Geophysical Research Abstracts
Vol. 20, EGU2018-5949, 2018
EGU General Assembly 2018

Decadal variability in the Northern Hemisphere winter circulation: Role of internal and external drivers

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Northern Hemisphere winter circulation is affected by both internal and external (solar-related) forcings. ENSO (El-Nino Southern Oscillation) and volcanic activity have shown to produce negative and positive North Atlantic Oscillation (NAO) responses, respectively. Recent studies show a positive NAO response related to both geomagnetic activity (proxy for solar wind driven particle precipitation) and sunspot activity (proxy for solar irradiance). Here the relative role of these drivers on Northern Hemisphere wintertime circulation is studied. The quasi-biennial oscillation (QBO) is used to study driver responses for different stratospheric conditions. Moreover, the effects are separated for early/mid- and late winter. Response to ENSO is mostly observed as negative pressure signal in the North Pacific, regardless of the QBO or time of the winter. However, the negative NAO signal in the Atlantic, as reported in previous studies, is observed only in late winter and in the easterly QBO phase during early/mid-winter. A positive NAO related to volcanic activity is more pronounced for westerly QBO in both early/mid- and late winter. A positive NAO is observed related to geomagnetic activity during easterly QBO phase in both early/mid- and late winter. Sunspots produce a positive pressure anomaly in the North Pacific in early/mid-winter regardless of the QBO, whereas late winter signal resembles a positive NAO in the easterly QBO. These results imply that the responses for all drivers in the Atlantic are significantly modulated by the QBO thus suggesting stratospheric pathway. Responses in the North Pacific remain similar in different QBO phases and thus suggest direct forcing from the troposphere by ENSO and bottom-up sunspot mechanism.