Application of Triple Doppler Wind LiDARs for the Study of Atmospheric Boundary Layer over a Mountainous Area

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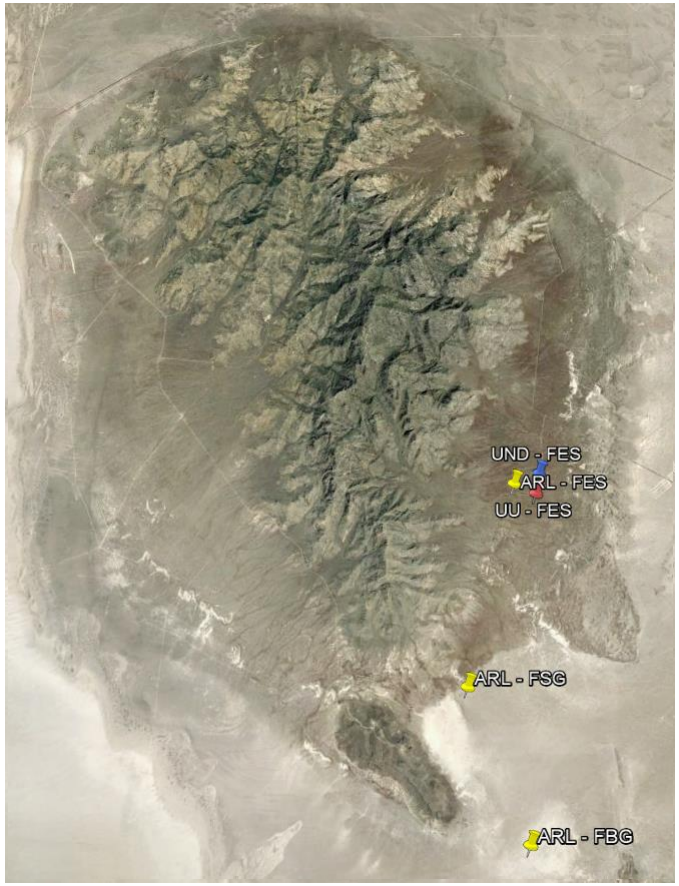
Presentation to MATERHORN Investigator Meeting (10/09/2014)

ARL Participation in MATERHORN

- Participated in both MATERHORN-X field campaigns

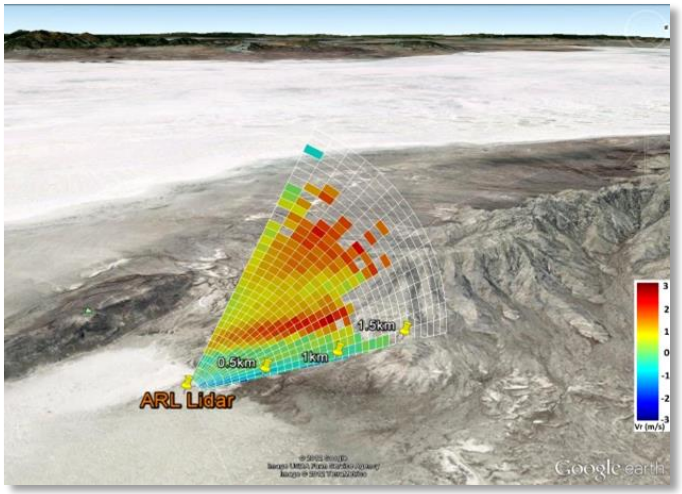
- **MATERHORN X-1 (Fall 2012):**
  IOPs 1 - 3 at Small Gap
  IOPs 4 - 6 at East Slope*
  IOPs 7 - 9 at Big Gap

- **MATERHORN X-2 (Spring 2013):**
  IOPs 4 - 6 at East Slope*
  IOPs 7 - 10 at NE of Granite Peak

