

# Observed Interannual Oscillations of Planetary Wave Forcing in the Northern Hemisphere Winter

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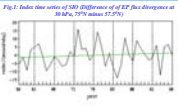
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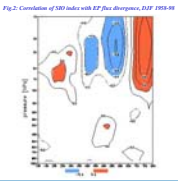
Recent observations suggest that the month to month and interannual variability in NH winter are dominated by an internal variability mode, a zonally symmetric meridional seesaw of atmospheric mass, the Northern Annular Mode or NAM. This is also connected to a meridional seesaw of zonal mean wind strength, which is strongly interrelated with planetary wave activity. The low frequency behaviour of the NAM, may, however, be also influenced by external forcing (like stratospheric ozone loss or increasing greenhouse concentration). Especially the influence of sea surface temperatures is discussed controversially. While Rodwell et al (1999) suggested a positive feedback between midlatitude SST and NAO (or NAM in a sense), Latif et al (2000) and Hoerling et al (2001) suggest that the bulk of oceanic influence comes from the tropics.

Using detrended NCEP reanalysis data for the winter months (DJF) 1958-98, the EP-flux divergence fields were computed for stationary planetary waves. Applying a teleconnectivity analysis to these fields we find two dipoles, one in the stratosphere and one in the troposphere which define interannual oscillation patterns of planetary wave forcing (Chen et al.2002). The differences in EP flux divergence between the centers of teleconnectivity can be used to construct index time series of these oscillations, the stratospheric and tropospheric interannual oscillation (SIO and TIO) indices. Both time series are statistically independent, ( $r=0.1$ ) suggesting different mechanisms of their variability.

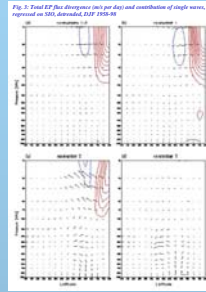
## The Stratospheric Oscillation of Planetary Wave Forcing



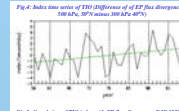
The SIO of EP flux divergence has a non-significant positive trend and strong interannual variability (Fig.1). In the positive phase it leads to a positive EP flux divergence anomaly in very high northern latitudes and a negative anomaly at mid-latitudes. There is virtually no effect in the troposphere (Figure 2).



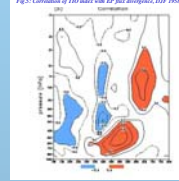
The pattern of EP flux divergence is mainly determined by contributions of zonal wave number 1 and 2. Wave 3 does not contribute in the stratosphere. Easterly momentum is being transported to lower latitudes in the lower stratosphere (Figure 3).



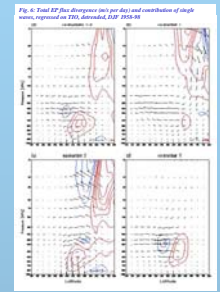
## The Tropospheric Oscillation of Planetary Wave Forcing



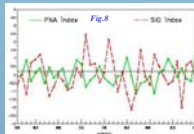
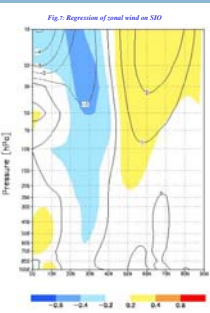
The TIO of EP flux divergence has a significant positive trend since 1958, overlaid by strong interannual variability (Fig.4). It shows the negative correlation between subtropical and subpolar jet regions plus some clear evidence of an impact on EP flux divergence in the lower stratosphere at the polar circle (Fig.5).



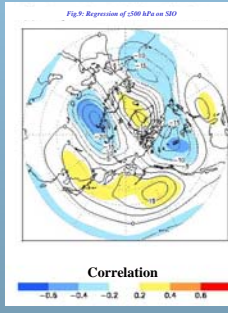
In the positive TIO phase we find enhanced equatorward propagation of planetary waves in the troposphere, upward and poleward propagation are reduced (Fig.6), EP flux divergence is enhanced in the polar stratosphere, WN1 and 2 counteract in the upper stratosphere, WN3 contributes only (but mainly) in the troposphere.



