Variability Structures of the Coupled Troposphere/Stratosphere Circulation

A contribution to KODYACS-PROVAM

AFO 2000

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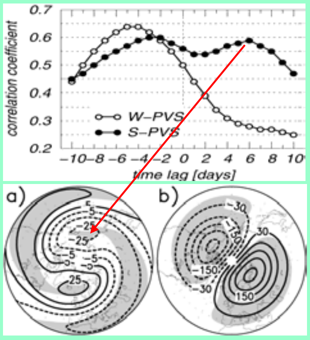
1.Introduction

*Honda et al. (2001) reported about a **significant negative correlation between the Aleutian and Icelandic lows** in mid January and February in NCEP reanalysis data (1978-93).*

Similar results were found in climate models by several authors for the whole winter, but not in observations.

Is this result biased by the stratospheric winds?



Weak polar vortex: troposphere impacts stratosphere

Strong Polar vortex: stratosphere feeds back to troposphere

2. Data and Method of Analysis

We used the wintertime (N,D,J,F,M,A) monthly means of sea level pressure (SLP) and zonal wind at 50 hPa with a horizontal grid resolution of 2.5º lat. X 2.5ºlog., covering the period 1948-2000 (NCEP reanalysis).

The seasonal cycle was removed by subtracting the long term mean of each month and detrended by subtraction of the five year running mean at each grid point.

The SLP data were stratified into three sub-samples

- **SPV** (Strong Polar Vortex): $u_{50hPa} > 20\ m\ s^{-1}$
- **N-SPV** (Non Strong Polar Vortex): $u_{50hPa} < 20\ m\ s^{-1}$
- **WPV** (Weak Polar Vortex): $0 < u_{50hPa} < 10\ m\ s^{-1}$

EP-Flux anomaly composites

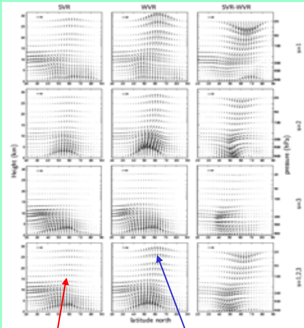


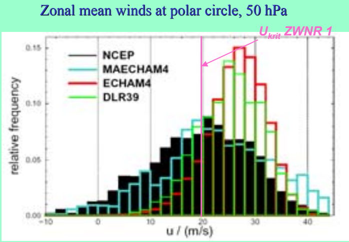
Figure 1: Eliassen-Palm flux composites for SVR, WVR and their differences. The vector at the upper left corner represents $10a\rho_0(0)\ m^3s^{-2}$ of the scaled E-P flux for individual waves, and $25a\rho_0(0)\ m^3s^{-2}$ for their sum. The scale for the differences is half of that of the respective composites.

Planetary wave energy is deflected equatorwards, westerly momentum transported polewards

Planetary wave energy propagates deep into the stratosphere, easterly momentum transported equatorwards

Model behaviour and sensitivity

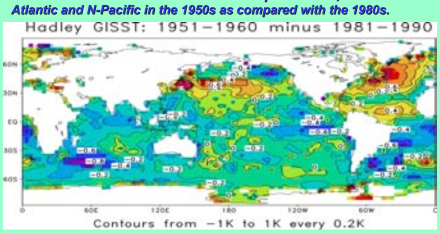
Zonal mean winds at polar circle, 50 hPa

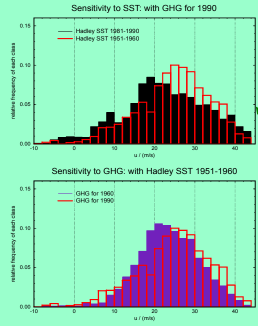


The models are heavily biased towards too strong winds.

Variability is reduced. MAECHAM4 performs best, but still is not perfect.

Observed SST were much colder in the tropics and SH, warmer in N-Atlantic and N-Pacific in the 1950s as compared with the 1980s.





DJF analysed only!

