# Magnetic Datasets from Non-dedicated Satellites

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# Motivation

- Enlarging datasets of magnetic space-based measurements interesting to space physics and geomagnetism

- Interested in satellites carrying platform magnetometers
  - Low-Earth orbit
  - Polar orbit
  - Increase MLT coverage
  - GOCE, GRACE-FO, in future others

# Motivation

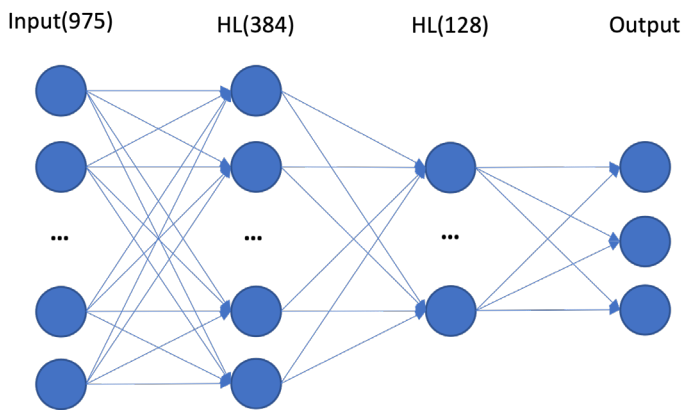
- Platform magnetometers are only roughly calibrated
  - Part of attitude and orbit control system (AOCS)
  - Engineered to an error below 500nT
- Our goal: post-launch calibration
  - Adjusting artificial disturbances
  - As much information as possible
  - Enable scientific application of the measurements

# Approach

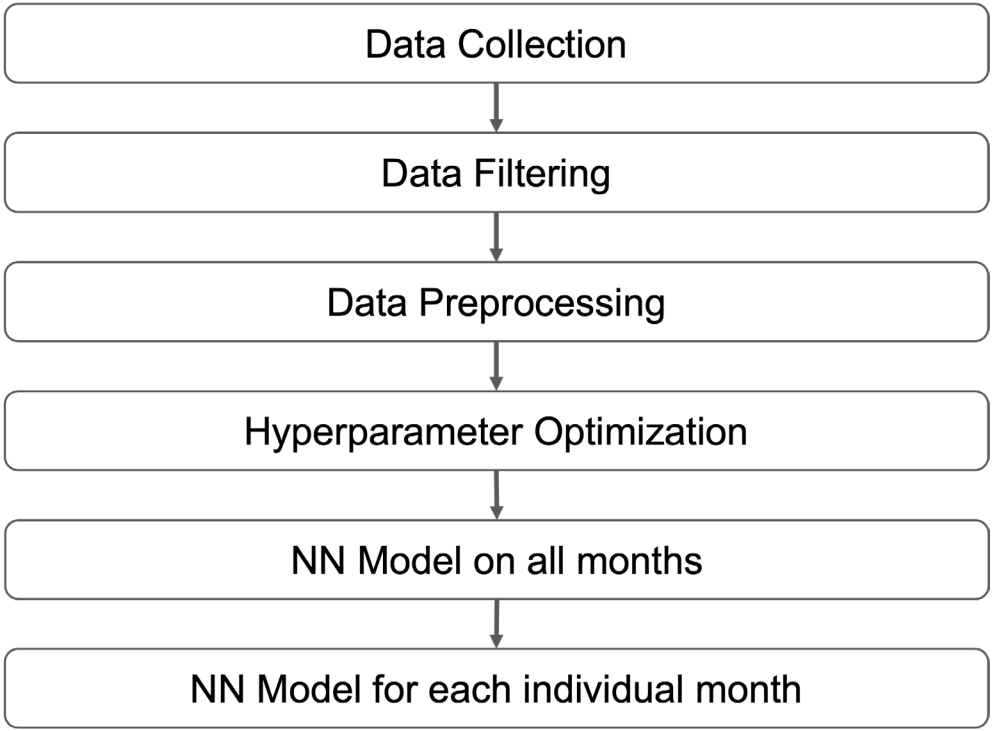
- Machine Learning-based calibration
- Neural networks
  - Automatic feature selection
  - Non-linearities between features
  - More available information can be incorporated
    - No manual feature preselection

