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Nonlinear Processes in Geophysics
Discussions

Interactive comment on "A Parallel Hybrid Intelligence Algorithm for Solving Conditional Nonlinear Optimal Perturbation to Identify Optimal Precursors of North Atlantic Oscillation" *by* Bin Mu et al.

Bin Mu et al.

23lukia@tongji.edu.cn

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Dear Reviewer,

Thank you for your helpful comments. Those comments are valuable for improving our paper, as well as the important guiding significance to our researches. The response to the comments are as following:

(1) Our paper aims to adopt a swarm intelligence algorithm based on the dimensional reduction strategy to solve the optimal precursors (OPRs) of the North Atlantic Oscilla-

tion (NAO) without the adjoint model. The solving performance is also one of the focus in this paper and has a certain significance in practical.

(2) In the studies of Jiang et al. (2013) and Dai et al. (2016), the algorithm they adopted to explore OPR is spectral projected gradient 2 (SPG2) [1]. The SPG2 was designed to solve the minimum problem of a nonlinear function under a set of constraints and has been widely used in the related research on CNOP [2-5]. The solving process using SPG2 needs to acquire the gradient information via the adjoint model. In their studies, they adopted the T21 quasigeostrophic (QG) global spectral model (T21L3), which is an ideal model with 3 layers, to simulate the NAO and selected the geopotential height as the variable to quantify the NAO. The adjoint model of the T21L3 is called to provide the gradient data for calculating extrema using SPG2. The description of the SPG2 is added to the section about related works in the revised version.

Our work is based on their studies, and we extend the CNOP method to the numerical model which does not have the adjoint model. We adopt a new generation of the fully-coupled model called the Community Earth System Model (CESM) to simulate the NAO, and CESM has no adjoint model. Thus, SPG2 and similar methods are not suitable for this situation. The proposed approach is adjoint-free and is optimized with multiple parallel frameworks. The reason we do not compare our results with the results of Jiang et al. and Dai et al. is no uniform standard to compare. It is almost meaningless to compare between different models (T21L3/CESM), different quantified variables (Geopotential height/Sea level pressure), different input (Potential vorticity/Zonal wind, Meridional wind, ...) and different resolution and solution space, etc.

(3) According to the definition, the OPR is the initial perturbation that is most likely to develop into a climate event under the constraint. The reasons for the climate events can be explained by OPR from a physical standpoint, and the nonlinear behaviors of the perturbations reveal the nonlinear effect of related factors to the climate event [6]. Finding the OPR that evolves into a climate event is helpful to understand the process

of the event onset [7]. It is possible to improve the forecast skill by detecting the initial perturbations within the sensitive area. Thus, it can provide information about the future development of the NAO, and the meaning of the OPRs will be explained in the revised version. Thank you for pointing this out.

(4) The main corrections and some explanation in equations:

Page 5, line 9: m denotes the number of spatial points, and n denotes the length of the time series.

Page 6, equation (6): u_0 in this equation means any perturbation, and u_0ˆ*(NAOˆ+) mentioned in line 6 of the same page denotes the OPR for NAOˆ+, which is a kind of initial CNOP (a special perturbation). The difference between them is the * symbol.

Page 6, equation (4): 'Trop' means 'tropical cyclone'. The equation (4) describes the objective function in the research of the identification of the sensitive area for the tropical cyclone, and the constraint chosen in this work adopts this function. We distinguish the objective function for tropical cyclone from the objective function of the NAO using the subscript 'Trop'. u', v', t', pi' denote the initial perturbations of zonal wind, meridional wind, temperature and surface geopotential respectively.

Page 6, line 20: The nonlinear model propagator denotes the integration process defined in the kinetic equations of the numerical model. Briefly, it stands for the nonlinear process of the model.

Page 7, equation (7): S_i denotes the iˆth sample data and n is the number of the samples. This equation handles the sample by subtracting the mean value of all samples and weighting according to the area of the grid. We have changed lat_i into lat(i), thank you.

Page 7, equation (8): The L is the eigenvector matrix, and Sigma is a diagonal matrix whose entries in the main diagonal are the corresponding eigenvalues.

Page 7, line 24: The random values of position (X) and the speed (V) obey the normal

distribution and ensure the perturbation satisfies the constraints given in equation (5).

Page 7, line 25: L_{1, ..., m} is an m times m eigenvector matrix, but is not a diagonal matrix (See the explanation for Page 7, equation (8)).

Page 4, line 18: "To explore the process of nonlinear..." means that we aim to find out what role the nonlinear played during the simulation. We' re sorry for our vague expression.

Page 18, line 11-12: The sentence means that the offspring particles would be generated through crossover operation and mutation with probability, and if the offspring particle is generated, the objective function value (fitness value) would be calculated.

We are sorry for our poor English and expression, and we will try our best to improve the manuscript. Once again, thank you very much for your comments and suggestions.

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Please also note the supplement to this comment:
https://www.nonlin-processes-geophys-discuss.net/npg-2019-25/npg-2019-25-AC1-supplement.pdf

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