Copernicus Evolution and Applications with Sentinel Enhancements and Land Effluents for Shores and Seas

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PU	**Public**
PP	Restricted to other programme participants (including the Commission Services)
RE	Restricted to a group specified by the consortium (including the Commission Services)
CO	Confidential, only for members of the consortium (including the Commission Services)

DOCUMENT INFORMATION

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DISCLAIMER

1. Introduction

The deliverable D2.4 “Assimilation and memory for limited area domains” states that advances in data assimilation developed as part of CEASELESS will be considered for implementation into

- The next-generation reanalysis configuration developed at ECMWF. This production of reanalyses is now part of the Copernicus Climate Change Service (C3S) where it is expected that progress in wave data assimilation will find its way into a future enhancement of C3S.
- The operational Copernicus Marine environment monitoring service (CMEMS) systems for the northwest European shelf seas component as provided by the Met Office.

2. ECMWF contributions

The production of analyses and forecasts of wave conditions over the world oceans is an integral part of ECMWF operational duties as well as in its re-analysis activities. For these reasons, research work in wave data assimilation carried out as part of the CEASELESS project fitted well within the core research activities of ECMWF.

As the horizontal resolution of ECMWF global systems are set to increase further, it will become necessary to adapt the global assimilation for wave data to the specificities of the coastal zone. Work started under CEASELESS will pave the way for future developments. Data assimilation on the experimental unstructured grid was a first step.

CEASELESS also promoted the use of Sentinel data. Careful analysis and interpretation of Sentinel-3 altimeter data have insured that the data are used in the operational global data analysis system and as well as in the global reanalyses from ECMWF (ERA5 and any future ones).

So was also, the use of in-situ observations, in combinations with altimeter data. Impact of using both data sets was assessed (Figure 1). Based on these results, it has become possible to add in-situ wave observations for future change to the operational wave data assimilation scheme as well as to the future reanalysis within the ramework of C3S service.

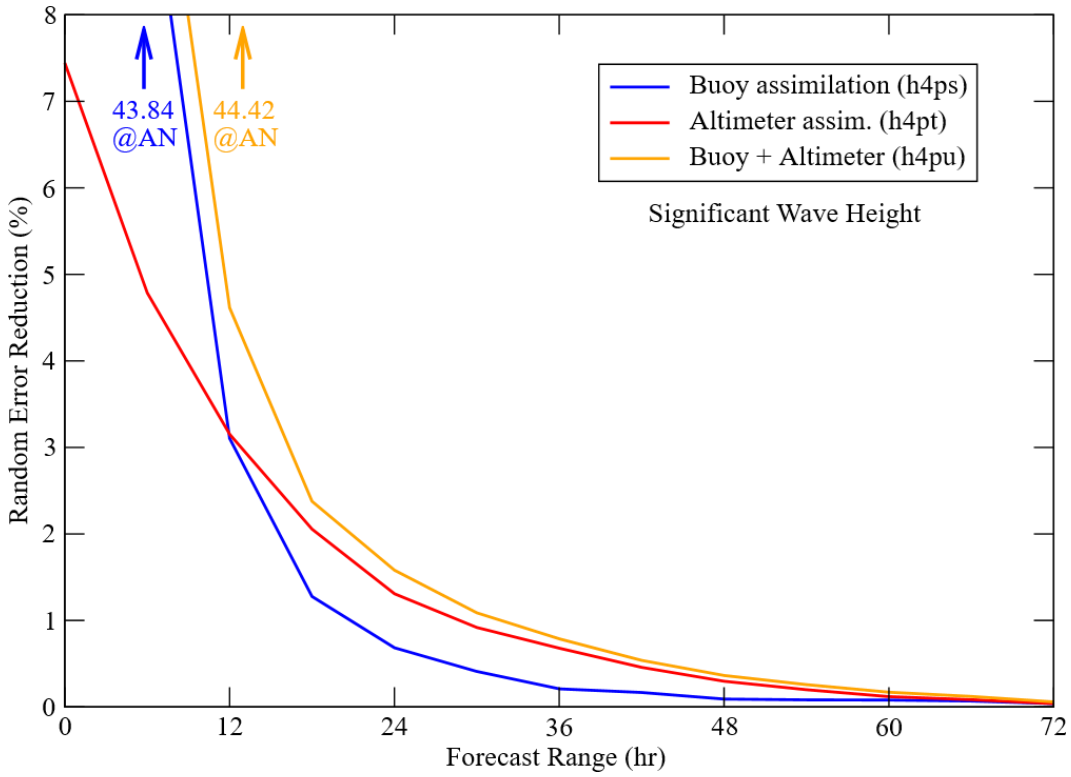

Figure 1. Random error reduction in Significant Wave Height (SWH) from data assimilation experiments compared to the experiment without data assimilation as verified by in-situ SWH data from all available in-situ data for forecast verifying over the whole month of October 2018. Note that the random error reduction of buoy-assimilation and the combined-buoy-altimeter-assimilation shoot out at analysis time to the values shown. Reproduced from work documented in section 2 of CEASELESS deliverable D2.2: "Assimilation impact for combined satellite/in-situ data (selected metocean variables)"

Background error specification for the wave data assimilation is currently reviewed. Work was also carried out in the context of the coupled atmosphere-wave data assimilation system. The potential is there for more positive impact. Further exploration is needed.