# Approach

- Input to model
  - Magnetometer measurements, currents, temperatures, magnetorquer activations, thrusters
  - telemetry data like status variables, flags, and others
- Model is Feed-Forward Neural Network
- Reference model is CHAOS7
  - Includes core, crustal, and large-scale magnetospheric parts
  - Heavily supported by Swarm
- Details in publications



# Approach


Data Collection
Data Filtering
Data Preprocessing
Hyperparameter Optimization
NN Model on all months
NN Model for each individual month

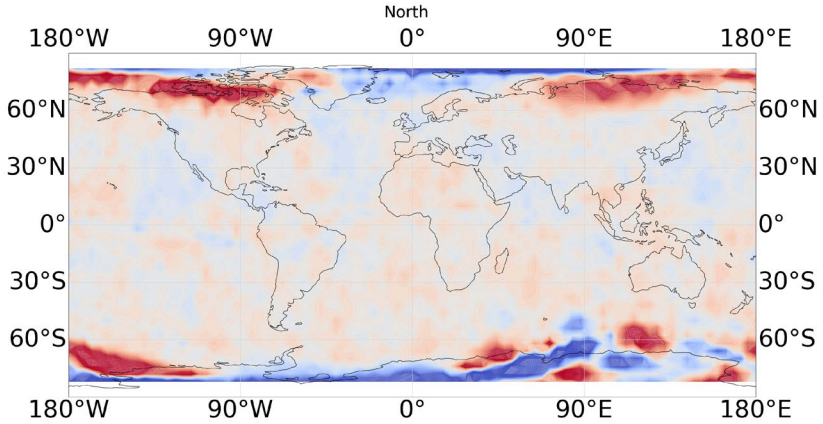
# GOCE

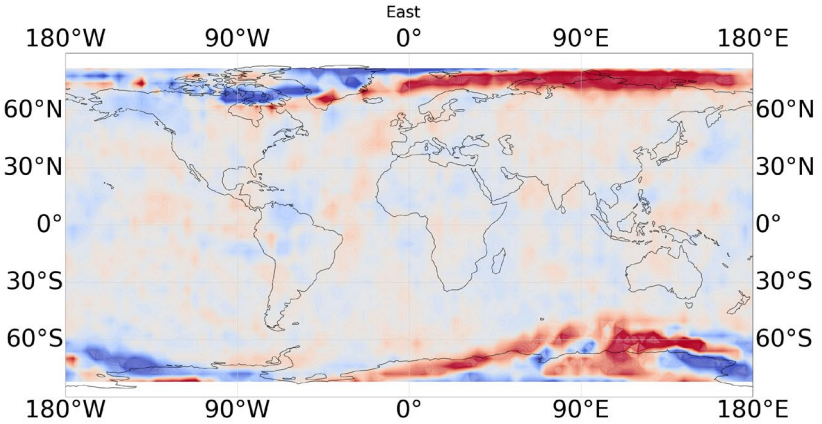
- Today we mainly focus on GOCE satellite
  - Similar approach applied to GRACE-FO satellite
- Gravity field and steady-state Ocean Circulation Explorer (GOCE)
  - Launched March 2009
  - Ended November 2013
  - 268km altitude
  - Very interesting due to high-precision satellite data gap
- After preprocessing
  - ~4.8mil. data points whole mission
  - ~975 features

