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Correcting attenuation in operational radars from both heavy rain and the radome using the observed microwave emission

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& thanks to J. Ovens, J. Sugier, T. Darlington & A. Curtis

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Introduction

- We present a technique using emission to monitor the attenuation for each PPI at each azimuthal angle.
- The technique measures TOTAL attenuation both from distant storms and from the radome (previously largely ignored).
- If the radome contribution is isolated, we have a useful constraint for other techniques such as gate-by-gate or differential phase.
- Some lab experiments suggest radome can be 3dB for 15mm/hr

  (e.g. Kurri and Huuskonen, 2008 and others).
- We show old radomes can be 2-3dB for only 2-3mm/hr.

  for new radomes can be 2-3dB for only 5mm/hr

Principle: All absorbers are emitters

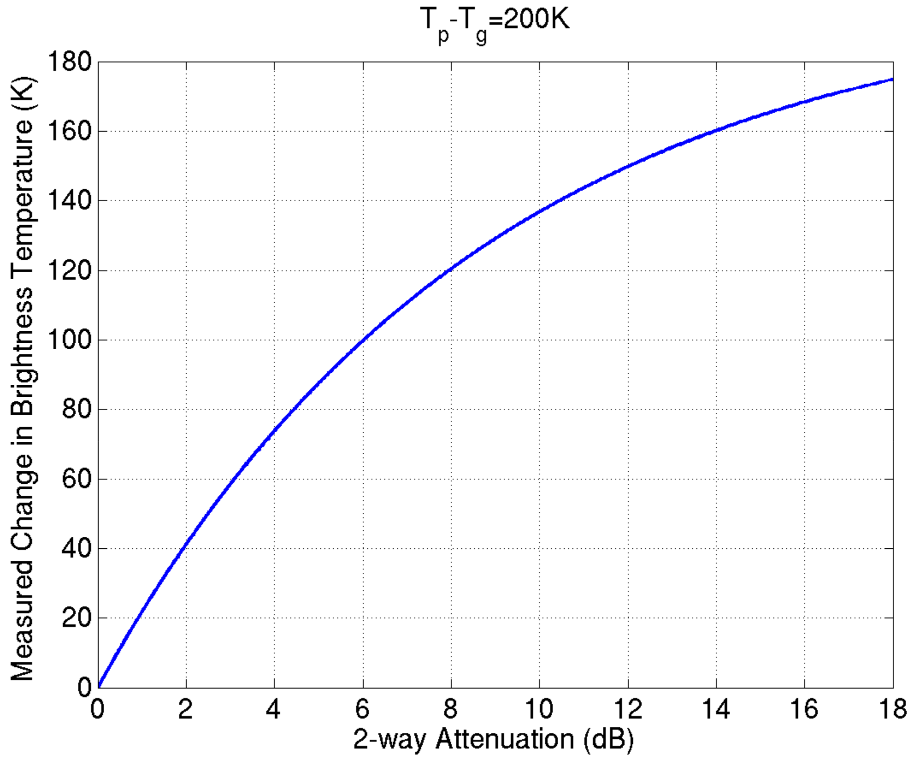
- Radars can act as radiometers if the increased receiver noise is measured. (Fabry 2001, 30th AMS Radar Conference, Munich)
- C-band brightness temperature at low elevation, T_g, ~80K (due to gaseous emission - mostly oxygen, about 25% water vapour).
- A fully attenuating radome/target has brightness temp, T_p ~280K.
- For fractional one-way attenuation, *f*, the measured temp, T_m is

$$T_m = f\, T_p + (1-f)\, T_g$$

By observing the increased noise temperature from dry conditions, ΔT

$$f = (T_m - T_g) / (T_p - T_g) = \Delta T / 200$$

Principle:
All absorbers are emitters



$$f = (T_m - T_g) / (T_p - T_g) = \Delta T / 200$$

– Approx. linear for small attenuations, so **two-way** radar attenuation is

~1dB / 20K change in brightness temperature.

– and for 10% accuracy need T_g and T_p accurate to ~10K.

Hardware

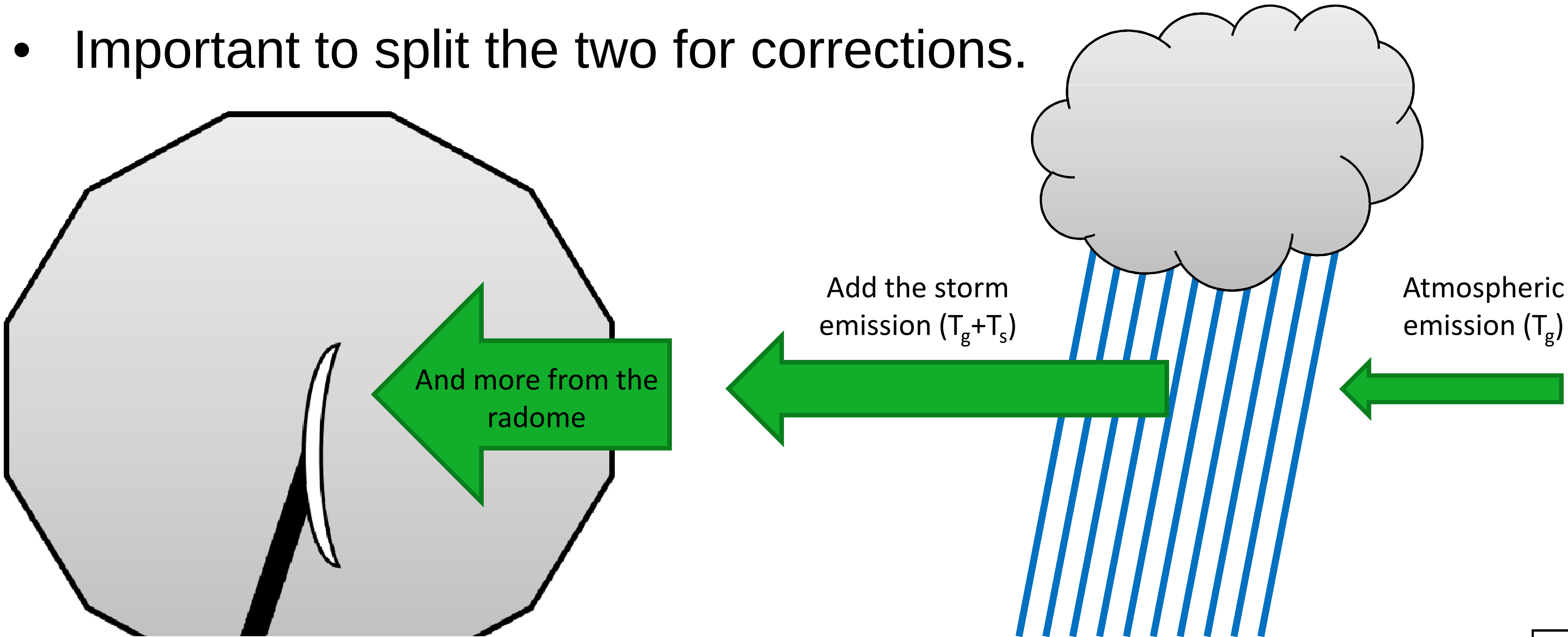
- UK C-band radar network, receiver noise equivalent to T_b ~1000K.
- Need to measure a 10K change to detect a 0.5dB 2-way attenuation.
- We need 10,000 samples of noise to achieve 10K accuracy (1%)

