Geomagnetic Activity Forecast - a Service for Prospectors and Surveyors

Proposal submitted in response to
Announcement of Opportunities AO/1-4246/02/NL/LvH

Pilot Project for Space Weather Applications

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Project Objective

Prediction of the level of geomagnetic activity in geographic regions which are of relevance to prospective users

We propose to provide a forecast on a daily basis of the level of expected geomagnetic field activity over the next three hours, the rest of the present day, one day ahead, and two days ahead. The forecast is based on solar, heliospheric, interplanetary, magnetospheric and ionospheric data. We do not predict solar activity – it is assumed to have been observed and reported.

Collaborators

The Danish Meteorological Institute (DMI)
has many years of experience in observation, analysis and interpretation of temporal variations of the geomagnetic field at mid and high latitudes

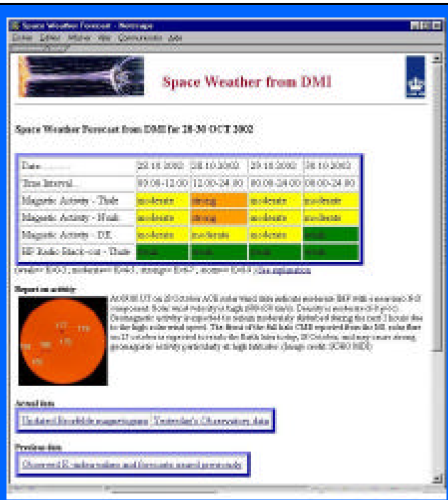
Baker Hughes INTEQ
consults oil companies on drilling operations in the North Sea

The Geological Survey of Denmark and Greenland (GEUS)
manages airborne magnetic anomaly surveys in Greenland

Present Services

Preparation Work

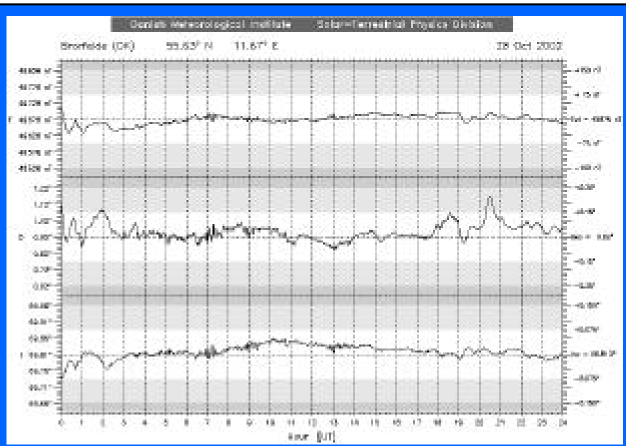
Preliminary Forecast



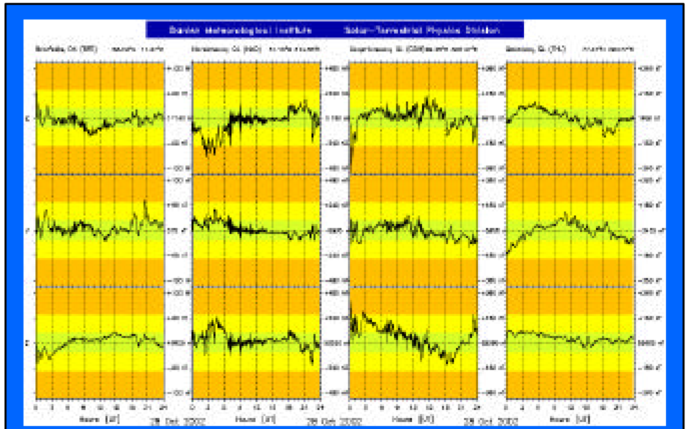
Preliminary setup for DMI's Geomagnetic Activity Forecast web page (for internal use only). This page is manually updated every work day shortly before 09 UT.

activity	K value	BFE range (nT)	NAQ range (nT)	GDH range (nT)	THL range (nT)
weak	0 - 3	≤ 24	≤ 96	≤ 72	≤ 72
moderate	4 - 5	25 – 84	97 – 336	73 – 252	73 – 252
strong	6 - 7	85 – 240	337 – 960	253 -720	253 -720
storm	8 - 9	> 240	> 960	> 720	> 720

Selected geomagnetic activity levels at Danish observatories (preliminary scale)



Variation of the total magnetic field intensity (top panel, scaled in nanoTesla), magnetic declination (center panel, scaled in degrees) and magnetic inclination (bottom panel, scaled in degrees) over a full day, according to recordings from the Brorfelde observatory (Denmark).



