A two-season impact study of the Navy's WindSat surface wind retrievals in the NCEP global data assimilation system

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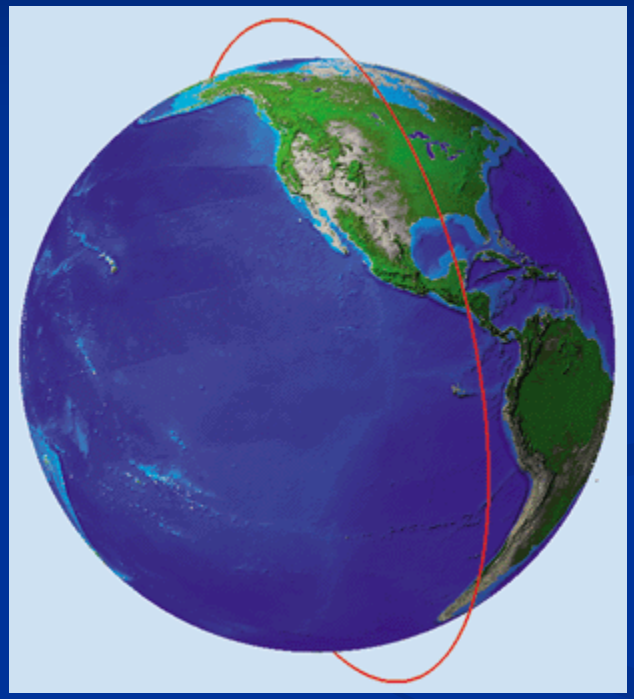
Outline

- WindSat overview and working progress
- Results of current work
  - Traditional stats diagnosis and anomaly correlation results
  - Forecast impact investigations
- Conclusion of current work
- Future work: ASCAT overview and preliminary stats

WindSat Orbit

- Sun-synchronous circular orbit
  - 830 km altitude
  - 98.7 degrees of inclination
  - 1800 Local Time of the Ascending Node (LTAN)
  - about 14.1 orbits per day
- 1800 LTAN for validation with QuikSCAT
- WindSat instrument has 1025 km swath width
- Launched on 6 Jan 2003



http://www.seaspace.com/news

Projected Capabilities

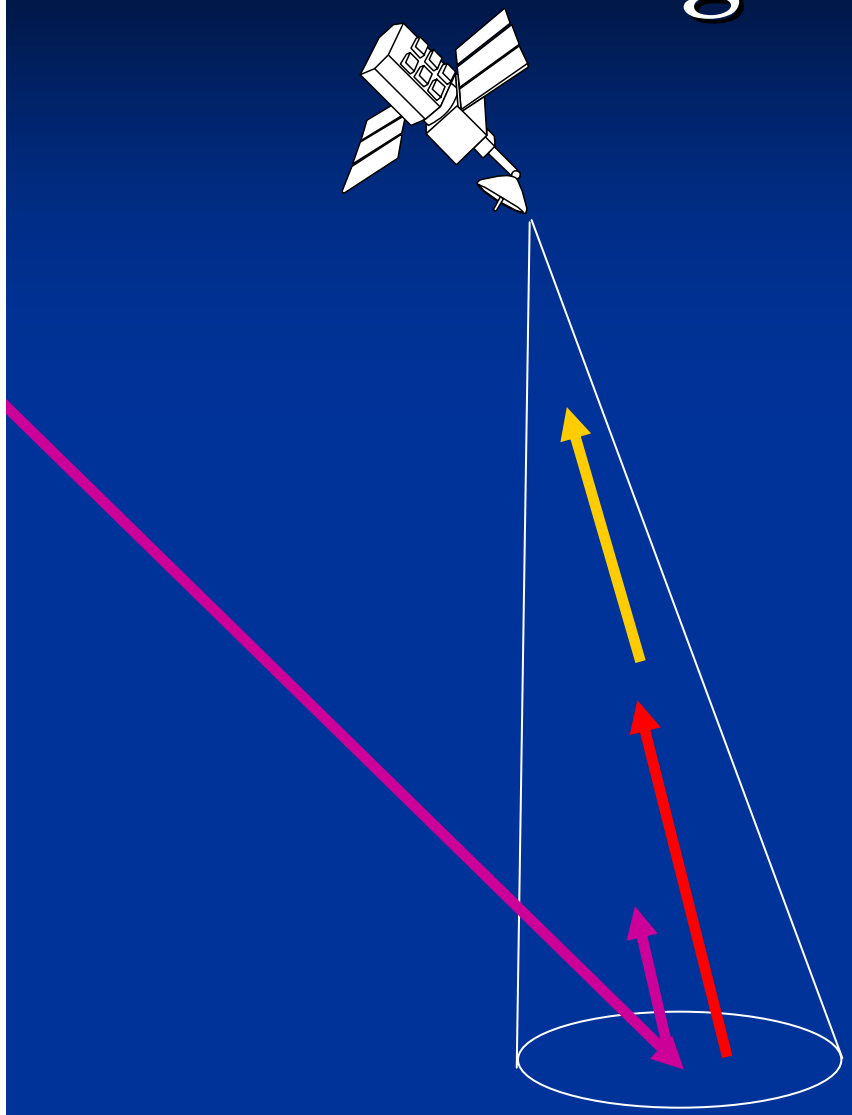
- Demonstrate the capability of polarimetric microwave radiometry to measure the ocean surface wind vector from space.
- How ocean surface physics changes with wind and boundary layer conditions.
- WindSat will aid with the forecast of short-term weather, issuance of timely weather warnings and the gathering general climate data.

How can WindSat measure wind speed and direction?

- Wind roughening the surface of the ocean causes an increase in the brightness temperature of the microwave radiation emitted from the water's surface.

- Multiple frequencies and polarizations allow for simultaneous retrievals of different surface and atmospheric parameters.

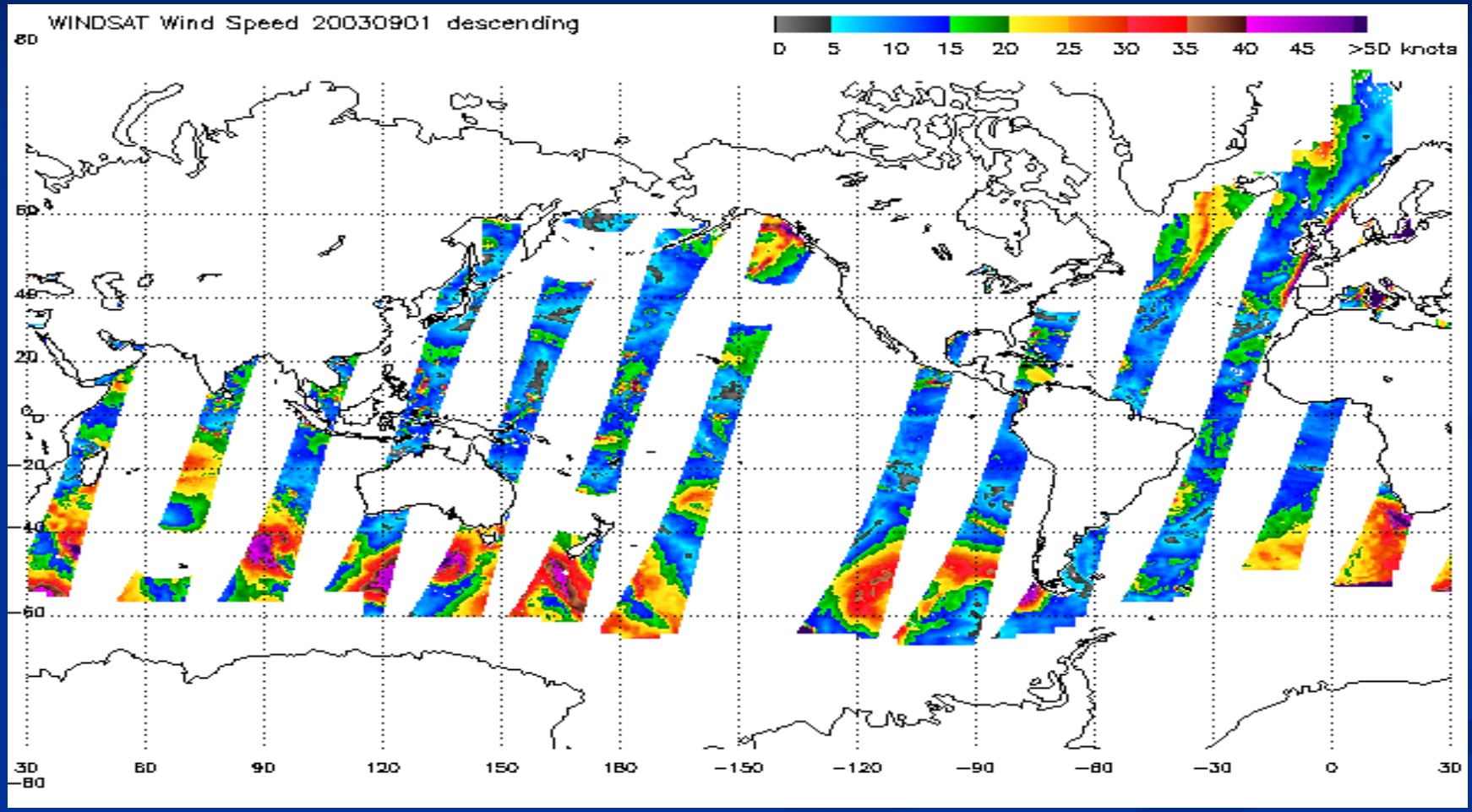
Ocean Brightness Temperatures



- Tb's measured by satellite radiometer consists of:
  - Signal that is emitted from the ocean surface and travels upwards
  - Upward traveling atmospheric radiation
  - Downward traveling atmospheric and cold space radiation that is scattered back from the ocean surface

http://www.ofcm.gov

Sample picture of WindSat wind speed from a preliminary wind vector retrieval algorithm.



http://manati.orbit.nesdis.noaa.gov/cgi-bin/ws_wdsp_day_noaa.pl

Initial Work

- Work with the JCSDA (Joint Center for Satellite Data Assimilation) to evaluate the forecast impact of assimilating Navy's WindSat data in the NCEP GDAS/GFS using T254 64 level version of the Global Forecast System (Version, November, 2005).
- The effect of adding NRL WindSat Version.2 wind vectors to the NCEP operational forecast system, was gauged.
- Data time period: 1 January – 15 February 2004

Initial Work

Table 1. WindSat Characteristics

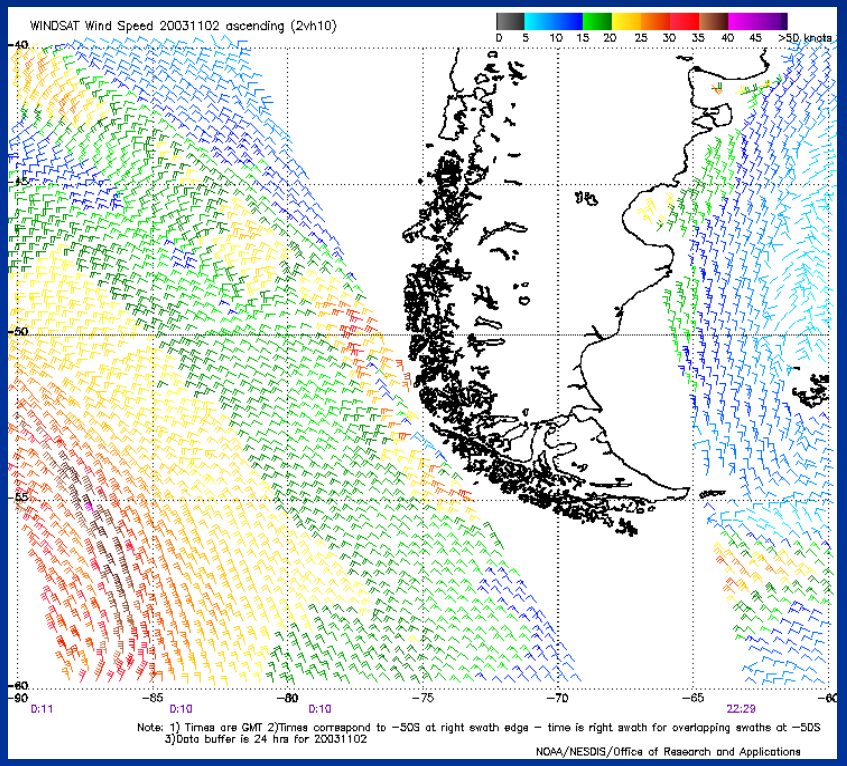
Frequency (GHz)	Polarization	Bandwidth (MHz)	Incidence Angle (deg)	Spatial Resolution (km)
6.8	V. H	125	53.5	40x60
10.7	V, H, ±45, L, R	300	49.9	25x38
18.7	V, H,± 45, L, R	750	55.3	16x27
23.8	V,H	500	53.0	12x20
37.0	V, H, ±45, L, R	2000	53.0	8x13

Initial Work

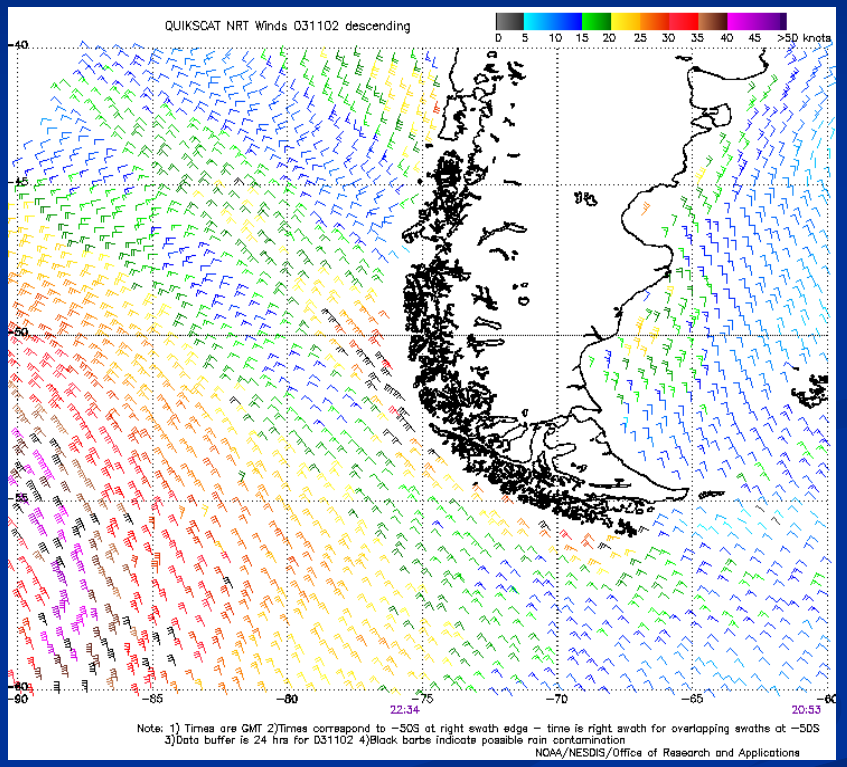
- The ocean surface wind vectors used in this study have been determined using a non-linear iterative optimal estimation method (Rodgers, 2000). The method also provides sea surface temperature, total water vapour, and cloud liquid water.
- Details of the scheme which uses a one layer atmospheric model and a sea surface emissivity model is found in Bettenhausen et al., (2006)..
- The Environmental Data Records (EDRs) generated by this scheme have been put into BUFR format at NCEP in preparation for operational use.
- The retrieval status of the records used had to be flagged ok, and the confidence status of the record had to indicate there were no problems in the retrieval process including those caused by rain, ice or land contamination

