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Discussions

Interactive comment on "Testing the validity of regional detail in global analyses of Sea surface temperature – the case of Chinese coastal waters" *by* Yan Li et al.

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Dear Referee: Thank you very much for the helpful comments on our manuscript "Testing the validity of regional detail in global analyses of Sea surface temperature - the case of Chinese coastal waters" (No: os-2018-137). For the revision, we fully considered all suggestions and give the item-by-item reply. Also we try our best to improve the English writing in our manuscript. And revised portion are highlighted in yellow in the manuscript. Once again, thanks very much for your comments and suggestions.

Best regards

Yan Li, Han von Storch, and coauthors

Major Comments:

1. What are the differences between the analyses products, including input data, expected feature resolution capability etc? What is the depth of each analysis compared to depth of the in situ observations?

Reply:

(1) There are some differences of data sources, bias adjustment and reconstruction method, etc. in the SST analyses products. Some analyses only use in situ observations, such as ERSSTv4 and COBE SST. Others use both in situ and satellite observations, such as OISST and HadISST. Details are shown as follows: 1) HadISST dataset. HadISST dataset is composed of the SST data from Marine Data Bank in the United Kingdom (mainly ship tracks) and the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). ICOADS is mainly from ships, buoys, automated platform types, moored buoys, drifting buoys, and near-surface measurements from hydrographic profiling studies. From 1982 onward, HadISST also consists of adjusted satellite-derived SST data from the AVHRR. Though data gaps in HadISST1 have been interpolated, the performance of HadISST1 in describing the SST variability in the China Seas, particularly in the inshore areas, is still questionable, because of the data sparseness and limitations of the interpolation techniques (Rayner et al. 2003; Zhang et al. 2005; Liu et al. 2015; Li et al., 2017). 2) COBE SST dataset. COBE SST also composes the ICOADS, U.K. Marine Data Bank, and U.S. Marine Meteorological Journals (Hirahara et al. 2012). To construct unobserved variability in data-sparse regions, satellite observations are incorporated into the present objective analysis scheme. However, the satellite observations are used only for constructing empirical orthogonal functions (EOF) that represent interannual-to-decadal SST variations; they are not used in the final COBE SST to preserve the homogeneity of the SST analysis for more than 100yrs. Hirahara et al. (2014) pointed out that this was because the use of satellite data for

the whole analysis makes the grid wise variability of SST analysis larger by 10%-20%, compared with that without the data. 3) ERSST v4 dataset. The historical ocean observations used for ERSST v4 analysis arise from the in situ ICOADS from 1854 to 2007, and from the Global Telecommunication System (GTS) receipts from NCEP after 2007. The ICOADS and GTS observations exhibit both random errors and systematic biases (Kennedy et al., 2011). Huang et al. (2016) pointed out that filters and EOF decompositions were used to reduce the effect of the random errors, and bias adjustments are applied to remove the systematic biases in the ERSST v4 analysis. 4) OISST dataset. This data set is the Optimum Interpolation (OI) SST Analysis Product, which uses Advanced Very High Resolution Radiometer infrared satellite SST data from the Pathfinder satellite combined with buoy data, ship data, and sea ice data SST data sets. In order to apply the correction for bias in OISST, the satellite data have been classified into daytime nighttime bins and corrected separately using the patterns of 15 day averaged in situ SSTs by NOAA's OI algorithm. The bias-corrected daytime and nighttime satellite SST, ship, and buoy SSTs are merged based on noise-to-signal ratio maps for each data type, which have averaged weights of 15.1, 15.1, 1.0, and 15.1, respectively. Therefore it can be interpreted as the bulk SST at about 0.5 m depth (Reynolds et al., 2007).

(2) The depths

The measurement depths of SST sensors vary because there is an abundance of data sources in the ICOADS. For example, Bulk carriers, vehicle carriers, gas tankers, and livestock carriers typically measure SST at a 7-m depth or deeper (Kent and & Taylor, 2006). Research vessels, fishing vessels, trawlers, support vessels, the Coast Guard, and sailing vessels all typically measure SST at a 4-m depth or shallower (Kent et al. 2007). However, these SST observations above are much sparser along the shoreline of China (Li et al., 2017). SST observations from hydrological stations of China are the water temperature at the depth of 0.5$\sim$1 meter below sea level (Li et al., 2018). Thus, it is very difficult to address all of the issues related to variations in observing

observation systems, changes in measurements, and depths that can lead to potential errors (Kent and & Woodruff, 2006, Woodruff et al. 2011).

2. What data do each of the analyses include in this location from the time period prior to the satellite era? Do some of the analyses include data from the same sources? Are the in situ observations used for the assessment definitely independent of the analyses?

