The performance of physics-based and empirical models during St. Patrick's day storm 2015

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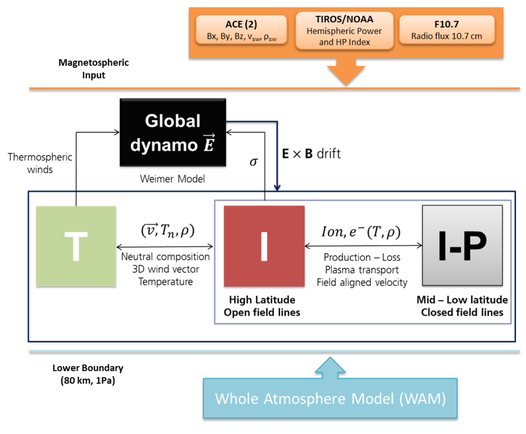
Knowledge of the variability of the **thermosphere – ionosphere (TI) system** is essential for many communication and navigation applications, especially during storm conditions, since the **ionospheric disturbances** will influence the propagation characteristics of radio waves. For this purpose, **physics – based and empirical models** help to analyze and understand the dynamics of ionospheric storms in the strongly interactive TI system.

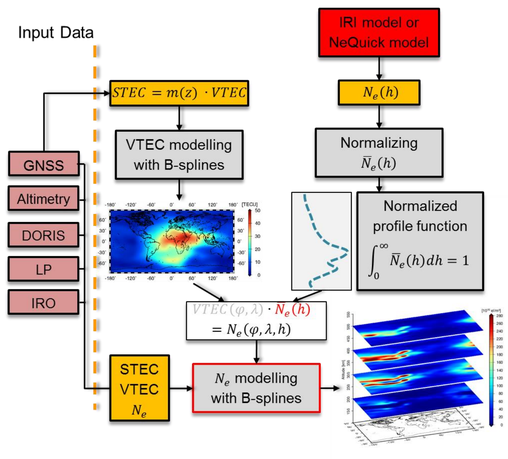
To characterize the TI system during storm conditions we will use the **TUM** empirical model and the physics based **CTIPe** model that will serve also as a background model for a new assimilation scheme named **TIDA**. The capabilities of the models will be demonstrated based on comparison of their results during the **St. Patrick's Day storm 2015** with ground and space based observations, like SWARM measurements, ionosondes and GNSS based TEC estimations.

CTIPe physics based model



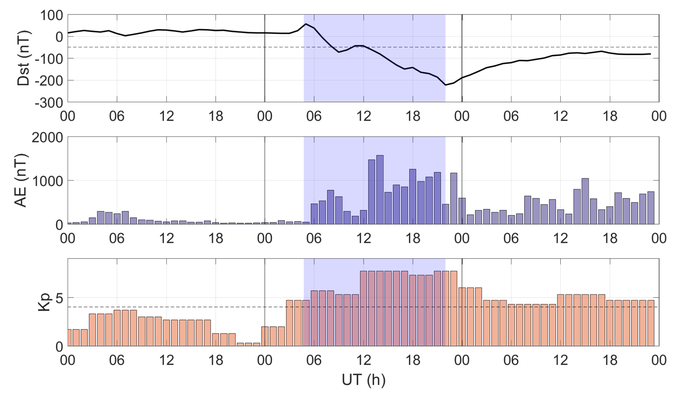
CTIPe is a global non linear **physics based** model that solves the equations of momentum, energy and composition for neutral and ionized atmosphere. It uses as inputs: ACE measurements, TIROS/NOAA auroral precipitation, solar UV, EUV, electric field [Weimer, 2005] model and the WAM for the lower atmosphere.

TUM empirical model



The **TUM** high resolution **empirical model** uses the separation approach [Hernández-Pajares, 2000] to calculate the 3D electron density. It uses as a background model IRI or Nequick to obtain the Ne profile in height, in combination with 2D VTEC maps calculated assimilating different sources of data like GNSS, altimetry or IRO.

