Session 8

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

Orhan Arıkan[1], Hakan Tuna[1], Feza Arıkan[2], Tamara L. Gulyaeva[3], and Umut Sezen[2]

[1]Bilkent University, Electrical and Electronics Engineering Dept. Bilkent, Ankara, 06800, Turkey
[2]Hacettepe University, Electrical and Electronics Engineering Dept. Bilkent, Ankara, 06800, Turkey
[3] IZMIRAN, Moscow, 142190 Troitsk, Russia

oarikan@ee.bilkent.edu.tr

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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

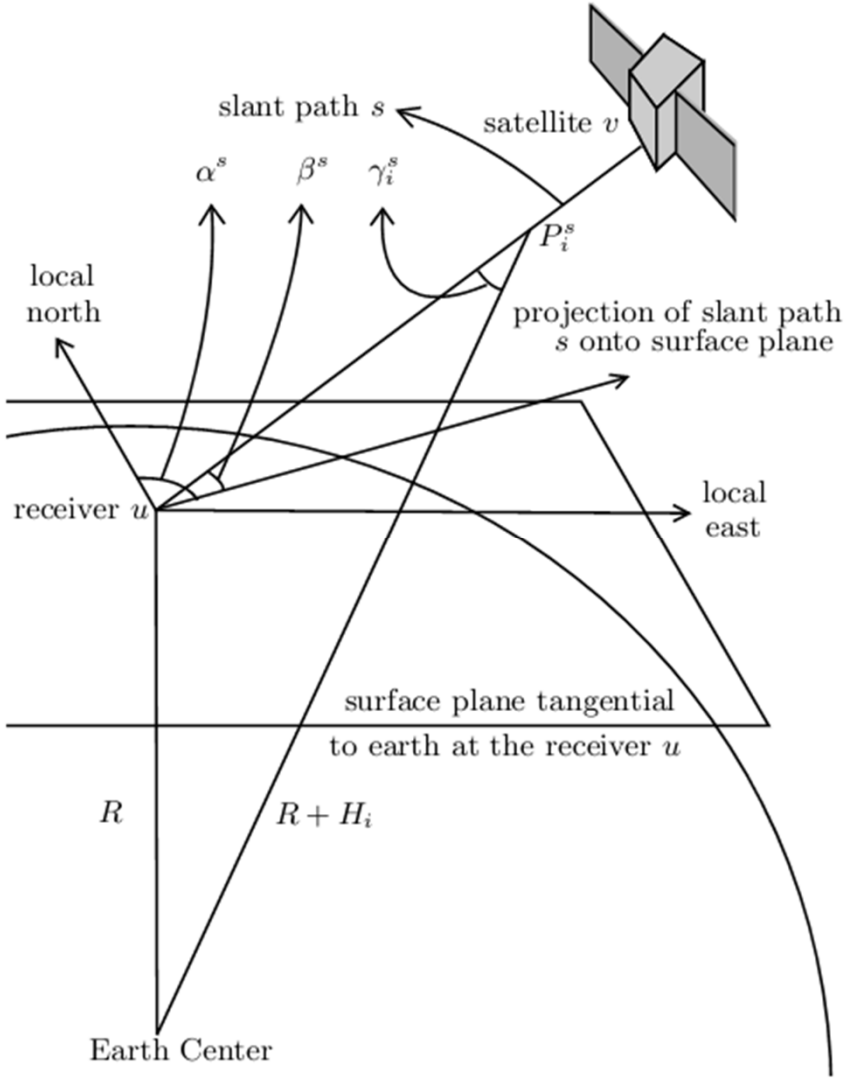
- International Reference Ionosphere extended to Plasmasphere (IRI-Plas) model can give an estimation of the vertical electron density profile for any given location and time, in the altitude range from about 100 km to 20,000 km.

