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Interactive comment on "Western Iberian winter wind indices based on significant wind events" *by* E. Mason et al.

E. Mason et al.

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Final response to referees #1 and #2 concerning manuscript OSD-2005-0002

As there is some overlap in the points raised by the two anonymous referees who have contributed to this discussion, in some cases we have chosen to address their comments jointly. We thank both referees for their contributions.

How tenable is the belief about the adverse affect of offshore transport on larval survival? The main objective of the paper has been to present an alternative method of constructing a coastal wind index. The usual (or classical) method for constructing such an index is to use the wind measurements from a local meteorological station to estimate the offshore Ekman transport. Such indices are of interest to fisheries managers because of the demonstrated relationships between upwelling, turbulence and fish recruitment, particularly at eastern boundaries. Whilst there is variability in the particular nature of these relationships, the type often reported is a significant negative relationship between offshore transport and recruitment. Such studies include: Bailey (1981) in the California Current System; Boyd et al. (1998) and Roy et al. (2001) with anchovy off the western Cape in South Africa; and for the Iberian region, Dickson et al. (1988), Borja et al. (1996, 1998), Santos et al. (2001) and Borges et al. (2003). The explanation given for the observed negative relationships is that offshore transport resulting from upwelling-favourable winds is detrimental to recruitment because eggs and larvae are transported offshore into hostile oceanic waters. This is, in our opinion, and presumably that of the other authors previously mentioned, a plausible mechanism. However, its action in the environment is non-uniform in time and space, being affected by variability in the wind forcing, by the stratification of the water column, by variations in the topography, and by the presence of freshwater from rivers. Furthermore, there are other environmental and non-environmental factors that also affect recruitment, such as temperature, turbulence, food availability, predation and density dependencies. The extent of the impact of offshore transport is therefore limited, and it is also difficult to estimate. Given this highly complex set of relationships between the environment and the ecosystem, simple indices of offshore Ekman transport perform remarkably well when compared with time series of fish recruitment and catches. If alternative indices are able to equal or better the performance of the classical offshore Ekman transport model, then these ought to be reported.

Concerning the effects of different wind-speed thresholds and durations: Making indices with different combinations of parameters using our method is straightforward. We experimented with a number of combinations, but opted only to present results using the 4 m/s, 4-day parameters, because these values were justified through the modelling study of Peliz et al. (2003). In response to referee #2, we are not aware of any observational evidence to support these particular values, although Santos et al. (2004) made their survey during a winter upwelling event off western Iberia: they used wind measurements from the Carvoeiro wind station, reporting maximum northerly wind speeds of 5-8 m/s in February 2000 (see our Fig. 2 which shows this event). Nevertheless, we point out that Peliz et al. (2003) use the 4 m/s parameter as a (northerly

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wind) forcing constant within their model, but this situation is unrealistic in nature.

We do acknowledge that a description of the use of other parameters is warranted in our paper. Here we provide a brief summary, which will be expanded upon in our submission to Ocean Science. As the thresholds are lowered there is an increase in the overall numbers of significant wind days recorded. The inter-annual trends are consistent with the 4 m/s 4-day index; for example, a 1 m/s 3-day index has peaks in the early 1950s, and at the end of the 1960s and the early 1970s, after which there is a general decline until the mid-1990s - this is very similar to the pattern shown in Fig. 3. On the other hand, as thresholds are increased the data tend to tell us only about extreme events. The example suggested by referee #1, 10 m/s 3 days, yields no events; this means that from 1948 to 2003 the northerly component of the wind speed provided by NCEP (at our selected gridpoint) was not greater than 10 m/s for any 3-day consecutive period. However, there were two occasions (August 1974 and January 1981) where the 3-day northerly mean did exceed 10 m/s.

Referee #2 comments on the length of the first wind event shown in Fig. 2 that occurred in November 1999, noting that this event would have been longer if not for one day of wind just below 4 m/s. It is true that in the real world this was an upwelling event that lasted longer than the 4 days as determined by our index parameters. But this is the nature of this index; if we lower the threshold in order to capture the entirety of the event, we introduce changes throughout the index that we may not necessarily want. And there are any number of arbitrary values that we can decrease (or increase) the parameters to. We therefore made an informed choice by invoking the results of Peliz et al. (2003).