Met Office Network Measurement:

- PRF 300Hz, max range ~450km, lots of empty gates.
- 1453 empty gates, 22 pulses per ° azimuth for 30,000 samples.
- Filter to remove any possible far range targets
- For each transmitted pulse, a 1165K noise source is injected at five empty gates to provide continuous calibration.

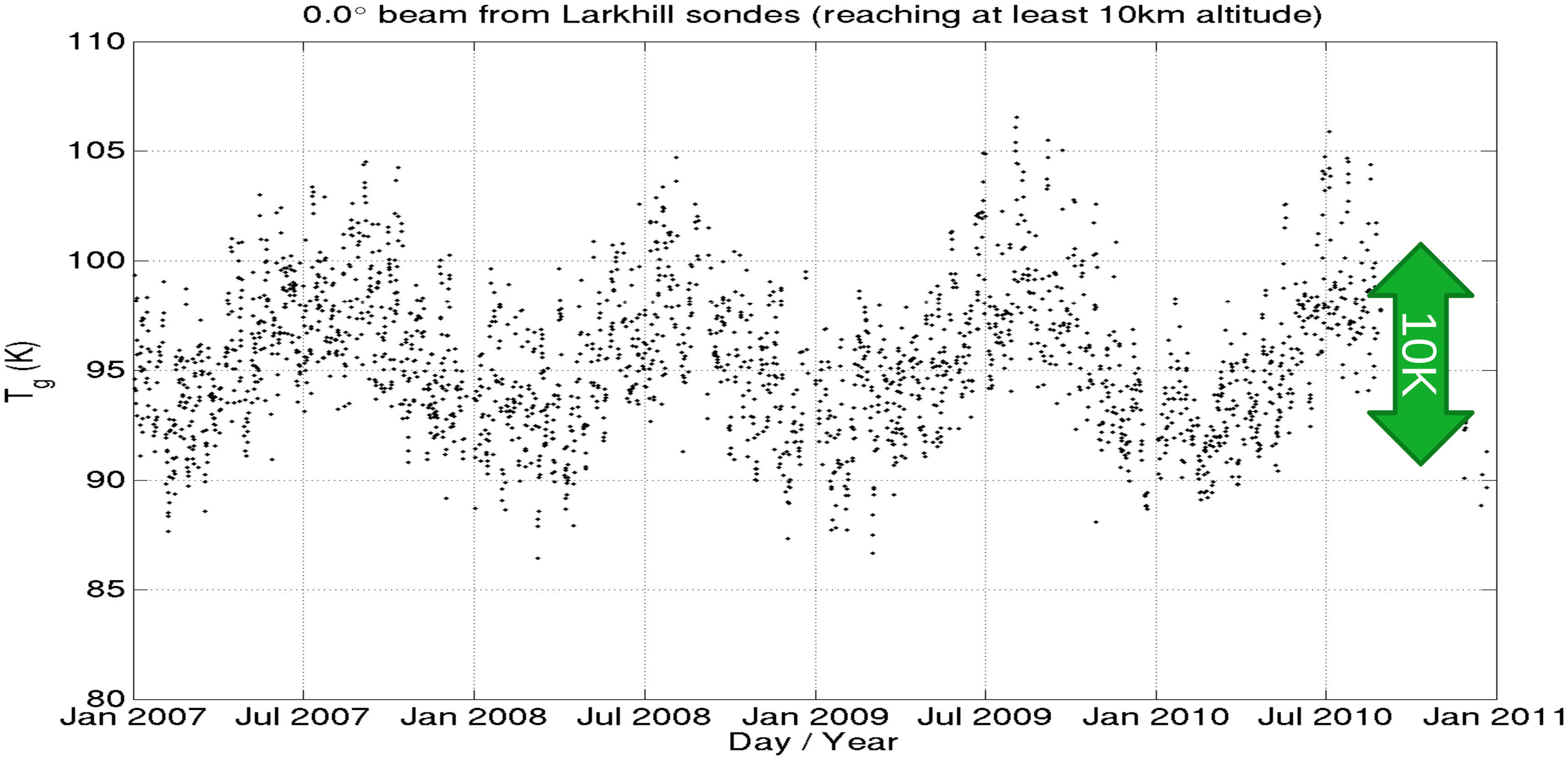
Distant Storms

- When rain is present, the radome attenuates the storm emission and adds its own emission.
- The recorded emission relates to the TOTAL attenuation.
- Important to split the two for corrections.



