We are very grateful to the reviewer for his efforts in reading carefully our manuscript and giving us very useful and concrete comments which hopefully will help us to improve largely the paper.

1) Comment from Referee:

In the text there are some vague conclusions, which are not supported by convenient dynamic analysis, or figures, they are not based on valid assumptions and they are not clearly outlined. In some cases the results are not sufficient to support the interpretations and conclusions and some statements regarding data shown in figures are not obvious and concise for the reader.

Author's response:

We believe that our conclusions being supported by considerations of the vorticity equation are not so vagued. We somehow stressed this fact in the text reformulating some paragraphs.

Author's changes in manuscript:

P 204, line 15 to 25 'Subsequently, the calculated positive …. change on the SAG circulation and its ecosystem'

was replaced by:

'Despite a statistically significant negative correlation between the NAO index and the wind vorticity, no unequivocal relationship between large climatic system and the interannual variability of the South Adriatic Gyre intensity was found due to additional effects of the vorticity advection from the Ionian. This can be explained by the fact that the Ionian circulation mode does not depend on the NAO variations. Therefore, the main result of this study is that the interannual variability of the South Adriatic cyclonic circulation is a result of the combined influence of the vorticity advection from the Ionian and the local wind-curl effect.'

P 213, line 18: 'The wind-stress curl, on its turn, prevailed in determining the current vorticity tendency in the central part of the southern Adriatic. The correlation between the NAO index and the frequency of the northerly wind clearly divides the Adriatic Sea into two parts with opposite behaviour: positive correlations occurred in the South Adriatic, whereas negative correlation

were observed north of 43 °N (Fig. 5b). Assuming that the winter convection is dictated mainly by the northerly winds, we can conclude that in the period of high and/or positive NAO values the winter convection is at its maximum and vice versa. This is opposite to what happens in the Northern Adriatic.'

was replaced by:

'The wind-stress curl, on its turn, affects the current vorticity tendency in the central part of the southern Adriatic however depending on the circulation mode of BiOS. In the cyclonic phase, the wind stress curl is presumably prevailing in determining the vorticity tendency, while in the anticyclonic phase the vorticity advection term becomes important. In conclusion, due to the varying importance of the vorticity advection term which depends on the Ionian circulation mode, it is not possible to establish clear relationship between NAO and the strength of the SAG.'

P 216, line 4 to 18 : 'This was explained in terms of the prevailing atmospheric flows over the larger Mediterranean area suggesting that the interannual variations of the strength of the SAG are associated with the large-scale climatic variations via the wind-stress curl forcing. The frequency of the northerly wind during the winter is positively correlated with the NAO index in the South Adriatic Sea, while it is out of phase in the North Adriatic. More frequent southerlies during the negative phase of NAO over the South Adriatic Sea results in the lower frequency of the bora wind. In contrary, the positive NAO phase is associated with the intensification of the northerly winds bringing dry and cold air from the Balkan peninsula and consequently stronger winter convection which implies the reinforcement of the deep water formation. Phytoplankton biomass as a function of wind does reveal the existence of the two regimes in the SAG, while the timing of the bloom is a linear function of the wind frequency. Due to the increased wind frequencies the bloom can retard up to two months. These results thus show that the timing is a function of the northerly winds and probably of the large-scale climatic systems.'

was replaced by:

'This was explained in terms of the prevailing atmospheric flows over the larger Mediterranean area suggesting that to a certain extent, the interannual variations of the strength of the SAG are associated with the large-scale climatic variations via the wind-stress curl forcing. Due to the rather important effect of the vorticity advection from the Ionian, characterized by the prevalent

decadal variability, there are no clear evidences of direct effect of large-scale climatic system on the interannual variability of the intensity of the SAG.'

2) Comment from Referee:

Statistical high correlation coefficient of even lagged correlation coefficient does not necessarily imply a dynamic link between 2 parameters.

Author's response:

The importance of the advection mechanism as a source of vorticity in the South Adriatic Gyre is not arrived only by calculating the lagged correlation between the current vorticities in the SAG and northern Ionian Sea. As it is explained in the manuscript, first, we evaluated the different terms of the vorticity equation and obtained the equation 8 (page 210, line 21), which shows that the wind stress vorticity is not the only possible source of vorticity but the vorticity advection from the adjacent area should also be taken into consideration. Only then, we calculated the lag correlation between flow vorticities in SAG and northern Ionian Sea in order to find evidences on the advection speed valid only for the statistically SIGNIFICANT correlation coefficient. This correlation coefficient is 97% significant for the 15 month phase-lag.

