2010 International Ocean Vector Winds Meeting
Barcelona, Spain
May 18 – 20, 2010

The RSS WindSat Version 7 All-Weather Wind Vector Product

Thomas Meissner
Lucrezia Ricciardulli
Frank Wentz

Remote Sensing Systems
www.remss.com

Outline

1. Overview: RSS WindSat V7 Level 2B Products
2. Wind Speed Algorithm
   - Rain Free Wind Speeds
   - Global Wind Speeds Through Rain
   - Wind Speed in Hurricanes
   - Blended All-Weather Wind Speeds
   - Performance Analysis
3. Wind Direction Algorithm
4. Tropical and Extratropical Cyclones
5. Summary + Outlook

RSS Version 7 Products

Intercalibrated multi-platform suite
100 years satellite data
Release in progress

DMSP SSM/I, SSMIS
8 Total, 4 currently operating

TRMM TMI

AMSR-E, AMSR

WindSat

QuikSCAT

WindSat V7 Level 2B Products

Product	Resolution + Required Channels			
	Very Low C-band ≥ 6.8 GHz 50 km	Low X-band ≥ 10.7 GHz 32 km	Medium K-band ≥ 18.7 GHz 22 km	High ≥ 37.0 GHz 10 km
SST	Yes	Yes	No	No
Wind Speed No Rain	**Yes**	**Yes**	**Yes**	**No**
Wind Speed Through Rain	**Yes**	**No**	**No**	**No**
Wind Direction	**No**	**Yes**	**No**	**No**
Water Vapor	Yes	Yes	Yes	No
Tot Liquid Water	**Yes**	**Yes**	**Yes**	**Yes**
Cloud Water	Yes	Yes	Yes	Yes
Rain Rate	**No**	**No**	**No**	**Yes**

Optimized swath width by combining **for and aft** looks at each band

Polarimetric Radiometer:

6.8 V H 10.7 V H +45 -45 LC RC 18.7 V H +45 -45 LC RC

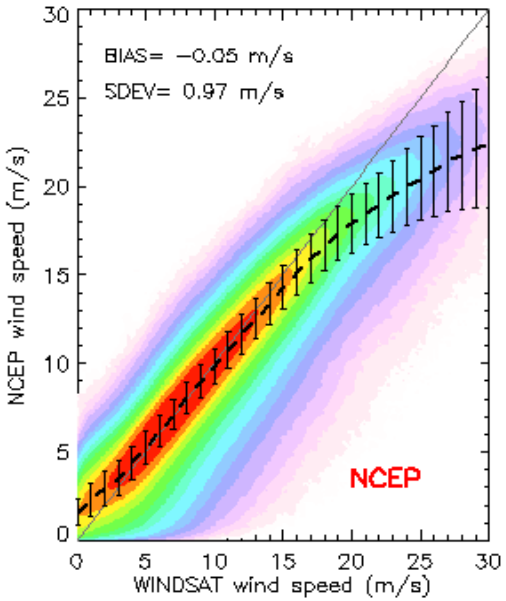
23.8 V H 37.0 V H +45 -45 LC RC

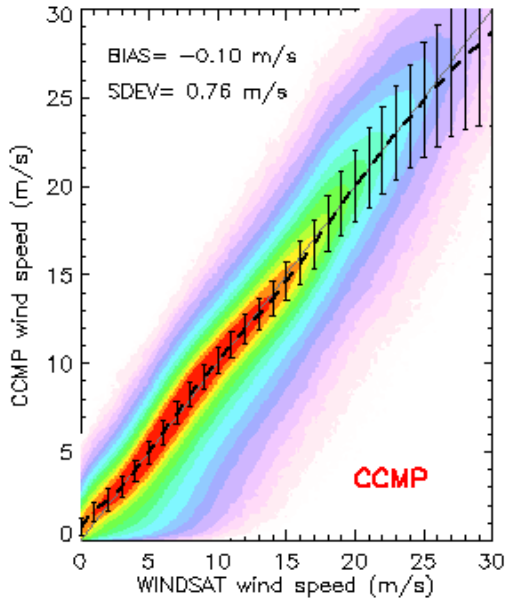
Wind Speed Algorithms

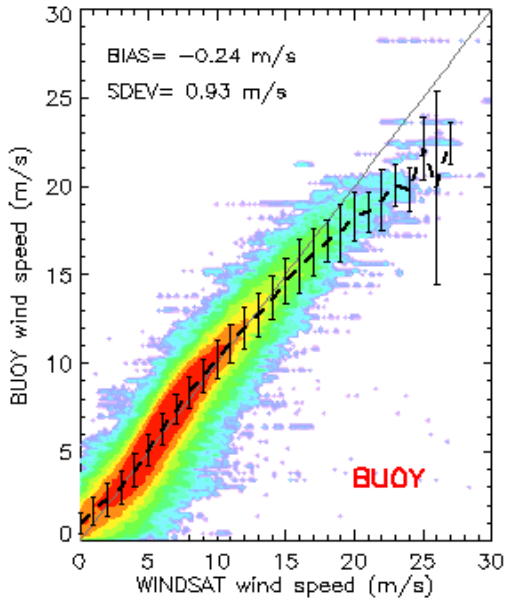
- No-Rain Algorithm (X-band)
  - Physical algorithm
  - Based on RTM (emissivity model)
  - Trained with random wind speed distribution
- H-wind (Hurricane) Algorithm (C-band)
  - Statistical algorithm
  - Trained from collocation of WindSat TB with HRD (Hurricane Research Division) wind speeds
  - **HRD winds need to be resampled to WindSat C/X band resolution**
    - Not possible to resolve small scale effects.
- Global wind speed through rain algorithm (C-band)
  - Wind speed below 10 m/s: Statistical algorithm
    - Trained from collocation of WindSat TB with NCEP GDAS wind speeds
  - Wind speed above 15 m/s: Semi-statistical algorithm
    - Lack of ground truth at high winds
    - Atmosphere statistical ensemble
    - Calculate emissivity from RTM
  - Smooth transition between 10 m/s and 15 m/s

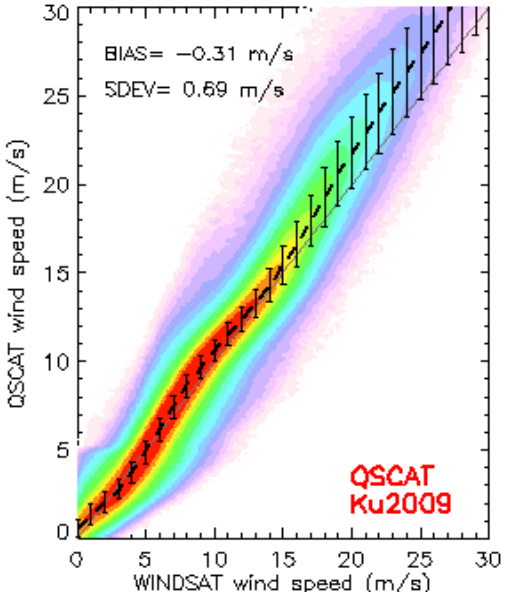
Winds in Rain:
OVWST meeting Seattle 2008, Meissner + Wentz, TGRS 47(9), 2009, 3065 - 3083

