# Application and Validation of Ultra High Resolution Wind, Backscatter, and Brightness Temperature

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# Objectives

- Refine methods for spatial resolution enhancement
  - Support land/ice studies and high resolution wind retrieval
  - Apply resolution enhancement methods to WindSat
- Develop improved algorithms for ultra high resolution wind retrieval ambiguity removal
- Validate ultra high resolution winds in severe storms
- Add rain and quality assurance flagging for ultra high resolution winds
- Investigate the use of model-based wind field estimation with enhanced resolution backscatter measurements

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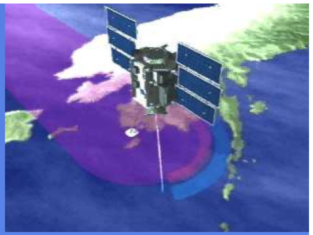
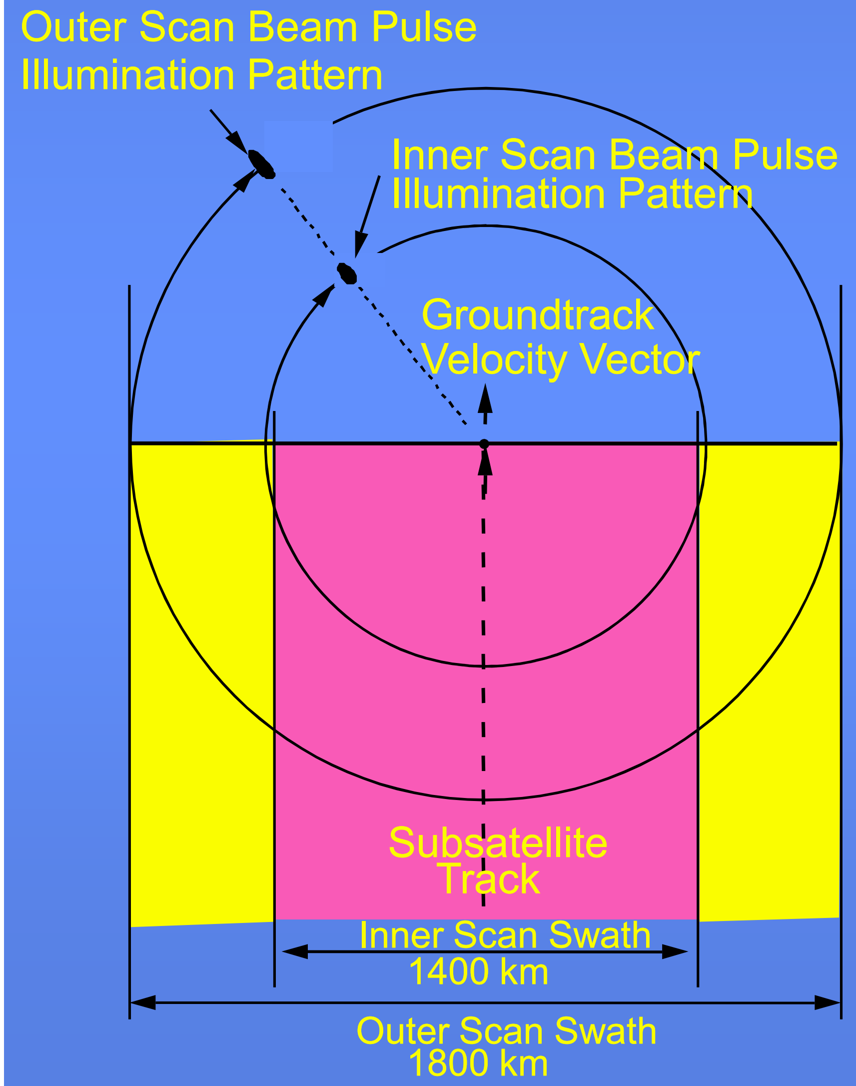
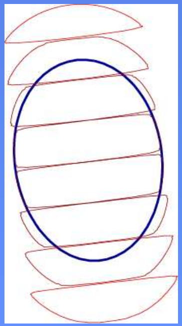
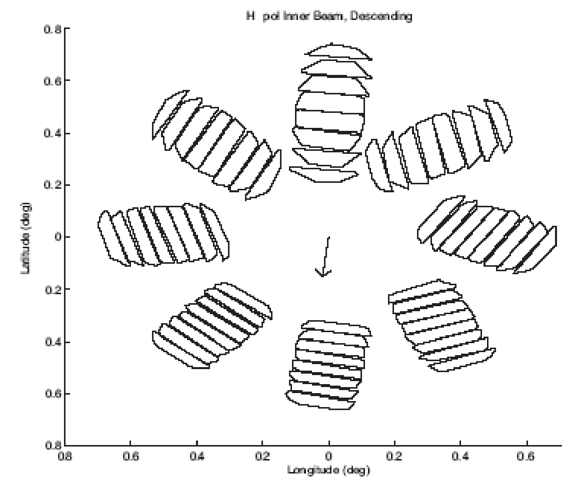
# SeaWinds Measurements

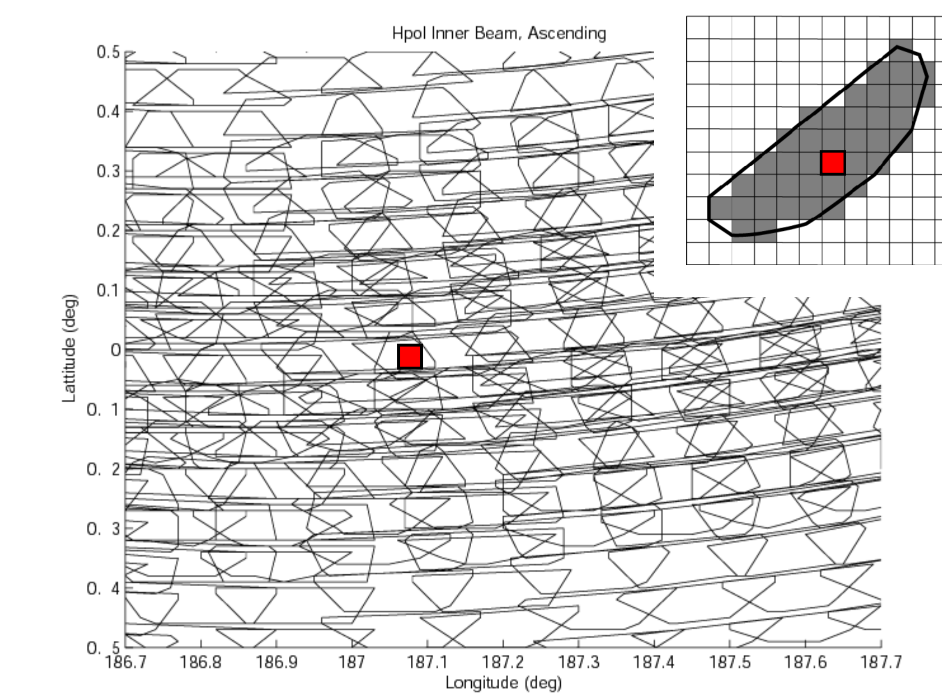




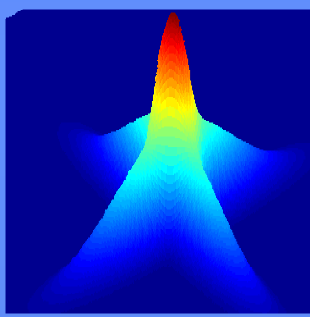
Slice Response ~ 6 x 25 km

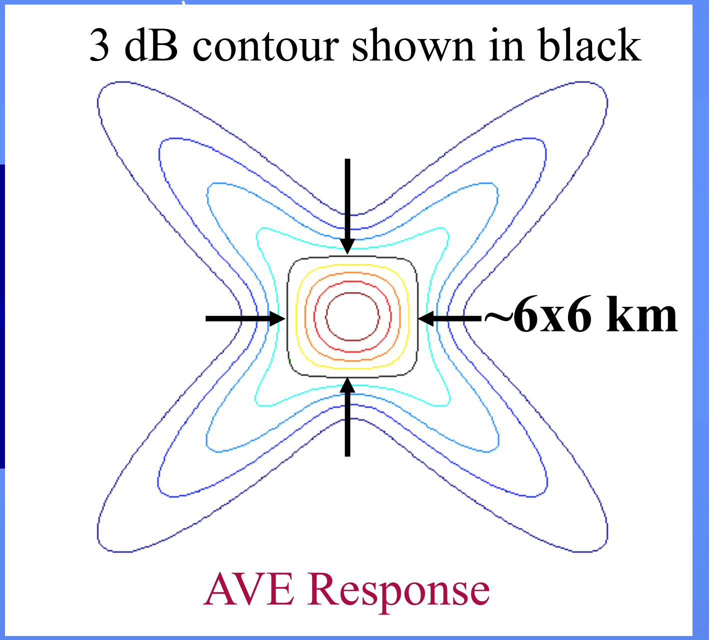


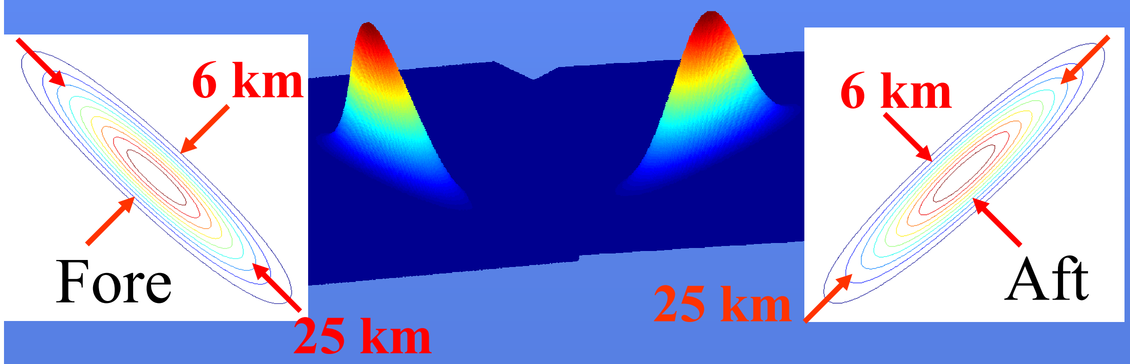



# Resolution Improvement

- The spatial response function and sampling define the effective resolution exploited by SIR reconstruction
- AVE response is the weighted average of measurement responses covering each pixel
  - Incomplete reconstruction
  - First iteration of the SIR algorithm

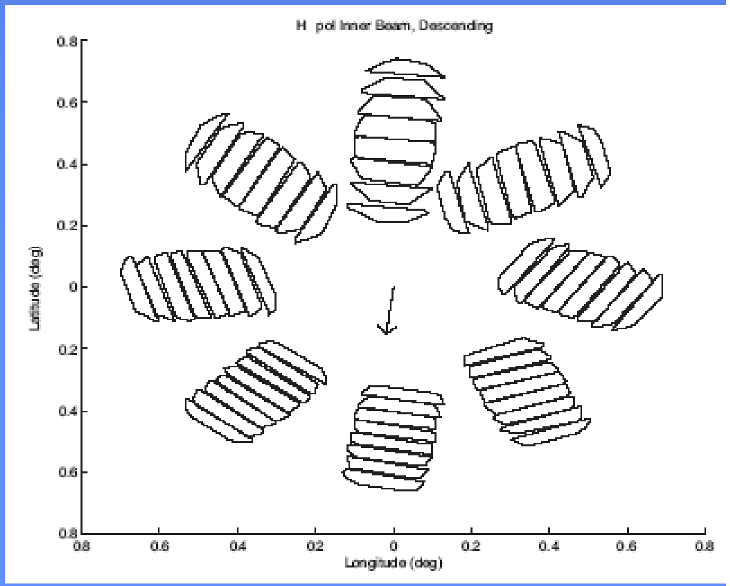




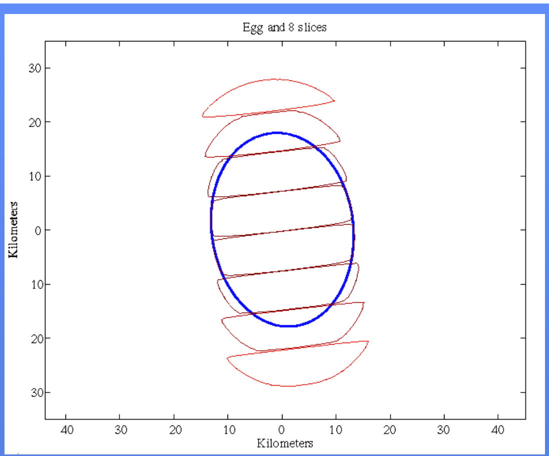




Individual 6 x 25 km “Slice” responses = product of azimuth antenna pattern and Doppler/range filtering

