The New Geophysical Model Function for QuikSCAT: Implementation and Validation

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Outline:

- GMF methodology
- New QSCAT wind speed and direction validation
- High winds
- Rain impact
- Uncertainty maps

Acknowledgements
This work is supported by NASA Physical Oceanography, Ocean Vector Wind Science Team

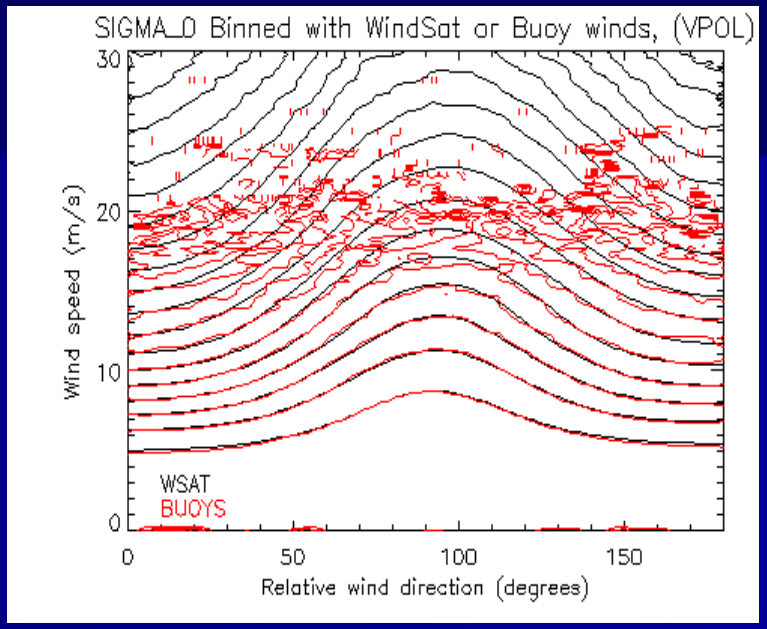
Motivation: Why did we need a new GMF?

- Despite the demise of QSCAT, QSCAT winds are still used in data assimilation and model reanalyses, research (i.e., cyclones, ENSO), cal/val.
- When Ku2001 was developed at RSS (Wentz and Smith, 1999), validation data at high winds were limited. GMF at high winds had to be extrapolated. Analyses showed Ku2001 overestimated high winds.
- Our focus has been to improve QSCAT high wind retrievals
- Recently, Meissner and Wentz (IEEE TGRS, 2009) developed an algorithm for all-weather WindSat wind retrievals, trained with HRD storms. (See poster by Meissner et al.)
- We have confidence in using WindSat wind speeds as ground truth for winds 20-30 m/s. WindSat provides many rain-free high winds observations in extratropics.
- Produce a climate data record of ocean vector wind, combining QSCAT with other scatterometers, by using consistent methodology.

The New GMF: Ku2011

The Geophysical Model Function (GMF) relates the observed backscatter ratio σ_0 to wind speed *w* and direction ϕ at the ocean's surface

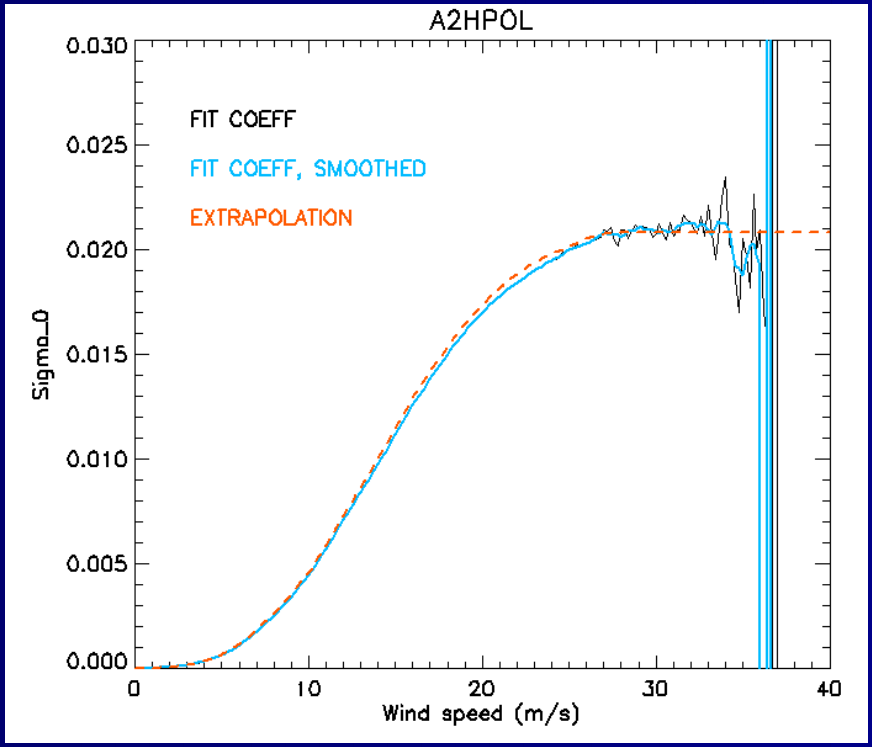
$$\sigma_0 \cong \sum_{i=0}^{N=5} A_i(w)_{pol} \cos(i\varphi_R)$$



- To develop the new GMF we used 7 years of QSCAT σ_0 colocated with WindSat wind speeds (90 min) and CCMP (Atlas et al, 2009) wind direction.
- WindSat also measures rain rate, used to flag QSCAT σ_0 when developing GMF
- We had hundreds of millions of reliable rain-free colocations, with about 0.2% at winds greater than 20 m/s.

STEP 1: HARMONIC COEFFICIENTS

- Minimal smoothing of fit coefficients
- Apply correction to A1-A5 for wind direction uncertainty (similar to Wentz and Smith, 1999)
- Decide saturation threshold for A1-A5 coeffs based on visual inspection
- A0 does not saturate



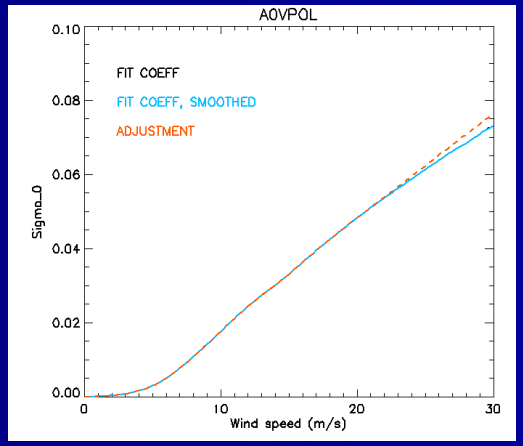
STEPS 2 to N: FINE TUNING

In this phase, we had numerous productive discussions with the JPL group about what to use for ground truth at high winds.

1. Focus on winds at 30 m/s and below; not enough confidence in ground truth for winds > 30 m/s.
2. Focus only on absolutely rain-free validation winds. Use extratropical high winds for validation, to minimize rain impact.
3. Finalize GMF, but keep open the possibility of adjusting it in the future when new high wind validation data is available.

FINE TUNING METHODOLOGY

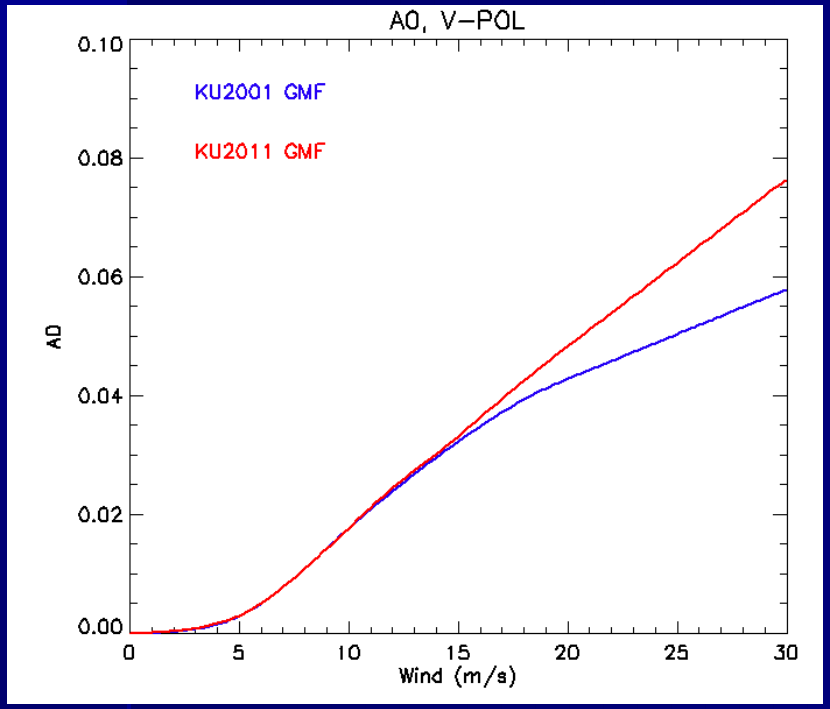
- Adjust A0 coeffs at very high winds to match WindSat in the desired range (20-30 m/s)
- Use Ebuchi plots (directional histograms) to diagnose A1, A2 at very low winds and test adjustments
- Make sure winds match buoys
- Check global wind PDF, no bumps



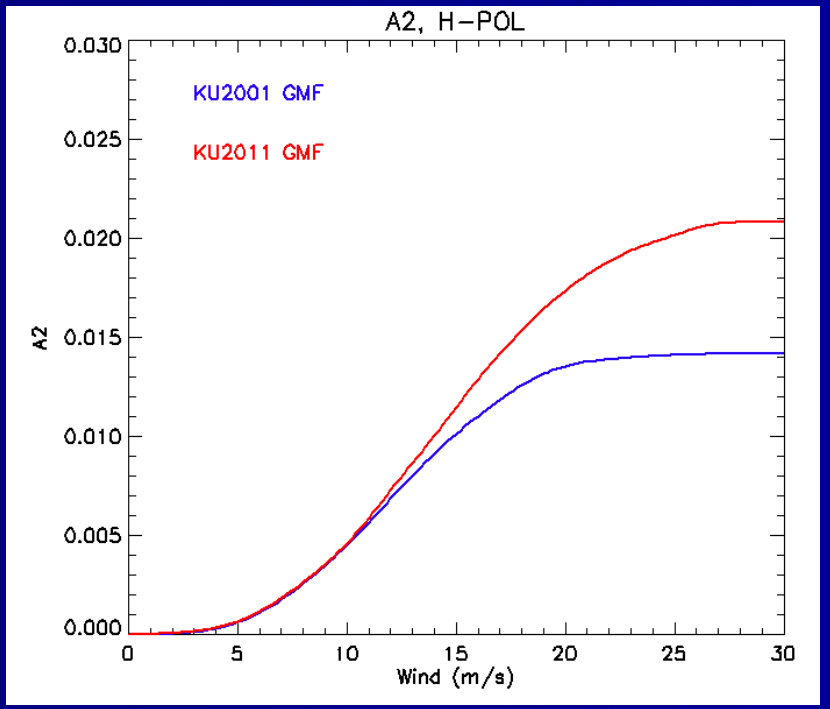
Ku2011 versus Ku2001

The most significant changes between Ku2001 and Ku2011 are for A0 and A2 coeffs, above 15 m/s.

