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Sezione di Venezia – Sistemi Marini e Costieri

European Centre for Medium-Range Weather Forecasts

Special Project 2007 - 2010

“Evaluation of the performance of the ECMWF meteorological model at high resolution”

Final Report

This is the final report for this project. Therefore we will provide a compact description of the reasons for the project, mention the intermediate results and finally present our latest conclusions. It is also clear that the improvement of a meteorological model, in this case the one developed and used at ECMWF, and in particular of the surface wind fields, is a permanent ongoing process. Therefore our results cannot be considered as conclusive of a research process, but simply as the picture of how the situation evolved till the present in the recent years.

The quality of the analyses and forecasts produced at ECMWF has been steadily improving along the years. This is due on one hand to the improved physical description and parametrisation of the physical processes that govern the evolution of the atmospheric fields. On the other hand a crucial role has been played by the ever increasing computer power and the largely improved efficiency of the numerical model. Both these factors have allowed a substantial increase of resolution.

The quality of the surface wind fields on the open oceans has been very good in the last four or five years, but less so close to land, especially in the enclosed basins. This is due to a number of reasons, including the accuracy with which the orography is described and a tendency of the model to underestimate the wind in the few hundreds of kilometres off the coast when blowing from land to sea.

In particular in the past years we have studied how the accuracy improved with the resolution of the model. It is interesting to note that, while the results are practically asymptotic on the oceans, on the inner basins there is a clear continuous upward (improvement) trend, a clear sign that the final target is still away.

We have experimented both with the present and past resolutions. Also before the introduction of T1279 we have done several experiments with this, roughly speaking 16 km, resolution. While clearly showing the expected improvements in the definition of the fields, somehow the results seemed to be disappointing. When analysing different resolutions, we compare, e.g. by scatter diagrams and checking the best-fit slope, the corresponding wind speeds. The point is that the surface wind speeds obtained with T1279 were only slightly different from the corresponding ones with T799, especially in the enclosed seas where we expected to see the best improvements.

Recently, and in particular during our latest experiments till one year ago, we had found substantial differences. In particular we found that the derived wave results in the Mediterranean Sea were much improved. This was found when these results were compared both to previous results and to

the measured data derived from buoys and satellite altimeters. Discussing the matter with ECMWF staff the improvement seemed to be related to improvements in the description of the orography. As the previous negative effects had various implications for the results, we decided to explore further these aspects of the problem. In particular we decided to make a detailed analysis of how the performance of the meteorological+wave model system operational at ECMWF varied in time, not only with the change of resolution, but also with all the improvements periodically introduced into the two, meteorological and wave, models. At this aim, while carrying on numerical experiments on specific cases (always useful to analyse events of particular interest), we have done a careful analysis, in space and time, of the quality of the wave results. For this purpose we have focused on the Mediterranean Sea and, as a side case of more difficult conditions of smaller inner sea with strong orographic influence, on the Adriatic Sea, the small basin enclosed between Italy and the Balcan countries. For this purpose we have used the Envisat altimeter data for the four year period January 2006 – December 2009. This covers almost the full period of use of T799. As at the present stage the extent of the T1279 operational data is not enough for a reliable conclusion, we have also analysed this resolution referring to the test period July – December 2009. Because of the test period, the wave data were not fully available as from the operational runs (only the global wave data is available for some months). Therefore we have run the WAM wave model, exactly with the present version operational at ECMWF, for the missing period. The result is a six-month period of T1279 Mediterranean wave data suitable for our analysis. While not covering a full winter period, the results, although with some approximation, provide a fair idea of the present situation.