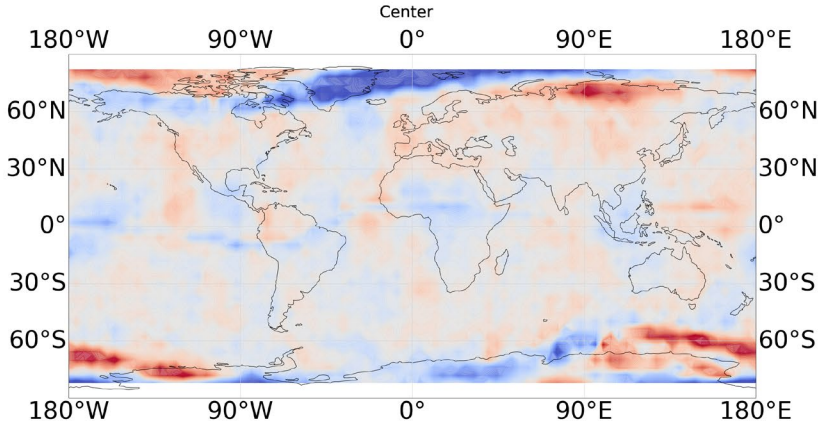
# Evaluation

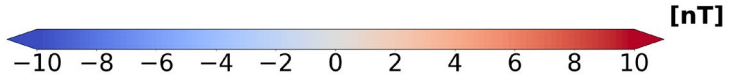
- Comparison to reference model CHAOS7
  - Low mean absolute residual of about 6.5nT for low- and mid-latitudes
- Validation of results for geophysical correctness
- Possible geophysical applications will be shown

