

## ***Interactive comment on “Assessment of the 3-D temperature and salinity observational networks in the Baltic Sea and North Sea” by W. Fu et al.***

### **Anonymous Referee #2**

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#### General comment

The growth of operational observation networks in northern Europe has been a largely organic process: sea level monitoring stations were located in harbours for shipping and in towns vulnerable to flooding, while hydrographic stations were frequently established over deep depressions in the sea floor. Once a time series was established, the value and scarcity of long data records results in the time series being maintained, even as the primary motivation for monitoring changes. Taking this into consideration, an article describing more objective methodologies for designing and evaluating monitoring networks, particularly in terms of their contribution to data assimilation, is of great value to the operational oceanographic community. As we enter a period where monitoring programmes are under review as a result of national economic pressures and

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intergovernmental agreements such as the Baltic Sea Action Plan and the EU Marine Strategy Framework Directive, the timing of this article is fortuitous.

The article authors are careful to restrict themselves to describing the output from their statistical analyses. Interpretation of the results in terms of the spatial and temporal spacing of observations would be useful, particularly in describing the occasionally counter-intuitive results. Some comparison to previous studies, such as the PEX work from the mid 1980s, would be helpful.

### Specific comments

Page 1628 line 4: '...correlations could reflect...' The use of 'could' highlights a problem with the paper: it would increase confidence in the results if more effort was made to relate the observed correlation patterns both to the physical processes in the model domain, and also to understand where the correlation patterns are perhaps a poor guide to the oceanography, such as where interaction with the bottom or coastlines in one dimension leads to a poor orientation of the resulting ellipsoid.

Page 1628 line 11: Is there a particular reason why the authors choose to use Levitus levels. I assume that they reflect neither the vertical resolution in the model or in the available data. Is it reasonable to use the same vertical resolution both in the Baltic and in the North Sea? OSPAR and HELCOM for example recommend sampling at different depth intervals.

Page 1628 line 14: The example of the difference in the longitudinal correlation coefficients at the surface and 250 metres does highlight the problem referred to in line 4 – in the Baltic, depths greater than 250 metres exist only in very restricted areas – the East Gotland Basin, Landsort Deep and Ulvö Deep. These are relatively small, deep holes with (we assume) very infrequent connection with adjacent deep holes. There is also little description of BSHcmod, but as a hydrostatic model, it may have trouble describing the vertical movements required to represent water exchange within these holes. This reviewer's opinion is that any assessment of the correlation length

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scale from these deep holes needs to be taken with a pinch of salt. In the far northern North Sea and Norwegian trench, there are large contiguous areas at > 250 metres, but the Norwegian trench is restricted in extent longitudinally, so it could be questioned whether data from this area should be included in an average assessment too. This limits the potential for a reliable assessment of the longitudinal correlation function to the northern North Sea.

An additional general point associated with the values given: while the correlation coefficients are a natural way to present the results of the analysis, it could be useful for the reader (particularly if the reader is a manager or commissioner of monitoring) to get some information on what the correlation coefficients mean in terms of station spacing for a certain (e.g. 1/e) information return (c.f. Figure 7)

Line 22: 'It is found that the surface level is more effectively covered with existing networks' More effective than what? What does this mean? Is the existing monitoring system adequate or excessive, or simply better than the deep water monitoring system?

Page 1629: line 4: This statement is highly debatable. I would say that the monitoring technology is a third quality factor, after the sampling scheme and the data quality assurance procedures. There are expensive, technologically advanced observation schemes producing garbage because of the absence of adequate quality assurance.

Page 1630: line 19: This point (that modelling & assimilation methods may have a large impact on the OSE/OSSES) does not appear to be discussed in detail later on. This is a significant omission, and should be taken up discussed more.

Page 1633: This information could be presented more clearly. I understand from this page that the proxy ocean data were produced by a model on a regular 3' x 5' grid. This model was initialized by running a coarse resolution model for 3 years to produce a dynamically consistent start field for the proper runs. The coarse model results were then interpolated onto the 3' x 5' grid, and the model was run with satellite data as-

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simulation. Model results were extracted at the standard Levitus depths. The model includes a nested grid for the Kattegat and Danish Straits, but the resolution of this nested model is not given. A 3' x 5' model grid would be unable to represent flows through the Sound, and could be expected to have difficulty in the Danish Straits too.

How were these data transformed to the Levitus levels? Was it some kind of spline interpolation, a simple data extraction of the nearest model level or was it a binning/averaging calculation? With the permanent halocline in the Baltic usually occurring at 60 – 80 metres in the deep basins, results from 75 metres may say something about halocline dynamics.

Page 1636: Why +/-120 km? Is this based on some dynamic judgement?

Page 1637 and Figure 4: Some of the correlation patterns shown in Figure 4a appear counter-intuitive and deserve more explanation. In particular, along the northern coast of the Gulf of Finland and along the southern Baltic coast, the orientation of the HCA suggests that cross-shore correlations are more significant than along coast ones. Given the residual surface flows both along the north German and Polish coasts, and along the southern Finnish coasts, I would have expected stronger along shore correlations. At 30 metres, the significantly poorer correlation is an interesting result. Could it be due to the development seasonal of stratification, which takes different lengths of time to develop in different areas of the Baltic, with increasing thermal stratification moving up from the south leading to east-west oriented HCAs?

