High-Resolution Marine Wind Retrieval Using Synthetic Aperture Radar

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As weather prediction systems continue to encompass an increasing range of scales, there is a practical need to combine simulated fields with observations that are valid on these newly resolvable space and time scales. Surface wind fields over the ocean are highly variable on scales of a few kilometers and an accurate specification is important for a wide variety of applications. The high horizontal resolution of synthetic aperture radar (SAR) offers the potential for sub-kilometer winds and SAR measurements by RADARSAT-1 may be well suited for incorporation into a coastal data assimilation system. We explore the feasibility of combining SAR observations and high-resolution numerical simulations for coastal regions of eastern Canada. In the context of a variational data assimilation approach, we consider estimation of vector wind fields from SAR. The scalar radar cross-section measured by SAR is a function mainly of Bragg scattering from capillary waves, which in turn varies roughly with wind speed. Although some scenes contain boundary layer roll convection, which is a good indication of wind direction, such features are not always present and the retrieval of the wind field is often underdetermined.

A wind calibration specific to SAR has yet to be performed. If SAR wind errors could be quantified, this would constitute an initial step toward the assimilation of such data into coastal models. Simple estimates of these errors are derived here using a variational approach. Collocations of ship/buoy, model, and SAR data have been assembled using 272 SAR acquisitions in May to November 2004, and processed on a 1 km grid resolution. The ship and buoy observations have been used as the reference dataset. The model winds are from analyses using the 15 km operational regional model at the Canadian Meteorological Centre (CMC). The ship and buoy data have been visually inspected, and the SAR data have been masked over land, sea ice, along beam seams, and where winds are below 3 m/s or over 33 m/s. Buoy observations within 90 minutes of a SAR acquisition have been used. They have been adjusted to the 10 m level and are considered valid within 50 km. A total of 5667 ship/buoy-model-SAR collocations have been obtained.

As a result of the scatterometer wind calibration effort (e.g. Stoffelen 1998), a relationship (CMOD) between wind and backscatter is available. Bragg scattering from capillary waves varies with wind speed, wind direction, SAR beam angle, and other processes. The empirical relation used here is CMOD5 (Hersbach 2003). CMOD has been derived using ERS scatterometry data. ERS is vertically polarized, whereas RADARSAT-1 is horizontally polarized, so we employ a polarization correction (Vachon and Dobson 2000).

The desired surface wind field is a weighted combination of the SAR observations and model winds that minimized a cost function assuming Gaussian error structures. The errors in the SAR backscatters and winds are chosen to best fit the ship/buoy winds. Given wind errors of 1.7 m/s, the best choice for SAR errors appears to be 1.5% of the backscatter (smaller than in Portabella et al. 2002).

The results support the Gaussian error distribution as assumed in the form of the cost function. The “retrieved versus observed” bias is significantly smaller than the “model versus observed” bias, so the incorporation of the SAR backscatter observations has improved the analysis when compared with the ship/buoy observations. Hence the use of SAR observations in a variational context appears to improve the surface wind analysis produced by the CMC system.

In situ observations are also erroneous (Stoffelen 1998) because they are not representative of large areas (i.e, they are point observations rather than spatial averages). In order to avoid pseudo-biases in SAR observations, all error types should be considered, that is, a SAR wind calibration is still required.

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