# QuikSCAT Spatial Response Function

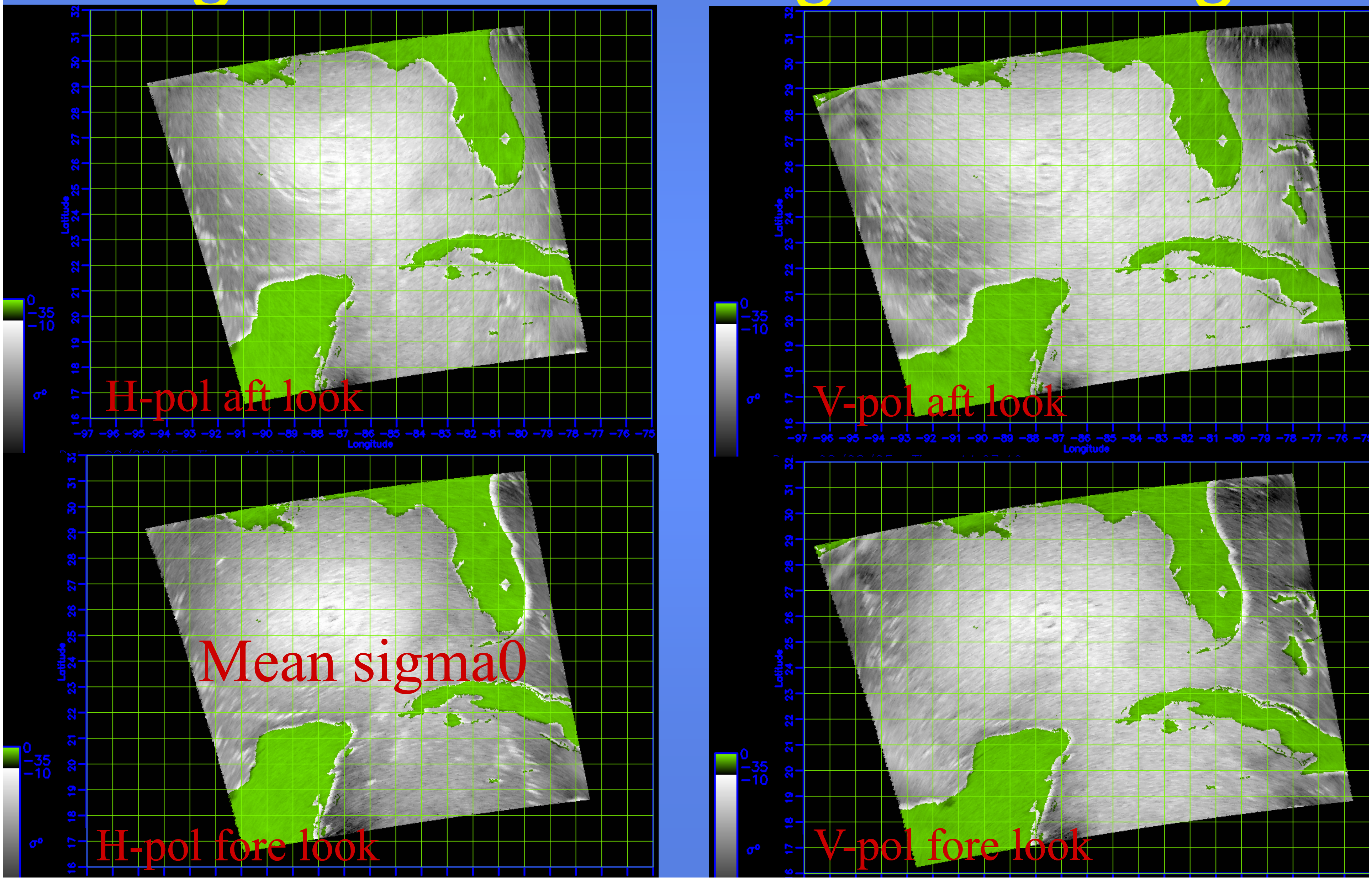



- Slices: spatial "rect" (1/0)
  - 8 sided figure
  - Nominally, ~6 km by 25 km
- Eggs: 2 dimensional polynomial
  - Nominally, ~ 25 km by 35 km
- Response function varies with azimuth angle and orbit position
  - Tabularized function
- Data and tables available from
  http://www.scp.byu.edu/software/Xshape/Xshape.html




I.S. Ashcraft and D.G. Long, The spatial response function of SeaWinds backscatter measurements," in "Earth Observations Systems VIII," W.L. Barnes, ed., *Proceedings of SPIE Vol. 5151*, pp. 609-619, 3-6 Aug 2003.

# Single Look UHR sigma-0 Images



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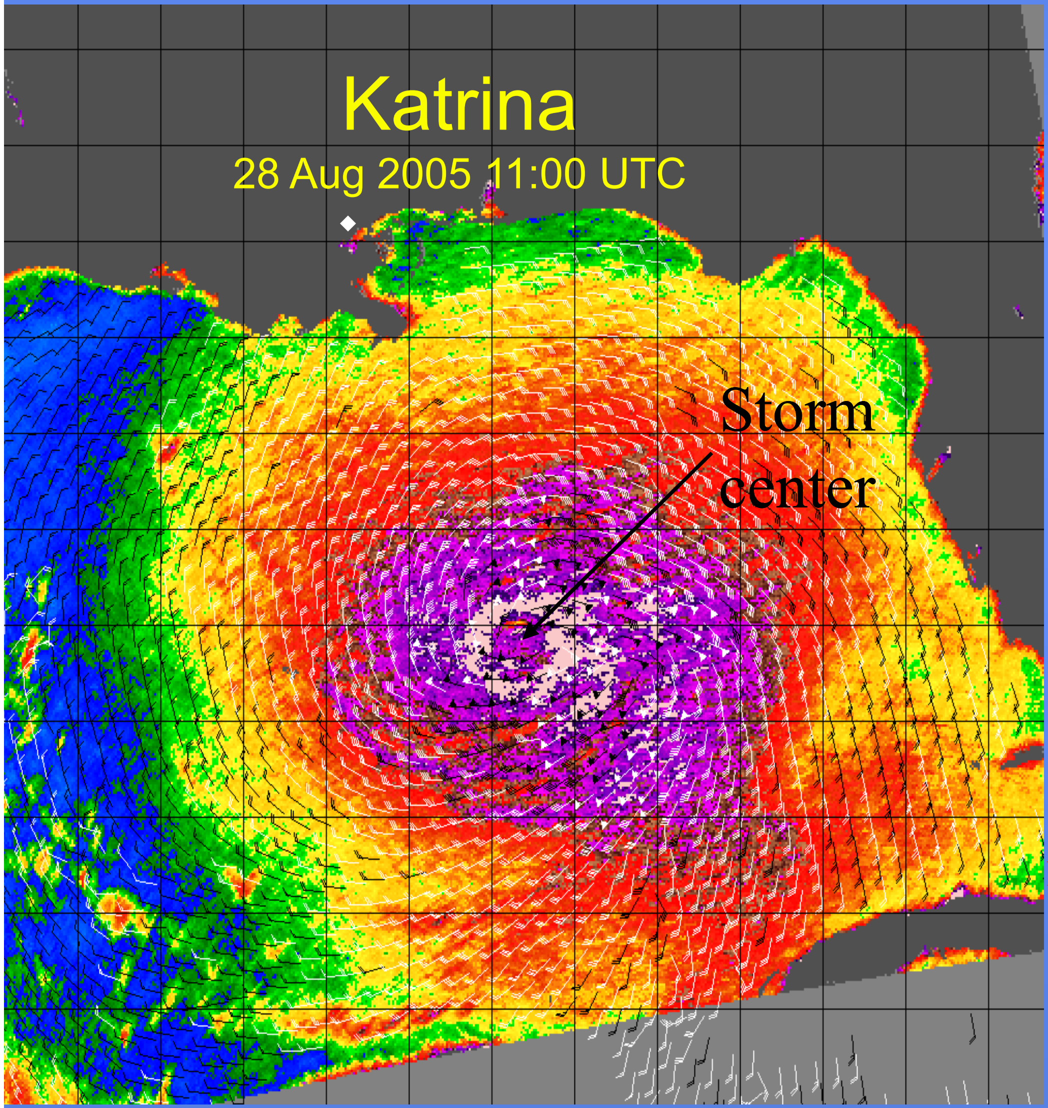
# High Resolution Wind Retrieval for SeaWinds




- QuikSCAT originally designed to make 25 km resolution ocean wind measurements
- 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
  - Useful for hurricane tracking, near-coastal studies

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

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# Buoy Comparisons*

50 km collocation radius w/only open ocean buoys

| | | speed | direction rms | | | |
|---|---|---|---|---|---|---|
| dataset | rms | bias | 3-20 m/s | 5-20 m/s | npts | |
| L2B | 1.26 | 0.046 | 24.03 | 19.06 | 156592 | 25 km |
| L2B ed | 1.23 | 0.027 | 18.84 | 16.14 | 151732 | |
| UHR | 1.58 | -0.533 | 31.61 | 26.29 | 15286960 | 2.5 km |
| UHR ed | 1.56 | -0.577 | 24.89 | 22.32 | 14578315 | |
| CLO | 1.58 | -0.535 | 24.61 | 21.53 | 15286960 | |
| CLO ed | 1.58 | -0.537 | 23.37 | 20.87 | 15173693 | |

CLO = UHR ambiguity closest to buoy

ed = buoy and selected direction within 90 deg

*Thanks to Mike Freilich and Barry Vanhoff

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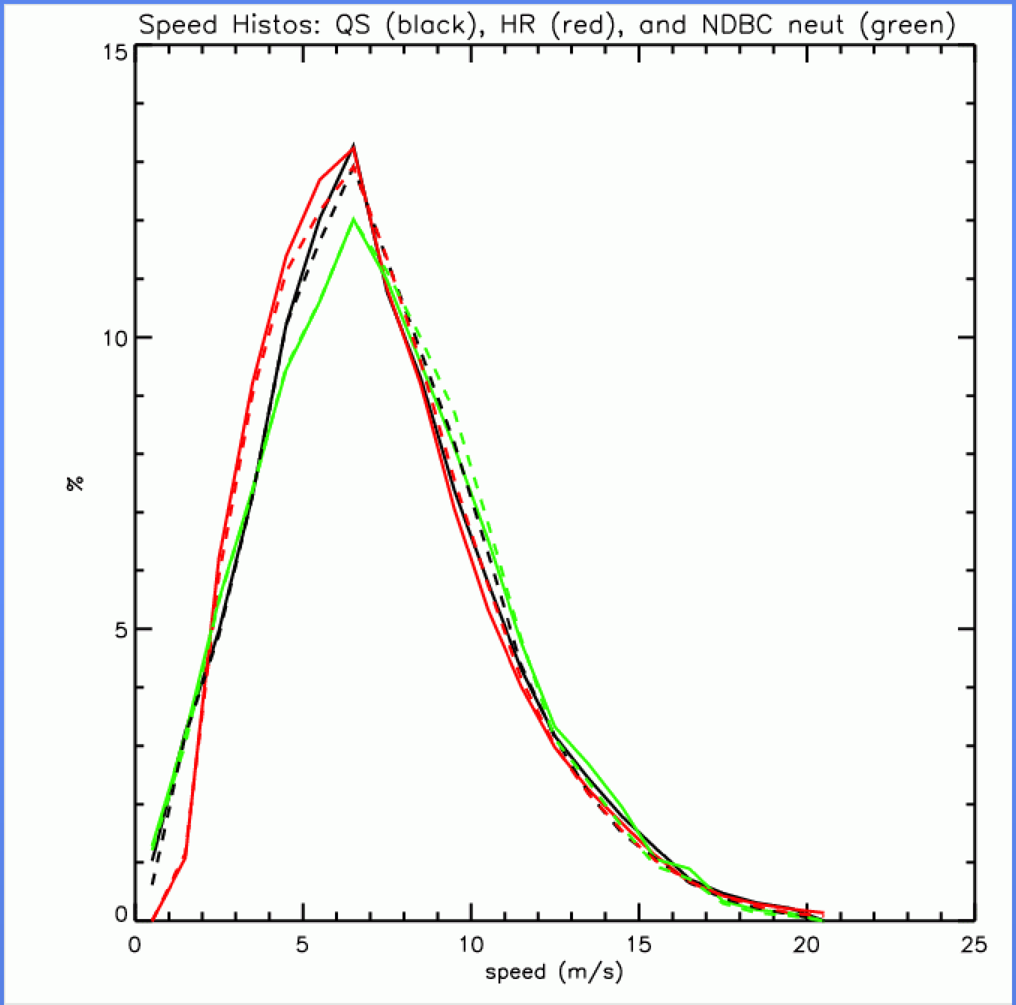
# UHR Validation with Buoys*

## Initial Results

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# UHR Validation with Buoys*

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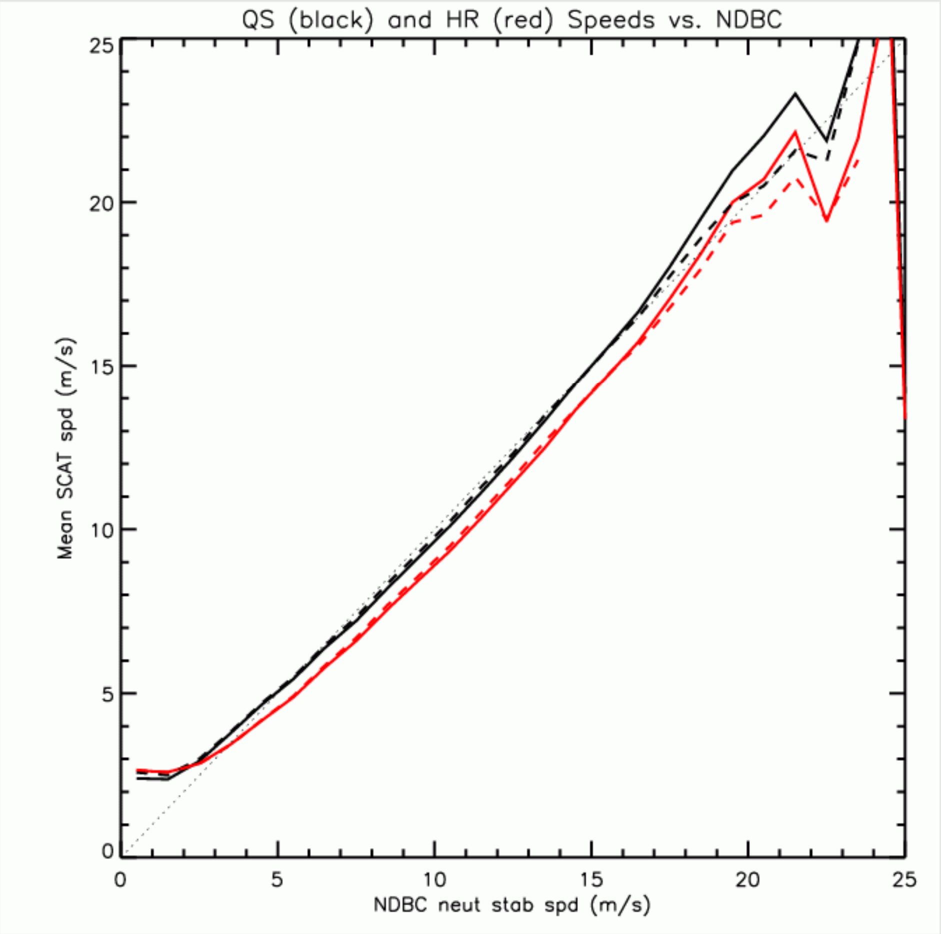


