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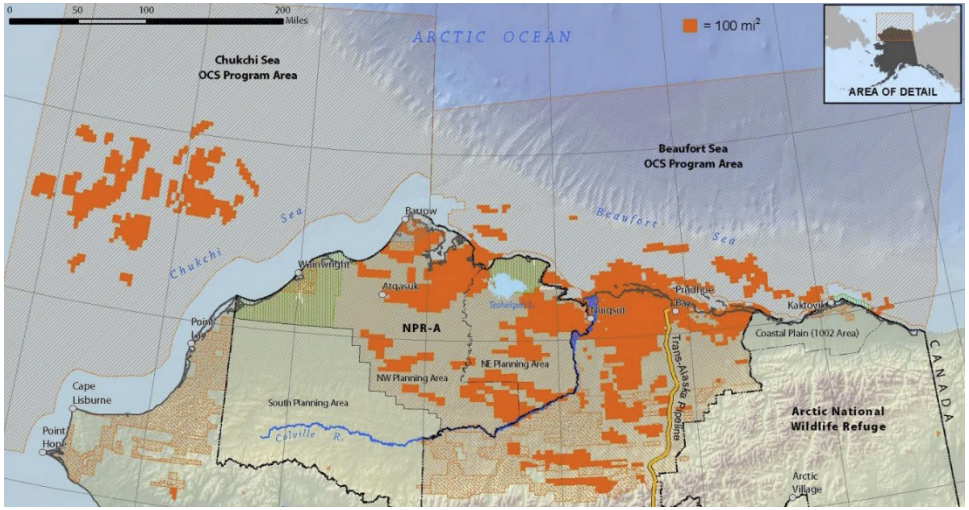
Improved Geomagnetic Referencing in the Arctic Environment

Benny Poedjono and Nathan Beck, SPE, Schlumberger; Andrew Buchanan and Luca Borri, Eni Petroleum Co.; Stefan Maus, SPE, Magnetic Variation Services; and Carol A. Finn, E. William Worthington and Tim White, US Geological Survey

eni MagVAR USGS Schlumberger SPE International

Challenges of Wellbore Positioning in the Arctic

- Challenges include:
  - Smaller horizontal magnetic field values at high latitudes
  - High inclination limitations
  - Time and expense considerations of gyroscopic surveys



Advances in Geomagnetic Referencing provide a viable alternative.

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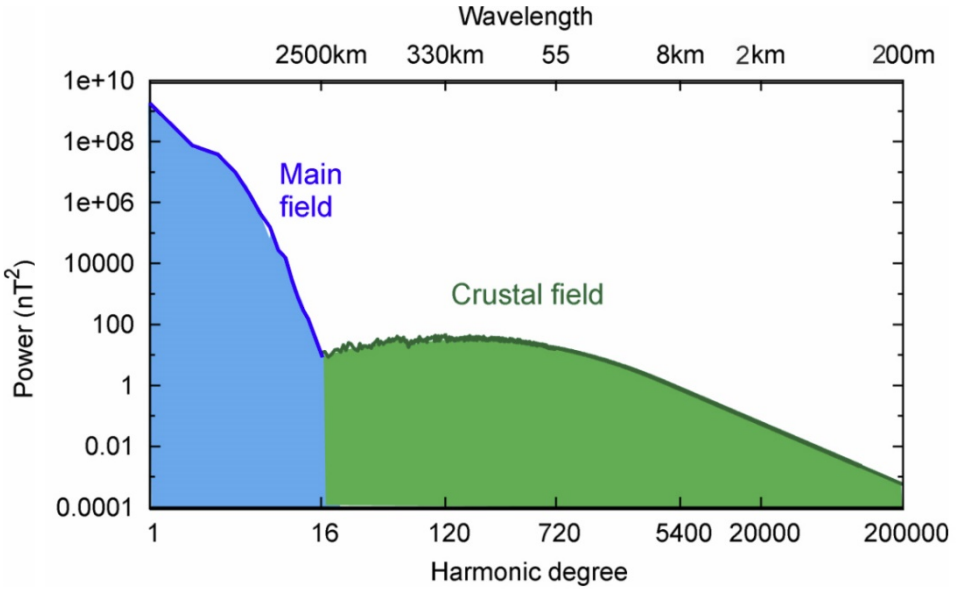
Geomagnetic Referencing at High Latitudes

- Smaller horizontal component in the Arctic means increased impact from crustal and drillstring magnetic interference
- Geomagnetic field consists of three components:
  - Main Field
  - Crustal Field
  - Disturbance Field



Knowledge of crustal field and real-time data on disturbance field are crucial.

