The Impact of Space Climate and Weather on the Atmospheric Global Electric Circuit

Colin Price[1], Yoav Yair[2], Gal Elhalel[1], Roy Yaniv[1]

[1]Department of Geosciences, Tel Aviv University, Israel
[2]InterDisciplinary Center (IDC), Herzliya, Israel

The Global Electric Circuit (GEC)

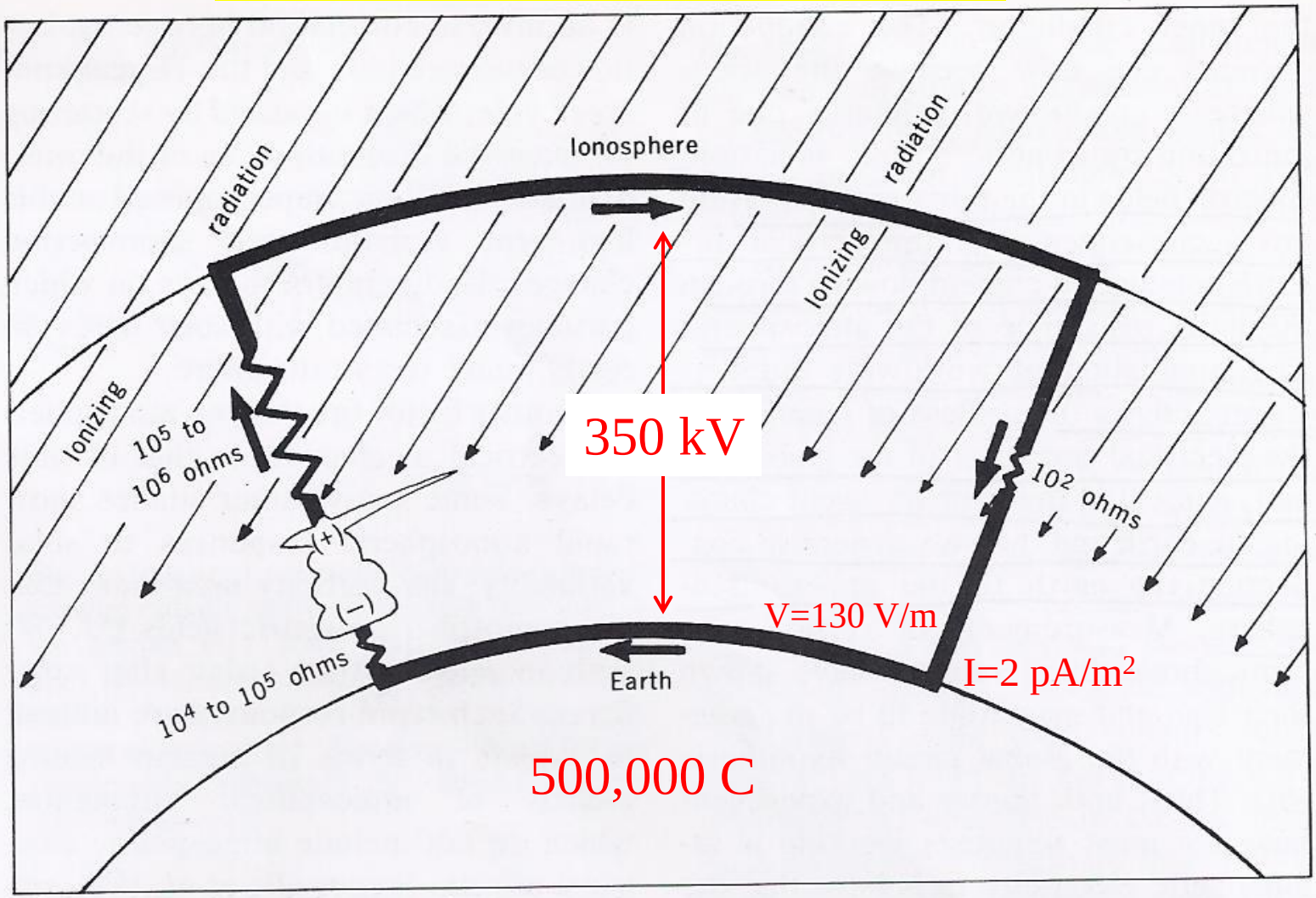
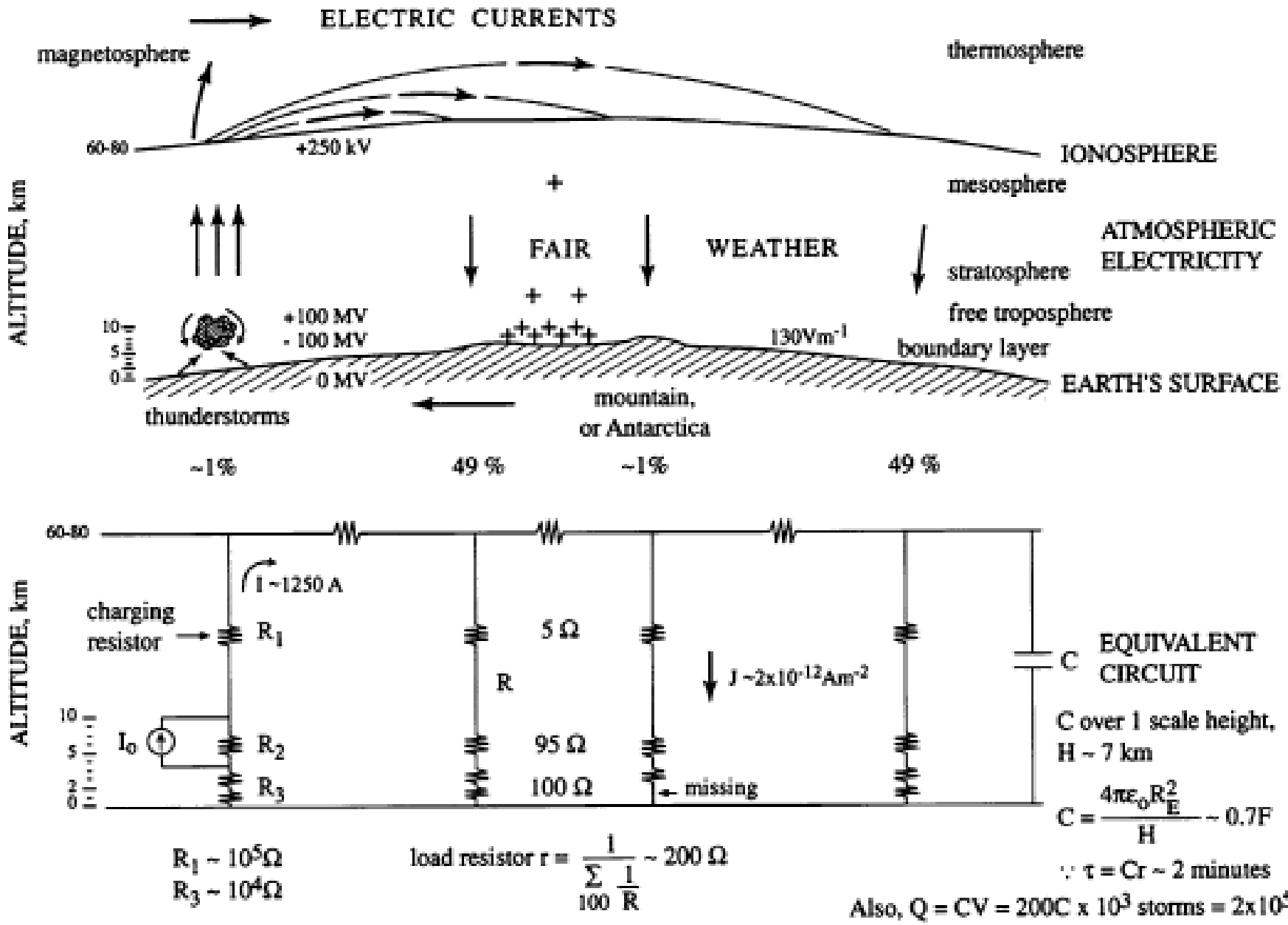


Fig. 3. Schematic of the global atmospheric electrical circuit illustrating relationships between resistive elements. The arrows indicate the accessibility of the controlling resistive element above the thunderstorm generator to the varying component of the ionizing radiation (*15*).

