Two-component wind vector fields from scanning aerosol lidars

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Spectral Sensor Solutions

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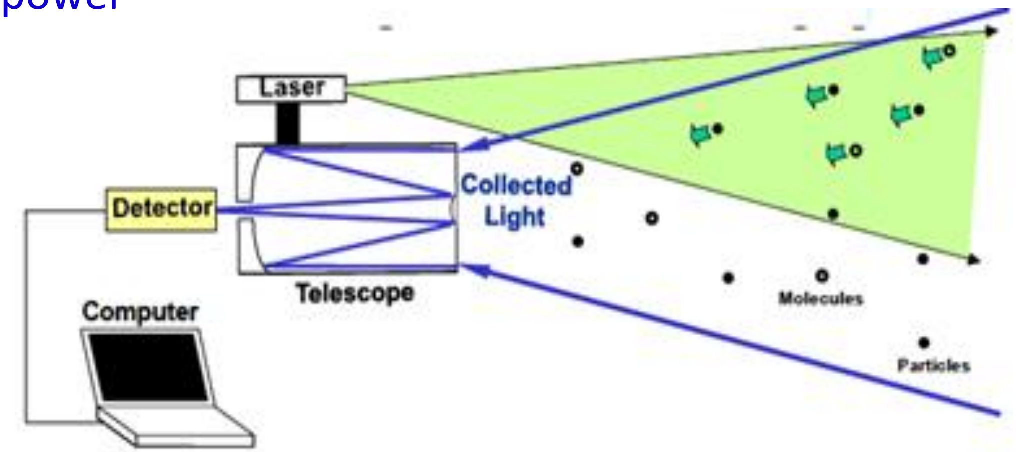
physics.csuchico.edu/lidar

Raman-shifted Eye-safe Aerosol Lidar (REAL)

- REAL is an ***aerosol backscatter*** lidar
  - Not a Doppler Lidar
  - Not a Raman Lidar
    - “Raman” refers to the wavelength conversion method used in its transmitter to generate 1.5 microns from 1.06 microns.
- Advantages of 1.5 micron wavelength
  - Maximize transmitted eye-safe power
  - Low sky background
  - Low molecular scattering
  - Atmospheric transparency
  - Good detector efficiencies
  - Leverage telecom advances



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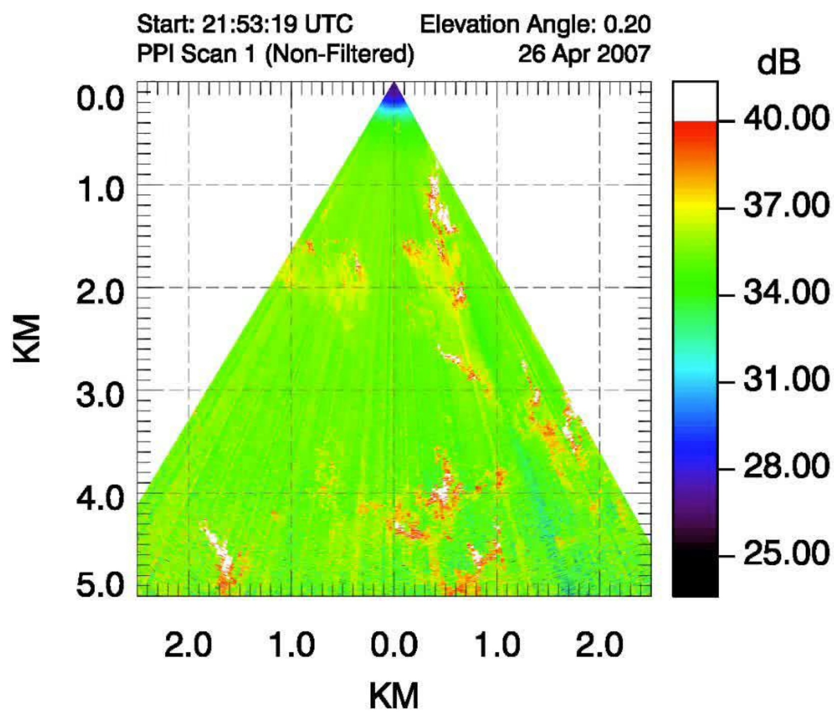
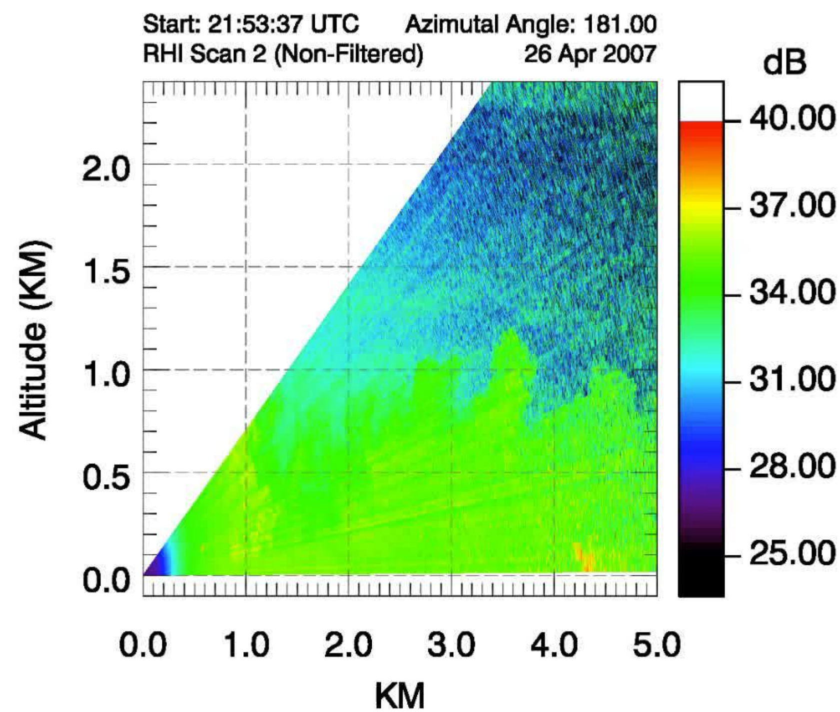
Atmospheric Imaging by Scanning





Horizontal (PPI)

Vertical (RHI)

