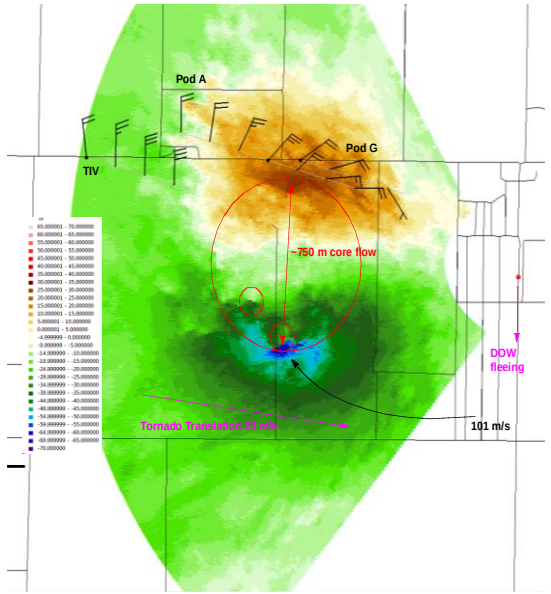
Radar and In Situ Wind Measurements Vs Damage Measurements

Josh Wurman, Karen Kosiba

Using material from Curtis Alexander, Jeff Snyder, Don Burgess and others



What does radar measure?

- Signal is just measured Power(time)

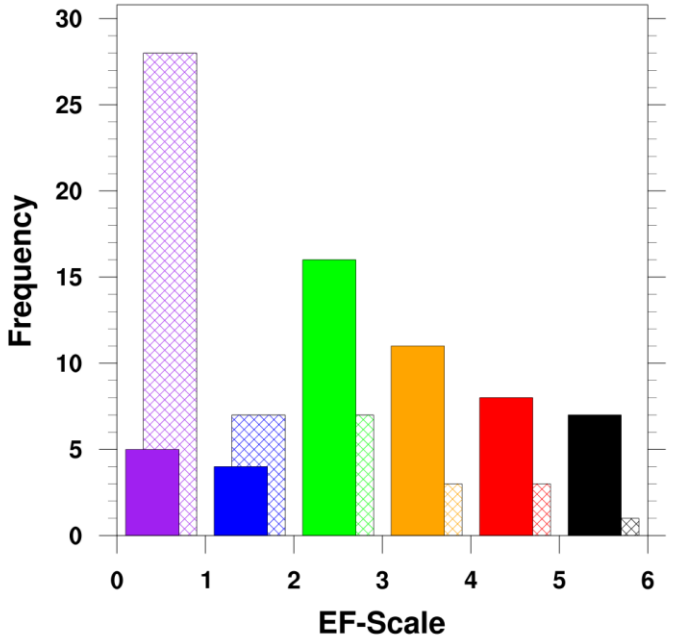
- Measured power depends on
  - antenna pattern (side lobes)
  - beam blockage (trees) (probably reduces measurement)
  - multi-path (ground reflecting) (may increase measurement)
  - integrated power-weighted return from scatterers moving in the wind.

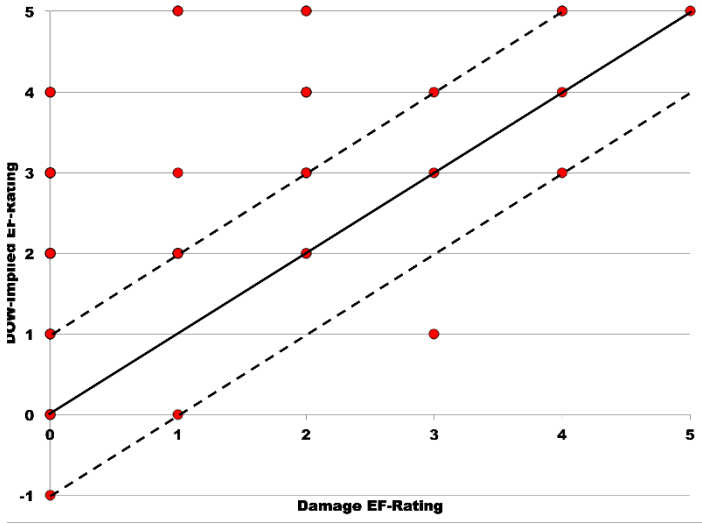
- No standard for dealiasing, SNR, deglitching, etc., spikes in a spectrum, Subjective. Even if standard were “peer” review, this has different “qualities”

What does a damage survey measure?

- Integrated/cumulative effect of wind during the event
- Integrated effect of different wind directions and intensities
- Effects of debris impacts
- Construction quality (and/or tree strength, blockage, etc.)

2013 was not the only year to have radar – damage wind estimates disagree with NWS-EF.





- **40% of DOW-observed tornadoes (~50) have DOW-EF 2 higher than NWS EF** (based on Alexander and Wurman, 2014 climatology)

- Would community accept a tornado damage-surveyed at EF3, UPGRADED by high quality radar measurement?
- Would community accept a tornado damage-surveyed at EF5, DOWNGRADED by high quality radar measurement?

Height of Radar Measurement

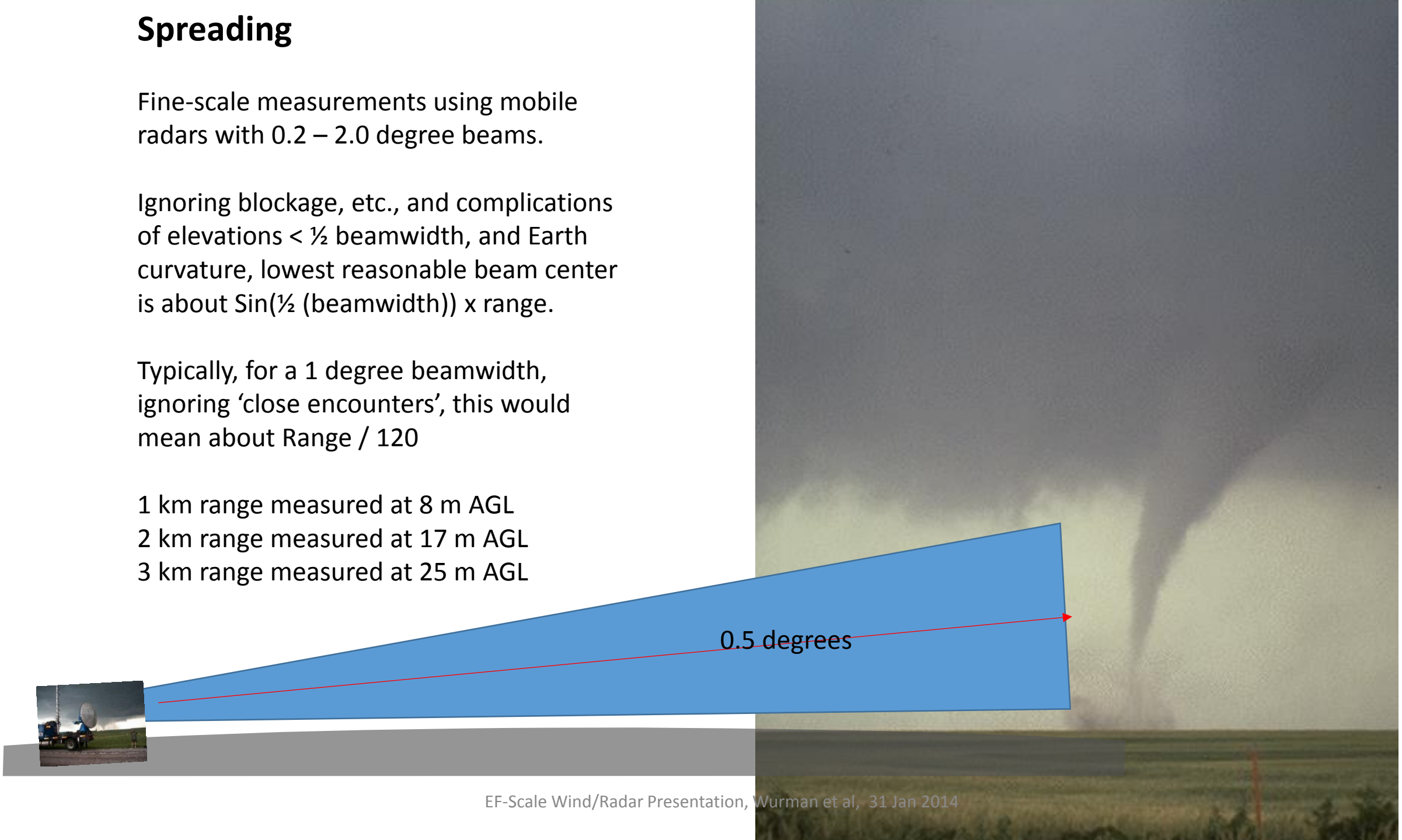
Spreading

Fine-scale measurements using mobile radars with 0.2 – 2.0 degree beams.