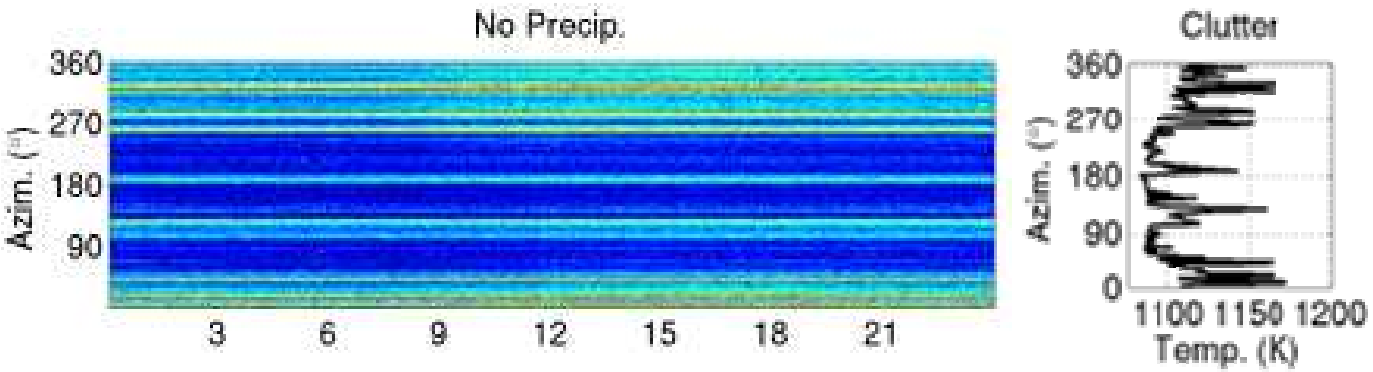
T_g: annual variation

- Calculated from Larkhill sondes reaching at least 10km altitude

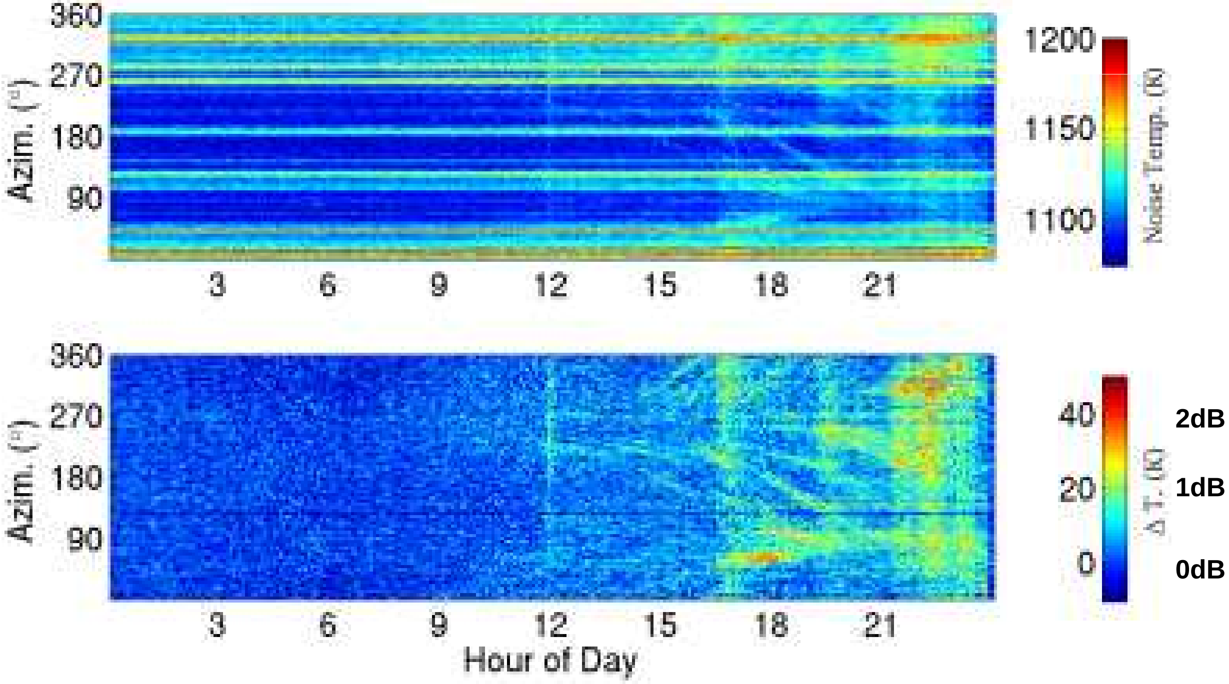


The 10 K annual cycle (from water vapour) must be allowed for otherwise ±5K from variation – equivalent to 0.25dB 2-way atten.

Remove Glowing Clutter



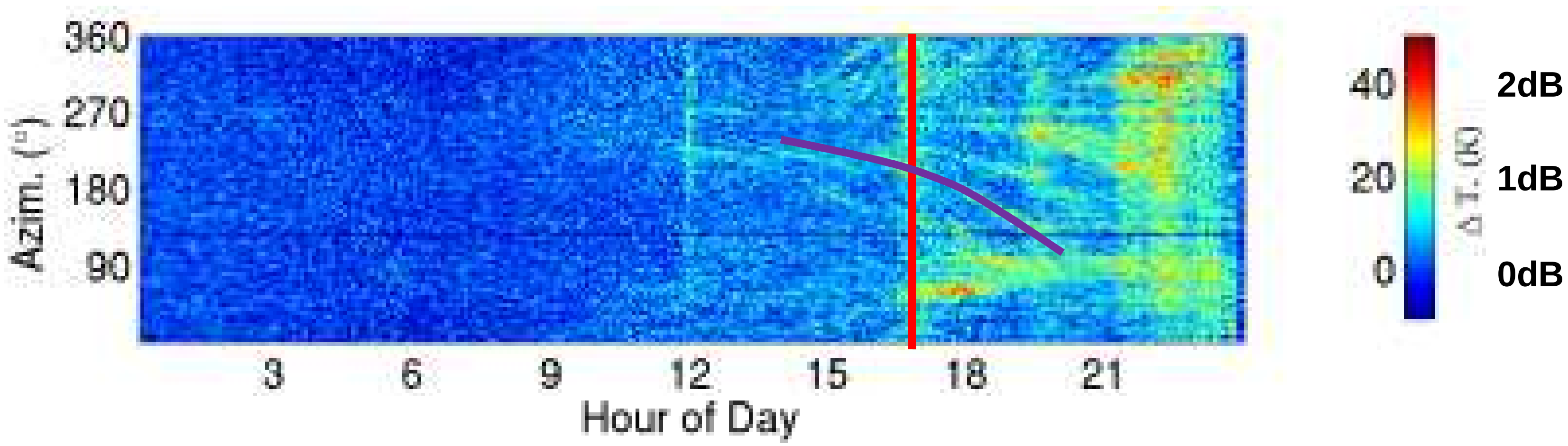
DRY DAY:Glowing ground clutter on lower beams – remains constant.



WET DAY: need to subtract the constant glowing clutter

SUBTRACT glowing clutter to reveal the increased noise ΔT, which can then be converted to attenuation.

