Capabilities of the CTIPe model to reproduce storm conditions

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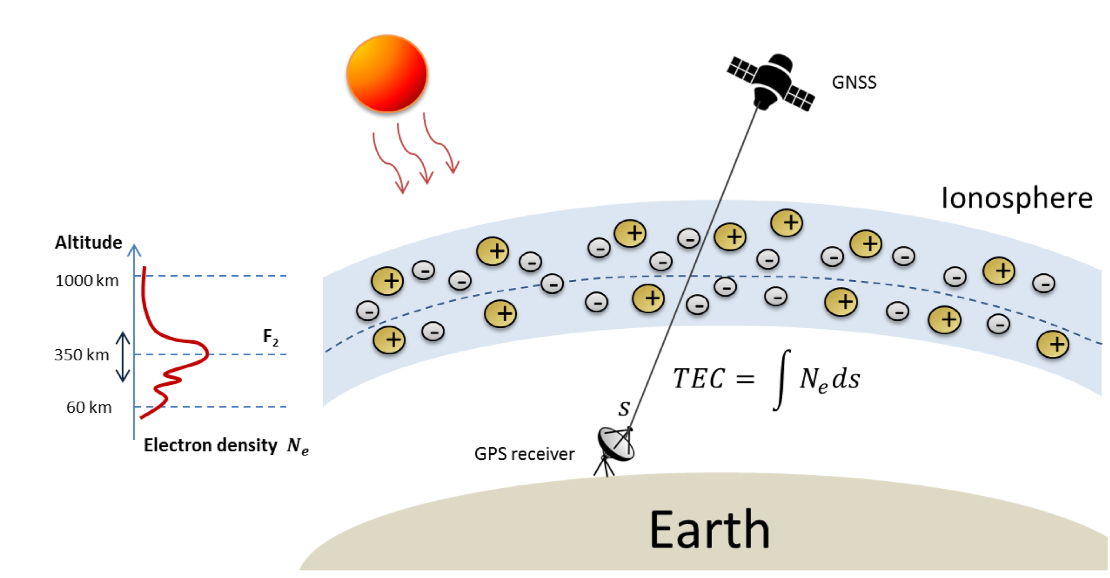
Since the ionosphere impacts communication and navigation applications relying on radio signal transmission, accurate monitoring and forecasting of the ionosphere is of great importance. For this purpose, **physics based modelling of the coupled thermosphere – ionosphere (TI) system** is rather important, because good forecast of ionospheric variability especially during storms need to consider the various physical driving processes in the thermosphere and ionosphere.

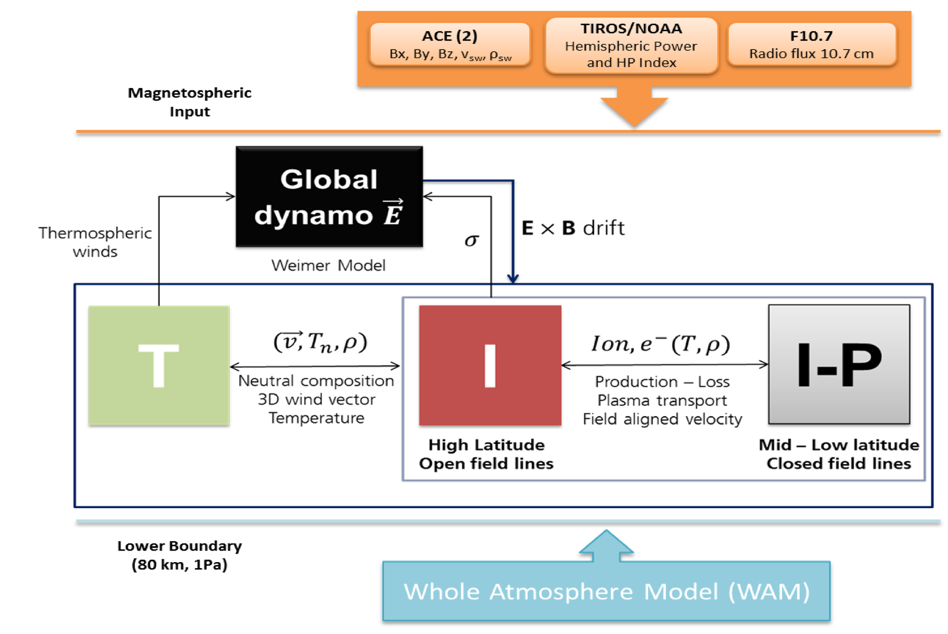
One of the state of the art numerical models is the **Coupled Thermosphere Ionosphere Plasmasphere electrodynamics (CTIPe) model**. Recent developments improved the capabilities of reproducing TI conditions during storms. These capabilities will be demonstrated based on comparison of CTIPe results during the **St. Patrick's Day storm on 17 March 2015** with ground and space based observations. We use SWARM measurements, ionosondes and GNSS based TEC estimations.

