



# A New Satellite Wind Climatology from QuikSCAT, WindSat, AMSR-E and SSM/I

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**Supported By:**  
**NASA's Earth Science Division**

**1. Status of RSS's Satellite Inter-Calibration Project**

**2. New WindSat Dataset**

**3. Climate Trends in Winds**



# Engineering Climate Data Records: The Problem



**Large Volume:** Over **100 satellite-years** of observations from Microwave Radiometers

## Microwave Imagers

SSM/I: F08, F10, F11 F13 ,F14, F15

SSM/IS: F16, F17, F18

TMI

AMSR-E and AMSR

WindSat

## Microwave Sounders

MSU: Tiros-N, NOAA 6, 7, 8, 9, 10, 11, 12, and 14

AMSU: NOAA 15, 16 ,17 18, and 19, Aqua, MetOP A

**Difficult Calibration:** Each sensor has its **unique set of problems**

**Sensor pointing and S/C attitude errors**

**Antenna pattern knowledge error**

**Scan-dependent errors**

**Sun intrusion and thermal gradients in Hot Load**

**Emissive Antenna**

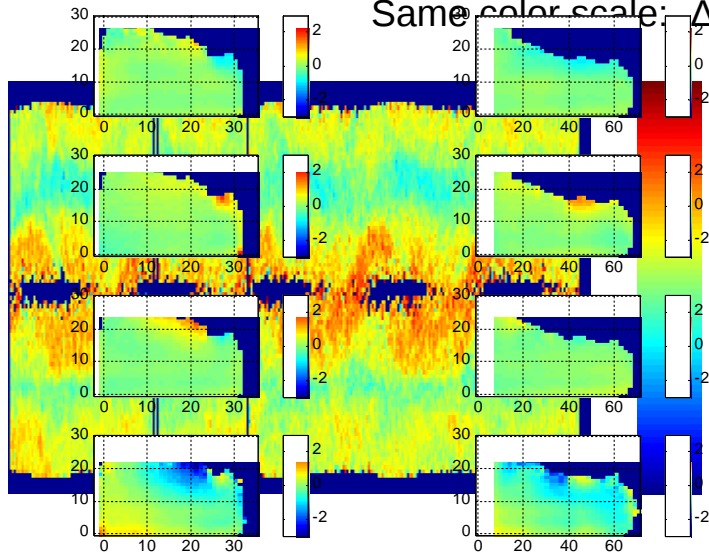
**High Precision Required:** Climate Variability is typically **1% of the Mean**



# Distinguishing Sensor Errors from RTM Errors: F16 37GHz

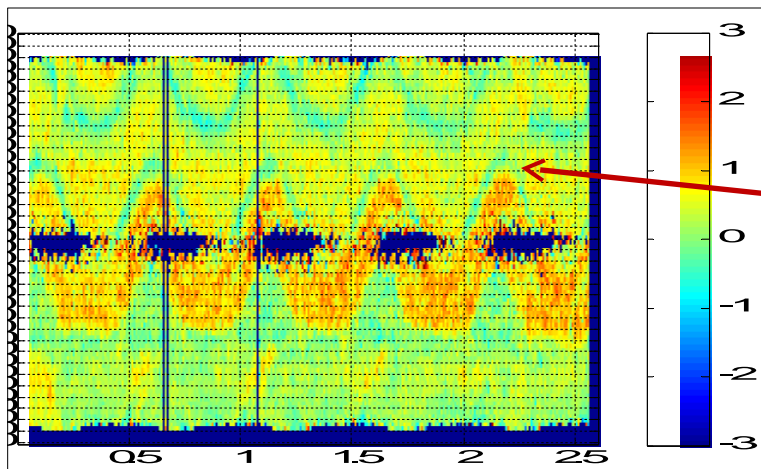
Same  $\Delta T_a$  (simulated minus measured) plotted versus different parameters

Same color scale:  $\Delta T_a$  goes from -3K to +3K

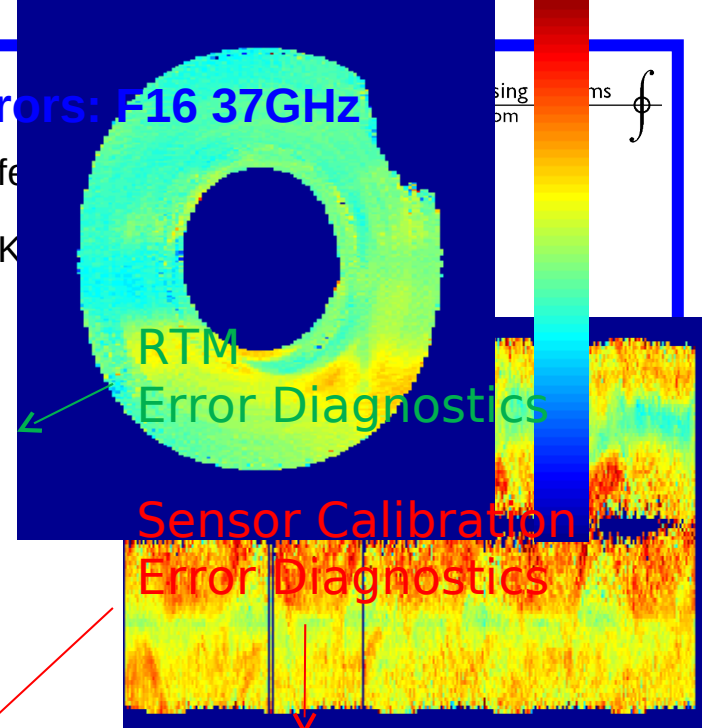


Y=Wind, X=SST

Y=Wind, X=Vapor



Orbit Position, South Pole to South Pole, X=Orbit number (5 years)

