Geophysical Research Abstracts
Vol. 19, EGU2017-15550, 2017
EGU General Assembly 2017

Boundary-layer processes: key findings from MATERHORN-X field campaigns

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Understanding of atmospheric boundary-layer processes in complex terrain continues to be an active area of research considering its profound implications on numerical weather prediction (WP). It is largely recognized that nocturnal circulation, non-stationary processes involved in evening and morning transitions as well gusty conditions near mountains are poorly captured by current WP models. The search for novel understanding of boundary-layer phenomena especially in critical conditions for WP models has been one of the goals of the inter-disciplinary Mountain Terrain Atmospheric Modeling and Observations (MATERHORN) program (2011-2016). The program developed with four main pillars: modelling (MATERHORN-M), experiments (MATERHORN-X), technology (MATERHORN-T), and parameterizations (MATERHORN-P), all synergistically working to meet new scientific challenges, address them effectively through dedicated field and laboratory studies, and transfer the acquired knowledge for model improvements. Specifically, MATERHORN-X is at the core of the MATERHORN program. It was built upon two major field experiments carried out in 31 September-October 2012 and in May 2013 at the Granite Mountain Atmospheric Science Testbed 32 (GMAST) of the Dugway Proving Ground (DPG). In this talk we will focus on results of data analyses from MATERHORN-X with emphasis on several aspects of the nocturnal circulation under low synoptic forcing when stable stratification occurs. The first part of the talk will discuss the evolution of nocturnal flows including both evening transitions on slopes and valleys as well as the occurrence of isolated flow bursts under very stable conditions. As far as the former is concerned we report on our latest understanding of mechanisms leading to evening transitions (e.g. shadow front, slab flow, and transitional front). As far as the latter is concerned, it is hypothesized that a link exists between isolated bursts in turbulent kinetic energy and low-level jets structure, a feature which is commonly found in the first 50-100 m from the ground. The second part of the talk will discuss the interaction between an isolated hill and an approaching (undisturbed) stably-stratified flow with emphasis on the dividing streamline concept. The hill was located northwest of and close to the Granite Mountain, and was approximately 60m in height. A suite of (smoke) flow-visualization, remote sensing and in-situ measurement assets were deployed. At small Froude numbers (Fr<1), a stratified flow approaching the hill either possesses sufficient kinetic energy to pass over the summit or else flows around the sides, with the dividing streamline separating the two scenarios. By applying a logarithmic approach velocity profile to the well-known Sheppard's formula based on simple energetics, an explicit representation for the dividing streamline height was derived and a new set of parameters were identified to determine the dividing streamline height. The analysis shows that there will always be a dividing streamline for real atmospheric stratified shear flows. This has relevant implications for modelling air-flow and dispersion in mountainous regions.