- 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

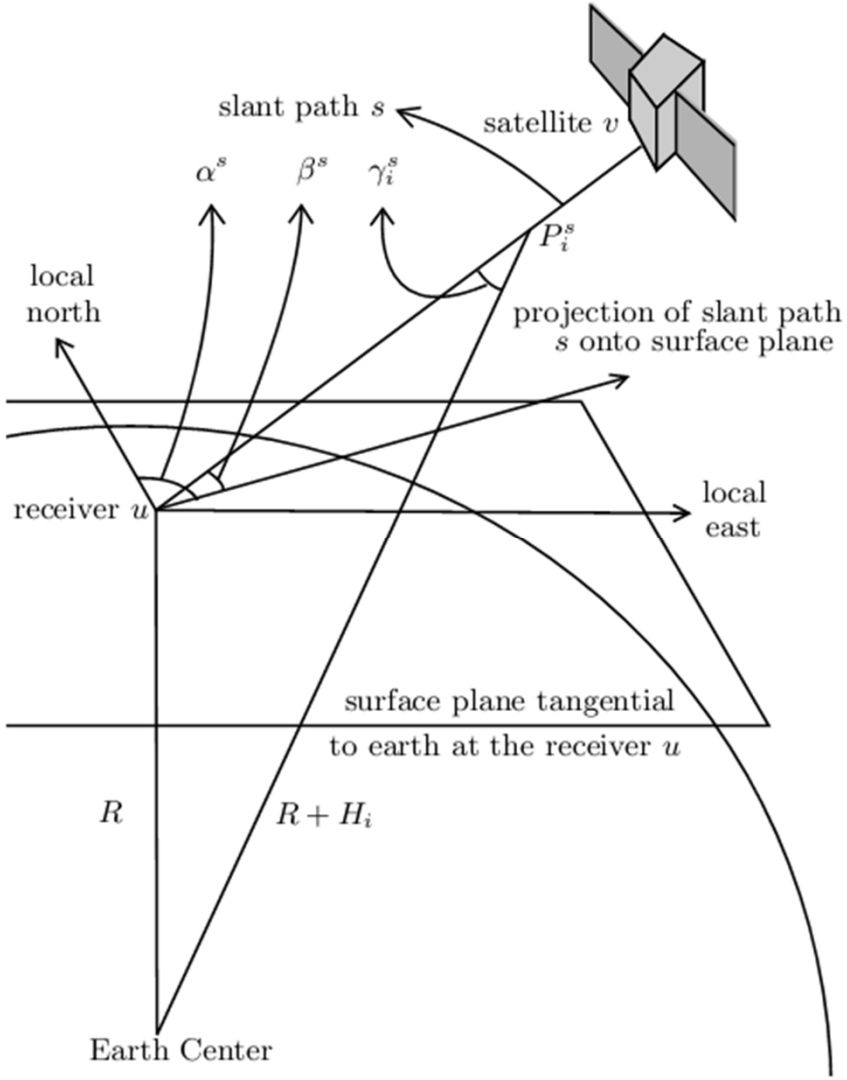


Calculation Steps

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

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

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

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

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

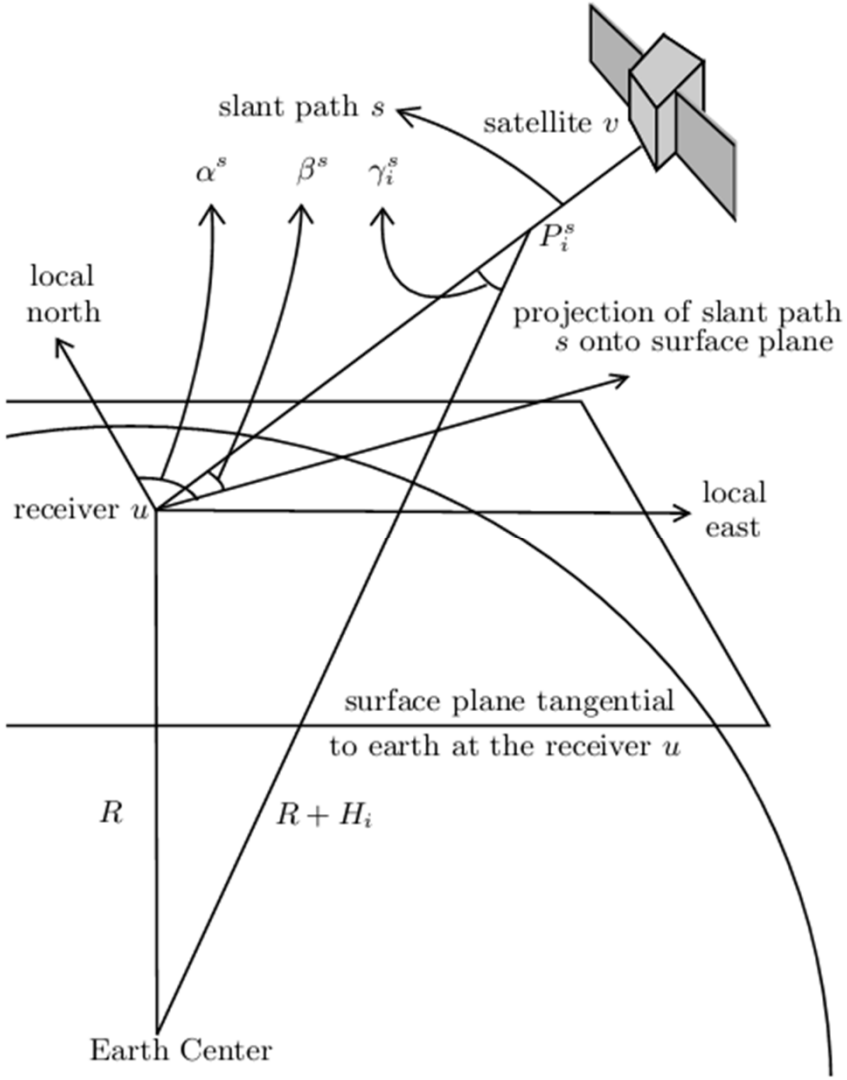
$$\begin{bmatrix} X(u) \\ Y(u) \\ Z(u) \end{bmatrix} = \begin{bmatrix} R\cos(\phi(u))\cos(\lambda(u)) \\ R\cos(\phi(u))\sin(\lambda(u)) \\ R\sin(\phi(u)) \end{bmatrix}$$

