

# Mid-latitude Ionosphere Variability and Modeling Including Space Weather Impact on VTEC and PPP

Randa Natras<sup>1</sup>, Dzana Halilovic<sup>2</sup>, Medzida Mulic<sup>3</sup>, Michael Schmidt<sup>1</sup>

<sup>1</sup>Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM), School of Engineering and Design, Technical University of Munich, Munich, Germany

<sup>2</sup>Department of Geodesy and Geoinformation, Vienna University of Technology, Vienna, Austria

<sup>3</sup>Faculty of Civil Engineering, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

[randa.natras@tum.de](mailto:randa.natras@tum.de)

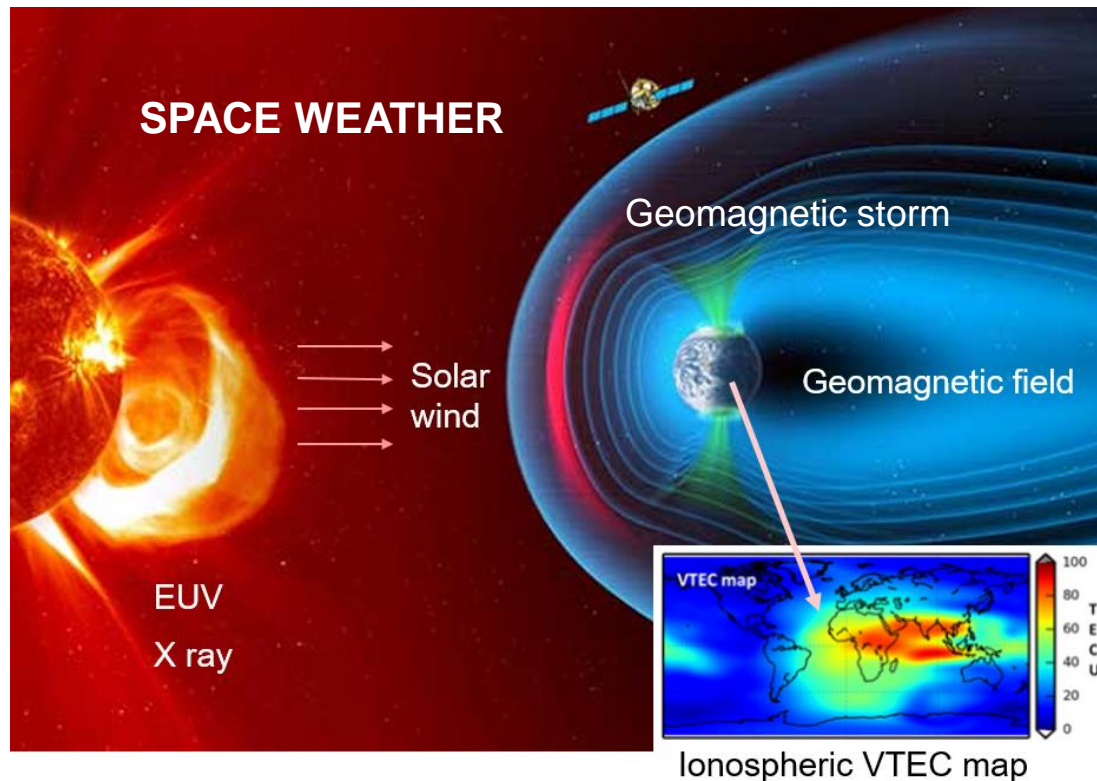
Symposium in Geodesy and Geoinformatics, IAT 2022, Sarajevo

June 24, 2022



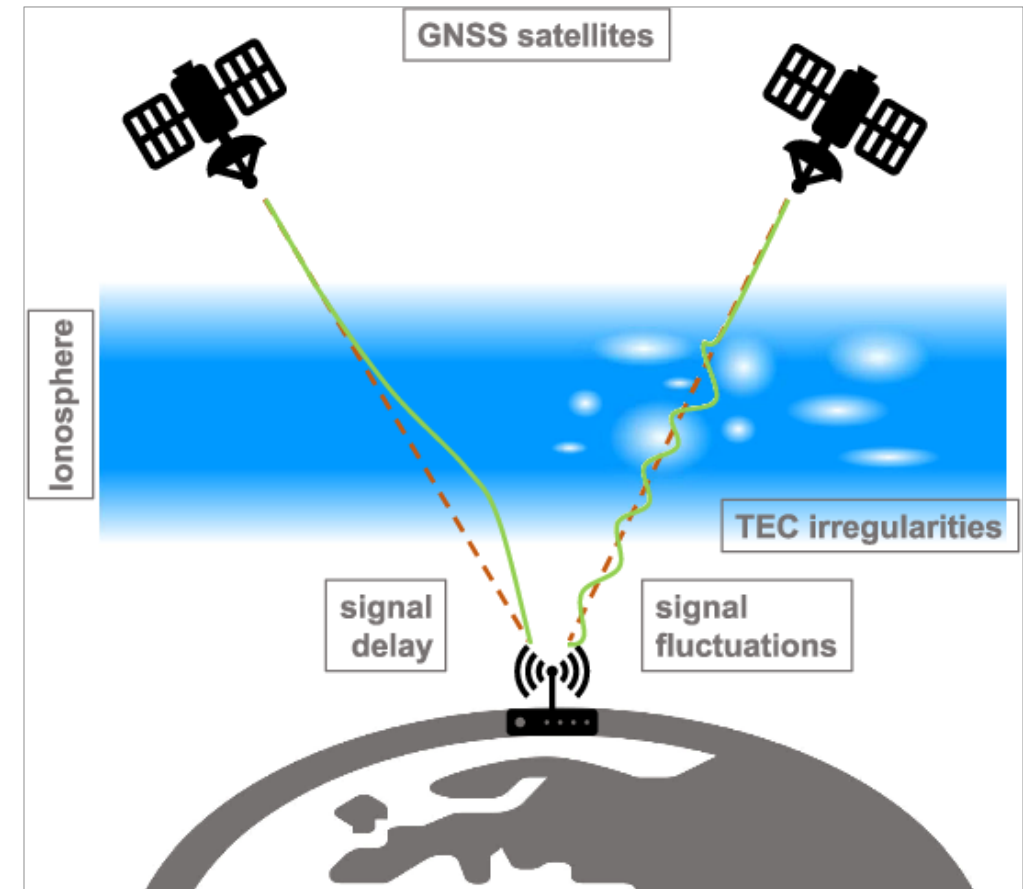
# Research problem

- Ionospheric refraction of GNSS signals
- Total Electron Content (TEC)
- Vertical TEC (VTEC)



