Biogeosciences
Open Access
Discussions

Interactive
Comment

Interactive comment on "Estimating temporal and spatial variation of ocean surface pCO_2 in the North Pacific using a Self Organizing Map neural network technique" *by* S. Nakaoka et al.

S. Nakaoka et al.

nakaoka.shinichiro@nies.go.jp

Comments:This paper presents maps of pCO2 in the North Pacific on a 0.25o x 0.25o grid from 2002 to 2008 using a self-organizing map neural network based on the he technique already applied in the North Atlantic by Telszewski et al. (2009). The technique to produce the maps is thoroughly described. The maps are compared to the LDEO climatology and the distribution of pCO2sea anomalies in winter 2003 and 2008 shows the contrasts between El Niño and La Niña years. It is not so easy to see how well the two methods compare. It would be better to show maps of differences for the comparison between the two methods.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Reply:

Dear Reviewer #2,

We thank the reviewer for thoughtful comments. We added the suggested map of differences to the updated manuscript. We also discuss the SOM estimates in 6 time series areas in relation to this map.

Comments: One interesting aspect of the NN is the possibility to produce high resolution maps. However, the fine scale features should be validated with observed data to make sure they really correspond to oceanic conditions.

Reply: In this study, we produced possible fine scale pCO2sea maps that can be validated at a resolution allowed by other studies. We have confirmed that our result could reproduce the fine scale features to some extent, such as meso-scale eddies by seeing the result with observed pCO2sea along the cruise tracks. We plan to make another article about it in near future. At this work, as far as we agree that one can not assume SOM's accuracy without thorough validation, we believe that comparison to 5 independent data sets in 6 basin regions representing the full range of biogeochemistry conditions characteristic for the basin, should be considered as a fair attempt to validate our results.

Comment:The paper tends to focus more on the technique and lacks some scientific interpretation of the maps.

Reply: It seems that a fair part of the revised manuscript focuses on science, however we agree that it's perhaps time to stop introducing neural networks and start using them for analysis. We take this advice onboard.

Comment:Including salinity as a parameter for the NN should be based on physical processes occurring in this region but it seems it was only introduced to improve the statistics: "The reason why inclusion of SSS improved the pCO2sea estimate is unclear

Reply: We agree that the motivation for including salinity was not clear in the original

submission and we revised the relevant parts of the manuscript to give a biogeochemical reasoning.

Comment:". Also, one objective of the paper is to estimate temporal variations but there is no discussion of any temporal trends.

Reply: We added a short explanation about the pCO2sea trend in section 2.7.2 as our response to Dr. Wanninkhof. It might have its limitations but we constructed it to the best of our knowledge.

Comment: p. 4577-4578 The North Pacific definition should be clarified and consistent throughout the manuscript. First, we read that it includes the subarctic and subtropical gyres. Then, "the North Pacific is characterized as a high nutrient, low chlorophyll region at high latitudes and as a low-nutrient, low chlorophyll region at low latitudes. I guess this refers to the subtropical North Pacific as, later on, the subarctic North Pacific is an upwelling area with high biological productivity. "The subarctic North Pacific is an upwelling area": specify the location of the upwelling.

Reply: We agree. We made an effort to improve the consistency in defining the study area and we specified the LNLC and the upwelling regions.

Comment: p. 4578: "there are quite large temporal and spatial variations of pCO2sea, the regional characteristics of which are generally understood from the LDEO climatology": this is a vague statement; it should be made more explicit by describing the characteristics.

Reply: We described it in more detail and rephrase the whole paragraph.

Comment: "Takamura et al. (2010) used MLR to reconstruct pCO2sea distributions as a function of SST and SSS from 1999 to 2006 (25oN to 40oN, 120oW to 150oW, 140oE to 170oE). They resolve regional differences in secular increasing trends, however their MLR technique could not be applied to spatial mapping": what is the meaning of the last sentence? Takamura et al. applied their MLD to map the region: 25oN to

40oN, 120oW to 150oW, 140oE to 170oE. Some information (measurements made, time range) about the station KNOT should be given as it is used in the work.

Reply: We found the description was incorrect and deleted the sentence. As for the description about the Station KNOT, we think the station is out of their study area.

Comment: Stephens et al., 1995 and Landrum et al., 1996 also mapped pCO2sea in the North Pacific. How do their works compare with the NN maps? Can we detect any pCO2sea trend?

Reply: Stephens et al. (1995) and Landrum et al. (1996) only showed ΔpCO2 distributions and not pCO2sea distribution. We added Stephens et al. (1995) as one of the historical achievements to map ΔpCO2.

Comment: p. 4579: The biological activity is important in spring and summer in the subarctic North Pacific but the chlorophyll and pCO2sea do not have the same time constants as low pCO2sea will persist after a bloom of phytoplankton due to the slow CO2 exchange with the atmosphere. How is this taken into account in the SOM?

Reply: The time lag between the bloom and pCO2's response is a very important and not very well measured/estimated element of the marine carbon cycle. At its current state or algorithm does not resolve this issue, no doubt adding to the estimates error. We thank you for bringing this up and we will focus our attention on this matter when commencing future estimates.

Comment: "The use of SSS in this study is consistent with the suggestion by Telszewski et al. (2009)": the mapping of Telszewski et al. is for the North Atlantic, why would the suggestion, made for the North Atlantic, be valid for the North Pacific?

Reply: As explained in the manuscript, the pCO2sea map produced by the 3-parameter SOM without SSS can't reconstruct high pCO2sea along the North Pacific Current (a region of high SSS gradient). We also added a more general reasoning for including SSS in the analysis as an accurate approximator for total alkalinity on which the

pCO2sea depends.