We also added in a revised version of the ms. the time-series of the advection term assuming constant speed as obtained from the lagged correlation calculations.
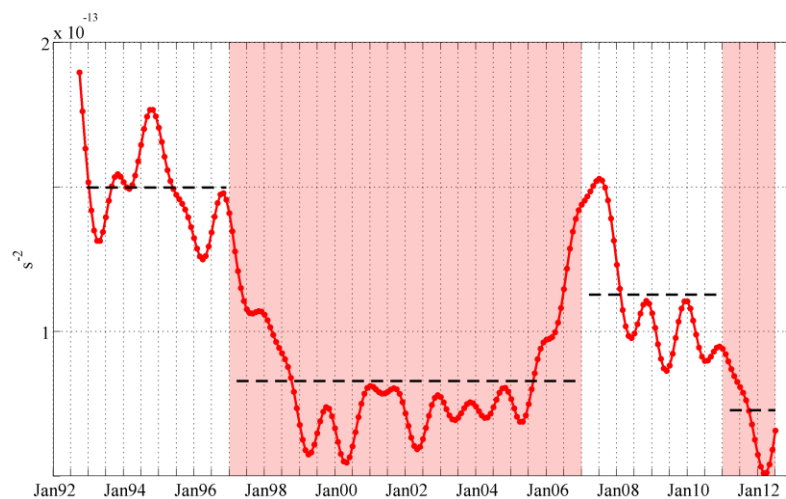
The figure clearly shows that during the cyclonic phases (red marked areas) the vorticity gradient Ionian-Adriatic is smaller than in the anticyclonic one resulting presumably in the reduced importance of the vorticity advection term. However, more explanation about the role of the advection term and its relation with BiOS will be given in the revised version of the ms.

Our conclusion about the correlation between NAO index and the wind stress vorticity is not that NAO is the direct cause of the circulation variations of the SAG and calculations of the correlation coefficients is not the only tool used to explain the mechanism. We first correlate wind-stress curl and the flow vorticity tendency considering also the vorticity advection from the Ionian. Then we analyzed the wind pattern for the negative and positive modes of NAO (showing that the stronger wind vorticity occurs during NAO- and vice versa) in order to explain the statistically significant negative correlation between NAO and wind curl obtained from figure 5a. (r= 0.6, sig. 95%).

<u>Author's changes in manuscript</u>:

P 211, line 14: 'The vorticity in the northern Ionian was analysed in order to estimate the vorticity advection through the Strait of Otranto.'

was replaced by:

'For this purpose, the vorticity in the northern Ionian was calculated in order to estimate the vorticity advection through the Strait of Otranto.'

P 211, line 25: 'In order to study whether possibly the vorticity advection from the Ionian plays a role in controlling the curl of the flow in the South Adriatic'

was replaced by:

'Second term which may contribute to the vorticity tendency in the SAP is the advection term. In order to study to what extent the vorticity advection from the Ionian plays a role in controlling the curl of the flow in the South Adriatic'

P 212, first line: we added: '(97% significant)' after: 'about 15 months'

P 212, line 3 to 16: 'advection from the Ionian may contribute to variations of the intensity of the SAG. It is interesting to note that the correlation between the wind-stress curl, i.e. the local vorticity input, and the current vorticity was apparently stronger in the period 1997-2006 than in the rest of the studied period. This can be explained by the fact that the period 1997-2006 was

characterized by the cyclonic phase of BiOS in the Ionian and in that case the vorticity advection term was proportional to the differences between absolute values of the Adriatic and Ionian vorticities. Before 1997 and after 2006 the Ionian was characterized by the anticyclonic circulation mode and the vorticity advection term was proportional to the vorticity sum. Therefore, in the Ionian cyclonic circulation phase the local input, i.e. the wind-stress curl, has a prevailing effect on the current vorticity and thus the correlation between the two is stronger. On the other hand, in the BiOS anticyclonic phase the vorticity advection term may become significant and probably of comparable importance as the wind-stress curl. Consequently, the correlation between the flow vorticity tendency and wind-stress curl is weaker.'

was replaced by:

