

The second Review of "Data assimilation of SMOS observations into the Mercator Ocean operational system: focus on the Nino 2015 event" by B. Benoit et al. (os-2018-113).

Although the manuscript is much improved by the region, I think that the current draft needs some confirmations of the correctness and modifications before accepting for the publication. So, I suggest to return the manuscript to authors in order to make another revision.

### **General comments**

1. I still doubt of the correctness of the cost function, that is, the equation 2. Authors should consider the specific comment 30 and check the correctness again. If the current equation is correct, a suitable explanation is required.
2. The explanation of the Desroix's method can also be improved. See the specific comment 37.
3. The explanation of Figure 16 is not updated, and not consistent with the current figure. See the specific comment 65.
4. I feel the English can be still improved. I suggest many modifications in the specific comments.

### **Specific Comments**

1. P1, L18: "data sets" can be replaced by "datasets".
2. P2, L2 "from space make possible": Please modify to "from space makes possible".
3. P2, L13 "Barrier Layer": please modify to "barrier layer". It is not necessary to use capital letters. The same mistake can be found in other places.
4. P2, L20, "Moreover": I suggest to replace it by "However".
5. P2, L22: I suggest to remove "a pattern".
6. P2, L23: ", see for example" can be removed.
7. P2, L26: "Figure 11" should be "Figure 1".
8. P3, L1: "SST, SLA and in situ observations are assimilated as currently done in the operational systems, see Martin et al., (2018).": This sentence should be removed since it is redundant with the sentences in L9-12.
9. P3, L7, "it is as strong as the 1997 one, see section 2.6 in (Von Schuckmann et al., 2018).": I suggest to modify this part to "it is as strong as the one in 1997 (Von Schuckmann et al., 2018)."
10. P3, L9, "(e.g. NINO3.4 for the Nino3.4 region in the central Pacific, see Barnston et

- al., (1997)).”: This can be modified to “(e.g., NINO3.4 index is defined as the averaged SST temperature over the area in 5S-5N, 120-170W; see Barnston et al., 1997).”
11. 3. P3, L10, “Modoki El Nino”: Please modify to “El Nino Modoki”.
  12. P3, L12: I suggest to add “and OSEs” after “the REF simulations”.
  13. P3, L15: “, see Fujii et al., (2015)” can be changed to “(Fujii et al., 2015)”.
  14. P3, L15: “I suggest to replace “Even if” by “Although”.
  15. P3, L28, “The signal to noise ratio is still not high today, thus retrieval algorithms”: I suggest to replace the part by “Since the signal to noise ratio is still not high today, retrieval algorithms”.
  16. P4, L3: I think it is better to replace “discussed in section 3” to “presented in section 3”.
  17. P4, L16, “Due to large known biases in precipitation”: I suggest to modify the part to “Because there are large known biases in precipitation”.
  18. P4, L21, “instead of Dai and Trenberth (2002).”: This part should be omitted because Dai and Trenberth (2002) is not used nor explained.
  19. P4, L26, “be found in (Lellouche et al., 2018).”: Please modify to “be found in Lellouche et al. (2018).”.
  20. P5, L6: I think in-situ observations are used in OSTIA. So it will be double-count if the system also assimilates in-situ SST data directly.
  21. P5, L17: I do not understand what “18-day products” means.
  22. P5, L22: It is better to explain the length of the assimilation cycle and the analysis date before this sentence.
  23. P6, L8, “an incremental analysis update, see (Bloom et al., 1996; Benkiran and Greiner 2008).”: I suggest to modify the part to “an incremental analysis update (Bloom et al., 1996; Benkiran and Greiner 2008).”
  24. P6, L22: I think there are also biases between model and data for sea level anomalies.
  25. P6, equation (1): Please change “d” to the bold letter.
  26. P6, L2: Please put a period after “for salinity field”.
  27. P6, L3: Please insert “Here, “ before “d is the ...”, and remove “(<>)” and add after the sentence “Salinity<sub>in-situ</sub> and Salinity<sub>model</sub> denote salinity values of in-situ data and in the model, and  $\langle \cdot \rangle$  indicates the mean.”
  28. P6, L10, “bias correction of T, S and dynamic height are computed”: The bias correction of the dynamic height is used in the analysis? If so, I think it is inconsistent with that at P6, L22.
  29. 3. P7, L10, “in the 3D-Var cost function (Eq.2).”: I suggest to modify this part to “in the following 3D-Var cost function:” and to move the flowing sentence before “In Figure 3” at

L18.

