Improving the short-range forecast of storm surges in the Southern-West Atlantic Continental Shelf using EnSRF data assimilation

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ABSTRACT

The assimilation of tide gauge and altimetry data into a 2D-barotropic numerical model for the Southern-West Atlantic Continental Shelf (SWACS) is presented in this work. For this, 4-day ensemble prediction system “Model for Storm Surge Simulations'' (MSSS, Dinápoli et al., 2021a) was implemented. MSSS was forced with the astronomical tide; daily continental discharge observations and the atmospheric variables of GEFS from NCEP. Tidal gauge and altimetry data were sequentially assimilated for 6 h every 1 h using the Ensemble Square Root Filter (EnSRF). Results show that EnSRF’s innovations produce a positive impact upon the forecast skill up to 1.5 days, then it is purely driven by the external forcing. Larger improvements (errors up to 5%) were observed at the northern SWACS where more chaotic processes forced by the atmospheric circulation explain a large part of the sea surface height variability. At the southern SWACS no larger improvements were found because of the strong tidal dynamic. Our results prove that the incorporation of EnSRF into MSSS can significantly improve the forecast of sea surface height in the SWACS and, evenmore, the accuracy of the short-range detection of storm surges.

1. AREA OF STUDY

The Southern-West Atlantic Continental Shelf (SWACS, Fig. 1) presents a barotropic dynamic:

- Tides constitute one of the strongest regimes, among the biggest in the world.
- Atmospheric circulation can be roughly separated into two regions:
  - South of 40 °S, driven by strong westerly and northwesterly winds;
  - North of 40 °S, driven by the South Atlantic High and modulated by its seasonal variability that can produce positive strong storm surges so-called “Sudestadas”.

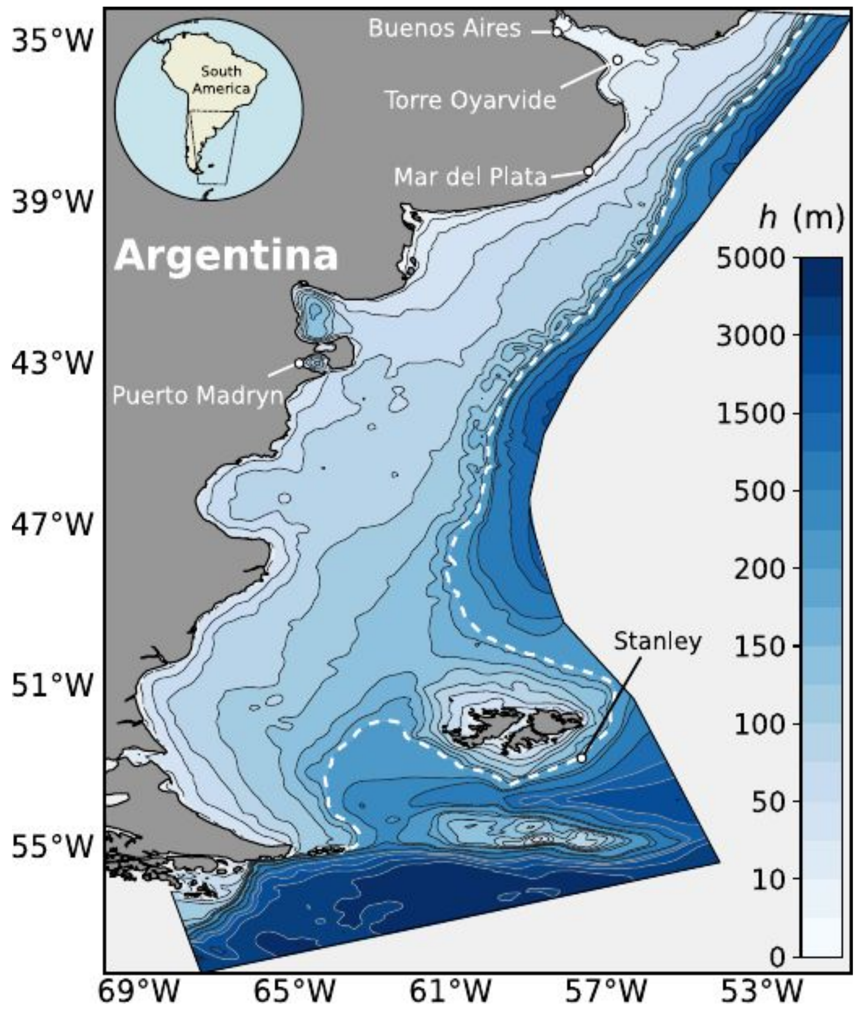

Figure 1. SWACS and location of the tidal gauges (circles). Isolines represent the bathymetry in meters.