A0 VPOL

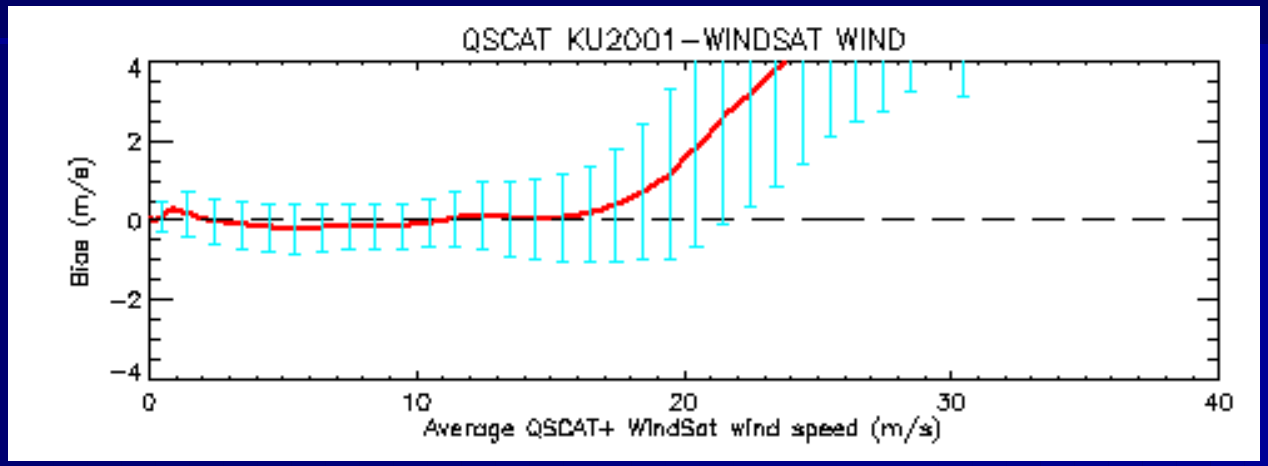


A2 HPOL

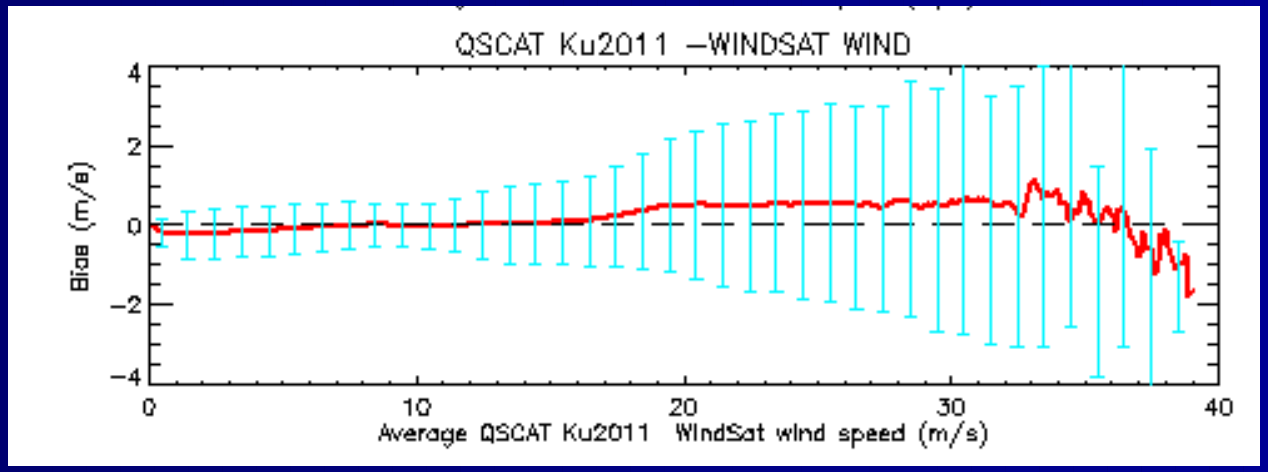


QSCAT VALIDATION: 5 yr statistics, global Comparison with WindSat

Ku2001

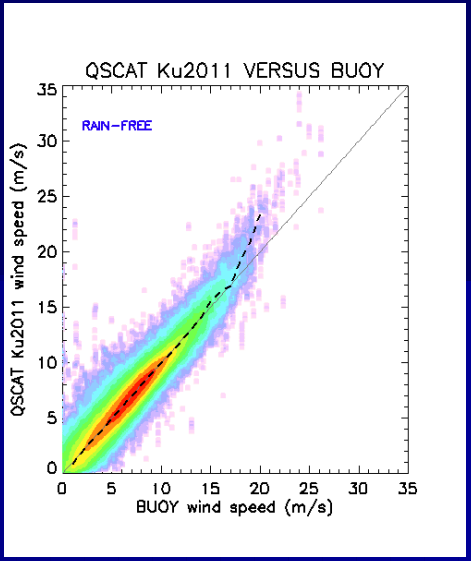


Ku2011

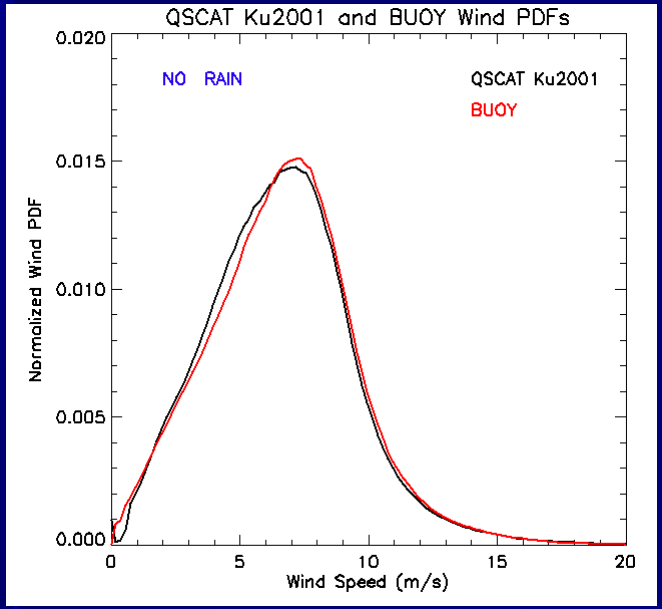


VALIDATION WITH BUOYS

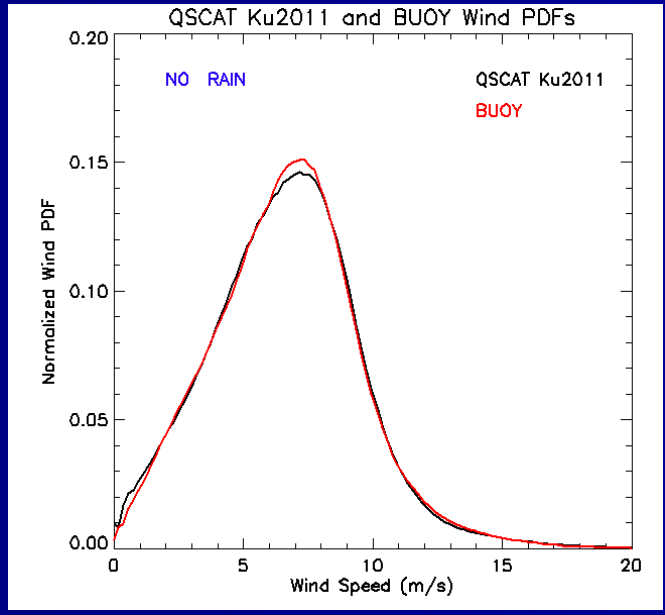
- 200 buoys, global, quality-controlled
- Rain-free observations only
- 1 hour, 50 km colocations
- QSCAT orbital data; 5 yrs



Ku2001



Ku2011

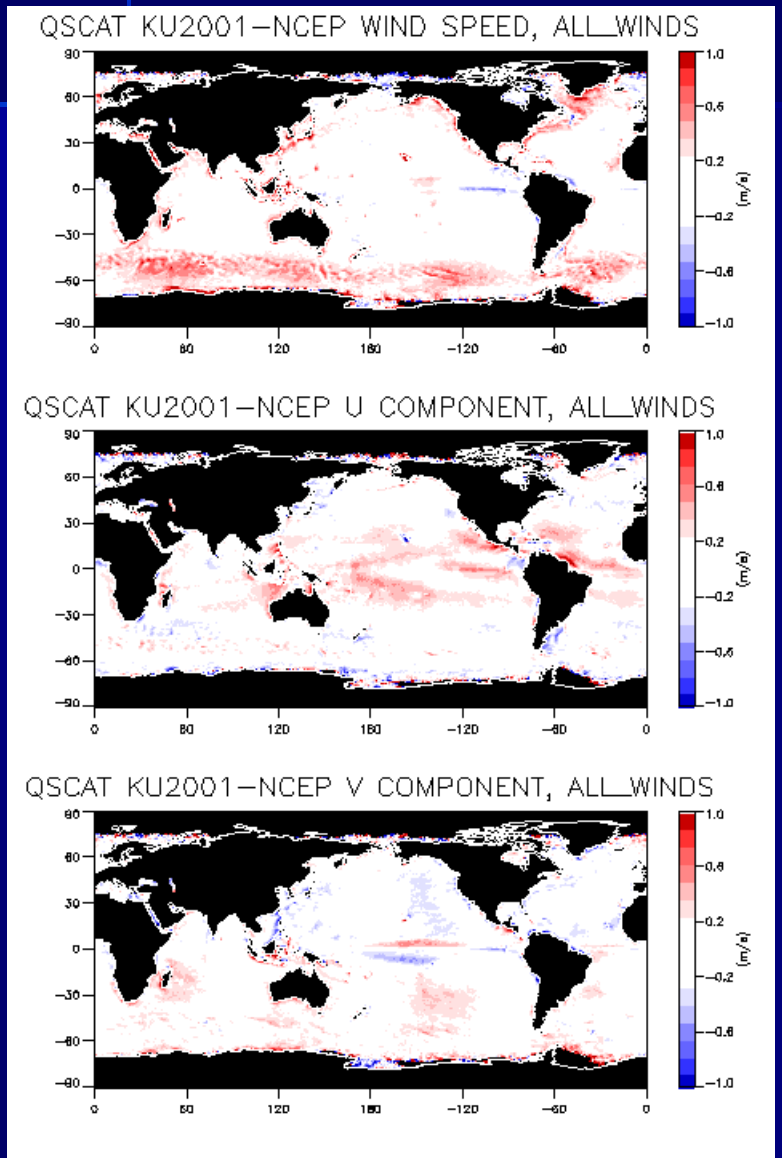


GLOBAL BIAS AND STANDARD DEVIATION: RAIN-FREE QSCAT-VALIDATION WINDS

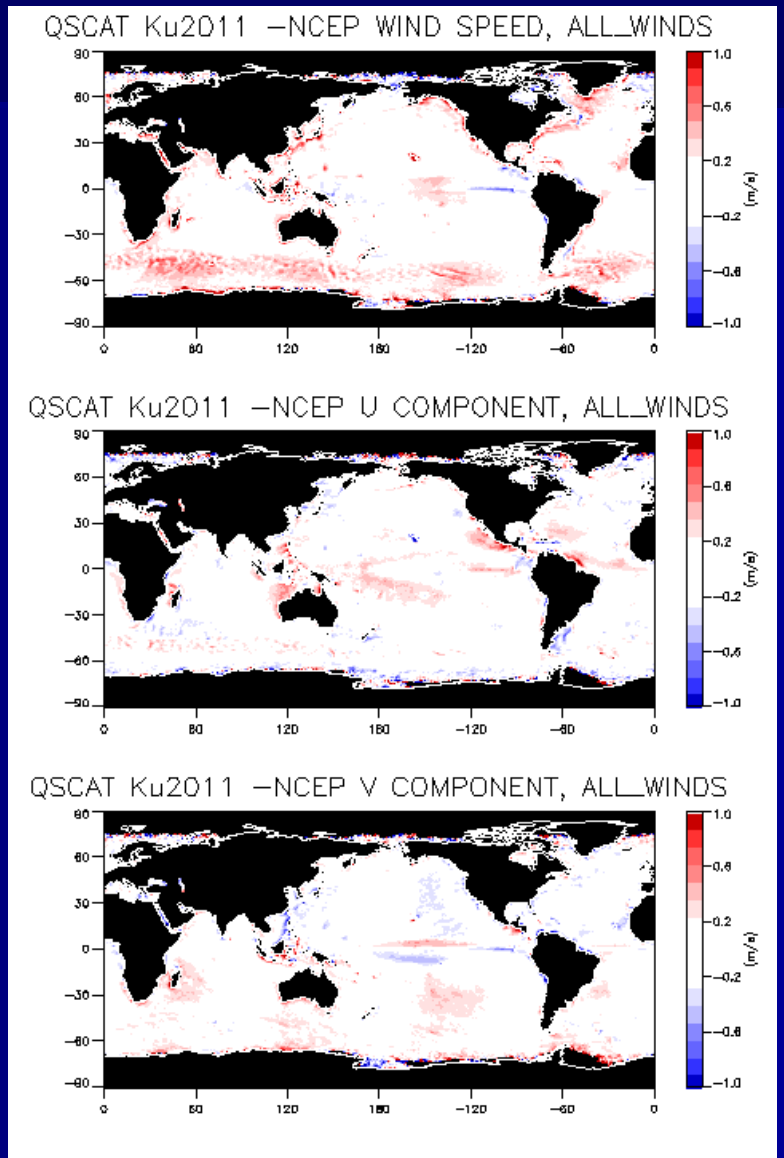
Ku2011-val	BIAS (m/s)	ST DEV (m/s)
BUOY	0.01	0.88
WINDSAT	-0.04	0.65
SSMI V6	-0.04	0.89
NCEP	0.10	0.95
ECMWF	0.44	1.08

