



Session 8

Online Slant TEC Computation from IRI-Plas: IRI-Plas-STECC

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Outline



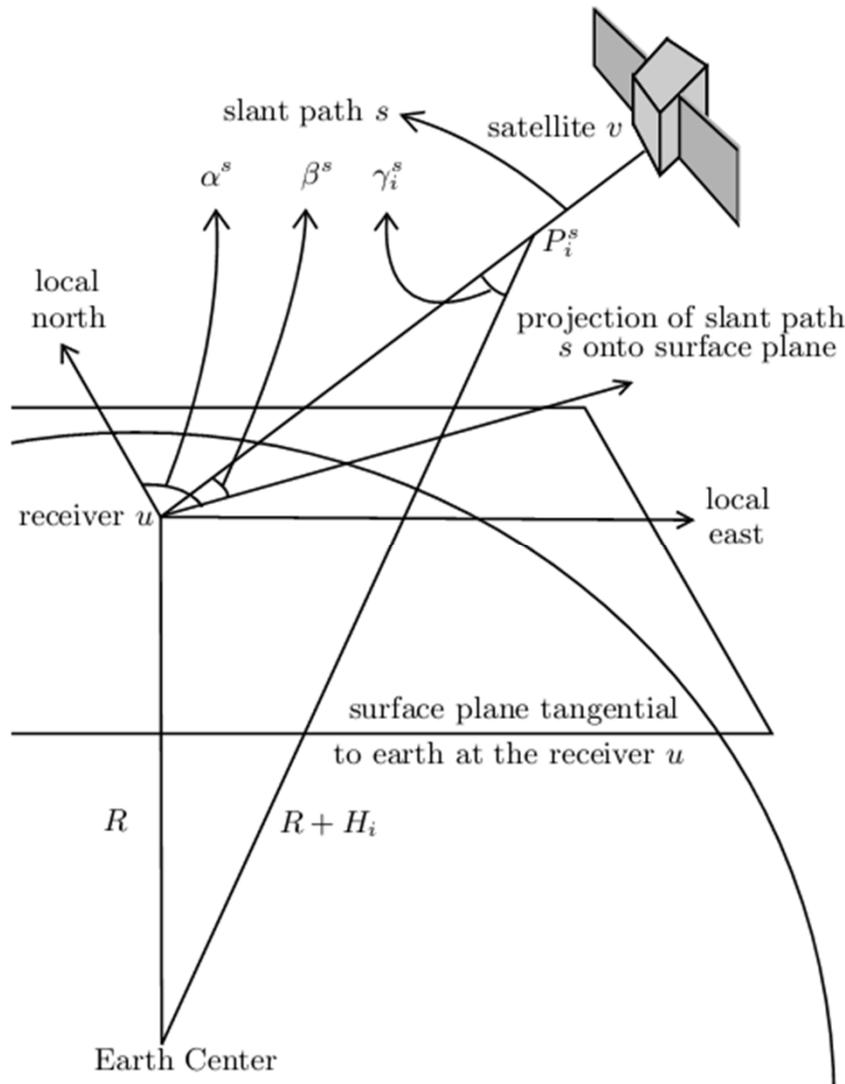
- Introduction
- STEC Calculation by Using IRI-Plas
- STEC Calculation Service
 - Single STEC
 - STEC vs. Time
 - STEC vs. Satellite Elevation Angle
 - STEC vs. Satellite Azimuth Angle
- Conclusion

Introduction



- International Reference Ionosphere extended to Plasmasphere (IRI-Plas) model can give an estimation of the vertical electron density profile for any given location and time, in the altitude range from about 100 km to 20,000 km.
- This information can be utilized to obtain total electron content between any given receiver and satellite locations based on the IRI-Plas model.
- This study explains how to calculate STEC values based on IRI-Plas model for any given receiver and satellite locations.
- Proposed method is implemented as a web based service, which also provides tools for analyzing STEC values with respect to time, satellite elevation angle and satellite azimuth angles.

