Synergistic use of polarimetric phased array radar and cell towers signals to map humidity in the PBL

Dusan Zrnic – based on results from:

Melnikov et al, 2011:"Maping Bragg scatter with a Polarimetric WSR-88D." JTECH

and

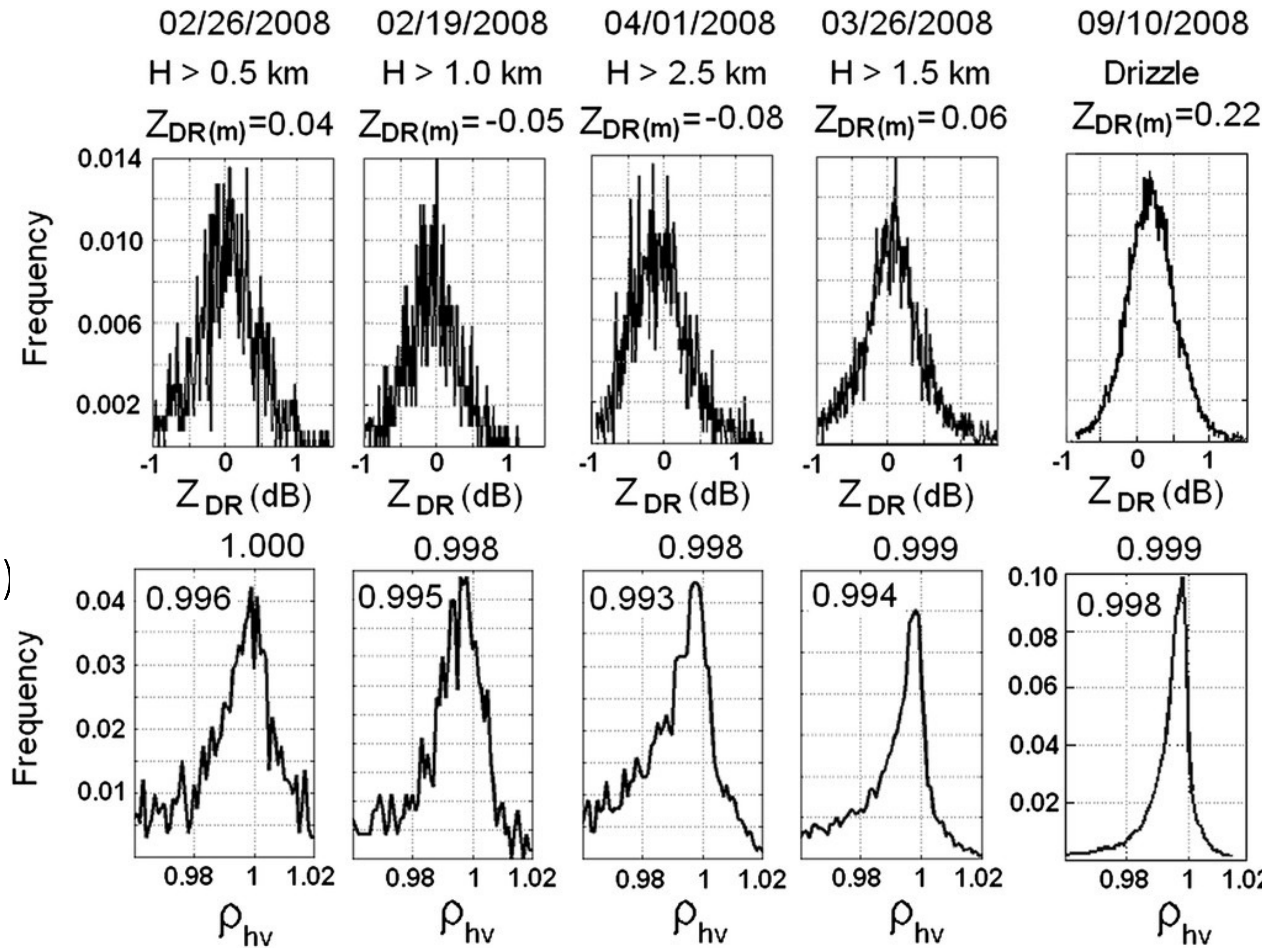
Report by M. Barts, Wireless Research Center, to NSSL 2021

Why Polarimetric Phased Array Radar?