Regional biases compared to NCEP

Ku2001-NCEP



Ku2011-NCEP

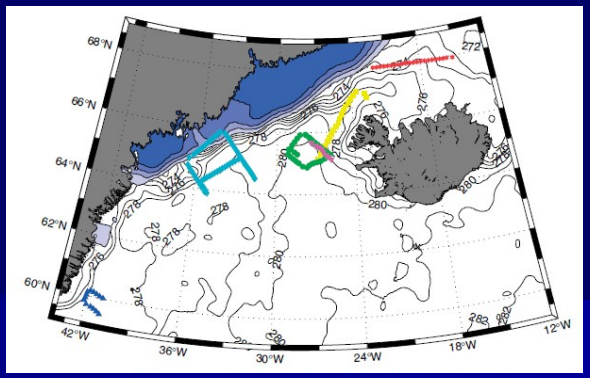


WIND SPEED

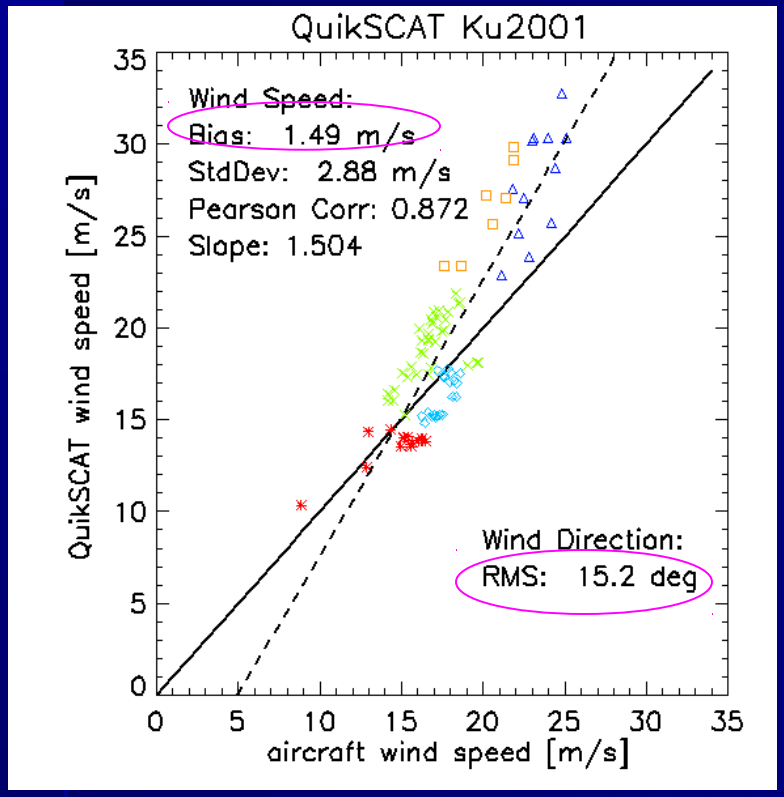
U

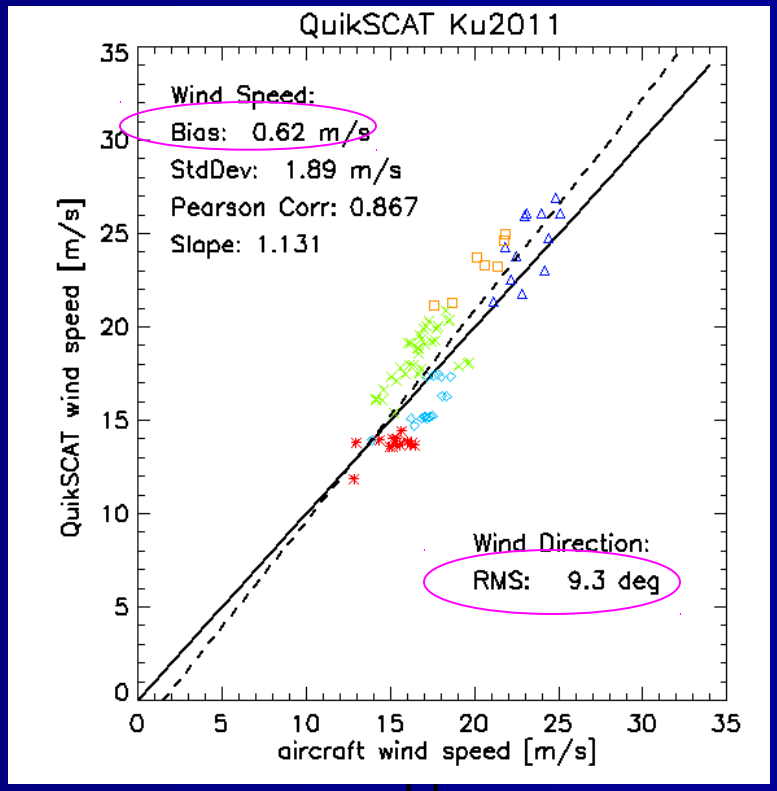
V

HIGH WINDS VALIDATION: AIRCRAFT



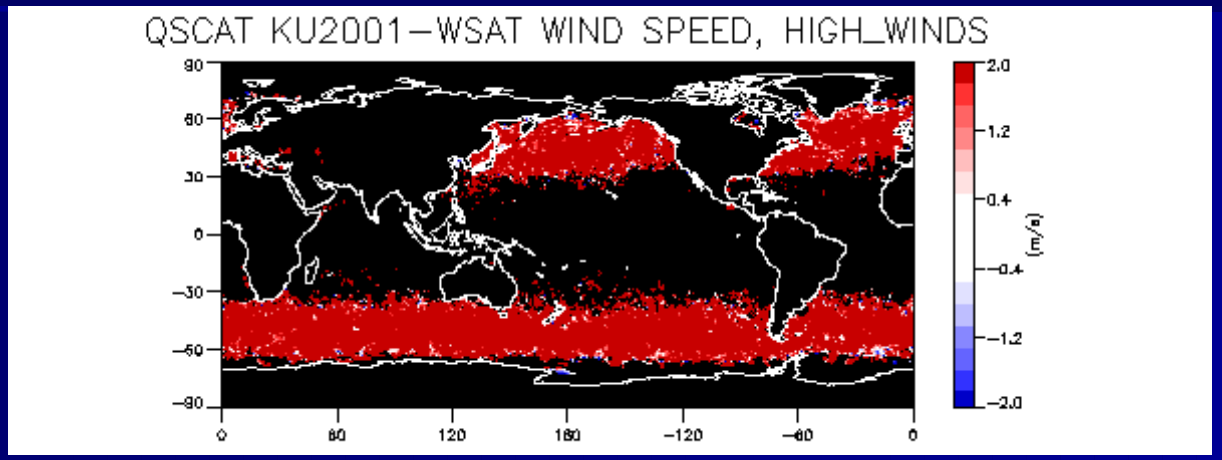
Aircraft turbulent probe observations taken during the Greenland Flow Distortion Experiment (GFDex), Feb and Mar 2007 (Renfrew et al, QJRMS 2009).



