Forecasting, Modelling and Monitoring GICs and other Ground Effects: Future Needs

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Outline of my talk

On Future Needs

From a user's (power operator's) point of view

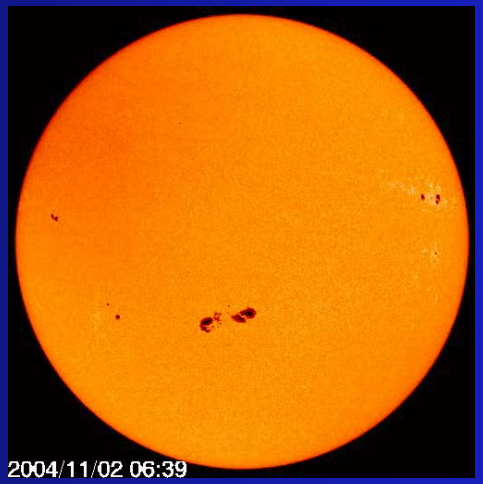
- Warnings long-beforehand (days to weeks)
- Forecasts of large storm events. Minor storms they can handle.
- Forecasts of E, from local dB/dt and a σ , so they can calculate GIC using power grid information because the power grid configuration is changing all the time.

From a scientist's and forecaster's point of view

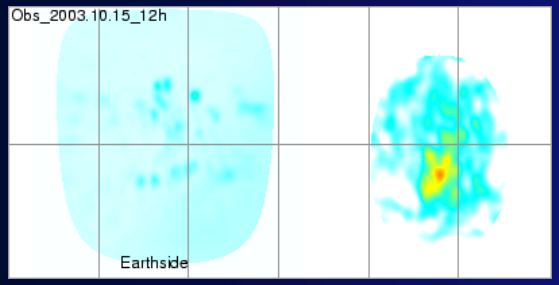
- Improved understanding of 3D CMEs (STEREO)
- To develop hybrid models including both theory and data based models.
- Improved monitoring of the solar wind (thru ILWS, LOIS) and of earth's magnetic field (thru network of magnetometers)

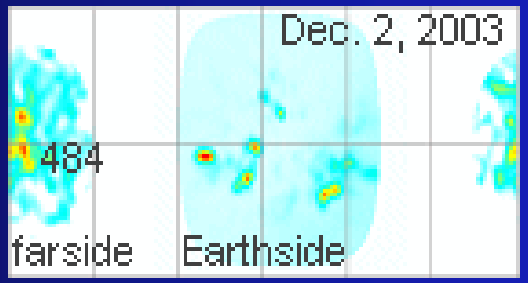
The importance of using helioseismic observations

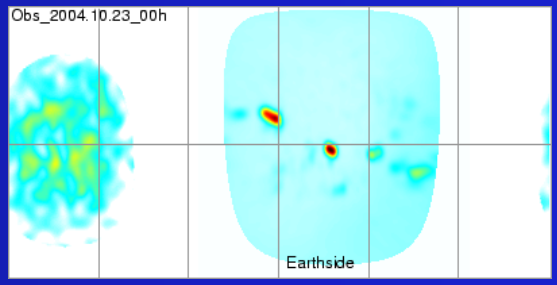
10486, 28 October 2003



10696, 2 November and 6 November 2004

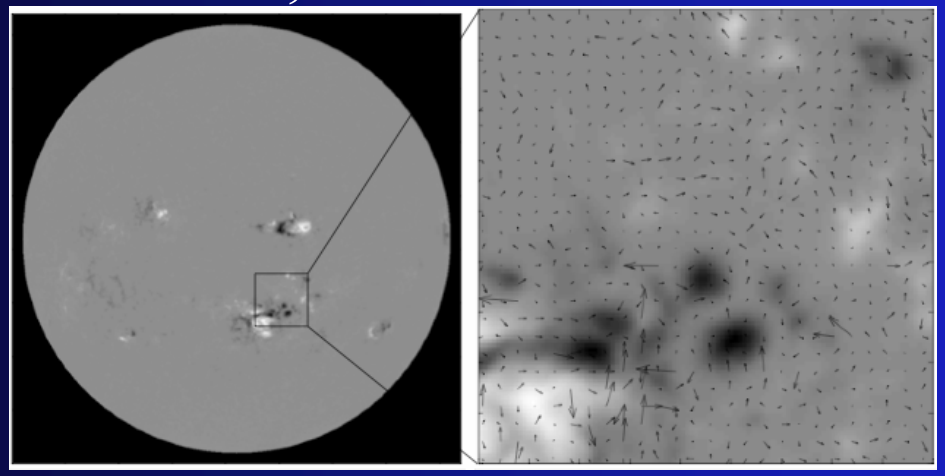


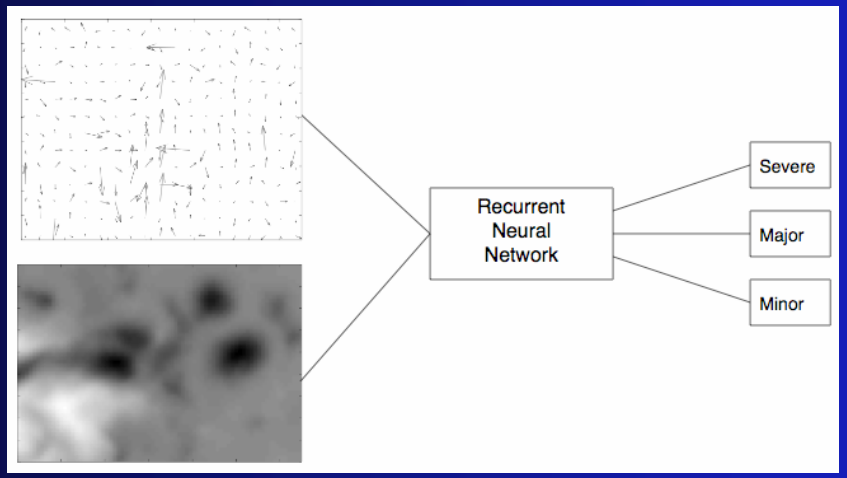




The importance of using time distance flow maps and vector field for neural network forecasting of solar flares and fast CMEs

AR 486, 29th of October 2003

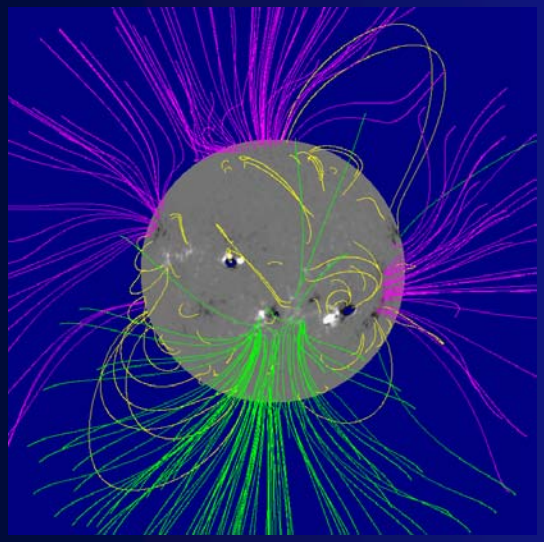




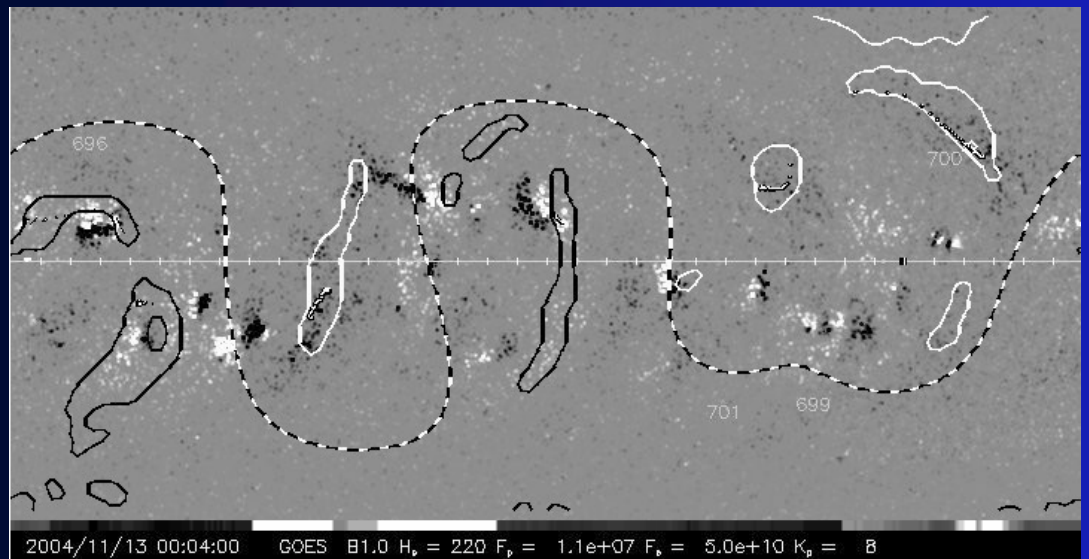
The importance of detecting the full halo CMEs