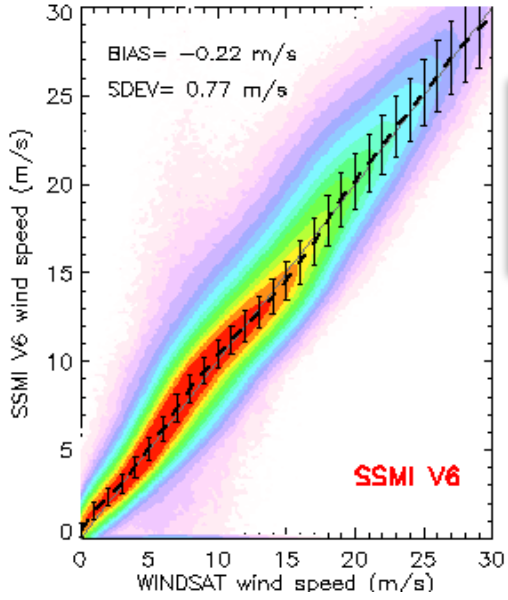
No-Rain Wind Speeds





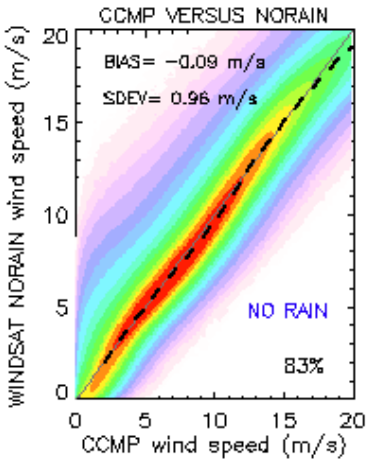


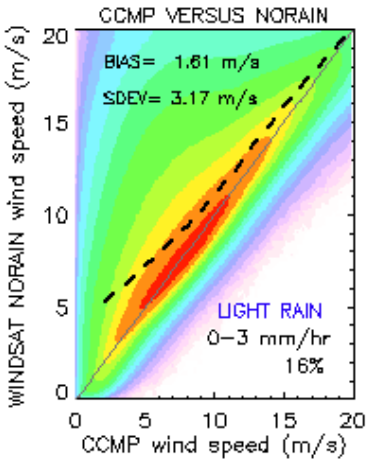


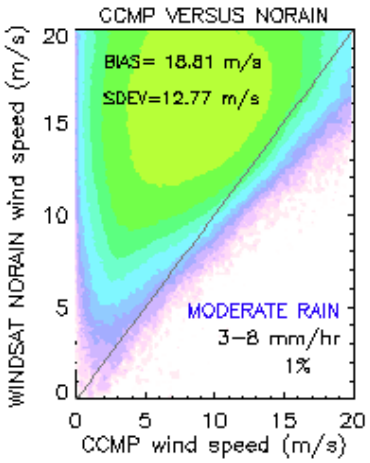


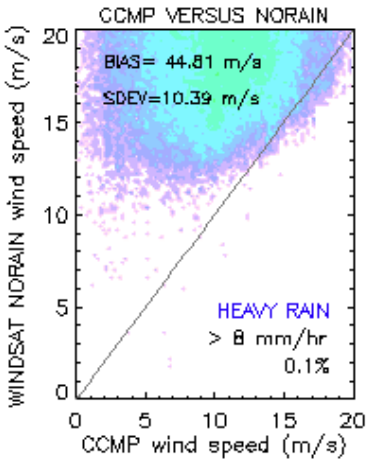
Post-hoc corrections were applied to all other products to align them with buoys

