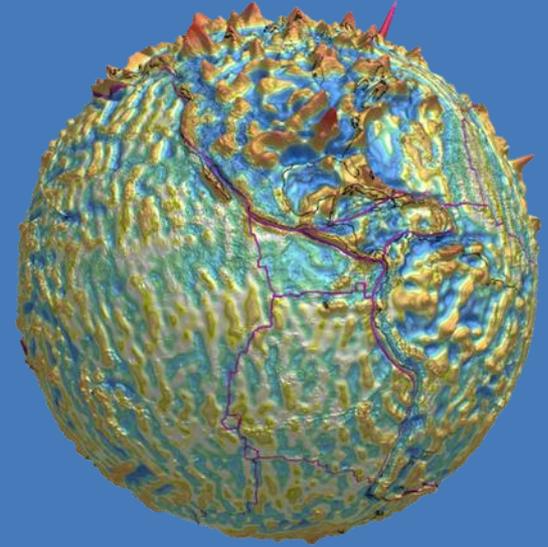


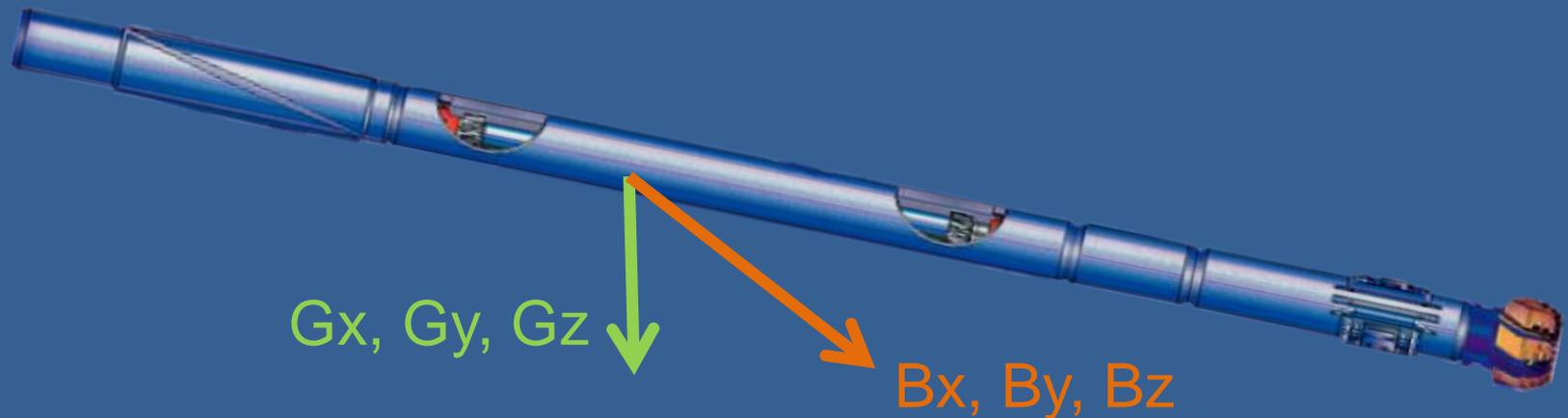
On-Site Disturbance Field Measurement:



A portable real-time disturbance
field monitoring station

Motivation

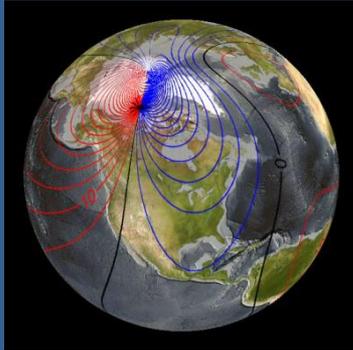
- MWD wellbore azimuth is determined relative to the geomagnetic field



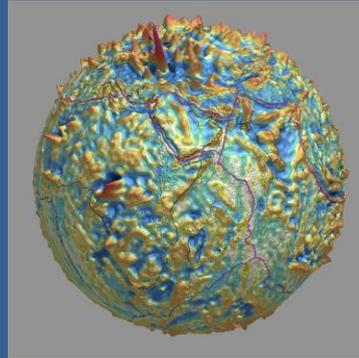
- Converting magnetic azimuth to true azimuth requires knowledge of the direction of the geomagnetic field, at the point of measurement downhole
- Since Earth's magnetic field varies spatially and with time, referencing against it requires measurement of the spatial and temporal variations

