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Interactive comment on "Evaluation of numerical models by FerryBox and Fixed Platform in-situ data in the southern North Sea" *by* M. Haller et al.

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Author's Response to Anonymous referee #1

The Authors would like to thank the anonymous referee #1 for the detailed and constructive review of the submitted manuscript. The responses to the comment points are found below:

1) The introduction is rather long with a lot of general information which in my view can be condensed.

According to the criticized length of the introduction (also by reviewer #2), several sentences in the introduction have been removed (i.e. introductory sentences about the FerryBox and the models, as they are described in more detail later on).

2) Such detailed presentation of the FerryBox system is beyond the scope of the paper. Reference to the Petersen et al. (2003) paper should be adequate.

The description of the FerryBox system in Section 2.1 is shortened. Especially some details of the operation and maintenance have been removed. However, the essential features of a FerryBox have to be described in the text as many readers from the outside may not be familiar with FerryBox systems. The reference to Petersen et al. (2003) was already included before.

3) “For remaining rivers, freshwater runoff climatologies are used” What is their significance in terms of flux, compared to the more accurately forced 5 German rivers mentioned above?

The amount of freshwater entering the greater North Sea that is handled by runoff climatologies is approximately 1/3 of the overall North Sea runoff in the BSHcmod model. In the German Bight which is the main target area, however, all major freshwater sources are based on observed runoff provided on a daily basis.

4) “The model assimilates InSitu and satellite SST” Insitu SST data are provided by SoO as said in the conclusions. The authors should also state here thatFerryBox SST data are not assimilated into the AMM7 model (it is only clarified in the conclusions).

The AMM7 model description has been extended. A more detailed description about the assimilation of FerryBox data is inserted as follows:

“Data assimilated include in-situ data and level 2 satellite SST data provided by the Global High-Resolution Sea Surface Temperature project (GHRSST). In-situ data are obtained from a variety of sources and include measurements taken by ships, moored buoys, and drifters. Satellite observations are obtained from the Advanced Microwave Scanning Radiometer-Earth observing system (AMSRE), the Advanced Along-Track Scanning Radiometer (AATSR), and the Advanced Very High Resolution Radiometer (AVHRR) instruments on board the NOAA and MetOp satellites. Also assimilated are

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data from the geostationary Spinning Enhanced Visible and Infrared Imager (SEVIRI), All data are quality controlled and a bias correction scheme, based on comparisons to in-situ and AATSR data, is applied to the AMSRE, AVHRR, and SEVIRI observations. A full description of the satellite data types and the scheme used to bias correct them can be found in (Donlon et al., 2012). It is worth noting that although a number of Ships of opportunity (SoO) data were assimilated into the system, including reasonable data density in the southern North Sea, the ferrybox data being used in this study was not available for assimilation and so was not included."

5) "The model assimilates in situ and satellite SST using an Optimal Interpolation scheme" Some additional information should be given here about the data assimilation approach. For example are insitu & SST the only observational data sets assimilated by the model? How frequently are these data sets assimilated by the model?

To address also these questions, the text about the AMM7 description has been extended:

"The system assimilates observations using an Optimal Interpolation scheme (Martin et al., 2007), with updates described in Storkey et al 2010 and adaptations to allow it to address the particular requirements for shelf applications (O'Dea et al., 2012). (Siddorn et al., 2007). The assimilation system uses First Guess at Appropriate Time (FGAT) scheme to calculate model/observation differences (innovations) which are converted to model increments using an iterative method. A daily analysis window is used, with the model being rerun for the same day with an Incremental Analysis Update (IAU) scheme to update the model state using these increments. Only SST data are assimilated. Temperature and salinity profile assimilation along with sea surface height assimilation are technically more challenging in the shelf environment and will be implemented as future developments to the system."

6) "Additionally, the climatological river runoff of more than 300 rivers all around the North-West shelf.." This is a very significant difference between the two models and

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I think more information is required on this issue. The following extractions of the manuscript are from the model description of BSHcmod and AMM7, respectively.

AMM7: “The input of freshwater into the North Sea by River runoff is daily averaged data for the following rivers (i.e. the Rhine, Ems, Weser, Elbe, Eider) derived from river gauge observations. For remaining rivers in the North Sea, freshwater runoff climatologies are used (in total 80 rivers).” BSHcmod: “River flow is specified for 320 European rivers whereby the temperature of the river water is specified as the SST of the model box at the river point and the river flow is specified by the river flow climatology. The river input is assumed to be of zero salinity. The method for obtaining and adjusting these climatologies is described in Young and Holt, 2007.”

