Observation and modeling of tropical cyclones wakes and their evolution

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Abstract: *Techniques using satellite altimetry can help to quantify changes in sea surface height in storm-affected regions during the months following tropical cyclones (Jansen et al., 2010; Haney et al., 2012; Mei et al., 2013; Sriver, 2013). Changes in sea surface height are closely linked to changes in ocean heat content, which enable direct estimates of the vertically integrated changes in ocean temperatures caused by tropical cyclones. However, limitations in the observational systems and in methodological approaches are likely to hamper severely significance of the results, because TC-induced SSH steric anomalies are small (~1cm) with respect to large scale SSH variations (~1m) and background variability. While SSH measurements from the current altimeter constellation shall be used for this study, it can be anticipated that the much larger coverage by the 2D SSH imaging capability of the SWOT satellite will enable more accurate estimate of these anomalies, and more direct and better tracking of the cold wake mesoscale processes. Indeed, as the surface fluxes quickly restore the pre-cyclonic SSTs (10-day timescale) and then erase the SST gradients, a 2D SSH imaging will enable to track at the monthly/seasonal timescale, for a given event, the sub-surface fronts associated with the sub-surface bolus of warm water anomaly, to better evaluate the spatial scales of the processes. Improved knowledge of the wakes restratification spatial and temporal scales is crucial to define a methodology for heat content uptake estimation. First results are presented to discuss the feasibility and representativeness of an approach combining all the observations available (Argo floats, satellite SSH, SSS, SST) conjointly with the understanding of processes that modeling experiments can offer*.

Hurricane Igor SST cold wake and associated vertical salinity and temperature profile changes

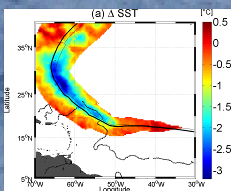

Figure 1: *Surface wake in Hurricane Igor. Post minus pre-hurricane Sea Surface Temperature*

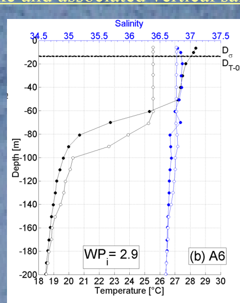

Figure 2: *Vertical profiles of temperature (black circles) and salinity (blue circles) measured before (filled circles) and after the storm (open circles) at an ARGO float located on the right side of the Igor track..*

A large cooling and deepening of the mixed layer is observed in the hurricane wake, associated with a warming of waters below the initial thermocline. Knowledge of the restratification scales and of the net heat outcome after restratification is the subject of the proposed investigation.

Sea level signature in the wake of hurricane Igor

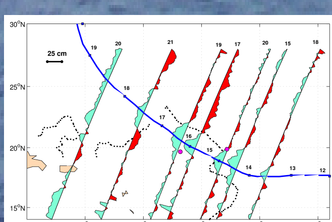

Figure 3: *Differences in sea level (elevation in red, depression in cyan) between successive Jason-1/2 altimeter tracks before and after Igor passage. Numbers above the tracks give the day for one altimeter track after Igor passage, the sea level difference being then computed using the altimeter track for the previous 10-day cycle. Igor eye track is materialized with the blue line, and squares and numbers indicate the Igor location for the day at 12Z.*

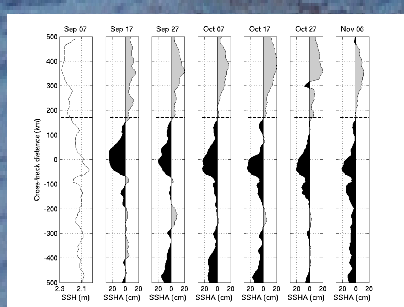

Figure 4: *Sea surface height anomalies for one Jason-2 orbit before (left, Sep 07) the Igor passage and differences, for the same orbit number, with values for the subsequent cycles.*

Jason-1 and -2 sea surface height anomalies (figure 3) show a trough in the hurricane wake that corresponds to the geostrophic adjustment with the depth averaged currents. This is at first order the result of the barotropic response leading to an upwelling driven by the divergence of the Ekman transport. At second order, the trough contains also the signature of the cooling the weeks following the hurricane passage. The anomaly propagates towards the west while vanishing (figure 4). Further tracking of these anomalies after the restratification has been completed, and a thorough composite analysis, should reveal if a net heat uptake can be observed, and how it depends on the phasing with the winter season.

Modeling of the sea level signature in a hurricane wake

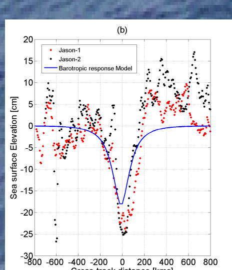

Figure 5: *Sea surface elevation change measured by Jason 1 (red dots) and Jason 2 (black dots) altimeters and prediction from the barotropic response from an idealized model (Ginis and Sutyrin, 1995) based on the GFDL azimuthal component of the wind stress*

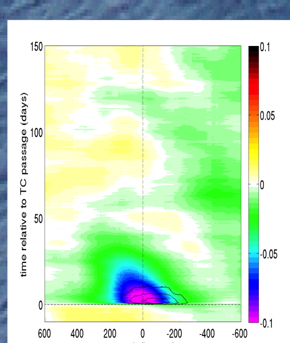

Figure 6: *Sea level anomaly evolution (shaded) and SST cooling (contours) as a function of cross track distance and time relative to the TC passage computed from tropical cyclones simulated over 20 years in a state-of the art ocean-atmosphere coupled model. Seasonal cycle is removed.*

Modeled evolution of SLA in the TC wake (Fig. 6) over a great number of TCs shows the westward propagation of TC-induced upwelling signal as observed in Igor wake (Fig. 4). Interestingly, SLA also shows an integrated warming of the water column after 50 days corresponding to an ocean heat uptake. Analyzing all the temperature tendency terms in the model will allow us to determine quantitatively the restratification processes in the wake and its seasonal and interannual variability.

The seasonal cycle has a major impact on the amount of ocean heat storage as winter entrainment restores back to the surface 60% of the subsurface heat content anomaly (see Fig. 7).

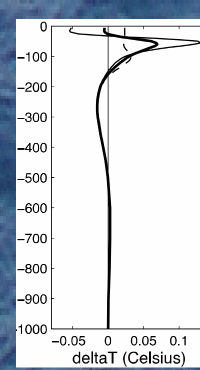

Figure 7: *Space- and time-averaged temperature anomaly profile induced by TCs in the coupled model: annual mean (bold black curve), summer months (i.e., cyclonic season, thin solid curve), and winter months (dashed curve). From Jullien et al. (2012).*

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