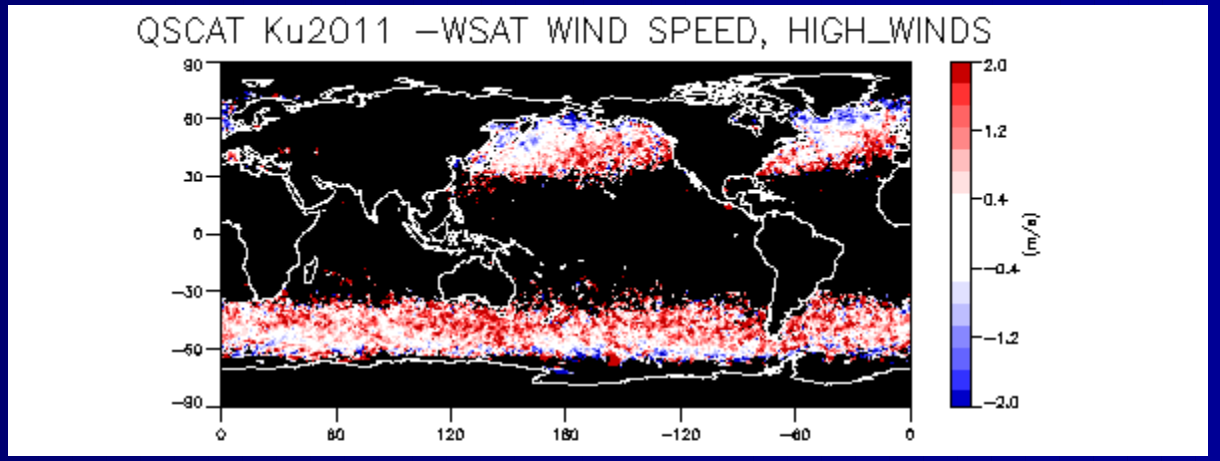


HIGH WINDS:
GLOBAL MAP QSCAT-WINDSAT

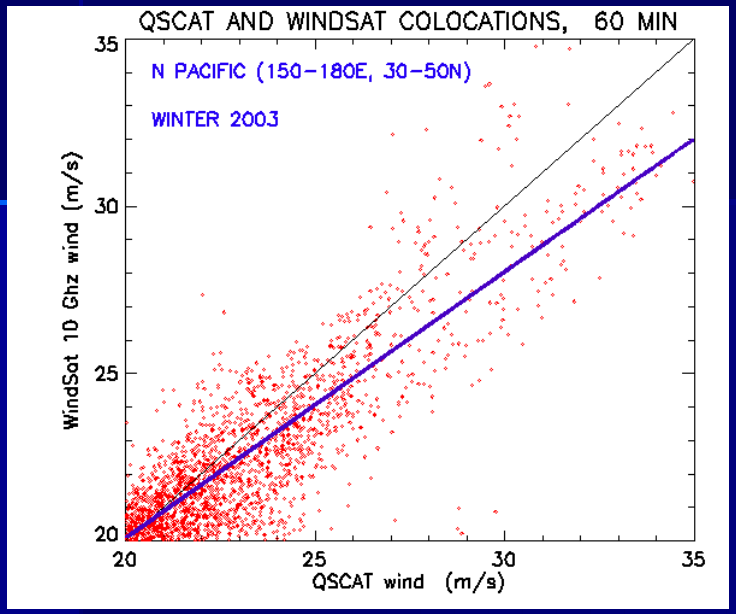
Ku2001

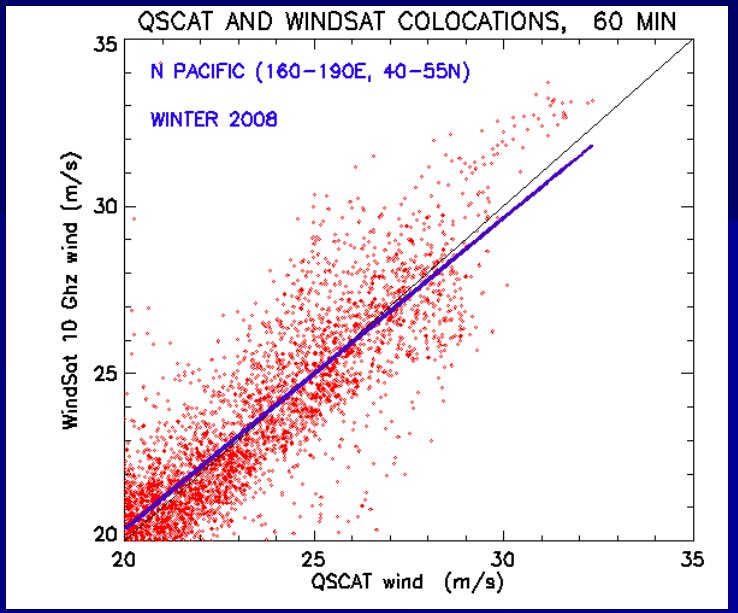


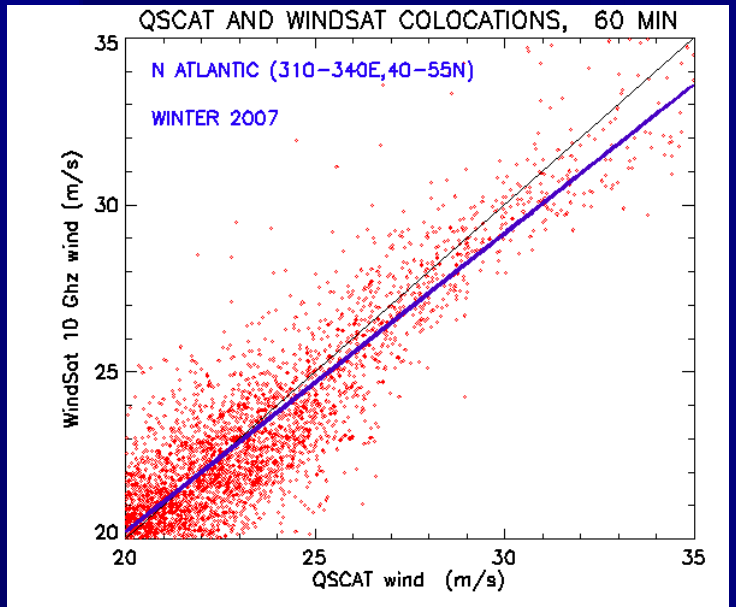
Ku2011

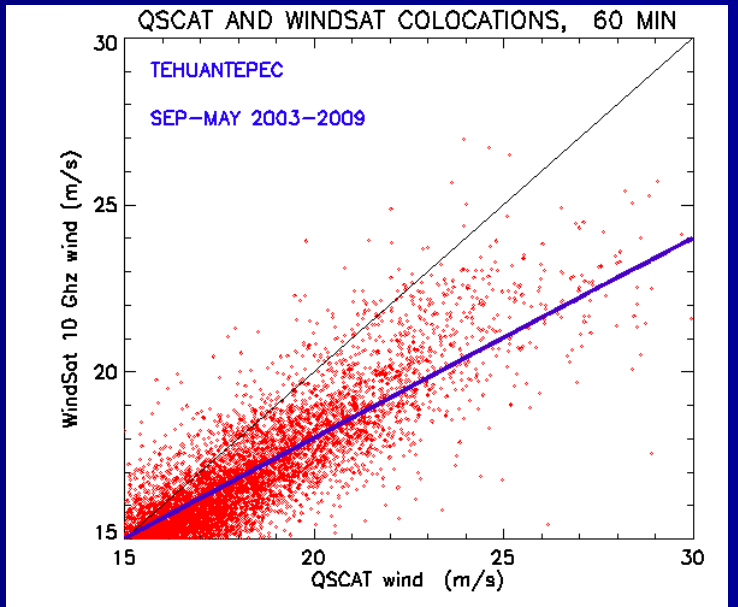


QSCAT VERSUS WINDSAT SWATH DATA

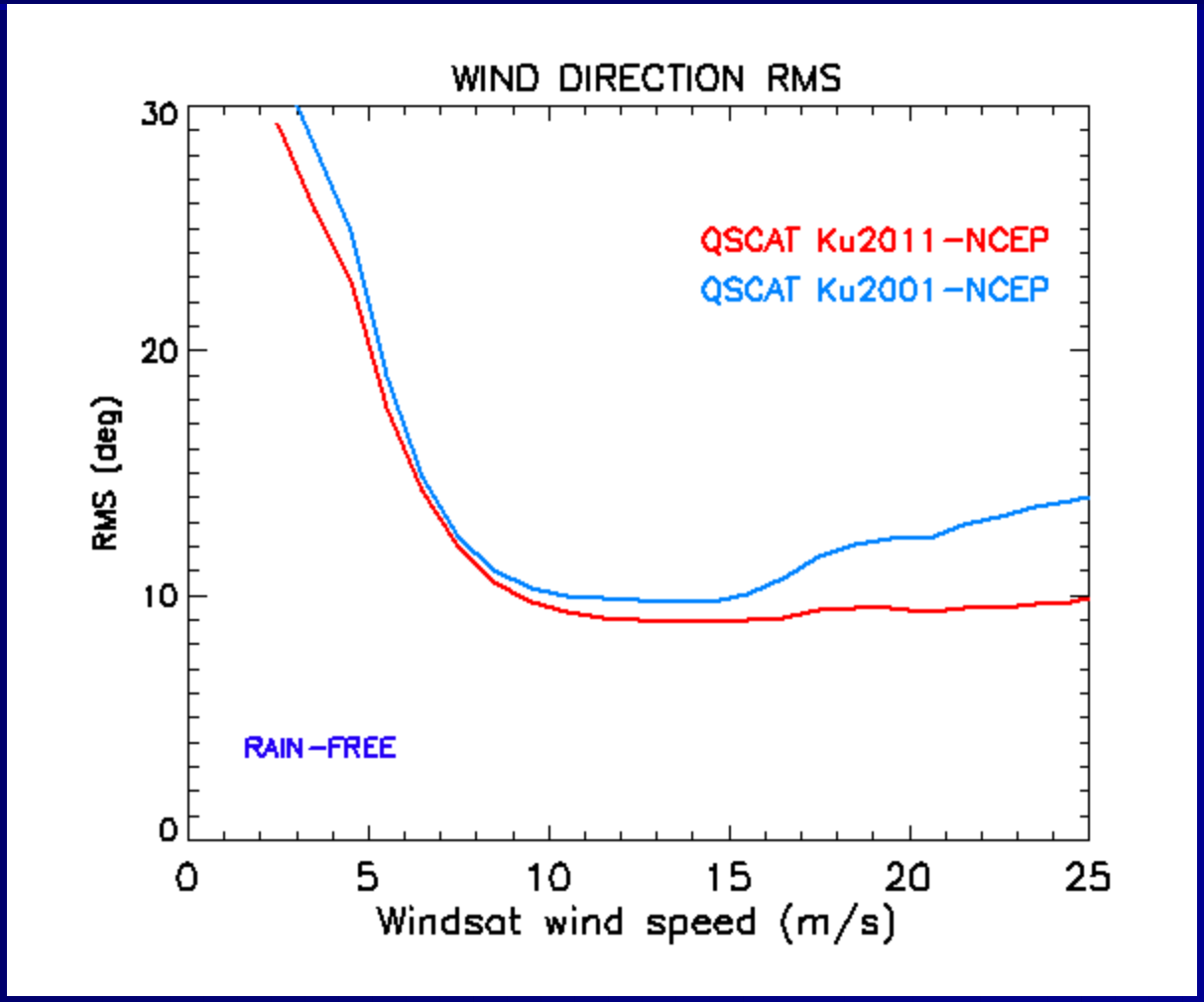






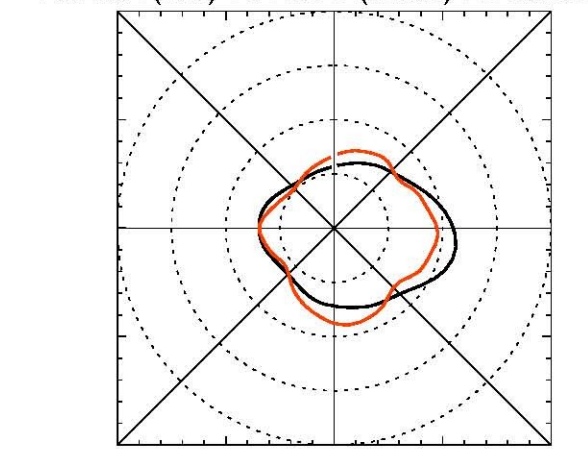


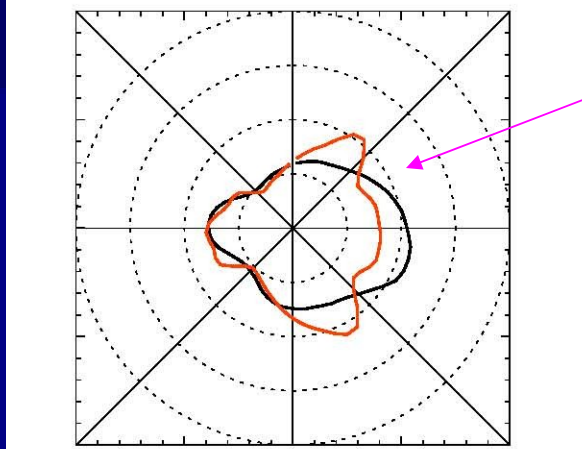
WIND DIRECTION VALIDATION



DIRECTIONAL HISTOGRAMS: LOW WINDS

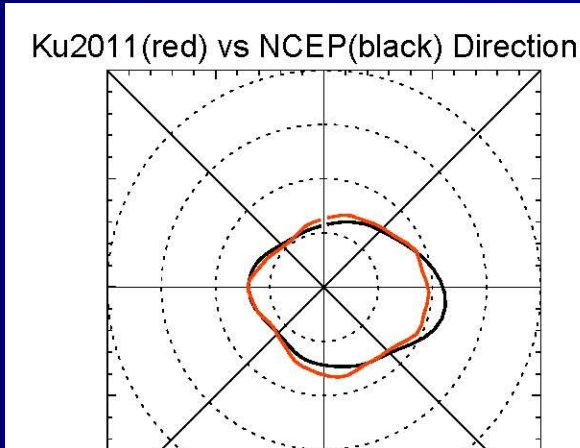
Ku2001
NCEP

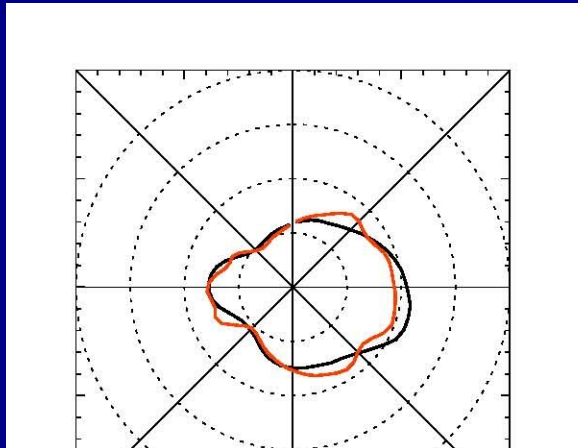




Two lobes

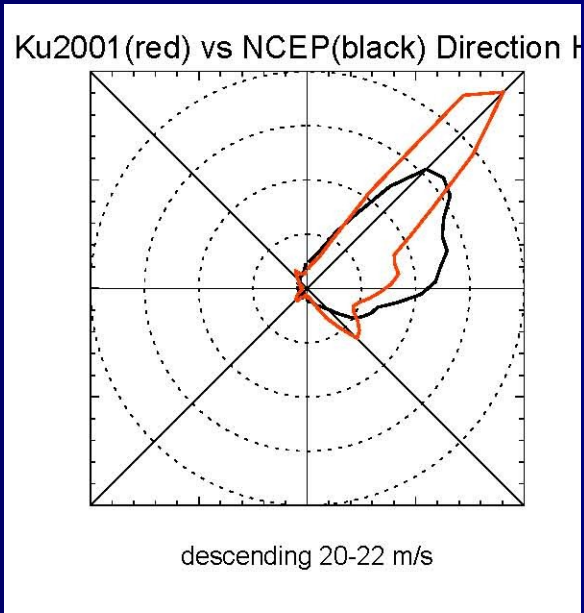
Ku2011
NCEP



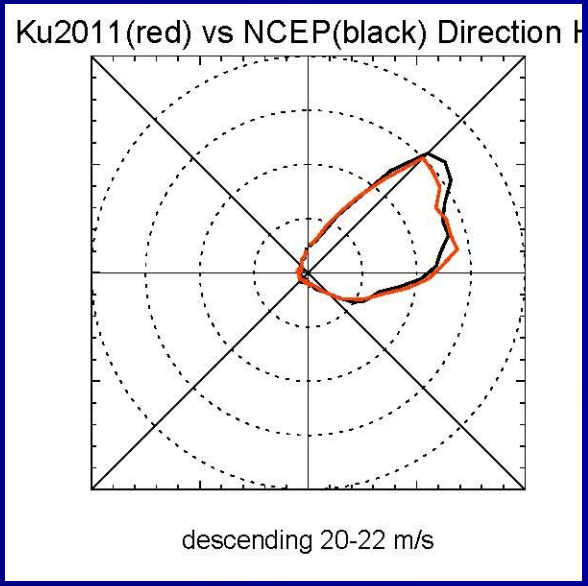


DIRECTIONAL HISTOGRAMS: HIGH WINDS

Ku2001
NCEP



Ku2011
NCEP

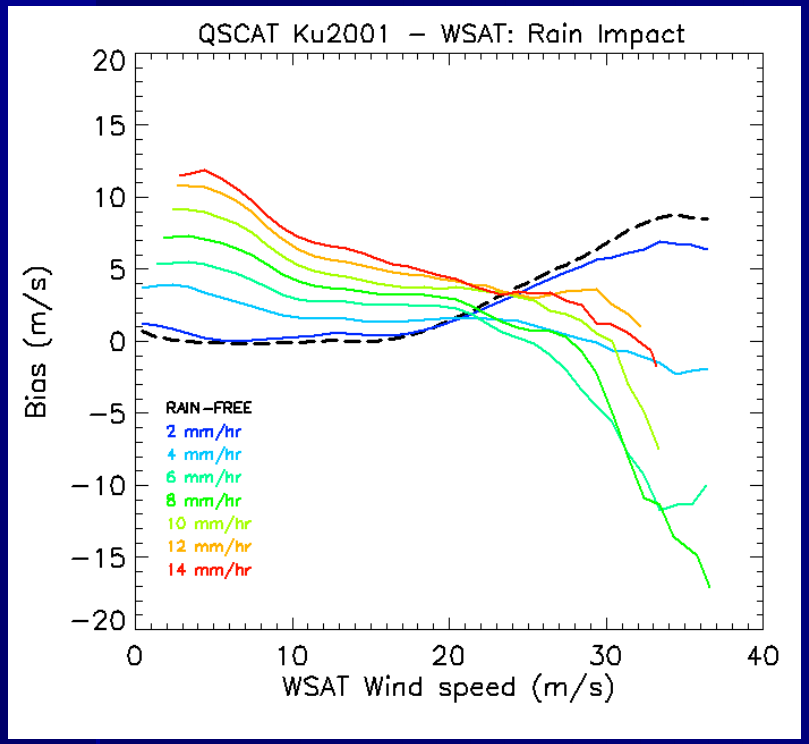


RAIN IMPACT ON WIND RETRIEVALS

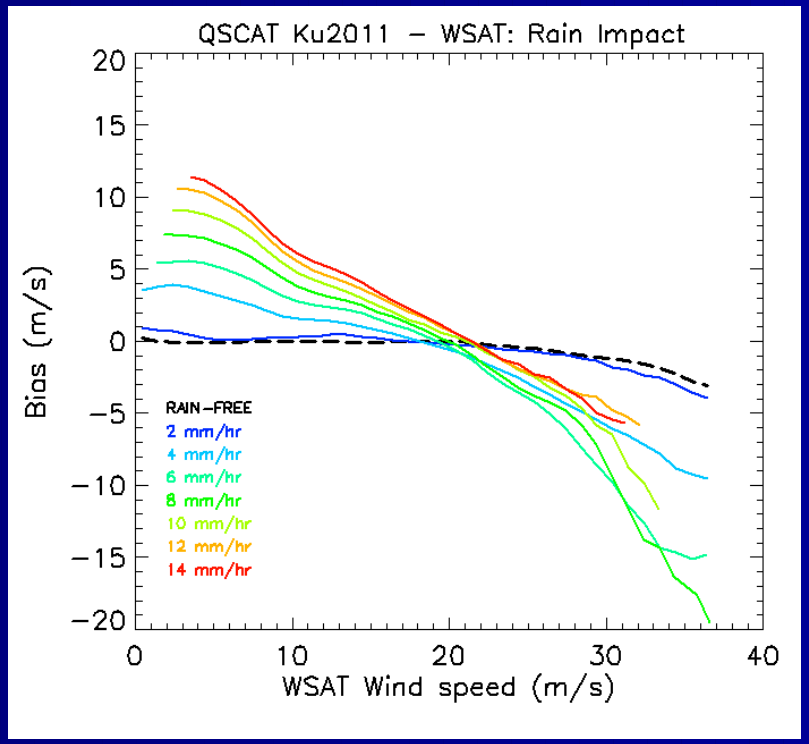
We used 5 yrs of WindSat wind retrievals in rain to determine statistics of rain impact on QSCAT

