

# The performance of empirical and physics based ionosphere models

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Knowledge for Tomorrow



# Outline

## ❑ Insight II

## ❑ Models

- **TUM**: Empirical model
- **CTIPe**: Physics based model

## ❑ Case Study: **St. Patrick day Storm 2015**

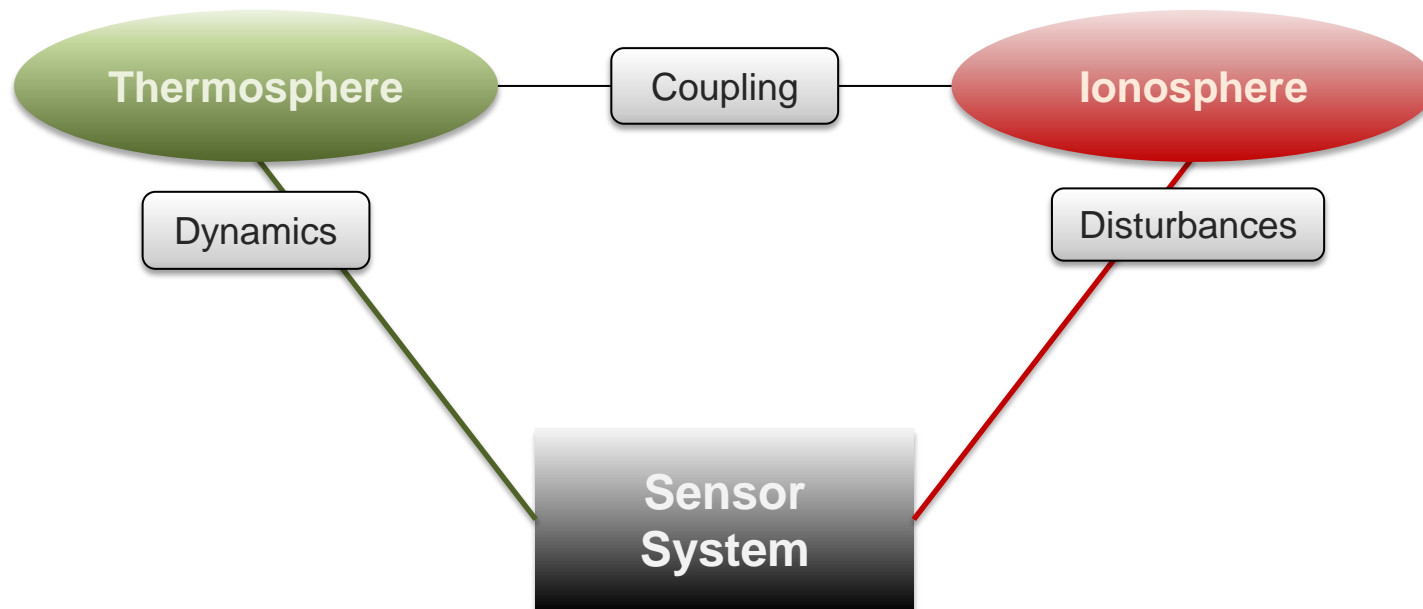
## ❑ Validation methods and measurements

- **TEC** map over Europe
- **Ionosonde** comparison
- **Self consistency** (dSTEC) analysis

