The impact of severe storms on forecasting the thermosphere – ionosphere system trough the assimilation of SWARM – derived neutral mass density into physics-based models

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DLR

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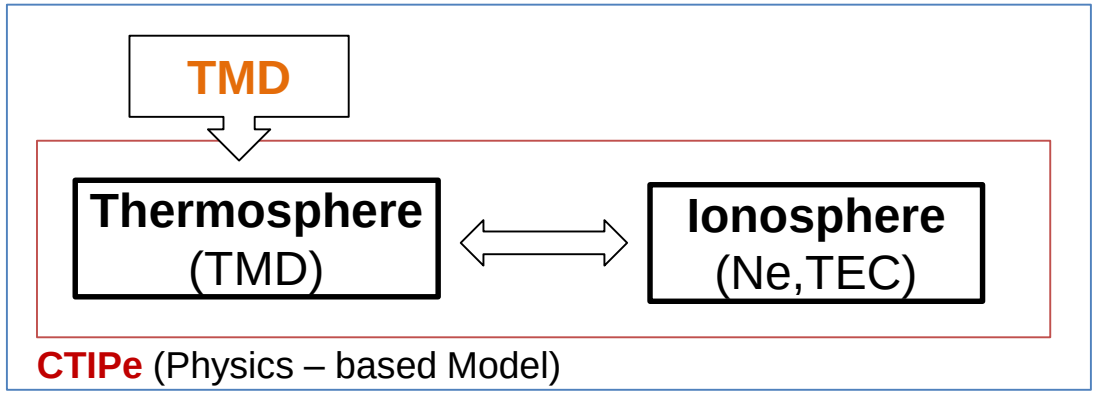
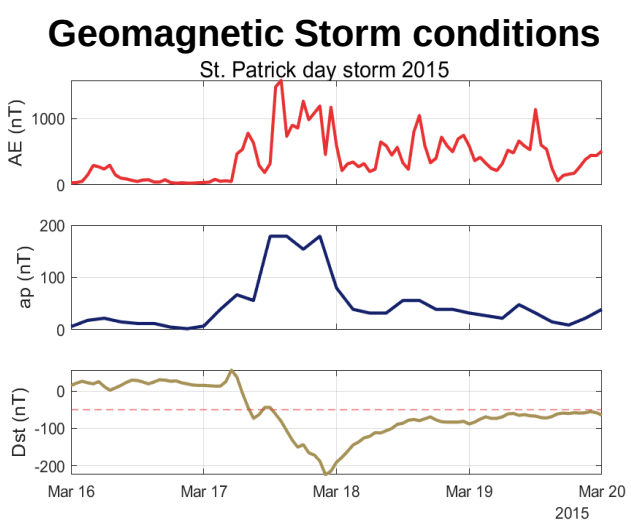
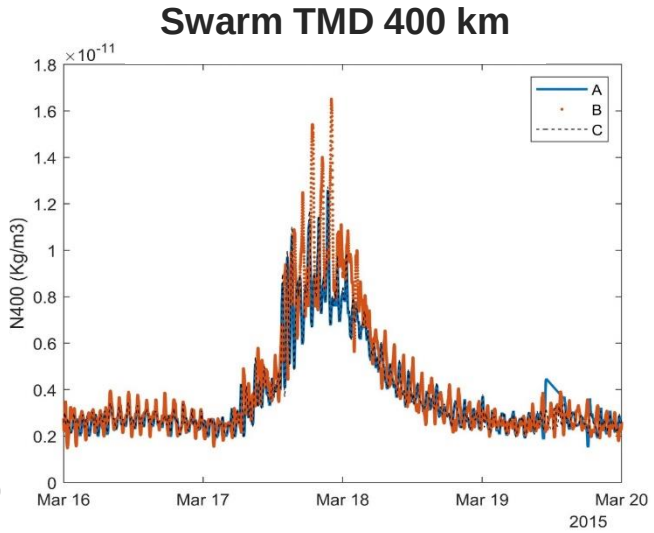


TIDA (Thermosphere Ionosphere Data Assimilation scheme)

Objective

- **Thermosphere – Ionosphere** (TI) system response to **storm conditions**.
- **Assimilate Thermospheric Mass Density** (TMD) derived from SWARM satellites into **physics – based model** CTIPe.
- Assimilating thermospheric parameters will improve the thermosphere, but **what happens in the ionosphere?**





What did we found out?

