Progress in Ultra High Resolution Wind and Rain Estimation

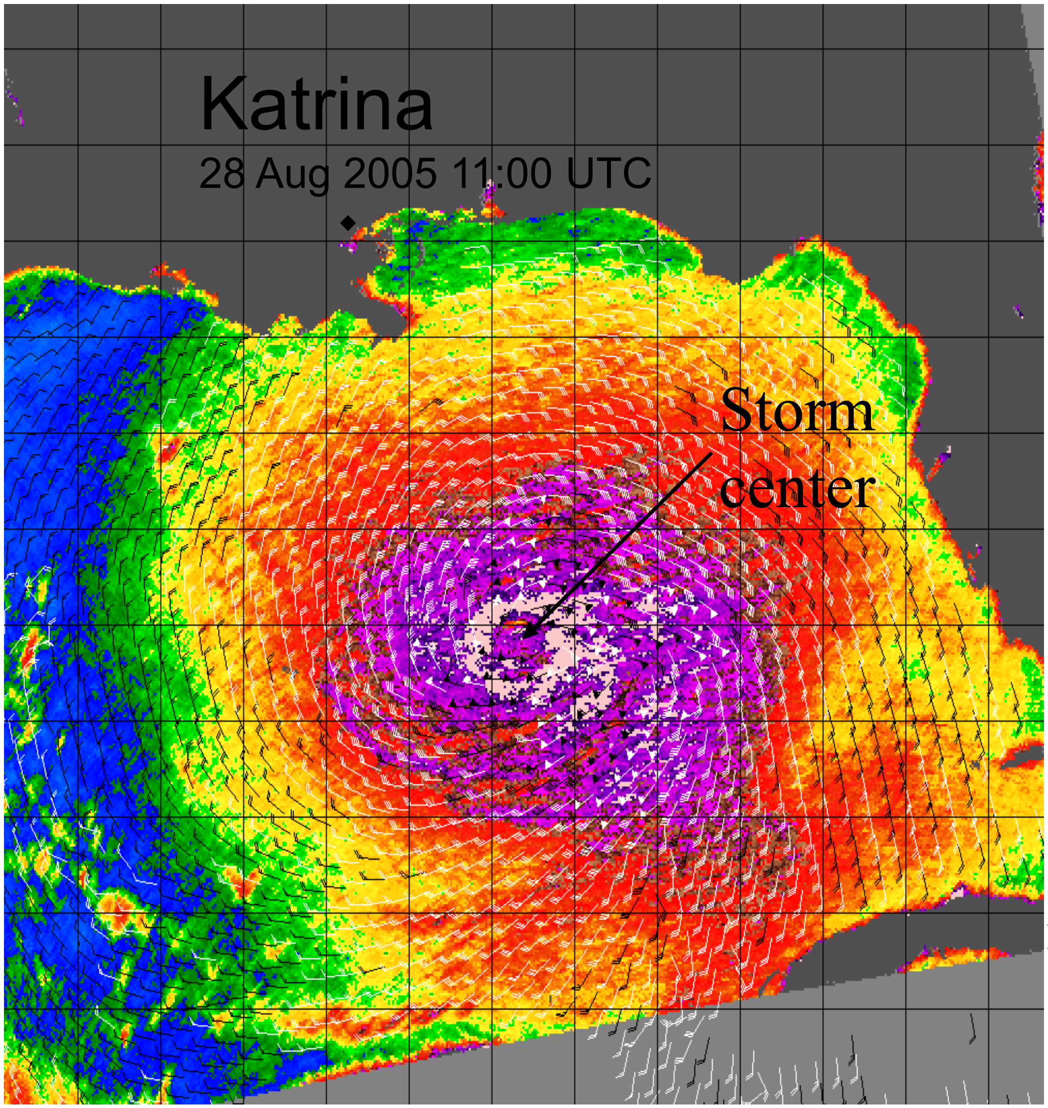
David G. Long
Brigham Young University

Progress

- Coastal land contamination product (*Poster*)
- QuikSCAT hurricane tracking (*Poster*)
- Hurricane model-based wind retrieval (*Paper*)

- Ultra-high resolution (UHR) simultaneous wind and rain retrieval (SWR)
- SAR-based wind & rain measurement

High Resolution Wind & Rain Retrieval for QuikSCAT



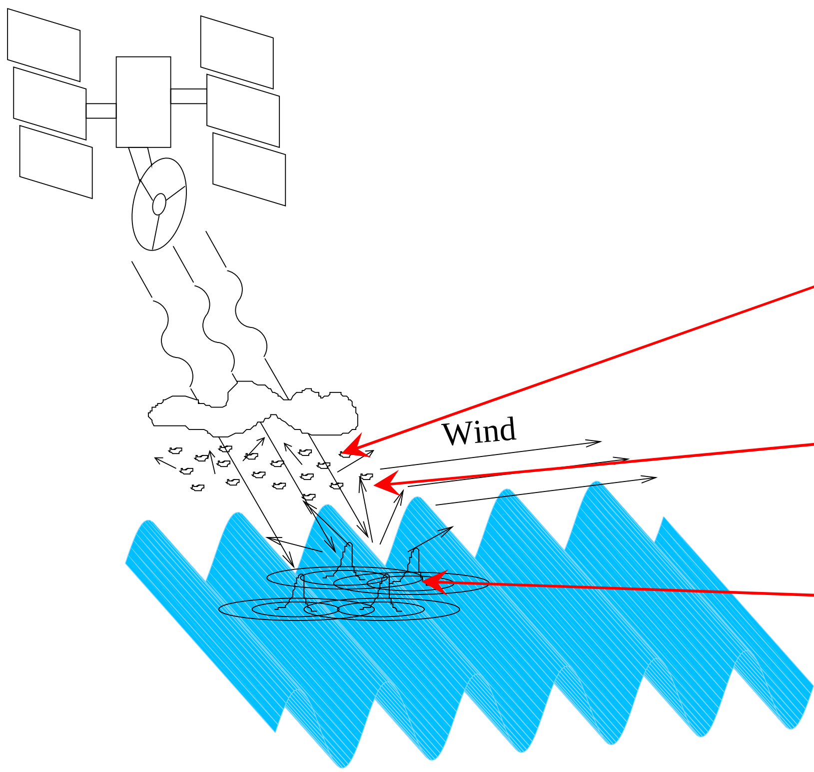
- Use reconstruction/resolution enhancement algorithm to produce 2.5 km/pixel sigma-0 estimates
- Estimate the wind at ultra high spatial resolution (UHR)
  - Value-added product
- 25 km Simultaneous wind/rain (SWR) retrieval techniques have proven viable for rain
  - Noisy compared to TRMM
- Extend SWR for UHR
  - Expect noisy, evaluate

http://manati.orbit.nesdis.noaa.gov/cgi-bin/qscat_storm.pl

(color) QuikSCAT ultra high resolution (2.5 km/pixel) wind speed
(barbs) conventional 25 km resolution L2B winds

Rain/Wind Backscatter Model

Ku-band



- Model for measured backscatter σ_M^o

$$\sigma^o = \left(\sigma_W^o + \sigma_{sr}^o\right)\alpha_R + \sigma_R^o$$

- Radar signal scattered by falling droplets σ_R^o
- Surface signal attenuated by atmospheric rain α_R
- Surface wind-induced σ_W^o backscatter perturbed by rain striking the water σ_{sr}^o