CACTUS - SIDC

The importance of solar MHD modelling



Full halo CMEs usually originate from bipolar helmet streamers (Zhao and Webb, 2003). **The probability for an Earth-directed CME to be geoeffective is near 100% if the associated HCS is basically parallel to the ecliptic plan;** it is only about 50% if the HCS is basically verticular to the ecliptic plan.



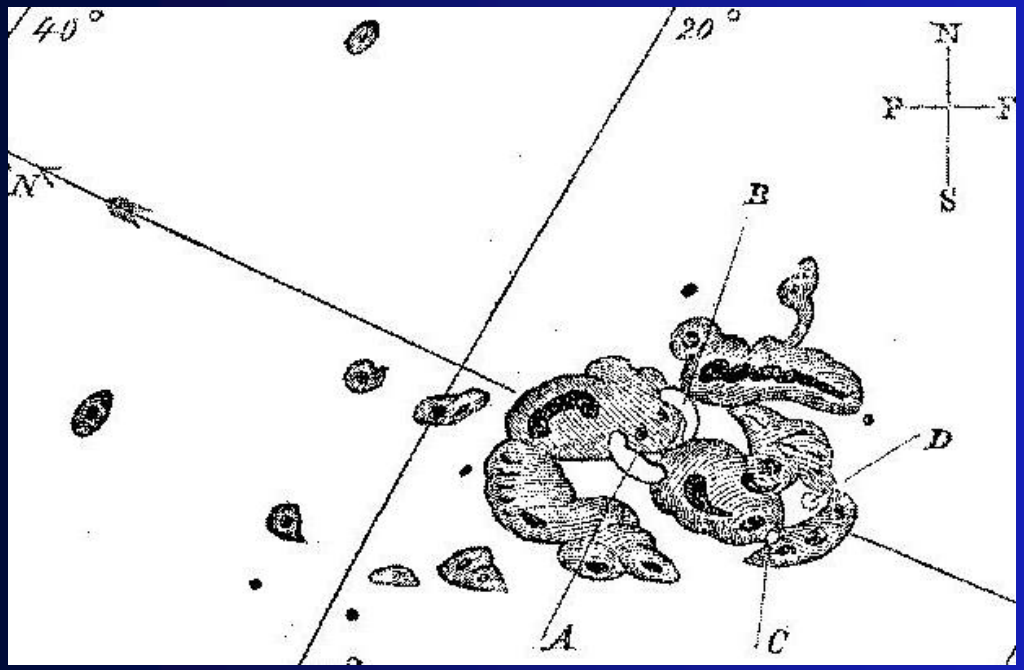
CMEs become Earth-directed when the associated **flare or active region is located less than 40 degrees from disk center** (Cane and Richardson, 2000)

Which Halo CME will hit Earth and cause large GIC and Ground Effects?

Let's look at some examples:

- The Carrington event September 1, 1859
- The September 24, 1909 event
- The May 14, 1921
- The March 13-14, 1989 event
- The Bastille event 2000
- The October- November, 2003 event
- The November 2004

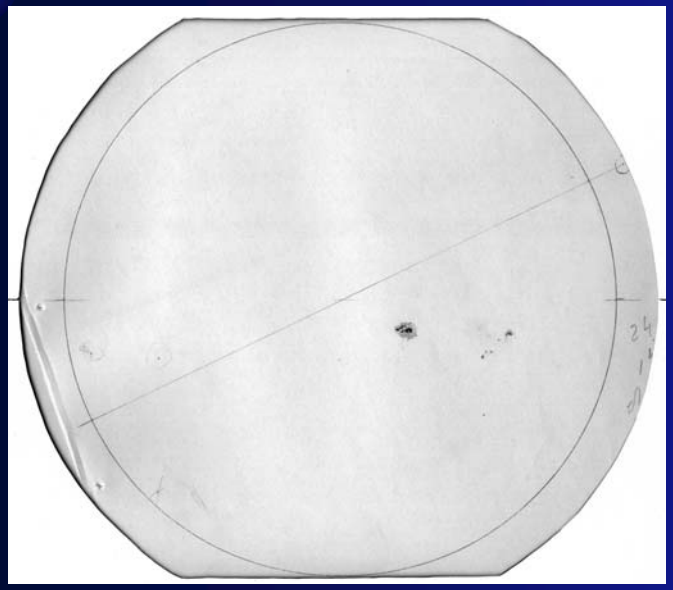
Carrington event 1859, September 1
Dst = -1750nT

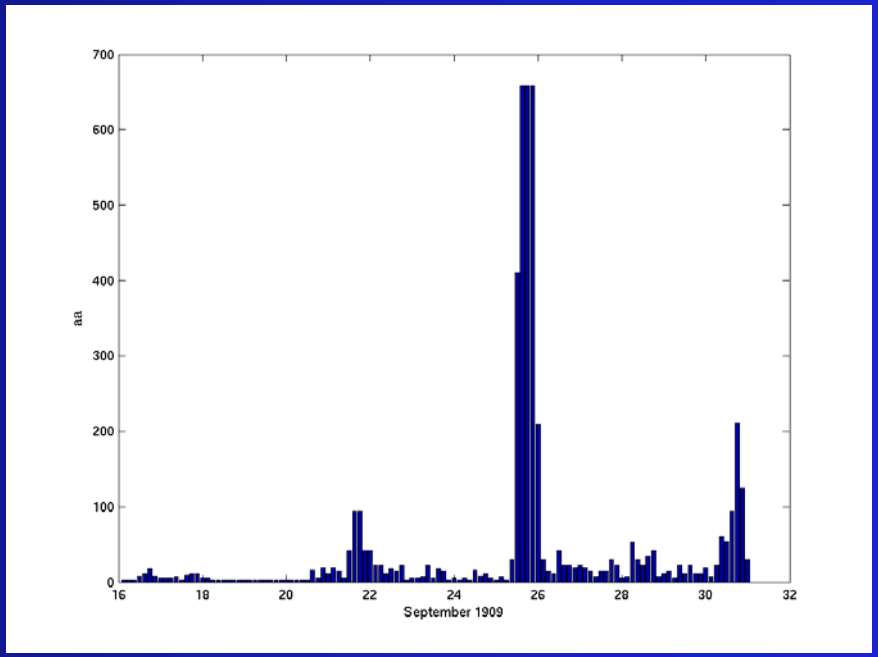


September 1-2, 1859:
Dst = -1760nT

A magnetic storm from August 28 to September 2 produced widespread effects on the telegraph system in Europe and North America.

