J16.1 PRELIMINARY ASSESSMENT OF ASCAT OCEAN SURFACE VECTOR WIND (OSVW) RETRIEVALS AT NOAA OCEAN PREDICTION CENTER

Khalil. A. Ahmad*
PSGS/NOAA/NESDIS/StAR, Camp Springs, MD
Joseph Sienkiewicz
NOAA/NWS/NCEP/OPC, Camp Springs, MD
Zorana Jelenak, and Paul Chang
NOAA/NESDIS/StAR, Camp Springs, MD

1. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) Ocean Prediction Center (OPC) is responsible for issuing marine weather forecasts, wind warnings, and guidance in text and graphical format for maritime users operating over the North Atlantic and North Pacific high seas, and the offshore waters of the continental United States. The OPC area of responsibility (AOR) extends from subtropics to arctic from 35° West to 160° East. These waters include the busy trade routes between North America and both Europe and Asia, the fishing grounds of Bering Sea, and the cruising routes to Bermuda and Hawaii.

The marine warnings issued by OPC are based upon the Beaufort wind speed scale, and fall into three categories: GALE (34 – 47 knots), STORM (48 – 63 knots), and HURRICANE FORCE (HF) for wind speeds of 64 knots or greater. These warnings are placed as labels on the North Atlantic and North Pacific Surface analysis charts produced by OPC four times daily at 00, 06, 12, and 18 UTC. OPC warnings have both safety as well as economic impacts.

In providing accurate marine warnings and forecasts, one of the most significant challenges facing an OPC forecaster is the scarcity of wind data over the vast ocean regions within the OPC's area of responsibility. The high quality, remotely sensed ocean surface vector wind (OSVW) data greatly help to fill in some of the immense data void between the sparse conventional surface observations within the OPC's AOR.

* *Corresponding Author Address:* Khalil A. Ahmad, NOAA Science Center, Room 405
5200 Auth Road, Camp Springs, MD 20746
Email: khalil.a.ahmad@noaa.gov

The SeaWinds scatterometer onboard QuikSCAT satellite was launched into space by the National Aeronautics and Space Administration (NASA) in June 1999. The SeaWinds scatterometer (henceforth, referred to as QuikSCAT) is a conical scanning, pencil beam radar operating at a Ku-band microwave frequency of 13.4 GHz that collects the electromagnetic backscatter return from the wind roughened ocean surface at multiple antenna look angles to estimates the magnitude and direction of the oceanic wind vector (Hoffman and Leidner, 2005). The OSVW data derived from QuikSCAT has a nominal resolution of 25 km, and post processing techniques have resulted in a finer resolution of 12.5 km. Both data products have been available in near real time (NRT) in operational National Centers for Environmental Prediction (NCEP) Advanced Weather Interactive Processing System (N-AWIPS) workstations at OPC since October 2001 and May 2004, respectively. The wide 1800 km swath, and the large retrievable wind speed range, along with the timely availability of the data have made QuikSCAT OSVW data a heavily used tool by OPC forecasters in their daily operations, specially, for the issuance of marine wind warnings. The forecasters have also become familiar with the strengths and limitations of the QuikSCAT data over the past several years (Von Ahn et al., 2006).

An additional source of OSVW data have become available in the large and mostly data void waters within the OPC's AOR after the recent launch of the Advanced Scatterometer (ASCAT) instrument, in October 2006, onboard Europe’s operational meteorological satellite system (MetOp-A) by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The MetOp-A satellite is the first in a series of three MetOp operational satellites of

EUMSAT Polar System (EPS) which is planned to provide continuous operational meteorological data until 2020.

ASCAT is an active C-band microwave sensor designed to measure the speed and direction of the near surface ocean wind vector, and it builds upon the experience gained from the C-band scatterometers onboard the European research satellites ERS-1 and ERS-2. The ASCAT measurements provide additional sampling of the oceanic wind vector, and reveal a different set of limitations and capabilities in comparison to QuikSCAT OSVW retrievals. The OPC's marine forecasters are now routinely viewing the data on a daily basis in the course of their operational shifts.