## ❑ Summary and Next steps



# INSIGHT II Interactions of Low-orbiting Satellites with Surrounding Ionosphere and Thermosphere

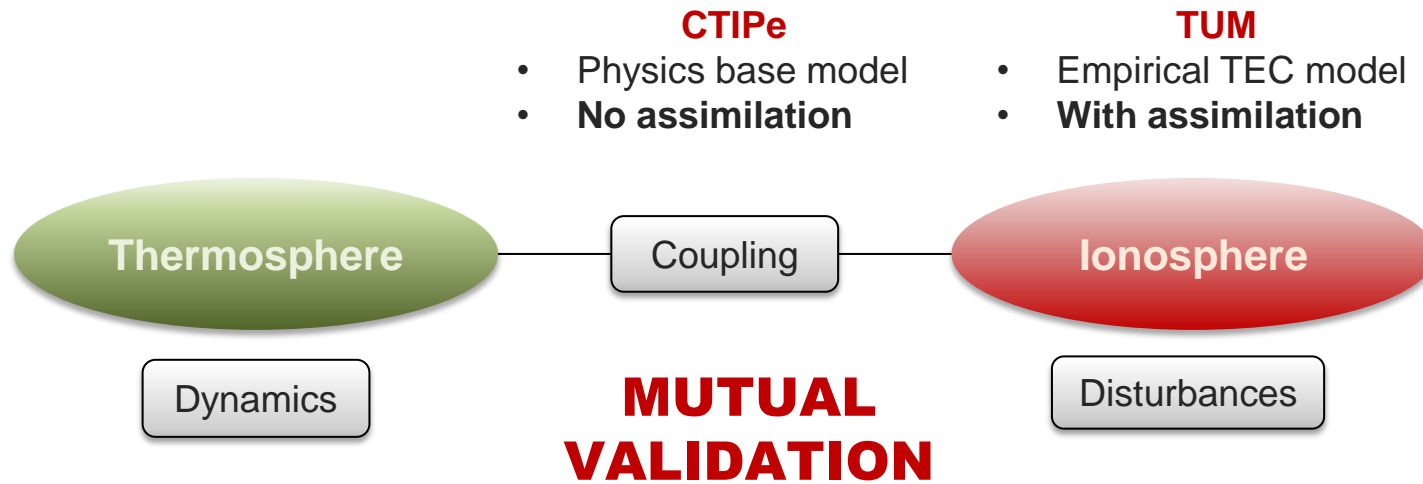


DFG (German Science Foundation)