2007 03 26 Horizontal (PPI) at CHATS (Canopy Horizontal Array Turbulence Study)

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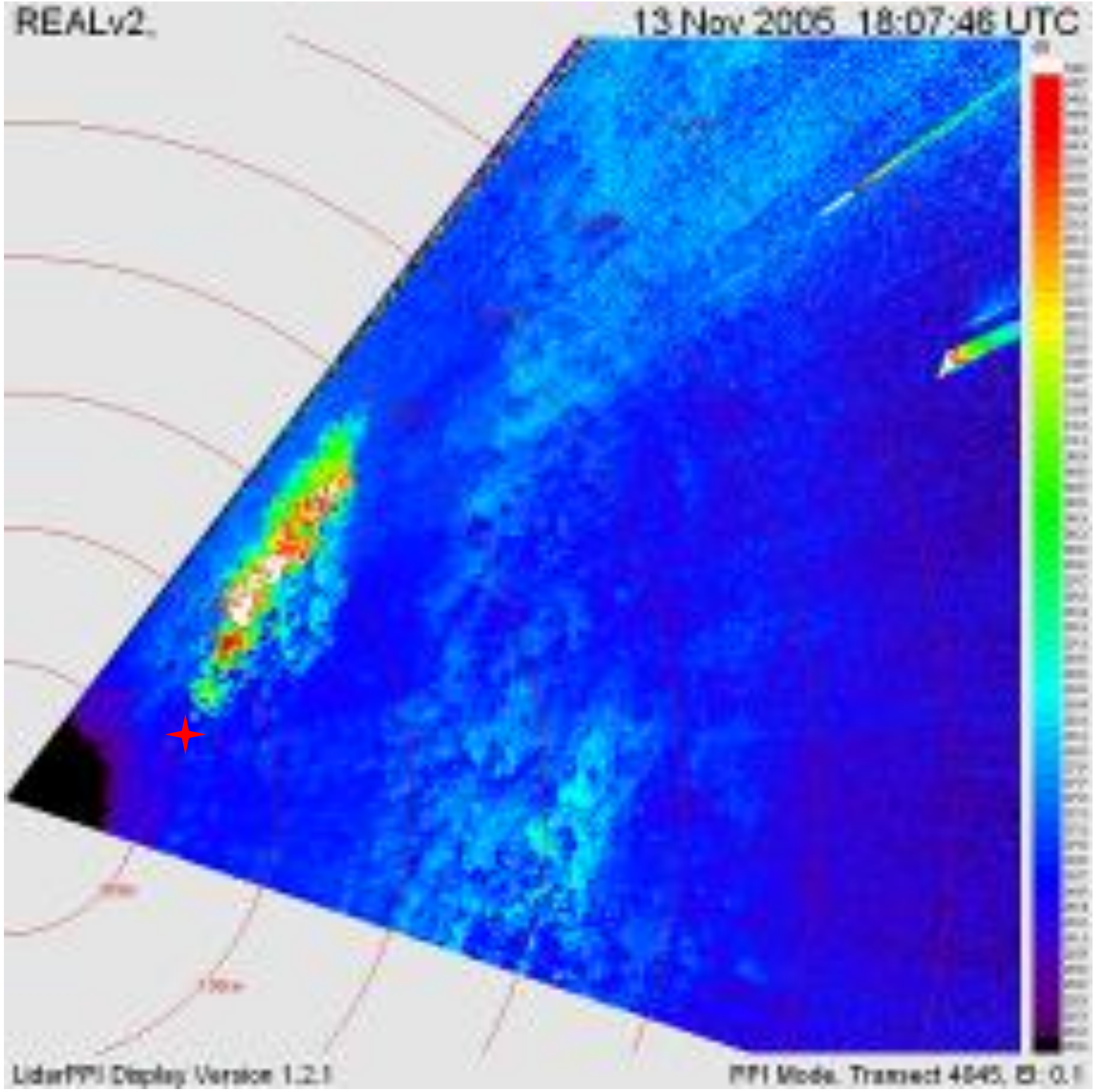
Plume Detection and Tracking for Pentagon Shield



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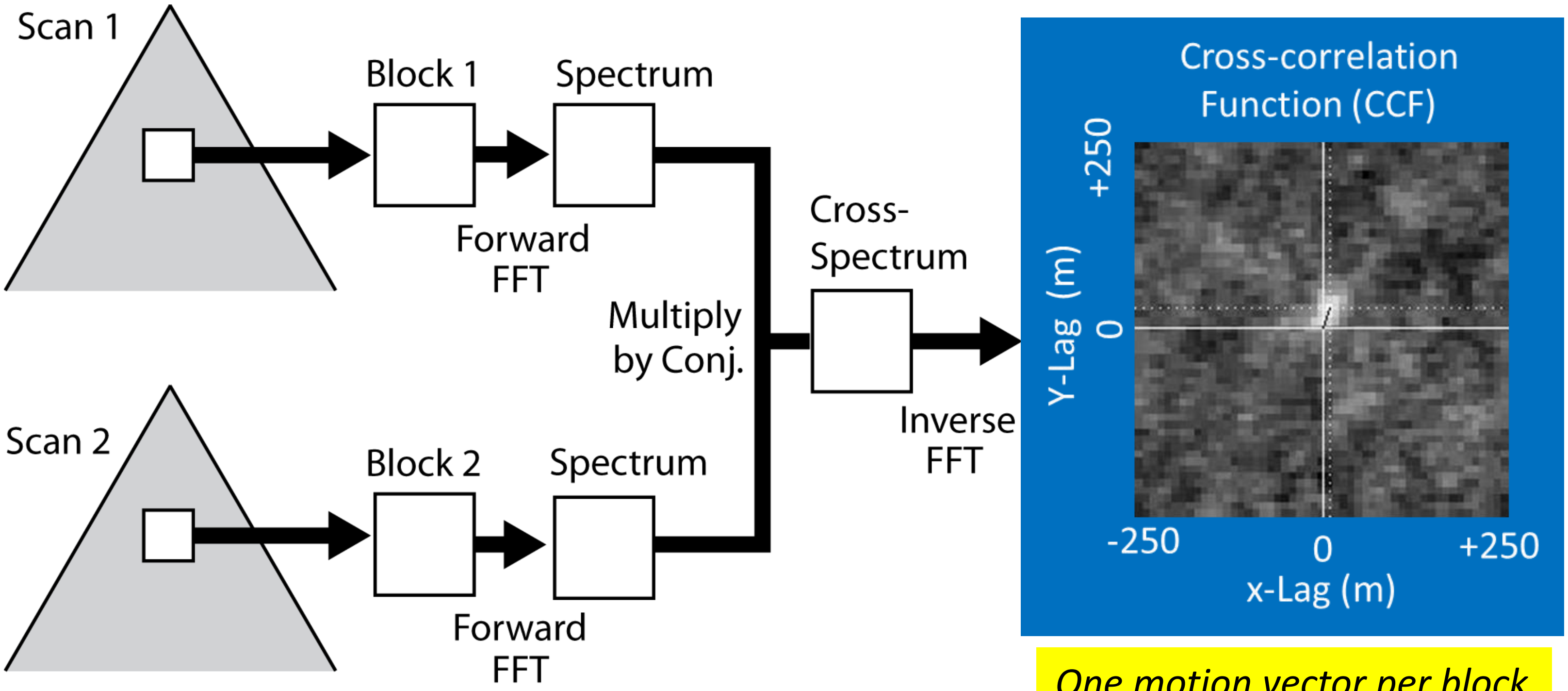
Wind Vector Estimation from Aerosol Motion

