The High Wind Speed Model Function from Space

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Study Motivation

- ASCAT systematically measures lower intensity tropical and extra-tropical cyclones than QuikSCAT
  - High speed model function systematic differences?
  - Resolution differences?
  - Added noise?
- It has been hypothesized that, at very high winds, the backscatter cross section becomes independent of wind speeds since the drag coefficient dependence on wind speed drops
  - Seems to be supported by QuikSCAT observations
  - Seems to be inconsistent with IWRAP observations
- Resolving this point is crucial for the viability of the Dual Frequency Scatterometer (DFS) on JAXA's GCOM-W2 mission for tropical cyclones

Hurricane Force Wind Observations

Data Source	Atlantic	Pacific	Total
QuikSCAT 12.5 km	112	83	195
QuikSCAT 25 km	101	67	168
ASCAT 25 km	0	2	2
GFS	20	18	38
ECMWF	4	0	4
OBS (ship/buoy)	4	11	15

Table 1. Number of passes with Hurricane Force winds in extratropical cyclones from the 12.5 km and 25 km resolution QuikSCAT, 25 km ASCAT, ship and buoy observations (OBS), GFS and ECMWF winds.

From Ahmad et al. (NOAA), 2009

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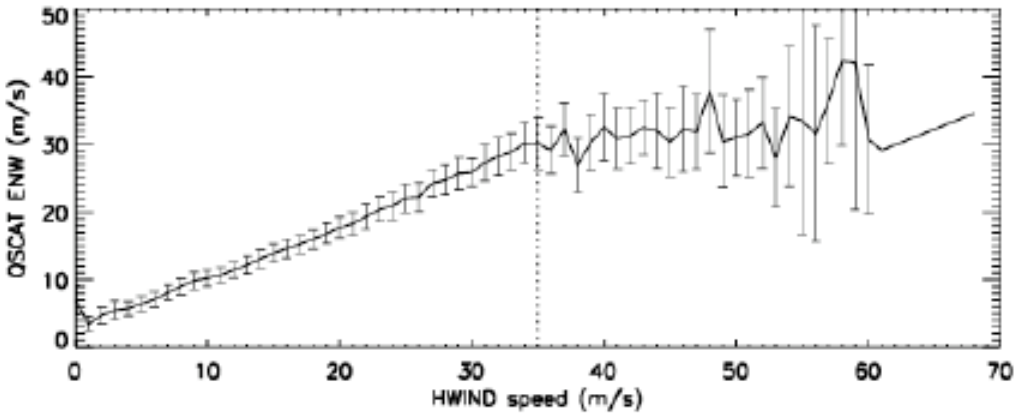
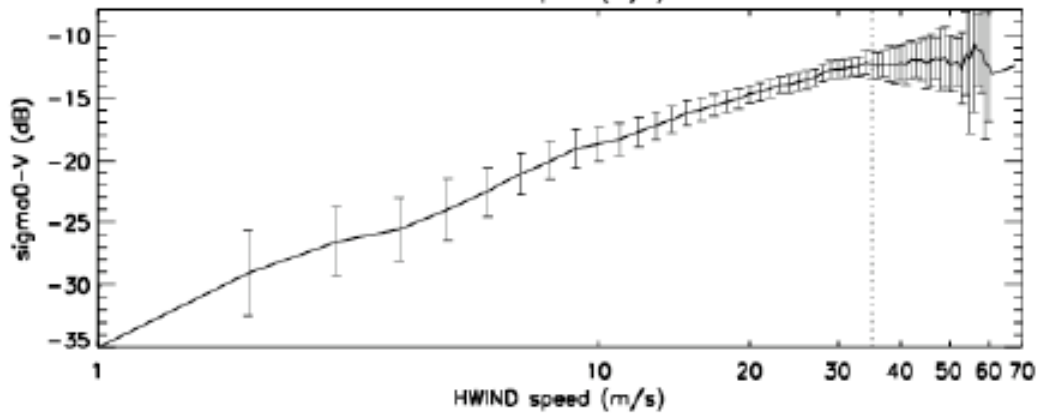
QuikSCAT and Hwind

