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ASSIMILATION OF WINDSAT WINDS INTO THE NAVY OPERATIONAL GLOBAL ATMOSPHERIC PREDICTION SYSTEM

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1. INTRODUCTION

The polar-orbiting WindSat instrument is a multi-frequency polarimetric microwave radiometer (Gaiser 2004) developed by the Naval Research Laboratory (NRL). WindSat vector wind observations are generated at Fleet Numerical Meteorology and Oceanography Center (FNMOC) from raw radiances using software developed by NRL (Bettenhausen et al. 2006). The operational assimilation of WindSat winds into the Navy Operational Global Atmospheric Prediction System (NOGAPS; Hogan and Rosmond 1991) at FNMOC was initiated in December 2006. Prior to the operational assimilation of the WindSat winds, thorough testing was conducted. The first tests that were performed compared the WindSat winds determined using an earlier version of the NRL algorithm and QuikSCAT winds with a global analysis made without the use of any satellite-derived surface wind observations. Next, global data assimilation experiments were performed using WindSat winds determined using the earlier version of the NRL algorithm. Finally, global data assimilation experiments were performed just prior to operational implementation using WindSat winds determined using the latest version of the NRL algorithm. In the next section we describe the results of these experiments.

2. RESULTS AND CONCLUSIONS

The NRL Atmospheric Variational Data Assimilation System (NAVDAS; Daley and Barker 2001) was implemented as the operational analysis for NOGAPS on October 1, 2003. The operational NOGAPS/NAVDAS 10m wind analyses for October 2003-February 2004, available four times a day (00Z, 06Z, 12Z, and 18Z), were used as the baseline for this initial comparison of WindSat and QuikSCAT vector wind observations. The 10m wind analysis fields come from half-degree global grids and are at approximate 55 km resolution, the nominal resolution of the NOGAPS T239 spectral forecast model. None of the analyses made during this period used any scatterometer winds or SSM/I wind speeds.

For each analysis time, the WindSat and QuikSCAT observations within a two-hour window centered on the analysis time were compared with the analysis wind at the observation location. Only WindSat and QuikSCAT observations that had two or more ambiguities were considered. For both sensors, the observation chosen was the one whose wind direction was closest to and within 90 degrees of the analysis wind direction at the observation location. For WindSat, we only examined observations for which the wind speed was less than or equal to 20 m/sec and all flags but the Wind Speed Flag were zero. For QuikSCAT, we only examined observations for which the wind speed was less than or equal to 20 m/sec and both the Rain Flag and Edge of Swath Flag were zero.

Statistics were computed for the differences between the observed and analysis wind directions and wind speeds for WindSat and QuikSCAT and were stratified by NOGAPS/NAVDAS analysis wind speed. We computed global statistics for the entire 5-month period. The total number of observations for each sensor binned by the NOGAPS/NAVDAS analysis wind speeds is displayed in Fig.1. The total number of observations for WindSat and QuikSCAT were just over 41 million and just over 29 million, respectively. The distribution of the observations with respect to the global analysis is quite similar for each sensor. We found that 61.3% of the WindSat observations and 60.6% of the QuikSCAT observations occurred when the analysis wind speed was less than or equal to 7.5 m/sec. The respective percentages when the analysis wind speed was less than or equal to 10 m/sec were 83.3% and 81.5%.

The wind speed and direction biases for the two sensors with respect to the NOGAPS/NAVDAS analyses are displayed in Fig. 2. In general, the wind speeds from both sensors are greater than the analysis wind speeds when the winds are light and are less than the analysis wind speeds when the winds are strong. The crossover point for QuikSCAT is approximately 15 m/sec while that for WindSat is a little less. The wind direction biases for the two sensors display a similar pattern with respect to the analysis wind speeds and are not significant. The wind speed and direction standard deviations are shown in Fig. 3. The WindSat wind speed standard deviations are smaller (greater) than

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those for QuikSCAT for wind speeds less (greater) than 12.5 m/sec. The wind direction standard deviations for WindSat are less than those for QuikSCAT except for the 5-10 m/sec bins. In general, the statistical properties of the observations from the two sensors are quite similar based on this comparison with independent analyses created without the use of either type of observation.

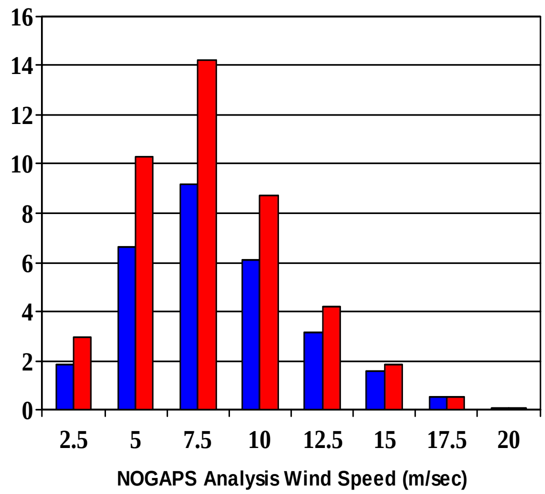

Fig. 1. Total number of QuikSCAT (blue) and WindSat (red) observations (in millions) for October 2003-February 2004.