First Motion Estimation Approach: **Cross-correlation Algorithm**



One motion vector per block

Schols, J. L. and E. W. Eloranta, 1992: The calculation of area-averaged vertical profiles of the horizontal wind velocity from volume-imaging lidar data. *J. Geophys. Res.*, **97**, 18 395–18 407.

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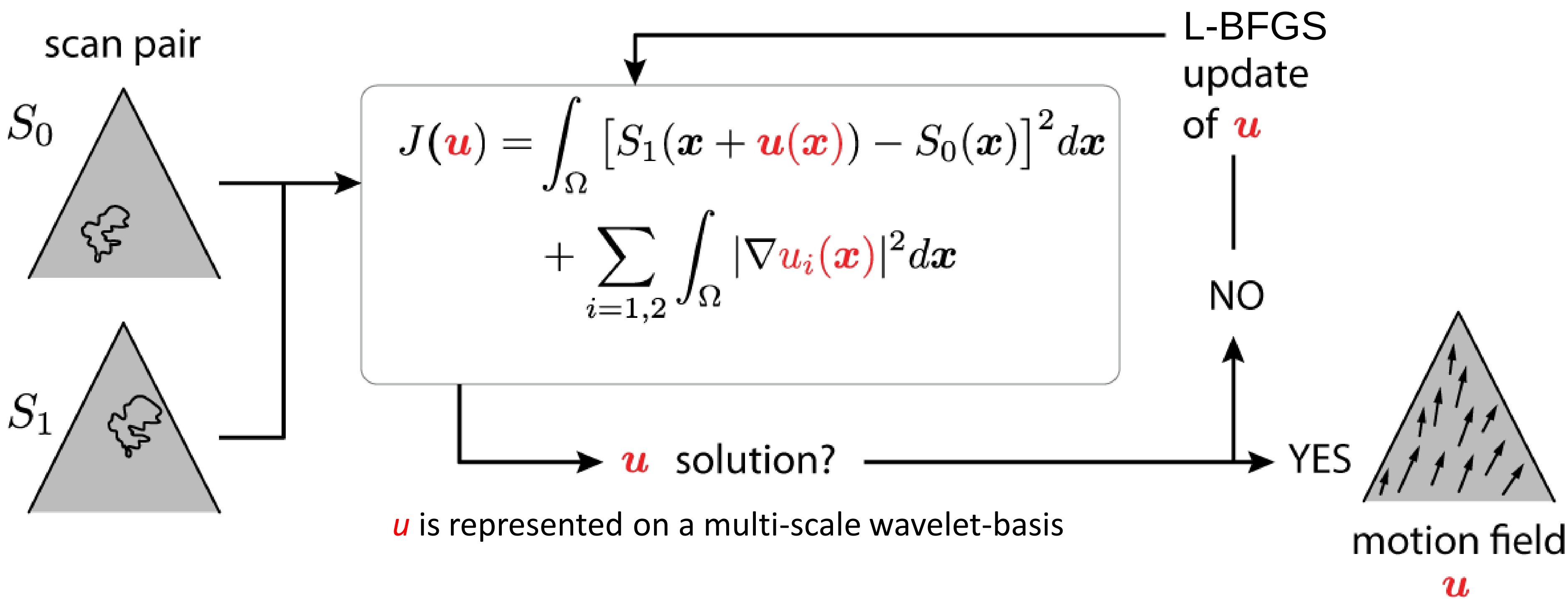
2^{nd} Motion Estimation Approach:
Wavelet-based Optical Flow Algorithm

