The REAL was developed with funding from the National Science Foundation (NSF).
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Raman-shifted Eye-safe Aerosol Lidar (REAL)

California State University Chico

Unlike commercially available Doppler and micropulse lidars, the REAL transmits very energetic laser pulses (130 mJ/pulse) at a low pulse rate (10 Hz) to produce images quickly. No temporal integration of the returns is required. It also transmits very short pulses (6 ns) and samples at a high rate (100M samples/s) to produce images with very fine-range resolution (1.5 m). It is an analog direct-detection aerosol lidar.

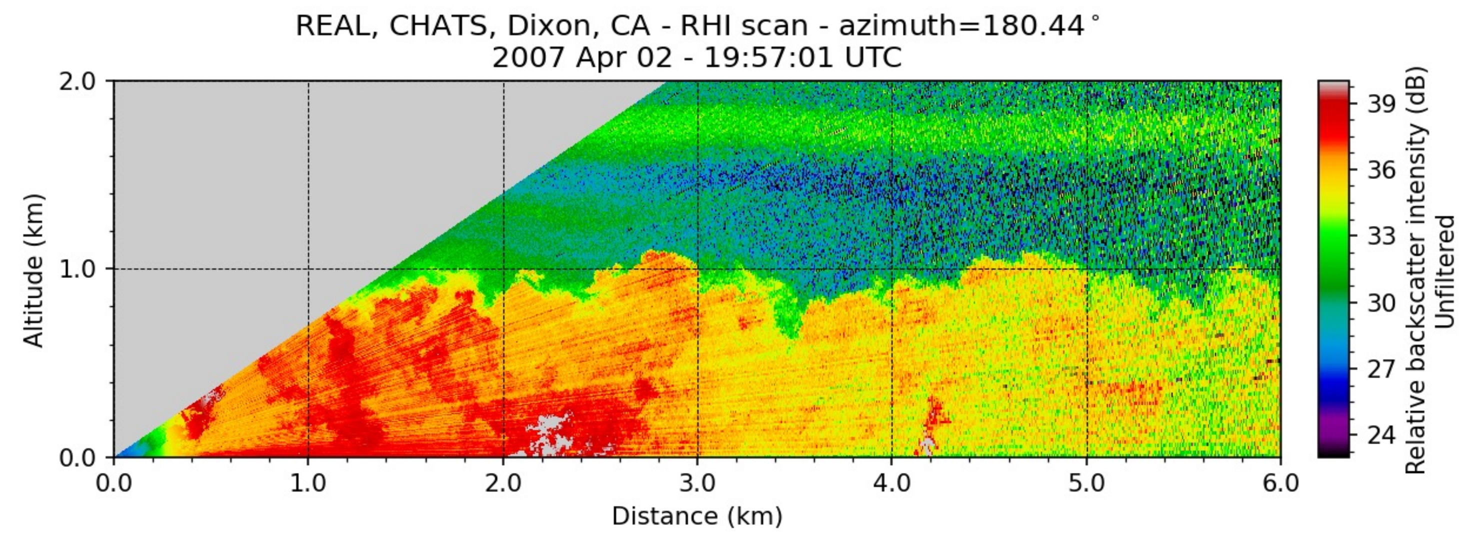
What can the REAL do?