STEC Calculation

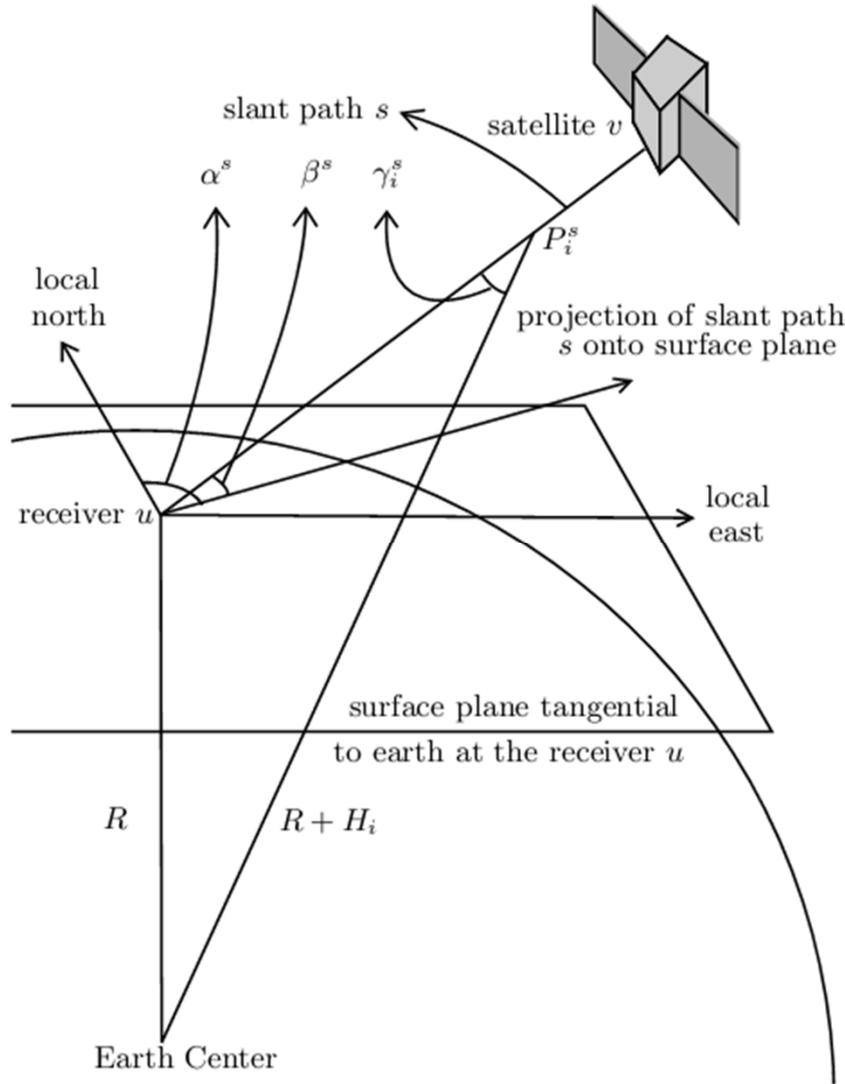


Calculation Steps

1. Input slant path parameters
2. Calculate slant path coordinates
3. Calculate STEC by using IRI-Plas

Symbol	Definition
$\phi(u)$	Latitude of Receiver u
$\lambda(u)$	Longitude of Receiver u
α^s	Satellite Elevation Angle The angle between the surface plane at the receiver u location and the slant path s
β^s	Satellite Azimuth Angle The clockwise angle between the local north vector at the receiver u location and the projection of the slant path s , onto the surface plane which is tangential to earth at the receiver u location

STEC Calculation



Calculation Steps

1. Input slant path parameters
2. Calculate slant path coordinates
3. Calculate STEC by using IRI-Plas

$$\gamma_i^s = \sin^{-1} \left(\frac{R}{R + H_i} \sin \left(\frac{\pi}{2} + \alpha^s \right) \right)$$

$$D_i^s = \left| \frac{\sin \left(\frac{\pi}{2} - \alpha^s - \gamma_i^s \right)}{\sin(\gamma_i^s)} R \right|$$

$$\begin{bmatrix} E(P_i^s) \\ N(P_i^s) \\ U(P_i^s) \end{bmatrix} = \begin{bmatrix} D_i^s \cos(\alpha^s) \cos \left(\frac{\pi}{2} - \beta^s \right) \\ D_i^s \cos(\alpha^s) \sin \left(\frac{\pi}{2} - \beta^s \right) \\ D_i^s \sin(\alpha^s) \end{bmatrix}$$

$$\underline{\underline{T}}^u = \begin{bmatrix} -\sin(\lambda(u)) & \sin(\phi(u)) \cos(\lambda(u)) & \cos(\phi(u)) \cos(\lambda(u)) \\ -\cos(\lambda(u)) & \sin(\phi(u)) \sin(\lambda(u)) & \cos(\phi(u)) \sin(\lambda(u)) \\ 0 & \cos(\phi(u)) & \sin(\phi(u)) \end{bmatrix}$$