Ignoring blockage, etc., and complications of elevations < ½ beamwidth, and Earth curvature, lowest reasonable beam center is about Sin(½ (beamwidth)) x range.

Typically, for a 1 degree beamwidth, ignoring 'close encounters', this would mean about Range / 120

1 km range measured at 8 m AGL
2 km range measured at 17 m AGL
3 km range measured at 25 m AGL



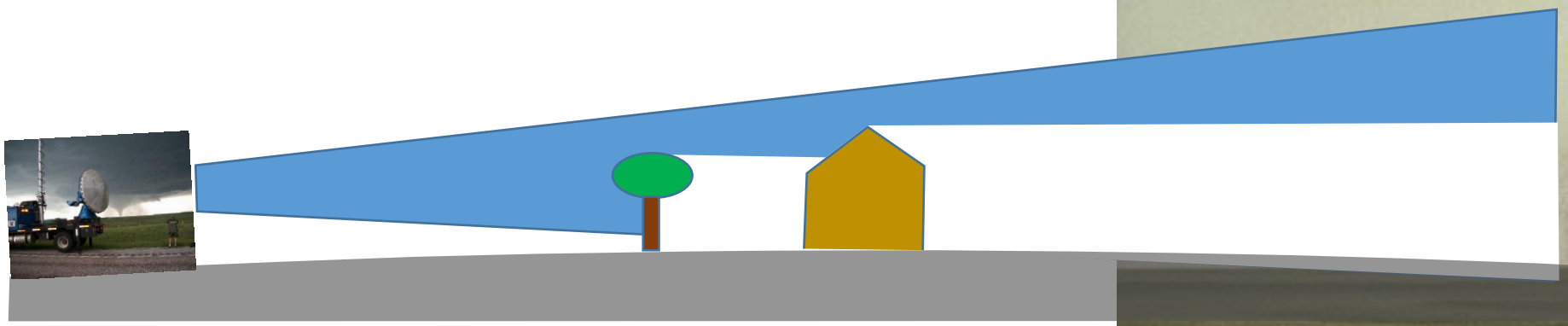
Blockage

Blockage below ~10-15 m.

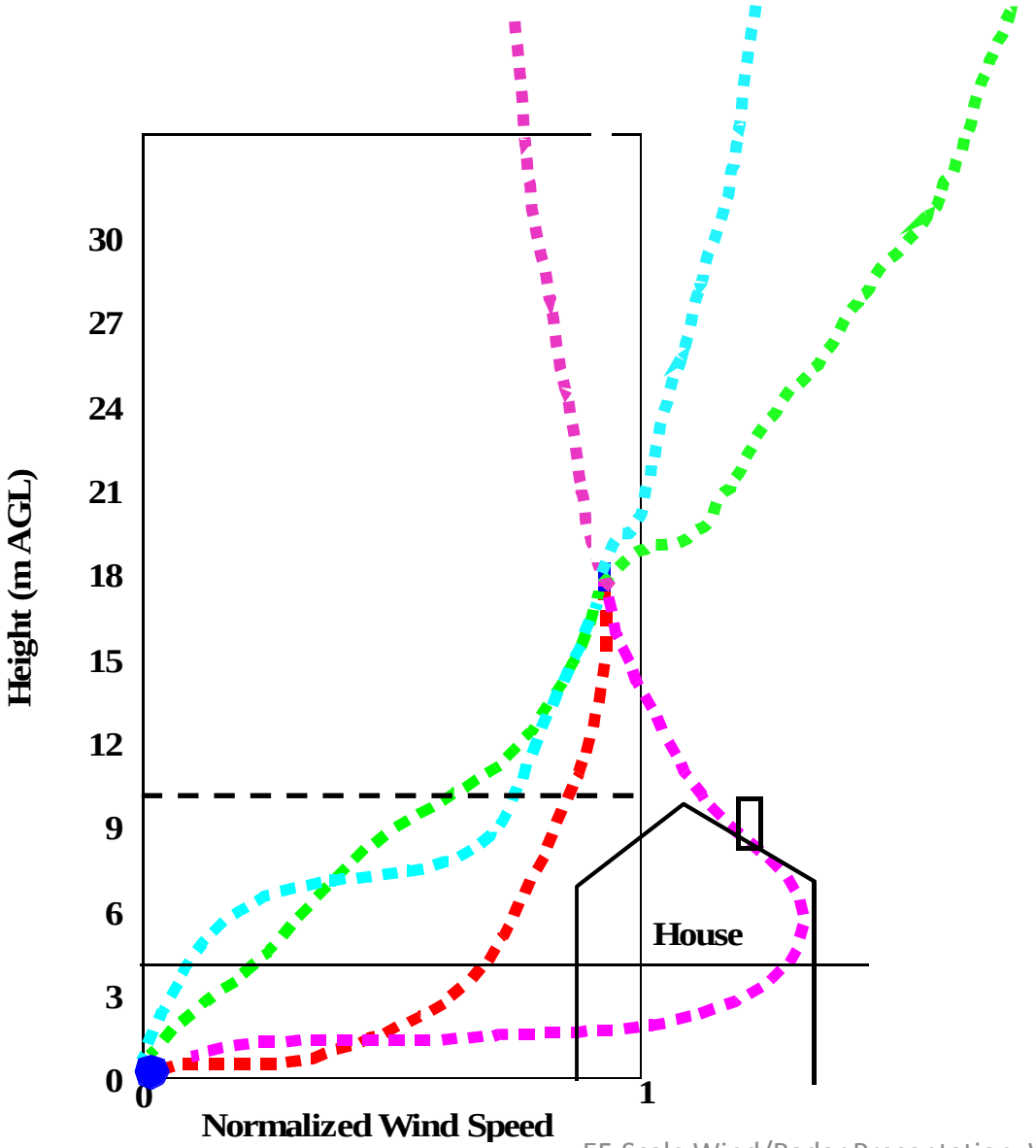
Especially true in areas with Dis

Maybe less true in very open areas, but this is a strong bias in radar low level wind studies

Not mitigated by K or W band ultra-narrow beams.

