Answer to Reviewer 2

This paper investigates changes in the Black Sea circulation as evidenced by altimetry. These changes are linked, as expected, with the wind forcing which is then used to reconstruct this variability for a period before altimetry started. The work is interesting but not presented carefully and detailed enough and includes a number of significant omissions and misinterpretations. Therefore it cannot be published in its present form. It will require rethinking and rewriting so major revision is recommended. But there is merit in it and can become a useful addition to the existing literature after careful consideration.

Suggested changes:

1. The title would have been better if it was something like "Interannual and decadal changes in the circulation of Black Sea as evidenced from altimetry". The suggested sea level trends are neither basin wide trends nor coastal trends.

Answer: The goal of this study is to investigate the sea level trends in the basin with the focus on its spatial heterogenity. It is not dedicated to the study of the Black sea dynamics, which was investigated earlier in the number of studies (e.g. Korotaev, 2001; 2003, Stanev et al., 2000; Kubryakov et al., 2016.)
In this study we provide the quantitative estimates of the spatial variability of the sea level rise in the basin and describe the main reasons of its heterogenity, which are the long-term changes of the Black sea large-scale and mesoscale dynamics. This is the main novelty of the study, which is dedicated to the understanding of the effects of the Black sea dynamics on the sea level rise in the basin.

2. lines 8-10: altimetry does not measure at coastal areas. Either tide-gauges should be used to substantiate a difference between coastal and open-sea sea level variance or this statement should be changed.

Answer: We respectfully disagree with the reviewer. Altimetry does measure near the coast, but these measurements are less accurate being constrained by the size of the altimeter footprint. Nevertheless, in the recent years, a great progress in improving the near-coast measurements has been achieved, which has affected the regional altimetry products, such as the Mediterranean and Black Sea products. The improvement in the coastal areas of the Mediterranean Sea has recently been demonstrated by Marcos et al. (Advances in Space Res., 2015).

The nearest points of the altimetry along-track measurements is situated at ~ 7 km distance from the coast (see fig.S1 in the attached file).

The resolution of the Black sea mapped regional product is 1/8° or ~12.5 km. Regional Black Sea array of mapped altimetry sea level anomalies (MSLA) is produced by the CLS Space Oceanography Division and distributed by Aviso, with support from Cnes (http://www.aviso.oceanobs.com/).

In order to be precise we should change the phrase in the Introduction "the sea level rise varied from 0.15-2.5 mm/year in the central part to 3.5-3.8 mm/year in coastal areas and 5 mm/year in the southwestern part of the sea" to "the sea level rise varied from 0.15-2.5 mm/year in the central part to 3.5-3.8 mm/year at the periphery of the basin and 5 mm/year in the southwestern part of the sea"

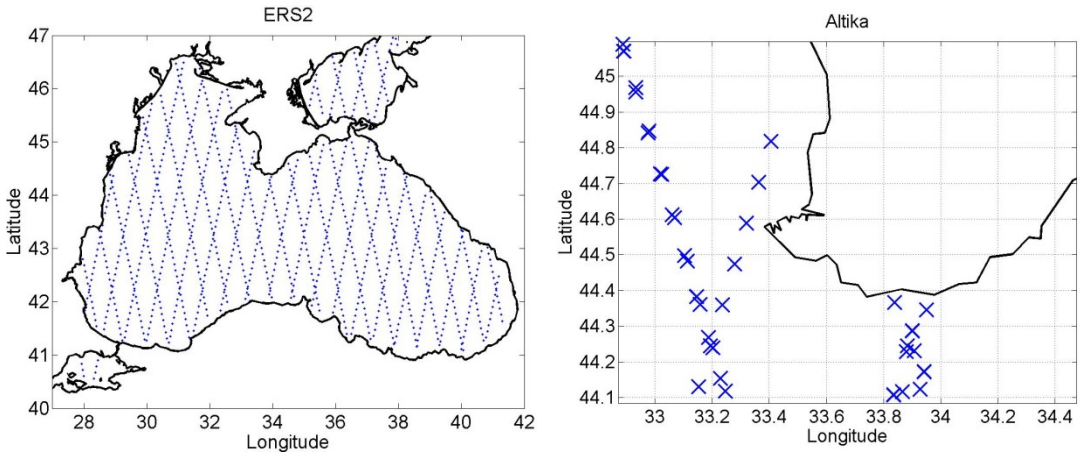

Fig.1 Left - Track position of ERS-2 altimetric measurements from the Black Sea regional dataset; Right – track position of the Saral\Altika near the Crimea. The distance between coast and nearest coastal point is ~ 7 km

3. Lines 11-14: If the explanation concerns the period 1993-2014 the relevant forcing should be the same not a different time period.

