

A sequential calibration technique to improve IRI-2016 using TEC estimates of the GNSS network in Europe

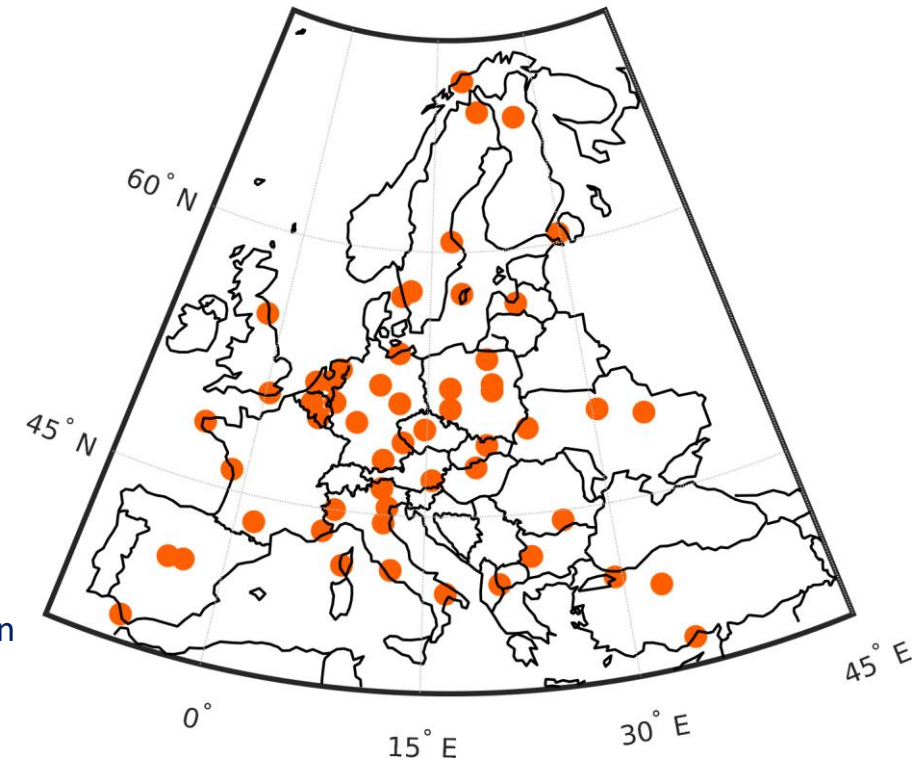
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- The integral part of Global Navigation Satellite System in **positioning and navigation**
- Limited the accuracy of position derived from GNSS signal due to **extreme distance and speed of satellite**
- The key role of **modelling the ionospheric delay** on the signal to achieve high accuracy in GNSS positioning
- We aim to introduce a **sequential calibration** based on the Ensemble Kalman Filter to develop **IRI2016** model over Europe

Improving the model limitations in simulating VTECS using the VTEC observations from a regional GNSS network

