Using TODWL soundings to establish expectations for precision airdrops

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Objectives

- Use existing WRF model and TODWL (Twin Otter 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 TODWL wind soundings between 30nm out from the RP and within a kilometer of the RP?

Conclusions

- Both WRF and TODWL soundings yield large scatter in the impact errors.
- **Errors in targeting (Release Point calculations) do not necessarily improve with soundings taken closer to the DZ.**
- Use of a series of real (ADWL) soundings on approach to DZ will improve targeting over the use of model winds at target. This will require rapid and temporally relevant “last minute” adjustments to RP.
- Rather than a single, non-representative sounding, a series 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.

Assets

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

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 TODWL)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 TODWL 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	1	1	1
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 1 second
2. Main is opened 500 feet AGL

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

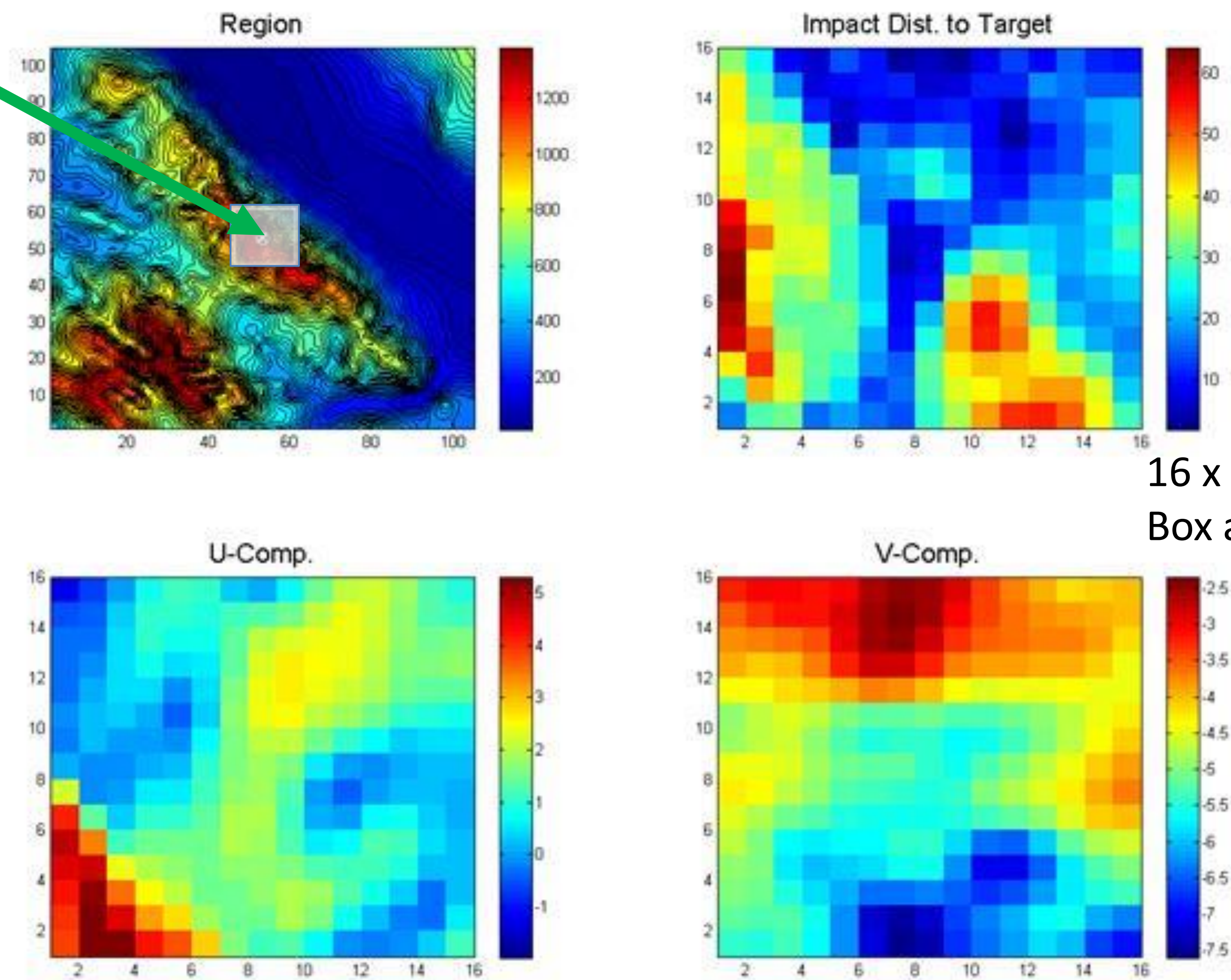
- Use individual WRF model grid point soundings closest to TODWL wind soundings to evaluate the variability of the BDFOM within the air drop simulation domain
- No instrument sampling or measurement errors
  - In the October cases, only spatial variability from the WRF model
- Used to illustrate the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



60

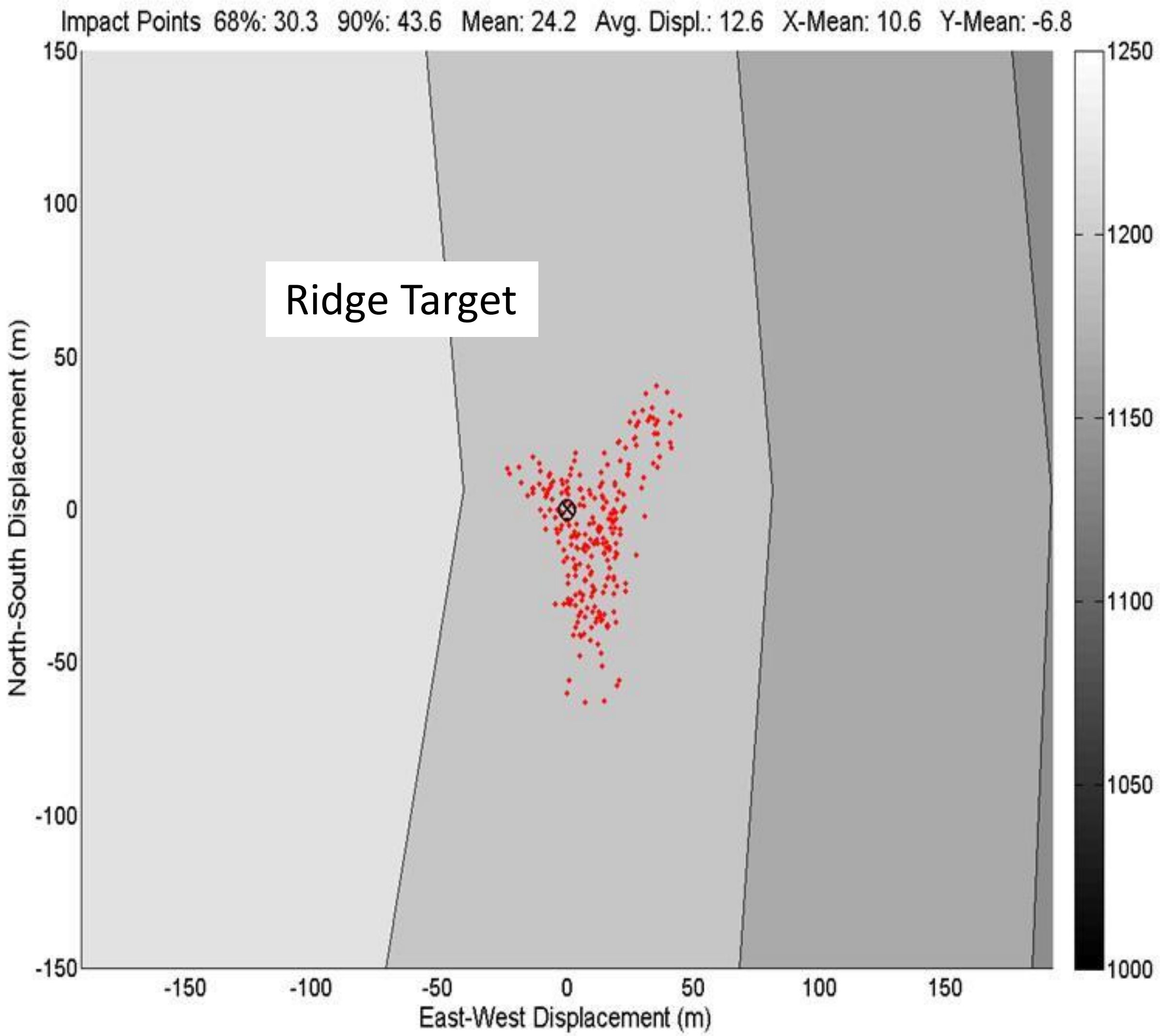
Distance (m)

0

16 x 16 km
Box around DZ

Winds (mps)
at 50m AGL

Impact Points for 10,000’ drop

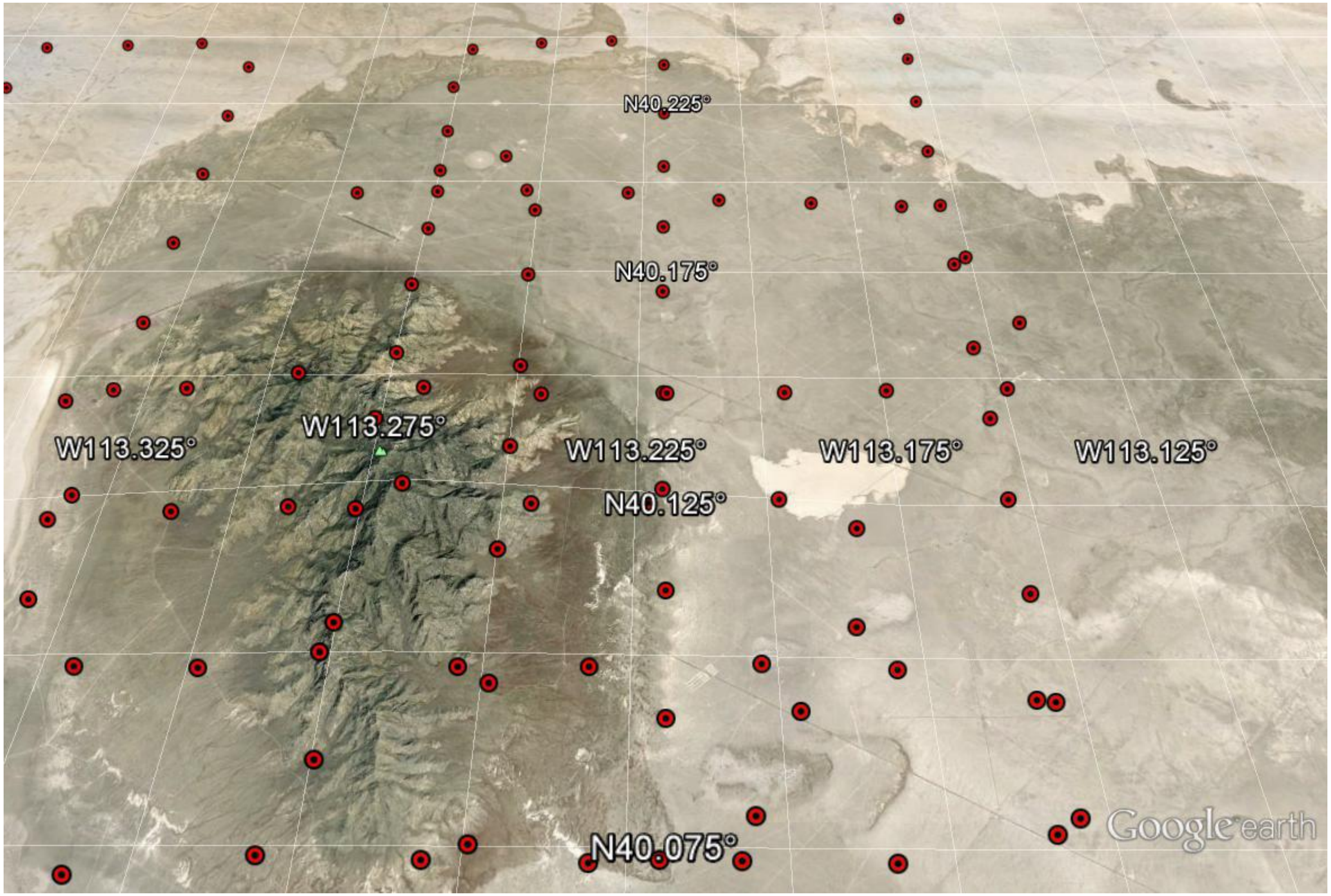


Terrain Height (meters MSL)