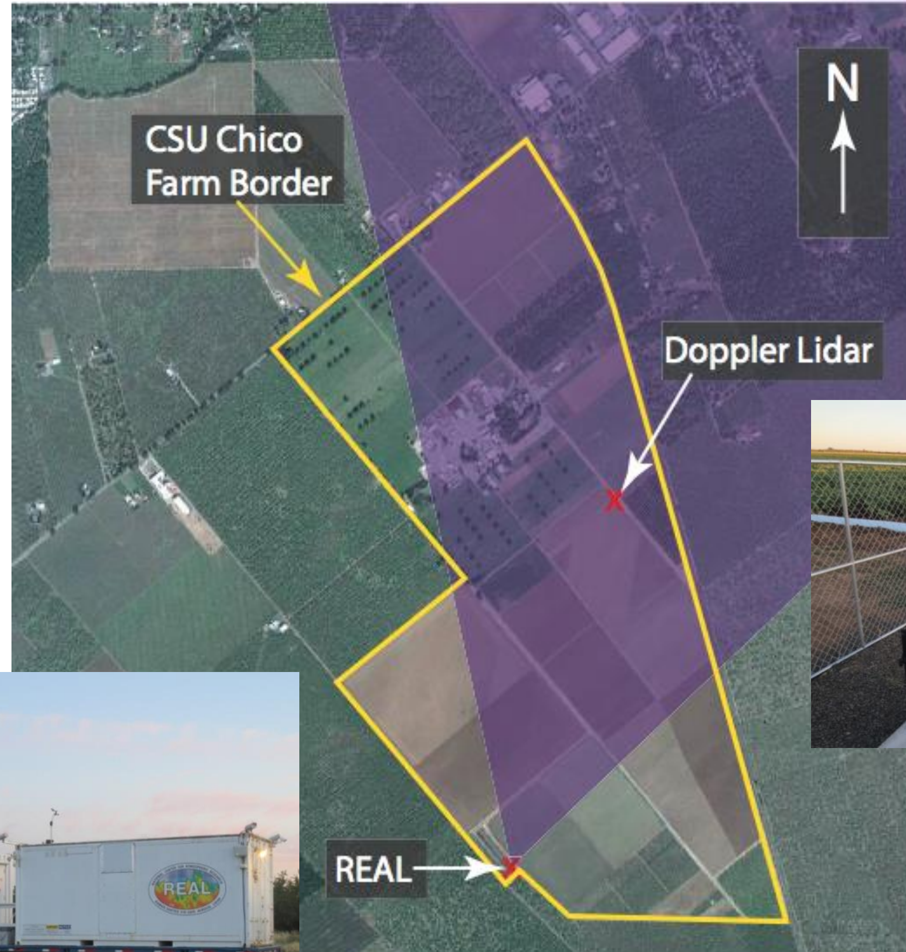


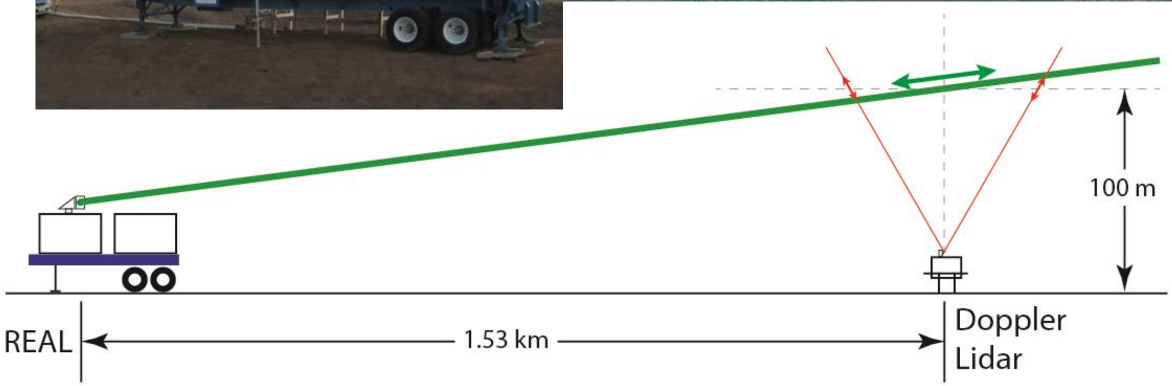
One motion vector per pixel

Dérian, P., P. Héas, C. Herzet and E. Mémin, 2013: Wavelets and Optical Flow Motion Estimation, *Numerical Mathematics: Theory, Methods and Applications*, **6**, 116-137.

2013 Chico California Experiment:

Comparison with Doppler Lidar





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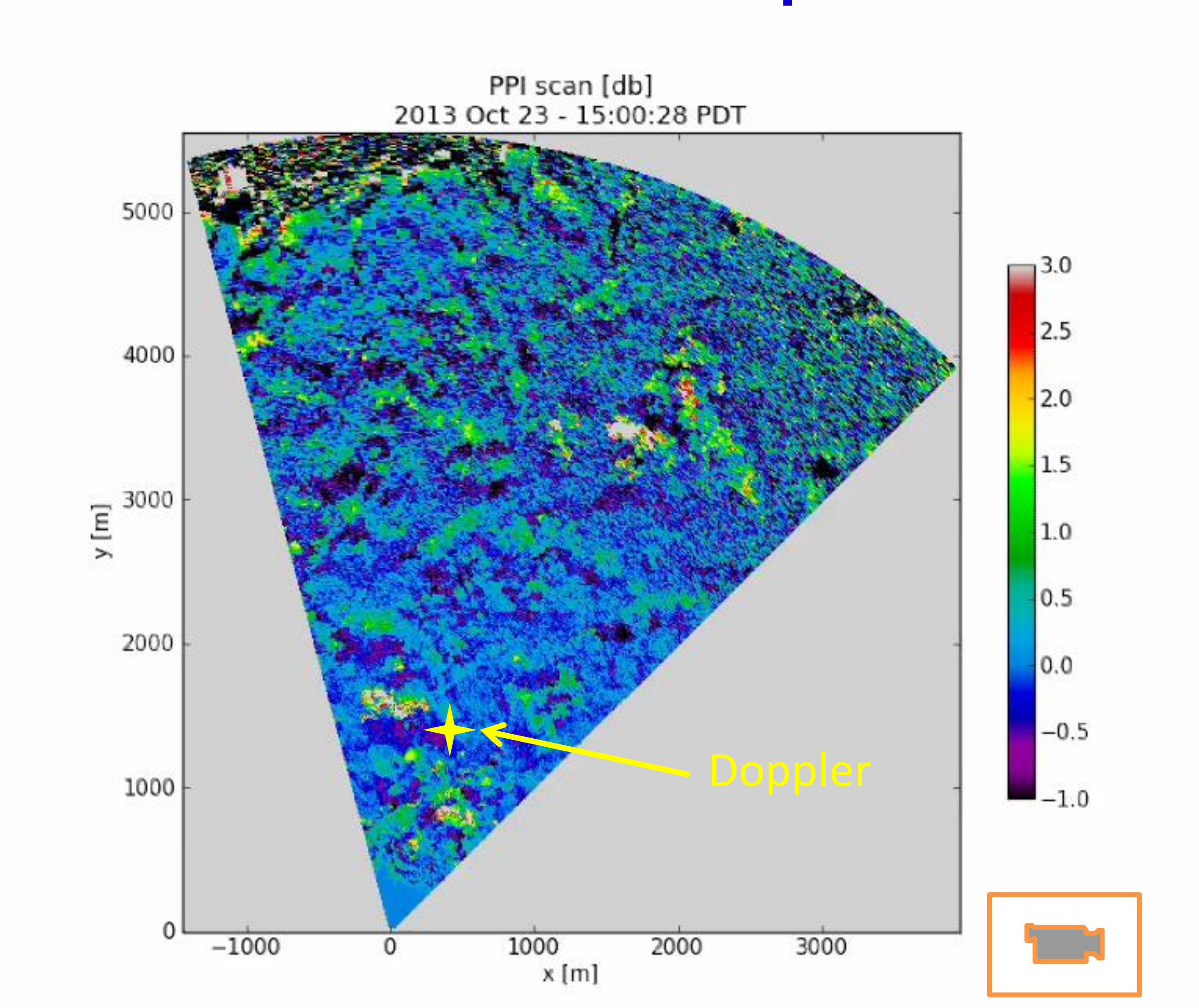
Aerosol Transport