# Difference: Calibration and CHAOS7

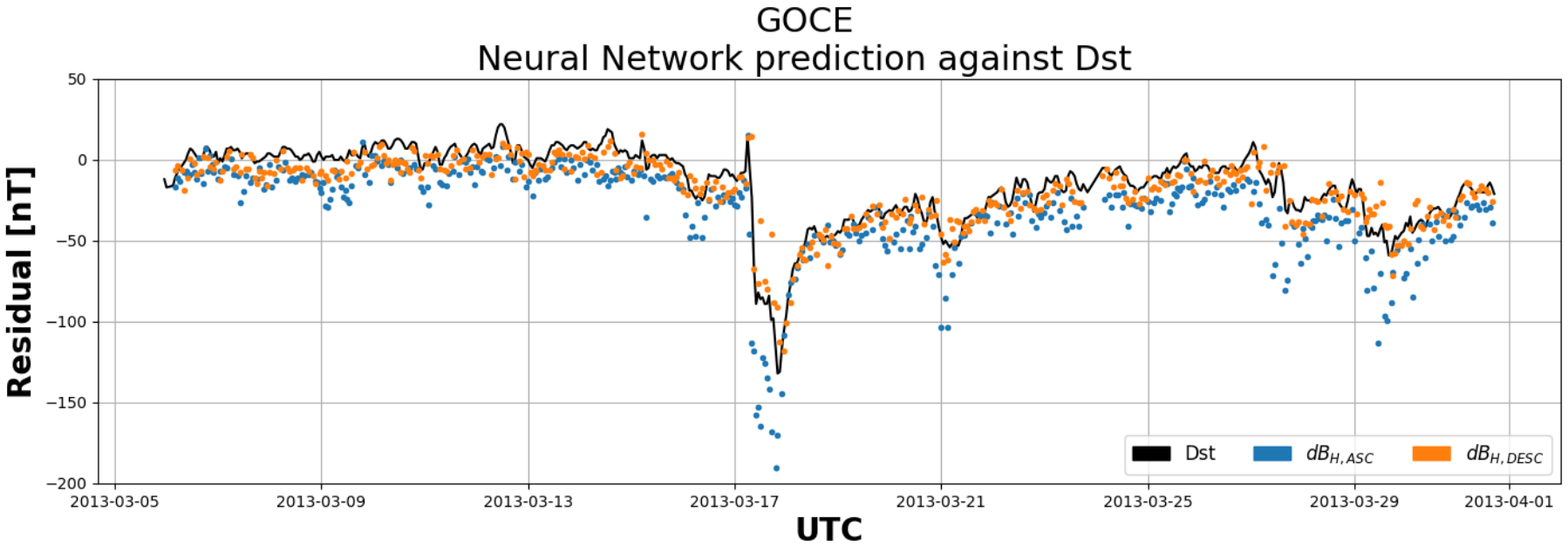


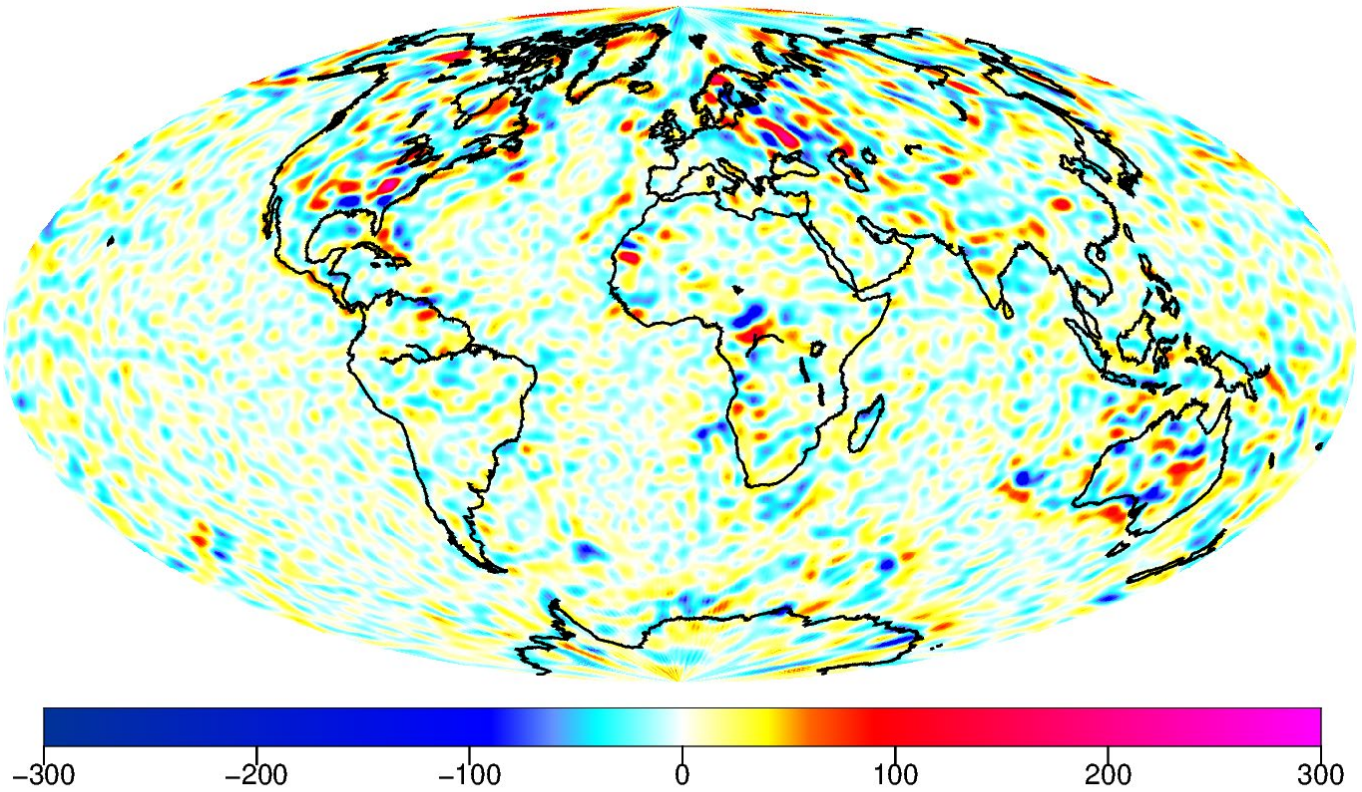



# Calibration Result during Magnetic Storm



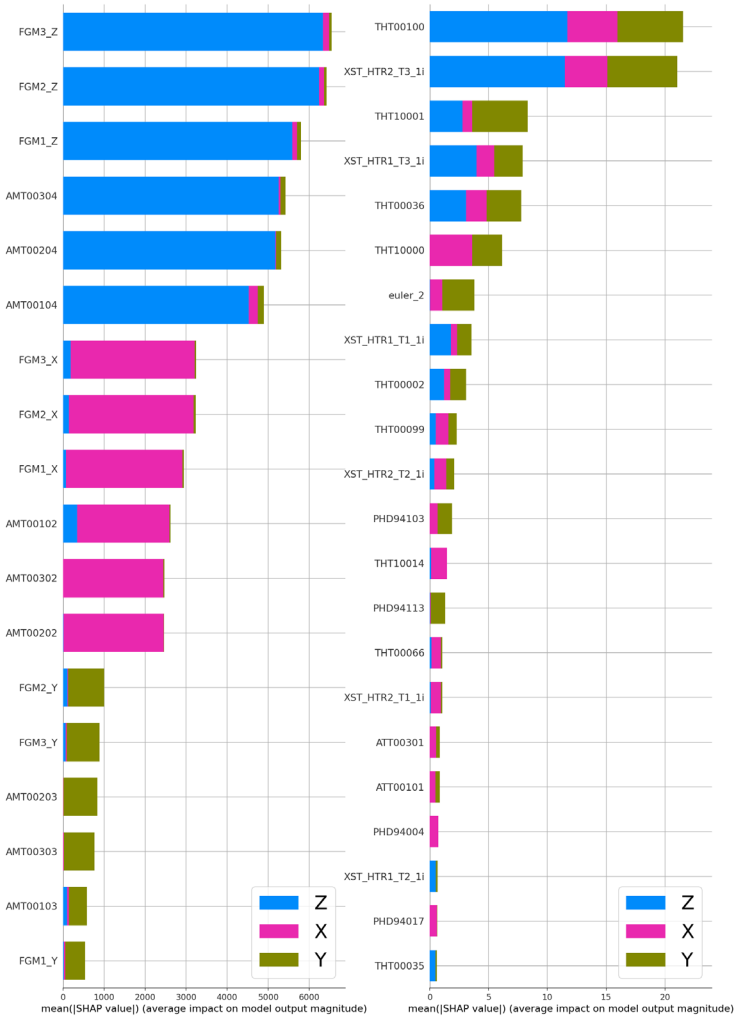
# Lithospheric Field Model derived from GOCE

Lithospheric field at the Earth's surface derived from calibrated GOCE data



# Feature Analysis

- Impact analysis using the SHAP method
  - Larger values imply larger contribution
- Most important are the magnetometers (left)
- Also valuable are temperatures, xenon tank heaters, some currents, and the magnetorquers (right)