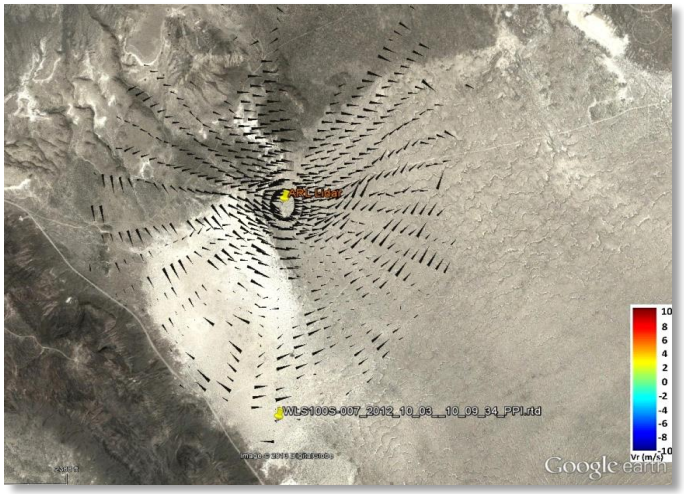


* IOPs: triple LiDAR coordinated scans with UND and UU

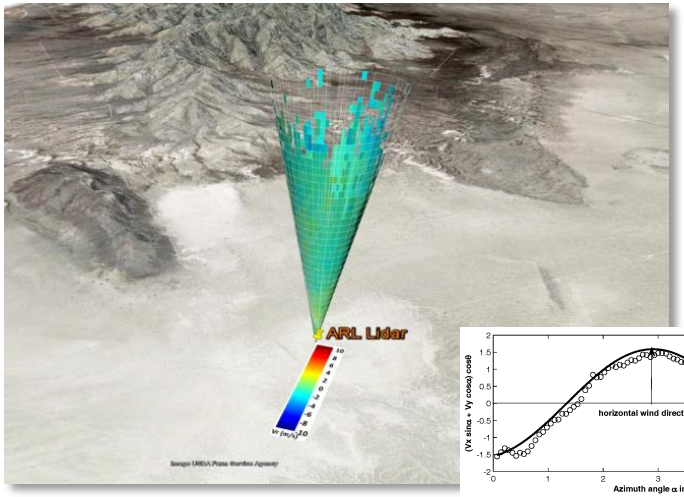
MATERHORN X-1 Locations and Scanning Patterns

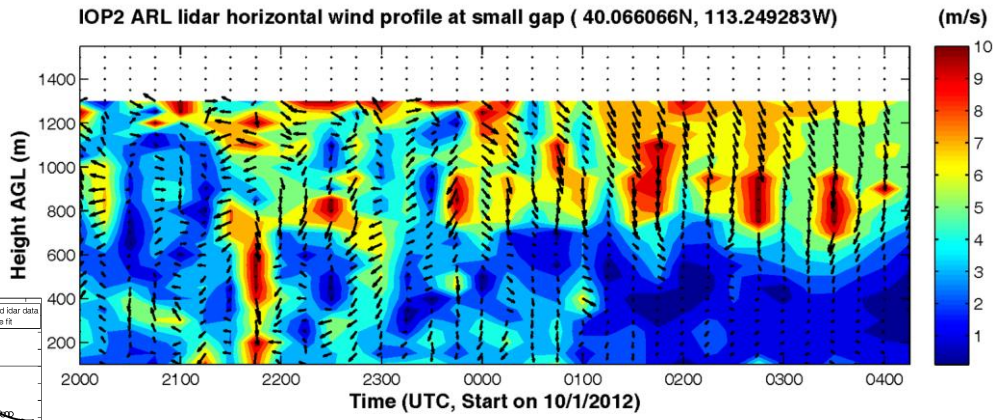


RHI at Small Gap



Near Ground PPI at Small Gap





VAD (PPI) at Big Gap

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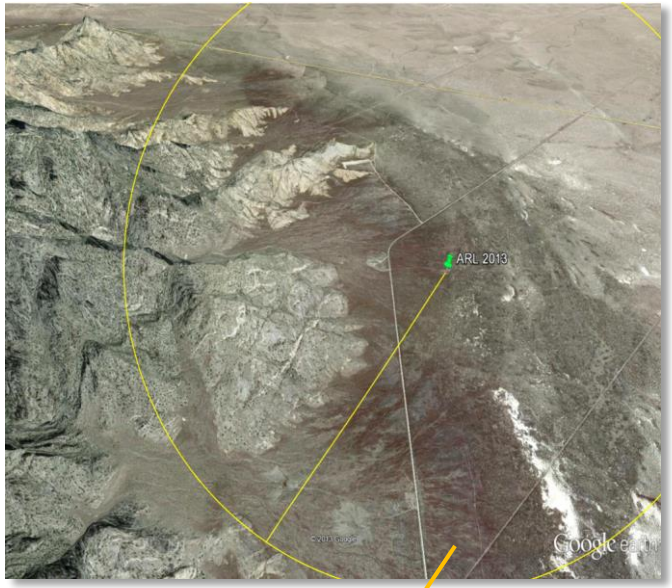
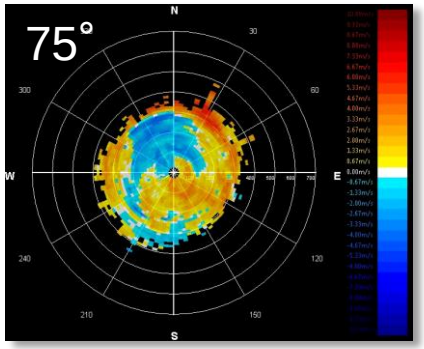
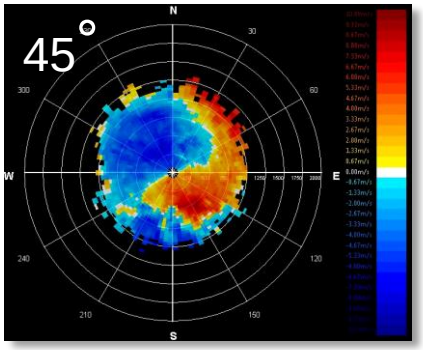
MATERHORN X-2 Locations and Scanning Patterns

