

Drivers of interannual UTLS water vapor - polar vortex covariability in the Northern Hemisphere

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RESEARCH QUESTIONS



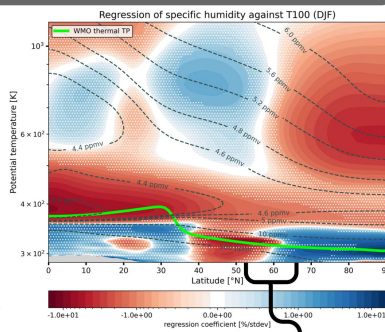
- How does polar vortex strength influence water vapor in the Upper-Troposphere-Lower-Stratosphere (UTLS) region?
- Which transport processes contribute the most to the identified interannual wet/dry anomalies?

DATA

- This investigation uses ERA5 reanalysis data from 1980 to 2022 on isentropic levels at 6-hourly temporal resolution.
- Preparation: Before any further analysis steps are taken all data is detrended and (for the daily case) deseasonalized.

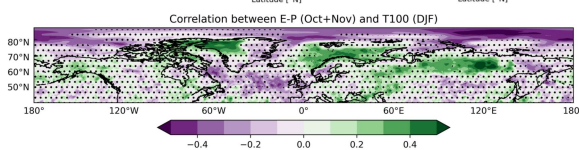
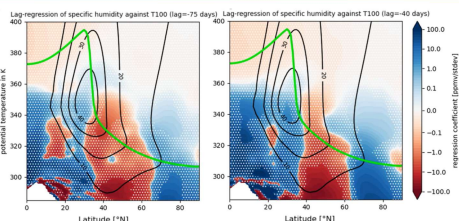
RESULT

- Linear regression of boreal winter (DJF) mean specific humidity (here divided by its DJF climatology) against T100 reveals significant wet and dry interannual anomalies in tropo- and stratosphere.



EXTRATROPICAL DIPOLAR TROPOSPHERIC SIGNAL

- Snapshots of lag-regression animation: The dipolar dry-wet pattern emerges early.



- Possible relation to humidity gradients caused by zonally inhomogeneous changes in the source via evapotranspiration minus precipitation (E-P) (e.g., driven by regional changes in the jets)

CONCLUSION

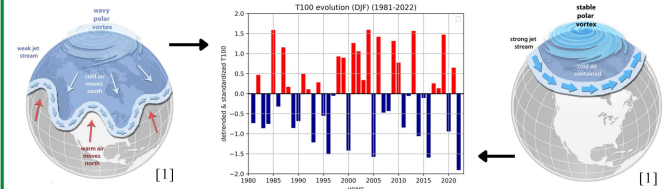
Under weak polar vortex conditions in NH winter...

- ...polar mid-stratospheric drying is mainly a result of horiz. eddy transport (related to the Brewer-Dobson circulation).
- ...extratropical LMS wetting is primarily driven by the tropopause shift, which creates stronger poleward gradients.
- ...extratropical tropospheric drying and wetting (appearing as a dipole in the zonal mean) can be linked to long-term precursors of the polar vortex weakening/breakdown.



METHODOLOGY

- T100 index:** To quantify polar vortex strength, we compute the 100 hPa polar-cap mean temperature (T100), which has high/low values under weak/strong polar vortex conditions.



- TEM budget:** We use the transformed Eulerian mean (TEM) tracer budget equation (Andrews et al., [2]) in isentropic coordinates to separate water vapor tendencies into their transport driven contributions:

$$\delta_t \bar{\chi}^* = -\bar{a}^{-1} \bar{v}^* \delta_\phi \bar{\chi}^* - \bar{Q}^* \delta_\phi \bar{\chi}^* - (\bar{\rho}_\theta a \cos \phi)^{-1} \delta_\phi (\bar{v} \bar{\rho}_\theta \bar{\chi}^* \cos \phi) - \bar{\rho}_\theta^{-1} \delta_\theta (\bar{Q} \bar{\rho}_\theta \bar{\chi}^*) + \bar{S}^*$$

Horizontal advection

Vertical advection

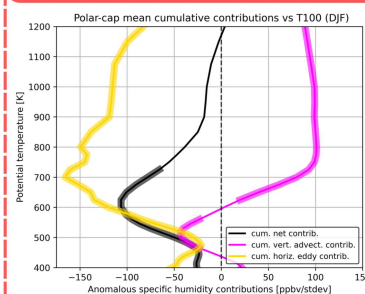
Horizontal eddy transport

Vertical eddy transport

Source

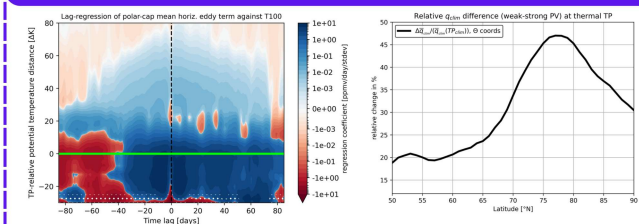
- with χ = specific humidity, ρ_θ = isentropic density, $\bar{\chi}^* = \frac{\partial \bar{\chi}}{\partial \rho_\theta}$ and $\hat{\chi} = \chi - \bar{\chi}^*$
- In the following, specific humidity is always density-weighted.

POLAR MID-STRATOSPHERIC DRYING



- Cumulative contributions of the transport terms to winter mean specific humidity reveal competing effects between horiz. eddy transport & vertical advection.

EXTRATROPICAL LOWER-MOST STRATOSPHERIC WETTING



- Lag-regressions in tropopause-relative coordinates reveal major horiz. eddy contribution to extratropical LMS wetting.
- Differences of clim. mean specific humidity interpolated to composites of TP positions in strong/weak polar vortex years visualize a strengthening of the horiz. equator-pole gradient.



REFERENCES

[1] Adapted graphic from NOAA Chemical Science Laboratory, <https://csl.noaa.gov/>, 2021

[2] Andrews, David G., Conway B. Leovy, and James R. Holton. Middle atmosphere dynamics. Vol. 40. Academic press, 1987