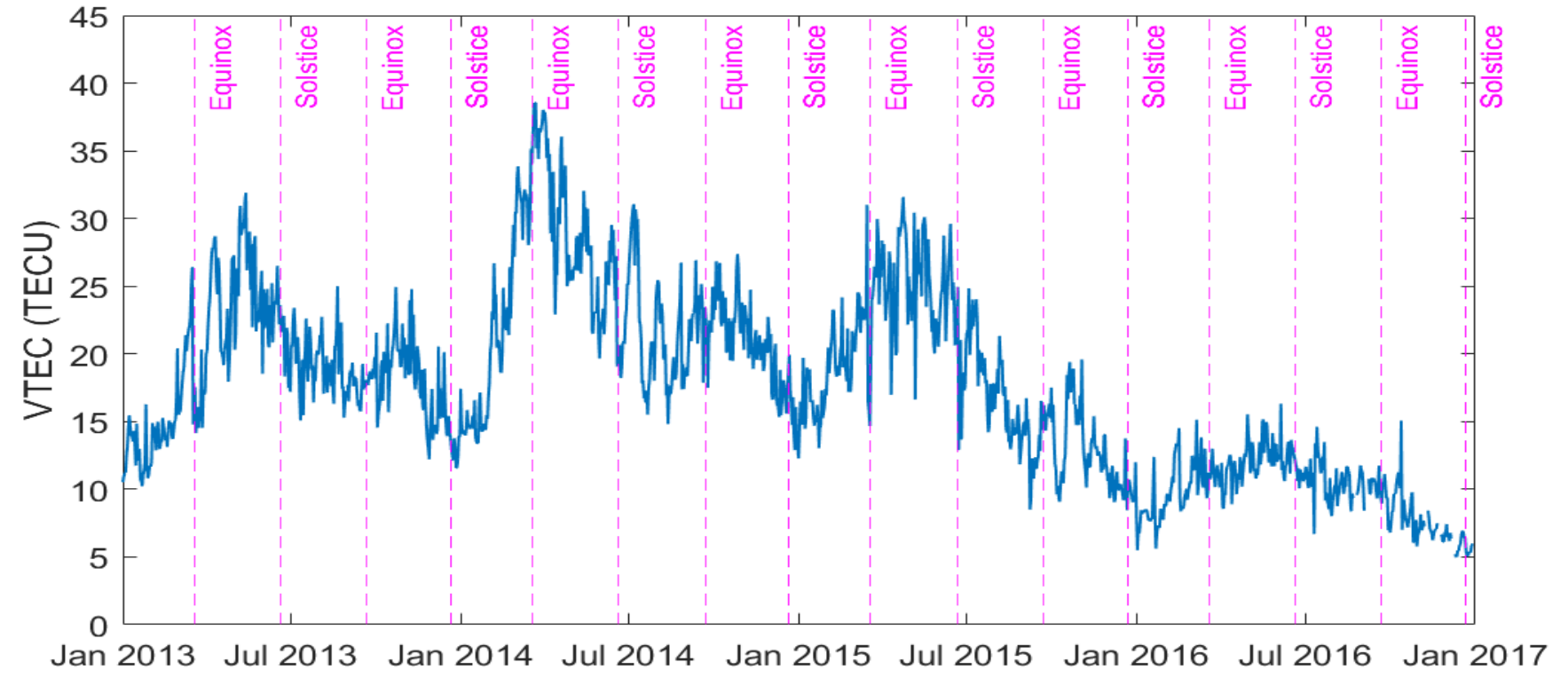
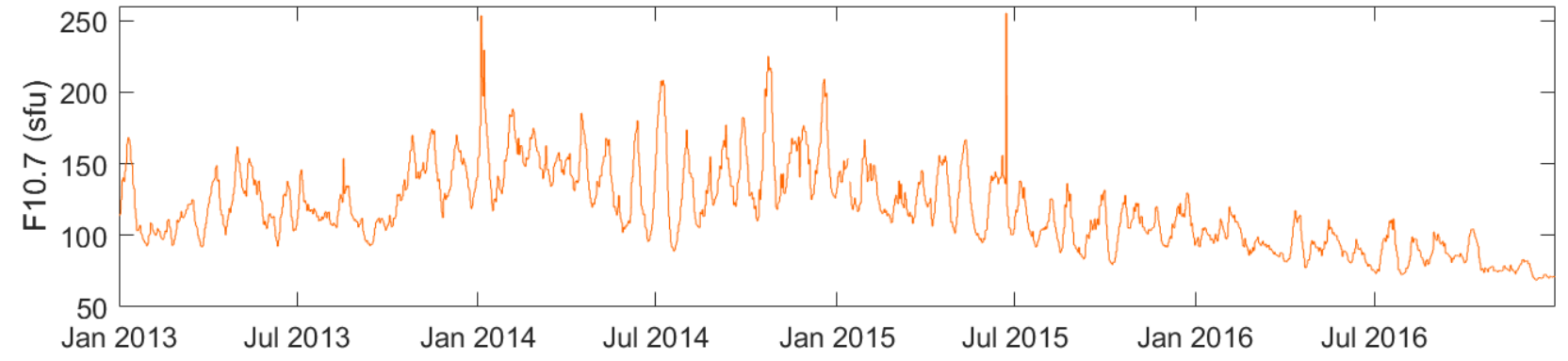
Adapted from: ESA (background), DGFI-TUM (VTEC map).