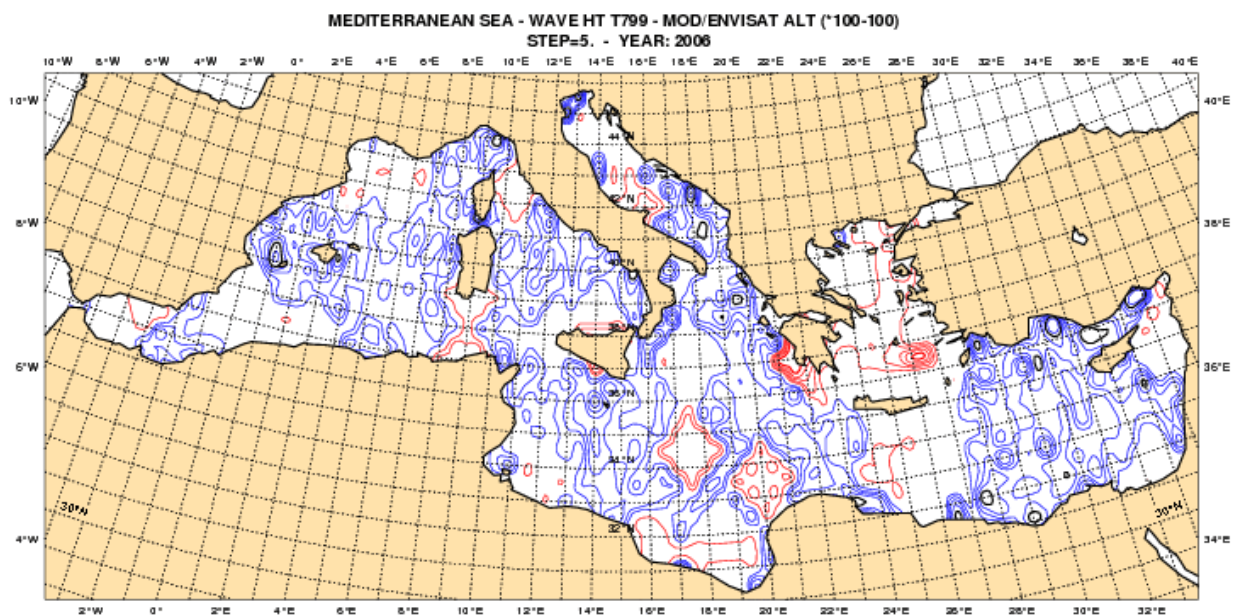


Figure 1 – Comparison between the operational T799 model versus Envisat altimeter wave heights in the Mediterranean Sea. The isolines, at 5% interval, show the difference with respect to 1 of the ratio model/altimeter. Results for 2006. Blue negative, red positive differences.

Our results concerning the progressive improvement of the T799 model are summarised in Figures 1, 2, 3, 4 showing the performance of the T799 driven Mediterranean wave model as compared to Envisat significant wave height data. The four figures concern years 2006, 2007, 2008, 2009 respectively. The comparison has been done on a half degree basis. We have considered the model results at 0.5 deg interval and interpolated these values, in space and time, at the various altimeter times and positions. Then each co-located couple model-altimeter data has been assigned to the closest 0.5 degree grid point. Finally the average ratio H_s model/ H_s altimeter has been evaluated for each grid point. Out of the resulting grid distribution, isolines have been traced (see the quoted