A new paragraph could be started at line 23 'Two factors...'. These factors deserve a more explicit discussion. For example, as the correlation calculation will be stopped when a grid becomes land, does this result in the HCA being strongly skewed.

Page 1638 and figure 5: Figure 5a appears to show much more spatial structure in the satellite SST compared with that from the proxy ocean, as well as smaller HCAs. While the text highlights possible agreement between the two data sources in the Kattegat and inner Danish waters, these are areas where strong flows are tightly constrained by

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the topography, so it is perhaps unsurprising that the orientation of the HCAs are similar in these areas. It would be useful to have some explanation of the almost systematic difference in correlation seen in the satellite data, compared to that seen in the proxy ocean and shown in figure 5b – which is rather difficult to interpret.

Page 1639 and figure 6: The results from the English Channel, at the surface and 30 metres are reasonable because of the nature of the tidal forcing and the topographical constraints on the flow. Similarly, the weak stratification in the Bothnian Bay can account for similarities between the surface and 30 metres.

Page 1640 and Table 1: Do we have some sort of measure of the uncertainty in estimates of  $a, b, c$ ,  $\alpha, \beta$  and  $\gamma$ ?

Page 1644: The result from the central and eastern Baltic is interesting, suggesting that existing ship (2004 - 2006) based CTD monitoring, complemented by the ferry-boxes available then, do a good job of describing the hydrography even close to the halocline. The lack of temperature data in the Gulf of Bothnia is also apparent, and it is interesting that the method flags salinity data as adequate. The statement (line 20) that 'a good effective coverage rate does not mean that the information is enough' should be qualified to indicate for what purpose the data are insufficient.

Page 1645: What is 'nearby' in terms of defining  $m$ ? Is there any restriction due to topography, or could a time series in the Belt Sea be constructed using data from west of Jutland, for example?

Page 1646 and figures 11 & 12: Intriguing that variation in the Bothnian Bay is sufficiently small that measurements on about 13 occasions per year were sufficient to give such a high explained variance. I assume that the relatively high values in the southern Belt Sea are due to the presence of the BSH Marnet automatic stations. It is intriguing however that the Läsö E. Buoy in the northern Kattegat did not appear to result in improved explained variance for either temperature or salinity. Is this due to poor placing of the buoy? Figures 11 and 12 clearly show that the explained variance

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approach 'punishes' stations monitored by say monthly CTD casts. These stations appear to have lower explained variance than the unsampled water around them.

### 3. Technical corrections

General comments: The definite article 'the' is necessary only where it clarifies or improves readability. There are too many 'the's in this article, which worsen readability. 'Data' is a plural, as is 'metadata' – unless there is a style guide which says otherwise. Regarding figures 4, 5a and 6, it would be easier to relate the areas discussed in the text with what is presented in the diagrams if there could be some background shading to indicate the positions of the various land masses.

Page 1628 line 3: forecast line 8: 'quite' is redundant: either the proxy ocean model is good, or not. line 20: salinity line 22: networks

Page 1629 line 2: 'the realistic ocean states' – delete 'the' line 7: suitably (adverb) line 8: 'will not be cost effective' line 10: XBT & CTD are not platforms, they are instruments. Delete 'and' from 'and etc.' line 21: 'hydrodynamic', rather than 'hydrodynamical' line 24: a reference to BALTEX would be useful, e.g. Raschke, E.: BALTEX: Baltic Sea Experiment. pp. 5-6 in Meteorologische Zeitschrift, Vol. 9, No. 1-2, 2000, 2nd Study Conference on BALTEX 1998 line 25: 'as it is' should read 'as they are' – but the clause is redundant and could be removed.

Page 1630 line 6: 'a lot of' is unspecific, and could be removed. Are there references to ODON & PAPA? line 9: 'the observational networks' – 'the' is redundant, as we are talking generally line 26: 'systems' should be plural.

Page 1631 line 1: 'Khare & Anderson' check for consistency with references line 6: Smith & Meyers 1996 is missing from the reference list.

Page 1632: line 24: is used

Page 1633: line 6: 'first', not 'firstly' (although the word could be omitted all together) line 10: three year period line 11: transformed, rather than converted. 'level' should be

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plural

Page 1634: line 21: temperature

Page 1635: line 1: there is spatial... line 2: Plag, not Plage line 13: Do you mean 'The Baltic Sea is characterized by a large annual cycle...'?

Page 1636: line 10: delete 'Meanwhile' line 13: coastlines line 14: somehow?? Surely the correlations should reflect the local features... line 18: Do you really mean 'On the other hand'? You present one advantage of the binning, then another. line 28: 'from the centre point outwards in every spatial bin'

Page 1638: line 26: which are essential line 27: 'can be clearly seen' rather than 'can be easily found'

Page 1639: line 12: great, rather than much line 22: delete 'Apparently'

Page 1640: Check value for 'a' in formula with that in Figure 7

Page 1643: line 8: Levitus

Page 1644: line 3: poorly

Page 1645: line 24: surely

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