Further investigations of the July 23, 2012 extremely rare CME: What if the rare CME was Earth-directed?

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European Space Weather Week 10, 18 November 2013, Antwerp, Belgium

Outline

- Introduction

i. Motivation for this work.
ii. STEREO mission
iii. Global MHD modeling

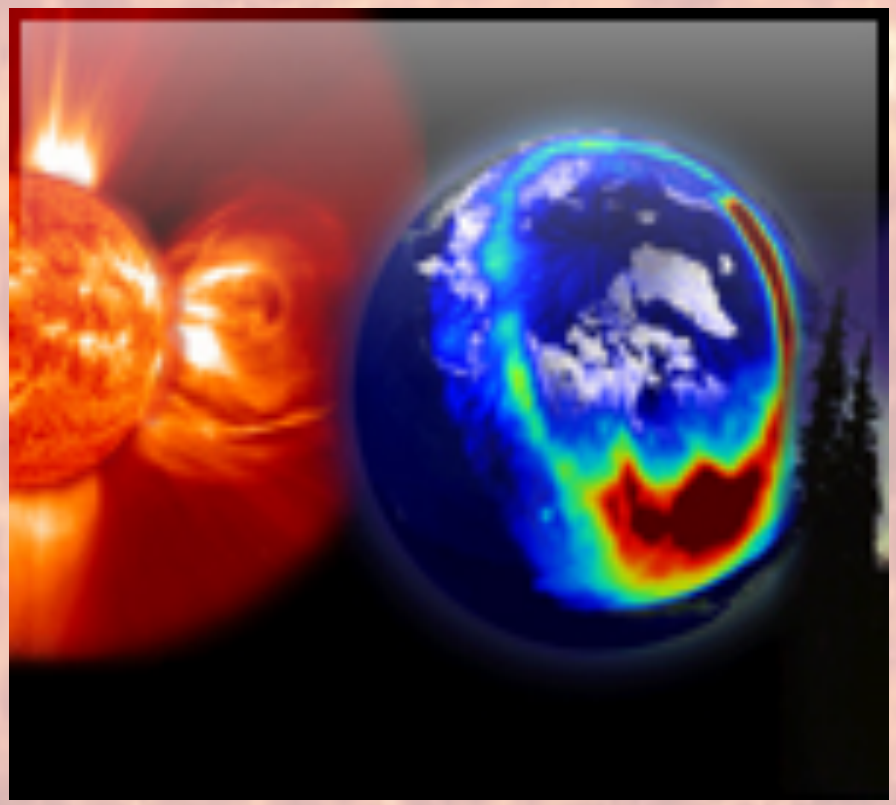
- Simulation Results:

i. July 23 event initial analysis (Ngwira et al., 2013b)
ii. Further analysis of July 23 event

- Summary and conclusions

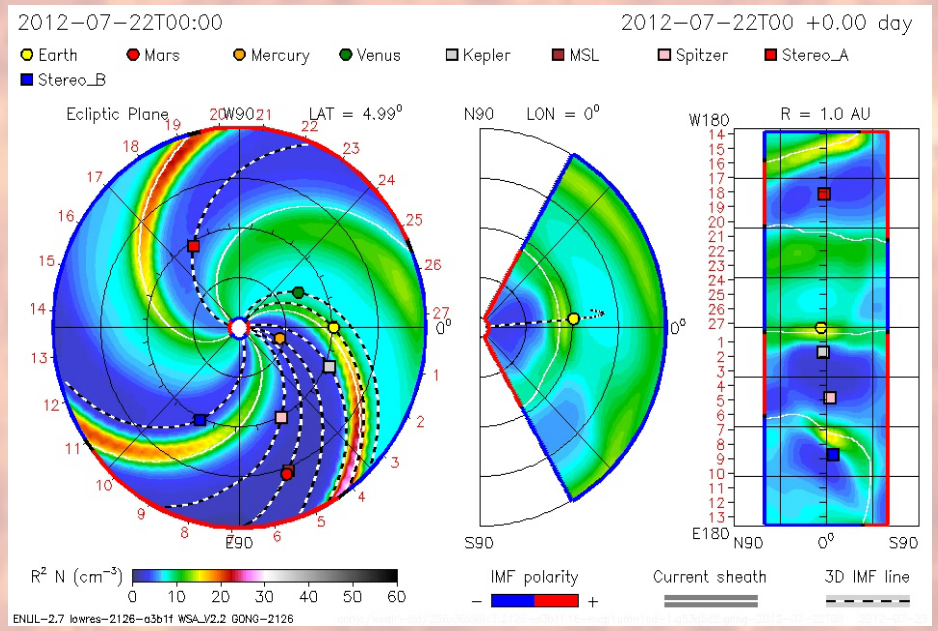
What is our interest?

- Extreme space weather impact on ground infrastructure.
- To determine the levels of induced electric fields on the ground during extreme space weather events.
- Application for hazard management of electric power systems against geomagnetic induced currents.



Motivation for this work

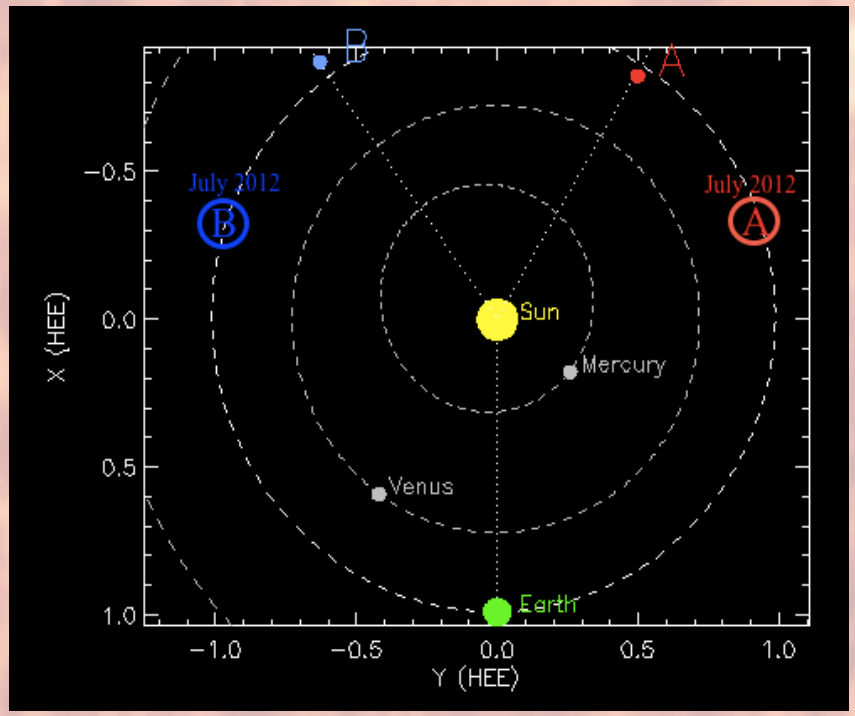
- On July 23, 2012, a CME was hurled from the Sun's active region AR1520 with a Rare speed of 2500 ± 500 km/s [Baker et al., 2013; Ngwira et al., 2013b].
- Event observed by NASA's STEREO (Solar TErrestrial RElations Observatory) ahead spacecraft.
- CME traveled a distance ~1 AU in about 19-hours.
- Maximum observed in-situ speed of 2300 ± 100 km/s.
- Question! What if this CME was Earth-directed?