The Sun September 24, 1909





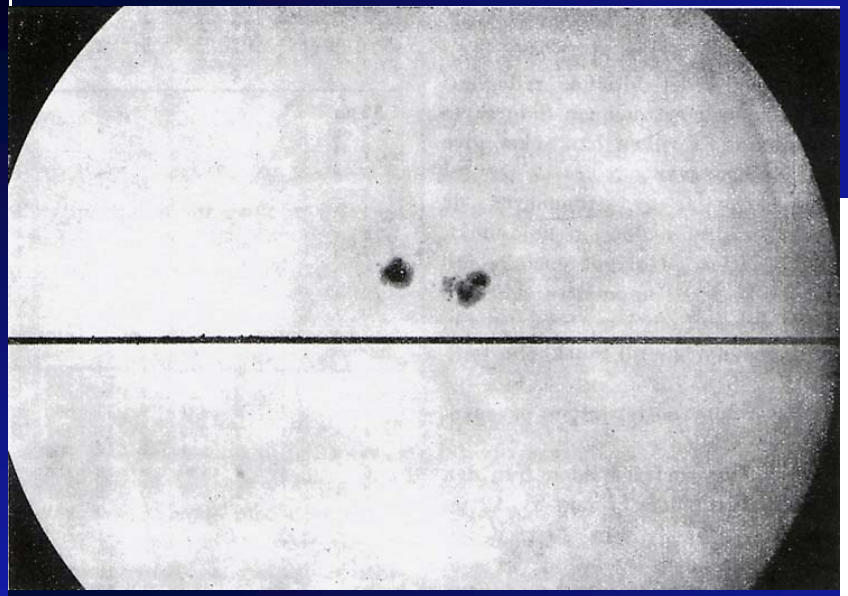
A flare was observed (spectroheliogram) by James Lockyer 10-11 a.m. (UT) September 24 .
The associated CME caused a geomagnetic storm on September 25.

The observation was made at Kalocsa,Hungary

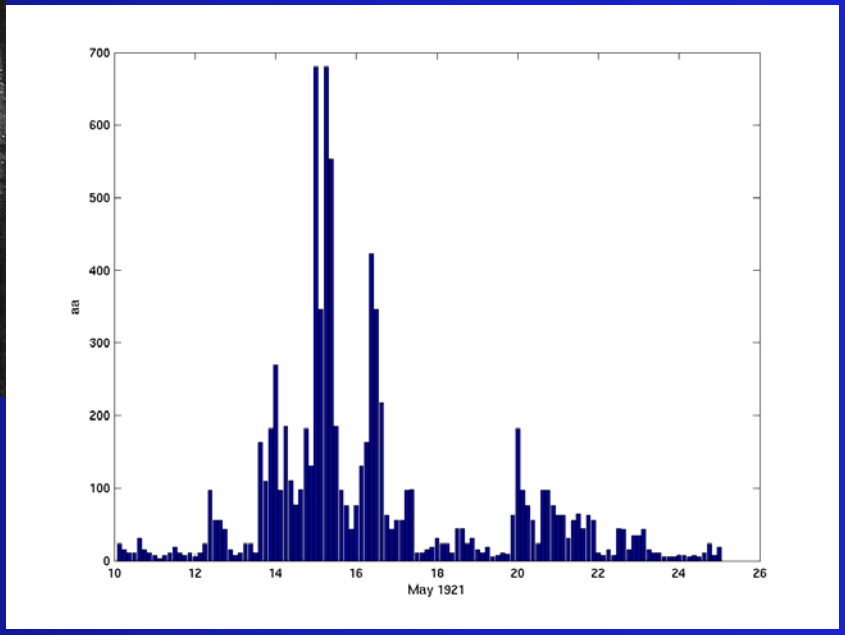
September 25,1909
aa = 658, 12-18

(March 1989 aa = 715, 13/3 21 - 3 14/3)

The Sun May 14, 1921

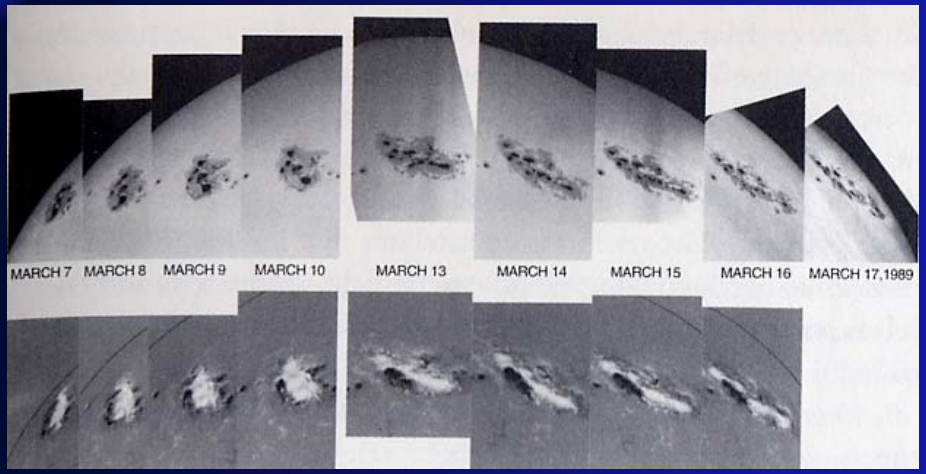


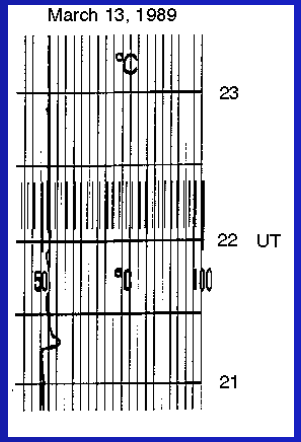
May 14 1921



1921 May 14, hour 21 and
May15, hour 3 aa = 680

The March 1989 event





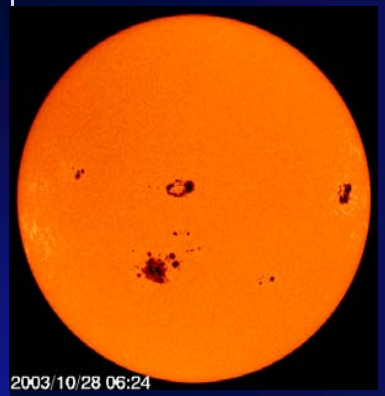
In Sweden
One of the generators of OKG's (Sydkraft's) nuclear plants was heated due to the geomagnetically induced current in
March 13-14 1989.

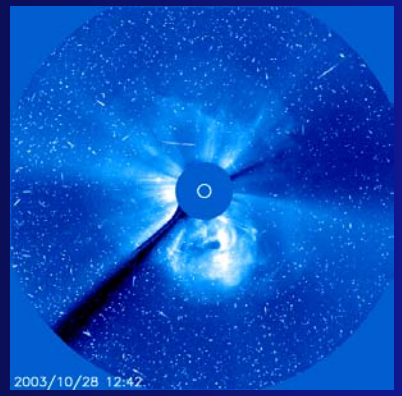
A white-light flare was observed on March 10 at AR 5935 and the SMM satellite's coronograph detected a large halo CME.
Late on March 13 the CME reached Earth.
The geomagnetic storm index Dst reached -589nT.

Superstorms: Dst < -300nT : 21 since 1957

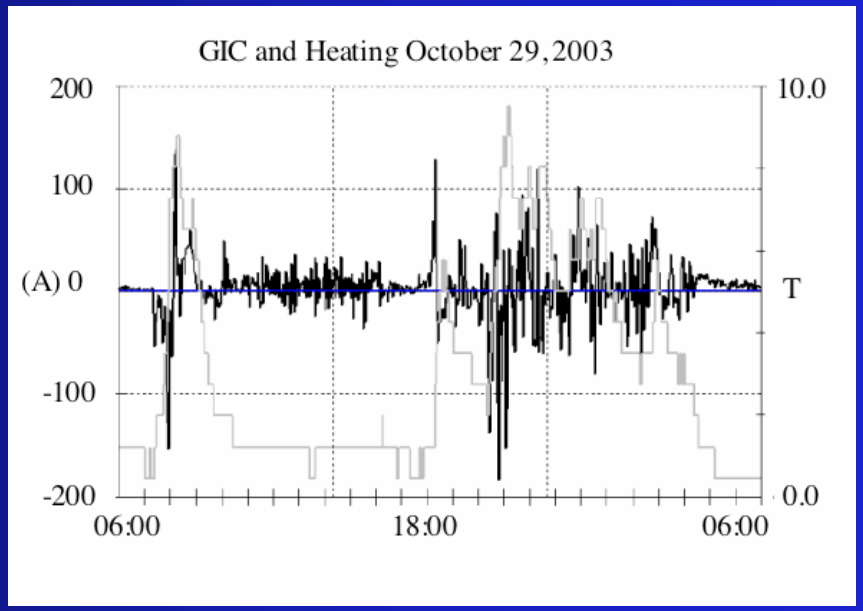
- October 29, 2003: Dst = -308nT
- October 30, 2003: Dst = - 342nT
- November 20, 2003: Dst = - 429nT
- March 14, 1989: Dst = -589nT
- September 1-2, 1859: Dst = -1760nT