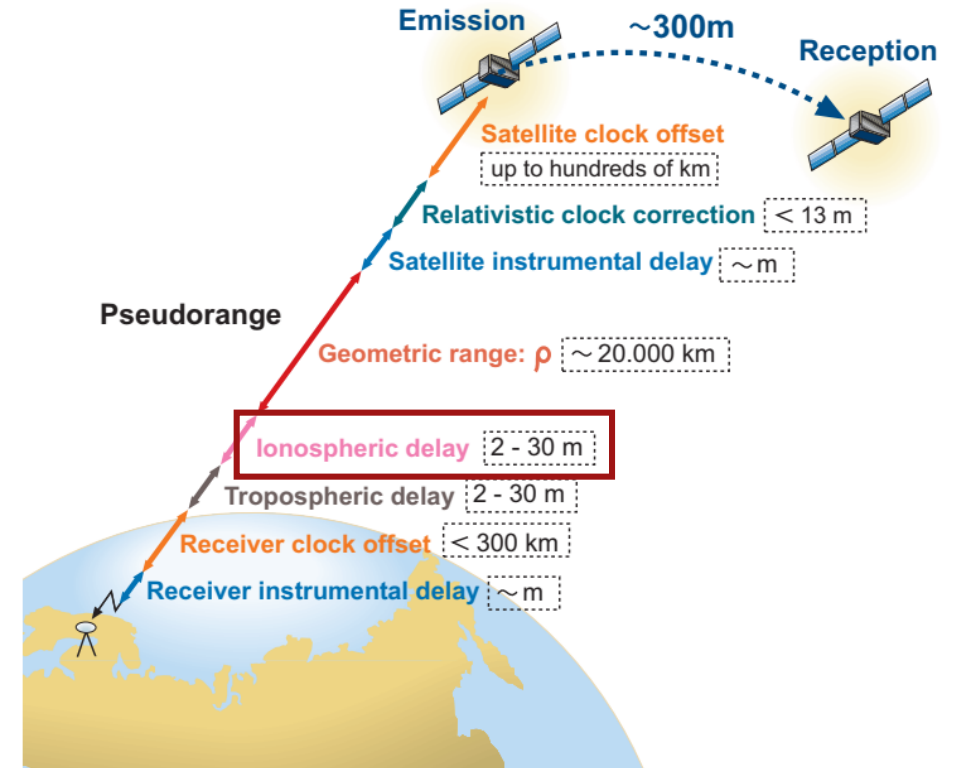


Fig1: The different time delay terms in the pseudorange

- **GNSS station** : Using GPS measurements of **56 IGS stations** within Europe with 30second sampling rate
- Calibration period : **September, 2017**
- STEC Determination Using GPS Measurements:

$$STEC = \left(\tilde{P}_4 - br - bs - \langle \varepsilon_p \rangle_{arc} + \varepsilon_L \right) \left(\frac{f_1^2 f_2^2}{40.3(f_2^2 - f_1^2)} \right)$$



- **IRI-2016** simulation VTEC based on:
 - Geodetic latitude and longitude
 - Local apparent Solar Time
 - Solar index or R12, Magnetic index and Ionosphere index (IG12)
 - Model coefficients of URSI or CCIR
- The key parameters of the model obtained by performing GSA
 - **URSI(771)**
 - **URSI(1752)**
 - **URSI(1327)**
 - **IG12**