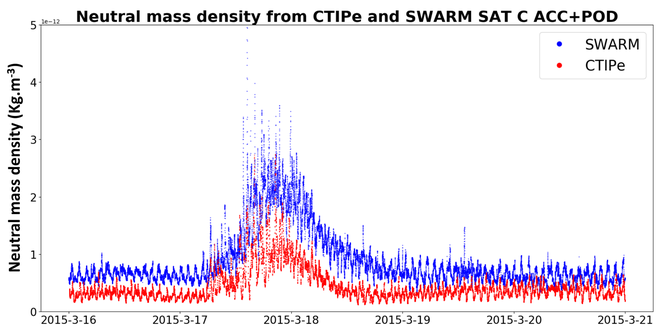
St. Patrick's day Storm 2015



Dst index displays the different storm phases: the **onset** (17/03 4UT), was followed by the **main phase** (17/03 6-00UT) with a steep decrease to a minimum below -200nT and **recovery phase** (until 19/03). **Auroral Electrojet** shows heating enhancement after onset. **Kp index** also displays an increase from 2 to 8 during the main phase of the storm.

Thermosphere: SWARM mass density

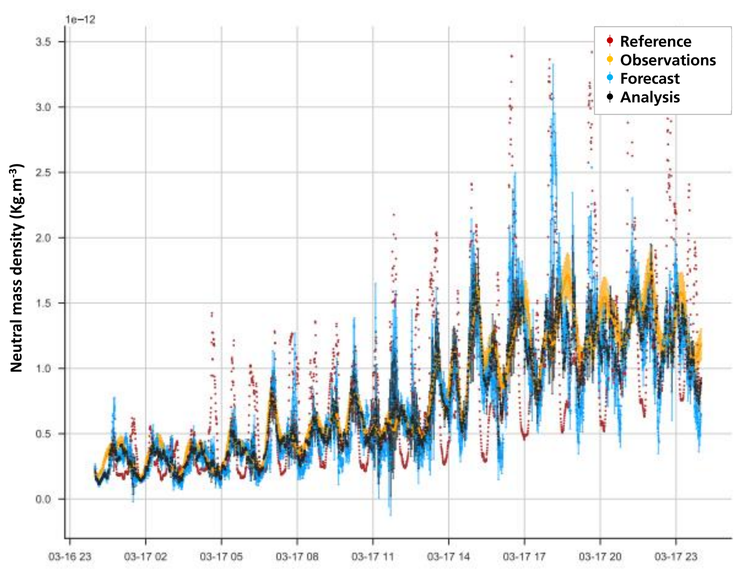
CTIPe vs. SWARM neutral mass density (NMD)



A significant increase of the **neutral mass density** (ρ) can be identified in the comparison between values derived from **SWARM** (blue) and **CTIPe** results (red). It was generated by the storm disturbances reaching a maximum one order of magnitude bigger than quiet values.

SWARM NMD Assimilation → TIDA

Thermosphere Ionosphere Data Assimilation (TIDA)

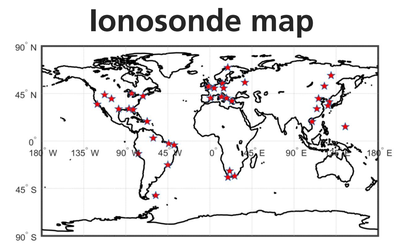


CTIPe serves as a background model for a **new assimilation scheme** named **Thermosphere Ionosphere Data Assimilation** (**TIDA**). This new scheme is based on an **Ensemble Kalman Filter** approach as required by the strongly forced nature of the modeled system.

The first step has been done assimilating **neutral mass density** from SWARM and considering **20% of uncertainty** in the measurements.

