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Vertical structure of the lower-stratospheric moist bias in ERA5 reanalyses and its relation to mixing processes

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Current NWP analyses and reanalyses are known to possess a moist bias in the lower stratosphere of the mid-latitudes [1]. An accurate representation of water vapor in the extratropical upper troposphere and lower stratosphere (UTLS), however, is crucial to correctly predict weather but also when climate models are verified against reanalysis products. This presentation uses a unique airborne multi-campaign water vapor profile data set to better characterize the vertical structure of this bias and to investigate its connection to mixing processes.

Highly-resolved water vapor profiles have been recorded with the differential absorption lidar (DIAL) WALES onboard the research aircraft HALO on various field campaigns since 2013. The high-resolution humidity profiles along the flight path provide high data availability across the entire UTLS in cloud-free situations. We analyzed mid-latitude data from more than 40 flights over the Northern Atlantic and Europe that cover a broad spectrum of synoptic situations and different seasons.

This comprehensive data set is used for a comparison with the European Centre for Medium-Range Weather Forecast's (ECMWF) ERA5 reanalysis. First, we show an example specific humidity distribution along a cross-section in the surrounding of an extratropical cyclone. The comparison to ERA5 indicates the largest positive and negative deviations in the UT, but on average no systematic differences. In contrast, we find a coherent layer of strongly overestimated humidity above the thermal tropopause (TP) persisting along the whole flight path. Second, the vertical structure of deviations is verified for all flights. On average, deviations in the UT are relatively weak (+15%) and the minimum bias (+10%) is found at the thermal tropopause. Above the TP, within a layer of 1-1.5 km the bias rapidly increases up to a maximum of +52% while it decreases again to 15-20 % by 4 km. Although the shape of the vertical structure is similar for each flight, variations of the moist bias are observed for different seasons. For instance, the overestimation in summer is more than twice as high as for autumn observations.

A possible explanation for this systematic moist bias is overestimation of mixing of water vapor into the LS. During one field campaign, WALES additionally observed ozone profiles which allow a classification of the observations into tropospheric, stratospheric and mixed air using H_2O-O_3

correlations in tracer-tracer space [2]. We demonstrate that the bias is particularly increased in air that was mixed in its history which indicates that mixing processes are not sufficiently well represented by ERA5.

References

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