Use of MATERHORN TODWL soundings in simulations of precision airdrops

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Objectives

- Use existing WRF model and ADWL (Airborne Doppler Wind Lidar) data sets to investigate the relative merits of single vs. multiple wind lidar soundings or model soundings on the wind drift error contribution to the precision of Precision Air Drops (PADs).
- More specifically, address the following questions:
  - What are the expected errors if a sounding taken up to 30nm from the drop zone (DZ) is the last known profile to be used to compute the bundle Release Point (RP)?
  - What , if any, are the benefits of having ADWL wind soundings between 30nm out from the RP and within a few seconds of the RP?

Assets

- Simplified Bundle Drift FOM (Figure of Merit) for sounding impacts on PAD accuracy.
- ADWL soundings taken during the MATERHORN experiment at DPG (Dugway Proving Grounds) in October 2012.
- WRF model output for DPG over that same period.

Simplified Bundle Drift Simulator (used in prior SWA PAD research)

- Simplified Bundle Drift Figure of Merit (BDFOM)
  - Assumes a massless payload; limited to the effects of wind profile variability in space and time.
  - Advection of the bundle by x,y distances by average winds in 50m layers during time spent in those individual layers.

- BDFOM = |Impact Point (IP) - Target Location (X) |
  - Use open cell diagram to illustrate the dependency of BDFOM on last wind profile used to compute RP
  - Use a scatter diagram to illustrate variability in simulated air drop accuracy generated from multiple instantiations of input wind profiles

BDFOM

- In this current study, drops are considered from ~10 Kf (model and ADWL)and 17.5 Kf (model only) MSL
- Fall speeds as shown in next slide.
- Transpose distant soundings to target location
- Calculate a RP
- Simulate bundle drifts through WRF model and ADWL wind fields at the target location.

Air Drop Fall Speed Profile

Sample Times for Each Air Drop Stage

Stage	**Fall Speed (fps)**	**3K feet (seconds)**	**10K feet (seconds)**	**17.5K feet (seconds)**
Stabilization	180	2	2	2
Ring Slot	96	22	95	175
Main	28	18	18	18
Total Time		**42**	**115**	**195**

Assumptions:

1. Near free fall is used for first 2 seconds
2. Main is opened 500 feet AGL

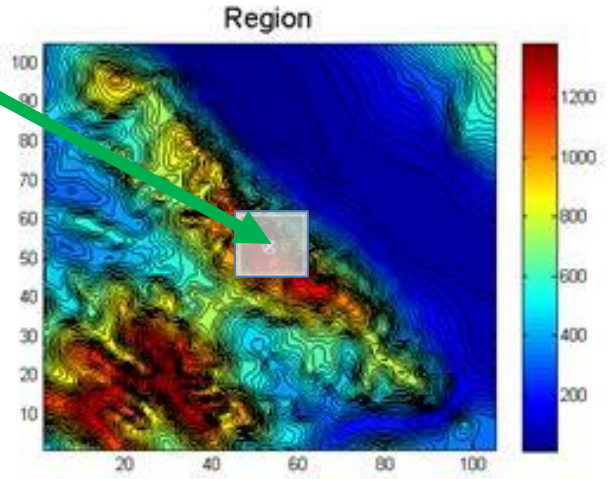
Simulated Air Drops Using Only WRF Wind Soundings (no lidar)

- Use individual WRF model grid point soundings closest to TODWL wind soundings to evaluate the variability of the BDFOM within the air drop simulation domain
- No instrument sampling or measurement errors
  - In the October cases, only spatial variability from the WRF model
- Used to illustrate the expected BDFOMs for either a model profile or ADWL profile at various distances from the DZ.

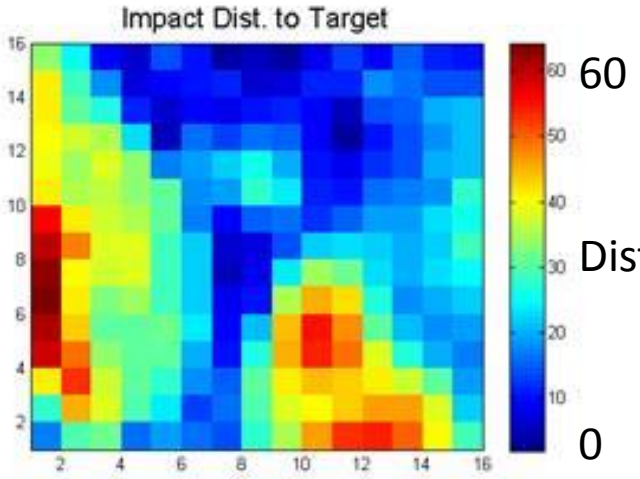
Example of BDFOM from prior PAD simulations near the Salinas Valley, CA.

Ridge Example BDFOM Spreads

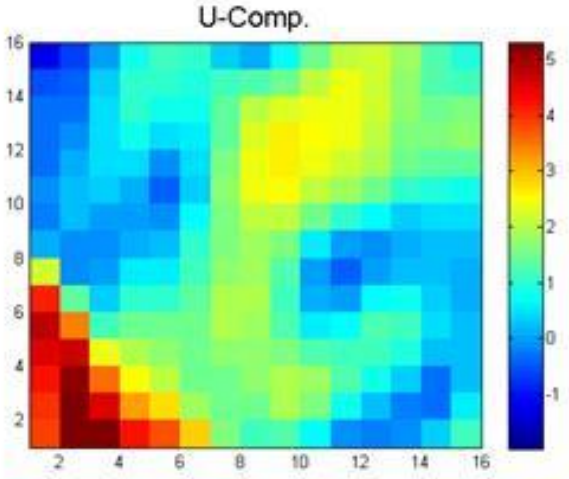
DZ



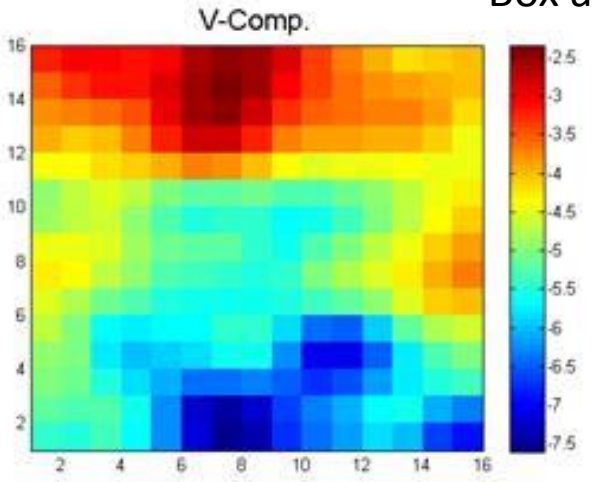
Height(m)



