VALIDATION AND EVALUATION OF QUIKSCAT ULTRA-HIGH RESOLUTION WIND RETRIEVAL IN THE GULF OF MAINE

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ABSTRACT

Researchers at Brigham Young University have created an experimental 2.5 km ultra-high resolution (UHR) wind product from the QuikSCAT scatterometer. This product adds to the standard 25 km and new 12.5 km resolution data provided by that satellite, and offers the potential for new access to coastal surface wind dynamics at the sub-mesoscale level. With its nineteen meteorological buoys, the Gulf of Maine provides an excellent test site for evaluating the UHR wind retrievals. Comparison with these buoys, mesoscale meteorological model winds, and standard QuikSCAT products throughout the month of October 2006 allows detailed investigation of UHR wind speed and direction. Even with a land contamination mask, the UHR product provides extended coverage near the coast. An additional ambiguity reselection routine improves wind direction agreement between the UHR winds and the other products. With this refinement, the ultra-high resolution winds show great promise in the coastal region.

***Index Terms*—** scatterometer, coastal ocean winds, enhanced resolution, ambiguity selection

1. INTRODUCTION

Since 1999, ocean vector winds from the satellite-based QuikSCAT instrument have been widely used. This Ku-band scatterometer was designed to retrieve wind speed and direction at a 25 km resolution, through normalized radar backscatter measurements and a geophysical model function. A more recently developed enhanced product now provides wind vectors at a resolution of 12.5 km [1]. QuikSCAT covers 90% of the globe in 24 hours; the spatial and temporal coverage provided makes scatterometer-derived wind data valuable for a variety of users. Because QuikSCAT takes multiple "looks" at the ocean surface, wind direction can be determined as well as wind speed. There are several possible solutions for each backscatter measurement, referred to as "ambiguities."

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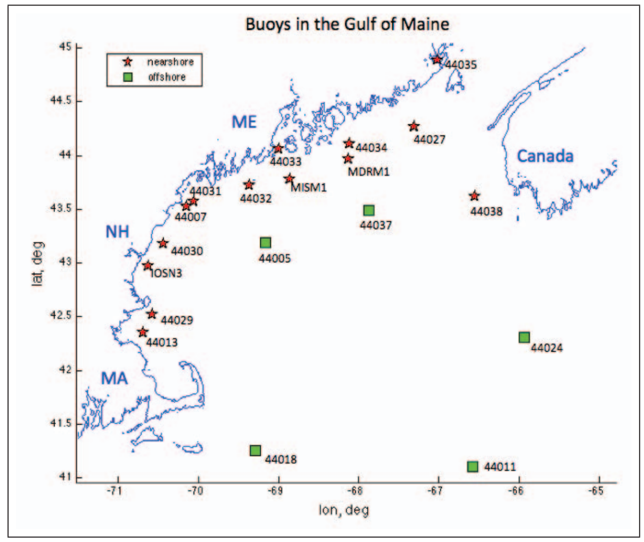

Fig. 1. Buoy network in the gulf of Maine

In many areas of the northeastern United States, the forecasting abilities of regional observing systems are complicated by land-ocean and atmosphere-ocean coupling in the coastal zone. Currently, satellite wind data is used in oceanographic and weather models but, although it is useful, it cannot resolve many near-shore processes. Coastal wind users need better tools to understand, model, and predict particular microscale meteorological features, such as the sea breeze and front and trough passages. A higher resolution satellite wind product could provide an important tool to meet these needs. One possible source would be synthetic aperture radar (SAR). However, although SAR systems provide an extremely high resolution (10 – 100 m) view of wind magnitude, they are not able to resolve wind direction. In addition to this drawback, unlike the twice-daily passes from QuikSCAT, coverage from even the two most accessible SAR instruments (Radarsat-1 and Envisat Advanced SAR) is infrequent at best. It is for these reasons that a high-resolution scatterometer wind product could benefit many users in the coastal ocean community. Potentially, this type of product could resolve processes closer to shore and in greater detail than current scatterometer retrievals, and yet provide vector winds at a better temporal resolution than SAR.