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

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

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

STEC Calculation



Calculation Steps

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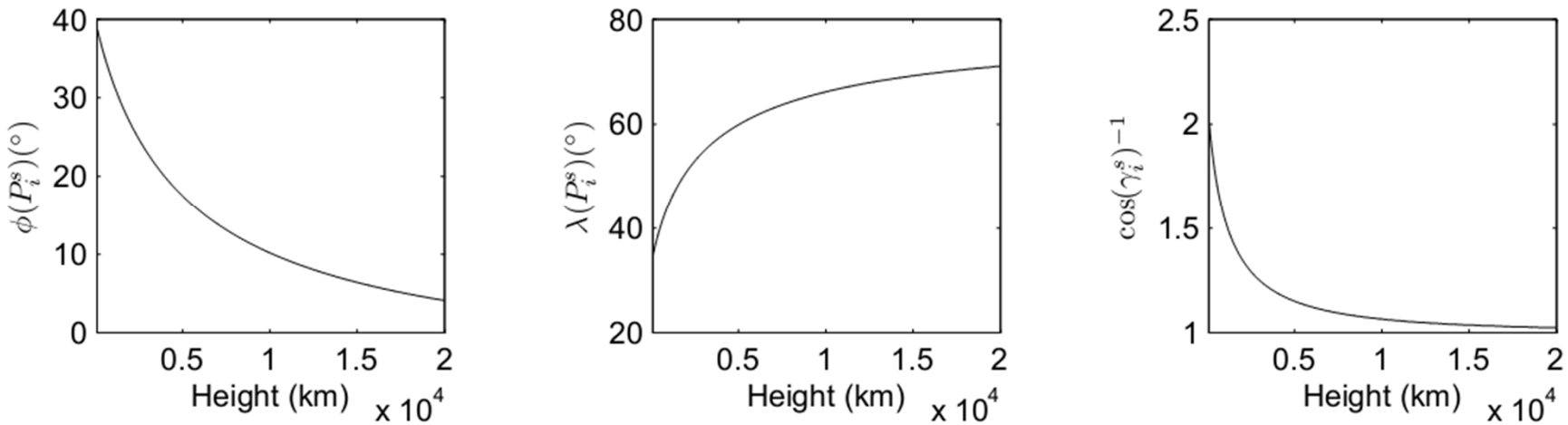
3. Calculate STEC by using IRI-Plas

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

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

STEC Calculation

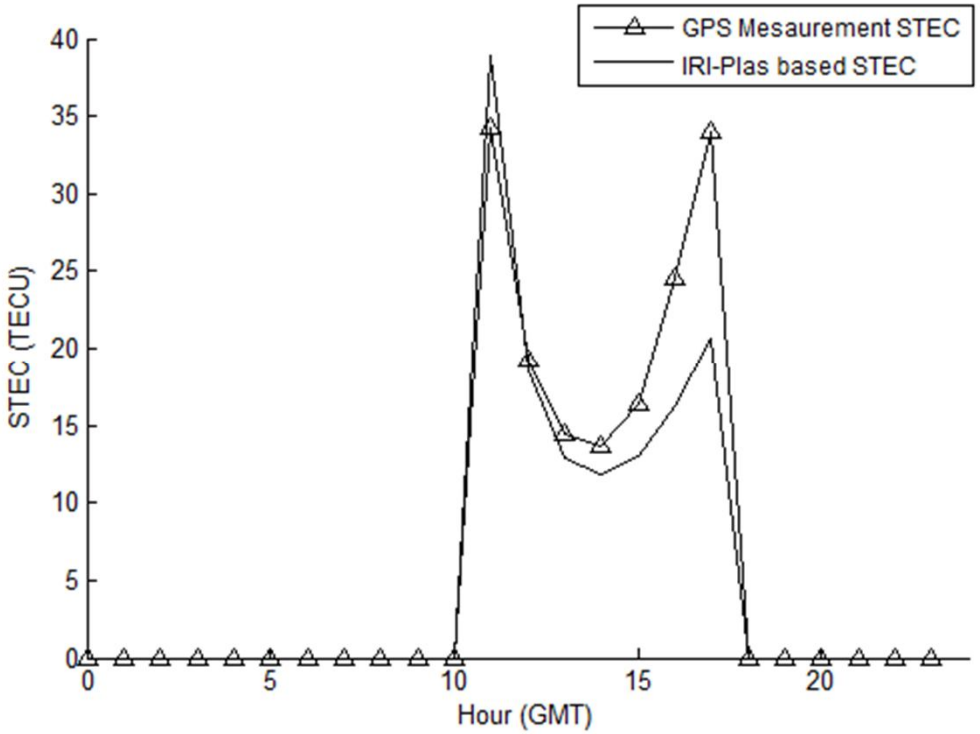
Latitude, longitude and slope of the slant path with respect to elevation



