Improving the ionospheric state estimate during geomagnetic storm time through assimilation of neutral density data

EGU 2022 – G5.1 Ionosphere, thermosphere and space weather: monitoring and modelling.

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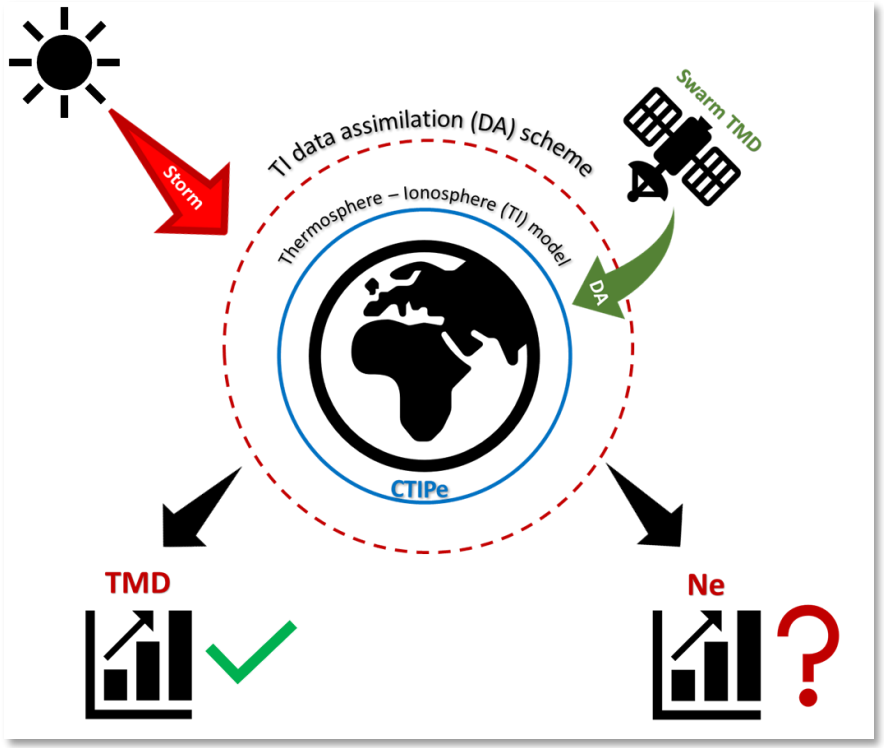
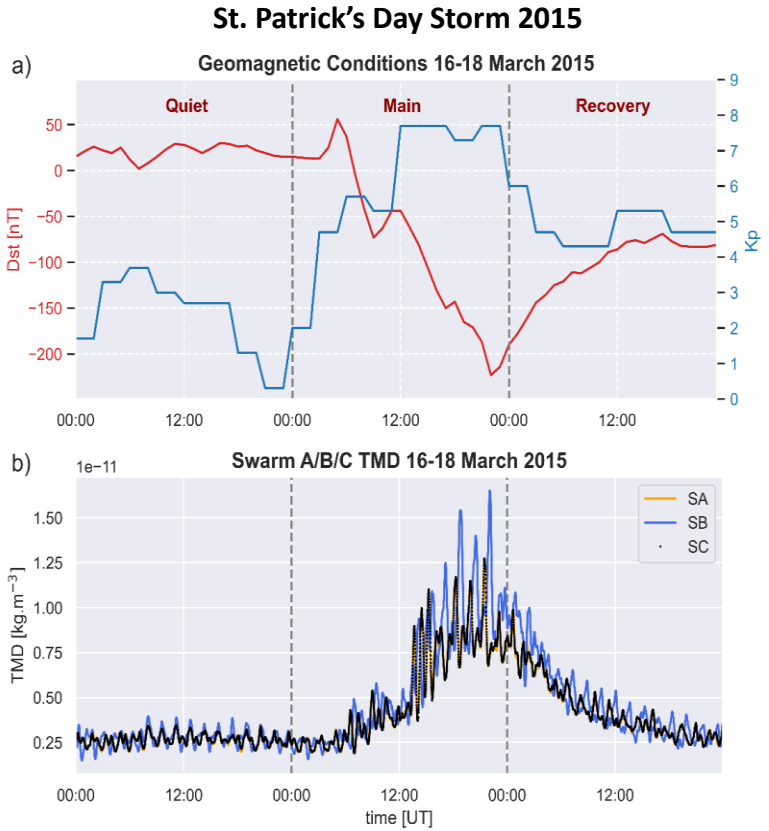
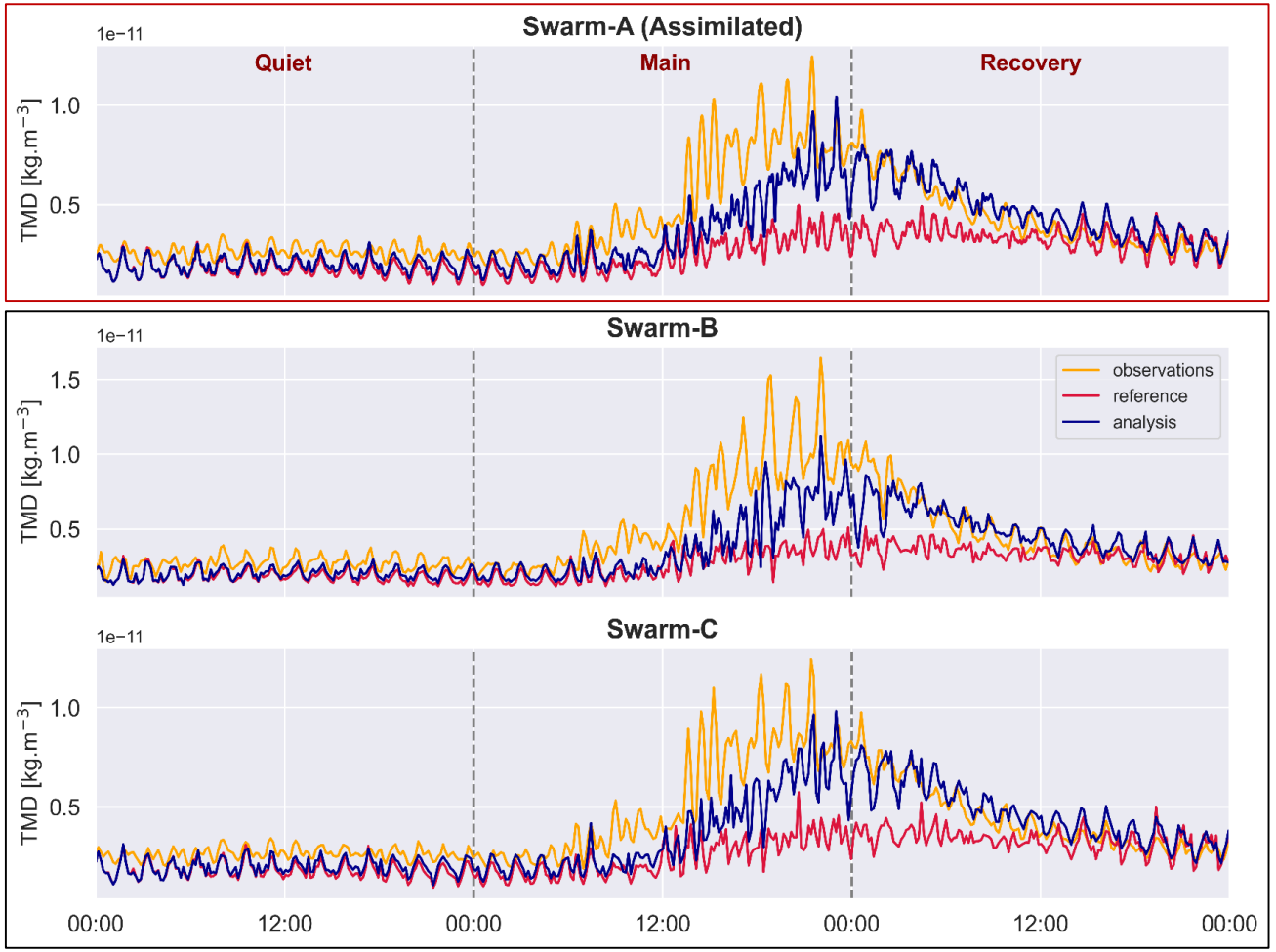
Can we improve electron density by assimilating neutral density during storm conditions?





