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A simulation study of SMOS VTEC-enhanced global ionospheric modeling

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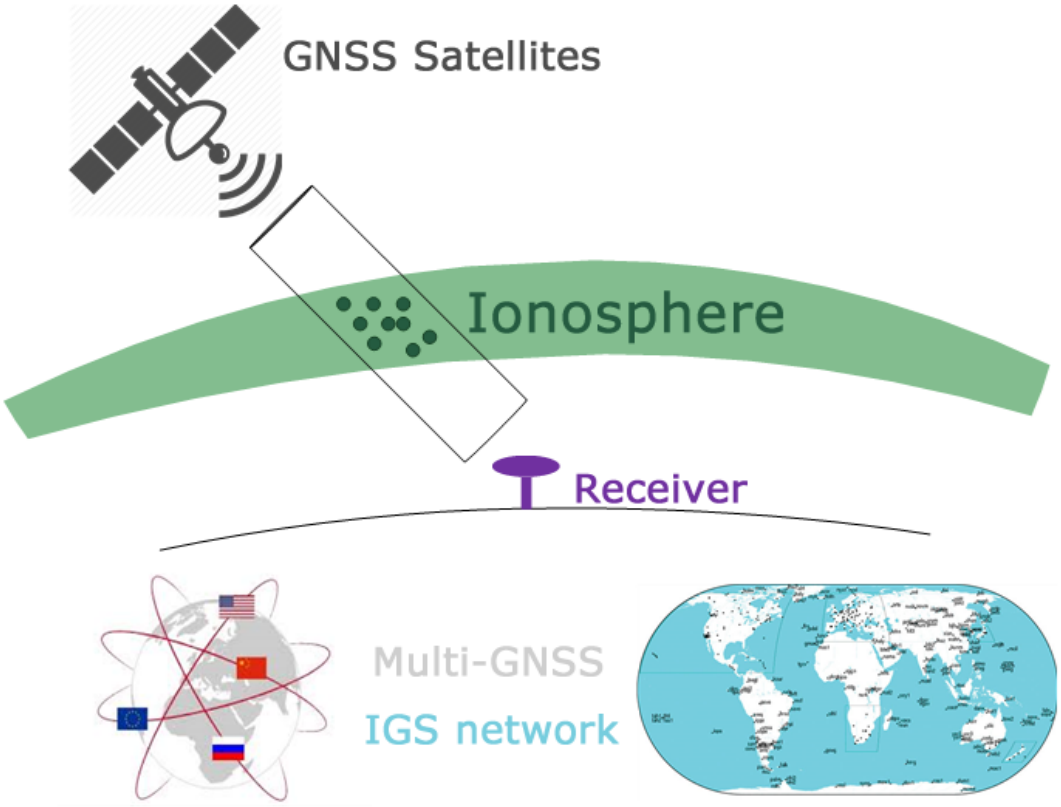
Ionosphere and Space Weather http://ionosphere.cn