- Dual-frequency obs.
- EPN SRJV (43.87°, 18.41°)



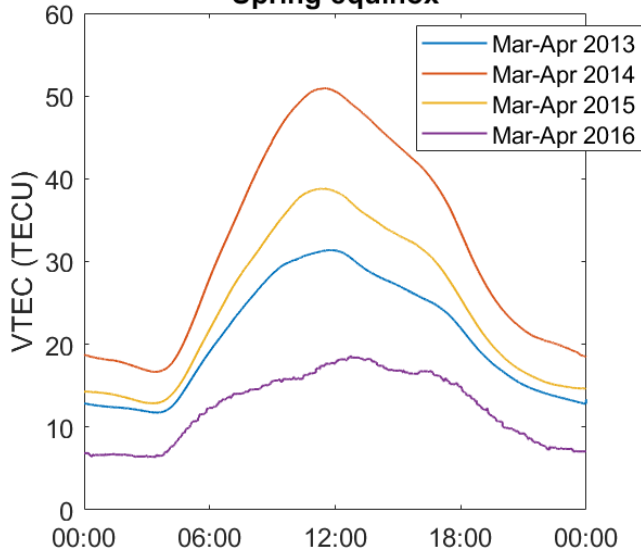
Source: <https://www.semanticscholar.org/paper/Detection-of-GNSS-Ionospheric-Scintillations-Based-Linty-Farasin/3bc53da7342d4cdcd1a8bacfdc92651aeb62d5dc>