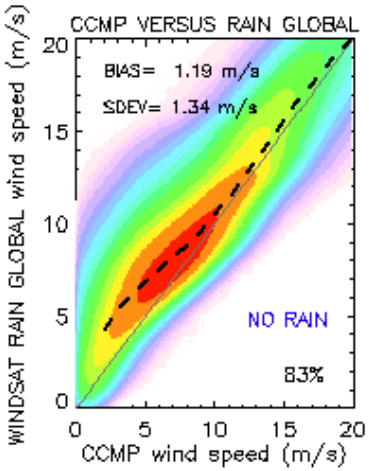
Global Wind Speeds in Rain

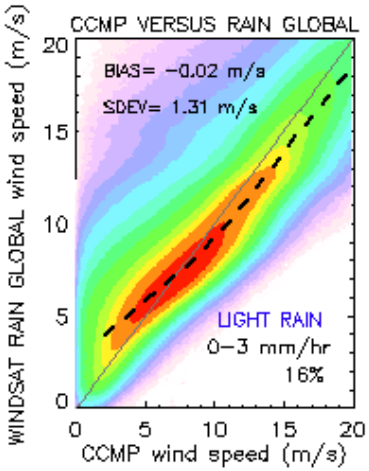


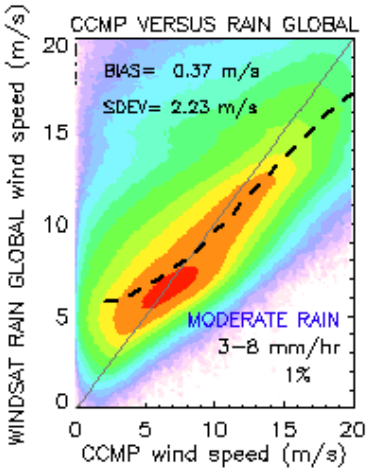


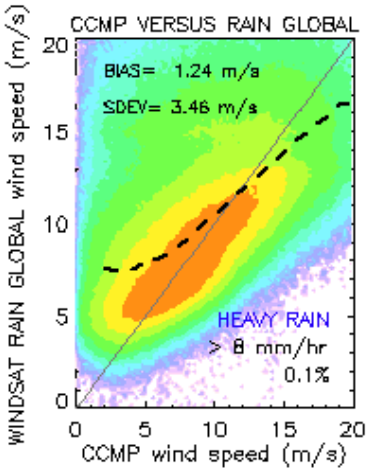




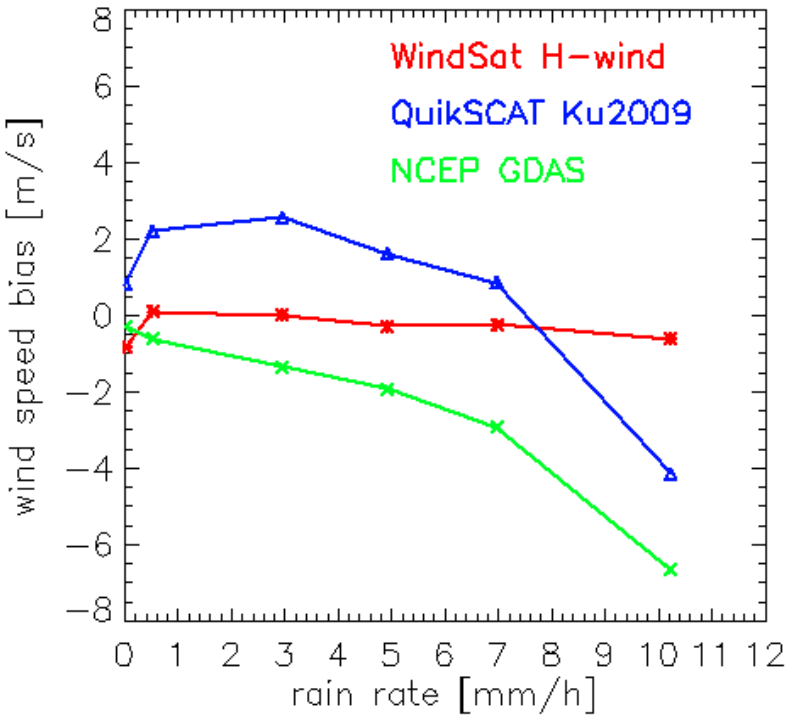


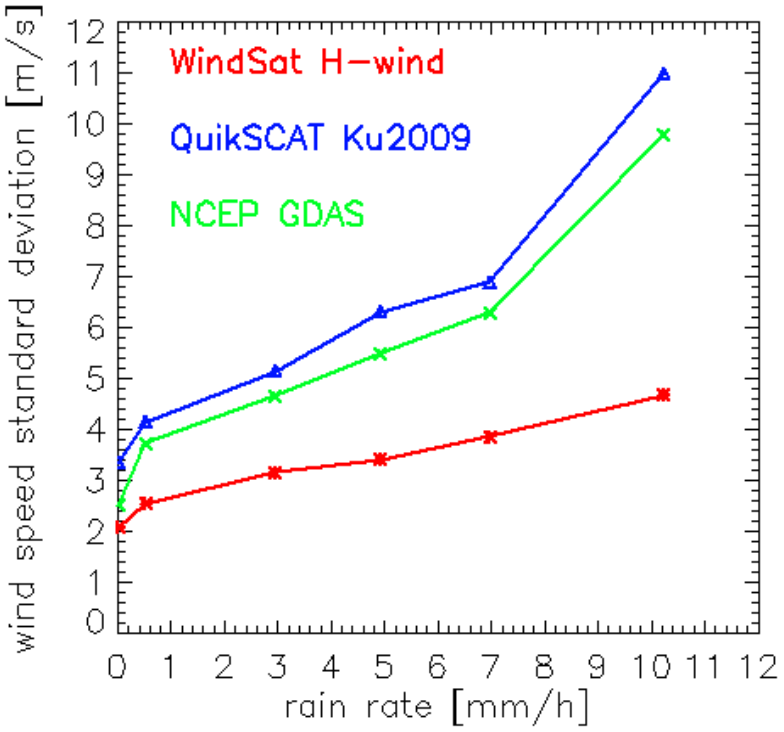






Hurricane Wind Speeds





Versus HRD wind speed

High Wind Speed Validation

- Validation for high wind speeds (> 25 m/s) is difficult
  - Few reliable *ground truth* observations
    - No buoys
    - QuikScat Ku 2001 high winds not valid (rain-free or rain)
    - Rain: All other radiometers invalid
    - NWP models unreliable in high winds
- Crucial question: Is emissivity model valid at high winds
  - Have assumed linear extrapolation
  - Does it saturate?
- H-wind algorithm has been trained + validated with HRD winds
  - Meissner + Wentz, IEEE TGRS 47(9), 2009, pp 3065 – 3083
  - **Assume that HRD winds are correct in tropical cyclones after resampling to WindSAt resolution**
  - H-wind algorithm does not use emissivity model
  - Global wind speed through rain algorithm uses emissivity model at high winds but no HRD winds
  - **Cross validation: Global algorithm versus H-wind**
  - **Indirect validation of emissivity model at high winds**
- WindSat high wind speeds will be used as basis for developing updated QuikSCAT geophysical model function
  - See presentation by L. Ricciardulli on Wednesday

RTM: Wind Induced Emissivity

WindSat TB over:

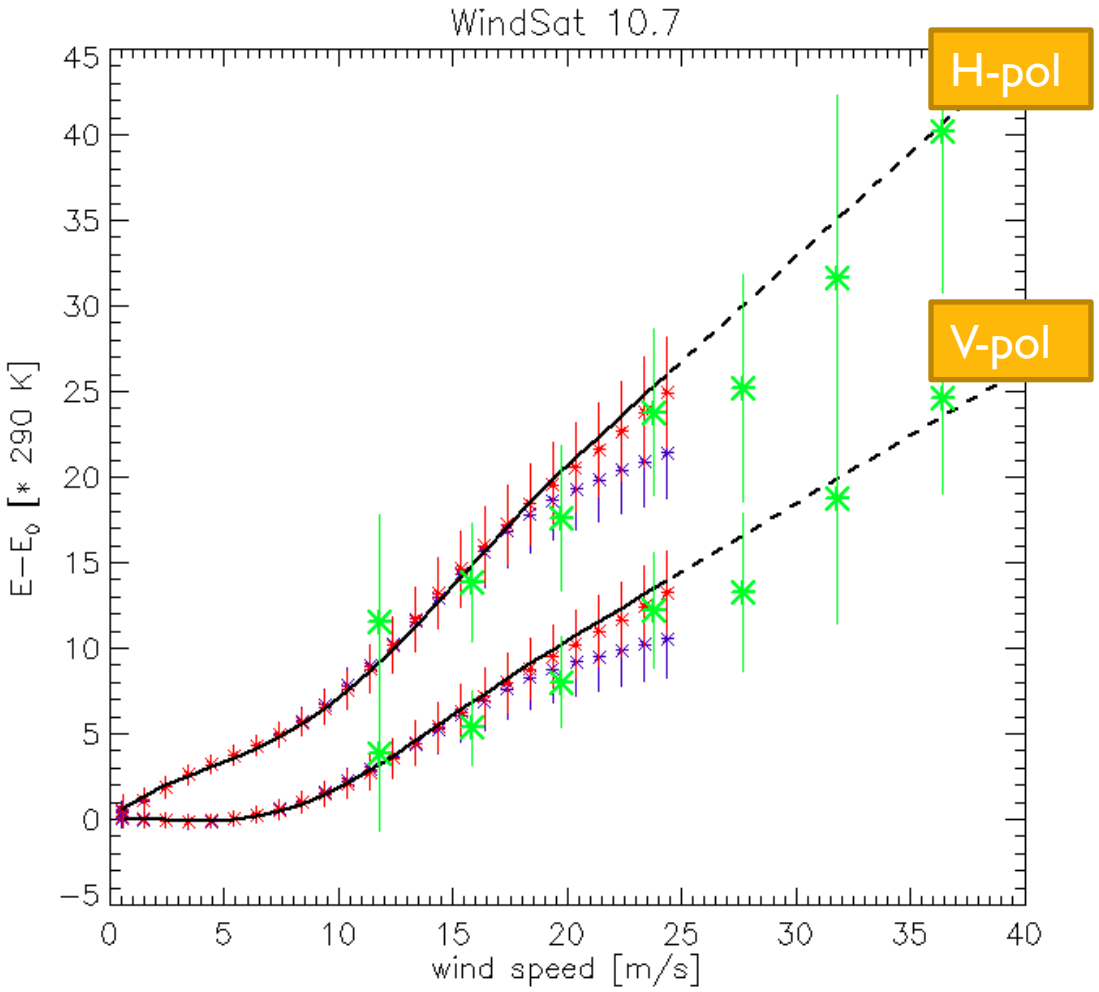
SSM/I F13 V6

QuikSCAT Ku2001

HRD

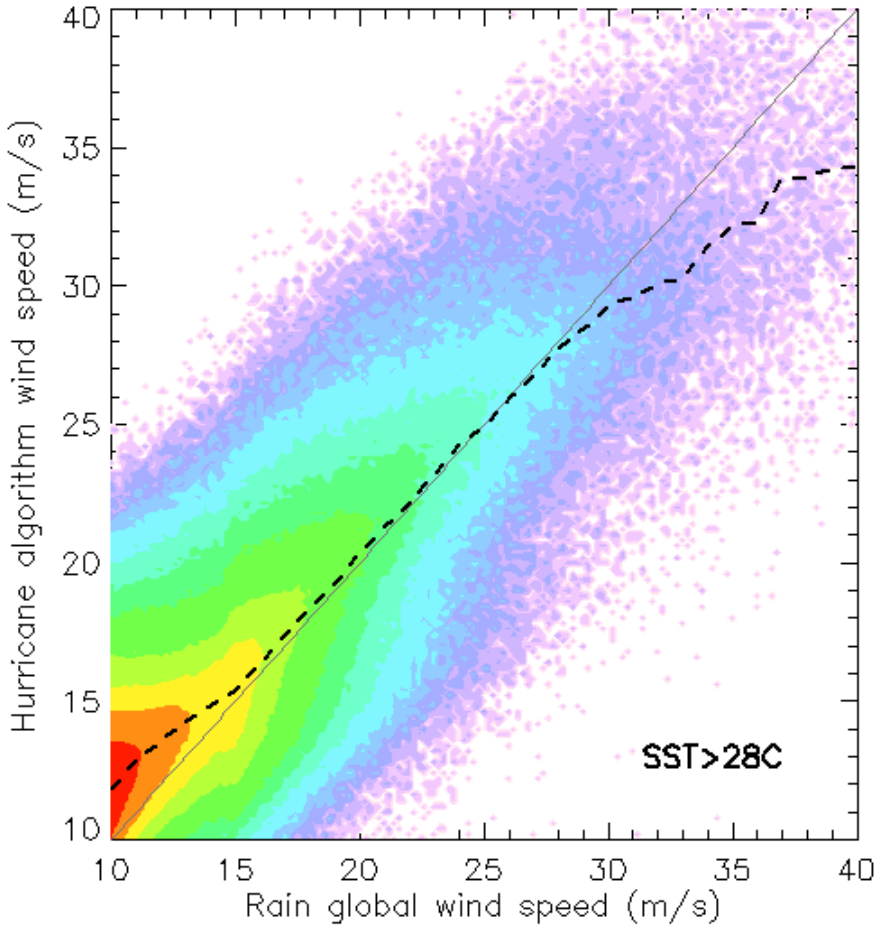
Challenge: Remove atmosphere (rain)

RTM
- best fit
- smoothed



Used for
- no-rain wind speed
- global wind speed through rain

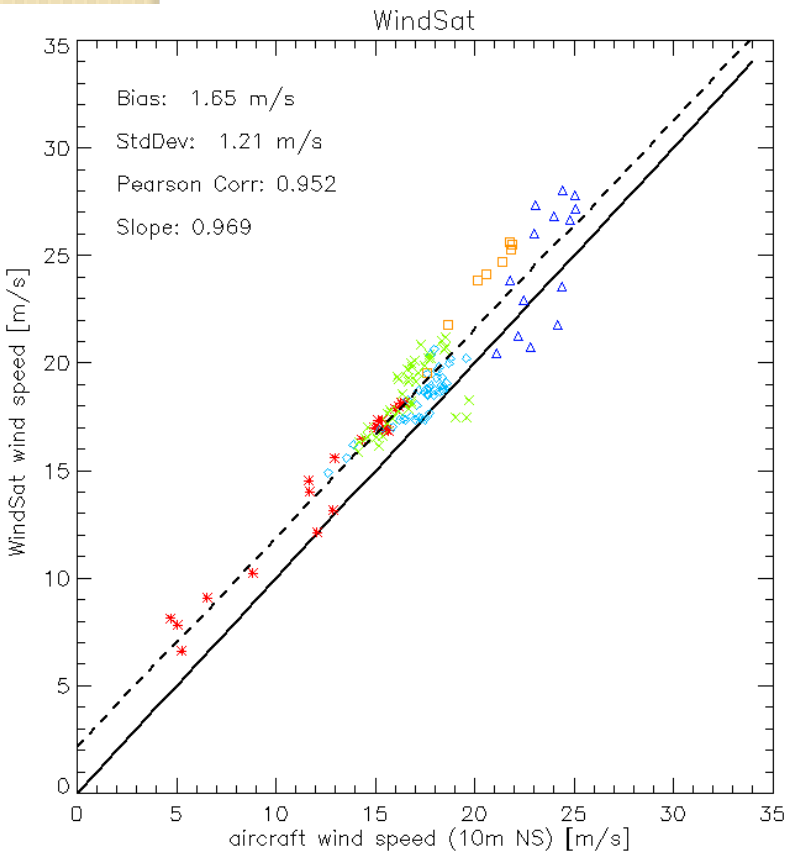
Wind Speed Through Rain Global versus H-Wind



No indication that wind emissivity model saturates at high winds

Consistency between H-wind and global wind through rain (RTM)

Greenland Tip Jet: Aircraft Measurement



- Renfrew et al. QJRMS **135**, pp. 2046 – 2066 (2009)
- Aircraft observations taken during the Greenland Flow Distortion Experiment (GFDex), Feb and Mar 2007
- 150 data points spread over 6 days with each data point equivalent to a 12 km spatial average
- Observations taken at 30-50 m above sea level and adjusted to standard 10m height

- Good correlation
- Overall positive bias
  - Sea ice zone
  - Instrument bias

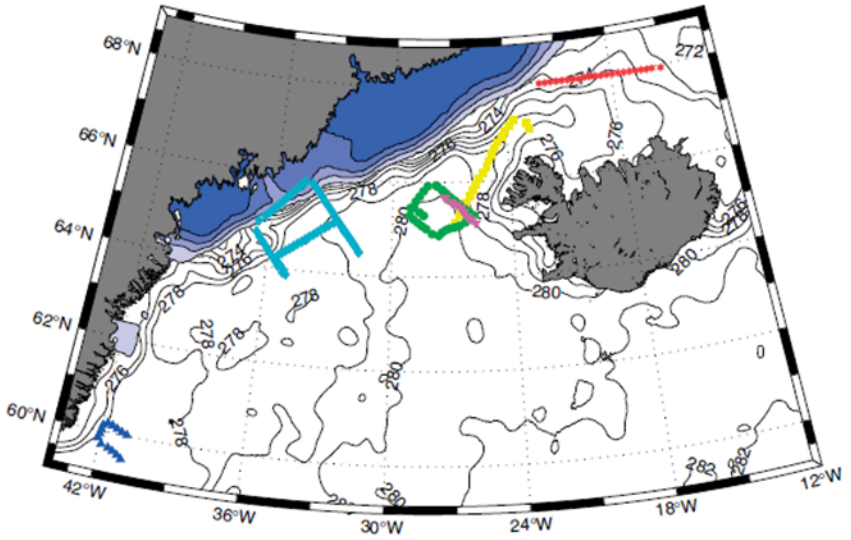
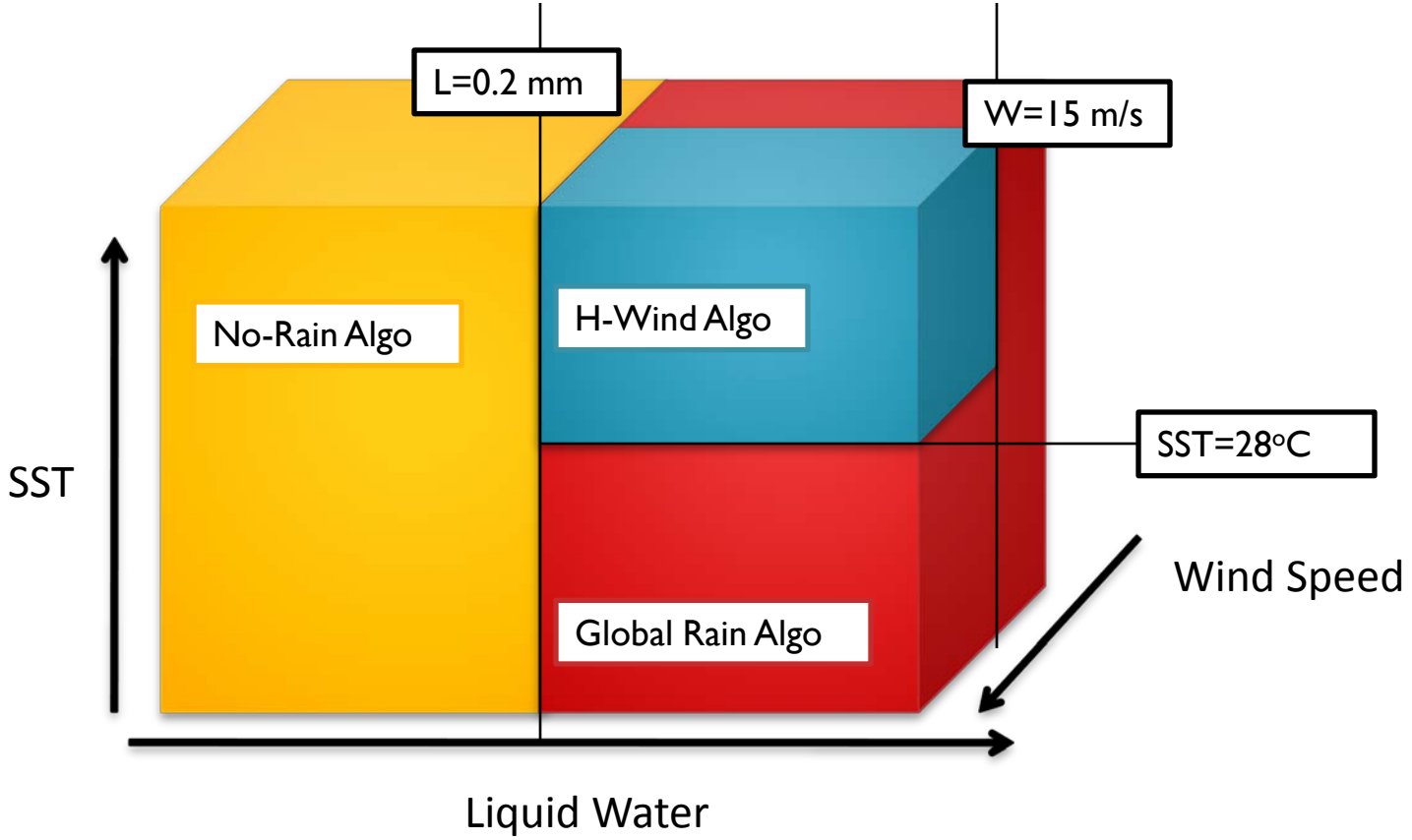