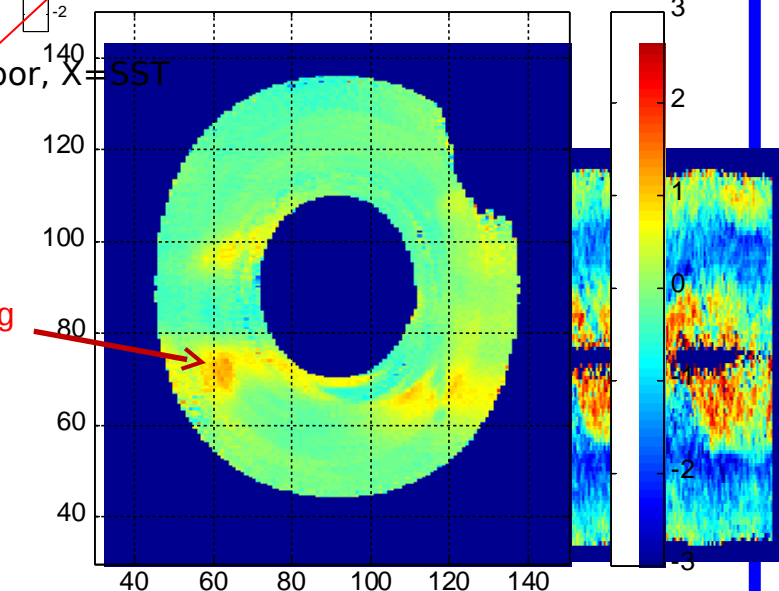


RTM Error Diagnostics

Sensor Calibration Error Diagnostics

Y=Vapor, X=SST

Sun intruding into hot load

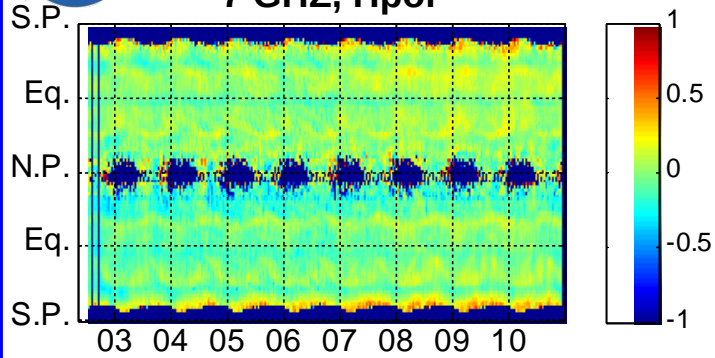


Y=Sun Polar Angle, X=Sun Azimuth Angle

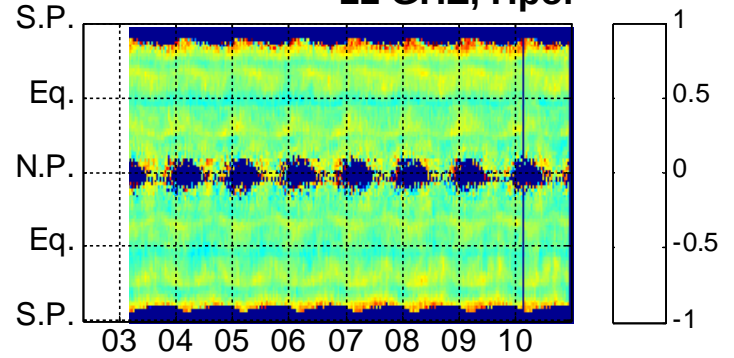


# Anomalous Signature in AMSR-E TA<sub>mea</sub> minus TA<sub>rtm</sub> Plots

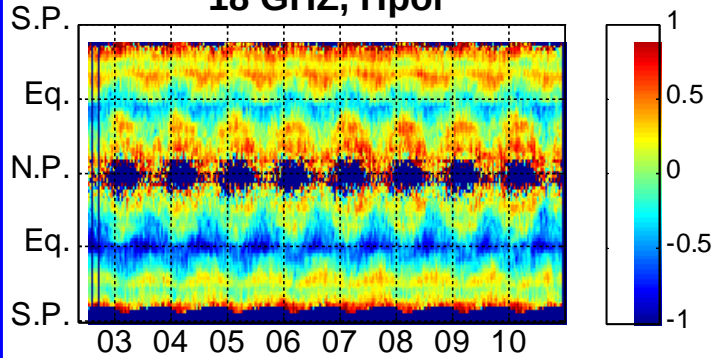
## 7 GHZ, Hpol



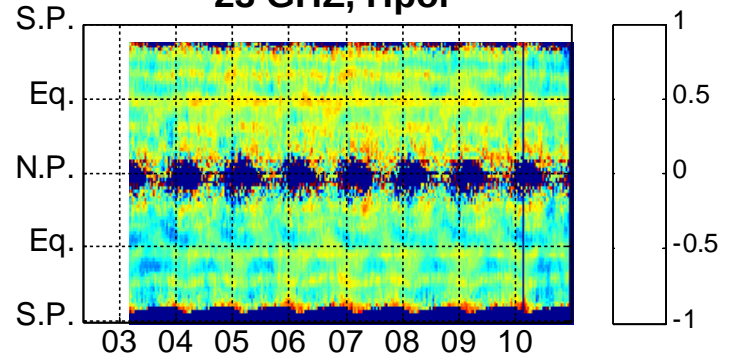
## 11 GHZ, Hpol



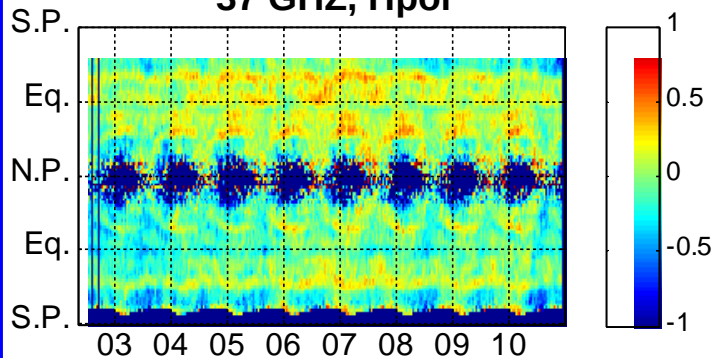
## 18 GHZ, Hpol



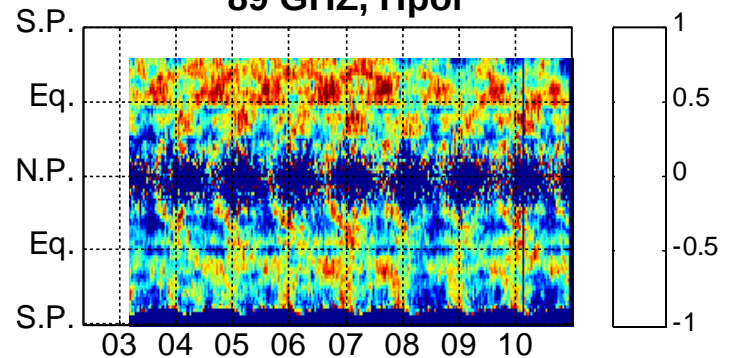