WindSat and QuikSCAT Wind Fields

WindSat



QuikSCAT



http://www.npoess.noaa.gov/polarmax

Initial Work

The satellite data used operationally within the NCEP Global Forecast System in 2004

HIRS sounder radiances	TRMM precipitation rates
AMSU-A sounder radiances	ERS-2 ocean surface wind vectors
AMSU-B sounder radiances	Quikscat ocean surface wind vectors
GOES sounder radiances	AVHRR SST
GOES, Meteosat atmospheric motion vectors	AVHRR vegetation fraction
GOES precipitation rate	AVHRR surface type
SSM/I ocean surface wind speeds	Multi-satellite snow cover
SSM/I precipitation rates	Multi-satellite sea ice
	SBUV/2 ozone profile and total ozone

Initial Work

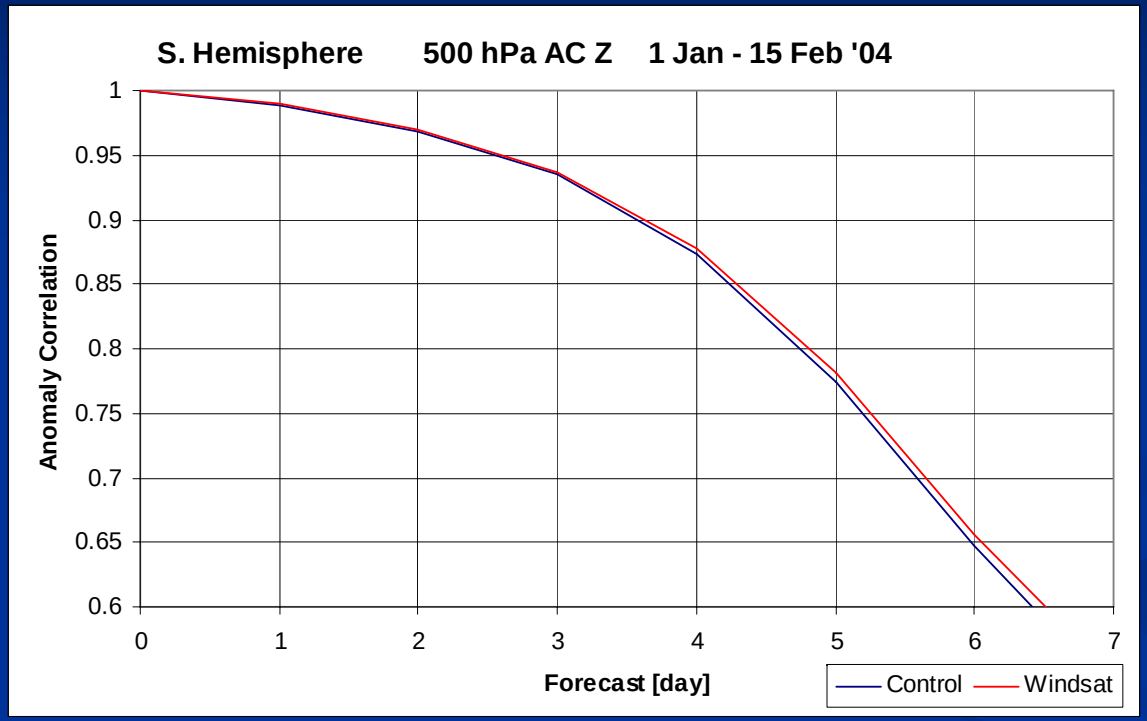


Figure 2. The 500HPa Geopotential Anomaly Correlations versus forecast period for GFS forecasts using the operational data base without QuikSCAT data (Control) and using the operational database without QuikSCAT data but with WindSat data (WindSat) over the Southern Hemisphere.

Initial Work

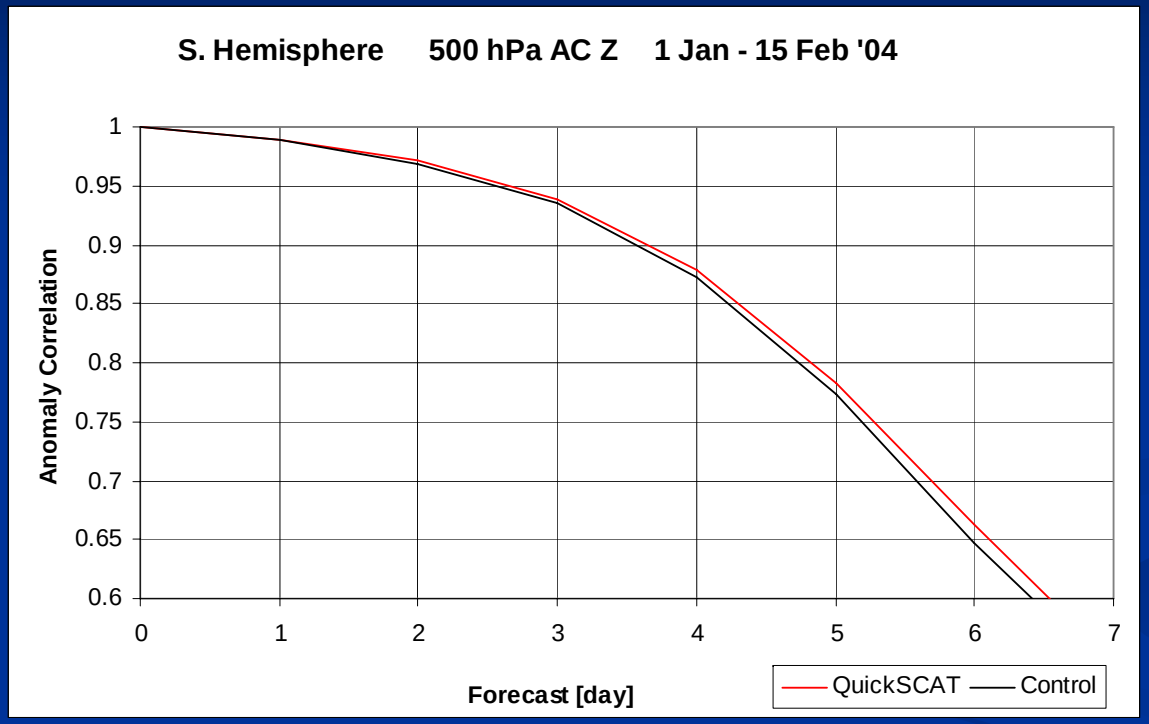


Figure 1. The 500HPa Geopotential Anomaly Correlations versus forecast period for GFS forecasts using the operational data base without QuikSCAT data (Control) and using the operational database including QuikSCAT data (QuikSCAT) over the Southern Hemisphere.

Initial Work

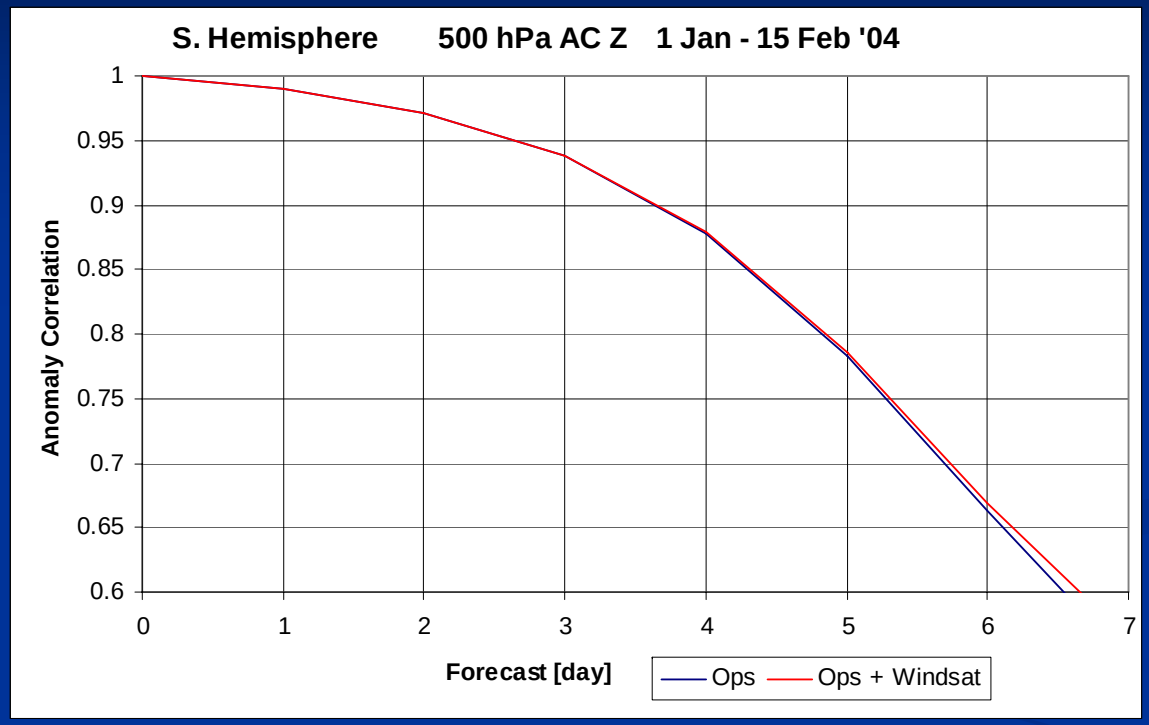


Figure 3. The 500HPa Geopotential Anomaly Correlation versus forecast period for GFS forecasts using the operational data base with QuikSCAT data (Ops) and for the operational data base with QuikSCAT data and WindSat data (WindSat) over the Southern Hemisphere.ndSat) .

WindSat (1° superob) and QuikSCAT (0.5° superob) data counts and RMS error (20040125)

Table for number of observation of WindSat vs. QuikSCAT data at 20040125

	00Z	06Z	12Z	18Z	Mean
WindSat	6473	7782	6839	7851	7236
QuikSCAT	39317	46659	35765	44281	41506

Table for velocity RMS difference of WindSat vs. QuikSCAT data at 20040125

	00Z	06Z	12Z	18Z	Mean
WindSat	1.5394	1.8168	1.5619	1.7945	1.6782
QuikSCAT	1.3018	1.3946	1.2493	1.3110	1.3142

Proposed Work

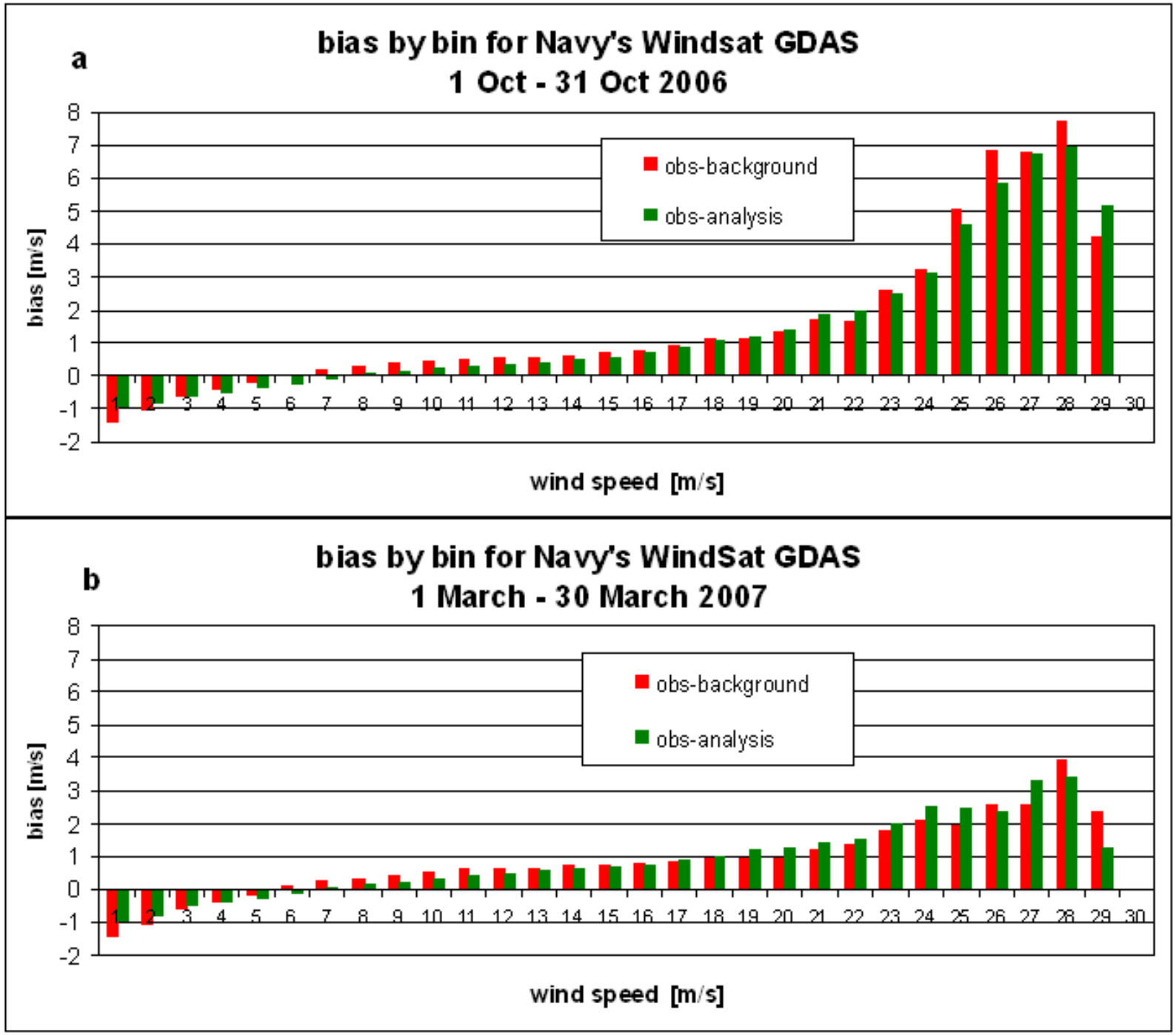
- Work with the JCSDA (Joint Center for Satellite Data Assimilation) to evaluate the forecast impact of assimilating Navy's WindSat data in the NCEP GDAS/GFS. A Jan 2007 version of the GSI and GFS were used and run at T382L64.
- Calculate standard deviation and bias by bins for Navy WindSat data to evaluate the quality control needed for operational use from the same time period.
- Data time period: 15 September – 31 October 2006 and 15 February – 30 March 2007

