Strat-Trop coupling:

Some 'new' aspects from models and observations

Hans-F. Graf

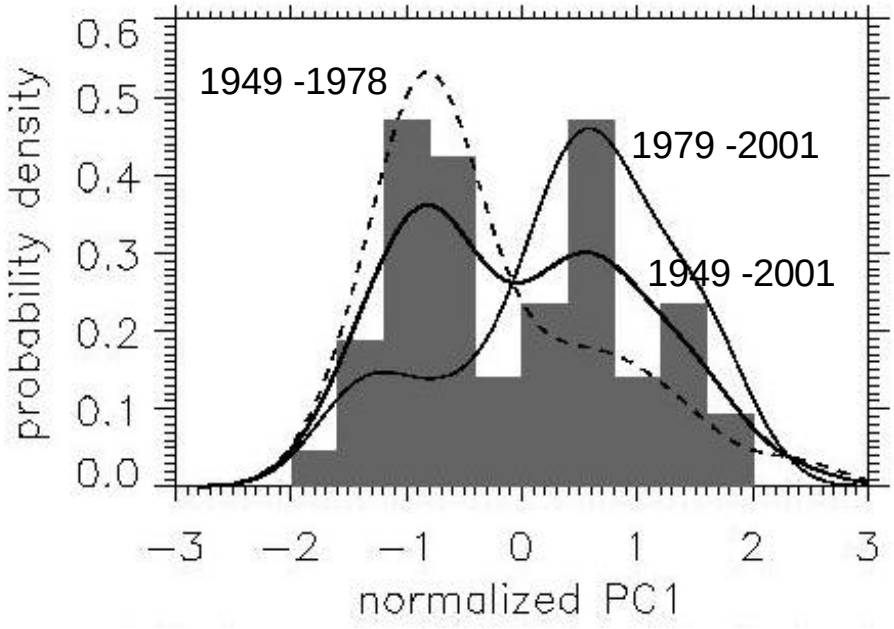
MPI Meteorology, Hamburg, Germany

In co-operation with Katrin Walter, Chen Wen, Jose Castanheira and Qian Li

Whistler, May 2003

Stratospheric Regimes

Christiansen (2002):



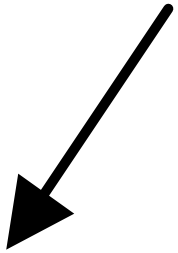
Probability density estimates of the leading normalized PC of 20 hPa geopotential height for northern hemisphere winter, based on NCEP reanalysis.

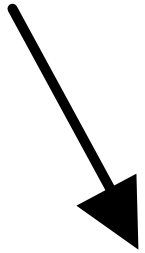
Two regimes: weak and strong polar vortex

Shift towards strong vortex regimes in the last decades

Polar Vortex Regimes

Monthly mean $u_{zon}(50\,hPa, 65\,N)$





> 20 m/s

Strong Vortex Regime (SVR)

< 10 m/s

Weak Vortex Regime (WVR)

Data: NCEP-Reanalysis 1958-1998, DJFM, daily means.

Perlwitz and Harnik, 2003 subm.

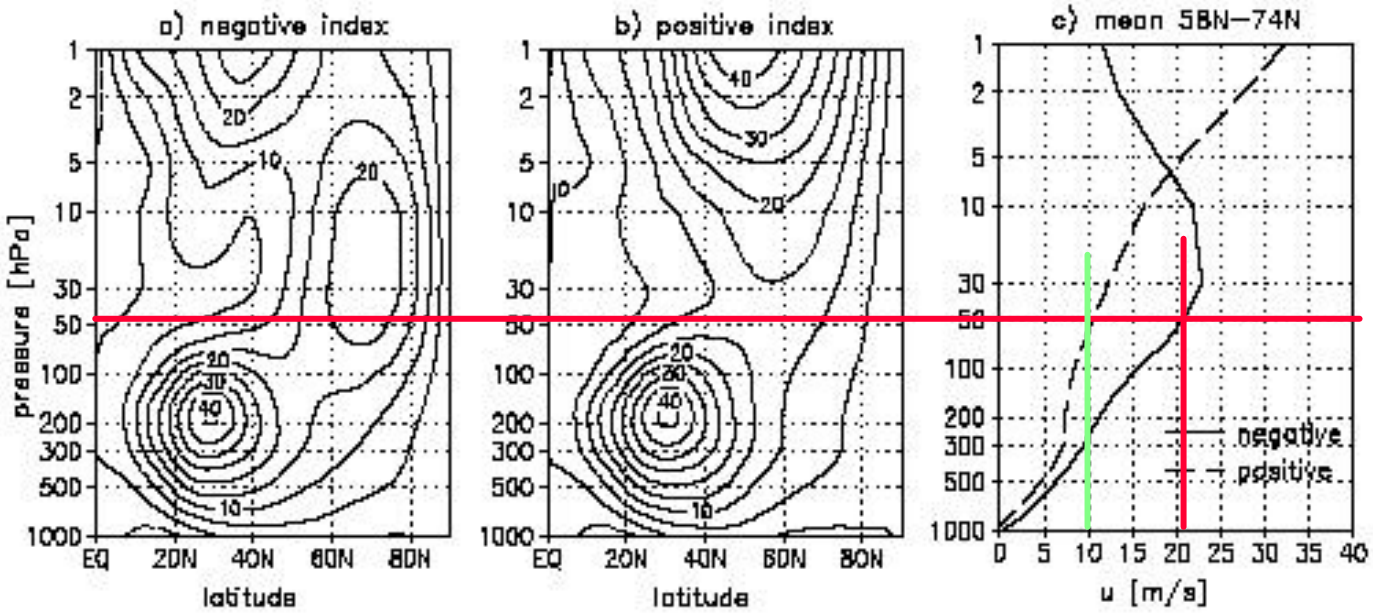
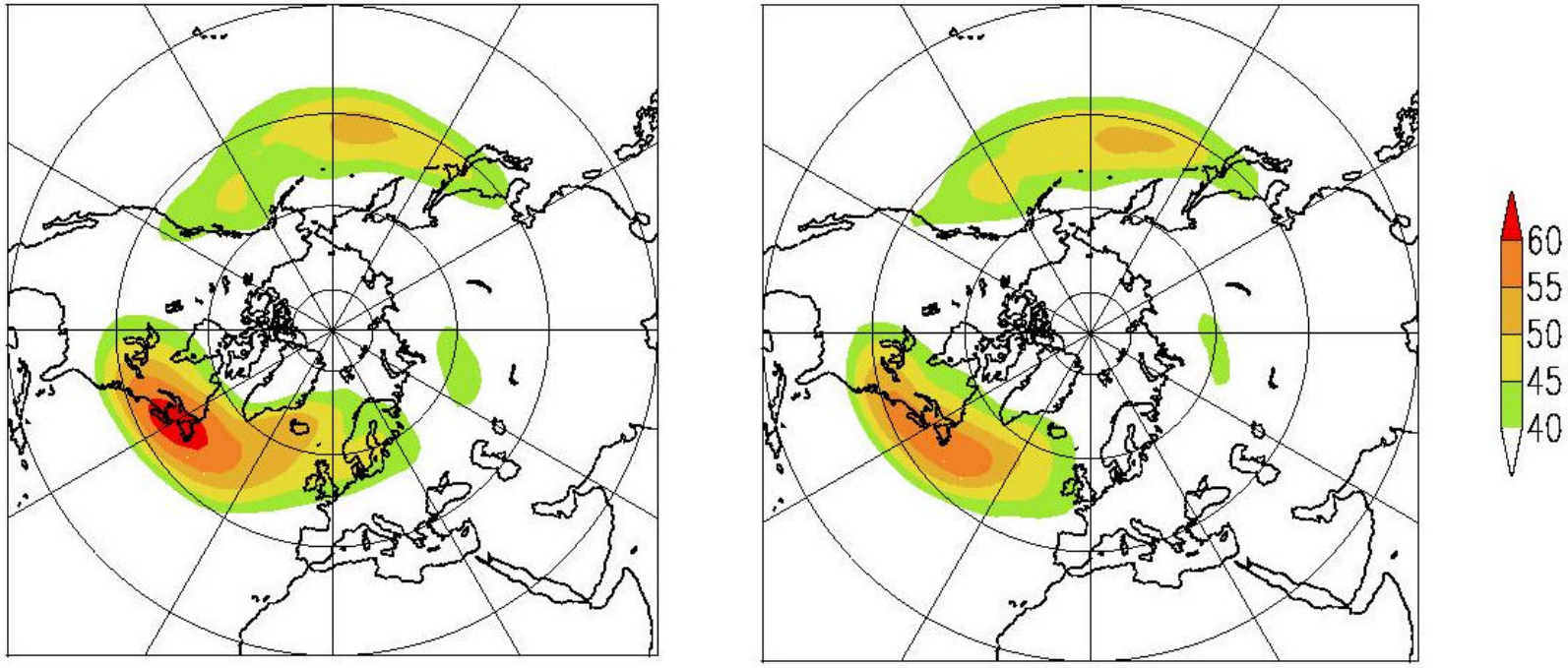