## 23 GHZ, Hpol



## 37 GHZ, Hpol



## 89 GHZ, Hpol



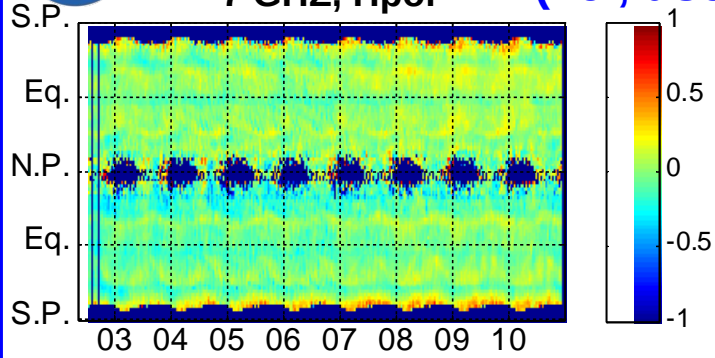


# 60 Megahertz change to AMSR-E 18.7 GHz channel

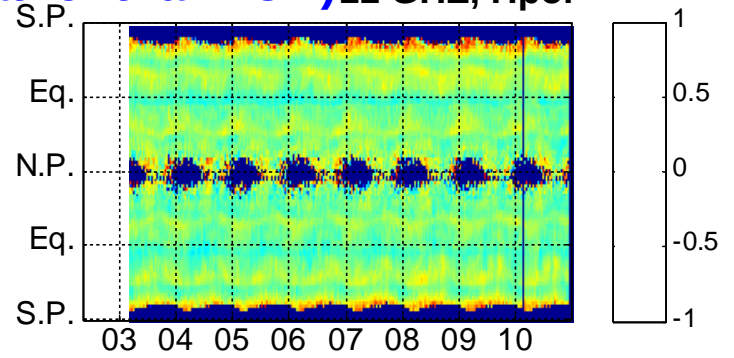


(i.e., use 18.64 GHz rather than 18.7)

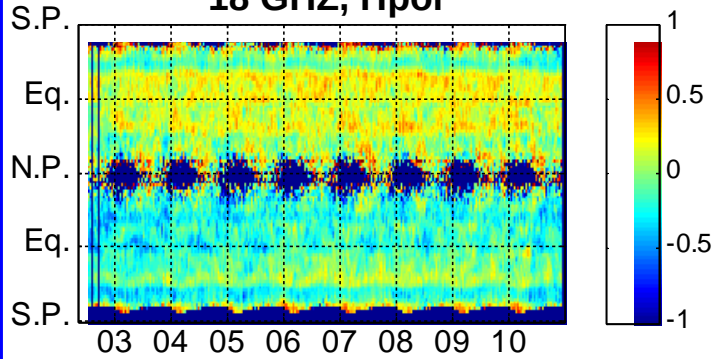
### 7 GHZ, Hpol



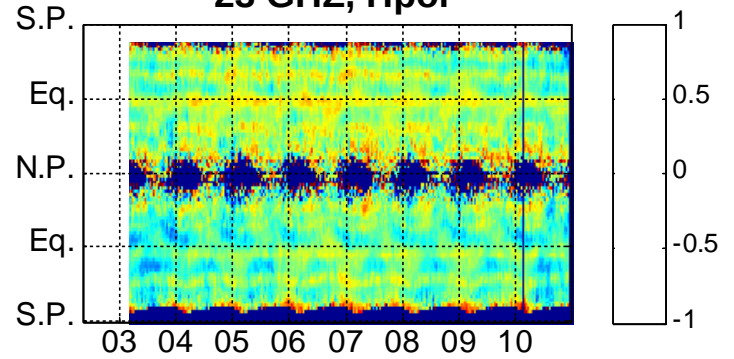
### 11 GHZ, Hpol



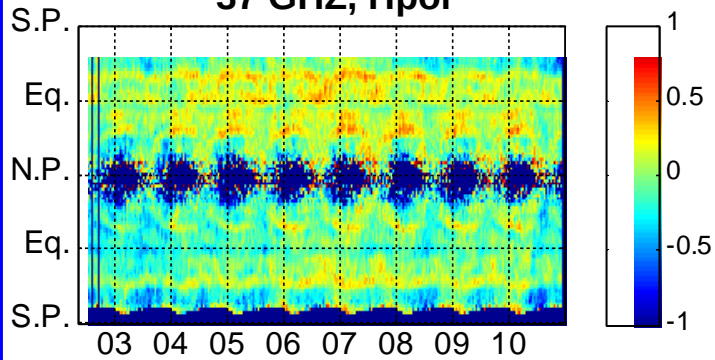
### 18 GHZ, Hpol



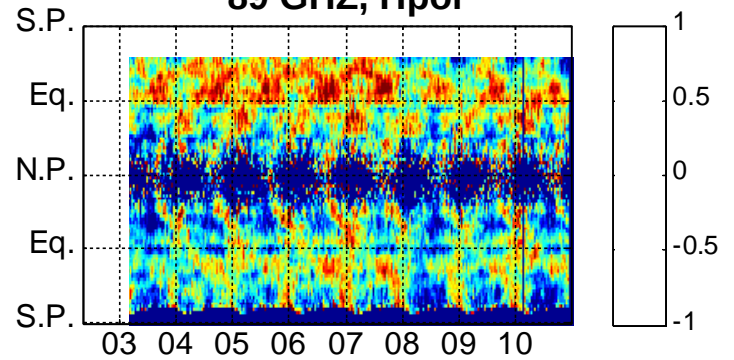
### 23 GHZ, Hpol



### 37 GHZ, Hpol



### 89 GHZ, Hpol



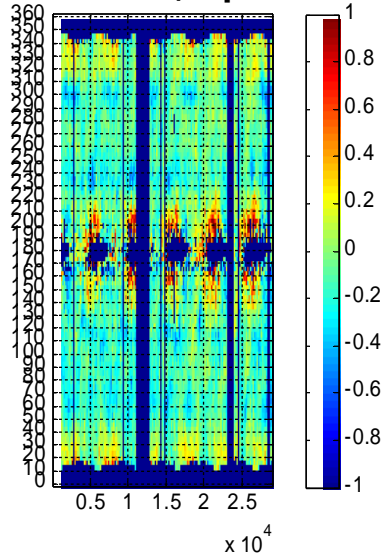
WindSat (750 MHz)  
AMSR-E (200 MHz)  
AMSR-E Adjusted



