SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2019
Project Title:	Evaluation of coastal climate trends in the Mediterranean area by means of high-resolution and multi-model downscaling of ERA5 reanalysis
Computer Project Account:	SPITBRAN
Principal Investigator(s):	Carlo Brandini Valerio Capecchi Francesco Pasi Stefano Taddei Valentina Vannucchi
Affiliation:	LaMMA Consortium - Environmental Modelling and Monitoring Laboratory for Sustainable Development
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	01/01/2018
Expected end date:	31/12/2020

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)	6000000	5800240	6000000	5971439
Data storage capacity	(Gbytes)	1000	5950	6000	9292 (10/06/2019)

Summary of project objectives (10 lines max)

The main aim of the SPITBRAN Special Project (hereafter SP) is to build a new climatic database of wind/wave regimes over the last 40 years (ie a hindcast), at high-resolution along the coasts of the Mediterranean Sea. This goal is achieved by using a cascade of state-of-the-art atmospheric and wave numerical models (BOLAM->MOLOCH->WW3), forced by the best (in terms of model cycle, output temporal frequency and horizontal resolution) reanalysis data currently available (ERA5). This new climatic database can provide many important inputs for the Integrated Coastal Zone Management (ICZM), with a particular focus on the North-Western Mediterranean Sea. This work will be partially connected with ongoing initiatives, such as the MAREGOT (www.lamma.rete.toscana.it/en/maregot) project, funded by the EU in the framework of the Italian-France Cross-border program, to which the LaMMA Consortium is involved as a partner.

Summary of problems encountered (10 lines max)

It was necessary to modify the EC_memory_per_task value in a job header, because of an out-of-memory error occurring in the pre-processing procedure of the BOLAM run. The new value was set to 8500mb from the default value (1024mb). This modification increased the number of SBUs needed to run the task (for a 24-hour long simulation, SBUs increased from about 300 to 1100/1200). This is the main reason why we had to require additional SBUs for the second year of the SP. Because of this SBUs over-consumption, a large part of the WW3 simulations were run on the Principal Investigator's computer facilities.

The tape space amount requested in the SPITBRAN proposal was under-estimated, mainly because of the need to temporary store the ERA5 data for initialising the BOLAM model (currently ecfs_status returns about 9 TB). However, a large part of these data are going to be removed from the ECFS filesystem, once the mesoscale simulations are performed.

Summary of plans for the continuation of the project (10 lines max)

An atmospheric/wave hindcast covering the period 1998-2018 has been produced during the first two years of the SP. Data are currently stored in the ECFS filesystem. During the last year, we plan to complete the hindcast for the remaining years available, that is from 1979 to 1997. To achieve this goal, we plan to request additional resources both for what concerns the SBUs and data storage capacity. The motivation for this request is due to: (i) the need to change the EC_memory_per_task value, that determines a SBUs unexpected over-consumption as explained above and (ii) the need to start the simulations since the year 1979 (instead of 1982 as initially foreseen) to have a picture of the hindcast over the longest period available (the 40-year long period 1979-2018) and draw more robust climatological conclusions. To justify this second point, it has to be stressed that, at the time of writing the SP Request, it was not clear to us the beginning of the availability of the ERA5 data.

List of publications/reports from the project with complete references

No publication or report was published.

Some preliminary results have been showed at the EGU conference 2019: S. Taddei, V. Capecchi, F. Pasi, V. Vannucchi, M. Bendoni, M. Perna, G. Vitale, C. Brandini. "Downscaling ERA-5 reanalysis data for coastal short-term and long-term risk assessment in the North Western Mediterranean Sea".

Part of the results of the SP (in particular those regarding the atmospheric simulations) are going to be presented in two conferences during the month of September 2019 (EMS Annual Meeting and AISAM conference).

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

In the framework of an inter-comparison activity among the BOLAM+MOLOCH hindcast and similar datasets developed recently in Italy (see the the SPITCERE Special Project and Bonanno, R, Lacavalla, M, Sperati, S. A new high-resolution Meteorological Reanalysis Italian Dataset: MERIDA. *Q J R Meteorol Soc*. 2019; 145: 1756- 1779), we show in Figure 1 the BIAS of BOLAM and MOLOCH modelled 2-metre temperature verified against observed data.