Figure 11: Composites of monthly mean zonal mean winds $\bar{u}$ in $[ms^{-1}]$ for the (a) negative and (b) positive index $U(2-10)$, based on 0.5 standard deviation. (c) Composites of vertical profile of $\bar{u}$ in $[ms^{-1}$ averaged between 58° and 74°N.

Storm Tracks

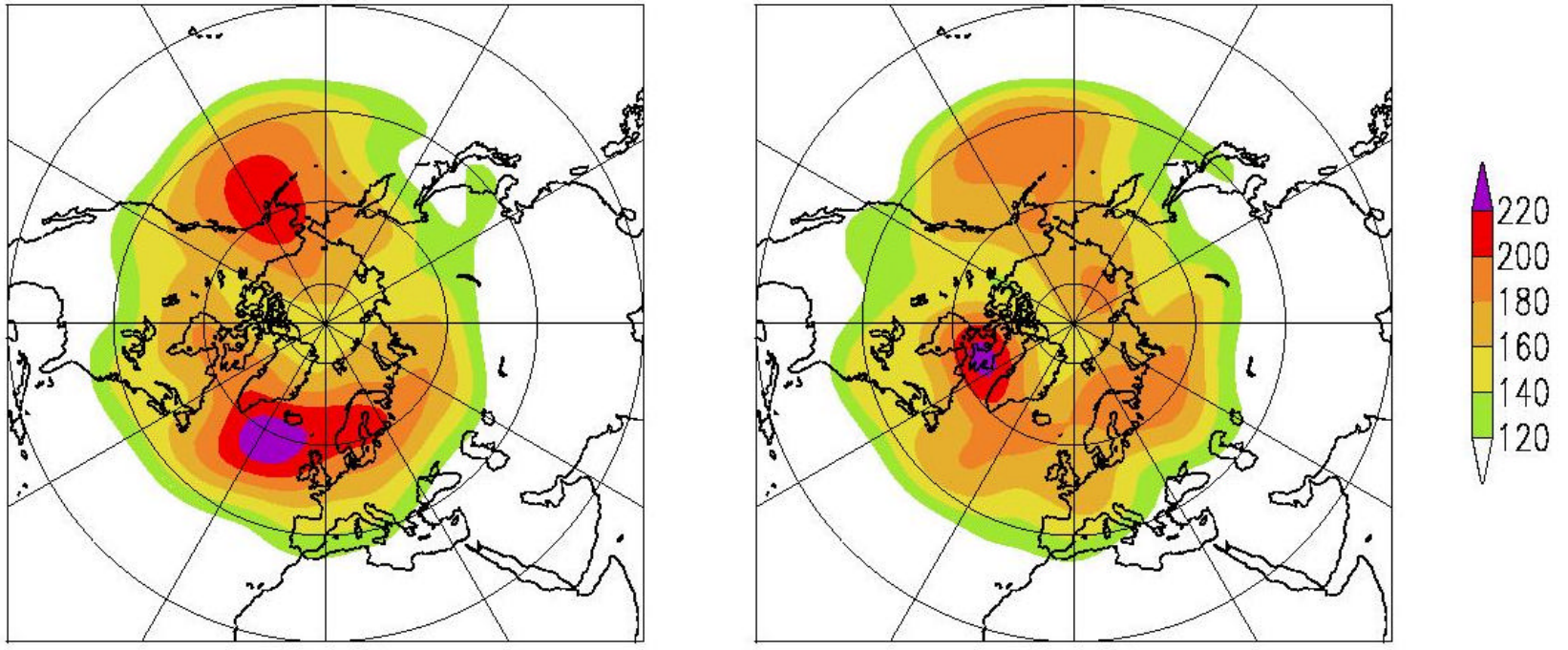
SVR **WVR**



Standard deviation of the 500 hPa geopotential height [gpm], bandpass filtered (Periods: 2.5-6 days).

Low Frequency Variability

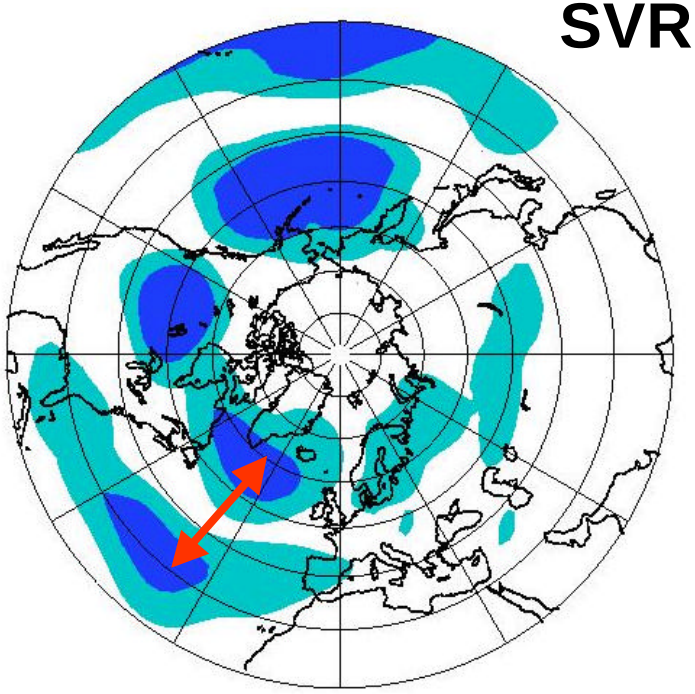
SVR **WVR**



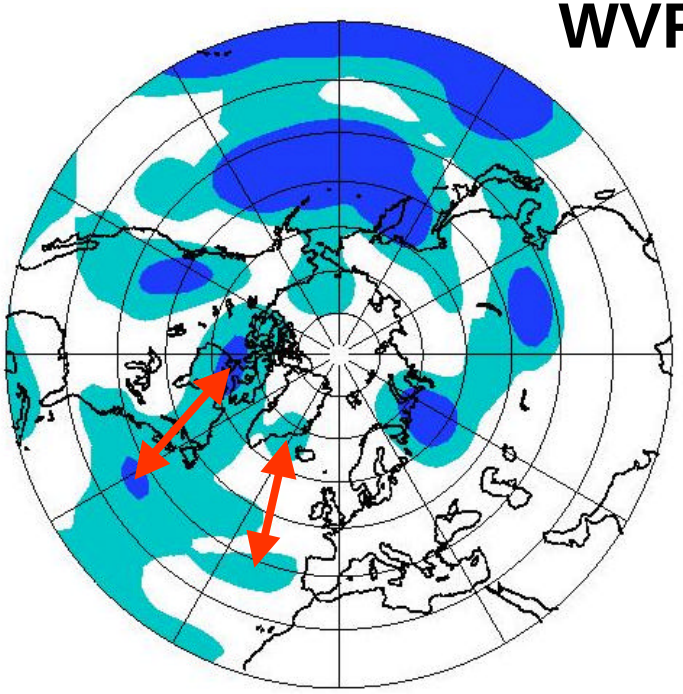
Standard deviation of lowpass filtered (Periods >10 days)
300 hPa geopotential height [gpm]

