Recent developments in geomagnetic referencing services

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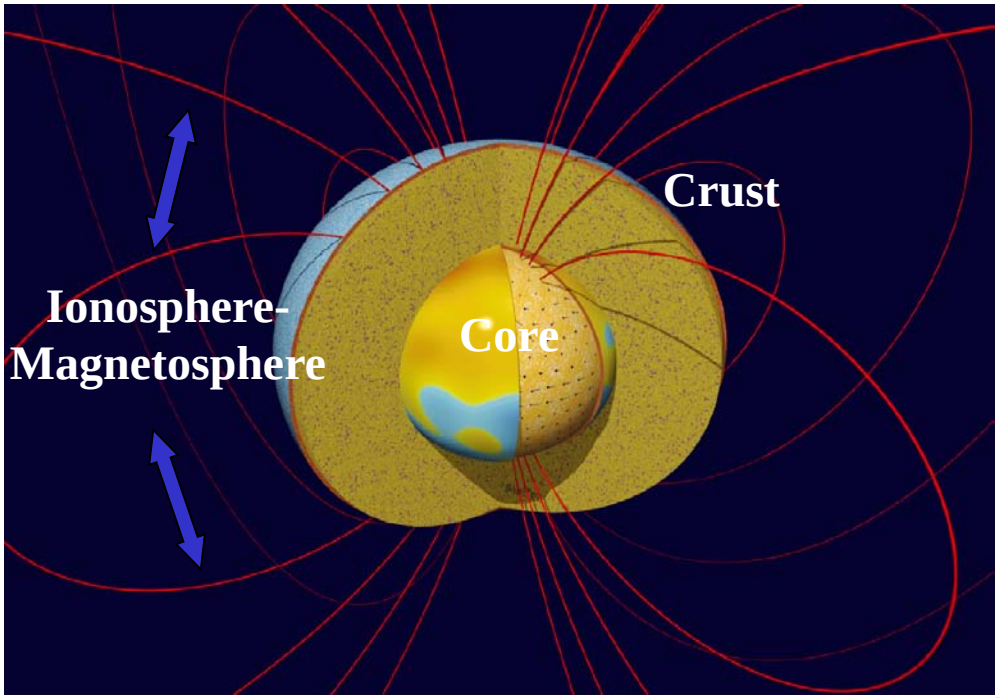
To cover…

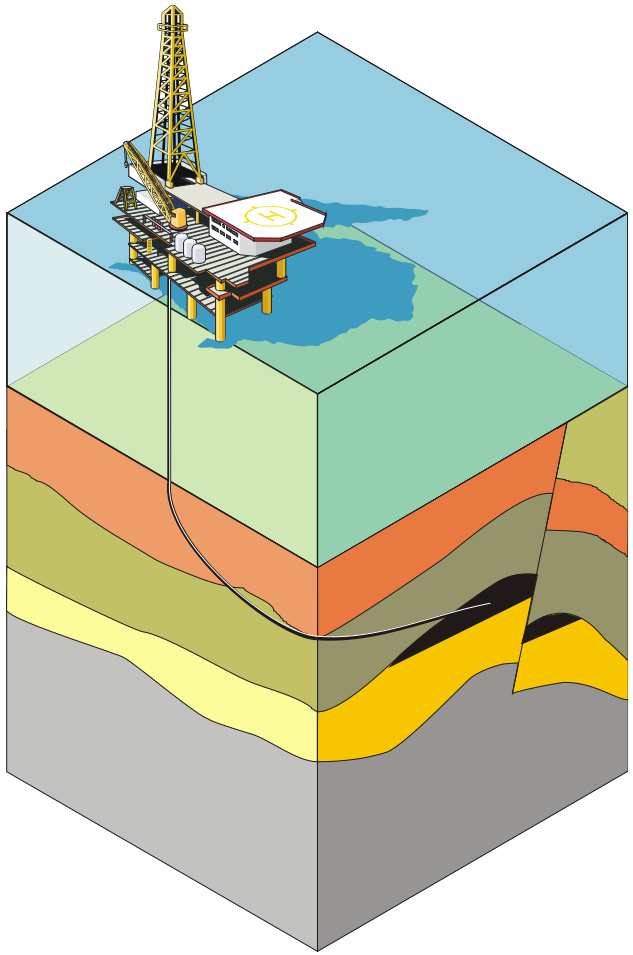
- Overview of services
- New global datasets
- BGGM
  - BGGM2012 update
  - are the confidence limits changing?
- Where are we on current activity cycle?
- Visit to Eskdalemuir observatory tomorrow

The Earth's magnetic field

- Most of the field is from the Earth's core
  - varies slowly with time (months to years)
- Local fields from magnetized rocks in Earth's crust
  - relatively stable with time
- Fields due to currents in the ionosphere and magnetosphere
  - variations from seconds to years



Geomagnetic referencing services



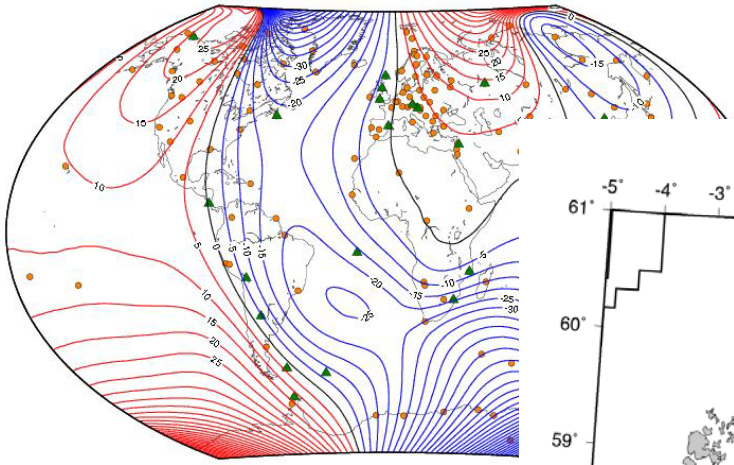
- BGGM – global main field model
  - includes quiet night time external field and long wavelength crustal field
- IFR - combines main field with estimates of local crustal field
  - higher spatial resolution of crustal field at drilling site
- IIFR - combines IFR with estimates of field from external sources
  - higher time resolution
  - supplied in real-time

Reducing uncertainties

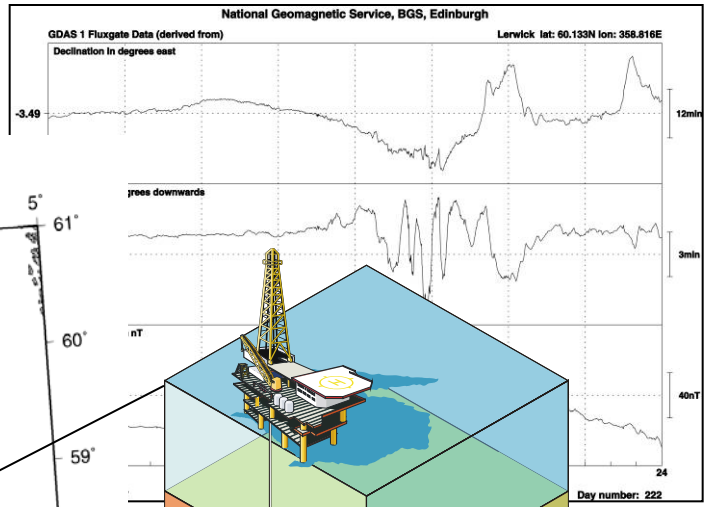
Reconstructing the magnetic field vector at the drill site