'advection from the Ionian may contribute to variations in the intensity of the SAG. It should be stressed that advection term is not equally important in all situations; while the Ionian circulation is in the anticyclonic phase the advection term is more important than in the cyclonic phase (Fig. 5). In earlier case the advection term is proportional to the vorticity sum of the Ionian and Adriatic while in the latter case the advection term is proportional to the difference between the two. Therefore, the local current vorticity input prevailed in the period 1997-2006 when the Ionian was in the cyclonic phase and the advection term is proportional to the vorticity differences between the Ionian and the Adriatic. Before 1997 and after 2006 the Ionian was characterized by the anticyclonic circulation mode and the vorticity advection term was proportional to the vorticity sum and thus more important. Therefore, in the Ionian cyclonic circulation phase the local input, i.e. the wind-stress curl, has a prevailing effect on the current vorticity and thus the correlation between the two is probably stronger. On the other hand, in the BiOS anticyclonic phase the vorticity advection term may become significant and probably of comparable importance as the wind-stress curl. Consequently, the correlation between the flow vorticity tendency and wind-stress curl is very likely weaker.'

P 212, line 20 (Fig. 5a) was changed to (Fig. 6)

P 213, line 11 (Fig. 6a) was changed to (Fig. 7a)

P 213, line 15 (Fig. 6b) was changed to (Fig. 7b)

P 224, before figure 5:

we added the figure of the time-series of the advection term.

Caption: Figure 5. Time series of the low pass filtered (13 months) current vorticity advection from the North Ionian Sea to the South Adriatic Sea. Areas shaded in red correspond to the time

periods of cyclonic circulation and the black dashed lines show the average values of the advection over each cyclonic/anticyclonic period.

P 224: number of figure 5 was changed to figure 6.

P 225: number of figure 6 was changed to figure 7.

P 226: figure 7 was deleted.

3) **Comment from Referee**:

In most cases the calculated correlation coefficient is low and without any reference to its statistical significance.

Author's response:

We presented in figure 6 the correlation between JFM NAO index and curl of wind stress instead of the low-pass time-series. It reveals the significant (>95%) and relatively high correlation (r= 0.6 in the SAG).

Generally, the statistical significance of the correlations was estimated and it was added everywhere in the manuscript.

correlation between jfm NAO index and wind stress vorticity,1988-2011
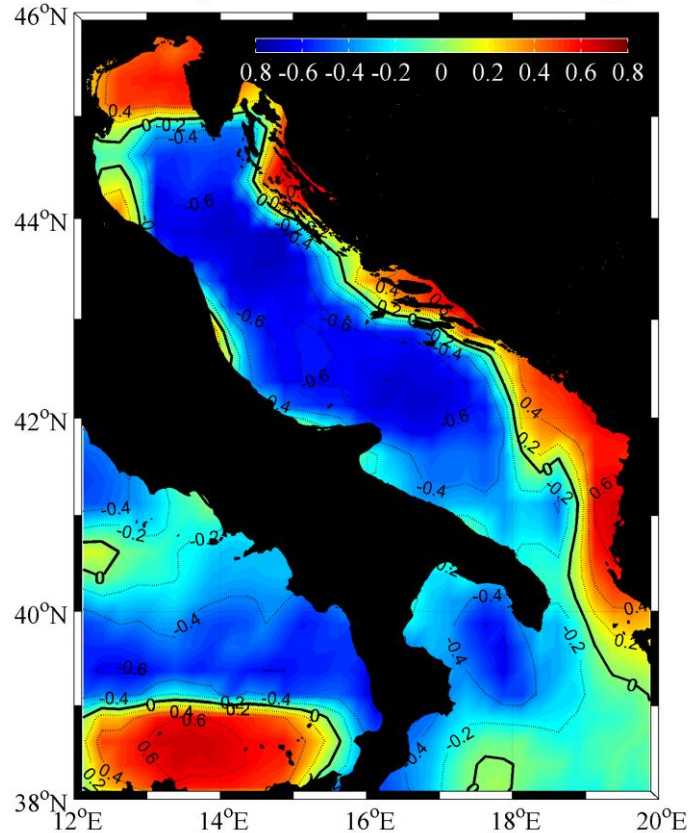
Author's changes in manuscript:

P 211, line 19: 'positive correlation coincided rather well with the center of the SAG'

was replaced by:

'statistically significant (95%) positive correlation coefficient coincides rather well with the centre of the SAG'

P 212, first line: we added: '(97% significant)' after: 'about 15 months'

P 212, line 18: … 'we compared time-series of the low-passed NAO index (13 month moving average) with the wind-stress curl' was replaced by 'we compared time-series of the wintertime NAO index with the wind-stress curl'

P 212, line 23: 'revealed negative correlation' was replaced by 'revealed the significant (95%) negative correlation'

P 224, fig. 5a: we changed the map to JFM,

Caption: 'Figure 5. Spatial distribution of the correlation coefficient of (a) the low passed filtered NAO index and wind-stress vorticity, and (b) JFM NAO index and the frequency of northerly winds, 1988-2011. The black solid line indicates the 0 correlation'

was replaced by:

Figure 6. Spatial distribution of the correlation coefficient of the JFM NAO index and wind-stress vorticity.