Teleconnectivity of the 300 hPa Geopotential Height

SVR



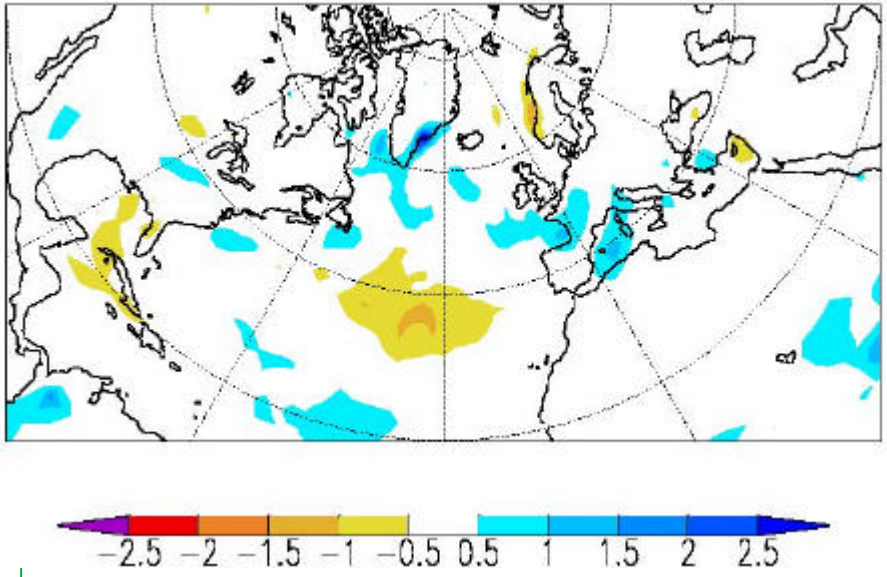
WVR



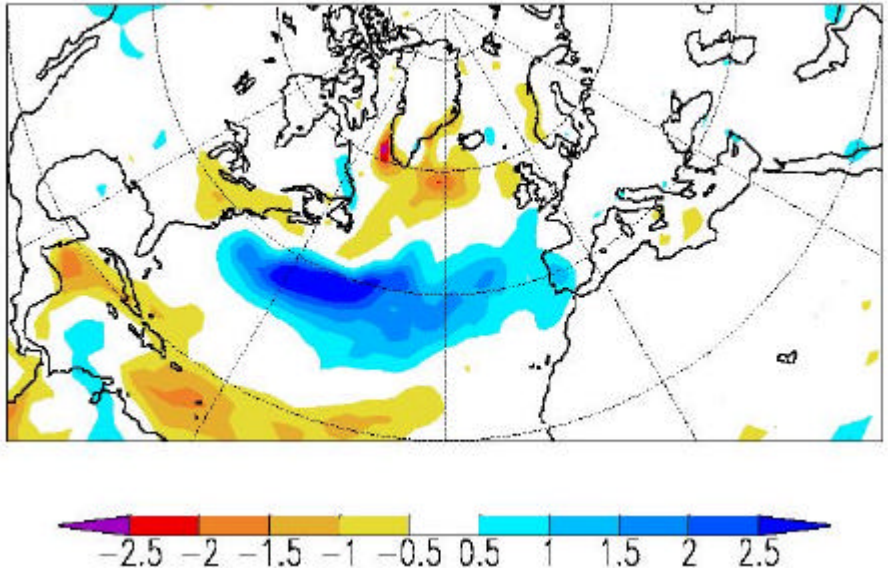
Periods >20 days. Light blue: -0.5, dark blue: -0.6.

Precipitation Rate in WVR

Western NAO Pattern Index >s /2



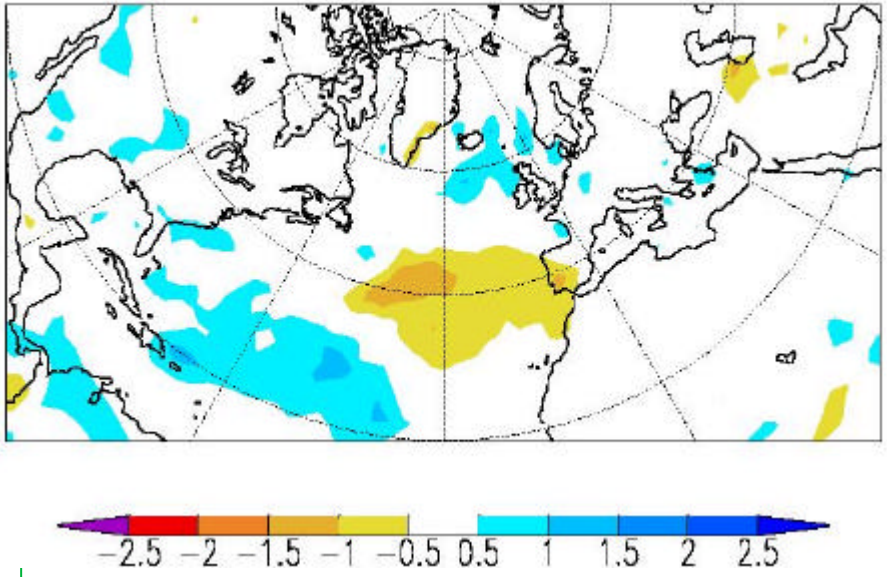
Western NAO Pattern Index < -σ/2



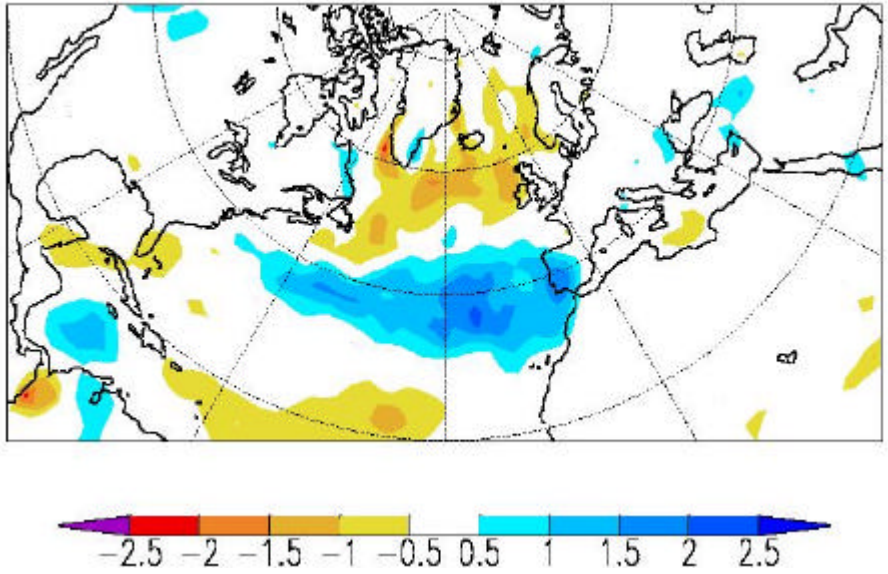
Composite monthly mean precipitation rate [mm/d] of the indicated months.

