Upper-Air Meteorological Instruments: Cost, Installation, Maintenance, and Data Use Considerations

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for

National Ambient Air Monitoring Conference
St. Louis, MO

August 8, 2016

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Upper-Air PAMS Background

- Previous Photochemical Assessment Monitoring Stations (PAMS) program required one upper-air meteorological site per network.
  - Four wind and temperature soundings per day*
- Many agencies deployed radar wind profilers (RWPs); several still operate.
- While RWPs provide useful data, aging equipment and related costs are issues.

*http://www.epa.gov/ttnamti1/files/ambient/pams/97workbook11.pdf

Upper-Air PAMS Background

- With the new ozone NAAQS, EPA proposed a change in the PAMS program to allow more flexibility
  - Will require 1-hr mixing height measurements
  - Will support measurements of other parameters (winds, temperature, etc.)
- PAMS monitoring at NCore sites will need to start by June 1, 2019

NAAQS – national ambient air quality standards

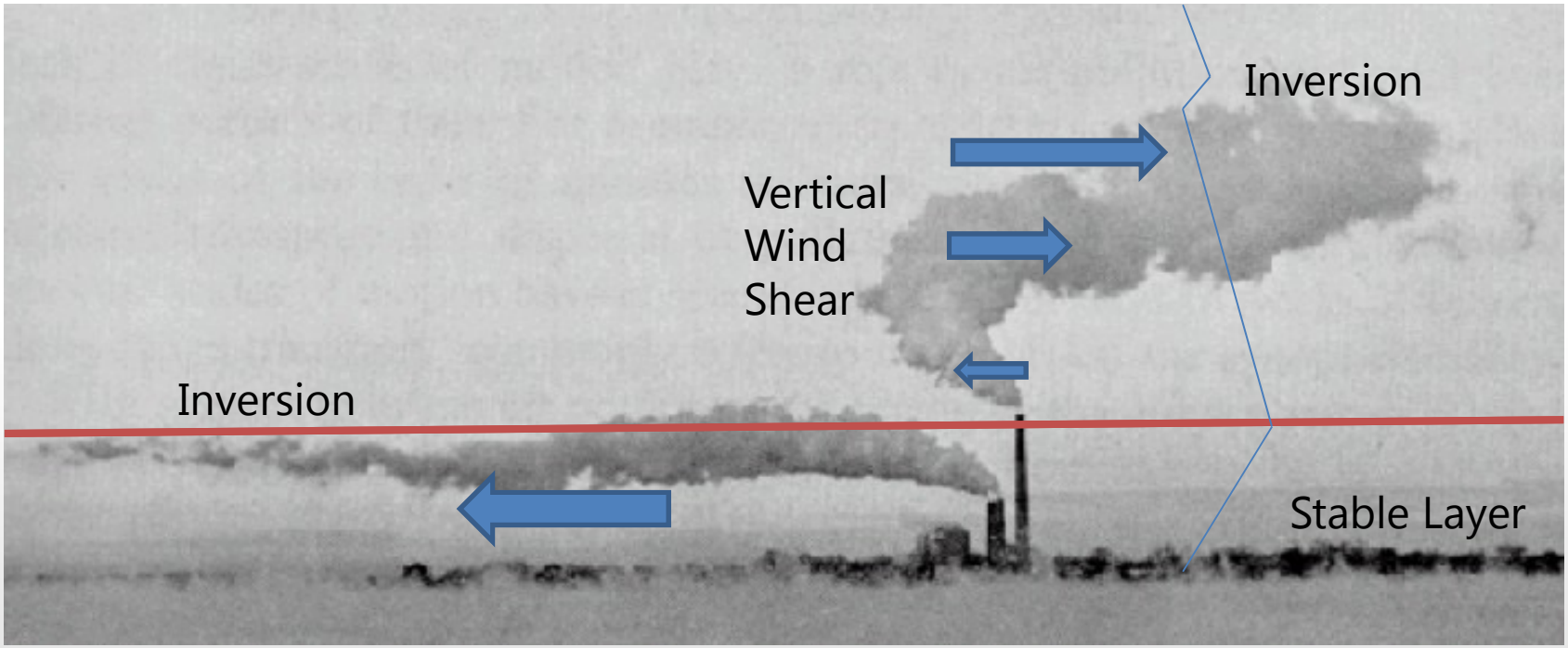
Today's Talk

Goal: To provide information on instruments that measure upper-air meteorology to help with future measurement decisions

- Upper-air meteorological basics
- Applications
- Instrument types
- Attributes and costs
- Logistics

