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Solar activity and recent climate change: Evaluating the impact of geomagnetic activity on atmospheric circulation

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"Realization of a potential impact of solar variability on our local environment has progressed a long way in the last few decades, from denial to partial acceptance, but a complete assessment of its reality and magnitude remains a distant goal." (Reid, 1999; page 3)

Abstract

Solar-climate studies have a long and controversial history and the relevance of solar activity to recent climate change remains unclear. Despite prevalent scepticism and uncertainty, recent developments in both solar and atmospheric sciences warrant the reinvestigation of possible solar-climate relationships. The advent of public access to enormous databases of solar and atmospheric variables encourages the reinvestigation of possible solar-climate relationships, particularly those involving solar-modulated geomagnetic activity variations. If further studies demonstrate that climate change has been influenced by geomagnetic activity then research can progress to predicting, modelling, and quantifying the effect. Conversely, if a geomagnetic-activity influence on climate change can be comprehensively disproved researchers can focus on alternative solar or terrestrial climate explanations.

This thesis has evaluated the potential role of solar variability in recent climate change through the statistical examination of the impact of solar-modulated geomagnetic activity on atmospheric circulation. Geomagnetic activity was parameterised using the AA index, while atmospheric circulation was parameterised using the Antarctic, Arctic, and North Atlantic Oscillation indices. These atmospheric circulation indices correspond to the leading causes of variability in the extra-tropical troposphere. Changes in these indices result from large-scale climate changes that are centred on the mid-latitudes. *NCEP/NCAR* reanalysis sea level pressure data were also used to examine the spatial signature of geomagnetic activity effects at the earth's surface. The link between geomagnetic activity and atmospheric circulation was evaluated at daily, annual, and decadal timescales. The analyses were performed on monthly and three-monthly averages of the atmospheric indices to investigate seasonal patterns.

The results indicate that geomagnetic forcing of atmospheric circulation in the northern hemisphere is temporally and seasonally restricted. Moreover, it is controlled by a stratospheric phenomenon known as the quasi-biennial oscillation (QBO), and it is reliant on the interaction of stratospheric and tropospheric circulation. When the data are restricted to January values after 1965, for years in which the January QBO is eastwards, the correlation coefficient between geomagnetic activity and the Arctic Oscillation is strong (r = 0.85; α = 0.05). In the southern hemisphere, statistically significant correlations are evident during March (r = 0.39) and are strongest after the early 1960s,

though the QBO plays no part in the relationship. For both hemispheres the relationships are evident at annual as well as decadal timescales and are therefore of practical significance.

Solar-modulated geomagnetic activity is therefore an important forcing mechanism for recent climate change. Specifically, many of the unexplained aspects of the recent changes in northern hemisphere climate, including the climate regime shift of the early 1960s, can be attributed to the effects of geomagnetic activity in the upper atmosphere. Interannual variations in the North Atlantic Oscillation should no longer be considered as 'climatic noise', while the strong positive trend and decadal variations evident since the 1960s can be attributed, in part, to solar forcing. The results also have implications for the relevance of atmosphere-ocean coupling to the Arctic and North Atlantic Oscillations and the importance of solar activity in southern hemisphere atmospheric circulation. Contrary to claims in the literature, the results of this study indicate that geomagnetic activity is not a viable proxy for solar irradiance variations or the solar-cycle length index. Long-term changes in land temperature are not well correlated to geomagnetic activity and the results of superposed epoch analysis indicate that there is no evidence of geomagnetic forcing of the atmosphere at daily timescales. This indicates that there must be a cumulative effect in the mechanism linking geomagnetic activity to atmospheric circulation that is not discernable in daily data.

Potential mechanisms, coupling geomagnetic activity variations to the lower atmosphere, were evaluated by examining the spatial signature of geomagnetic activity in *NCEP/NCAR* reanalysis zonal wind and temperature data and by comparing geomagnetic activity to solar irradiance, stratospheric aerosol, and total-column ozone data. The reanalysis data extend from the surface to the lower stratosphere in both hemispheres and are available for 17 geopotential heights ranging from 1000 hPa to 10 hPa and 2.5° intervals of latitude and longitude. Through a process of elimination, the results indicate that solar-modulated geomagnetic activity is relevant to tropospheric circulation through the coupling of the upper and middle atmospheres, and the subsequent propagation of stratospheric circulation anomalies to the troposphere through planetary wave activity.

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