The main differences of both models exist for one thing in the daily averaged river runoff data for BSHcmod which AMM7 has not. And for another thing, the different numbers of included rivers is greater for AMM7. This is mainly due to different model coverage.

7) Section 2.6 “i. English coast Point at 53.553_ N 0.241_ E (p1). ii. Oyster Ground point at 54.04_ N 5_ E (p2). iii. German Bight Point 54.17_ N 7.45_ E (p3)” Coastal areas are expected to be "difficult" from the numerical modelling perspective, particularly if there are significant riverine inputs. Why not examine the performance of the model in an off shore station as well?

Data from offshore fixed stations are very sparse in the North Sea, especially for longer timescales. That is why FerryBox data can fill this gap in operational monitoring. Additional data sources could be research cruises in that time period. The performance of the models has been, however, examined for offshore regions with the FerryBox data that are regularly provided. At Oyster Ground point (p2) no riverine influence could be found for the analysed time period.

8) “ship measurements of up to 10 km around the respective positions” It seems to be a particularly large radius. Please explain.

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This information in the manuscript has not been correct, we are sorry for that. The radius around a respective position is up to 5 km. However, in coastal areas like the German Bight near the Elbe river mouth is can be still a drawback while for the most parts of the transect we think that this is appropriate.

9) Text repeated twice text at the end of 2.6

The doubling has been removed.

10) “temperature measurements, it is not feasible to compare them with water samples that will be analyzed later in the laboratory” However several probes on the FerryBox provide temperature measurements. Are there significant deviations between them? Also why not compare with Satellite data?

The FerryBox system has indeed several water temperature measurement units on board. The applied thermistor sensor from Falmouth Scientific Instruments (FSI) has a resolution of 0.0001 °C and an accuracy of ±0.01 °C. In an analysis of FSI data with water temperature observations from Aanderaa optode a mean difference between both data sets amounts to 0.005 °C. Comparison with satellite data has been performed before. Grayek et al. (2011) compared the same FerryBox route (Cuxhaven-Immingham, CuxImm) with OSTIA satellite data of 2007 and 2008 and found good agreement.

11) “It is believed that the bias is due to the relatively long way of the water pumped from outside into the FerryBox whereas MARNET temperature sensors are in close contact” This is a serious drawback. Temperature must be recorded right in front of the inlet.

The warming inside the FerryBox system is a drawback, indeed, but measurements at the inlet itself are for most FerryBox systems not possible. A study has been made by Hartman et al (personal communication) from National Oceanographic Centre Southampton (NOCS). They mounted an additional temperature sensor on the ship‘s

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hull to compare the received temperature values with those measured inside the FerryBox system. Our compromise consists of a comparison with fixed stations close to our FerryBox transect. We could compare our water temperature observations with continuous measurements at MARNET stations German Bight.

12) “FerryBox water temperature measurements have been bias corrected by a simple additive correction method” This seems a very crude approach and to my view inappropriate since the problem is not linear. In other words the error in the temperature reading will be different if the sea water temperature is 6, 10, 14 etc

We decided to take that into account. However, analyses show that this effect seems to be small and is overlaid by others, like e.g. the displacement error between the MARNET station and the FerryBox positions (5 km distance at maximum). So, the temperature dependence is found to be -0.0092 K-1 and the determination coefficient is 0.01 (see Fig.1). Altogether, this is not very convincing. This leads us to the opinion to continue with additive correction method.

13) Summary and conclusions: “Both model results predict poorly the variations of water temperatures and salinity near the coasts, and in particular in the cold Scottish coastal current. It could be argued, that this is due to weak vertical mixing, especially at the end of summer (only for BSHcmod v4). In the German Bight, scattering of modelled and observed data is higher than for central parts of the North Sea.” The advantage of using models is that you can explore hypothesis into great depth and thus I think that the authors should go a little deeper into this and investigate which is the prevailing mechanism or its relative contribution.

Mixing in shallow shelf seas has two main and quite different sources, i.e. bottom friction and wind/wave mixing. The overestimation and underestimation of mixing processes holds for different regions and different reasons. Vertical mixing underestimation is supposed to be a cause for weak (BSHcmod) model performance in terms of water temperatures near the English coast while overestimation of vertical mixing could

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be a reason for weak simulation of salinity of AMM7 for Oyster Ground (p2). To discuss in detail the mixing would be beyond the scope of this paper; however, we refer to the BSHcmod model description in Dick et al. (2001), where the mixing scheme has been described in detail.

14) A finding of this work is that both models have similar performance scores in terms of SST. As AMM7 model is assimilating in situ & satellite SST data and BSH does not, a more in depth discussion is needed on this issue.

The statistics for the root mean square error show clearly a difference between the AMM7 (which contains data assimilation of SST) and BSHcmod (which will contain data assimilation in the future). But that holds only for the water temperatures where the data assimilation brings a benefit while for salinity SSS is not available for assimilation. Additionally, different atmospheric forcing (output from NWP models from DWD in case of BSHcmod, and from UK Met Office in case of AMM7) are used. There has been included a section in the conclusion that deal about the AMM7 performance:

"The bias in the AMM7 seems higher than one would expect in an assimilating model and is slightly at odds with other results (e.g. O'Dea et al, 2012 which finds a bias of around 0.1 K). This may at least be partly explained by the inability of the model to represent shallow water processes and river flows, which are particularly important in this region, and may also be partly explained by observation errors (with the potential issues arising due to bias correcting the Ferrybox data to a single point on its transect)."

15) Summary and conclusions: "Previously, FerryBox transect data ... southern Aegean Sea". This whole paragraph should be placed in Section 3 (Results and Discussion).

We follow here the suggestions of both reviewers #1 and #2 to structure the end of the paper in a way that the majority of text from the conclusions is put into a new section called "Discussion" and the conclusions part is strongly trimmed to a concise section.

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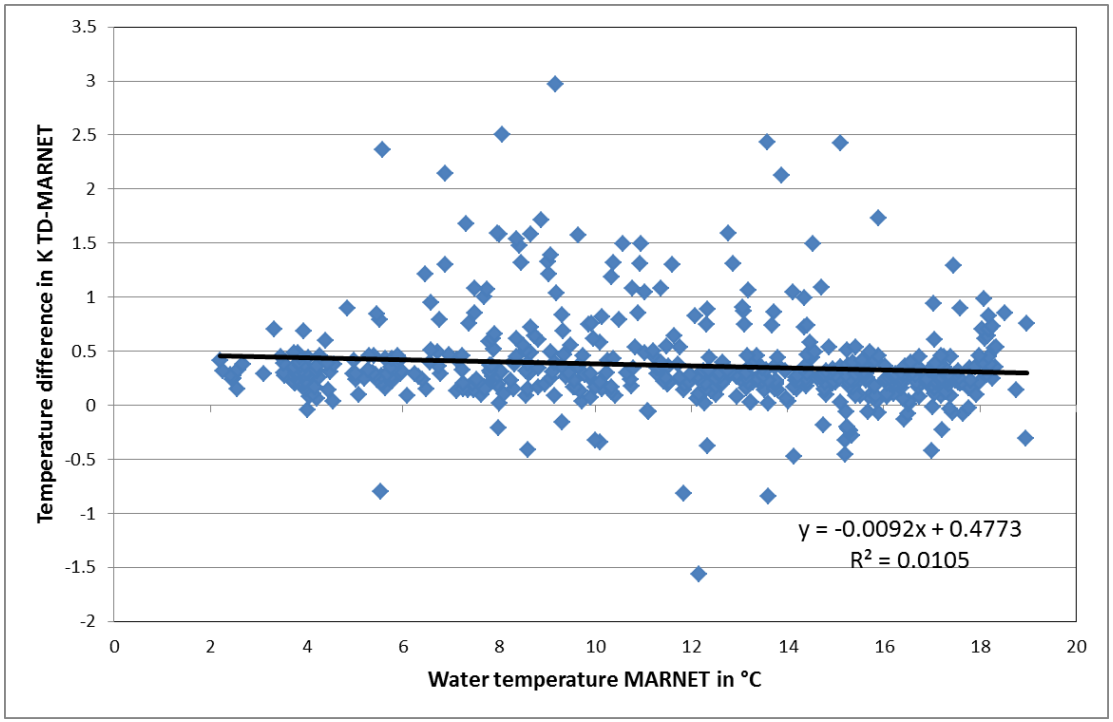

Fig. 1. Temperature difference FerryBox-Marnet

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