Ultra-High Resolution ASCAT Products & Progress in Simultaneous Wind/Rain Retrieval

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Ocean Vector Wind Science Team Meeting
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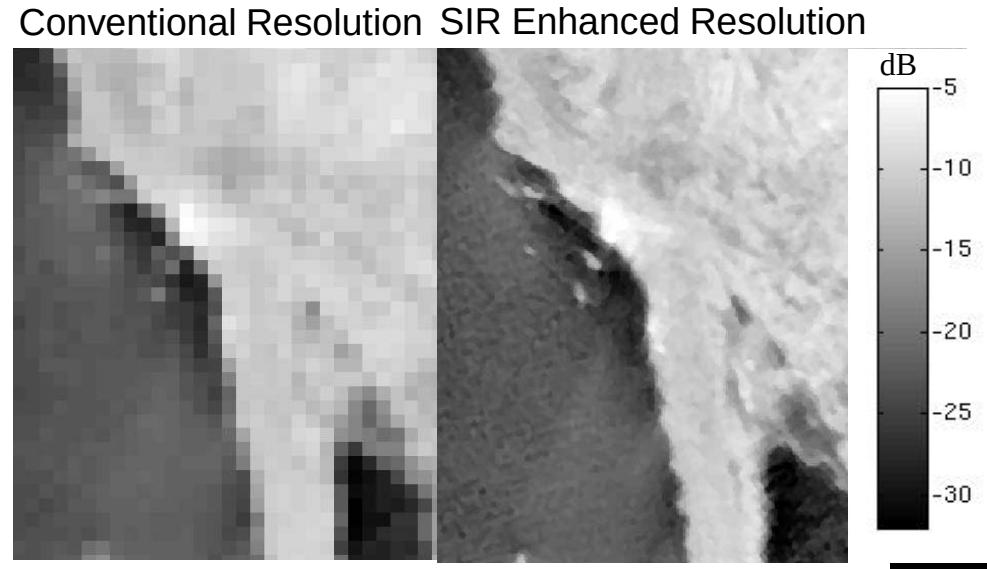
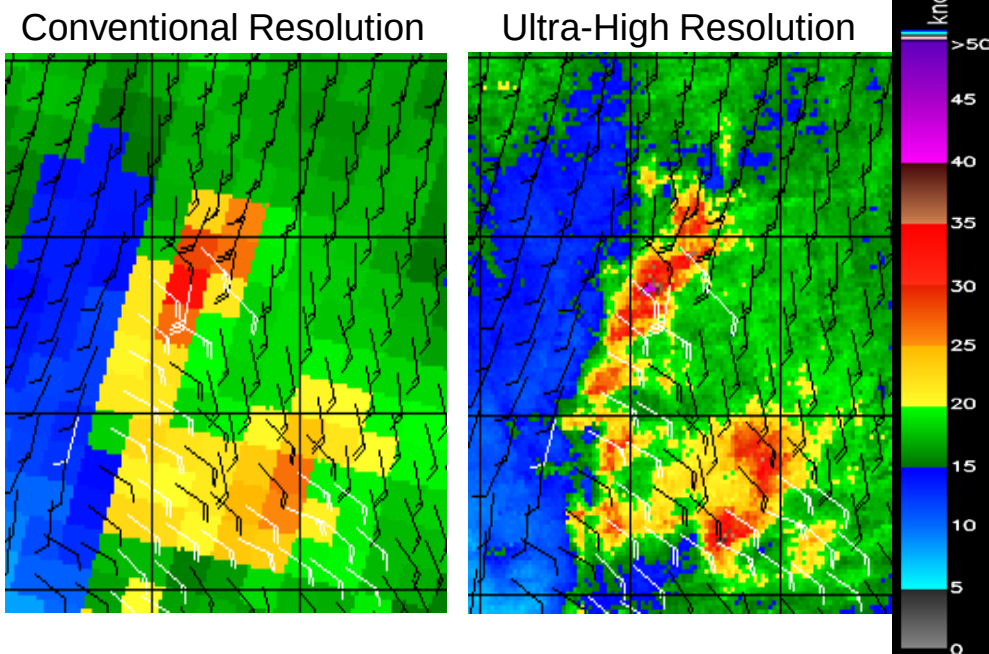
Introduction

- **σ^0 imaging**
  - SIR/AVE optimized for ASCAT
  - Beta version of ASCAT enhanced resolution land/ice products now available at the Scatterometer Climate Record Pathfinder (www.scp.byu.edu)
- **Wind**
  - Ultra-high resolution (UHR) (1.25 km/pixel) ASCAT wind processing now operational
- **Simultaneous wind/rain (SWR) retrieval**
  - Bayes estimator selection to optimally select between wind-only, SWR, and rain-only retrieval
  - Rain flag and correction

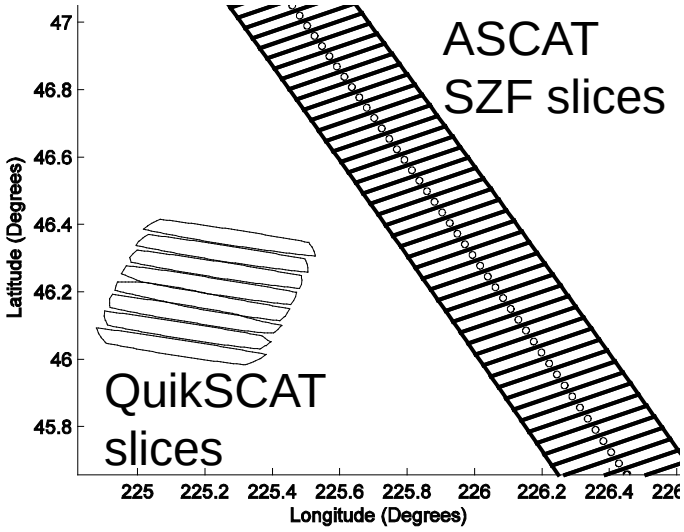




ASCAT Resolution Enhancement

- ASCAT SZF comparable to QuikSCAT L1B slices
  - Reconstruction to enhance resolution
    - Single pass for winds
    - Multipass for land/ice
  - SZF slice spatial response function derived with aid of Julian Wilson

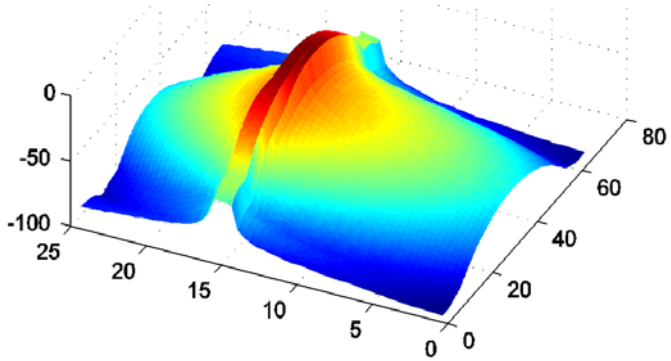
6 dB spatial response



- Adapt NSCAT version of SIR to deal with incidence angle
  - Two images: σ^0 at 40º (A) and incidence angle slope (B)

$$\sigma^0_{\mathrm{dB}} = \mathcal{A} + \mathcal{B}(\theta_i - 40^\circ)$$

  - SIR algorithm “tuned” for ASCAT



ASCAT slice response function

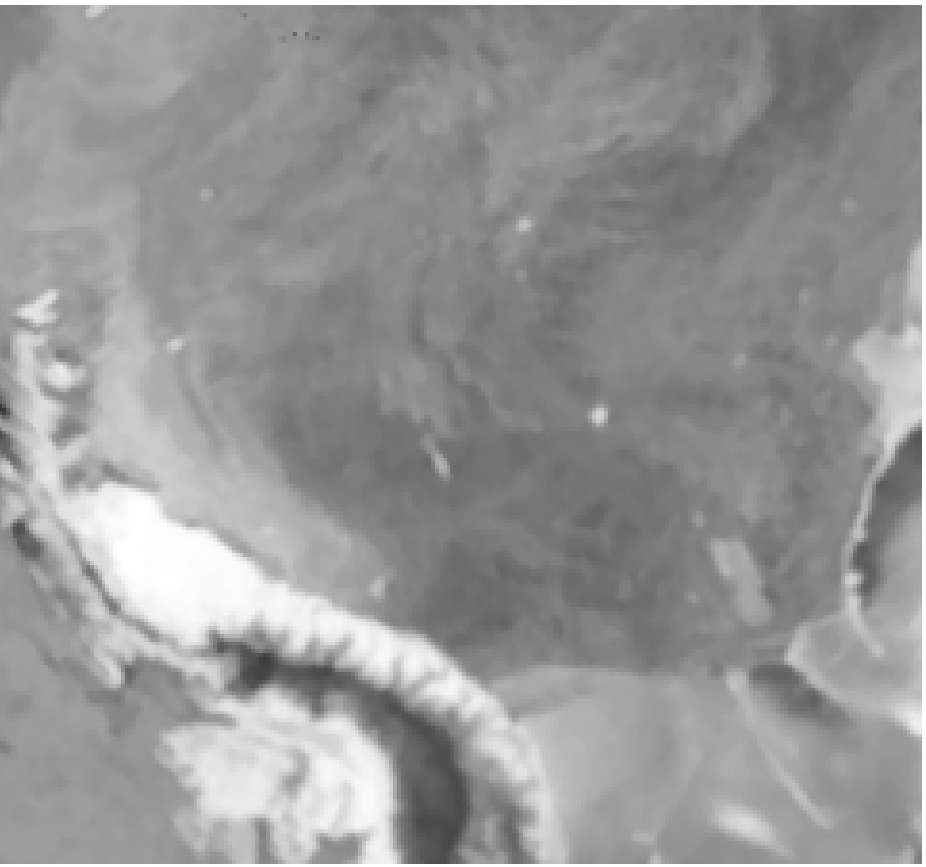
ASCAT Enhanced Resolution Land/Ice Images

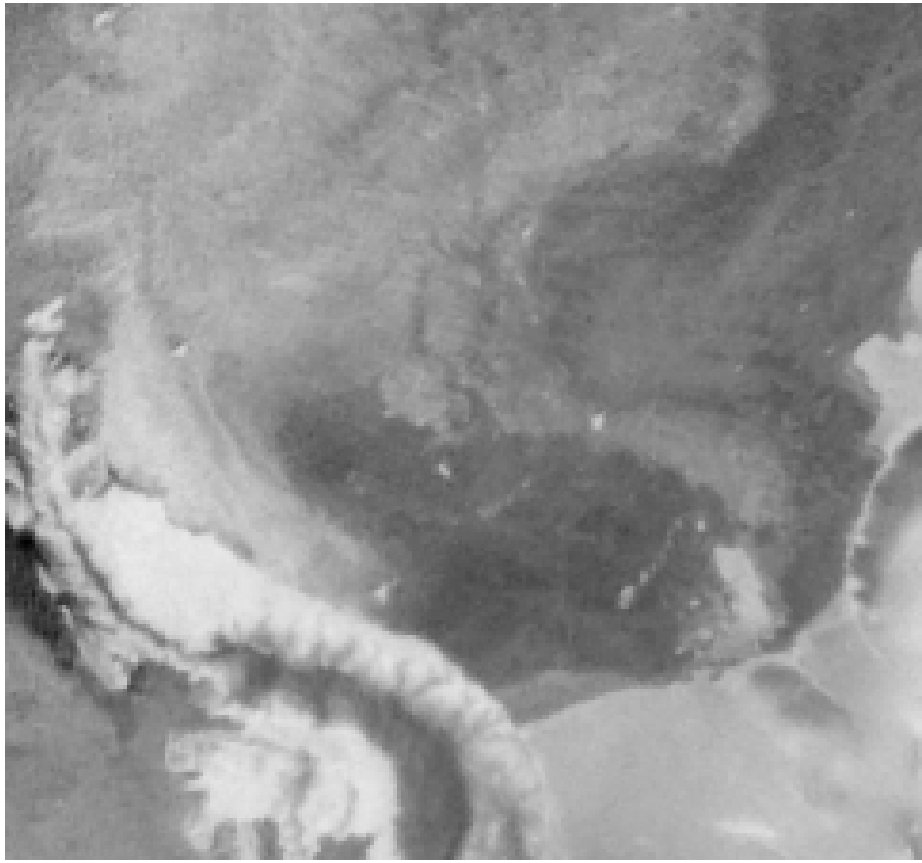
- Images on standard grids
  - Aids in comparison and data fusion with other sensors
- Resolution enhanced products: AVE, SIR, none (gridded)
  - AVE and SIR enable higher spatial resolution
  - Support studies otherwise not possible
  - Standard incidence angle
- Trade noise, spatial and temporal resolution
  - Combine multiple passes
    - Separate single pass, local time-of-day, daily, multi-day products
  - Longer integrations improve spatial resolution, reduce noise
    - Smooth temporal change
  - Local time-of-day products provide high temporal resolution while combining multiple passes in the polar regions

Image data now available from the Scatterometer Climate Pathfinder www.scp.byu.edu

