Comparison of QuikSCAT SeaWinds data with buoy data from the National Data Buoy Center for the Gulf of Alaska.

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ABSTRACT

Buoy data from the National Data Buoy Center (calculated to the 10 m height) was compared with QuikSCAT data from approximately the same time and location. In the past researchers had only looked at far offshore buoys so that the data would not be contaminated by the shoreline winds. This study was done to see if the satellite data is valuable along the coast as well. It was found that the QuikSCAT wind speed had a RMS error of 1.4 ms^{-1}. The wind direction in four out of six buoy locations showed RMS errors of less than 20° when light winds were taken out. It was shown that derived winds from the QuikSCAT/SeaWinds satellite are a useful data set and may aid the forecasting and warning of winds in the outside waters of Southeast Alaska and the Gulf of Alaska.

1. Introduction

Polar orbiting satellites have been around since the early 1960s (NOAA NESDIS 2007). Scatterometers, an instrument that can determine wind speed and/or direction from the state of the ocean surface, were first put on polar orbiting satellites in 1973. The Quick Scatterometer (QuikSCAT) satellite was launched by NASA 19 June 1999 to replace NSCAT. This satellite is in a circular, sun-synchronous orbit 803 km above the Earth. The satellite orbits the Earth every 101 minutes (14.25 orbits per day) and covers about 90% of the Earth's ice-free oceans a day. The SeaWinds instrument on QuikSCAT is an active microwave radar (Callahan and Lungu 2006). This instrument takes measurements of the sea surface and derives the wind speed and direction; a detailed description of how it does this can be found in section two.

Ebuchi et al. (2002) found RMS errors of 1 ms^{-1} for wind speed and 20° for direction when comparing QuikSCAT to offshore buoys. This surpasses the mission requirement for wind speed of 2 ms^{-1} (for wind speeds between 3-20 ms^{-1}) and matches the mission requirement for direction (for wind speeds between 3-30 ms^{-1}) (Callahan and Lungu 2006). QuikSCAT data has been implemented into numerical weather prediction (NWP) models since 2002 and has improved model forecasts according to Chelton and Freilich (2005) but is underutilized. The lifetime of the mission was only expected to last about three years, five years at most but has now greatly surpassed that (Chelton et al. 2006). Japan also had as satellite, ADEOS-II, with the SeaWinds instrument on it. This satellite was launched in December of 2002 but lost power less than a year later (NASA JPL 2007).

The purpose of this paper is to show the quality of QuikSCAT winds along the coast in the Gulf of Alaska by comparing them to National Data Buoy Center (NDBC) buoys. All previous research has used this method, but has limited their study to far offshore buoys so that their data would not be contaminated by the shoreline. Measurements taken on the edges of the satellite scan tend to have more error, this may be why previous researchers chose to do this. However, these edges can contaminate data over the entire ocean, therefore this is not a fair assumption. There are a lot of mariners in the Gulf of Alaska; therefore, it is important to have accurate forecasts and warnings for this region. Data are sparse over the ocean so having additional information such as scatterometer winds would be a helpful forecast tool. As stated above no research has been done to see if this data is accurate near the coast so this paper hopes to answer that question for forecasters at the National Weather Service offices in the Alaska Region.