Ionosphere GNSS TEC



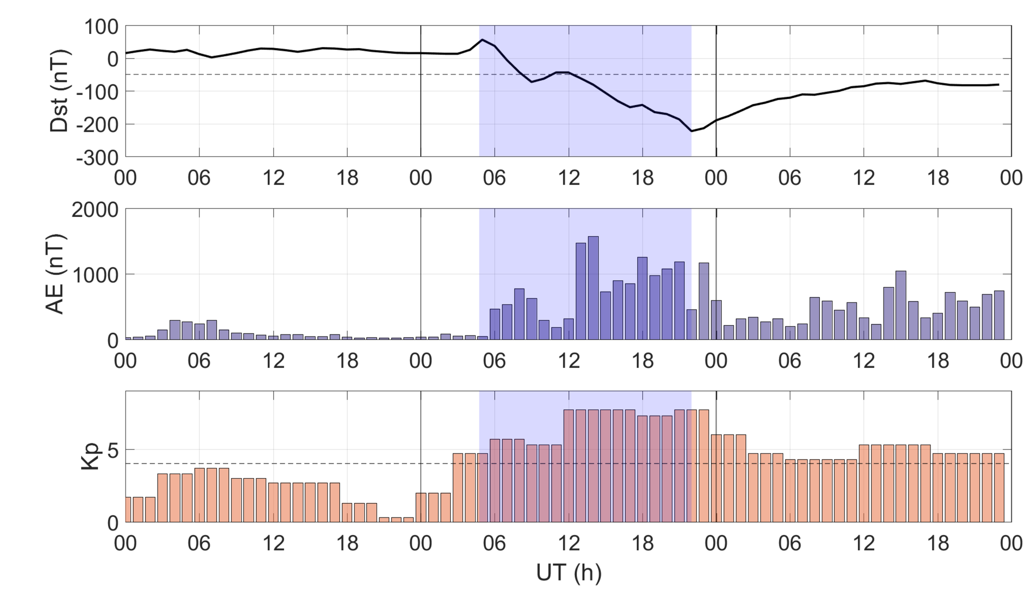
Maps of ionosphere's **Total Electron Content** (**TEC**) in near real time derived from **GNSS** measurements, are a powerful tool for detecting ionospheric storms and monitoring their behavior. TEC can be calculated integrating the electron density N_e along a ray path ds, and measured in TEC units (1 TECU = $10^{16}\, e^-/m^2$).

CTIPe 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.