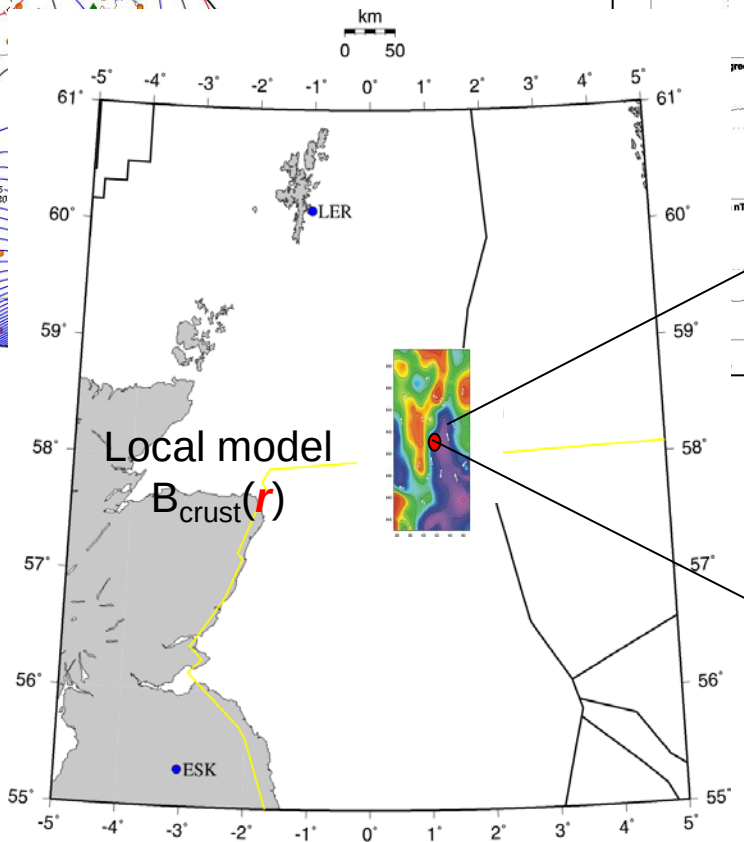
$$B = B_{main}(\boldsymbol{r}, t) + B_{external}(\boldsymbol{r}, t) + B_{crust}(\boldsymbol{r})$$

Global model - $B_{main}(\boldsymbol{r}, t)$



Observatories – $B_{external}(\boldsymbol{r}, t)$

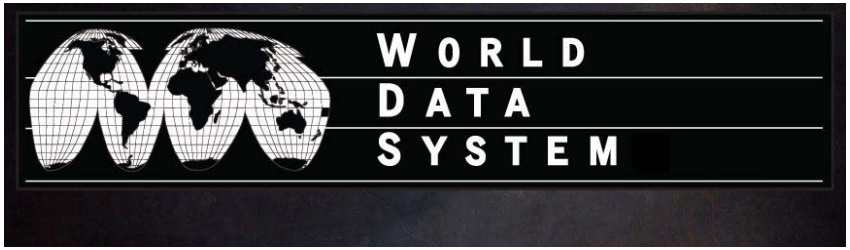




Global data gathering efforts - ground

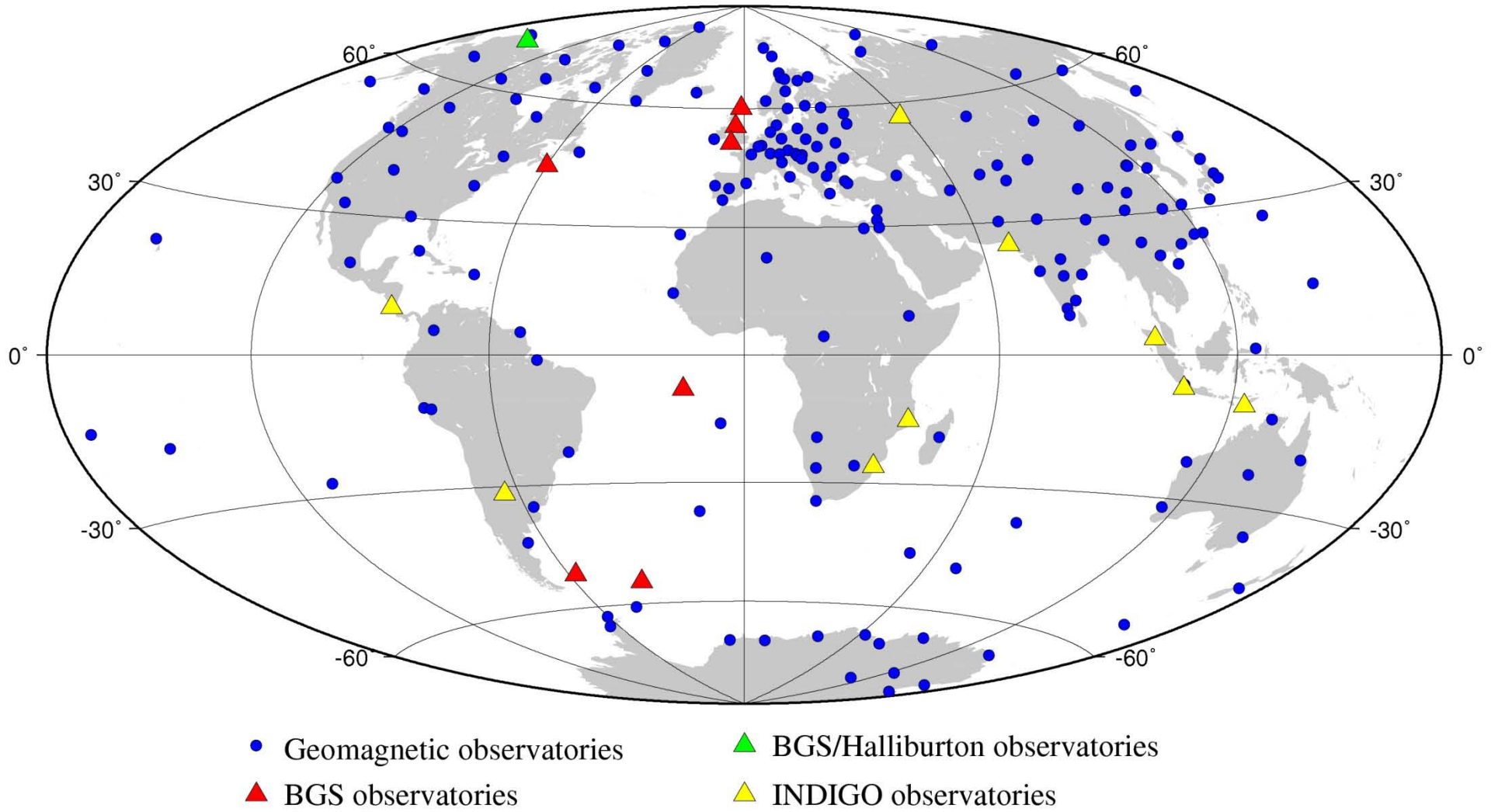
- BGS part of the new ICSU Interdisciplinary Body, the World Data System
- BGS has lead role in INTERMAGNET
- Currently there are ~160 observatories, in 2011 more than 100 are members of INTERMAGNET