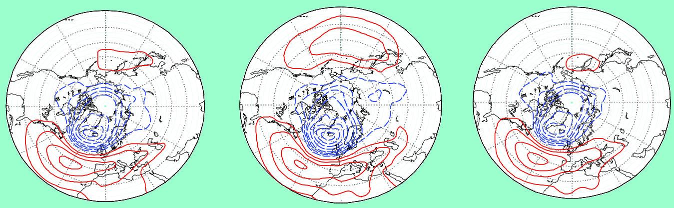
Different SSTs make a big effect on the strength of the N-polar vortex. Warmer tropical SST and colder midlatitude SST go along with weaker vortex.

***Observed SST changes** since 1951 would have **weakened** the N-polar vortex for constant GHG.*

***Observed GHG changes** would have **strengthened** the vortex if the SSTs had remained the same as in the 1950s.*

Teleconnections

Regression patterns of SLP uppon the normalized Greenland time series multiplied by –1. Contours are (..., -6.0, -4.5, -3.0, -2.25, -1.5, -0.75, 0.75, 1.5, 2.25, 3.0).



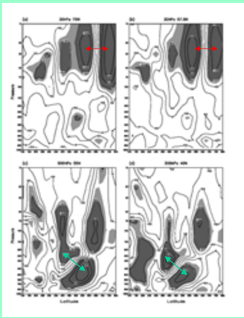
All data **SVR only** **WVR only**

Correlation coefficients brtween the Pacific, Atlantic and Greenland detrended time series of the averaged area-weighted SLP anomalies. The values in the upper right of the matrix are for the main winter (December-February 1951-98), and values in the lower left are for the extended winter (November-April 1951-98).. Values marked with an asterisk are above the 95% significance level, considering that only one-half of the months in each subset are independent for a conservative measure of the statistical significance.

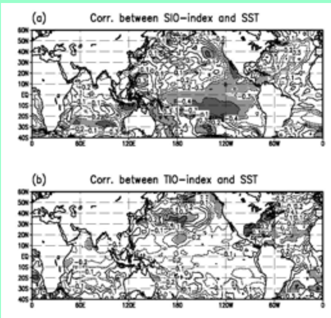
	All Data			SVR			N-SVR			WVR		
	Pac.	Atl.	Greenl.	Pac.	Atl.	Greenl.	Pac.	Atl.	Greenl.	Pac.	Atl.	Greenl.
Pac.	--	0.13	-0.31*	--	0.25	-0.44*	--	-0.06	-0.10	--	-0.11	0.03
Atl.	0.10	--	-0.68*	0.21	--	-0.65*	0.03	--	-0.66*	-0.02	--	-0.71*
Greenl.	-0.23*	-0.67*	--	-0.40*	-0.67*	--	-0.10	-0.65*	--	0.00	-0.64*	--

Atlantic and Pacific SLP significantly negatively correlated ONLY in the SVR regime, NOT in N-SVR nor WVR

SIO/TIO: Stratospheric/Tropospheric Interannual Oscillation:



One point correlation maps between EP flux divergence at 30hPa, 75N and 57.5N (SIO,top) and 500hPa, 55N and 300hPa, 40N (TIO, bottom)



Correlation of SIO and TIO on global SST 1958-1998, detrended, shaded areas are statistically significant at 95/99%

Tropical SST is related to upper stratospheric EP flux divergence, midlatitude SST to tropospheric, influencing the relation between polar and subtropical jet, and determining the strength of the lower stratospheric polar vortex. SIO and TIO are not significantly correlated, hence we may take them as independent processes. Tropical SST anomalies lead upper stratospheric by 3 seasons, there is no time lag relationship between midlatitude SST and EP-flux divergence on a monthly time scale.

Conclusions:

1. ***The lower stratospheric circulation in high latitudes´influences tropospheric variability and teleconnections via impacts on planetary wave propagation. The Honda et al. results are due to sampling effects (1978-93 were mostly years with strong polar vortexes).***
2. ***GCMs used for climate forecast are biased towards too strong winds at the polar circle in the lower stratosphere. They therefore also are biased in their variability structures and teleconnectivity.***
3. ***At least in the models, sensitivity of the stratospheric circulation to observed SST changes is as big as to greenhouse gas increase. The relative contribution of midlatitude SST anomalies (influencing synoptic eddy activity) versus tropical SST (influencing deep convection, the subtropical jets and the stratospheric residual circulation) needs to be studied further. Be careful with coupled Ocean-Atmosphere models!***