EGU24-3534, updated on 11 Aug 2024
https://doi.org/10.5194/egusphere-egu24-3534
EGU General Assembly 2024

Perturbation Potential Energy Bridging North Atlantic Ocean Forcing to Atmospheric Multidecadal Variability in the North Atlantic

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The North Atlantic sea surface temperature anomalies (SSTA) are considered an important origin of the North Atlantic atmospheric multidecadal variability. Employing the perturbation potential energy (PPE) theory, we analyzed the energetics linking North Atlantic Ocean forcings to atmospheric multidecadal variability. Supporting the previous model results, a cyclic pattern involving the Atlantic multidecadal oscillation (AMO) and North Atlantic tripole (NAT) is observed: positive AMO phase (AMO^+, similarly hereafter) ->NAT^-->AMO^-->NAT^+, with a phase lag of approximately 15~20 years. An atmospheric mode characterized by basin-scale sea level pressure anomaly in the North Atlantic is associated with the AMO, which is termed as the North Atlantic uniformity (NAU). The AMO^+ induces positive uniform PPE anomalies over the North Atlantic through precipitation heating, leading to decreased energy conversion to perturbation kinetic energy (PKE) and a large-scale anomalous cyclone. For the NAT^+, tripolar SSTA result in tripolar PPE anomalies through accumulated tripolar precipitation. Anomalous energy conversions occur where the PPE anomaly gradient is large, which is explained by an energy balance derived from thermal wind relationship. The PKE around 15°N and 50°N (25°N and 75°N) increases (decreases), forming the anomalous anticyclone and cyclone at subtropical and subpolar region, respectively, known as the North Atlantic Oscillation (NAO). The reverse holds for the NAT^- and AMO^-. As the phases of the ocean modes alternate, the energetics induce the NAU^-, NAO^-, NAU^+, and NAO^+ in sequence. The SSTA-PPE-PKE energetics processes contribute a comprehensive understanding of how the ocean influences atmosphere in the North Atlantic.