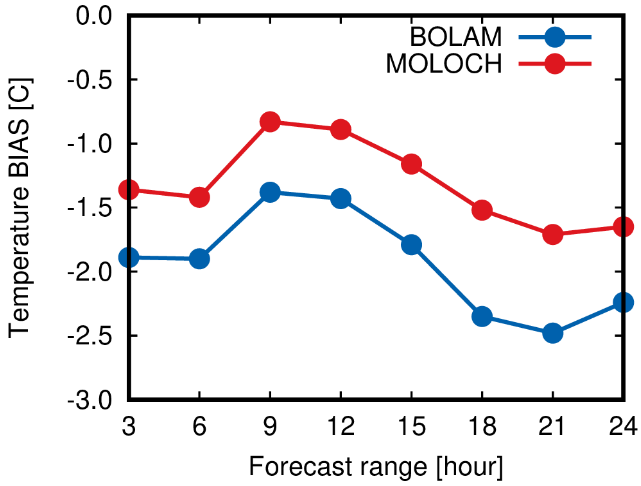


Figure 1. 2-metre temperature BIAS of BOLAM and MOLOCH data verified against observed values

As ground-truth, we chose the ARPA meteorological stations belonging and managed by the Italian Civil Protection Department. This dataset consists of a significantly high number of stations, with roughly 2800 thermometers spread over the Italian domain. The data were properly validated through consistency criteria based on spatial coherence as explained in the above mentioned reference. The verification activity was performed only for the year 2015 and an update is foreseen for the beginning of 2020. From Figure 1, it is evident that both the BOLAM and MOLOCH model suffer from a cold bias regarding 2-metre temperature. This is a well-known issue regarding these two models and it has been forwarded to the developers. As a first guess, we can argue that the cold BIAS is partially due to a lack of cloudiness in the initial conditions, that causes a quick drop of the temperature field in the first hours of the simulation. Further investigations are ongoing to understand and partially reduce this BIAS.

Regarding the precipitation predictions, Figure 2 shows the Hanssen and Kuipers discriminant (hereafter HK; range -1 to 1; perfect score 1; 0 indicates no skill) evaluated for different daily precipitation thresholds for the dense rain-gauges network described above (Bonanno et al, 2019). The HK score measures the ability of the forecast to separate the “yes” events from the “no” events.

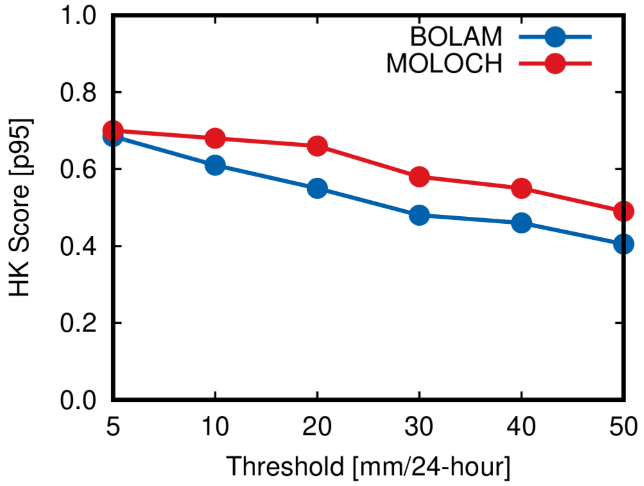


Figure 2. The HK score of the cumulative daily precipitation data as a function of observed rainfall thresholds (year 2015 only)

The BOLAM and MOLOCH outputs are also used as forcing fields for the WaveWatch III (WW3) wave model implemented on the whole Mediterranean Sea. The wave model uses an unstructured grid with variable resolution from about 500 m to 30 km (see Figure 3). Along the coastline, the resolution is: 500 m for the Tuscany coast, and the Bonifacio and Messina straits; 1 km for the Sardinia and Corsica coasts; 3 km for the Tyrrhenian coast, and Gibraltar strait; 6 km for the rest of Mediterranean coast. The bathymetry used is the high resolution EMODNET - version 2018. The original EMODNET bathymetry has been also improved along the Tuscan and Ligurian coast (up to the 100 m depth) by using data from nautical charts.