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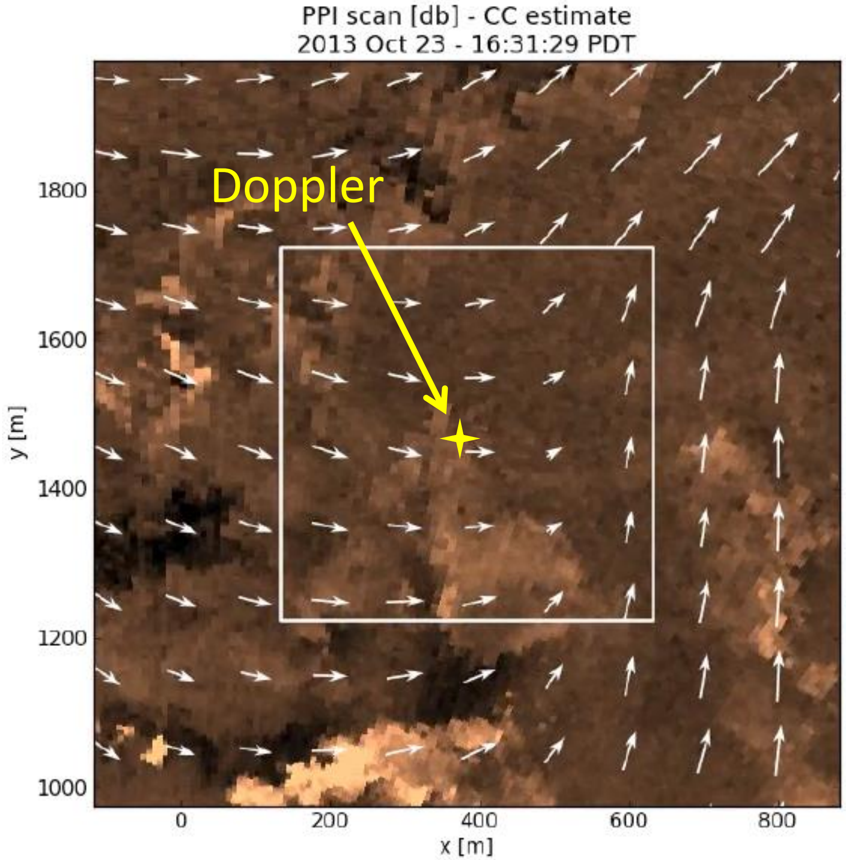
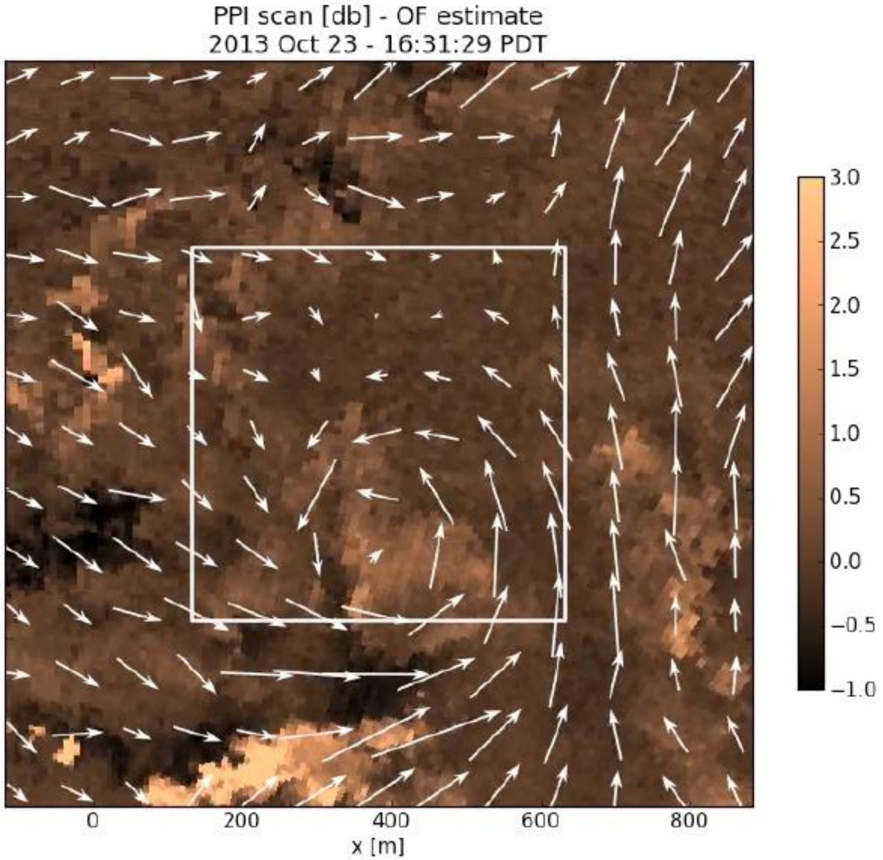
Wind Vector Estimation Comparison



