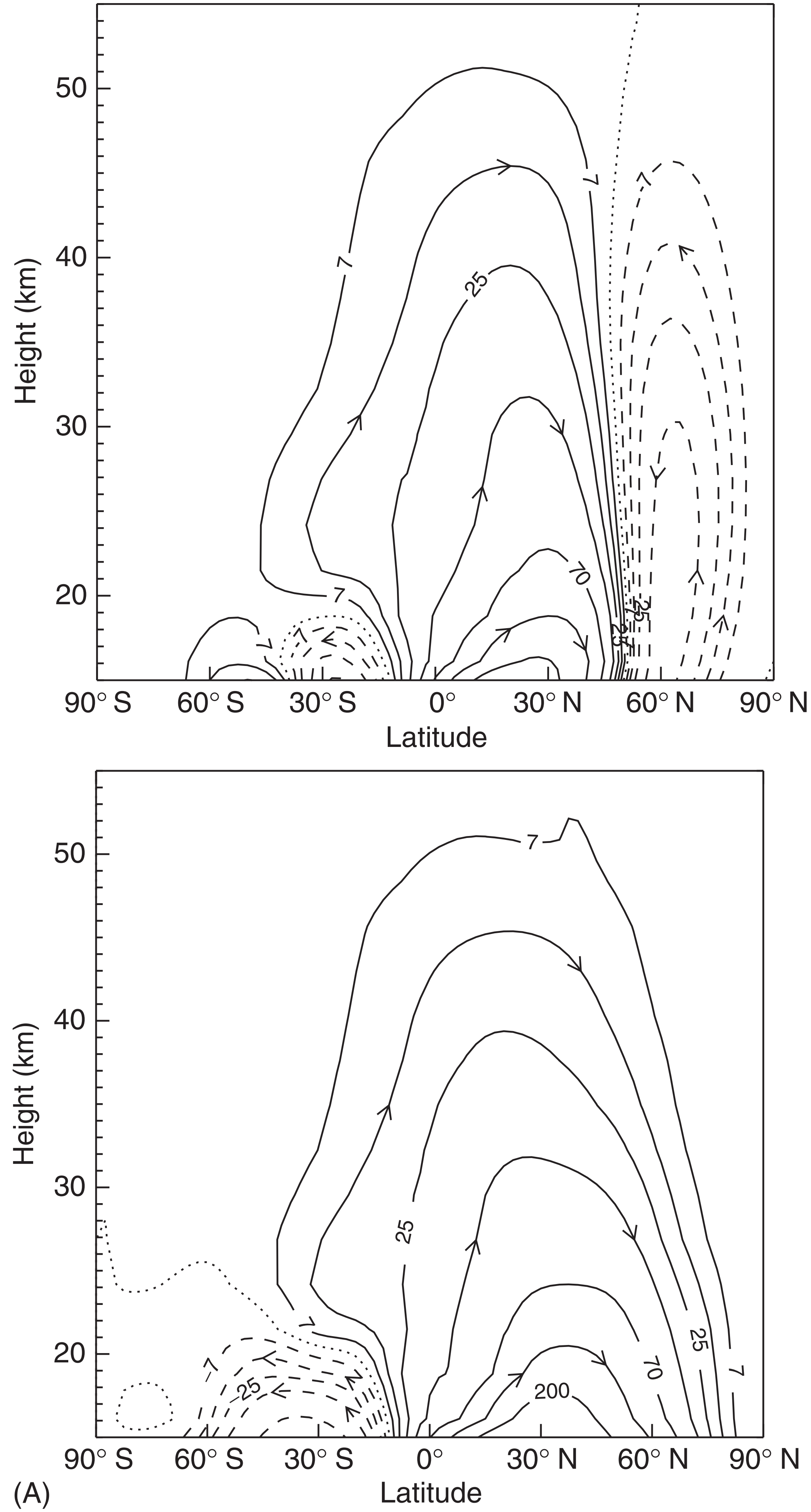


Dry isentropic circulation interpolated to sigma coordinates (10^9 kg s^{-1})

Fig. 11

January circulation in the stratosphere

Streamfunction units are kg/m/s



Eulerian mean circulation

Residual circulation (roughly the same as the circulation in isentropic coordinates)