2. MATERIALS AND DATA

- The Model for Storm Surge Simulations (MSSS) is a modification of the scientific community numerical ocean model CROCO.
- MSSS covers the SWACS with a curvilinear grid in order to focus the numerical domain on the continental shelf (resolution between 2 km to 15 km).
- Astronomical tide composed by the constituents M_2, S_2, N_2, K_2, K_1, O_1, Q_1 and P_1 from the TPXO9 model.
- Daily observations of runoff provided by the National Institute of Water and the National System of Hydric Information, Argentina.
- Atmospheric products derived from the 21-member GEFS produced by NCEP.
- Ensemble Square Root Filter (EnSRF) is used to data assimilation:
  - Tidal data collected by the Hydrographic Service of the Navy and Global Sea Level Observing System
  - Remote data from Global Ocean Along-track L3 Sea Surface Heights Reprocessed Tailored for Data Assimilation.

Total water level observations were assimilated every 1 h during 6 h (Fig. 2).

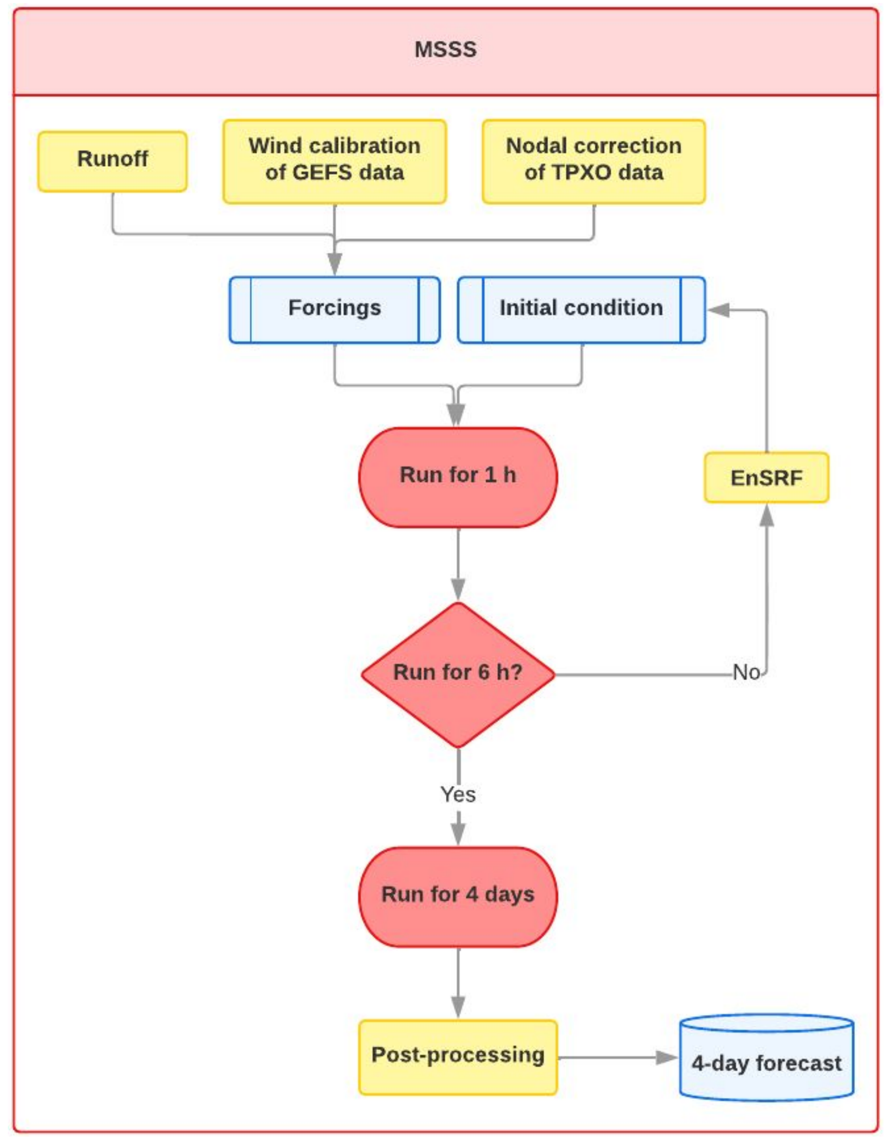

Figure 2. MSSS operation scheme.

3. RESULTS

Fig. 3 presents the time series of observations (black dots), control case (NoEnSRF, blue line) and EnSRF (red line) 2 days forecasts at the five available stations previous to the storm surge event. Tidal gauges (white dots), altimeter tracks (orange lines) observations and 6 h analysis window (brown shades) are also shown. Results show the good capability of EnSRF to produce more accurate initial conditions, correcting the biases and timing of the numerical solutions. Larger enhancements are observed at northern stations (Buenos Aires, Torre Oyarvide and Mar del Plata) where winds present the highest nonlinear impact on the sea surace height. At Puerto Madryn and Stanley the effect of the assimilation because of their strong tidal dynamic.