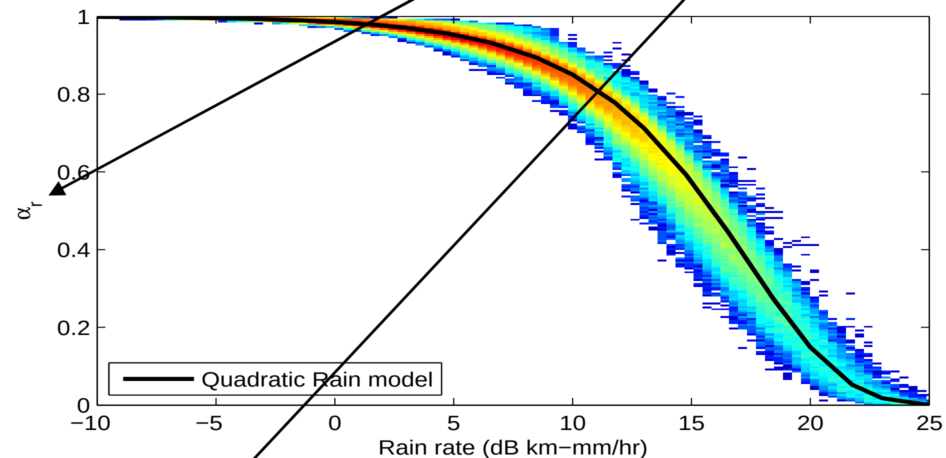
Simplified equivalent model: $\sigma^o = \sigma_W^o \alpha_R + \sigma_S^o$

SWR Rain Model Function

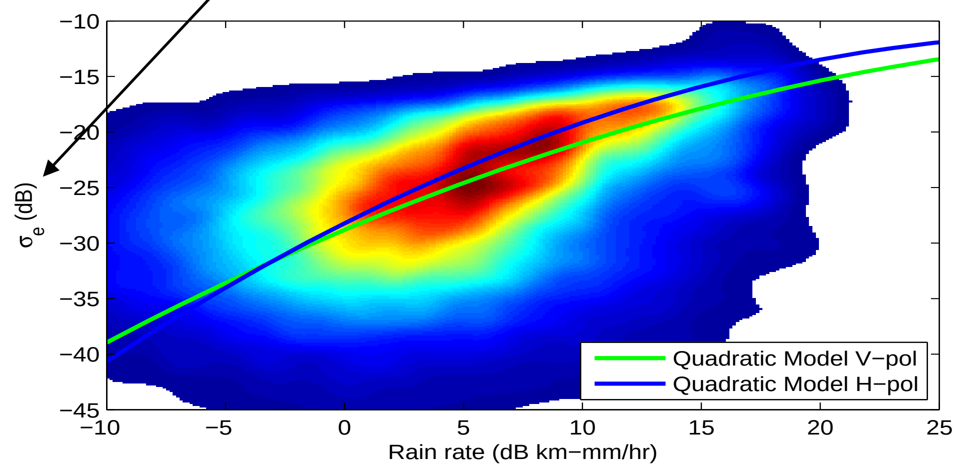
(tune for UHR)

$$\mathrm{GMF}_r(u, d, R, \ldots) = \mathrm{GMF}(u, d, \ldots)\alpha(R) + \sigma^{\circ}_{eff}(R)$$

$$\sigma^o = \sigma^o_W \alpha_R + \sigma^o_S$$



- Collocated TRMM PR & NCEP winds
- PR PIA and rain
- TRMM rain rate vs. effective rain backscatter estimates
  - NCEP vs. TRMM PR resolution



Simultaneous Wind-Rain Retrieval

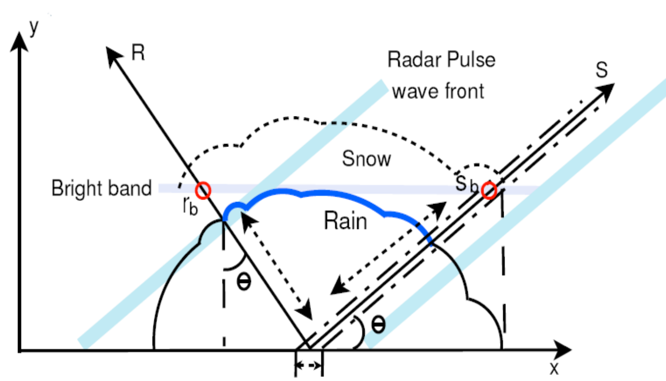
- Measurement model $\sigma^o = M_R(S,\chi,P,\omega,I,R) + noise$

$$p(\sigma^o \mid S,\chi,R) = \prod_k \frac{1}{\sqrt{2\pi\varsigma^2}} \exp\left\{-\frac{1}{2}\frac{(\sigma^o - M_R(S,\chi,P,\omega,I,R))^2}{\varsigma^2}\right\}$$

- MLE – log-likelihood function

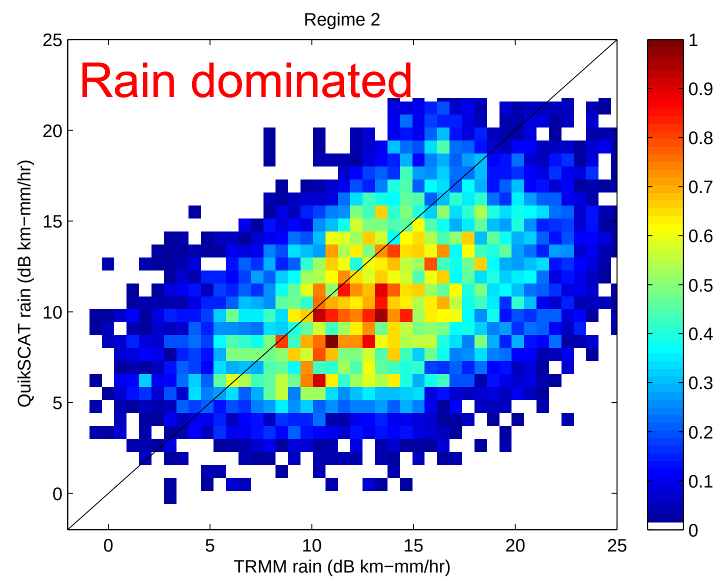
$$(\hat{S},\hat{\chi},\hat{R})_{MLE} = \arg\max(S,\chi,R \mid \sigma^o)\left\{-\frac{k}{2}\log(2\pi\varsigma^2) - \frac{1}{2}\sum_k \frac{(\sigma^o - M_R(S,\chi,P,\omega,I,R))^2}{\varsigma^2}\right\}$$

