Satellite Altimeter Detection of Global Very Extreme Sea States (VESS)

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MOTIVATION

- It has been reported that 3G wave models that perform well in most of the dynamic range exhibit bias in VESS - HS > 14 m
- VESS increasingly sampled by in-situ sensors in recent decades but mainly near continental margins and in Northern Hemisphere
- The VESS regime may provide a good test of new source term physics
- Good atmospheric forcing during recent decade of multiple altimeter missions that overlap global scatterometer coverage – a “golden age”?
- WMO-IOC JCOMM Expert Team on Wind Waves and Storm Surges has recommended the development of a catalogue of VESS (HS>14 m) cases
- Provide a more accurate baseline for the “control” runs of climate simulations for extreme events than standard hindcast products

APPROACH

- VESS sampled to date from in-situ sources biased toward basin margins, use altimeters to scan for global occurrences of storm peak HS > 12 m
- Even “corrected” Q/C final processed data contain many spurious spikes, so tedious man-machine quality control selection procedure applied
- Scan entire TOPEX, JASON-1, ENVISAT datasets 1992-2007
  - Apply published bias adjustment regressions to ALT data
  - Median filter along orbit segments to reduce influence of noise to produce candidate list
  - Refer to coincident weather maps and wind fields to filter remaining spurious spikes and summarize occurrences by satellite, basin and HS range
- Hindcast the most extreme case found – HS ~ 20 m in central North Atlantic extratropical “bomb” of February 9, 2007

Principle Conclusions

- Number of VESS storms proportional to basin size but it appears North Atlantic best tuned to produce the most extreme VESS per unit area.
- Of 260 VESS cases, only 2 appear to be associated with tropical cyclones attesting to great difficulty for a satellite altimeter to see inside the core of intense tropical cyclones
- The highest VESS of 20.2 m was detected in the North Atlantic extratropical cyclone of February 8, 2007
- QuikSCAT scatterometer appears to provide sufficient dynamic range and coverage to allow an accurate specification of wind field properties in VESS regime BUT
- The QSCAT -1/F13 model function, now the official NASA project model function , is believed to be seriously biased (high) above wind speeds of 20 m/s
- The evolution of the wind field in the February, 2007 storm reveals a surface wind field of unprecedented intensity (peak average wind speed of 83-knots!) and scale
- At least the variant of the WAM-class model applied here provides a hindcast in good agreement with the satellite altimeter data in this storm