Markson (1978)



Rycroft et al. (2000)

Impact of Solar Flares

(1964-67)

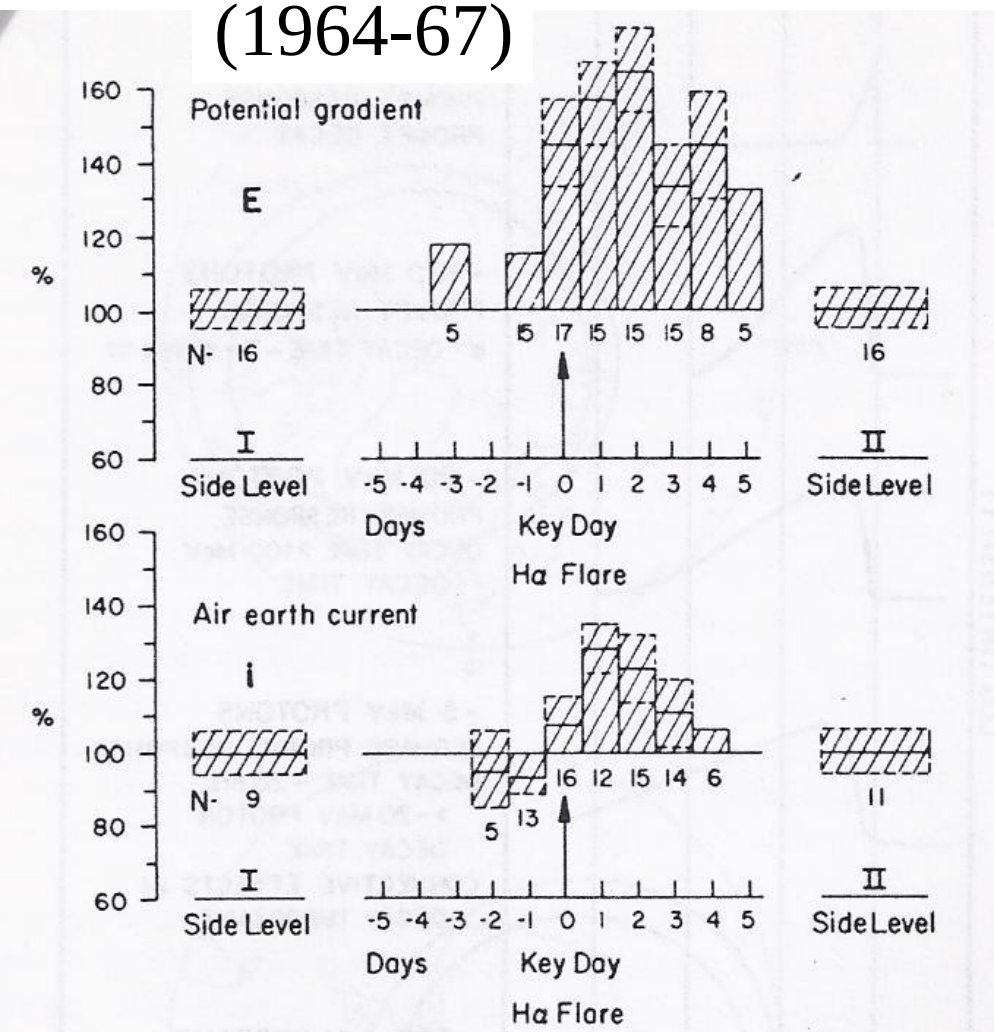
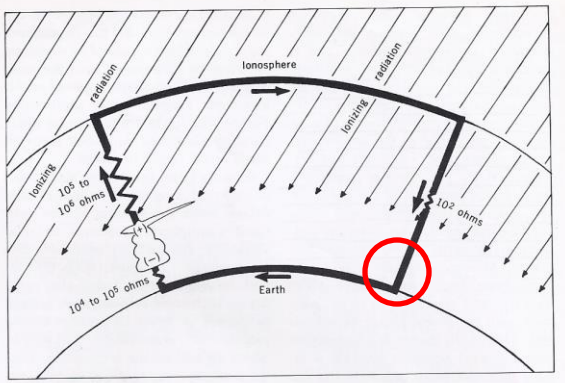


Fig. 8. Groupings of hourly means (percentage) of electric field (top) and air-earth current (bottom) around flare days during 3 years of generally low, solar activity levels (1964–1967), as measured at the



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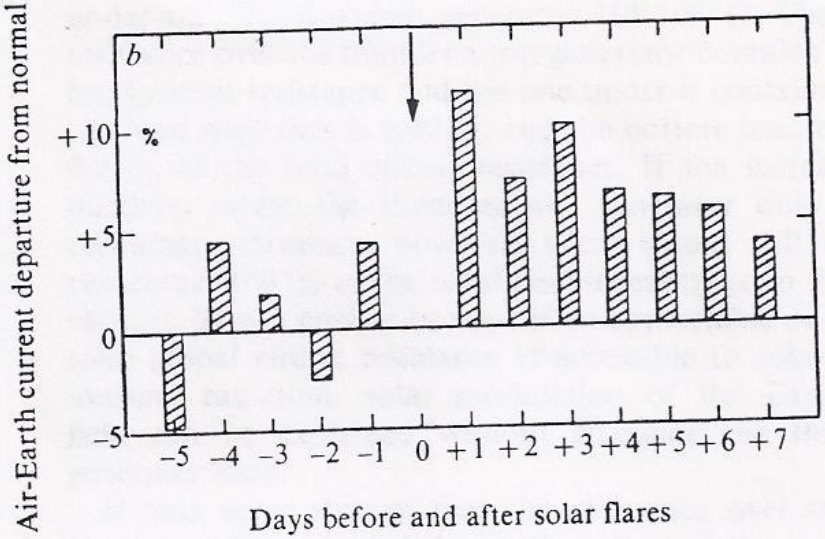
Hawaii (1960-61)



Cobb(1967)

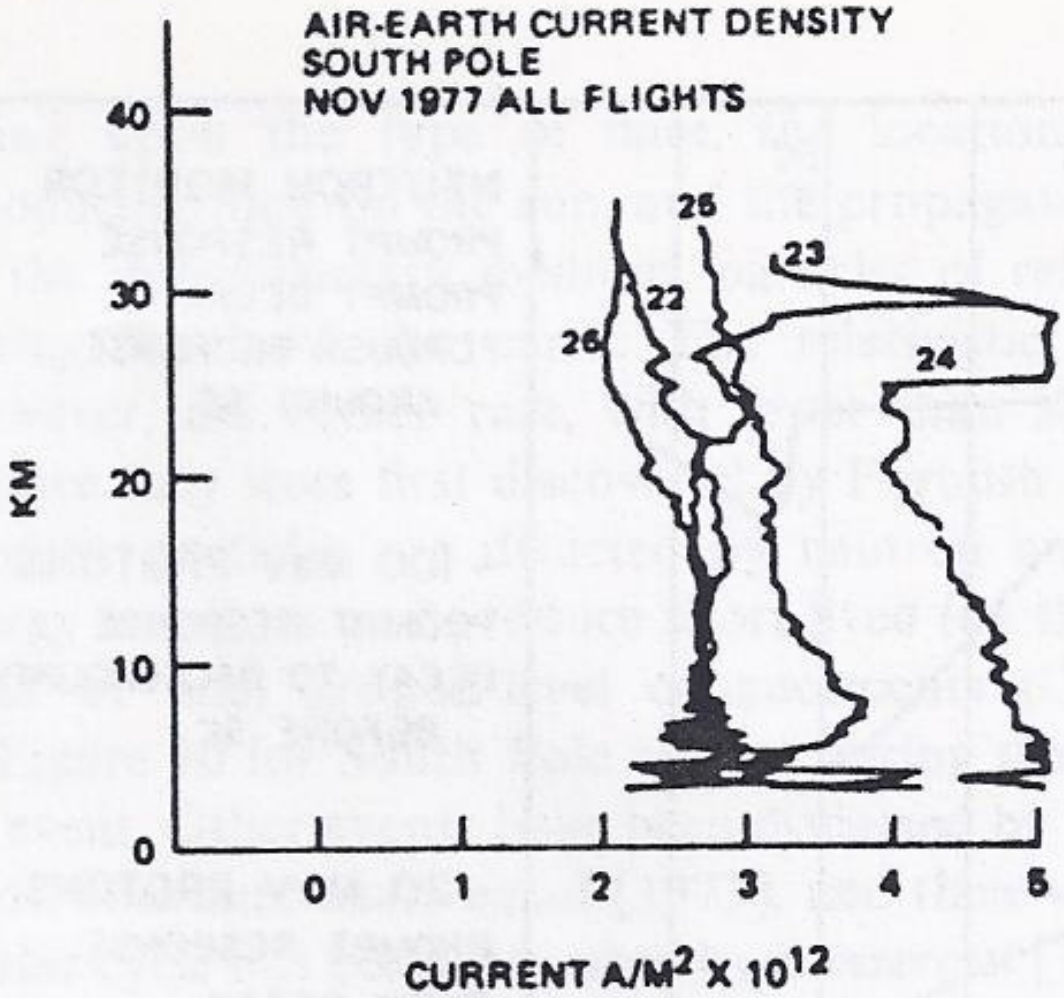
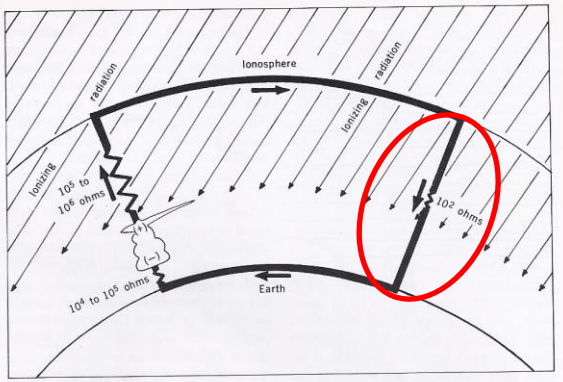


Fig. 9. Air-earth current densities measured during balloon flights from the South Pole during November 22, 1977. The days in November are indicated on each curve. A solar flare occurred at 0945 UT on November 22 [Cobb, 1978].