LOW WINDS → POSITIVE BIAS
HIGH WINDS → NEGATIVE BIAS

Ku2001



Ku2011



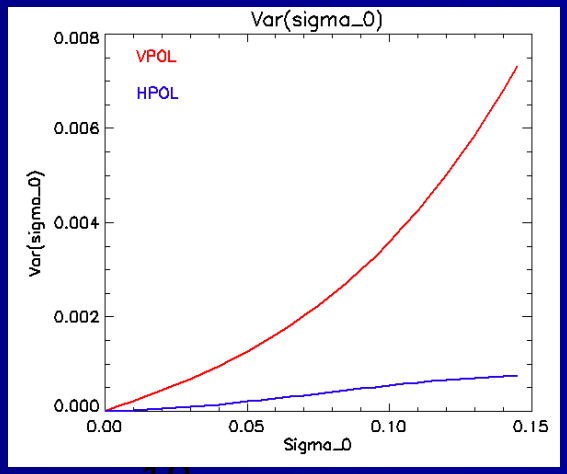
RETRIEVAL UNCERTAINTY: χ^2

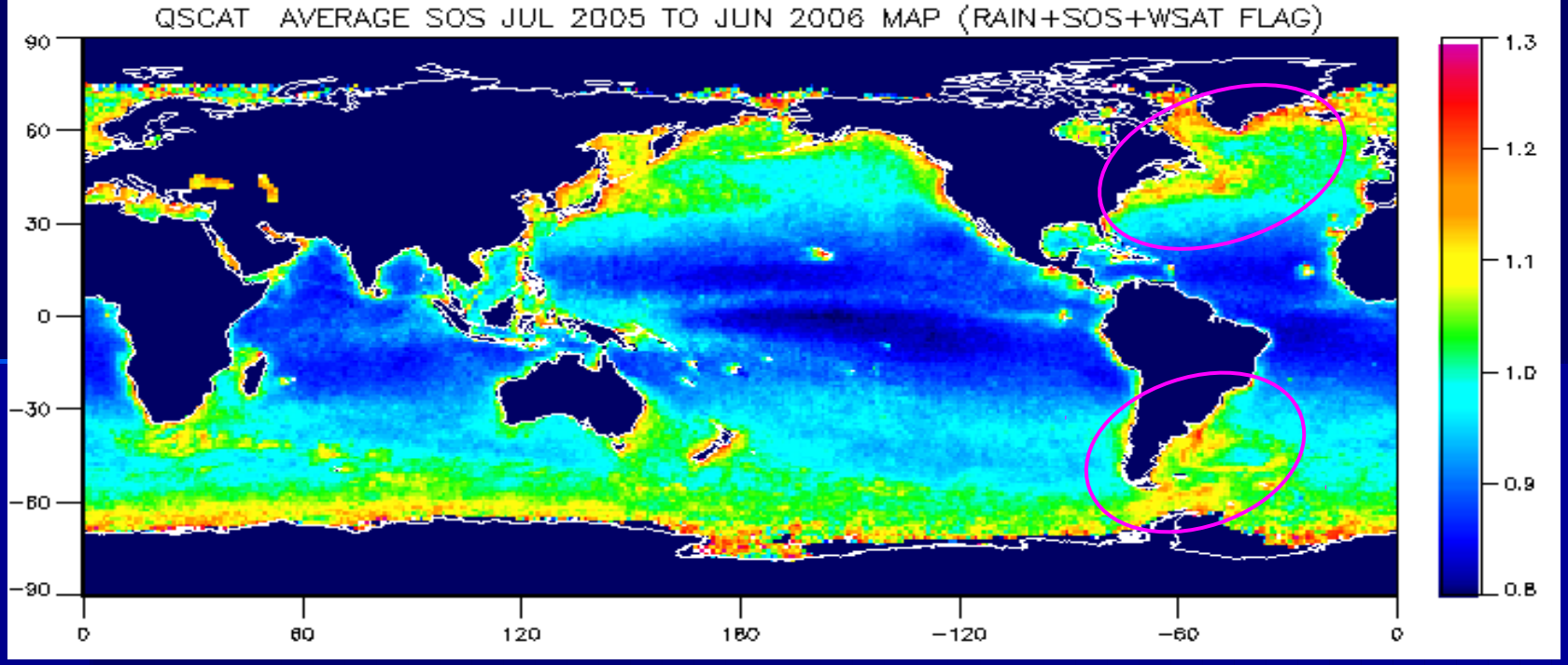
For each cell, with i=1,N observations, the χ^2 is a measure of the departure of the observed σ_0 from the GMF using the retrieved wind speed and direction

$$\chi^2 = \frac{1}{N} \sum_{i=1}^{N} \frac{(\sigma_{obs} - \sigma_{model})^2_i}{\mathrm{var}(\sigma_{obs})}$$

Where var(σ_{obs}) represents the measurements' noise

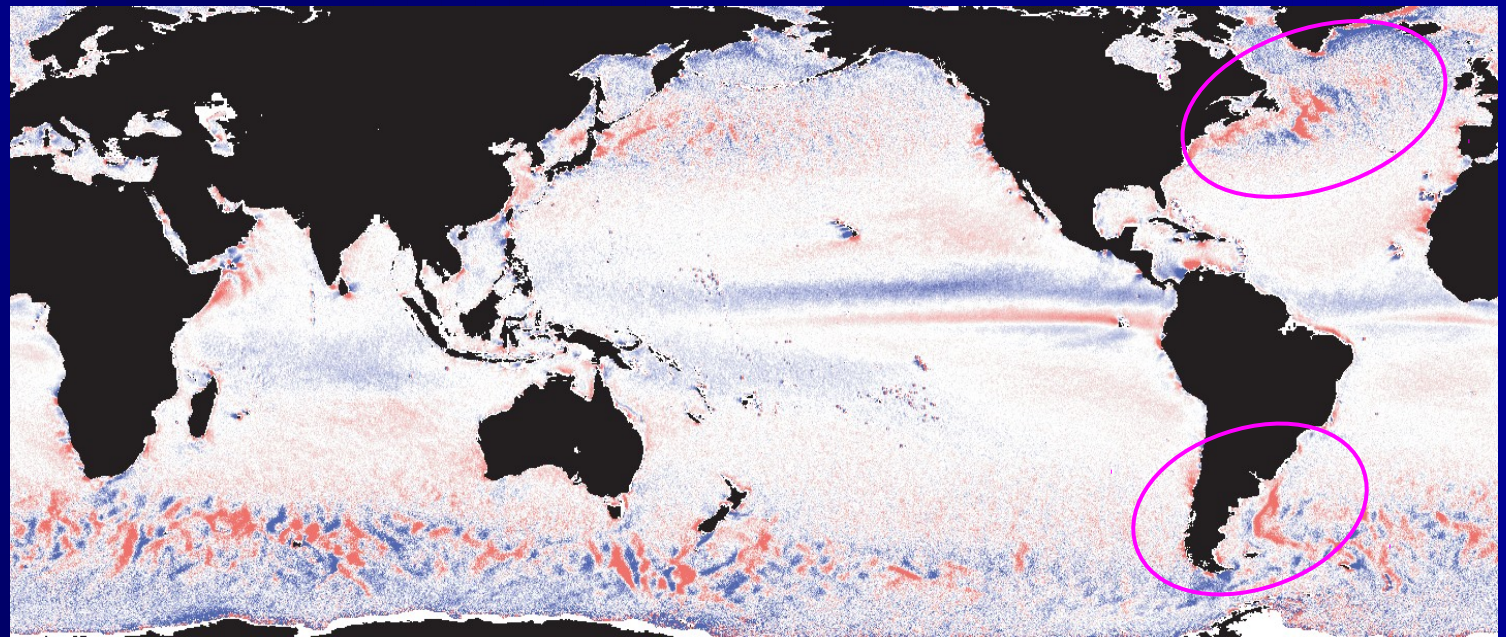
$$\mathrm{var}(\sigma_{obs}) = a + b\sigma_{obs} + c\sigma^2_{obs} + d\sigma^3_{obs}$$





χ^2

Wind stress divergence (Chelton et al, Science, 2004)



SUMMARY

- QSCAT winds were reprocessed with a new GMF developed with special attention to high winds
- WindSat winds used for calibrating GMF.
- Multi-year validation QSCAT Ku2011 rain-free winds with global buoys, NCEP, CCMP, aircraft measurements.
- Available at www.remss.com . Swath data, and daily, weekly, monthly gridded 0.25-deg maps.
- WindSat geophysical products also available on the same website.

FUTURE PLANS

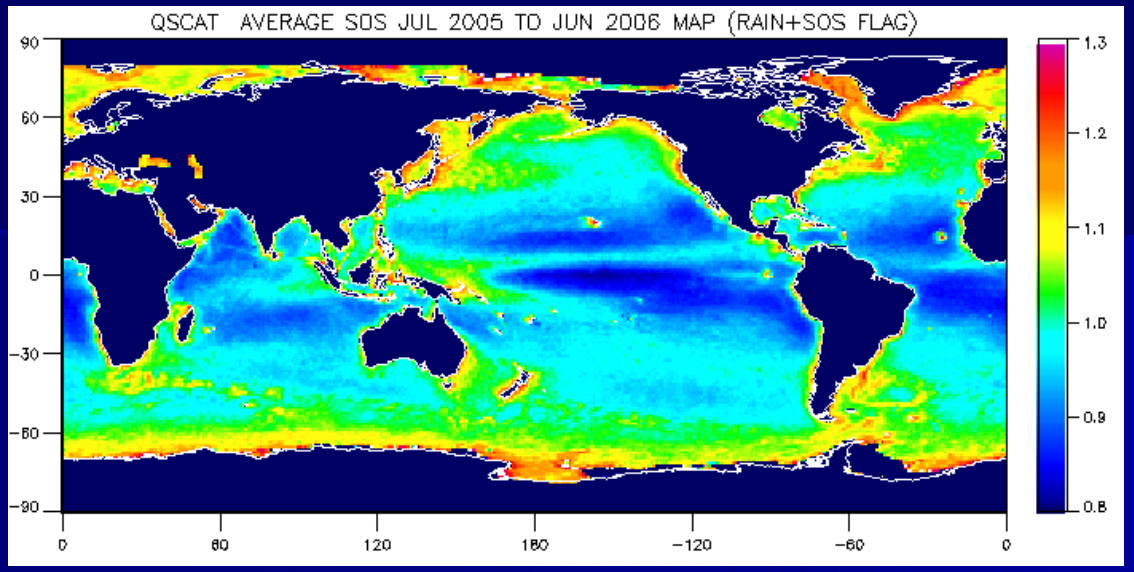
- We plan to use similar methodology to develop a new GMF for ASCAT calibrated to WindSat.
- Produce a climate-quality ocean vector wind dataset, using QSCAT and ASCAT
- Develop an ocean surface stress model function
- Analyze and quantify uncertainties in wind retrievals.
- We need more validation data at high winds, rain-free, extratropical.

Thank you

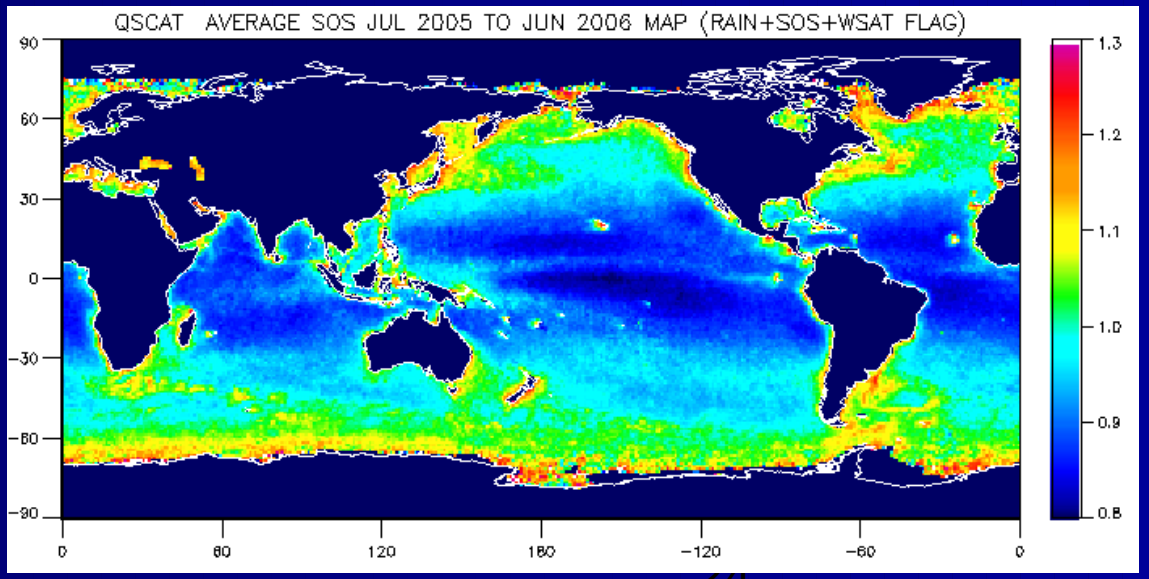
Additional slides

χ^2 MAPS (aka SOS)