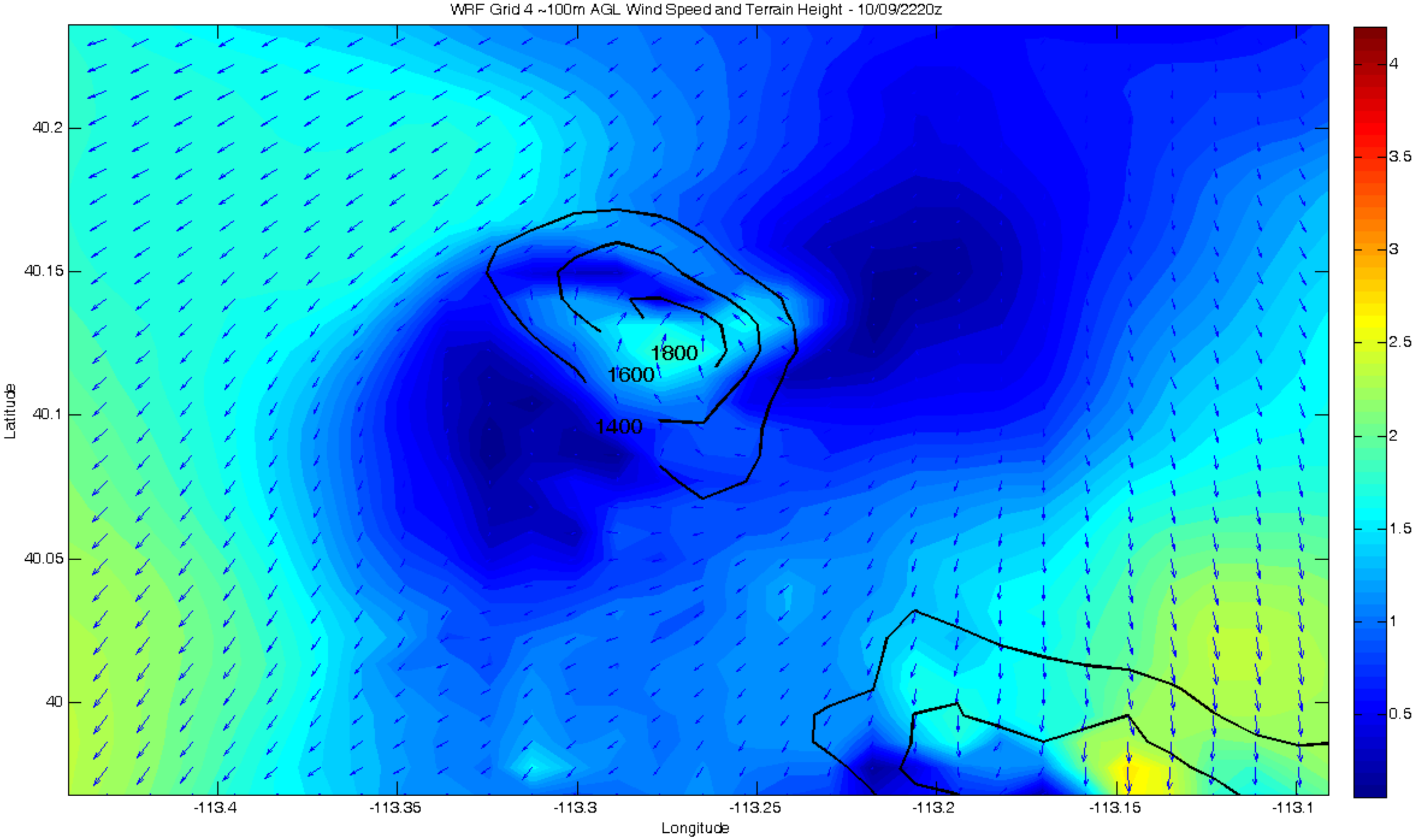
Dugway case study

- October 2012 during ONR/NSF MATERHORN experiment at Dugway Proving Grounds.
- 3000 TODWL sounding between Salt Lake City and Granite Mountain as well as over and around Granite Mountain. Only using soundings on approach to DPG and near PAWSII test site.
- Output from the WRF model for the same period of time.

Granite Mountain, DPG



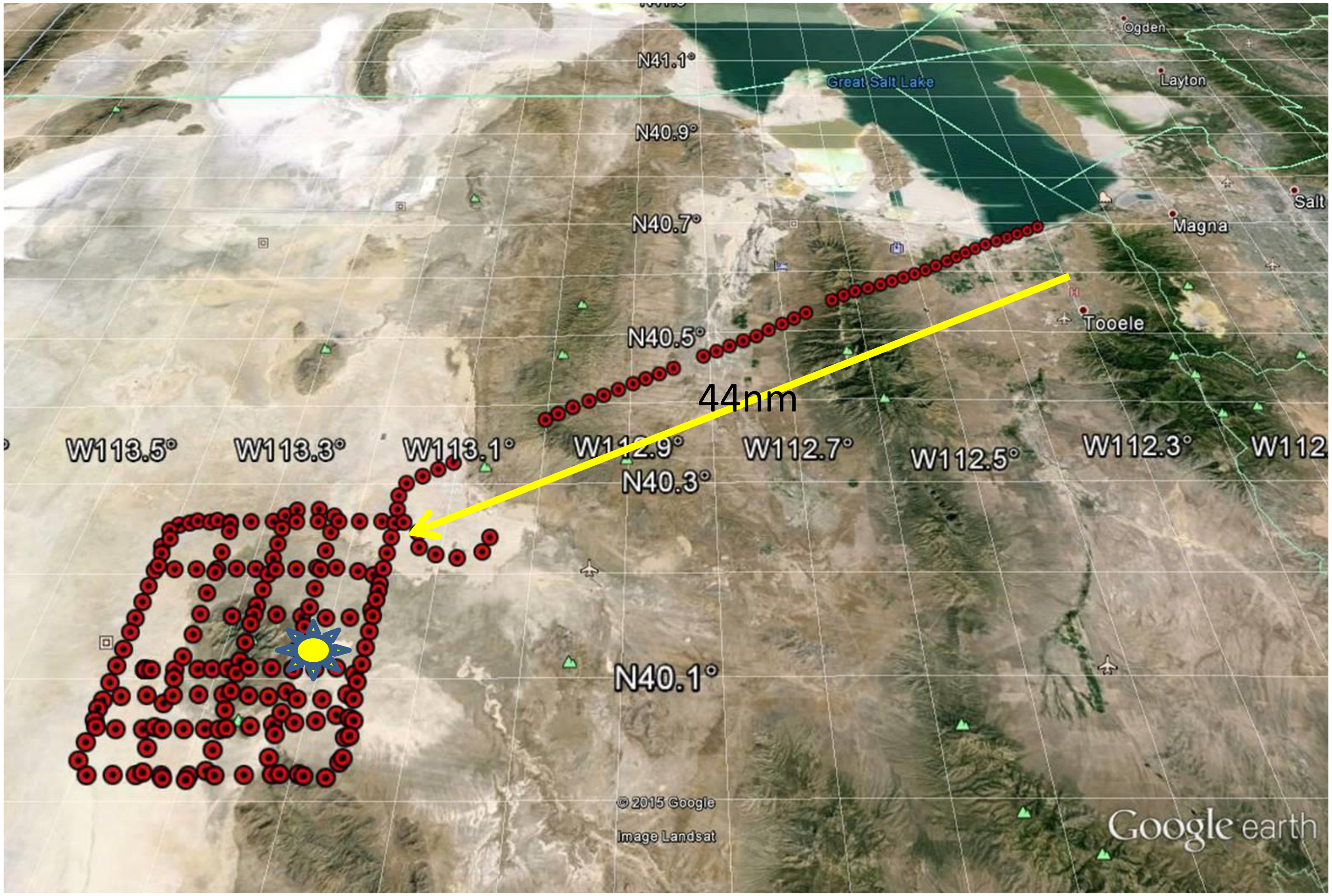
Example of WRF model output winds (100m agl) around Granite Mountain



Dugway case studies

- October 06,09,10 and 17, 2012 during ONR/NSF MATERHORN experiment at Dugway Proving Grounds.
- TODWL 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 PAWSII operations site.
- Output from the WRF model for the same period of time and along the same path as TODWL.

TODWL wind sounding locations October 10, 2012

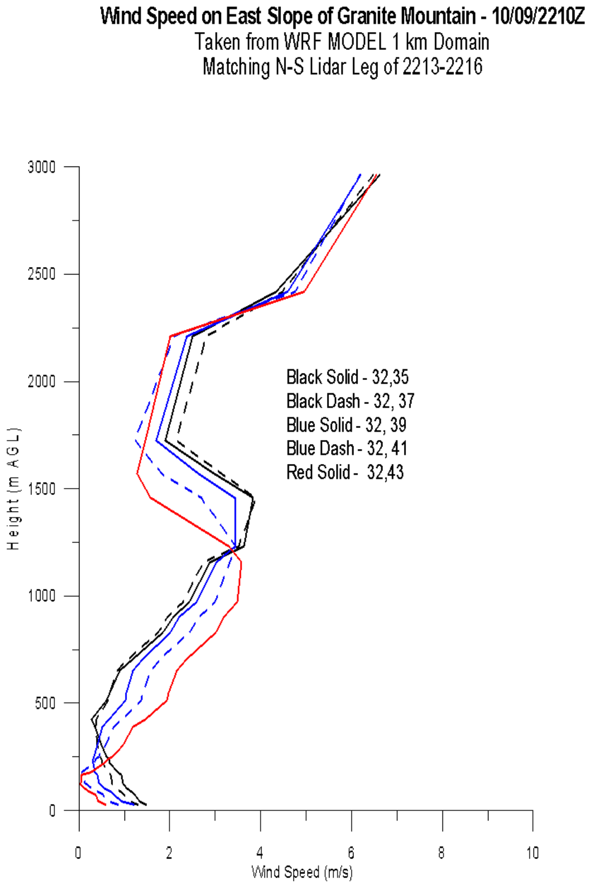


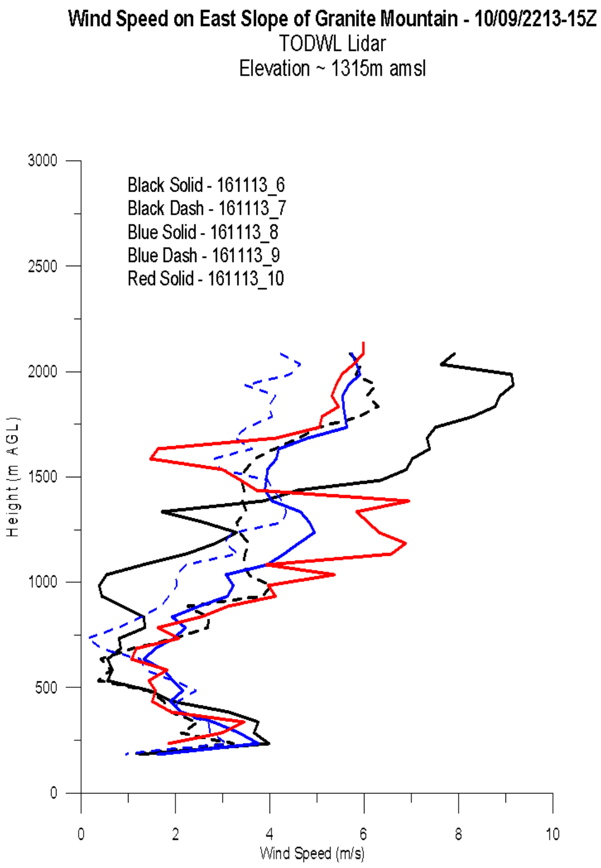
WRF/TODWL wind profile comparisons

- Example case for DZ location close to the PAWSII 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 TODWL sounding.