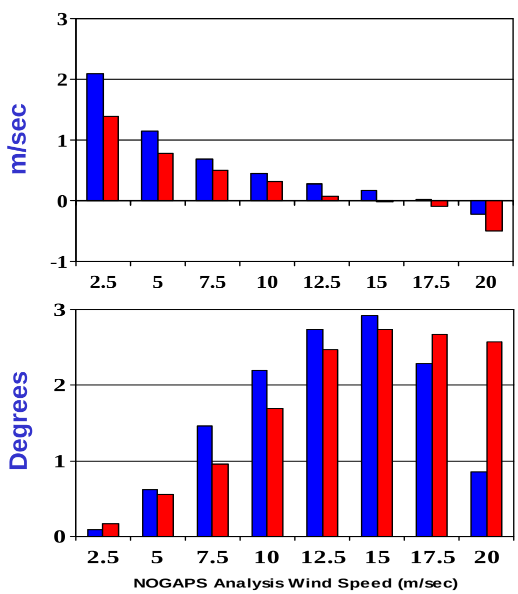

Fig. 2. QuikSCAT (blue) and WindSat (red) wind speed (top) and direction (bottom) biases with respect to the NOGAPS/NAVDAS analyses October 2003-February 2004.

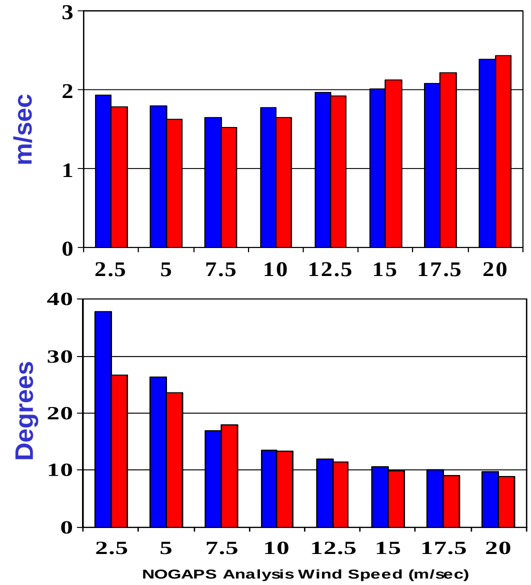

Fig. 3. QuikSCAT (blue) and WindSat (red) wind speed (top) and direction (bottom) standard deviations with respect to the NOGAPS/NAVDAS analyses October 2003-February 2004.

Data assimilation experiments were conducted to determine the impact of the assimilation of WindSat observations. The operational configuration of NOGAPS/NAVDAS using a T239L30 global spectral model (239-wave, triangular truncation, 30 vertical levels) and the assimilation of all available conventional and satellite observations except those from WindSat provided the control run (CNTL). The experimental run (WSAT) was identical to the control run but included the assimilation of WindSat observations. The typical coverage for the 6-h observation window used by a 00Z NAVDAS analysis for WindSat and QuikSCAT is illustrated in Fig. 4.

WindSat winds are processed in a manner similar to that developed for QuikSCAT. Up to four aliases (possible observed wind vectors) are available at each location; currently the alias whose direction is closest to the NAVDAS analysis background surface wind direction is chosen. After quality control is performed (e.g., rejecting duplicate and flagged observations), superobs are generated in 1.5° prisms over oceans. Prisms are defined with a height of 1.5° latitude and a width that varies by latitude to give both roughly square areas and an integer number of prisms in a latitude band. These superobs are formed by averaging the available innovations (observation minus background) and are used at the average location as single-level observations. A minimum of eight observations are required to form a superob, and a kinetic energy adjustment is applied to ensure that the resultant speed and mean speed are the same.

