A mesoscale model-based climatography of daytime atmospheric boundary layer heights over complex terrain

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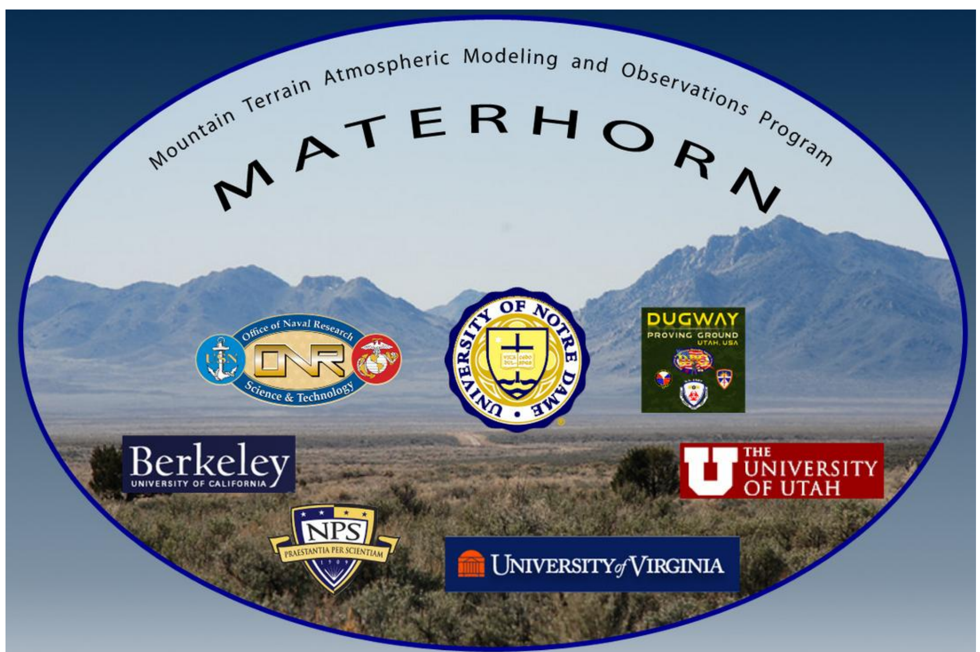
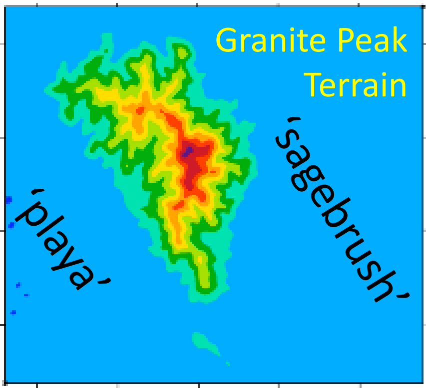


ICAM meeting, Innsbruck
1 September 2015

Introduction: Granite Peak

Granite Peak, an isolated mountain rising ~800 m above the surrounding terrain located in the Dugway Proving Ground, Utah. Investigation area of the MATERHORN-X field campaigns (fall 2012-spring 2013).



Introduction: questions

- What are typical ABL heights around Granite Mountain?
- What is the spatial variability of ABL heights and how is variability related to surface type differences and orography?
- How well does an operational forecast model at high resolution simulate the ABL heights?

Introduction: objectives

- Construct a multi-year climatography of daytime ABL heights around Granite Peak
- Evaluate simulated ABL heights with ABL heights observed during the MATERHORN project

