45th General Meeting of the ISCWSA, March 17 2017. The Hague, Netherlands

New approach to quantify uncertainty for high-resolution magnetic reference models

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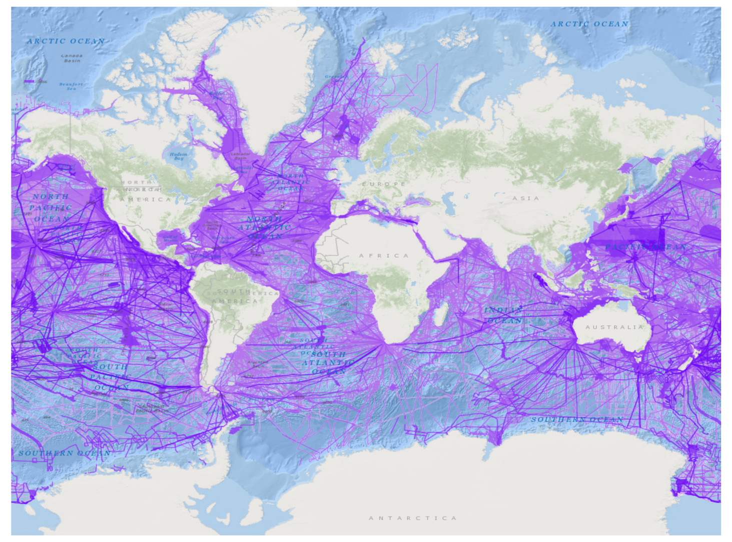
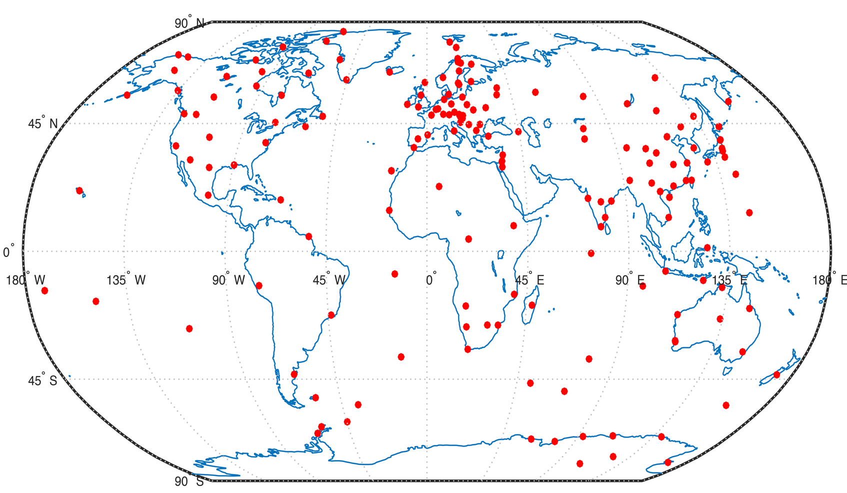
Introduction

Better estimation of uncertainties in global high-resolution reference models allows for managing the collision risk in closely spaced wellbore position. The ISCWSA MWD magnetic error model was originally developed using a lower resolution BGS Geomagnetic Model (BGGM) in 1993 (ref. SPE 67616). Subsequently multiplier values were developed (ref. SPE 151436) to account for the relative changes in the errors for higher-resolution models. One of the key challenges in estimating errors in the angular components (dip and azimuth) is that ship and airborne sensors usually only collect total field information. Here we present a new approach to error estimation for higher-resolution models by combining total field survey data and observatory vector magnetic data in a statistically consistent manner.



NCEI's GEODAS magnetic survey database



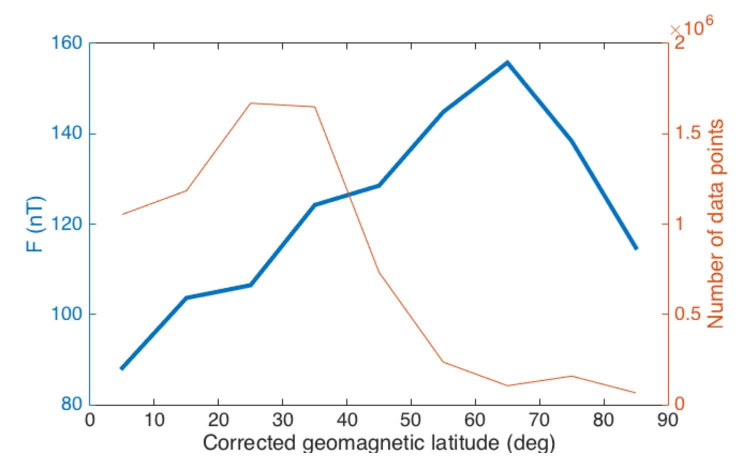
Location map of geomagnetic observatories