- **Assimilated data**: Swarm – A TMD observations normalized to the common altitude of 400 km.
- **Period:** 16-19 March 2015 containing St. Patrick's Day storm
- Days are classified are quiet (16), main phase (17) and recovery (18)
- **State vector**: Updates the forcing parameters and the necessary quantities to calculate neutral density.
- **Assimilation window**: 10 minutes
- TMD uncertainty is 10%

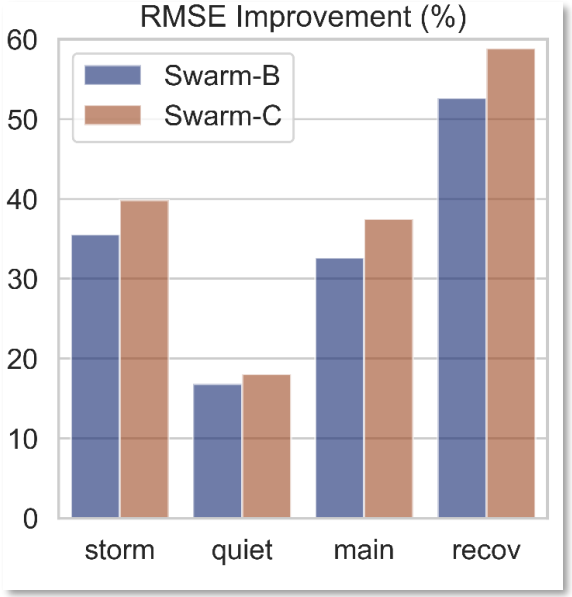
What happens on the thermosphere? Neutral density



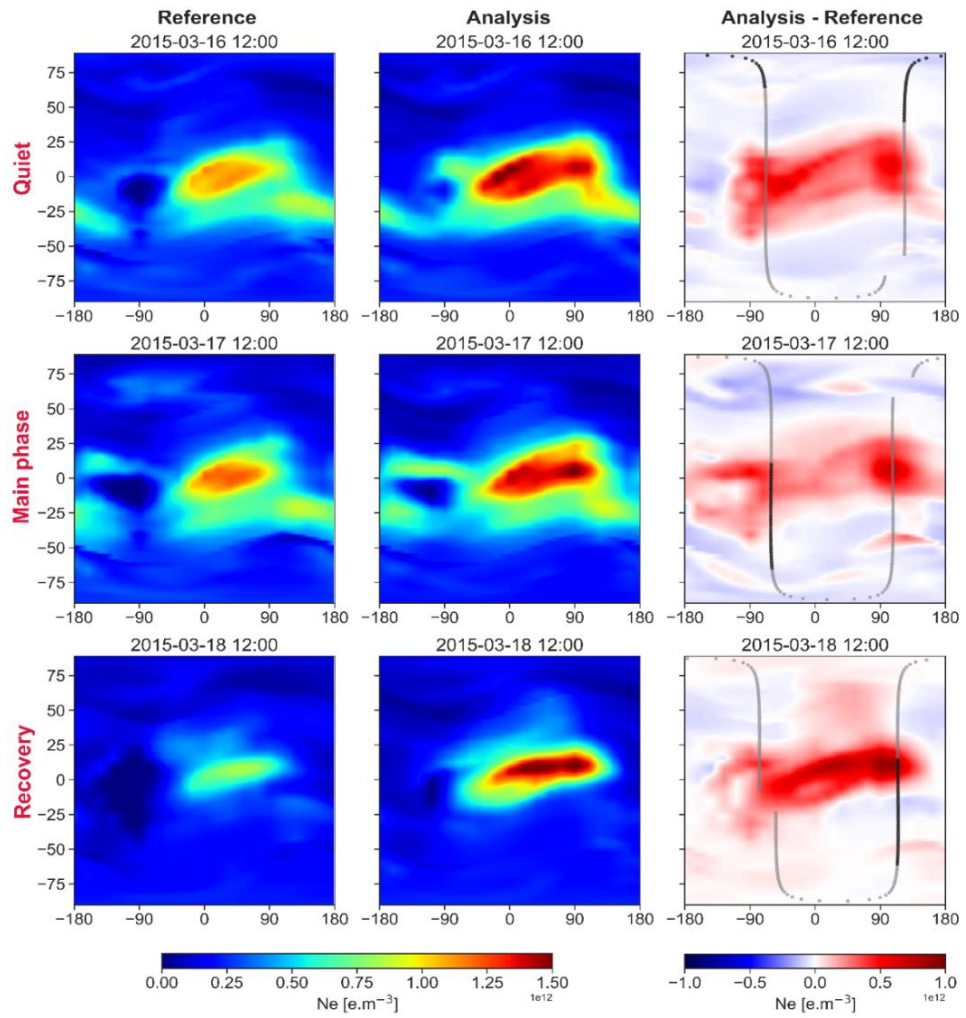
Swarm – B/C TMD along the orbit RMSE improvement