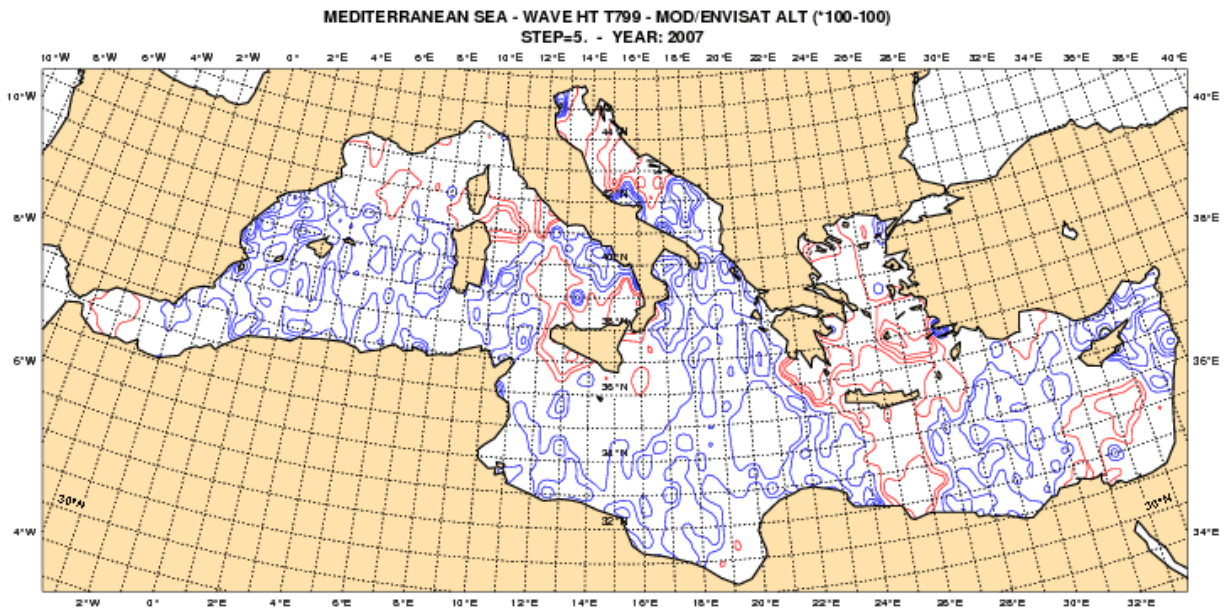


Figure 2 – As Figure 1, but for 2007.

figures). However, as the percentage differences would be small with respect to the (more or less) unitary values, before plotting all the values these have been multiplied times 100, then the difference with respect to 100 has been considered. Positive values (model>altimeter) have been plotted red; negative ones (model<altimeter) blue. So each unit means a 1% difference between model and satellite significant wave heights. Because of the large number of isolines, these have been traced at 5% intervals.

As mentioned above, Envisat data has been used for this validation. No use has been done of the Jason and Jason2 data because their spacing between adjacent orbits is too wide to derive meaningful isolines. While the about one month return period of Envisat means that relatively few data is available at each grid point, their dense distribution in space ensures some meaningful overall view of the situation. Clearly some odd values may be present at certain locations.