Reply: The 26 coastal hydrological stations at the coastline of China have been taking routine observations since 1960, with few missing data. All of these in-situ SST data from 1960 to 2015 are provided by the National Marine Data and Information Service (NMDIS) of China and have been quality controlled and homogenized recently by Li, et al., (2018). These SSTs data from coastal hydrological stations have never been merged into HadISST, COBE SST or other gridded SST analyses. Therefore, the homogenized long-term SST observations along the Chinese coast can be used for evaluation on these analyses.

3. Are there uncertainties included with any of the SST analysis products? What do they look like around the coast?

Reply: As we mentioned above, the main data source of these SST analyses is ICOADS SST. However, the spatial distribution of the data density and coverage of this data set vary in the ICOADS because of the uneven distribution of ship routes and the existence of several data-sparse regions (Woodruff et al. 2011). To understand the data density and coverage of the observations over the China Seas and their adjacent waters, the numbers of SST observations from the ICOADS R2.5 (which are in the International Maritime Meteorological Archive (IMMA) format covering) are counted up for each 1° grid over this region in our previous work (see Figure 1 in Li et al., 2017). The numbers of SST observations from ICOADS R2.5 are not well distributed over the China Seas, especially in the Bohai Sea and the Yellow Sea. The data density is much sparse in these areas. Thus, the limited data coverage of the inshore areas can lead to high uncertainties in the estimates of SST variability in these regions.

Reference: Yan Li, Lin Mu, Yulong Liu, et al. 2017. Analysis of variability and long-term trends of sea surface temperature over the China Seas derived from a newly merged regional data set. Climate Research, 73: 217-231.

4. Coastal satellite observations of SST are not as reliable as for the open ocean – this should be covered in the discussion.

Reply: Yes, we agree with it and added a comment in the revision; however this is hardly of significance for our study.

5. How is the LH homogenisation applied? Need more detail on how the correction is obtained.

Reply: Sea surface temperature (SST) measurements from 26 coastal hydrological stations of China had been homogenized and analyzed in our previous work (Li et al., 2018). For avoiding repetition, we simply summarize the homogeneity process in the revised paper, that is, "Monthly mean SST series were then derived and subjected to a statistical homogeneity test, called the Penalized Maximum T (PMT) test (more details can be found in Li et al., 2018). Homogenized monthly mean SST series were obtained by adjusting all significant change points which were supported by historic metadata information".

6. Using annual means results in removal of a lot of temporal variability. There could be variation of the results in different seasons. Have you looked into this at all?

Reply: In our work, we consider annual mean values. Some analyses with seasonal mean values are also calculated, but these are not covered by our present account and merely summarized.

7. If you want to include a comparison to the NOAA OI-SST analysis, this needs a separate results section, rather than presenting it in the conclusions. Similarly, the OI-SST analysis is introduced in the abstract alongside the other analyses, but the

same method was not applied to this analysis (similarly in section 2 etc). This needs rewording.

Reply: Thanks for your suggestion. The fourth SST product, OISST uses Advanced Very High Resolution Radiometer infrared satellite SST data from the Pathfinder satellite combined with buoy data, ship data, and sea ice data, covering from 1982 to present. Due to its high spatial resolution of 0.25°x0.25°, it is used in the concluding section for clarifying some additional aspects, such as the global gridded SST datasets point to higher temperatures which may be caused by their coarse resolution. Following the comment, we modified the abstract, introduction and discussion in the revised paper.

Specific comments:

1. Table 1: Replace "commonly used" with "used in this study" as there are other datasets available which are also well-used. Include the download date of the datasets too.

Reply:" Table 1. Global gridded SST datasets that are commonly used for climate studies" is modified as "Table 1. Global gridded SST datasets that are used in this study".

2. Figure 1: Are you able to reproduce this plot if it's already been published? Otherwise need to replot in a different form.

Reply: Fig.1 has been replotted in a different form. Actually, the identified breakpoints information in Li et al (2018) was shown only in Table 2.

3. Line 124-125: Need evidence to back up this statement. Also, what are your criteria for "consistent"? Suggest moving some of the information in the Appendix to here.

Reply: The information about "The consistency of homogenized SST data set with homogenized SAT data set" in the Appendix A is moved into Section 3.

4. Line 132: The LH dataset is not an analysis. Line 134: How are the matchups performed? Is there an interpolation to the observation location?

Reply: “Local homogenized SST-analysis” is modified as “Local homogenized SST” in the revised paper.

5. Line 157: 9 cases is more than "a few", suggest reword.

Reply: “the standard deviations are in most cases (17) larger for LH, and only in few cases (9) smaller.” is modified as “65.4% of the standard deviations (17) are larger for LH, and 34.6% cases (9) smaller.”

