Observations of the evening transition processes on opposing slopes of a north-south oriented mountain

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Abstract

The MATERHORN[a] (Mountain Terrain Atmospheric Modeling and Observation) Program is a multi-university, multidisciplinary research initiative designed to improve numerical weather prediction in complex terrain and to better understand the physics of complex terrain flow phenomena across a wide range of scales. As part of MATERHORN, field campaigns were conducted at Dugway, UT, USA in Autumn 2012 and Spring 2013. A subset of the campaigns included dense observations along the East Slope of Granite Peak (40.096° N, -113.253° W), as well as additional observations on the opposing west facing slope. East Slope observations included five multi-sonic anemometer eddy covariance towers (two with full energy budget stations), eleven small energy budget stations, fifteen automated weather stations, a distributed temperature sensing (DTS) system, hot-film anemometry, infrared camera surface temperature observations and up to three Doppler lidars. West Slope operations were less intense with three main towers, two of which included sonic anemometry and one, which included full surface energy balance observations. For this presentation, our analysis will focus on characterizing and contrasting the response of mean wind circulations and thermodynamics variables, as well as turbulence quantities during the evening transitions on both the East Slope and West Slope when solar irradiation differences of the slope surfaces is extremely large.

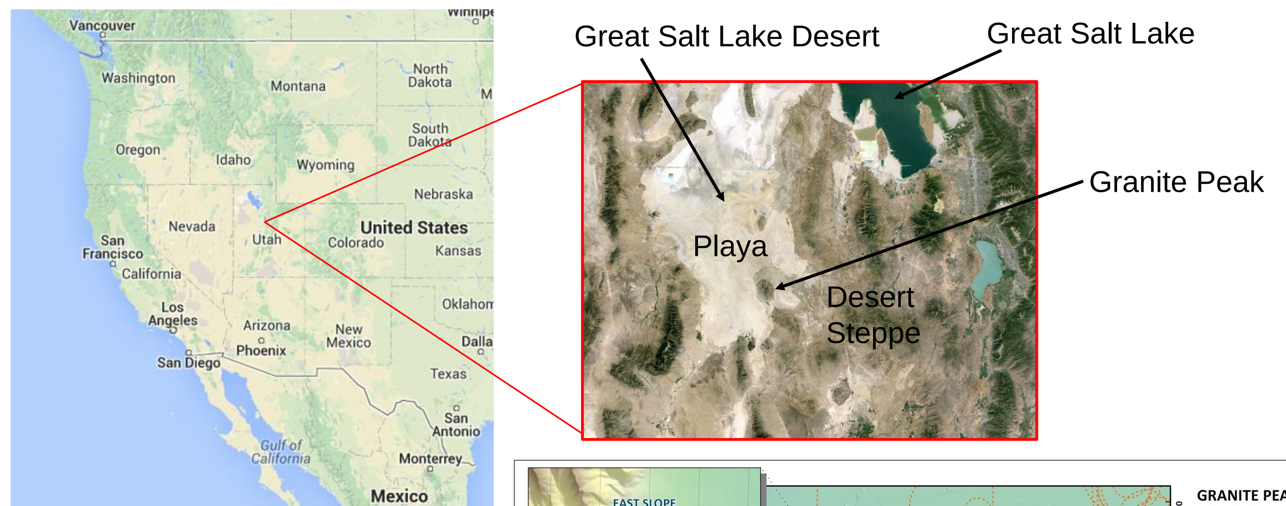
Overall Project Objective

Improve numerical weather prediction in complex terrain

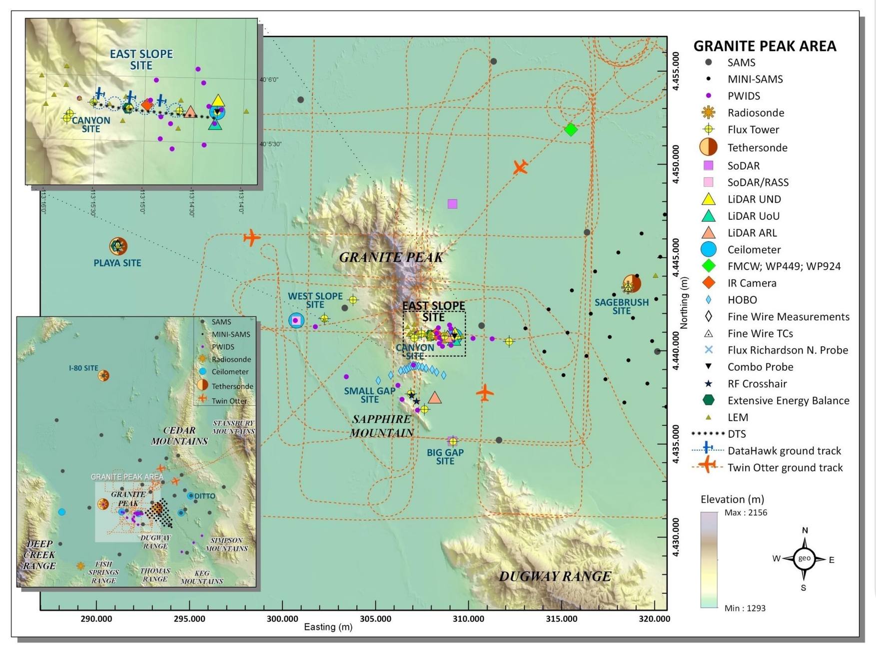