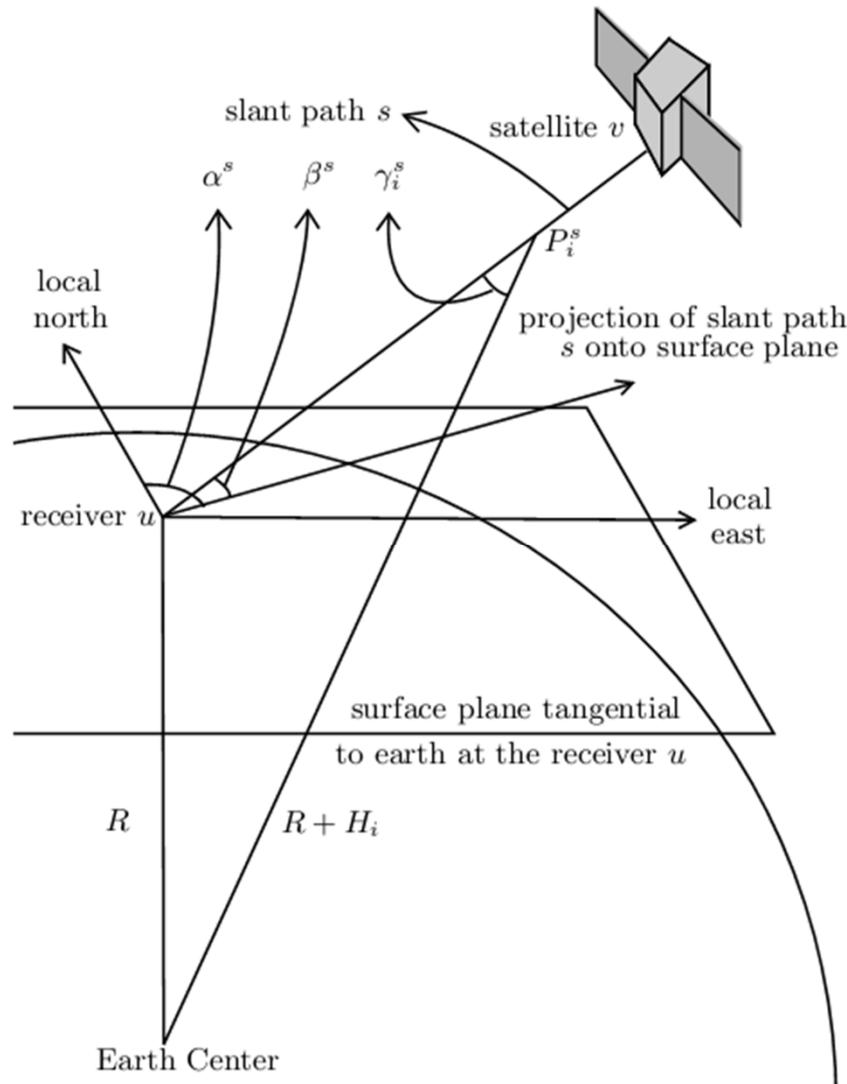
$$\begin{bmatrix} X(u) \\ Y(u) \\ Z(u) \end{bmatrix} = \begin{bmatrix} R \cos(\phi(u)) \cos(\lambda(u)) \\ R \cos(\phi(u)) \sin(\lambda(u)) \\ R \sin(\phi(u)) \end{bmatrix}$$

$$\begin{bmatrix} X(P_i^s) \\ Y(P_i^s) \\ Z(P_i^s) \end{bmatrix} = \underline{\underline{T}}^u \begin{bmatrix} E(P_i^s) \\ N(P_i^s) \\ U(P_i^s) \end{bmatrix} + \begin{bmatrix} X(u) \\ Y(u) \\ Z(u) \end{bmatrix}$$

$$\phi(P_i^s) = \frac{180}{\pi} \tan^{-1} \left(\frac{Z(P_i^s)}{\sqrt{X(P_i^s)^2 + Y(P_i^s)^2}} \right)$$

$$\lambda(P_i^s) = \frac{180}{\pi} \tan^{-1} \left(\frac{Y(P_i^s)}{X(P_i^s)} \right)$$