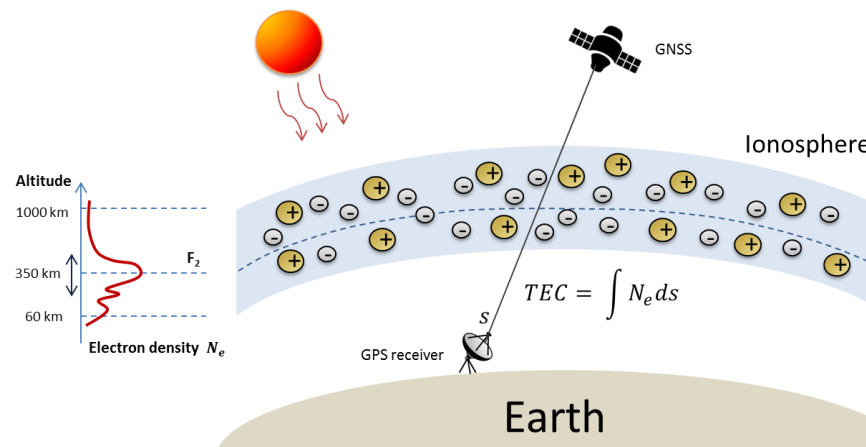
Grant number 273590813



# INSIGHT II



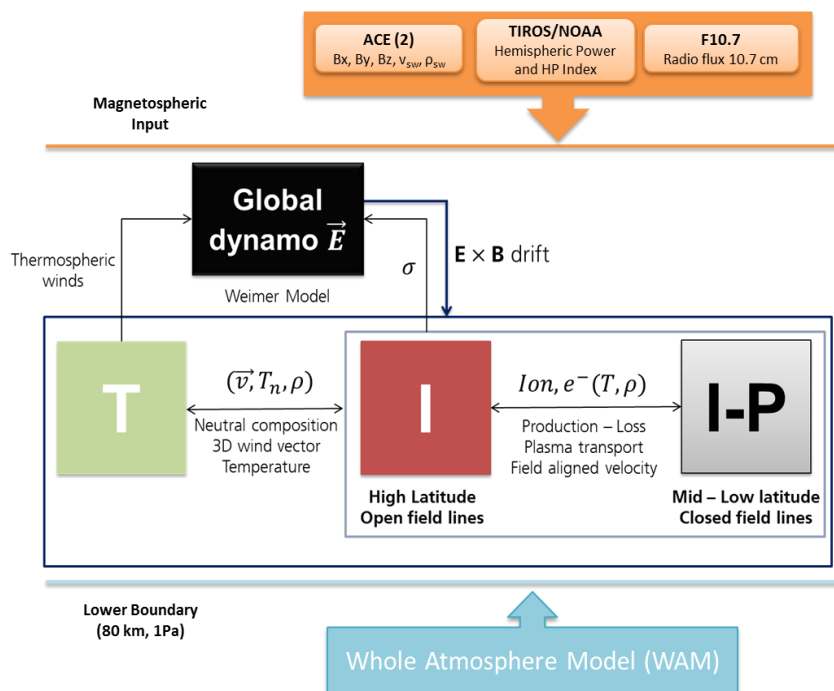
## STORM CONDITIONS



# Models: CTIPe and TUM

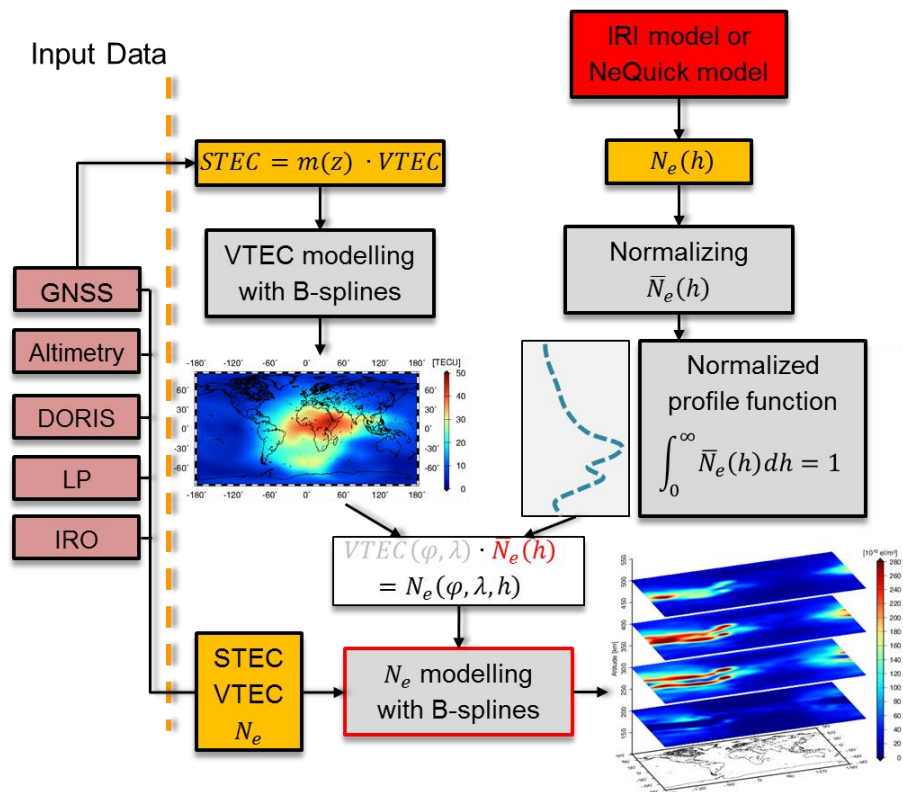
## CTIPe

Physics based model  
No assimilation

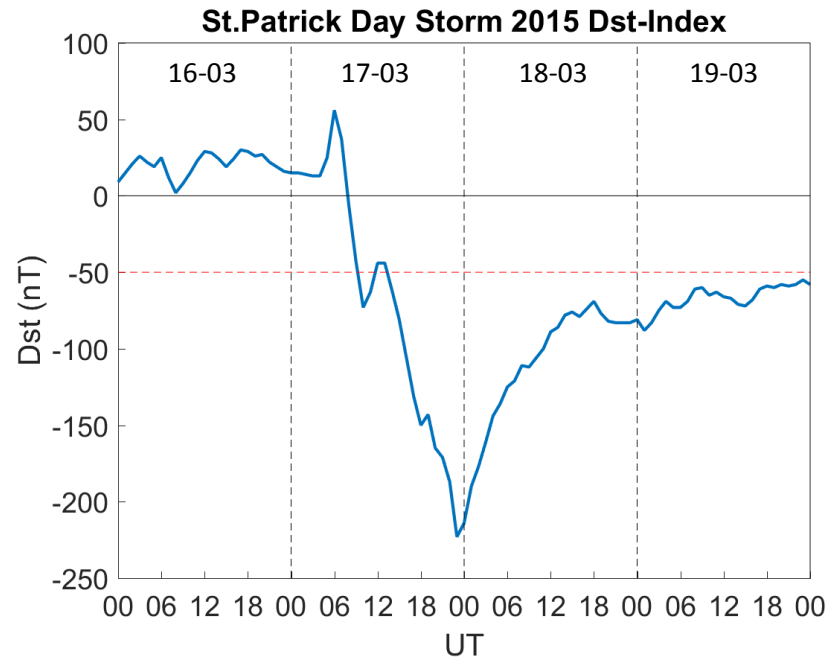


## TUM

Empirical model  
Assimilation

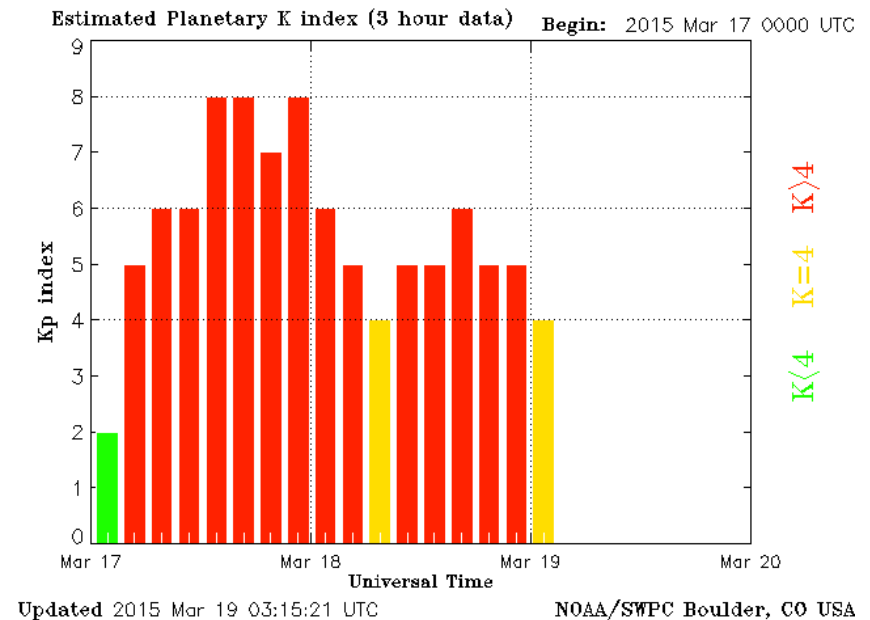


# Case Study: St. Patrick day storm 2015



- Dst index descend to values  $< -200$  nT
- Kp index increases from 2 up to 8

- G4 Level (severe) geomagnetic storm
- Caused by a CME the 15th March



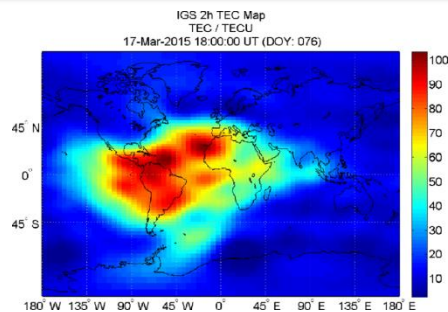


# Validation methods and measurements

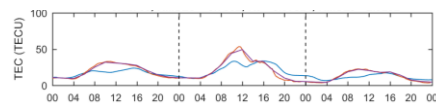
## MEASUREMENTS

### VALIDATION METHODS

**TEC map**  
(Europe)

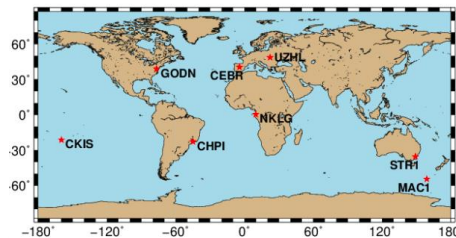


Local  
**Ionosonde**  
comparison

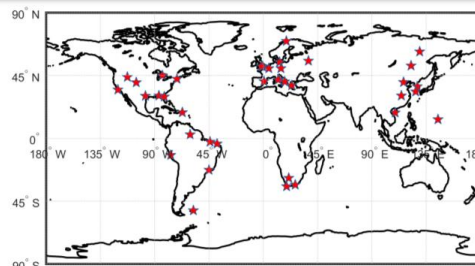


**TEC time series**

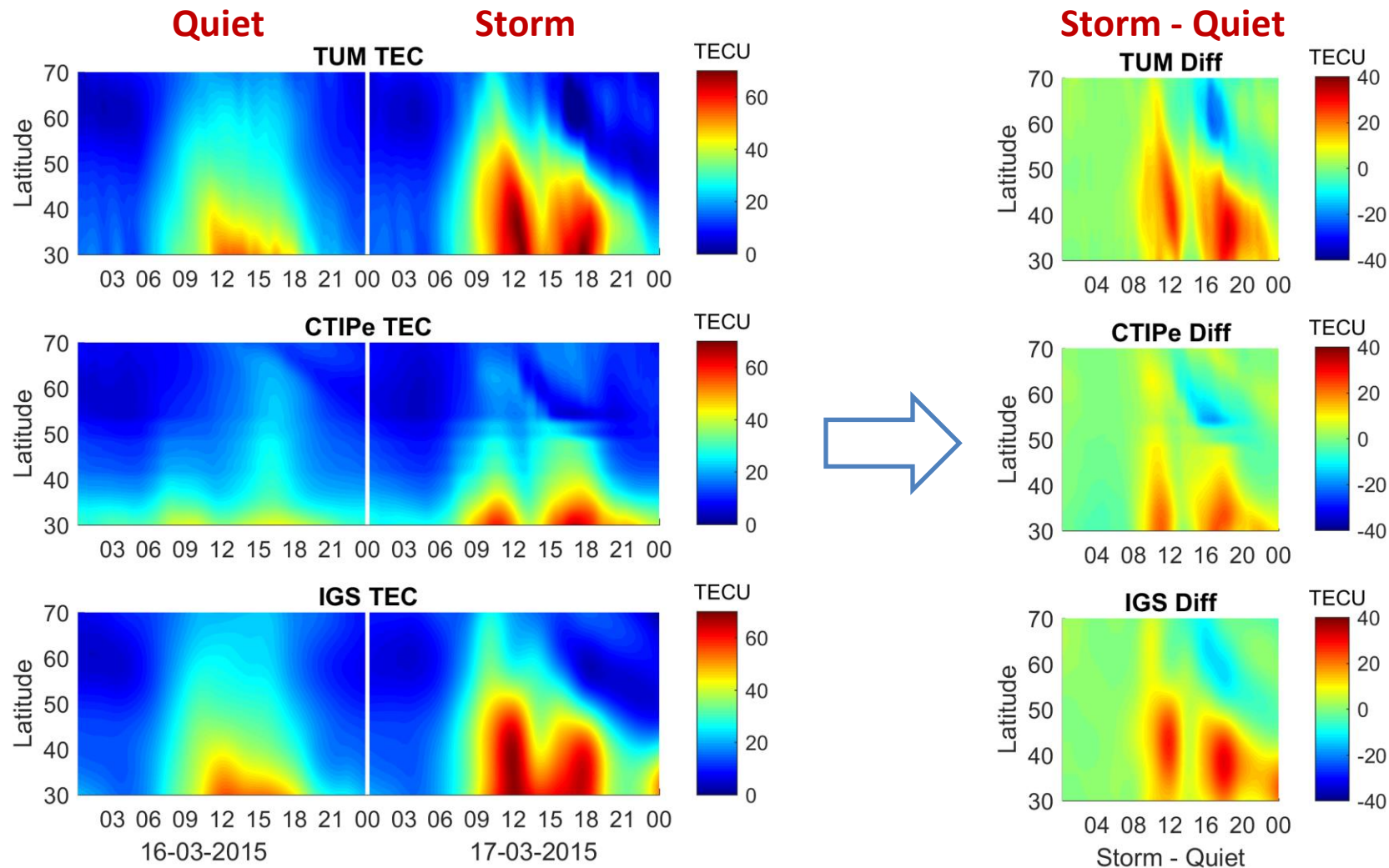
**dSTEC** self-  
consistency  
analysis



