Ocean Sci. Discuss., 8, C475–C482, 2011
www.ocean-sci-discuss.net/8/C475/2011/

Ocean Science
Discussions

Interactive comment on "Sea surface temperature anomalies, seasonal cycle and trend regimes in the eastern Pacific coast" *by* A. Ramos-Rodríguez et al.

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Received and published: 29 July 2011

Answers to reviewer's comments:

The paper needs a thorough editing for English usage.

The paper was sent to an English language editor to improve the readability of the text.

Page 1216 line 25: "alternance" is a French word not commonly used in English.

Change to "alternation" or "cycling".

We now use alternation or cycling, depending on the context.

Introduction: Isaacs (1976, Some ideas and frustrations about fishery science. CalCOFI Reports 18, 34-43) is regarded as the first to use "regime" in the sense of alternative states of ocean ecosystems, an idea which is part of the "alternative stable states" paradigm since about 1970. Lluch-Belda and sons were leaders in developing and applying this idea to sardine-anchovy cycles and other problems in fisheries oceanography, but the concept of climate or ecosystem regimes originated earlier.

We changed the text to:

"Isaacs (1974) when talking about some issues concerning fishery science used the term "regime" referring to the prevailing of particular conditions -either biological, oceanographical, climatic, etc., over others. In this sense, a "regime" is more like an "episode", in which there is hegemony of a trend in a variable of interest."

Section 2-2: Rodionov's RSD detects points in time series when discontinuities occur. The authors need to explain the RSD plot in Fig. 2c. It looks like they have coloured the time periods (regimes) between detected regime shifts, but then what does the color scale mean?

We added to the text:

"Note that we used the regime mean obtained with the RSD to every SST monthly anomaly series to make the figure 2c, hence the color bar is representing the mean value for the regime detected in the same units as SST (°C)."

The caption of figure 2 now reads:

"Figure 2. Total solar radiation (a), Hovmöller diagram for SST monthly anomalies (b) and the same type of diagram for RSD applied to SST monthly anomalies (c). The colorbar in 2c represents the mean value for the regime detected trough RSD in the same units as SST (°C)."

Section 2-3: The explanation of how the theoretical or expected seasonal amplitude of SST was derived is not at all clear. How did you calculate annual mean and range of solar irradiance by latitude and then how did you regress observed annual ranges of SST and irradiance to get the expected annual range of SST? The applications of these data in 3.1 and 3.3 is very interesting and informative, but we readers want to be sure we understand what you did

The text now includes a more detailed explanation and the formulae used:

"To calculate the deviations from the amplitude of seasonal cycle we computed for every pixel the annual mean solar irradiance. The latter is a function of the latitude and day of year. We use equations based on the spherical law of cosines and equations modified from Spencer (1971) and Jacobs et al. (2004). First, we obtain the solar declination for a given year using,

$$\delta_t = \epsilon \cdot sin((d_t - (21 + 28 + 31)) \cdot \frac{\pi}{182.5}) \cdot \frac{\pi}{180} Eq.1 \quad (1)$$

where, δ_t is the solar declination, ϵ is the Earth's axial tilt (23.44deg) and d_t is time in Julian days. To obtain the solar altitude or azimuth (α) series for a particular latitude we used,

$$\alpha_t = asin(sin(Lat) \cdot sin(\delta_t) + cos(Lat) \cdot cos(\delta_t) \cdot cos(Y_t)) \cdot \frac{180}{\pi} Eq.2 \quad (2)$$

where, Lat is a given latitude in radians and Y_t is the hour of the day. For every latitude in the study (pixel), α was computed, and then the solar irradiance for such latitude ($Irr_{Lat|t}$)was calculated as

$$Irr_{Lat|t} = sin(\alpha_t \cdot \frac{\pi}{180}) \cdot Irr_{net} Eq.3 \quad (3)$$

where Irr_{net} is the amount of net solar irradiance received by the Earth's surface (344 W m^{-2}). We assumed an albedo of 0.3, hence the net solar irradiance used was 240.8 W m^{-2}. The amplitude of the solar irradiance for each latitude was obtained calculating the statistical range. This results in a theoretical latitudinal solar irradiance amplitude series, which is used to compute regressions (from equator to 60N and from equator to 60S) against the mean SST seasonal amplitude to obtain a theoretical curve of latitudinal SST amplitude based on solar radiation (figure 1a)."

Section 3-1: The description of these results would be easier to read if it was presented as a list. For each latitudinal band, does the observed annual SST range differ from the expected, and why? I understand that for the California Current, summer upwelling results in summer SST lower than expected, and this results in an annual SST range less than expected. Please explain how seasonal upwelling in the Peru Current system is different and results in an annual SST range greater than expected.

A table is now included with seven different latitudinal bands. And the text now reads:

"From 44 to 30N is an area influenced by both the California current and coastal upwelling. This is a template zone with a seasonal SST range of about 5-6°C, nevertheless upwelling and California current make this area cooler and more homogeneous, thus reducing the seasonal cycle and the SST range falls below the TC (0.45-1.5°C) with smaller differences in the latitudinal band 36-34N."