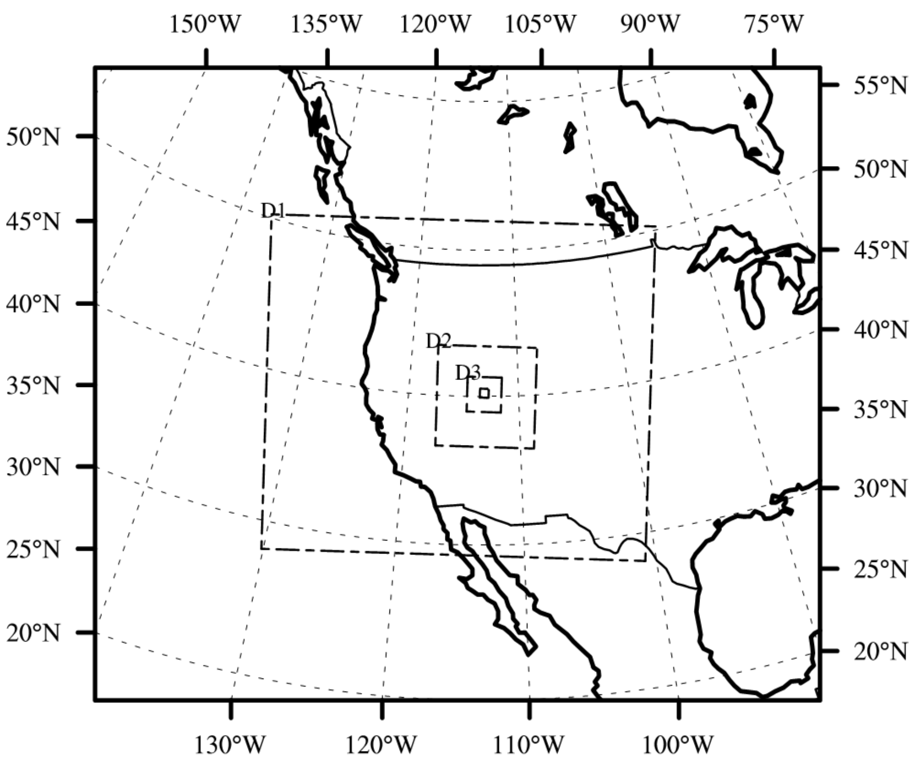
Methods

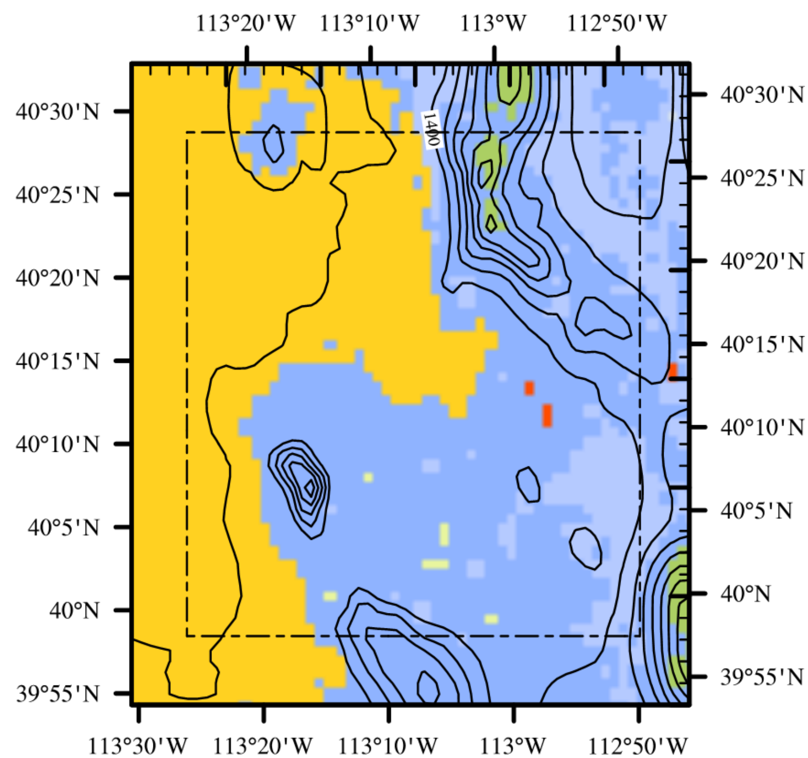
The NCAR-ATEC 4-Dimensional Weather (4DWX) Modeling System

- Based on the WRF modeling system, developed by the NCAR Research Applications Laboratory (Davis et al., 1999; Liu et al., 2008).
- Provides high-resolution weather analysis and forecasting at hourly intervals in eight forecast cycles every day
- Uses advanced data assimilation to optimally use all available observations
- 4 domains: 30, 10, 3.3, 1.1 km; 37 vertical levels
- YSU PBL scheme (PBL height from Ri based method), MO surface layer, NOAH LSM

Methods

Inner domain size of 60x60 grid points





Two years of 4DWX output (1 July 2012 to 30 June 2014) are used in this study.

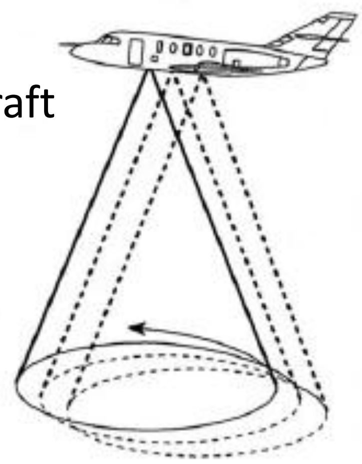
Methods

Twin Otter Doppler Wind Lidar (TODWL)