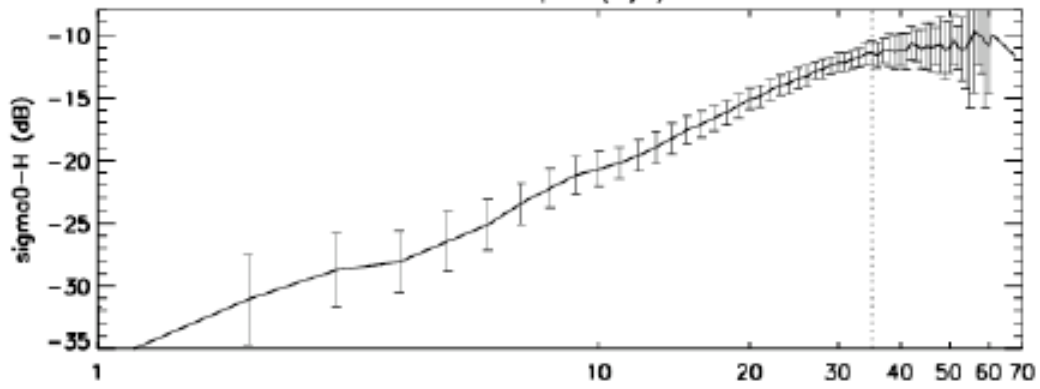
QSCAT U_{ENW}



QSCAT σ_o-V



QSCAT σ_o-H



Liu and Tang, OVWST 2009

12 Hurricanes in 2005 were used. Those with more than 50% chance of coincident rain occurrence were removed.

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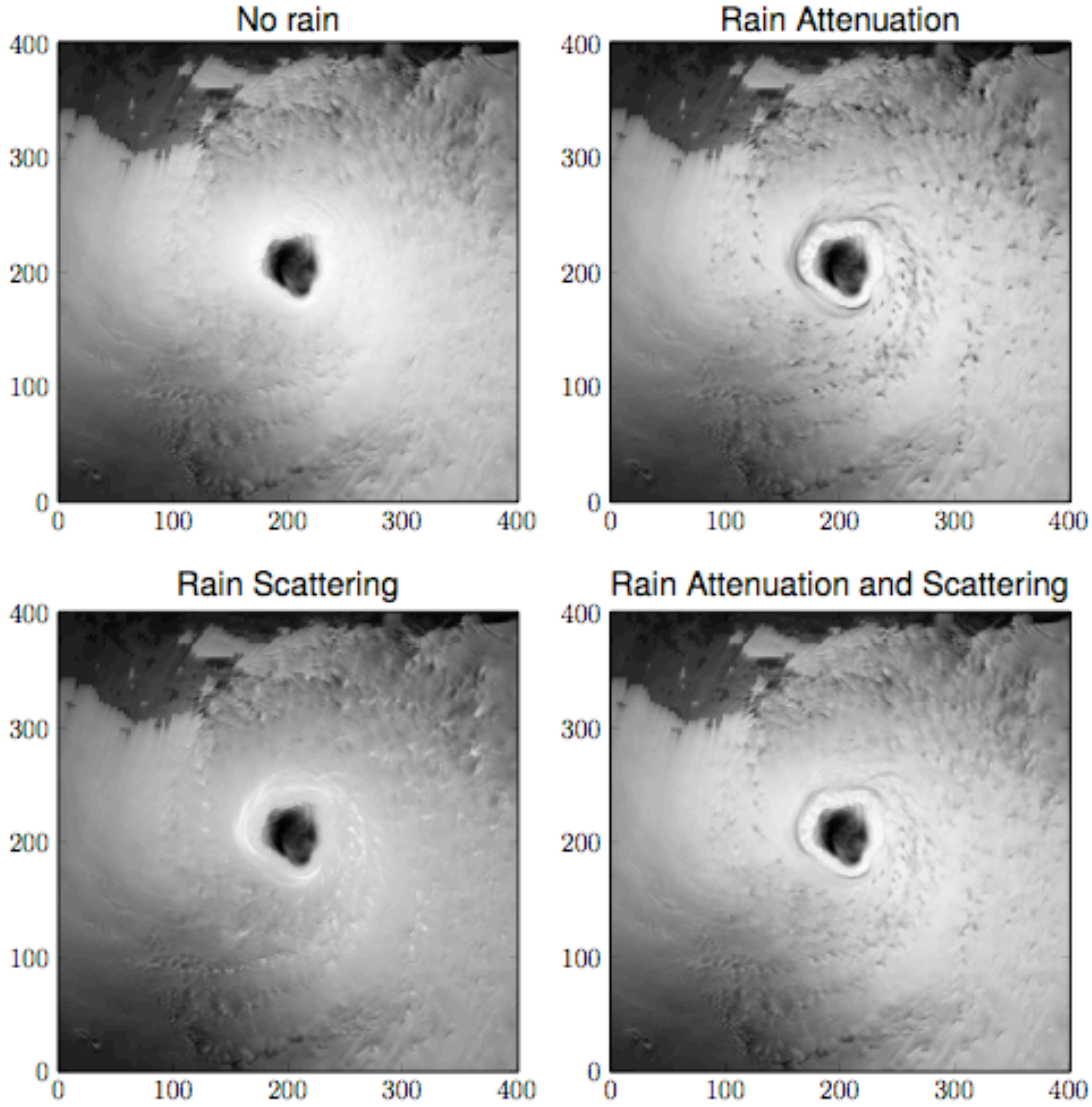
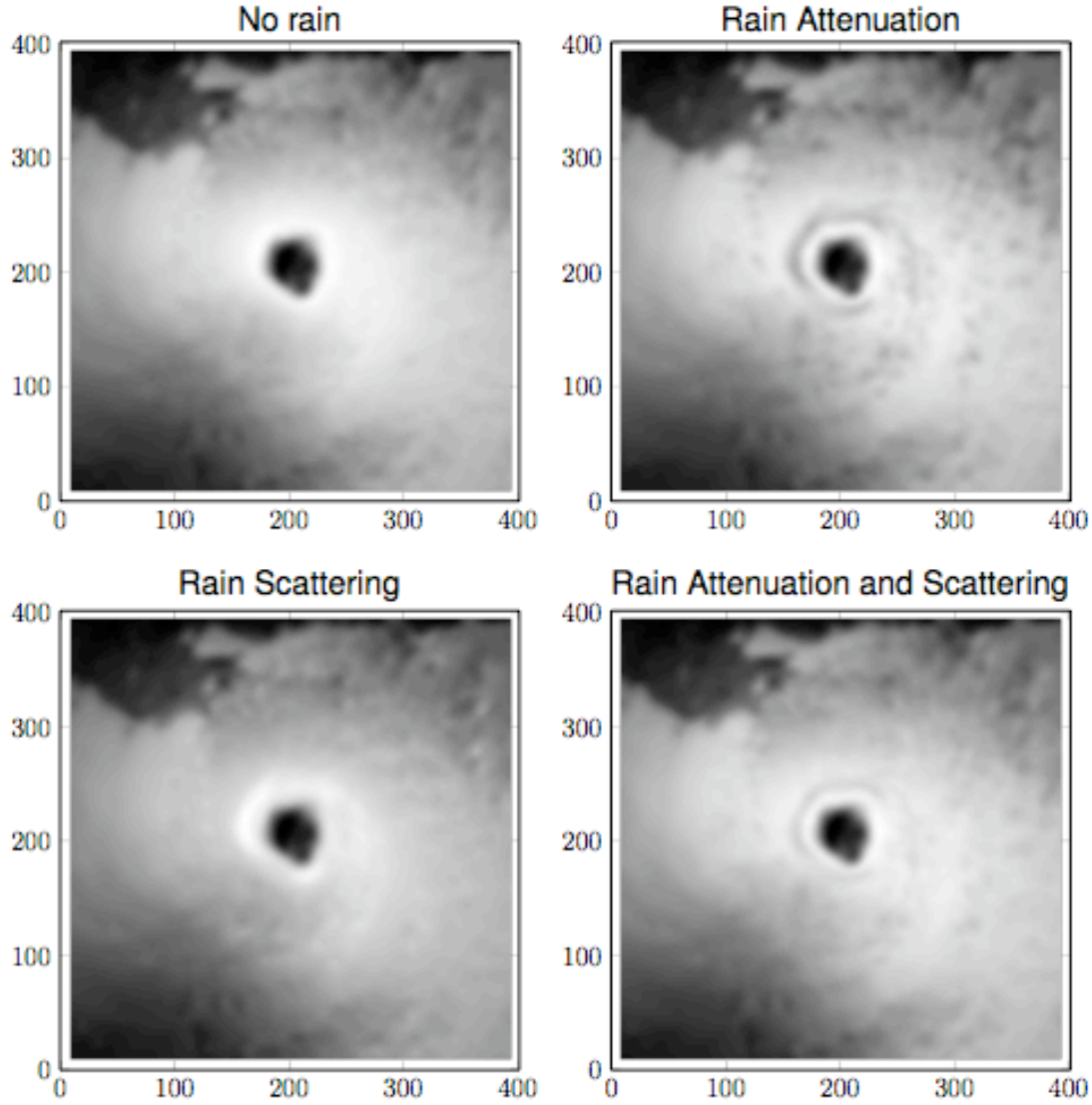
Study Approach

- Use WRF simulated tropical and extra tropical cyclone winds
  - Looked at over 10 cases for Katrina, Rita, Helene
  - WRF constrained by GFDL fields
  - WRF resolution: 1.3 km
- Assumed that IWRAP high speed model functions (Esteban-Fernandez, JGR, 2007) were correct
- Simulated high resolution sigma0 fields
  - Can examine wind only (rain-free) fields
  - Can add rain attenuation or backscatter
- Degraded resolution of sigma0 fields by convolving with a 2D hamming filter
  - 25 km, 50 km, 100 km
- Estimated GMF's by simple binning
  - Not optimal, but representative