30. P7, Equation (2): I still think there is something wrong in the equation (2). First,  $\mathbf{H}$  in the fourth term of the righthand side must be different from the one in the second term. So, I recommend to substitute  $\mathbf{H}$  in the fourth term with  $\mathbf{H}_\xi$ . In addition, I think  $\mathbf{d}_\xi$  must be defined as follows:

$$\mathbf{d}_\xi = \langle SSS_{SMOS} \rangle - (\langle SSS_{model} \rangle + \mathbf{H}_{\xi 2} \mathbf{x}) .$$

In this form, the bias is corrected for the model values using  $\mathbf{x}$ , while the raw SMOS values are used for the innovation because the bias correction of SMOS,  $\xi$ , will be applied to the raw values of SMOS. Here,  $\mathbf{H}_{\xi 2}$  is the linear operator which interpolates  $\mathbf{x}$  to the positions of SMOS observations. If this is correct, the equation (3) is satisfied. Also, authors imply that  $\mathbf{x}$  and  $\xi$  cannot be determined independently in the explanation of Fig. 3. It means the  $\mathbf{x}$  is included in the definition of  $\mathbf{d}_\xi$ , because otherwise  $\mathbf{x}$  can be determined independently. I would like to ask authors to check the equation again, and if I am not correct, they should carefully explain the equation so that I can understand it. You must also denote that what  $\mathbf{B}_\xi$ ,  $\mathbf{R}_\xi$ ,  $SSS_{SMOS}$ , and  $SSS_{model}$  represent in the text. (Definitions of all mathematical symbols must be defined in the text.)

31. P7, L16: “(<>)” is not necessary here and should be removed.
32. P7, L18, “In Figure 3, examples of salinity bias near the surface ( $\mathbf{x}$ ) without (a) (Eq.1) and with (c) (Eq. 2) the SSS bias term ( $\xi$ ) are shown.”: I suggest to modify the sentence to “Figure 3a and c show examples of the model salinity bias,  $\mathbf{x}$ , near the surface without and with the estimation of the bias of SMOS data,  $\xi$ .”
33. P7, L19, “where the SSS bias (Figure 3b) influences the bias correction of salinity (Figure 3c) with smaller scales.”: I suggest to modify the part to “where the estimated bias of SMOS data (Figure 3b) influences the estimated model salinity bias (Figure 3c) with smaller scales.”
34. P7, L20, “There may also be opposite sign but amplitudes are the same.”: I do not know what authors intend to explain by this sentence.
35. P8, L3, “in the bias correction, see also (Lellouche et al., 2018).”: I suggest to modify the part to “in the bias correction (see also Lellouche et al., 2018).”
36. P8, L5: “, see Eq. 3” should be removed.
37. The explanation of the method based on Desroixers et al. (2005) is improved, but still not clear. In my understanding, the system assumes that  $\mathbf{R}_\xi$  is diagonal and calculate the optimal factor of each diagonal element separately. If so, they should explain about that at first. Then, they forgot to define  $\mathbf{d}_\xi^{a_i}$  and  $\mathbf{R}_\xi^i$  ( $i = 1, 2, \dots, n$ ) and probably the equation (4) should be

$$r_{\xi}^i = \frac{E[d_{\xi} d_{\xi}^{a_i}]}{R_{\xi}^{i-1}} .$$

Here,  $d_{\xi}$ ,  $d_{\xi}^{a_i}$ , and  $R_{\xi}^{a_i}$  are an element of  $\mathbf{d}_{\xi}$ ,  $\mathbf{d}_{\xi}^{a_i}$ , and  $\mathbf{R}_{\xi}^{a_i}$ . Please note that the number on the right shoulder of R is  $i-1$ . I recommend authors to improve the description with considering the comments above.

38. P8, L12: This sentence says that the prior error have already increased over regions with sparse in-situ data and near the coast. Is it correct?
39. P8, Figure 4: It is more appropriate to show the product  $r_{\xi}^1 r_{\xi}^2 r_{\xi}^3 r_{\xi}^4 r_{\xi}^5$  instead of  $r_{\xi}^5$ .
40. P8, L21: I suggest to remove “, see Eq.6.”, and to move the following sentence after the equation with removing the last part “, see an exemple in Figure 5”.
41. P9, L18: It is better to mention that the forecasted field is mostly independent of the reference data because those data have not been assimilated yet.
42. P9, L19 “Figure 6 shows the time-series of Root-Mean-Square Errors (RMSEs) between the model near-surface salinity (6 m depth) compared to in situ observations (dotted lines) and between the model SSS (0.5 m depth) compared to the bias-corrected SMOS SSS (solid lines) for both simulations (REF in black, SMOSexp in red).”: I suggest to modify the sentence to “Figure 6 shows the time-series of Root-Mean-Square Errors (RMSEs) of the model near-surface salinity at 6 m depth with respect to in situ observations (dotted lines) and of the model SSS (0.5 m depth) with respect to the bias-corrected SMOS SSS (solid lines) for both simulations (REF in black, SMOSexp in red).”
43. P10, L5 “is very weak”: I suggest to replace “weak” to “small”.
44. P10, L11: “Figure 11” should be “Figure 1”.
45. P10, l23: Please modify “3.1.1” to “3.1.2”.
46. P20, L28: “in agreement with (Kidd et al., 2013)” can be modified to “in agreement with Kidd et al. (2013)”,
47. P20, L32, “changes to the SMOS SSS data assimilation”: I suggest to replace the part to “changes brought by SMOS SSS data assimilation”
48. P20, L33, “The largest magnitudes (saltier)”: I suggest to modify it to “The largest high-salinity anomaly”
49. P11, L8: “Figure 11” should be “Figure 1”.
50. P11, L9 “Both the REF and SMOSexp simulations represent the decrease in time of the salinity peaking in fall 2015 at this latitude, for the longitude between 160°E 10 and 120°W.”: I suggest to modify the sentence to “Both the REF and SMOSexp simulations represent the decrease of the salinity in fall 2015 between 160°E and 120°W.”
51. P11, L11, “salinity anomaly is lower”: I think “salinity anomaly is smaller” is better.
52. P11, L15, “it is not the case when we are looking at model fields time changes”: I suggest