STEC Calculation



Calculation Steps

1. Input slant path parameters
2. Calculate slant path coordinates
3. Calculate STEC by using IRI-Plas

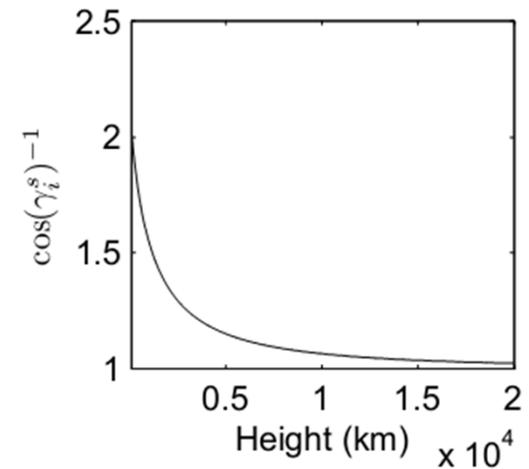
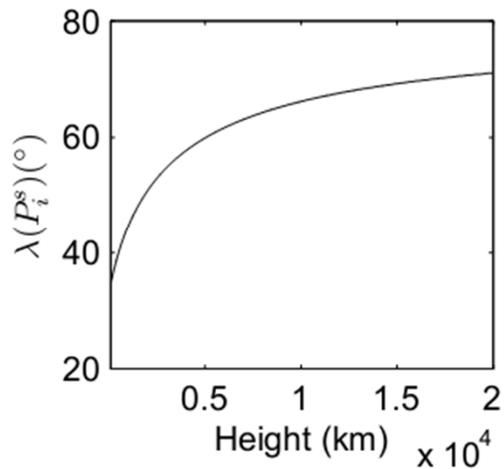
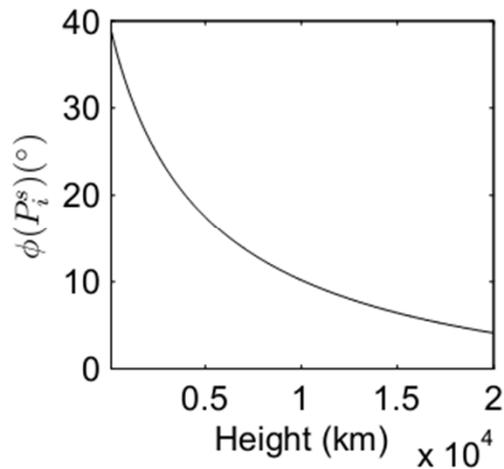
$$STEC^s = \sum_{i=1}^I Ne(\phi(P_i^s), \lambda(P_i^s), H_i) \Delta H_i^s$$

