SAR-derived Winds from Hurricanes: Assimilative Blending with Weather Forecast Winds

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ABSTRACT

We use a variational data assimilation method to combine remotely sensed SAR (synthetic aperture radar) wind data from Hurricane Isabel (2003) with other sources of winds, including scatterometer, and a blended surface wind analysis combining QSCAT and the NCEP reanalysis. Resulting winds are validated with *in situ* buoy observations. We show that the newly-constructed winds are consistent with independent observations. Preliminary results suggest they are an improvement over QSCAT/NCEP blended winds.

Keywords: SAR-derived winds, Hurricane Isabel, variational data assimilation.

1 INTRODUCTION

In September 2003, Hurricane Isabel developed to category 5 intensity north of the Caribbean, and moving toward the northwest, weakened to category 2 as it made landfall in North Carolina. To generate high-quality marine wind estimates for this hurricane, we start with RADARSAT-1 SAR-derived wind data, and generate new marine winds by using a variational data assimilation method to combine the SAR data with background fields consisting of QuikSCAT (QSCAT), or alternatively, QSCAT/NCEP (National Centers for Environmental Prediction) analysis winds. Resultant winds are shown to compare favorably with *in situ* buoy winds relative to what is achieved with the QSCAT/NCEP winds. The variational method uses constraints to create an optimum combination of winds, in the sense of minimization of a cost function measuring the misfit between observations and background input field data, and constraining non-geophysical features in the spatial derivatives. QSCAT/NCEP winds are obtained by blending QuikSCAT scatterometer data with NCEP reanalysis winds [*Chin et al.*, 1998; http://dss.ucar.edu/datasets/ds744.4/]. Section 2 briefly describes Hurricane Isabel and the methodology. Section 3 gives marine wind results and Section 4 gives conclusions.

2 HURRICANE ISABEL

Hurricane Isabel was first categorized as a Tropical Storm in the central Atlantic Ocean on 6 September 2003. It intensified to a category 5 hurricane and moved westward, north of the Caribbean and Bahamas. On 14 September, Isabel's movement slowed, after turning towards the northwest. Cooler waters over which it passed prevented further intensification. It continued to weaken as it headed toward the North Carolina coast, making landfall as a category 2 hurricane at Ocracoke Island between Cape Hatteras and Cape Lookout, with maximum sustained winds near 85 kts around 17 UTC on 18 September.

Our variational methodology [*Pegion et al.*, 2000; *O'Brien et al.*, 2003; *Bourassa et al.*, 2002; *Morey et al.*, 2005] is an objective technique based on minimization of a cost function, which measures misfit to observations, and smoothing with respect to several background fields. The influence of a background field is controlled by weights on the smoothing constraints. These are objectively derived by a cross validation method, which removes observations from the input to the cost function and determines tuning parameters by the insensitivity of the output field to the removed observations.

3 MARINE WIND RESULTS

Figure 1 gives wind speed estimates for Hurricane Isabel, and also locations of two NDBC (National Data Buoy Center) buoys, which collected wind data. Winds from QuikSCAT data for the two swaths during the period from 06 to 18 UTC on 18 Sept. 2003 are given in Figure 1a. Using background data consisting of winds from the two QuikSCAT swaths, *plus* QSCAT/NCEP winds, which are also used as background data to fill the gaps between the QuikSCAT swaths, we used the variational method to assimilate the observed SAR-derived data. The NCEP/QSCAT winds are shown in Figure 1b. The SAR wind field map is for 11 UTC on 18 Sept., as shown in Figure 1c following the analysis of *Shen et al.* [2006], completely covers Isabel's eye and shows details not present in QuikSCAT images. Our resulting blended winds appear in Figure 1d.

In terms of background wind fields, we also tried filling the gaps between QuikSCAT swaths with CMC winds, or alternately QuikSCAT data, by including swaths over an extended time, ± fifteen hours centered on the analysis time. In either case, the resulting winds were about the same as shown in Figure 1d, which use QSCAT/NCEP data to fill the QuikSCAT gaps. This result occurs because the storm's central region is covered by QuikSCAT swaths, and although QSCAT/NCEP data may differ significantly from QuikSCAT data in this region, these wind maps are all very similar in less rapidly varying storm regions which make up the swath gaps, *and* in this analysis high values for weights are used, so that the SAR data is dominant.

For winds in excess of 20 ms^{-1}, buoys 41001 and 41002 may have some bias, as may also occur for the blended winds, resulting from the curl constraint in the variational method - sometimes the shear is changed as the variational method attempts to match the changes in the background curl. Overall, our final blended winds tend to be similar to buoy data, and QSCAT/ NCEP blended winds. While buoy 41002 recorded 24.8 ms^{-1}, the SAR measured 24 ms^{-1}, NCEP/QSCAT suggests 27.5 ms^{-1}, and our blended winds got 24.7 ms^{-1}.

