Using b-splines to Model Total Electron Content derived from Radio Occultation measurements by COSMIC satellites over the African region

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Outline

- Necessity for TEC modeling
- TEC from COSMIC radio occultation (RO) Data
- TEC Data organization
- The b-spline modeling technique
- Model validation using reserved RO TEC
- Model Validation using ionosonde TEC
- Conclusions

Necessity for TEC modeling

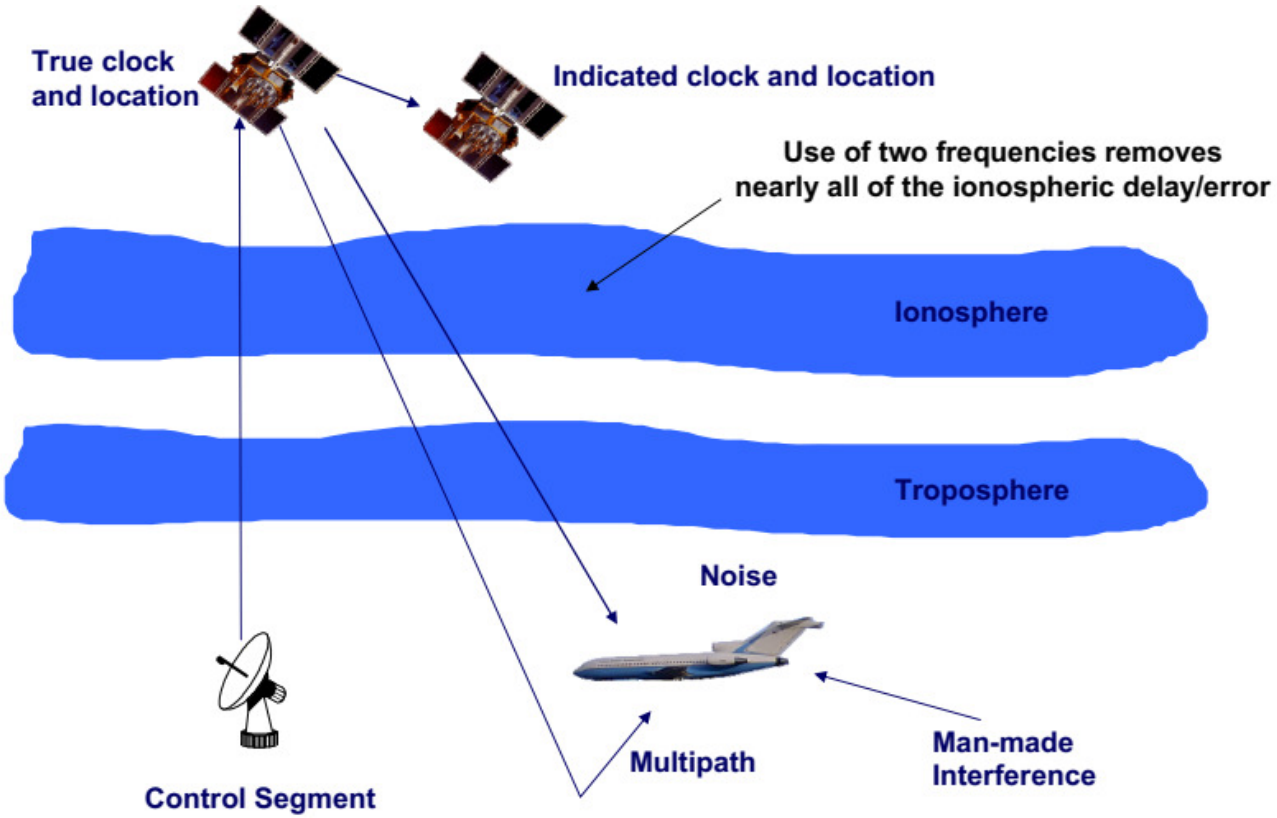


Figure: 1 (From MITRE presentation)

Examples of TEC models: NeQuick, International Reference Ionosphere, Klobuchar model