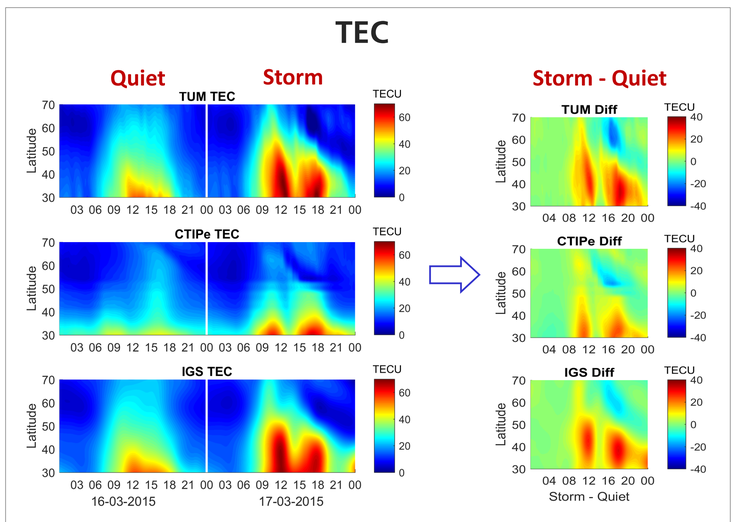
Ionosphere: GNSS TEC and Ionosonde data

Ionosonde map



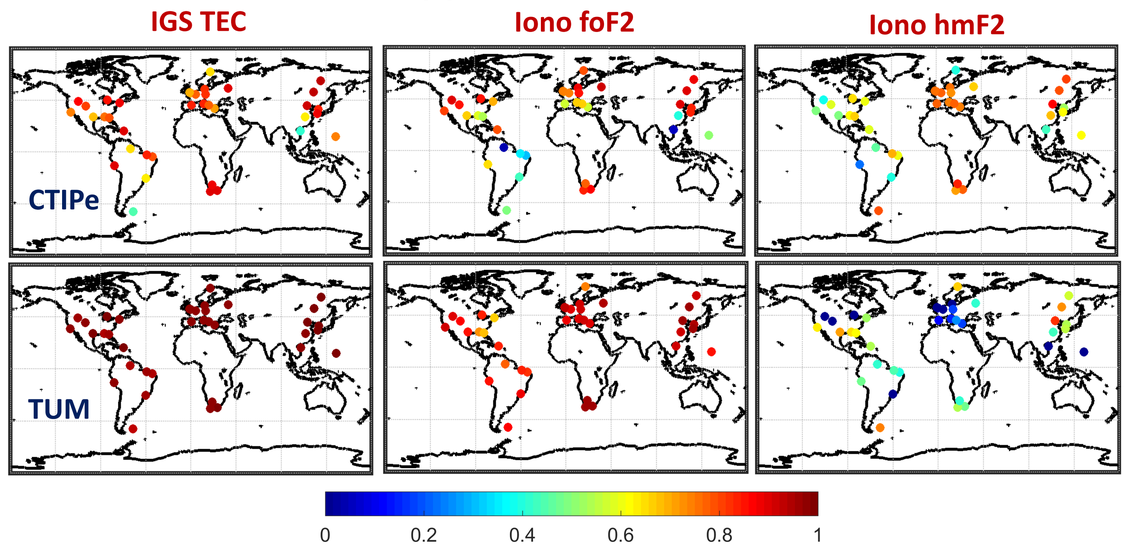
Geographical location of the ionosondes of the GIRO-DB for the St. Patrick day Storm 2015

TEC



CTIPe vs IGS TEC for a fixed longitude of 10E and Latitudes over the European region (30-70N)

CORRELATION COEFFICIENT (R)



Correlation coefficient (R) for IGS TEC, foF2 and hmF2 at all the geographical locations of the ionosonde map

Conclusions

- CTIPe and TUM can reproduce the ionospheric disturbances produced by the 2015 St. Patrick day geomagnetic storm.
- TEC derived from GNSS shows very good agreement for both models. However foF2 critical frequency and maximum high of F2 layer from ionosonde data show latitudinal dependency with the model results.
- Neutral mass density derived from SWARM satellite in comparison with CTIPe results indicates that the thermospheric storm conditions are underestimated by the model.
- The assimilation of SWARM measurements by TIDA code improves the estimation of CTIPe background model neutral mass density, although a more accurate estimation of the uncertainty is needed for achieving better the results.

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