GOCE Gradiometer data and Ionospheric Dynamics

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Introduction

We examine the presence of residual non-gravitational signatures in gravitational gradients over the geomagnetic poles using the cross track gradient (V_{yy}), the trace of the gravitational gradient tensor (GGT) and external datasets. The external datasets consist of Equivalent Ionospheric Currents (EICS) and Spherical Elementary Current amplitudes (SECS) that are derived from terrestrial magnetic disturbance measurements and Canadian Ionosphere and Atmosphere Model (C-IAM) predictions.

The EICS and SECS are interpolated into the along track satellite position and they are used to calculate electromagnetic energy flow (Poynting flux-vector), whereas the predictions derived from the C-IAM are used for understanding the variations of the ionospheric dynamics during quiet and storm periods. We found that the disturbances are highly correlated with the Poynting vector which also includes the information of intense ionospheric dynamics that occur during magnetic storms.

We develop a dynamic input-output system using Poynting vector (input) and GGT trace (output) to determine their relationship via a data-driven impulse-response model. This model is applied to 954 GOCE ascending tracks (March-April, 2011) to predict the output of the dynamic system and correct the EGG disturbances.

Analyses

Differences with the ITGS-Grace2014k model

GOCE EGG measured gradients are compared with the GRACE satellite-only model computed gradients at satellite altitude for specific bandwidth interval (180-300s).

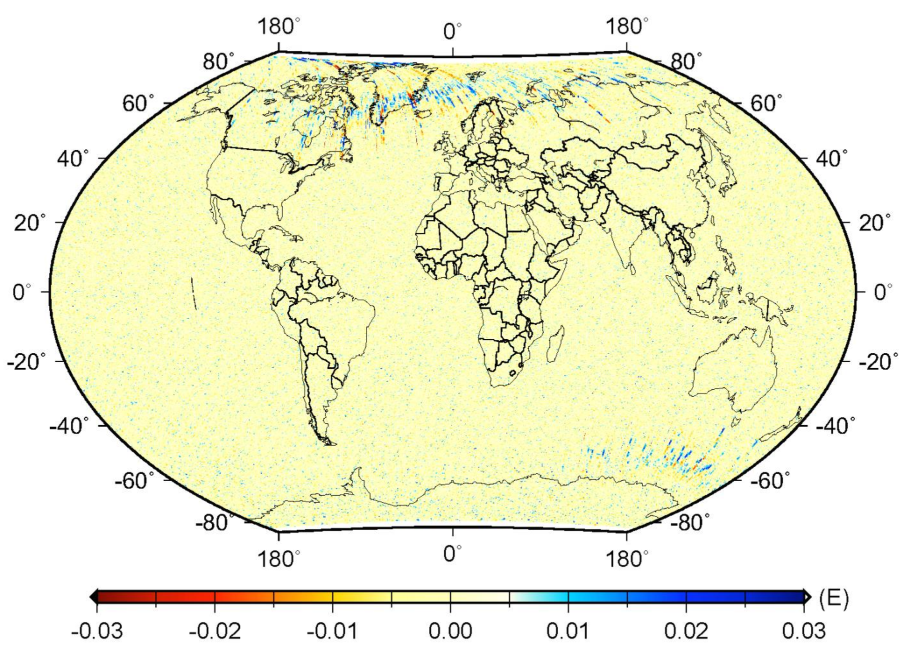


Fig. 1: GOCE cross-track gravitational gradients are compared with the ITGS-Grace2014k calculated gradients. The model is expanded up to shd 200 and V_{yy} both from the model and GOCE measurements are filtered into the same frequency band (180-300). Note the bandwidth is NOT the optimum EGG bandwidth (10-200s).

The larger differences over the geomagnetic poles hint the errors that are due to the V_{yy} measured by GOCE EGG.

Equivalent Ionospheric Currents (EICS)

EICS, horizontal currents and SECS, vertical currents are used to understand the satellite environment. The gridded data (Weygand, 2011) are interpolated into the satellite position and epoch and correlation analyses are performed along the satellite track.