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

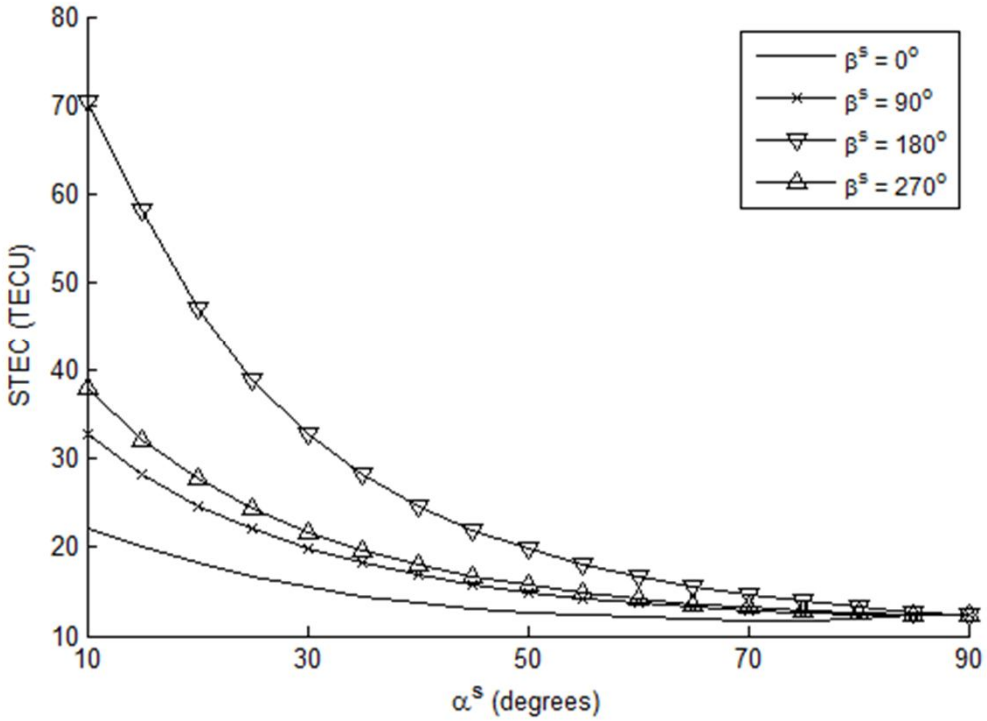
STEC Calculation

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



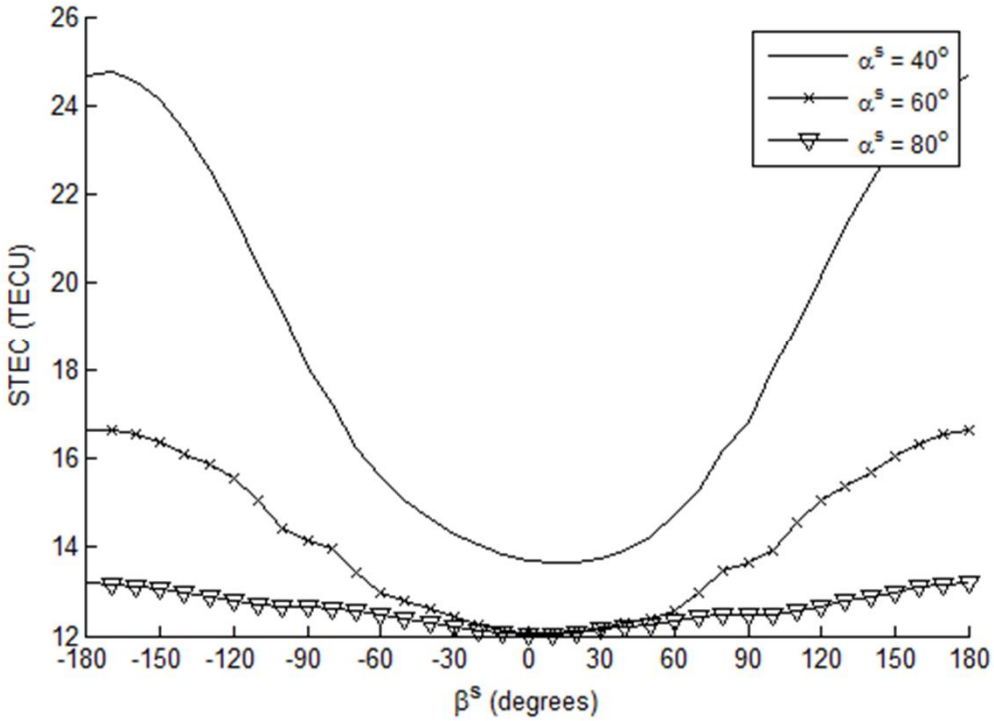
STEC Calculation

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.

