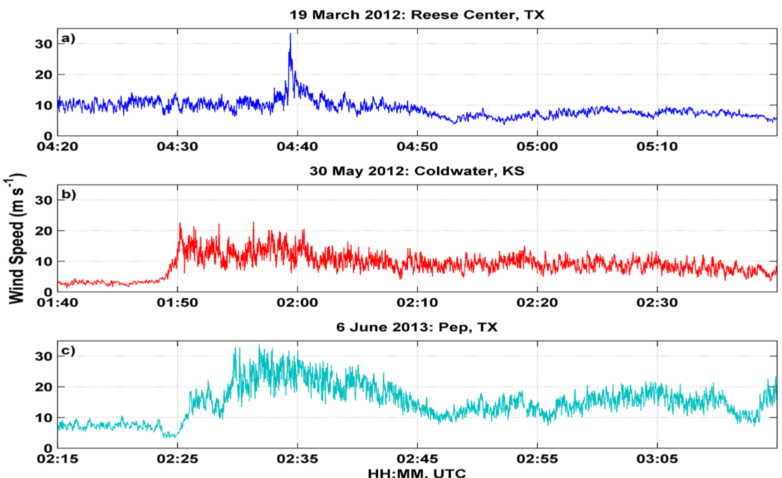
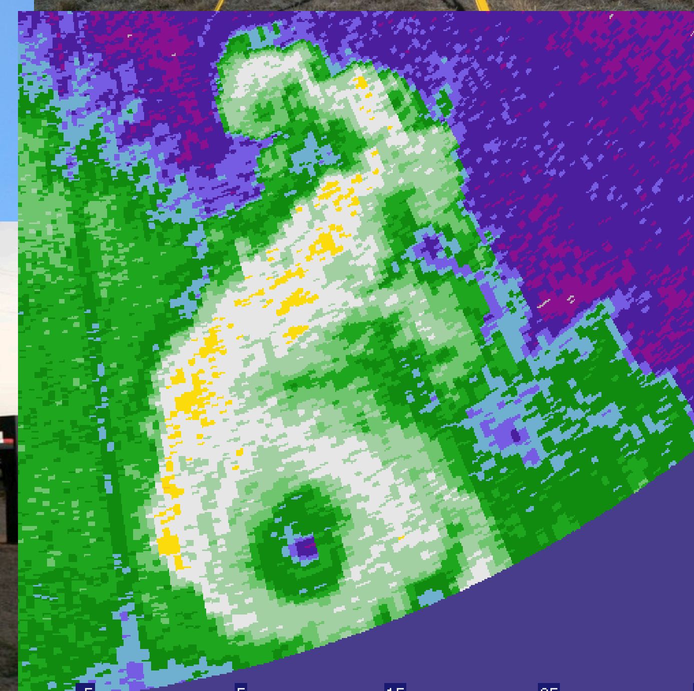
MEASUREMENT TYPES AND THEIR DATA

ALL THE INSTRUMENTS…

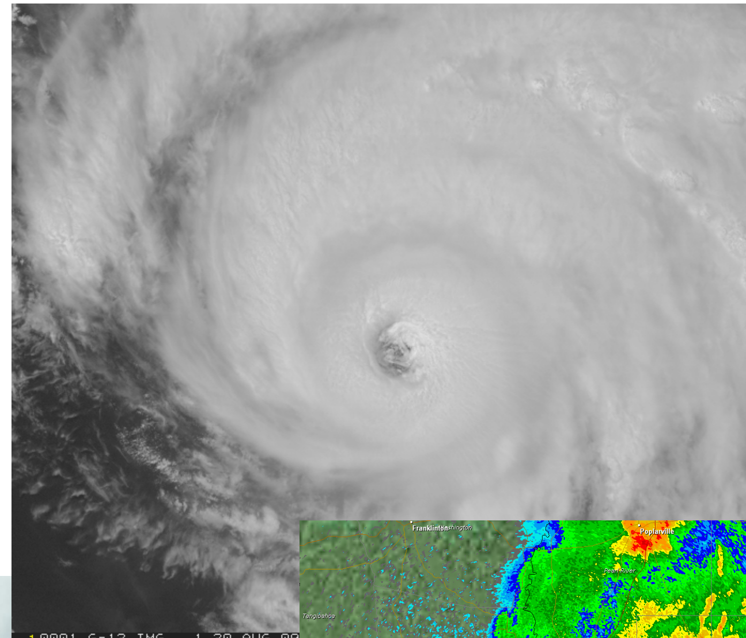


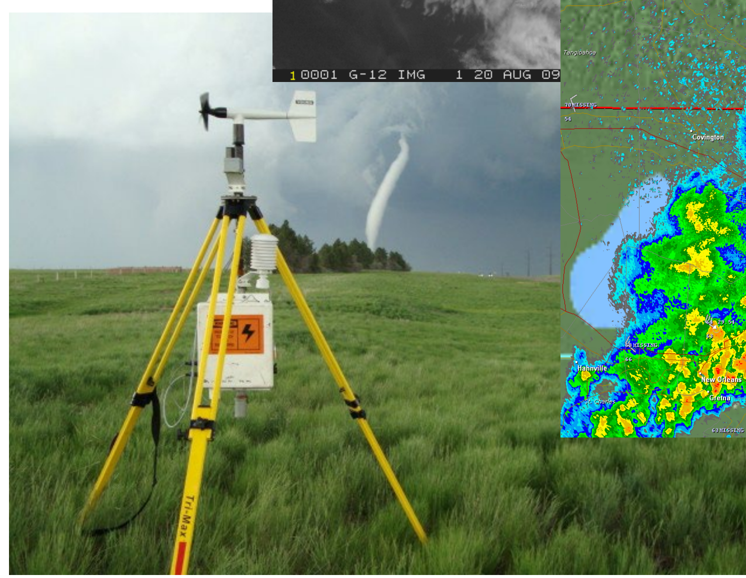


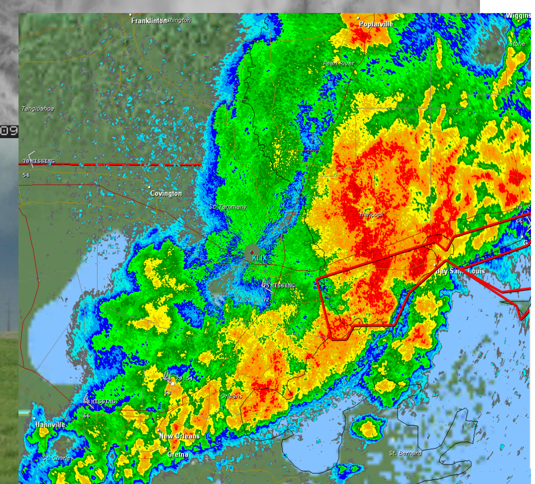
TWO CLASSES OF MEASUREMENTS

- Direct Methods
  - Taken in place, instruments in direct contact with atmospheric property you are trying to measure

- Indirect Methods
  - Atmospheric properties measured from a distance (i.e., no direct contact).
  - Also referred to as remote sensing.

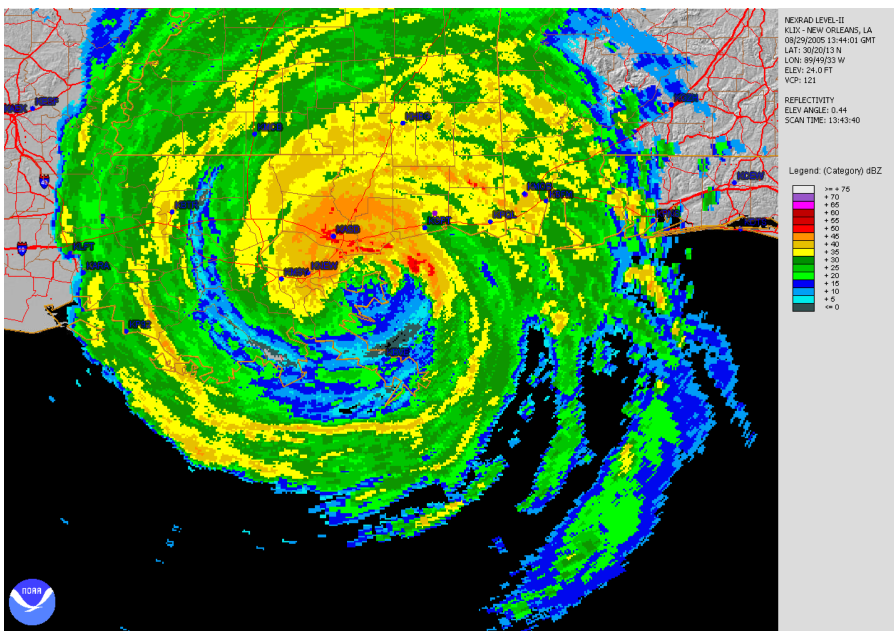


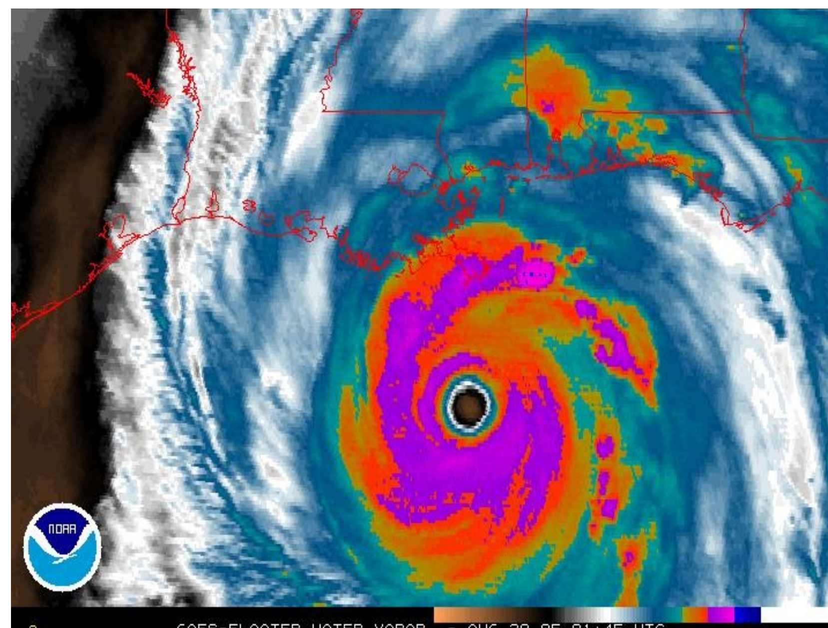




INDIRECT MEASUREMENTS

- Two forms:
  - Active sensors – transmit and receive energy
  - Passive sensors – just receive energy





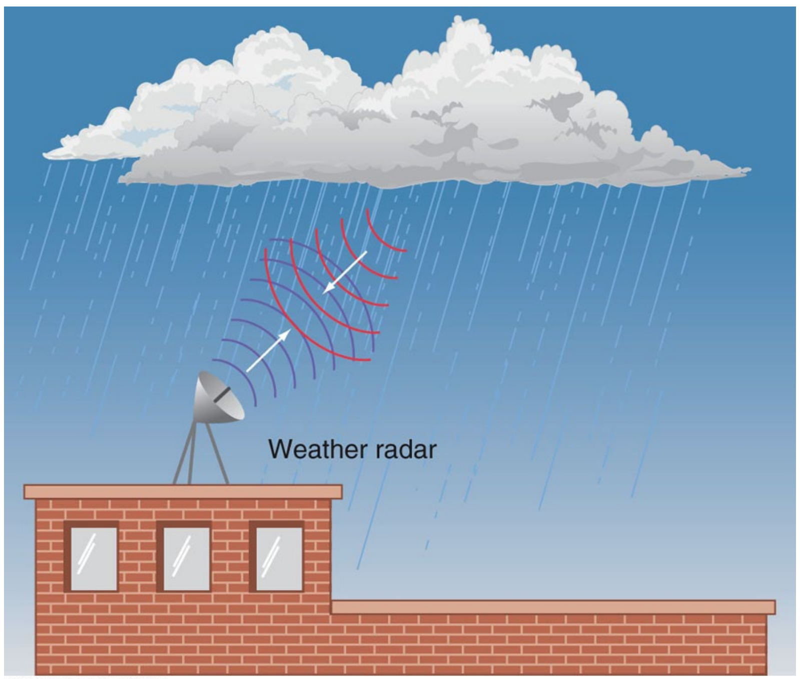
REMOTE SENSING OF WIND: THREE "-DARS"

- Radar (**Ra**dio **D**etection **a**nd **R**anging)
  - Microwave pulse bounces off rain drops / larger dust particles.
  - Good for looking at rain, storm structure, and "radial velocity"
  - What you see on TV.
- Sodar (**So**und **D**etection **a**nd **R**anging)
  - Sound pulses used like sonar.
  - Good for wind speed / direction changes with height (profile)
  - Used frequently in wind energy
- Lidar (**Li**ght **D**etection **a**nd **R**anging)
  - Laser bounces off of aerosols and smaller dust particles in the atmosphere.
  - Frequently used in wind energy for wind profiles
  - Typically lose signal with rain.

RADAR

- Used to track and measure precipitation.
- Can also get information on storm relative winds. This is useful for determining if a storm is severe or capable of producing a tornado.
- Ground – based. Each radar can only “see” 100 – 200 miles out.
- Examples