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Cobb (1978), Roble (1985)

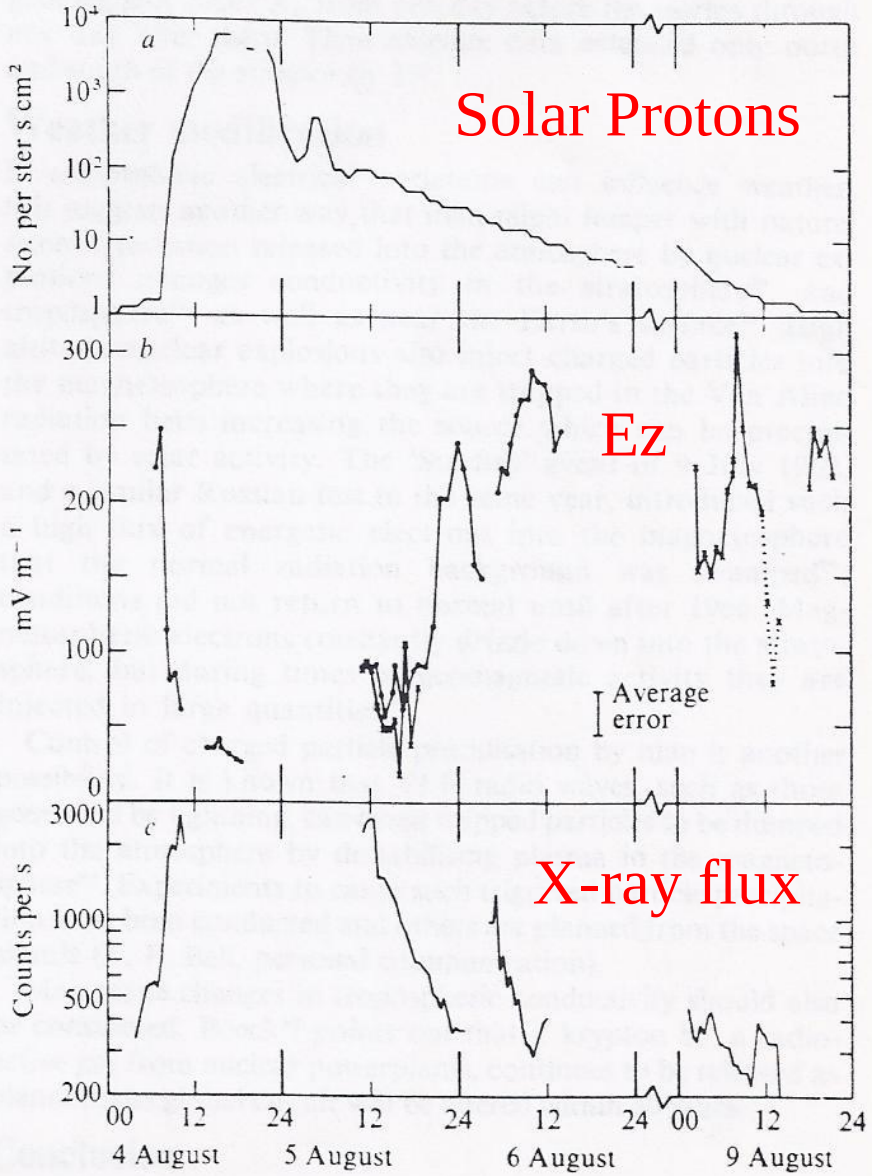
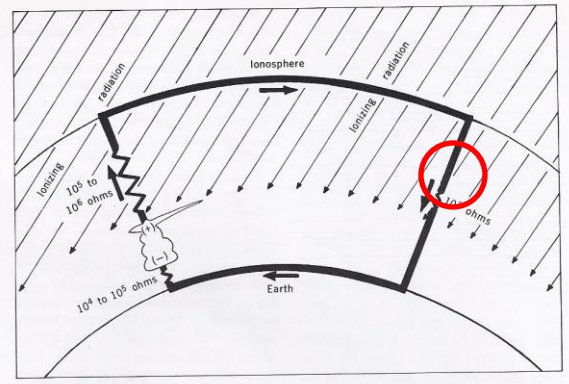


Fig. 5 Comparison of simultaneous measurements of solar protons from a satellite $E_p > 60$ MeV (*a*); vertical electric field from two balloons at 30 km over Canada, ●, Thompson; ×, College (*b*); and radiation intensity as recorded by X-ray detectors on the balloons (*c*). Solar flare occurred at 0617 on 4 August 1972.

Impact of solar ionising radiation on atmospheric electric fields at 30km

Holzworth and Mozer (1977)
Markson (1978)



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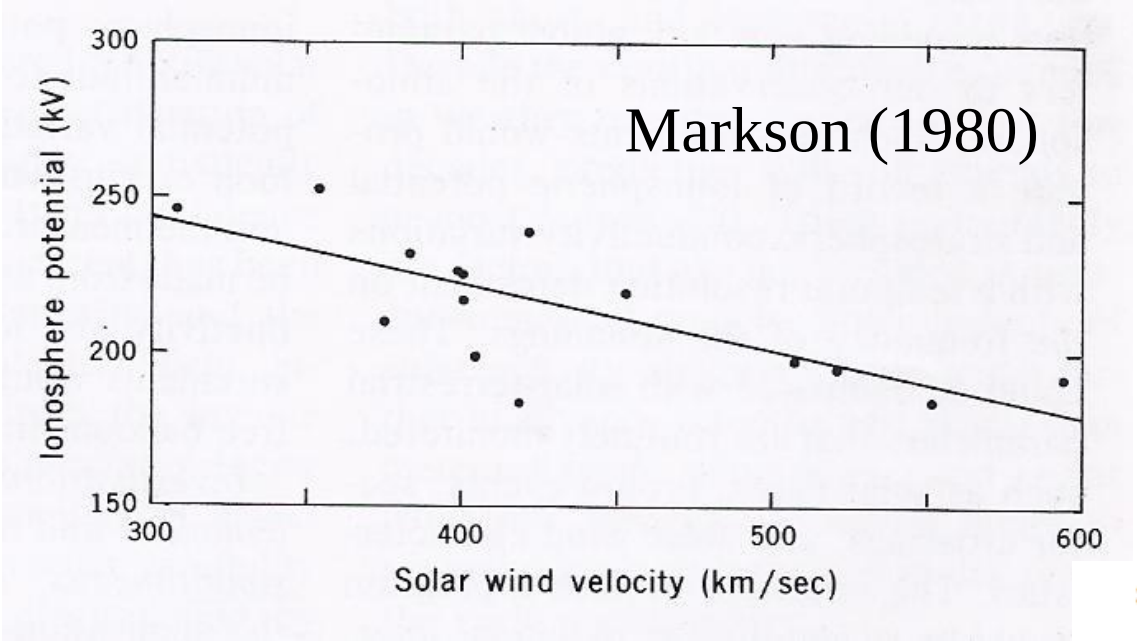
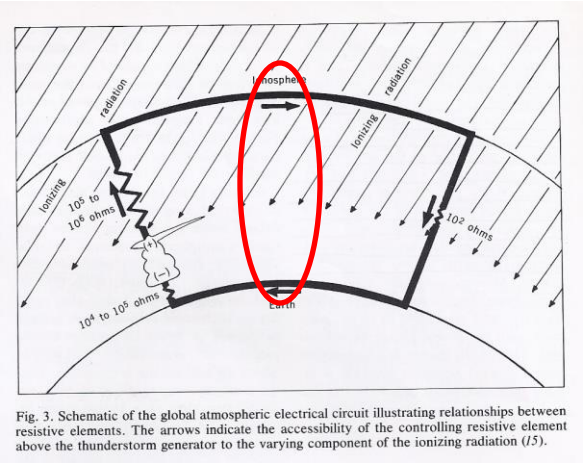
Ionospheric Potential





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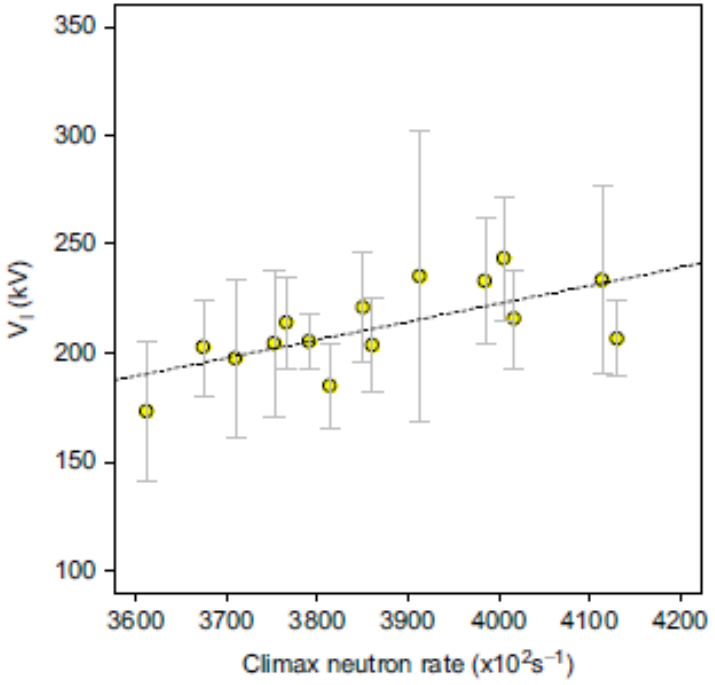
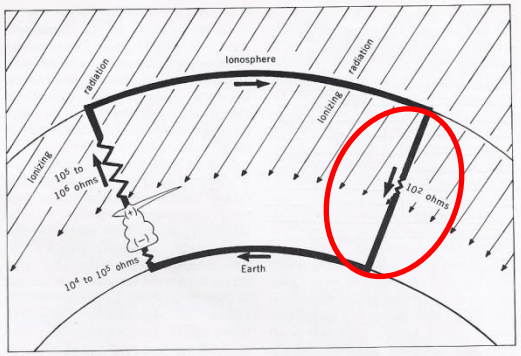