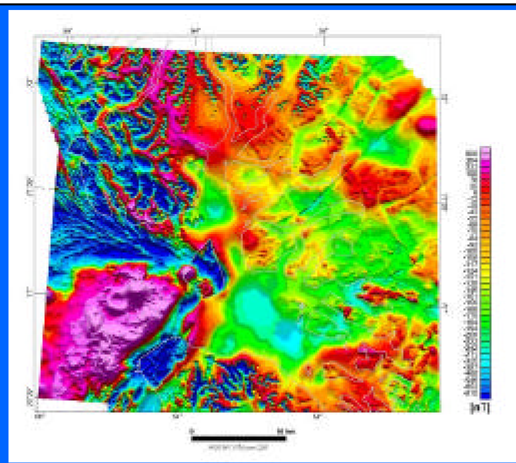
Variation of the magnetic field components in geographic north (X), east (Y) and downward (Z) directions recorded on Oct 28, 2002, at the Danish and Greenlandic geomagnetic observatories

Prospective Users and User Needs

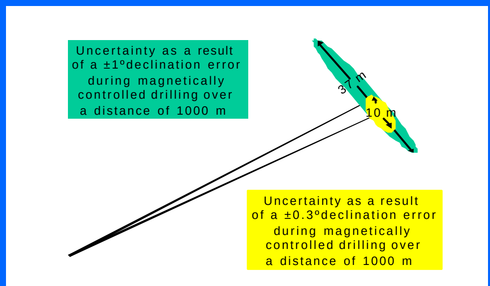
Who is interested in a region-specific geomagnetic activity forecast ?

- **Prospecting companies**, specifically oil companies, which perform directional drilling controlled by devices based on the local magnetic field vector orientation.
- **Magnetic anomaly survey services** which map static magnetic anomalies originating in the Earth's crust and mantle.

Both user groups conduct magnetic field measurements which are often complicated, time-consuming and consequently expensive. Severe temporal variations of the geomagnetic field render their measurements useless. They have therefore a viable interest in obtaining reliable short-term predictions of the level of disturbance of the geomagnetic field in order to optimize their operation plans.



Magnetic field intensity of crustal anomalies after subtraction of the core field. The area around Uummannaq (Greenland west coast) is depicted. The coast line and border of the Greenland Ice Cap are shown by grey lines.



Effect of declination uncertainty reduction on directional drilling accuracy

Approach

Methodology

Input Data Sources

Forecast Time Frames

Geomagnetic Activity Forecast: Methodology

Hours-Ahead Forecast

Input:	Real-time solar wind and IMF parameters Real-time geomagnetic activity parameters
Processing:	Neural network
Output:	Forecast 3 hours ahead

Days-Ahead Forecast

(1) Persistent, large-scale solar variations

Input:	Solar and heliospheric observations Real-time solar wind measurements Real-time geomagnetic activity parameters
Processing:	Neural network
Output:	Predicted solar wind and IMF at ACE up to 3 days ahead

(2) Bursty, transient phenomena

Input:	Solar and heliospheric observations of CME, sf, radio burst, X-ray enhancement, SEP enhancement
Processing:	Cluster analysis and neural network classifiers
Output:	Classification of solar events, selection of appropriate forecast parameters and method

Primary data sets

(1) remote sensing of the sun and solar corona

(2) *in-situ* sensing of the solar wind and interplanetary magnetic field

(3) *in-situ* sensing of solar X-ray and energetic proton flux in the magnetosphere

(4) *in-situ* sensing of the magnetic variations at ground level

(5) most recent solar activity reports and solar activity archives

All data foreseen to be used in this project are acquired with already existing equipment. No new monitoring systems and sensors need to be deployed.