ICSU
International Council for Science



INTERMAGNET

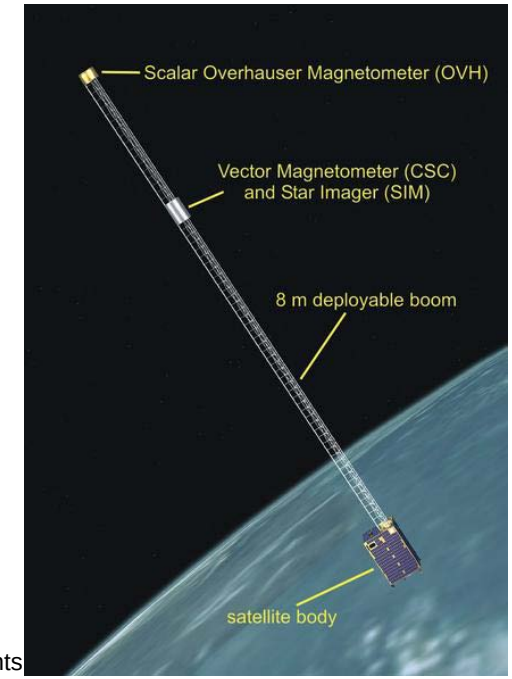
BGS investing in observatories around the world



Global data gathering - satellites

Ørsted

- Launched 1999
- Danish-led mission
- BGS is an Ørsted international science team
- Altitude 640-850 km, all local times sampled in 2.2 years
- **Scalar data still being returned**



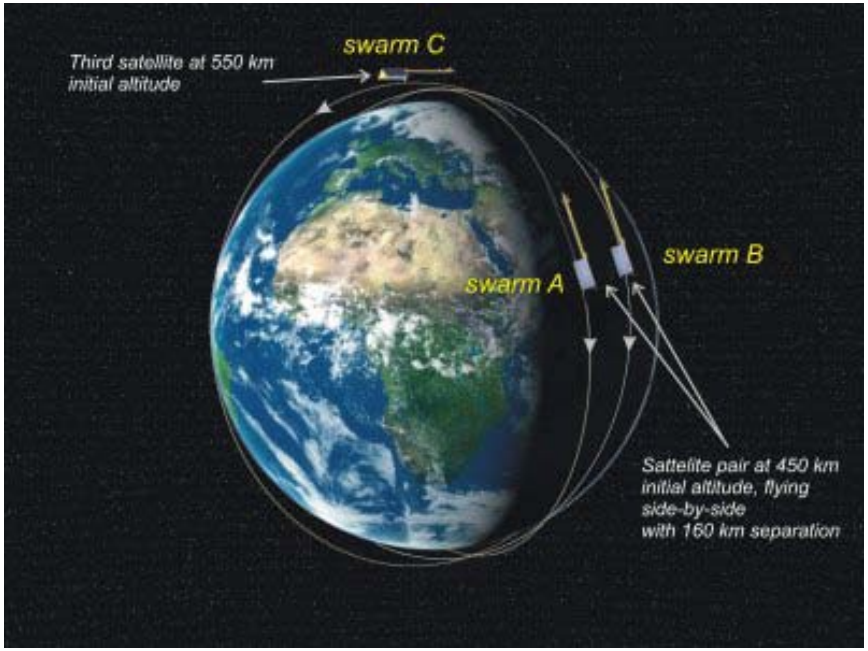
CHAMP

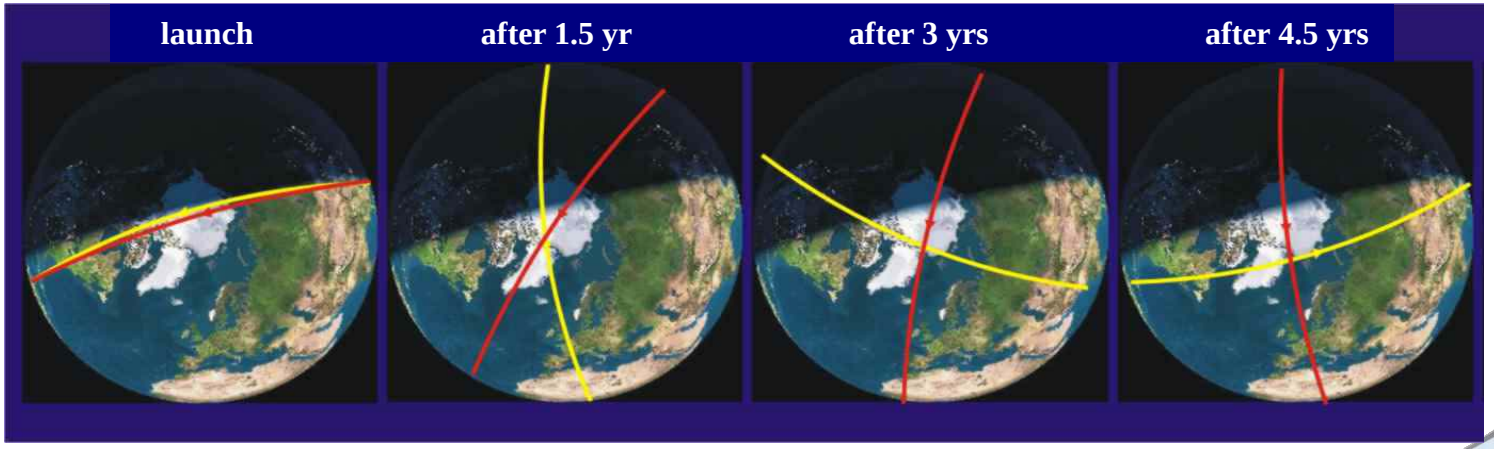
- Launched 2000
- German-led mission
- BGS is a CHAMP international science team
- Altitude 330-450 km, all local times sampled in 4-5 months
- **Satellite re-entered atmosphere and burnt up 19 Sep 2010**

Global data gathering - satellites

Swarm

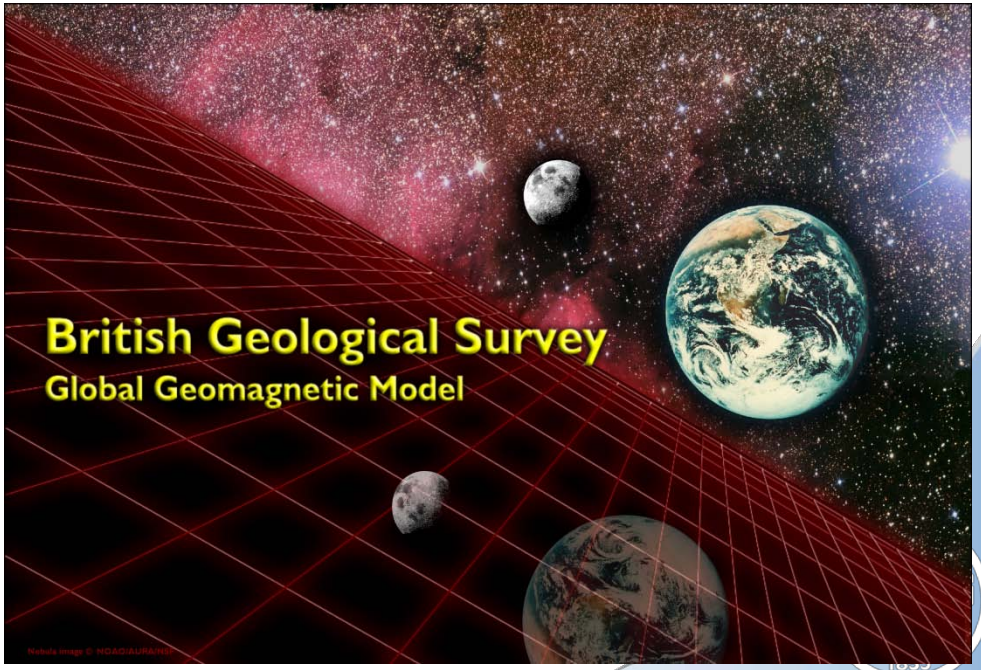
- ESA Earth Explorer Opportunity Mission
- For study of the dynamics of the Earth's magnetic field and its interactions with the Earth system
- Launch due October 2012
- Mission life 4+ years
- BGS one of 6-institute consortium developing the Level 2 Processing Facility