Replace

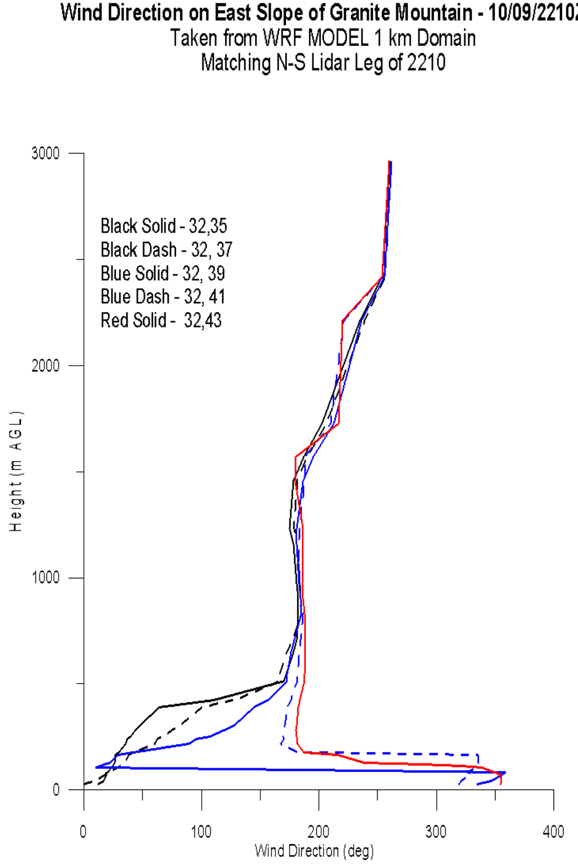
East Slope Wind Speed from TODWL and WRF