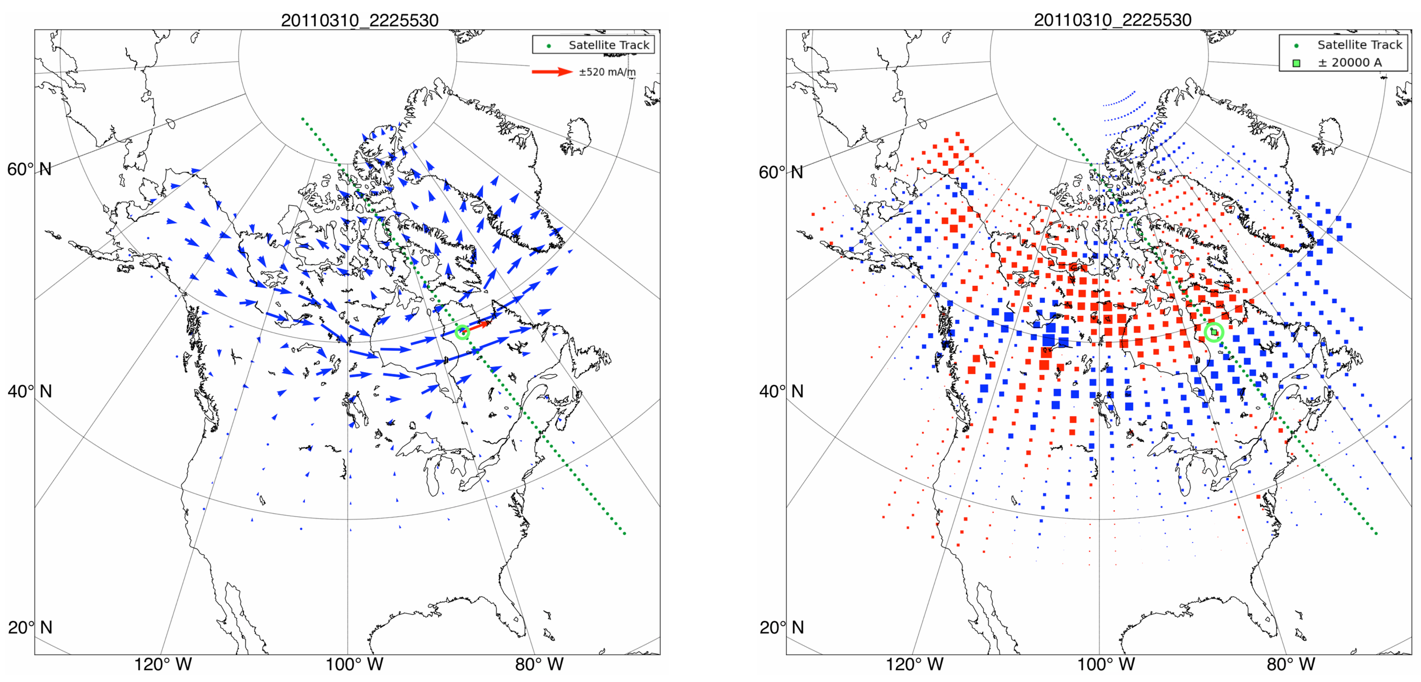


Fig. 2: Example of EICS (left) and SECS (right) that are measured at 22:55:30 on March 10th, 2011. Note the larger east-west current and negative to positive variation at the satellite's position.

C-IAM Predictions

C-IAM electric potential predictions are used to examine the enhancement of the ionospheric dynamics during magnetic storms. The Canadian SuperDARN data and Kp index are used in the simulations (Martynenko, 2014).