- TMD assimilation has a direct **impact on the thermosphere** with an average **improvement of a 36%** with respect the reference run (CTIPe model).
- The **effect on the Ionosphere** is more localize to the European – African sector, **improving the TEC estimation up to 50%.**

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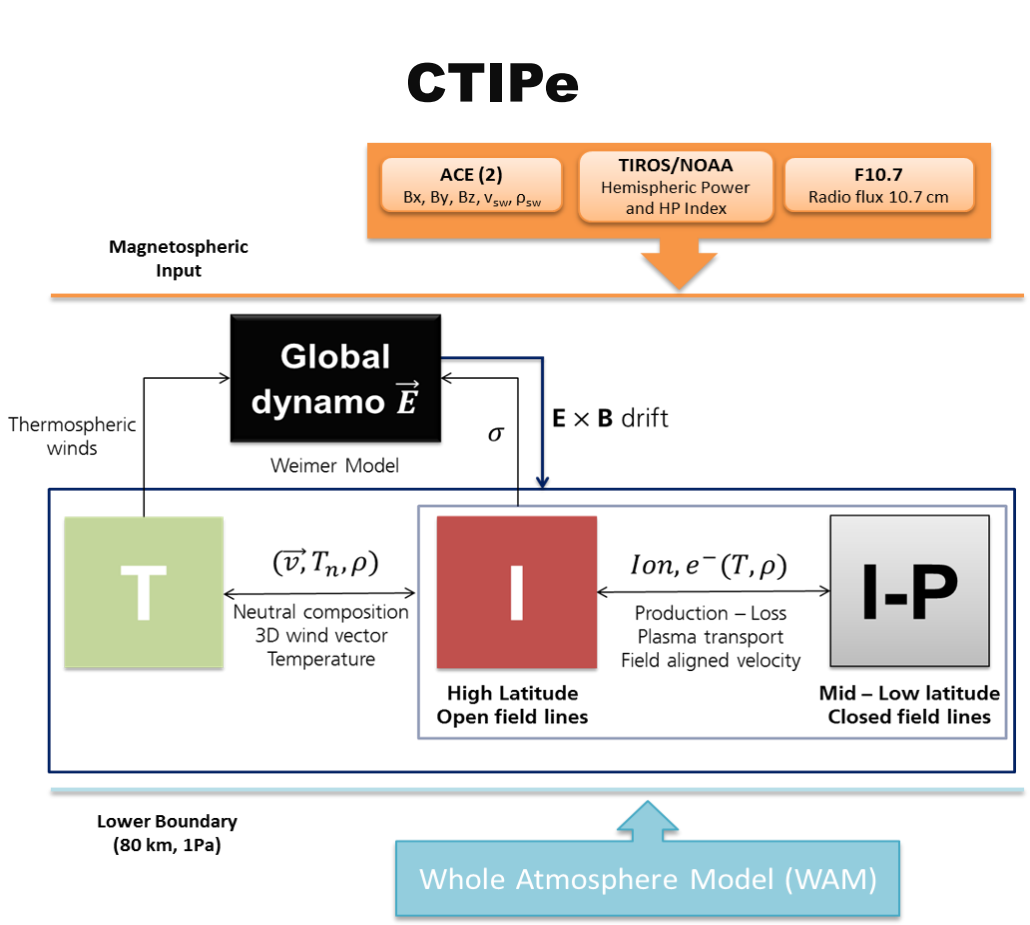
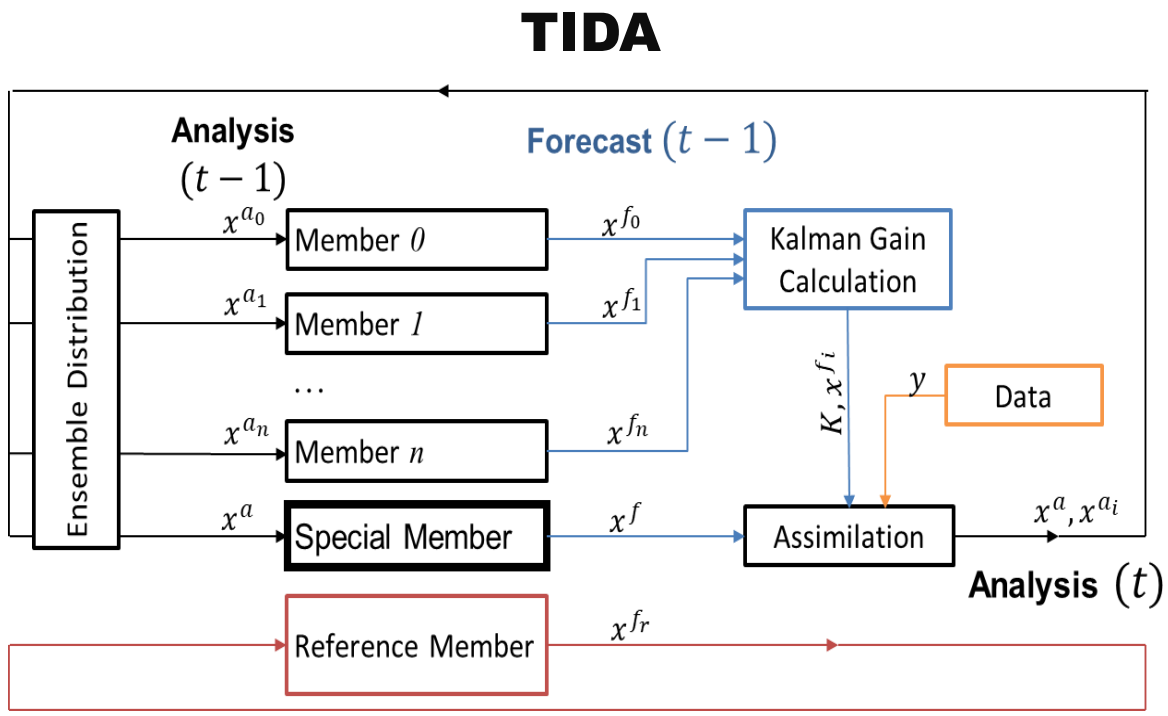
CTIPe model + TIDA data assimilation scheme

