# Dual-Wavelength Humidity Profiles Using S-PolKa During the DYNAMO Field Campaign

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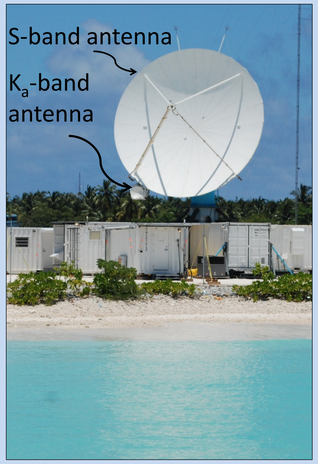
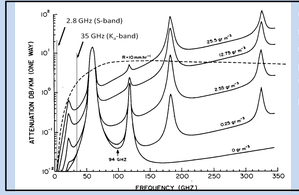
## Introduction




- 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



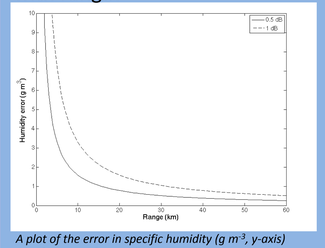

*One-way atmospheric attenuation (dB km$^{-1}$) plotted as a function of frequency (GHz) for different water vapor content values (g m$^{-3}$) (from Lhermitte, 1987).*

## Humidity Retrieval Method

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

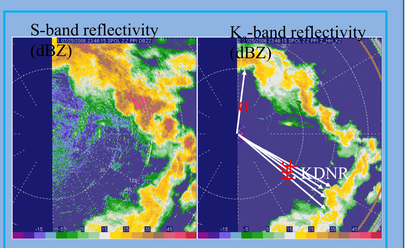
- Estimate atmospheric attenuation ($A_g$)
  - ➢ Compare S- and $K_a$-band reflectivity
    - ❑ Avoid contamination by liquid water attenuation
    - ❑ Average 10 or more range gates to reduce measurement noise
  - ➢ Create ray segments
    - ❑ Radar to cloud
    - ❑ Cloud to cloud
  - ➢ $A_g$ (dB km$^{-1}$)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

- Humidity retrieval error decreases with range!



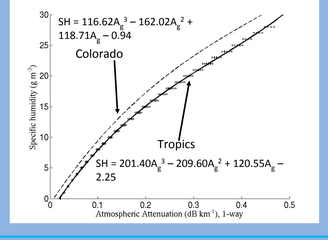

*A plot of the error in specific humidity (g m$^{-3}$, y-axis) as a function of range (km, x-axis) for an error in the difference between S- and $K_a$-band reflectivity of 0.5 (solid line) and 1.0 (dashed line) dB*

- Min range ~ 15 km



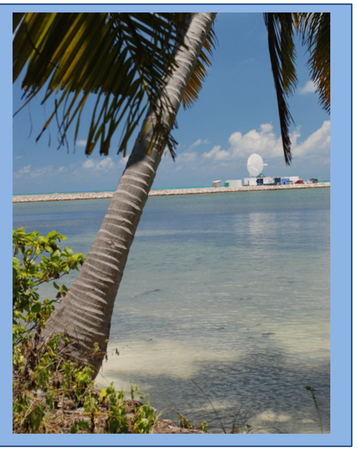

Examples of possible ray segments for humidity retrieval

- 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

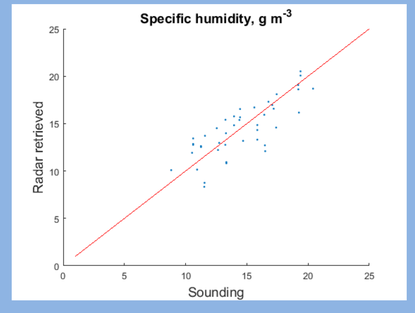
- Located on Addu Atoll, Maldives in the central Indian Ocean
- NCAR S-PolKa radar deployed from 1 October, 2011 to 15 January, 2012
- Operated 24/7
- First deployment of real-time automated humidity retrieval technology
- 3 hourly soundings ~ 8 km from S-PolKa
- Soundings provide opportunity to verify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



## Humidity Verification


- 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

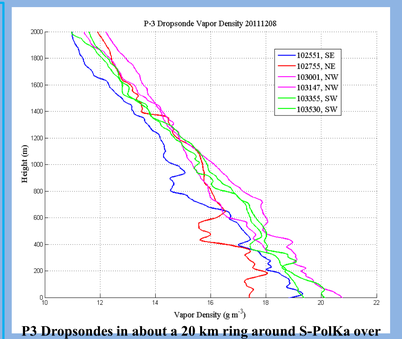
- Increasing the region of radar retrieved humidity in the comparison impacts statistics
  - ➢ Bias increases
  - ➢ RMSD increases
  - ➢ Correlation decreases
- Most likely due to natural spatial variations in humidity




| 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 |

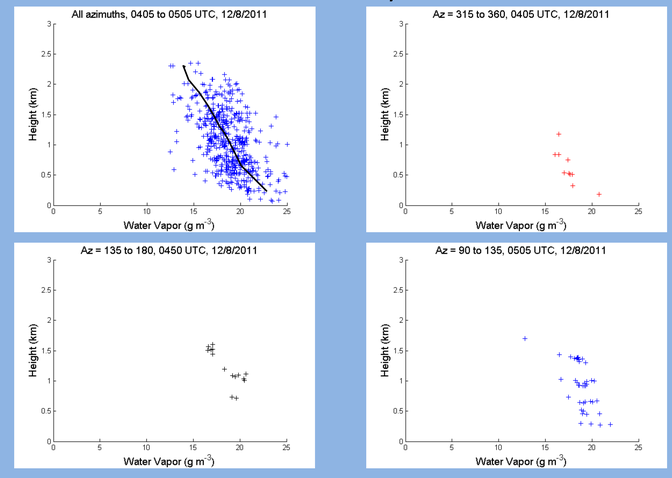
## Spatial Humidity Variations in DYNAMO

- 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