

Recent breakdown of the seasonal linkage between the winter North Atlantic Oscillation/Northern Annular Mode and summer Northern Annular Mode

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The summer Northern Annular Mode (NAM) and the winter North Atlantic Oscillation (NAO)/winter NAM have a positive correlation from the mid-1960s to the 1980s. Namely, when the winter NAO/NAM is in a positive phase, the following summer NAM tended to be a positive phase. During the period from the mid-1960s to 1980s, the NAO/NAM signals extended to the stratosphere in winter. Also, lower tropospheric warm anomaly over northern Eurasia in winter associated with the positive phase of NAO/NAM continued to spring. In summer, the annular anomalies in the temperature and 500-hPa height fields appeared and high-latitude westerly was enhanced following the winter positive NAO/NAM. However, after circa 1990, the seasonal linkage was broken, i.e., the winter-to-summer correlation became insignificant. The stratospheric signal in the winter NAO/NAM became weak and summer signals associated with the winter NAO/NAM almost disappeared. Seasonal evolutions of atmospheric circulation and sea surface temperature (SST) anomalies associated with the winter NAO are examined for early good linkage period and recent poor linkage period. We discuss the possible causes of the linkage breakdown such as stratospheric ozone, North Atlantic SST, and Atlantic multidecadal oscillation, besides chaotic internal variability in the climate system. Simulations with the Community Earth System model suggest that the ocean and/or sea ice with inter-seasonal memories possibly cause the linkage, besides large internal variability through which the linkage can take place by chance.

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