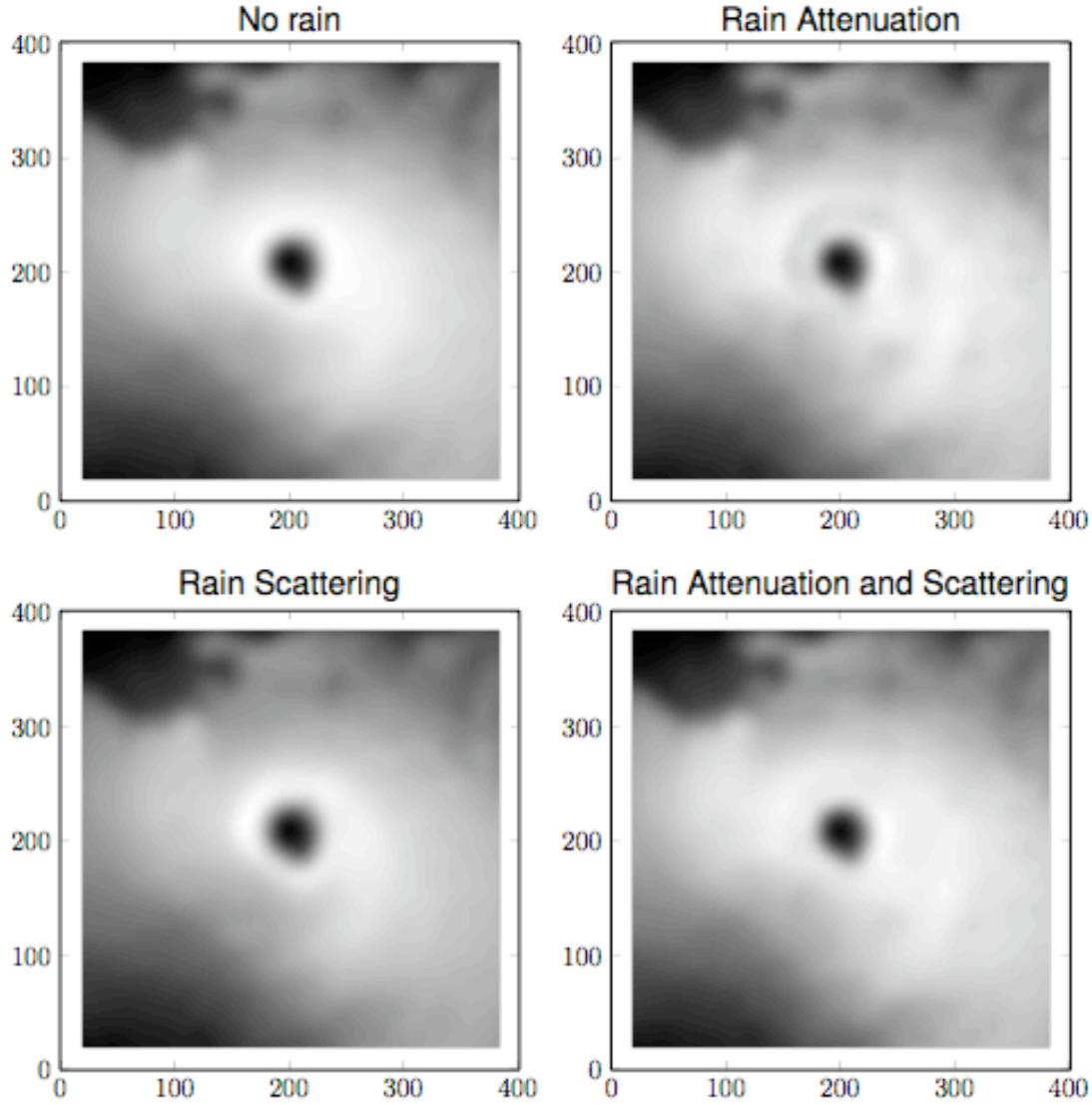
Katrina Sigma0
1.3 km Resolution



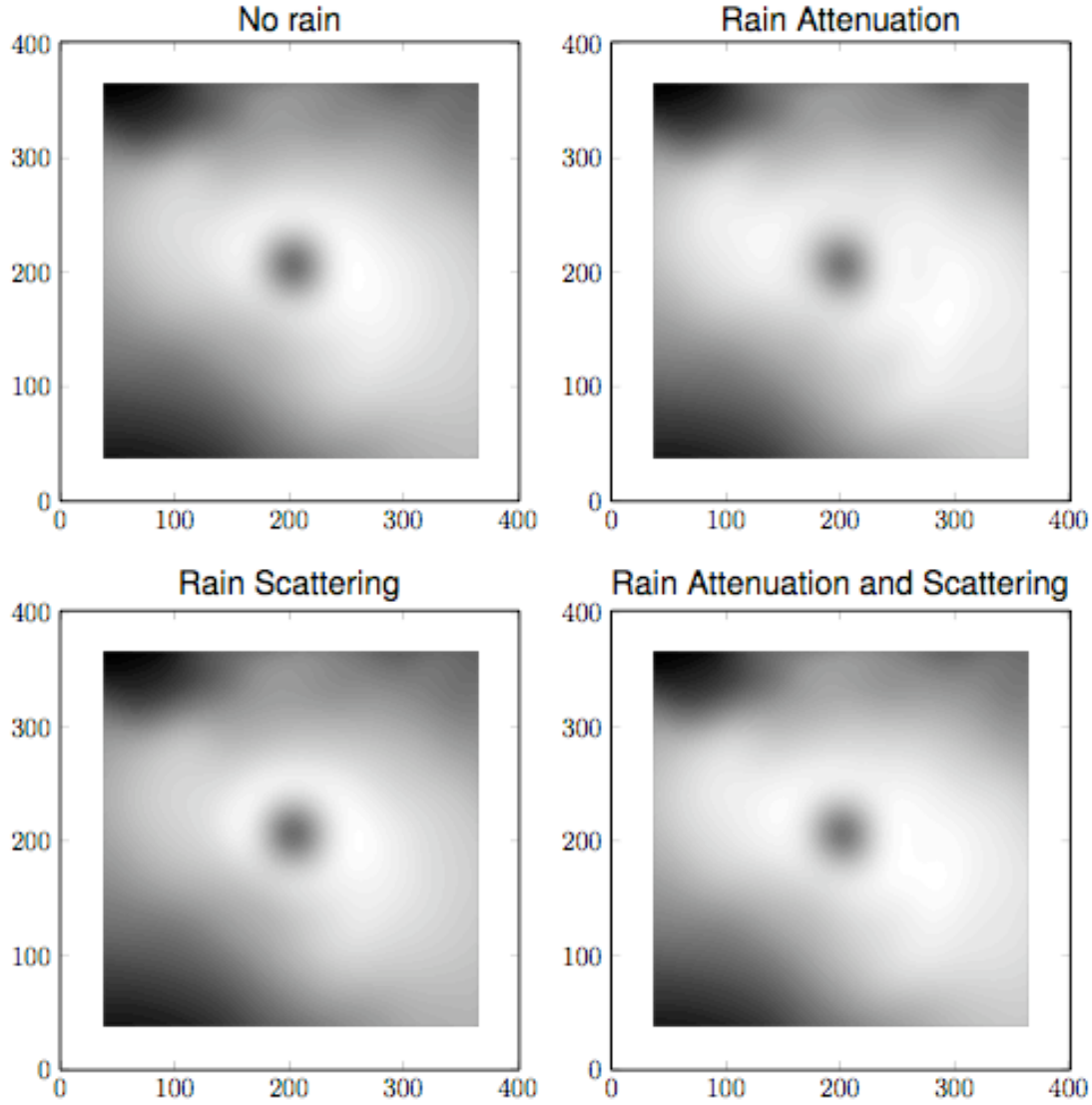
Katrina Sigma0
25 km Resolution



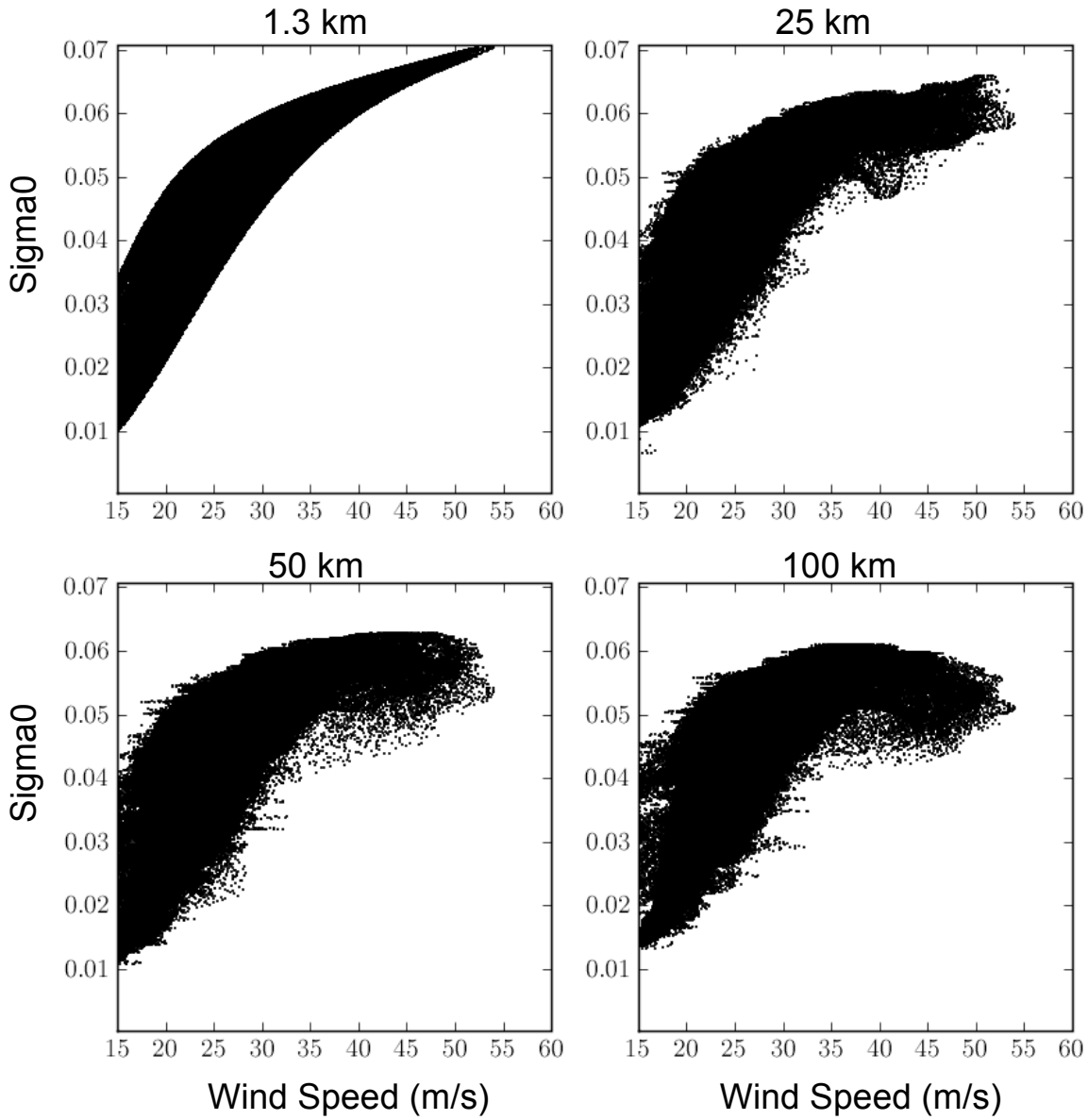
Katrina Sigma0
50 km Resolution



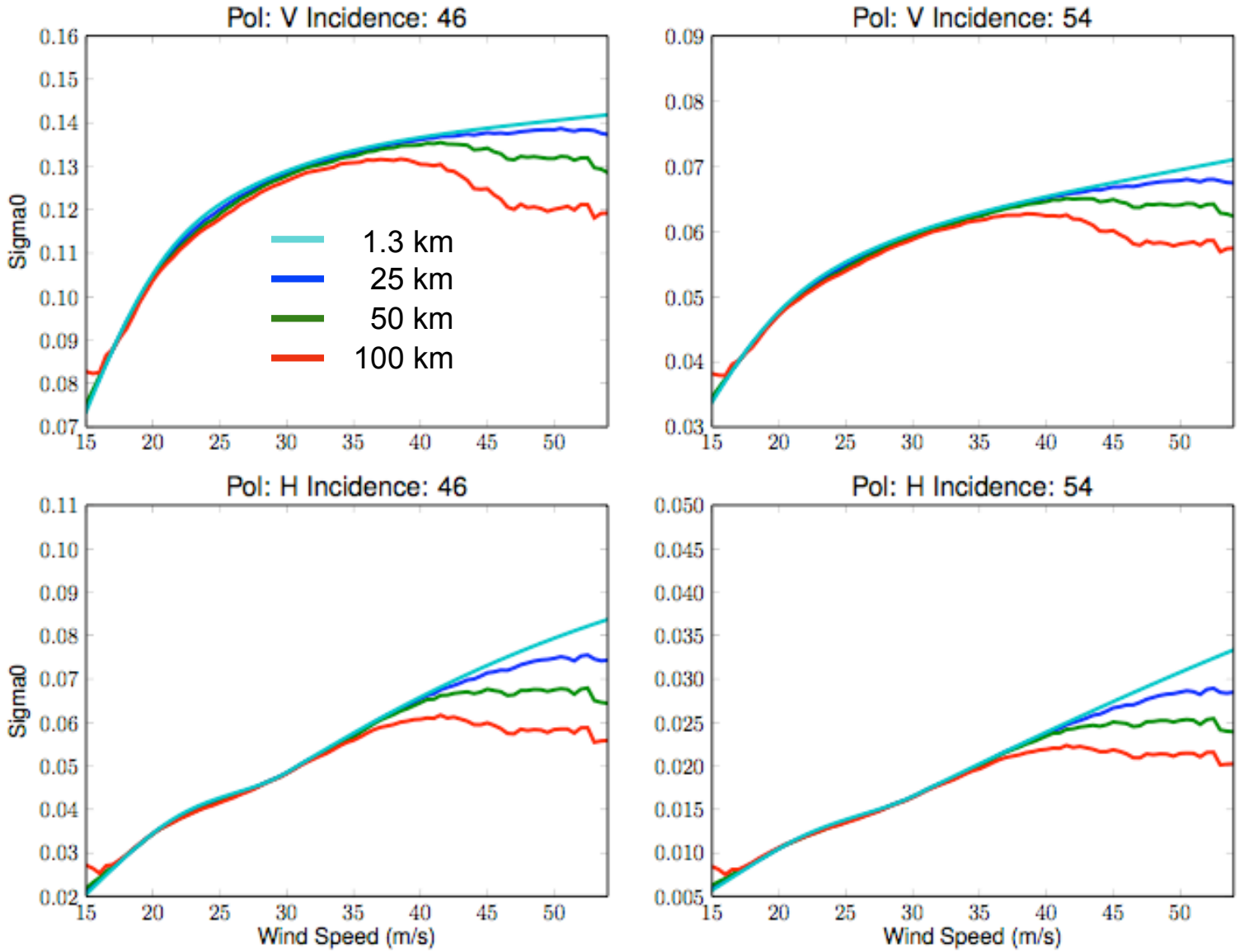