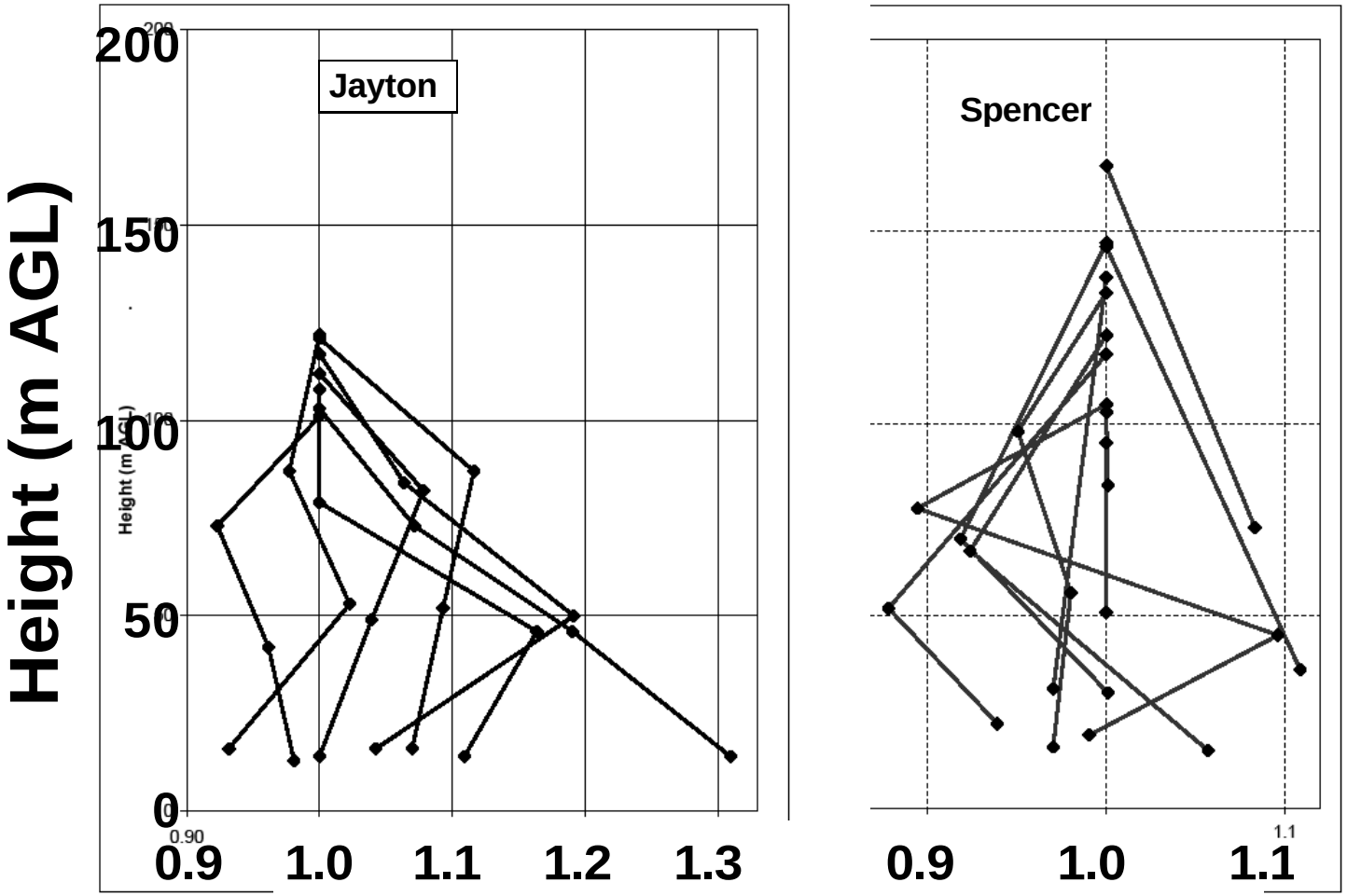


How do radar measurements at XX m AGL compare to 10 m AGL?



Study of two tornadoes found no strong dependence dVmax/dZ ~ 0 for 15 m < Z < 100 m

Wurman, J., C. Alexander, P. Robinson, and Y. Richardson, 2007c: Low Level Winds in Tornadoes and Potential Catastrophic Tornado Impacts in Urban Areas. *Bull. Amer. Meteor. Soc.* **88**, 31-46.



05 June 2009: Goshen County, WY

Wurman, J., K. A. Kosiba, P. Robinson, 2012: In-Situ, Doppler Radar and Video Observations of the Interior Structure of a Tornado and Wind-Damage Relationship. *Bull. Amer. Meteor. Soc*.

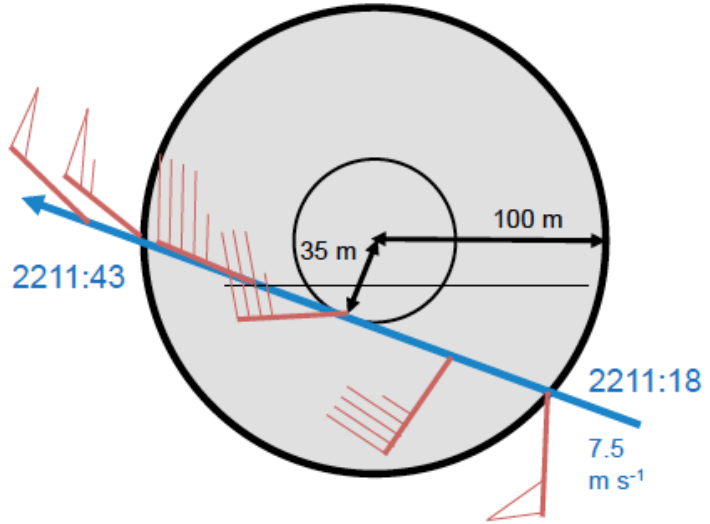


Figure 4. Schematic illustration of transect of tornado by Tornado Intercept Vehicle (TIV). The tornado, with a radius of maximum winds of 100 m, propagates toward 110 degrees at 7.5 m s^{-1}, with the center of circulation passing 35 m north northeast of the TIV, resulting in measurements through a chord of the tornado as shown. Wind barbs show measurements of V_g at 3.5 m AGL with pennants indicating 50 m s^{-1}, full barbs 10 m s^{-1}, and half barbs 5 m s^{-1}. Times are in UTC.

TIV transect through major portion of core flow

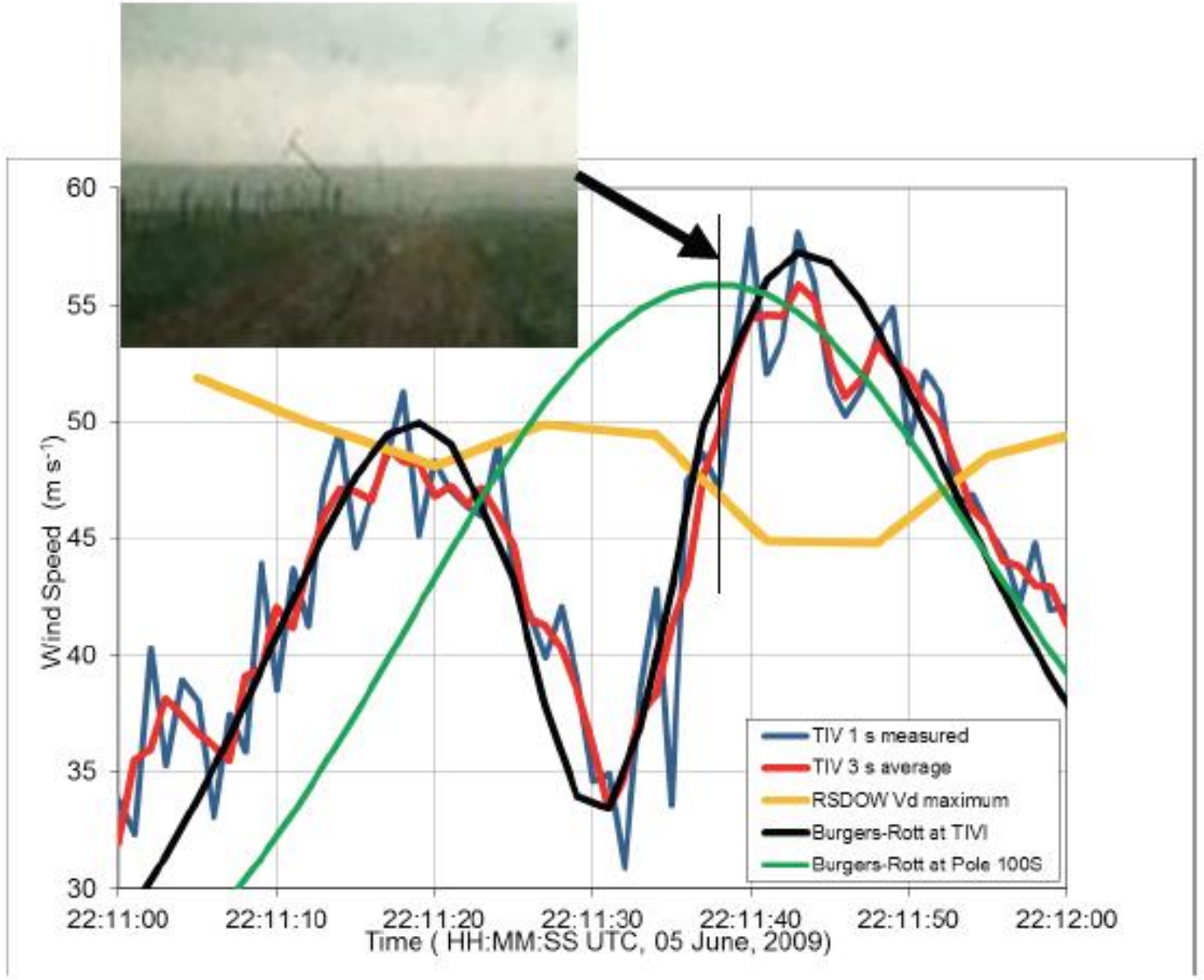
Rapid-Scan observations above

Rapid-Scan DOW EF-3 (nearly EF-4)