Remove Glowing Clutter

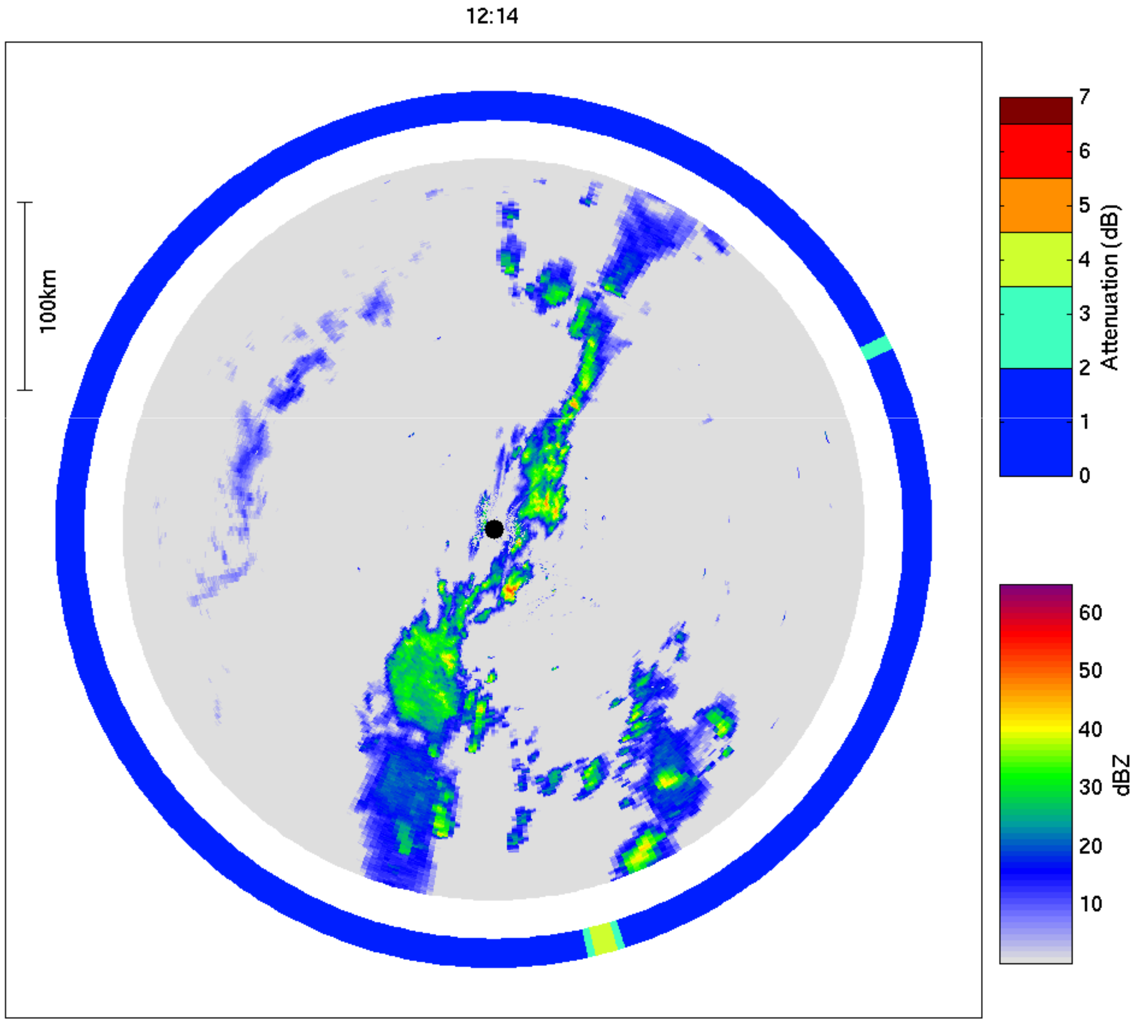


Vertical lines are the radome, as much as 2dB in this case

Curves show distant storms passing the radar, 1.5dB in this case

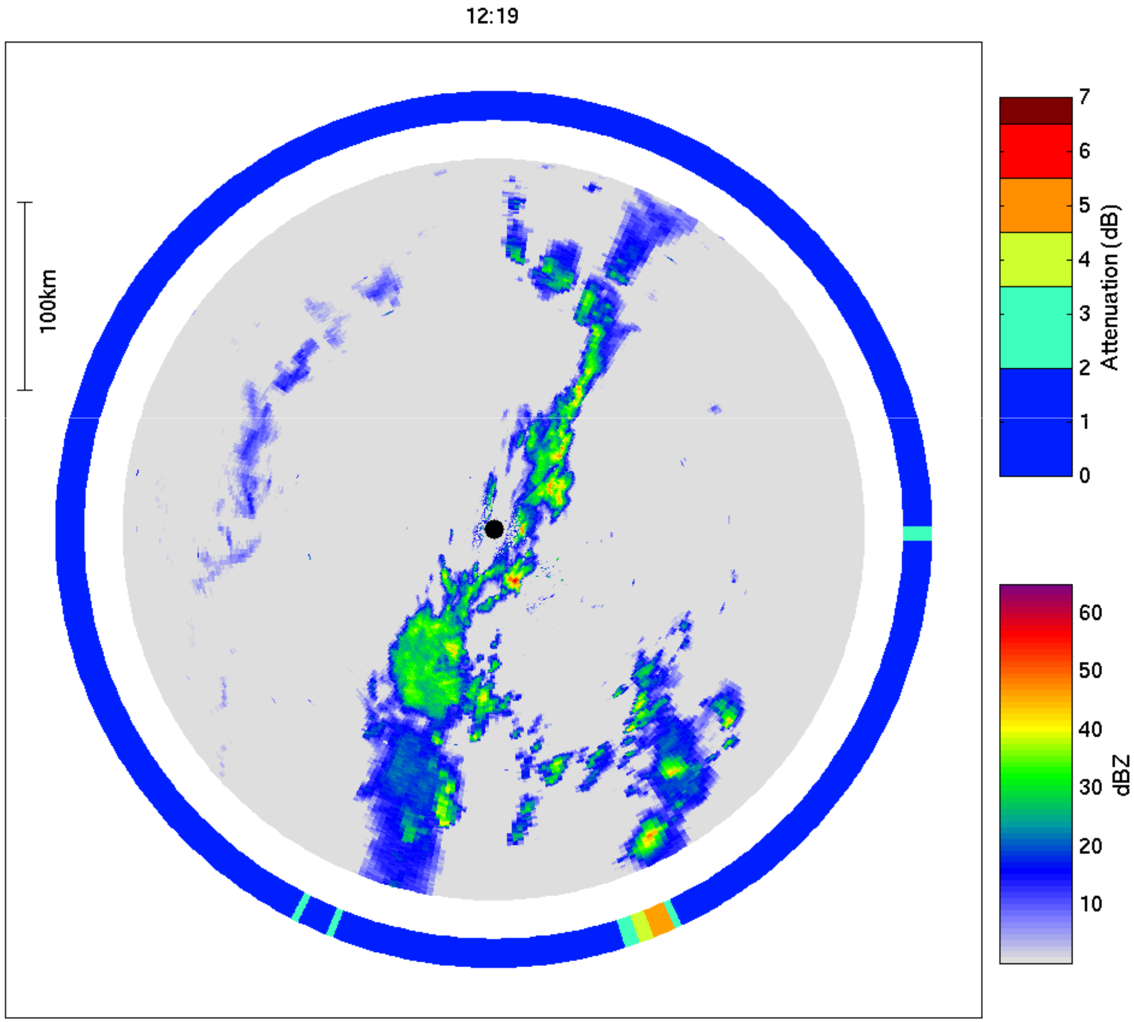
The radome attenuation isn't constant with azimuth, what controls that?

