Forecasting secular variation using accelerated core surface flows

Ciarán Beggan
Kathy Whaler

British Geological Survey, Edinburgh, UK
School of GeoSciences, University of Edinburgh, UK

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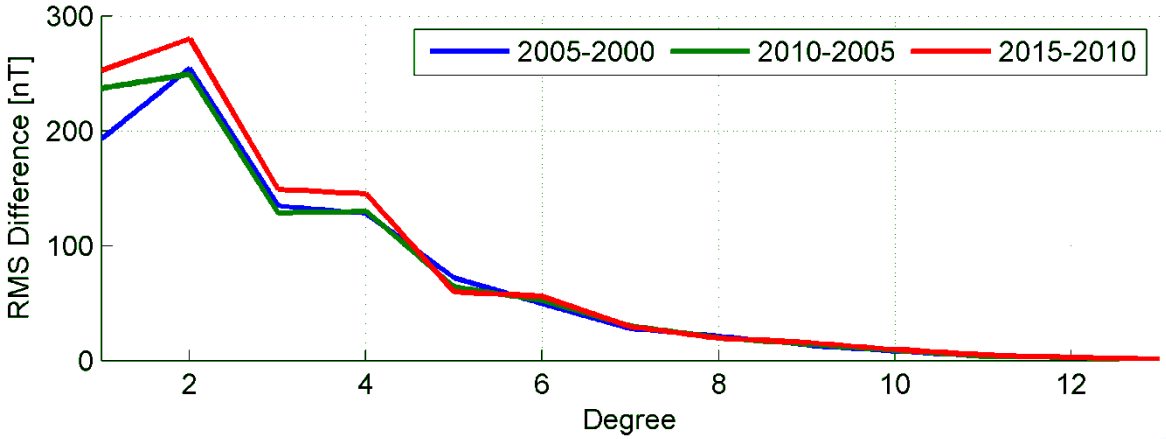
Session:

Magnetic Field variation

- CHAOS-5 main field variation
  - RMS differences (to degree 13):

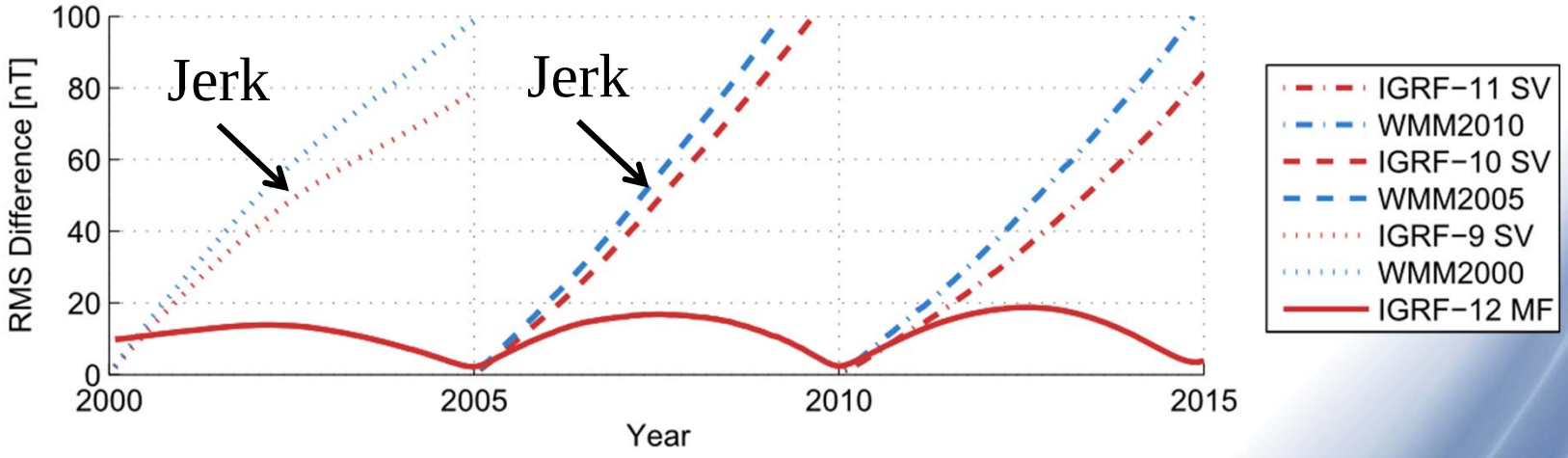
Years	Total RMS difference [nT]
2005 – 2000	382
2010 – 2005	400
2015 – 2010	440