The first data assimilation experiment was conducted using observational data from August 14-

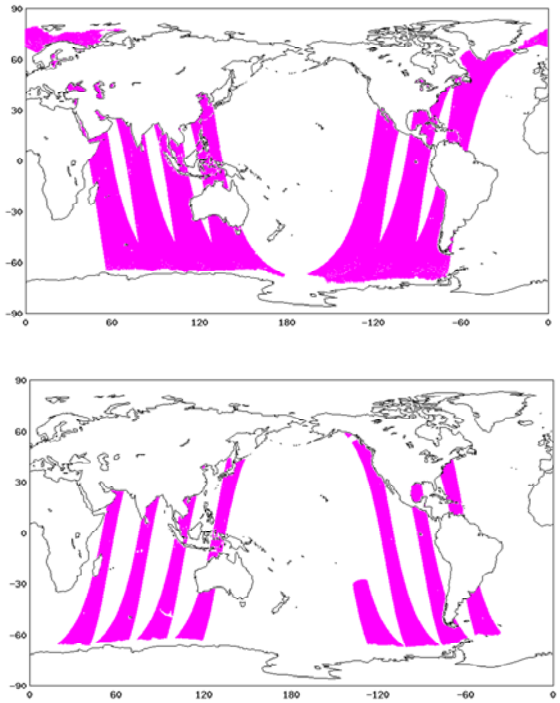

Fig. 4. Typical coverage for QuikSCAT (top) and WindSat (bottom) for a 6-h observation window centered on 00Z.

September 30, 2004. The WindSat winds were determined using an earlier version of the NRL algorithm. The extratropical impact of the assimilation of the WindSat winds was neutral, as illustrated by the 500 mb geopotential height anomaly correlation scores for the Northern and Southern Hemispheres displayed in Fig. 5. To assess the tropical impact, the TC track forecasts of NOGAPS were evaluated for the test period. This was a particularly active period with 12 hurricanes (including Charley, Frances, Ivan, and Jeanne), 5 typhoons, and 7 tropical storms. The NOGAPS tropical cyclone track forecast errors for the two experiments are illustrated in Fig. 6. While there were small improvements in the track forecasts out to 96h with the assimilation of the WindSat observations, they were not statistically significant. For this first experiment using an earlier version of the NRL algorithms the overall impact of the assimilation of the WindSat observations was neutral.

The final data assimilation experiment was conducted using observational data from November 8-24, 2006. The WindSat winds were determined using the latest version of the NRL algorithm, which was run operationally at FNMOC. The extratropical impact of the assimilation of the WindSat winds was positive at the longer forecast lengths, as illustrated by the 500 mb and 1000 mb geopotential height anomaly correlation scores for the Northern and Southern Hemispheres displayed in Figs. 7 and 8. At both levels, the impact in the Southern Hemisphere was greater than that in the Northern Hemisphere. For both hemispheres, the

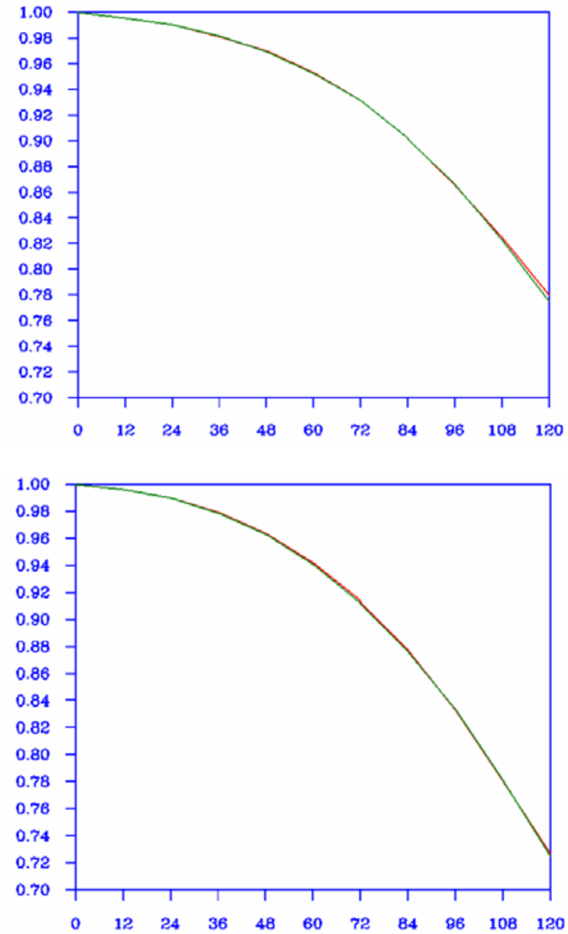

Fig. 5. CNTL (red) and WSAT (green) 500 mb geo-potential height anomaly correlation scores for the Northern (top) and Southern (bottom) Hemispheres, August14–September 30, 2004.

