Stratospheric influence on Northern Hemisphere ENSO teleconnections in winter

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Motivation

There are a number of observational and modelling studies demonstrating an extra-tropical El Niño/ Southern Oscillation (ENSO) signal in the stratosphere (van Loon and Labitzke, 1987; Hamilton et al., 1993a,b; Sassi et al., 2004; Manzini et al., 2006). The influence of ENSO on the European climate is more strongly debated. Here, we investigate ENSO wintertime teleconnections to the extra-tropical Northern winter hemisphere with the help of the general circulation model ECHAM5. In contrast to: I) Manzini et al. (2006) we analyze ECHAM5 model results for a longer period including more ENSO events; II) Merkel and Latif (2002) we investigate the effect of different vertical resolutions compared to their study, focussing on the horizontal resolution.
Recent observational results indicate a surface signal over Northern Europe during El Niño events resembling the negative North Atlantic Oscillation (NAO_) phase due to the downward propagation of the stratospheric anomalies. Therefore we examine the role of stratosphere-troposphere coupling on the ENSO teleconnections by analyzing time-height sections of zonal mean temperature and zonal mean wind differences between El Niño events and neutral conditions. We also show frequency distributions of the NAO index during the different ENSO phases as well as wENSO surface anomalies over Northern Europe.
The comparison of the different model setups with each other and with observations can improve our understanding of the underlying atmospheric processes and assess, whether ENSO teleconnections via the stratosphere may be a source of seasonal predictability for the Northern Europe winter.

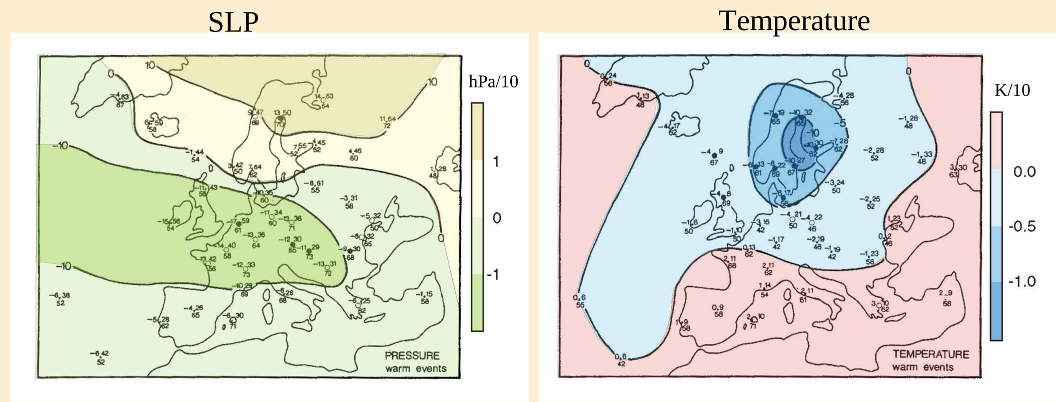


Fig. 1: Composite anomaly maps for Sea Level Pressure (SLP) (left) and temperature (right) for 26 ENSO warm events during JFM season from 1880 to 1988 (Fraedrich and Müller (1992), revised by Brönnimann (2007)).

Model description

General circulation model ECHAM5 (Roeckner et al., 2006; Manzini et al., 2006)
- horizontal resolution: T31 (3.75° x 3.75°)
- vertical resolution:
  - Low-top model: L19 → 19 vertical model levels; model top at 10 hPa/~30 km
  - High-top model: L39 → 39 vertical model levels; model top at 0.01 hPa/~ 80 km

Experimental setup

- prescribed Sea Surface Temperatures (SSTs) from HadlSST1 dataset (Rayner et al., 2003)
- ECHAM5: T31L19 including 6 ensemble members with transient SSTs (1900-1998)
- MAECHAM5: T31L39 5 ensemble members with transient SSTs (1x 1900-2005, 4x 1950-2005)
- For the analysis the overlapping period 1957/58 to 1997/98 between model and ERA40 data is used.

ENSO analysis

- ENSO index: time series of the Niño 3.4 index (5°N-5°S, 120°-170°W) as 5-month running mean using data from the model, based on the period 1953-2005 (Fig. 2).
- Values above a threshold +1std for at least 4 month are marked as warm ENSO event (wENSO) and values above a threshold -0.4°C for at least 6 month are identified as cold ENSO event (cENSO) (Trenberth, 1997) → Tab. 1.