# Solar activity vs. daily VTEC

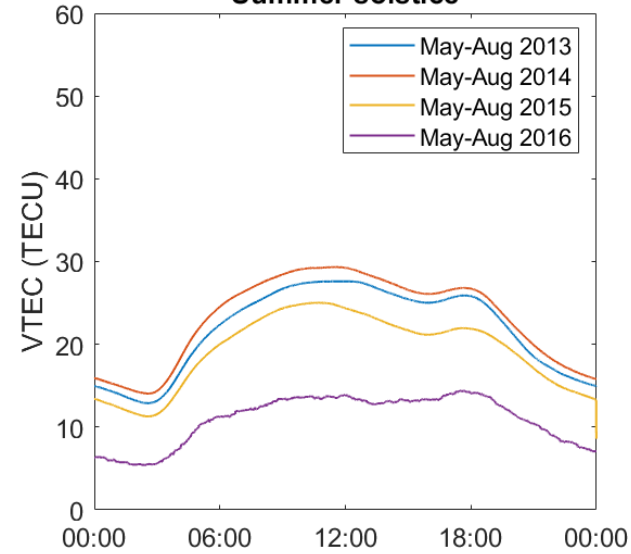


# Seasonal VTEC

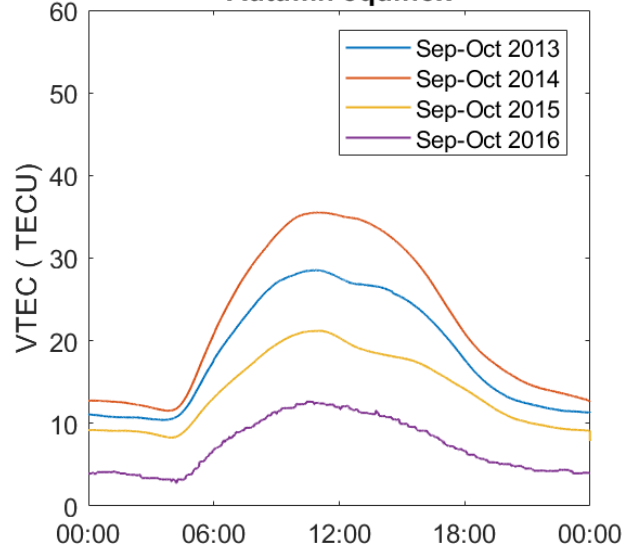
### Spring equinox



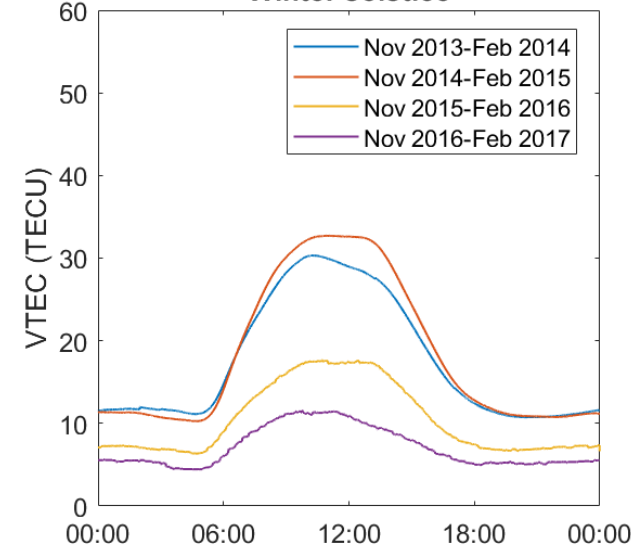
### Summer solstice



### Autumn equinox

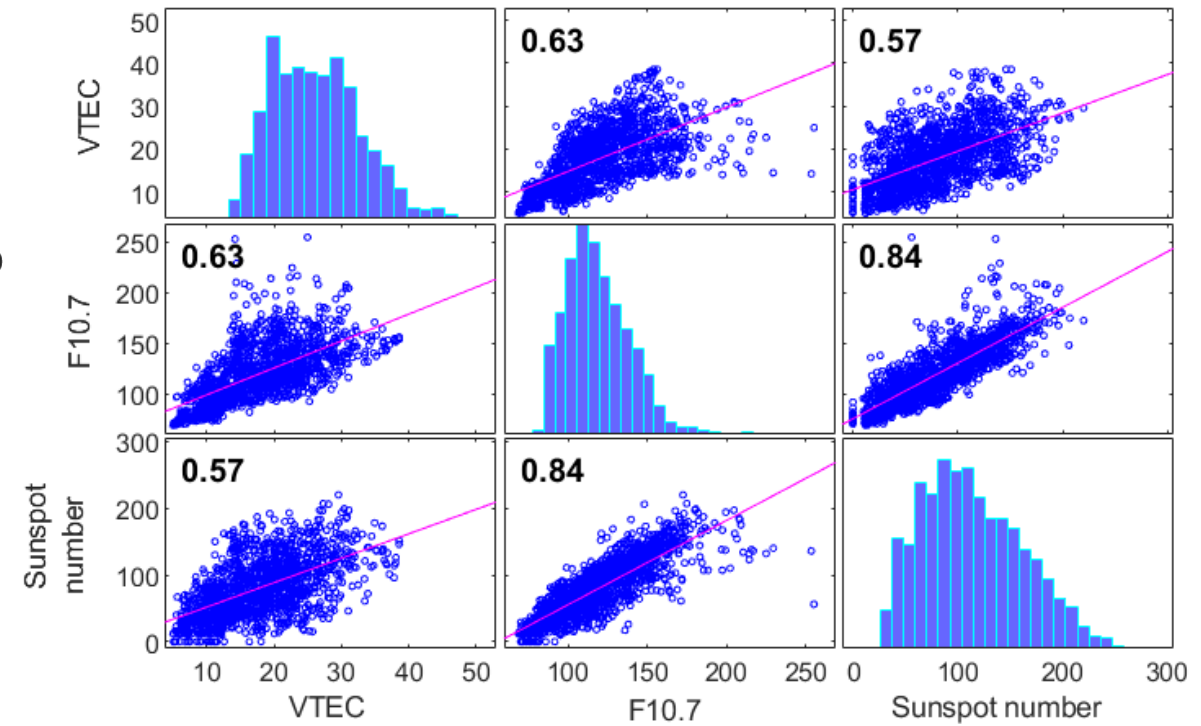