ASCAT & QuikSCAT Comparison

V-pol *A* Images





ASCAT Slice (SZF)
5.255 GHz
σ^0 at 40º

2.225 km pixels

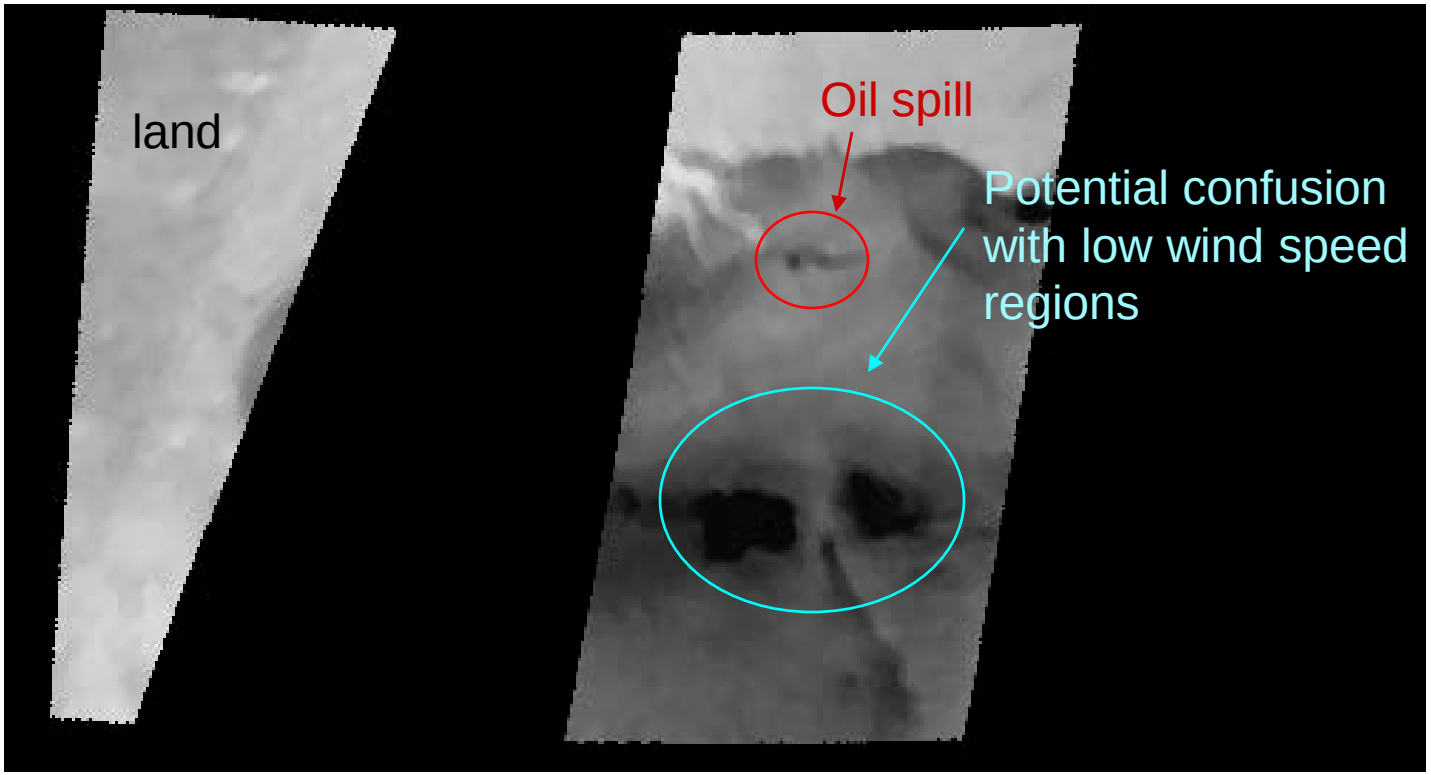
QuikSCAT Slice
13.4 GHz
σ^0 at 54º

JD 214, 2008

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

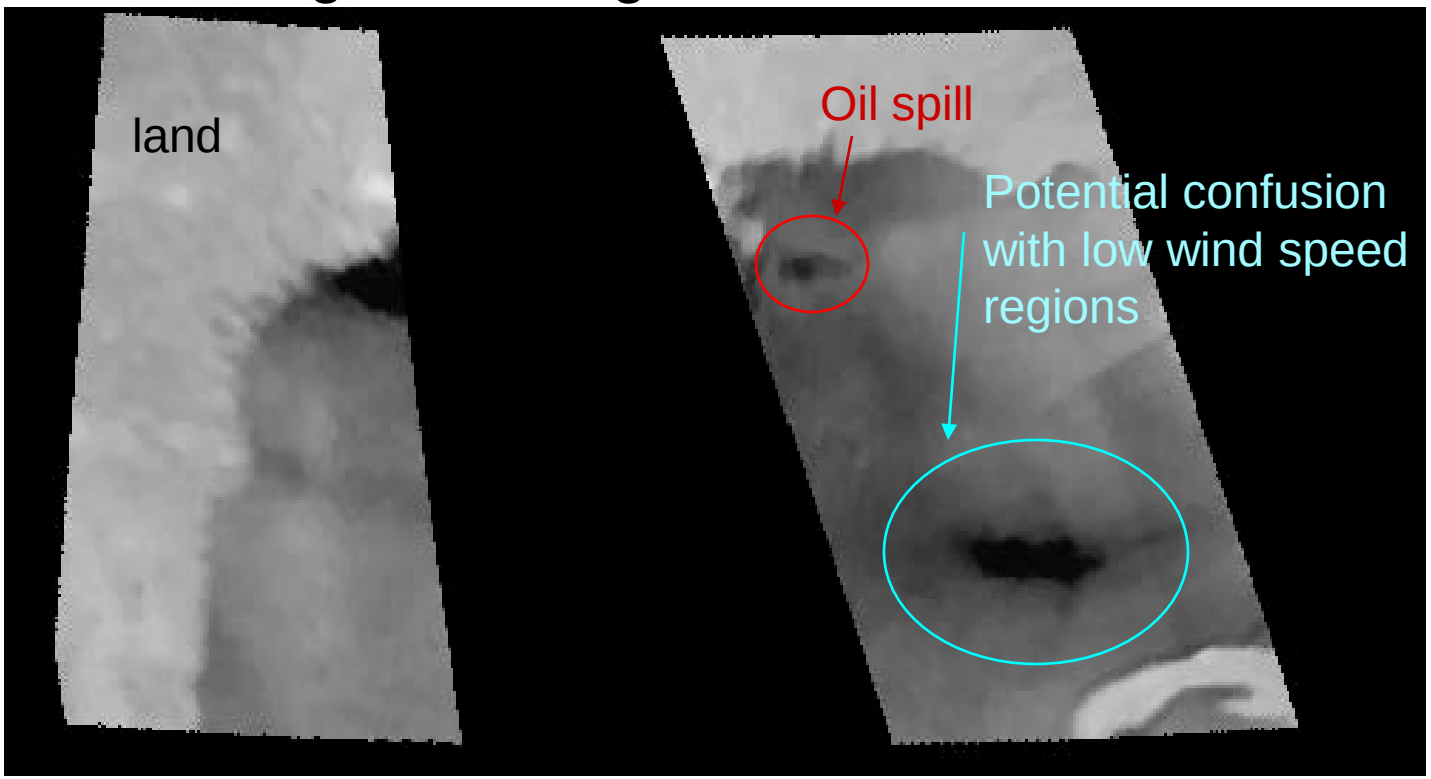


JD 117, 2010, two days after leak begins

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

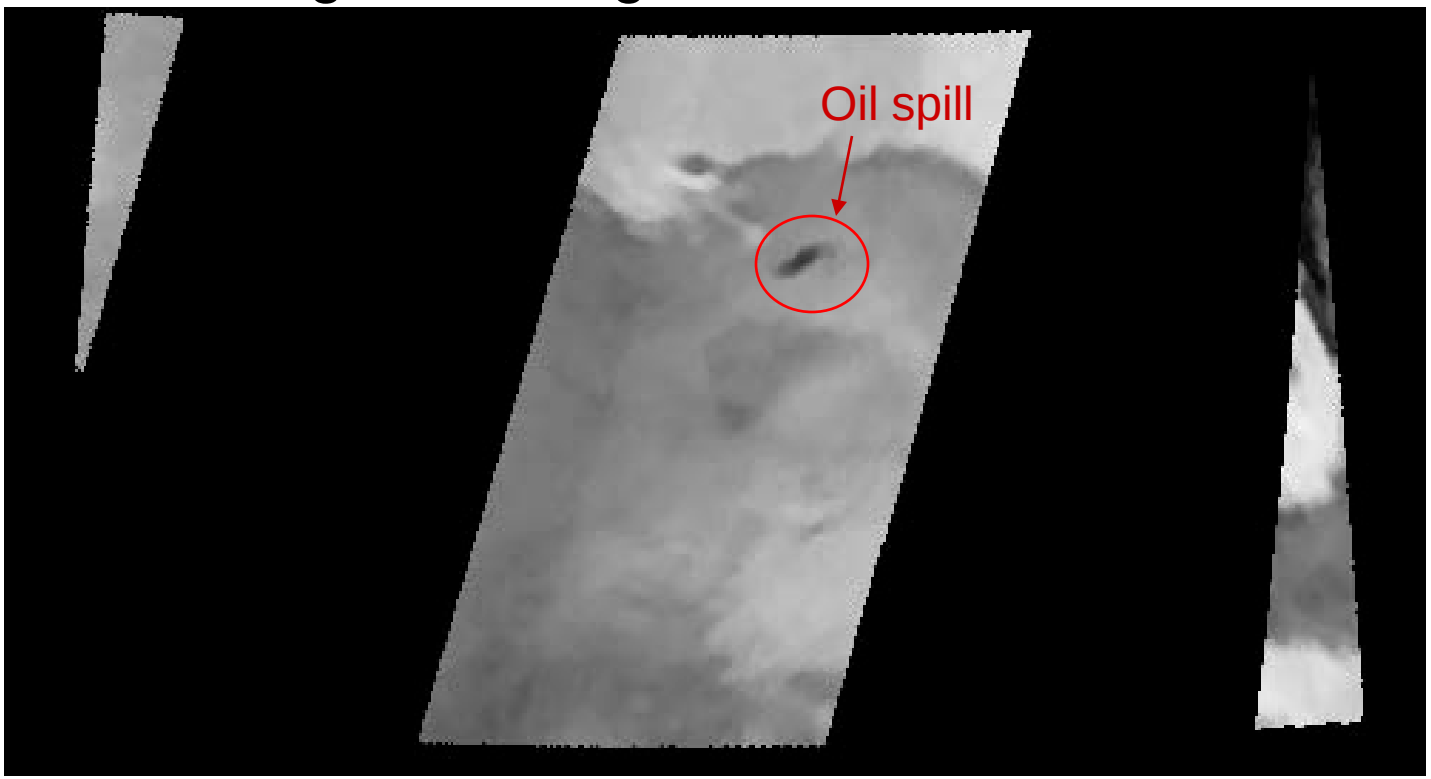


JD 118, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

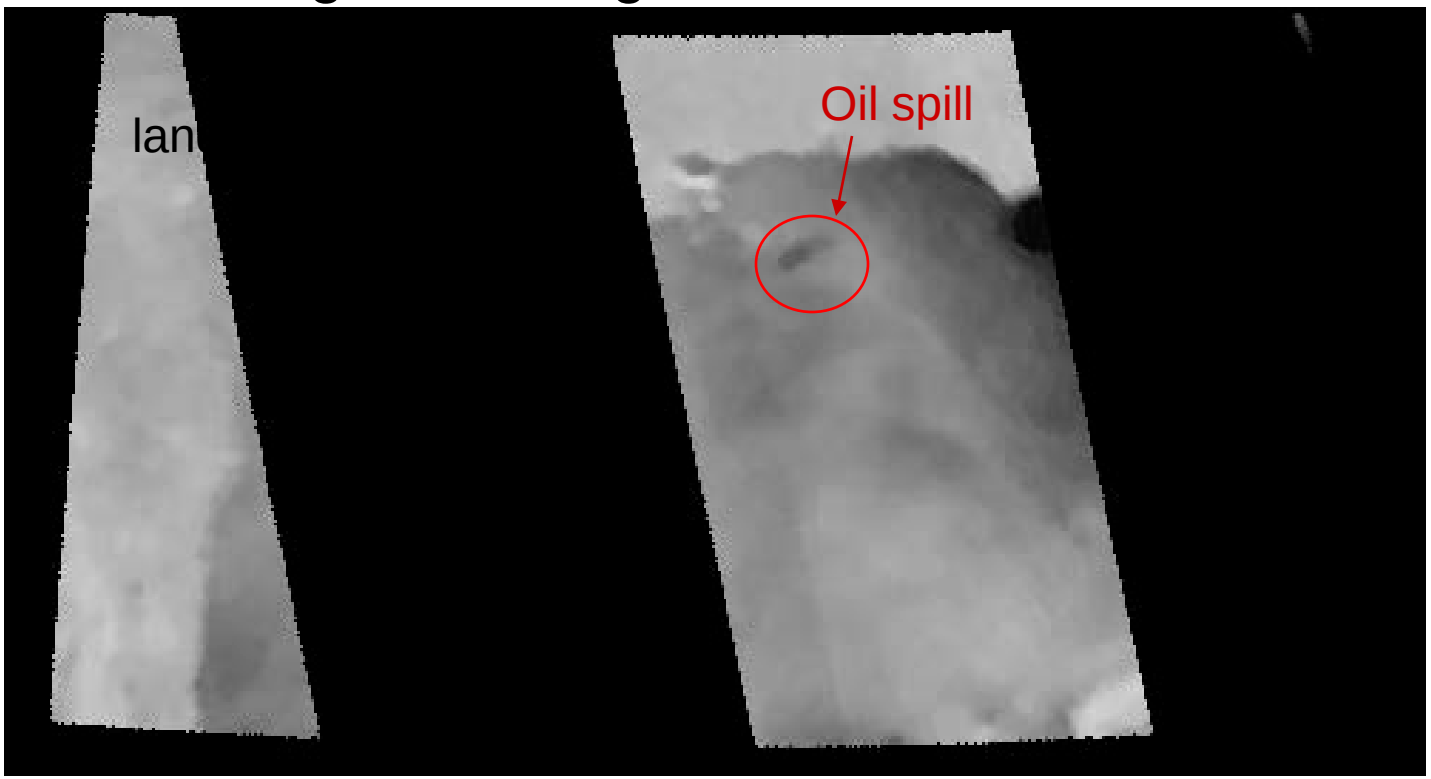


JD 119, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

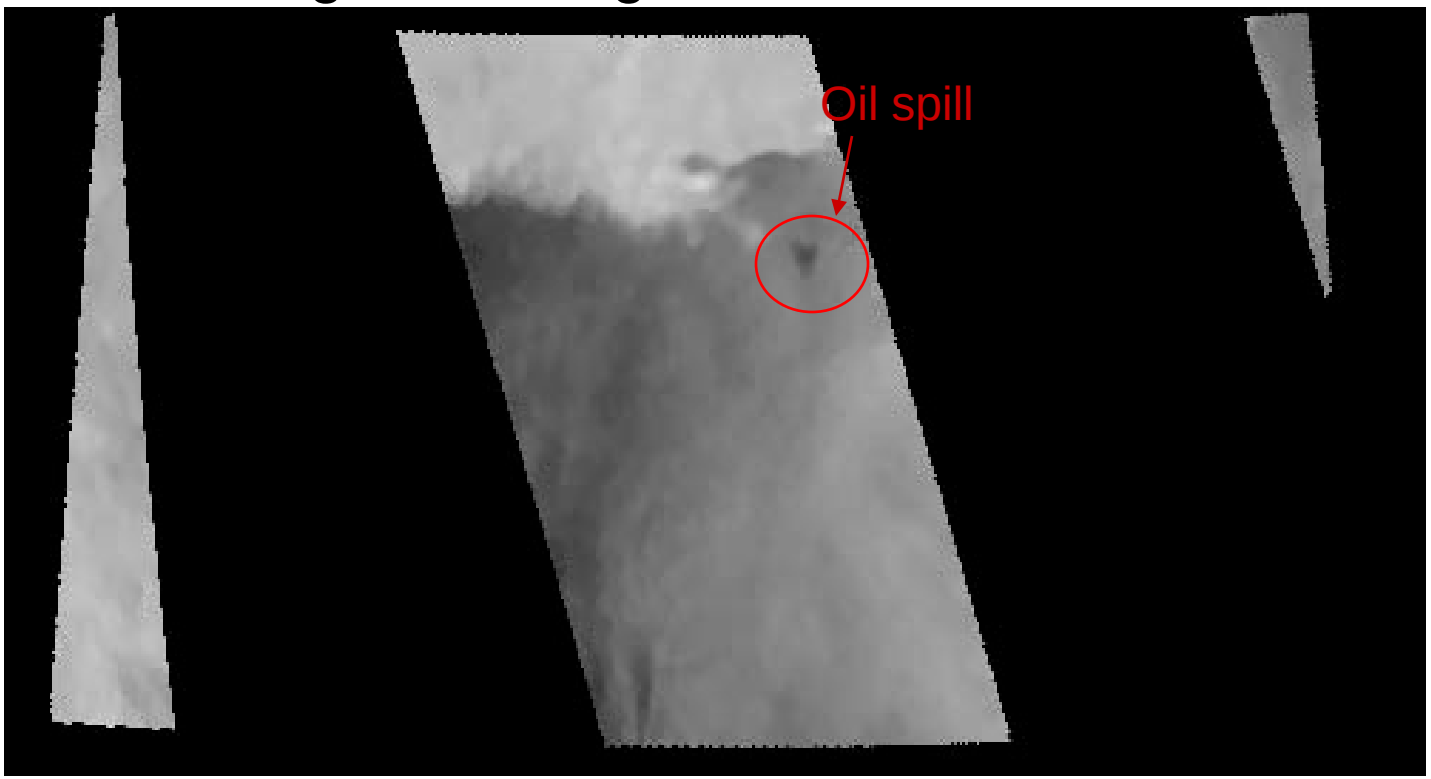


JD 120, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

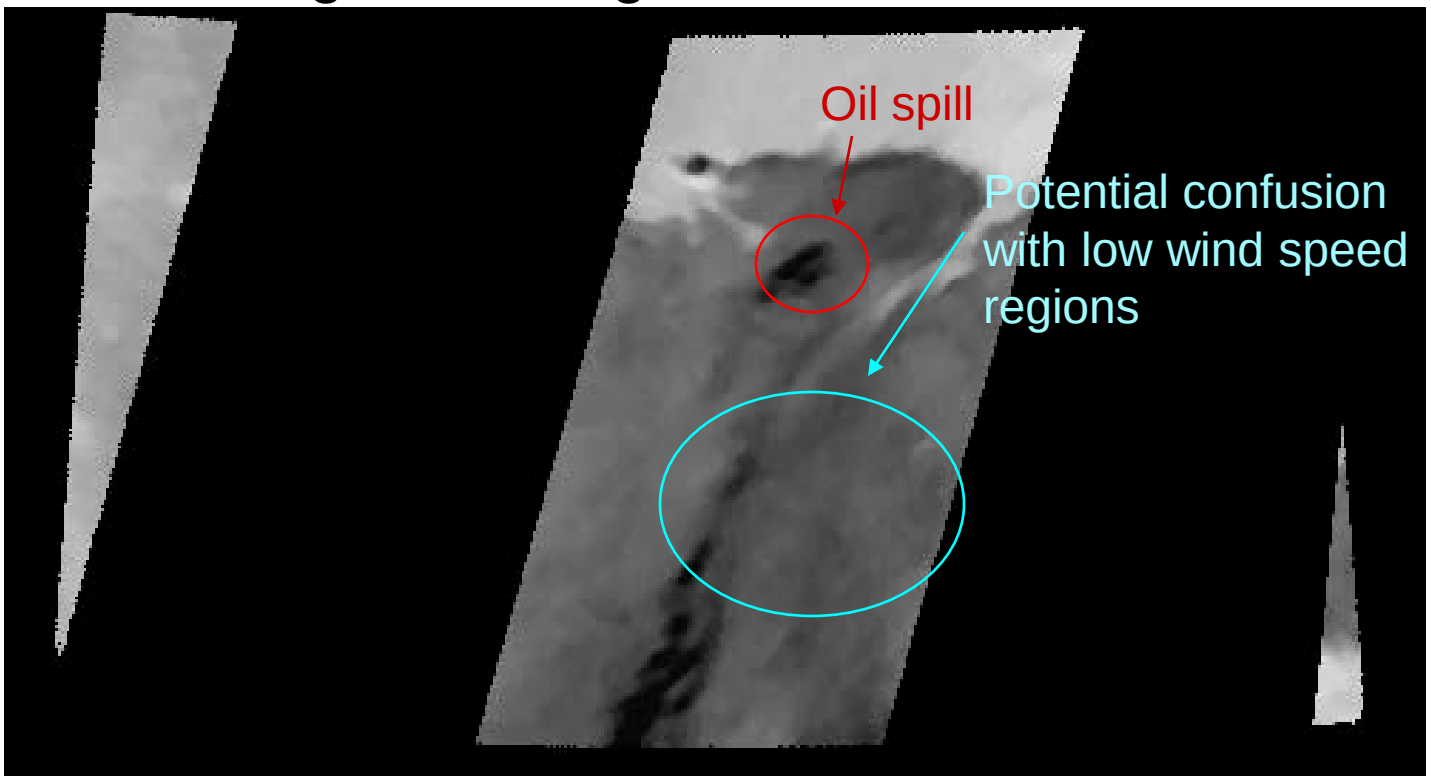


JD 122, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

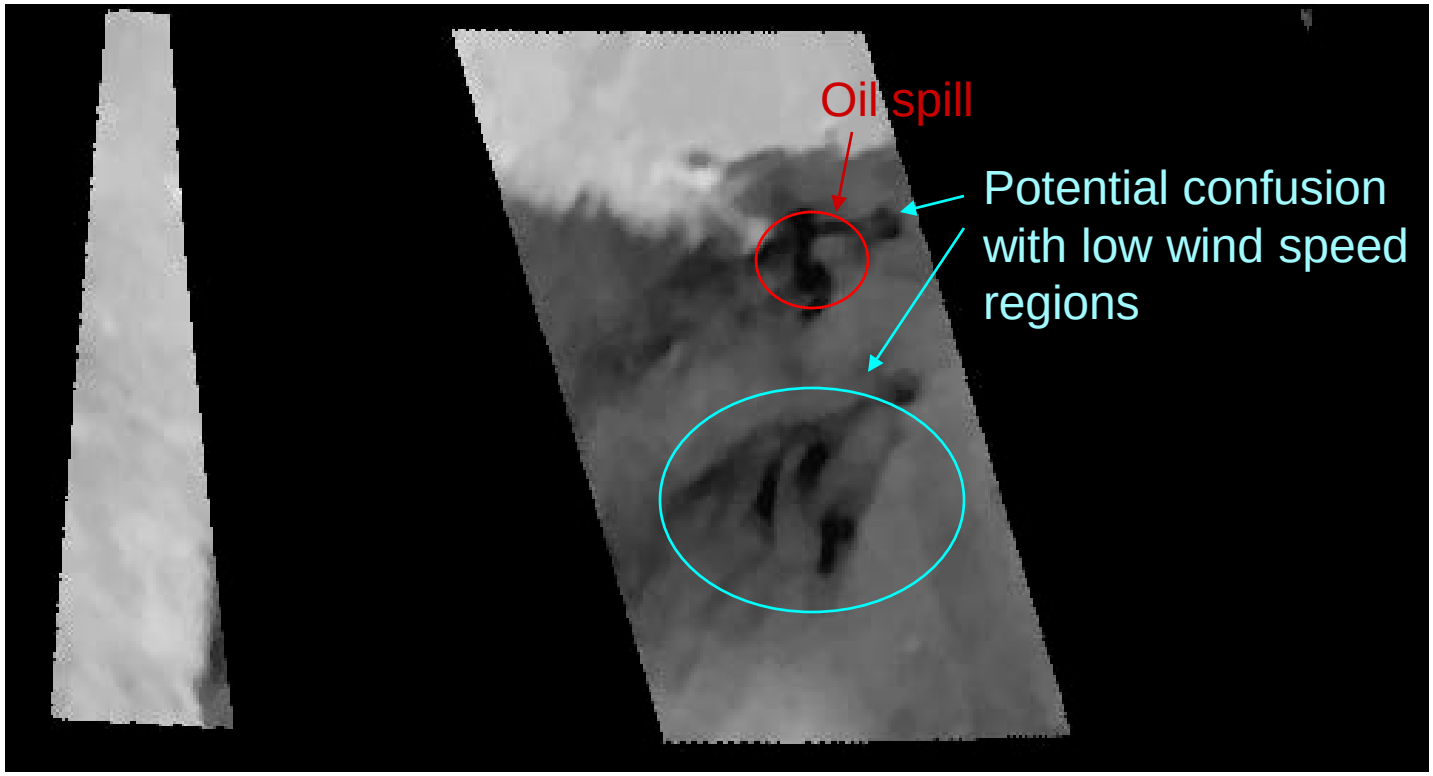


JD 124, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

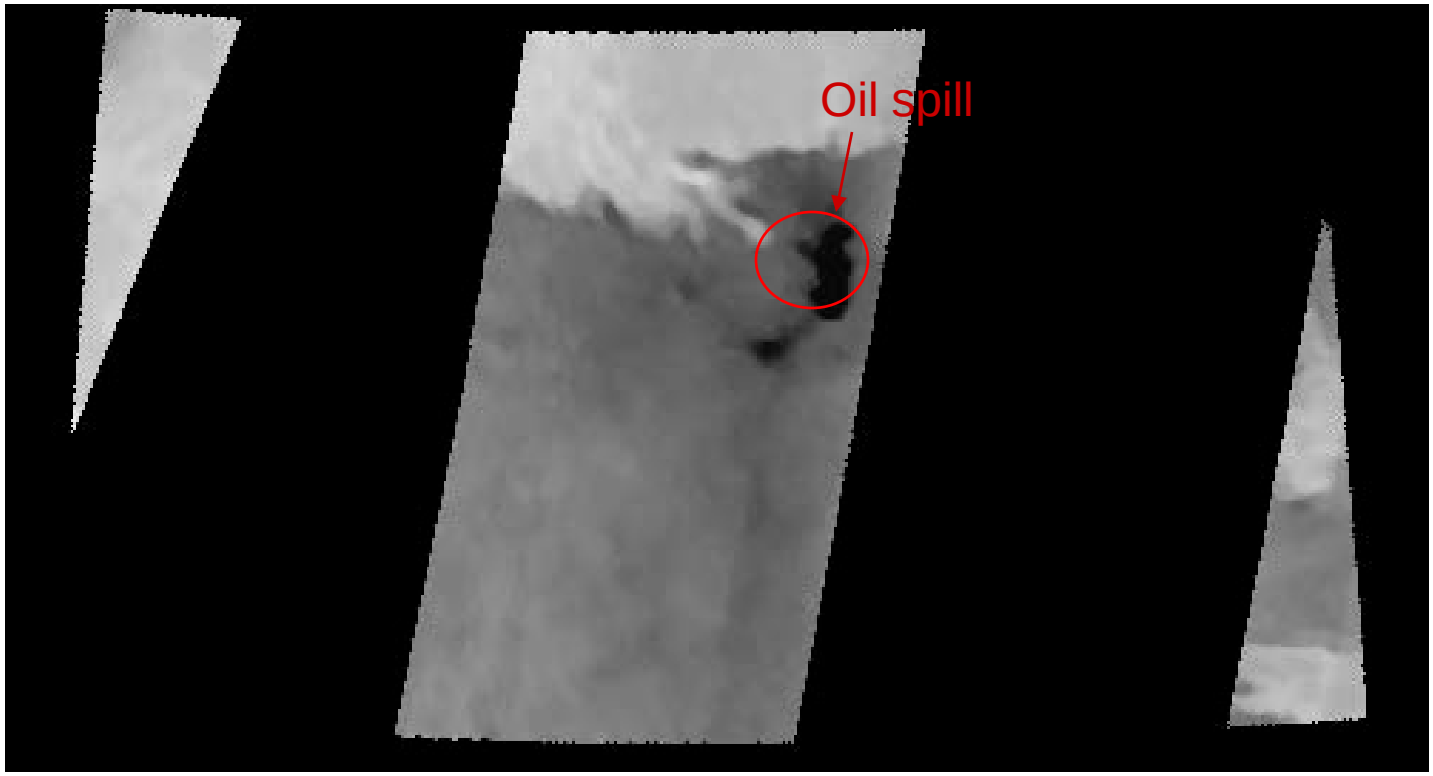


JD 127, 2010