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

conical scans below the aircraft

azimuth angle steps of 30°

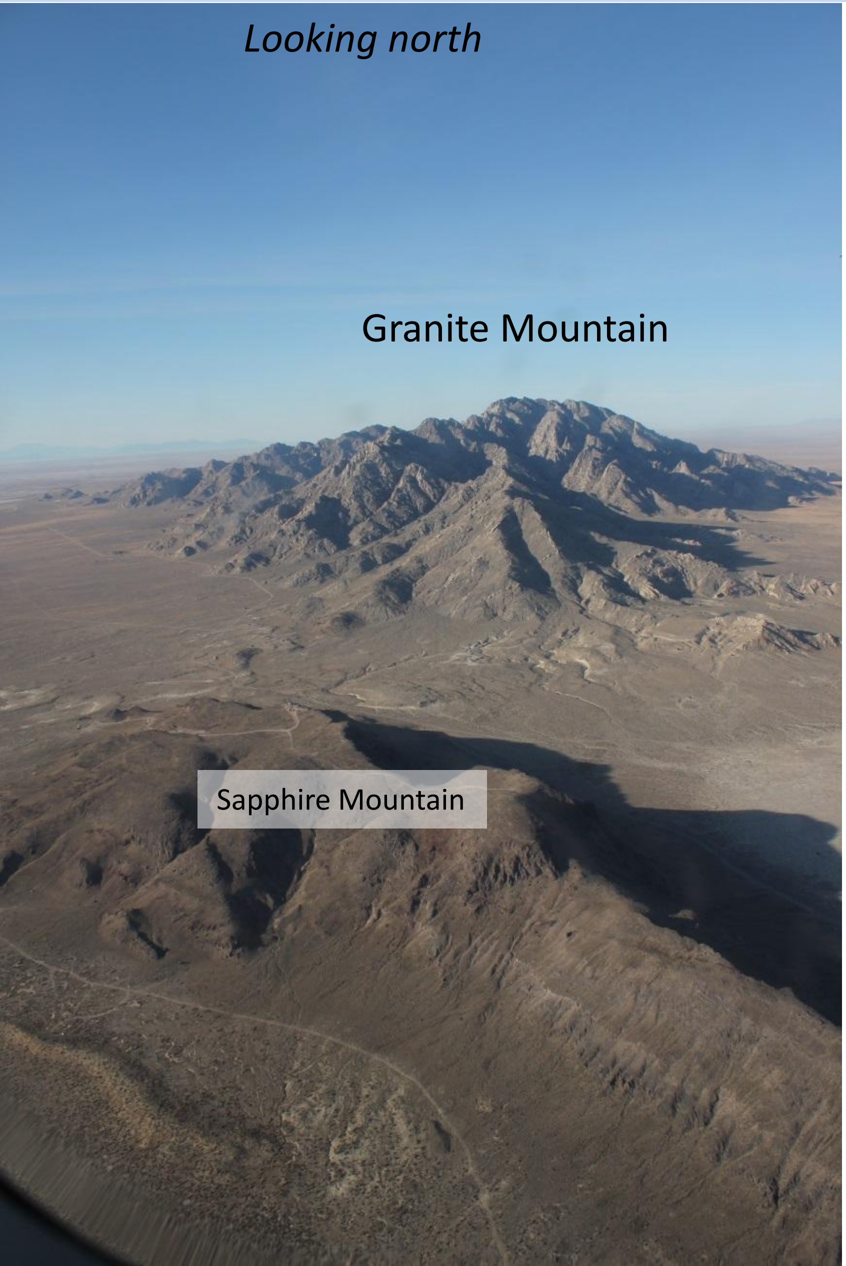


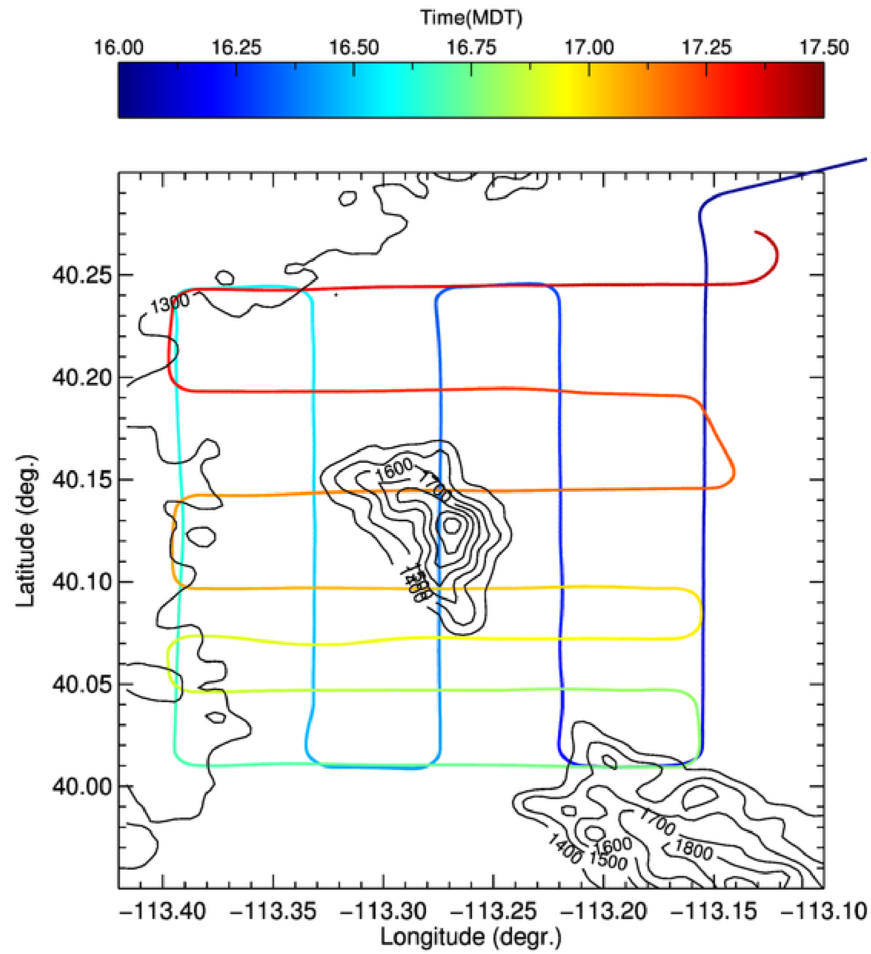
U,V,W with 50 m vertical resolution with ΔX ~ 1 - 1.5 km