Magnetic Field Components

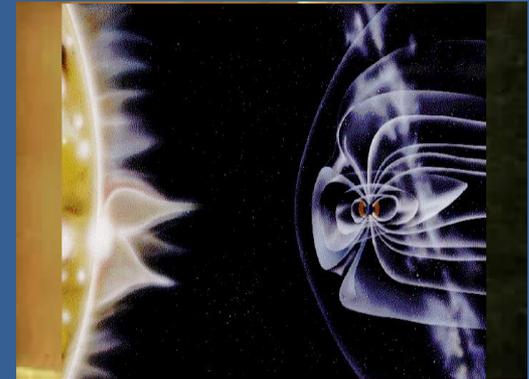
Main Field



Crustal Field



Disturbance Field

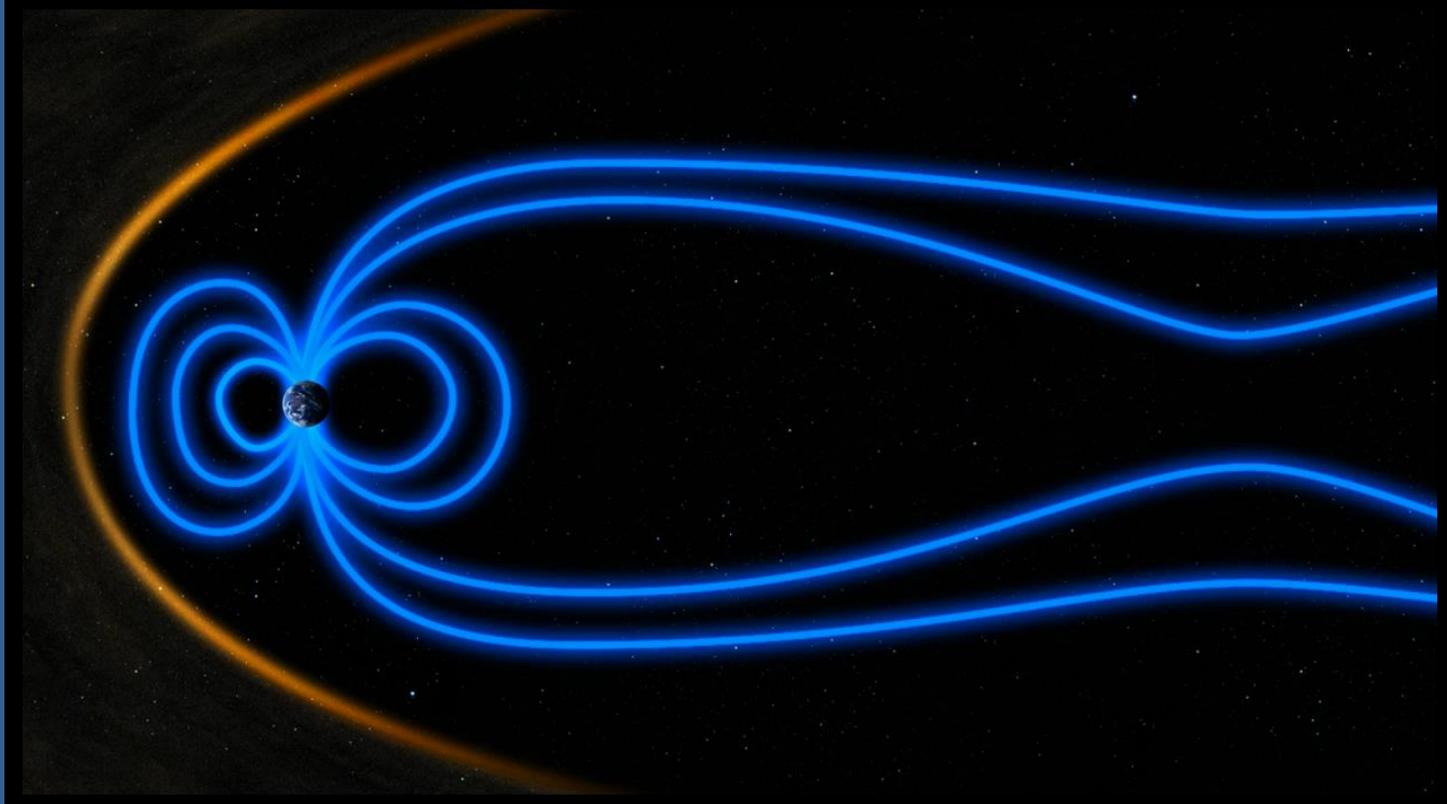


Disturbance field components

- **Stable component:** originates from the ring current; varies with solar cycle
- **Seasonal component:** periods of months to 1 year, accounted for by global measurements and subsequent modeling
- **Rapid variations:** solar storms, diurnal variations, auroral events – short timescale typically less than 2 weeks, events with large magnetic swings



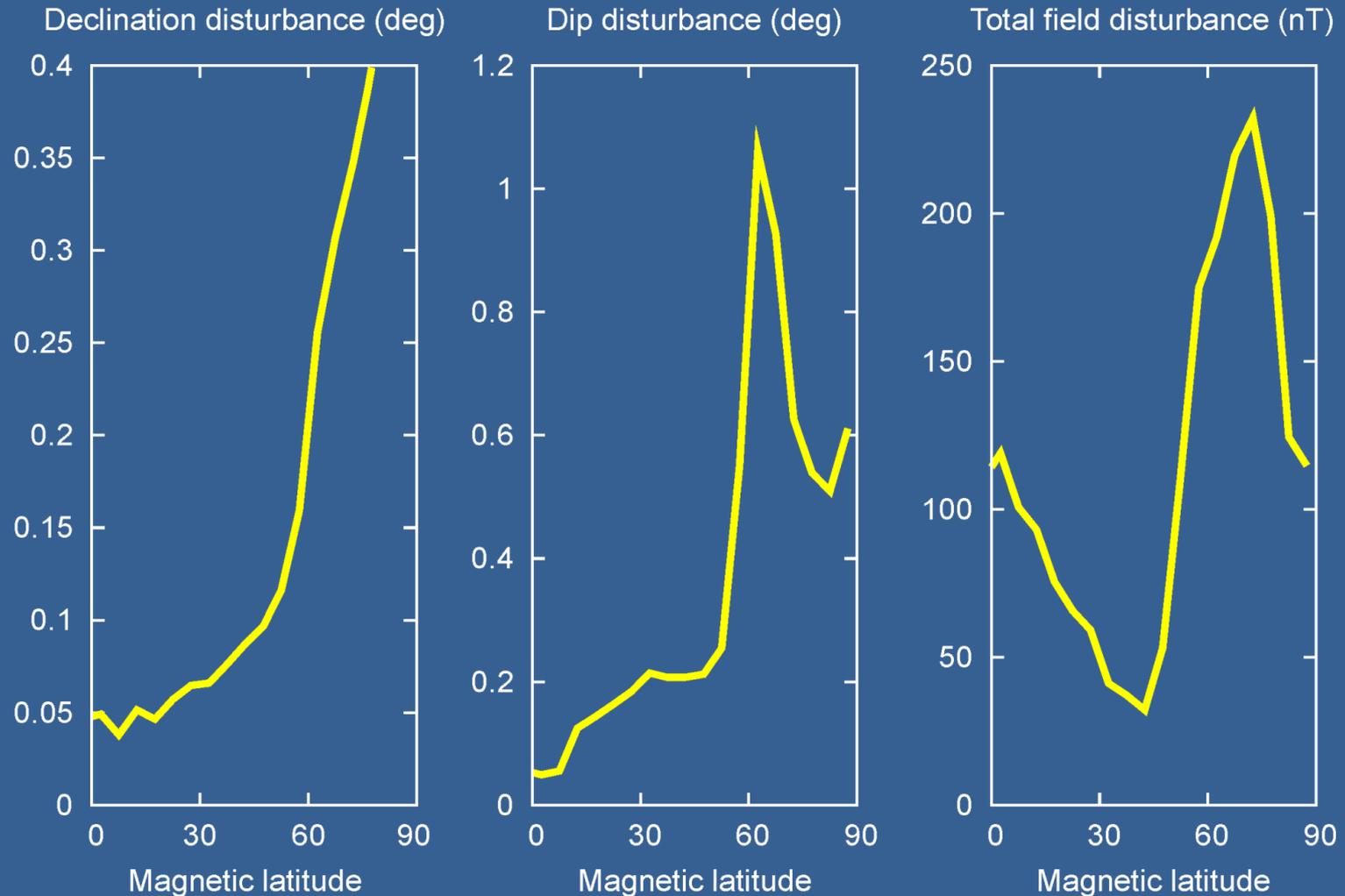
Source of Disturbance Field



- The solar wind deforms Earth's fields steadily and impulsively
- This requires disturbance field monitoring to capture time variation

