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Ocean Science Discussions

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Interactive comment

Interactive comment on "Do sun spots influence the onset of ENSO and PDO events in the Pacific Ocean?" *by* Franklin Isaac Ormaza-González and María Esther Espinoza-Celi

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Dear reviewer, we are grateful for your time put on our manuscript and appreciate the comments made on it. We would like to make some notes with most respect and without intending any conflictive discussion. We think the paper contributes a better understanding of the ENSO (La Niña and El Niño) and also PDO and AMO longer scales fluctuations. We are sorry we have taken some time to reply you, but, as per your suggestion, we have revised the entire paper, we have reviewed and have re-rewriting many parts with the help of two well-known British scientists. We also were waiting for the second reviewer appraisal; we have now that. We will try to reply every

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point you did, in the hope you re-consider your first revision.

1.- No robust results. The full paper is telling correlation numbers from the beginning to the end, without any efforts to understand or explain the related physical processes and underlying mechanism. We took as dependent variables, four indexes plus SST and anomaly SST from different oceans areas placed in the equatorial Pacific Ocean (from 170W to 82W) in which are regions areas 3.4 (5°North-5°S, 170-120°W) and 1+2 (0-10°S, 90°W-80°W). The first is the reference area for ONI and MEI indexes as well as SST and anomaly SST and it is an open area; whilst the second area is where much of what happens in 3.4 is reflected, but this one is close to coast. These four variables are inter-related and used to determine ENSO processes (El Niño, La Niña and neutral episodes), which are interannual, lasting 12-18 months. The AMO and PDO refer to SST behaviour of the North Pacific and Atlantic which are larger oceanic areas than 3.4 and 1+2. The relationship between and AMO and PDO is widely accepted (as shown in the paper) and ENSO is associated somehow to PDO; thus, during cold phase PDO, La Niña events are more frequent and intense than El Niño. When PDO is on warm phase the contrary. The most intense and damaging El Niño (fully developed) occurred between 1980-2000, which is a period of warm phase PDO. Two most intense and prolonged La Niña happened during colds phase PDO (1954-1979) and 2001-present. The independent variable was the monthly SS from 1954 to 2017 represent 6 cycles. The SS is an accepted way to estimate Sun activity and “The Sun’s activity cycle governs the radiation” (Bhowmik and Nandy, 2018), which in turn affects the heat content of the ocean surface and therefore the indexes above mentioned; in the section Introduction we explain thoroughly. We add, Higginson et al. (2004, paragraph 39) said “Our analyses of recent SOI fluctuations, El Niño frequency and intensity, suggest a coupling between the âĹij11âĂŘyear solar luminosity cycle and the SOI. Specifically, if we filter the SOI for El Niño (shaded gray) and La Niña (solid black bars) excursions, the more gradual quasiâĂŘcyclic trend of the SOI is inversely correlated with Sunspot Index (SSI) with approximately 24 months lag”. See Fig 1. The SOI index is part of the ENSO, but we did not consider it, because it is highly volatile.

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So, we have a clearly defined dependent and independent variables. We tried to evaluate the possible relationship taking the whole period of six cycles together, individual cycles and their ascending and descending phases, plus 1990-2017 and 2000-2017, per each variable and lag times of 6, 12, 24, 36 and 48 months Understandably there is an enormous amount of correlations, we did take the most important and perhaps risking being too reiterative and tedious we decided to report them for all variables and combinations, but our intention is to show how most of them are in concordance and all signalling how the dependent variables correlate with the independent one. Also, the intention was to show the reader them, so they can also judge and not only us. Nonetheless what we think, we have significantly reduced the number of correlations shown (please see new rewritten manuscript). Every effort was made to explain the poor and high correlations in terms of physical and oceanographic processes. It can be seen in lines: 245-254, 231-237, 260-263, 268-273, 277-285, 300-310, 318-326, 333-336, 342-347, 353-374, 384-388, 399-403, 410-413 and so on.