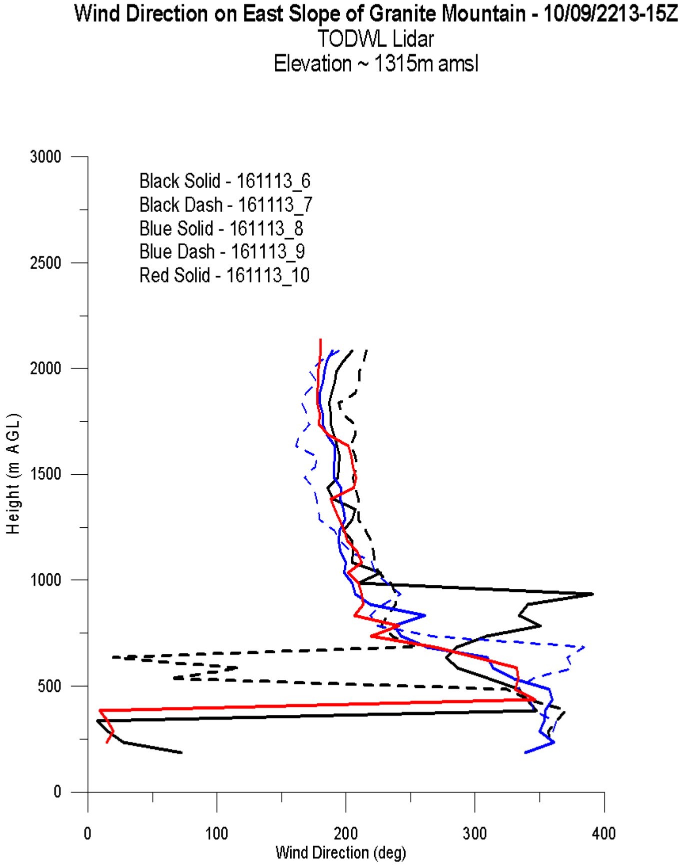




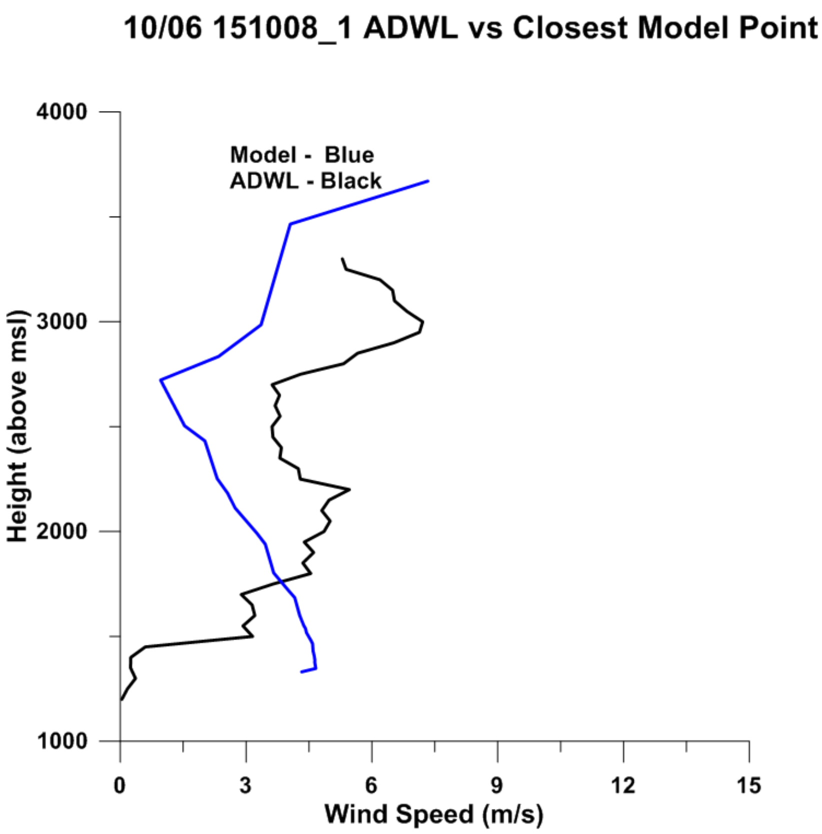
Replace

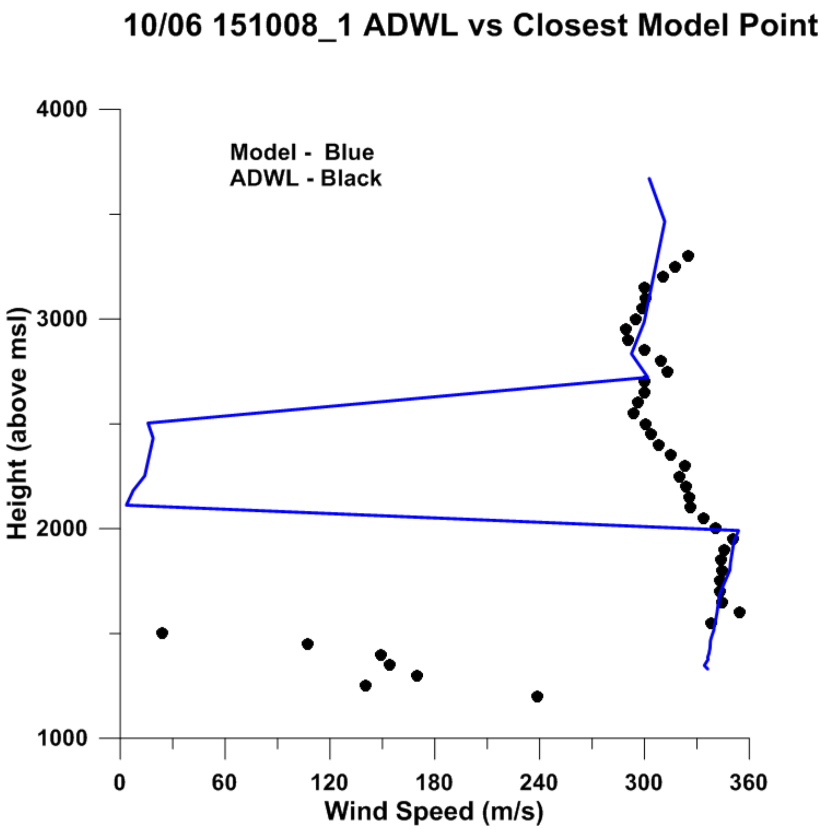
East Slope Wind Dir. from TODWL and WRF



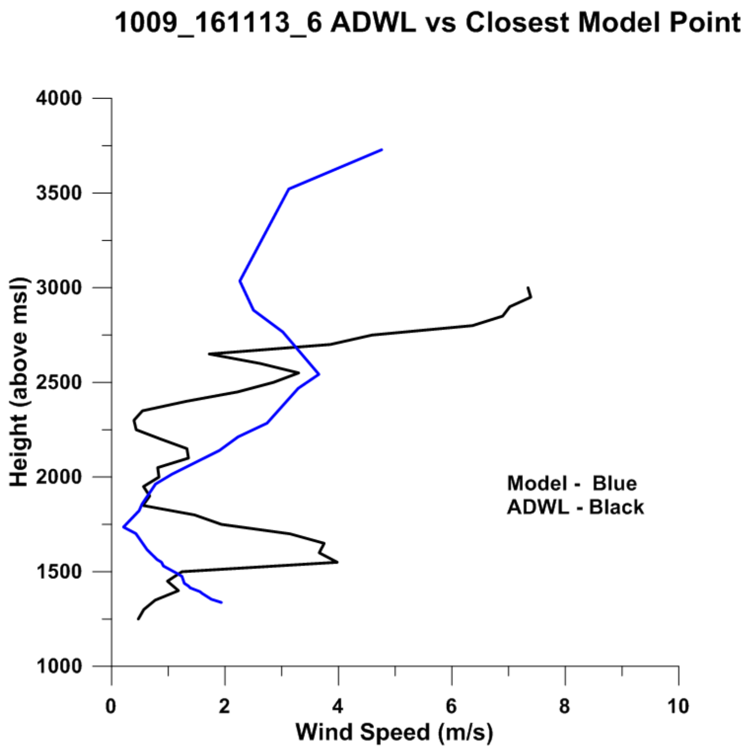


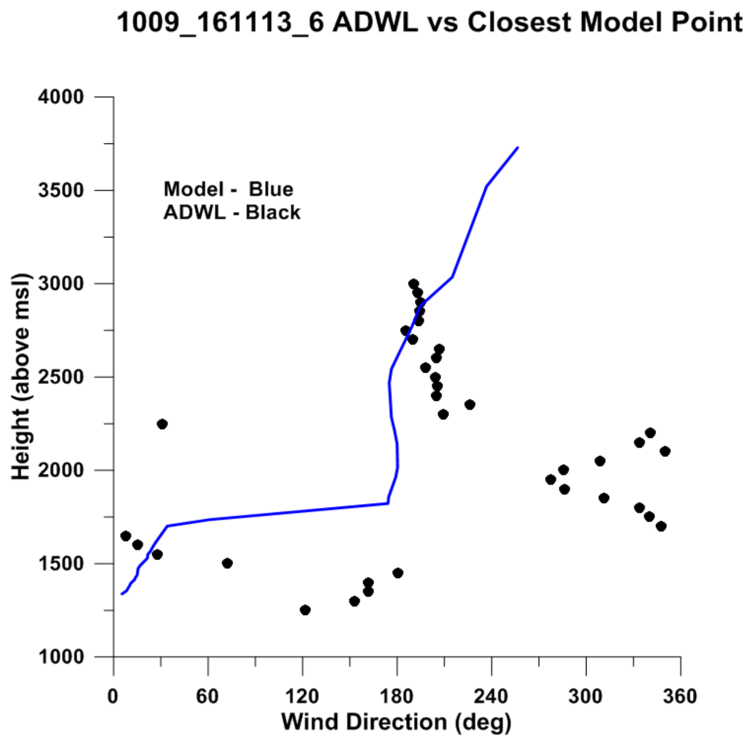
10/06/12 wind profiles at DZ



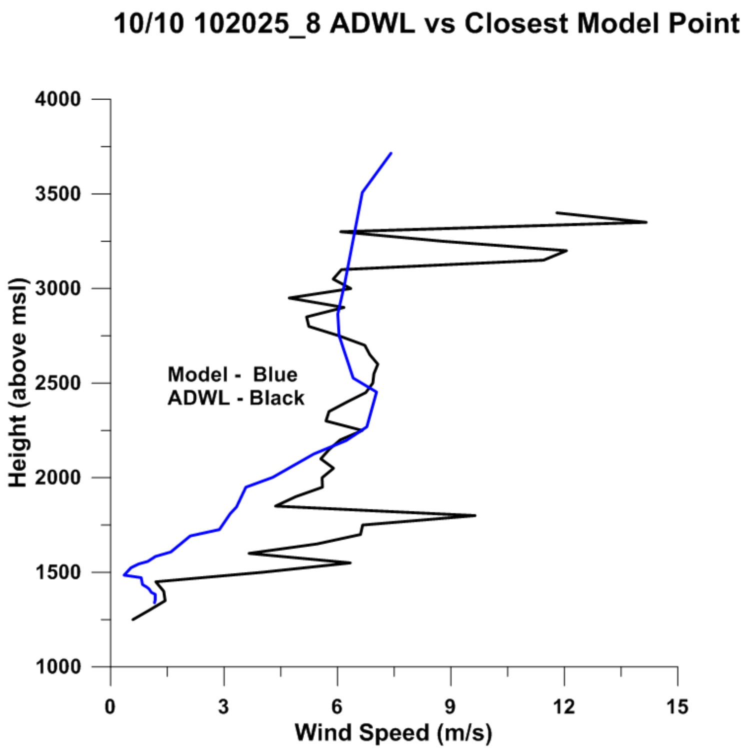


10/09/12 at DZ

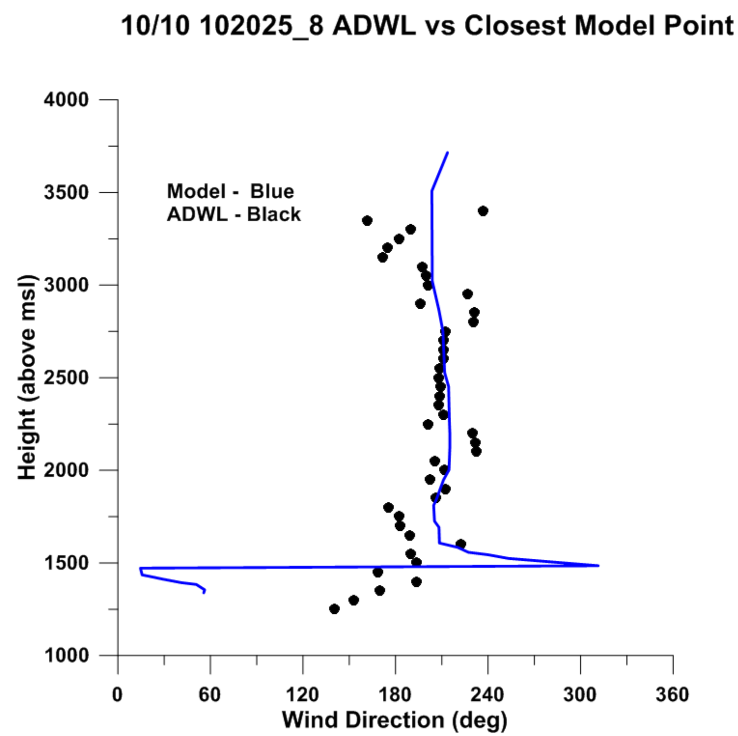

1009_161113_6 ADWL vs Closest Model Point
Height (above msl)
4000
3500
3000
2500
2000
1500
1000
0
2
4
6
8
10
Wind Speed (m/s)
Model - Blue
ADWL - Black


1009_161113_6 ADWL vs Closest Model Point
Height (above msl)
4000
3500
3000
2500
2000
1500
1000
0
60
120
180
240
300
360
Wind Direction (deg)
Model - Blue
ADWL - Black

10/10/12 at DZ



10/10 102025_8 ADWL vs Closest Model Point
Model - Blue
ADWL - Black
Height (above msl)
Wind Speed (m/s)
4000
3500
3000
2500
2000
1500
1000
0
3
6
9
12
15

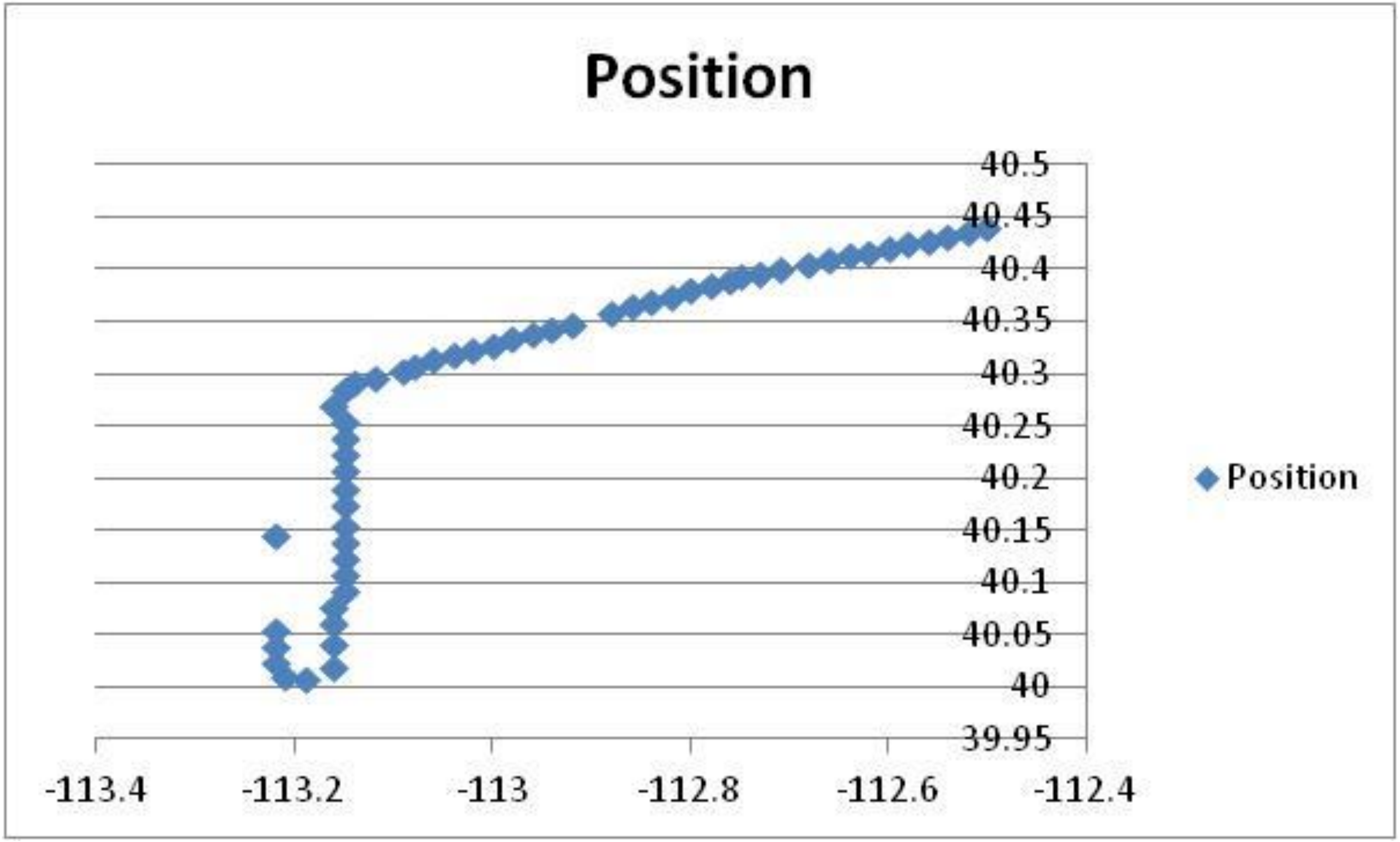


10/10 102025_8 ADWL vs Closest Model Point
Model - Blue
ADWL - Black
Height (above msl)
Wind Direction (deg)
4000
3500
3000
2500
2000
1500
1000
0
60
120
180
240
300
360

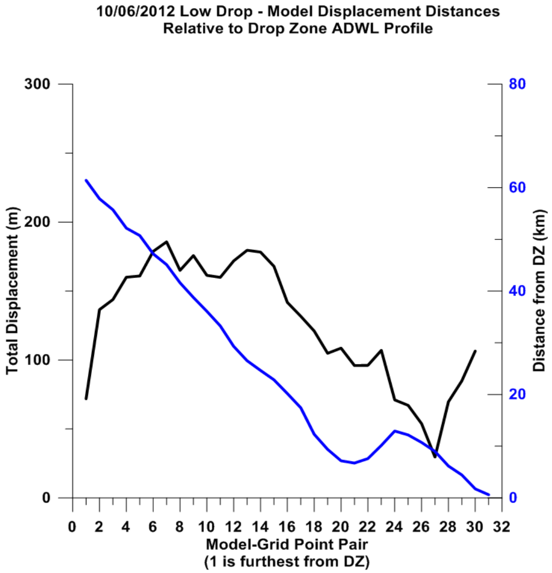
Setup for WRF simulations of BDFOM

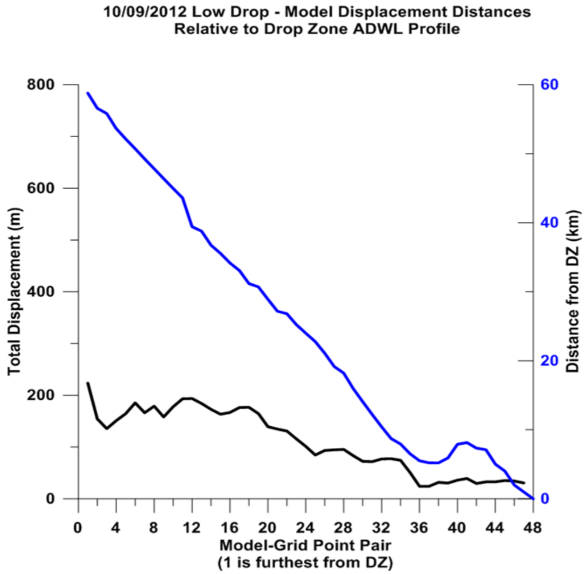
- Locate the WRF soundings nearest to those obtained with the TODWL on an approach path to the Granite Mountain test area.
- Compute BDFOM for drops from 10000’ to the surface; also from 17500’ to the surface.