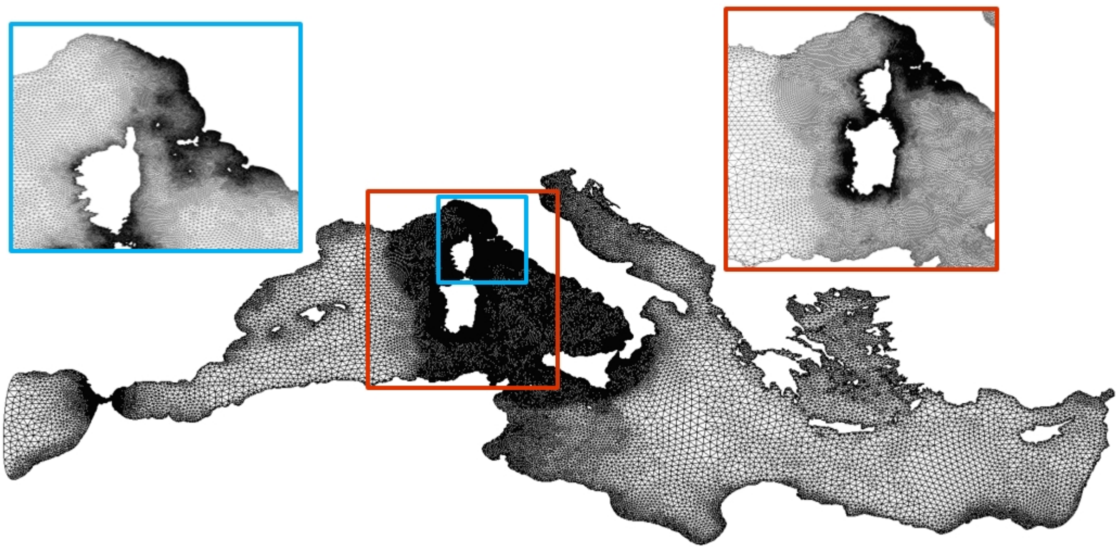


Figure 3. WW3 unstructured grid

The WW3 model has been calibrated on different time periods and in different areas. A first calibration was done for the storm from 24/10/2018 00:00 UTC to 01/11/2018 00:00 UTC: the wave height and direction, the peak period, obtained by the wave model was compared with the measured by the Giannutri (offshore), Gorgona (offshore), Castiglione delle Pescaia (coastal), Gombo (coastal) Buoy installed by the Tuscany Region administration and the Capo Mele (offshore) Buoy installed by the Ligurian Regional Environmental Protection Agency (location in Figure 4). Two types of parameters were analyzed in the calibration process. The first was on the time step: it was compared 60’’ and 30’’. The second was performed on three types of parameterization of the source terms defined as ST2 (Tolman and Chalikov, 1996), ST3 (Bidlot et al., 2005), ST4 (Ardhuin et al., 2010).