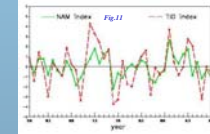
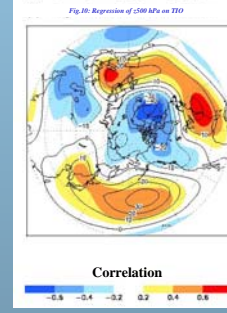
## SIO and atmospheric circulation



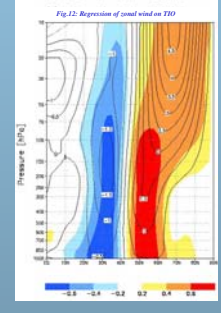
SIO is correlated with the zonal wind in the upper stratosphere (Fig.7). The correlation is weak in high latitudes (QBO effect and Brewer-Dobson circulation?). It is also correlated with a PNA like pattern in the mid troposphere ( $r=-0.39$ , Figs.8 and 9) and something like the W-Europe-Siberia pattern.



## TIO and atmospheric circulation

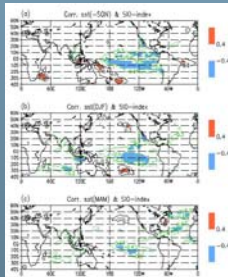
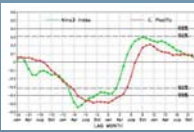


TIO is correlated with tropospheric (strong) and stratospheric (moderate) zonal wind (Fig.12) and with a NAM like pattern in the mid troposphere ( $r=0.69$ , Figs.10 and 11), including strong effects in N-Pacific



## SIO and global Sea Surface Temperature (SST)

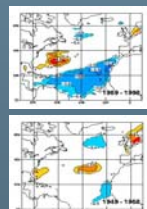
The SIO is significantly negatively correlated with the tropical SST leading up to 3 seasons. Positive SST in the Niño3 region in summer lead weak westerlies in the upper stratosphere in high northern latitudes and strong easterlies in the tropical upper stratosphere in boreal winter. We may expect an influence of the QBO phase.



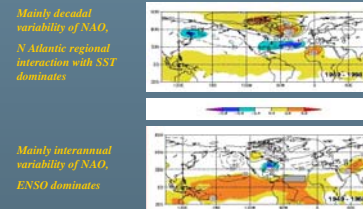
Tropical SST is coupled to the atmosphere in two ways:

- SIO: Via the Brewer-Dobson circulation in the stratosphere including a modulation by the QBO
- PNA: Via planetary waves in the troposphere

During the recent decades (1969-98) the NAO in winter was more closely related to SST in the North Atlantic than it was in the decades before (1949-68), Walter and Graf (2002). Hence the results of the above analysis are biased towards a stronger link between TIO and North Atlantic SST.



Correlation of the North Atlantic SST with a standard NAO index



Linear regression (gpm/K, contours) and correlation between tropical North Atlantic SST (hatched region) and the 500 hPa height, JFM, NCEP reanalyses, linear trend subtracted.

## TIO and global Sea Surface Temperature (SST)

TIO is correlated in winter mainly with midlatitude SST both in the North Atlantic and North Pacific (no time lag), the correlation becomes stronger in the North Atlantic and vanishes in the North Pacific when the atmosphere leads by one season. TIO and its connection to SST describes the interaction of SST fields with synoptic activity (fast transient eddies), planetary waves in the troposphere and their impact on the stratospheric circulation.

TIO obviously is of tropospheric origin and is closely related to the production and propagation of planetary wave energy. The relative strength of the impact of TIO on the zonal wind field in comparison to that of SIO may be the reason for the very weak or negligible impact of tropical SST on Eurasian climate. However, this relation may change in time...

The connection between NAO and North Atlantic SST in winter was not stationary during the 20th century.

A strong regional influence on tropical Atlantic SST was existent during times with enhanced decadal variability and preferably positive NAO index.

The influence of tropical SST (including ENSO) was dominant when the NAO variability was decreased and mainly concentrated on interannual variations.

## Conclusions

- There exist two modi of planetary wave forcing in the atmosphere which can be determined by analyzing EP flux divergence.
- One of these modi is acting in the stratosphere only, another is basically tropospheric with impact on the lower stratosphere.
- Indices of the two modi are correlated separately with NAO/NAM and PNA patterns.
- The connection between SIO and PNA may be virtual and arise from the coexisting impact of ENSO on tropospheric planetary waves and on the stratospheric Brewer Dobson residual circulation

- Tropical and midlatitude SST coupling with the atmosphere may vary in strength, leading to different teleconnections in different periods
- SST has a strong influence on stratospheric circulation. Tropical SST leads upper stratospheric circulation by several seasons (El Nino!). QBO is probably modulating the effect.
- Midlatitude SST mainly follow the atmospheric circulation
- Keep the effects of SST in mind when evaluating coupled Ocean-Atmosphere models

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