Example approach to Granite Mtn. (08/09/15)

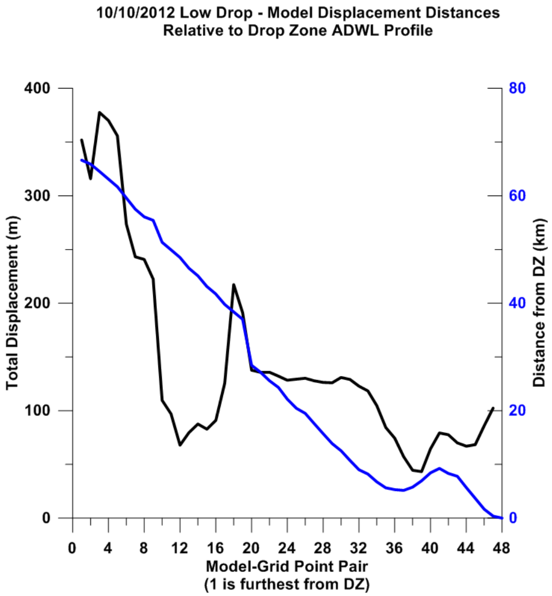


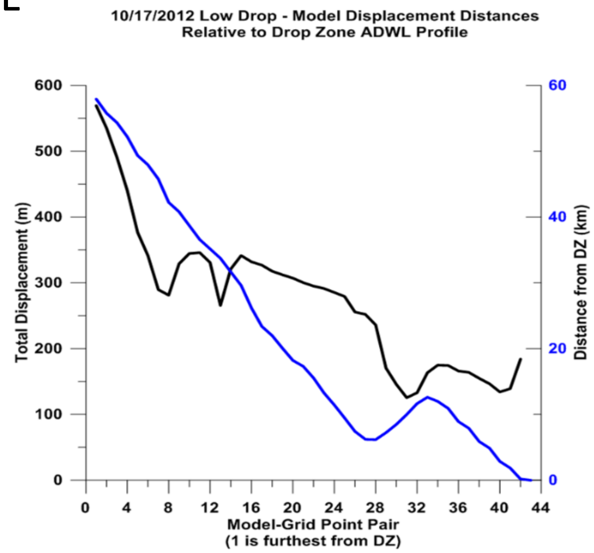
Approach timeline using model

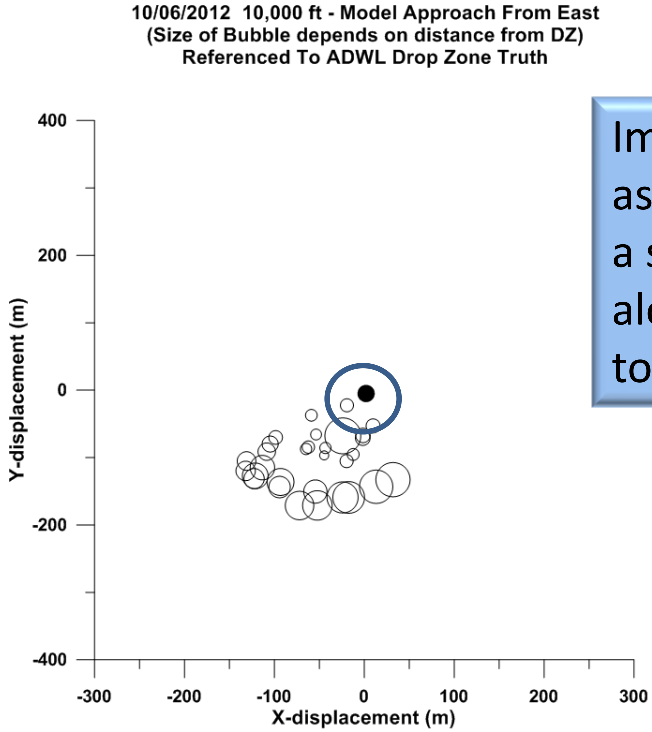




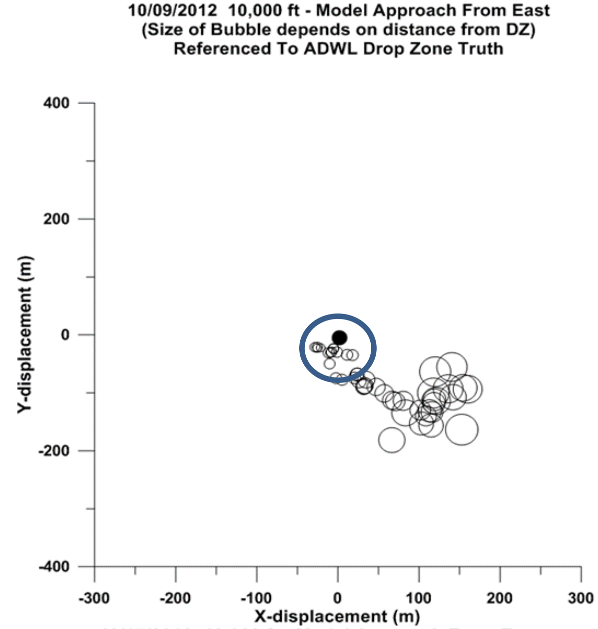
Note: True winds at DZ are those obtained with TODWL