Method

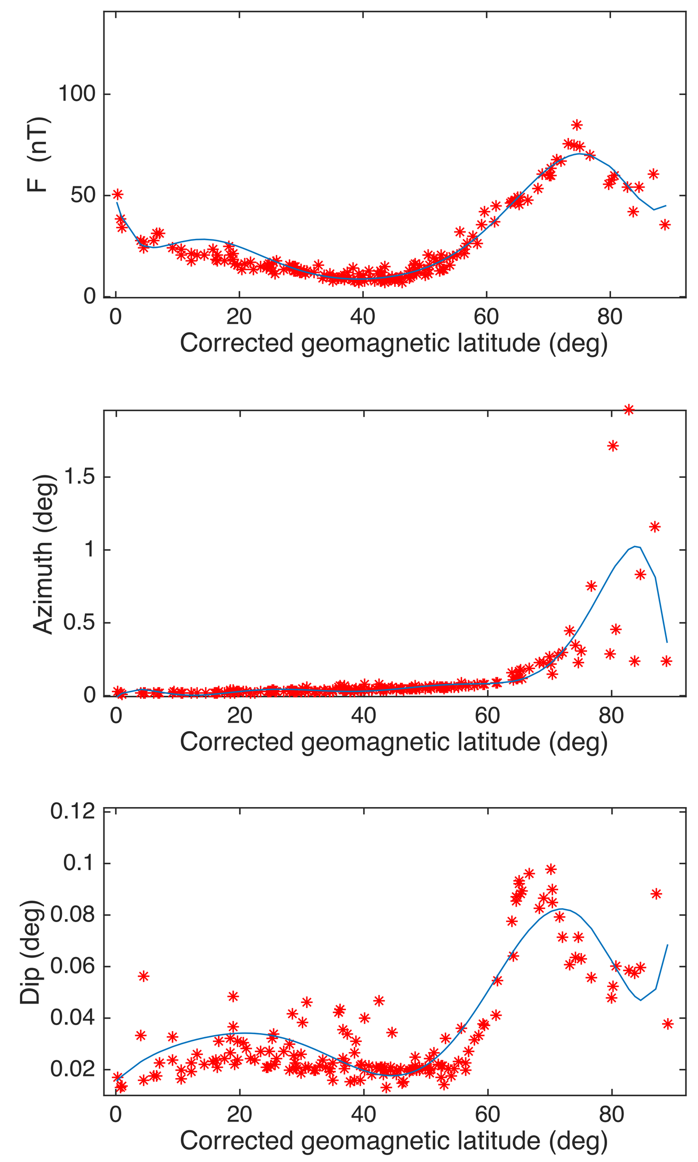
- We use NOAA's HDGM crust+core (HDGM_A, degree and order 720, 56 km resolution)
- NOAA's public GEODAS (GEOphysical DAta System) database provides crustal error for total field data.
- Global geomagnetic observatories provided errors for all components
- Calibration of the observatory errors using GEODAS errors following Chulliat et al., (2014)
- Errors due to magnetic disturbances are calculated separately using trend-removed observatory data.
- All errors are combined to provide total errors

Errors	Total Field	Dip (deg)	Azimuth (deg)	X (nT)	Y (nT)	Z (nT)	H (nT)
Main, crustal and steady external	107	0.19	0.29	154	70	117	152
Disturbance field	29	0.04	0.26	37	25	27	37
Combined Error	111	0.20	0.39	158	74	120	157

Table 1. Error budget for HDGM crust and core only model (HDGM_A).



Crustal error of HDGM_A model determined from GEODAS data



Disturbance field errors of HDGM_A at observatories

Error model

To provide uncertainty estimates for all geomagnetic components that are statistically consistent, we use the combined errors of X, Y and Z components from Table 1 and the geometrical relationships between the various components to propagate errors to the other components.