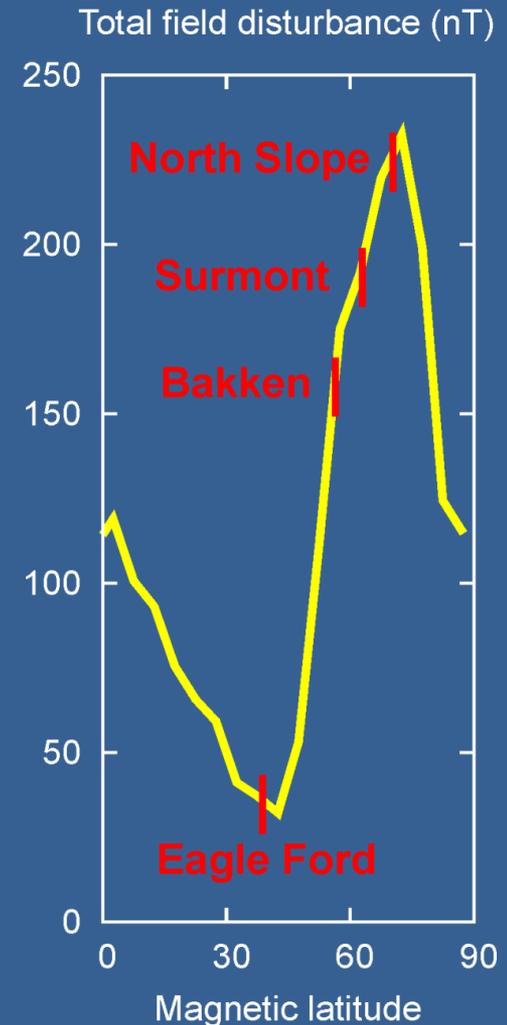
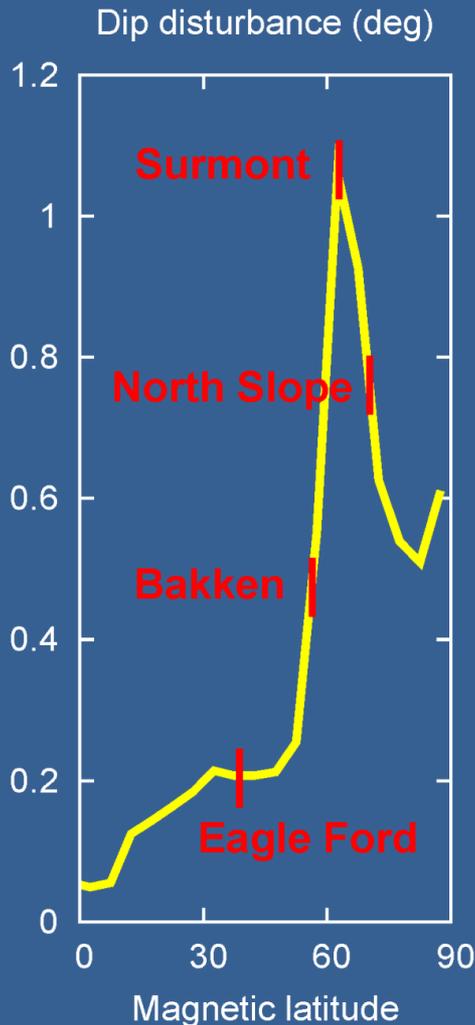
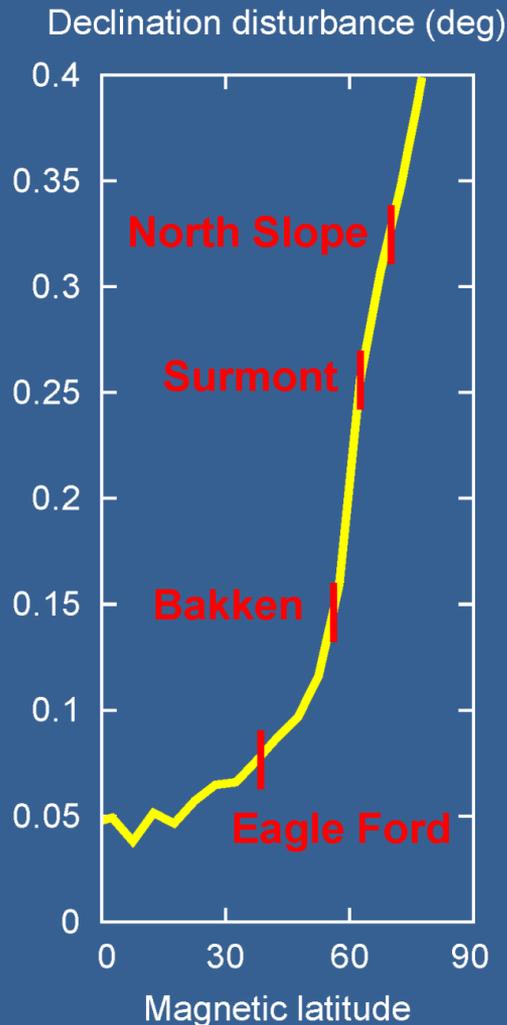
Disturbance Field Averages