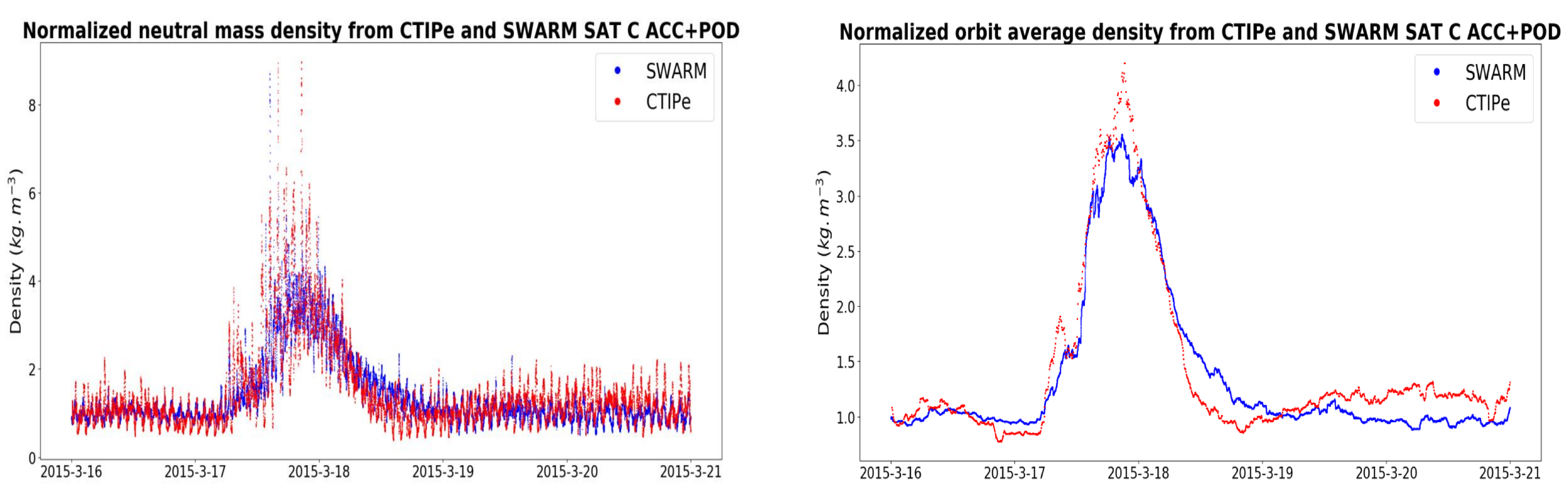
St. Patrick's day Storm 2015



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

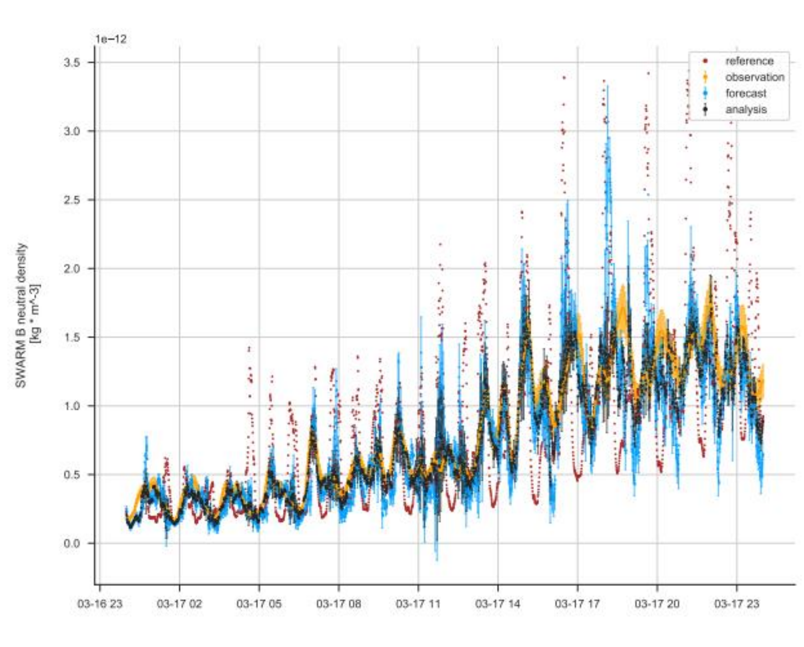
CTIPe vs. SWARM neutral mass density



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. The good agreement of both, indicates that the model characterized the storm thermospheric conditions very well.

Next step

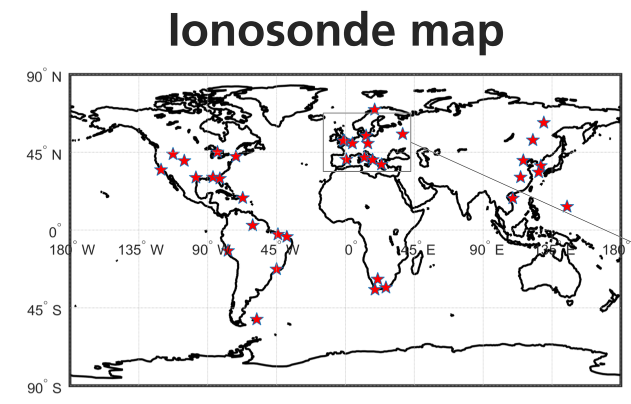
Thermosphere Ionosphere Data Assimilation (TIDA)