- To detect weak reflections off turbulent eddies at the top of PBL
- The PAR can adapt its scanning strategy: length of observations (time to devote for a set of measurements), number of samples to integrate (dwell time), polarization (combine H and V on reception or transmit H only), average power, and location of observations
- Dual polarization is needed to identify the Bragg scattering via
  - Z_{DR} (dB) close to zero and
  - High correlation coefficient ρ_{hv} above 0.99

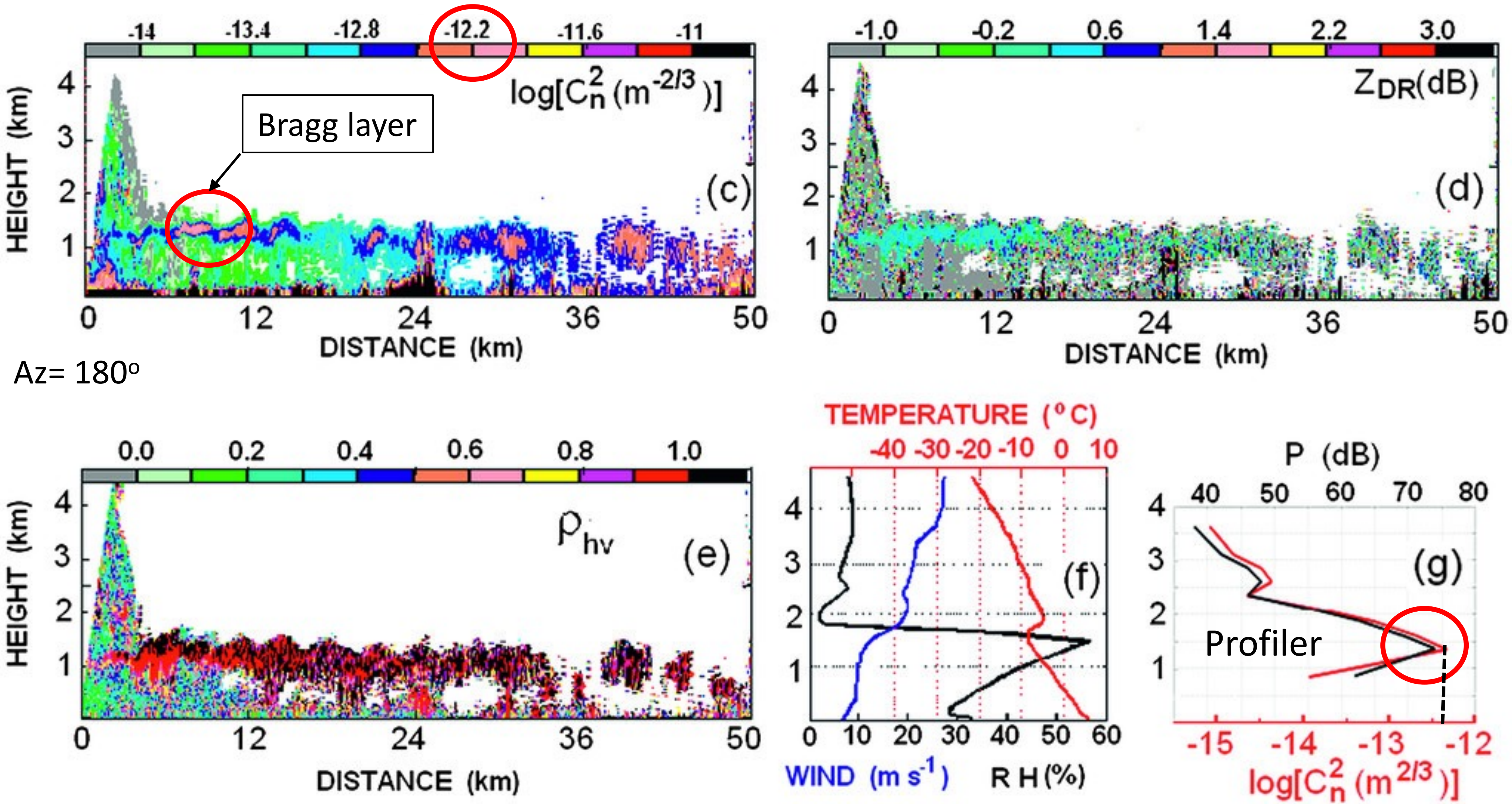
Histograms: Z_{DR} and ρ_{hv}; from the top of PBL in regions dominated by turbulent eddies (C_n^2)