Winds observed by TIV anemometer in Goshen County, Wyoming, 2009, tornado

Vtiv (3 m AGL) > Vdoppler (30-100 m AGL)

Wind measurements compared to real-time damage documention



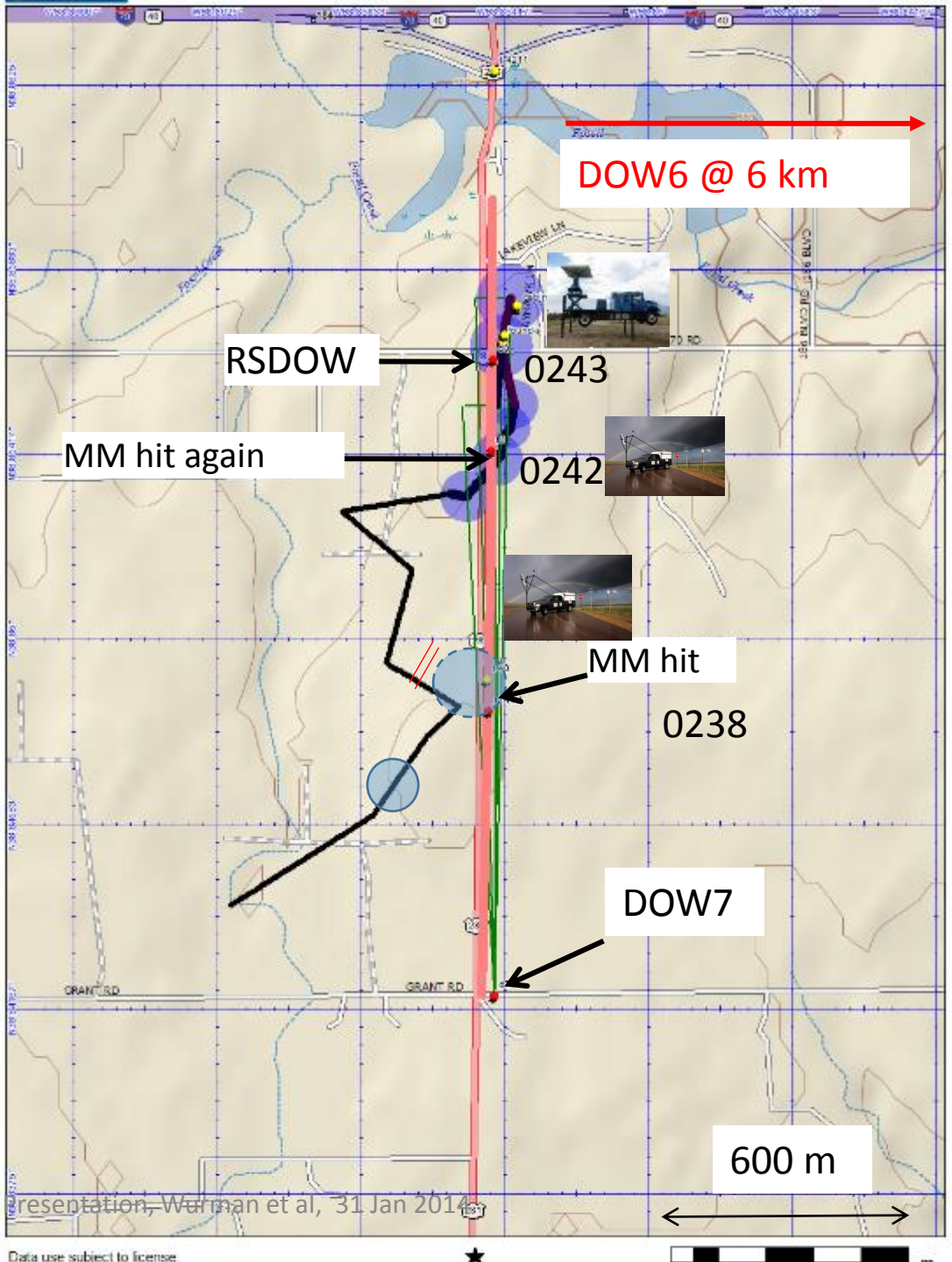
TIV wind transect data fit to Burgers-Rott profiles

2012 May 25
Russell, Kansas

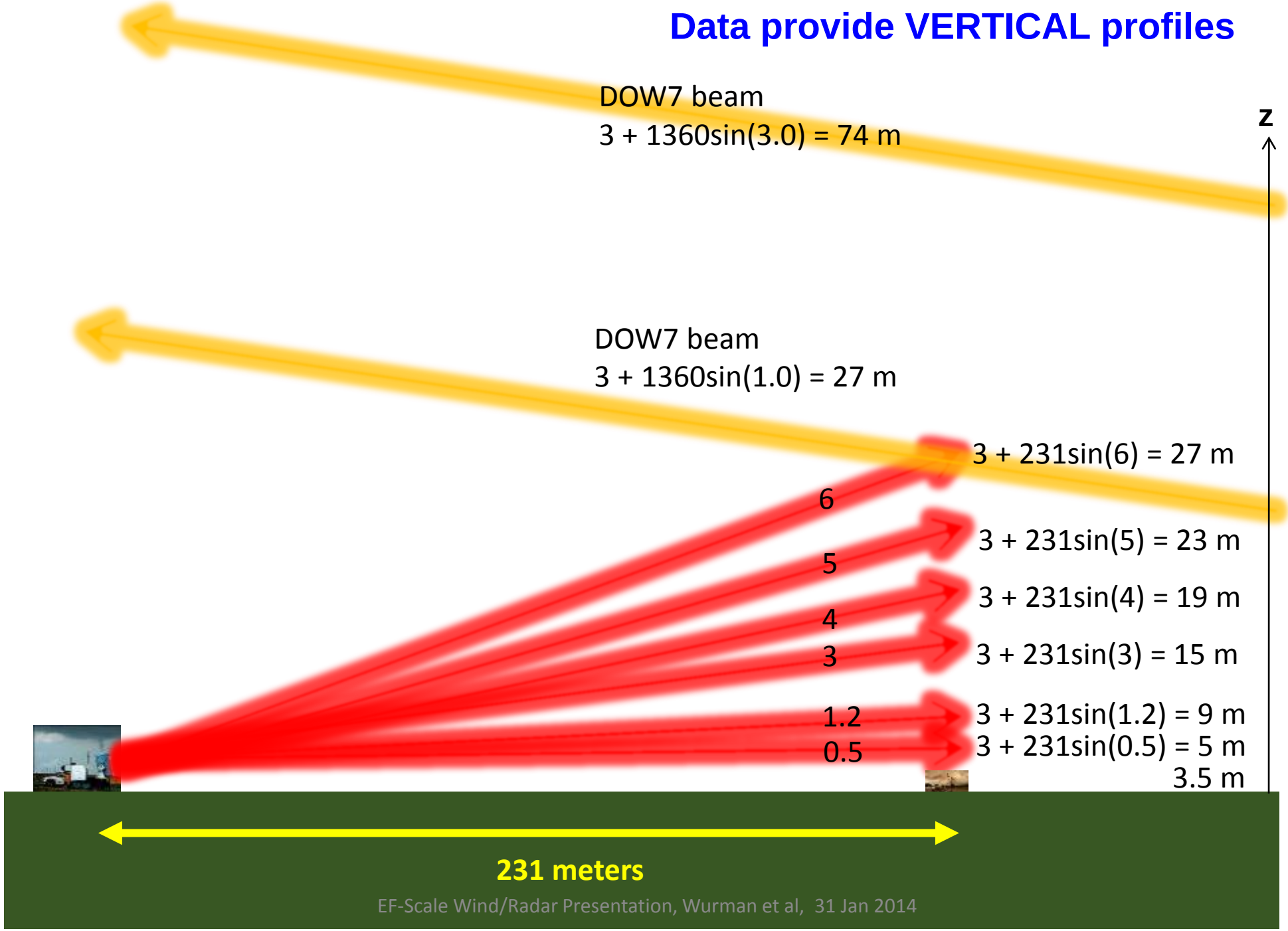
In Situ and Very Fine-Scale Radar Observations in a Tornado