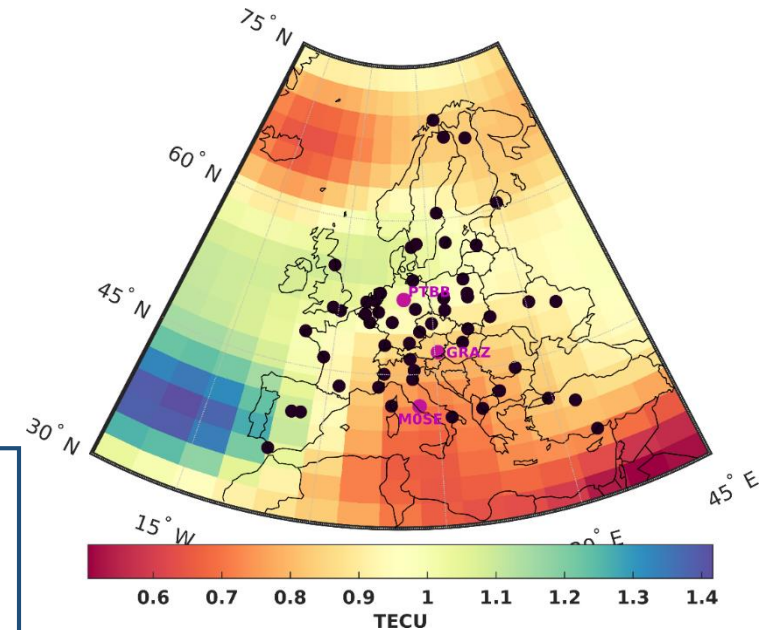
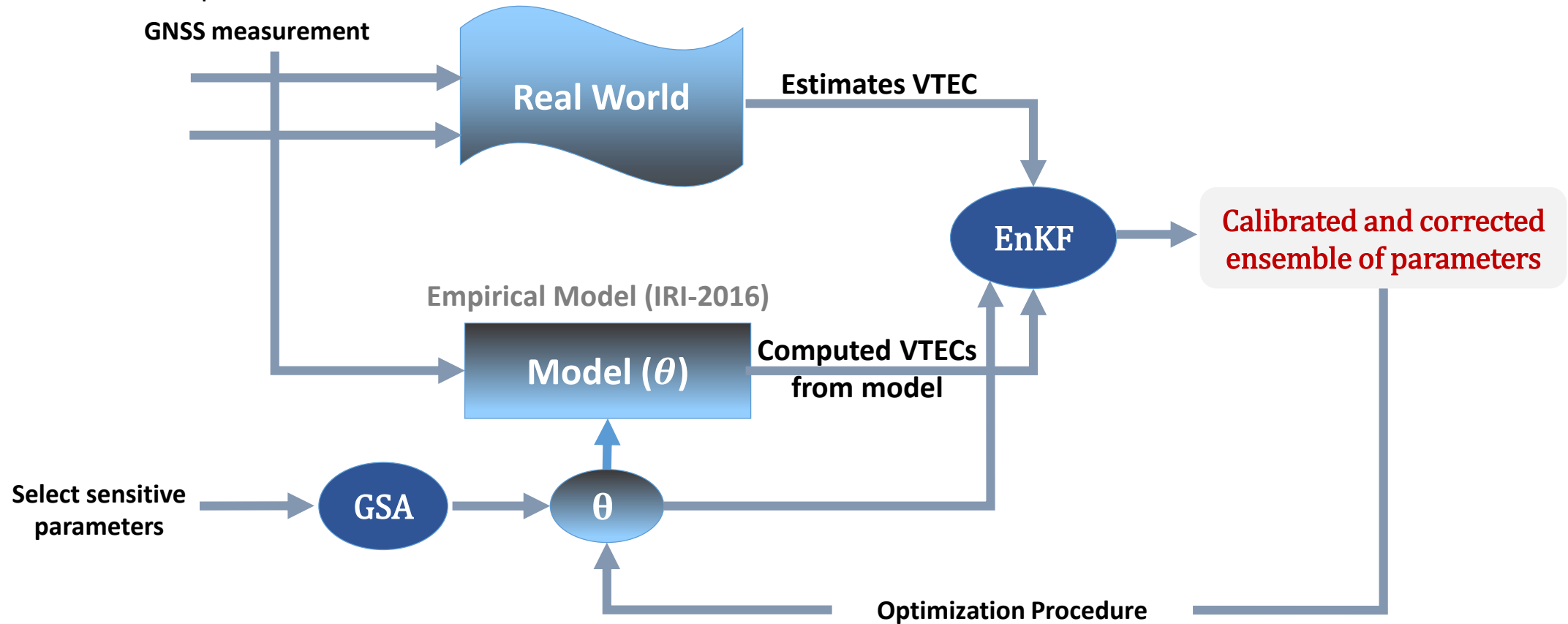


Fig2: An overview of the IGS stations within Europe. The background correspond to the mean of RMS of VTECs from CODE-GIM. The black and purple circles show the stations used for calibration and validation, respectively.

3. Method (Sequential Calibration Based on Ensemble Kalman Filter)

- **Setup of C-EnKF**

- Ensemble member : **90**
- Calibration window : **15 minutes**
- Observations in each epoch : **53 VTECs**



4. Results

- Assessment the C-EnKF-IRI method in **forecasting of VTECs** using the calibrated parameters of previous day.
- The mean of RMSE between the model and GPS-VTEC estimates are reduced from **2.5 to 1.1 TECU** in C-EnKF procedure during the 29 (2th-30th) days of September.
- The monthly average of differences between C-EnKF-IRI and IGS-IONEX is within the range of **1.18 – 2.02 TECU**, while that of the original IRI is within the range of **2 – 3.7 TECU**.
- C-EnKF-IRI performs as good as the 11-days delayed IONEX fields in estimating ionospheric delays in a SPP application.