$$\Delta H_i^s = \frac{\Delta H_i}{\cos(\gamma_i^s)}$$

STECC Calculation



Latitude, longitude and slope of the slant path with respect to elevation

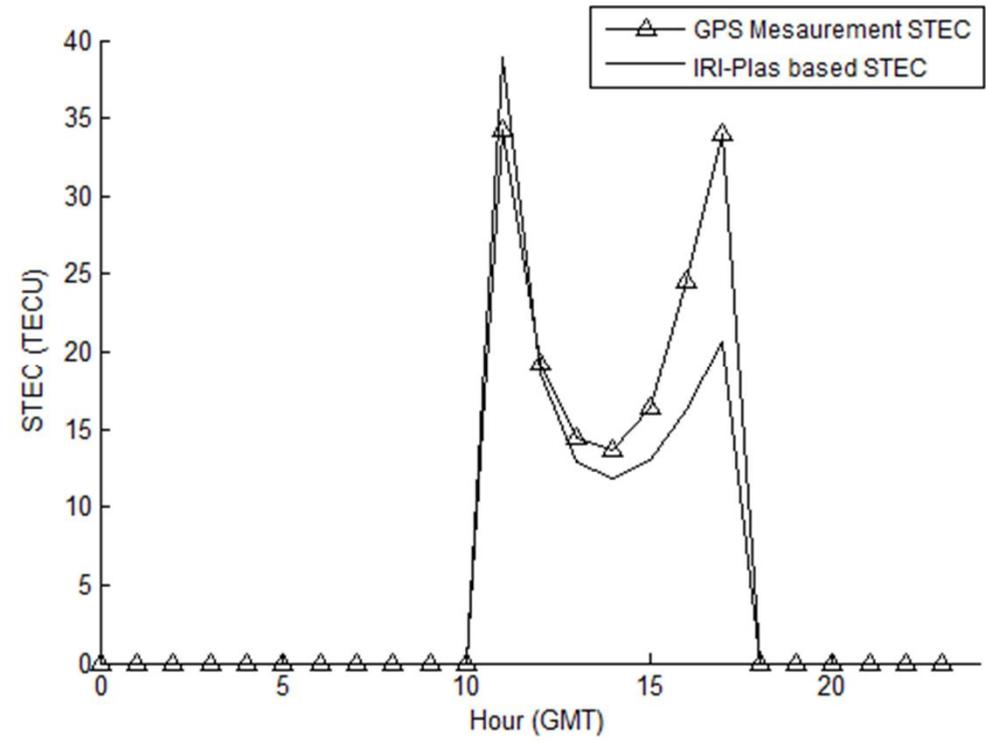


a) $\phi(P_i^s)$, b) $\lambda(P_i^s)$ and c) $\cos(\gamma_i^s)^{-1}$ as the elevation increases, for input parameters $\phi(u) = 39.92^\circ$, $\lambda(u) = 32.85^\circ$, $\alpha^s = 28^\circ$ and $\beta^s = 126^\circ$.

STEC Calculation



STEC with respect to hour
Receiver: Ankara (39°N 32°E), Satellite No: 7
Date: 22 April 2009



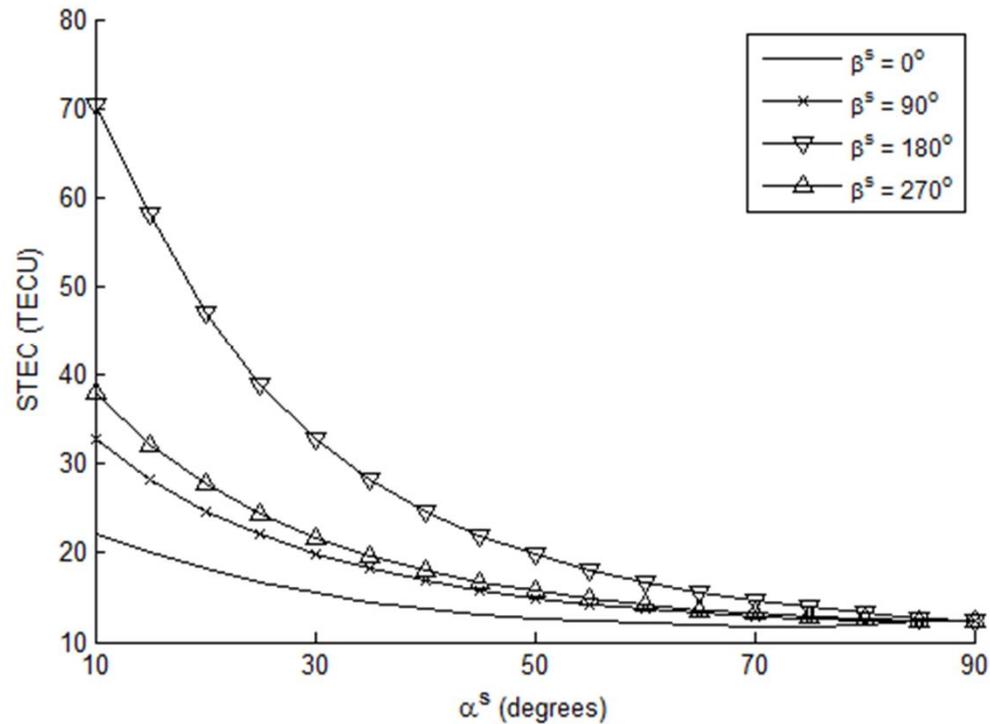
STEC Calculation



STEC with respect to satellite elevation angle (alpha)