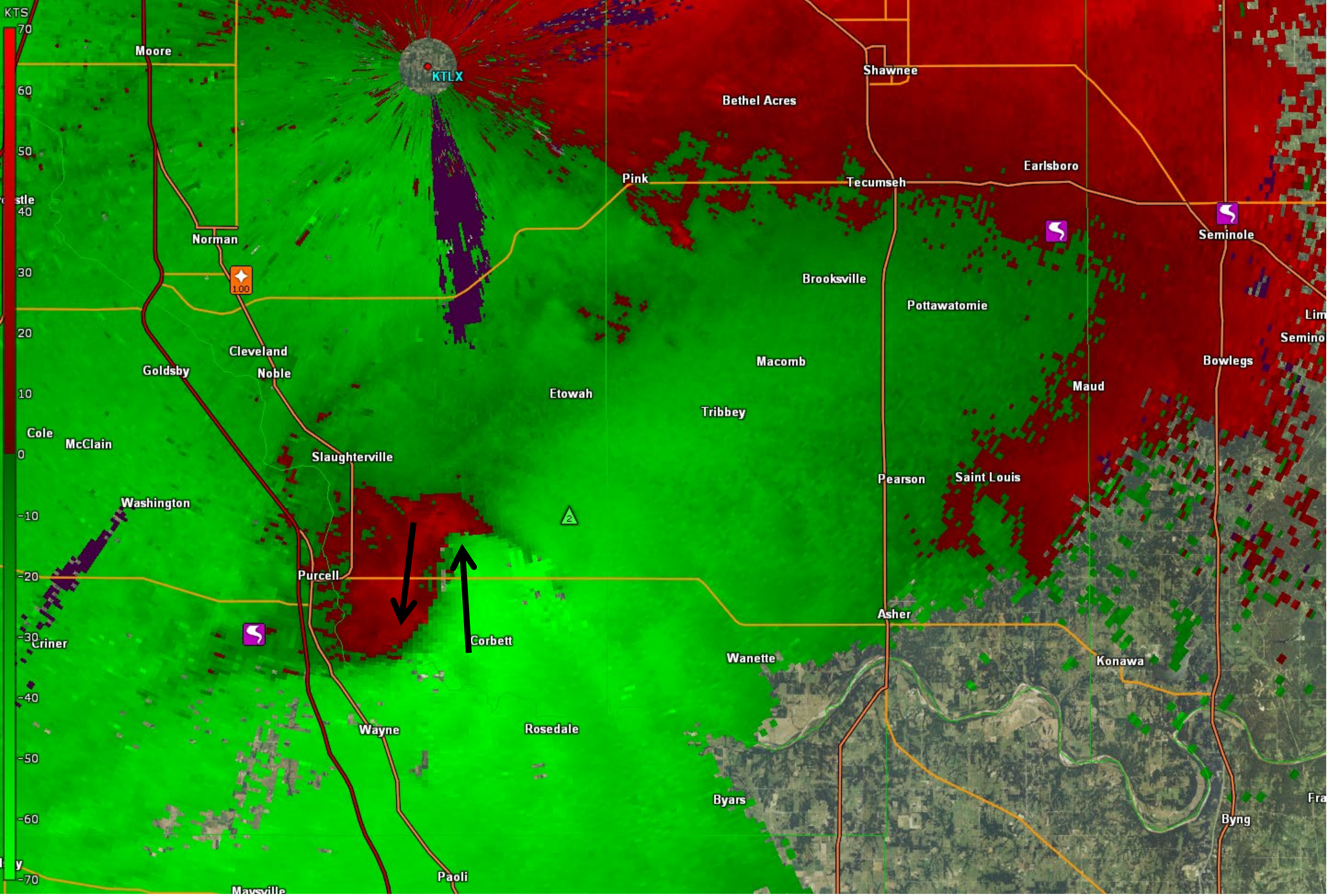
RADAR BASICS



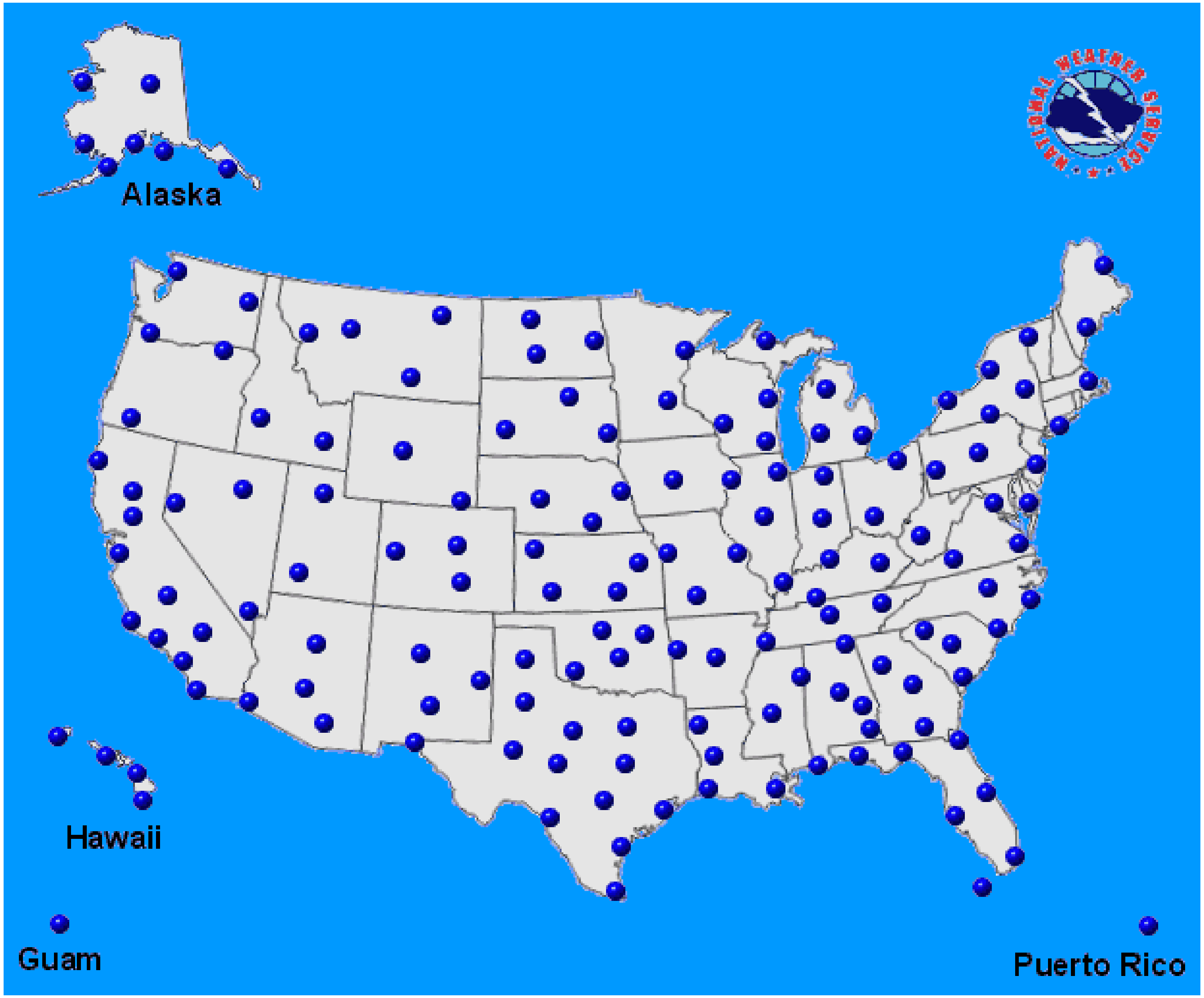
- <u>Electromagnetic</u> energy transmitted into atmosphere
- Backscattered energy ("radar echo") measured by radar and displayed
- The <u>larger</u> the object, the more <u>energy</u> that is returned.
- Sources of backscattering: <u>raindrops</u>, hail, snow, <u>bugs</u>, dust, ground targets, debris

WSR-88D DOPPLER RADAR

- We can see:
  - Reflectivity – the energy ”sent back” by the hydrometers (or debris) in a storm
  - Radial velocity – The RADIAL motion of the raindrops.


KTS
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
KTLX
Moore
Norman
Shawnee
Bethel Acres
Earlsboro
Pink
Tecumseh
Seminole
Brooksville
Pottawatomie
Cleveland
Noble
Goldsby
Macomb
Bowlegs
Etowah
Tribbey
Maud
Cole
McClain
Slaughterville
Washington
Pearson
Saint Louis
Purcell
Asher
Criner
Corbett
Wanette
Konawa
Wayne
Rosedale
Byars
Byng
Paoli
Maysville

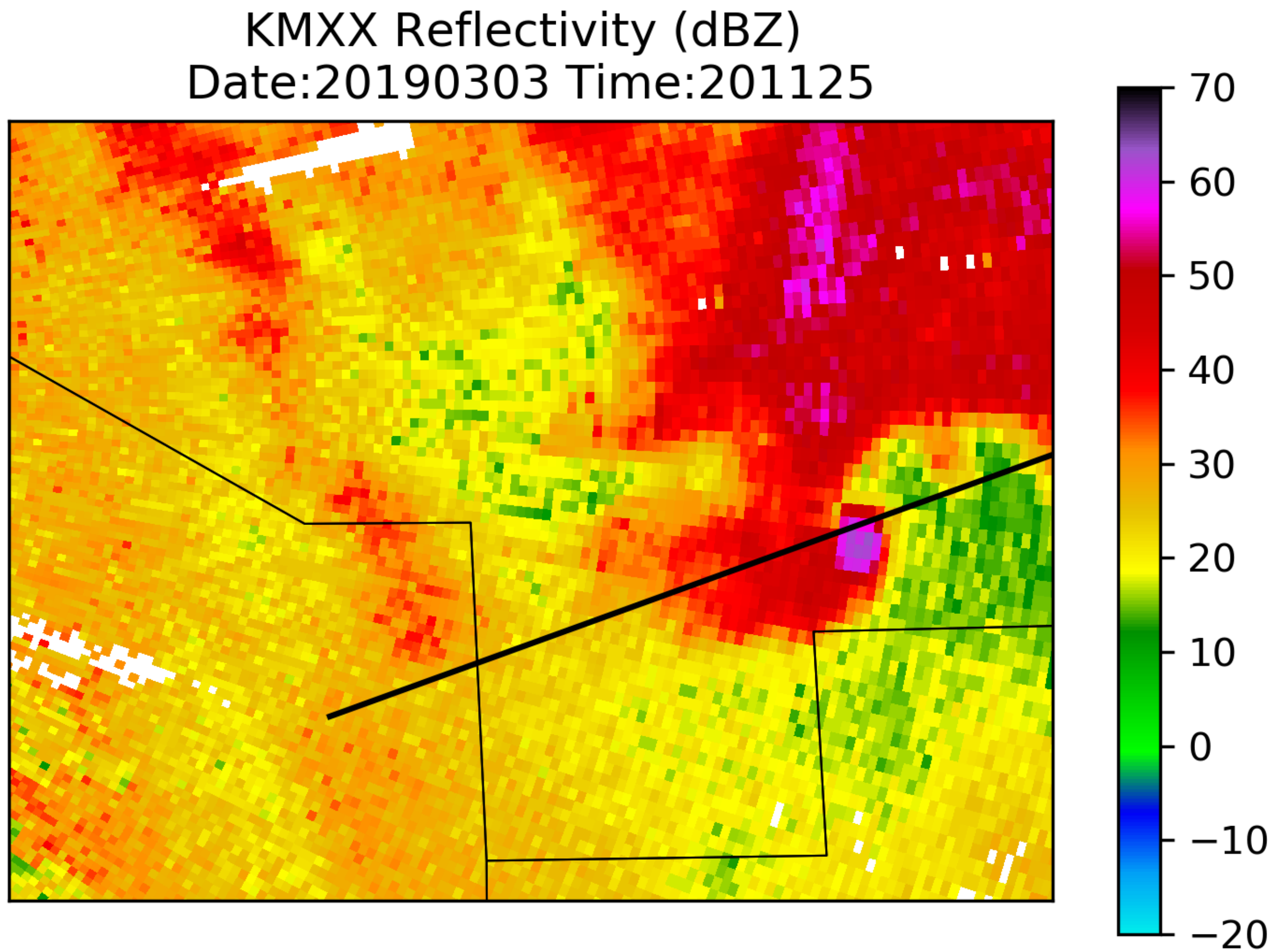
WSR-88D NETWORK



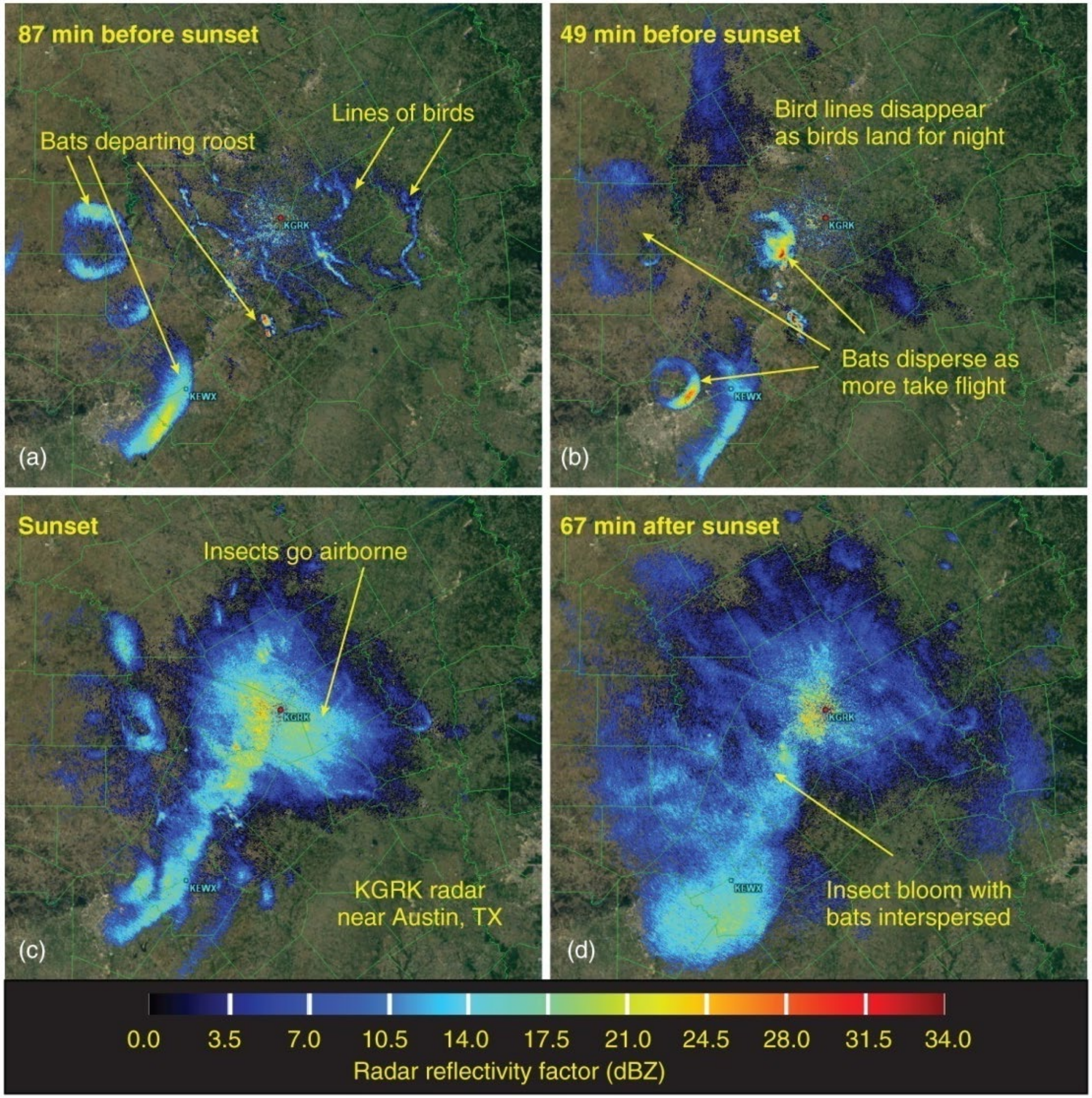
WSR-88D DOPPLER RADAR

- We can see:
  - Reflectivity – the raindrops in a storm
  - Radial velocity – The RADIAL motion of the raindrops.
- We can't see:
  - The actual wind speed/ dir.
  - Close to the ground
  - Tornadoes
- Or can we….?