Animation courtesy of M. Leila Mays

NASA's STEREO mission

- The STEREO mission comprises two twin spacecrafts launched in October 2006.
- Mission objective is to understand CME initiation and propagation.
- Together with SOHO, "special" CME observations can be made.
- In-situ solar wind plasma and magnetic field data measured by the PLASTIC and IMPACT instruments respectively.



http://stereo-ssc.nascom.nasa.gov/where.shtml

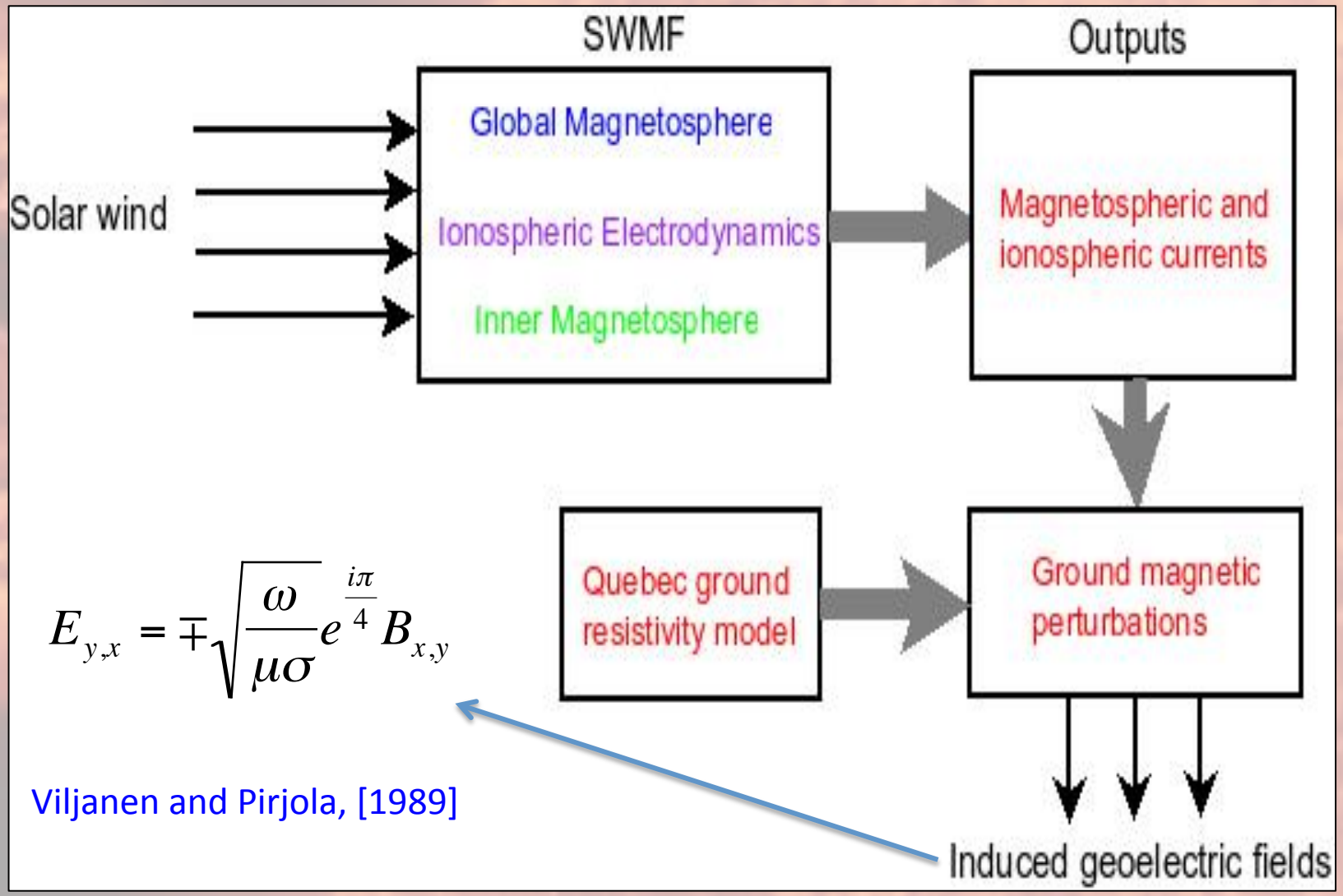
July 23, 2012 event studies

- Russell et al, [2013] provides an account of the STEREO-A magnetic field, plasma and energetic particle observations.
- Baker et al., [2013] studied the event using geomagnetic storm forecast model and found that the Dst would have been about 500 nT had the CME been Earthward directed.
- Ngwira et al., [2013b, accepted in SW] used a global MHD model to analyze the response of the ground induced electric fields.