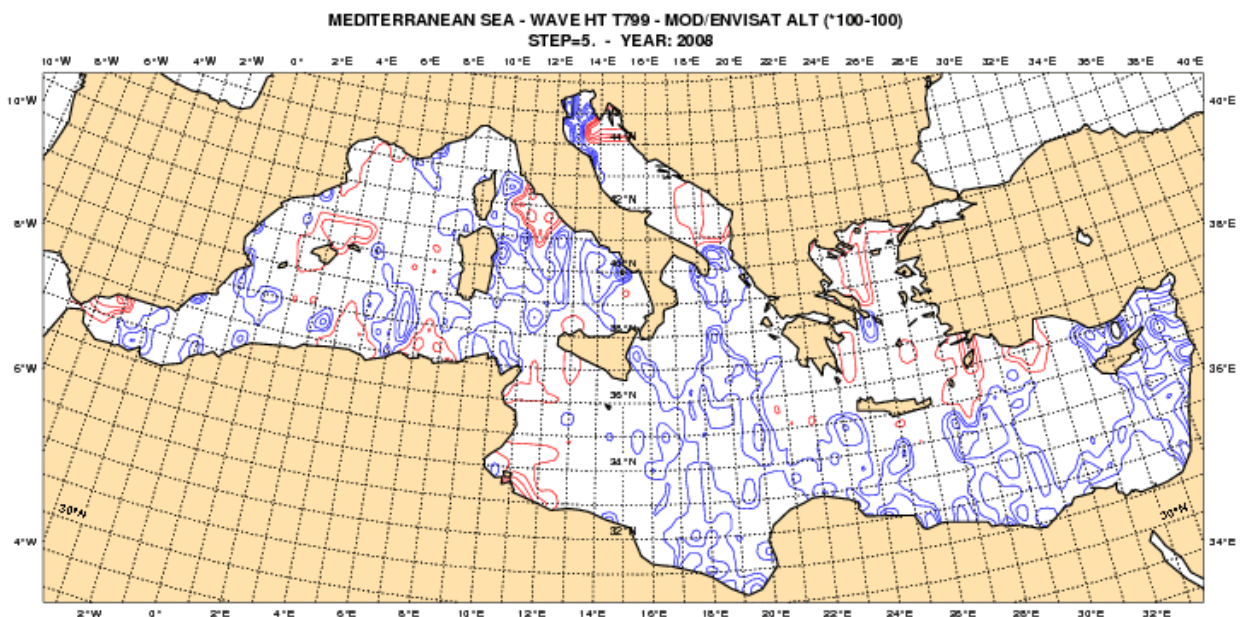


Figure 3 – As Figure 1, but for 2008.

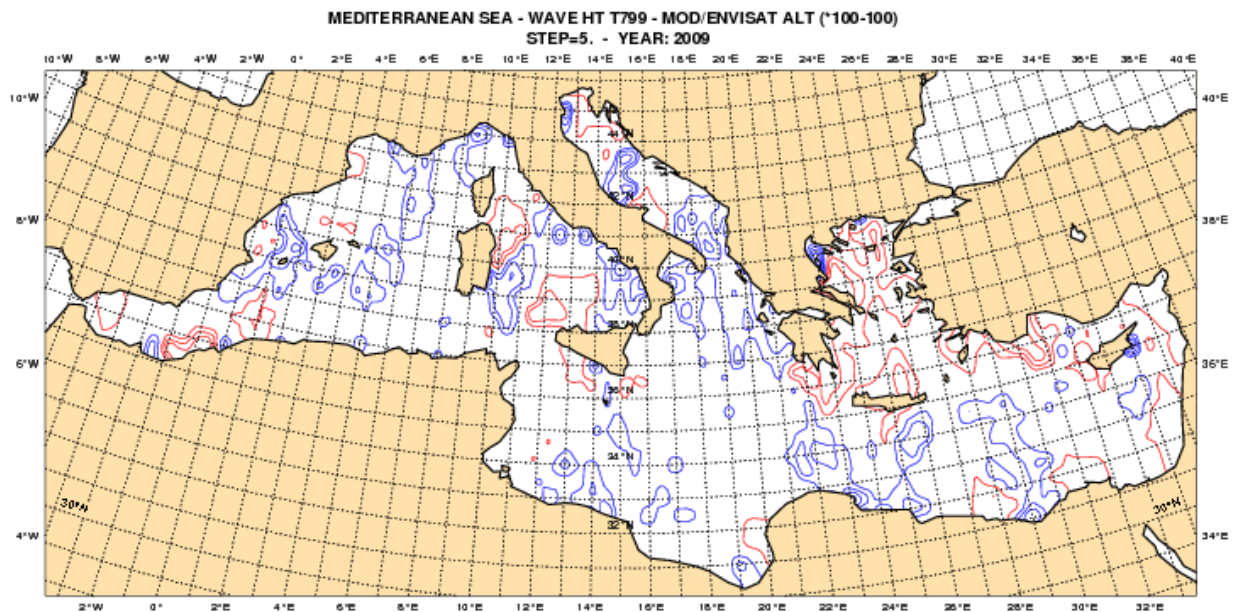


Figure 4 – As Figure 1, but for 2009

While considering the single values, in our analysis we have disregarded ratios obviously wrong (too large or too small) and those associated to very low wave heights when the ratio model/altimeter is not a suitable parameter to judge the performance of the models.

Looking at Figure 1 we see the typical situation we have often discussed, i.e. a diffused underestimate, stronger in the narrow gulfs, corner areas and enclosed seas. According to these results a remarkable exception is the Aegean Sea where there is hardly any difference between model and altimeter. Without going into a detailed quantification, for the purpose of this project it is sufficient to look in sequence at the results for 2006, 2007, 2008, 2009, i.e. to Figures 1, 2, 3, 4 respectively, to appreciate the overall progressive improvement. The gradual thinning of the number of isolines indicates that, independently on the resolution, the surface wind, hence wave heights, have steadily improved during these four years. At 2009 there are still limited areas with a 5-10%, occasionally larger, underestimate. However, at large the results look very good.

