DRO/DOPS/Laboratoire d'Océanographie Spatiale

Altimeter microwave surface observations in extreme events

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Abstract: *Sea surface estimates of local winds, waves, and rain rate conditions are crucial to monitor extreme oceanic events such as tropical cyclones (TC) and extra-tropical lows. Passive and active microwave satellite sensors are very valuable for that purpose but their measurements still suffer from well documented limitations: insufficient resolution, poor wind vector retrievals in rainy conditions, possible saturation of the microwave signals. Altimeter dual-frequency measurements are shown to provide interesting along-track information related to surface wind speed, wave height, and vertically integrated rain rate at about 6-km resolution, to complement wide-swath sensors measurements. The standard altimeter wind speed products are inaccurate at high winds due to lack of calibration data and we attempt to remedy that issue using QuikScat/Jason matchup measurements at winds > 18 m/s. The altimeter capability is illustrated by examining a few Jason-1 and -2 altimeter passes over selected cases of hurricanes and extra-tropical storms. The altimeter high wind algorithm is also potentially useful for near real time maritime forecast applications and will be evaluated at NCEP this year. We also wish in this poster to emphasize the potential of the coming CFOSAT mission carrying both a scatterometer and a wide-swath wave instrument to better evaluate extreme events strength thanks to companion wind/wave measurements.*

High-wind altimeter algorithm tailored with QuikScat winds

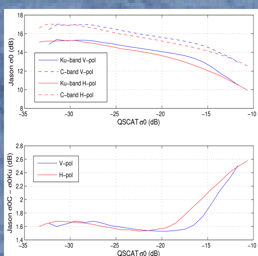


Figure 1: Behavior of altimeter NRCSs as a function of the omnidirectional QuikScat NRCS.

Little attention has been given to the altimeter wind speed data for operational purpose because of its poor ground sampling. Moreover, most wind speed retrieval algorithms have been calibrated to match a limited wind speed range and feature artificial saturation at high wind speeds (figure 2 top). Indeed figure 1 shows that altimeter NRCS saturate less than QuikScat scatterometer NRCS.

Such altimeter sensitivity was exploited by Young (1993) to derive high wind speed data from Geosat measurements in tropical cyclones. It has since been shown that the more recent dual-frequency altimeter capabilities enable to derive useful wind/wave/rain information in tropical cyclones (Quilfen et al., 2006, 2010).

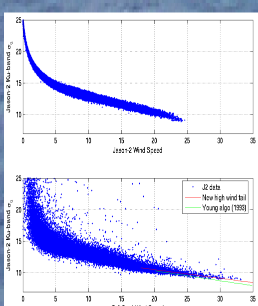
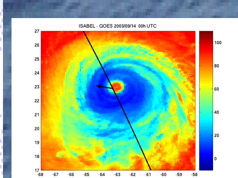


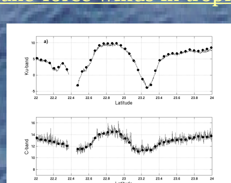
Figure 2: Behavior of altimeter NRCSs as a function of the QuikScat wind speed.

Much attention has also been given to exploit the reduced QuikScat high wind sensitivity to estimate wind speeds up to hurricane force winds (32 m/s). The figure 2 bottom shows a well defined altimeter NRCS decrease with increasing QuikScat wind speed up to hurricane force winds, colocated measurements lacking beyond. Exploiting the accurate altimeter and scatterometer NRCS measurements, a new simple high wind branch has been derived. 3177 data points have been used in the 18-30 m/s wind speed range, edited for rain contamination. Such high wind branch is also valid for the Jason-1 and Envisat altimeters after applying correction factors for the NRCS (Queffeulou, 2010).

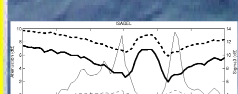
High wind algo:
U = 96.98-7.32*sig_Ku(dB) for U>18 m/s

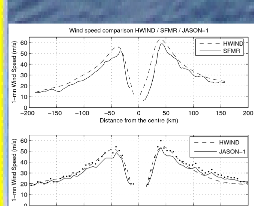
Altimeter-derived hurricane-force winds in tropical cyclones





Dual-frequency altimeters can retrieve wind speed in rainy areas. The 20Hz Jason-1 altimeter waveforms have been reprocessed in the case of the cat-5 cyclone Isabel to recover usable NRCS data (top right figure: waveform max intensity and 1Hz automatic gain control). It can be observed that Ku-band signal decreases faster than at C-band, reaching a minimum for the maximum columnar rainfall rate in the eyewall while C-band minimum is located near the surface maximum wind speed. An iterative wind speed/rain rate algorithm gives the estimated Ku and C attenuations and effective NRCS (figure below).