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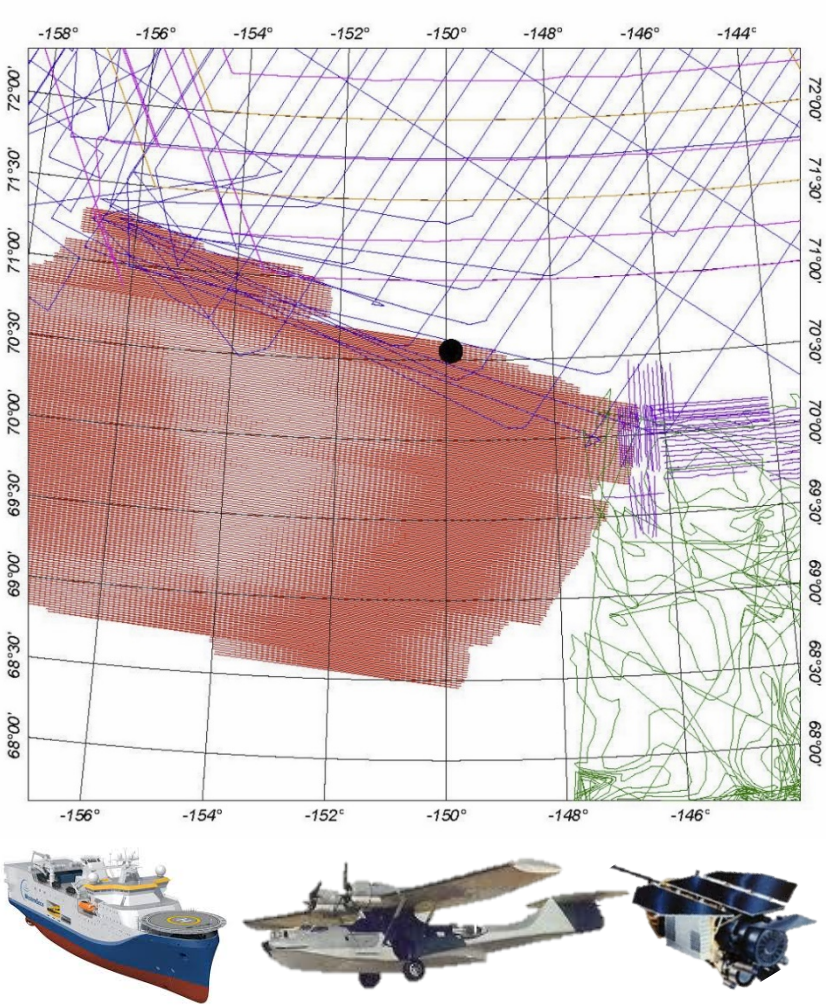
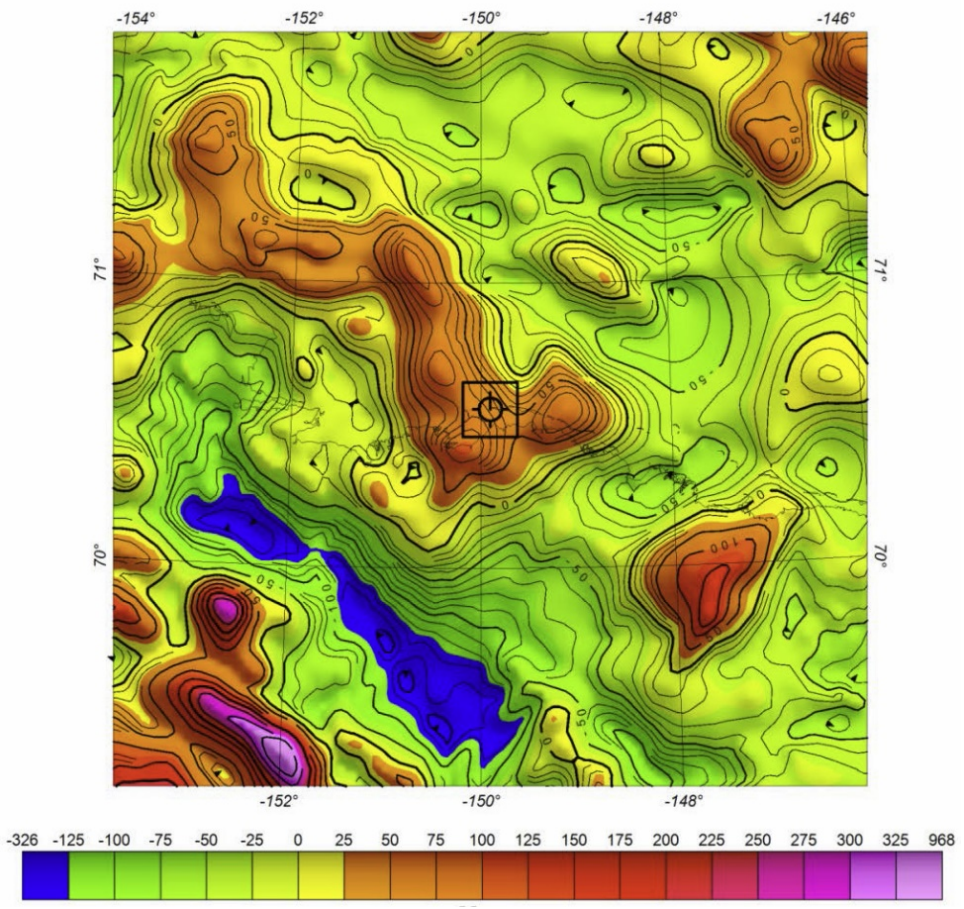
Crustal Field Model

- Important to cover entire wavelength spectrum:
  - Satellite data for long wavelengths, ≥ 250 km
  - Local aeromagnetic surveys for shorter wavelengths
- Strong emphasis on quality control and validation