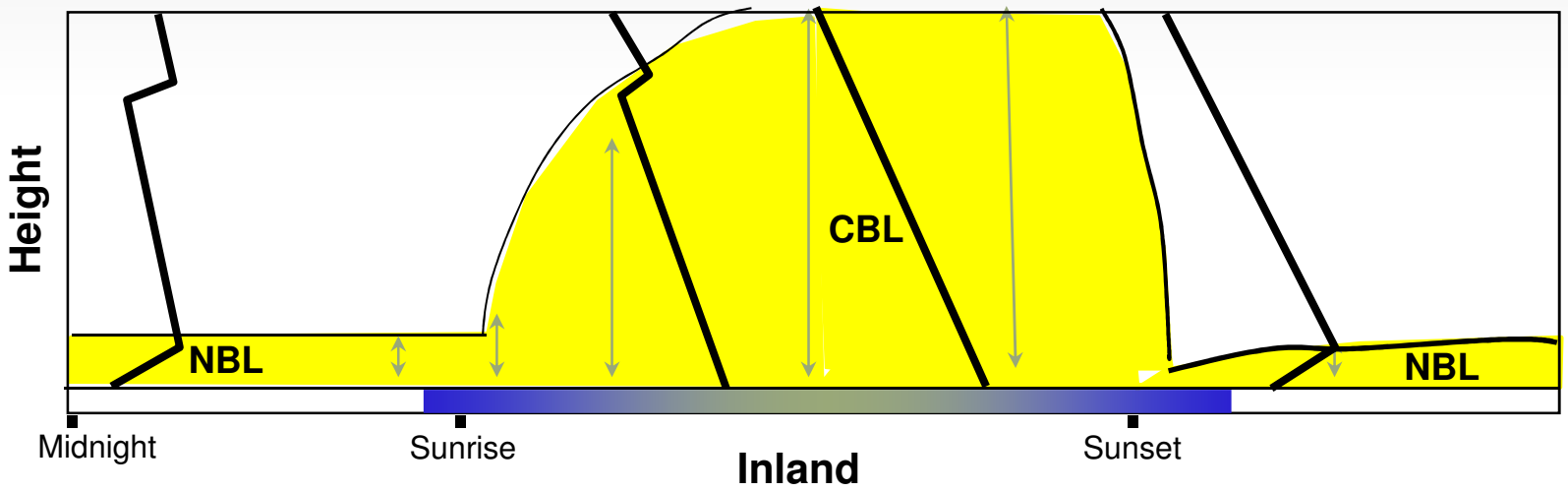
Upper-Air Meteorology

It's a 4-dimensional process



http://www.met.reading.ac.uk/Research/boundary_layer/research/

Upper-Air Meteorology



= **Surface-based mixing depth**

= **Surface-based vertical mixing**

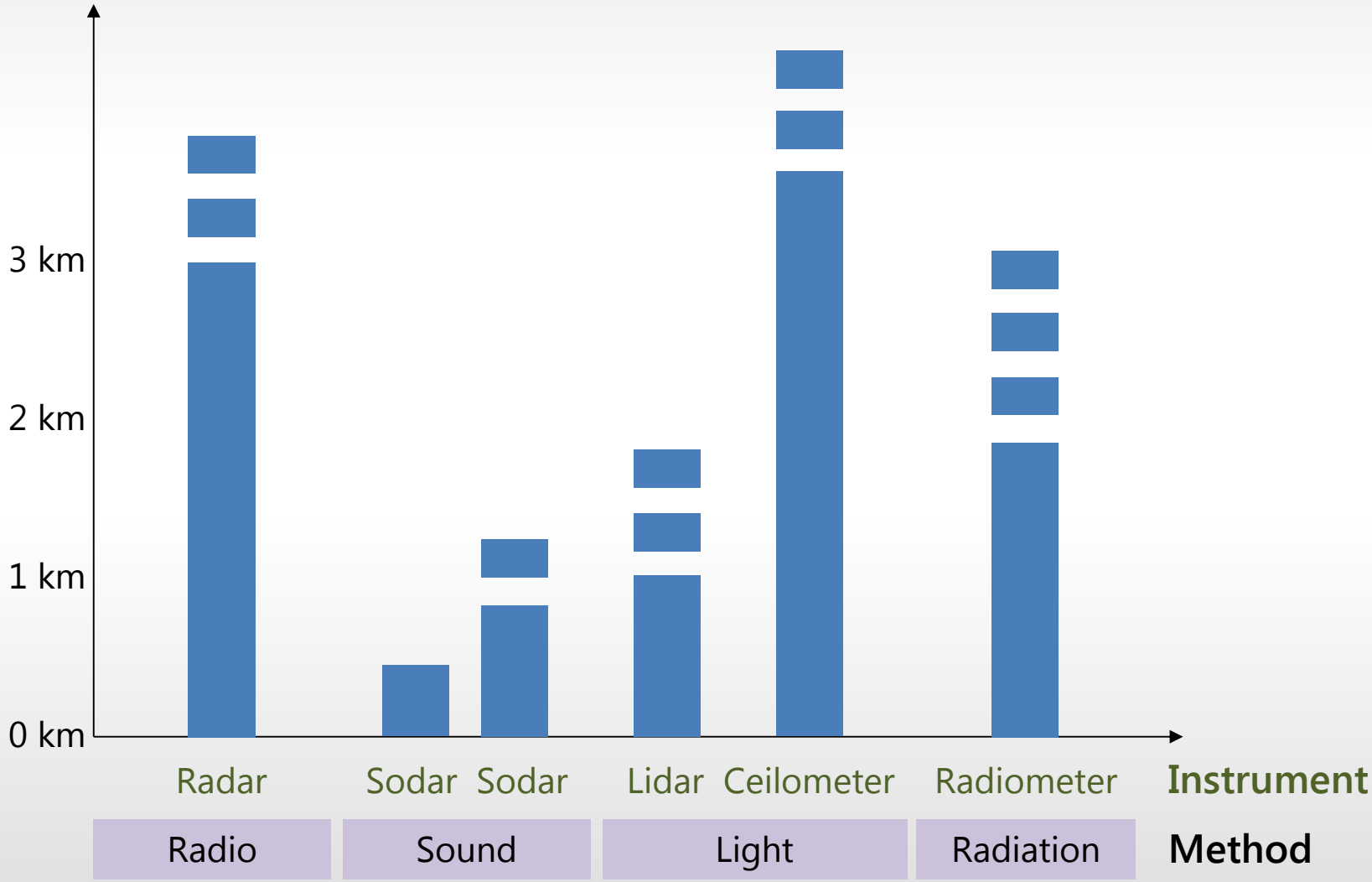
RL = Residual Layer
CBL = Convective Boundary Layer
NBL = Nocturnal Boundary Layer
MBL = Marine Boundary Layer

