USGS
science for a changing world

Geomagnetic Observatories, Variometers, and Repeat Stations: Reporter Review

E. W. Worthington

June 28, 2015

U.S. Department of the Interior
U.S. Geological Survey

A39 Session Summary

- 20 Presentations, 1 withdrawn
- 19 Posters

- Observatories and Operations
- E-field monitoring and conductivity studies
- Data processing

USGS

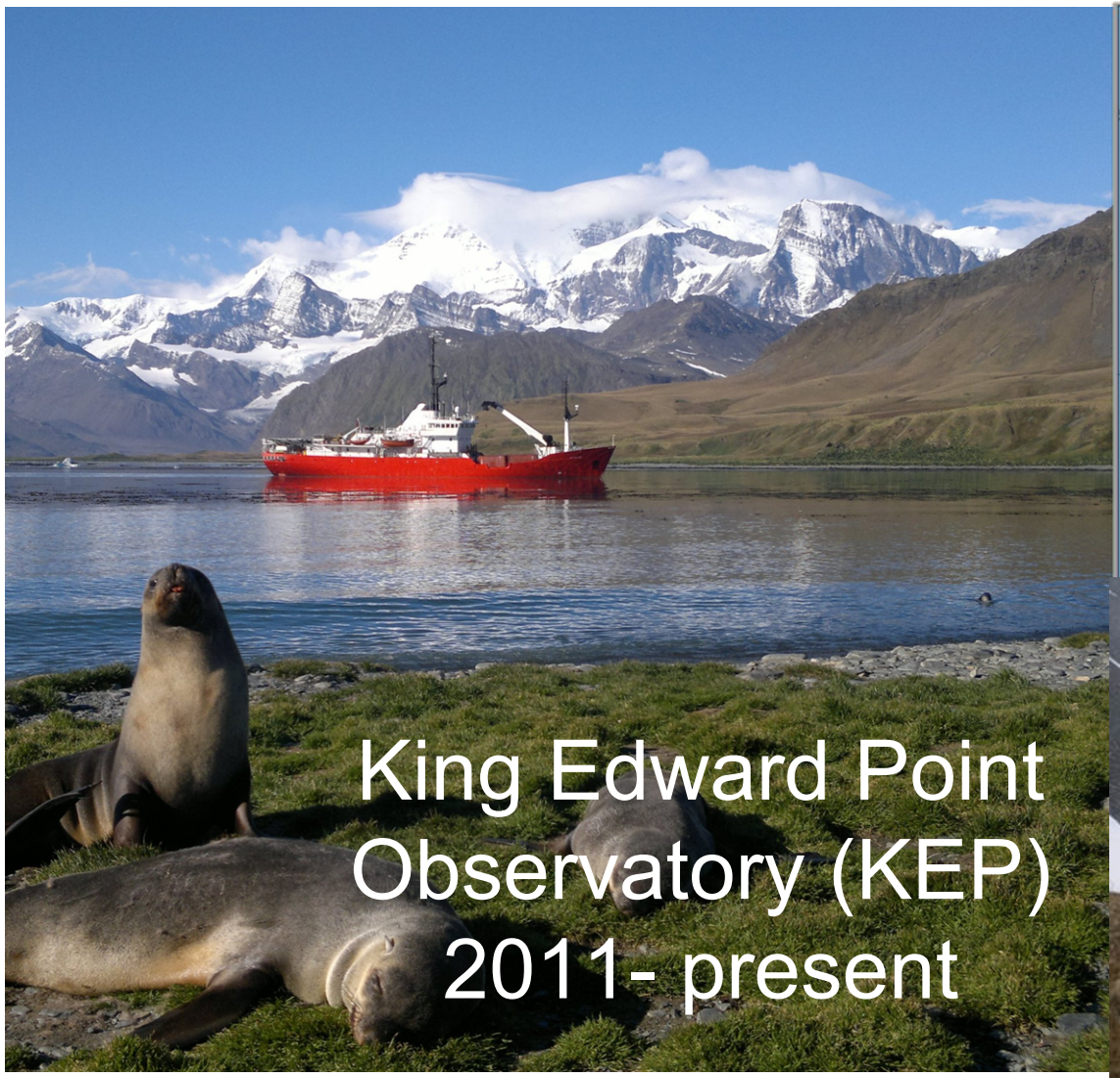
Observatories and Operations

- Observatories
  - 2 – BGS
  - 4 – Russian
  - 1 – Indian
  - 1 - Czech
- Observatory Practices

