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Estimating energy dissipation of hurricanes on the upper ocean by satellite data of cold tracks

M. Ribo and A. Turiel
Institut de Ciencies del Mar (CSIC)

Storm track prediction has been improved with better numerical models and satellite observations, but intensity prediction is still one of the unsolved aims for a better forecast of high impact cyclones. It has been demonstrated that hurricanes intensity is very sensitive to the magnitude of Sea Surface Temperature (SST). Since some time ago there is evidence of oceanic cooling along the cyclone tracks, mainly caused by upwelling, turbulent mixing and heat transport.

In our study we present a methodology to process satellite SST maps to obtain a precise delimitation of hurricane-induced cold tracks, which are wakes of cold water resulting from wind-driven upwelling from beyond the thermocline. There are some problems with satellite remote-sensing data at many visible and infrared wavelengths, as cloud coverage which accompanies the cyclones precludes acquisition. Microwave is the only available wavelength being able to penetrate clouds (but it is sensible to the presence of liquid water as rain), and microwave SST estimates correspond to some centimetres and not only to skin SST, so this type of SST maps is more representative of the actual surface temperature. In order to demonstrate the potential of our technique, in this study we have used Optimally Interpolated (OI) SST images from Microwave Radiometer SSTs at 0.25º resolution (data produced by Remote Sensing Systems). Singularity exponent maps were then derived from these SST maps. We obtain a singularity exponent at each point in a given map with the aid of a dedicated, wavelet-based technique known as singularity analysis. The singularity exponent is a measure of the local regularity or irregularity of a function (in our case, SST) at a given point, disregarding the amplitude of the local gradients. The map of singularity exponents derived from SST reveals oceanic structures such as currents, filaments, eddies and fronts, even if they produce only a subtle effect on SST. When singularity analysis is applied, cyclone-associated cold tracks have clean, well-defined frontiers and can hence be easily delimited.

Atlantic, Caribbean, Gulf of Mexico and Eastern Pacific hurricanes produced between 2005 and 2008 were analyzed for the determination of the affected area of the sea surface cooling. To define the oceanic cooling along the hurricane tracks, observational analysis were made for each hurricane comparing SST maps and the singularity images with the hurricane tracks superimposed. For the numerical delimitation of the visually-delimited affected area, two thresholds were fixed, one for the SST variation and one for the singularity exponents. Singularity threshold was used to delimitate the boundary of the affected area, using those values that were greater than the threshold proposed. Values of SST variation higher than the temperature threshold were used to fill the affected area. The result was a graphical representation of the affected area of each hurricane analyzed. We have then used these tracks to estimate the energy dissipated by a hurricane in the cold-track generation.

To that goal we have evaluated the thermocline temperature combining monthly climatologies of temperature and Mixed Layer Depth (MLD) at each point of the affected area; then, we have estimated the mass of water mobilized by the storm-induced upwelling by its impact in lowering surface temperature. Once the volume of water mobilized is known upwelling-associated dissipated energy can be estimated as the variation of potential energy for that water mass. Knowing the variation of the potential energy, the removed power can be calculated for each day (taking into account that we are working with daily images).

One of the areas we have studied is the Gulf of Mexico and the Caribbean Sea, what is considered a Mediterranean Sea (named American Mediterranean Sea). Hence, the methodology used here could be applied for the Mediterranean Sea. Although our methodology has been applied so far to very intense cyclones (in fact, hurricanes) due to the limitations in the acquired data, it could be applied in a future to any storm and area when the technology of acquisition devices is improved. Satellite SST maps used in this study have a ¼-degree (∼25 kilometre)

resolution, which is a too low resolution for the Mediterranean Sea. Higher spatial resolution is recommended to analyze Mediterranean cyclone-induced cold tracks and in general for a better energy dissipated determination. In our study we show that there is a relation between ocean-atmosphere energy transfer and cyclone intensification. This property gives hints about cyclone intensification and could be used to improve forecasts and the estimation of cyclone impact at the Mediterranean countries.