(1-sigma, magnetic storm*) *Defined here as $K_p \geq 6$



Disturbance Field Averages

(1-sigma, magnetic storm*) *Defined here as Kp ≥ 6



Typical Storm-Time Disturbances

Alberta

Magnetic variation data for MEA



Meanuk, 17-Mar-2015

Typical Storm-Time Disturbances

Alberta
1-minute averages

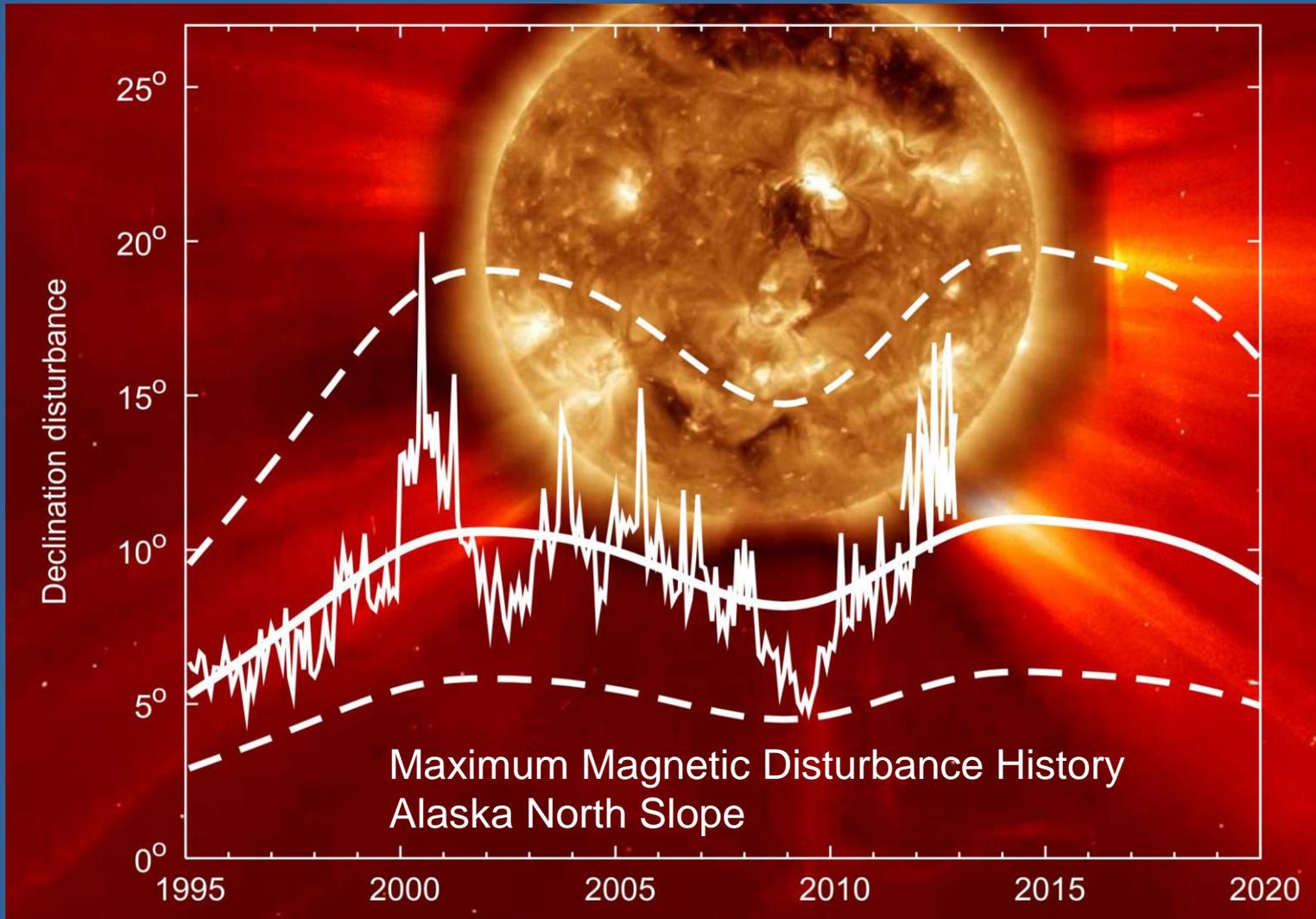
Magnetic variation data for MEA



Meanuk, 17-Mar-2015

Field changes by 500 nT from 1 minute to next

Disturbance Fields Maximums

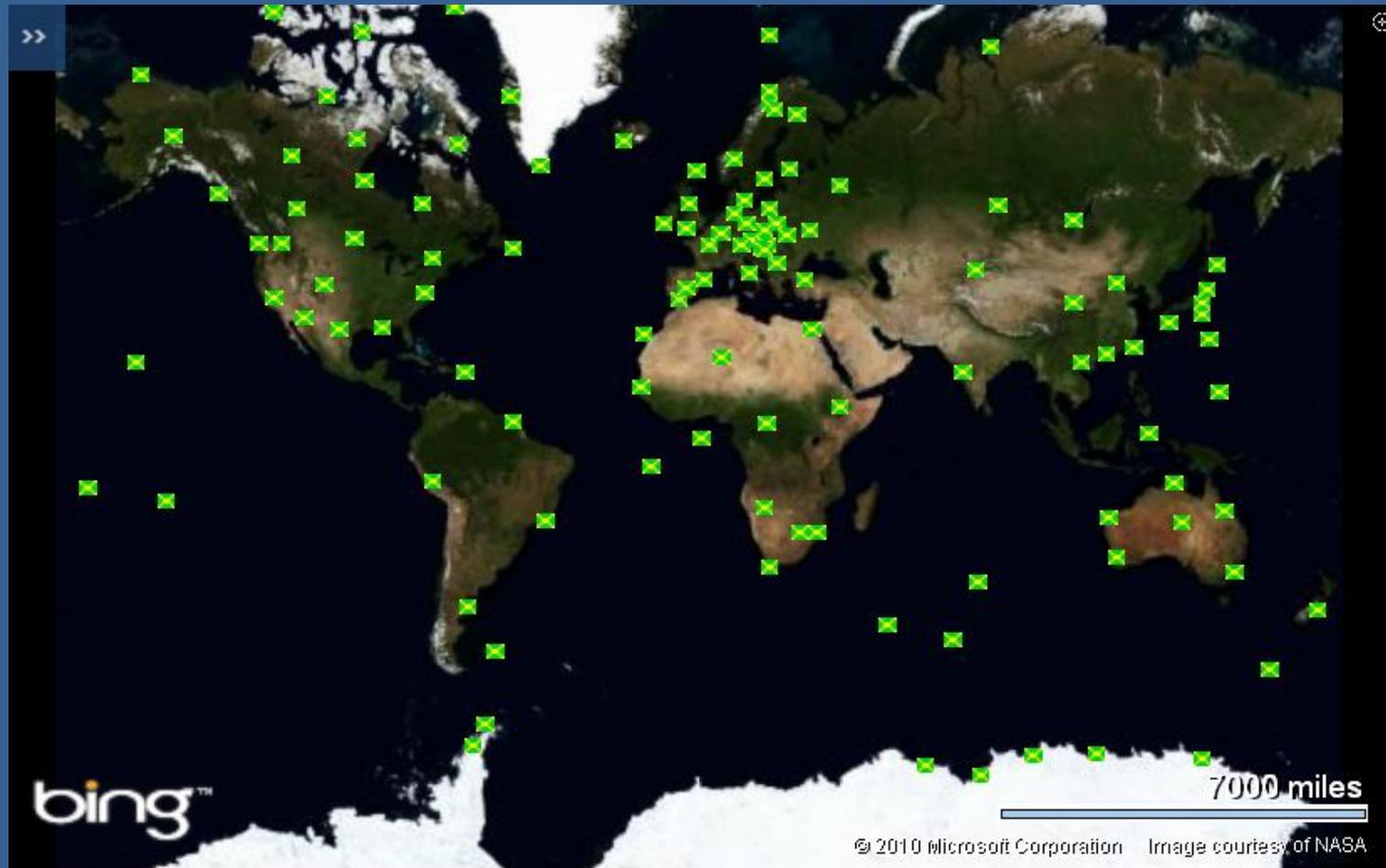


Impact on Wellbore Position and QC