SNR (aerosols): PBL height determination using wavelet analysis

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

MATERHORN field site

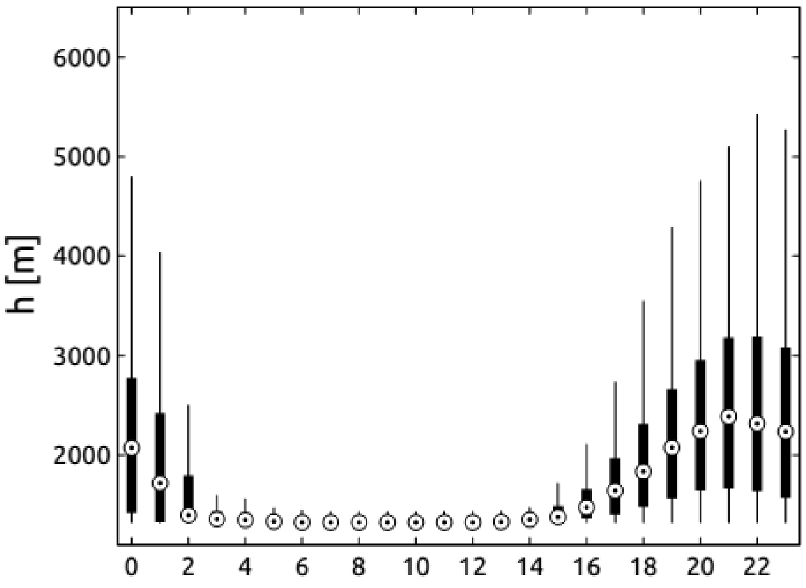




Typical TODWL flight pattern at 4 km MSL

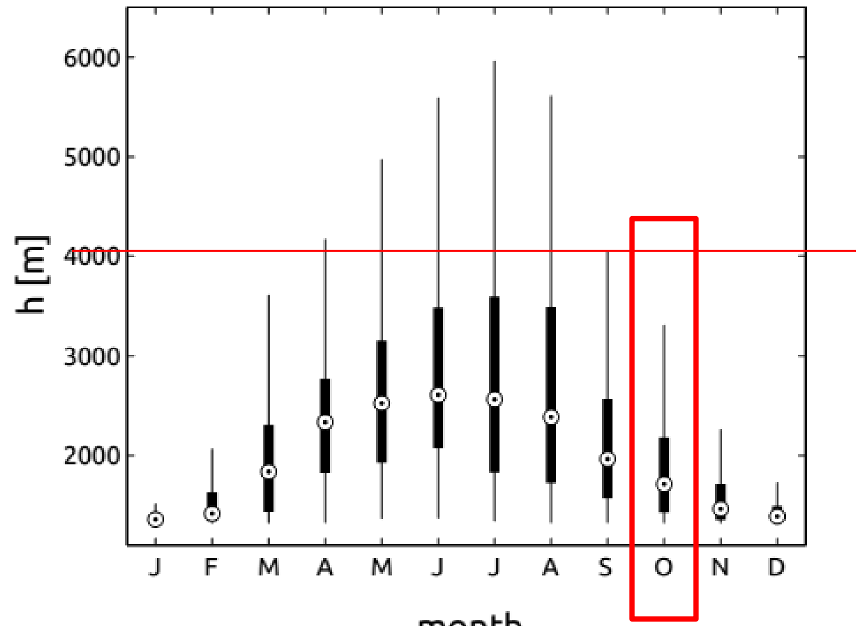
Climatography: typical ABL heights

Diurnal cycle



MDT=UTC-6

Seasonal cycle



