

# ESA Pilot Project

## Real-Time Forecast Service for Geomagnetically Induced Currents

### The Team

- **Swedish Institute of Space Physics**  
(H.Lundstedt, P. Wintoft, M. Wik, IRF-Lund & L.Eliasson, IRF-Kiruna)
- **Finnish Meteorological Institute**  
(R. Pirjola, A. Viljanen & A. Pulkkinen)
- **ELFORSK AB**  
(Å.Sjödin & H. Swahn)



# Our GIC Pilot Project website ([www.lund.irf.se/gicpilot/](http://www.lund.irf.se/gicpilot/))

Address: <http://www.lund.irf.se/gicpilot/>

ESA Pilot Project

Real-time forecast service for geomagnetically induced currents

Lund

**IRF**  
Swedish Institute of Space Physics

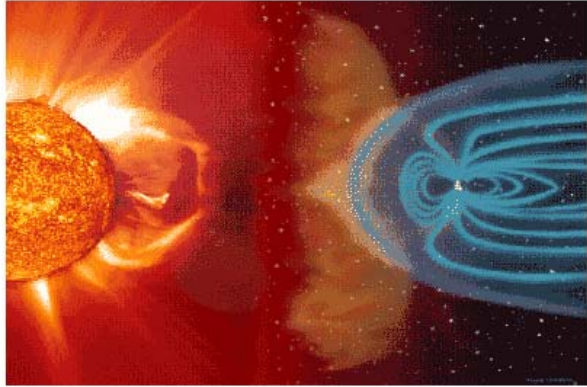
Lund Space Weather Center

### 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](#)

### Documents and Data

- [GIC data](#)
- [GIC pilot project poster \(pdf\)](#)
- [Internal information](#)

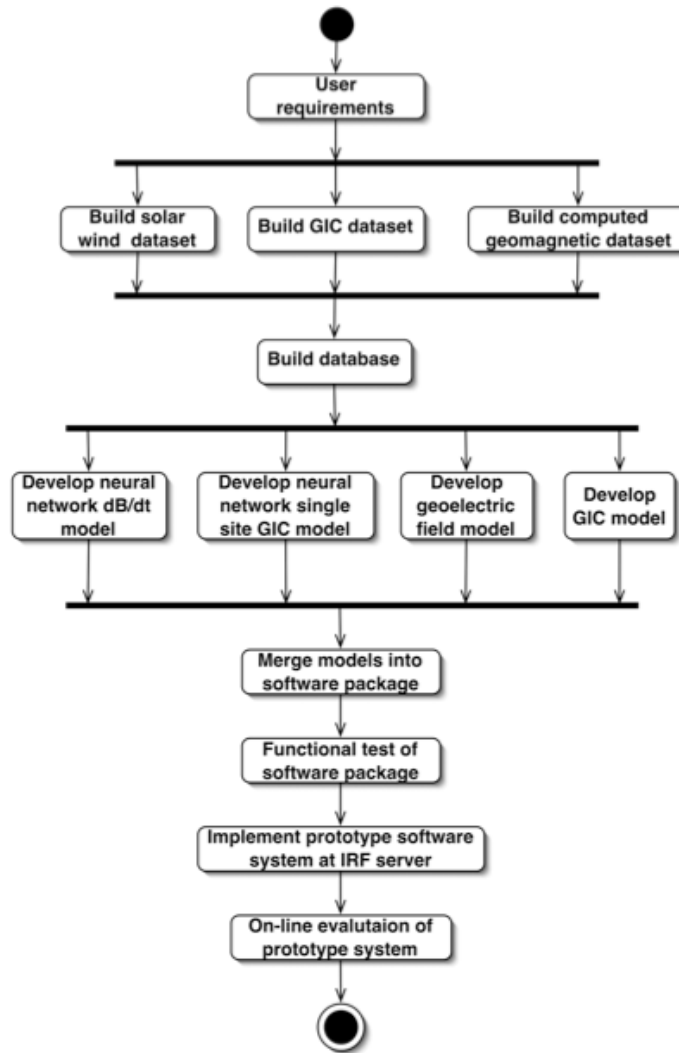
**ELFORSK**  
SVENSKA ELFÖRETAGENS FORSKNINGS- OCH UTVECKLINGS - ELFORSK - AB



Contact [Henrik Lundstedt](mailto:henrik@lund.irf.se), Swedish Institute of Space Physics in Lund