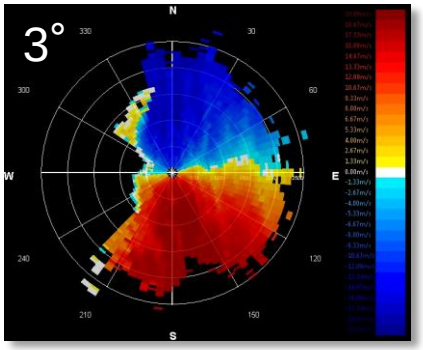
ARL



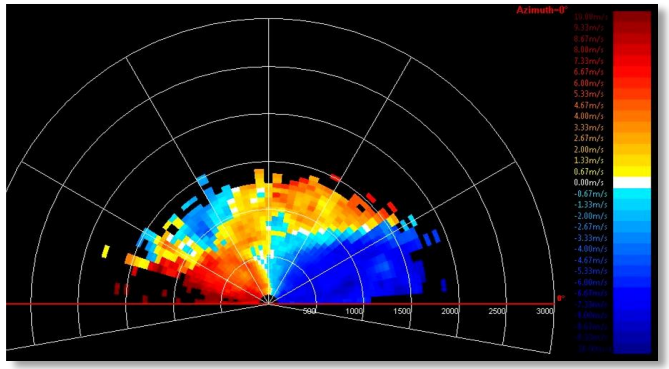
PPI Scans



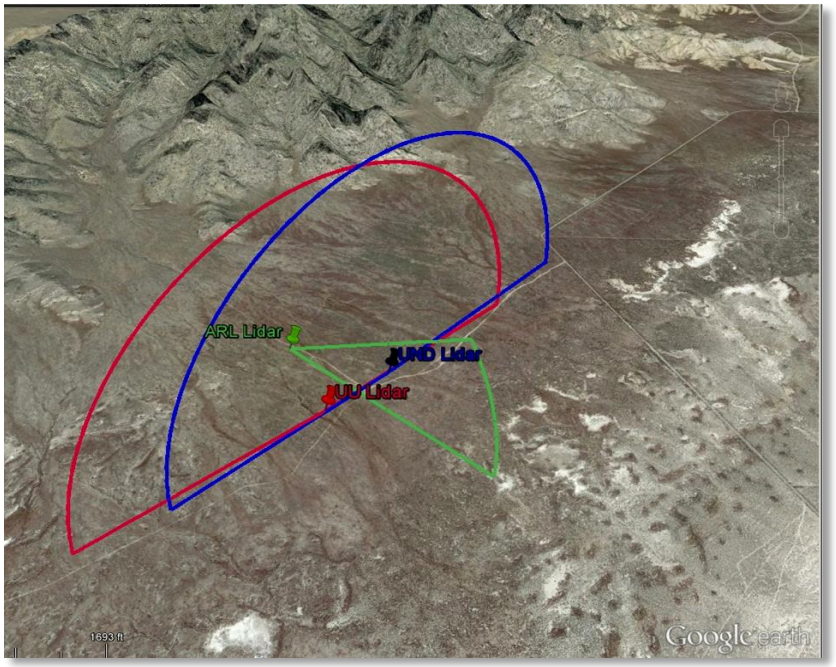




RHI Scans



Triple LiDAR Scans at East Slope MATERHORN X-1



LiDARs:

ARL: Leosphere Windcube 100s

UND/UU: Halo Photonics Stream Line

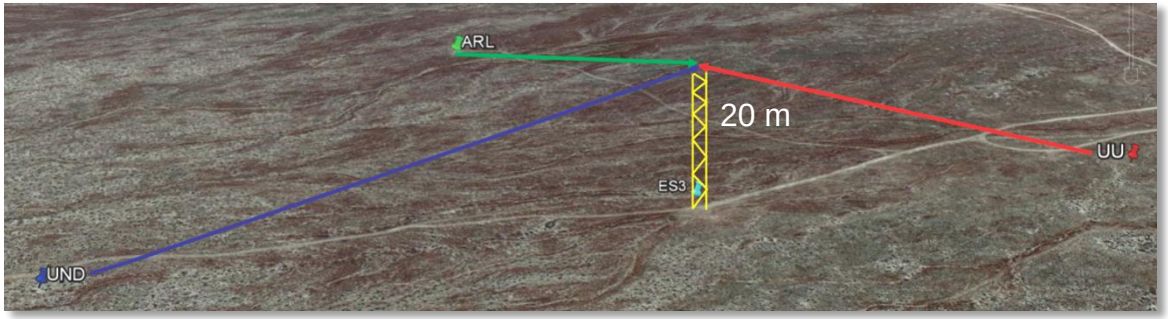
Setup:

- ARL LiDAR scanned RHI downslope towards ES2 tower
- UND and UU LiDARs scanned coplanar RHI
- Data used for virtual tower if all three LiDAR beams crossed within 5 s

Challenges:

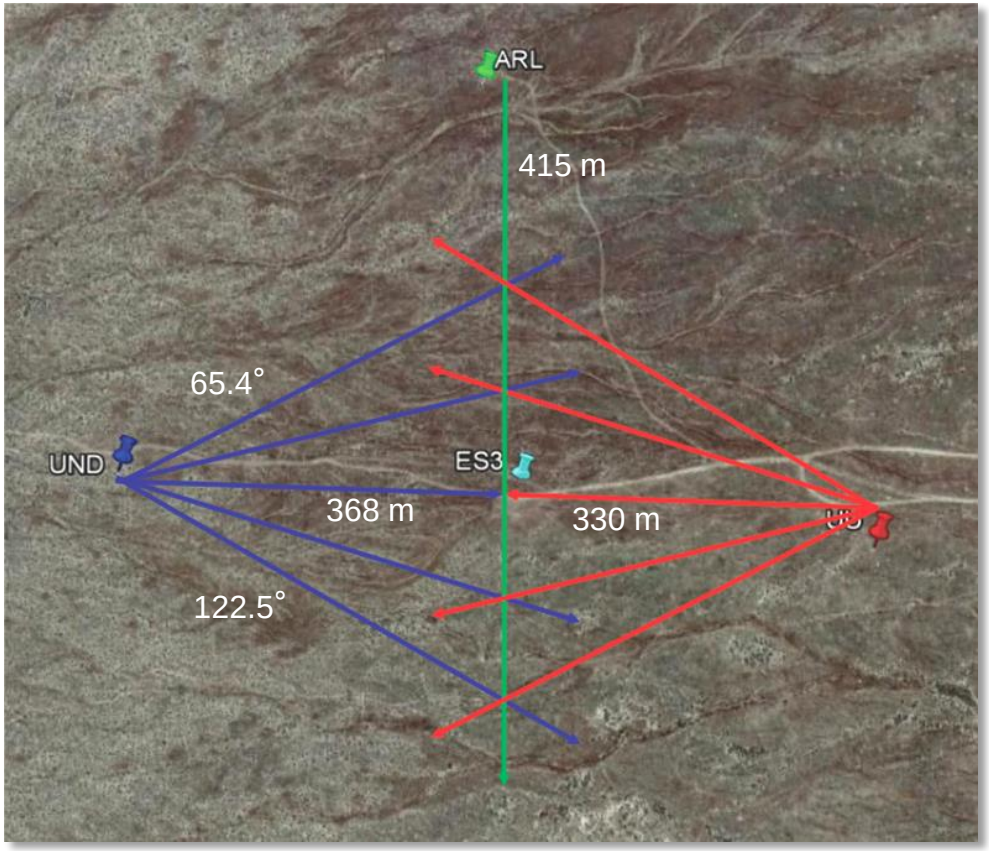
- UND and UU LiDARs were only able to be programmed to continuously scan one RHI
- UND and UU LiDARs scanned outside of the possible beam intersection area, limiting the potential beam crossings
- LiDAR synchronization issues

Triple LiDAR Scans at East Slope MATERHORN X-2



Phase 1: Stare Scans

- All three LiDARs starred at the ES3 20 m Sonic
- Comparison with sonic used for 3-D vector retrieval verification



Phase 2: 3-D Tower Mode

- Halo programming improved, Halos could scan multiple RHIs, intersecting the ARL LiDAR RHI
- Improved synchronization - after a series of 160, 45° RHI scans, Halos were within 10 s of each other
- Created (5) 3-D VT more than 300 m in height spaced 100 m apart

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Comparison of LiDAR Stare Scan Data with Sonic

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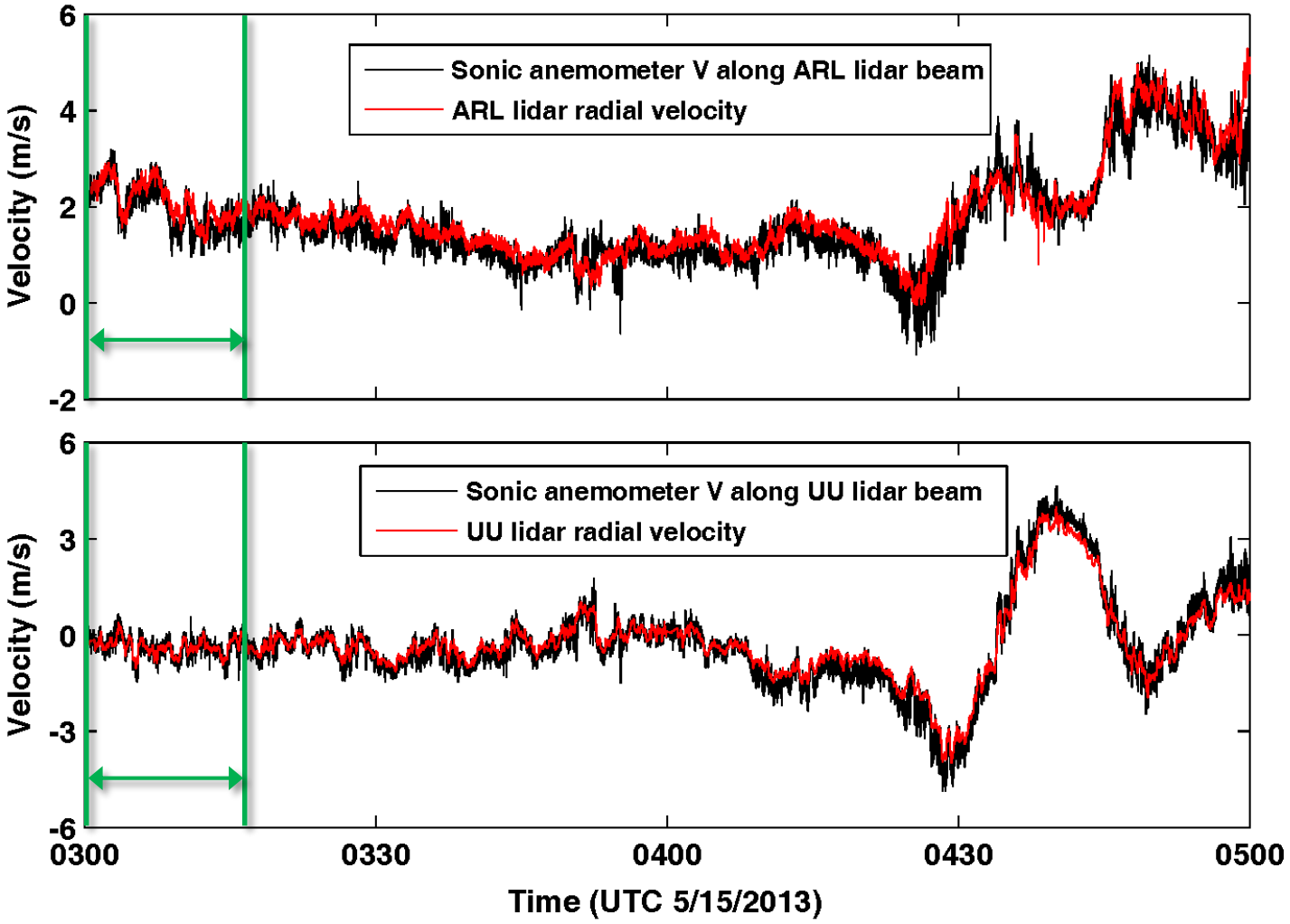