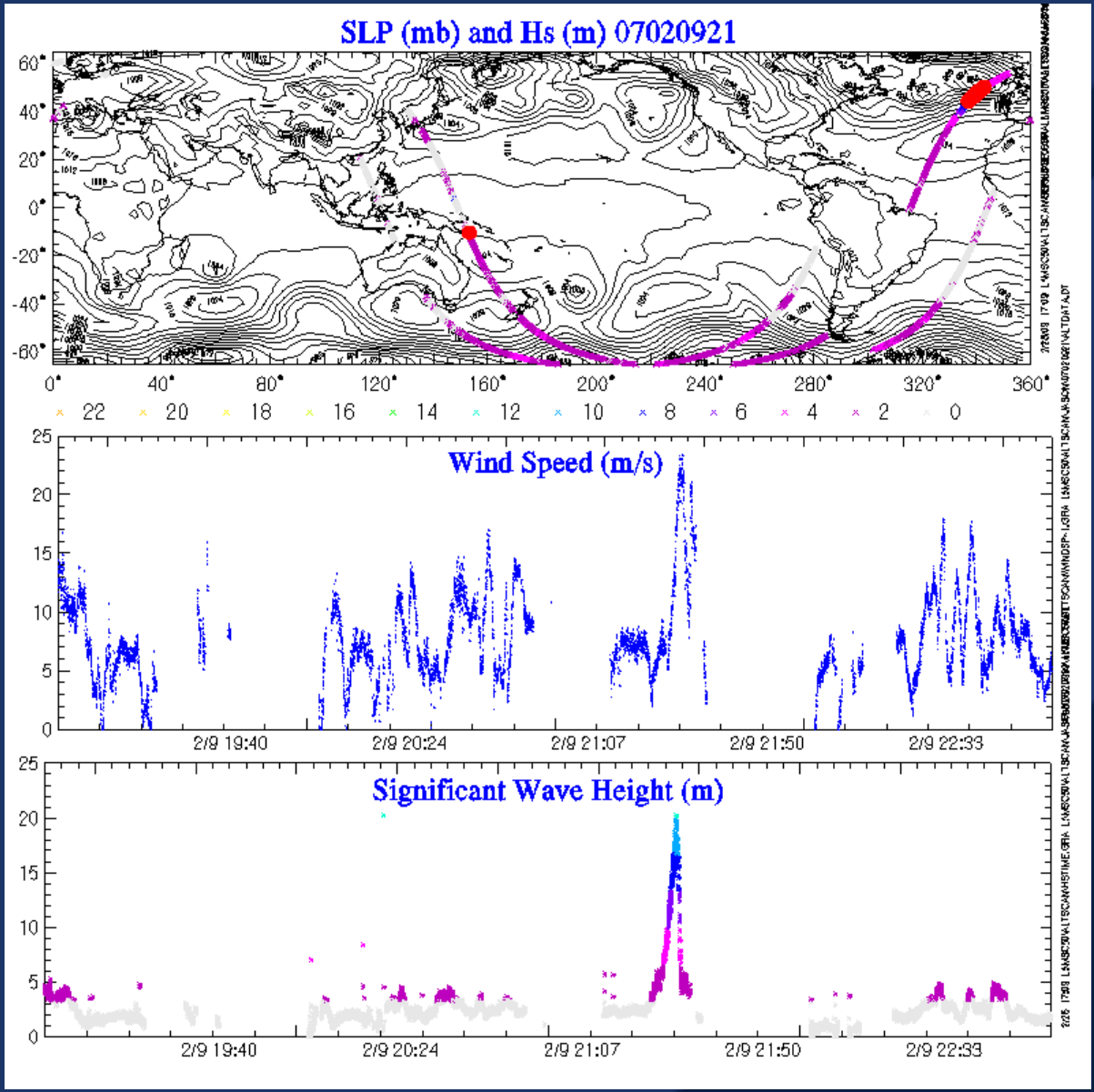
In-situ Measurements of VESS

Measurement	Storm	Basin	Hs (m)
RRS Discovery	Rockall Trough	North Atlantic	18.5
Polarfront	Nov 2001	North Atlantic	15.5
MEDS 44137	Halloween Storm	North Atlantic	16.9
MEDS 44141	Halloween Storm	North Atlantic	14.6
NDBC 46003	Jan 1991	North Pacific	16.9
Portland Buoy	Dec 2007	North Pacific	14.2
K Buoy 62109	Dec 2007	North Atlantic	18.3
42040	Ivan (2004)	Gulf of Mexico	16.0
42040	Katrina (2005)	Gulf of Mexico	16.9
Norwegian Platform	Jan 2006	North Atlantic	15.5
Redhawks	Rita (2005)	Gulf of Mexico	14.2
Marlin	Ivan (2004)	Gulf of Mexico	15.4

Altimeter Data Sources

Satellite	Period Scanned	Calibration Applied	Source
TOPEX	Sept, 1992 – Sept, 2004	Time Variable	Queffeulou 2004
JASON-1	Jan, 2002 – Dec. 2007	HsAdj=1.0072*Hs+0.092	Picot et al. 2003
ENVISAT	Sept. 2002 – Dec 2007	HsAdj=1.0327*Hs-0.183	Queffeulou 2003

900+ VESS that survived median filter subjected to visual Q/C scan as exemplified here



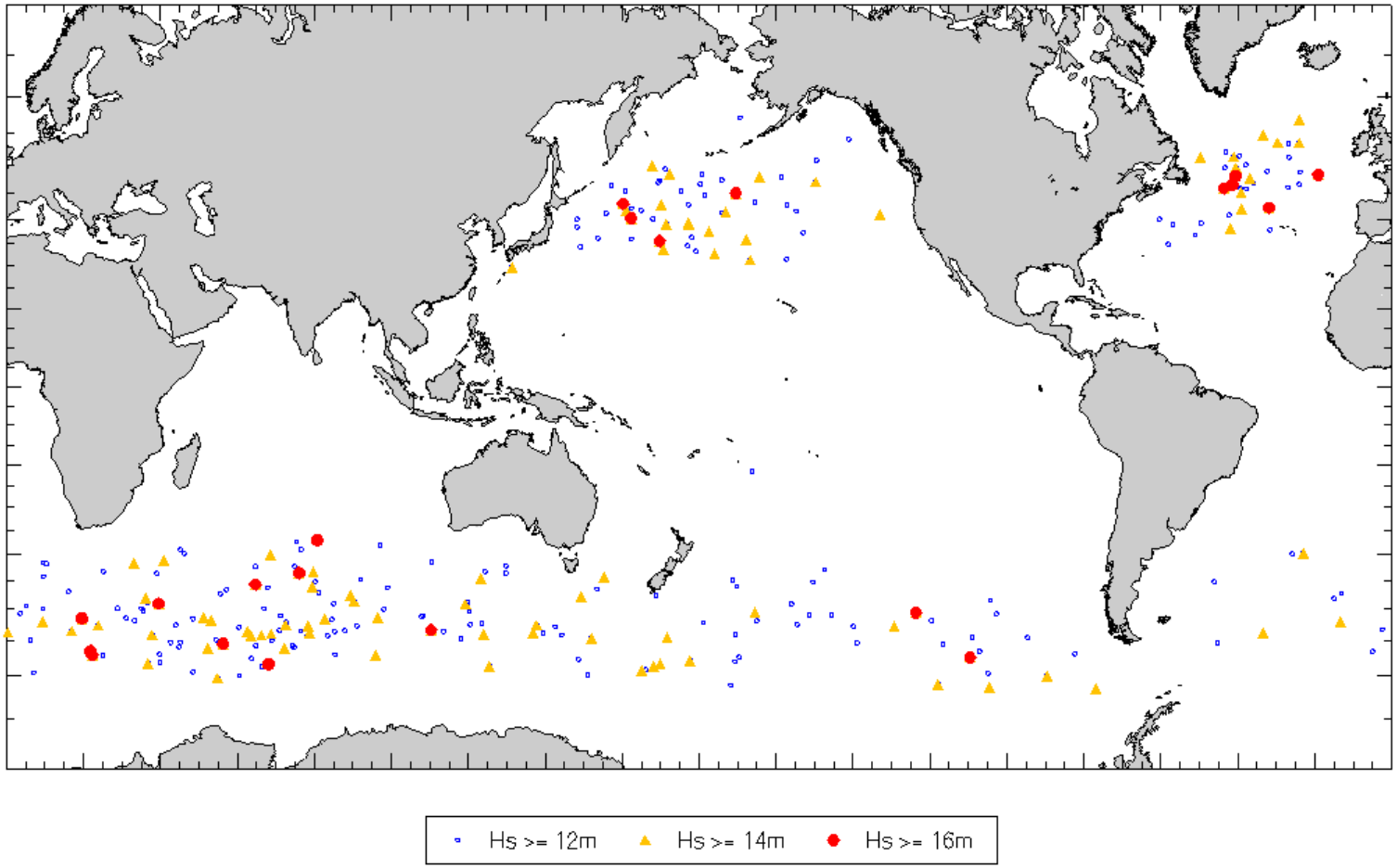
Distribution of Detected VESS Storm Peaks