Link : <mailto:henrik@lund.irf.se>

# Work plan



WP  
100

WP  
200

WP  
300

WP  
400

# WP 100 - URD (IRF)

## URD draft submitted

GIC Issue 1

2003-10-20

1(16)

### **A space weather forecast system for geomagnetically induced currents**

#### **User Requirements Document**

ESTEC Contract Number 16953/02/NL/LvH

Issue 1

#### **Prepared by:**

Peter Wintoft, IRF-Lund

Henrik Lundstedt, IRF-Lund

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#### **Approved by:**

Lars Eliasson, IRF-Kiruna

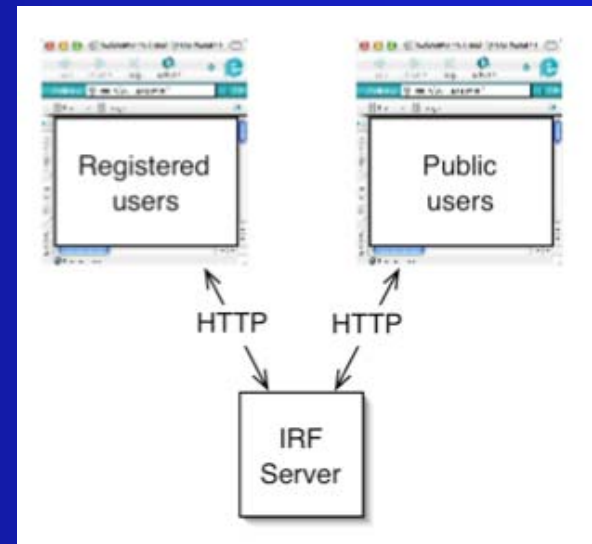
Åke Sjödin, Elforsk AB

# URD



Fig. 1. The power transmission network in northwestern Europe. The line just north of Oskarshamn marks the modelled area.

- One hour forecasts
- For a zone, GIC index
- For a station, GIC
- For a transformer GIC
- Graphical interface (map)



# URD

## 3.2 Constraint requirements

|               |  |
|---------------|--|
| <b>CON.1.</b> | One hour prediction horizon. (Mandatory)   |
| Source        | 1.2, 2.5   |
| <b>CON.2.</b> | 95% accuracy of zonal average absolute GIC. (Goal)   |
| Source        | 1.2, 2.5   |
| <b>CON.3.</b> | 95% accuracy of zonal maximum absolute GIC. (Goal)   |
| Source        | 1.2, 2.5   |
| <b>CON.4.</b> | The power grid data is confidential and shall be accessible only to the project team.  |
| Source        | 2.4.8.4  |
| <b>CON.5.</b> | The measured GIC data from the Swedish power grid may not be published. However, plots and other summary information may be published. |
| Source        | 2.4.8.3  |

# WP 200 - Data base

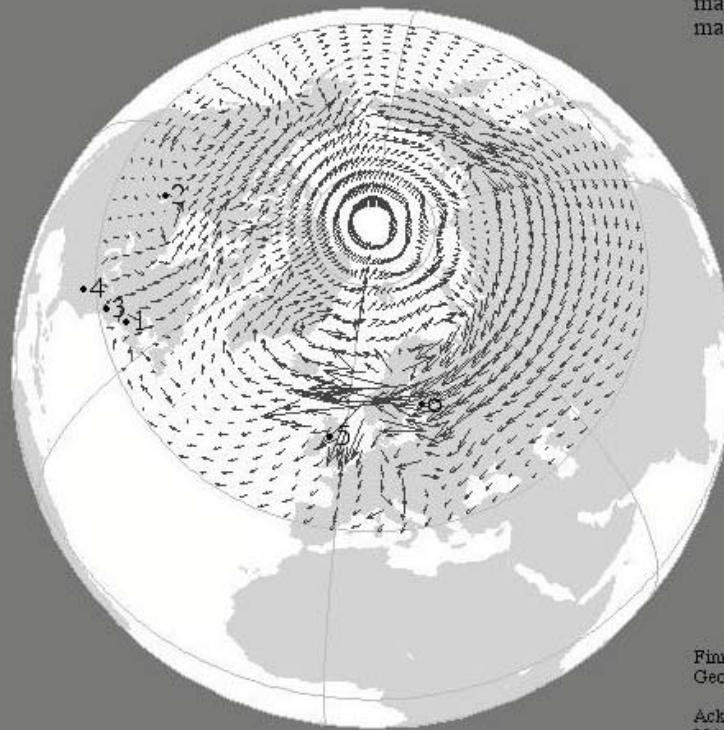
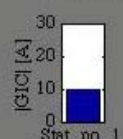
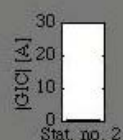
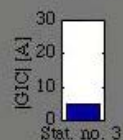
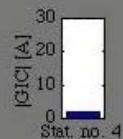
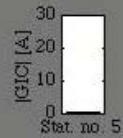
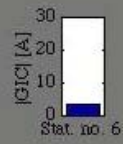
The data base contains