USGS

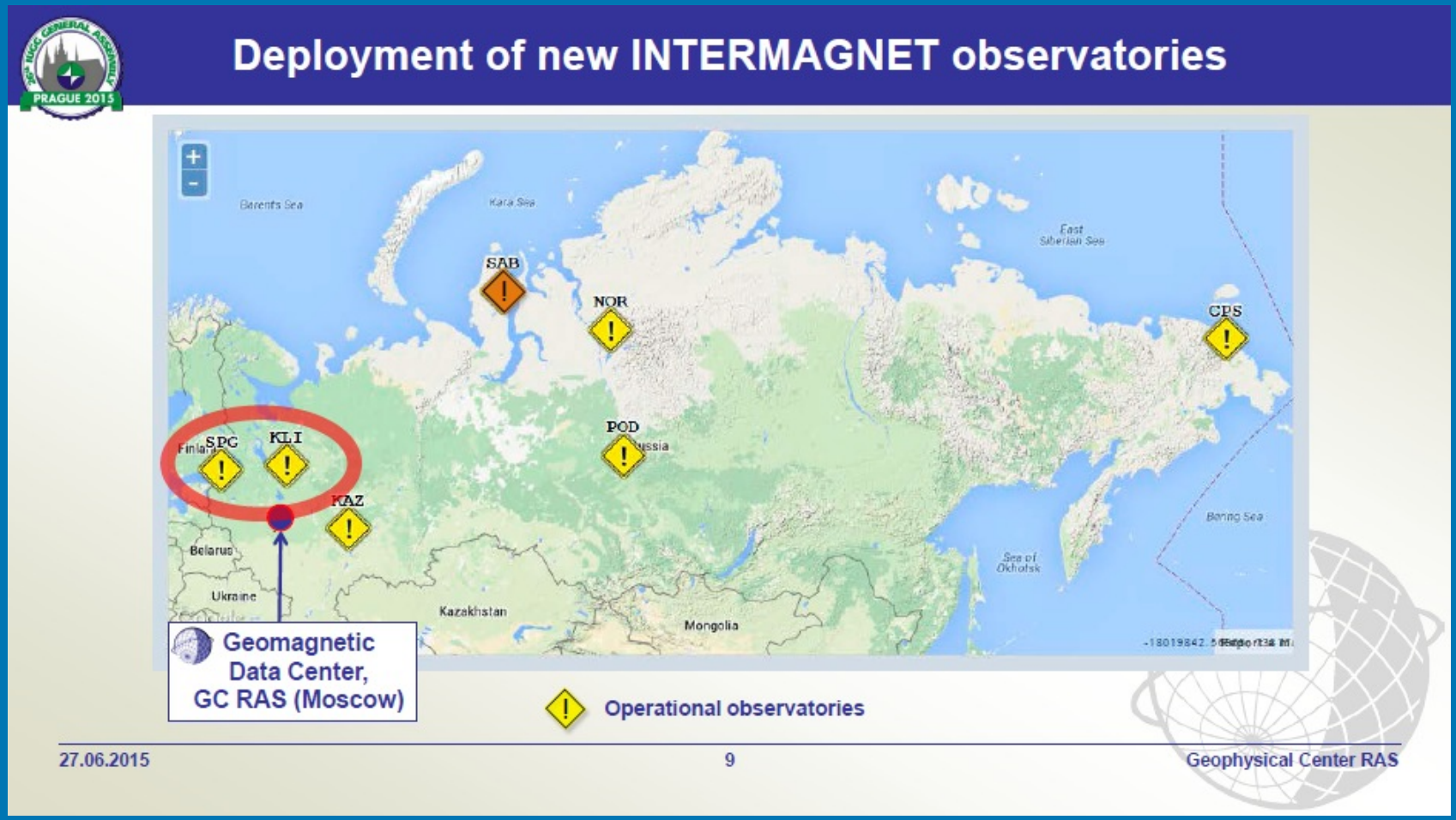
Sable Island Observatory (SBL) 1999 – present

Geographic: 43º55’55’6”N 299º59’25’8”E
Geomagnetic: 53º18’36”N 015º19’41”E
5m above MSL.



King Edward Point Observatory (KEP) 2011- present

Russian Observatories



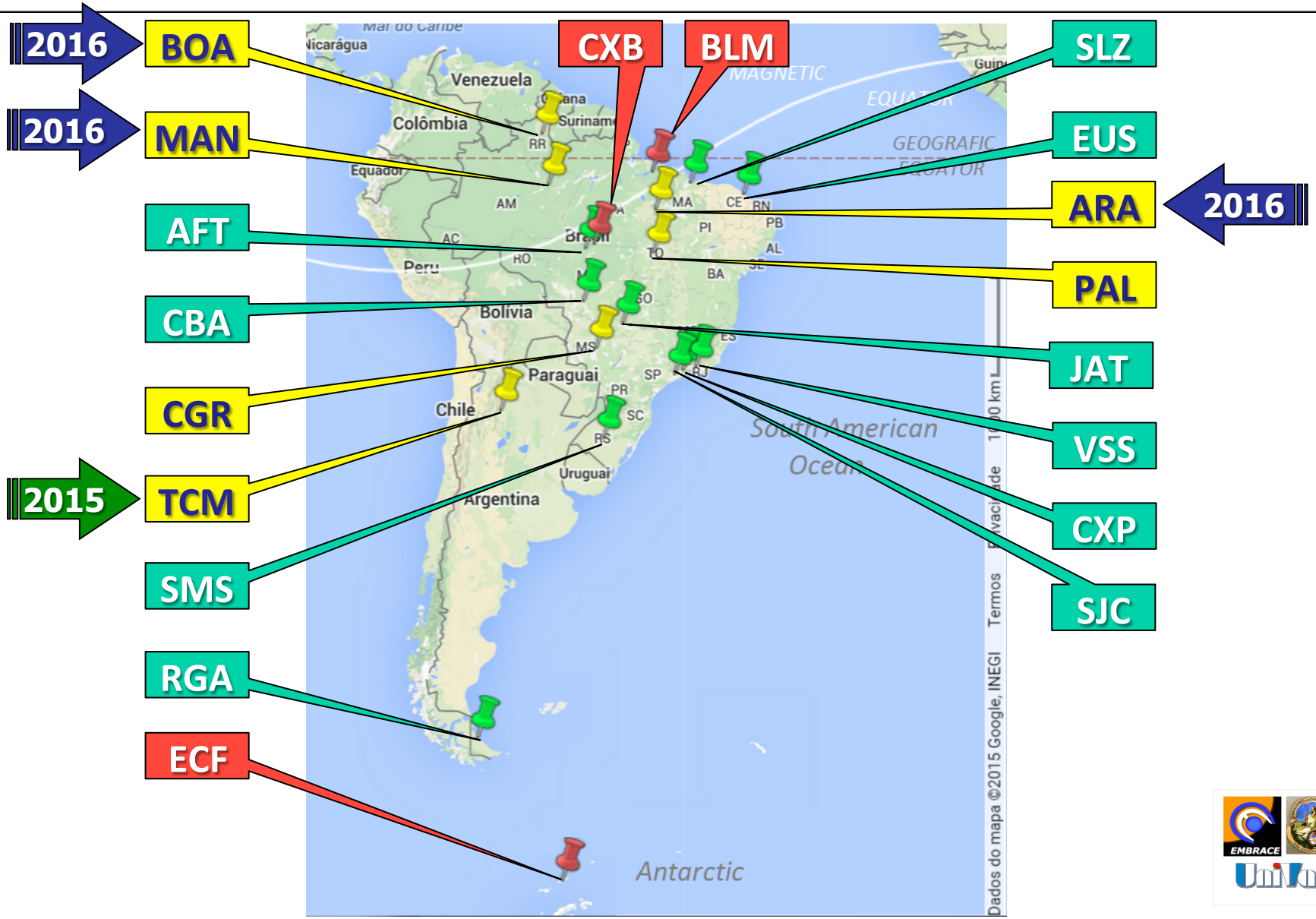
USGS

South American EMBRACE Network

- Measure variations with Induction Coils
- Data sent to HQ in real-time
- Equatorial Electrojet is present
- Are trying to remove QDC for SW purposes
- Computing K_{SA}, K style index for South America
- Estimate a Dst proxy