- Systematic disturbance field contributions do change your well trajectory
 - See Maus, S. *Systematic and Random Contributions to the Disturbance Field (IFR 2)*. ISCWSA Proc., 2014.
- By correcting for the disturbance field you will have fewer surveys failing QC
- With disturbance field monitoring drilling can continue through magnetic storms, reducing down time

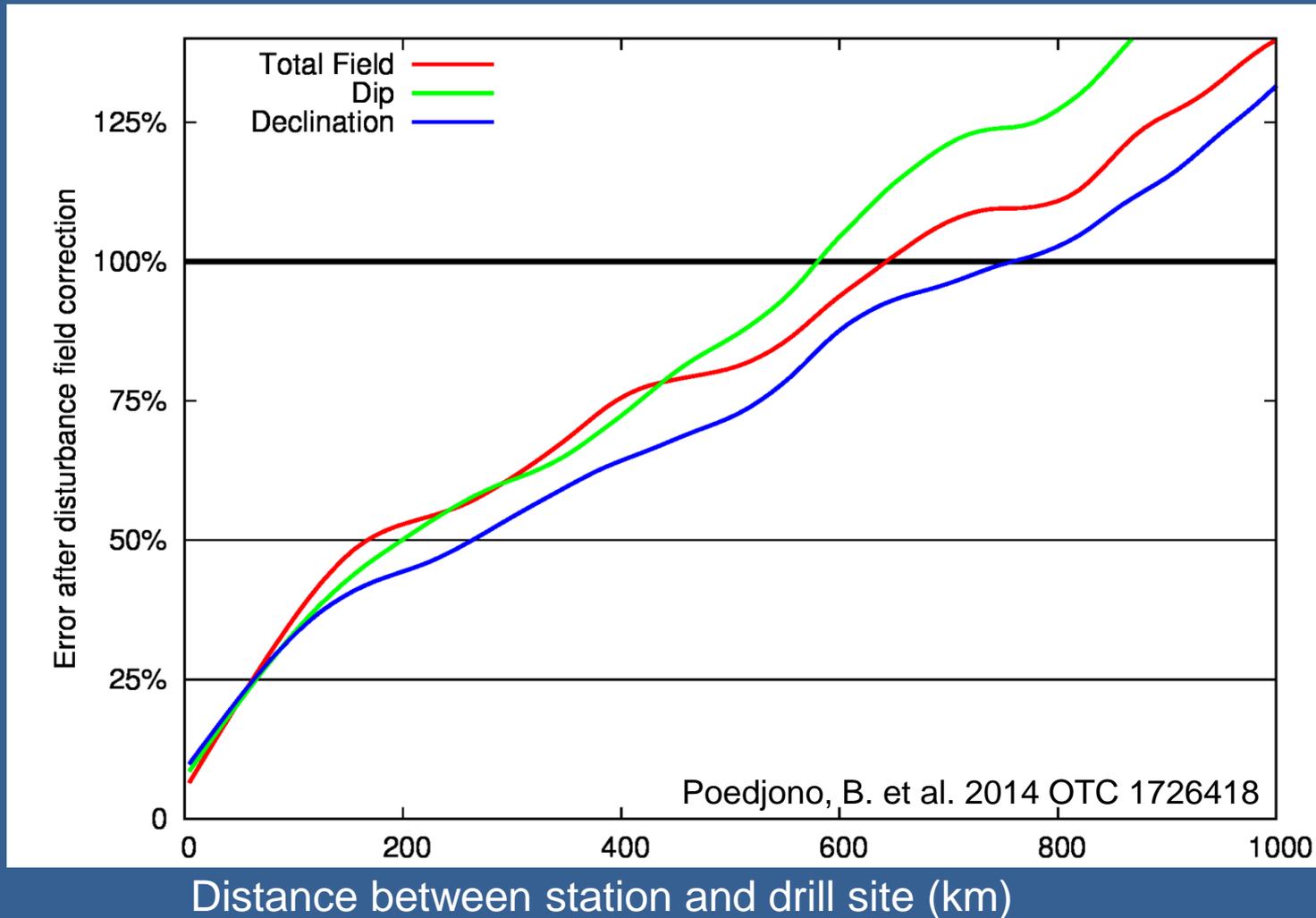
Fixed Magnetic Observatories

- A network of observatories provide sparse coverage of the globe
- These require interpolation to be used for IIFR service

