# Response to the Editor

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Dear Editor,

many thanks for your constructive suggestions, please find below a pointwise reply to all of them, where your comments are in italic.

1. *the station that displays very regional characteristics'. The sentence is a bit cryptic. On the one hand, they both correlate with ENSO, but one is "very regional". The message should be more specific and accurate.*

   Thank you for the comment, we propose the following change.

   > We investigate whether there are correlations between temperatures on the Eastern South Pacific coast, influenced by the Humboldt Current System, and El Niño–Southern Oscillation (ENSO) events, using a set of 16 oceanic and atmospheric temperature time series from Chilean coastal stations distributed between 18° and 45° S. Spectral analysis indicates periodicities that can be related to both internal and external forcing, involving not only ENSO, but also the Pacific Decadal Oscillation, the Southern Annual Mode, the Quasi–Biennial Oscillation and the lunar nodal cycle. We carry out a nonlinear time series analysis. An asymptotic neural network test for chaos based on the largest global Lyapunov exponent indicates that the temperature dynamics along the Chilean coast is not chaotic. We calculate local Lyapunov exponents that characterize the short–term stability of the series. Using a cross entropy test, we find that just two stations in northern Chile, one oceanic, Iquique, and one atmospheric, Arica, present a significant positive correlation of local Lyapunov exponents with ENSO, with Iquique being the station that presents the greater number of regional characteristics that help it to correlate with ENSO differently from the rest. This work, having a large–scale study area and using time series from hitherto unused sources (naval records), reveals the nonlinear dynamics of climate variability in Chile.

2. *l. 25: "negative trend observed in the PDO" : is this a trend in the mean or in the variance ?*

   Reading the article in detail, we see that Falvey and Garreaud [2009] refer to the trend in the average temperatures. We will clarify this in the article.

3. *l. 50: "rigorously": use a more specific word. In what sense is this 'rigorous'.*

   Rigour here is a specific word; we mean mathematical rigour, so we can write that: "mathematically rigorous".

4. *equation p. 7: The equation only makes sense if $\delta$ is a line-matrix (meaning a vector), while it is defined as a norm p. 6. There is also confusion about the old / italic convention. The $J_{m-t}$ is a Jacobian (a matrix), and so should $T_M$, but $T_M$ appears both in boldface and in plain. While the development is classical, many readers might not get why only the largest eigenvalue $\nu_1$ (and not the other ones) survives under the limit $M \to \infty$.*

   Thank you for the comment, you are right and we have revised and made consistent the mathematical notation throughout the paper, esp. Sections 2.2 and 2.3. Of course $\delta$ is a vector and that was a typo. Also, we have clarified why only the largest eigenvalue survives asymptotically.

5. *p. 7: You mention the 'first approach', .... but never the 'second approach'*

   see next comment

6. *Methods have not been fully presented before the Results section. At this point, the reader understands the definition of the short-term Lyapunov exponent in a dynamical system where the Jacobian is available, but not the algorithmic methods and choices that allow for the estimation of the short-term Lyapunov exponent from an empirical (uni-variate) time series, and how critical are these algorithmic choices. Little to nothing is said about the feed-forward neural network model (l. 220) and the BIC that are central to the results.*

   Thank you for the comments, we have re-worked Sections 2.2 and 2.3 and inserted a new Section in the Appendix dedicated to neural networks modelling of random dynamical systems, see our reply to point 4. of Referee 1.

7. *p. 12: "this does not happen". Not clear what "this" refers to (negative LLE for all time series ?). Using positive wording (LLEs are positive for AST) might help.*

   We have clarified as follows:

   Boxplots of the LLEs versus steps ahead are shown in Fig.6 and 7. Clearly, the sea surface temperature series approach the global exponent faster than the atmospheric series. For instance, for $M = 28$ steps ahead, the boxplots of the LLEs are already negative for all the SST series, with the exception of Puerto Montt; Fig.6.On the contrary, for $M = 28$ all AST time series still have positive LLEs.