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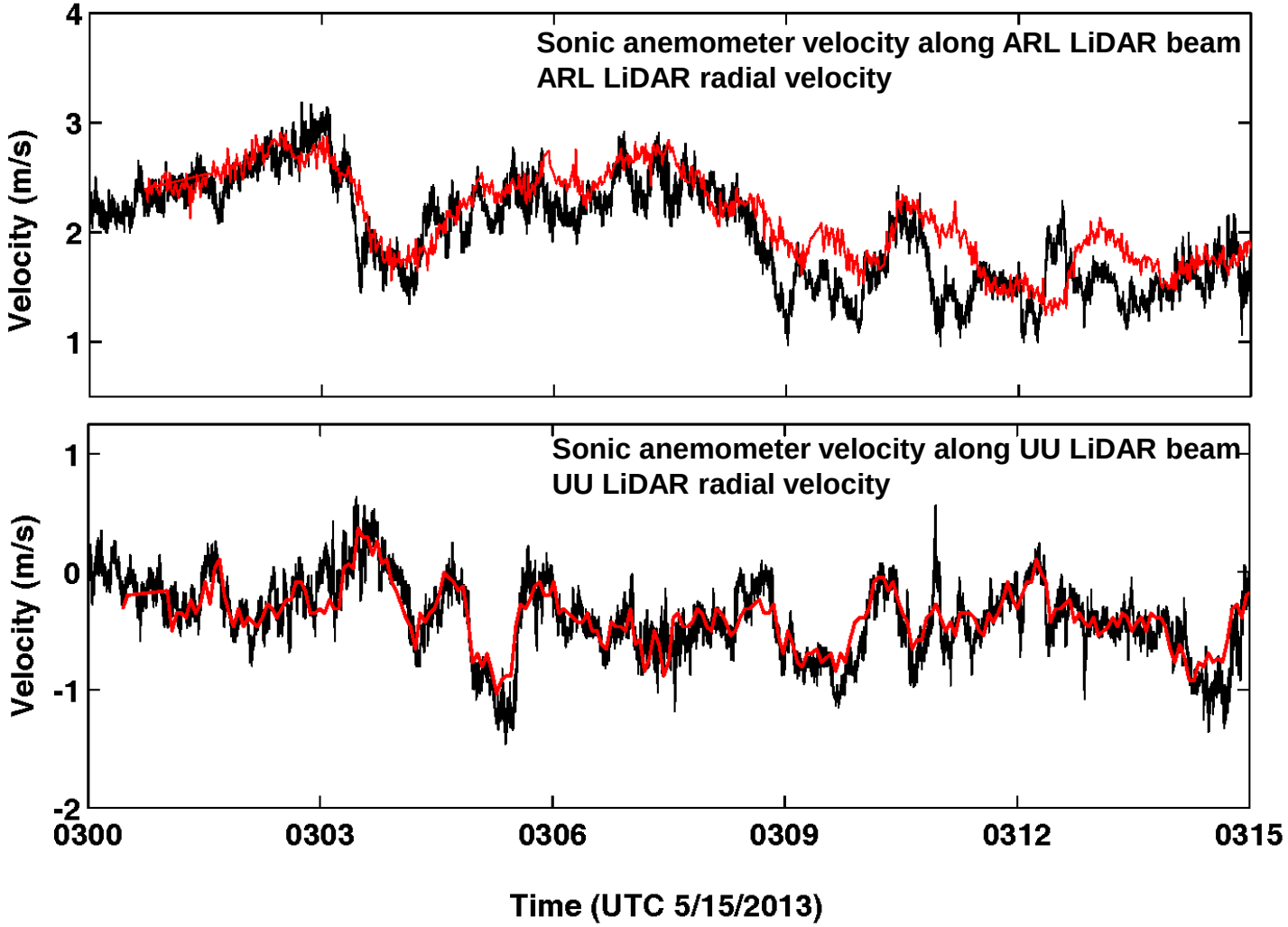
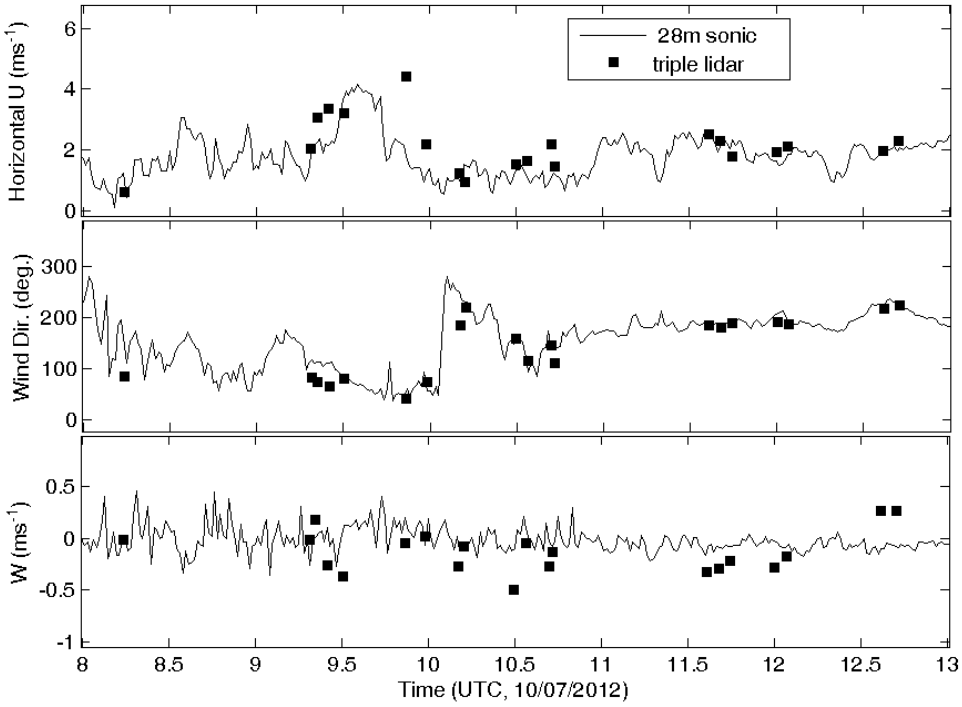
Comparison of LiDAR Stare Scan Data with Sonic (zoomed)