"To the south, from the Equator to 28S we find the Humboldt or Peru current region and intense coastal upwelling. This region is embedded in a tropical area and it should have a smaller SST range (around 2-3°C) but due to the cold current and the upwelling the seasonal cycle is much greater ($>$6°C). Consequently, the range is above the TC (values between 0.8-5.1°C) with largest differences in the upwelling region between 4 and 12S (4 to 5.1°C)."

Page 1222 line 9: "Southern Oscillation" should be capitalized

Changed now to "El Niño Southern Oscillation".

Section 3-2: It would help in this discussion to consistently use the labels "solar cycle" and "SST regime". As now written, it is not always obvious what is meant by cycle, regime, or period.

We changed this accordingly throughout the text.

The authors argue that the cold and warm regimes (1 and 2) have significantly different areas under the TSI curves. Solar irradiance is the power of solar radiation and is normally measured per unit area (W m^{-2}). Solar irradiation is the total amount of solar energy that is accumulated on an area over a period of time. So one refers to power and the other to energy. Therefore, the authors are correct that integrating the TSI curve over time does give irradiation or energy. The problem is that integrating 11 to 12-year cycles over two successive regimes depend on (1) where the regime shift is located relative to the cycles, (2) the lengths of the regimes, and (3) actual changes in solar radiation. The abstract says TSI was integrated over 1952-1975 (24 years) and 1977-1999 (23 years), but the SST regimes are 1950-1978 and 1979-1999. The low-irradiance solar cycle during the second half of the 1950-1978 cold regime may be

important, but the authors should be careful about how they present these results.

We eliminated some details from the abstract in order to avoid confusion. And we explain in section 3.2 that the integration is carried out over full solar cycles present in every SST regime, and these differ in length. The results now read:

"The area below the curve is the energy received in the period of integration. To compare the energy received during successive pairs of solar cycles we computed the area below the curves. The first integration is carried out for two consecutive cycles, from 1954 to 1975 (a total of 22.5 years), and the second also for two consecutive cycles, from 1976 to 1996 (a total of 21 years). The difference between the area below the TSI curves of the first and second SST regimes is of about $3{\cdot}10^{8}$ J m-2."

Page 1224 lines 5-6: This sentence is meaningless. Rewrite and/or expand.

Sentence eliminated.

Page 1224 line 15: change "zonal" to "meridional" or "latitudinal"

The whole sentence now reads:

"TA in figure 3a clearly denotes a latitudinal gradient explained by the SST mean latitudinal range. . . "

Section 3-3: There are some valuable results here, but the discussion would be easier to understand if the authors explicitly stated that (1) changes in the annual (=seasonal) amplitude of SST (TA) are not caused by overall warming or cooling, but by processes

that result in seasonal warming or cooling, and (2) changes in the residuals (TR) are caused by seasonal warming or cooling that is out of phase with the seasonal cycle warming/cooling due to solar irradiance (TC). I think this is implied in the words "interaction with the Humboldt Current" on page 1224 lines 24-25. However, there is confusion about this in the sentences on page 1225 lines 4-6 and lines 13-15.

Paragraph now includes at the beginning:

"It is important to notice that latitudinal TA is caused by seasonal changes in solar radiation; meanwhile changes in TR are likely caused by physical processes such as ocean currents capable of modifying the phase of the seasonal warming/cooling cycle due to solar irradiance."

1225 lines 4-6 and lines 13-15 were modified to:

Lines 4-6
"The southernmost portion (52-60S) shows the lowest negative residuals (-5 to -7°C) and lowest temperatures (around 5°C) and is influenced by the Antarctic circumpolar current."

Lines 13-15
"This region should have tropical and homogenous temperature based on the latitude but it has a greater temperature changes during seasonal cycles than expected. This is due to the cold Humboldt current and seasonal upwelling."

Page 1226 lines 5-6: replace "as evidence of the power of the currents" with "by".

It now reads: "...they alter the SST range near the coast by distributing the energy received to other latitudes..."

Page 1226 line 26: replace "on earth" with "of the time series".

It now reads: "...30yr of the time series..."

Page 1227 lines 6-7: Considering my comment on section 3.3 above, the alteration of TA or TR by ENSO events is not a new observation. El Niño has long been known to be a seasonally phase-locked event (peak SSTA along Peru coast in December-January), hence its name.

The text now cites some works about this characteristic of ENSO:

Section 3.3
"It is worth noting that ENSO events have a strong effect over the seasonal cycle, amplifying it or reducing it (Trenberth, 1997; Galanti and Tziperman, 1999; Neelin et al., 2000)."

Conclusions
"We corroborated that some climatic variability, such as ENSO events, is capable of altering the amplitude of the seasonal cycle. This has been recognized by many authors and some of them report that its effect can be superimposed on the long-term climatic alterations."

I would like to thank for the comments and the review.