Such an enhanced scatterometer product wind product is currently being created at Brigham Young University [2]. Before these experimental wind retrievals can be used to investigate near-shore dynamics, they must be fully evaluated in the coastal region. Previous work concentrated on wind magnitude validation [3]; this study focuses on directional analysis.

2. METHODS

2.1. Data

The experimental 2.5 km ultra-high resolution (UHR) wind product is, like the standard QuikSCAT products, available twice daily in all weather. The extensive information provided by the full data record from 1999 to the present, and the wide-swath, high spatially- and temporally-sampled nature of this UHR wind product could offer new access to coastal surface wind dynamics at the sub-mesoscale level. To begin the analysis, an introductory survey investigated the UHR retrievals for the one month of data (October 2006). The data were produced using the AVE algorithm [2], and the ambiguity was selected according to an algorithm that chooses the closest 25 km vector.

The dense network of buoys in the Gulf of Maine provide an ideal testbed for this study (see Figure 1). Further information was assembled by comparing the UHR winds with standard QuikSCAT 25 km and 12.5 km Level 2B (L2B) swath retrievals (produced by the NASA Scatterometer Projects and distributed by the NASA Physical Oceanography Distributed Active Archive Center at the Jet Propulsion Laboratory). Each type of scatterometer data was collocated with each buoy by finding all pixels within a 10 km radius of the buoy location and taking the average for both speed and direction. If there were no pixels within the specified radius, no matched pair was declared. There were 1330 pairs possible in October 2006; collocation produced 725 pairs for the UHR retrievals and 557 and 171 pairs for the L2B 12.5 km and 25 km winds respectively.

Comparison of UHR wind magnitude with that of the standard QuikSCAT products, as well as with winds from a regional mesoscale meteorological model (run jointly by University of New Hampshire and AER, Inc.), indicated that the high UHR wind speeds along the coast were an artifact of land contamination. The data were re-produced using a land contamination removal algorithm [4], and the new masked wind retrievals avoided most of the near-shore bias.

Figures 2 and 3 show sample swaths of UHR wind magnitude, with model vectors overlain. Additionally, the circles representing buoys are colored according to the same scale as the UHR magnitude image. In the image from October 1, convection cells are visible, and the offshore flow present on the 21st of October created a wind shadow off of Cape Cod that is beautifully shown in the scatterometer data.

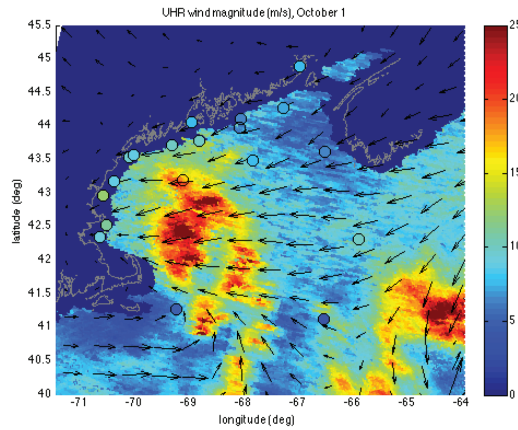

Fig. 2. Landmasked UHR and buoy wind magnitude for Oct 1, 2006; model wind vectors shown in black; buoy speeds in circles.

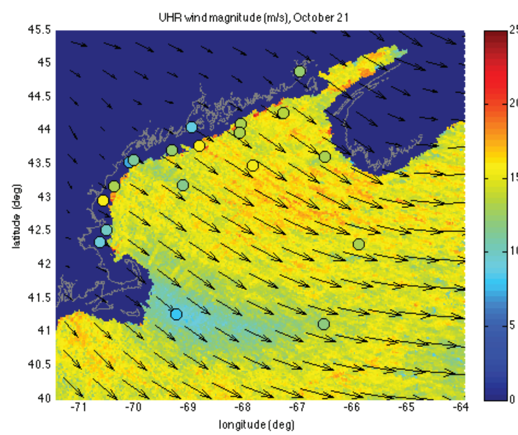

Fig. 3. Landmasked UHR and buoy wind magnitude for Oct 21, 2006; model wind vectors shown in black buoy speeds in circles.