ARL

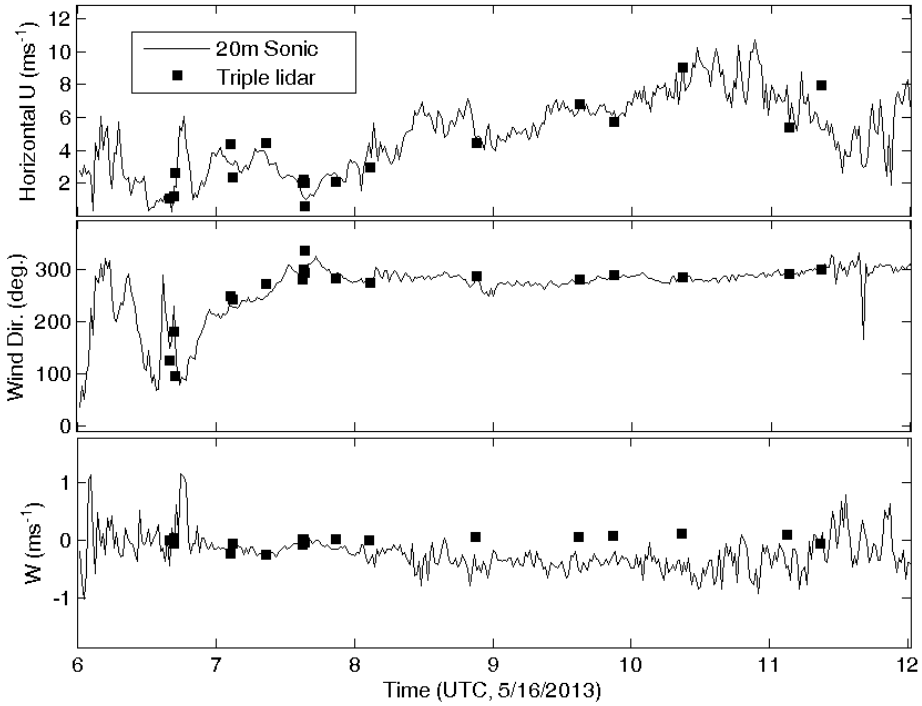


Wind from Triple LiDARs Compared with Sonic Anemometer

10/07/2012 data - 1 min averaging time



05/16/2013 data - 1 min averaging time



$$rms\,error = \left[\frac{\sum_{n=1}^{N} (x_l - x_s)_n^2}{\sum_{n=1}^{N} (x_s^{\,2})_n^2} \right]^{1/2}$$

U = 0.31 m/s

WD = 4.7°

W = 0.18 m/s

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Examples of Triple LiDAR Retrieved Virtual Towers