2. Data and Methods

2.1 *QuikSCAT SeaWinds Scatterometer*

The SeaWinds instrument on QuikSCAT has a rotating dish with two scanning pencil beams 6° apart (Fig. 1). The swath of every orbit is 1,800 km wide and contains 76 wind vector cells (WVC) in 1624 rows. The WVC's are initially the shape of the satellite beam, an oval, but are then interpolated into a 25x25 km grid spacing. Each WVC can be measured up to four times from four different viewing angles by the scatterometer, each of these measurements are called ambiguities. SeaWinds is an active microwave radar that sends out a pulse with a frequency of 13.4 GHz which hits small capillary waves on the ocean surface and the backscattered power is recorded by the scatterometer. From the backscattered power and the multiple measurements taken, the wind speed and direction can be derived using the Geophysical Model Function (GMF). This is an empirical model developed from numerous comparisons with buoys and is a relationship between the backscatter cross-section and a function of wind speed, wind direction, azimuth angle and incidence angle, radar frequency and polarization of the satellite. A medium filter is then used on the four wind direction ambiguities. The filter algorithm is initialized by the vector ambiguity that is the highest ranked and closest to the GFS NWP wind field (Callahan and Lungu 2006). According to Hoffman and Leidner (2004) this ambiguity removal process is correct 95% of the time. The QuikSCAT satellite also has instruments on it that can determine rain rate. While SeaWinds can take measurements through clouds and precipitation, the precipitation tends to disturb the sea surface and cause inaccurate backscattering. When this occurs the wind barbs are flagged as a black barb so that forecasters realize that there is a certain amount of uncertainty with that measurement. In this study the Normalized Objective Function (NOF) Rain Flag index was examined along with actual radar data to determine error (Mears et al.).

All QuikSCAT data were obtained from the NASA Jet Propulsion Laboratory (JPL) and read by an IDL program also provided by JPL. About four orbits cross a portion of the Gulf of Alaska each day. As stated above every scan is 1,800 km wide and each measurement is made in a 25 km grid point. To limit this data only the first four days in January, April, July, and October 2006 were used to see if there was any variability in error by season. This data was then constricted to only measurements within 25 km of any chosen buoy.

2.2 *National Data Buoy Center Buoys*

The NDBC buoys that were chosen for this study are shown in Fig 2. All buoys are used in forecasting on a daily basis and all are more than 30 km from the coast, as that is where QuikSCAT data becomes available (Perlin et al. 2004). The six buoys chosen are located within the marine forecast/warning areas of the NWS Alaska Region. Three are along the coast of the

Alaskan Panhandle and fall under the Juneau, AK Weather Forecast Office (WFO) area of responsibility. The other three are located within the Anchorage WFO area of responsibility; one of them being farther off shore into the Gulf of Alaska (buoy 46001). The marine zones in which these buoys are located are highlighted in Fig. 3. The buoy winds are measured at 4 m rather than the meteorological convention of 10 m. The QuikSCAT winds are measured at 10 m, in order to compare the two, the buoy winds were adjusted to 10 m using a Fortran program developed by Liu and Tang (1996). This algorithm uses the height of the anemometer, thermometer and hygrometer (not available) and the measurements taken from them to calculate the new wind speed. Wind direction is assumed to be the same as at 4 m. Since relative humidity was not available on the chosen buoys, 80% RH, as suggested by Liu and Tang, was used.

2.3 *Comparison of wind speed and direction*

The buoy winds were set as the control for the satellite winds to be compared to. They were compared within 30 minutes and 25 km of each other. When more than one satellite measurement was taken within those parameters, they were averaged. Some buoy data within the 16 day period was missing. Buoys 46001, 46080, 46083 and 46084 were missing April wind data. Buoy 46083 had April wind speed but not direction. Buoys 46083 and 46078 were also missing some days in October. This would not greatly affect comparisons as there were multiple measurements each day. The *u* and *v* components of the wind were compared along with wind speed and direction. The RMS error and biases were calculated for each buoy location, month, and for all the data. To see how well the NOF rain flag index performed, all flagged data were taken out and the new RMS error was compared to the original. Because the QuikSCAT winds are only valid for wind speeds greater than 3 ms^{-1}, the light wind speeds were taken out of the data set to see if that improved RMS error (Callahan and Lungu 2006).

