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
Table 1. WindSat Characteristics

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

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

<table>
<thead>
<tr>
<th></th>
<th>00Z</th>
<th>06Z</th>
<th>12Z</th>
<th>18Z</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>WindSat</td>
<td>6473</td>
<td>7782</td>
<td>6839</td>
<td>7851</td>
<td>7236</td>
</tr>
<tr>
<td>QuikSCAT</td>
<td>39317</td>
<td>46659</td>
<td>35765</td>
<td>44281</td>
<td>41506</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>00Z</th>
<th>06Z</th>
<th>12Z</th>
<th>18Z</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>WindSat</td>
<td>1.5394</td>
<td>1.8168</td>
<td>1.5619</td>
<td>1.7945</td>
<td>1.6782</td>
</tr>
<tr>
<td>QuikSCAT</td>
<td>1.3018</td>
<td>1.3946</td>
<td>1.2493</td>
<td>1.3110</td>
<td>1.3142</td>
</tr>
</tbody>
</table>
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 20 m/s are rejected.
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
Results of Current Work Cont.

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

\[
FI = 100 \times \left( \sqrt{\frac{\sum_{i=1}^{N} (C_i - A_i)^2}{N}} - \sqrt{\frac{\sum_{i=1}^{N} (D_i - A_i)^2}{N}} \right) \div \sqrt{\frac{\sum_{i=1}^{N} (C_i - A_i)^2}{N}}
\]

Error in control  Error in experiment  Error in control
Results of Current Work Cont.

- Vertical time series impacts:
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
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 electromagnetic 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 25 km.
- 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
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
Acknowledgements

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- John Derber and Lars Peter Riishojgaard for giving insightful advice
- 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
Backup Slides