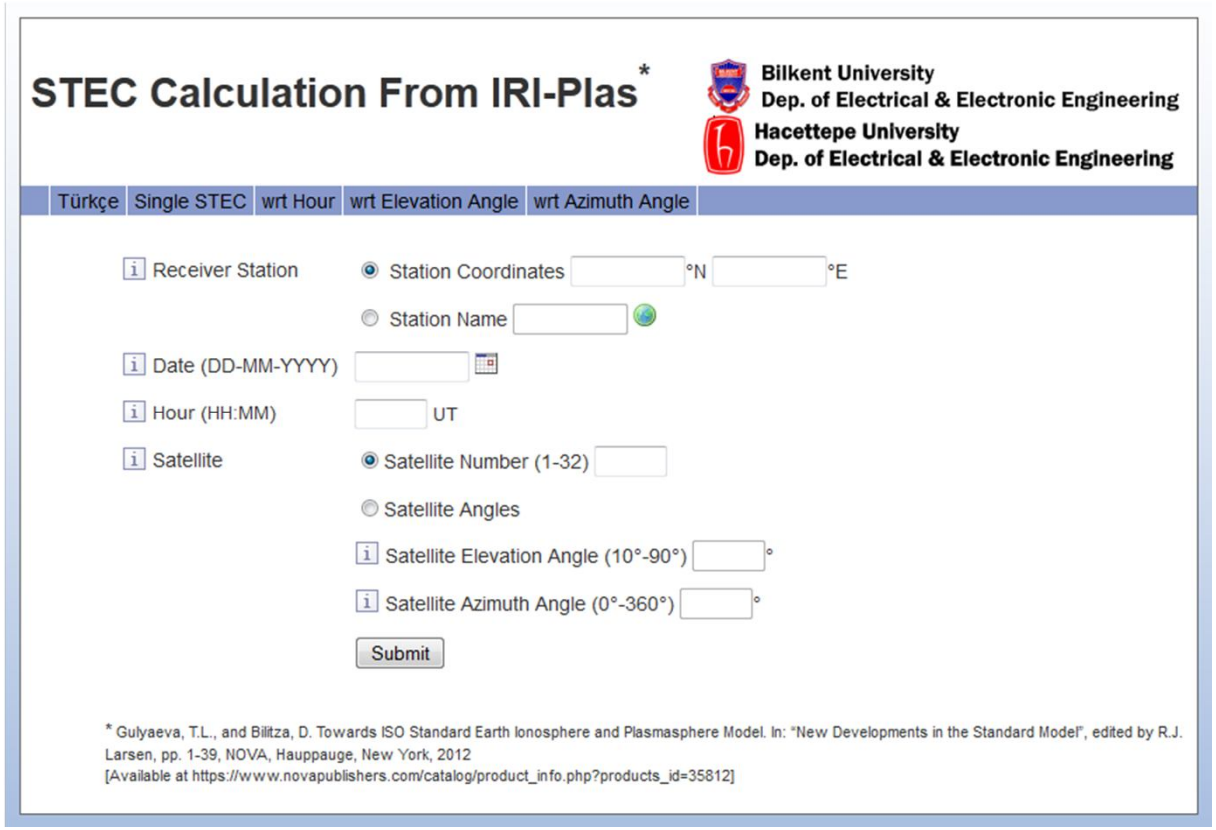
www.ionolab.org

- 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.

