Climate Patterns and the Forcing of the Polar Stratosphere in Winter

Yvan J. Orsolini[1] (orsolini@nilu.no), **Alexei Karpechko**[2], **Grigory Nikulin**[3]

[1]*Norwegian Institute for Air Research,* [2]*Finnish Meteorological Institute,* [3]*Laboratoire de Meteorologie Dynamique du CNRS*

Introduction

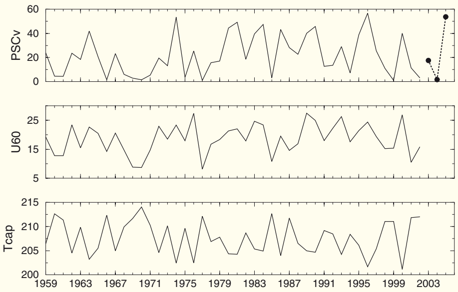
In the northern hemisphere, large-scale waves originating in the troposphere strongly condition the wintertime circulation of the stratosphere. The highly variable wave amplitudes and fluxes in the troposphere, and the varying upward propagation conditions (both vertical and meridional) contribute to the high inter-annual and intra-seasonal variability of the northern hemisphere polar temperatures and vortex.

We re-examine the nature of tropospheric perturbations that lead to a cold (warm) winter stratosphere, and high ozone depletion potential: can we identify concomitant features in the tropospheric circulation when the stratosphere is anomalously cold?

Polar stratospheric cloud volume (PSC_v) as a vortex diagnostic

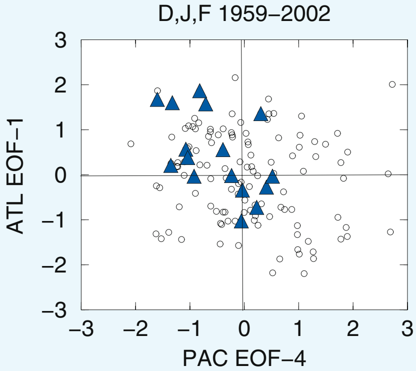
A measure of the coldness of the winter stratosphere that is widely used in ozone research is the polar stratospheric cloud (PSC) potential, measuring the three-dimensional extent of the stratospheric region where PSCs can form, at temperatures below a threshold of typically 190K. When scaled by the chlorine loading, the seasonally averaged PSC volume is tightly connected to ozone loss for that year. PSCv is expressed in millions of cubic kilometers, and is highly non-Gaussian. We also use the 475K temperature averaged over the polar cap (latitudes above 60N), and the zonal-mean zonal wind at 60N at 475K, as a measure of the polar vortex strength.

DATA: winter (DJF) months for the ERA-40 period (1959-2002), 132 months in total.



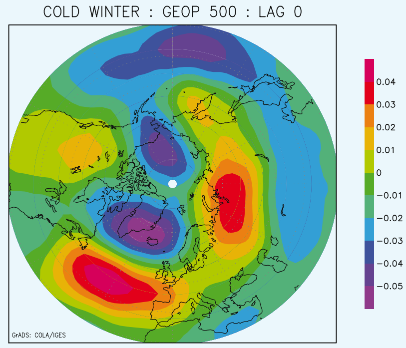
Cold months with extreme PSC_v

The indices of the PAC EOF-4 and the NAO are shown for all the 132 (DJF) months of the ERA-40 record, and for the months of PSC_v exceedance (large triangles). These particular months tend to cluster (8 of them) in the quadrant where the NAO is positive and the PAC EOF-4 is negative. In other words, large PSCv (and potentially large ozone loss) are found during months characterised by the absence of the Alaskan ridge and by a positive NAO.



The composite of the 500mb geopotential height departures from the climatology for all the 16 months during which the stratosphere was anomalously cold, shows, at high latitudes:

i. a negative geopotential anomaly over the North Atlantic, part of a meridional dipole that is characteristic of a positive NAO phase and a deepened Icelandic Low.
ii. a north-south elongated negative anomaly straddling Alaska and extending toward the Pole.
iii. a positive anomaly over Northern Asia and Siberia, which may be indicative of an intensified, poleward-extended Siberian High.



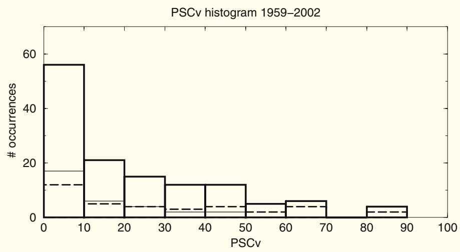
The "Alaskan" ridge as a Pacific climate pattern

The leading Pacific winter patterns are described in many studies, e.g. Pavan et al. [2000], and comprises the Pacific-North America (PNA) pattern (32%), the West Pacific pattern (20%), and higher order regional Pacific patterns. The EOF-4, explaining 7% of the sectorial variance, characterised by a trough/ridge closely resembling the one seen in the cold winter 500-mb composites.