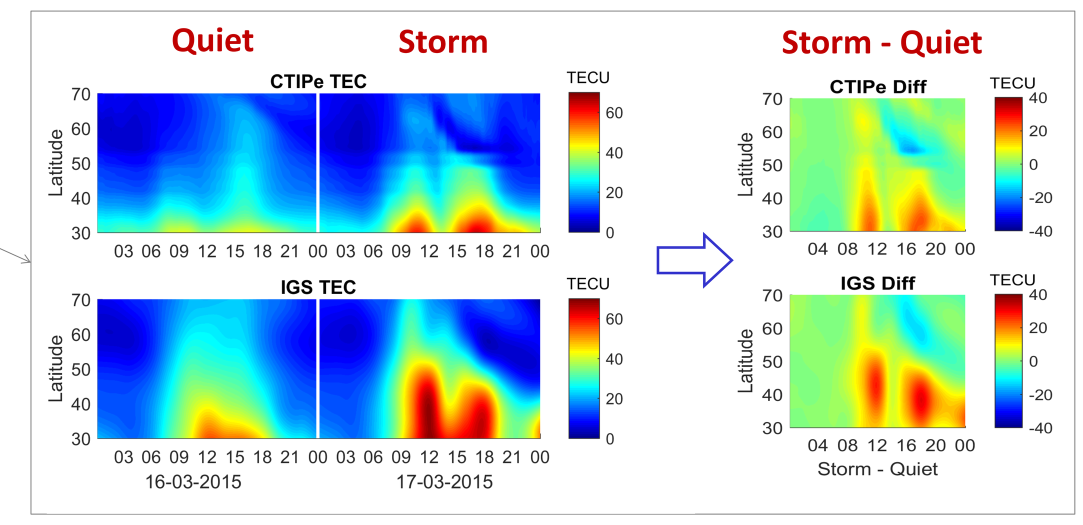
CTIPe will serve as a background model for a **new assimilation scheme** named **Thermosphere Ionosphere Data Assimilation** (**TIDA**). This new scheme is based on an **Ensemble Kalman Filter** approach as required by the strongly forced nature of the modeled system. The first step has been done assimilating **neutral mass density** from SWARM.