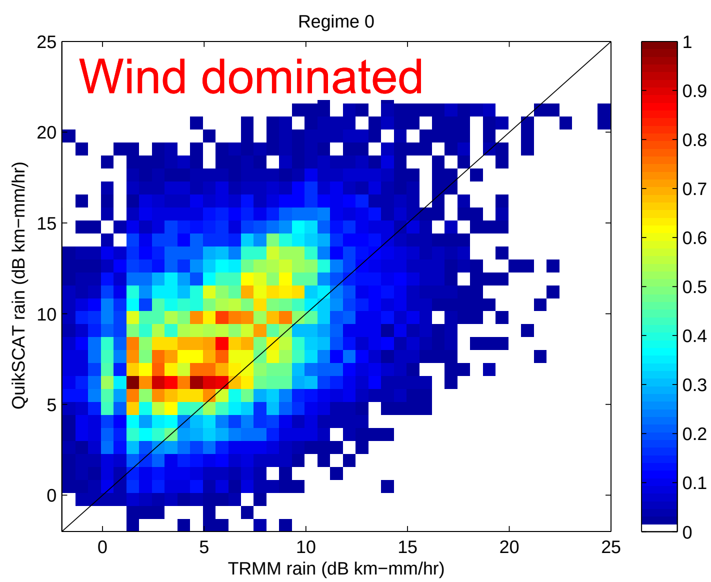
- UHR implementation

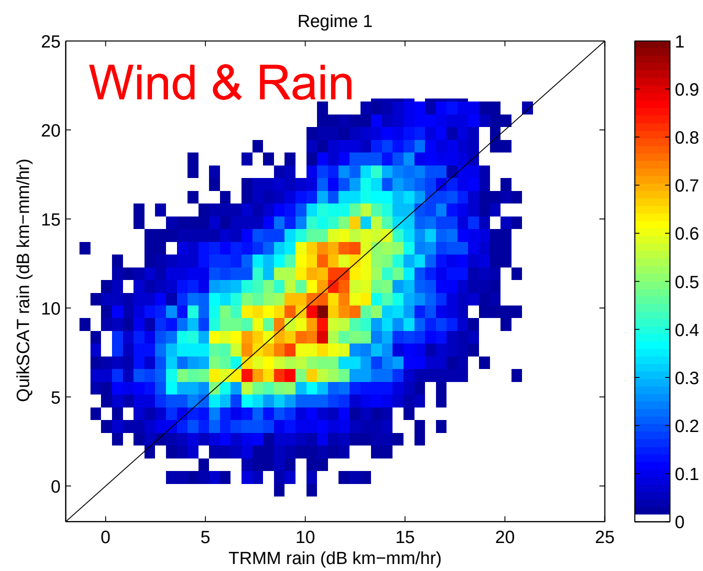


UHR SWR Rain Accuracy

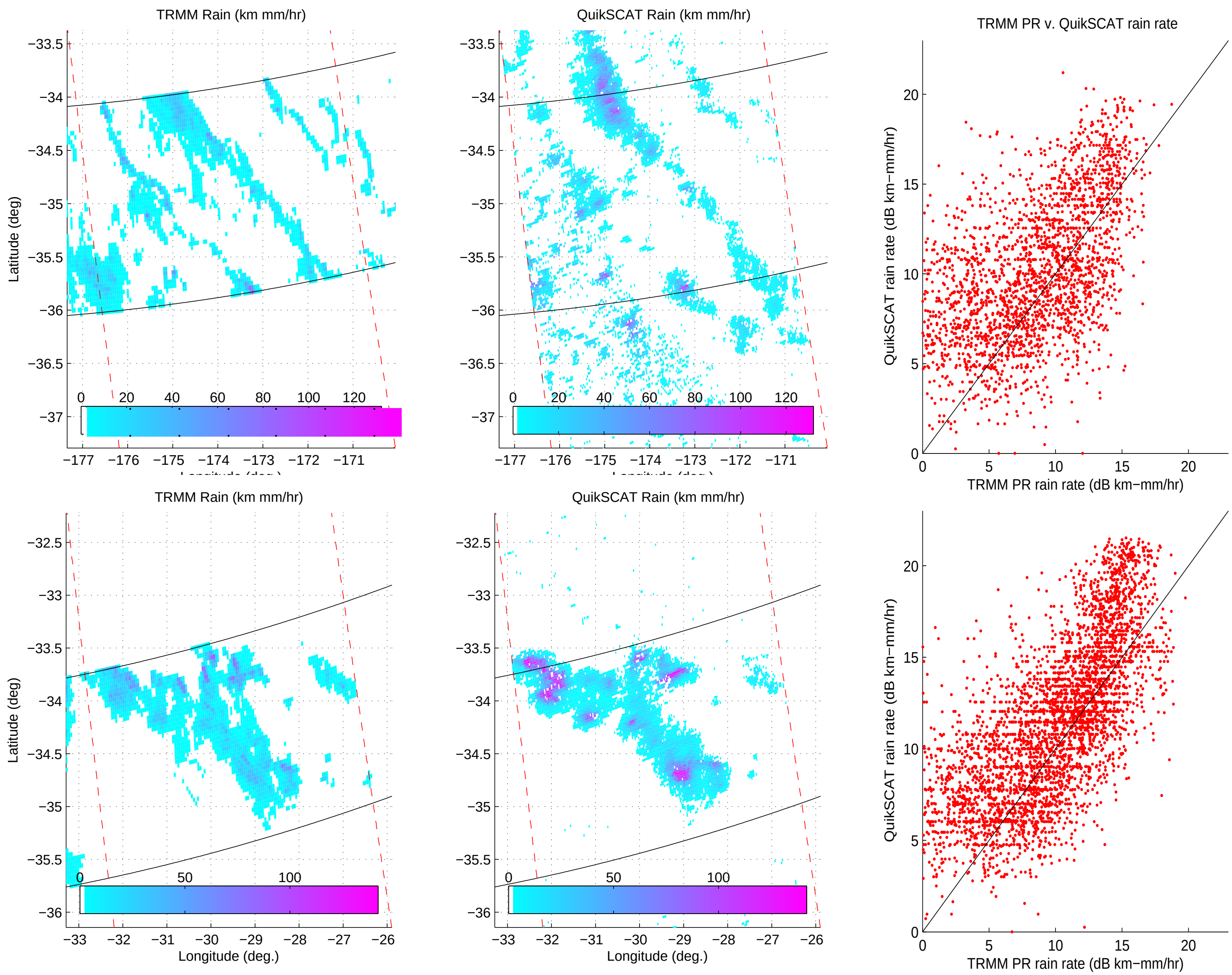
- Apply conventional simultaneous wind/rain retrieval
  - Minimize MLE to estimate wind and rain
- TRMM vs. QuikSCAT rain rates
  - High variance
- Regime 0 – biased high, wind backscatter mapped into rain space
- Regime 1 – unbiased wind & rain
- Regime 2 – biased low, rain backscatter mapped into wind space





