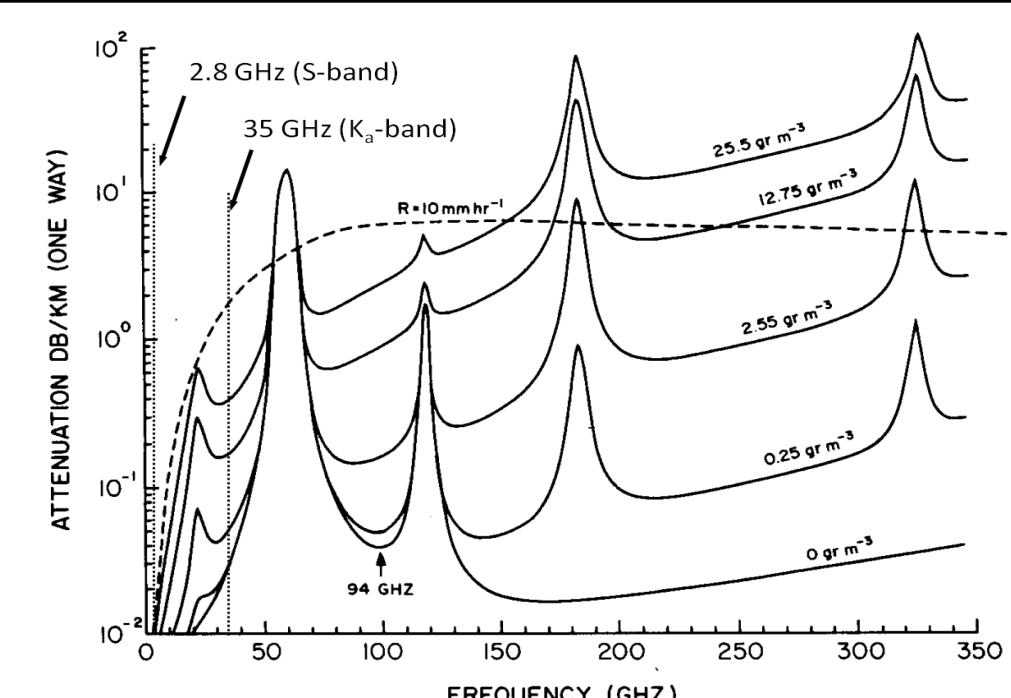


Introduction



- NCAR S-PolKa radar makes simultaneous S- and K_a -band measurements
 - Matched beam widths
 - Matched range gates
- Rayleigh reflectivity differences related to K_a -band attenuation by liquid and gas
- The atmospheric attenuation at K_a -band can be related to the path-integrated humidity



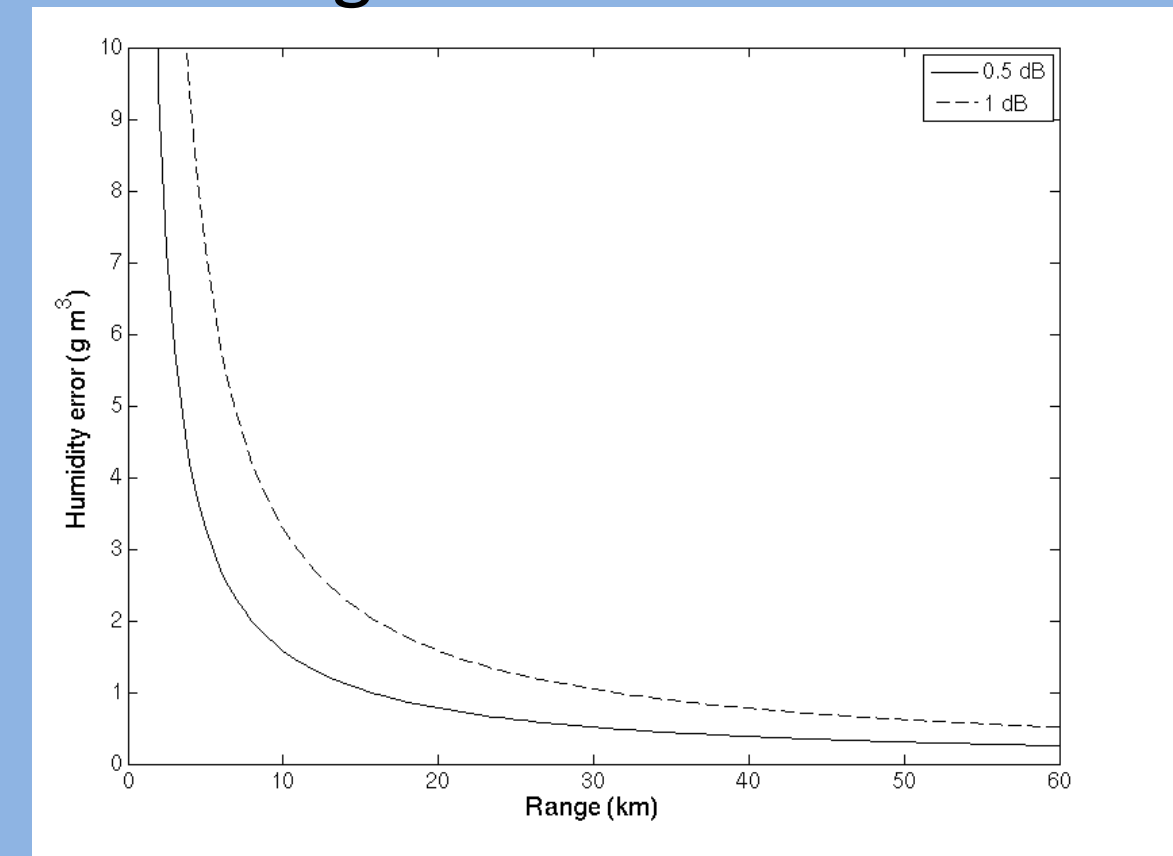
One-way atmospheric attenuation (dB km^{-1}) plotted as a function of frequency (GHz) for different water vapor content values (g m^{-3}) (from Lhermitte, 1987).