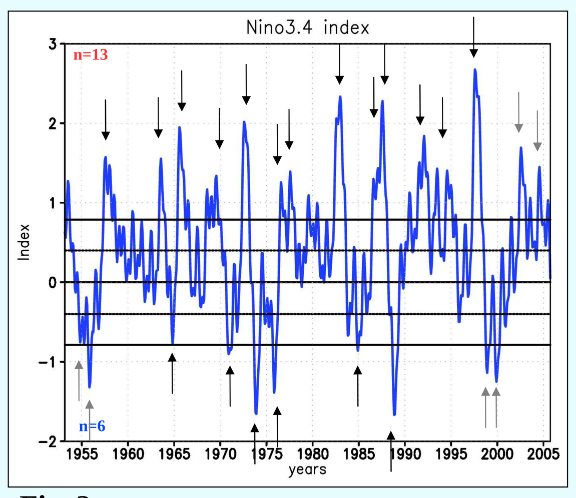


Fig. 2

El Niño	La Niña	Neutral	
1957/58	1954/55	1953/54	1980/81
1963/64	1955/56	1956/57	1981/82
1965/66	1964/65	1958/59	1983/84
1968/69	1970/71	1959/60	1985/86
1972/73	1973/74	1960/61	1989/90
1976/77	1975/76	1961/62	1990/91
1977/78	1984/85	1962/63	1992/93
1982/83	1988/89	1966/67	1993/94
1986/87	1998/99	1967/68	1995/96
1987/88	1999/00	1969/70	1996/97
1991/92		1971/72	2000/01
1994/95		1974/75	2001/02
1997/98		1978/79	2003/04
2002/03		1979/80	2004/05

Tab. 1: used El Nino (red), La Nina (blue) and neutral (black) winters used for the analysis; gray marked years are not considered for this analysis.

NAO analysis

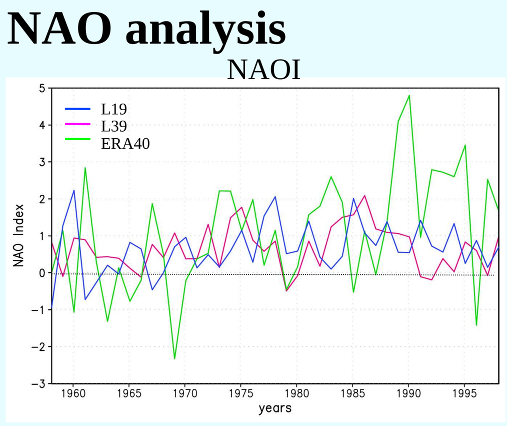


Fig. 3a

- NAO index: normalized SLP difference between Stykkisholmur/Iceland and Lisbon/Portugal for the JFM season (1958 to1998).
- (Fig. 3a): Ensemble mean of the NAOI for L19, L39 and ERA40 data.
- (Fig. 3b): Frequency distribution for the NAO index during the different ENSO phases indicate equal probability for NAO condition during JFM season.

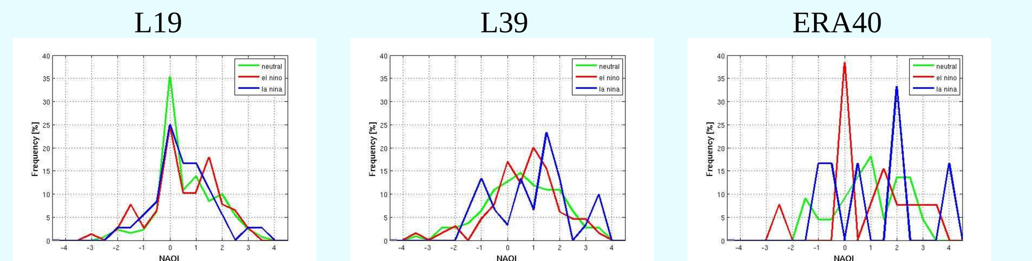


Fig. 3b

ENSO simulations

500 hPa DJF geopotential height anomaly [gpm]

