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Resolving spatial dynamics at polar latitudes using the GROMOS-C radiometer on Svalbard and the Nordic meteor radar cluster

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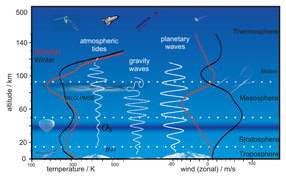
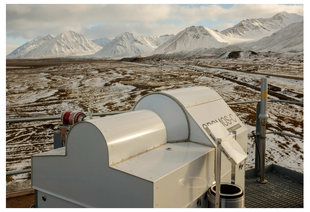
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

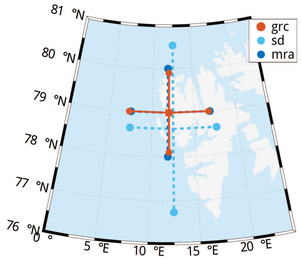
Motivation



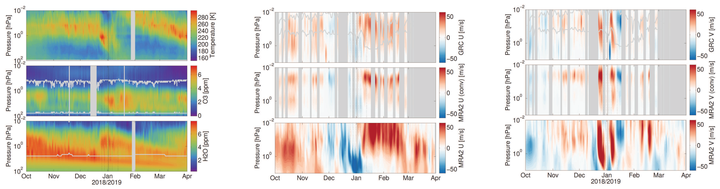
The variability of the middle atmosphere is driven by a variety of atmospheric waves covering various spatial and temporal scales. In particular, the northern winter mesosphere/ lower thermosphere at mid- and polar-latitudes shows a huge variability related to planetary waves, which can disturb the polar vortex leading to large scale coupling effects like sudden stratospheric warmings (SSWs) altering the vertical propagation conditions of tides and gravity waves.

GROMOS-C observations at Ny-Ålesund

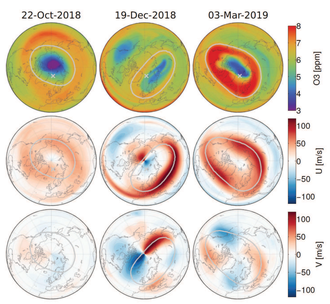


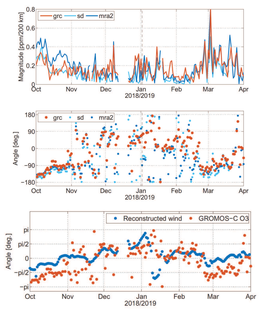


GROMOS-C is state of the art radiometer with beam steering capability covering the four cardinal directions to infer spatial gradients in the ozone volume mixing ratio (VMR) (Schranz et al., 2020). Further, GROMOS-C can be used for horizonal wind observations. The map shows the GROMOS-C beam positions at the stratosphere and the grid points next to these from MERRA2 and WACCM-SD.

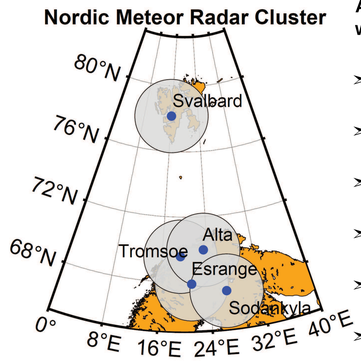


During the winter season 2018/19 GROMOS-C measured the polar ozone VMR indicating the evolution over the winter season in dependence of the polar vortex. At the begin and the end of the winter season the polar vortex forms an effective meridional transport barrier sustaining low ozone VMR in the polar cap. The GROMOS-C measurements indicate the modulation of this gradient by planetary waves, as well as a strong meridional intrusion of ozone into the polar cap during an SSW.





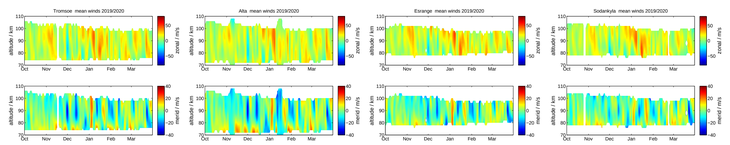
ASGARD

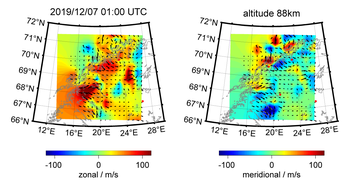


Asgard – Atmospheric Survey for Gravity wAves Regional Dynamics

- Nordic meteor radar cluster joined effort within ARISE-IA
- 3DVAR retrieval to obtain horizontally resolved wind fields
- entirely new possibility to investigate atmospheric dynamics at the MLT
- on campaign basis temporal resolution of 10 min achievable
- advanced nested retrieval in preparation to include Svalbard
- new data products for data assimilation into general circulation models

