Raman-shifted Eye-safe Aerosol Lidar (REAL) at California State University, Chico

Shane D. Mayor, Ph.D.
Departments of Physics and Geosciences
California State University, Chico

Photo taken March, 2009

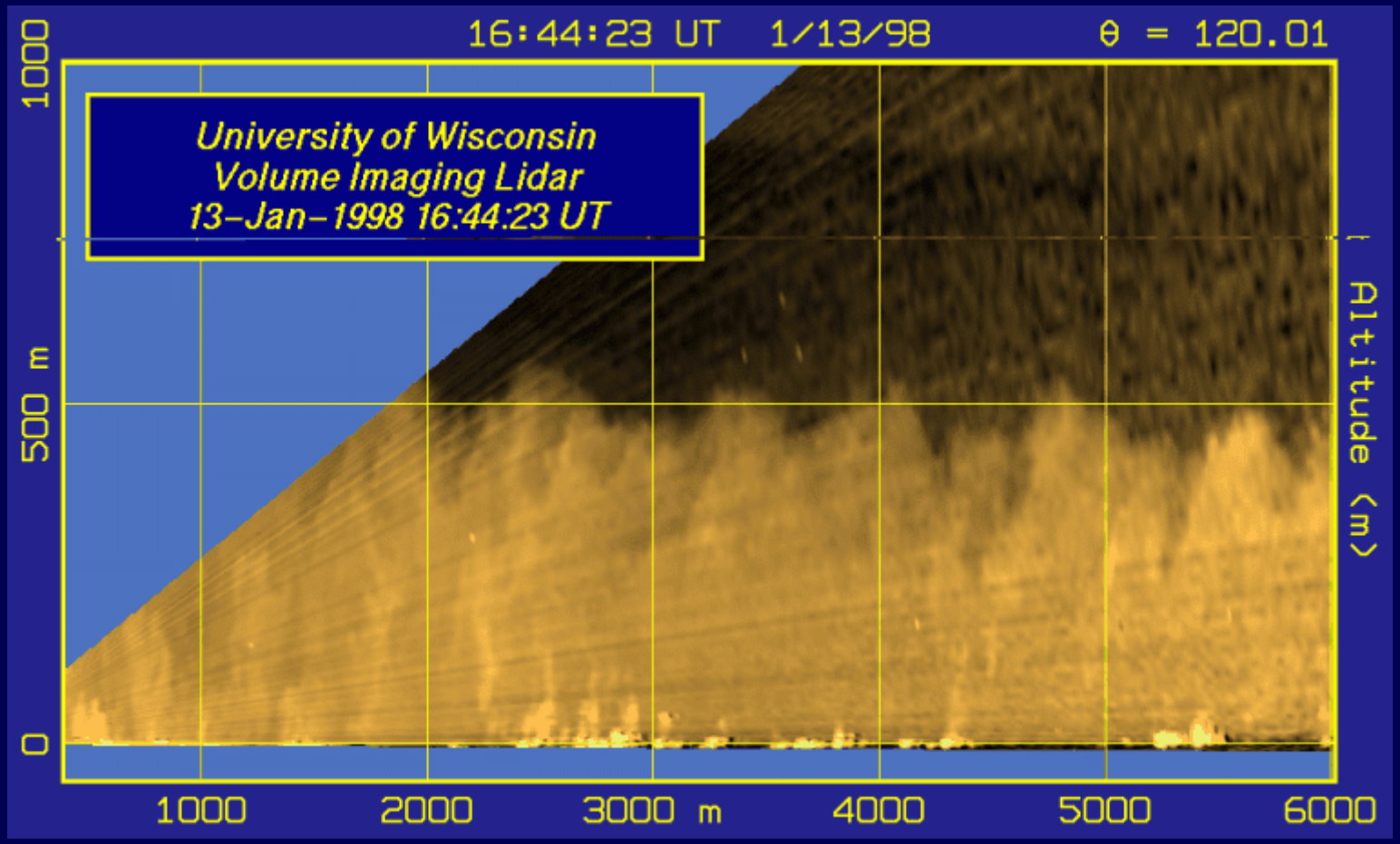
sdmayor@gmail.com
www.phys.csuchico.edu/lidar

Outline:

1. Motivation
2. Engineering challenges
3. Recent Observations
4. Future

1. Motivation

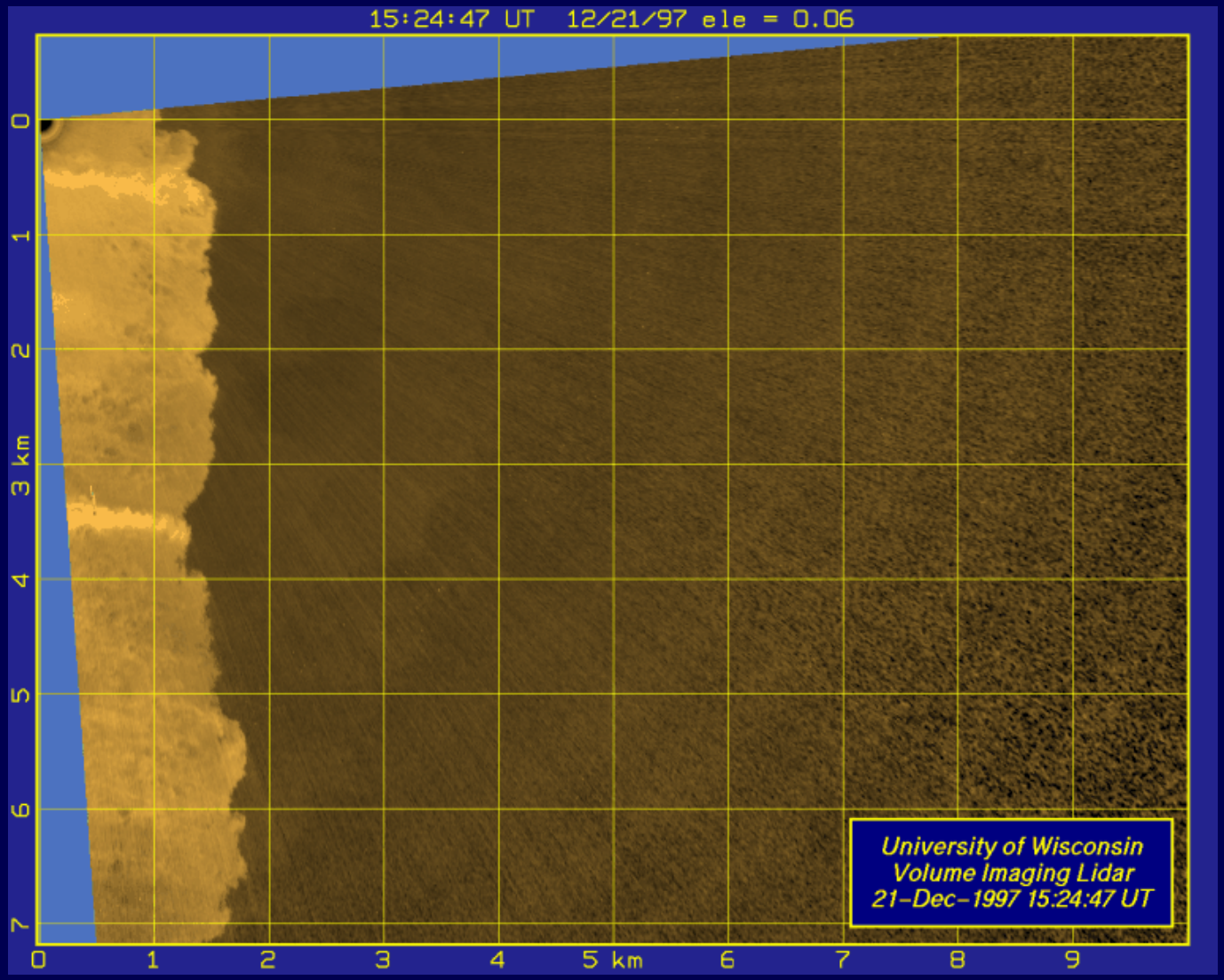
Dec 1997 - Jan 1998: Lake-Induced Convection Experiment (Lake-ICE)



Click the image or here to download and play MPEG time-lapse animation of this case.

University of Wisconsin Volume Imaging Lidar Observations
courtesy Dr. Edwin Eloranta

Dec 1997 - Jan 1998: Lake-Induced Convection Experiment (Lake-ICE)



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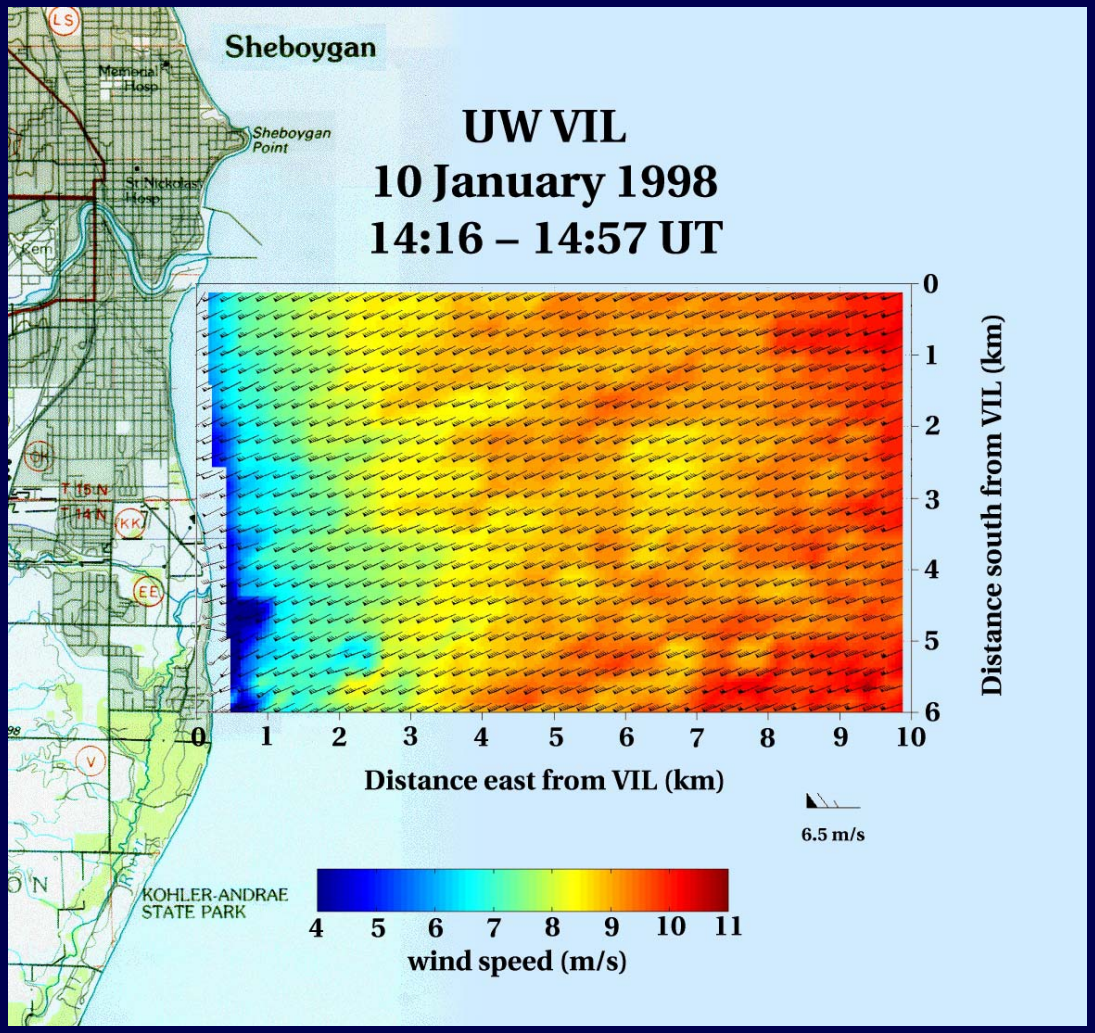
University of Wisconsin Volume Imaging Lidar Observations
courtesy Dr. Edwin Eloranta

Uses of the backscatter images:

- Vector flow fields
- Boundary layer depth
- Entrainment zone structure
- Coherent eddy structure
- Eddy lifetime
- Gravity wave activity
- Model verification