Use of annual catches and a 5-year running average: Our use of annual catches and a 5-year running average follows the work of Borges et al. (2003), who used the same sardine catch data as we did, though from 1946-1991. These authors performed a number of statistical analyses on the catch data, showing them to display long-run movements with strong memory. In relation to the annual catches, Borges et al. (2003)

obtained highly-significant correlations between annual sardine recruitment estimates and these catch values. They went on to base the rest of their study on the catch data, because the recruitment time-series is only from 1978-1999. For these reasons we chose to use the annual catch data. Concerning our use of a backward 5-year running average of the significant wind data, Borges et al. (2003) showed that in any particular year, winter upwelling off western Iberia may have a negative impact on catches for up to 5 consequent years, although the effect is strongest in the first 6-18 months.

Balance between SUFWE and SOFWE: Calculation of the hybrid index involves counts of 4 or more days with wind vectors between 180-270° true, and speed $>=$ 4 m/s. It is therefore not a summation of the SUFWE and SOFWE indices. The hybrid index was developed in response to our observation that the SUFWE relationship with sardine catches weakened in the 1980s and 1990s. We observed that during this time SOFWE winds increased, and, reasoning that they must have an influence on offshore transport (through the mechanism proposed by Tilburg, 2003), combined them with the SUFWE index. Both referees ask about the use of weighting in the hybrid index, with referee #2 pointing out that offshore transport in response to offshore winds is confined to a much shallower depth than it is in the case of upwelling-favourable winds. We have not used weighting because the bulk ($>$ 50%; Santos et al., 2005a) of the sardine eggs and larvae are usually found in the top ˜5 m of the water column, so that in terms of the effect on offshore transport of eggs and larvae, offshore and northerly winds can be considered equal.

Justification for omission of years 1999, 2000: Note that 1999 (2000) corresponds to winter 1999/2000 (2000/2001). Omission of an ‘exceptional’ year from a wind/larval recruitment time series in order to demonstrate a better correlation was done by Bailey (1981). In our data, the year 1999 may be considered exceptional, because of the in situ evidence reported by Santos et al. (2004) for a mechanism of retention of sardine larvae that was in operation in February 2000, during upwelling-favourable wind activity off western Iberia. These upwelling-favourable winds can be seen in our Fig. 2; Fig. 2b shows that it was a 10-day SUFWE, which is rather large. Santos et al. (2004) found that, despite the upwelling, the sardine larvae were retained inshore through the joint effect of the Iberian Poleward Current (IPC) and the Western Iberian Buoyant Plume (WIBP). Both of these features vary on seasonal and inter-annual scales, particularly off western Iberia. The operation of this mechanism would therefore contribute to a breakdown of a negative relationship during the time concerned, justifying our omission for the year 1999 in the regressions presented in Table 2. Omission of the year 2000 is based on the exceptionally high regional rainfalls that were experienced over western Iberia in the winter of 2000/2001 (severe flooding was reported in northern Portugal), suggesting that the WIBP would have had a significant presence, and so the retention mechanism reported by Santos et al. (2004) may have again been in operation. Chlorophyll concentrations were also particularly high off western Iberia during the months January-March 2001, which would favour sardine recruitment (P. Oliveira pers. com.). Nevertheless, we do not wish to suggest that the retention mechanism described by Santos et al. (2004) was influential in only the winters of 1999/2000 and 2000/2001; we have no further data to describe its inter-annual variability.

Omission of the winters 1992-1998 in Table 2 was intended to demonstrate the difference between the regressions for the hybrid and SUFWE indices, which we attribute to the role played by the offshore winds during the 1990s.

The breakdown in the negative relationship: Referee #1 enquires about the breakdown in the negative relationship between catches and the hybrid wind index that occurs in the mid- to late 1990s; sardine catches decrease, when the index is predicting an increase (Fig. 6). Other studies have also revealed changes in sardine abundances in the 1990s (Santos et al., 2001; Stratoudakis et al., 2003; ICES, 2002). Precisely what is driving these changes is, for the present, unknown, although studies such as Santos et al. (2005) suggest the role of climate to be important. Fishery management orders in response to the declining abundances will have had some impact on the annual catch values as well.