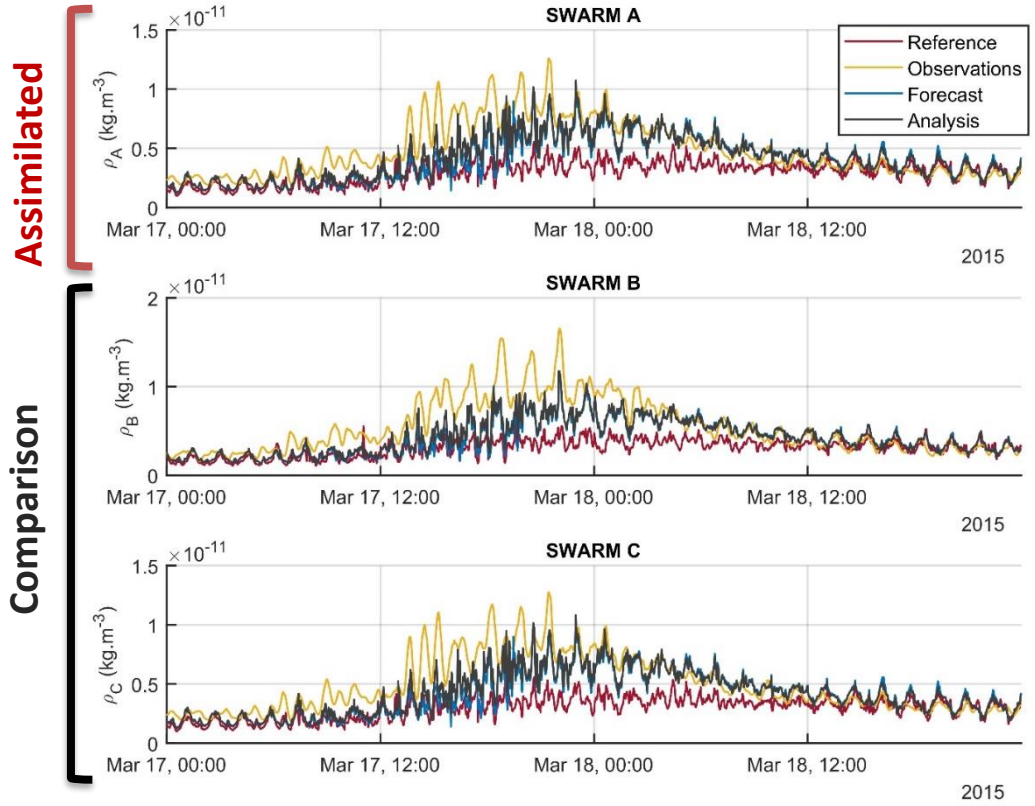




State Vector $x = \begin{bmatrix} model\ forcing \\ model\ state \end{bmatrix}$ → $x^a = x^f + K(y - h(x^f))$, $y^f = h(x^f)$ KF update equation

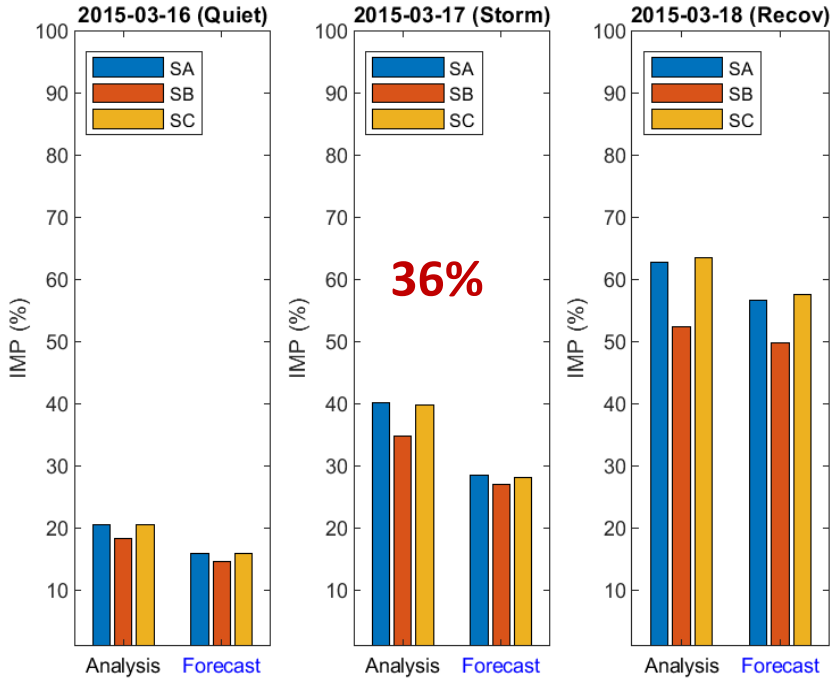
$$x = \{F_{10.7}, |v_{sw}|, \rho_{sw}, B_N, B_\theta, T_n, \gamma_O, \gamma_{O_2}, \gamma_{N_2}, M, U, V\}$$