Ionosphere: GNSS TEC and Ionosonde data

Ionosonde map

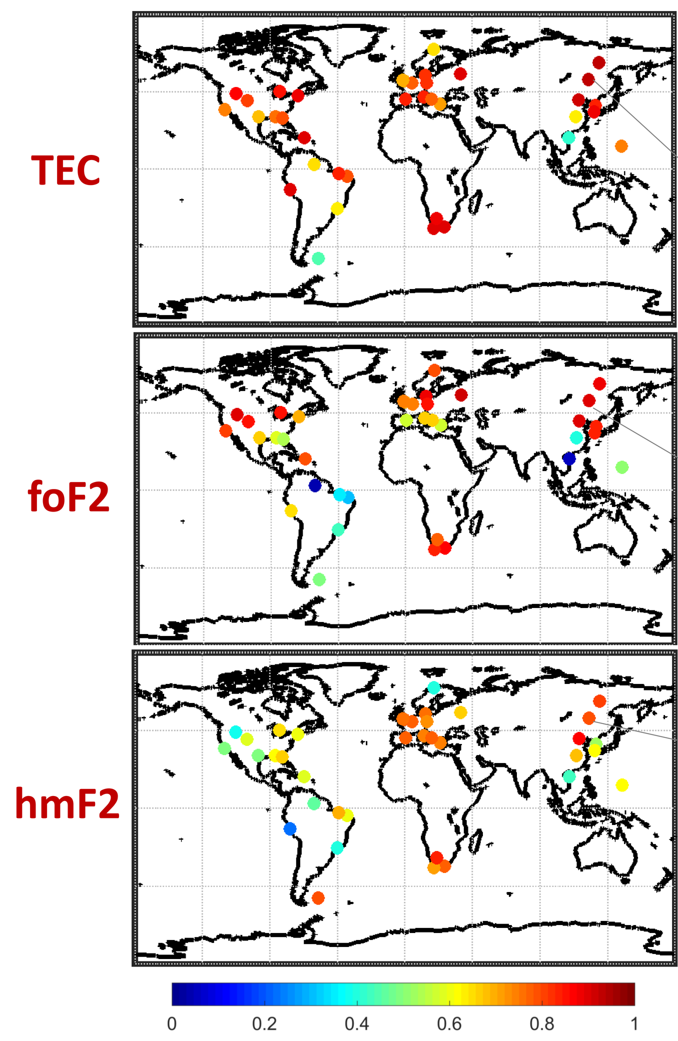


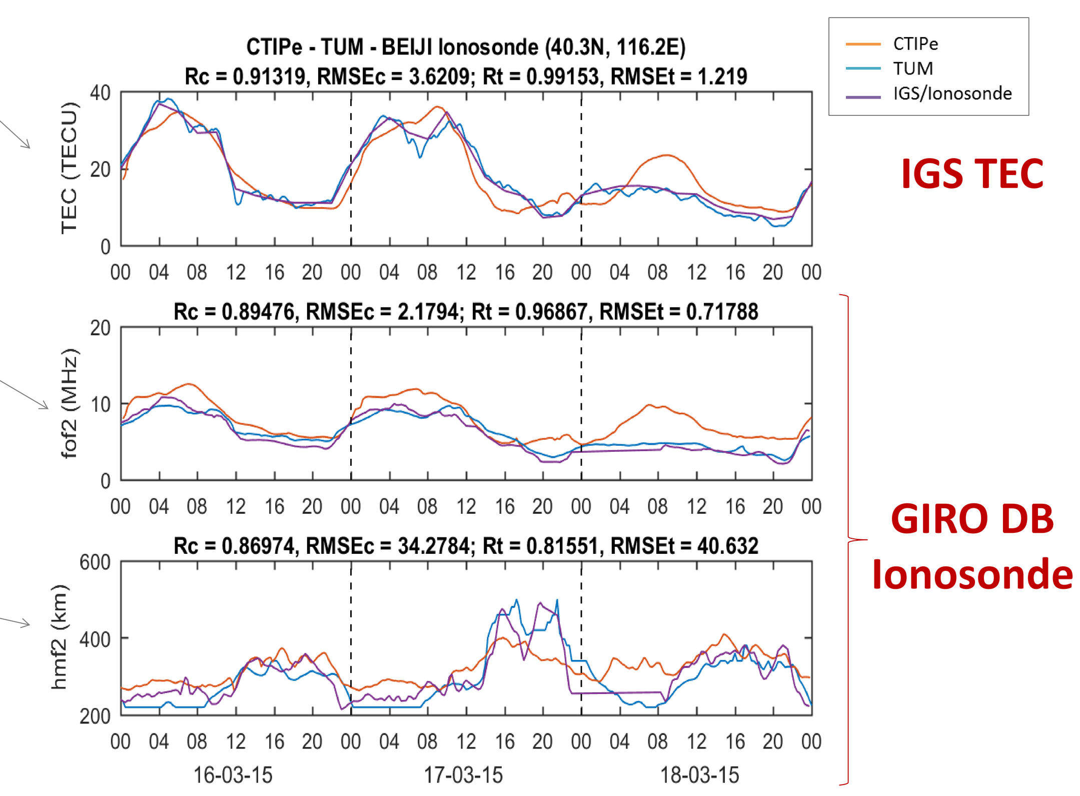
(1) TEC



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

(2) Correlation Coeff (R)





TEC, foF2 and hmF2 for a fixed ionosonde location (Beijing)

(1) CTIPe TEC differences quiet – storm day show an enhancement of plasma density, with a two lobes structure at mid-low latitudes. **IGS TEC** exhibits the same enhancement during the main phase of the storm, extending to higher latitudes .

(2) CTIPe TEC correlates well with **IGS TEC**. **Critical frequency foF2** differs from ionosonde values in the equatorial region and **maximum peak height hmf2** has better results in the European – African sector.

Conclusions

- CTIPe can reproduce the ionospheric disturbances produced by the 2015 St. Patrick day geomagnetic storm as well as its thermospheric drivers.
- Neutral mass density derived from SWARM satellite in comparison with CTIPe results indicates that the thermospheric storm conditions are correctly characterized by the CTIPe model.
- TEC derived from GNSS shows very good agreement with the model. However foF2 critical frequency and maximum high of F2 layer from ionosonde data show latitudinal dependency with the CTIPe model results.
- Next step in the study of TI dynamics during storm conditions will be done using a new assimilation scheme TIDA based on and Ensemble Kalman Filter.

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