Terrestrial Impacts of Global Geospace Modeling of an Ensemble of Storms

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Abstract

Modeling the terrestrial impacts of the sun's solar wind is critical to understanding geomagnetic storms. We use a database of 144 storms from 2010-2019 and showed how these storms affect magnetometers on the ground. We also extracted profiles of the magnetic field along the magnetotail. Skill scores are assigned to the individual stations on the ground based on how well they can forecast magnetic indeces like SYM-H and AL. We us our Space Weather Modeling Framework's geospace configuration. Our model includes coupling of 3D MHD solver (BATSRUS), the Rice Convection Model, and the Ridley Ionospheric Model. We have found that all stations have a positive Heidke Skill Score which is encouraging in terms of space weather forecasting.

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SOLSTICE Solar Storms & Terrestrial Impacts Center

OBJECTIVE

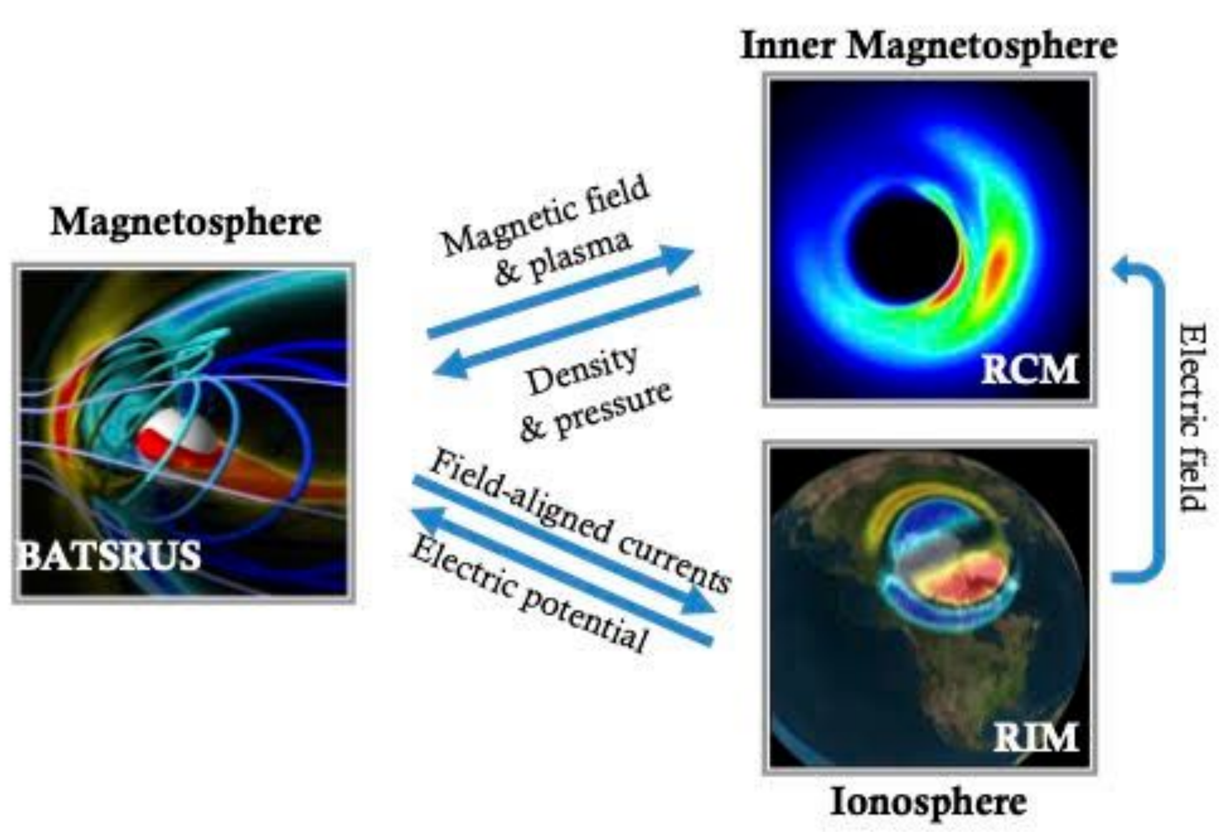
Can we use the Space Weather Modeling Framework (SWMF) to simulate and predict ground magnetometers in the high-latitudes and mid-latitude regions?

