A two-season impact study of ASCAT surface wind retrievals in the NCEP Global Data Assimilation System

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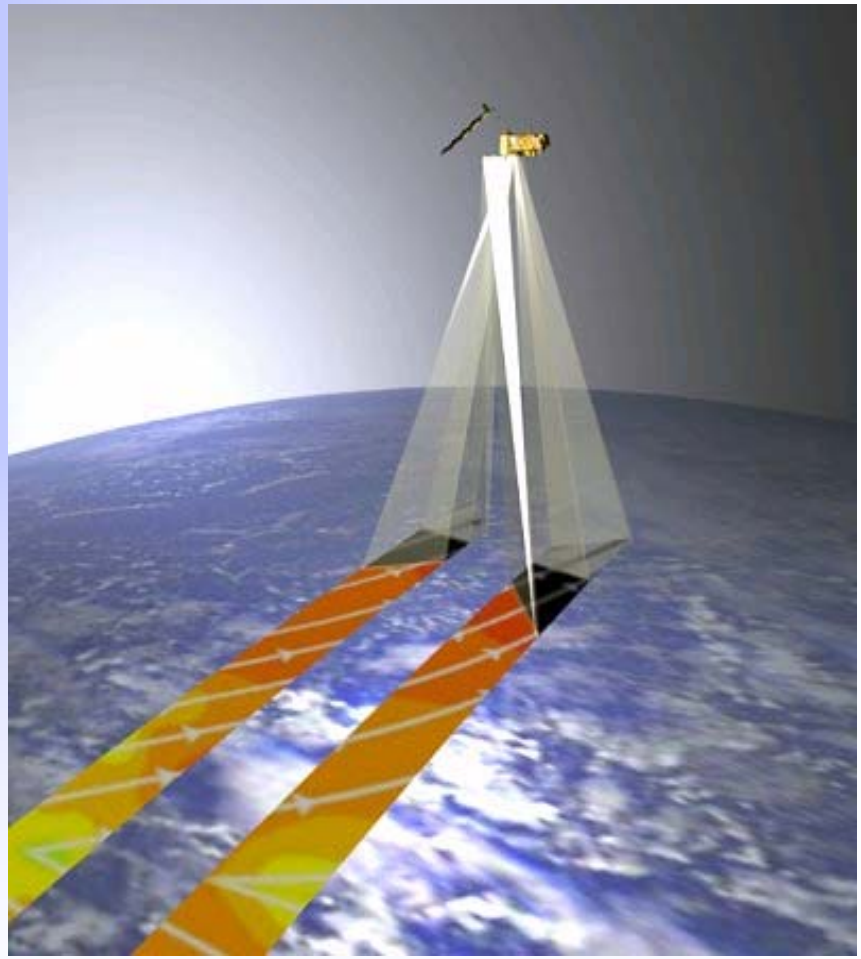
Outline

- ASCAT overview and work progress
  - Sensor overview
  - Experiment design
- Results from ASCAT analysis
- Results from forecast verification
  - Traditional stats diagnosis and anomaly correlation results
  - Forecast impact investigations
- Conclusions
- Future work

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 October 2006



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 at a resolution of 50 and 25 km.
- Two wind vector solutions instead of four (QuikSCAT and WindSat).

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

Proposed Work

- Work with the JCSDA (Joint Center for Satellite Data Assimilation) to evaluate the forecast impact of assimilating ASCAT data in the NCEP GDAS/GFS
- Conduct experiments during two seasons
- Use the latest versions of the GDAS/GFS
- Use the high resolution ASCAT data
- Determine quality control procedures
- Investigate analysis and forecast impacts of assimilating ASCAT
  - Anomaly Correlations
  - Forecast Impact

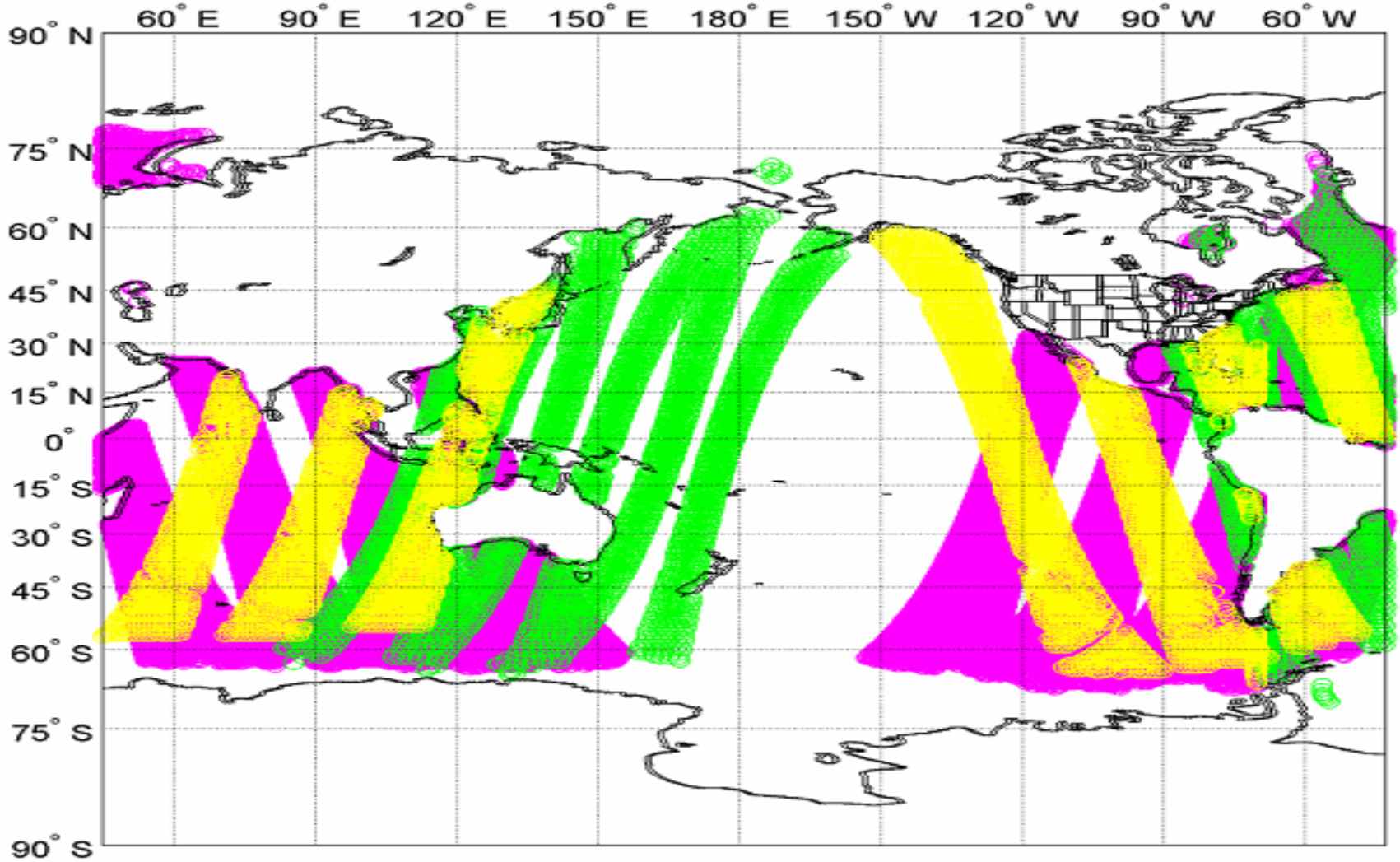
ASCAT Assimilation Experimental Design

- December 2007 version of GDAS/GFS with modifications for:
  - Thinning routine for winds (Kistler, Su)
  - FOTO (first order time interpolation) (Derber, Treadon, Kleist, et al.)
- Used GDAS/GFS operational resolution of T382L64
- Used July-August 2007 and December 2007 – January 2008 data
- All operational data types were used including QuikSCAT (WindSat is not used in operations yet).

ASCAT Assimilation Experimental Design Continued

- High resolution (25km) ASCAT data used
- Data used at 6 hour synoptic time with +/- 3 hour window
- Thinned instead of superobed ASCAT data
  - Thinned to 100 km
- ASCAT quality control:
  - Non-ocean observations rejected (GFS land, sea, ice flag)
  - Observations that differ by more than 5 m/s from the background are rejected (U, V).

ASCAT, WindSat, QuikSCAT orbit 20071205 00Z

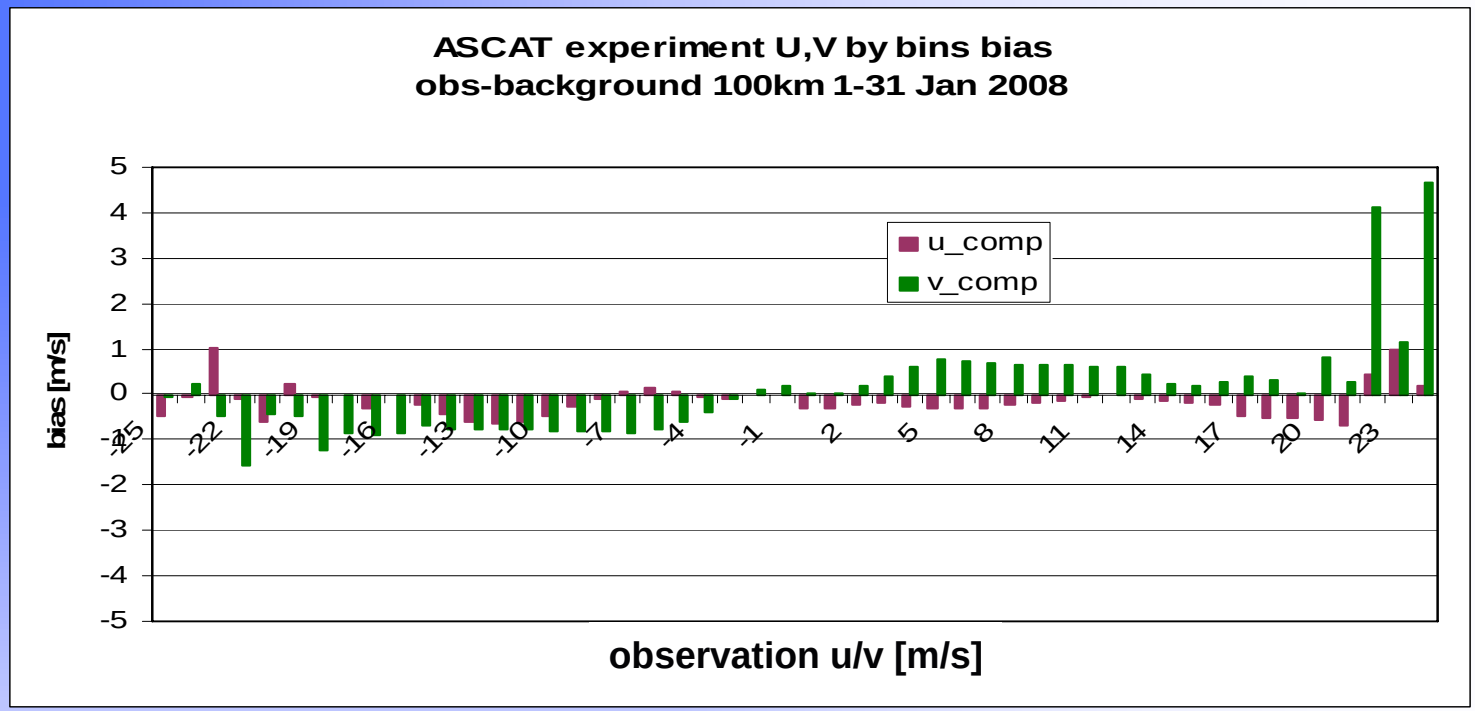


ASCAT WindSat QuikSCAT

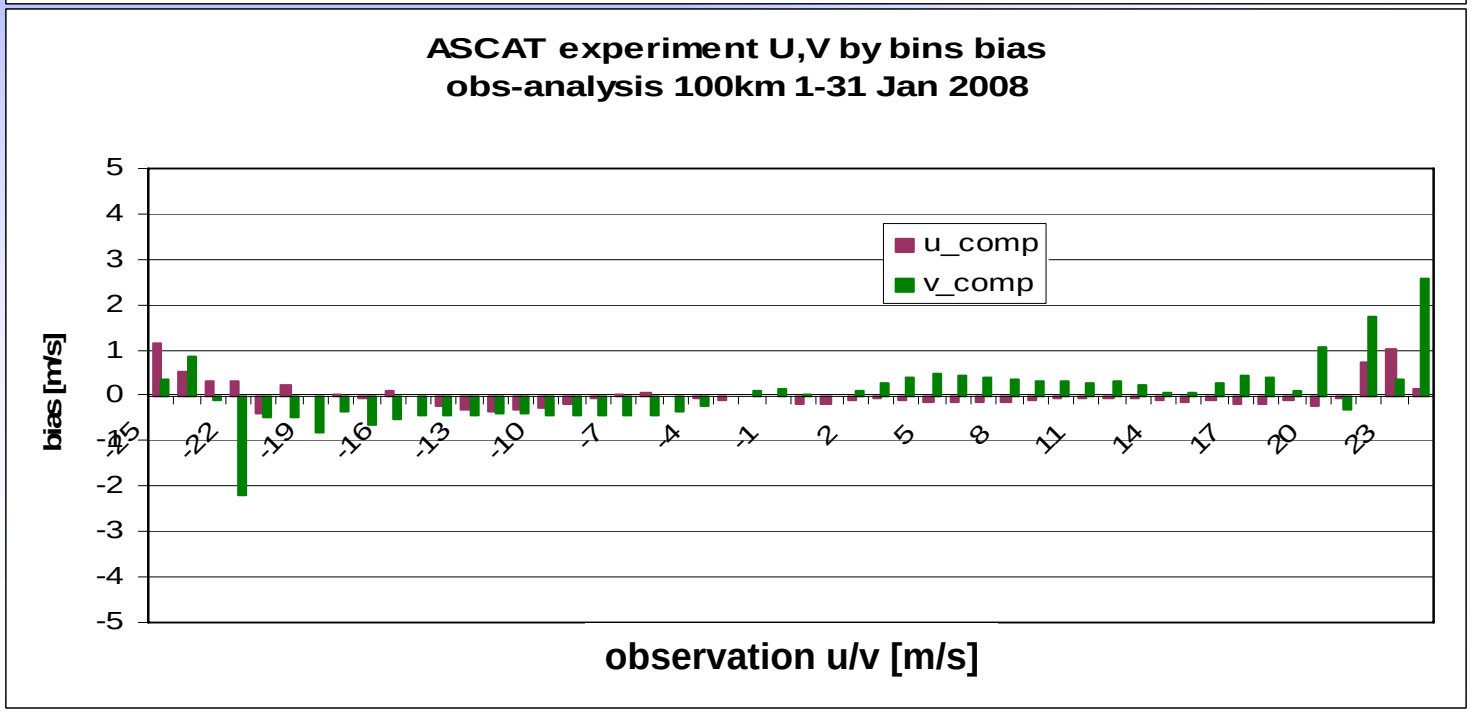
ASCAT statistics results of Aug 2007 and Jan 2008

- By bins in terms of observation wind speed and observation u/v of O-B and O-A
  - u/v and wind speed counts
  - u/v and wind speed bias
  - u/v and wind speed standard deviation
  - u/v and wind speed RMS

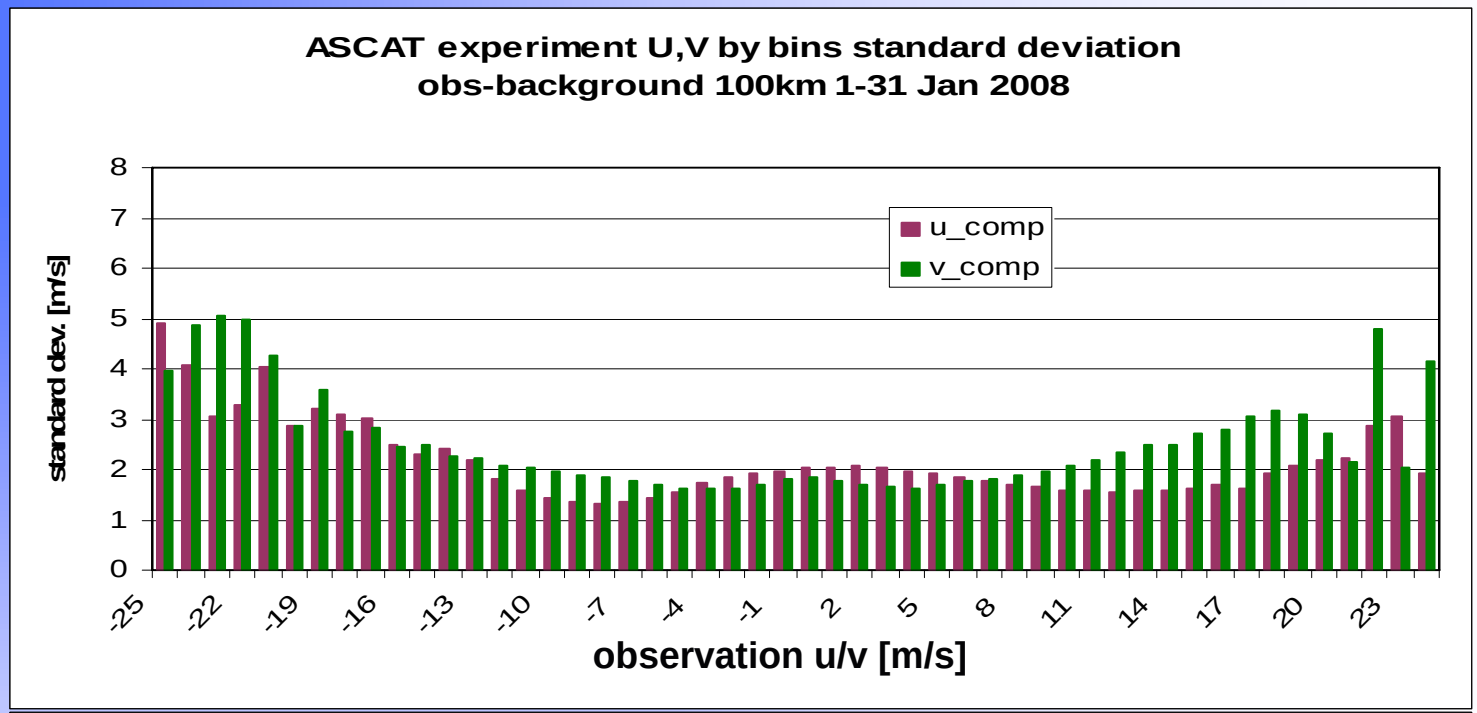
O-B →


ASCAT experiment U,V by bins bias
obs-background 100km 1-31 Jan 2008
bias [m/s]
u_comp
v_comp
observation u/v [m/s]

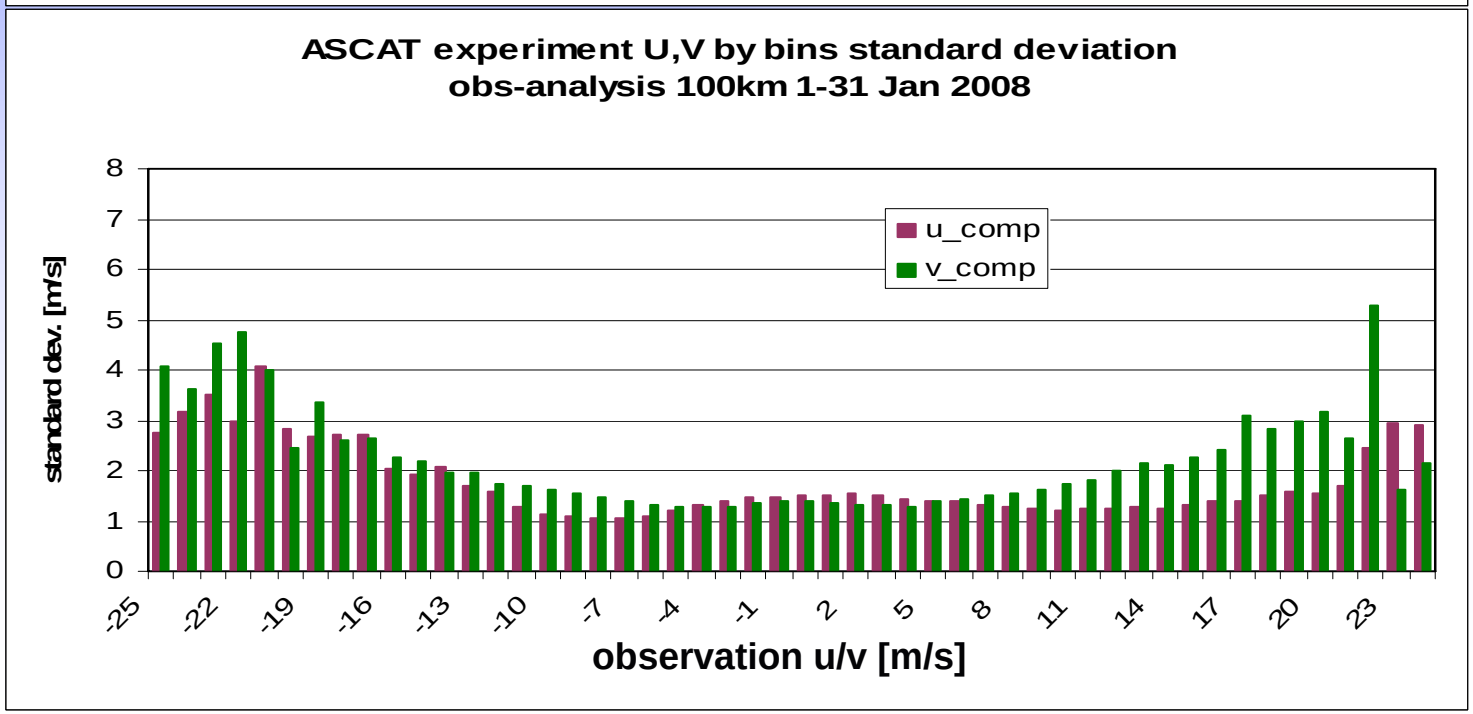
O-A →


ASCAT experiment U,V by bins bias
obs-analysis 100km 1-31 Jan 2008
bias [m/s]
u_comp
v_comp
observation u/v [m/s]

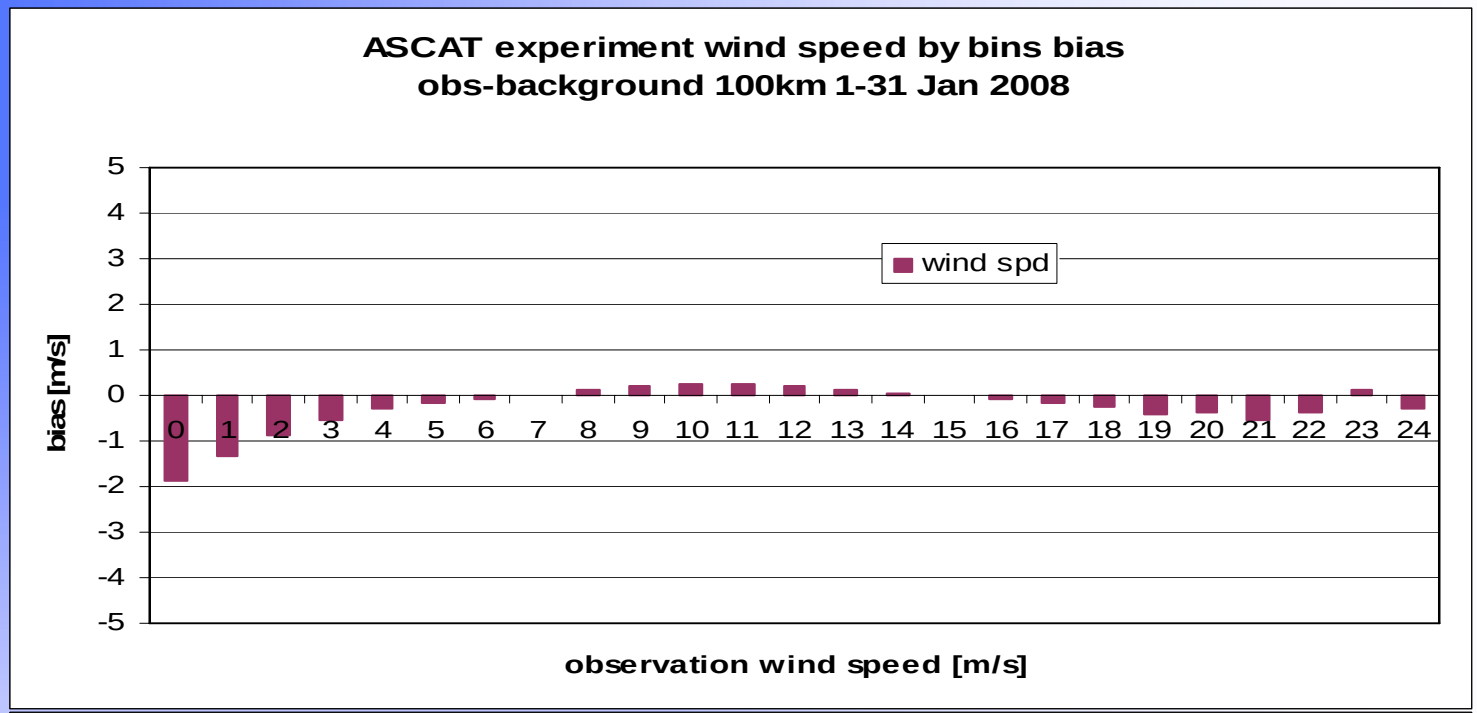
O-B →


ASCAT experiment U,V by bins standard deviation
obs-background 100km 1-31 Jan 2008
standard dev. [m/s]
u_comp
v_comp
observation u/v [m/s]