In the section Results and discussion every correlation is explained and understood. This section has been rewritten to make clearer what you mention. In the same form, the section conclusions have been modified accordingly. Thus, the results are robust (consistent correlations with $p<0.01$) and explained for the purpose, which basically "attempts to understand how the sunspots may affect low and high frequency oceanic events such as the Pacific Interdecadal Oscillation (PDO), the Atlantic multidecadal oscillation (AMO), anomalous sea surface temperatures, and El Niño and La Niña events".

2.- Not valid methods. For the solar impacts on climate, it's true that correlation has been used widely in previous studies. There is always a problem while using correlation since a relative high correlation number might just be caused by occasional in phase of two variables. So, a long data record is necessary while considering the relationship between the sun spots numbers and other climate indices. Again respectfully. If the method is not valid for this paper; why should it be OK for previous accepted and re-

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ported studies. Every scientific method has shortcoming and limits. Recently, a paper correlating SS and rain over Europe has been published, and is reporting correlations factors similar with lag times in the range reported by us: "…. Taking into account cause and effect, it is suspected that increases in Central European rainfall are actually triggered by the solar minimum some 3–4 years before the rainfall month, rather than the lagging solar maximum…." (see, Laurenz et al. 2019). Similarly, Higginson et al. (2004) reported SS association to SOI index; this index is part of ENSO, with similar length of data (see Fig. 1). Thus, these paper are talking about cause-effect. Correlation analysis can be accepted to find any association between an independent (SS) and dependent (SST, Anomaly SST, ONI, MEI, PDO, AMO) variables. All variables are inter-annual and decadal (not climatological). These correlations are logical as the dependent variables are affected by the sun radiation, which in turn can be estimated by sun spot activity (see formula 1, line 55). Simply, the physical process is energy from the most important source (sun) being transferred to sea surface water and loosing energy through other processes (evaporation, upwelling, friction, for example). In the present case we are not even attempting to say that dependent variables are only affected by SS. Not at all, but SS play its role, and this role sometimes is poor (low r2) and sometimes is important (high r2). These indexes are also affected by others oceanographic and even anthropogenic variables (see Laurentz et al., 2019). Consistent higher correlations were found in area 3.4 than 1+2; why? In 1+2 there are more intense dynamic processes affected by winds, interaction of different ocean water mass (north and south equatorial currents), transport of panama Bay heat content mediated by trade winds from the Atlantic, higher and variable cloudiness due to the geographical variability of the ITCZ (intertropical convergence zone), Humboldt and Cromwell upwelling, etc. whilst in 3.4 do not exist upwelling, cloudiness is less affected by land-atmospheric processes, not trade winds from the Atlantic. The outcome of the higher correlation values in 3.4 is logical.

2. ... This study did the correlations between the sun spots numbers with other variables for each individual cycle (âĹij11 years) and even for the ascending or descending

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phases (only 4-5 years), which is not meaningful to my understanding. During such a short period, a high correlation number just means that the sun spots number is in phase with other climate indices occasionally The paper analysed the whole length of 6 cycles (1954-2017) of SS (monthly counts) and a period from 1990 to 2017. The correlation r2 of the 6 cycles showed consistency (even though at lower r2) with those analysed during shorter periods (1990-2017), individual cycles (around 130 months) and ascending/descending phases (around 5 years, 60-70 months). See lines 161-163, number of samples. El Niño event is aperiodic but tends to occur every 2-5 years (24-60 months) and it tends to last around 12-15 months. On the other hand, the lag time is on average period of 24-36 months. Thus, there would be at least one El Niño or La Niña event in every ascending or descending phase. At least 60 points (SS, index) were linearly correlated. On the other hand, it has been reported that a required size of the sample is 25 or more (David, 1938). In here, the freedom degrees are around 58 or more. When one dependent variable correlates well with its independent variable the r2 get closer to 1, that would imply is the only cause; but in this case the sun spots (solar activity) are not only cause of the index variation, and reasons are given for that. Respectfully, 6 ascending and 6 descending phases were analysed, and at all times the indexes were in “phase” at lower or higher value (r2) in a consistent manner. To us, to be in “phase” would mean the SS (sun energy) is the only force affecting the index directly and so the slope of the linear regression will be similar (or almost) in every ascending phase. It is hard to say the pair of variables were in “phase” when the slopes were different in every ascending/descending phase (we are going to add one or two graphs to the paper to show this). The p-values were always «0.01, so that means chances to be phase occasionally are very low. Finally, imagine, we have an area of ocean surface with the same initial SST, without any cloudiness, winds, currents, etc. being irradiated by a single slightly variable source of energy. Can we say the heat content would be directly influence by the source? The answer is yes. If the source have higher energy (ascending phase) the heat content will increase and vice versa. A change of 1.5 Wm-2 (1289 cal/hour) between peak and valleys of the SS probably is important, although the IPPC (2001) has consider this value not significant in forcing climate. Climate is understood a time spam over 30 years (https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html).