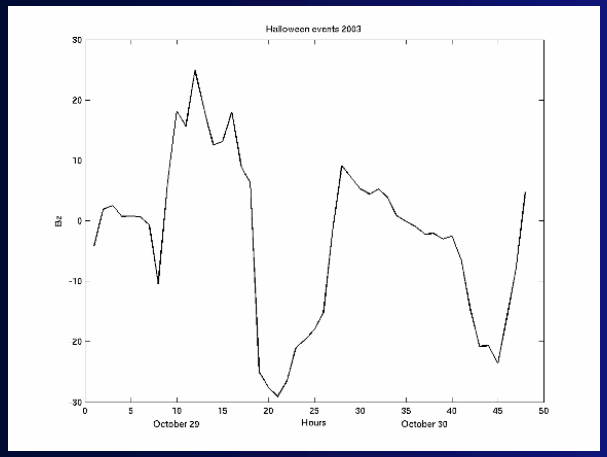
The halo CME of October 28 arrived at 05 UT on October 29





October 29, 2003: Dst = -308nT



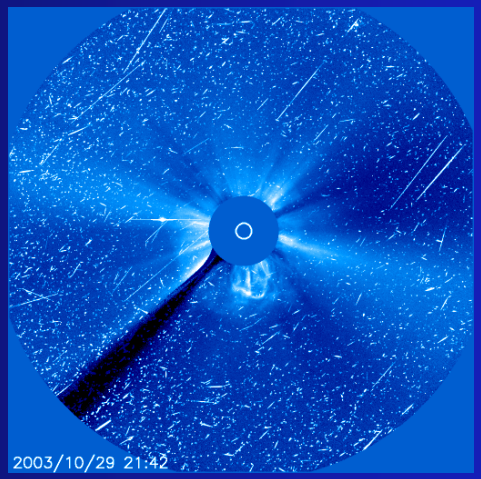


(Courtesy H. Swahn, 2003)

Transformer oil heated 10 degrees!
GIC ≈ 173A

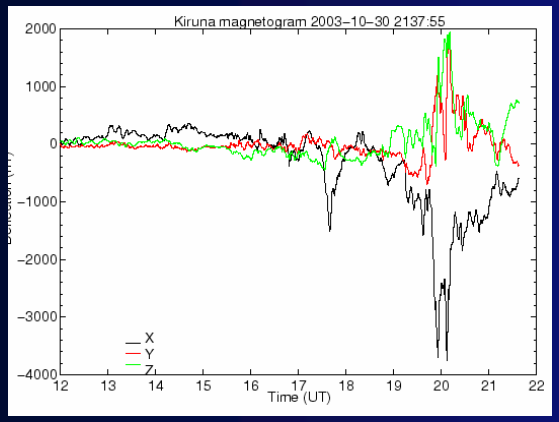
Power outage in Malmö

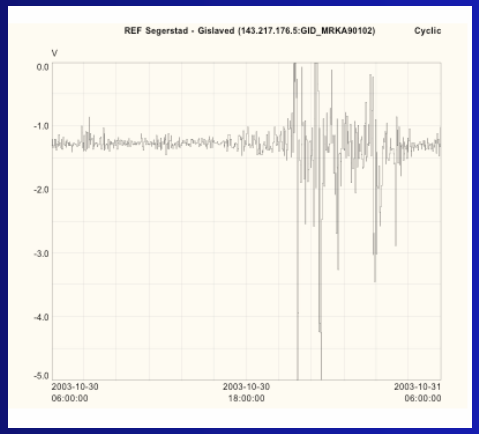
2003-10-30 at 21:07:15 (20:07:15 UT) The tripping of a 130-kV power line in the Malmö caused an outage of 50 000 customers. The outage time ranged from 20 to 50 minutes. (Sture Lindahl, ELFORSK report 2004)



The halo CME arrived ~16.20-30UT October 30, 2003:
Dst = - 342nT

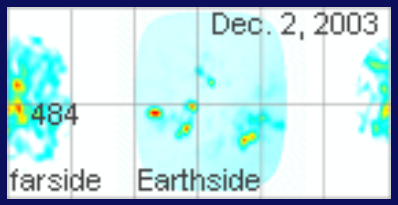
Power Outage in Southern Sweden, October 30, 2003

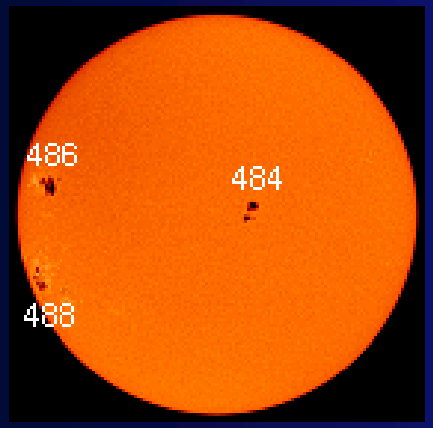


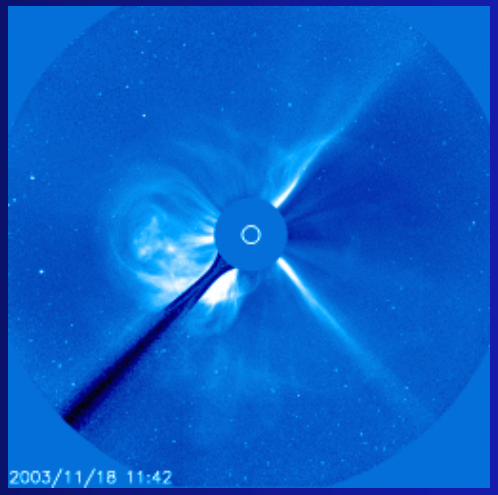


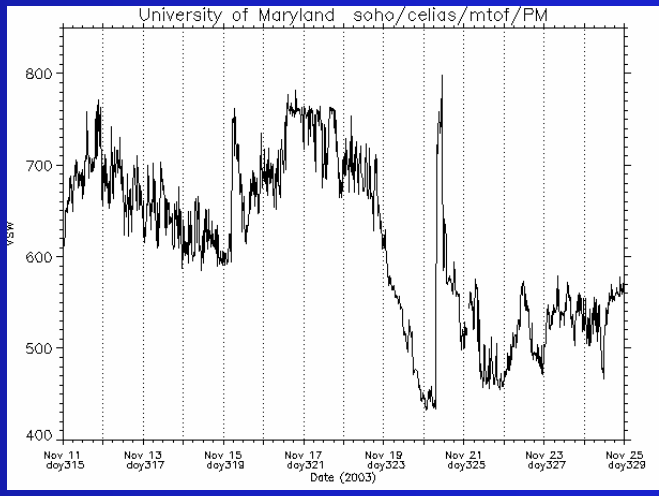
Courtesy Sydsvenskan Bild.