4 CONCLUSIONS

We studied marine winds for Hurricane Isabel, constructing wind fields using a variational data assimilation method to blend remotely sensed data with background wind fields. The variational approach is a standard objective formulation. Our analysis focused on a SAR image that captured Isabel's eye. The variational method was used to assimilate the SAR data, providing new information about Isabel's central region. Preliminary results suggest that blended winds are comparable with buoy winds and superior to QSCAT/NCEP winds. However, rain flagging is an ongoing concern for remotely sensed wind fields.

ACKNOWLEDGEMENTS

This work is supported by the Panel on Energy Research and Development (Environmental Offshore Factors), the Canadian Space Agency, and the Chinese National Natural Science Foundation project No.40676095.

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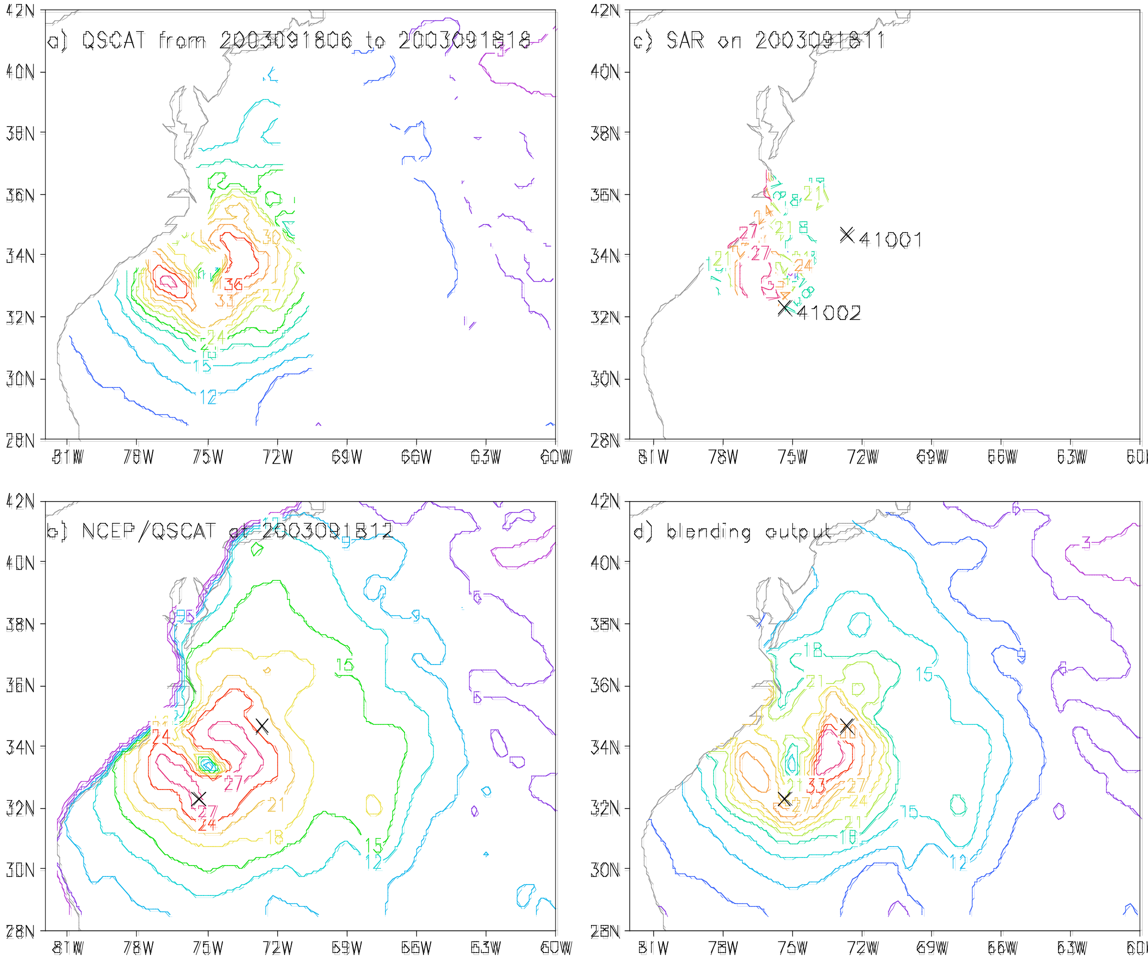

Figure 1. (a) Winds (m/s) from QuikSCAT scatterometer data for swaths during period from 06 to 18 UTC on 18 Sept. 2003; (b) QSCAT/NCEP winds, used as background data to fill the gaps between the QuikSCAT swaths; (c) the SAR image for 11 UTC on 18 Sept.; and (d) the final blended winds. Buoy 41001 is at (34.683° N, 72.662° W), and 41002 is at (32.31° N, 75.35° W).