2.2. Statistical analysis

Prior research focused on individual buoy-satellite pass analysis and direct comparison of buoy wind magnitude with that from the different scatterometer winds [3]. In this study, statistical methods were used to analyze the month of scatterometer-buoy pairs, including mean and standard deviation calculations. Speed and direction residuals (scatterometer minus buoy) were organized according to buoy wind speed, buoy station, and cross-swath position [1].

These statistical analyses indicated that the UHR wind direction did not agree with buoy winds or coincide with the direction from the other scatterometer products. To determine the source of the discrepancy, the focus shifted from a monthly summary to the individual satellite passes throughout the month.

2.3. Ambiguity re-selection

Detailed examination of the UHR data demonstrated that there were significant errors in the wind direction in 61 of the 70 passes; it was hypothesized that the initial choice of ambiguity was flawed. During creation of the data, the original selection process was designed to choose the ambiguity that was nearest in direction to the standard 25 km QuikSCAT product. However, comparison with 12.5 km and 25 km data indicated this selection process had malfunctioned. A new algorithm selected one of the four UHR ambiguities for which the product of speed and direction was closest to that of the L2B 12.5 km product. The reselected data (UHR-RS) proved to agree better with both the standard QuikSCAT winds and the model winds for 51 of 70 passes, and better in part of the swath for 13 passes. Figure 4 shows the improvement in direction for a small section of the October 1 image shown above in Figure 2.

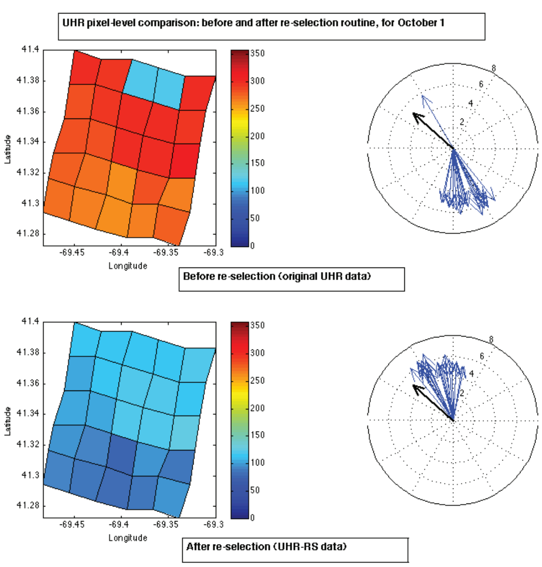

Fig. 4. Pixel-level comparison of speed and direction for a small area before and after re-selection routine. Color of pixel indicates direction in degrees; arrows on rose show wind vectors from the above UHR pixels (blue) and a near-by buoy (bold black).

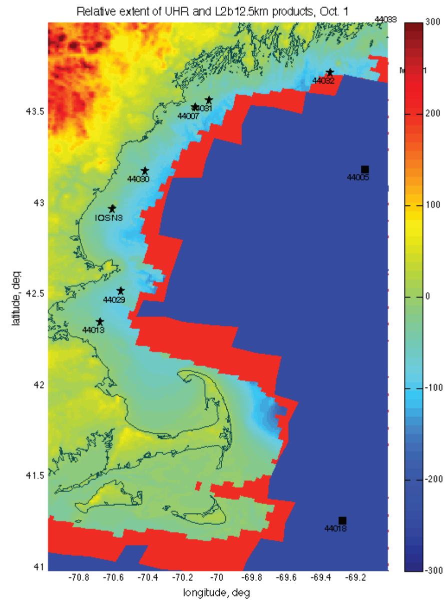

Fig. 5. Relative extent of L2B 12.5 km and UHR data for Oct 1, 2006, shown on top of Gulf of Maine bathymetry. UHR data is shown in red, covering a greater near-shore area than the blue 12.5km data.