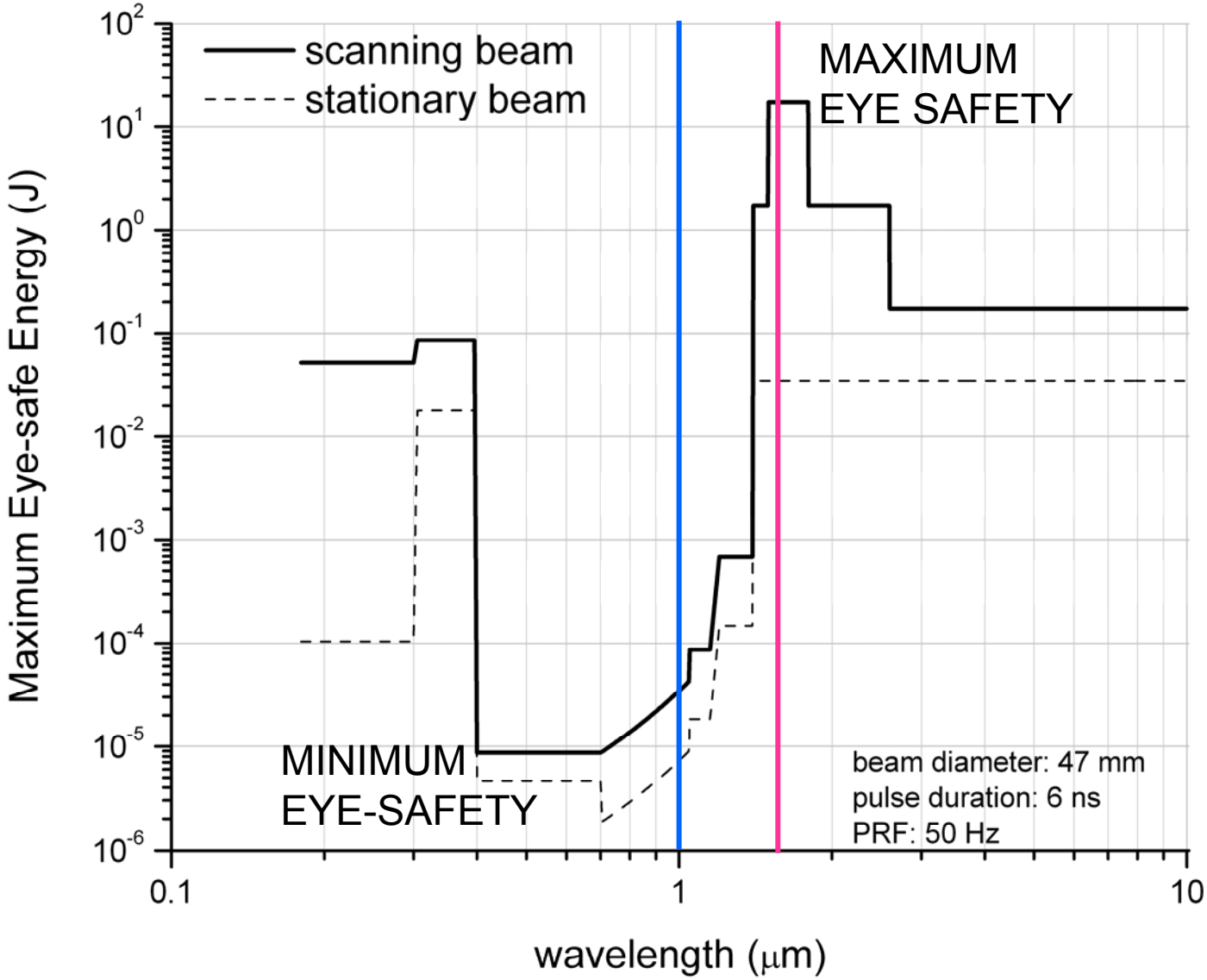


Publications:

Mayor and Eloranta, 2001: Two-dimensional vector wind fields from volume imaging lidar data, *J. Appl. Meteor.*, **40**, 1331-1346.

Mayor, Spalart, Tripoli, 2002: Application of a perturbation recycling method in the large-eddy simulation of a mesoscale convective internal boundary layer, *J. Atmos. Sci.*, **59**, 2385-2395.

Mayor, Tripoli, Eloranta, 2003: Evaluating large-eddy simulations using volume imaging lidar data, *Mon. Wea. Rev.*, **131**, 1428-1452.

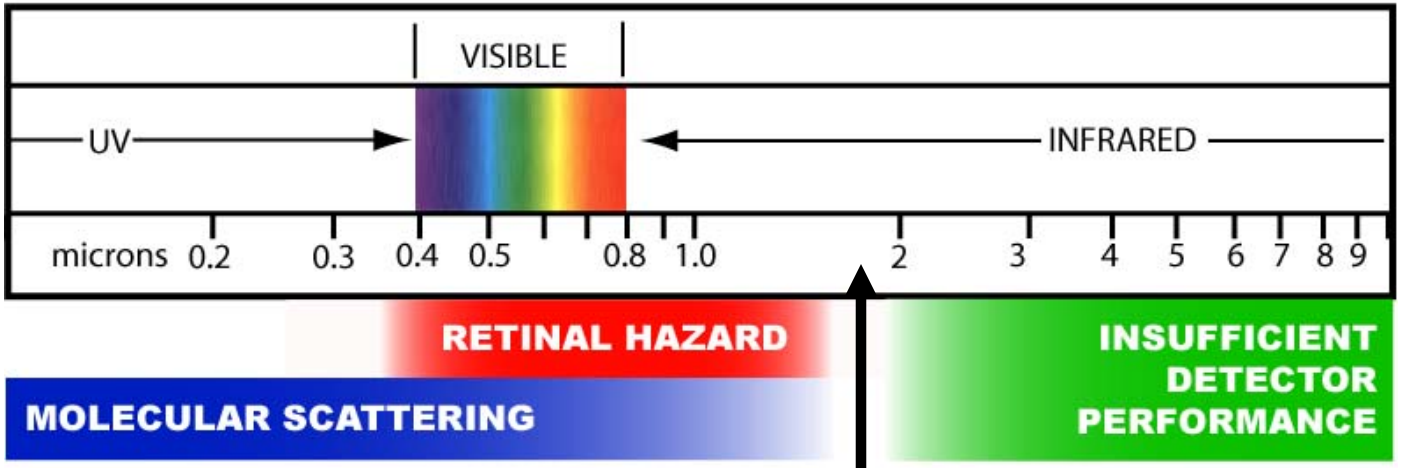


Spuler, S. M. and S. D. Mayor, 2007: Raman shifter optimized for lidar at 1.5 microns, *Appl. Optics*, **46**, 2990-2995.

Optical region of the electromagnetic spectrum

Short wavelengths

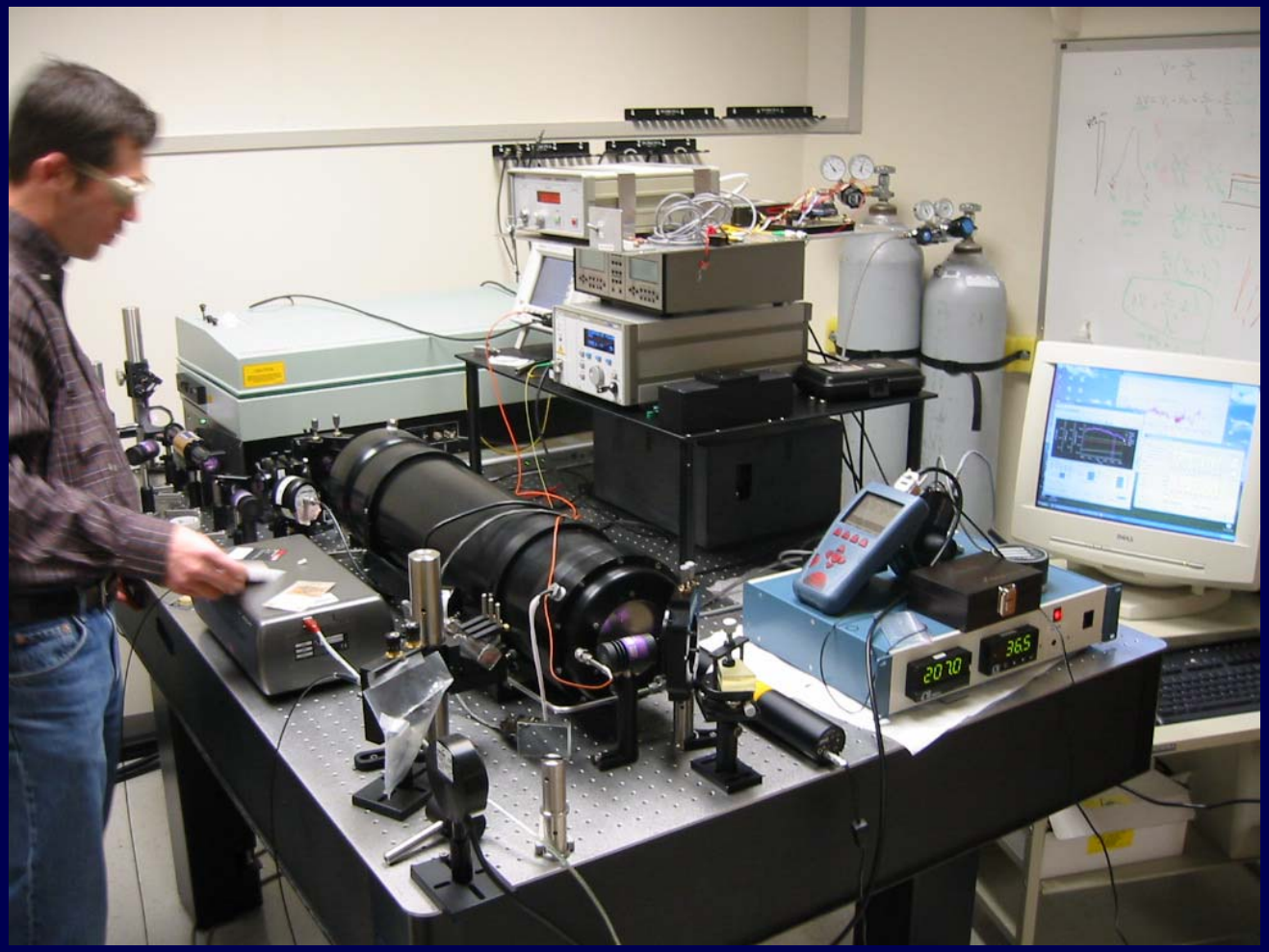
Long wavelengths



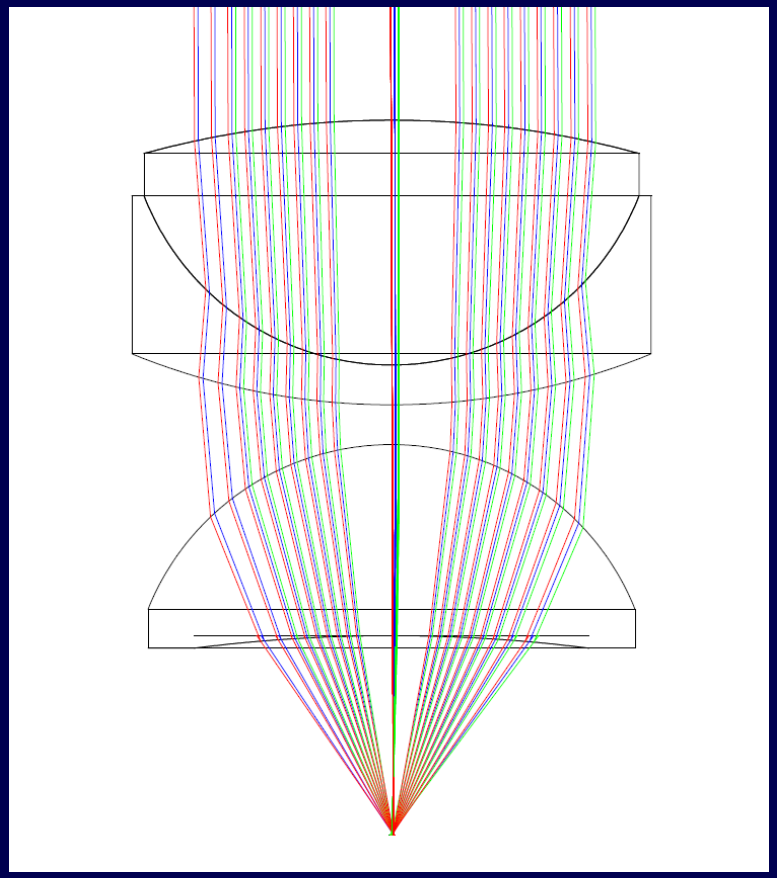
REAL operates at 1.5 microns

- Invisible beam
- Maximum eye-safety
- Low molecular scattering
- Good performance photodetectors
- Low sky background radiation
- Atmospheric transparency
- Use telecom optics & components

