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Discussions

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 much appreciate your time put on our manuscript and consider invaluable your comments made on it. We would like to make some notes to them with most respect and without intending any conflictive discussion.

Similar comments were done from the AR1. We have responded her/him and we deem much of the reply to AR1 will satisfy yours (hope so). Please see the attached document or you could please go directly to the reply to AC1. In any case, we are trying to respond to your comments.

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 rewritten many parts with the help of two well-known British scientists.

We will try to reply every point you mentioned, in the hope you re-consider your first revision.

1) You. In this paper the authors are exploring the relationship between sunspots and their impact on ENSO and PDO in the Pacific Ocean. It was difficult for me to find an answer to the title's question, "Do sun spots influence the onset of ENSO and PDO events in the Pacific Ocean?" It is difficult for me to tease out the main points of the paper because I find the structure unclear and the figures don't effectively summarize the main points either. Annotation of the figures could help address this.

We. We think the paper contributes to a better understanding of the ENSO (La Niña and El Niño) interannual events and also PDO and AMO decadal scales fluctuations. There have been many studies on how the SS could affect ENSO processes (please see introduction section), rain in Europe (Laurenz et al., 2019), SOI (Higginson et al., 2014), etc. Here we attempt to use as many variables as we can in different oceanic areas: Equatorial Central Pacific (area 3.4), Eastern equatorial Pacific (area 1+2), Northern hemisphere Pacific and Atlantic basins using 6 indexes. So far, forecasting models do not take into account the influence of sun spots number or any parameter that measures the solar energy heating the surface area. Perhaps, this is one of the reasons why sometimes they fail to predict El Niño (area 3.4) and its impact (in area 1+2 for example). Nonetheless what said, we do accept the paper has a weak and perhaps confusing writing, which has been amended by the edition and revision of two scientists from UK. All sections have been worked, specially abstract and results/discussion and conclusions. The manuscript is now stronger. Figures have been reduced to 10 and we are working on improving their captions.

2) You. There was clearly a lot of work done but I do not feel like it is presented in a

way that effectively supports their arguments and that correlations are insufficient for their claims, which remain a bit unclear. I recommend that this article be rejected as its structure is unclear and hard to read, main questions are not outlined clearly, and the presented statistics don't support the conclusions being made.

Thank you very much for recognizing the amount of work done, yes we run over hundreds of tests that included spectral analysis, non-linear regression analysis and multiple regression analysis was tried. It was a painstaking work, though very perfectible one. We did believe to show how SS correlate to these indexes and how they are consistent, our objective was that, it did not attempt to model SS and ENSO and PDO. We tried to find if there is any influence of SS on the ENSO and PDO indexes

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). Fig. 1 shows the variation of ONI in terms of SS ascending phases of the six cycles (left panel) with a lag time of 24 months and per each cycle (right panel). The linear regression curves at SS close to zero shows that the ONI is somewhere between 0C to -2C, whilst in the range 50-200 sun spots the ONI is predominantly positive. Overall all ascendant phases together give an r2 ($p<0.01$) of 0.11, in some cycles (22 and 23) the r2 was 0.6. We deem this a clear evidence on how SS (read solar radiation) affect the studied indexes. âĂČ ———— Fig. 1. Linear regression curves for all ascendants phases of cycles 19-24 (left panel) and per each cycle (right panel). Note. This figure is going to be part of the revised manuscript. ————

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 other oceanographic and even anthropogenic variables (see Laurenz et al., 2019). Consistent higher correlations were found in area 3.4 compared to region 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 it does not exist upwelling, cloudiness is less affected by land-atmospheric processes, there are not trade winds from the Atlantic, not upwelling in Panama Bay, etc. not Humboldt neither Cromwell, although variable SOI occurs. The outcome of the higher correlation values in 3.4 is logical as it was for other indexes though variable correlation. Note. The three last paragraph were taken from Reply to AC1.

3) You. The paper reads like a list of rËĘ2 values and Pearson correlation coefficients and is lacking a coherent narrative. Not every correlation needs to be typed out, they can be in a table or figure and referred to. In these long lists it is hard to identify the most important ones.

We mainly used r2, in a very few occasions used Pearson coefficients, perhaps we lack of good written narrative, but we think now it has been improved (see revised manuscript). Of many dozens r2 we tried to get the most relevant, even though we are aware we have written too many risking being tedious and repetitive, but we want the readers have chance to see much of the correlation found so they can judge. By choosing the best one, you could perhaps eventually become biased. Perhaps it was our naivety to have written a lot of r2 and their respective p-value. Respectfully, we do think report r2 and its respective p-value have to be done to show how strong (not casual) is the correlation.