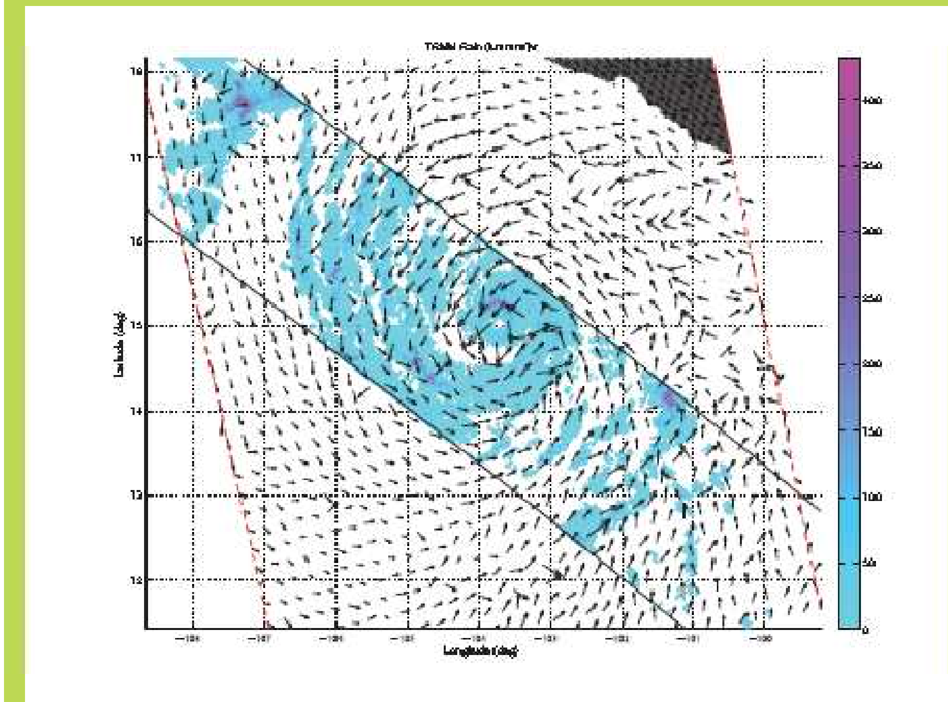


UHR SWR Co-location Examples

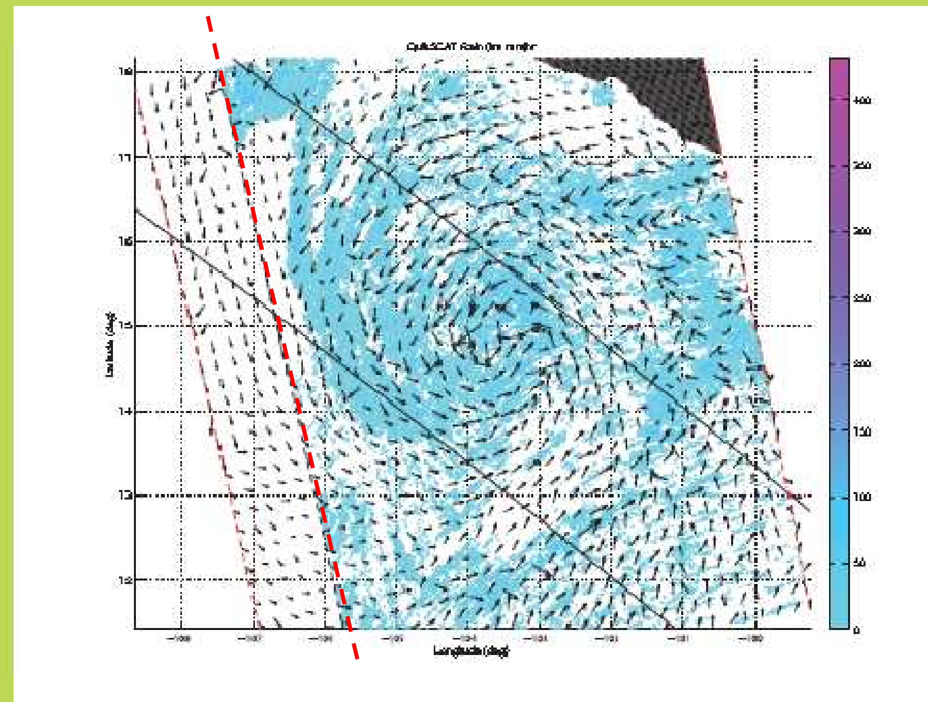


Hurricane Example

TRMM PR

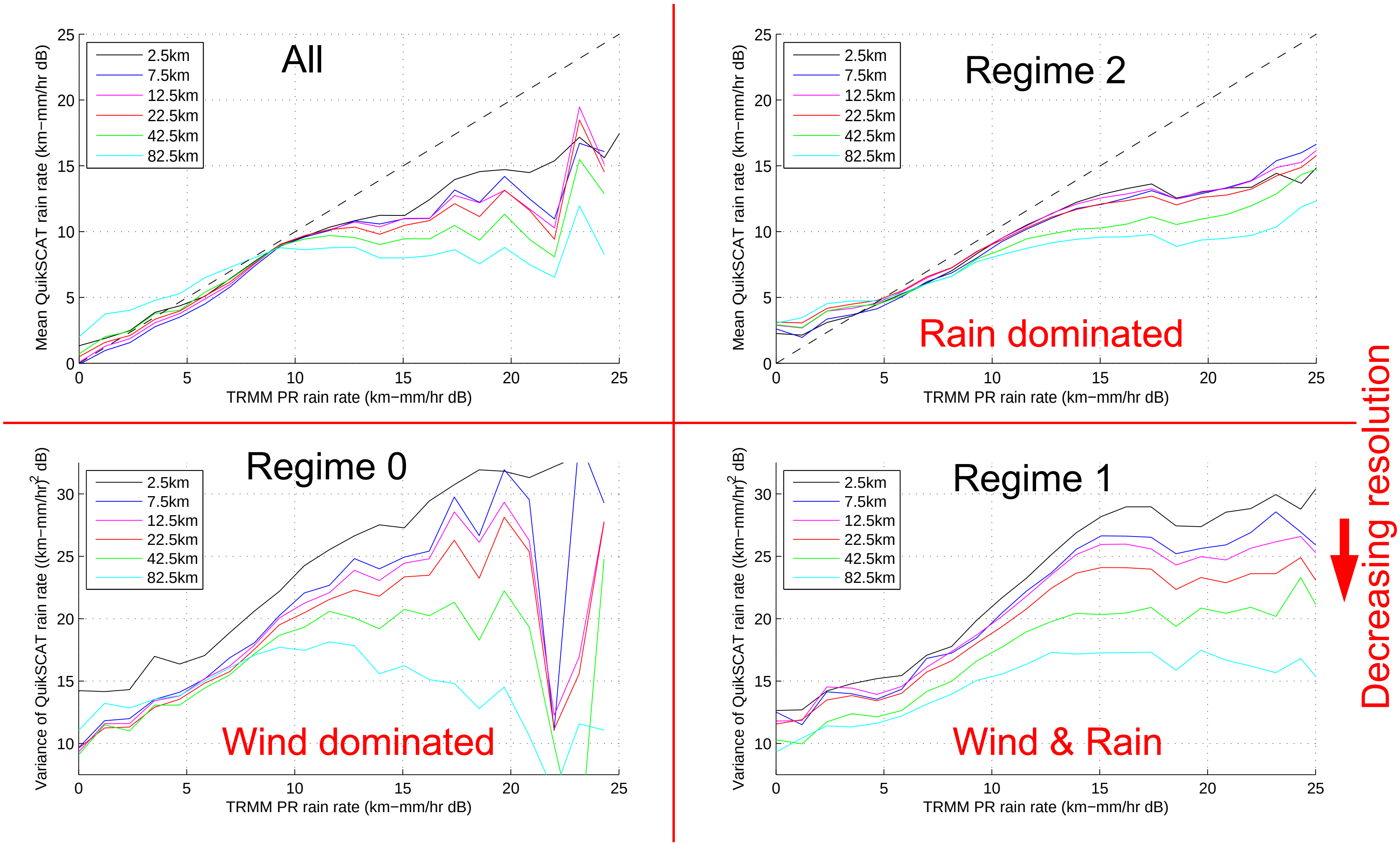


QuikSCAT UHR SWR



Resolution Reduction Study

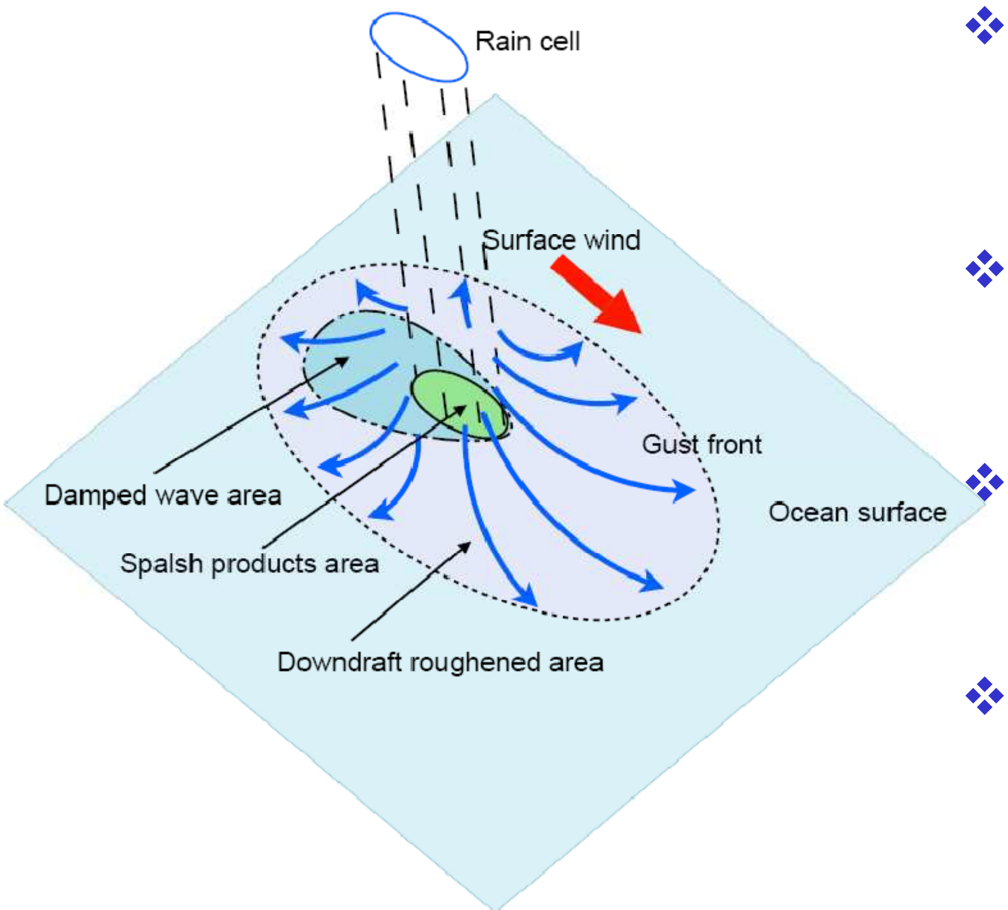
Can rain estimate error be reduced by degrading resolution?



19 Nov 2008 - DGL

Beam filling error is resolution sensitive…

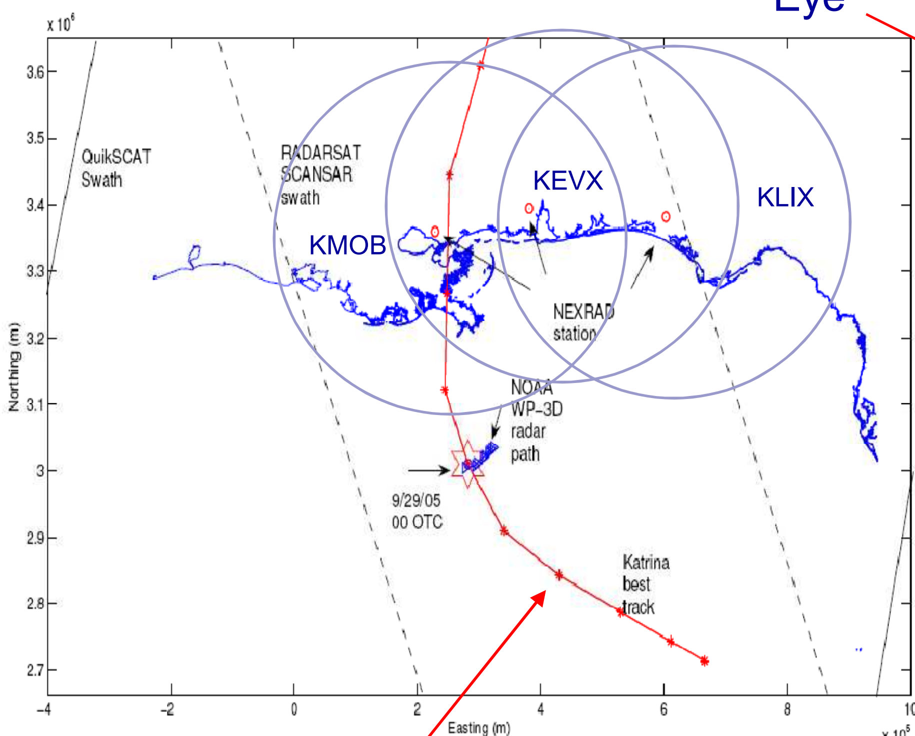
Surface Effects of Rain on Radar Measurements



