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Report on the activity.

In this report I describe the activity carried out during my agreed staying at the European Centre for Medium-Range Weather Forecasts (ECMWF, Reading, U.K.). The staying lasted from April 20th till May 15th.

As already described in the original proposal, the focus of the research during the indicated period was the effect of rain on the attenuation of wind waves during their motion on the ocean.
The report is structured in different parts describing, the basic process I have been working on, the reasons why this process requires attention, the models, meteo and wave, used to get the needed information on wind, wave and precipitation. The description of the approach to the problem is followed by a discussion on the obtained results, at least till the point that could be reached during the described staying, and the prospect for the future.

1 - The basic proces.

The wind waves are due to the wind blowing on the sea surface. The stronger the wind, the wider the sea or the area where the wind blows and the longer the time the wind has been blowing, the higher and longer the waves. When the waves leave the area where the wind blows, or the wind abates, they propagate undisturbed on the sea surface for long distances, eventually reaching a coast where they discharge, more or less violently, their energy. These waves are called swell.

The problem for practical application is to estimate the possible modifications of these waves, i.e. swell, during their possibly long distance transfer (that on the ocean can take days). Various processes may happen. One of these is for the swell to pass through a rainy area (not too windy). It is known, qualitatively at least, that rain has an interaction with wind waves. The problem we have framed is to quantify, as far as possible, the attenuation of swell due to the rain affect. We exclude windy areas because in that case the wind effect would overcame completely the effect of the rain.

2 - Why this problem requires attention

Similarly to the weather forecasts that we daily listen either from radio or television, or read on newspapers and tablets, a similar information exists also for the state of the sea, i.e. for the waves. Indeed it is nowadays possible, knowing the weather, i.e. wind, conditions, to know days in advance which will be the state of the sea, i.e. the characteristics of wind waves like wave height, period (hence wavelength) and direction, in any area of the world. In general both the weather and the wave forecasts are produced by mean of physical-mathematical models that for their complexity need the use of big computer and major operational centres. The European Centre for Medium-

Range Weather Forecasts, ECMWF, is daily running a meteo-ocean model on global scale, producing weather and wave forecasts up to 15 days. The larger the area, the more sophisticated the physical system we conceive and the amount of data that we need at disposal to carry out the daily forecast. Aiming at always better forecasts, i. e. with smaller errors, more processes need to be taken into account. Presently the effect of rain on wind waves is not considered, although its potential relevance, although limited, had already been highlighted in the '90s.

Similarly to the direct effect of wind, also for rain the longer its duration the stronger its effect on the waves. Also, the longer the distance run by waves, the greater the chances of coming across waves, the stronger the rain effect and the easier to find a quantified result to then introduce into the operational models. This implies to work at a global scale, something possible only at a large operational centre where all the information are available from the local archive and where it is possible to run large scale extended experiments.

3 - The models used.

The present meteorological model works with a global resolution of 16 km, while the wave one with 25 km resolution. Both the models have a detailed description of the physics involved whose implications are evaluated at the knots of a grid covering the whole globe (ocean for waves). The evaluation in time, i.e. forecasts, are done with 10 min step and are made available at 1 hour step (3 h till not long ago). The archive of the past analysis is available at 6 hour interval.

For our present purpose we need information on the wave characteristics, wave height, mean period, mean direction of propagation, the rain distribution over the globe, specified in space and time(i.e. where, when and what) and wave measurements in the open sea to compare the model results with the measured truth.