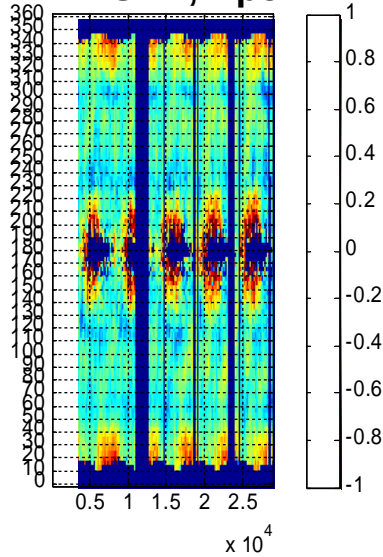


# WindSat Before Calibration

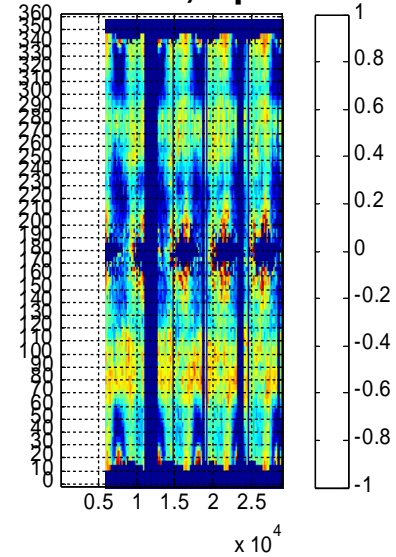
### 7 GHZ, Hpol



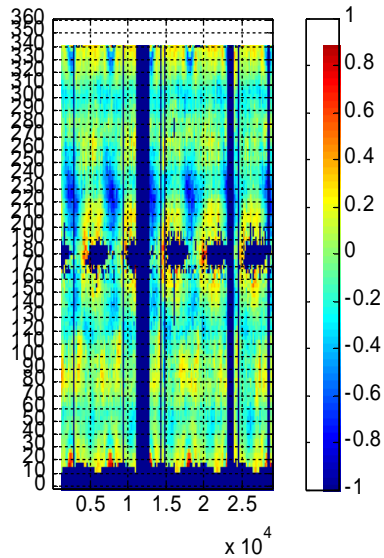
### 11 GHZ, Hpol



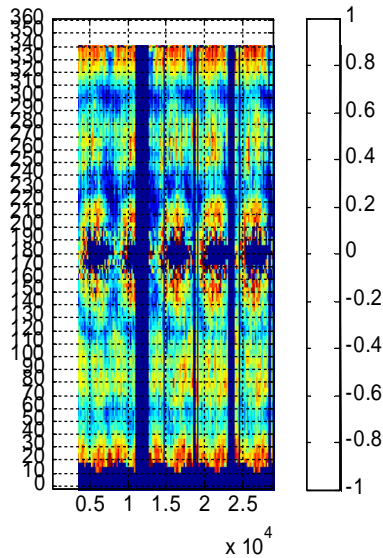
### 19 GHZ, Hpol



### 23 GHZ, Hpol



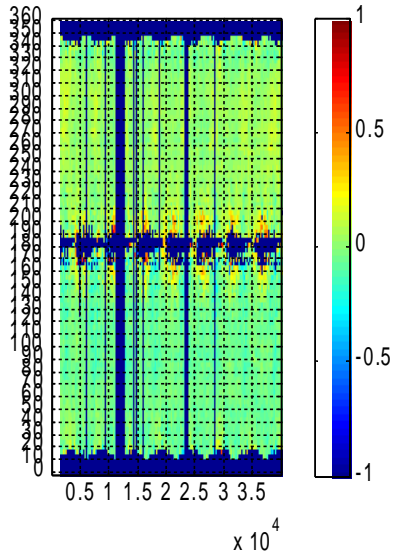
### 37 GHZ, Hpol



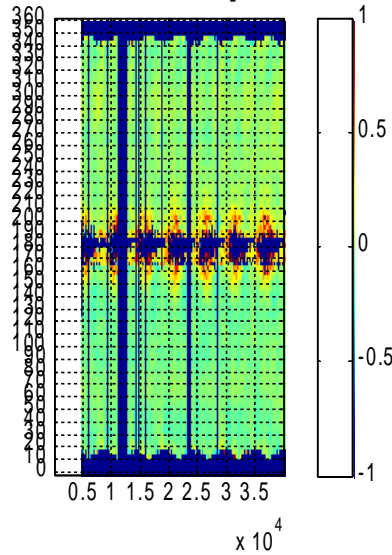


# WindSat After Calibration

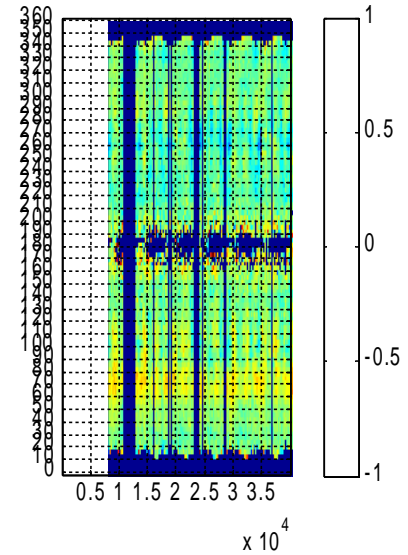
### 7 GHZ, Hpol



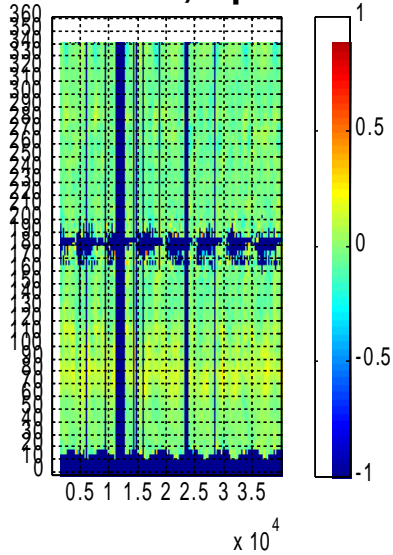
### 11 GHZ, Hpol



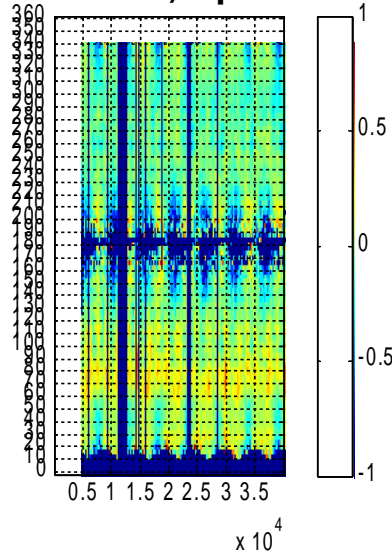
### 19 GHZ, Hpol



### 23 GHZ, Hpol



### 37 GHZ, Hpol





## Current Status of V7 Development F13 SSM/I, AMSR-E, and WindSat DONE !!

Sensor	Time Period	Ascending Node Times
SSM/I F13	May 1995 – Nov 2009	6 am $\pm$ 25 minutes
AMSR-E	Jun 2002 – Present	1:30 pm $\pm$ 0 minutes
WindSat	Feb 2003 – Present	6 am $\pm$ 0 minutes

