SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2016
Project Title:	Effect of heavy rain on the development of tropical cyclones
Computer Project Account:	SPITWM
Principal Investigator(s):	Luciana Bertotti
Affiliation:	SMAR, Venice, Italy
Name of ECMWF scientist(s) collaborating to the project	(not officially) Jean Bidlot
Start date of the project:	2014
Expected end date:	2016

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	500000.00	462070.87	500000.00	36109.45
Data storage capacity	(Gbytes)	200		200	

Summary of project objectives

The aim of the present project, as clearly indicated in the title, is to investigate the influence of rain on the process of growing and developing of tropical cyclones, analysing all the processes that concur to their development. Last year we had focused on, although not the most relevant, probably the most difficult one, i.e. the attenuation of wind waves by rain while they propagate on the sea. We are presently finalising the work in this direction. At the same time we have explored the sensitivity of the model results for hurricanes to some of the source functions.

Summary of problems encountered

Technically no particular problem has been encountered. As the previous year, a practical aspect is that, because of the heavy access to the archive, the large volume of storage of the intermediate data, and the required interaction with local staff, large part of our work needs to be conveniently done at ECMWF. Last Fall we could not come because of extensive periods abroad. However, we are cooperating with other institutions on the problem of the hurricanes, and we report some first results in this respect, also connected to rain.

Summary of results of the current year

A basic problem that has emerged in the last few years is that the operational model systems do not take into account the effect of rain on wind and waves. This reflects several parallel processes whore relevance is progressively emerging. The subtle point is that it is not the direct effect of the rain of waves that is important, but rain does affect, and changes the way they develop, the processes that dominate the evolution of a wave fields. The key point is that the evolution of a wave field is a dynamical equilibrium between generation (input by wind) and dissipation (white-capping). Our previous results show that an intense rain cancels completely the white-capping, hence the drain of energy from the wave system, and reduces at a substantial level the input by wind. The reasons for the latter is not yet clear. A basic point is likely to be the reduced smoothness of the sea surface, and the consequent 'sliding' of the wind on the wave profile with a substantially reduced or cancelling of the Miles-Janssen process of wind input to waves. Most likely only the process devised by Jeffreys in the first half of the last century is still active, with a correspondingly reduced input to waves.

We considered introducing this process in the modelling of a hurricane. However, the correct physical representation of what is going on the surface of the sea under wind of the order of 50 m/s or more is not obvious at all. It is well known that, while the surface drag coefficient increase with wind speed till 30 m/s or so, at higher speeds there is a levelling of the coefficient, with also a possible reduction. This is thought to be due to a) the physical cut of the wave crests by the wind, b) the filling of the wave troughs by foam so that wind slides horizontally on the sea surface cancelling or strongly reducing the effect of the Miles-Janssen generation process. While the level of rain in a hurricanes can be extremely high, the mechanics of the surface is not clear, i.e. if, for what roughness is concerned, how the opposite effects of rain and wind combine to determine the level of roughness. The difficulty stems from the fact that there is a lot of parameterization in modelling an extreme process as a hurricane. Therefore it is much simpler to study the sensitivity of the results to changing a process rather than determining if a certain process improves the final results.

For the above reasons we have continued our study on the influence of rain on the attenuation of wind waves. This is done in the absence of wind because the although reduced uncertainty in the driving wind field would introduce an error potentially larger than the effect we are exploring.

There for we have continued exploring the attenuation of swell in the tropical areas, simply because there it is easier to find conditions without an appreciable wind. To find and evaluate the influence of the rain we split each spectrum into a number of significant different partitions, in so doing we applied the “spectra partitioning” technique, described in the paper by Portilla et al. 2015.
Our temporary results are summarized in the Figure 1 where we see the different performance of the Ecmwf model with respect to the altimeter wave height data according to the different rain rate. The information is not provided by the single plots, with a slight underestimate of the model versus the measured data. Rather, the relevant finding is given by the comparison among the four plots. It is clear that the underestimate by the model decreases with the increase of the rain rate. Because the model does not consider the effect of rain, this must correspond to a different, on average, measured wave height in the different conditions. In practice we have found that, granted all the other conditions, the measured wave heights decrease with increasing rain rate. Conclusion: rain attenuates waves at a rate we can now estimate. That will be out next step.