BGS Global Geomagnetic Model

- For directional drilling
- Produced every year since 1991
- A high temporal and spatial resolution model
- Accuracy quantified

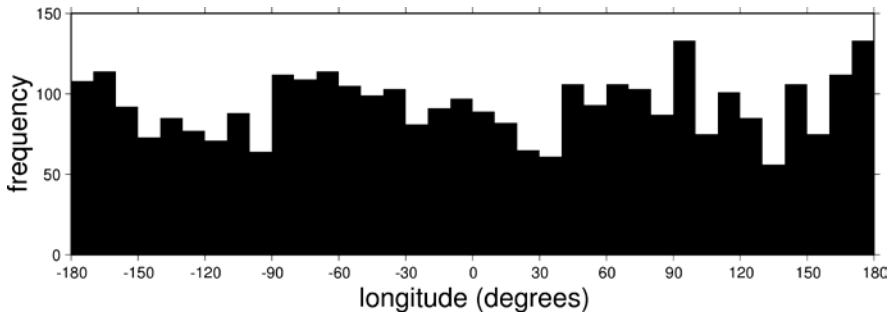


New for BGGM2012

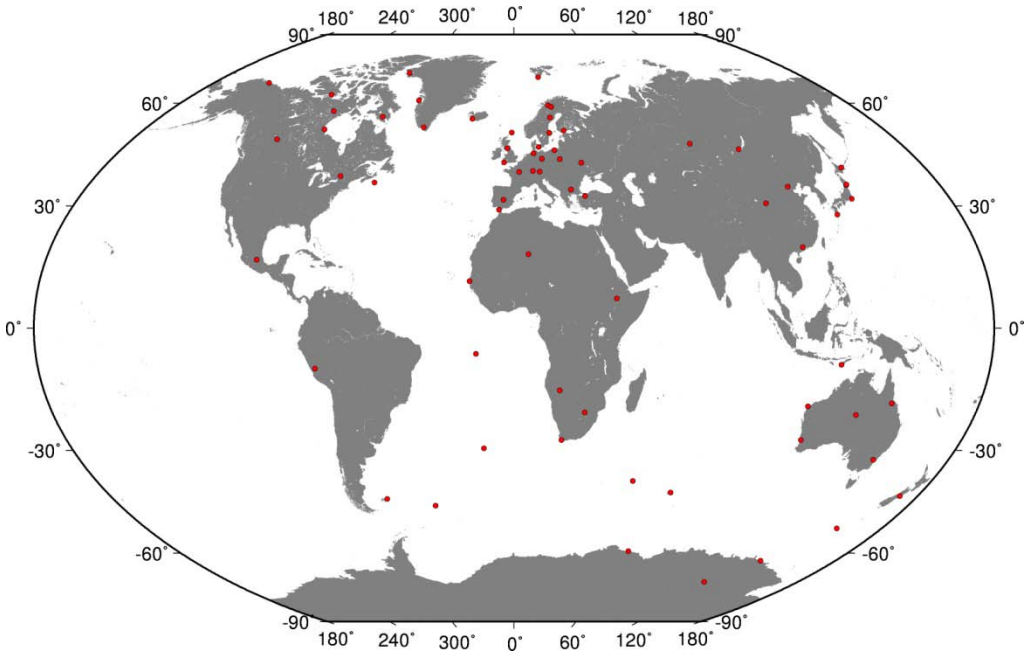
- New data: Ørsted scalar and observatory vector data, particularly in 2011

- Comparing predictive field from polynomial extrapolation and physics-based core flows

2011 Ørsted data

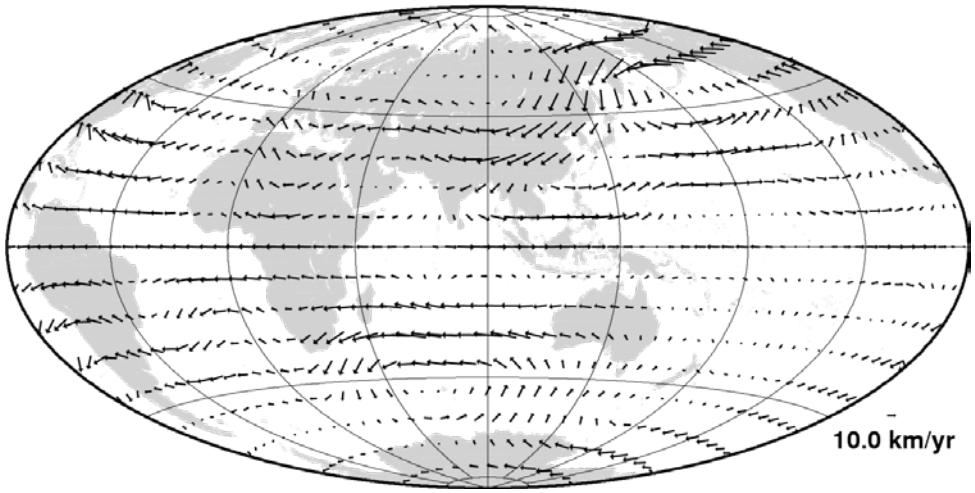


2011 observatory data



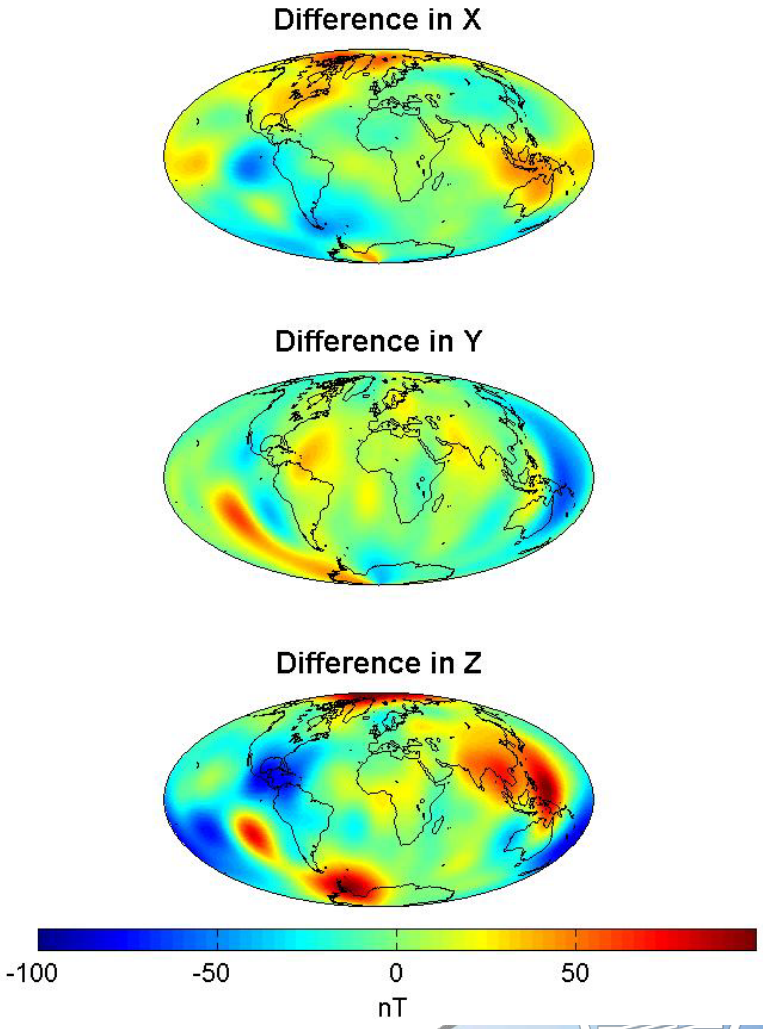
Core flows for predicting the magnetic field BGGM 2011 retrospective analysis