The data are either publicly available and accessible via FTP and HTTP or are acquired with sensors and acquisition systems operated by DMI.

(1) Solar and Heliospheric Observatory (SOHO)

Extreme Ultraviolet Imaging Telescope (**EIT**)

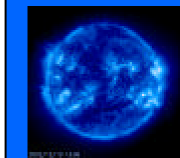
Identification of coronal holes

Michelson Doppler Interferometer (**MDI**)

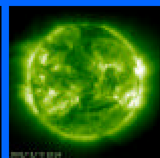
Development of sunspots and associated magnetic field configurations

Three Large Angle and Spectrometric Coronagraphs (**LASCO**)

Outburst and initial development of CME (within 30 solar radii)



EIT 171 Å



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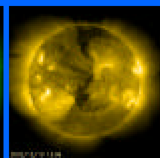
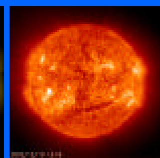
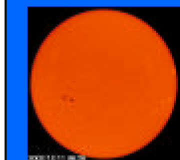


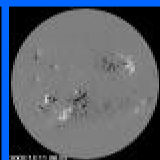
EIT 284 Å



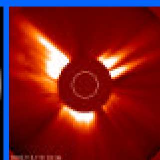
EIT 304 Å



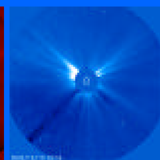
MDI continuum



MDI magnetogram



LASCO C2



LASCO C3

(2) Advanced Composition Explorer (ACE)

Solar Wind Electron, Proton, and Alpha Monitor (**SWEPAM**)

Dynamic pressure at the magnetopause, size of the magnetosphere

Magnetic Field Experiment (**MAG**)

Intensity and orientation of the IMF, geo-effectiveness of IMF

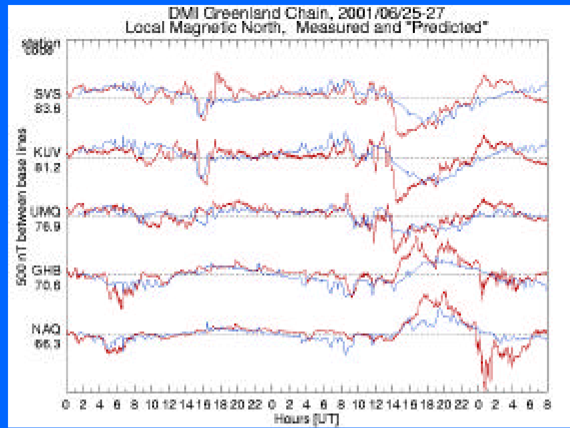
Electron, Proton and Alpha Monitor (**EPAM**)

Suprathermal particle flux

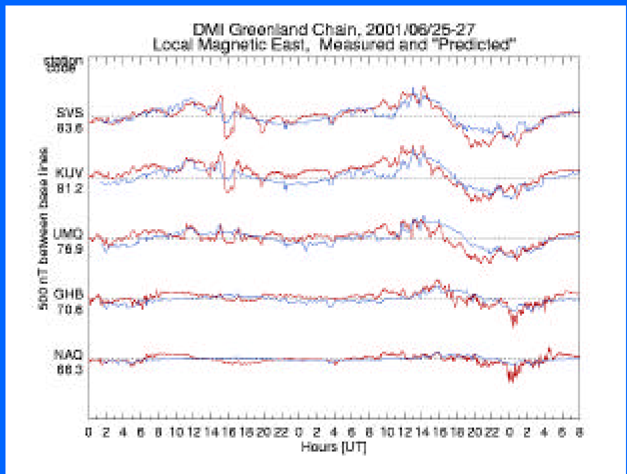
Solar Isotope Spectrometer (**SIS**)