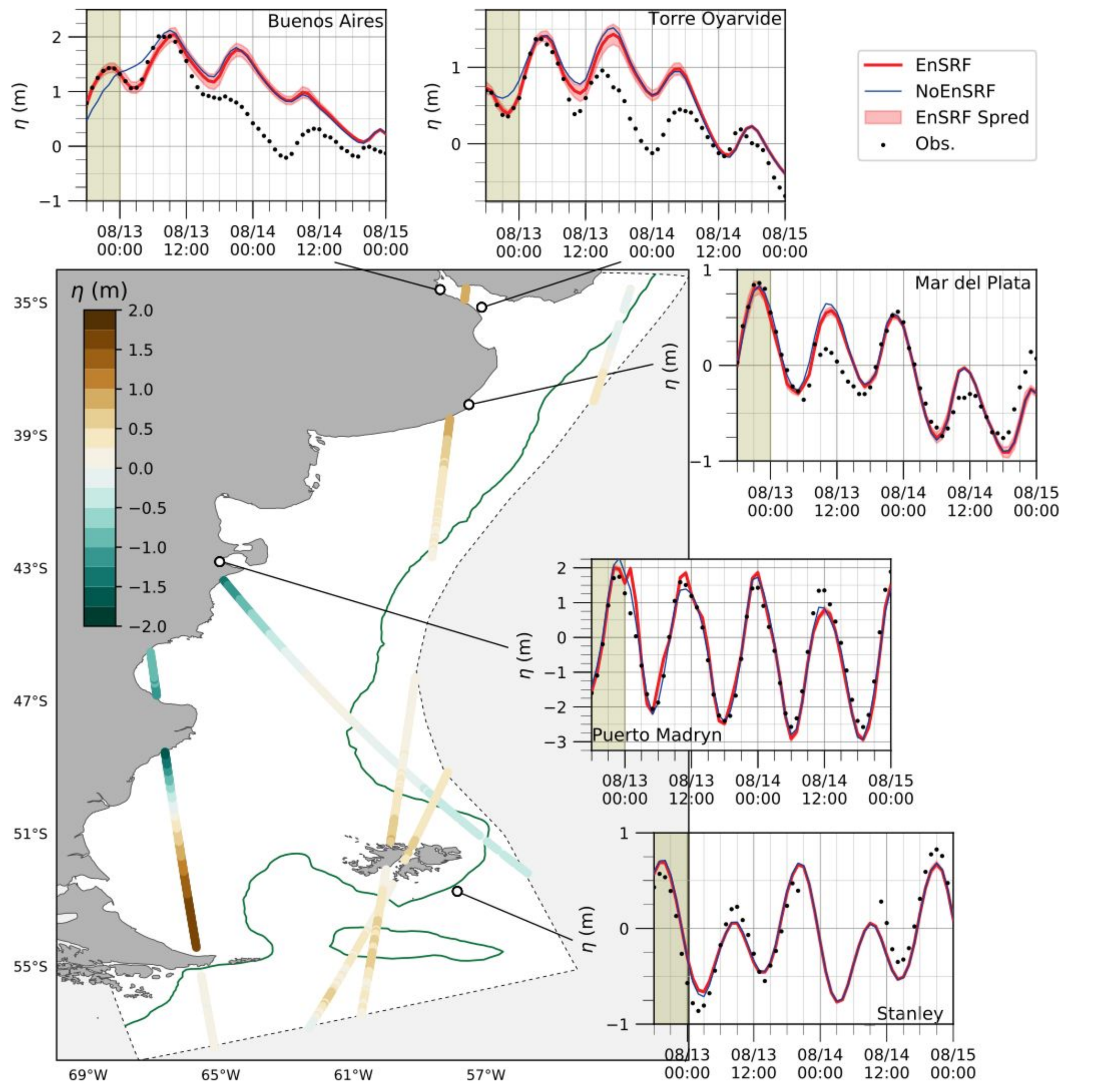

Figure 3. MSSS forecasts

The major benefit of EnSRF is observed during the first 12 h of the forecast, when the model solution presents a proper representation of both the tidal and the surge components. Innovations linger up to 1.5 days, and then the system is purely driven by external forcing. This last suggests that the first 2 days of MSSS’ forecasts will have a strong observational component and the remaining 2 days will be driven by the atmospheric forecast.

4. CONCLUSIONS

Results show that EnSRF produces more accurate initial conditions, which remove biases and correct the timing of the numerical solutions. The main enhancements were observed at the northern SWACS where non-deterministic atmospheric processes account for most of the sea surface height variability. Forecast accuracy is better within the first 12 h, which supports the implementation of MSSS, considering that GEFS products are updated every 6 h. Because of the computational low cost of both EnSRF and MSSS and the short time needed to run them (approx. 20 min), it is foreseen to transfer MSSS to the Meteorological Service of Argentina for operative implementation.

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