Deepwater Horizon Oil Spill

Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images

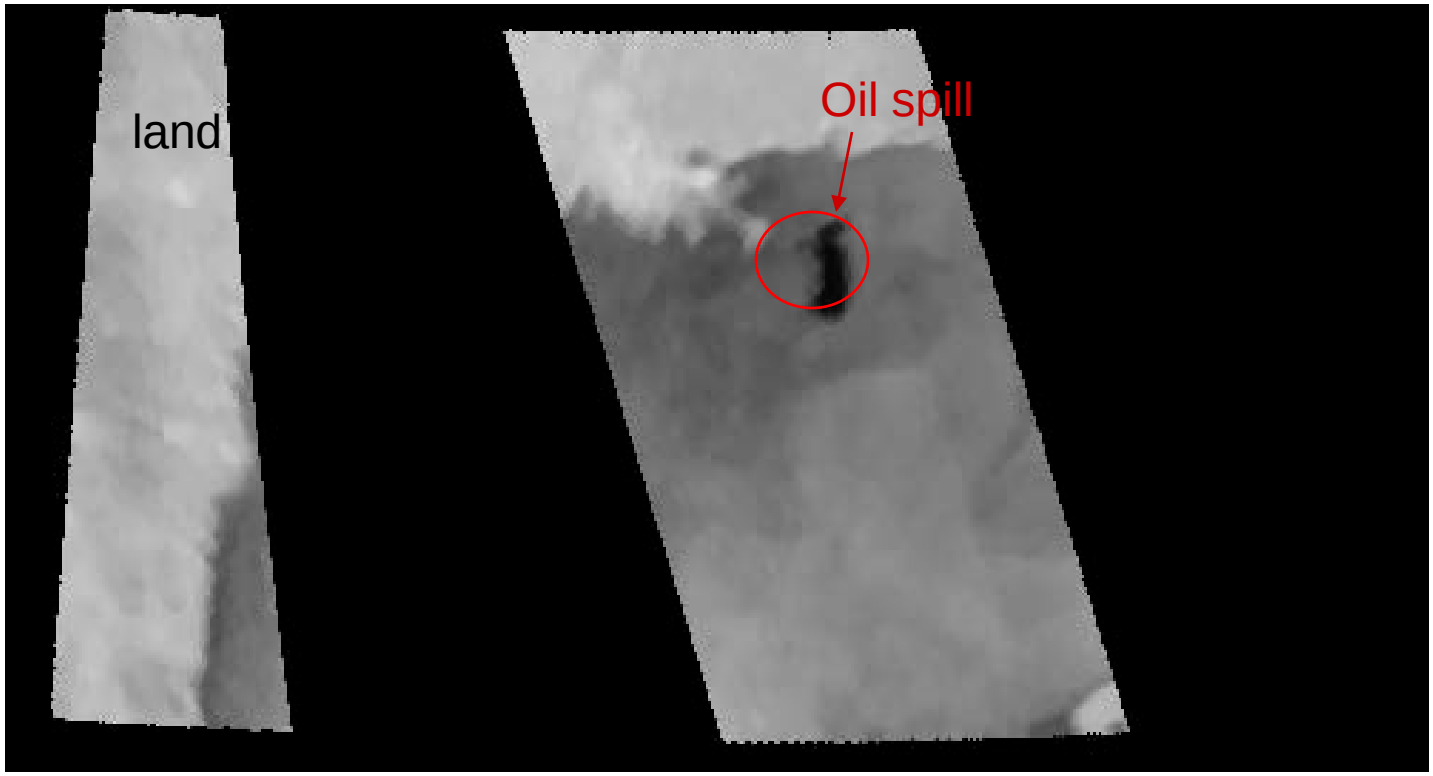


JD 131, 2010

Deepwater Horizon Oil Spill

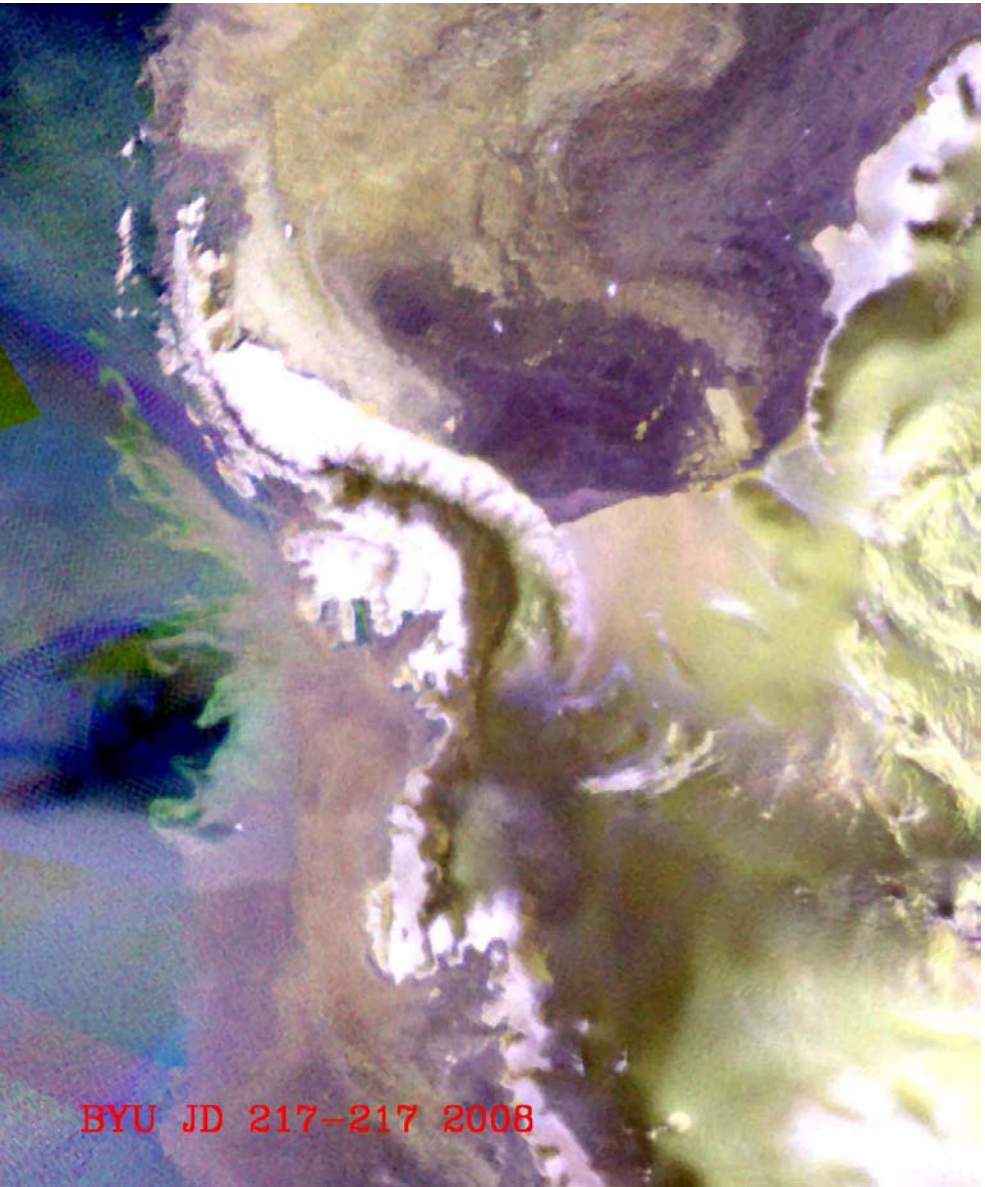
Enhanced Resolution ASCAT Observations

- Spill alters wave spectrum, visible in enhanced resolution sigma-0 images



JD 132, 2010

Enhanced Resolution ASCAT & QuikSCAT



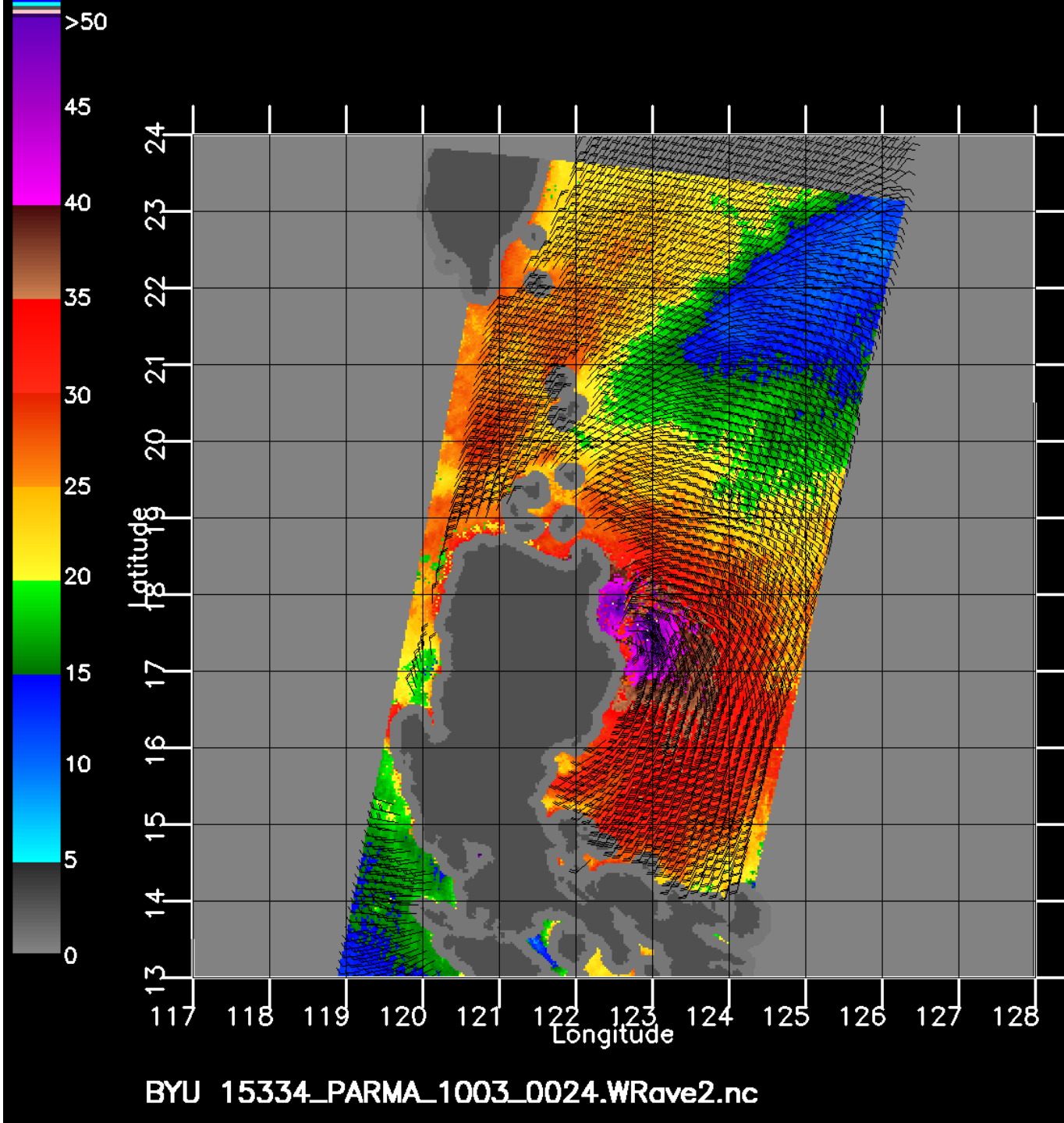
- Enhanced resolution false color image using a single day (JD 217, 2008) of data from Ku-band QuikSCAT and C-band ASCAT.
  - Red: QuikSCAT h-pol σ^o at 46º
  - Green: QuikSCAT v-pol σ^o at 45º
  - Blue: ASCAT v-pol σ^o at 40º
  - Open ocean is blue/green. Dark purple is young first year sea ice. Older first year and multi-year sea ice are yellow/gold. Glacial ice that has melted/refrozen is white, with unmodified firn showing as browns and golds. Icebergs show up a as white.
- *Dual-frequency offers more discrimination capability than single frequency*