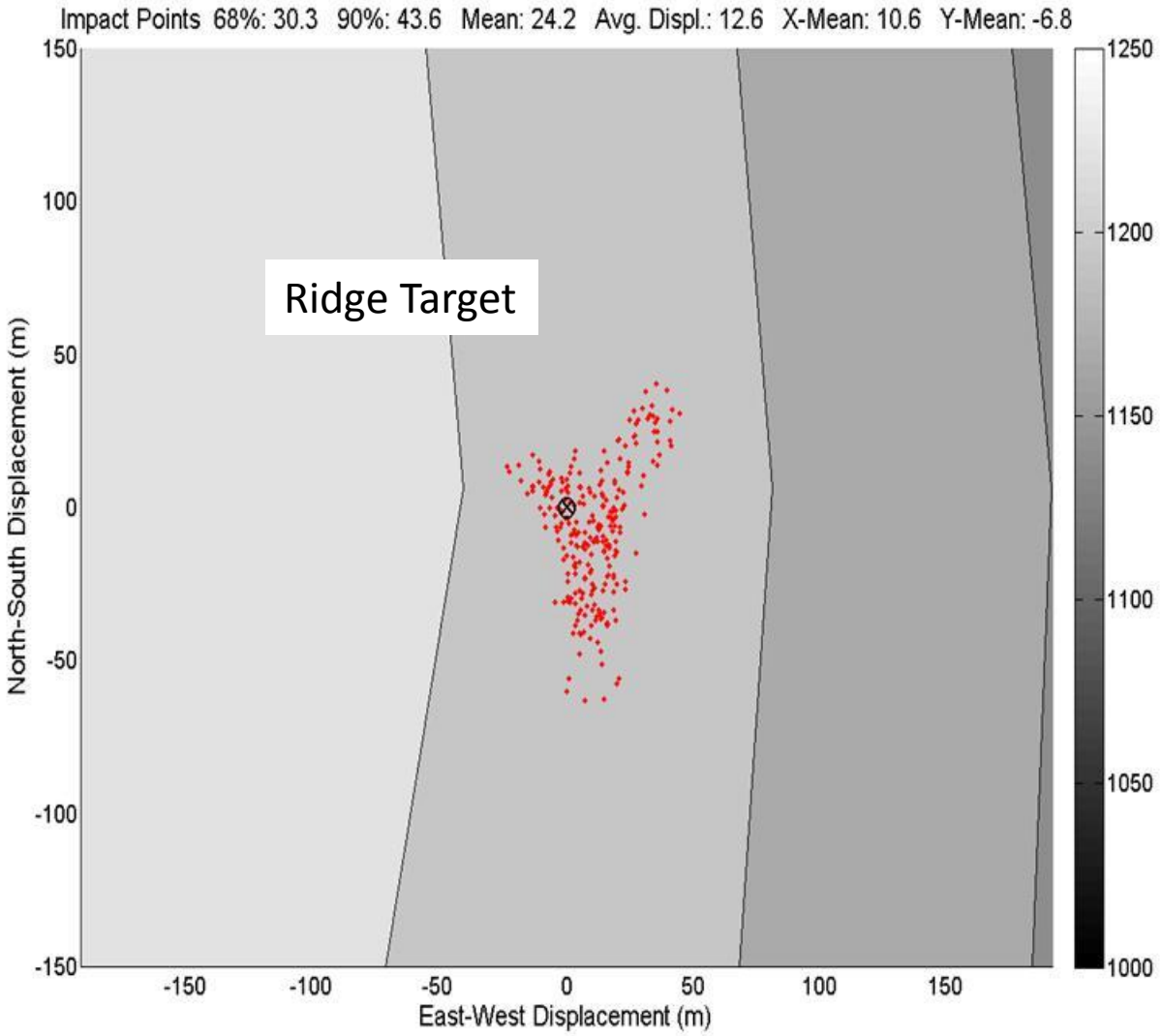
16 x 16 km
Box around DZ



Winds (mps)
at 50m AGL



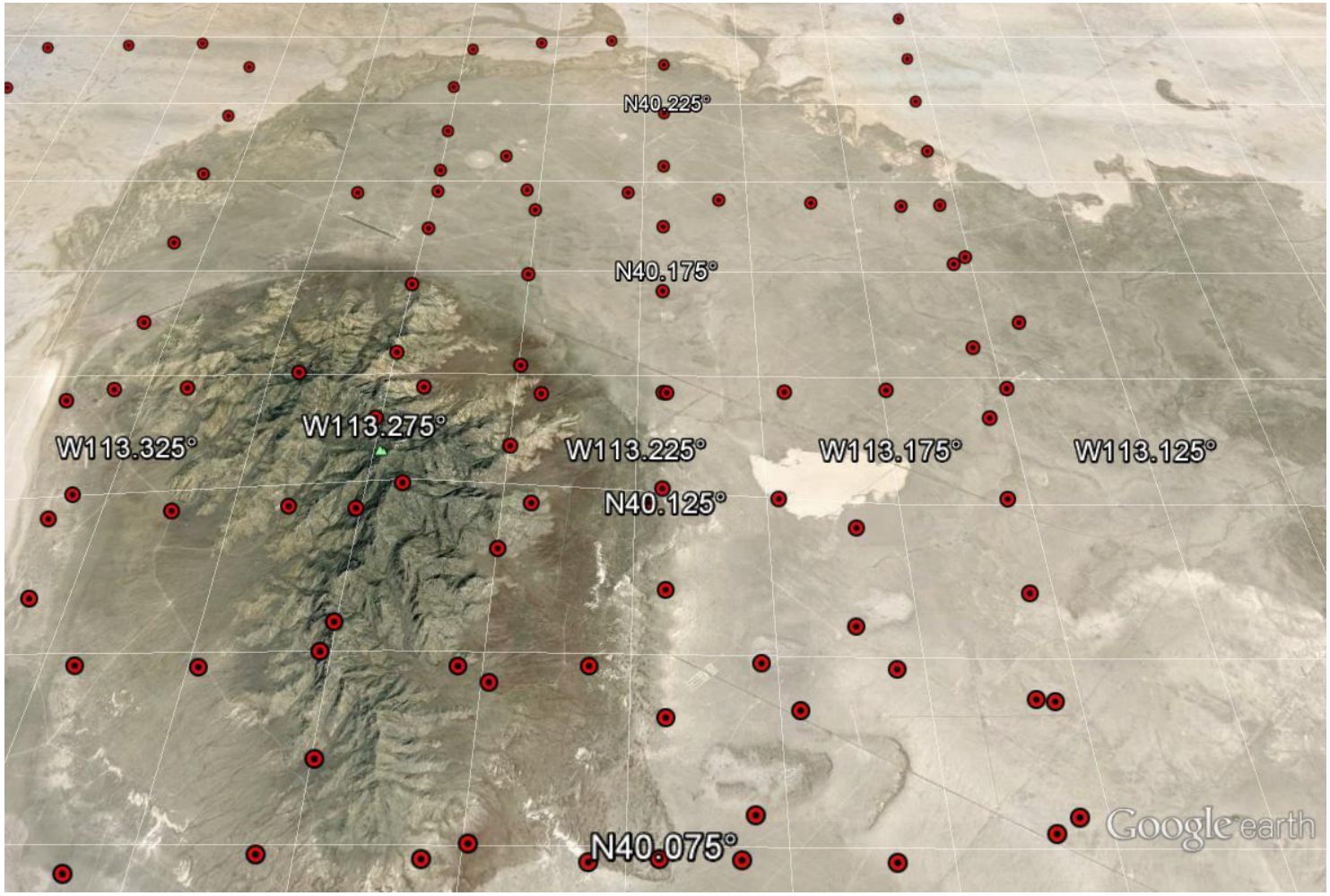
Impact Points for 10,000’ drop



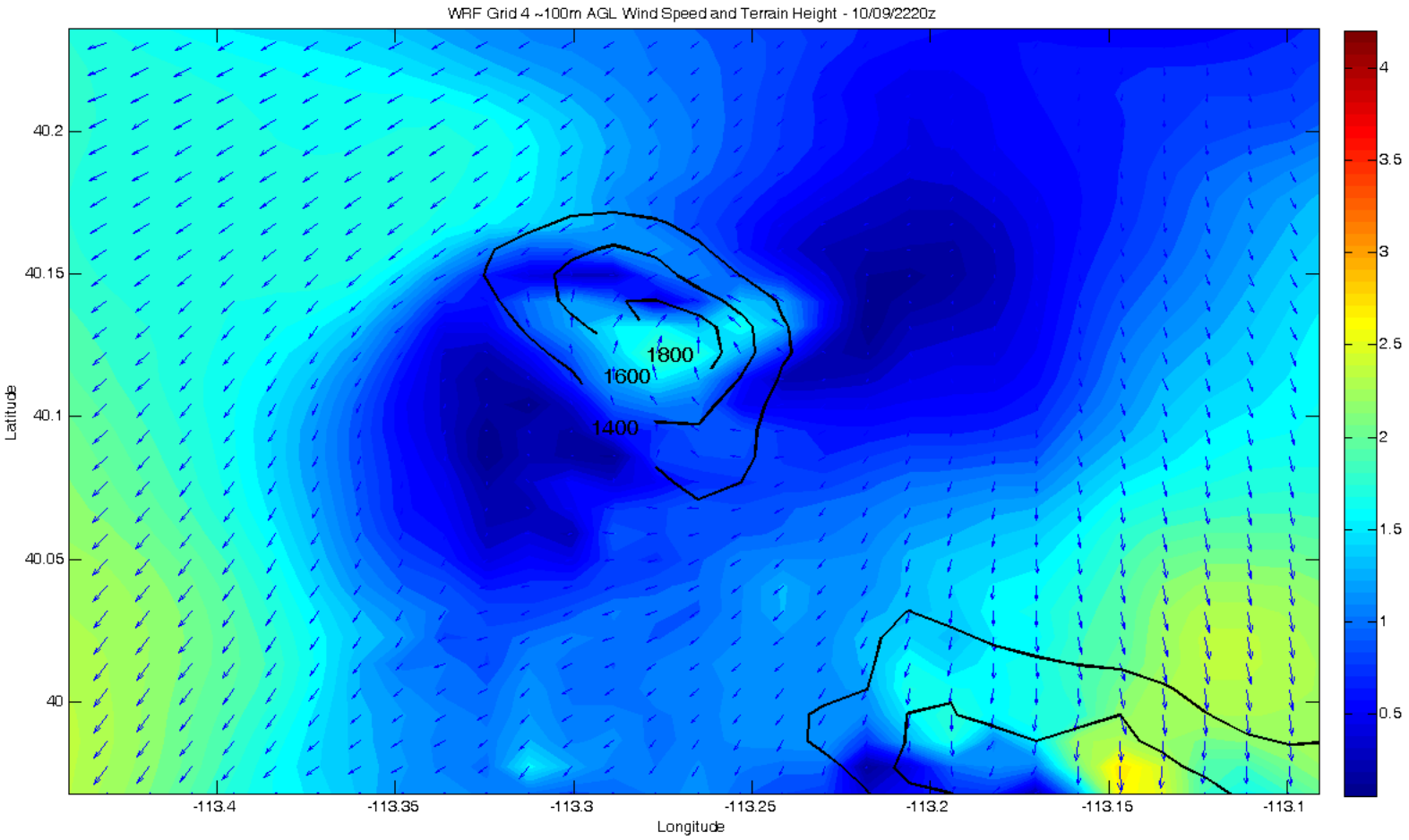
Terrain Height (meters MSL)

MATERHORN cases

Granite Mountain, DPG



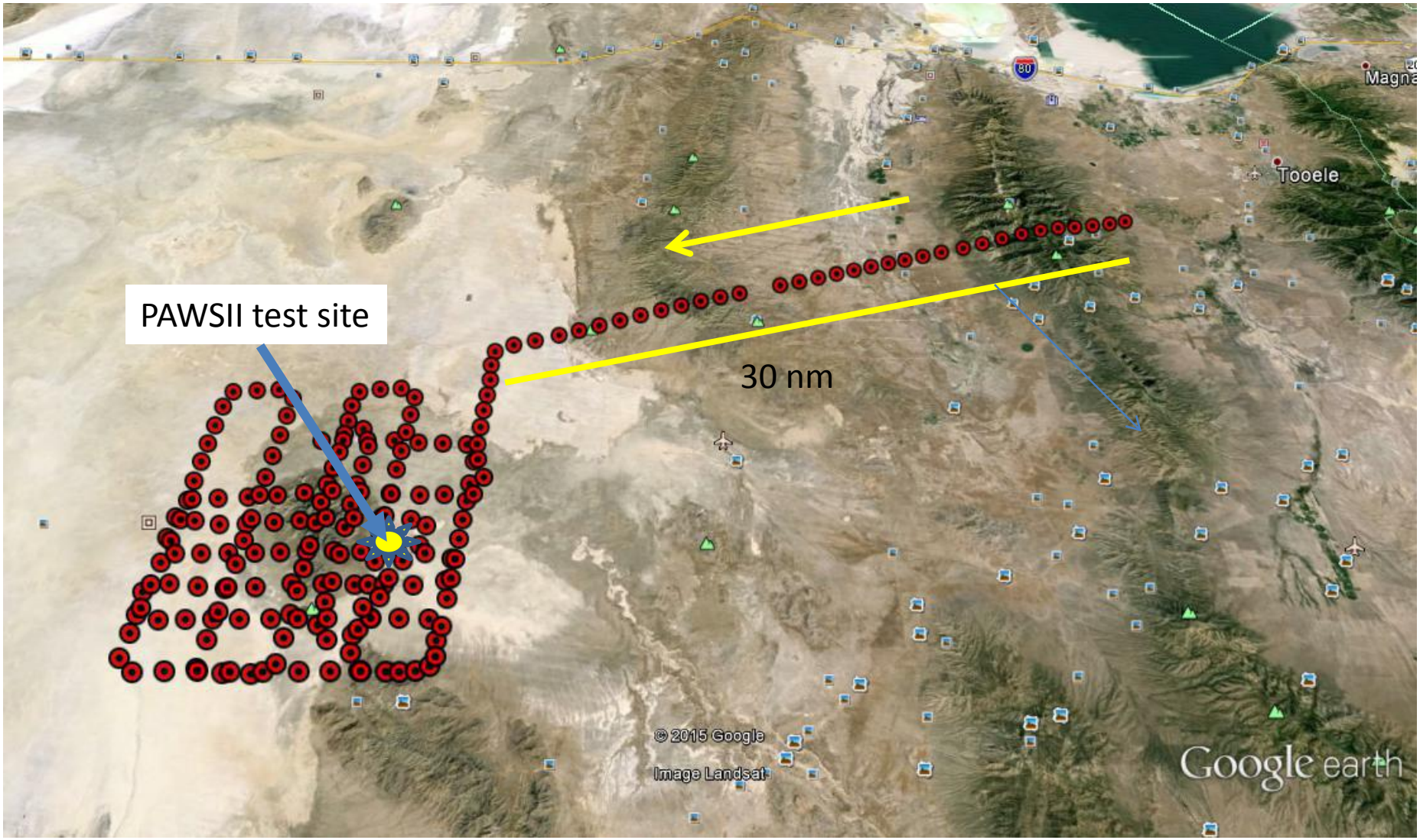
Example of WRF model output winds (100m agl) around Granite Mountain