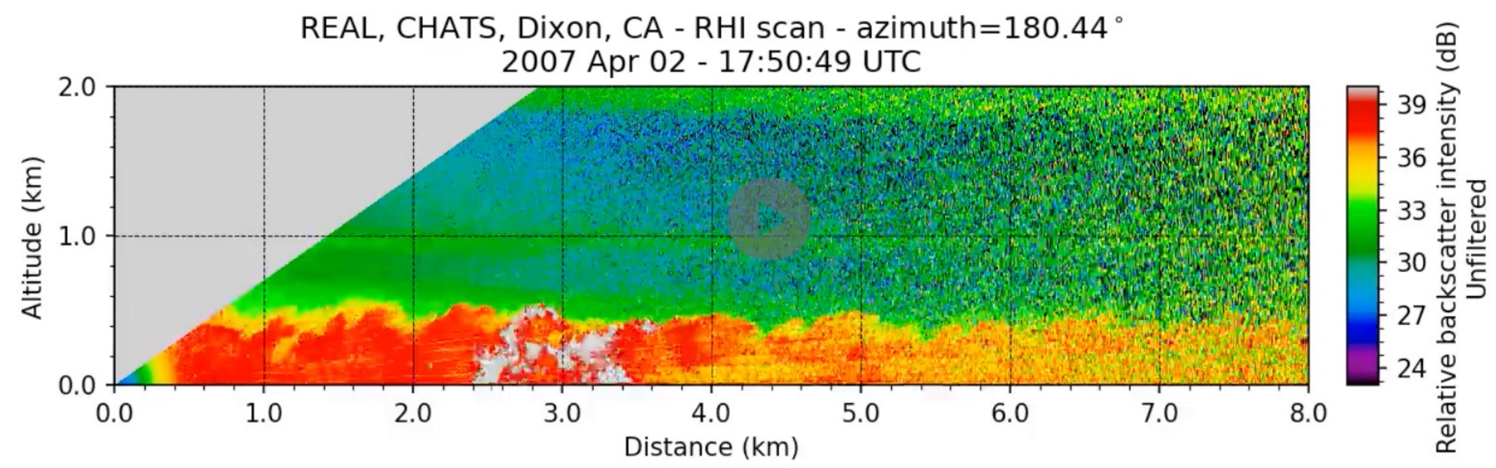
The REAL can contribute to all boundary layer and microscale meteorological experiments.

Because atmospheric aerosol is present everywhere and a great tracer of atmospheric structure and flow, a high performance lidar like the REAL can visualize many different aspects of the lower atmosphere. Here are just a few examples of past observations.

1. Boundary Layer Height and Entrainment Zone Structure

By performing rapid (15 s) RHI scans such as the one to the left, REAL excels at observing the structure and vertical evolution of convective boundary layers, especially polluted and shallow ones where the entrainment zone offers sharp contrast. A Haar wavelet-based analysis algorithm can be applied to the images to automatically and objectively delineate the top edge.





Mayor, S. D., and S. M. Spuler, 2004: Raman-shifted Eye-safe Aerosol Lidar, *Appl. Optics*, **43**, 3915- 3924.

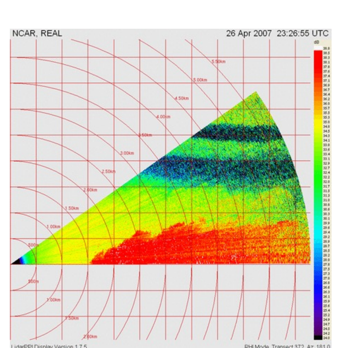
Spuler, S. M. and S. D. Mayor, 2007: Raman shifter optimized for lidar at 1.5-micron wavelength. *Appl. Optics* , **46**, 2990-2995.

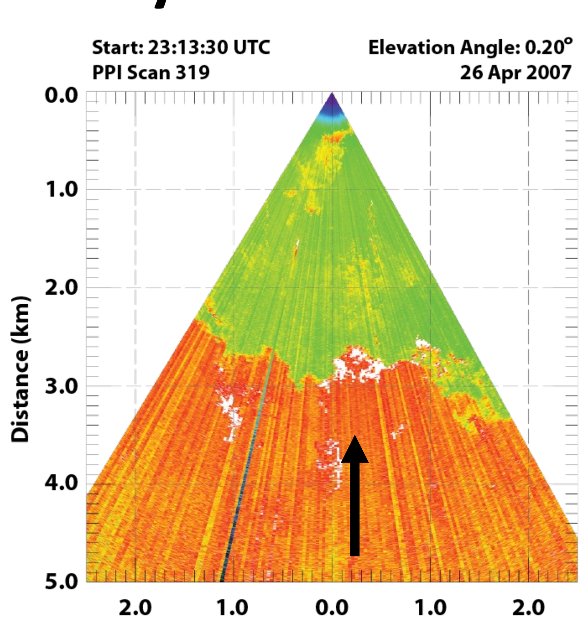
Spuler, S. M. and S. D. Mayor, 2005: Scanning Eye-safe Elastic Backscatter Lidar at 1.54 microns, *J. Atmos. Ocean. Technol.*, **22**, 696-703.