### Winter solstice



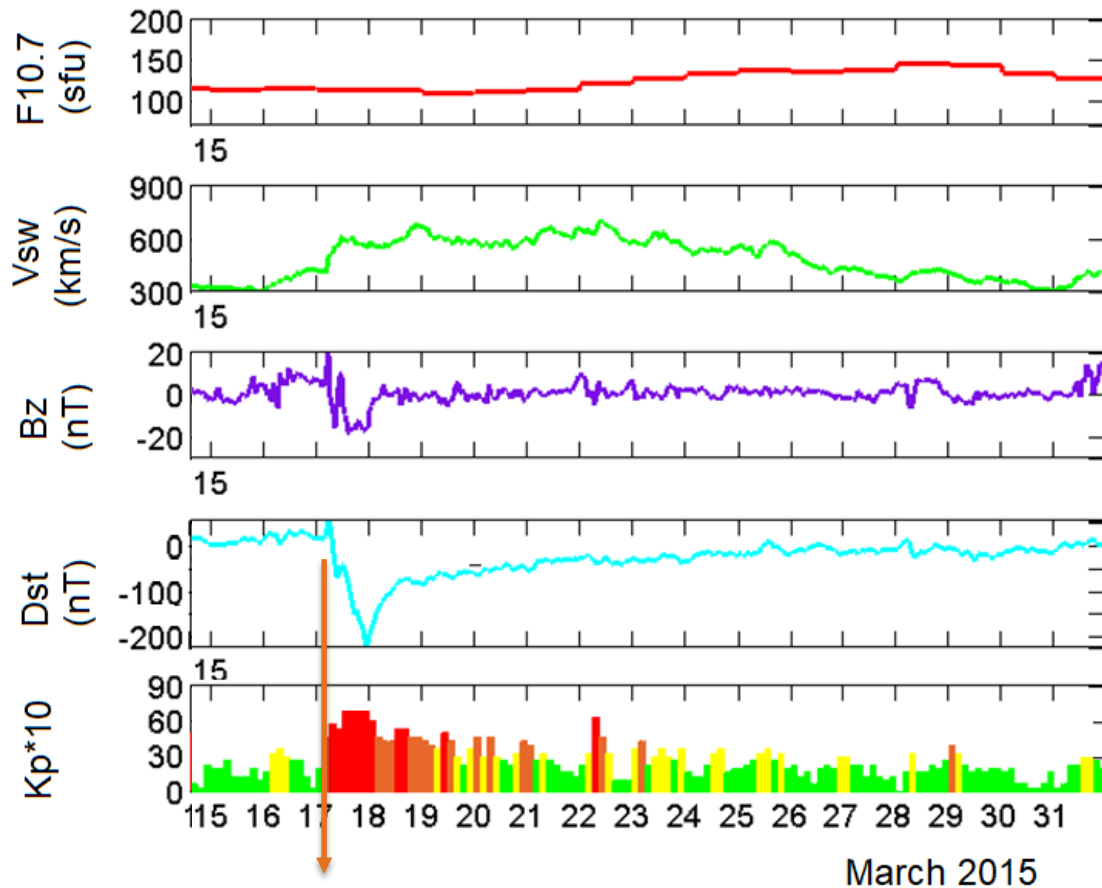
# VTEC and solar activity

### Correlation Matrix



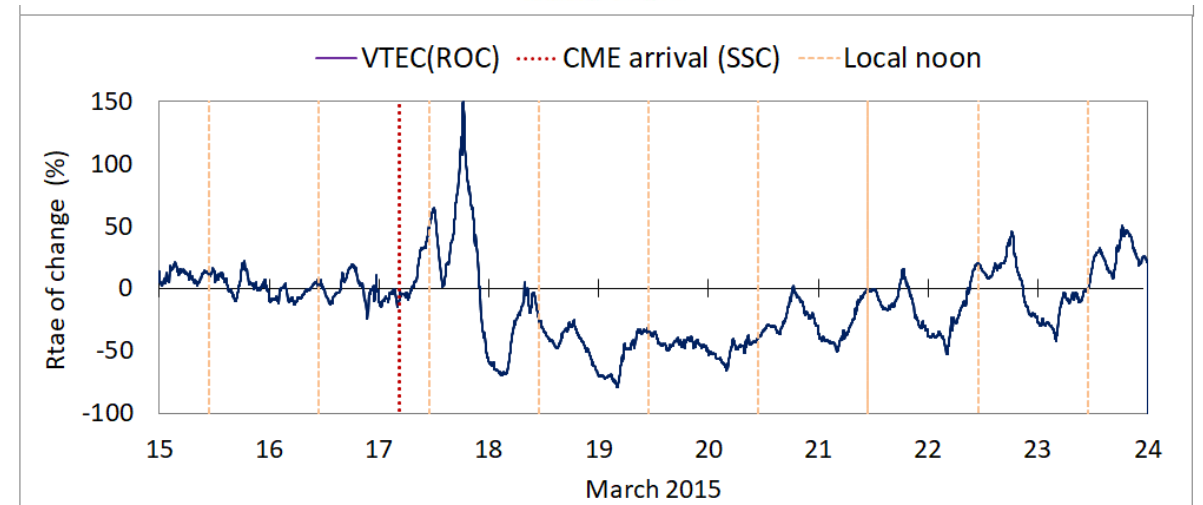
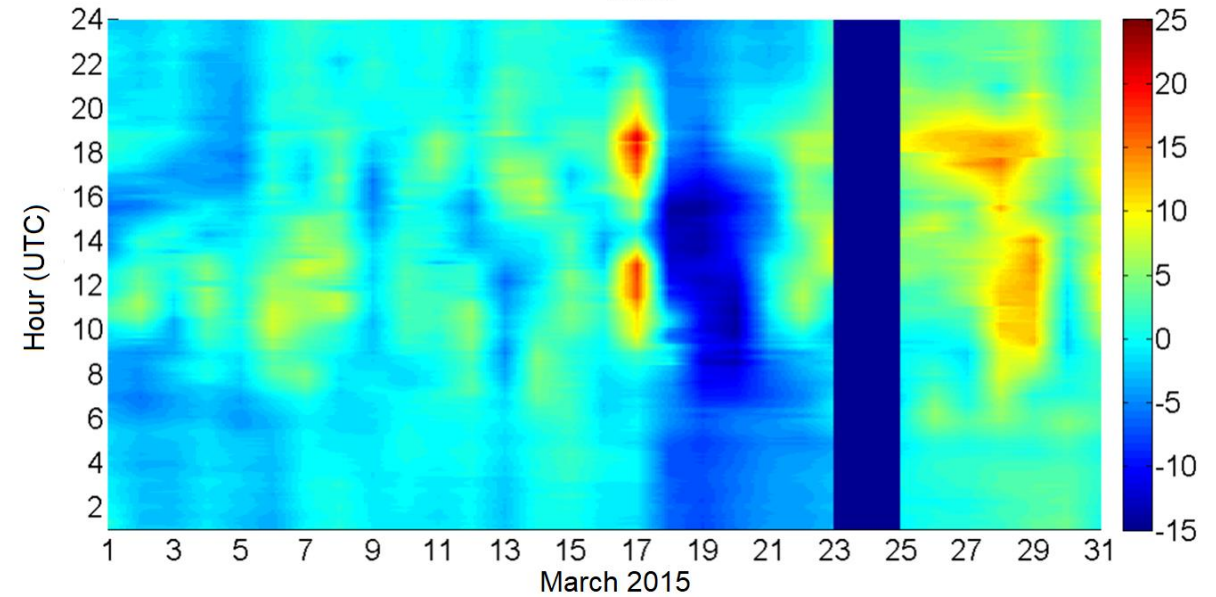
# Space weather in March 2015