Satellite	North Atlantic	North Pacific	Southern Oceans	Total
TOPEX Hs >12	7	9	16	32
> 14	2	5	3	10
> 16	2	1	1	4
JASON Hs >12	27	40	138	205
> 14	14	15	58	87
> 16	3	3	10	16
ENVISAT > 12	2	5	16	23
> 14	0	1	3	4
> 16	0	0	0	0
TOTAL Hs > 12	36	54	170	260
> 14	16 (44%)	21 (39%)	63 (38%)	101 (39%)
> 16	5 (14%)	4 (7%)	10 (6%)	20 (8%)

The low VESS detection rate for ENVISAT is unexplained?

Distribution of 12+ Meter Significant Wave Height

As Measured from the TOPEX, ENVISAT and JASON Altimeters



A Start at Associating Storm Properties to VESS:

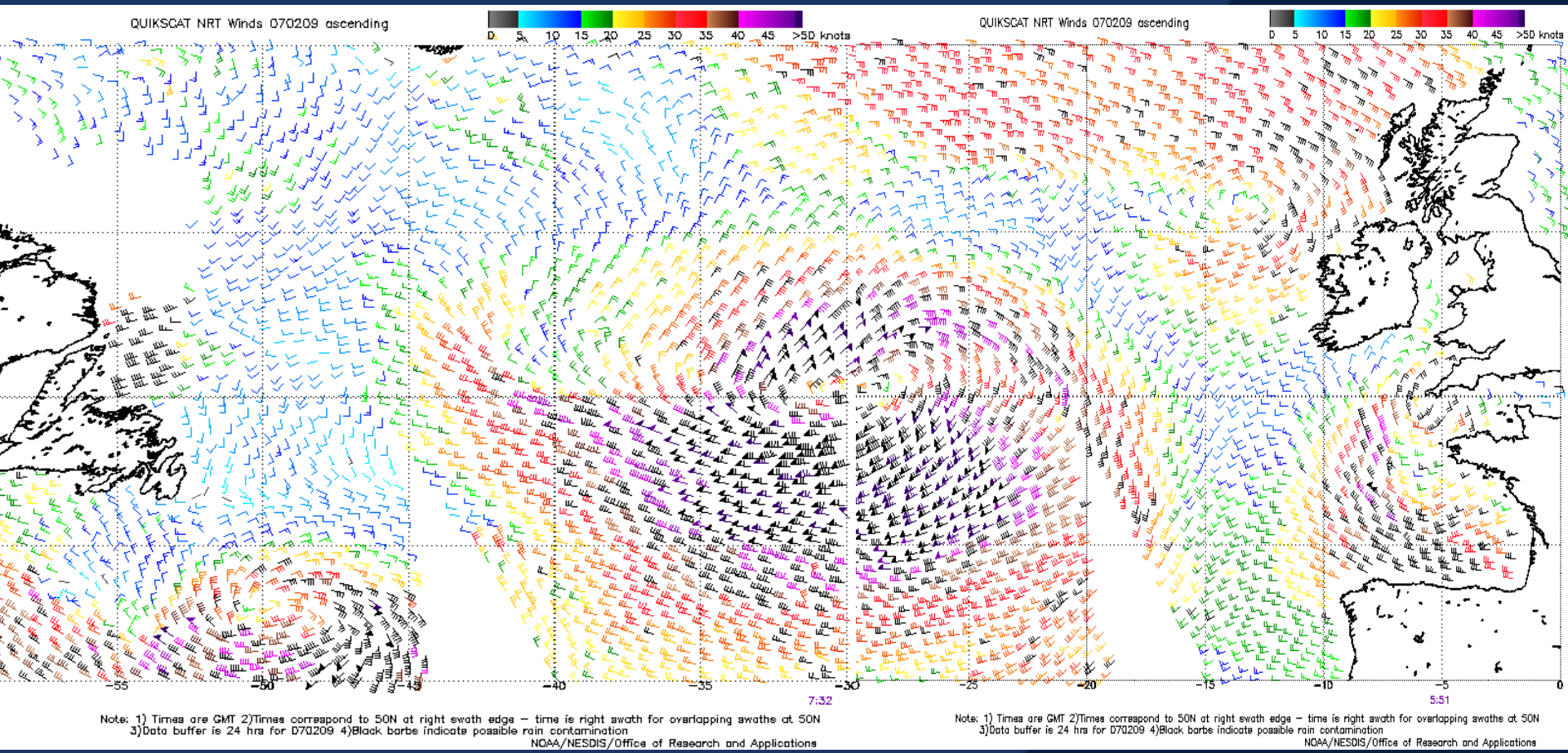
Storm peaks > 14m Detected: Mean Pressure and Deepening Rate