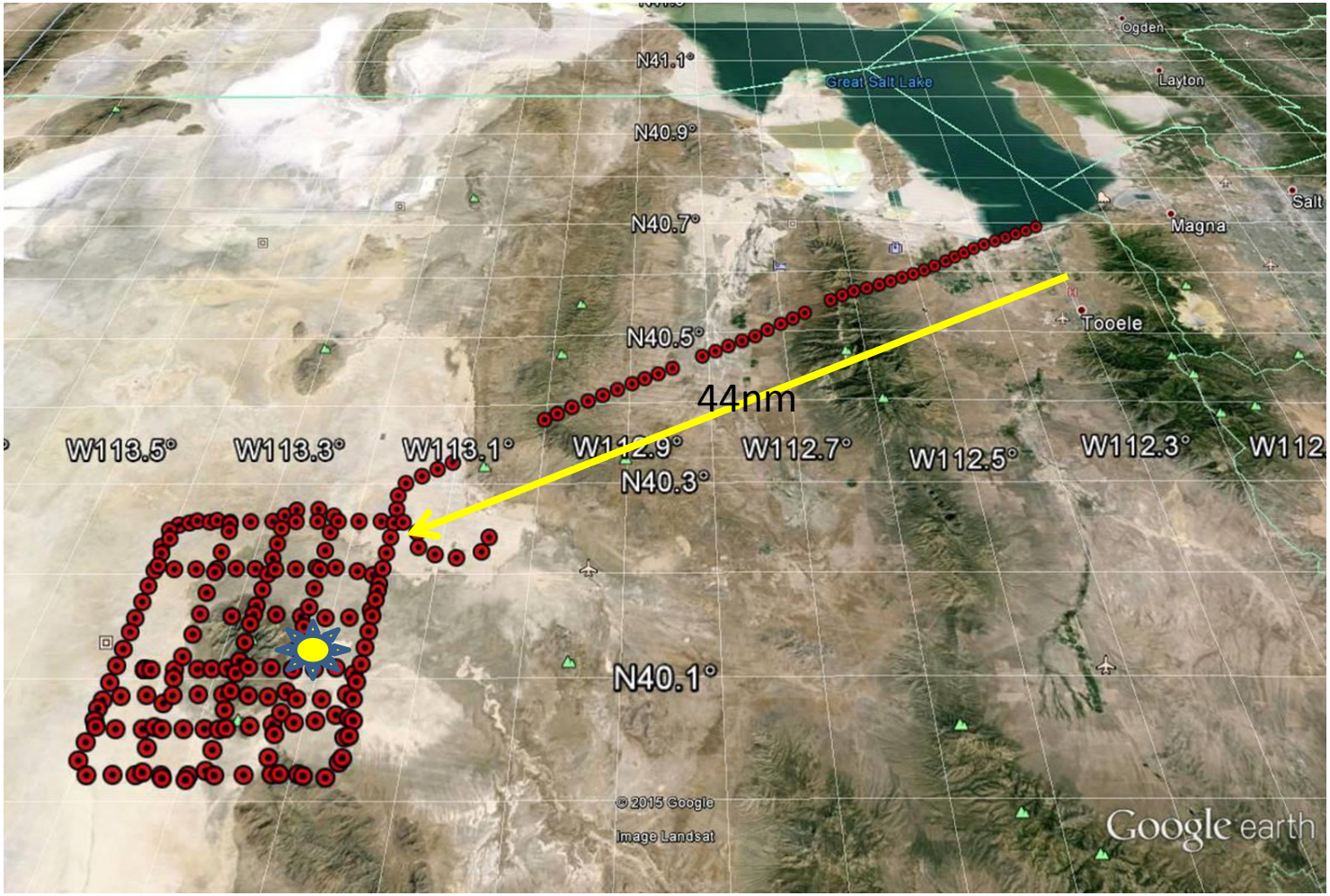
Dugway case studies

- October 06,09,10 and 17, 2012 during ONR/NSF MATERHORN experiment at Dugway Proving Grounds.
- ADWL soundings between Salt Lake City and Granite Mountain as well as over and around Granite Mountain. Only using soundings on approach to DPG and near MATERHORN operations site.
- Output from the WRF model for the same period of time and along the same path as TODWL.

ADWL wind sounding locations October 9, 2012



ADWL wind sounding locations October 10, 2012

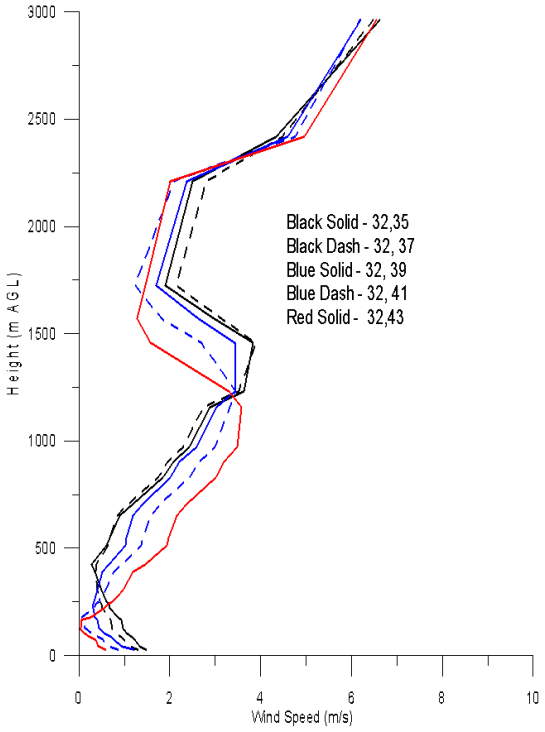


WRF/ADWL wind profile comparisons

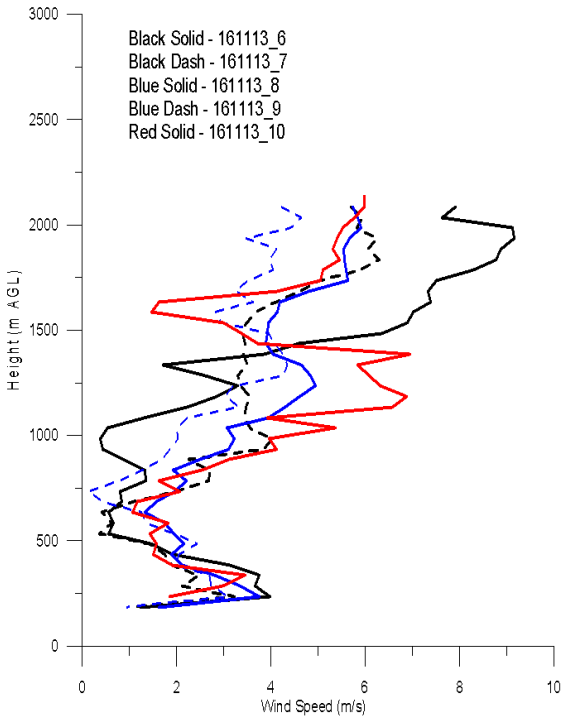
- Example case for location close to the MATERHORN operations center site just on the eastern side of Granite Mountain.
- Use WRF model output for the approximate times (~ 5 minutes) and locations (.5km) of ADWL sounding.

East Slope Wind Speed from TODWL and WRF

Wind Speed on East Slope of Granite Mountain - 10/09/2210Z
Taken from WRF MODEL 1 km Domain
Matching N-S Lidar Leg of 2213-2216

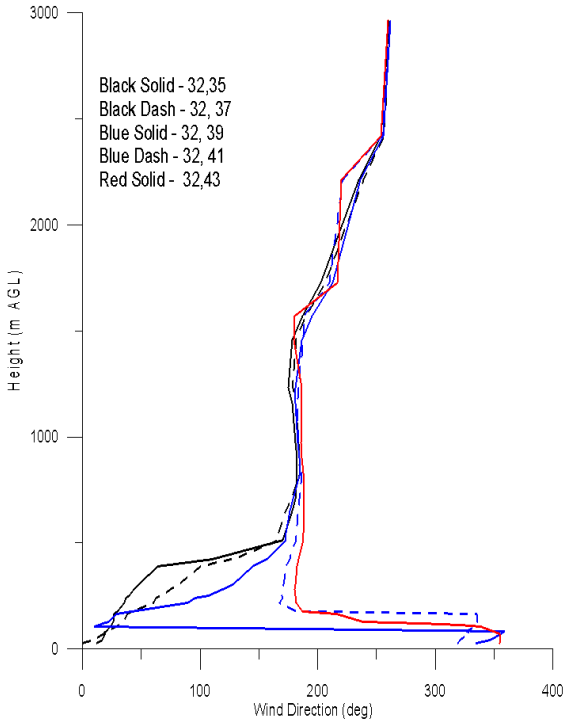


Wind Speed on East Slope of Granite Mountain - 10/09/2213-15Z
TODWL Lidar
Elevation ~ 1315m amsl