UHR ASCAT Wind Retrieval

- Single-pass processing of ASCAT data enables production of ultra-high-resolution (UHR) winds
  - AVE enhanced resolution sigma-0 fields are generated separately for each “flavor” (fore / mid / aft)
  - Winds are retrieved for each UHR pixel using KNMI algorithm
    - Fine scale wind features visible
    - 1.25 km/pixel WVCs
    - Effective resolution lower, estimated to be ~10-12 km
  - Ambiguity selection: closest to EPS 12.5 km winds
    - Improved UHR selection algorithms in development, as is ASCAT UHR SWR
- ASCAT UHR wind much less noisier than QuikSCAT UHR winds
  - Effective resolution of ASCAT UHR coarser than QuikSCAT UHR
- “Postage stamp” processing similar to QuikSCAT UHR “Postage stamp” processing for NOAA “invest” areas and named storms
  - Code now being installed at NOAA/NESDIS
  - Sample results below

ASCAT UHR Hurricane Observation Example

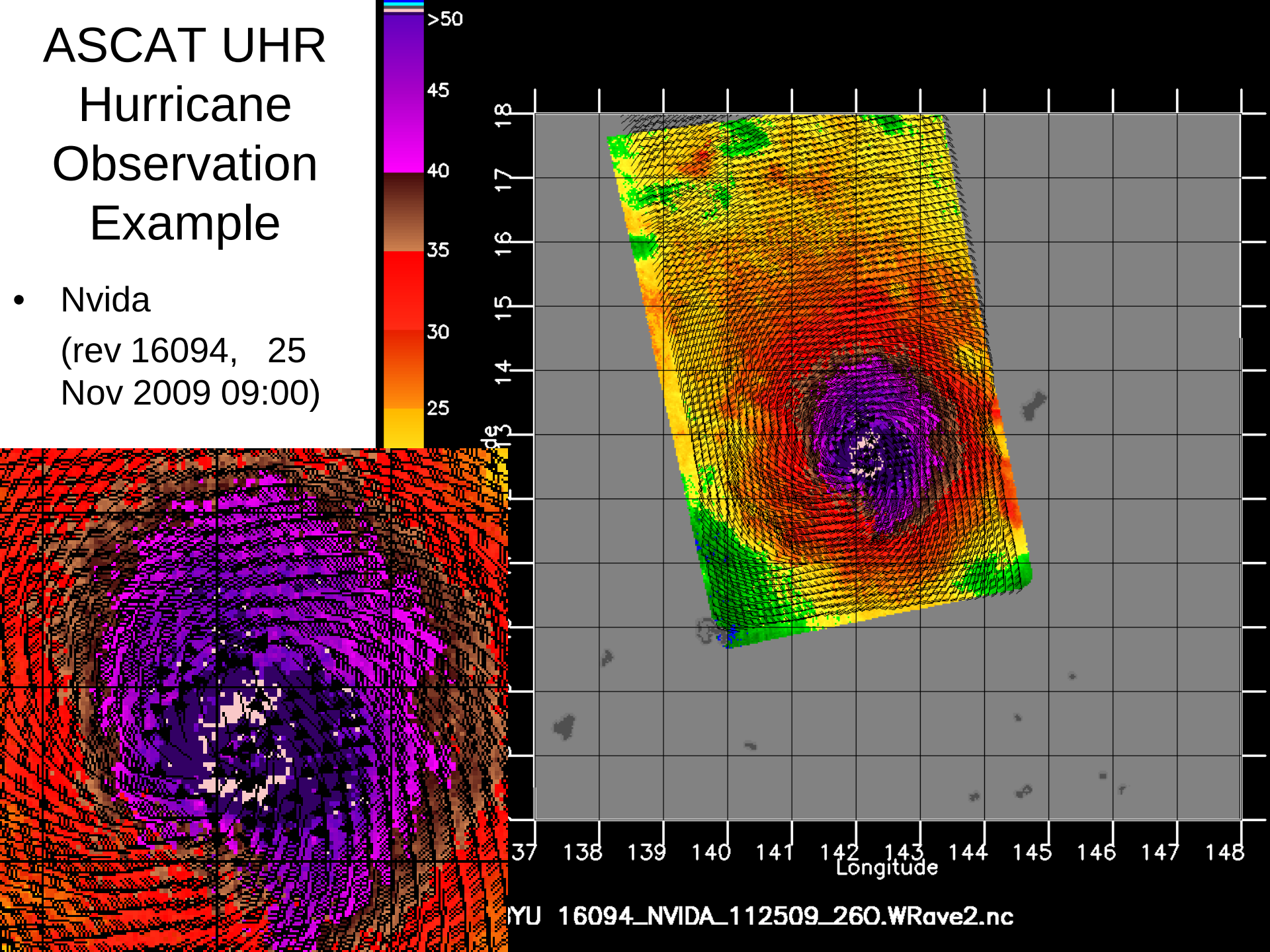
- Parma (rev 15334, 23 Oct 2009)



ASCAT UHR Hurricane Observation Example

- Nvida

  (rev 16094, 25 Nov 2009 09:00)



QuikSCAT*

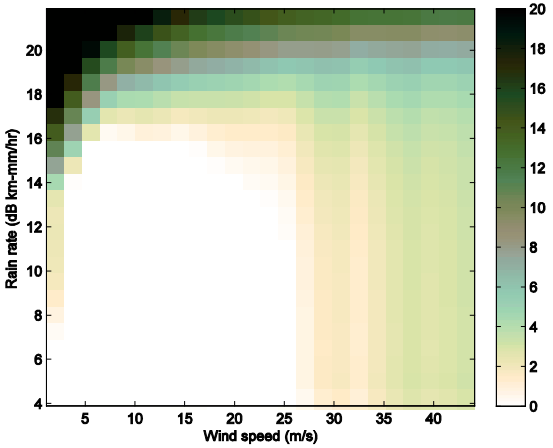
Simultaneous Wind/Rain Retrieval

- Rain affects 4 to 10% of observations
- Several estimators
  - Wind-only (W-O) (conventional wind retrieval)
    - Good wind performance
    - Severe bias during rain
  - Simultaneous Wind-Rain (SWR)
    - Noisy in non-raining cases
    - Good during low to moderate wind and rain
  - Rain-only (R-O)
    - Good during high to extreme rain with low wind
- How can we optimally choose which estimator to use when true conditions are unknown?
  - Ideal choice: Chose estimator with minimum squared error, e.g. Cramer-Rao lower bound (CRB)
  - Bayes algorithm for regime selection developed (paper in review)

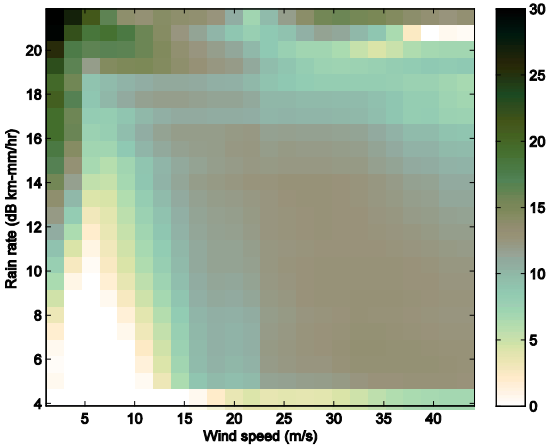
*This also applies to ASCAT which is also sensitive to rain. ASCA can retrieve rain using simultaneous wind/rain retrieval, see C. Nie and D.G. Long, "A C-Band Scatterometer Simultaneous Wind/Rain Retrieval Method," *IEEE Transactions on Geoscience and Remote Sensing,* Vol. 46, No. 11, pp. 3618-3632, 2008.

Cramer-Rao bound for various estimators

W-O Speed CRB



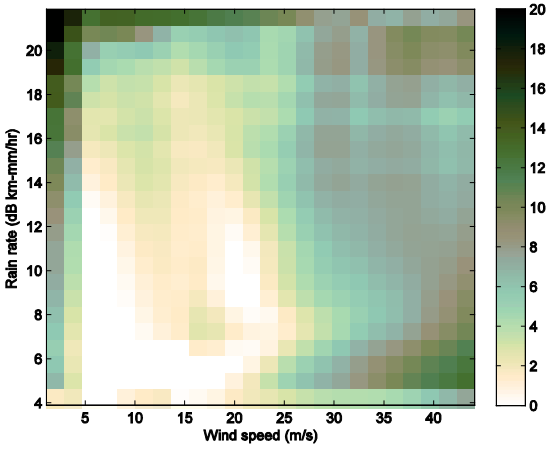
SWR Rain CRB



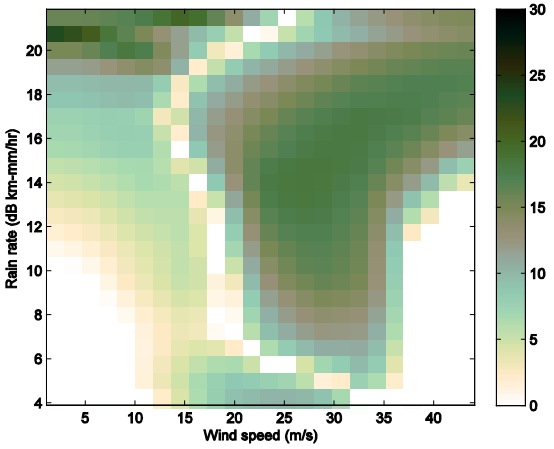
Rain Rate

Wind Speed

SWR Speed CRB

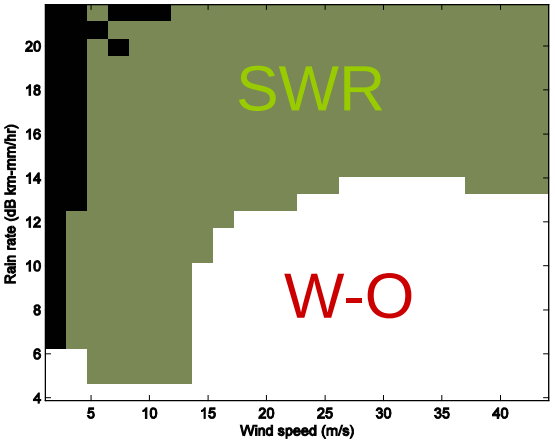


R-O Rain CRB



Estimator Selection Regimes (Minimum CRB)

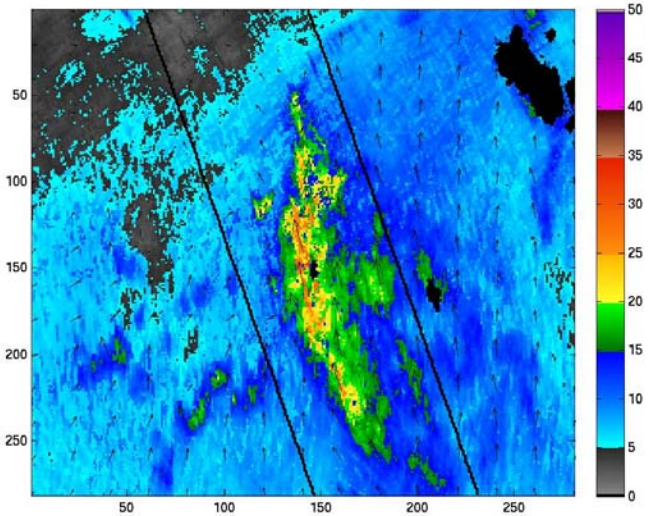
R-O



Using Monte Carlo simulation, best estimator (which has the smallest error for a given wind and rain) is mapped above

QuikSCAT UHR Case Study

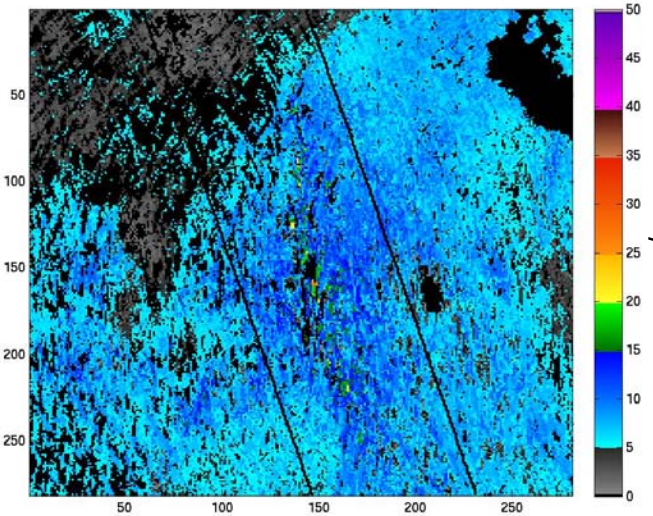
QuikSCAT W-O speed



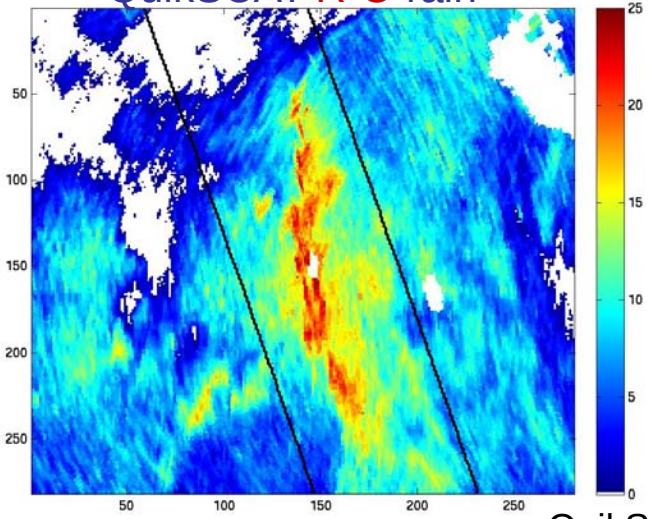
Wind and rain estimates from each retrieval algorithm (estimator)

Now choose one estimator

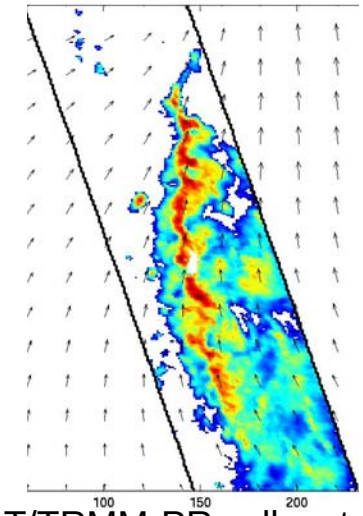
QuikSCAT SWR speed



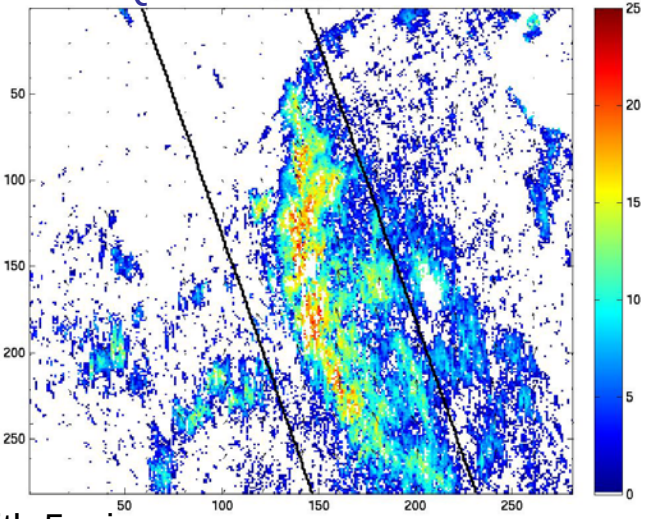
QuikSCAT R-O rain



"True" TRMM PR Rain



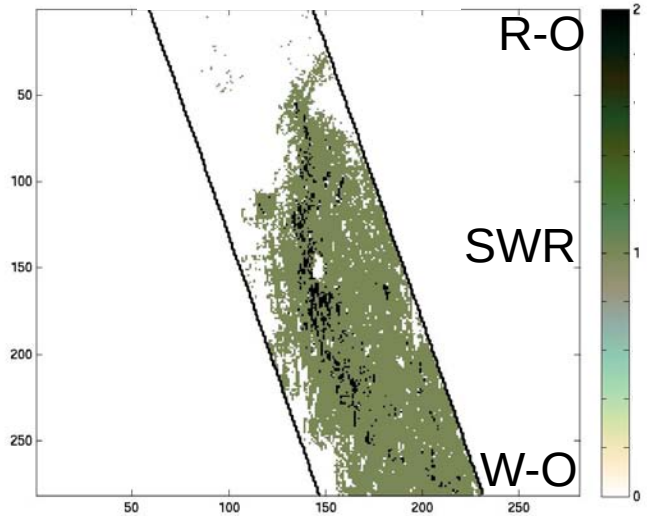
QuikSCAT SWR rain



QuikSCAT/TRMM-PR collocated with 5 mins

Case Study Estimator Selections

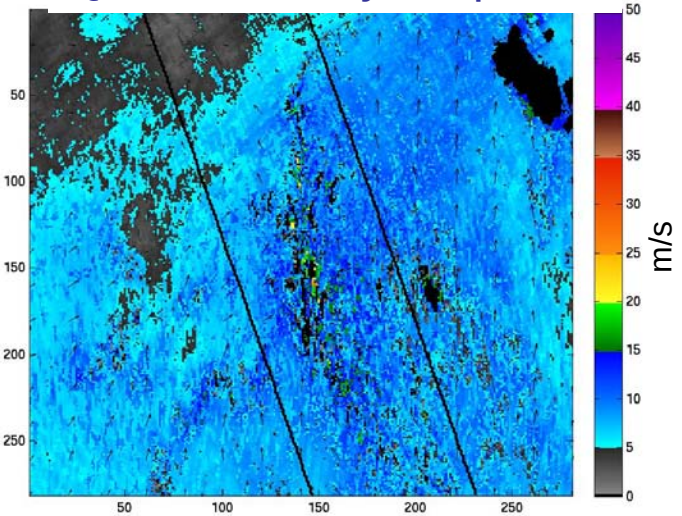
Ideal selector



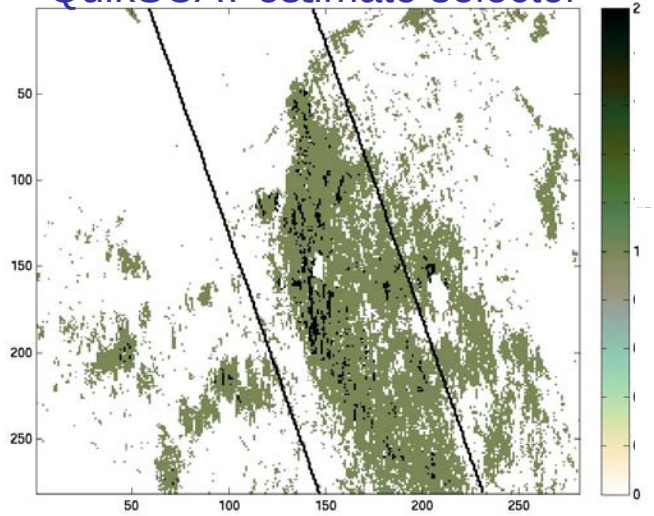
Ideal selection based on TRMM-PR rain

Bayes algorithm for selection based on QuikSCAT measurements – a new type of rain impact flag