1. INTRODUCTION

The Earth's magnetic field on its surface is a result of the ionosphere and nearby geomagnetic responses. Geomagnetic indices are used to measure the level of geomagnetic storms. These indices are derived from ground magnetometers and thus being able to predict storms or indices requires a stronger prediction of ground magnetometers. In this study we evaluate our Space Weather Modeling Framework's (SWMF) ability to predict disturbances at ground magnetometers. SWMF is used operationally at the Space Weather Prediction Center (SWPC) to predict geomagnetic storms.

2. METHODOLOGY

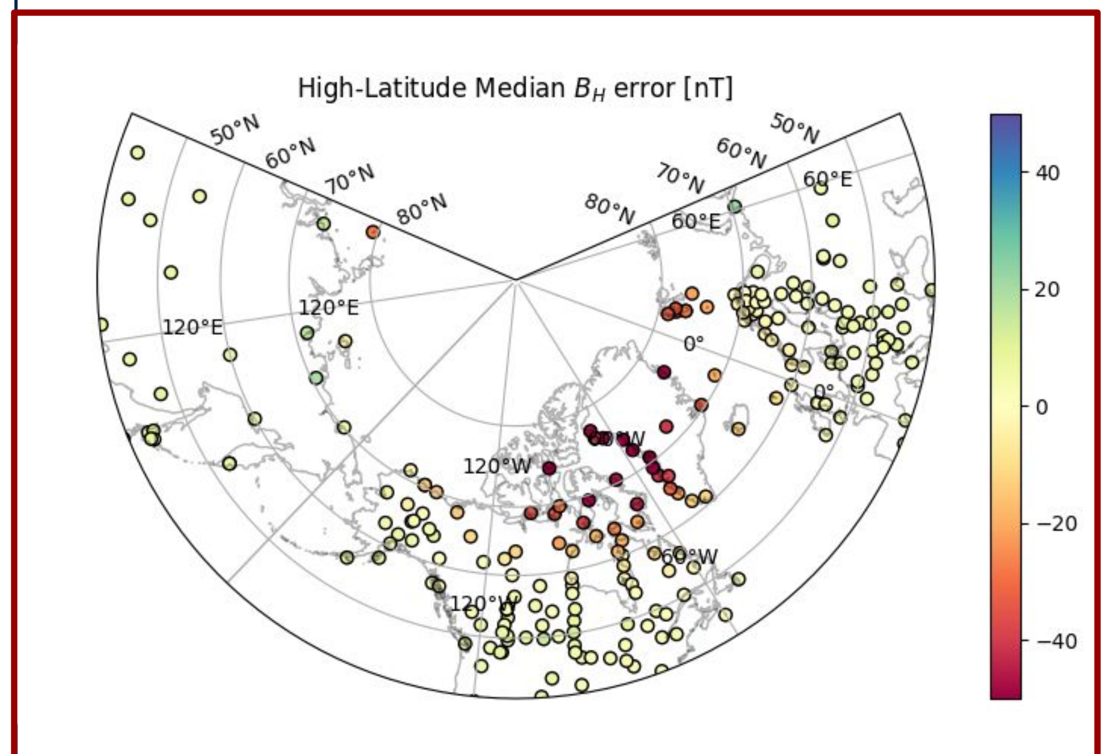
SWMF is comprised of coupled models that simulate the geomagnetic environment. The magnetosphere is modeled by an ideal 3D magnetohydrodynamic (MHD) solver, the Block Adaptive Tree Solarwind Roe Upwind Scheme (BATSRUS). This is coupled with the Rice Convection Model (RCM) describing the ring-current. Lastly, the Ridley Ionosphere Model is a potential field solver used to describe the currents and conductances in the ionosphere.