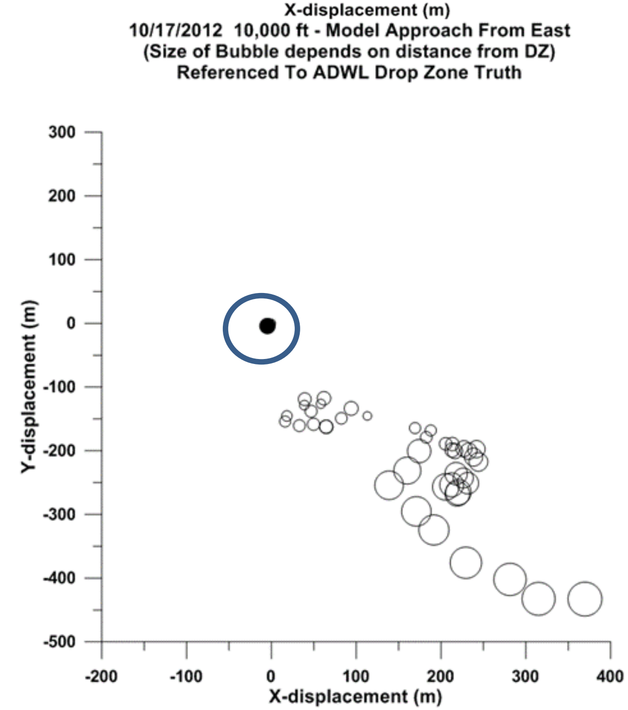


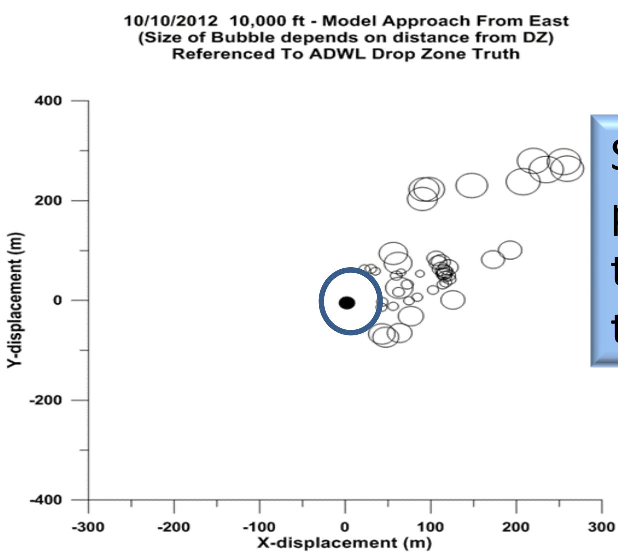


Impact errors associated with a series of profiles along the approach to the DZ



50m radius drop zone

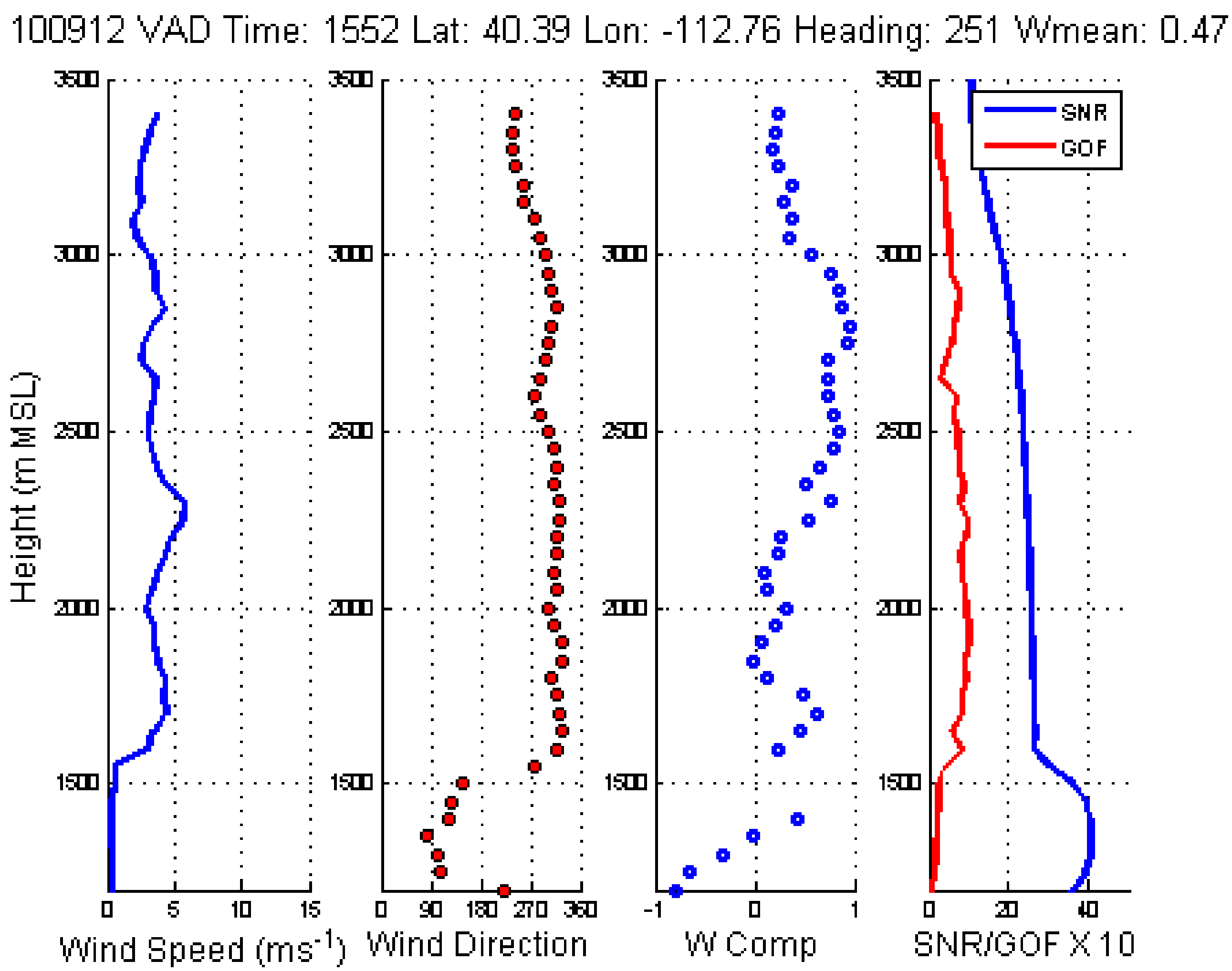




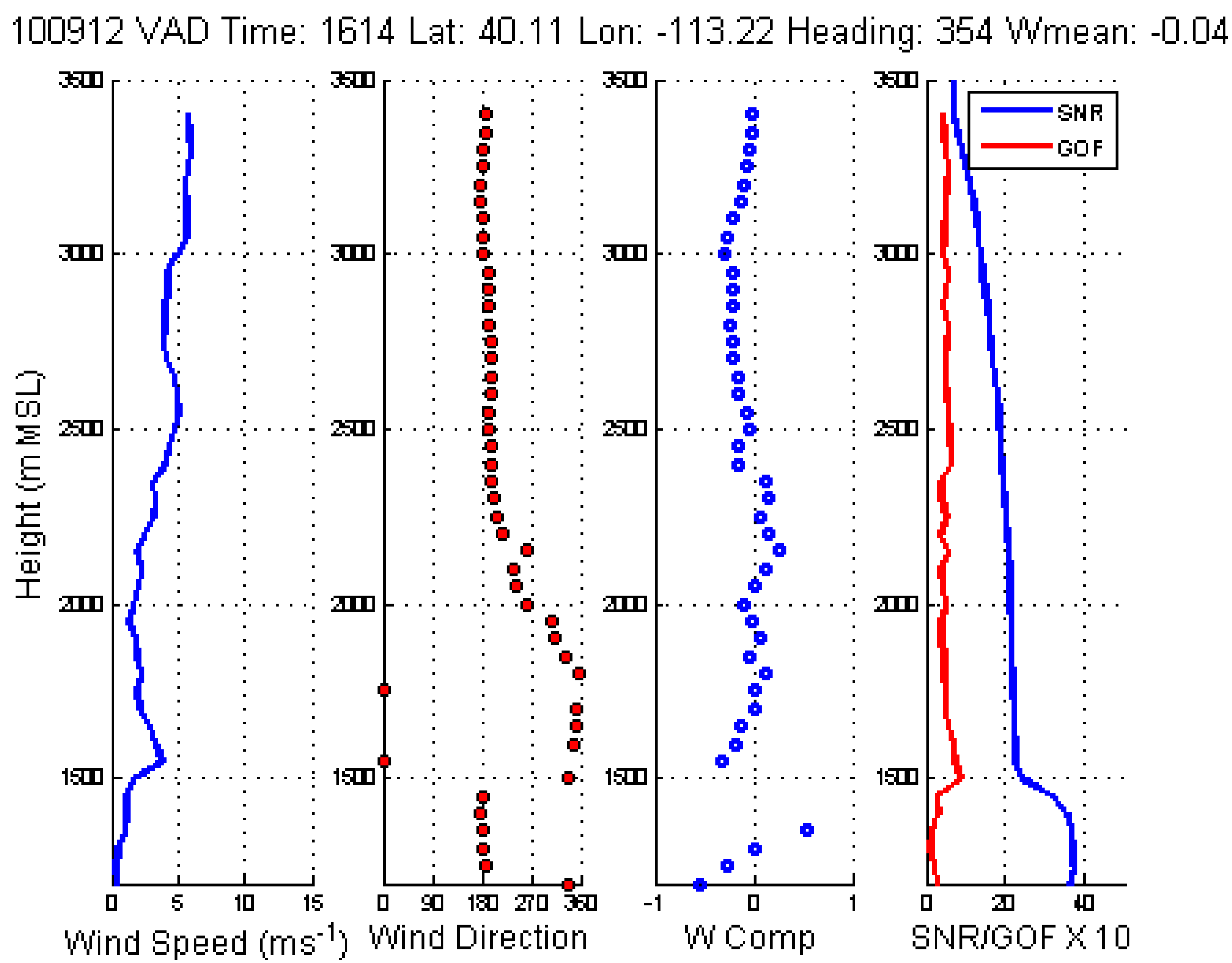
Size of circle is proportional to the linear distance to the DZ

Impact errors based upon TODWL profiles

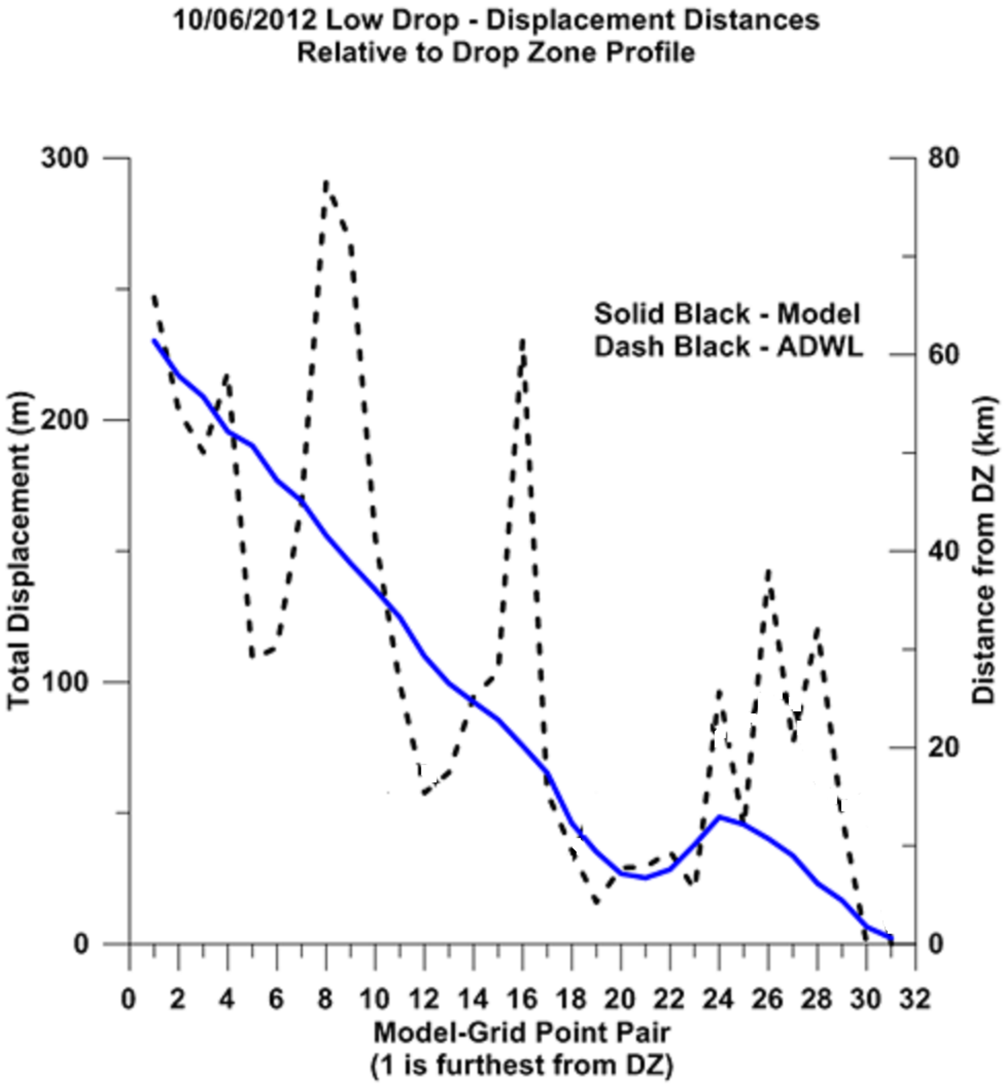
TODWL sounding on approach to MATERHORN control site