Impact in the Thermosphere

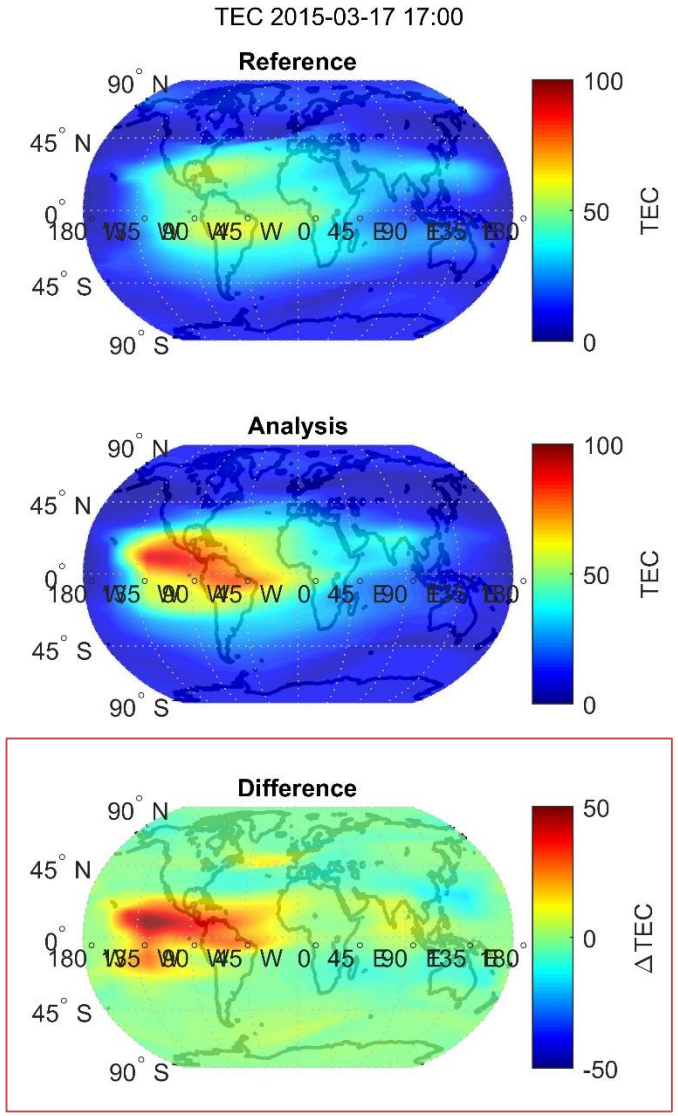


$$\mathbf{IMP}(\%) = \frac{\mathrm{RMSE(ref)} - \mathrm{RMSE(analysis)}}{\mathrm{RMSE(ref)}} x\ 100$$

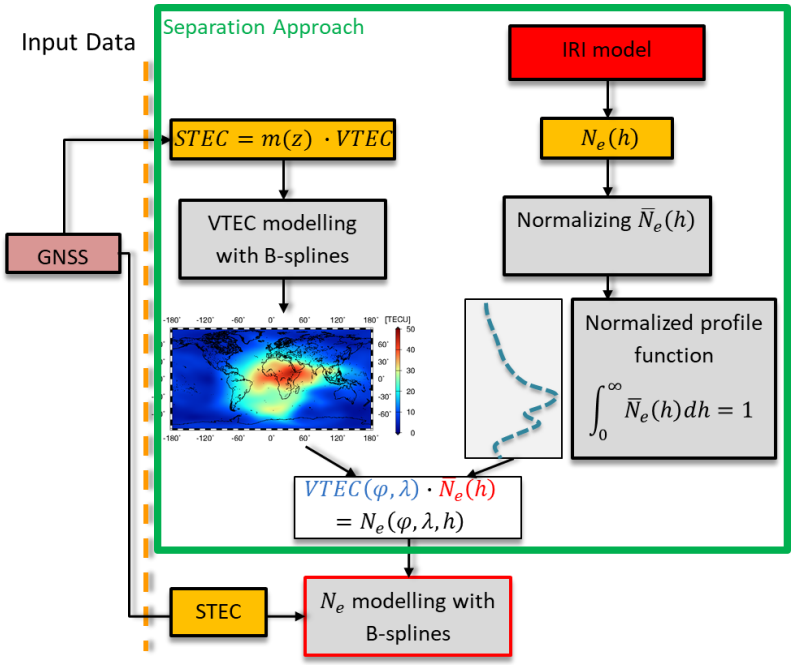
- In the experiment SwarmA-400km is assimilated, and compared to B and C satellites.
- TMD **observations** are compared to **reference**, **forecast** and **analysis** estimations, where:
  - **Reference** is the background model run with no assimilation
  - **Forecast** is the first guess or prior state estimate
  - **Analysis** is the estimation with all the observations
- Average **TMD improvement of 36%**