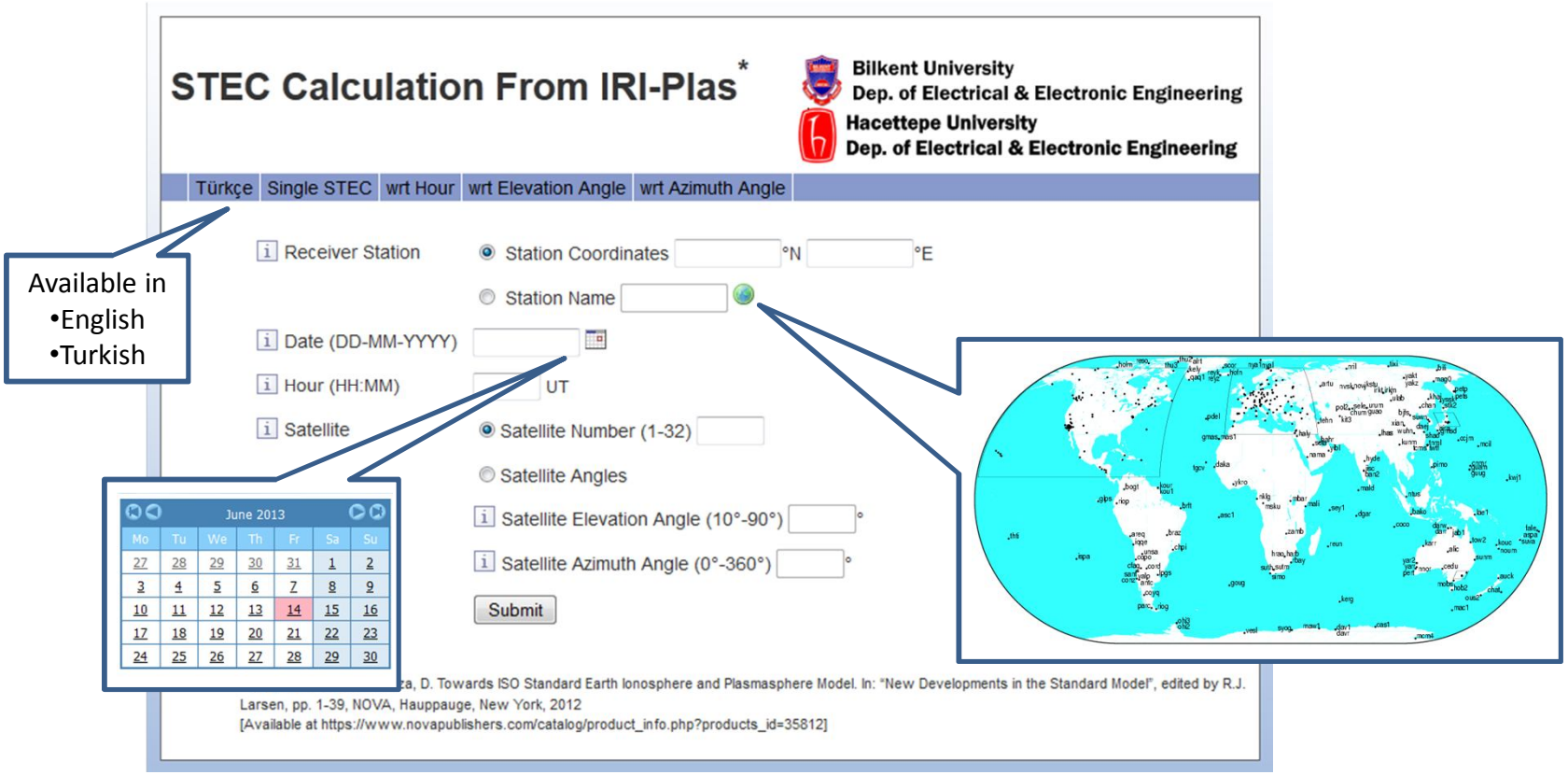
STEC Service

www.ionolab.org



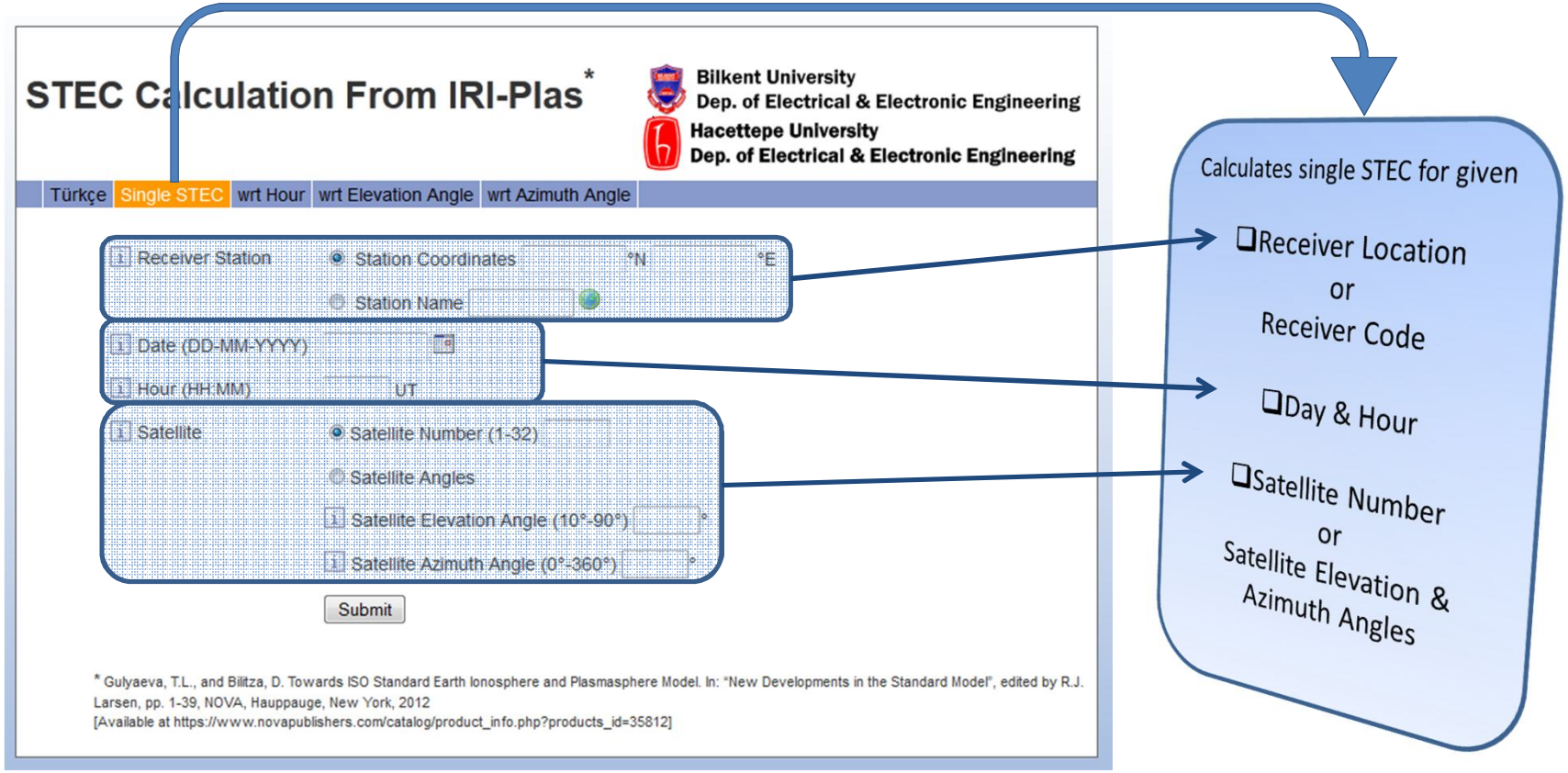
STEC Service

www.ionolab.org



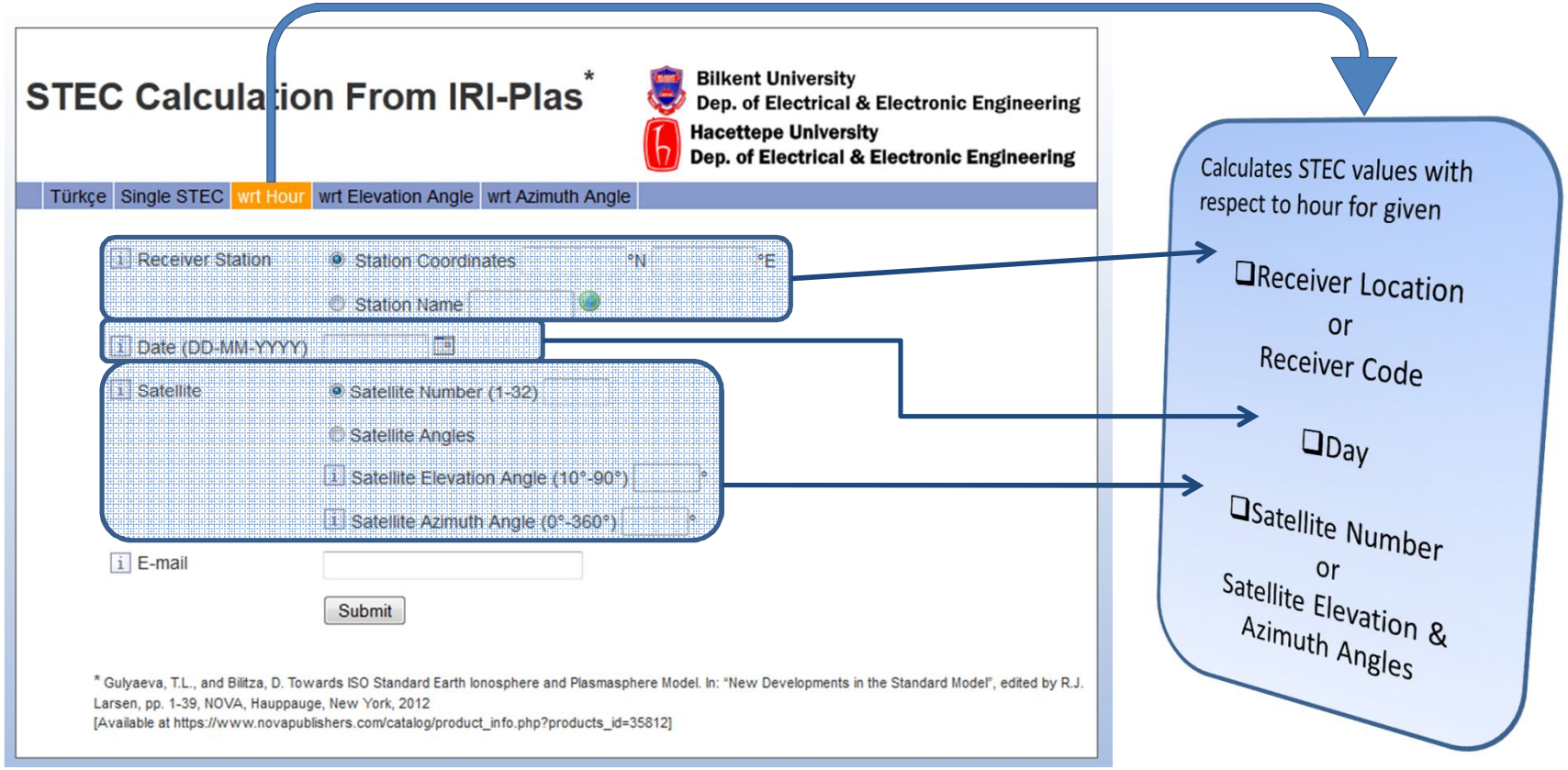