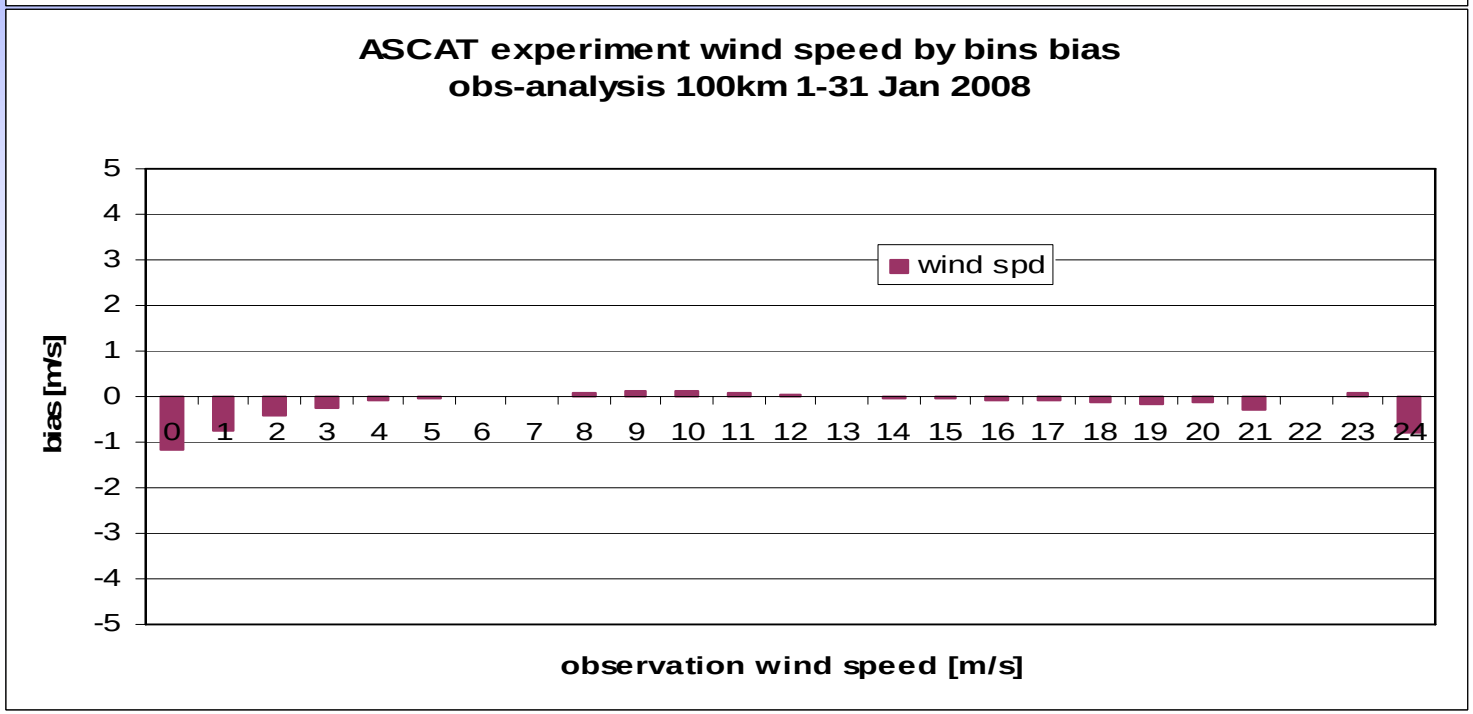
O-A →


ASCAT experiment U,V by bins standard deviation
obs-analysis 100km 1-31 Jan 2008
standard dev. [m/s]
u_comp
v_comp
observation u/v [m/s]

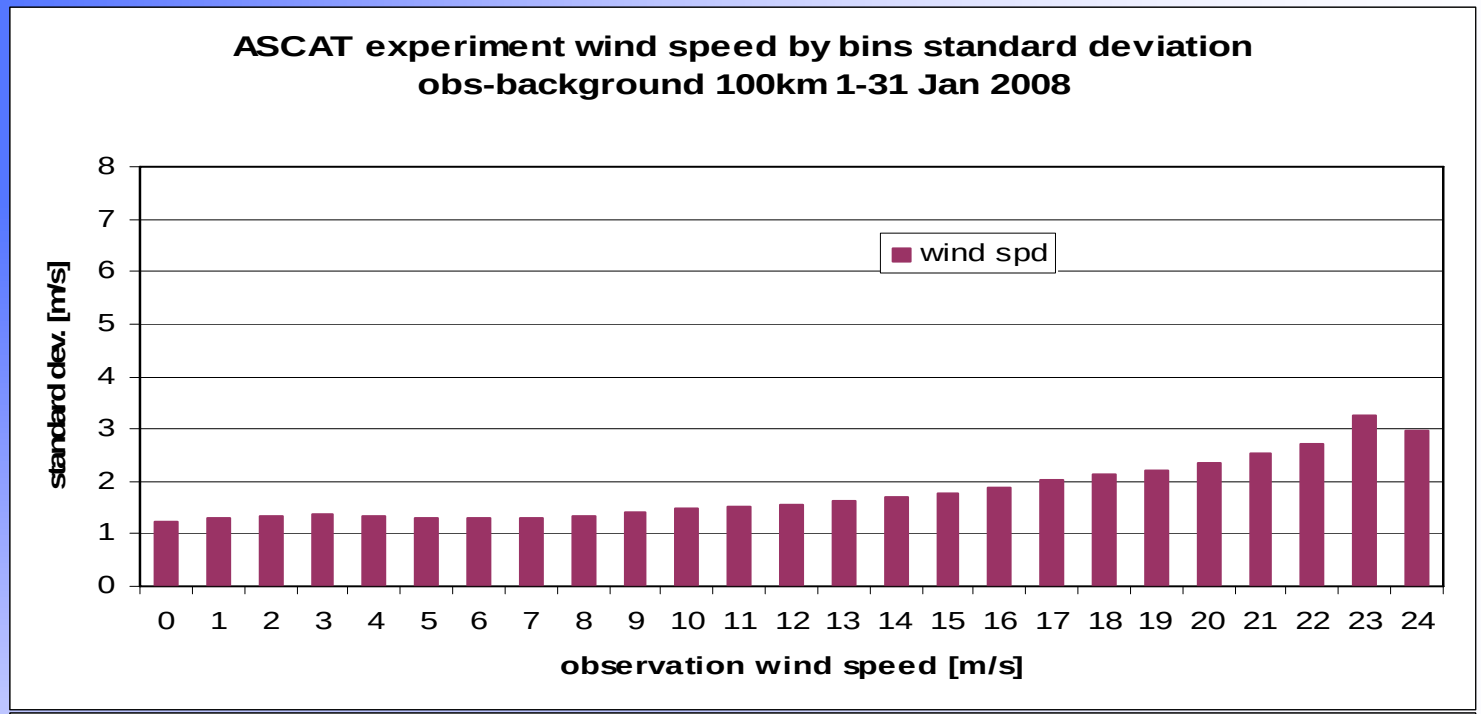
O-B →


ASCAT experiment wind speed by bins bias
obs-background 100km 1-31 Jan 2008
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

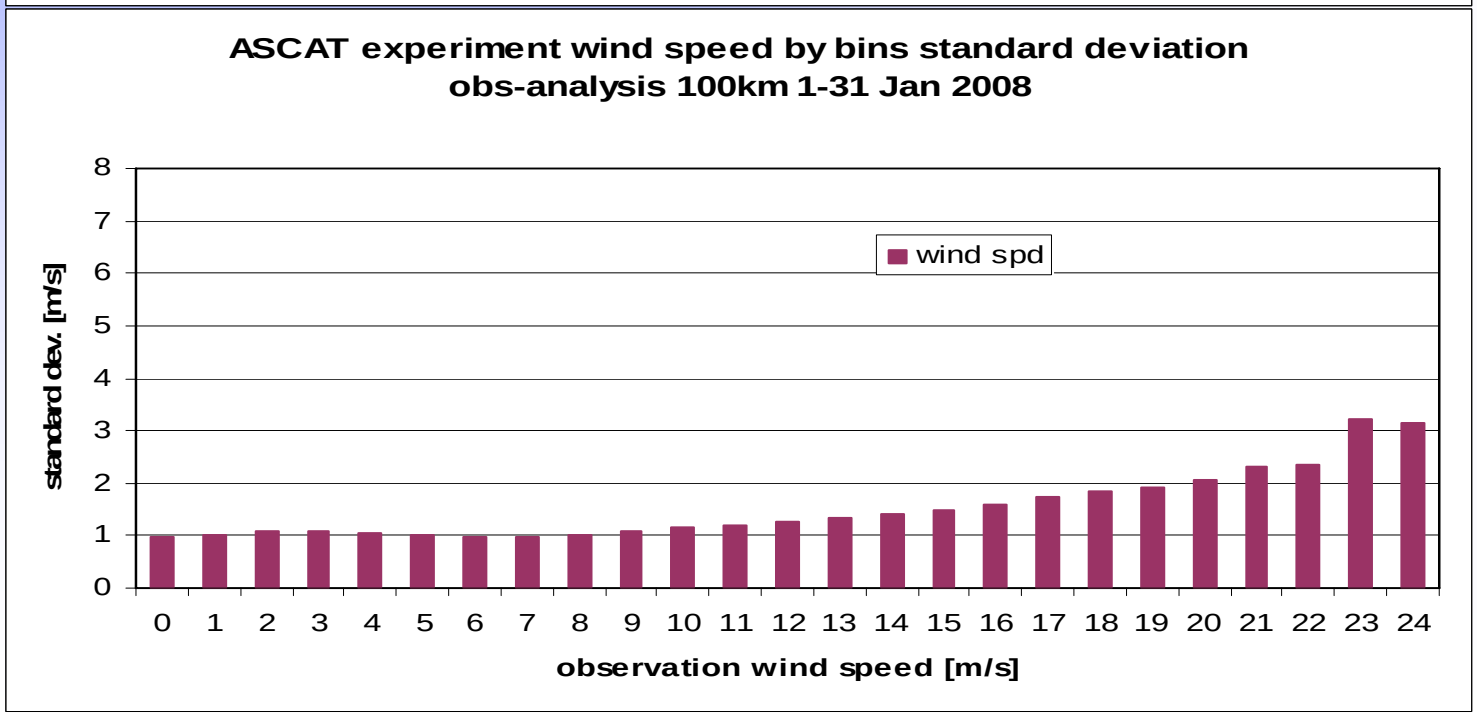
O-A →


ASCAT experiment wind speed by bins bias
obs-analysis 100km 1-31 Jan 2008
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

O-B →

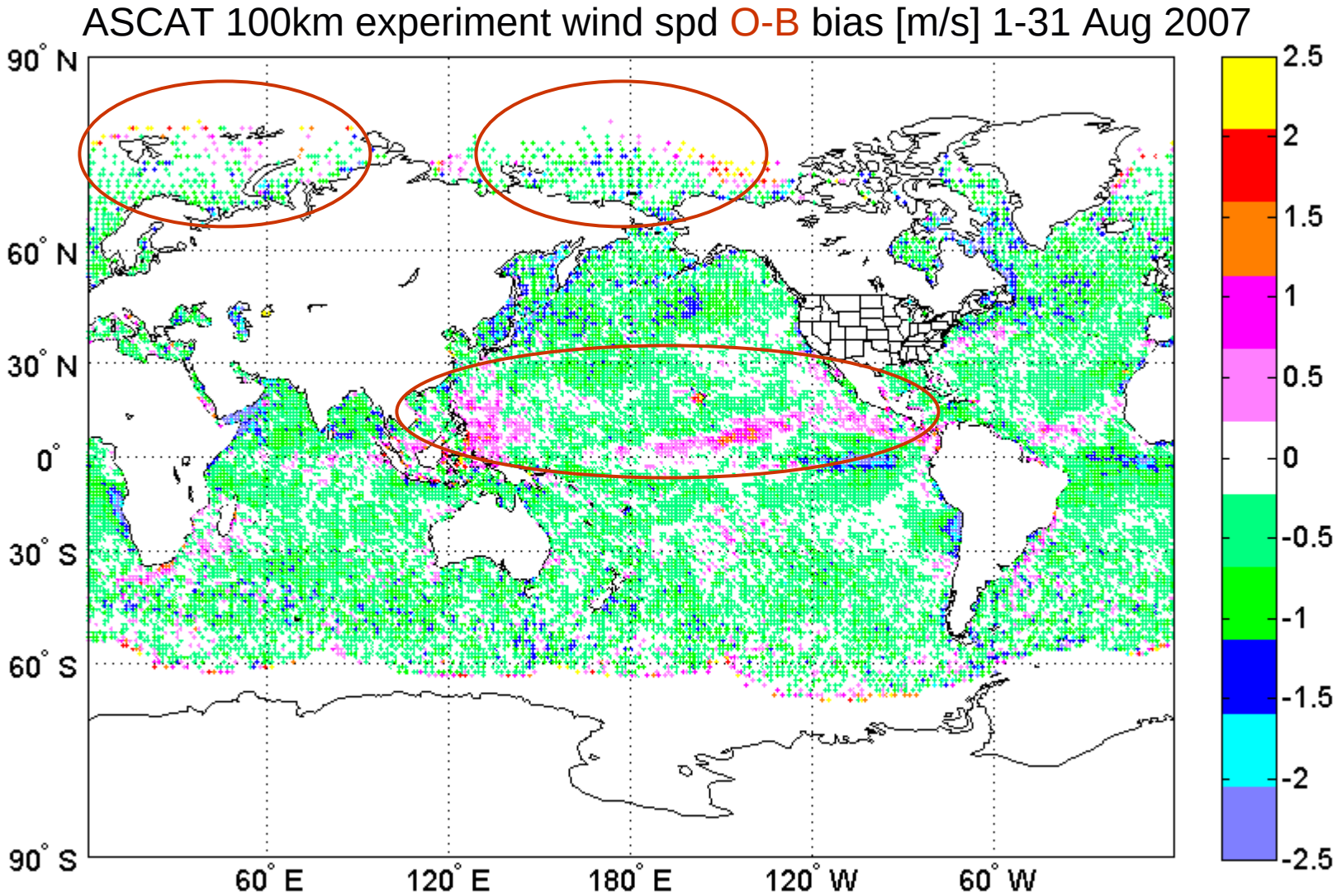

ASCAT experiment wind speed by bins standard deviation
obs-background 100km 1-31 Jan 2008
standard dev. [m/s]
0 1 2 3 4 5 6 7 8
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

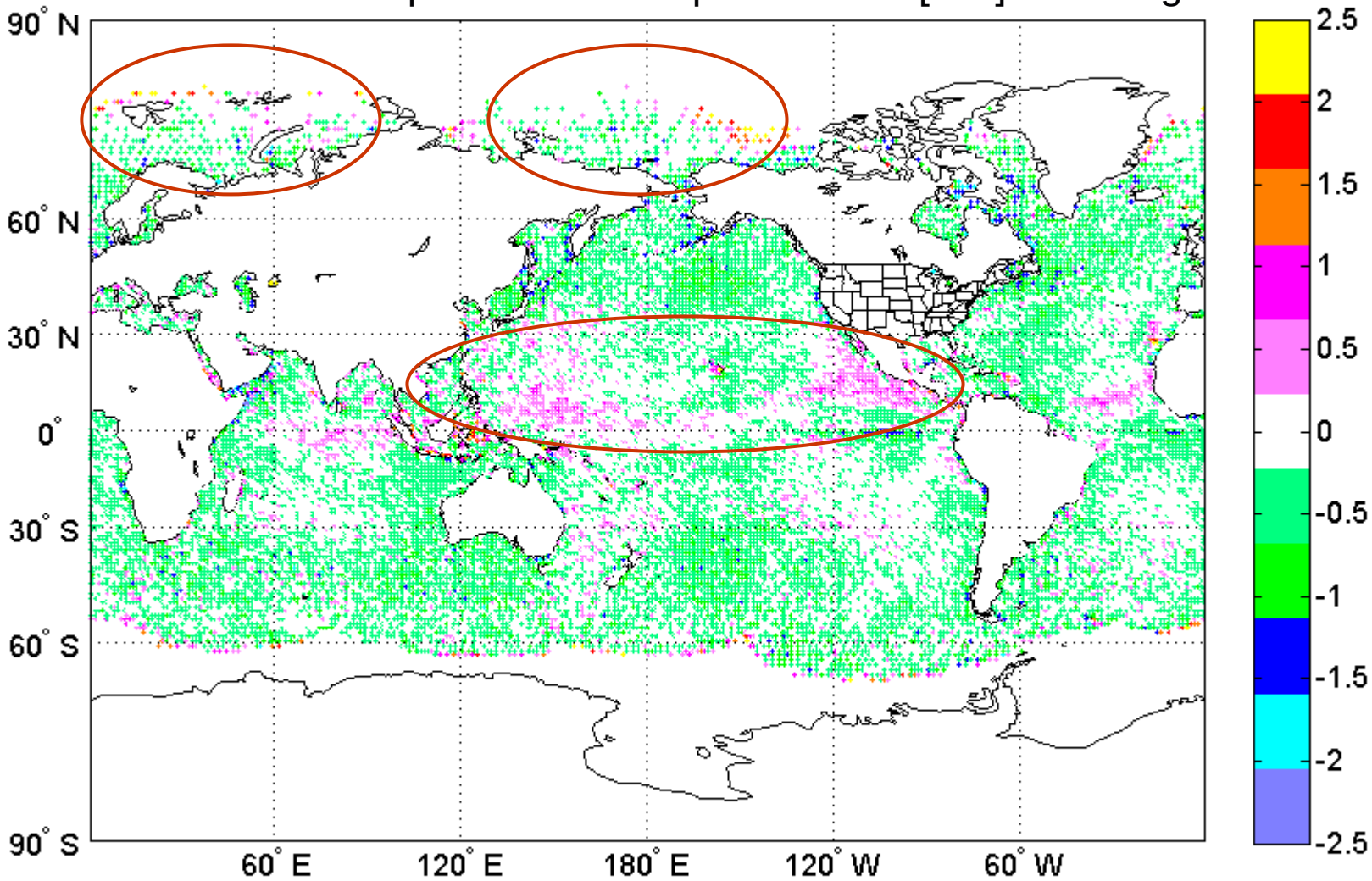
O-A →


ASCAT experiment wind speed by bins standard deviation
obs-analysis 100km 1-31 Jan 2008
standard dev. [m/s]
0 1 2 3 4 5 6 7 8
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

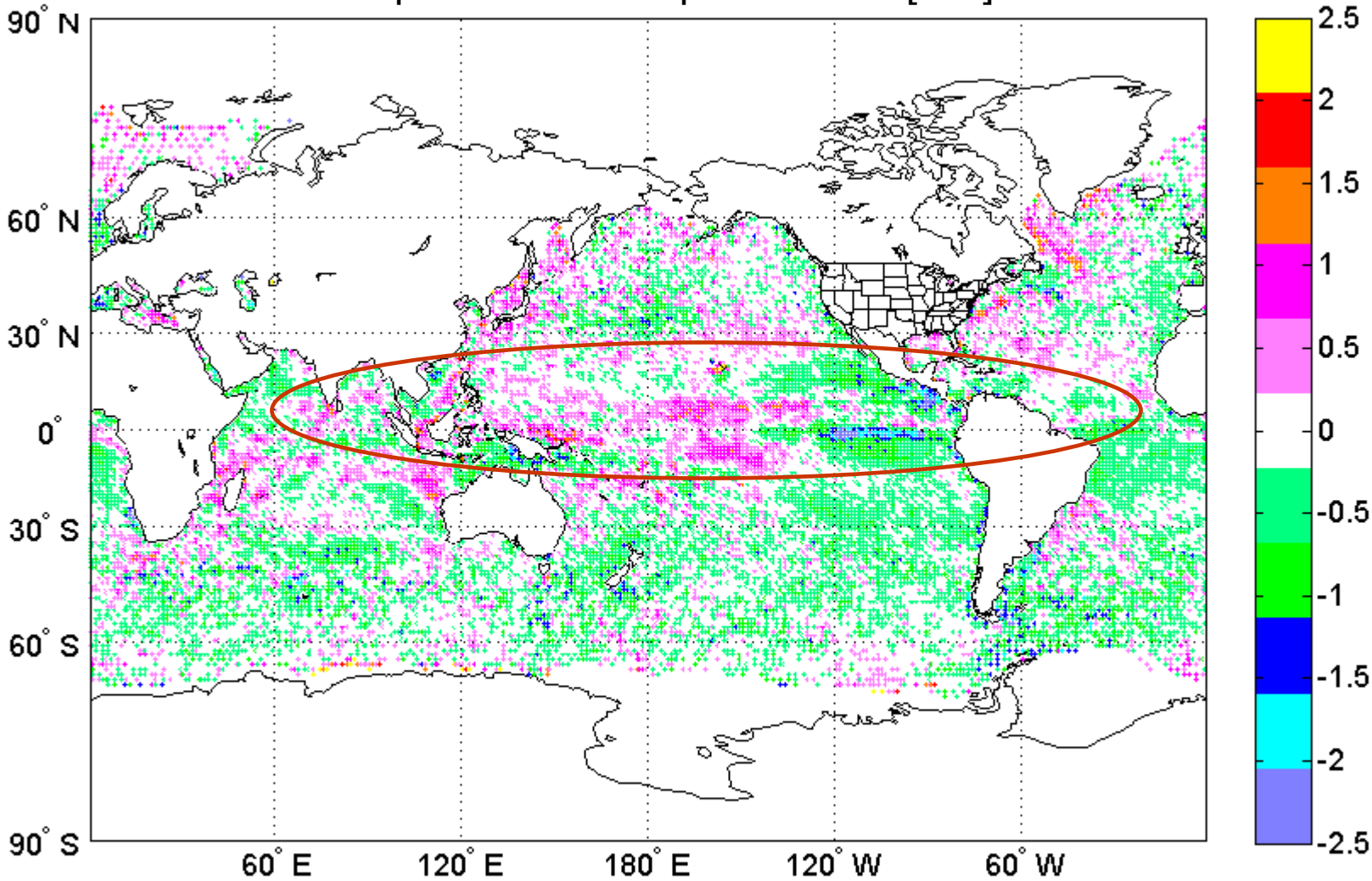
ASCAT geographic statistics results of Aug 2007 and Jan 2008 cont.

- By bins in terms of lon/lat of O-B and O-A
  - u/v and wind speed bias
  - u/v and wind speed standard deviation
  - u/v and wind speed RMS

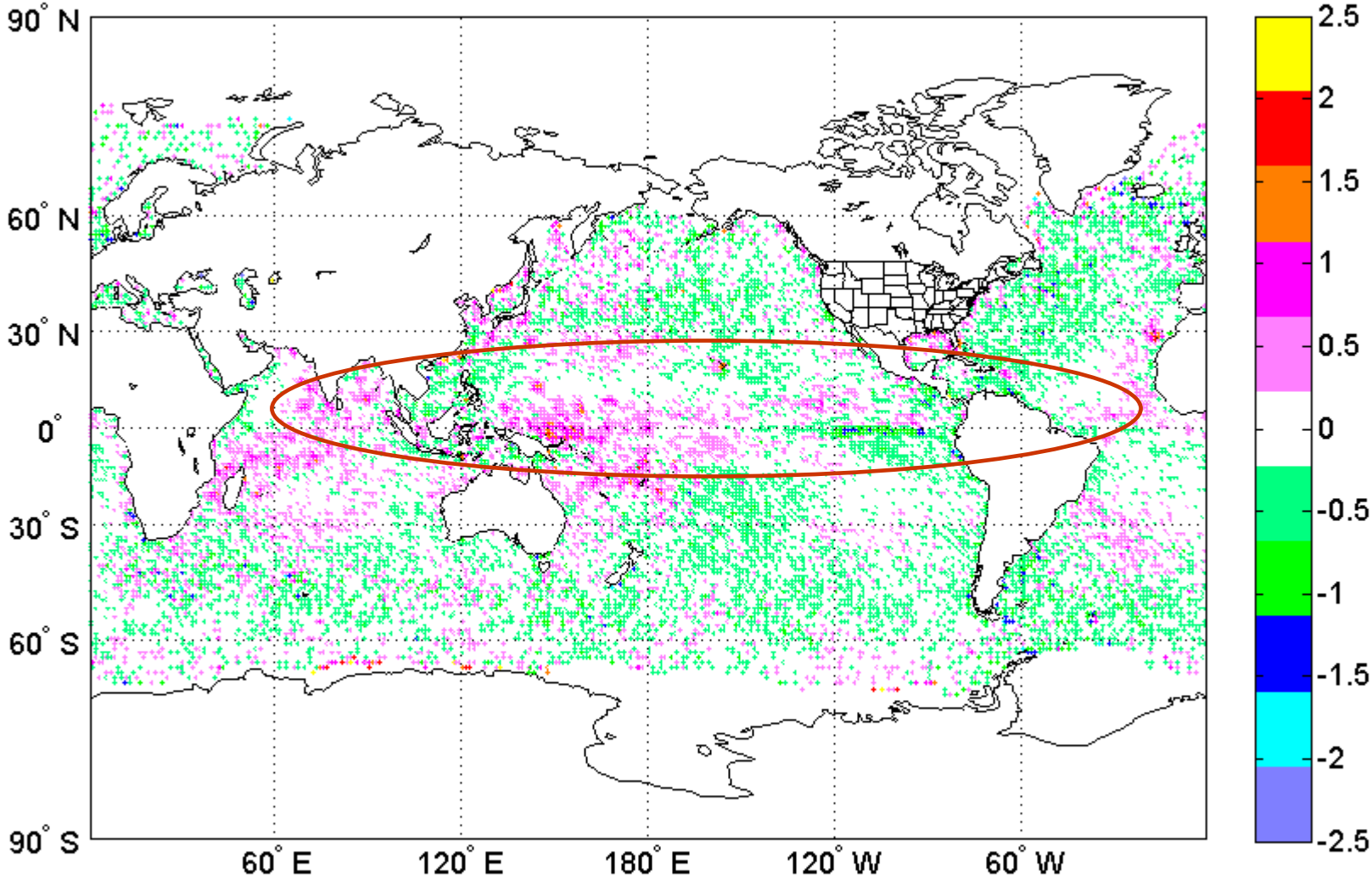

ASCAT 100km experiment wind spd O-B bias [m/s] 1-31 Aug 2007
90° N
60° N
30° N
0°
30° S
60° S
90° S
60° E
120° E
180° E
120° W
60° W
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5


ASCAT 100km experiment wind spd O-A bias [m/s] 1-31 Aug 2007
90° N
60° N
30° N
0°
30° S
60° S
90° S
60° E
120° E
180° E
120° W
60° W
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5