	North Atlantic	North Pacific	Southern Ocean
Number of Peaks	16	21	64
Minimum Pressure	960	964	951
Maximum Deepening Rate	26	19	15

Note: pressures from NCEP/NCAR Reanalysis-1 so bias possible

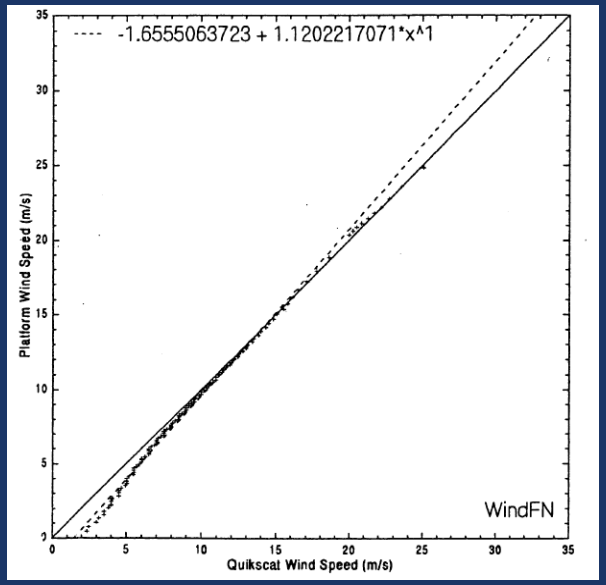
Let’s have some fun and hindcast the worst case
North Atlantic storm of February 7-10, 2007

- QuikSCAT swaths provided excellent monitoring of the time and space evolution of the surface wind field
- Important to use an unbiased scatterometer model function
- MSC50 North Atlantic wave model serves as a good platform
- WAM Cycle-3 class (published CSOWM model- 1994 vintage which incorporated asymptotic C10 to 2.2 x 10-3), not Wu
- Kinematic reconstruction of wind field was straightforward

