Influence of tropospheric circulation patterns on the winter middle and high-latitude mesosphere

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1 Summary

Role of tropospheric large-scale circulation in mesospheric variability of the Arctic

- Connection of stratosphere with ENSO and NAO well established
- Observations show possible connection of tropospheric circulation and mesosphere/lower thermosphere (MLT).
- We performed numerical simulations to show this connection.

Hypothesis

Middle atmosphere circulation from the stratosphere to the lower thermosphere at middle and high latitudes is closely related to lower atmosphere circulation patterns like NAO and ENSO.

2 ENSO-related variability of the mesosphere

State of the Art

- The middle atmosphere during winter is connected with El Nino-Southern Oscillation (ENSO).
- The stratospheric polar vortex is weaker during El Nino.
- Stratospheric sudden warmings are more frequent during El Nino winters.
- Most analyses refer to the stratosphere, here we are interested in the MLT and its relation to the troposphere.

VHF meteor radar

- Horizontal winds from Doppler shifted VHF signal from meteor trails.
- Vertical wind profiles 80-100 km.
- Collm, 51.3°N, 13.0°E.

MUAM numerical model

- 3D grid point model.
- Surface to lower thermosphere.
- Primitive equations.
- Parameterized gravity waves, radiation, latent heat release.
- Lower boundary from MERRA temperatures and geopotential heights.
- 9 runs for El Nino and La Nina conditions, resp.
- Results confirm stronger zonal winds in the upper mesosphere during El Nino.

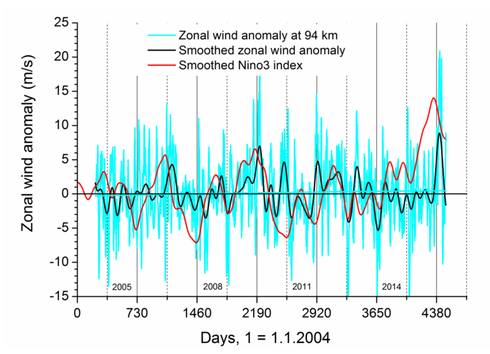

Fig. 1: Collm (51°N, 13°E) zonal mean winds at 94 km and Nino-3 index. Very strong westerlies are observed during the late 2016/2017 winter, when an extreme El Nino event was registered.

Fig. 2: Correlation coefficients of Collm zonal winds and Nino-3 index (Jacobi et al., 2017).

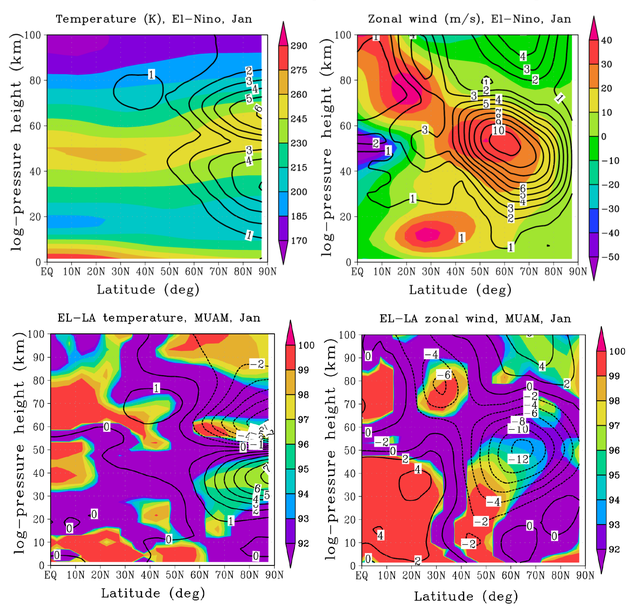

Fig. 3: Upper row: MUAM January mean temperatures (left) and zonal winds (right) and standard deviations. Lower row: Differences El Nino – La Nina and significance level (colors).

3 Mesosphere and NAO

State of the Art

- The stratospheric polar vortex is connected with the NAO.
- Early observations indicate a possible connection of NAO and MLT (e.g. Jacobi, 2000).
- Numerical model experiments mainly refer to the lower middle atmosphere.

MUAM experiments

- MUAM model runs with assimilated ECMWF. temperatures from five years each with positive (1983, 1984, 1993, 2005, 2015) and negative (1979, 1982, 1985, 1987, 2010) NAO index.
- Analysis of mean circulation and planetary waves.
- Results show a deeper polar vortex for positive NAO up to the upper mesosphere, but reversal in the MLT (Fig. 4).
- This is connected with a weaker SPW1 during positive NAO winters. SPW2 in turn tends to be stronger for positive NAO.