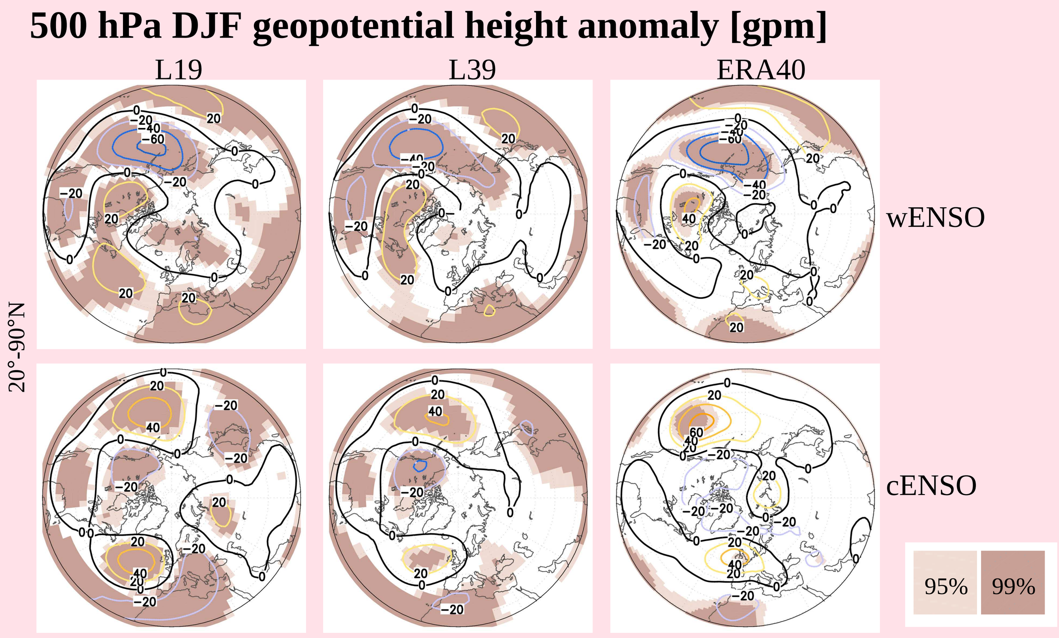


Fig. 4

- The wENSO and cENSO geopotential height anomalies for the L19 and L39 model at 500 hPa correspond with ERA40 data.
  → The PNA pattern for warm and cold ENSO events is reversed.
- The tropospheric anomalies show a good agreement with former studies (van Loon and Madden, 1981; Hoerling et al., 1997; Horel and Wallace, 1981).

30 hPa DJF geopotential height anomaly [gpm]