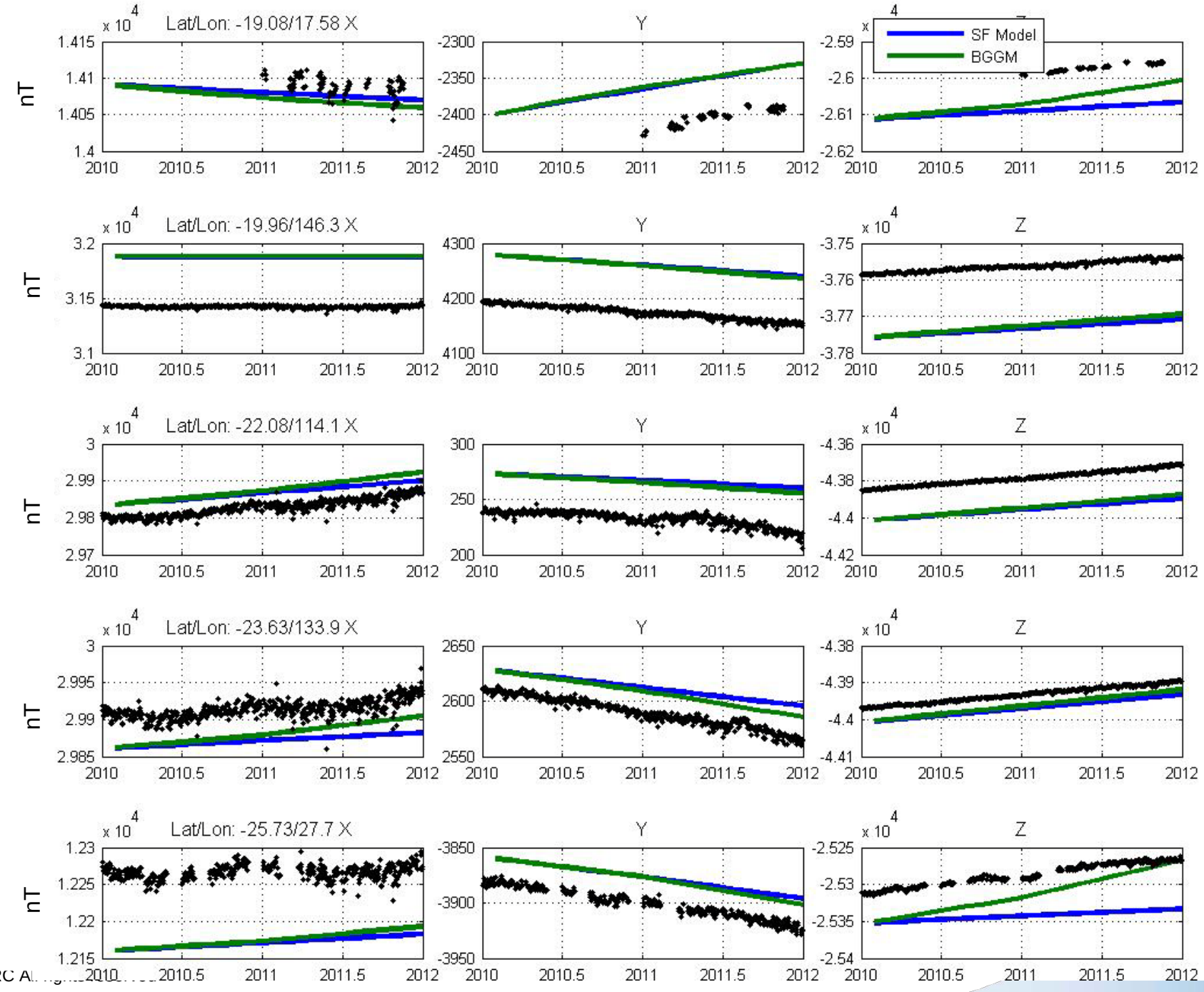
- Create a steady core flow model to degree 13:
  - use BGGM2011 field estimates from 2006 to 2010
  - frozen flux assumption; geostrophic constraint
  - predict the magnetic field beyond 2010 and compare with independent data



Retrospective analysis 2010-12

- Begin at 2010.0
  - Advect magnetic field forward in time on a monthly timestep for 2 years
- After two years the field predicted by BGGM and Steady Flow (SF) diverge
- Compare BGGM prediction and SF prediction to observatory data NOT used in modelling process



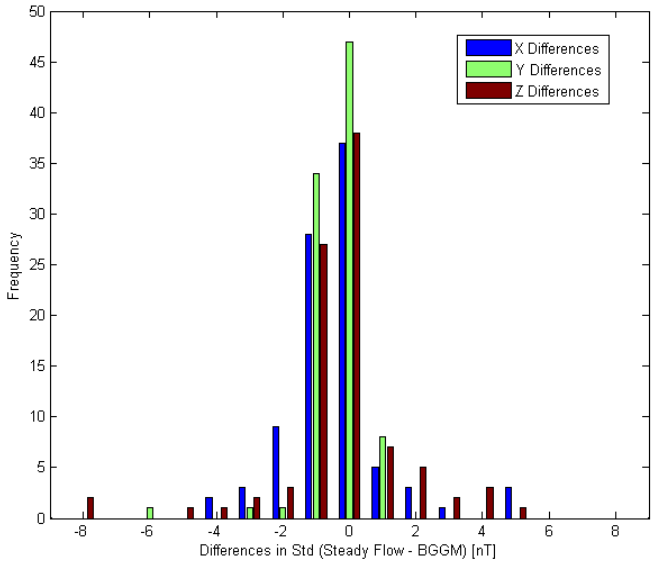


Global statistics

- Conclusion:
  - prediction of SF almost as good (on average) as the current method over two years
- Caveats:
  - BGGM prediction has acceleration, SF does not yet
- Next step:
  - include acceleration into flow models

Statistic	SF	BGGM
X Std	11.80	11.74
X MAD	8.58	8.54
Y Std	6.50	6.41
Y MAD	4.41	4.33
Z Std	8.80	8.50
Z MAD	6.53	6.25