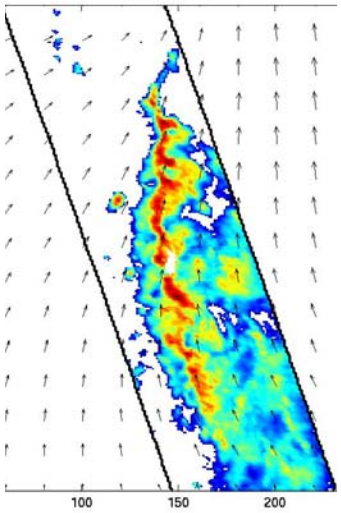
QuikSCAT Bayes speed*



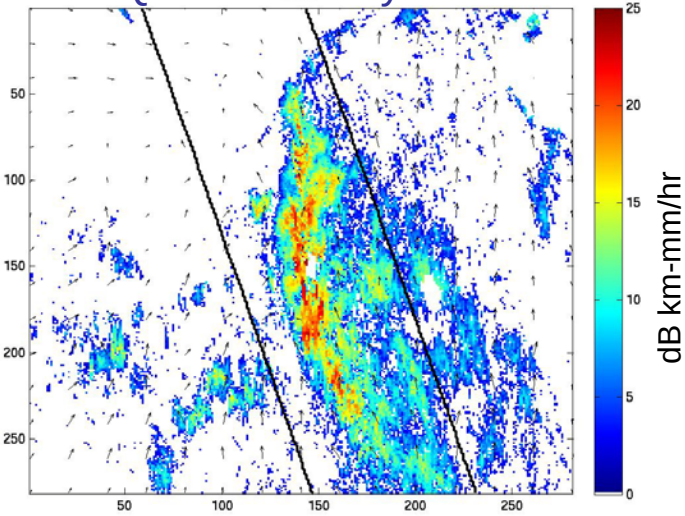
QuikSCAT estimate selector



"True" TRMM PR Rain



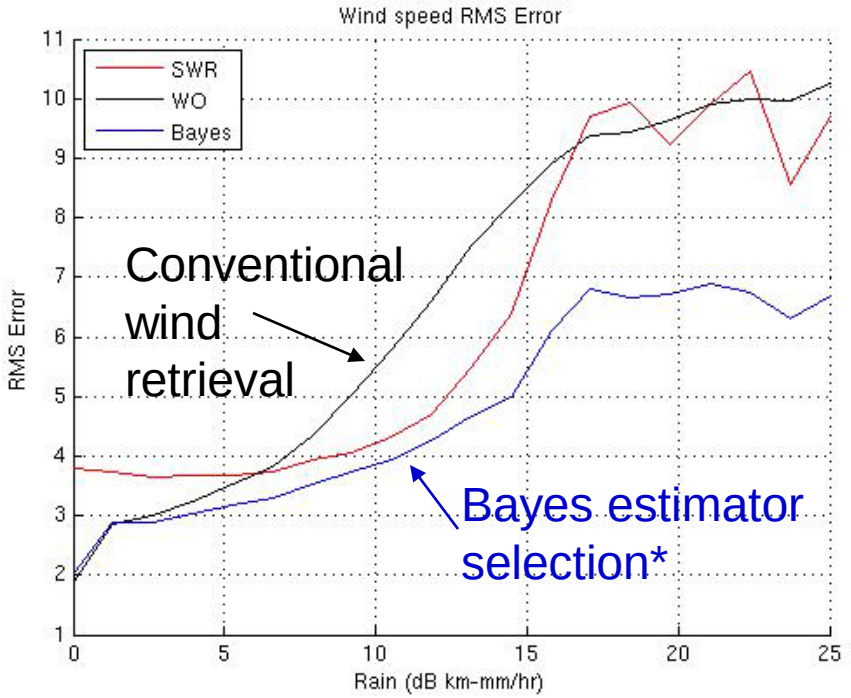
QuikSCAT Bayes rain

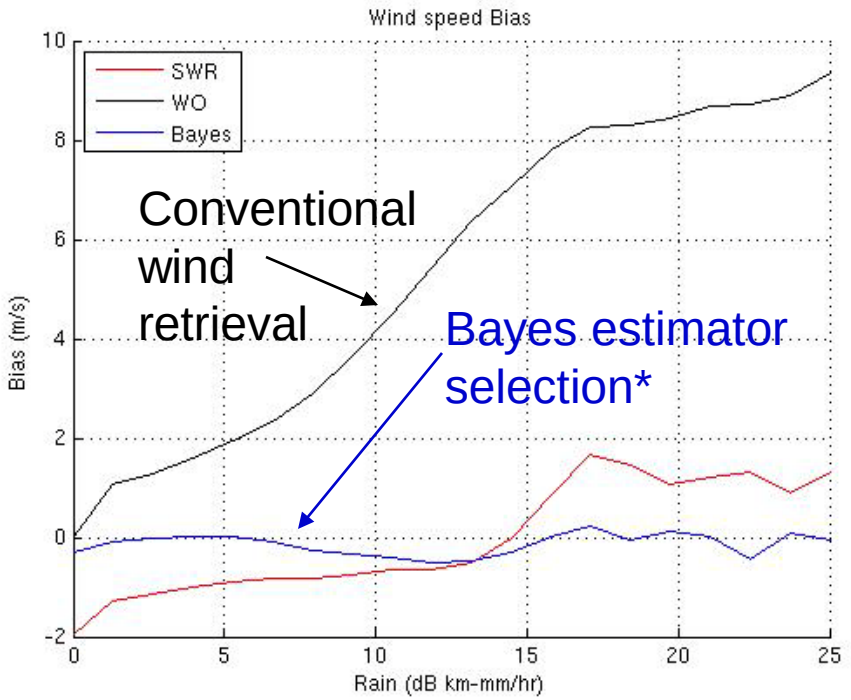


*rain-only selection results in no-speed

Overall Wind Performance

(averaged over hundred's of QuikSCAT/TRMM-PR collocations





- Bayes estimator selection (between W-O, SWR, R-O) has reduced error compared to conventional wind-only retrieval
  - Substantially reduced bias
  - Smaller RMS error

* rain-only retrieval results in discarding of high error winds

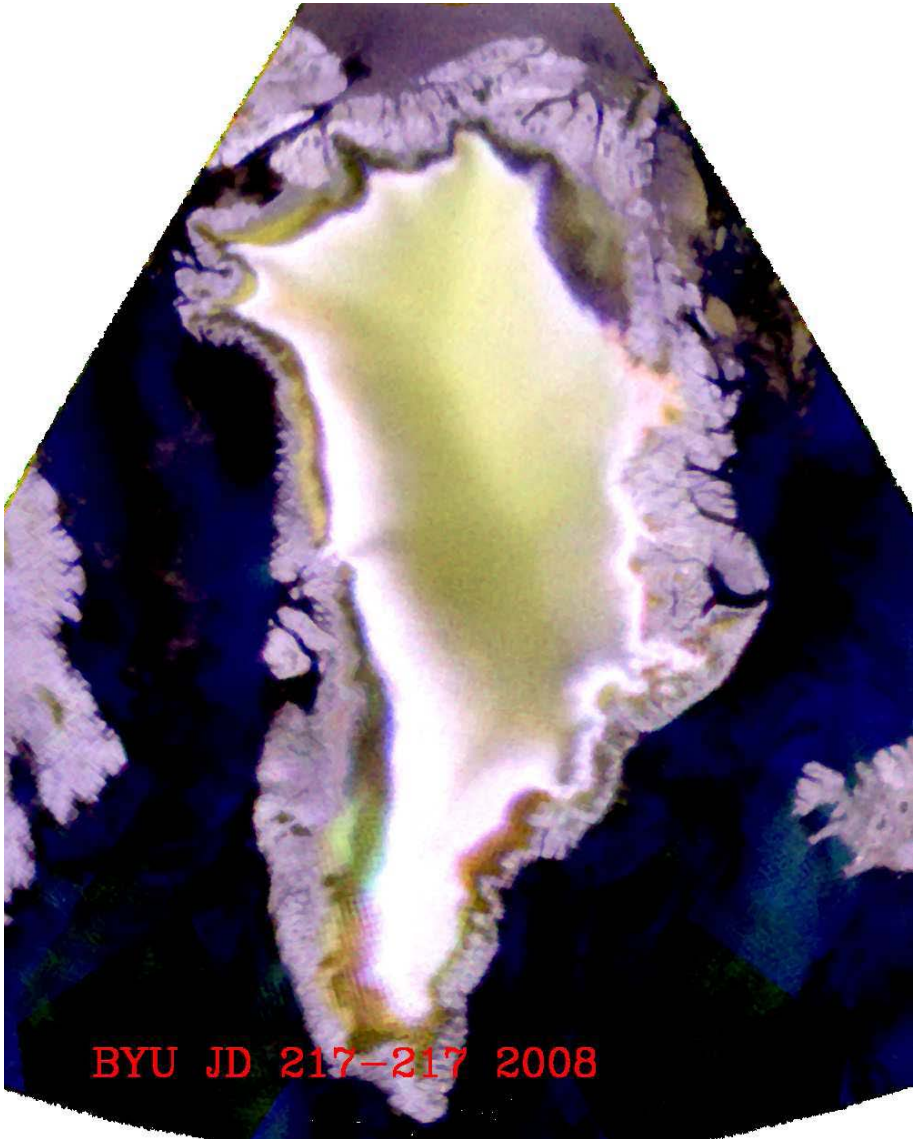
Summary

- *Enhanced resolution processing effective for ASCAT*
- High resolution land/ice SZF-based images now available from the Scatterometer Climate Record Pathfinder web/ftp site www.scp.byu.edu
- ASCAT Ultra-High-Resolution (UHR) wind products now going operational at NOAA/NESDIS
  - In time for 2010 hurricane season
  - Custom “postage stamp” regions available “on demand”
- Validation of QuikSCAT *Bayes estimator selection* between wind-only (conventional), simultaneous wind/rain, and rain-only retrieval
  - An effective rain impact flag
  - Papers in review

Greenland

Dual Frequency Scatterometry

- Single day (JD 217, 2008) false color enhanced resolution image of Greenland from QuikSCAT and ASCAT
  - Red: QuikSCAT h-pol
  - Green: QuikSCAT v-pol
  - Blue: ASCAT v-pol
  - Purple corresponds to land. Summer melt on the ice sheet periphery is the darker region between the white and purple regions. Refrozen melt-zone is bright white. Unmelted firn in central Greenland is brown and gold
  - (Texturing in the lower left portion of the melt zone is an artifact of the diurnal melt cycle due to using passes at different times of the day)
- Combined, the two scatterometers offer more discrimination capability than either alone



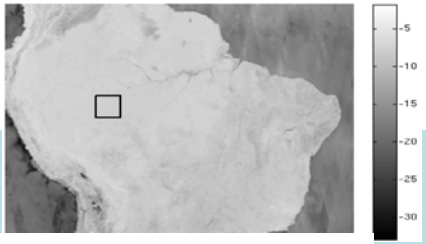
Backup Slides

Linear model for sigma-0 vs incidence angle

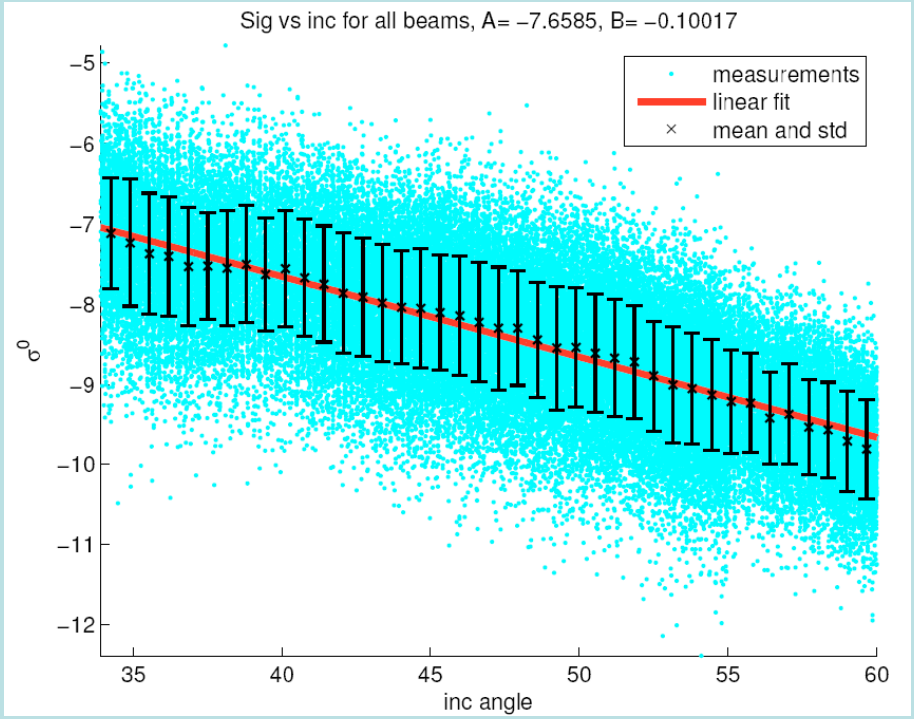
$$\sigma^0_{\mathrm{dB}} = \mathcal{A} + \mathcal{B}(\theta_i - 40^\circ)$$

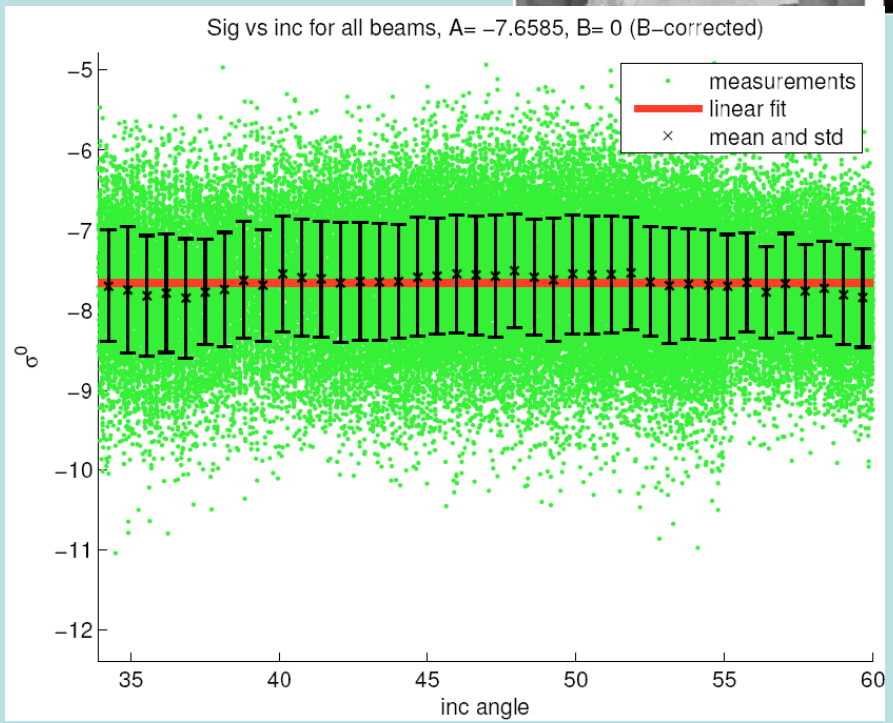
$\mathcal{A}$ is the σ^0 value at $\theta_i = 40^\circ$, and $\mathcal{B}$ is the slope of the fit