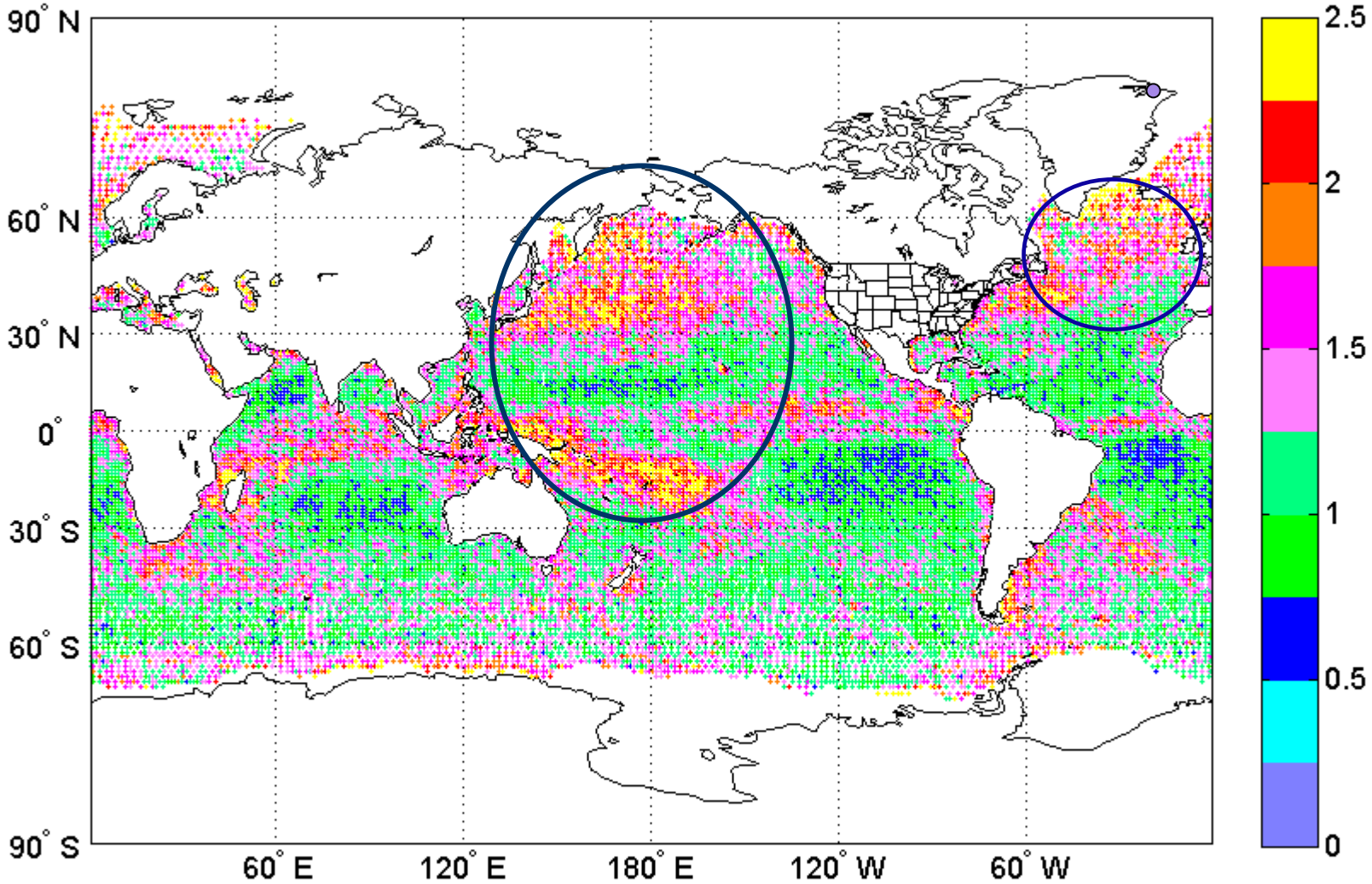
ASCAT 100km experiment wind spd O-B bias [m/s] 1-31 Jan 2008



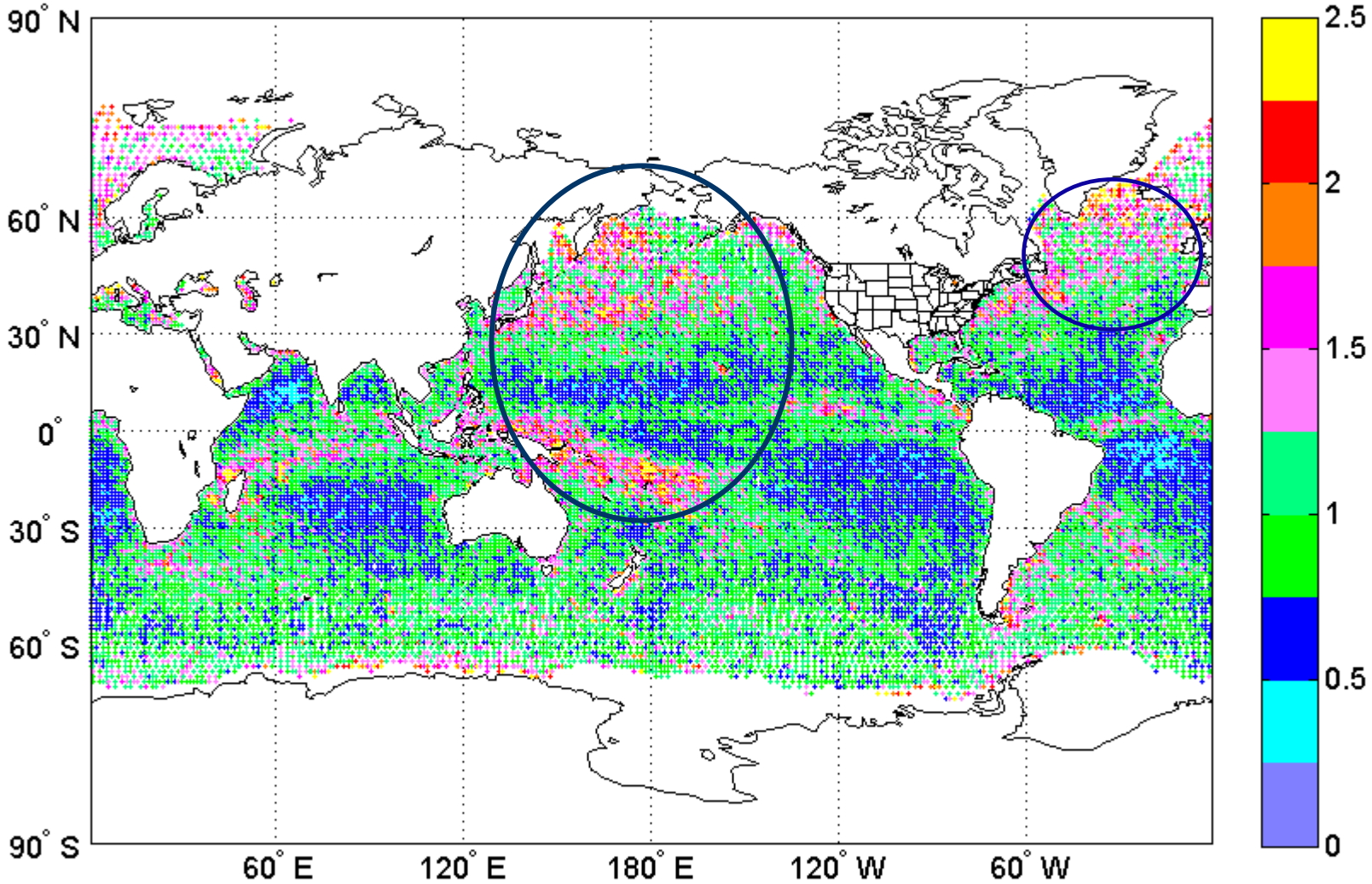
ASCAT 100km experiment wind spd O-A bias [m/s] 1-31 Jan 2008



ASCAT 100km experiment wind spd O-B standard dev. [m/s] 1-31 Jan 2008

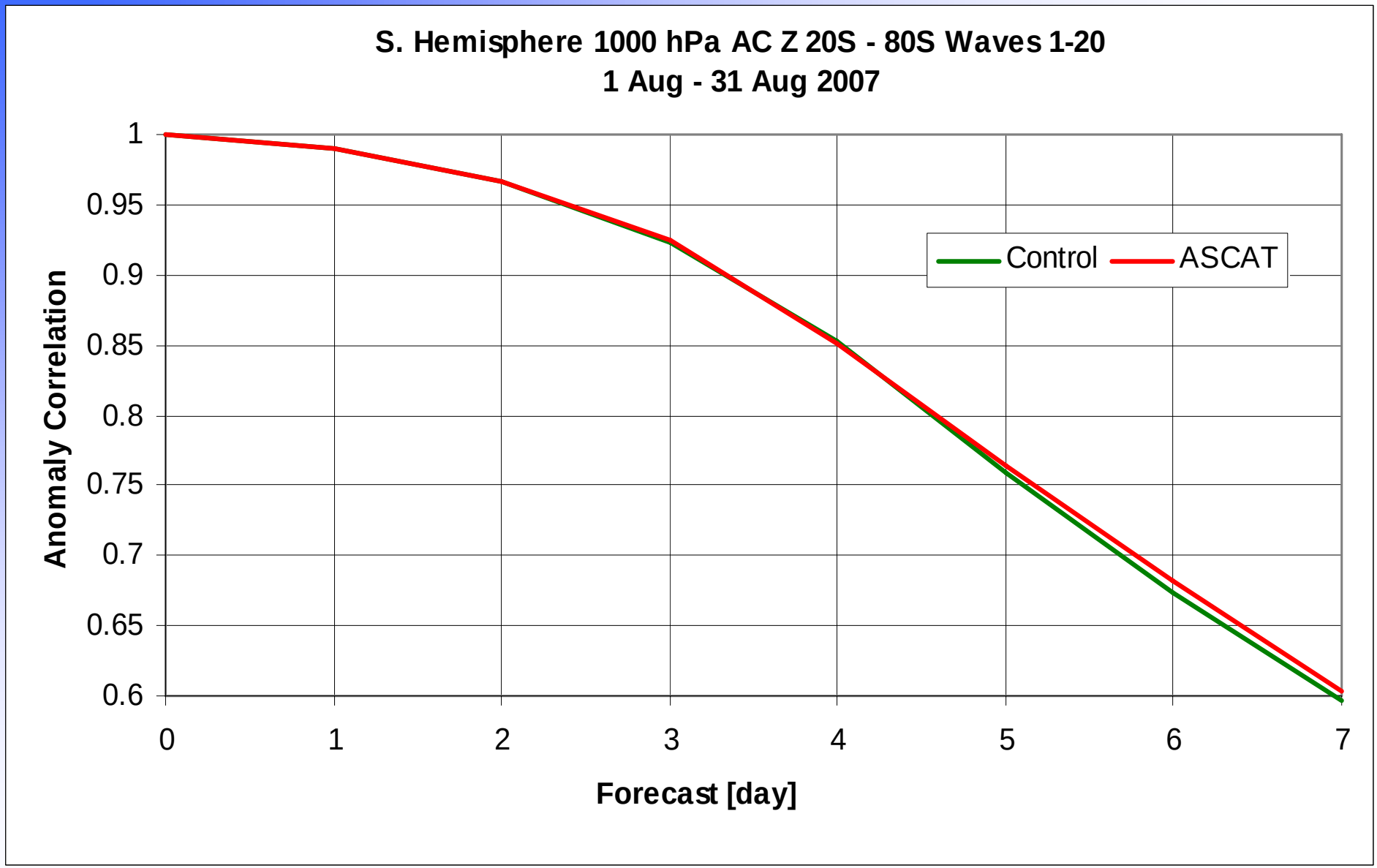


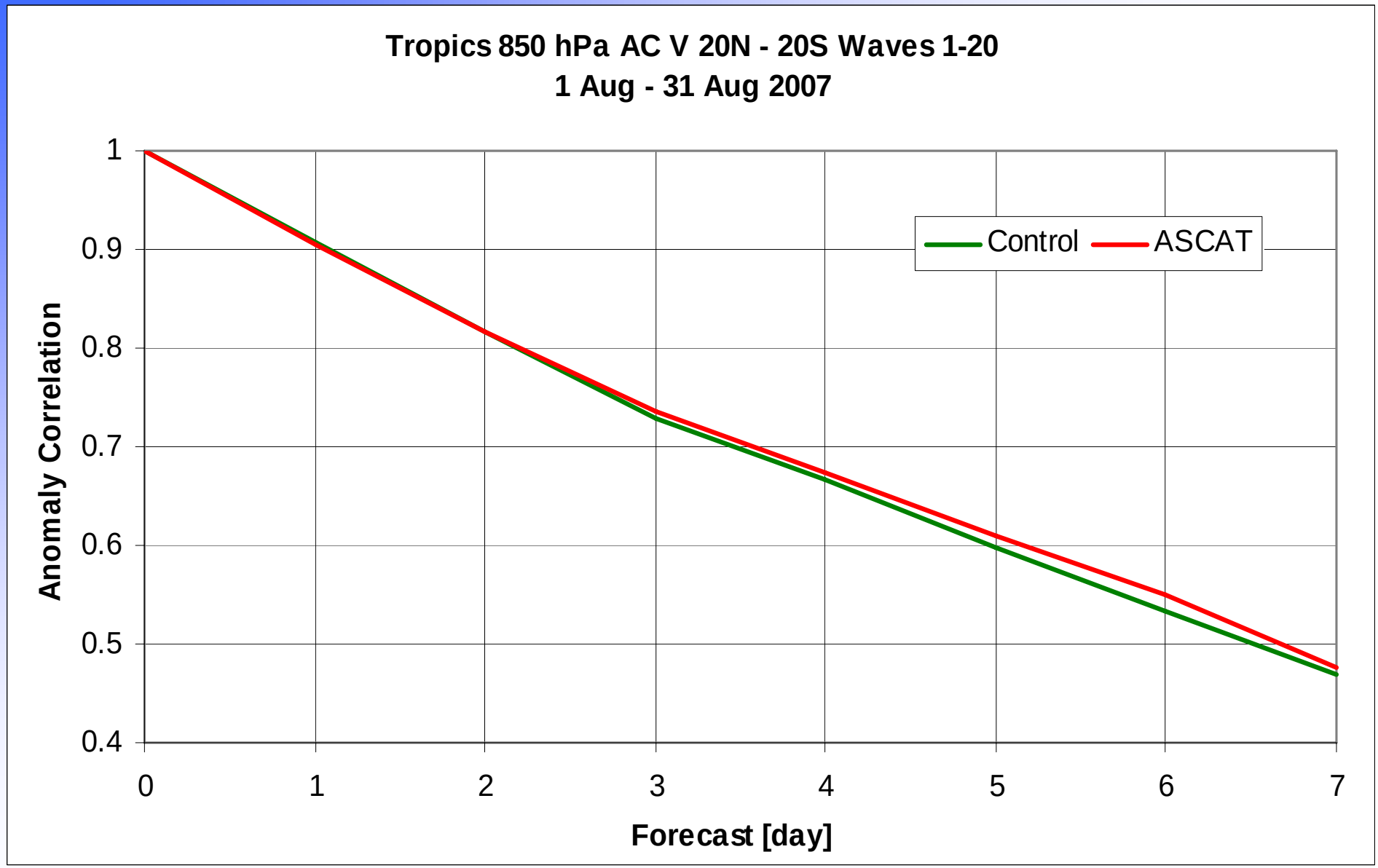
ASCAT 100km experiment wind spd O-A standard dev. [m/s] 1-31 Jan 2008

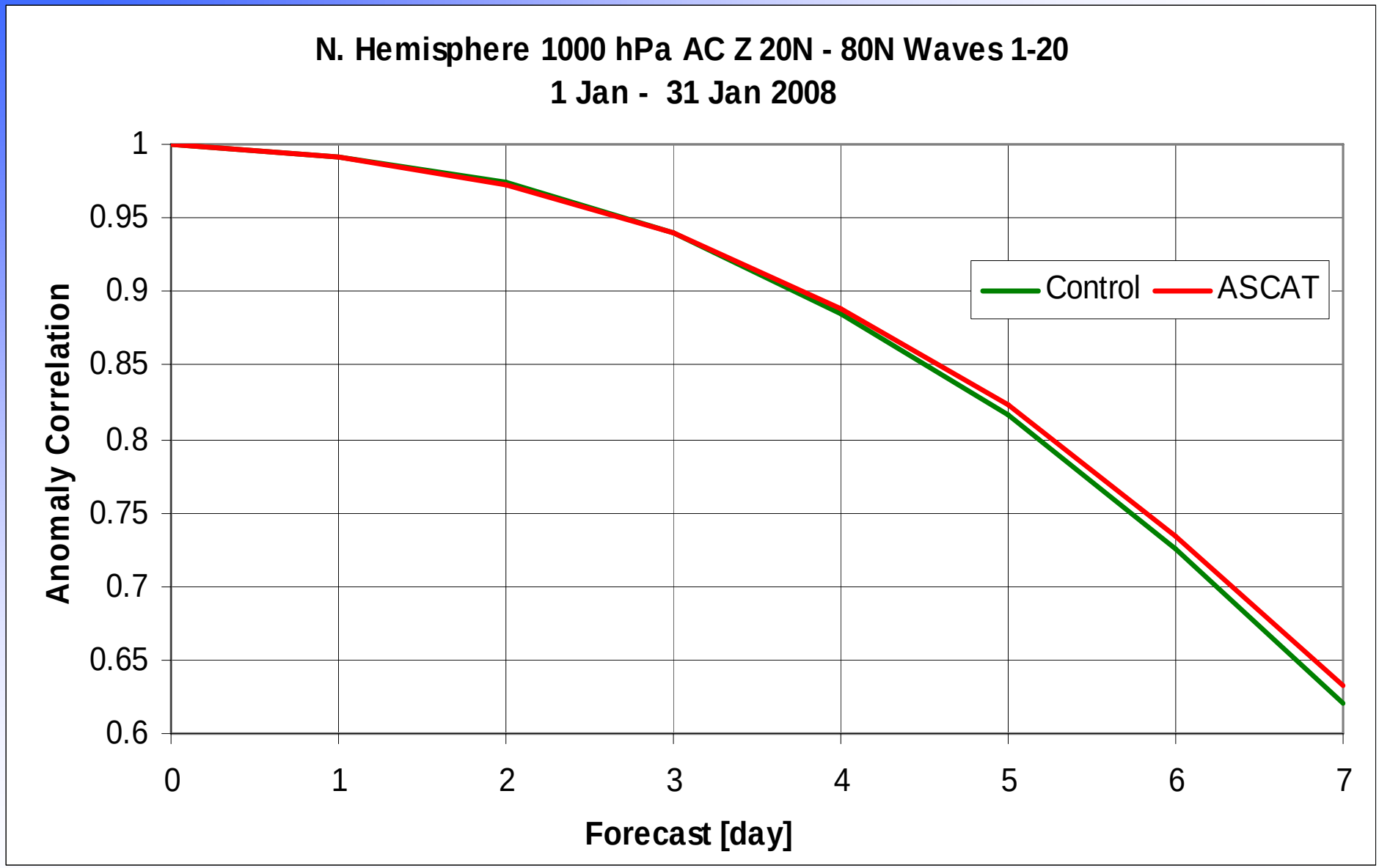


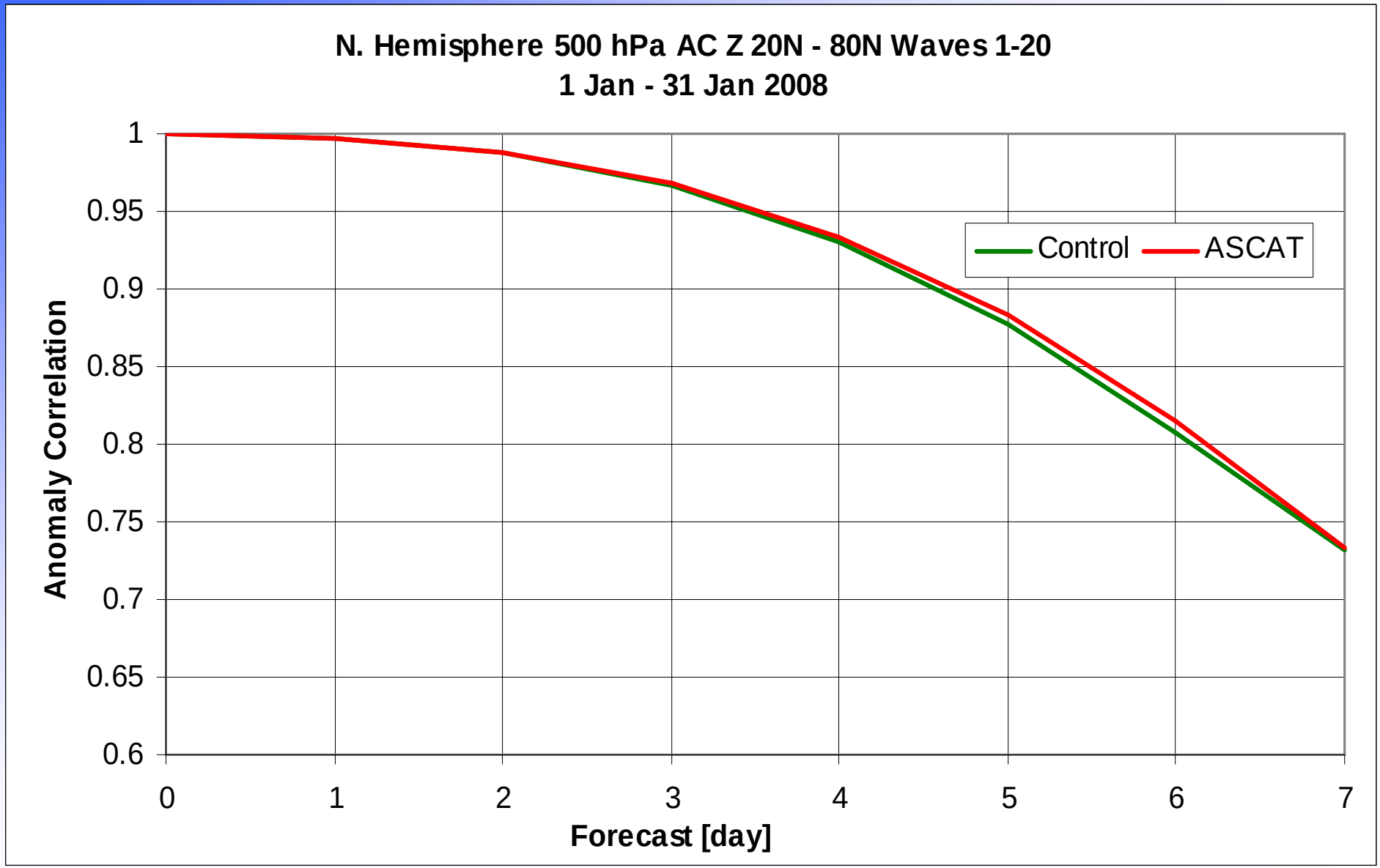
Results from forecast verification

- Anomaly Correlation (AC) results and day 5 AC time series
- Geographic forecast impact (FI) investigations for ASCAT retrieval data
- Vertical time series impacts for ASCAT retrieval data


S. Hemisphere 1000 hPa AC Z 20S - 80S Waves 1-20
1 Aug - 31 Aug 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
ASCAT


Tropics 850 hPa AC V 20N - 20S Waves 1-20
1 Aug - 31 Aug 2007
Anomaly Correlation
1
0.9
0.8
0.7
0.6
0.5
0.4
0
1
2
3
4
5
6
7
Forecast [day]
Control
ASCAT


N. Hemisphere 1000 hPa AC Z 20N - 80N Waves 1-20
1 Jan - 31 Jan 2008
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
ASCAT


