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Boreal summer tropical-extratropical teleconnection

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Abstract

During boreal summer, the upper-level easterly controls entire tropics and westerly jetstream retreats poleward. How a heat source within tropical easterly regime excites an extratropical response is discussed with theoretical models. Two mechanisms, the role of the southerly conveyer belt embedded in easterly flows and the coupling of baroclinic and barotropic modes by easterly vertical shear, may let a heat source in the tropical easterly regime to generate extratropical response.

Analysis of the most recurrent coupled pattern of interannual variability between Northern Hemisphere extratropical circulation and tropical convection reveals a boreal summer circum-global teleconnection (CGT) pattern (as the leading singular vector decomposition (SVD) mode). The CGT consists of a zonal wavenumber five structure and is primarily positioned within the jetstream-waveguide with five elevated centers preferably located in the northeast Atlantic-West Europe, Central Asia, Northeast Asia, North Pacific and North America. This CGT pattern is associated with enhanced Indian summer monsoon (ISM) rainfall and eastern tropical Pacific cooling. Significant rainfall and temperature anomalies occur along the CGT path, thus the CGT acts as a primary system to convey influences of tropical thermal forcing to extratropics. The second SVD mode of tropical convection and extratropical upper level circulation represents a coupling between an enhanced tropical Western North Pacific rainfall and a meridional, tri-polar vorticity anomaly pattern over the western-central North Pacific. The extratropical circulation patterns represented by the SVD1 and SVD 2 modes closely resemble, respectively, the EOF2 and EOF1 modes of the upper-level extratropical circulation. As such, they are potential sources of predictability for forecast of boreal summer extratropcial circulation. The tropical-extratropical teleconnection patterns depicted by the two leading SVD modes are clearly distinguished by the developing and decaying phases of the El Niño-Southern Oscillation (ENSO) cycle, suggesting the importance of ENSO in modulating tropical precipitation heat source and related extratropical response. Note however, even without ENSO impacts, the anomalous ISM can act as a primary tropical forcing to generate the CGT mode.

Based on an ensemble of atmosphere general circulation model (AGCM) response to a suite of randomly distributed thermal forcing throughout the tropics, we found that the CGT is the preferred internal mode of the extratropical response. Particularly, the CGT is sensitive to the heating anomalies located over the ISM domain, the South China Sea, and North American monsoon and the cooling anomalies over the Equatorial Central Pacific. In response to the diabetic heating anomalies associated with the strong ISM, the AGCM can reproduce the main structure of the CGT, except the center over the northeast Atlantic-West Europe, which is suggested to be a result of barotropic instability over the exit region of the Atlantic jet stream.

A `relay` scenario is proposed to explain the global extent of the CGT. The European wavetrain excited in the jet exit region of the North Atlantic may enhance the anomalous Central Asian High and thus the northern Indian-Pakistan rainfall. The enhanced ISM rainfall in turn reinforces the Central Asian High and further stimulates downstream Asian-Pacific Rossby wavetrain that extends to North Pacific and North America. The interaction between the extratropical wavetrain and the ISM heat source may be instrumental in understanding the circum-global structure of the boreal summer wavetrain. While the barotropic instability in the exit region of the North Atlantic jetstream may be responsible for the recurrence of the CGT, the precise mechanism responsible for generation and maintenance of the CGT remains elusive.