The Isabel cyclone was particularly well observed thanks to the CBLAST air/sea interaction experiment taking place during the three days covering the Jason-1 pass time. A special HRD (Hurricane Research Division) wind analysis has been performed at the altimeter time to provide the best wind analysis to compare with the altimeter (bottom left figure, courtesy M. Powell). Both the Young algo (solid line) and the new high wind branch (points) have been displayed. We find very good agreement in the wind field intensity and shape up to 50 m/s, which is very encouraging. Overestimation of the peak wind may be explained by the underestimation of the altimeter rain rate derived from the Marshall-Palmer relationship which is not calibrated for that high rainfall rate. Indeed, Monte-Carlo simulations of the inversion process (Quilfen et al., 2010) show that underestimation of 30 mm/hr rain rate by 30% results in overestimation of the wind speed by about 5 m/s. Such altimeter rainfall rate biases are found when compared to TRMM data.

Hurricane-force winds in extra-tropical storms from Jason-2 and QuikScat

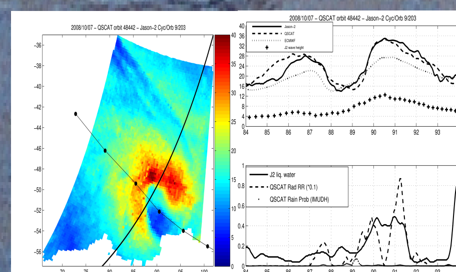
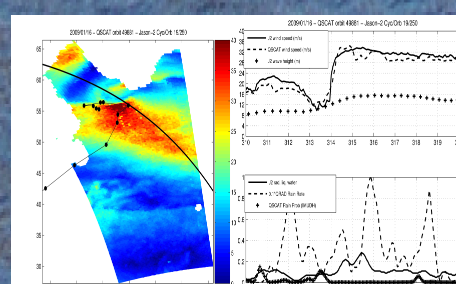


Figure 3 and 4: south indian (top) and north atlantic (bottom) oceans storms. Left: QuikScat wind field, Jason-2 track (solid line) and 6-hr storm track (black circles)
Right: wind and wave fields (top); different rain indicators (bottom)



Figures 3 and 4 present two storm cases, in the south indian and north atlantic oceans, for which hurricane-force winds have been measured by Jason-2 and QuikScat. The retrieved wind speed profiles are compared at the altimeter track locations (and accounting for the time difference) and show good agreement although the different measurements times still induce differences. The moderate rain rate may also impact theQuikScat retrieved wind speed (theoretically ~ 5 m/s at 10mm/hr and 30 m/s) although the QuikScat rain flag is not set on.

Very large wind speed gradients are retrieved from the higher resolution altimeter measurements for the atlantic storm (figure 4). Beyond this sharp front, hurricane-force winds extend for hundreds of kilometers.

Altimeters perform robust companion measurements of the sea-state. Sensitivity of such significant wave height measurements to the storm intensity is certainly to be exploited in order to better characterize the storm strength.

For the Indian ocean storm, Jason-2 intersected the hurricane-force wind region across the fast moving storm track and measured wave heights locally of the order of 12 meters. The northern atlantic storm was almost steady for 2 days near the Jason-2 track time and this exceptionally large fetch results in a wide ocean area suffering from extreme sea conditions (SWH > 15 m/s).

Refining the altimeter algorithm for high wind speeds thus enables us to obtain coherent wind/wave information in extreme conditions

Towards more informative sea state parameters to characterize storms

Sea state information has long been used as a proxi to characterize extreme events. The figure below (left) shows the dominant wave period measured at a buoy location near the spanish coasts. A series of waves with dominant period close to 20 seconds has been measured more than 2 days (January 18/19) after the explosive deepening of the atlantic storm as sampled by Jason-2 and QuikScat for the case presented above. It is approximatively the time such a wave group takes to travel the atlantic ocean. These waves can be tracked by using the Envisat Synthetic Aperture Radar (SAR) imagettes to follow their trajectories back to the generation area. The figure below (right) shows the period of the waves, whose period is above a given threshold, at the 3-hr time step the closest to the Jason-2 altimeter time (see figure above). The waves close to the bay of Biscay are those corresponding to the first peak as measured by the buoy, generated by the storm active before the one sampled by the altimeter . The second observed peak (January 18/19) corresponds to the waves generated by the hurricane-force winds sampled by the altimeter. The SAR tracking tool bring to light a very large area covered by extreme waves (> 15 meters as measured by the altimeter). The amount of wind input necessary to generate such long waves is still to be evaluated and to be related to the storm intensity as given by a scatterometer-type instrument whose signals certainly saturate.

Such a topic will benefit from the coming CFOSAT mission that will embark two wide-swath sensors measuring the surface wind and the wave spectrum.