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Application of Satellite Altimeter Data to the Coastal Protection of Northern Cuba

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The actions of sea waves caused by both hurricanes and tropical storms, pose a major threat to housing and infrastructure on the northern coast of Cuba. A new wave protection system is now planned in Havana and many protection and beach restoration works are needed for the future development of the coast. In order to carry out proper design procedures, reliable data are required on both extreme Significant Wave Height (SWH) and on storm surge. Despite the geographical proximity, the similarity of the problem and the wealth of information and analysis available about hurricane effects on the United States, very little is known about the sea climate on the Southern side of the Gulf of Mexico. No wave buoys are available at a reasonable distance from the island of Cuba and the local area weather and wave models lack any kind of experimental calibration. This is a typical situation where satellite data – integrated with adequate simulation systems – might prove to be an essential design and planning tool.

While historical global Numerical Weather Prediction (NWP) data are of course available for points near the island, their quality is often not adequate to evaluate the effects of tropical cyclones; it therefore useful to carry out detailed analyses of single events by making use of all available satellite data.

The following pictures show an example of integration between altimeter data and Holland parametric hurricane model (Eqs. 1-3) for Hurricane Maria, on September 5, 2005. (Córdova and Lamazares, 2012).

$$V_c(r) = V_{max}\sqrt{\left(\frac{R_{max}}{r}\right)^B exp\left[1-\left(\frac{R_{max}}{r}\right)^B\right]} \quad (1)$$

$$V_{max} = \sqrt{\frac{B(p_n - p_c)}{\rho_e}} \quad (2)$$

$$R_{max} = 46.29exp(-0.0153V_{max} + 0.0166\varphi) \quad (3)$$

where is the wind velocity at generic distance from hurricane centre, *B* is the peakedness parameter (in this case *B*=1.25); the maximum wind velocity; the maximum radius; the latitude at hurricane centre; the atmospheric pressure; the minimum pressure at the hurricane centre and the air density.

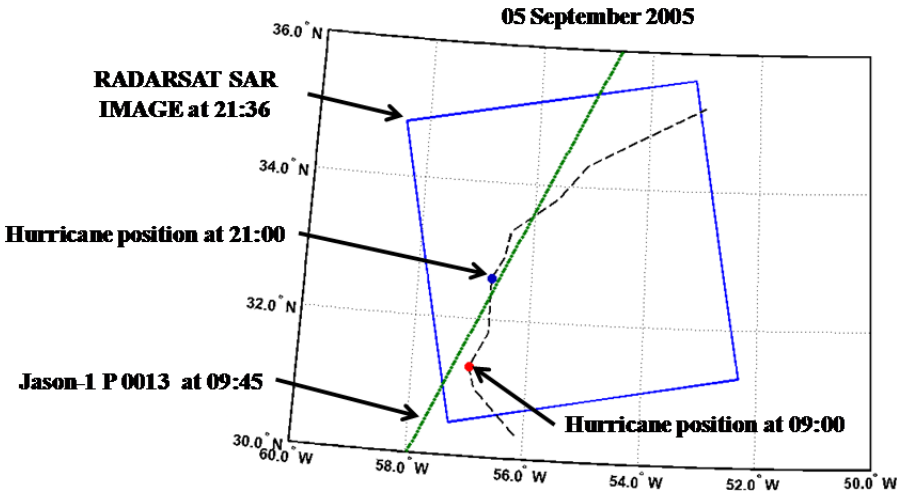

Figure 1. Hurricane Maria centre trajectory with Jason-1 Altimeter Passage.

The position of the Hurricane centre at 09:00 GMT is derived from NOAA analyses (Figure 1). Wind data from both altimeter and radiometer are available for Jason-1 satellite at 09:45 and have been used to calibrate the model parameters (Figure 2). Once the parameters are known, the model equations can be used to estimate wind and wave fields in different positions along the track of the hurricane centre. This in turn provides useful information about winds and wave heights to be expected along the coast.