Wimbledon storm - 1214



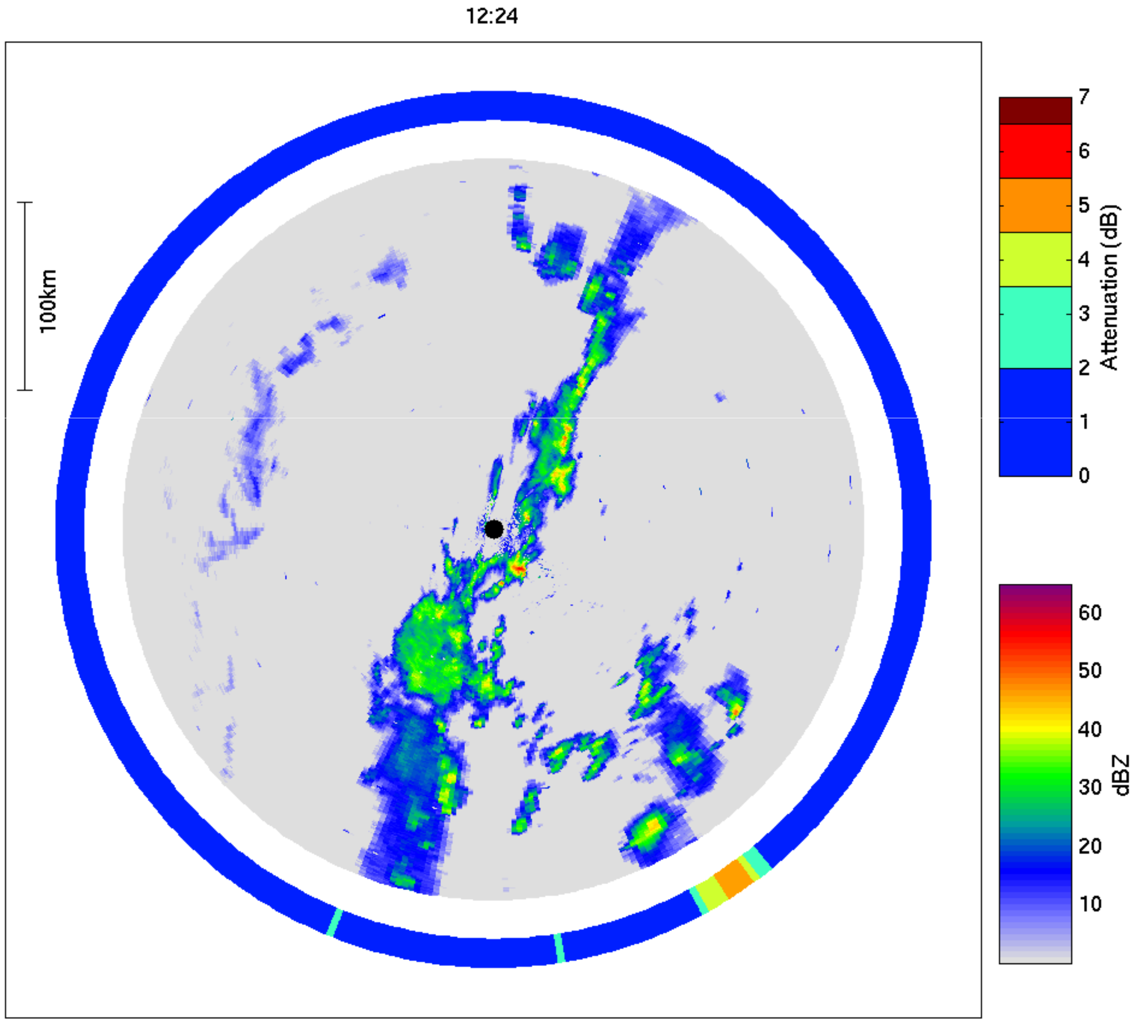
4dB max attenuation

Wimbledon storm - 1219



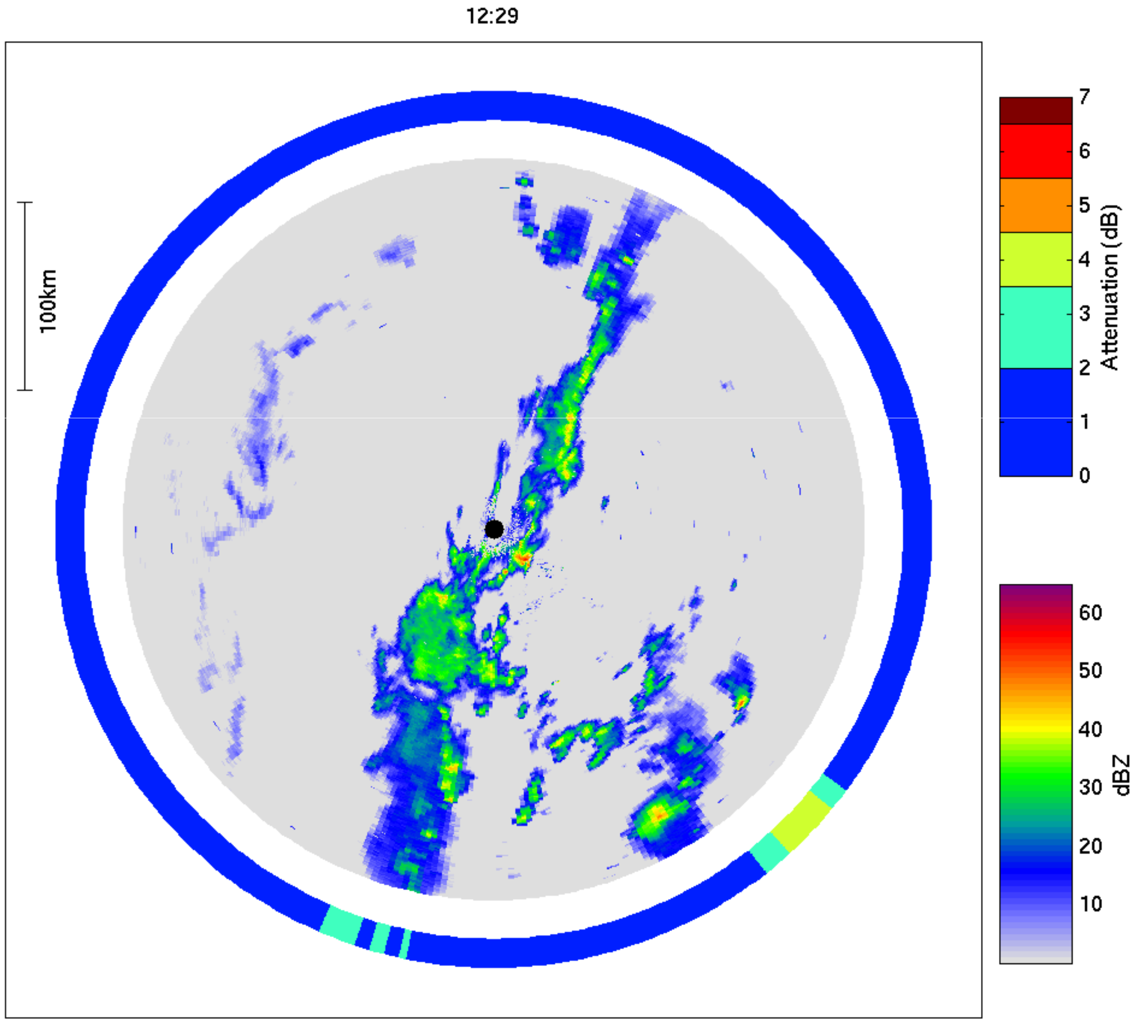
5dB max attenuation

Wimbledon storm - 1224



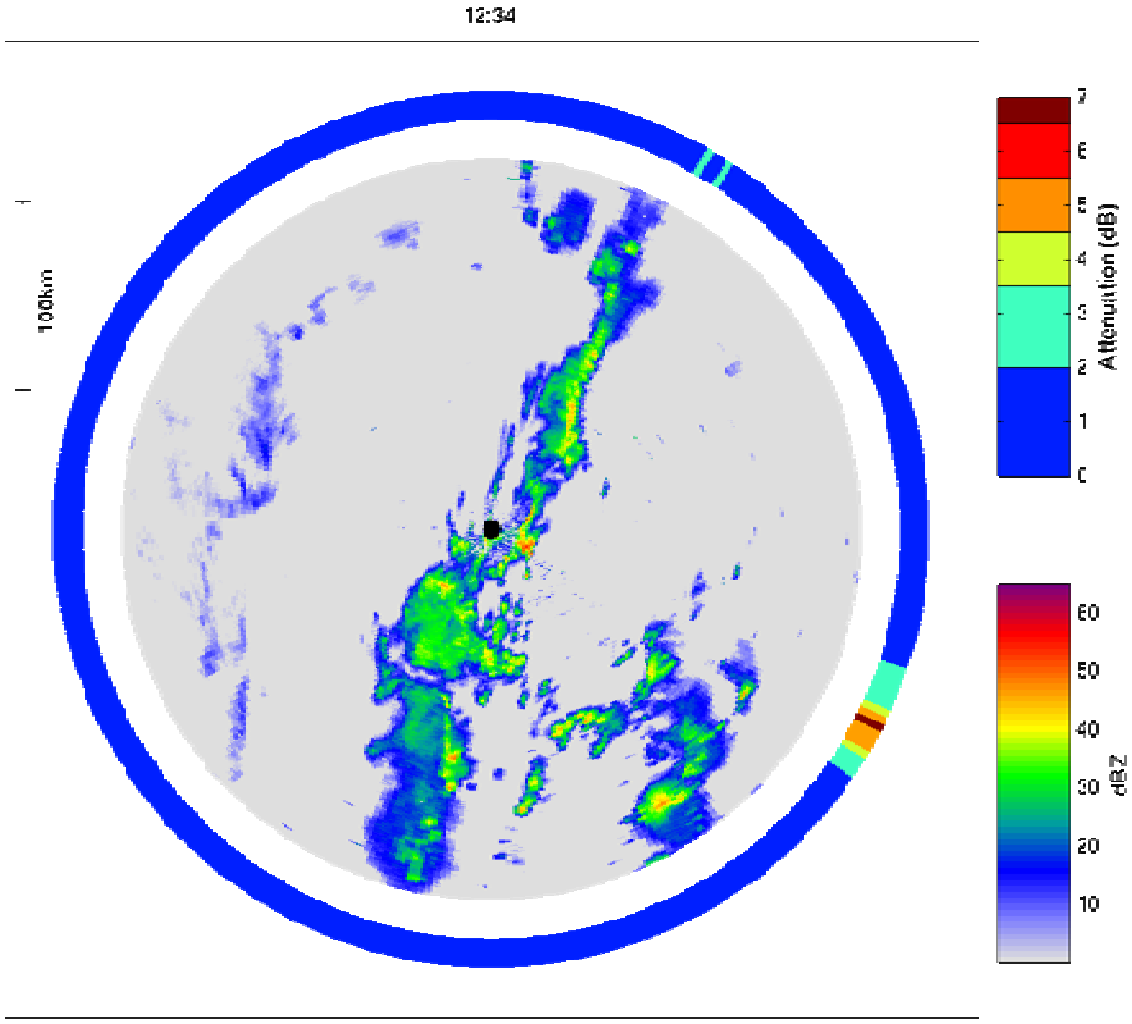
5dB max attenuation

Wimbledon storm - 1229



4dB max attenuation

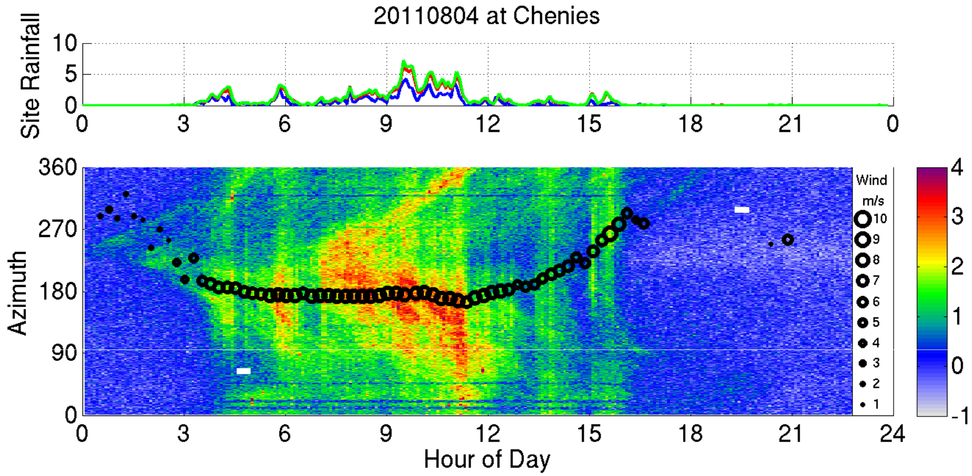