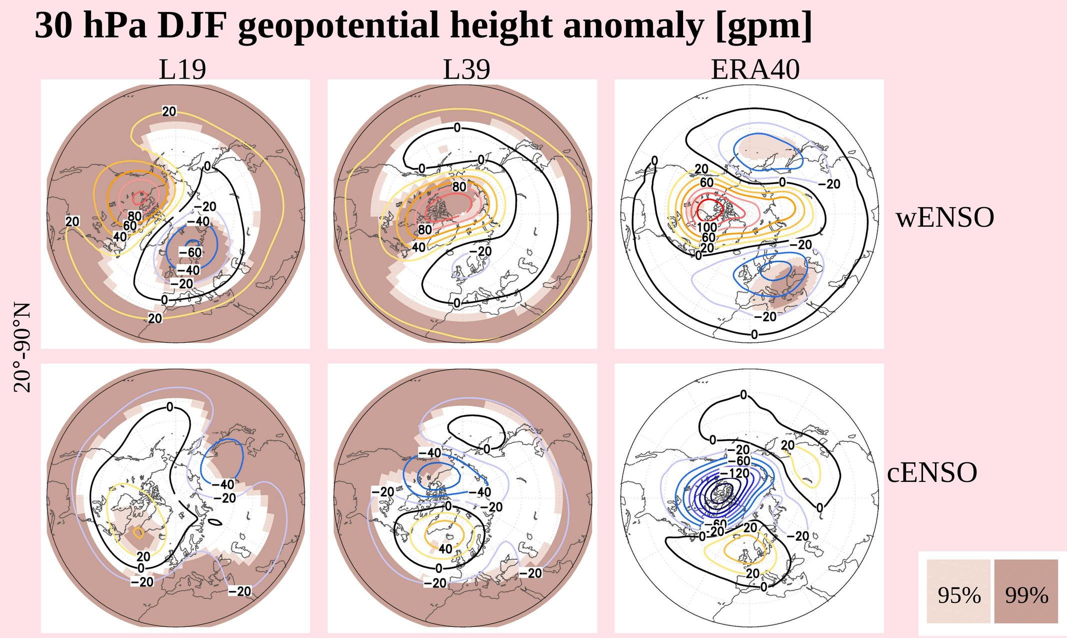


Fig. 5

- Composites for wENSO events show for L39, as observed, weak stratospheric polar vortex.
- The differences in the stratospheric signal for the ENSO warm and cold phase can be explained by different planetary wave forcing for both ENSO events (not shown here).
- For this reason a nearly reversed signal with a strengthening and cooling of the stratospheric polar vortex is found for La Niña events.
- The results for L19 show less agreement with observations.
- The anomalies are weaker for cENSO than for wENSO → Thus only wENSO anomalies are shown for the rest of this paper (Fig. 6-9).

30 hPa wENSO geopotential height anomaly [gpm]

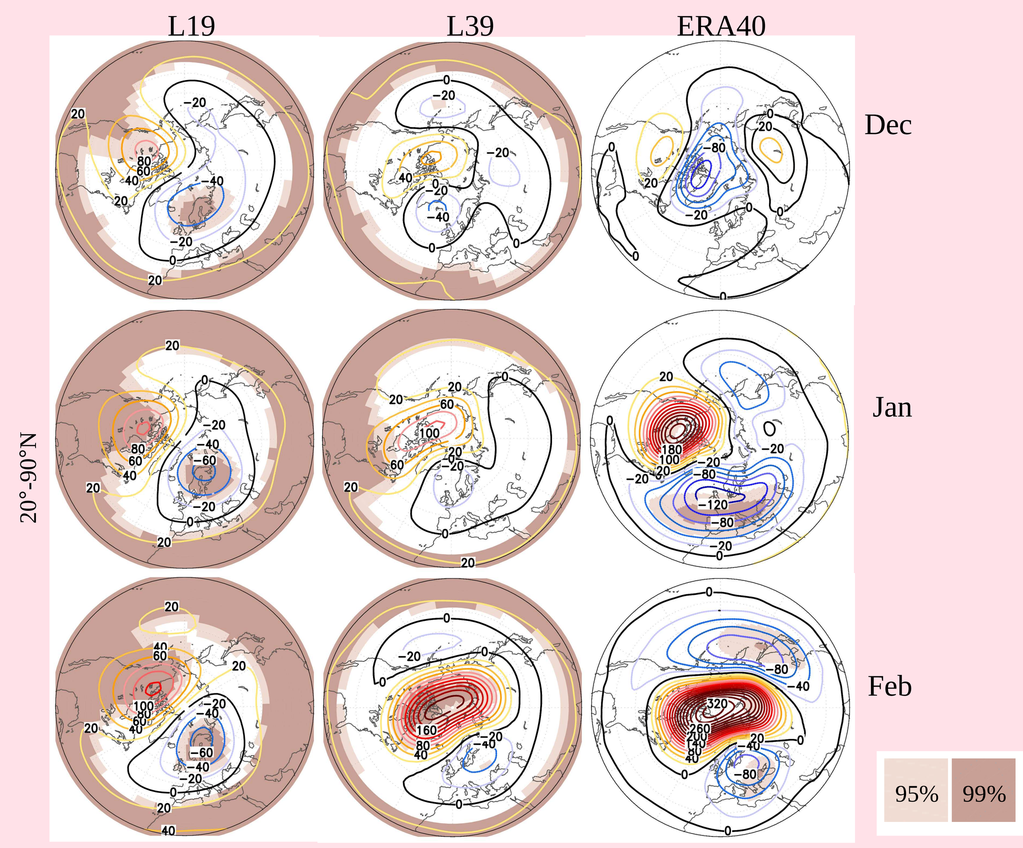


Fig. 6

- The observed seasonal evolution of geopotential height anomalies in the stratosphere during wENSO is only simulated by the L39 model version.

