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Interactive comment on "Water exchange between the Sea of Azov and the Black Sea through the Kerch Strait" *by* Ivan Zavialov and Alexander Osadchiev

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We strongly appreciate the reviewers' suggestions and comments that served to improve the article. In response to them, first, we added results of numerical modelling that supported the results obtained from analysis of satellite imagery. Second, we clarified methods of detection of surface-advected outflows from the Sea of Azov to the Black Sea and bottom-advected inflows in the opposite direction based on agreement between Chl-a and TSM satellite imagery. Third, we modified the interpretation of influence of wing forcing on inflows from the Black Sea to the Sea of Azov and provided a more thorough physical background based on both satellite data and numerical modelling. Finally, we adopted many specific comments and recommendations from the reviewers, reworked the structure of the manuscript, and improved the quality of English text and figures. The detailed reply to reviewers' comments and description of changes made in the manuscript are given below and in the attached file.

1. The purpose of this paper was to analyze water exchange between Sea of Azov and Black sea. For this analyze author used satellite images and wind data. The author use TSM and CHL-a characteristics to trace spreading of AP and BP in the area. However on the page 5, author claims that: "above mentioned characteristics are prone to significant variability and not act as passive tracers".

Response:

Thank you for this valuable comment. In the revised version of the manuscript we used joint analysis of sea surface temperature (SST), concentrations of chlorophyll a (Chl-a) and total suspended matter (TSM) retrieved from optical satellite data. These characteristics are prone to significant variability and not act as passive tracers. Thus these characteristics cannot be used for straightforward identification of inflow of freshened waters from the Sea of Azov to the Black Sea. However, these processes and their temporal scales are different for SST (diurnal cycle of solar radiation), TSM (episodic wind-induced bottom resuspension events), and Chl-a (synoptic and seasonal biological cycles). Thus, joint analysis of SST, TSM, and Chl-a distributions can be used for accurate detection of spreading of AP in the Black Sea. We applied the following scheme of identification of AI events and detection of borders of AP basing on satellite data. Inflow events were identified by elevated concentration of Chl-a in the Kerch Strait and the adjacent coastal area of the Black Sea, because Chl-a has the lowest short-term variability among the considered sea surface characteristics and are not affected by wind/wave-induced sediment resuspension. If an inflow event was detected, we analyzed areas of elevated TSM, Chl-a, and elevated (in summer) or reduced (in winter) SST associated with formation of AP in the northeastern part of the Black Sea. If general forms and spatial scales of these areas were similar, we defined borders of

AP basing on gradient of TSM that is the most stable passive tracer of AP in absence of episodic wind-induced bottom resuspension events. If areas of TSM, Chl-a, and SST anomalies were not consistent with each other, we assumed that areas of elevated TSM and reduced SST (in winter) were modified by wind-induced resuspension and mixing of AP with subjacent sea. In this case we defined borders of AP basing on gradient of Chl-a that is the most stable tracer of AP during intense wind forcing conditions. These issues were described in the text. Also we applied calibrated hydrodynamic modelling using the BSAS12 model to prove the results obtained from the analysis of satellite imagery. Salinity distributions simulated by BSAS12 in the study region showed good agreement with detection of AP and BP at satellite imagery, that is explicitly described in the revised version of the manuscript and illustrated by Figures 2, 8, 11. Thus, the applied method of identification of AP and BP and the obtained results are supported by both satellite data and numerical modelling.

2. According to this paper AI events are induced by northeastern wind events, with speed >5 m/s, and during all other wind conditions the unidirectional flow towards the north occur. I would agree that during some exceptional events unidirectional flow can take place, but would suggest that water exchange in estuary should be two-way process, with simultaneous outflow and inflow events.

Response:

Many thanks for this important comment. We totally agree that water exchange through the mouth of a positive estuary is typically a two-way process with in- and outflows happening at the same time. However, it is not the case of narrow and shallow central part of the Kerch Strait, which width and depth are equal to 3 km and 3-4 m. In absence of external forcing water exchange through the Kerch Strait indeed is a two-way process. However, due to the dominating role of a barotropic component in the total pressure gradient along the strait (Figure 5 in the revised version of the manuscript), even moderate wind forcing at the study region induces a one-way water exchange in the narrowest part of the strait which defines water exchange between the Azov and

Black seas. Numerical simulations show that a two-way water exchange occurred in the Kerch Strait only during weak wind forcing conditions which total annual duration was 34 – 54 days in 1992 – 2010, which is only 9-15% of the whole year (Table 1). This result is also supported by previous in situ observations (Ivanov, 2011) and numerical modelling (Stanev et al., 2017) of water exchange in the Kerch Strait. Thus, one-way water exchange was observed during the majority of the year. This point was described in the text.

3. As regards spreading of BP in the Sea of Azov using TSM satellite images, seems very unreliable information. As well as TSM was mentioned as not reliable tracer. Rather it can show wind-induced resuspension of sea-bottom sediments.

Response:

TSM is not a reliable marker of SA water in the Black Sea because TSM increases over shallow areas in case of resuspension of bottom sediments. Thus, areas of elevated TSM can be induced by both sediment resuspension and spreading of SA water in the Black Sea. However, spreading of BS water in the Sea of Azov is indicated by reduced values of TSM in the shallow area adjacent to the Kerch Strait. Thus, resuspension of bottom sediments which increases TSM at the study region can not be misleading for detection of SA water indicated by reduced TSM especially at shallow areas. Thus, TSM is not a reliable marker of SA water in the Black Sea, but is a reliable marker of BS water in the Sea of Azov. Moreover, in the revised version we analyzed both TSM and Chl-a and identified SA water in the Black Sea as areas of reduced TSM and Chl-a. This procedure provides more confidence in detection of SA water, as compared to usage of only TSM. Thus, the scheme of identification of BI events and detection of borders of BP at satellite imagery is relatively straightforward, as compared to identification of AI events. However, we assume that BP is not manifested by anomalies of TSM and Chl-a in the surface layer during low wind forcing conditions, while during strong wind forcing conditions resuspension of bottom sediments can induce elevated concentrations of TSM in the surface layer that also hinders identification of BP. As a result, many of BI events are not detected by optical satellite imagery. Also salinity distributions simulated by BSAS12 in the study region showed good agreement with detection BP in the Sea of Azov at satellite imagery, that is explicitly described in the revised version of the manuscript and illustrated by Figure 11.

4. In my opinion in present stage, presented paper does not give correct or reliable information regarding water exchange between the Sea of Azov and Black Sea. However, current simulations by operative model or some additional measurements could increase value to this paper.

Response:

According to your recommendation we applied calibrated hydrodynamic modelling using the BSAS12 model to prove the results obtained from the analysis of satellite imagery. Salinity distributions simulated by BSAS12 in the study region showed good agreement with detection of AP and BP at satellite imagery, that is explicitly described in the revised version of the manuscript and illustrated by Figures 2, 8, 11. Thus, the applied method of identification of AP and BP and the obtained results are supported by both satellite data and numerical modelling.

5. As it is mentioned in the paper, circulation in the surface layer in the northeastern part of the Black Sea is dominated by a westward current along the continental slope and an anticyclonic eddy, which is regularly formed between this current and the coast near the Kerch Strait. How big influence eddy have on spreading the freshwater from the Sea of Azov.

Response:

Thank you for this point. Mesoscale eddies formed in the Black Sea near the Kerch Strait can largely influence spreading and mixing pattern of SA waters that inflow to the Black Sea and propagate westward along the southeastern shore of the Crimean Peninsula. Satellite data and numerical modelling reveal that AP are regularly en-

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trained by mesoscale eddies that can significantly intensify cross-shelf transport of freshened water inflowing from the Sea of Azov. The resulting transport of freshened water to the deep part of the Black Sea can largely affect local biological and geochemical processes. This issue was discussed in the text, however, thorough study of this feature is beyond the scope of our study.

6. On the page 6, author mentions that they use Chl-a as a stable tracer for AP in the Black Sea. Does this mean, that satellite images of Chl-a can be used only during big concentrations of Chl-a, and for example in winter periods this method cannot be used?

Response:

Concentration of Chl-a in the Sea of Azov is larger than in the Black Sea during the whole year, including winter period. Thus, the applied method of detection of AP can be used for any periods of the year.

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2019-2/os-2019-2-AC3-supplement.pdf

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