Applications to Air Quality

- Model assimilation and verification
- Daily forecasting
- Data analysis for understanding and characterization
  - Transport
  - Dispersion
  - Fumigation
  - Source contribution
- Exceptional event demonstrations

Photo by Don Blumenthal of STI on July 12, 1987

Measurement Height



Instruments

Instrument	Wind Profiles	Temp. Profiles	Inversions	Mixing Heights	Moisture Profiles	Cloud Base Height
RWP	X			X		
RWP with RASS*	X	X	X	X		
Sodars	X			/		
Doppler Lidars	X			/		
Ceilometer				/		X
Radiometer		X	X		X	

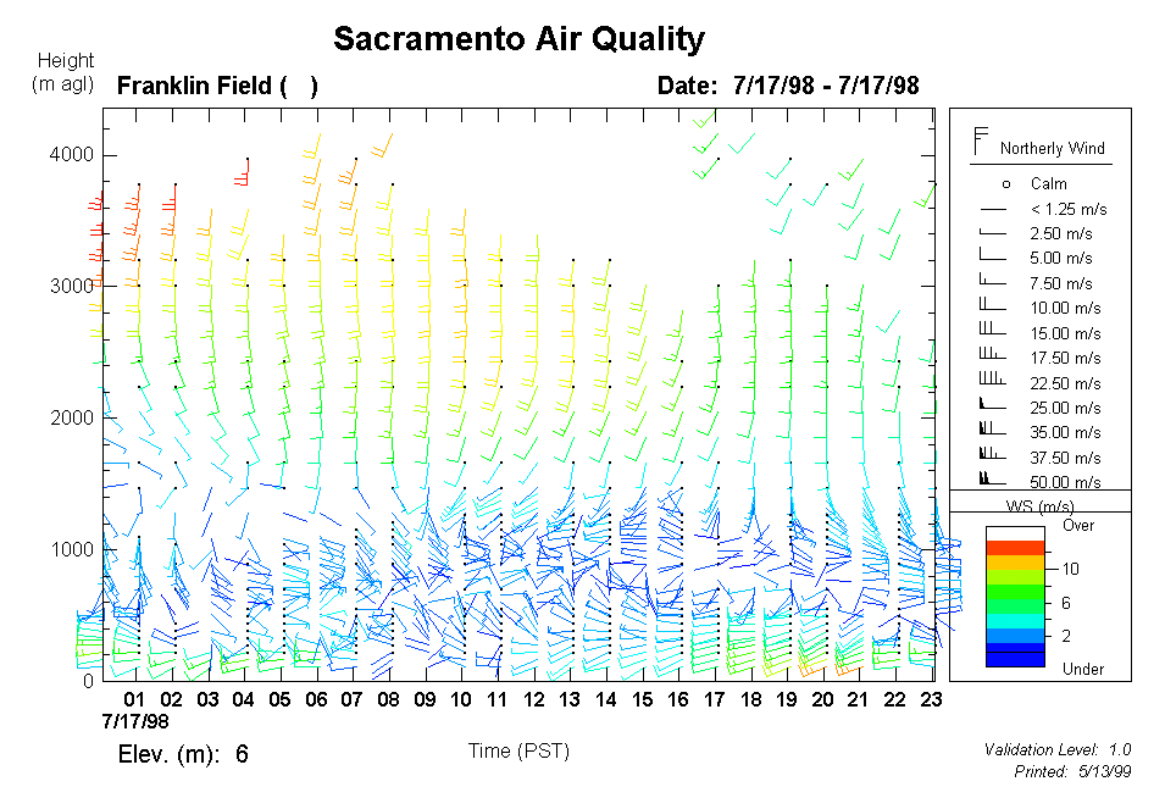
X = all instruments
/ = some instruments have algorithms
* Radio Acoustic Sounding System