8. *The discussion on p.15 is not easy to follow. I understand that LLE may increase or decrease during an El-Niño event, and this depends on the epoch. l. 259 one refers to a "marked decrease" during the 192-1973 event but the reader will not know how well it is "marked" and what this means.*

   We have added the relevant figures to facilitate the comphrehension. Please see the following revised paragraph:

   In the case of the atmospheric stations, that in Antofagasta, the 1 month window shows unstable behavior throughout the entire record and shows a temperature change (higher to lower) during the 1972–73, 1982–83 and 1997–98 El Niño events (see the highest temperature peaks in Fig.D4c). In the case of Arica, for the same window, a decrease in the unstable part is observed for the same El Niño events plus that of 2014–16 (see the highest temperature peaks in Fig.D4a). For its part, Puerto Montt, in its 1 and 6 month windows, behaves in the same way as Antofagasta in its oceanic record, that is, it shows continuous and unstable behavior throughout the entire time series (see Fig.D1h and D4h). The same occurs with Rodelillo for the 1 month window (see Fig.D4e); its behavior is similar to that of Antofagasta and Puerto Montt. Finally, for the 1 year window in Serena, instability seems to increase from 1971 to 1982–83, which is where it coincides with the El Niño event of that year, the behavior decreases and increases again to coincide with El Niño of 1987–88 and likewise, a peak of instability coincides with El Niño of 2014–16 (see Fig.D6d).

9. *More broadly, I would strongly encourage the authors to reconsider their choices of figures. On the one hand, the boxplots (Fig. 6) linking the short-term to long-term Lyapunov exponents are interesting but perhaps they can go in the appendix or supplementary material. By contrast, the presentation p. 15 describing the evolution of indices through time must be supported by figures (especially given that, l. 273, you acknowledge that the result presentation so far lays upon a "visual comparison", which the reader cannot reproduce).*

   Thank you, we have inserted the relevant figures, see the following revised paragraph.

   In the case of the oceanic stations, we may note the following by a visual comparison: in Antofagasta the expected behavior is observed, that is, the whole series shows continuos instability for the 1 and 6 month windows, always showing the same behavior throughout the record (see Fig.D1c). This may be due to the warm water pool that is always found here simulating an El Niño. The same continuos pattern is observed for the 1 year window, only this time the behavior is completely stable (see Fig.D3c). Arica shows instability throughout the record for the 1 month window, where instability decreases during El Niño events of 1953–54, 1958–59, 1963–64, 1965–66, 2009–10 and 2014–16 (see Fig.D1a). During the 6 month and 1 year windows, it becomes more stable than unstable and shares the same behavior with Talcahuano, where the third cut can be located lower than the other two and a very marked variability in the LLE can be seen (see Fig.D2a, f and D3a, f). In these two stations the trajectory of the phase space for the second cut is interrupted (see Fig.4). In Talcahuano, interesting behavior is only observed, with respect to the ONI, for the 1 month window, where the instability for the first cut, 1949–1974, decreases during El Niño events of 1953–54, 1958–59, 1963–64, 1965–66, 1968–69 and 1972–73, to show rising behavior in the third cut of 1991–2020 during El Niño events of 1991–92, 1994–95, 1997–98; 2002–03, 2004–05, 2009–10 and 2015–16 (see Fig.D1f). In the case of Iquique, the 1 month and 1 year windows have stable/unstable behavior, it is the only series in which the peaks of both the stable and unstable part coincide with several El Niño events of 1987–88, 1991–92, 1994–95, 1997–98, 2002–03, 2004–05, 2006–07, 2009–10, 2014–16, 2018–19, 2019–20 (see Fig.D1b and D3b). For the 6 month window, the behavior is stable throughout the record, but the stability peaks continue to coincide with the same El Niño events, with the exception of 2002–03, 2004–05, 2006–07, 2018–19 and 2019–20 (see Fig.D2b). Finally, Valparaíso, in the 1 month window, shows a decrease in the unstable part that corresponds to El Niño events of 1968–69, 1972–73, 1982–83, 1997–98 and 2014–16 (see Fig.D1e).