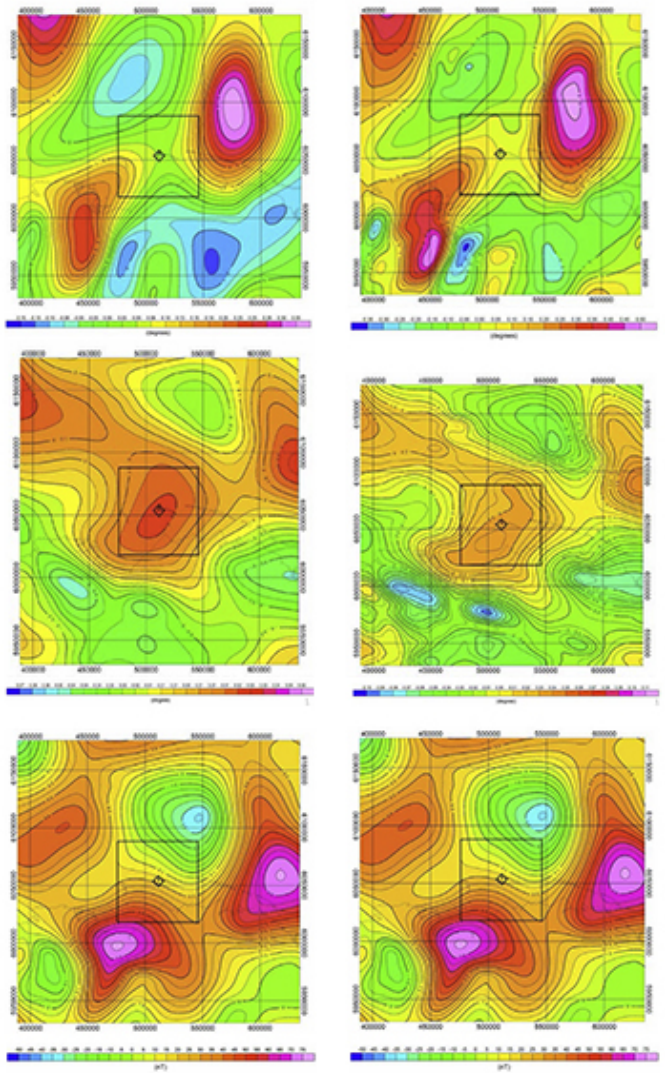
Crustal Field Model

- Data from various sources are merged
- 3-D magnetic model is generated, showing total field strength
- Laplace's differential equation is used to estimate field vector



Crustal Field Model

- Data are used to produce 3D maps of crustal residuals starts at mean sea level to maximum drilling TVD for:
  - Declination
  - Dip
  - Total magnetic intensity



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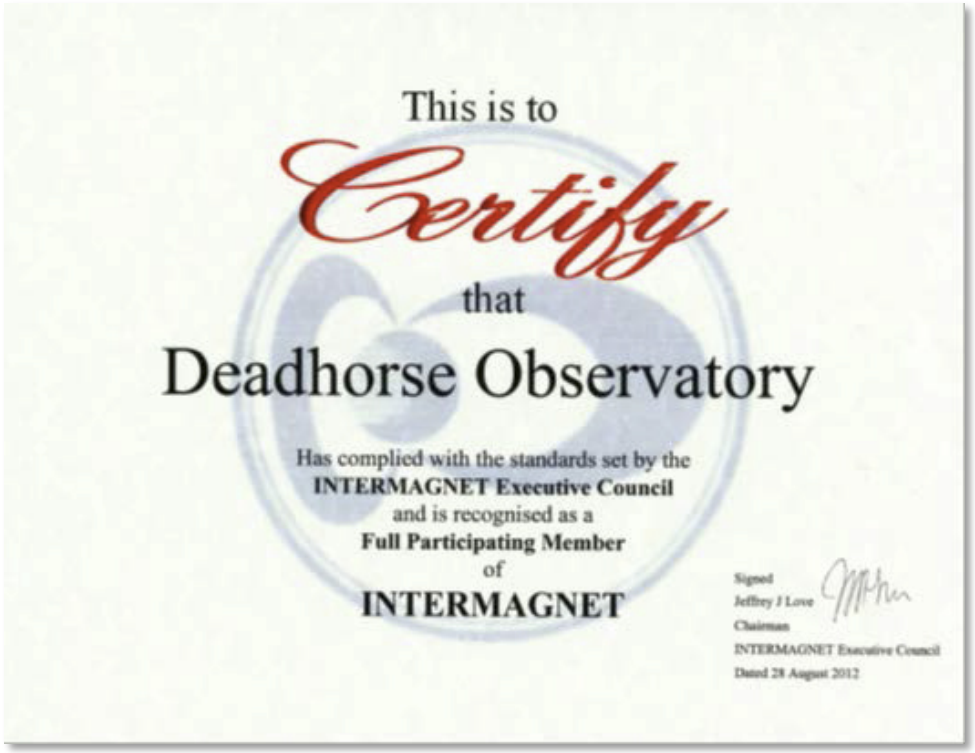
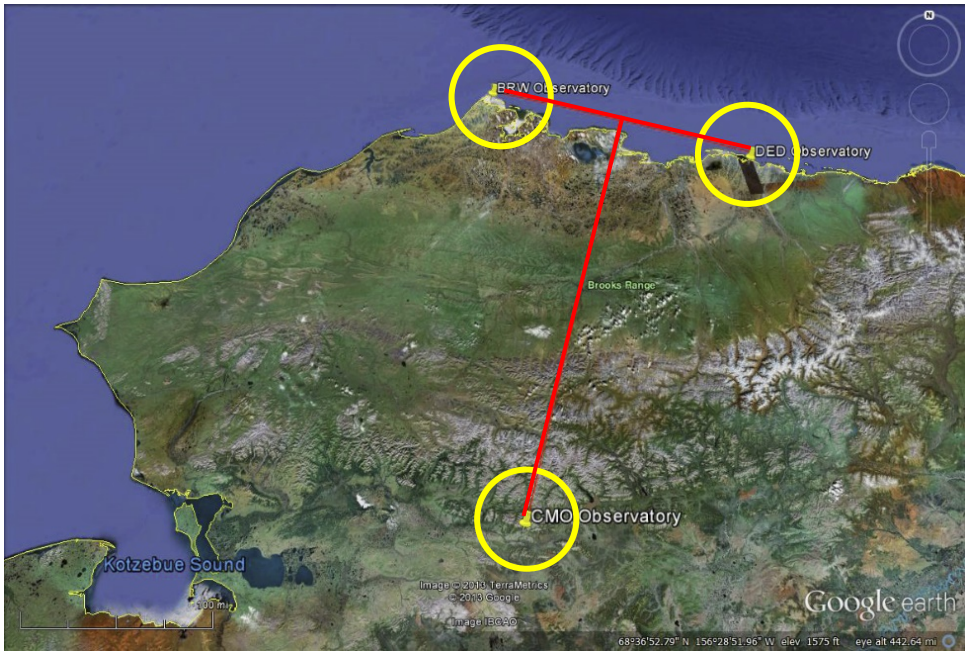
Magnetic Observatory Data