Precipitation Rate in WVR

Eastern NAO Pattern Index >σ/2



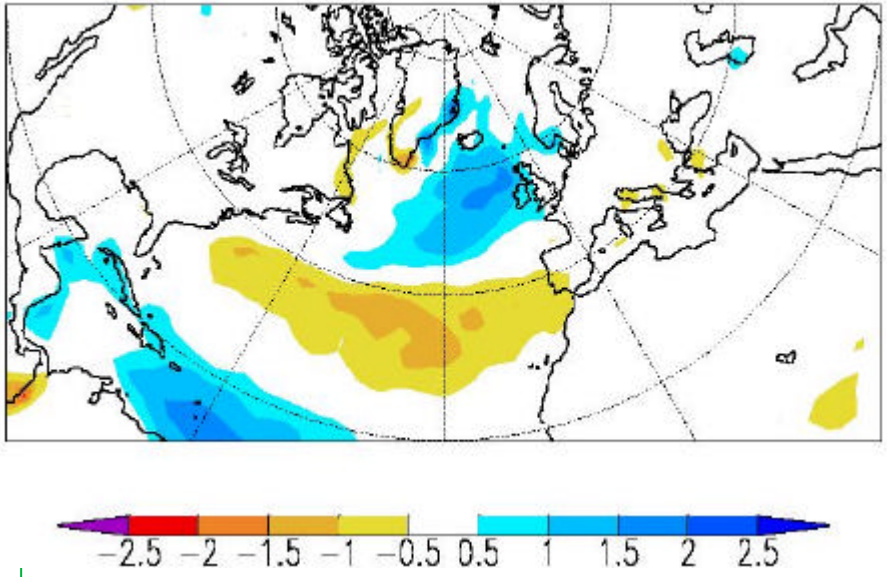
Eastern NAO Pattern Index < -σ/2



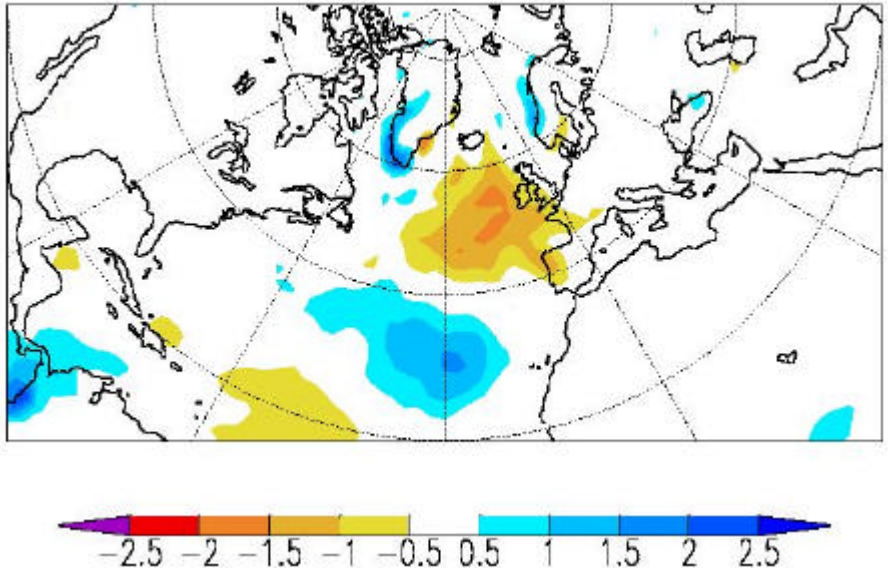
Composite monthly mean precipitation rate [mm/d] of the indicated months.

Precipitation Rate in SVR

SVR NAO Index >σ/2



SVR NAO Index < -σ/2



Composite monthly mean precipitation rate [mm/d] of the indicated months.

Conclusions (1)

AO

Coupled stratosphere-troposphere "mode": two polar vortex regimes

"NAO-like"

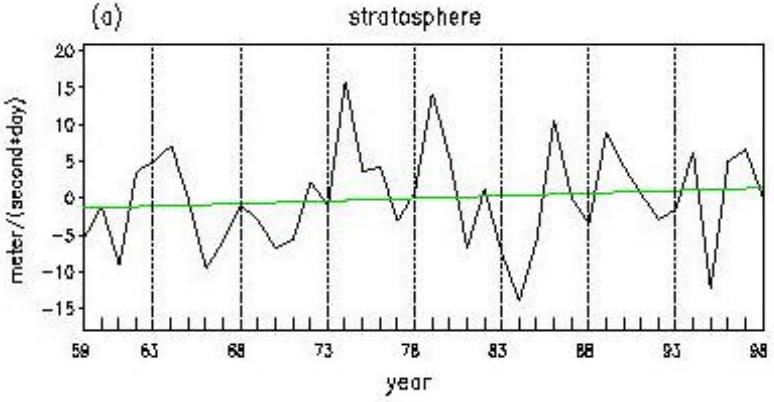
Meridional dipole teleconnection patterns in the troposphere

North Atlantic tropospheric circulation

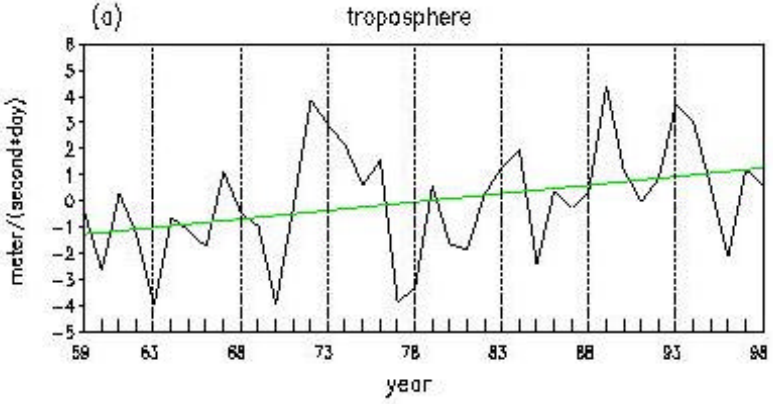
Synoptic variability

A teleconnectivity study of EP flux divergence in a meridional plane was performed....

SIO

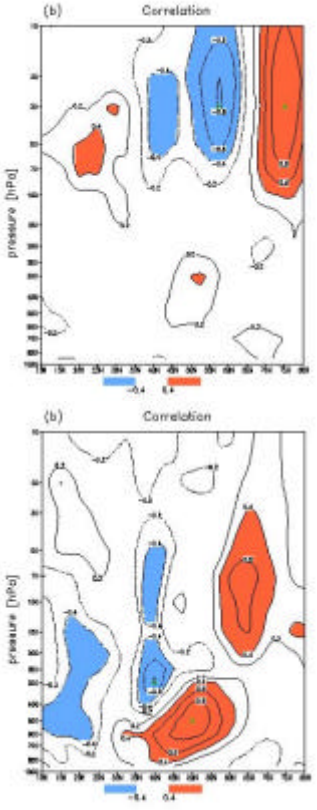


TIO



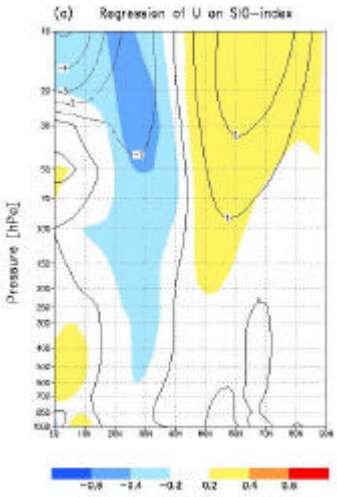
Stratospheric and tropospheric indices are not correlated (r<0.1)