(Melnikov et al. Mapping Bragg Scatter with Polarimetric WSR-88D; 2012 JTECH))

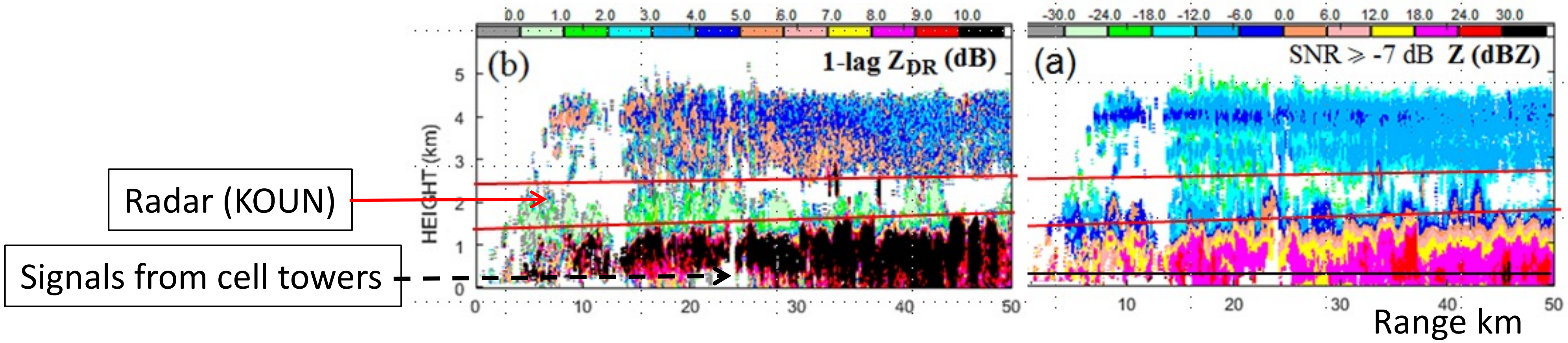


Vertical Cross Sections (KOUN), RAOB, and Profiler data

KOUN, log(C_n^2) = -12.2 to -12.6;   Profiler, log(C_n^2) = -12.4; The two agree very well



Humidity: at top of PBL from the structure parameter of Bragg scatterers; close to ground from cell tower signals



July 18, 2013; Az = 191° from ERAD 2016

Polarimetry identifies Bragg - structure parameter $(C_n)^2$

$(C_n)^2$ ~ vertical gradient of humidity: May need a model or Differential Absorption Lidar?

Cell tower signals can quantify humidity near the surface

Combine radar and cell tower signals

Relation for Retrieving Humidity (Eq. 11.149a, Doviak and Zrnic 2006)

$$C_n^2 = \frac{a^2 \varepsilon^{2/3} T_l R_f}{(1 - R_f) g d < \theta > / dz} \left(\frac{K_\phi}{K_m} \right) \times 10^{-12} \left(\frac{d < \phi >}{dz} \right)^2$$

where:

C_n^2 = Structure parameter measured with radar

$\varepsilon^{2/3}$ = Eddy dissipation rate measured with radar

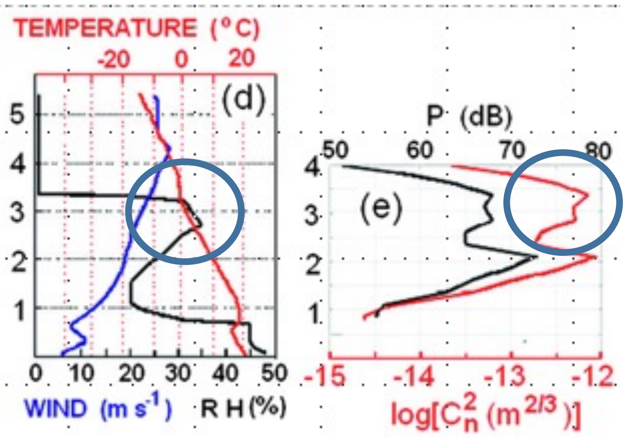
Symbols in black indicate quantities which can be parameterized (fairly well known)

Need to solve for

$\frac{d < \phi >}{dz}$ = Potential refractive index gradient unknown (mainly affected by humidity)

$\frac{d < \theta >}{dz}$ = Potential temperature gradient unknown (parameterise or model?)