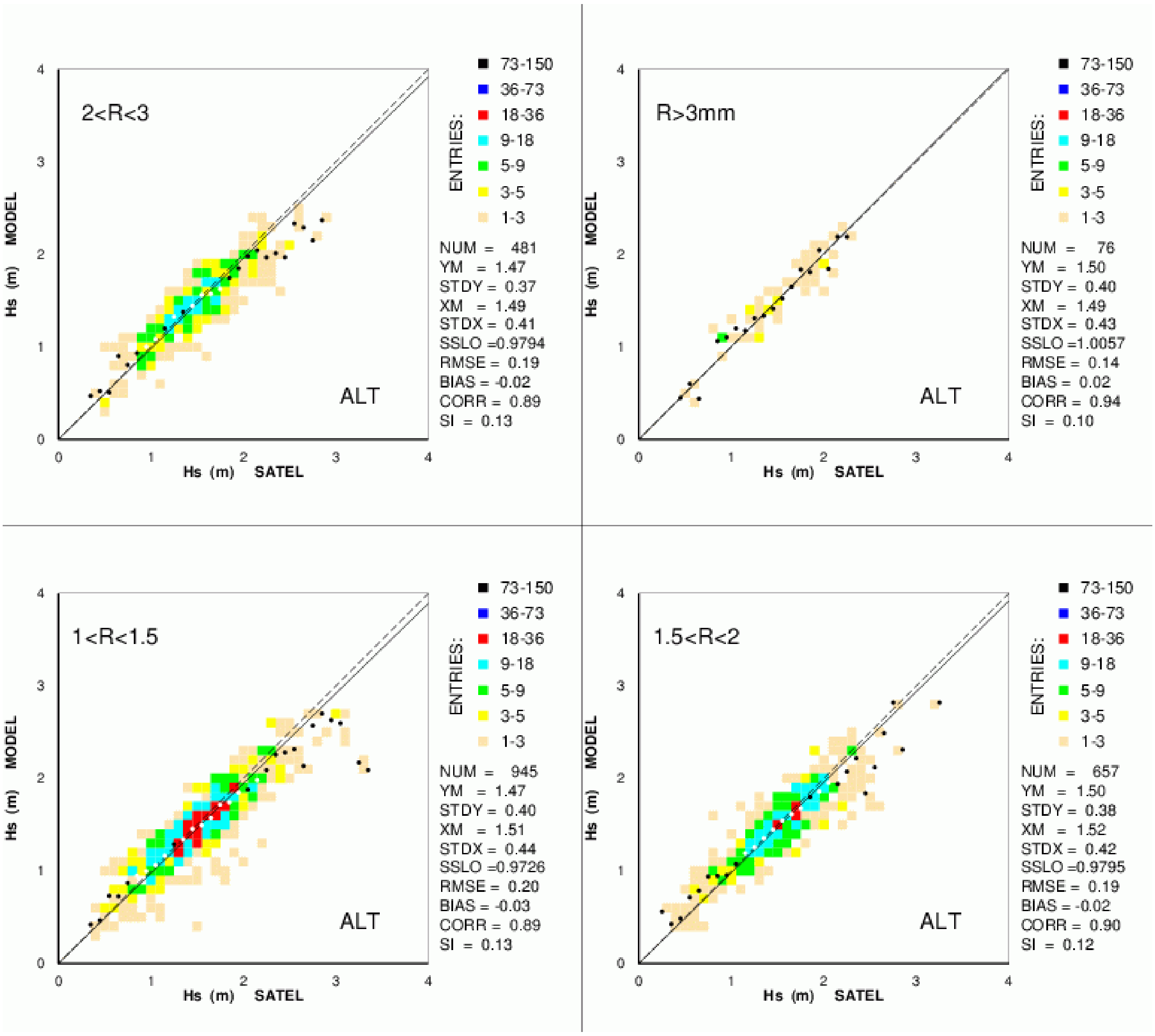

Figure 1 – Comparison between Ecmwf modelled wave heights and corresponding altimeter measured data. The underestimate decrease with increasing rain rate.

List of publications/reports from the project with complete references

2015 L.Cavaleri, L.Bertotti, and J.-R.Bidlot
"Waving in the rain"
Journal of Geophysical Research, doi:10.1002/2014JCO10348.

2015 Portilla,J, L.Cavaleri, and G.Ph.van Vledder
"Wave spectra partitioning and long term statistical distribution"
Ocean Modelling, http://dx.doi.0rg/10.1016/ocemod.2015.06.008, 13pp.

Summary of plans for the continuation of the project

The problem we have tackled during these last two or three years, i.e. the influence of the rain on the generation and dissipation of ocean waves, is extremely complicated. The reason is because, affecting the characteristics of the sea surface, the rain influences all the excanges (heat, momentum, energy, matter, etc) between the atmosphere and the ocean. This overall problem can be tackled step by step. In the next three years we plan 1) to clarify and quantify the attenuation of waves by rain, 2) to quantify, also using parallel measurements, the effect on the generation, 3) some of the aspects in a hurricane, i.e. to check if even in those extreme conditions the analysis of the performance of the coupled (atmosphere-ocean) models reveals a different performance in the rainy and non-rainy areas of these extreme meteorological systems.