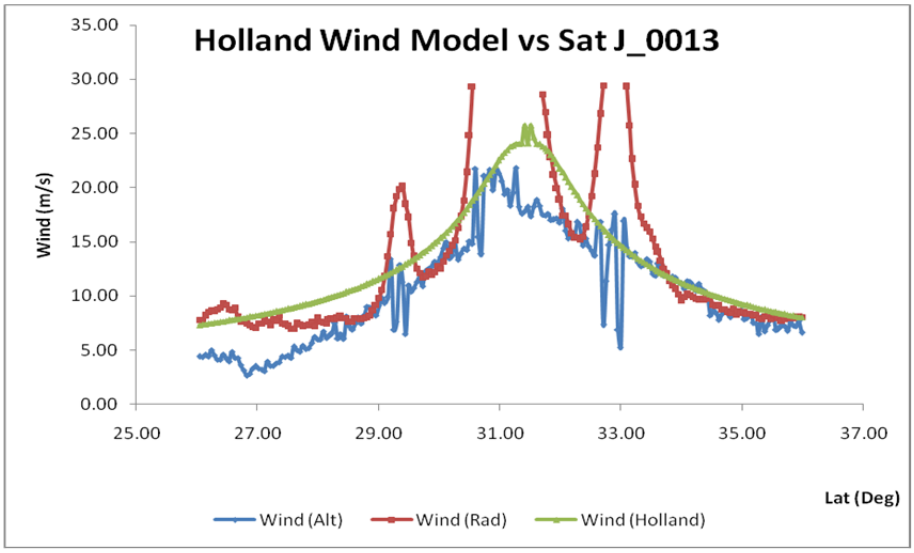

Figure 2. Holland Model with Jason-1 Altimeter and Radiometer wind data.

While the SWH is obviously an important aspect in storm risk evaluation and in the design of protection works, the increase of the mean sea level is equally relevant; part of it takes place on shallow water, due to the interaction of the bathymetry with the waves (set up) and can be computed easily enough, but the effects of the wind and of the air pressure offshore (storm surge) are much more

difficult to evaluate and to forecast. Information on the probability of such an effect can be obtained by analyzing tide gage data, which normally are widely available: Cuba National Network, for instance provides water height records for a number of locations (Gonzales 2011). Wave gauge however are located on or near the coastline and they are not always a safe indicator of storm surge offshore. Satellite altimeter data are a precious help.

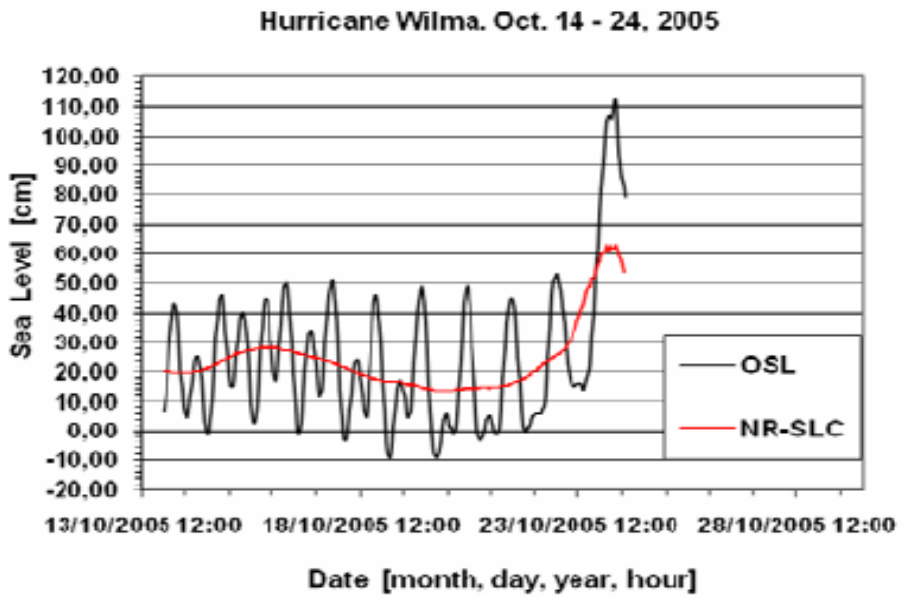

Figure 3. Water height record at Siboney tide gauge station (Gonzales 2011).