Harrison and Usoskin (2010)

Solar cycle and Jz



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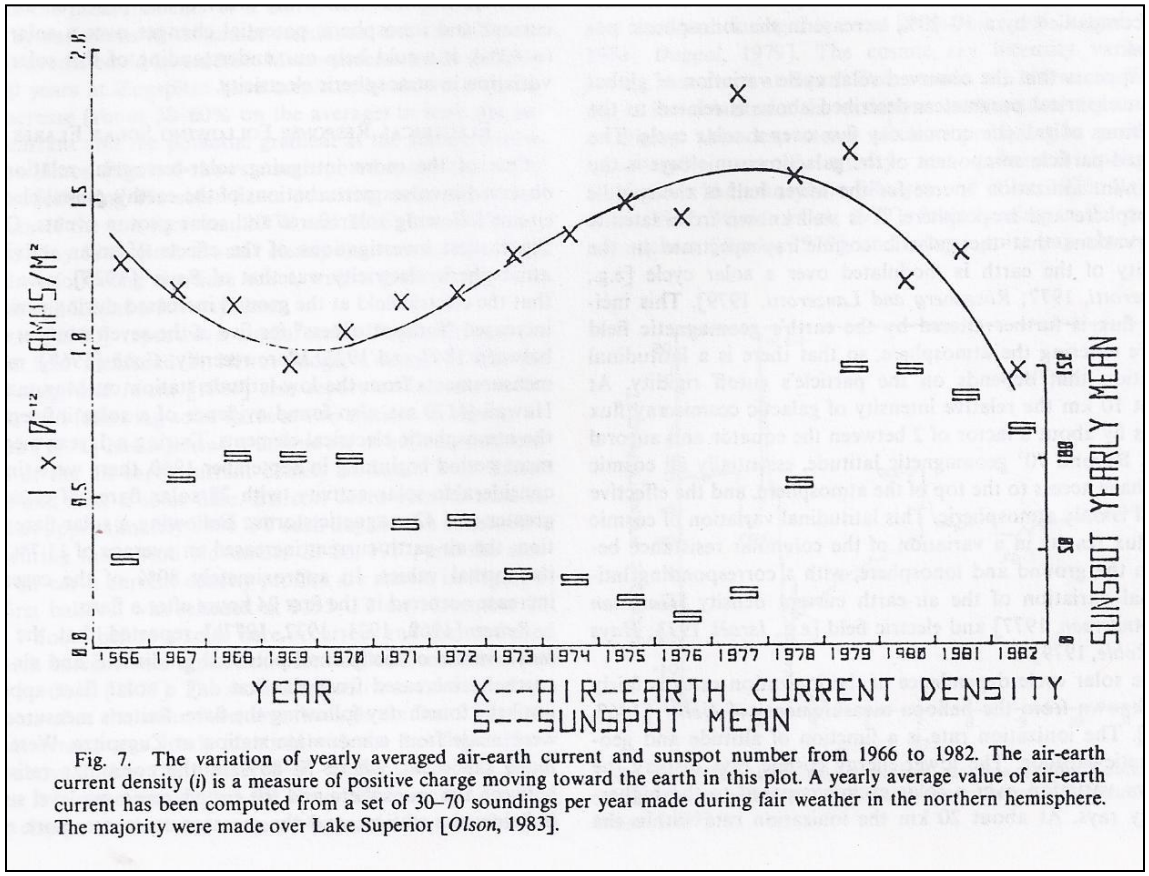


Fig. 7. The variation of yearly averaged air-earth current and sunspot number from 1966 to 1982. The air-earth current density (*i*) is a measure of positive charge moving toward the earth in this plot. A yearly average value of air-earth current has been computed from a set of 30–70 soundings per year made during fair weather in the northern hemisphere. The majority were made over Lake Superior [*Olson*, 1983].

Olson (1977, 1983); Markson (1980); Roble (1985)

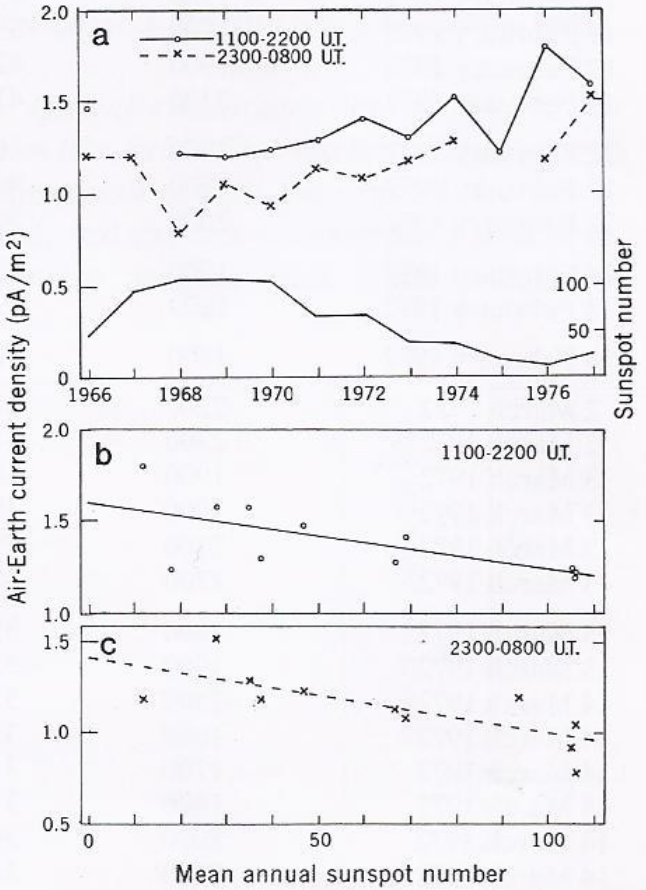


Fig. 5. Variation of air-earth conduction current density (a measure of ionospheric potential) through a solar cycle period. These are the results of more than 300 balloon ascents by D. E. Olson (Department of Physics, University of Minnesota, Duluth). The data were divided into two sets, one corresponding to the hours of maximum electric field due to the U.T. diurnal variation, the other to the hours of minimum in this cycle. Scatter diagrams showing the inverse correlation between current density and sunspot number have been made for each data set.

Solar Cycle in Thunderstorm Frequency?