- solar wind data
- geomagnetic field data (IMAGE, Brofelde, Wingst)
- GIC data
- power grid data (Southern Sweden).

The data is transferred into a MySQL data base.

Our earlier developed interface in Java will be rewritten to work with MySQL data base (PW).

# WP 300 - Geoelectric field and GIC Models (FMI)



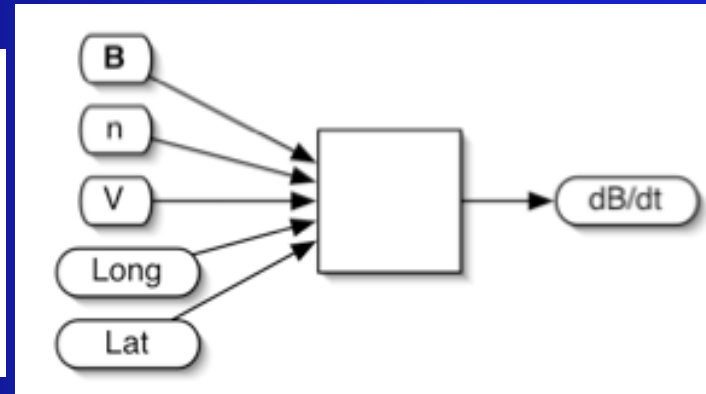
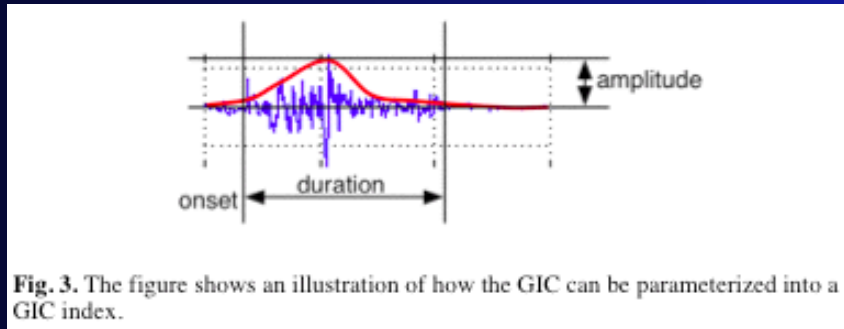
Date: April 6, 2000  
Time: 23:28 UT  
max(|GIC|): 10 A  
max(|j|): 4.7 A/m

Finnish Meteorological Institute  
Geophysical Research

Acknowledgements:  
MACCS, GIMA, CANOPUS, SAMNET,  
GSC, Russian, WDC and IMAGE magnetic  
data was used. Scottish power, Gasum Oy  
and EPRI SUNBURST Network provided  
the GIC data

# WP 400 Forecasts (IRF)

- **Local dB/dt from solar wind (IRF)**



- **Goelectric field from the magnetic field (FMI)**

The electric field can be calculated from  $E(\omega) = Z(\omega) B(\omega)$

- **GIC from goelectric field (FMI)**

After the goelectric field is known, GIC in the network can be determined by using dc circuit theory. It requires that the geometrical and geographical configuration of the system and its resistances are known.

# WP 500 - Service Implementation ( new magnetometer in Southern Sweden from DMI giving new magnetic field data) (IRF)

## Fluxgate Magnetometer FGE

Since the 1920th DMI has been involved in the development and production of instruments for use at magnetic observatories and the La Cour instruments such as the QHM and the BMZ well as the La Cour variometers have been used and are still being used world wide in more than 60 different countries.