2. Engineering Challenges



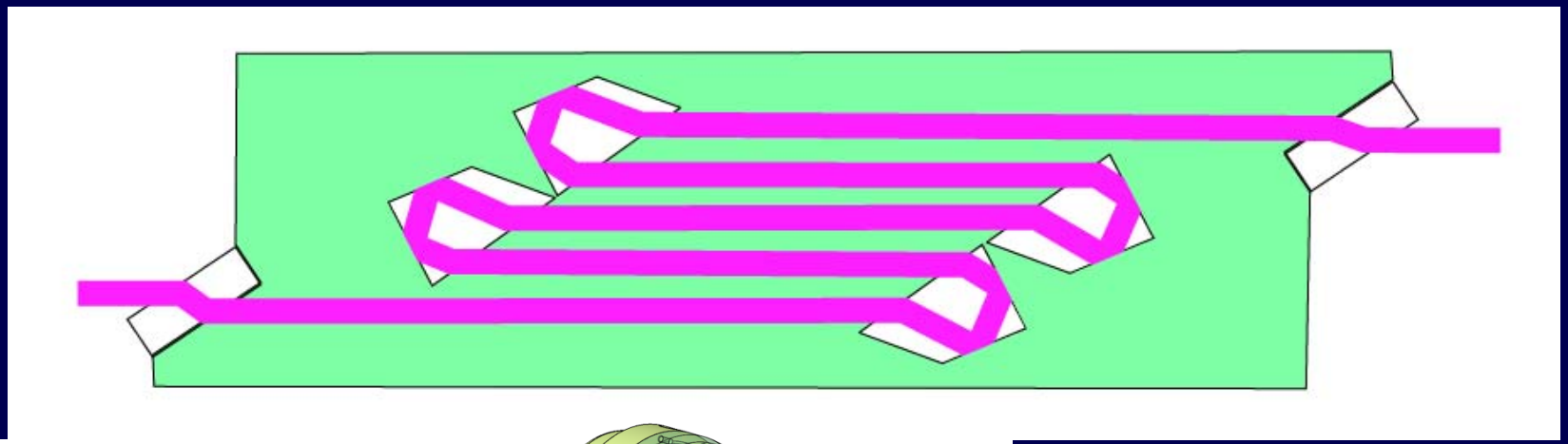
Off-the-shelf InGaAs APD

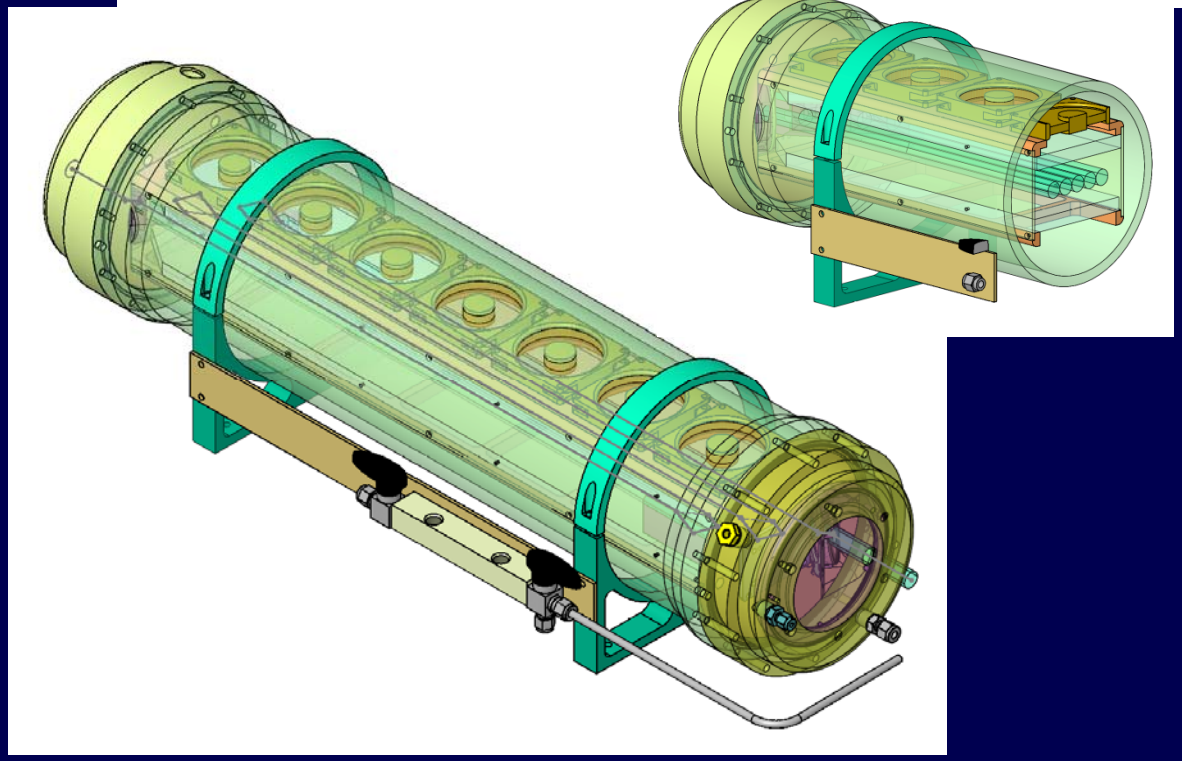


Custom Focusing Lens

200-micron active area of photodetector drives the design…

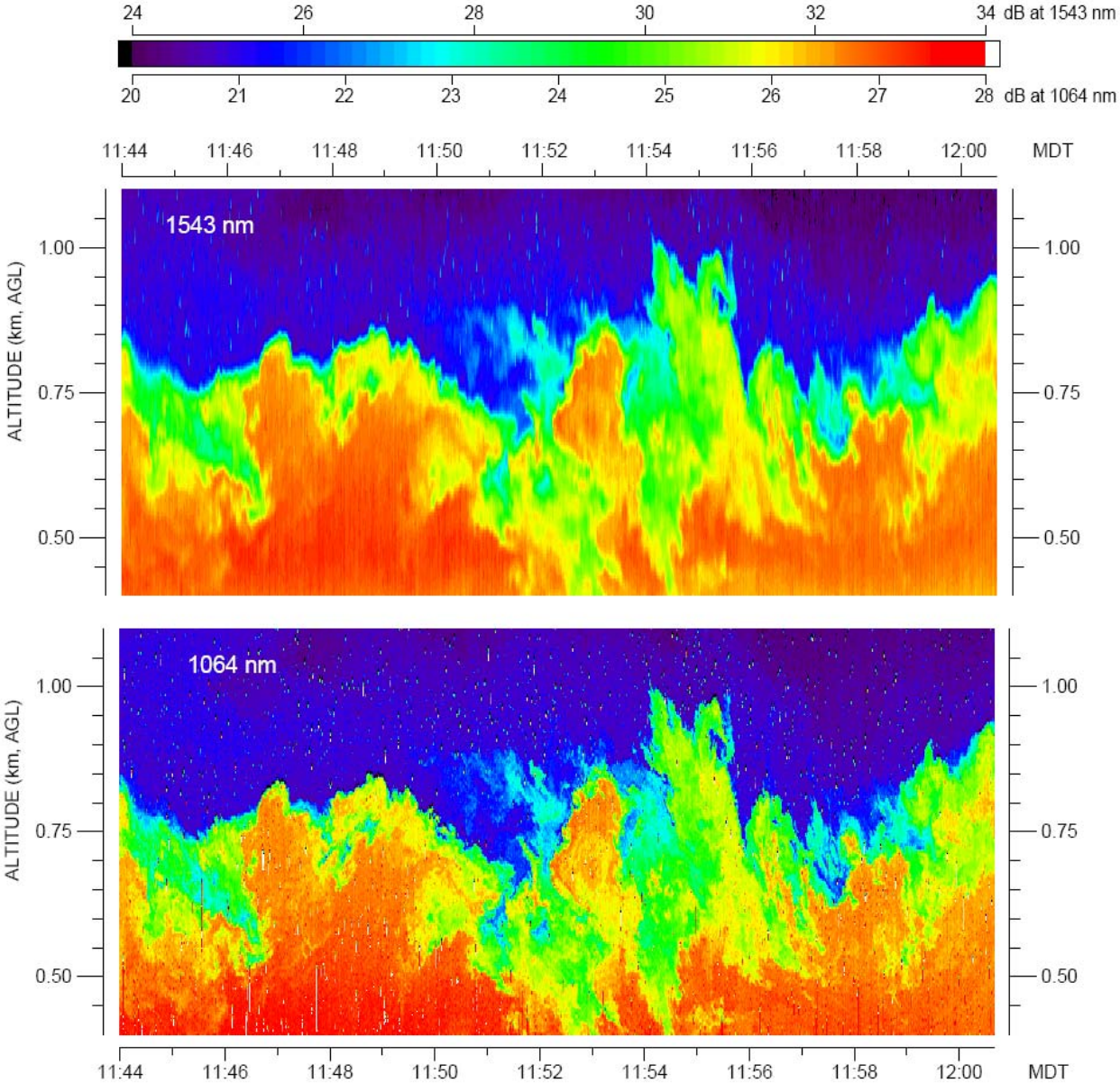
Wavelength conversion from 1.064 to 1.543 microns: Stimulated Raman Scattering in CH_4