Fig. 12

Relevance of isentropic circulation: Zonal-mean methane concentration

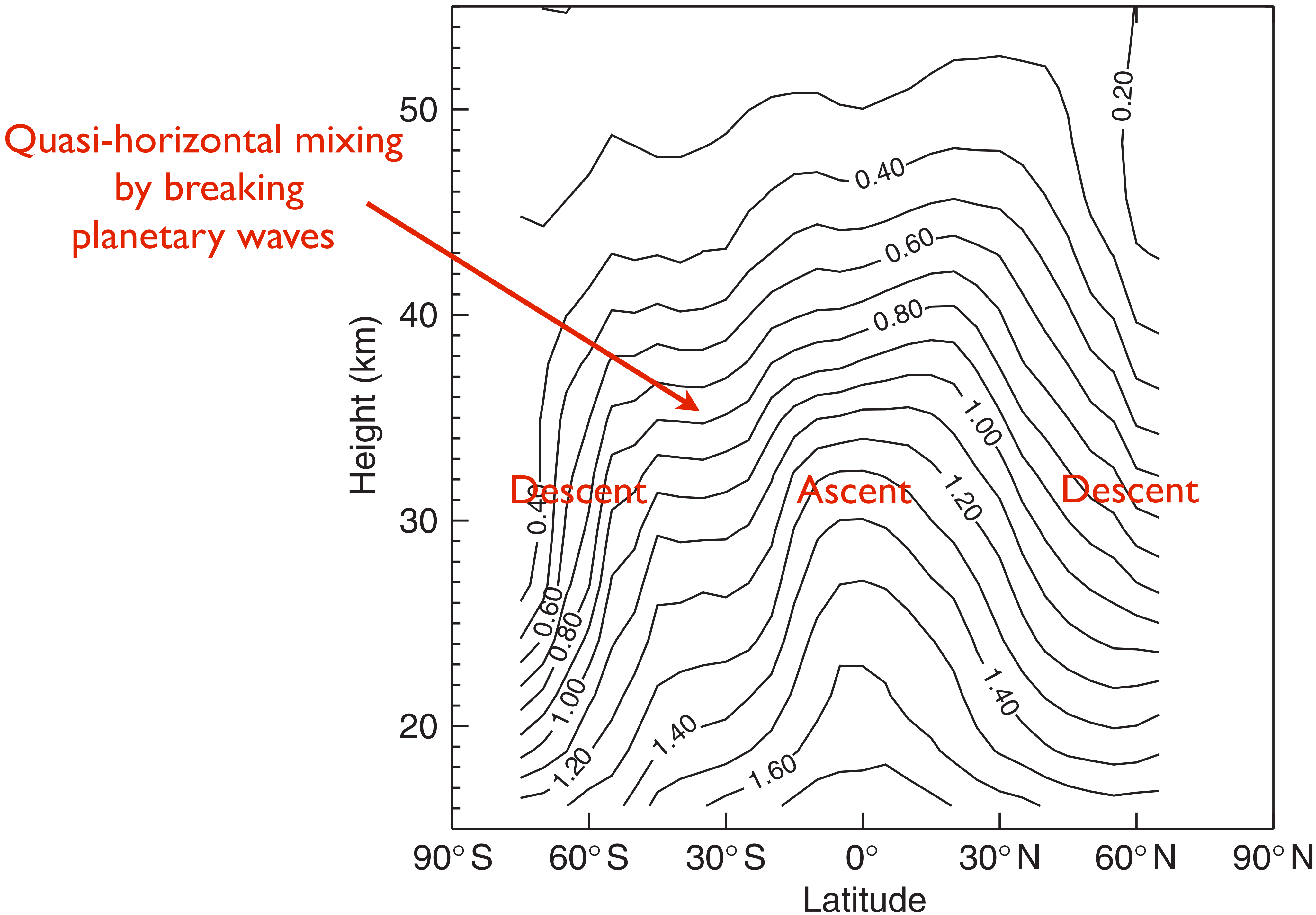


Figure 5 Zonally averaged mixing ratio of methane for October (1993–1999) as measured by Halogen Occultation Experiment (HALOE) on the UARS. Contour interval is 0.2 ppmv.