Specific Experiment Goals

- Improved understanding of physical processes associated with transition periods in complex terrain - Generalize the governing physics of slope/valley transition dynamics and turbulence
- Link physics across scales (dissipation scales of turbulence to synoptic scales)
- Develop improved parameterizations for poorly modeled physical processes in complex terrain

Field Campaigns
Dugway Proving Ground, UT

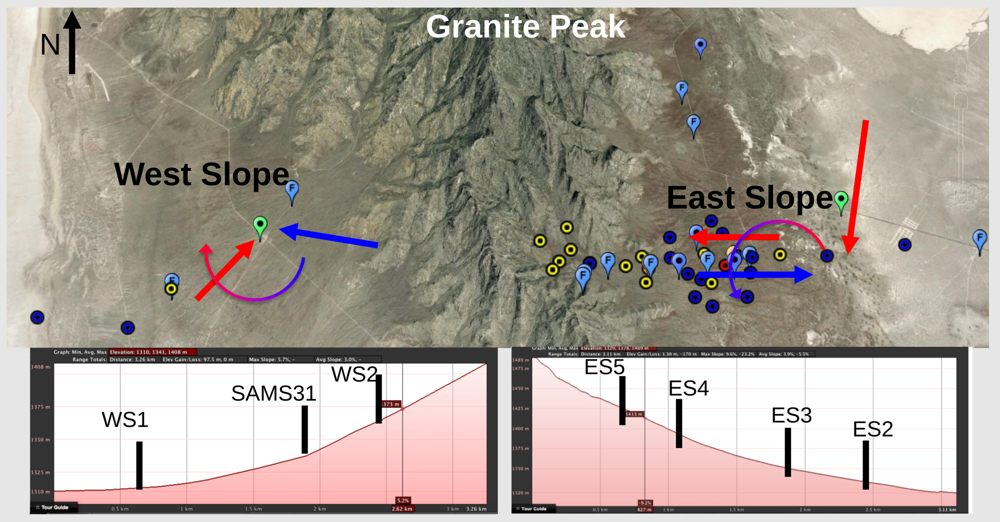


- Field campaigns were conducted at the U.S. Army Dugway Proving Ground (DPG) in Utah's West Desert
- Fall Campaign: 10 Intensive Observation Periods (IOPs)
  - Focus: Thermally Driven Winds/Dry
- Spring Campaign: 10 IPS
  - Focus: Synoptically Forces/Moist
- Massive deployment of instrumentation and use of DPG GMAST (Granite Mountain Atmospheric Sciences Testbed) facility: aircraft (manned and unmanned), towers, lidars, sodars, radars, radiosoundings, RF soil moisture, fine-scale turbulence)



More information may be found at:
http://www3.nd.edu/~dynamics/materhorn

Granite Mountain Slope Experiments



A wide range of measurements were made on both east and west facing slopes of Granite Mt. to better understand the dynamics of the evening transition processes on opposing aspects. In the figure above, the blue arrows indicate typical nocturnal wind directions and the red arrows indicate typical daytime flows for clear sky days with minimal synoptic forcing. The circular arrows illustrate the wind direction changes during transition.

West Slope
The site was instrumented with two main 28 m towers (WS1 and WS2) with sonic anemometers at: 0.5, 2, 5, 10, 20, and 26 m. WS2 also measured the full energy budget. A 10 m tower SAMS31 measured mean meteorological variables.