Cross Correlation



Optical Flow

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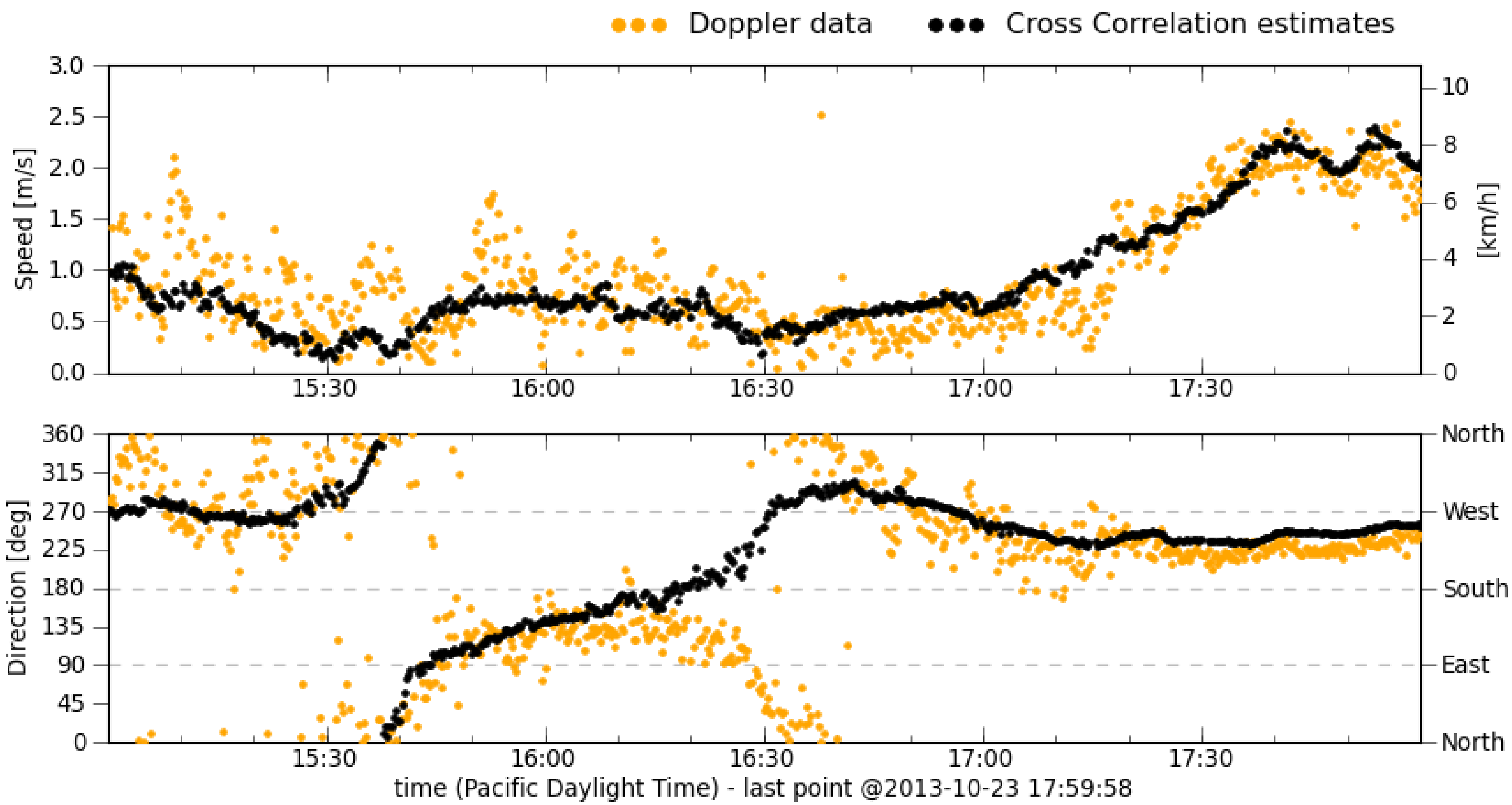
4-hour Time-series Comparison of Wind Speed and Direction Between **Cross Correlation** and Doppler Lidar



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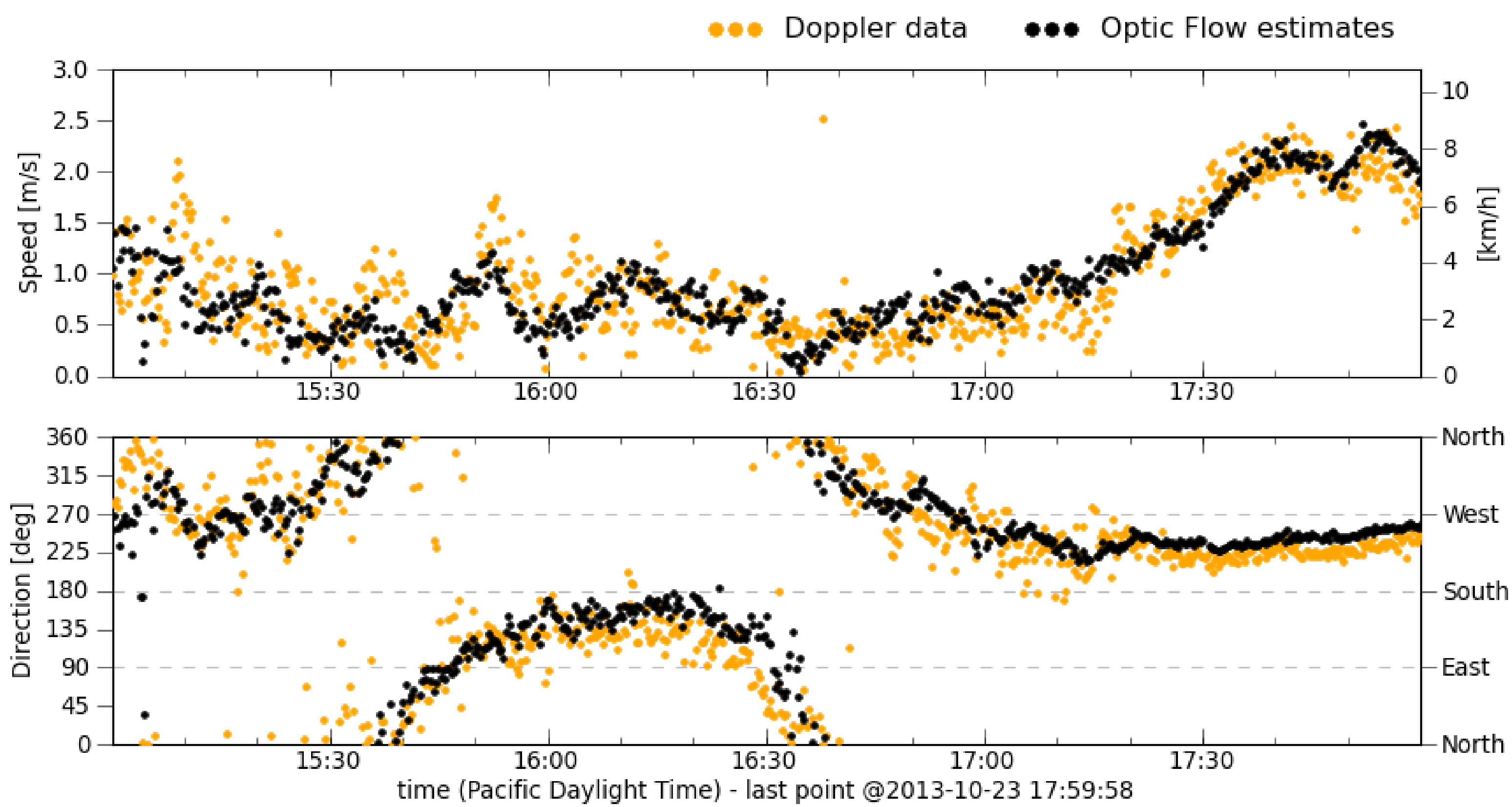
4-hour Time-series Comparison of Wind Speed and Direction Between **Wavelet Optical Flow** and Doppler Lidar