The potential utility of the ASCAT data is still under evaluation by OPC, and not fully integrated into operations. In this paper, we present a preliminary assessment of ASCAT OSVW as potential replacement for QuikSCAT in support of OPC operations, with emphasis on the utility of the data in detecting Hurricane Force (HF) extratropical cyclones, and estimating the appropriate wind warning category. In the following section, we provide a brief description of the ASCAT sensor and the data availability at OPC. In section 3 we investigate the ASCAT oceanic sampling contributions. Examples of ASCAT retrievals are shown in section 4. The utility of ASCAT measurements in detecting HF extratropical cyclones is discussed in section 5. The paper concludes with a brief summary in section 6.

2. ASCAT DATA AVAILABILITY AT OPC

The ASCAT sensor is a microwave radar operating at a C-band frequency of 5.255 GHz. ASCAT utilizes two sets of three vertically polarized fan-beam antennas to illuminate two 550 km wide swaths on either side of the satellite ground track. To retrieve the oceanic wind vector, the backscatter measurements from each beam are spatially averaged, using a 2D hamming window, in the along- and cross-track directions, and gridded into nodes. For each node within the swath, a set of three (one for each beam) averaged backscatter measurements at two different horizontal scales are generated, resulting in two wind vector products with 50- and 25 km horizontal resolution.

The ASCAT OSVW data products are processed at NOAA National Environmental Satellite, Data, and Information Service (NESDIS) in near real time, utilizing a wind retrieval processing system that was developed by the Royal Netherlands Meteorological Institute (KNMI) scatterometer team. The NRT 50 km resolution retrievals from ASCAT have been available in operational N-AWIPS workstations at the OPC since June 2007. The high resolution data at 25 km spacing, the ASCAT directional ambiguities, and the ability to toggle on/off the wind vectors that were flagged via the KNMI Quality Control (QC) flag were added to N-AWIPS in October 2007. The ASCAT OSVW products available in A-WIPS are linearly interpolated (from 50- and 25 km resolution) into 25- and 12.5 km horizontal spacings. The N-AWIPS display enables the forecasters to view the ASCAT data acquisition time, adjust the colors for specific wind speed ranges, and highlight the wind vectors that failed the KNMI QC flag. An example of ASCAT N-AWIPS display is shown in Figure 1.

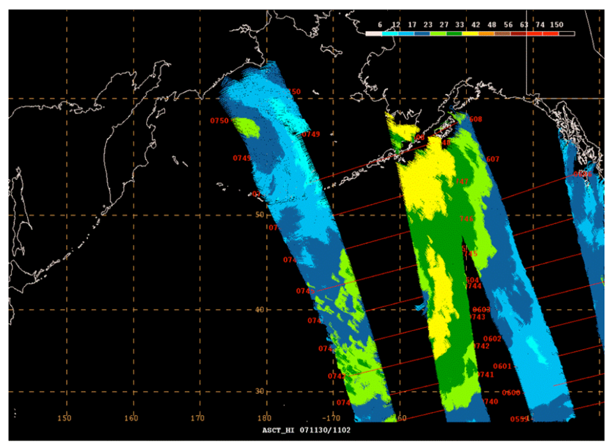

Figure 1. N-AWIPS display of two ASCAT ascending passes over the North Pacific from 0750 and 0608 UTC 30 Nov 2007 showing ocean vector winds color coded for wind speed in knots according to the color scale in the upper right corner. Timelines showing the data acquisition time are shown in red with values in UTC.

3. ASCAT OCEANIC SAMPLING

The open ocean remains a data void area. Reliable OSVW measurements, initially from QuikSCAT, and now from ASCAT greatly help to eliminate the substantial gaps between conventional in-situ observations (from ships and buoys) over the ocean.