High Energy Electrons and Ions, ionospheric proton events

Comparison of measured polar magnetic perturbations* and disturbances derived from ACE observations [Weimer et al., 2002]



*data provided courtesy of J. Watermann, Danish Meteorological Institute



(3) Geosynchronous Operational Environmental Satellites (GOES)

Space Environment Monitor (**SEM**) System

Magnetospheric measurements of: X-ray intensity distribution; energetic particle flux; magnetic field vector

Proton events, polar cap absorption events

(4) Ground-based magnetometers

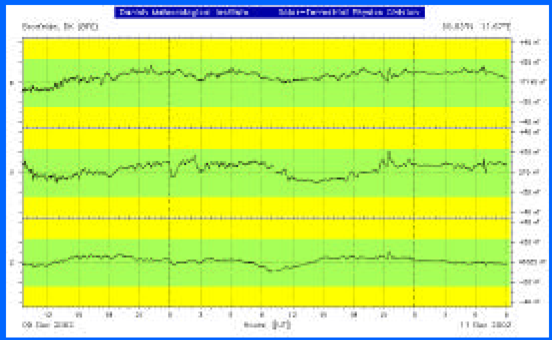
Danish Geomagnetic Observatory (**BFE**)

Greenlandic Observatories and Variometer Stations (**NAQ**, **STF**, **GDH**, **THL**)

Norwegian High and Mid Latitude Variometer Stations
(**NAL, LYB, SOR, TRO, AND, LEK, ROR, DOB, BER**)

Current magnetic activity in the European sector of the ionosphere

Magnetic response to the impact of the solar wind in the immediate past



Brorfelde (Denmark) geomagnetic observatory

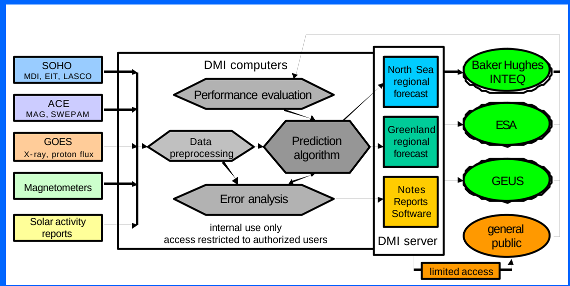
(5) Solar activity reports and archives

Summary of Solar Observations from Space and Ground

Recurring Phenomena e.g.,
- Coronal holes
- Large sunspots and sunspot groups
- Interplanetary sector structure

Combination of Schemes and Algorithms

Service Evaluation



General structure of the project work flow

Prediction Error Analysis

Statistical analysis of **predicted *versus* observed** geomagnetic activity levels

- How are errors distributed, are they random or are they biased?
  Do the predicted values tend to be too low or too high?
- How do the errors depend on the level of activity?
  Are they small at low activity and large at high activity?
  If there is a bias, is it different between low and high activity?
- How do the errors depend on the history?
  Does the prediction performance differ between steps from low to high activity and the opposite, that is, steps from high to low activity?
- How do specific solar wind and magnetospheric conditions affect prediction performance?
  Is the error season-dependent ? (note that the ionospheric current system and the overall level of geomagnetic activity are season dependent)
- Under which conditions does which algorithm work best?

Performance evaluation

Evaluation criteria

- How often would the user have decided to postpone a planned operation as a result of receiving a forecast of unfavorable geomagnetic conditions?
- How often would the decision have been right, how often wrong?
- How much time and money could have been saved or lost over one year if the user would have relied entirely on the forecast, in contrast to a situation in which he would have never relied on a forecast?

Summary

We propose to set up a procedure to forecast the level of geomagnetic activity in various geographic regions within a time interval of up to 3 days.

The scheme is based on neural network techniques and uses real-time data from existing interplanetary space probes, magnetospheric satellites and ground-based facilities.

Users will be prospecting companies and magnetic anomaly survey services.

Two-fold product assessment: Statistical prediction error analysis
Performance evaluation (economic criteria)