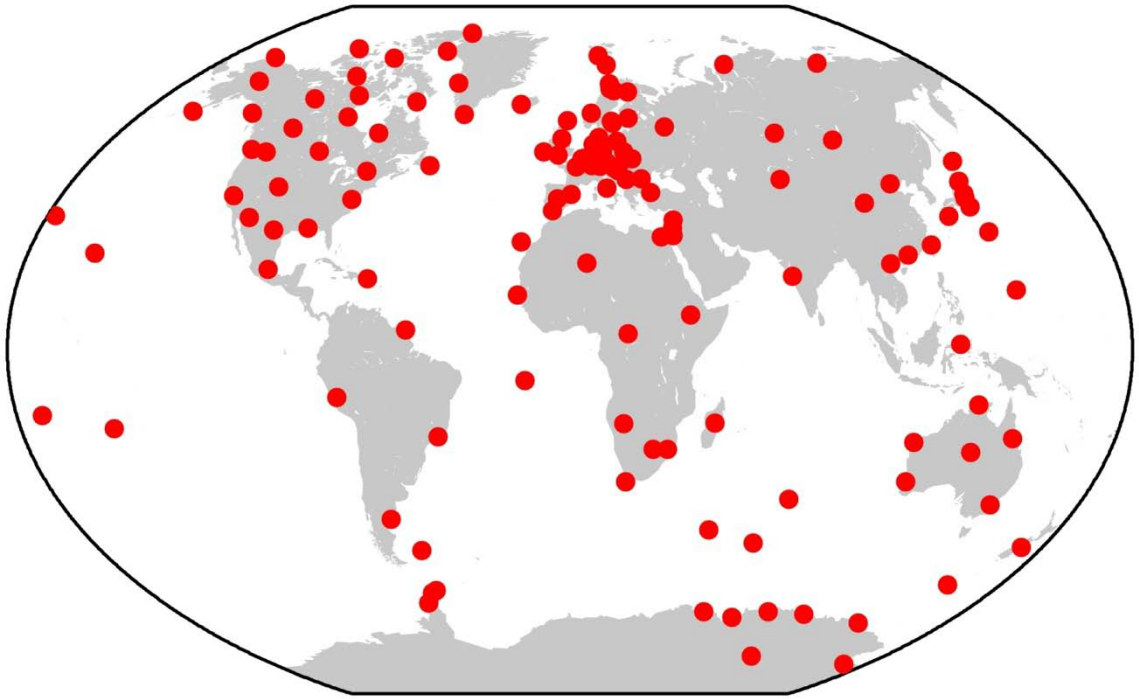
Differences in Std values



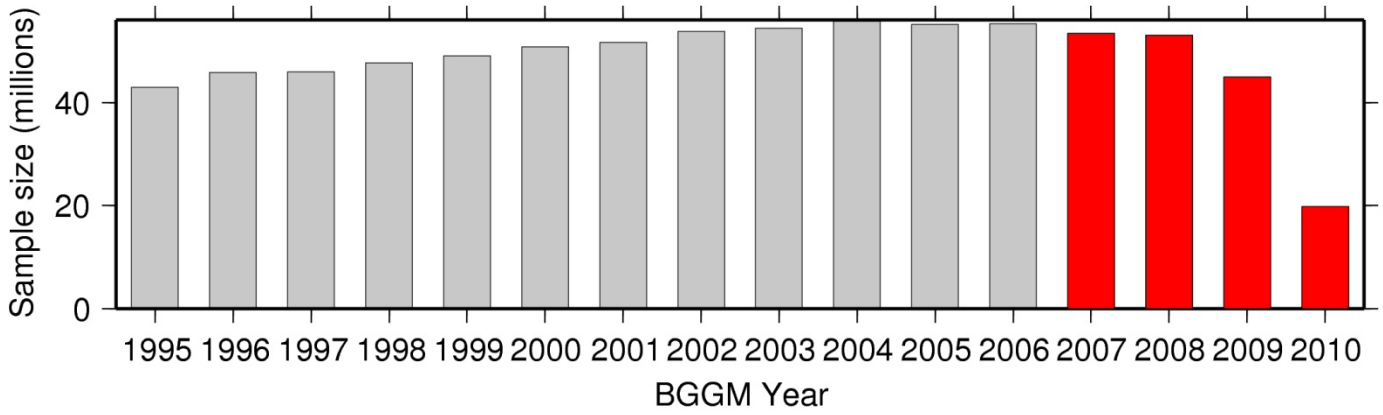
BGGM uncertainties – update of analysis for ISCWSA March 2009 (reported in SPE 119851)

- Ideally would like to use downhole magnetic data, however
  - difficult to obtain
  - in wide range of formats
  - can be contaminated
- Solution: simulate downhole data with observatory minute values not used in deriving model under test
  - good coverage in time allowing testing of series of annually revised models over > one solar cycle

Distribution of observatory data



adding in new data from originally selected observatories

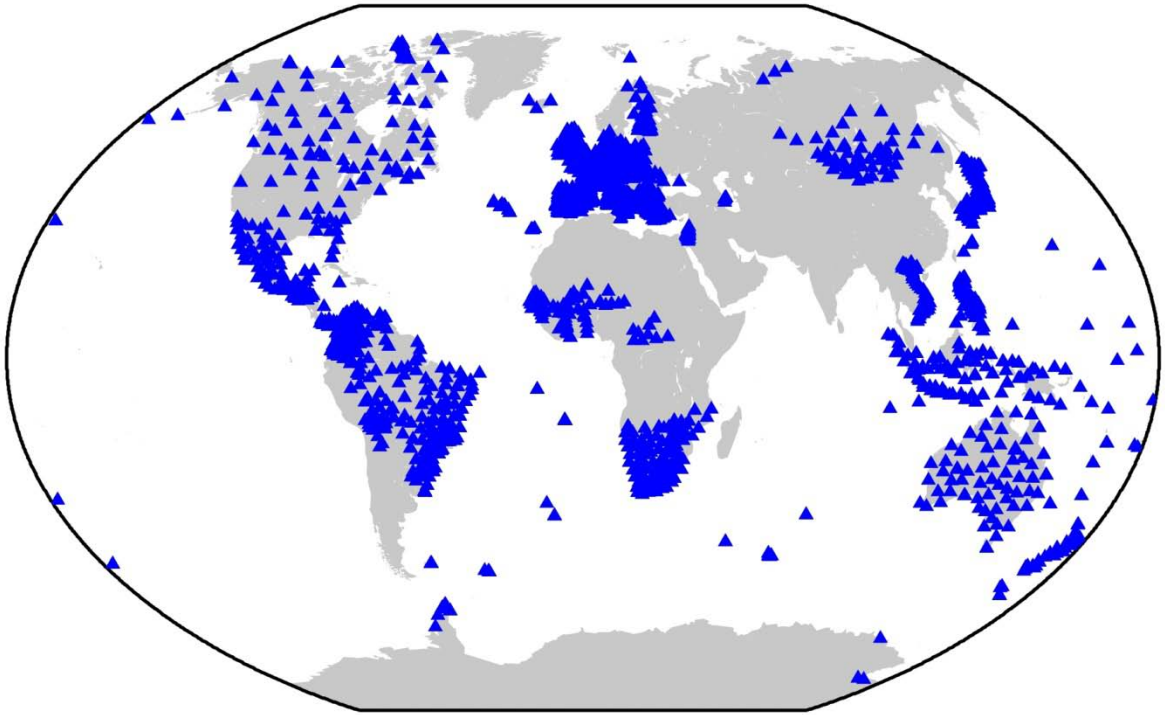


Are observatory data representative of magnetic measurements downhole?