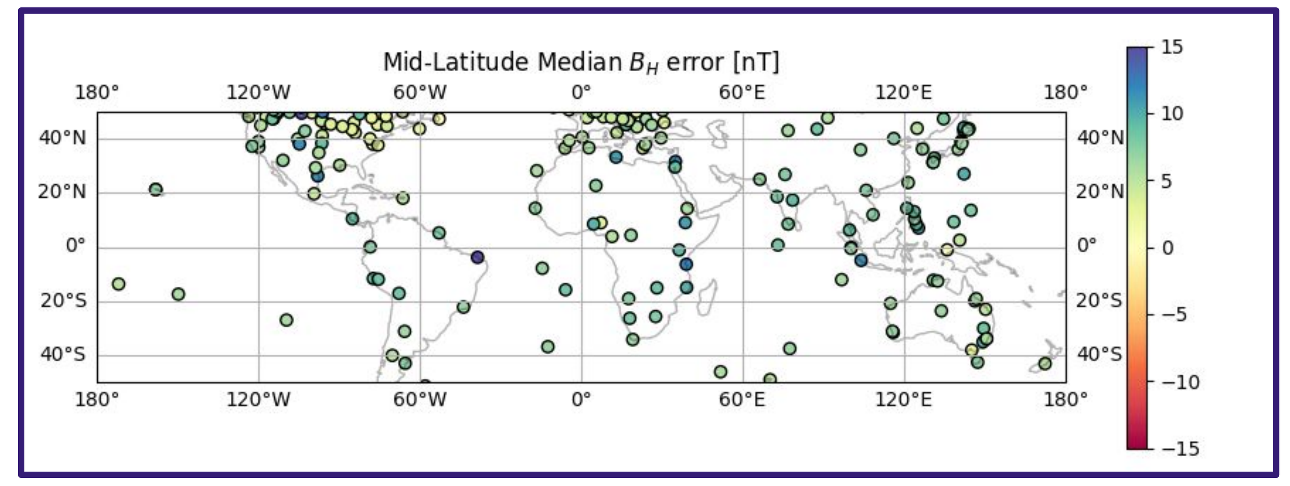


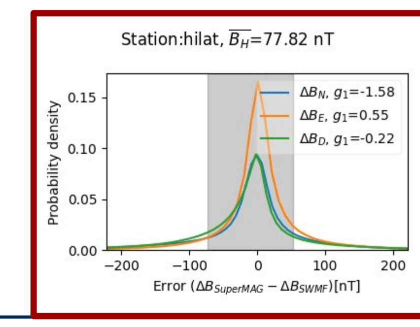
A total of 122 storms was run from 2010-2019. The data set comprises events with Disturbance Storm index (Dst) minimum below a threshold of -50 nT. Virtual magnetometers were placed around the simulation globe and compared with observations using the SuperMAG database. The stations' horizontal (to the ground) component is used to compare observation and simulation data. Both the simulation and the observations have 1 minute cadence..

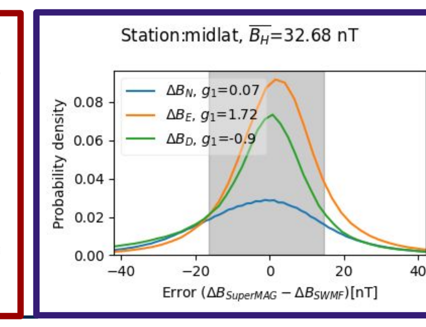
3. RESULTS: ERROR ANALYSIS

The differences between the observations and simulation results have a normal distribution. Shown below is the median value of each individual station. $\mathrm{Error}(\Delta\mathbf{B}) = \Delta\mathbf{B}_{\mathrm{SuperMAG}} - \Delta\mathbf{B}_{\mathrm{SWMF}}$