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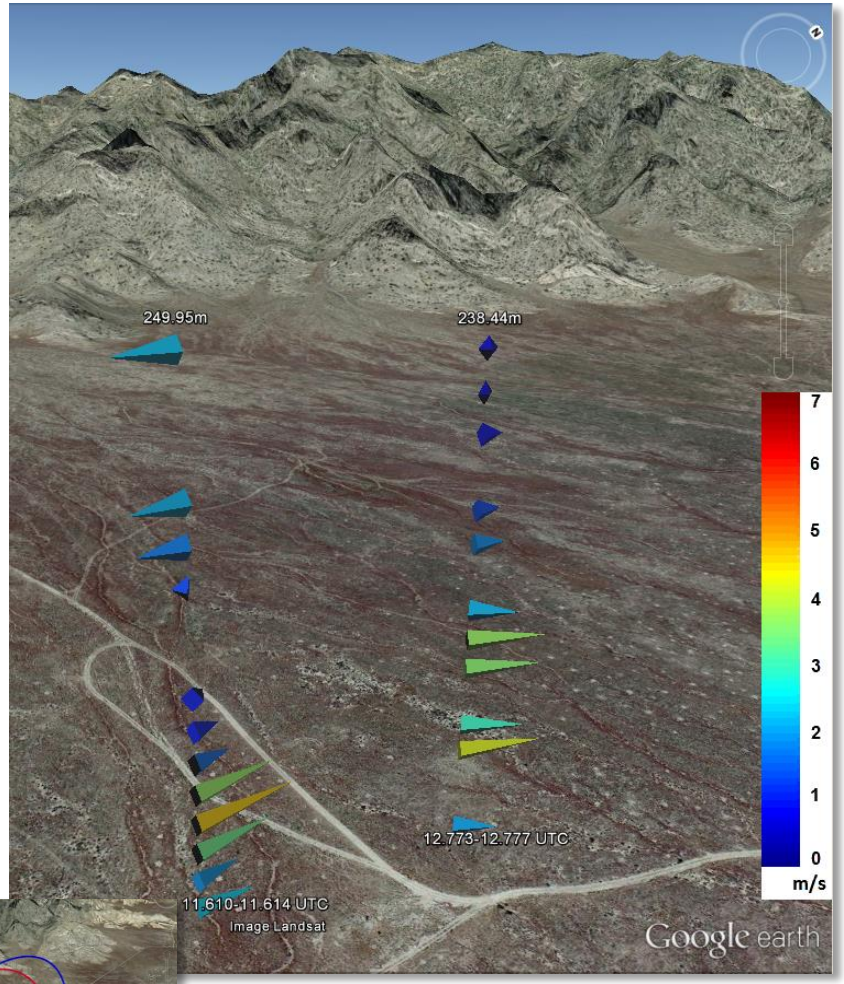
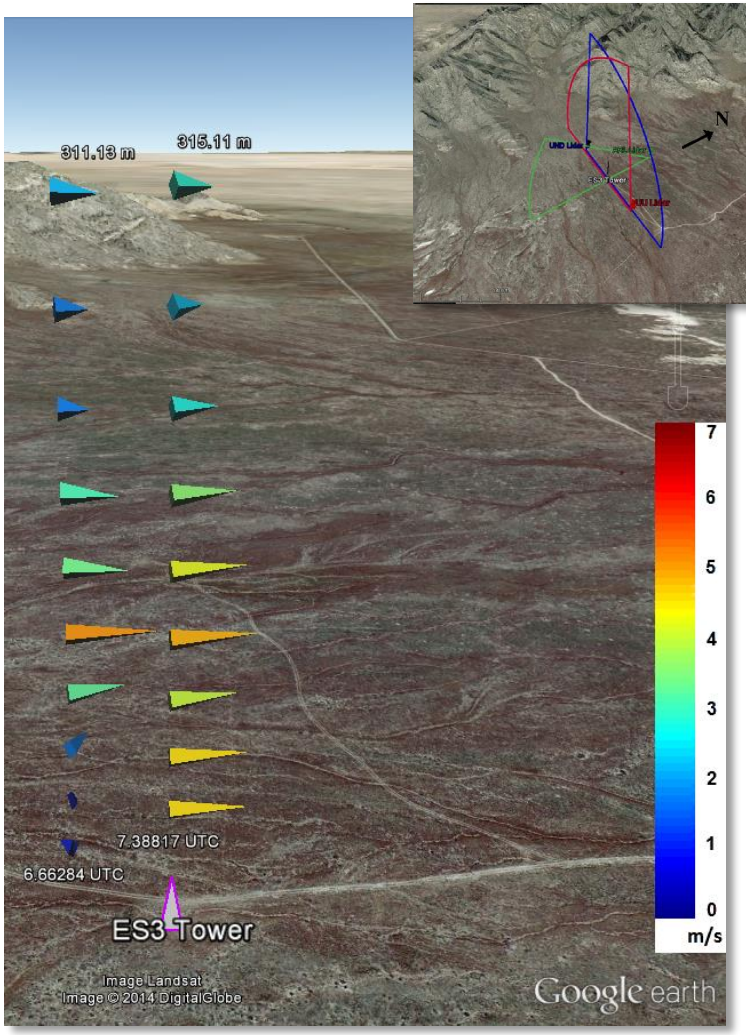