The stratospheric 50mb-geopotential anomalies associated to the fourth Pacific pattern reveal that, the positive, ridged phase is associated with greater polar heights, and decreased heights over Canada. The total composited geopotential heights for the positive phase show the polar vortex ridged over the North Pacific, displaced toward Eurasia and elongated toward Canada. One may conjecture that the north-south orientation of the ridge/trough, its longitude near the background planetary wave ridge/trough, and its marked poleward extension are conducive to enhanced meridional heat fluxes and upward propagation, and hence to a warm stratosphere.

Histogram of PSC_v

We examined changes in the histogram of PSC_v, for both phases of leading Pacific patterns, but found that only the PAC EOF-4 had a marked influence: in its negative phase, the PSCv distribution has a longer tail than in the positive phase, when no values larger than 50 were found. The later, with its pronounced Alaskan ridge extending to the pole, is hence associated to a less extreme PSC potential.

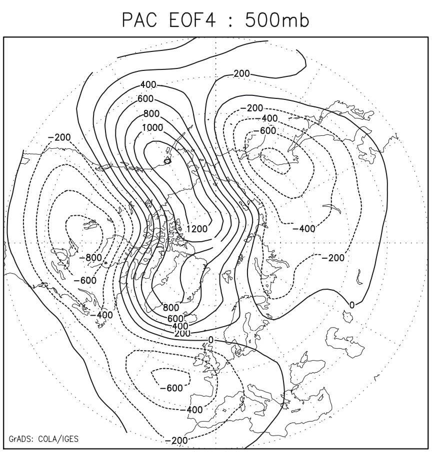


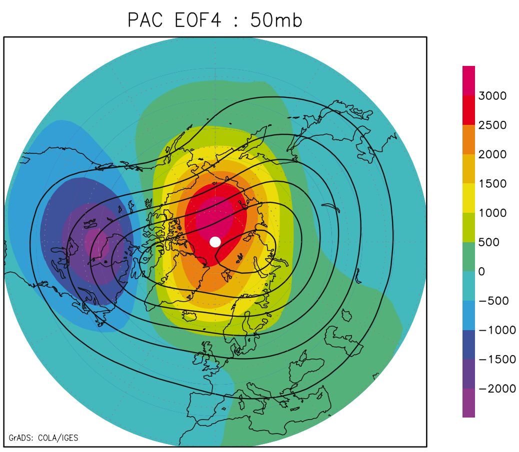
Conclusions

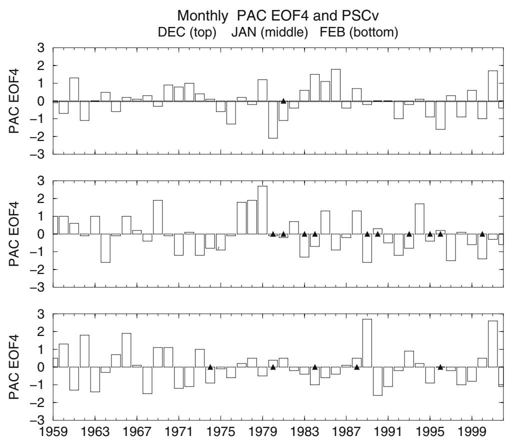
- North Pacific ridging events are important to "rock" the stratosphere.
- Cold winter months, large PSC volume and potential ozone loss, occurrences are characterised by the absence of north Pacific ridges east of the dateline, and by a positive NAO.

There is a need to better understand the origin and decadal variability of the winter North Pacific ridge. The years during which PSCv was above exceedance (triangles) largely occur when the PAC EOF-4 is in its negative phase. During the mid nineties, the stratosphere had high PSC potential, the pattern was in negative phase for a prolonged set of years.

This is of particular importance in a changing climate, as we expect that the stratosphere would be subject to dynamical feedbacks involving changes in the planetary wave propagation. The rising sea-surface temperatures due to global ocean warming will impact the generation of planetary waves, and their upward propagation into the stratosphere, which is a highly non-linear process that depends on the state of the stratosphere itself.







References

- Pavan, V., S. Tibaldi and C. Brankovic, Seasonal prediction of blocking frequency: results from winter ensemble experiments, Q. J. R. Meteorol. Soc., 126, 2125-2142, 2000b
- Orsolini, Y.J. and F.J. Doblas-Reyes, 2003, Ozone Signatures of Climate Patterns over the Euro-Atlantic Sector in the Spring, Quart. J. Roy. Meteor. Soc., 129, 3251-3263.