The satellite OSVW data coverage is determined by the instrument capabilities, and the orbit characteristics. For ASCAT, the MetOp-A orbital period, and altitude, along with fan-beam scan geometry allow for a simultaneous coverage of two 550 km swaths, one on each side of the MetOp-A satellite ground track. Each swath is offset from the satellite nadir by about 360 km. Therefore, the 1100 km ASCAT coverage consists of two 550 km swaths separated by a 720 km nadir gap for a total width of about 1820 km. This configuration yields an average daily OSVW coverage of about 70% of the global ocean (between ± 60° latitude). By comparison, QuikSCAT, with its continuous 1800 km wide swath, samples about 93% of the global ocean each day. The difference in daily coverage between ASCAT and QuikSCAT is due to the 720 km nadir gap. Figure 2 shows a typical example of oceanic coverage from ASCAT and QuikSCAT ascending passes.

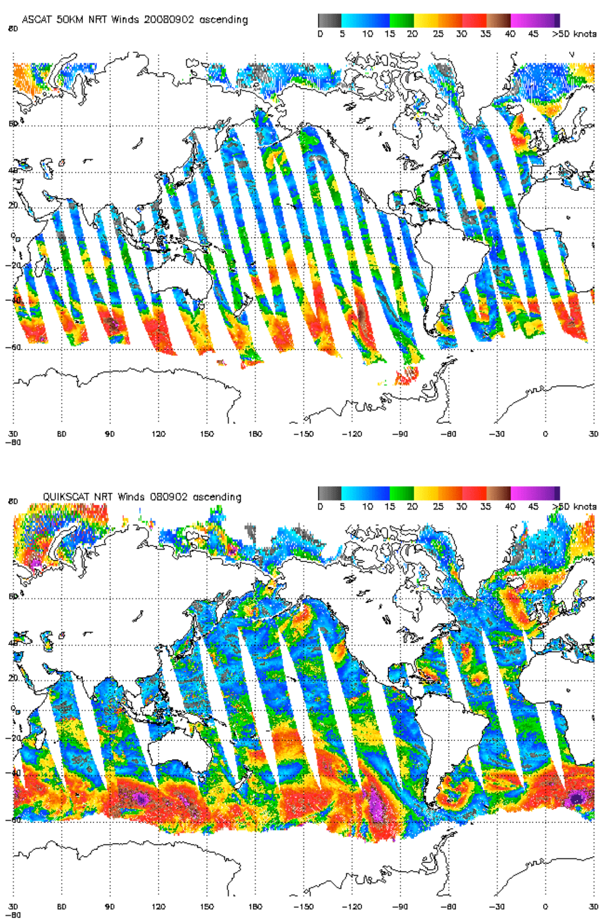

Figure 2. Daily coverage of ascending passes from ASCAT (upper panel) and QuikSCAT (lower panel) from 02 September 2008.

To further examine the coverage of ASCAT OSVW for wind warning and short term forecast purposes, the number and frequency of passes or hits were recorded for selected locations of meteorological interest. As an example, for the area of the climatological wind maximum off of Cape Mendocino, California (located at 40N 125W) two graphs were created. The first, shown in Figure 3, compares the number of ASCAT and QuikSCAT passes over a 29-day ASCAT repeat cycle period. The second graph, given in Figure 4, shows the frequency of the time differences between subsequent ASCAT passes for that location.

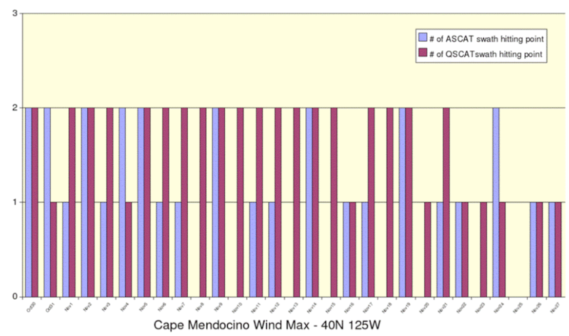

Figure 3. Daily count of passes from ASCAT (blue) and QuikSCAT (maroon) over the point 40°N - 125°W. This point is the climatological wind maximum off of Cape Mendocino, CA. GALE conditions persist across these waters during summer and fall months. These waters are heavily traveled by recreational, fishing, and commercial vessels.