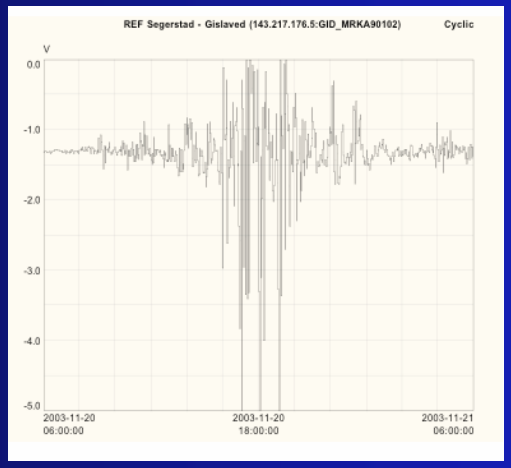
Active Regions 484/486/488 one rotation later

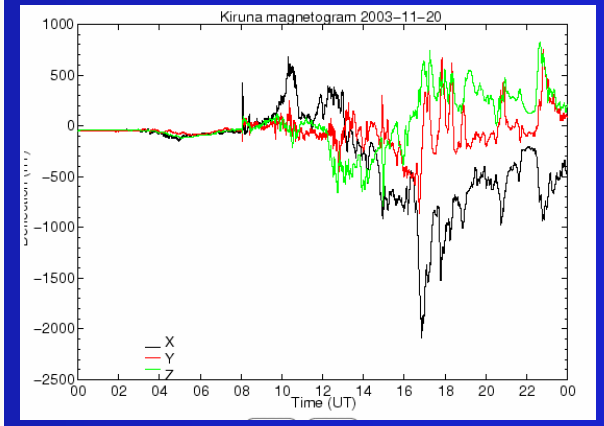




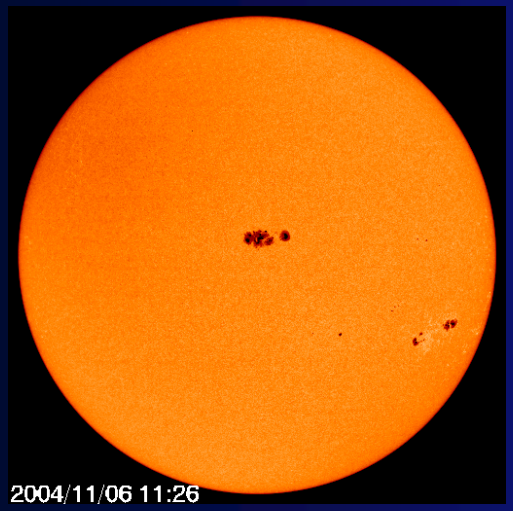


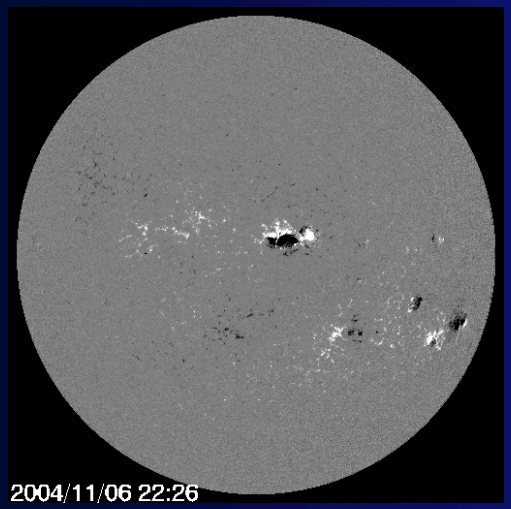


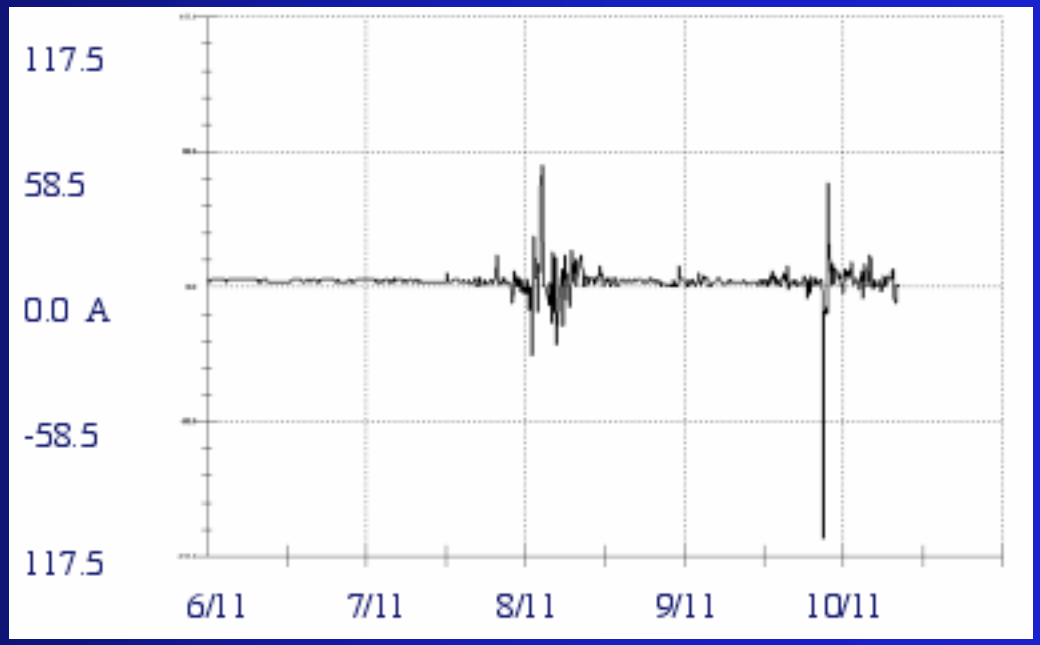




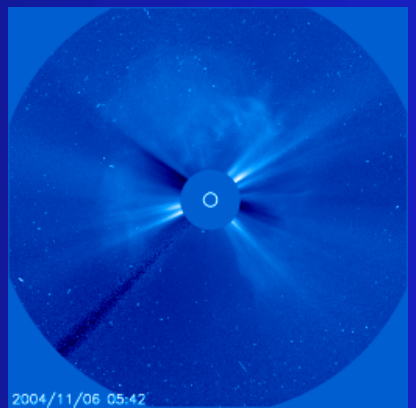
GICs November 6-10, 2004

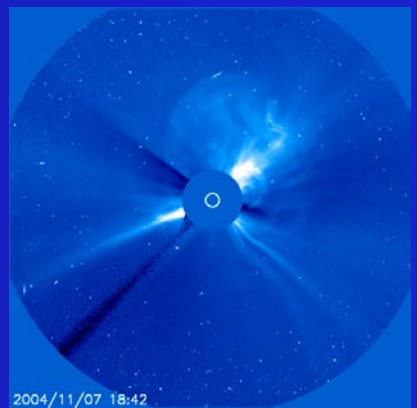




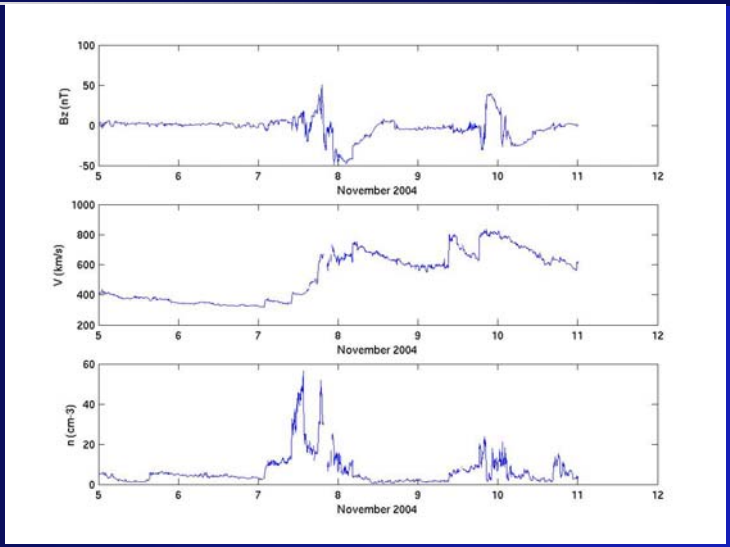


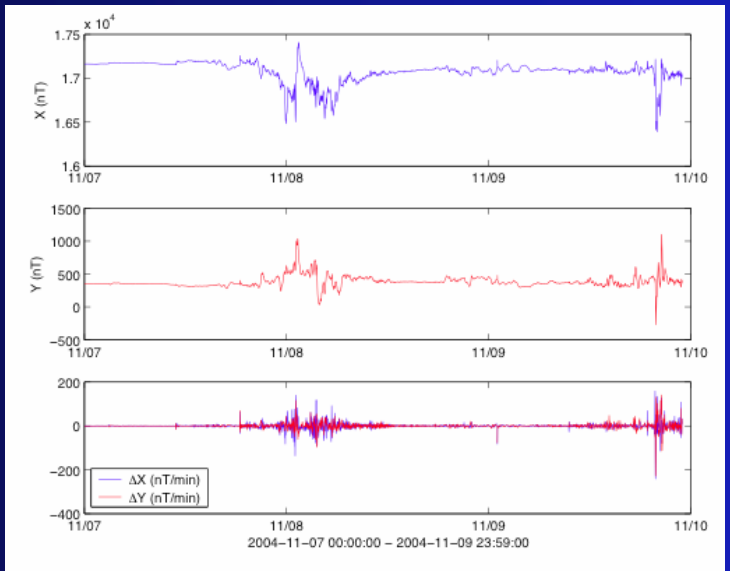
(Courtesy H. Swahn, 2004)