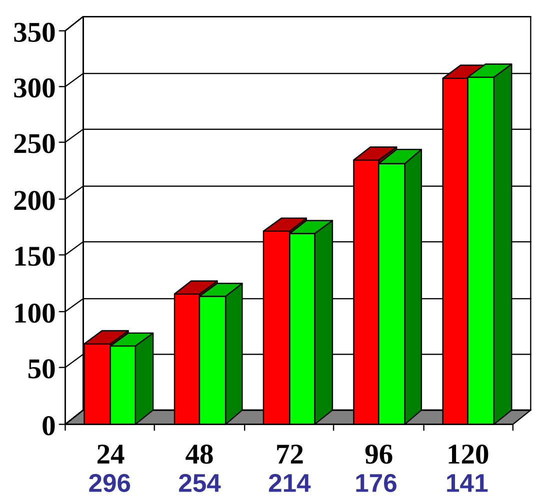

Fig. 6. NOGAPS tropical cyclone track forecast errors (nm) for CNTL (red) and WSAT (green) runs, August 14–September 30, 2004. The number of cases is denoted below the forecast length (h).

impact for the 1000 mb level was greater than that for the 500 mb level.

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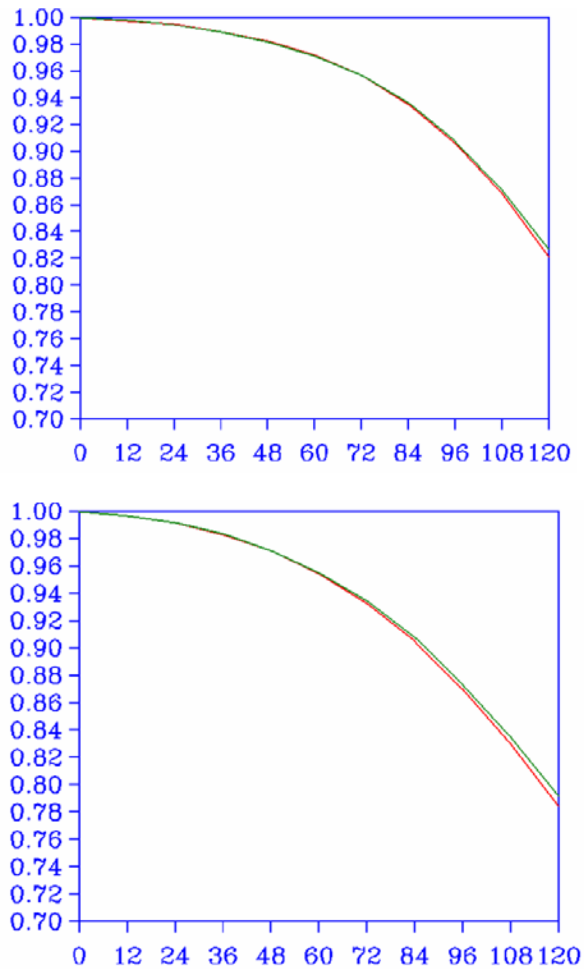

Fig. 7. CNTL (red) and WSAT (green) 500 mb geopotential height anomaly correlation scores for the Northern (top) and Southern (bottom) Hemispheres, November 8-24, 2006.

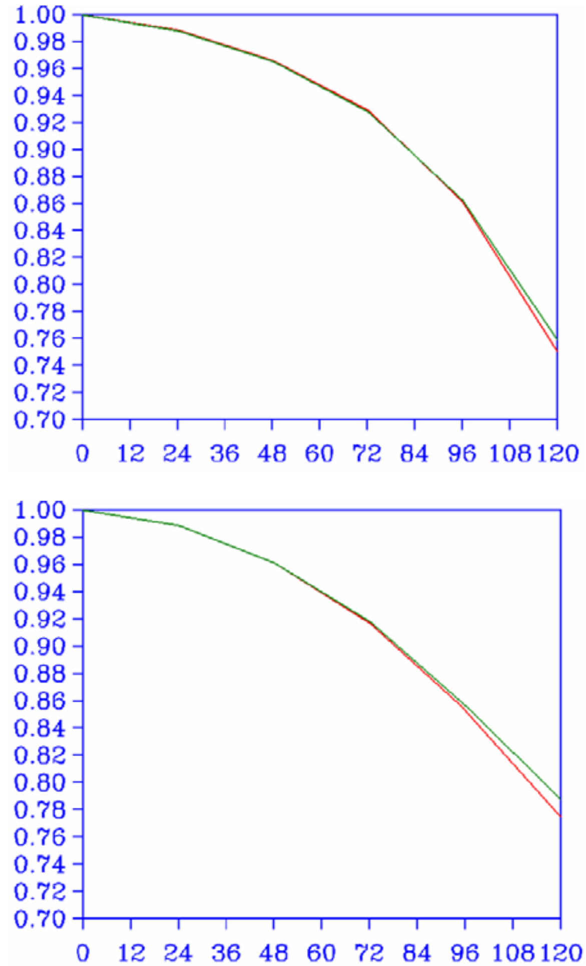

Fig. 8. CNTL (red) and WSAT (green) 1000 mb geopotential height anomaly correlation scores for the Northern (top) and Southern (bottom) Hemispheres, November 8-24, 2006.

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