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Ocean Science Discussions



# *Interactive comment on* "Trends in coastal upwelling intensity during the late 20th century" *by* N. Narayan et al.

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**Response to the review by Andrew Bakun**

We would like to thank Andrew Bakun for his effort in reviewing our manuscript, and making many useful suggestions to improve its quality. We completely agree with his observation that the scattered nature in table 1 is an issue to be addressed in the discussion. Such a discussion will be included in the manuscript. In the following comments from the reviewer will be given in italics.

**1.Upwelling favorable wind intensity time series.** *There is a potential long-term artifact in all maritime data-based wind time series (Ramage, 1987; Cardone et al., 1990) due to inadequately-corrected long-term trends in anemometer heights, reporting and*

*data coding conventions, etc.* The following text would be added to the discussion.

**Ramage (1987) and Cardone et al. (1990) give many reasons for the likelihood of an artificial long-term trend contaminating the wind stress time series (especially the COADS dataset), for example the one related to the monotonically increasing proportion of anemometer measurements to Beaufort estimates in the available distribution of maritime wind reports. Bakun (1992) analyses the wind stress trends obtained off the Iberian peninsula and detected that there exist two overlapping trends, the artificial one related to the artifact and the real one thought to be associated with the gradual strengthening of continental thermal low pressure cells. Since separating the effect of their respective roles was difficult, Bakun (1992) analyzed the spatial patterns of the wind stress trend in the periphery of the North Atlantic gyre and determined that the long-term trends adjacent to the seasonally heated land masses showed increasing trends, whereas the locations away from these regions showed decreasing trends. Additionally, Schwing and Mendelssohn (2002) show that the increasing wind stress is confined to the main upwelling zone as well as the the seasonal period in which the thermal low pressure zone develops. Fortunately, we note that the problem arising from increasing proportion of anemometer measurements to Beaufort estimates is more prevalent in the time period 1900-1950 (Cardone et al., 1990). Since our analysis is mainly based on the data after 1960's the effect of artificially generated trend will be minimal. The high degree of scatter in the time series which is independent of the increasing trends, could be from the above mentioned reasons.**

**2.SST contrast time-series.**

*This class of indicator assumes that the major variation in the offshore SST gradient is controlled by the upwelling-affected near-coastal segment. But that is not necessarily so.*



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We acknowledge the fact that sea surface temperature is a mixed signal and by itself cannot be used as a direct measure of coastal upwelling intensity. However, we have used SST as support index for coastal upwelling intensity, provided there is an increase of upwelling-favorable winds. Since there are no long term measurements of upwelling velocities in the ocean, SST along with wind stress and biological productivity remain the best alternative to study long term variabilities in the coastal upwelling intensity. The passage below will be added to the discussion elaborating this.

**SST has been used as an indicator of coastal upwelling in previous studies (eg. Nyaker and VanCamp 1994, McGregor et al 2007). But the SST along the upwelling affected near-coastal segment is a mixed signal which could be altered by various factors. For example, decrease of surface mixing in the ocean could affect the offshore SST gradient. Similarly, intense storm activity in the offshore regions could deepen the mixed layer offshore while entraining cooler waters into the surface affecting the SST. Long-term changes such as climate change related relaxation of equatorial Walker circulation (Vecchi et al., 2005), could also change the SST gradient. Therefore any increase/decrease of SST along the coastal upwelling zone cannot be used as a primary indicator of coastal upwelling intensity, but it can be used as a secondary indicator of coastal upwelling intensity when there is an accompanied increase in the upwelling favorable wind.**

The additional references suggested by the reviewer will be added to the Bibliography.

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Interactive comment on Ocean Sci. Discuss., 7, 335, 2010.