USGS

The Embrace Network



Setup of observatories

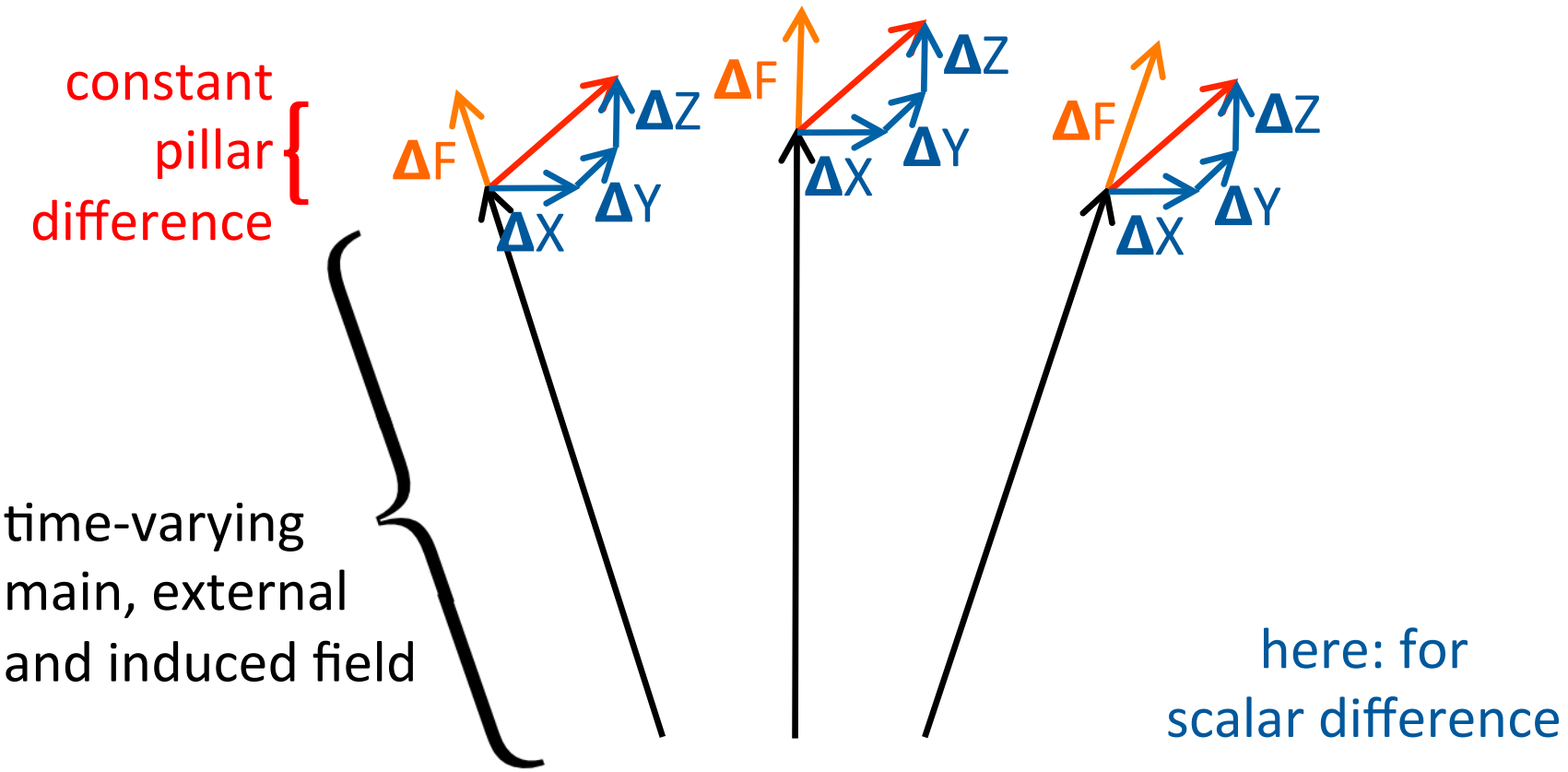
fluxgate theodolite (DI-flux)

pillar differences
ΔX, ΔY, ΔZ,
ΔD, ΔI, ΔH,
ΔF

absolute scalar (PPM)

variometer (here: FGE)

Adding pillar differences



A new Method for D/I measurements!

Proceeding is as follows :

- **Set vertical circle to 90° and do the E_{up} and W_{up} measurements like the usual first two D measurments (check leveling).**
- **Repeat that with vertical circle set to 70° and 110° .**
- **Set vertical circle to 270° and do the $E_{down}$and W_{down} measurements.**
- **Repeat that with vertical circle set to 250° and 290° .**

Advantages of the new Method:

- **No meridian need to be calculated**
- **Adjustment to zero always with the same wheel (horizontal).**
- **The slope of reading is small. Adjustment is easy.**
- **Only one single “flip over”.**
- **12 measurements instead of 8 measurements. Improvement of accuracy due to statistics. Outliers can be identified.**
- **Allows to avoid very steep telescope position.**

Automatic Baseline Controlling dIdD (ABCD) magnetometer basics

- Based on a dIdD magnetometer
- Suspended instrument
- Coils can be rotated around the sensor
- Recording instrument with autocalibration capability
- Calibration on regular intervals by program or on remote command