wENSO influence on the NAO

Downward propagation

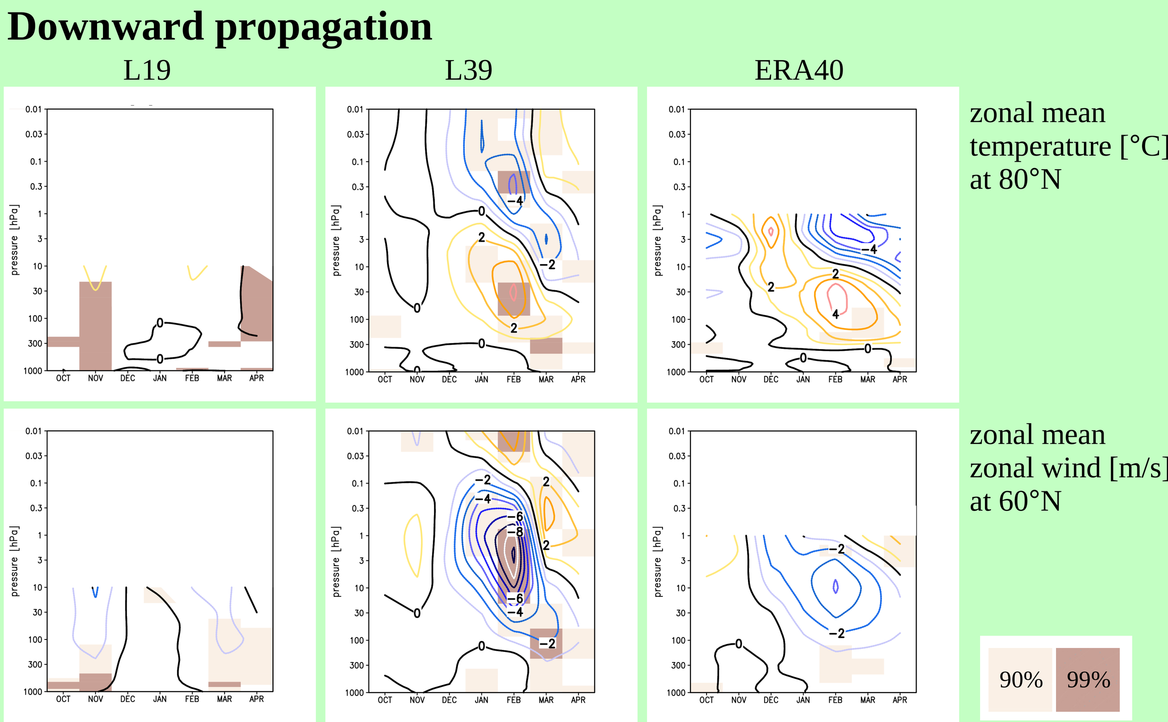
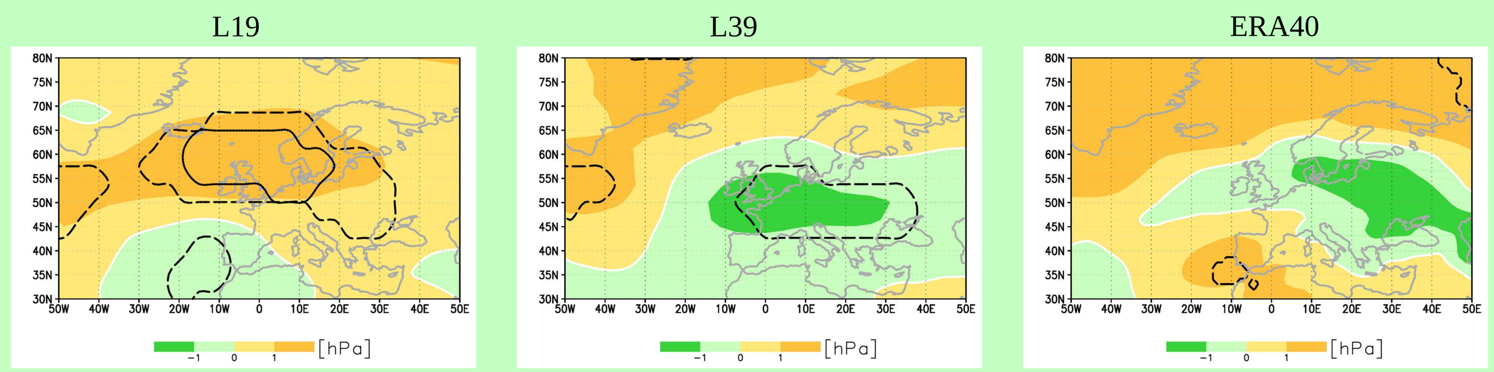


