Core Field Modeling with the Iridium® Constellation

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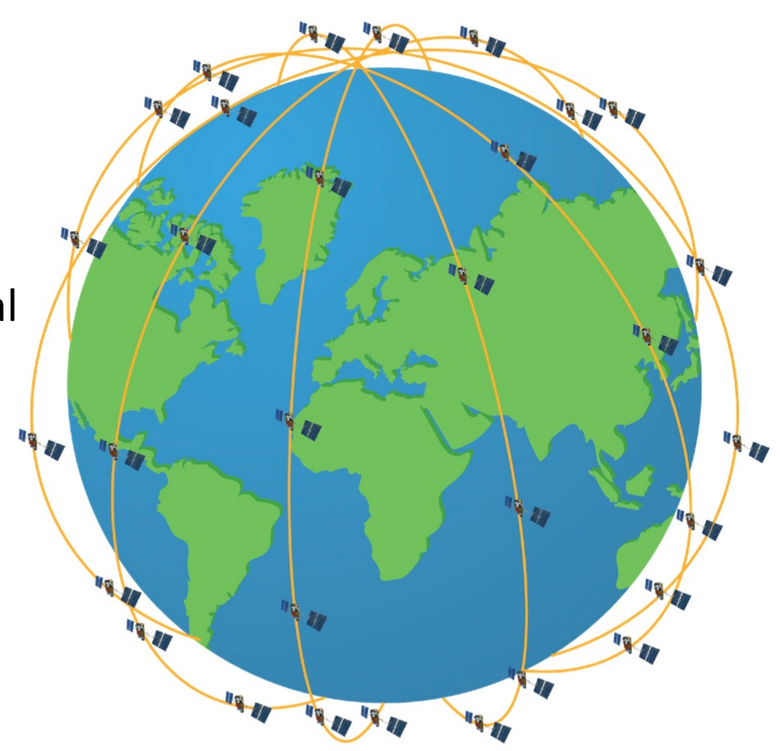
Abstract

The World Magnetic Model (WMM) is a geomagnetic core field model that is widely used for navigation by governments, industry and the general public. In recent years, the model has been derived using high accuracy magnetometer data from the Swarm mission. This study explores the possibility of developing future core field models in the post-Swarm era using data from the Iridium satellite constellation. Iridium magnetometers are primarily used for attitude control, so they are not designed to produce the same level of accuracy as magnetic data from scientific missions. Iridium magnetometer errors range from 30 nT quantization to hundreds of nT errors due to spacecraft contamination and calibration uncertainty, whereas Swarm measurements are accurate to about 1 nT. The calibration uncertainty in the Iridium measurements is identified as a major error source, and a method is developed to calibrate the spacecraft measurements using data from a subset of the INTERMAGNET observatory network producing quasi-definitive data on a regular basis. After calibration, the Iridium data produced core field models with approximately 20 nT average error and 50 nT maximum error. The Iridium-based models were shown to meet the WMM error tolerances, indicating that Iridium is a viable data source for future WMMs.

