Ocean Sci. Discuss., 9, C1793–C1800, 2013
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Ocean Science
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Interactive Comment

Interactive comment on "Optimal adjustment of the atmospheric forcing parameters of ocean models using sea surface temperature data assimilation" *by* M. Meinvielle et al.

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Received and published: 4 September 2013

We would like to thank the anonymous referee number 2 for his positive appreciation of the work done in this paper and for his constructive comments that help us improving the quality of the manuscript. All the comments are addressed below, and a revised version of the paper including the corrections is attached.

1. There is definitely many problems which can be addressed by the use of a model. Here the question of the long term behavior and trends of the model is highlighted. By correcting monthly means of the forcing parameters, we showed that the interannual

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variability of the run is not significantly modified. However, our corrections help to reduce long term trends like the warm bias in the intertropical region. As a consequence, the work presented in our paper is more designed for the purpose of improving the long term mean state of the model than for producing accurate high frequency hindcast. The fifth paragraph of the introduction has been precised as follow (bold sentences):

"In the present paper, we make one step further than the past idealized studies to estimate a set of corrections for the atmospheric input data from the ERAinterim (ERAi hereafter) reanalysis for the period from 1989 to 2007. **Ocean modeling can be used to answer a number of particular questions, and given the focus chosen, the forcing optimization will be designed differently. Here we aim to address the problem of long term trends and biases in the model, with the final objective of improving the mean state of the ocean in long term hindcast simulations, without modifying its interannual or high frequency variability.** We use a sequential method based on the SEEK filter."

2. To be more acurate, the sentence has been changed by: "All fluxes are calculated at every model grid point with classical bulk formulas which take as input the near-surface atmospheric variables (air temperature and humidity, zonal and meridional wind speed and precipitation), downward **atmospheric** fluxes (short wave and long wave radiation) and the ocean surface variables calculated by the model (SST and surface currents velocity)."

3. Yes, the variable used is the air temperature, and according to the height the input air temperature was observed (2 m or 10 m for example), a low level lapse rate correction is applied. The correction is part of the bulk formula used in NEMO, base on the formulation of Large and Yeager (2004). There is no need to change the text, the use of the air temperature in Bulk formula being very standard. However θ_a in this paragraph has been changed by T_a to avoid confusions.

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About the wind speed, we corrected the text by explicitely mentionning the 10 m reference: “The turbulent fluxes involve the knowledge of $X_A = (T_a, q_a, U_{10})$ the atmospheric state, with T_a being the air temperature, q_a the specific humidity and U_{10} the relative wind speed **at ten meters above the surface**”.

4. In the present study we used the forecast variables from ERAinterim. This forecast is instantaneous for the pronostic variables of the model (ie, the variables which are assimilated: temperature, humidity and wind speed). All the model forecast fluxes (ie, not assimilated) like the radiations and precipitation are integrated over the time step. Before using these last outputs they have been processed to obtain a consistent daily mean value which will be used in the model. We added the following to explain this in the section 2.1: “Near surface variables (air temperature and humidity, wind speed, downward radiation and precipitation) from atmospheric reanalysis (here ERAi) used to specify surface boundary condition of the model are characterized by large uncertainties at global scale. **Temperature and humidity are instantaneous forecasts at 2 m above the ocean surface and will be mentioned as t_2 and q_2 respectively thereafter. Zonal and meridional wind speed are instantaneous forecast at 10 m above the surface, and will be noted u_{10} and v_{10}. Atmospheric radiation and precipitation fluxes are 12 hour integrated forecasts. ERAi outputs were available to us every 6 hours.** We thus propose here to estimate corrections of t_2, q_2, u_{10}, v_{10}, rad_{sw}, rad_{lw} and $precip$.”

5. Since the general concept of the study and its implications in long term runs has been clarified in the introduction (comment 1), modifying the end of the paragraph 2.2 seems not relevant any more to the co-authors.

6. The issue of the numerical cost of our method was mentioned too early in the text. To clarify, we moved it to the end of Section 3, as following: “**In practice, the whole**

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procedure is repeated monthly between 1989 and 2007, which results in running 200 times the model over the 19 years period to complete the ensemble experiments, and thus to obtain the set of forcing corrections. Such an important amount of simulations and could be a critical difficulty with a higher resolution model."

7. The last paragraph of page 2503 has been modified as follow: "In figures 4 and 5, we notice that for the major part of the world ocean the corrections are consistent with the assumed forcing uncertainties (e.g. -1 to 1 $^{\circ}C$ for the 2 m air temperature, 1.5 to 1.5 m/s for wind speed, or -20 to 20 W/m^2 for shortwave downward radiation)**, which is comparable to the 1989–2006 mean differences between the forcing parameters of ERAi and DFS4.3 (Brodeau et al., 2010) (not shown).** Furthermore, temperature and humidity corrections have a similar behavior, consistently with the strong correlation of these two variables. The same comment can be made regarding shortwave and longwave radiation corrections. On the other hand, the large scale structure of the corrections is mostly zonal. For example, we obtain a mean shortwave radiation (rad_{sw}) correction of of approximately +15 W/m^2 in the intertropical band, and -15 W/m^2 for mid-latitudes. Longwave radiation corrections have an opposite behavior with negative corrections in the intertropical band (-5 W/m^2) and positive corrections at mid-latitudes (5 W/m^2). The corrections obtained with our method are thus physically reasonable in terms of large scale intensity and structure."

8. The issue of model resolution and WBC separation is effectively too complex to be discussed here. So we decided just to stick to fact, that is that: "As mentioned in section 3.1, **the water masses and front positionning in these regions are not properly represented in our ocean model**."

9. Applying the procedure independently for each month prevents from the propaga-

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tion of the remaining errors. A figure showing the correlation between the net heat flux timeseries computed from ERAi and ERAcor has been added to the manuscript, and the text has been implemented as follow: "Although this procedure does not allow to test the corrections actually computed by the data assimilation method, **the 1989–2007 net heat flux time series computed from the parameters after correction and from the original ERAi variables are well correlated (**> 0.5 **in the intertropical band), which gives an insight on the good stability of the corrections (e.g., Fig. 10). Furthermore,** we can evaluate the corrections in terms of impact in the model focusing on the results in the intertropical band where this post-processing has not a drastic impact on the solution since it is the region of correction maximum validity."

10. We modified the conclusion part (from the beginning to "The diagnostic of the computed correction itself...") to focus the beginning of the conclusion on the main results. The new version is:

"In this study we explored the feasibility of a sequential data assimilation methodology to estimate monthly corrections of ERAi forcing parameters using real SST observations. Independent monthly data assimilation experiments have been performed over the period 1989-2007 to compute a corrected forcing dataset ERAcor (without correcting the model state), to be used in a free model run. The prior probability distribution of the parameters has been characterized by the intra-seasonal and interannual variability of ERAi reanalysis, and ensemble experiments of 200 members were performed to estimate the forecast error covariance matrix. Implementing such a methodology in a realistic case is challenging, by the care needed to make assumptions and methodology developments. The initialization procedure of the experiments is crucial to avoid the propagation of potential initial condition errors unrelated to the forcing. For this matter, initial condition as consistent as possible with the surface observations has been extracted from a strongly constrained simulation. Moreover, the impact of the forcing on the model state had to be isolated from other model errors in the ensemble experiments with a robust diagnostic approach. Finally, the residual excessive corrections have been limited by a truncation of the prior probability distribution of the parameters as described in Skandrani et al. (2009).

This paper illustrates the benefit of using an objective method to estimate forcing corrections. This method has been demonstrated successful in identifying properly the monthly forcing impact on the model state:

- For every given month, the computed corrections applied to a free model run have the same impact as the analysis step on the model SST.
- The net heat flux budget resulting from ERAcor (highly positive in ERAi database) is balanced at the global scale, and the potentially unrealistic negative trend observable in the time-series of this flux in the ERAi database (leading to ocean cooling) over the whole time period has been removed.
- Parameters corrections computed improve the long term mean state of a free (without data assimilation) simulation with respect to ocean surface observations, and can guide typical ad hoc forcing corrections mostly used to adjust forcing parameters (e.g. Brodeau et al., 2010).

We have not evaluated the consistency of the interior dynamics by comparing our results to observations. Indeed, since the consistency of the corrections is mainly assessed for the intertropical band, it would be first useful to construct a comprehensive forcing dataset including these corrections without introducing any discontinuity in the forcing field before looking at the behavior of the global ocean circulation. However we diagnosed the equatorial undercurrent in the simulation forced by ERAcor and it turned out that the corrected forcing leads to a better representation (in terms of intensity) of this important equatorial circulation feature than ERAinterim with respect to TAO observations (not shown). As a further step, one could envisage applying a similar method to an operational system for short term forecast in present day operational

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systems. Indeed, the ocean state correction can present some inconsistency with the forcing parameters used, whereas our approach proposes an alternative to keep the interactive ocean-atmosphere link while correcting efficiently the ocean surface state.

The diagnostic of the computed correction itself ...”

11. Here we suggest to construct the prior probability distribution of the parameter by using as standard deviation the difference in magnitude between reanalyses instead of the amplitude of interannual variability used in the present study. The sentence can be modified as following: “the definition of parameter prior probability distribution could also **be based on the magnitude differences observed** between different atmospheric reanalyses instead of intra-seasonal and interannual variability **of a single reanalysis**”.

12. To make clearly the disctinction between VOS-based and reanalyses-based products, the text can be modified as follow: “Results should be first subject to further evaluation by comparison with available atmospheric or fluxes observations like TAO/TRITON, PIRATA (Pilot Research Moored Array in the Tropical Atlantic), RAMA, **and reconstructions based on reanalyses and satellite observations like OAflux (Yu and Weller, 2007) or TROPFlux (Praveen Kumar et al., 2011) databases. VOS-based products like NOCS (Berry and Kent, 2009) database can also be useful to conduct further evaluation of our correction as far as we consider a region with acceptable sampling error (Gulev et al., 2007)** This work would make possible to identify more precisely the strengths and weaknesses of the method, to have a more critical look on the results, and to identify the benefit of the corrections in every particular application.

13. ”**A wider perspective concerns the implementation of reanalyses. While**

in the construction of an ocean reanalysis, it is certainly useful to extend the ocean state control vector to the forcing parameters to avoid the propagation of forcing errors in the system (e.g., Cerovecki et al., 2011), our methodology could also be valuable to provide improved ocean boundary information for the implementation of atmospheric reanalyses. Indeed, our approach is not only dedicated to the simulation of the ocean state and can be viewed as an objective way of controlling the air-sea interactions. More precisely, one could envisage to improve boundary conditions in atmospheric models by not using anymore the SST directly but the atmospheric parameters corrections produced by the assimilation of the SST in an ocean model.“

14. We had the paper edited by the co-authors who have altogether more than 150 papers published in English. We corrected what we found justified.

Please also note the supplement to this comment:
http://www.ocean-sci-discuss.net/9/C1793/2013/osd-9-C1793-2013-supplement.pdf

Interactive comment on Ocean Sci. Discuss., 9, 2493, 2012.