6. Figure 2c: Looks like a strong correlation but offset by a bias - elaborate on this.

Reply: The local data indicate markedly lower temperatures, which may mainly be because of coastal upwelling. In the China Seas, most of the coastal upwelling currents occur at the ECS and the northern SCS, other small upwelling currents at the tops of the Liaodong Peninsula and Shandong Peninsula (Figure 1). The consensus of previous studies is that coastal upwelling currents results in cooling SST at these coastal areas (Xie S P, 2003; Guan et al., 2009; Su et al., 2012). Owing to the coastal upwelling, SST along the coast of the eastern Hainan was 1$\sim$2°C lower than ambient offshore water, and SST in the Yangzte River Estuary was 2-3°C lower than ambient offshore water; 10m sea temperature along the coast between eastern Guangdong and southern Fujian provinces was lower than surrounding sea water about 5°C (Zhao et al., 2001; Xu et al., 2014; Xie et al., 2016). Station 15 (Pingtan) to Station 19 (Yunwo) along the East China Sea coast are at the upwelling areas. In our study, we find that the in situ shoreline SSTs from Station 15 to Station 19 are colder than global gridded SST data, with the value of below -2°C.

7. Line 201: The effect of satellites on the SST analyses is important - this information should be included in the introduction (as mentioned above in general comments as part of the differences we might expect between analyses and in situ dataset).

Reply: Reliable SST retrievals from satellites start in in the early 1980s while in situ observations are available much earlier but have changed substantively through time in both their methods of measurement and where the measurements are taken. Since 1980s the Advanced Very High Resolution Radiometer infrared satellite SST data from the Pathfinder satellite are available. These data improve SST sampling, especially in the Southern Ocean and coastal areas (Smith et al., 2008; Lima and Wethey 2012). These data are incorporated into HadISST and OISST combined with buoy data, ship data, and sea ice data SST data sets.

8. Lines 202 - 204: Check these values.

Reply: the values are correct. But for avoid misunderstanding, “Fig. 3d; this corresponds to a mean difference of 0.04K at the southern stations during that time, and a mean difference 0.04K at the northern stations (Fig. 3b)” is modified as “Fig. 3d; this corresponds to a mean difference of 0.04K at the southern stations from Stations 11-26 during that time, and a mean difference 0.04K at the northern stations from Stations 1-10 (Fig. 3b)”

9. Line 208: Elaborate on what is meant by "degenerate" and the implications of this on the results.

Reply: “degenerate” is a technical term, which is well defined and explained in the relevant literature. It is related to the problem with multiple eigenvalues. For details refer to the textbook of von Storch and Zwiers (1999) or other literature on the “significance” of EOFs.

10. Figure 6: What are the anomalies to?

Reply: “Figure 6. Spatial variability of the EOF1 (a); EOF2 (b) mode of the differences between LH anomalies and LA-ERSST anomalies (LH anomalies minus LA-ERSST anomalies). And the time coefficient series of PC1(c) and PC2 (d) from 1960 to 2015.” is modified as “Figure 6. EOF analysis of the differences LH-LA-ERSST: Top: EOF spatial patterns (EOFs), bottom: principal components (time coefficients)."

11. Line 323: Do the SST analyses already attempt to include quality-controlled, homogenized data? (This information should be included in the introduction, see general comments above)

Reply: The quality-controlled homogenized SST data have not been included in the SST gridded analyses. We add this information into the revised introduction.

12. Line 326: There are already several projects dedicated to quality control and homogenization of in situ data - suggest including some information from a literature review here. However, it's also worth including the comment that it is useful to keep some high-quality data separate from that available for analyses, for validation activities such as this one.

Reply: Following with the comment, we have added conclusions of previous studies in the revision: There are several projects or researches dedicated quality control and homogenization of in situ data (Kuglitsch et al., 2012; Hausfather et al., 2016; Minola et al., 2016). It is useful to keep some high-quality data separate from that available for analyses, for validation activities such as our work and others' work (Hausfather et al., 2017).

References:

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Minola, L., Azorin-Molina, C., & Chen, D. L. (2016). Homogenization and assessment

of observed near-surface wind speed trends across Sweden, 1956-2013. Journal of Climate, 29(20), 7397-7415. https://doi.org/10.1175/JCL1-D-15-0636.1.

Kuglitsch, F.G., Auchmann, R., Bleisch, R., Bronnimann, S., Martius, O., & Stewart, M. (2012). Break detection of annual Swiss temperature series. Journal of Geophysical Research, 117(D13105), 1-12. https://doi.org/10.1029/2012JD017729.

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