IGRF and WMM series

- Secular variation forecasts from :
  - IGRF-9, 10 and 11 (to degree 13)
  - WMM2000, WMM2005, WMM2010 (to degree 12)

Year	IGRF SV	WMM SV
2005	79	98
2010	109	122
2015	84	104



Can we improve on this?

- IGRF-12 SV candidate submissions
  - Instantaneous SV extrapolations
  - Data assimilation into geodynamo models
  - Core Flow / Accelerated core flows

- Look at forecasts from core flows derived from SV and SA
  - Flows from inversion of *SV only*
  - Flows from inversion of *SV and SA*
  - Flows with steady acceleration from *SV and SA*

Assumptions

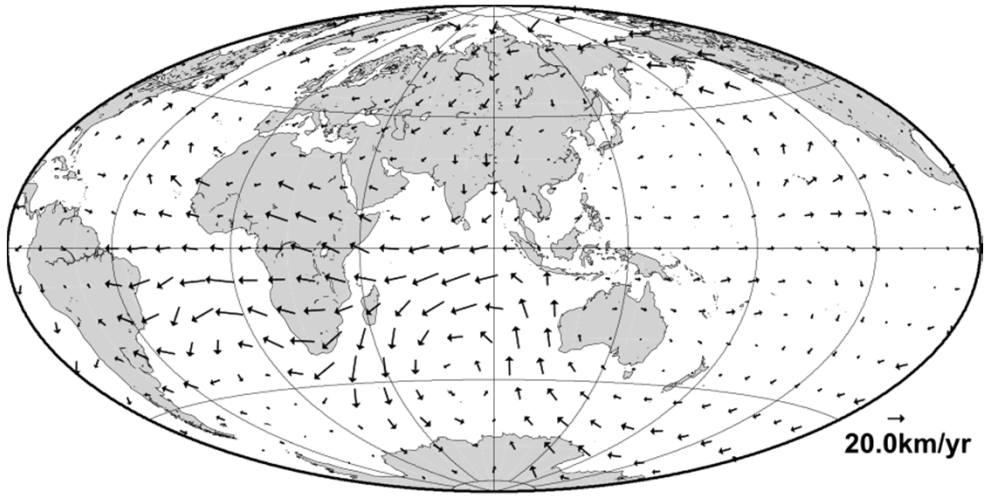
- Frozen flux approximation
  - No diffusion assumed

- Solve for *toroidal and poloidal flow* and accelerations
  - Compute flow and accelerations to degree 14
  - Bloxham ‘strong’ norm damping above degree 8
  - Slightly damped to impose geostrophic flow

- Use SV and SA from ~160 observatory and 648 ‘virtual observatory’ satellite data
- Solve flow and acceleration models in six sets of years:
  - 2001-2005; 2003-2005; 2001-2007; 2001-2010; 2005-2010; 2007-2010;

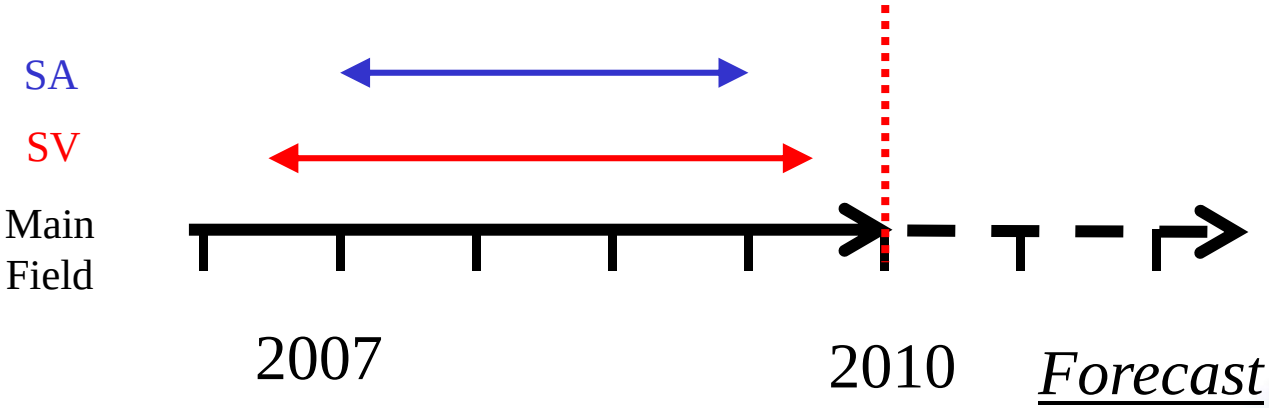
Example models [2007 - 2010]