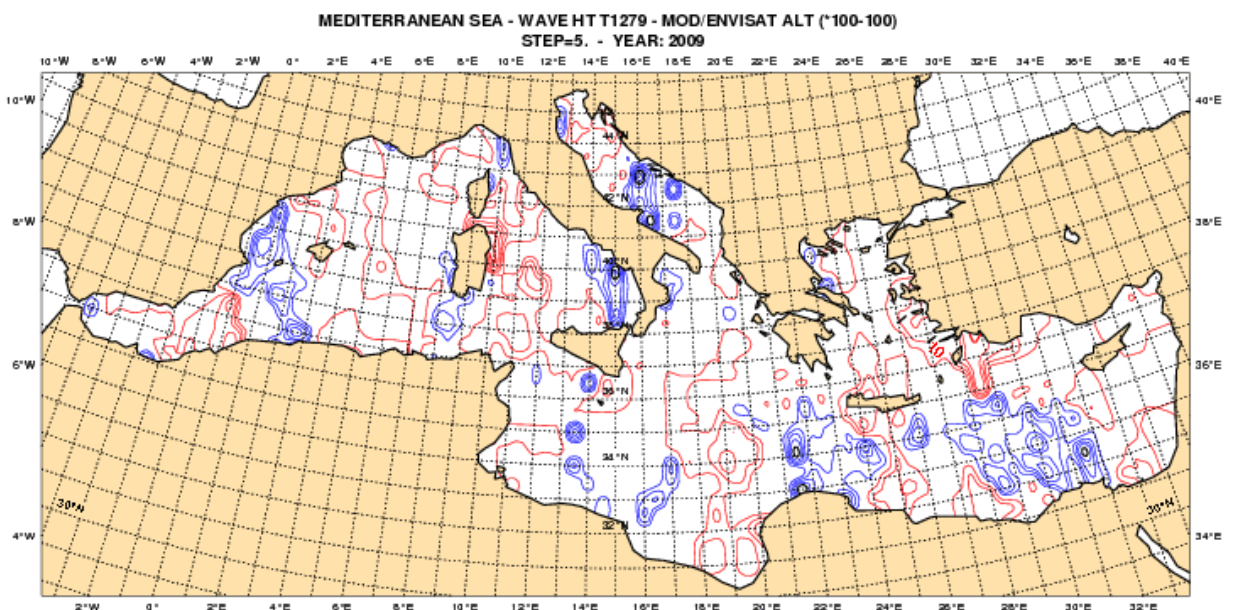


Figure 5 – As Figure 1, but for 2009 and for the experimental T1279.

In this respect it is interesting to look in Figure 5 at the results for T1279. Remember this has been only a six month test, July to December 2009, hence the uncertainty (confidence limits) of these results is (are) larger than in the corresponding Figure 4. In any case we find enlightening that somehow the T1279 results seem less good, at least in some aspects, than the ones for T799. We see that in a general ‘good’ comparison, there are several areas where we see substantial underestimates. This suggests that the single increase of resolution is not necessarily due to lead to a step improvement. Rather, for each resolution an adaptive period is required during which progressive adaptations – improvements lead to the long term clear advantage with respect to the