- Model appropriate for regions with no azimuth anisotropy

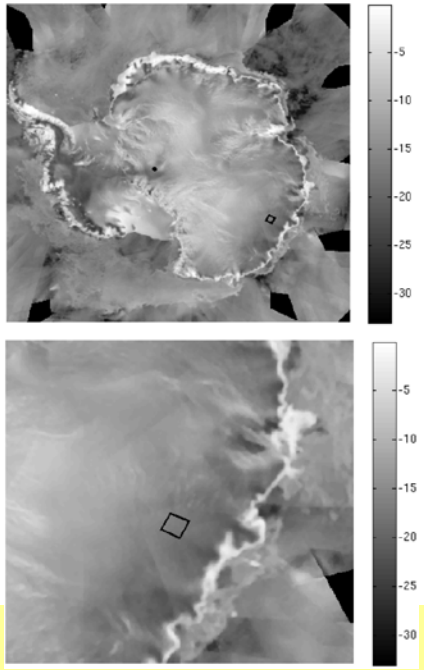


Amazon Rain Forest Example



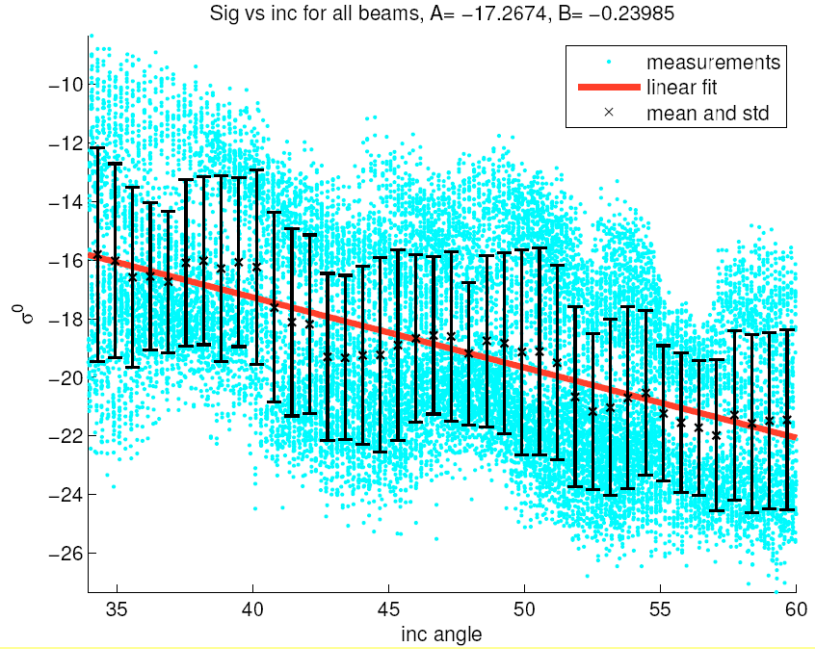


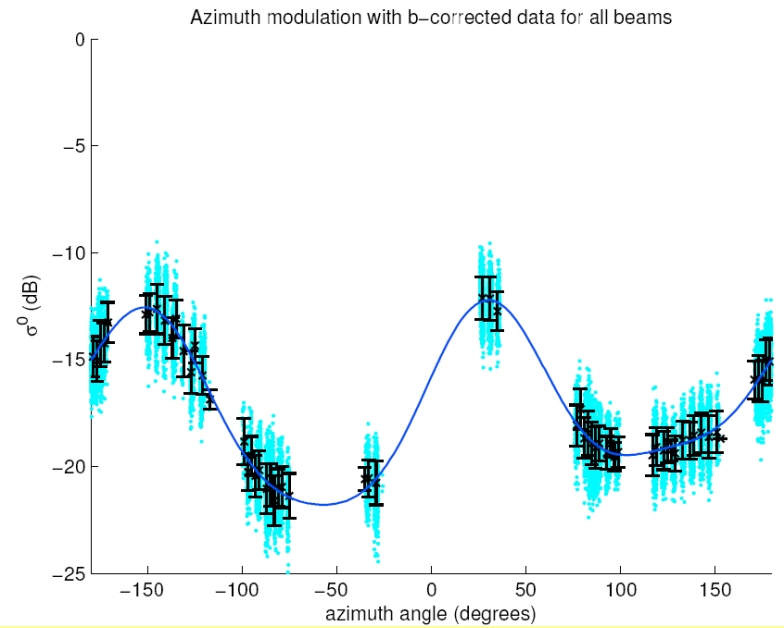
Backscatter Anisotropy



- Due to sastrugi and topography, some polar regions exhibit anisotropic backscatter response
  - Corrections methods have been developed and will be applied to Scatterometer Climate Record Pathfinder images

Wilkes Land Example

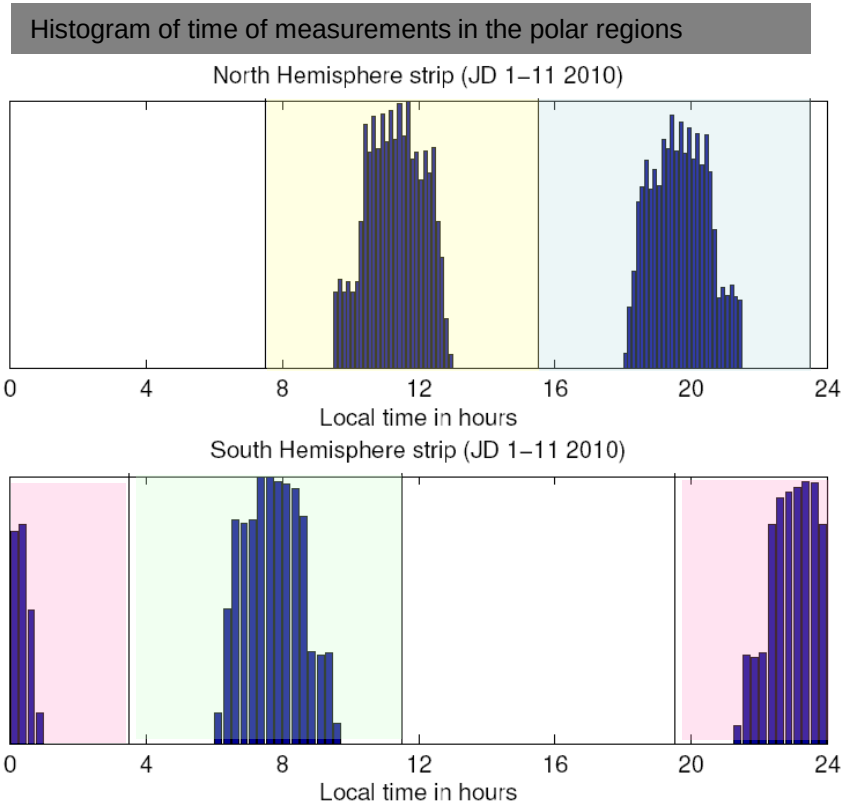


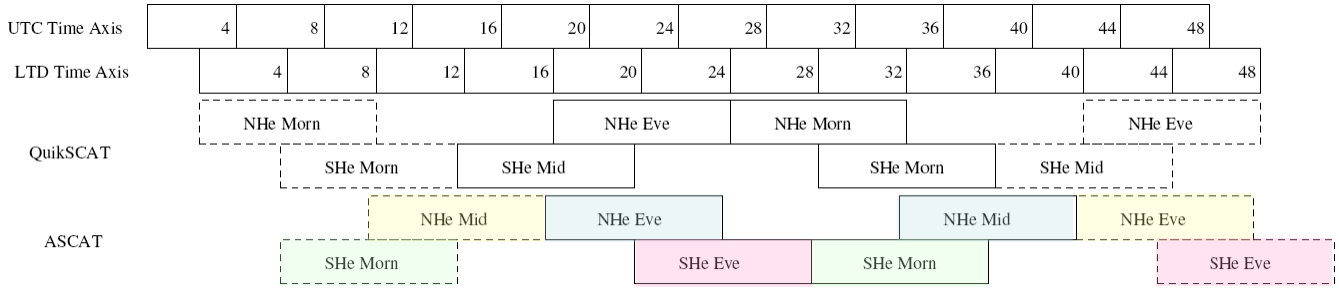


ASCAT Local Time-of-Day Images

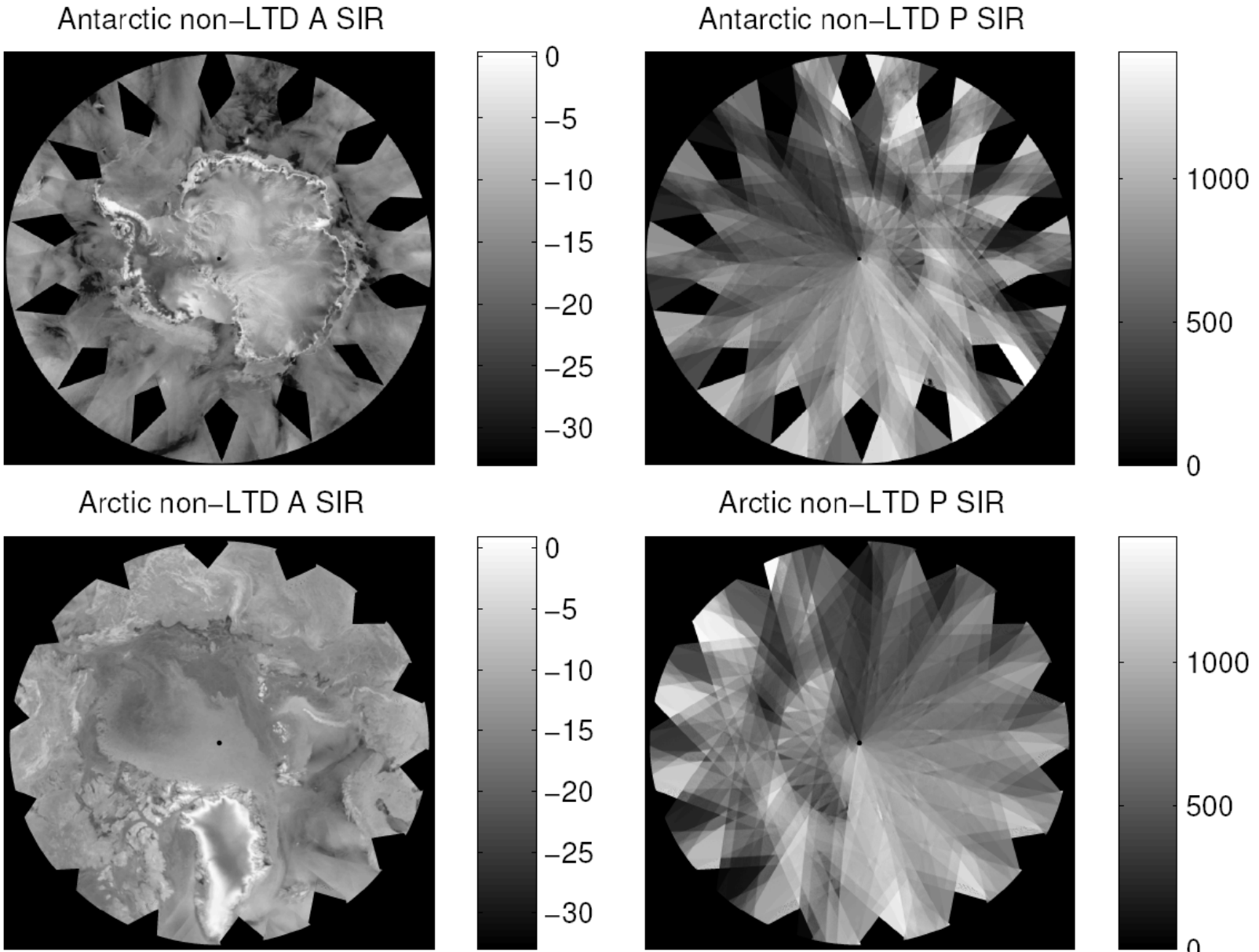
- ASCAT observes the poles many times each day
  - Local time of each pass varies in one of two general times
- Multiple measurements combined to make images
  - Diurnal features are averaged together, leading to loss in temporal resolution
- Solution: combine only measurements from similar local-time-of-day

  Local Time [min] = UTC [min] + 4 [min/deg] x longitude [deg]
- Two images each 24 hour period
  - Optionally combine several days separately for each local time of day