Relative Humidity (from RAOB) and C_n^2 (from profiler)



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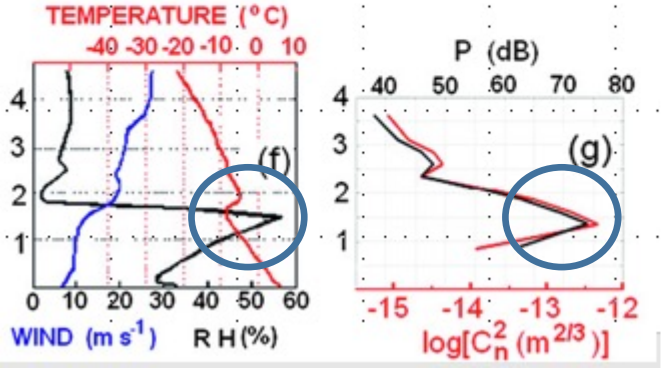

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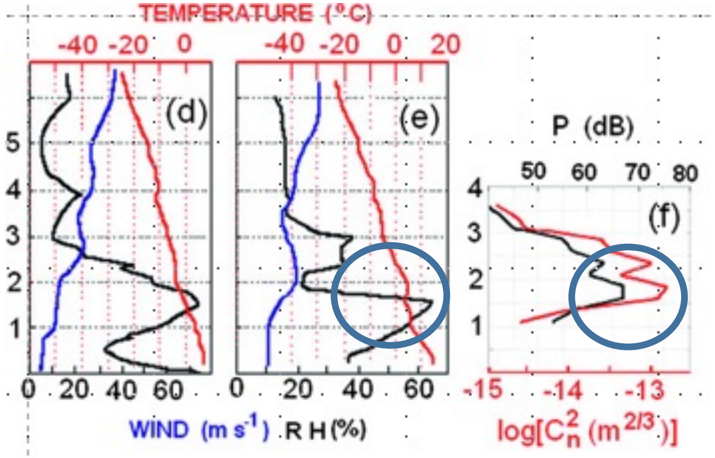

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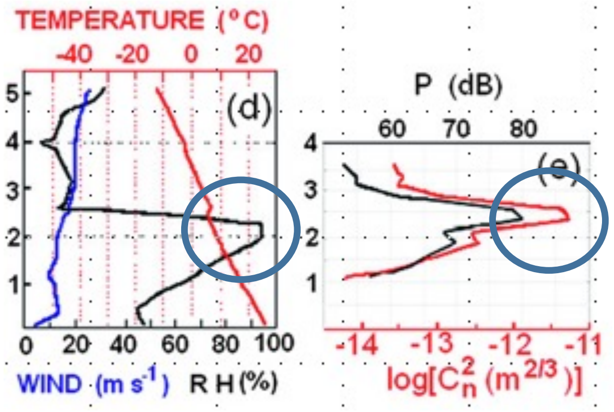