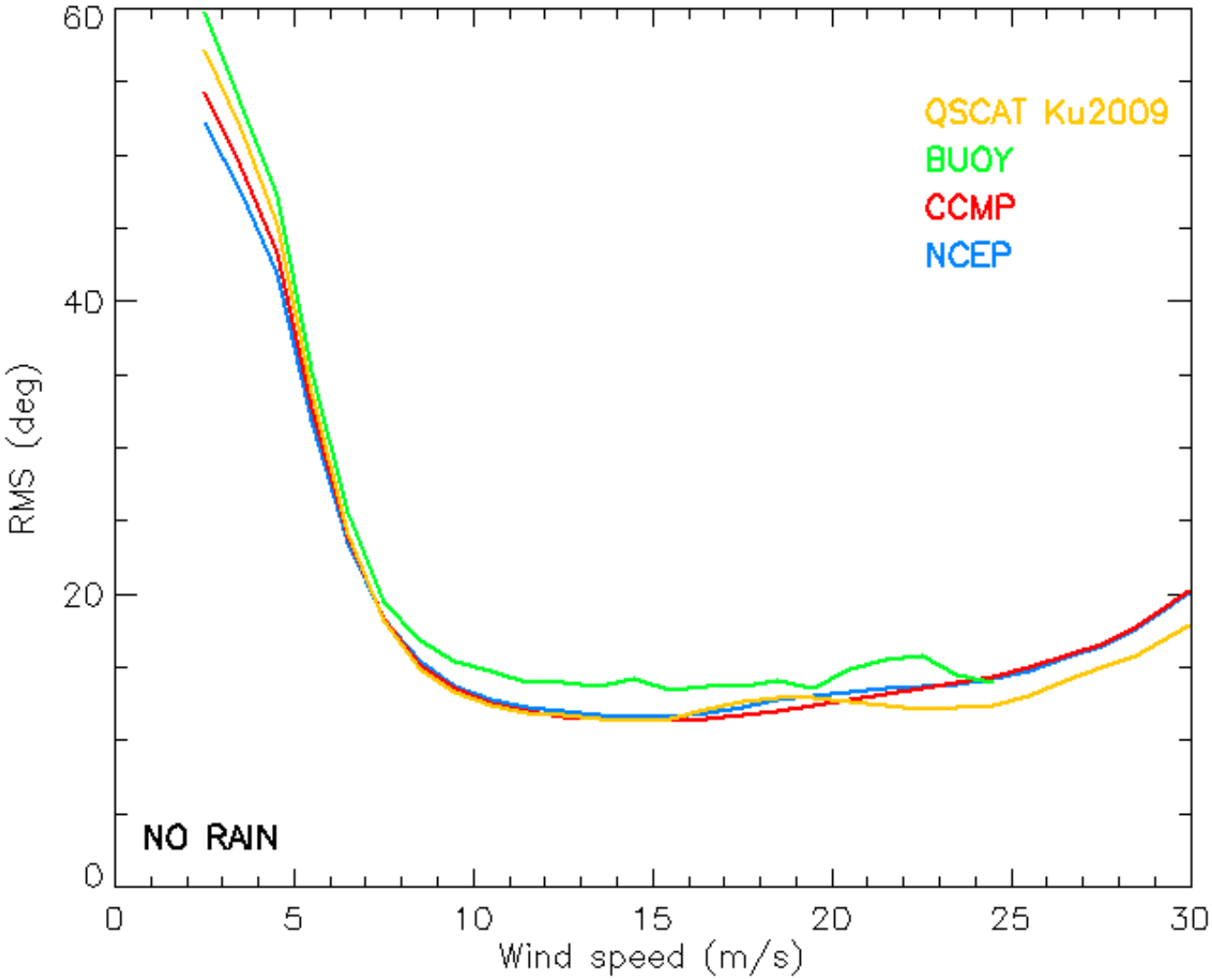
Figure 2. Locations of the observational database points. Data are from the low-level legs of flights B268 (triangles), B271 (stars), B274 (squares), B276 (diamonds), B277 (upturned triangles) and B278 (circles). SST (contours every 1K) and sea-ice concentration (shading every 20%) from the OSTIA dataset on the 5 March 2007 is also shown. This figure is available in colour online at www.interscience.wiley.com/journal/qj

All-Weather Wind Speed

- Blending between no-rain, global wind speed in rain and H-wind algorithms
- Takes place in L, T, W space
- Smooth transitions between zones