- Crustal field component not representative of hydrocarbon geology
  - some observatories sited on volcanic rocks have very large crustal fields (>1° and 1000 nT)
  - would make errors larger than expected for hydrocarbon geology
- Poor spatial coverage
- Solution: adjust observatory data using more realistic crustal field estimates
  - remove modelled observatory bias from (observed-model) differences
  - order differences, get limits and combine with more realistic crustal field limits

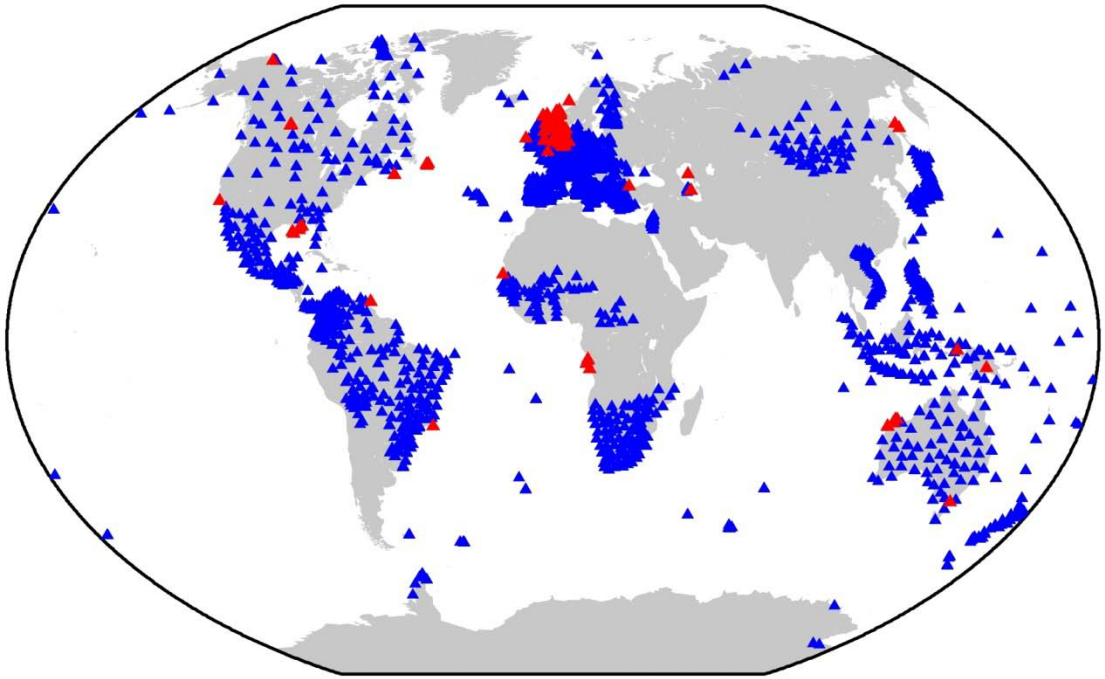
More realistic crustal field estimates (1)

- Land-based magnetic vector surveys



More realistic crustal field estimates (2)

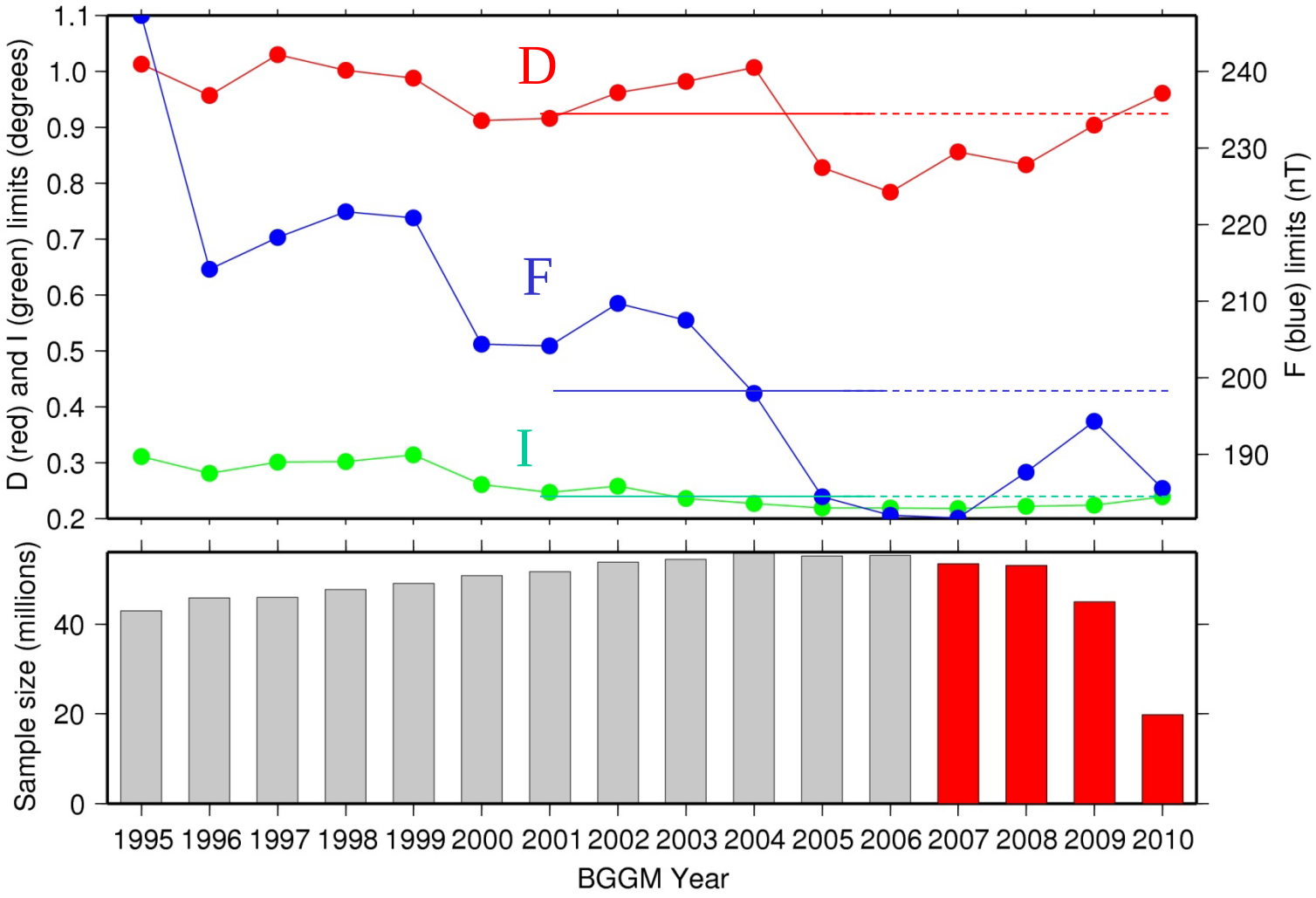
- plus airborne and shipborne magnetic data local to oil & gas fields