N. Hemisphere 500 hPa AC Z 20N - 80N Waves 1-20
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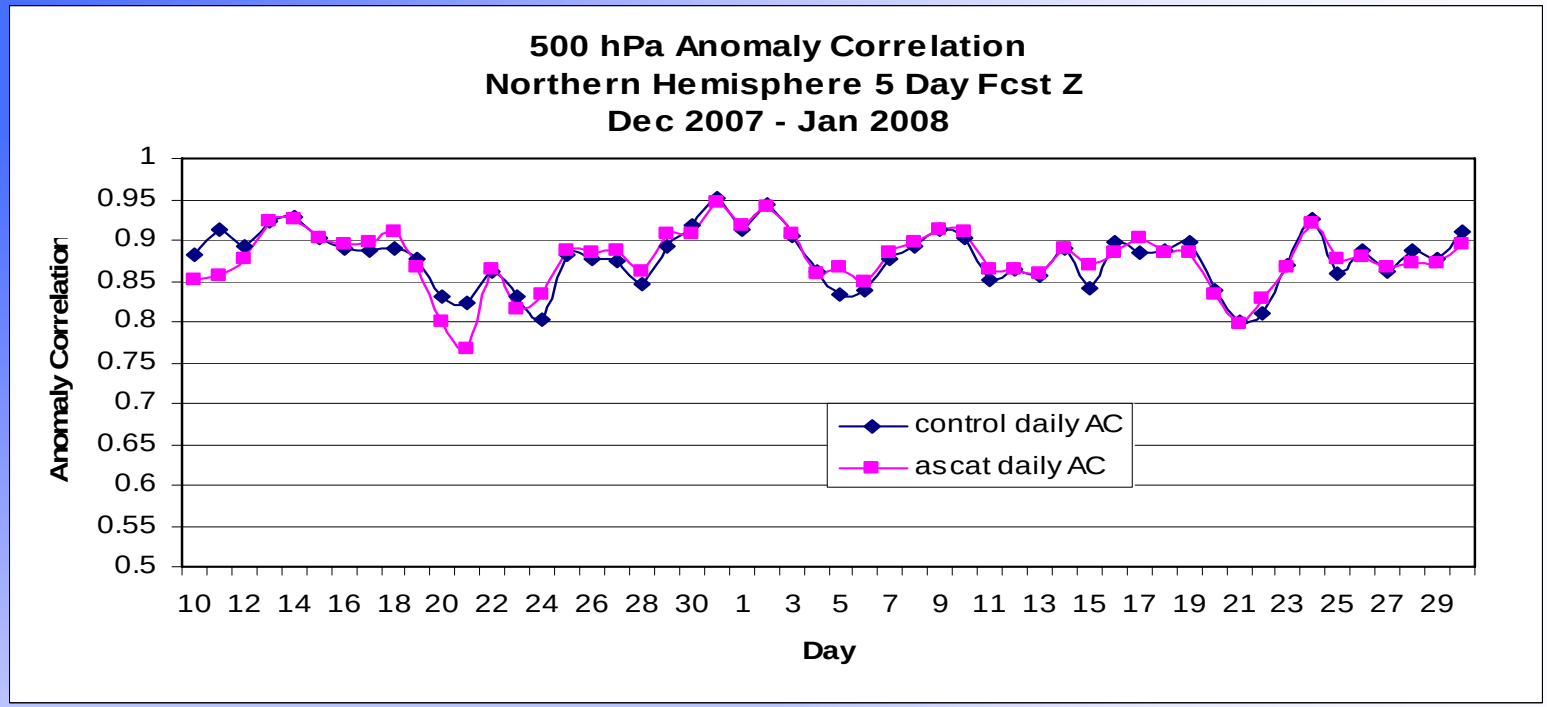
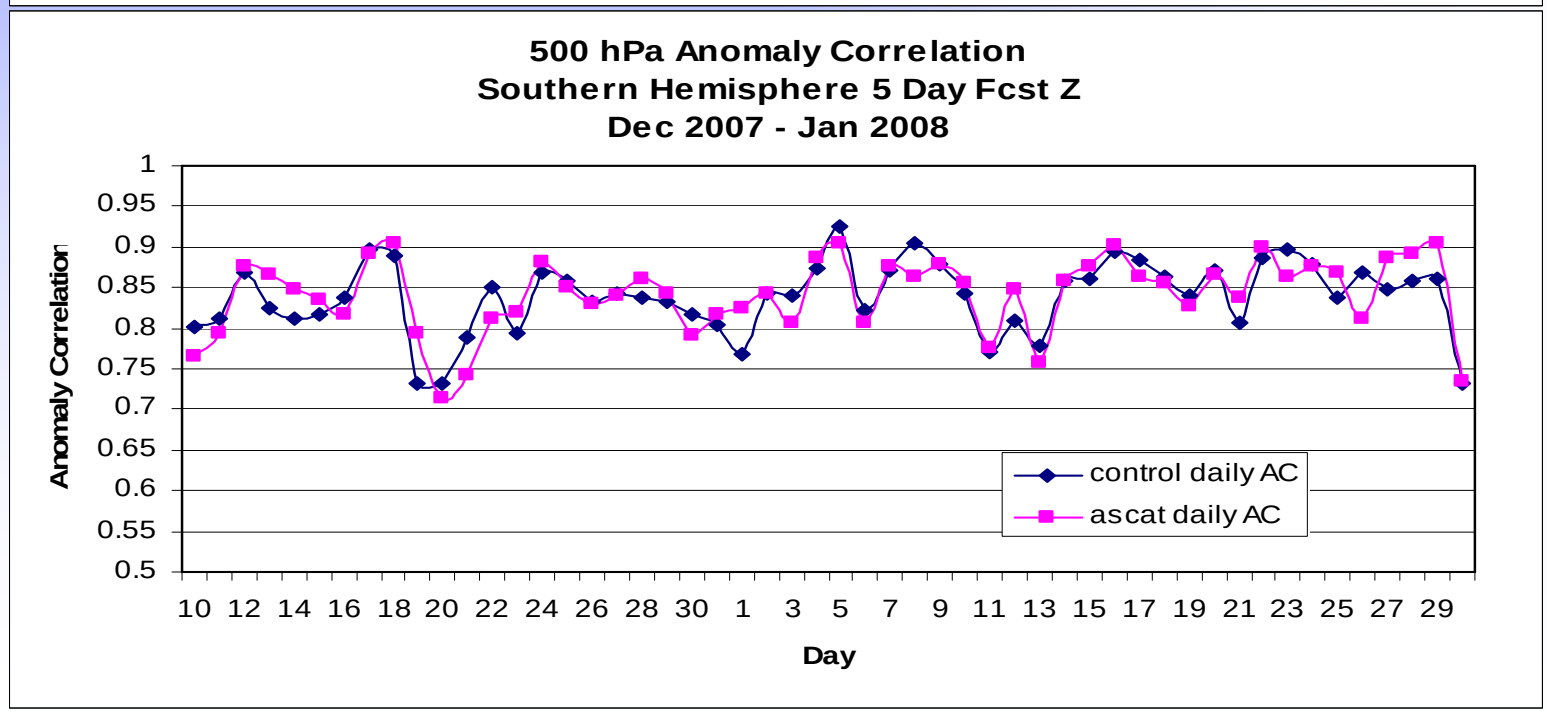
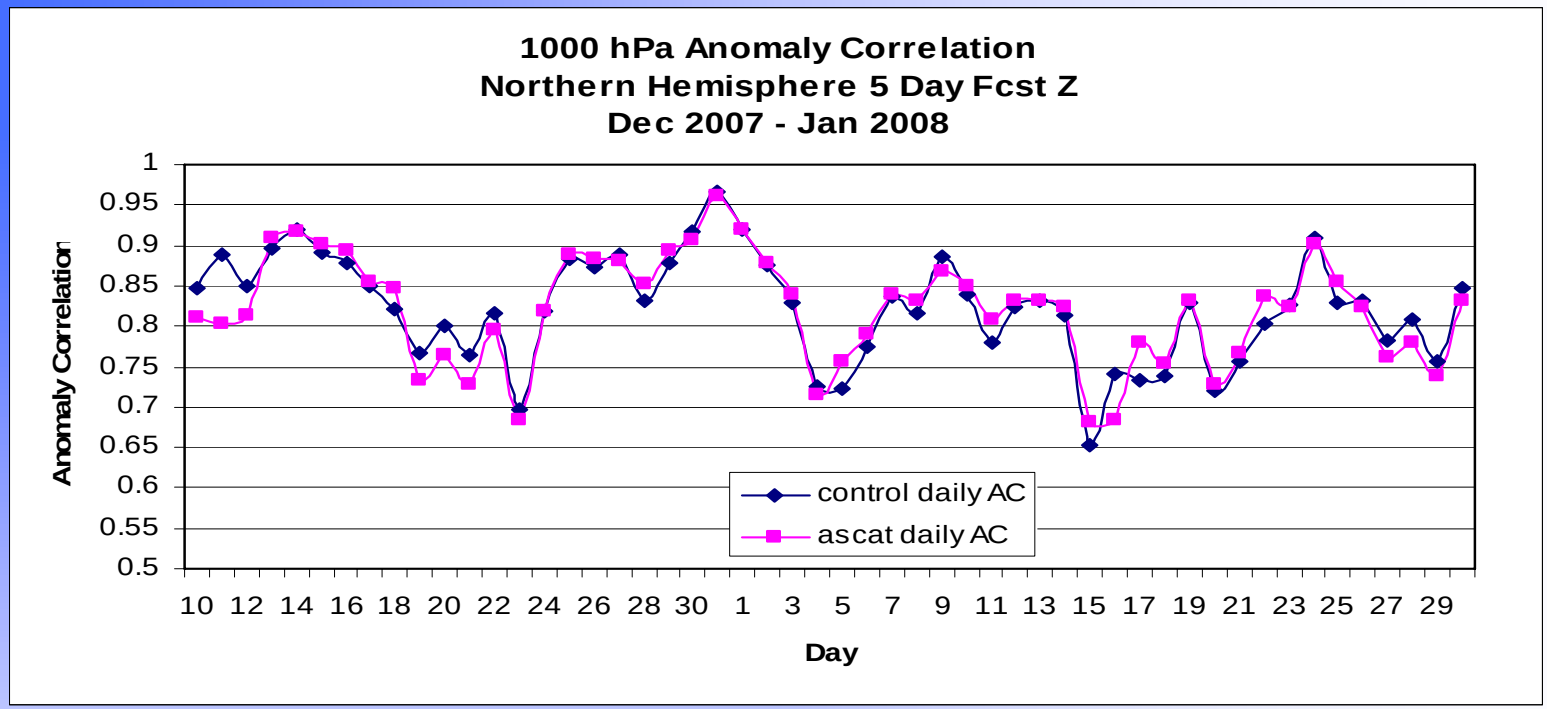
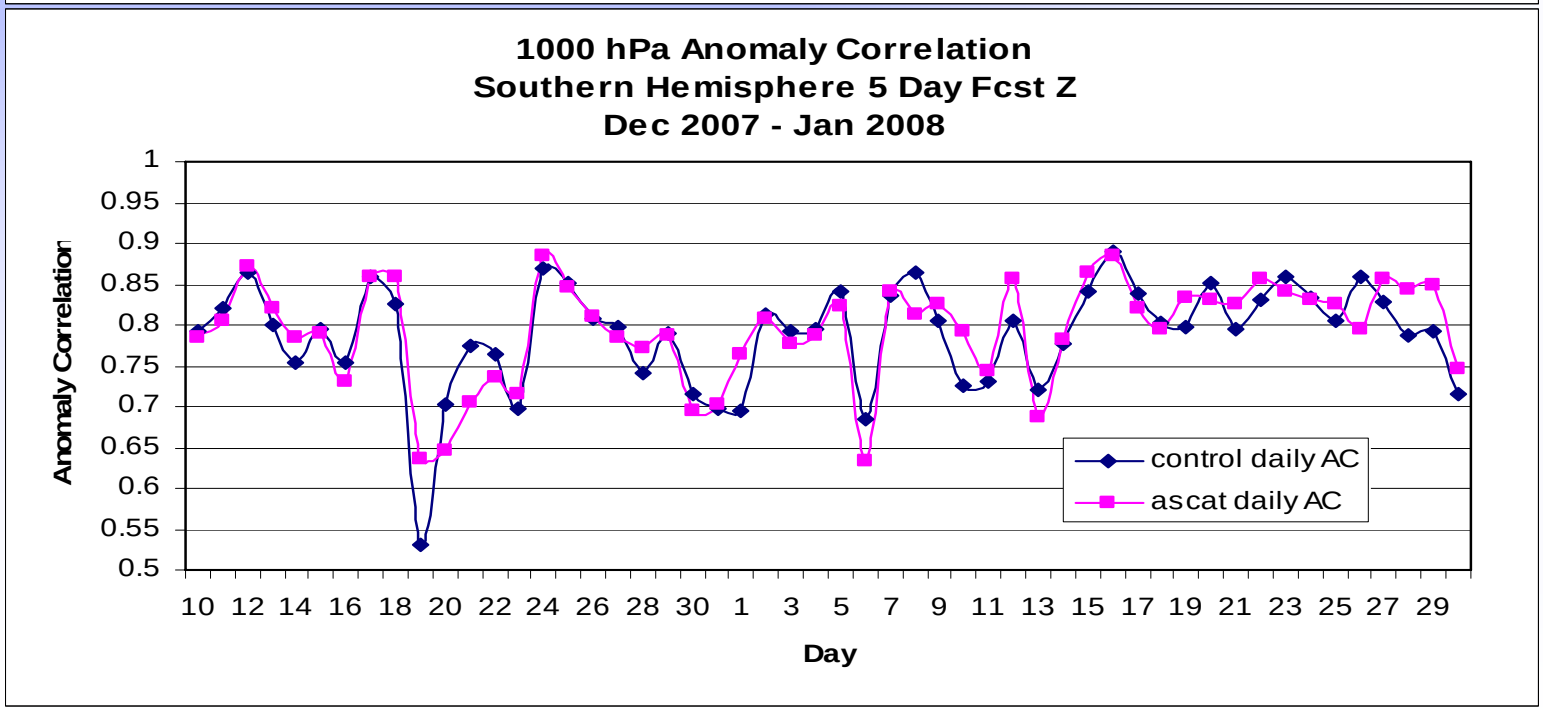
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
1
2
3
4
5
6
7
Forecast [day]
Control
ASCAT


500 hPa Anomaly Correlation
Northern Hemisphere 5 Day Fcst Z
Dec 2007 - Jan 2008
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Day
control daily AC
ascat daily AC


500 hPa Anomaly Correlation
Southern Hemisphere 5 Day Fcst Z
Dec 2007 - Jan 2008
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Day
control daily AC
ascat daily AC


1000 hPa Anomaly Correlation
Northern Hemisphere 5 Day Fcst Z
Dec 2007 - Jan 2008
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Day
control daily AC
ascat daily AC


1000 hPa Anomaly Correlation
Southern Hemisphere 5 Day Fcst Z
Dec 2007 - Jan 2008
Anomaly Correlation
1
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0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Day
control daily AC
ascat daily AC

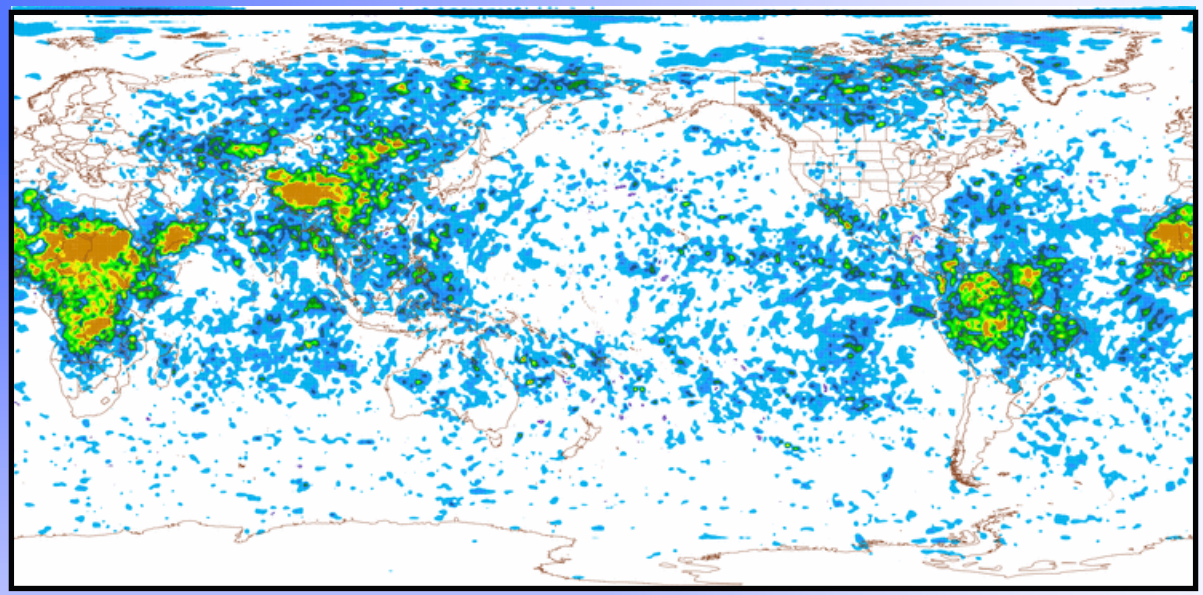
Results from forecast verification Cont.

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

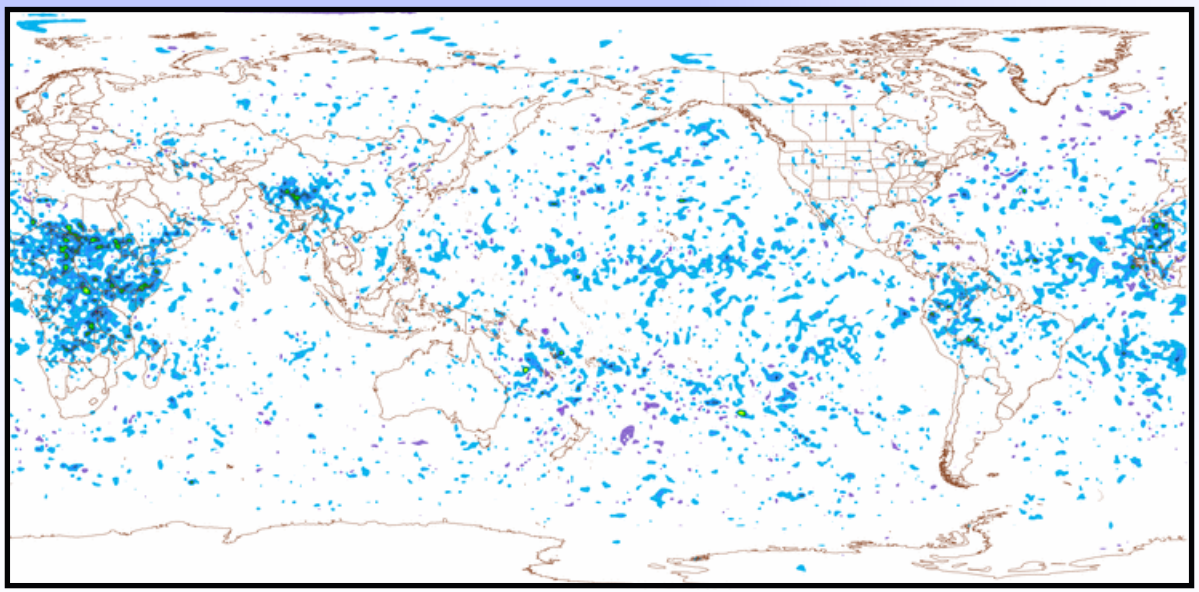
$$FI(x,y) = 100 \times \{ [\sqrt{\frac{\sum_{i=1}^{N} (C_i - A_i)^2}{N}} - \sqrt{\frac{\sum_{i=1}^{N} (E_i - A_i)^2}{N}}] / \sqrt{\frac{\sum_{i=1}^{N} (E_i - A_i)^2}{N}} \}$$

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

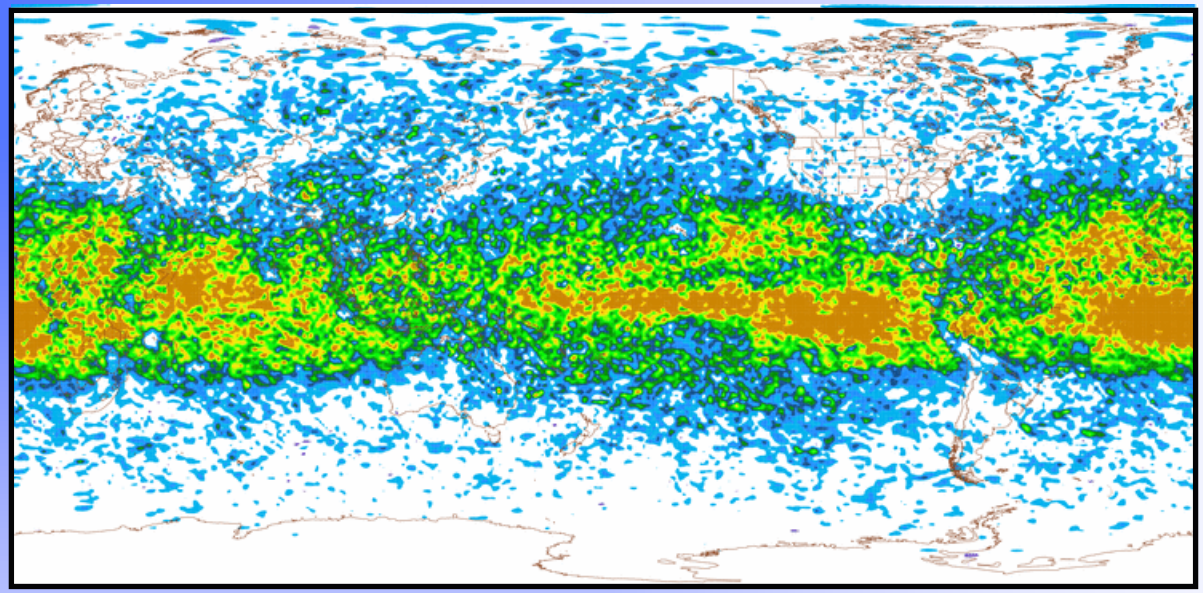
(a) 10m WIND SPEED FCST IMPACT [%] 6HR ASCAT 1-31 Aug 2007



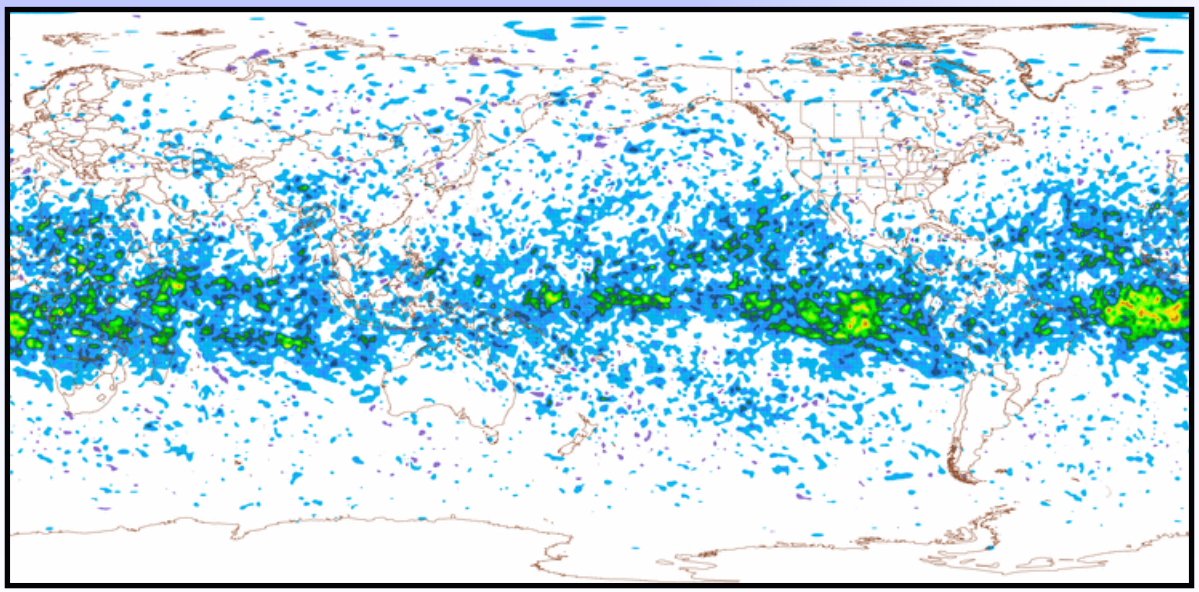
(b) 10m WIND SPEED FCST IMPACT [%] 24HR ASCAT 1-31 Aug 2007



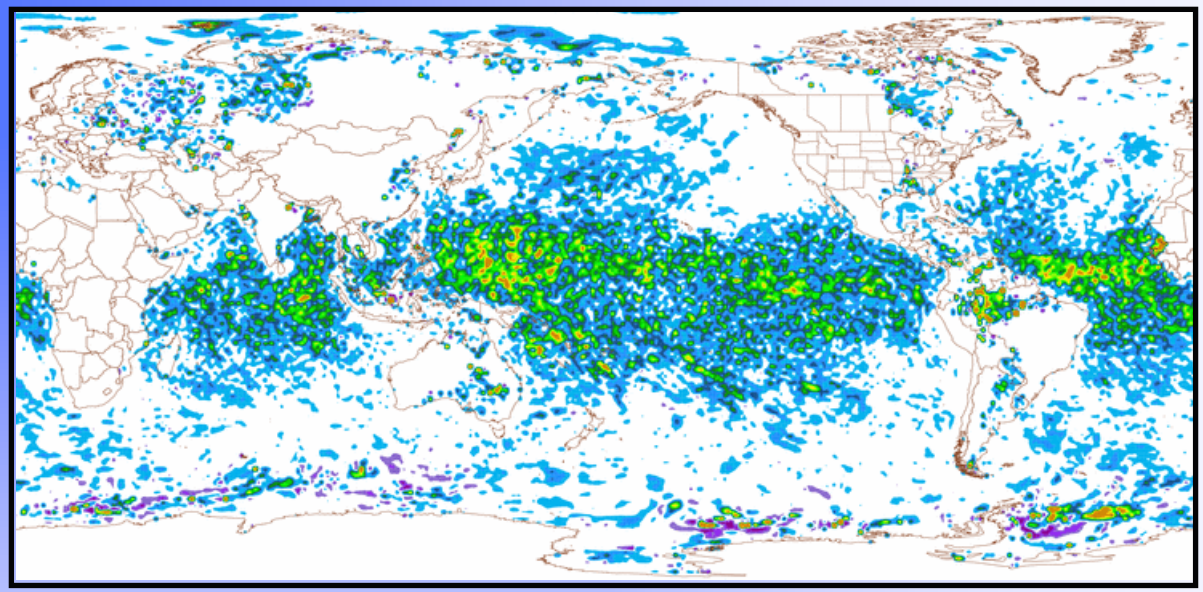
(a) 500hPa WIND SPEED FCST IMPACT [%] 6HR ASCAT 1-31 Aug 2007



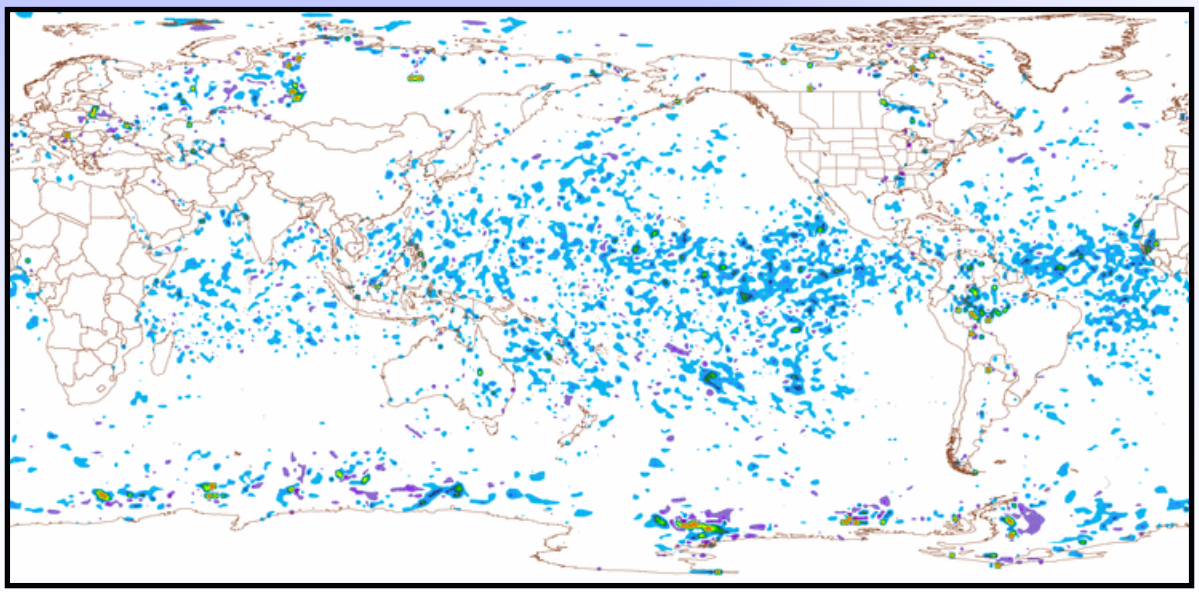
(b) 500hPa WIND SPEED FCST IMPACT [%] 24HR ASCAT 1-31 Aug 2007



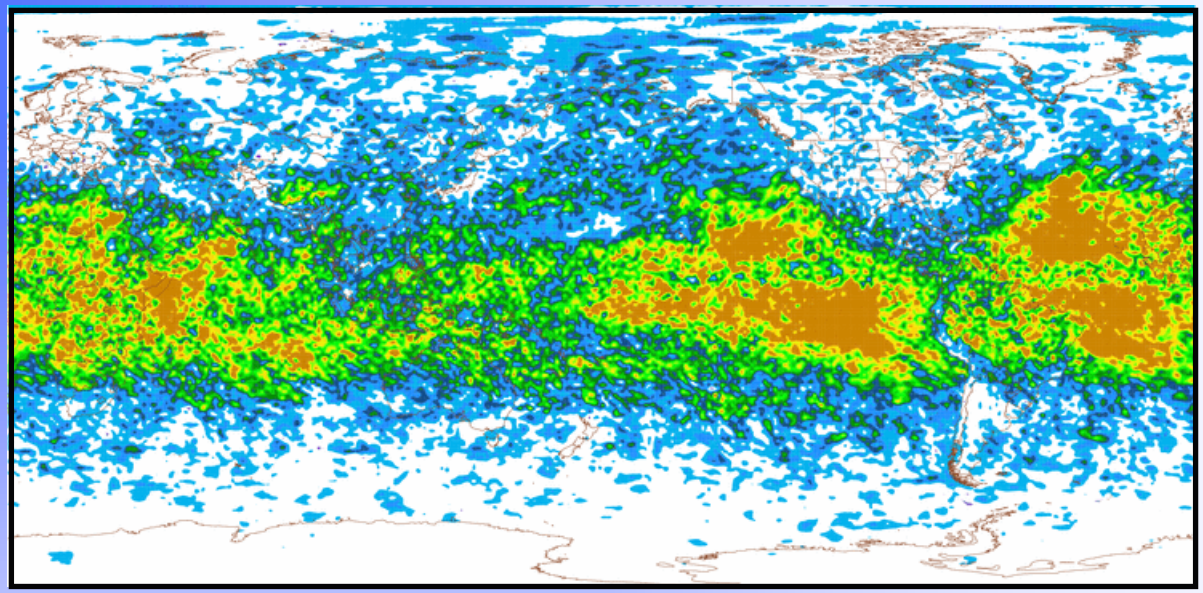
(a) 1000hPa TEMP FCST IMPACT [%] 6HR ASCAT 1-31 Aug 2007