Humidity Retrieval Method

- Exclude non-Rayleigh echoes :
 - Bragg scatter
 - Drops > 1 mm
 - Bird echoes
 - Partial beam blockage
 - Ground clutter
 - Side-lobe ...

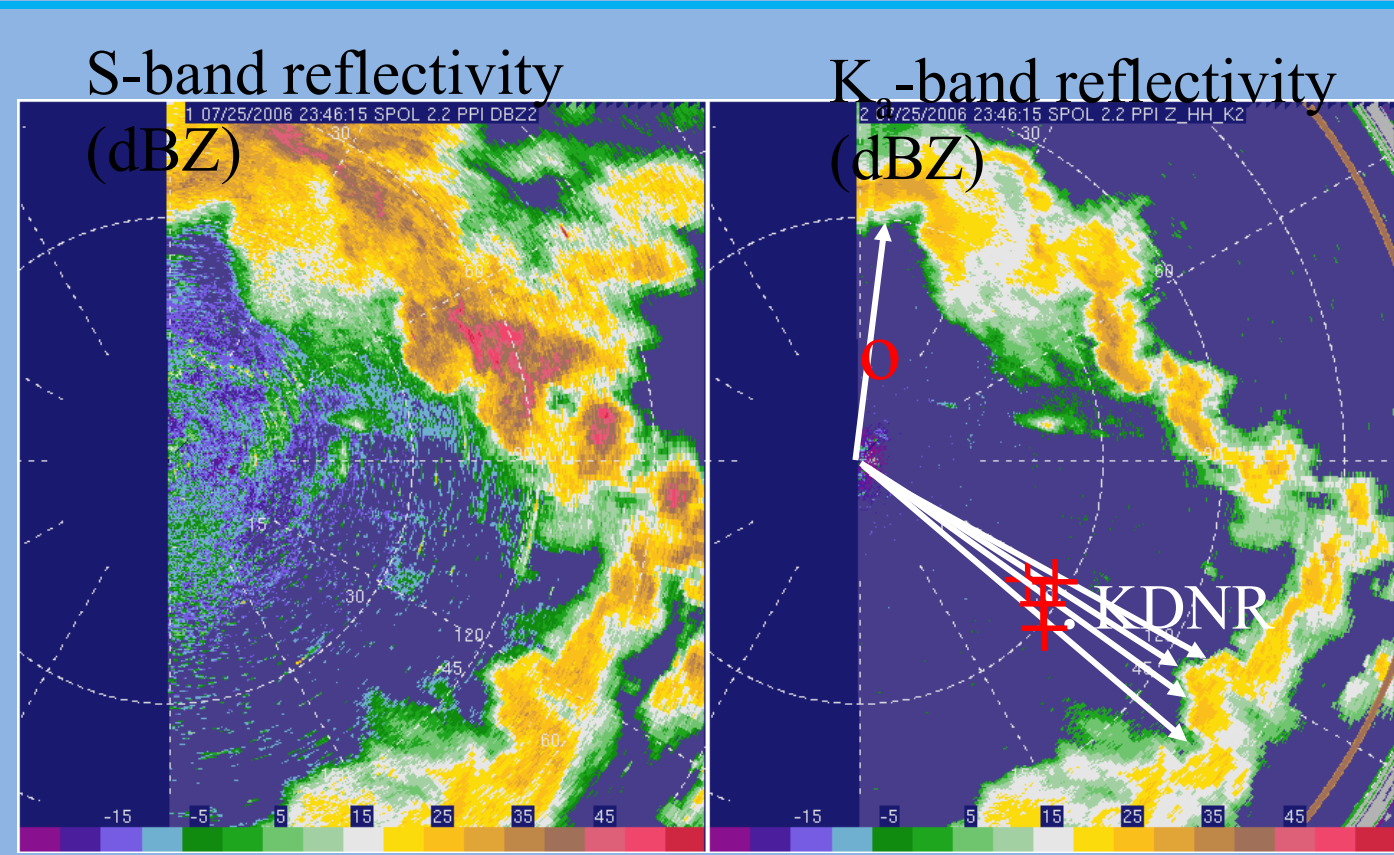
- Estimate atmospheric attenuation (A_g)
 - Compare S- and K_a -band reflectivity
 - ❑ Avoid contamination by liquid water attenuation
 - ❑ Average 10 or more range gates to reduce measurement noise
 - Create ray segments
 - ❑ Radar to cloud
 - ❑ Cloud to cloud
 - $A_g (\text{dB km}^{-1}) = (\text{dBZ}_S - \text{dBZ}_{K_a})/\text{range}$
 - ❑ Attenuation errors decrease with increasing range