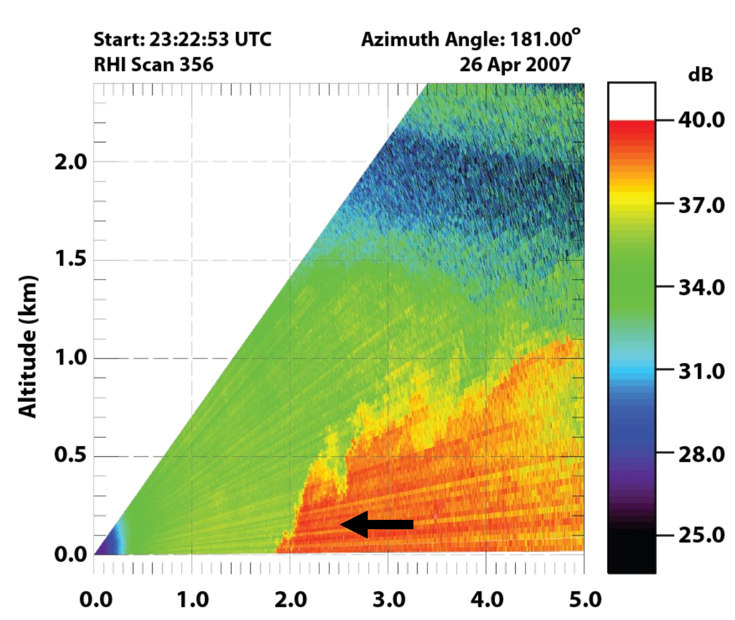
2. Detection and tracking of density current fronts

By alternating the collection of RHI and PPI scans REAL can track the horizontal and vertical movement of density current fronts.

Mayor, S. D., 2011: Observations of seven atmospheric density current fronts in Dixon, California, *Mon. Wea. Rev.*, **139**, 1338-1351.



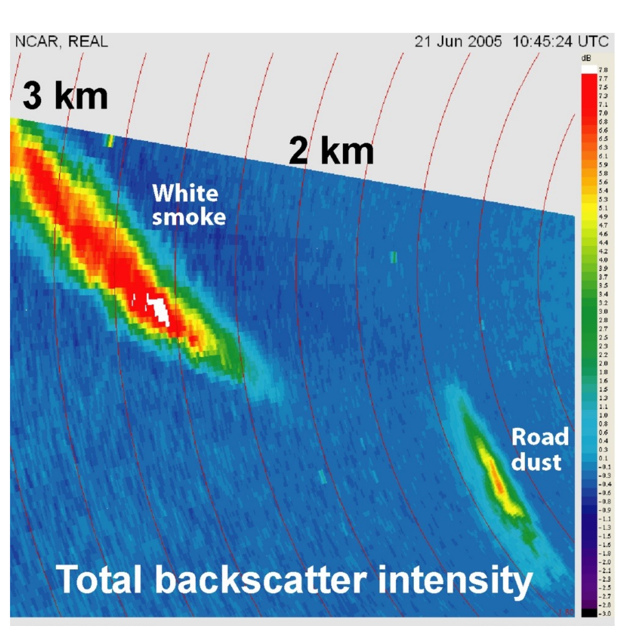


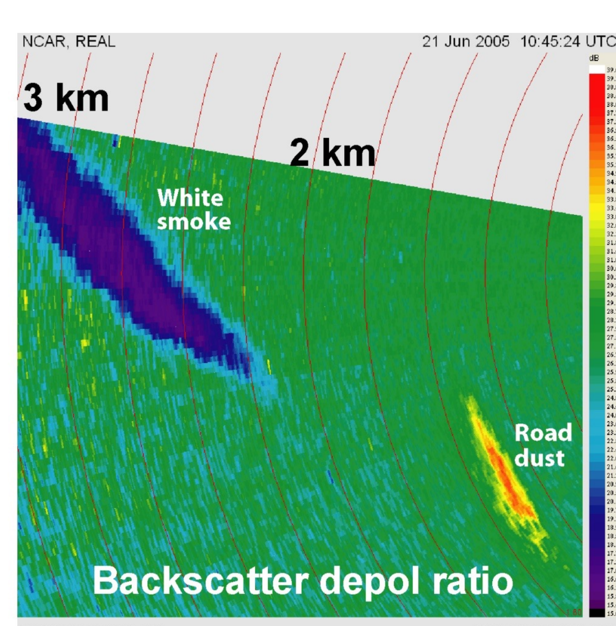


3. Polarization sensitivity

REAL transmits linearly polarized infrared laser pulses and detects backscatter polarization simultaneously in two channels: parallel and perpendicular. From this, it is capable of distinguishing spherical from non-spherical particles.