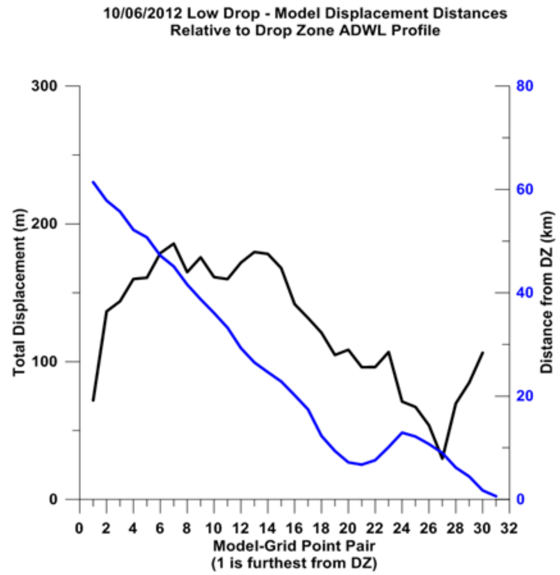


TODWL sounding near DZ

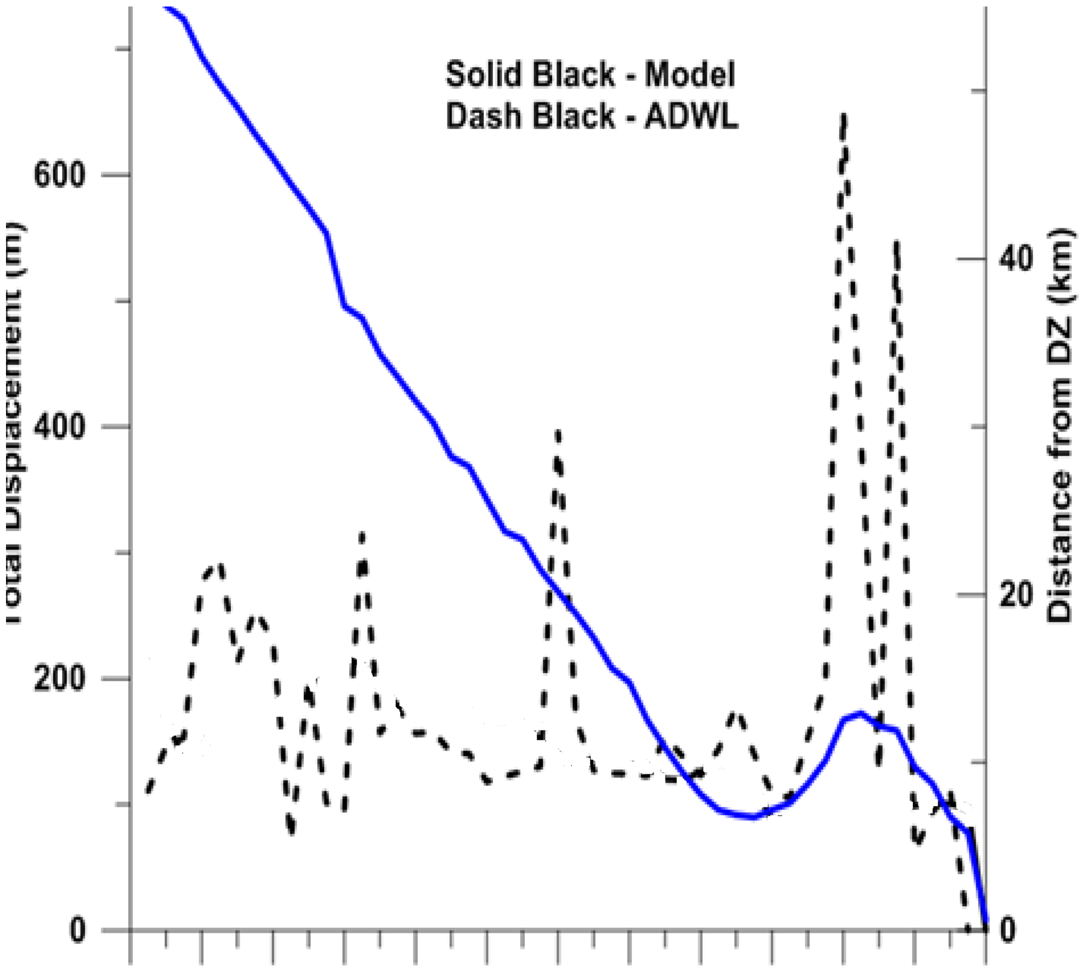


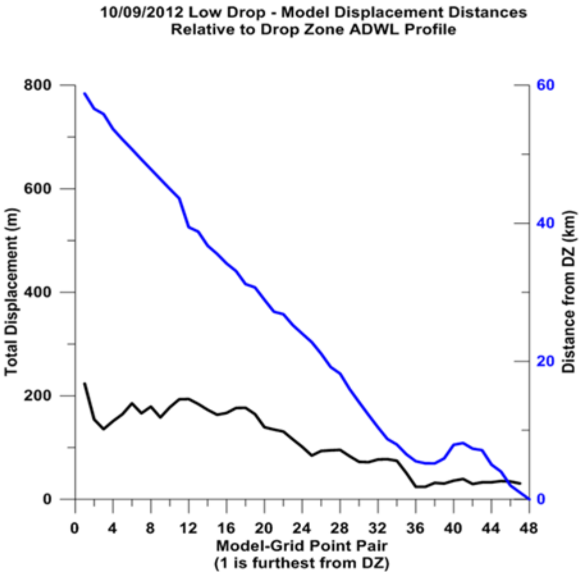
10/06/12 approach time line



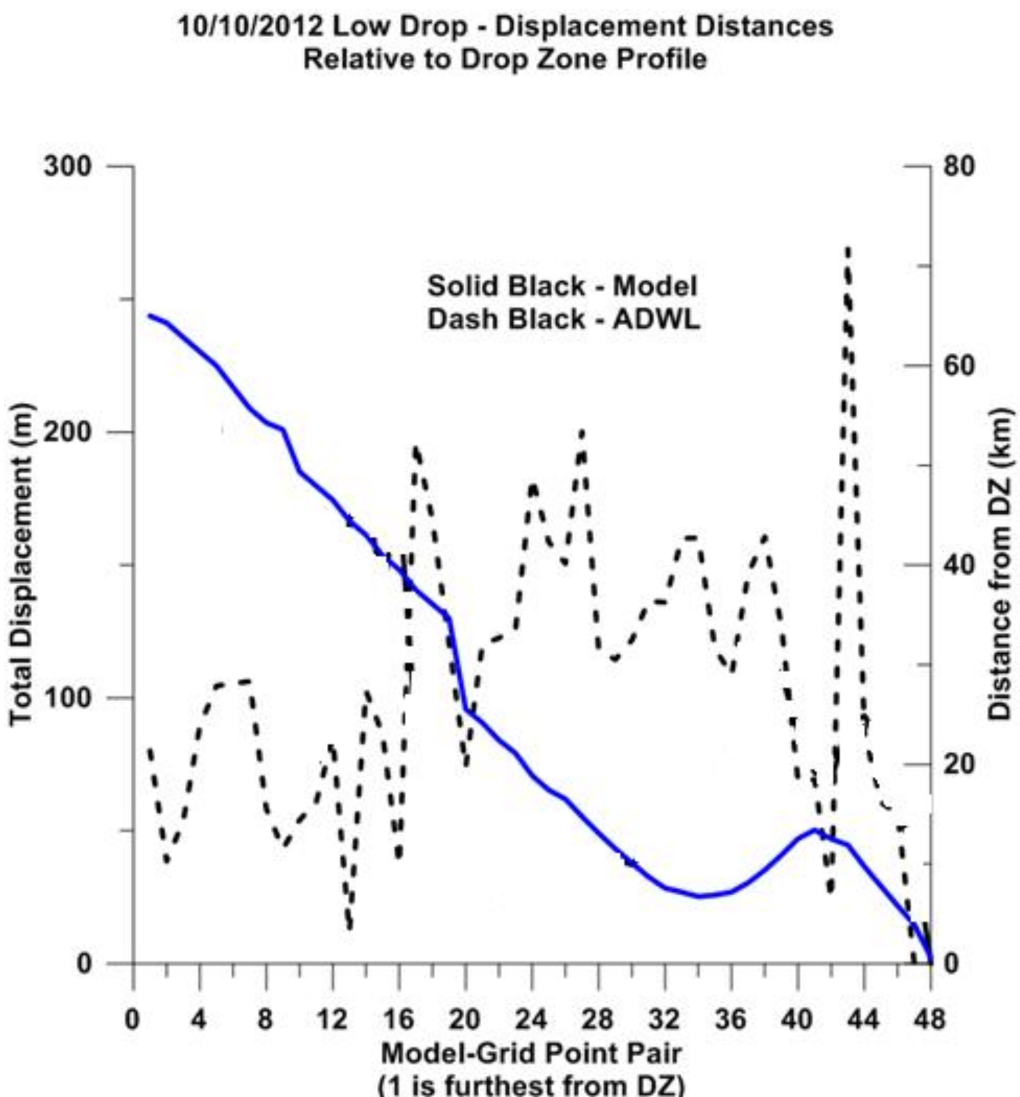


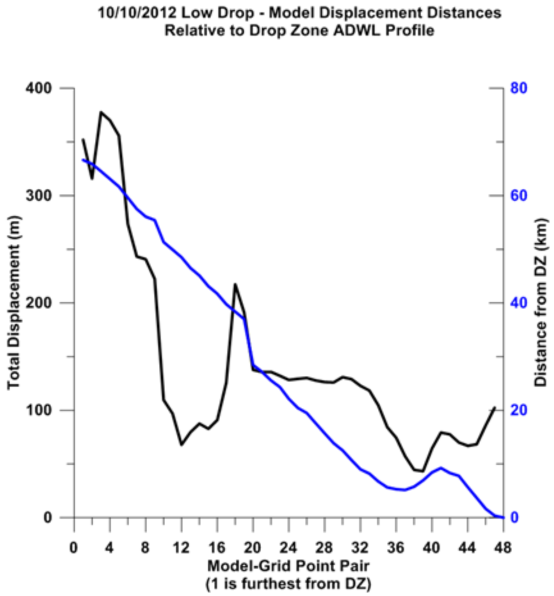
10/09/12 approach time line



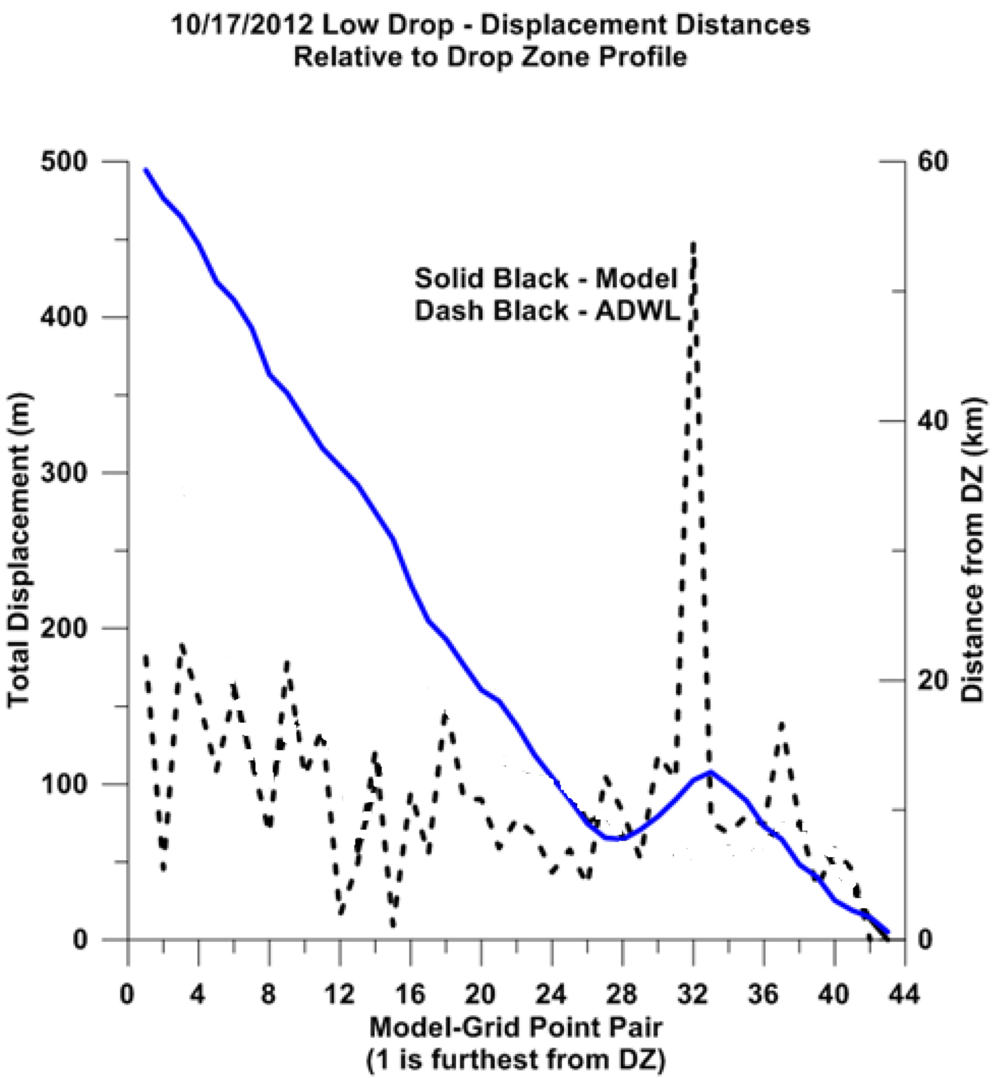


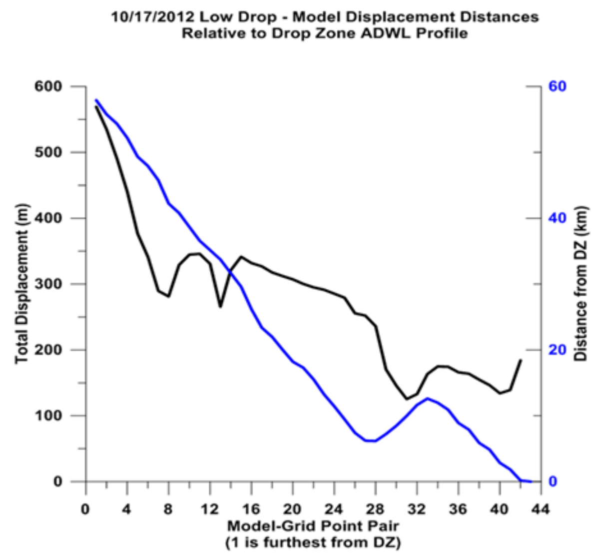
10/10/12 approach time line

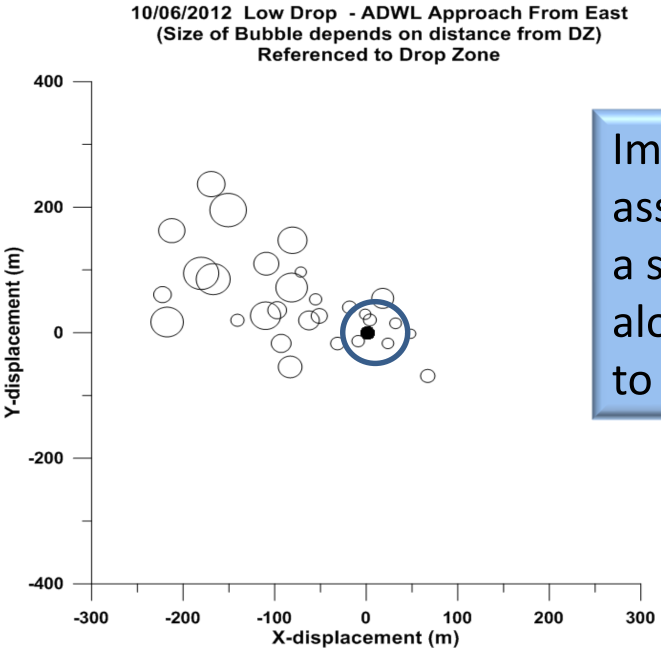




10/17/12 approach time line