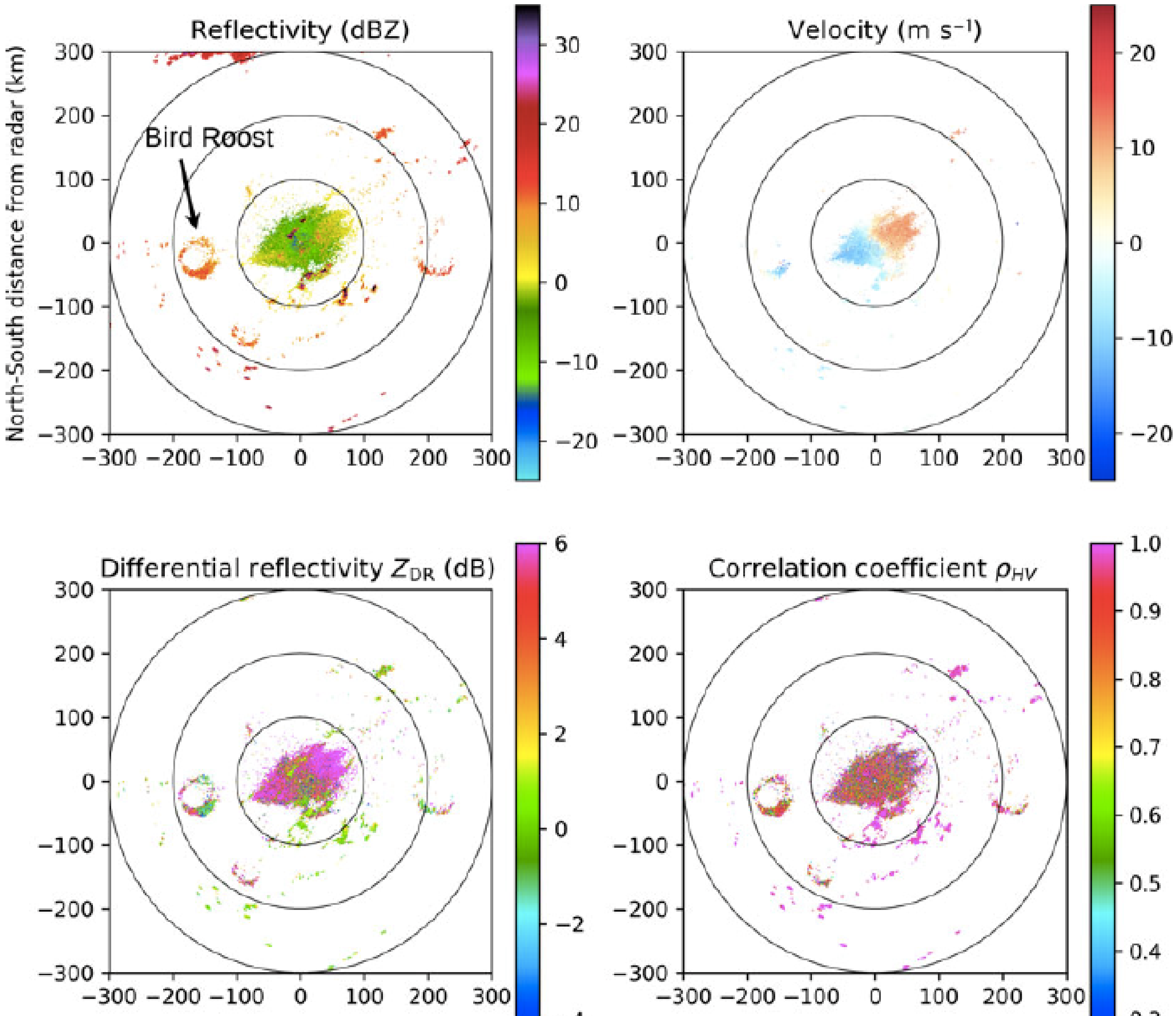
3 MARCH 2019 BEAUREGARD, AL TORNADO DEBRIS SIGNATURE



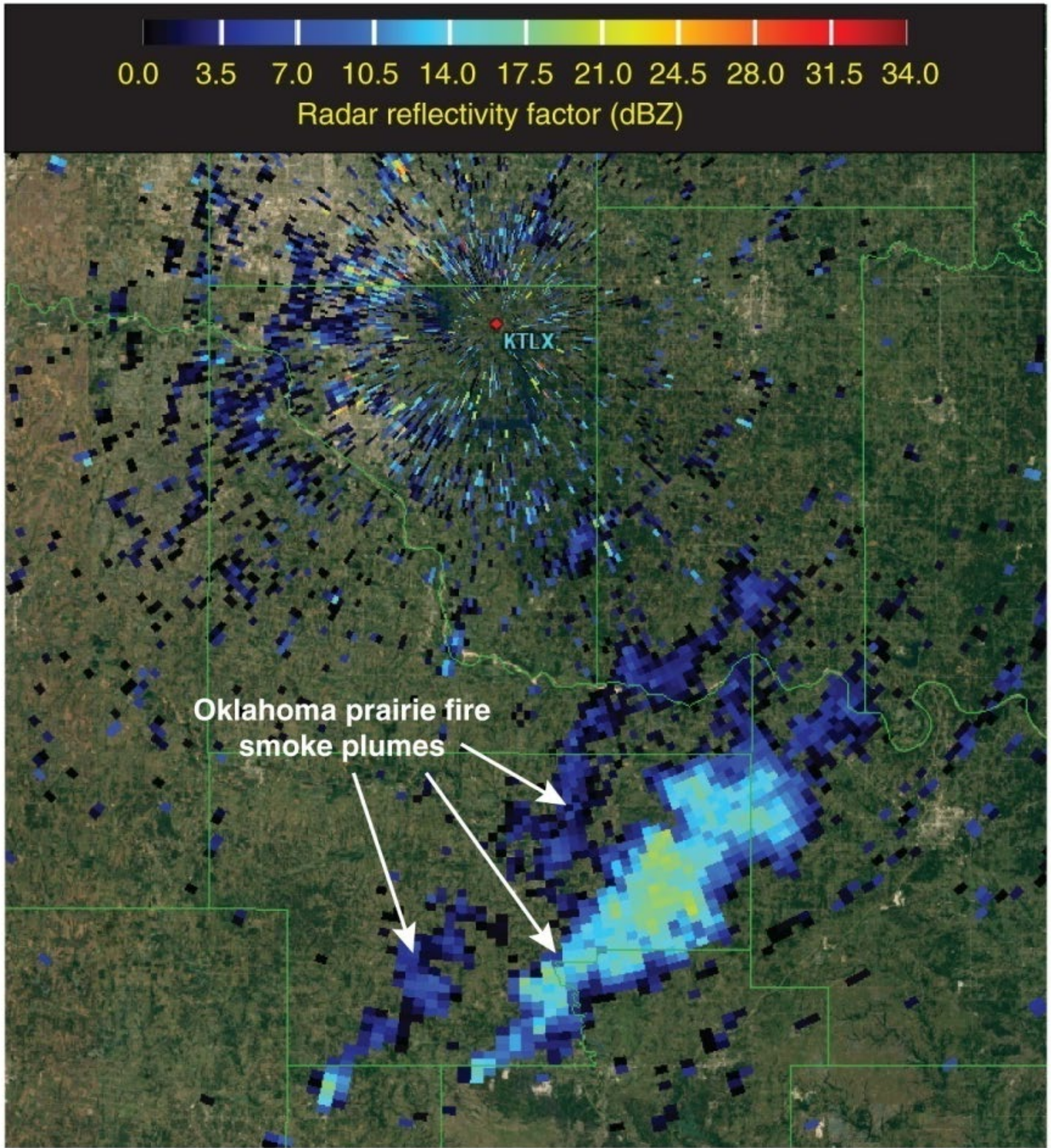
EXAMPLES: BIRDS / BATS



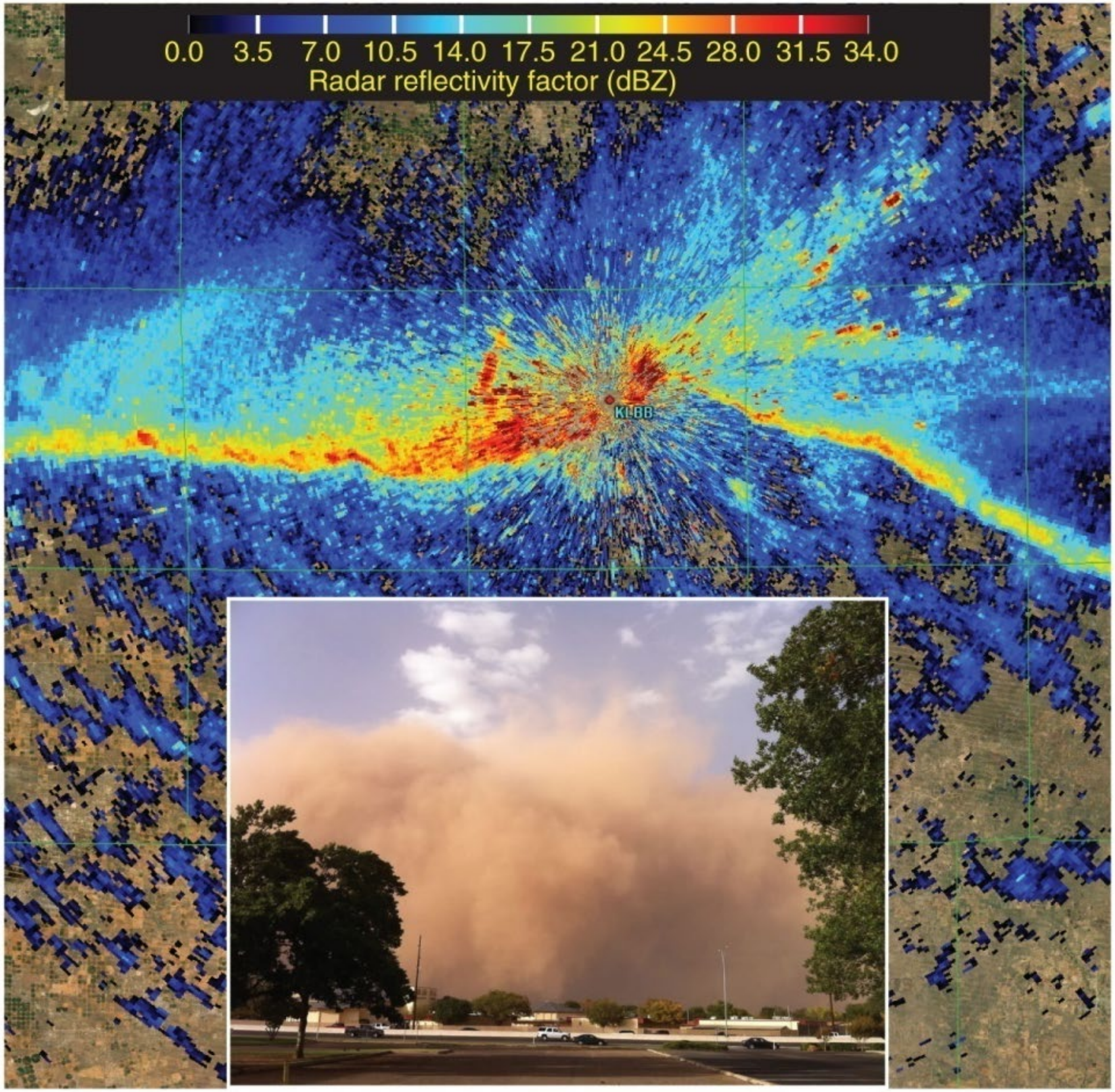
EXAMPLES: BIRDS / BATS



EXAMPLE: SMOKE PLUMES



EXAMPLES: DUST



RESEARCH RADARS

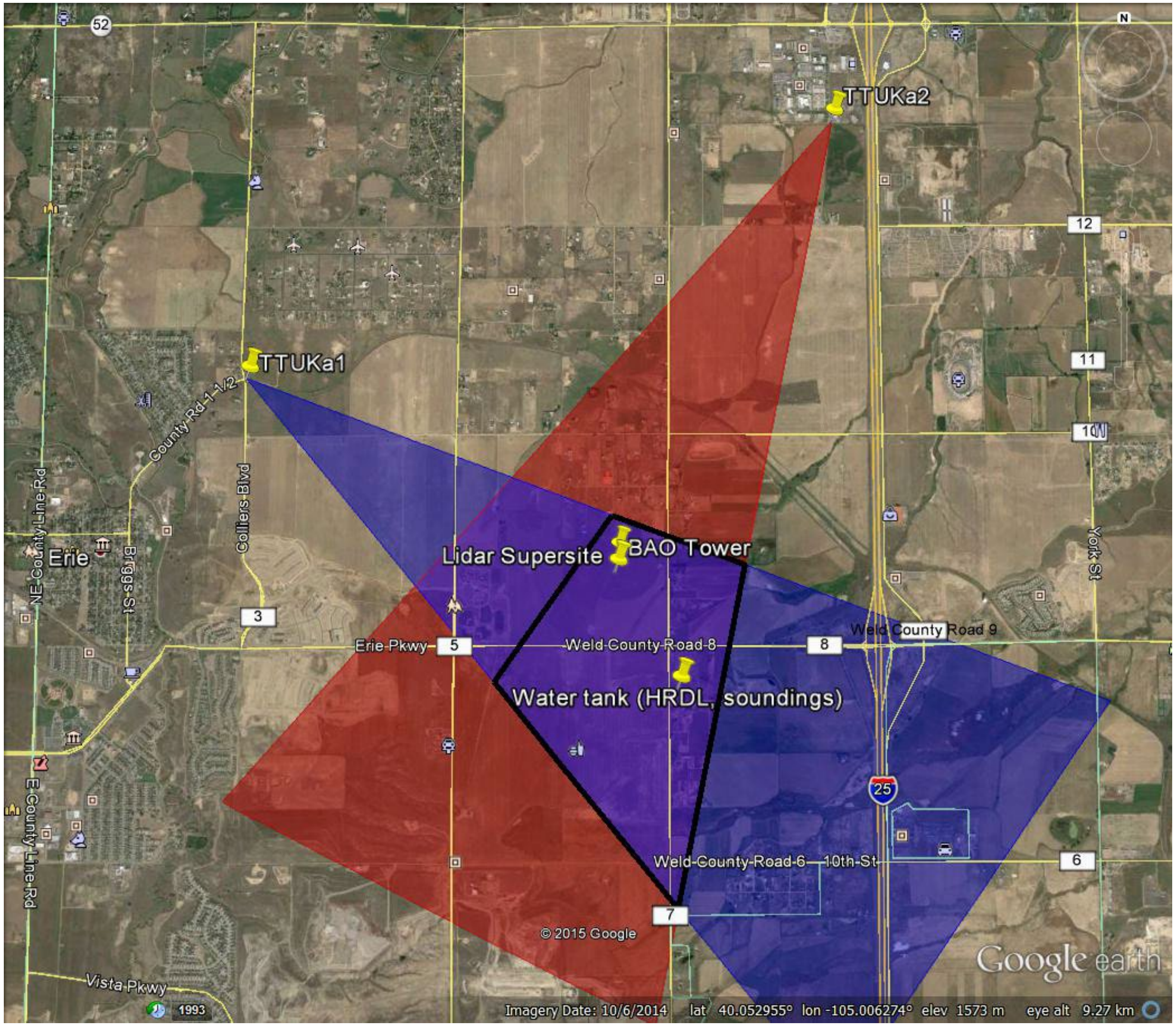
Doppler on Wheels (DOW) –
Center for Severe Weather Research

