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Three-dimensional reconstruction of gravity waves in the UMLT derived from dual OH airglow observations using a tomographic retrieval

Rebecca Winkler-Zurlinden¹, Patrick Hannawald², Gunter Stober³, Sabine Wüst², and Michael Bittner^{1,2}

¹Institute of Physics, University Augsburg, Germany (rebecca.winkler-zurlinden@uni-a.de)

²German Aerospace Center, German Remote Sensing Data Center, Oberpfaffenhofen, Germany (patrick.hannawald@dlr.de)

³Institute of Applied Physics, Bern, Atmospheric Dynamics and Meteor Physics, Bern, Germany (gunter.stober@unibe.ch)

Gravity waves transport momentum and energy vertically and horizontally and play a key role for the circulation in the upper mesosphere and lower thermosphere (UMLT). They can experience convective or dynamic instabilities or undergo nonlinear interactions with the background flow. The UMLT is of particular importance, as gravity waves frequently reach their breaking levels in this region, often referred to as the turbopause.

This altitude range is observed using two FAIM cameras measuring the OH-airglow emission centered at approximately 86 km altitude, with a full width at half maximum of about 7–8 km, from different locations. By applying a newly developed tomographic reconstruction technique to coordinated dual-camera OH-airglow observations of the same air volume, the three-dimensional structure of gravity waves in the UMLT can be recovered. The resulting volumetric data provide detailed information about horizontal and vertical gravity-wave features, representing a middle-atmosphere sounding technique complementary to established methods such as lidar or radar observations.

To characterize these waves, vertical wavelengths are extracted in a dedicated post-processing step by applying a two-dimensional FFT to selected altitude layers of the tomographically reconstructed volume. This approach provides access to vertical phase progression and vertical wavelength information that is fundamentally unattainable with a single OH airglow imager. By analyzing the phase differences of the wave signals in the FFT spectra between different altitude layers, the vertical propagation angle can be derived. In combination with the horizontal wavelength, this enables the determination of the vertical wavelength and thus a full three-dimensional gravity-wave characterization.

First results from this dual-FAIM tomographic approach are presented, demonstrating both the feasibility and the performance of the method. The analysis is based on coordinated OH-airglow observations from FAIM installations at Oberpfaffenhofen (lon = 11.28, lat = 48.09) and Otlica (lon = 13.91, lat = 45.94) over a one-year period. These data are used to assess retrieval quality, identify sensitivity limits for vertical wavelength derivations, and demonstrate the enhanced scientific

value of three-dimensional gravity-wave characterization for multi-instrument analyses of middle-atmosphere dynamics.

Within the project GIGAWATT, a collaboration of the German Aerospace Center, the University of Augsburg and the University of Bern, we are currently advancing this work by incorporating new measurements and combining complementary observational techniques, including radiometric temperature and wind observations in the stratosphere and lower mesosphere and multi-static OH airglow tomography, to establish a high-resolution gravity-wave observatory for the Alpine region. This work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the project number 540878795.