(airborne) Observations in complex terrain

(and some other neat stuff)

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Mark Sghiatti (MS student, July 2013)

+ 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)

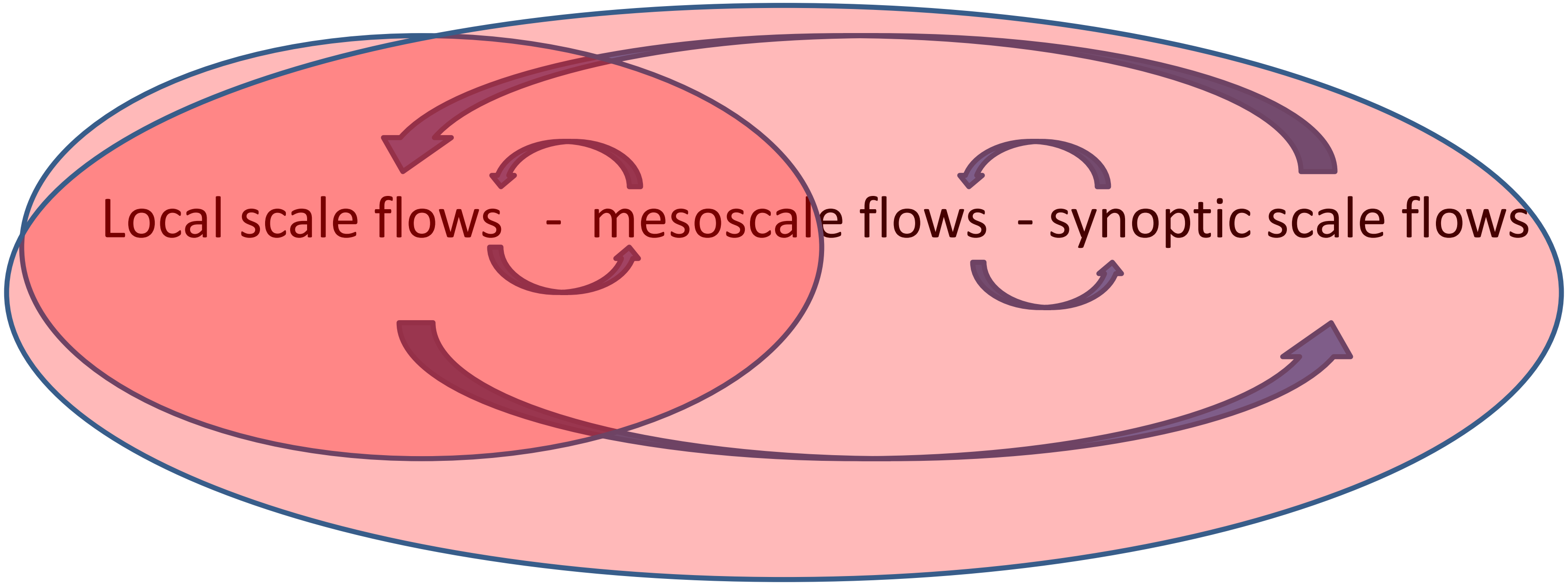
Hoch (UU), Hocut(UND), Wang (ARL)

and more

MATERHORN meeting , 06 September 2013
University of Notre Dame

Motivation for airborne measurements

Multi-scale flow interaction



- To capture interaction between mesoscale and synoptic scale flows, wind measurements at high spatial resolution over horizontals 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

