STUDIES OFTHE INFLUENCE OF RAINFALL UPON SCATTEROMETER ESTIMATES FOR SEA SURFACE STRESS: APPLICATIONS TO BOUNDARY LAYER PARAMETERIZATION AND DRAG COEFFICIENT MODELS WITHIN TROPICAL CYCLONE ENVIRONMENTS

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The use of satellite scatterometers to probe the winds in and near strong tropical cyclones (TCs) is a valuable tool for both numerical weather prediction (NWP) and weather forecasters. The presence of widespread rain in these storms complicates the estimates for surface winds from the satellite products . Improvements in the techniques to infer surface winds from the satellite observations, which remove the effects of rain contamination at the ocean surface, will improve the modeling efforts as they pertain to the prediction of TC intensity. This study will demonstrate the use of collated and simultaneous high-resolution rain measurements obtained from nearby Next-Generation Radar (NEXRAD) and NASA Quick Scatterometer (QuikSCAT) measurements, respectively. Through the application of the National Oceanic and Atmospheric Administration (NOAA)/Atlantic Oceanographic and Meteorological Laboratories (AOML)/Hurricane Research Division (HRD) TC wind analysis (H*WIND; Powell and Houston [1996]), we will study the dependence of a surface normalized radar cross-section (NRCS) on the TC wind-speed and rain-rate. The objective is to better observe and understand the dependence of the drag coefficient upon the surface stress across a wide range of conditions and spatial scales within these storms.

This study will demonstrate the ability of QuikSCAT to estimate the air-sea momentum and thermodynamic fluxes within TCs, even though rain has a significant impact upon the air-sea interface. Previous and ongoing work by the authors has demonstrated the effects of significant rain-rates upon the surface roughness (normalized radar cross section) within high-wind environments. These results provide the quantitative evidence and support for the appreciable increase of the NRCS as a function of rainrate at wind speeds as high as 40 m/s.

The deficiencies of recent studies of air-sea momentum exchange in hurricanes [e. g., Moon, et al, 2004; Emanuel, 2003] is that they apply surface drag coefficients which do not take into account the impact of rain-rates and the subsequent roughing of the ocean surface. Thus, thedo not allow for appropriate spatial variations of this parameter within TCs.. They indicate that, at high wind-speeds, sea-spray and breaking waves will likely influence the spatial variations of the drag coefficient. However, their analyses were limited since there previously existed little available data to address this issue largely because there has been a lack of direct observations of the drag coefficient in the presence of rain.

The physical modeling of the relationship between sea-surface wind-speeds from 5 to 15 m/s and microwave radar backscatter has advanced to a mature area of knowledge [Plant, 2003]. Bragg scattering is the generally accepted interpretation of observations made by scatterometers under these wind conditions. This approach relates the normalized radar cross section measurements (NRCS) to the small scale centimeter wave spectrum and thereby to the surface friction velocity and wind stress. The increase of winds are then related to the growth of the wave spectrum, which is well approximated by closed form mathematical functions. For wind-driven seas, the aerodynamic roughness (a key parameter in the log-wind profile, and translatable to a drag coefficient) can be mapped to geometric roughness (shape) of the surface water waves. For these conditions, there is a relationships between two electromagnetic polarizations H-pol and V-pol, where the NRCS for V-pol clearly exceeds that for H-pol. Therefore, the radar NRCS should be related to sea surface roughness with terms such as RMS wave height and/or slope, within a certain range of the sea surface spectrum. For higher wind regimes, additional physical considerations become important, and this elementary relationship between surface roughness and wind (or stress) breaks down.

For winds above 15 m/s this situation becomes much more diverse because of wave breaking, air flow separation from the surface [Donelan, et al, 2004; Bourassa, et al, 2009] and the growth of sea-spray which extracts momentum from the wind and creates direct impacts of water particles on the sea surface [Andreas, 2004]. The aerodynamic roughness becomes distinctly different from the geometric roughness elements that create the NRCS. However Donelan, et al, [2004] suggest that aerodynamic roughness and other wave characteristics are still correlated in that they both saturate at wind speeds greater than roughly 33 m/s.

Among the results to be presented are QuikSCAT measurements for TCs Claudette (2003) and Ike (2008), both of which made landfall along theTexas coastline, near Houston. The NEXRAD rain reflectivity snapshots, available every 6 minutes, show that there was wide-swath of rain coverage for both of these storms. Simultaneously, the surface wind estimates from the NOAA/AOML/HRD H*WIND product indicated a wind-speed maximum of 90 kts. Both the NEXRAD observations and H*WIND products will enable us to select and compare (NRCS) effects in both rain and non-rain areas. The methodology to be presented demonstrates how the influence of the atmosphere can be removed in order to observe the total surface NRCS [Weissman and Bourassa, 2008].

This presentation will illustrate that there is a strong correlation between high rain-rates and high wind-speeds particularly in the regions which encircle the eye of the TC. This means that a major fraction of the air-sea interface within areas of high-wind is affected by rain-impact induced roughness . When rain impacts affect this total roughness, we need to understand the consequences upon the subsequent the air-sea momentum and thermodynamic exchanges. One implication is that the drag coefficient (and thus the wind-stress) estimated in the regions of high winds will be affected by the high rainrate. The QuikSCAT NRCS, believed to represent the momentum transfer for typical conditions, is shown to be affected by high rain-rates (> 5 mm/hr) even within areas of very high wind speeds. Possible impacts upon the NRCS and how these translate to changes in the wind-stress are discussed.

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