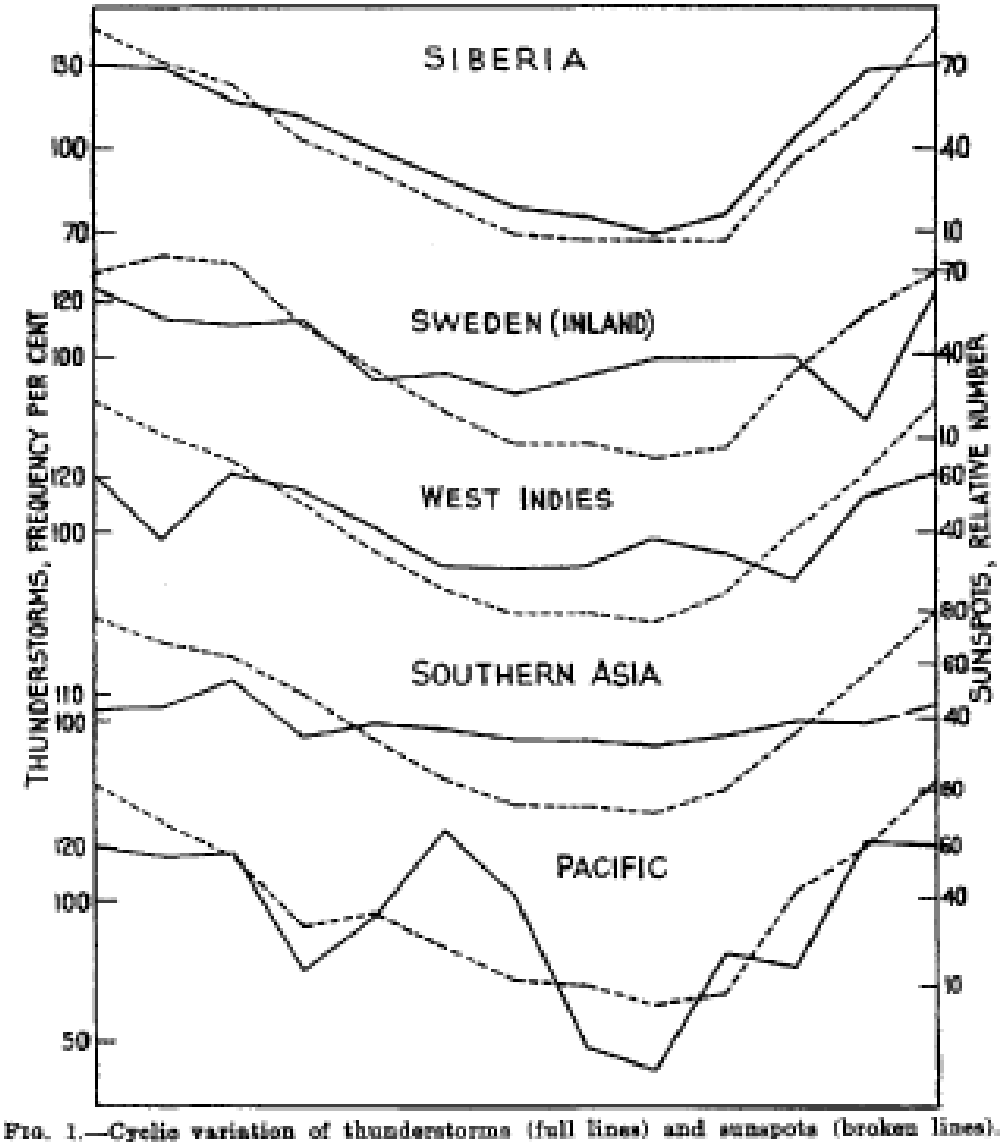
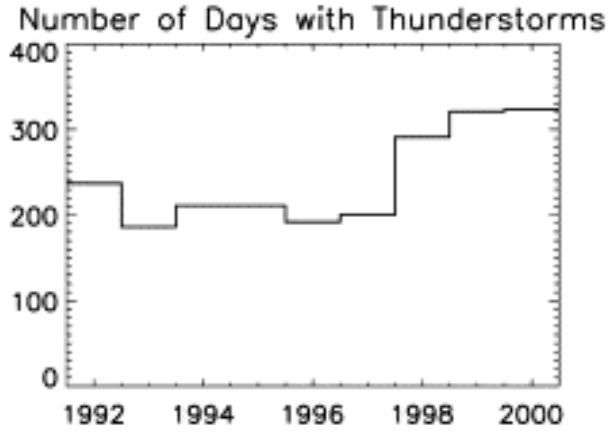


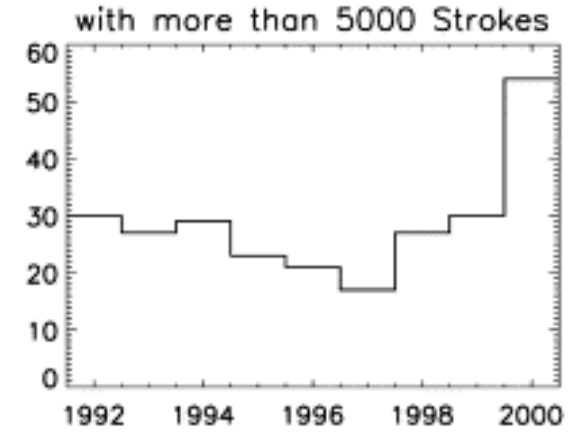
FIG. 1.—Cyclic variation of thunderstorms (full lines) and sunspots (broken lines).

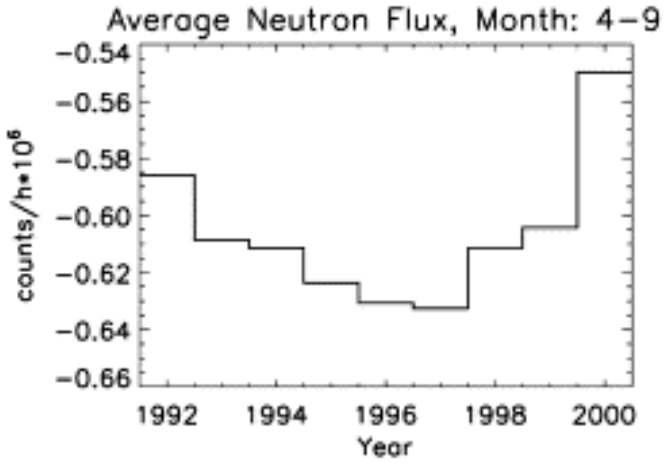
Data from 1866-1932

(Brooks, 1934)

Stringfellow (1974) showed similar relationships for UK from 1930-1973 (4 solar cycles)



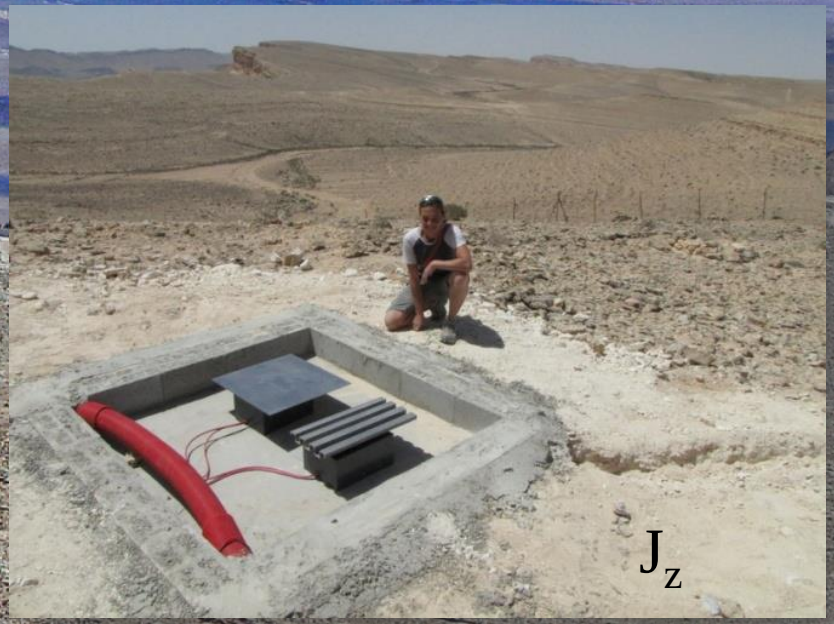


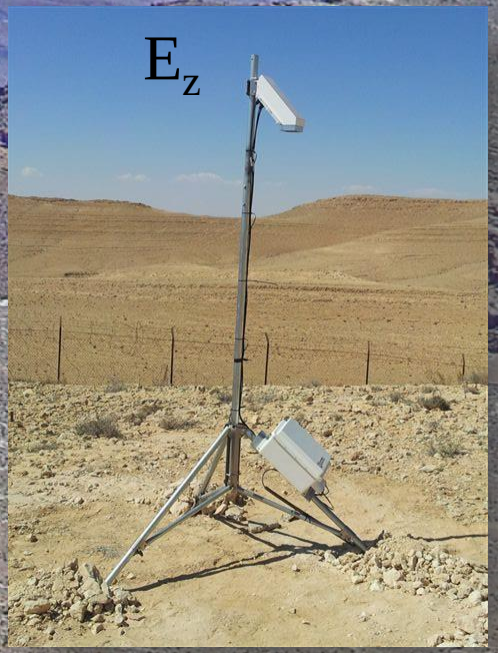


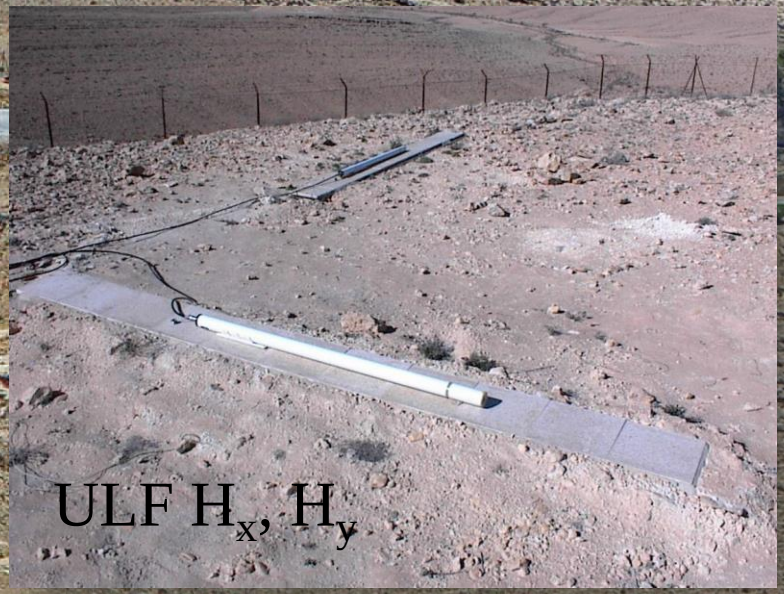
European Thunderstorms
(Austria and Germany)
Data from ground networks
April-September