Constant Flow



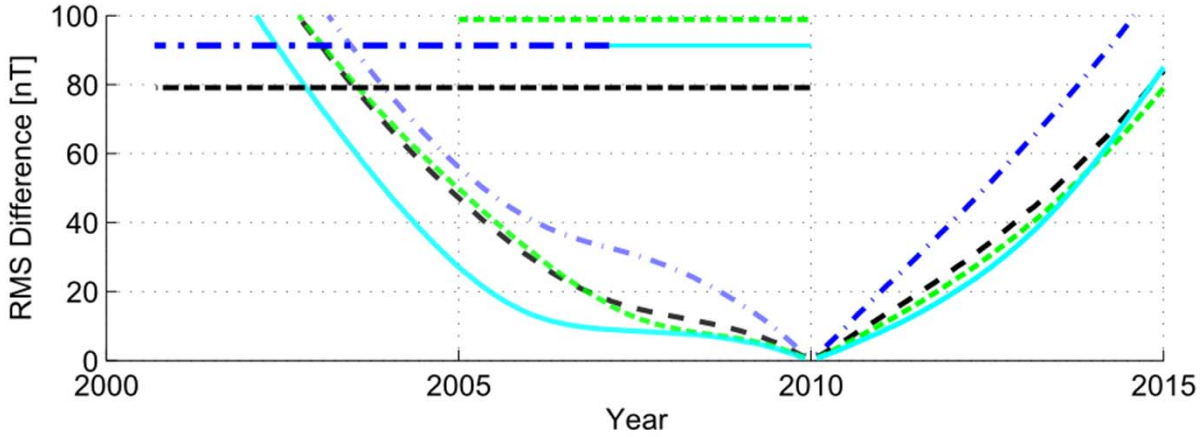
Forecasting

- Start at year e.g. 2005 or 2010
  - Compute MF coeffs from model (e.g. CHAOS-5)
  - Use core flow and/or acceleration to compute instantaneous SV and SA for timestep (i.e. 1 month)
  - Add to MF, update Gaunt/Elsasser matrices
  - Compute RMS difference
  - Repeat ..
- Can also compute hindcasts

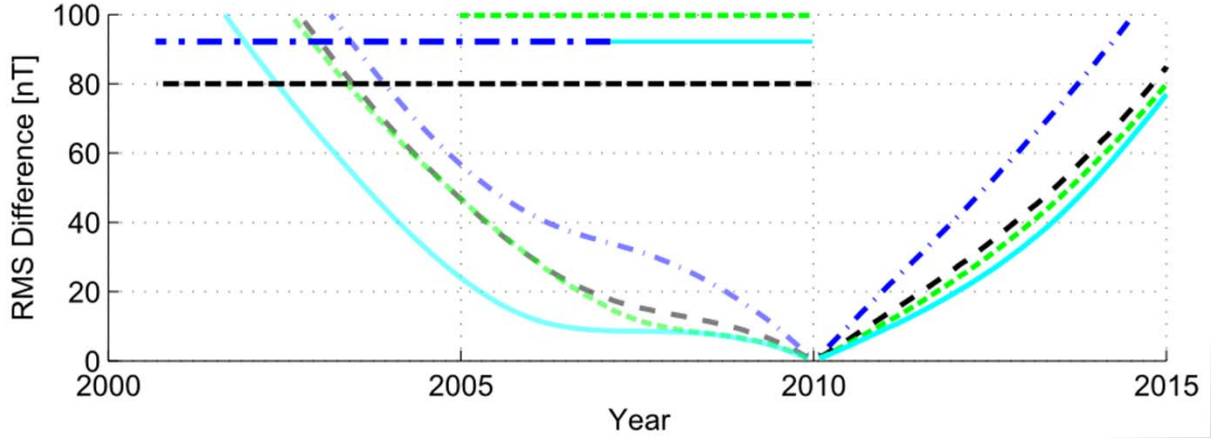


Flow model (2010-2015)