Fig. 7

- A weakening and warming of the stratospheric polar vortex occurs with a simultaneously cooling of the mesosphere during Jan/Feb (L39 and ERA40 data).
- The following downward propagation of the polar temperature (Fig. 7, top) and the zonal wind (Fig.7, bottom) anomalies can be tracked from mid to late winter in L39 and ERA40.
- For the L19 model there is no clear vertical propagation of temperature and wind anomalies.
- Significant anomalies are analysed in the lower troposphere during March, reaching the surface for L39.

SLP anomalies for March/April (MA)



2m temperature anomalies for MA

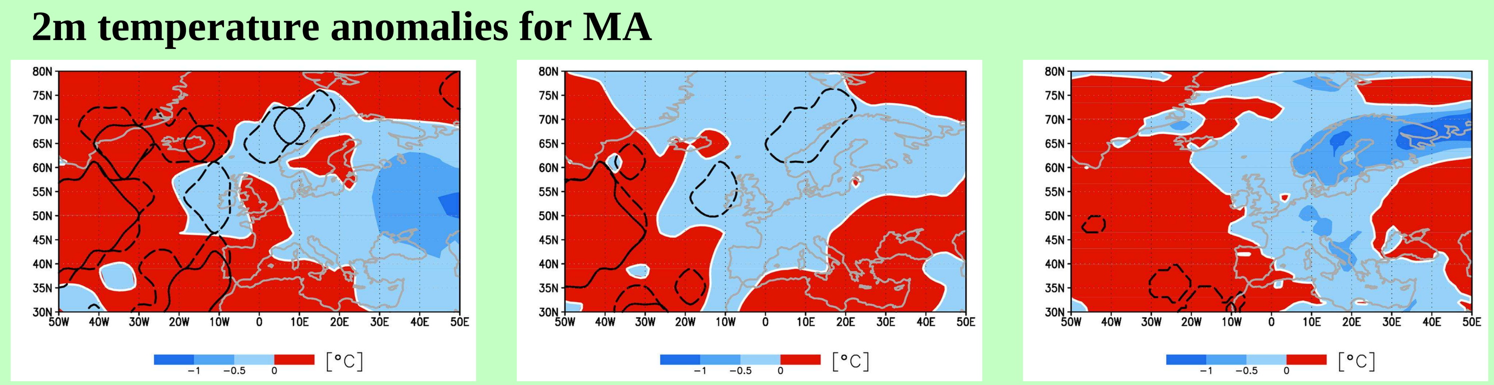


Fig. 8

- For spring higher pressure is analysed over Iceland/partly over Scandinavia for all 3 data sets, whereas lower pressure is located over central and western Europe only in L19 and L39 model (Fig.8 , top).
- Lower temperatures are simulated over North Eastern Europe by the L39 model, as for ERA40 data (Fig. 8, bottom).
- The anomalies are a magnitude smaller than the observations by Fraedrich and Müller (1992) (Fig. 1).
- In contrast to Fraedrich and Müller (1992) (Fig. 1)., we find a NAO_ like pattern for the MA season in ERA40 data, L39 and partly in L19.