3. Results

The most significant finding of this research was the error in wind direction. The total RMS error for wind direction was 38.52°. The worst RMS error for direction occurred in July (48.32°) and with buoy 46001 (55.43°). Once all the rain flagged data were taken out of the data set, the direction RMS error did not change very much, in fact it increased to 38.93°. Some of the flagged data were in fact an accurate representation of the wind vector and at many times the worst errors were not flagged at all. When taking a closer look at those with the greatest direction error it was found that many of them also had very light wind speeds. When the times with light buoy winds (< 3 ms^{-1}) were taken out of the data set, the direction RMSE decreased to 26.67°. As stated previously, one of the reasons for using QuikSCAT is due to limited observations over the ocean. If the buoys are down, meaning even less observations, then a forecaster may only have this information to analyze. Therefore, the times with light satellite winds were taken out of the data set as well to see if there was a minimum value that forecasters should consider valid. Taking out the winds below 3 ms^{-1} did not account for many of the error points, therefore 5 ms^{-1} was chosen as the minimum. This also greatly improved the direction RMSE down to 28.95°. With both the light buoy winds and the light satellite winds taken out of the data set, the RMSE decreased even lower to 24.25°. The key result from doing this is not these values for the total data set but the differences between months and buoy locations.

Figures 4-6 show how the RMSE changed when each criterion was taken out. From these plots it is shown that four out of the six buoy locations had direction RMS errors below the mission requirement of 20°.

Another interesting finding related to direction error was that on average all the wind directions had a clockwise bias, meaning that the satellite wind direction was usually more veered clockwise. The biases for direction, speed, *u* and *v* components by month and buoy location are shown in figure 7.

The total wind speed RMS error was 1.4 ms^{-1} with buoy 46001 having the highest RMS error of 2.41 ms^{-1} (Fig. 4-6). The mission requirement for wind speed RMS error is 2 ms^{-1} (Callahan and Lungu 2006). Taking out the light winds did not greatly improve the speed RMSE. Figure 8 shows how the satellite wind speed compared with the buoy wind speed over the total data set. In general the *u* component of the wind vector had a higher RMS error than the *v* component. These differences were not significant enough to study further.

4. Discussion and Conclusions

This study shows that the QuikSCAT winds in the near shore regions did better than the buoy location 46001 offshore winds. The direction RMS error for buoy 46001, which is the buoy in the middle of the Gulf of Alaska (Fig. 2), was greater than that of buoy 46084, which is along the outside waters of the Alaskan Panhandle. Both of these data sets had 30 compared observations in the data set and were both missing April data. The reason for this significant difference is unknown at this time. One explanation for this error could be precipitation, but the rain flagged data did not seem very useful in reducing error. A larger data set may improve this. Also, using other rain flagging algorithms may improve this. The mission requirement for direction was met in four out of six buoys after the light winds were taken out. This is understandable because wind direction is more variable at light speeds and the satellite mission requirement for direction is only valid for speeds between 3-30 ms^{-1}. Therefore, forecasters can use this data but take caution with the direction of light winds. The mission requirement for wind speed is 2 ms^{-1} and all the data fit within this requirement except for buoy 46001. No significant trends in wind speed have been found at this time. A larger data set may be necessary to do so.

Forecasters can get near real time (NRT) QuikSCAT data within 90 min, and the oldest data they receive is just 3 hours old. NOAA employees can plot the satellite wind barbs on their AWIPS system and overlay NWP winds as well as buoy and ship observations. The barbs can also be color coded to easily see warning criteria wind speeds (Von Ahn et al. 2006). This allows them to see the accuracy of each data set in a very convenient manner.

This instrument appears that it would be of great use to the Alaska Region National Weather Service forecasters. Continued work needs be done to determine any trends in wind speed and larger than average errors offshore. This research may also be expanded by the NWS offices themselves to include a larger data set.

Acknowledgements
I would like to thank the professors of the Meteorology department especially Dr. Scott Steiger and Dr. Steve Skubis for all their help with this research. I would also like to thank the 2007 Senior Meteorology Class for all their support. Thank you to Tom Ainsworth and Carl Dierking of the Juneau, AK National Weather Service for their assistance and inspiration for this research.

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