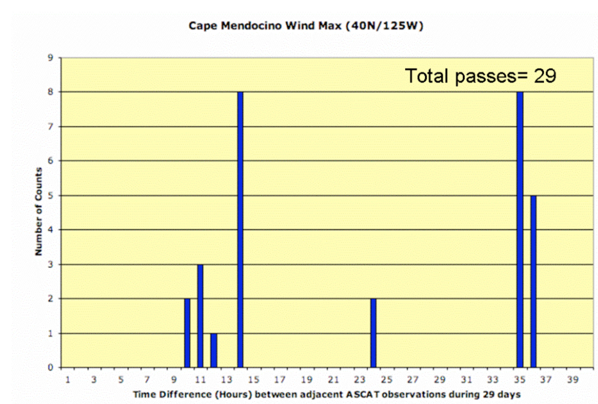

Figure 4. The number of ASCAT passes as a function of the time difference between passes in hours for the point 40°N - 125°W during the 29-day ASCAT repeat cycle.

From the results shown in Figure 3 and Figure 4, it can be seen that over the 29 day period, QuikSCAT sampled the Cape Mendocino location with 47 passes, while ASCAT had only 29 hits over that location. Further, the results indicate that ASCAT has 13 time periods every 29 days when the temporal interval between successive passes exceeds 30 hours. In comparison, QuikSCAT has a maximum temporal interval of 18 hours at any given global location. The large temporal intervals between consecutive ASCAT passes limit the utility of the ASCAT OSVW data as a sole source of OSVW to support the OPC warning function.

4. ASCAT WIND RETRIEVALS

4.1 RAIN-FREE CONDITIONS

Comparisons between ASCAT and QuikSCAT near simultaneous wind speeds in non-raining conditions reveal good agreement between the ASCAT retrievals and the winds derived from QuikSCAT for low to moderate wind speed range. However, as the wind speed exceeds about 25 knots, the ASCAT retrievals exhibit a wind speed low bias, which increases with increasing the wind speed. The low bias of ASCAT retrievals compared to QuikSCAT is likely attributed to the different operating frequencies and incidence angle sensitivity, different model functions used to infer the wind vector, and the larger footprint and lower resolution.

Figure 5 depicts an example of wind retrievals derived from ASCAT and QuikSCAT over an extratropical cyclone in the Pacific Ocean from 22 December 2007. The figure is a four panel image showing (from top to bottom) the NCEP Global Forecast System (GFS) 10-m winds (0600 UTC), two ascending 25 km ASCAT passes (0650 and 0830 UTC), two descending 25 km QuikSCAT passes (0440 and 0620 UTC), and the corresponding overlapping coverage from QuikSCAT and ASCAT passes. All wind speeds are identically color coded according to the scale in the upper right corner of the ASCAT image. By examining the first three panels, it can be seen that for low and moderate winds (displayed as shades of blue) different wind retrievals are in reasonable agreement. However, biases in different retrievals become evident for higher wind speed ranges. For example, while QuiKSCAT indicates the presence of Hurricane Force (HF) winds on the western side of the cyclone (shown in red), ASCAT retrieves STORM force winds

