



Structures and formation mechanisms of the North Atlantic Oscillation and the ENSO modulation

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Applying a cluster analysis to daily data from NCEP-NCAR reanalysis which covers the winters (December through March) for 1958-2015, this study examines the structures and formation mechanism of the North Atlantic Oscillation (NAO). It is found that the NAO pattern described by the first empirical orthogonal function mode of the 250 hPa height anomalies over the North Atlantic (105°W - 30°E) can be well approximated by nine NAO-like patterns. These NAO-like patterns have a seesaw structure over the Arctic and North Atlantic sector and a Pacific center of different signs, and they are significantly modulated by both the anomalous tropical convection over the western Pacific and stratospheric polar vortex. Stratospheric signals occur about one month before the NAO events and strong (weak) polar vortex favors the positive (negative) phase of the NAO. The convection anomalies can modulate the structure of the NAO patterns through exciting Rossby wave trains. Usually, reduced (enhanced) convection anomalies favor a positive (negative) Pacific anomaly for either phase of the NAO patterns. Furthermore, the influence of the El Niño-Southern Oscillation (ENSO) on the NAO-like patterns is also examined. It is found that among the nine NAO-like patterns, three patterns are significantly modulated by ENSO for their frequencies. For the three ENSO-modulated NAO patterns, one bears its resemblance to the traditional AO pattern with the Pacific center and Arctic center of the same signs. This pattern is of positive polarity of the NAO, and it occurs more often in cold ENSO winters than in warm winters. While the other two have their Pacific centers of opposite signs. However, of these two patterns, the one of negative phase occurs more often in cold ENSO winters than in warm winters, and the one of positive phase occurs more often in warm ENSO winters. This implies that the two patterns of positive phase of the NAO have opposite trends for their frequencies of occurrence during ENSO winters. This fact gives a possible explanation for the uncertainty in the ENSO-NAO relation in some previous studies.