Variation of uncertainties by model release year

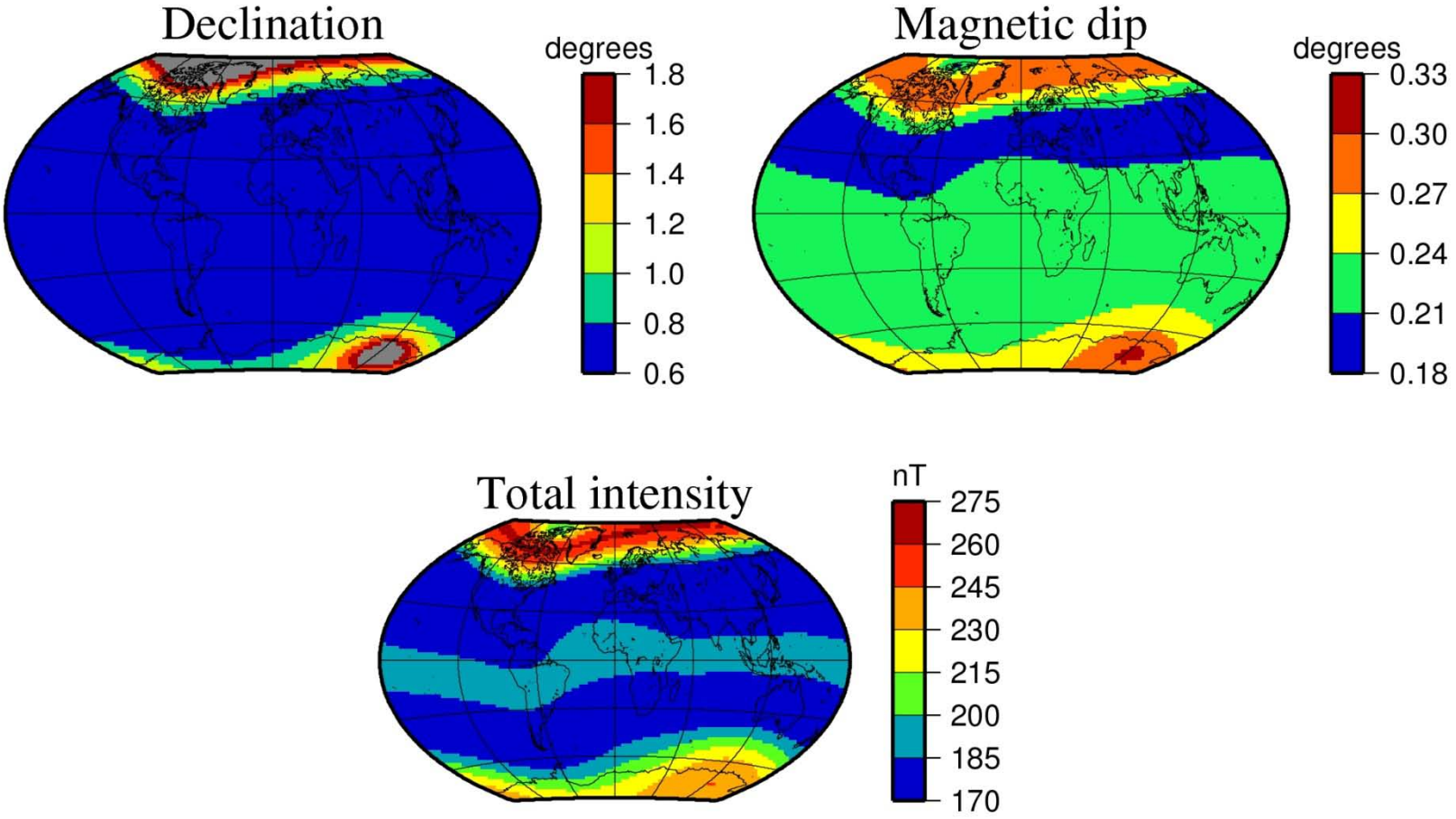
Conclusion: the limits are still valid for BGGM2007 and subsequent models

95.4%



Variation of uncertainties with location

- 95.4% confidence limits



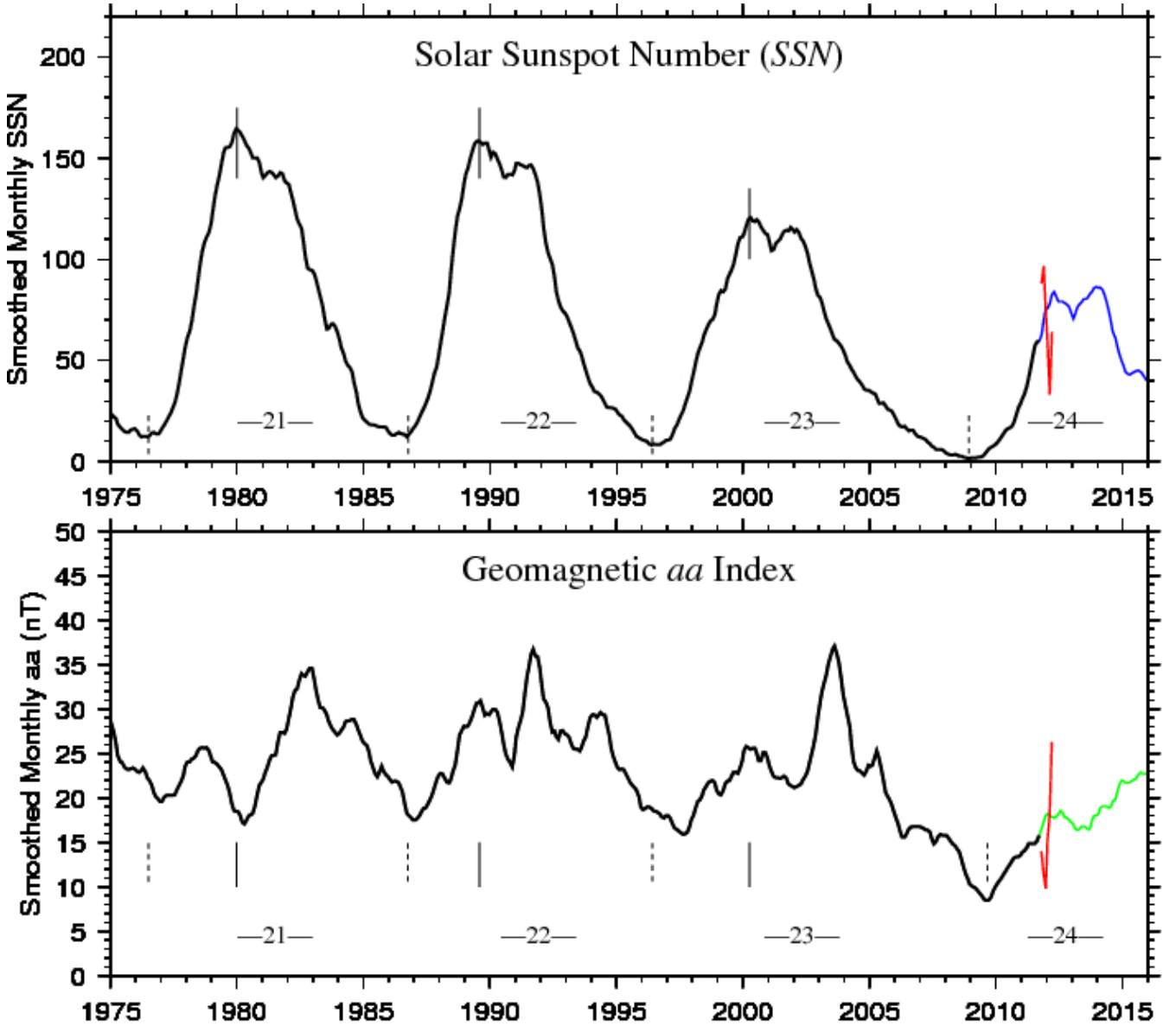
Look-up tables for 6 confidence levels online

Feedback from error sub-committee

- look-up tables for 6 confidence levels difficult to implement in error models
- tables are for BGGM only

- using the 95.4% table
  - for declination investigate revising error terms AZ (constant) and DBH (H dependent)
  - provide 1 table that contains appropriate 1-sigma values for error propagation purposes and multiplying up for confidence of upwards of 95%

Predicted solar and geomagnetic activity levels



Eskdalemuir visit agenda

Time	
0830	Pick-up Radisson Blu
1030	Arrive + coffee & snacks
1045	Introduction presentation
1100	Tour of the observatory
1230	Final presentation
1300	Leave Eskdalemuir observatory
1400	Lunch Peebles
1530	Leave Peebles
1630	Arrive Edinburgh Radisson Blu