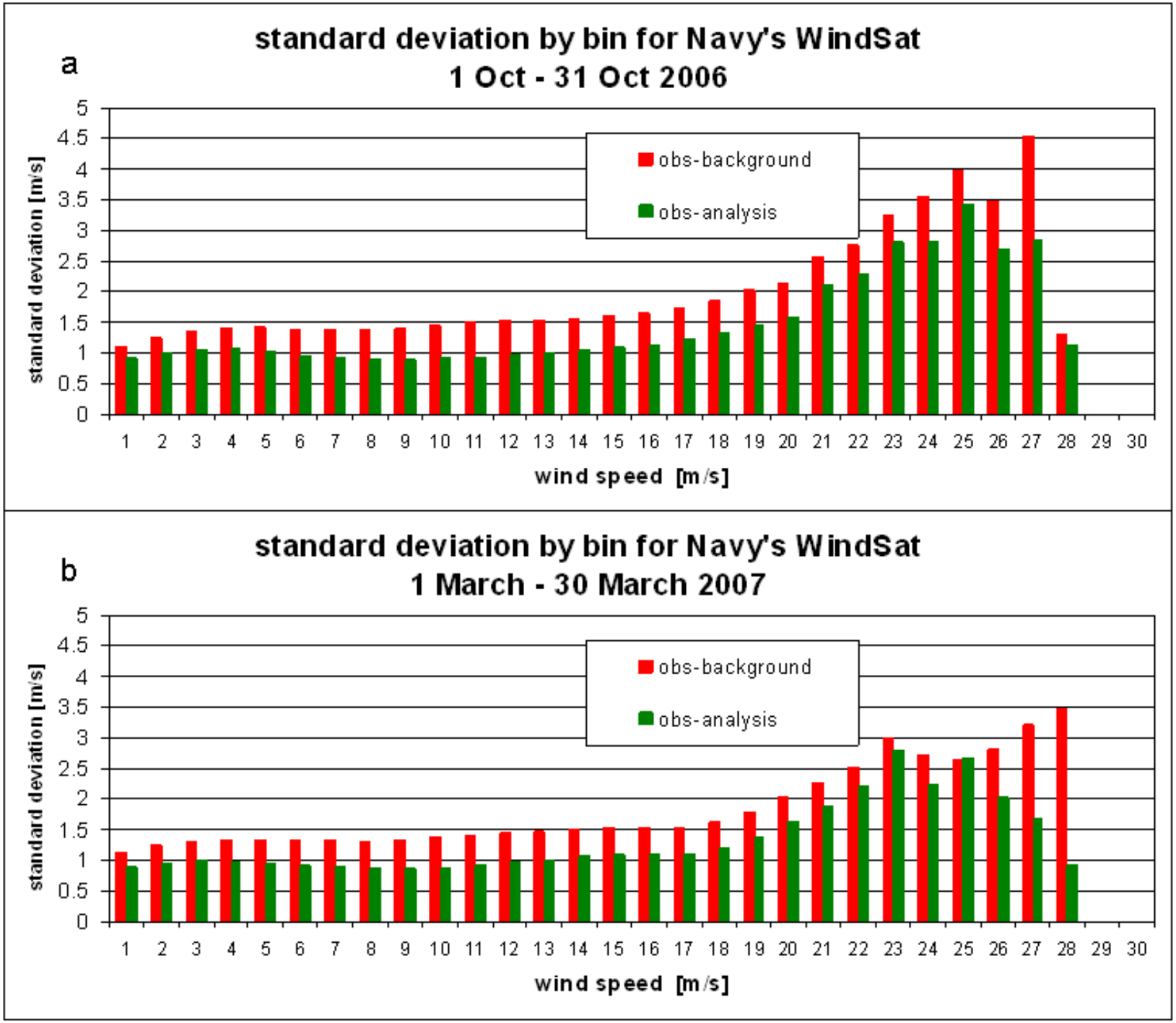
Work on Retrieval Impact

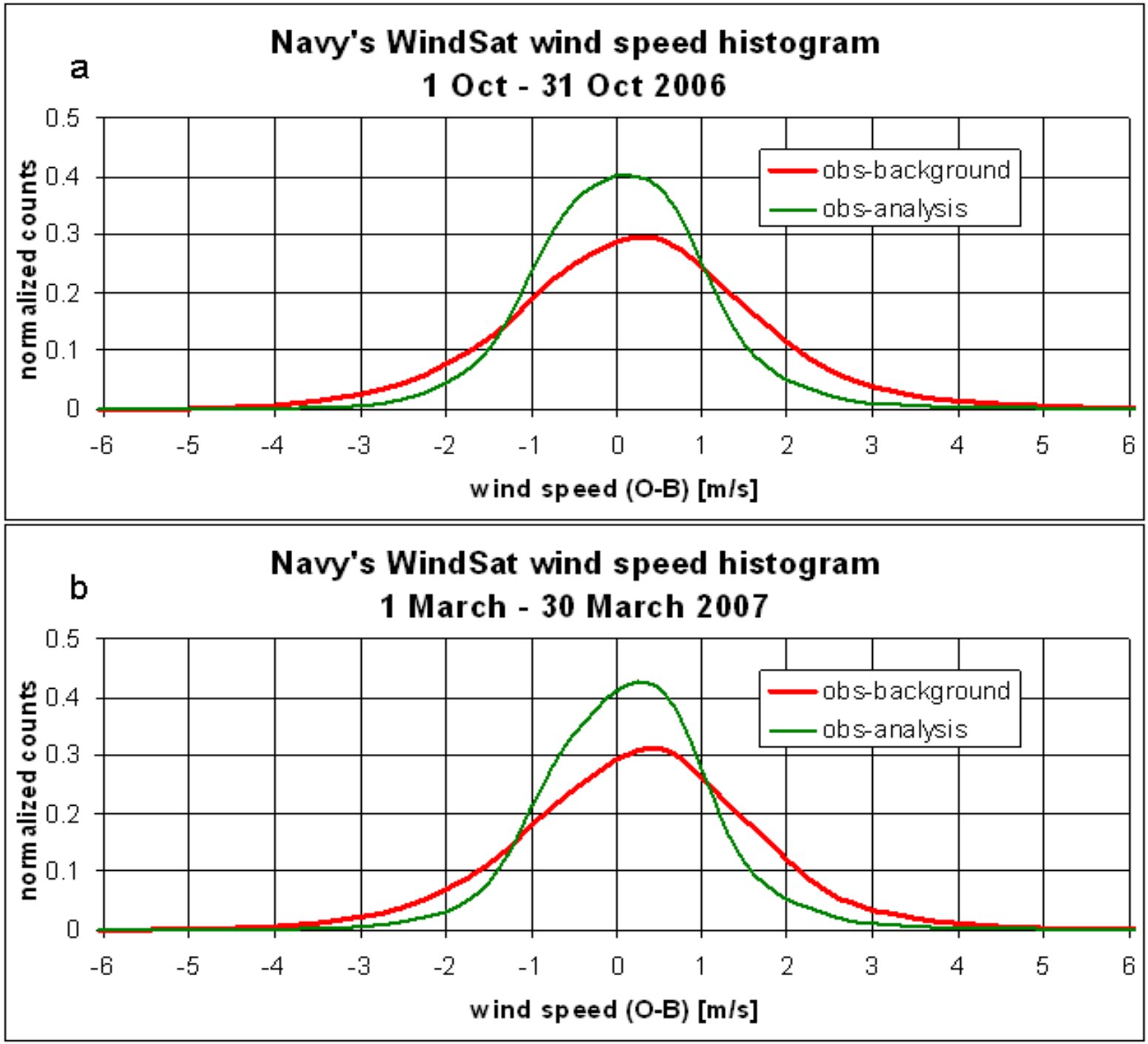
- Run GFS with all data types including QuikSCAT (control)
- Run GFS with Navy version of WindSat retrievals
- Investigate anomaly correlations and forecast impact for WindSat retrievals
- Investigate vertical time series forecast impacts for WindSat retrievals

WindSat Quality Control Used for Assimilation Experiments

- Data used only at 6 hour synoptic time with a plus/minus 3 hour window.
- If the absolute value of the observed wind component is more than 6 ms^{-1} from the corresponding background wind component the observation is eliminated. This only removed the extreme outliers.
- Any observations that are over 20m/s are rejected.


a
bias by bin for Navy's Windsat GDAS
1 Oct - 31 Oct 2006
bias [m/s]
wind speed [m/s]
obs-background
obs-analysis
b
bias by bin for Navy's WindSat GDAS
1 March - 30 March 2007
bias [m/s]
wind speed [m/s]
obs-background
obs-analysis

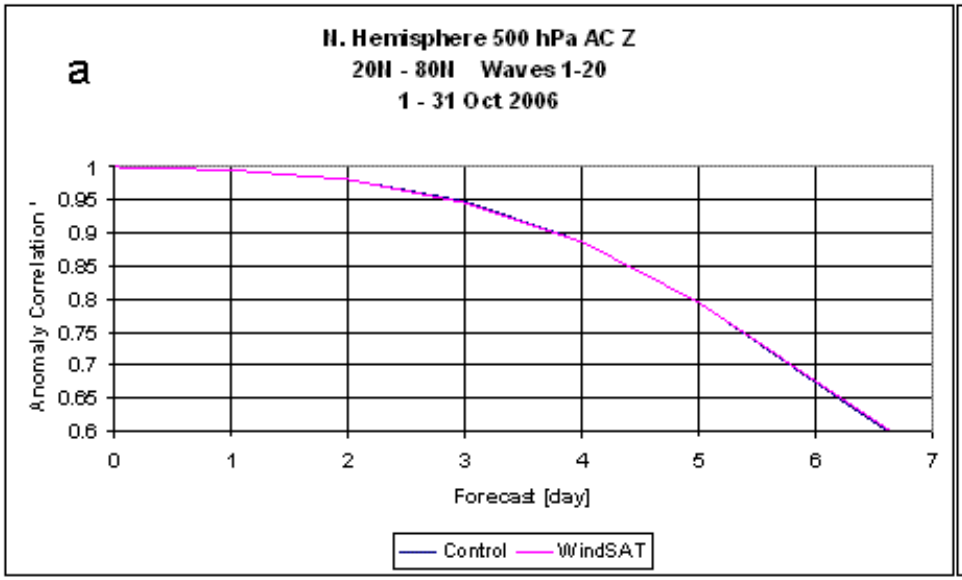

a
standard deviation by bin for Navy's WindSat
1 Oct - 31 Oct 2006
standard deviation [m/s]
wind speed [m/s]
obs-background
obs-analysis
b
standard deviation by bin for Navy's WindSat
1 March - 30 March 2007
standard deviation [m/s]
wind speed [m/s]
obs-background
obs-analysis


a
Navy's WindSat wind speed histogram
1 Oct - 31 Oct 2006
normalized counts
0.5
0.4
0.3
0.2
0.1
0
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
wind speed (O-B) [m/s]
obs-background
obs-analysis
b
Navy's WindSat wind speed histogram
1 March - 30 March 2007
normalized counts
0.5
0.4
0.3
0.2
0.1
0
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
wind speed (O-B) [m/s]
obs-background
obs-analysis

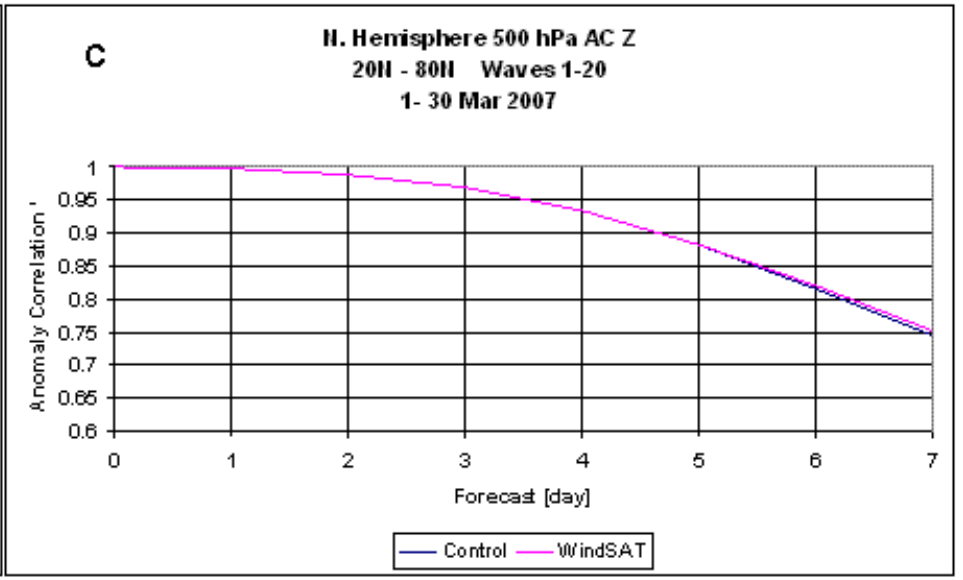
Results of Current Work

- Anomaly Correlation (AC) results and daily AC scores time series
- Geographic forecast impact (FI) investigations for Navy WindSat retrieval data
- Vertical time series impacts for Navy WindSat retrieval data