## Geomagnetic storm: March 17



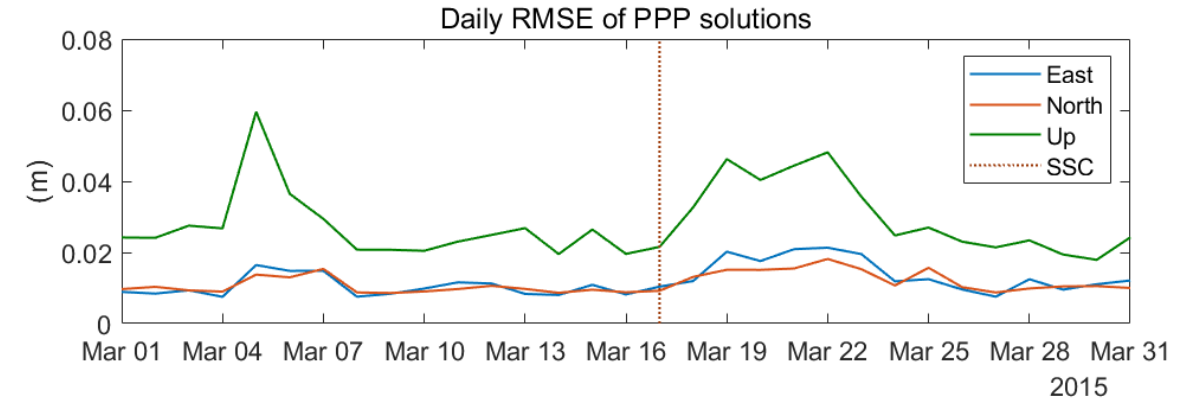
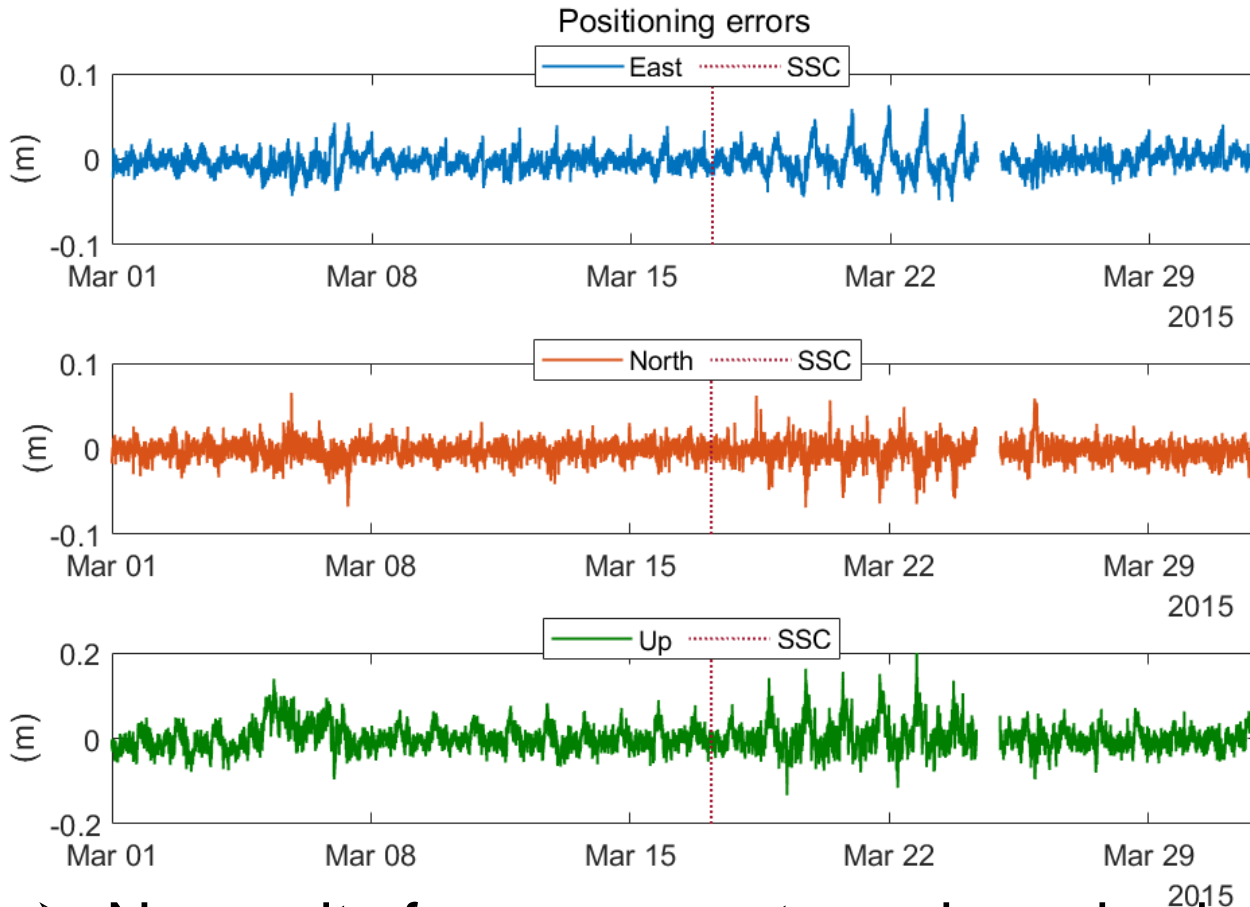
Storm sudden commencement (SSC)

$$dVTEC = VTEC - VTEC_{\text{mean}}, \text{ GNSS EPN SRJV}$$



# Effect on Precise Point Positioning (PPP)

Dual-frequency, L3 linear combination



Terrestrial weather  
(snowfall)