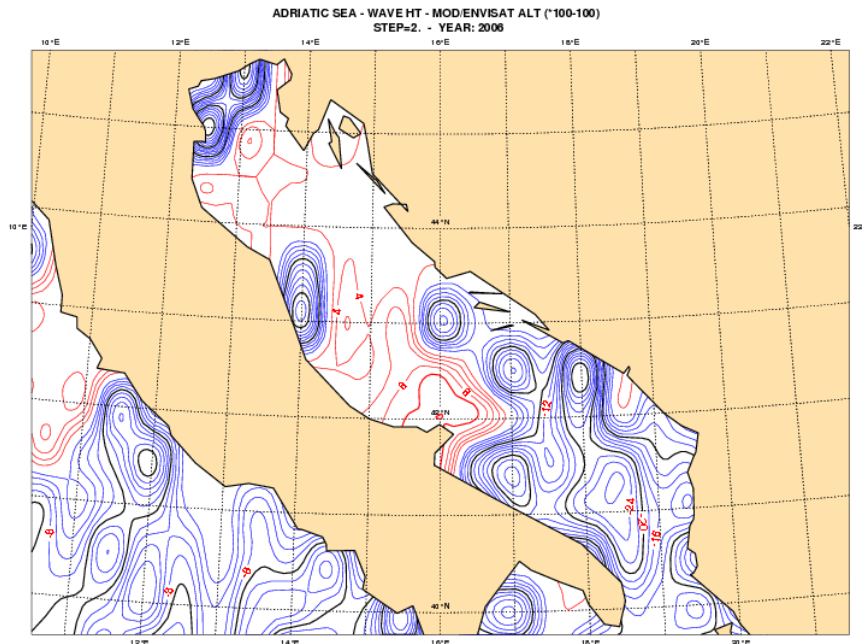


Figure 6 – As Figure 1, but for the Adriatic Sea. Isolines at 2% difference.

previous (lower) resolution. Following the above analysis of the overall Mediterranean Sea, we have then focused our attention on the (see above) smaller Adriatic Sea. Figures 6 to 9 shows the overall analysis of the average ratios model/altimeter wave heights in the years from 2006 to 2009 respectively. The strong dependence of the results on the bordering orography, hence on the dominant meteorological pattern possibly varying from year to year, impedes the general consistent progressive improvement we have seen in the Mediterranean. For instance, the positive area (red isolines) at 44.5 degree North we see in Figure 8 is probably due to a strong bora blowing through the gulf of Quarnaro, between the South protruding small Istria peninsula and the Croatian islands. Note that the same bora seems poorly represented in the more northern Venice gulf (most northerly part of the basin). Because these bora events, strong and dry, are associate to a wide high pressure centred over Central Europe, they appear only in certain years where the overall meteorological pattern leads to strong anti-cyclonic situations over Europe. As this is not always the case, the subsequent surface wind and consequent model/altimeter ratios may vary substantially from year to year.

In any case, looking in general at Figures 6 to 9, we see also here a positive trend when moving from 2006 to 2009, with a substantial extension of the areas where the model wave heights are, although by little, larger than the altimeter ones (note that the isolines are here traced at 2% differences).

The parallel comparison of the T1279 results (Figure 10, to be compared with Figure 9) leads to the same comments issued above for the Mediterranean. The general pattern between the two figures is

the same, but the differences between model and altimeter results appear larger for T1279 than for T799.

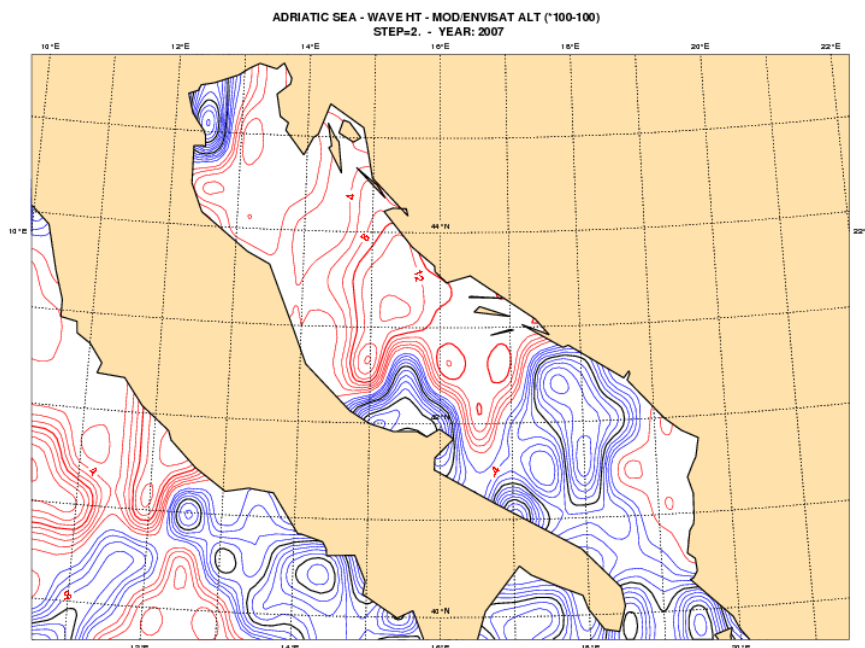


Figure 7 – As Figure 6, but for 2007.