Wind Directions

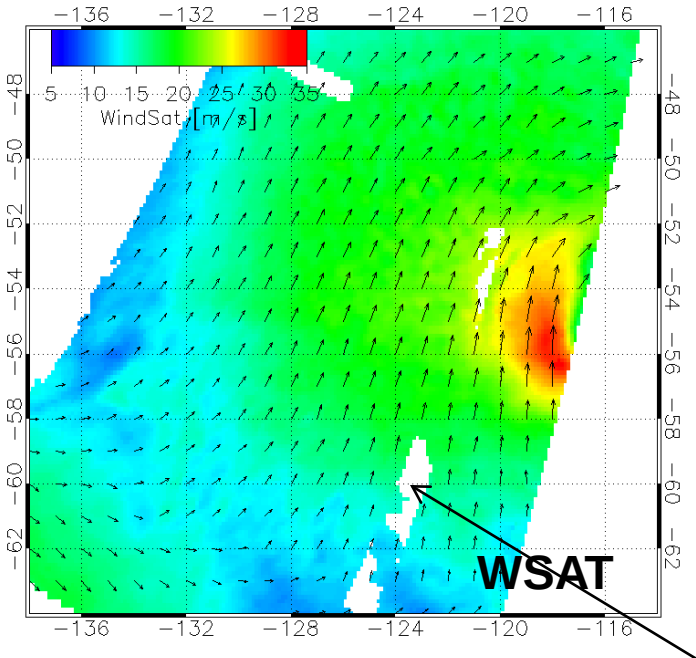


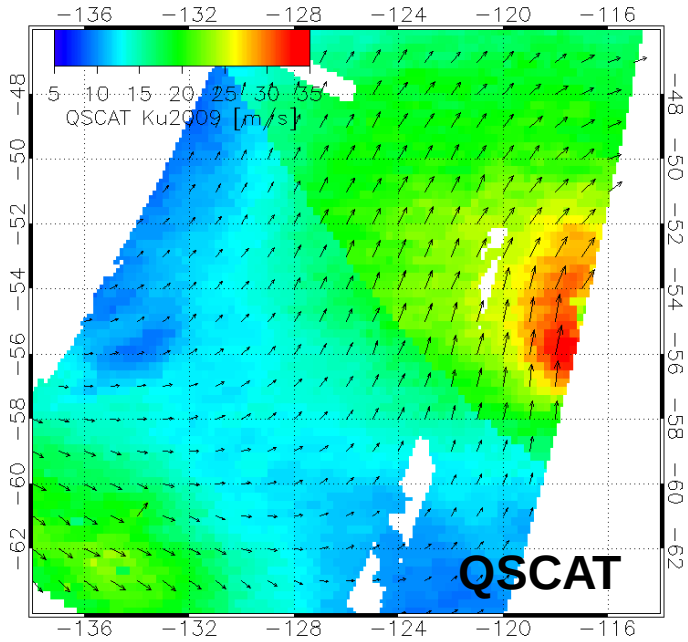
Wind Directions

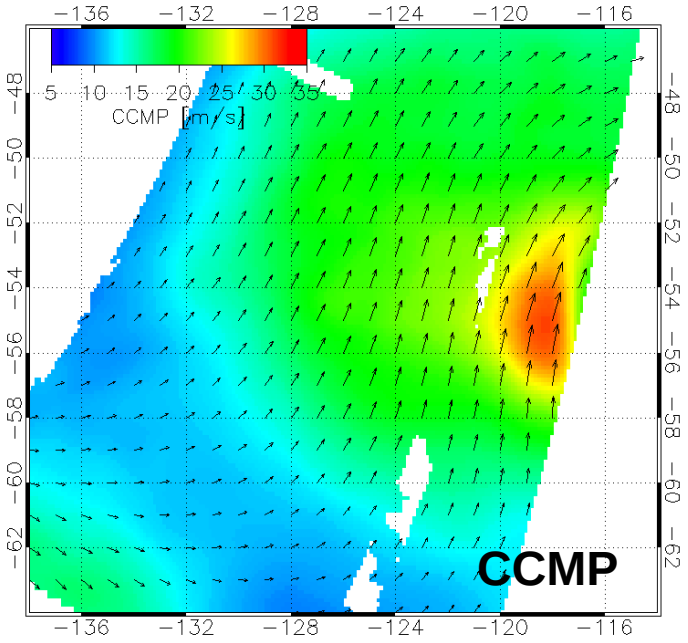
RMS [deg]	low winds (<6 m/s)	moderate winds (6-12 m/s)	high winds (> 12 m/s)
no rain	40	16	11
light rain (< 3 mm/h)	52	27	18
moderate rain (3 – 8 mm/h)	61	44	35
heavy rain (> 8 mm/h)	65	52	49