Known problems at the present stage

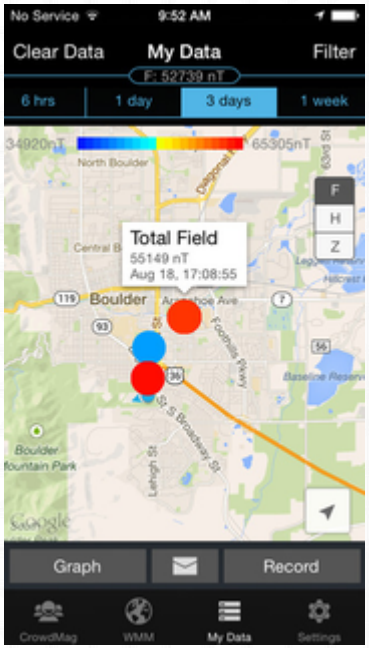
- Optical system moves relative to ABCD magnetometer
- Long initial drift
- Angle encoder has thermal sensitivity
- In case of external reference mark optical system works only during the night

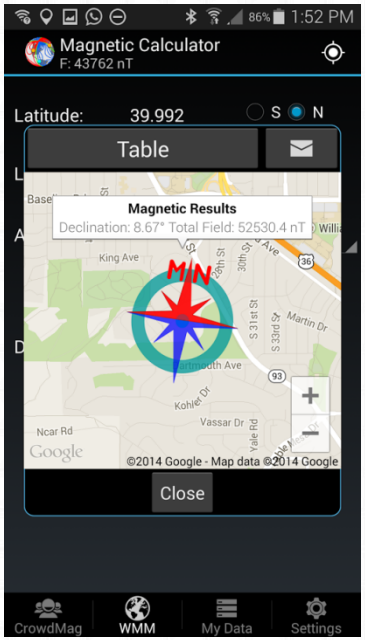
CrowdMag (M. Nair)

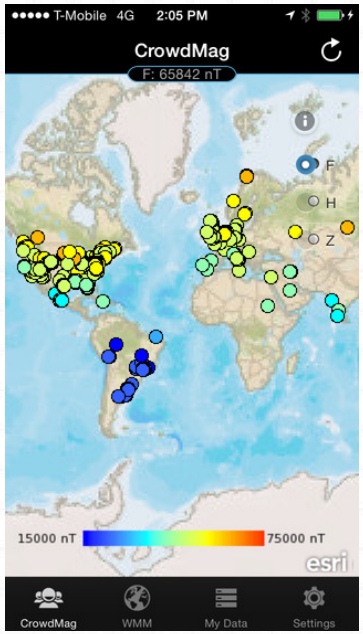
- Uses magnetometer in a smart phone
- Has low sensitivity and subject to noise
- Downloadable App
- Potential for 1 billion data sources

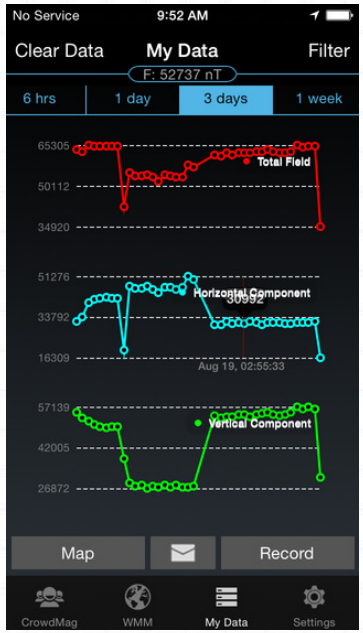
USGS

CrowdMag Apps









CrowdMag apps are now available at Google play store and Apple iTunes. In addition to measuring magnetic data, these phones also comes with a World Magnetic Model (WMM2015) calculator.

E-Field and Conductivity Studies

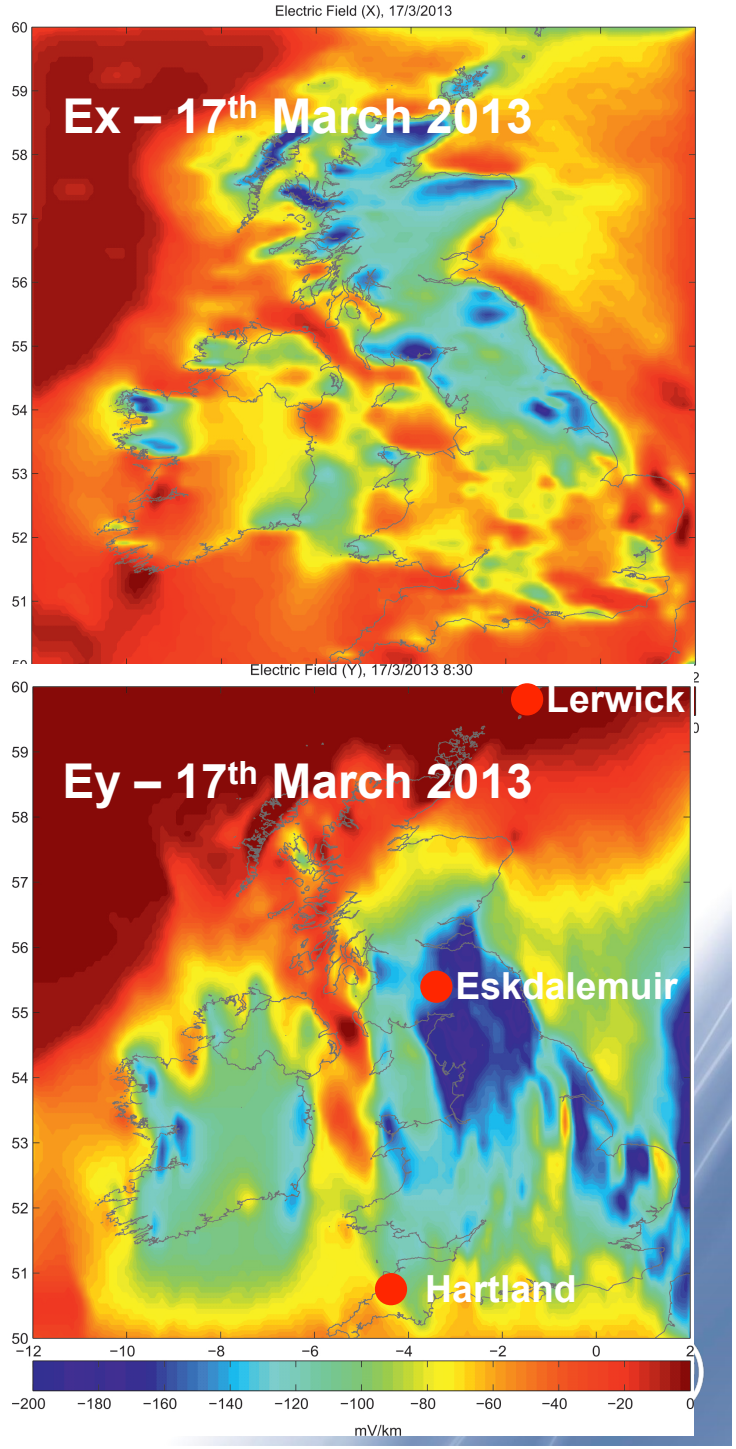
- Thomson et al., BGS operations
- Finn et al., USGS operations
- Both papers had the ultimate goal of validating conductivity models for GIC's