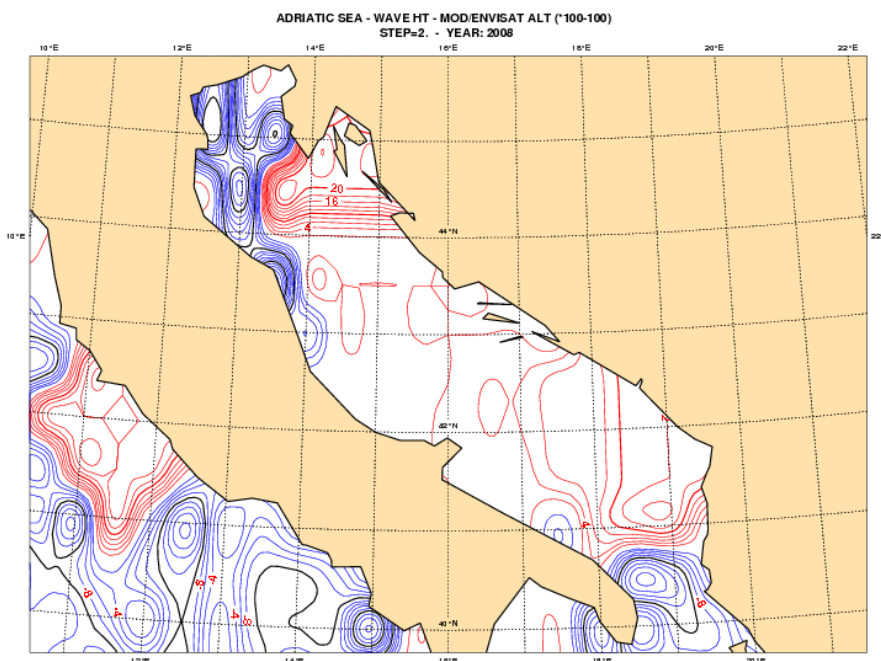


Figure 8 – As Figure 6, but for 2008.

We conclude summarising what said above. In the long term an increase of resolution implies a general improvement of the model performance. However, this does not happen at once, i.e. at the moment of the change. Rather, at least in the case of T799 to T1279, the higher resolution seems to provide for the analysed period less good results. However, if compared with the initial results of T799 in 2006, the difference, positive for T1279, is macroscopic. The evidence we derive is that the full potential of each resolution is fully reached only through a long term process of adaptations and

smaller improvements that is likely to last the full period (a few years) of operational activity of the new resolution. Some results we have obtained later in 2010 confirm indeed this steady tendency of