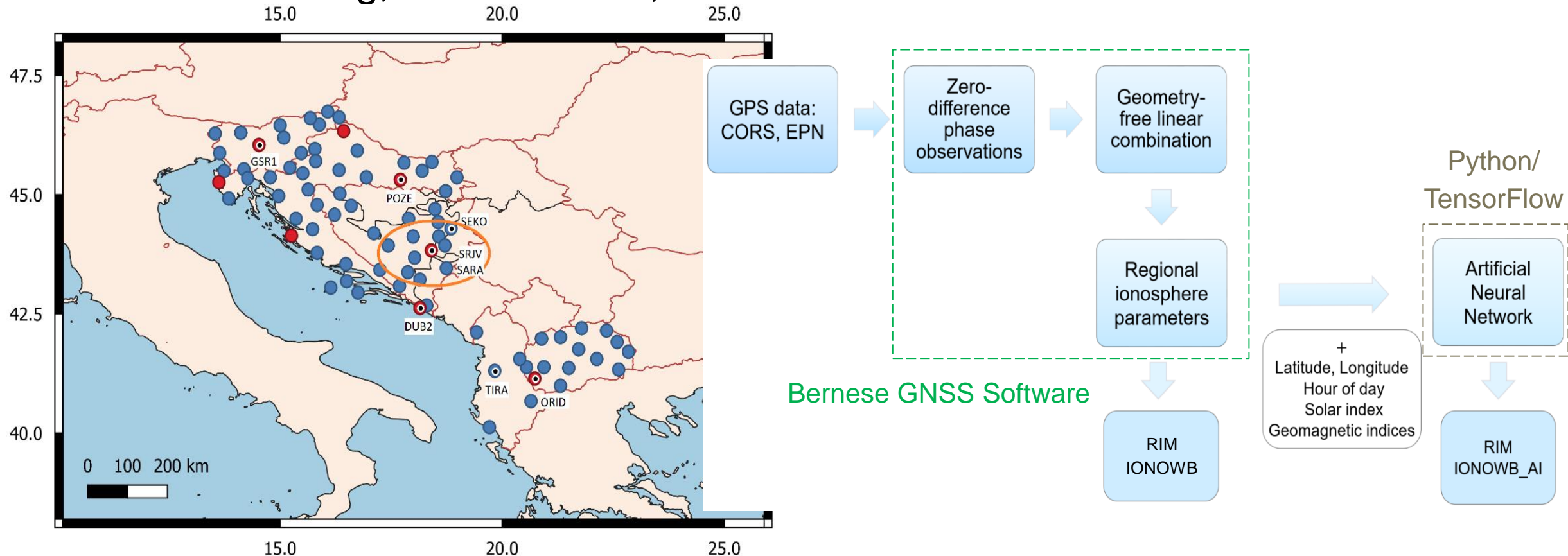
Space weather

Natras, R. et al. (2019): GNSS ionospheric TEC and positioning accuracy during intense space and terrestrial weather events in B&H, DOI: 10.15292/geodetski-vestnik.2019.01.73-91

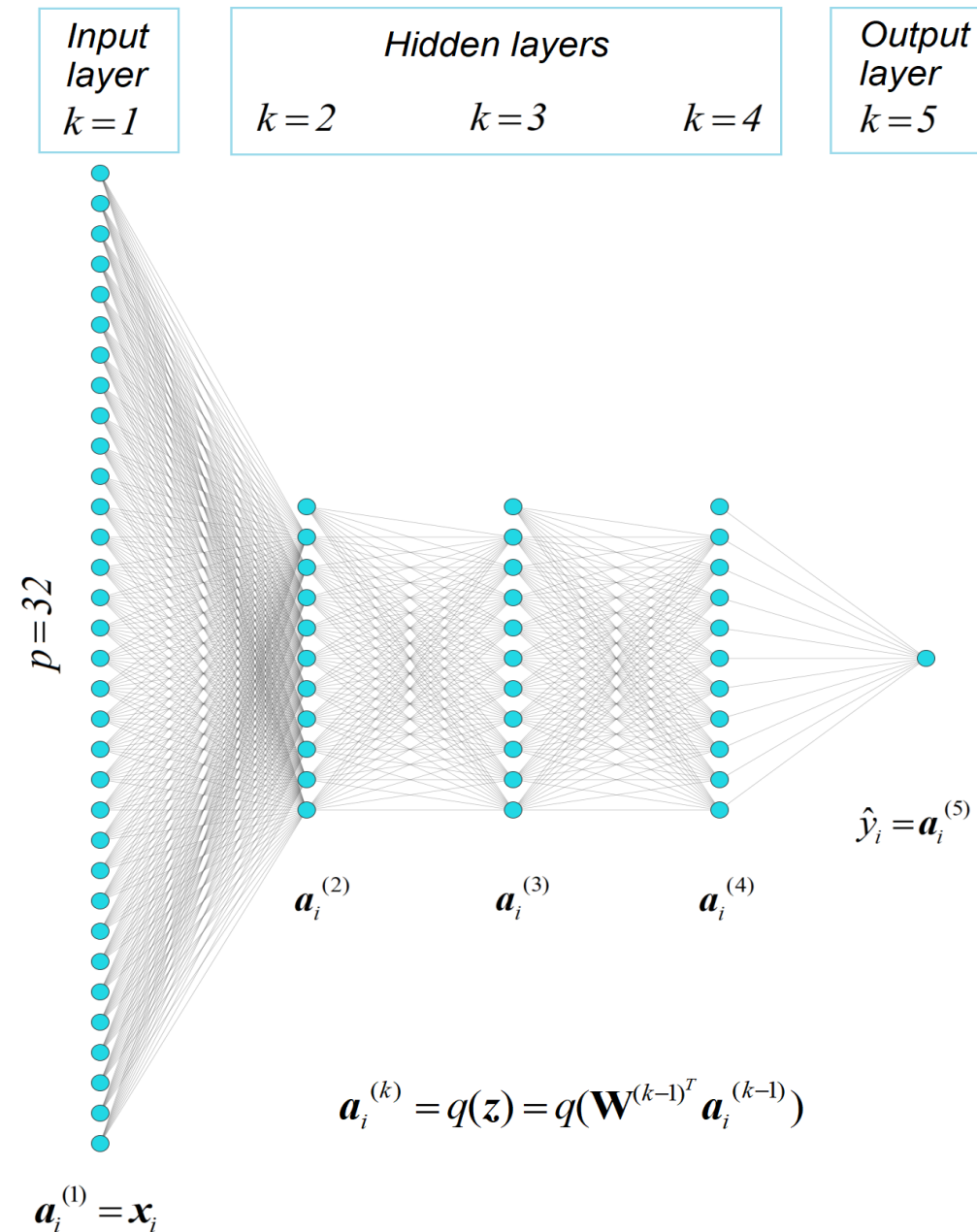
- Necessity for an accurate and precise ionosphere model based on GNSS observations to correct for the ionospheric effects in positioning solutions.

# Regional ionosphere models (RIM) based on CORS data and machine learning

- Natras, R. et al: Regional ionosphere delay models based on CORS data and machine learning, NAVIGATION, under review