WindSat versus CCMP Wind Direction Wind – Rain Performance Matrix

High Southern Latitude Storm 04/01/2006 14:30 UTC

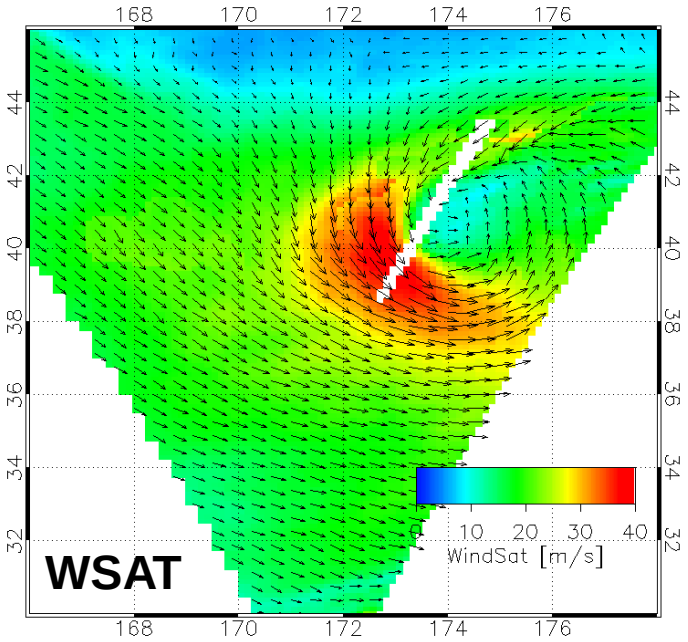


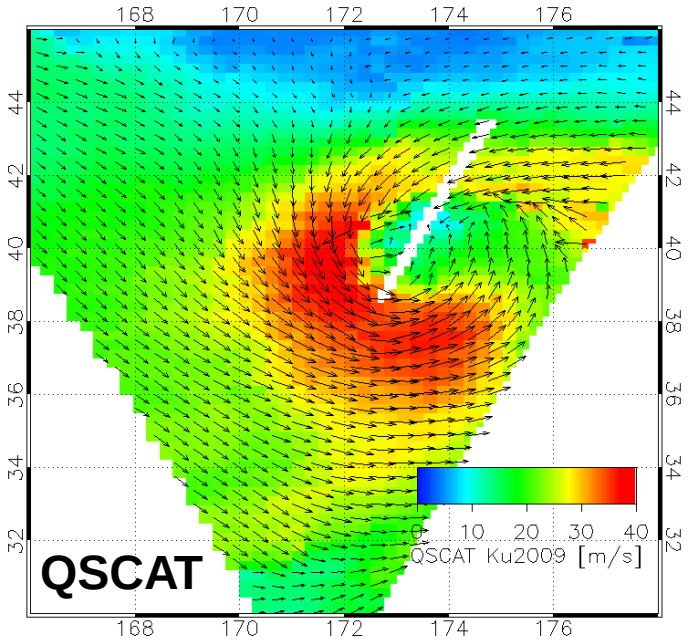


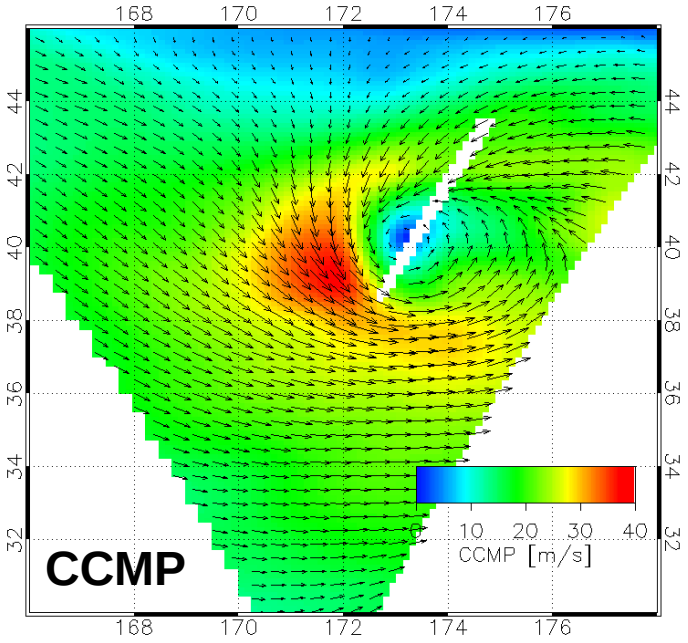


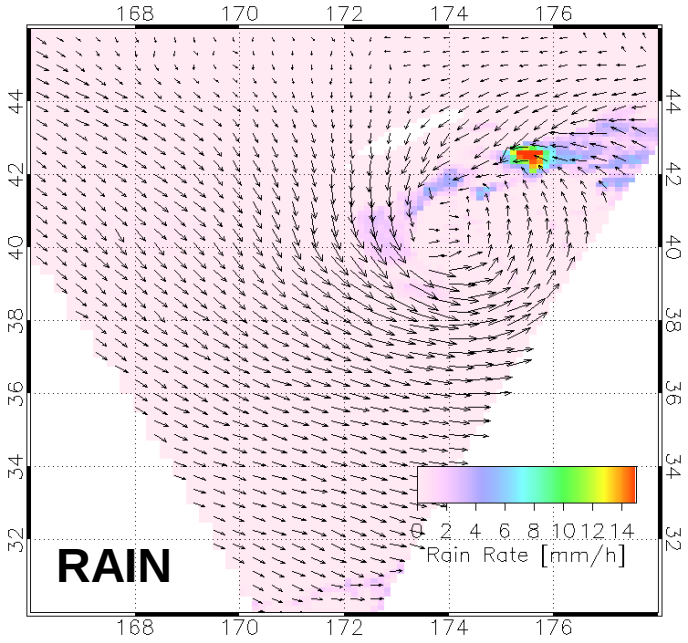
Rain in cell
No C-band

Northern Latitude Extratropical Storm
17/02/2003 19:30 UTC

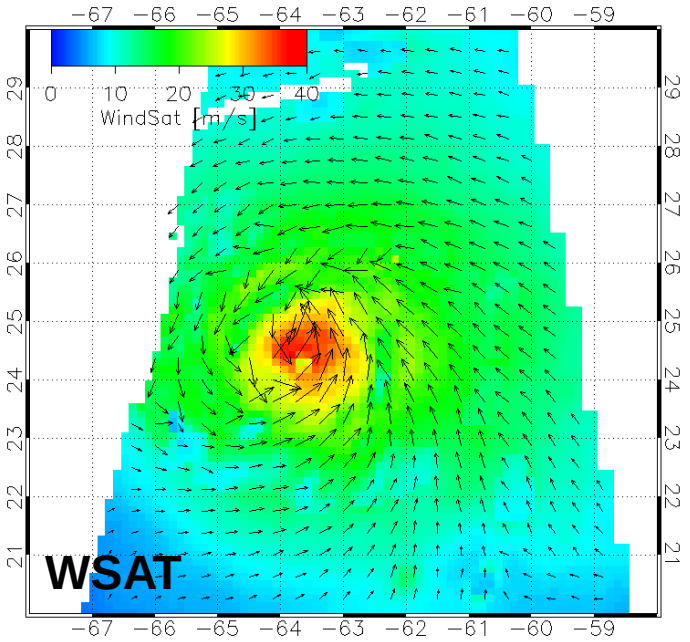

168 170 172 174 176
44 42 40 38 36 34 32
10 20 30 40
WindSat [m/s]
WSAT

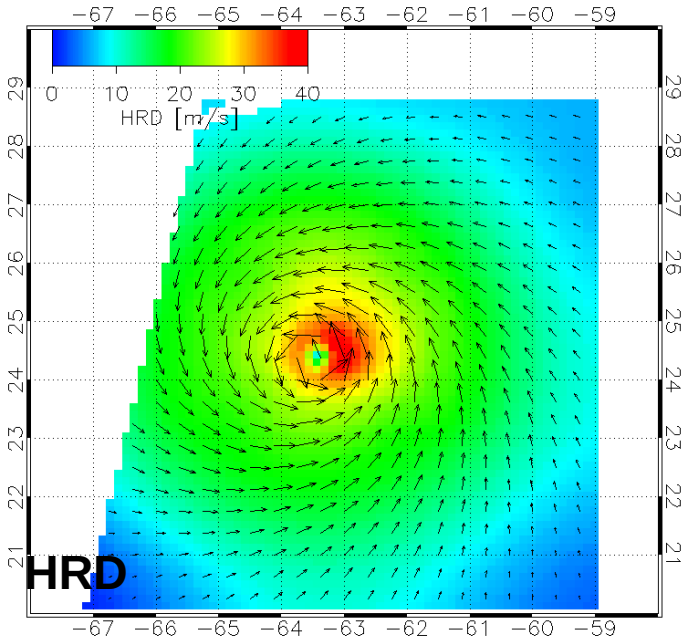

168 170 172 174 176
44 42 40 38 36 34 32
10 20 30 40
QSCAT Ku2009 [m/s]
QSCAT

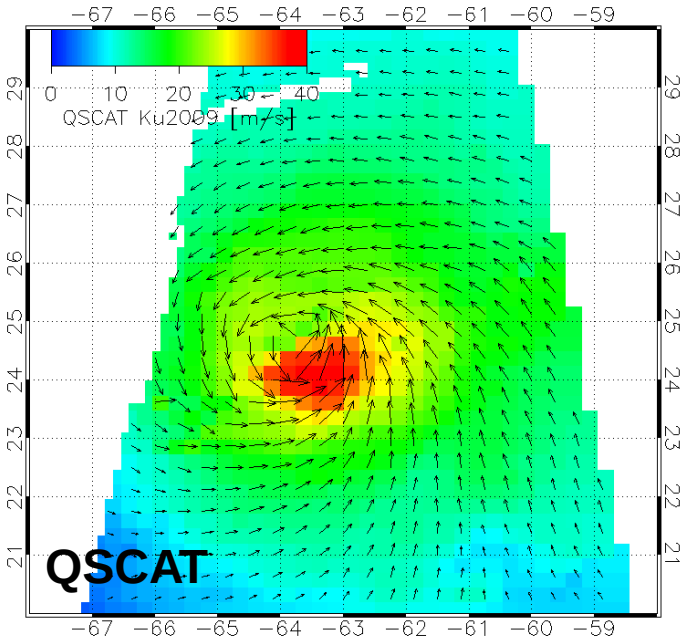

168 170 172 174 176
44 42 40 38 36 34 32
10 20 30 40
CCMP [m/s]
CCMP

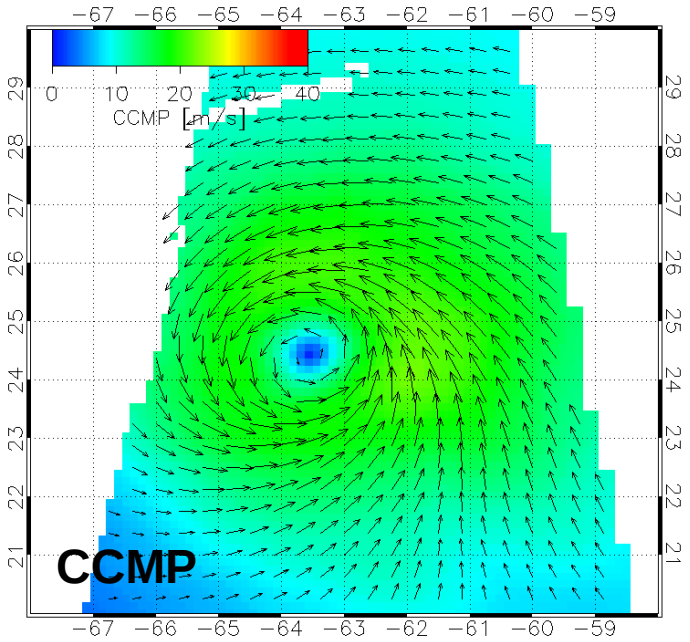

168 170 172 174 176
44 42 40 38 36 34 32
0 2 4 6 8 10 12 14
Rain Rate [mm/h]
RAIN