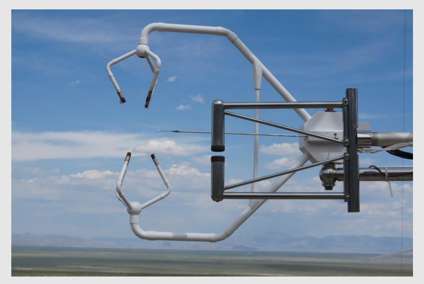
East Slope
The East Slope was the most highly instrumented region of the campaign with 5 tall flux towers (greater than 20 m), 2 full energy balance stations, doppler lidars, distributed temperature sensing (DTS) system, and an array of small met stations (LEMS and PWIDS).

28 m WS2 tower on West Slope

Radiation instrumentation used on East Slope

One of three doppler lidars used during the experiment on the East Slope

20 m ES5 tower on East Slope



2 m CSAT3 sonic and KH2O hygrometer at ES5

PWID located along Granite Mt. Ride line

LEMS on the East Slope

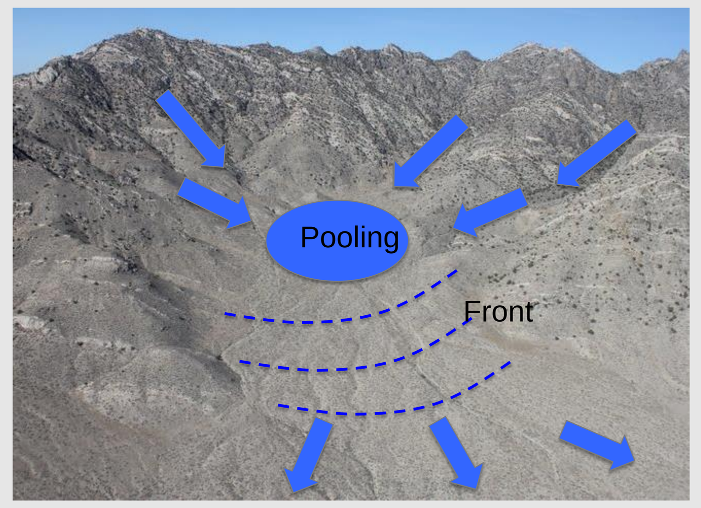
2.2km transect of DTS temperature measurements along the East Slope at 0.5m and 1m elevation (2m spatial resolution, 15s temporal resolution)

Evening Transition Results

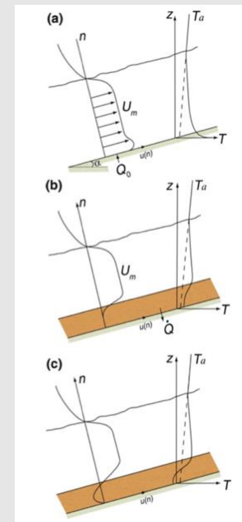
East Slope Transition Process

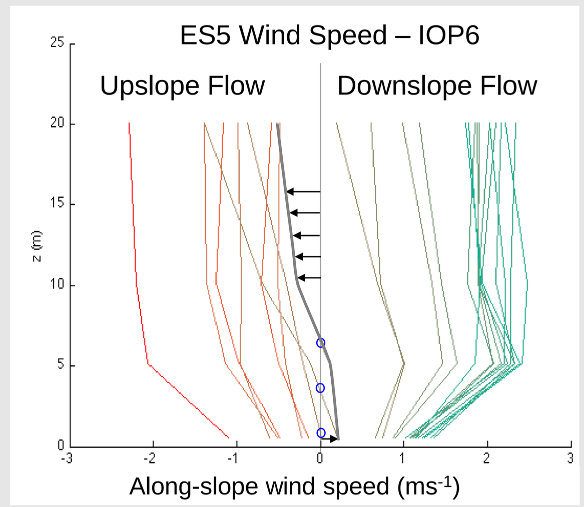
The East Slope of Granite Mt. has been thus far been analyzed in greater detail than the West Slope. During the Fall IOPs that have been analyzed, the evening transition (identified by wind direction changes) appears to fall into at least three categories: Non-local Front, Sliding-Slab transition and Synoptically perturbed.

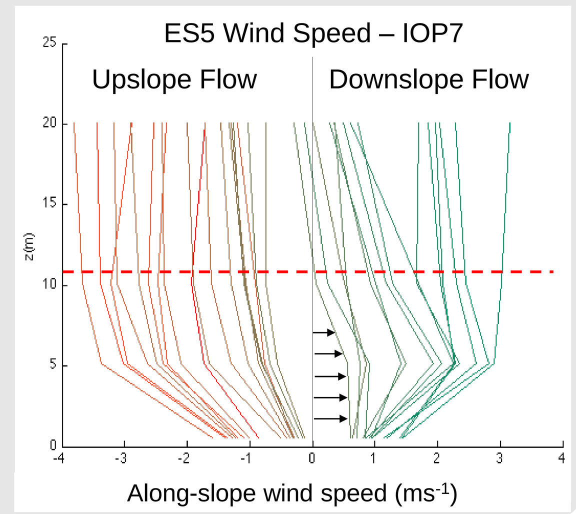
Non-local Front



Sliding-Slab[c]