Receiver: 39°N 35°E

Date: 22 April 2009 12:00 GMT



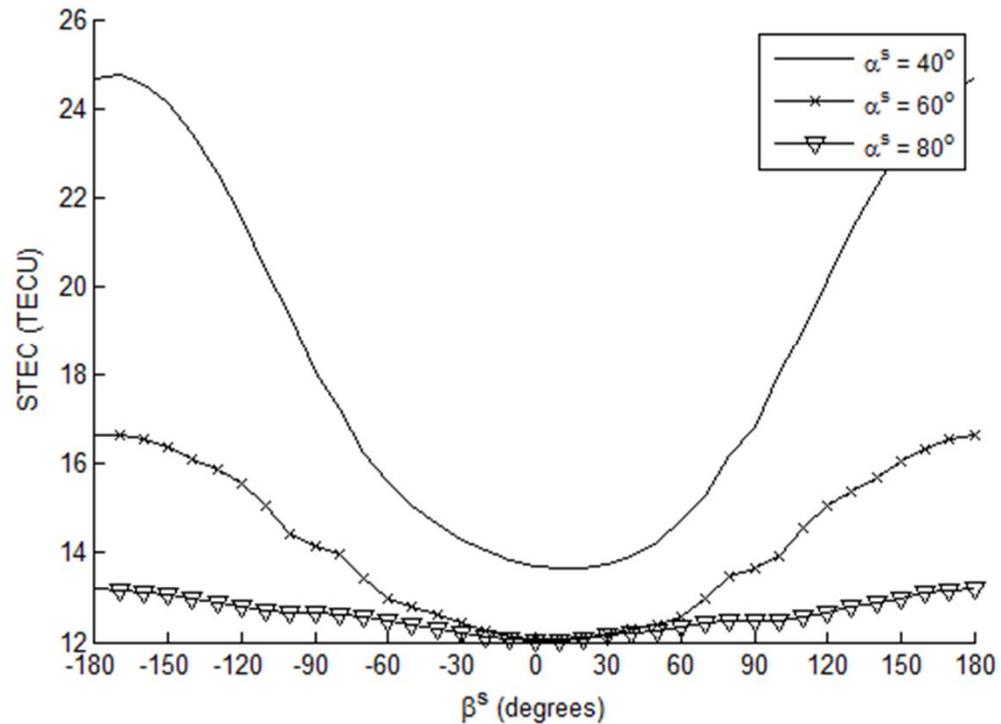
STEC Calculation



STEC with respect to satellite azimuth angle (beta)

Receiver: 39°N 35°E

Date: 22 April 2009 12:00 GMT



STEC Service



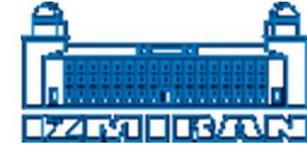
- STEC calculation methodology presented here is implemented as a web based service available to everyone.

www.ionolab.org

- STEC calculation service provides tools for examining STEC values with respect to time, satellite elevation angle and satellite azimuth angle parameters.
- User can input any receiver and satellite locations as well as receiver codes and satellite numbers.

STEC Service

www.ionolab.org



STEC Calculation From IRI-Plas*



Bilkent University
Dep. of Electrical & Electronic Engineering



Hacettepe University
Dep. of Electrical & Electronic Engineering

Türkçe Single STEC wrt Hour wrt Elevation Angle wrt Azimuth Angle

Receiver Station Station Coordinates °N °E
 Station Name

Date (DD-MM-YYYY)

Hour (HH:MM) UT

Satellite Satellite Number (1-32)
 Satellite Angles
 Satellite Elevation Angle (10°-90°) °
 Satellite Azimuth Angle (0°-360°) °

* Gulyaeva, T.L., and Bilitza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
[Available at https://www.novapublishers.com/catalog/product_info.php?products_id=35812]

STEC Service

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STEC Calculation From IRI-Plas*



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Dep. of Electrical & Electronic Engineering