Katrina Sigma0
100 km Resolution



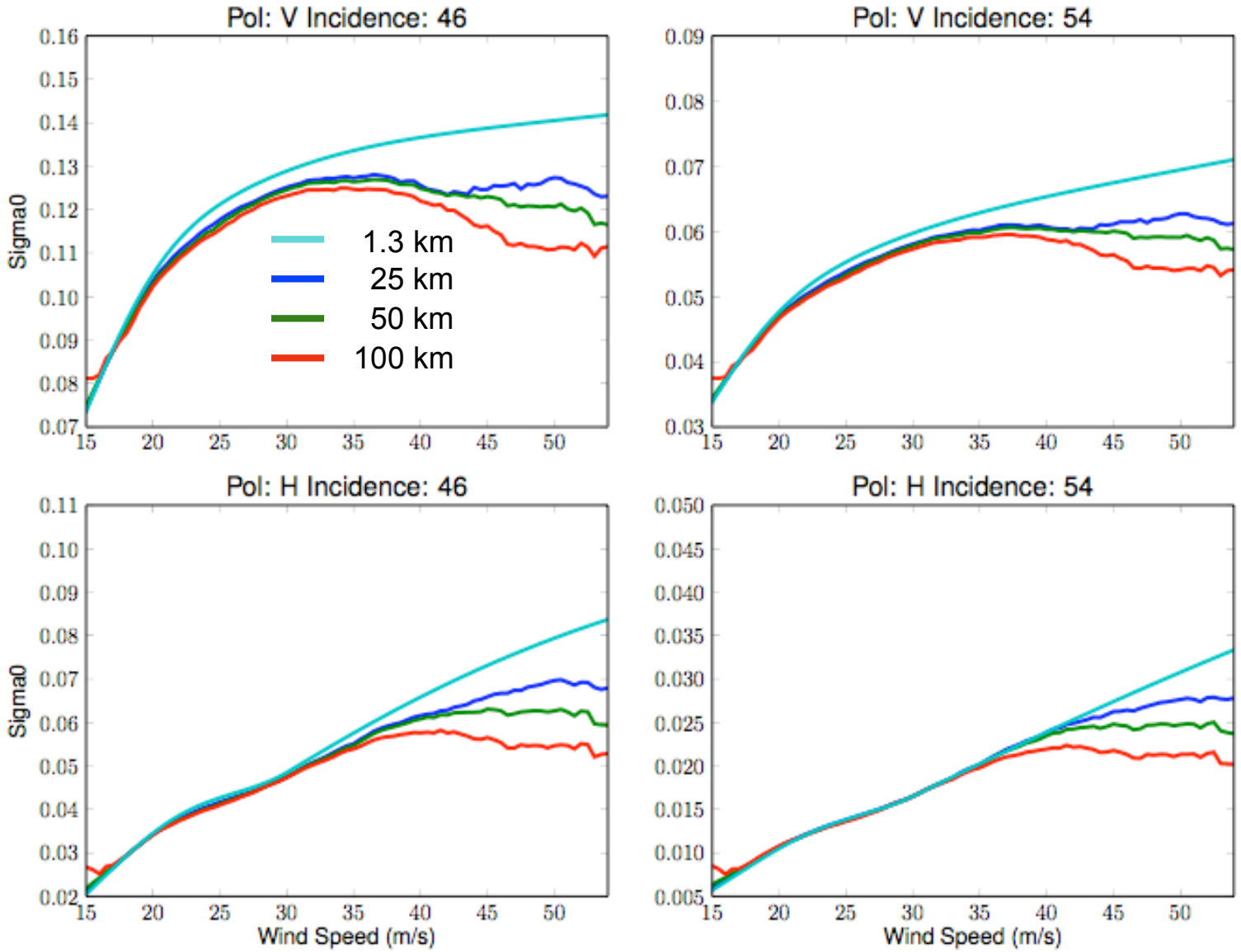
Katrina, Rain Included
Sigma0 vs Speed Scatter Plot



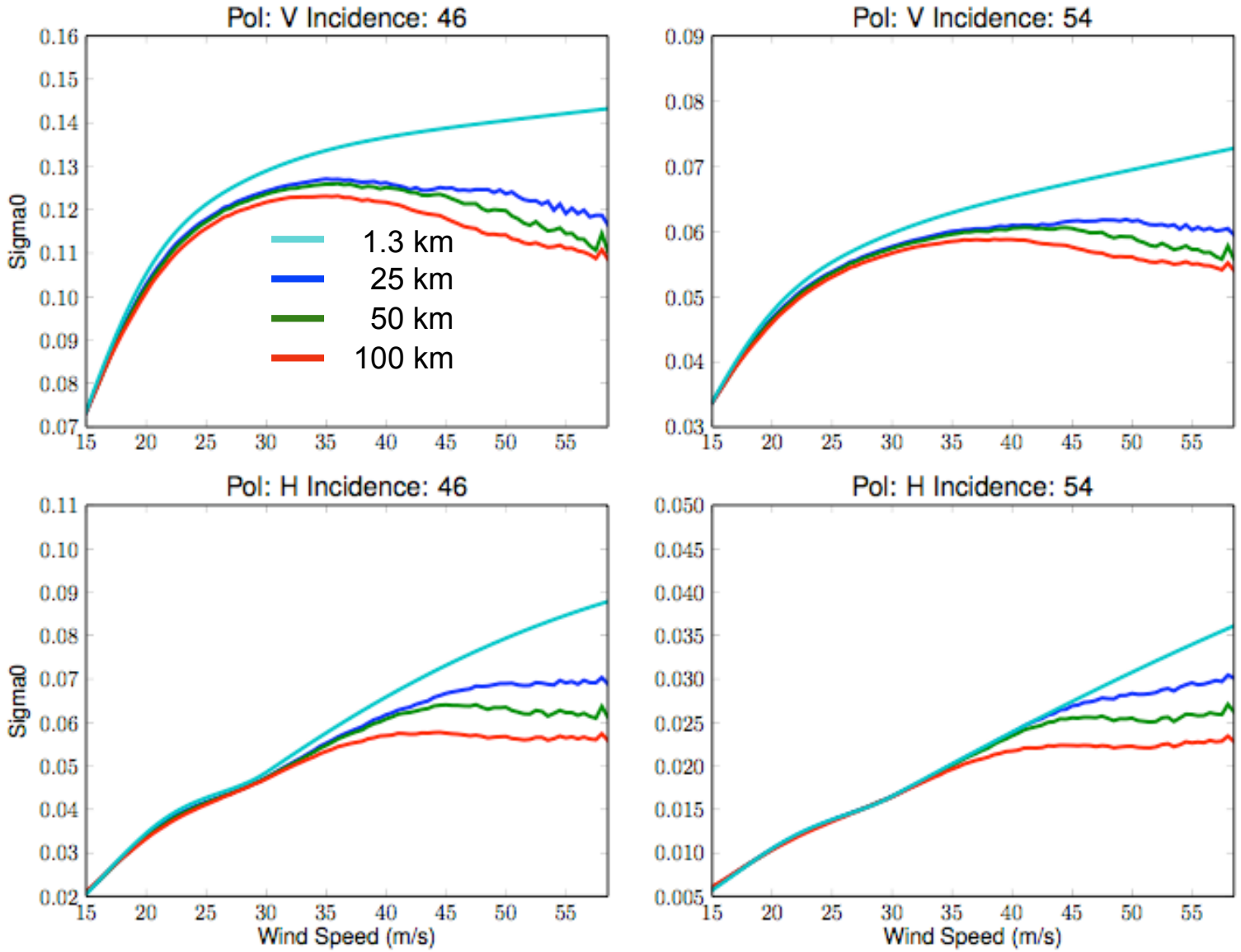
Katrina GMF, Azimuth=0, No Rain
Ground Truth: WRF Winds