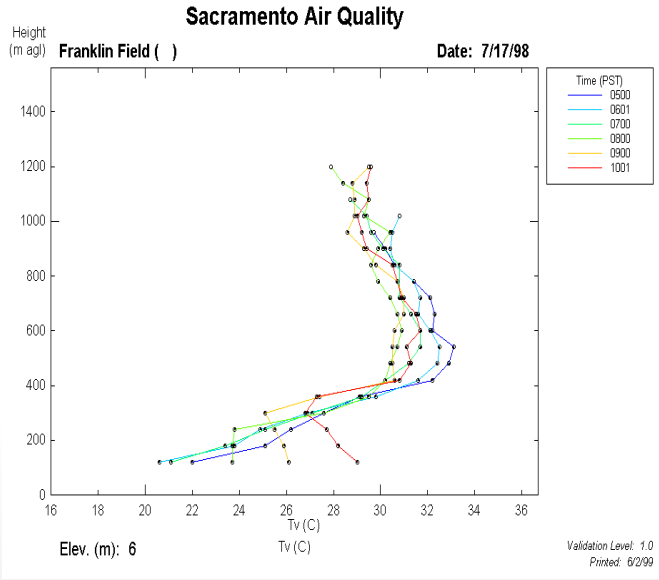
RWP with RASS

- Pluses
  - Measures key parameters (winds, temp, mixing height)
  - Excellent height coverage (100 to 3500 m agl)
  - Long life
  - Unattended operations
- Minuses
  - High acquisition and repair costs
  - Substantial infrastructure
  - RASS is noisy
  - Few manufacturers
  - Large footprint