Remaining 5 SSM/I and the F16 and F17 SSM/IS will soon follow

**New QuikSCAT Geophysical Model Function Incorporates V7 Calibration Standards**

F13, AMSR-E, WindSat and QuikSCAT form the Backbone for the Satellite Wind CDR

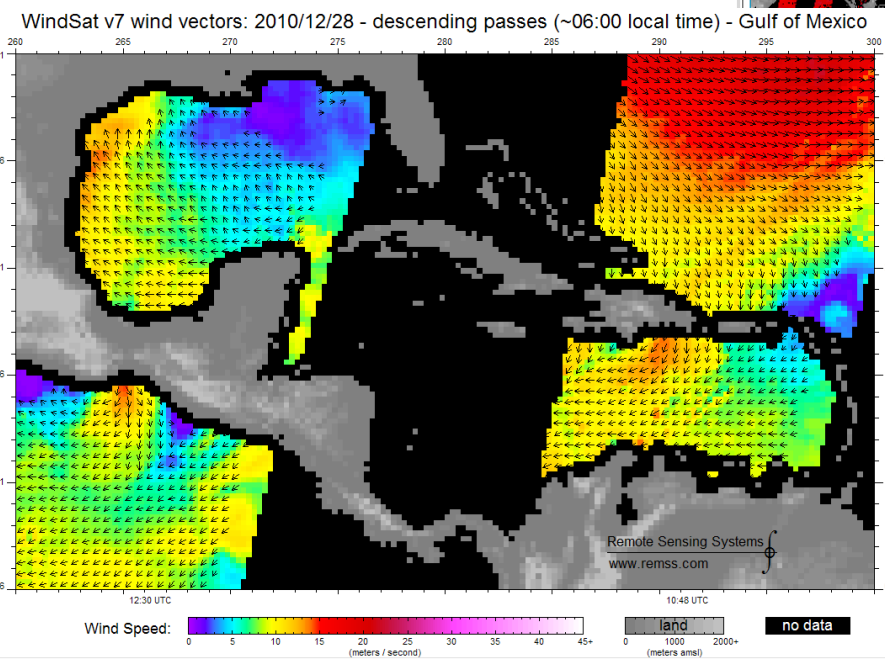
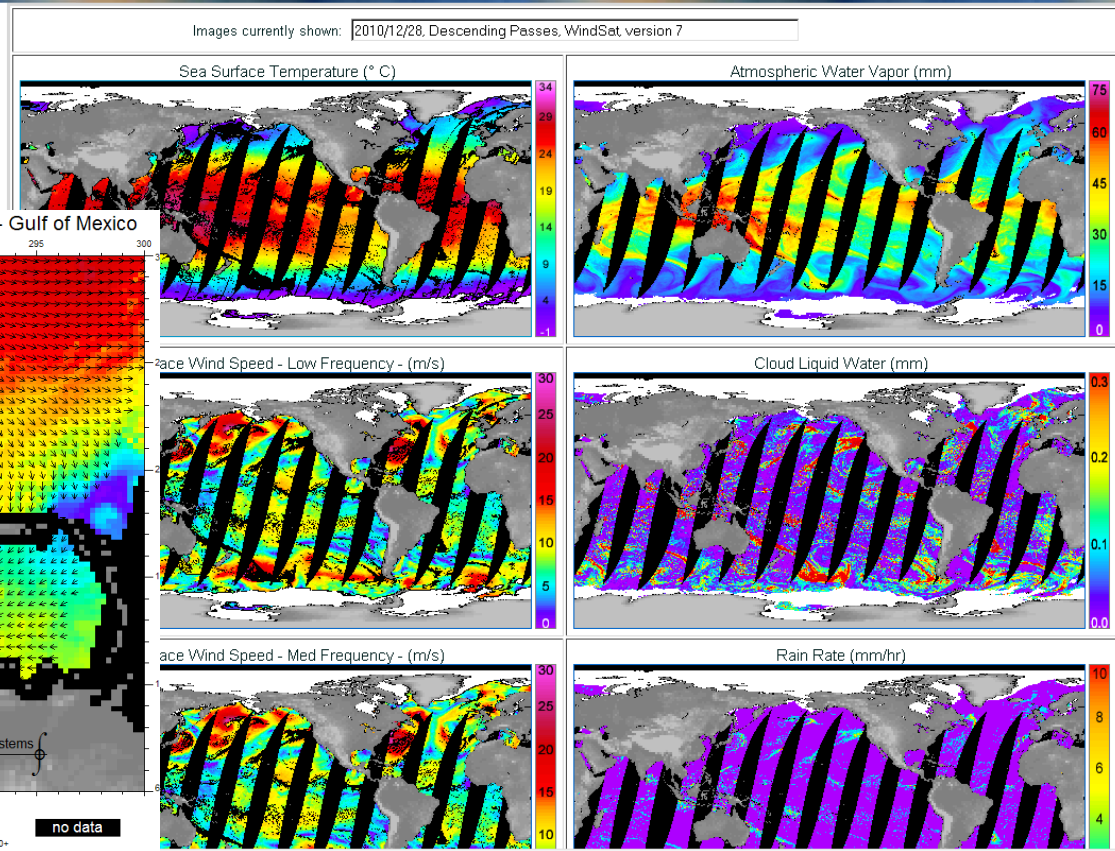
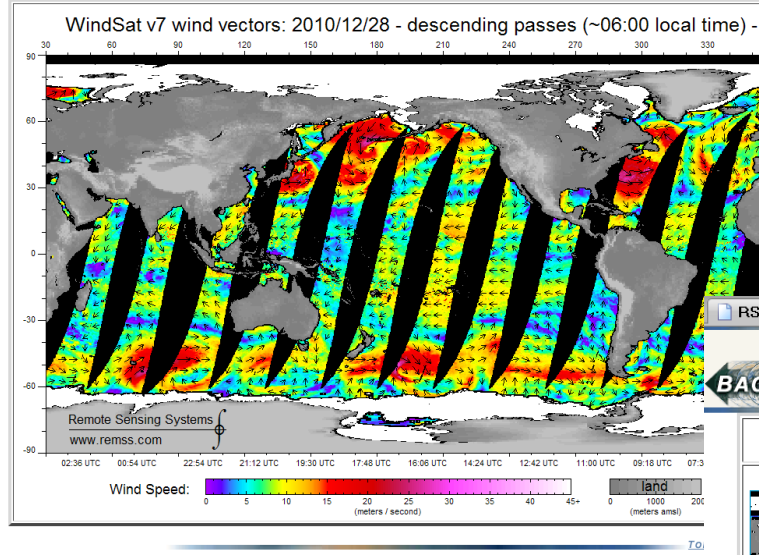
All data, both brightness temperature and ocean products, are freely available