Answer: We agree with the reviewer. The phrase "A long-term increase of the cyclonic wind curl over the basin *from 1979 to 2014* strengthened divergence in the center of the Black Sea that led to an increase of sea level near the coast and a decrease in the center of the basin" should be changed to "A long-term increase of the cyclonic wind curl over the basin strengthened divergence in the center of the Black Sea that led to an increase of sea level near the coast and a decrease in the center of the basin"

4. Lines 16-19: How do you know that the variability is “well reconstructed” for the period before altimetry as you have no data?

Answer: We agree with the reviewer. The phrase “The DSL variability in the Black Sea depends strongly on the basin-averaged wind curl and is well reconstructed using the ERA-Interim winds from 1979 to present, including the time when altimetry data was unavailable. The reconstruction can be used to correct historical tide gauges data for dynamic effects, which are usually neglected in the analysis of the Black Sea tide gauge records.” should be changed to “The DSL variability in the Black Sea depends strongly on the basin-averaged wind curl. In the study we show that the DSL variability on interannual and seasonal time scales can be reconstructed with a reasonable accuracy using simple linear regression of wind curl data from atmospheric reanalysis. Before the emergence of altimetry data the measurements at the periphery of the basin (e.g. coastal tide gauges) were used to estimate the basin-averaged sea level rise. As the DSL trends at the basin periphery do not reflect the change of mean water volume, they should be subtracted for the correct estimation of the basin-averaged sea level trends. The method presented in the study can be used to correct historical estimates of basin-averaged sea level rise on dynamic effects using atmospheric reanalysis data.”

5. Lines 18-19: Why do tide gauges need corrections for what happens away from the coast? They provide direct measurements of sea level. In any case as altimetry does not provide information closer to ~30km from the coast this suggestion is erroneous.

Answer: We agree with the reviewer. This statement should be rewritten more precisely. The estimates of the basin-averaged sea level rise from tide gauges needs correction on the dynamic effects, not tide gauges themselves. DSL trends impact on the estimates of the sea level rise, if we measure only at the periphery of the basin. This impact can be subtracted using given in the study method.

The nearest points of the altimetry along-track measurements is situated at ~ 7 km distance from the coast (see fig.S1 in the attached file). The resolution of the Black sea mapped regional product is 1/4° or ~12.5 km.

Several studies have shown that the data in the closest point of altimetry-track is well correlated with the tide gauges measurements (Korotaev et al., 1998 (in russian); Stanev et al., 2000; Peneva et al., 2001; Goryachkin et al., 2001, 2003 (in russian); Kubryakov et al., 2013; Avsar et al., 2015; Volkov and Landerer, 2015).

6. There is significant literature concerning sea level rise for the Black Sea (for example Stanev et al., 2000; 2002; Tsimplis et al, 2004 and Volkov and Landerer- which is referenced) discuss sea level rise in the Black Sea and assessing mass addition to the basin as well as steric effects. These are more relevant than a general discussion of what causes global sea level rise.

Answer: We agree with the reviewer. Several references should be added to the introduction to better represent the previous research.

7. Section 2 data. Need to describe the dataset properly. While there is a paper (Volkov and Landerer, 2015) which argues that the altimetry data set can be used as is in the Black Sea with the imposed DAC for pressure and wind, their argument is based on comparison with tide gauges and their finding that such a correction does not improve the agreement with tide gauges in RMS terms of monthly values. This does not necessarily mean that there are no "trends" is the pressure and wind fields which are artificially and in a spatially coherent manner added as a correction to the se level field through DAC. Thus in, my view, the physical argument that the constraints imposed by the Turkish Straits to water exchange do not permit the use of DAC is the correct one. The argument about RMS change can only partly justify the use of correction and probably not in the context of trends. In addition to the doubts I have in relation to the atmospheric correction it is unclear which other corrections are used and what is their uncertainty. Do the data have a GIA correction and how large it is? While it is not likely to be large it will provide confidence to the data process to express it clearly.