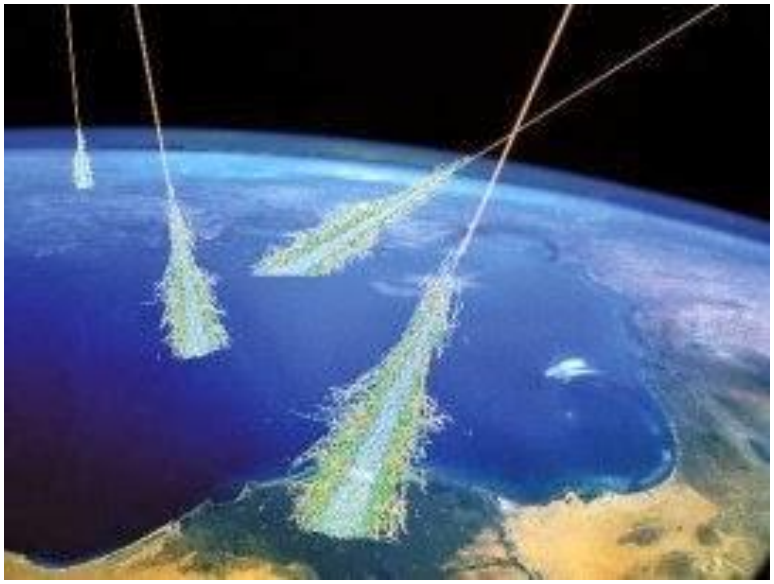
Schlegel et al. (2001)