EP flux divergence ZWN 1-3 regressed on TIO and SIO

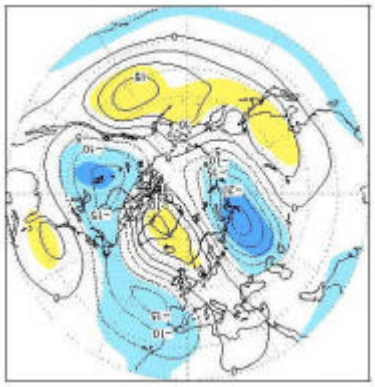


***SIO** correlated with zonal wind in upper stratosphere and*

***With PNA** like pattern (r=-0.39) in the mid troposphere and something like the W-Europe-Siberia pattern*

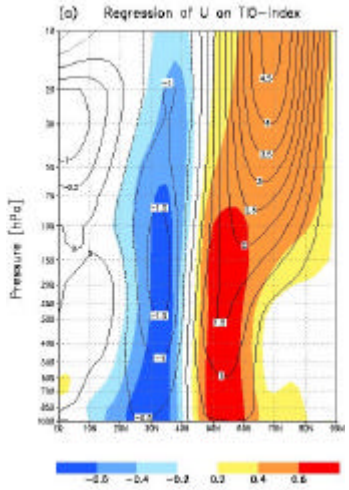


Z 500 hPa

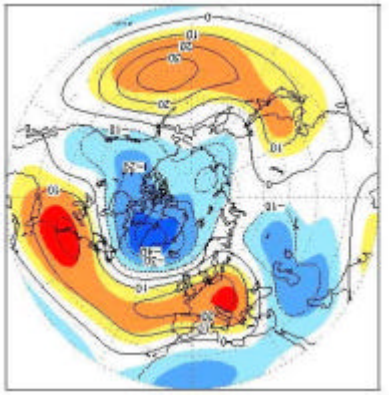


***TIO** correlated with tropospheric and stratospheric zonal wind and*

***With NAO** like pattern in the mid troposphere (r=0.69), but including strong effects in N-Pacific*



Z 500 hPa



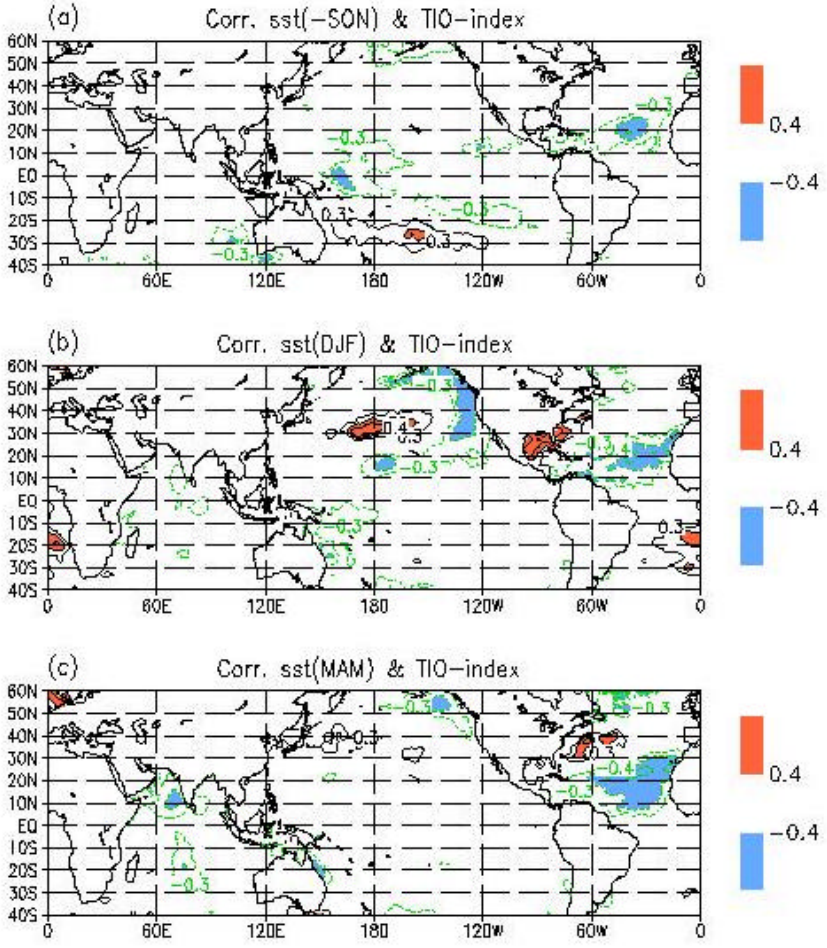
SIO and TIO are statistically independent

At least in 1958-98 TIO has much stronger impact on circulation than SIO. Was this always the case?

Both indices are connected with well known (but not well understood...) variability patterns in the troposphere.

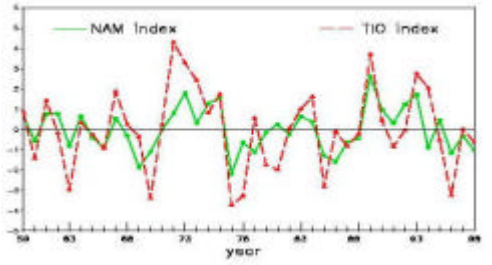
We‘ll have a closer look at the links to global SST...

Correlation/regression of TIO with global SST



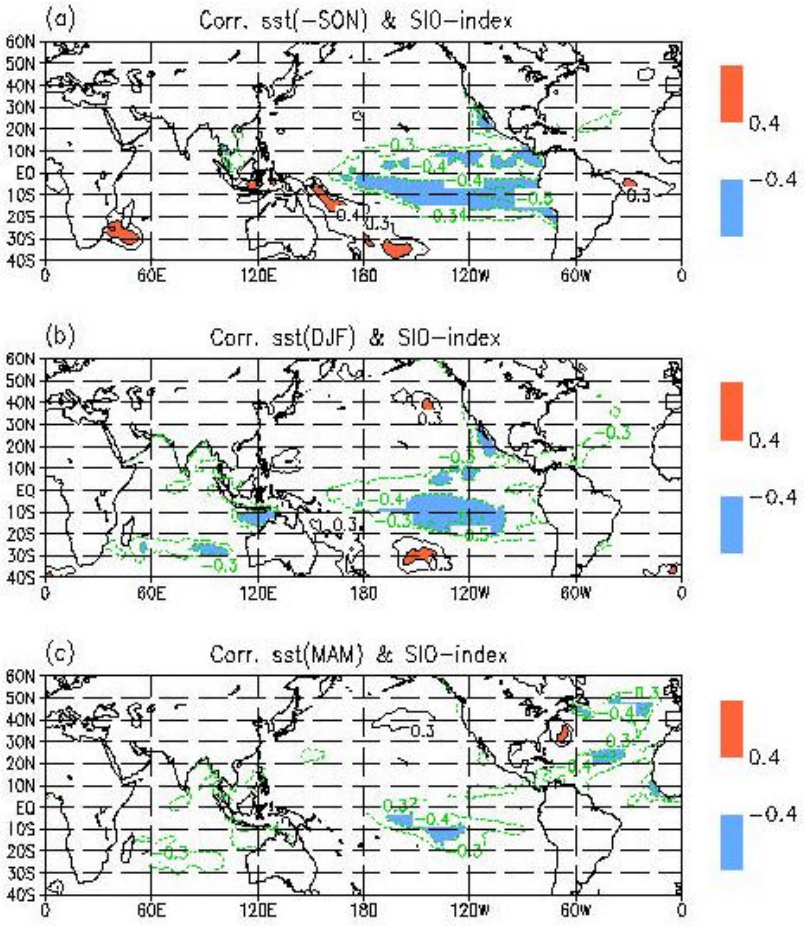
TIO is connected with midlatitude SST instantaneously and the atmosphere leading in N-Atlantic

TIO is also significantly correlated with NAM or NAO index, r=0.69

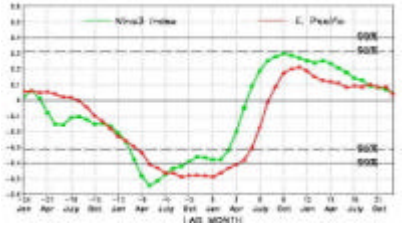


Classic: TIO and its connection to SST describes interaction of SST fields with synoptic activity (fast transient eddies), plantary waves in the troposphere and their impact on stratospheric circulation.