In recent years DMI has developed and started to produce highly stable fluxgate magnetometer type FGE, which is suitable for digital recording of the magnetic field at observatories and in the field.

The main idea behind this effort has been to construct a reliable and very stable instrument, which does not suffer from annoying drift with time and temperature.

The FGE magnetometer has analog outputs enabling use to adapt the instrument to their own data logging systems. An optional build-in AD-converter is also available.

### Features

3 linear core sensors mounted on a marble cube for good mechanical stability.

Compensation coils on quartz base for highest temperature stability.

Highly stable digitally controlled compensation of main field. Very good long time stability.

Nonmagnetic electronics which may be placed close to the sensor head in a thermostatically controlled room to avoid any temperature drift.

2 built-in temperature sensors.

### Optional features

Suspended sensors for optimal baseline stability.

Battery operation.

Build-in 16 bit AD-converter (Adam module)

### Specifications

Analog output:  $\pm 10V$   
 Dynamic range: User specified  
 Resolution: 0.1 nT  
 Compensation field range:  $\pm 64\ 000$  nT  
 Compensation field steps: 150 nT  
 Misalignment of sensor axis:  $< 2$  mrad  
 Long time drift:  $< 3$  nT/year  
 Temp. coeff. of sensor:  $< 0.2$  nT/ $^{\circ}C$   
 Temp. coeff. of electronics:  $< 0.1$  nT/ $^{\circ}C$   
 Resolution of temperature: 0.1  $^{\circ}C$   
 Band pass: DC to 1 Hz

### Spec. of optional suspension

Range of compensation:  $\pm 0.5'$   
 Factor of compensation:  $> 200$

### General information

Size of sensor: 190 x 190 x 190 mm  
 9.5 kg  
 Size of suspended sensor: 250 x 250 x 550 mm  
 20 kg  
 Size of electronics: 160x90x360 mm  
 3.0 kg  
 Power requirements: 230 VAC, 3W  
 Operating temperature: 0 to 60 $^{\circ}C$  Optional  
 Optional power supply: 10-18 VDC, 3 W

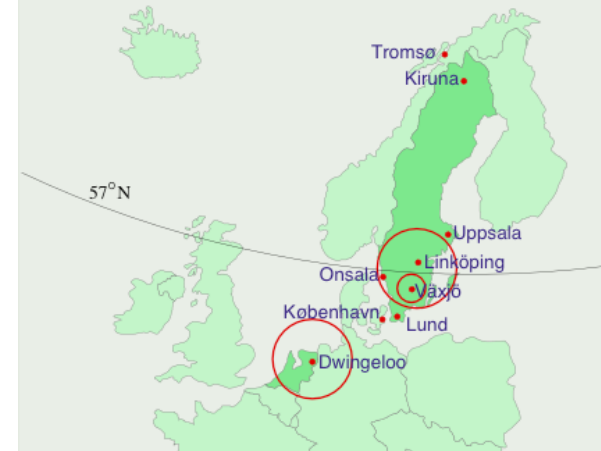
### Optional digital output:

8 ch / 16 bit ADAM AD-converter



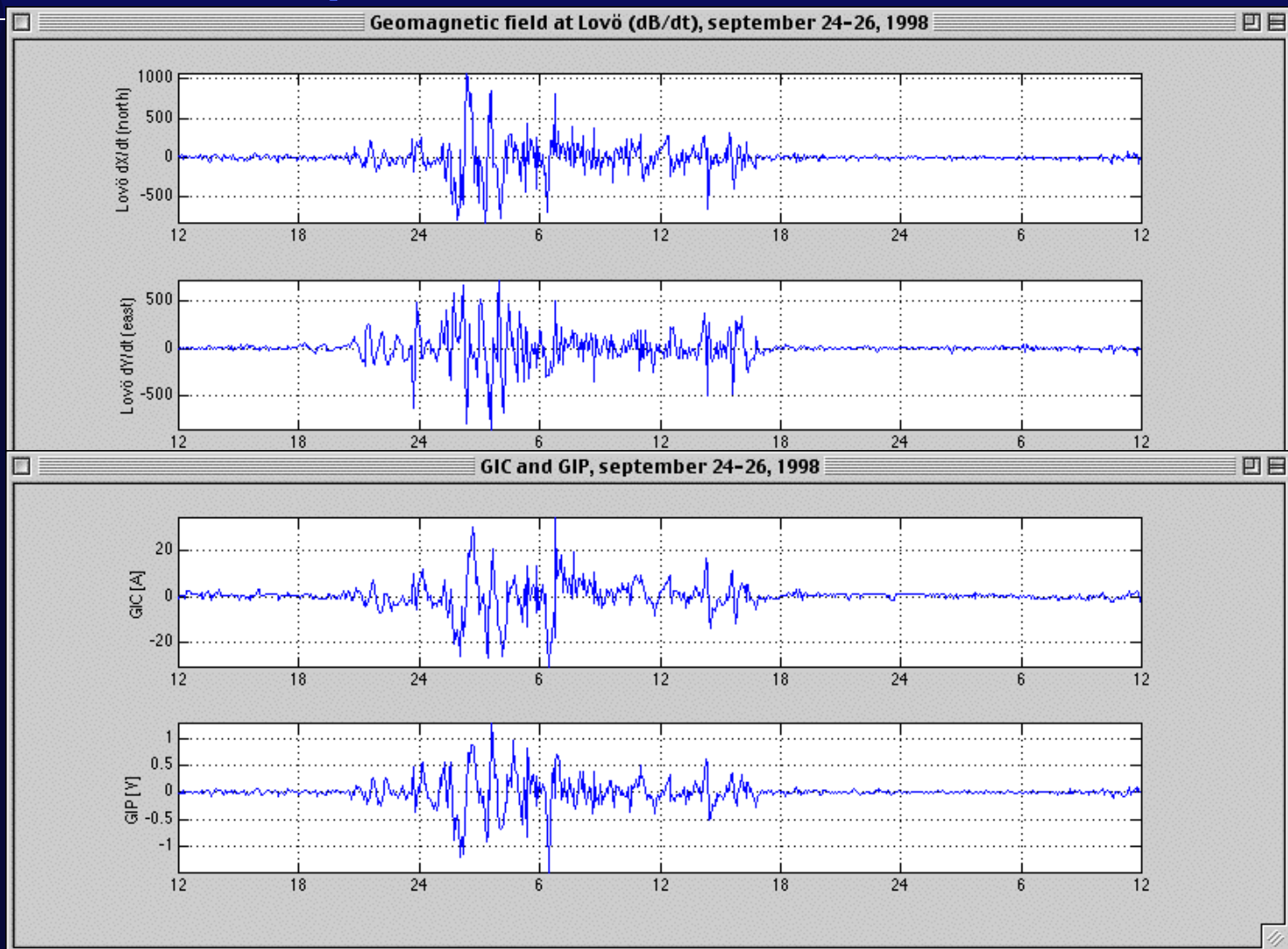
*In order to avoid drift due to tilt of the instrument pier, which is often the main cause of baseline drift, a special version of the magnetometer is available in which the sensors are suspended by two crossed bronze bands to compensate the tilt.*

### LOFAR and LOIS sites

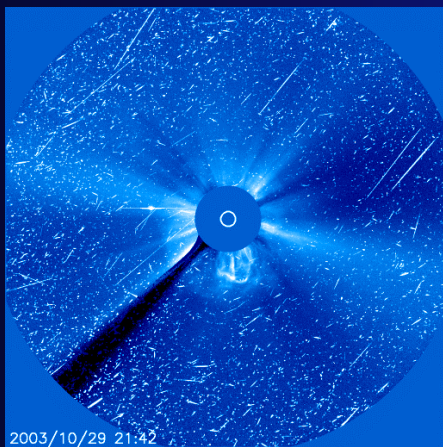


Meeting on December 1  
 In Lund about the  
 Financing (~12k€).  
 The infrastructure  
 ready.

# WP 600 - Testing , Cost-benefit analysis (GIC Events) September 24-26, 1998



# Then halo CME of October 29 arrived at 17 UT on October 30



Discussions with operators during the storm. They made adjustments but not enough

Power systems effected, power outage 20:07 in Malmö  
GICs > 200 A were measured.