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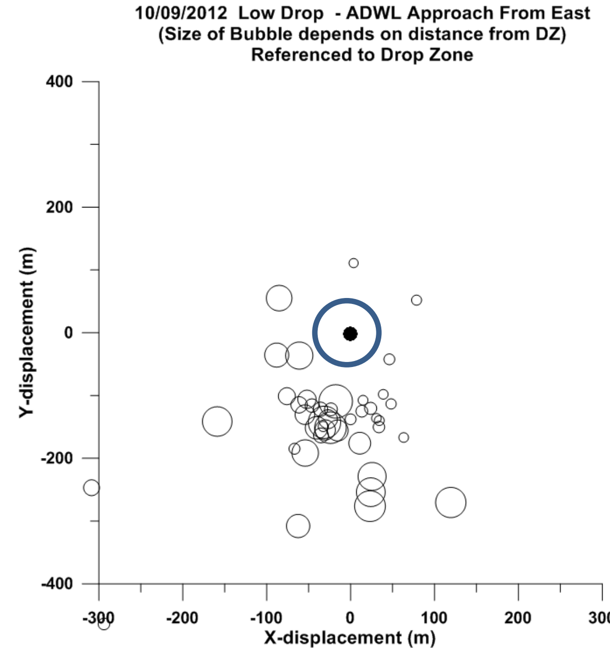
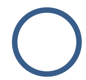
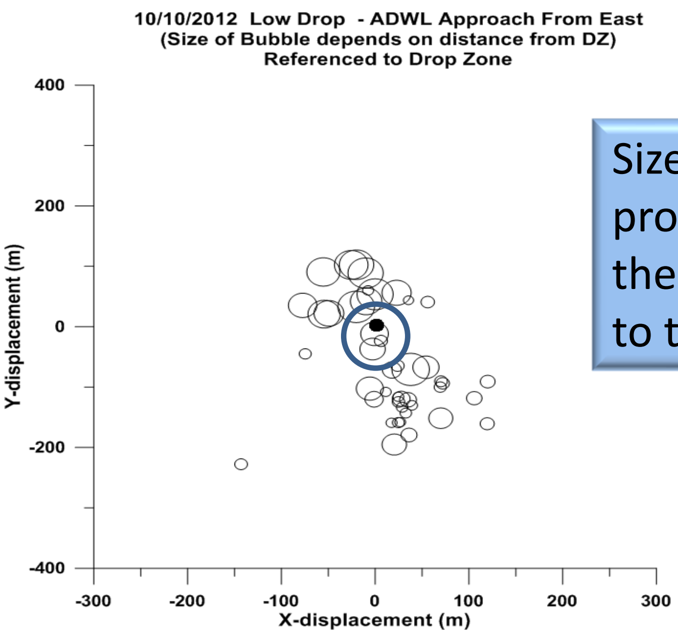
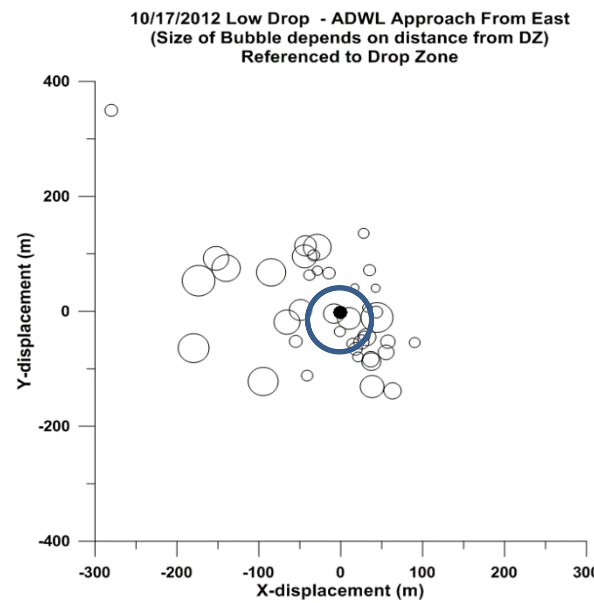




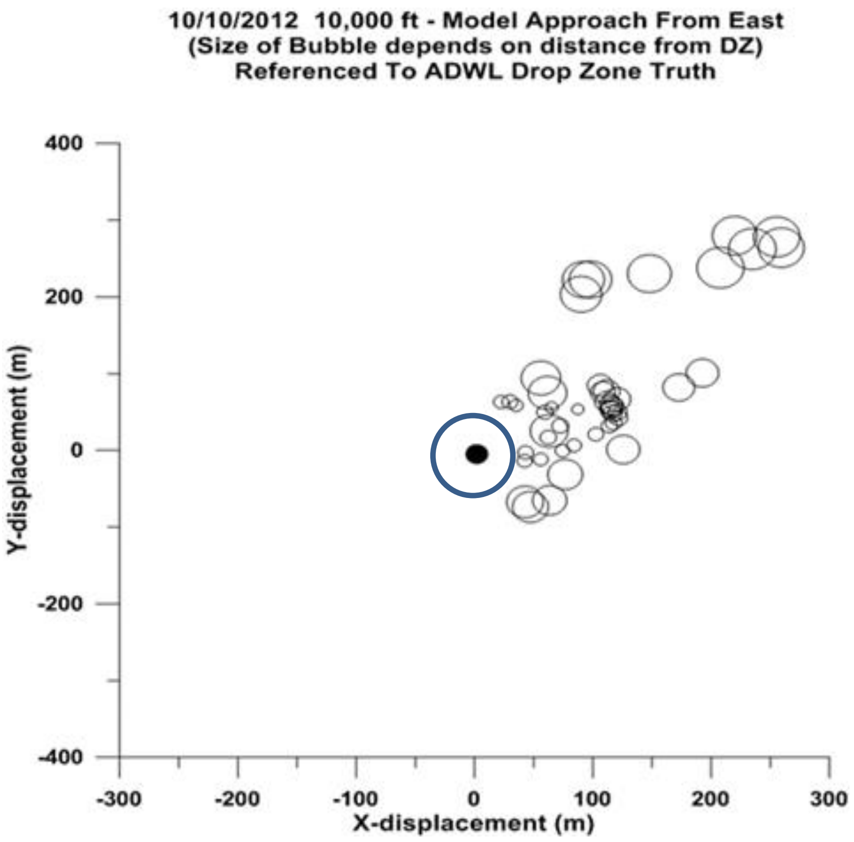
50m radius drop zone

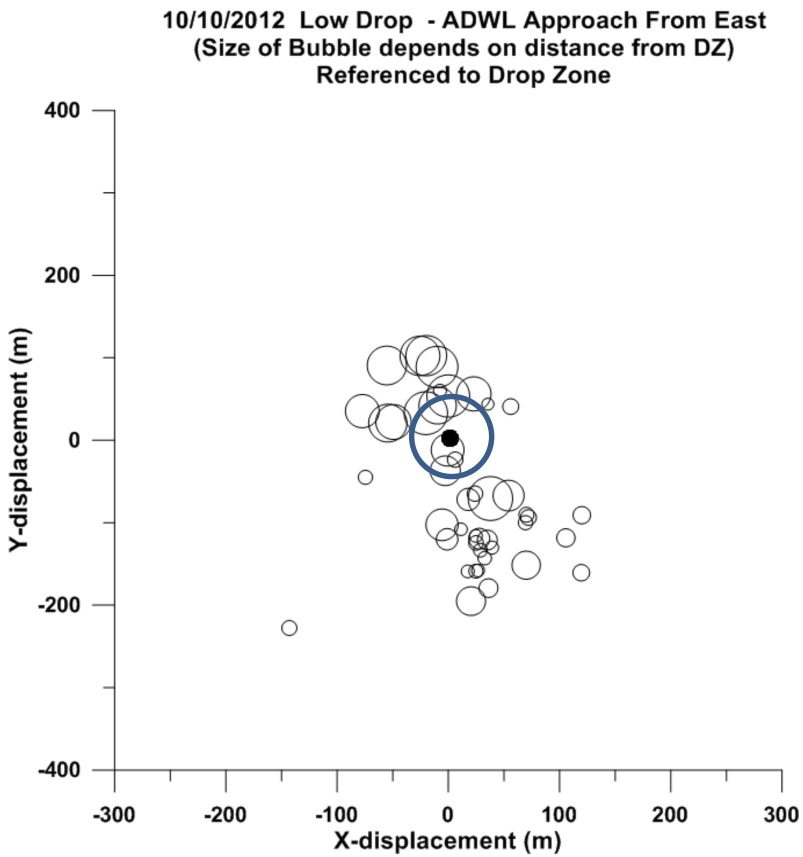


Size of circle is proportional to the linear distance to the DZ



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





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