- Humidity retrieval error decreases with range!



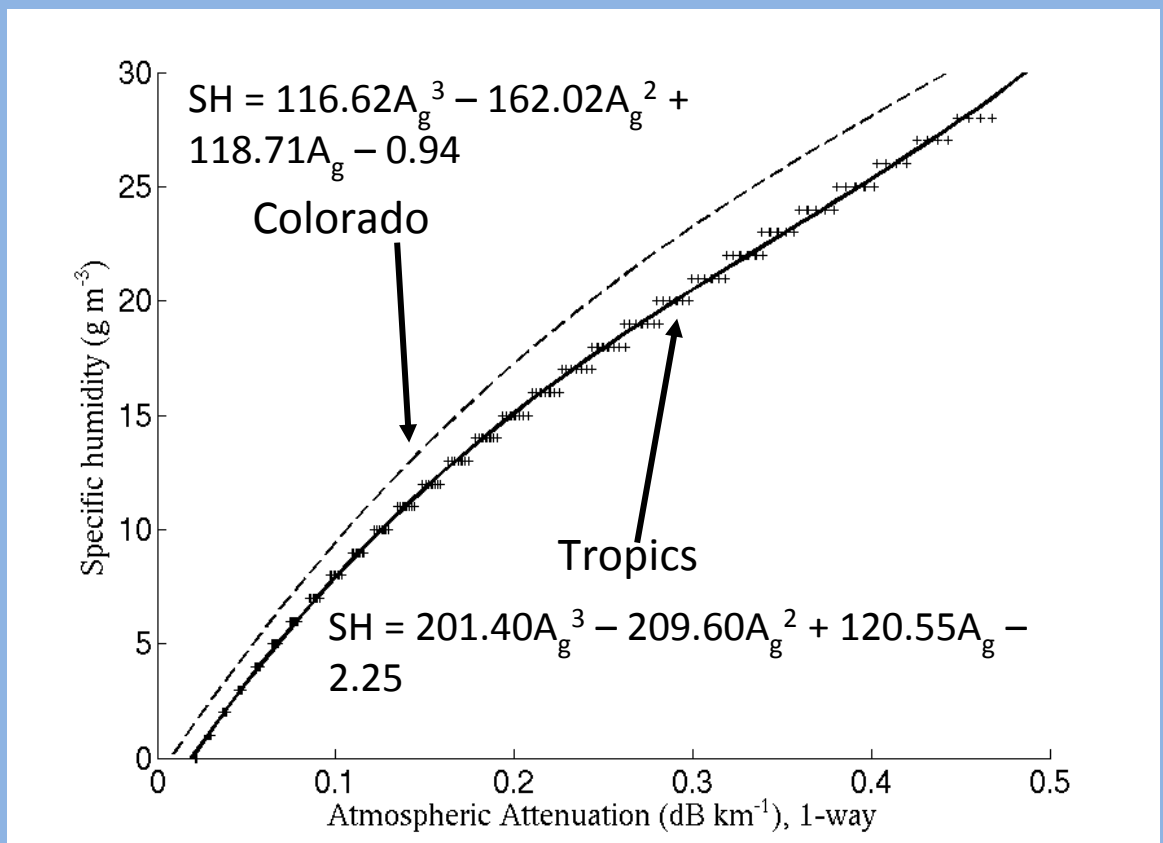
A plot of the error in specific humidity (g m^{-3} , y-axis) as a function of range (km, x-axis) for an error in the difference between S- and K_a -band reflectivity of 0.5 (solid line) and 1.0 (dashed line) dB