Modeling platform

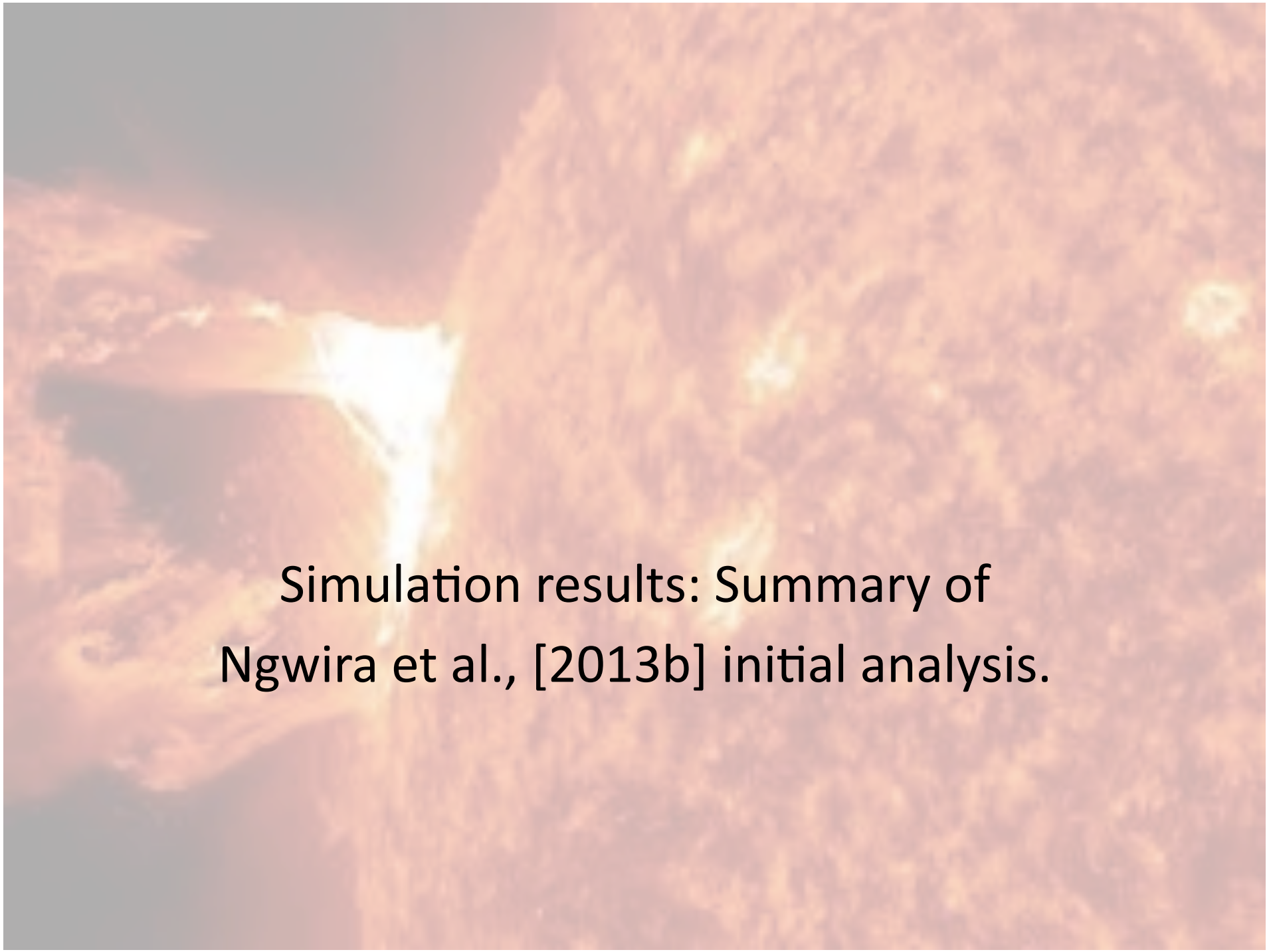
- Consider STEREO-A observations to represent the upstream L1 solar wind boundary conditions.
- Space Weather Modeling framework (SWMF): University of Michigan physics-based model [Toth et al., 2005].
- The global magnetosphere is represented by the Block-Adaptive-Tree Solar wind Roe-type Upwind Scheme code (BATS-R-US) [Powell, 1999].
- We use the SWMF 2013 version through the CCMC run-on-request system.
- All modeled results are at 1-minute sampling.

Ground electric field modeling chain

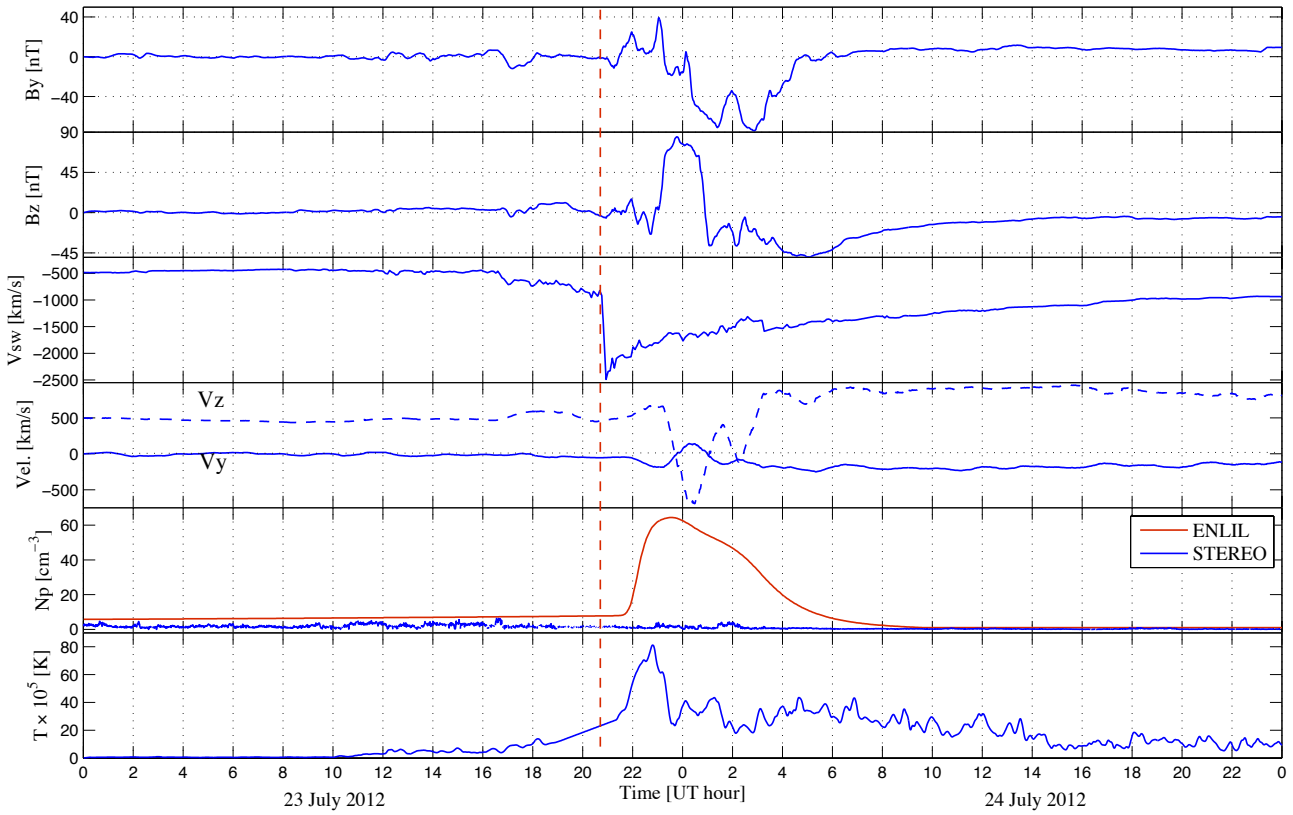


$$E_{y,x} = \mp\sqrt{\frac{\omega}{\mu\sigma}}e^{\frac{i\pi}{4}}B_{x,y}$$

Viljanen and Pirjola, [1989]

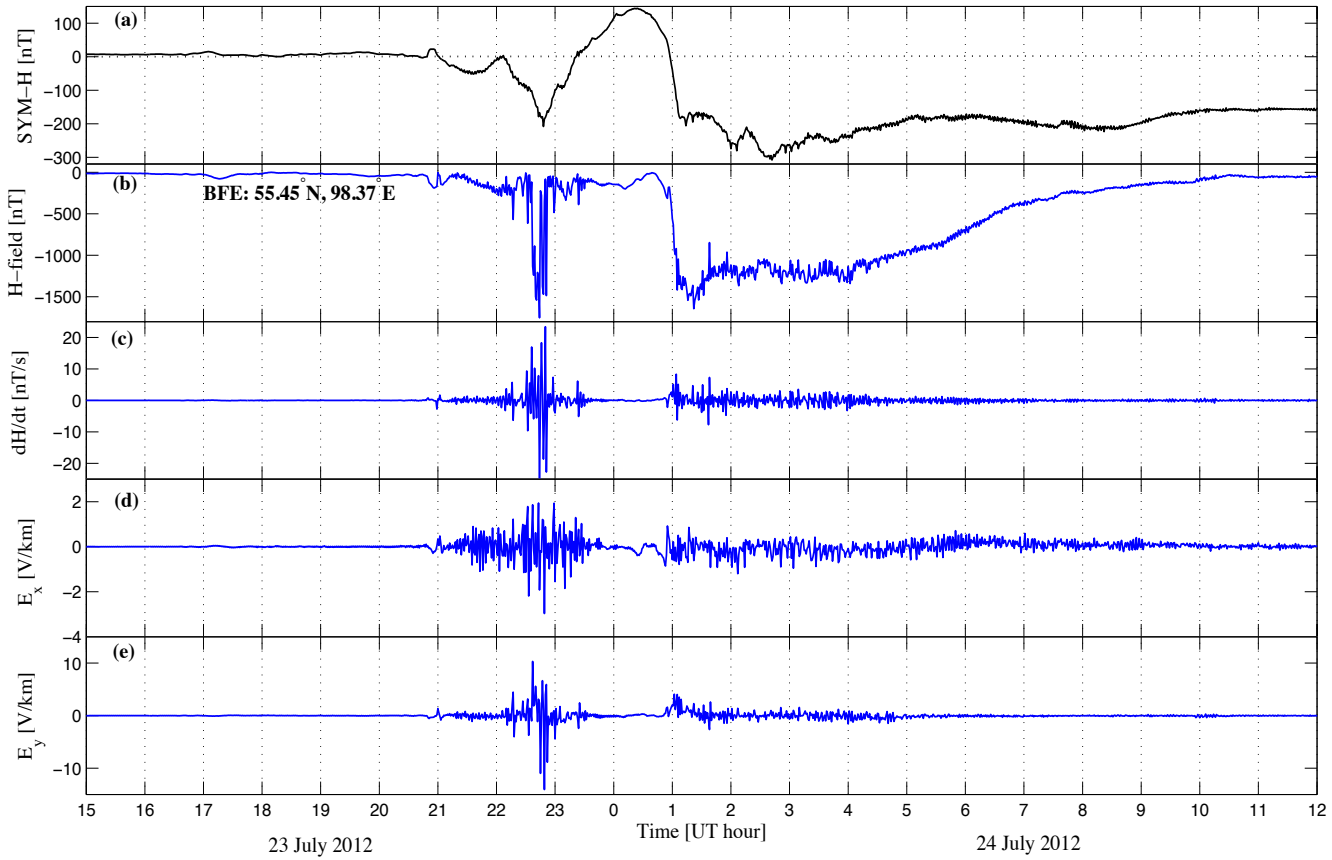

Simulation results: Summary of
Ngwira et al., [2013b] initial analysis.

STEREO-A observations/ENLIL density



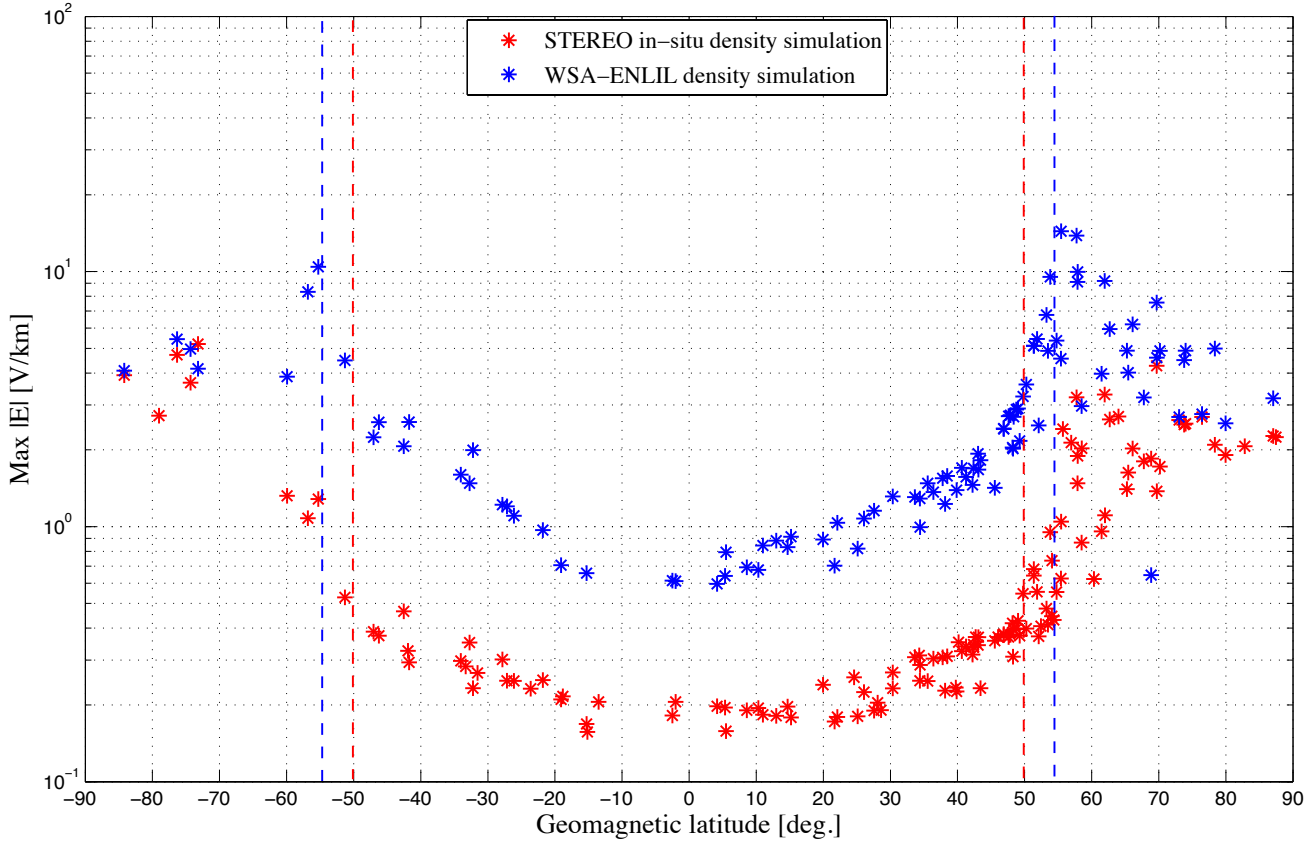
Ngwira et al., [2013b]

Geomagnetic/geoelectric field response



Ngwira et al., [2013b]