The COSMIC radio occultation (RO) TEC Data

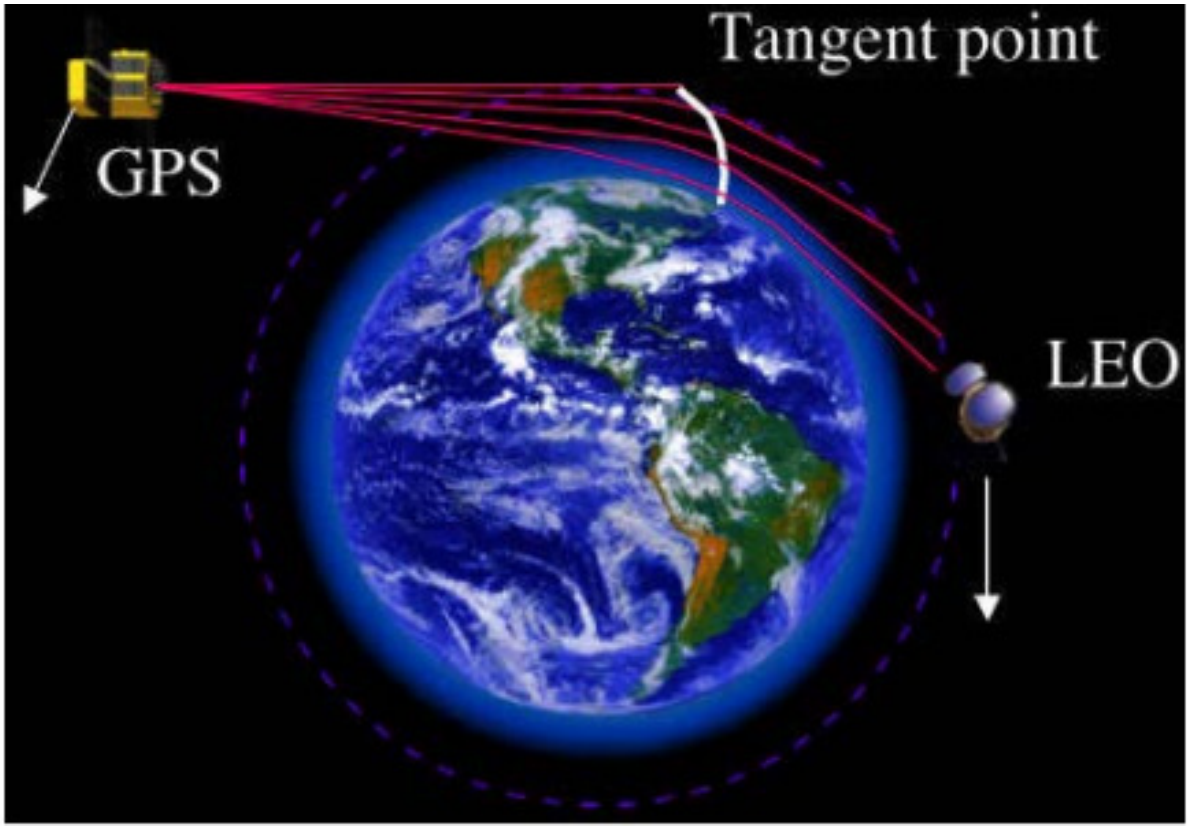
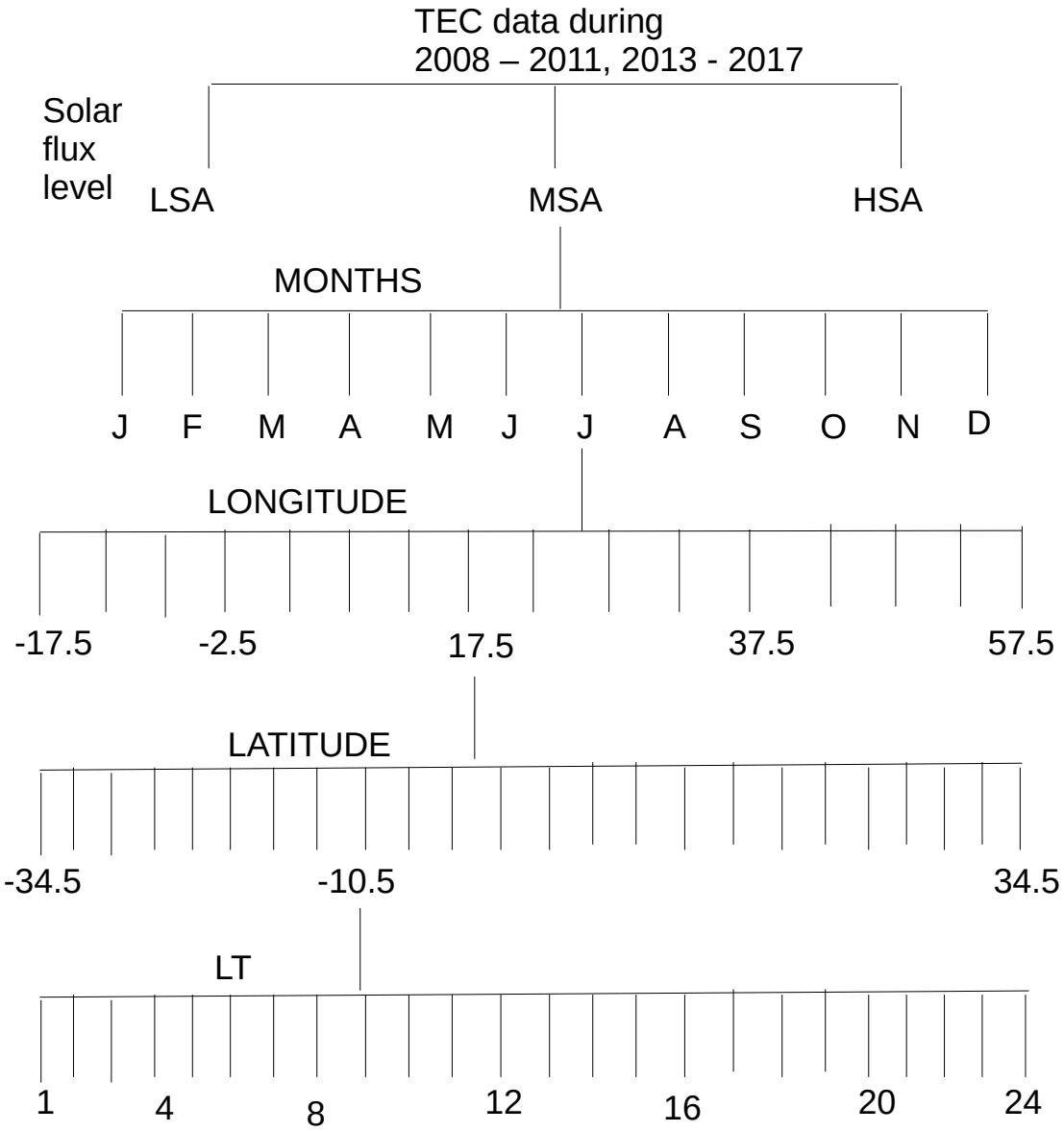