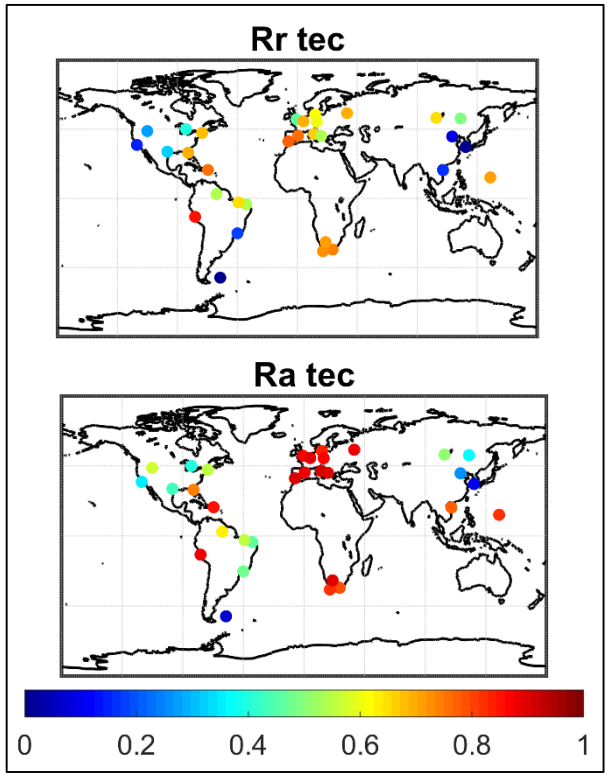


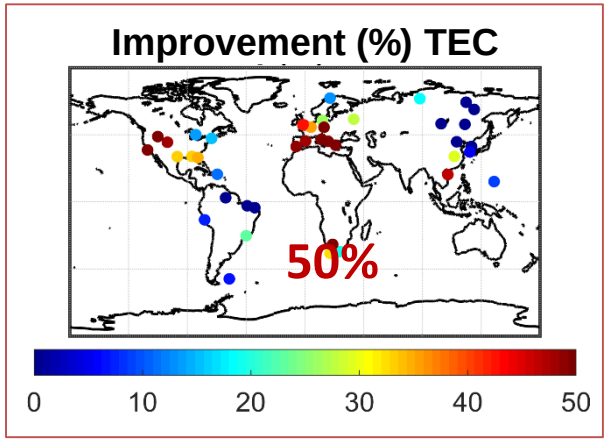
Impact in the Ionosphere



- Differences between **reference** run and **analysis** state **Total Electron Content** (TEC) show the impact of TMD assimilation in the ionosphere.
- Comparison with TEC obtained from the **B-Spline Electron Density Model (TUM)** quantifies the improvement in the Ionosphere.
- European – African sector TEC **improvement of 50%.**



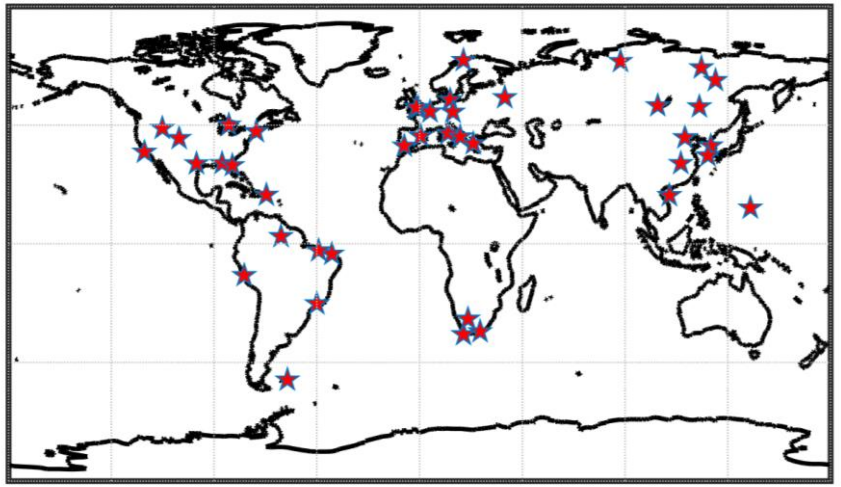




Validation with measurements (IGS TEC and Ionosonde fof2)

