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High-resolution observations of a gravity wave event over the Netherlands

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Atmospheric gravity waves (GW) are small-scale propagating disturbances that arise due to the vertical forcing of air parcels by topography, convection, wind shear, jet streams, frontal systems and other tropospheric sources. GWs play a key role in the transfer of energy, and produce turbulence when they dissipate. This can lead to clear air turbulence (CAT) at higher altitude layers, which is a risk for aviation. GWs can be trapped in the lower atmosphere, propagating only horizontally, in which they can impact the state of the atmosphere. Knowledge about heavy waves (and turbulence) in the boundary layer is still limited and contributes to uncertainties in weather and climate models.

Here we present observations of a strong GW event in the night and early morning of June 30, 2022. The GWs were generated by outflow from a frontal system over the North Sea and Belgium, and reached a large part of the Netherlands. Several wave trains travelled over the Netherlands, with similar direction but distinct phase speed and wavelength. This event was captured by many sensors that are part of the KNMI observational network. From our weather radars, automatic lidar ceilometer and surface observation network the GW propagation properties are determined. At our Cabauw supersite, part of the Ruisdael Observatory, Doppler lidar and microwave radiometer measurements provide detailed insight in the vertical profiles of the passing GWs. They show fundamental mode ducted GWs, trapped in the lower 500 m with a vertical velocity amplitude up to 3 m/s. Above this altitude, the waves are evanescent and are observed to decay with height. The Doppler lidar also allows us to observe GW-generated turbulence and derive vertical profiles of eddy dissipation rate, due to its high temporal resolution of 1s. Finally, the 200-m mast in-situ observations highlight the influence of the GWs on the meteorological variables, showing large amplitude oscillations in pressure, temperature, relative humidity, wind speed and wind direction.

This comprehensive set of observations may serve as a testbed for high resolution weather models that aim to capture these type of GW events. As this work also highlights the ability to detect GWs by the different components of our KNMI observational network, it provides a starting point to further explore the occurrence and properties of these GWs in the Netherlands, including the North Sea.