WIND RETRIEVAL OF TROPICAL CYCLONES USING C-BAND SYNTHETIC APERTURE RADARS

Jochen Horstmann[1], Xiaofeng Li[2] and Bill Pichel[2]

[1]NATO Undersea Research Center, La Spezia, Italy
[2]NOAA/NESDIS, Camp Springs, USA

Abstract: In the last decade several synthetic aperture radar (SAR) images of tropical cyclones have been acquired by the European satellite ENVISAT as well as the Canadian satellite RADARSAT-1. These SAR images provide a unique opportunity to investigate the utility of SAR data for estimation of extreme winds as well as for the improvement of forecasting tropical cyclones. Using the SAR wind retrieval algorithm WiSAR, we have obtained good accuracies (root mean square error of 18° and 1.5 ms^{-1}) for low to moderate wind speed conditions. WiSAR was especially adjusted for use with the satellites ERS, ENVISAT and RADARSAT-1, all operating at C-band at either HH- or VV polarization in transmit and receive. The algorithm enables one to retrieve wind fields with a resolution of up to 300 m over a swath width of up to 500 km (for the RADARSAT and ENVISAT wide-swath modes). WiSAR has been implemented at the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) of the University of Miami where it is used to generate wind field maps from SAR images on a semi-operational basis for monitoring of tropical cyclones.

The possibility of estimating extreme winds using SAR data is investigated utilizing ENVISAT ASAR data acquired at VV polarization and RADARSAT-1 SAR data acquired at HH polarization. The resulting SAR-retrieved wind fields are compared to results of high-resolution numerical models as well as in situ measurements collected by aircrafts and buoy data. Furthermore, the limitations of the methodologies, in particular the geophysical model functions (GMF) for retrieving wind speeds, will be discussed with respect to tropical cyclones considering SAR and scatterometer measurements. These investigation show the influence of sea state (in particular of swell) and heavy rain on the NRCS and therefore on the wind speed retrieval as well as the limitations due to sensors. Finally, the utility of SAR for estimating extreme winds as well as the shape and size of the eyes of tropical cyclones will be discussed with respect to tropical cyclone forecast.

Derivation of the sea surface wind field from SAR is a two-step process: In the first step wind directions are extracted from wind-induced phenomena that are aligned in wind direction. The orientations of these features are derived by determining local gradients of the normalized radar cross section (NRCS) from the SAR data. In this approach, a SAR image is sequentially smoothed and reduced to resolutions of 100, 200, and 400 m. The resulting three SAR images retain spatial scales greater than 200, 400, and 800 m. From each of these images, local directions defined by the normal to the local gradient (to within a 180° ambiguity), are computed. Pixels associated with land, surface slicks, and sea ice, are masked and excluded from the analysis. From all of the retrieved directions, only the most frequent directions in a predefined grid cell are selected. The 180° directional ambiguity can be removed if wind shadowing, which is often visible in the lee of coastlines, is present. These features or other a priori information, e.g., weather charts,

atmospheric models or in situ measurements are used to remove ambiguities. In the second step wind speeds are retrieved utilizing a GMF that describes the dependency of the NRCS on the local near-surface wind and imaging geometry. For C-band, VV-polarization, there are a number of popular model functions. The most commonly used is Cmod4 and the most recently developed is Cmod5. Each of these GMFs is directly applicable for wind speed retrieval from C-band VV polarized SAR images. For wind speed retrieval from C-band SAR images acquired at HH-polarization (i.e., the configuration for RADARSAT-1 images), no similar well- developed GMF exists. To meet this deficiency a hybrid model function is used that consists of one of the prior mentioned GMF and a C-band polarization ratio (PR). The PR used in this study neglects wind speed and wind direction dependence, but nevertheless shows good results when utilized for wind speed retrieval from RADARSAT-1 SAR imagery. The Cmod4 GMF underestimates the surface wind for speeds greater than 20 ms^{-1} or so. The Cmod5 algorithm was specifically designed to provide better estimates of the NRCS at higher wind speeds. Differences between Cmod4 and Cmod5 for low to moderate wind speeds are relatively minor. At high wind speeds (>25 ms^{-1}) however, the differences become quite significant.

Keywords: Tropical cyclones, Ocean surface winds, synthetic aperture radar, radar backscatter