Geophysical Research Abstracts
Vol. 15, EGU2013-9106, 2013
EGU General Assembly 2013

Estimating Turbulence in Mountainous Regions from Airborne In Situ and Remotely-Sensed Data

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Turbulence in atmospheric flow over and around orographic obstacles has been at the focus of numerous studies in the past. Reasons for this range from primary interest in the turbulence-generating processes (gravity-wave breaking, downslope windstorms etc.) to, more recently, issues regarding flight safety.

Our work focuses on the observational analysis of turbulence during events of boundary-layer separation and rotor formation. The study is based on observations from two recent field campaigns over the Medicine Bow Mountains in SE Wyoming (NASA06) and the Sierra Nevada in Southern California (T-REX). During these campaigns, the University of Wyoming King Air (UWKA) research aircraft flew straight-and-level legs aligned with the mean wind direction to document the variation of flow and turbulence over the mountain ridges. Aircraft in situ data of wind, pressure and temperature were recorded at a frequency of 25 Hz. The Wyoming Cloud Radar (WCR), carried aboard UWKA, measured Doppler vertical wind velocities at multiple levels at a frequency of 30 Hz.

The objective of this work is to quantify turbulence intensity during the observed boundary-layer separation and rotor formation events. To this end, estimates of the variance of vertical wind speed and the eddy-dissipation rate are computed from airborne in situ as well as remotely-sensed data. The comparison of two wave events during the NASA06 campaign reveals similar turbulence intensities with maximum eddy-dissipation rates in the range 0.25-0.30 m^2 s^{-3}. The dynamic origin of turbulence, however, appears to be different. For 26 January 2006, results are indicative of a breaking gravity wave aloft leading to wave-induced boundary-layer separation and rotor formation, with maximum turbulence levels located in the rotor interior. In contrast, on 5 February 2006, the lee wave pattern aloft remained laminar while the boundary-layer flow was heavily perturbed. The spatial distribution of turbulence in the flow suggests that turbulence originated from bluff-body separation of the boundary layer at the mountain peak.
Preliminary results from the T-REX field campaign provide a similar picture. Regions of strong turbulence from wave-induced boundary-layer separation and rotor formation exist in the lee of the Sierra Nevada. Besides, highly turbulent flow patches can be found right behind smaller but steep crests of the main ridge of the Sierra Nevada.

The type of analysis employed in this study is expected to be valuable in general for detection of strong turbulence in mountainous terrain and for quantification of its intensity.