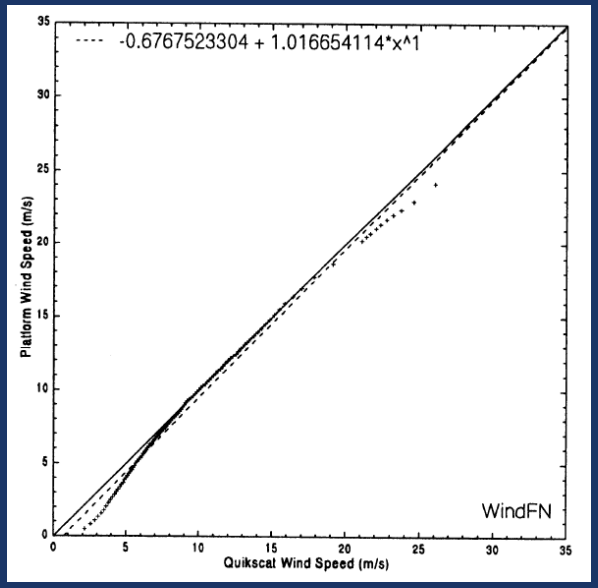


QuikSCAT vs platform wind speeds

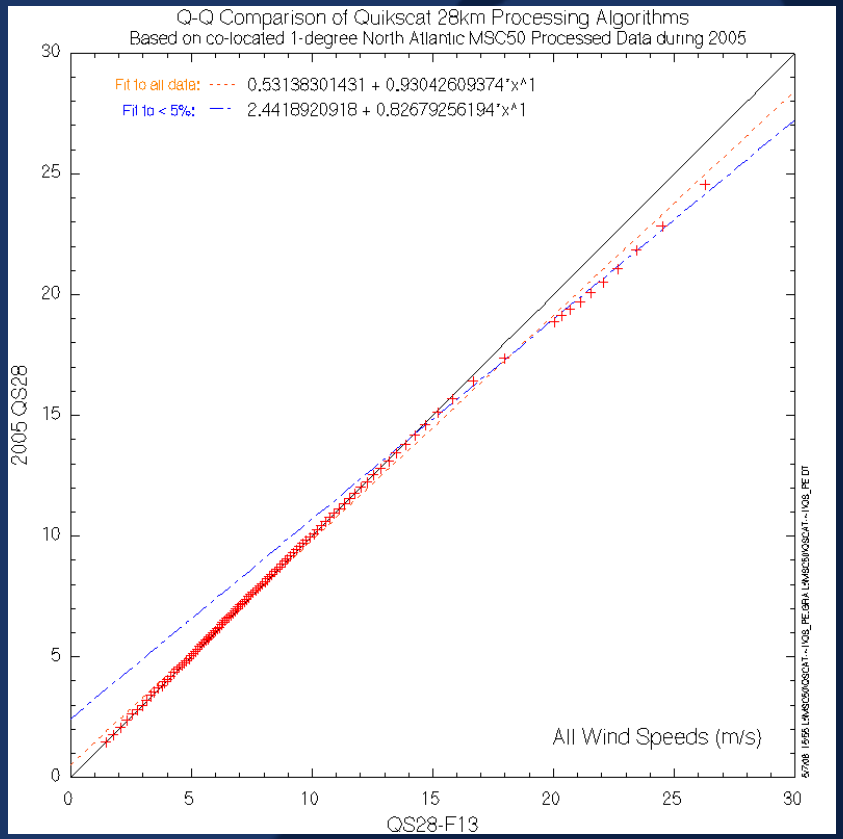
QSCAT-1



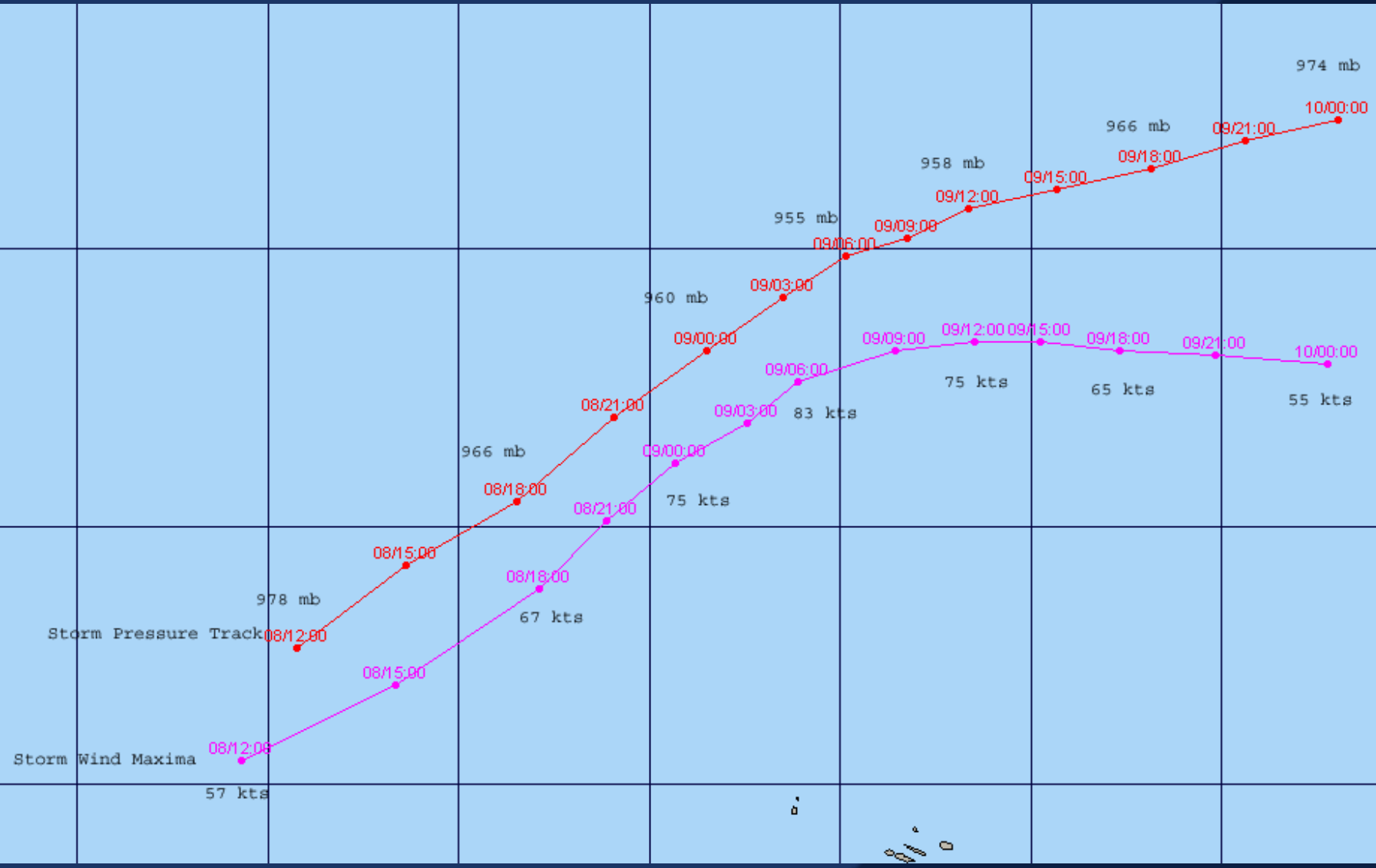
QSCAT-1/F13