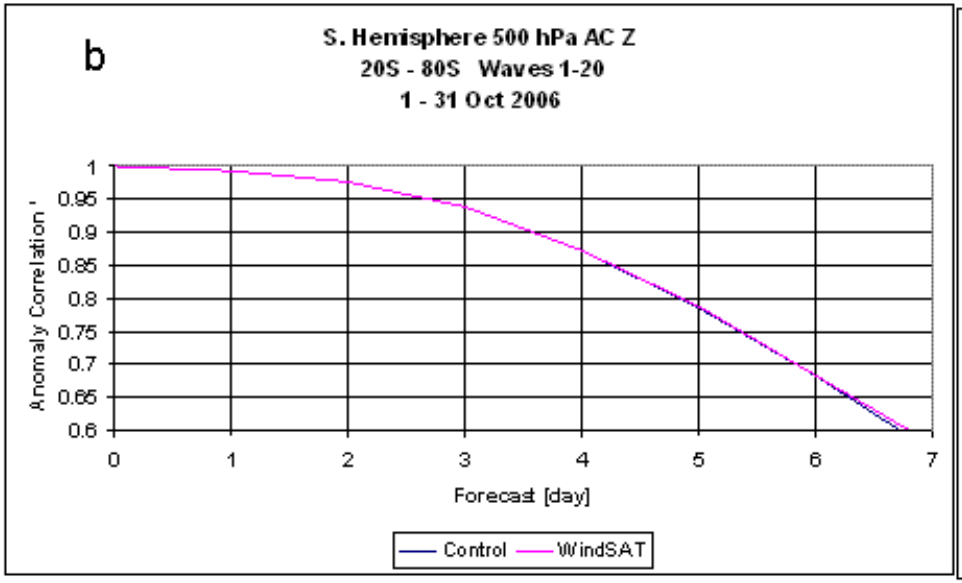
a


N. Hemisphere 500 hPa AC Z
20N - 80N Waves 1-20
1 - 31 Oct 2006
Anomaly Correlation '
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0 1 2 3 4 5 6 7
Forecast [day]
Control
WindSAT

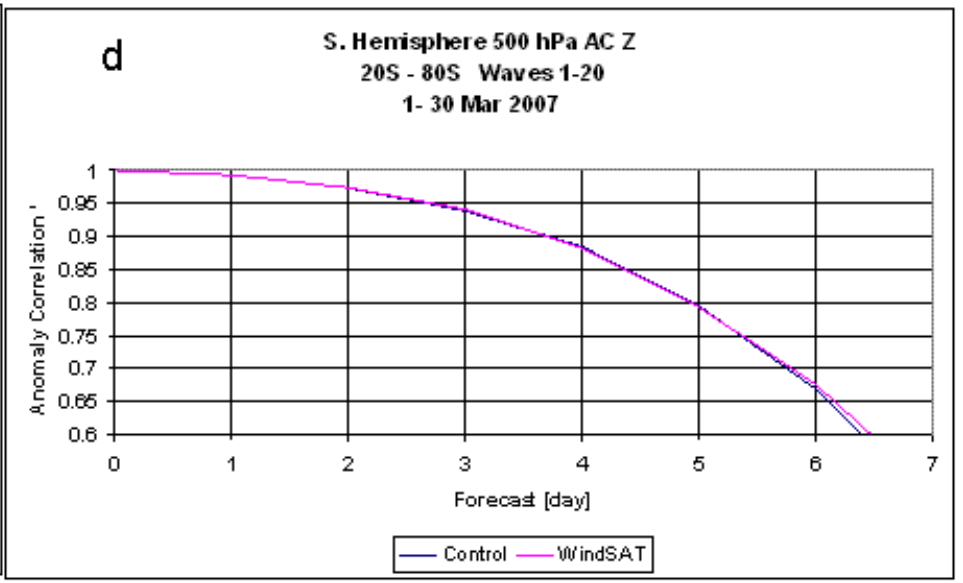
c


N. Hemisphere 500 hPa AC Z
20N - 80N Waves 1-20
1- 30 Mar 2007
Anomaly Correlation '
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0 1 2 3 4 5 6 7
Forecast [day]
Control
WindSAT

b


S. Hemisphere 500 hPa AC Z
20S - 80S Waves 1-20
1 - 31 Oct 2006
Anomaly Correlation '
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0 1 2 3 4 5 6 7
Forecast [day]
Control
WindSAT

d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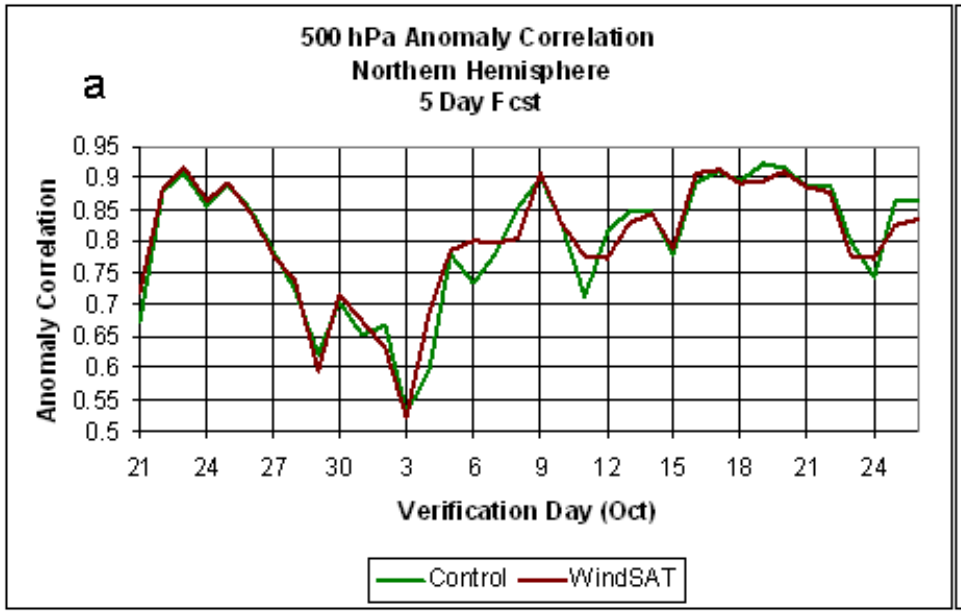
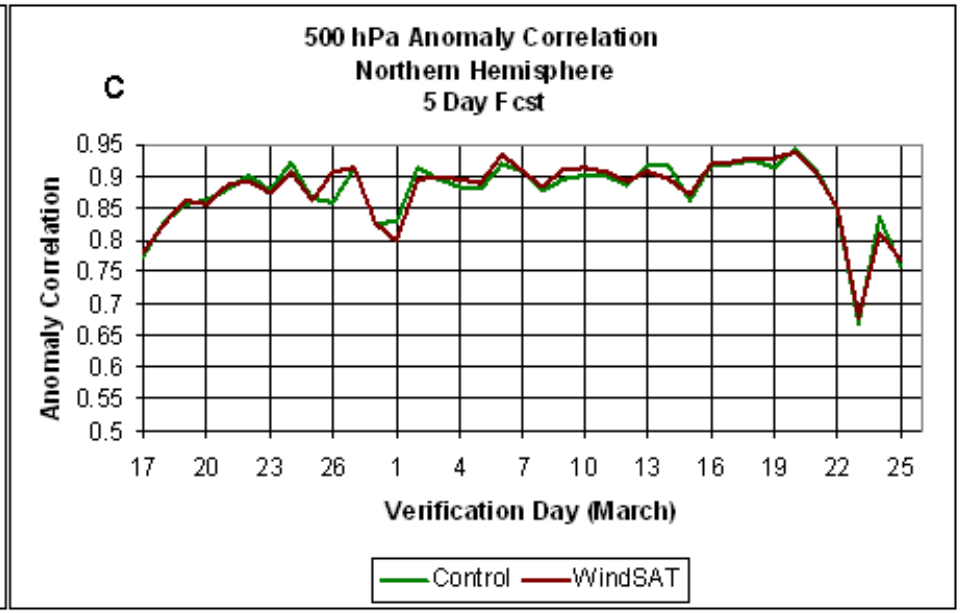
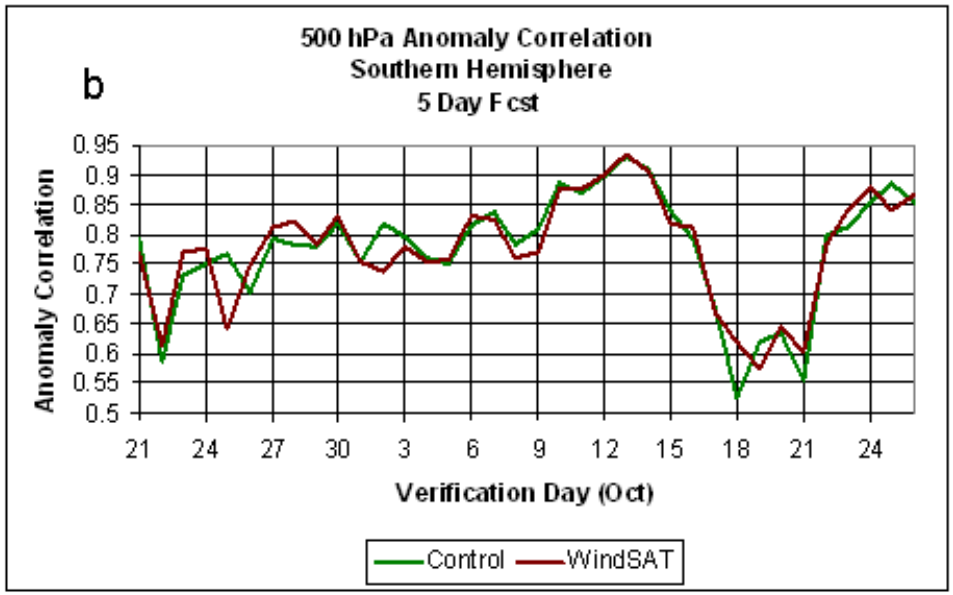
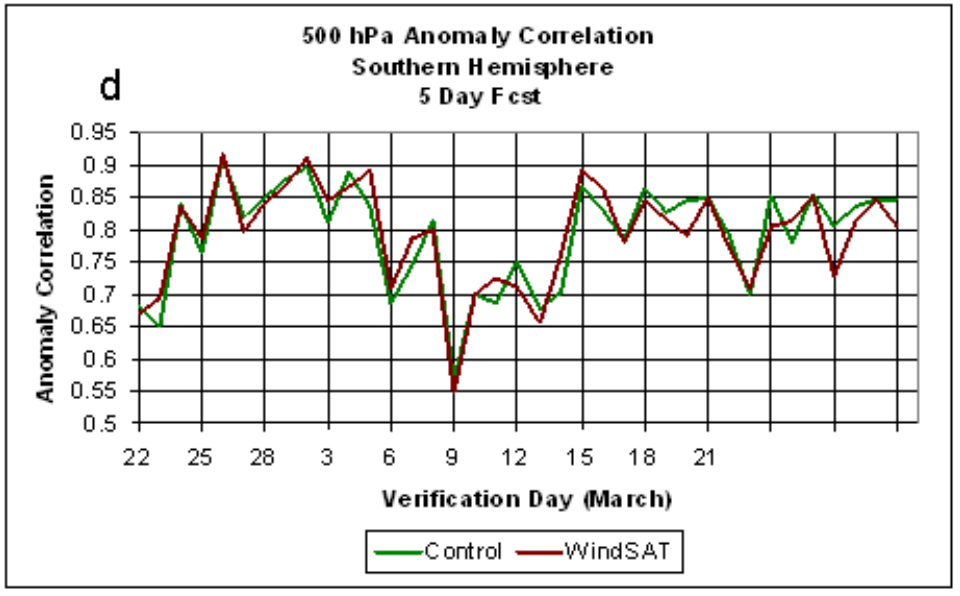
20S - 80S Waves 1-20
1- 30 Mar 2007
Anomaly Correlation '
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0 1 2 3 4 5 6 7
Forecast [day]
Control
WindSAT


a
500 hPa Anomaly Correlation
Northern Hemisphere
5 Day Fcst
Anomaly Correlation
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
21 24 27 30 3 6 9 12 15 18 21 24
Verification Day (Oct)
Control
WindSAT


c
500 hPa Anomaly Correlation
Northern Hemisphere
5 Day Fcst
Anomaly Correlation
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
17 20 23 26 1 4 7 10 13 16 19 22 25
Verification Day (March)
Control
WindSAT


b
500 hPa Anomaly Correlation
Southern Hemisphere
5 Day Fcst
Anomaly Correlation
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
21 24 27 30 3 6 9 12 15 18 21 24
Verification Day (Oct)
Control
WindSAT


d
500 hPa Anomaly Correlation
Southern Hemisphere
5 Day Fcst
Anomaly Correlation
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
22 25 28 3 6 9 12 15 18 21
Verification Day (March)
Control
WindSAT

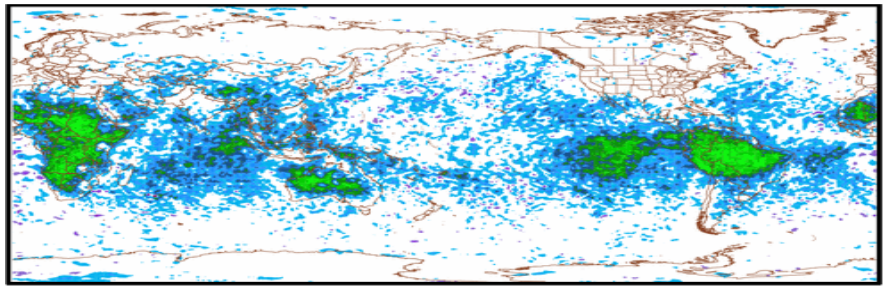
Results of Current Work Cont.