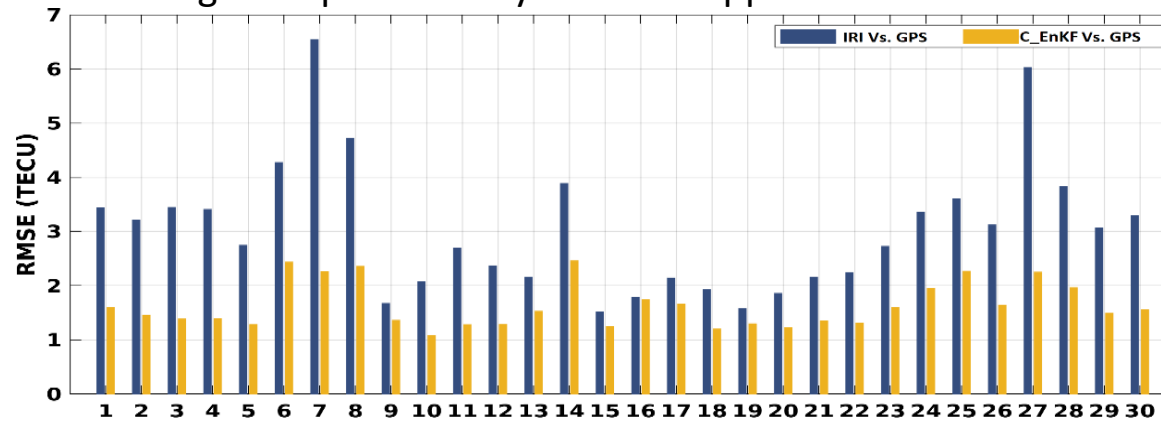


Fig5 : An overview of hourly mean variations of RMSEs during September, 2017.

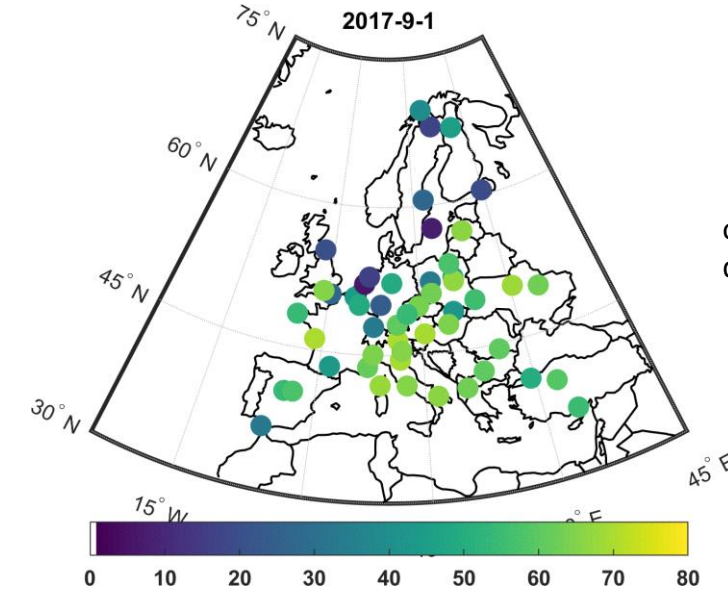


Fig 3: Spatial distribution of improvements (%) during September, 2017.

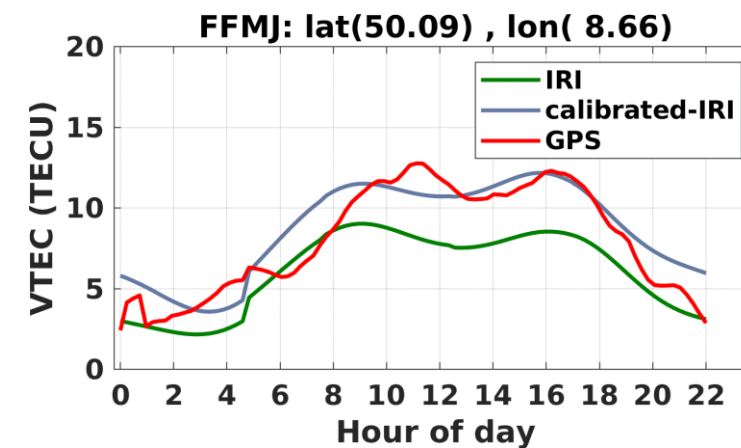


Fig 4: Time-series of VTECs during September,4, 2017.

Findings:

- Introducing the novel approach in order to calibrate model using geodetic observation
- The better performance of C-EnKF-IRI in forecasting of VTECs compared to the original model.
- The ability of C-EnKF-IRI model in estimating ionospheric delays as good as the current IGS product but with less delays.

Future Plan:

- Investigating the method in more **SPP** applications
- Estimating VTECs from **Galileo, GLONASS and BeiDou**
- Using other data sources such as **radio occultation**
- Imposing **constraints** on the parameters to be estimated