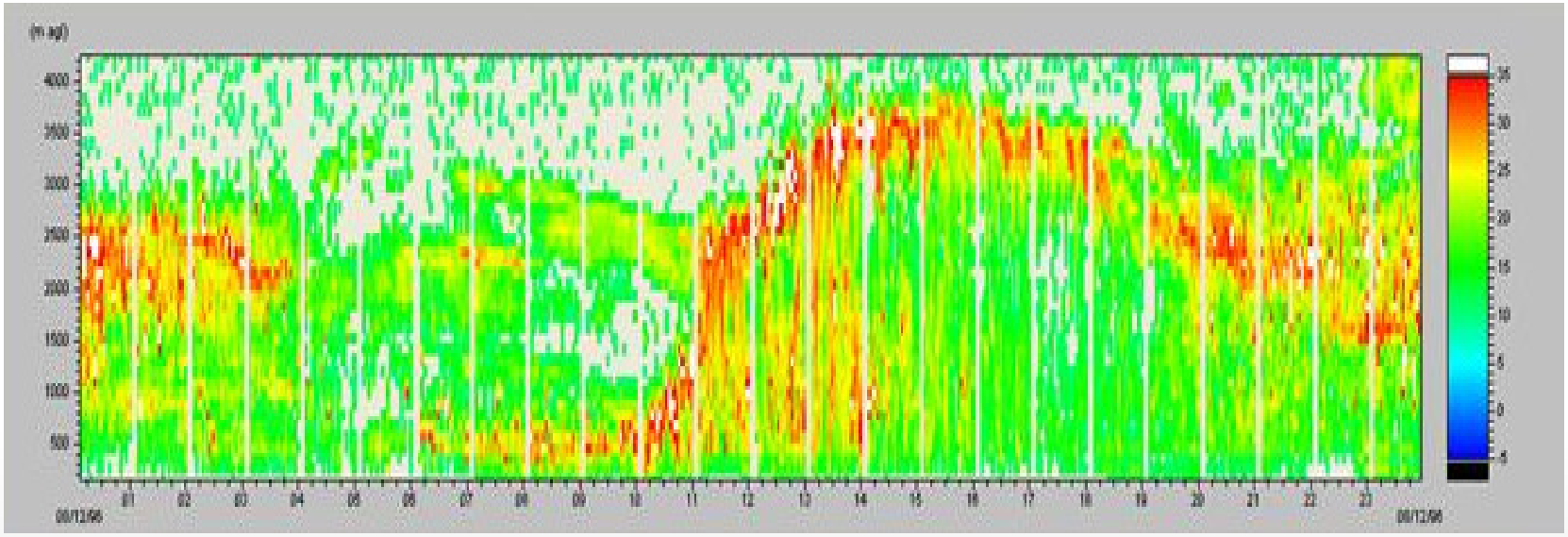
Irvine RWP with RASS

Radar Wind Profiler with RASS



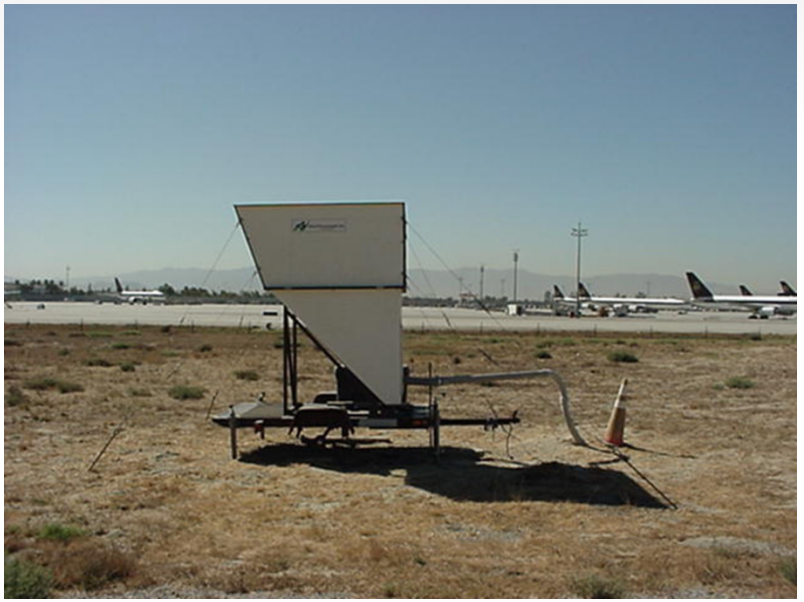


RWP – Mixing Heights



Sodars

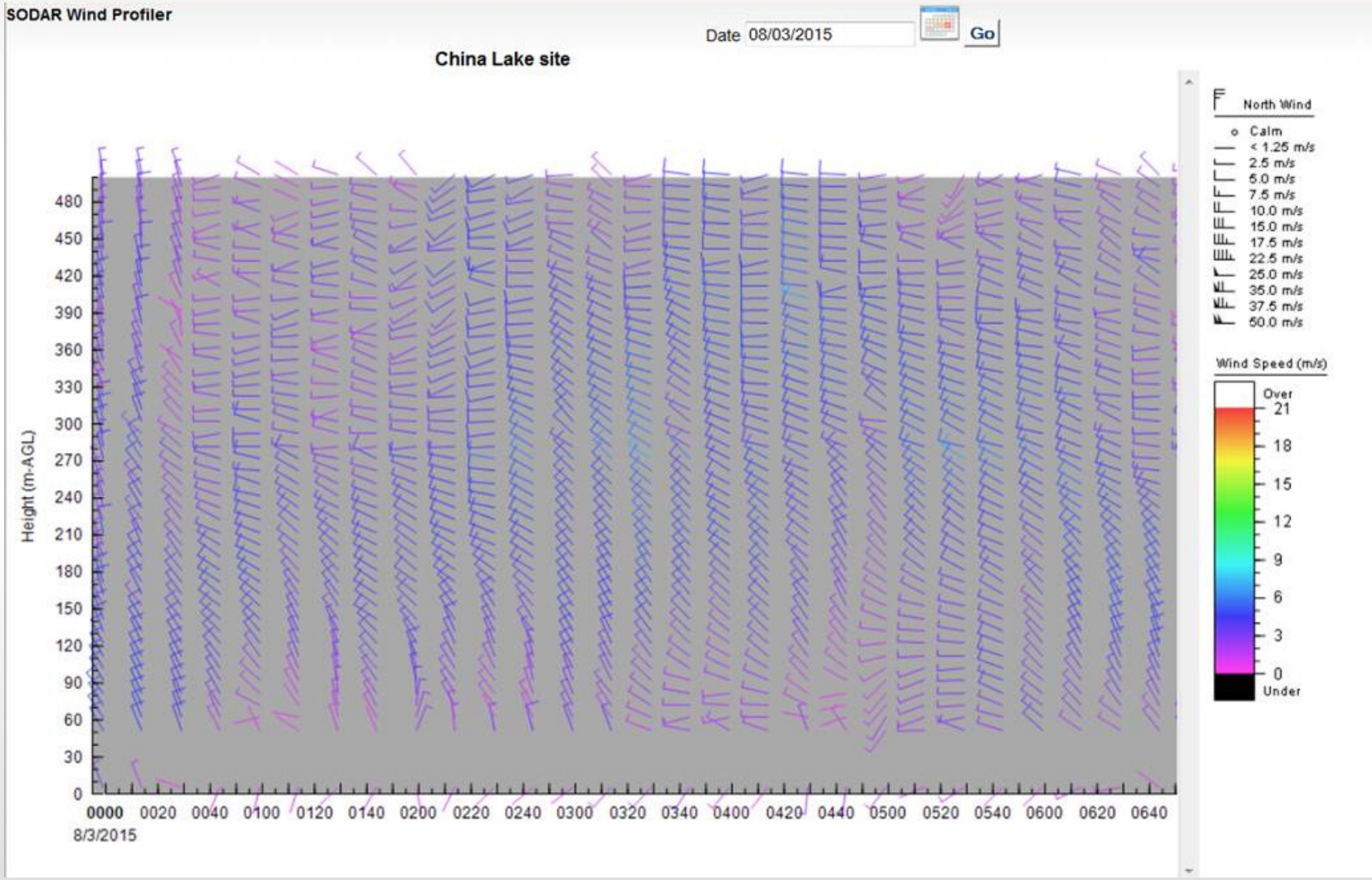
- Pluses
  - Wind and mixing heights (on some)
  - Relatively low-cost
  - Can run on solar
  - High vertical resolution
  - Unattended operations
  - Several manufacturers
  - Smaller footprint