Outline

1. Global ionospheric VTEC modeling
2. Some improvements
3. SMOS VTEC-enhanced ionospheric modeling

01 Global ionospheric modeling

Data Source: IGS GNSS Network

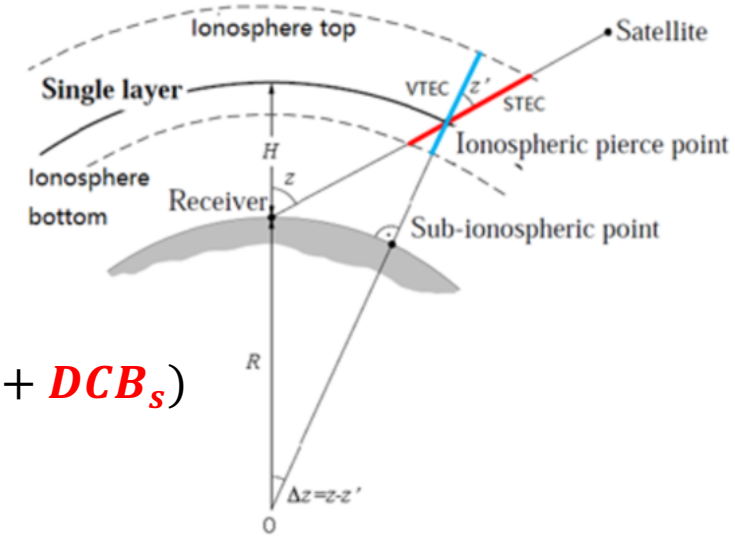


- ✓ Global ionospheric TEC maps by using the GNSS observations from worldwide IGS stations

Methodology: Spherical Harmonics Function

$$\begin{cases} P = \rho_0 + c(dt_R - dt_s) + \boldsymbol{I} + T + c(b_R + b_s) + M + \varepsilon \\ \lambda\Phi = \rho_0 + c(dt_R - dt_s) - \boldsymbol{I} + T + c(\phi_R + \phi_s) + M + \varepsilon - \lambda N \end{cases}$$

$$P_1 - P_2 = \frac{40.3(f_2^2 - f_1^2)}{f_1^2 f_2^2} STEC + c(DCB_r + DCB_s)$$

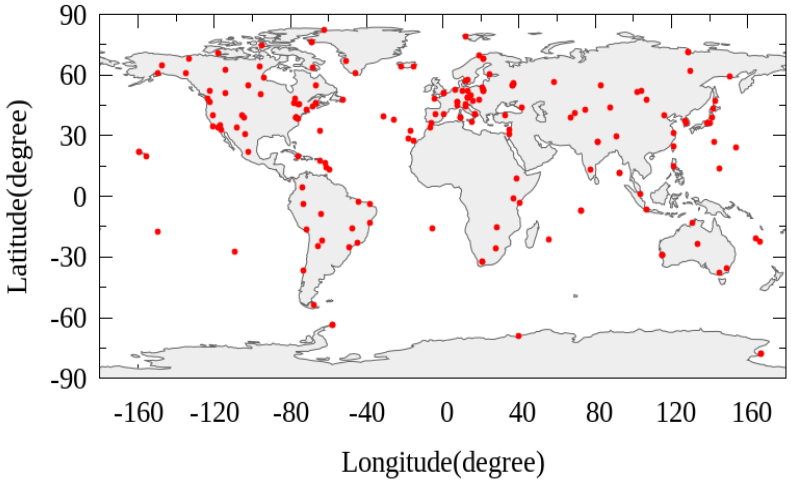


$$P_1 - P_2 = \frac{40.3(f_2^2 - f_1^2)}{f_1^2 f_2^2} mf(z) \cdot \boldsymbol{VTEC} + c(\boldsymbol{DCB_r} + \boldsymbol{DCB_s})$$

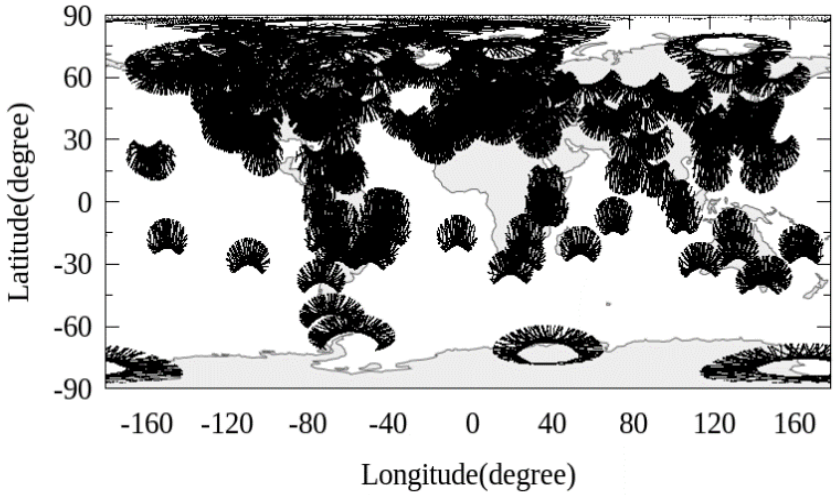
$$VTEC(\varphi, \lambda) = \sum_{n=0}^{n_{max}} \sum_{m=0}^{n} \tilde{P}_{nm}(sin\varphi)(\boldsymbol{a_{nm}} \cos(m\lambda) + \boldsymbol{b_{nm}} \sin(m\lambda))$$