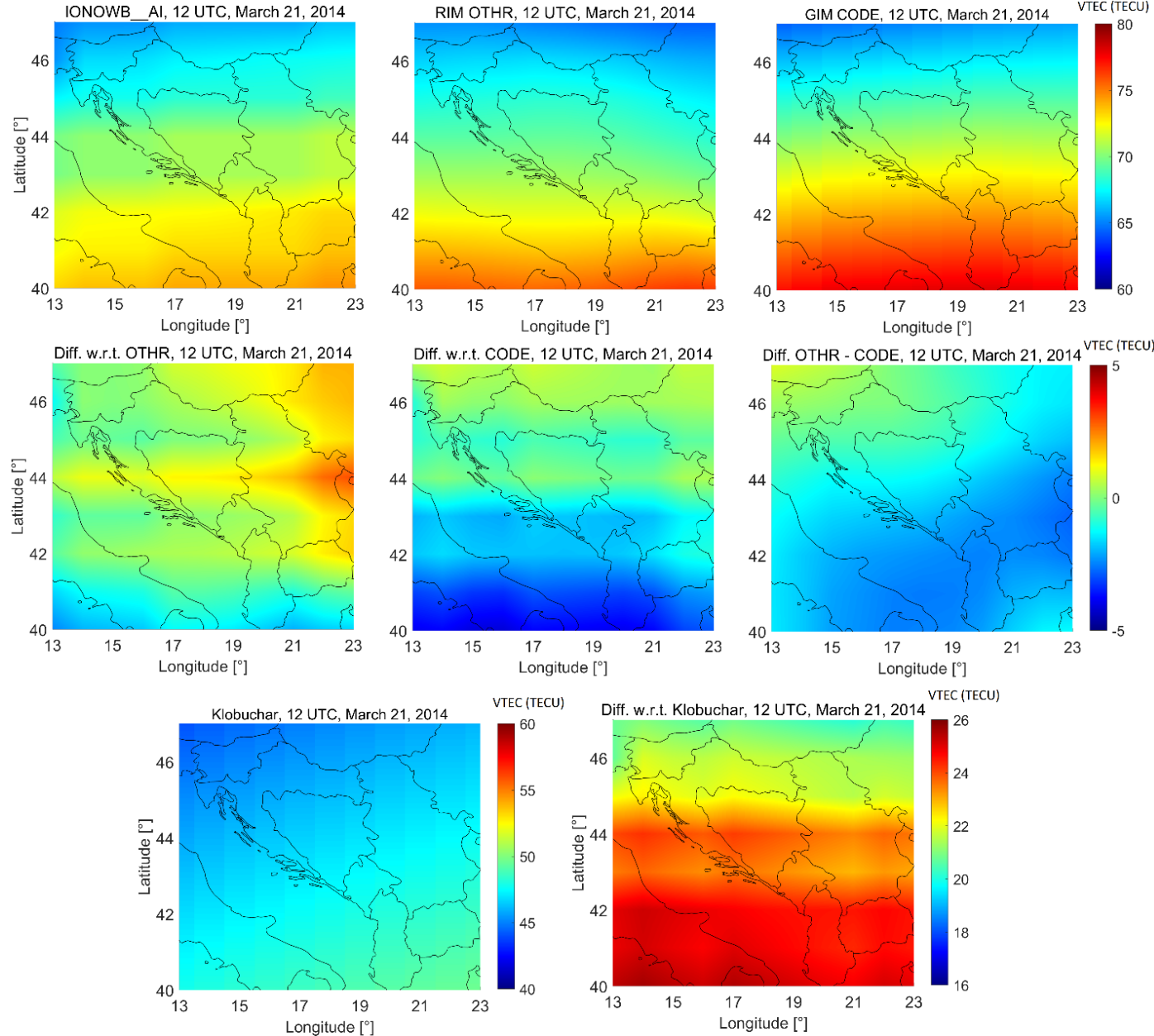
# AI / Machine Learning: Artificial Neural Network (ANN)





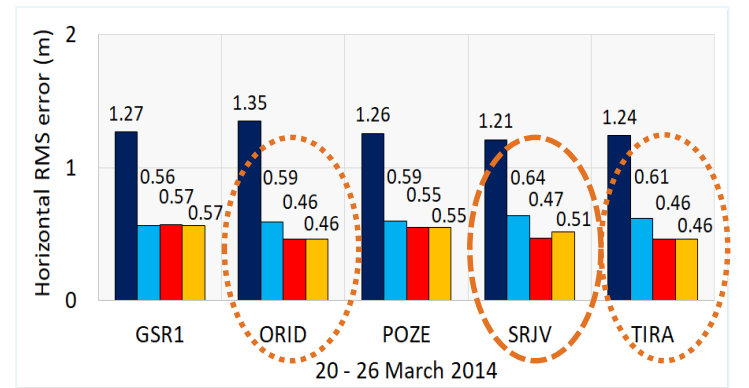
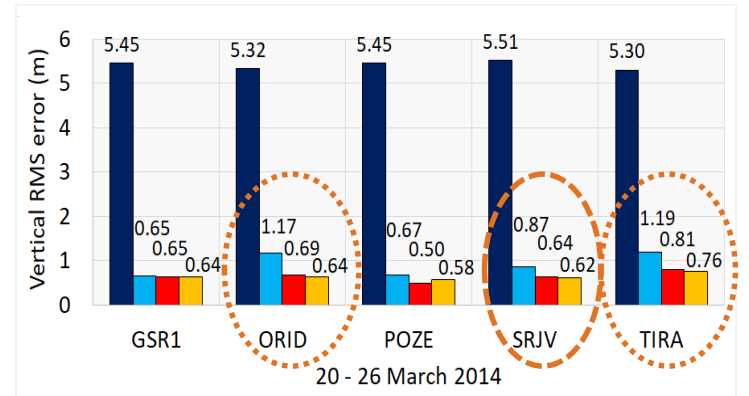
# March 21, 2014 → Solar maximum

## VTEC Maps



## Single-frequency PPP

■ NO IONO MODEL ■ GIM\_CODE ■ IONOWB ■ IONOWB\_AI



## Conclusion

- VTEC variability (EPN SRJV): daily, seasonal, semi-annual, solar cycle and space weather dependable variations.
- Space weather → rapid, major disturbances: 50% to 150% VTEC change.
- Position errors at the dm-level: to 6 cm (east), 7 cm (north) and 20 cm (up).
- RIMs development utilizing dense CORS networks in the Western Balkans.
- To address the needs of GNSS users for an effective ionospheric correction.

## Thank you for your attention!

Randa Natras

Technical University of Munich

[randa.natras@tum.de](mailto:randa.natras@tum.de)