- Deadhorse Observatory:
  - Established March 2010 at Prudhoe Bay
  - Collaboration with USGS
  - Certified as INTERMAGNET Observatory in 2012



Magnetic Observatory Data

- Additional real-time data:
  - USGS observatories in Barrow and College
  - Provide unique visualization of geomagnetic field during active periods
  - High level of spatial resolution
  - Identical low noise, high resolution instrumentation



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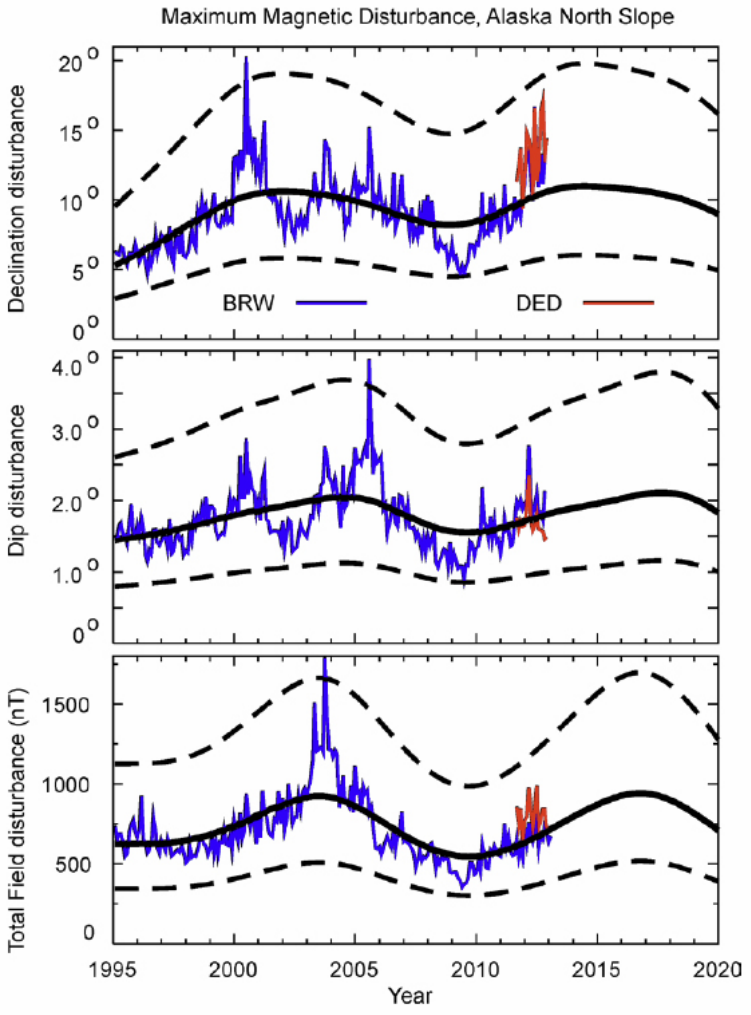
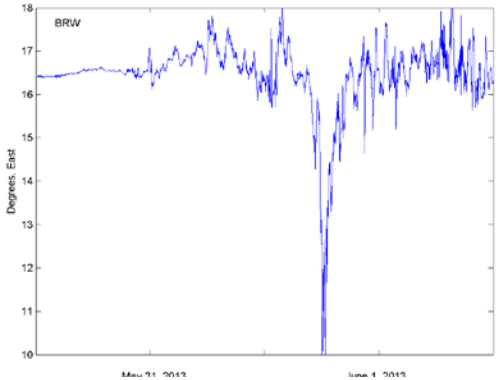
Characterizing Maximum Magnetic Disturbance Field

- Solar Maximum characterization (11 years cycle)
- Based on 1-minute averaged measurements from two observatories from 1995 to present
- Residual values transformed into declination, dip, total field

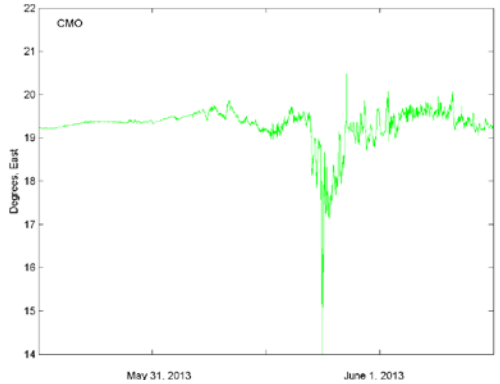


Declination During Magnetic Storms

- Large magnetic storm occurred June 1, 2013
- Declination differs significantly over small geographic separation of observatories.