Figure: 2 (from Schreiner, et al. (1999). Analysis and Validation of GPS/MET Radio Occultation Data in the Ionosphere, radio sci.)

Inversion Techniques and Issues of filtering

TEC Data organisation (1/3)



TEC Data organisation (2/3)

- A total of 331,776 TEC data values were needed to exist in 16 longitudinal, 24 latitudinal, 3 solar flux, 12 monthly, and 24 hourly bins, in order to determine the model coefficients.

- However, from the data of the entire study period, only 121,447 bins were filled with TEC data values

TEC Data organisation (3/3)

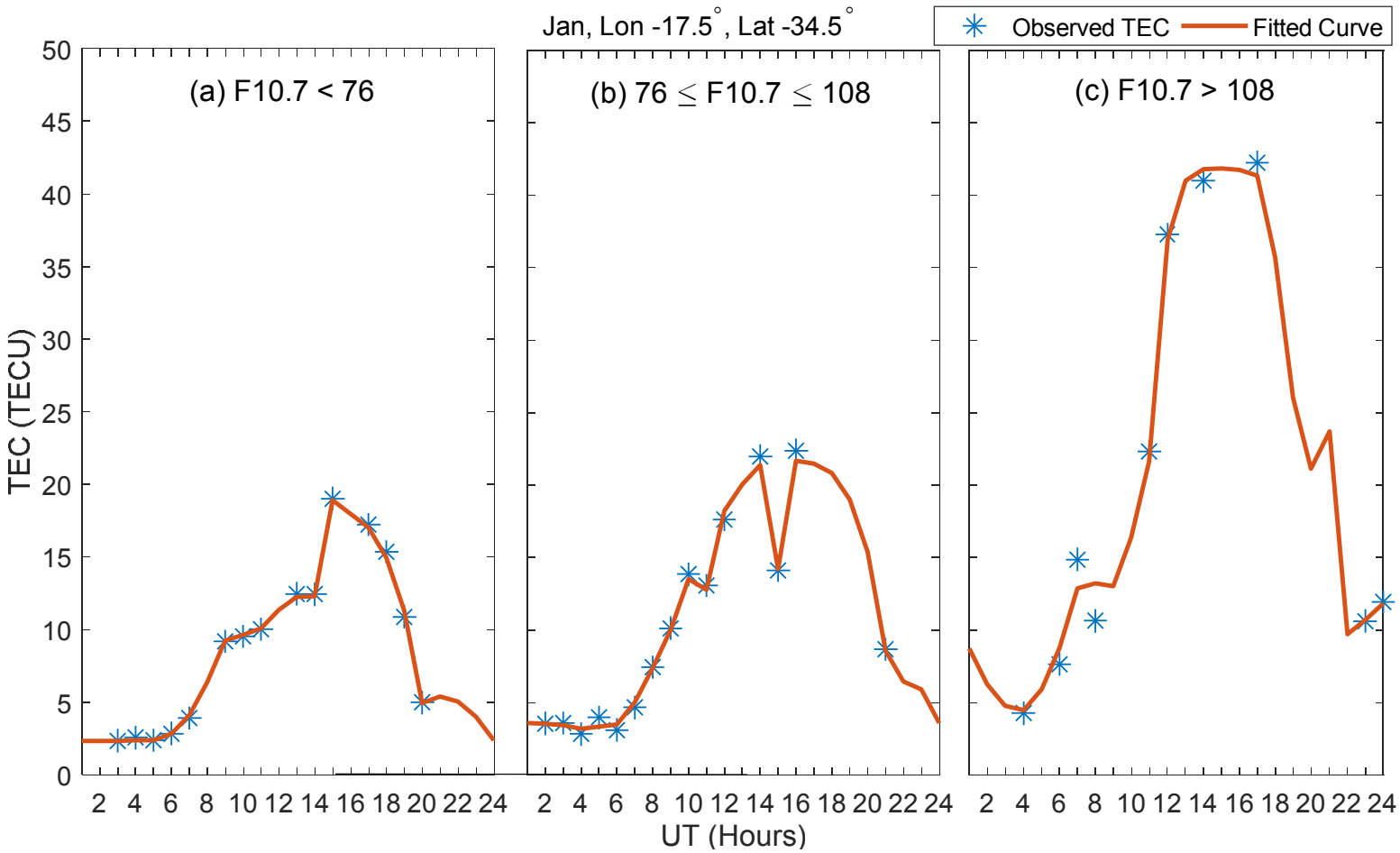


Figure: 3 Estimating Missing TEC values

B spline modeling technique

The TEC over African region was expressed as:

$$\mathrm{TEC}(\mathrm{t},\mathrm{d},\mathrm{F},\lambda,\varphi) = \sum_{i=1}^{24}\sum_{j=1}^{12}\sum_{k=1}^{3}\sum_{l=1}^{16}\sum_{m=1}^{24} a_{ijklm} N_i(t) \times N_j(d) \times N_k(F) \times N_l(\lambda) \times N_m(\varphi)$$

De-Boor, C. (1978): A Practical Guide to Splines, Springer, New York, USA.