- Splash products scatters scatterometer signal
  - Ring-waves dominate VV-polarization C-band
- Turbulence under the water attenuates the Bragg wave spectrum
- Sea surface roughness also affected by the airflow associated with rain cell
- Atmospheric backscattering and attenuation

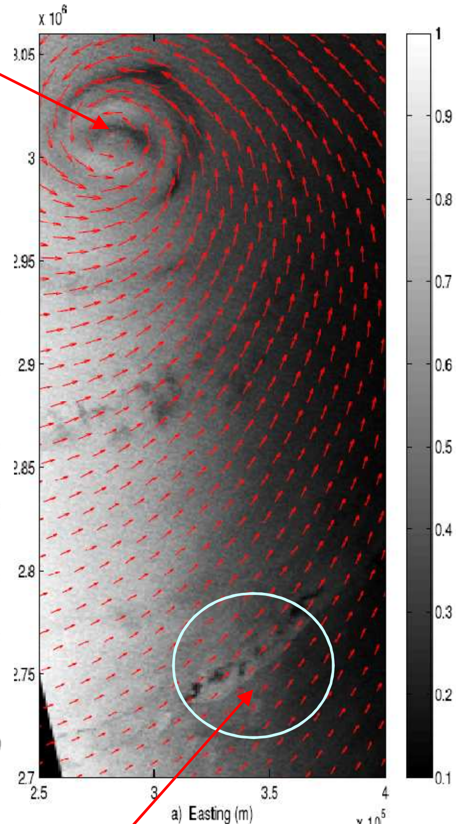
Coincident Rain Study Set

- C-band RADARSAT ScanSAR images 9/29/05 ~00 OTC
- NEXRAD
- QuikSCAT (within few mins)
- H*wind



