Geophysical Research Abstracts
Vol. 14, EGU2012-13327, 2012
EGU General Assembly 2012

Wave-induced boundary-layer separation: A case study comparing airborne observations and results from a mesoscale model

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Wave-induced boundary-layer separation (BLS) results from the adverse-pressure gradient forces that are exerted on the atmospheric boundary-layer by internal gravity waves in flow over orography. BLS has received significant attention in recent years, particularly so, because it is a key ingredient in the formation of atmospheric rotors. Traditionally depicted as horizontal eddies in the lee of mountain ranges, rotors originate from the interaction between internal gravity waves and the atmospheric boundary-layer.
Our study focuses on the first observationally documented case of wave-induced BLS, which occurred on 26 Jan 2006 in the lee of the Medicine Bow Mountains in SE Wyoming (USA). Observations from the University of Wyoming King Air (UWKA) aircraft, in particular, the remote sensing measurements with the Wyoming Cloud Radar (WCR), reveal strong wave activity, downslope winds in excess of 30 m/s, and near-surface flow reversal in the lee of the mountain range. The fine resolution of WCR data (on the order of 40x40 m̂2 for two-dimensional velocity fields) exhibits fine-scale vortical structures ("subrotors") which are embedded within the main rotor zone.

Our case study intends to complete the characterisation of the observed boundary-layer separation event. Modelling of the event with the mesoscale Weather Research and Forecast Model (WRF) provides insight into the mesoscale triggers of wave-induced BLS and turbulence generation. Indeed, the mesoscale model underpins the expected concurrence of the essential processes (gravity waves, wave breaking, downslope windstorms, etc.) leading to BLS.
To exploit the recorded in situ and radar data to their full extent, a quantitative evaluation of the structure and intensity of turbulence is conducted by means of a power spectral analysis of the vertical wind component, measured along the flight track.
An intercomparison of observational and modelling results serves the purpose of model verification and can shed some more light onto the limits of validity of airborne observations and mesoscale modelling. For example, the exact timing, magnitude, and evolution of the internal gravity waves present in the mesoscale model are carefully analysed. As for the observations, measures of turbulence gained from in situ and radar data, collected over complex topography within a limited period of time, must be interpreted with caution. Approaches to tackling these challenges are a matter of ongoing research and will be discussed in concluding.