Kosiba and Wurman, 2013

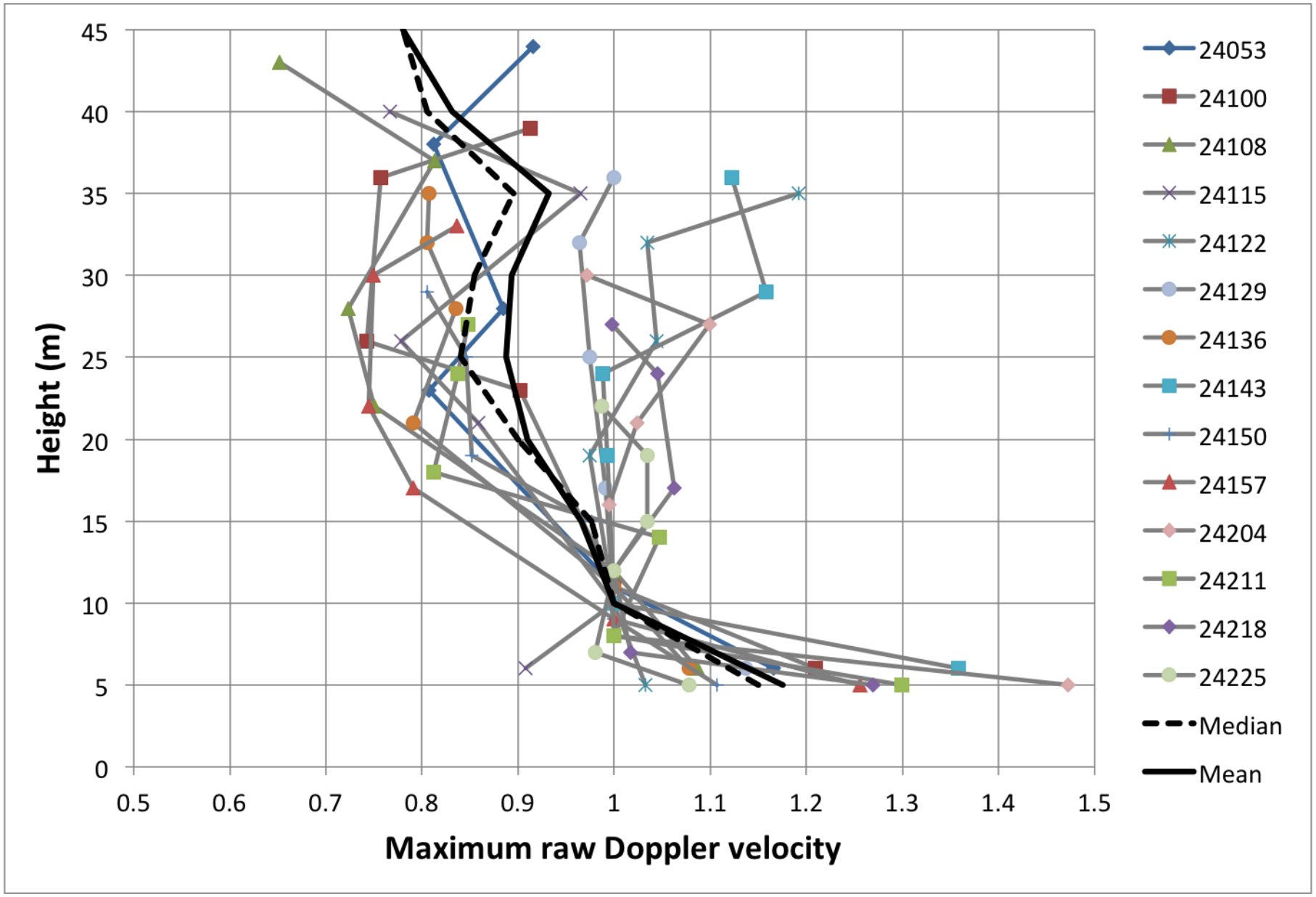
- **In-Situ obs @ 3.5 m AGL**
- **Several RSDOW slices 5-40 m AGL. Every 7 seconds.**
- **DOW7 slices 27 and 75 m AGL**
- **DOW6 slices 100 m – 2 km**
- **Maximum V near 5 m AGL**



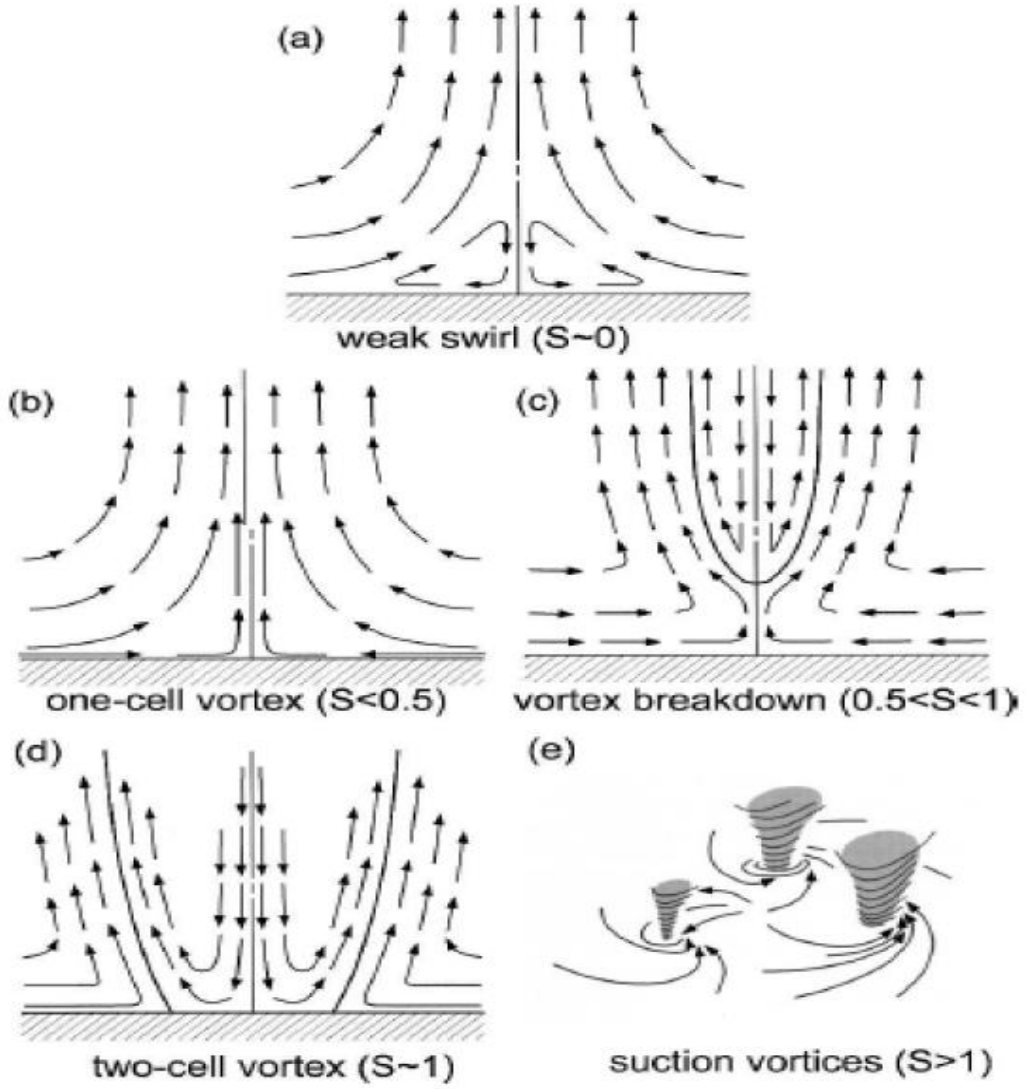
Data provide VERTICAL profiles

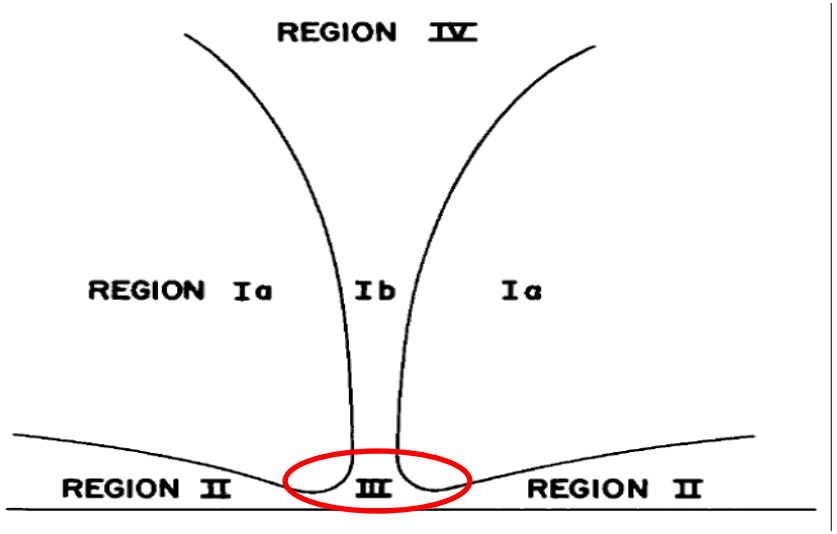


Maximum Tornado Velocity near or below 5 m AGL



How does vortex structure affect dV/DZ?





