



Consistent QBO-dependent effect of geomagnetic activity on the Northern Annular Mode during the 20th century

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Several earlier studies have shown that geomagnetic activity (GA), as a proxy for energetic particle precipitation into the atmosphere, affects the winter-time Northern Annular Mode (NAM), which is the dominant circulation pattern in the northern hemisphere during winter. It has also been found that the quasi-biennial oscillation (QBO) modulates the relationship between GA and NAM. However, some of the earlier studies on this QBO modulation have been mutually conflicting, with some studies suggesting a stronger positive relation in the easterly phase of the QBO, while other studies suggest a stronger positive relation in the westerly phase of the QBO.

Here we study the QBO-GA-NAM relationship using a QBO reconstruction covering the whole 20th century. We find that the QBO modulation of the GA-NAM relation is temporally variable, which explains the earlier, seemingly differing results. Positive GA-NAM relation is found to be valid in the easterly QBO phase at 30 hPa during the whole 20th century. We also find that the QBO at 30 hPa represents the Holton-Tan relation for the surface circulation better than QBO at 50 hPa, and that the Holton-Tan relation is only observed during early/mid winter, while an anti-Holton-Tan relation is found in the late winter for strong geomagnetic activity. These results emphasize the variable but systematic response of NAM to energetic particle precipitation during the entire 20th century, and underline the importance of considering the preconditioning of the atmosphere when studying the solar-related effects upon climate.