Correlation/regression of SIO with global SST

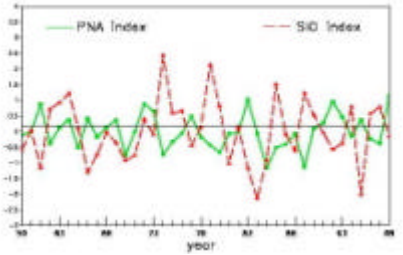


SIO is connected to tropical SST leading up to 3 seasons



SIO is also neg. correlated to PNA (r=-.39)

Virtual correlation



Tropical SST is coupled to atmosphere in two ways:

a) SIO:Via the Brewer –Dobson circulation in the stratosphere

b) PNA:Via planetary waves in the troposphere

Conclusions (2)

Two statistically independent EP flux divergence teleconnections exist (one in the upper stratosphere, one in the troposphere and lower stratosphere)

The upper stratospheric TC is preceeded by strong SST anomalies in the tropical equatorial Pacific, the tropospheric is mainly leading N-Atlantic SST.

A refraction index $n_k^2(y,z)$ has been defined for planetary waves (Matsuno, 1970).

Planetary waves tend to avoid negative values and are attracted by the maximum positive values of the refractive index.

Index of refractivity (Matsuno, 1970)

Meridional potential vorticity effect

$$n_k^2(y,z) = \frac{\bar{q}_f}{\bar{u}} - \left(\frac{k}{a\cos f}\right)^2 - \left(\frac{f}{2NH}\right)^2$$

Planetary wave number effect

Latitude effect

Zonal mean wind effect

$$\bar{q}_f = \frac{2\Omega}{a}\cos f - \frac{1}{a^2}\left[\frac{(\bar{u}\cos f)_f}{\cos f}\right]_f - \frac{f^2}{r_0}\left(r_0\frac{\bar{u}_z}{N^2}\right)_z$$

Latitude and meridional gradient of *u*

We propose a new kind of analysis of the Refractive index:

- we are interested in the probability of planetary waves to propagate in the meridional plane

- therefore we just analyze the frequency of negative indices (i.e. those where planetary waves cannot propagate) in a meridional plane