The error in (X, Y, Z) was propagated onto F, Dip, Az and H components by the following relationship.

$$\delta H = \sqrt{[(\delta X)^2(\cos Az)^2 + (\delta Y)^2(\sin Az)^2]}$$

$$H\,\delta Az = \sqrt{[(\delta X)^2(\sin Az)^2 + (\delta Y)^2(\cos Az)^2]}$$

$$\delta F = \sqrt{[(\delta H)^2(\cos Dip)^2 + (\delta Z)^2(\sin Dip)^2]}$$

$$F\,\delta Dip = \sqrt{[(\delta H)^2(\sin Dip)^2 + (\delta Z)^2(\cos Dip)^2]}$$

The propagated errors (δH=151 nT, δF=136 nT, δDip = 0.20 deg., δAz = 0.35 deg. and $H\delta Az$ = 4864 nT) are close to the error budget values suggesting that the error analysis is internally consistent. To address the geometrical effect at poles, the error for δAz is given as $\sqrt{(0.21)^2 + (4864/H)^2}$

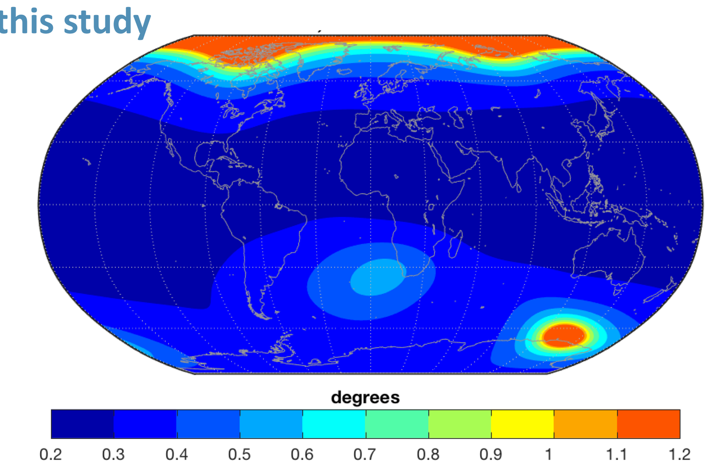
	Total Field	Dip Angle	Azimuth (Constant)	Azimuth (BH Dependent)
	MFI (nT)	MDI (Deg)	AZ (Deg)	DBH (Deg.nT)
HDGM_A (this study)	136	0.20	0.21	4864
HDGM (ISCWSA)	107	0.16	0.30	4118
IGRF/WMM (ISCWSA)	157	0.24	0.43	6029

Table 2. The new Error model is compared with ISCWSA error models.

Conclusions

- Errors are calculated bottom-up using magnetic survey data and observatory data
- Preliminary results show that the model errors are consistent with the observed errors
- Next step is to compare the error model with actual MWD data.

Map of Azimuth errors of HDGM_A based on this study



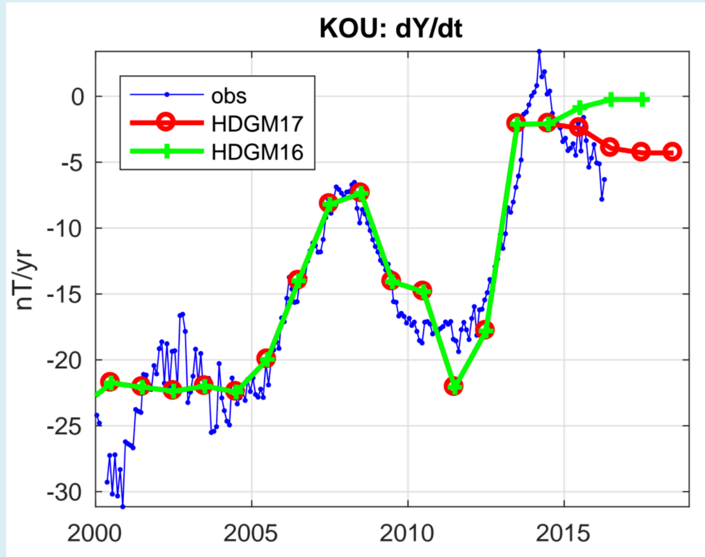
References

1. Chulliat, A., Macmillan, S., Alken, P., Beggan, C., Nair, M., Hamilton, B., ... & Thomson, A. (2015). The us/uk world magnetic model for 2015-2020.
2. Maus, S., Nair, M. C., Poedjono, B., Okewunmi, S., Fairhaid, D., Barckhausen, U., ... & Matzka, J. (2012, January). High-Definition Geomagnetic Models: A New Perspective for Improved Wellbore Positioning. In *IADC/SPE Drilling Conference and Exhibition*. Society of Petroleum Engineers.
3. Williamson, H. S. (2000). Accuracy prediction for directional measurement while drilling. SPE 67616 *SPE Drilling & Completion*, *15*(04), 221-233.