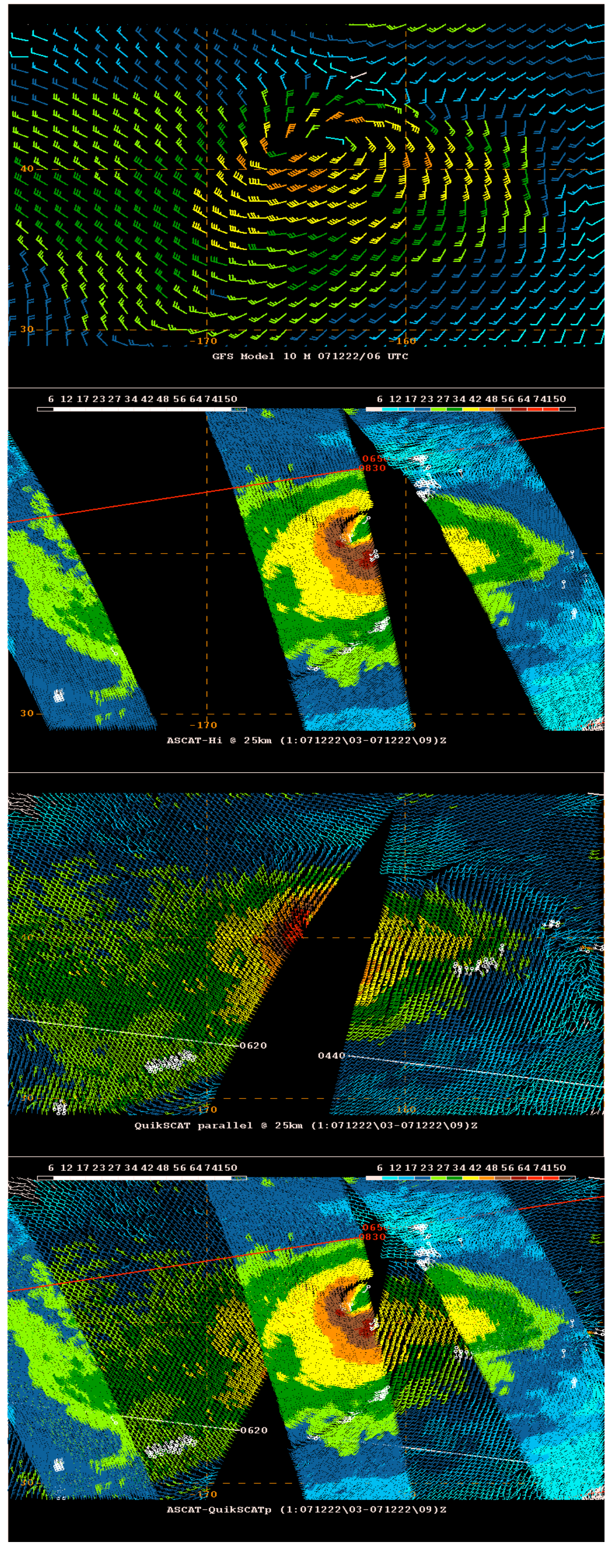

Figure 5. Four panel from 22 December 2007 showing from top to bottom, GFS 10-m model output, ASCAT passes, QuikSCAT passes, and overlapping ASCAT and QuikSCAT passes over Pacific Ocean. (See text for more details).

(dark brown), and the GFS model output shows winds of only GALE force (orange) for the corresponding location. As will be discussed in section 5, the low wind speed bias in ASCAT retrievals makes the use of these winds as a basis for determining warning category difficult, especially for the higher warning category of Hurricane Force winds.

The last panel of Figure 5 illustrates how the ASCAT and QuikSCAT satellite systems can complement each other to provide a more complete picture of the surface wind field. In this particular example, the cyclone center fell in the gap between QuikSCAT passes. The ASCAT ascending pass from 0830 UTC nearly filled the gap left by QuikSCAT, and revealed an area of winds to 60 knots.

4.2 RAIN EFFECTS

In areas of heavy rain, the Ku-band QuikSCAT retrievals suffer from rain contamination resulting often in an overestimate of the wind speed. On the other hand, the C-band ASCAT shows less impact of rain in the retrievals. Shown in Figure 6 is a four panel from 24 December 2007 showing (in a clockwise fashion) 12.5 km resolution QuikSCAT (1000 UTC), GOES-IR 0952 UTC, GOES-IR 1500 UTC, and two 25 km ASCAT passes (1500 and 1320 UTC). On this date a strong cold front with extensive convection was exiting the OPC Offshore forecast waters. The display of rain contaminated winds for QuikSCAT was turned off. QuikSCAT shows winds to Storm force in advance of the cold front with isolated winds to Hurricane Force. The Hurricane Force (HF) winds are obviously rain contaminated and are discredited by OPC forecasters. ASCAT shows GALE force winds whereas QuikSCAT had winds to STORM force. The ASCAT winds as compared to QuikSCAT do appear to be quite smooth with little variation in advance of the cold front.