Wimbledon storm - 1234

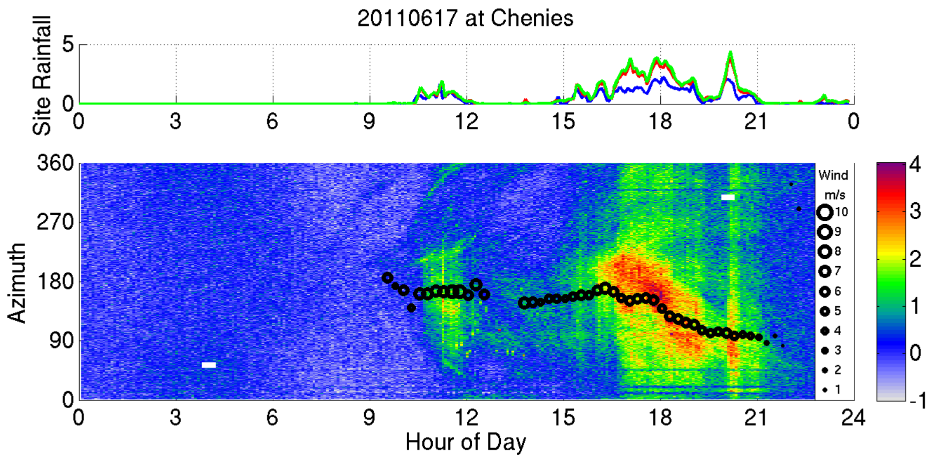


7dB max Attenuation: only 20% left

Wet radome: Wind effect

- Display total attenuation after clutter removal.
- Black circles: wind direction from the Doppler

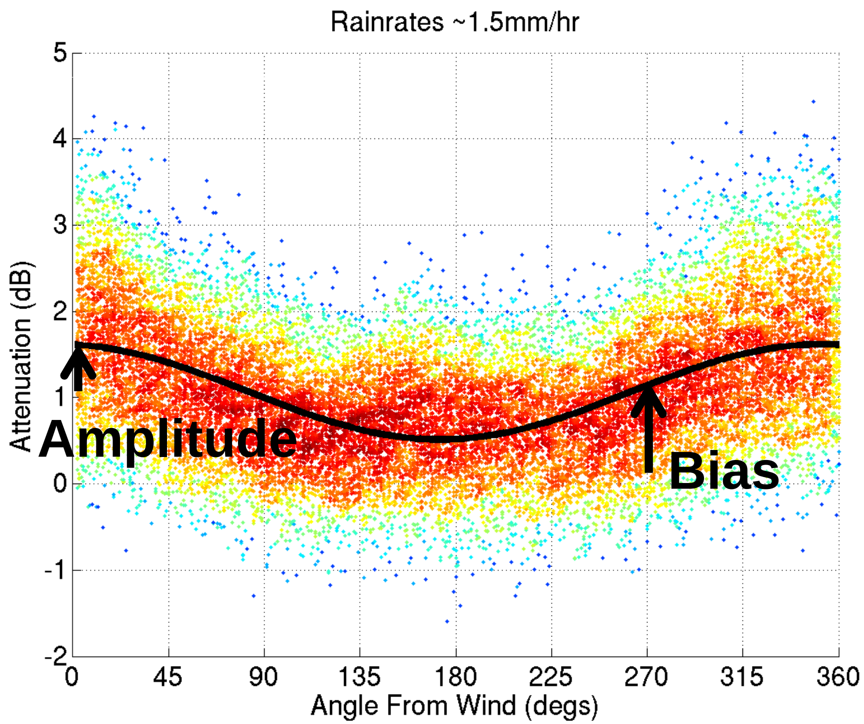




- Radome has most attenuation into the wind.
- Little to no attenuation on leeward side of antenna

