Variability of the northern hemisphere polar stratospheric cloud potential: the role of North Pacific disturbances

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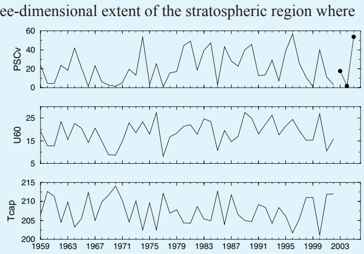
Introduction

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 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 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 (PSCv)

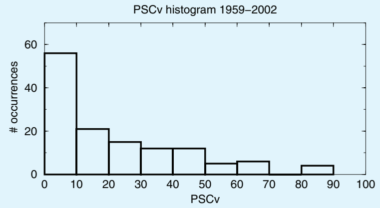
A measure of the coldness of the winter stratosphere that is widely used in ozone research is the polar stratospheric cloud (PSC) potential, measuring the three-dimensional extent of the stratospheric region where PSCs can form, at temperatures below a threshold of typically 190K. When scaled by the 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.



Histogram of PSCv

We construct "cold winter" or " high PSC potential" composites based on the exceedance criterion PSCv > 50 (millions km^3), met in 16 cases (12%)



Cold months with extreme PSCv

"Cold-winter" composites, i.e. departures from the climatology for all the 16 months during which PSCv was high, are shown for geopotential at 500mb and 50 mb, for three monthly lags. Black contours are climatology, green contours statistical significance.

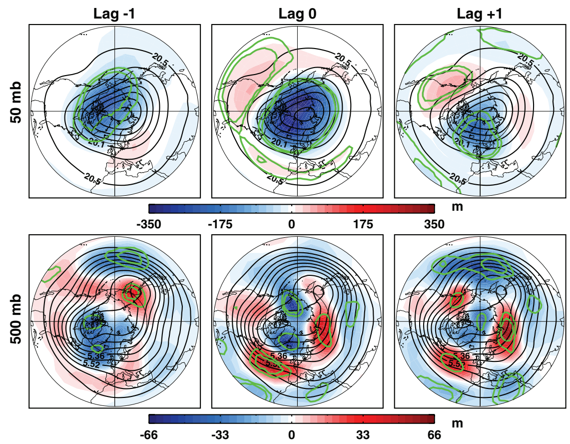
Lag –1 (Precursory)
- Dipole over the Pacific sector, with High over the Far East
- North Atlantic Low

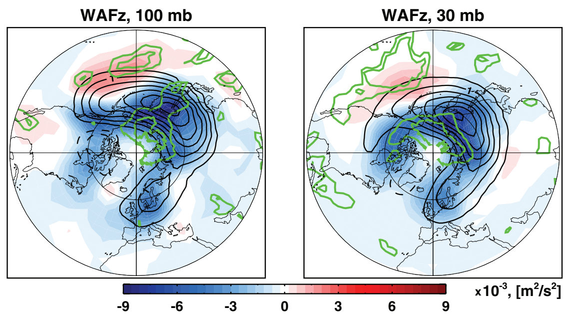
Lag 0 (Coincident)
- NAO-like meridional dipole over Atlantic
- Alaskan trough

Lag +1 (1 month after)
- More zonal at high latitudes
- Wave-3 Highs over mid latitudes

Importantly, large PSCv occurrences are preceded by a large dipole anomaly over the North Pacific. The positive lag tropospheric response to a cold stratosphere is similar to the annular mode structure.

The composites of the vertical component of the wave activity flux, WAF, (i.e. eddy meridional heat flux) at 100mb and 30mb reveal that the flux deficit leading to a cold stratosphere is located over the North Pacific, which is also the region of flux climatological maximum.



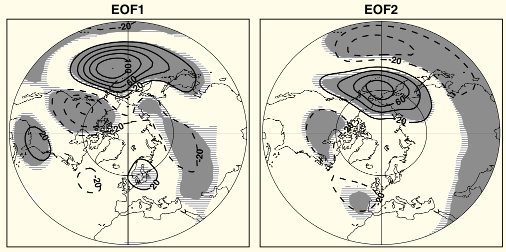


Leading Pacific climate patterns

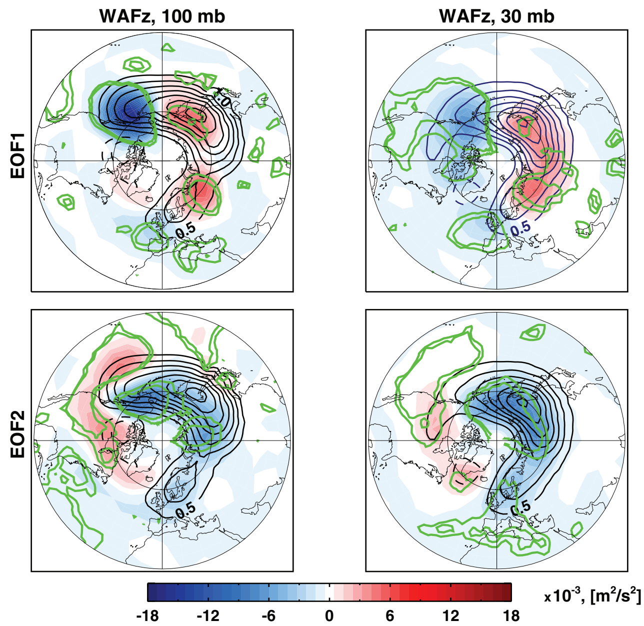
In winter, the two leading sectoral Pacific patterns derived from EOF analysis (Pavan et al., 2000) are the Pacific-North America (PNA) pattern (32% variance), and the West Pacific pattern (20%).

	Lag -1	Lag 0	Lag 1
EOF1 (PNA)	-0.21	-0.21	-0.18
EOF2 (West PAC)	**0.67**	-0.03	0.06

Table: Mean indices of the two leading Pacific EOFs for months of PSCv exceedance.



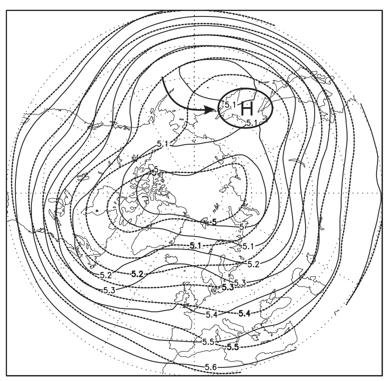
Their WAF anomalies reveal that the positive phase of the West Pacific pattern is the closest to the cold winter composite.



Conclusions

Tropospheric disturbances in the Pacific sector are important to cool the stratosphere, exerting a strong influence on PSC potential, and hence potential O_3 depletion.

Precursory anomalies to a cold stratosphere resemble a West-Pacific pattern, with a High over the Far-East indicative of an East-Asian monsoon amplification (Takaya and Nakamura, 2005). This Pacific-type amplification is characterised by westward-propagating anomalies leading to inward breaking polar vortex in the troposphere. The position of these Pacific disturbances wrt the background planetary wave structure is important, as it leads to a breaking of the background planetary wave trough, lessening WAFs into the stratosphere.



Schematics: Dec 95 (coldest winter month in ERA40) geopotential at 500mb, and winter climatology (dashed). Note breaking of the trough, and high anomaly over Far East

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