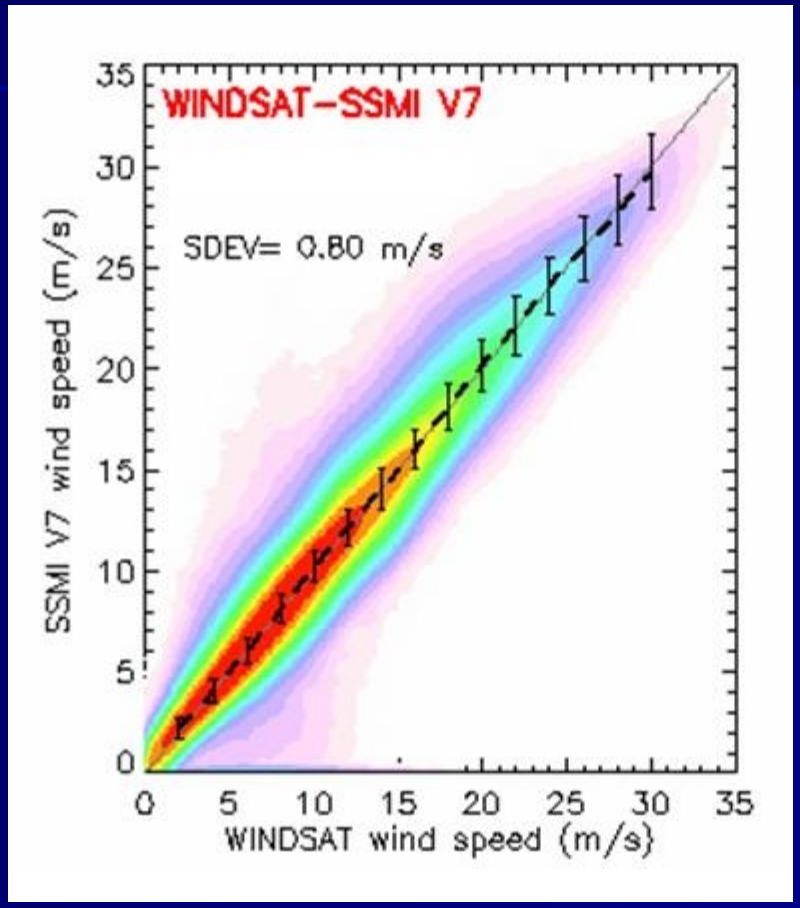
QSCAT RAINFLAG
+
LOW SOS QUALITY FLAG

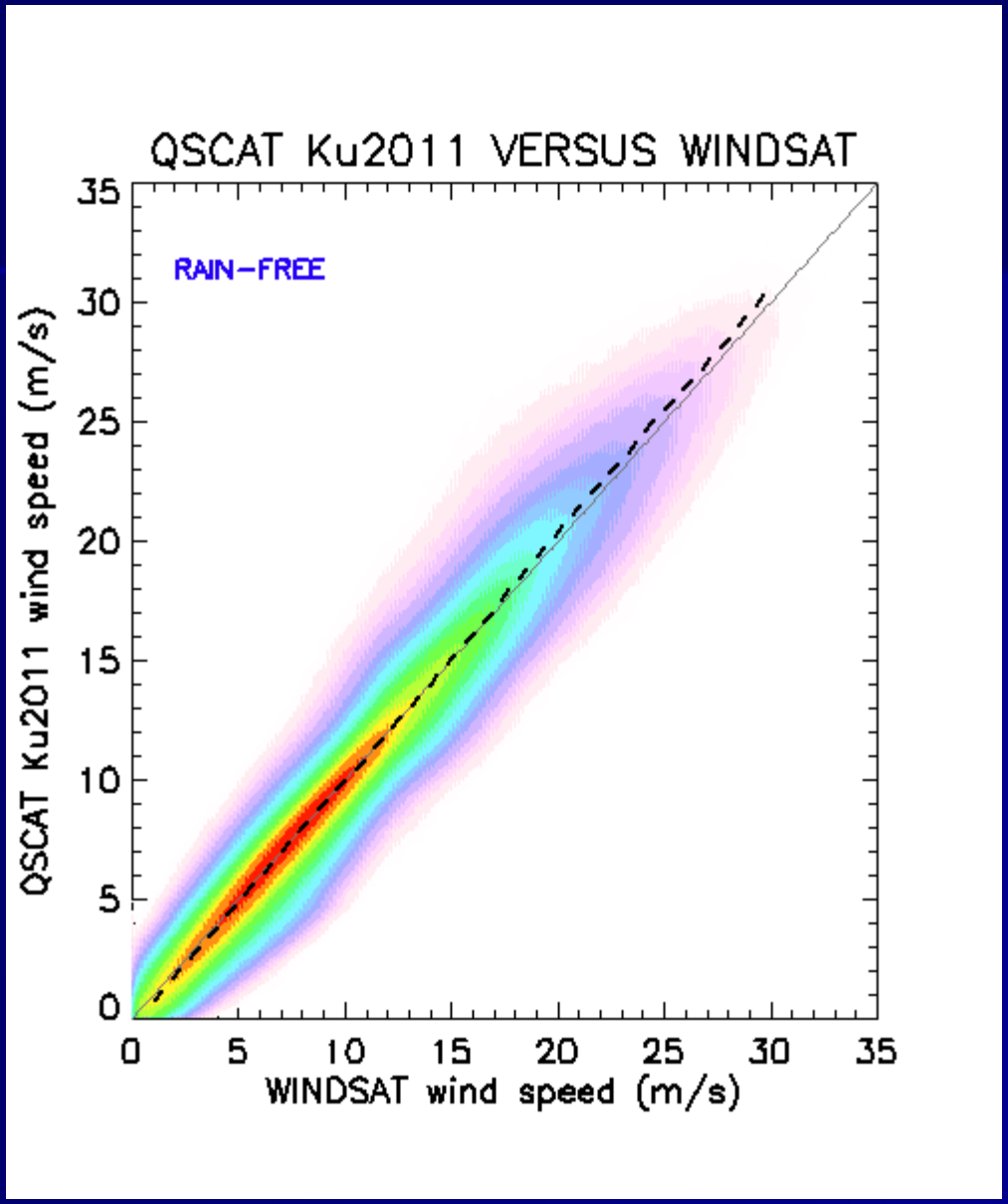


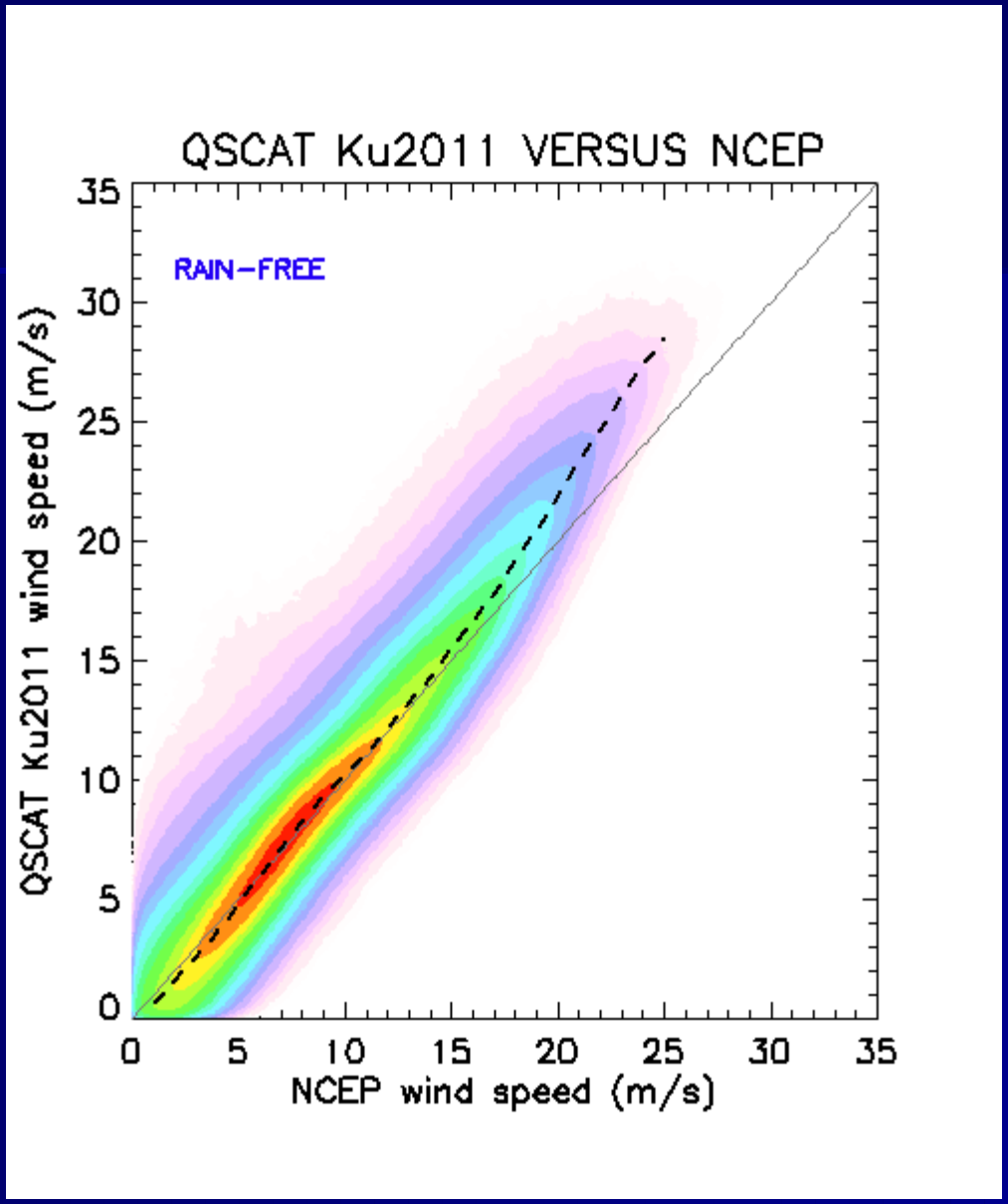
QSCAT RAINFLAG
+
LOW SOS QUALITY FLAG
+
WSAT RAINFLAG

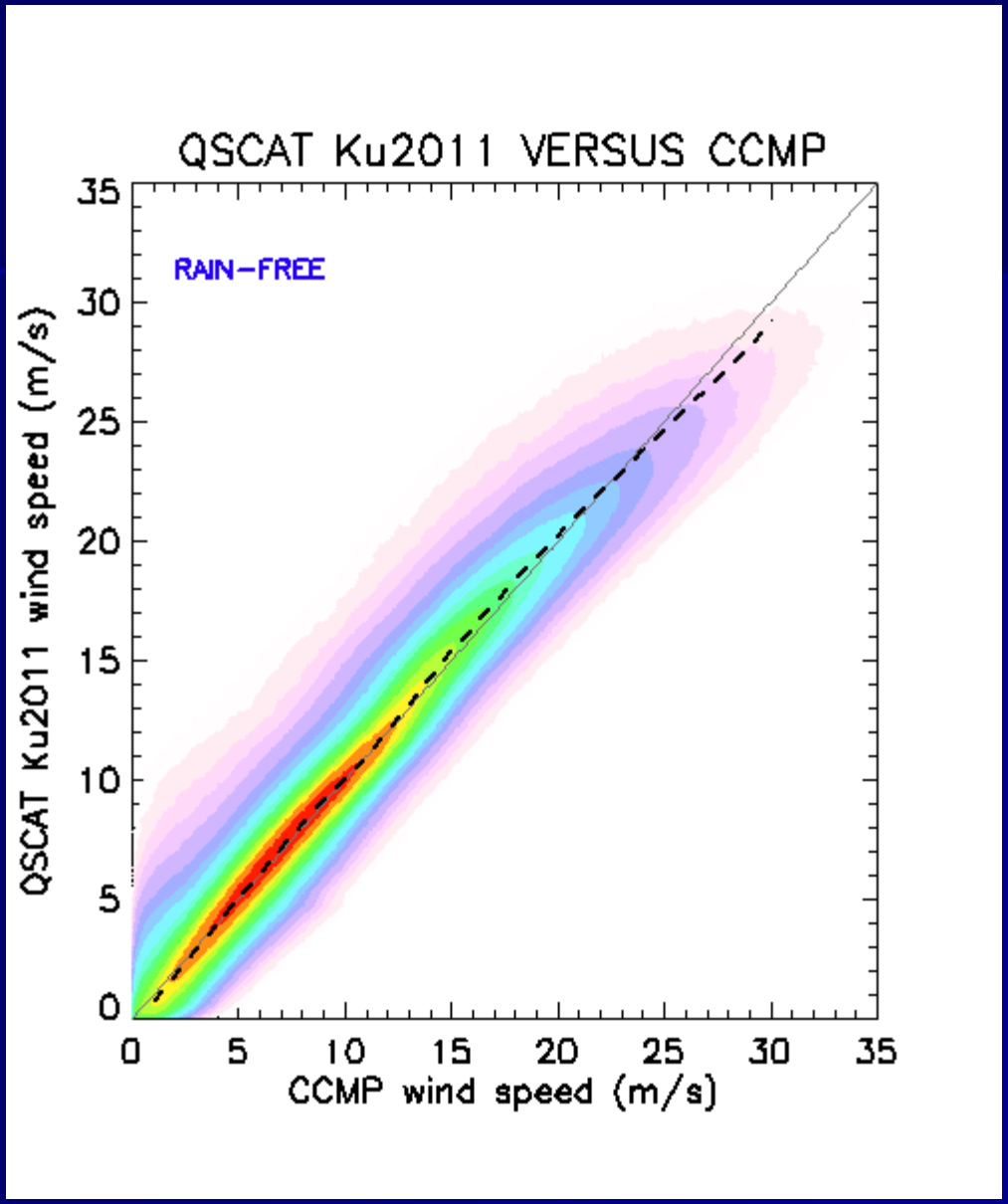


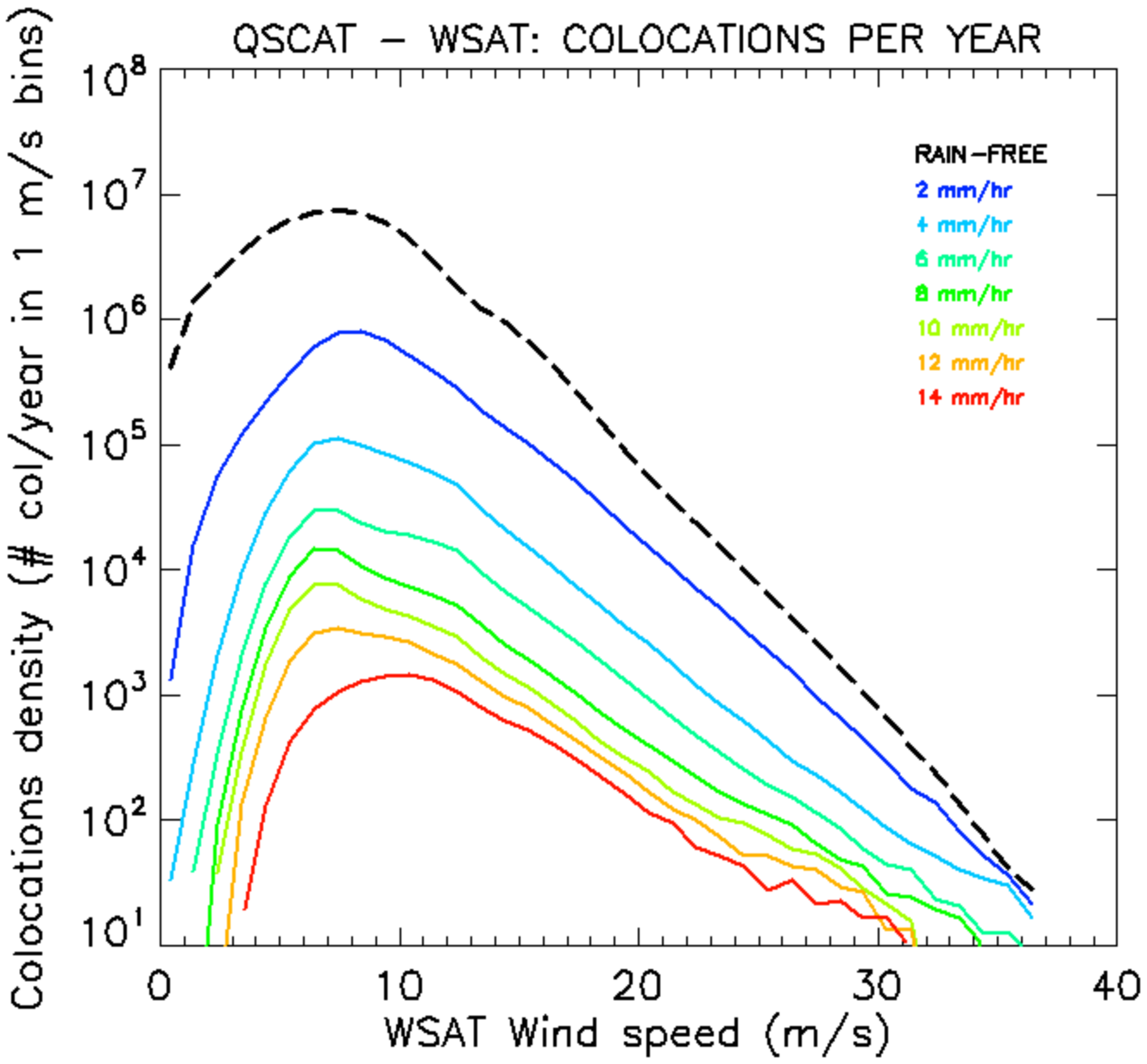
DOES WINDSAT MATCH SSMI ?