$$\mathrm{RMSE} = \sqrt{\frac{\Sigma(\mathrm{Obs} - \mathrm{Mod})^2}{\mathrm{N}}}$$

$$\mathrm{IMP}(\%) = \frac{(\mathrm{RMSE}_r - \mathrm{RMSE}_a)}{\mathrm{RMSE}_r} 100$$



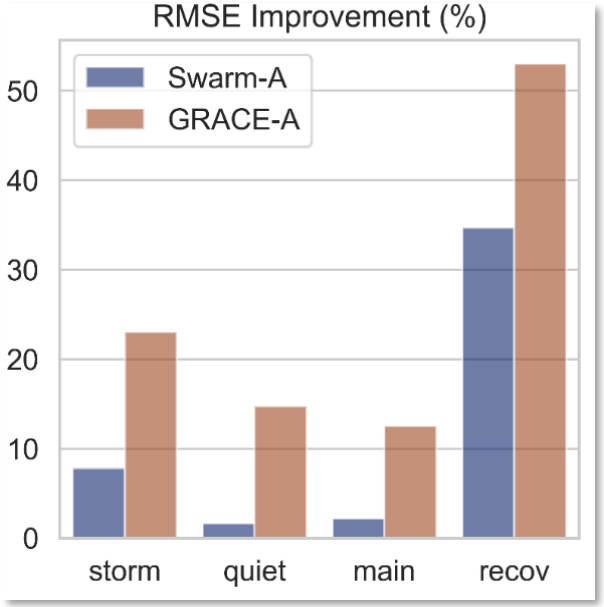
What happens on the ionosphere? Electron density (400 km)