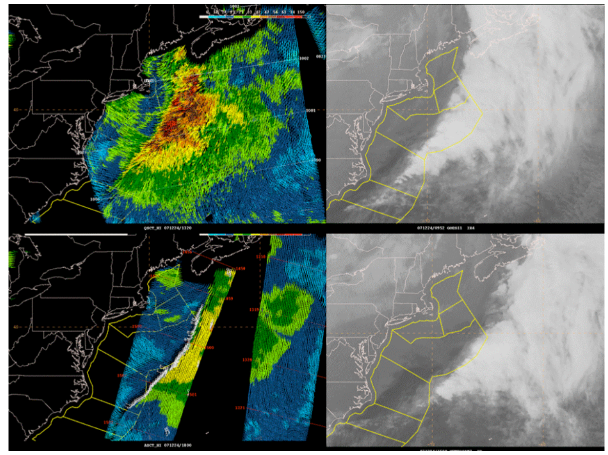

Figure 6. Four panel from 24 Dec. 2007 showing clockwise from upper left, 12.5 km QuikSCAT winds for 1000 UTC, GOES-IR 0952 UTC, GOES-IR 1500 UTC, and ASCAT 1500 and 1320 wind vectors. Wind speeds are color coded according to the scale in the upper right of the QuikSCAT image. Minimal Gale force winds are yellow, strong Gale – orange, Storm force – dark brown, and Hurricane Force - red. The white OSVW in the ASCAT image failed the KNMI quality control process.

5. ASCAT WARNING UTILITY IN HURRICANE FORCE EXTRATROPICAL CYCLONES

Extratropical cyclones are synoptic scale low pressure weather systems that occur in the middle latitude of the Earth with wind circulation rotating (counterclockwise / clockwise) in the (Northern / Southern) Hemisphere. These weather systems vary on scale from 100 km to about 4000 km in diameter, and have an average life cycle of about five days from genesis to death. Extratropical cyclones occur frequently during fall, winter and early spring over the North Atlantic and Pacific oceans. They are a principal source of warning criteria in the OPC waters of responsibility, with associated wind conditions that can vary from SUB-GALE to HURRICANE FORCE (HF).

Extratropical cyclones that reach HF intensity present a significant threat to safety at sea. Dangerous winds and waves associated with these extreme cyclones can result in loss of life and property. These cyclones can also generate swell that cause destructive conditions along coastlines thousands of miles away.

Prior to QuikSCAT, the OPC forecasters infrequently received ship observations of HF wind strength but had no means to consistently detect or warn for these extreme conditions. The HF warning category was added in December 2000, once it became clear that QuikSCAT was able to detect the HF conditions. Using QuikSCAT enabled the OPC forecasters to more accurately identify these dangerous storms, and keep the mariners apprised of their track and intensity (Von Ahn et al., 2006).

During the winter season of 2007-2008, OPC conducted a study to quantify the utility of ASCAT wind data as a potential replacement for QuikSCAT to support the OPC operations in issuing HF warnings for extratropical cyclones. The study methodology, and results obtained are discussed in the following sub-sections.

5.1 STUDY METHODOLOGY

As discussed earlier, The OPC produces four surface analyses for the North Pacific and Atlantic Oceans each day consisting of isobars, fronts, cyclone locations, and intensity. As part of the analysis process each weather system meeting wind warning criteria (GALE, STORM, and HURRICANE FORCE) is labeled with the appropriate warning category. These analyses serve as the basis for High Seas text warning and forecast bulletins. Forecasters use all available observational sources such as QuikSCAT, ASCAT, and ship and buoy observations to estimate warning categories.

All surface analysis charts (for North Pacific and Atlantic basins) during the period from 01 October, 2007 till 15 May, 2008 were collected and examined to identify all extratropical cyclones marked with a HURRICANE FORCE label. Each cyclone was assigned a unique tracking number. Then, surface analysis charts were used to track each cyclone while it maintained HF conditions. For each 6-hour synoptic time, we recorded the location of the cyclone, and the range of maximum wind speeds retrieved from ASCAT and QuikSCAT pass(es). Also, for comparison purposes, we recorded maximum wind speed values from two Numerical Weather Prediction (NWP) models: the NCEP GFS 10-m, and the European Centre for Medium-Range Weather Forecasts (ECMWF) 10-m winds. Further, available in-situ observations from ships and buoys were also recorded.