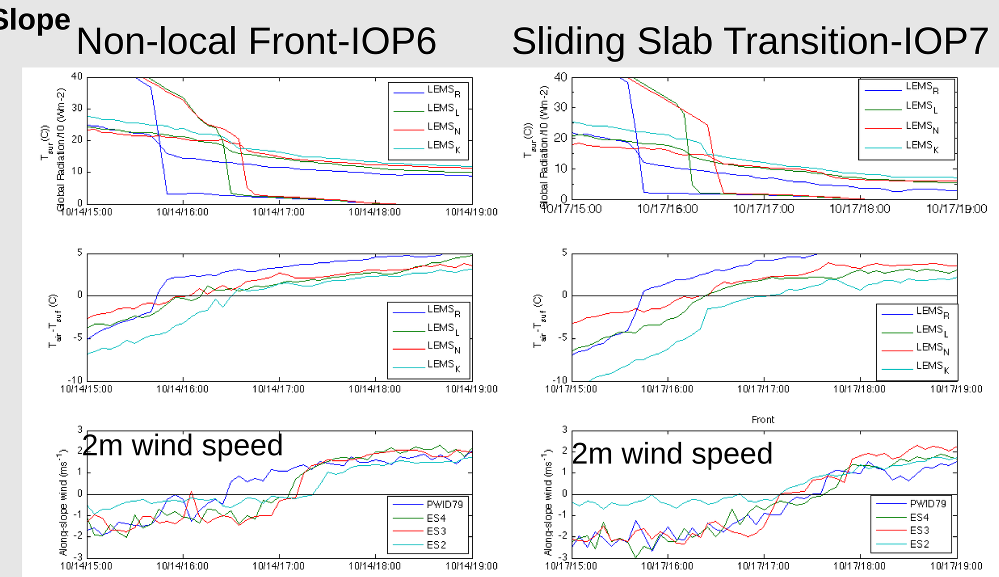




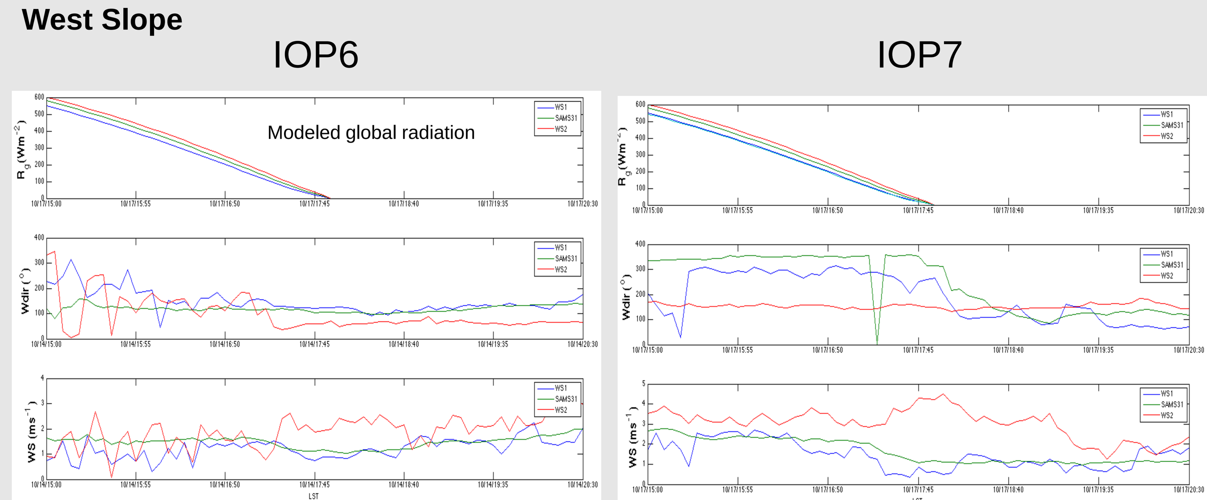


General East and West Slope Transition Characteristics

East Slope



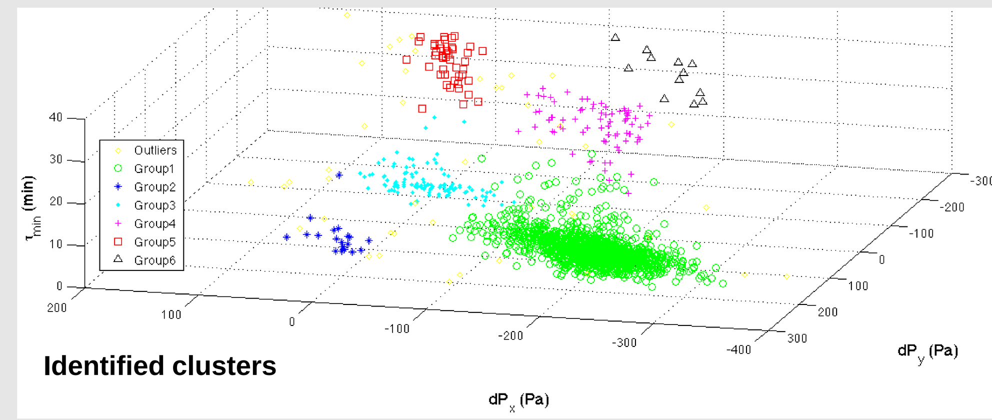
West Slope

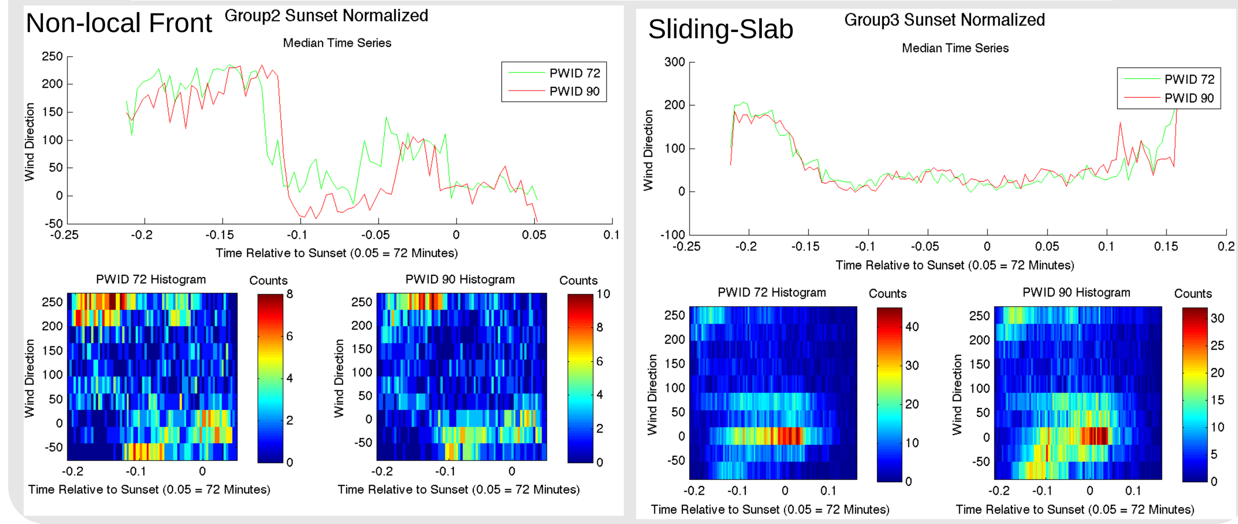


Note that modeled clear sky global radiation is presented for 10/17/2012 for both days.

Clustering Analysis Results

To better understand the links between various forcing mechanism leading to either the Non-local Front or Sliding-Slab transition formation, a statistical analysis was conducted using various clustering techniques. The techniques are designed to identify different patterns in data. Data for the analysis were used from the MATERHORN campaign as well as four additional years worth of data from PWIDS sensors that are permanently installed at the GMAST facility. DBSCAN[b] was used to separate flow regimes using various inputs. The most successful clustering occurred when using inputs of (i) large scale pressure gradient (dPx and dPy) and (ii) the time delay of the two-point velocity structure function minimum (t_{min}) on towers along the East Slope.





Summary Points

- Wind direction transition on the East and West Slope follow clockwise and counterclockwise rotation patterns consistent with Whiteman[c]
- East Slope evening transition is characterized by both Non-local Front and Sliding Slab flow mechanisms
- West Slope flow transition regimes are not as clearly identifiable
- The DBSCAN clustering algorithm appears to be promising in identifying and grouping flow regimes on the East Slope

Acknowledgements

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[c]Whiteman, CD, 2000: Mountain Meteorology: Fundamentals and Applications. No. PNNL-12063. Pacific Northwest National Laboratory, Richland, WA (US).

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