Mini-Sodar – Ontario

- Minuses
  - Main product is wind; other data products on some sodars
  - Limited height coverage (~200 to 800 m depending on model)
  - Limited height coverage in high winds
  - Noisy

Sodars

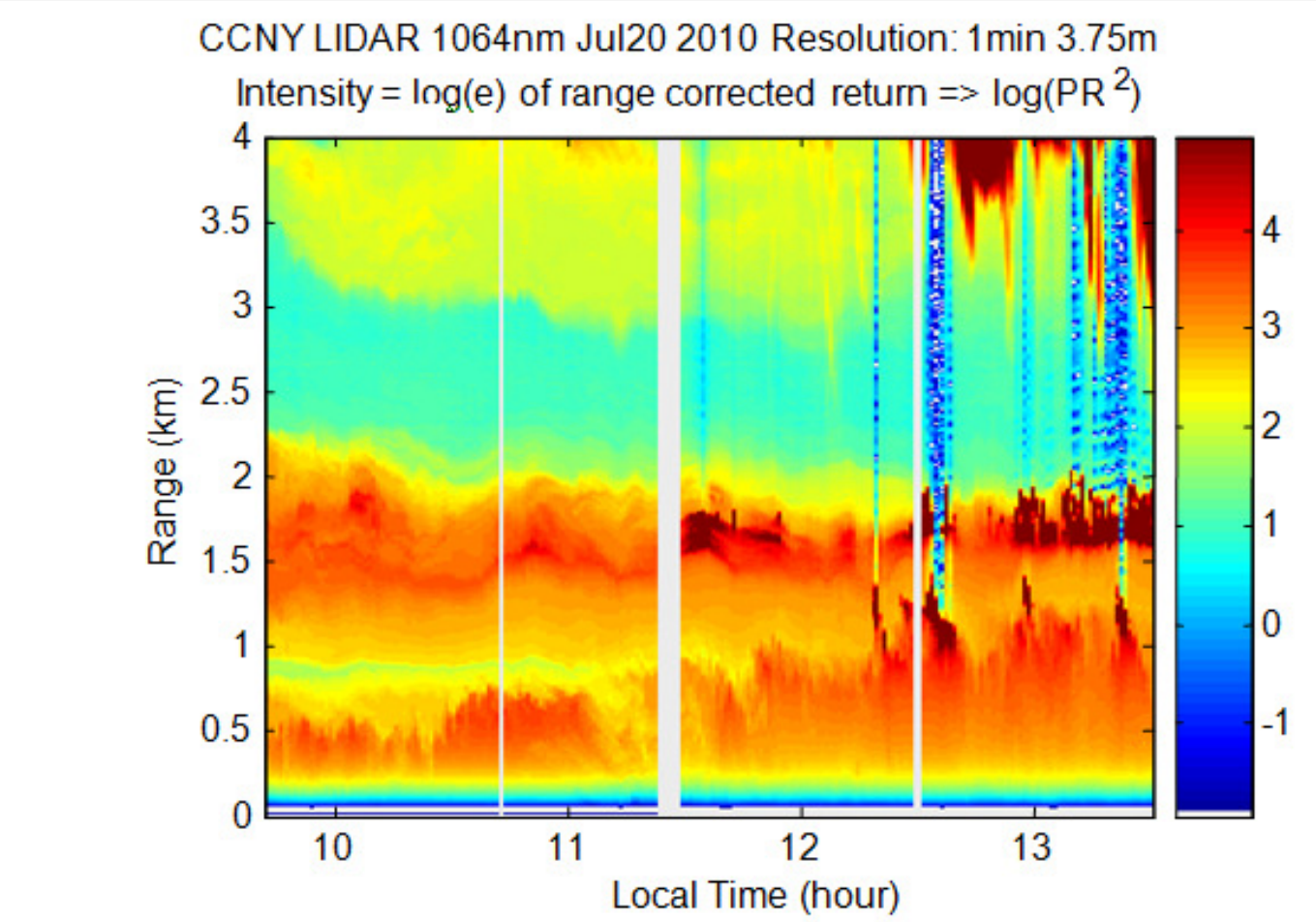

SODAR Wind Profiler
Date 08/03/2015
Go
China Lake site
North Wind
Calm
< 1.25 m/s
2.5 m/s
5.0 m/s
7.5 m/s
10.0 m/s
15.0 m/s
17.5 m/s
22.5 m/s
25.0 m/s
35.0 m/s
37.5 m/s
50.0 m/s
Wind Speed (m/s)
Over
21
18
15
12
9
6
3
0
Under
Height (m-AGL)
480
450
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
0000 0020 0040 0100 0120 0140 0200 0220 0240 0300 0320 0340 0400 0420 0440 0500 0520 0540 0600 0620 0640
8/3/2015