Best track location of Katrina Eye

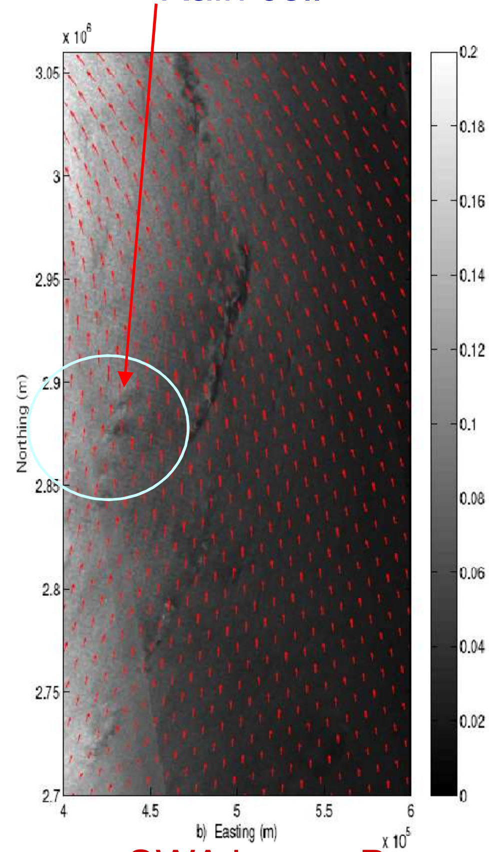
Eye



Rain band

SWA image A

Rain cell

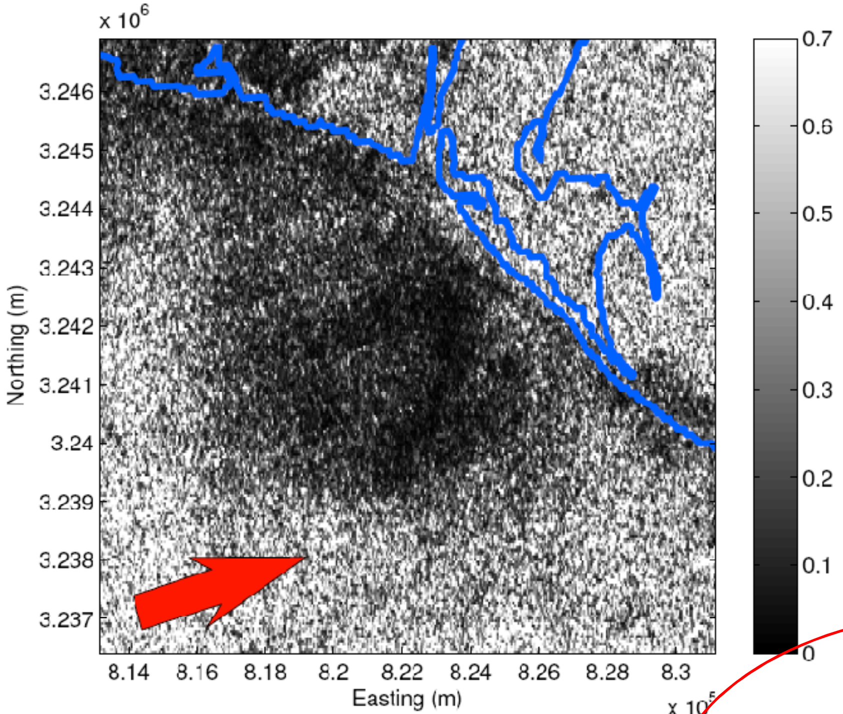


SWA image B

Rain Atmospheric Attenuation and Backscatter on SAR Measurements

- Atmospheric attenuation factor
- Path integrated attenuation (PIA) in dB
- Atmospheric attenuation
- Volume backscattering coefficient
- Observed volume backscattering cross-section
- Atmospheric backscatter

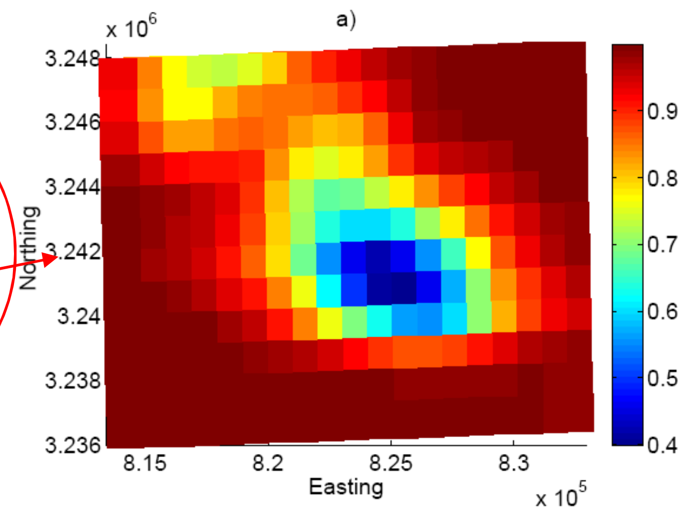
Rain cell at incidence angles between 22 and 23.6 degrees
(C-band)