Factors

1. Solar/Geomagnetic activities
2. Equatorial ionization anomaly(EIA)
3. Neutral wind
4. **in-homogeneous observations**



IGS stations

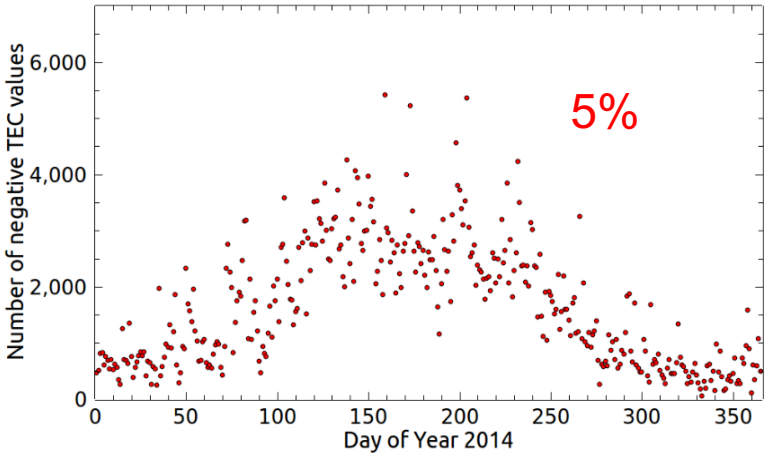


Ionospheric pierce points

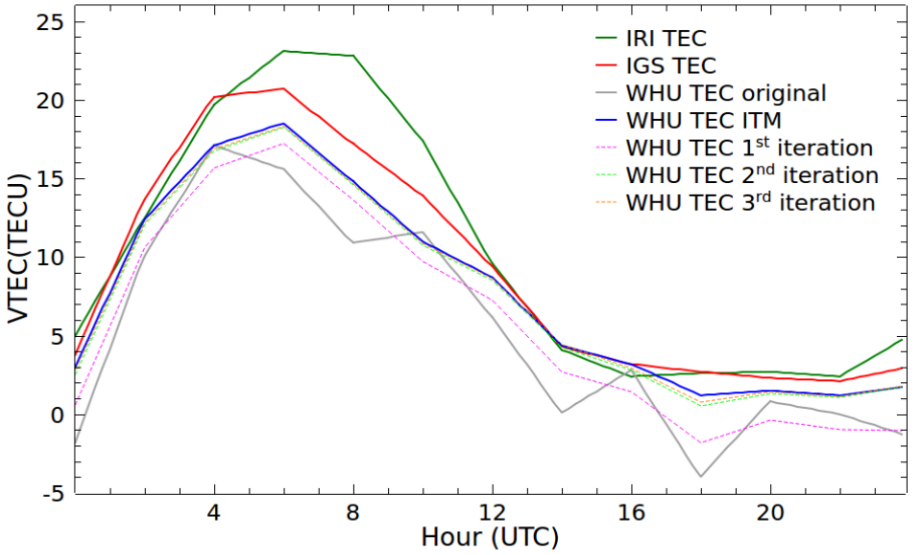
02

Improvements

Improvement: using empirical model



Original SH model VTEC



(50˚S, 100˚E) VTEC, DOY 230, 2014

The empirical model (IRI) is used to eliminate the negative TEC values

doi: 10.1016/j.jastp.2016.05.014

Improvement: prior information

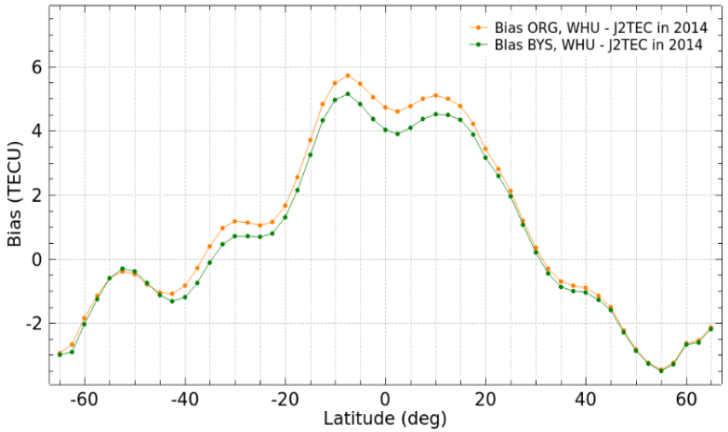
$$\begin{cases} \hat{X} = \left(A^T P A + {\Sigma_{\bar{X}}}^{-1}\right)^{-1}\left(A^T P L + {\Sigma_{\bar{X}}}^{-1}\bar{X}\right) \\ \hat{\sigma}^2 = \dfrac{V^T P V + {V_X}^T {\Sigma_{\bar{X}}}^{-1} V_X}{n}, V = A\hat{X} - L, V_X = \hat{X} - \bar{X} \end{cases}$$

$\bar{X}$: prior parameters (SH coef. & DCB)