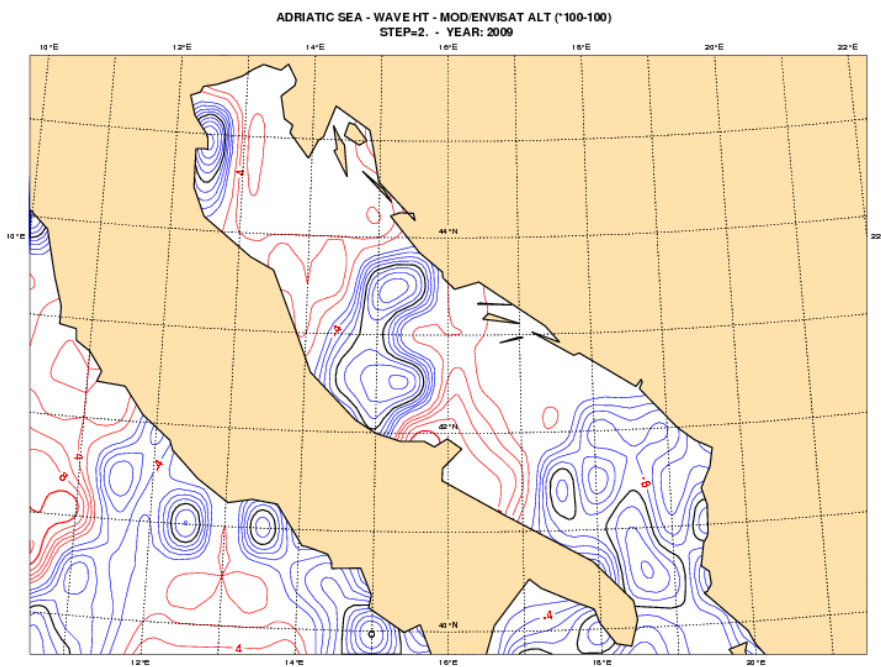


Figure 9 – As Figure 6, but for 2009.

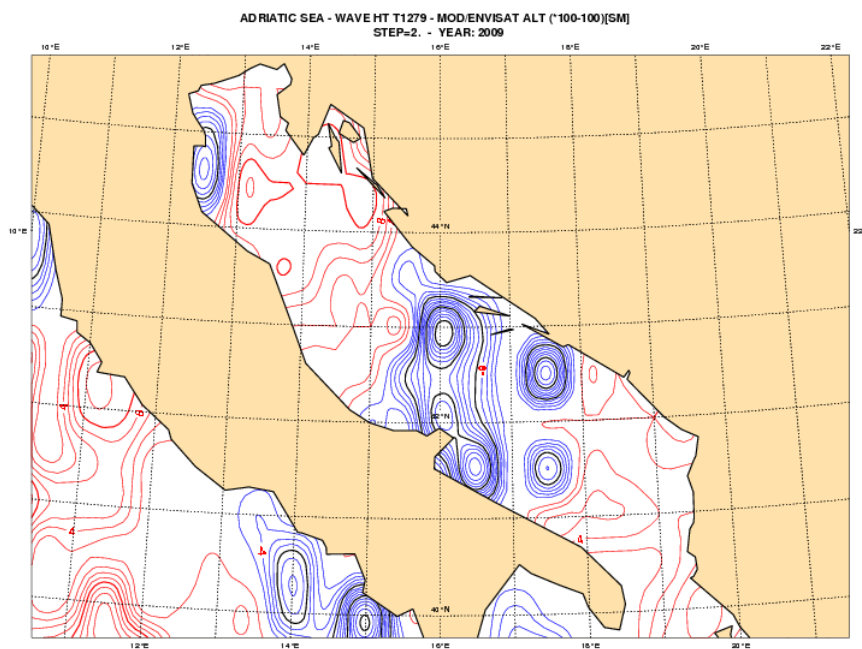


Figure 10 – As Figure 5, but for the Adriatic Sea.

T1279 to improve further on the quality of the surface winds throughout the Mediterranean Sea.

We conclude listing the publications of the past three years dealing with the work carried out during, and corresponding to, the project.

Ardhuin, F., L.Bertotti, J.-R.Bidlot, L.Cavaleri, V.Filipetto, J.-M.Lefevre, and P.Wittmann, 2007, Comparison of wind and wave measurements and models in the Western Mediterranean Sea, *Ocean Engineering*, Vol.34, Issues 3-4, pp.526-541

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Bertotti, L., and L.Cavaleri, 2008, Analysis of the Voyager storm, *Ocean Engineering*, Vol. 35, No.1, pp. 1-5.

Bertotti, L., and L.Cavaleri, 2008, The predictability of the Voyager accident, *Nat. Hazards Earth Syst. Sci.*, 8, pp. 533-537..

Bertotti, L., and L.Cavaleri, 2009, Wind and wave predictions in the Adriatic Sea, *Journal of Marine Systems* (available on line)

Bertotti, L., and L.Cavaleri, 2009, Large and small scale wave forecast in the Mediterranean Sea, *Nat. Hazards Earth Syst. Sci.*, 9, pp. 779-788.

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