Radar Observation Duration

- Radar measurements << 3 second duration
- Not known if 3 seconds is most relevant duration for damage
  - Building response time to wind?
  - Damage from debris impacts instantaneous and cumulative
- Unknown effects of << 1 second gusts
- Cumulative effects are clearly important

DOW observations of 31 May 2013 Tornado

31 May 2013 had very rapidly moving sub-tornadic vortices. Propagation speed as high as 79 m/s.

Wurman, Kosiba, Robinson, Marshall: 2014, BAMS (January)

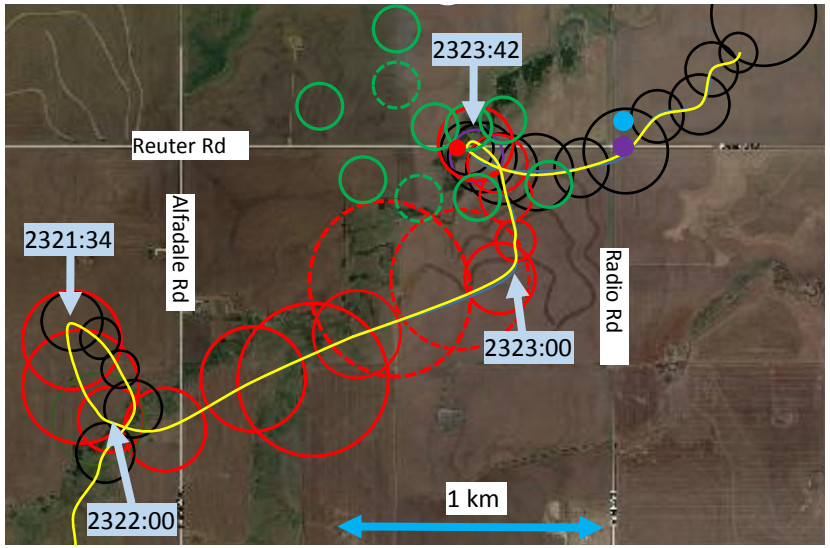


Figure 6. Smoothed track of interior sub-vortex as measured by the Rapid-Scan DOW. Yellow line is approximate center of circulation. Red and black circles delineate, at selected times, the approximate region enclosing the maximum tangential velocity, V_{tm}. Blue boxes label selected times along the track in HHMM:SS UTC. Dots represent start (red) and end (blue) locations of the Samaras team's vehicle, and its location in photographs in Figure 9 (purple) after first responders repositioned the vehicle. Green circles delineate vortices impacting the same area shortly afterwards. The vortex executes a loop at 2321:34, moves rapidly east-northeastward from 2322:00 until 2323:00, then more slowly north-northwestward, becoming stationary over Reuters road and the vehicle, then moves east-northeastward again.

Rapidly propagating small sub-vortices would cause only << 1 second intense gusts at surface.

Also, it is not known if the V = f(Z) results for tornadoes are the same in this type of fast moving small vortex.

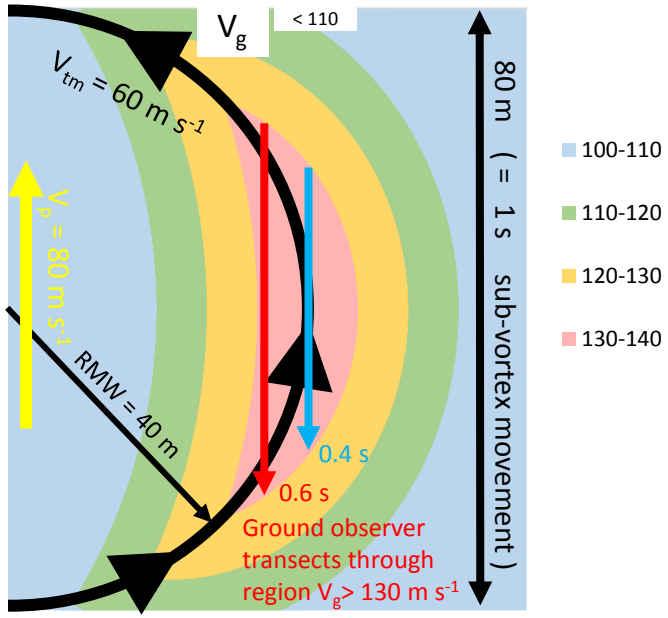
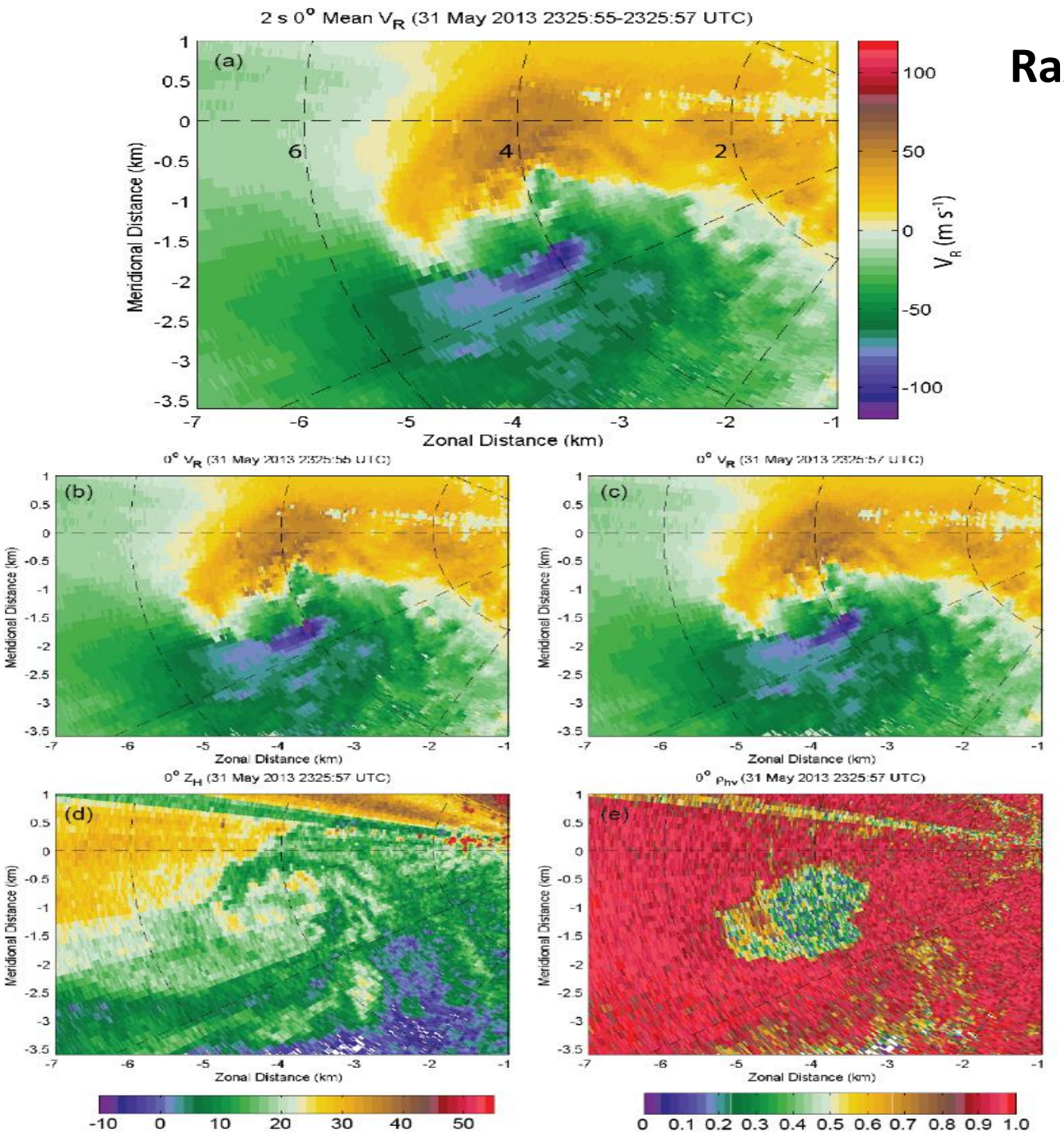


Figure 7. Schematic of strong V_g side of rapidly moving sub-vortex. Very fast V_p = 80 m s^{-1}, adds to peak tangential winds V_{tm} = 60 m s^{-1}, at and near the radius of maximum winds resulting in peak V_g = 140 m s^{-1}. However, due to very fast V_p, the duration of V_g > 130 m s^{-1} over a stationary object or observer is ≤ 0.6 s.