Hacettepe University
Dep. of Electrical & Electronic Engineering

Türkçe Single STEC wrt Hour wrt Elevation Angle wrt Azimuth Angle

Receiver Station Station Coordinates °N °E

Station Name

Date (DD-MM-YYYY)

Hour (HH:MM) UT

Satellite Satellite Number (1-32)

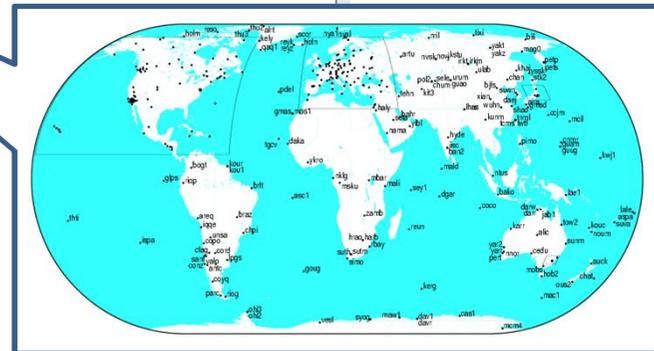
Satellite Angles

Satellite Elevation Angle (10°-90°) °

Satellite Azimuth Angle (0°-360°) °

Available in
•English
•Turkish

June 2013						
Mo	Tu	We	Th	Fr	Sa	Su
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30



Larsen, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
[Available at https://www.novapublishers.com/catalog/product_info.php?products_id=35812]

STEC Service

Single STEC



STEC Calculation From IRI-Plas*

Bilkent University
Dep. of Electrical & Electronic Engineering
Hacettepe University
Dep. of Electrical & Electronic Engineering

Türkçe **Single STEC** wrt Hour wrt Elevation Angle wrt Azimuth Angle

Receiver Station
 Station Coordinates °N °E
 Station Name

Date (DD-MM-YYYY) [calendar icon]
Hour (HH-MM) [dropdown] UT

Satellite
 Satellite Number (1-32)
 Satellite Angles
Satellite Elevation Angle (10°-90°) [input] °
Satellite Azimuth Angle (0°-360°) [input] °

Submit

Calculates single STEC for given

- Receiver Location or Receiver Code
- Day & Hour
- Satellite Number or Satellite Elevation & Azimuth Angles

* Gulyaeva, T.L., and Blitza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
[Available at https://www.novapublishers.com/catalog/product_info.php?products_id=35812]

STEC Service

STEC with respect to Hour



STEC Calculation From IRI-Plas*

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Dep. of Electrical & Electronic Engineering

Türkçe Single STEC **wrt Hour** wrt Elevation Angle wrt Azimuth Angle

Receiver Station
• Station Coordinates °N °E
• Station Name

Date (DD-MM-YYYY)

Satellite
• Satellite Number (1-32)
• Satellite Angles
 Satellite Elevation Angle (10°-90°) °
 Satellite Azimuth Angle (0°-360°) °

E-mail

Calculates STEC values with respect to hour for given

- Receiver Location or Receiver Code
- Day
- Satellite Number or Satellite Elevation & Azimuth Angles

* Gulyaeva, T.L., and Blitza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
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STEC Service



STEC with respect to Satellite Elevation Angle

The screenshot shows the 'STEC Calculation From IRI-Plas' web interface. At the top, it lists 'Bilkent University Dep. of Electrical & Electronic Engineering' and 'Hacettepe University Dep. of Electrical & Electronic Engineering'. Below this is a navigation bar with tabs: 'Türkçe', 'Single STEC', 'wrt Hour', 'wrt Elevation Angle' (highlighted in orange), and 'wrt Azimuth Angle'. The main form contains several input fields: 'Receiver Station' with radio buttons for 'Station Coordinates' (selected) and 'Station Name'; 'Date (DD-MM-YYYY)' and 'Hour (HH-MM)' with a 'UT' label; and 'Satellite Azimuth Angle (0°-360°)'. There is also an 'E-mail' field and a 'Submit' button. A callout box on the right, titled 'Calculates STEC values with respect to satellite elevation angle for given', lists three input parameters: 'Receiver Location or Receiver Code', 'Day & Hour', and 'Satellite Azimuth Angle'. Arrows point from the 'Station Coordinates', 'Date', and 'Satellite Azimuth Angle' fields in the form to these respective parameters in the callout box.