Figure 4. Buoys location

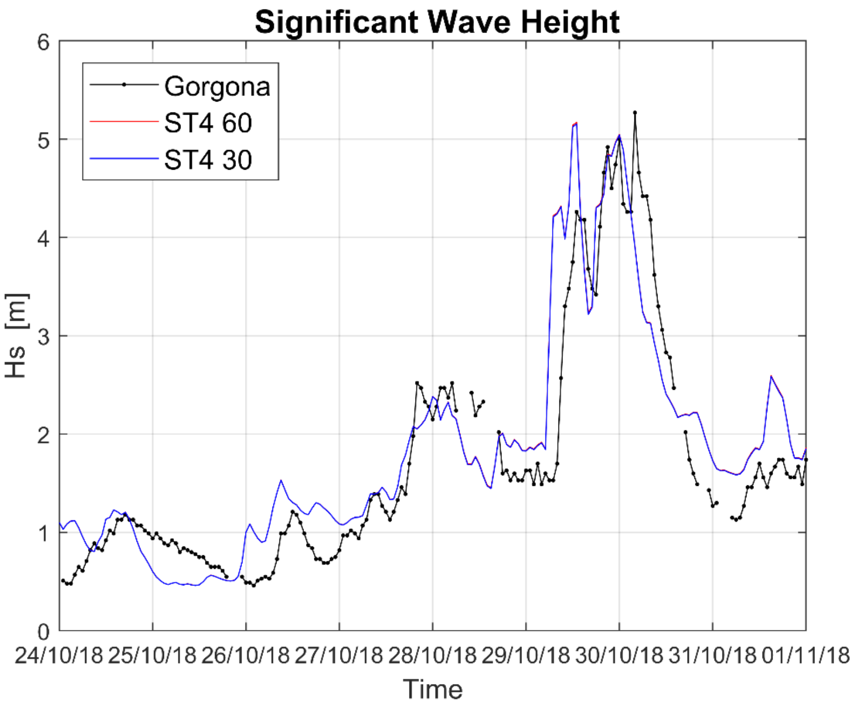


Figure 5. Comparison for the period 24/10/18 – 01/11/2018 between the wave height time series measured by the Gorgona Buoy (in black) and obtained by the model with a time step of 60'' (in red) or with 30'' (in blue)

Figure 5 shows the result of the calibration process on the time step, using the same formulations of the source terms (the ST4). Since there are no significant differences between the two time steps, in the calibration on the parameterization of the source terms, the time step is assumed equal to 60''.
A comparison between the significant wave height obtained with different parameterization of the source terms of the WW3 model has been made by the Taylor diagrams. The similarity between two set of data is quantified in terms of their correlation, their centered root-mean-square difference and the amplitude of their variations (represented by their standard deviations). The simulated significant wave height that has the best agreement with observations will match nearest the point marked on the x-axis.