Model validation using reserved COSMIC RO TEC (1/2)

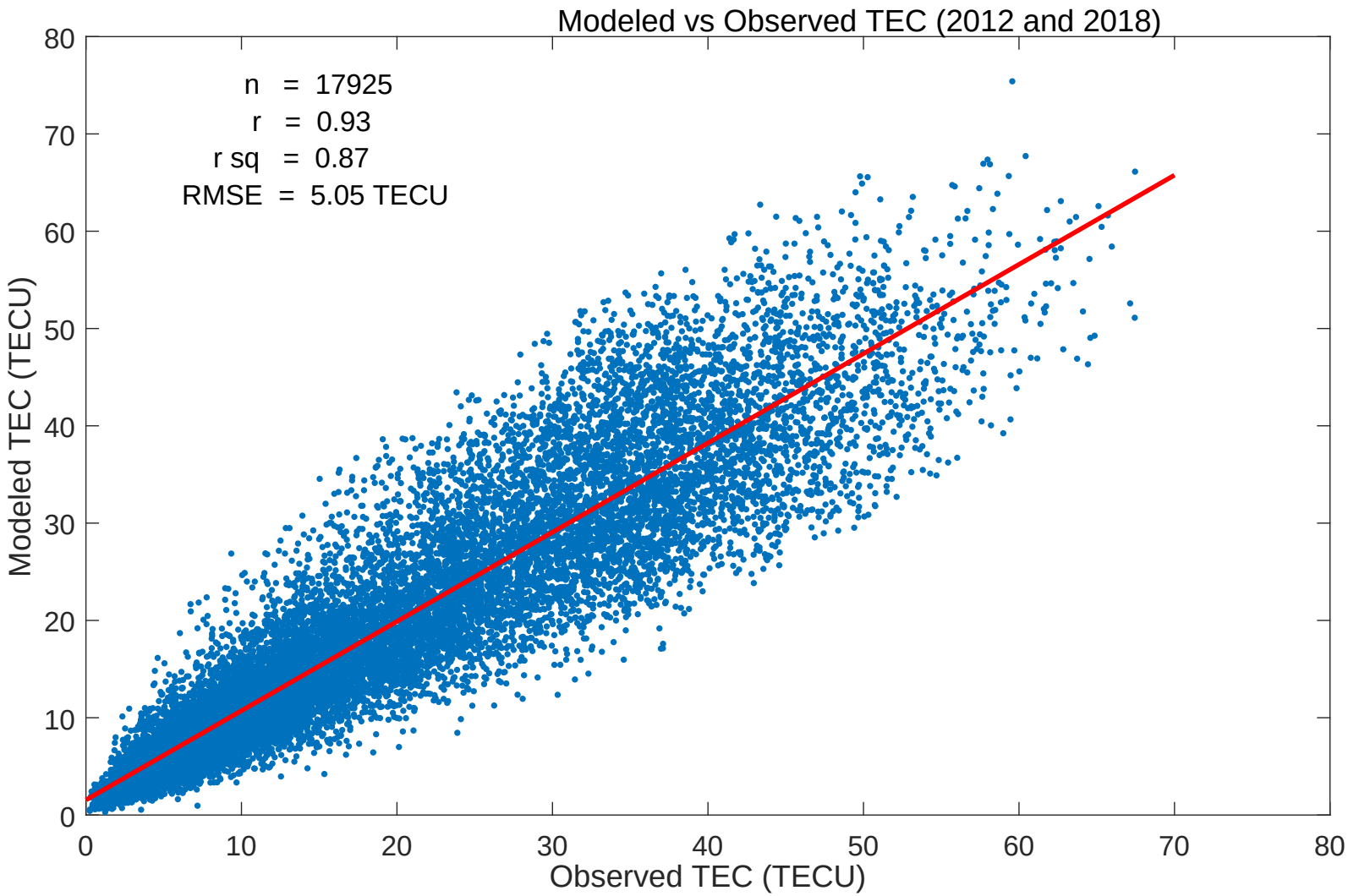


Figure: 4

Model validation using reserved COSMIC RO TEC (2/2)