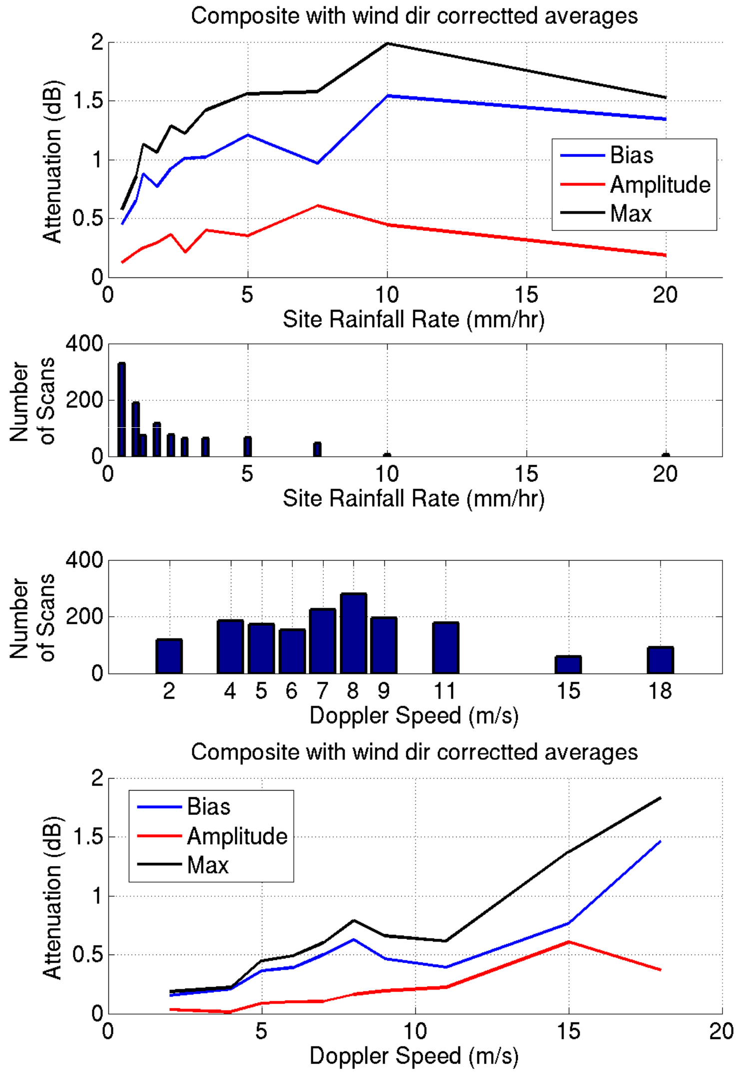
Wet radome: Wind effect

- Fit azimuthal variation in attenuation to a sine wave.
- Plot angle with respect to Doppler wind
  - Peak into wind
  - Bias is average attenuation
  - Amplitude is increase at front.
- Average over a number of days for composites with rainrates and wind speed.



