Review of: *"The Sampling Method for Optimal Precursors of ENSO Event"*

June 2023

Overview

An algorithm for computing optimal precursors for ENSO events using the Zebiak-Cane model. Such algorithm consists of independently sampling the dynamical model in order to obtain the mode that maximizes the amplification of SST anomaly (for El Niño events). The maximization is carried out by the theory previously published in Shi and Sun 2023, in Nonlinear Processes in Geophysics. Their results contain the spatial structure of said precursors and their ability to describe ENSO events is tested against the adjoint method benchmark.

In my opinion, the article is concise, well written and the topic matches the journal's scope. The results presented herein are novel, since they stem from an application of a recently published theory in this very journal. I would recommend its publication, provided that my comments are considered.

General comments

1. In the Introduction (Lines 50-55), the authors state that "there is a great similarity between optimal precursors and the optimal initial errors obtained by CNOP approaches, in terms of spatial structure and localization." The readers would appreciate a few sentences as to why this is the case, since it is not, in my opinion, trivial. Are the optimal initial errors the predictors for ENSO in the ZC model?

2. In Lines 64-70, the authors speak about optimal energy growth. Typically optimal energy is attained when the system (say, Navier-Stokes) is initialized with the optimal mode. Can the authors say something about the formal/mathematical connection between these optimal modes and the adjoint methods? Could they potentially have the same spatial structure as other CNOP approaches? Is there literature that applies the optimal growth theory with ENSO?

3. Regarding the optimal energy growth, it might be useful to cite the seminal work on linear energy growth by Reddy and Henningson:

   Reddy, S., and Henningson, D. (1993). Energy growth in viscous channel flows. Journal of Fluid Mechanics, 252, 209-238. doi:10.1017/S0022112093003738

4. Line 114: can the authors explain the choice of $\tau = 9$?
5. Line 114: can the CNOP's spatial structure change as a function of τ?
6. I understand the Section 2.2 is a brief summary of Shi and Sun 2023, although the reader would benefit from a couple extra words on the actual statistical machine learning algorithm employed. How is the objective function actually maximised? If evaluating $J(\mathbf{u}_0 + \epsilon \mathbf{v}_0)$ requires solving the equations to find out $\mathbf{T}(\tau)$, how can it be less costly than the adjoint method? Can the authors give an intuition?
7. Line 235: For La Niña events, how would your algorithm change (in the language of Section 2.2)?
8. For Figures 3 and 4, some sort of error bars would be useful. Could the authors possibly use the theory and bounds of Shi and Sun 2023 to compute some uncertainty bars?

Minor/Technical comments

1. Line 2: I suggest using "tropical Pacific" instead of "tropic Pacific".
2. Line 51: It would be helpful to clarify what "spring predictability barrier" means and its causes.
3. Line 60: I suggest to use SPB instead of "spring predictability barrier".
4. Line 61: remove "the" in "the turbulence".
5. Line 67: replace "reivew" by "review".
6. Line 94: replace "futhre" by "further".
7. Lines 111-112: awkward phrasing: "Since the target quantity required to maximize that we concern...".
8. Eq. (6): "$\mathbb{S}^{d-1}$" is not defined until way later. I would suggest defining it immediately below.
9. Line 237: replace "such" by "so".