- Kusvhinov et al., Conductivity study near Hawaii, using offshore Total Field measurents and on shore vector measurements

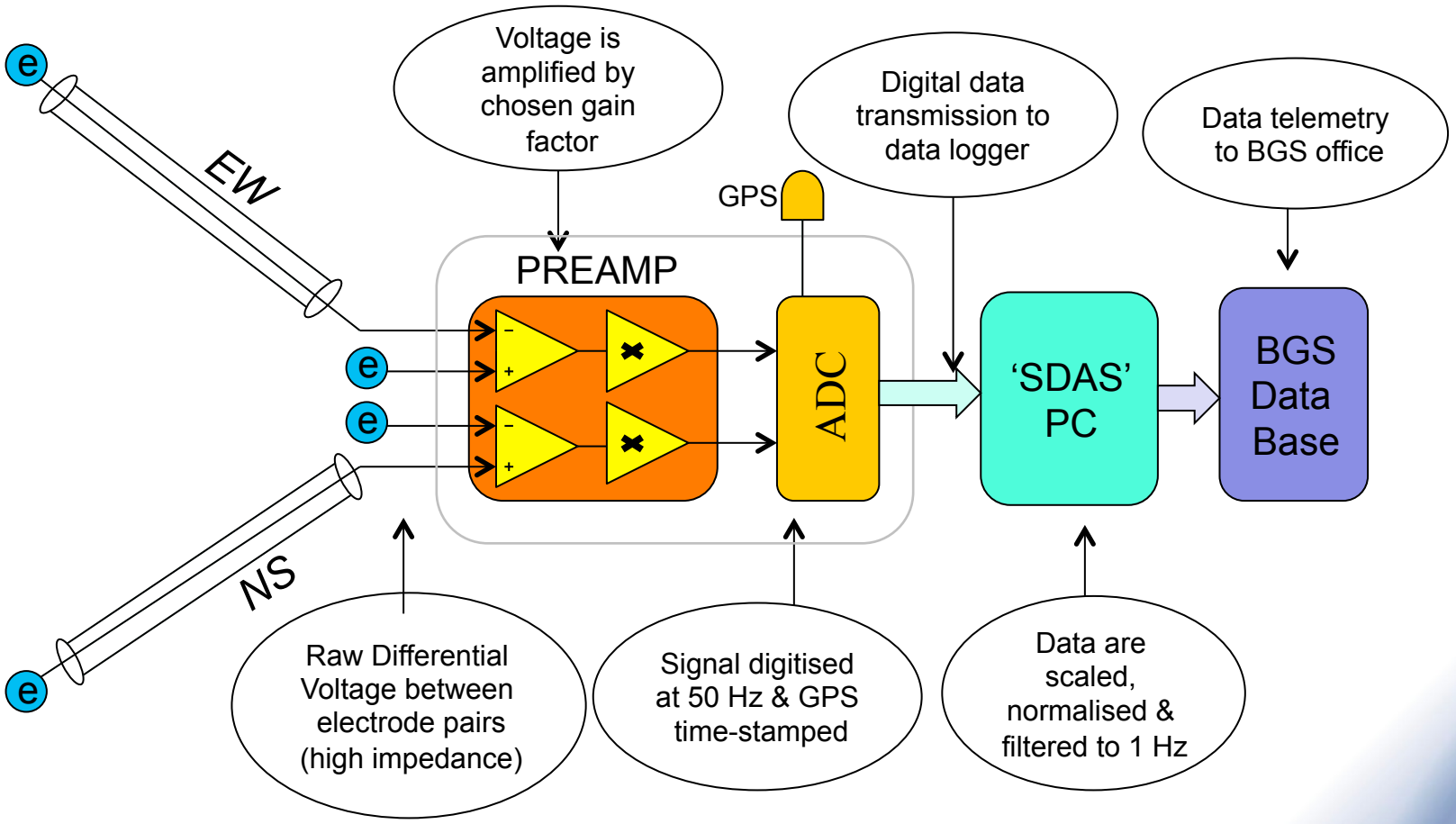
USGS

A Rationale for Long Term Geo-Electric Field Monitoring

- Validating models of surface electric fields that cause geomagnetically induced currents in power grids
- Providing additional monitoring of space weather impact at ground level
  - E.g. Supporting WMO aims
- Long term monitoring to study space weather and space climate variability
  - How does E-field variability relate to solar wind driving and the magnetospheric response?
- Long term monitoring to study Earth structure
  - Classic magnetotellurics