BRW



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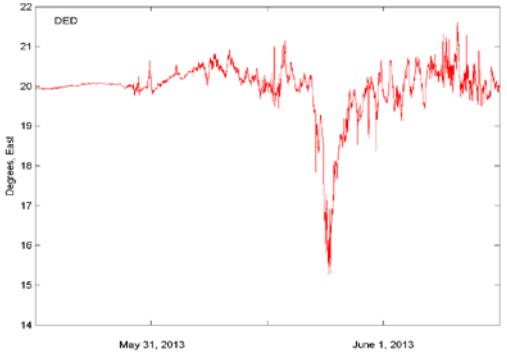

DED

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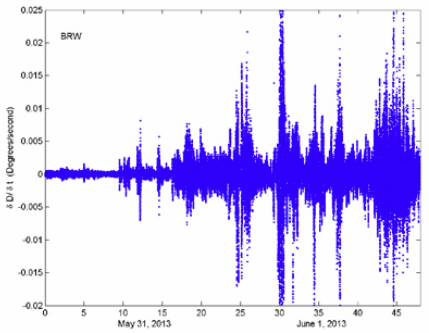
Applying Higher Frequency Observatory Data

- Higher frequency data are more useful in describing disturbance fields
- Maximum change exceeds 0.02°/second at all three sites
- Rapid changes can significantly impact drilling operations.



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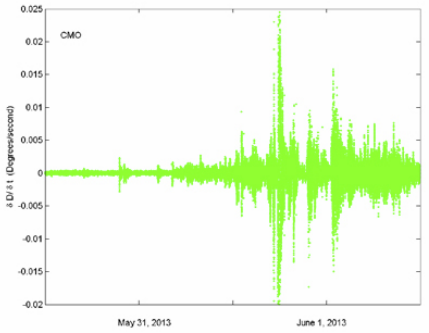

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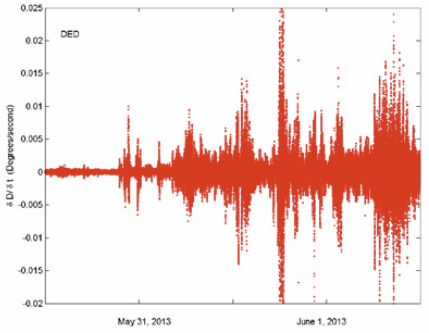

DED

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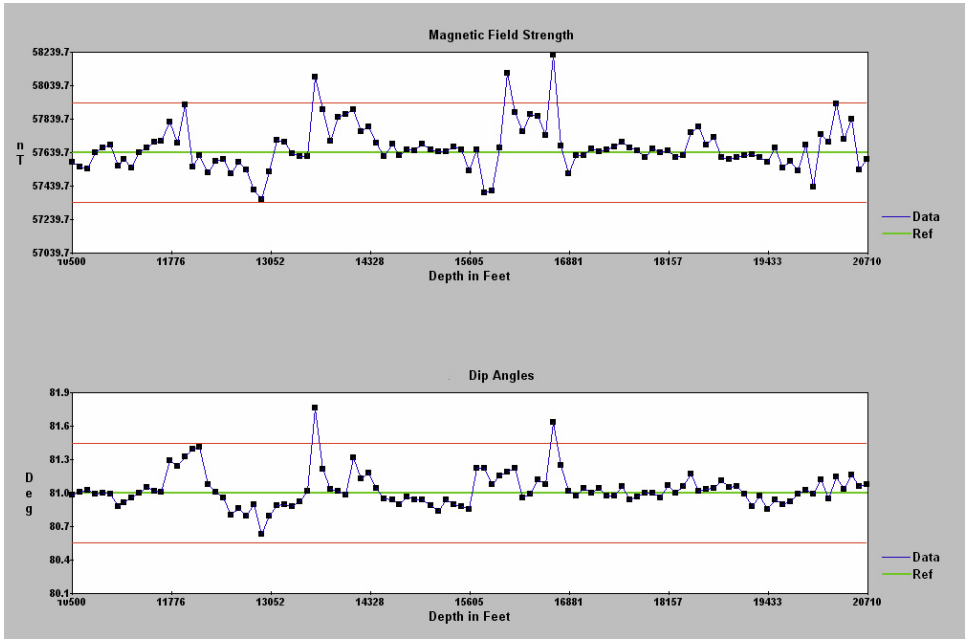
DED versus MWD Reading Comparisons