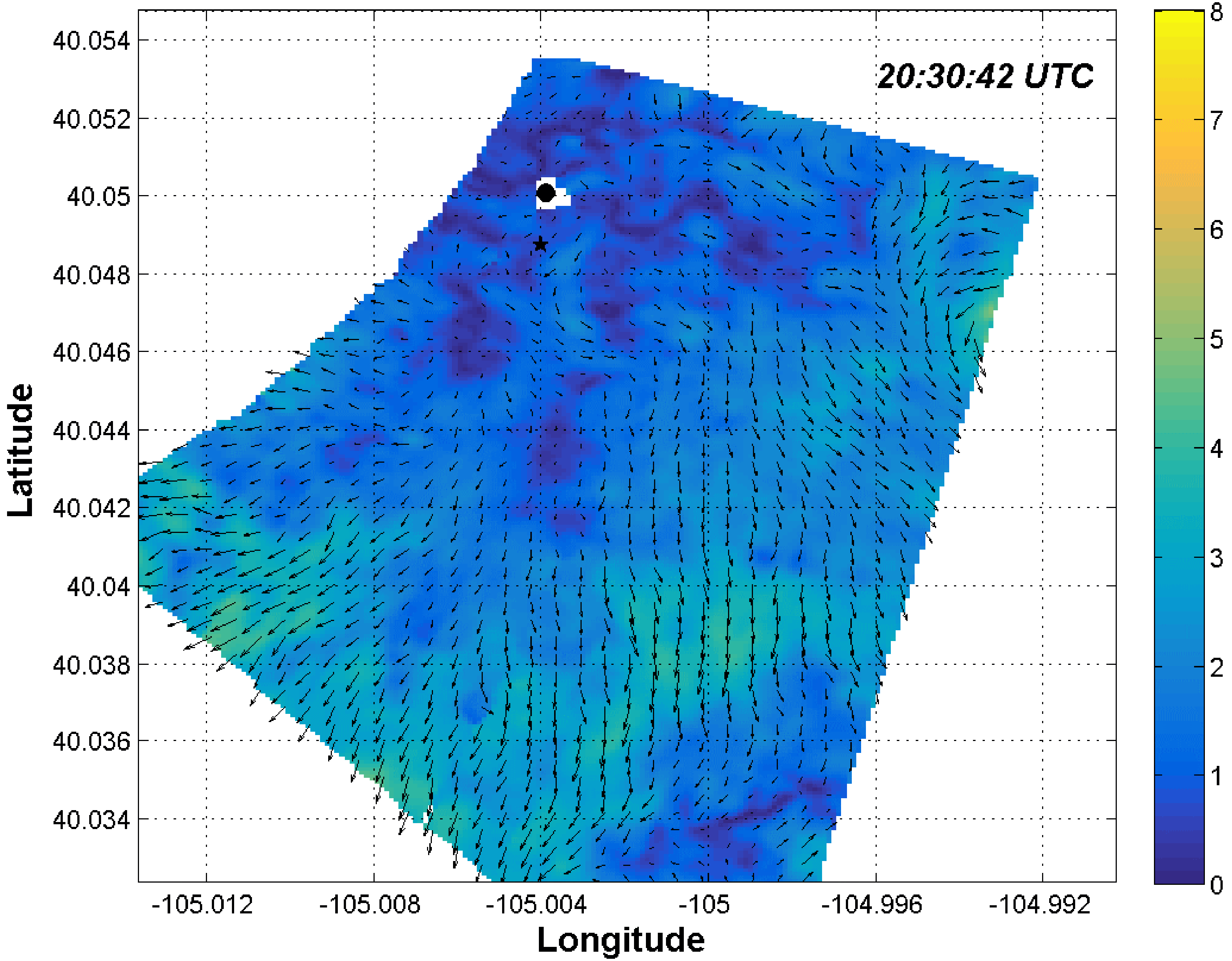
Shared Mobile Atmospheric Research
and Teaching Radar (SMART-R)

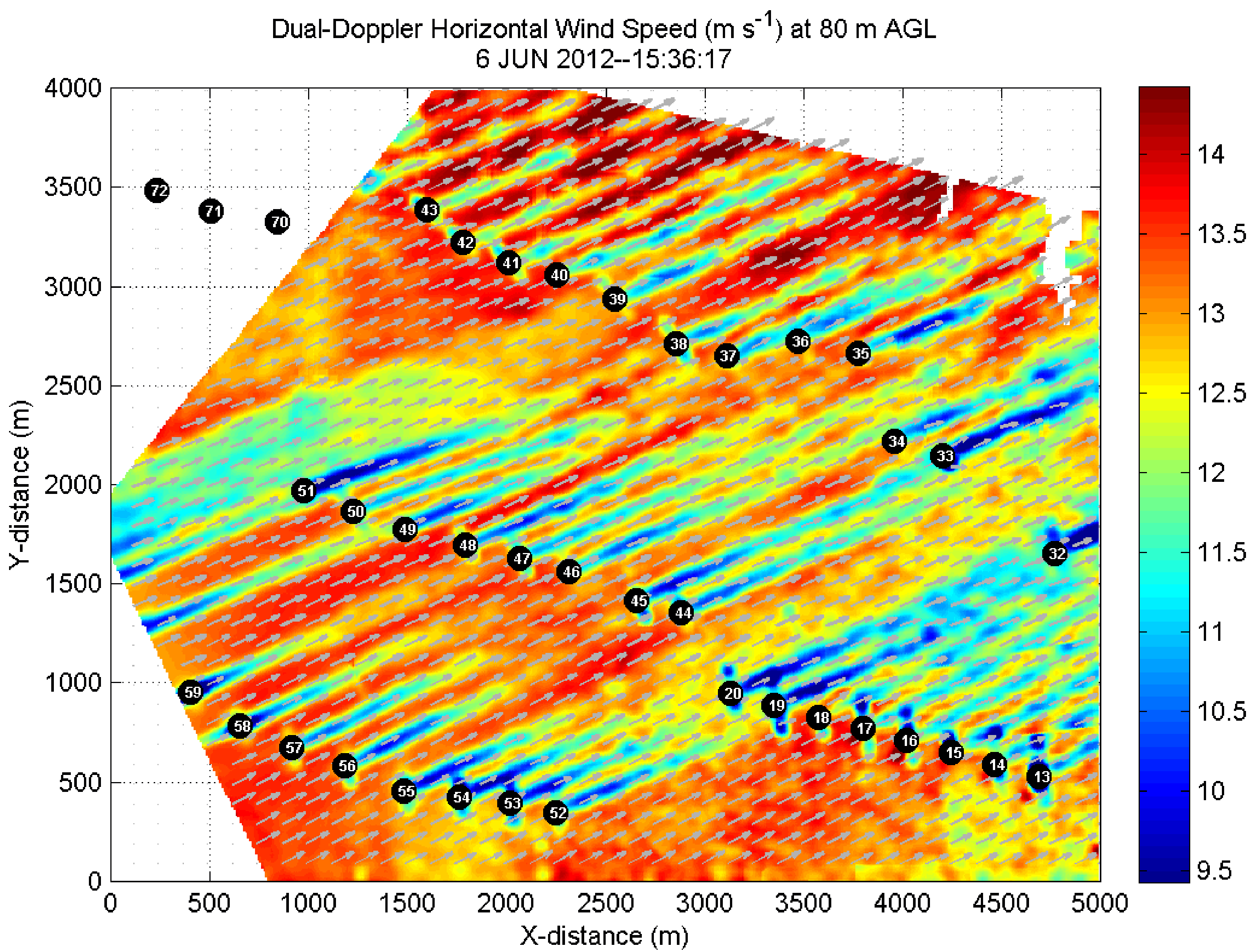
University of Massachusetts
Tornado Radar

TTU Ka Band Doppler radar

31 MARCH 2016 XPIA DATASET




20:30:42 UTC
Latitude
Longitude
40.054
40.052
40.05
40.048
40.046
40.044
40.042
40.04
40.038
40.036
40.034
-105.012
-105.008
-105.004
-105
-104.996
-104.992
0
1
2
3
4
5
6
7
8


Dual-Doppler Horizontal Wind Speed (m s-1) at 80 m AGL
6 JUN 2012--15:36:17
Y-distance (m)
X-distance (m)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
72
71
70
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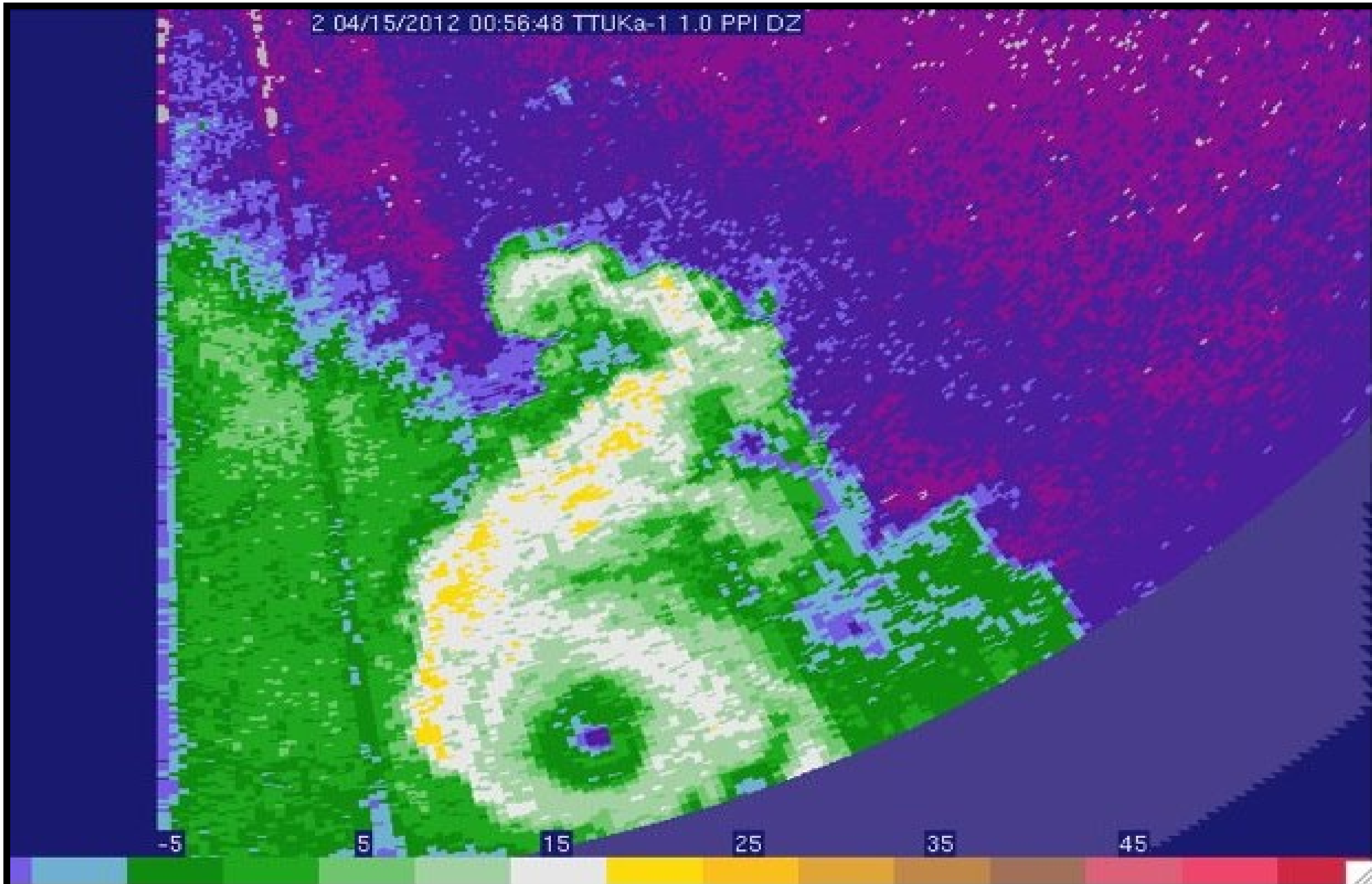
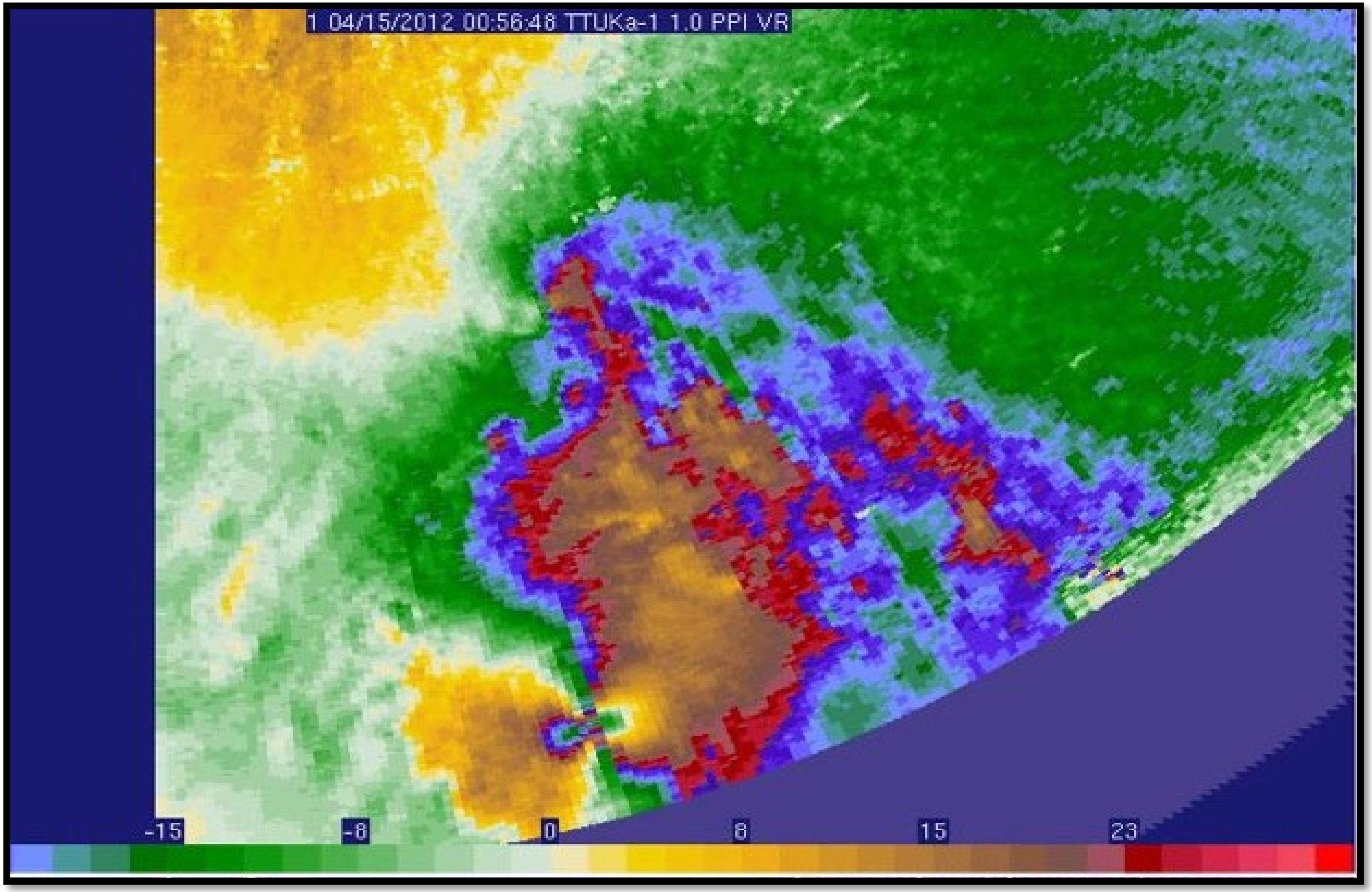
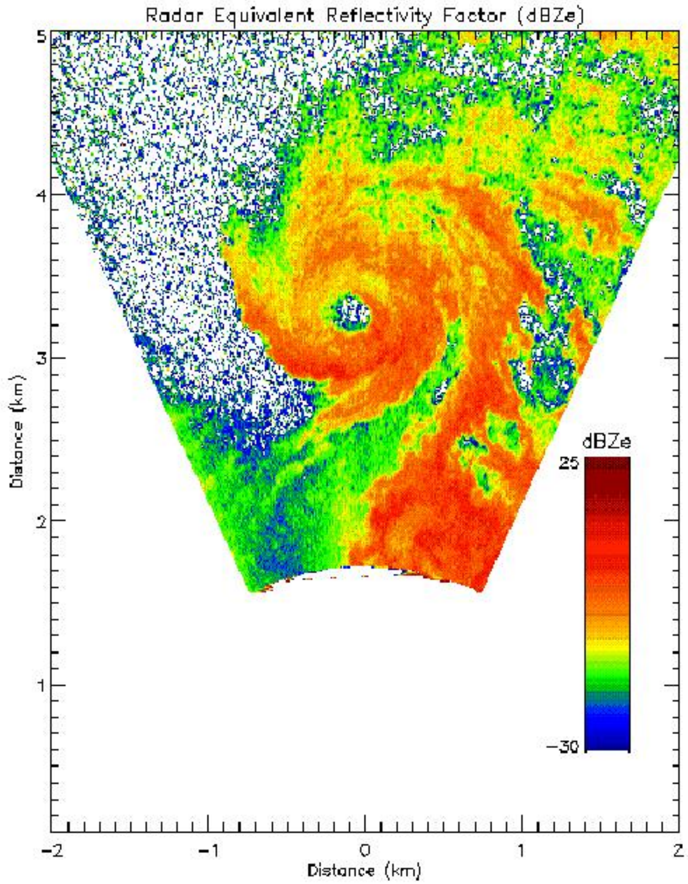
TTUKA TORNADO RADAR DATA
15 APRIL 2012: REFLECTIVITY