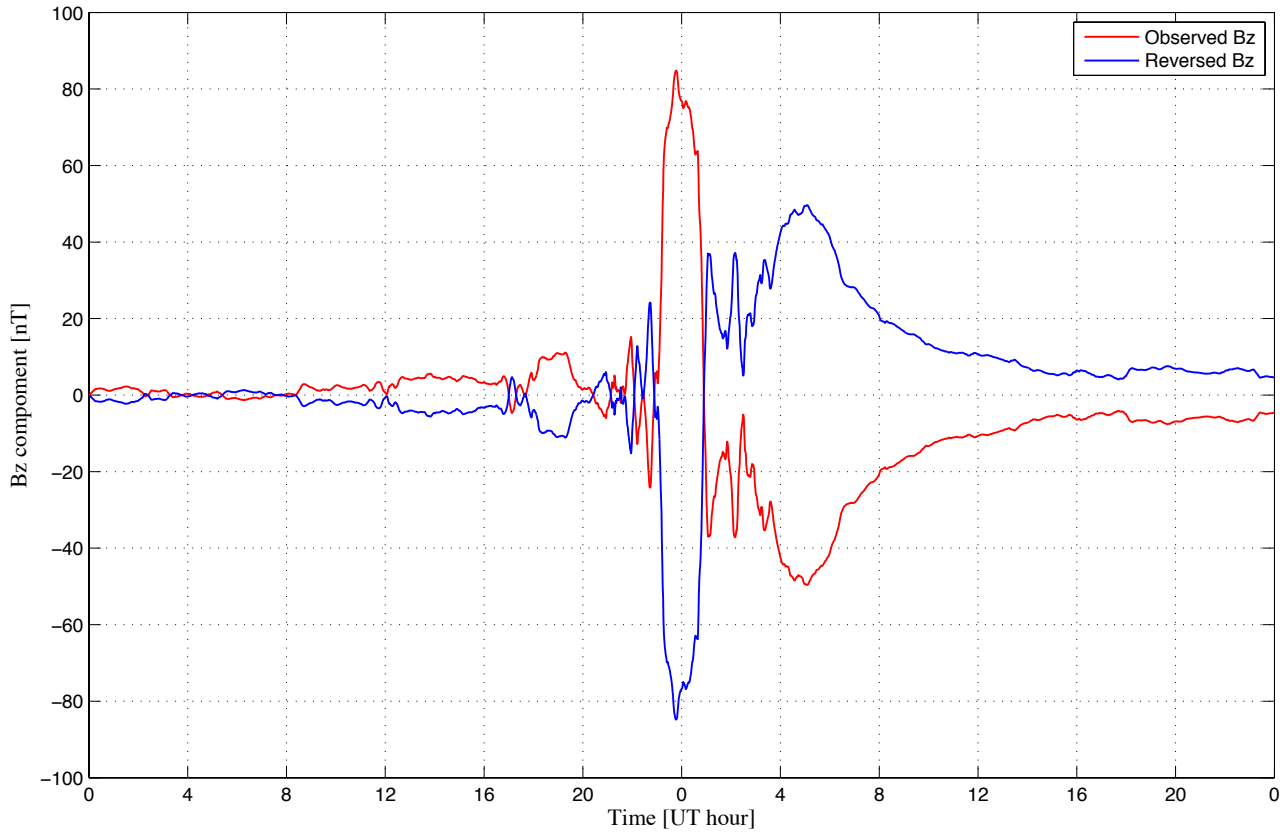
Maximum global geoelectric fields



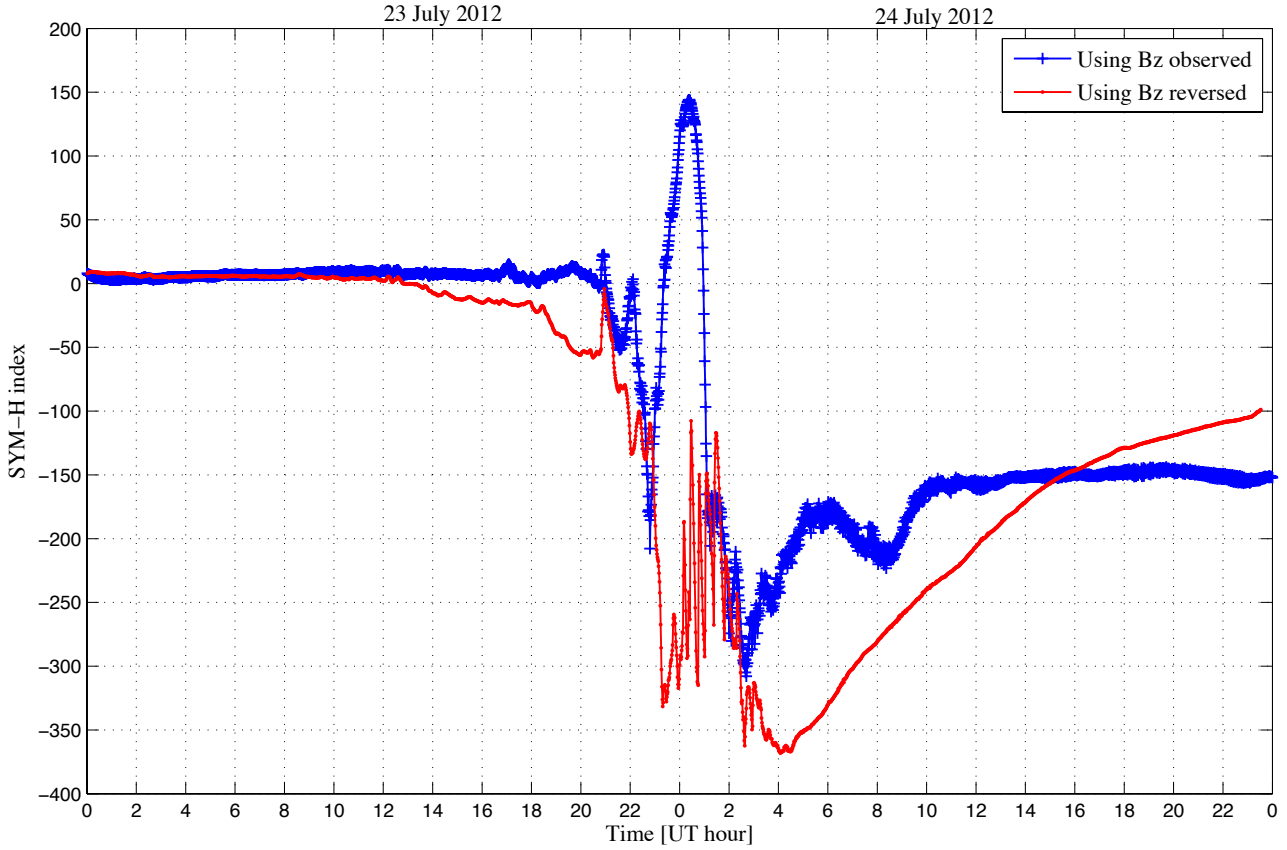
Ngwira et al., [2013b]

Simulation results: Further analysis of July 23 event.

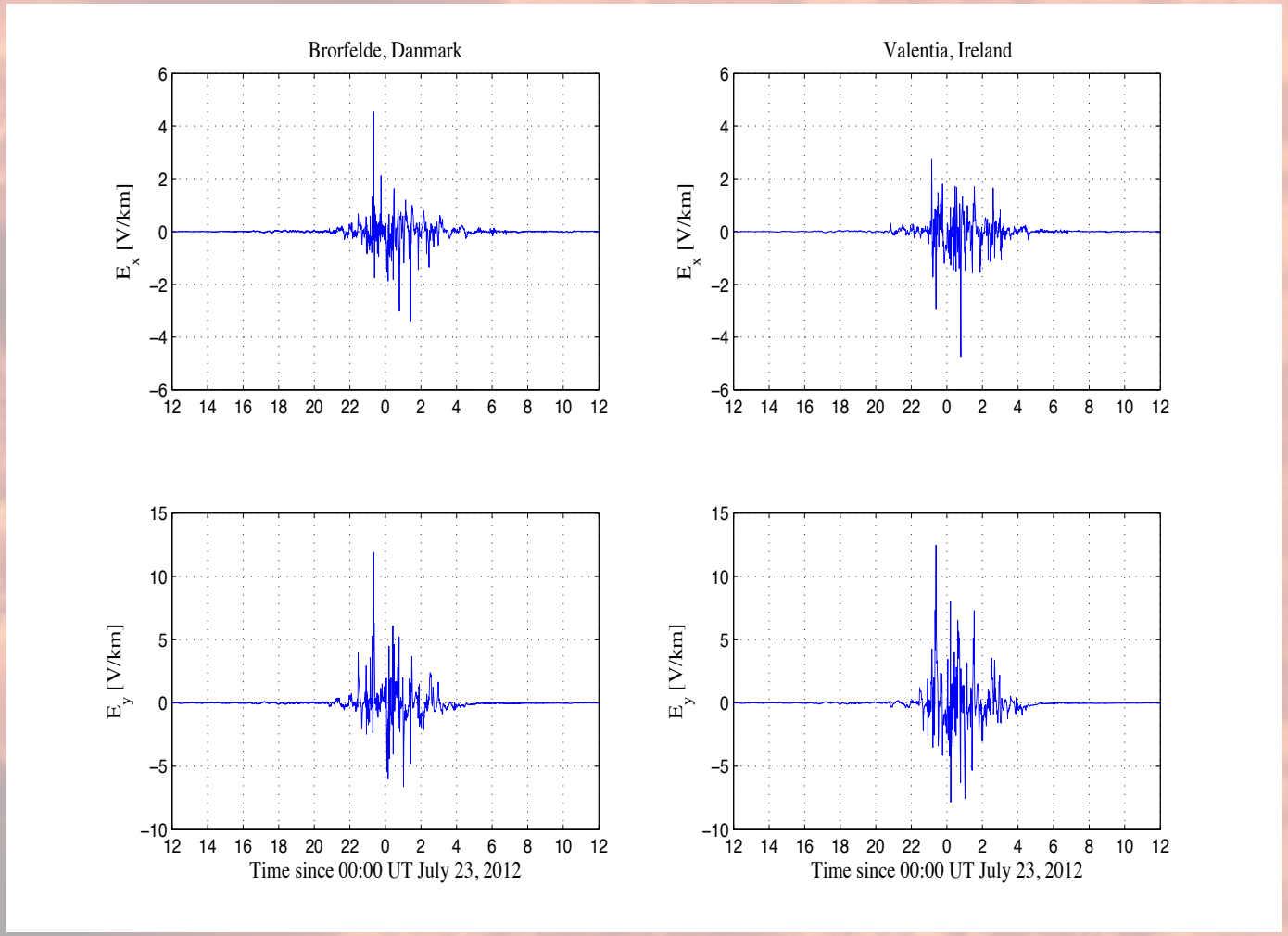
What if Bz was reversed?