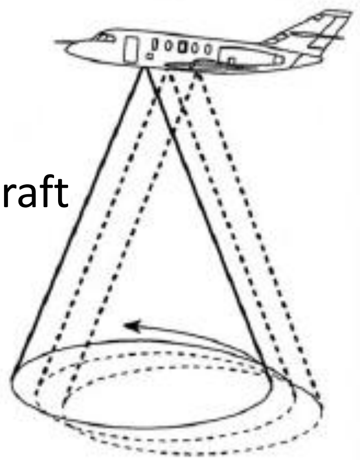
side door mounted scanner

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°



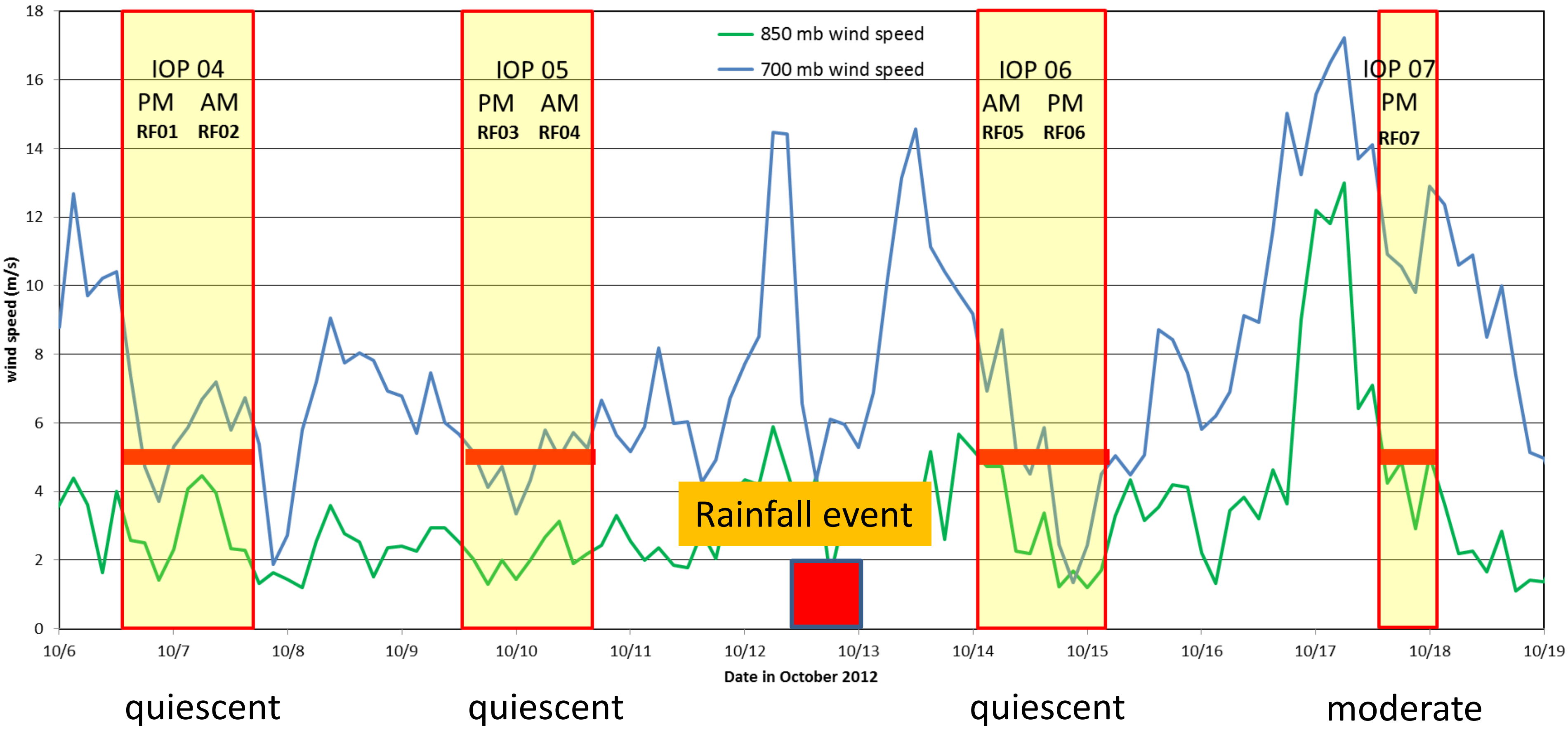
TODWL data products

- Downward conical scans (12 point step stare)
  - Off-nadir angle of 20 -30 degrees
  - 20 -25 seconds for full 360 scan (ΔX ~ 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)

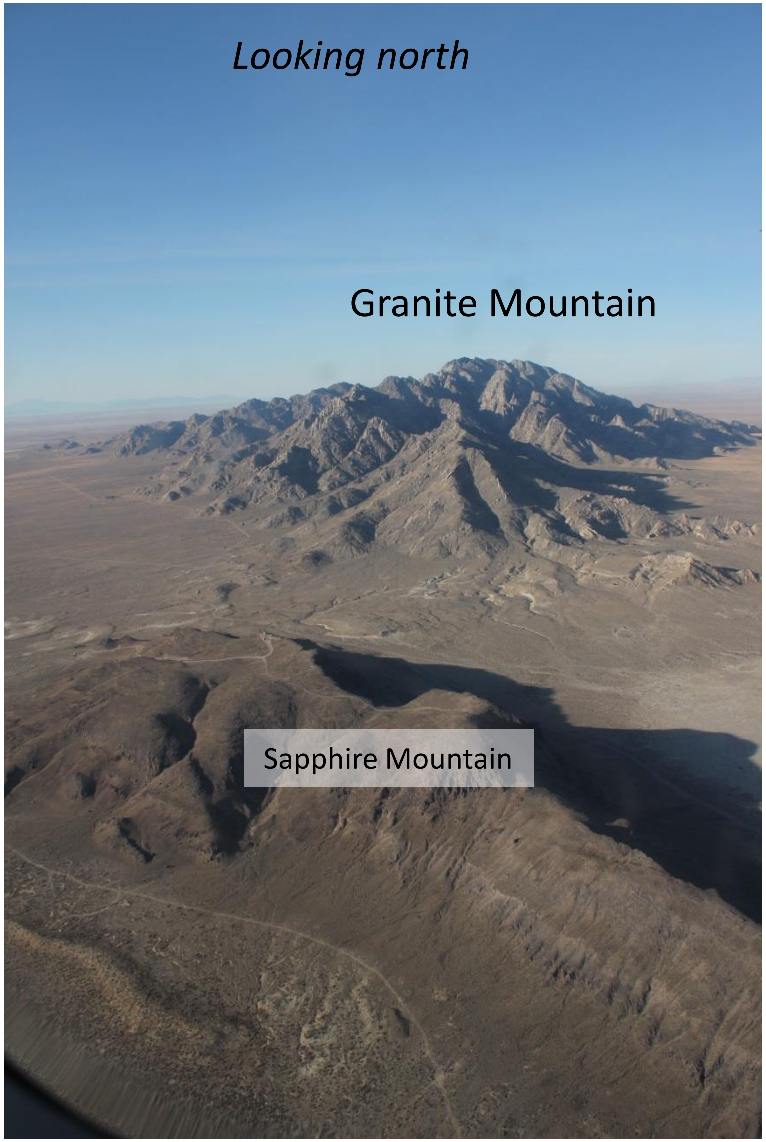
Additional Twin Otter Measurements, e.g. ***in situ*** fluxes, meteorological variables, surface temperature, particle counts

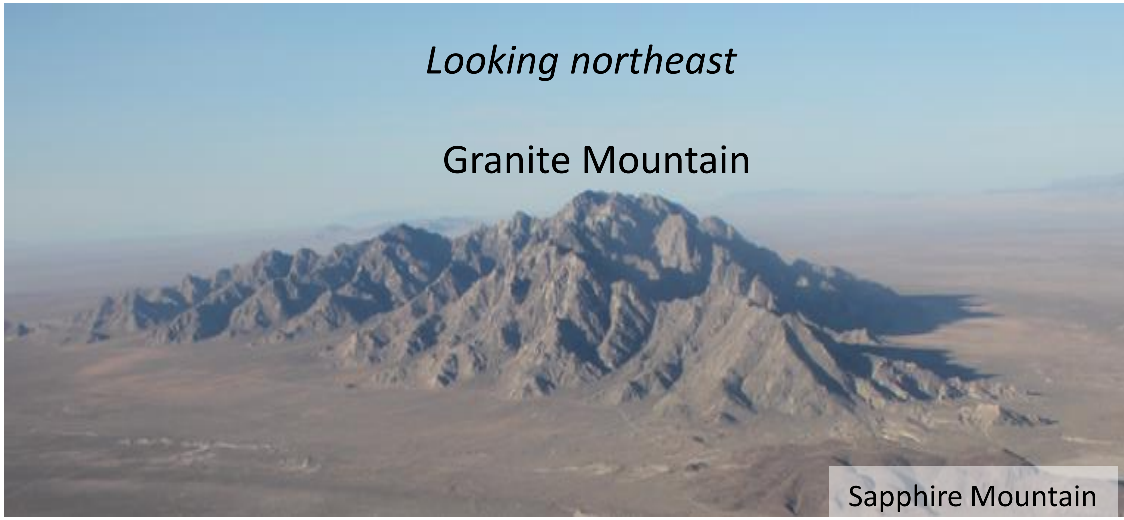
MATERHORN-X Fall - airborne

- 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





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)