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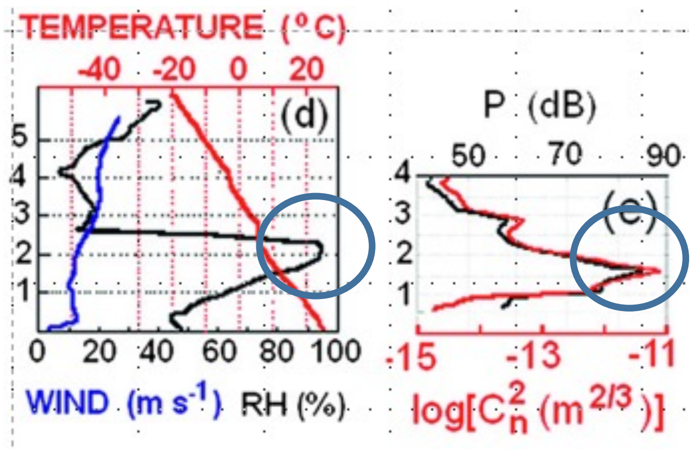
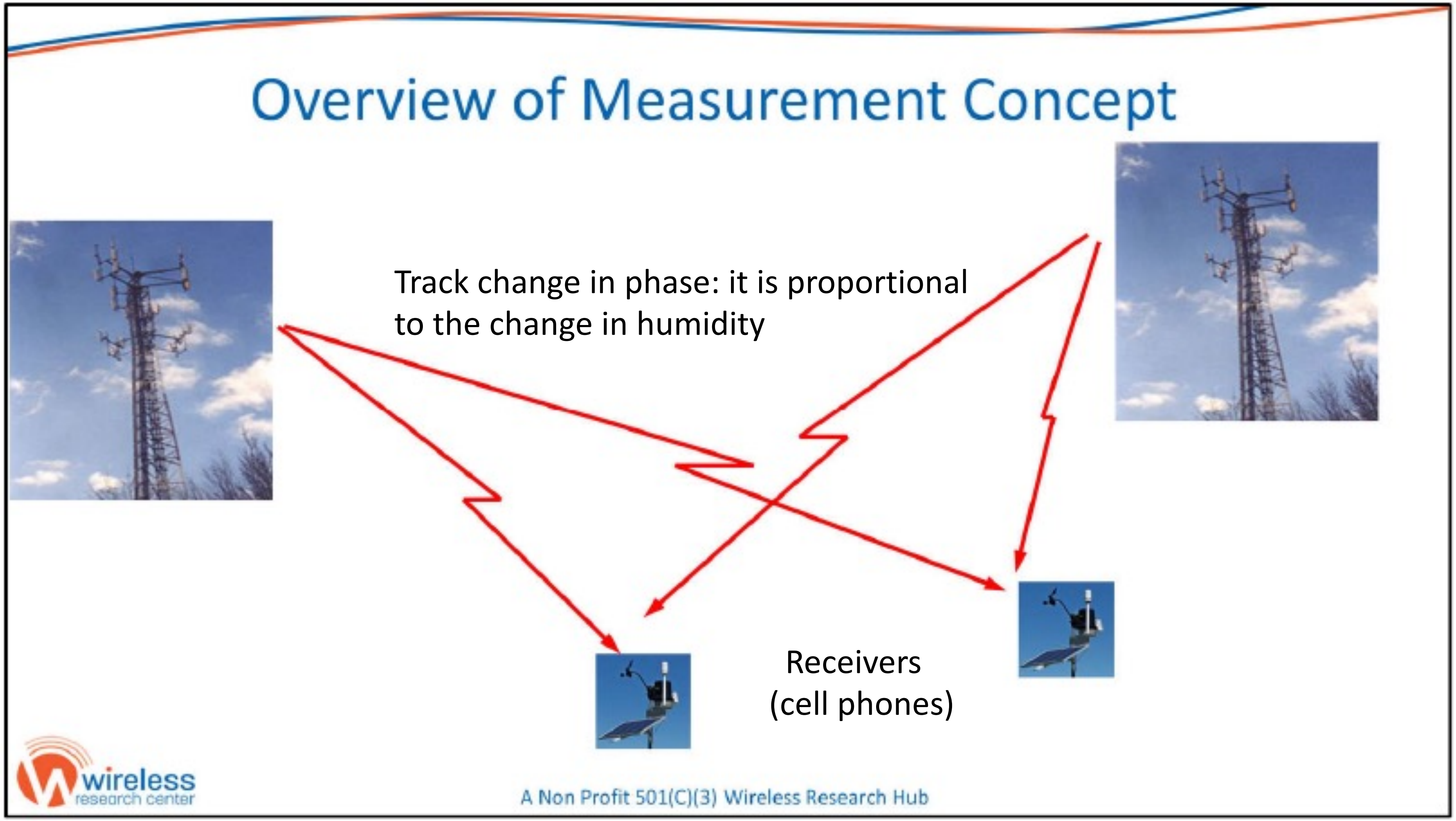