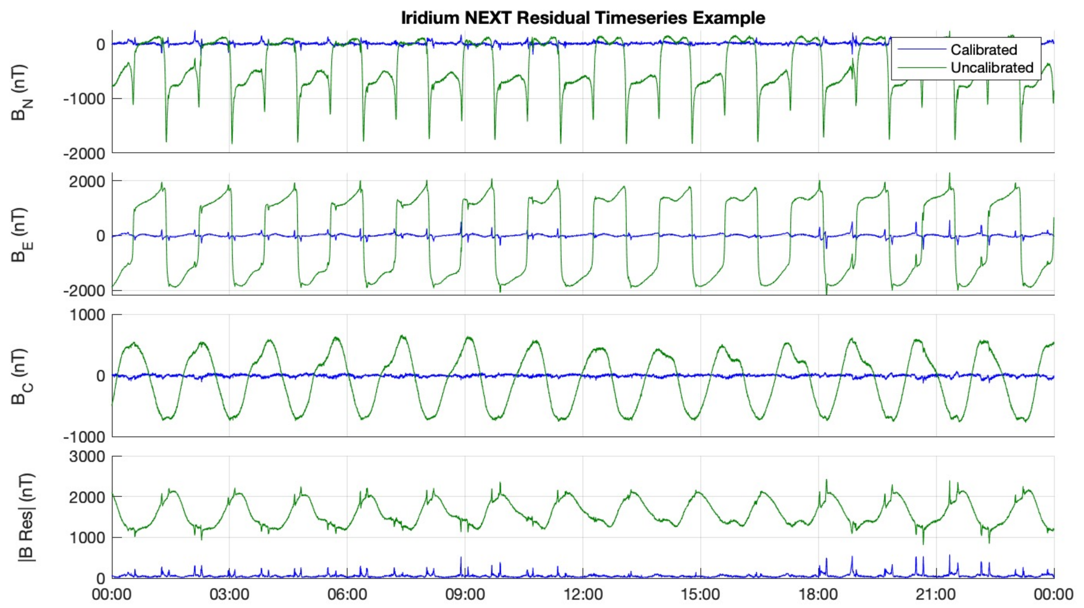
Iridium Orbits and Data

- Iridium NEXT constellation (2017-current)
- 66 satellites + spares
- 6 orbital planes evenly spaced in local time
- 778 km altitude
- 86.4 deg inclination
- 3-axis fluxgate magnetometer
- 1/8 Hz typical sample rate



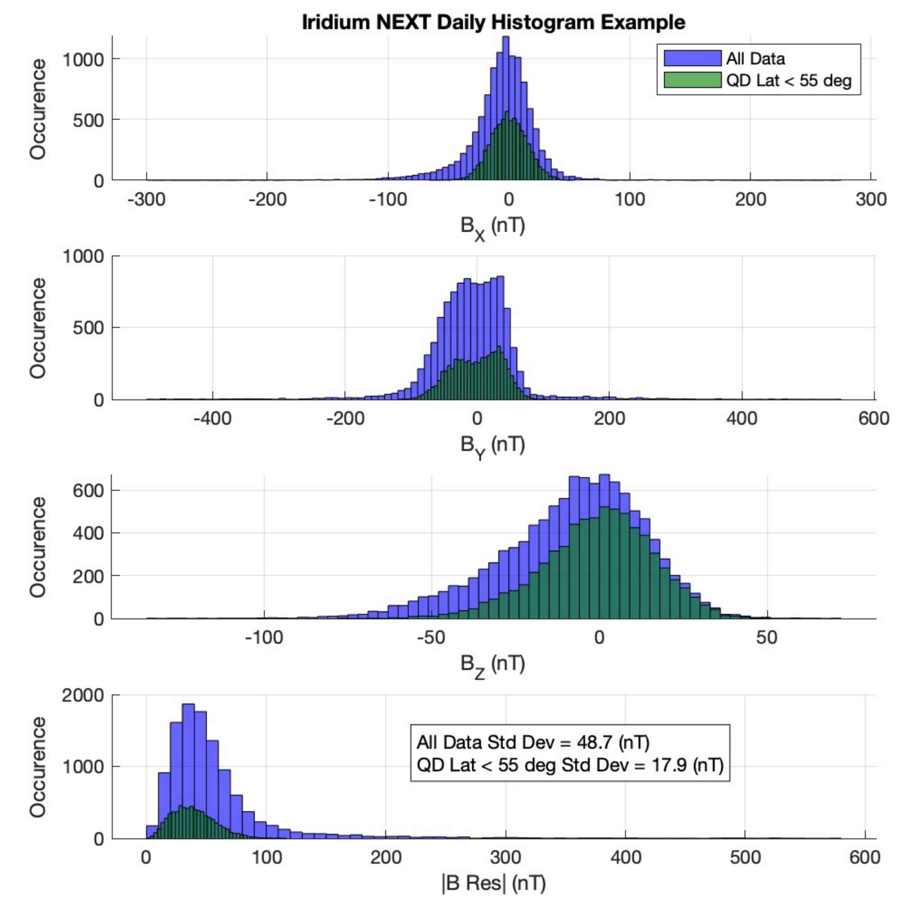
- Iridium magnetometers are intended for attitude control: accuracy requirements are much lower than a scientific mission that focuses on measuring the magnetic field (e.g. Swarm)
- Various contamination sources exist, and some corrections for known signals have been applied by Iridium/Applied Physics Laboratory (APL)

Can we take advantage of the large constellation of lower-quality measurements to produce a satisfactory core field model?

