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Temporal response of the polar troposphere and stratosphere to changes in the global atmospheric electric circuit associated with solar wind variability

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The surface meteorological response in the polar regions to fluctuations in the dawn-to-dusk interplanetary magnetic field (IMF) component, B_y, indicates that a coupling between the Sun and Earth's weather occurs via the global atmospheric electric circuit (GEC). In particular, the difference between the mean surface pressures during times of high positive and high negative IMF B_y is 1 - 2 hPa in Antarctica and occurs on a relatively fast timescale compared to other proposed Sun-weather connections. Specifically, the observed time lag between the solar wind perturbation of the ionosphere-to-ground electric potential (and hence the vertical fair-weather current) and the ground level response is up to about 1 day. Here we extend this result and present further evidence that a solar wind–lower atmosphere coupling occurs via the GEC throughout the troposphere which in turn affects the stratosphere. We do this using NCEP/NCAR reanalysis data to determine the time lag of the peak correlation between IMF B_y and geopotential height for different pressure levels in the troposphere and stratosphere.

In Antarctica, there is a statistically-significant correlation between IMF B_y and geopotential height within the troposphere, but not within the stratosphere. The peak in the correlation is observed at higher time lags in the upper troposphere (2 - 4 days) than in the lower troposphere (0 - 1 day). The amplitude of the correlation has a periodicity of about 27 days, associated with the effect of the rotation of the Sun on the periodicity of the solar wind magnetic field at Earth. In the Arctic, the time lag between IMF B_y and the meteorological response is significant and similar at different pressure levels in the troposphere and is about 0 - 1 day. A significant response is seen in the stratosphere with a time lag of about 10 days. We interpret the existence of a time lag of less than a few days in the troposphere as evidence in support of a mechanism involving the action of the GEC on cloud physics within a part of the troposphere. The increase in the time lag with increasing altitude is suggestive of an upward propagation of the influence of the solar-wind-induced variability in the lower troposphere, by conventional meteorological processes. This is in contrast to the apparent downward propagation of meteorological effects to the lower troposphere from the stratosphere due to other mechanisms associated with solar variability, involving ultra-violet radiation or energetic particle precipitation.