Solar wind 5-11 November, 2004
Brorfelde magnetograms
7 to 9 November





ESA GIC Pilot Project

ESA GIC Pilot Project

http://www.lund.irf.se/gicpilot/

Google

ESA Pilot Project

Real-time forecast service for geomagnetically induced currents

Lund

Swedish Institute of Space Physics

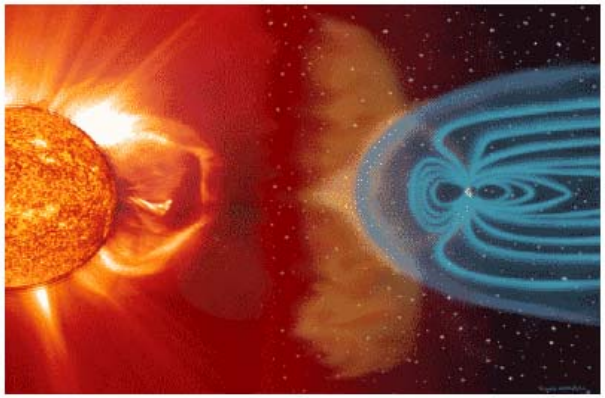
Lund Space Weather Cent

Project Summary

The goal of the project is to develop a forecast service to be used by electrical power companies to mitigate the effects of geomagnetically induced currents (GIC) caused by the space weather.Swedish power companies (Elforsk) are the users of the service and shall also take active part in the project.

The service developer is the Swedish Institute of Space Physics (IRF) in collaboration with the Finnish Meteorological Institute (FMI).

The project shall result in a software package implementing a prototype service, and a cost-benefit analysis of the service. The service shall also be coordinated with the Space Weather European Network (SWENET).



Learn more about GIC

- IRF-Lund
- FMI
- NRCan
- SEC
- Metatech Corp.
- Nordic GIC Network
- Topical Group Ground Effects

Documents and Data

- Prototype GIC forecast service
- GIC pilot project poster (pdf)
- Internal information

ELFORSK

SVENSKA ELFÖRETAGENS FORSKNINGS- OCH UTVECKLINGS - ELFORSK - AB

esa

Contact Henrik Lundstedt, Swedish Institute of Space Physics in Lund

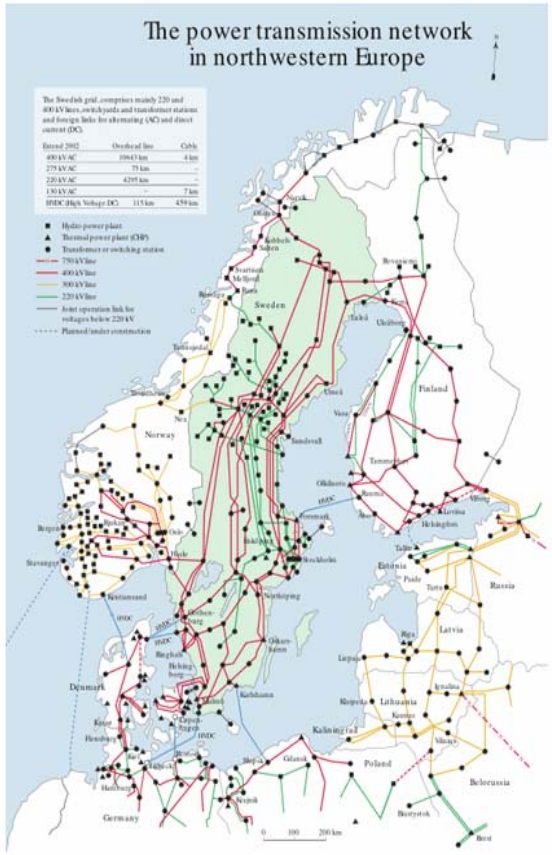
Prototype GIC Forecast Service

Welcome to Adobe GoLive 6

Prototype GIC Forecast Service

Warning long beforehand

- Active regions/ Sunspots on far side ?
- Front side halo Coronal Mass Ejections ?
- Solar wind shock ?
- Geomagnetic storm ?

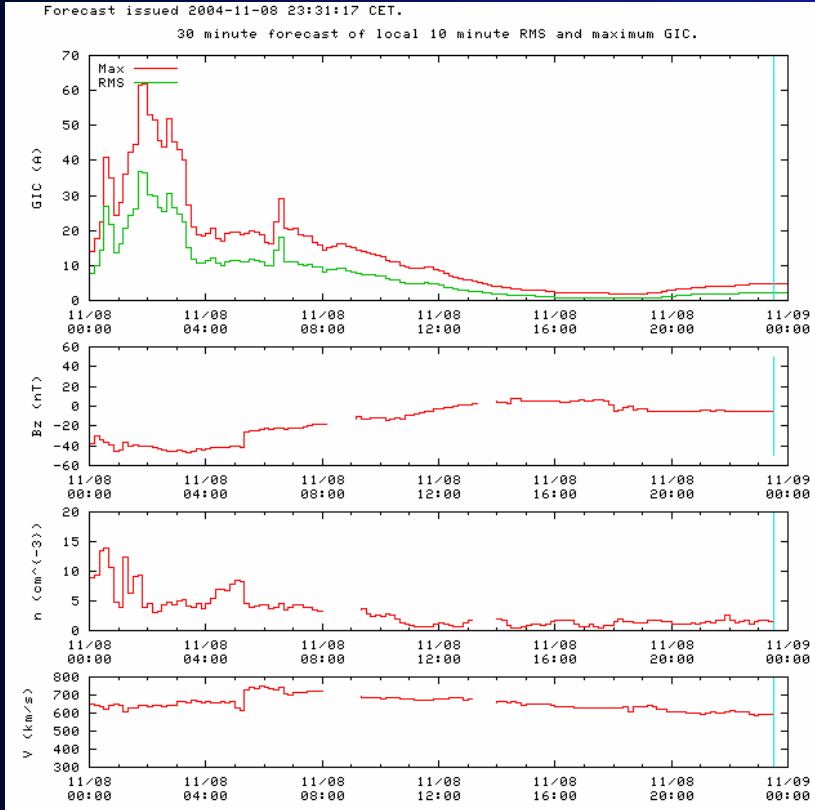


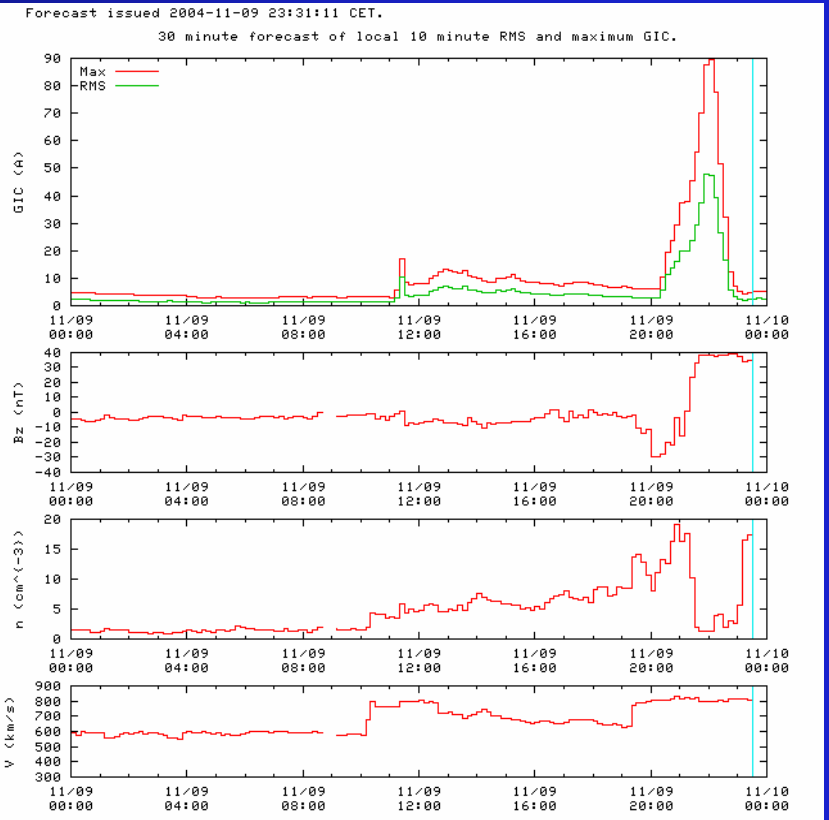
Short-term forecasts

- dB/dt at Brorfelde and Uppsala
- GIC for one station in Southern Sweden
- GIC for any station in Southern Sweden and for current power grid configuration (internal)

