Analysis of Three - Dimensional Elliassen-Palm Fluxes In the Lower Stratosphere

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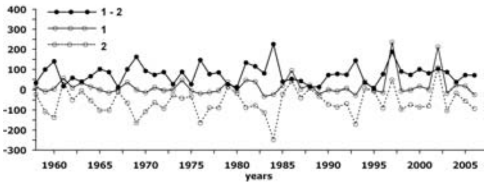
Data and Methods

$$\vec{F} = \begin{pmatrix} -\overline{u'v'} \\ \dfrac{2\Omega\sin\varphi}{S} \times \left[\overline{v'T'}\right] \end{pmatrix}$$

As proposed by **Eliassen and Palm** (1961)[1]

$$\vec{F}_s = \frac{p}{p_0}\cos\varphi \times \begin{pmatrix} v'^2 - \dfrac{1}{2\Omega a\sin 2\varphi}\dfrac{\partial(v'\phi')}{\partial\lambda} \\ -u'v' + \dfrac{1}{2\Omega a\sin 2\varphi}\dfrac{\partial(u'\phi')}{\partial\lambda} \\ \dfrac{2\Omega\sin\varphi}{S} \times \left[v'T' - \dfrac{1}{2\Omega a\sin 2\varphi}\dfrac{\partial(T'\phi')}{\partial\lambda}\right] \end{pmatrix}$$

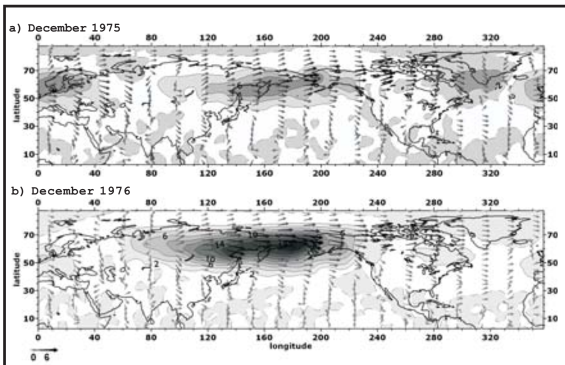
As proposed by **Plumb** (1985)[2]



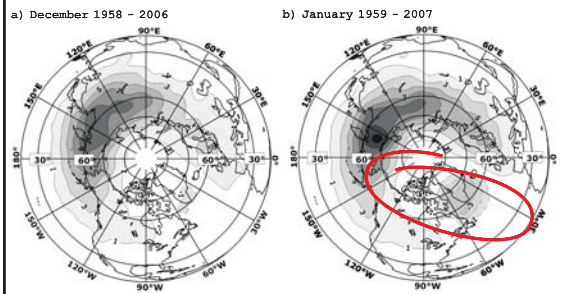
1) Eliassen, A. and E. Palm,1961: On the transfer of energy in stationary mountain waves. *Geofys. Publ., No. 3, 1-23*
2) Plumb, R.A., 1985: On the three-dimensional propagation of stationary waves. *J. Atmos. Sci., 42, 217-229*

The monthly mean NCEP/NCAR reanalysis data were used at the standard levels 100, 70, 50, 30, 20, 10 hPa for each month (November - March)

The vertical flux Fz is associated not only with the eddy heat flux, but also with the longitudinal particularities of the second term, the contribution of which is compared with that of the first term. The second terms disappear after its averaging on the longitude, therefore, two - dimensional EP fluxes can not indicate longitudinal particularities of the upward and downward propagation of planetary waves and their forcing on the atmospheric circulation.



Activity Flux F_s for the Northern Hemisphere December stationary wave field at 30hPa Arrows - horizontal component; contours - vertical ($\times10^{-5}m^2/s^2$)



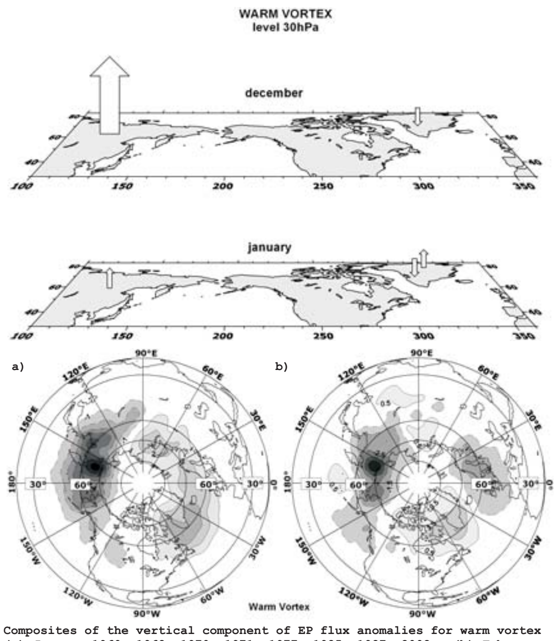
49-year mean of the monthly mean vertical component Elliassen-Palm fluxes at 30 hPa ($\times10^{-5}m^2/s^2$)