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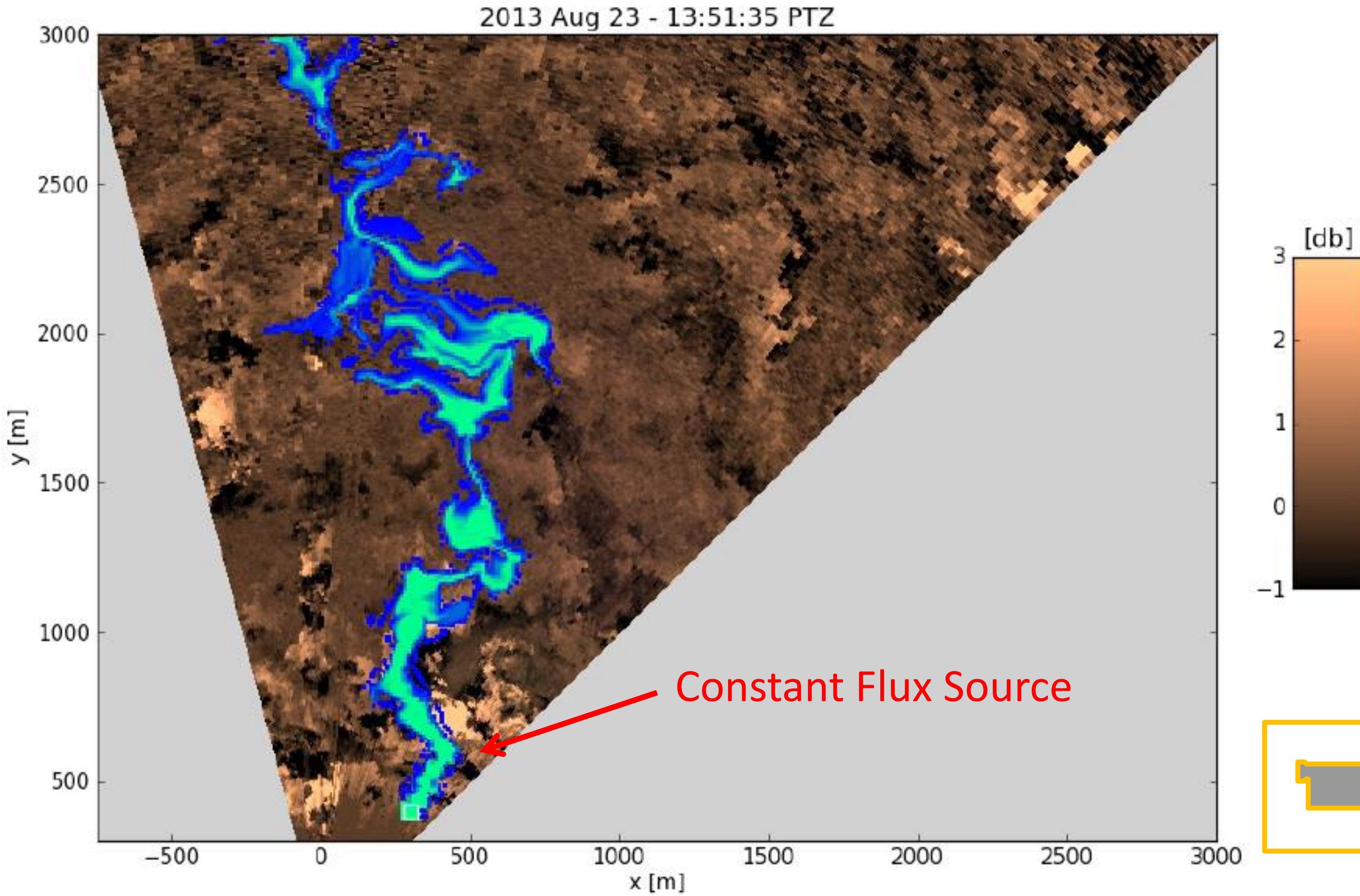
Virtual Release Into an Actual Wind Field



How would virtual smoke from a constant flux source be transported and dispersed by the actual measured wind field?

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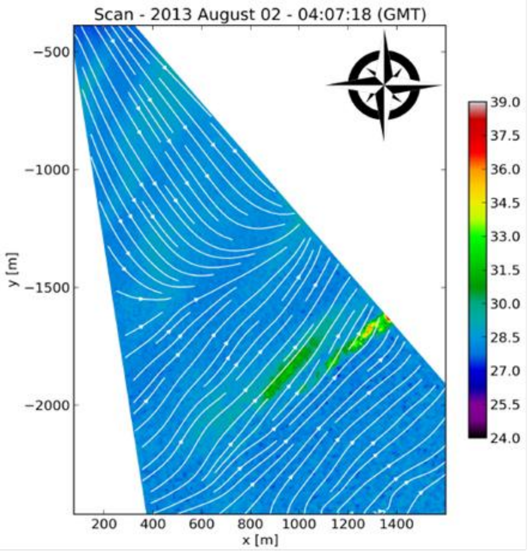
SAMPLE: Scanning Aerosol Micropulse Lidar-Eyesafe