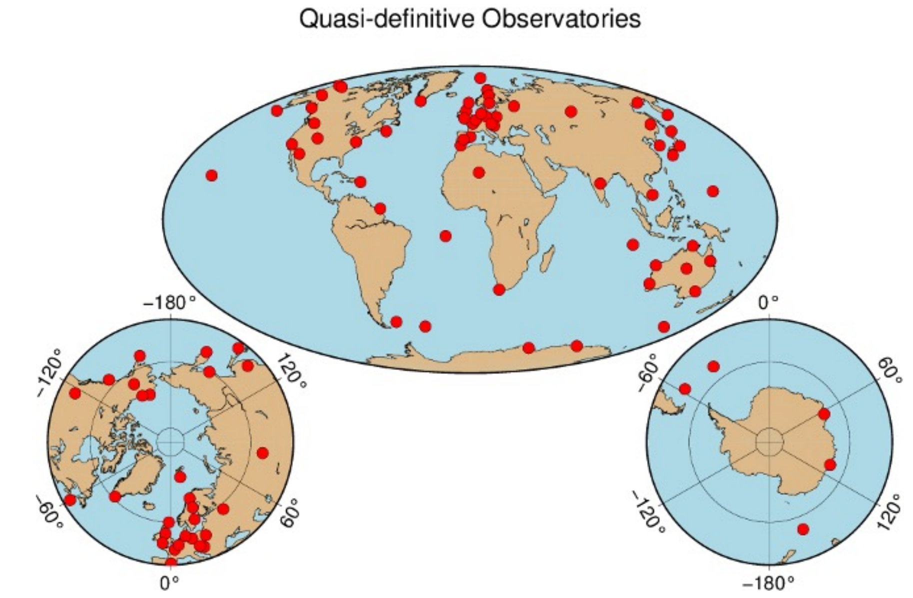


- Factory calibration results in >1000 nT errors relative to CHAOS-7.2
- Calibration relative to an independent reference is required

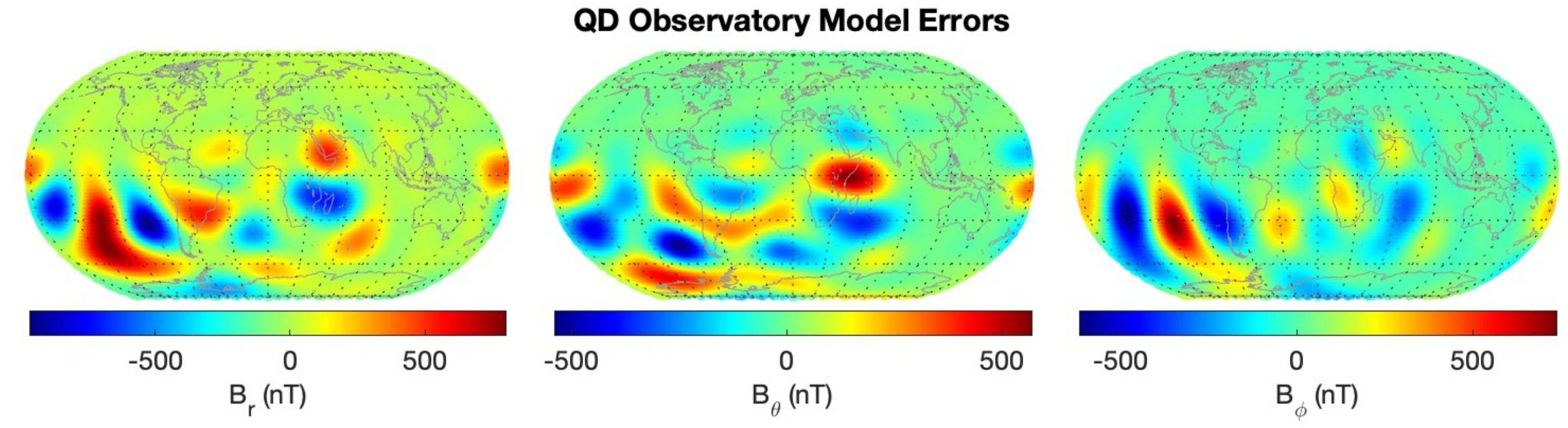
Calibrating Iridium Data



- Daily linear calibration relative to assumed core field model
$$b_{cal} = A*b_{meas} + B$$
- Use low-latitude data for calibration to reduce errors associated with high-latitude disturbances (|QD Lat| < 55)
- Calibrated residual standard deviations are 20-40 nT relative to CHAOS-7.2