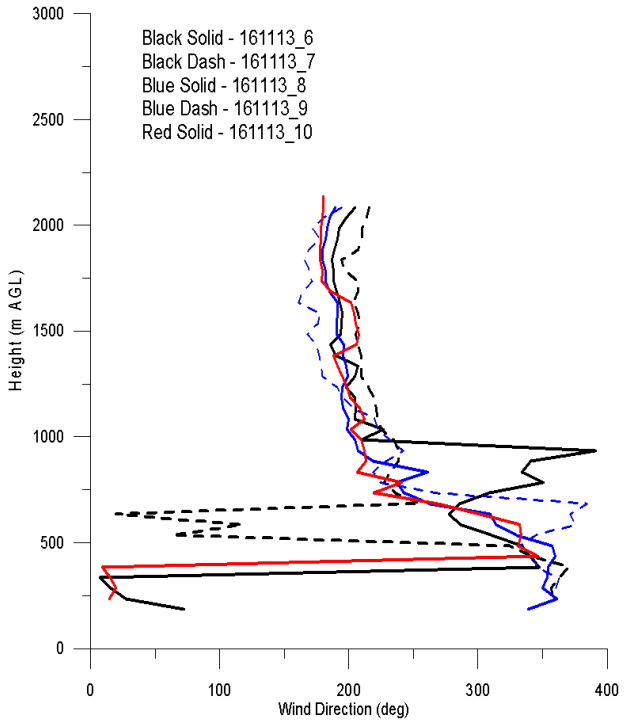


East Slope Wind Dir. from TODWL and WRF

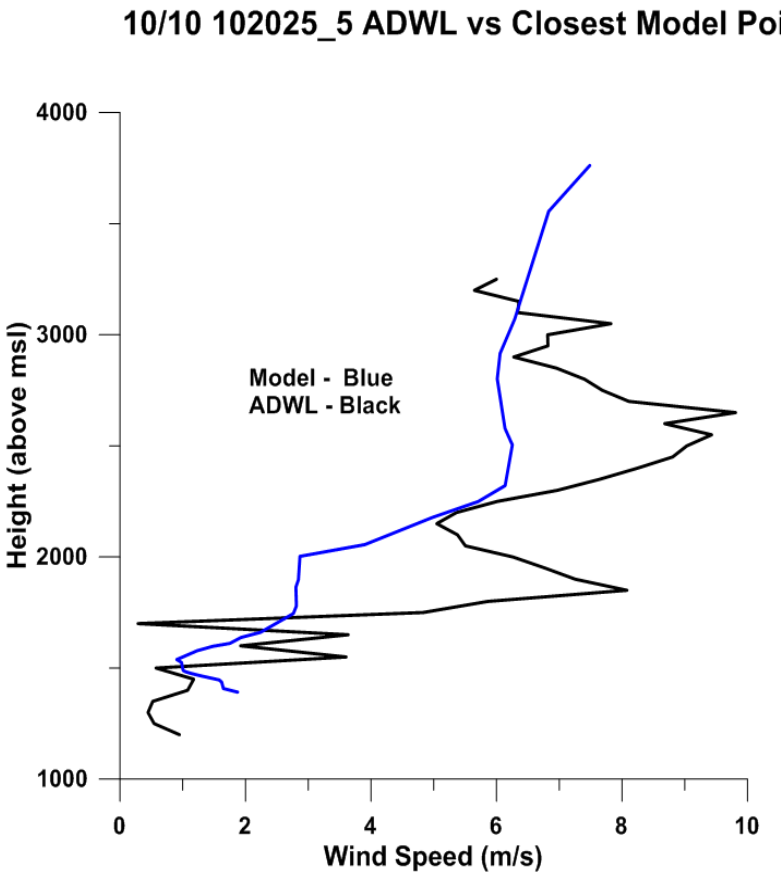
Wind Direction on East Slope of Granite Mountain - 10/09/2210Z
Taken from WRF MODEL 1 km Domain
Matching N-S Lidar Leg of 2210

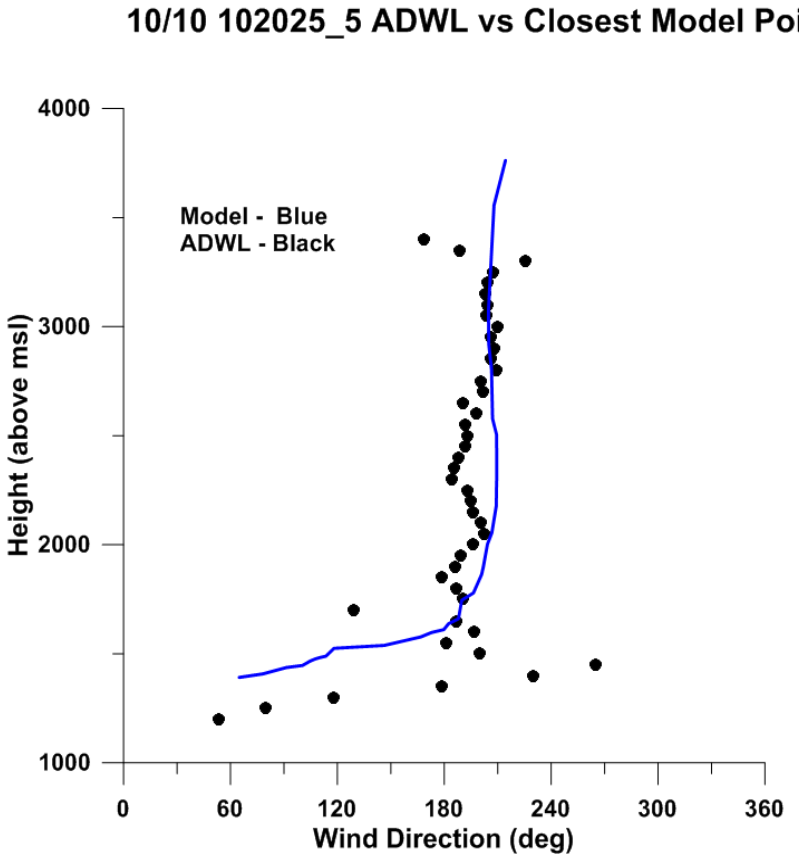


Wind Direction on East Slope of Granite Mountain - 10/09/2213-15Z
TODWL Lidar
Elevation ~ 1315m amsl



Comparison between WRF and ADWL soundings within 1 km of the target DZ





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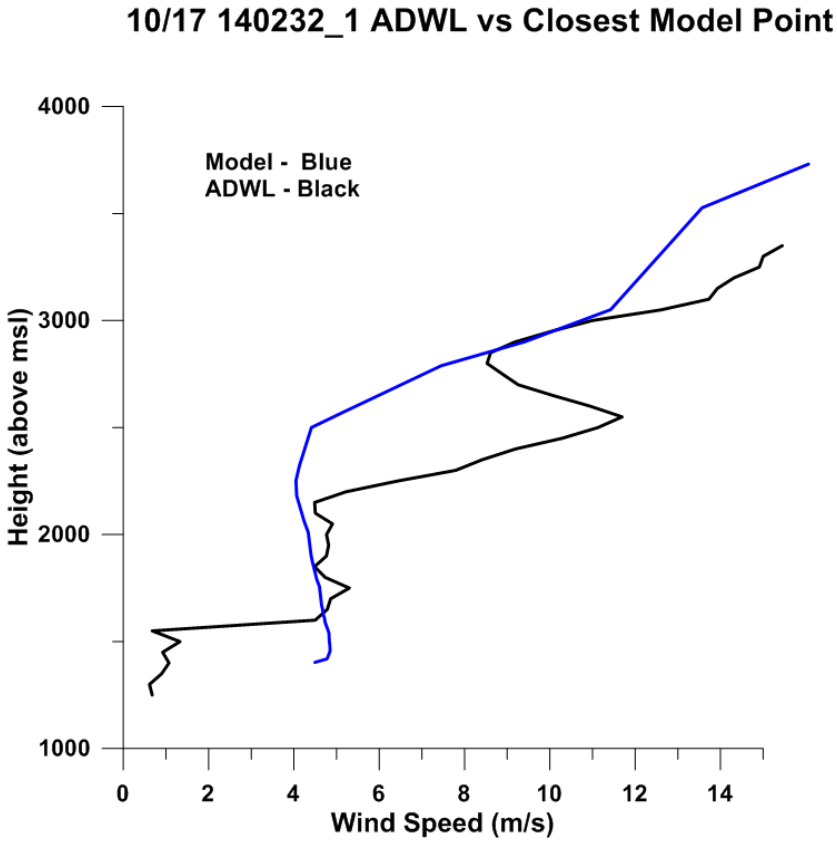
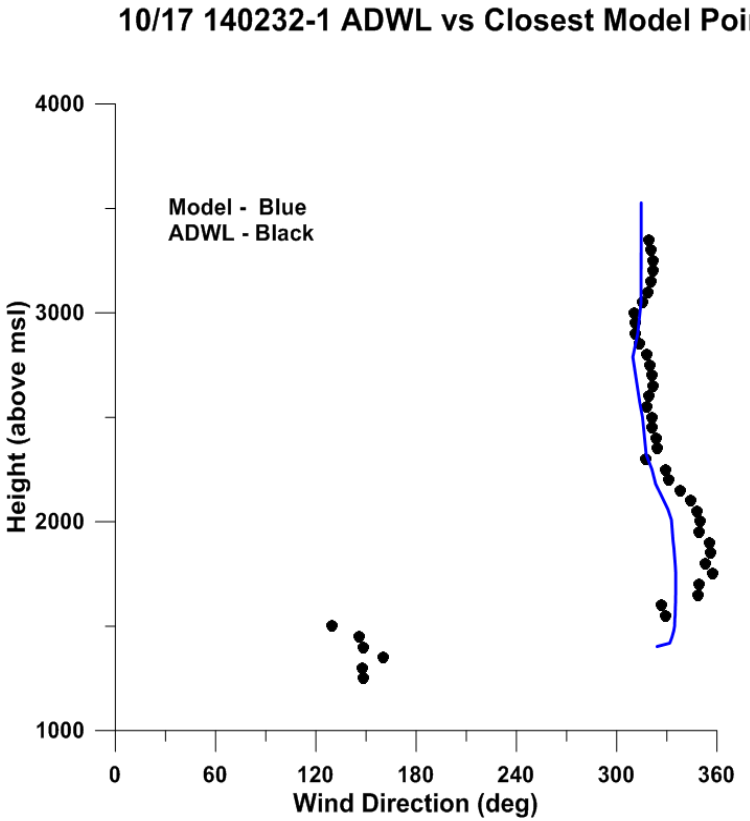