**foF2**  
**hmF2**

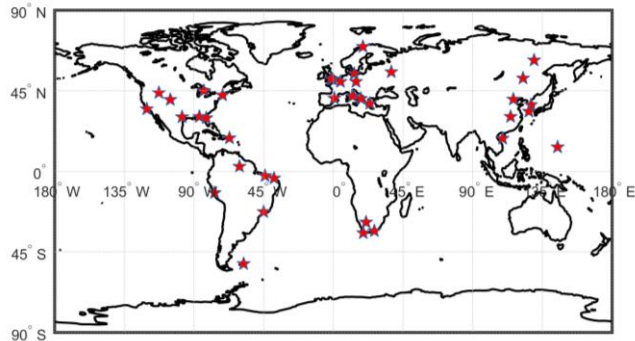


# Validation: TEC map over Europe (10E)





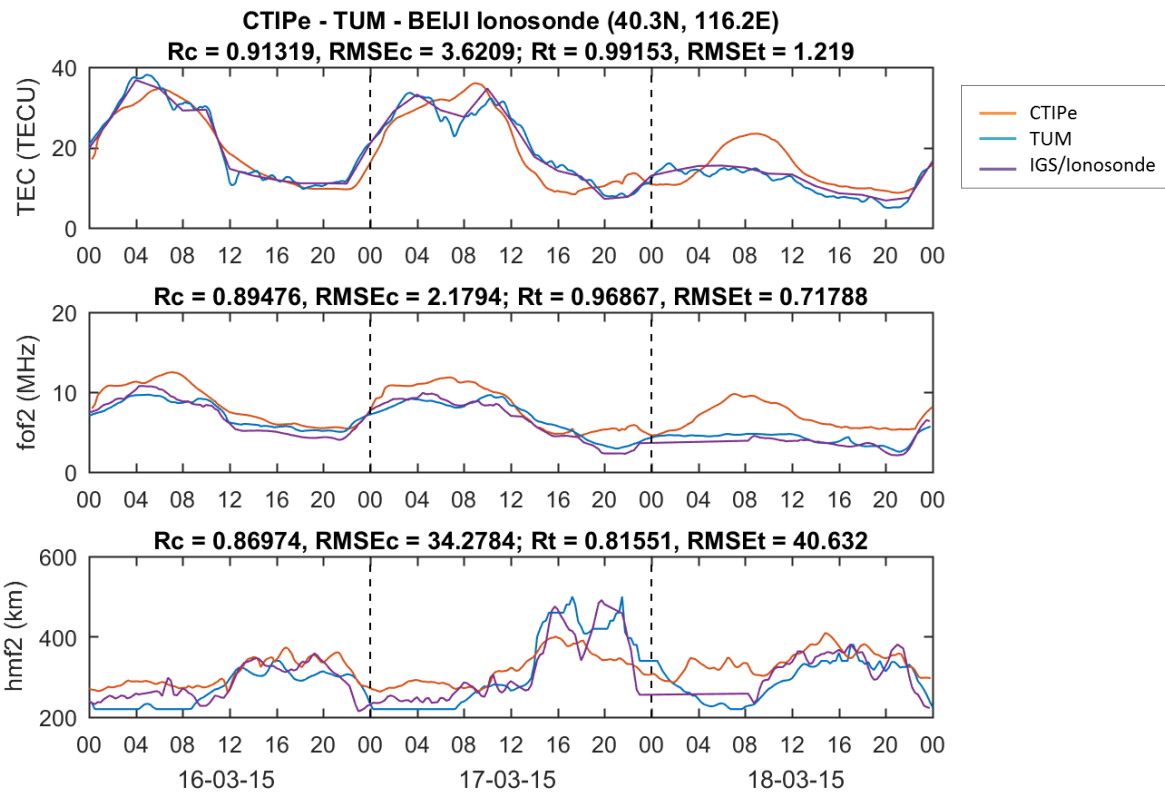
# Validation: Local Ionosonde comparison