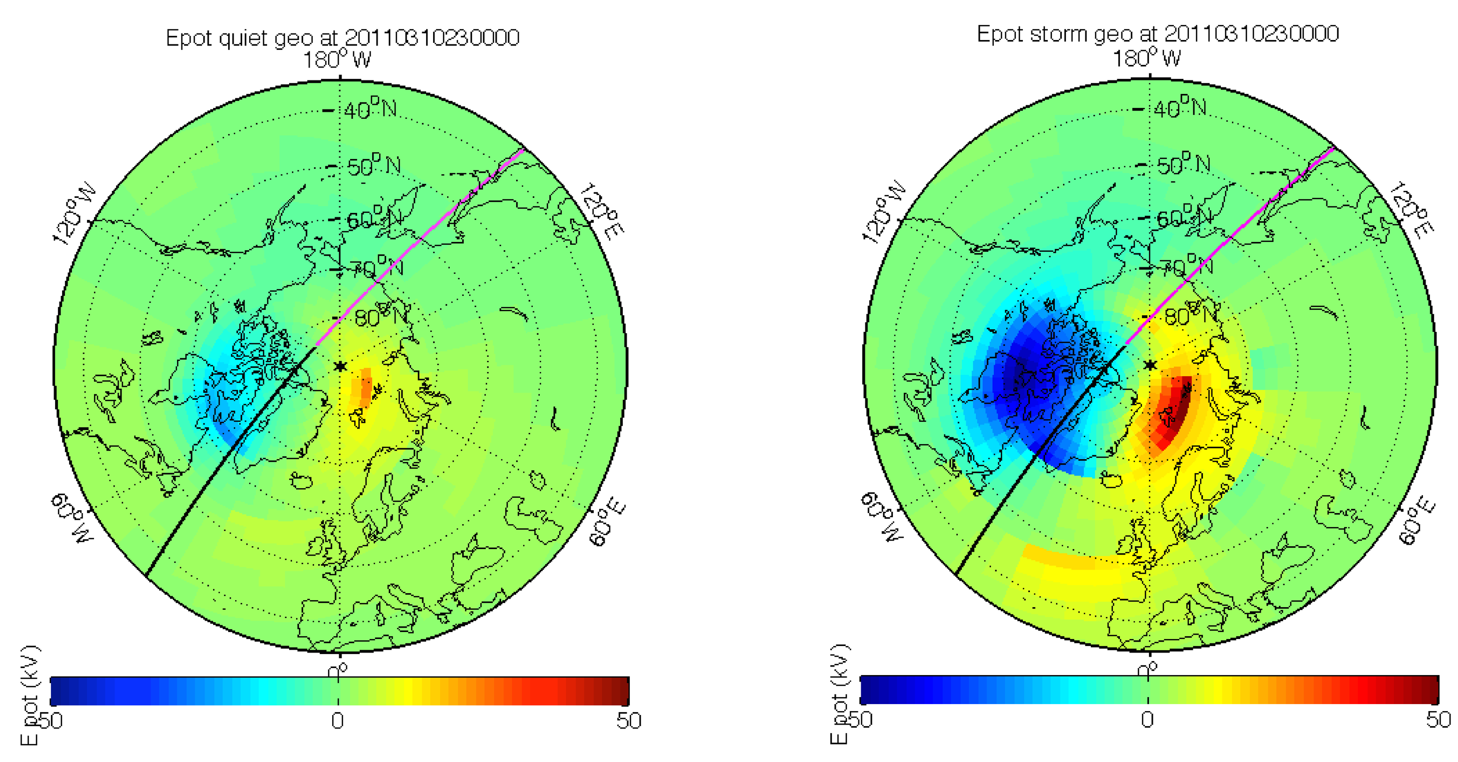


Fig. 3: Electric potential for quiet (left) and storm (right) period for March 10th, 23:00:00 UTC. Note the enhancement over Northern Canada and Southern Greenland during storm period. The satellite passes over a negative potential during evening time (black-ascending track) and a positive electric potential region during morning time (magenta-descending).

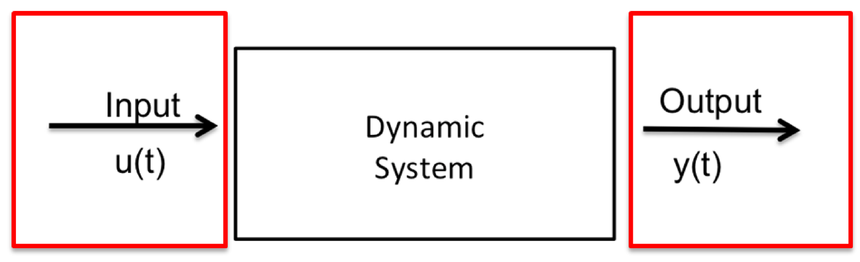
Method

Impulse Response Method

The input-output dynamic system approach is used in our analysis in which an input signal (Poynting vector) is introduced to linear/non-linear dynamic system and an output signal (EGG disturbances) is produced based on the response of the system.

