Geomagnetic Activity Forecast:
User Specifications and
Initial Analysis and Modeling Results

Space Weather Applications Pilot Project
Contract 16983/03/NL/LvH

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Regions of interest to the users collaborating in this project

User Requirements and User Specifications

(1) directional well drilling survey management

Accuracy of the BGGM model corrected for crustal anomalies (uncorrected in parantheses)

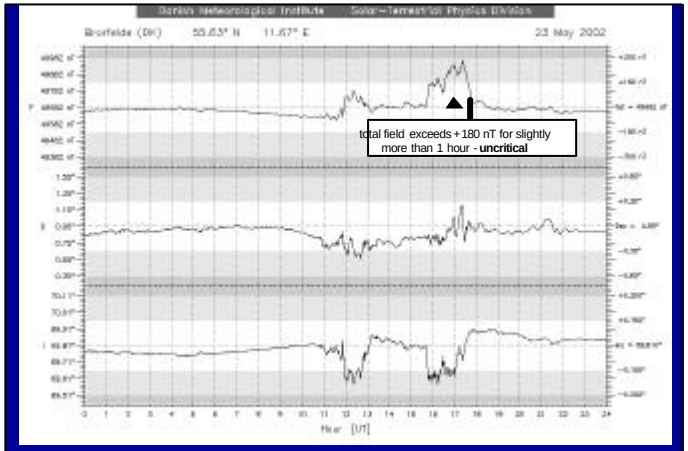
- Declination ± 0.30° (± 1.05°)
- Dip Angle ± 0.08° (± 0.47°)
- Field Intensity ± 40 nT (± 361 nT)

Acceptable deviations from nominal values if Brorfelde is used

- Declination ± 0.35°
- Dip Angle ± 0.25°
- Field Intensity ± 180 nT

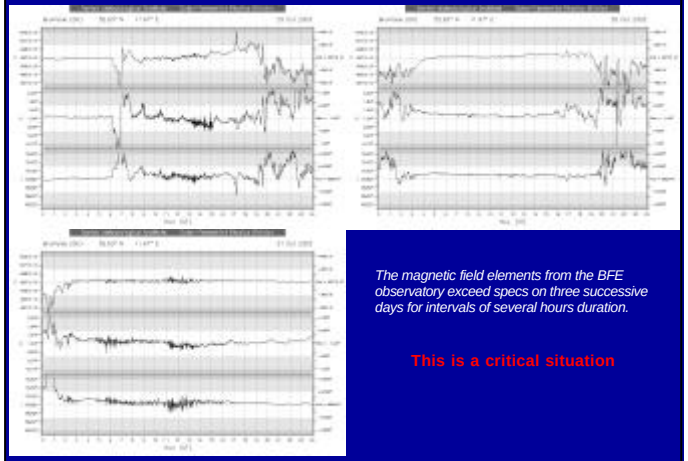
- A well drilling operation lasts up to 4 weeks and runs 24 hours a day 7 days a week.
- Geomagnetic reference measurements are made every 30 m drill distance (this is called a “stand”). Drilling speed varies between 1 m/s and 50 m/s. 30-40 m/s is a typical number.

  During a typical drilling activity a magnetic field datum is taken about once every hour.
- Single point deviations from the specified limits (”outliers”) are uncritical and will either
  - be flagged invalid and neglected, or
  - points will be measured again when opportunity arises
- Sequence of apparently ”wrong” numbers can cause a problem and may necessitate repetition of measurements over the entire segment affected or control measurements by a different method, e.g., a gyro – time-consuming, costly and thus to be avoided.
- **Information primarily desired:**
  Warning of severe long-lasting perturbation of the geomagnetic field – intense geomagnetic storm.
- **Possible action:**
  Suspend drilling and perform other tasks (e.g., borehole casing).



acceptable deviations from reference levels:
(all three conditions must be met)

180 nT total field
0.35° declination
0.25° inclination

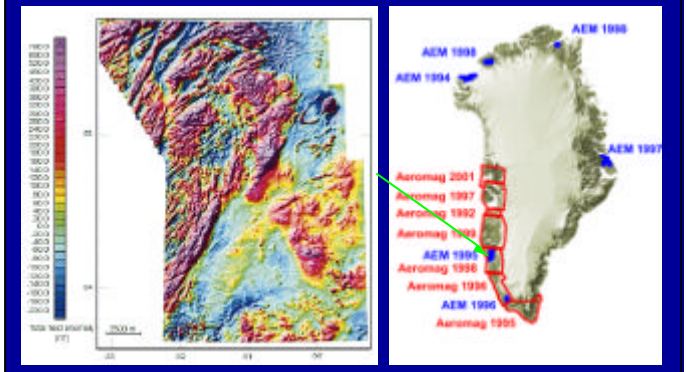


The magnetic field elements from the BFE observatory exceed specs on three successive days for intervals of several hours duration.

This is a critical situation

User Requirements and User Specifications

(2) crustal magnetic anomaly survey



Magnetic anomaly map compiled from the 1998 aeromagnetic survey data

Magnetic anomaly survey specifications

Sensor altitude	60-300 metres above ground
Line separation	100 m - 500 m
Aircraft speed	30 m/s - 70 m/s
Sampling frequency	10 Hz
Diurnal tolerance	maximum of **10 nT** from a **chord of 1 min** length
Number of line kilometres	20 000 km - 140 000 km
Duration of one flight	6 hours
Duration of survey	1 - 4 month
Magnetic variation reference	one magnetic base station

Large-scale magnetic variations can be corrected for, using data from the reference station – small-scale magnetic variations render the affected survey segment invalid and necessitate a repetition of the segment

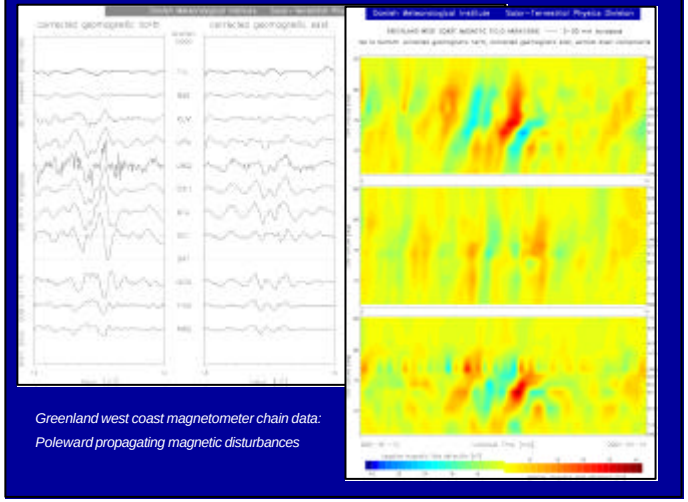
Parameters of importance for survey optimisation

- Geomagnetic activity
- Weather
- Pilot rest time
- Airport opening hours
- Aircraft maintenance

The survey supervisor examines every morning records of geomagnetic activity and weather forecast and decides whether a survey flight can be performed now or later during the same day or need to be postponed. In case of rapid magnetic variations a flight will not commence.

Information primarily desired
Warning of occurence of small-scale magnetic variations over the next eight hours and over the subsequent eight hours

Possible action:
Reschedule flight to a later time/day and perform other tasks (e.g., give pilots rest time and/or perform aircraft maintenance)



Greenland west coast magnetometer chain data:
Poleward propagating magnetic disturbances

Two different pieces of information are required

(1) Prediction of excessive magnetic disturbances in the survey area

(2) Information on the spatial coherency of magnetic field variations

Information required but not yet available

What is the relation between spatial and temporal scales of geomagnetic variations along the Greenlandic coast?

Question posed differently

If a certain distribution (in the frequency domain) of a magnetic field time series from a base station is given, what is the probability that the associated spatial distribution of the magnetic variation exceeds the tolerance limits set by supervisor of the aeromagnetic survey?

This question needs to be addressed in our project in order to find out whether the present requirement

" maximum of **10 nT** from a **chord of 1 min** length "

needs to be modified or not

Statistical analysis of geomagnetic field deviations from quiettime values: Results from the Brorfelde Observatory (BFE), Denmark

Procedure:

(1) Collect 16 years of Brorfelde data

(2) Determine regular quiet time diurnal variation (Sq) as a function of season

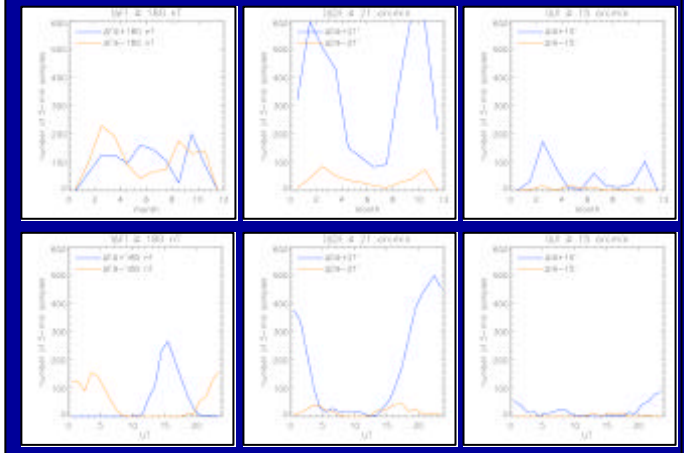
The dependence on solar activity, using f10.7 or e10.7 as proxy, will be added later

(3) Subtract Sq from the data and generate 5-min samples

(4) Compute statistical distributions of disturbances exceeding the Baker Hughes INTEQ specs

(a) Distributions of ΔF, ΔD and ΔI as functions of UT

(b) Distributions of ΔF, ΔD and ΔI as functions of season



Results

Large magnetic deviations from quiet time values are very unevenly distributed.

Results (cont.)

Winter season (December/January) is the magnetically quietest time.
ΔF and ΔI never exceed the tolerance limits, ΔD exceeds the limits occasionally.

Summer is less quiet than winter but better than the months around equinox.

Equinox times are statistically most disturbed, and the limits set by Baker Hughes INTEQ are most often exceeded.
ΔF, ΔD and ΔI exceed the specs often, and ΔD is most prominent in this respect.
This is specifically true for positive ΔD (northward directed ionospheric current).

Results (cont.)

Noon hours are the magnetically quietest period.
(note: at Brorfelde local magnetic noon corresponds to ≈10 UT).
ΔF and ΔI never exceed the tolerance limits, ΔD exceeds the limits occasionally.

Afternoon hours often experience large positive variations in ΔF but less so in ΔD and ΔI. This indicates the existence of westward currents poleward of BFE.

Midnight hours are most disturbed in ΔD with astromg dominance for positive values (northward ionospheric currents). This may be an effect of substorm current wedges.

Conclusion

Directional well drilling in the North Sea should concentrate on the Dec/Jan time interval. Equinox times should be avoided.

The hours shortly before noon UT (approximately noon MLT) will render the most reliable borehole magnetometer measurements.