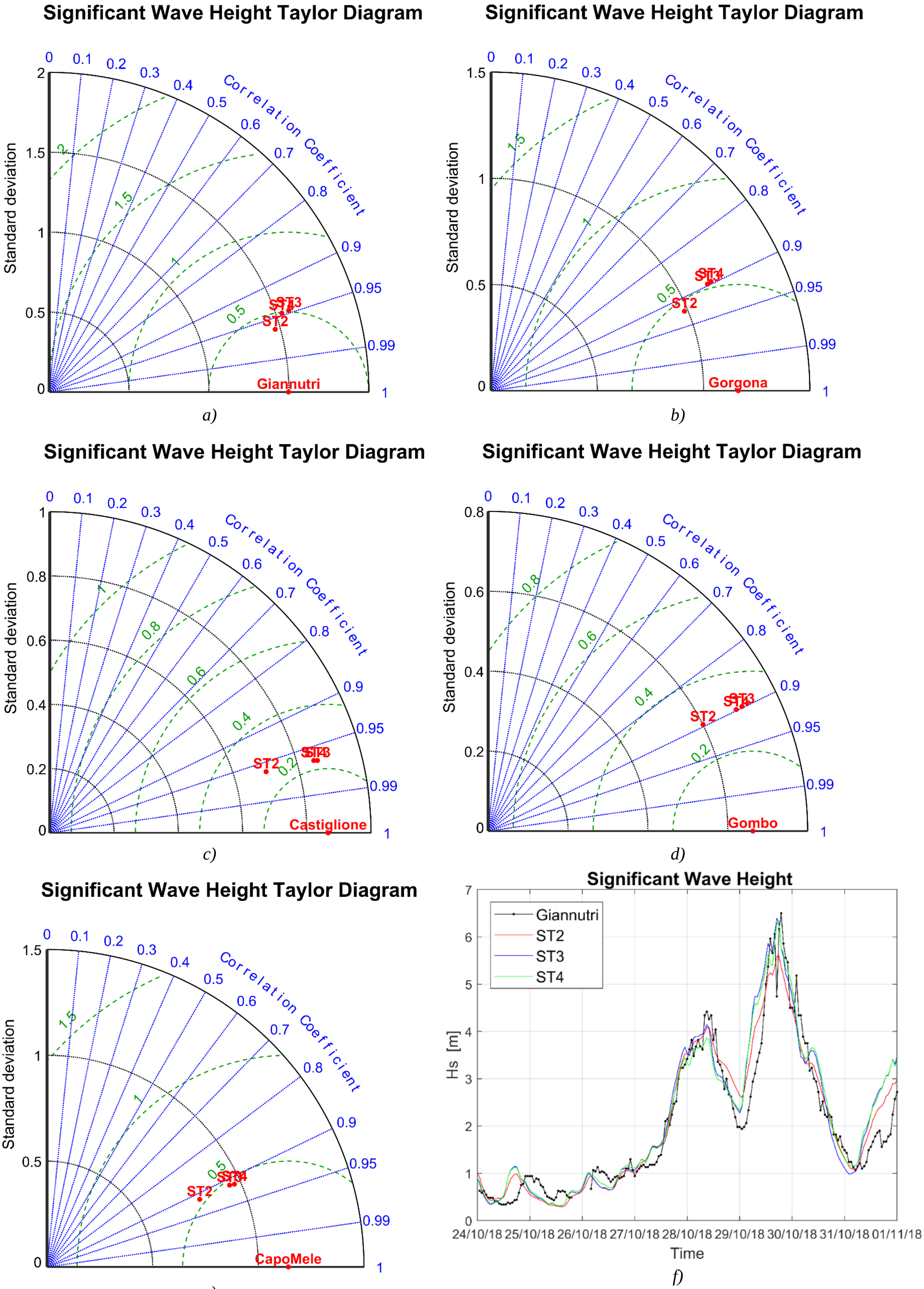


Figure 6. Calibration results: Taylor diagram for (a) Giannutri, (b) Gorgona, (c) Castiglione della Pescaia, (d) Gombo, (e) Capo Mele and time series of the significant wave height for the period 24/10/18 – 01/11/2018

The Taylor diagrams in Figure 6 highlight that the three parametrizations have a similar correlation coefficient and a good agreement with the data of the buoys. The more important differences are on the standard deviation values. The ST3 parameterization and above all the ST4 have a standard deviation value very similar to that of the data observed by the buoys. For these reason the selected parameterization is the ST4.

A preliminary validation of the WW3 model was done on the period between 2010-2018. In particular, the significant wave height is shown for the Giannutri Buoy in Figure 7. The results highlight a good agreement between the two series of data for the significant wave height with a correlation value higher than 0.9.