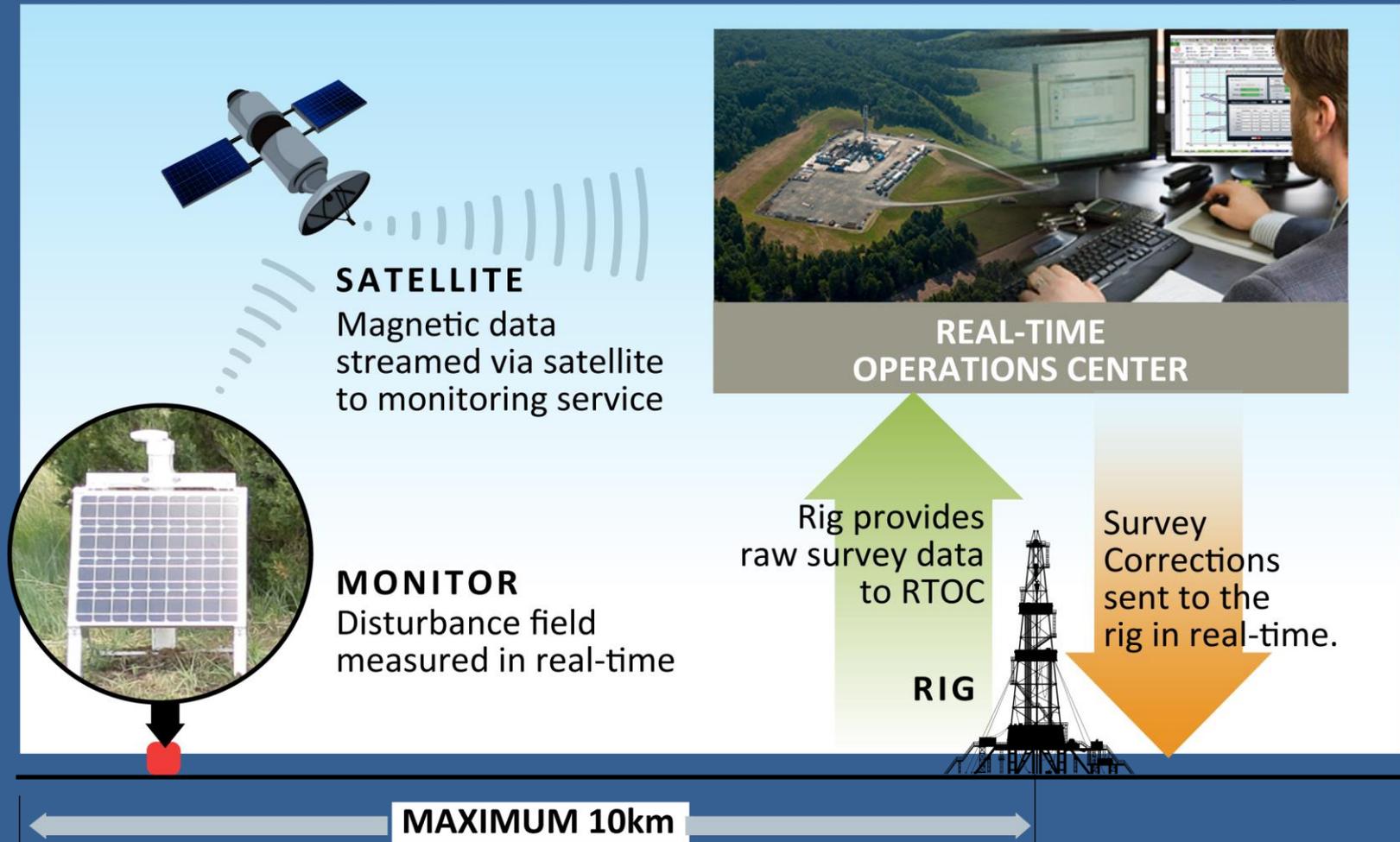


Benefit of On-Site Measurement

Assuming only 1 nearby station is used for the IFR2 correction:

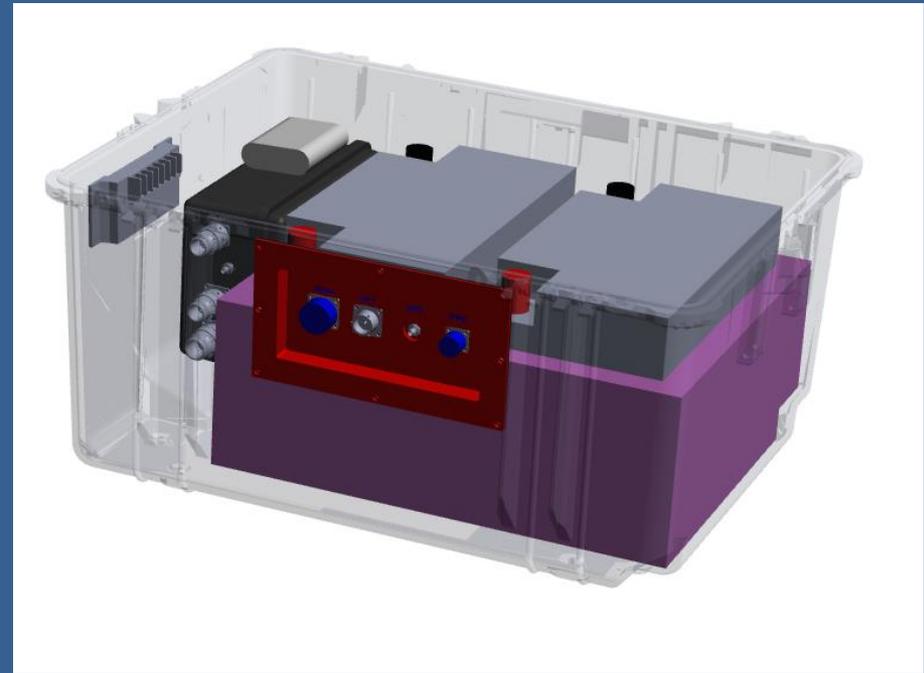


Local and Real-time Disturbance Field Monitoring



Monitoring Station Hardware

- Ruggedized hardware for reliable field operation
- Remote data collection, control, and health monitoring for ease of operation



