Gravity-wave induced rotors

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Abstract

One of the main sources of internal gravity waves in the atmosphere is the forcing by airflow over topography (hills, mountains). Depending on the properties of the background flow (temperature- and wind profiles), this type of forcing leads to two types of waves: evanescent waves and trapped waves. The former travel throughout the troposphere and can even reach the stratosphere, where they can influence the large scale flow e.g. by wave breaking. The latter phenomenon also induces severe turbulence which can be hazardous for air traffic . The other type of waves are trapped in the lower atmosphere between the ground and a few kilometres aloft and are called lee waves. As these waves are bounded by the ground the are interacting with the atmospheric boundary layer, which is dominated by turbulent friction. The main phenomenon induced by the interaction of lee waves and the atmospheric boundary layer are so-called rotors, horizontal vortex rolls located beneath the wave crests. In contrast to the very smooth flow within lee waves , the rotor flow is very turbulent and can be also a hazard for aviation in mountainous terrain. For the latter reason, there have been intensive research activities on rotors by means of large field experiments like T-REX (Grubisic et al., 2008) and high resolution numerical simulations (e.g. Vosper, 2004; Smith and Skyllingstadt, 2009) in the last decade.
Here we contribute to the rotor problem by laboratory experiments performed in the large stratified towing tank at Meteo-France in Toulouse and supplemental numerical simulations by a Large-Eddy-Simulation model. (Knigge et al., 2010, Knigge, 2012). These experiments were performed for some idealized situations with respect to the environmental flow, where the main focus was on the influence of an inversion at top of the atmospheric boundary layer. The results provided an regime diagram for the formation of rotors quite similar to the investigations by Vosper (2004). In combination with the LES simulations some typical characteristics of the rotor flow (e.g. dimensions, velocity fields, turbulence) have been obtained and compared to recent field observations on rotors. As experienced by glider pilots since a long time, rotors can be almost found every time under the wave crests between the surface and boundary layer height (see e.g. Etling, 2014). Hence they constitute a hazard to low level aviation close to mountains.

Etling, D. (2014): Atmospheric gravity waves and soaring flight: Physical principles and practical applications. 104 pp., as e-book freely available under www.schwerewelle.de.
Grubicics, V. and 14 Coauthors (2008): Bull.Am.Met.Soc. 89, 1513-1533.
Knigge, C. (2012): PhD thesis (in German), 155 pp, University Hannover, Germany.
Knigge. C., Etling, D., Paci, A. and O. Eiff (2010): . Q.J.Roy.Met.Soc.136, 442-450.
Smith, C.D. and E.D. Skyllingstad (2009): J.Atmos.Sci., 66, 3147-3164.
Vosper, S. (2004): Q.J.Roy.Met.Soc., 130, 1723-1748

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