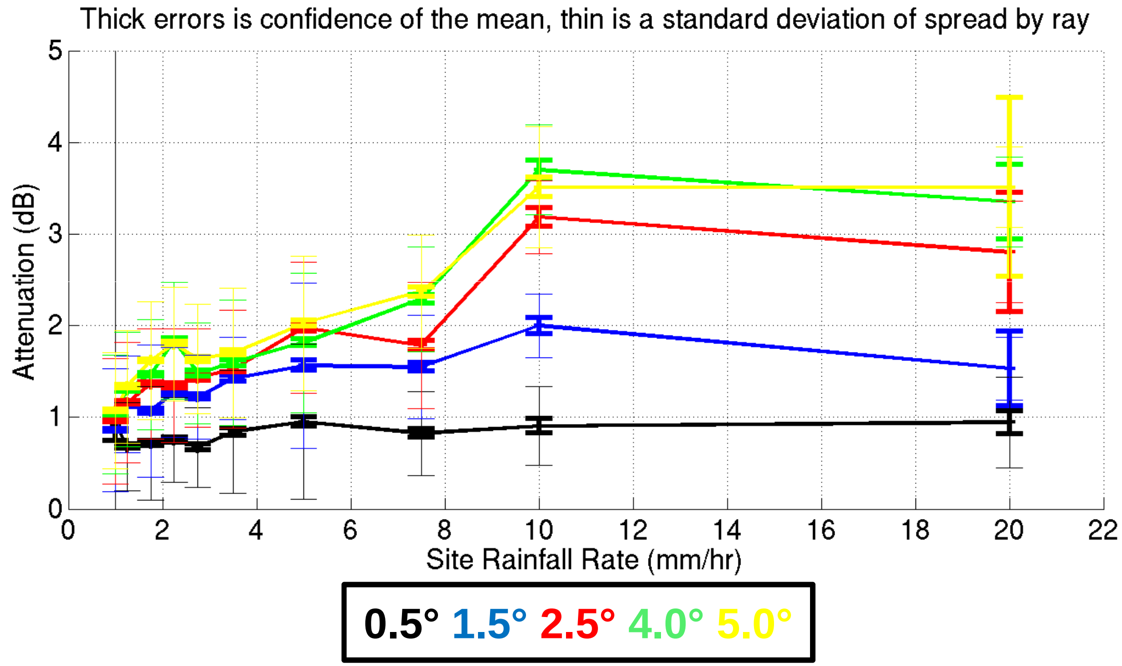
Wet radome: Wind effect

- Model radome attenuation as sine wave
  - Peak into wind
  - Bias is average attenuation
  - Amplitude is increase at front.
- Average over a number of days for composites with rainrates and wind speed.
- In heavier rain more attenuation on all sides.
- Windier weather increases windward/leeward difference.



Wet radome: Wind effect

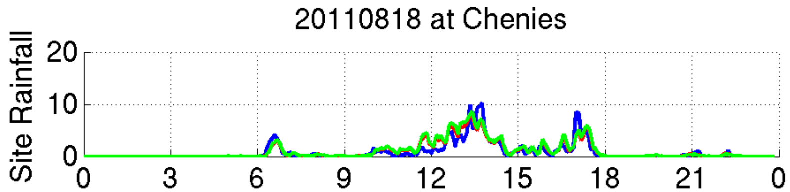
- NOT the same at all elevations.
- Much more attenuation at higher elevation angles
- The elevation with respect to the radome equator is important

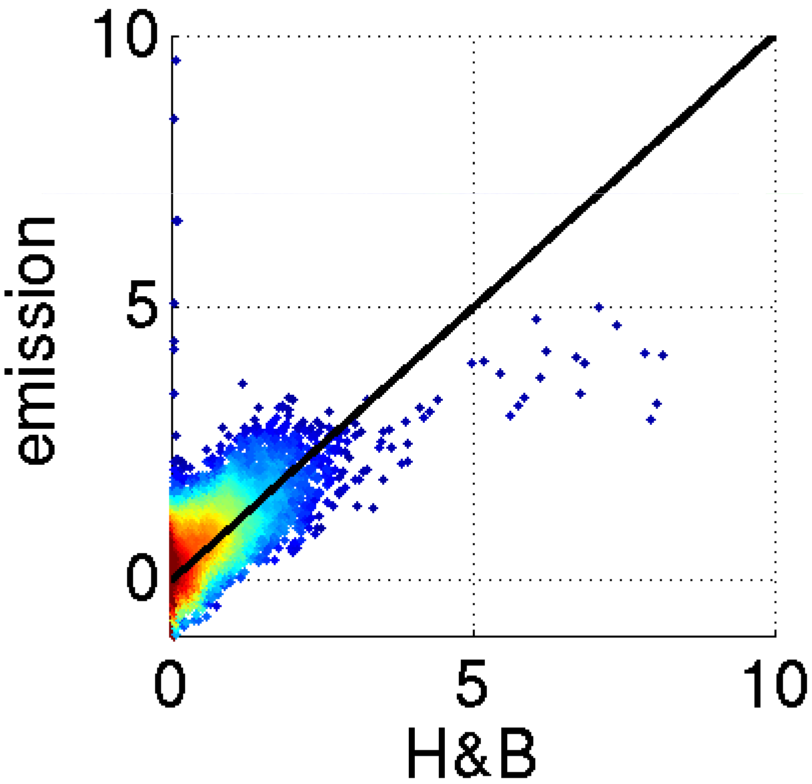


- Heavier rain (rare in UK) can give higher attenuations.
- A lot of variation cannot use an empirical correction.

Distant Storms: 18 Aug 11

- ~60mm in the day, more than August average!
- Compare emission and the Hitschfeld & Bordan method
- Good average, a lot of spread
- Suggests H&B has too much attenuation above 5mm/hr.





Summary

- Emission should provide a constraint on total storm attenuation for other correction algorithms.
- Emission technique requires no assumption on hydrometeor size distribution, shape or state (wet/dry).
- Variation in gaseous brightness temperature is small (10K) and easy to correct.
- Radome attenuation varies with azimuth and elevation (2dB between 0.5° and 2.5° beams in 10mm/hr rain), based on wind speed and direction.
  - Stronger radome attenuation into the wind (up to at least 1dB).
- Emission is the only way to directly measure radome attenuation and it's variation with azimuth.

- **Neglecting the attenuation of the radome may be cause of problems and poor performance of gauge/radar comparisons.**

Other examples