Validation Deployments

Bakken, North Dakota



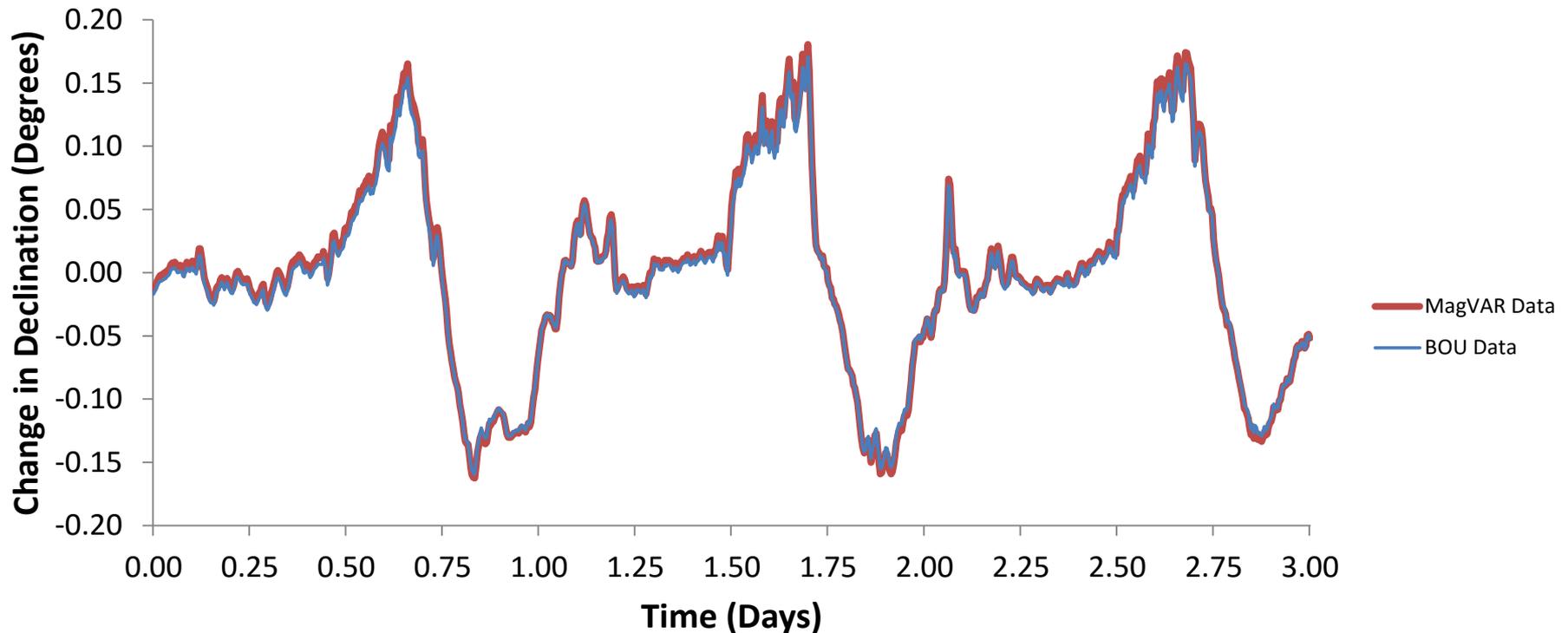
Loveland, Colorado



Validation: Boulder Observatory

Declination Validation with Boulder Observatory

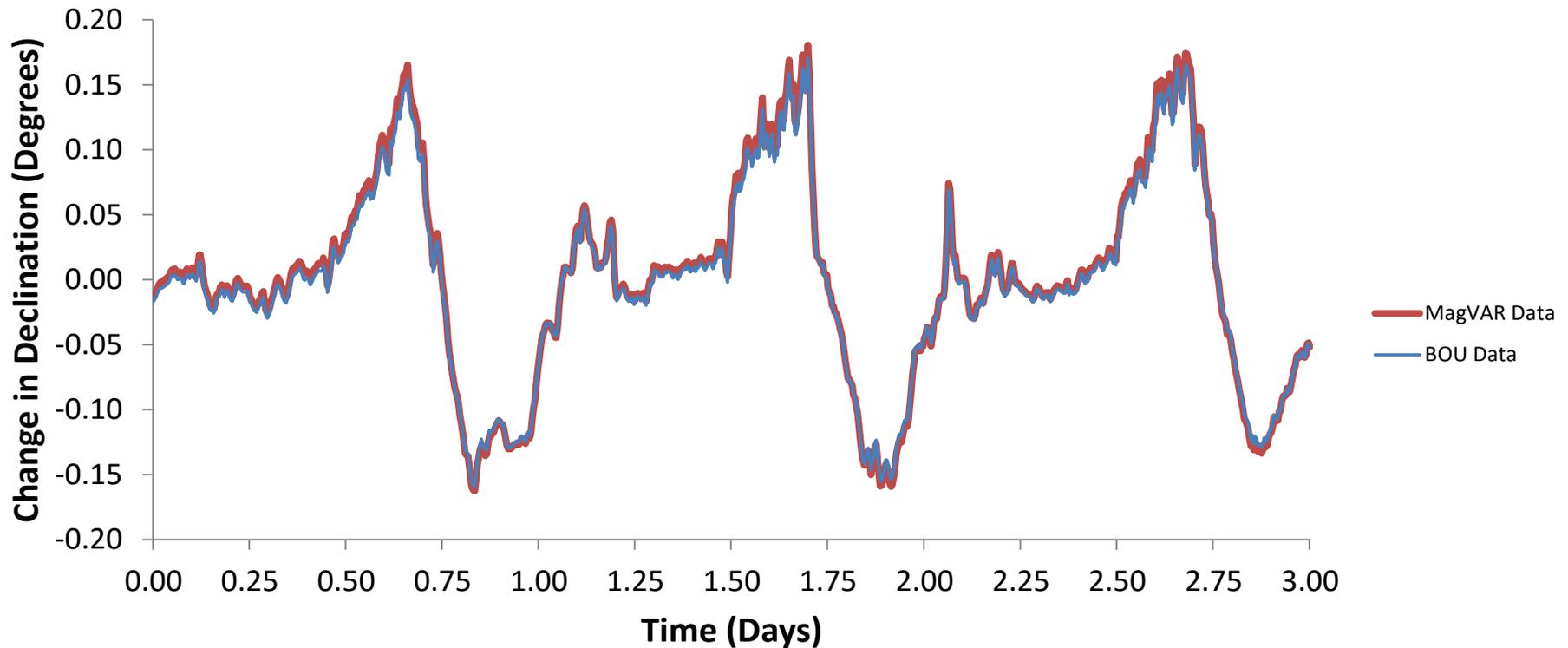
**Comparison of BOU Observatory Declination Data to MagVAR Station 2
3-day representative data from 7/30/2015 to 8/01/2015**