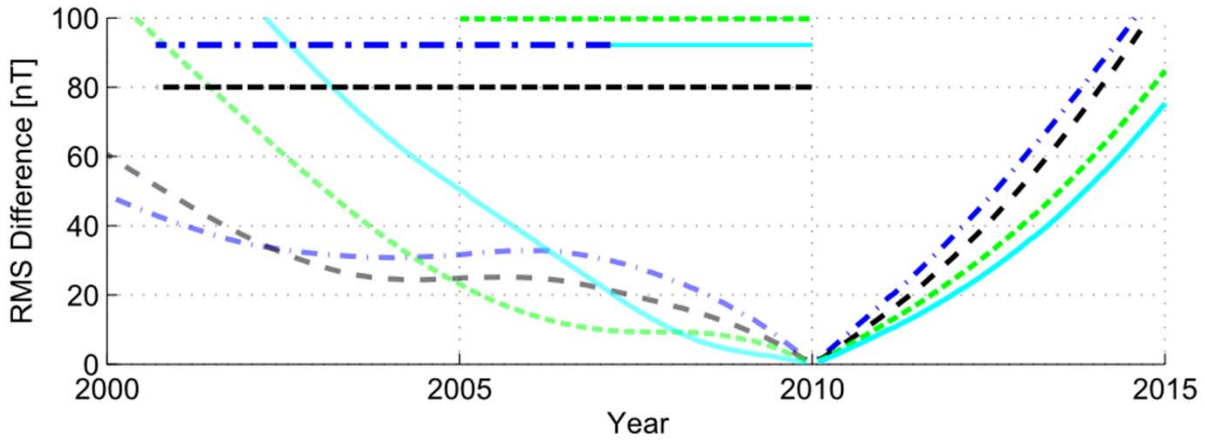
SV only



SV and SA



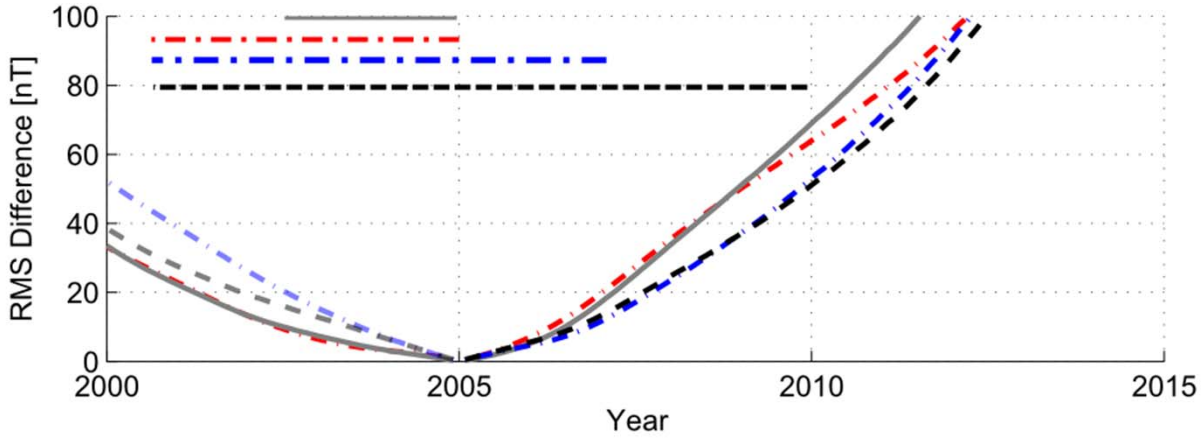
Flow model with acceleration (2010-2015)