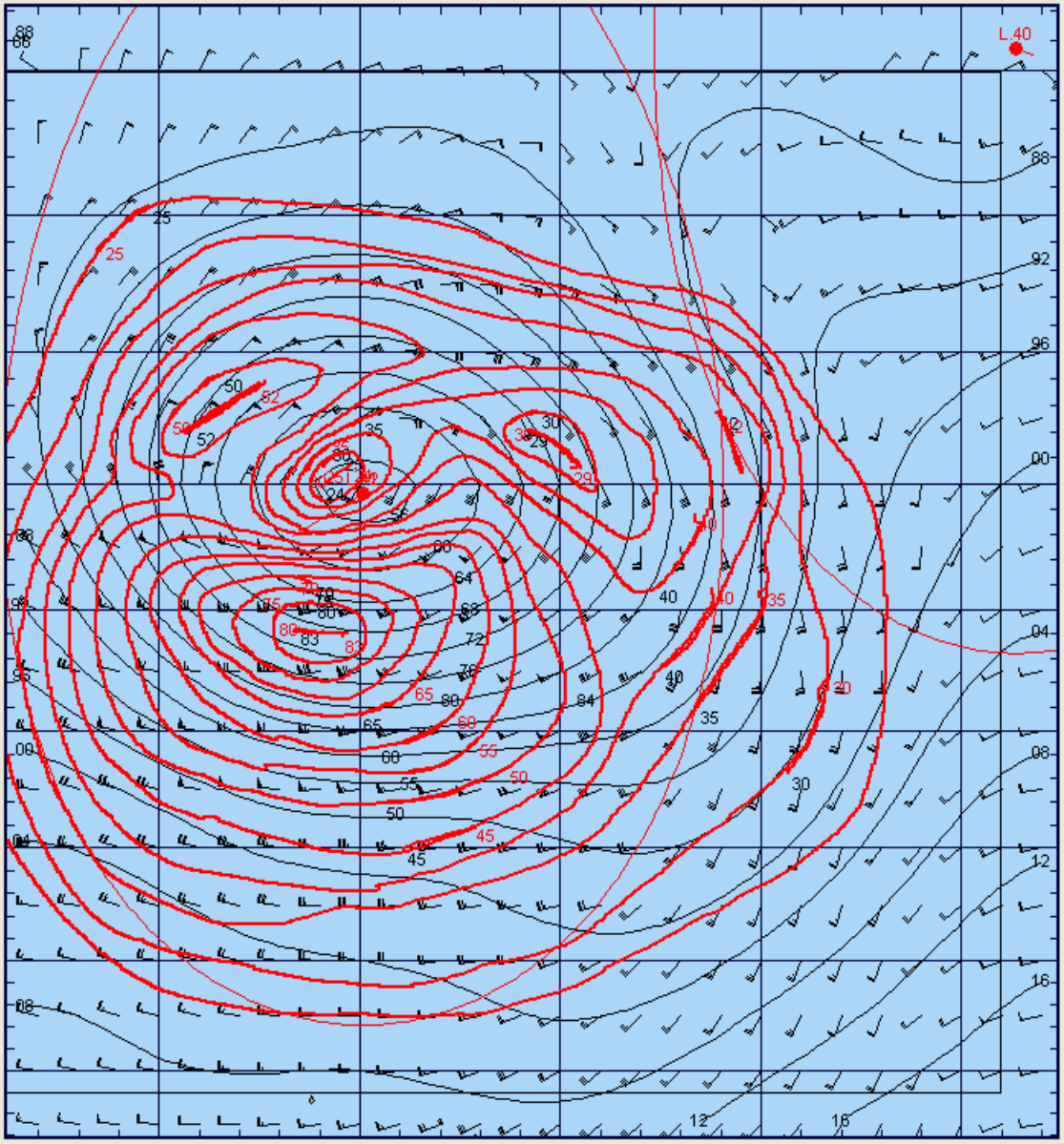
Difference between QSCAT-1 and QSCAT-1/F13 scatterometer model function wind speed retrievals in one year of North Atlantic QuikSCAT measurements