$\Sigma_{\bar{X}}$: prior covariance matrix

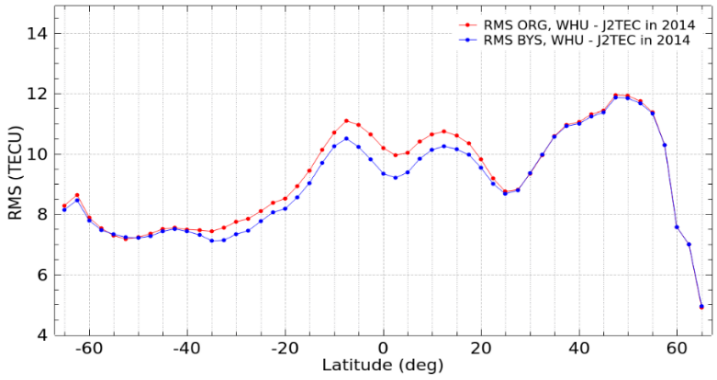
Essentially, it is to use new observations to update the prior parameters and variance covariance.

RMS consistency with IGS GIMs

	IGS	CODE	JPL	ESA	UPC
Prob.	89.86%	89.32%	70.96%	97.81%	96.16%
Min	-0.42	-0.48	-0.52	-0.20	-0.27
Max	1.46	1.39	0.77	1.43	1.19
Mean	0.28	0.28	0.10	0.39	0.33



Latitudinal Bias (vs JSON VTEC)



Latitudinal RMS (vs JSON VTEC)

doi: 10.3390/rs10010063

Improvement : GPS+GLONASS

Approach	1	2	3
GPS	1.793	1.684	1.586
GLONASS	-	4.949	1.588

App\Res		(0, 1)	(1, 2)	(2, 3)	(3, 4)	(4, 5)	>=5	<=3
1	G	42.99%	28.99%	16.61%	6.97%	2.50%	1.94%	88.59%
2	G	48.11%	27.55%	12.91%	5.70%	2.86%	2.87%	88.57%
	R	21.61%	19.94%	15.65%	11.25%	9.01%	22.54%	57.21%
3	G	52.90%	27.61%	11.11%	4.35%	2.49%	1.54%	91.61%
	R	20.87%	19.56%	15.86%	10.91%	8.44%	24.36%	56.29%