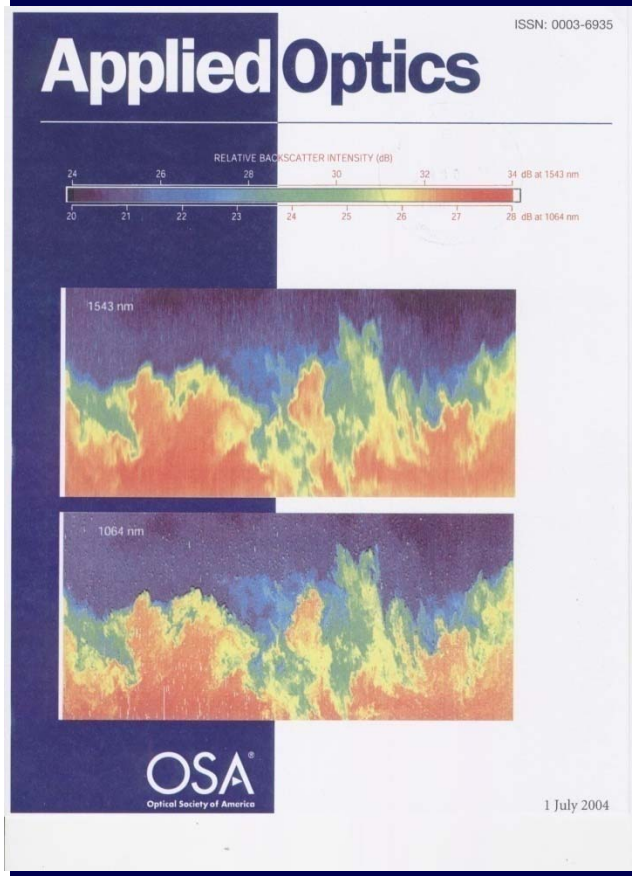




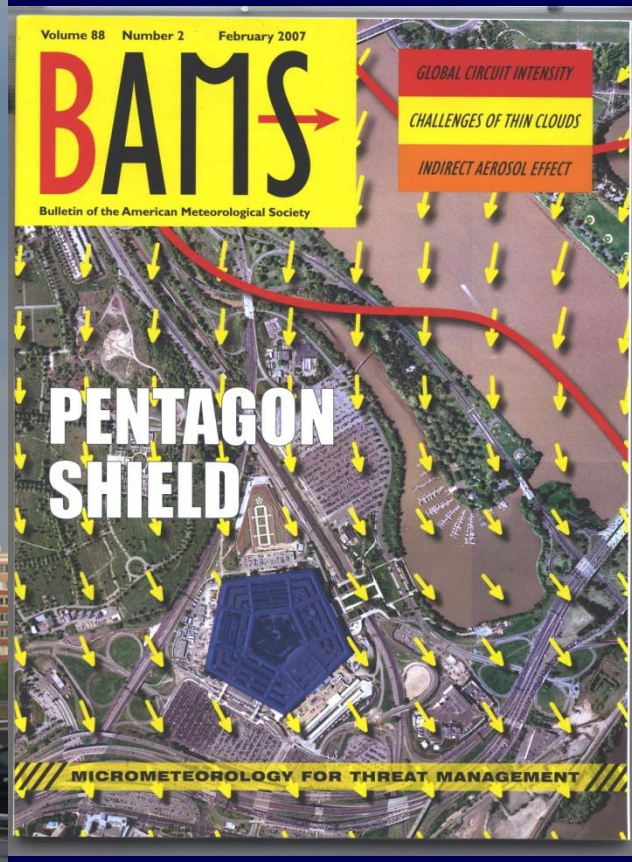
<u>Key Features</u>

- multi-pass
- CH_4 circulation
- coating-free
- injection seeding



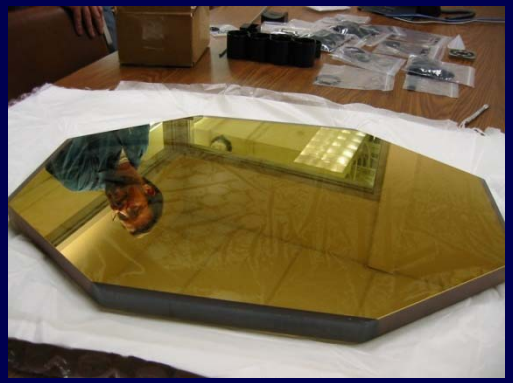


Mayor, S. D. and S. M. Spuler, 2004: Raman-shifted Eye-safe Aerosol Lidar, *Applied Optics*, **43**, 3915-3924.



Warner, T., et al., 2007: The Pentagon Shield Field Program – Toward Critical Infrastructure Protection. *Bull. Amer. Met. Soc.*, **88**, 167-176.

Poor-man's "lightweight" beam-steering unit mirrors

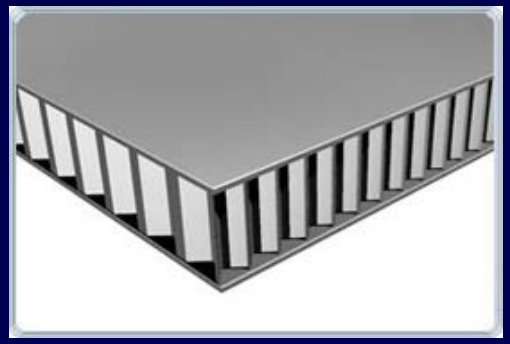


1" thick
Zerodur mirror
(40 x 60 cm)

+

RTV
Silicon adhesive

+

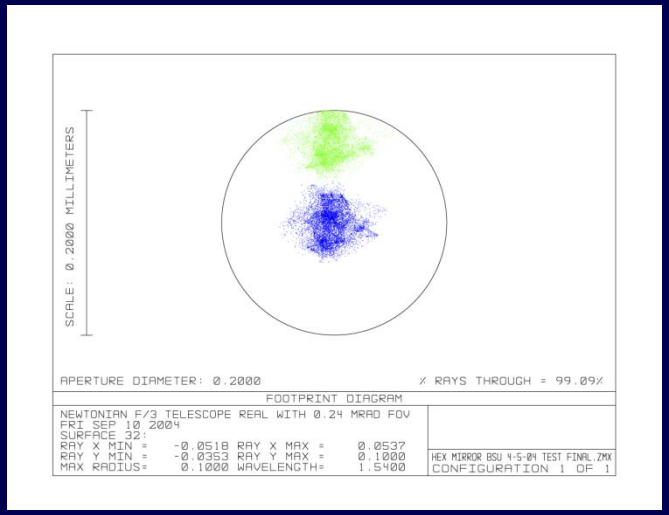


1.5" thick Hexcell
aluminum
substrate

<u>Requirement</u>: 10 waves over full aperture

<u>Result</u>: Adequate flatness

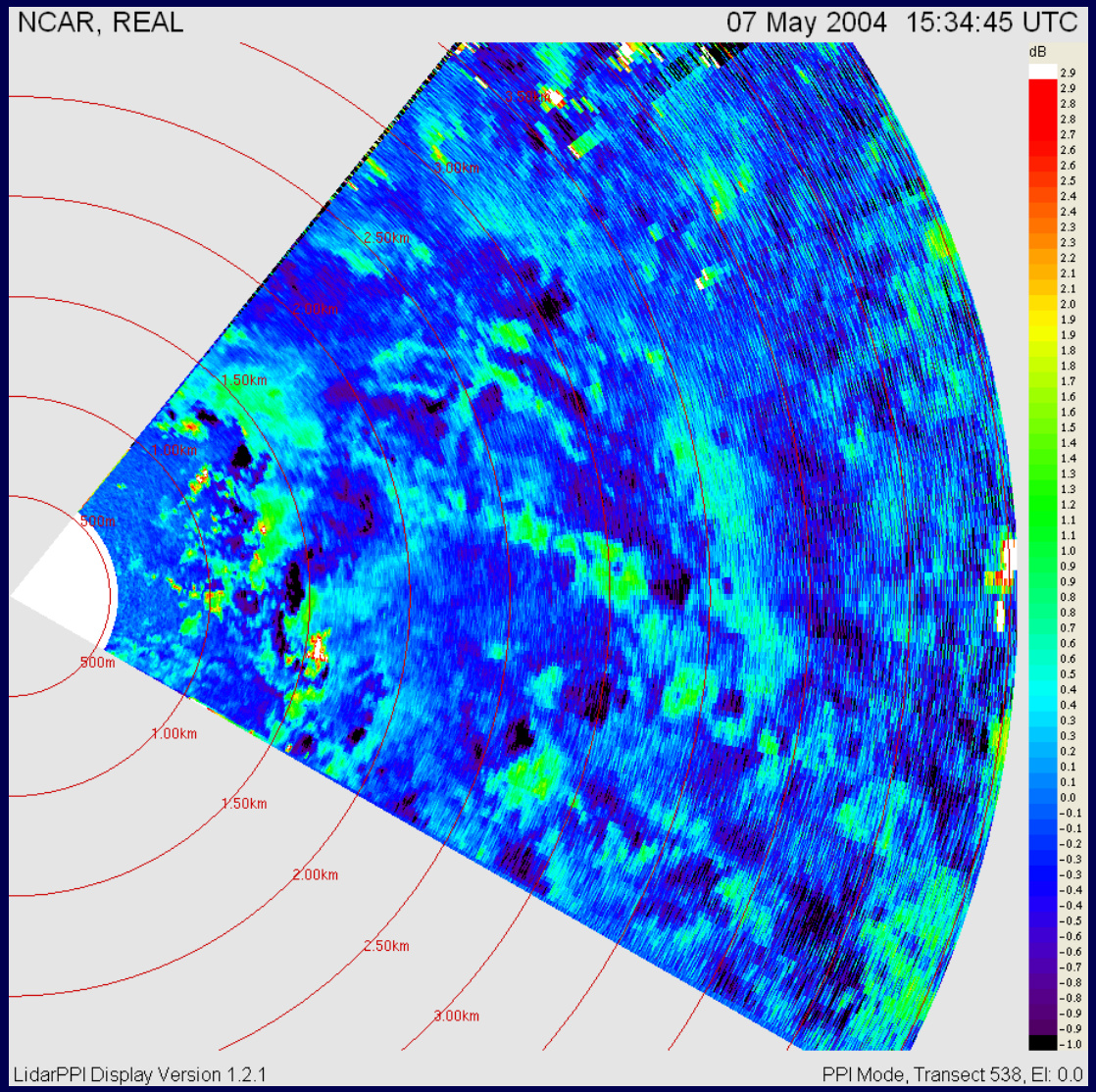
<u>Weight</u>: 14 kg (25% of traditional solution)



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.

Washington DC

[Click here or the Image to go to the webpage hosting the animation.]