- S3 Development Goals:
  - Operation at 1.5 microns
    - Similar advantages as REAL
  - Small SWaP and unit cost
  - Low operations and maintenance costs
- Development Status
  - Prototype (shown at right)
  - 2nd Gen. system delivered to DPG
- Test Status
  - Sensitivity currently w/in factor of ~2 of REAL
  - Successful retrieval of winds from plume measurements in a low-aerosol desert environment
  - Not yet tested over a wide range of background aerosol levels



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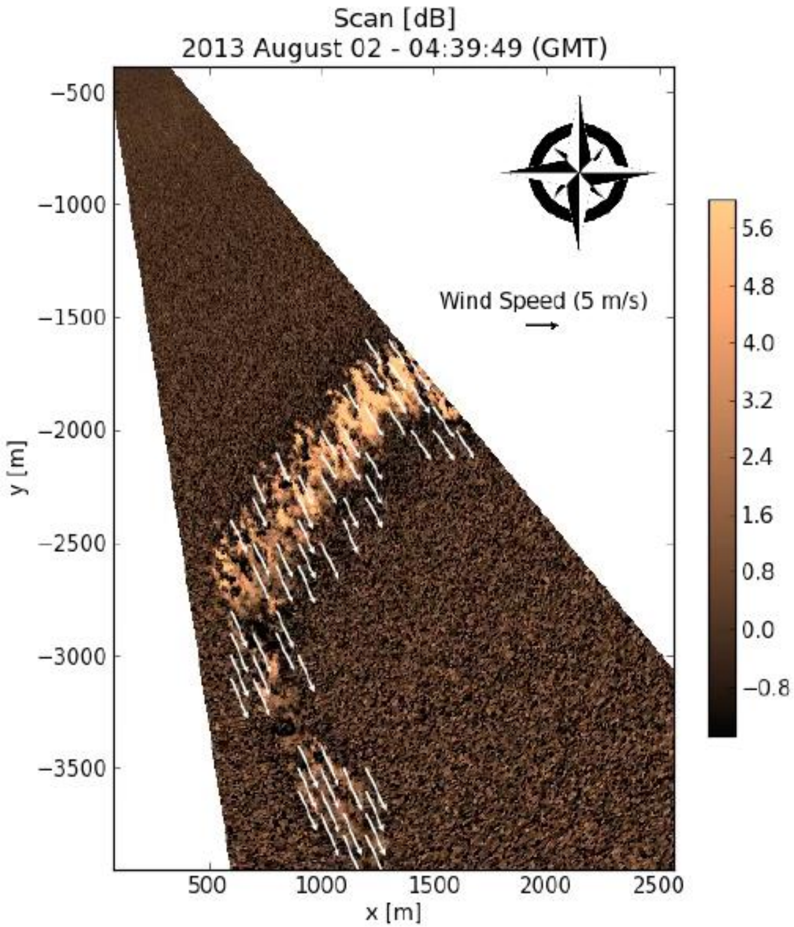
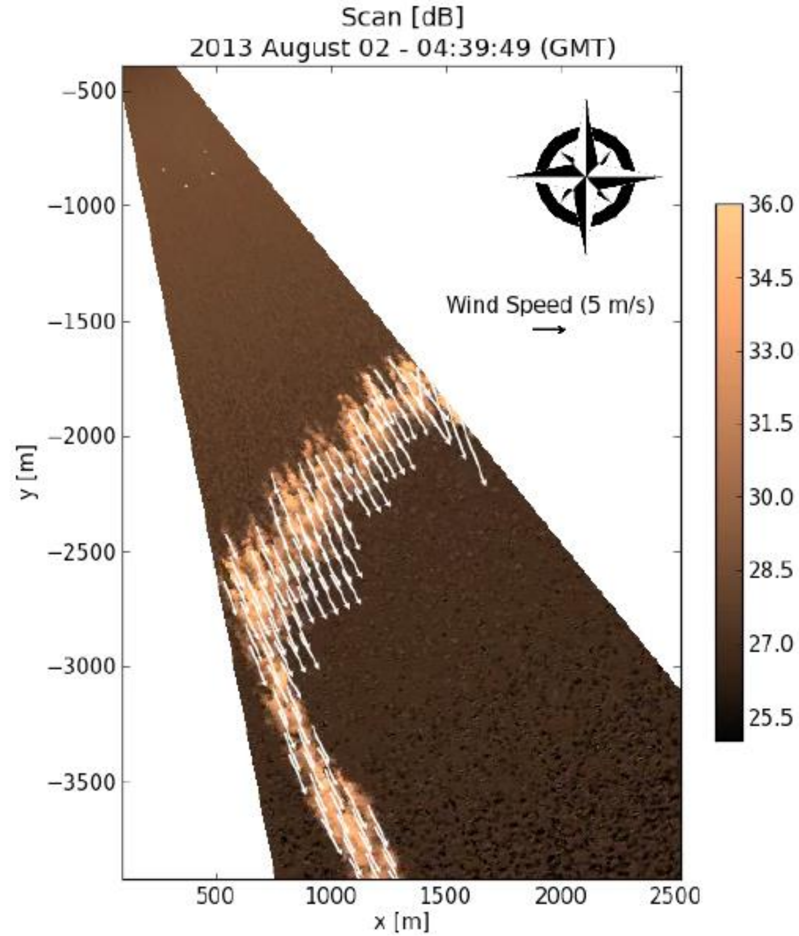
Wind Estimation From SAMPLE Data



Cross Correlation



Optical Flow

Conclusions

- We have demonstrated the simultaneous capability to detect, map, and track plumes while also measuring the wide area wind fields around the plumes.
- Wind estimation algorithms can derive two-component wind vectors from aerosol measurements made by elastic backscatter lidars.
- Retrieved wind vectors agree well with anemometer and Doppler lidar measurements.
- The wavelet-based optical flow algorithm resolves higher spatial detail than the current cross-correlation technique.
- High spatial resolution is possible even over large spatial areas.
- Wind vector computations have been demonstrated in real-time with Graphical Processing Units (GPUs).
- Testing of these techniques with small-SWaP eyesafe lidars has begun.
- The integration of these results into real-time T&D models could provide a valuable capability for Homeland Security and National Defense: real-time source estimation and prediction of areas threatened by a hazardous release.

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