Doppler Lidar

- Pluses
  - Measures winds
  - Mixing heights (on some)
  - Very high time and vertical resolution
  - Unattended operations
  - Several manufacturers
  - Small footprint
- Minuses
  - Doesn't provide data in or above fog/clouds
  - Expensive, but that is changing
  - Height coverage can be limited

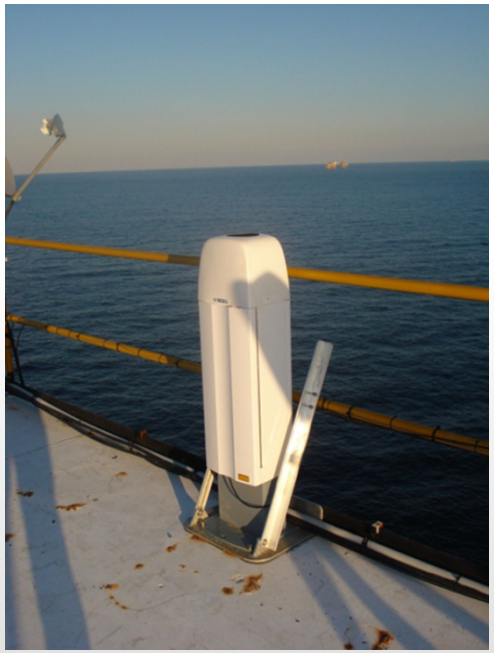
Photo from Leosphere WindCube lidar manufacturer's website: http://www.leosphere.com/products/3d-scanning/windcube-100s200s400s

Doppler Lidar



Ceilometer

- Pluses
  - Measures cloud base height
  - Measures mixing height (on some)
  - Excellent height coverage (10 to 10,000 m agl)
  - Unattended operations
  - High time and vertical resolution
  - Inexpensive to acquire and operate
  - Very small footprint
- Minuses
  - No winds or temperature