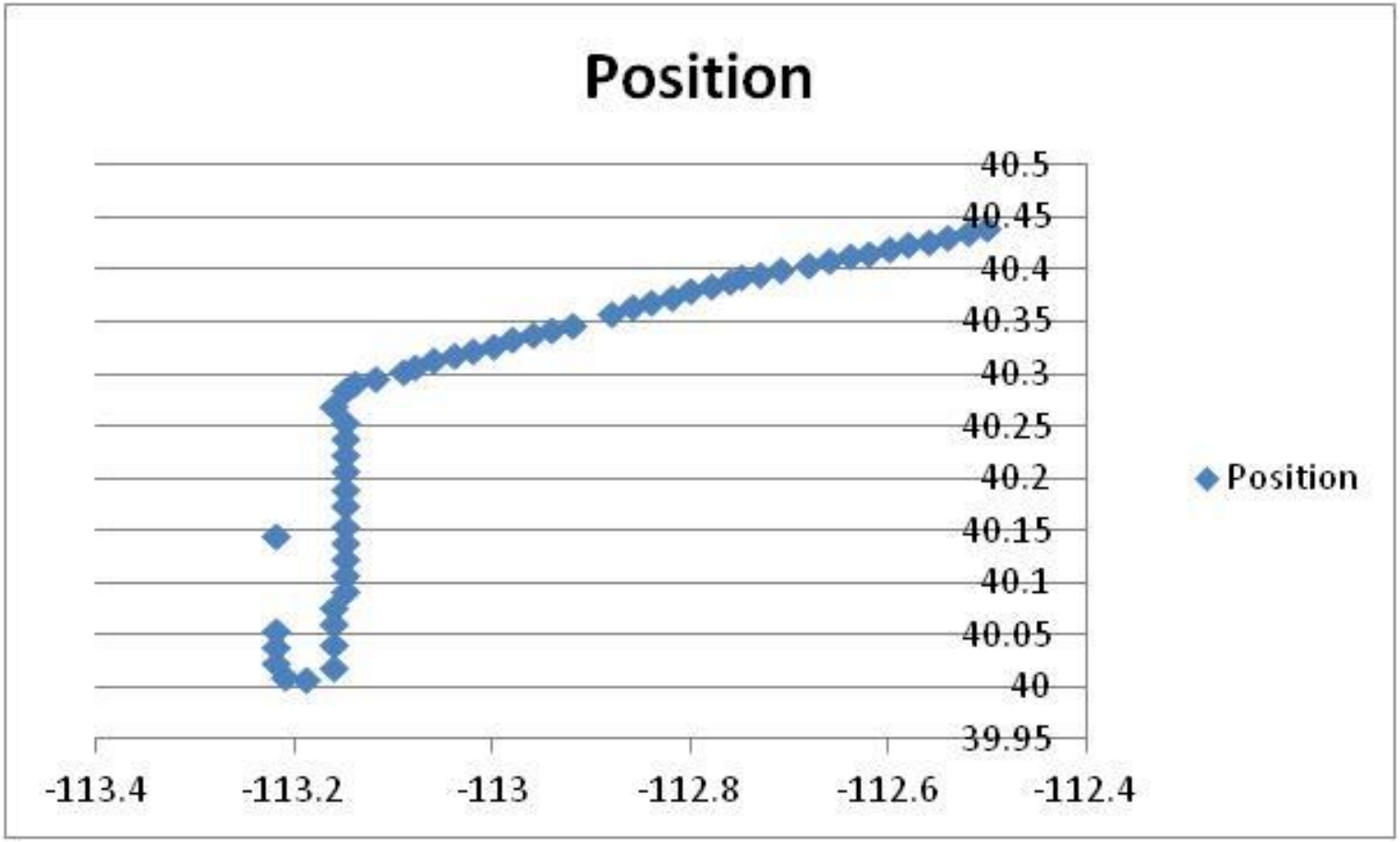


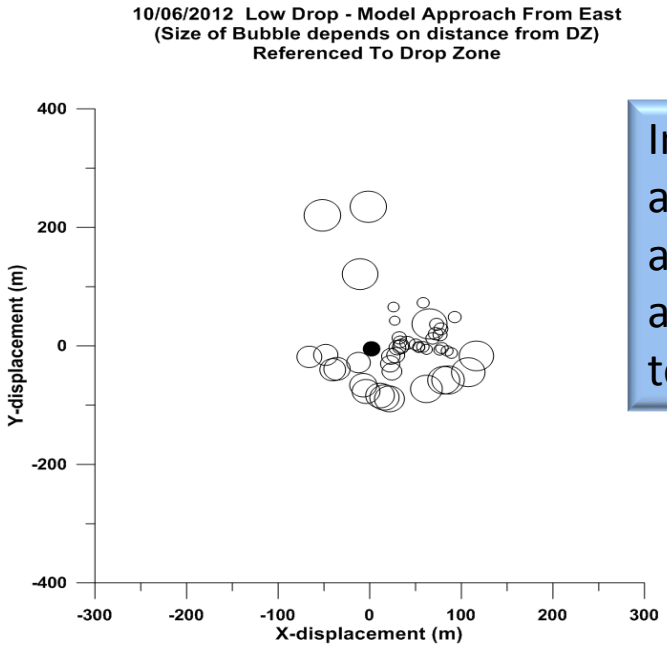
Impact errors based upon WRF model

Setup for WRF simulations of BDFOM

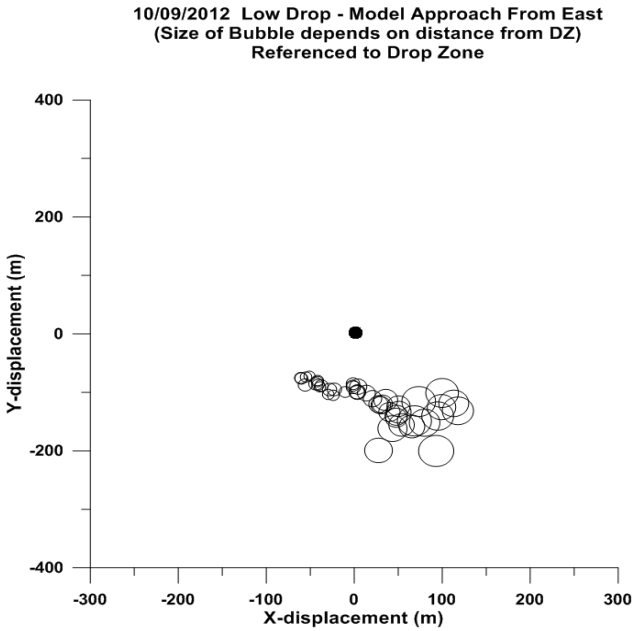
- Locate the WRF soundings nearest to those obtained with the ADWL on an approach path to the Granite Mountain test area.
- Compute BDFOM for drops from 10000’ to the surface; also from 17500’ to the surface.

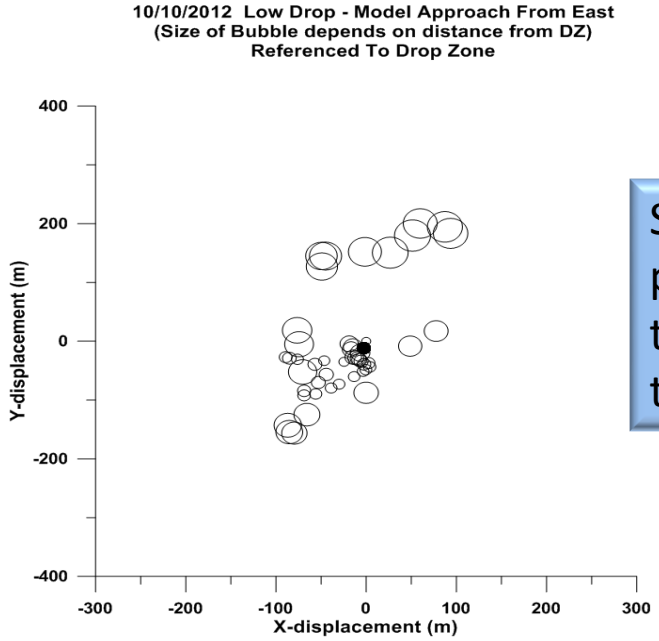
Approach to Granite Mtn. (08/09/15)



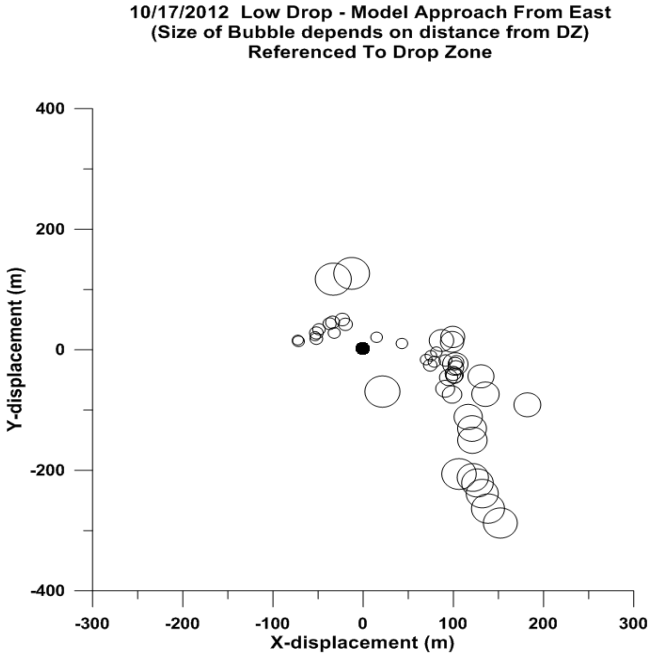


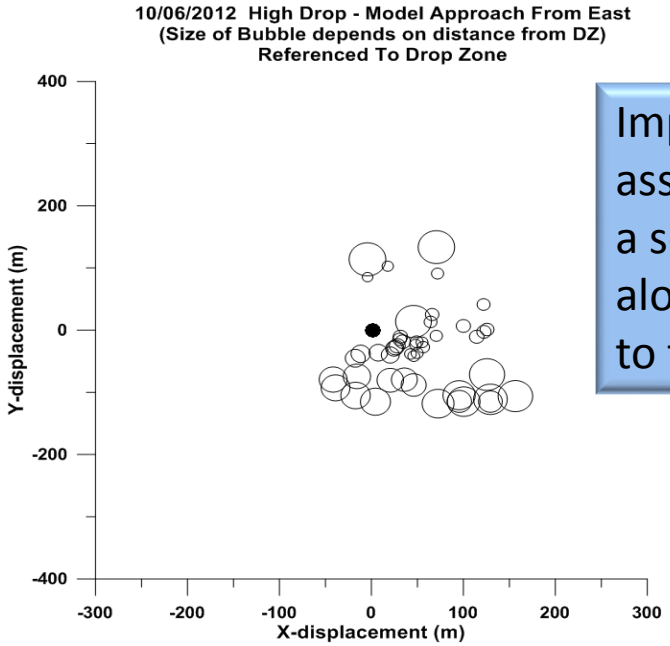
Impact errors associated with a series of profiles along the approach to the DZ