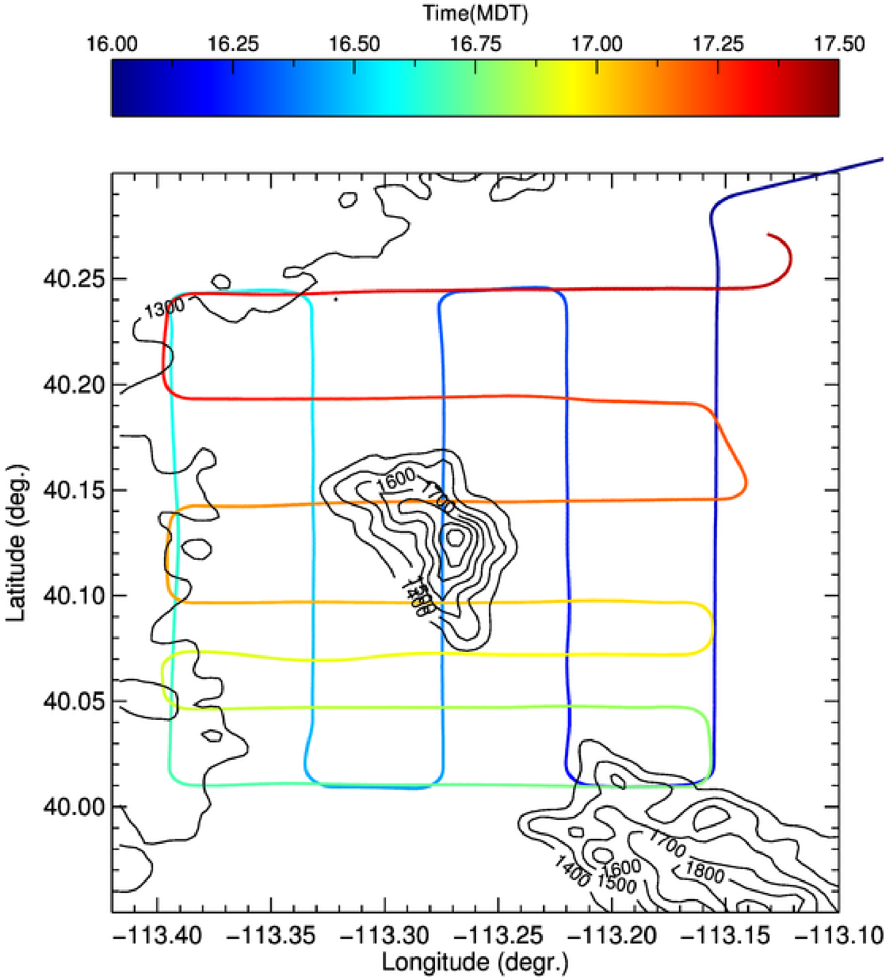
- Separation of the atmospheric boundary layer and the formation of atmospheric rotors (in collaboration with Stefano Serafin, University of Vienna)

- 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

- 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

Afternoon flight (RF03)