ESA GIC Pilot Project

IRF Real-time forecasts of GIC event on November 8 and 9

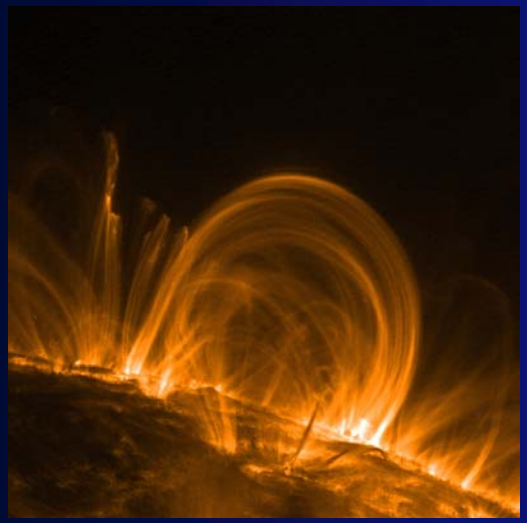




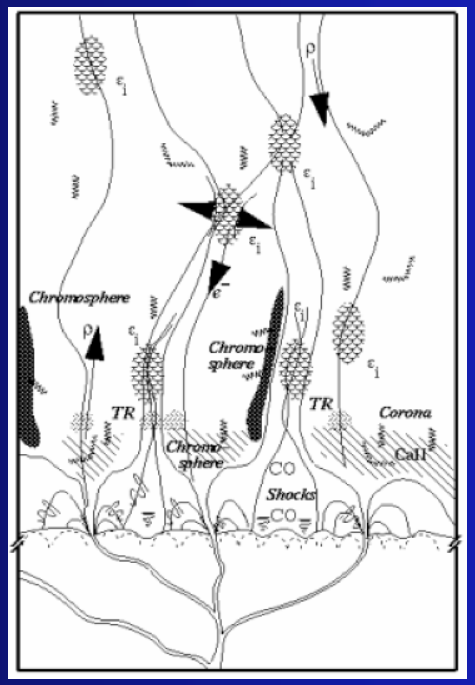
(http://solarwind.lund.irf.se/forecast/gic/index.html)

We need a better understanding of the 3D nature of CMEs

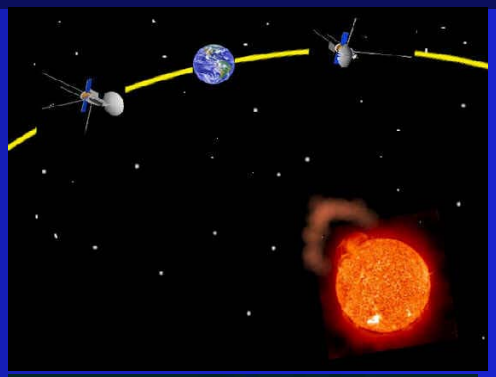
Cycle 24 - 3D Complex plasma structures

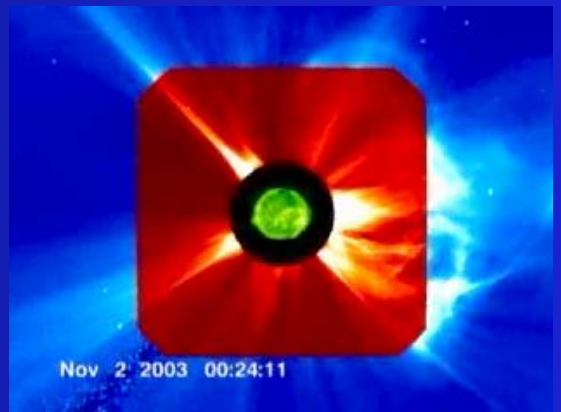


3D - Reconnection

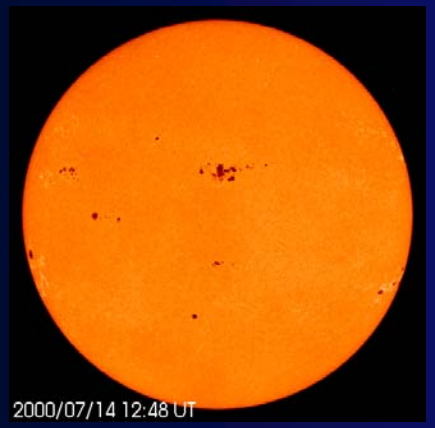


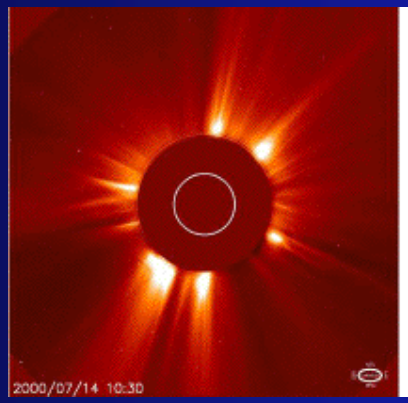
Courtesy: A. Title 2004

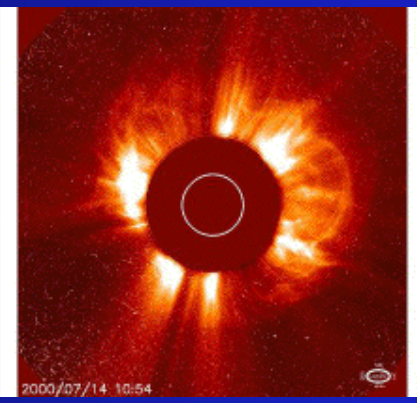


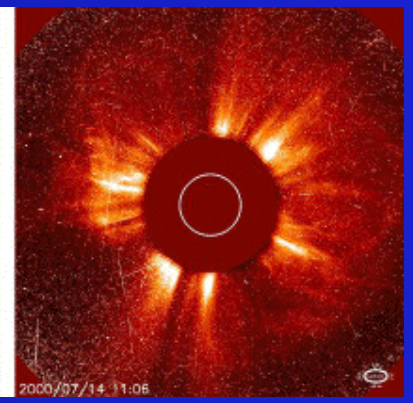


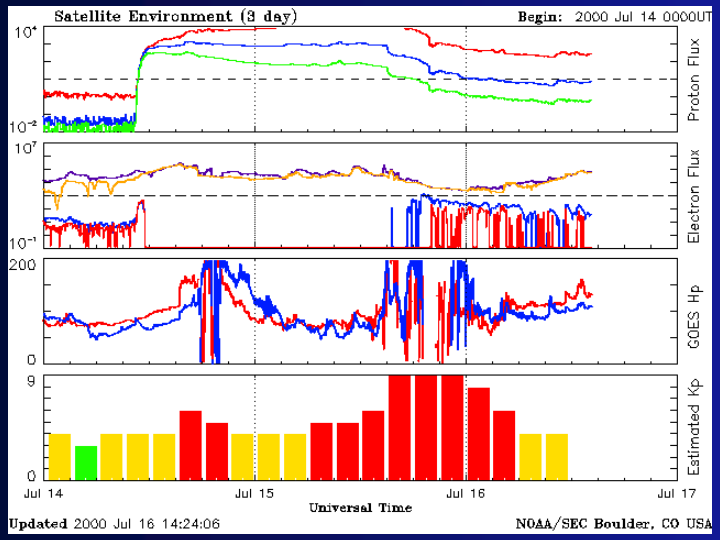
Sometimes we need a better solar wind monitoring