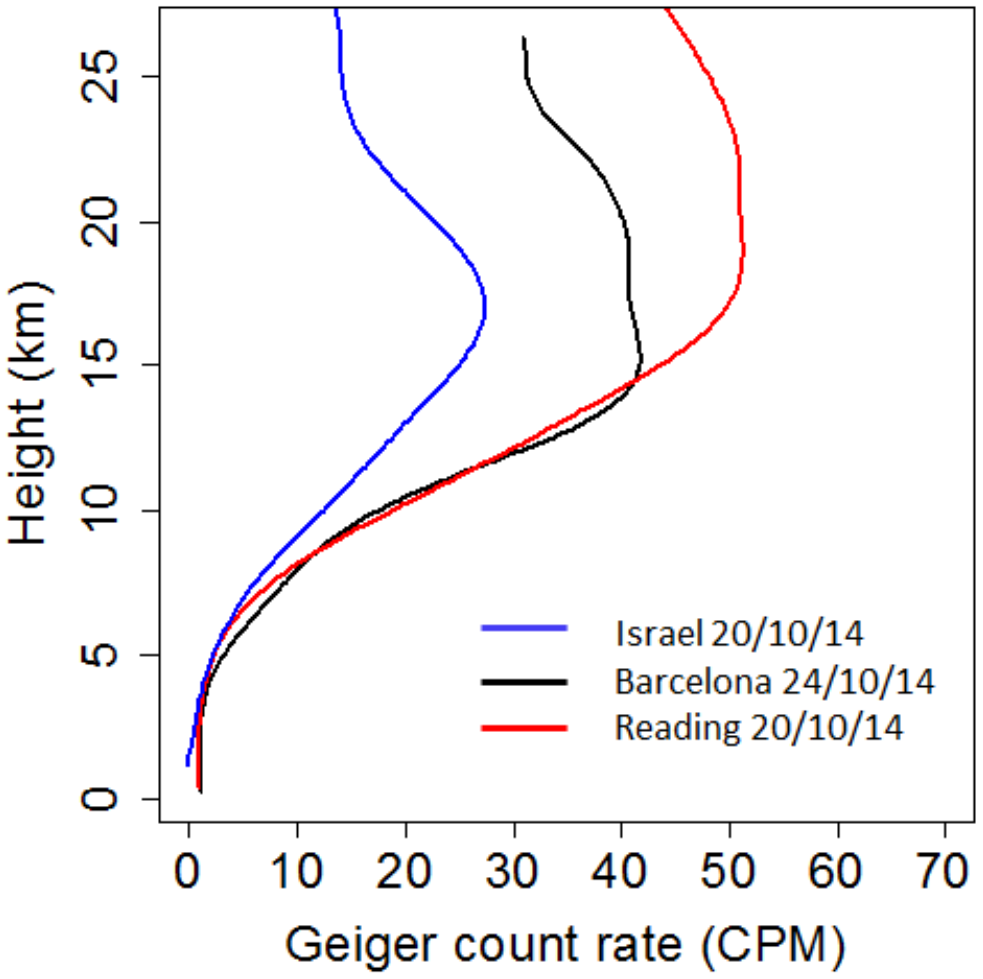
Mitzpe Ramon, Israel





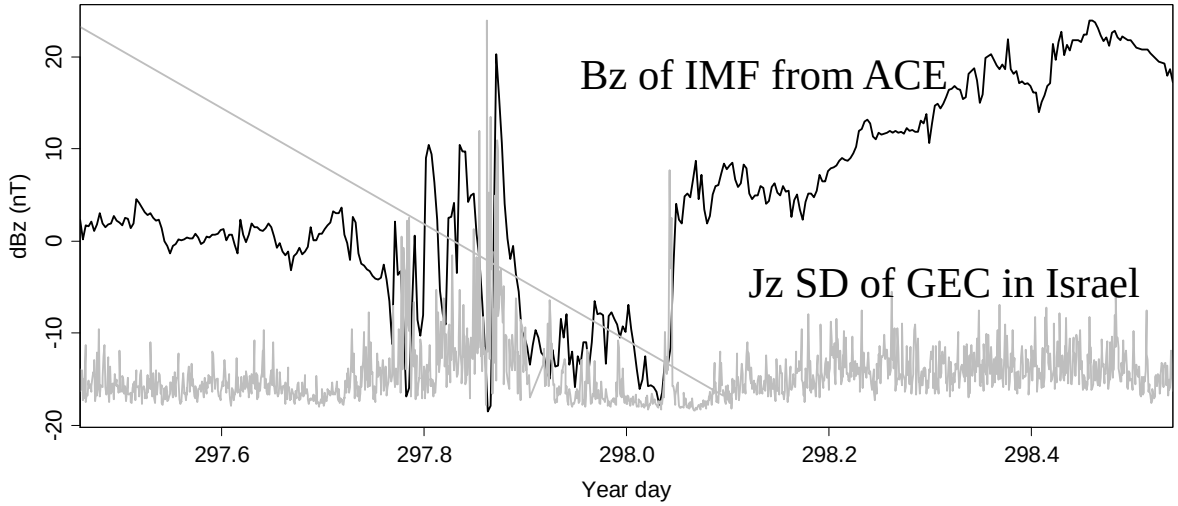


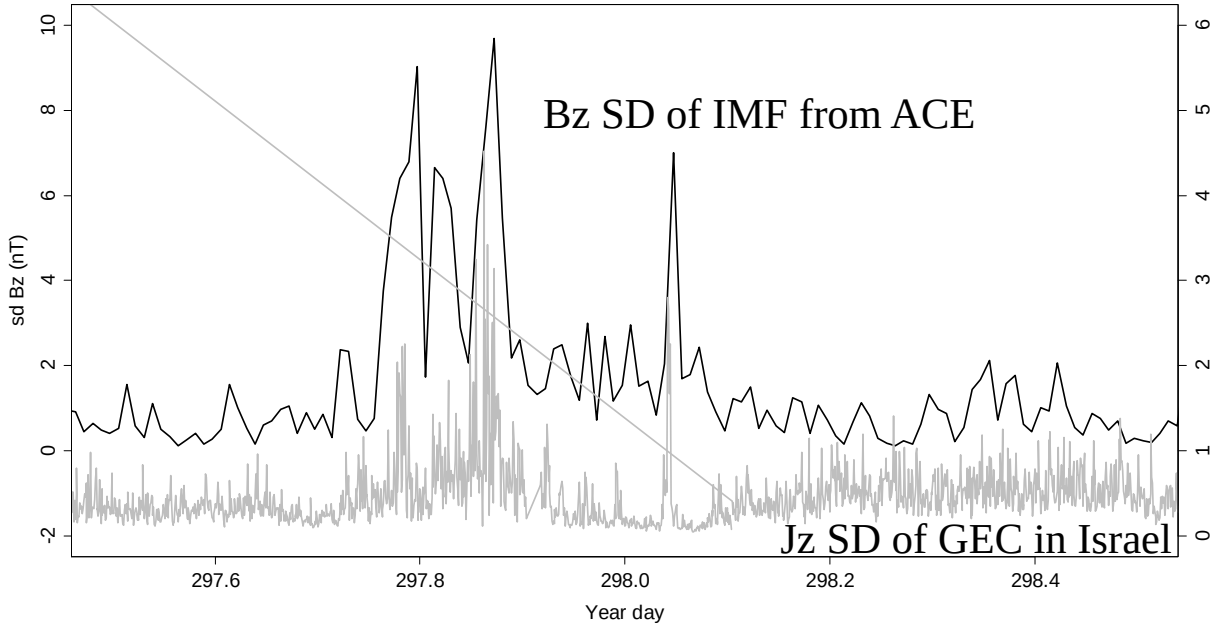


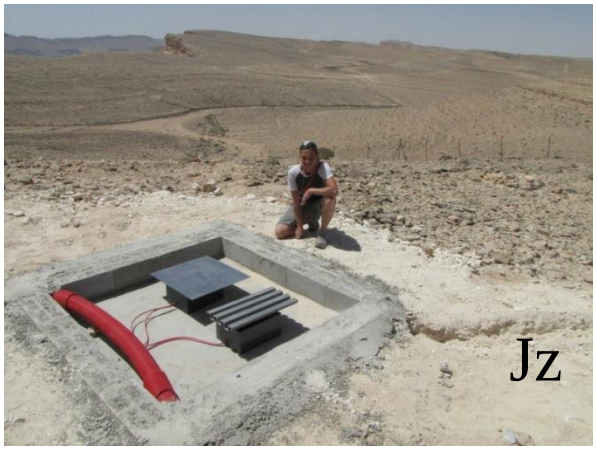


Ionization produced by cosmic rays

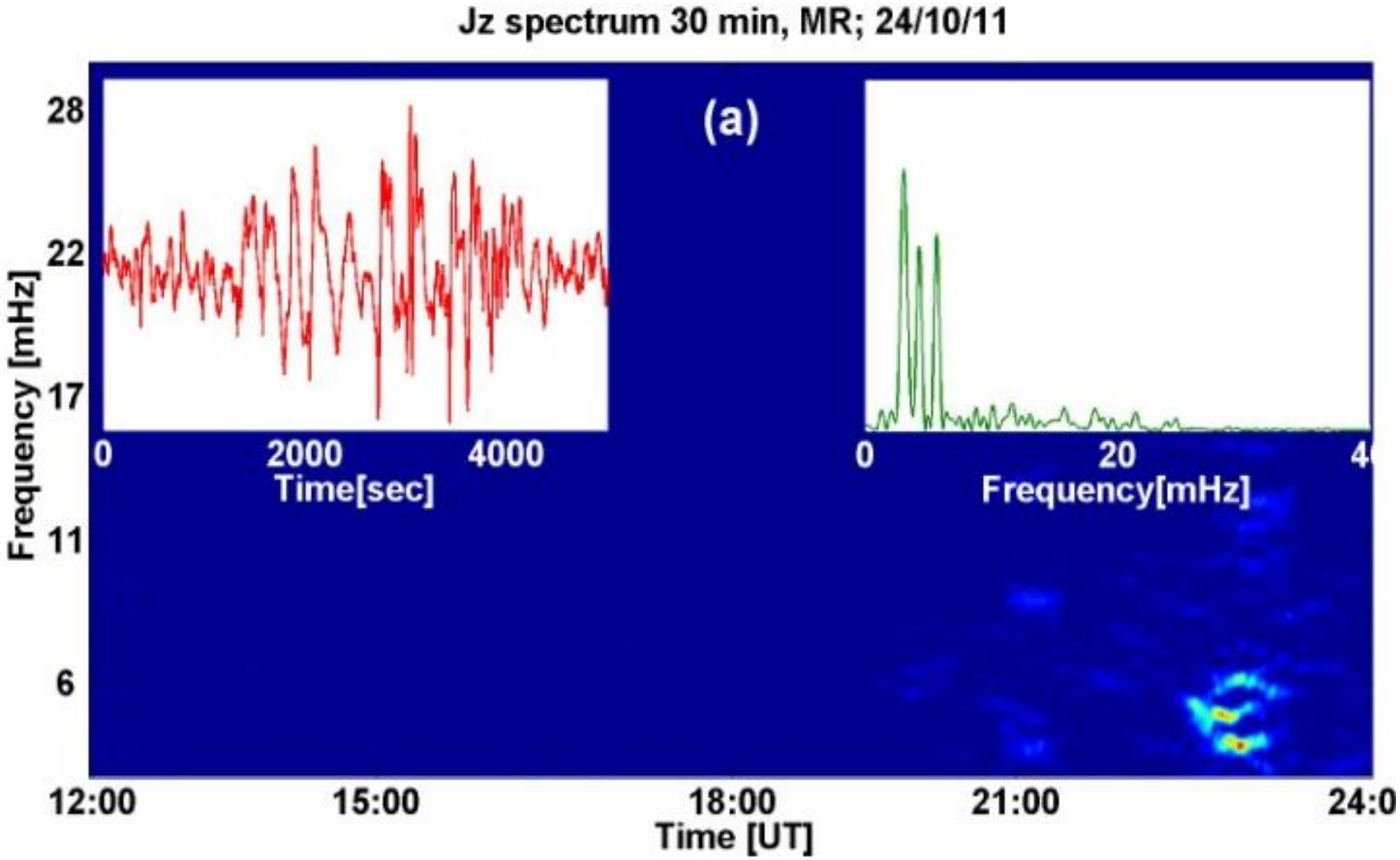
Solar Proton Event : 24 October 2011





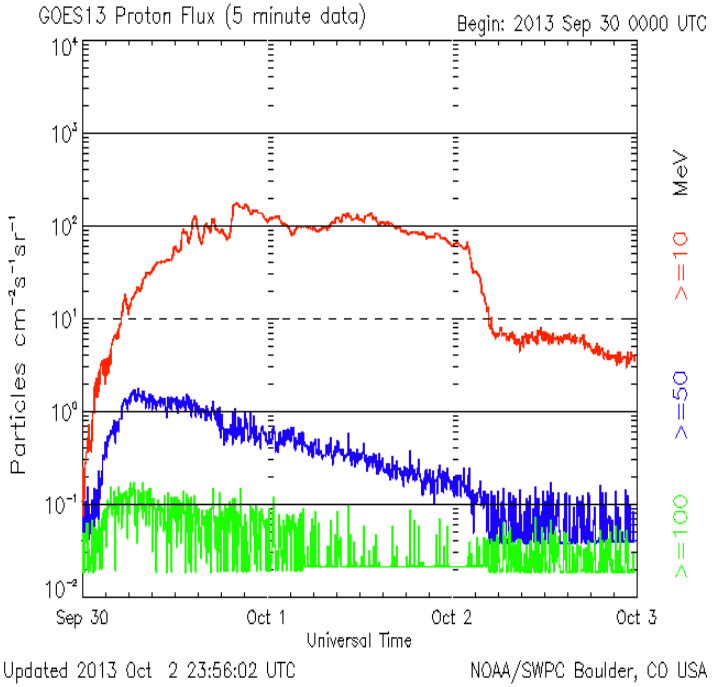


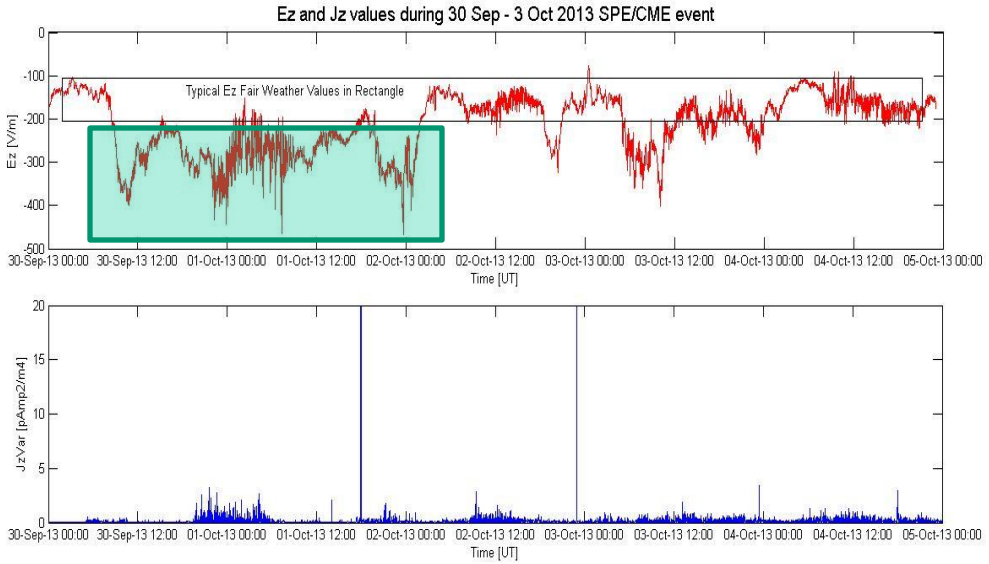
Elhalel et al. (2014)