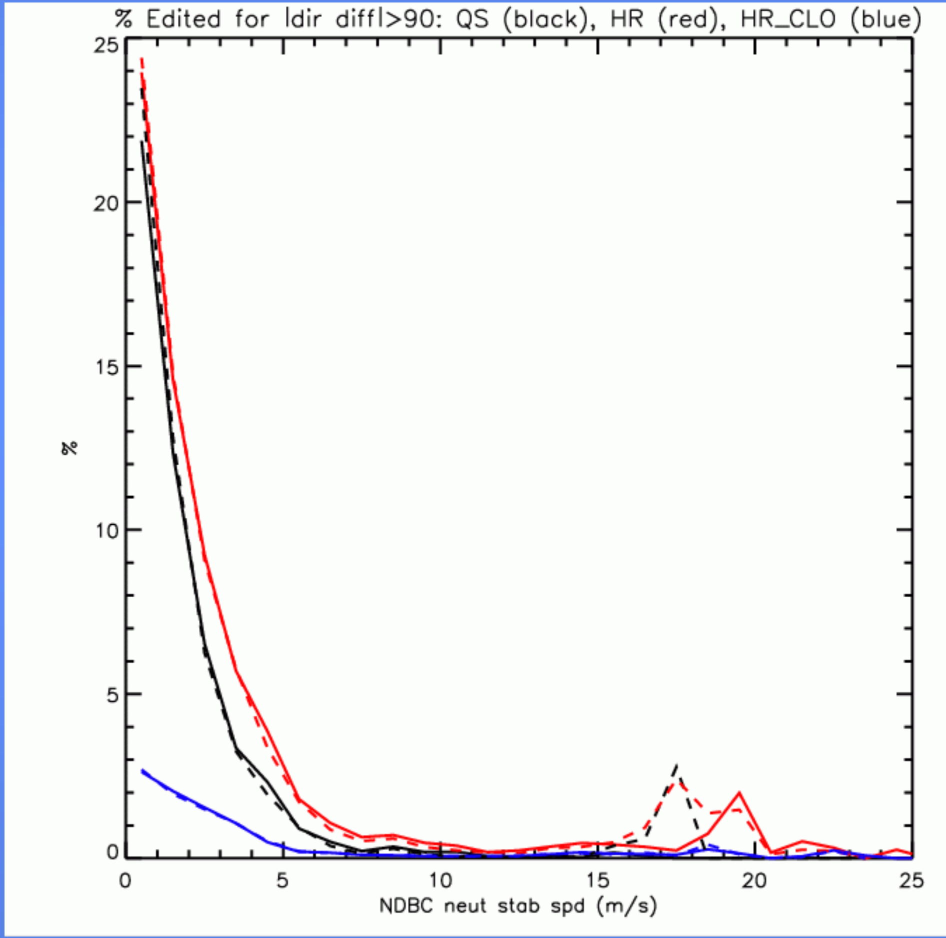


* Thanks to Mike Freilich and Barry Vanhoff

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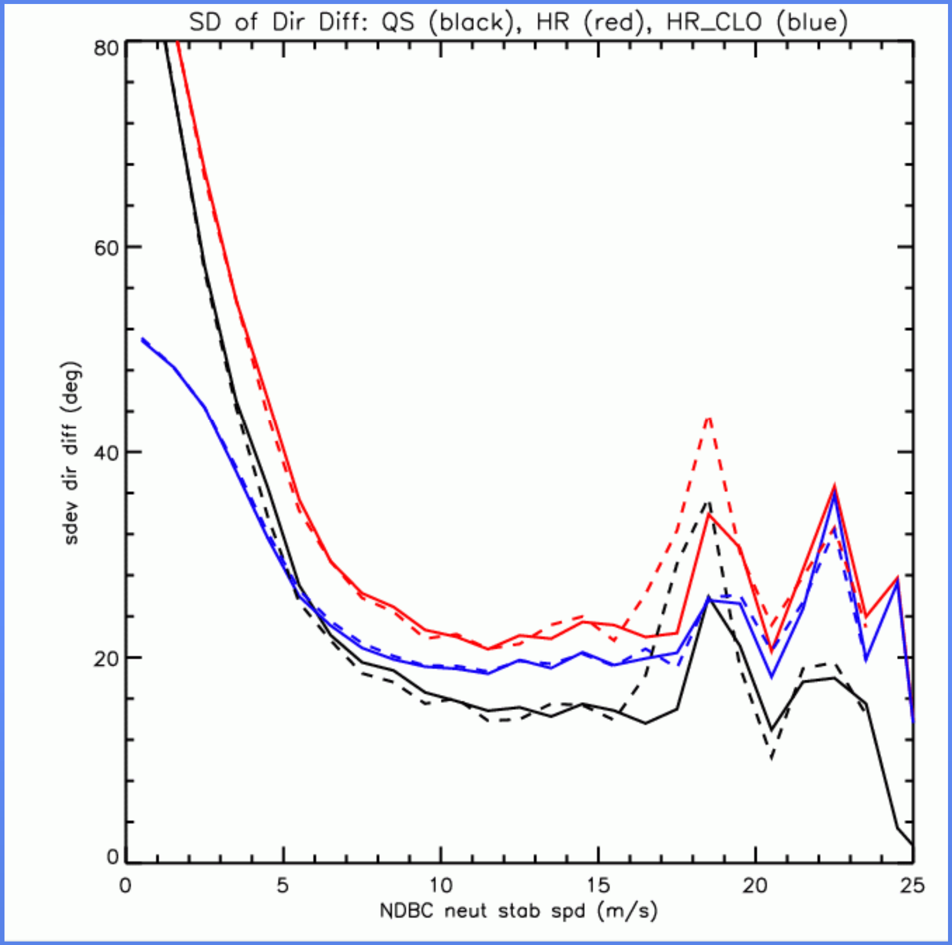
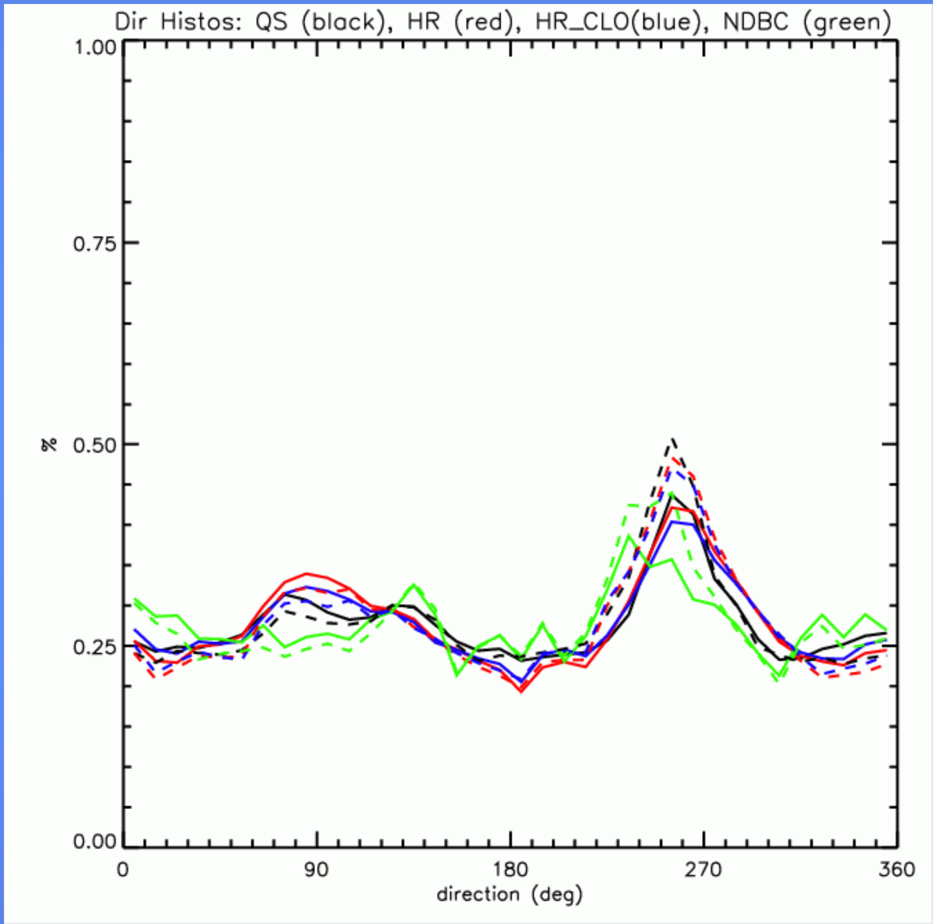
# UHR Validation with Buoys*

## Initial Results




* Thanks to Mike Freilich and Barry Vanhoff

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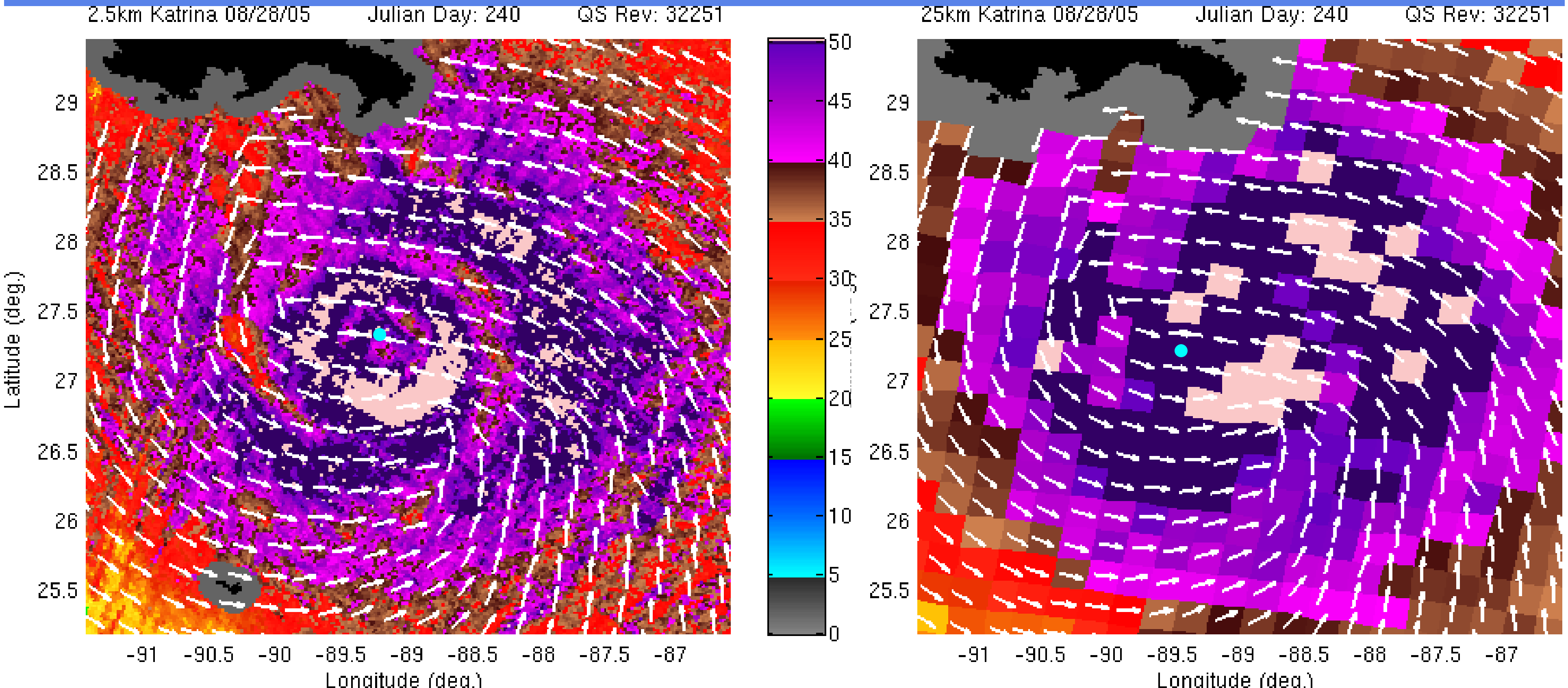
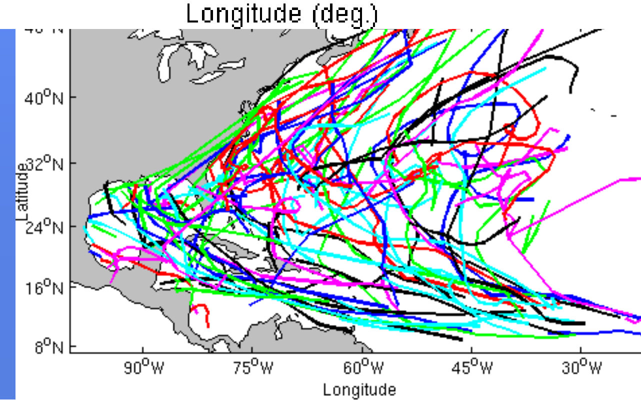
# Hurricane tracking



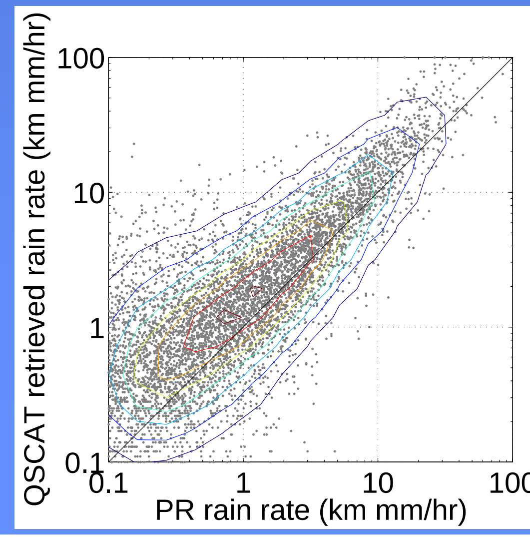

Postage stamp images of all storms during the QuikSCAT era processed and available on Paul Chang's web site