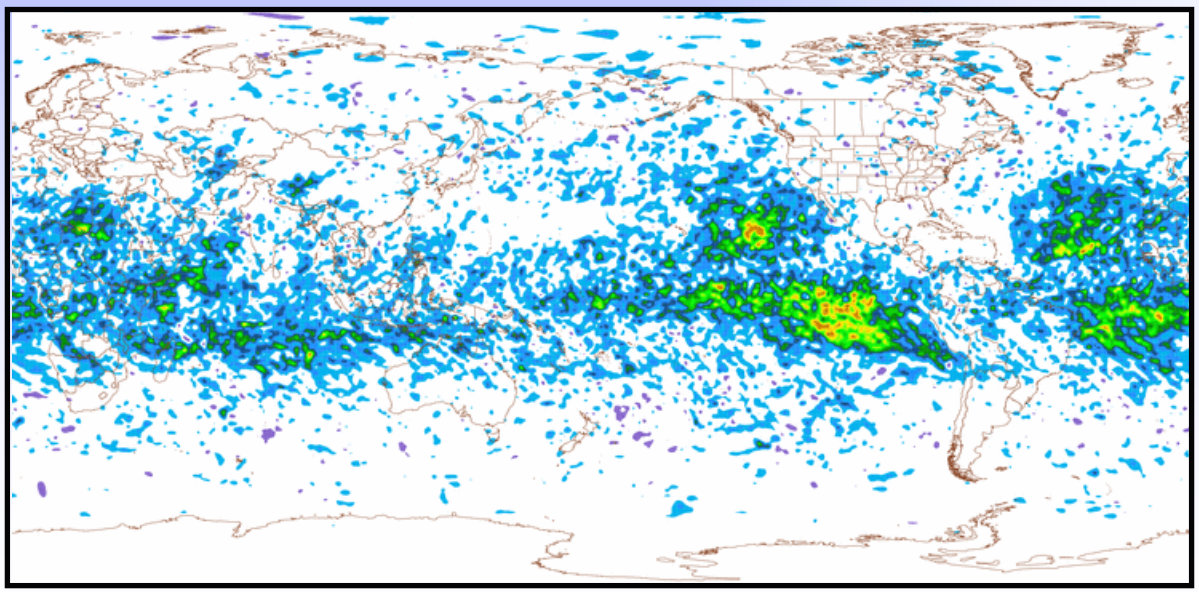
(b) 1000hPa TEMP FCST IMPACT [%] 24HR ASCAT 1-31 Aug 2007



(a) 500hPa TEMP FCST IMPACT [%] 6HR ASCAT 1-31 Aug 2007



(b) 500hPa TEMP FCST IMPACT [%] 24HR ASCAT 1-31 Aug 2007

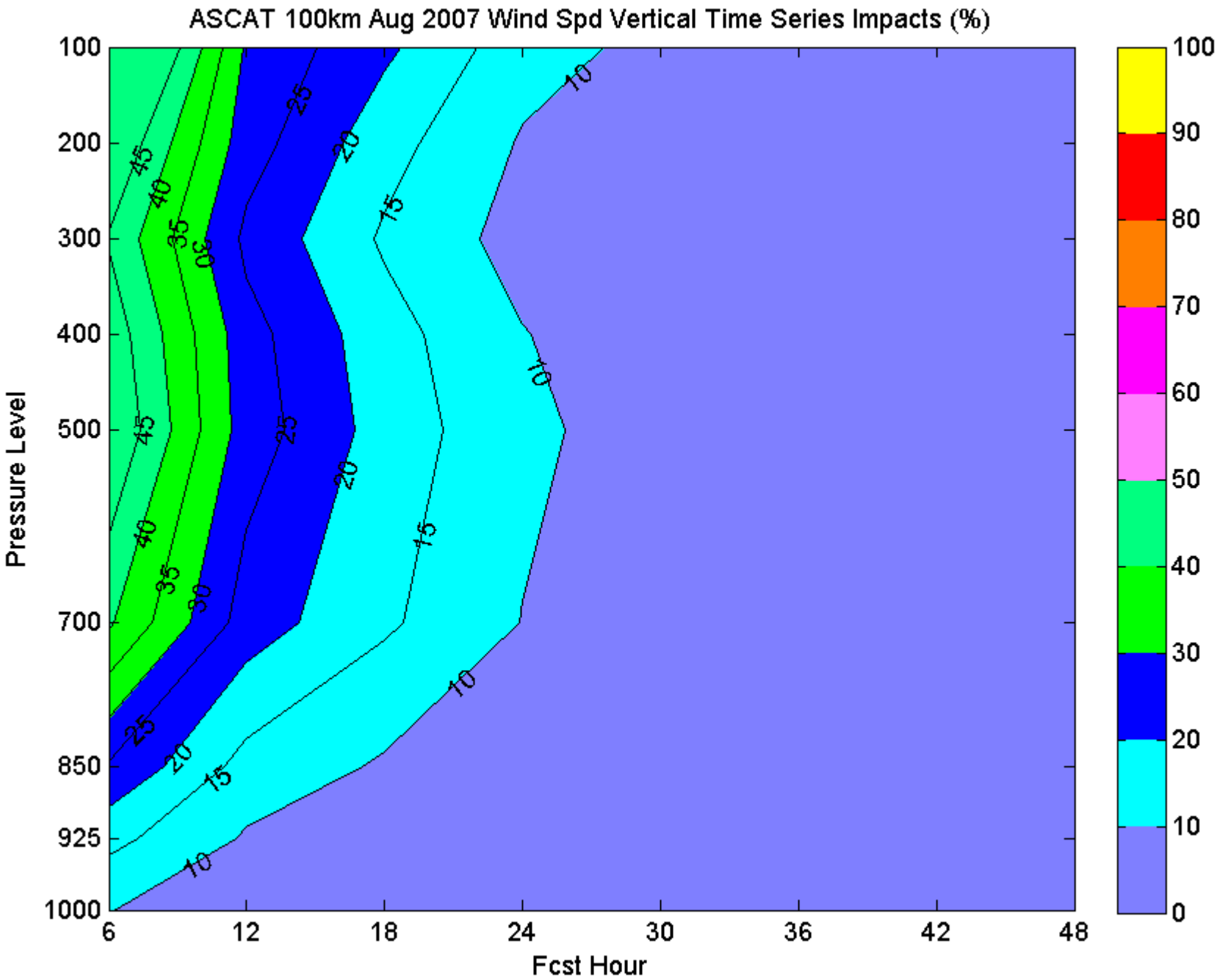


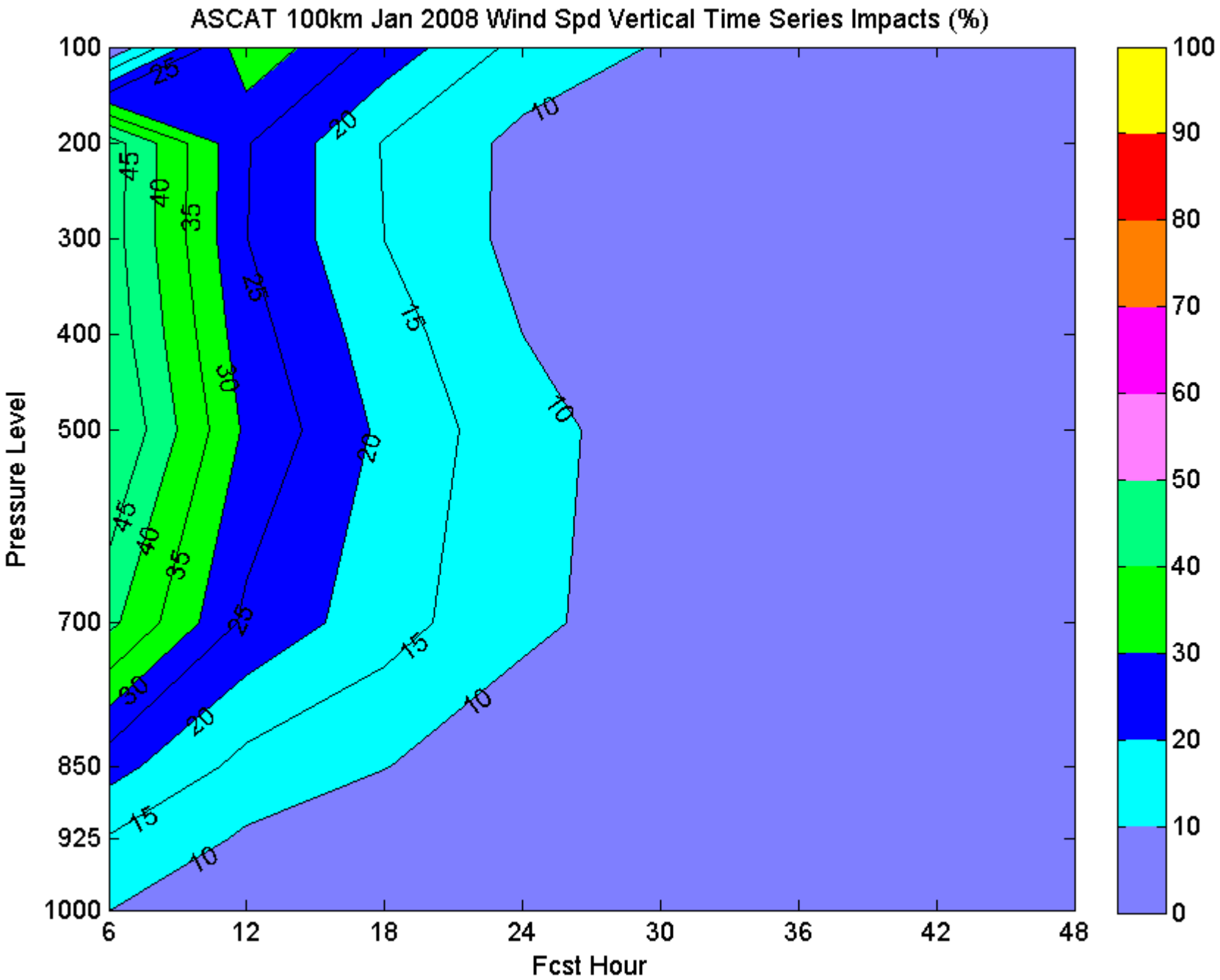
Results of from forecast verification Cont.

- Vertical time series impacts for ASCAT retrieval data

$$FI(t,z) = 100 \times \left[\frac{\sqrt{\frac{\sum_{i=1}^{X} (C_i^{'} - A_i^{'})^2}{X}} - \sqrt{\frac{\sum_{i=1}^{X} (E_i^{'} - A_i^{'})^2}{X}}}{\sqrt{\frac{\sum_{i=1}^{X} (E_i^{'} - A_i^{'})^2}{X}}} \right]$$

Area ratio weighting ⟶ $$\mathrm{A}'i = \mathrm{A}i \times \frac{\sin(\phi i + \frac{\Delta}{2}) - \sin(\phi i - \frac{\Delta}{2})}{2\sin(\frac{\Delta}{2})}$$


ASCAT 100km Aug 2007 Wind Spd Vertical Time Series Impacts (%)
Pressure Level
100
200
300
400
500
700
850
925
1000
6
12
18
24
30
36
42
48
Fcst Hour
45
40
35
30
25
20
15
10
0
90
80
70
60
50


ASCAT 100km Jan 2008 Wind Spd Vertical Time Series Impacts (%)
Pressure Level
100
200
300
400
500
700
850
925
1000
6
12
18
24
30
36
42
48
Fcst Hour
0
10
20
30
40
50
60
70
80
90
100

Conclusions of ASCAT analysis

- There are unsolved problems near the poles in the ASCAT analysis due to observations that may be contaminated by ice.
- Large O-B standard deviations are noted in the central Pacific and north Atlantic.
- Improvements of O-A standard deviations are noted in the ASCAT analysis.

Conclusions of current work

- Anomaly correlations show neutral to modest improvements.
- Positive Forecast Impacts occurred in the wind and temperature fields
- Greatest Forecast Impacts occurred of the wind and temperature fields in the Tropics and at 500 hPa
- Positive Forecast Impacts of the wind field are noted at all levels of the GFS through 48 hours.

Future work

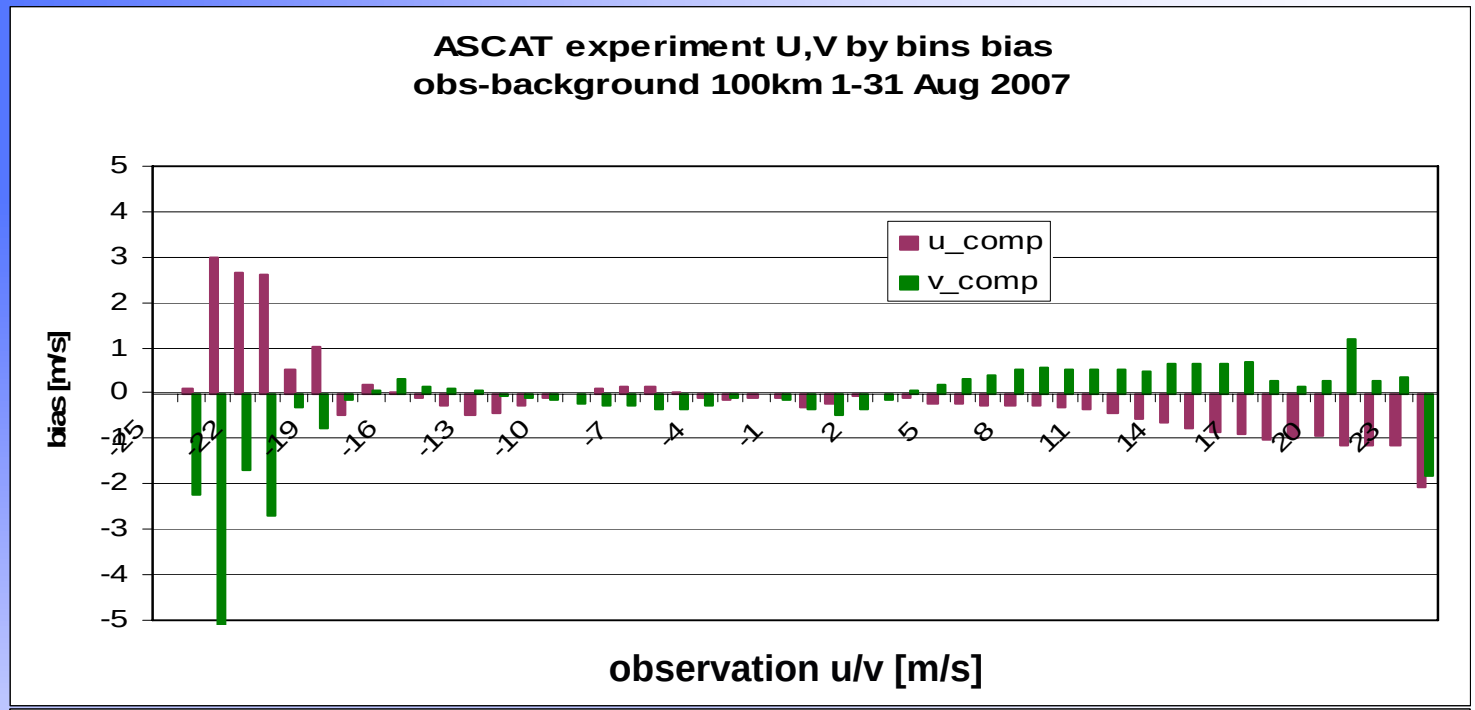
- Continue working on the quality control procedures:
  - identify and remove observations that are contaminated by ice near the poles.
  - Investigate, in greater detail, regions of high bias and standard deviations for possible improvements.
- Develop and test new thinning techniques in the GSI
  - adaptive thinning algorithms from Leslie et al.
  - other resolutions (150, 50 km box)

Acknowledgements

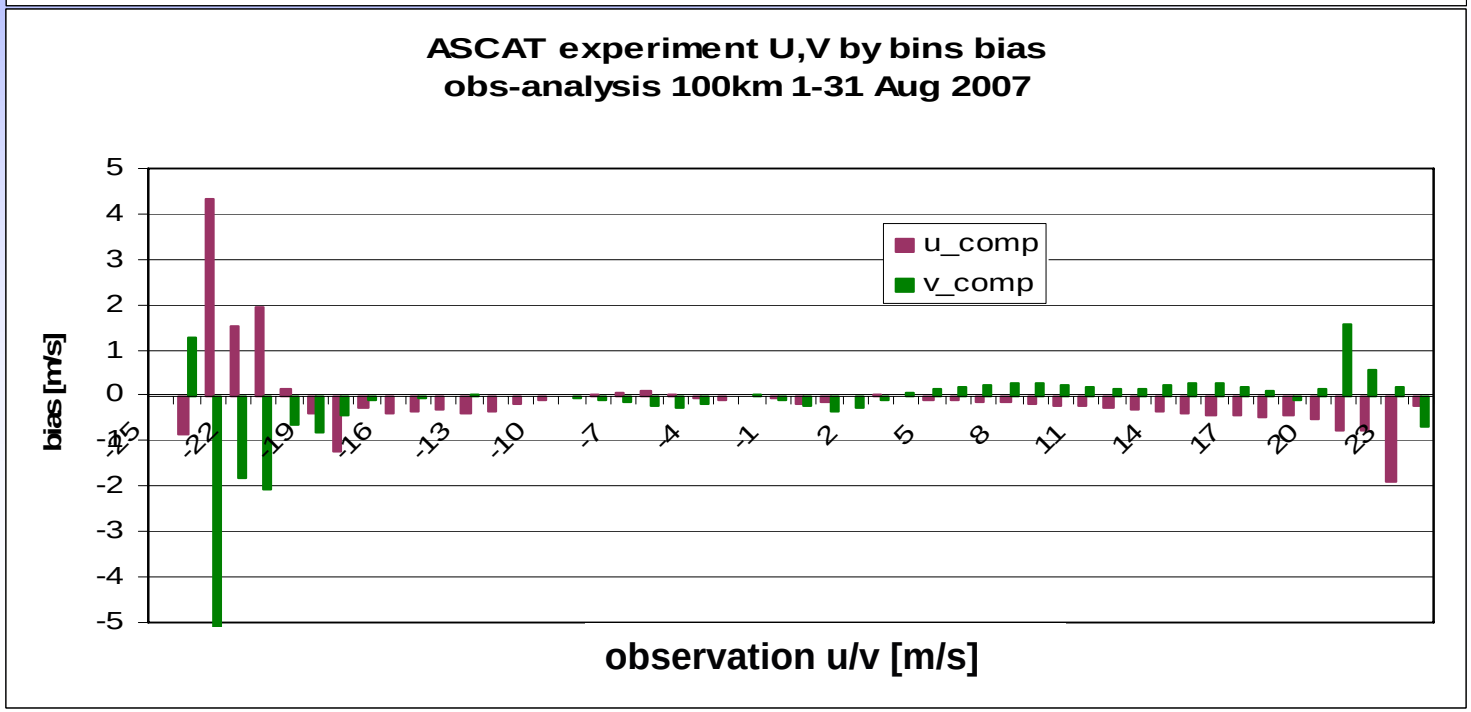
- Stephen Lord (NCEP) for GFS/GDAS, computer resources and tape space
- Zorana Jelenak for providing ASCAT data
- Prof. Michael Morgan (UW-AOS) for local computer resources
- John Derber, Lars Peter Riishojgaard and Paul Chang for giving insightful advice
- Russ Treadon for helping with GSI code
- Dennis Keyser and Stacie Bender for collecting and processing our various data streams
- The JCSDA for the computer time required for this study

Back up slides

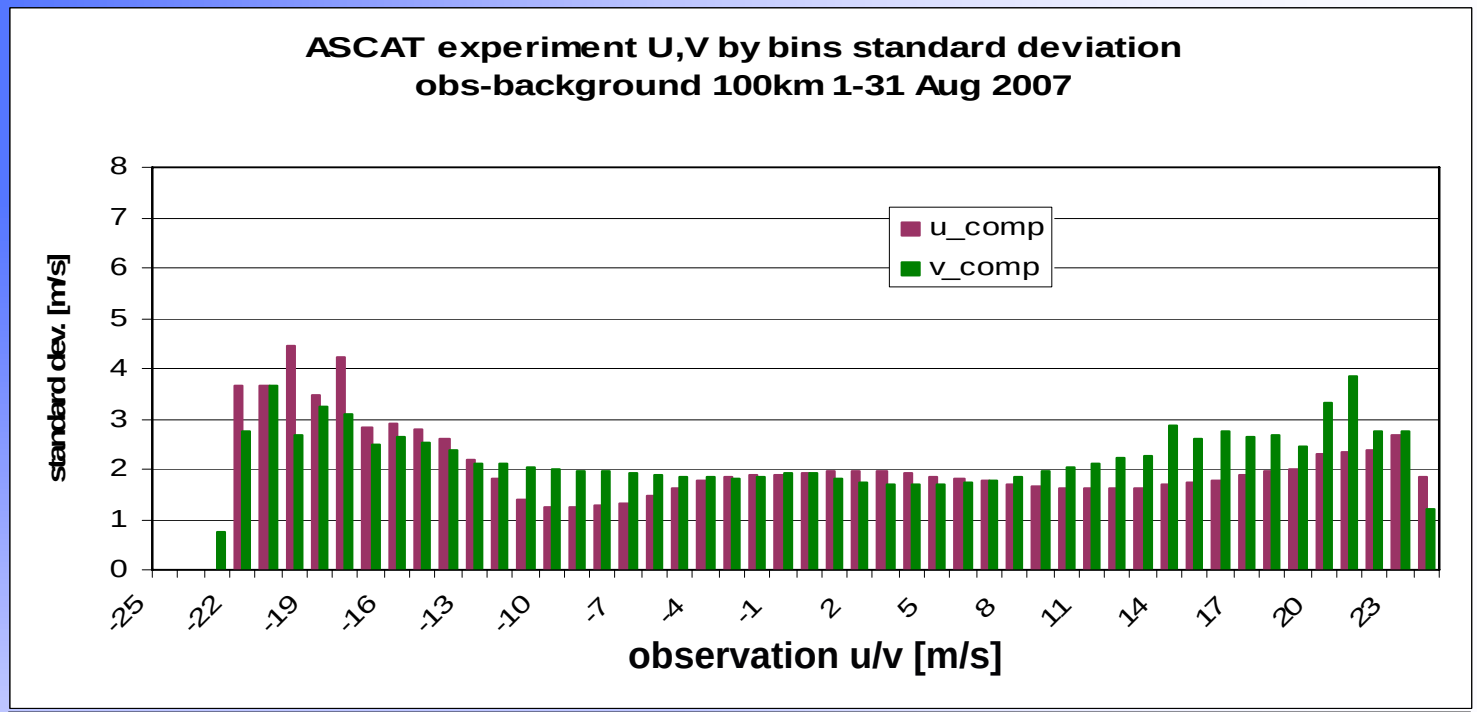
O-B →


ASCAT experiment U,V by bins bias
obs-background 100km 1-31 Aug 2007
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
-25
-22
-19
-16
-13
-10
-7
-4
-1
2
5
8
11
14
17
20
23
u_comp
v_comp
observation u/v [m/s]

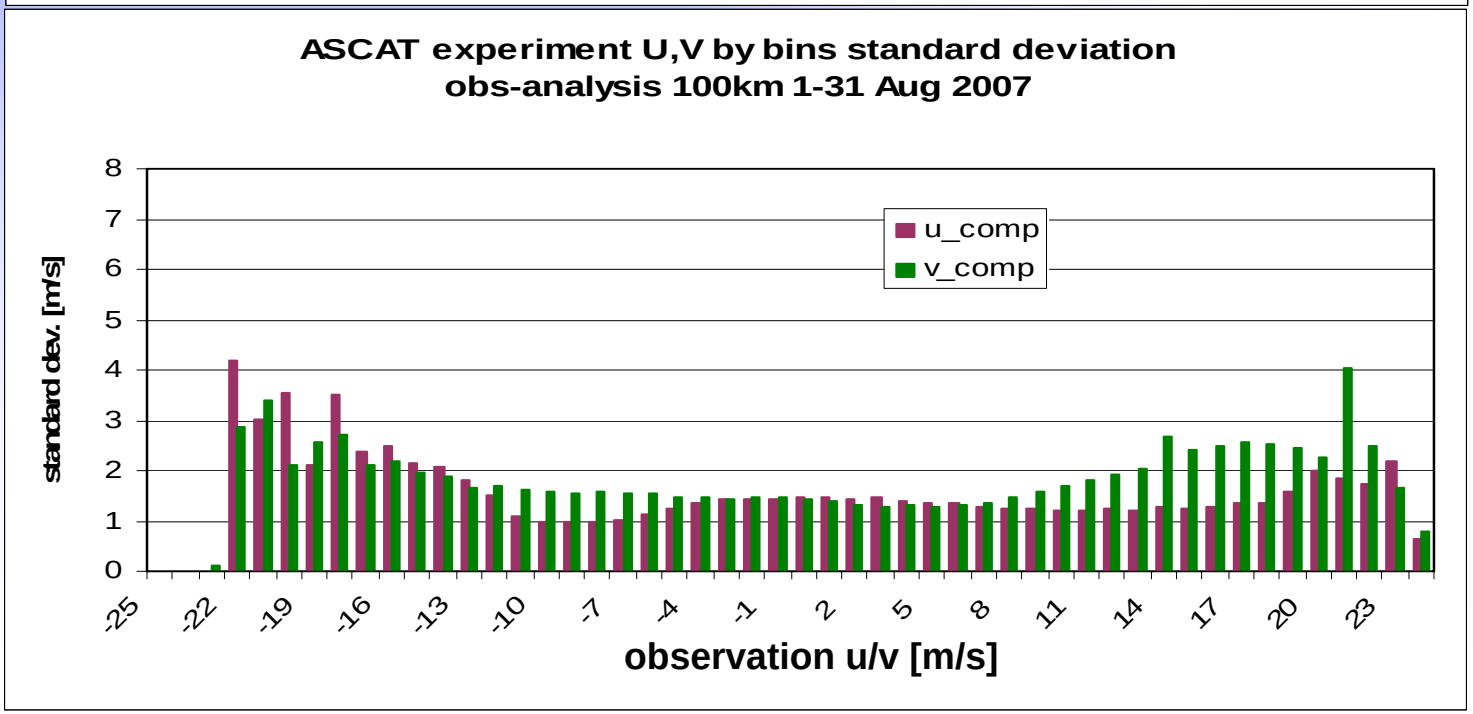
O-A →


ASCAT experiment U,V by bins bias
obs-analysis 100km 1-31 Aug 2007
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
-25
-22
-19
-16
-13
-10
-7
-4
-1
2
5
8
11
14
17
20
23
u_comp
v_comp
observation u/v [m/s]