- Min range ~ 15 km



Examples of possible ray segments for humidity retrieval

- Estimate Humidity
 - Use microwave propagation model to develop relationship between specific humidity (SH) and A_g .
 - ❑ Run model many times over possible range of atmospheric conditions (P, T and SH)
 - ❑ Fit curve of SH as a function of A_g (shown below for the Caribbean and Colorado)
 - Plug estimated A_g into best fit equation to compute SH



S-PolKa at DYNAMO

- Located on Addu Atoll, Maldives in the central Indian Ocean
- NCAR S-PolKa radar deployed from 1 October, 2011 to 15 January, 2012
- Operated 24/7
- First deployment of real-time automated humidity retrieval technology
- 3 hourly soundings ~ 8 km from S-PolKa
- Soundings provide opportunity to verify dual-wavelength humidity retrieval

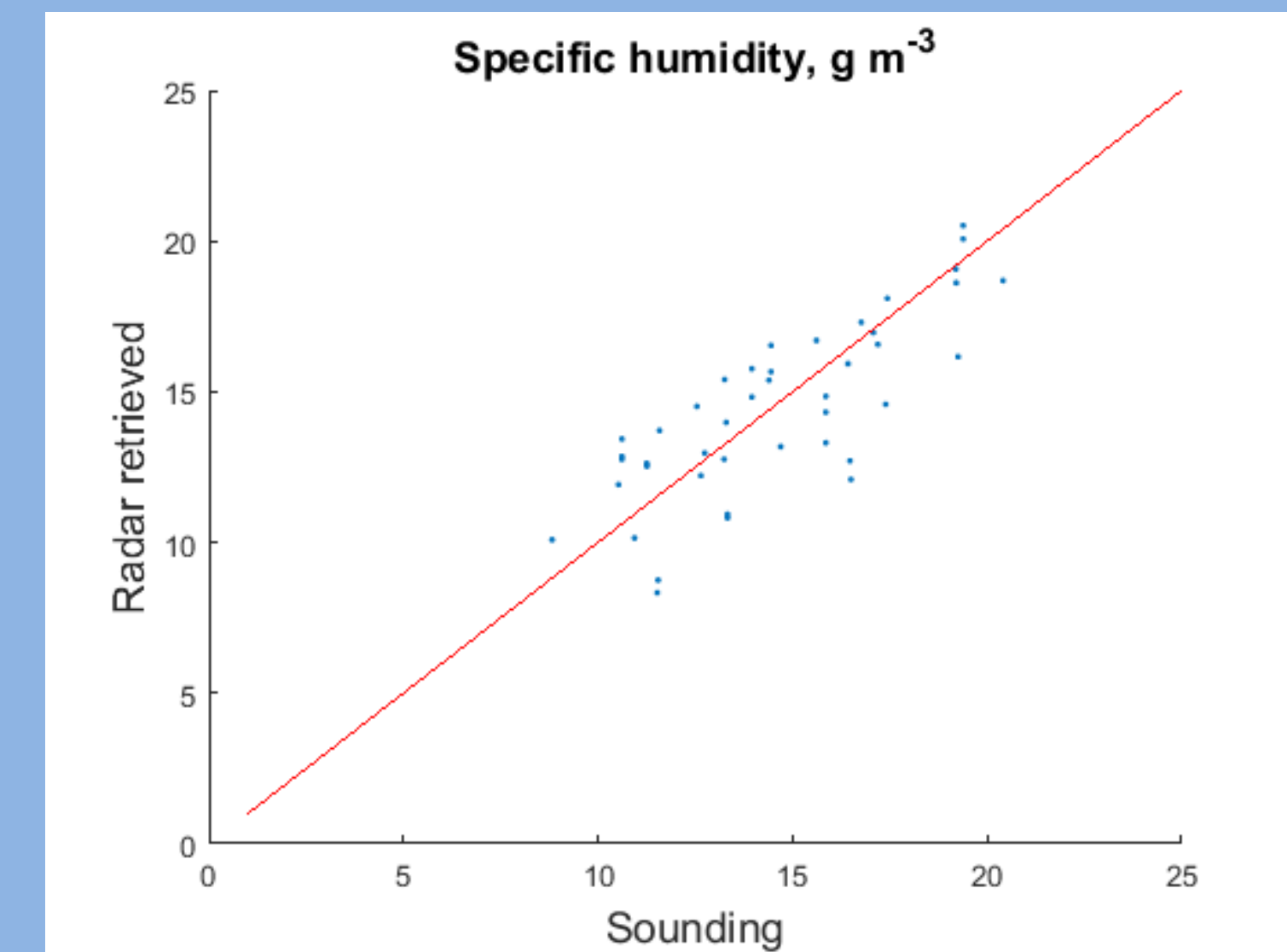


Humidity Verification



- Increasing the region of radar retrieved humidity in the comparison impacts statistics
 - Bias increases
 - RMSD increases
 - Correlation decreases
- Most likely due to natural spatial variations in humidity