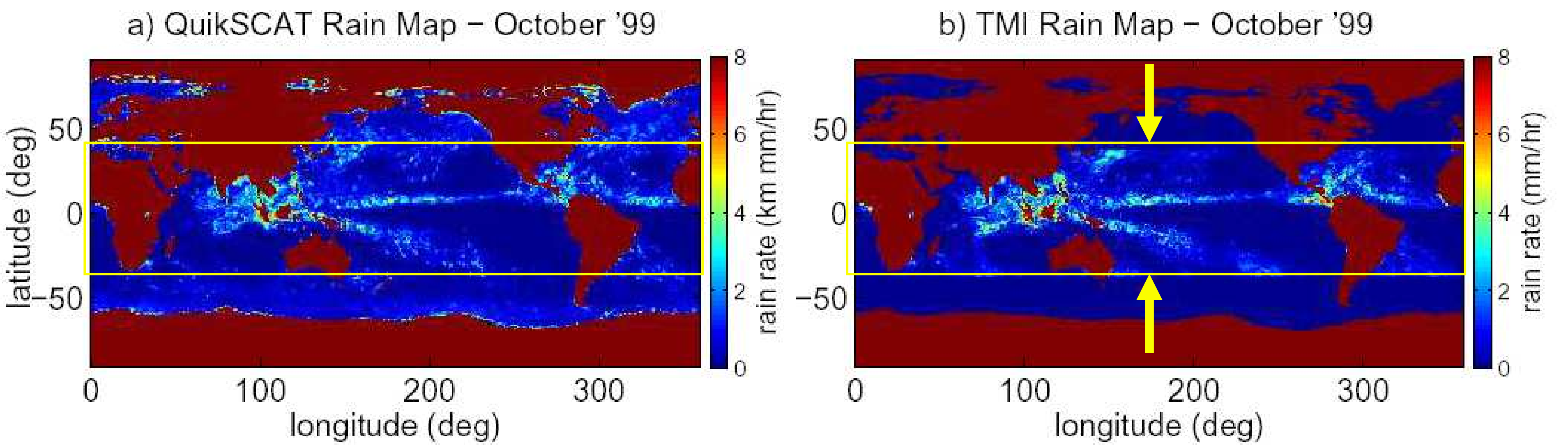
http://manati.orbit.nesdis.noaa.gov/cgi-bin/qscat_storm.pl



# QuikSCAT Simultaneous Wind/Rain Validation

- QuikSCAT-derived rain rates vs TRMM-derived rain rates & NEXRAD
  - QuikSCAT has higher variability
  - Broader coverage

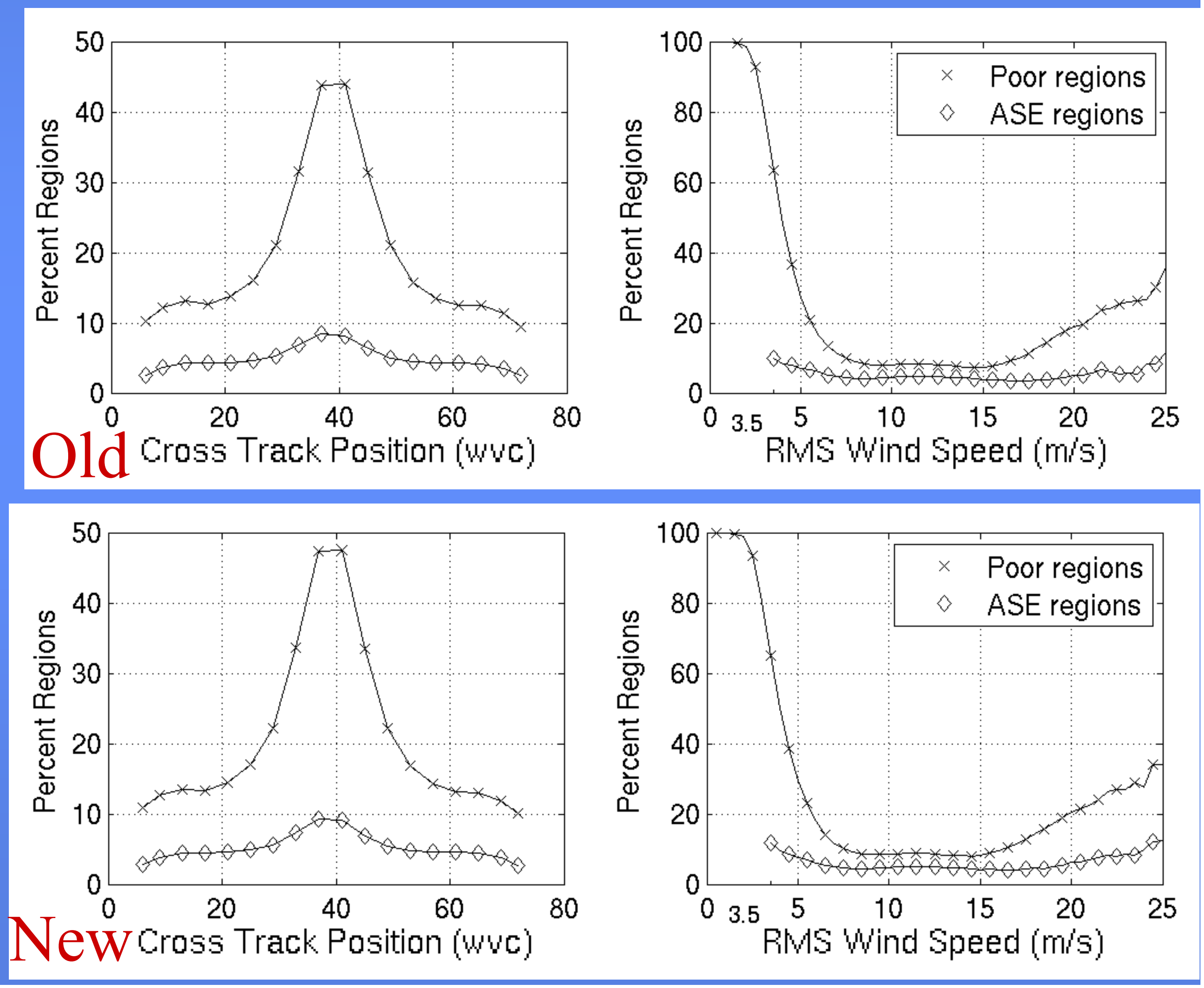


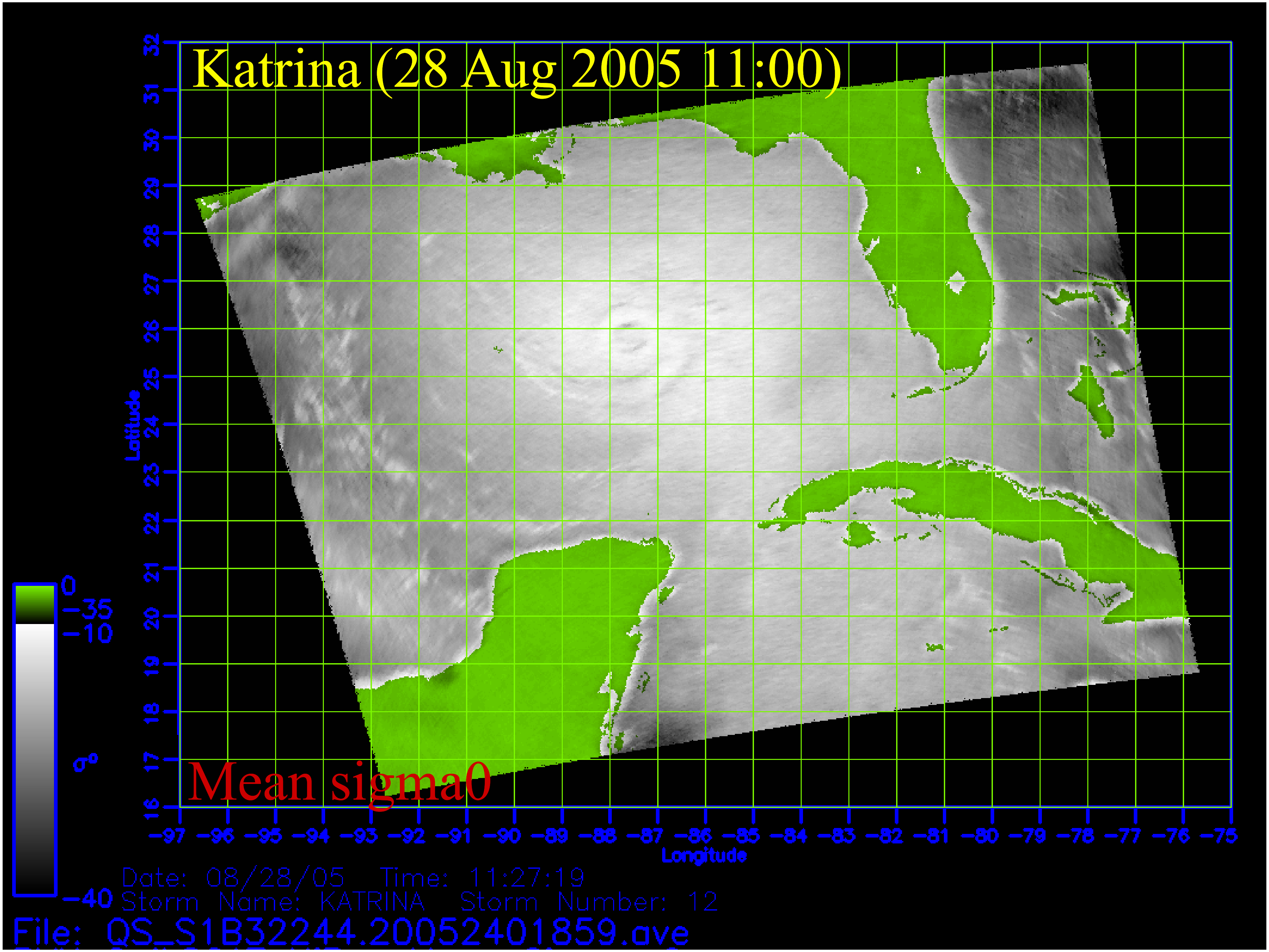
# QA Analysis Summary

## Compare new L2B with old

- 95% of 8 wvc × 8 wvc regions do not contain substantial ambiguity errors
- ~5% of the regions flagged with substantial ambiguity ‘errors’
- Noisy wind vectors or ambiguity sets with limited solution vectors are also flagged
  - False alarm probability 1.5%
  - Missed detection probability 3% of regions w/ambiguity selection errors (corresponding to ~0.25% of total)
- Performance of new L2B is slightly worse at nadir and high wind speeds, similar elsewhere




Method described in:
D.W. Draper and D.G. Long, An Assessment of SeaWinds on QuikSCAT Wind Retrieval, *Journal of Geophysical Research*, Vol. 107, No. C12, pp. 3212-3226, Dec. 2002.


Katrina (28 Aug 2005 11:00)
Mean sigma0
Latitude
Longitude
0
−35
−10
σ°
−40
Date: 08/28/05 Time: 11:27:19
Storm Name: KATRINA Storm Number: 12
File: QS_S1B32244.20052401859.ave

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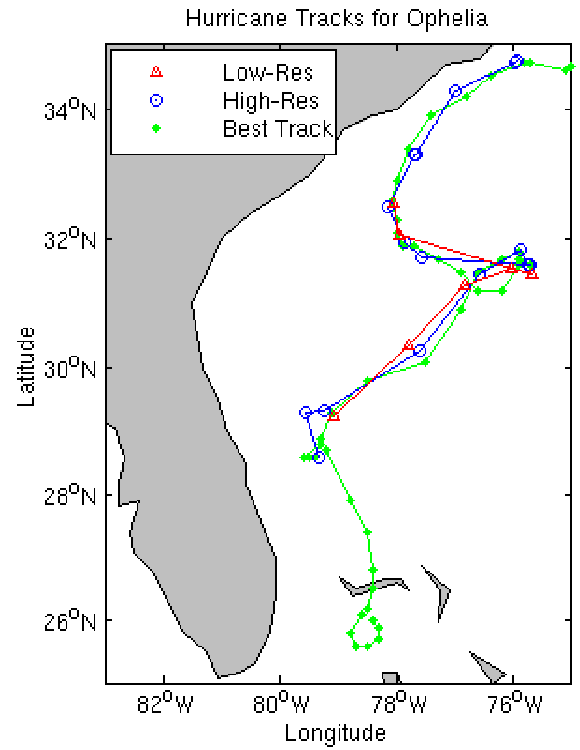
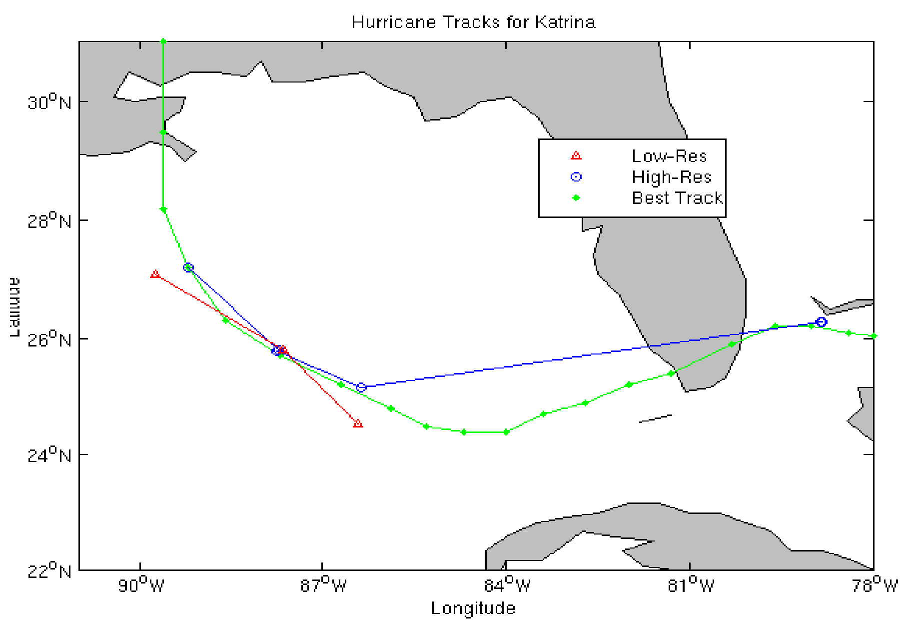
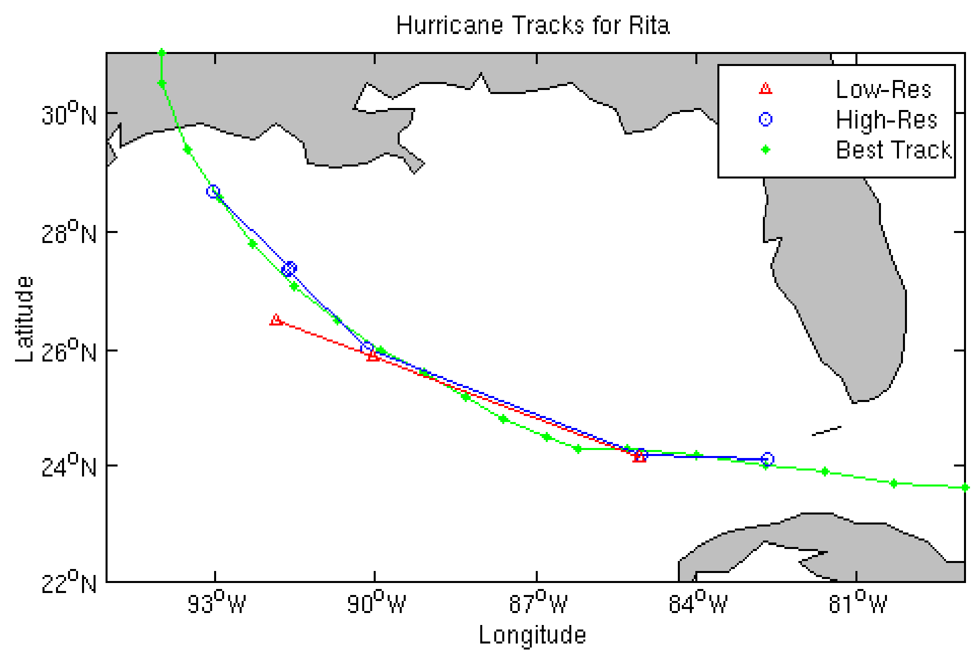
# Track comparisons for key 2005 storms