Swarm – A / GRACE Ne along the orbit RMSE improvement

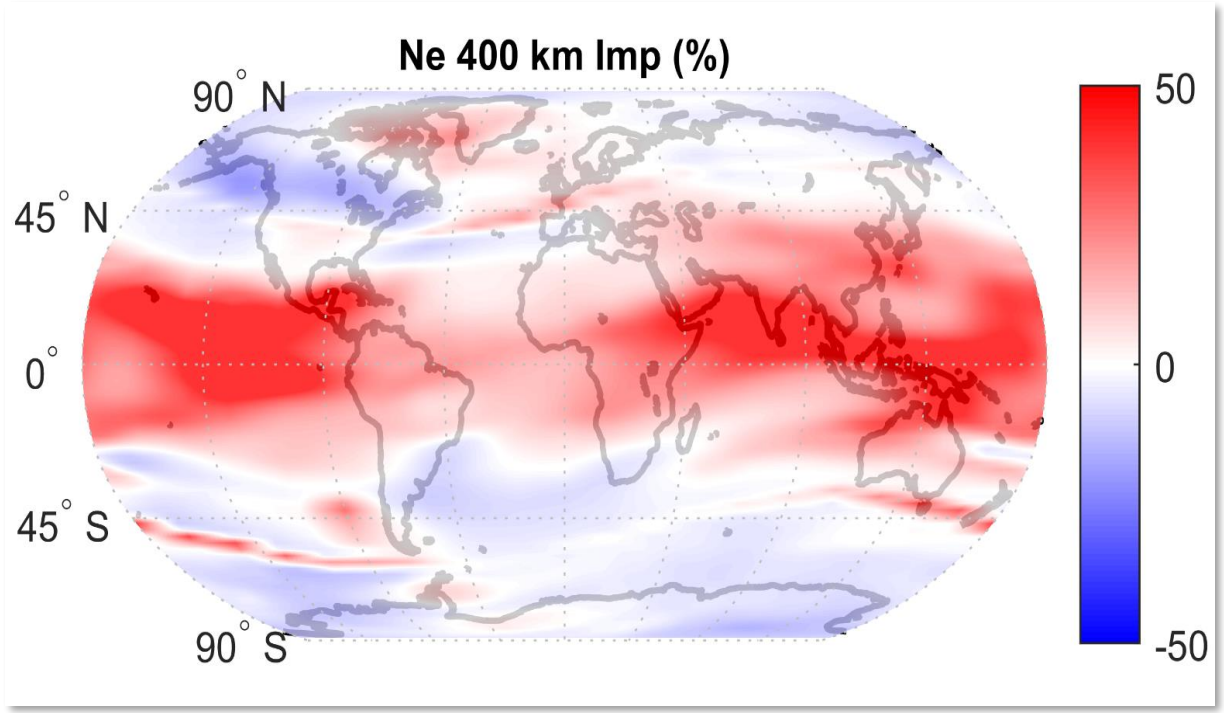
$$\mathrm{RMSE} = \sqrt{\frac{\Sigma(\mathrm{Obs} - \mathrm{Mod})^2}{\mathrm{N}}}$$

$$\mathrm{IMP}(\%) = \frac{(\mathrm{RMSE}_r - \mathrm{RMSE}_a)}{\mathrm{RMSE}_r} 100$$



What happens on the ionosphere? Global Electron density improvement

- **Electron density global improvement** at 400 km between analysis and reference with respect to the **B-Spline electron density model**.
- For the three days of the storm
- Lower RMSE → Better fit of the model to observations
- Improvement (%) of RMSE of the analysis and reference differences.
- Positive values are **areas of improvement** (red)
- The main area of improvement is around the **equatorial region** (-45, 45) deg latitude.
- The **effect depends on altitude**. The positive improvement decreases for altitudes higher than 600 km.



$$\mathrm{IMP}(\%) = \frac{(\mathrm{RMSE}_r - \mathrm{RMSE}_a)}{\mathrm{RMSE}_r} 100$$

Summary

- **Assimilation of neutral density** measurements into a physics-based model **during storm conditions** in capable of **correct the thermosphere and the ionosphere** (with limitations).
  - Neutral density improves along the orbit of the non assimilated Swarm – B/C satellites up to 40%
  - Electron density difference maps (analysis – reference) show the effects of TMD DA
  - Electron density improvement along the orbit of Swarm-A and GRACE are 8% and 22% respectively.
  - The **global electron density improvement** map shows the areas affected by TMD assimilation.
  - The **largest improvement in the electron density** estimates takes place during the **recovery phase** (negative storm driven by composition changes)

Dynamic Earth Special Issue (In review)
"Improving estimates of the ionosphere during geomagnetic storm conditions through assimilation of thermospheric mass density"
I. Fernandez-Gomez, T. Kodikara, C. Borries, E. Forootan, A. Goss, M. Schmidt and M. Codrescu
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