Sea Surface Height (SSH) routinely provided through the ESA Earth Observation eSurge programme for storm surge monitoring and forecasting (http://www.storm-surge.info/) can be correlated with tide gauge data to provide information storm about storm surges (Figure 4)

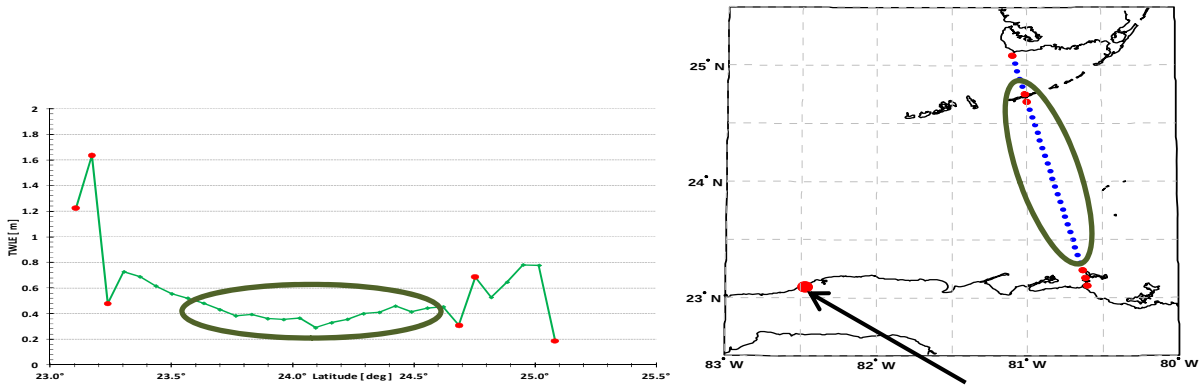

Figure 4. Satellite altimeter SSH (left) along Envisat track (cycle 42, absolute orbit 19095, relative orbit 4) on 25 October 2005 (Right) (eSurge data). Arrow points shows the tide gauge Siboney location.

While obviously very few altimeter passes are available in the vicinity of the tide gauges, the combined application of satellite altimeter SSH, coastal water level height and numerical modelling should provide a reliable estimate of storm surge values, and thus contribute towards an improvement of the design technique for coastal protection.

SOME REFERENCES

Reale, F.; Dentale, F.; Pugliese Carratelli, E.; Torrisi, L. Remote Sensing of Small Scale Storm Variations In Coastal Seas. *Journal of Coastal Research* **2013**, 30(1), 130-141.

Pugliese Carratelli, E.; Dentale, F.; Reale, F. On the effects of wave-induced drift and dispersion in the Deepwater Horizon oil spill. In *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise*, AGU Geophys. Monogr. Ser., vol. 195, edited by Y. Liu et al., pp. 197–204, AGU, Washington, D. C., USA, doi:10.1029/2011GM001109.

González, M.H. Extreme non-regular sea level variations in Cuba under the influence of intense tropical cyclones. *Serie Oceanológica* **2011**, *8*.

Pugliese Carratelli, E.; Cordova, L.F.; Lamazares, R.; Reale, F.; Ocampo Torres, F.J. Use of Hurricane Data to Assess the Influence of Foam and Spray on SAR Imagery and Altimeter Data. In *RADARSAT Hurricane Applications Project Workshop*, October 5, 2010.

Smith, J.M. Wave and Storm Surge Modeling. In *Proc.* of 6th SCACR – International Short Course/Conference on Applied Coastal Research, Lisbon 2013.

Johannessen, A.; Chapron, B.; Alpers, W.; Collard, F.; Cipollini, P.; Liu, A.; Horstmann, J.; da Silva, J.; Portabella, M.; Robinson, I.S.; Holt, B.; Wackerman, C.; Vachon, P.. 2013 Satellite Oceanography from the ERS Synthetic Aperture Radar and Radar Altimeter: A Brief Review. In: Fletcher, K., (ed.) *ERS Missions: 20 years of observing Earth.* Noordwijk, The Netherlands, European Space Agency, 199-224.

Salgueiro, G.; Córdova, L.; Lamazares, R.; Téllez, Y. Aplicación del modelo atmosférico MM5 para la simulación de vientos asociados a huracanes. Ingeniería Hidráulica y Ambiental, CIH, Instituto Superior Politécnico José Antonio Echeverría (Cujae), vol. 35, no. 1, pp. 3-16. (2014).

Córdova, L.; Lamazares, R. Simulación de los campos de vientos y oleaje asociados a huracanes. Ingeniería Hidráulica y Ambiental, CIH, Instituto Superior Politécnico José Antonio Echeverría (Cujae), vol. 33, no.23, pp. 50-65. (2012).