10/07/2012

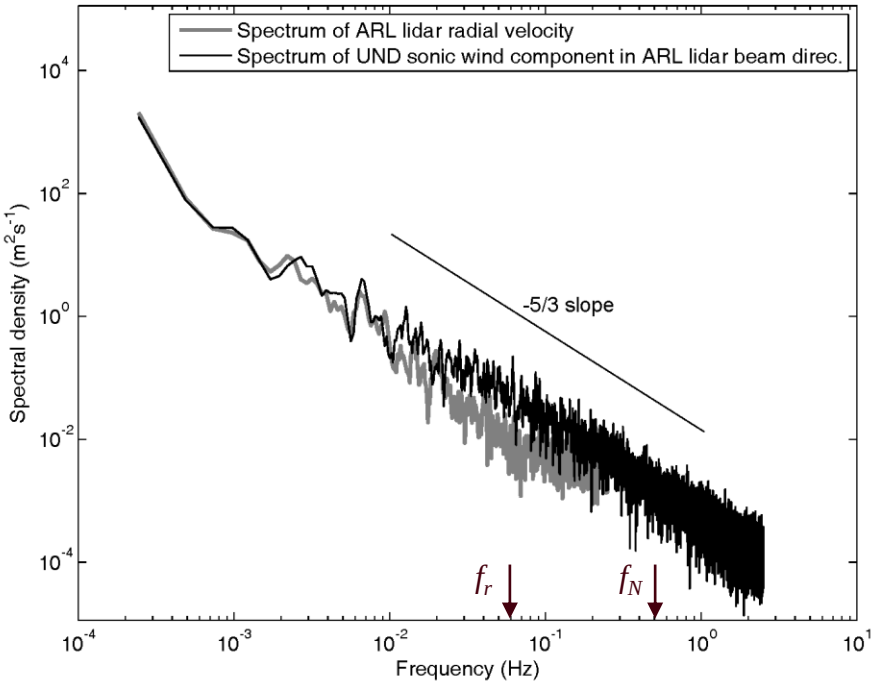


05/16/2013

Comparison of the Sonic and LiDAR Radial Winds in Spectral Domain

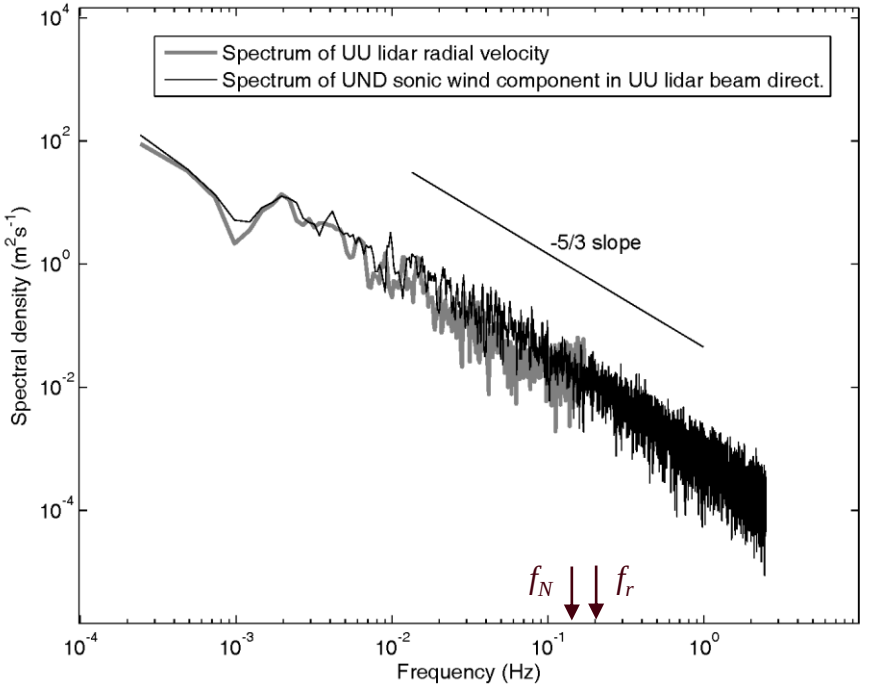
ARL LiDAR Compared with Sonic Anemometer

Range gate: 50 m, sampling frequency: 1 Hz



UU LiDAR Compared with Sonic Anemometer

Range gate: 18 m, sampling frequency: 0.25 Hz



f_N = Nyquist frequency

f_r = Resolvable eddies, $f_r = \frac{k\bar{U}}{2\pi}$ where $k = \frac{2\pi}{gl}$

Summary

- A substantial LiDAR data set was obtained during the MATERHORN-X field campaigns, containing rich information about the wind field over mountainous terrain.
- Triple LiDAR work indicates the combined LiDARs have the potential to directly measure the large turbulent eddies without assumptions.
- There are clear advantages of three coordinated LiDARs compared to towers: mobility and ability to reach much higher altitudes.
- To obtain accurate 3-D wind vector retrieval, the temporal and spatial synchronization between LiDARs is imperative!
- Suggestion to LiDAR manufactures, please put scanner controller for multiple LiDARs in one unit for this type of work.

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Questions ?

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MATERHORN ARL funding from the Air Force Weather Agency (AFWA)