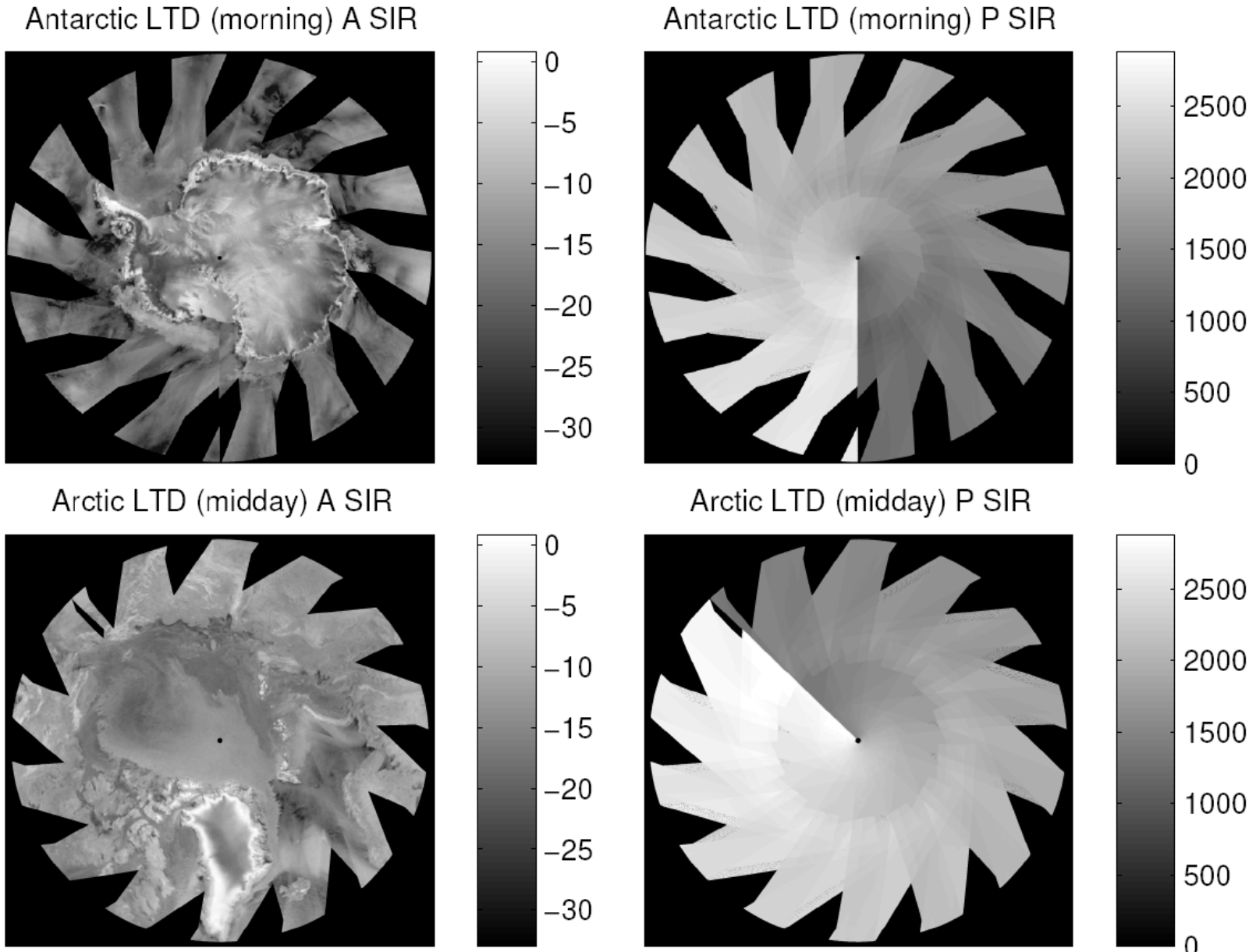




All-Day Images

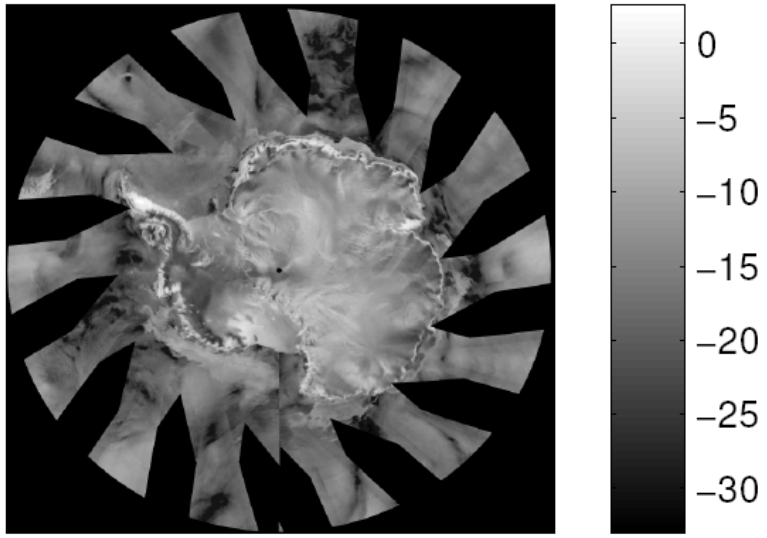


Morning LTOD Images

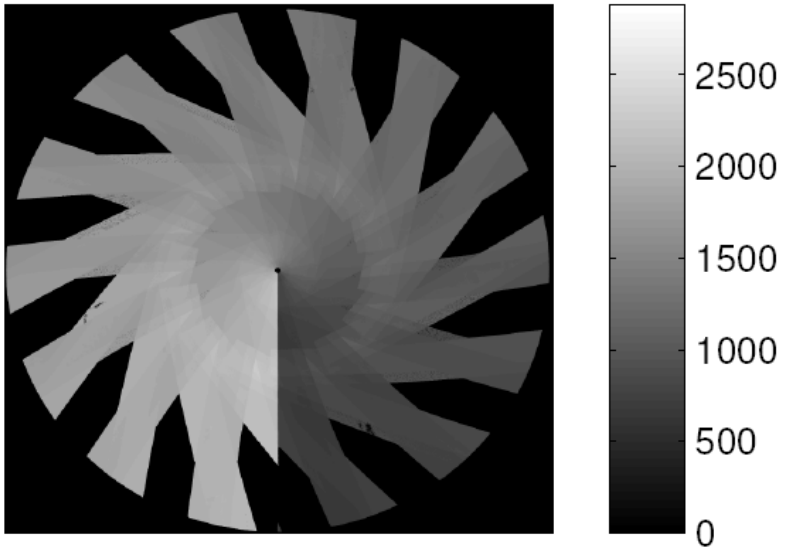


Evening LTOD Images

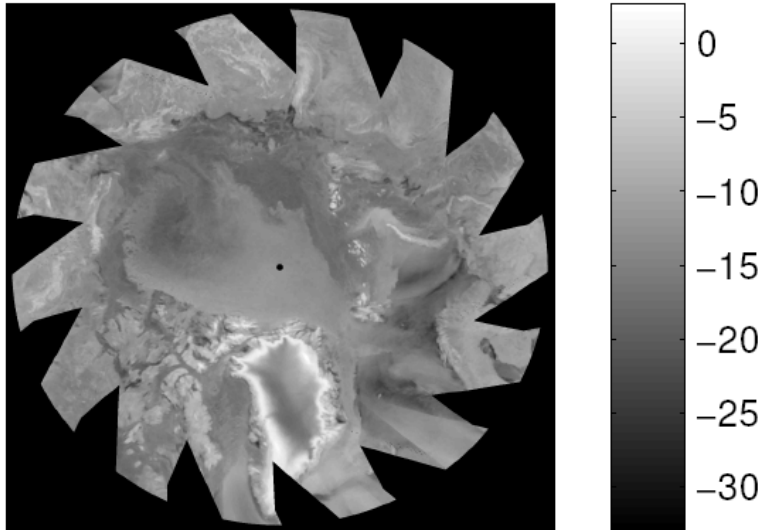
Antarctic LTD (evening) A SIR



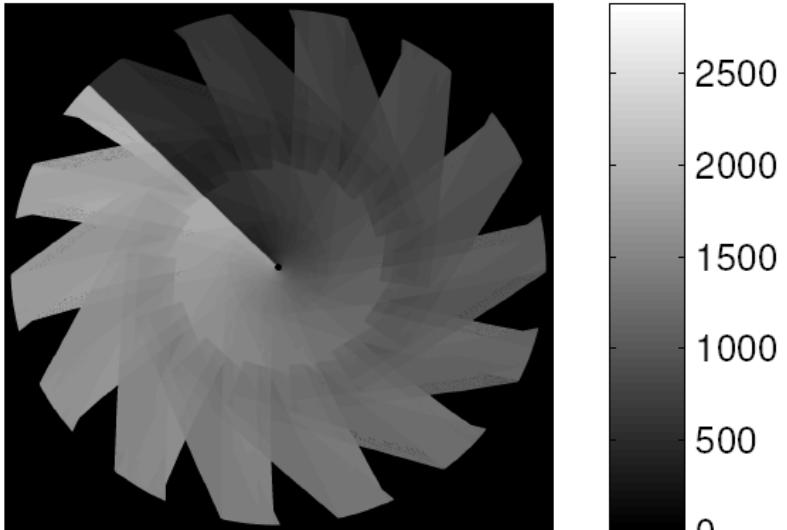
Antarctic LTD (evening) P SIR



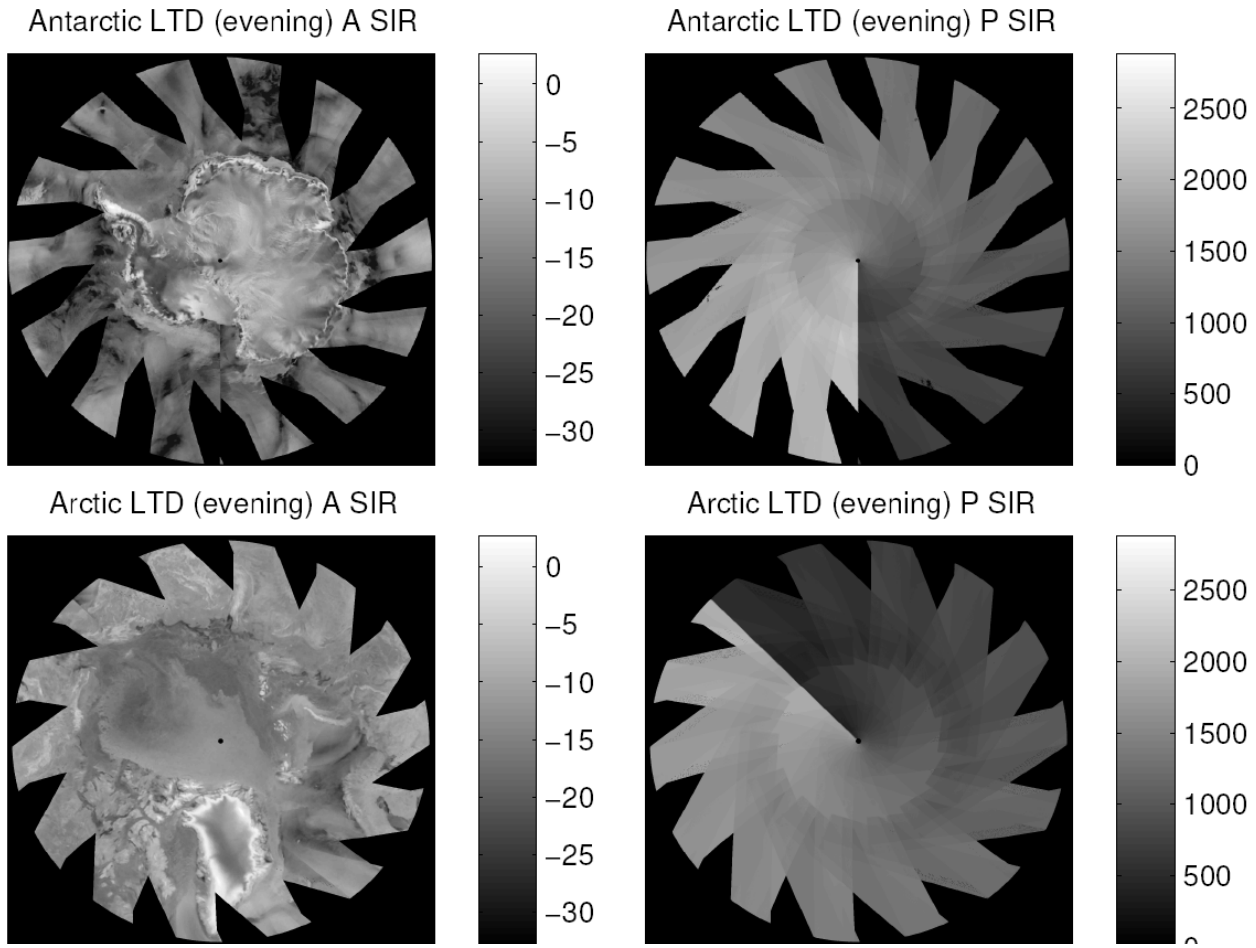
Arctic LTD (evening) A SIR



Arctic LTD (evening) P SIR



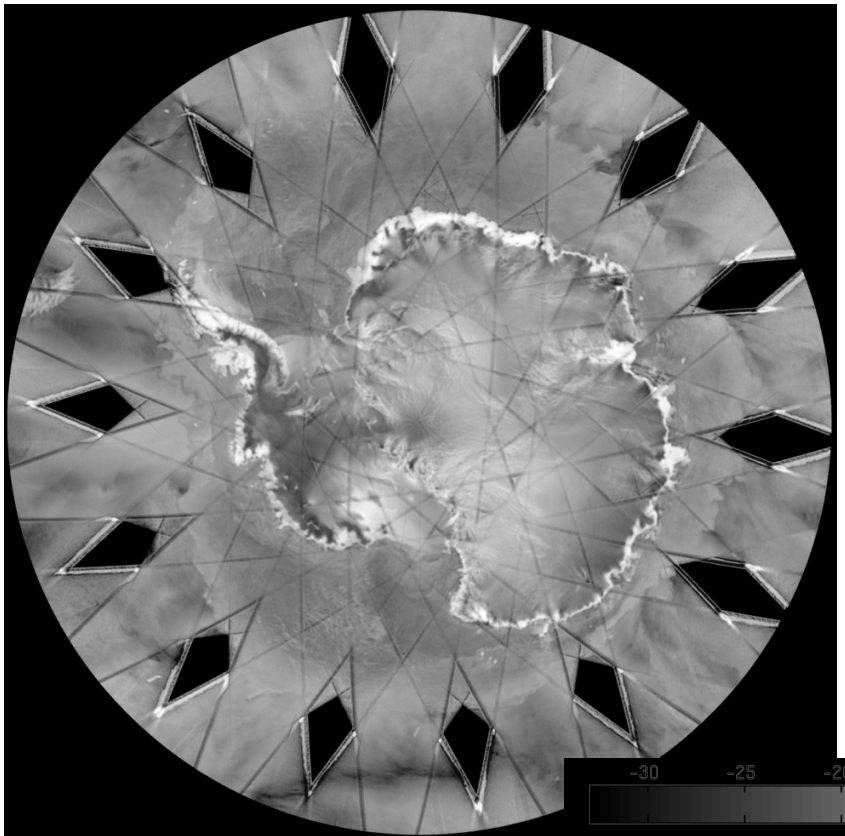
2 Day LTOD Images



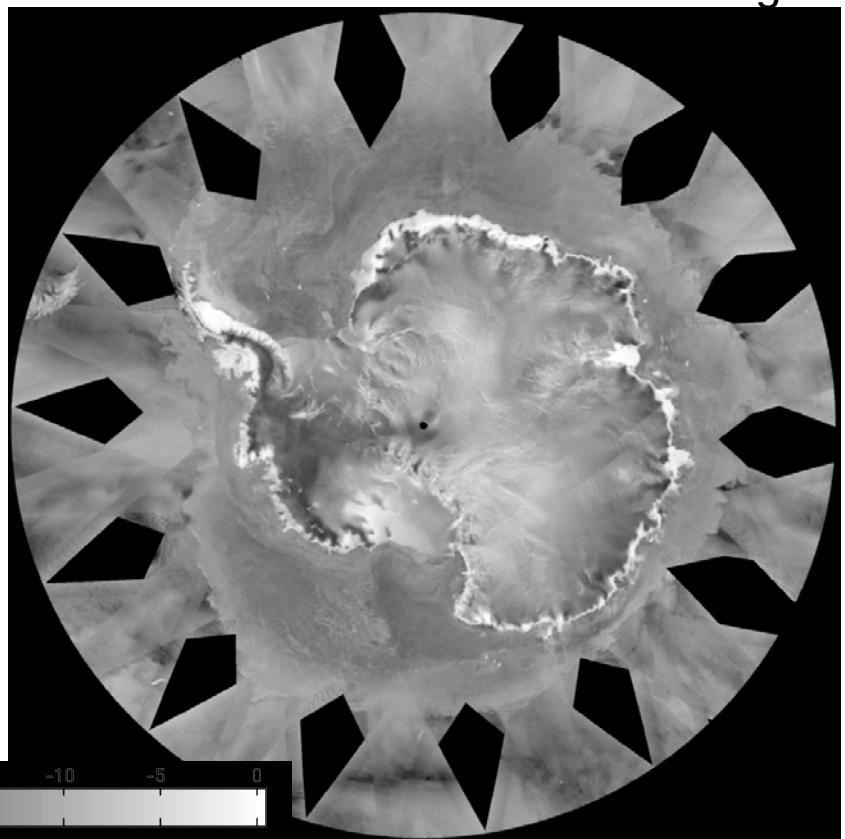
Incidence Angle Trimming

- SZR (25 km “egg”) data incidence angles: 25°-65°
  - Center beams restricted to 33.9°-55°
- Applied same restriction to SZF (slice) data
  - (Raw data covers broader incidence angle range)

Full SZF data

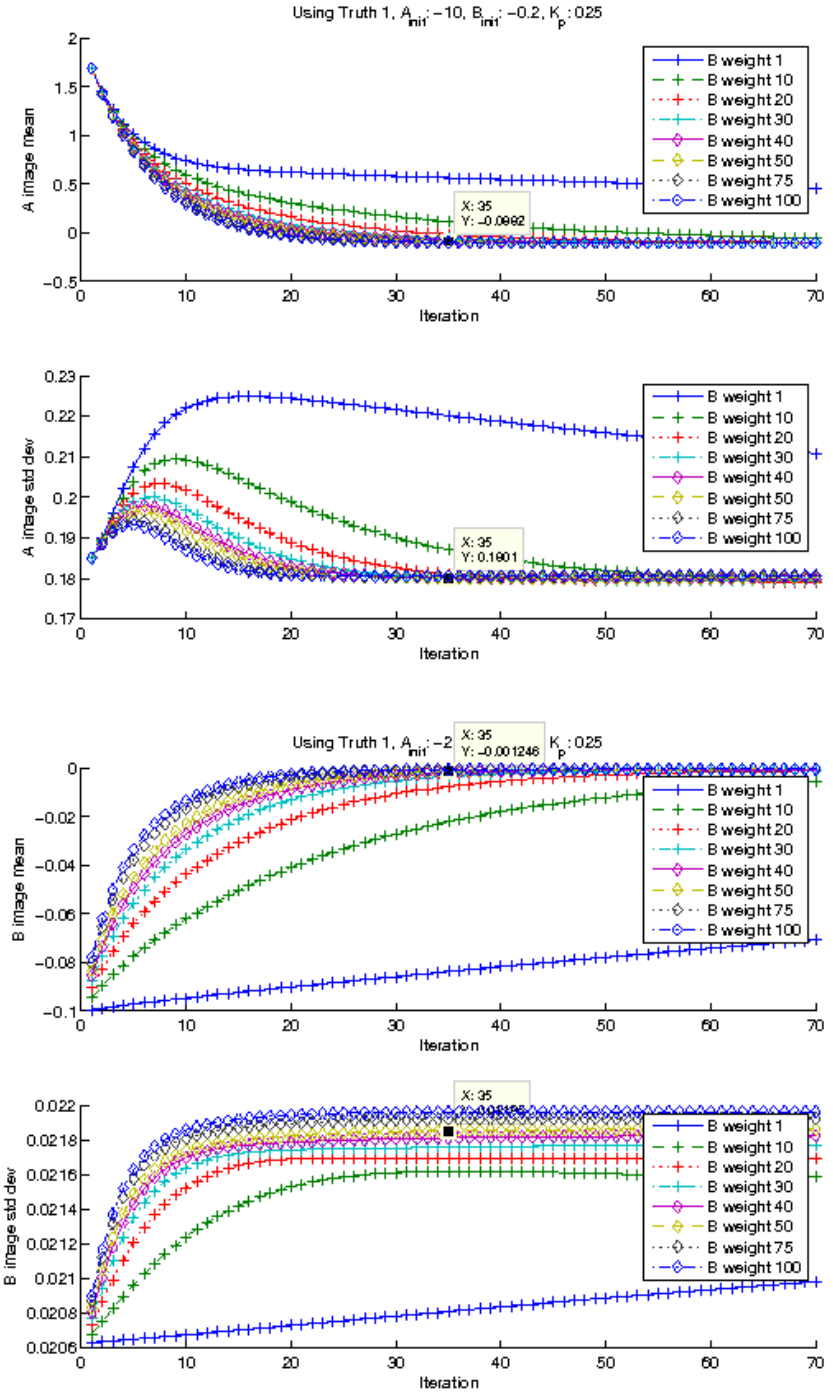


Trimmed incidence angles



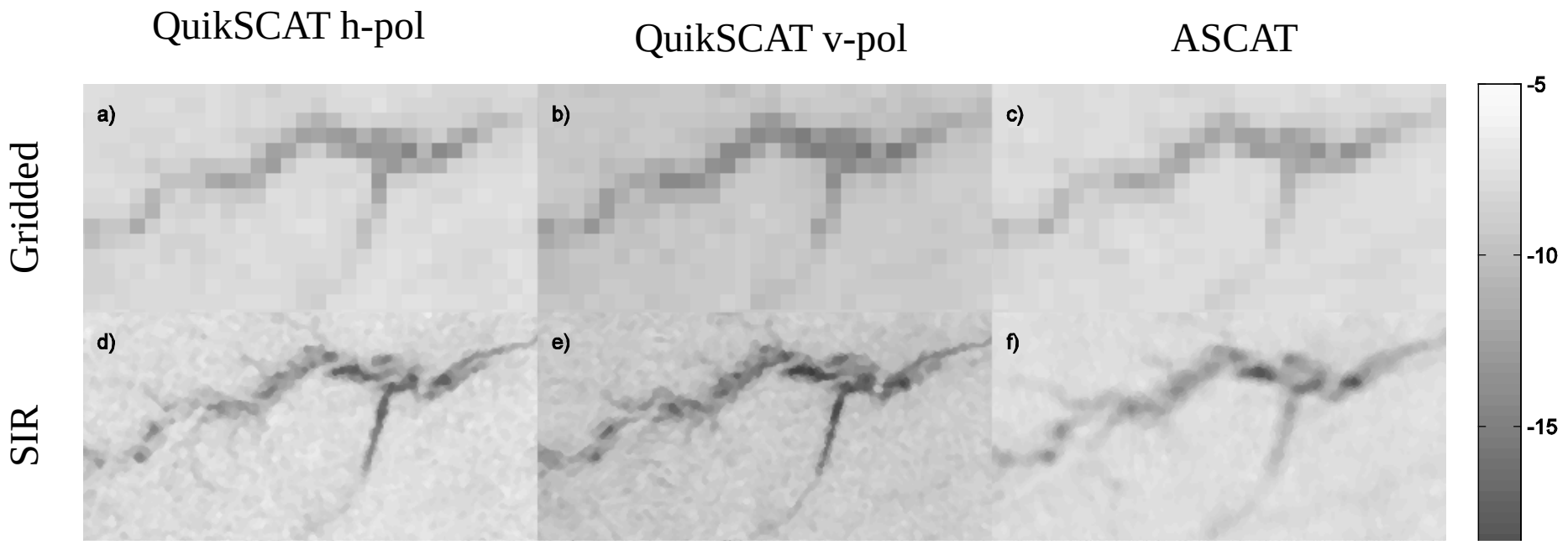
“Tuning” SIR for ASCAT SZF

- Simulation used to select “optimum” SIR algorithm parameters
- Number of iterations
  - N_{its} = 35 (slices)
- Initial values
  - A_{init} = -15 dB
  - B_{init} = -0.25 dB/deg
- B weighting
  - B_{weight} = 50
- Incidence angle clipping
  - Fore/aft: 33.9° - 60°
  - Mid: 33.9° - 55°
- Median filtering optional