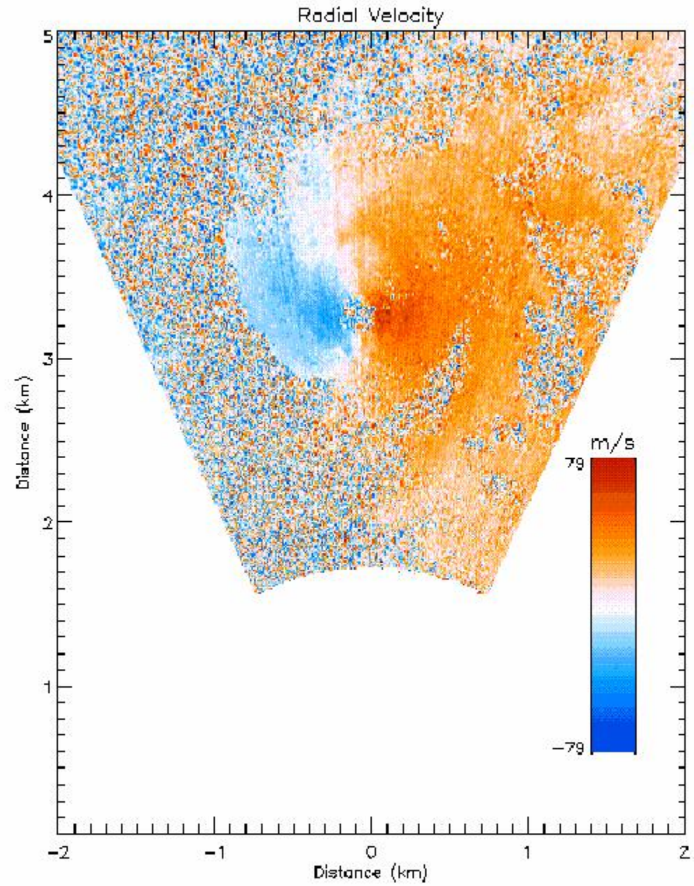
TTUKA TORNADO RADAR DATA
15 APRIL 2012: RADIAL VELOCITY



3 MAY 1999 OKC TORNADO FROM UMASS RADAR DATA



Reflectivity



Velocity

LIDAR BENEFITS

- Low-level radar data can be messy…even in the Plains.
- Vertical velocity only possible with a third radar or integration of continuity equation.
- Clear-air data tough to acquire even for "sensitive" systems.

PROFILING LIDAR TYPES

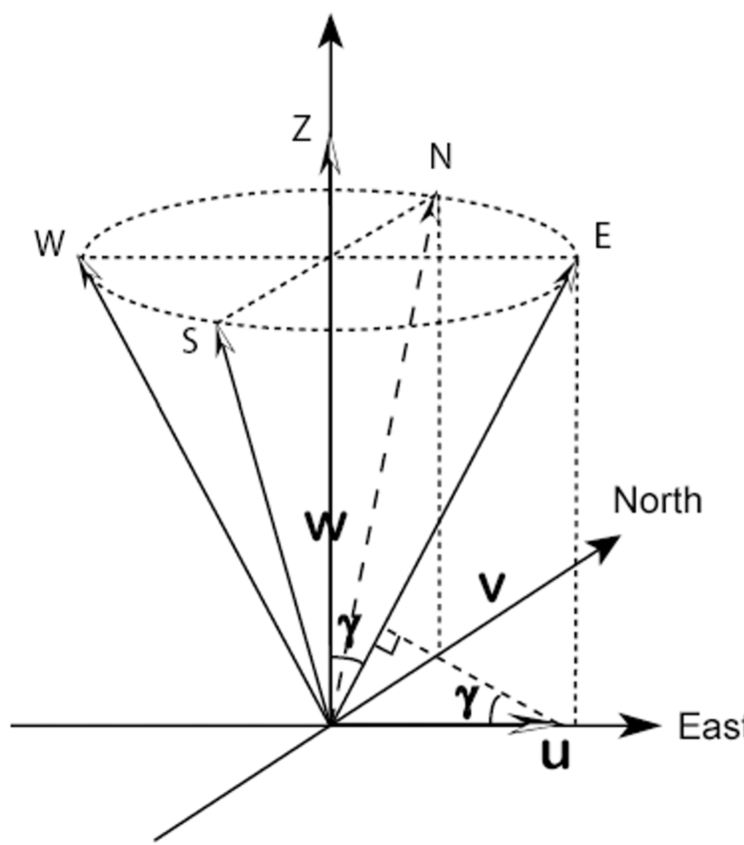
- Pulsed lidar
  - WindCube

  - Uses a modified Doppler Beam Swinging (DBS) technique

  - 5 beams emitted simultaneously.

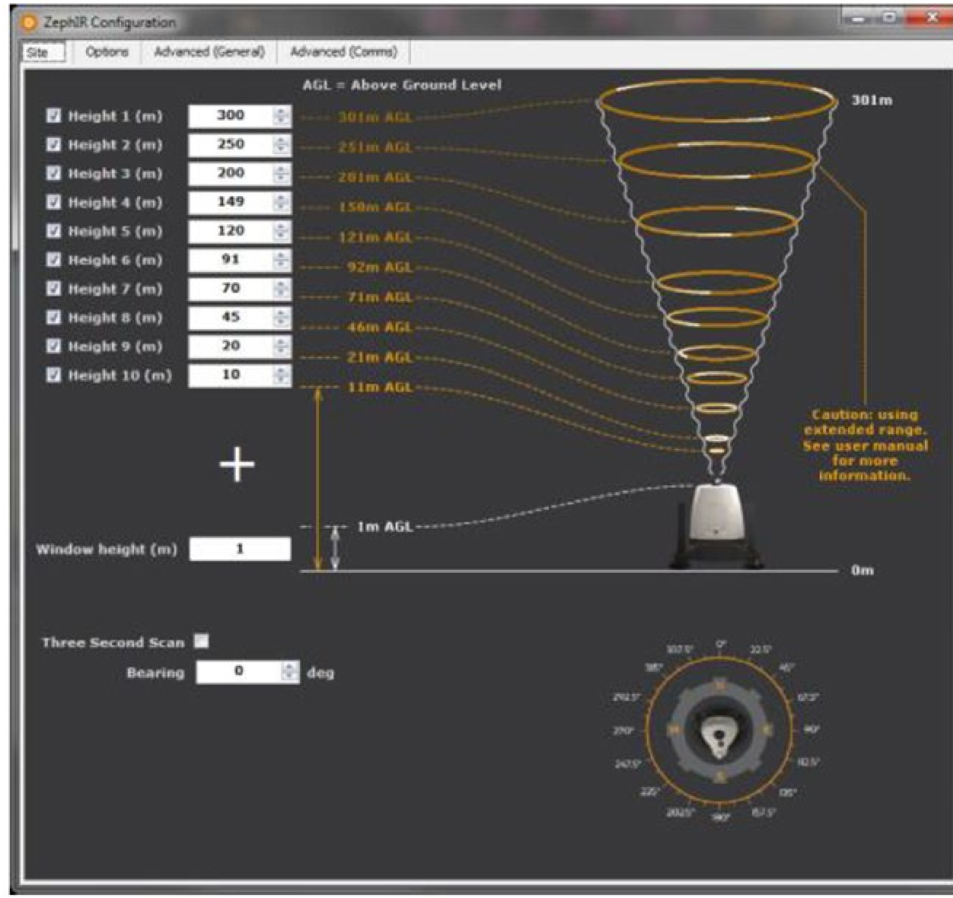
  - Lowest level is 40 m

  - ~ 30 m range gate spacing; ~ 4 secs for full profile



PROFILING LIDAR TYPES

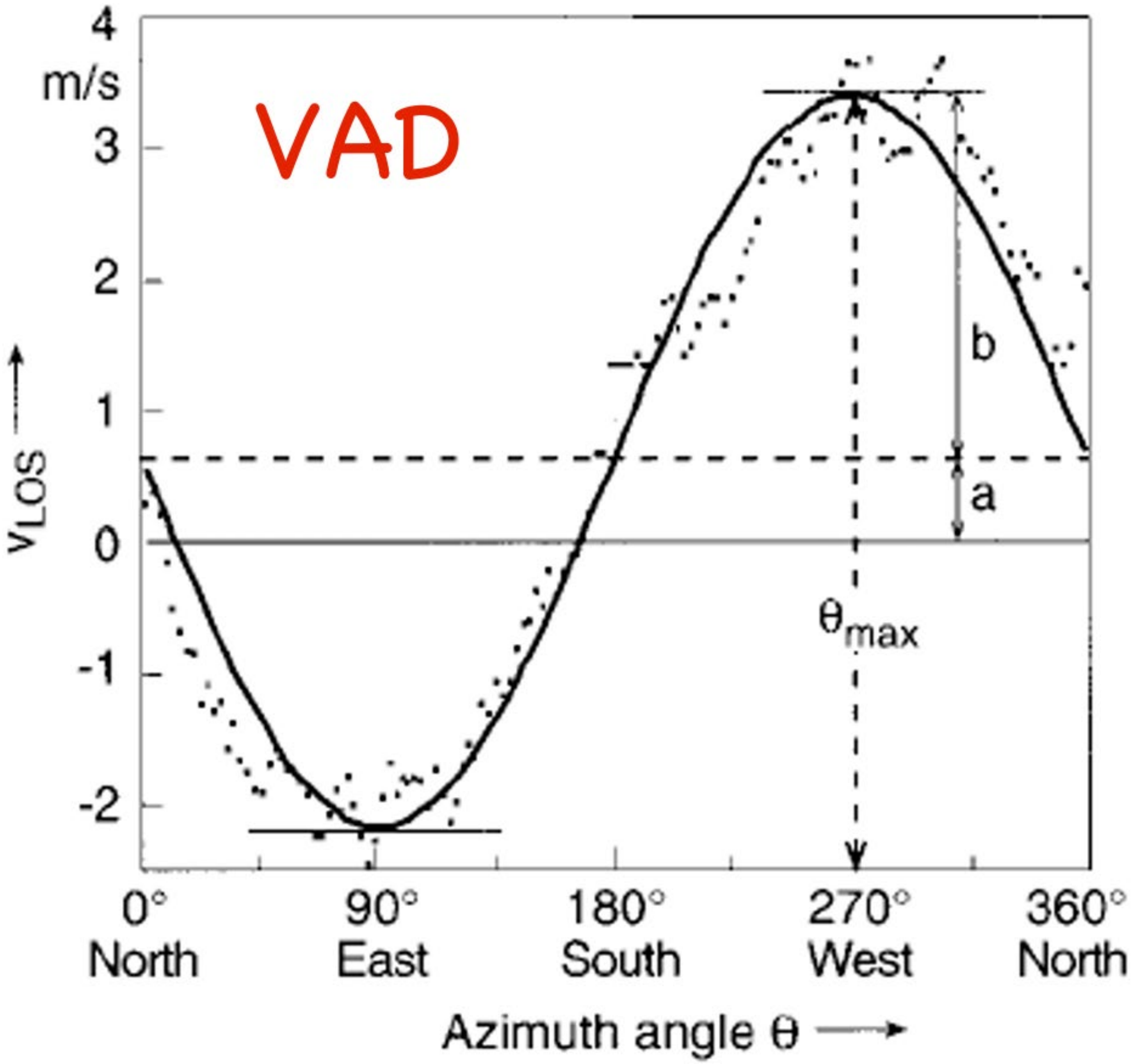
- Continuous Wave:
  - Prism performs a complete 360 for each level.
  - The VAD technique is used to get a wind speed / direction for a given level.
  - Variable range gates; ~15 sec scans.
  - Allows for data collection as low as 10 m.
  - Requires surface measurement for initial WD guess.

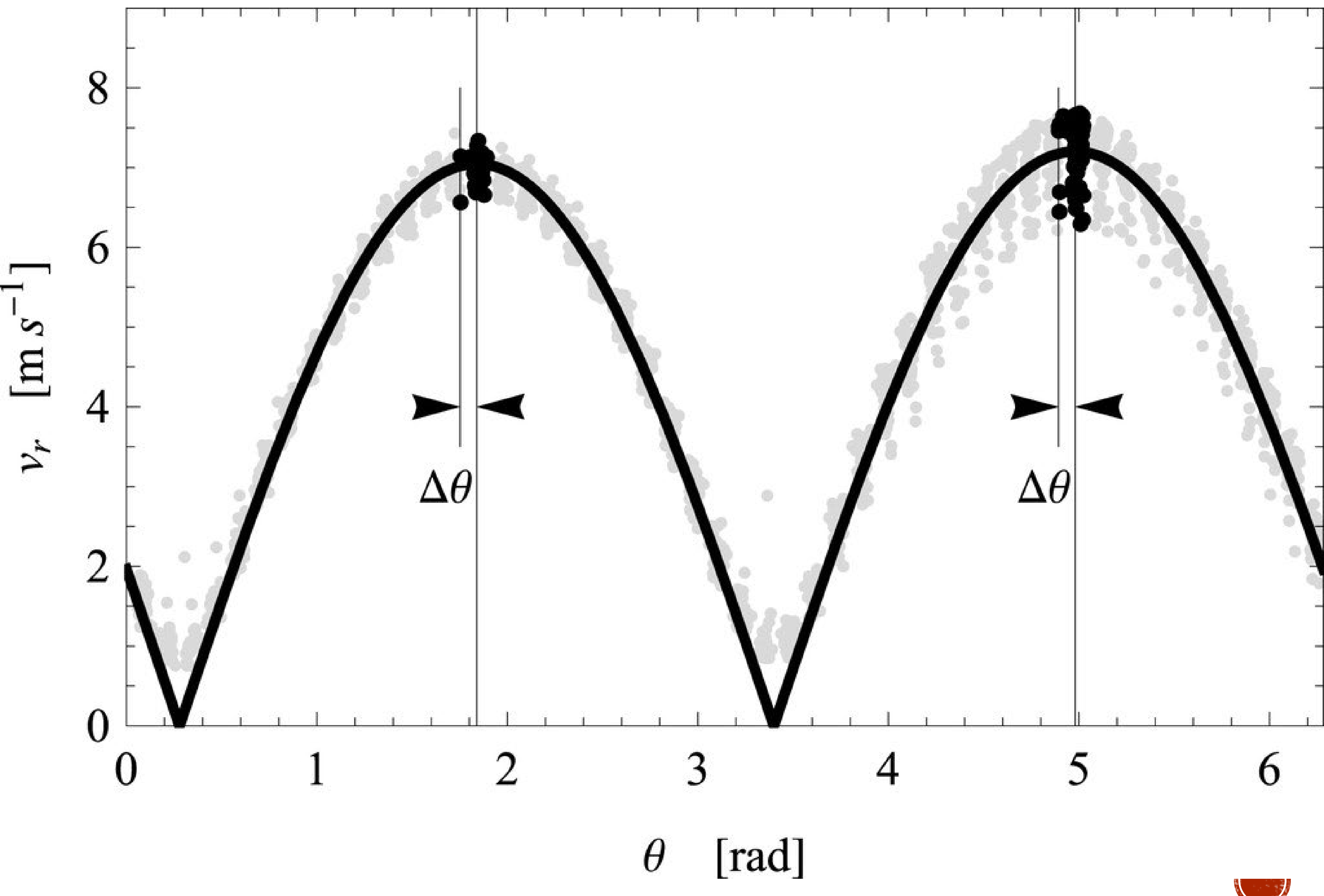


PROFILING LIDAR

- ZyphIR 300 Profiling Lidar
- 10 heights between 29 m and 143 m.
- WS, WD and Vertical Velocity within each height bin.
- Rigorous testing has classified these units as “bankable”.