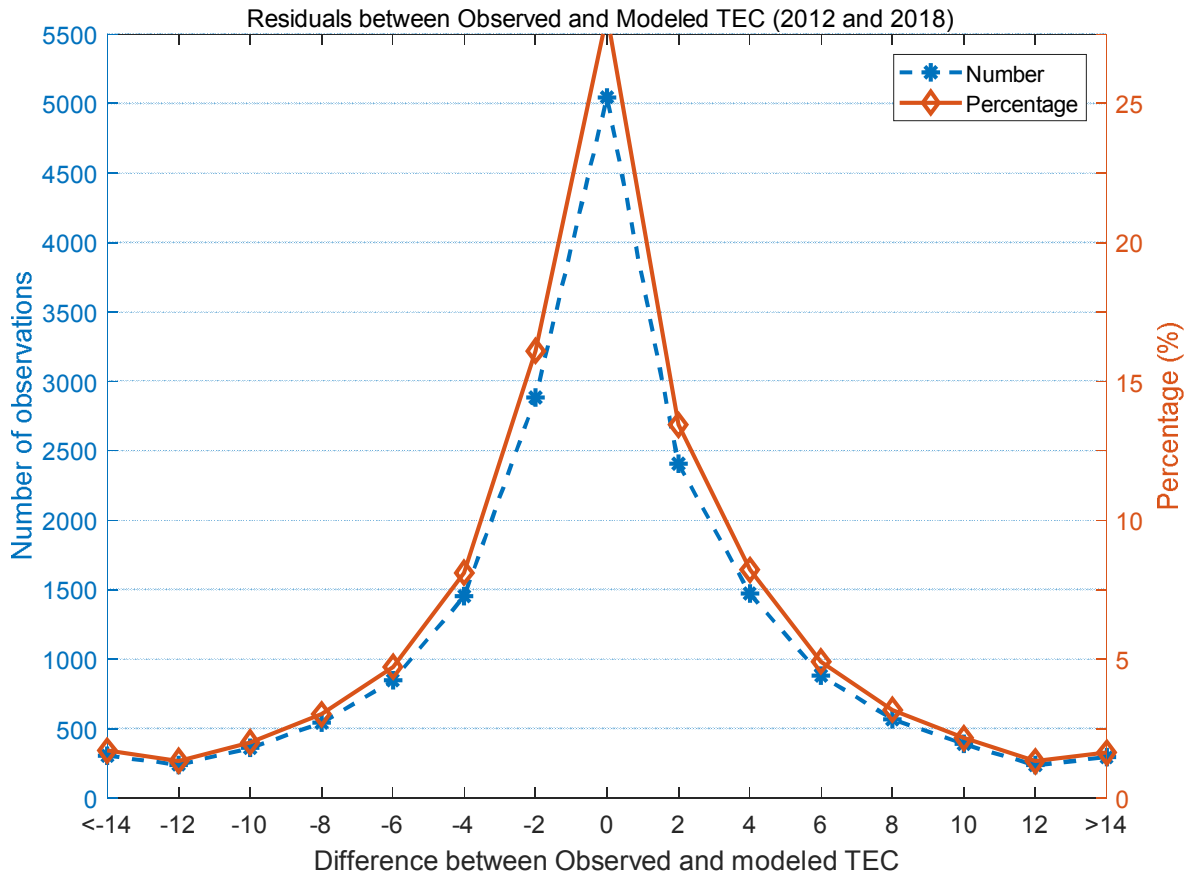


Figure: 5

Model validation using Ionosonde TEC (1/2)