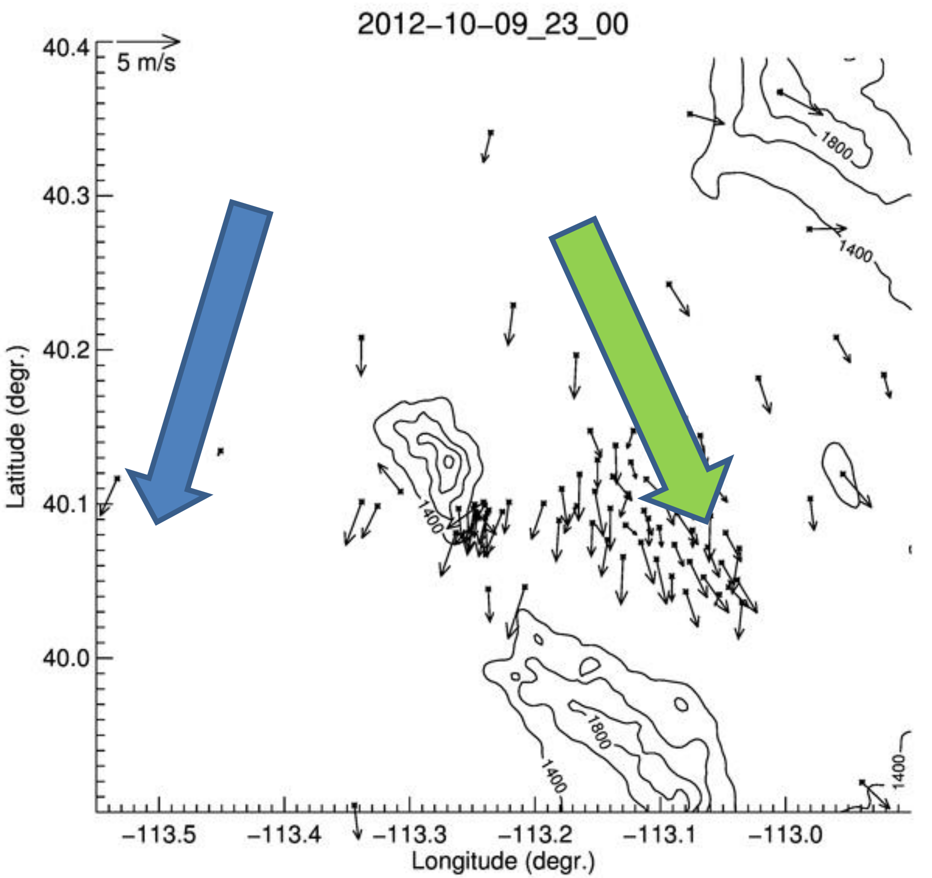


Example 09 October 2012, afternoon

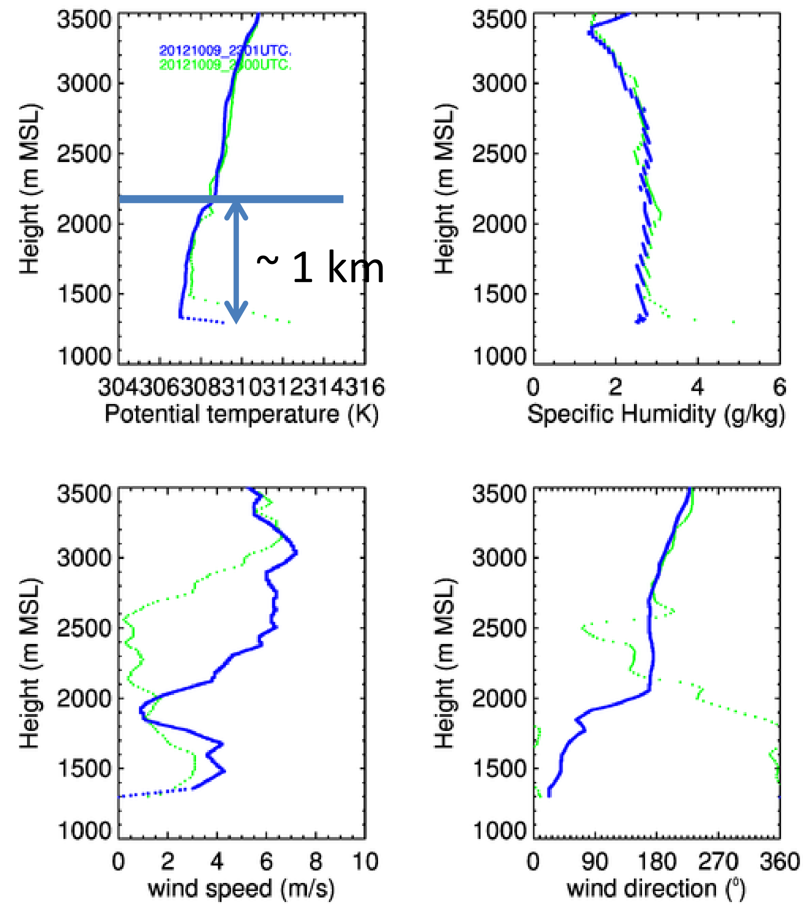
1700 LT

Playa site = blue

Sagebrush site = green

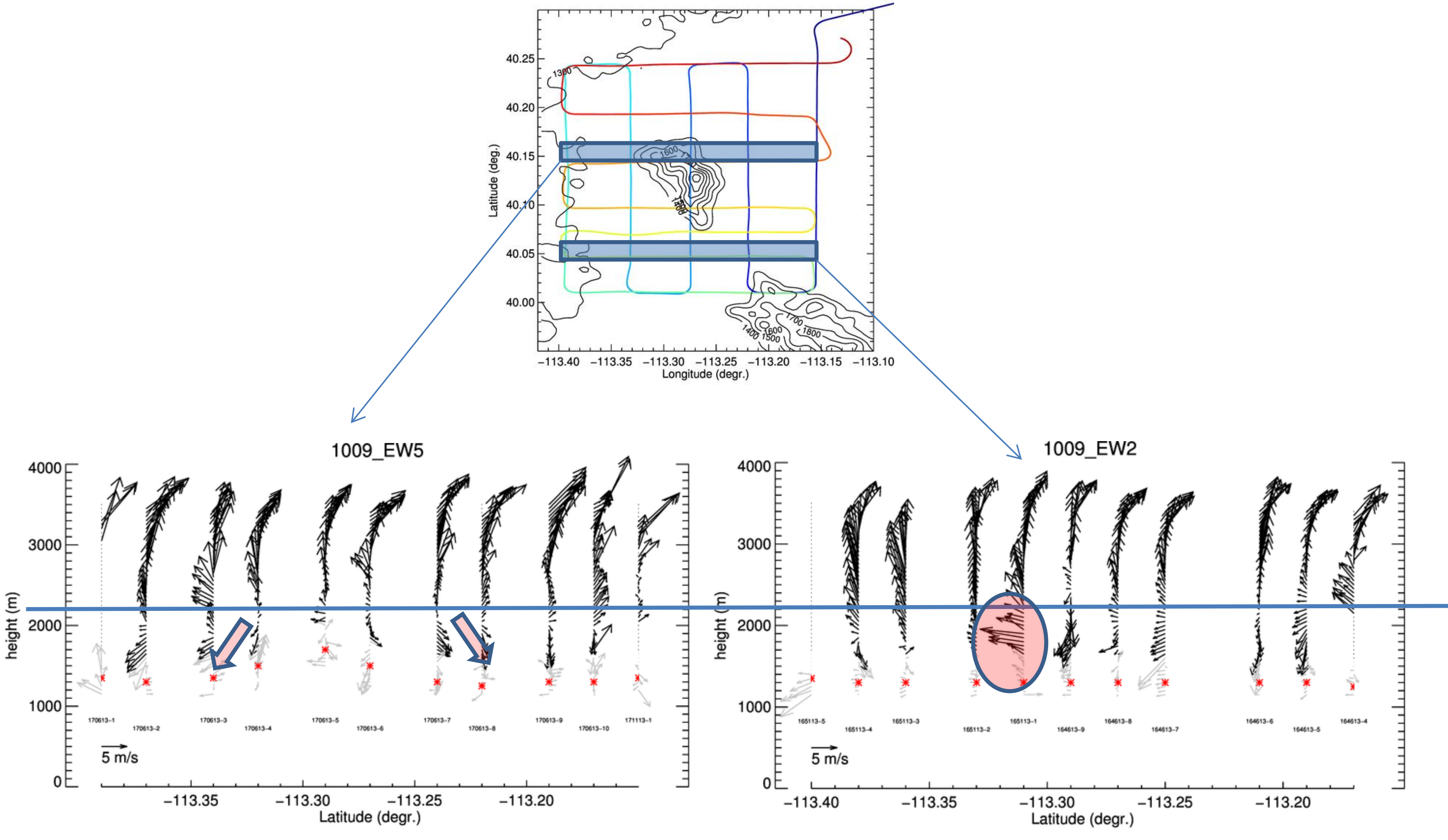