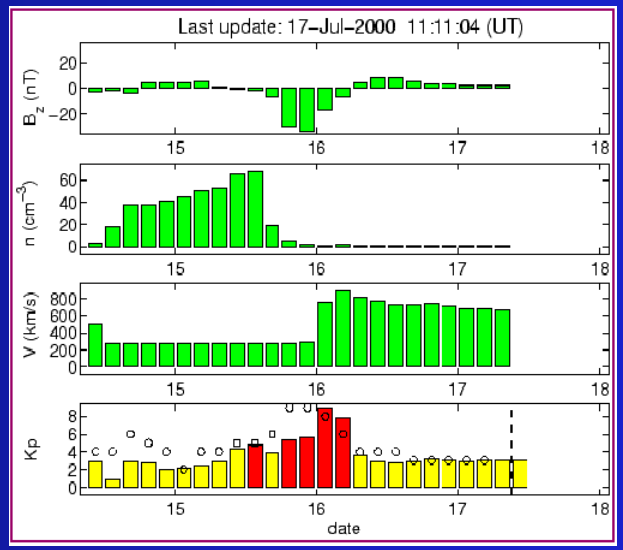






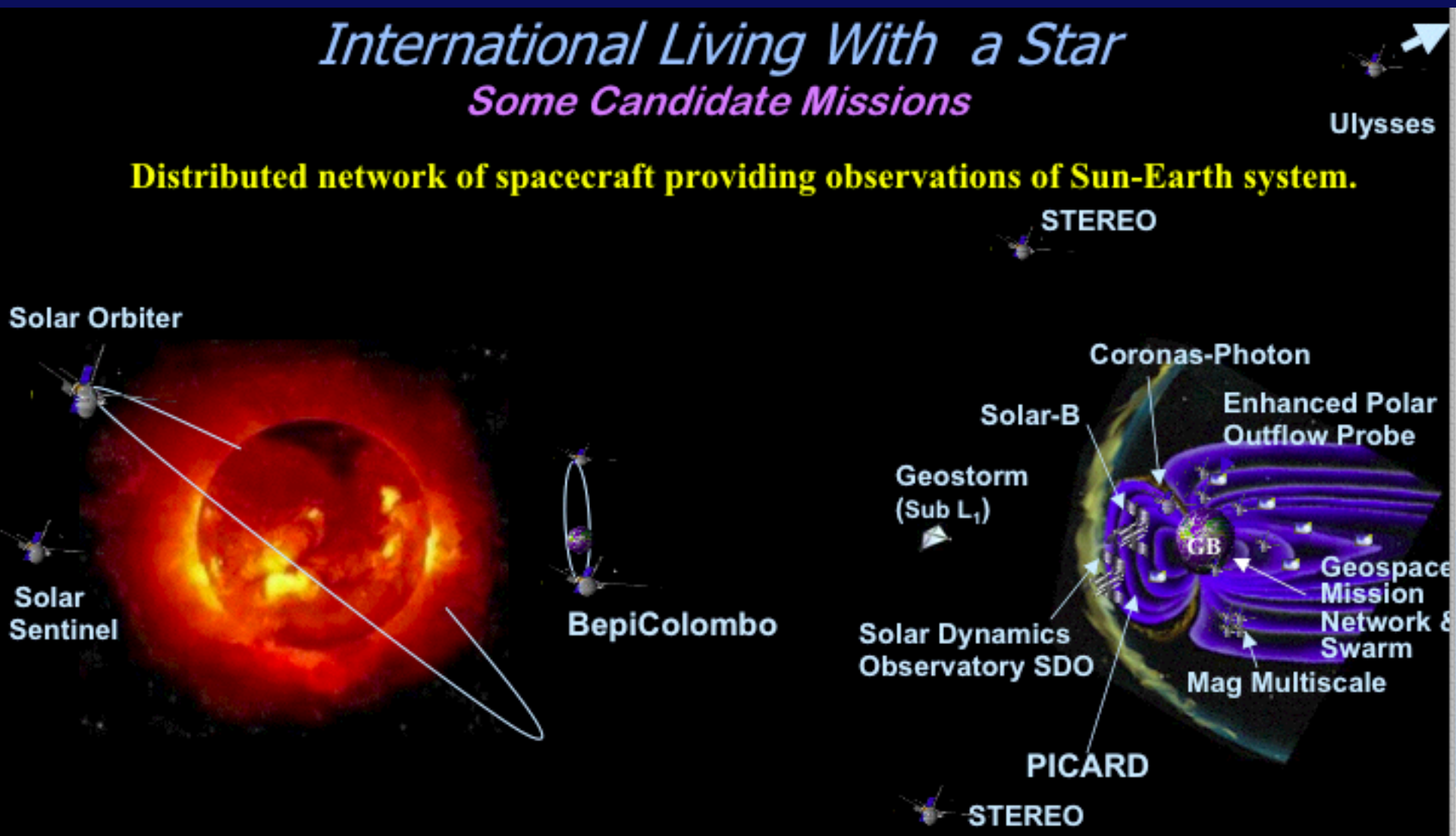






International Living With a Star

Some Candidate Missions



- *Solar-Heliospheric Network* observing Sun & tracking disturbances from Sun to Earth.
- *Geospace Mission Network* with constellations of smallsats in key regions of geospace.

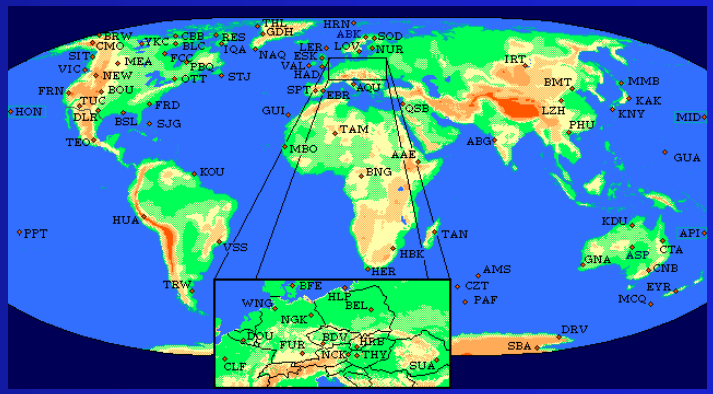
New ground monitoring facilities

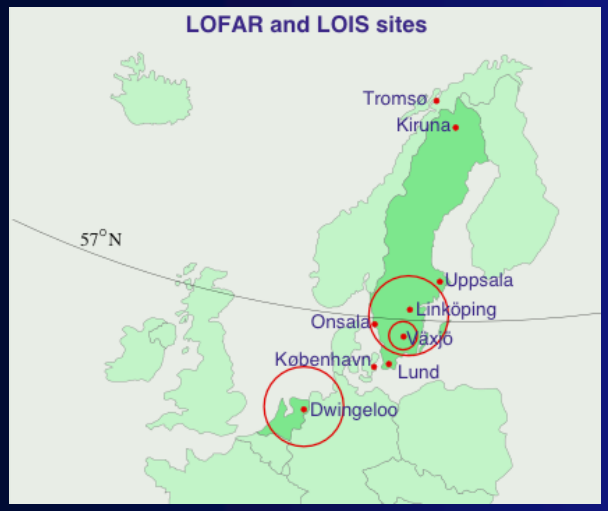
Real-time magnetic field data really needs to be easily available

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

INTERMAGNET

IMAGE





A magnetometer in
Risinge, Växjö

Conclusions 1: Future Needs - Hybrid models and better monitoring

To achieve the operator's needs

- Helioseismic observations
- Solar MHD models
- Neural networks integrating all knowledge into real-time forecasts
- Improved monitoring and data coverage

Conclusions 2: Future Needs

No high solar activity - No big GIC and Ground Effects: The Sun has always the last word! So what's next?

- A low next solar cycle 24?
- A Gleissberg maximum: 2030-2040? (New Carrington event?)
- A Maunder Minimum: 2100?

THE END