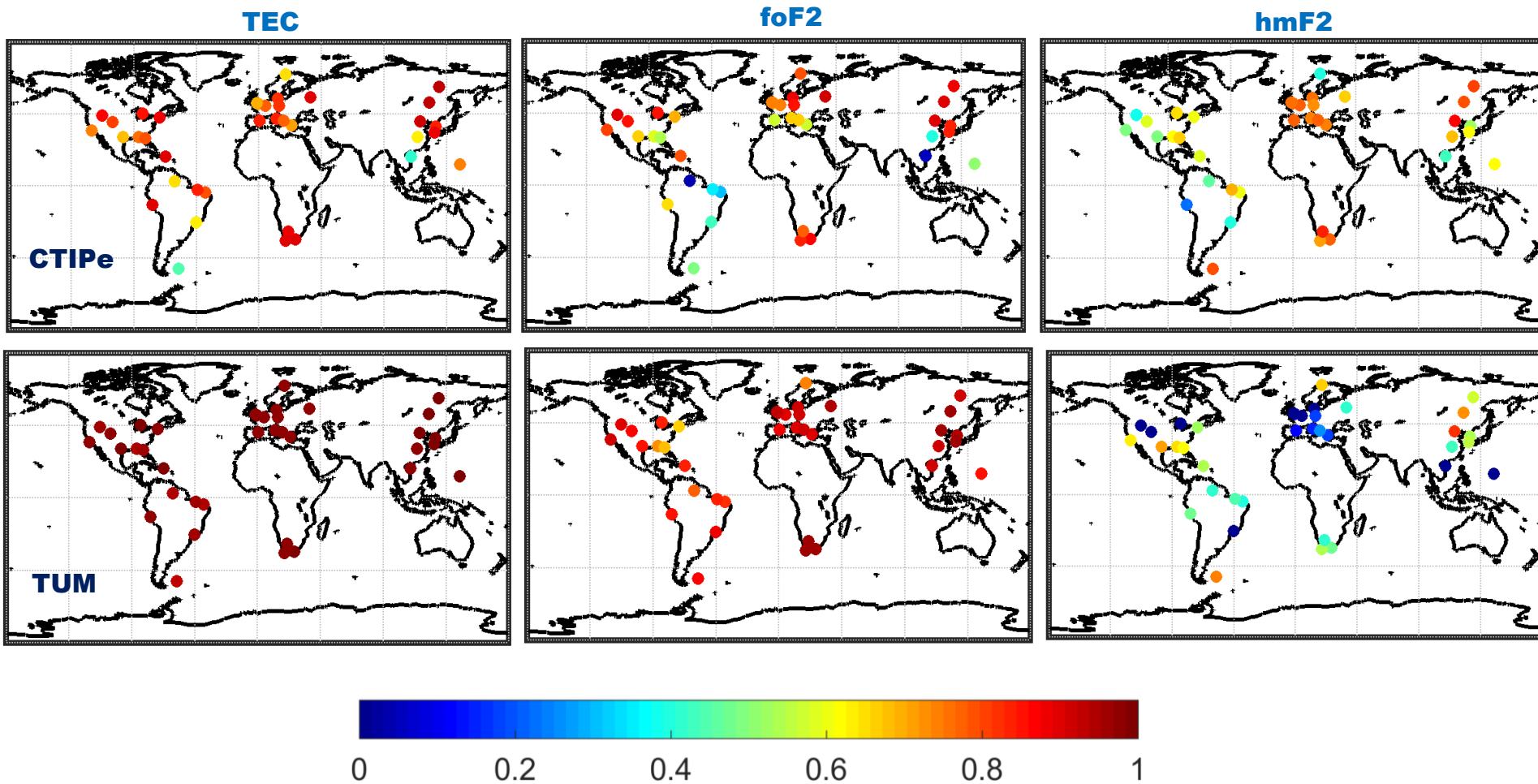
IGS TEC

GIRO DB  
Ionosonde

The geographical locations of the **stations available** for the analysis are shown in the figure