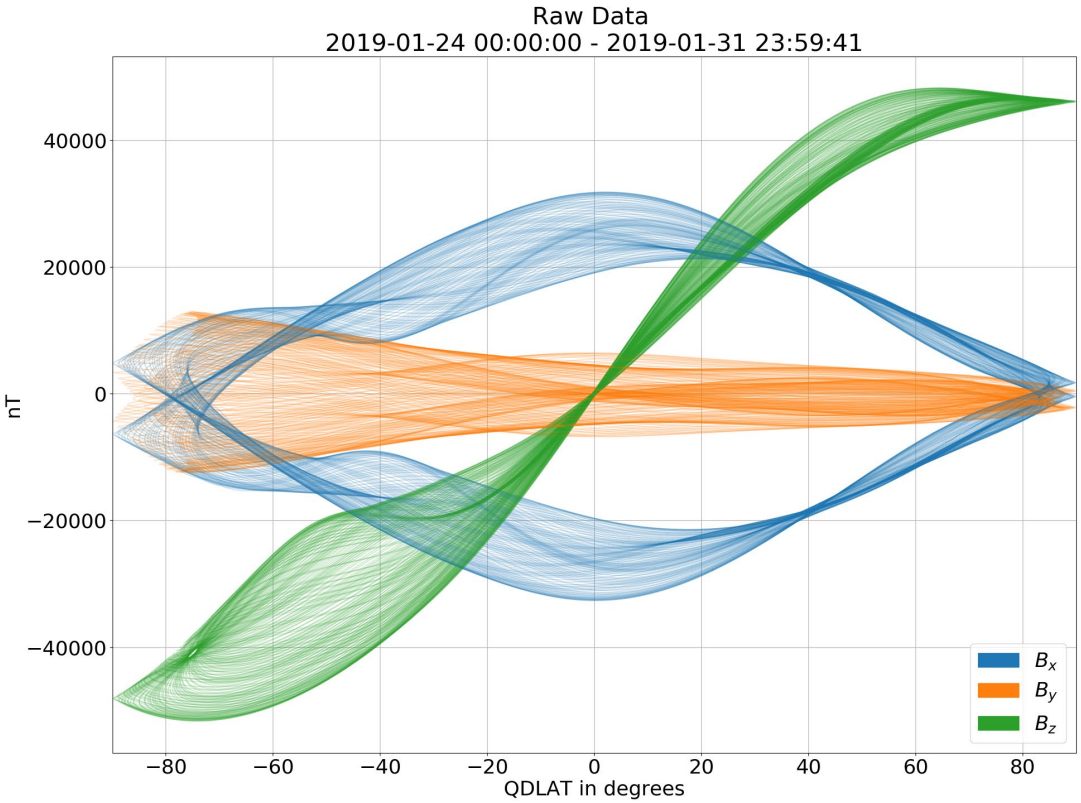
# Conclusion

- We achieved a low residual for the calibration
- Large-scale geophysical applications are possible
- The Swarm satellite enables a true swarm of satellite
  - The proposed approach is well applicable to other satellites

- Magnetic datasets from non-dedicated satellites are available
  - https://isdc.gfz-potsdam.de/platform-magnetometer/

