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Analysis of NCEP's extended wave forecast from the Global Ensemble Forecast System

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This study investigates the extended wave forecast from the NCEP's Global Ensemble Forecast System, under the project "Extending Maritime Hazard Information to Week Two and Beyond". The study on 20 years re-forecast of NOAA global ensemble members will improve our understanding of potential wave hazards for vessels at sea, looking at sub-seasonal marine weather, including two-week period and beyond maritime hazard probability. The initial conditions, model configuration, and the source terms are explored and discussed. Special attention is dedicated to the wave model initialization and the effect of input winds on the wave ensemble forecast system. Eight experiments were run with the wave model WAVEWATCH III, version 7.12, for the period from 2016/08/24 to 2016/10/18, when tropical and extratropical cyclones were found in the Pacific and the Atlantic Oceans. The wave ensemble setup selected corresponds to the NCEP's Global Ensemble Forecast System (GEFS), version 12, with a mosaic of three grids with resolutions: Southern Ocean (1/3°), Arctic Ocean (1/3°), and Global (1/4°). The wave model is run with input/dissipation source term ST4 (Ardhuin et al. 2010), nonlinear interactions using DIA (Hasselmann et al., 1985), and third-order propagation scheme (UQ) with GSE alleviation (PR3). The wave model is forced by GEFS winds from a 20-y reforecast simulation.

The reforecast data of the atmospheric ensemble is composed of 5 members with one cycle per day, and forecast range of 16 days. Once a week (on Wednesdays) the simulations are expanded to 35 days with a total of 11 members. The spatial resolution of surface winds is 0.25° for the first 10 days and 0.5° for the subsequent forecast lead time. The impact of the initial conditions in the wave model is investigated through eight different WW3 groups of simulations (with 5 members each), where the restart files used for the model initialization of the consecutive cycles are generated at different forecast lead times: [1] 24-hours (1 day) forecast step; [2] 2-days; [3] 3-days; [4] 5-days; and [5] 7-days. Test [6] was run with no restart file, to evaluate the propagation of the initial error throughout the forecast range. Test [7] was run with the same restart file (control) for all the 5 forecast members, i.e., it starts with no spread which progressively grows from the propagation of the atmospheric spread to the wave fields. Finally, test [8] was run with 1-day restart files (from test [1]) but with the same wind forcing (control) for all the members, i.e., it starts with a small spread that is progressively decreased to zero due to the lack of spread from the single wind input.

The results are evaluated using NDBC and Copernicus buoys, excluding stations close to the coast. An additional assessment is done against altimeter data, where the cyclonic areas are selected for an independent analysis using cyclone tracks from IBTracks. The evaluation is performed based on traditional error metrics, such as bias, RMSE, scatter index, and correlation coefficient, applied to single ensemble members as well as to the arithmetic ensemble mean. The ensemble spread of wind speed and significant wave height is analyzed through rank histograms (Talagrand diagrams) to evaluate if the ensemble is over- or under- confident, and how the atmospheric spread is propagated to the wave spread.

Figures 1 and 2 summarize part of the results. The largest initial spread is found in the WW3 simulation with 7-days restart file, as expected, which progressively decreases in simulations started with the 5, 3, 2, and 1 day restart

files. The spread generated from the 7-days restart is five times the 3-days restart simulation, which shows how sensitive the spread in the initial conditions is relative to the forecast lead time that produces the restart file. The initial spread of WW3 simulations from the 1-day restart file is very small, and reflects the low uncertainty of the wave prediction in this forecast range. Interestingly, the effect of different spreads in the initial conditions of the wave simulations is confined to the first four days of the forecast (Figure 1B). Therefore, the influence of the initial condition shrinks in the first forecast days while the importance of wind inputs becomes dominant. Consequently, the impact of the initial conditions in WW3 at forecast ranges beyond one week is very small, being the skill and spread of the wind inputs the most important features to consider.