Size of circle is proportional to the linear distance to the DZ





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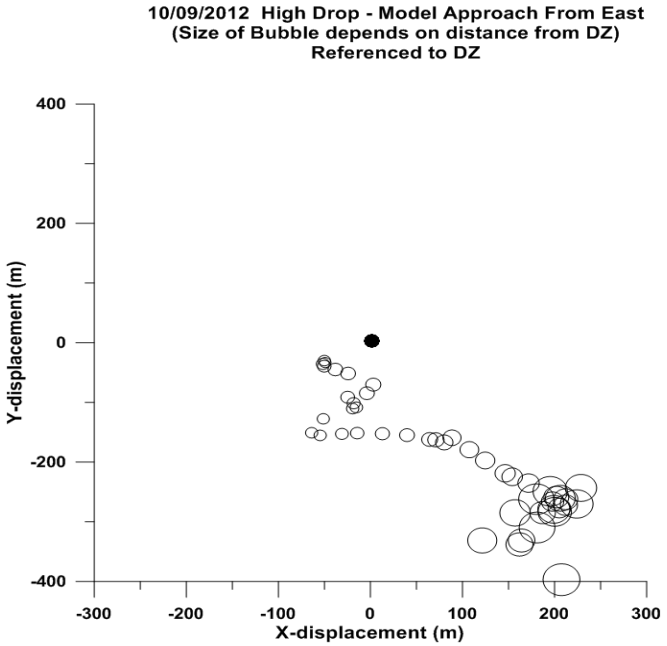
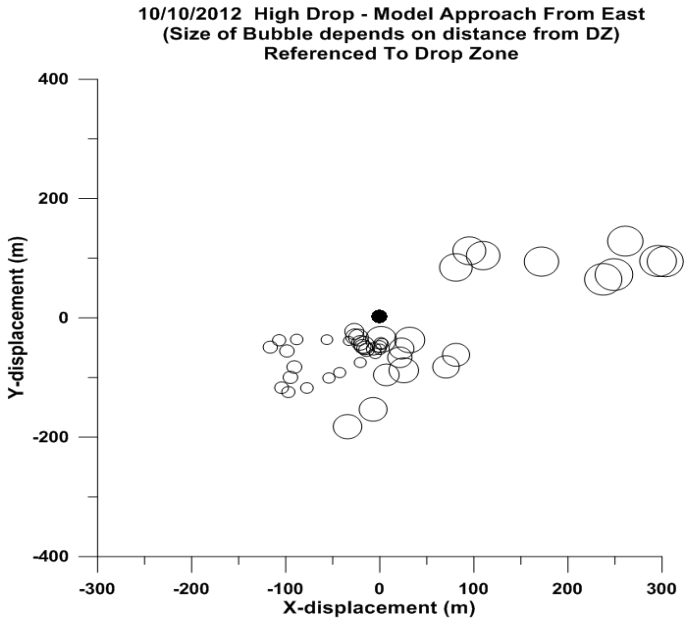
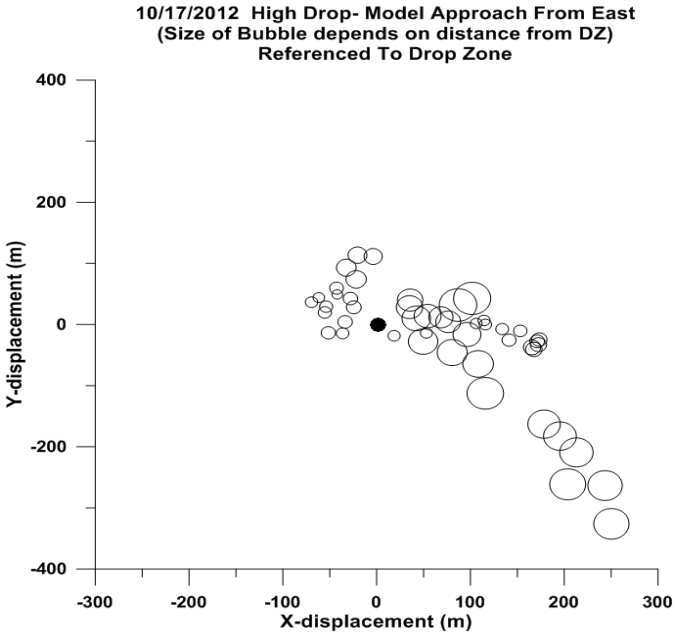