5.2 STUDY RESULTS

Based on the OPC forecaster analyses, during this study period, a total of 44 Atlantic and 50 Pacific extratropical cyclones were estimated to have reached HF intensity, with a monthly distribution as shown in Figure 7.

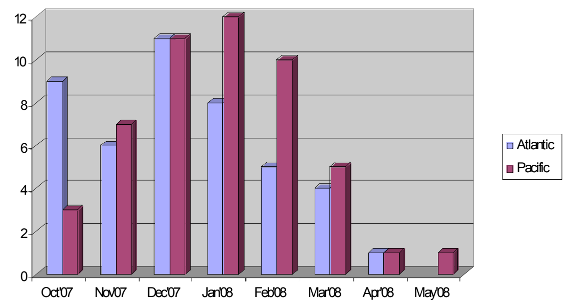

Figure 7. Monthly distribution of the HF extratropical cyclones over the North Atlantic and Pacific oceans during the 2007-2008 season. The maximum activity was observed in December for the Atlantic basin, and in January for the Pacific.

Data Source	Atlantic	Pacific	Total
QuikSCAT 12.5 km	112	83	195
QuikSCAT 25 km	101	67	168
ASCAT 25 km	0	2	2
GFS	20	18	38
ECMWF	4	0	4
OBS (ship/buoy)	4	11	15

Table 1. Number of passes with Hurricane Force winds in extratropical cyclones from the 12.5 km and 25 km resolution QuikSCAT, 25 km ASCAT, ship and buoy observations (OBS), GFS and ECMWF winds.

The number of passes that observed HF winds within the 94 extratropical cyclones, for the six observational data sources, are listed in Table 1. Results indicated that 195 QuikSCAT (12.5 km) passes, and 168 QuikSCAT (25 km) passes retrieved HF winds. However, for the 25 km ASCAT product, only two passes showed winds of HF intensity. In essence, only about 1% of the HF events detected by QuikSCAT were observed by ASCAT. The limited number of ASCAT passes of Hurricane Force winds are due to both the low wind speed bias and reduced coverage (as compared to QuikSCAT).

By examining the remaining data sources, it can be seen that the GFS winds were in agreement with QuikSCAT about 20% of the time with 38 analyses or short term forecasts with HF conditions. It should be noted that GFS does assimilate QuikSCAT winds (along with other data sources), thus it is unclear how many GFS conditions or short term forecasts would have contained winds of HF intensity without QuikSCAT data. This study clearly illustrate the superiority of QuikSCAT data in detecting HF winds within extratropical cyclones.

6. SUMMARY

The ASCAT OSVW data provides additional temporal and spatial sampling of the oceanic wind vector within the large and mostly data void OPC AOR. Preliminary evaluations indicate that ASCAT can reliably retrieve low to moderate surface wind speeds in all weather conditions. This performance represents an improvement over QuikSCAT, which suffers from an artificially rain inflated retrievals in areas of rain. However, for higher wind speeds, ASCAT retrievals are found to have a low wind speed bias, which increases with increasing wind speed.

A study conducted by OPC to evaluate the ASCAT HF warning capability revealed that about 99% of the HF wind events detected by QuikSCAT were not observed or not retrieved by ASCAT. This is mainly attributed to the ASCAT low wind speed bias, along with its limited swath coverage which significantly degrade the utility of the instrument to support the OPC warning function across all wind warning categories, specially for the dangerous HF conditions.

6. REFERENCES

Hoffman, R.N., and S.M. Leidner, 2005: An introduction to the near-real time QuikSCAT data. Wea. Forecasting, **20**, 476-493.

Von Ahn, J., M., J. M. Sienkiewicz, and P.S. Chang, 2006: The operational impact of QuikSCAT winds at the NOAA Ocean Prediction Center. Wea. Forecasting, **21**, 523-539.