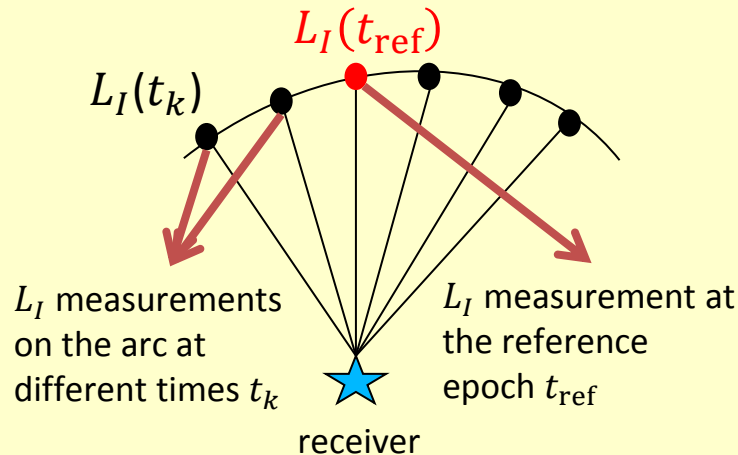


# Validation: Local Ionosonde comparison maps (R)



# Validation: dSTEC self – consistency analysis

- A comparison for the **test period** including the **St. Patrick Storm event** was performed.
- The validation method is based on the **self-consistency analysis (dSTEC)**.



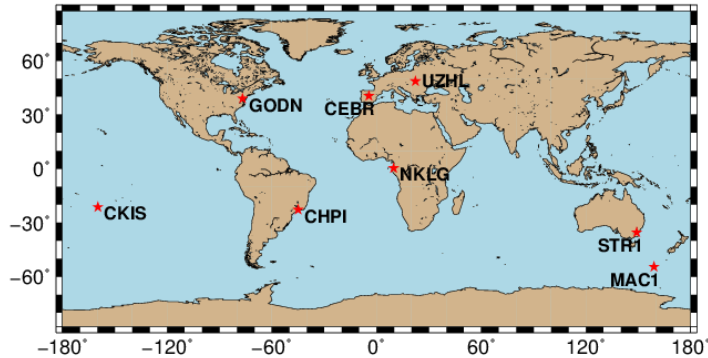
Analysis of the  $dSTEC_{\text{obs},k}$  values from a continuous arc by subtracting a reference observation

- The self consistency analysis is based on the comparison of ...
- ... **differenced STEC values computed from the GPS geometry-free linear combination** of carrier-phase observables (along a phase-continuous arc):  $dSTEC_{\text{obs},k}$
- ... and **differenced STEC values computed from the VTEC maps**:  $dSTEC_{\text{map},k}$