RaxPOL Observations for 31 May 2013 Tornado

(Snyder and Bluestein)

Left: Average of two consecutive scans at 0 degree elevation angle (scans separated by 2 s)

Peak 2 s Average V_R for these scans: 115 m/s

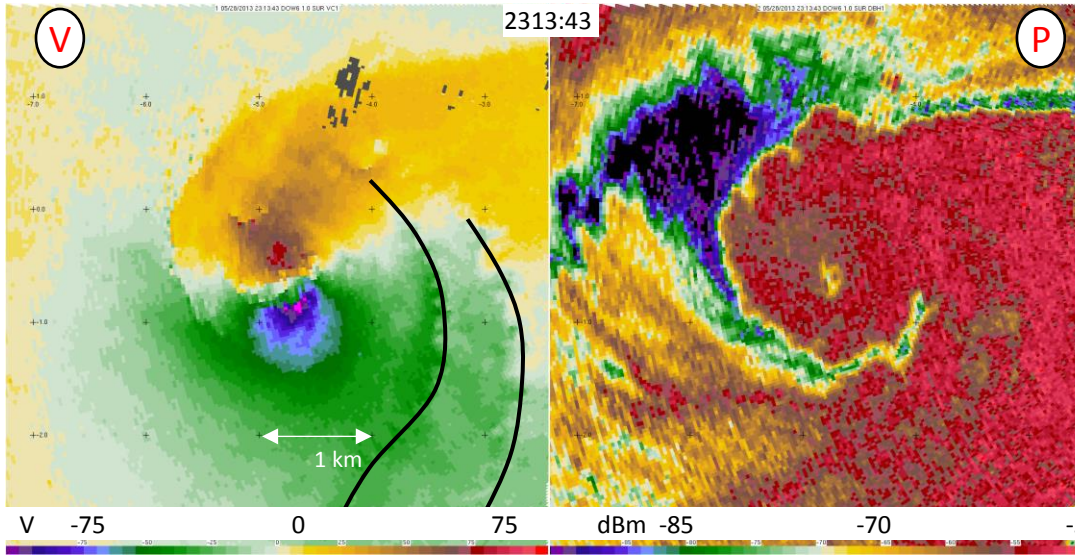
Neither of the individual scans captured the highest VR (>130 m/s)

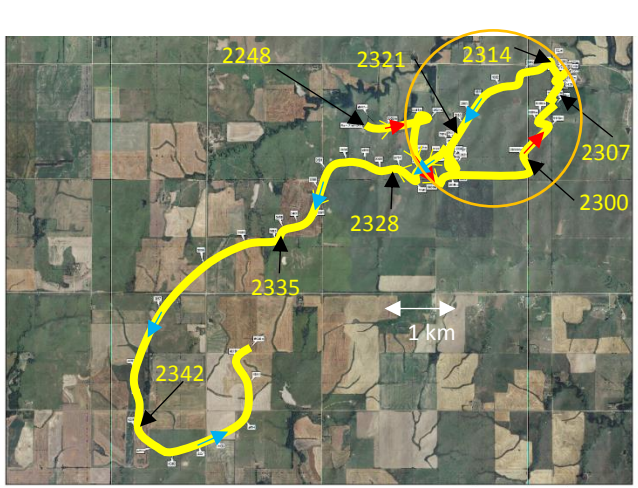
Antenna boresight: <0 AGL Owing to partial beam blockage from clutter, only the very top part of the beam is illuminated at the range of the tornado. SNR is still > 20 dB

Bennington, Kansas, 28 May 2013

Extremely slowly moving tornado near

Intense winds would have impacted some locations for O[300 s]





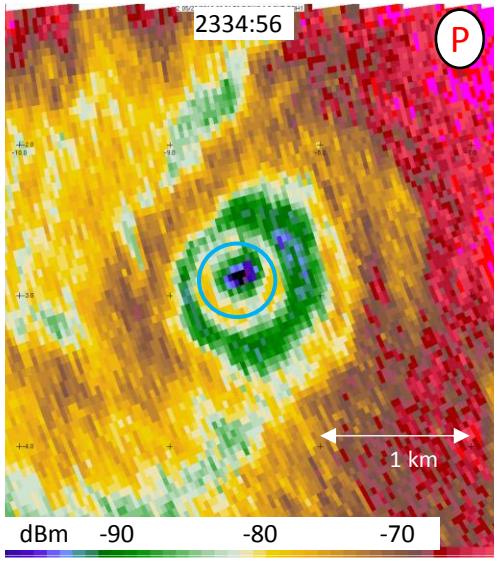


Figure 11. **(top)** Doppler Velocity (left) and Received Power (right) in Bennington, Kansas tornado on 28 May 2013. Winds exceeded 118 m s^{-1} at 47 m AGL. **(Bottom left)** looping track of tornado from 2247-2347 UTC. Tornado formed before 2247, but DOW-based locations are less precise since the DOW was in motion. Tornado was nearly stationary from 2308-2313, moving less than 80 m over 300 s, and traced multiple loops during that and other periods, remaining within a 2.5 km diameter circle (orange) for 2000 s. **(Bottom right)** Discontinuous debris ring echo (DRE) as tornado passes over region with trees. (Wurman et al, 2014)

Discussion

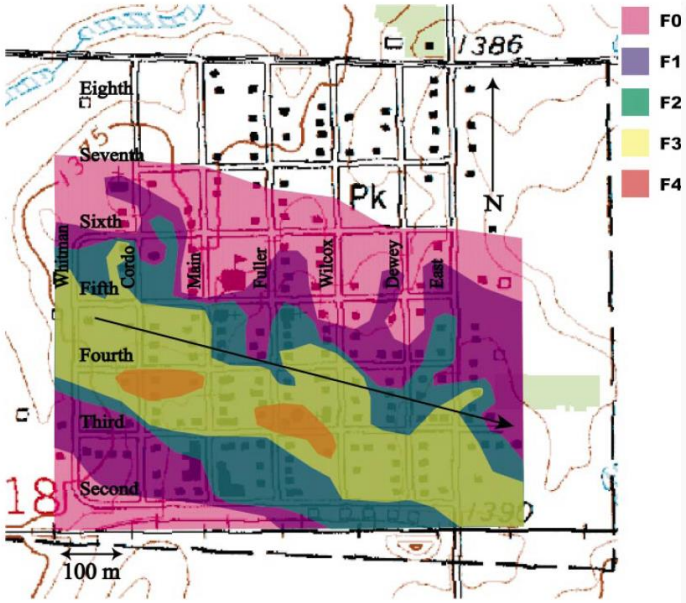
- Can radar measurements at higher heights be adjusted to 10-m height?
- Can radar measurements of short duration be adjusted to 3-sec winds or some other length of time interval important in damage intensity
- How should radar winds be used to rate tornado intensity and max winds?
- Are there standards for documenting radar wind estimates for tornadoes?
- Is there a repository to archive radar wind measurements for tornadoes?