Fig. 13

Mean meridional circulation on dry and moist isentropes:

averaging on θ_e surfaces (moist isentropes) gives simplest circulation

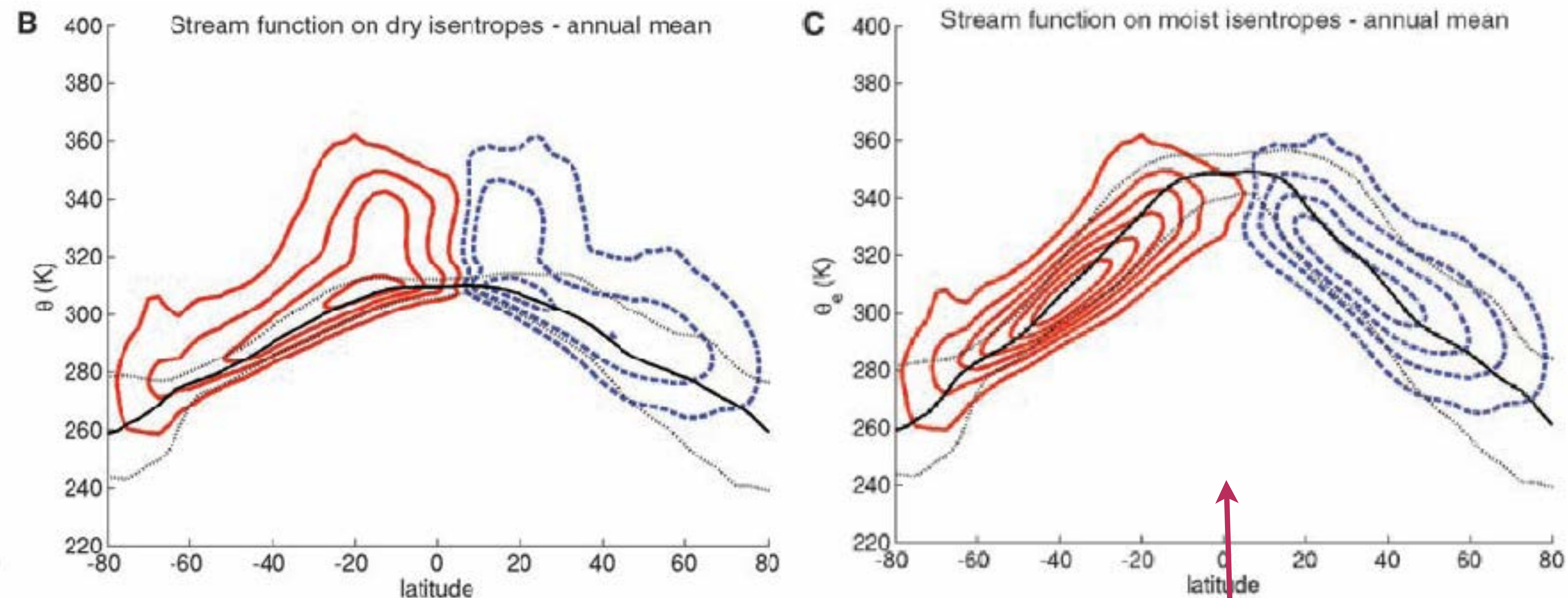


Fig. 1. The global mean circulation from the NCEP-NCAR Reanalysis. (**A**) Stream function on pressure surfaces Ψ'_p. (**B**) Same as (A) for the stream function on dry isentropes Ψ'_θ. (**C**) Same as (A) for the stream function on moist isentropes Ψ'_{θ_e}. Contour interval is 2.5×10^{10} kg s^{-1}. Solid contours are positive values of the stream function and correspond to northward flow at low levels, whereas dashed contours are negative values of the stream function and correspond to southward flow at low levels. In (B) and (C), the thin solid line and two dotted black lines show the 50, 10, and 90 percentiles, respectively, of the surface potential or surface equivalent potential temperature distributions.

Moist isentropes give very simple circulation

(Pauluis et al, Science, 2008)

Fig. 14