Replies to Reviewer #1's Comments

The paper provides a brief description of the motivation for producing ensemble ocean forecasts together with an overview of the different methods for generating them. A brief description of how ensembles are assessed is also provided. A table is included which lists some existing operational ensemble ocean forecasting systems. The paper is a useful introduction to the methods for ocean ensemble forecasting and the status of the field.

We would like to thank the Referee for the time and effort invested in reviewing our manuscript, as well as for the valuable comments and suggestions provided. All points raised have been addressed in the revised version, and below we offer point-by-point responses to each comment

- *Main comments*

The structure of the text in section 1.1 could be improved. The text doesn't seem to clearly follow the different options for ensemble production as shown in Fig. 2.

Thank you for pointing this out. We have incorporated the following discussion on DA-based ensemble forecasts in Section 2 (previously Section 1.1):

"*Data Assimilation-Based Ensemble Forecasts*. Ensemble forecasts in data assimilation are typically generated by introducing multiple, slightly different estimates of the current system state to capture uncertainties in observations and model parameters while accounting for the "error of the day". For example, in an Ensemble Kalman Filter (EnKF), observations can be perturbed, or not, Whitaker and Hamill, 2002; Hoteit et al., 2015), and the model is then integrated from these perturbed initial states, sampled according to the estimated initial-state statistics derived from previous forecasts and the most recent observations, resulting in an ensemble of forecasts. Additional perturbations may be introduced to the model physics or inputs to represent other sources of uncertainty, as demonstrated in Monte Carlo (MC) ensemble forecast methods (Hoteit et al., 2018; Sanikommu et al., 2020). This collection of forecasts provides a probabilistic picture of future conditions, reflecting both initial condition and model uncertainties."

More references could be included to give the reader more information about particular advances, as suggested in the minor comments below.

We have carefully considered all of the references suggested by the Reviewer and incorporated them into the revised manuscript at the appropriate points. Thank you.

Table 1 is quite an ad hoc selection of different systems and not all up to date. Some suggestions for improving it are included in the minor comments below.

We have cited, to the best of our knowledge, additional systems as suggested by the Reviewer. Thank you.

- *Minor comments*

The section numbering seems quite ad hoc. Perhaps all sub (and sub-sub) sections could be made into new main sections.

We have carefully reviewed and updated our section structure to ensure better clarity and coherence.

Line 31. Suggest rewording to "…to communicate forecast confidence to end users for better decision making."

Done. Please refer to line #25 in the revised manuscript.

Figure 1 caption. Not sure why SST is specified as the observation type – the rest of the Fig and caption are more general.

Thank you for bringing this to our attention. We have removed the mention of "SST" from the figure caption to better reflect its general context, as suggested by the Reviewer.

Line 58. Fig. label is incorrect.

Corrected. Thank you.

Line 74. "Alternatively, …". The initial condition uncertainty is an additional source of uncertainty rather than an alternative to those mentioned previously.

Thank you for pointing this out. We have revised the text to clarify that the initial condition uncertainty is an additional source of uncertainty (please see line #68 in the revised manuscript). We appreciate your helpful suggestion.

Line 70. Some references for ocean model stochastic model schemes would be useful here, e.g. from Storto et al., 2021, Brankart et al., 2015.

Thank you for suggesting these references. We now cite them in the revised manuscript (please see line #68).

Line 76. It wasn't clear to me how EDA schemes fit into these options.

This short article is focusing on ensemble forecast methods, whether the perturbations are heruistic, dynamical, or from EDA. We are hoping that the new paragraph we included on DA should address the Reviewer's comment.

Line 79. Lateral boundary and surface forcing perturbation schemes might still be needed for some applications where the available atmospheric and global ocean ensembles may not be appropriate in a given operational setting. Perhaps some references could be included on these, e.g. Storto et al., 2023. You could also mention about the uncertainty in other inputs such as the rivers, e.g. Zedler et al., 2023.

Thank you for the suggestion. We now mention other sources of uncertainties including bathymetry and rivers forcing. We have also incorporated all the suggested references into the revised manuscript (please refer to line #74-75).

Line 100. You don't mention CRPS here which is often used to assess ensemble forecasts.

We have incorporated information about CRPS (please refer to line #118-120 in the revised manuscript). Thank you for the suggestion.

Line 110. Do you mean global systems here? Some regional operational forecasting systems have been running ensembles for a long time, e.g. TOPAZ (Bertino et al., 2008).

Thank you for drawing our attention to this detail. We have clarified in the revised manuscript that this statement is particularly applicable to global systems (please see line #25).

Line 115. Missing comma between “horizons” and “the”.

Corrected. Thank you.

Line 119. Perhaps it could be stated that table 1 is a selection of systems, rather than a comprehensive list (which is difficult to provide).

Thank you for the suggestion. We have corrected the caption as suggested. It reads now: “Table 1: Summary of selected operational ensemble forecasting systems worldwide.”

Table 1:

The FOAM ensemble includes internal physics perturbations according to Lea et al. 2022.

The Bluelink system now runs an operational 1/10° global ensemble using the EnKF (Brassington et al., 2023).

The ECMWF ocean system is an ensemble system (Zuo et al., 2019) and could be included.

A couple of surface wave systems are listed, but others also run ensemble wave forecasts, e.g. MeteoFrance, UK Met Office.

Seasonal forecast systems are mostly ensemble-based systems but only the BoM system is listed. See https://climate.copernicus.eu/seasonal-forecasts.

A regional system that could also be included is described by Röhrs et al., 2023.

We appreciate the Reviewer's observation regarding the difficulty of listing all operational systems. Consequently, we have updated the table to include several additional operational systems, as suggested.

Line 130. SWOT is now flying so this sentence should be amended.

Thank you for the update regarding the SWOT mission. In the revised manuscript, we have amended the sentence to acknowledge that SWOT is now operational. It reads:

“Ensemble forecasts are also needed to provide error statistics for the ocean analysis systems to better exploit the high-density observations from upcoming and newly operational satellite missions, such as Surface Water Ocean Topography (SWOT) (Fu and Ubelmann, 2014).”

Line 133. Ocean forecasting systems have been produced by DA system for a long time so I wasn’t quite sure why this sentence was included.

We have revised this sentence to “Ocean forecasts have long been produced by data assimilation (DA) systems and are now routinely used operationally”.