- Geographic forecast impact (FI) investigations for Navy WindSat retrieval data:

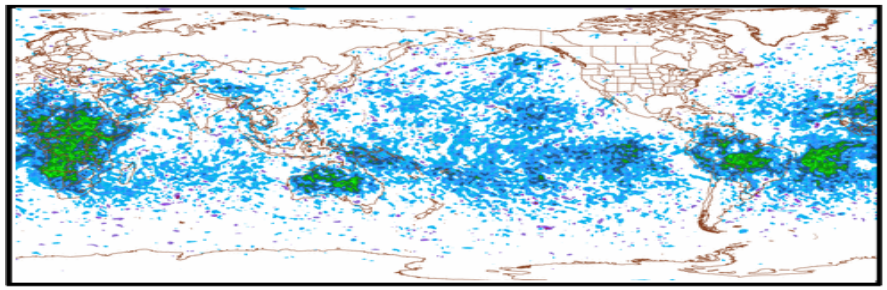
$$FI = 100 \times \left\{ \left(\sqrt{\frac{\sum_{i=1}^{N} (C_i - A_i)^2}{N}} - \sqrt{\frac{\sum_{i=1}^{N} (D_i - A_i)^2}{N}} \right) \Big/ \sqrt{\frac{\sum_{i=1}^{N} (C_i - A_i)^2}{N}} \right\}$$

Error in control **Error in experiment** **Error in control**

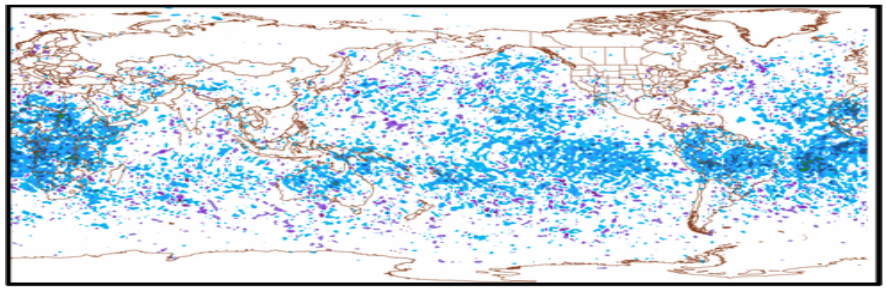
(a) 10M WIND SPEED FCST IMPACT 6-HR NAVY WINDSAT OCT 2006



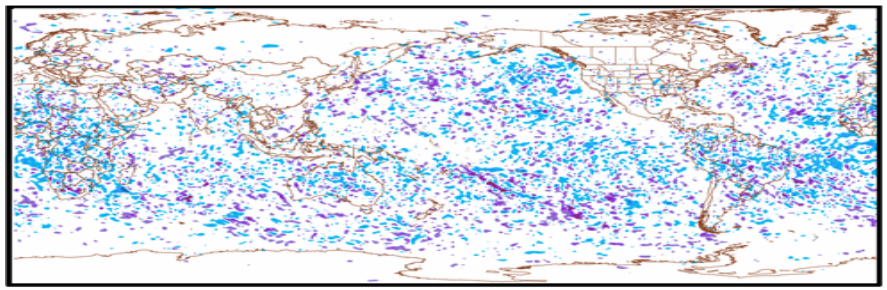
(b) 10M WIND SPEED FCST IMPACT 12-HR NAVY WINDSAT OCT 2006



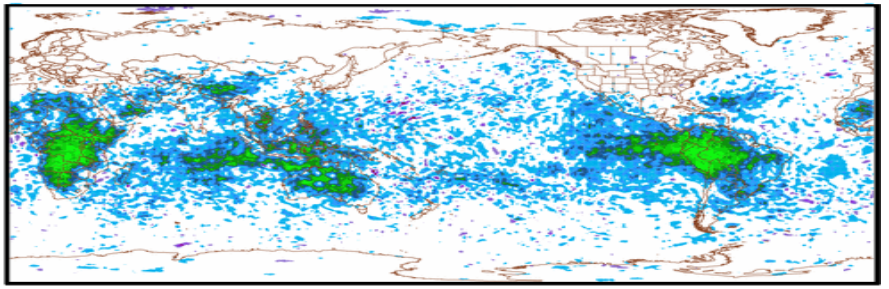
(c) 10M WIND SPEED FCST IMPACT 24-HR NAVY WINDSAT OCT 2006



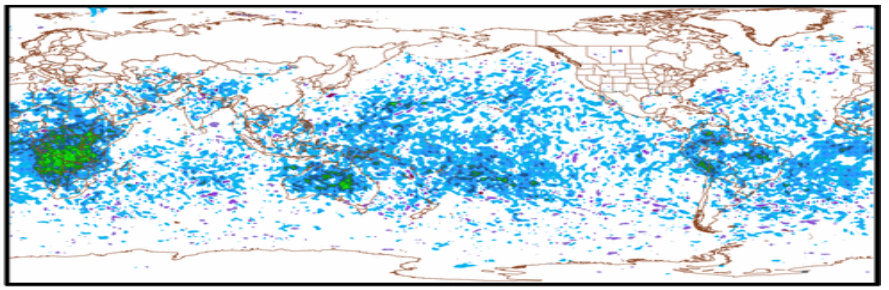
(d) 10M WIND SPEED FCST IMPACT 48-HR NAVY WINDSAT OCT 2006



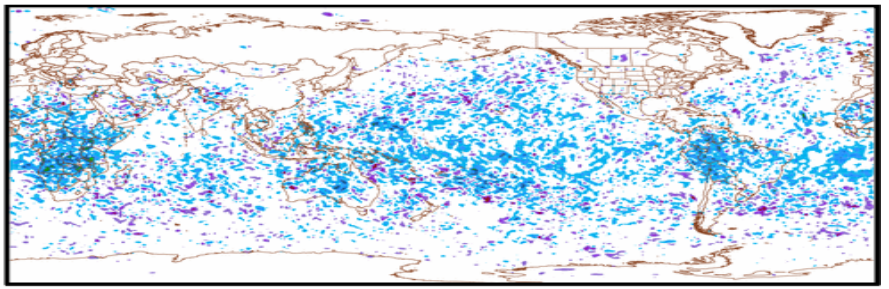
(e) 10M WIND SPEED FCST IMPACT 6-HR NAVY WINDSAT MARCH 2007



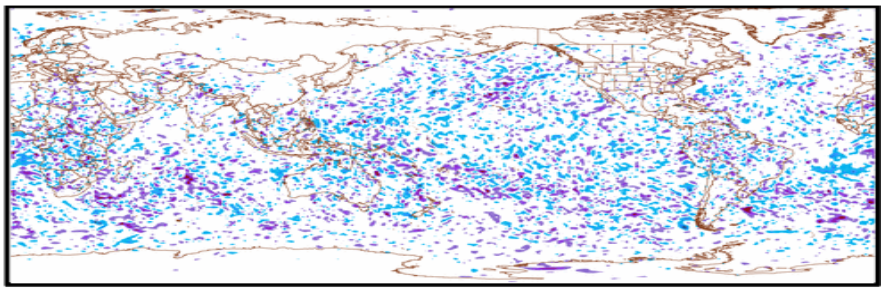
(f) 10M WIND SPEED FCST IMPACT 12-HR NAVY WINDSAT MARCH 2007



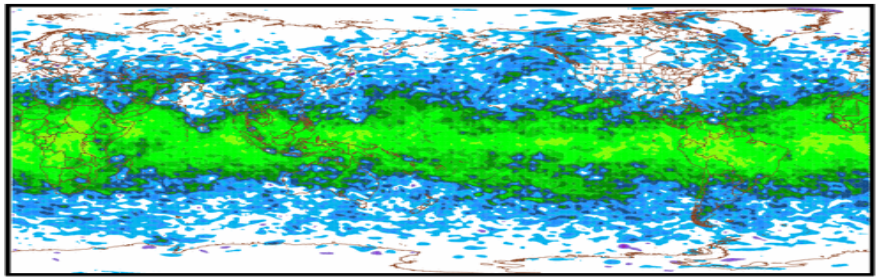
(g) 10M WIND SPEED FCST IMPACT 24-HR NAVY WINDSAT MARCH 2007



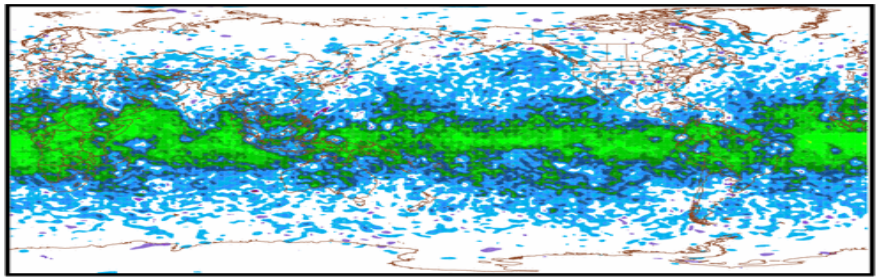
(h) 10M WIND SPEED FCST IMPACT 48-HR NAVY WINDSAT MARCH 2007



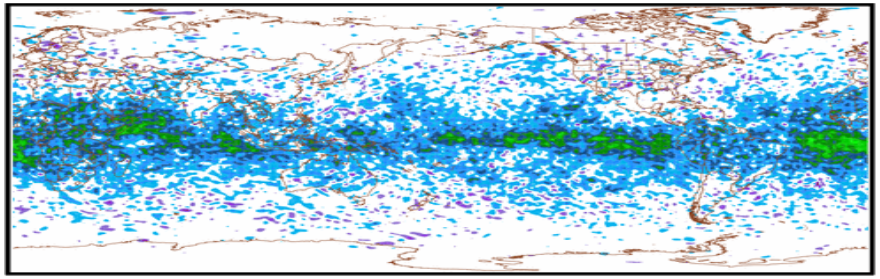
(a) 500hPa SPEED FCST IMPACT 6-HR NAVY WINDSAT OCT 2006



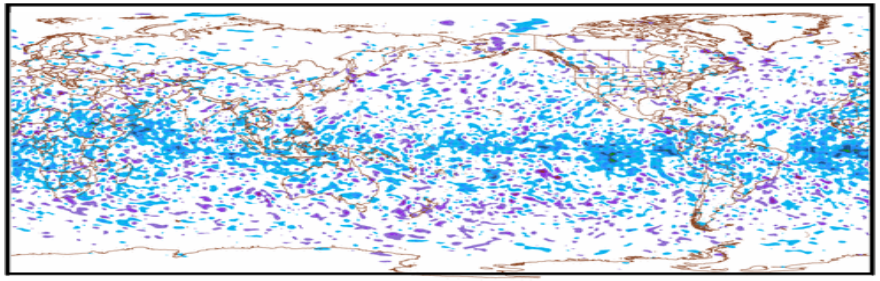
(b) 500hPa WIND SPEED FCST IMPACT 12-HR NAVY WINDSAT OCT 2006



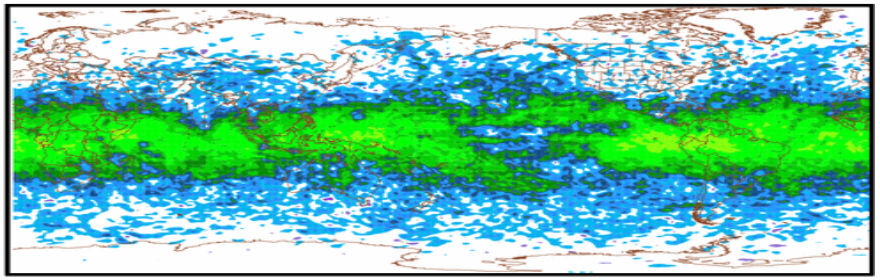
(c) 500hPa SPEED FCST IMPACT 24-HR NAVY WINDSAT OCT 2006



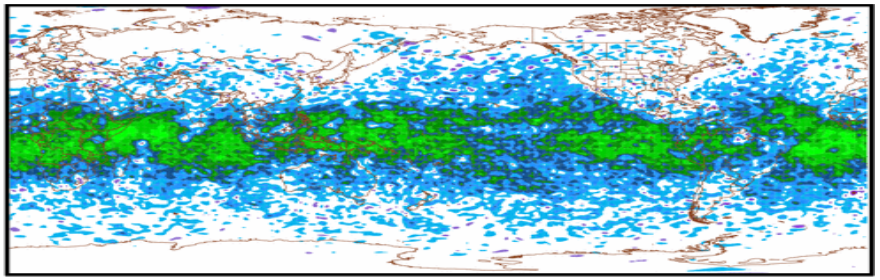
(d) 500hPa SPEED FCST IMPACT 48-HR NAVY WINDSAT OCT 2006



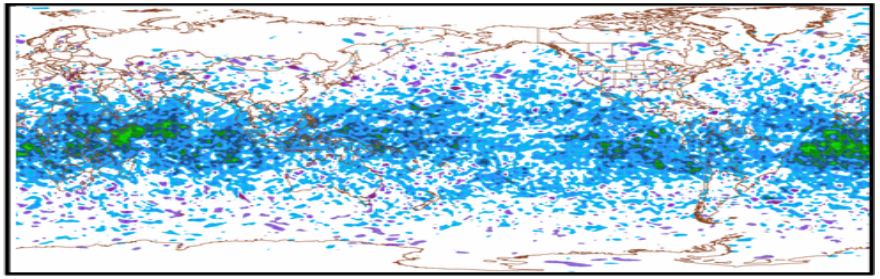
(e) 500hPa SPEED FCST IMPACT 6-HR NAVY WINDSAT MARCH 2007



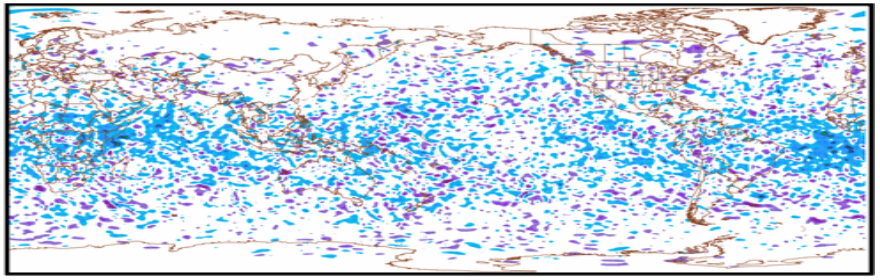
(f) 500hPa SPEED FCST IMPACT 12-HR NAVY WINDSAT MARCH 2007



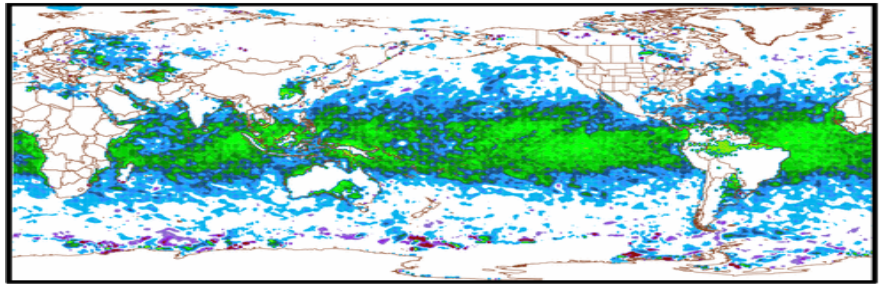
(g) 500hPa SPEED FCST IMPACT 24-HR NAVY WINDSAT MARCH 2007