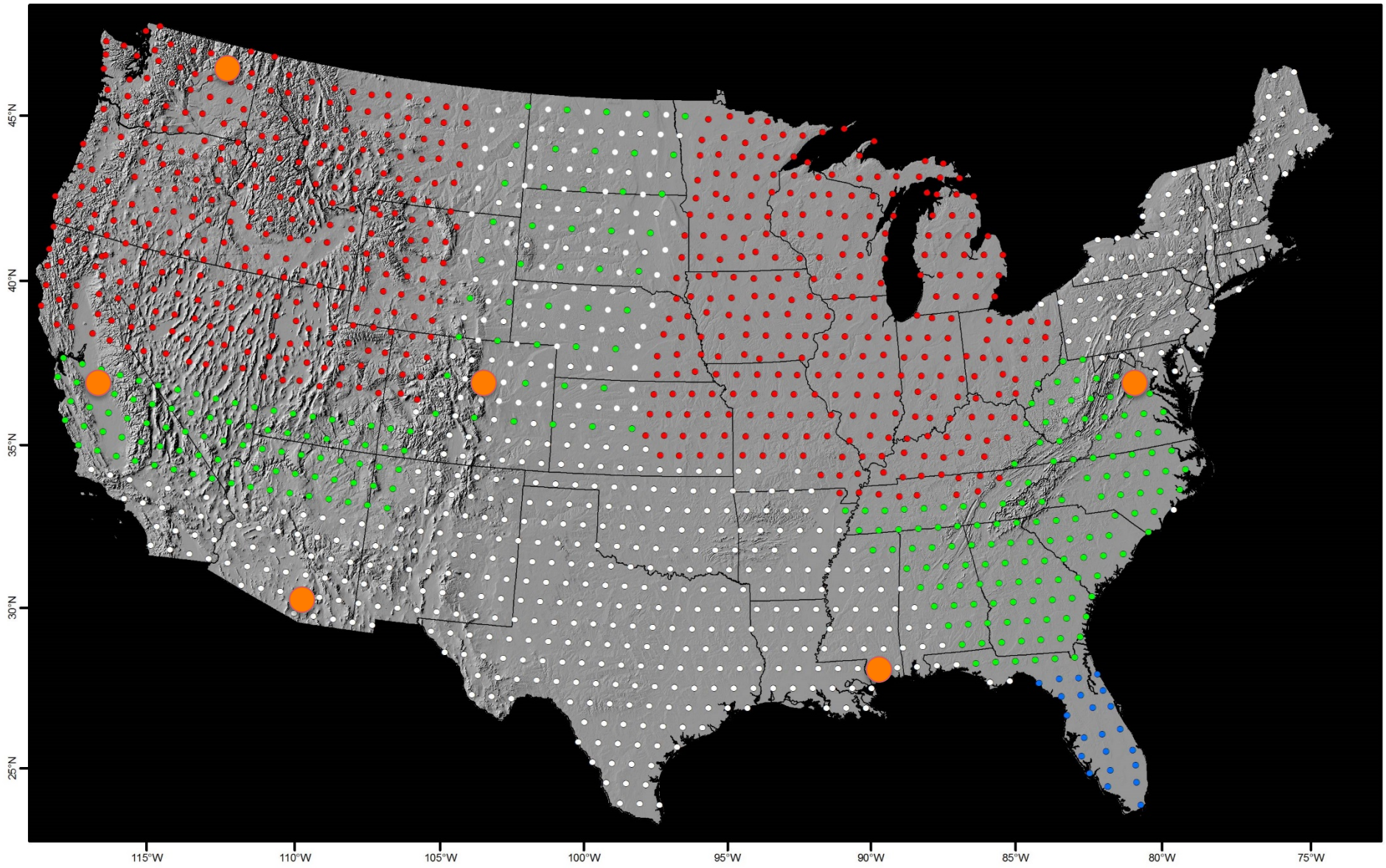
Geo-Electric Observatory



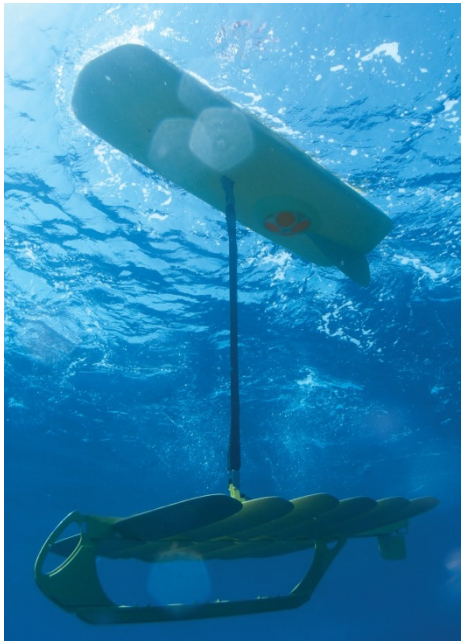
Conclusions

- Monitoring has been more or less continuous since 2012
  - Lerwick has probably been most problematic
- It's been a learning curve
  - Hardware and filtering perhaps need (fine?) tuned, e.g.
    - Electrode degradation over time – how often to be replaced?
    - Relatively short lines (~100m) – limited scope for increase
    - High frequency noise, jumps and spikes
    - Rainfall and probably temperature variations too
- Comparisons with modelled E-field
  - Clear local differences w.r.t measured E-field (the 'classic MT problem')
    - Regional field (e.g. length of power line scale) not yet determined
  - Signal to noise issue: only seen a few storms to analyse
  - Not fully dealt with un-modelled periodic sources: tides and *Sq*
  - But some agreement with regional scale models gives support to modelling methodology

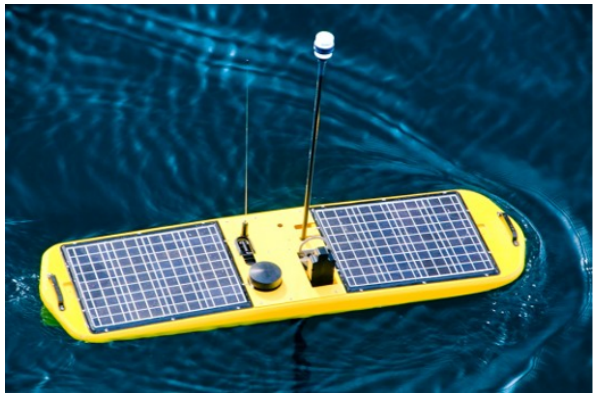
EarthScope and USGS MT + USGS observatories