4) Comment from Referee:

Moreover there is no comparison of the findings with other higher resolution data or results from interannual numerical simulations of the basin (e.g. Mantziafou et al 2008, Janekovic et al 2014), whose setup includes all the basin dynamics.

Author's response:
The cited papers consider specific climatic conditions related to the extreme winter conditions of the year 2012 so it is hard to include the two suggested references in our paper. Moreover, in a new version of the ms. we do not consider any more winter mixing and the dense water formation since we, as suggested by both reviewers, eliminate the entire portion of the ms. treating the phytoplankton phenology as related to winter mixing.

5) Comment from Referee:

P. 205, lines 21-22. Dense water formation takes place in small spatial and temporal scales. Interannual dense water formation rates, among other, are related to the number and intensity of the high frequency events of the atmospheric forcing (air-sea heat fluxes and wind) during winter, which are smoothed out in the current analysis (spatial and temporal averages and high frequency filtering) as well as the preconditioning of the area. The intensity of the gyre, which is a related to convection in the center of SAG, is the outcome of the interaction of all the above (and actually much more) forcings with the SAG circulation. The authors should rephrase the text: "the interannual variability of the dense water formation rate is due to the combination of

two factors: winter air sea heat fluxes and the intensity of the SAG" accordingly and include references of relative studies (eg. Mertens, C., Schott, F., 1998.)

Author's response:

We changed the phrase.

Author's changes in manuscript:

P 205, line 21: 'interannual variability in the dense water formation rate is due to the combination of two factors: winter air-sea heat flux and the intensity of the SAG'

was replaced by:

interannual variability of the dense water formation rate is due to variety of factors such as surface buoyancy loss resulted from heat and freshwater exchanges, wind forced preconditioning of surface layer density through doming of isopycnals and advective changes in density via variations in the near surface temperature and salinity (Josey et al, 2011) . Preconditioning depends also as we will show here on the intensity of the SAG due to the local wind vorticity input and the vorticity advection from the Ionian.'

P218, line 1: we added: 'Josey, S. A, Somot, S., and M.Tsimplis: Impacts of atmospheric modes of variability on Mediterranean Sea surface heat exchange. J. Geophys. Res., 116, C02032, doi:10.1029/2010JC006685, 2011.'

6) Comment from Referee:

The authors should also include and explain in section 3(Data and Methods) the way they calculate mean values of wind stress?

Author's response:

As suggested it was explained in the manuscript.

Author's changes in manuscript:

P 207, line 11 (under Eq. 2): we added:

'The 6 hourly wind stress curl estimated from Eq. (1) was firstly time-averaged over monthly periods and finally spatially-averaged in the black boxes of Fig. 1.'

7) Comment from Referee:

In fig. 6 parallel wind stress vectors give high wind stress curl. How can this be explained?

Author's response:

The flow doesn't have to have an apparent vortex to have vorticity. The concept of vorticity is very well explained in "An Introduction to Dynamic Meteorology" by James R. Holton, Gregory J. Hakim. In the figure 4.6 a, (page 103) the linear shear flow with vorticity and the curved flow with zero vorticity is clearly shown.
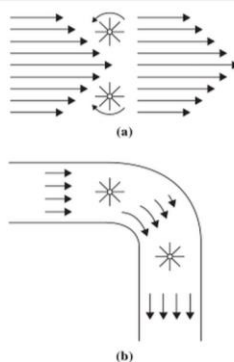

FIGURE 4.6 Two types of two-dimensional flow: (a) linear shear flow with vorticity and (b) curved flow with zero vorticity.

In the figure 6 of the manuscript, although the wind vectors are parallel, the vorticity is generated by the gradient of the zonal (maridional) component of the wind in the y (x) direction.

