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Winds of winter: How solar wind driven particle precipitation can affect northern winters

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Solar wind drives the variability in the near Earth space. Coupling of solar wind and the magnetosphere feeds energetic particles into the inner magnetosphere through reconnection in the magnetotail. During the declining phase of the solar cycle long-lived high-speed solar wind streams are more commonly observed at Earth's orbit. These accelerate particles to higher energies and in the process lead to enhanced particle precipitation into the atmosphere. Electrons from tens to hundreds of keV precipitate down to the mesosphere and upper stratosphere, where they can create nitrogen and hydrogen oxides. During winter, nitrogen oxides have enhanced lifetime in the polar night. They can descend down to the mid-stratosphere and destroy ozone, which leads to cooling of the high-latitude stratosphere. This enhances the meridional temperature gradient and westerly winds under the thermal-wind balance, thus accelerating the polar vortex. This mechanism is successfully modeled by chemistry-climate models. Dynamical changes in the stratosphere can descend down to the troposphere. During strong polar vortex, the northern annular mode (NAM) is anomalously positive. Positive NAM encloses the cold arctic air into the polar region and enhances the westerly winds at mid-latitudes. Enhancement of westerlies bring warm and moist air from Atlantic to the Northern Eurasia causing positive temperature anomalies. At the same time negative temperature anomalies are observed in the Northern Canada and Greenland. Our recent observations show that the positive relation between precipitating electron fluxes/geomagnetic activity and NAM exists during winter. Positive NAM pattern is observed during the declining phase of the solar cycle at least since the late 19th century. We also find that the quasi-biennial oscillation (QBO) of equatorial winds strongly modulate this relation at high latitudes. These results give additional evidence that not only solar electromagnetic radiation but also the solar wind can affect the climate.