SAR signature of rain cell

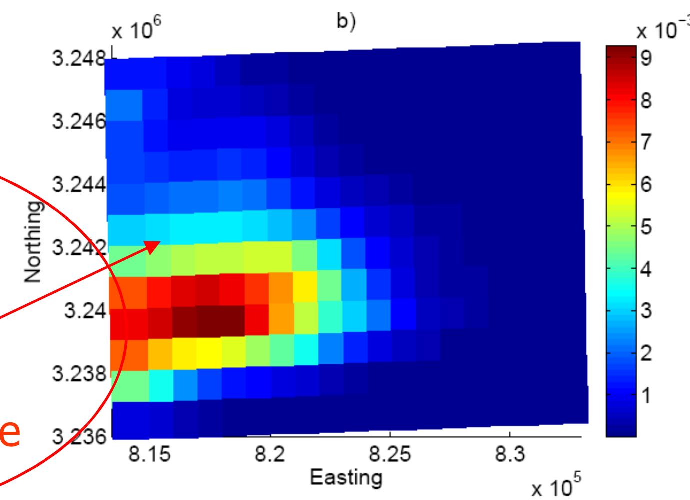
Attenuation

Significant at heavy rain



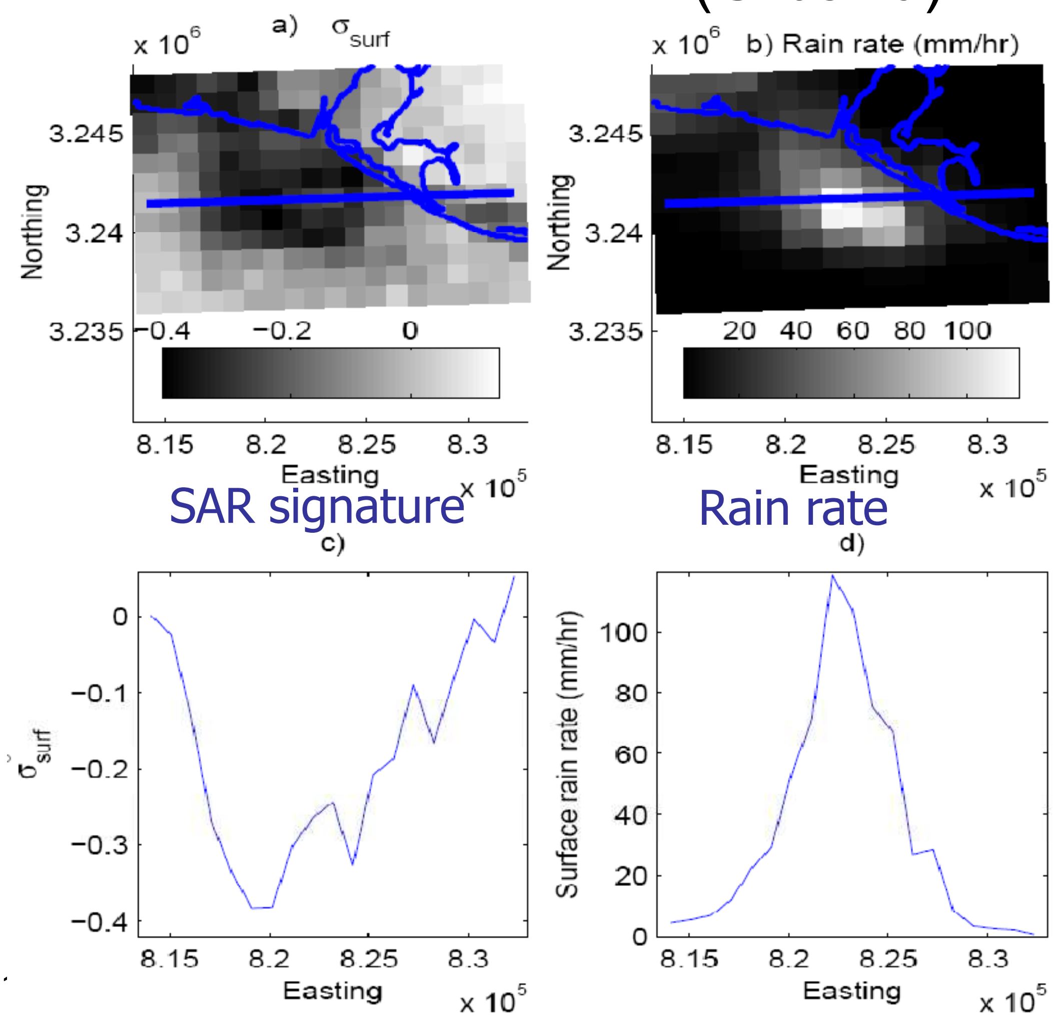
Atmospheric backscatter

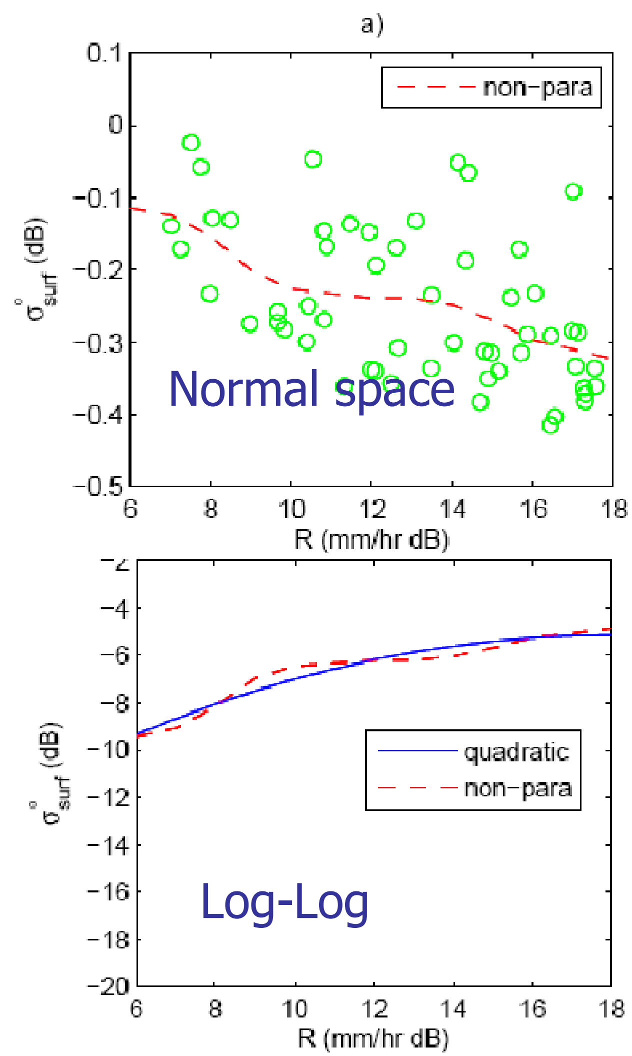
Insignificant at low incidence angle



Rain cell at incidence angles between 28 and 31.7 degrees

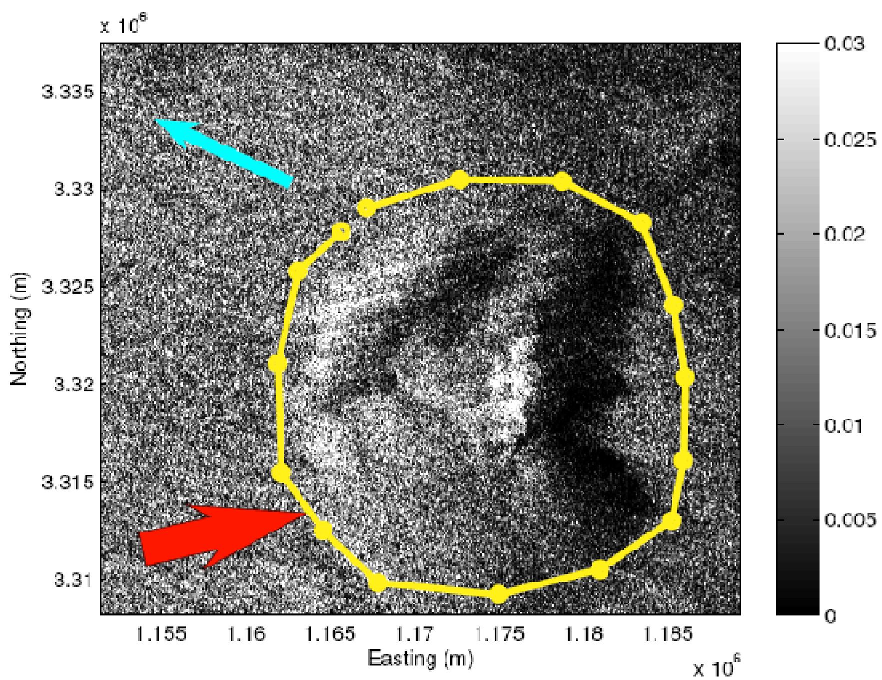
(C-band)





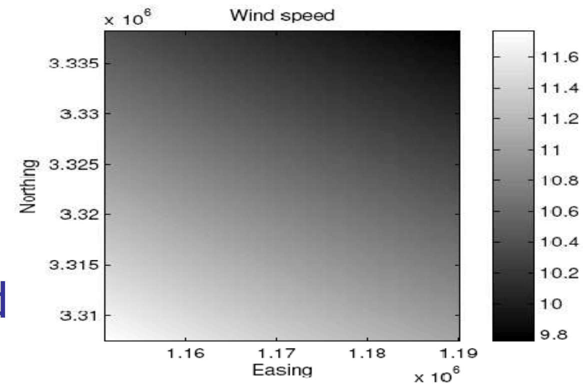
Rain cell at incidence angles between 44 and 45.7 degrees

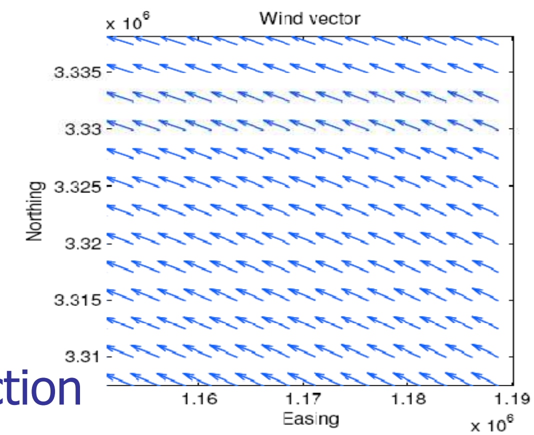
(C-band)