$$dSTEC_k = dSTEC_{\text{obs},k} - dSTEC_{\text{map},k}$$

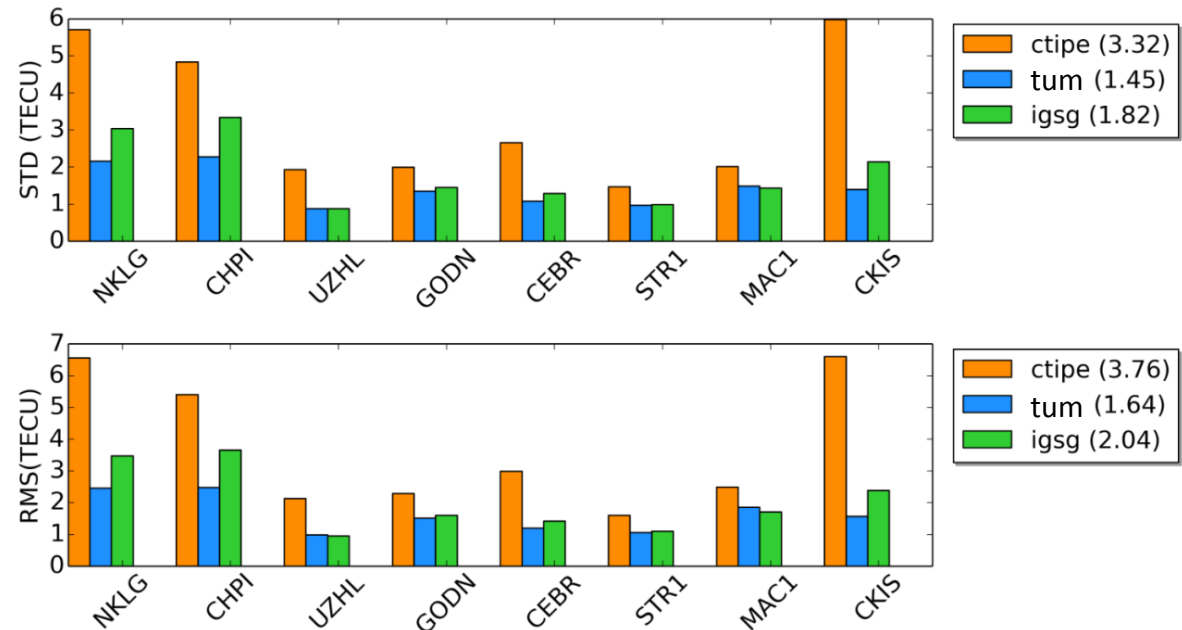


# Validation: dSTEC self – consistency analysis



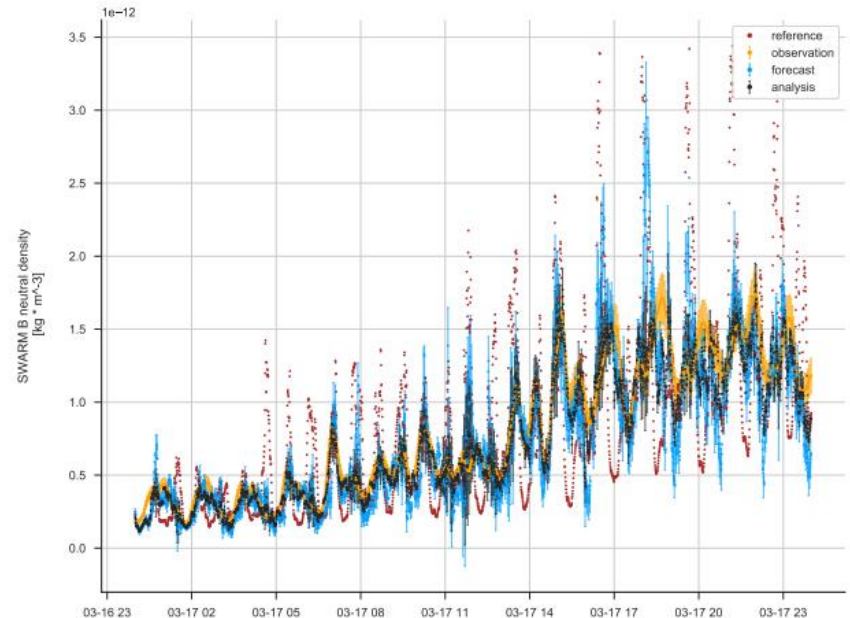
- The geographical locations of the **stations selected** for the analysis are shown in the figure
- The test receivers chosen globally are located at **low** and **high latitudes**, which can estimate the VTEC model accuracy at regions characterized by **strong variable VTEC activity**

**Summary of the statistics:**  
Average standard deviations (STD) and average RMS deviations of 3 models presented at 8 stations covering the days March 16-18, 2015 from dSTEC analysis.



# Summary and Next steps

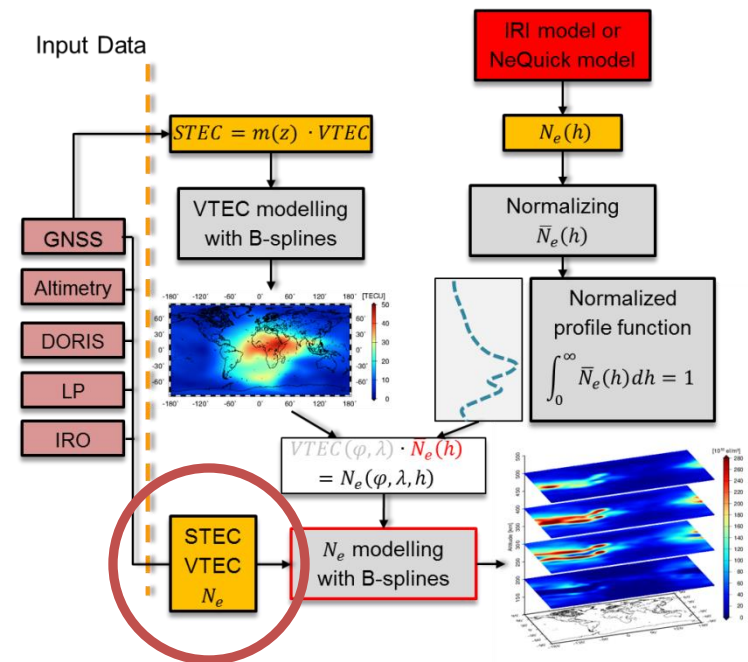
- **CTIPe** and **TUM** models analysis during **storm conditions** using IGS TEC and Ionosonde data.
- Both models can reproduce the **TEC storm characteristics**.
- **CTIPe** results show **latitudinal dependence** with better results in high and mid latitudes than the equatorial region.
- **Next Steps: CTIPe assimilation** of SWARM neutral density.





# Summary and Next steps

- **CTIPe** and **TUM** models analysis during **storm conditions** using IGS TEC and Ionosonde data.
- Both models can reproduce the **TEC storm characteristics**.
- **TUM** show very good **agreement with TEC and foF2**, however hmF2 calculations needs further improvement.
- **Next Steps:  $N_e$  independent of the empirical model**



**Thanks for your attention!**