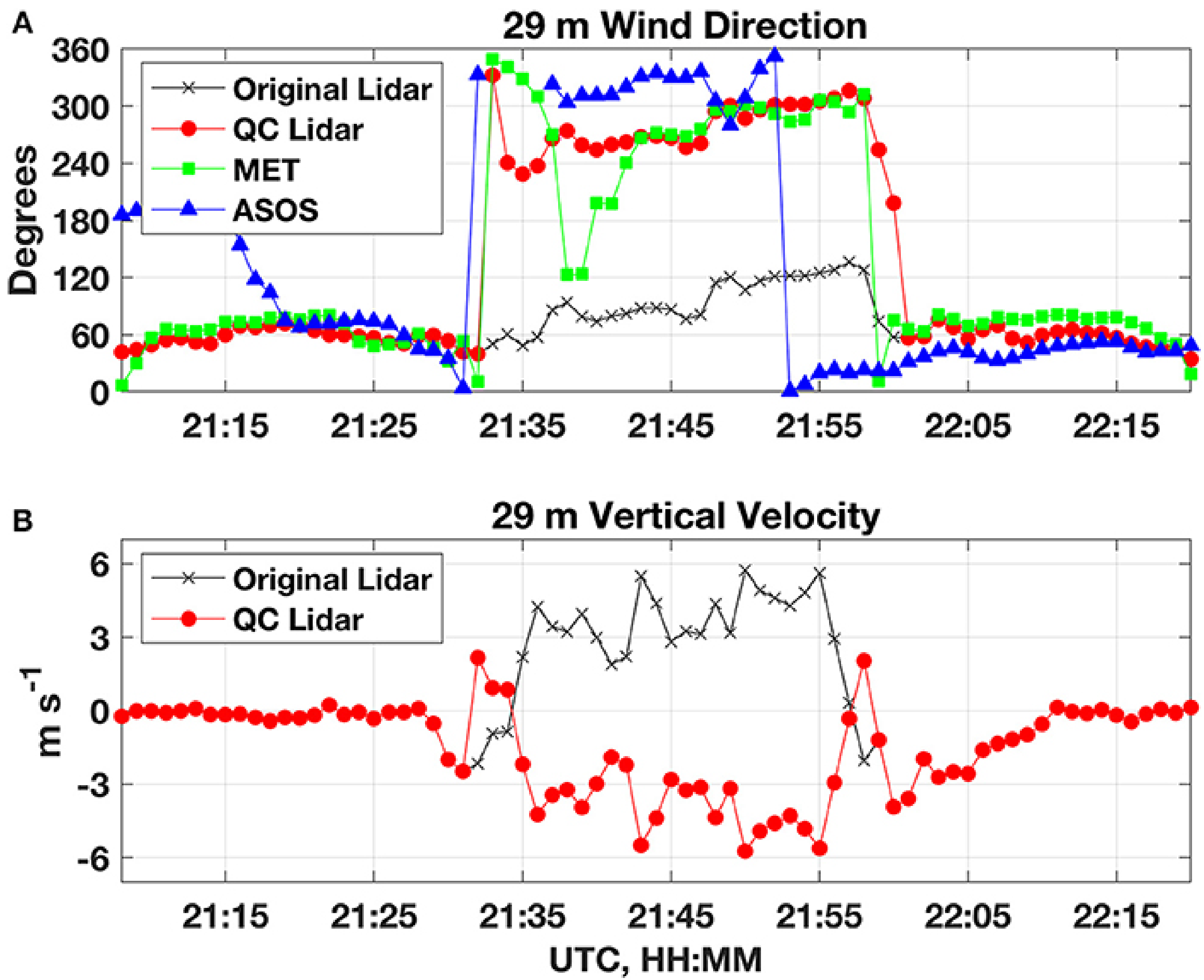
PROFILING LIDAR TYPES



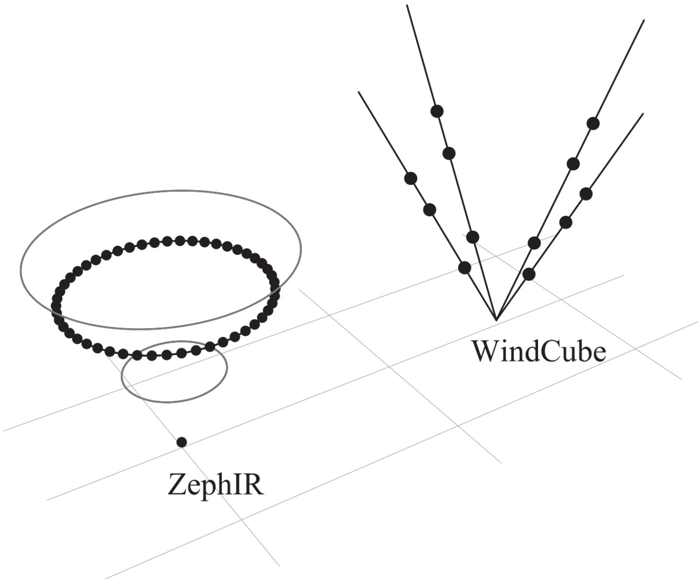


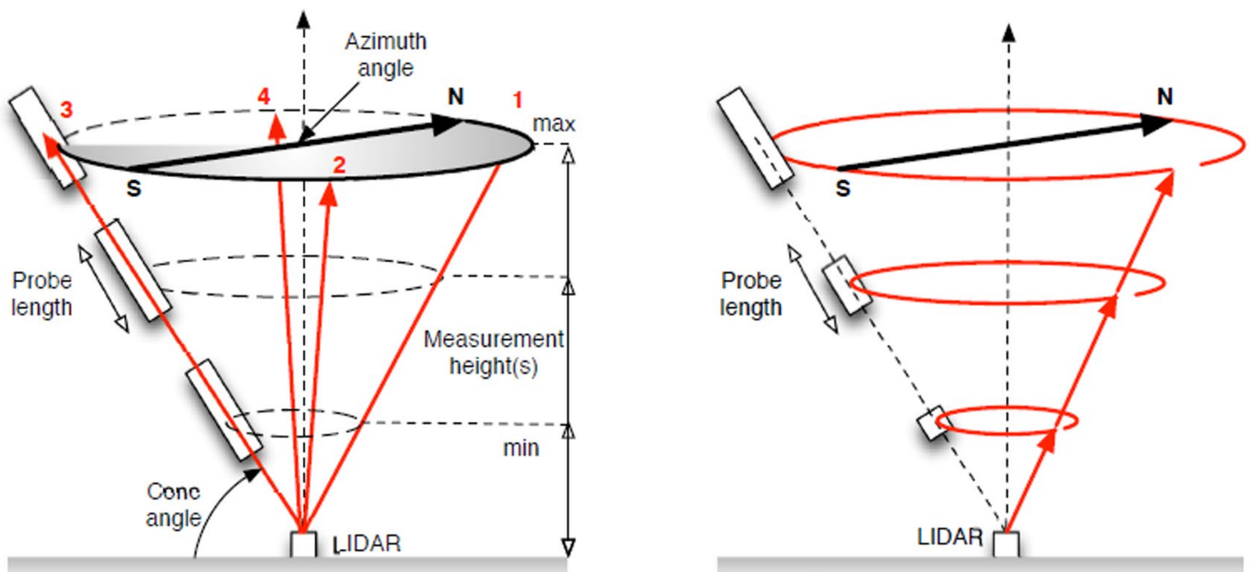
8
6
4
2
0
v_r [m s^{-1}]
$\Delta\theta$
$\Delta\theta$
0
1
2
3
4
5
6
θ [rad]