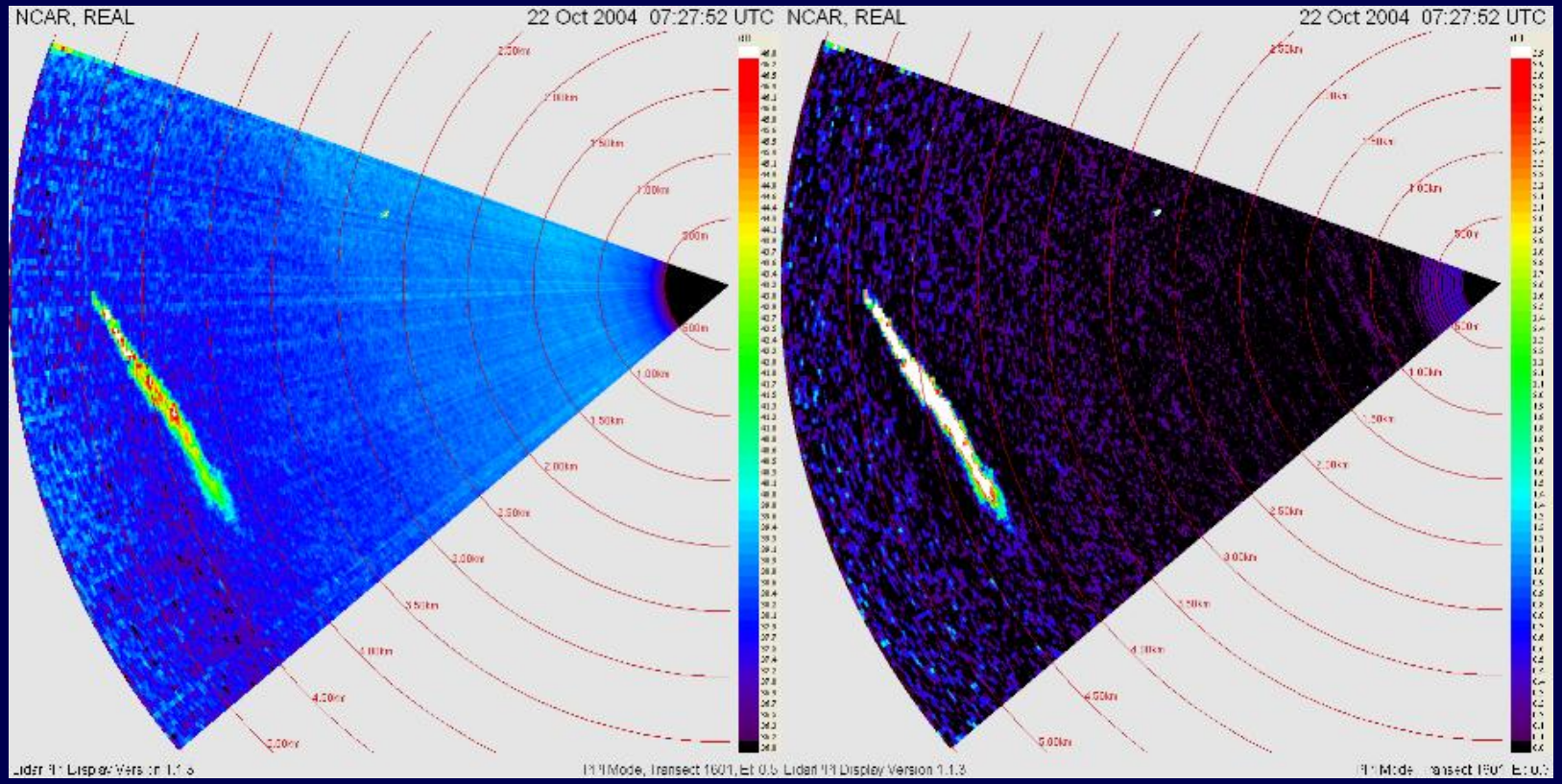
High-pass median filtered data

5 km range

U.S. Army Dugway Proving Ground, Utah, Oct. 2004

release EDTX 09

Point release *Bacillus subtilis var. niger* of from 5.0 km



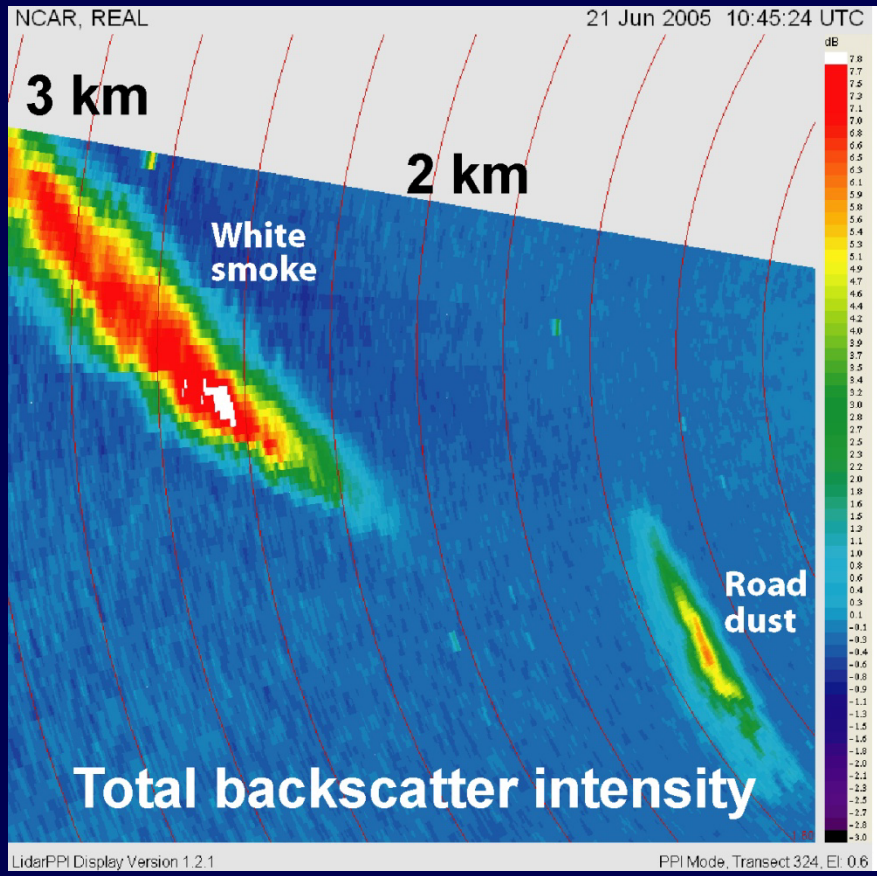
Unfiltered

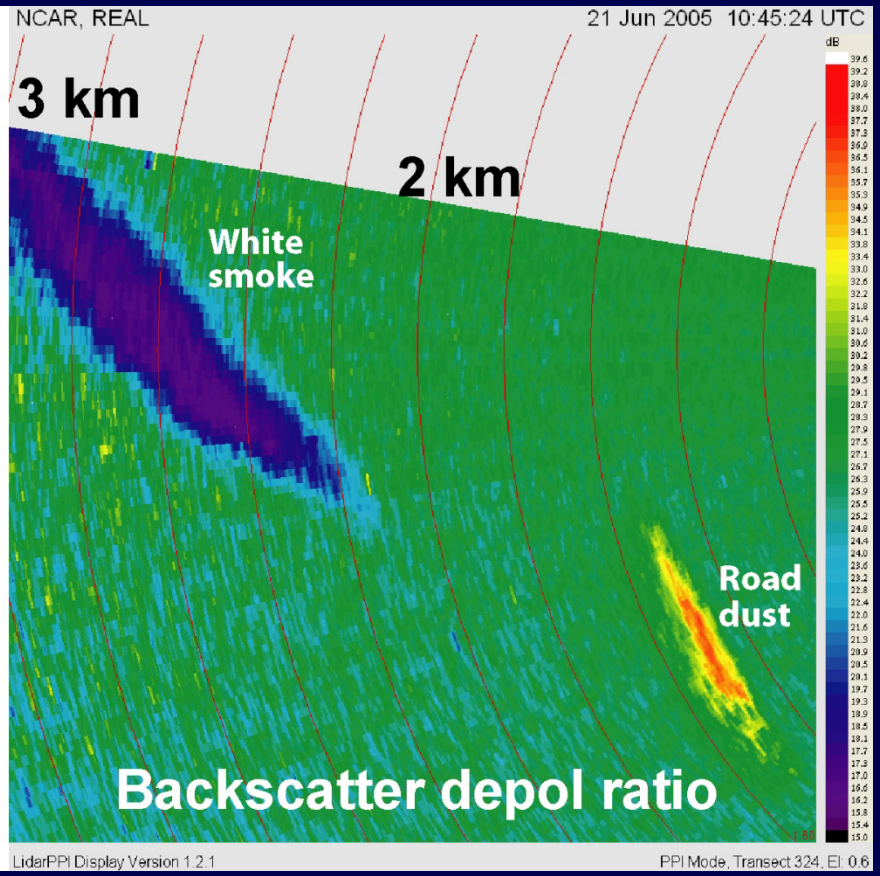
High-pass median filtered

Click on this link or the image to play the animation.

Horizontal scan, 44 minutes duration
5.5 km range total, 500 meter range rings

Dugway Proving Ground, Utah, June 2005





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.

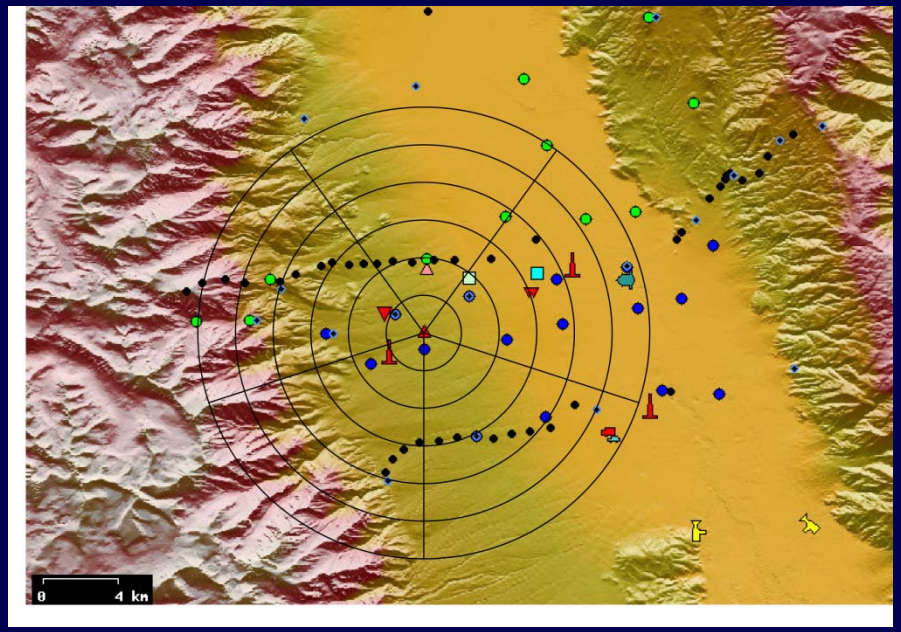
ITT REAL

ITT

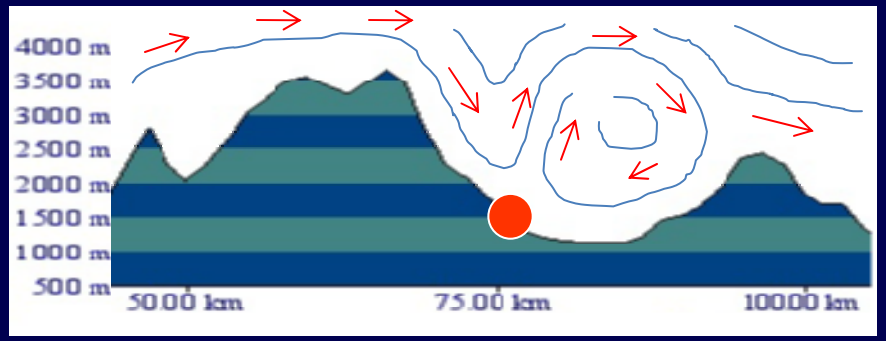
Engineered for life

3. Observations

Terrain-induced Rotors Experiment (T-REX) : March and April 2006.



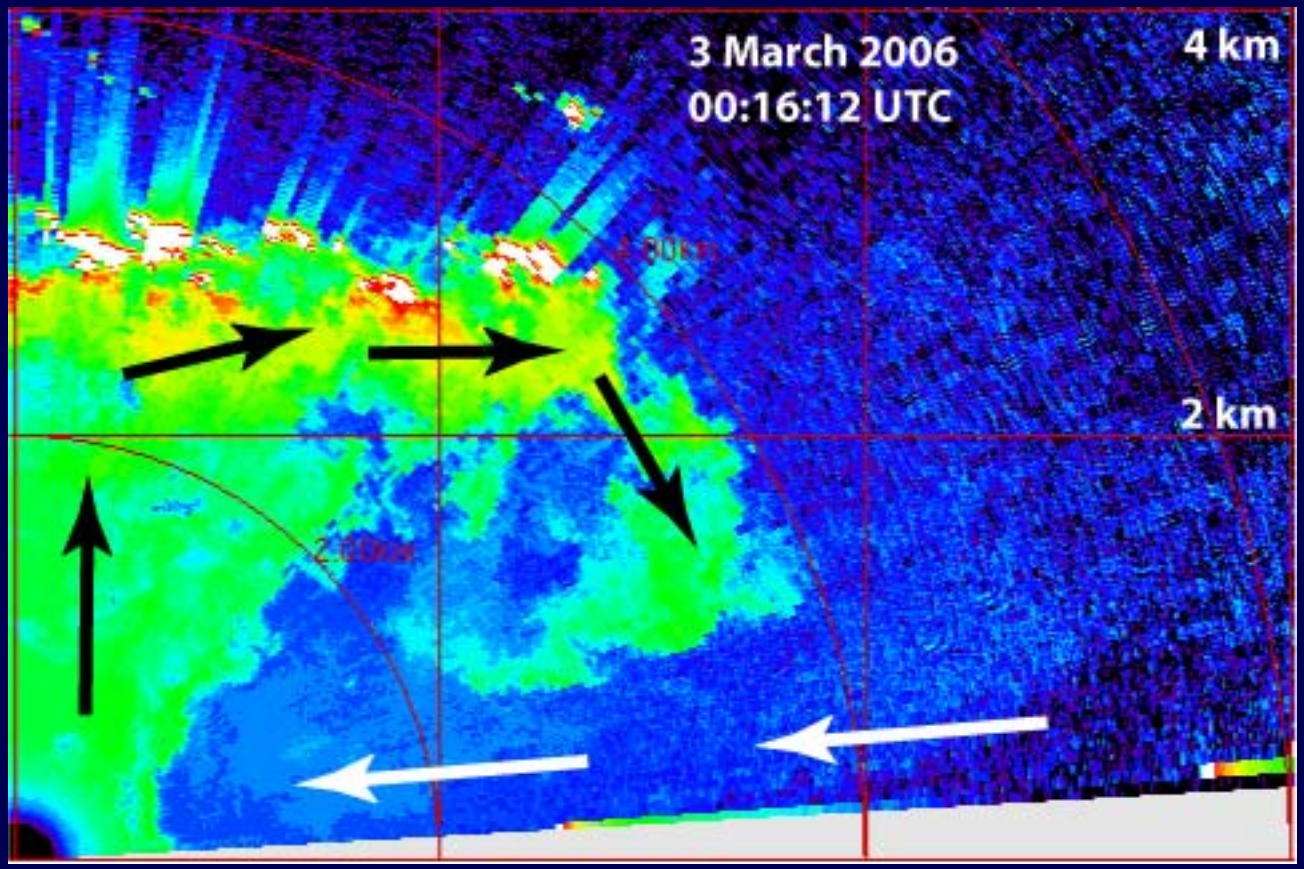
Hydraulic Jump and Rotor Circulation



Results from T-REX

T-REX: 2 March 2006

Click her or on the image to download and play time-lapse MOV file



Publications:

Doyle, J. D., V. Grubisic, W. O. J. Brown, S. F. J. De Wekker, A. Dornbrack, Q. Jiang, S. D. Mayor, M. Weissmann, 2009: Observations and numerical simulations of subrotor vortices during T-REX. *J. Atmos. Sci.,* **66**, 1229-1249.