NAOI seasonal evolution

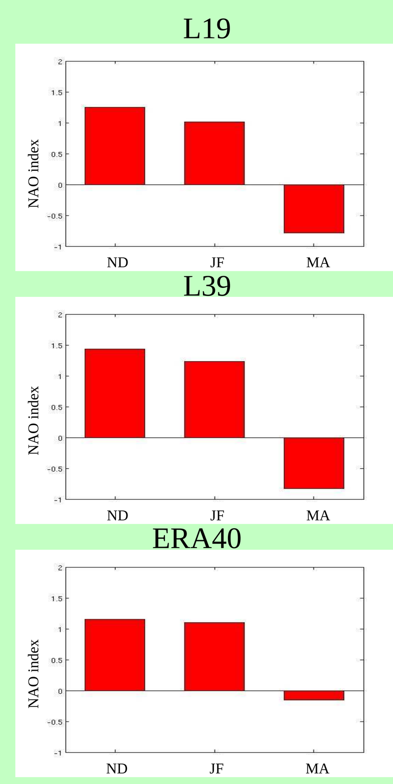
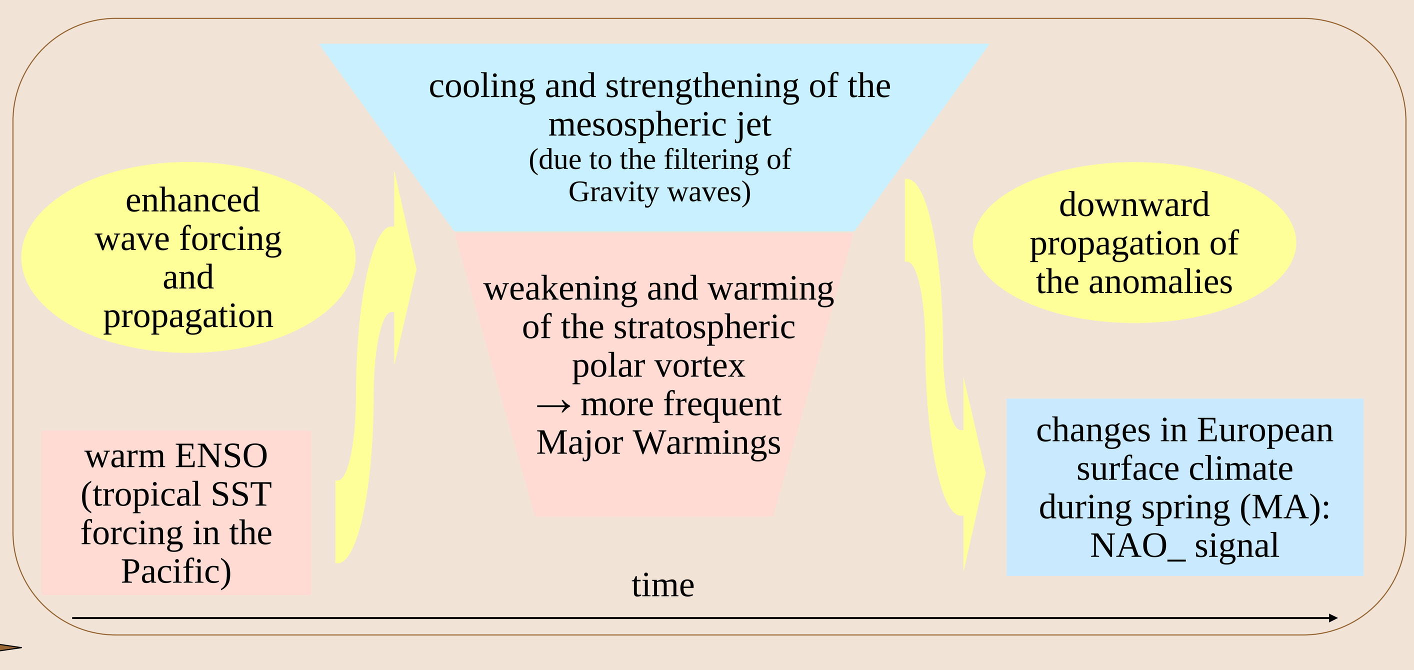


Fig. 9

- Model and observational data indicate a seasonal shift to NAO_ pattern during spring (MA), whereas Fraedrich and Müller (1992) analysed a "canonical" El Niño late winter signal during JFM.

Conclusion

- Analysing ENSO events for the time period 1957/58 to 1997/98 the teleconnection pattern in the troposphere and stratosphere show significant results especially for wENSO events.
- Significant teleconnection patterns in the stratosphere, according to observations, are only found for the high-top model (L39).
- cENSO anomalies don't show a clear significant signal → more La Niña events and/or more model simulations are needed to better detect cENSO events.
- NAO_ like pattern is found for ERA40, L39 and partly L19 data during spring (March/April).
- The ECHAM5 simulations for the 1957/58 to 1997/98 period confirms the following ENSO influence on the NAO.



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