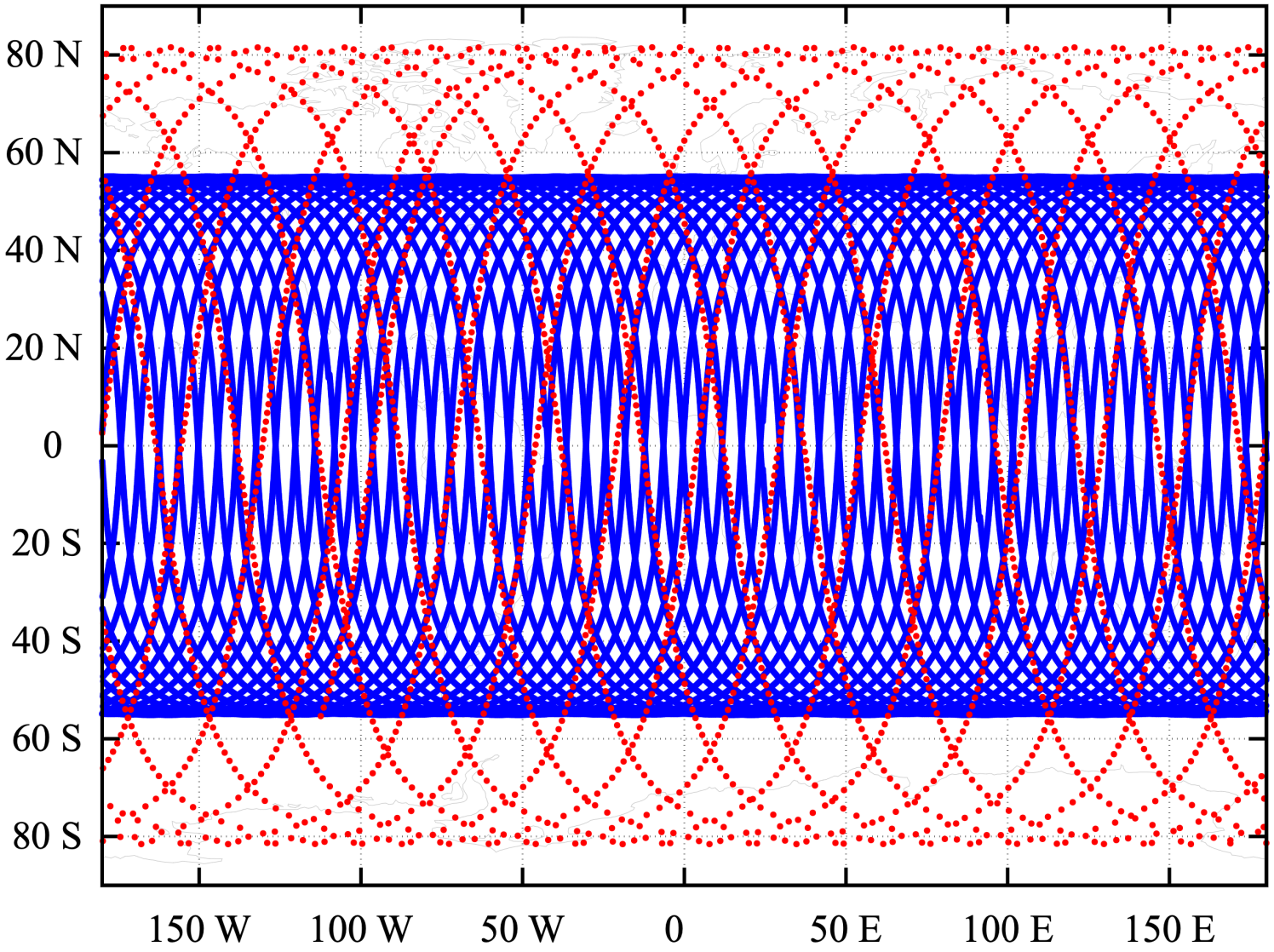
	RMS		
App.	1	2	3
CODE	2.625	2.898	2.333
JPL	3.779	4.383	3.751
ESA	4.355	4.789	4.228
UPC	3.917	4.377	3.870
IGS	2.934	3.456	2.790