PROFILING LIDAR TYPES



PROFILING LIDAR TYPES

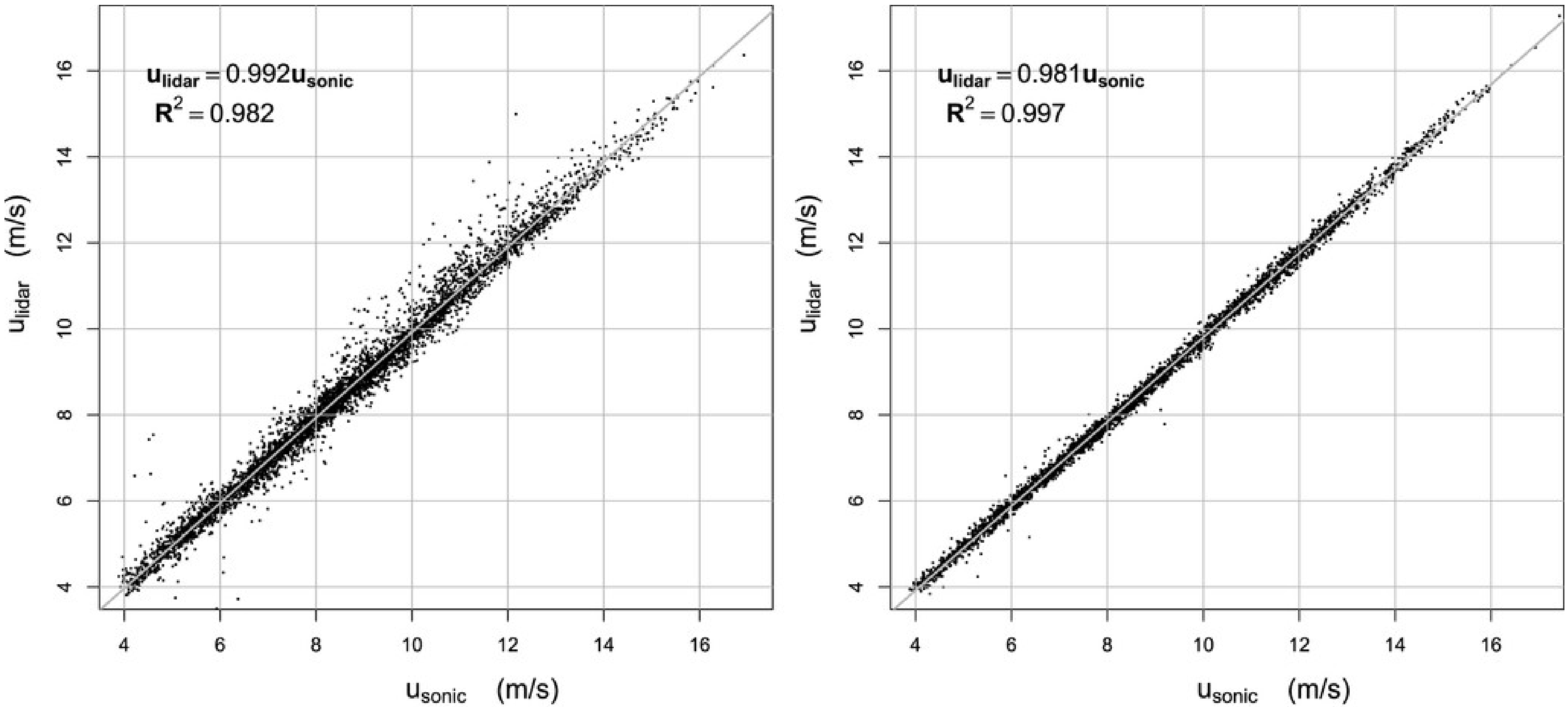




(a) Pulsed DBS lidar

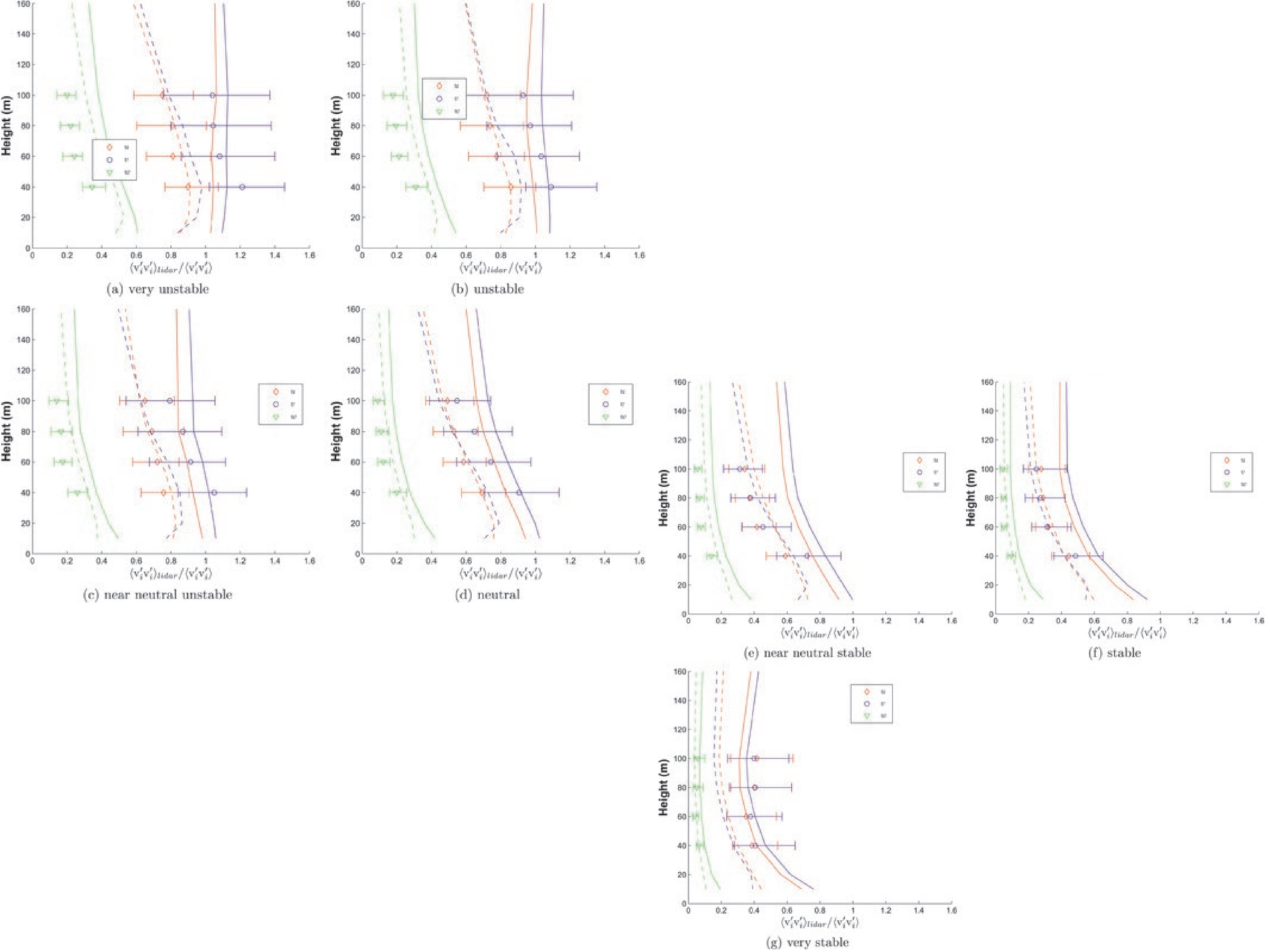
(b) Continuous Wave VAD lidar

PROFILING LIDAR TYPES



(a) ZephIR

(b) WindCube



(a) very unstable

(b) unstable

(c) near neutral unstable

(d) neutral

(e) near neutral stable

(f) stable

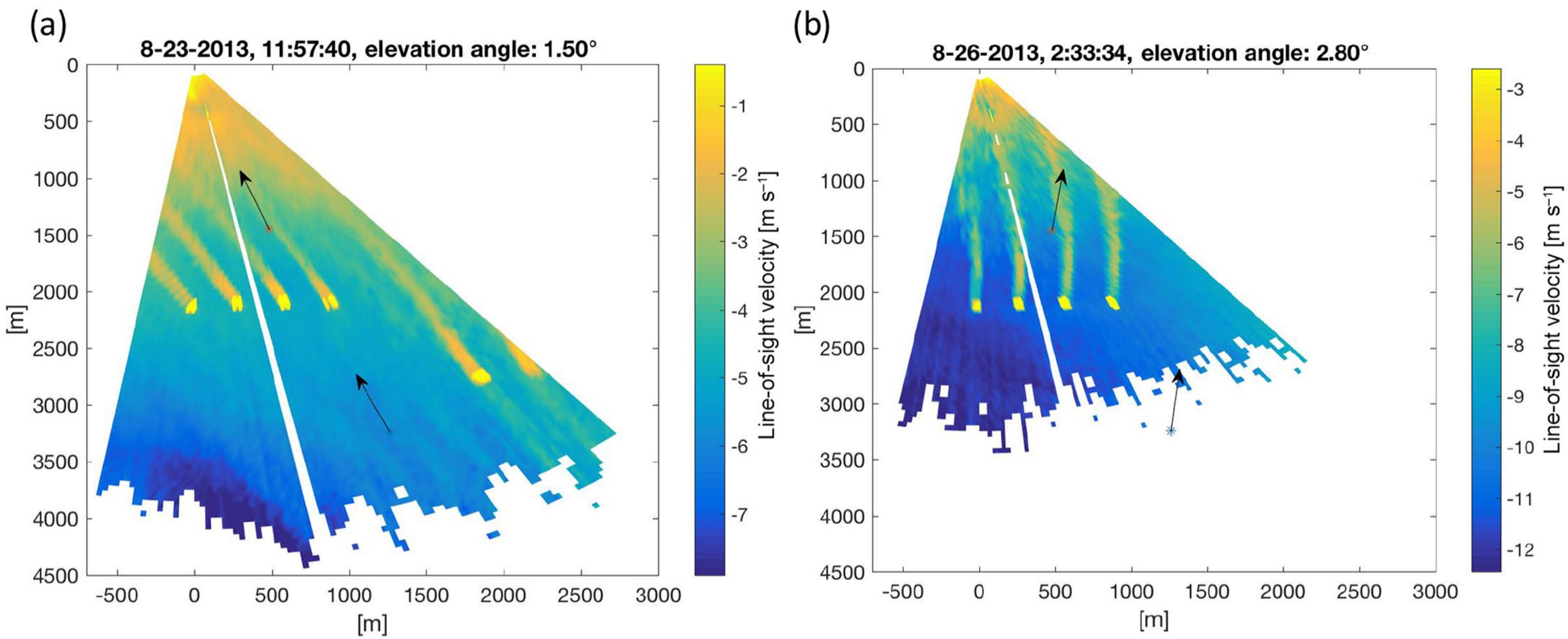
(g) very stable

OTHER LIDAR TYPES

- Scanning Wind lidar

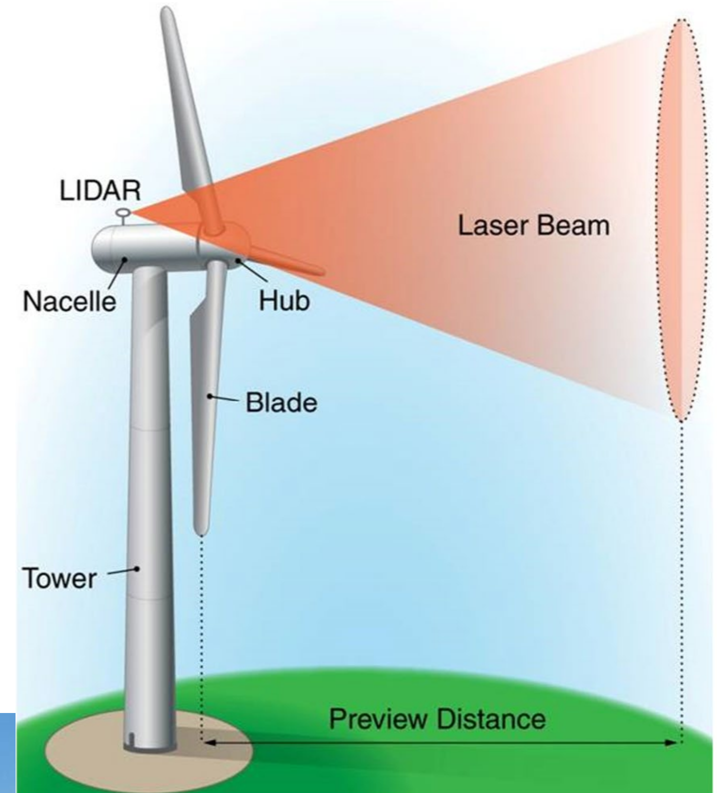
OTHER LIDAR TYPES

- Scanning Wind lidar

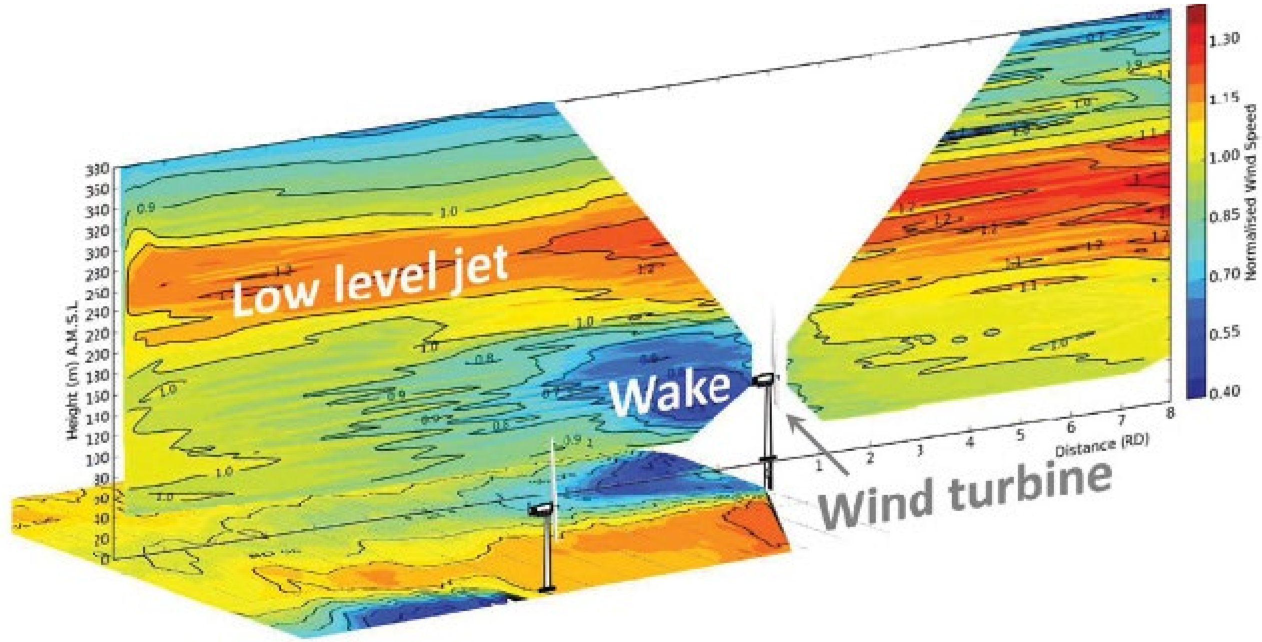


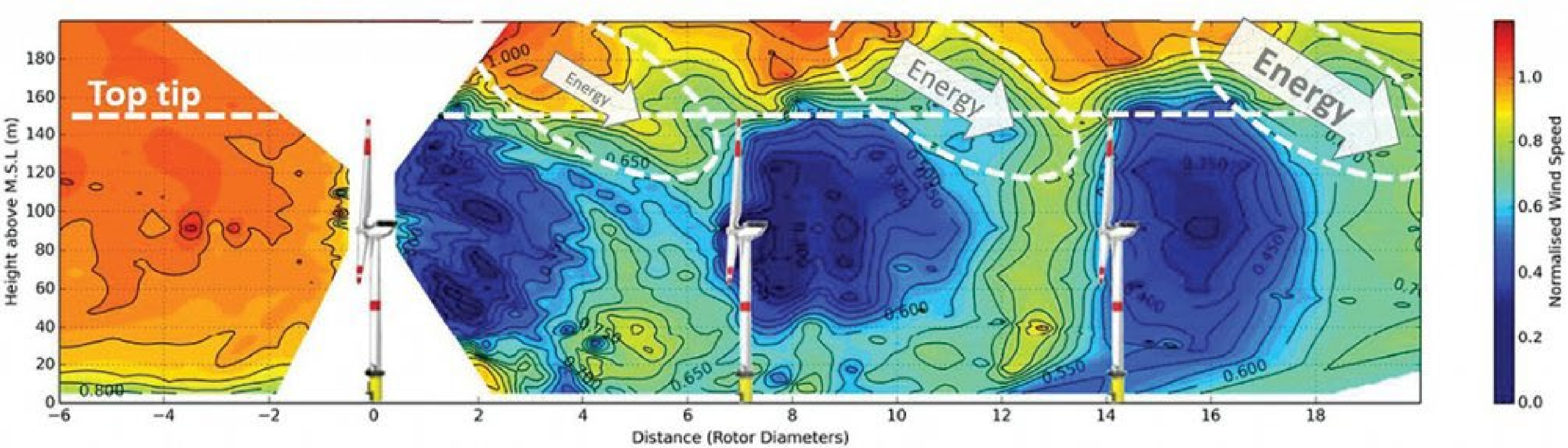
OTHER LIDAR TYPES

- Nacelle Mounted Lidars
  - "look ahead"
  - Mostly used for turbine control and wake ID



