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Symmetry breaking of North Atlantic Oscillations: A new perspective

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Our observations reveal that the North Atlantic Oscillation (NAO) exhibits a symmetry breaking between its positive (NAO+) and negative (NAO-) phases, in which the NAO- (NAO+) with large (small) amplitude and long (short) persistence is displaced westward (eastward). Further calculations show that blocking days occur frequently over North Atlantic (Eurasia) after the NAO- (NAO+) peaks, thus indicating that for the NAO- the blocking occurs upstream due to its retrogression, whereas for the NAO+ the blocking occurs downstream through the eastward energy dispersion.

Motivated by a unified nonlinear multi-scale interaction (UNMI) model, we examine the physical cause of the symmetry breaking of the NAO. It is found that because the westerly wind prior to the NAO+ (NAO-) onset is strong (weak) and shifted northward (southward), a NAO+ (NAO-) pattern with small (large) amplitude is easily formed through the preexisting eddy forcing due to its initial strong (weak) downstream energy dispersion. When the NAO+ (NAO-) grows, the westerly wind is subsequently strengthened (reduced) so that it can further strengthen (weaken) the downstream energy dispersion of Rossby waves through reduced (intensified) nonlinearity of the NAO+ (NAO-) and an increase (decrease) in the difference between its group velocity and phase speed. Both the intensified (reduced) westerly wind and small (large) NAO amplitude can induce the eastward (westward) movement of the NAO+ (NAO-) according to a nonlinear phase speed. Thus, the above results suggest that the evolution of the NAO+ (NAO-) tends to be a linear (nonlinear) process, leading to a symmetry breaking of the NAO between its two phases.