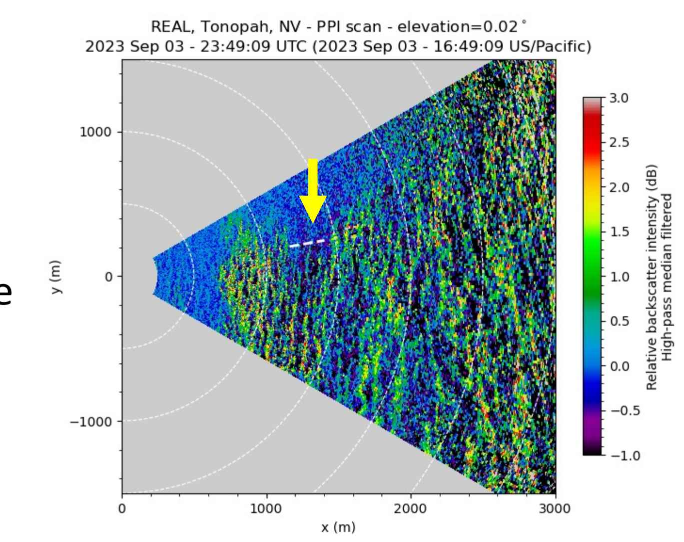
Mayor, S. D., S. M. Spuler, B. M. Morley, E. Loew, 2007: Polarization lidar at 1.54-microns and observations of plumes from aerosol generators. *Opt. Eng.*, **46**, 096201.

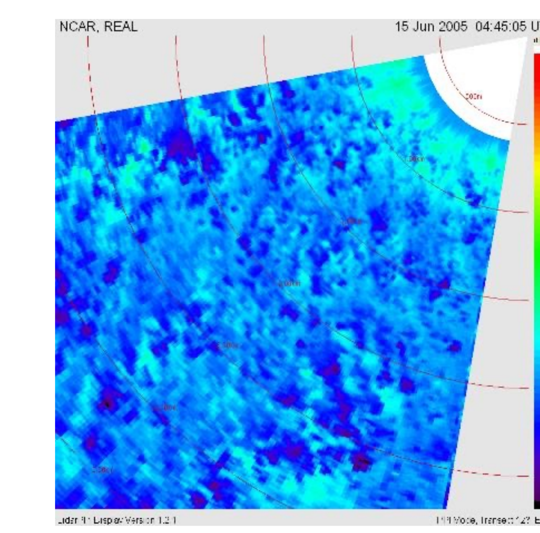




4. Turbulent coherent structures in the surface layer

REAL can scan horizontally and nearly horizontally to reveal coherent structures in the atmospheric surface layer. During more stable conditions, we often see waves and "linear streaks". During unstable conditions, we can see gust structures. The examples to the right include a recent example from M²HATS project in Tonopah, NV, and an older example from Dugway, UT, in 2005.