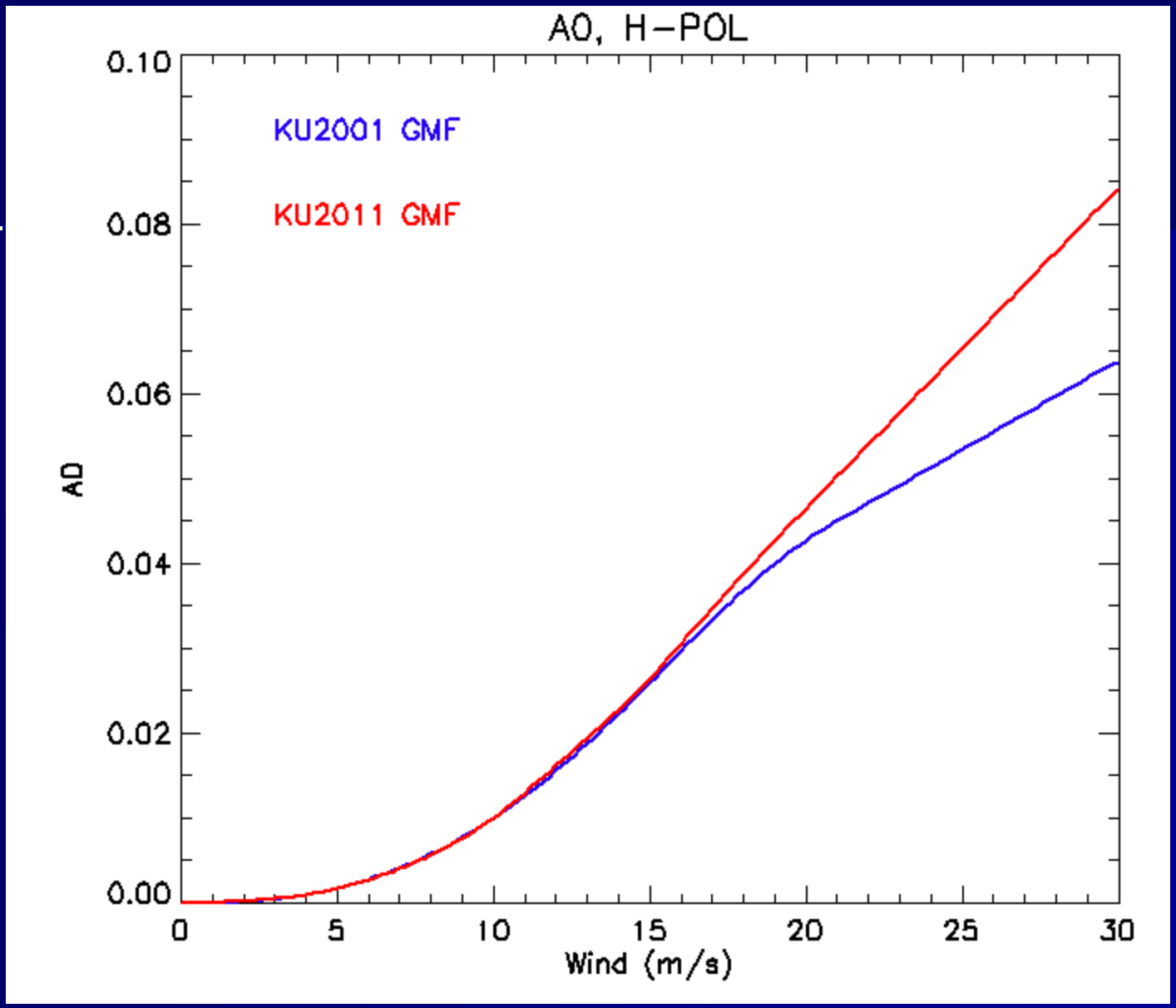


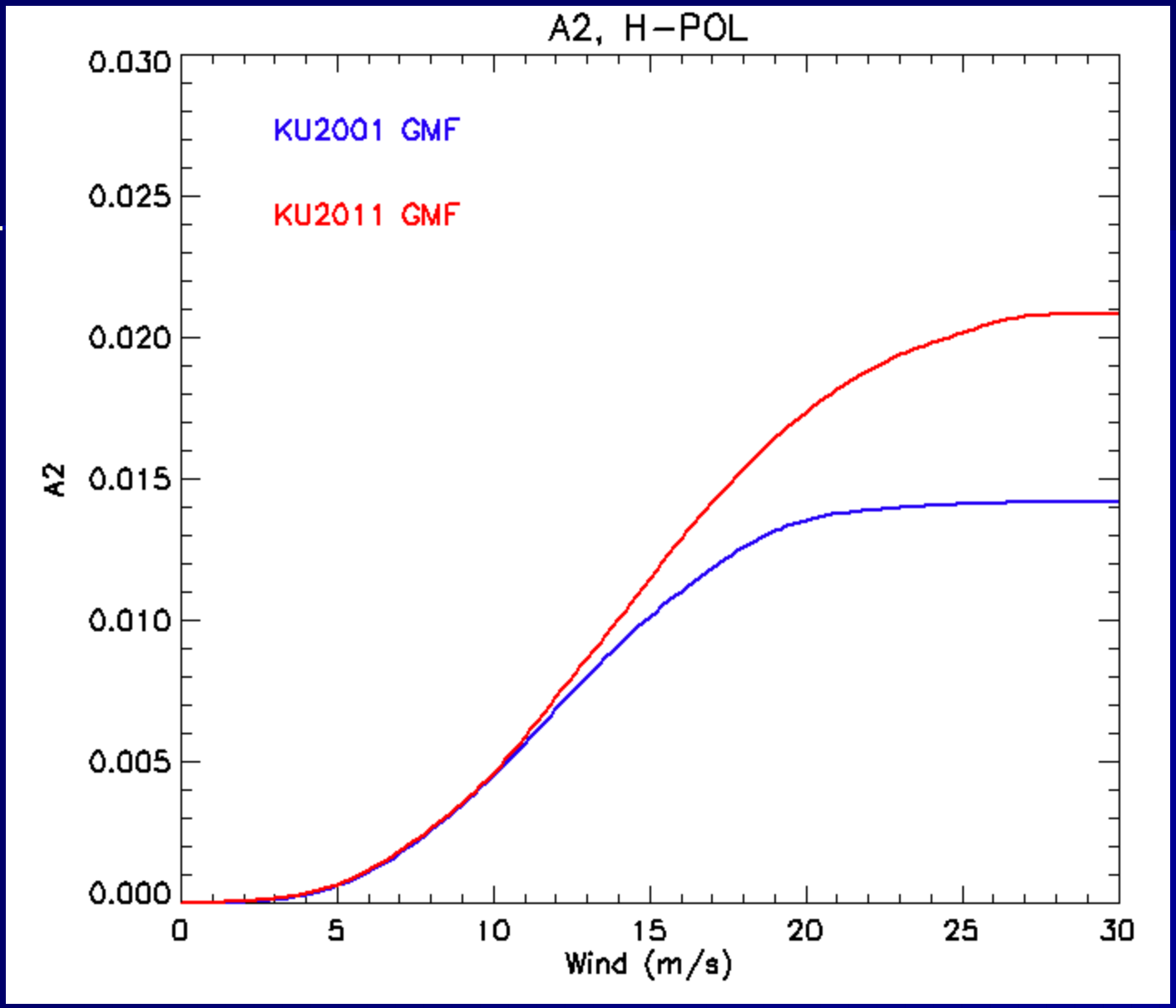

QSCAT Ku2011 VERSUS WINDSAT
RAIN-FREE
QSCAT Ku2011 wind speed (m/s)
WINDSAT wind speed (m/s)
0
5
10
15
20
25
30
35

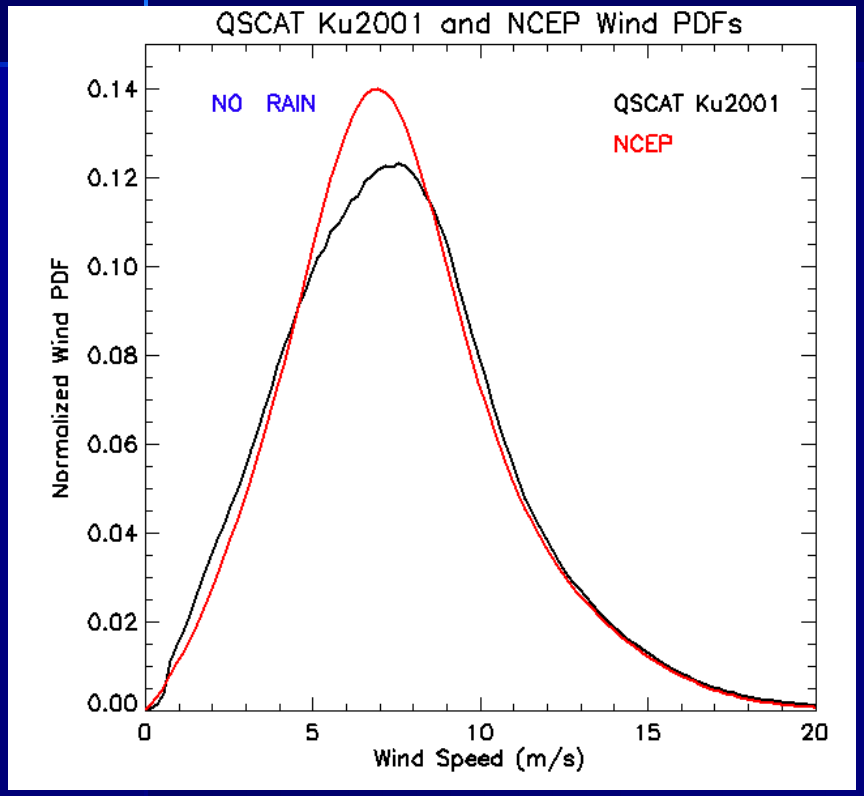

QSCAT Ku2011 VERSUS NCEP
RAIN-FREE
QSCAT Ku2011 wind speed (m/s)
NCEP wind speed (m/s)
0
5
10
15
20
25
30
35

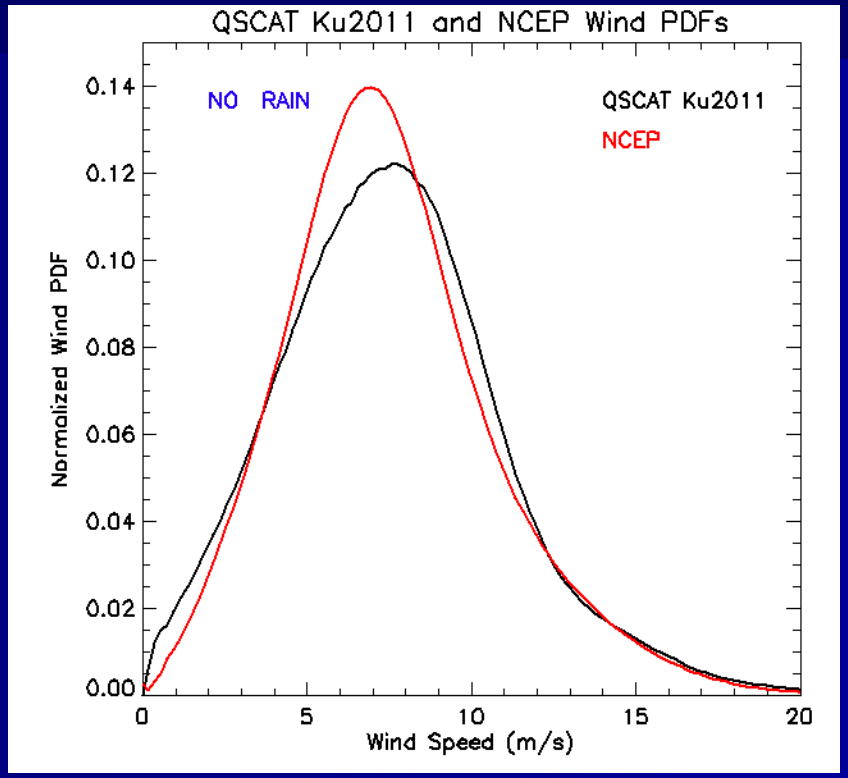

QSCAT Ku2011 VERSUS CCMP
RAIN-FREE
QSCAT Ku2011 wind speed (m/s)
CCMP wind speed (m/s)
0
5
10
15
20
25
30
35