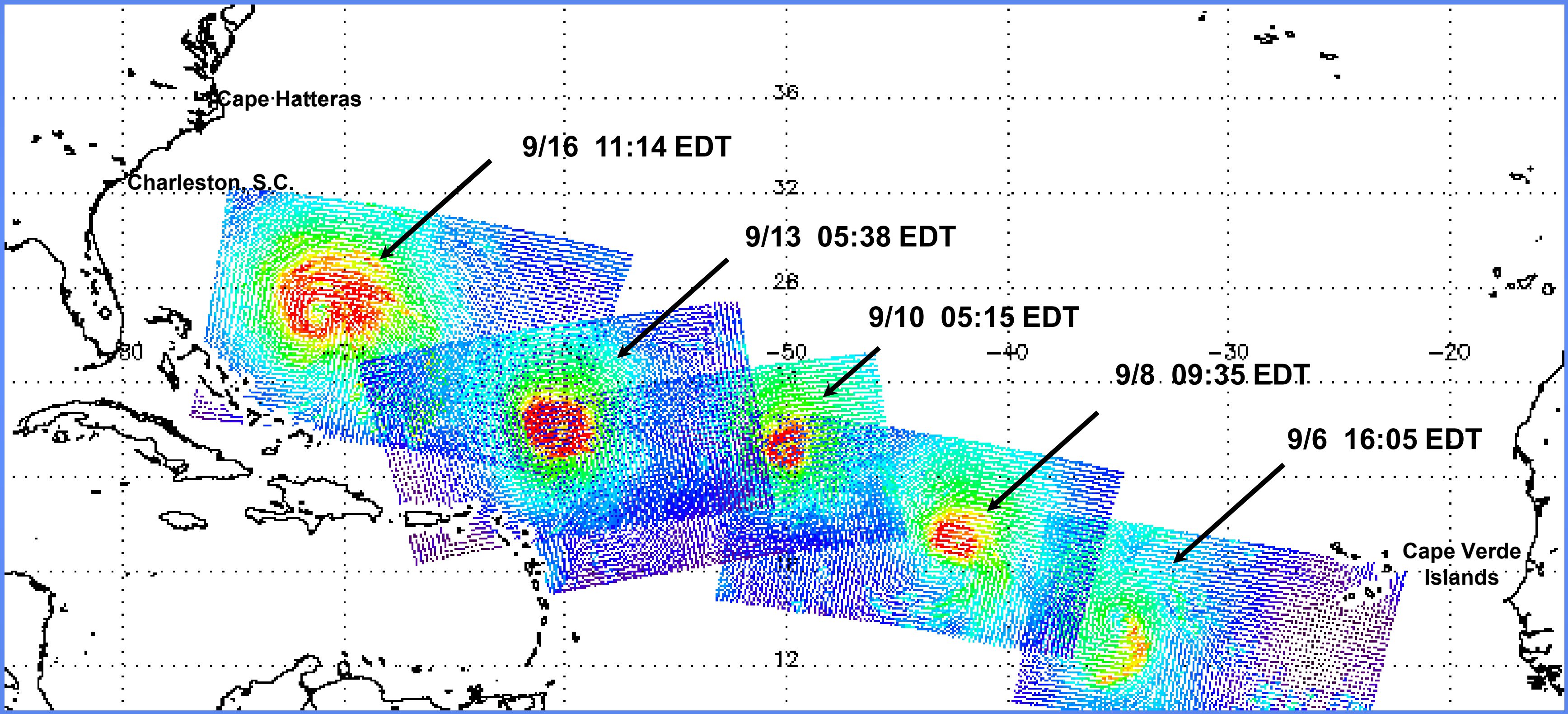
- Ultra high resolution winds
  - Direction not required
- UHR center fixes more accurately match "best-track" storm centers
  - More usable cases



# QuikSCAT and SeaWinds Track Isabel




**QuikSCAT and SeaWinds track hurricane Isabel from its formation near the Cape Verde Islands along its track across the Atlantic toward the US Eastern seaboard**

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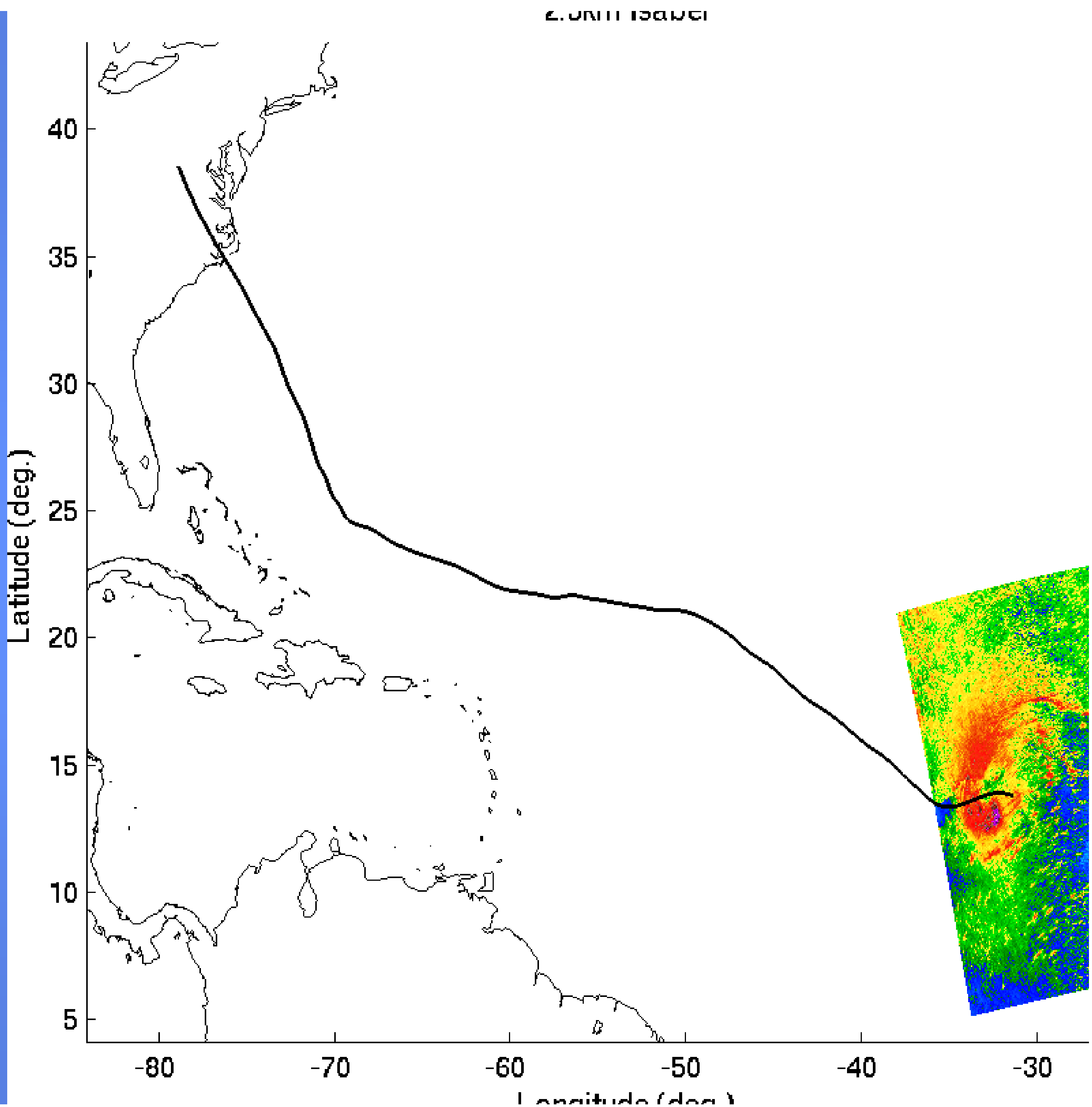
# QuikSCAT and SeaWinds Track Isabel



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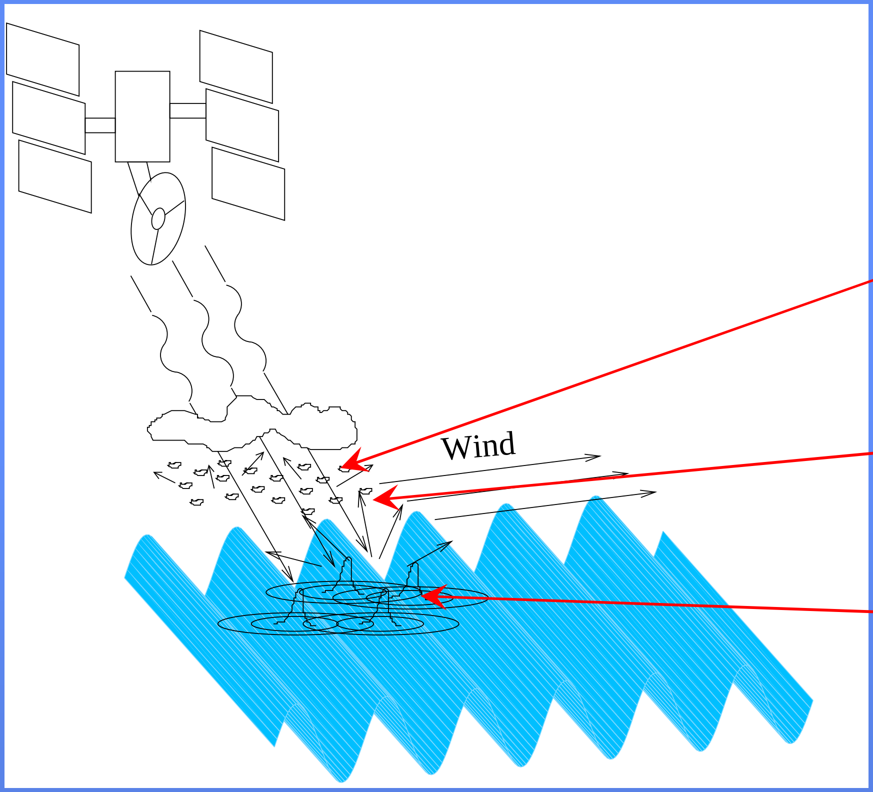
# Rain/Wind Backscatter Model

## Ku-band




- Model for measured backscatter $\sigma^o_M$

$$\sigma^o_M = \left(\sigma^o_w + \sigma^o_{sr}\right)\alpha + \sigma^o_r$$

- Radar signal scattered by falling droplets $\sigma^o_r$
- Surface signal attenuated by atmospheric rain $\alpha$
- Surface wind-induced $\sigma^o_w$ backscatter perturbed by rain striking the water $\sigma^o_{sr}$

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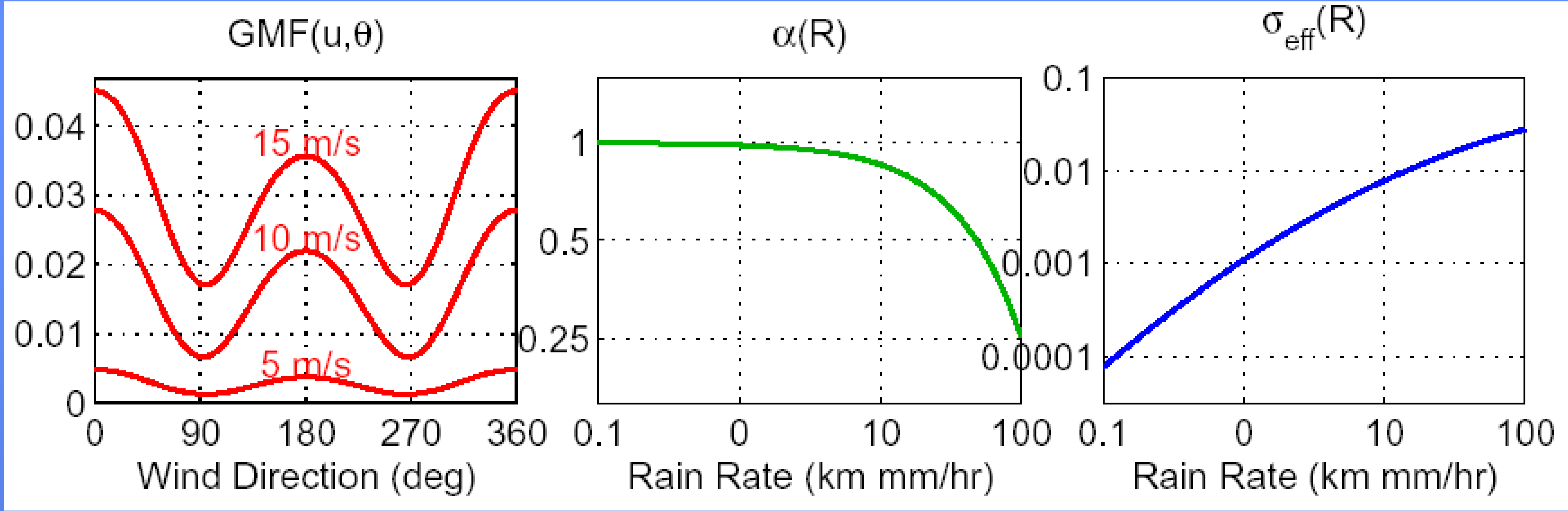
# Ku-band Wind/Rain Model

Rain/wind model: $\sigma^{\circ}_{m} = \sigma^{\circ}_{w}\alpha + \sigma^{\circ}_{eff}$