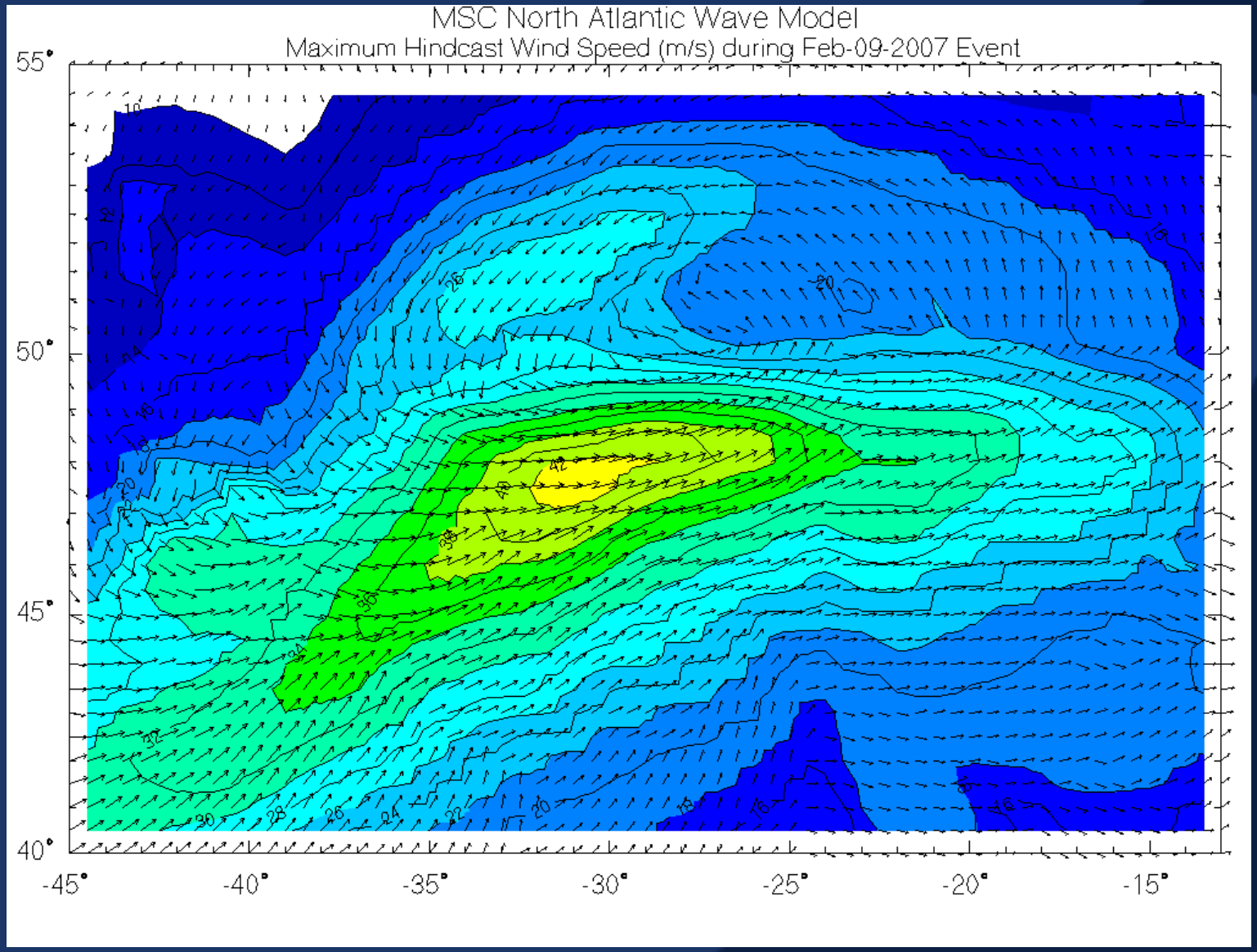


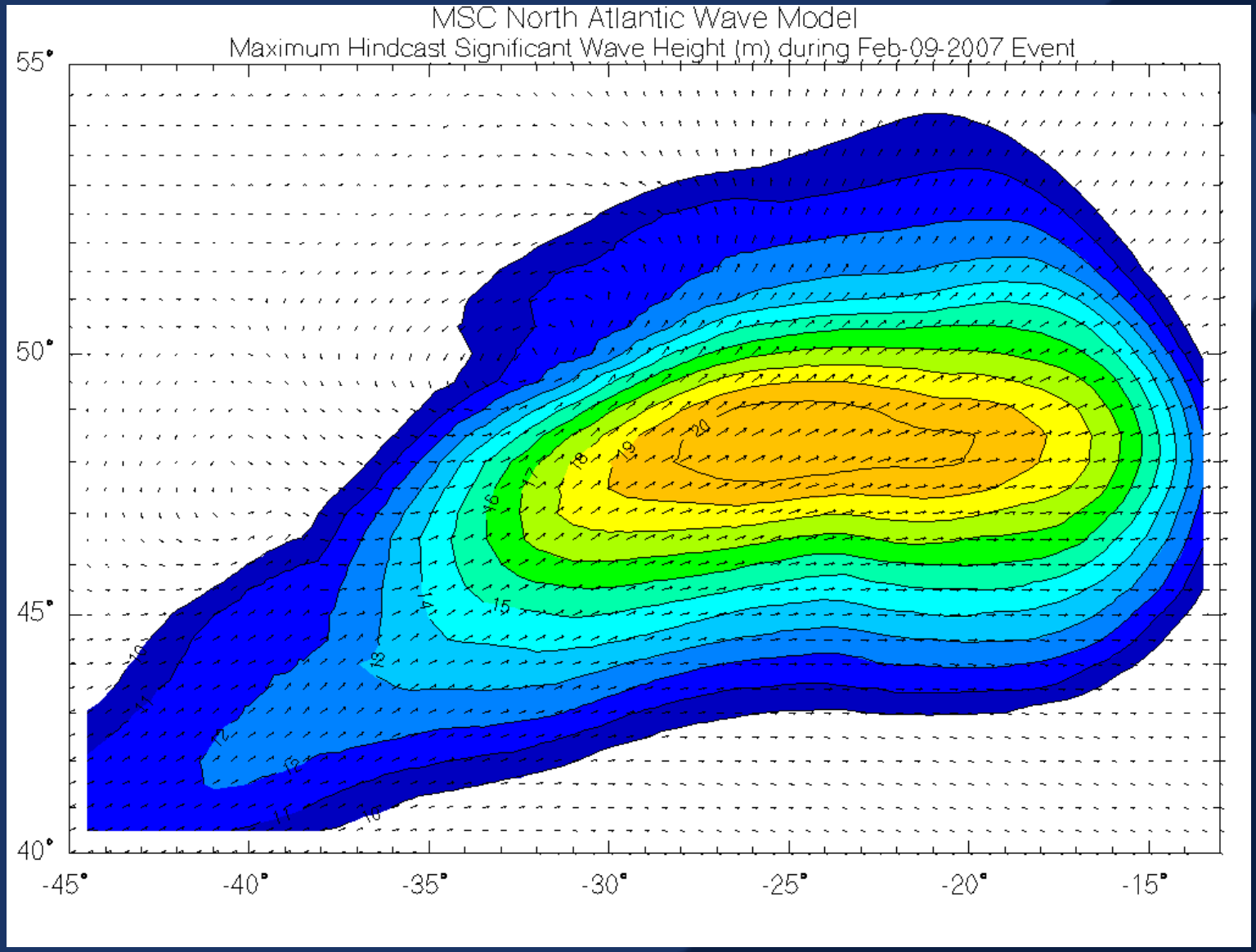
Red: Storm track/central pressure; Violet: continuity on jet streak and core wind speed max 3-hourly