SAR signature of rain cell

Wind speed

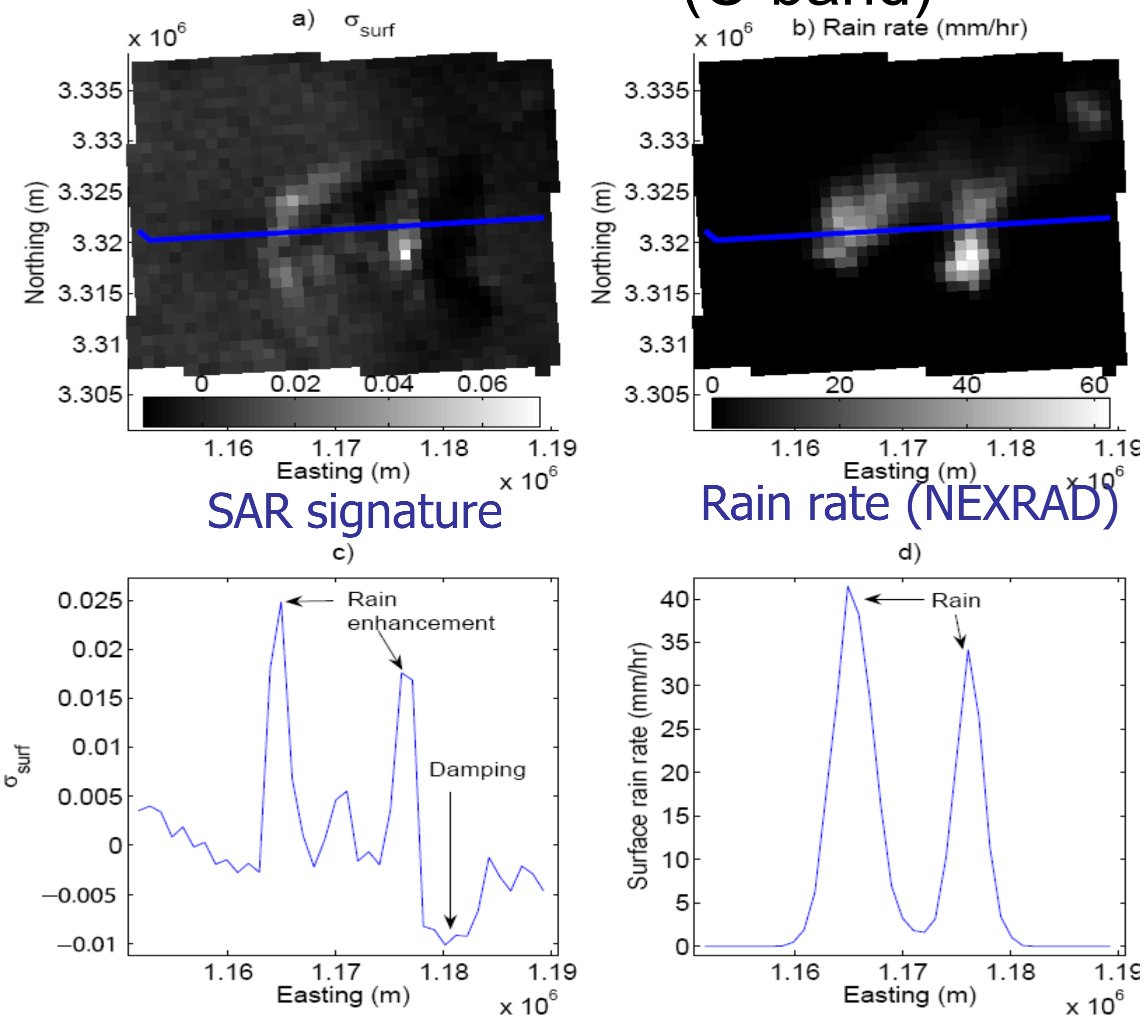


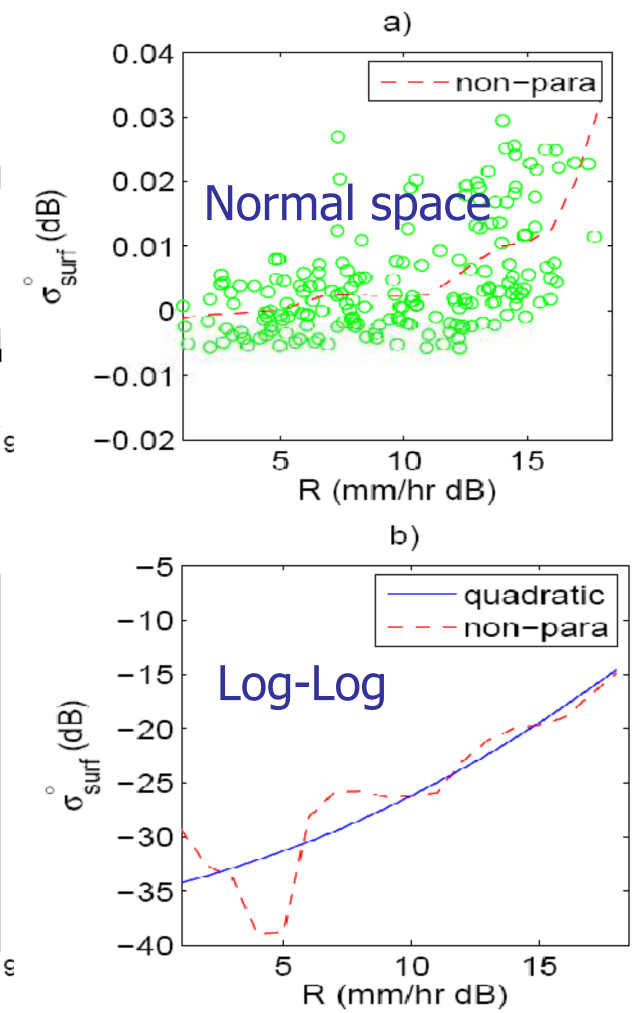


Wind direction

Rain cell at incidence angles between 44 and 45.7 degrees

(C-band)





Summary

- UHR SWR retrieval is a viable, high resolution rain retrieval algorithm (in absence of TRMM PR)
  - High noise levels
  - Tradeoff between resolution and estimate variance
- Simplistic polarization model to “recalibrate” ScanSAR SWA images
  - Tuned using collocated H*wind surface wind fields
- SAR-derived GMF consistent with the scatterometer-derived GMF
  - When HH and VV polarizations is considered
- Backscatter damping/enhancing observed in C-band SAR images

M.P. Owen and D.G. Long, "Land Contamination Compensation for QuikSCAT Near-Coastal Wind Retrieval", to appear, *IEEE Transactions on Geoscience and Remote Sensing,* 2008.

C. Nie and D.G. Long, "A C-Band Scatterometer Simultaneous Wind/Rain Retrieval Method", to appear, *IEEE Transactions on Geoscience and Remote Sensing,* 2008.

S. Nielsen and D.G. Long, "A Wind and Rain Backscatter Model Derived from AMSR and SeaWinds Data", to appear, *IEEE Transactions on Geoscience and Remote Sensing,* 2008.

B.A. Williams and D.G. Long, "Estimation of Hurricane Winds from SeaWinds at Ultra High Resolution", *IEEE Transactions on Geoscience and Remote Sensing,* Vol. 46, No. 10, pp. 2924-2935, 2008.