Ocean Sci. Discuss.,
doi:10.5194/os-2016-69-AC2, 2016

Ocean Science Discussions
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EGU

Interactive comment on "Effects of the basin dynamics on sea level rise in the Black Sea" *by* A. A. Kubryakov et al.

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Received and published: 31 October 2016

Answer: Thank You for your comments. At first we would like to clarify - the main goal of the study is quantitative estimation of spatial heterogeneity of sea level rise (i.e. average trends of sea level – important climatic signal) in the Black Sea and its relation with dynamic processes.

We do not discuss the water balance in the manuscript. We do not want to introduce the new mechanism driving the Black Sea dynamics, because it is well known from previous studies. We provide this information in the article text during the discussion of the "3.2 Dynamic sea level variability". Here we provide the references on the major researches (not all, of course) dedicated to the study of the impact of the wind curl on the dynamic sea level. Sorry, during the manuscript preparation, we missed one really

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Discussion paper

important reference “Stanev, E. V., P.-Y. Le Traon, and E. L. Peneva, 2000, Seasonal and interannual variations of sea level and their dependency on meteorological and hydrological forcing. Analysis of altimeter and surface data for the Black Sea, J. Geoph. Res., 105, 17203-1721”, which is one of the basic studies of altimetric sea level in the Black Sea . However, the results of the (Stanev et al., 2000) are advanced in the later study (Graek et al., 2010) that is cited in the text.

All cited studies provide an explanation about the simple mechanism of the reaction of the basin sea level on the change of the cyclonic wind curl: wind curl intensify the cyclonic circulation, as a result sea level rises on periphery and decreases in the basin center. Again, this is well known issue of the Black sea dynamics, and we do not want to “discover” it.

However, we feel that it is important to illustrate this mechanism to the reader. That is why we provide the figure 2, that brings no new information, but just needed for illustrative purposes (for our opinion). This is in agreement with reviewer comments.

The new in this article is the description of the long-term trends of the Black Sea level related to the long-term trends changes of the Black Sea dynamics and wind . We, for the first time, give the quantitive estimations of the impact of the large-scale and mesoscale circulation changes (DSL) on the Black sea level rise and its spatial heterogenity. This is the main novelty of the manuscript.

We are ready to change the Introduction part to more clearly define the manuscript goals and the state of art in this field.

Below we provide answers on the reviewer comments step by step:

1) Reviewer: “Unfortunately, the material is presented in such a way that the reader, who is not aware of the research in this field, could get an impression that the analysis of satellite altimeter data in the Black Sea and the understanding based on these data starts in 2016. ”

Answer: This is not exactly true. Article has at least 20 references on papers interpreted altimetry data for the Black Sea since 2001 till 2016. Particularly, one of the first paper describing the Black Sea level from altimetry data is Korotaev, 2001, that is cited in the text. During the discussion of the Black Sea dynamic sea level variability we missed one really important reference "Stanev, E. V., P.-Y. Le Traon, and E. L. Peneva, 2000, Seasonal and interannual variations of sea level and their dependency on meteorological and hydrological forcing. Analysis of altimeter and surface data for the Black Sea, J. Geoph. Res., 105, 17203-1721", which is one of the basic studies on altimetric sea level in the Black Sea. However, the results of the (Stanev et al., 2000) are advanced in the later study (Graek et al., 2010) that is cited in the text.

As, the main goal of this study is the investigation of the sea level trends, the introduction is mostly dedicated to the studies of the Black sea level rise. The review of the studies dedicated to the dynamic sea level variability in the Black Sea is given in section "3.2 Dynamic sea level variability". We believe that this part can be moved in the Introduction to avoid the possible false impression.

2) Reviewer: "I do not know whether the authors are unaware of the research in this field or they purposely presented completely unbalanced presentation of the state of the art... One example is the basic idea of the relationship between wind stress curl and sea level observed from satellites, which is known short after the first satellite altimeter missions.... The second example is the dynamics of coastal and open-ocean sea level (Fig. 2d)."

Answer: Also, we cannot fully agree with the reviewer. The information about previous researches on the dynamic sea level variability is given in section "3.2 Dynamic sea level variability". We provide a shot review about the previous and modern studies, which highlight the basic idea of the relationship between wind stress curl and sea level in a first paragraph:

"The main feature of the Black Sea dynamics is the cyclonic Rim current encircling

the basin over the continental slope. As a result of the cyclonic circulation, the DSL is lower in the center of the basin and higher along the periphery (Oguz et al., 1993; Korotaev et al., 2001). The seasonal variability of the Black Sea circulation is driven by changes in the wind curl averaged over the basin. (Stanev, 1990; Korotaev, 2001, Graek et al., 2010). In winter, the cyclonic wind curl and, therefore, the onshore Ekman transport increase and cause divergence in the center of the basin by moving water to the basin's periphery The compensating vertical uplift (Ekman suction) in the center of the sea brings dense deep water masses to the surface, while light surface waters move towards the coast (Korotaev, 2001; Kubryakov et al., 2016). The redistribution of mass and volume results in a decrease of sea level in the basin's center, and an increase along the coastline. In summer, the cyclonic wind curl weakens, Ekman divergence decreases and the water accumulated along the coast flows back into the basin's interior (Zatsepin et al., 2002; Kubryakova, Korotaev, 2016)."