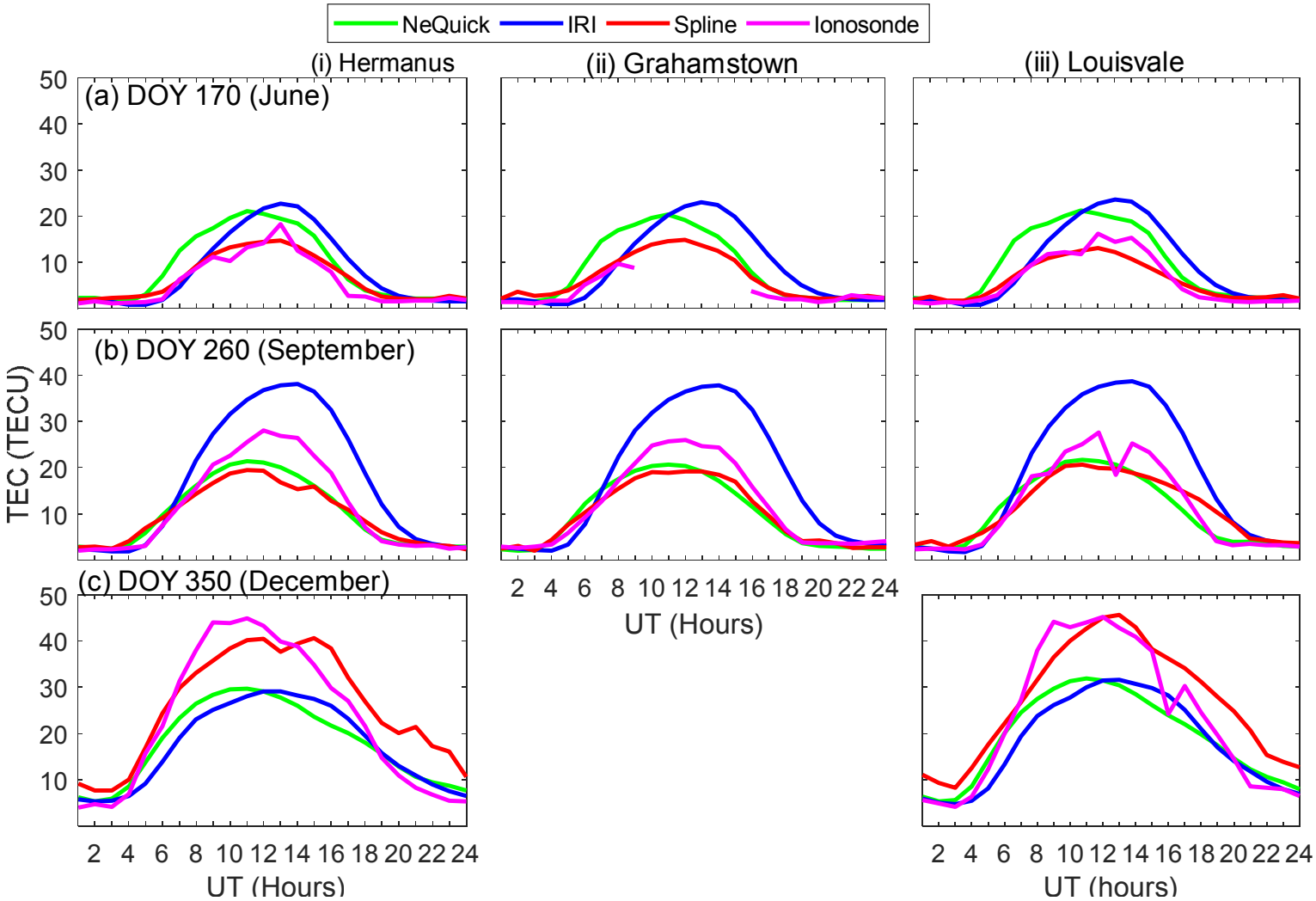


Figure: 6

Model validation using Ionosonde TEC (2/2)

r and RMSE associated with estimation of TEC observed at ionosonde stations by models (data for year 2013)

Ionosonde station (number of observations)	Model	r	RMSE (TECU)
Hermanus (n = 5110)	Spline	0.92	4.64
	IRI-2016	0.86	5.45
	NeQuick 2	0.92	4.10
Grahamstown (n = 4450)	Spline	0.88	5.56
	IRI-2016	0.82	6.29
	NeQuick 2	0.86	5.27
Louisville (n = 4543)	Spline	0.94	3.82
	IRI-2016	0.87	5.62
	NeQuick 2	0.94	3.73

Conclusions (1/2)

- TEC data obtained from RO by COSMIC satellites were binned according to local time, seasons, solar flux level and spatially.
- The coefficients of b-splines that were fitted to the binned data were determined by means of the least square procedure
- Validation exercise revealed that

  (i) the observed and the modeled TEC correlate highly,

  (ii) the modeled TEC closely approximates the observed TEC.

Conclusions (2/2)

- Validation of our model using TEC obtained from ionosonde stations yielded r values > 0.92 and RMSE < 5.56 TECU.
- The validation results imply that our model can estimate fairly well TEC that would be measured by ionosondes over locations which do not have the instrument.

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(c) Developers of NeQuick and IRI Models

(d) World data center at kyoto University, Japan (Kp and Dst)

(e) NOAA (F10.7 flux and ionosonde measurements)

(f) COSMIC data analysis and archive center

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The End

Thanks for Listening