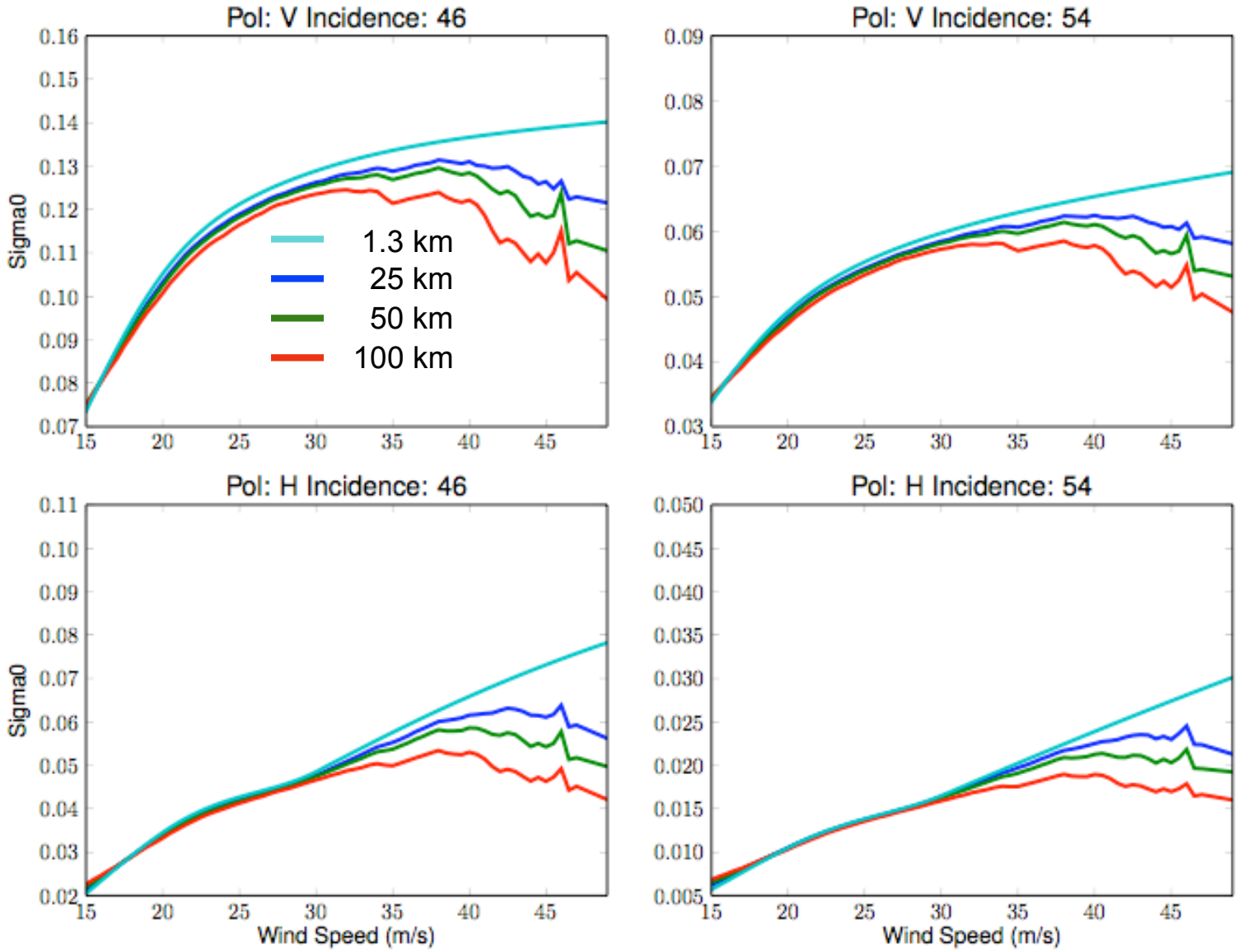
Katrina GMF, Azimuth=0, With Rain
Ground Truth: WRF Winds



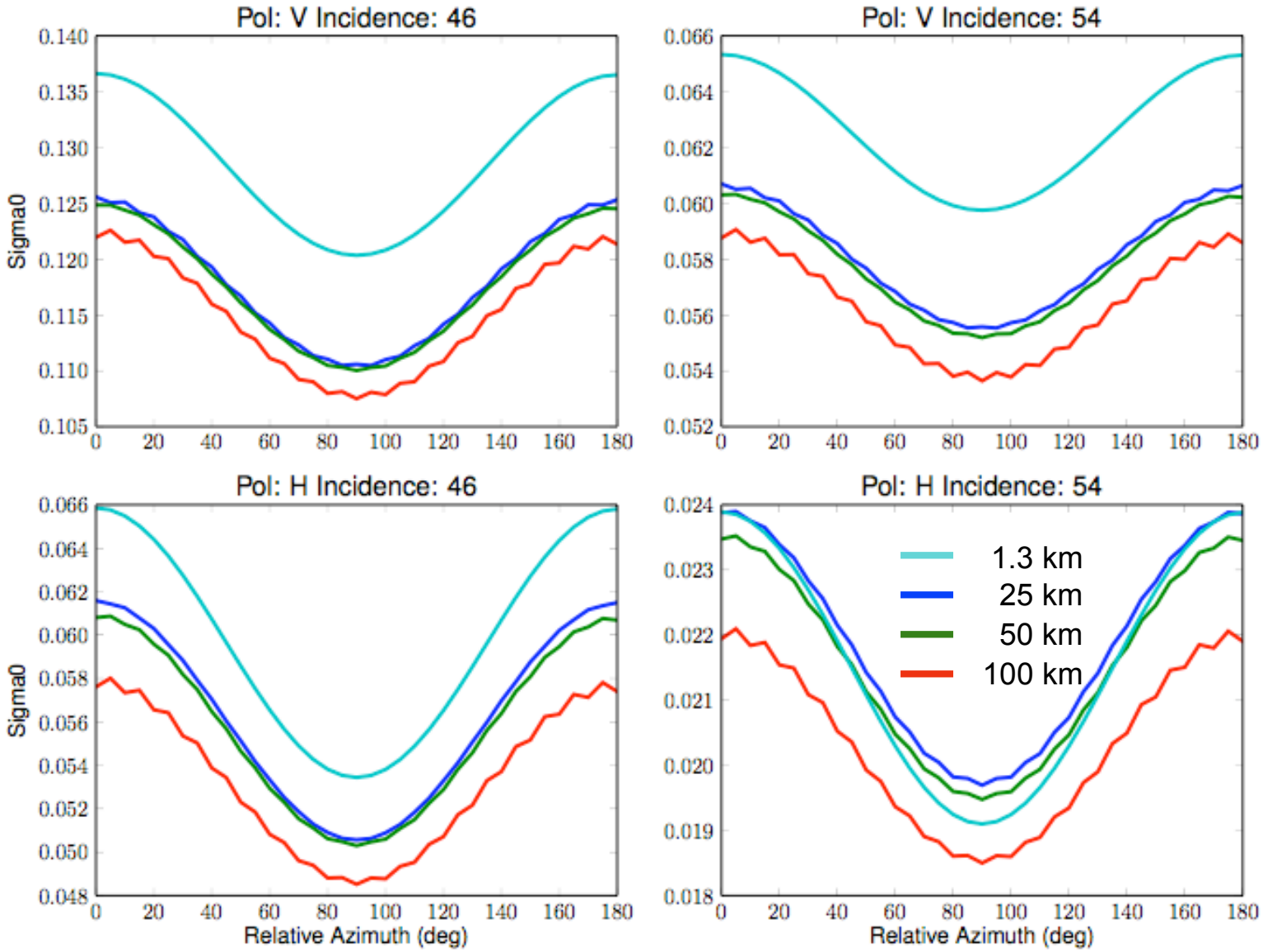
Rita GMF, Azimuth=0, With Rain
Ground Truth: WRF Winds