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

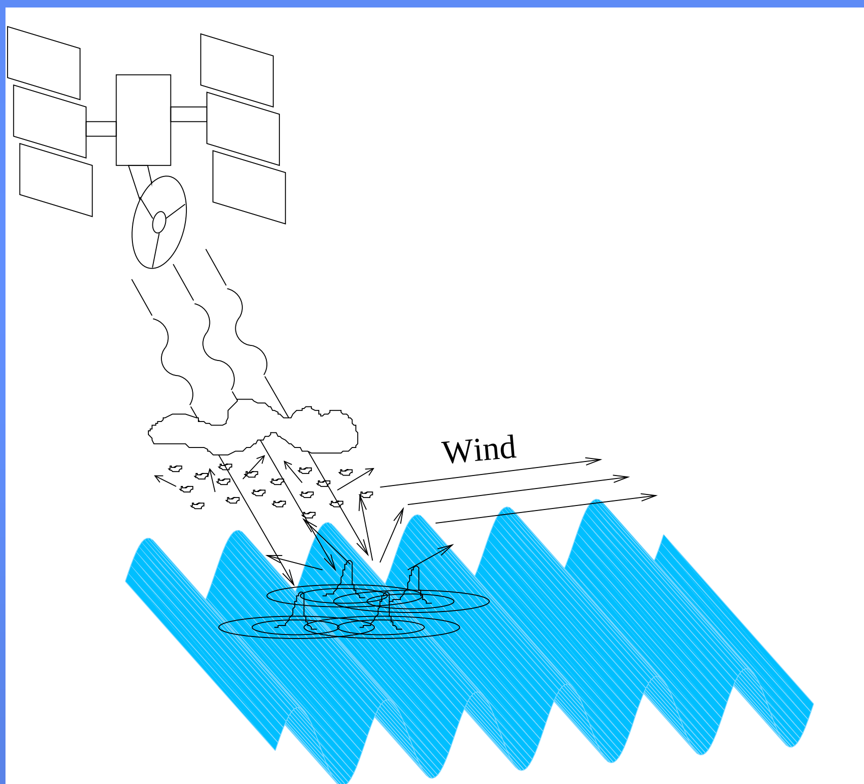



Model parameters derived from colocated TRMM PR and QuikSCAT data

D.W. Draper and D.G. Long, Evaluating the Effect of Rain on SeaWinds Scatterometer Measurements, Journal of Geophysical Research, Vol. 109, No. C02005, doi:10.1029/2002JC001741, 2004.

# Rain/Wind Backscatter Model

## C-band

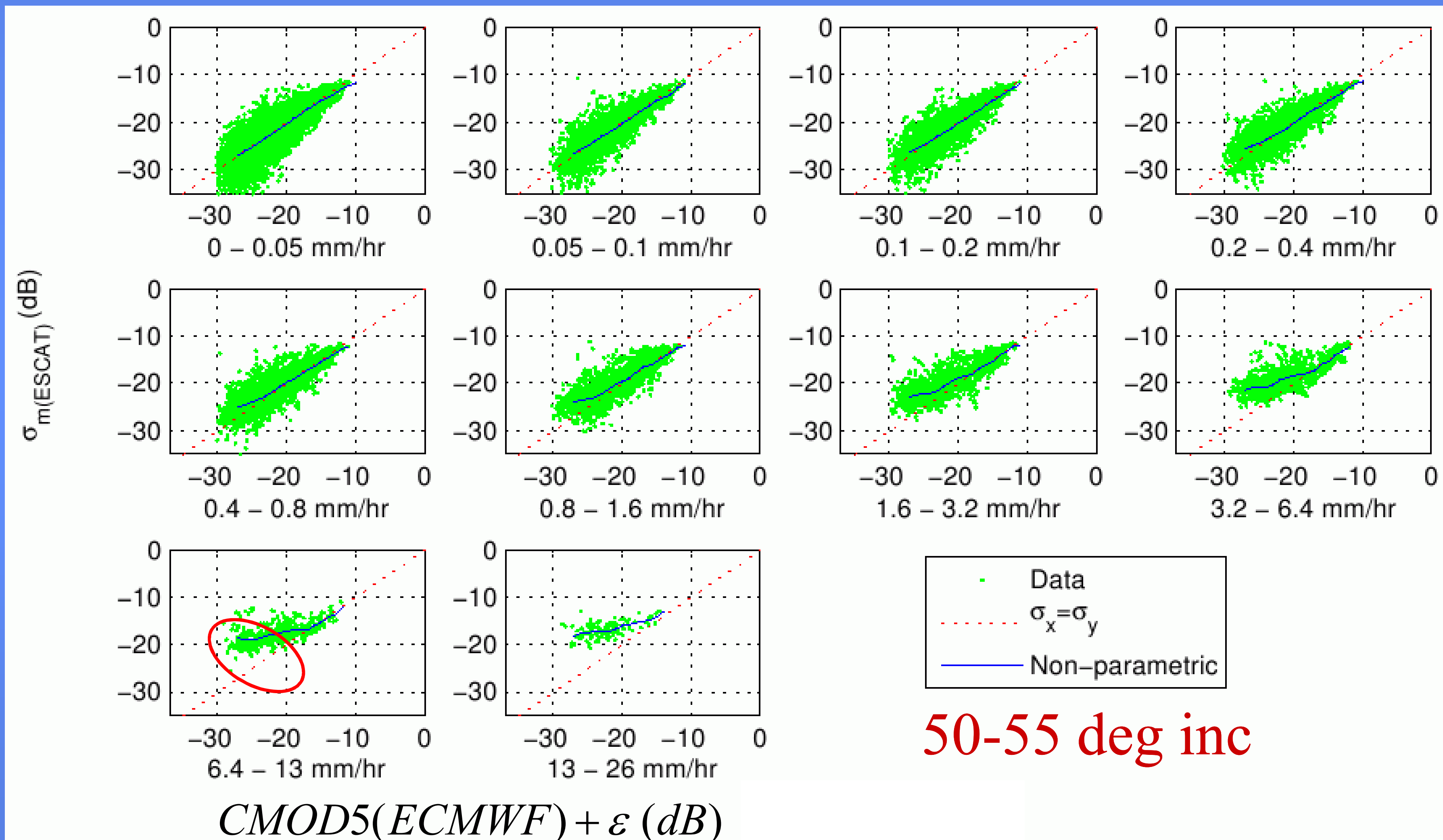



- Model for measured backscatter $\sigma_M^o$

$$\sigma_M^o = \left(\sigma_w^o + \sigma_{sr}^o\right)\cancel{\alpha} + \cancel{\sigma_r^o}$$

- At C-band, attenuation and rain backscatter are negligible
- Surface perturbation can be important at high incidence angle
  - No significant pattern observed at low incidence angles

# C-band Rain Effects



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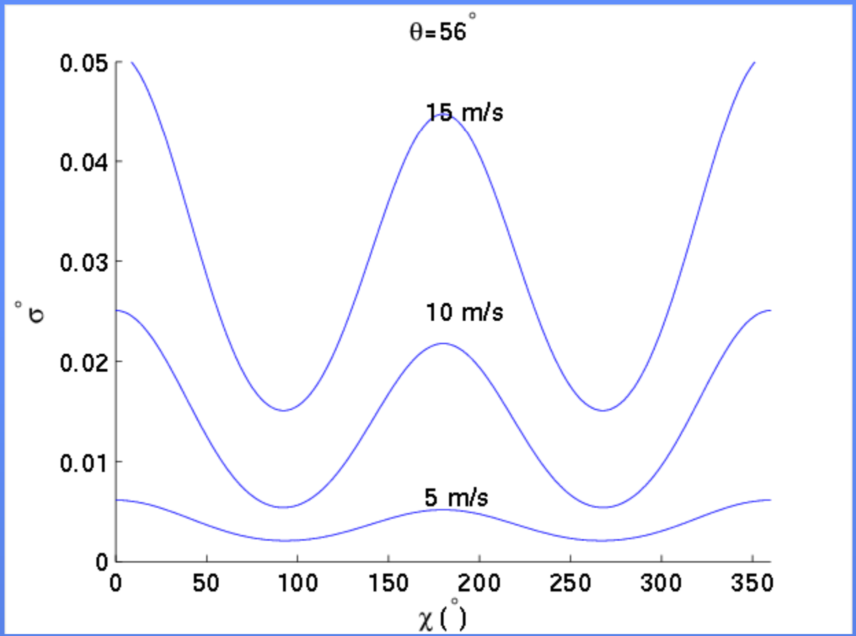
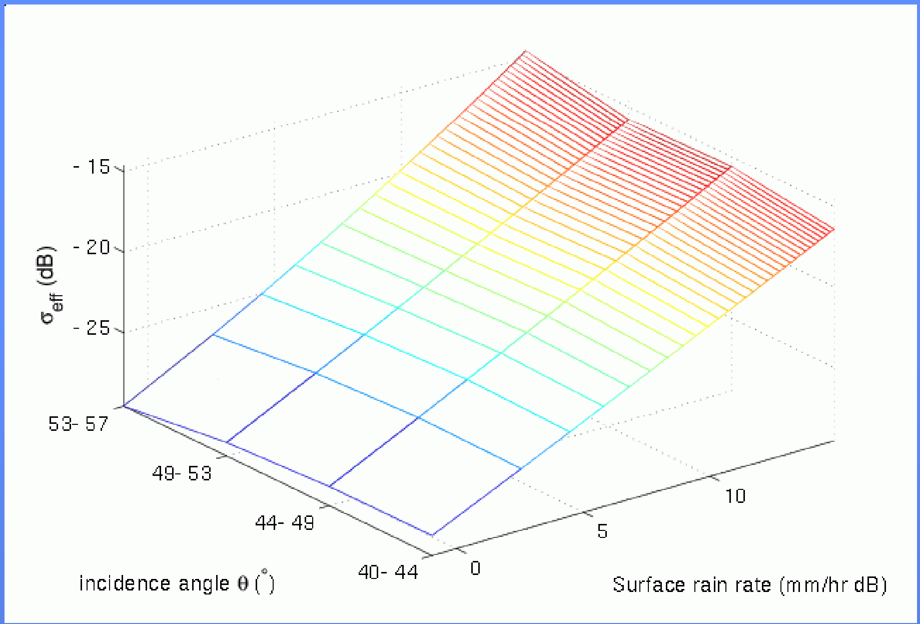
# C-band Wind/Rain Model

Rain/wind model: $\sigma_m^o = \sigma_w^o + \sigma_{eff}^o$

$$GMF_r(u,d,R,\ldots) = CMOD5(u,d,\ldots) + \sigma_{eff}^o$$




Model parameters derived from colocated TRMM PR and QuikSCAT data

C. Nie and D.G. Long, “A C-band Wind/Rain Backscatter Model,” in review, IEEE TGARS.

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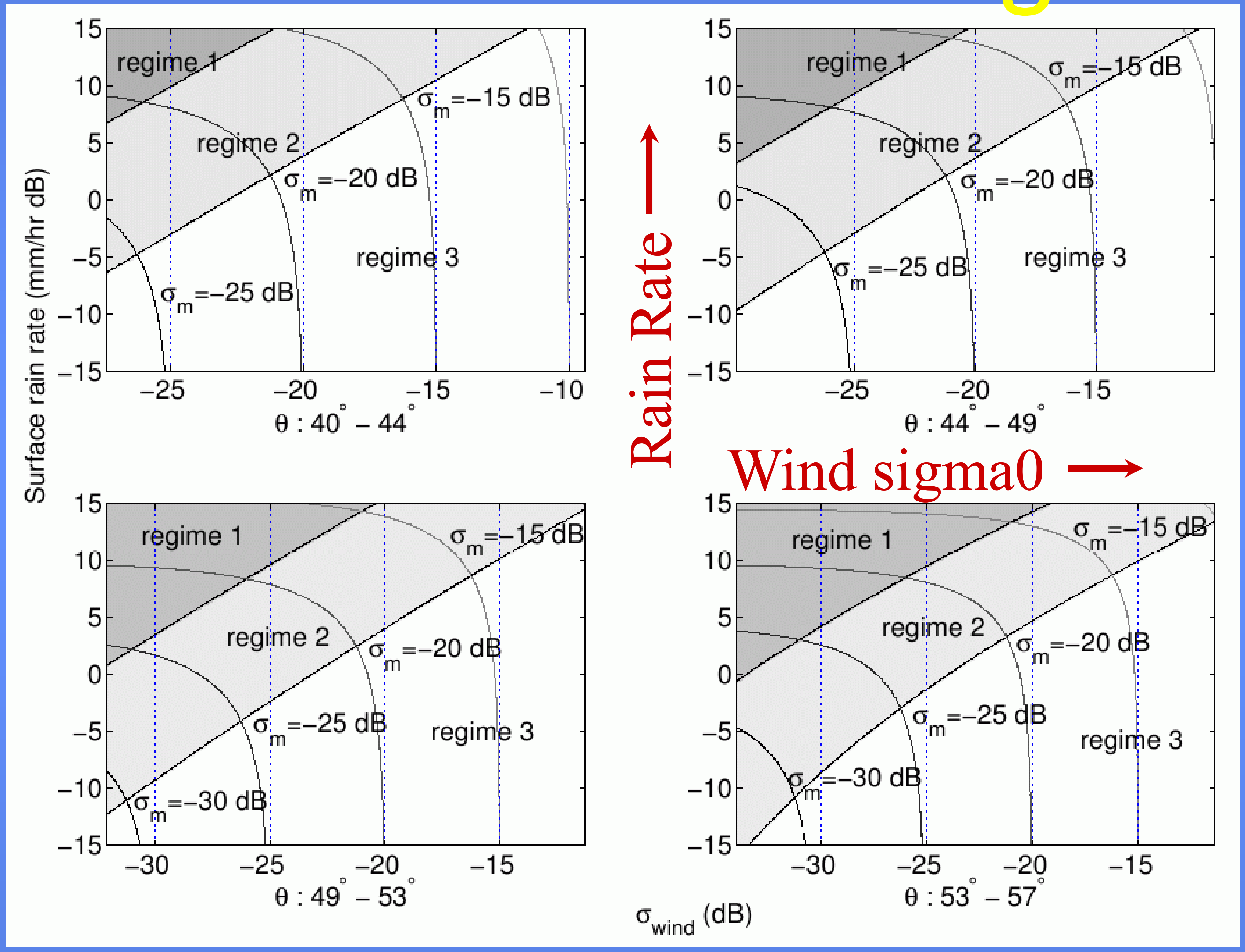
$$\sigma^{o}(u,\chi,R) = GMF(u,\chi) + \sigma_{eff}(R)$$