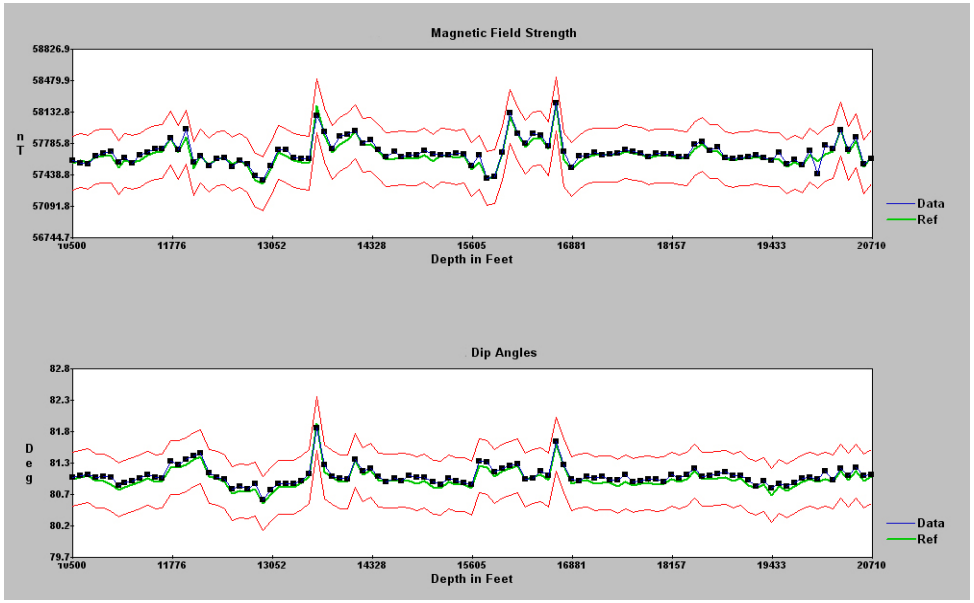
- Raw MWD measurements of field strength and dip are compared to main field model (green line)
- Erratic nature of points and crossed FAC lines could indicate:
  - MWD tool failure
  - Interference from nearby wellbores
  - Magnetic minerals in mud, magnetic sediments, etc.



Based on comparison with model, drilling ahead would be prohibited.

DED versus MWD Reading Comparisons

- MDW measurements are compared to DED observatory data
- Close match in data indicates MWD tool is accurate
- DED data is shown to be more accurate than main field model predictions



Based on comparison, drilling ahead would be permitted

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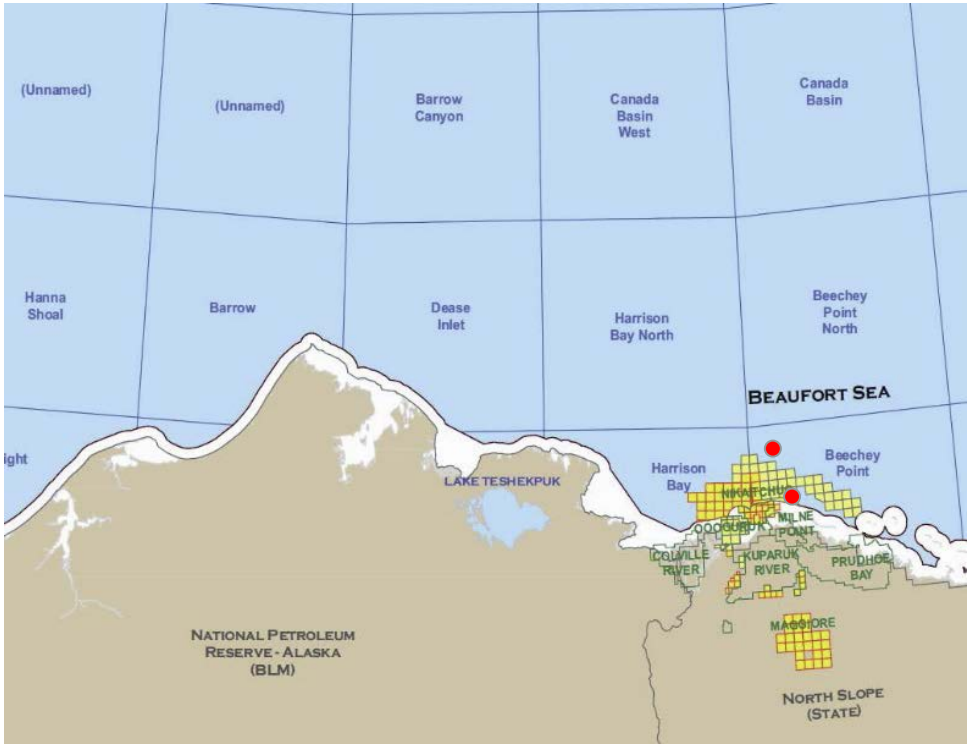
Case History–Nikaitchuq Field Exploitation