4) You. Their argument hinges on these statistics but I do not believe that they can sufficiently support their claim that ENSO and PDO are driven by sun spots. This is

because correlation does not imply causation, slightly misleading from their title, and correlations can be artificially high due to a brief periods of in-phase activity. These caveats should be mentioned and can be remedied with longer time series.

Please see answer to comment 2, and also reply to AR1. Again respectfully, our titular question we think is answered without any misleading, and correlations cannot be considered artificial, it that was the case the slopes of linear regression should have been the same, are not. For these reason we decide to report most of slopes, r2 and p-value to demonstrate consistency through time, space and between indexes. Many other researchers have done so (e.g. Laurenz et al. 2019, please references).

We know, high correlation does not necessarily mean causation. That depends on the variables. If you for example correlates % of people that have access to internet in developing countries through the last 25-30 years (https://cacm.acm.org/magazines/2018/7/229046-bringing-the-internet-to-the-developing-world/fulltext), you will have a good r2, but you cannot say % of access is due to time. But if we measure photosynthesis rate (see e.g., http://biol14042013.blogspot.com/2013/02/factors-limiting-rate-of-photosynthesis.html) in a water body and irradiance (e.g. 600 nm wave length), probably there will be a good correlation (fig 2) of any regression analysis done. Then you and we could talk about causation, light is the independent variable and photosynthesis rate de dependent one. Laurenz et al. (2019) in their paper they talk that SS triggers rain events. . . . âĂČ ———— Fig, 2. Rate of photosynthesis in terms of irradiance. Figure taken from http://biol14042013.blogspot.com/2013/02/factors-limiting-rate-of-photosynthesis.html. ————-

5) You. I do not think that the methods used can answer the titular question. There needs to be more interpretation and context with the rËĘ2 values, rather than listing them. More error and uncertainty discussion would also improve the paper.

We. The title opens the question about SS possible influence on ENSO and PDO

and the way to answer was legitimate use of linear regression analysis which allows to determine correlation and its p-value, thus respectfully we deem we answer the question. Yes, sure, there is room to improve interpretation, explanation and context. Please see lines (version attached to AR1): 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

6) You. Therefore, as is I do not think these statistics can be used as a predictor for ENSO. This paper would require structural overhaul with clearly defined sections and goals.

We. Again respectfully. If the method is not valid for this paper; why should it be OK for previous accepted and reported 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). 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". The SOI index is part of the ENSO, but we did not consider it, because it is highly volatile. Thus, Higginson et al. (2004), Laurenz et al., (2019) and others in the reference section are talking about cause-effect.

7) You. The figures should be annotated and streamlined to be more easily interpreted and more clearly support the main arguments. Additionally, the paper requires editing by a native English speaker, much of the science gets lost in the presentation. You are right dear reviewer. It has been done. Two figures have been compiled together and we have reduced from 12 to 10.

Finally, we are indeed grateful again for you review, your time to analyze and write the review, we know how busy you should be. Your comments have made us to improve our paper. Can we acknowledge your contribution, in the respective section? Again, we have been very respectful, if any expression caused an inconvenience, we apologize indeed.

Sincerely,

Franklin I. Ormaza-González and María Esther Espinoza-Celi,

âĂČ References. Bhowmik and Nandy. 2018. Prediction of the strength and timing of sunspot cycle 25 reveal decadal-scale space environmental conditions. NATURE COMMUNICATIONS | (2018) 9:5209. https://doi.org/10.1038/s41467-018-07690-0 Higginson, M. J., M. A. Altabet, L. Wincze, T. D. Herbert, and D. W. Murray (2004), A solar (irradiance) trigger formillennial-scale abrupt changes in the southwest monsoon?Paleoceanography,19, PA3015, doi:10.1029/2004PA001031 Laurenz, L., H.-J. Lüdecke, S. Lüning (2019): Influence of solar activity on European rainfall. J. Atmospheric and Solar-Terrestrial Physics, 185: 29-42, doi: 10.1016/j.jastp.2019.01.012

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2018-125/os-2018-125-AC3-supplement.pdf

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2018-125, 2018.

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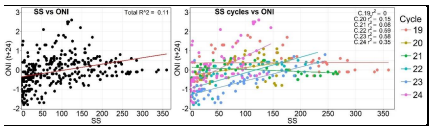
Reply to Anonymous Referee #2
April 2, 2019

Fig. 1. Linear regression curves for all ascendants phases of cycles 19-24 (left panel) and per each cycle (right panel).



Note. This figure is going to be part of the revised manuscript.

Fig. 1.

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Fig. 2. Rate of photosynthesis in terms of irradiance. Figure taken from http://biol14042013.blogspot.com/2013/02/factors-limiting-rate-of-photosynthesis.html.

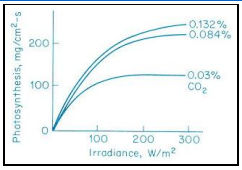

Fig. 2.