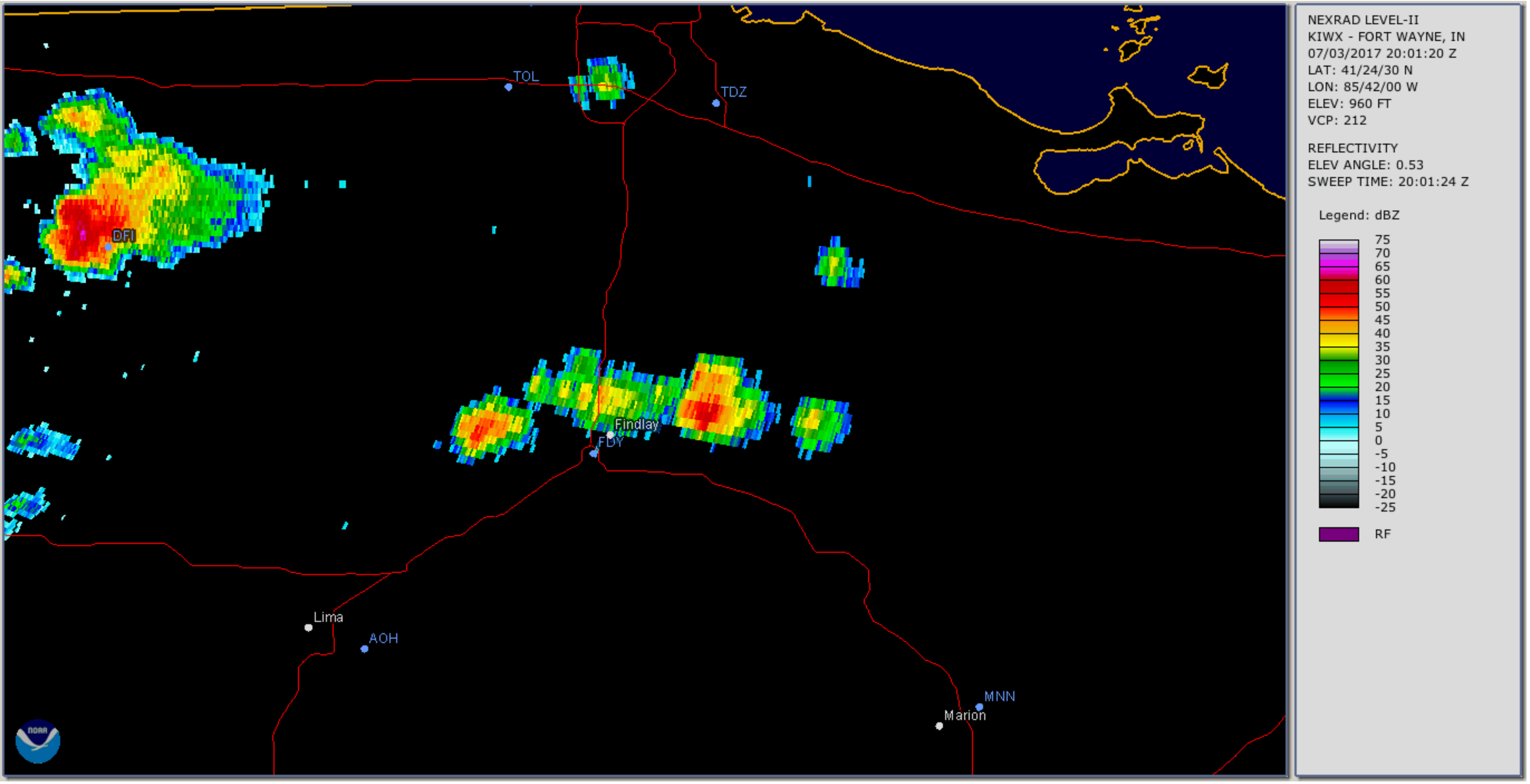
OTHER LIDAR TYPES



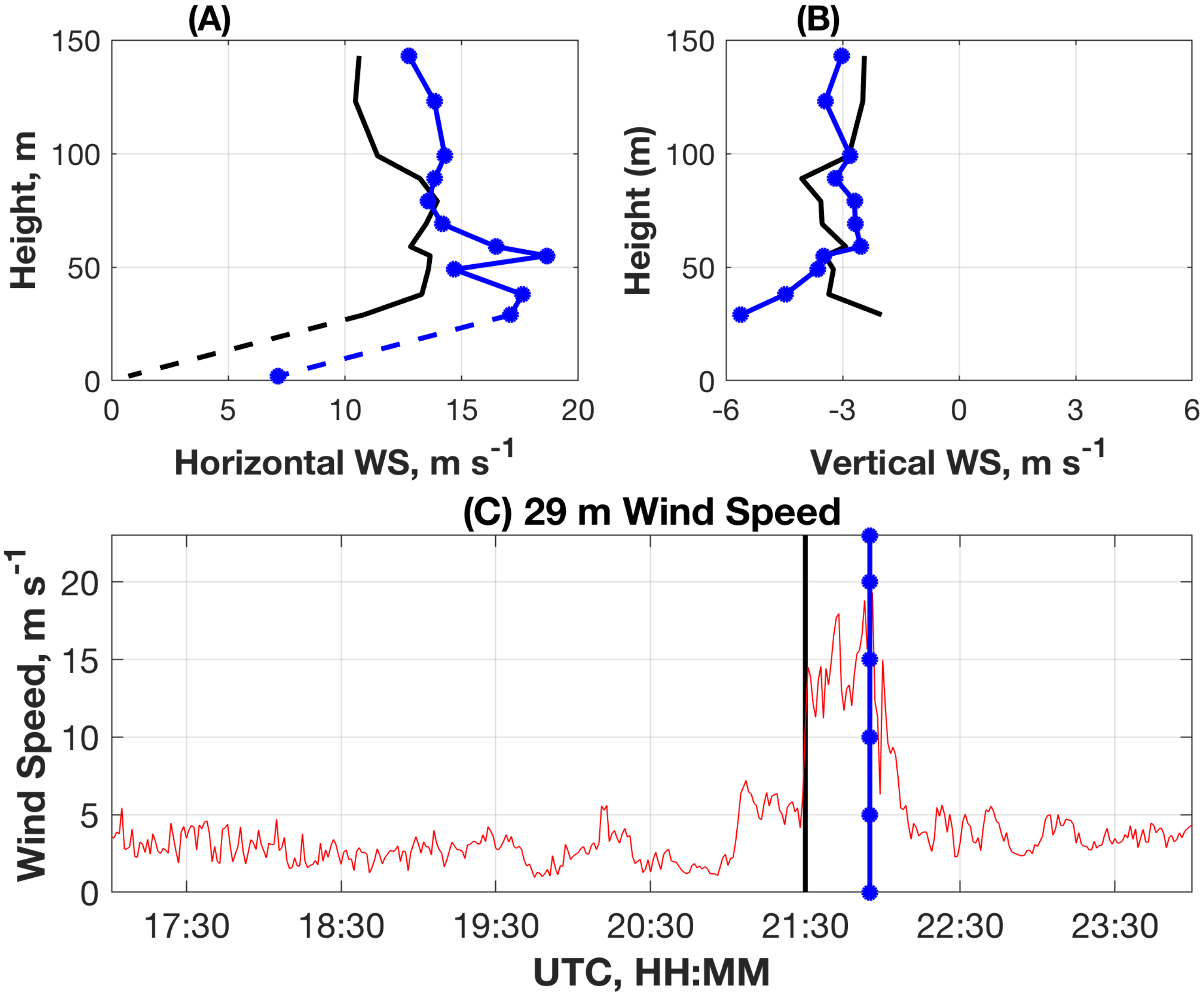


LIDAR DATA CASE STUDY

- Analyzed several "pulse" thunderstorm types from July 2017



LIDAR CASE STUDY



MEASUREMENT COMPARISONS

- New techniques should be verified with proven methods.
- "Proven" methods for measuring wind generally include some type of anemometer.

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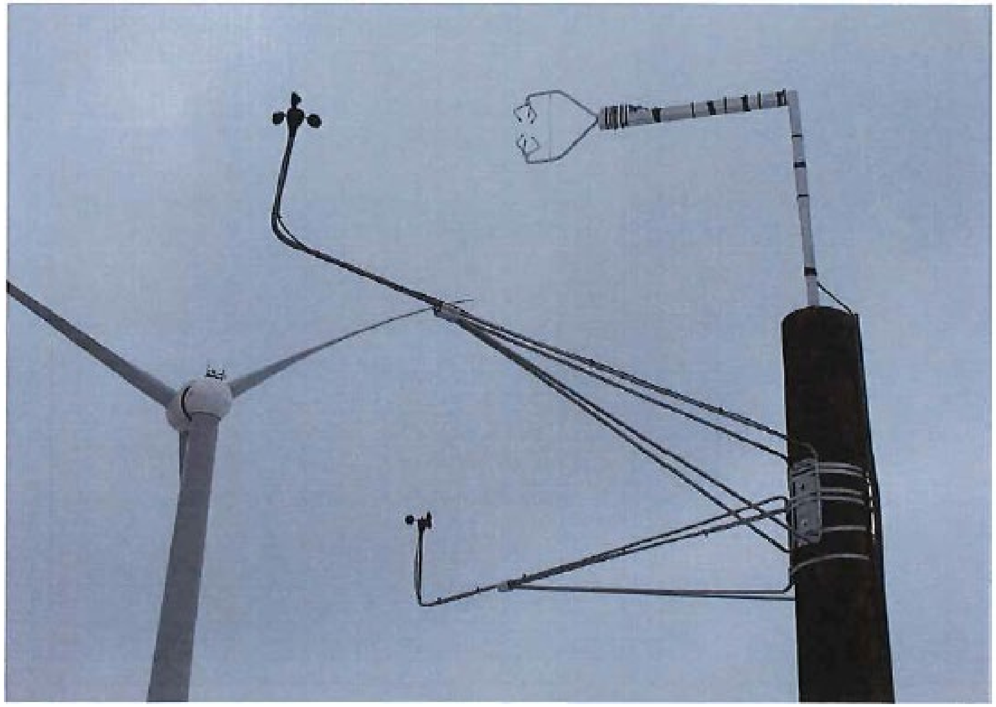
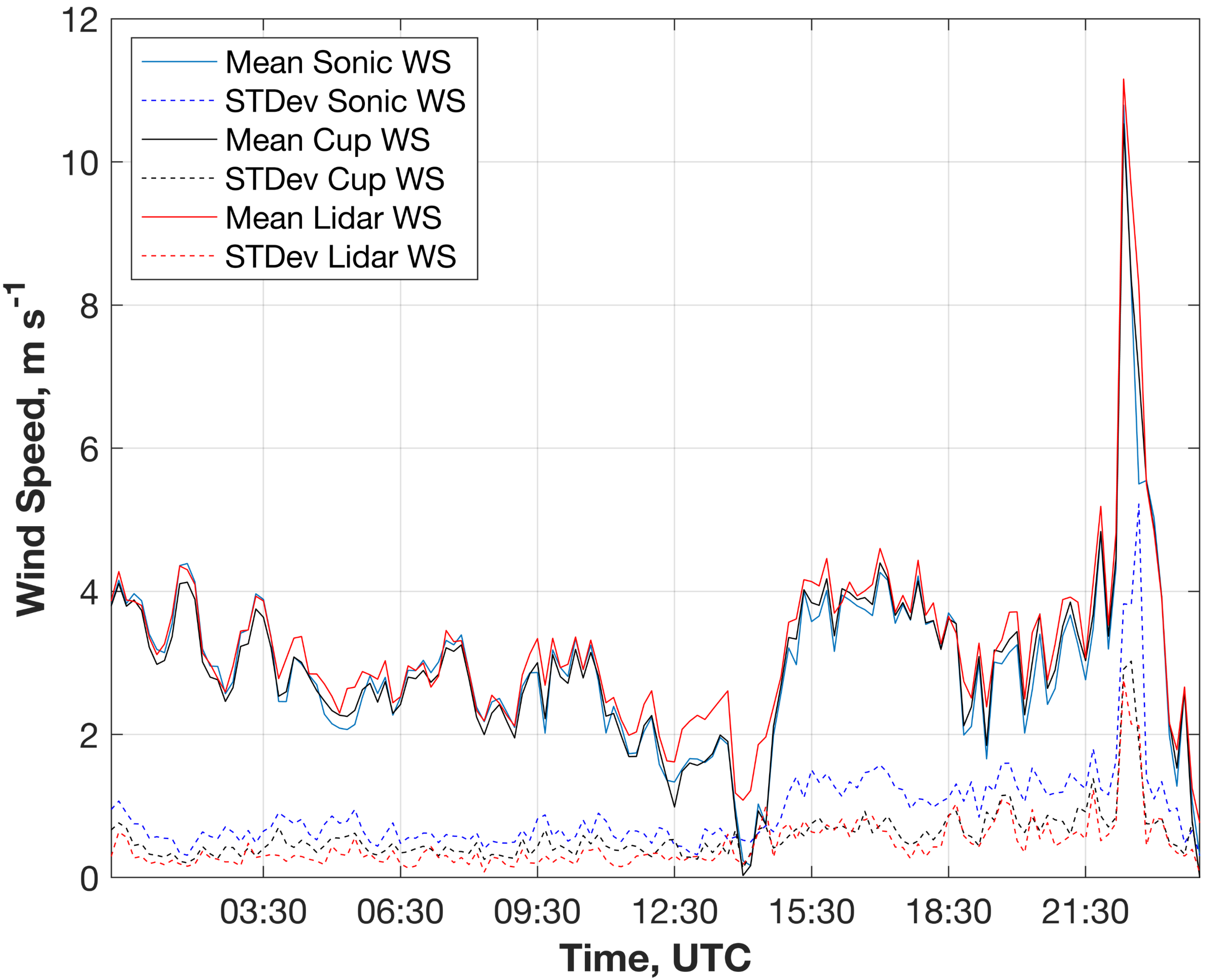
Model 81000 (c) 2001 R. M. Young Company

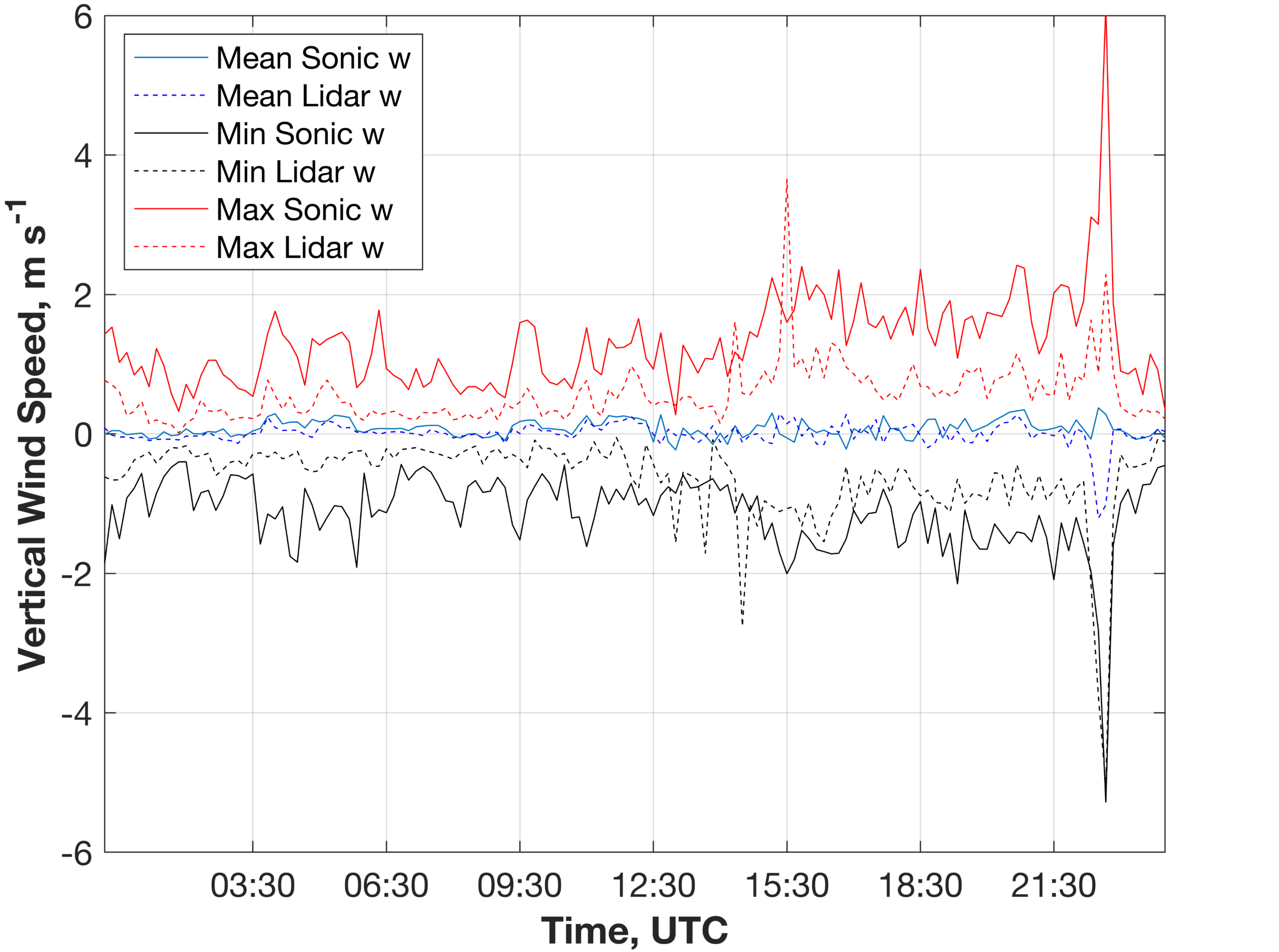
LIDAR CASE STUDY

- Compare to lidar data to anemometers data.
- 2 NRG 40C cup anemometers (scalar wind speed)
  - 28 m AGL
- 2 NRG wind vanes
  - 25 m AGL
- CSATB Sonic
  - 30 m AGL
  - U,V, and W
- 10 min. Statistics





Mean Sonic WS
STDev Sonic WS
Mean Cup WS
STDev Cup WS
Mean Lidar WS
STDev Lidar WS
Wind Speed, m s-1
Time, UTC
0
2
4
6
8
10
12
03:30
06:30
09:30
12:30
15:30
18:30
21:30



Mean Sonic w
Mean Lidar w
Min Sonic w
Min Lidar w
Max Sonic w
Max Lidar w
Vertical Wind Speed, m s-1
Time, UTC
6
4
2
0
-2
-4
-6
03:30
06:30
09:30
12:30
15:30
18:30
21:30

RESULTS

- "Volume" averaging smooths smaller scales of turbulence in both radar and lidar data.
- ZyphIR Lidar performed well in moderate to heavy precipitation.
- Hydrometer fall-speeds likely influenced vertical velocity estimation in lidar data.