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*. In Press.

Canopy Horizontal Array Turbulence Study (CHATS)
15 March – 11 June 2007, Dixon, California

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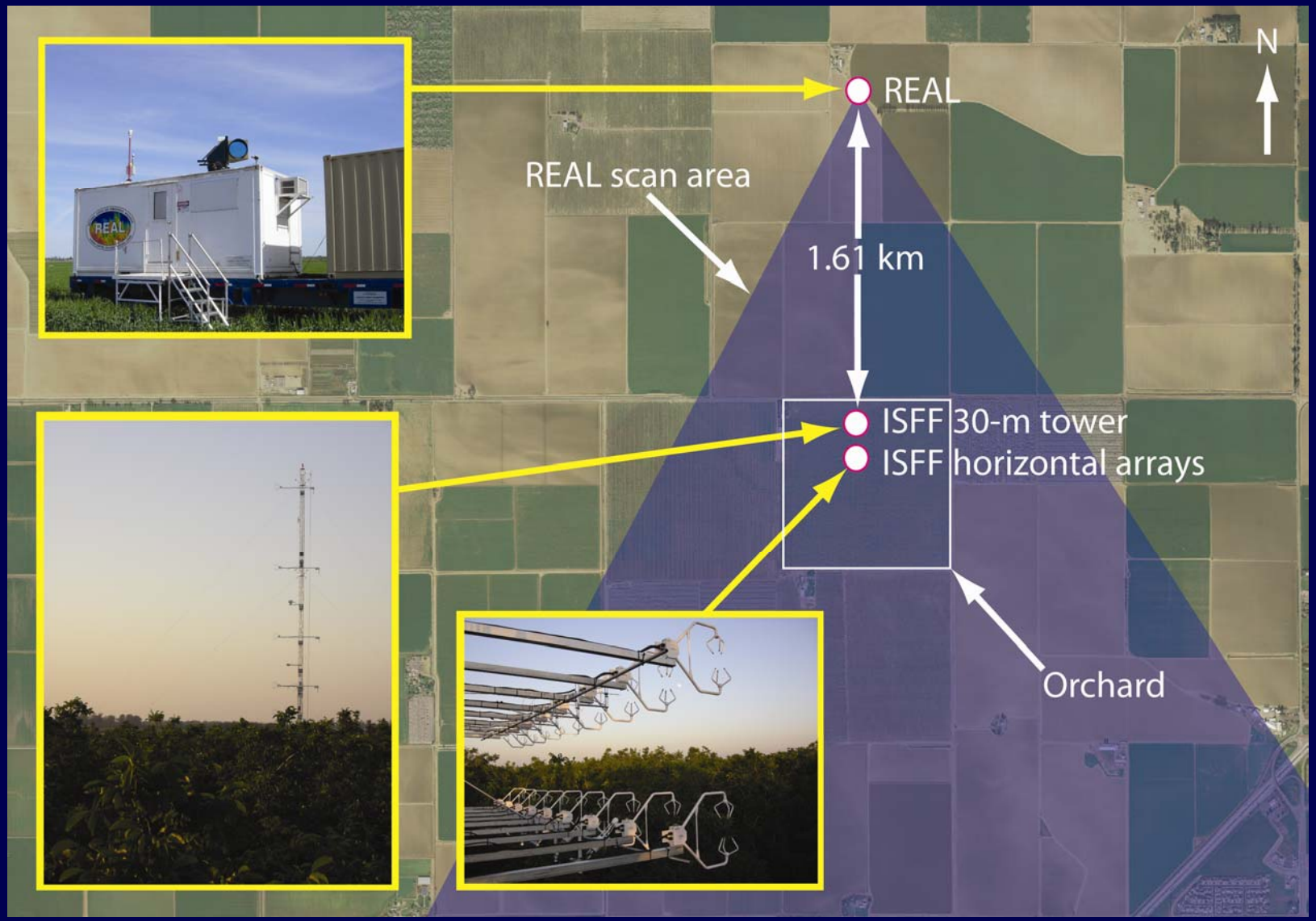
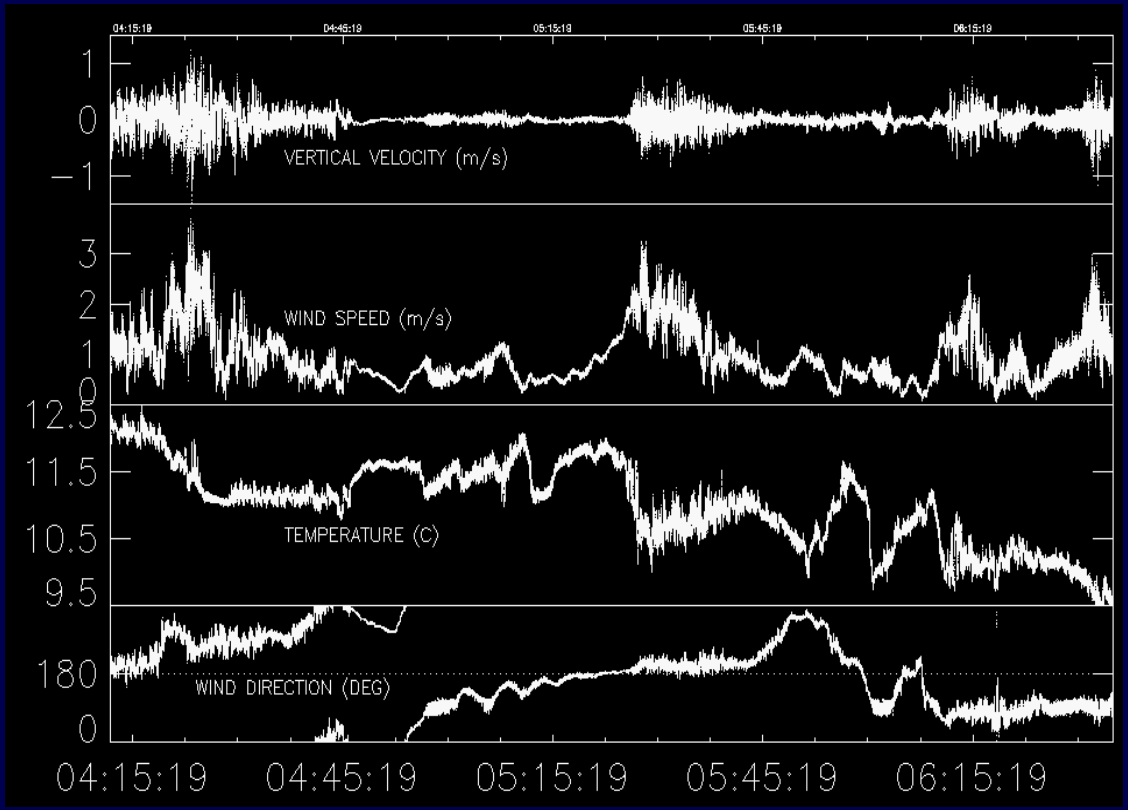


CHATS, 15 March – 11 June 2007, Dixon CA

21 March 2007: 04:12 – 6:35 UTC
(7:12 PM to 11:35 PM PDT)

(Sunset: 7:20 PDT)

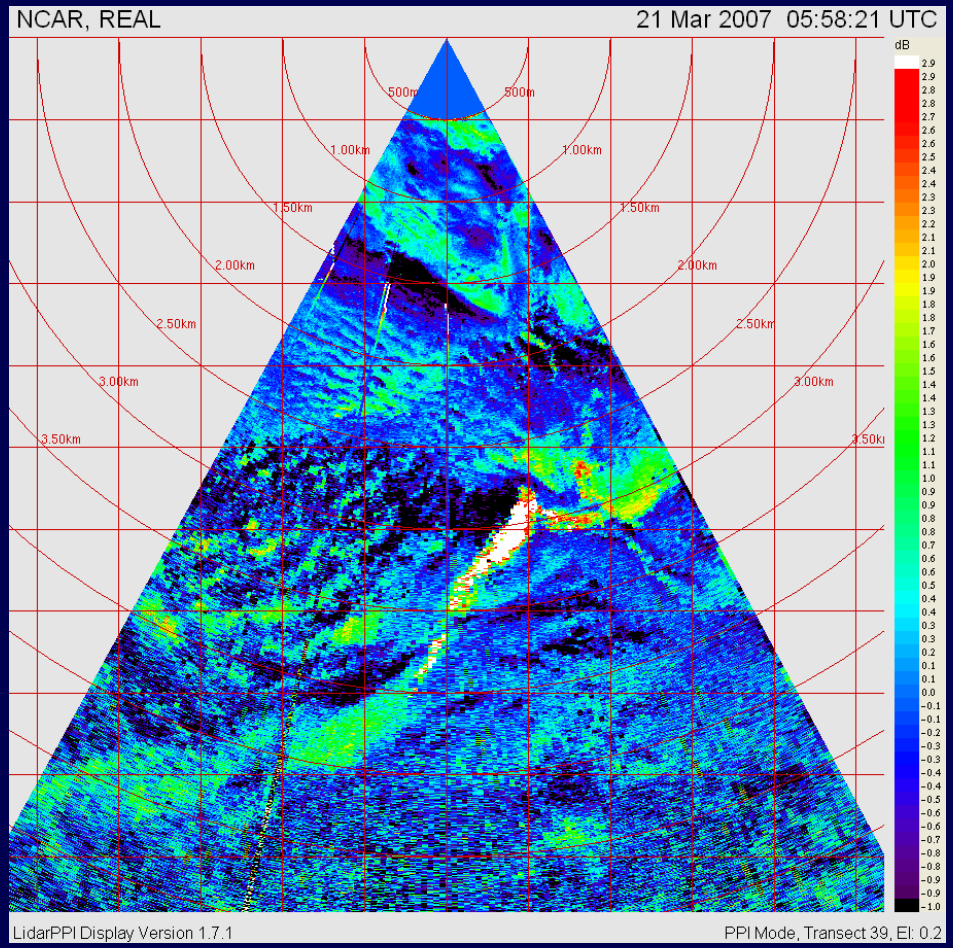


2 hours 23 minutes duration

21 March 2007: 04:12 – 6:35 UTC
(7:12 PM to 11:35 PM PDT)

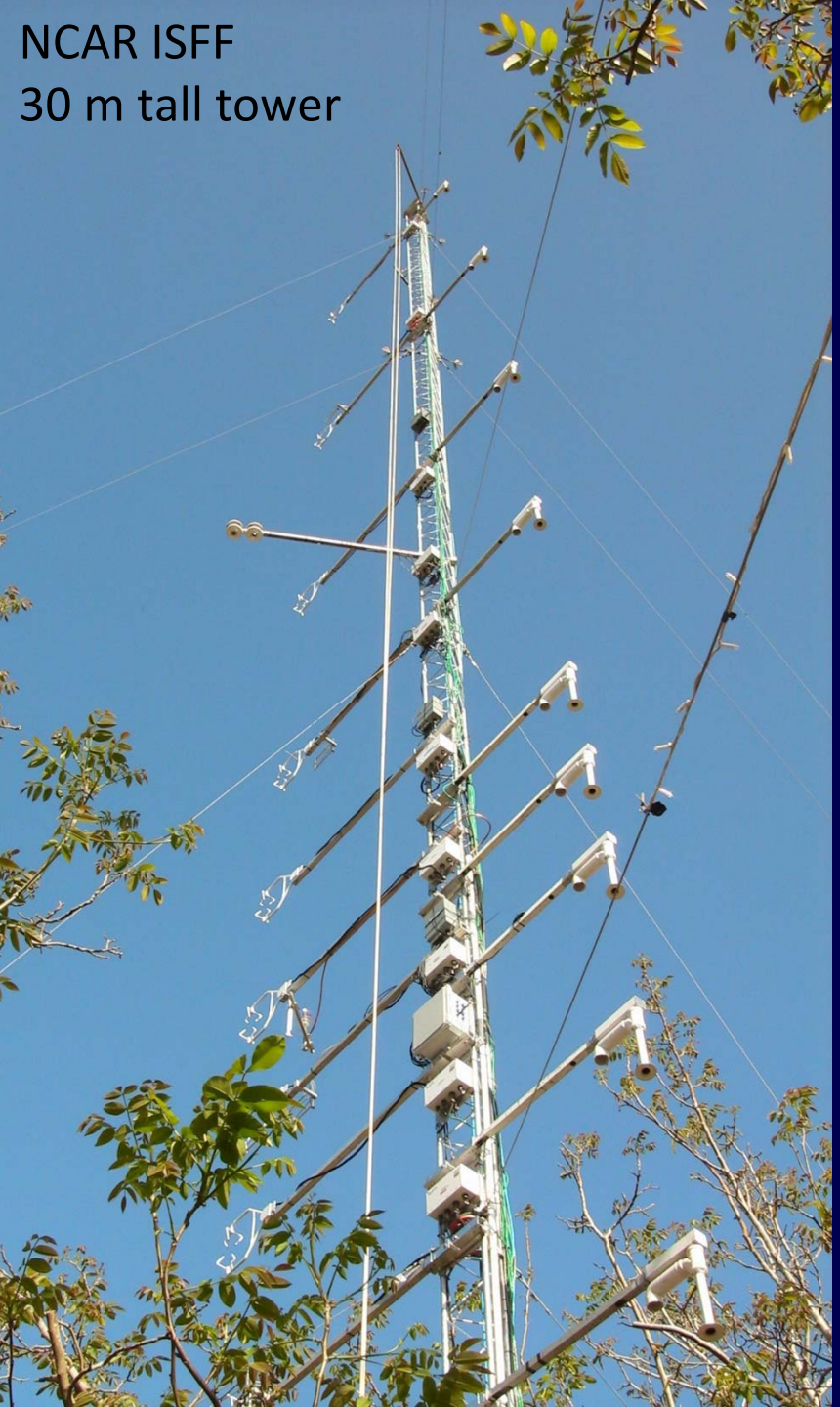
(Sunset: 7:20 PDT)