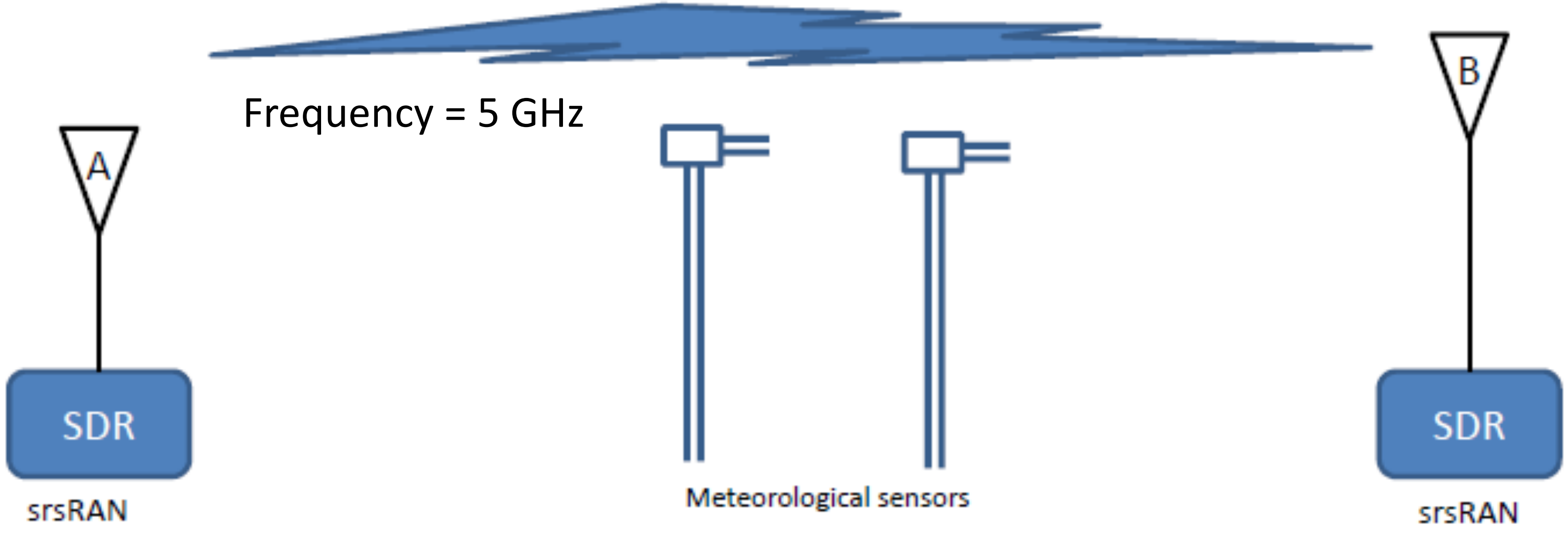
(5)

Case	RH(%)	$\log(C_n^2)$
1	32	-12.2
2	55	-12.4
3	62	-12.8
4	95	-11.3
5	95	-11.1

NSSL has funded Wireless Research Center to Demonstrated the Concept



Experiment Overview
Proposed by WRC



Station A functions as an eNB and sends beacon data including PSCH channel data

Station B is receive only, can use a much higher gain antenna, to receive and decode PSCH data from eNB

Stations are situated so that 1st Fresnel zone clears terrain

Humidity/temp/pressure sensors placed along path to sample at LOS path

Epilogue

- Measurement of humidity near ground using the phase of cell tower signals is technically feasible, and has in it favor:
  - Ubiquitous presence of cell tower
  - Simplicity of receivers (primitive cell phone)
  - It is a passive sensor, consequently does not crowed the EM spectrum
  - Decodes (detects) only the carrier that has no intelligent information therefore would not encroach on privacy
- Radar measurement of humidity at top of the PBL has never been done
  - Relations relating gradients of humidity in elevated layers to radar signal are known
  - It is not straight forward how to apply these to the top of the PBL
  - Further, additional information from models or instruments (DIAL) may be needed to estimate the unknown parameters