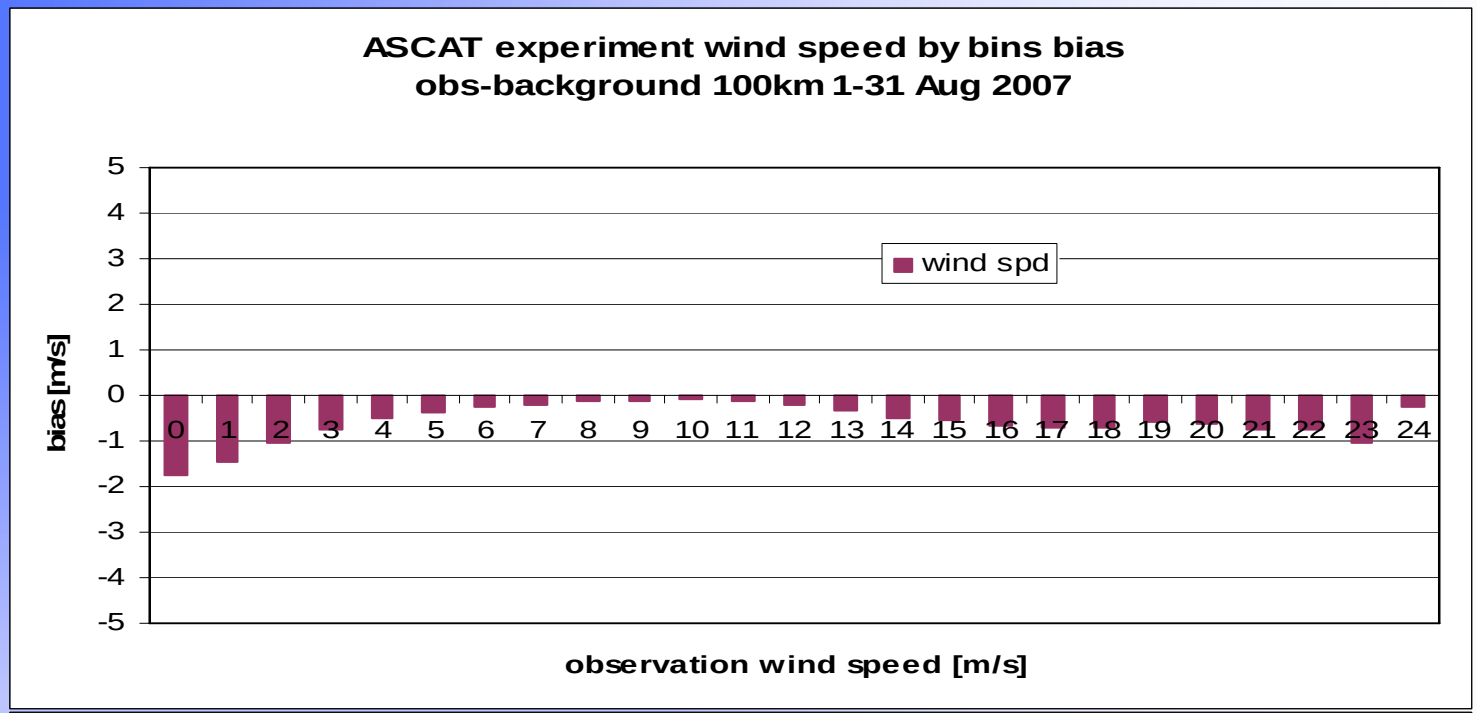
O-B →


ASCAT experiment U,V by bins standard deviation
obs-background 100km 1-31 Aug 2007
standard dev. [m/s]
u_comp
v_comp
observation u/v [m/s]

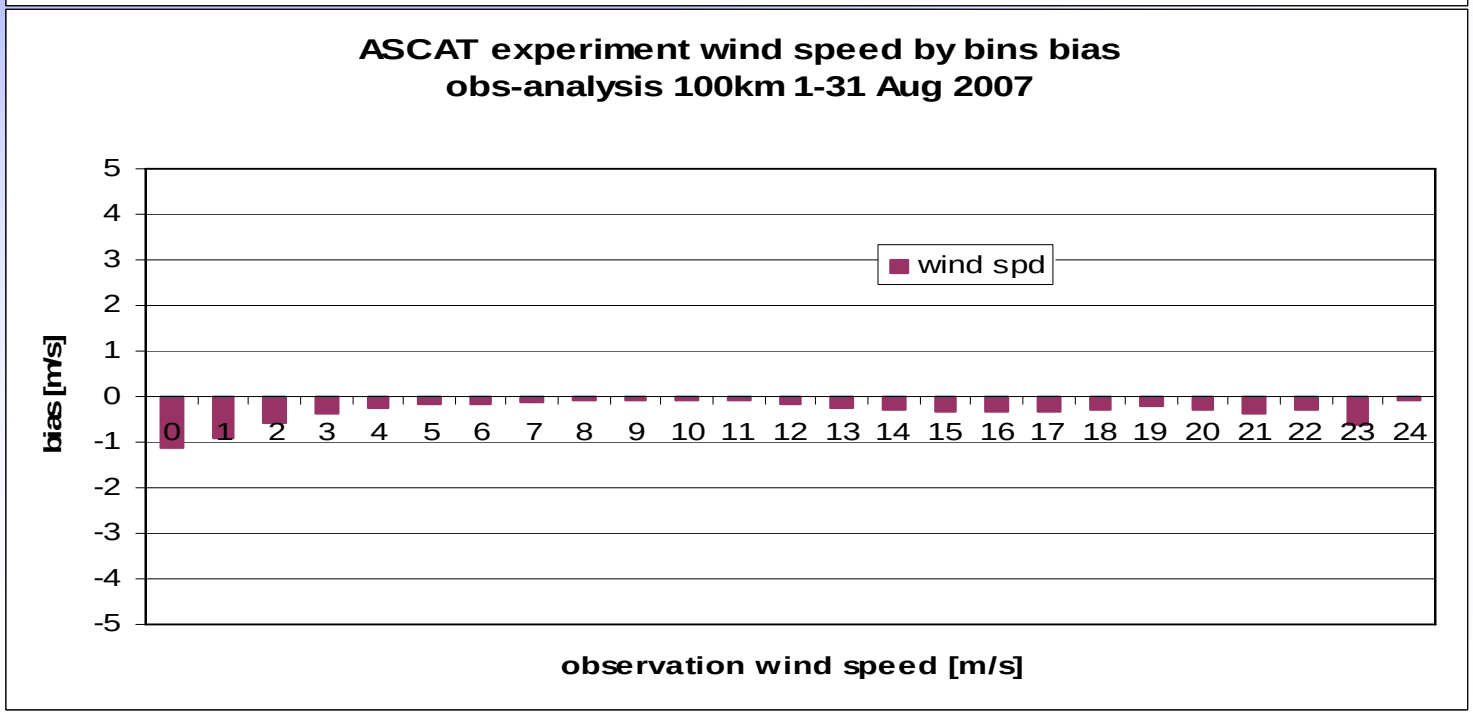
O-A →


ASCAT experiment U,V by bins standard deviation
obs-analysis 100km 1-31 Aug 2007
standard dev. [m/s]
u_comp
v_comp
observation u/v [m/s]

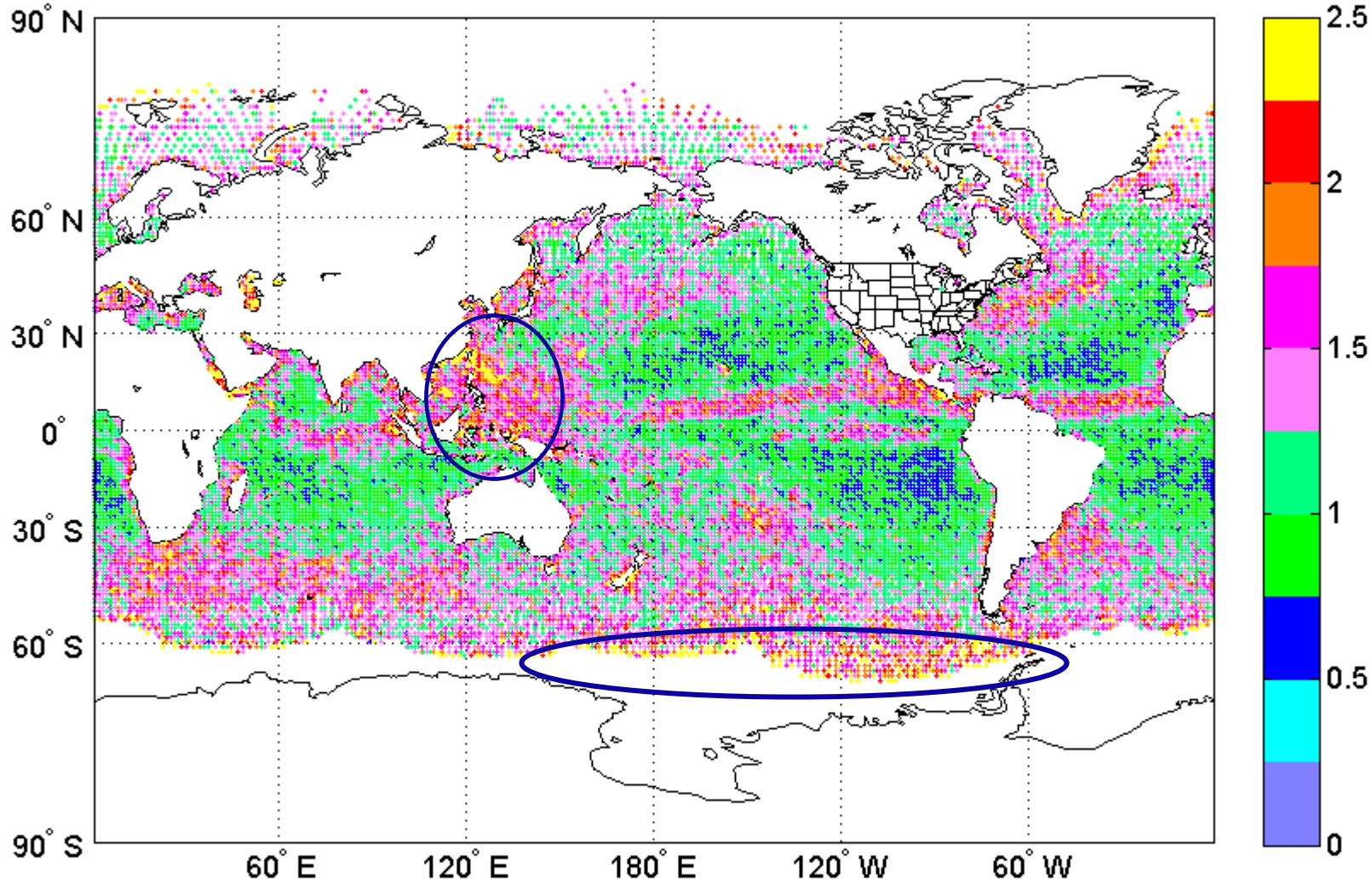
O-B →


ASCAT experiment wind speed by bins bias
obs-background 100km 1-31 Aug 2007
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

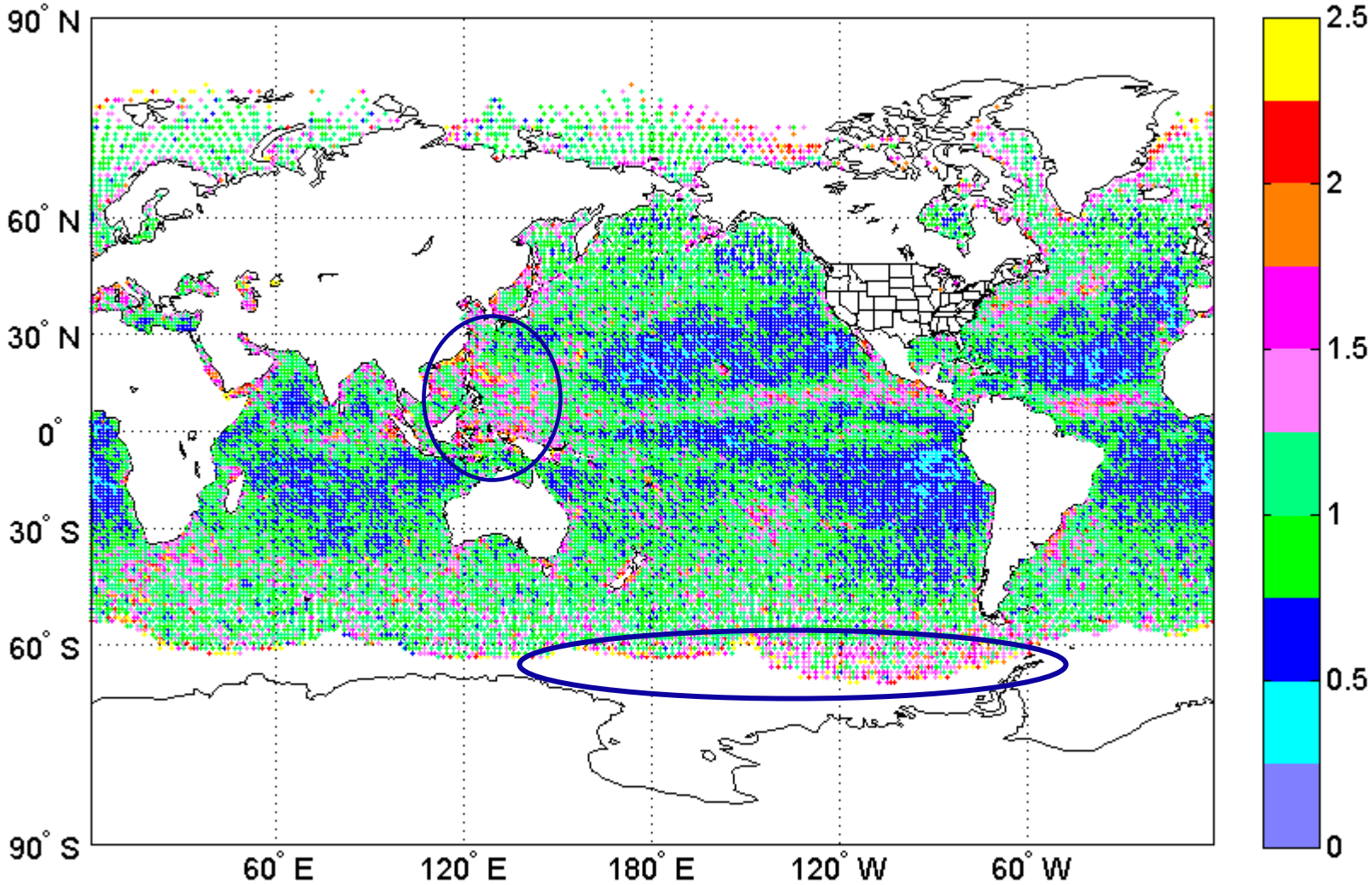
O-A →

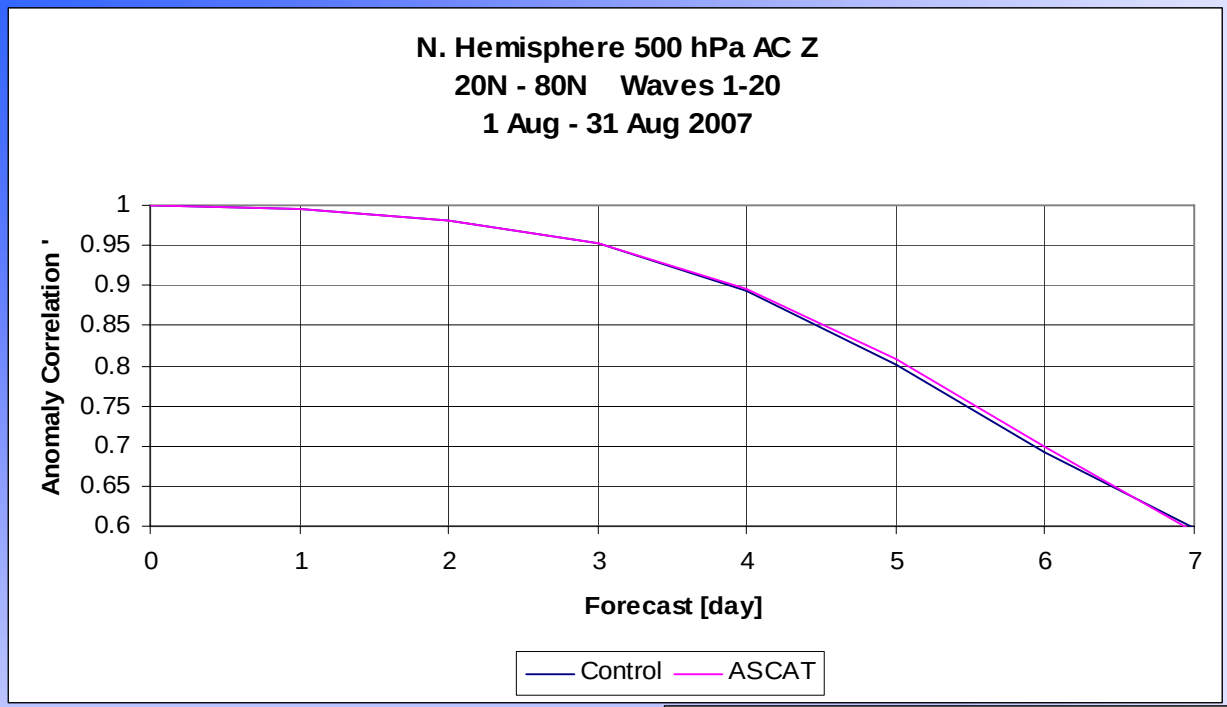

ASCAT experiment wind speed by bins bias
obs-analysis 100km 1-31 Aug 2007
bias [m/s]
5
4
3
2
1
0
-1
-2
-3
-4
-5
wind spd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
observation wind speed [m/s]

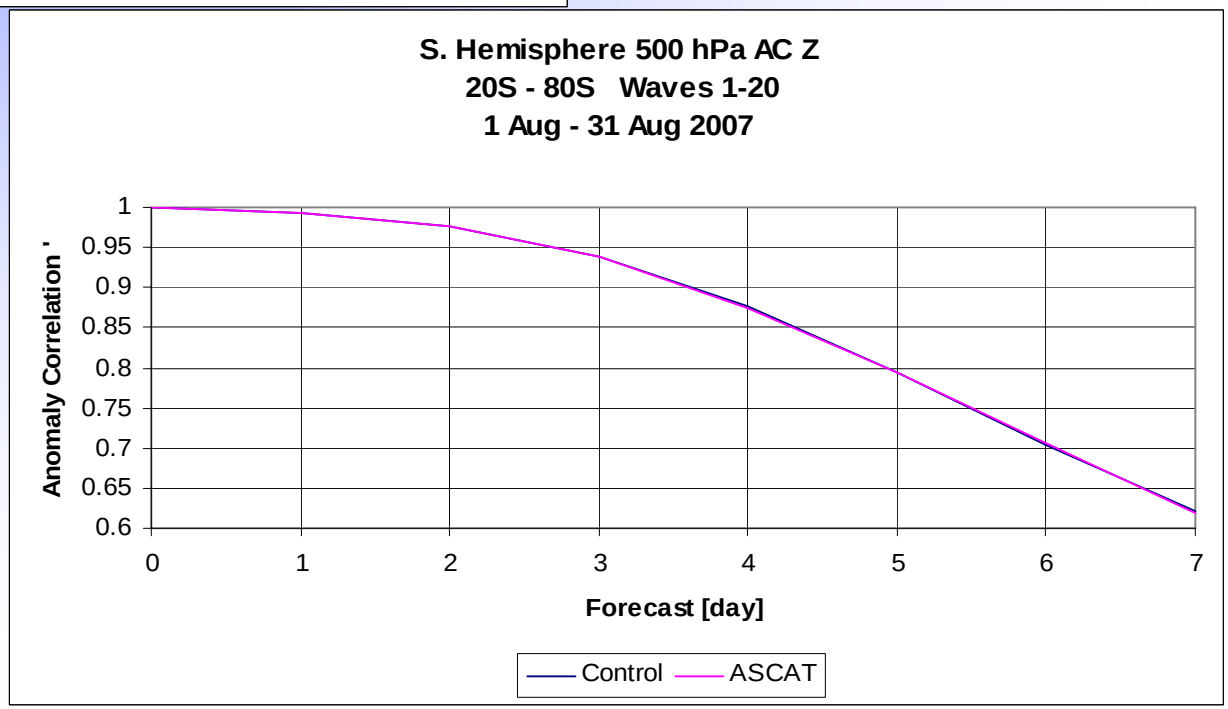
ASCAT 100km experiment wind spd O-B standard dev. [m/s] 1-31 Aug 2007

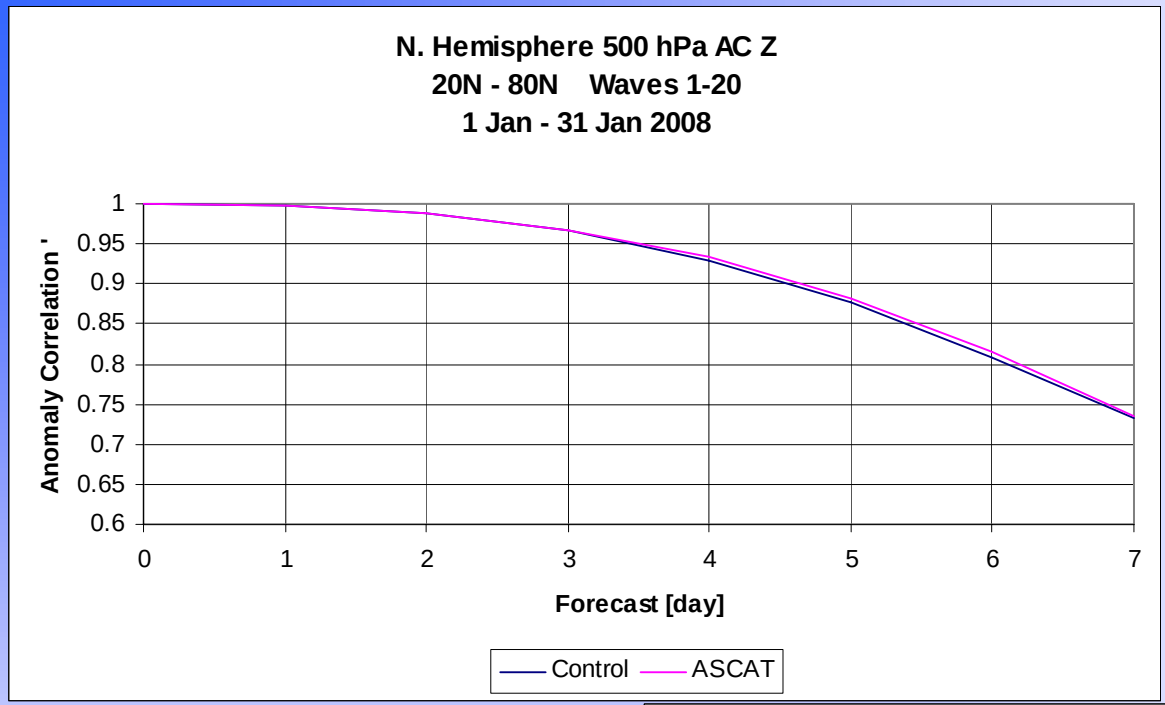


ASCAT 100km experiment wind spd O-A standard dev. [m/s] 1-31 Aug 2007




N. Hemisphere 500 hPa AC Z
20N - 80N Waves 1-20
1 Aug - 31 Aug 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
ASCAT


S. Hemisphere 500 hPa AC Z
20S - 80S Waves 1-20
1 Aug - 31 Aug 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
ASCAT


N. Hemisphere 500 hPa AC Z
20N - 80N Waves 1-20
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0.6
0
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2
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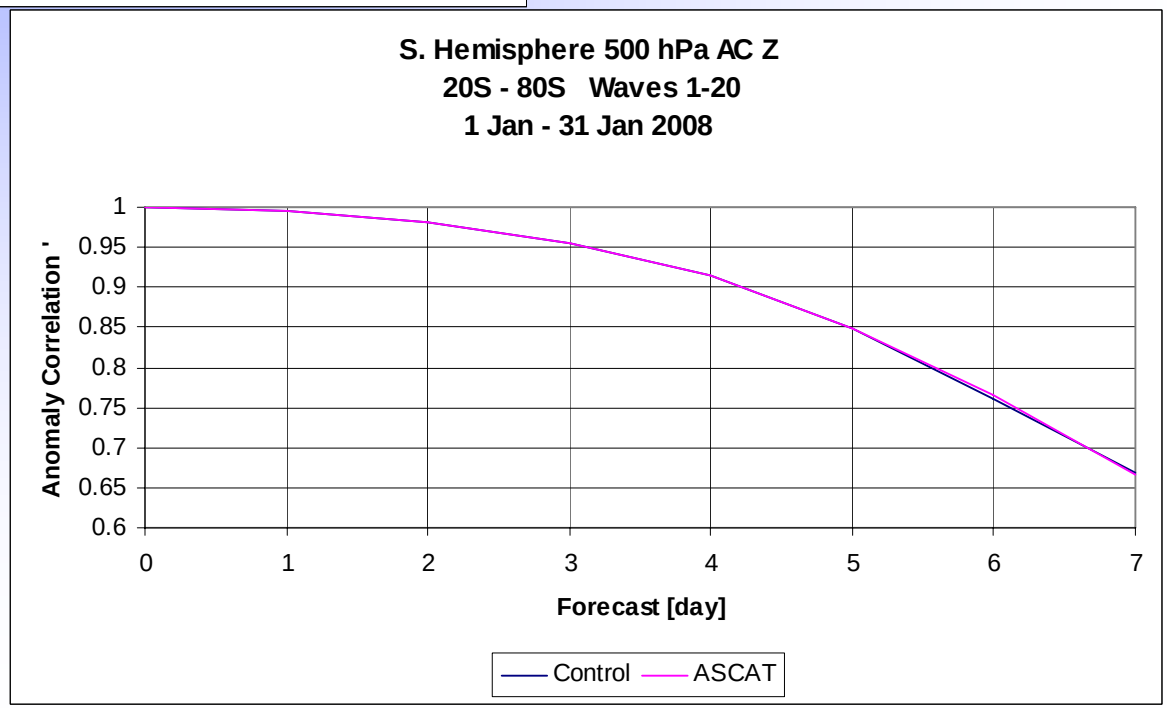
4
5
6
7
Forecast [day]
Control
ASCAT