# C-Band Wind Rain Regimes




- Regime 1: rain dominates wind backscatter – poor quality wind estimates
- Regime 2: both wind and rain important – retrieve wind *and* rain rate
- Regime 3: rain effects insignificant – wind estimates unaffected by rain

Note: globally, only about 3% of all ERS far-swath data affected by rain

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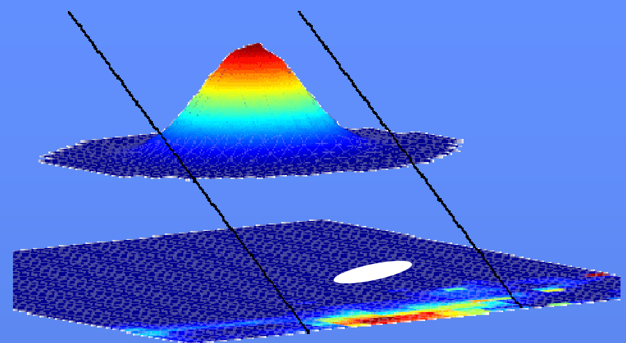
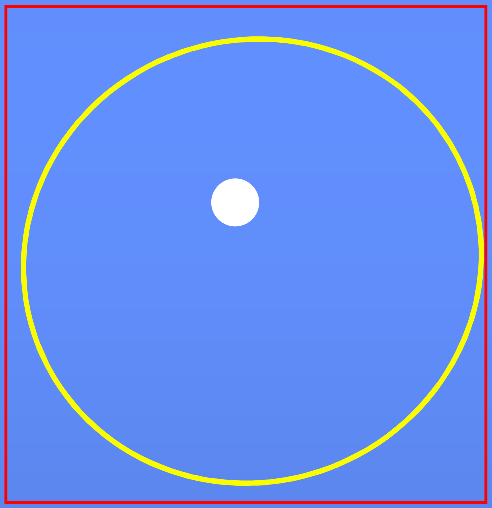
# ERS Simultaneous Wind/Rain Retrieval

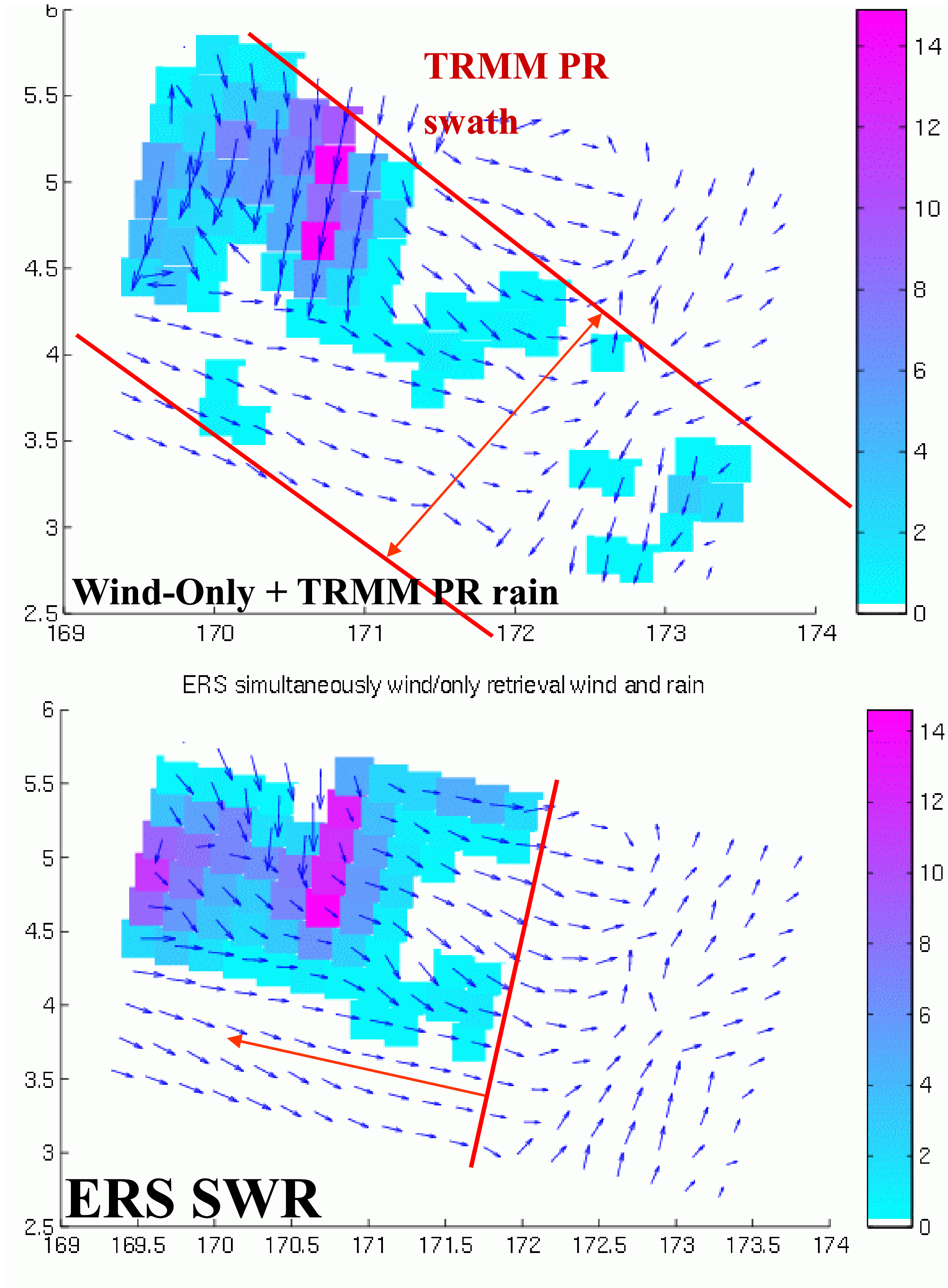
- Sensitivity of ERS sigma-0 measurements to rain in the outer swath suggest that simultaneous wind/rain retrieval possible for ERS
  - Response function-weighted rain rate
  - Wind estimates less noisy than at Ku-band
  - Beam filling

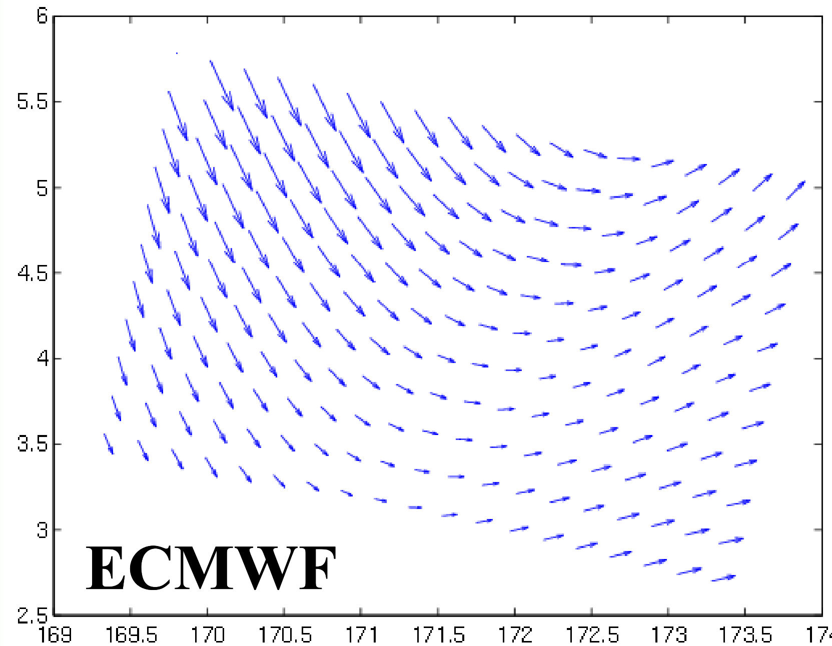




- Higher incidence angle range of ASCAT suggests higher rain sensitivity, can enable rain retrieval over much of swath

# ERS SWR Example

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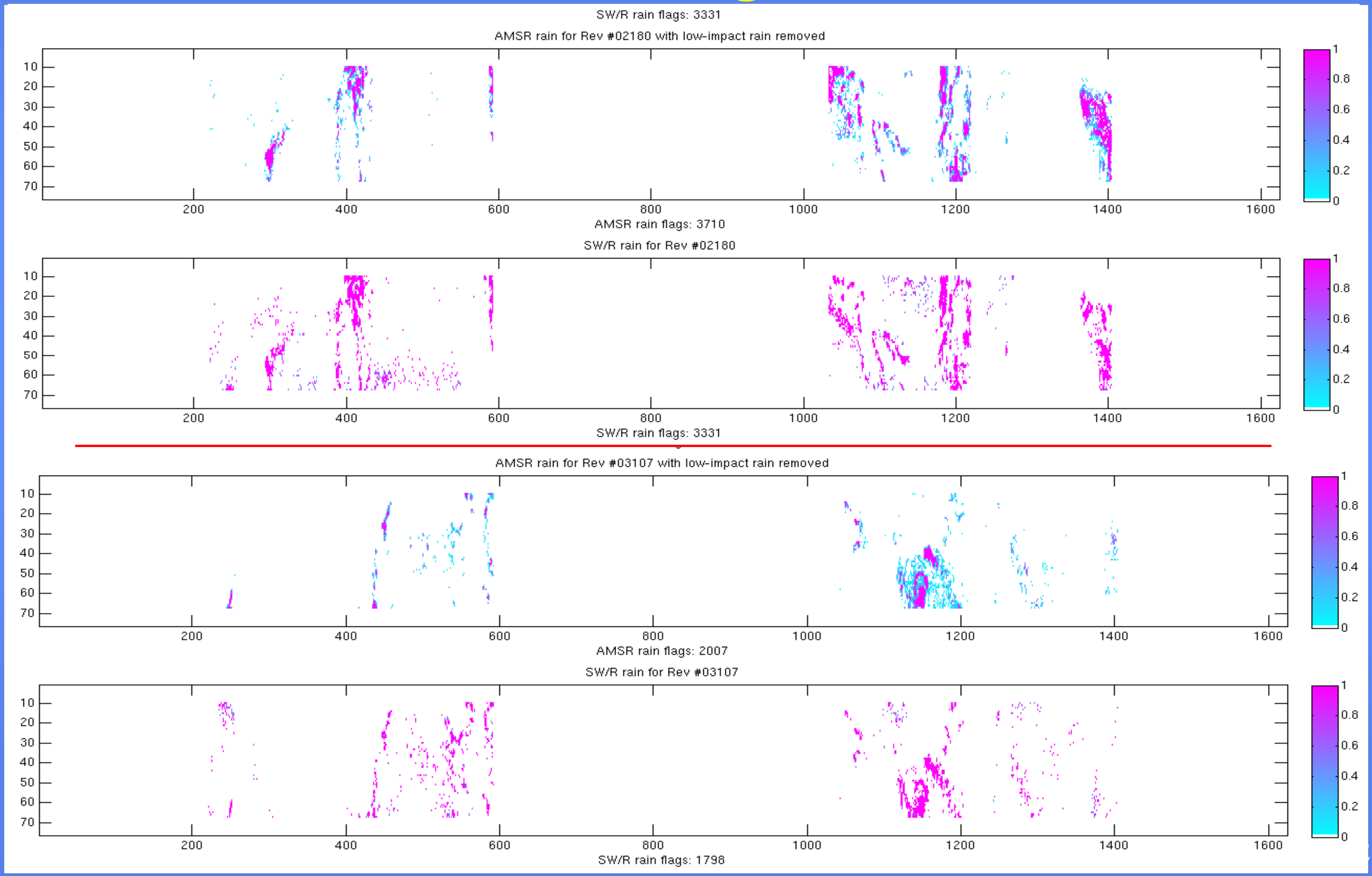
# New QuikSCAT rain impact flag vs SWR

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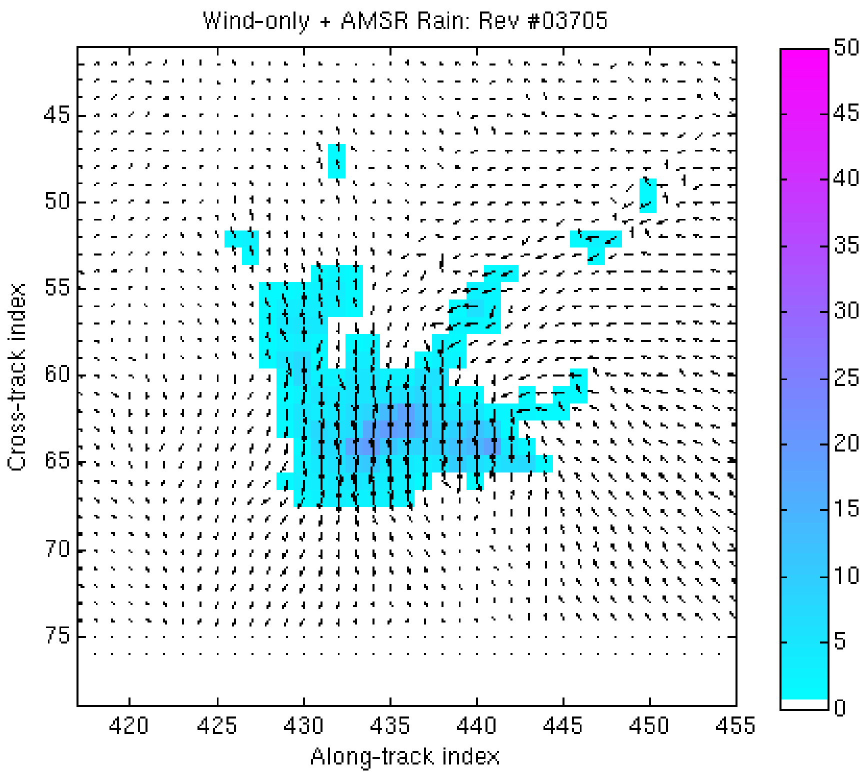
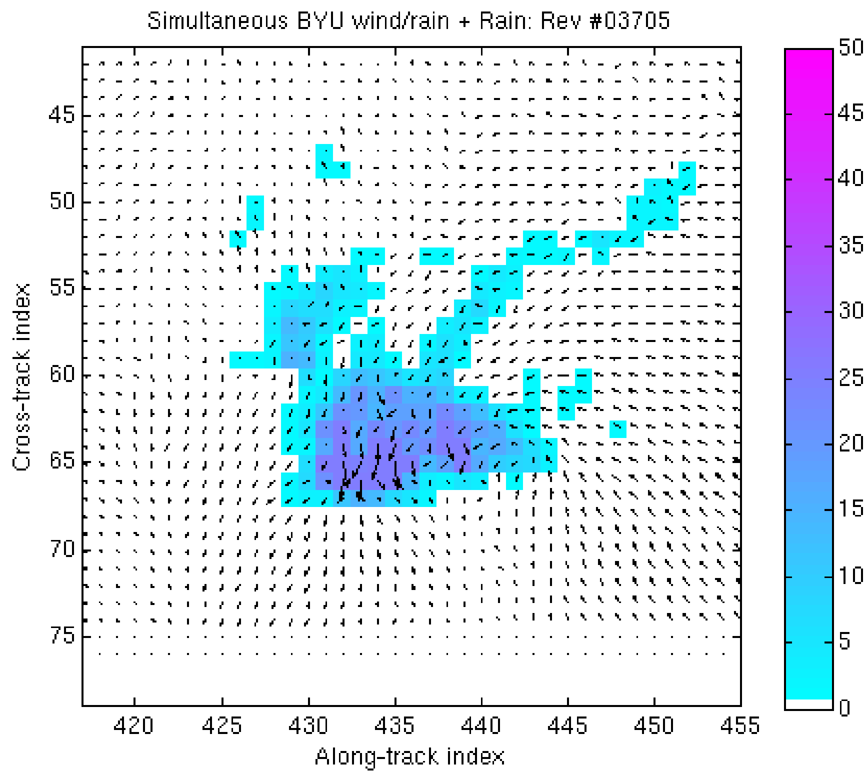
# QuikSCAT SWR vs AMSR Rain