Surface observations



Radiosonde observations

wind profiles for E-W legs 09 October

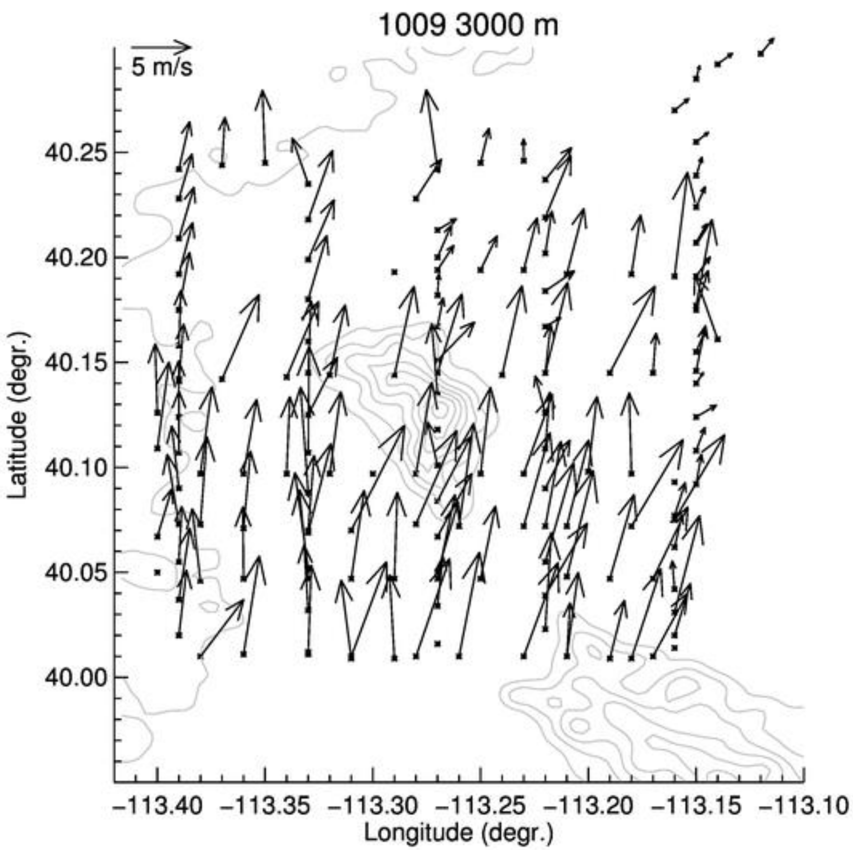


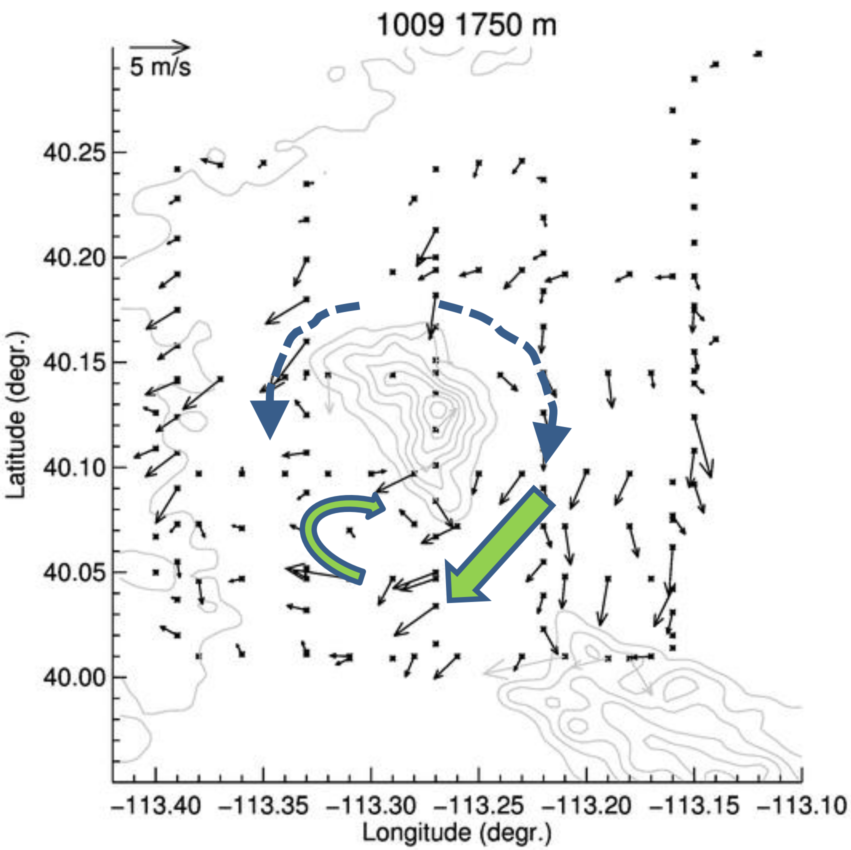
Flow around Granite Mountain and channeling through southern gap