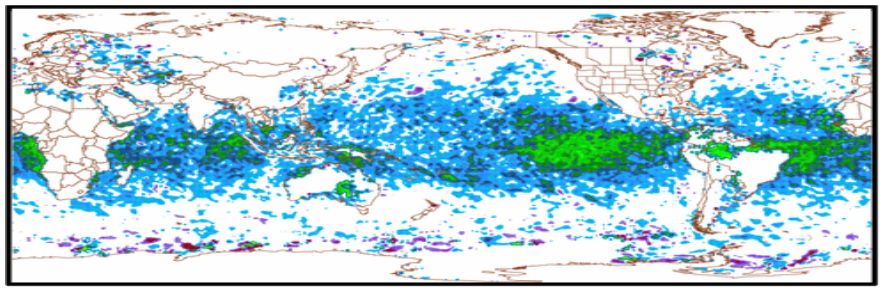
(h) 500hPa SPEED FCST IMPACT 48-HR NAVY WINDSAT MARCH 2007



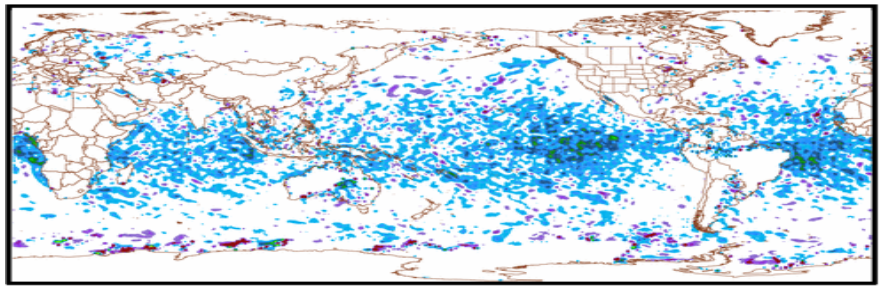
(a) 1000hPa TEMP FCST IMPACT 6-HR NAVY WINDSAT OCT 2006



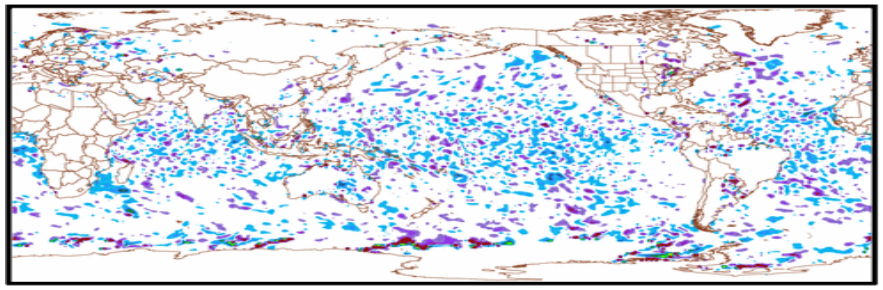
(b) 1000hPa TEMP FCST IMPACT 12-HR NAVY WINDSAT OCT 2006



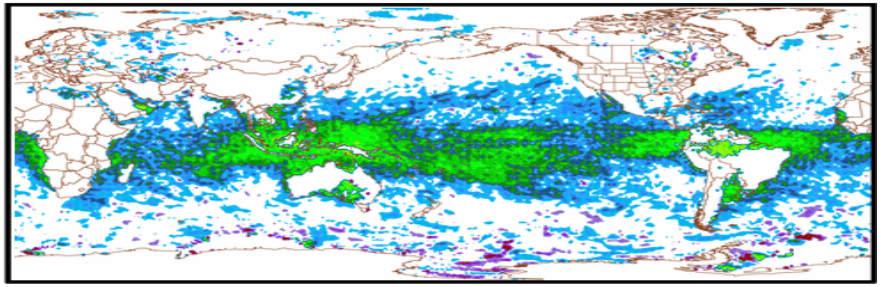
(c) 1000hPa TEMP FCST IMPACT 24-HR NAVY WINDSAT OCT 2006



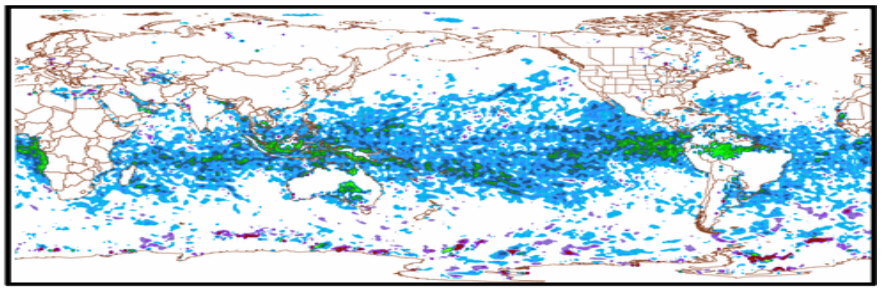
(d) 1000hPa TEMP FCST IMPACT 48-HR NAVY WINDSAT OCT 2006



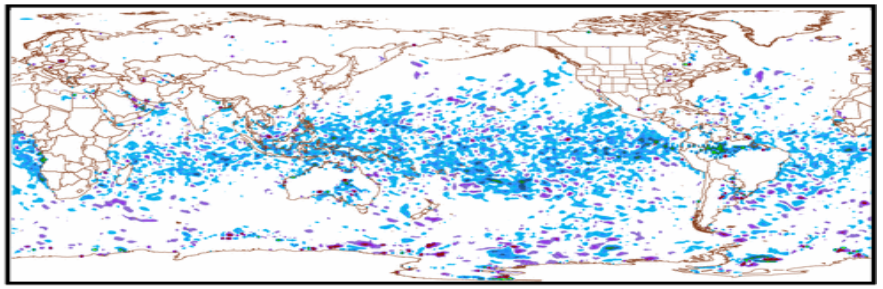
(e) 1000hPa TEMP FCST IMPACT 6-HR NAVY WINDSAT MARCH 2007



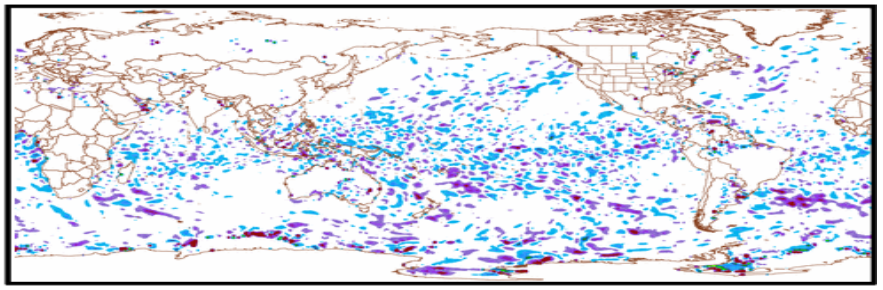
(f) 1000hPa TEMP FCST IMPACT 12-HR NAVY WINDSAT MARCH 2007



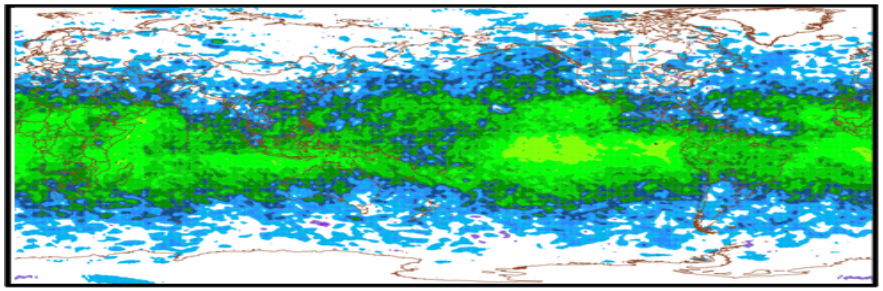
(g) 1000hPa TEMP FCST IMPACT 24-HR NAVY WINDSAT MARCH 2007



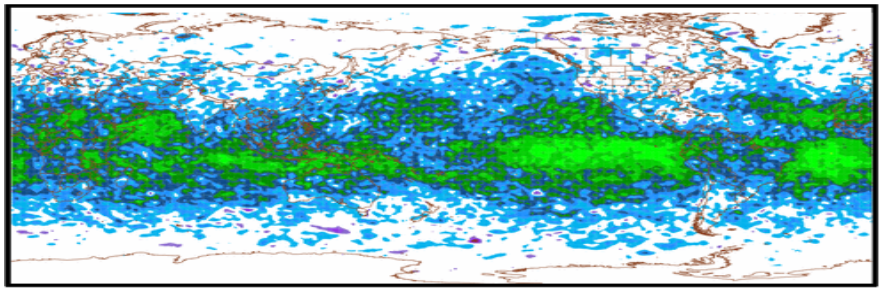
(h) 1000hPa TEMP FCST IMPACT 48-HR NAVY WINDSAT MARCH 2007



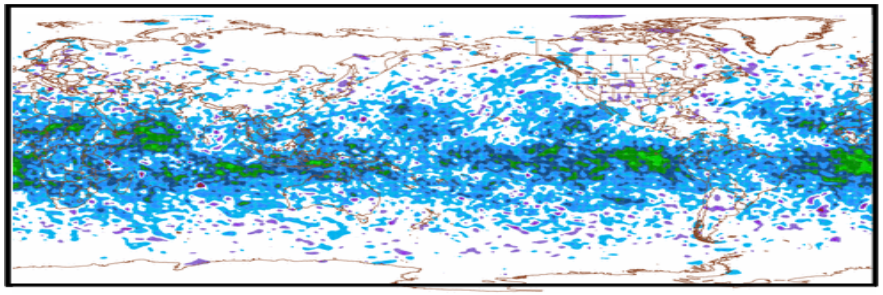
(a) 500hPa TEMP FCST IMPACT 6-HR NAVY WINDSAT OCT 2006



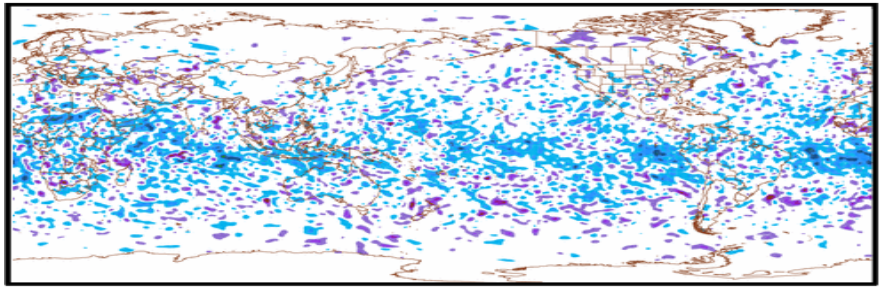
(b) 500hPa TEMP FCST IMPACT 12-HR NAVY WINDSAT OCT 2006



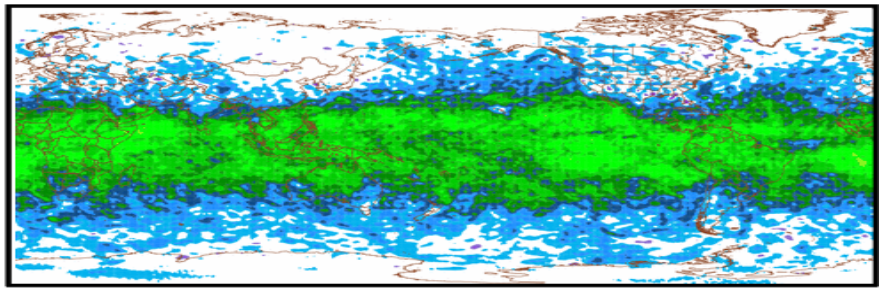
(c) 500hPa TEMP FCST IMPACT 24-HR NAVY WINDSAT OCT 2006



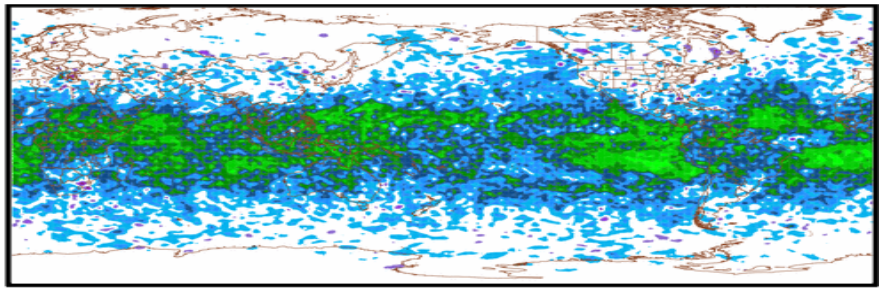
(d) 500hPa TEMP FCST IMPACT 48-HR NAVY WINDSAT OCT 2006



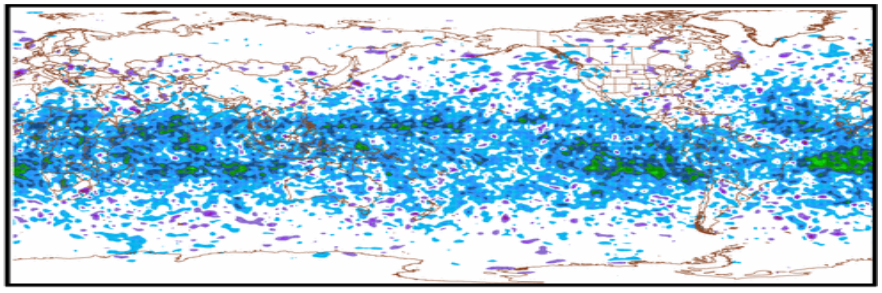
(e) 500hPa TEMP FCST IMPACT 6-HR NAVY WINDSAT MARCH 2007



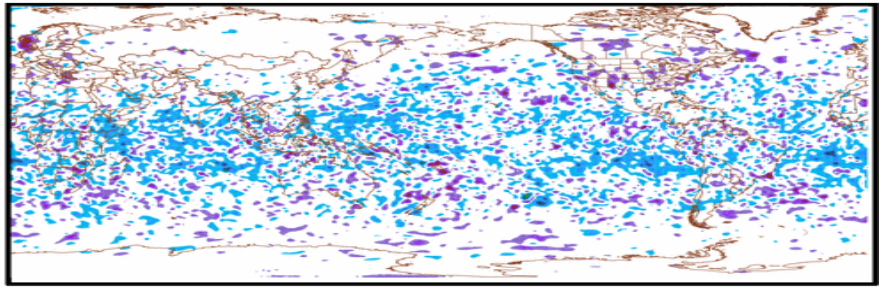
(f) 500hPa TEMP FCST IMPACT 12-HR NAVY WINDSAT MARCH 2007