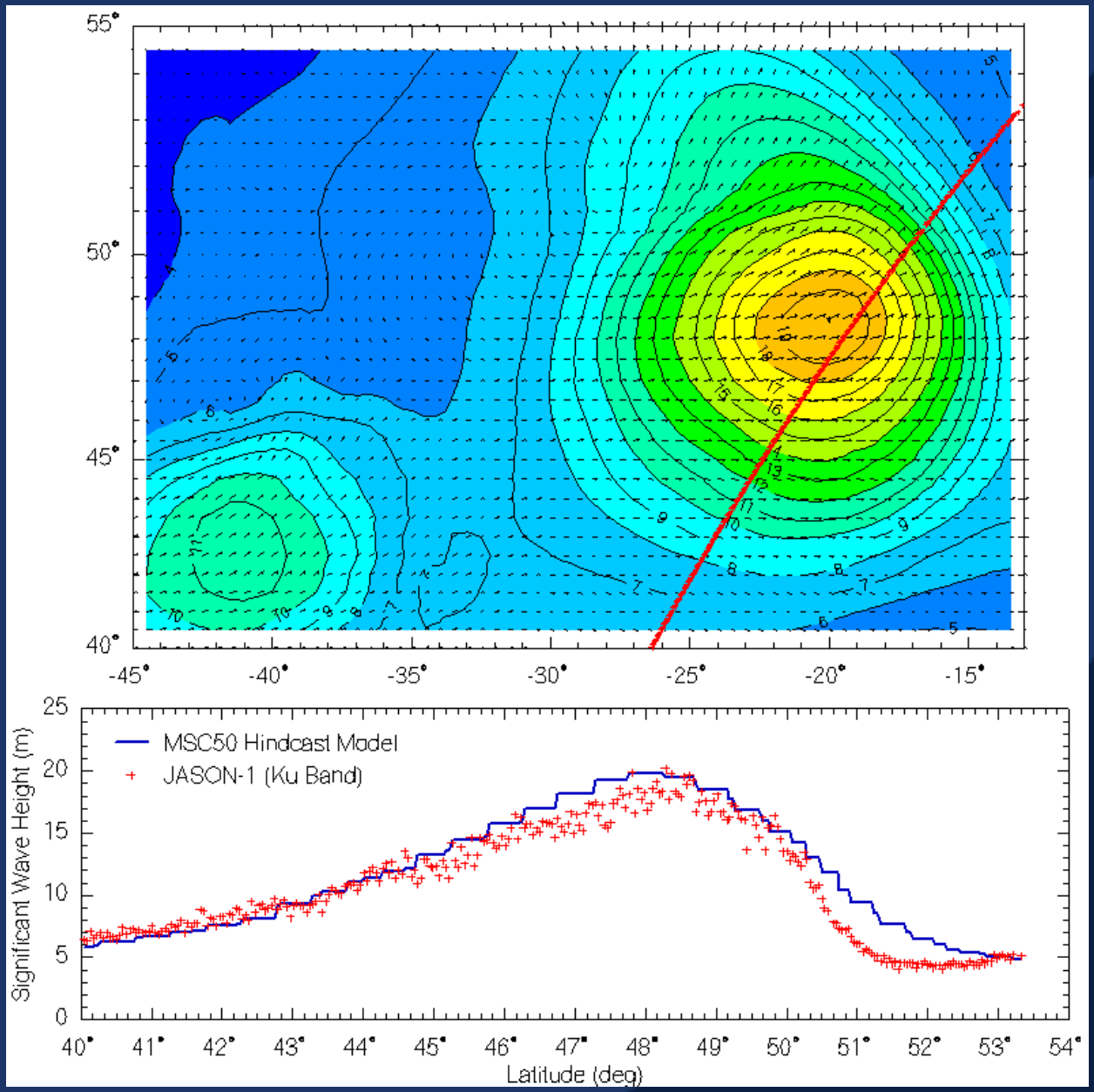


Digitized hand drawn wind speed isotachs (knots) at storm peak – note 83-knot jet max




MSC North Atlantic Wave Model
Maximum Hindcast Wind Speed (m/s) during Feb-09-2007 Event
55°
50°
45°
40°
-45°
-40°
-35°
-30°
-25°
-20°
-15°


MSC North Atlantic Wave Model
Maximum Hindcast Significant Wave Height (m) during Feb-09-2007 Event
55°
50°
45°
40°
-45°
-40°
-35°
-30°
-25°
-20°
-15°


55°
50°
45°
40°
-45°
-40°
-35°
-30°
-25°
-20°
-15°
MSC50 Hindcast Model
JASON-1 (Ku Band)
Significant Wave Height (m)
0
5
10
15
20
25
40°
41°
42°
43°
44°
45°
46°
47°
48°
49°
50°
51°
52°
53°
54°
Latitude (deg)

Principle Conclusions

- Number of VESS storms proportional to basin size but it appears North Atlantic best tuned to produce the most extreme VESS per unit area.
- Of 260 VESS cases only 2 appear to be associated with tropical cyclones attesting to great difficulty for a satellite altimeter to see inside the core of intense tropical cyclones
- The top ranked case, a detected peak storm VESS of 20.2 m the North Atlantic extratropical cyclone of February 8, 2007, was hindcast.
- QuikSCAT scatterometer appears to provide sufficient dynamic range and coverage to allow an accurate specification of atmospheric forcing BUT
- The QSCAT -1/F13 model function, now the official NASA project model function , is believed to be seriously biased (high) above wind speeds of 20 m/s
- The evolution of the wind field in the February, 2007 storm reveals a surface wind field of unprecedented intensity (peak average wind speed of 83-knots!) and scale
- At least the variant of the WAM-class model applied here provides a hindcast of the most extreme VESS storm detected in good agreement with the satellite data -
- Can it still be “It’s the winds stupid?”