The production of reanalyses is now part of the Copernicus Climate Change Service (C3S). Any developments made in the operational system will eventually make its way to the reanalysis system because ECMWF reanalyses are based on operational cycles, albeit with special care for the use of the best available observations. Hence, the future ECMWF reanalysis ERA6 (expected in 2023) will benefit directly from work carried under CEASELESS. Therefore, it is expected that progress in wave data assimilation will naturally find its way into a future enhancement of C3S. Assimilation of Sentinel-3 and Jason-3 significant wave height data is in the process of being incorporated into current reanalysis ERA5 system.

3. Met Office contributions

Within CEASELESS, the Met Office has worked to develop a regional wave data assimilation capability, using a combination of satellite altimeter and in-situ observations. The key system components used are based on community codes for wave modelling (WAVEWATCH III®) and ocean model data assimilation (NEMOVAR). The focus region for this work has been the continental shelf seas of northwest Europe, hereafter labelled as the Northwest Shelf (Figure 2). This same region is a service delivery area for the Met Office within its commitments to provide model-based analyses and forecasts of physical ocean, wave and biogeochemical parameters to the Copernicus Marine Environment Monitoring Service (CMEMS; http://marine.copernicus.eu).

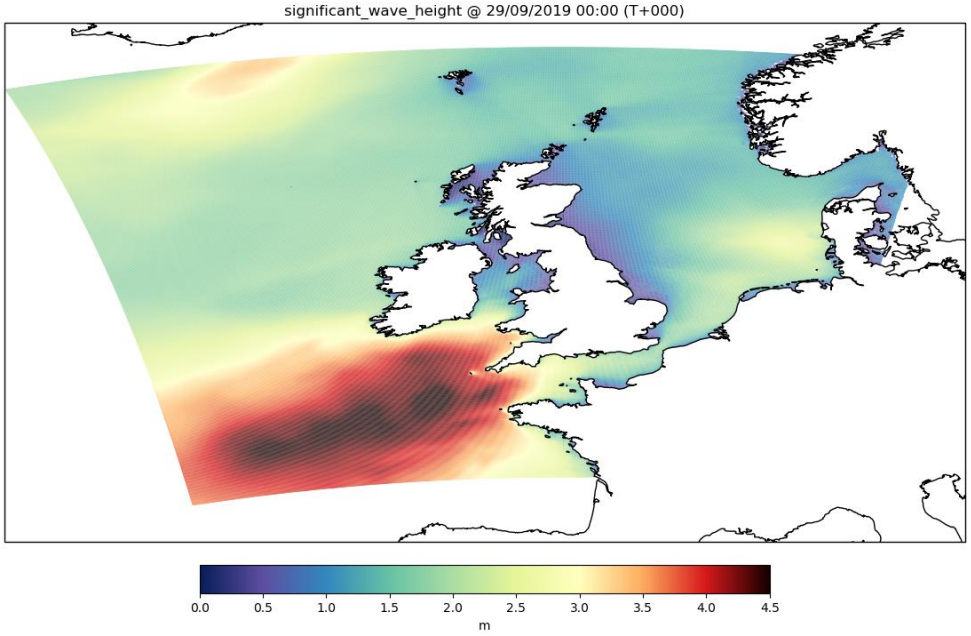

Figure 2. Model domain for the AMM15 wave model used to underpin CMEMS Northwest Shelf operational analysis-forecast wave products.

Figure 3 reproduces the key result from work documented in section 7 of CEASELESS deliverable D2.2: “Assimilation impact for combined satellite/in-situ data (selected metocean variables)”. The figure demonstrates that, through introducing data assimilation across the model domain used to cover the Northwest Shelf, a reduction in (root mean squared) differences between model and observations can be achieved with a system memory of up to 18 hours and that the differences are substantive for the first 3-6 hours after the analysis (T+0). Improvements versus the free running wave model presently used to generate CMEMS Northwest Shelf products (http://marine.copernicus.eu/documents/QUID/CMEMS-NWS-QUID-004-014.pdf) are of order 5-10cm in the relatively energetic open waters environments of the central North Sea and approaches from the Northeast Atlantic. A more modest 1-2cm improvement is achieved in less energetic coastal zones. The conclusions that can be drawn from these results are that: 1) as a proof of concept, the CEASELESS regional data assimilation experiments have demonstrated that CMEMS regional wave products can be improved through the addition of data assimilation; and 2) that these improvements will be focused on the analysis part of the daily analysis-forecast products. The use of data assimilation should also be pulled through to wave re-analysis product delivery.