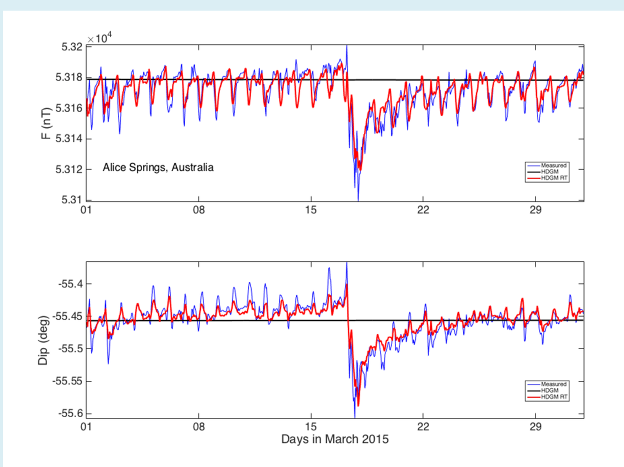
Geomagnetic Updates

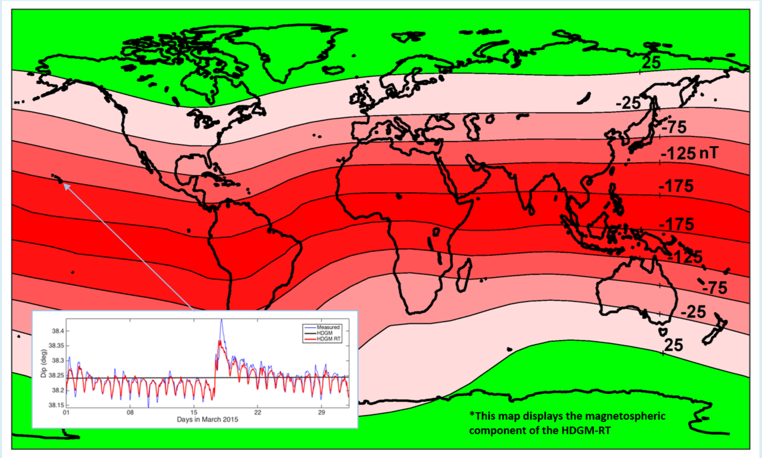
New HDGM (2017) Model

Using European Space Agency's Swarm satellite data, we recently updated the main field and secular variation parts of High Definition Geomagnetic Model (HDGM) model. The 2015-2016 models were retroactively updated with new Swarm data.



The Real Time add-on to the High Definition Geomagnetic Model (HDGM-RT) includes a model of Earth's external disturbance field which provides near real-time estimates of magnetic effects from current systems in the magnetosphere and ionosphere.

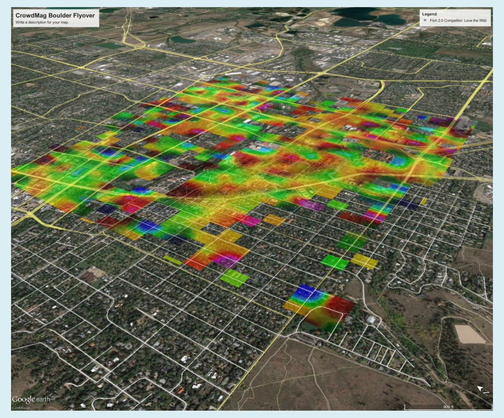


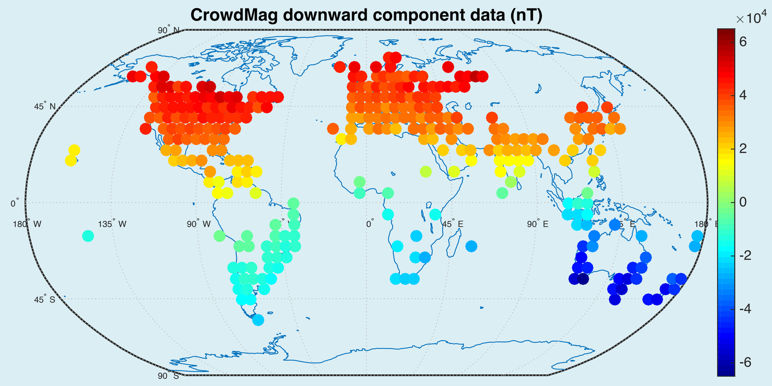


https://www.ngdc.noaa.gov/geomag/HDGM/index.html

Magnetic data from smartphones!

NOAA's CrowdMag project aims to crowdsource magnetic data from smartphones. The project aims to map local and global magnetic field by combining large amount of data to reduce the overall noise and produce robust results.





https://www.ngdc.noaa.gov/geomag/crowdmag.shtml