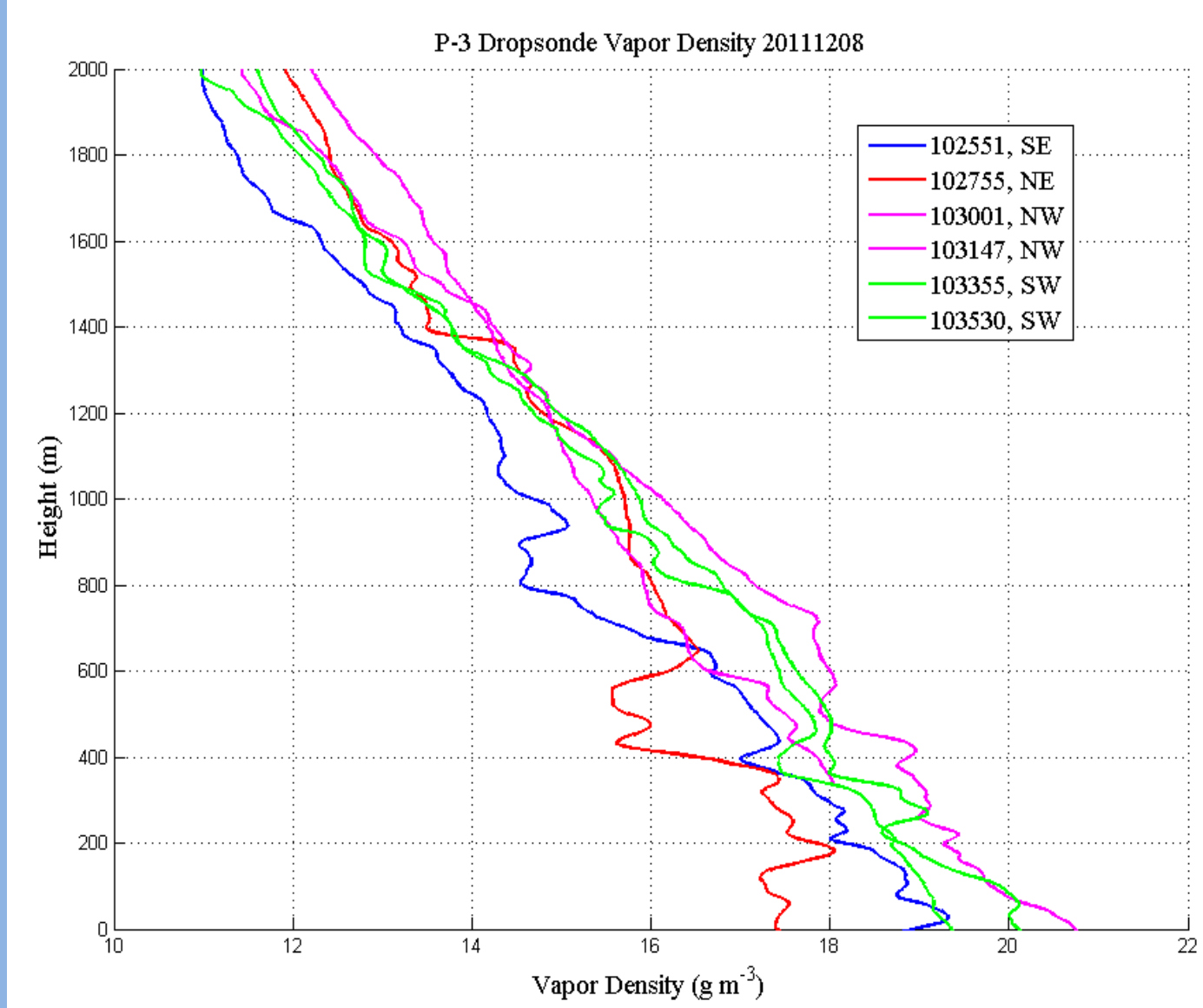
- Humidity retrievals over 4.5 month period compared to soundings in close proximity
 - Azimuth ± 2 deg from sounding
 - 10 km > Range > 20 km from radar
- 44 data points of comparison
- Bias between sounding and radar humidity = -0.14 g m^{-3}
- RMSD = 1.57 g m^{-3}
- Correlation coefficient = 0.79