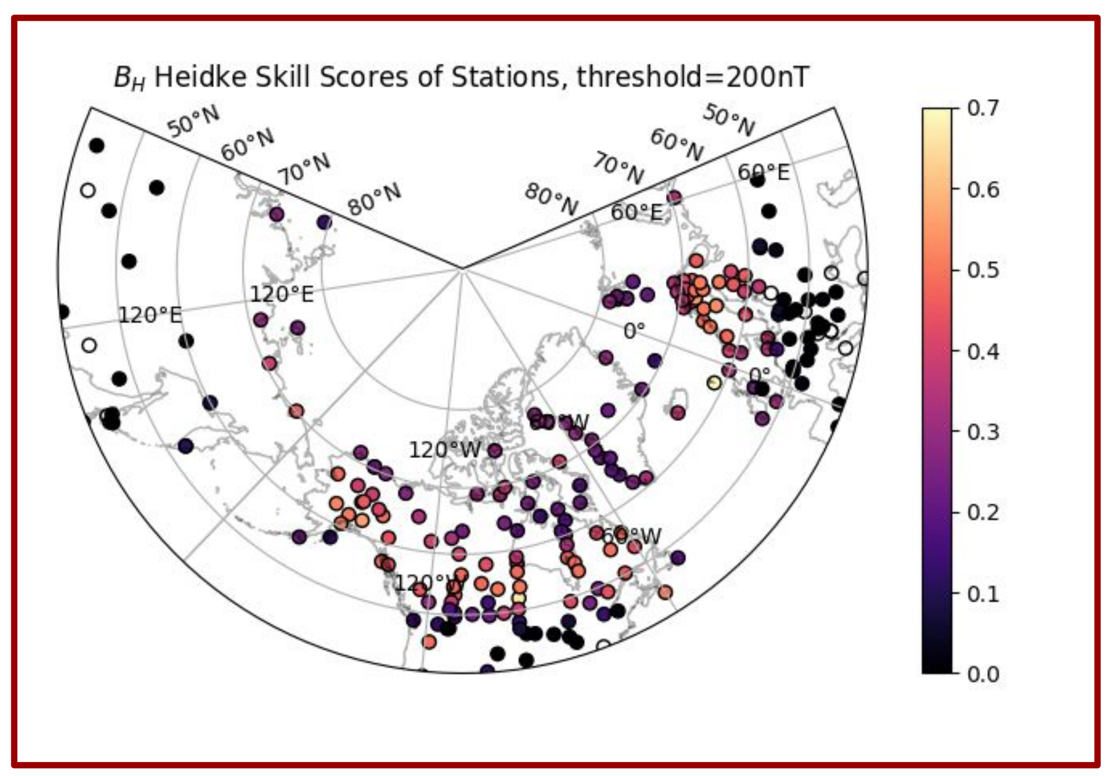
4. DISCUSSION: ERROR ANALYSIS

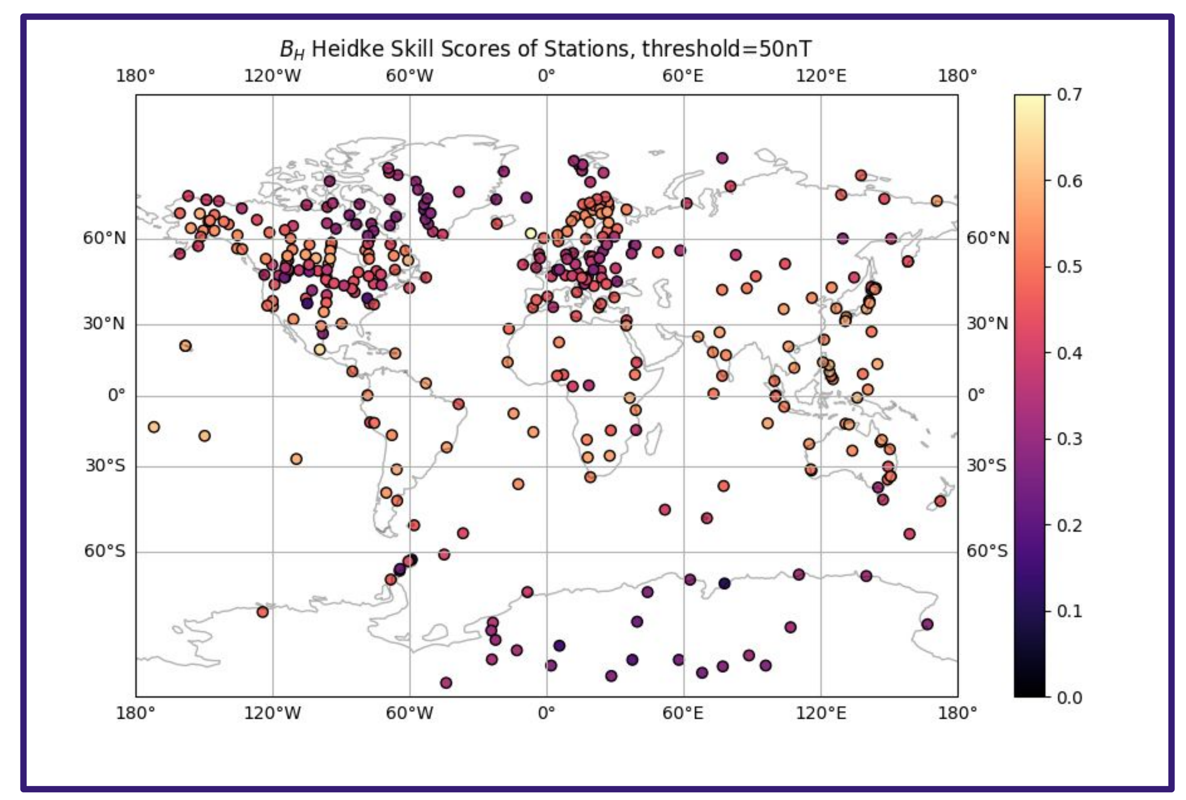
- The median error for the stations is centered around 0 nT.
- The higher latitude errors become more negative towards the poles showing a tendency to overpredict in that region.
- The mid-latitude shows a median error of 5 nT which shows the simulation's tendency to underpredict in the region.

5. RESULTS: HEIDKE SKILL SCORE

The Heidke Skill Score (HSS) is the measure of the simulation ability to predict a threshold value in the magnetometer stations. A threshold value of 50 nT is chosen for mid-latitude stations since that is the criterion in picking these individual storms. A threshold value of 200 nT is chosen for higher latitudes to detect the strong auroral currents found in the region.

$$\mathrm{HSS} = \frac{2(\mathrm{Hit}\cdot\mathrm{Neither} - \mathrm{Miss}\cdot\mathrm{False\ positive})}{(\mathrm{Hit}+\mathrm{Miss})(\mathrm{Miss}+\mathrm{Neither}) + (\mathrm{Hit}+\mathrm{False\ positive})(\mathrm{False\ positive}+\mathrm{Neither})}$$





6. DISCUSSION: HEIDKE SKILL SCORE

- The mid-latitudes show strong agreement of an HSS around 0.6 which makes the model a good predictor of geomagnetic events in the ring current such as Dst.
- In the region of the auroral oval the simulation shows a strong agreement of an HSS around 0.4 with sharp decreases on the border.
- The sharp decrease in HSS above and below the auroral region shows an opportunity for improved physics for that region.

7. CONCLUSIONS

- The simulation is able to predict mid-latitude perturbations of 50 nT well which is important for ring current indices such as SYM-H and Dst.
- The simulation is able to predict strong high-latitude currents around the auroral region which is important for the auroral electrojet.
- There are sharp decreases in HSS bordering the auroral region which shows an opportunity in improving the physics or conductances in the Ridley Ionosphere Model.