Comment: p. 4580: "We presented the change of the pCO2sea distribution in response to the ENSO events": what is the mechanism for the link between ENSO and pCO2 for the region 10oN-60oN? How far north will ENSO affect pCO2?

Reply: As described by Alexander et al. (2002), ENSO affects SST, SSS and MLD (probably CHL as well) over the North Pacific through the teleconnections. It is reasonable to expect that the pCO2sea is affected by these factors.

Comment: 2.2 Training data set (SST, MLD, CHL, SSS) Why are the in-situ data corresponding to the pCO2sea not used to train the SOM? There might be some differences between the satellite datasets and the in-situ values.

Reply: Fundamentally the SOM technique can not be used outside its training realm and therefore the same set of interconnected parameters has to be used during training and mapping. As we do not have in-situ measurements of training parameters in every 0.25 degree cell for every day between 2002 and 2008 we must use data from other sources. This is an often neglected but very important aspect of the SOM application. To clarify the difference between the used datasets and in-situ values, we show the differences of SST, CHL and SSS between the datasets and the in-situ values in the last paragraph of section 2.2.

Comment: "The parameters are gridded onto a frequency of one per day": does it mean that daily maps are obtained from 2002 to 2008? What is the temporal resolution of the SOM?

Reply: Original output has daily resolution. This information is added to the revised manuscript.

Comment: 2.3. pCO2sea datasets for labelling p. 4583: It would be clearer to separate the presentation of the pCO2 dataset from the method of labelling. ". . .accompanied by supplementary values of observed atmospheric and oceanic parameters": are they

Interactive
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

SST, MLD, CHL, SSS? The parameters should be listed or the sentence should be removed as it does not provide any information.

Reply: We agree. We removed the sentence as you suggested.

Comment: 2.6 Reconstructing pCO2sea distributions in winter at high latitudes Is there any difference in the subtropical region between the SOM with and without CHL? Is the role of CHL limited to the subarctic region in spring and summer?

Reply: We found that the difference between 3-parameters SOM and 4-parameters SOM in the region was 1.6 ± 15.9 μatm. In this study, we don't indicate that the role of CHL is limited to the subarctic region in spring–summer period. The CHL dataset is needed to distinguish the region and the time where/when high biological activity in spring-summer period as well as in autumn-winter period.

Comment: 2.7.2 Improvement in the NN scheme p. 4587 "The reason why inclusion of SSS improved the pCO2sea estimate is unclear": what is the salinity range in the North Pacific? Where are the most important salinity variations?

Reply: We rephrased the paragraph to provide a more relevant explanation for inclusion of the SSS. As you can see in Table 2, the salinity range is from 30.15 to 35.69. We have not done any sensitivity studies allowing us to specify regions and/or periods where/when the variability in salinity influences the pCO2sea the most. However we show in the manuscript that the estimate of temporal pCO2sea variation along the North Pacific current (where spatial salinity gradient is rather large) was significantly improved.

Comment: p. 4588 Adding or subtracting a trend is not an improvement in the NN scheme, it is another term of equation 1.

Reply: We changed the section title to "Changes in the estimate scheme".

Comment: 3.1 Mapping of seven-year averaged monthly pCO2sea distributions The comparison between the climatology and the SOM would be easier to see by plotting

the map of the differences.

Reply: We agree. The section was updated accordingly and the map of differences was added.

Comment: "the resolution of the SOM is much higher and the results more precisely resolve some oceanic features": this should be demonstrated and supported by some data.

Reply: We rephrased the sentence to state that the SOM's higher resolution allows for a more detailed analysis, which was our mis-stated intention originally.

Comment: 3.2. Reproducibility of temporal pCO2sea variations. Why there are so few observed data at the time-series station KNOT?

Reply: Wakita et al. (2010) calculated pCO2 from DIC and TA using CO2SYS (Pierrot et al., 2006). Since they sometime didn't measure TA, they couldn't calculate pCO2sea. That was the reason. But the pCO2sea data in July 2003 was added in the Figure 9(a) since they found the TA and DIC data at the period.

Comment: 3.3 Difference of pCO2sea distributions during ENSO events "The patterns of SST anomalies in Fig. 9 are typical of El Nino and La Nina winters": what is meant by "typical"?

Reply: We added the reference (Alexander et al., 2002) in the sentence. They showed the correlation coefficient distribution between Southern Oscillation Index (SOI) and SST, and we found that the pattern is quite similar with the SST patterns in winters of 2003 and 2008. For example, positive SST anomaly in 2003 and negative anomaly in 2008 are apparent in the eastern subarctic region, the eastern subtropics and the western subtropics where the correlation coefficients indicate positive values. On the other hand, negative SST anomaly in 2003 and positive anomaly in 2008 are apparent in the mid-latitudes of the central North Pacific where the correlation coefficients show negative values. That was the reason why we used the term "typical".

Interactive
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Comment: "The pCO2sea anomaly related to ENSO events is easily discernible": there should be a description of the patterns and some explanation of the mechanisms explaining the patterns.

Reply: Thank you for your suggestion. Since we found the quantitative discussion about the variation in the eastern subarctic region was missing in the original manuscript, we added the explanation about it in the revised version.

Comment: What is the extent of the influence of El Nino?

Reply: According to Trenberth and Caron (2000) and Alexander et al. (2002), ENSO affects global atmospheric and ocean circulation. As for carbon cycle, since the upwelling from the subsurface off the coast of Peru is prevented during the El Nino period, oceanic CO2 emission to the atmosphere in the region is weaken during the period. Therefore, atmospheric CO2 variation, which is important for air-sea CO2 exchange variation, is also affected by ENSO (Keeling et al., 1995). Consequently, ENSO should affect global carbon cycle through these effects.

Interactive comment on Biogeosciences Discuss., 10, 4575, 2013.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper