# Altimeter microwave surface observations in tropical cyclones

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Surface measurements in tropical cyclones (TCs) are difficult to obtain and only microwave sensors below 15 Ghz can penetrate the deep convective clouds surrounding the areas where surface winds are the largest (Quilfen et al., 2007). These kind of measurements are crucial to complement the Dvorak TC intensity analysis as obtained from infrared/visible measurements (Velden and Coauthors, 2006). Moreover, multi-frequency measurements are needed to separate wind and rain effects in intense rainy areas.

We analyze in this study the ability of Jason-1 dual-frequency altimeter measurements to provide estimates of surface winds, waves, and rainfall rate in the case of two cat-5 hurricanes. Isabel and Wilma are particularly interesting to present very different structures (eye size and visibility, asymmetries), although scaled at the same intensity at the time of Jason-1 overflight. This offers a good test bed to show that the altimeter can be used to distinguish such features. Variability of the surface wind speed and rainfall rate is well characterized along the altimeter ground track. As expected from the eyewall conical shape, the maximum rainfall rate occurs slightly more outward than the maximum surface wind speed (MSWS). Contrary to Wilma showing an eyewall replacement cycle at the altimeter observation time, Isabel MSWS and rain rate structures are very symmetric.

Altimeter measurements in Isabel are compared with the Stepped Frequency Microwave Radiometer (SFMR, Uhlorn et al., 2007) measurements and with the Hurricane Research Division (HRD) wind analysis, showing good agreement of the wind profiles but underestimation of the SFMR and altimeter winds by comparison with the HRD ones. In the Wilma case, there are no direct surface measurements to compare with the altimeter. Altimeter MSWS estimate at 62.7 m s−1 may not coincide with the peak wind estimated at 67 m s−1 from flight level-based measurements in the best track reanalysis. However, estimated altimeter MSWS values are suggested to be biased low because of the rather large footprint (~8 / 9 kms) in high sea state conditions and because the wind speed retrieval empirical model may underpredict the radar cross section at the high wind speed encountered in the rainy areas of the TC eyewalls. The availability of more than 15 years of dual-frequency altimeter measurements, together with the continuous improvement of TC intensities estimates, is a motivation to revisit the original work performed by Young (1993) to better exploit the modern altimeter dual-frequency capabilities.

We also present the unique altimeter capability to perform companion sea state measurements. The sea state accounts for space/time integrated effects of the storm action and significant wave height (SWH) measurements can thus partially limit effects of the poor altimeter sampling. We compare the altimeter SWH measurements with values predicted by a parametric model to interpret the observed sea state. Maximum SWH generated in the field of a TC can be predicted using this model and estimates of the speed of the storm, the MSWS, and the radius of maximum winds (Young, 2003). The predicted maximum SWH at 15.3 m for Isabel is in good agreement with the altimeter measurement at 14.7 m. For Wilma, it is significantly lower at 11.6 m than the altimeter measurement at 14.2 m. Accordingly, a significantly larger equivalent fetch x would be needed to produce the maximum SWH measured by the Jason-1 altimeter for the Wilma case. The observed sea state may thus indicate underestimation of the Wilma intensity estimate provided in the TC Extended Best Track Dataset, or the fact that the radius of maximum wind is a poor proxy for a TC size as commonly used in the wind and wave parametric models. This remains open to further investigation. Sea state measurements can help to better analyze the strength of extreme events, especially when usual methodologies using aircraft or geostationary satellites measurements are less applicable. It provides an integrated quantity well suited to characterize the storm action and its strength over an area of a few tens of km2. However, wide-swath sea state sensors with better coverage of the active TC areas will be more adapted to provide useful operational information.
Rainfall rates deduced from the altimeter measurements are compared from those derived from the TRMM instruments. Good qualitative agreement is found with the Precipitation Radar data but the altimeter maximum rainfall rates in the TC eyewall are significantly lower. Given the well-defined behavior of Ku-band radar cross section, a tuning of the Marshall Palmer relationship is suggested to improve the rainfall rate altimeter retrievals.

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