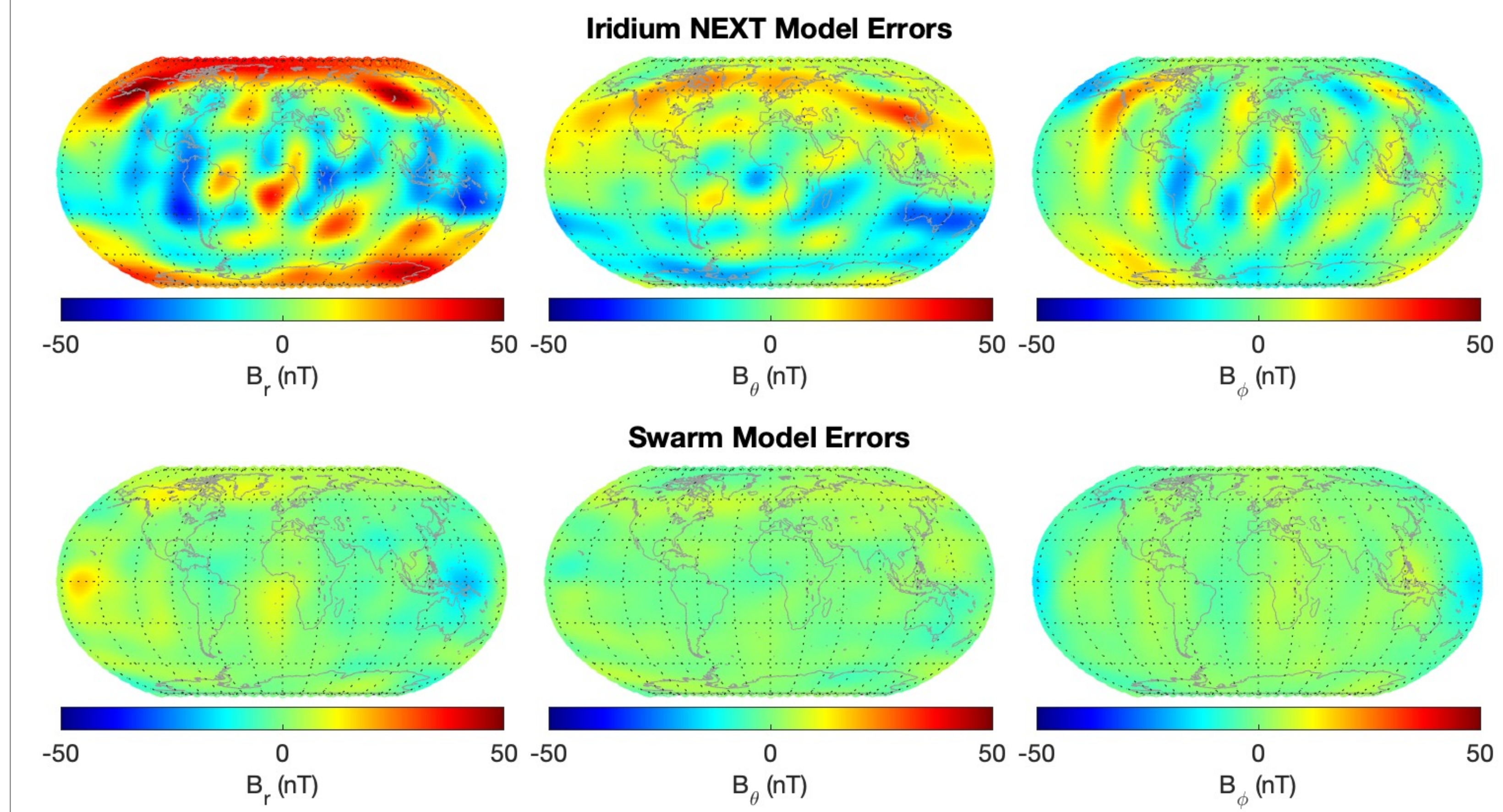


- For future models, we can't calibrate Iridium data using existing core field models
- Solution: derive a low-order core field model from 59 quasi-definitive observatories for Iridium calibration
- These observatories reliably produce data within 6 months of acquisition

