Local processes modifying atmospheric humidity in an Arctic fjord environment

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1. Motivation & objectives

Better understanding of interactions between surface, atmospheric boundary layer and low-level clouds in a complex Arctic environment at Ny-Ålesund (78° N), Svalbard.

Humidity determines cloud formation: Local processes impacting surface fluxes and transport of humidity are linked to low-level clouds.

→ Investigate local-scale variability of water vapor in Kongsfjorden

→ Influence of fjord environment on spatial distribution of humidity?

Fig. 1: Map of the Kongsfjorden area. The red star shows the location Ny-Ålesund. (Source: https://toposvalbard.npolar.no[1])

Fjord environment characterized by:

- Orography
- Glaciers
- Heterogeneous surface types: open water, seasonal snow cover, ice, etc.

2. Observations

Measurements at AWIPEV station, Ny-Ålesund.

Microwave radiometer (HATPRO)

- Retrieval of integrated water vapor (IWV) and liquid water path (LWP)
- 360° azimuth scans at 30° elevation angle 2 times/hour

  → along path IWV and LWP

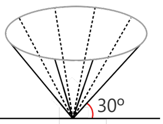

Fig. 2: Sketch of HATPRO scan pattern.

Raman lidar (KARL)

- Operated during polar night and clear sky periods
- Vertically resolved water vapor mixing ratio[2]

Wind lidar (WindCube)

- Continuously operated
- Measurement requires aerosols for backscattering

Radiosondes

- Launched once per day at 11 UTC

3. General spatial humidity distribution

Mean relative humidity between 1 and 1.1 km from radiosonde ascents

- Higher (lower) relative humidity towards the fjord (mountains)

Pattern is clearest in autumn (October – December)

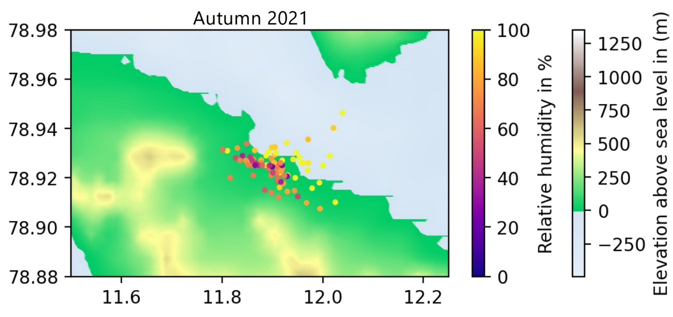

Fig 3: Mean relative humidity between 1 and 1.1 km (filled circles) at the respective sonde location for all radiosonde ascents in autumn 2021. (Topography information from: https://topex.ucsd.edu/cgi-bin/get_data.cgi[3])

4. Possible local processes related to humidity variability

Selection of cases based on IWV distribution (Fig. 4) during cloud and advection free days

Case 1: Clear IWV pattern → higher IWV in the direction of the fjord

Increased humidity layer around 0.9 km (Fig. 5)

- Humidity transported by N wind (Fig. 6) from fjord?
- Lower layer drier due to S-E wind from Kronebreen/mountains?

Case 2: No spatial IWV pattern

Wind direction is presumably constant from S-E (Fig. 6) and higher wind speeds (not shown)

- Stronger wind speed prevents small scale spatial pattern from forming?

Lower water vapor mixing ratio

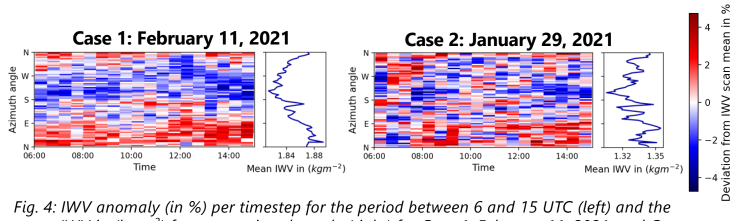

Fig. 4: IWV anomaly (in %) per timestep for the period between 6 and 15 UTC (left) and the mean IWV in (kgm^{-2}) for every azimuth angle (right) for Case 1, February 11, 2021, and Case 2, January 29, 2021.

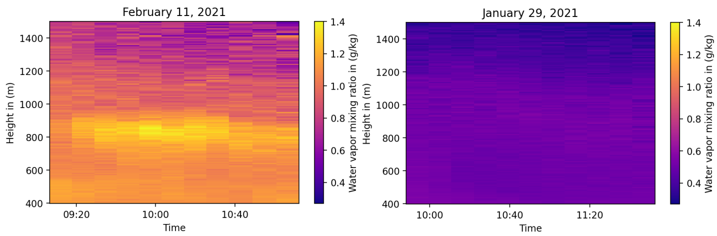

Fig. 5: Water vapor mixing ratio below 1.5 km measured by a Raman lidar for Case 1, February 11, 2021, (left) and Case 2, January 29, 2021 (right).

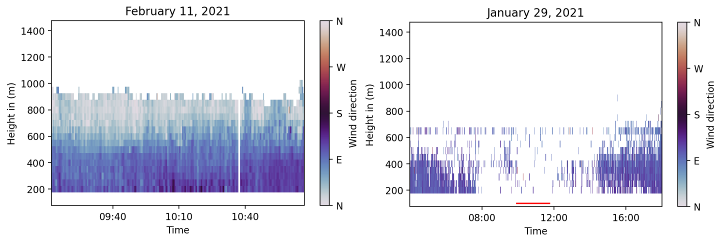

Fig. 6: (left) Wind direction during the Raman lidar measurement by a wind lidar. (right) as left but between 4 and 18 UTC. Time period covered by the Raman lidar indicated by the red line.

5. Conclusions

- Radiosondes reveal a distinct humidity pattern along the coastline in the autumn
- Similar pattern found in HATPRO azimuth scans for a low wind speed, advection free case

Outlook

- Study further cases and local water vapor variability in the fjord using the highly resolved ICON-LEM
- Investigate linkage to LWP and low-level clouds

References

1- Provided by the Norwegian Polar Institute.

2- Kulla and Ritter, 2019, Water Vapor Calibration: Using a Raman Lidar and Radiosoundings to Obtain Highly Resolved Water Vapor Profiles, Remote Sensing , Vol. 11, No. 6

3- Smith, W. H. F., and D. T. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, Science, v. 277, p. 1957-1962, 26 Sept., 1997.

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