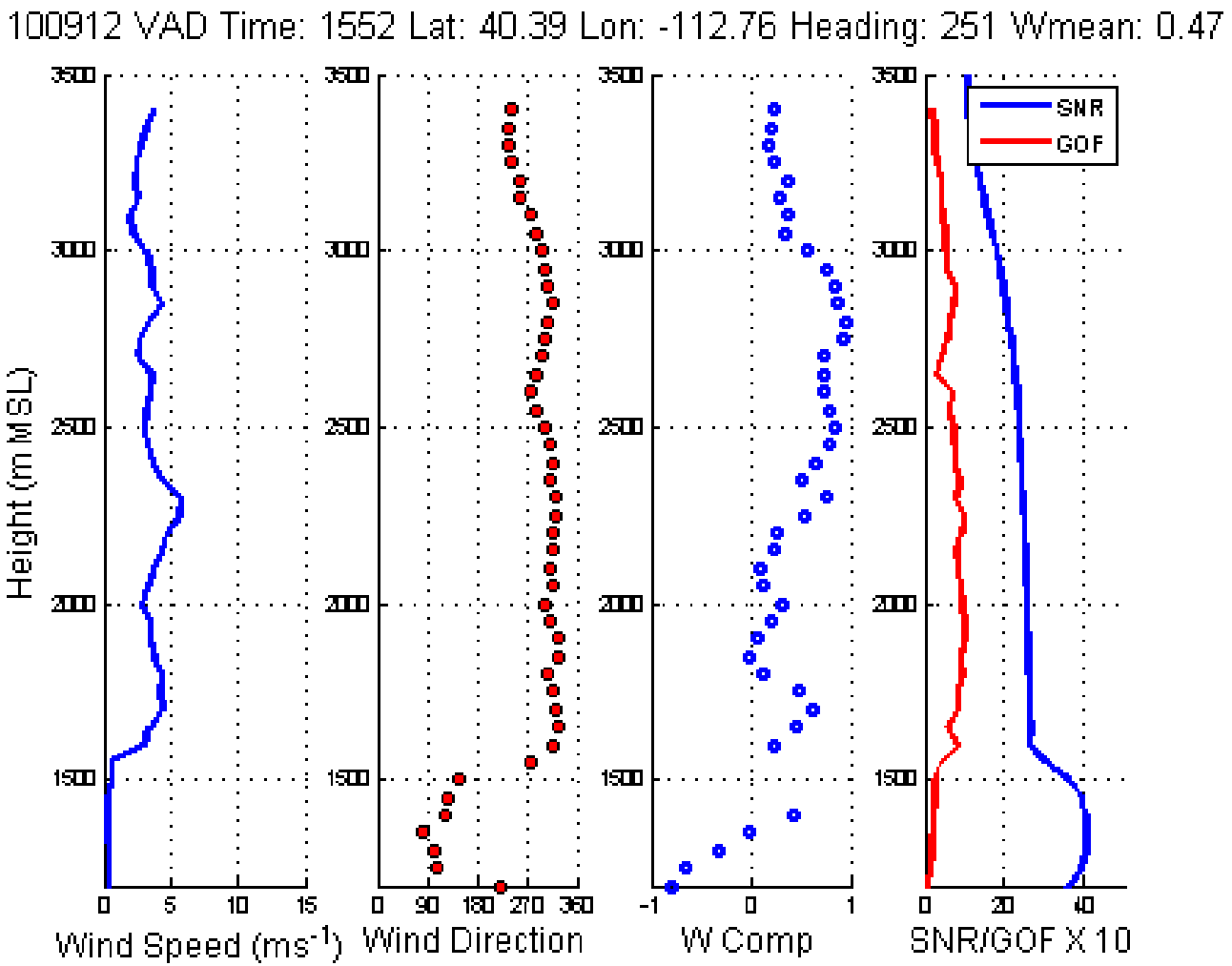


Size of circle is proportional to the linear distance to the DZ

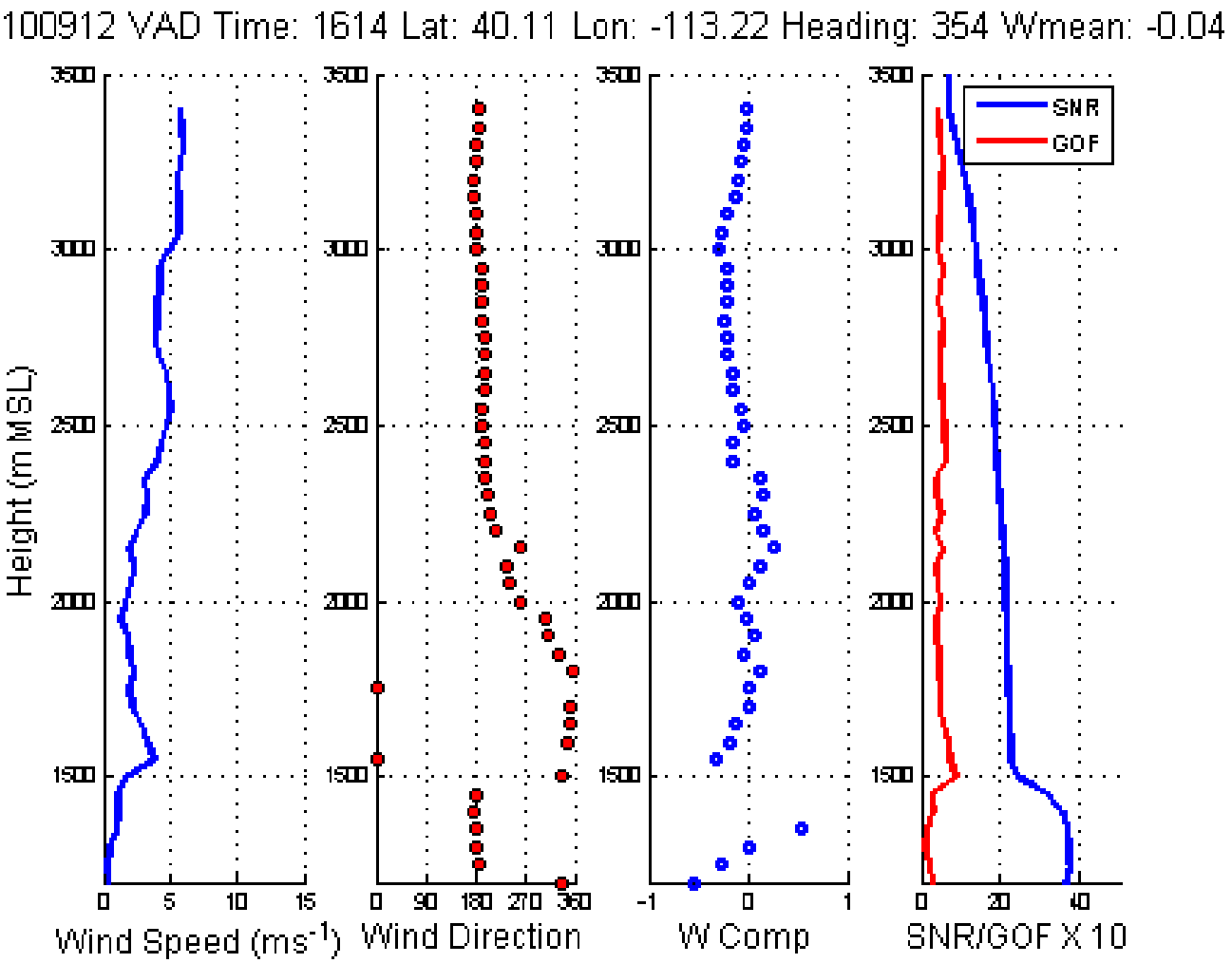


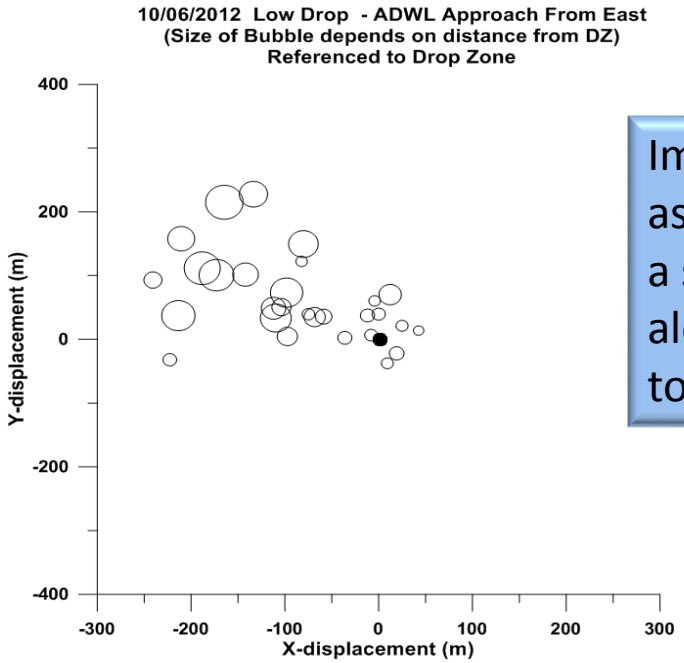
Impact errors based upon ADWL profiles

ADWL sounding on approach to MATERHORN control site

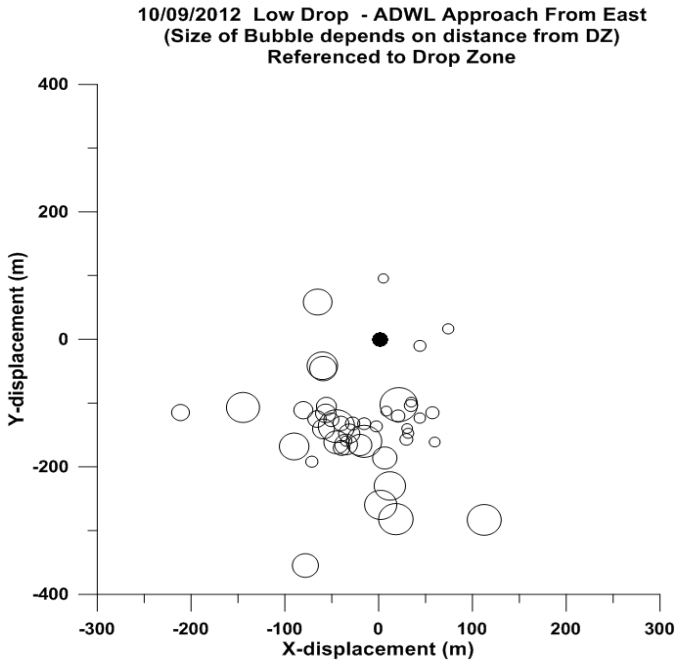


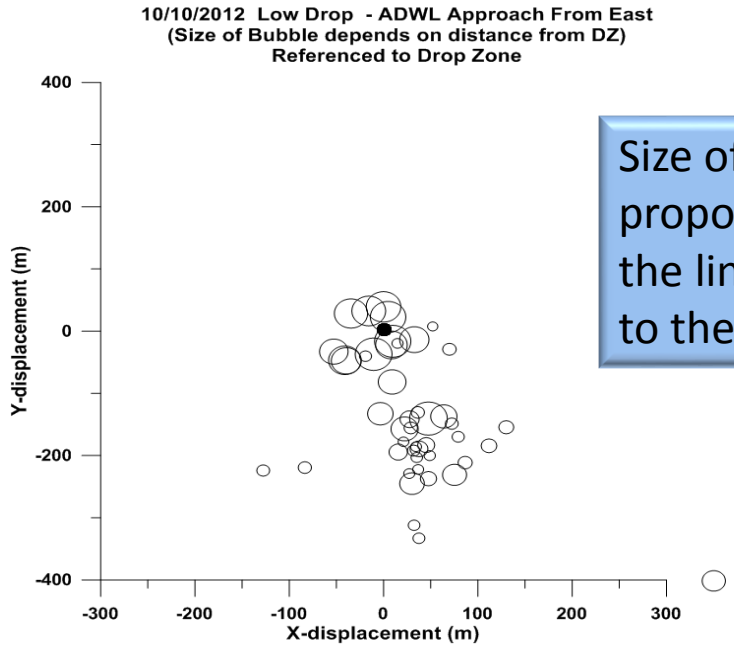
ADWL sounding near MATERHORN site



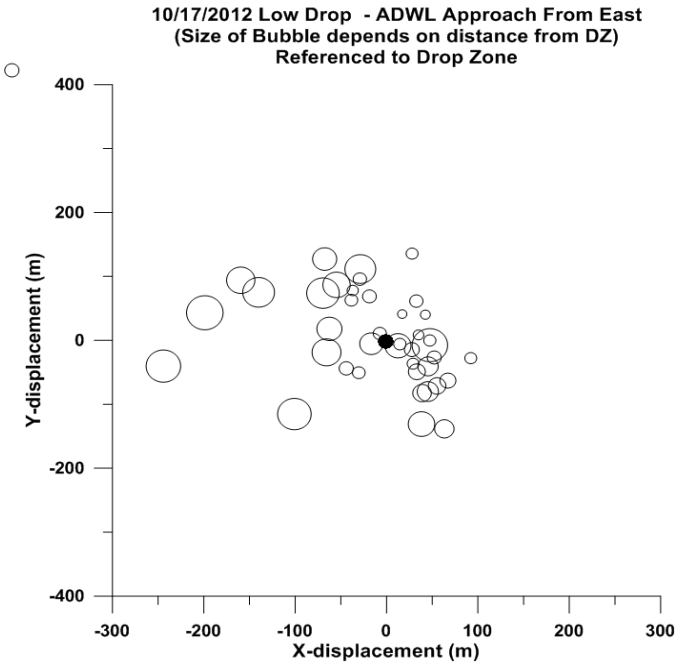


Impact errors associated with a series of profiles along the approach to the DZ

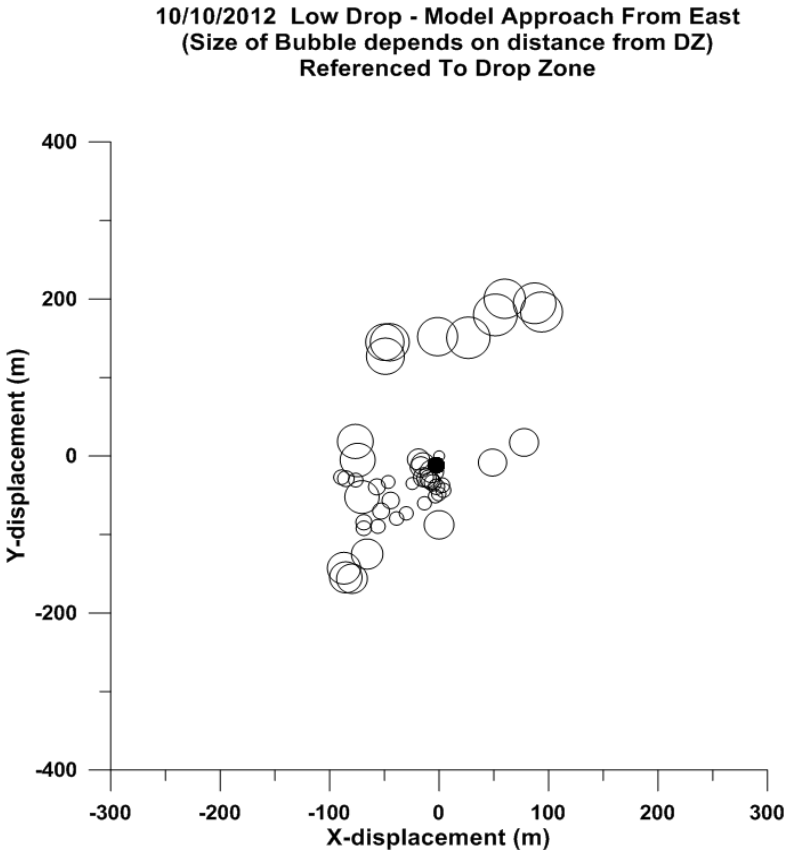


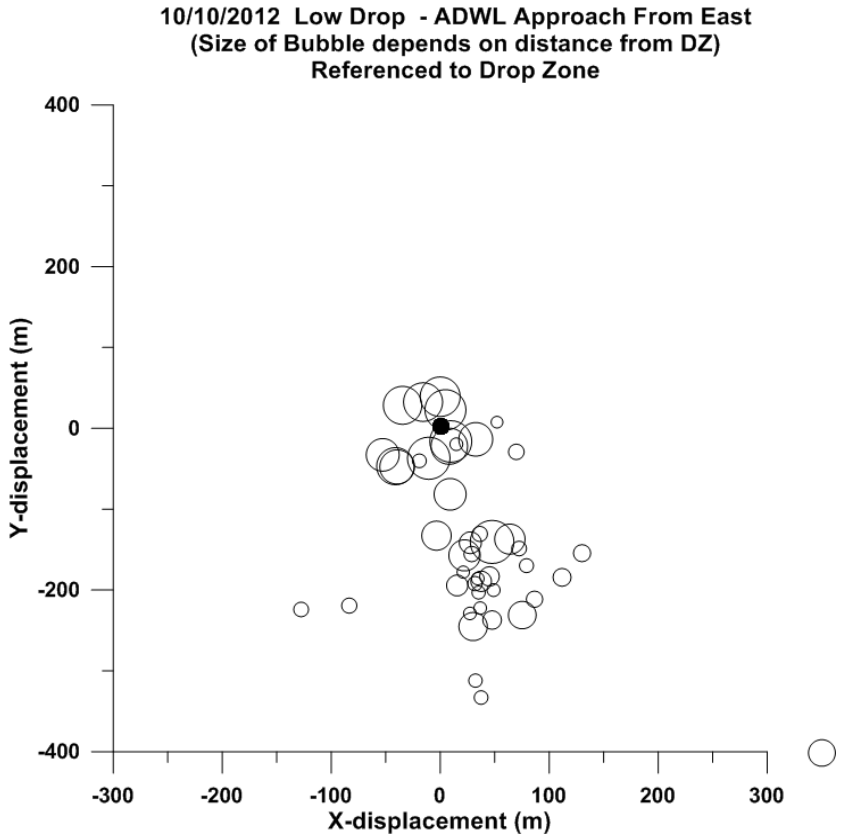


Size of circle is proportional to the linear distance to the DZ



Comparison between WRF and ADWL impact errors for 10/10/12 case





Conclusions

- Both WRF and ADWL soundings yield large scatter in the impact errors.
- Error in targeting does not necessarily improve with proximity to the DZ.
- Rather than a single, non-representative sounding, a line of soundings provides a superior basis for :
  - generating PDFs of likely bundle drifts derived from drop simulations applied to several (~30) independent wind profiles.
  - expressing the likelihood of success for drops of differing criticality.