- General patterns similar, calibration offset
  - Simultaneous Wind/Rain calibrated to TRMM PR
  - AMSR calibrated to SSM/I



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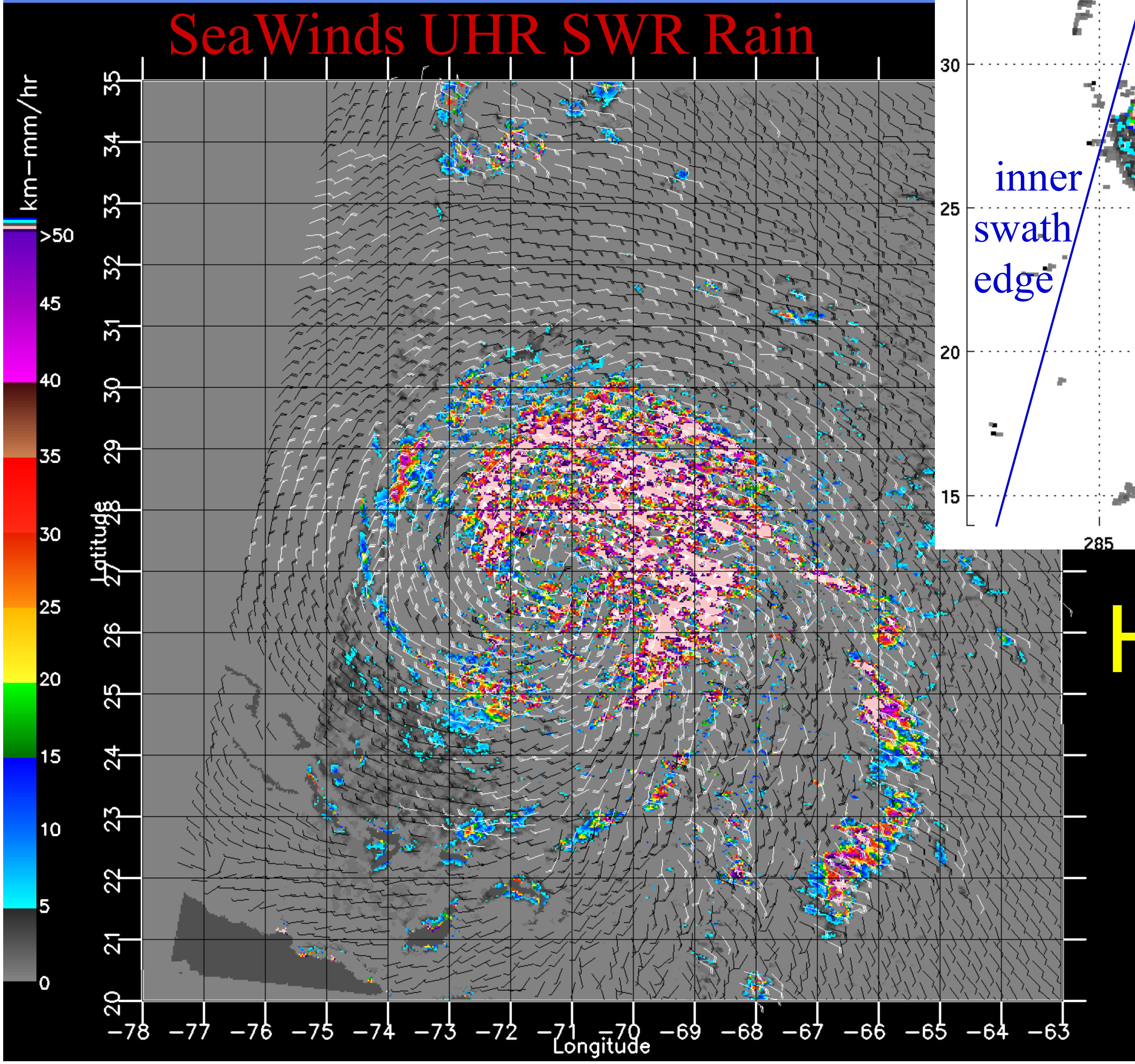


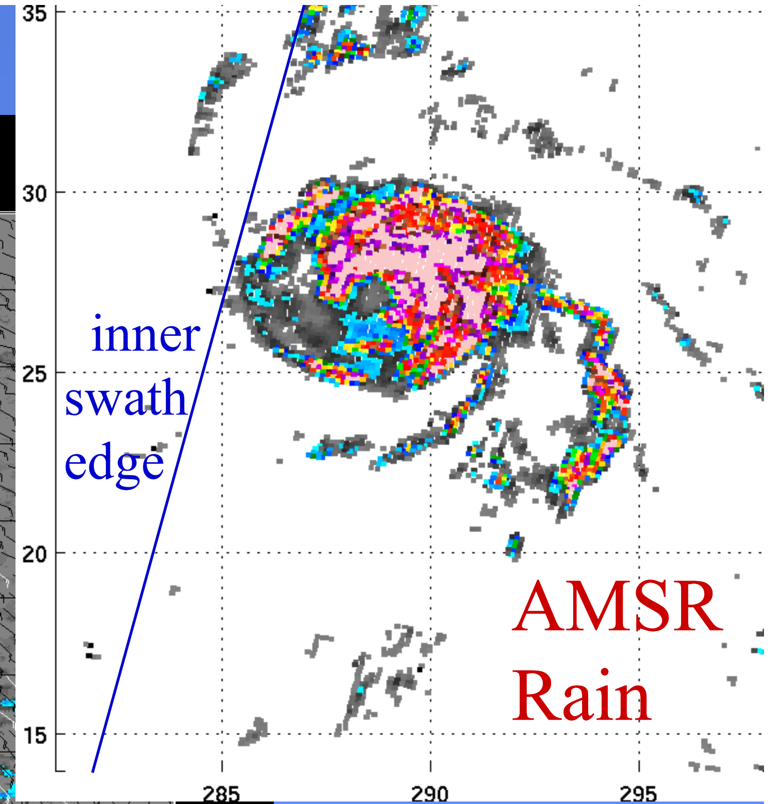


# Hurricane Isabel

(16 Sep 2003)

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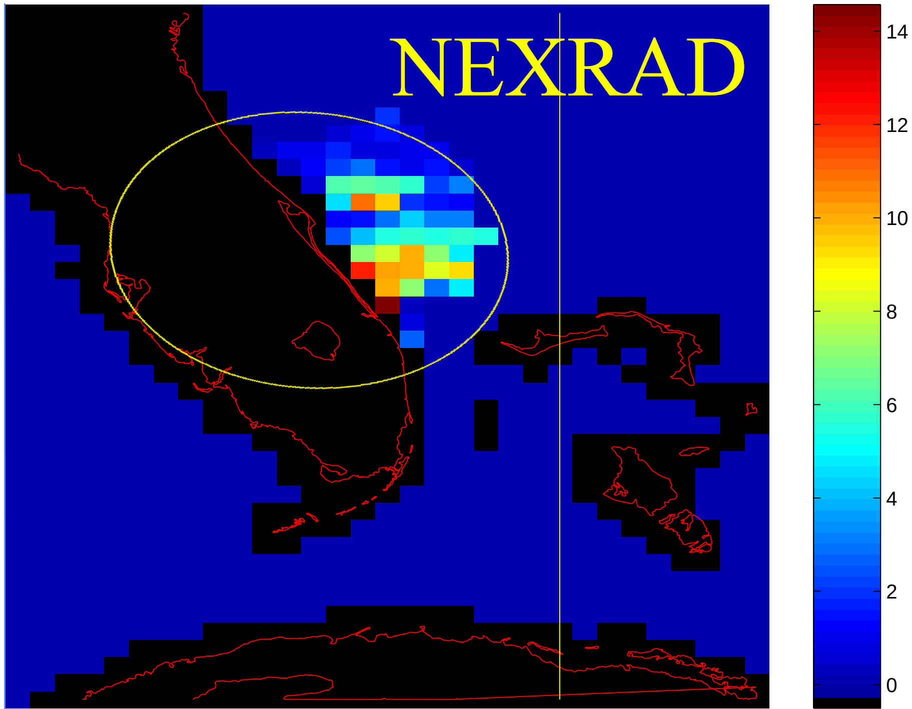
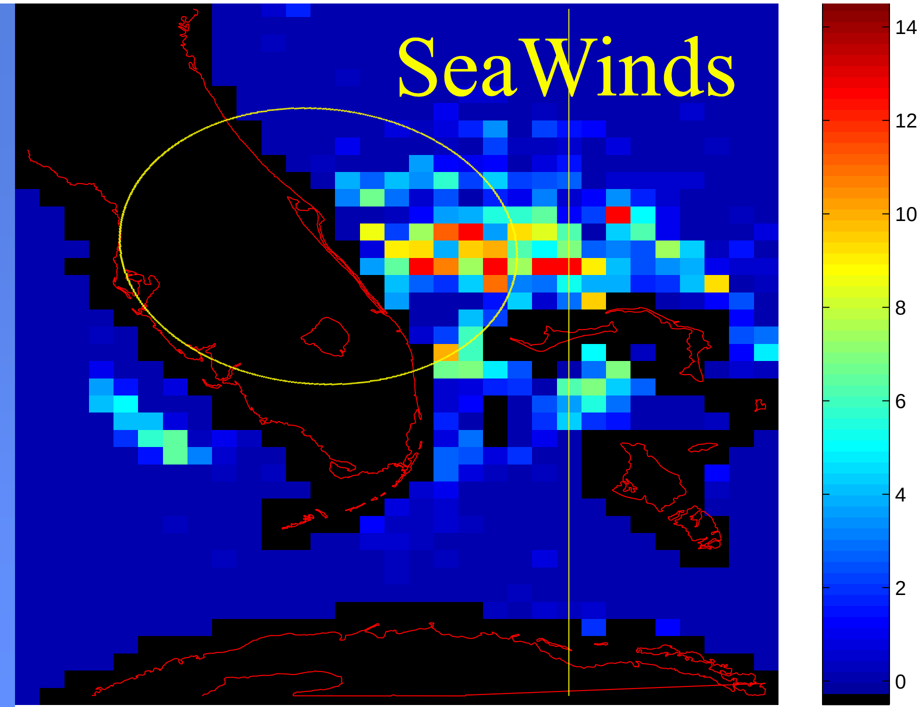
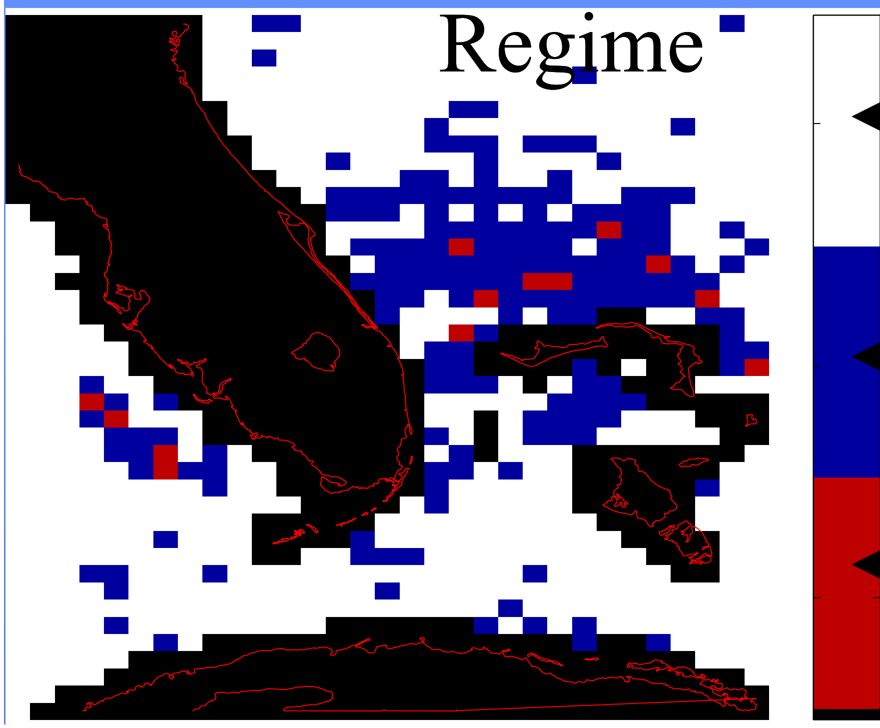
# Rain Flag Frances

(9/4/2004 23:15 UTC)




Wind dominated
– rain has no impact

Wind and rain

Rain dominated
– wind inaccurate

Simultaneous wind/rain retrieval regime estimates

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# Conclusions

- Ultra high resolution winds
  - Higher spatial resolution
  - Higher noise level than L2B
  - Demonstrated utility in hurricane tracking
- Rain effects
  - C-band scatterometry sensitive at higher incidence angles and rain rates
    - Can simultaneously retrieve wind and rain
  - QuikSCAT SWR useful as a rain flag