Geophysical Research Abstracts
Vol. 18, EGU2016-1408, 2016
EGU General Assembly 2016

Relationships between Optimal Precursors Triggering the Onset of North Atlantic Oscillation Events and Optimally Growing Initial Errors during Onset Prediction

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Based on a viewpoint that the North Atlantic Oscillation (NAO) is a nonlinear initial-value problem, the predictability of NAO events onset is studied by investigating the links between the optimal precursor (OPR) to NAO events onset and the optimally growing initial error (OGE) in onset prediction. The problem is explored with the method of conditional nonlinear optimal perturbations (CNOP) and a triangular T21, three-level, quasigeostrophic global spectral model.

By solving CNOPs of the corresponding nonlinear optimization problems, we found that during the prediction of NAO onset, there are two kinds of OPRs triggering the positive event (NAO+) and the negative event (NAO-) respectively. For each OPR, there are two types of OGEs: a type-1 OGE, which causes an overprediction of NAO onset, and a type-2 OGE, which underestimates the NAO onset.

Numerical results show that with the optimization time of 3 days, a type-1OGE bears a great resemblance to OPR, and the similarity index between them is 0.98 for both NAO+ and NAO-. A type-2 OGE is also characterized by a similar pattern, but with the opposite sign. With the extension of the optimization time, the similarity index between OPR and type-1 (type-2) OGE gradually decreases to 0.82 (-0.81) for NAO- and 0.87 (-0.57) for NAO+ when the optimization time is 7 days. However, in the linear regime, such high similarity relationship between OPR and OGE can only be found with the optimization time of 3 days.

Further analysis reveals that a type-1 (type-2) OGE has a similar growth behavior to that of the corresponding OPR of the same-phase (opposite-phase) NAO event, and both develop into a dipole anomaly pattern. This similarity between OPR and OGE suggests that the nonlinear process plays an important role in the NAO event. This similarity relationship also suggests that targeted observations over sensitive areas may be carried out in advance to eliminate OGE (as many as possible) in the prediction of NAO onset. Thus, the improved observation network will help to better capture the spatial structure of precursors that trigger NAO onset and will increase the ability to predict NAO events.