The winter months and sardine spawning are not the only interests: Our method may have diverse applications. We wanted to demonstrate it by comparing it with sardine abundances, for which negative correlations have previously been reported (Dickson et al., 1983; Borges et al., 2003). Hence our use of only the winter months, which is the time that sardine spawning takes place off western Iberia. We are currently applying the method to time-series of remotely-sensed chlorophyll concentrations.

Minor corrections: The minor corrections pointed out by both referees will be corrected in our final submission. The Roy et al. (2001) reference is listed below.

Remaining comments from Referee #1: R2 is the determination coefficient. In fact the negative relationship between the hybrid index and the annual catches is very strong between 1952-1980, with R2 = 0.28 and P = 0.003.

The outstanding points made by Reviewer #1 will be further addressed in our final submission to Ocean Science: Ţ "Pages 5, 6; section 3. There should be some sort of significance test, especially to improve on the cases of vagueness in section 4 (5th line - “We believe”; page 7 line 2 - “may be”)." Ţ "Final paragraphs of the discussion. This is all rather general. Progress really wants some explanation of dependencies here."

Remaining comments from Referee #2: It was 15 counts of no SUFWE for 1976-2003. However, our plot in Fig. 3 is perhaps misleading in that the year 2003 is not shown. November and December 2003 did not have SUFWEs, and this is the 15th such occurrence. We will change the range in the caption from 1948-2003 to 1948-2002, and mention the 2003 information in the text.

We did neglect to discuss the opposing yearly means for the 1999 NCEP/Carvoeiro u-velocities. Amongst the main reasons for differences between the two wind vector data sets is that NCEP values are representative of open ocean conditions, whilst the Carvoeiro winds are measured at (and influenced by) a meridional boundary; they are therefore more isotropic (in the north/south direction) than the NCEP values, as is evident by comparing the magnitudes of the mean u components from NCEP and

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Carvoeiro (NCEP is consistently greater), and is also easily seen in Fig. 1a/b, particularly during the summer upwelling season. A 4-day 4 m/s wind event implies a relatively pronounced and persistent atmospheric pattern, so that we may expect divergence between the NCEP and Carvoeiro data to be minimal during the course of an event. For these reasons we do not think that the difference between the 1999 u-velocity means would have any significant impact on the calculated index for that year. Our greatest concern was that the trend of our indices should be similar whether from NCEP or Carvoeiro, and this is the case: we produced significant wind plots (similar to Figs. 3 and 4) using the wind station data and these showed similar trends to the NCEP data, but were by no means identical as is to be expected. We chose to continue using the NCEP data, for the reasons stated in the paper.

Papers by Stratoudakis et al. (2003) and Santos et al. (2002) contain information about sardine stock sizes and distributions. The former showed that there were marked reductions in sardine egg and larval presence off northern Portugal between 1985 and 2000; they suggest that environmental factors are responsible for this decline, namely winter upwelling. Acoustically-estimated distributions of sardine were shown to exhibit comparable changes (Santos et al., 2002; ICES, 2002). Santos et al. (2005) state that the reasons for these changes in the biological components of the ecosystem are not clearly understood. Santos et al. (2005) also explain that reductions in fishing effort, introduced by fisheries managers in response to declining sardine populations, have contributed to the decreasing annual catches in recent years. Yet they go on to say that these measures alone are insufficient to fully explain the low catches, and that the role of the environment is likely to be significant. This reduction in fishing effort can be expected to have an affect on the performance of our index, so that use of annual recruitment estimates rather than annual catches may be better for the 1990s onwards.

We will include more information on the vector correlation technique, but would strongly recommend that interested persons consult the cited references, Crosby et al. (1993) in particular.

We will take the comments on the use of colour in the plots into consideration in our final Ocean Science submission, and will also include a map of the region.

Additional references introduced in this reply:

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