8) Comment from Referee:

P 209,line26: How is it justified that the wind speed 5m/s is the threshold in generating vertical mixing? (Northerly winds with wind speed higher than 1m/s (p. 209, line 3) or 5m/s (line 25) are taken into account?

Author's response:

Following referees suggestions we eliminated entire part of the ms. treating the vertical convection, dense water formation and phytoplankton phenology.

9) Comment from Referee:

P 212 lines 5-16:There is no figure or calculation to support this argument. There is no apparent stronger correlation between wind curl and current vorticity in the period 1997-2006.

Author's response:

Please refer to the response of the 2nd comment.

Author's changes in manuscript:

It was explained at the 'Author's changes in manuscript' of the comment 2.

10) Comment from Referee:

p.212: Correlation of NAO and wind stress curl is very low and I don't find any similarity between fig.3 and fig.5a.

Author's response:

Please see the response to the 3rd comment.

Author's changes in manuscript:

It is explained in the 'Author's change in manuscript' of the comment 3.

In addition: p 212, line 26 to the end: we deleted this part:

'Spatially, the area of the maximum absolute value of the correlation between the wind-stress curl and NAO coincided with the area where we observed the highest correlation between the current vorticity tendency and the wind-curl (compare Figs. 3 and 5a)'

11) Comment from Referee:

p.213. The authors find that positive NAO phase is correlated to a) weaker positive vorticity and thus weaker cyclonic circulation in the SAG and at the same time to b) higher frequency of cold northerly winds and maximum convection in SAG. These results are contradictory. These two correlations have opposite impact to the intensity of convection in the center of SAG.

Author's response:
As mentioned before, the part of the ms treating the frequency of northerly winds was removed.

Author's changes in manuscript:
P 208, line 24 to p 209 line 27: 'Since the northerly cold and dry… in generating the vertical mixing.' was deleted.

12) Comment from Referee:

P 211, lines 19-25: Maximum correlation between wind stress and current vorticity in SAG does not coincide the center of the SAG where correlation coefficient from -0.4 to 0.4 exist and the authors' conclusion that the most important mechanism responsible for the variations of the current vorticity is the wind stress cannot be justified.

Author's response:
We changed the phrase.

Author's changes in manuscript:
P 211, line 19: 'the maximum positive correlation coincided rather well with the center of SAG' was replaced by: 'an area of the statistically significant (95%) positive correlation coefficient close to the centre of the SAG coincides rather well with the minimum of the sea level height'

P 215, line 15: 'correlation reaches maximum in the centre of the SAG' was replaced by 'correlation reaches local maximum close to the centre of the SAG'

P 215, line 18: 'the dominant mechanism' was replaced by 'an important mechanism'

13) Comment from Referee:

P.212 top: The maximum lagged correlation between the spatially averaged vorticity in the northern Ionian and the south Adriatic is very low (0.4) and no comment on its significance is mentioned so how can the authors draw any conclusion about the advection of the vorticity from Ionian?

Author's response:

The correlation of 0.4 is significant enough (97%) and the figure of advection time-series also supports our conclusion about the importance of the vorticity advection term.

The importance of the advection term is explained in the 'Author's response' of the comment 2.

Author's changes in manuscript:

P 212, line 1: after 'about 15 months' we added: '(97% significant)'

Please see the 'Author's changes in manuscript' of the comment 2.

14) Comment from Referee:

P 214: What is the unit of the frequency of days with northerly winds during winter in figure 7? How many days is 0.1 (10% of the whole winter days, namely 9 days?). Moreover, northerly winds are the winds within 2nd and 3rd quadrants, namely 180 degrees width? Isn't this too much? Please clarify the reasoning of your choices.

Author's response:

As mentioned before the part of the ms treating the frequency of northerly winds was removed.

15) Comment from Referee:

How is the phytoplankton biomass correlated to NAO, as this is implied at the title of the manuscript? This last section, according also to authors, needs more detailed analysis

Author's response:

As mentioned before, we removed entire part of the ms. Treating the phytoplankton phenology. Subsequently we changed the ms. title:

Title was changed to:

'Long-term variability of the South Adriatic circulation in relation to large scale climatic pattern'

The other changes in the manuscript:

P 204, line 4: 'altimetry' was replaced by 'altimetric'.

P 204, line 14: 'characterized by lower positive values' was replaced by 'characterized by lower positive or slightly negative values'.