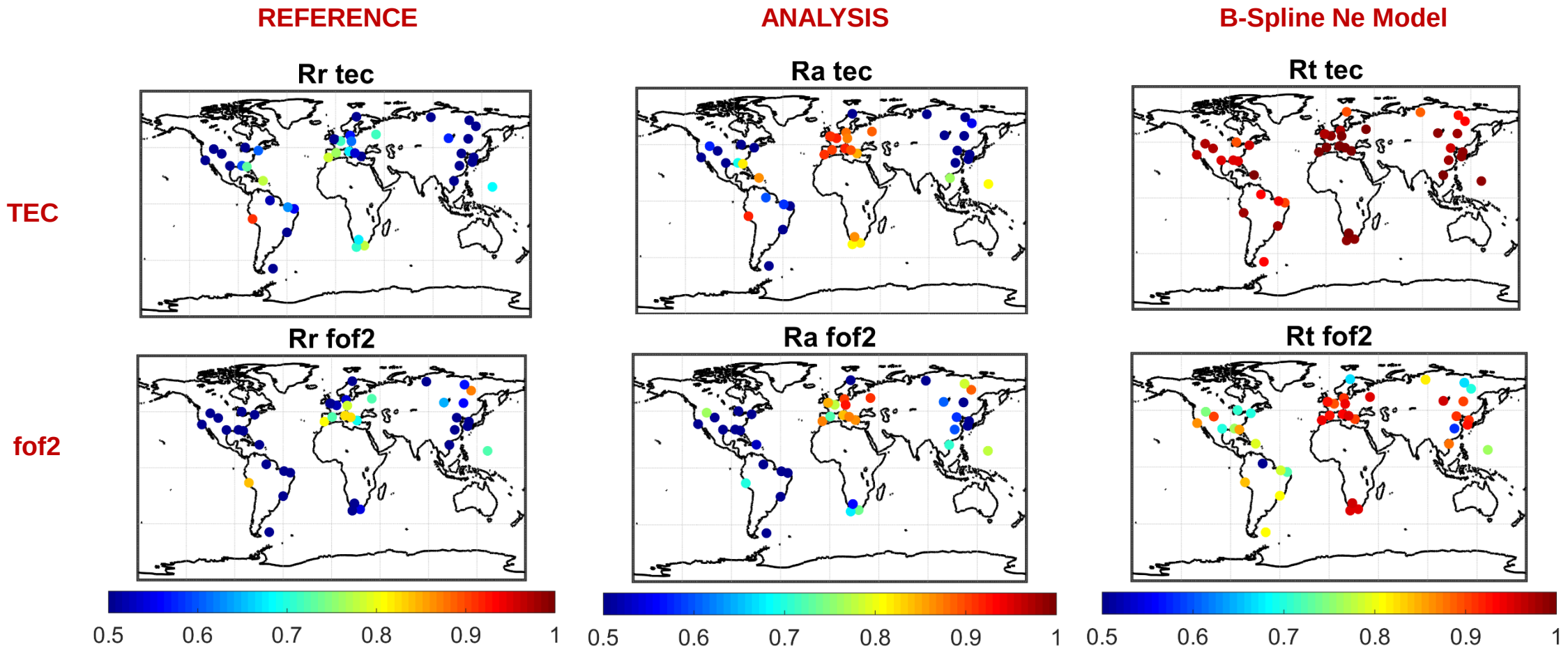
- **Total Electron Content (TEC):** Global Navigation Satellite Systems (GNSS) measurements are used to determine the total number of electrons along a path between the receiver and radio transmitter and generate Total Electron Contents (TEC) maps. As TEC maps effectively describe the average behaviour of the ionosphere, in this study, GNSS based TEC data provided by the International GNSS Service (IGS) is used to evaluate the effects in the ionosphere.

- **Ionosonde foF2 and hmF2:** Another source of validation data is ionosonde stations that provide electron density measurements in the Earth's ionosphere. We will use F2 layer parameters like the foF2 (critical frequency) and hmF2 (peak height) from the GIRO database to assess the state of the ionosphere.



The geographical locations of the **stations available** during the St. Patrick day Storm 2015.

Validation with measurements (IGS TEC and Ionosonde fof2)



Summary

- Differences in thermospheric mass density and total electron content between the **reference** run and **analysis** estimates are an indicator of how the **Thermosphere - Ionosphere system is affected by the assimilation of thermospheric observations,** specially during storm conditions.

- Thermospheric mass density assimilation has a direct **impact on the thermosphere** with an average **improvement of a 36%** with respect to observations.

- The **effect on the Ionosphere** is more localize to the European – African sector, **improving the TEC estimation up to 50%.**