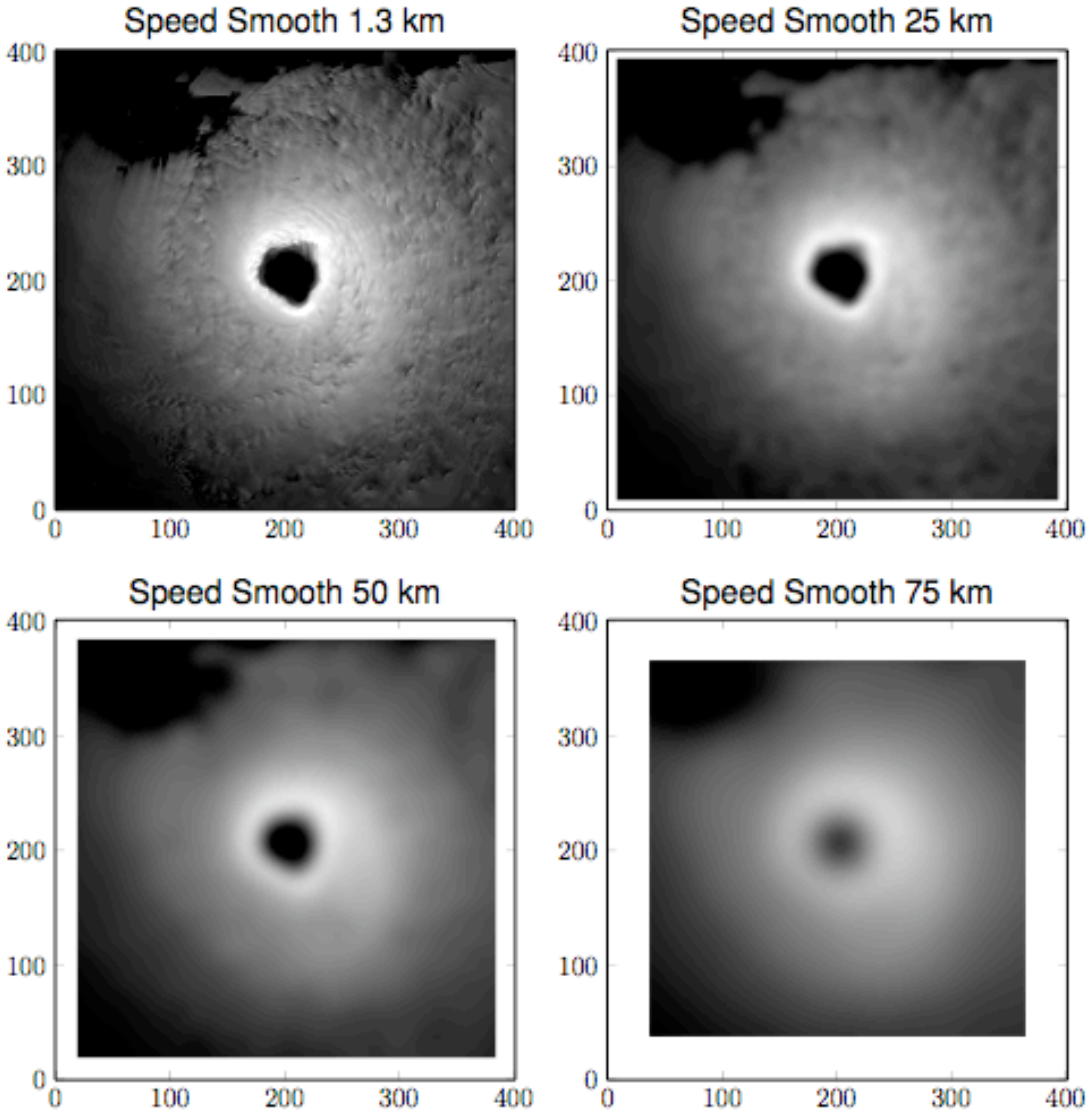
Helene GMF, Azimuth=0, With Rain
Ground Truth: WRF Winds

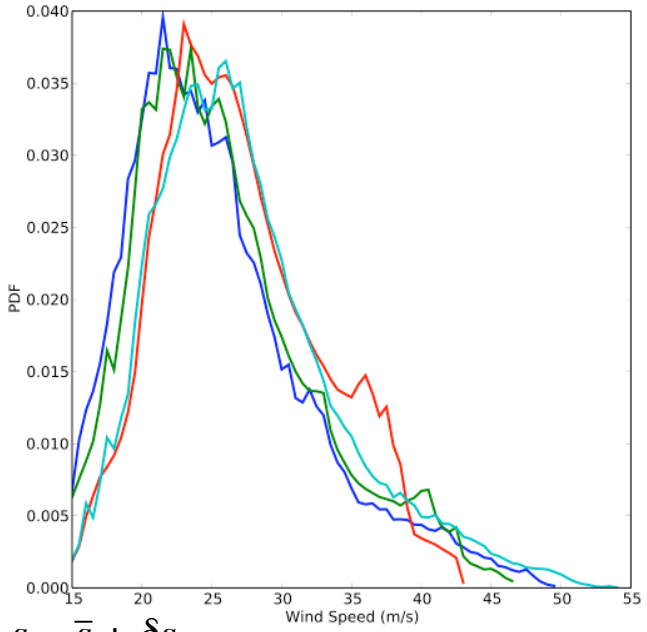


Katrina GMF, Speed=40m/s, With Rain Ground Truth: WRF Winds



Katrina
Average Wind Speed





$$s = \bar{s} + \delta s$$

$$\langle s \rangle = \langle \bar{s} + \delta s \rangle = \bar{s}$$

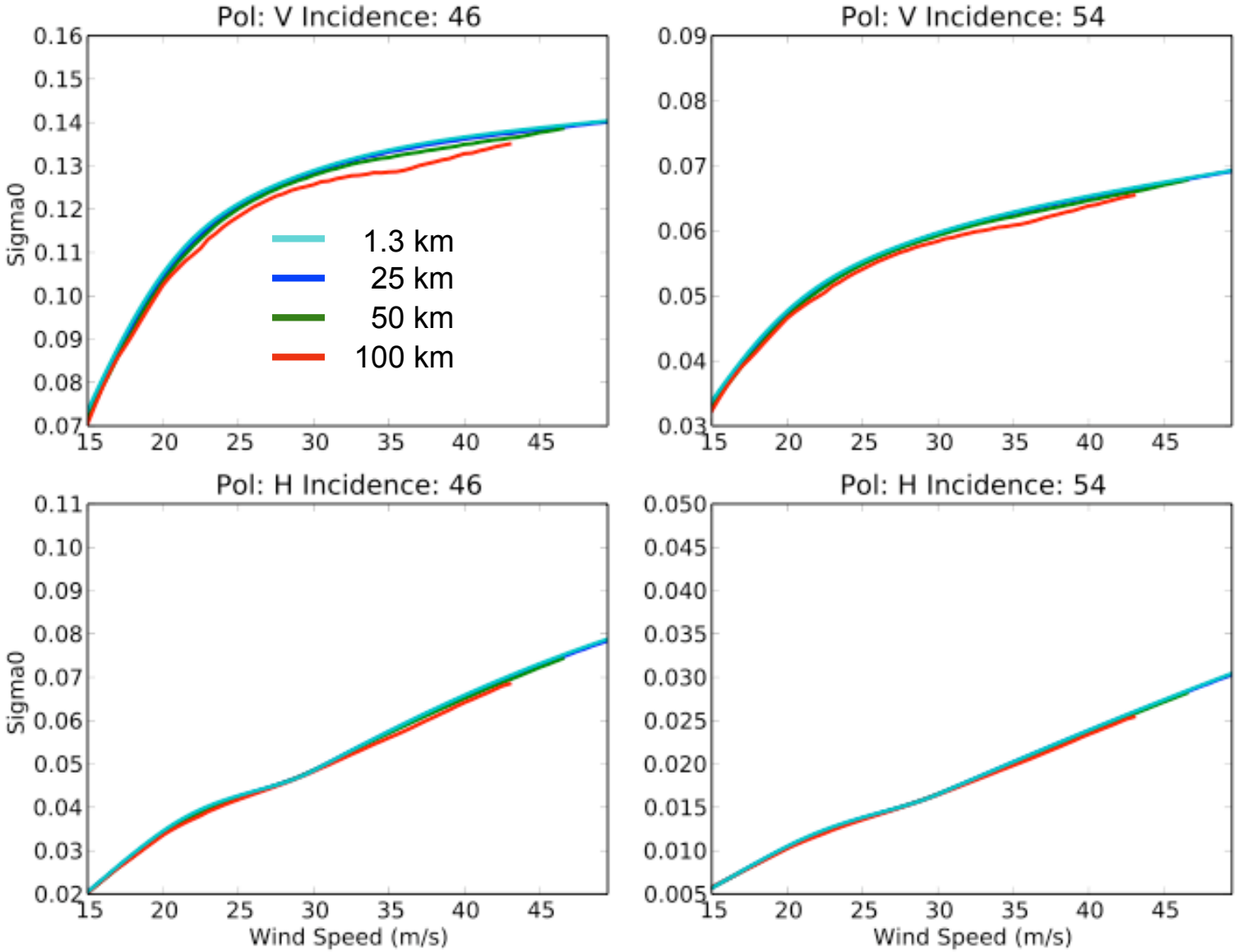
$$\sigma_0 \approx s^a = (\bar{s} + \delta s)^a \approx \bar{s}^a (1 + a\frac{\delta s}{\bar{s}} + \ldots)$$