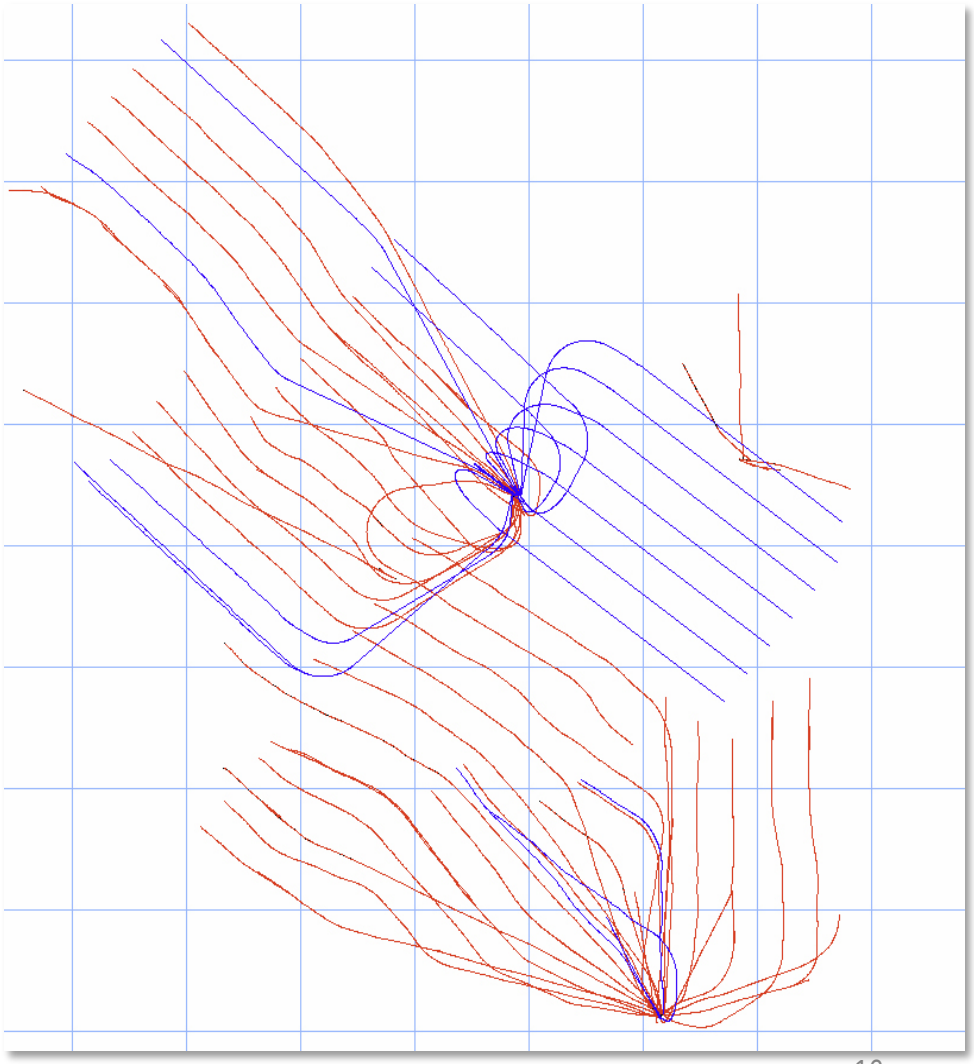
- Development in two primary surface locations:
  - Coastal Oliktok Point
  - Spy Island offshore
- Drilling program based on alternating producer/ injector wells
- Approx. 1,200 ft between each producer and injector to optimize production



Faulting taken into consideration during well planning.

Case History–Nikaitchuq Field Exploitation

- Well lengths and density make minimizing collision risk a challenge
- Incorporating DED observatory data and the North Slope geomagnetic reference model has enabled meeting well placement and anticollision objectives.



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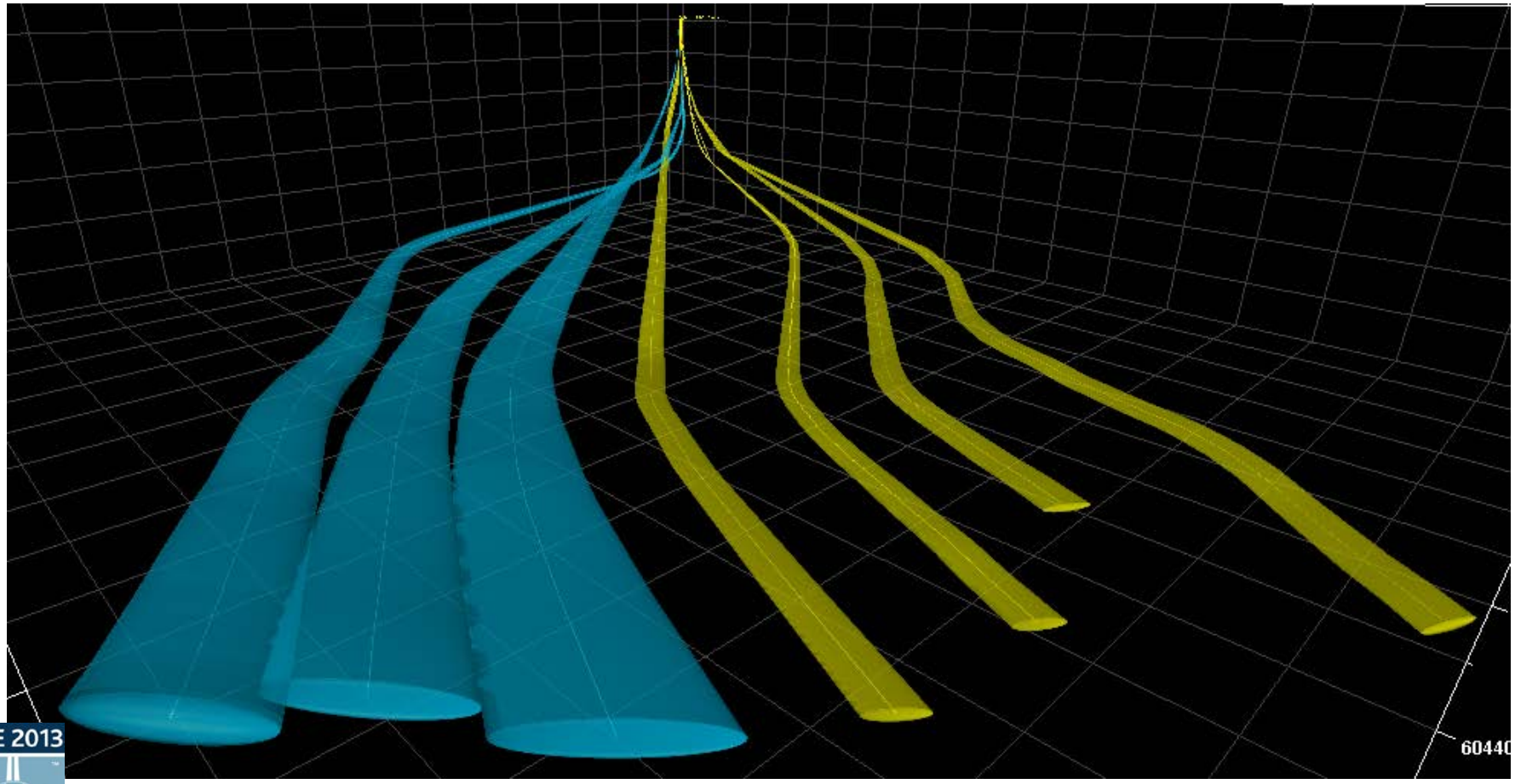
Case History–Nikaitchuq Field Exploitation