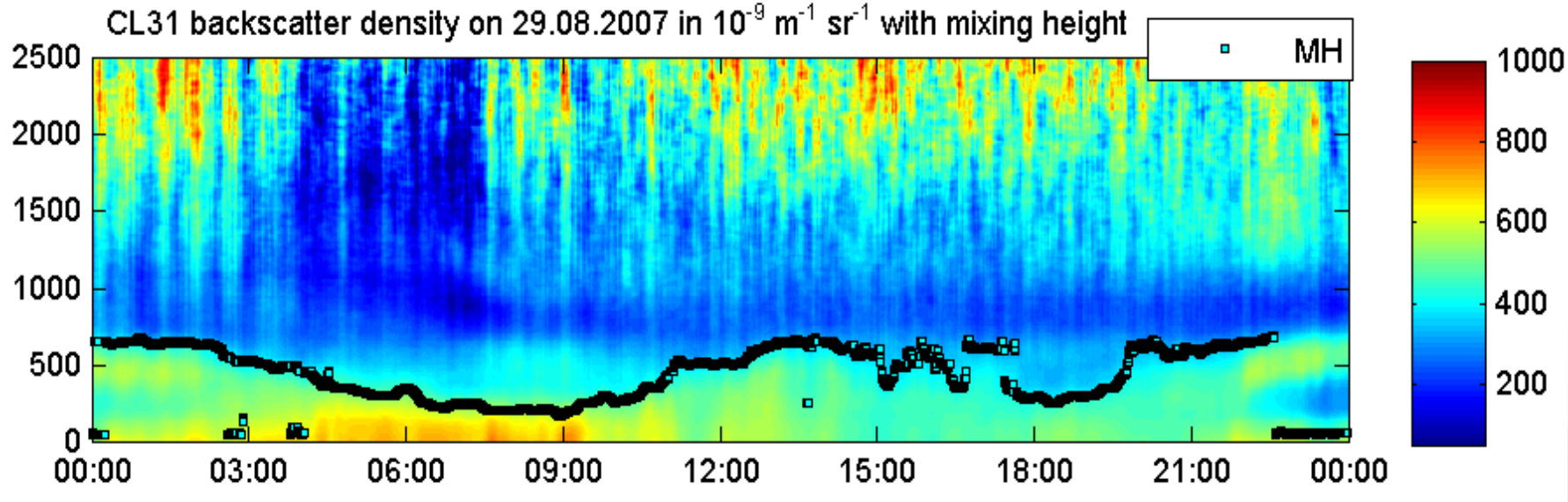


Ceilometer – Gulf of Mexico

Ceilometer

Backscatter and Boundary Layer Heights

Seattle, WA



Microwave Radiometer

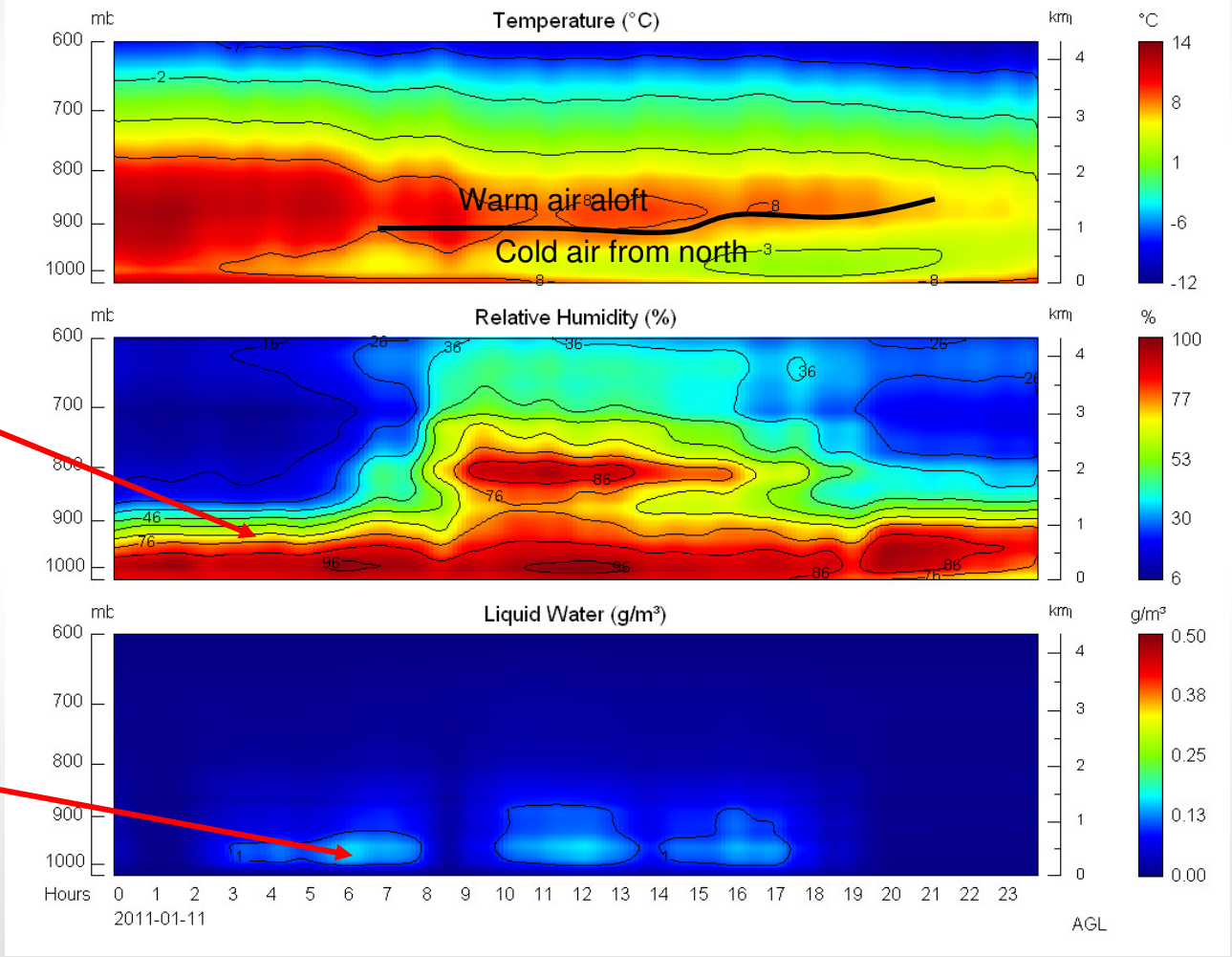
- Pluses
  - Measures temperature, relative humidity (RH), liquid water
  - Excellent height coverage (~10 to 10,000 m agl)
  - Unattended operations
  - High time and vertical resolution
  - Small footprint
- Minuses
  - No winds
  - Moderately high acquisition cost (~$150K)
  - Indirect measure of parameters (can lead to non-detects of inversions, for example)
  - Few manufacturers

Microwave Radiometer – Gulf of Mexico

Microwave Radiometer

Strong RH gradient near the top of the cloud layer

Increased levels of liquid water in the cloud layer



Chevron Oil Platform ST-52B over Gulf of Mexico near Louisiana coast

Operational Considerations

- Siting
  - Interference from other electronics or objects
  - Neighbors (noise disturbances)
  - Station power (solar if no line power)
  - Infrastructure (concrete pad, security fence, etc.)
- Data management
  - Data transfer methods (cellular, satellite, etc.)
  - Data volume and complexity
  - Quality control methods
  - Visualization

Closing Thoughts

- Day-to-day variability in air quality is mostly controlled by meteorology
- Several important meteorological parameters
- No silver bullet instrument
- Selection depends on your needs, applications, and resources
- Consider operation requirements
- Technology is improving and costs are coming down

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