In the case of the atmospheric stations, that in Antofagasta, the 1 month window shows unstable behavior throughout the entire record and shows a temperature change (higher to lower) during the 1972–73, 1982–83 and 1997–98 El Niño events (see the highest temperature peaks in Fig.D4c). In the case of Arica, for the same window, a decrease in the unstable part is observed for the same El Niño events plus that of 2014–16 (see the highest temperature peaks in Fig.D4a). For its part, Puerto Montt, in its 1 and 6 month windows, behaves in the same way as Antofagasta in its oceanic record, that is, it shows continuous and unstable behavior throughout the entire time series (see Fig.D1h and D4h). The same occurs with Rodelillo for the 1 month window (see Fig.D4e); its behavior is similar to that of Antofagasta and Puerto Montt. Finally, for the 1 year window in Serena, instability seems to increase from 1971 to 1982–83, which is where it coincides with the El Niño event of that year, the behavior decreases and increases again to coincide with El Niño of 1987–88 and likewise, a peak of instability coincides with El Niño of 2014–16 (see Fig.D6d).

10. *The spectral analysis section 4.1 should be part of the result presentation, not the discussion.*

    At present this section is both results and discussion. We then should separate them, with the main findings in the results section with all the spectral peaks obtained for each station specified and here in section 4.1 adding possible explanations to the periods found and in which other studies these periodicities have appeared.

11. *Attributing spectral peaks to forcing or processes (lunar perigee subharmonic, QBO) is a delicate task, with significant risks of misattribution. Using the conditional (with the magic phrase "may be") is a wise precaution, but somewhat unsatisfactory. For example, in this particular case, can you check the phase coherence of the signal with these processes?*

    Thank you for the comment. We are aware this is a bit speculative but we support it by citing several articles about sedimentation data where high energy peaks can be related to the QBO. Our analysis is similar to that of the works we mention as we find in our data periods that have been already associated to QBO. Of course this is a correlative analysis and we will investigate the relationship between the QBO and the spectral peaks in a future work and give the discussion of this topic the space it deserves.

12. *The discussion of the nonlinear analysis (section 4.2) is also a bit tedious, some would say speculative. It is fine to formulate hypotheses, but consider the following advices: - refer to figure numbers when you describe a specific feature (to help the reader make its own judgments. For example, when you write "it is also possible to observe similar dynamics", "it can be noted by eye")*

    See 17 below.

13. *Discuss and describe possible ways to verify your hypotheses. What would it take to verify the teleconnection processes; verify the role of the atmospheric teleconnections, the role of the Pacific anticyclone, or the fact that disturbances coming from the equator only influence the northern part of Chile).*

    We will mention the matter. In general this will require a lot more data, and would be for future studies to look at.

14. *avoid non-necessary conditional (e.g.: "it is also possible to observe" : you observe it, or you don't).*

    Thanks, we will check and amend.

15. *l. 412 : "but rather Southern Annual Mode" : the sentence is unclear.*

    Yes, it should be written the other way round:

    > As this station is located south of the southern limit influenced by El Niño, we can postulate that El Niño is not responsible for the climate variability that may occur in this station, but rather Southern Annual Mode (SAM) (González-Reyes, 2013), since we can see an unstable dynamics also in the oceanic part (Puerto Montt–SST).

16. *l. 450 : a table with cross-entropies would help.*

    Thanks, we can add this.

17. *These line-by-line comments bring me to the broader editorial concern. - Overall, I consider that you need a better discussion strategy for section 4.1. The section is lengthy, and it leaves the reader unsatisfied because many hypotheses are expressed but the reader will struggle to make his/her own opinion. -Once you have presented the methods (and again, consider that at the reader lacks algorithmic details, with a discussion of the critical aspects of the algorithmic choices) my advice would be to focus on fewer elements that emerge out of your analysis, but treat them in a way that effectively helps future studies to build on them. -Remember that ESD's focus on the functioning of the Earth system. This is not the journal for presenting tons of data nor focusing on overly local aspects.*

    [This must mean 4.2 rather than 4.1.] There's a saying about working more on a text to make it shorter — i.e., it needs time and effort to condense ideas into a shorter text. We'll do our best to improve section 4.2 by shortening it.

## References


M. Falvey and R. D. Garreaud. Regional cooling in a warming world: recent temperature trends in the southeast Pacific and along the west coast of subtropical South America (1979–2006). *Journal of Geophysical Research: Atmospheres*, 114(D04102):1–16, 2009. doi: 10.1029/2008JD010519.