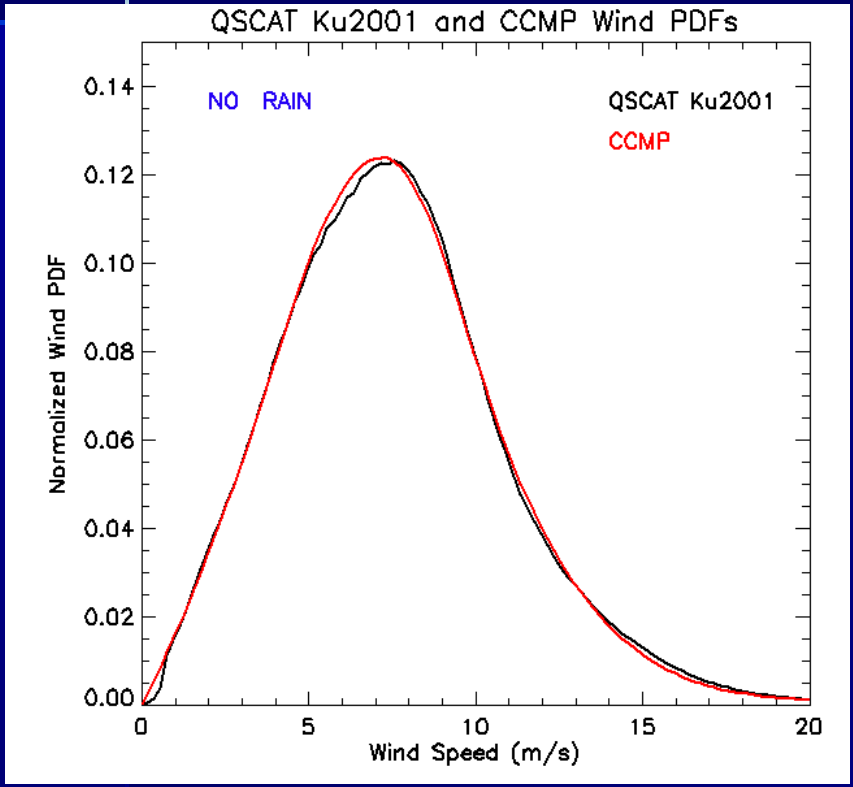

QSCAT – WSAT: COLOCATIONS PER YEAR
Colocations density (# col/year in 1 m/s bins)
WSAT Wind speed (m/s)
RAIN-FREE
2 mm/hr
4 mm/hr
6 mm/hr
8 mm/hr
10 mm/hr
12 mm/hr
14 mm/hr
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0
10
20
30
40

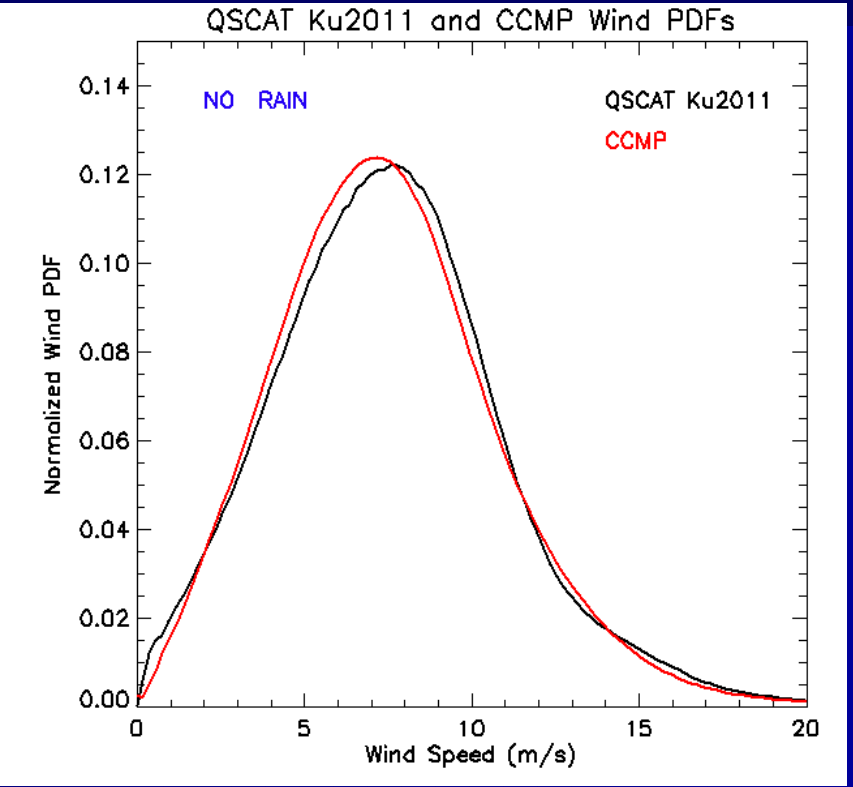

A0, H-POL
KU2001 GMF
KU2011 GMF
A0
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
25
30
Wind (m/s)

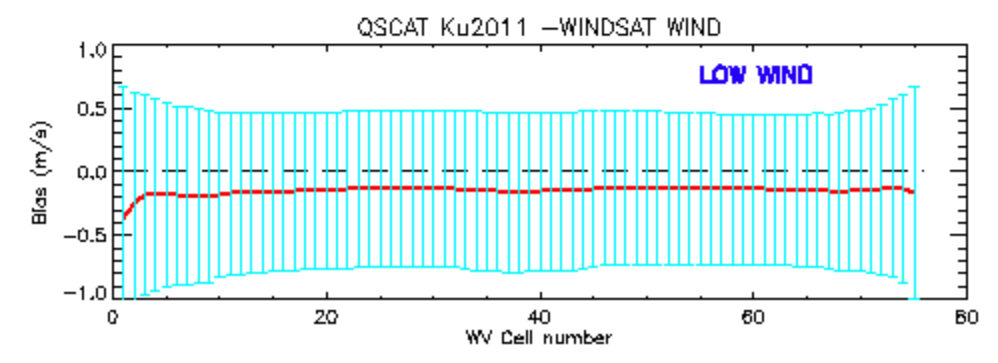

A2, H-POL
KU2001 GMF
KU2011 GMF
A2
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
5
10
15
20
25
30
Wind (m/s)

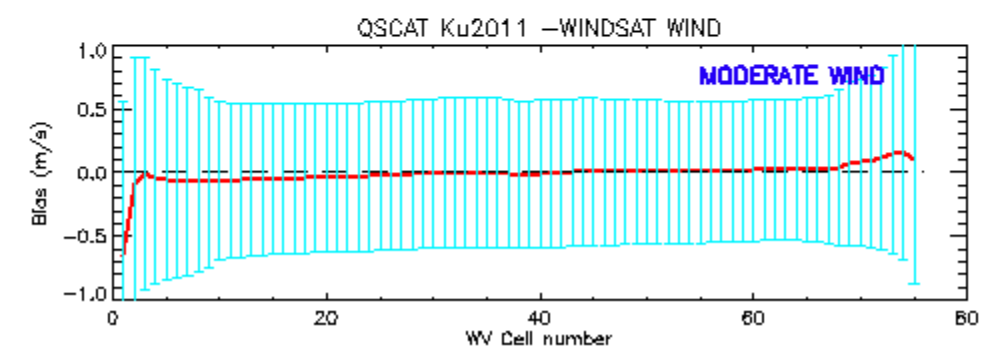

QSCAT Ku2001 and NCEP Wind PDFs
NO RAIN
QSCAT Ku2001
NCEP
Normalized Wind PDF
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
Wind Speed (m/s)

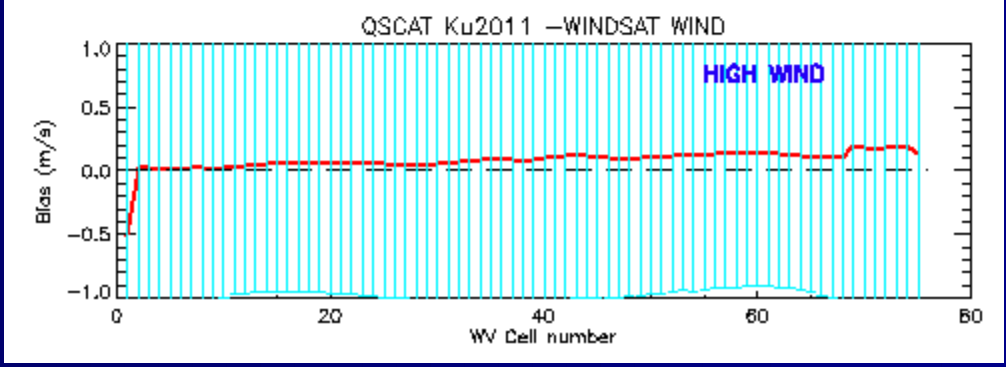

QSCAT Ku2011 and NCEP Wind PDFs
NO RAIN
QSCAT Ku2011
NCEP
Normalized Wind PDF
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
Wind Speed (m/s)

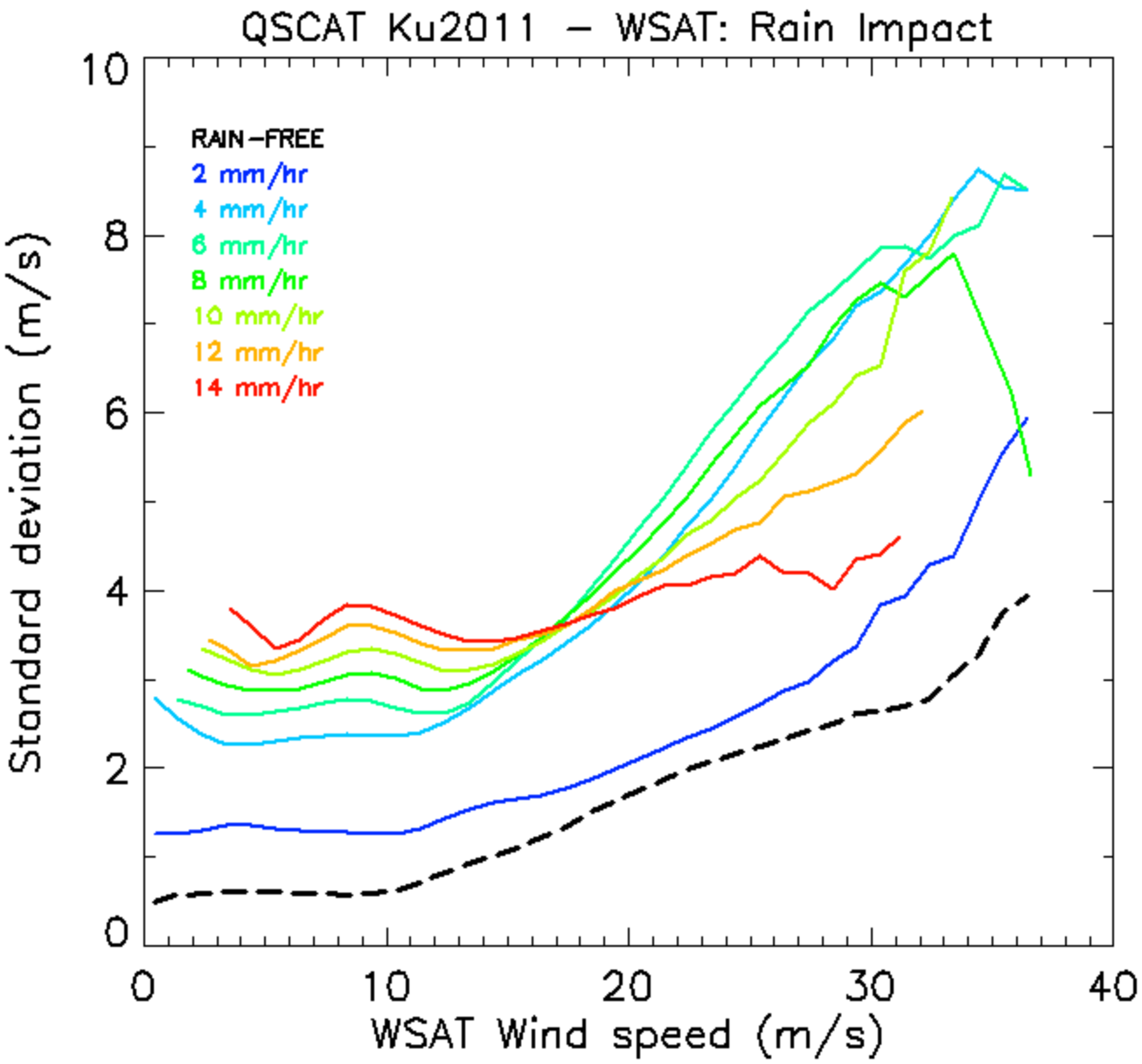

QSCAT Ku2001 and CCMP Wind PDFs
NO RAIN
QSCAT Ku2001
CCMP
Normalized Wind PDF
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
Wind Speed (m/s)


QSCAT Ku2011 and CCMP Wind PDFs
NO RAIN
QSCAT Ku2011
CCMP
Normalized Wind PDF
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
5
10
15
20
Wind Speed (m/s)


QSCAT Ku2011 –WINDSAT WIND
LOW WIND
Bias (m/s)
1.0
0.5
0.0
−0.5
−1.0
0
20
40
60
80
WV Cell number


QSCAT Ku2011 –WINDSAT WIND
MODERATE WIND
Bias (m/s)
1.0
0.5
0.0
−0.5
−1.0
0
20
40
60
80
WV Cell number


QSCAT Ku2011 –WINDSAT WIND
HIGH WIND
Bias (m/s)
1.0
0.5
0.0
−0.5
−1.0
0
20
40
60
80
WV Cell number


QSCAT Ku2011 – WSAT: Rain Impact
RAIN-FREE
2 mm/hr
4 mm/hr
6 mm/hr
8 mm/hr
10 mm/hr
12 mm/hr
14 mm/hr
Standard deviation (m/s)
WSAT Wind speed (m/s)
0
2
4
6
8
10
0
10
20
30
40