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Discussions

Interactive comment on "Imprint of external climate forcing on coastal upwelling in past and future climate" *by* N. Tim et al.

N. Tim et al.

nele.tim@hzg.de

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We thank the reviewer for evaluating our manuscript. The main concerns of the reviewer are discussed below.

The consideration of broad regions and the lack of careful analyses inhibit the ability to interpret results. The authors consider vertical transport in broad regions that are probably more sensitive to wind-stress curl over the open ocean than to alongshore winds.
The regions chosen as representative for the upwelling in the Eastern Boundary Upwelling Systems are not only a narrow band near the coast, but also include the adjacent ocean. This area is supposed to be still related to the alongshore winds as the

jet of coastal parallel winds is slightly offshore and wind stress curl develops due to the relaxation of wind speed towards the coast. Therefore, the strength of upwelling in the whole region should be related to the alongshore wind, to the sea level pressure gradient and, thus, to the Bakun hypothesis (Bakun, 1990). We checked that upwelling in the regions that were chosen for our study do present a uniform evolution of upwelling. We calculated the correlation between the latitudinal mean of the gridboxes which are closest to the coast with the latitudinal means of all other gridboxes. The correlations decay with the distance from the coast, and vanish at the edges of the chosen regions. Thus the regions used here do cover the area of upwelling and are suitable for representing the upwelling in the Eastern Boundary Upwelling Systems in the simulations.

The main objectives of the analyses should also be stated more clearly. It is unclear whether the authors seek to investigate the impact of natural or anthropogenic external forcing on coastal upwelling, curl-driven upwelling, the validity of Bakun's 1990 hypothesis, or some combination of these options.
The main objective of the analysis is to detect whether the upwelling in the Eastern Boundary Upwelling Systems shows a long-term trend and if these possible trends may be related to external climate forcing. This is obviously strongly related to the Bakun hypothesis. It is not our goal to investigate the mechanism (e. g. CO2) that lead to changes in upwelling but to analyse if the upwelling has changed linearly over the last millennium, the last 150 years and if it will in the next 100 years. We will make our goals more clearly in a revised version.

I appreciated the authors' mathematical description of forced and internal components of variability on p 2905. However, this construction did not appear to be utilised later in the analysis, and it did not incorporate the authors' filtering at various frequencies. Perhaps more significantly, the change in the months considered between the past and future simulations was not discussed or included in the mathematical analysis.

The mathematical description is the base of the statistical analysis used here. Correlating the three simulations of an ensemble shows us if the external or the internal forcing drives the temporal variations. The construction is used in the manuscript whenever correlating simulations of the same ensemble.

The second significant issue that prevents clear interpretation of the results is the muddled investigation of the "imprint of external forcing on the drivers of upwelling".
The upwelling in the Eastern Boundary Upwelling Systems are driven by the trade winds. The strength of the trade winds is clearly related to the sea level pressure gradient. Thus, investigating the imprint of external climate forcing on the sea level pressure gradient and the wind stress is consequential.

Section 6 of the manuscript ("Imprint of external forcing on stratification") was unexpected. If stratification is to be considered as part of the analyses, perhaps it should be introduced earlier in the manuscript. However, the authors do not perform an analysis of stratification; instead, global patterns of SST are considered. These SST patterns are not compared with upwelling.
We included the analysis on stratification to investigate a more indirect impact of external climate forcing on upwelling, too. The correlation pattern of two simulations of the ensemble provide a map on where the impact of the external climate forcing on the SST is large, larger than the impact of the internal forcing. Thus, figure 9 indicates that the impact of the external climate forcing on the sea surface temperature and therefore on the stratification is lower in the EBUS compared to other regions of the same latitude. We present global patterns here only to show all regions simultaneously, but the arguments refer only to the upwelling regions. We see no correlation of SST across simulations in the upwelling regions, i.e. in the regions where SST is mostly controlled by upwelling. indicating that the stratification is not influenced by the external forcing either.

Finally, I suggest the authors highlight the differences between use of a single

model ensemble and the multi-model analysis of Wang et al. (2015). Comparing the future projection of one model to that of multiple models, as is done here, is one option for discussion. However, the real strength of using a single-model ensemble is the ability to more clearly distinguish internal variability from the forced response.
This will be more clearly stated in the revised version.

References:
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