ASCAT & QuikSCAT Comparison

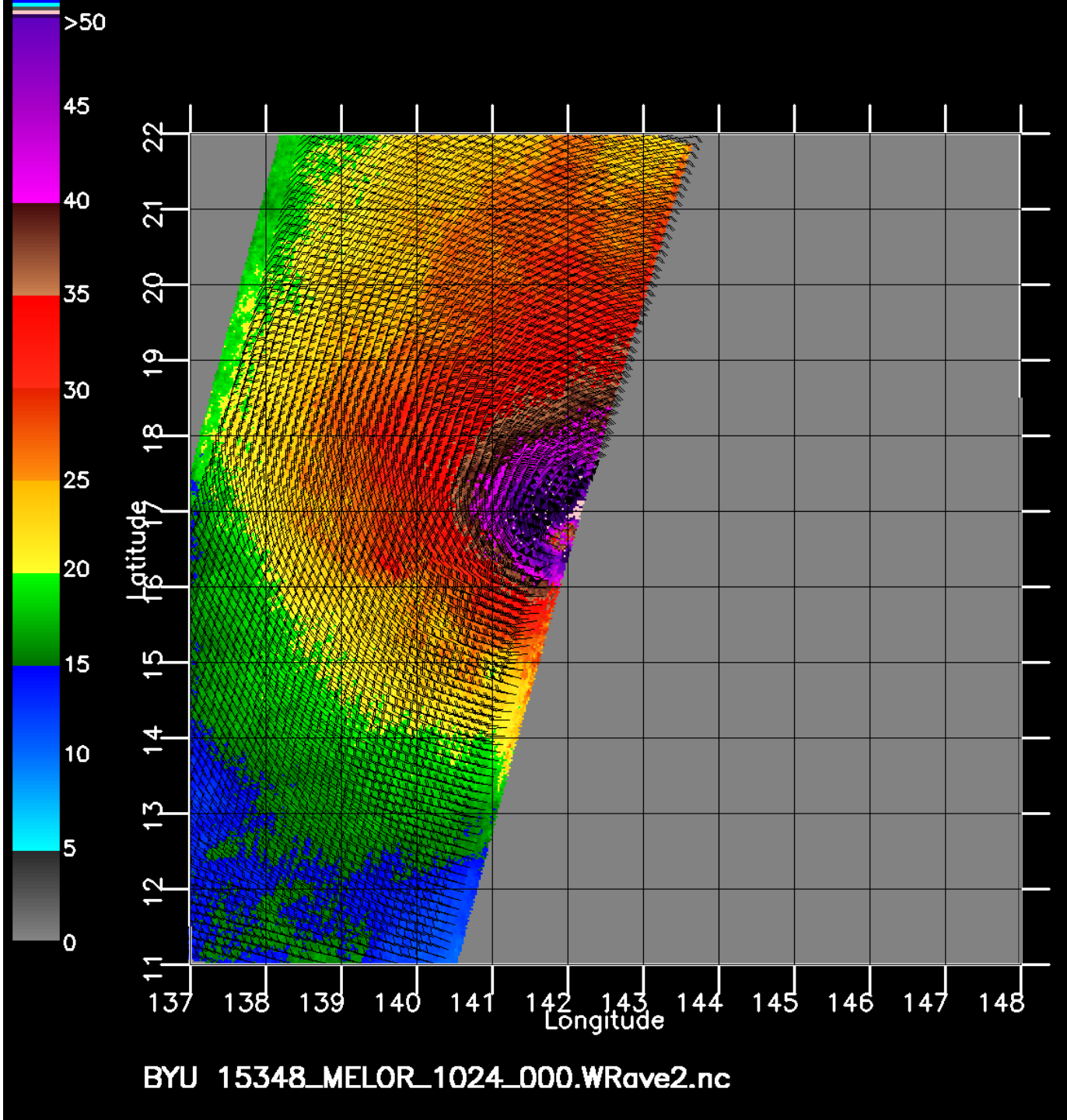
A Images of the Amazon (sigma-0 in dB)



single day of data

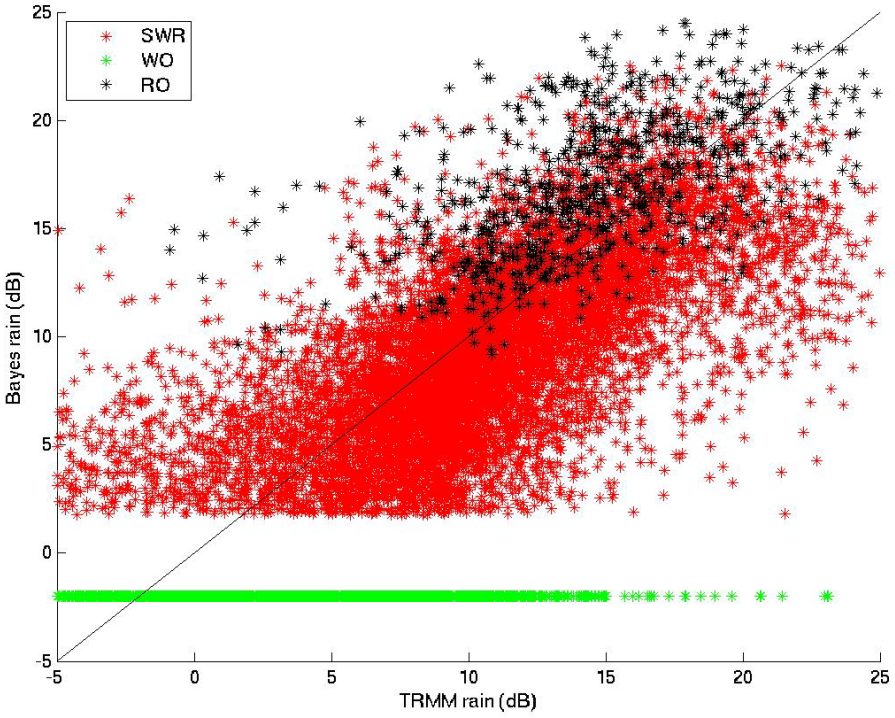
ASCAT UHR Hurricane Observation Example

- Melor (rev 15348, 24 Oct 2009)

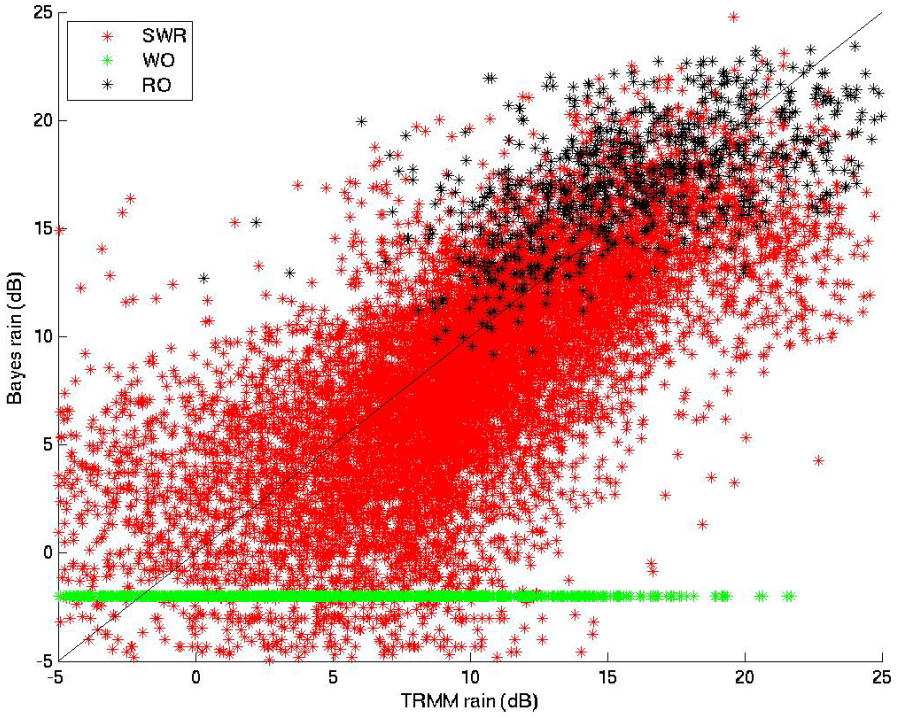


Case Study Rain Comparison

Selected Estimates*



Ideal Selection**



Rain Rate

Wind Speed

* SWR rain estimates less than 1.5 km-mm/hr (light mist) are discarded to reduce noise

** Over TRMM-PR swath

Raining versus non-raining

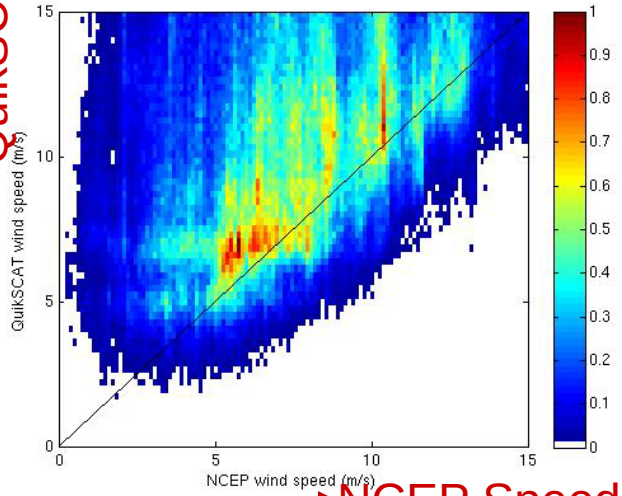
Overall Wind Performance

(averaged over hundred's of QuikSCAT/TRMM-PR collocations)

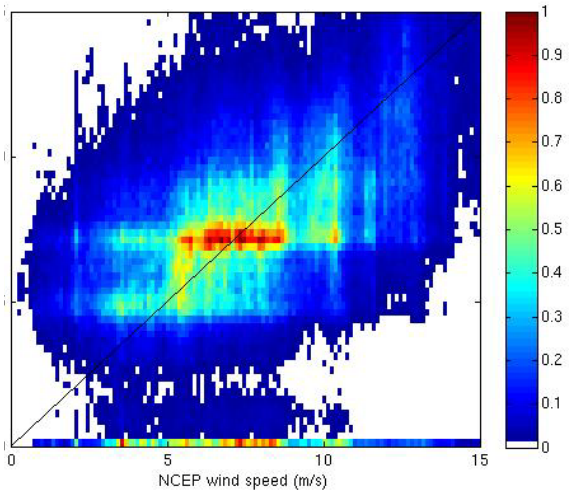
QuikSCAT Speed

NCEP Speed

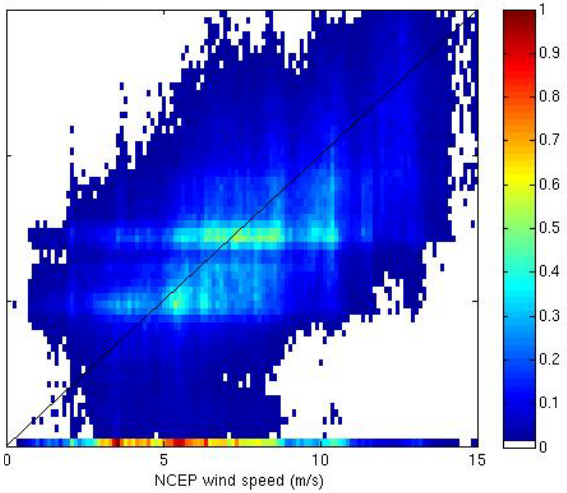
Wind-Only *Raining*



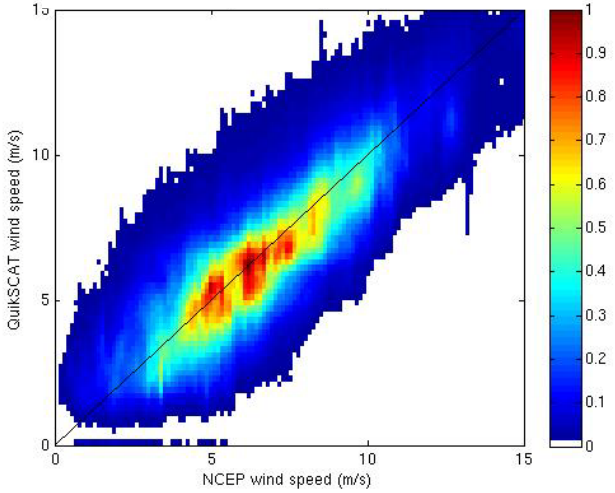
Bayes *Raining*



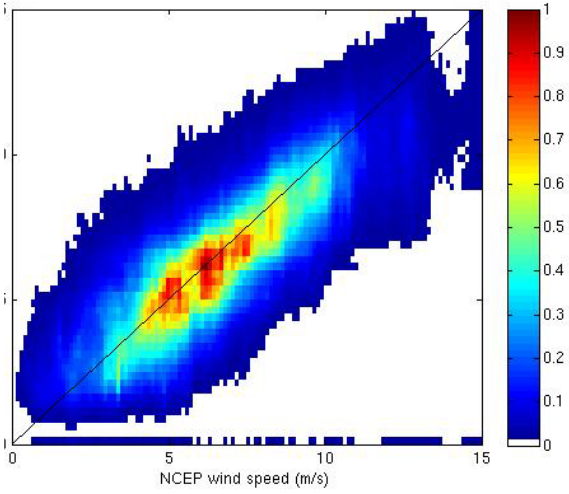
SWR *Raining*



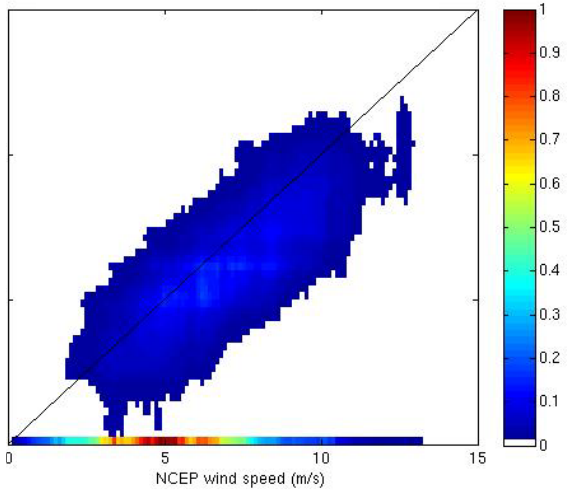
Wind-Only *Non-Raining*



Bayes *Non-Raining*

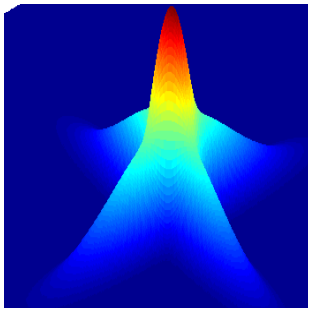


SWR *Non-Raining*



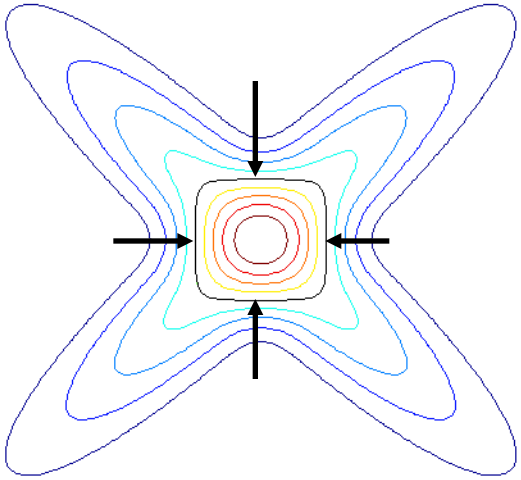
Resolution Enhancement

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

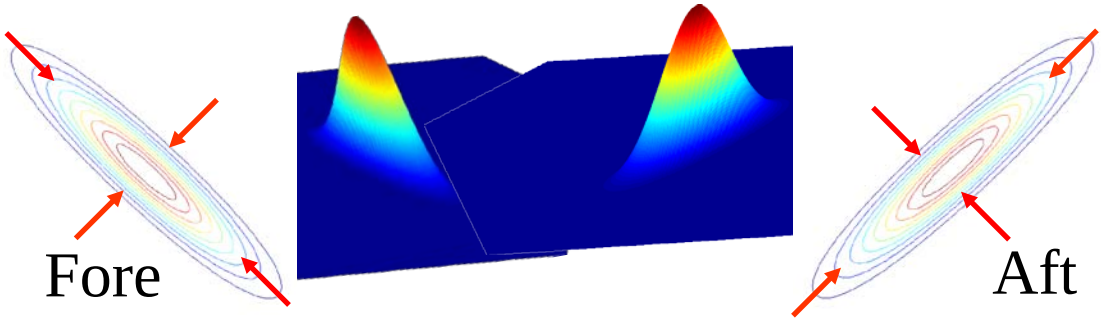


Combined response

3 dB contour shown in black



AVE Response



Individual measurement spatial responses = product of antenna pattern and Doppler/range filtering