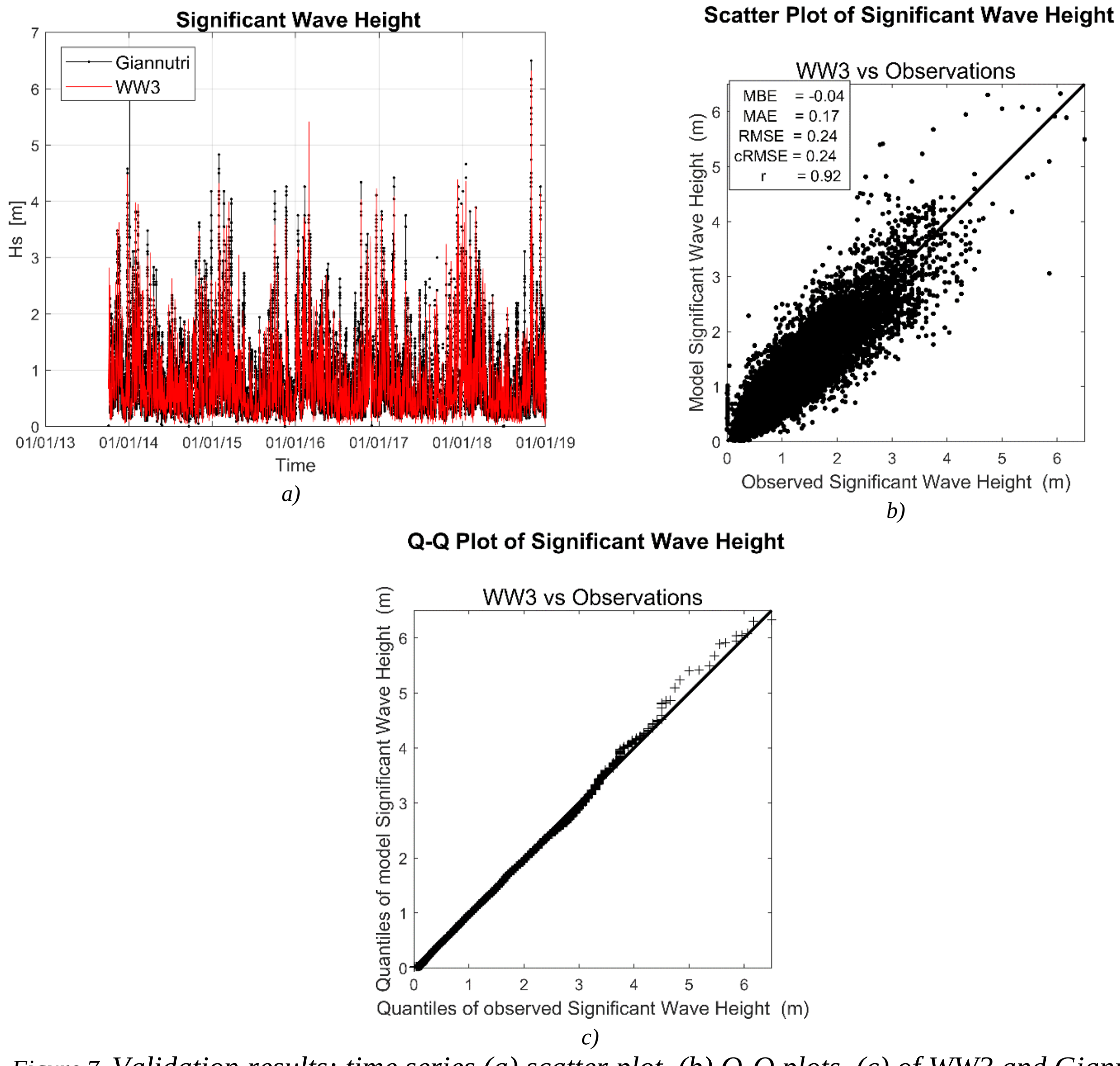
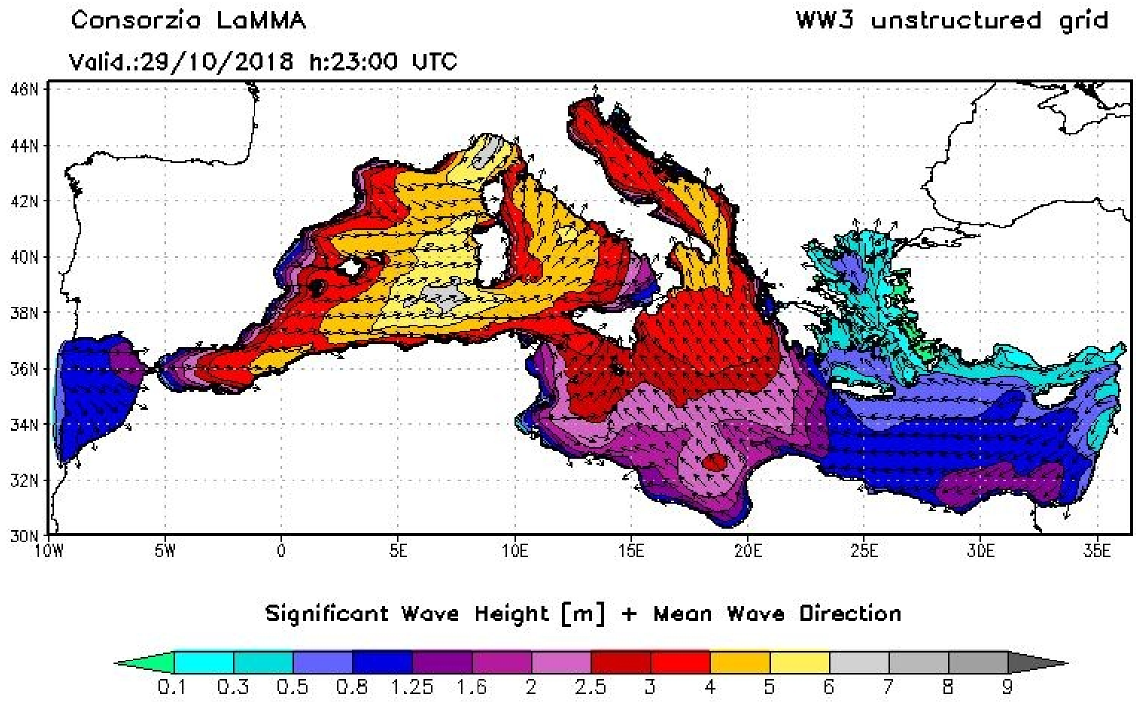
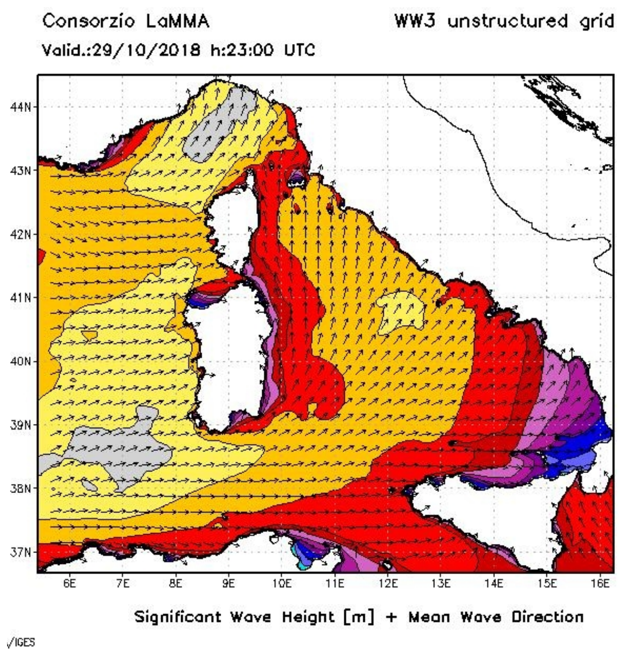