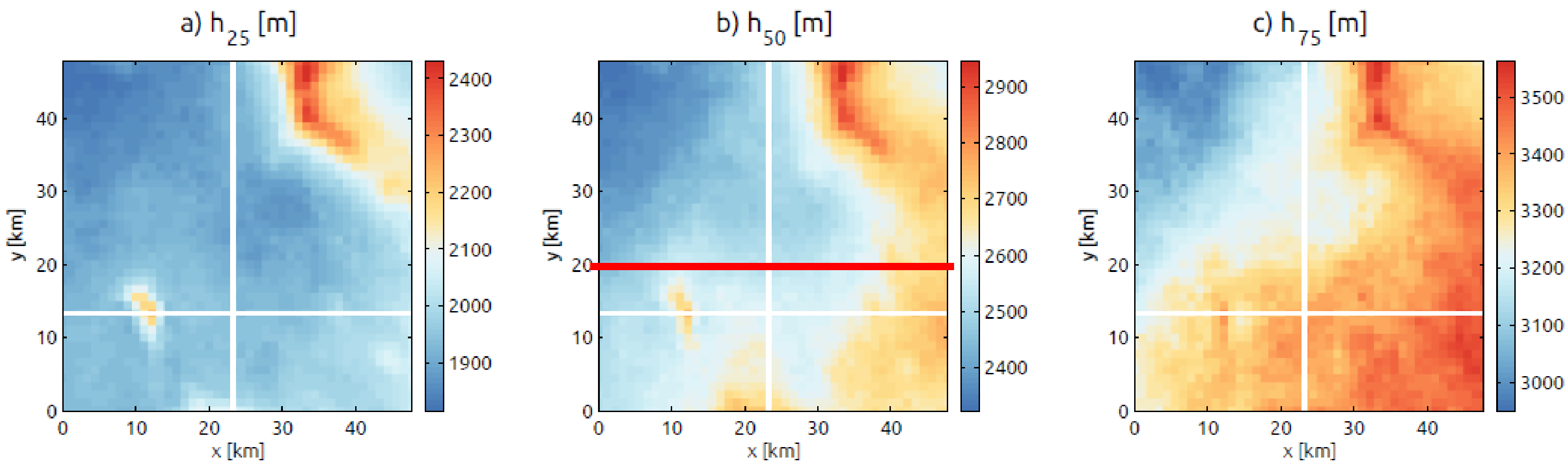
climatography: spatial ABL height variability

Daytime output from April to October

First quartile

median

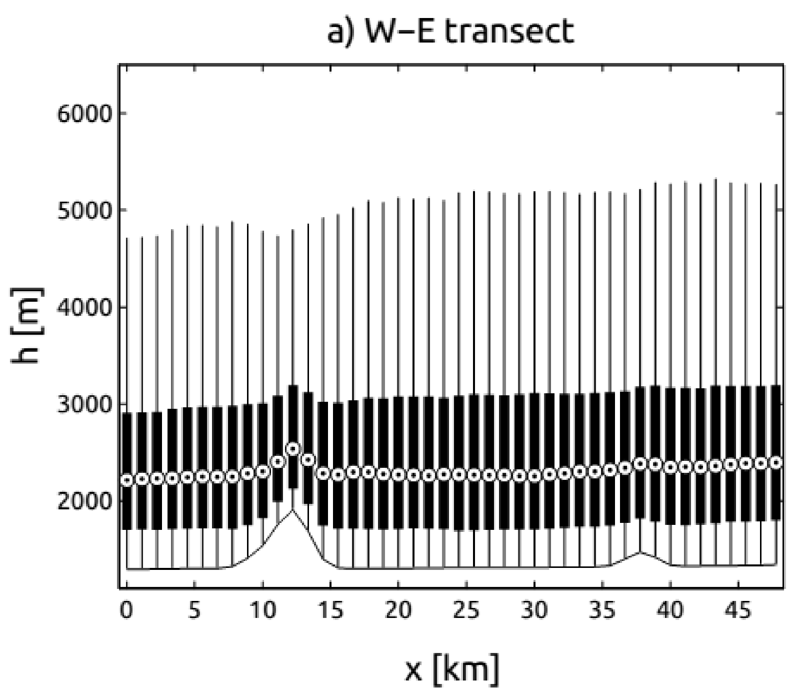
Third quartile



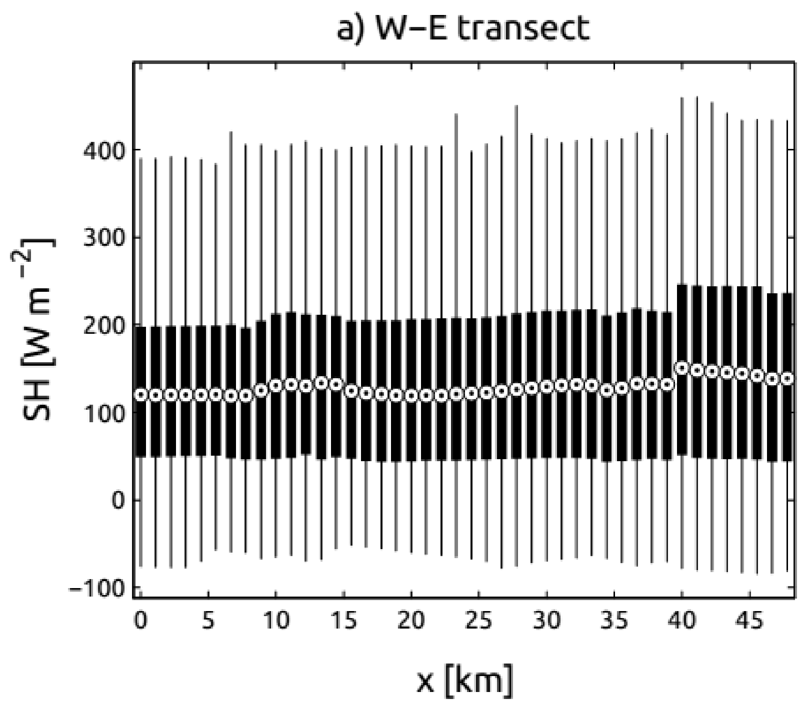
Gradual increase of CBL height from west (playa) to east (sagebrush), and from north to south