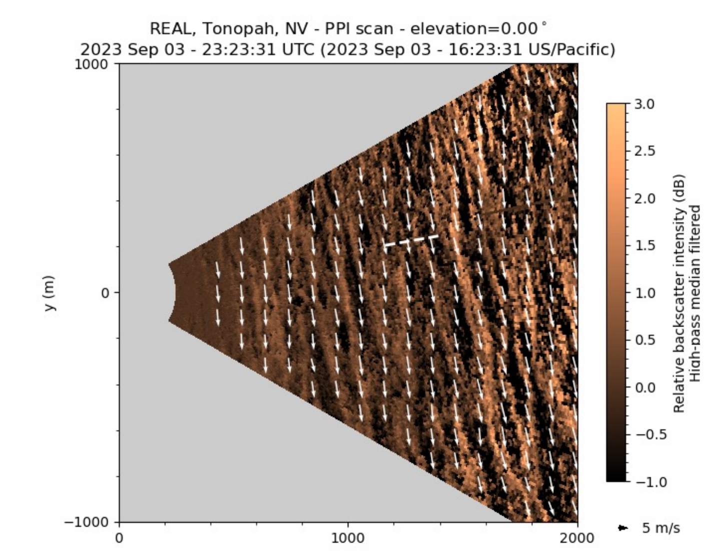


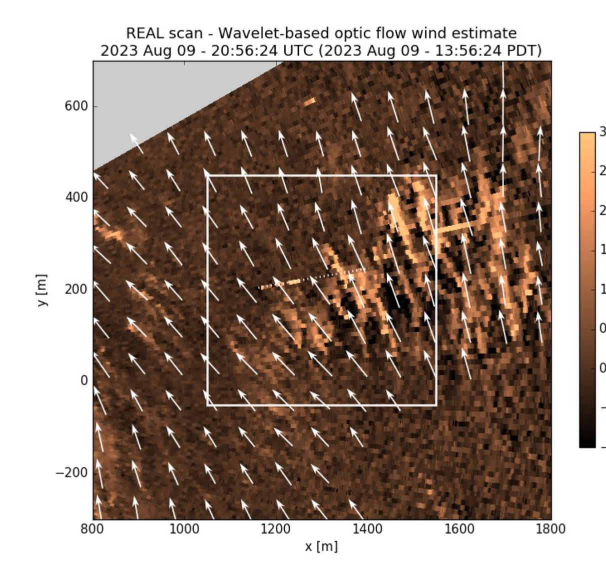


5. Vector wind fields

When the PPI images from REAL contain lots of coherent structures, a wavelet-based optical flow algorithm can be applied to derive 2-D and 2-component horizontal vector flow fields. This is a computer vision approach to wind field measurement. The name of the software is *Typhoon* and it was developed by Dr. Pierre Dérian. The solutions contain a vector at every pixel.

Dérian, P., C. F. Mauzey, and S. D. Mayor, 2015: Wavelet-based optical flow for two-component wind field estimation from single aerosol lidar data. *J. Atmos. Ocean. Technol.*, **32**, 1759-1778.

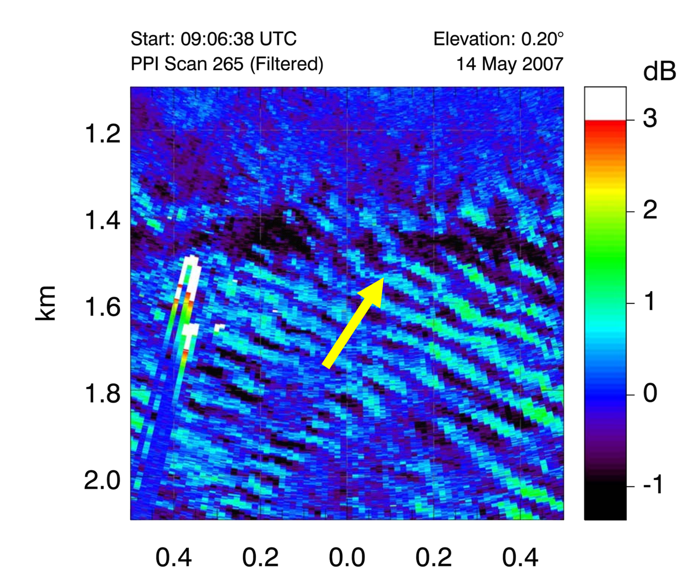


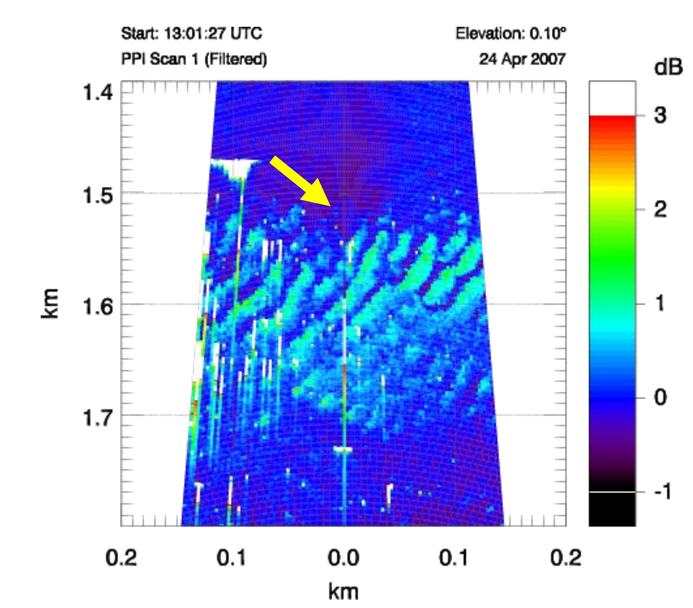


6. Canopy waves

REAL collected over 1600 frames of canopy waves during CHATS. These are shear-driven waves in stably-stratified conditions (Kelvin-Helmholtz Instability billows). Further inspection indicates that it can see very fine scale structure of primary and second instabilities.