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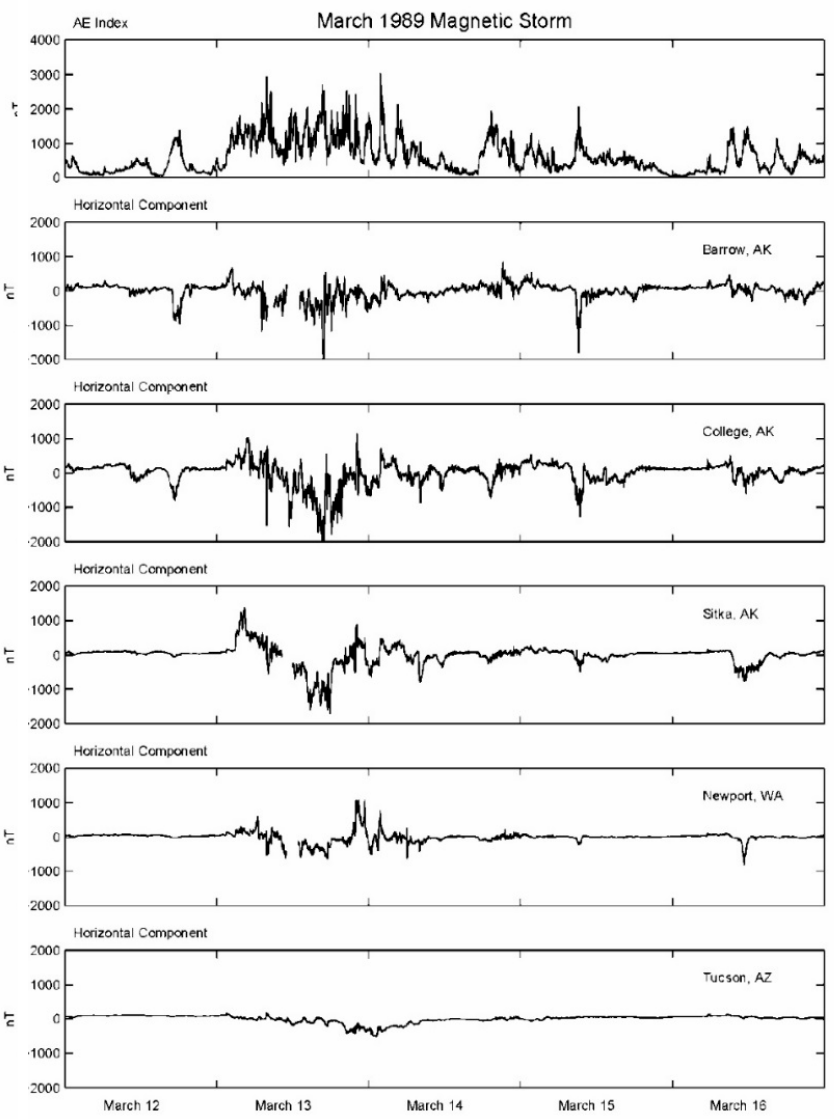
Beyond MWD: Applications for Space Weather

- Observatory data can also play a role in diagnosis of space weather conditions
- Large magnetic storms can cause loss of communication, affect GPS accuracy, damage satellite electronics, etc
- One-second observatory data can help compute auroral electrojet index



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Summary and Conclusions

- Challenges to MWD in Arctic:
  - Escalating level of solar activity
  - Unmodeled crustal anomalies
  - Complex reservoirs requiring great surveying precision
  - Increased impact of drillstring magnetic interference

- Advanced geomagnetic referencing can meet the challenge:
  - Precise real-time wellbore positioning with MWD
  - Nikaitchuq experience as blueprint for success in other challenging environments

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