The forecast error as a function of the forecast lead time is presented in Figure 2. Figure 2A shows the RMSE for the simulations using 1-day restart files, for the five members plus the ensemble mean. The result indicates larger errors of the individual ensemble members and highlights the better performance of the ensemble mean. This feature is more evident on forecast lead time beyond five days, which reinforces the importance of the ensemble modeling and probabilistic forecast compared to single deterministic products. The RMSE of the ensemble mean is at least 20% better than the control run, i.e., the RMSE for forecast day 10 of the ensemble mean has the same value of forecast day 6 of the control run.

Figure 2B shows the RMSE resulting from the eight different initial conditions. The largest errors are found in the initialization with no restart, followed by the 7, 5, 3, 2, and 1 day restart files. Thus, increasing the initial spread by generating restart files further in forecast lead time leads to larger RMSE and so other methods to properly manage the spread on the nowcast must be considered. Once again, these differences among different initial conditions converge to similar RMSE after the fifth forecast day.

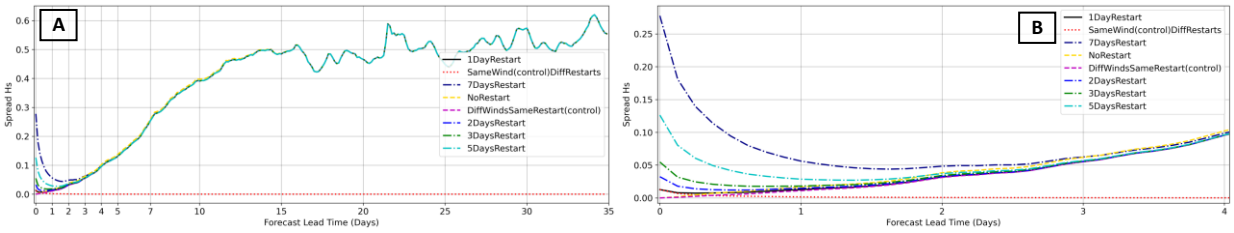

Figure 1 – Spread of the wave ensemble with five members. The plot on the right amplifies the first four days of forecast.

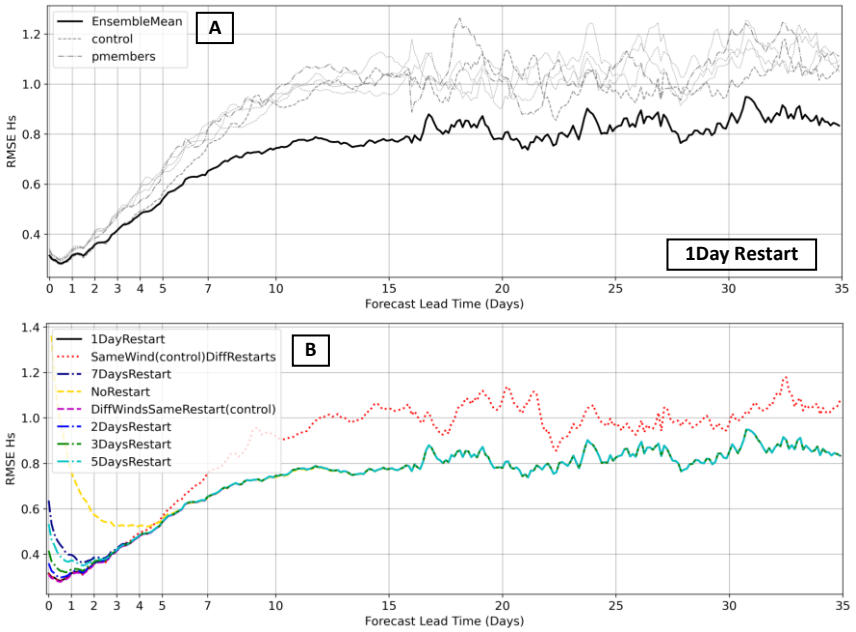

Figure 2 – RMSE as a function of the forecast lead time for the first test (panel A; using 1day restart files) and comparing all tests (panel B).