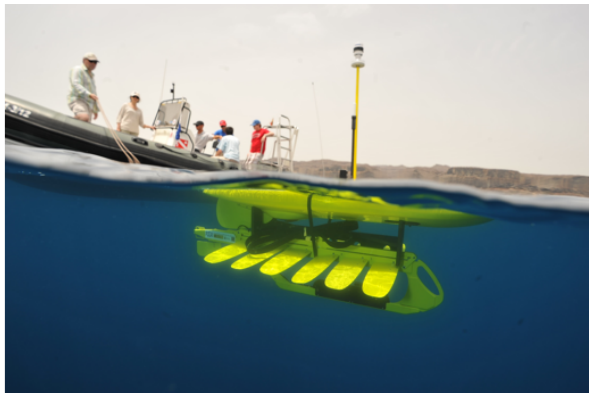


Observation platform: Wave Glider (Liquid Robotics/Schlumberger)



- Autonomous
- Wave and sun powered
- Can be fixed at one location for days (weeks)
- Linked to Iridium satellites (thus allowing for data control and data retrieve in near real time)
- Can be remotely manipulated





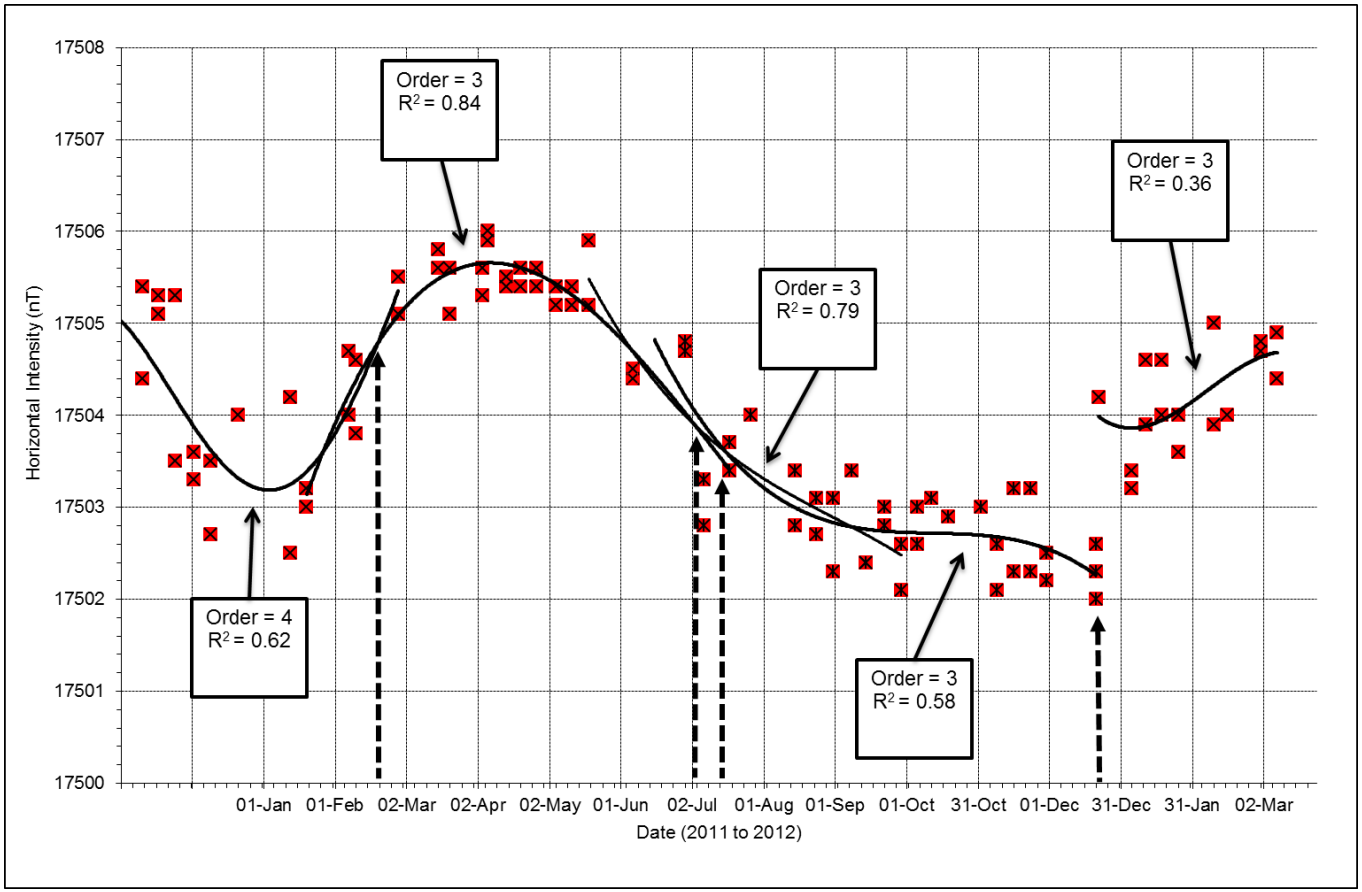
Data Processing

USGS

Data Processing Operations

- Operational QC task shared between 4 staff on weekly rotation
- Point of contact for engineers and observatory staff
- Data quality checked and corrected in real-time or next-day basis (Monday-Friday)
- Real-time data processing systems checked for faults and managed during routine downtime