4 - The approach to the problem

I have focused my attention on the tropical zone because it is often characterised by limited wind and frequently intense rain, plus a long swell from both the northern and southern hemisphere. In particular I have considered the zone between 30 degree northern and southern latitudes. I have explored the last five years of wind, waves and rain data of ECMWF. Besides I have collected all the satellite data of wave height available on the ocean. Also buoy data around the world have been collected. For each satellite and buoy datum (significant wave height, defined in space and time), I have evaluated the corresponding wave model result, checking at the same time the conditions about wind and rain. This information allows a direct comparison between model and measured data that, together with the rain information, allows an estimate of the potential attenuation of swell due to rain. Proper consideration of wind is essential. In fact the delicate intercomparison I mean to do cannot be done in windy areas because the wind has a much stronger effect on waves, and therefore it would not be possible to appreciate the fine tuning required for determining the slight attenuation due to rain.

Because the more intense the rain, the stronger its effect on waves, it is not possible to work on all the data as a single block, but we need to carry out the analysis for different rain rates. Once the single attenuation rate figures are available, it will then be possible to formulate a general formulation to be then implemented in the operational models.

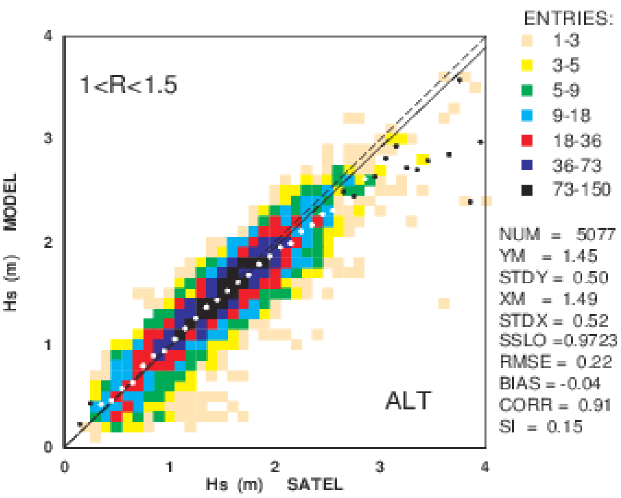
5 - The obtained results

The results obtained during the present staying at ECMWF are only preliminary. The volume of data to analyse is enormous, although well defined, and each single datum requires a keen verification of the local (in space and time) conditions to be able to consider it for the final statistics. Till now I have been able to obtain some definite results from one part of the data. These show that there is undoubtedly an attenuation by rain of the oceanic waves, and that this, although small, and smaller with respect to other dominant factors (e.g. wind input and wave breaking) presently considered in the operational wave models, still is at a level that it will be necessary to consider it if we want, as claimed from various source and required by industry, navigation and harbour authorities, a further improvement of the wave model performance. Therefore an already fundamental result has been obtained, i.e. to show the relevance of the process and the need to consider it in the wave models expected to be operative in the near future. The next stage is to precise a quantification that I outline in the following.

6 - A look to the immediate future

As previously mentioned, now we know with sufficient certainty that rain does attenuate wind waves. As expected and physically reasonable, the stronger the rain the stronger the attenuation. Also, the longer the waves, the more limited is the effect of the rain on them. While some theoretical formulation has been offered in the '90s, no measured evidence in the field was available. The research I have described is filling this void and, once completed, will provide the full information required for a direct implementation into the operational models.

The analysis and the full definition of the results is not something that could be done in three or four weeks. However, during my staying at ECMWF I have succeeded in defining completely the problem, framing the required approach and devising a methodology for the best use of the available information that, once completed, will provide the final required information. As an example of the achieved results, the figure below presents the comparison of wave height (m) between wave model results and satellite data for a rain intensity between 1.0 and 1.5 mm/h.



What is needed is the information at very small scale, order of few kilometres, of both rain and wave height. Being the heavy rain a localized event, both in time and space, it is necessary to make use of meteo and wave models with a resolution higher than the present one, used operationally. This will imply the run of devoted experiments with finer, time and space, output resolution with a consequent production of a tremendous amount of data. Their full availability at hand is what is necessary for this research and this is something possible at a centre as ECMWF, the only place in Europe up to the level. I plan to complete my work during another staying at ECMWF that I hope to be able to do in some immediate future.

Luciana Bertotti

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