wind pattern 09 October 2012

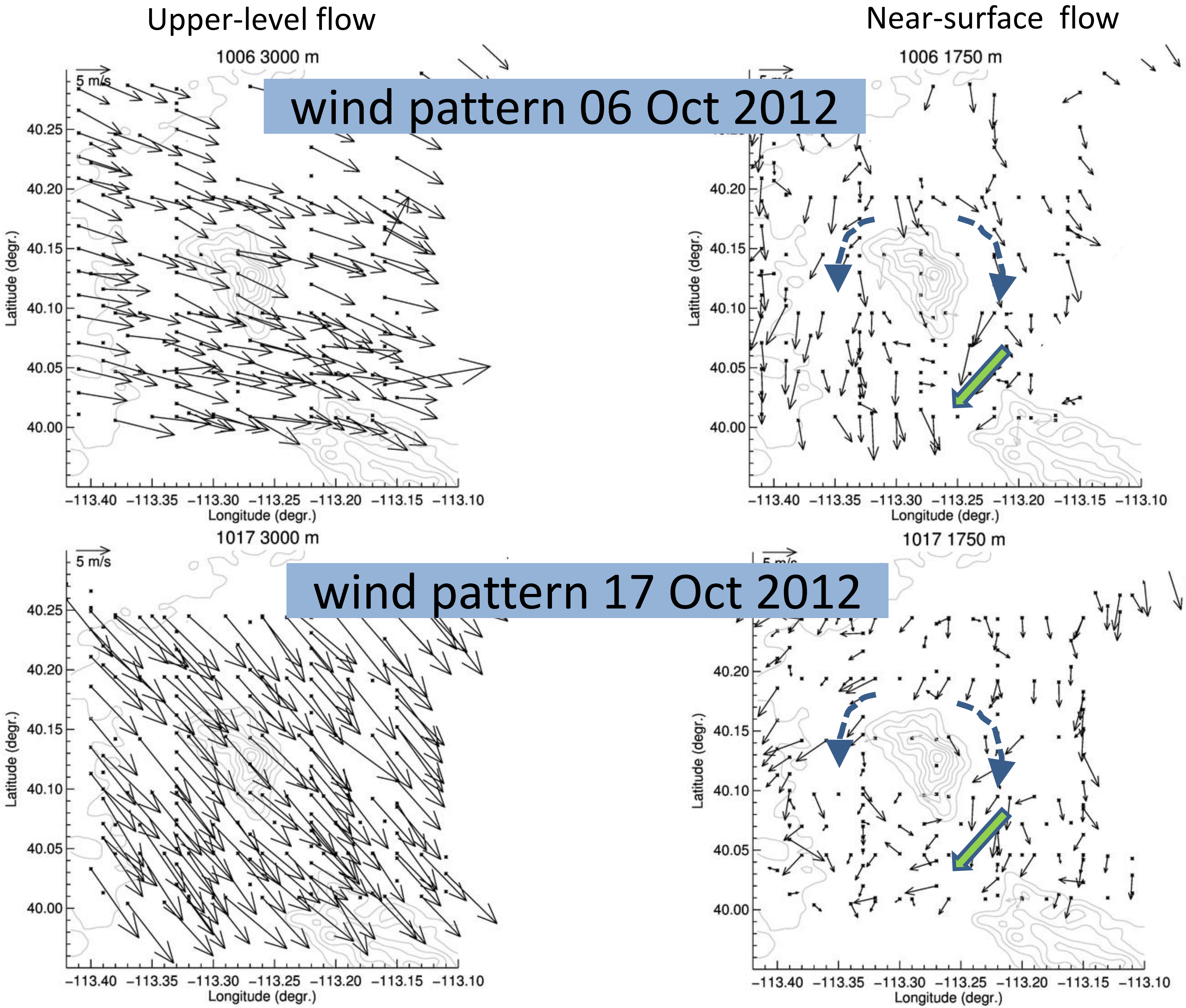
Upper-level flow

Near-surface flow



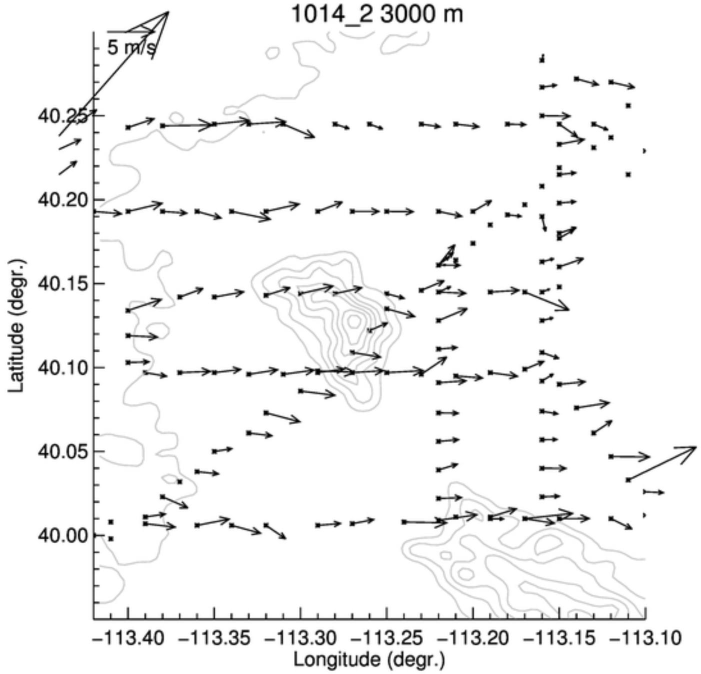


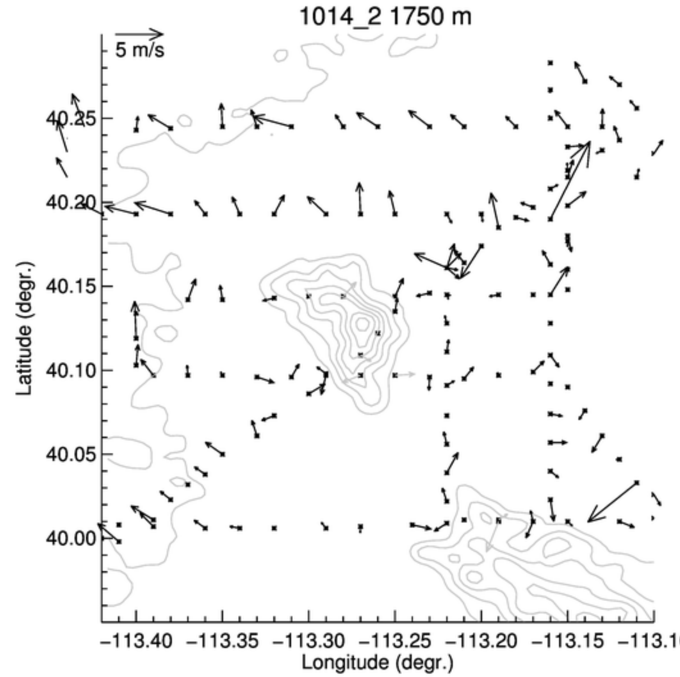
OTHER AFTERNOON EXAMPLES?



Upper-level flow
Near-surface flow
wind pattern 06 Oct 2012
wind pattern 17 Oct 2012
1006 3000 m
1006 1750 m
1017 3000 m
1017 1750 m
5 m/s
Latitude (degr.)
Longitude (degr.)
40.00
40.05
40.10
40.15
40.20
40.25
−113.40
−113.35
−113.30
−113.25
−113.20
−113.15
−113.10