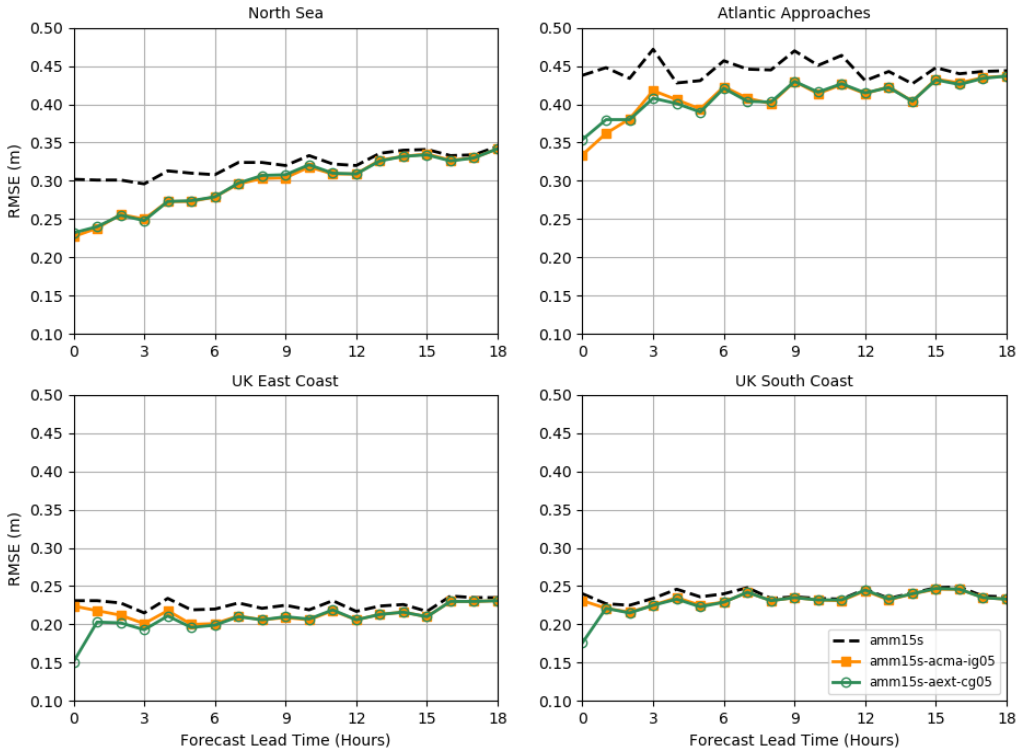

Figure 3. Root mean square errors for significant wave height predictions in North Sea, Atlantic Approaches, UK East and South Coast regions of the Northwest Shelf domain. The three experiments tested correspond to a model run without data assimilation (amm15s, black dashed line); assimilation of satellite altimeter and in-situ wave observations in open waters (amm15s-acma-ig05; gold line); and assimilation of satellite altimeter and in-situ wave observations in open and coastal waters (amm15s-aext-cg05; green line).

These results are timely in that they will be fed into the Met Office work to review feasibility and planned introduction of wave data assimilation into CMEMS Northwest Shelf products. Through the CEASELESS work, the benefits are clear. The next steps, to be taken outside of the CEASELESS project, will concern a review and development of the workflow required to integrate wave data assimilation within the Met Office's CMEMS production systems. As of April 2020, these are anticipated to comprise a two-way coupled ocean-wave model, within which the ocean model will have already included a data assimilation capability. This is based on the same NEMOVAR software used for the waves data assimilation experiments within CEASELESS. Key concerns for the system development are then:

1. Developing and improving automated observation retrieval and quality control procedures required to transition from the CEASELESS experimental system to an operational production suite.

2. Reviewing and testing the update cycle method used in the wave data assimilation to ensure compatibility with both the ocean data assimilation cycle and coupling frequency required for the two models to be run together. At present these are different, with the waves assimilation method using direct initialisation once every 6 hours, whilst the ocean assimilation is run inline with the model dynamics during its analysis cycle.

3. Reviewing the in-situ wave observations regularly available for the Northwest Shelf and developing software to download and ingest these from the CMEMS service in near-real time.

The present timeline to undertake this review and recommend an implementation plan will be designed to deliver by September 2020, with implementation taking place as part of a CMEMS service continuation contract (Met Office expects to understand the status of any continuation in 2021).
In addition to the pull through to CMEMS, the work undertaken in CEASELESS is planned to pull through to a wider audience through the availability of software and configuration information developed by the Met Office into community code repositories. Specifically, the code developed to enable spectral update of the two-dimensional wave spectrum, used by the model at initialisation, will be made publicly available via the WAVEWATCH III Github repository at https://github.com/NOAA-EMC/WW3. The target for these developments in the master branch of the repository are at version 7 of the model (presently the master is released at version 6.07), but the code is anticipated to become publicly available within the repository development branch on a much short timescale (early 2020). Similarly, configuration information required to enable NEMOVAR to develop increments for the significant wave height field will be made available in the NEMOVAR git repository at (https://git.ecmwf.int/login?next=/projects/NEMO/repos/nemovar/browse) by early 2020.