Multi-GNSS is beneficial for ionospheric modeling

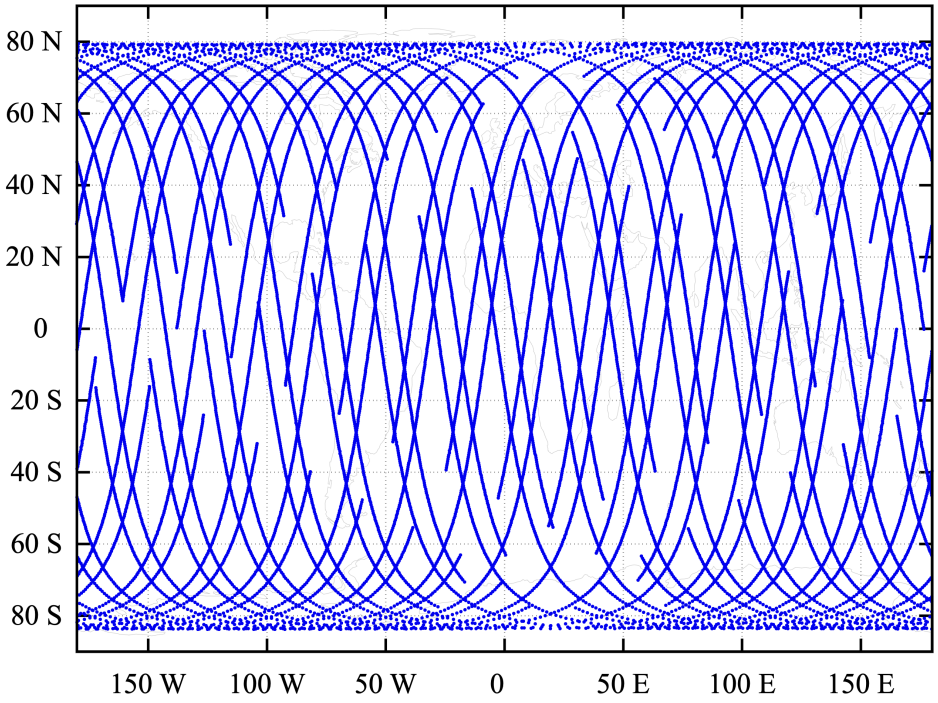
Improved, but limited.

03 SMOS VTEC-enhanced modeling

SMOS simulation: GPS+SMOS (1 day)



