Eliassen-Palm Flux Calculation

Eliassen Palm flux is defined as

$$\{F_\phi, F_p\} = \{-a\cos\phi\overline{u'v'}, fa\cos\phi\frac{\overline{v'\theta'}}{\theta_p}\},$$

where a is the radius of the Earth, f the Coriolis parameter, ϕ is latitude, θ the potential temperature and (u,v) the zonal and meridional wind.

$\frac{\partial\theta}{\partial p}$ is computed from the time-mean (for the period of interest), zonal mean value of the potential temperature using a centered finite difference in log-pressure coordinates. Eddy-flux terms are computed from the zonal anomalies for each day, and the product is zonally-averaged and then time averaged for whatever averaging period of interest is chosen by the user.

EP-flux divergence is computed using centered finite difference. The results are interpolated in the vertical to equally spaced points in log(p) for display purposes. Also, only every other latitude point is shown.

Scaling of EP-Flux for Display

Edmon et al, 1980 devote considerable space to discussions of the proper way to dsipaly EP Fluxvectors and their divergence. Their goal was to have non-divergent vector fields "look" nondivergent in the display coordinates, and to have the area integral of the EP Flux divergence in display coordinates directly represent the integrated angular momentum tendency. For a graphical display in latitude-pressure coordinates, the scaling factors are

$$\{\tilde{F}_\phi, \tilde{F}_p\} = \cos\phi * \{\frac{1/a * F_\phi}{s_\phi}, \frac{F_p}{s_p}\}$$

where a is the radius of the Earth and the scale factors, s, are linked to the aspect ration of the graphic on the page. Note the additional factor of $\cos\phi$. We adopt this scaling with $s_\phi = \pi(radians)$ and $s_p = 10^5(Pa)$ even though we are using a log-pressure vertical coordinate for our display. We find that this gives an adequate display of the vectors even though it does not strictly meet the criteria set out in Edmon et al, 1980.

In Edmon et al, 1980, the divergence is also scaled as well. However, here we do not scale div(F) at all. In this way the values at a point on the graph represent the tendency in the angular momentum per unit mass. If the option to display the zonal acceleration is used instead, then what is displayed is $\frac{\partial u}{\partial t} = \frac{1}{a\cos\phi} div(F)$. The contours have been smoothed using NCAR Graphics Commend Language (ncl.ucar.edu) spline under tension set to default values.

Finally, we allow for additional scaling in the vertical to enhance the smaller vectors in the stratosphere to make them visible on the same graphic as the tropospheric vectors. Two methods are adopted. In the first, the vectors are scaled by a factor inversely proportional to pressure, $rfac = sqrt(1000.0/p)$. This method is commonly adopted, for example in Taguchi and Hartmann, 2006). In the second we optionally allow all vectors above 100 mb to be multiplied by a scale factor, typically chosen to be 5.0.

Notes

These calculations were make for the real-time monitoring of EP-Flux, and were done using many approximations. In addition the vectors have been scaled for visual display. As a result, the vectors have meaning in terms of their relative magnitude only. Use at your own caution!

References

Edmon, H. J., B. J. Hoskins, and M. E. McIntyre, 1980: Eliassen-Palm cross sections for the troposphere. *J. Atmos. Sci.*, **37**:2600–2616

Taguchi, M., and D.L. *Hartmann*, 2006: Increased Occurrence of Stratospheric Sudden Warmings during El Niño as Simulated by WACCM. , 19, 324–332