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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 mod-

elling. 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 premise of this paper is a study the water exchange through the Kerch Strait. My assessment is that the authors rather studied sediment resuspension due to wind/wave events which is insufficient to infer the true water exchange that also exists without sediment addition. Sediment resuspension is highly variable, but this should not be used to claim that the water exchange is too. More specific ocean data with mooring measurements and/or calibrated hydrodynamic modelling would be better suited to quantify this water exchange. Without such, most of the paper remains pure speculation and is of little scientific value.

Response:

Thank you for this valuable comment. We totally agree that the sediment resuspension due to episodic wind/wave events strongly affects optical satellite imagery and can be misleading for identification of water exchange events. TSM distribution indeed 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 AP. However, 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. 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 according to your recommendation we applied a 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. A starting point should be to explore the seasonal cycle of density differences across the strait to identify any possible seasonality of the forcing. The existence of a density gradient (in conjunction with a barotropic pressure gradient) should induce a steady exchange circulation typical for positive estuaries.

Response:

Thank you for this comment. Based on the results of numerical modelling, we explored variability of baroclinic and barotropic force in the Kerch Strait during 1992 – 2017. We show that the total pressure gradient along the strait is governed by a barotropic component, due to relatively large average difference of water level (0.1 m) in the southern and northern ends of the strait. Density gradient along the strait indeed exists; however, its value does not exceed 6 kg/m3. As a result, the role of a barotropic component in the total pressure gradient in the strait is by one order of magnitude greater than the role of a baroclinic component. Thus, circulation through the Kerch Strait is not steady

and unidirectional, but has large synoptic variability of intensity and direction governed by episodic wind forcing events. Also annual variability of the total pressure gradient in the strait does not show any seasonality. It supports our results that water exchange through the Kerch Strait has wind-govern synoptic variability, and do not show seasonal dependence on river discharge rate to the Sea of Azov. These issues were thoroughly described and discussed in the manuscript.

3. Indeed the water exchange through the mouth of a positive estuary is typically a two-way process with in- and outflows happening at the same time. Indeed, this exchange may be weaker or enhanced by winds as demonstrated in several studies before. To claim that winds are the sole initiator of episodic exchange flows is not aligned with previous studies on density-driven exchange flows in positive estuaries.

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, 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). Thus, one-way water exchange was observed during the majority of the year. 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. This point was described in the text.

4. Section 2: Give information on seasonal variations of density and differences across the Strait.

Response:

We agree with this point. We added variability of sea level and density gradients, as well as total pressure gradient along the Kerch Strait during 1997 and 2007 obtained from numerical modelling (Figure 5).

5. Page 4, line 21: A persistent residual tidal flow of $\sim$5 cm/s could move substantial volumes of water through the strait as compared with rare episodes.

Response:

Barotropic tidal current in the Kerch Strait is less than 5 cm s-1 except the narrowest part of the strait where they are equal to 6-10 cm s-1 during peak flow (Ferrain et al., 2018). However, maximal velocity of 2-days averaged tidal current in the Kerch Strait is less than 5 cm s-1 and its flow direction reverses during the tidal cycle. Thus, tidal current does not form a persistent residual flow and its role in water exchange between the Black and Azov seas can be regarded as negligible. This issue was clarified in the text.

6. Page 7: The authors claim that the area of an AP can substantially increase over time. In fact, it's the effect of mesoscale eddies (as obvious from the images) and the associated entrainment that causes this effect. However, this feature does NOT imply any increase in freshwater discharge rate.

Response:

Many thanks for this comment. We agree that increase of the area of AP showed at the related figure is caused by entrainment by a mesoscale eddy that was proved by numerical modelling. Thus, the observed feature does not relate to increase in freshwater transport through the Kerch Strait. In the revised version of the manuscript we verified all cases of freshwater inflow detected at satellite imagery by numerical

modelling. We selected only AP that were spreading as an alongshore current and did not consider AP were entrained by a mesoscale eddy. Thus, in the revised version of the manuscript we modified dependences between wind forcing conditions and spatial/volume characteristics of AP which reproduce intensity of freshwater discharge through the Kerch Strait in response to local wind forcing conditions.

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2019-2/os-2019-2-AC1-supplement.pdf

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