Climatography: spatial ABL height variability

CBL height



Surface sensible heat flux

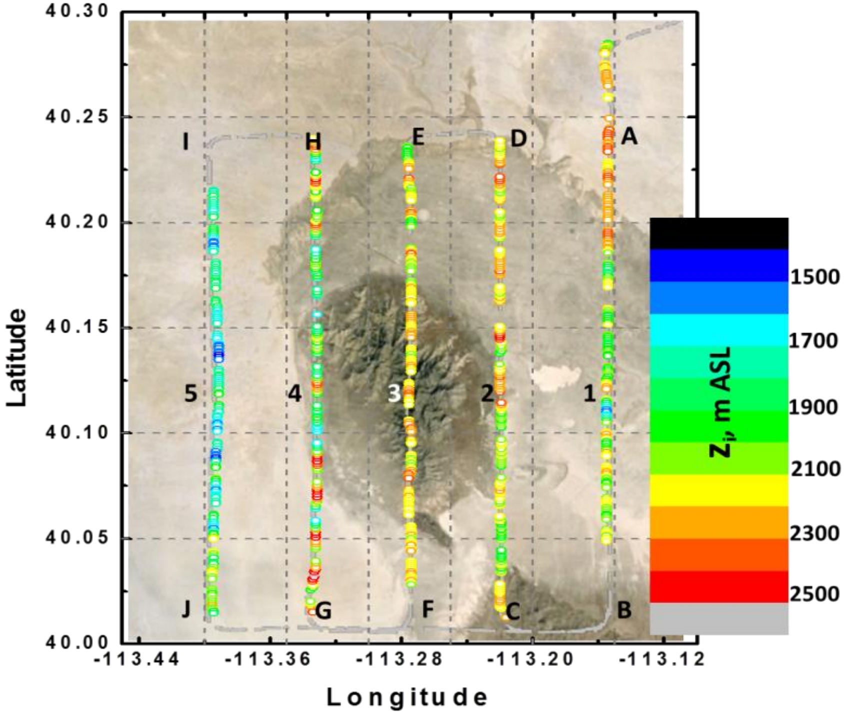


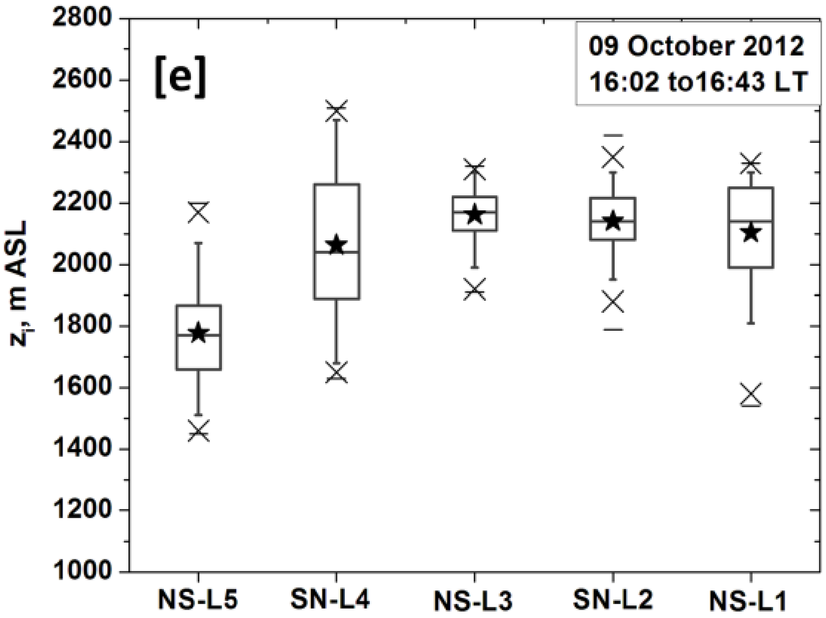
~ 30% difference in ABL depth between Playa and Sagebrush areas

~ 25% difference in sensible heat flux; can only explain ~50% of ABL height difference