(g) 500hPa TEMP FCST IMPACT 24-HR NAVY WINDSAT MARCH 2007

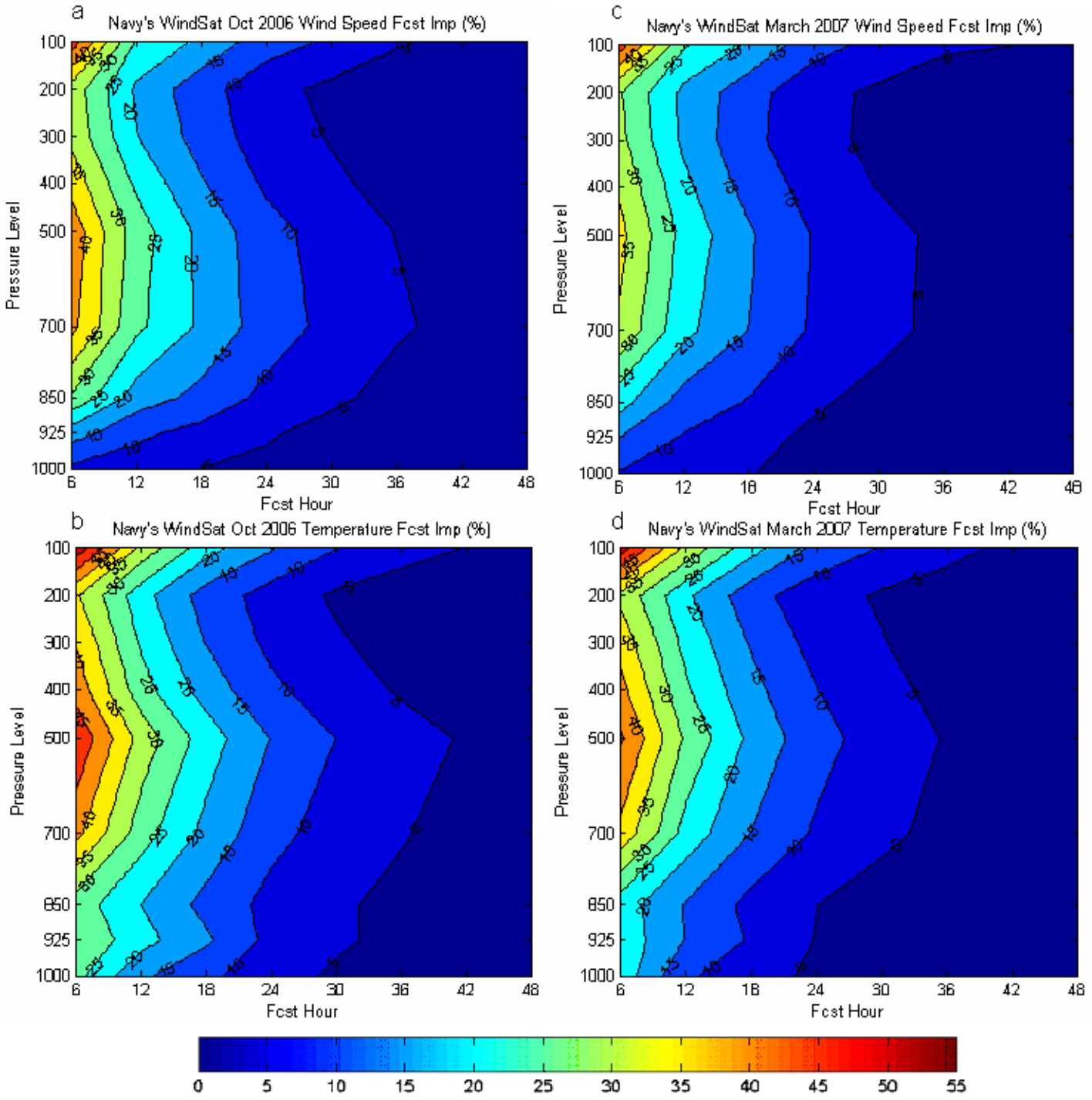


(h) 500hPa TEMP FCST IMPACT 48-HR NAVY WINDSAT MARCH 2007



Results of Current Work Cont.

- Vertical time series impacts:

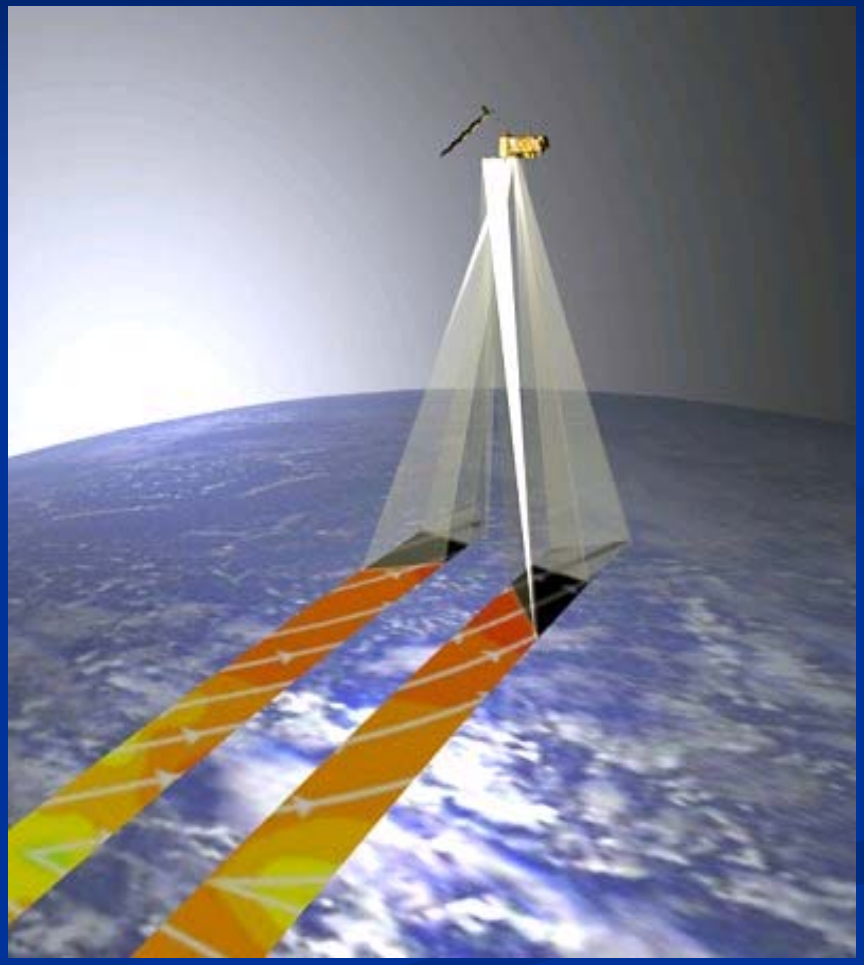

a
Navy's WindSat Oct 2006 Wind Speed Fcst Imp (%)
c
Navy's WindSat March 2007 Wind Speed Fcst Imp (%)
b
Navy's WindSat Oct 2006 Temperature Fcst Imp (%)
d
Navy's WindSat March 2007 Temperature Fcst Imp (%)
Pressure Level
100
200
300
400
500
700
850
925
1000
Fcst Hour
6
12
18
24
30
36
42
48
0
5
10
15
20
25
30
35
40
45
50
55

Conclusions

- Anomaly correlations show neutral to modest positive impacts at mid latitudes
- Positive Forecast Impacts occurred in the wind, temperature, and height fields
- Greatest Forecast Impacts occurred in the Tropics and at 500 hPa
- Positive Forecast Impacts are noted at all levels of the GFS through 48 hours

ASCAT Overview

- The Advanced Scatterometer (ASCAT) is one of the new-generation European instruments carried on Meteorological Operational Polar Satellite (MetOp)
- Measures ocean surface wind speed and direction
- Launched aboard MetOp in May 2007



ASCAT scanning principle

http://www.esa.int/esaLP/SEMBWEG23IE_LPmetop_0.html

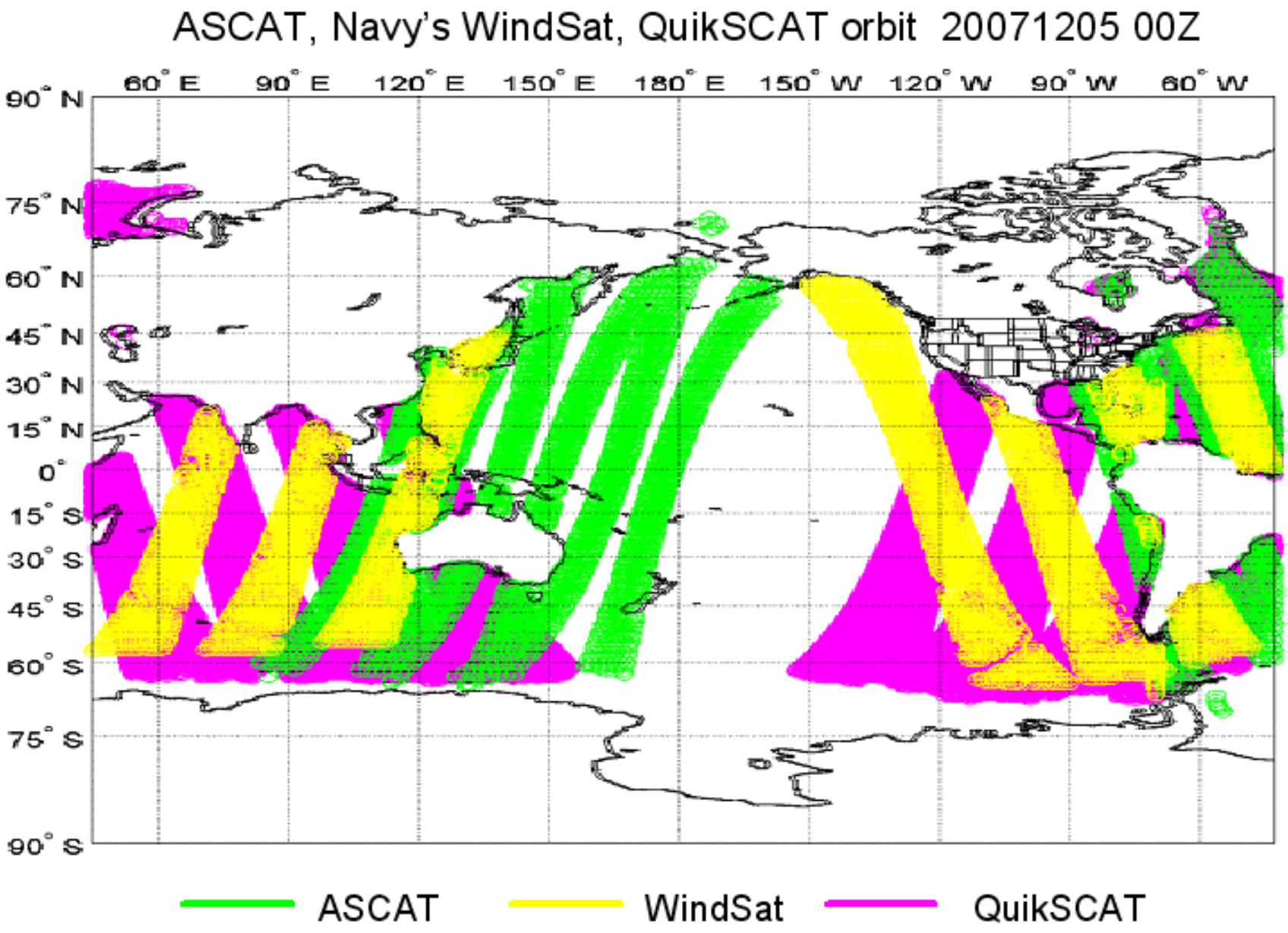
ASCAT Overview

- ASCAT uses radar to measure the electromagnatic backscatter from the wind-roughed ocean surface.
- The ASCAT mission employs two sets of three antennas to make observations in two 550 km wide swaths
- ASCAT products will provide two swaths of wind vectors simultaneously at a resolution of 50 km and 25km.
- Two wind vector solutions instead of four compared to QuikSCAT and WindSat winds.

http://www.esa.int/esaLP/SEMBWEG23IE_LPmetop_0.html

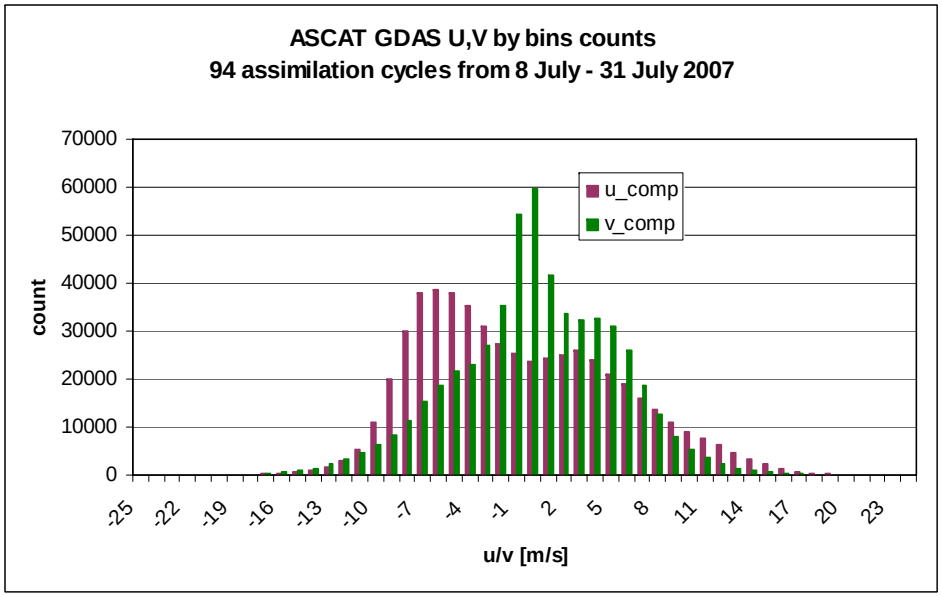
ASCAT Assimilation Experimental Design

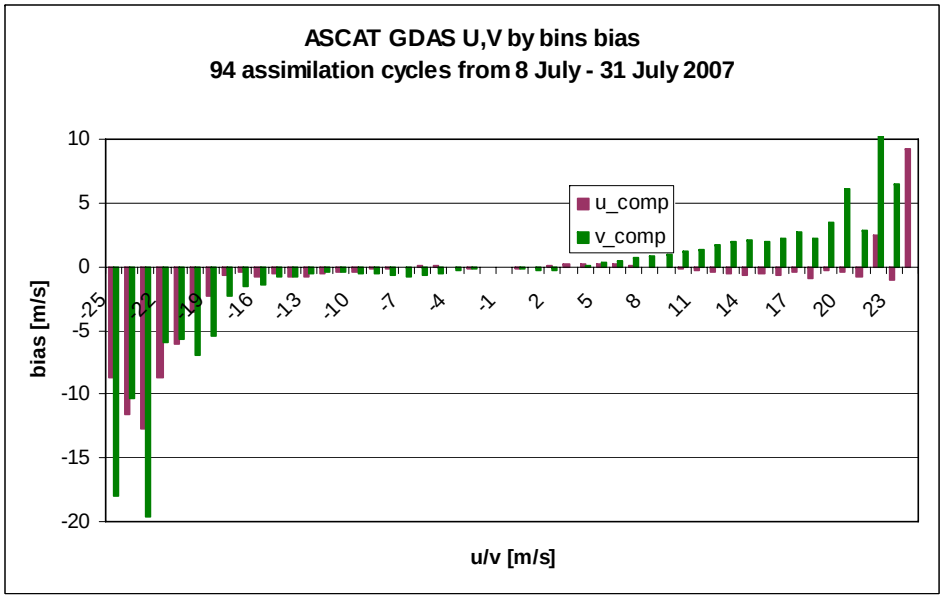
- Develop quality control procedures for ASCAT retrieved winds.
- Thinning vs. superobing ASCAT data
- With ASCAT, QuikSCAT and WindSat winds
- Focus on identifying impacts in the lowest layers and how the ASCAT information propagates vertically within the GFS