# Remote Sensing Systems WindSat Data Released

April 2011

- SST, 3 different wind products, wind directions, vapor, cloud, and rain rates
- Wider swaths due to using both fore and aft looks
- First all-weather winds available





## WindSat V7 Ocean Products

### For combining forward and aft observations:

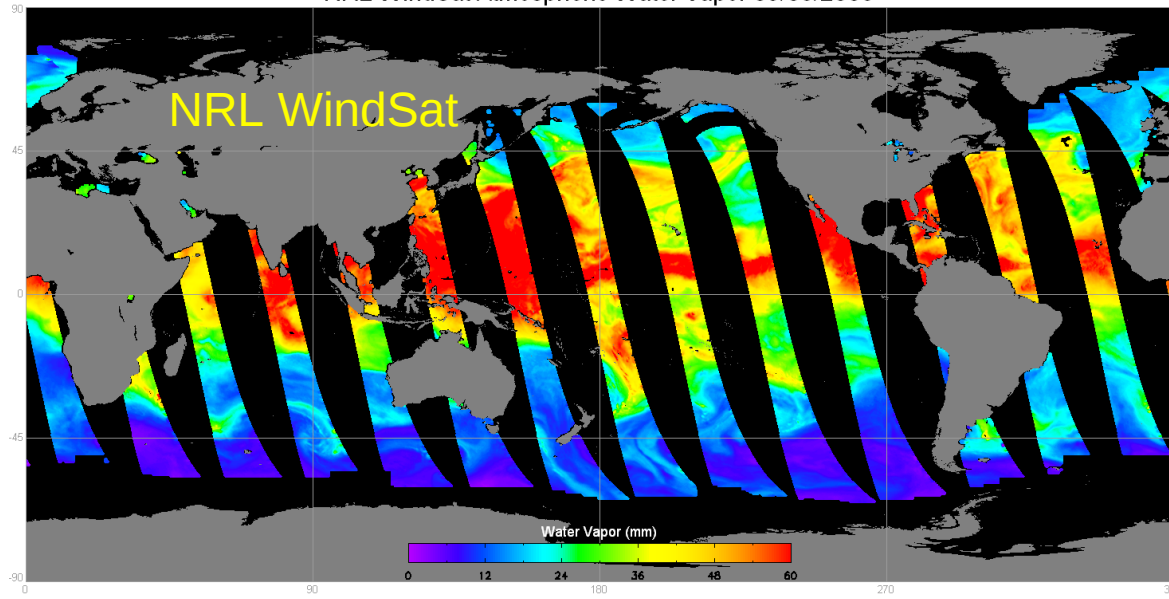
- A very elaborate Optimum Interpolation use to directly map swath data to a fixed Earth grid.
- 400 million pre-computer target weights to avoid in-line matrix inversions
- 1/8 degree (about 10 km) Earth grid (reporting grid, NOT resolution)

Product	Resolution + Required Channels			
	≥ 6.8 GHz 50 km	≥ 10.7 GHz 32 km	≥ 18.7 GHz 22 km	≥ 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
Liquid cloud water	Yes	Yes	Yes	Yes
Rain rate	No	No	No	Yes

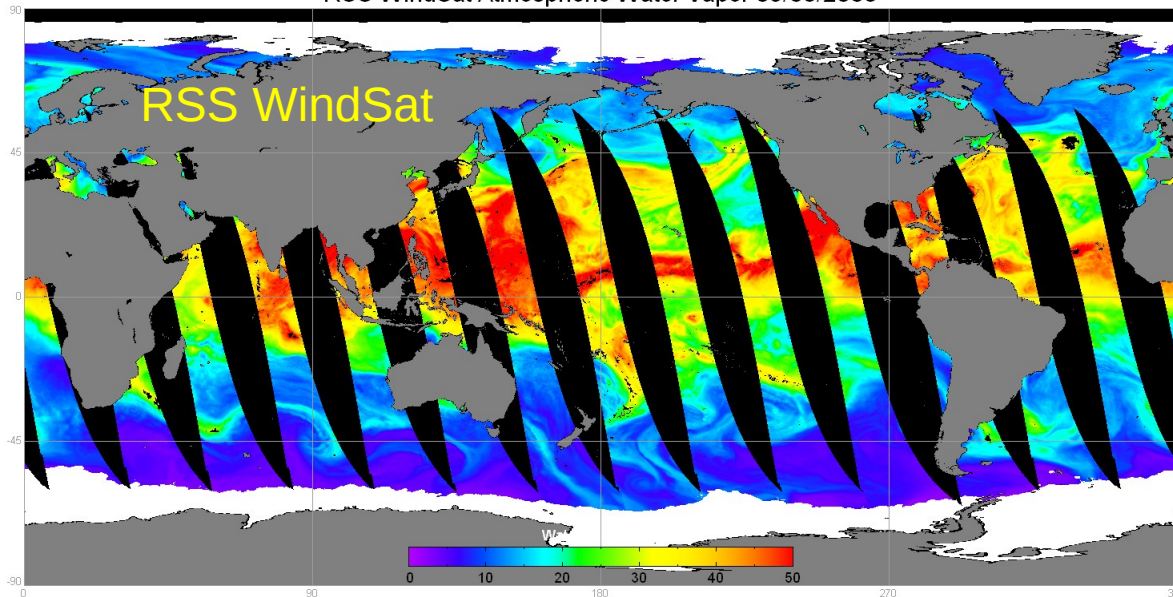


# Combining Forward & Aft Observation Provides Wider Swath

NRL WindSat Atmospheric Water Vapor 09/05/2003



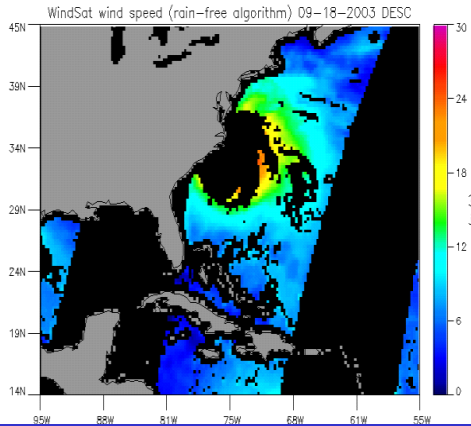
RSS WindSat Atmospheric Water Vapor 09/05/2003