- to modify the part to “it is not the case when we look at the time-evolution of model fields”
53. P11, L16, “Indeed, an impact can be seen on the other surface variables.”: This sentence can be omitted, and the next sentence can be started from “Indeed,”.
  54. P11, L20, “but it this effect”: Please omit “it”.
  55. P11, L21, “the eastern warm water pool migration”: I suggest to modify the part to “the eastward warm water pool migration”.
  56. P11, L23, “Tropical Instability Waves (TIWs), see Figure 14.”: I suggest to change this part to “Tropical Instability Which will be shown later.”
  57. P11, L31, “, see Qu et al., (2014)”: I suggest to change the part to “(e.g., Wu et al., 2014)”.
  58. P12,L4, “33-day TIWs are”: I suggest to change this to “TIWs, which has a 33-day period, are”.
  59. P12, Figure 14: It looks to me that TIWs do not propagate in parallel to the line representing the speed of 0.25 m/s.
  60. .P12: It is very interesting that assimilating SMOS data enhances the activity of TIWs. It would be nice if some discussion why the activity of TIWs are enhanced by the SMOS data assimilation.
  61. P12, L29, “between the TAO observations and SMAP/SMOS observations and Argo analysis”: I suggest to change the part to “among the TAO, SMAP/SMOS, and Argo analysis”.
  62. P12, l29, “There is an improvement in the cold tongue during the end of summer, in fall 2015 and during the last 2 months of the SMOS simulation (15a) in the region where the data assimilation of SMOS reduces the freshening.”: I suggest to modify the sentence to “There is an improvement in the cold tongue during the end of summer, in fall 2015 and during the last 2 months of the SMOS simulation (Figure 15a). The data assimilation of SMOS reduces the freshening in this region.”
  63. P13, L2, “Obviously, the assimilated 4-days SMOS data are smoother but are able to capture the large scale variability.”: I am not sure what “4-days” means. I also suggest to change the sentence to “Obviously, the time-series of the assimilated 4-days SMOS data is smoother but able to capture the large scale variability.”
  64. P13, L6, “This also shows that the observation error should not be increased locally depending on the precipitation.”: I suggest to modify the sentence to “This also shows that the observation error is not necessarily increased locally depending on the precipitation.” I also point out it is difficult to judge whether the observation error is increased by local precipitation or not. At least, I think some of the increase of the observation error is caused by local precipitation.
  65. P13, Figure 16: The description of the figure is not consistent with the current figure.

Probably the figure is updated but the description is not updated.

66. P13, L 15, “This reflects the overestimation of E-P that the data assimilation tends to correct and the SMOSexp experiment is saltier in regions where precipitation is higher.”: I suggest to modify the sentence to “This reflects the tendency that the SMOS data assimilation reduce the low salinity biases by mitigating the overestimation of E-P in the regions of large precipitation.”
67. P13, L19: please correct “3.2.1” to “3.2.2”.
68. P14, L10 “for other purpose”: Authors should give readers some examples about this.
69. P14, L30 “This also reflects that the overestimation of E-P is corrected by data assimilation through salting in regions where precipitations are higher.”: I suggest to modify the sentence to “This also reflects that the overestimation of E-P is mitigated by the data assimilation through salting in the regions of large precipitation.”
70. P15, L3, “But, an impact on SSH have been seen through TIWs which have been reduced (amplitude and propagation speed) and then strengthened in the eastern part of the basin during the last half of the 2015 year.”: I suggest to change the sentence to “But, an impact on TIW have been seen through SSH fields. Amplitudes and propagation speed of TIWs are reduced while their activity is enhanced in the eastern part of the basin during the last half of 2015.”
71. P15, L4 “through a positive feedback.”: There is no explanation on the positive feedback.
72. The caption of Figure 2: The “and” at the beginning of the second line can be removed.
73. The caption of Figure 3: This caption is not modified according to the revision of the main text. In particular, Eq 1a and 1b are not used in the current draft.