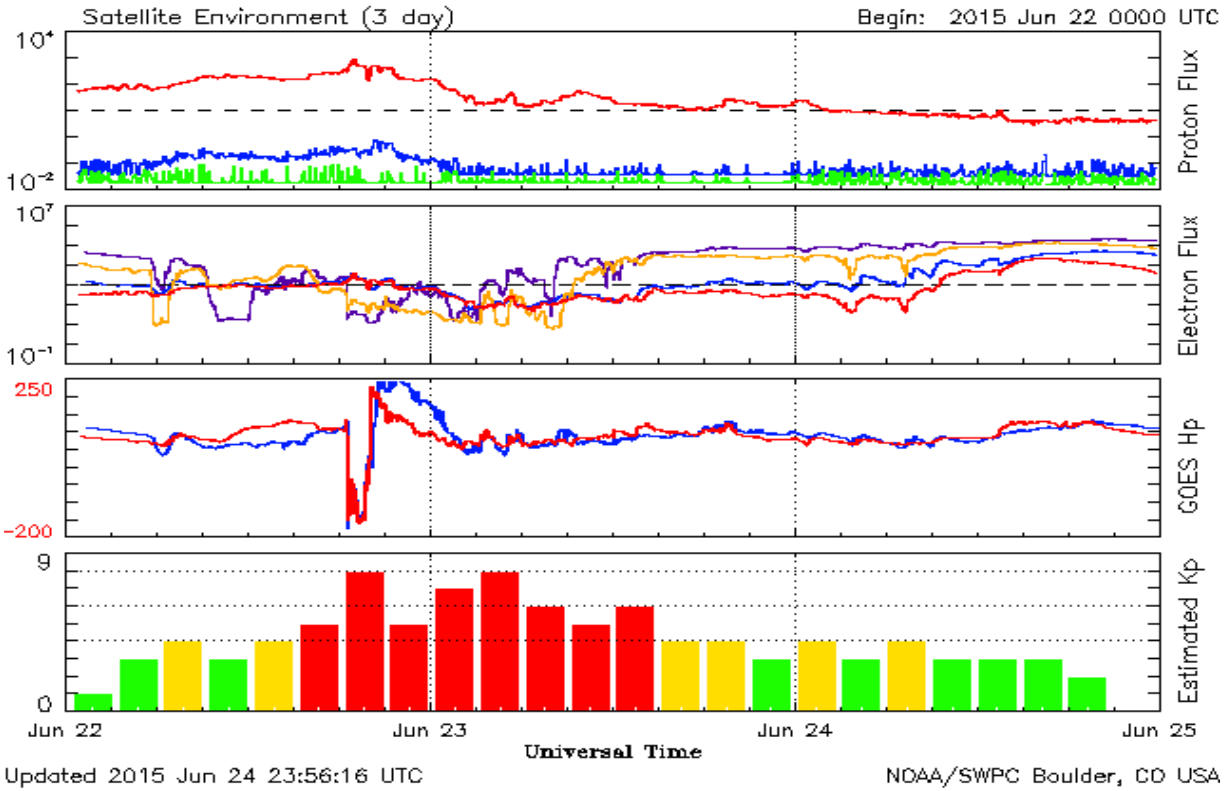
"ULF Pulsations in Fair Weather Current"

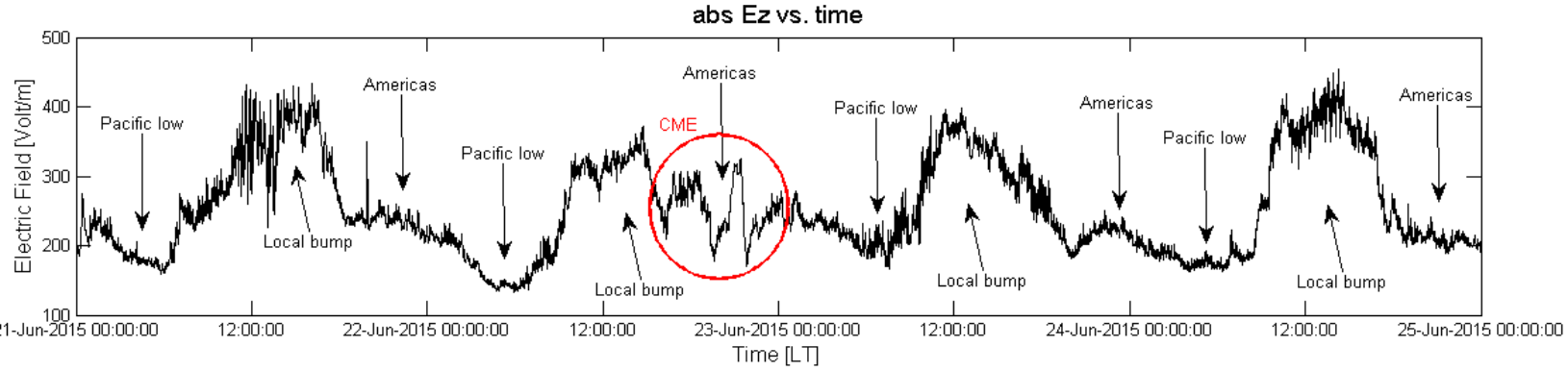
Solar Proton event 30Sep-1 Oct 2013



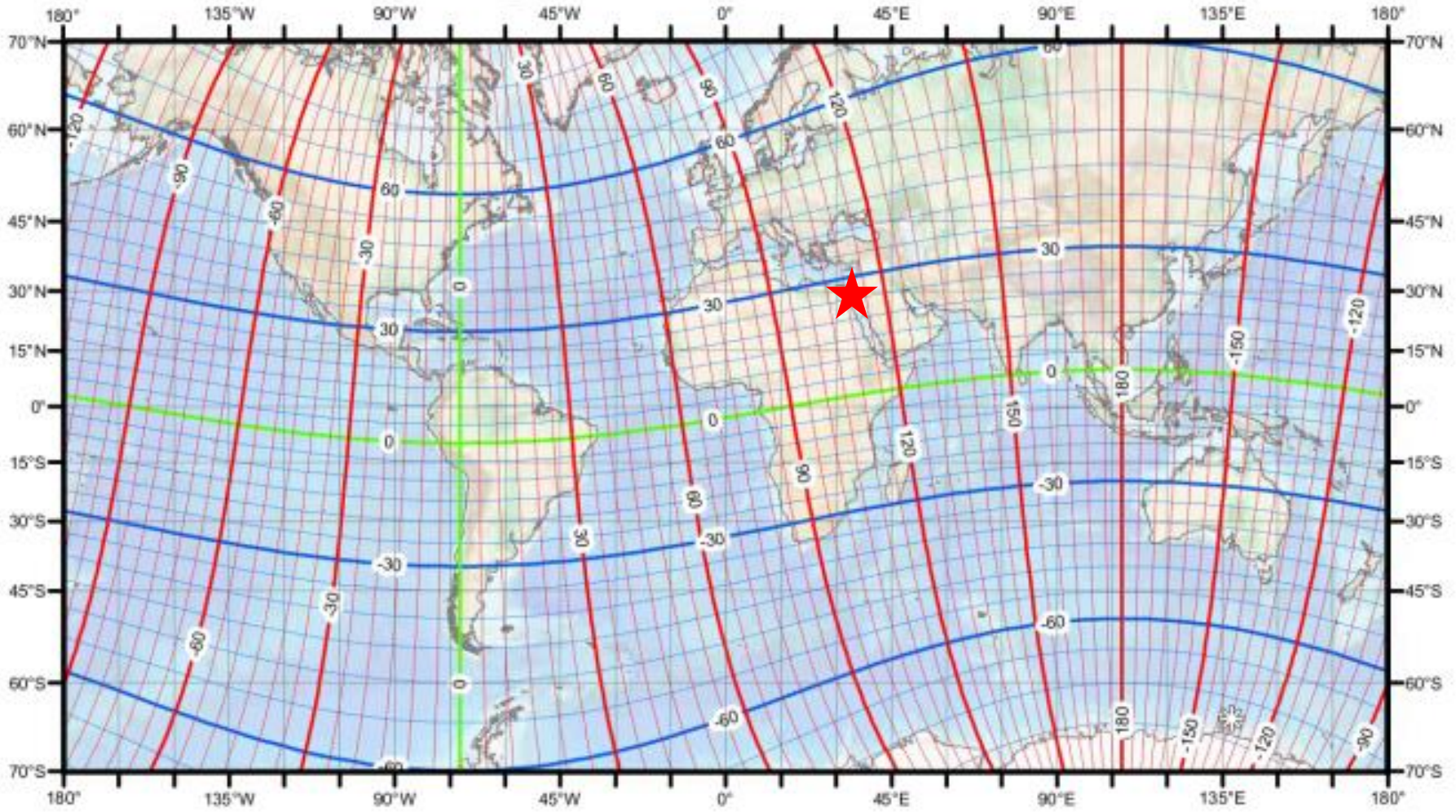


CME 22-23 Jun 2015





US/UK World Magnetic Chart -- Epoch 2010
Geomagnetic Coordinates



Units: degrees
Countour Interval: 5 degrees
Map Projection: Mercator

Summary and Conclusions

- The Earth's atmosphere can be described as a global electric circuit (GEC) with quasi-static surface E-fields and electric currents.
- The generator of all the electrical parameters in the GEC are the 1000-2000 global thunderstorms that constantly generate approximately 1 Ampere of current per storm flowing to the upper atmosphere, and returning in fair-weather regions.
- The global circuit parameters have been shown to be sensitive to solar flares, SPEs, changes in solar wind velocity, cosmic ray flux, geomagnetic storms, and the 11-year solar cycle.
- Theoretically, the GEC can be monitored from a single site on the globe, providing a unique geophysical method to monitor space weather impacts on Earth from the ground.
- Although it is likely that most space weather effects on the GEC impact the atmospheric conductivity, there is some evidence that the thunderstorms themselves may be impacted by space weather and space climate, causing changes in thunderstorm statistics.
- If so, this may have implications for various climate feedbacks.