Baseline fitting – piecewise polynomials



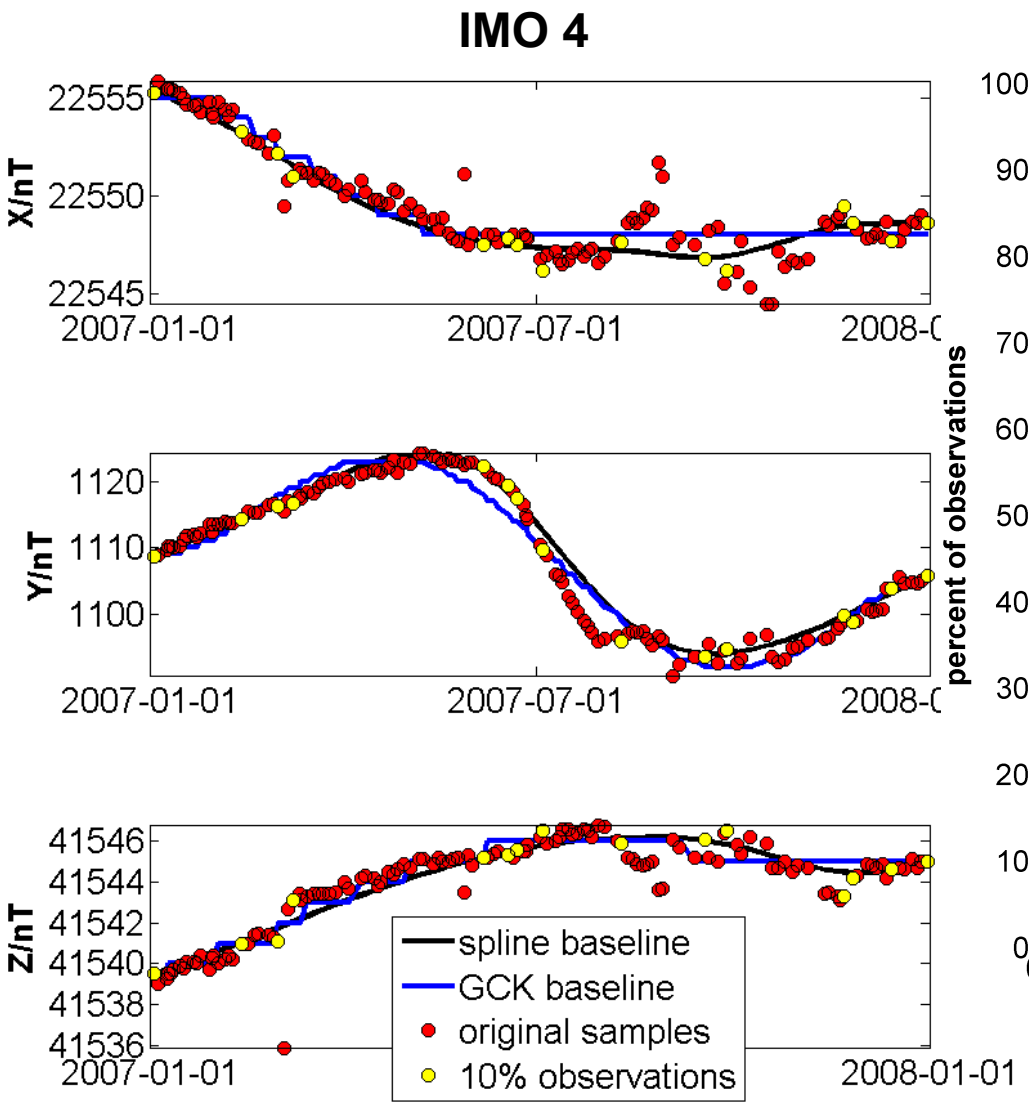
Clarke, E., Baillie, O., Reay, S J., Turbitt, C W. (2013) A method for the near real-time production of quasi-definitive magnetic observatory data *Earth, Planets and Space*, 65 (11). 1363-1374. 10.5047/eps.2013.10.001

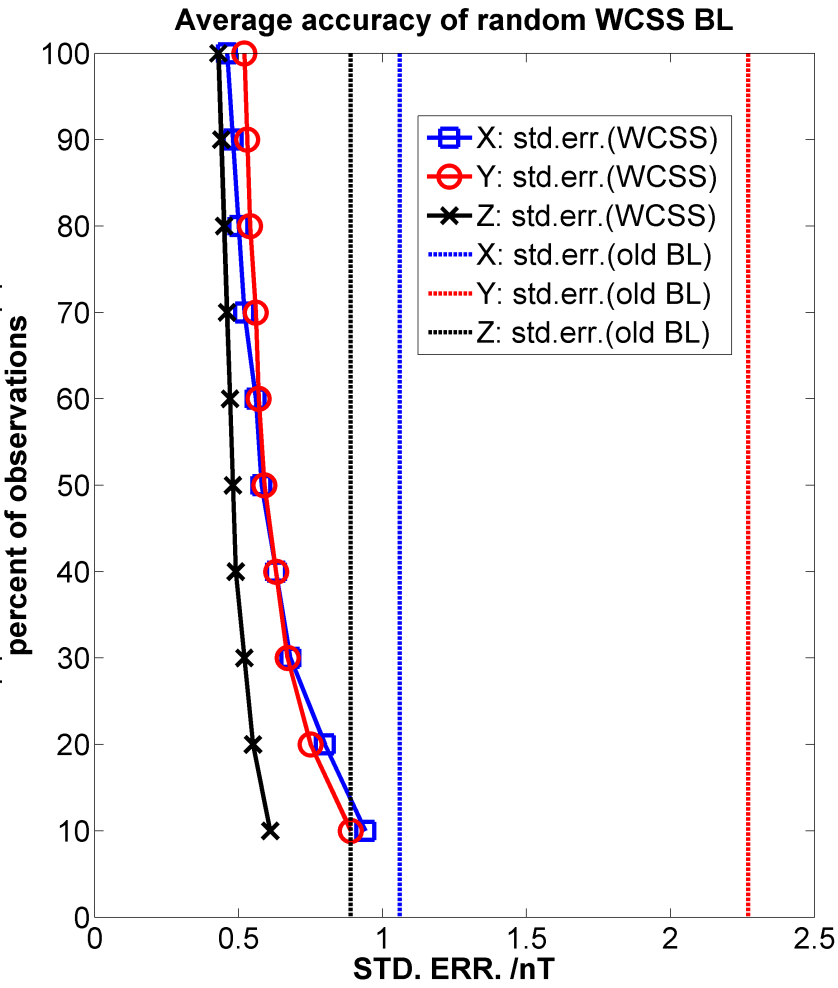
Mandic, I

- Improved baseline fitting
- Employed Cubic Spline Interpolation
- Fitting is guided by the baseline values

USGS

“Efficiency” of WCSS





Improving Absolute Measurement Errors

- Quality training and frequent retraining
- Eliminate poor observers
- Consider using residual method

- Improve total field mag (F)
- Keep DI-Flux in good calibration
- Automate computations

USGS

Data filtering

- Vik, used Teager Operator for real-time spike removal. Mainly lightning.
- Getmanov, Filtering to remove industrial noise. Linear piecewise approximation and cubic spline models were shown

USGS