The figure 2 is given to illustrate the basic ideas given in the cited studies, which are crucial to understand the impact of the wind curl on the sea level rise. For our opinion, it is useful for the illustrative purposes. Some readers can be unfamiliar to the Black Sea dynamics (for example specialists that work with tide gauges data), that is why figure 2 is in the text.

We believe that we can improve the phrase in the text:" As expected, the seasonal time series of DSL in the coastal (depths less than 500 meters) and central (depths more than 2000 meters) parts of the basin are negatively correlated (fig.2d). " to "As it is known (Stanev et al., 2000; Korotaev et al., 2001), the seasonal time series of DSL in the coastal (depths less than 500 meters) and central (depths more than 2000 meters) parts of the basin are negatively correlated (fig.2d)."

3) Reviewer: Knowing this example, I find nothing new in the statement of authors (p. 11: A simple regression allows to reconstruct both the seasonal and interannual variability of DSL from the wind data alone.)

Answer: As far as we know, the reconstruction of the DSL spatial field from the wind curl data on the interannual time scales was not done before. We'll be very appreciated to obtain references on previous study demonstrated such reconstruction. We think that the obtained results are important for the correction of the sea level rise from the historical tide gauges measurements.

4) Reviewer: "The strong coincidence between basin bathymetry and correlations patterns is well seen". They have to know that this is not coincidence at all. Fig. 3 is just an illustration of the role of the Ekman pumping, which is largely addressed in the Black Sea literature. This "coincidence" reflects the dynamics of pycnocline (sea level just mirrors it)."

Answer: We agree that "Coincidence" is not good term, "similar spatial patterns" is better.

However the reviewer not exactly true interprets observed phenomena. The dynamics of pycnocline is the secondary process defined by wind curl. The wind curl determines the intensity of water divergence from the center to the periphery. The redistribution of the sea level driving by the Ekman transport causes the downwelling motions over the continental slope, and consequent pycnocline displacement. Moreover, in the shelf areas, (for example in the very large North-Western shelf), where the correlation is also positive and high, we can not talk about pycnocline at all. There is no main pycnocline in this shallow zone. In winter there is no stratification at all, and the dynamic sea level redistribution is caused by barotropic motions.

That is why in manuscript we wrote:

"The seasonal variability of the Black Sea circulation is driven by changes in the wind curl averaged over the basin (Stanev, 1990; Korotaev, 2001, Graek et al., 2010). In winter, the cyclonic wind curl and, therefore, the onshore Ekman transport increase and cause divergence in the center of the basin by moving water to the basin's periphery. The compensating vertical uplift (Ekman suction) in the center of the sea brings dense

deep water masses to the surface, while light surface waters move towards the coast (Korotaev, 2001; Kubryakov et al., 2016). The redistribution of mass and volume results in a decrease of sea level in the basin's center, and an increase along the coastline. In summer, the cyclonic wind curl weakens, Ekman divergence decreases and the water accumulated along the coast flows back into the basin's interior (Zatsepin et al., 2002; Kubryakova, Korotaev, 2016)."

And again "Therefore, the spatial distribution of the Black Sea trends presented in fig.1c can be explained by two factors: a) the rise of the mean Black Sea level by 3.15 mm/year due to the change of water mass/volume in the basin and b) the increase of Ekman divergence in the center of the sea due to the strengthening of the cyclonic wind curl over the basin"

5) Reviewer: I would ask what new they would find when using about a 20-year long data set.

The main new results of the paper are:

1) The impact of the long-term wind curl change on the intensification of the Black Sea large-scale circulation and increase of the sea level rise in the coastal zone 2) The impact of the changes of the Black sea mesoscale circulation on the sea level rise in the basin 3) The reconstruction of the DSL spatial fields using reanalysis data. It should be used to correct previous estimates of the Black sea level rise in the basin 4) Spatial distribution of the Black Sea dynamic sea level trends 5) Interannual variability of the dynamic sea level in 1992-2015

Please also note the supplement to this comment:
http://www.ocean-sci-discuss.net/os-2016-69/os-2016-69-AC2-supplement.pdf

Interactive comment on Ocean Sci. Discuss., doi:10.5194/os-2016-69, 2016.