wind pattern 14 Oct 2012

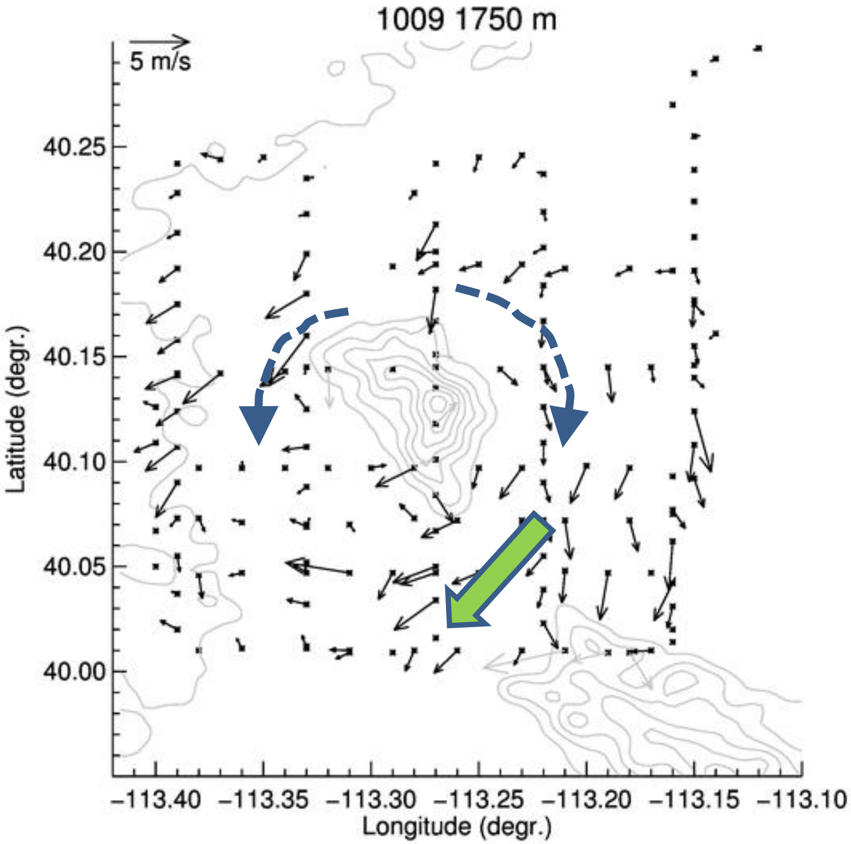


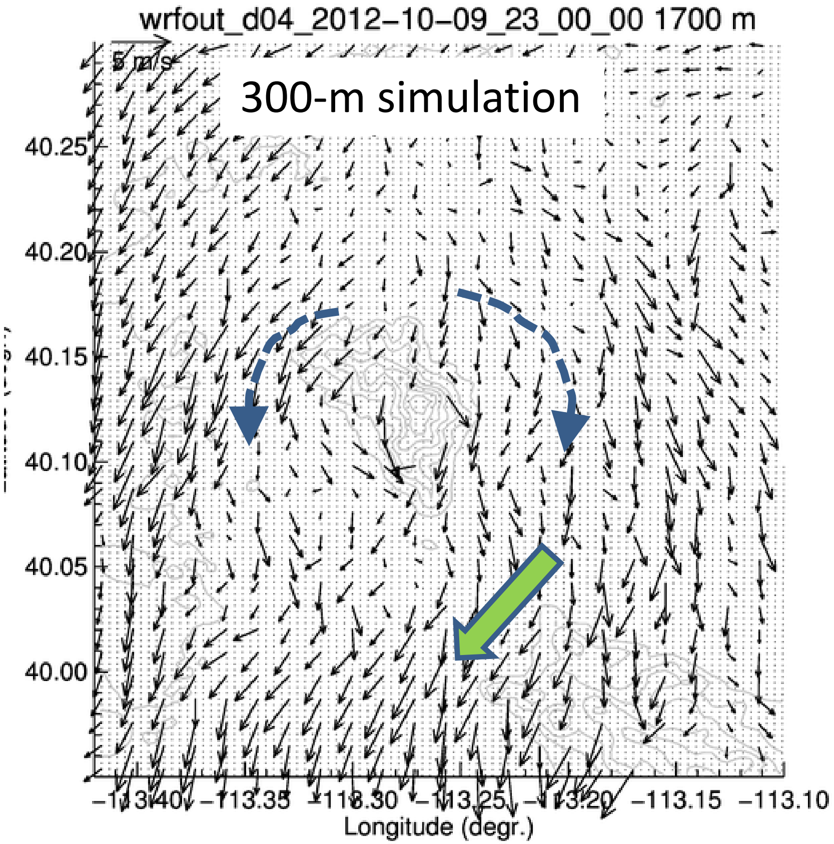


DOWNVALLEY/UNDETERMINED ?

This situation occurred 2 days after rainfall event!

Preliminary example of comparison with Very Large Eddy Simulation (VLES), now operational for Dugway Proving Ground



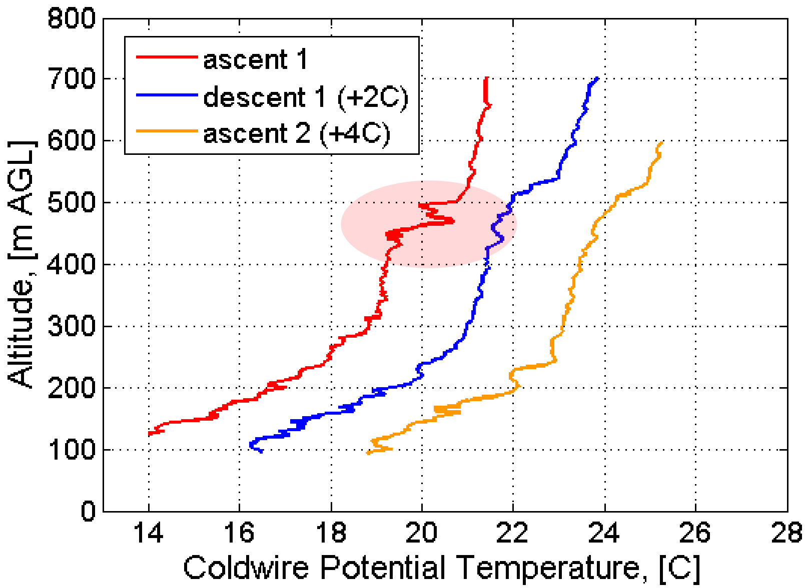


Courtesy of Yubao Liu, NCAR

some other neat stuff

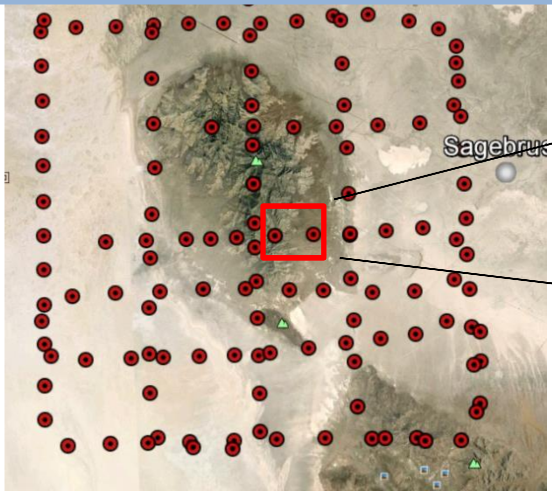
‘overturning event’ from DataHawk observations

October 10, ~ 11 AM LT



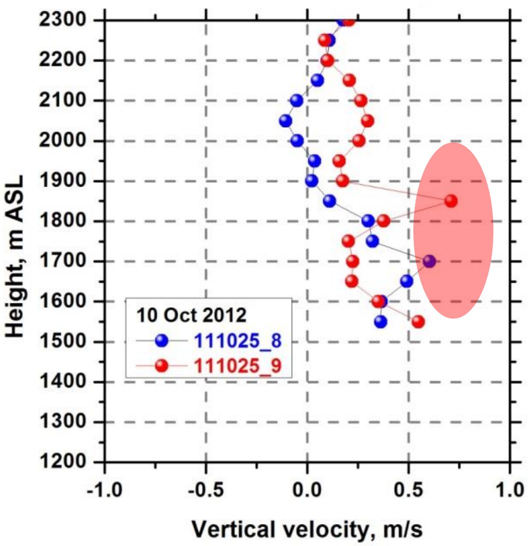
DataHawk observations show evidence of an ‘overturning’ event at about 500 m AGL (Ben Balsley/Dale Lawrence) .

Gound-based and airborne DWL profiles

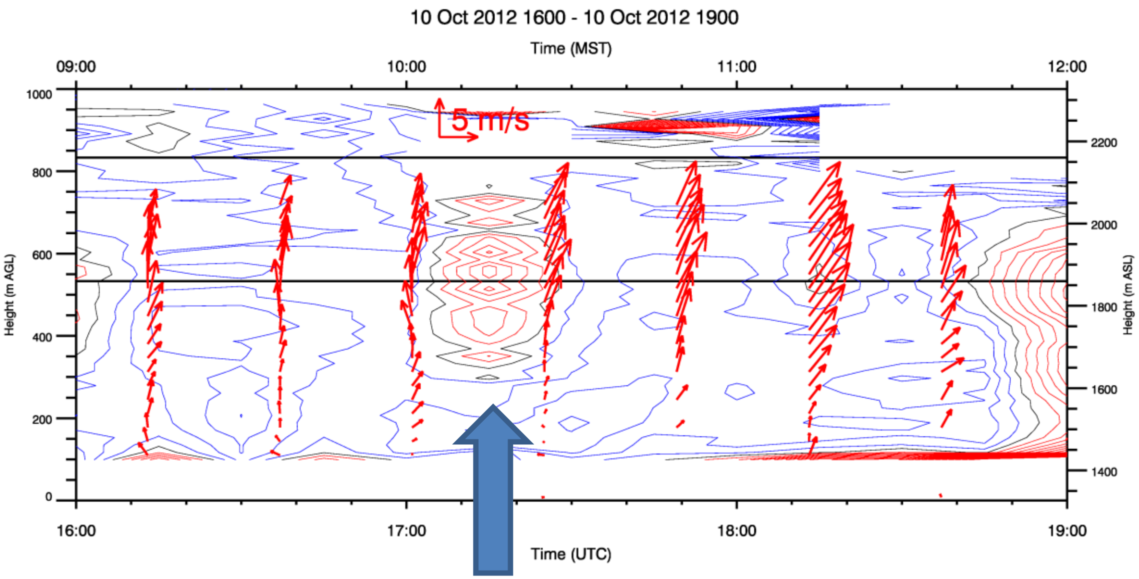


Locations with wind profiles from TODWL on 10/10

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



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

MATERHORN-T

Development of an autonomous tether-powered hexa-copter for atmospheric profiling