For $\frac{\delta s}{\bar{s}} << 1$, easier at high winds

$$\langle \sigma_0 \rangle \approx \bar{s}^a + \ldots$$

$\langle\ \rangle$: Spatial Average

Katrina GMF, Azimuth=0, No Rain
Ground Truth: Average WRF Speed/Direction



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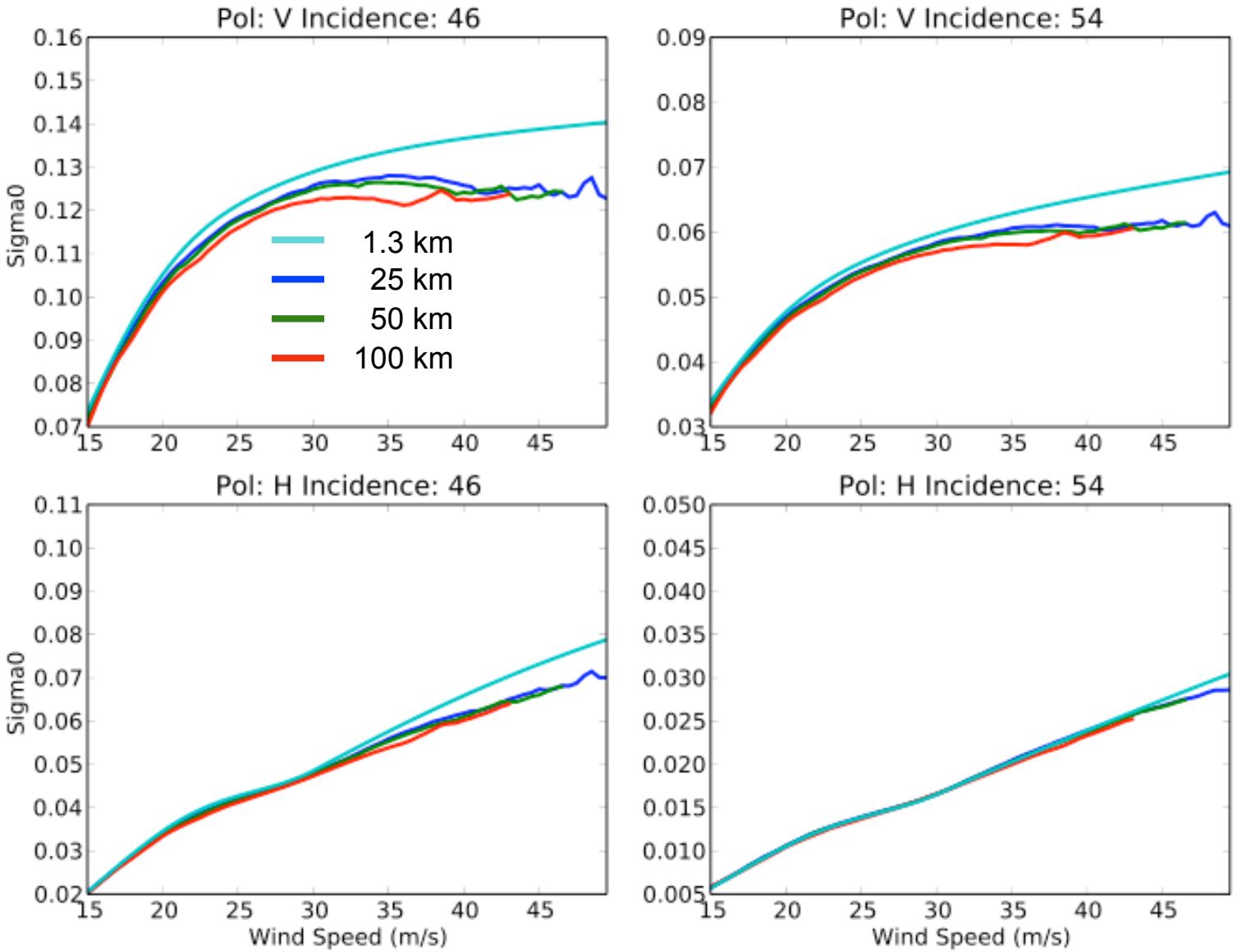