# Backup

# Data Analysis



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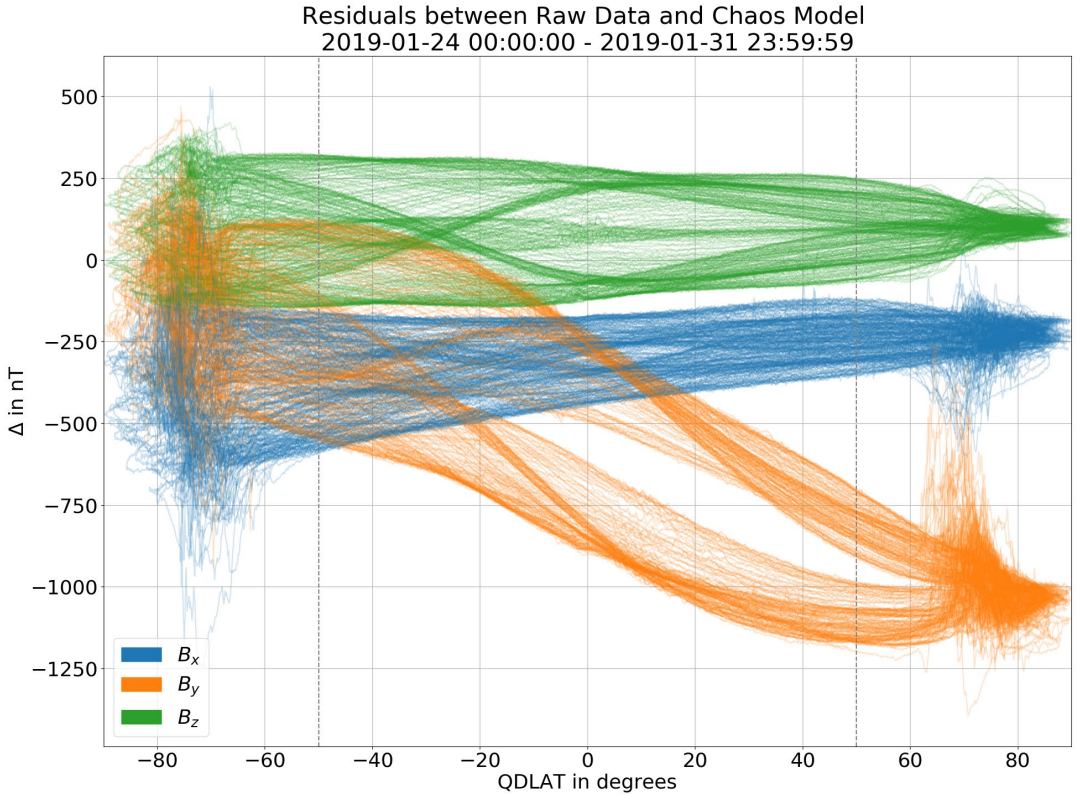
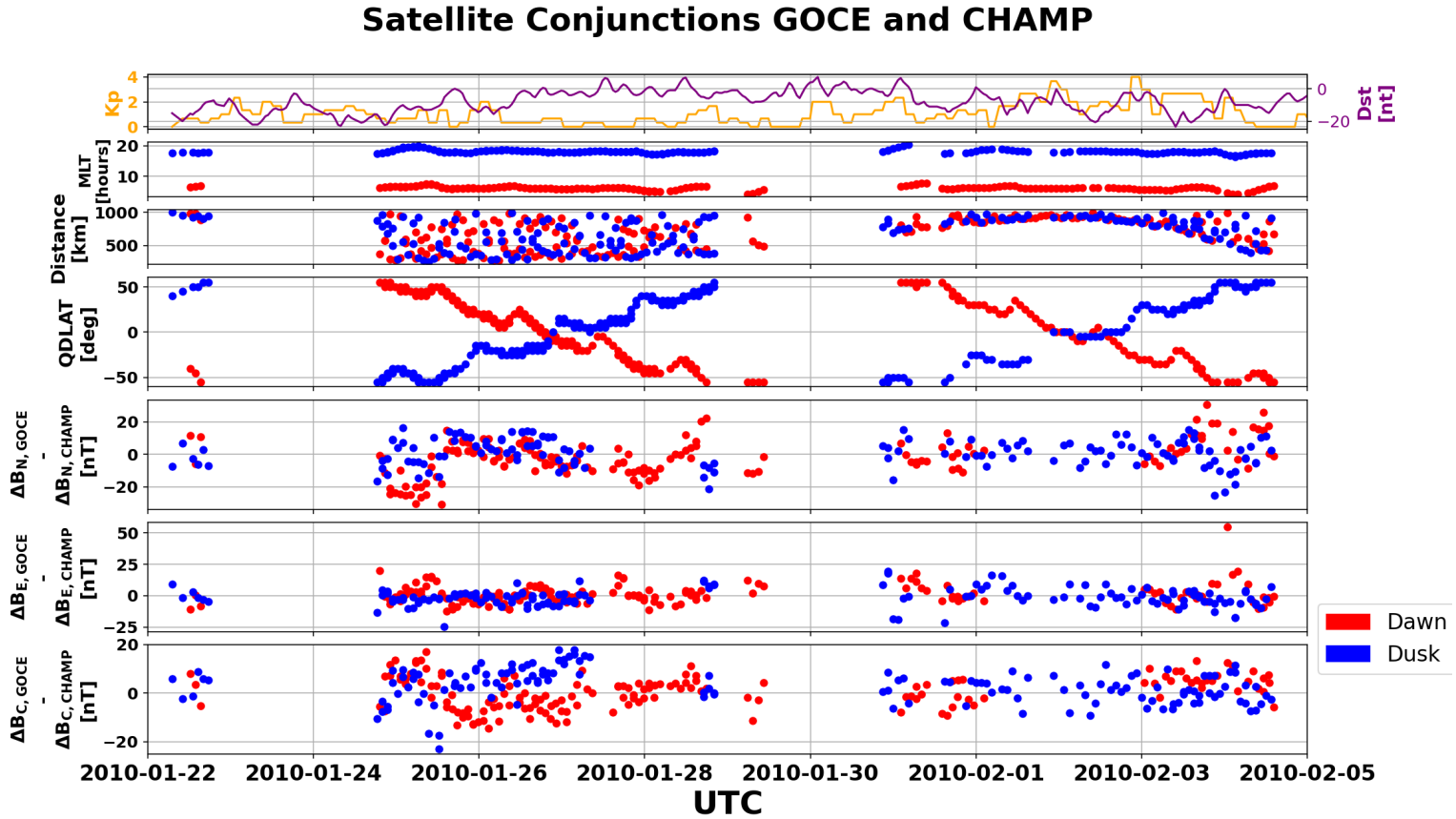


# CHAMP Conjunctions



# Comparison to Analytical Method