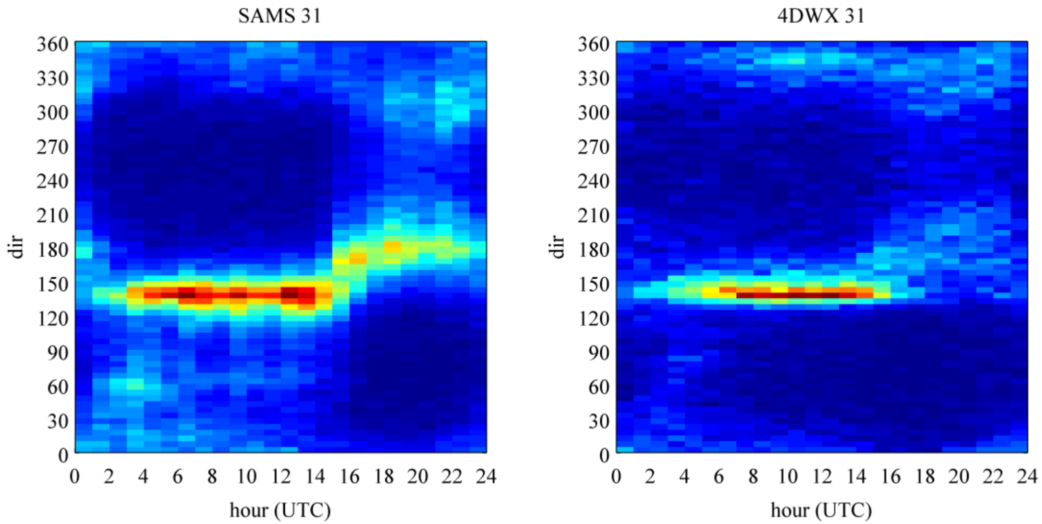
UVA engineering students

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.

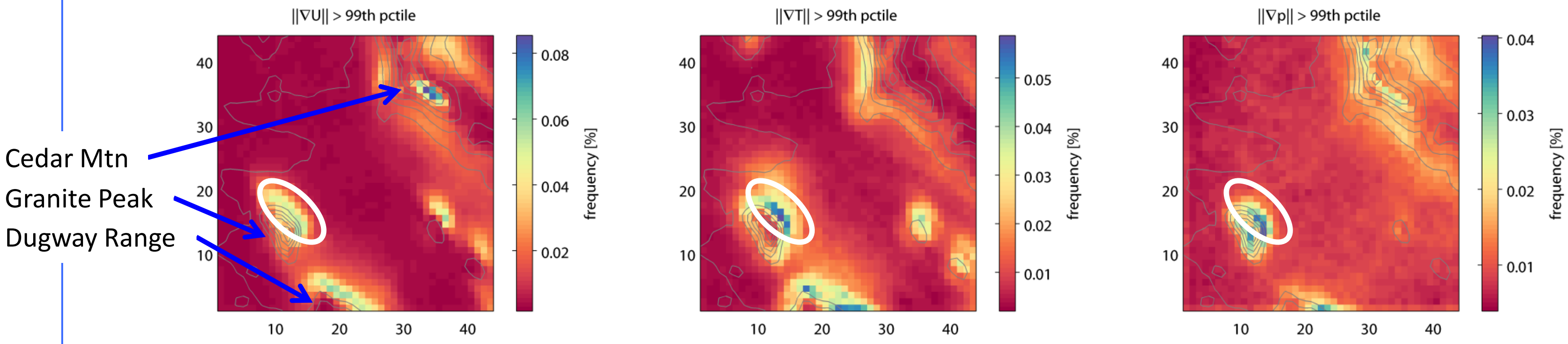


Are 4DWX simulations good enough, in a climatological sense?

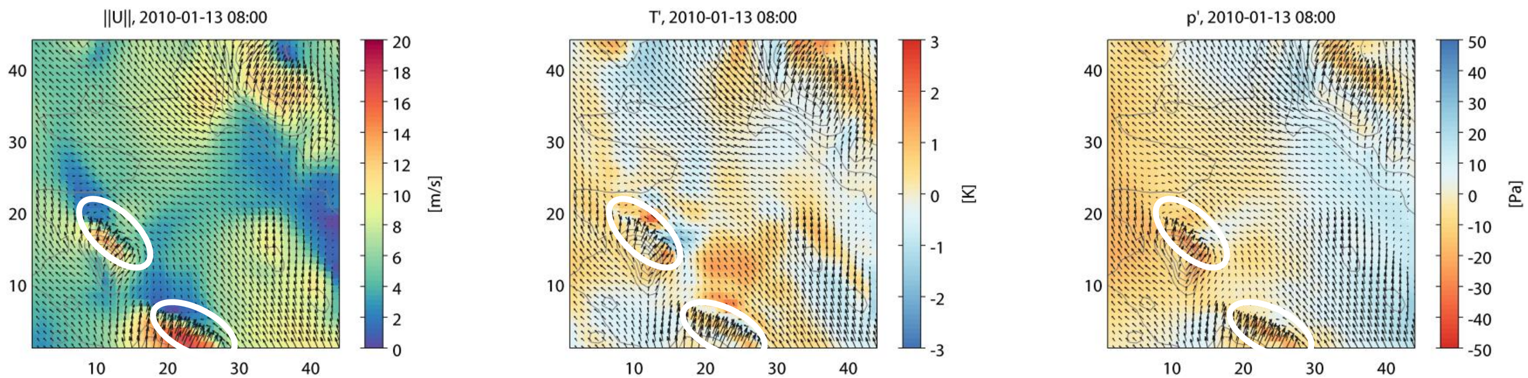
One example: station 31, west of Granite Peak

Work by collaborator Stefano Serafin (University of Vienna)

- 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):

- De Wekker, S.F.J., Y. Liu, J.C. Knievel, S. Pal, G.D. Emmitt, 2013: Observations and simulations of the wind structure in the boundary layer around an isolated mountain during the MATERHORN field experiment.

- 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

- Liu, Y., Y. Liu, J.C. Knievel, J. Pace, D. Zajic, S.F.J. De Wekker, 2013: LES simulation of synoptic, mechanic-forcing, and thermally-driven flow interaction of Granite Mountain, UT.

- Serafin, S., S.F.J. De Wekker, and J.C. Knievel, 2013: Boundary-Layer Phenomena in the Vicinity of an Isolated Mountain: A Climatography Based on an Operational High-Resolution Forecast System

- 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