S. Hemisphere 500 hPa AC Z
20S - 80S Waves 1-20
1 Jan - 31 Jan 2008
Anomaly Correlation '
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0.9
0.85
0.8
0.75
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0.65
0.6
0
1
2
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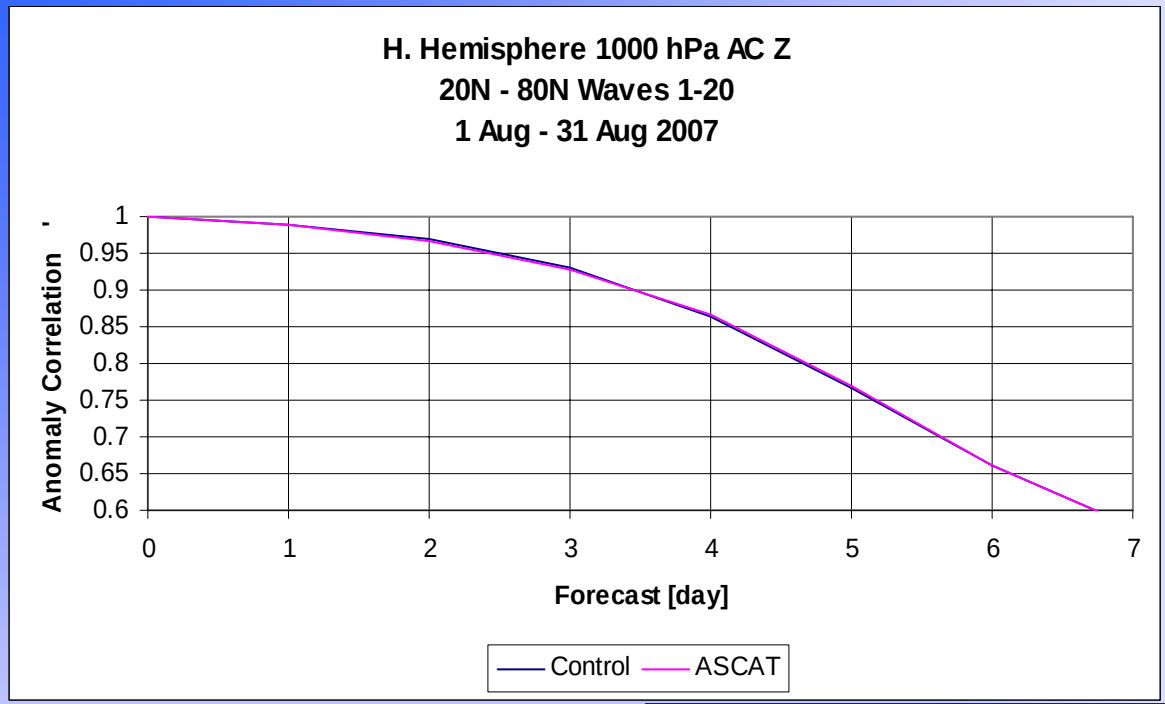
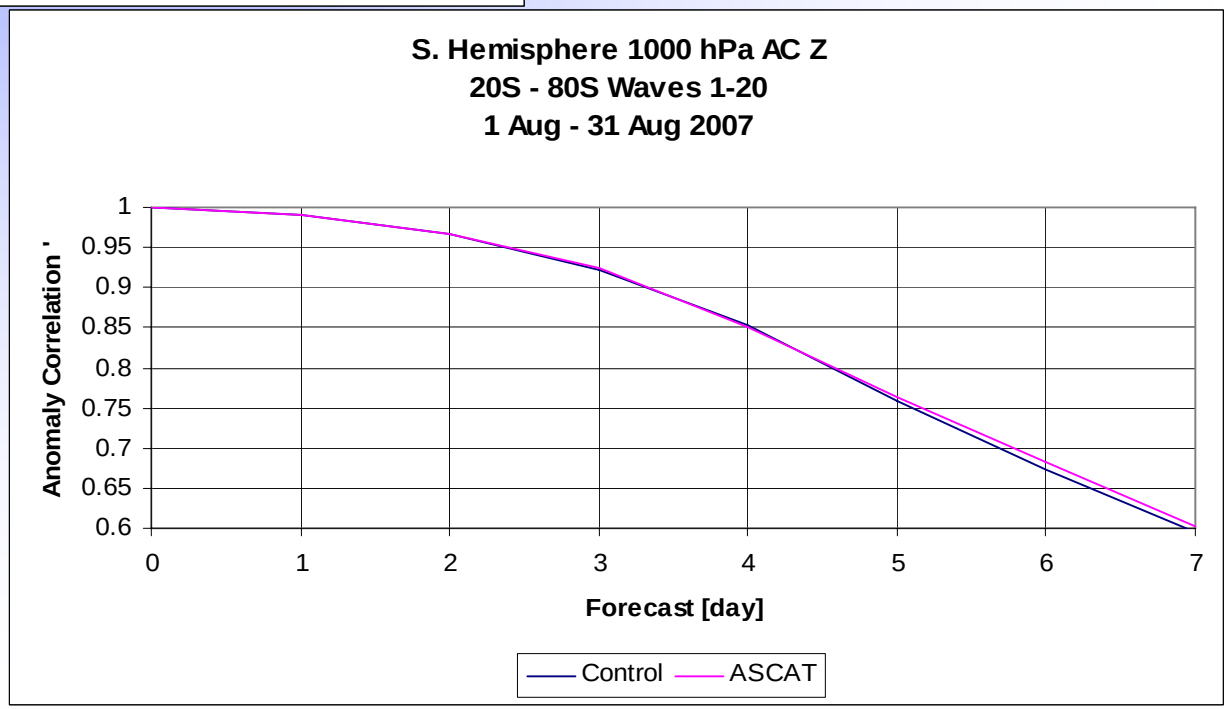
6
7
Forecast [day]
Control
ASCAT


H. Hemisphere 1000 hPa AC Z
20N - 80N Waves 1-20
1 Aug - 31 Aug 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
ASCAT


S. Hemisphere 1000 hPa AC Z
20S - 80S Waves 1-20
1 Aug - 31 Aug 2007
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
1
2
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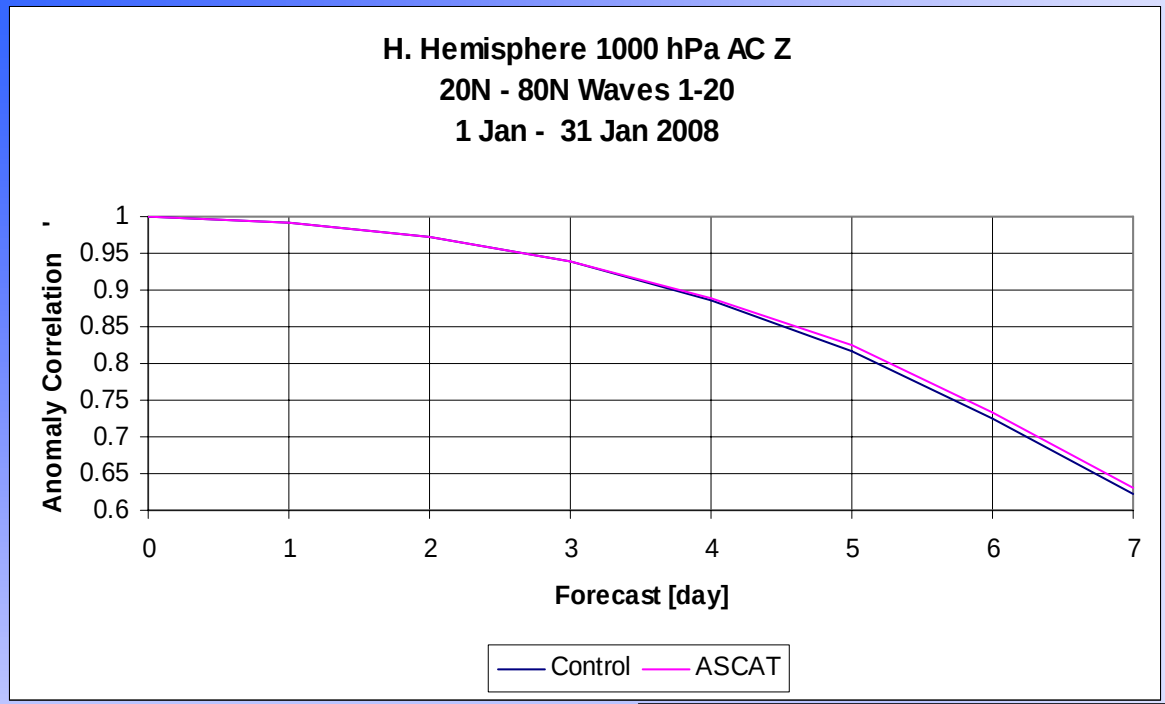
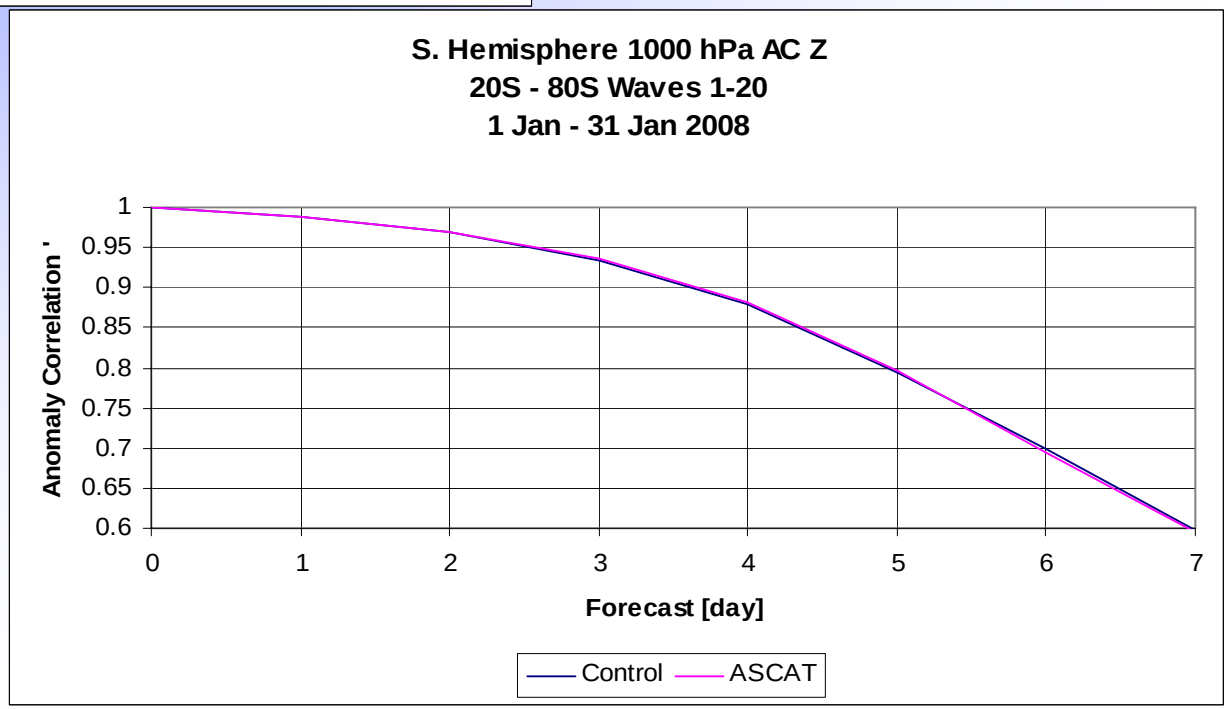
4
5
6
7
Forecast [day]
Control
ASCAT


H. Hemisphere 1000 hPa AC Z
20N - 80N Waves 1-20
1 Jan - 31 Jan 2008
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
ASCAT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1 Jan - 31 Jan 2008
Anomaly Correlation
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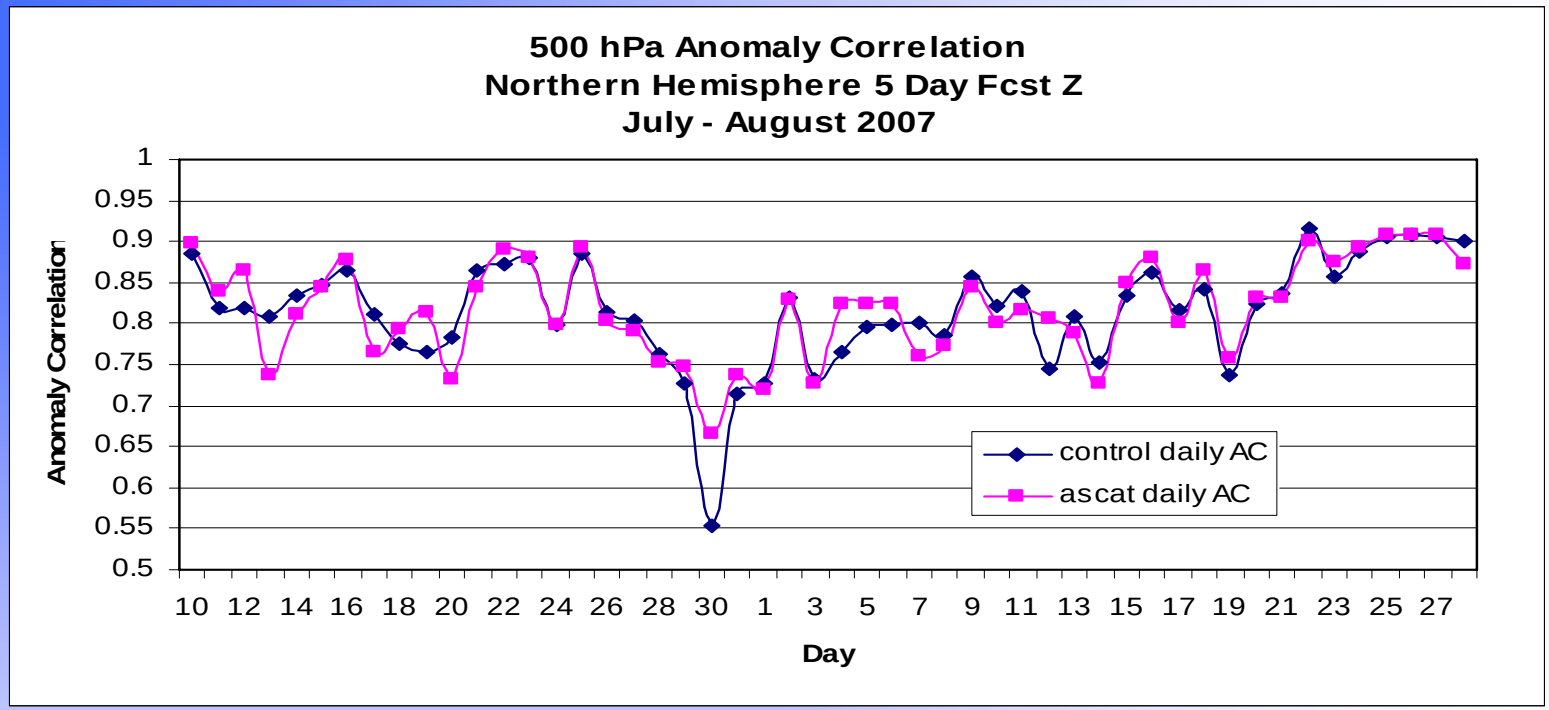
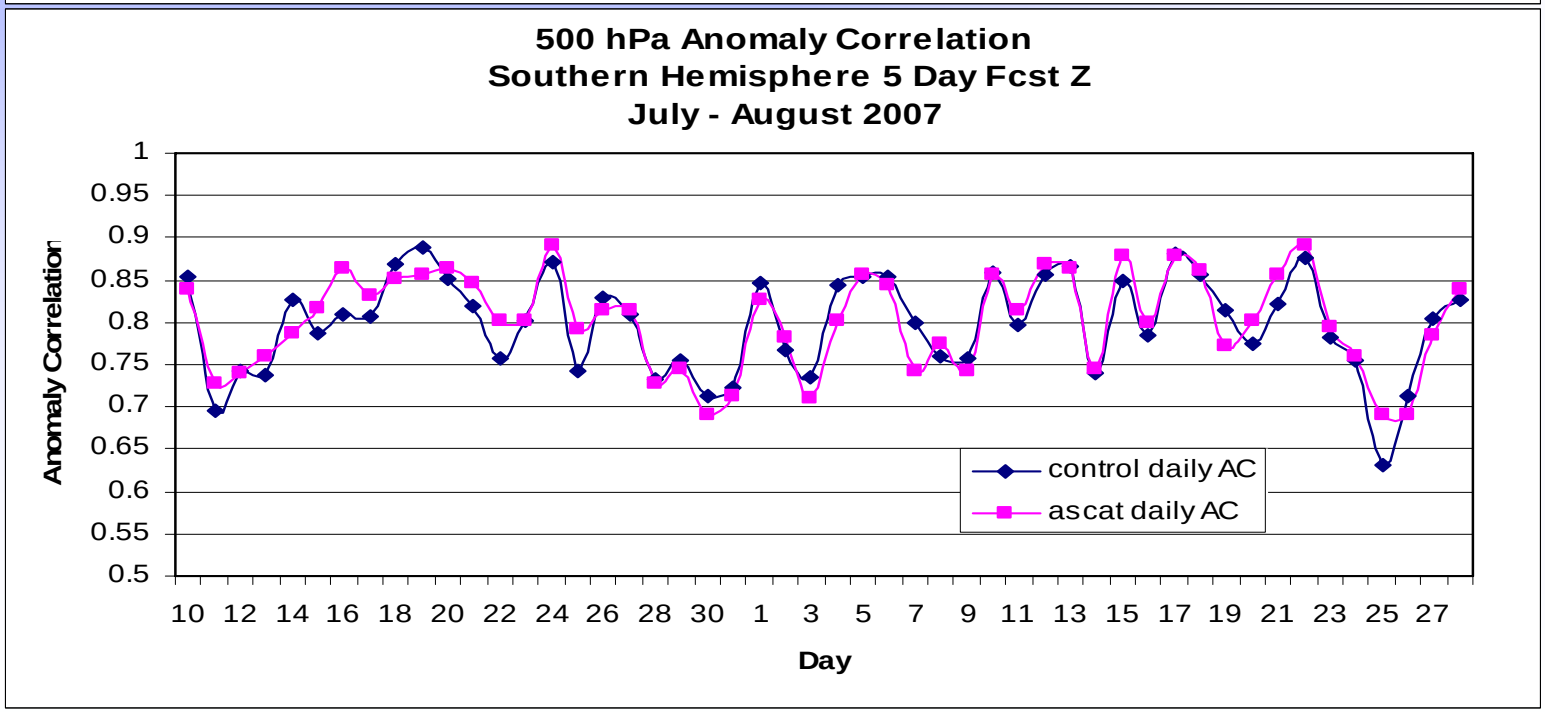
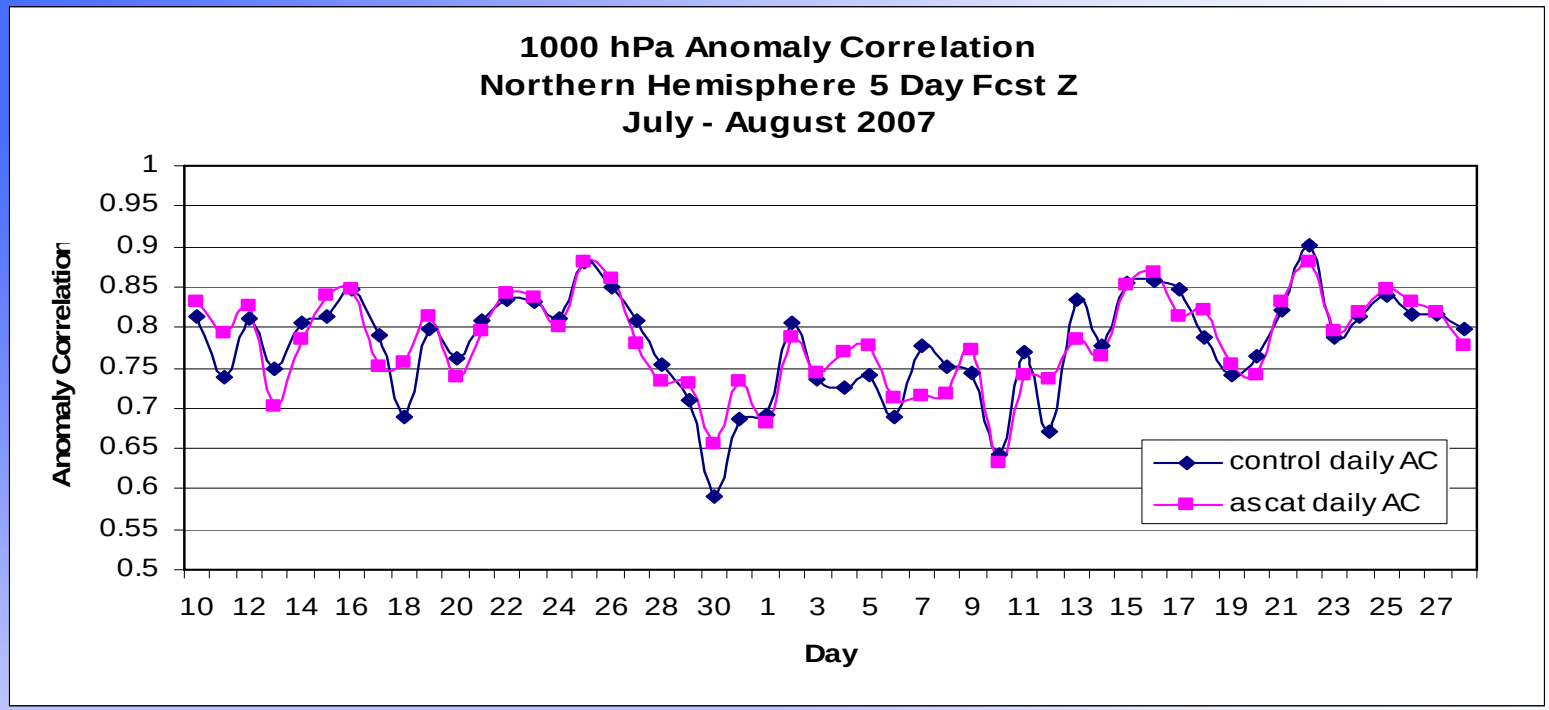
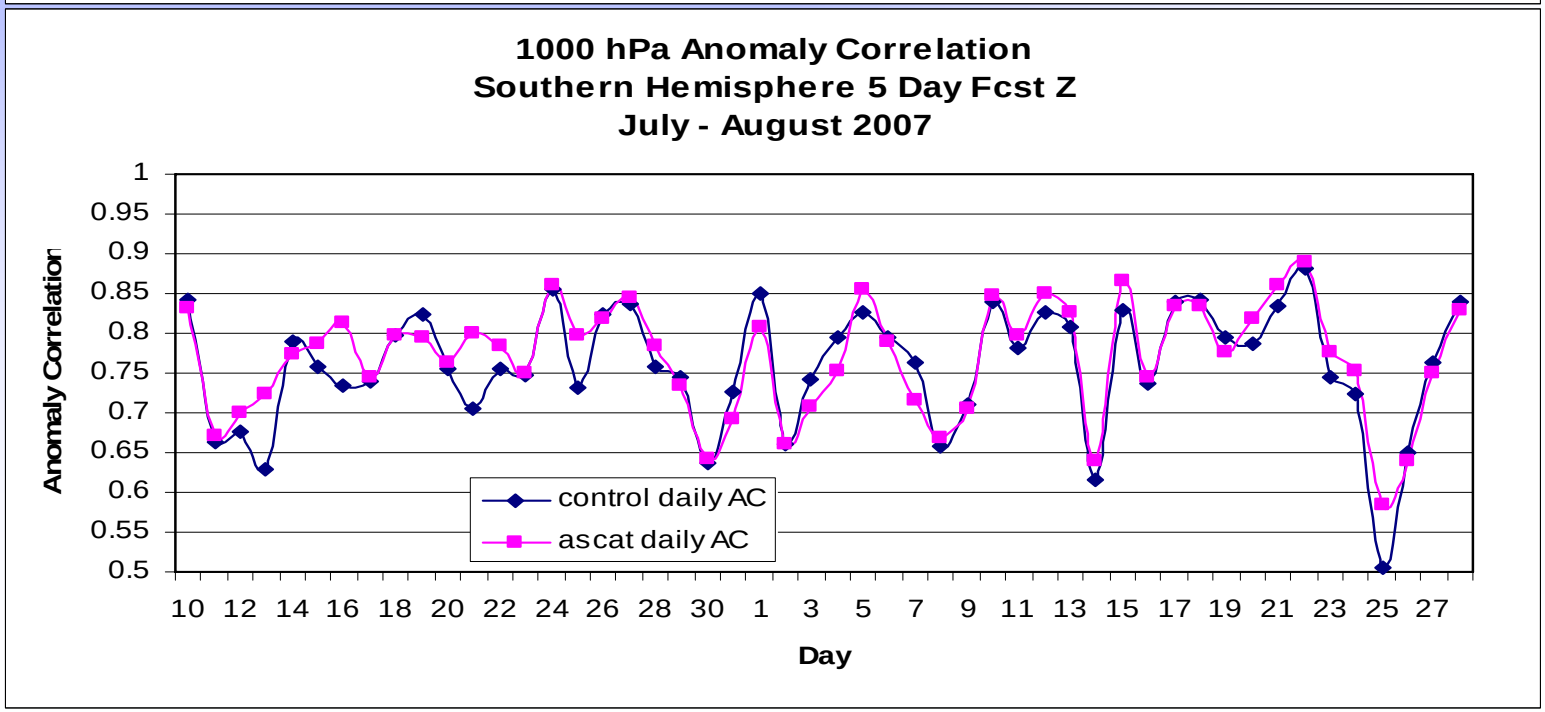
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
1
2
3
4
5
6
7
Forecast [day]
Control
ASCAT

