Seasonal and short term variability of atmospheric waves at mid-latitudes derived from ground-based observations and reanalysis data

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Atmospheric waves, e.g., gravity and tidal waves, play a key role for our understanding of the circulation in the Earth's atmosphere. These waves couple different atmospheric layers from the troposphere to the mesosphere by the transport of momentum and energy over a wide range of scales. For quantifying the different waves in the middle atmosphere high resolution observational data is still needed. For this purpose we use the daylight-capable Rayleigh-Mie-Raman (RMR) lidar at Kühlungsborn (54° N, 12° E) and the co-located meteor radar at Juliusruh (55° N, 13° E) to investigate both wave phenomena from temperature as well as wind data covering altitudes between 30 and 100 km. Extensive data sets of 6 years lidar and 9 years radar observations are utilized to derive the seasonal variation of both wave types. Data decomposition is done using a spectral filtering technique to separate gravity and tidal waves based on their specific periods and vertical wavelengths. Inertia gravity waves and tides show a reduced activity during summer, while gravity waves with periods of 4-8 h gain in importance especially above 55 km altitude seen from the lidar data as well as from the radar observations in the MLT region. This is presumably caused by the large horizontal phase speeds of these gravity waves allowing them to propagate into the mesosphere. Besides the seasonal variation, the short term variability of gravity and tidal waves on time scales of days is addressed using an outstanding 10-day continuous lidar measurement in May 2016. We will present here a case study revealing a large temporal variability of a diurnal tidal wave. The wave occurs only between 40 and 60 km and vanishes after a few days. This is related to an enhancement of gravity waves with periods between 4 and 8 h that coincides with the vanishing tide. Reanalysis data from MERRA-2 will be presented for this case study to provide additional wind information in this altitude range, where radar measurements are not available. A comparison of the temperature and wind information affirms whether there is a fixed phase relation of the diurnal tidal wave in the temperature and the wind data. This knowledge helps to improve the interpretation of the seasonal variation of tides from different observables. The findings are excellent to provide deeper insights into the forcing of the atmosphere from below due to waves and they clearly show the importance of a measurement acquisition on a routine basis with high temporal and spatial resolution.

Key words: Vertical Coupling, Gravity Waves, Tides, Dynamics