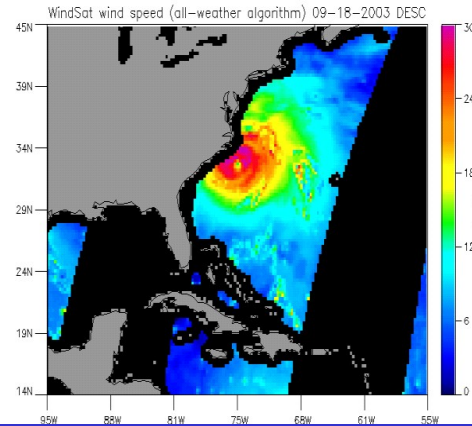


# New Winds-Through-Rain Product

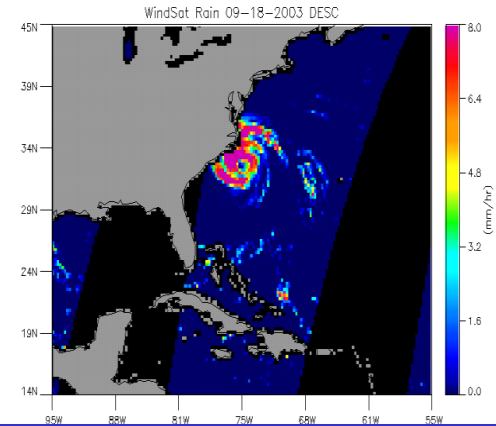
Rain-free WindSat



All-weather WindSat



Rain rate



## Satellite - BUOY Wind Speed [m/s]

**Bias**   **Standard Deviation**

Rain Rate	WindSat all-weather algorithm	QuikSCAT Ku 2011
no rain	0.04	0.9
light rain 0 - 3 mm/h	0.70	2.3
moderate rain 3 - 8 mm/h	0.02	3.6
heavy rain > 8 mm/h	-0.05	4.5



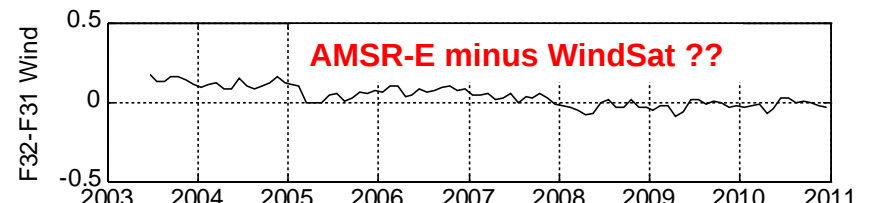
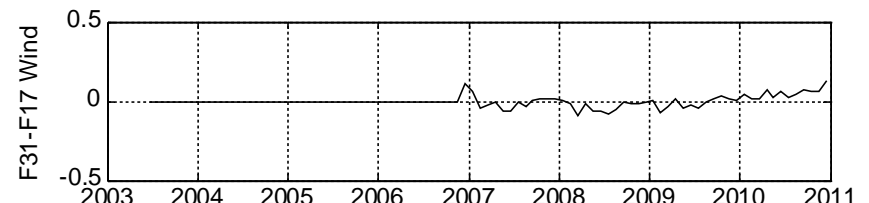
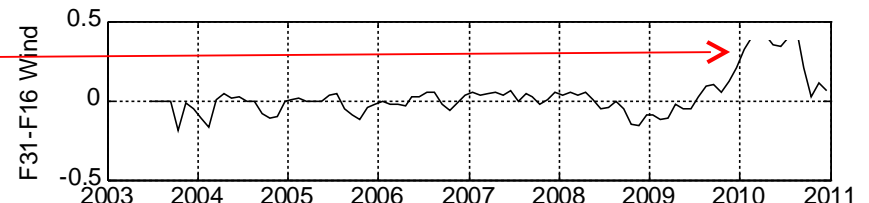
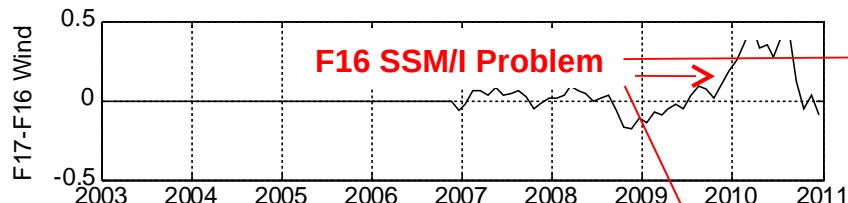
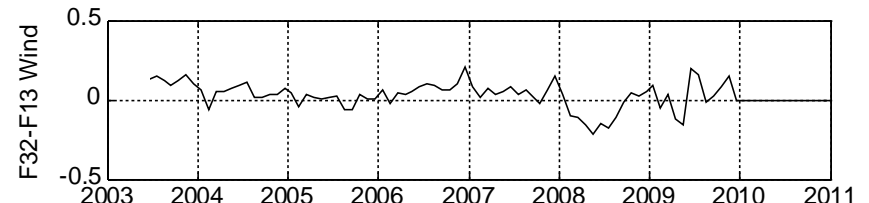
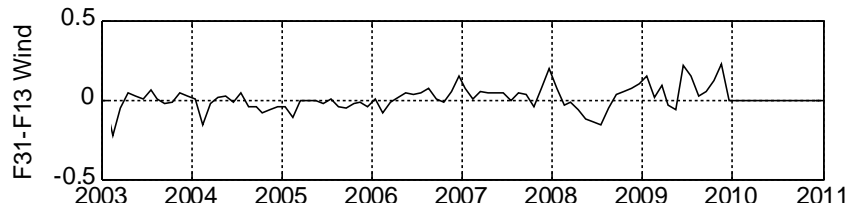
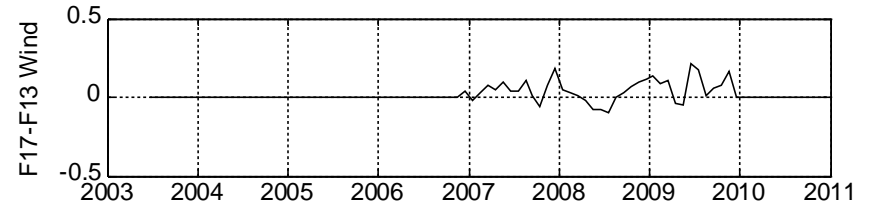
## Decadal Trends in Wind Speed

- Calibration methodology is designed to NOT affect trends in the observations
- Climate studies require an accuracy at the 1%/decade level or better.
- It is an outstanding question as to whether this is achievable.