An important aspect of the 3DVAR retrieval is that there are almost no systematic biases between the radar systems. Therefore, we compute the instantaneous winds for each radar and compare the daily mean winds obtained by an adaptive spectral filtering to check the general morphology. Potential differences are included as additional error in the covariances in the 3DVAR retrieval. The winter season 2019/2020 was characterized by a stable polar vortex and no major SSW occurred. Thus, we further investigate the minor early warming at 1st December 2019.

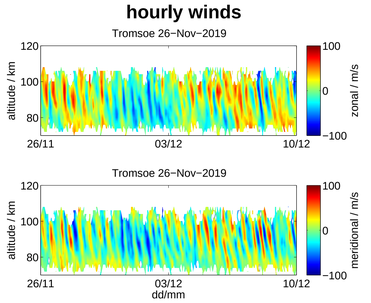




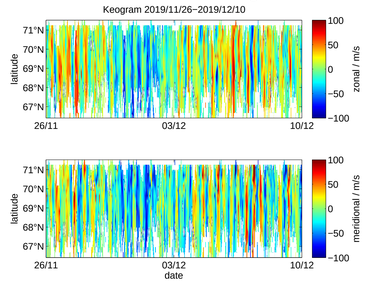
3DVAR wind retrievals

- 3D wind tomography in the observation volume
- optimal estimation with zero wind a priori
- full error propagation through covariance matrix
- robustness against random sampling
- 3D wind retrieval on a regular 30x30 km grid

Classical time vs. altitude time series of hourly winds



Time vs. latitude keogram at 90 km altitude and 18.8°longitude



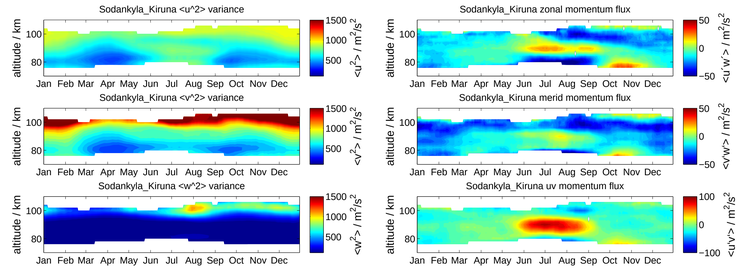
Reynolds stress obtained from meteor radar retrievals

Hocking, 2005 introduced a technique to estimate the gravity wave momentum flux for meteor radars based on a Reynolds decomposition. The mean flow includes the background mean winds and the tidal dynamics (diurnal and semidiurnal) and the gravity waves are considered as fluctuation term.

$$\vec{u} = \overline{\vec{u}} + \vec{u}' \quad (1)$$

The new momentum flux retrieval uses an adaptive spectral filter technique to separate the background mean flow from each observed radial velocity. Further, the retrieval includes a full Earth Geometry (WGS84) to account for the geodetic coordinates for each meteor to reduce projection errors for the zonal and meridional wind with respect to their position on Earth as well as its actual time of occurrence and altitude to minimize a contamination between mean values and gravity wave fluctuations. The Reynolds stress tensor is then easily obtained using Hocking, 2005;

$$\tau_{ij} = \rho\overline{u_i' u_j'} = \rho \cdot \begin{pmatrix} u' \\ v' \\ w' \end{pmatrix} \cdot (u', v', w') = \rho \cdot \begin{pmatrix} u'^2 & u'v' & u'w' \\ v'u' & v'^2 & v'w' \\ w'u' & w'v' & w'^2 \end{pmatrix} \quad (2)$$



Conclusions

- GROMOS-C measures spatial distribution of ozone volume mixing ratio
- spatial gradients show planetary wave signatures and polar vortex evolution
- during SSWs a strong meridional transport of ozone occurs
- successful campaign of Nordic meteor radar cluster
- 3DVAR retrieval robust against varying number of available radars
- new possibility to investigate spatially resolved wave dynamics
- 3DVAR analysis including Svalbard meteor radar (mosaic and nest retrieval)

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