Figure 7. Validation results: time series (a) scatter plot, (b) Q-Q plots, (c) of WW3 and Giannutri Buoy significant wave height

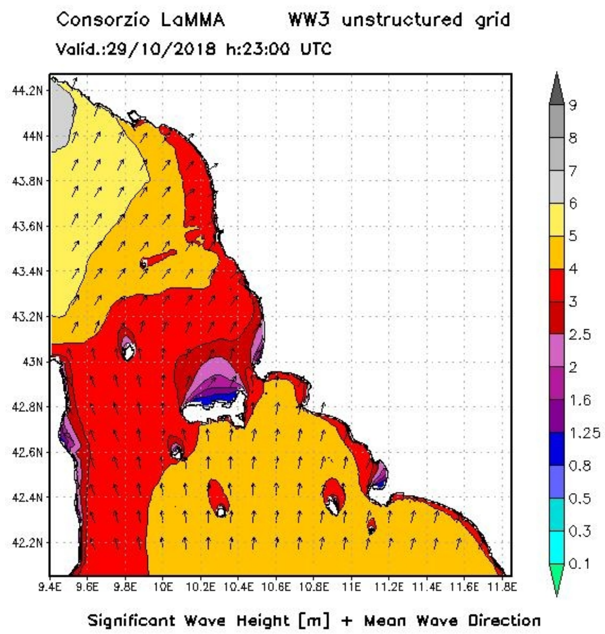
Below in Figure 8 we show the significant wave height spatial distribution obtained by the WW3 model for the storm of 29th October 2018 at different resolution: the whole Mediterranean Sea, the Tyrrhenian Sea and the sea in front of the Tuscany coast.



a)



b)



c)

Figure 8: Significant wave height spatial distribution 29/10/2018 – 23:00 UTC: a) Mediterranean Sea, b) Tyrrhenian Sea, c) Tuscany Sea