- we do this for each zonal wave number separately

- we use NCEP reanalysis data and model data

NCEP Reanalysis 30-90^{0}N

Frequency in % of negative refractive index during periods of

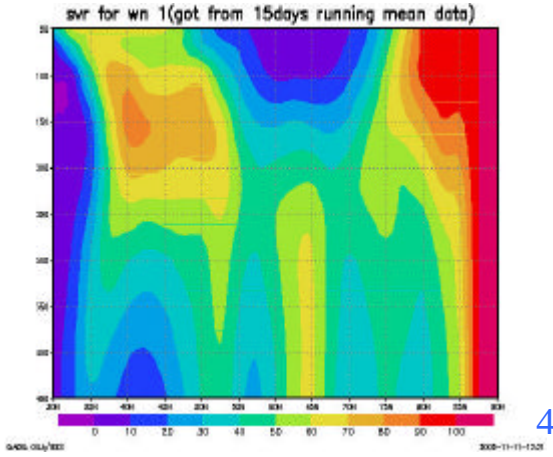
Strong polar vortex

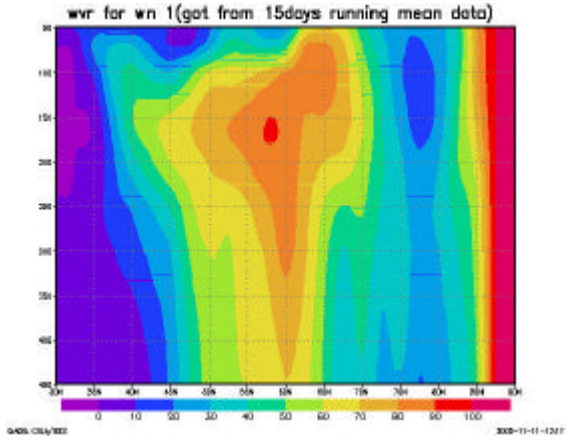
Weak polar vortex

50hPa

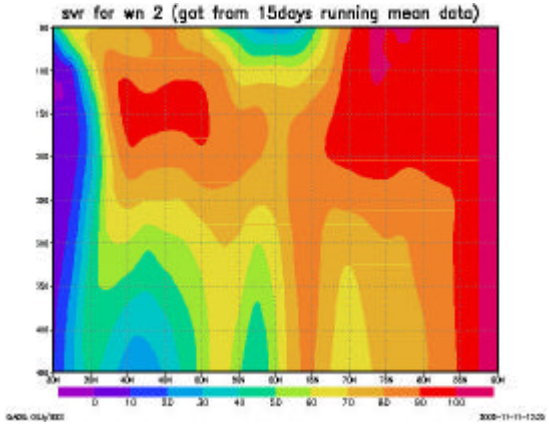
450hPa

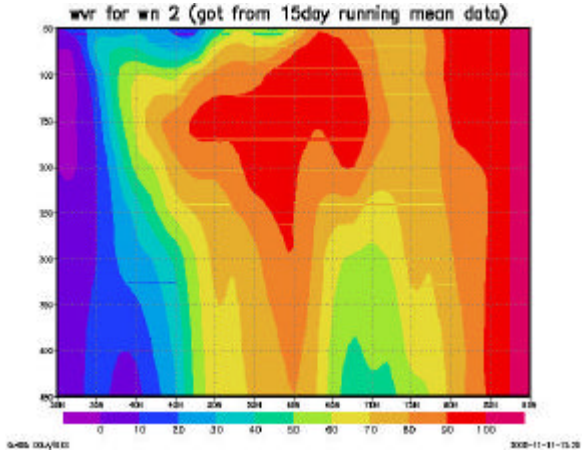
ZWN 1





ZWN2

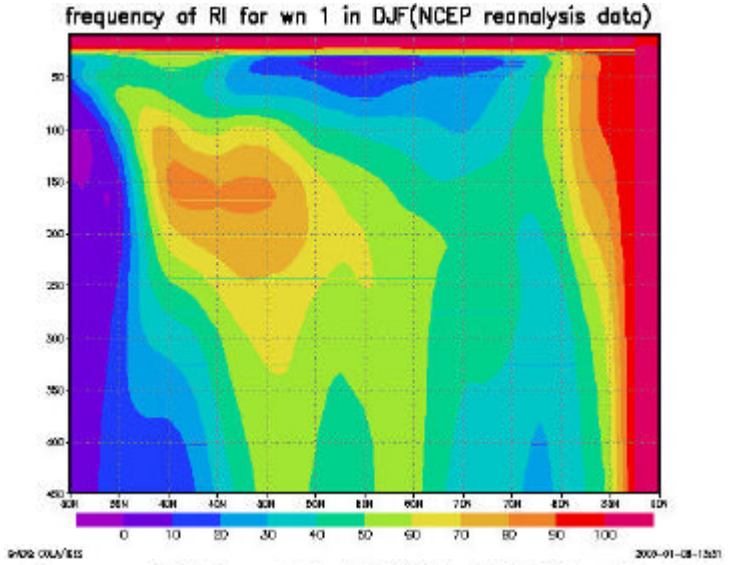


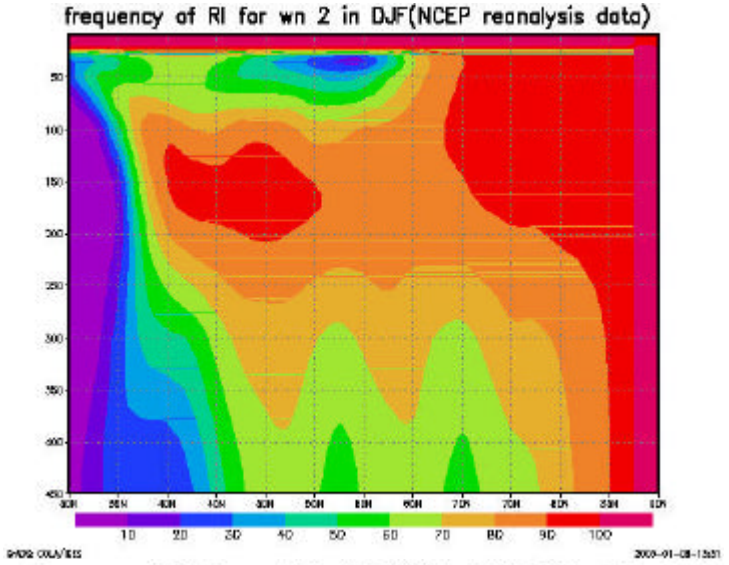


NCEP vs. Model, negative Ri frequency

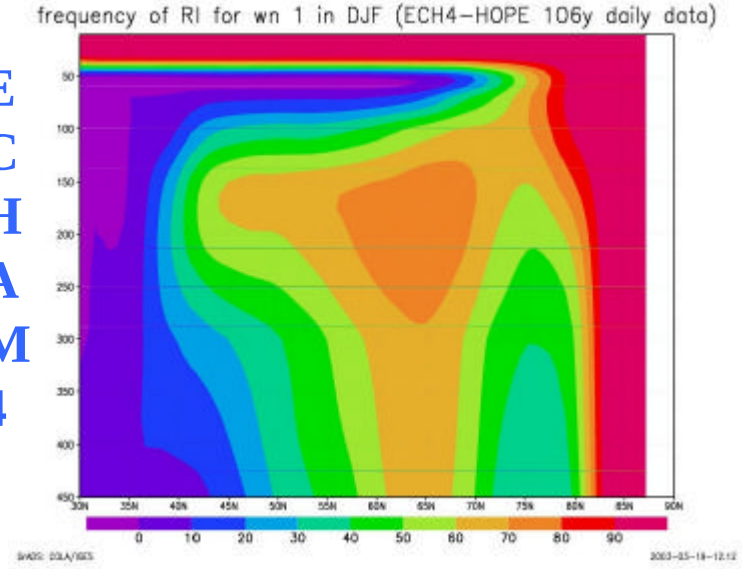
Max-Planck-Institut für Meteorologie
Max Planck Institute for Meteorology