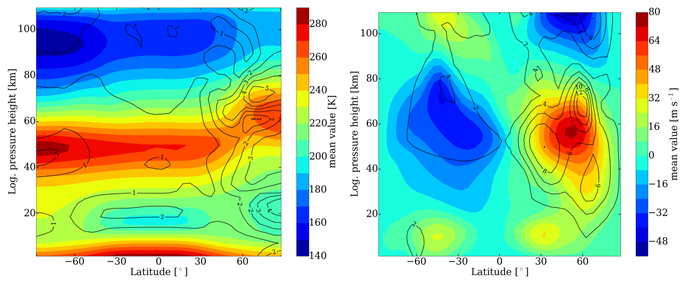

Fig. 4: January mean temperature (left) and zonal wind (right) for positive NAO index (color), and standard deviation (contours).

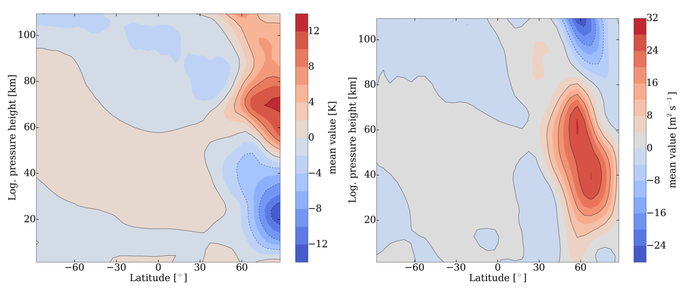

Fig. 5: Differences of January mean temperature (left) and zonal wind (right) positive – negative NAO index.

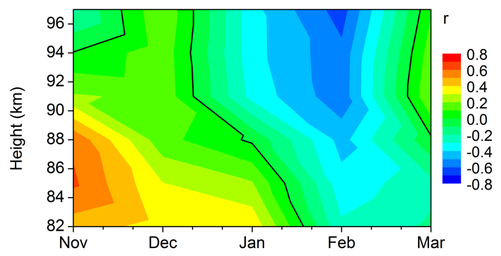

Fig. 6: Correlation of Collm monthly zonal winds and NAO index.

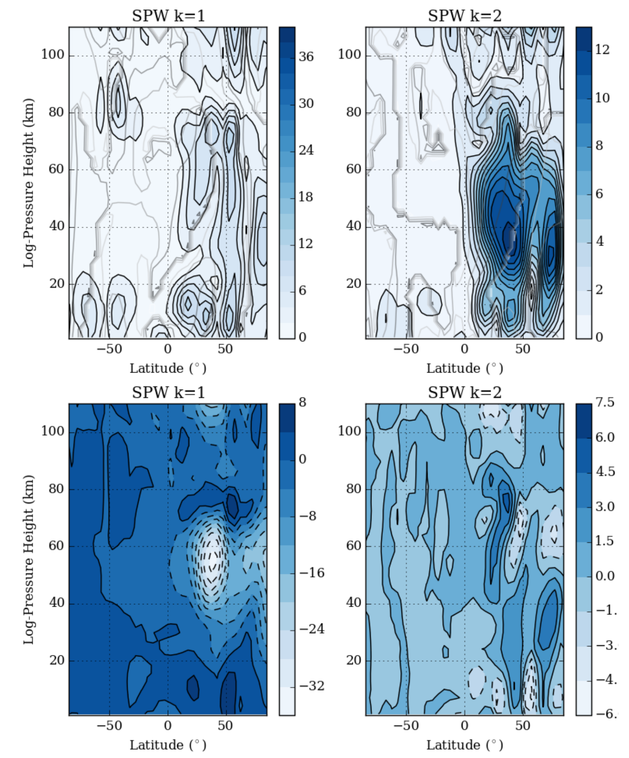

Fig. 7: SPW 1 and 2 in zonal wind for positive NAO January (upper panel), and differences positive – negative NAO winters.

4 Conclusions and final remarks

Conclusions

- ENSO signature is visible in the Arctic middle atmosphere up to the MLT.
- Visible in radar observations and qualitatively confirmed by numerical modeling.
- NAO variability influences MLT circulation at high latitudes in winter.

Perspectives

- Analysis of vertical coupling processes including the mesosphere using MERRA-2 and ERA5 reanalyses
- MLT radar network over Europe

References

- Jacobi, Ch., 2000: Midlatitude mesopause region winds and their connection with Euro-pean and Asian tropospheric parameters, Theor. Appl. Climatol., 65, 231-243.
- Jacobi, Ch., T. Ermakova, D. Mewes, and A.I. Pogoreltsev, 2017: El Niño influence on the mesosphere/lower thermosphere circulation at midlatitudes as seen by a VHF meteor radar at Collm (51.3°N, 13°E), Adv. Radio Sci., in press.

Acknowledgements

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