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Climate effects of high-speed solar wind streams

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High-speed solar wind streams (HSS) are the most effective driver of magnetospheric energetic particles and geomagnetic activity. HSS and, thereby, the flux of energetic particles maximize in the declining phase of the solar cycle when the solar polar coronal holes have equatorial extensions that emit HSS to the ecliptic. The amount of kinetic and thermal energy of solar wind is miniscule compared to the dense atmosphere, but the atmospheric effects of HSS can be greatly amplified by electromagnetic and chemical reactions. HSS-related energetic particle precipitation (EPP) can cause dramatic changes in chemistry, energetics and dynamics of the upper atmosphere. EPP creates NO_x molecules that can be transported down to the stratosphere during polar winter, leading to ozone loss. There is increasing evidence that HSS-related effects have important consequences even to the tropospheric climate, especially in winter at high latitudes. HSS have been found to modulate regional/hemispheric climate patterns in winter, in particular the NAO/NAM oscillation, the dominant climate pattern in the northern hemisphere. The positive phase of the NAO/NAM oscillation is systematically favored in winters of the declining phase of the solar cycle.
HSS-effects are strongly dependent on the phase of the Quasi Biannual Oscillation (QBO) of equatorial winds. Positive relation between HSS and NAO/NAM is found to be valid in the easterly QBO(30 hPa) phase during the whole 20th century. EPP related ozone loss and consequent enhancement of polar vortex is significantly stronger in the easterly QBO phase than in the westerly phase. The Holton-Tan relation between QBO and the polar vortex has been found to be valid only during early/mid winter, while an anti-Holton-Tan relation is found in the late winter for strong geomagnetic activity. These results indicate an intimate, global connection between low and high latitudes, and underline the importance of considering the preconditioning of the atmosphere when studying the solar (wind)-related effects upon climate. We review the above observations and compare the effects of solar wind and solar irradiance to northern winter climate.