STEC Service

Single STEC



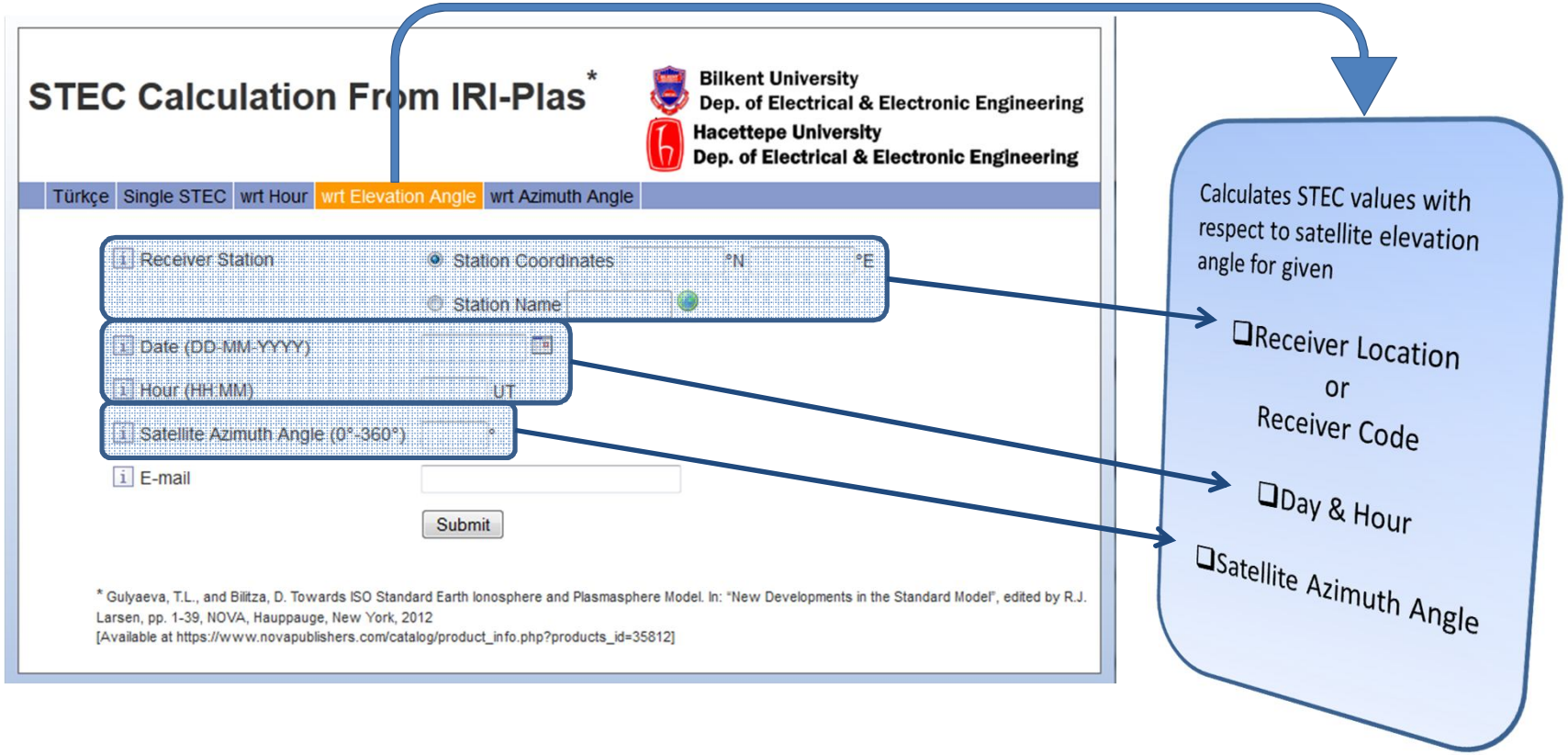
STEC Service

STEC with respect to Hour



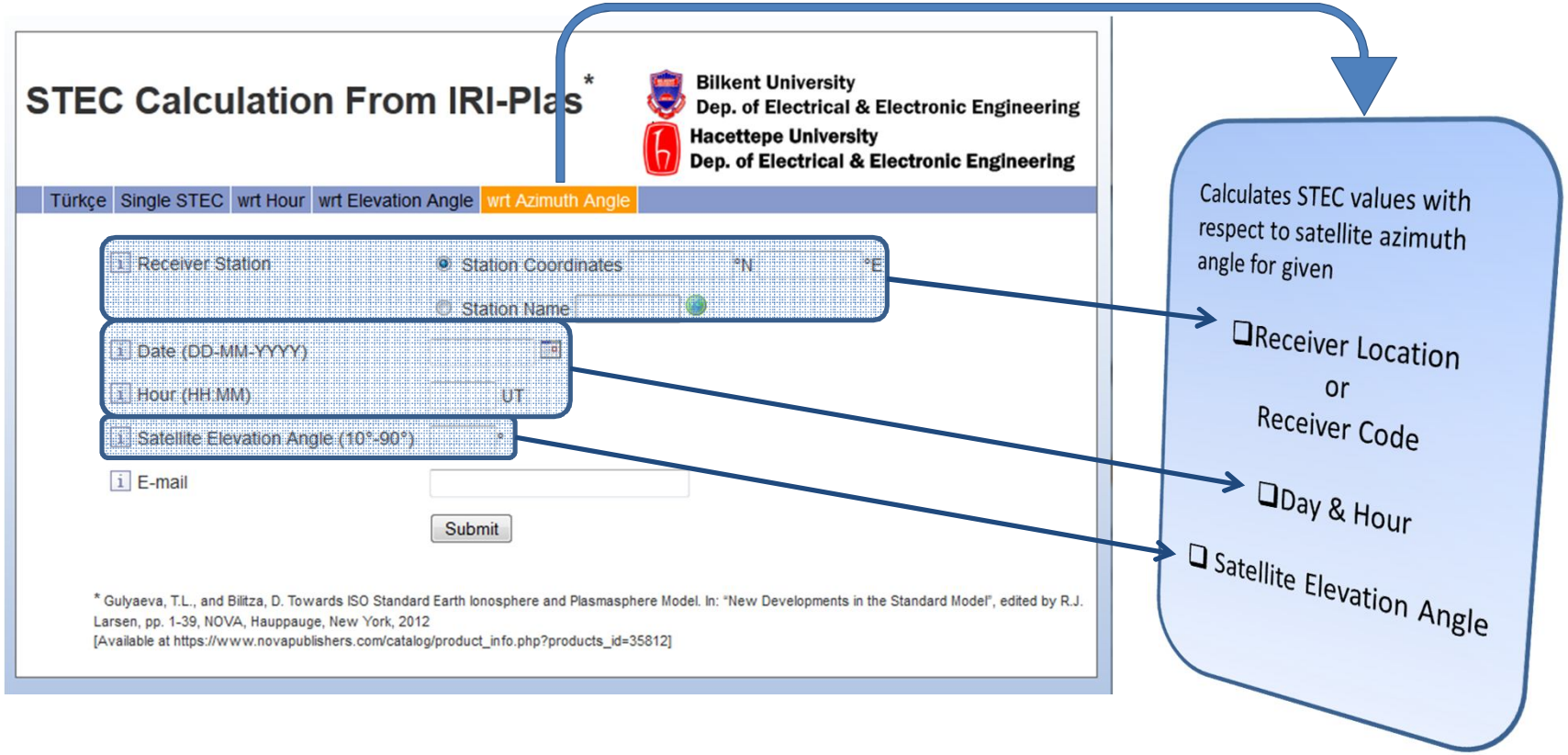
STEC Service

STEC with respect to Satellite Elevation Angle



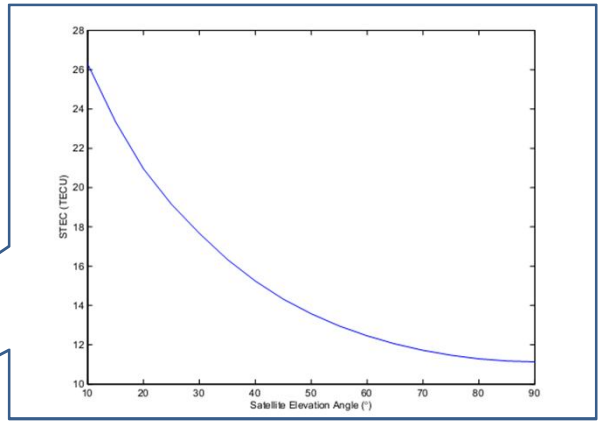
STEC Service

STEC with respect to Satellite Azimuth Angle



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.