Data filter (Sounding site at azimuth = 140 deg, range = 8km)	RMSD	Bias	Corr	# point
138>az>142, 10> range>16	1.57	-0.14	0.79	44
130>az>150, 10> range>16	1.73	-0.26	0.75	276
130>az>150, 10> range>25	1.75	-0.54	0.74	517
110>az>170, 10> range>25	1.77	-0.17	0.68	1533
50>az>230, 10> range>25	1.86	0.03	0.62	3867
all az, all range	2.12	0.53	0.57	9878

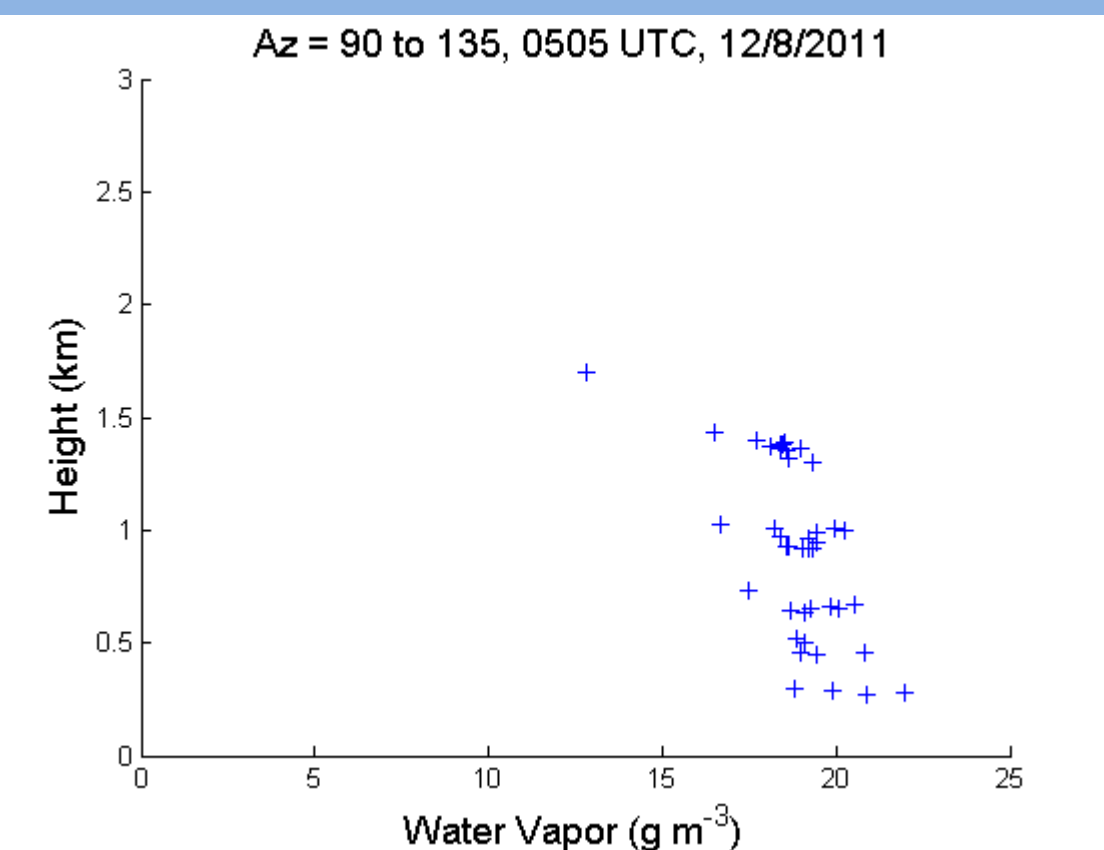
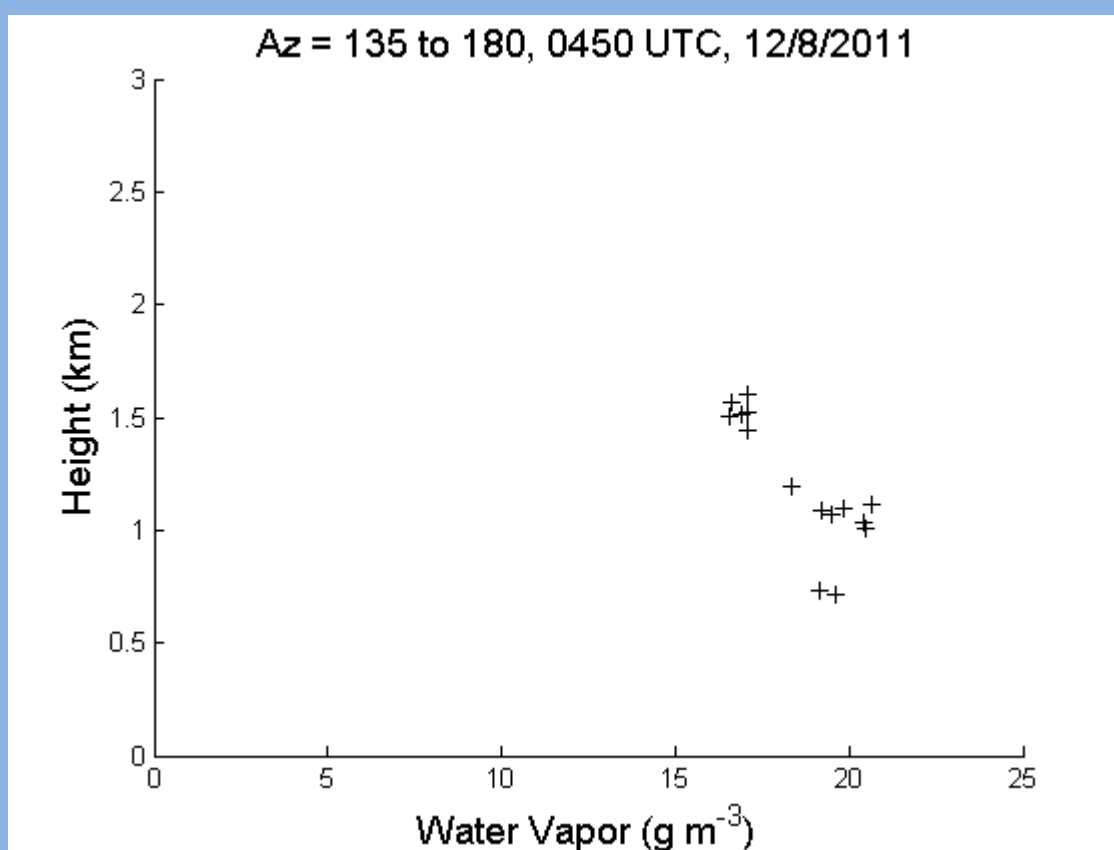
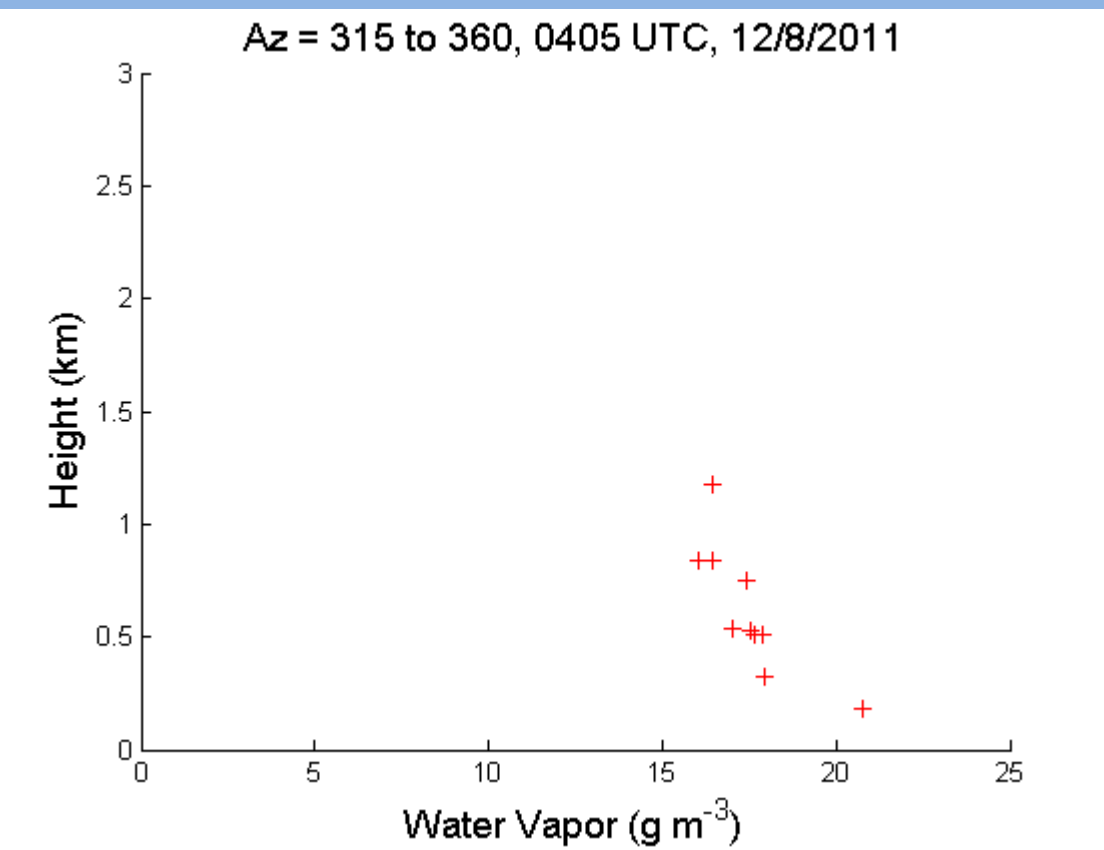
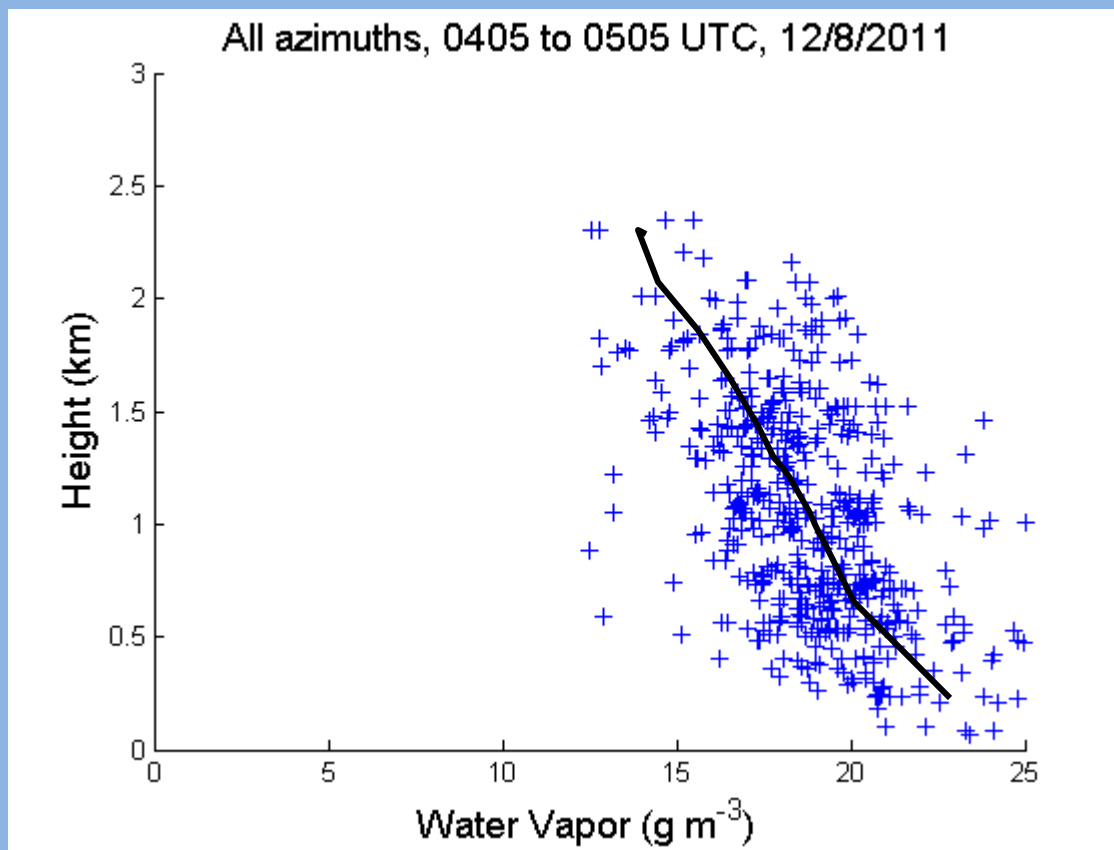
Spatial Humidity Variations in DYNAMO

- Humidity in the tropics is highly variable spatially and temporally
- The dropsonde data at right were all collected within 10 minutes in an ~20 km radius ring around S-PolKa
- Water vapor can vary by more than 4 g m^{-3} between these nearby measurements!
- Single soundings not representative of the environment mean
- Single soundings do not capture variability of humidity



P3 Dropsondes in about a 20 km ring around S-PolKa over a 10 minute period.

Radar-Retrieved Humidity from DYNAMO



- Humidity retrievals from 1 hour of data and 360 degrees of azimuth show large variance (top left)
- Parsing the data into 45 degree sections over 1 volume time (15 min) results in coherent profiles
- The parsed profiles show the spatial and temporal differences in the low level humidity
- The mean of 1-hour of radar-retrieved humidity (black line) represents larger, known, spatial and temporal scales

Summary and Conclusions

- S-PolKa was deployed for 4.5 months in tropical Indian Ocean
- Dual-wavelength radar humidity retrievals were verified with soundings
- The humidity retrievals can measure more of the spatial and temporal variability of the tropical humidity than soundings in many situations
- The mean humidity retrievals represent larger scale environments that soundings cannot capture
- The spatial and temporal variability AND mean of humidity are critical for modeling/understanding tropical weather system development and evolution