Spencer, South Dakota, 1998 DOW EF-5

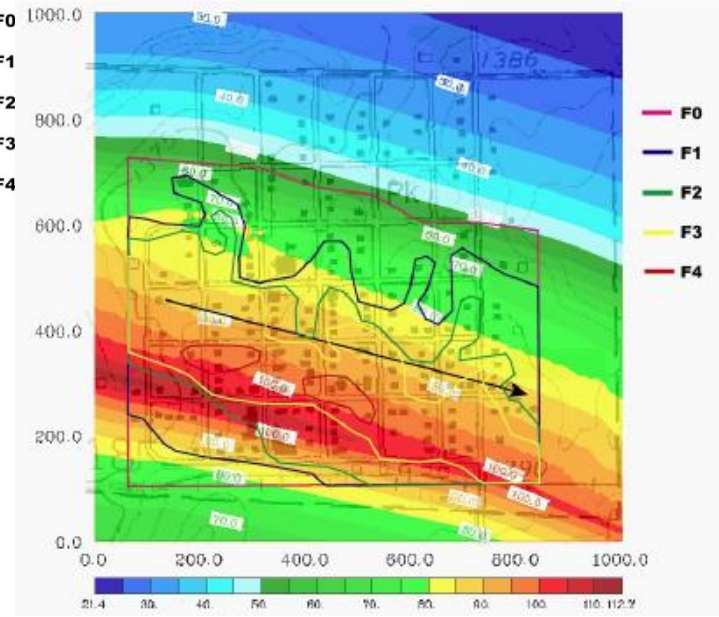
Radar winds at 20-30 m AGL
And radar-derived 3-second, ¼ mile, accelerations, etc. compared to damage survey contours

Wurman and Alexander (2005)

Damage Survey F-Scale



Radar peak ¼ mile winds

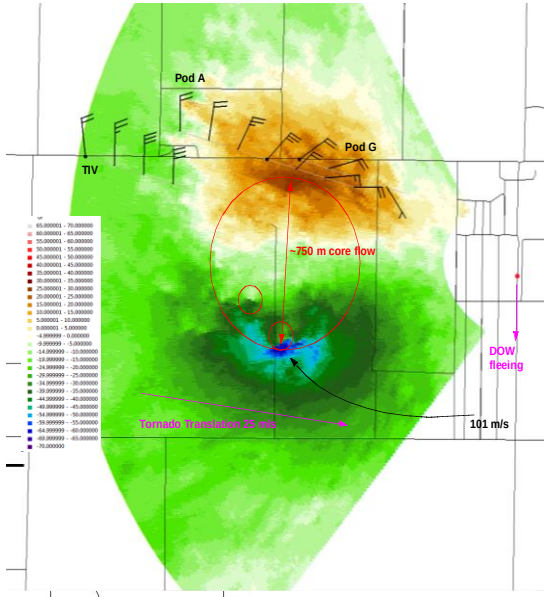


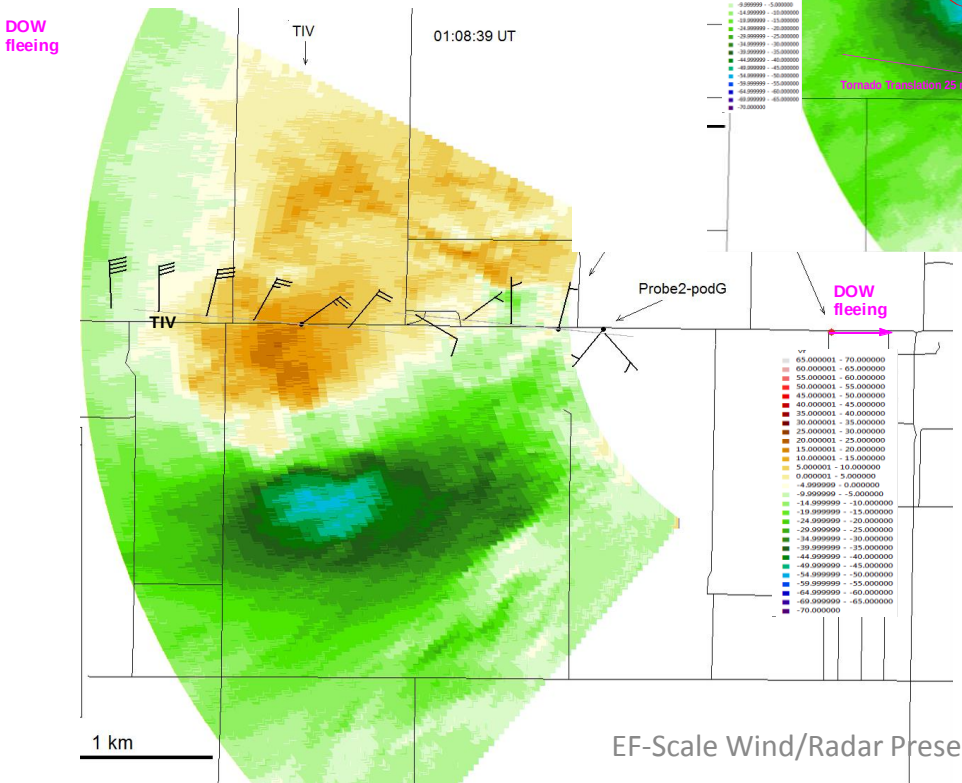
Damage Survey

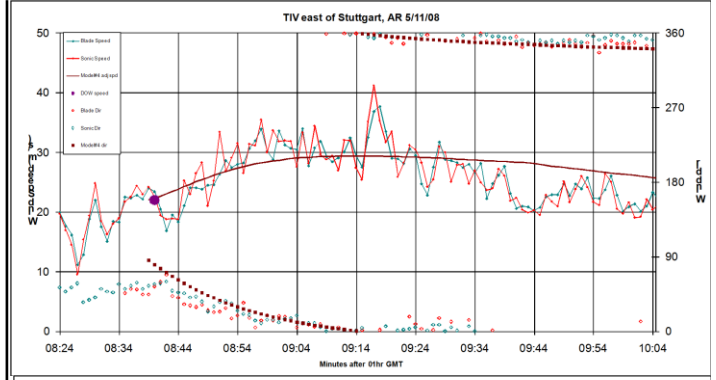
DOW Winds

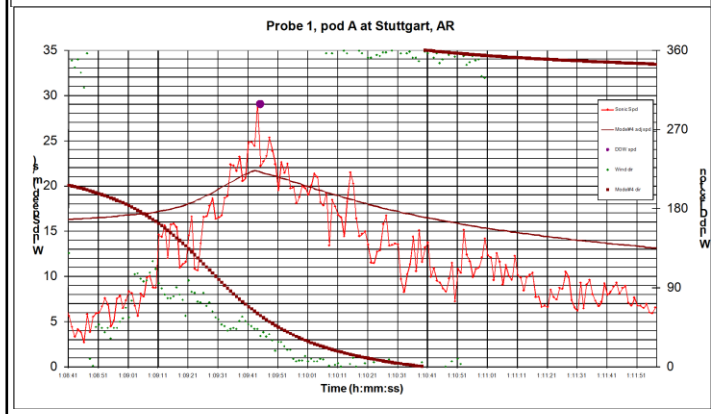
Radar + 1-3.5 m AGL

Observations in Stuttgart, Arkansas, 2008 tornado **DOW EF-5**







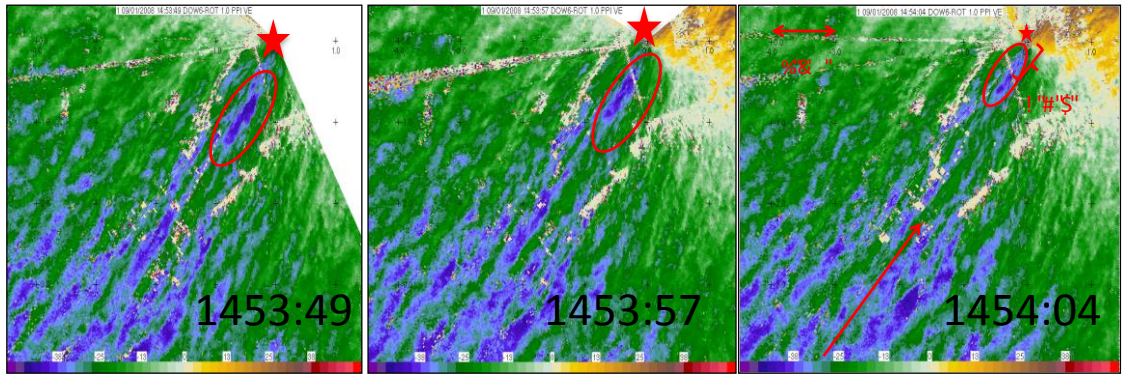


(Vmax = 102 m/s)

TIV 3-m winds 90% as intense as DOW 250 m winds. No apparent inward turning of winds in sector sampled by TIV.

Pod 1-m winds 50-60% as intense as DOW winds. 40-50 degree inward turning in this sector.

Winds vs Damage



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1454:13

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1454:18

1454:19

1454:20