Wind and turbulence structure in the boundary layer around an isolated mountain: airborne measurements during the MATERHORN field study

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http://www3.nd.edu/~dynamics/materhorn/index.php

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Motivation for airborne measurements

- To capture interaction between mesoscale and synoptic scale flows, wind measurements at high spatial resolution over horizontal distances of at least a few tens of km are required.

-> *airborne Doppler wind lidar measurements* can provide these measurements
Twin Otter Doppler Wind Lidar

TODWL (Twin Otter Doppler Wind Lidar) has been operated since 2002 by CIRPAS (Center for Interdisciplinary Remotely Piloted Aircraft Studies), a part of the Naval Postgraduate School, Monterey, CA.

2 µm coherent detection
side door mounted scanner
Range: 0.3 – 21 km depending upon aerosols
Accuracy: < 0.10 m/s in three components

conical scans below the aircraft
azimuth angle steps of 30°
TODWL data products

- Downward conical scans (12 point step stare)
  - Off-nadir angle of 20 -30 degrees
  - 20 -25 seconds for full 360 scan (~ 1 - 1.2 km)
  - U,V,W with 50 m vertical resolution
  - SNR (aerosols)

- Downward stare (nadir samples)
  - 5 seconds between conical scans
  - W with 50 m vertical resolution
  - SNR (aerosols)

- Forward stare

Additional Twin Otter Measurements, e.g. *in situ* fluxes, meteorological variables, surface temperature, particle counts
Objectives of MATERHORN- airborne measurements

Provide MATERHORN with high resolution wind data at the mesoscale that provide the background information needed to interpret the many surface-based remote sensing and *in-situ* observations collected around Granite Mountain.

Investigate spatial PBL structure and interaction of boundary layer flows with Granite Mountain.

Investigate the benefit of assimilating airborne lidar data in forecasting models and its impact on mesoscale predictability.

Evaluate Eddy Diffusivity Mass Flux parameterization over land in the presence of organized structures (convective rolls) – separating vertical fluxes of heat and mass by turbulence and organized sub-meso/meso-scale structures.
- Twin Otter in Utah between 5 October and 18 October, 2012, participated in 4 IOPs
- Missions lasted ~ 4 hours
- 7 research flights yielded ~3000 wind profiles between surface and 3400 m MSL

Rainfall event
Example Flight pattern 09 October 2012

Afternoon flight (RF03)

• Aircraft was based out of Salt Lake City ~ 20 minute to Granite Mountain
• Climb to ~ 4 km MSL (~1500 m above Granite Peak)
• North-south and east west legs of ~20-30 km
• Low level flights
Expected surface flow patterns

Mesoscale nighttime down-valley and daytime up-valley flows

Slope flows

Gap flows
Example 09 October 2012, afternoon

Surface observations

Radiosonde observations

1700 LT

Playa site = blue
Sagebrush site = green

~ 1 km
Aerosol structure and PBL height 09 October

09 October 2012
Spatio-temoral variability in the ABL depths

Distance: ~ 1 km
Northerly ‘mesoscale’ upvalley flows more pronounced and deeper over Playa
Spatial structure in large scale flows aloft. Flows above 2500 m much stronger over Playa
wind profiles for E-W legs 09 October

Flow around Granite Mountain and channeling through southern gap
wind pattern 09 October 2012

Upper-level flow

Near-surface flow

OTHER AFTERNOON EXAMPLES?
Upper-level flow

1006 3000 m

Near-surface flow

1006 1750 m

wind pattern 06 Oct 2012

wind pattern 17 Oct 2012
This situation occurred 2 days after rainfall event!
Preliminary example of comparison with Very Large Eddy Simulation (VLES), now operational for Dugway Proving Ground

Courtesy of Yubao Liu, NCAR
Summary

- 7 successful research flights were conducted during MATERHORN-X collecting data during 4 afternoons and 3 mornings in quiescent to moderate synoptic conditions
- Started an investigation of spatio-temporal variability of PBL structure and flow interaction with Granite Mountain
- Typical PBL depth around 1000 m AGL corresponding to height of Granite Peak – large spatial variability
- recurring pattern of northerly thermally driven upvalley flows flowing around Granite mountain with channeling through gap. One afternoon flight after a rainfall event deviates from this pattern -> importance of surface forcing appears obvious
- Very Large Eddy Simulation modeling at 300 m horizontal resolution – shows promising results

Outlook:
vertical velocities,
in-situ aircraft measurement, (fluxes!),
organized convective structures/thermal and interaction with flows,
assimilation of wind data from airborne Doppler lidar data in WRF,
LES simulation at 30-m planned for select cases etc.

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Flow around/over Granite Mountain: Morning Transition

D6 (DX=33m)
W (m/s)

Animation from
14:50 – 17:50 UTC
4 May 2012;
Every 2 minutes

TWR 8,16,32m Wind

Current Time: 445
Current bottom_top stag: 2

Frame 1 in File wrfout_d06_2012-05-04_14:50:00

Courtesy of Yubao Liu, NCAR
Multi-scale flows and boundary layer structure during the morning transition period: a case study from the MATERHORN field study


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INTRODUCTION

We studied the atmospheric boundary layer structure and dynamics during the morning transition period of one intensive observational period of the Mountain Terrain Atmospheric Modeling and Observations (MATERHORN) field experiment at Dupuyt Provings Ground (an army test range in Utah, USA) in Fall 2012.

We use high-resolution data from an airborne Doppler lidar, three ground-based Doppler lidars, in-situ measurements from an unmanned aerial vehicle, and high resolution numerical simulations.

DATA

Twin Otter Doppler Wind Lidar (TODWL)

Obtaining Wind Data

Since the 1990s, DWR has used a continuously operating mesoscale radar (DMWR) developed by the NOAA Research Applications Laboratory (RAL). The system is based on the DWR. It is driven by airborne radar, uses a grid spacing of 0.1 km in its innermost domain, and provides wind analyses and forecasts at hourly intervals. Since May 2012, the system is also running operationally in a very large-scale simulation mode with a grid spacing of 0.3 km in the innermost domain.

MATERHORN

The MATERHORN field study was conducted at the US Army, Dupuyt Provings Ground, from 20 September through 21 October, 2012.

The field study consisted of ten 24-hour long IOPs.

5: Base

6: 24-hour-long IOPs (0600LT-1200LT, 1200LT-1800LT, 1800LT-0000LT)

2: Precipitation Events

In this poster, we are focusing on the morning transition period of IOP 06 on 10 October 2012, which was classified as a quiescent nighttime IOP.

RESULTS

East slope where intensive ground-based observations were made, including those from DataHawk, and ground-based Doppler Lidars.

Flight pattern on 10 October 2012 (left), and the observed (model) and simulated wind patterns (right). The flights were generally from the south-southeast at about 5 m/s. The southwesterly flow acceleration through the gap is evident in both the observed and simulated wind field.

DataHawk observations (left) show evidence of an overturning event at about 300 m AGL.

Airborne Doppler lidar observations (right) show increased upward vertical velocities at this location.

In this poster, we are focusing on the morning transition period of IOP 06 on 10 October 2012, which was classified as a quiescent nighttime IOP.

CONCLUSIONS

Observations from simultaneous deployment of multiple ground-based and airborne in situ and remote sensors, and from simulations at very high resolution model a coherent picture of the flow pattern and boundary layer. The morning transition period in the MATERHORN field experiment. We are performing a detailed analysis of the model simulations to understand the processes underlying the 'overturning' event and the spatio-temporal variability in convective boundary layer height.

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