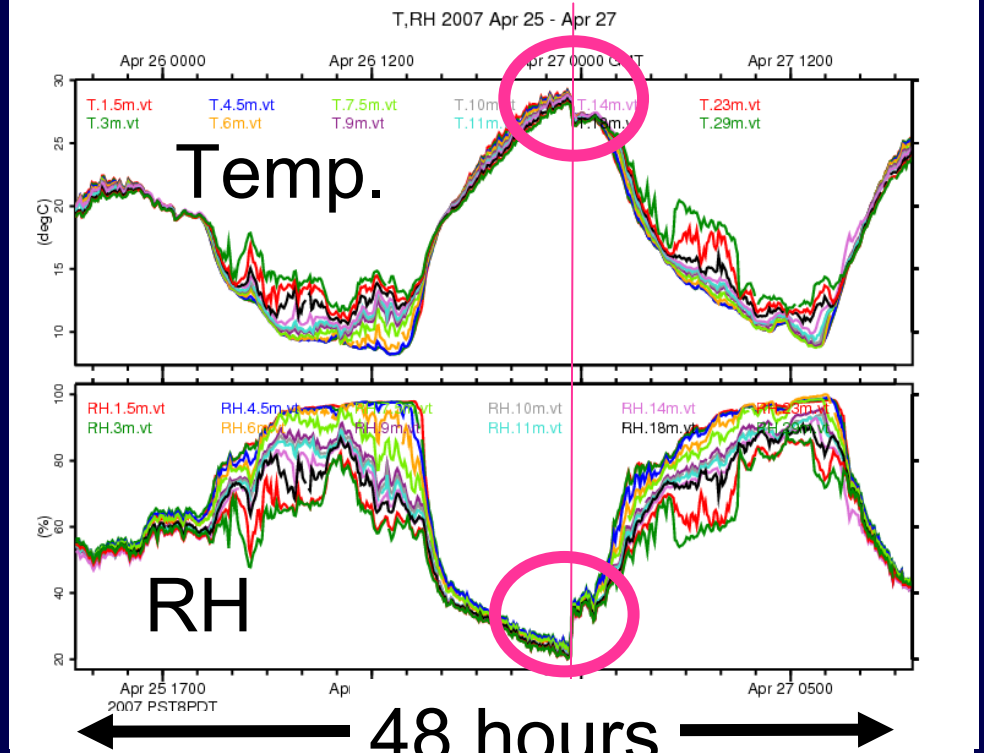
[Click here or the image to go to the webpage hosting the animation.]