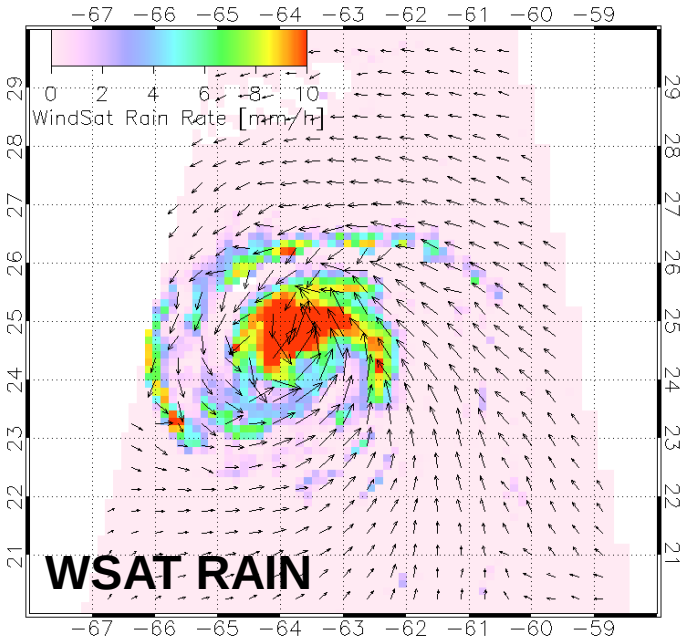
Hurricane Fabian
09/04/2003 10:30 UTC

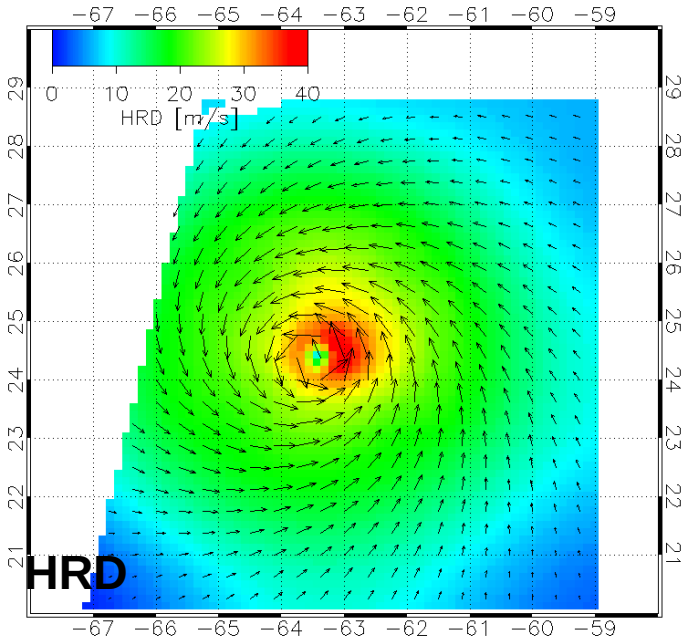

WSAT
WindSat [m/s]
0 10 20 30 40
−67 −66 −65 −64 −63 −62 −61 −60 −59
21 22 23 24 25 26 27 28 29

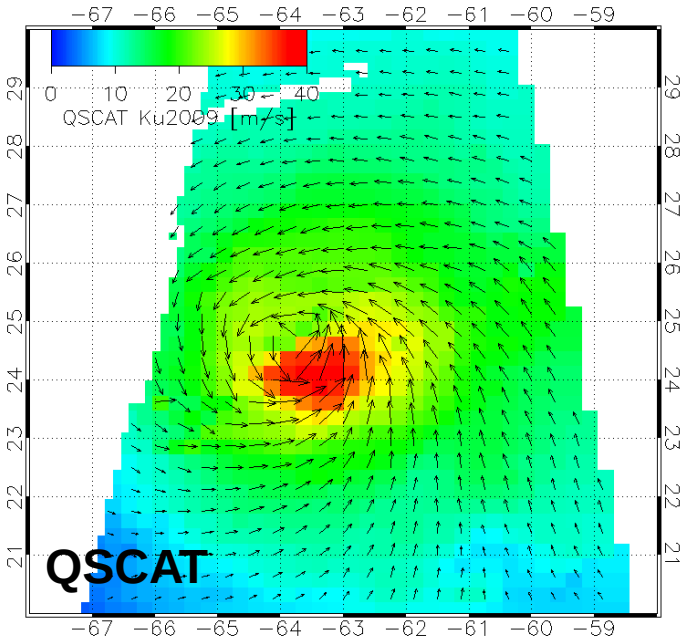

HRD
HRD [m/s]
0 10 20 30 40
−67 −66 −65 −64 −63 −62 −61 −60 −59
21 22 23 24 25 26 27 28 29

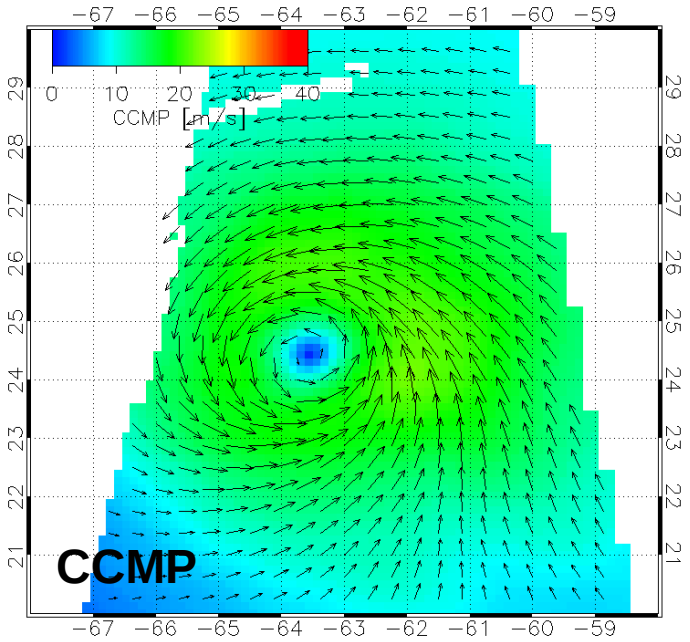

QSCAT
QSCAT Ku2009 [m/s]
0 10 20 30 40
−67 −66 −65 −64 −63 −62 −61 −60 −59
21 22 23 24 25 26 27 28 29


CCMP
CCMP [m/s]
0 10 20 30 40
−67 −66 −65 −64 −63 −62 −61 −60 −59
21 22 23 24 25 26 27 28 29


WindSat Rain Rate [mm/hr]
WSAT RAIN


HRD [m/s]
HRD


QSCAT Ku2009 [m/s]
QSCAT


CCMP [m/s]
CCMP

Summary: All-Weather Winds

- Version 6: Rain areas needed to be blocked out
- Version 7: Rain areas will have wind speeds
  - C-band required: only WindSat , AMSR-E, GCOM
  - Possible with only X-band (TMI, GMI)
  - Degradation in Rain