3. RESULTS

Overall, the reselected data in the Gulf of Maine shows the value of the UHR wind retrievals. The near-shore coverage is an improvement over the L2B 12.5km data, even with the land mask applied, and the reselection process did not degrade this near-shore data. Figure 5 shows the Massachusetts Bay region with the UHR-RS data coverage area shown in red and the extent of the L2b 12.5 km data shown in blue. This example is from October 1, but the difference between the coastal coverage two products is similar for all of the October passes. A proxy for this is seen in the number of buoy collocation pairs for each data type; the UHR product reaches within 10 km of the near-shore buoys 46% of the possible 980 matches, whereas the 12.5 km data only finds a pair 23% of the time.

In Figure 6, a latitudinal slice has been taken through the standard 12.5 km, the original UHR, and the UHR-RS data. The slice shows the wind data through 41.5 degrees N Latitude (+/- 0.05 of a degree). The reselected data shows less scatter in the magnitude and direction data. Much of the noise has been removed, and the UHR-RS means correspond much more closely with those of the L2B 12.5 km data. Remaining errors in UHR-RS direction can primarily be explained by the 180 degree ambiguity (whether the wind is blowing to or from a direction); this type of error is inherent in scatterometer re-

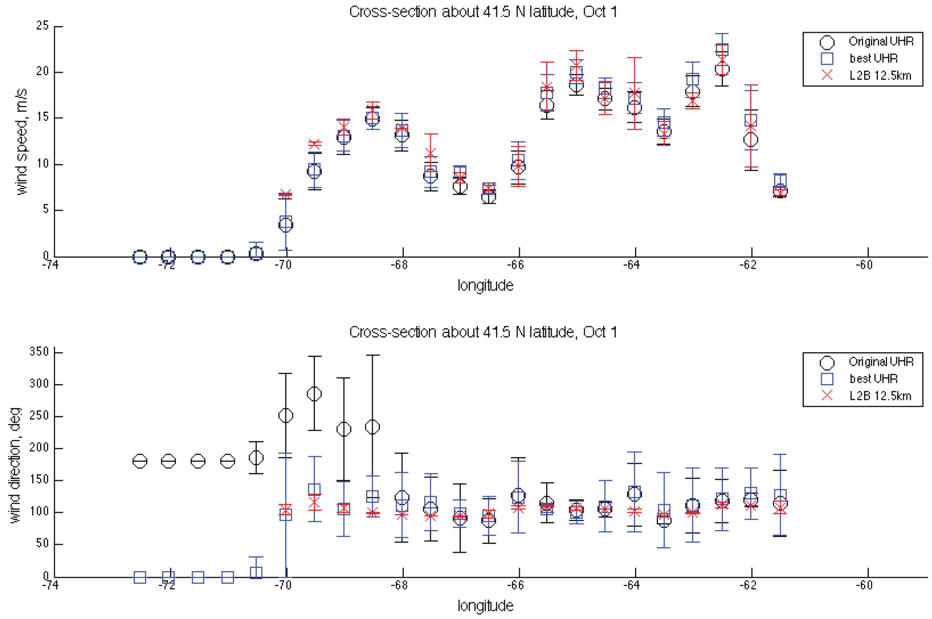

Fig. 6. Latitudinal slice of wind magnitude and direction

trievals, and may be lessened by filtering techniques.

This preliminary work indicates the great potential of the ultra-high resolution scatterometer winds. Further research will be vital in quantifing the benefits, both in terms of increased near-shore coverage and sub-mesoscale dynamics. Oceanic and atmospheric phenomena can be investigated through relating the UHR product to other data. Sea surface temperature (satellite infrared and microwave), air-sea temperature difference (through buoy data), ocean currents (drifters and high-frequency radar), true color imagery, and SAR data could all help increase our understanding of what the UHR retrievals can tell us.

4. ACKNOWLEDGMENT

The authors would like to note the importance of *in situ* information from the National Buoy Database and the Gulf of Maine Ocean Observing System.

5. REFERENCES

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