Spatial PBL height from airborne Doppler lidar

Example: Afternoon 9 October 2012

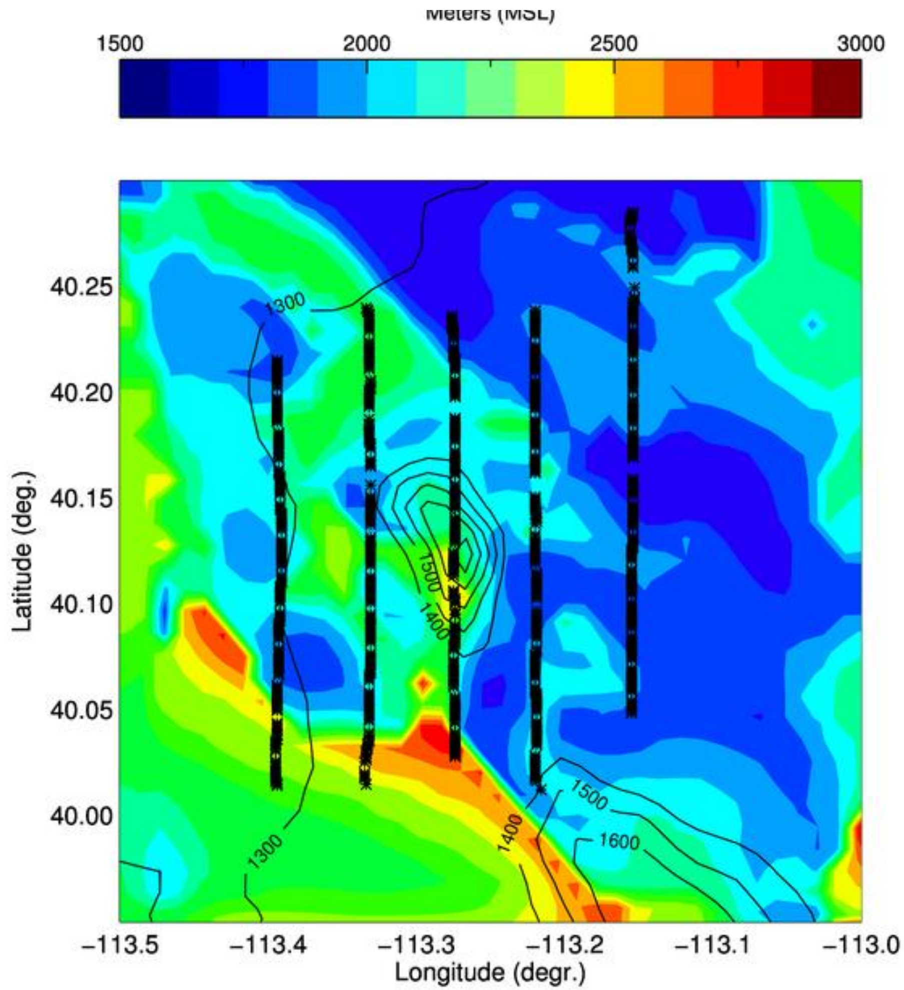




ABL height larger on the eastern side (sagebrush plain) than on the western (playa) side