Validation: Boulder Observatory

B_{total} Validation with Boulder Observatory

Comparison of BOU Observatory Declination Data to MagVAR Station 2
3-day representative data from 7/30/2015 to 8/01/2015



Validation: Boulder Observatory

Summary:

- *MagVAR data shows good agreement to observatory data*
- *MagVAR data has higher cadence (1 second) than the observatory network (1 minute)*
- *MagVAR stations are deployed on-site, rather than using a signal from possibly hundreds of miles away*

Raw Data Web Monitor

Well Data App
Jonathan

mvro.magvar.com/#/admin
Welcome, mvadmin492380! (logout)

Magvar Remote Observatory

Home

Selected Station: Station 2

Stations

Station 2

Displayed Metric: Voltage

| Station ID | MOMSN | Transmitted | Received | Type Code | Voltage (V) | Box Temp (°C) | Mag Temp (°C) |
|------------|-------|---------------------|---------------------|-----------|-------------|---------------|---------------|
| Station 2 | 1 | 2015/07/24 06:00:59 | 2015/07/24 18:07:38 | 6 | 12.9V | 29.0°C | 13.0°C |
| Station 2 | 2 | 2015/07/24 08:00:15 | 2015/07/24 18:08:03 | 6 | 12.9V | 28.0°C | 13.0°C |
| Station 2 | 3 | 2015/07/24 10:00:30 | 2015/07/24 18:08:19 | 6 | 12.8V | 26.5°C | 13.0°C |
| Station 2 | 4 | 2015/07/24 12:00:08 | 2015/07/24 18:08:33 | 6 | 12.8V | 25.0°C | 13.0°C |
| Station 2 | 4 | 2015/07/24 14:00:26 | 2015/07/24 18:08:52 | 6 | 12.7V | 24.0°C | 13.0°C |
| Station 2 | 4 | 2015/07/24 16:00:14 | 2015/07/24 18:09:09 | 6 | 12.7V | 23.5°C | 13.0°C |
| Station 2 | 5 | 2015/07/24 06:00:14 | 2015/07/24 18:09:21 | 6 | 12.6V | 23.0°C | 13.0°C |
| Station 2 | 6 | 2015/07/24 20:00:12 | 2015/07/24 18:09:50 | 6 | 12.6V | 22.5°C | 13.0°C |
| Station 2 | 6 | 2015/07/24 22:01:07 | 2015/07/24 18:10:03 | 6 | 13.3V | 23.0°C | 13.0°C |
| Station 2 | 7 | 2015/07/25 00:01:07 | 2015/07/24 18:10:16 | 6 | 13.7V | 23.5°C | 13.0°C |

View Detailed
Station Settings

Notifications

[Jul 31, 2015, 3:25 PM]: Station configuration created: Station Configuration [Station ID: Station 2, IMEI: 300234062942610, RockBlock Serial Number: 8741, Instrument Id: 005, Status: Active]

[Jul 31, 2015, 3:52 PM]: Permissions By Username changed from [[2]] to [[2]]

[Jul 31, 2015, 3:52 PM]: Permissions By Role changed from [[]] to [[admin]]

Disturbance Field Data Access

Well Data App x pomme.magvarinternal.com/mvro/#/client Jonathan

Magvar Remote Observatory Welcome, client! (logout)

Station: Station 1

From: Mon Jul 06 10:49 AM To: Thu Aug 06 04:49 AM

| Reference Values | | | | | |
|------------------|---------------|---------------|-------------|-----|-------------|
| UTC Offset | Minute Offset | Second Offset | Total Field | Dip | Declination |
| +0 | 0 | 0 | 0 | 0 | 0 |

Apply Changes

| Corrected Values | | | |
|---------------------------------------|-------------|---------|-------------|
| Measurement Time (Offset by 0h 0m 0s) | Total Field | Dip | Declination |
| 2015/07/06 10:49:33 | 50.000nT | 84.932° | 36.284° |
| 2015/07/06 16:49:33 | 49.847nT | 85.029° | 36.191° |
| 2015/07/06 22:49:33 | 49.585nT | 85.087° | 36.243° |
| 2015/07/07 04:49:33 | 49.355nT | 85.059° | 36.327° |
| 2015/07/07 10:49:33 | 49.192nT | 85.052° | 36.259° |
| 2015/07/07 16:49:33 | 49.264nT | 84.965° | 36.243° |
| 2015/07/07 22:49:33 | 49.076nT | 84.963° | 36.184° |
| 2015/07/08 04:49:33 | 48.842nT | 85.044° | 36.192° |
| 2015/07/08 10:49:33 | 48.597nT | 84.976° | 36.160° |
| 2015/07/08 16:49:33 | 48.645nT | 85.026° | 36.166° |
| 2015/07/08 22:49:33 | 48.527nT | 85.107° | 36.130° |
| 2015/07/09 04:49:33 | 48.595nT | 85.077° | 36.178° |
| 2015/07/09 10:49:33 | 48.464nT | 85.044° | 36.160° |
| 2015/07/09 16:49:33 | 48.774nT | 85.073° | 36.202° |
| 2015/07/09 22:49:33 | 48.348nT | 85.074° | 36.278° |
| 2015/07/10 04:49:33 | 48.523nT | 84.995° | 36.315° |
| 2015/07/10 10:49:33 | 48.261nT | 85.088° | 36.277° |
| 2015/07/10 16:49:33 | 48.576nT | 85.105° | 36.326° |

Export to CSV

Displayed Metric: Total Field

Legend: Total Field (nT)

Summary and Conclusions

- Disturbance field monitoring at high latitudes is highly beneficial
- Proximity of measurement to drill site is of importance
- Validation studies show that quality is on par with fixed observatories
 - Absolute level needs to be provided by a complete model
- A portable disturbance field monitoring station with satellite uplink allows for ready deployment anywhere on the globe