The causality of the Poynting vector and GOCE EGG disturbances is NOT known. Therefore, our system is a black-box model. Starting with a linear approach is acceptable and external sources other than ionospheric dynamics, e.g., instrumental and calibration errors are NOT considered as inputs to the system.

We assume that the only input that contributes the EGG disturbances is the ionospheric dynamics.



$$H(s) = \frac{Y(s)}{U(s)}$$

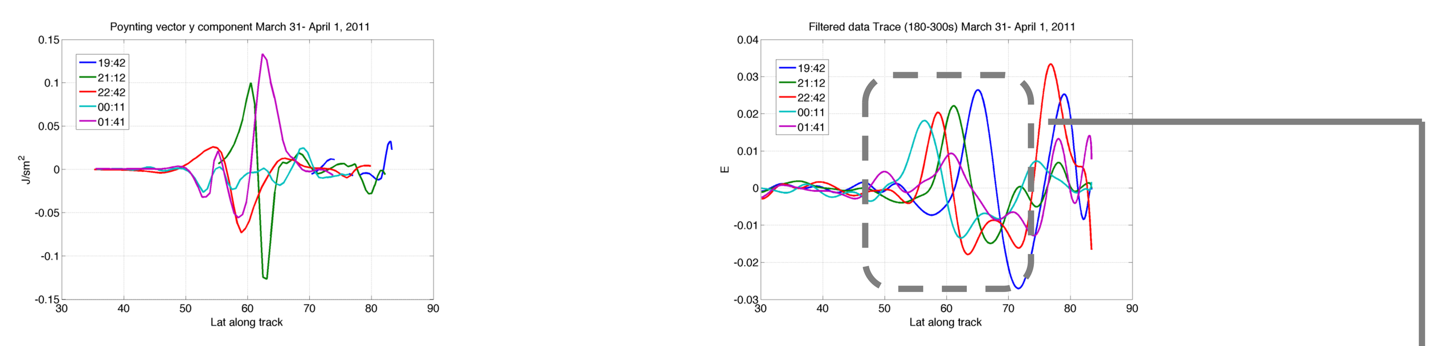


Fig. 4: Representation of an input-output dynamic system. The input of our system is Poynting vector, whereas the output is the GGT trace. H(s) is predicted empirically using input-output information.

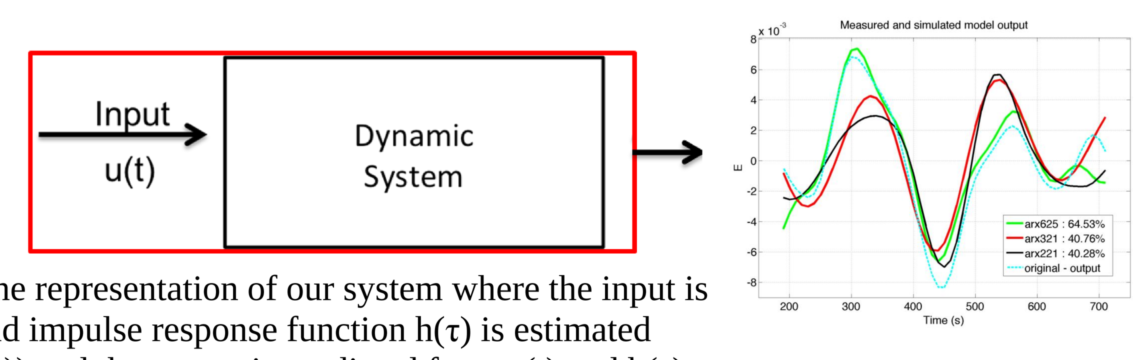
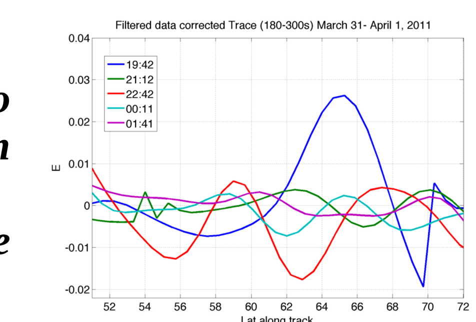


Fig. 5: The representation of our system where the input is known and impulse response function h(τ) is estimated (from H(s)) and the output is predicted from u(t) and h(τ). ARX model of sixth order is applied in our analysis.