Comparison of PBL heights from 4DWX simulations and from observations

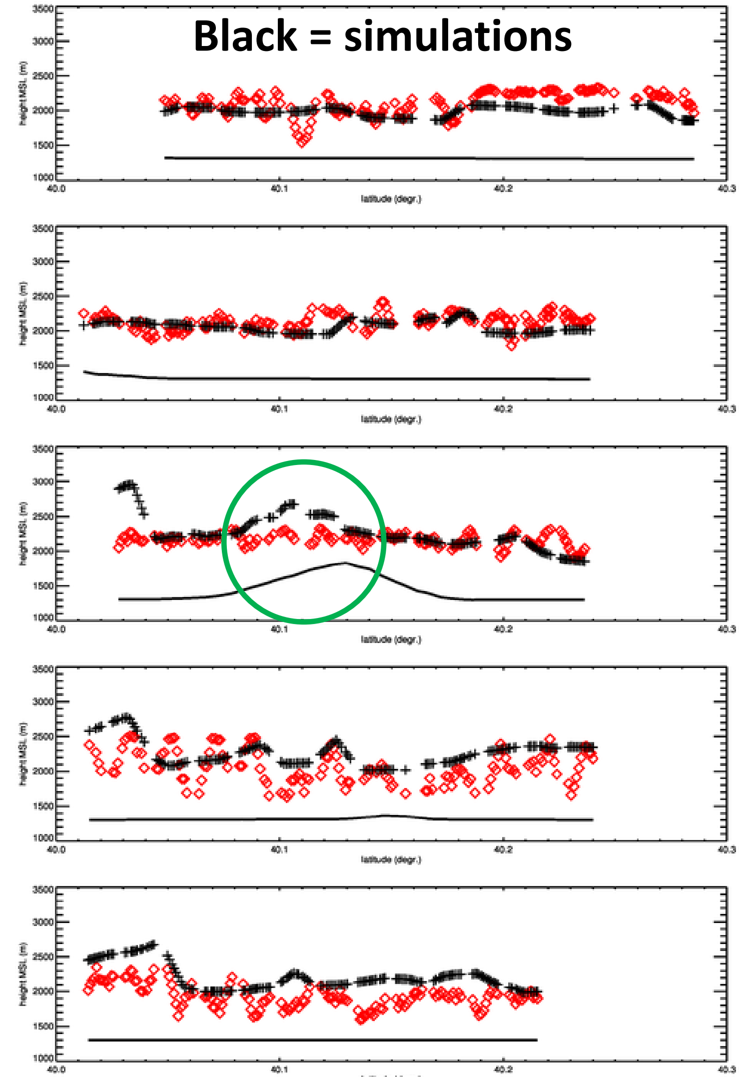
PBL height in meters (MSL) from 4DWX



9 October 2012, 23 UTC

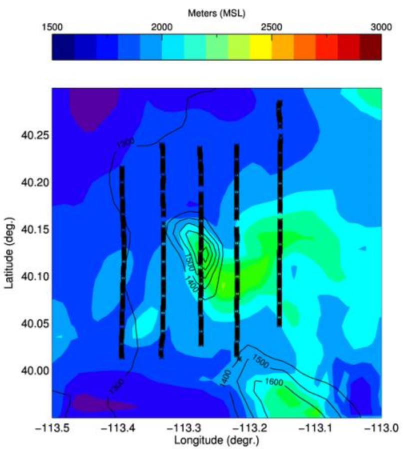
Red = observations

Black = simulations

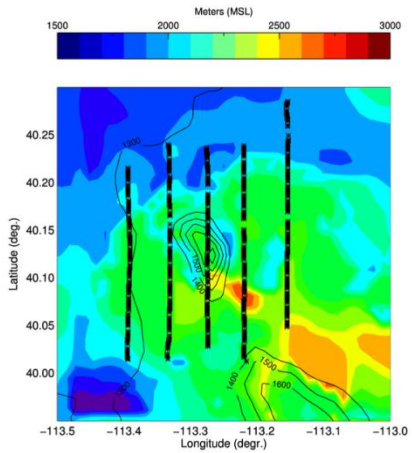


Comparison of ABL heights from 4DWX simulations and from observations

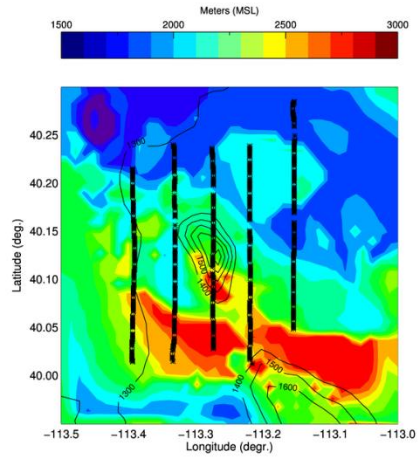
MDT=UTC-6 20 UTC



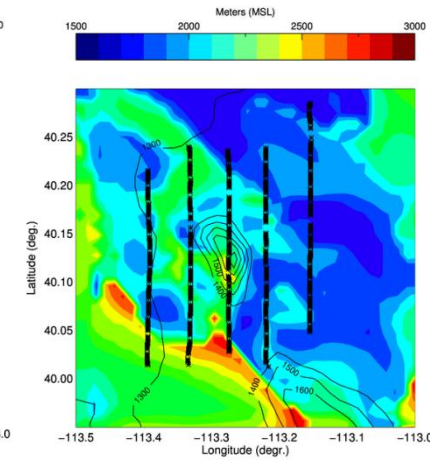
21 UTC

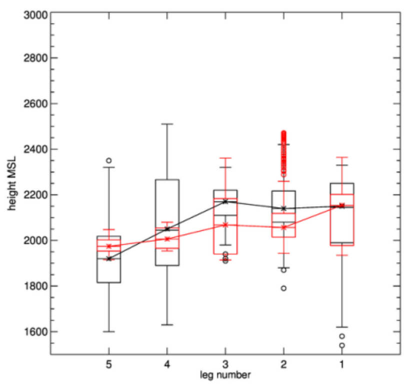


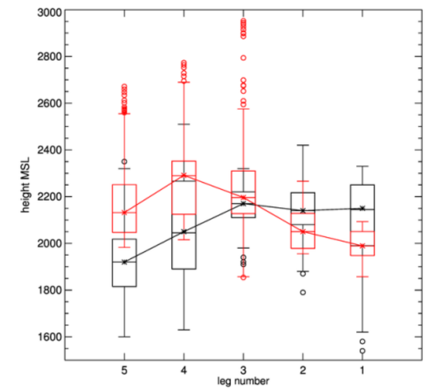
22 UTC



23 UTC







Red = observations

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Summary

ABL height climatography from two years of 4DWX output was constructed and provided good guidance for flight planning -> in-situ turbulence measurements in and above ABL, see poster by Sghiatti et al. (P2.32)

ABL height climatography shows that the ABL height around Granite Peak has a marked spatial heterogeneity. General increase of ABL heights toward east and south from climatography. Sensible heat fluxes differences only cannot explain ABL height differences -> See talk by Stefano Serafin, 3:15 PM today

Evaluation with observations challenging. Overall spatial trend reasonably well simulated. For cases studied so far, small-scale ABL height variability in observations larger than in simulations. Simulated ‘bulging’ ABL heights over Granite Peak do not seem to appear in observations

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