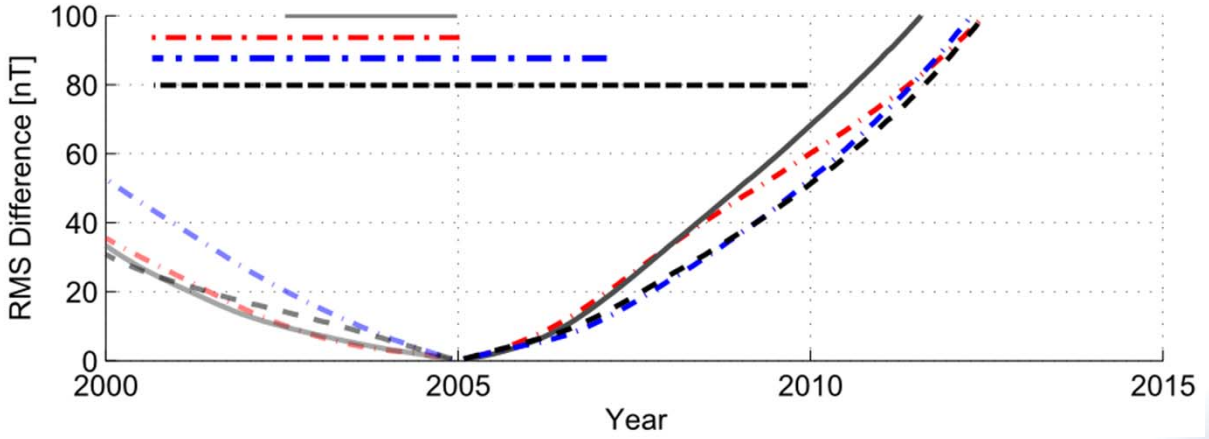
RMS Diff [nT] at 2015.0	SV only	SV and SA	SF with accel	IGRF-11	WMM2010
2001-2007	113	111	113	84	104
2001-2010	85	84	107		
2005-2010	80	79	85		
2007-2010	77	85	75		

Flow model (2005-2010)