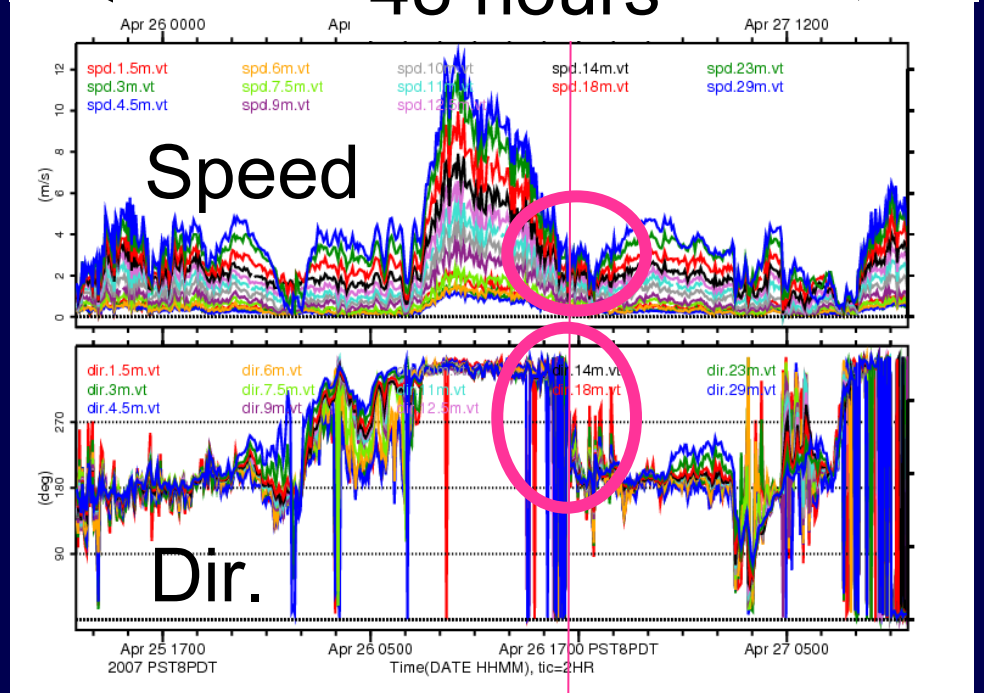
2 hours 23 minutes duration

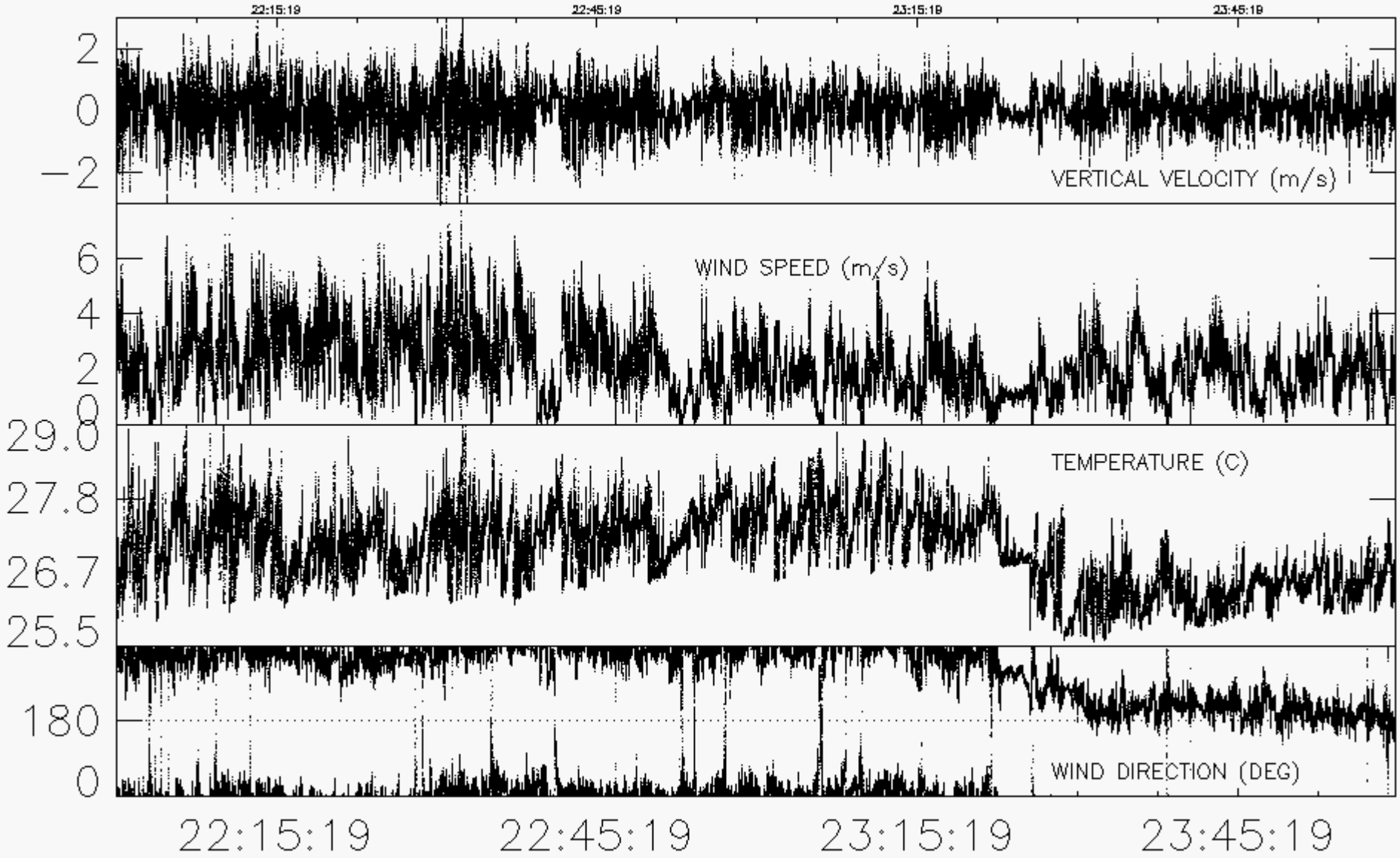
NCAR ISFF
30 m tall tower





48 hours



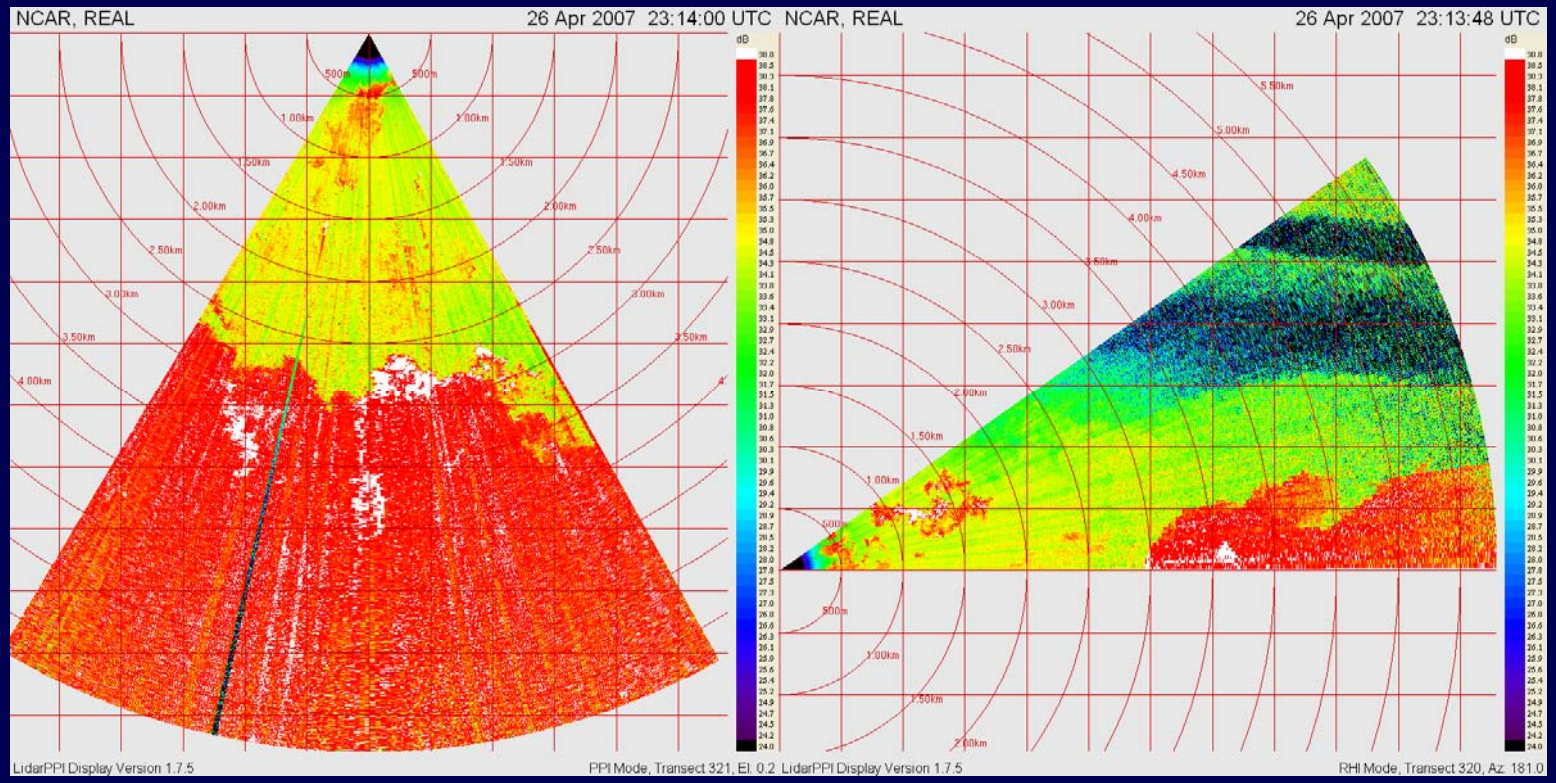


z/L at 12.5 m changing rapidly from -2.0 (strongly unstable) to -0.6 (unstable)

z/L at 12.5 m changing more slowly from -0.5 (unstable) to -0.2 (weakly unstable)

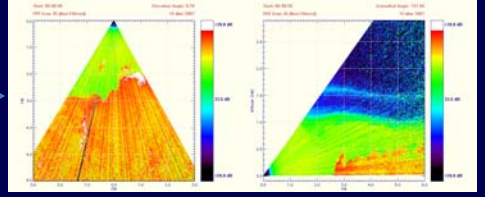
REAL at CHATS: 22:00 UTC 26 April – 00:00 UTC 27 April

Sea-breeze Front (Delta Breeze front)

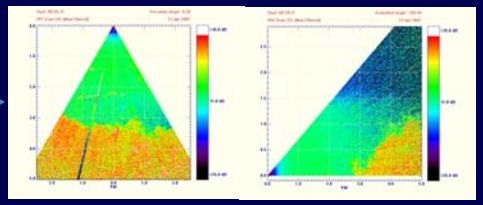


- Click here or on image to go to animation on web
- 2-hour time-lapse animation, 500 m range rings
- 3.5 dB change in backscatter intensity
- Average frontal speed: 5.8 km / 51 minutes = 1.9 m/s

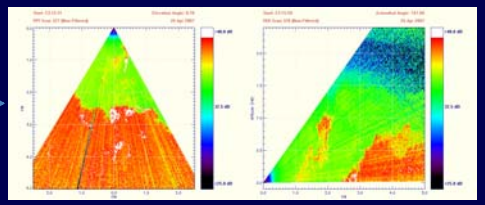
				15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11					



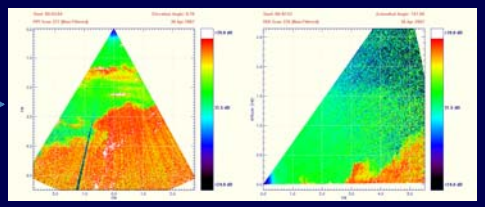
15 March
00:50



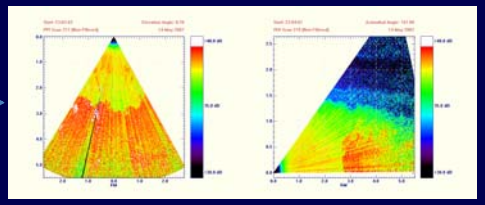
24 April
00:37



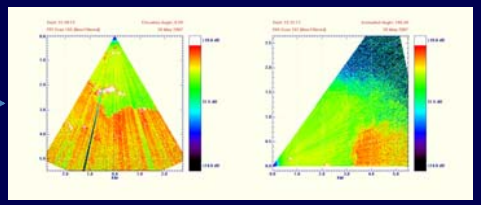
26 April
23:25



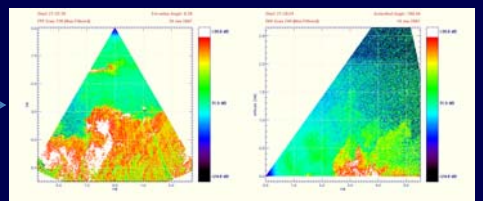
1 May
01:00



14 May
23:13

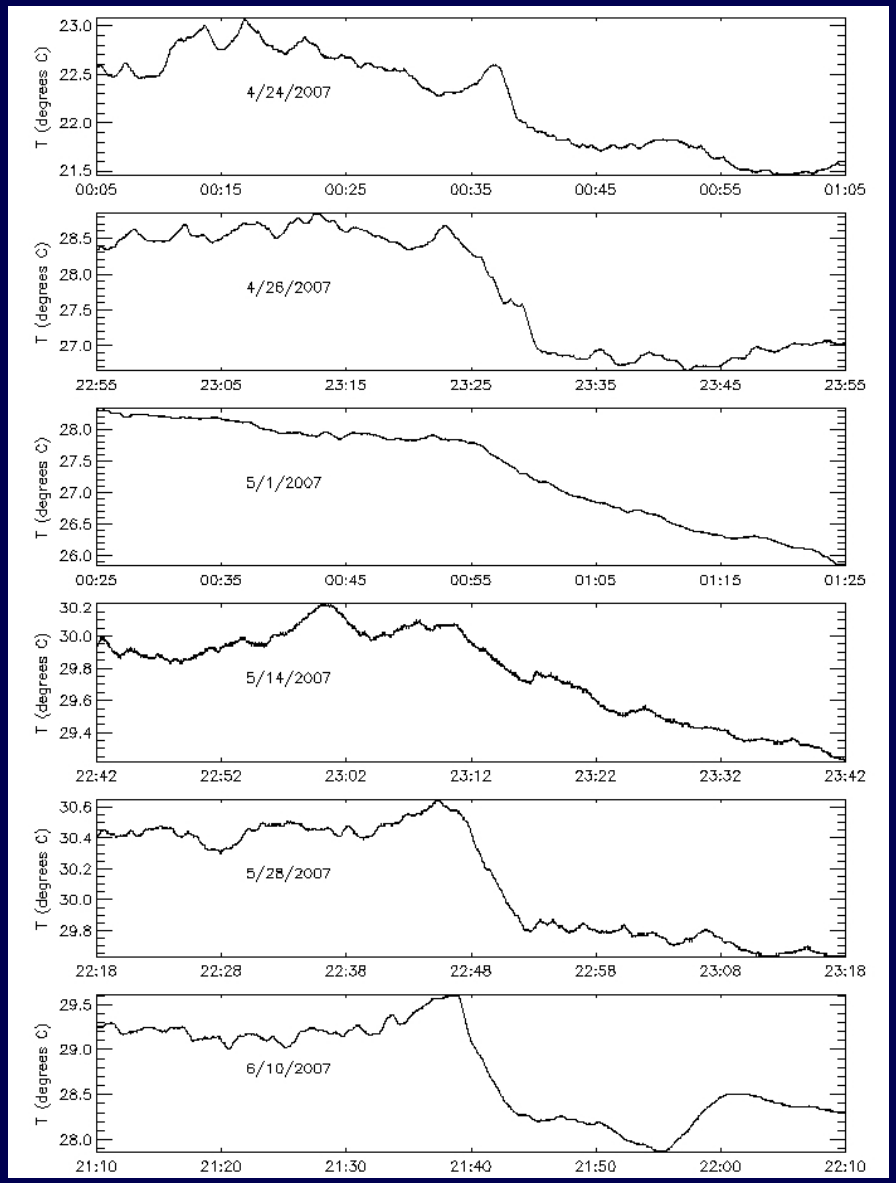


28 May
22:49

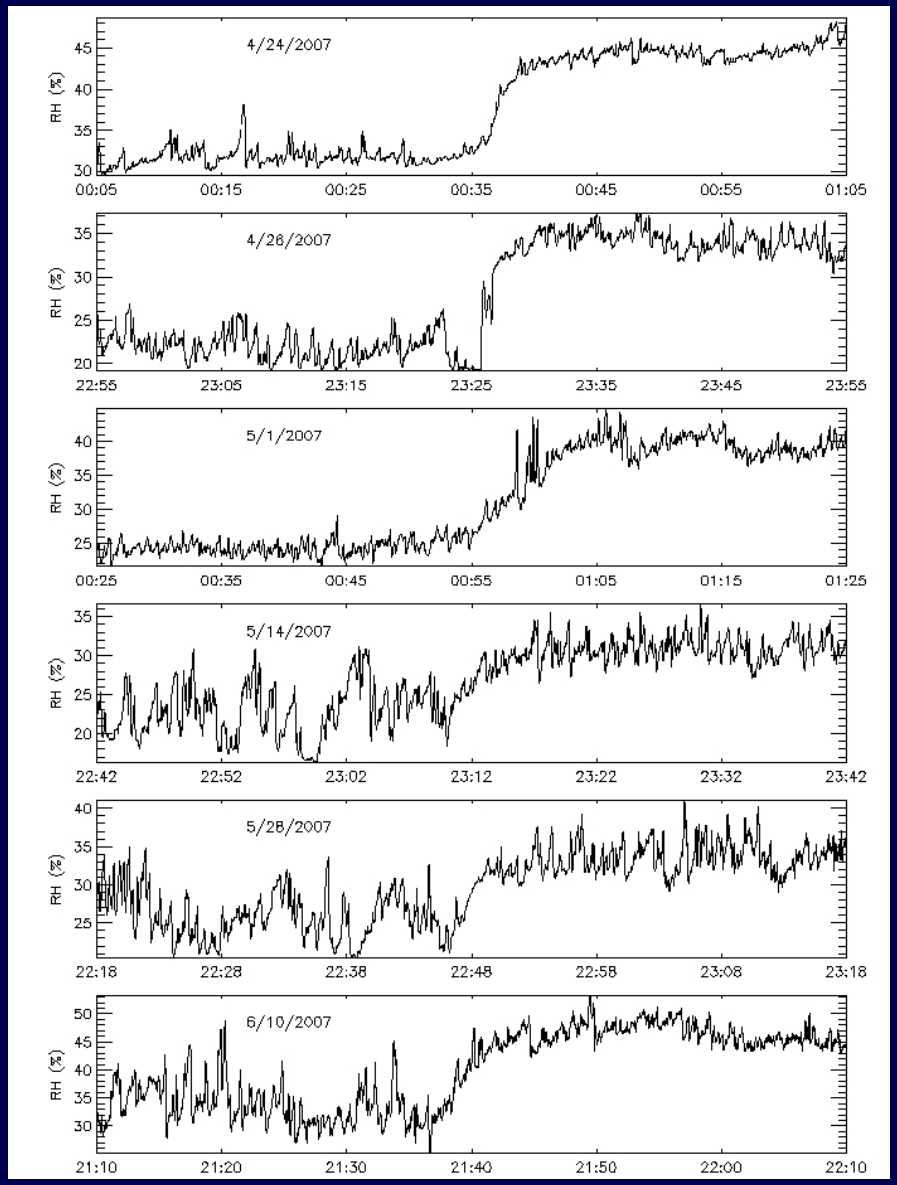


10 June
21:39

Temperature



Relative Humidity



Future

- Algorithm development:
  - vector flow fields
  - boundary layer height
  - aerosol plume boundaries
- Improve understanding of lidar sensitivity to particles
- Estimate aerosol optical depth using multi-angle technique
- Deploy again to study Delta Breeze Fronts

REAL is field-transportable and available for use.

Thank you!

For more information: http://phys.csuchico.edu/lidar

Taken from the Chico State Farm at Sunset. January, 2009