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Understanding the "New Arctic" with Novel Observations and Modeling from (AC)³ and MOSAiC

Title:
Water vapour in the central Arctic: How well do remote sensing observations and models perform?

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Abstract (max. 1000 words):

Water vapour is the strongest greenhouse gas and contributes to the rapid warming of the Arctic via the water vapour feedback loop (Ghatak and Miller, 2013; Wendisch et al., 2023). Besides a warming of the Arctic, observations and reanalyses also indicate an increase of the integrated water vapour (IWV) in certain regions and seasons, especially around Svalbard (Norway) in late autumn and early winter (Maturilli and Kayser, 2017; Parracho et al., 2018). However, different reanalyses strongly disagree on the magnitude or even the sign of the IWV trends in the central Arctic (Rinke et al., 2019). The trend uncertainties are likely related to the lack of high-quality water vapour observations, for example from radiosondes launched at ground stations. No ground stations exist on the sea ice, and satellite remote sensing observations are uncertain or not available due to clouds, the polar night or the emission signal from the sea ice.

This study evaluates the quality of IWV and specific humidity profiles of four state-of-the-art models and two satellite products in the data-sparse central Arctic for a whole year. The evaluated models include

- the European Centre for Medium-Range Weather Forecast (ECMWF) reanalysis v5 (ERA5),
- the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) from NASA's Global Modeling and Assimilation Office (GMAO),
- the Coupled Arctic Forecast System (CAFS) from National Oceanic and Atmospheric Administration Physical Sciences Laboratory (NOAA-PSL),
- the ICOsahedral Non-hydrostatic (ICON) model from the German Weather Service and the Max Planck Institute for Meteorology.

The considered satellite products are

- the Infrared Atmospheric Sounding Interferometer (IASI) combined soundings products, which use the observations onboard the Metop satellites and performed best in the Arctic according to Crewell et al. (2021),
- a novel IWV retrieval using microwave observations from the Advanced Scanning Microwave Radiometer 2 (AMSR2) developed by Rückert et al. (2023).

The year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition provides excellent reference observations. The quality of IWV is analysed with respect to the ship-based microwave radiometer (MWR) observations. Three of the four models underestimate IWV in dry conditions while both satellite products have a dry bias in moist conditions. Consistently, the models (satellite products) also underestimate the lower tropospheric specific humidity in the cold seasons (summer) with respect to the reference given by radiosonde observations.

As many specific humidity biases throughout the year seem to be related to humidity inversions, we further analysed how they are represented in the different data sets using the radiosondes as reference. The occurrence of near-surface humidity inversions is well caught by the models throughout the year and by the ground-based MWRs in winter. However, inversion strength and

depth often differ from the radiosonde observations. Additionally, we quantified how humidity inversion misrepresentations affect the downwelling longwave radiation in clear sky conditions using radiative transfer simulations. These misrepresentations of the inversions result in deviations of the downwelling longwave radiation of ±8 W m^{-2}.

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