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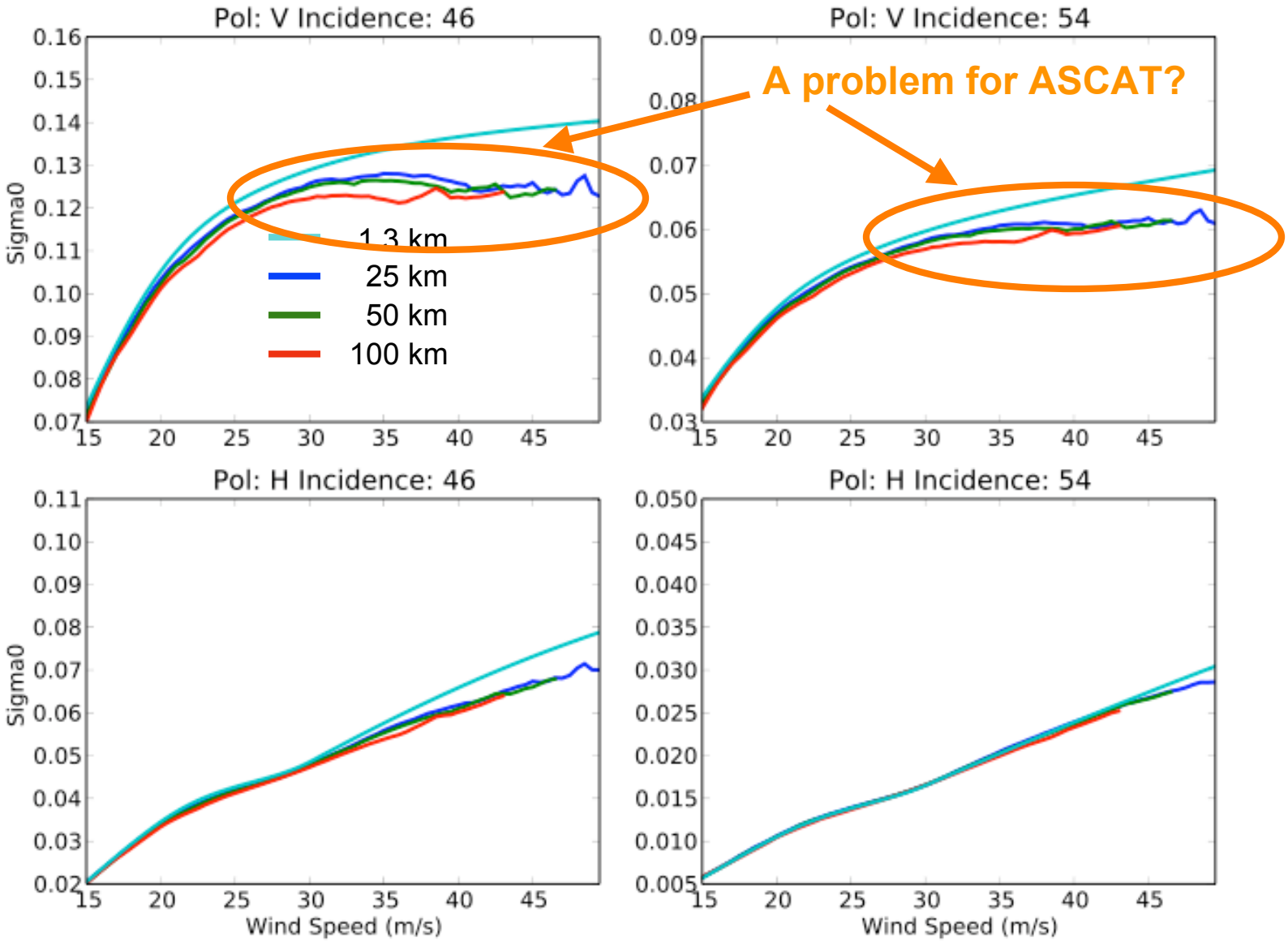
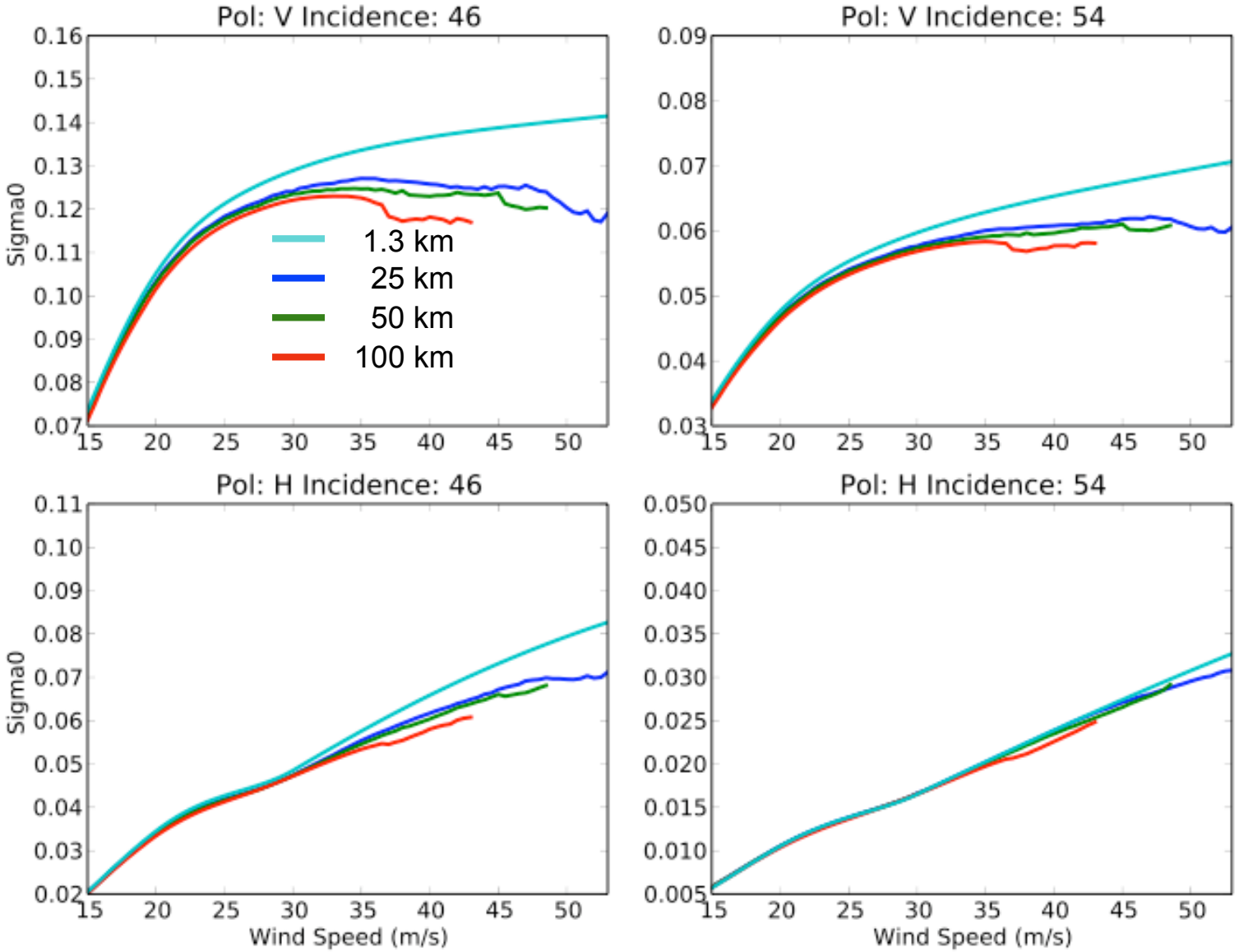


Rita GMF, Azimuth=0, With Rain
Ground Truth: Average WRF Speed/Direction



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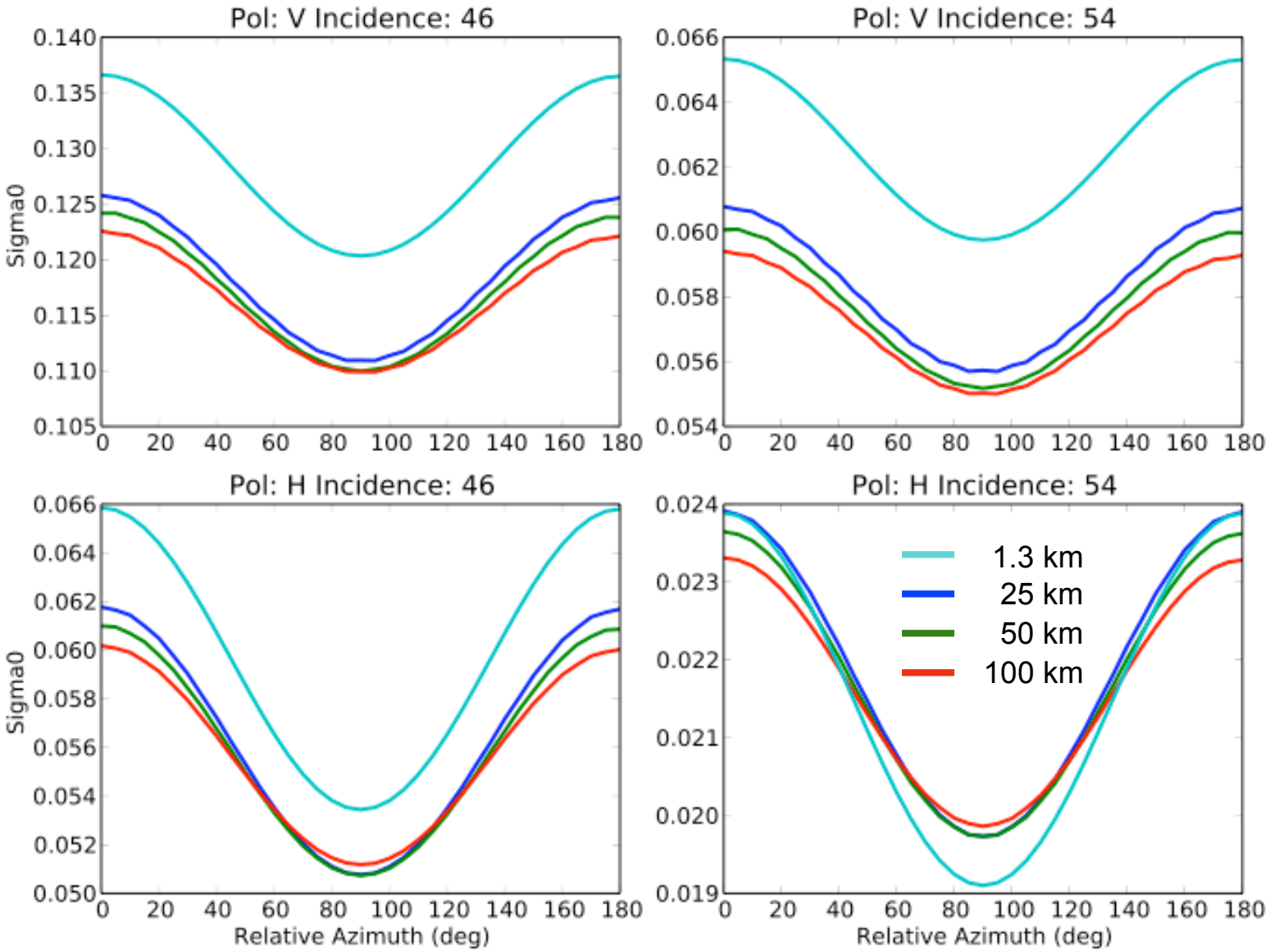

Conclusions

- Spatial variability of the high speed wind field can have a significant distortion on the GMF retrieved from low-resolution spaceborne data
  - Spatial resolution effects dominate
  - Rain contamination also plays a role for very high winds
  - There is always a flattening of the estimated model function relative to the true model function at high speeds
    - No additional physical mechanism need be invoked
  - Speed is more distorted than directional modulation
- A more consistent model is achieved by deriving a model function with wind speeds and directions averaged to a size consistent with the imaging footprint
  - The GMF still exhibits distortions at high speeds, but mainly due to rain contamination
  - Lower speeds, consistent with the averaging area, are retrieved
    - **Be careful when validating scatterometer winds against point measurements or high resolution measurements!**
  - H-pol is less affected than V-pol