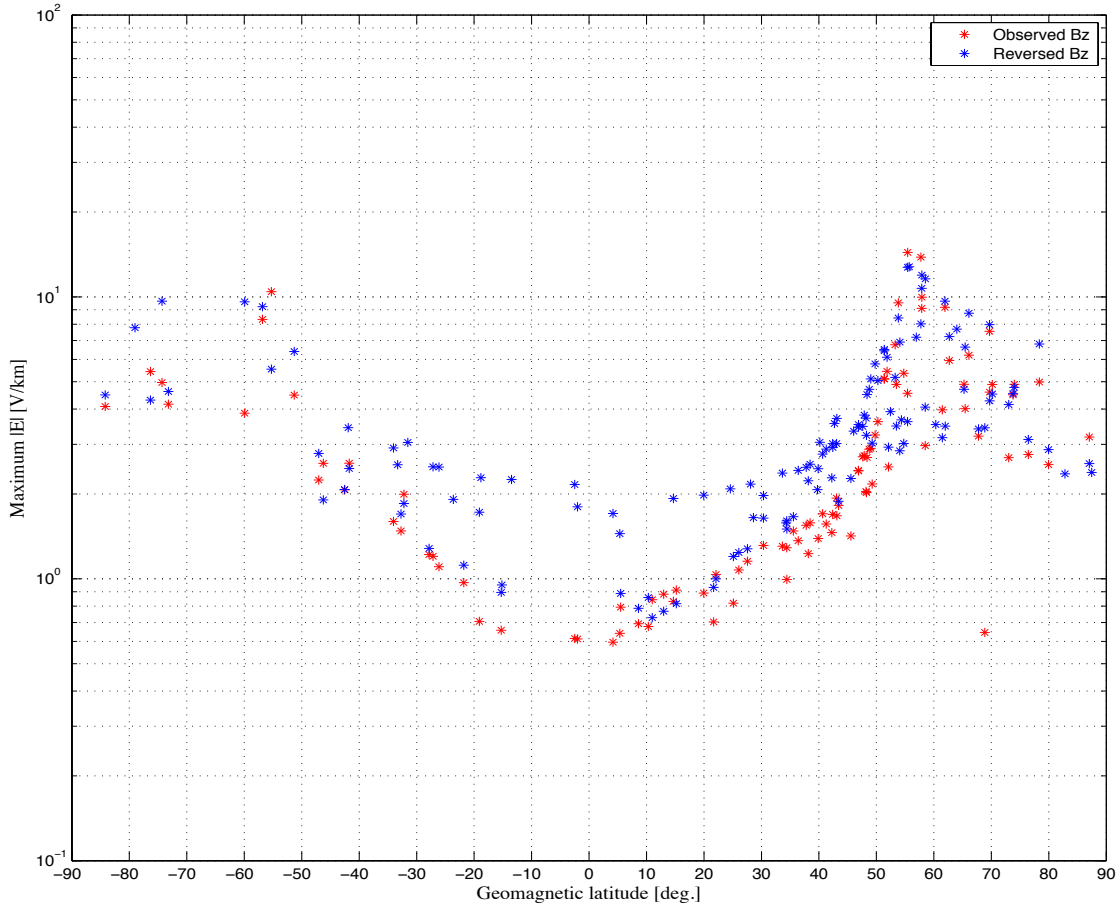
Dst index comparisons



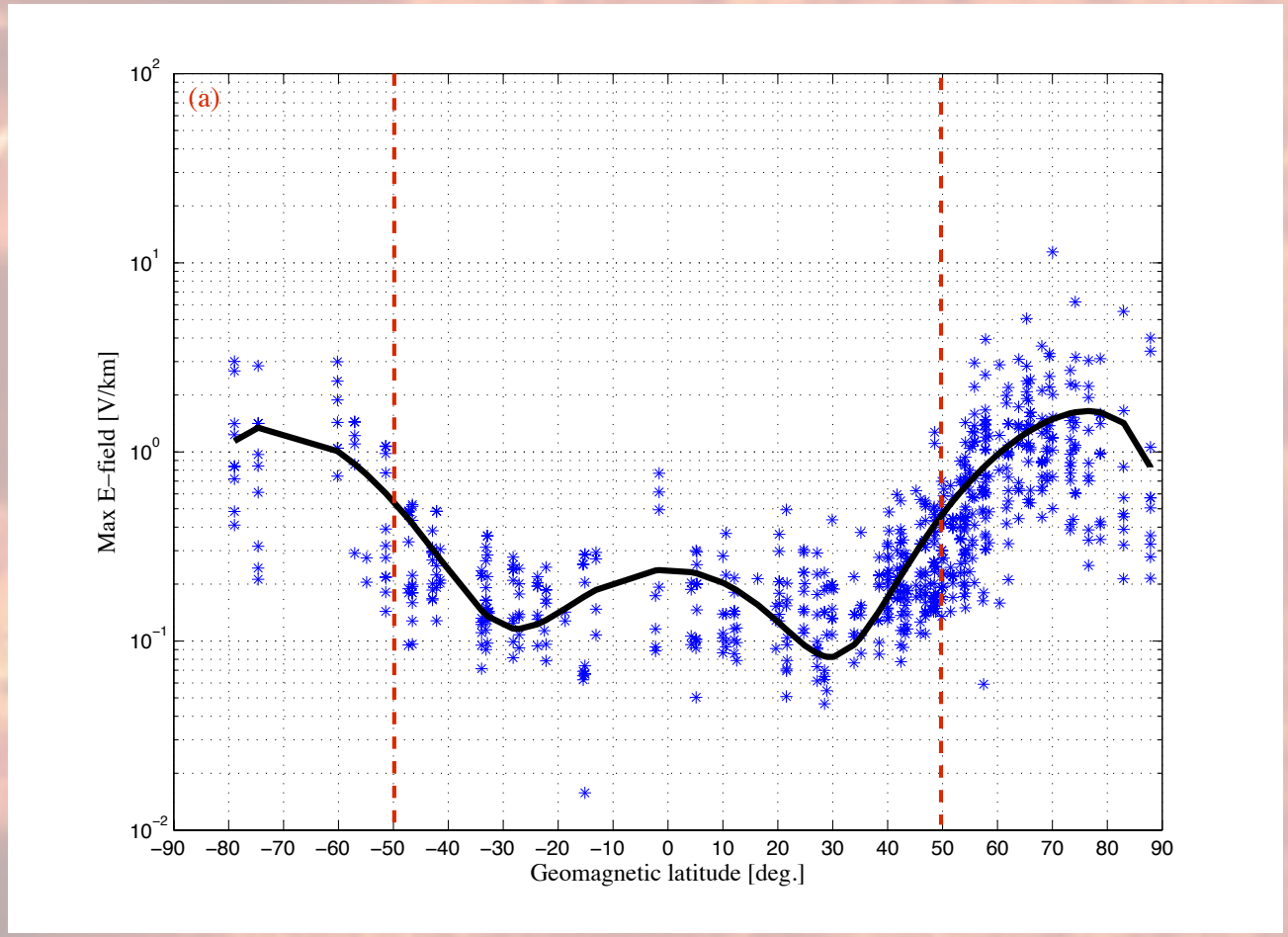
Sample electric field time series



Electric field response using observed & reversed Bz

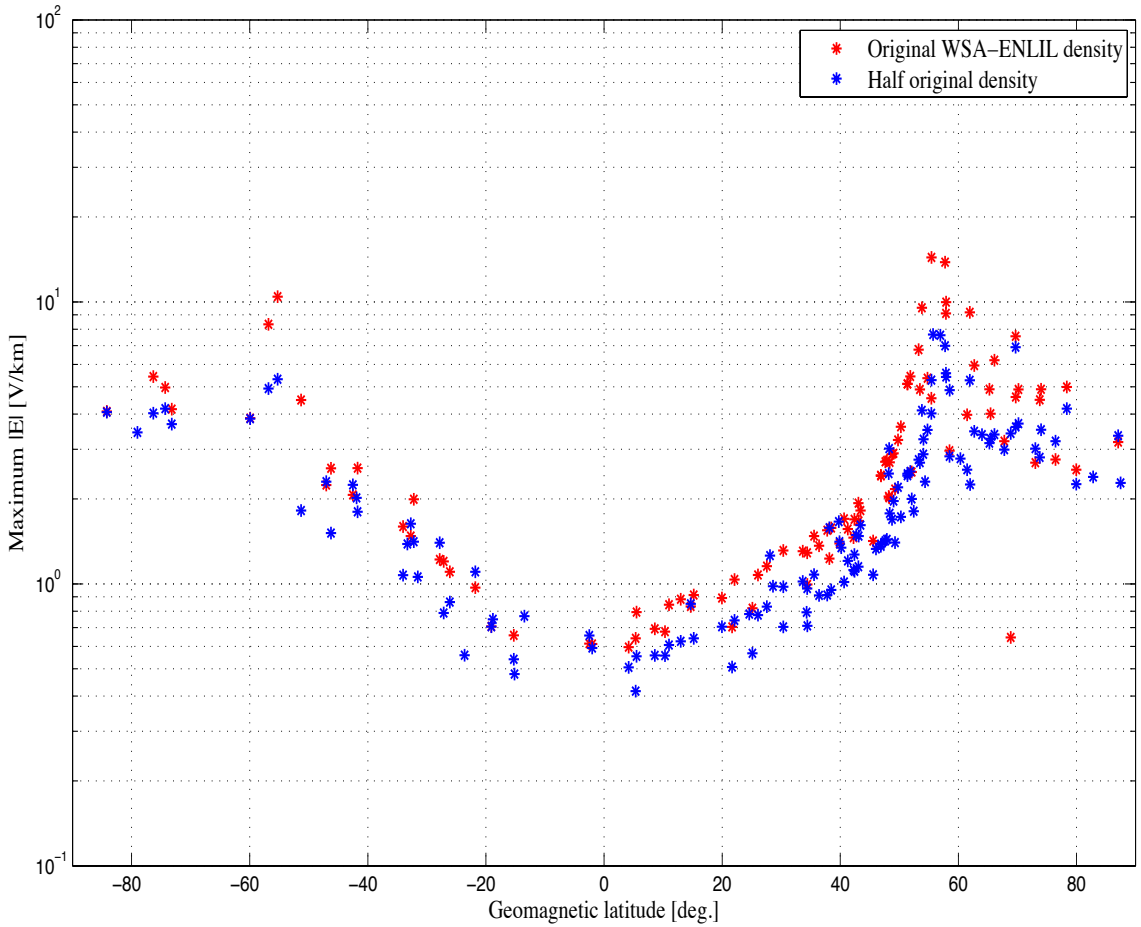


Comparisons with previously observed events



Ngwira et al., [2013a]

Original Vs half WSA-ENLIL density



Summary of results

- Maximum simulated electric field around 12-14 ± 2 V/km.
- Comparable to March 1989 and Halloween 2003 storm effects.
- Weak dependence between sign of Bz and E-field also seen by Wintoft et al., [2005].
- Noteworthy mid-latitude induced electric fields about 2-5 times compared to records of previously observed earth-directed events.

Conclusions

- The 23 July 2012 event produced one of the fastest CMEs on record.
- CME was directed away from Earth but towards one of NASA's STEREO spacecrafts.
- We used STEREO-A observations as upstream L1 driving conditions for the MHD simulations.
- Had the CME hit Earth, it would have produced some of the largest geomagnetically induced electric fields.
- However, these are comparable to March 1989 and October 2003 storms.
- Study has important practical application for risk management of power network grids.

Acknowledgements

- This research work is sponsored through the EU/FP7 EURISGIC Project funding.