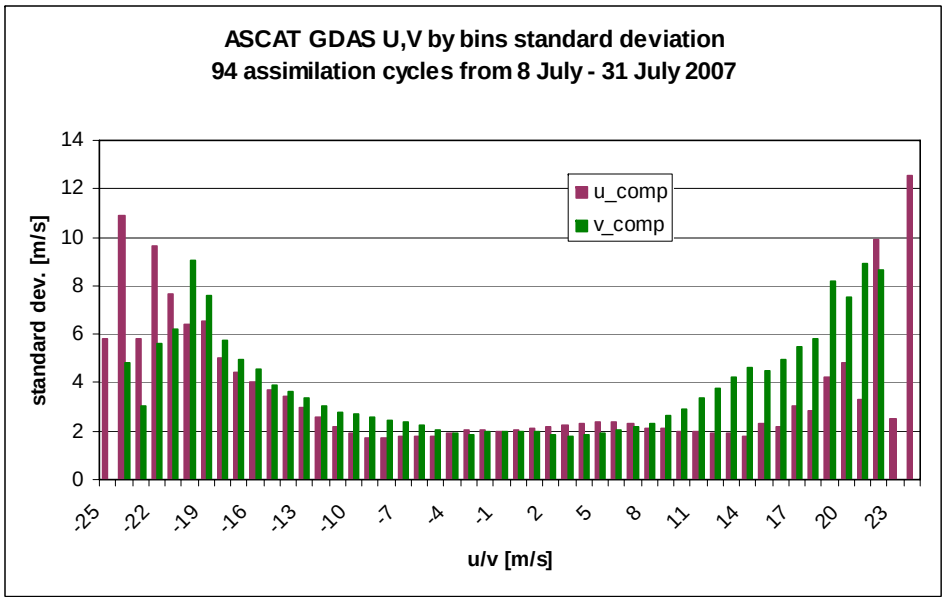

ASCAT, Navy's WindSat, QuikSCAT orbit 20071205 00Z
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
ASCAT
WindSat
QuikSCAT

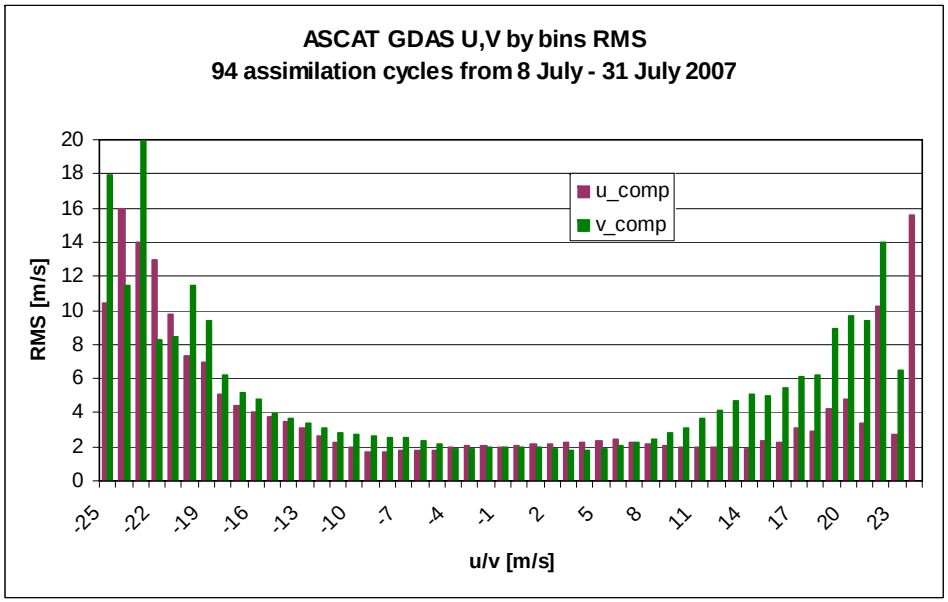
Preliminary ASCAT statistics

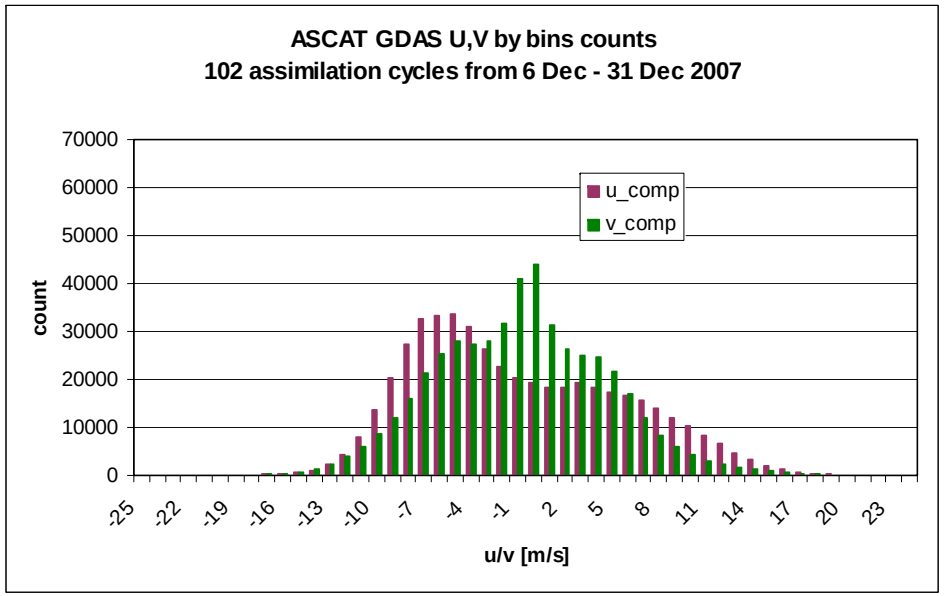
- Preliminary results for July 2007 and Dec 2007
  - U/V by bins counts
  - U/V by bins bias
  - U/V by bins standard deviation
  - U/V by bins RMS

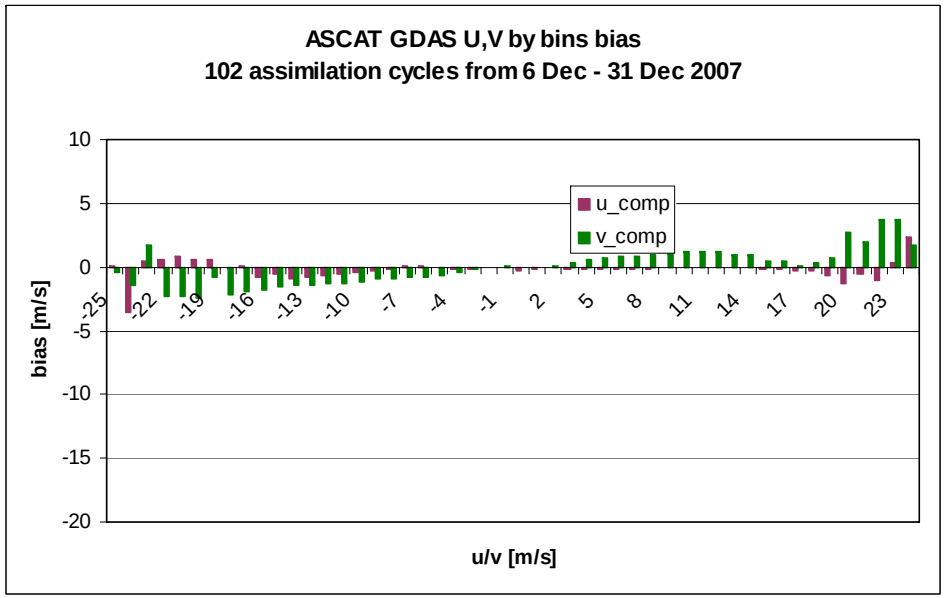

ASCAT GDAS U,V by bins counts
94 assimilation cycles from 8 July - 31 July 2007
count
u/v [m/s]
u_comp
v_comp

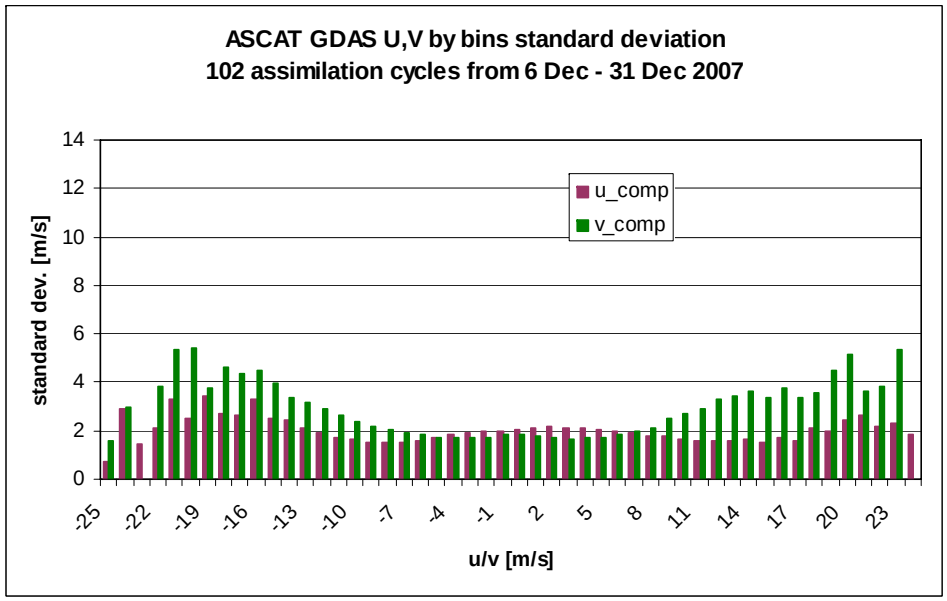

ASCAT GDAS U,V by bins bias
94 assimilation cycles from 8 July - 31 July 2007
bias [m/s]
u/v [m/s]
u_comp
v_comp

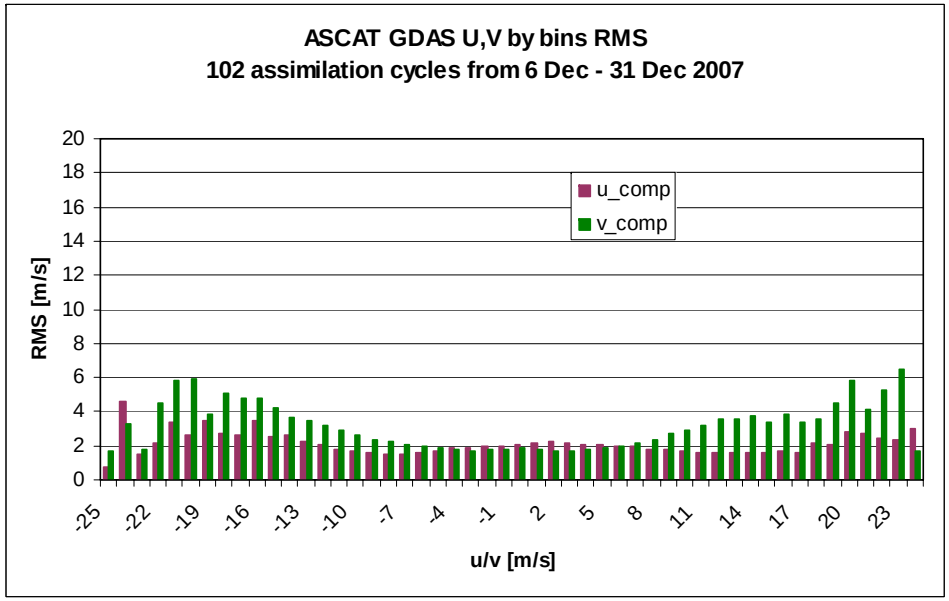

ASCAT GDAS U,V by bins standard deviation
94 assimilation cycles from 8 July - 31 July 2007
standard dev. [m/s]
u/v [m/s]
u_comp
v_comp


ASCAT GDAS U,V by bins RMS
94 assimilation cycles from 8 July - 31 July 2007
RMS [m/s]
u/v [m/s]
u_comp
v_comp


ASCAT GDAS U,V by bins counts
102 assimilation cycles from 6 Dec - 31 Dec 2007
count
u/v [m/s]
u_comp
v_comp


ASCAT GDAS U,V by bins bias
102 assimilation cycles from 6 Dec - 31 Dec 2007
bias [m/s]
u/v [m/s]
u_comp
v_comp


ASCAT GDAS U,V by bins standard deviation
102 assimilation cycles from 6 Dec - 31 Dec 2007
standard dev. [m/s]
u/v [m/s]
u_comp
v_comp


ASCAT GDAS U,V by bins RMS
102 assimilation cycles from 6 Dec - 31 Dec 2007
RMS [m/s]
u/v [m/s]
u_comp
v_comp

Acknowledgements

- Dr. Tom Zapotocny for leading WindSat project at UW
- Prof. Michael Morgan (UW-AOS) for local computer resources
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- Peter Gaiser/ Mike Bettenhausen for providing Navy WindSat data
- Zorana Jelenak for providing ASCAT data
- Dennis Keyser and Stacie Bender for collecting and processing our various data streams
- The JCSDA for the computer time required for this study