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Discussions

Interactive comment on "The relationship between Arabian Sea upwelling and Indian monsoon revisited" *by* X. Yi et al.

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We thank the reviewer for the detailed reading of the manuscript and for the suggestions for improvement. In the following, we sketch how we plan to eventually revise this manuscript to address these suggestions.

General comments: Model validation: We agree with the reviewer's comment on the necessity of a proper validation for the model. Since the observational vertical velocity data are very limited, we have tried to validate the model output SST with the observational HadISST and the satellite dataset AVHRR. However, both of them have their weaknesses. The HadISST has a spatial resolution of 1°, which is ten times coarser than the model so it makes little sense using it. The resolution of AVHRR is comparable

to the model but its temporal coverage is shorter as the model covers the period from 1950 to 2010 and the AVHRR covers the period from 1985 to 2009. Nevertheless, we decided to use the AVHRR for validation because it is still adequate for the comparison and analysis with its 25-year time series and it is the best source we have. We are also aware that the validation part in the manuscript is not clear and we will improve it in the next version by including other variables. However, as stated, a direct comparison with vertical velocities is virtually impossible, so that the validation has to be indirect..

Dynamical mechanism analysis: Coastal upwelling is mainly driven by the wind-stress. Therefore, no new mechanisms could be found that link the large-scale atmospheric forcing and upwelling in this area. As stated in the title, the focus of our study is to estimate to what extent upwelling in the Arabian Sea is connected to the Indian Monsoon, as it has been assumed in previous studies, mostly dealing with the interpretation of proxy records. The main conclusion of our study is that this link in this simulation is weak and that other atmospheric patterns not directly connected to the Indian Monsoon more responsible for the variability of upwelling. We will expand the physical discussion of the differences between the atmospheric patterns that drive upwelling and the atmospheric patterns more closely related to the Monsoon, but we see little value in analysing in detail the mechanisms that drive coastal upwelling locally, as this is already well known.

Specific comments: Terms: We accept the reviewer's suggestions and will rephrase the mentioned terms as follows: "upwelling indices": drop this term in the abstract "ka": change to "thousand years" "western and eastern Arabian Sea": change to "western and eastern Arabian Seas" "the red contour. . .": rephrase to "the coastal region surrounded by the red line demonstrates the study area"

High resolution contributes to capture upwelling variability: This statement should be self-explanatory. A higher resolution does not guarantee that the small-scale dynamics are perfectly captured, but it seems obvious that a higher resolution model has the possibility to be more realistic at small scales than a model with a coarse resolution, in

which small-scale dynamics are not represented other than by parametrizations. The extension of the upwelling region along the western Arabian Sea coast is about 90km (Rixen et al., 2000), which is less than 1°. So with a resolution of 1/10° the model should be able to capture the upwelling variability better than a typical global ocean with a resolution of 1°, although this is, of course, not guaranteed.

Page 2689, Lines 9-12, the first mode of EOF only account for 10% of the variance, The reviewer is correct that the variance explained by the leading EOF is small. But this is indicative of the point that we are trying to make in the study. Upwelling in the Arabian Sea has a complex structure (in the model). Coastal upwelling is not well connected to off-shore upwelling, and the interpretation of ocean cores distributed in the Arabian Sea as indicators of upwelling and indirectly of Monsoon, is not what we see in this model simulation. The main focus of our study, as reflected in the title, was not to explain upwelling variability in the whole Arabian Sea, but test the assumed connection between Monsoon forcing and upwelling in the context of this high-resolution simulation. The EOF spectrum of upwelling is very flat, as correctly pointed by the reviewer. The leading EOF explains 10% of the variability and mainly represents coastal upwelling in the Western Arabian Sea. This EOF is mainly driven by the upwelling-favorable winds. The rest 90% of the variability is distributed over the lower order EOFs, and this already indicates that upwelling in the region displays very noisy patterns, and not spatially coherent structures. This indicates that although we can see the main signal of the driving wind-stress, upwelling in the Arabian is not as spatially coherent as it may be expected. Probably the role of small-scale ocean dynamics is not negligible. This underlines again the main point of ours study, that it is not justified to interpret a few proxy records in the Arabian Sea as indicators of Arabian Sea upwelling and, indirectly, indicators of past Monsoon intensity. In the revised version, we will nevertheless expand this section and try to be more specific on the factors that drive the upwelling variability not related to coastal upwelling.

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