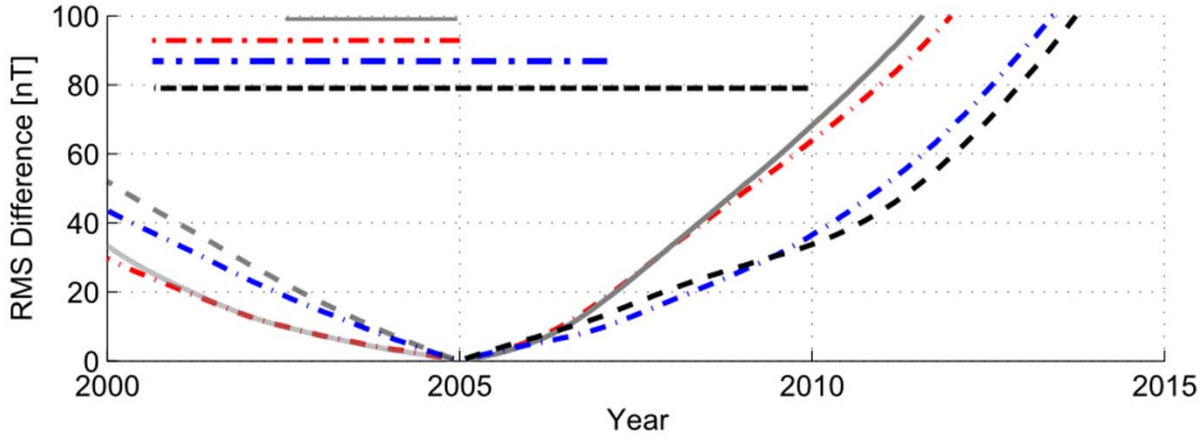
SV only



SV and SA

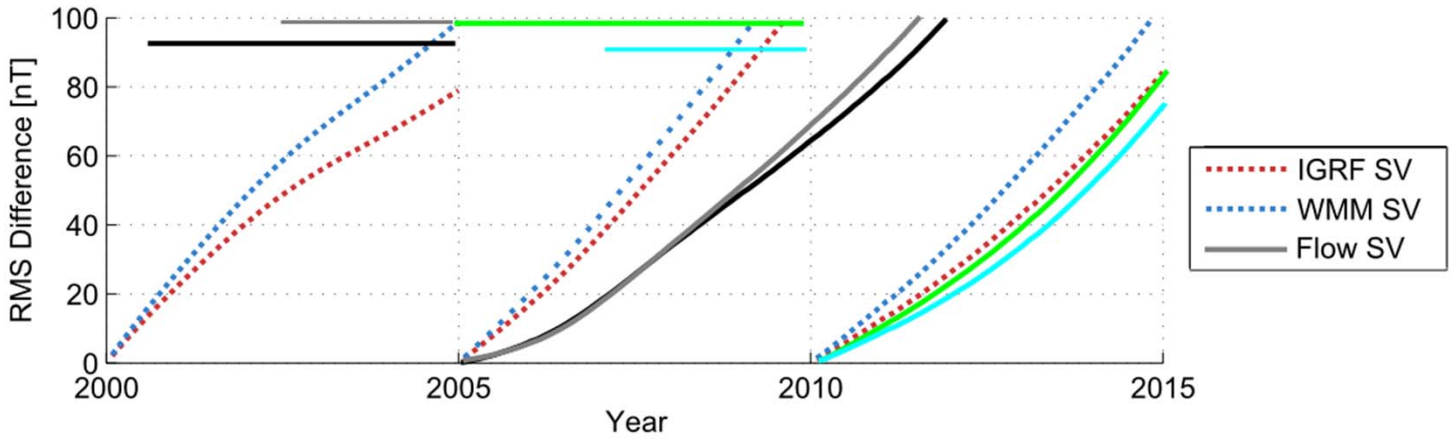


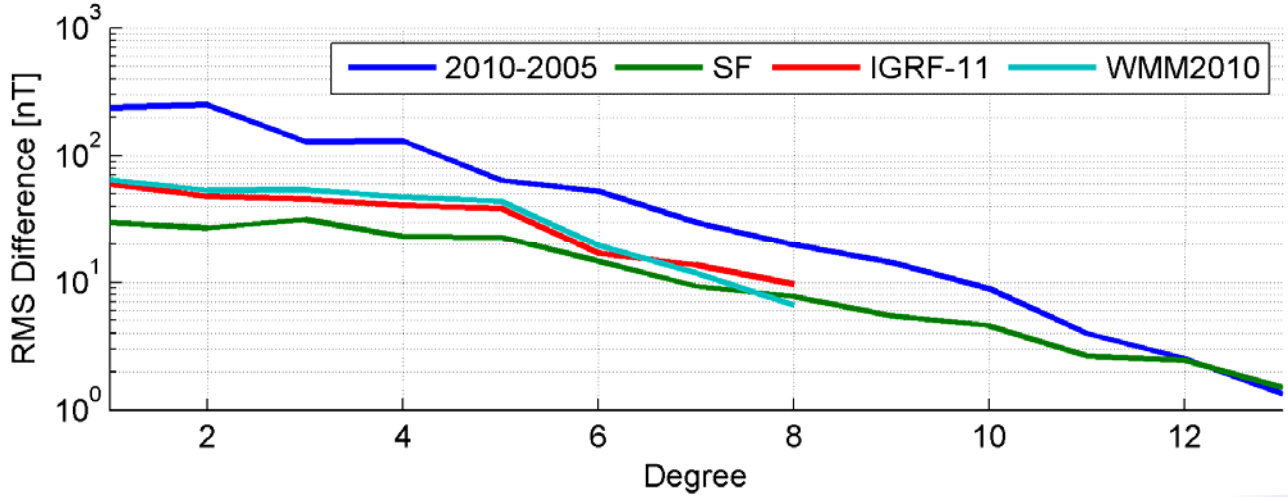
Flow model with acceleration (2005-2010)



RMS Diff [nT] at 2010.0	SV only	SV and SA	SF with accel	IGRF-11	WMM2010
2001-2005	64	60	64	109	122
2003-2005	69	68	68		

Improvements over previous generations?





Conclusions

- Usually able capture > 75% of the field change
- Jerks/accelerations are significant for goodness of forecast
- Core flows using 3-5 years of data are best
- *Slightly better* to *somewhat better* than standard instantaneous SV extrapolation