The estimated model is applied to 954 tracks to estimate the EGG disturbances and remove them from the original trace.
The residual trace is within the noise level of the instrument.



Results

The trace obtained from filtered series is downsampled (10s) to the EICS sampling rate. The model is applied to the downsampled data and the trace is eliminated from the effect coming from the ionospheric dynamics.

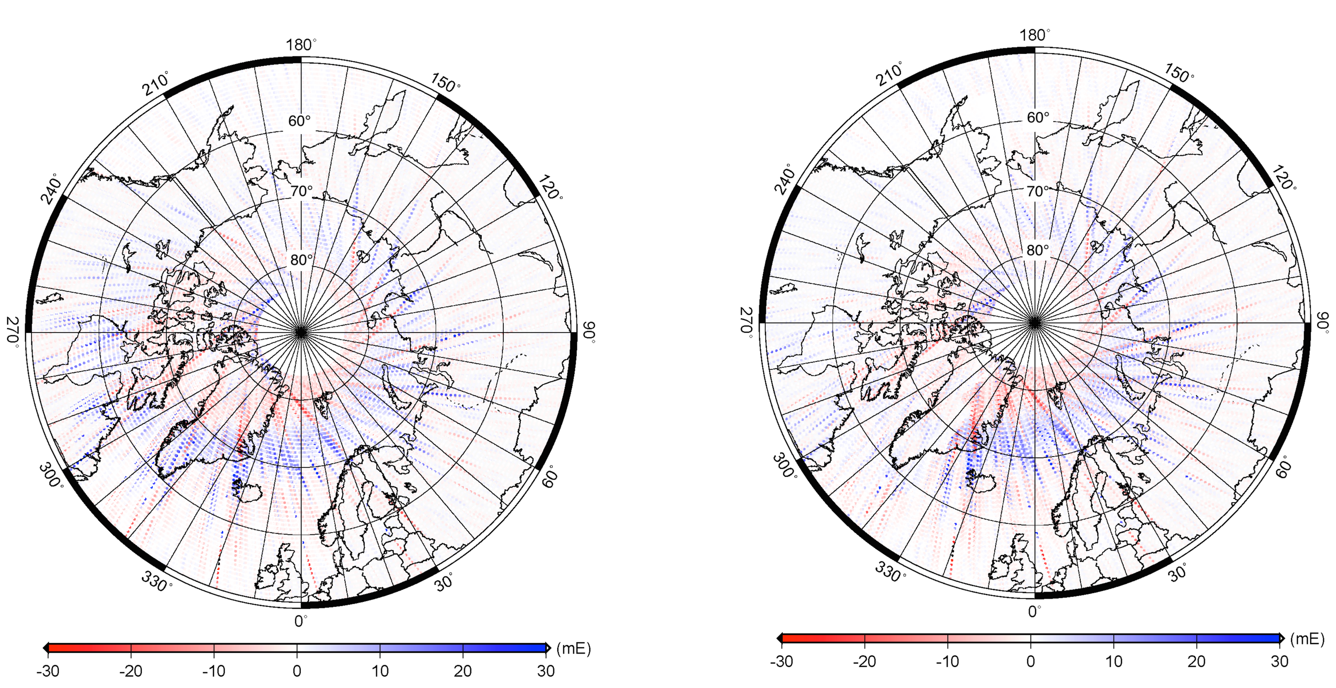


Fig.6: Trace obtained from filtered GGT diagonal components interpolated into 10s interval (left) and corrected trace by using the ARX model (right), for March-April 2011. Note the improvement over Canada and western Greenland.

Conclusions

- This study is the first to demonstrate the causality between the disturbances observed in GOCE measurements and ionospheric dynamics over the geomagnetic poles.
- We demonstrate that intense dynamics in the satellite environment degrade the quality of the GOCE EGG gravity products.
- We predict the disturbances by using external datasets and a data-driven impulse-response model to correct the GGT trace.

*We also showed that the accelerometers are capable of measuring the variations in the ionosphere and their use at low orbits is useful for ionospheric modelling.

Bibliography

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1st Joint Commission 2 and IGFS Meeting International Symposium on Gravity, Geoid and Height Systems 2016, September 19-23 2016, Thessaloniki, Greece