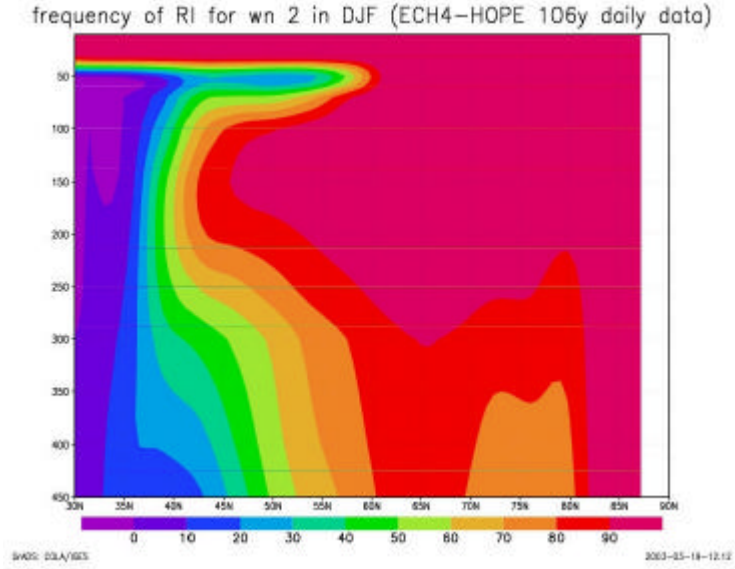
NCEP



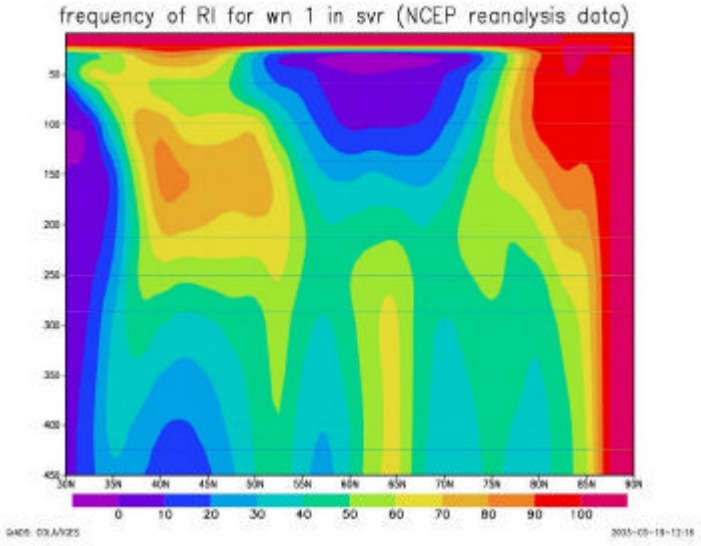


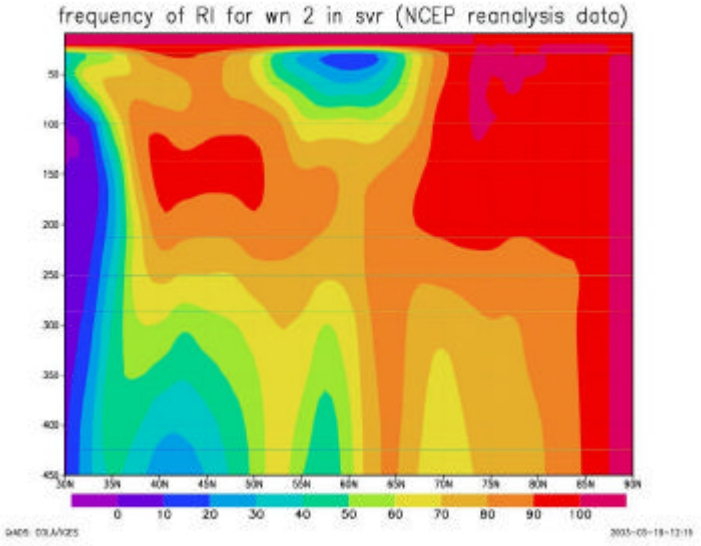
ECHAM4

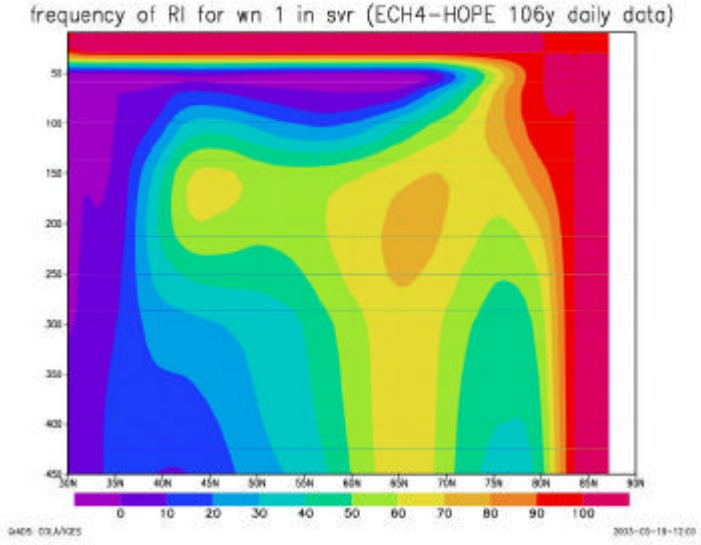


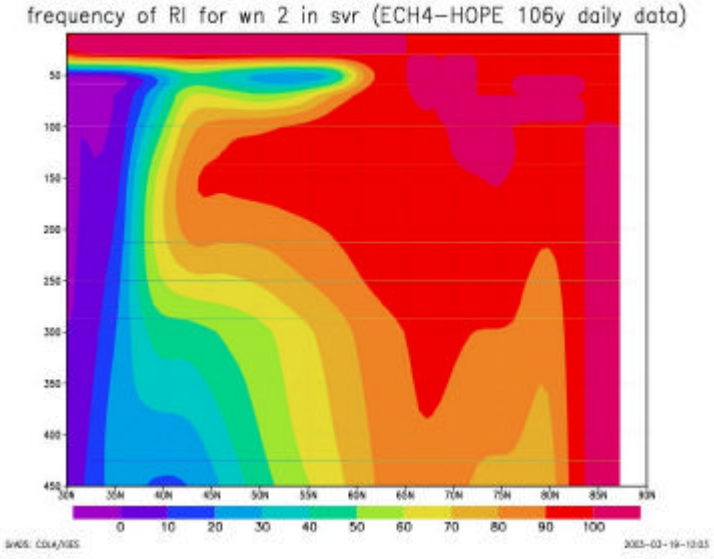


NCEP vs. Model negative Ri, SVR

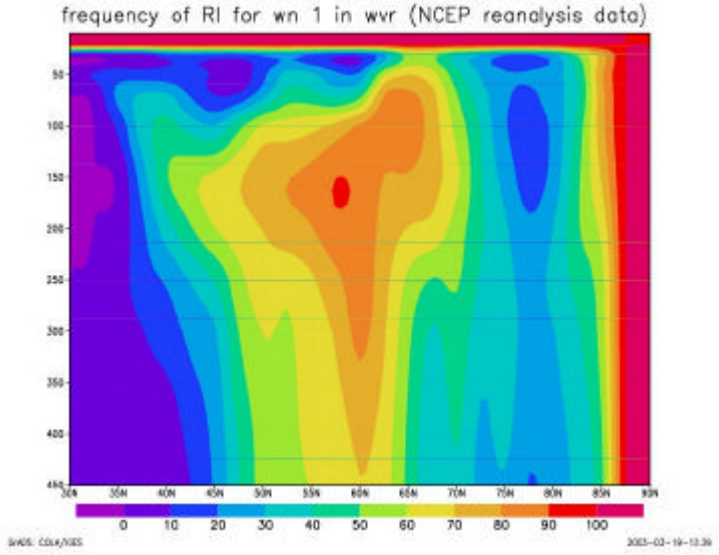


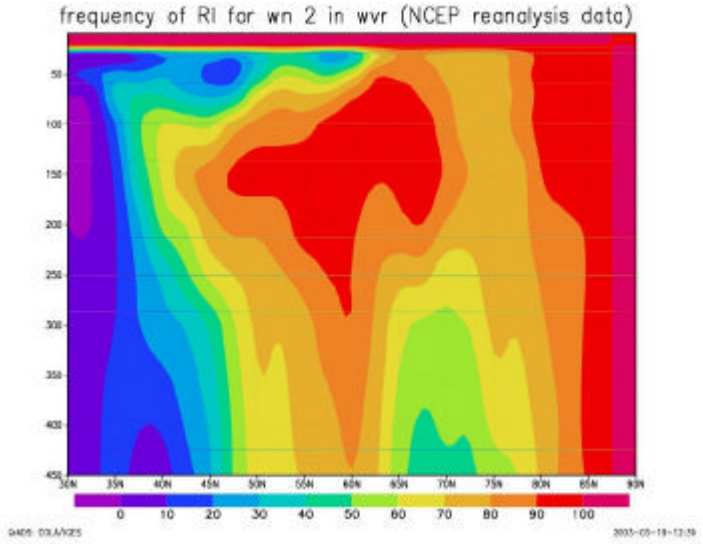


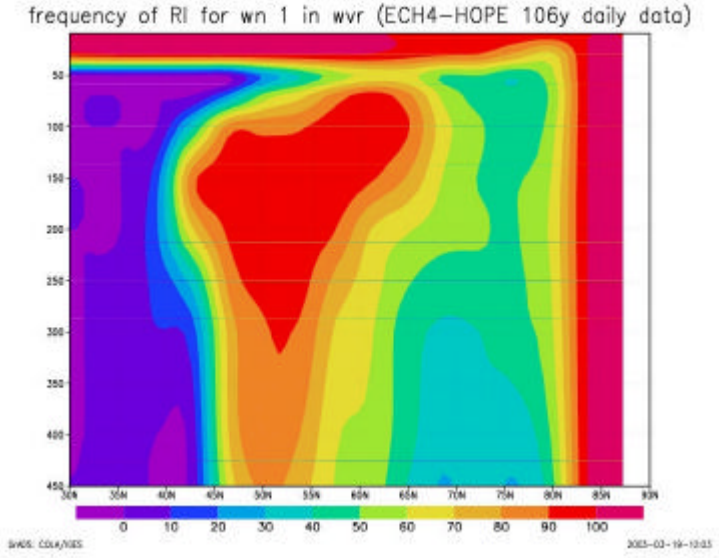


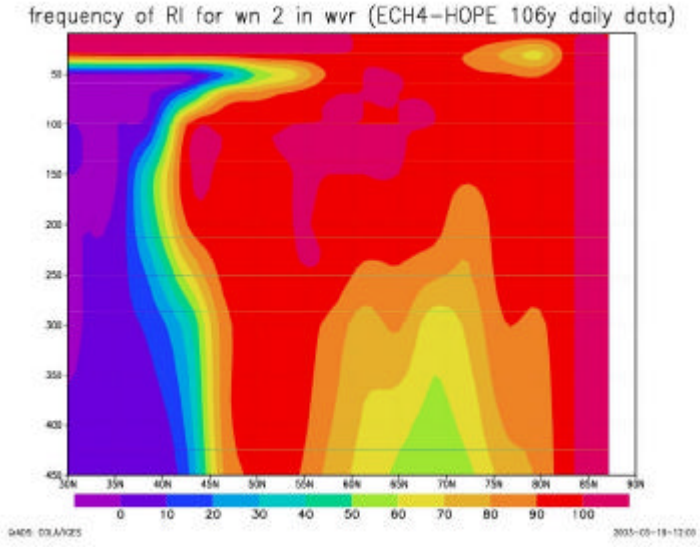


NCEP vs. Model negative Ri, WVR









Conclusions (3)

Potential planetary wave propagation in the troposphere and lower stratosphere is clearly different between strong and weak polar vortex in re-analysis data.

There are also clear differences between the frequencies of negative Ri of re-analysis data and the model (ECHAM) which in part may explain the cold polar bias of the model.

We should investigate this behaviour systematically for all models.