STEC Calculation From IRI-Plas^{*}

Bilkent University
Dep. of Electrical & Electronic Engineering

Hacettepe University
Dep. of Electrical & Electronic Engineering

Türkçe Single STEC wrt Hour wrt Elevation Angle wrt Azimuth Angle

Receiver Station
Station Coordinates °N °E
Station Name

Date (DD-MM-YYYY)

Hour (HH-MM) UT

Satellite Azimuth Angle (0°-360°)

E-mail

Submit

Calculates STEC values with respect to satellite elevation angle for given

- Receiver Location or Receiver Code
- Day & Hour
- Satellite Azimuth Angle

* Gulyaeva, T.L., and Biliza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
[Available at https://www.novapublishers.com/catalog/product_info.php?products_id=35812]

STEC Service



STEC with respect to Satellite Azimuth Angle

STEC Calculation From IRI-Plas *

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Hacettepe University
Dep. of Electrical & Electronic Engineering

Türkçe Single STEC wrt Hour wrt Elevation Angle **wrt Azimuth Angle**

Receiver Station Station Coordinates °N °E Station Name

Date (DD-MM-YYYY)

Hour (HH:MM) UT

Satellite Elevation Angle (10°-90°)

E-mail

Calculates STEC values with respect to satellite azimuth angle for given

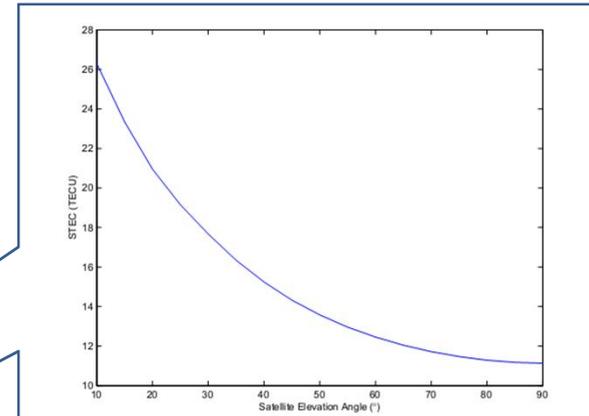
- Receiver Location or Receiver Code
- Day & Hour
- Satellite Elevation Angle

* Gulyaeva, T.L., and Blitza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model. In: "New Developments in the Standard Model", edited by R.J. Larsen, pp. 1-39, NOVA, Hauppauge, New York, 2012
[Available at https://www.novapublishers.com/catalog/product_info.php?products_id=35812]

STEC Service



- An email together with the results is sent to the provided e-mail address when the computations are completed.
- Results are presented with both text and plots.



IONOLAB-STEC <ionolabstec@gmail.com>

to me ▾

IRI-Plas based STEC estimation results requested from www.ionolab.org at 2013/05/13 14:01:05

Calculation results and the plot are attached

2 attachments — [Download all attachments](#)

20130513_140105.pdf
2K [View](#) [Download](#)

20130513_140105.txt
2K [View](#) [Download](#)

```
STEC simulation results obtained from www.ionolab.org by using IRI-Plas
.....
Date: 20100519
Time: 05:00 GMT
Receiver Location: 66.0000N 66.0000E
Satellite Azimuth Angle: 55.00 degrees
.....

Satellite Elevation Angle  STEC (TECU)
10.00 26.2939
15.00 23.3475
20.00 20.9495
25.00 19.1549
30.00 17.6666
35.00 16.3448
40.00 15.2396
45.00 14.3283
50.00 13.5770
55.00 12.9605
60.00 12.4550
65.00 12.0461
70.00 11.7191
75.00 11.4675
80.00 11.2855
85.00 11.1741
90.00 11.1318
.....
```

Conclusion



- A mathematical method for precise calculation of STEC values from IRI-Plas is presented. IRI-Plas model, which is an updated version of IRI, can estimate the electron density profile up to 20,000 km height, and therefore has the capability to estimate GPS based measurements.
- Presented method is implemented as a web based service, and freely available to use at www.ionolab.org
- Web based STEC calculation service provides tools for entering receiver codes and satellite numbers for comparison of the results with real measurements.
- This unique space weather service can be extended to provide any IRI-Plas value along the STEC ray path depending on the demands from the users in the future.