Mayor, S. D., 2017: Observations of microscale internal gravity waves in very stable atmospheric boundary layers over an orchard canopy. *Agric. For. Meteorol.* **244-245**, 136-150.

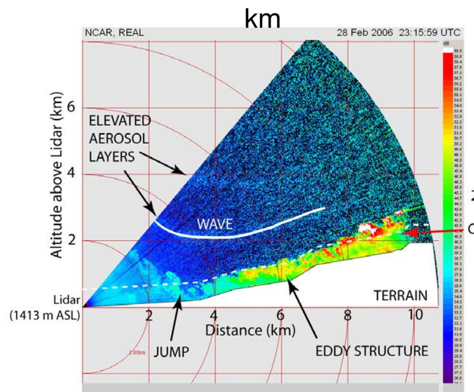


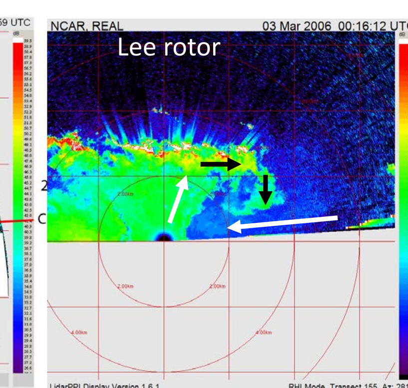


7. Flow over complex terrain

Although not its best performance due to reduced pulse energy, the REAL provided useful data in the Terrain-induced Rotors Experiment in the Owens Valley of California in 2006. Shown to the right are a rotor (left) and a hydraulic jump (left) in the lee of the Sierra Nevada Mountains.

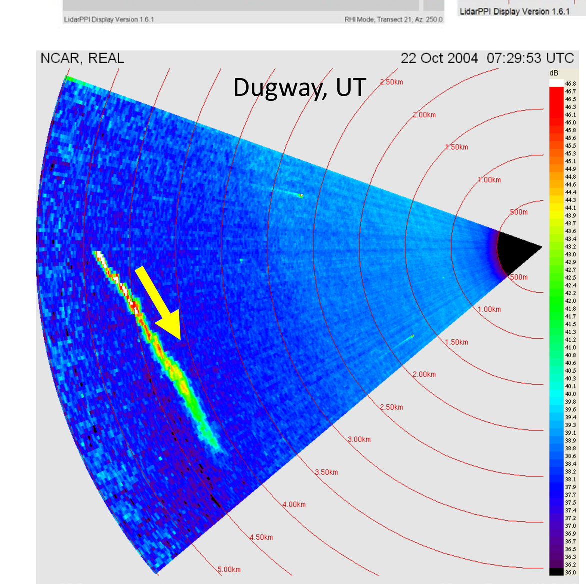
De Wekker, S. F. J. and S. D. Mayor, 2009: Observations of atmospheric structure and dynamics in the Owens Valley of California with a ground-based, eye-safe, scanning aerosol lidar. *J. Appl. Meteor. Clim.*, **48**, 1483-1499.

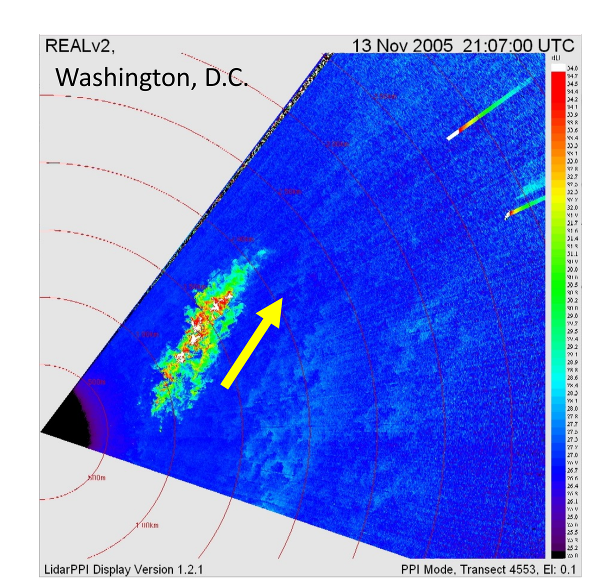




8. Dispersion of aerosol plumes

REAL can detect very small changes in particle concentration and subvisual aerosol plumes. Extensive testing was conducted for the DOD and copies of the REAL were created for national security applications.





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