# Inter-Comparison of Satellite Wind Time Series

## F13 SSMI, F16 & F17 SSM/IS, WindSat, and AMSR-E



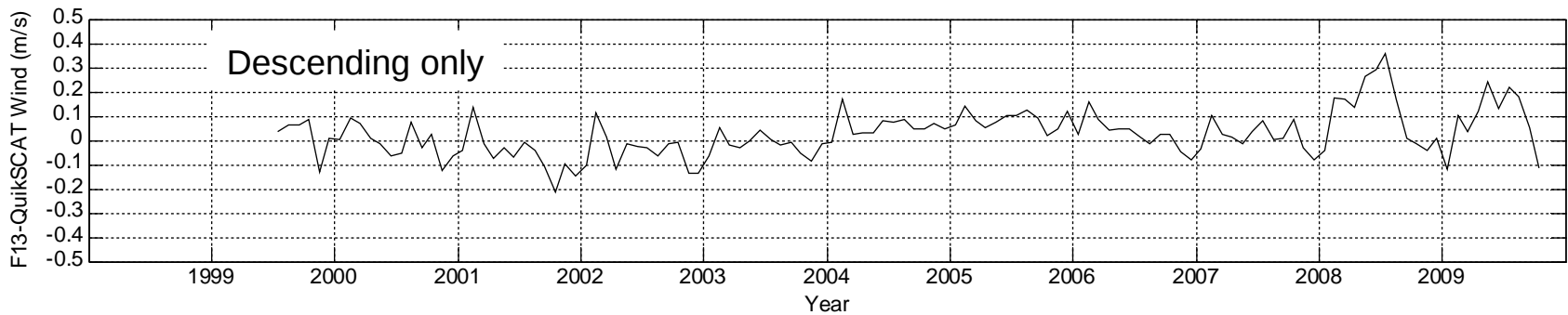
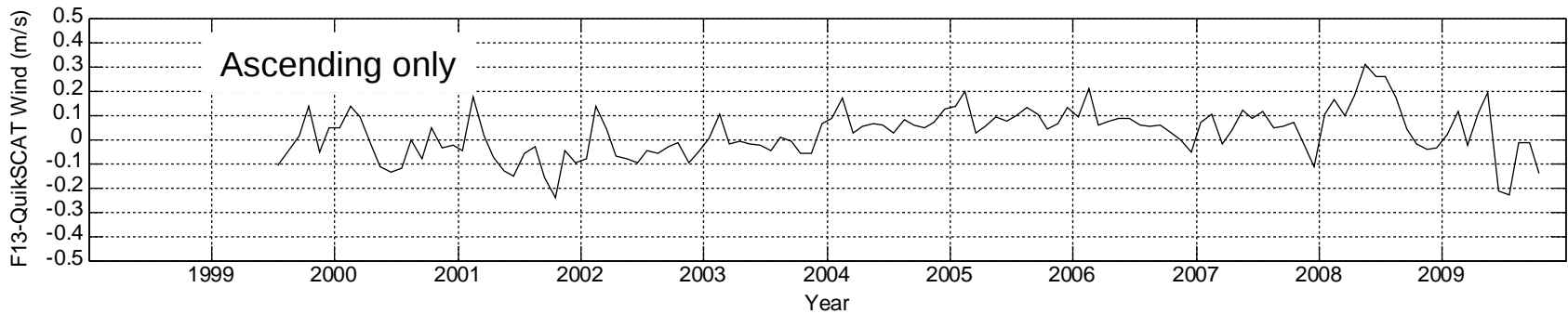
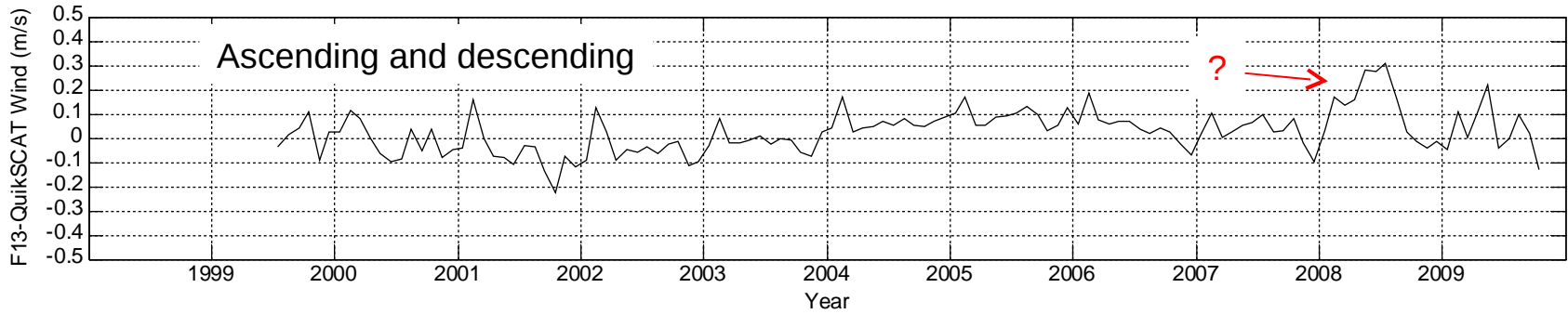
Year

Year



# Inter-Comparison of Satellite Wind Time Series

## F13 SSMI and QuikSCAT





## Recent Paper on Satellite Wind Time Series from Altimeters

### Global Trends in Wind Speed and Wave Height

R. Young\*, S. Zieger, and A. V. Babanin

*Science* : 22 April 2011

“Altimeter provides by far (and seemly only) the longest duration record”

No mention of any scatterometer or radiometer results!

Geographically patterns similar to those reported by us (Science 2007)

**But** amplitude of trends (2.5%/decade) are over twice as high as found by us and others.

Winds increasing by 2.5%/decade would have serious implication w.r.t. the global hydrological cycle (big increases in rain).

Paper claims that the 99<sup>th</sup> percentile winds are increasing by “at least 7.5%/decade”  
( A very gutsy call)

Assuming the authors were truly unaware of the existing body of research in this area, this paper provides a valuable “independent data point”.





# Summary

## **Satellite Inter-Calibration Project progressing slow but sure**

- V7 SSM/I F13, AMSR-E, and WindSat Completed
- New QuikSCAT GMF calibrated to V7 standards
- Remaining 5 SSM/I and the F16 and F17 SSM/IS will soon follow

## **Newly released WindSat Dataset**

- Wider Swath
- Winds through Rain
- Multiple, quasi-independent estimates of ocean products

## **Decadal Trends in Winds being Assessed**