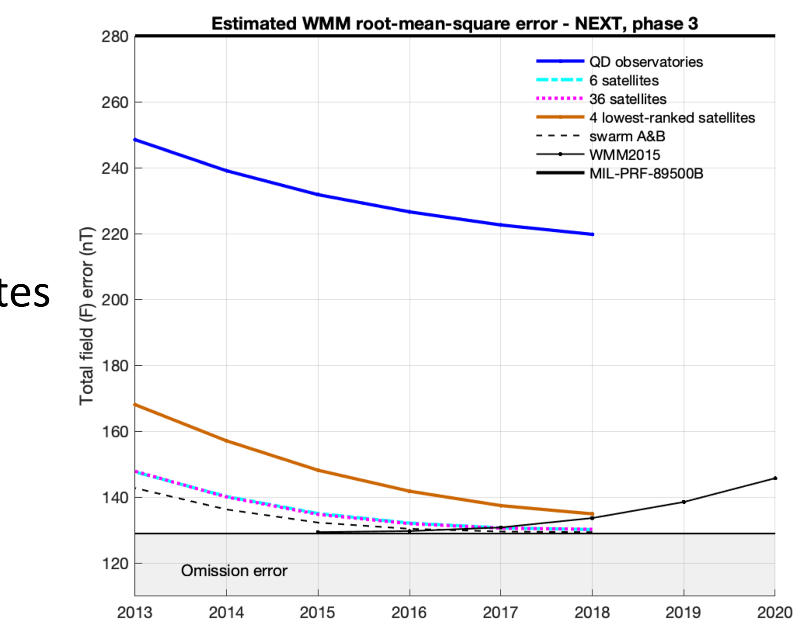


- Observatory model errors are large (>500 nT) because of sparse spatial sampling
- Can this model be used to satisfactorily calibrate Iridium data?

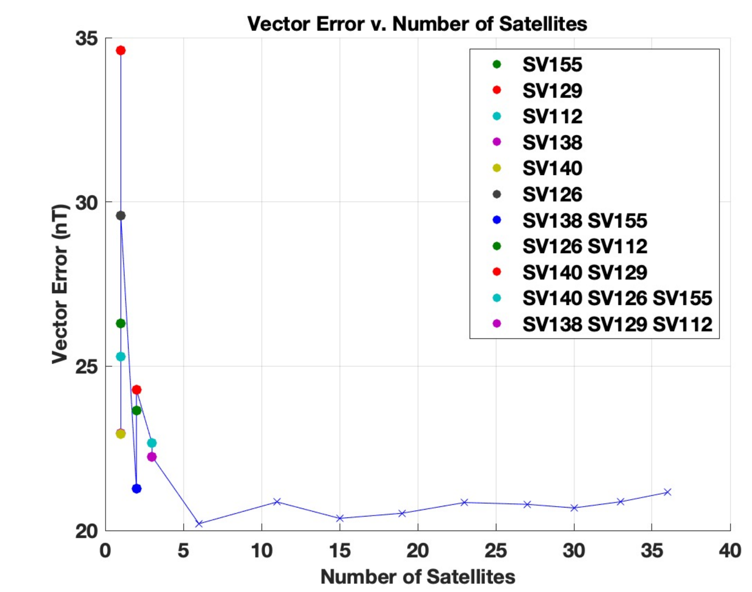
Model Results



- A 2018 WMM model was developed using Iridium data from 2018-03-01 to 2019-04-29
- Model is evaluated backwards in time to compare to existing data and determine whether Iridium can meet WMM requirements
- Iridium model has 20 nT average error and 50 nT maximum error
- Model using highly-accurate Swarm data for the same time period and modeling assumptions has 6 nT average error and 15 nT maximum error
- Large errors in the QD observatory model used for calibration do not directly translate to Iridium model



- Iridium model meets WMM error requirements over 5-year interval
- Model improves by selecting satellites with smaller residuals



- Iridium satellites were ranked relative to CHAOS-7.2 model
- Model using one satellite from each plane with smallest residuals produces lowest global error

Conclusions

- Iridium calibration can be constrained using a model derived from QD observatory data, despite large errors in the observatory model
- Iridium model meets WMM requirements, demonstrating that Iridium is a viable option for producing future WMMs