Observations in complex terrain
(and some other neat stuff)

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+ collaborators:

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Jason Knievel/Yubao Liu (National Center for Atmospheric Research)
Stefano Serafin (University of Vienna)
Dale Lawrence/Ben Balsley (University of Colorado)
Jim Doyle (Naval Research Laboratory)
Hoch (UU), Hocut(UND), Wang (ARL)
and more

MATERHORN meeting, 06 September 2013
University of Notre Dame
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 aircraft

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.

Dave Emmitt is TODWL PI

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 ( $\Delta X \sim 1 - 1.2$ 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 (for prospecting turbulence structures)

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

- 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
- Low level flights during each flight
- Co-funded by ONR and ARO
MATERHORN FIELD SITE

Looking north
Granite Mountain

Looking south
Dugway Range
Sapphire Mountain
Granite Mountain

Looking northeast
Granite Mountain

Sapphire Mountain
Research topics

• **Spatiotemporal evolution and variability of (thermo-) dynamic structure and depth of the atmospheric boundary layer** (this talk and Sandip Pal’s talk in afternoon)

• **Retrieving wind and turbulence data from airborne Doppler lidar and airborne in-situ data** (in collaboration with Dave Emmitt, Simpson Weather Associates)

• **Comparison of ground-based and airborne Doppler lidar during an overturning event observed by the DATAHAWK unmanned aerial vehicle** (in collaboration with Lawrence, Hoch, Hocut, and Wang)

• **Assimilation of airborne Doppler lidar data in numerical weather prediction models** (in collaboration with Jason Knievel and Yubao Liu, National Center for Atmospheric Research)

• **Separation of the atmospheric boundary layer and the formation of atmospheric rotors** (in collaboration with Stefano Serafin, University of Vienna)

• **Evaluation of Eddy Diffusivity Mass Flux parameterization over land in COAMPS** (in collaboration with Jim Doyle, Naval Research Laboratory)
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
Example 09 October 2012, afternoon

1700 LT

Surface observations

Radiosonde observations
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

Near-surface flow

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.
some other neat stuff
‘overturning event’ from DataHawk observations

October 10, ~ 11 AM LT

DataHawk observations show evidence of an ‘overturning’ event at about 500 m AGL (Ben Balsley/Dale Lawrence).
Airborne Doppler lidar observations show increased upward vertical velocities at this location.

Ground-based Doppler lidar observations also show increased upward vertical velocities at this location. Contour lines of vertical velocity are drawn every 0.1 m/s with red upward and blue downward motions.

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

Locations with wind profiles from TODWL on 10/10
Development of an autonomous tether-powered hexa-copter for atmospheric profiling

UVA engineering students
Work by collaborator Stefano Serafin (University of Vienna)

**Research interest:** Interaction between dynamically forced flows and the BL. Example: wave-induced BL separation.

**Question:** Is wave-induced BLS a likely event in the lee of Granite Peak?

**Tool:** Operational 1.1-km WRF runs (4DWX) from NCAR-RAL.

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Are 4DWX simulations good enough, in a climatological sense?

**One example:** station 31, west of Granite Peak
• BLS: strong gradients of $U$, $p$ and $T$. Where does this happen more often?

• The intensity of $U$, $p$ and $T$ gradients can be used to identify BLS events. E.g.:

• A typical BLS scenario: S flow with LLJ and strong veering in the BL (SE to SW).
Summary

7 successful research fights were conducted during MATERHORN-X collecting data during 4 afternoons and 3 mornings in quiescent to moderate synoptic conditions.

-Airborne Doppler wind lidar data show that northerly topographically driven winds are diverted around Granite mountain with channeling and flow acceleration through the southern gap.

-Very Large Eddy Simulation modeling at 300 m horizontal resolution – shows promising results.

-an ‘overturning’ event was documented with the DATAHAWK UAS in the boundary layer over the eastern slope of Granite Mountain and supported by vertical velocity data from ground-based and airborne Doppler lidar data.

-Preferential locations for boundary layer separation in the lee of DPG's Granite Peak were pinpointed and the typical atmospheric conditions responsible for these have been identified using 4DWX.
Upcoming Conference Presentations (AGU 2013 and AMS 2014):


• Pal, S., S.F.J. De Wekker, and G.D. Emmitt, 2013 Investigation of the spatio-temporal variability of atmospheric boundary layer depths over mountainous terrain observed with a suite of ground-based and airborne instruments during the MATERHORN field experiment.

• Sghiatti, M.D., S. Pal, G.D. Emmitt, and S.F.J. De Wekker, 2014: Turbulence structure in the daytime boundary layer around an isolated mountain from in-situ airborne measurements

• Knievel, J.C., Y. Liu, S.F.J. De Wekker, J. Pace, W.Y.Y. Cheng, Y. Liu, 2013: Simulation of meso-gamma-scale morning-transition flows at Granite Peak, Utah with NCAR’s WRF-based 4DWX and observations from the MATERHORN 2012 field campaign


• Godwin, G.D. Emmitt, S. Greco, S.F.J. De Wekker, 2013: Evaluating the accuracy and representativeness of Airborne Doppler Wind Lidar winds in complex terrain