3. Overstated conclusion. There might be some connection between the sun spots number and other climate indices such as PDO and decadal ENSO. However, I do not believe we can do a prediction for El Niño or La Niña events only based on sun spots numbers as stated by the authors in the abstract and conclusion. Re-reading, the way the abstract was written, you are quite right. It could lead the reader to arrive that conclusion is overstated. We are trying to put in the front line the fact that solar activity variation of energy in magnitude and quality (radiation spectre changes in the ascending/descending phase and cycles) affects the indexes. We do not pretend to forecast El Niño La Niña events just by using SS, not at all. However, it is heuristically reasonable to suggest the not occurrence of a full-fledged moderate-strong el Niño till 2020-2021. We said this when writing the paper by early 2018, and in fact by mid-2018 models were suggesting an El Niño in August-September, it did not happen, actually the region 3.4 and 1+2 cooled down by the end of 2018. The latest report from http://www.bom.gov.au/climate/enso/#tabs=Overview is saying "The El Niño–Southern Oscillation (ENSO) remains neutral. However, the Bureau's ENSO Outlook remains at El Niño WATCH, meaning there is approximately a 50% chance of El Niño developing during the southern hemisphere autumn or winter...". Nonetheless, NOAA view is that a weak El Niño conditions are present now and to expect to continue through the Northern Hemisphere spring 2019 (~55% chance), https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf. The fact is, El Niño is not fully-fledged; id est, the meteorological (SOI) and oceanographic are not connected. At this moment (march 24, 2019) the oceanographic and meteorological variables have not fully couple yet. During the 2108 and 2019 the SS have been very low in numbers (see text) and for many weeks they have disappeared from the sun, thus the sun energy is at the lowest radiation. Perhaps a fully fledged El Niño needs a "little" extra solar energy. The new ascending

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phase would happen in 2019, having a lag of 24 months or so, 2020-2021 is not unreasonable period in which a fully-fledged El Niño could occur.

4. Not well organized and written.

We followed your suggestion, a well-known and prestigious Professor from UK helped with edition and review. Revised manuscript is being submitted. Finally, again we appreciate the time put to our paper. Your comments have made us to improve it.

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Fig. 1 from Higginson *et al.* (2004)

Plot of long-term SOI over the past 50 years overlaid by SSI (total solar irradiance) best fit lagged by 24 months. Intervals when the SOI is significantly above the SSI curve are marked with solid black bars, and significant intervals when it drops below the SSI are indicated by cross-hatching. The largest negative excursions of the SOI from the SSI are shaded dark gray.

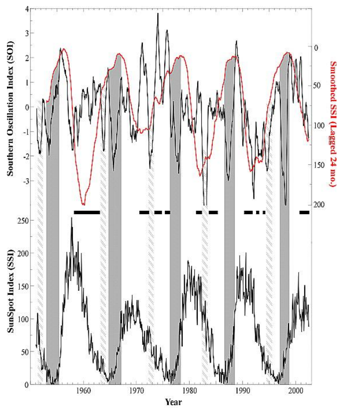

Fig. 1. Fig. 1 from Higginson et al. (2004) Plot of longâĂŘterm SOI over the past 50 years overlaid by SSI (total solar irradiance) best fit lagged by 24 months. Intervals when the SOI is significantly above th

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