SMOS simulation: 15 Orbital plane, 3 Sat/OP, 1 hour



Altitude: 750km

Inclination: 98.5°

Orbital plane: 15

Adjacent orbit phase factor: 1

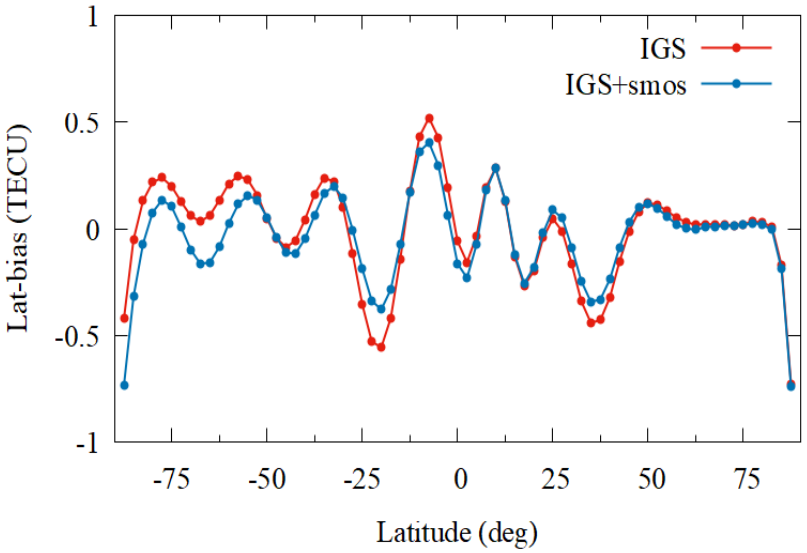
Satellite/OP: 3

Argument of perigee: 90°

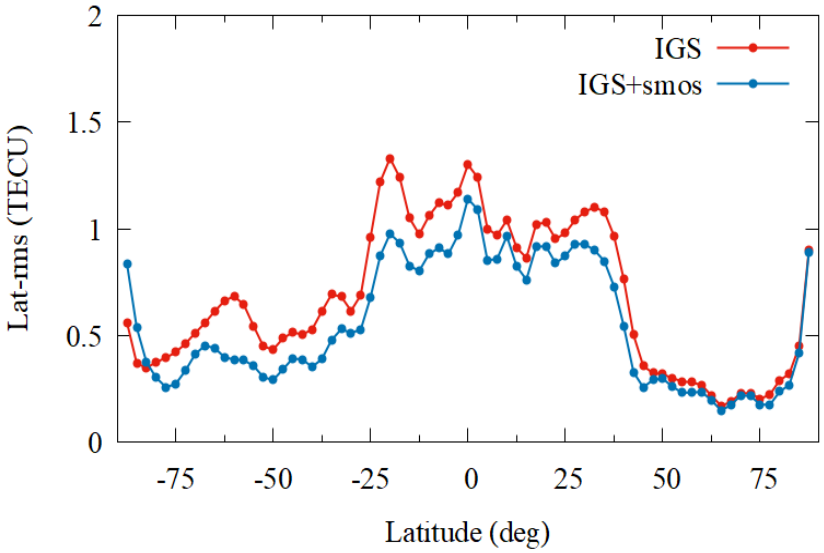
Eccentricity: 0

VTEC values are simulated by using **NeQuick model**

SMOS simulation: Ionospheric Modeling



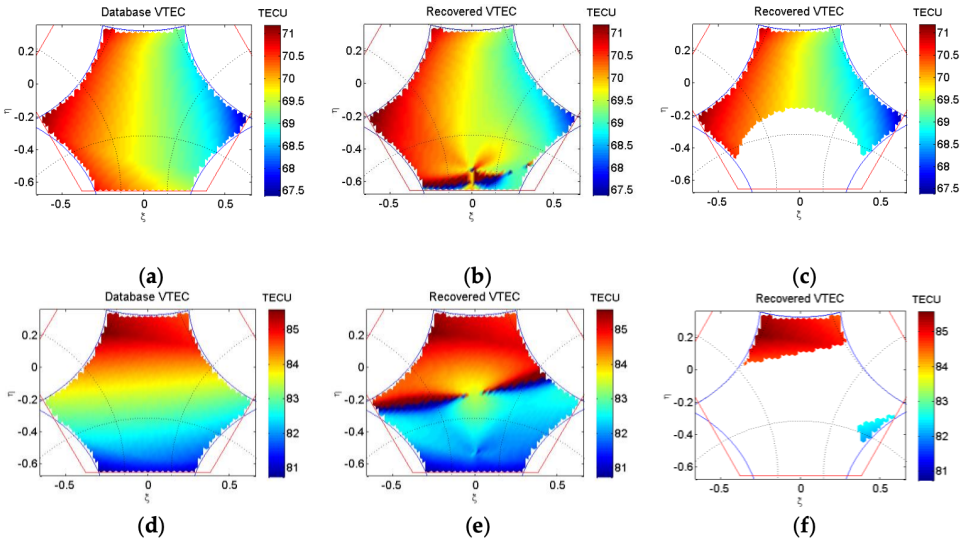
Latitudinal Bias



Latitudinal RMS

Summary

- Multi-source observations can improve the ionospheric model
- Potential deviation between GNSS VTEC and SMOS VTEC
- Considering plane observations (SMOS), more data are helpful



Roselena Rubino, doi:10.3390/rs12101604

Thanks for attention.

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