Climate

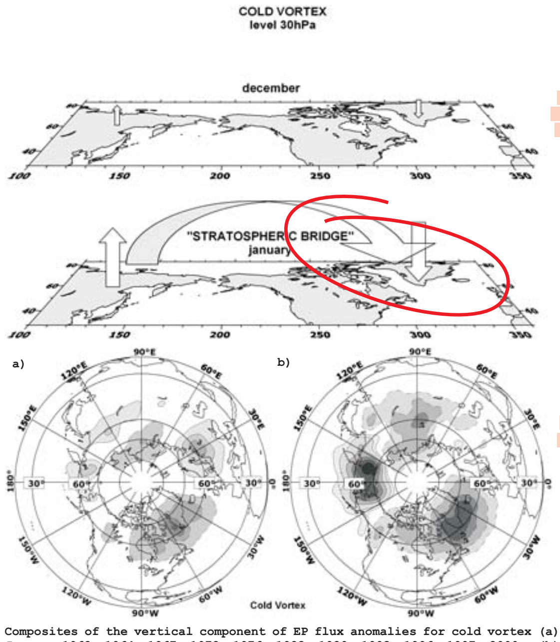
Large penetration of the planetary waves from the troposphere to stratosphere (positive Fz) is observed over Siberia, while the weak downward wave propagation occurs over North Atlantic and southern Greenland (negative Fz) in December, which is strengthening in January-February and weakening in March. The downward signal is small in comparison with the wave penetration from the troposphere to stratosphere, however, as shown below, it plays a large role in the stratosphere troposphere coupling.

Scheme of the upward and downward propagation

The significant increase of planetary wave penetration into the stratosphere over the northern Eurasia occurs in December before the stratospheric warmings in January together with small variations of the downward signal in the North Atlantic. Cumulative accumulation of the eddy energy from the troposphere to stratosphere in December leads to stratospheric warmings in January. A decisive significance for stratospheric warming appearances (cooling of the Arctic stratosphere) has the strengthening (weakening) of the planetary wave penetration during early winter. This is the well-known preconditioning for the stratospheric warming generation.



Composites of the vertical component of EP flux anomalies for warm vortex (a) January 1960, 1968, 1970, 1971, 1977, 1985, 1987, 2002 , (b) February 1966, 1973, 1979, 1980, 1984, 1989, 1999, 2001 ($\times10^{-5}$ m^2/sec^2).

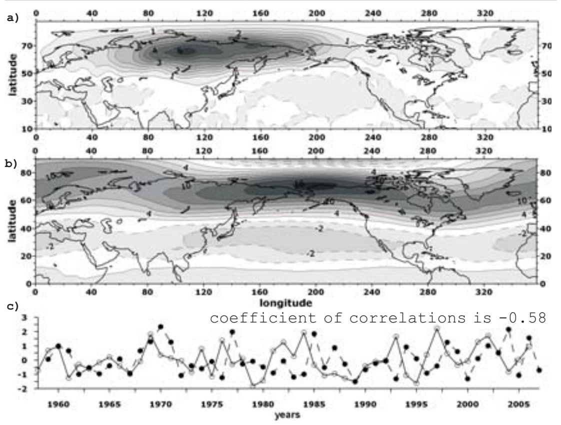


Composites of the vertical component of EP flux anomalies for cold vortex (a) January 1962, 1964, 1967, 1972, 1976, 1983, 1989, 1993, 1996, 1997, 2000 , (b) February 1959, 1964, 1967, 1974, 1976, 1986, 1988, 1996, 2000 ($\times10^{-5}$ m^2/sec^2)

The opposite situation is observed for the cold stratospheric vortex in January: very weak penetration of the planetary waves from the troposphere to stratosphere over the northern Eurasia and insignificant downward Fz fluxes over the North Atlantic in December.

Under these conditions, the interaction of the wave processes between the North Pacific and North Atlantic ("stratospheric bridge") is being formed due to a refraction of planetary waves from the strong westerlies in the stratosphere and can influences on the NAO in the troposphere.

Predictor of the potential for a SSW



First EOF of the vertical component of the EP flux anomalies ($\times10^{-5}m^2/s^2$) for December 1959-2006 (a), zonal wind anomalies (m/s) for January 1958-2007 at 30 hPa (b), PCs of the first EOF for the EP flux - solid line, dashed line for zonal wind (sign reversed) (c).

Correspondence between the interannual variations of the Fz PC in December and zonal wind PC in January. The most prominent deceleration of the stratospheric polar jet is observed over Chuckotka and Alaska in January after the strengthening of the planetary wave penetration to stratosphere in previous December. Lifetime of the wave - mean flow interaction is about one month during early winter.

	Nov	Dec	Jan	Feb	Mar
Nov	-0.44	-0.47	-0.26	-0.05	0.15
Dec	-0.06	-0.29	-0.58	-0.27	-0.04
Jan	0.13	0.26	0.43	0.23	0.02
Feb	0.16	0.21	0.47	0.38	0.06
Mar	0.26	0.32	0.14	0.35	-0.13

Correlation between PC of the 1[st] EOF of EP-flux (z - component) and PC of the 1st EOF of zonal wind anomalies at 30hPa

It should be noted that negative correlations take place during early winter (November December), but not in February - March. During late winter there exist the statistically significant (on 95% of confidence) positive correlations of zonal wind anomalies in January with a subsequent penetration of planetary waves in February (0.47), for example.

Conclusions

1) Interaction of planetary waves with zonal-mean circulation in the stratosphere has large differences in the early (November-December) and mid- to late (January-March) winter

2) The downward wave signal propagation is indicated in the lower stratosphere over North Atlantic with its most prominent signature in January - February for the cold stratospheric vortex in the Arctic.

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