Investigating the Space Weather Impact of the 2003 Halloween Geomagnetic Storm by the Ground Magnetic Field Variations: a Global View

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Abstract
Space weather is the phenomenon of solar storms and other events in space that can have an impact on Earth. They are a major concern for power grids which can be severely damaged by geomagnetic field variations during such natural phenomena. To reduce such impact and the possible consequences following, the study aims to determine how the storm's impact spreads across the earth during a strong event, the October 29th, 2003 Halloween Storm. The impact of the Halloween Storm is analyzed by using global maps of geomagnetic variations to find where it is received and how it propagated. The map is generated with kriging Interpolation and cross-correlation is done on specific latitudinal distribution chains and longitudinal distribution chains. The maps show that impacts are received first in high-latitude regions and then propagate toward mid- and low-latitude regions. The regions of impact during the first storm are on the magnetic dayssides while the regions of impact during the second storm are on magnetic midnight sides. The cross-correlation study shows that the magnetic latitude distribution is the dominant factor over the longitude distributions. High-latitude regions are the most intensively impacted regions, such as Norway, Finland, Sweden, and Canada. The mid-latitude countries such as France, UK, and the US can also be impacted during such extreme events. Taking a global view of space weather impacts can help us to understand and mitigate the hazardous impacts of modern society.

1 Introduction

Space weather is the phenomenon of solar storms and other events in space that can have an impact on Earth. The main source of space weather is the Sun, which can produce solar flares, coronal mass ejections (CMEs), and high-speed solar wind streams that cause significant impacts on modern society (?, ?), affecting technologies such as radio communication, GPS and GNSS systems, and satellite communications, high-latitude aviation, Mining operations, power grids and natural gas pipelines. The results can disrupt radio communications, endanger astronauts, cause errors in GPS and GNSS systems, lose satellite communications, expose pilots and passengers to higher levels of radiation in high-latitude aviation, overload power grids, and accelerate corrosion of natural gas pipelines. As a result, space weather has significant implications for national security due to the capability to damage critical infrastructures, such as the electric grid. The US has a large space-based infrastructure and is almost exclusively reliant on an aging and stressed power grid, making it vulnerable to the effects of space weather. To mitigate these effects, the US has established a Federal Operating Concept for Impending Space Weather Events, which focuses on operational and crisis planning. Space weather study has become one of the most important research recent years.

These solar storms can cause intensive magnetic field variations on Earth, so called geomagnetic storms (?, ?)(?, ?) when they reach Earth. A geomagnetic storm is defined as an interval of time when a sufficiently intense and long-lasting interplanetary convection electric field leads, through a substantial energization in the magnetosphere-ionosphere system, to an intensified ring current sufficiently strong to exceed some key threshold of the quantifying storm time Dst index. (?, ?). When the solar storm reaches the Earth, the interplanetary magnetic field (IMF) will connect with the Earth's magnetic field at a distance of several Earth's radius and transport the energy and plasma from solar wind into Earth's magnetosphere and ionosphere, then to the ground. (?, ?)(?, ?) A southward IMF is an essential precondition for geomagnetic storms. When the IMF is primarily northward, only a relatively weak geomagnetic storm will result (?, ?). Geostorms result in anomalies and disruptions to modern conveniences such as electrical power distribution networks. The strongest geomagnetic storm during the last three decades is the 2003 Halloween storm [Berger et al., 2020].

-add how magnetic field reconnection causes geomagnetic storm/aurora

Examining magnetic field variations caused by this great storm at a global scale allows for a better understanding of how different regions of the earth are impacted differently. It can help mitigate space weather impact in a global picture.

In this research paper, we explain the methodology and data used in section 2; present the results of global maps of magnetic field variations, and latitude and longitude difference of magnetic field variations during the storms in section 3; discuss the physics behind these results and conclude a summary in section 4.

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