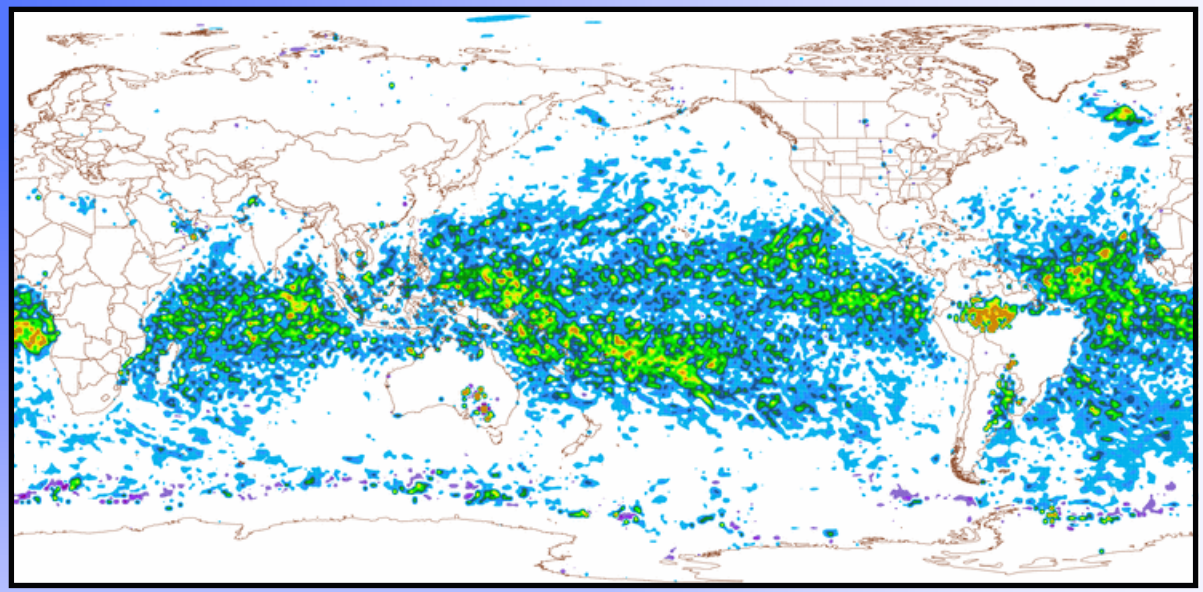

500 hPa Anomaly Correlation
Northern Hemisphere 5 Day Fcst Z
July - August 2007
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Day
control daily AC
ascat daily AC


500 hPa Anomaly Correlation
Southern Hemisphere 5 Day Fcst Z
July - August 2007
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Day
control daily AC
ascat daily AC

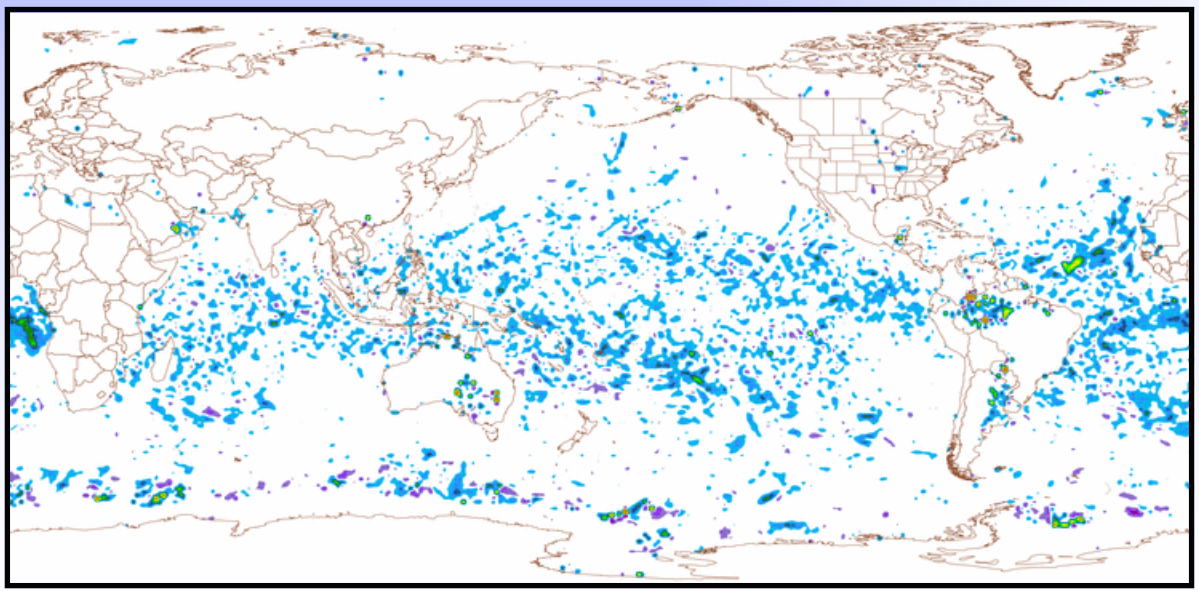

1000 hPa Anomaly Correlation
Northern Hemisphere 5 Day Fcst Z
July - August 2007
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Day
control daily AC
ascat daily AC


1000 hPa Anomaly Correlation
Southern Hemisphere 5 Day Fcst Z
July - August 2007
Anomaly Correlation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Day
control daily AC
ascat daily AC

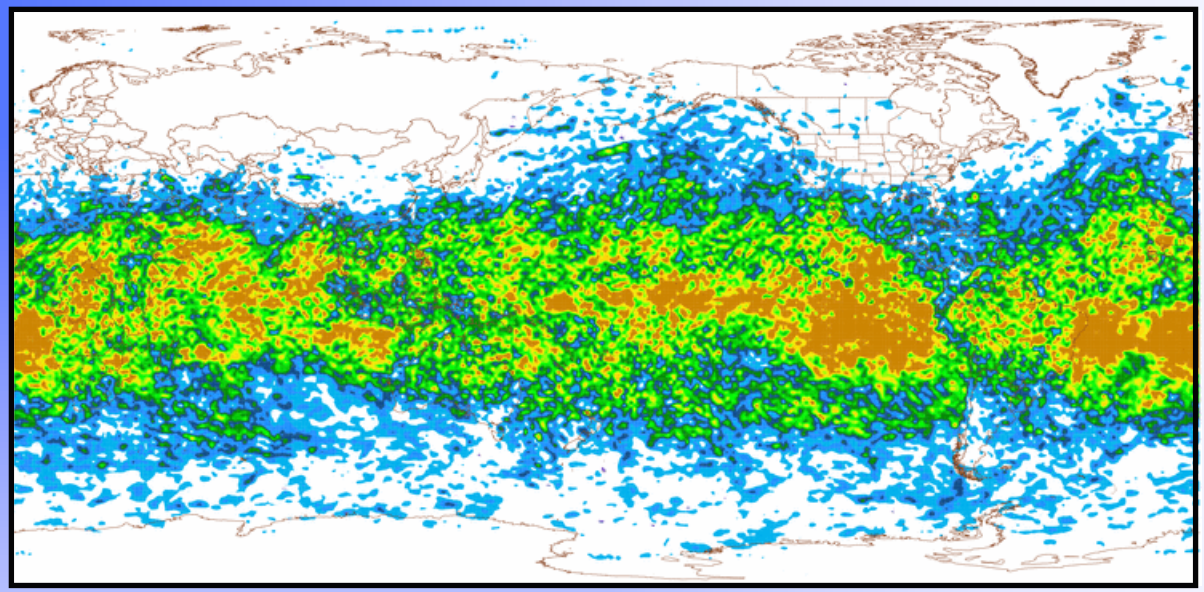
(a) 1000hPa TEMP FCST IMPACT [%] 6HR ASCAT 1-31 Jan 2008



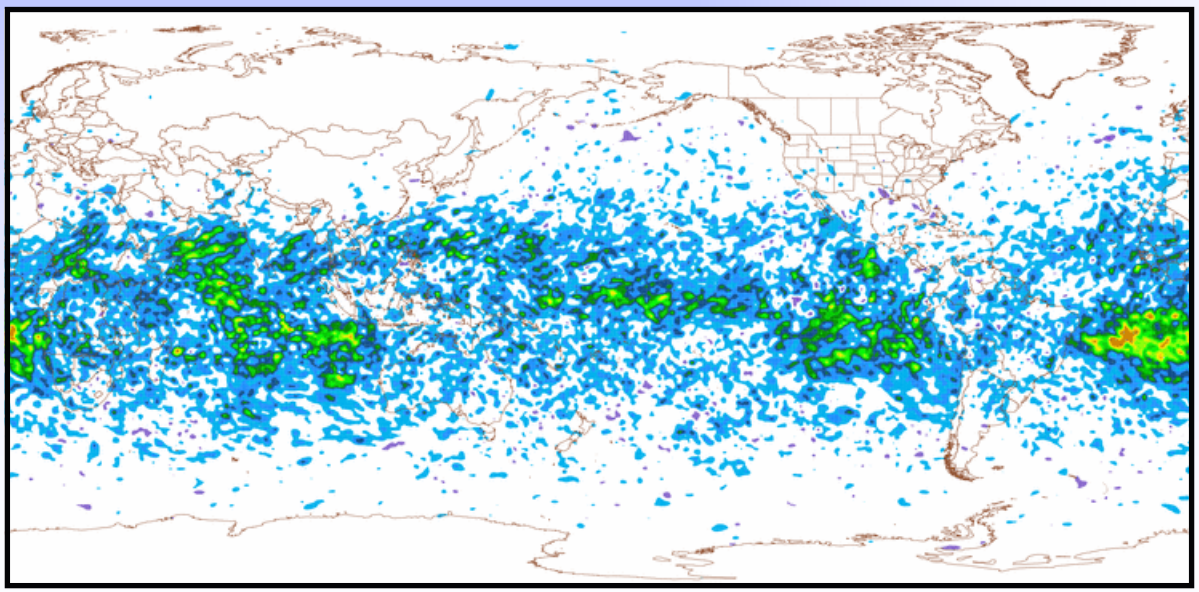
(b) 1000hPa TEMP FCST IMPACT [%] 24HR ASCAT 1-31 Jan 2008



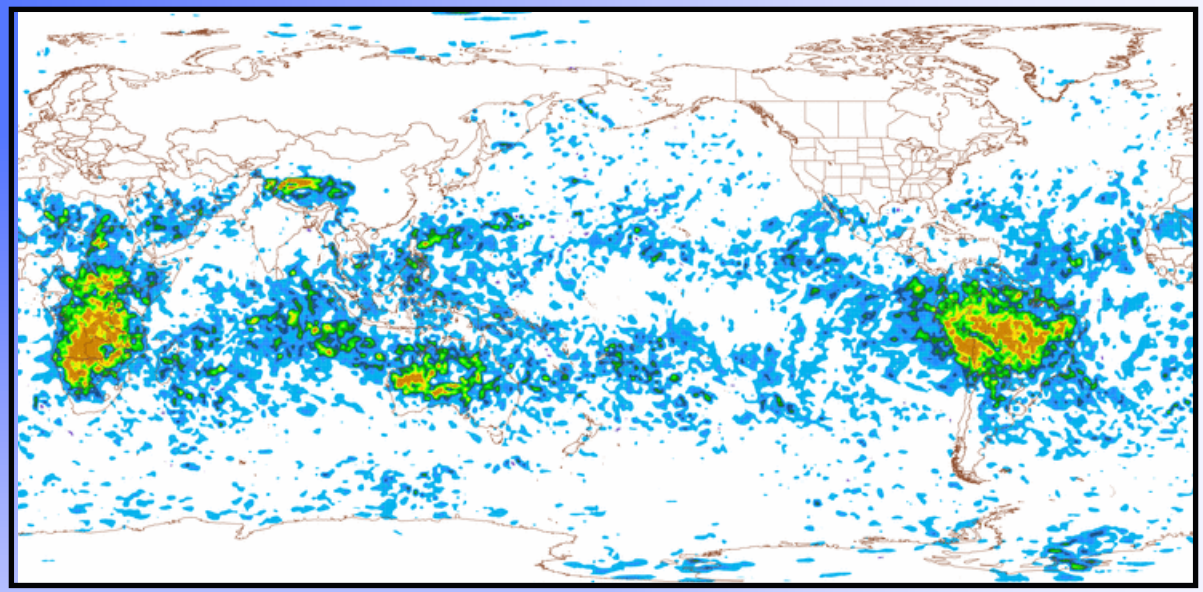
(a) 500hPa TEMP FCST IMPACT [%] 6HR ASCAT 1-31 Jan 2008



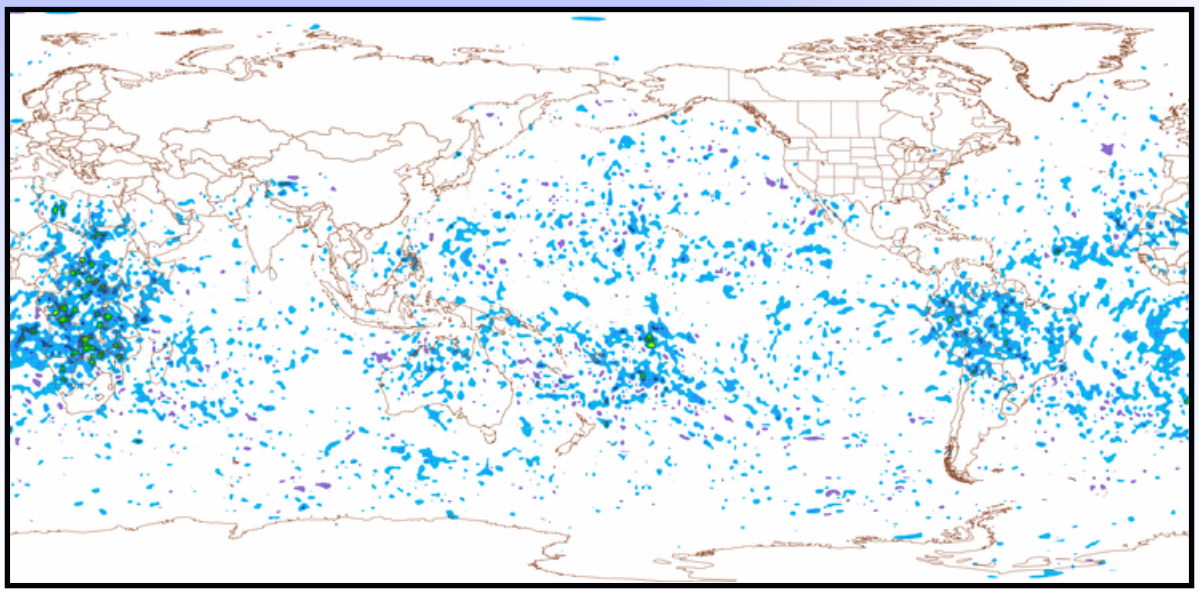
(b) 500hPa TEMP FCST IMPACT [%] 24HR ASCAT 1-31 Jan 2008



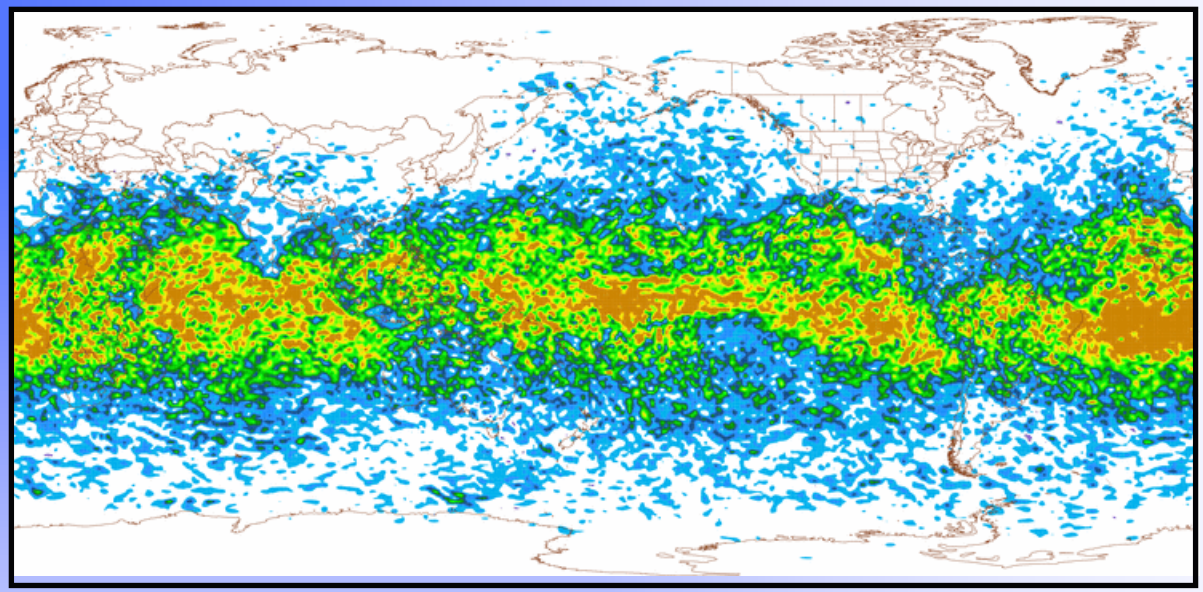
(a) 10m WIND SPEED FCST IMPACT [%] 6HR ASCAT 1-31 Jan 2008



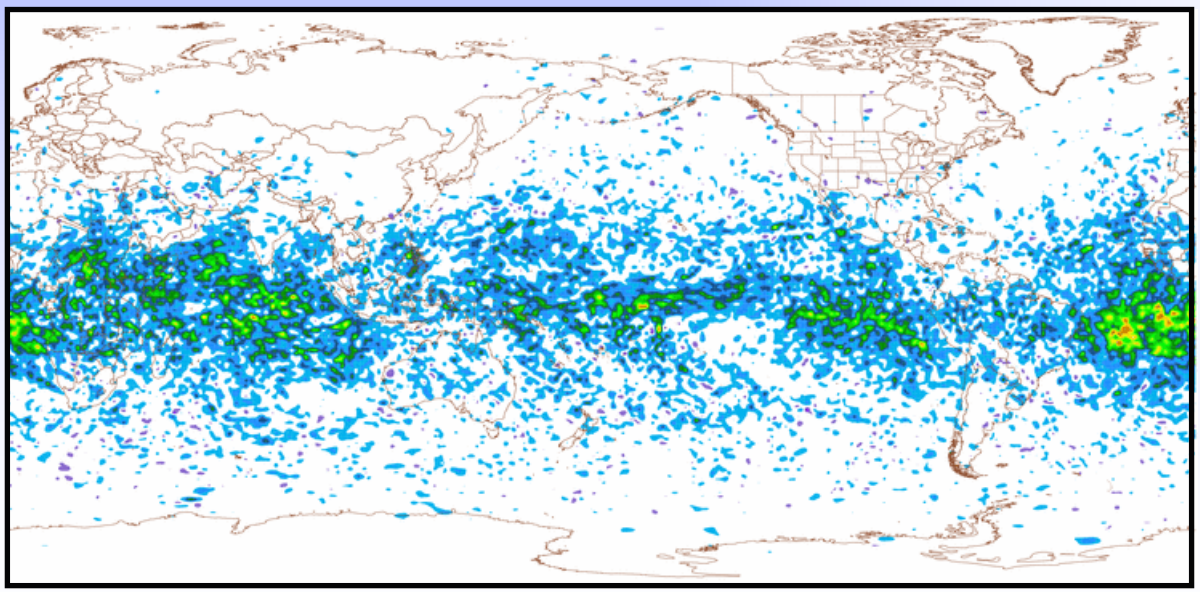
(b) 10m WIND SPEED FCST IMPACT [%] 24HR ASCAT 1-31 Jan 2008

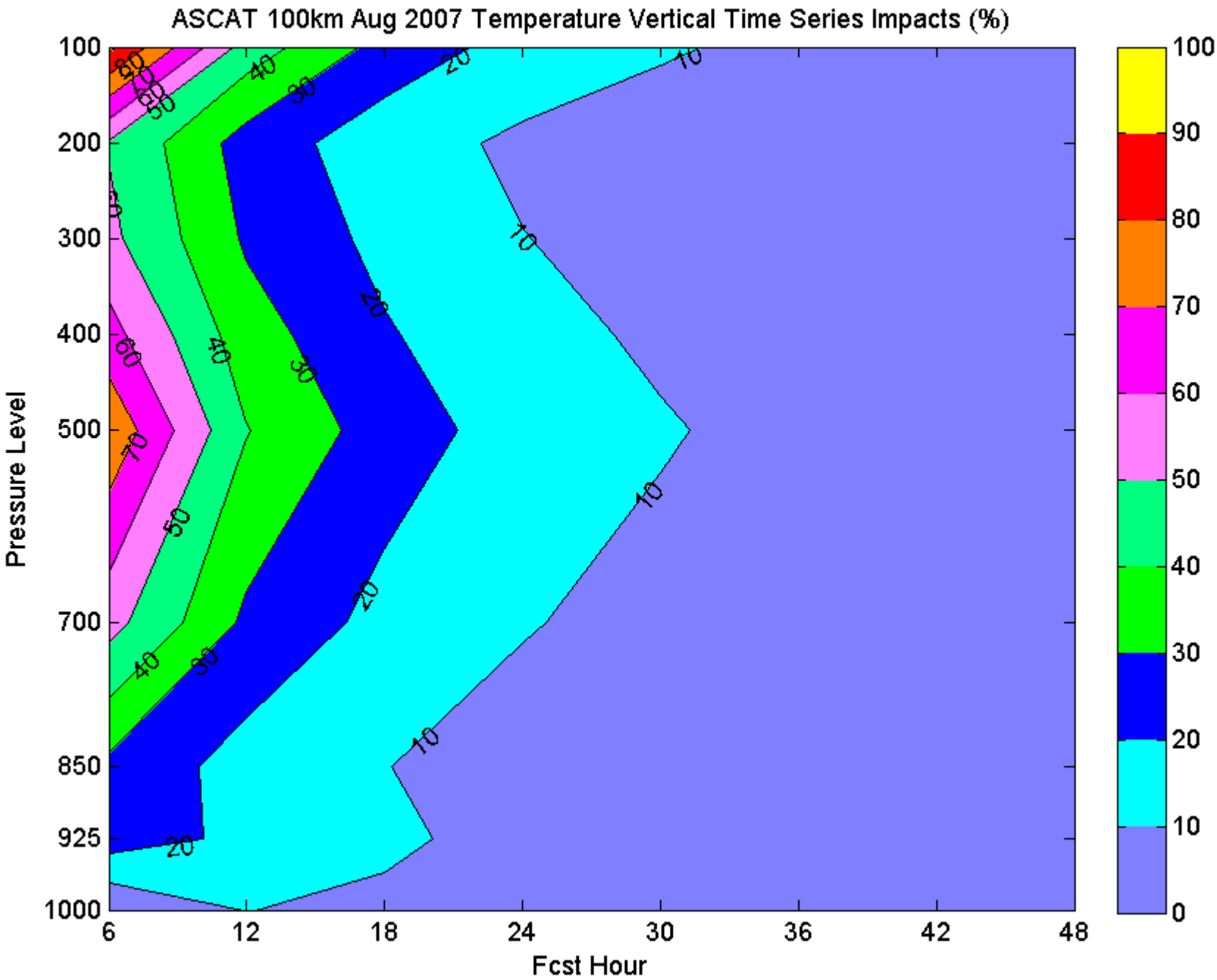


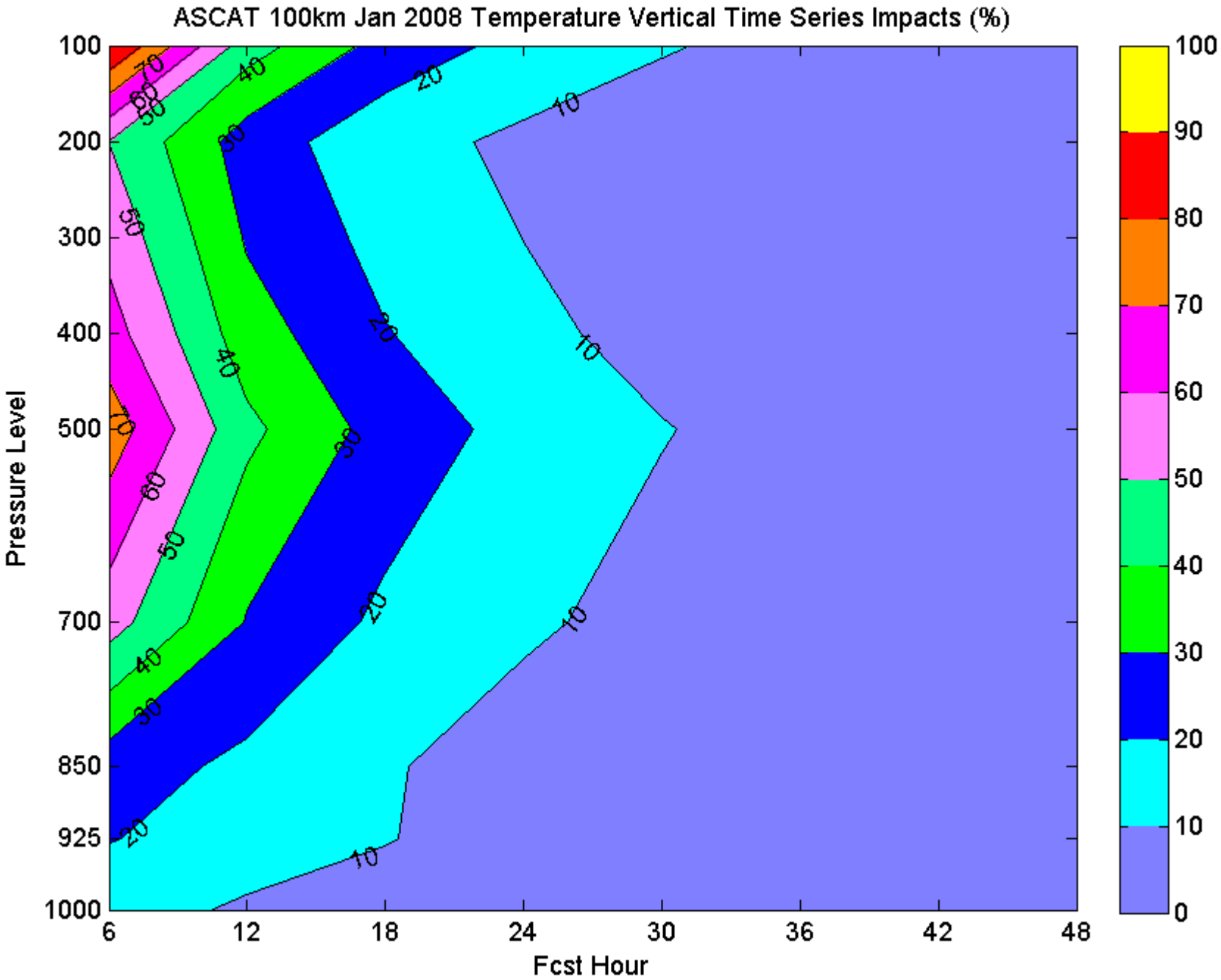
(a) 500hPa WIND SPEED FCST IMPACT [%] 6HR ASCAT 1-31 Jan 2008



(b) 500hPa WIND SPEED FCST IMPACT [%] 24HR ASCAT 1-31 Jan 2008




ASCAT 100km Aug 2007 Temperature Vertical Time Series Impacts (%)
Pressure Level
100
200
300
400
500
700
850
925
1000
6
12
18
24
30
36
42
48
Fcst Hour
0
10
20
30
40
50
60
70
80
90
100


ASCAT 100km Jan 2008 Temperature Vertical Time Series Impacts (%)
Pressure Level
100
200
300
400
500
700
850
925
1000
6
12
18
24
30
36
42
48
Fcst Hour
70
60
50
40
30
20
10
0
90
80