Answer: We should point out that the main purpose of applying the DAC correction to altimetry data is **to reduce the aliasing** that results from the barotropic response of the ocean to the variable high frequency atmospheric forcing. For this reason, the use of the DAC correction is necessary. The DAC combines the high frequency bands (periods <20 days) from a barotropic model with the low frequency bands (periods >20 days) from the inverted barometer (IB) correction. We agree with the reviewer that changes in sea level pressure over the Black Sea (including trends) enter the DAC IB correction, and this can introduce spurious sea level changes. However, this is exactly what Volkov and Landerer (2015) addressed by adding the IB correction back to altimetry data and comparing these data to tide gauges. The result shows that adding back the IB correction does not significantly improve the comparison. The RMS differences reported in the paper refer to month-to-month changes as well as to trends. Note that according to a recent study by Volkov et al (2016 – referenced in the manuscript), the constraints imposed by the Turkish Straits are not anymore effective at the interannual and longer time scales, at which the Black Sea level responds to sea level pressure changes in a pure inverted barometer manner. The use of GIA correction would be necessary for tide gauge records, but we

did not use tide gauges in our paper. Please note that we use a standard altimetry product that is routinely corrected for instrumental errors and geophysical effects. It is beyond the scope of our manuscript and not necessary for the objectives of the study to present details on the corrections applied to the altimetry product (the details can be found in dedicated literature that is referenced on the AVISO web site).

8. The general uncertainties on the altimetry trends need also to be addressed. While the uncertainty for global trends has been stated to be 0.4-0.6 mm/yr (with one exception of 0.9 mm/yr) several statements about larger uncertainties in regional trends exist. An uncertainty of 1 mm/yr would render some of the suggested spatial variance in trends insignificant though of course there are some strong gradients demonstrated.

Answer: We agree with the reviewer. We will add the estimates of the data uncertainties and trend uncertainties to the revised version of the paper.

9. The same point about uncertainty and trends holds for all the physical parameters used. Trends are stated without much consideration of their significance.

Answer: We agree with the reviewer. We will add the estimates of the trend uncertainties to the revised version of the paper.

10. My understanding of the circulation features of the Black Sea suggests strong seasonality. This paper does not deal with this at all. Are these trends consistent during the year or are they an expression of strengthening of seasonal circulation? This requires extra work.

Answer: The Section 3.2 (Paragraph 1-3) and figure 2 describes the seasonal variability of the Black Sea dynamic sea level. The increase of the cyclonic wind curl on interannual time scale leads to the intensification of the basin cyclonic circulation, as a result sea level rises on periphery and decreases in the basin center. This effect is well seen on the interannual time scales for the time series smoothed with a 365-day moving average (see fig.4 b,d; fig.5 b,c), i.e. this effect is observed for yearly-averaged data. The seasonal variability does not affect the estimates of the average DSL trends.

11. The figures should demonstrate the limitations of altimetry by leaving the 30-40 km near the coast blank rather than closing the contouring. This is done for figures 6b,c and d but not for Fig 6a or any other contour plot. With the Black Sea at around 260km at its narrowest having 60-80 km of information lost is a significant percentage of area.

Answer: As we mentioned above, altimetry provides measurements near the coast and the accuracy of these measurements has been improved. A reasonable comparison with tide gauges (Volkov and Landerer, 2015) suggests that the use of near-shore data points in AVISO product is justified. Therefore, we respectfully disagree with the reviewer and decide not to leave the near-shore regions blank.

The nearest points of the altimetry along-track measurements is situated at ~ 7 km distance from the coast (see fig.S1). Several studies have shown that the data in the closest point of altimetry-track is well correlated with the tide gauges measurements (Korotaev et al., 1998 (in Russian); Stanev et al., 2000; Peneva et al., 2001; Goryachkin et al., 2001, 2003 (in russian); Kubryakov et al., 2013; Avsar et al., 2015; Volkov and Landerer, 2015).

In this study we use the standard mapped satellite sea level anomaly product without any extrapolation. The resolution of the Black sea mapped regional product is 1/8° or ~12.5 km.

12. The straight lines at Figure, 5 and 7b (trends) are not persuasive. A step change seems also a good alternative.

Answer: We agree that in these figures the linear trends can vary for different periods of time. However, the main task of this study is to understand the spatial variability of the Black sea level trends during the whole investigation period. That is why in figures 5 and 7b we use approximation by linear function to understand the average changes of the investigated parameters.