P 210, line 1: 'The different terms of the vorticity equation were analysed in order to evaluate the various sources of current vorticity.'

was replaced by:

'The vorticity equation was analysed in order to evaluate the importance of various sources of current vorticity'

P 210, line 8: 'Since we assume the barotropic flow, the internal pressure gradient (the third term on the right) can be negligible. We also ignore the bottom stress.'

was replaced by:

'Since we assume the predominance of the barotropic flow, the internal pressure gradient (the third term on the right) can be ignored. We also neglect the bottom stress.'

P 211, line 4: 'The interannual variability prevailed in both wind-stress curl and current vorticity in the South Adriatic (Figs. 2a and 2b),'

was replaced by:

'The interannual variability prevailed also in the wind-stress curl (Fig. 2a),'

P 211, line 10: 'current vorticity Eq. (8)' was replaced by: 'flow vorticity equation (8)'

P 212, line 22: 'was practically null' was replaced by 'was statistically insignificant'

P 215, line 10: 'Possible local forcing is sought' was replaced by 'Local forcing is analysed'

P 215, line 11: 'were looked for in the vorticity from the adjacent area' was replaced by 'were looked analysing the vorticity in the adjacent area'

P 215, line 17: 'current vorticity was partially induced by the local wind vorticity input' was replaced by 'current vorticity tendency can partially be explained in terms of the local wind vorticity input'

P 215, line 25: 'evidenced' was replaced by 'revealed'

P 215, line 27 and P 216, line 1: 'become more important' was replaced by 'become larger and presumably more important'

P 216, line 20: 'The ESA Ocean Colour CCI Team is thanked for providing OC-CCI chlorophyll data; NASA for providing SeaWiFS, MODIS and MERIS chlorophyll data.' is removed.

P 217, line 16: 'convention' was replaced by 'convection'

The following references related to the phytoplankton phenology were deleted:

P 217, line 8: 'Collins, A. K., Allen, S. E., Pawlowicz, R.: The role of wind in determining the timing of the spring bloom in the Strait of Georgia, Canadian Journal of Fisheries and Aquatic Sciences, 66, 1597-1616, 2009.'

P 217, line 10: 'Dutkiewicz, S., Follows, M., Marshall, J., and Gregg W.: Interannual variability of phytoplankton abundances in the North Atlantic, Deep-Sea Research II, 48, 2323-2344, 2001.'

P 217, line 12: 'Moline, M.A., and Prézelin B.B.: Palmer LTER 1991-1994: Long-term monitoring and analyses of physical factors regulating variability in coastal antarctic phytoplankton biomass, in situ productivity and taxonomic composition over subseasonal, seasonal and interannual time scales. Marine Ecology Progress Series, 145, 143-160, 1996.'

P 218, line 19: 'Racault, M.-F., Le Quéré, C., Buitenhuis, E., Sathyendranath, S. and Platt, T.: Phytoplankton phenology in the global ocean. Ecological Indicators, 14(1):152163, 2012.'

P 218, line 25: 'Santoleri, R., Banzon, V., Marullo, S., Napolitano, E., D'Ortenzio, F., and Evans, R.: Year-to-year variability of the phytoplankton bloom in the southern Adriatic Sea (1998–2000): Sea-viewing Wide Field-of-view Sensor observations and modeling study, J. Geophys. Res., 108(C9), 8122, doi: 10.1029/2002JC001636, 2003.'

P 218, line 32: 'Siegel, D.A., Doney, S.C., and Yoder, J.A.: The North Atlantic spring phytoplankton bloom and Sverdrup's critical depth hypothesis. Science, 296: 730-733, 2002.'

P 219, line 1: 'Sverdrup, H.U.: On conditions of the vernal blooming of phytoplankton. Journal du conseil international pour l'exploration de la mer 18, 287-295, 1953.'

P 219, line 7: 'Williams, R. G. and Follows, M. J.: Physical transport of nutrients and the maintenance of biological production, In Ocean Biogeochemistry, pp. 19-51, Springer Berlin Heidelberg, 2003.'

P 219, line 9: 'Xu, Y., Cahill, B., Wilkin, J. and Schofield O.: Role of wind in regulating phytoplankton blooms on the Mid-Atlantic Bight, Continental Shelf Research, 6, S26–S35, 2012.'

P 219, line 11: 'Yamada, K. and Ishizaka, J.: Estimation of interdecadal change of spring bloom timing, in the case of the Japan Sea. Geophysical Research Letters 33: doi: 10.1029/2005GL024792. issn: 0094-8276, 2006.'