Great Salt Lake
Salt Lake City
Tooele
Provo
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40
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6
Image Landsat
© 2015 Google
33.2 mi
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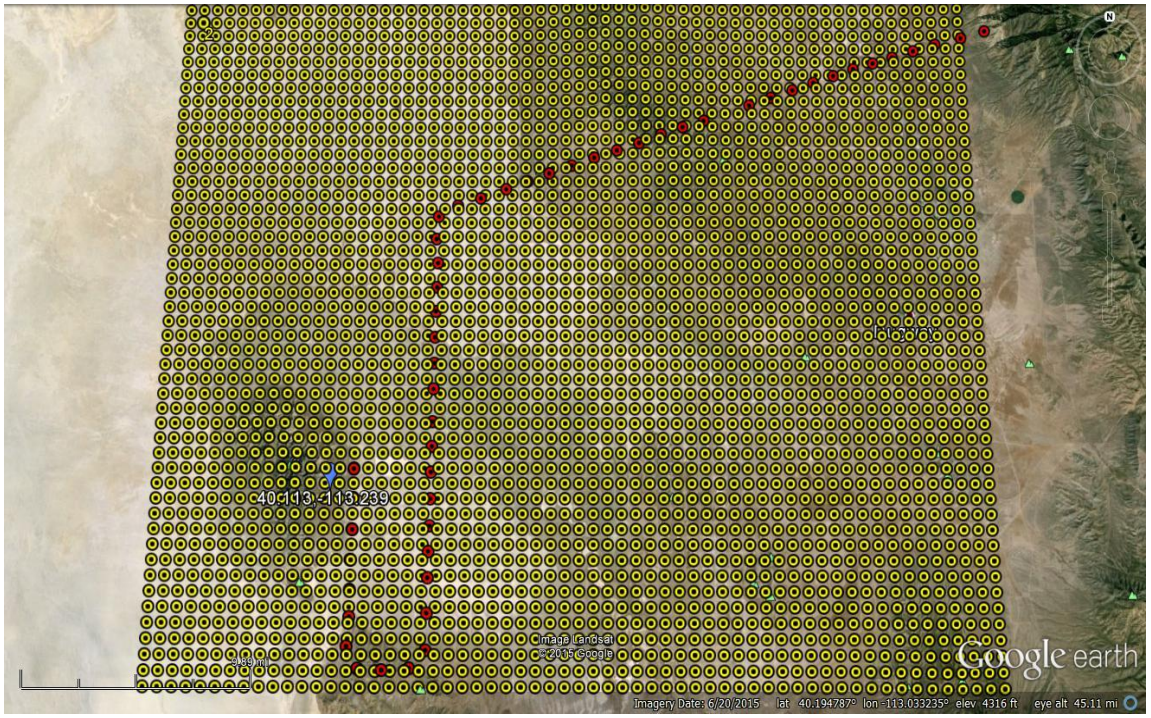
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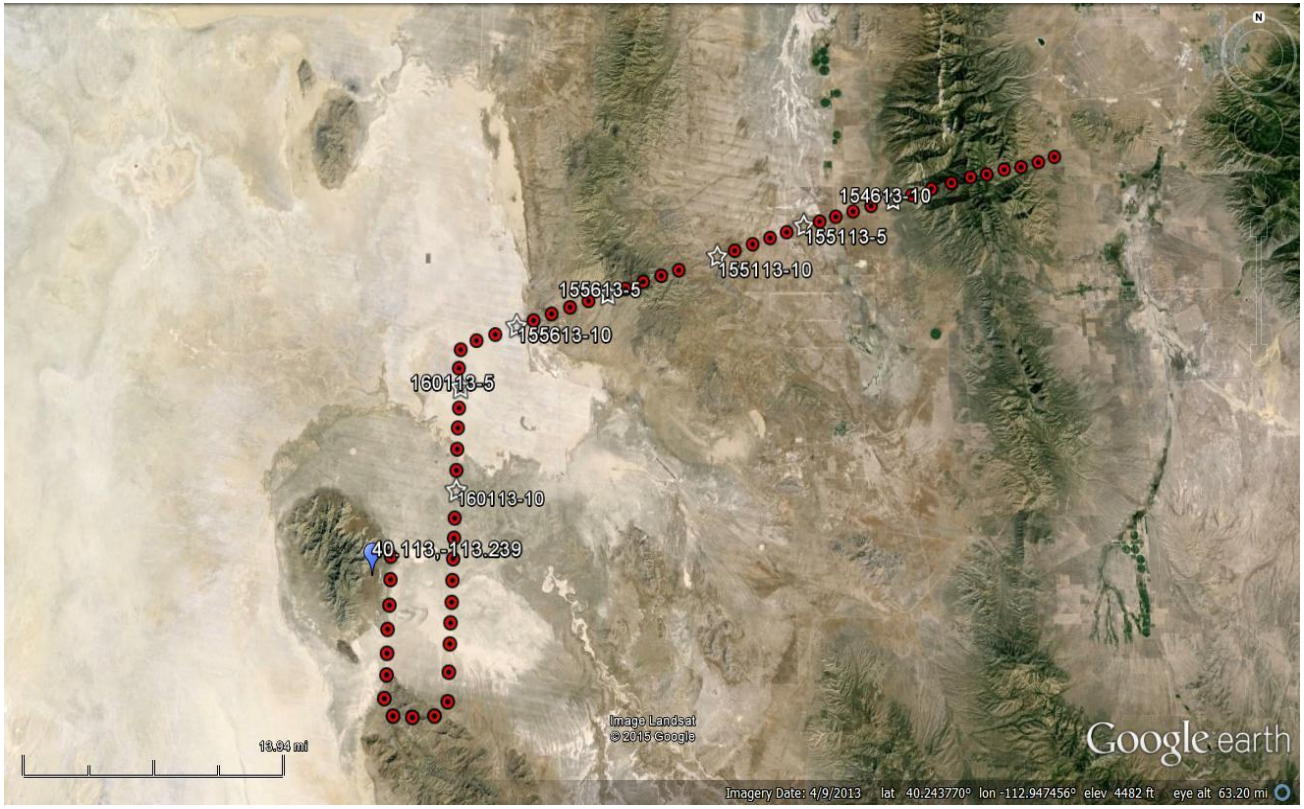
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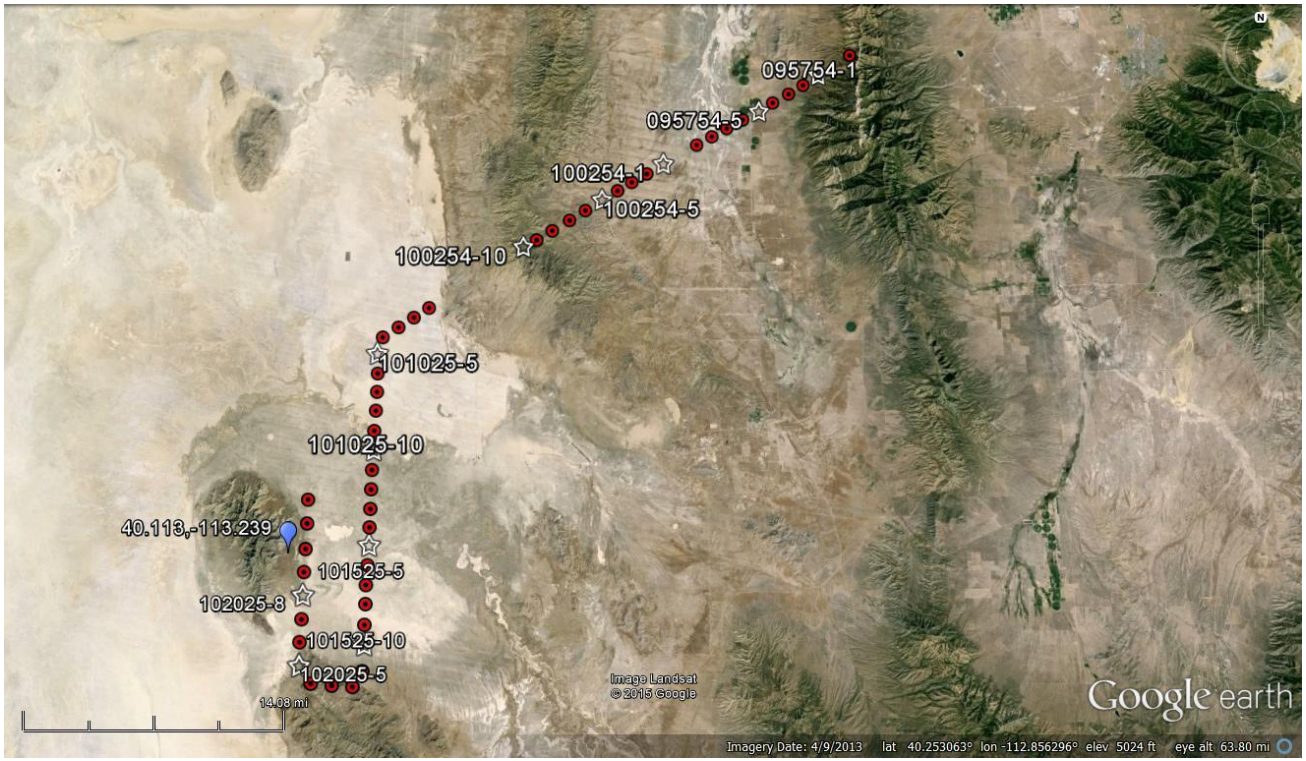
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© 2015 Google
Google earth
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