

# Real-Time US Total Electron Content Product Description Document

## Part I – Mission Connection

- a. Product Description - The US Total Electron Content (US-TEC) product is designed to specify TEC over the Continental US (CONUS) in near real time. The product uses a Kalman Filter data assimilation technique driven by data from ground-based Global Positioning System (GPS) dual frequency receivers. The primary data stream comes from the Maritime and Nationwide Differential GPS (M/NDGPS) real time network of stations operated by the US Coast Guard (USCG). As of Oct 2004 there were about 60 M/NDGPS stations ingested into the model. This number has been gradually increasing and will be augmented by Federal Aviation Administration/Wide Area Augmentation System (FAA/WAAS) data, and stations operated by the Forecast System Laboratory (FSL). This product has evolved from collaboration among Space Environment Center (SEC), National Geodetic Survey (NGS), National Geophysical Data Center (NGDC), and FSL.

The primary display is the map of *Vertical TEC* over the CONUS for a given 15 minute interval in TEC units ( $1 \text{ TECU} = 10^{16} \text{ electrons m}^{-2}$ ). New maps are normally available about 13 minutes after a given interval, and are updated every 15 minutes. The contour interval is variable, but is typically about 1 TEC unit up to 20 TEC, and gradually increases above. The map also displays the GPS sites used in the current assimilation cycle; the total number of sites is displayed in numerical form below the map. Secondary displays include the *TEC Uncertainty* and the *Recent Trend*. There are also movies of the three maps, for the current day and the previous day, showing the behavior of the ionosphere by those measures.

The full description of the Kalman filter process is provided in the *Technical Documentation*. The model calculates receiver biases, but uses satellite biases from the University of Bern <http://www.aiub.unibe.ch/download/>. Some statistics on the reliability of the GPS data feed and on the accuracy of the TEC estimates can be found on the *Validation* link. Note that the model has not performed in real-time through many extreme storm events so the estimates of uncertainty should be treated with caution during large events. The link to *Significant Storm* illustrates the performance of the model during the Halloween Storm of Oct 29-30, 2003. The simulation illustrates the extreme TEC values and large gradients that are possible during geomagnetic storms.

- b. Purpose - The product is designed for single and dual frequency GPS applications. The TEC and slant path maps can be used to estimate the GPS signal delay due to the ionospheric electron content between a receiver and a GPS satellite. Of particular interest to users is the link to data files which provides not only tabular values of the total electron content, but also values of line-of-sight (LOS) or slant path electron

content to each GPS satellite in view over the CONUS. For each GPS satellite in view the LOS maps provide  $1^\circ \times 1^\circ$  two-dimensional grids over the CONUS.

- c. Audience – The target audience for this experimental graphical product, plus the relevant text data files, is very large. As single frequency GPS has become more embedded into the national infrastructure, serious users in fields such as precise surveying, commercial and general aviation, shipping, and emergency management, to cite some prominent examples, have an interest in knowing if their GPS use may be degraded by a disturbed ionosphere. Conversely, they would also want to know if the GPS would improve as the ionosphere calms after storm. There are many other applications of GPS that are expected to use the US-TEC product for situational awareness.
- d. Presentation Format - The US-TEC map is a Web based graphical product, consisting of the graphics, *Vertical TEC*, *TEC Uncertainty*, and the *Recent Trend*. In addition ASCII text files containing relevant data are also available, as are technical documentation, validation, and significant storm output.
- e. Feedback Method – We are always seeking to improve our services and products based on user feedback. Comments regarding the US-TEC Product should be sent to the feedback e-mail address on the Web page containing the product.

## **Part II – Technical Description**

- a. Format and Science Basis – US-TEC is produced by a Kalman filter based data assimilation algorithm for imaging the earth's ionosphere in four dimensions using GPS data. The algorithm also relies on third party software in the form of the IRI95 ionospheric model. A full description of the mathematical theory behind the model and information on the real-time data processing may be found at: [http://sec.noaa.gov/ustec/USTEC\\_TechnicalDocument.pdf](http://sec.noaa.gov/ustec/USTEC_TechnicalDocument.pdf) . A sample of the product, showing vertical total electron content is shown in Figure 1.

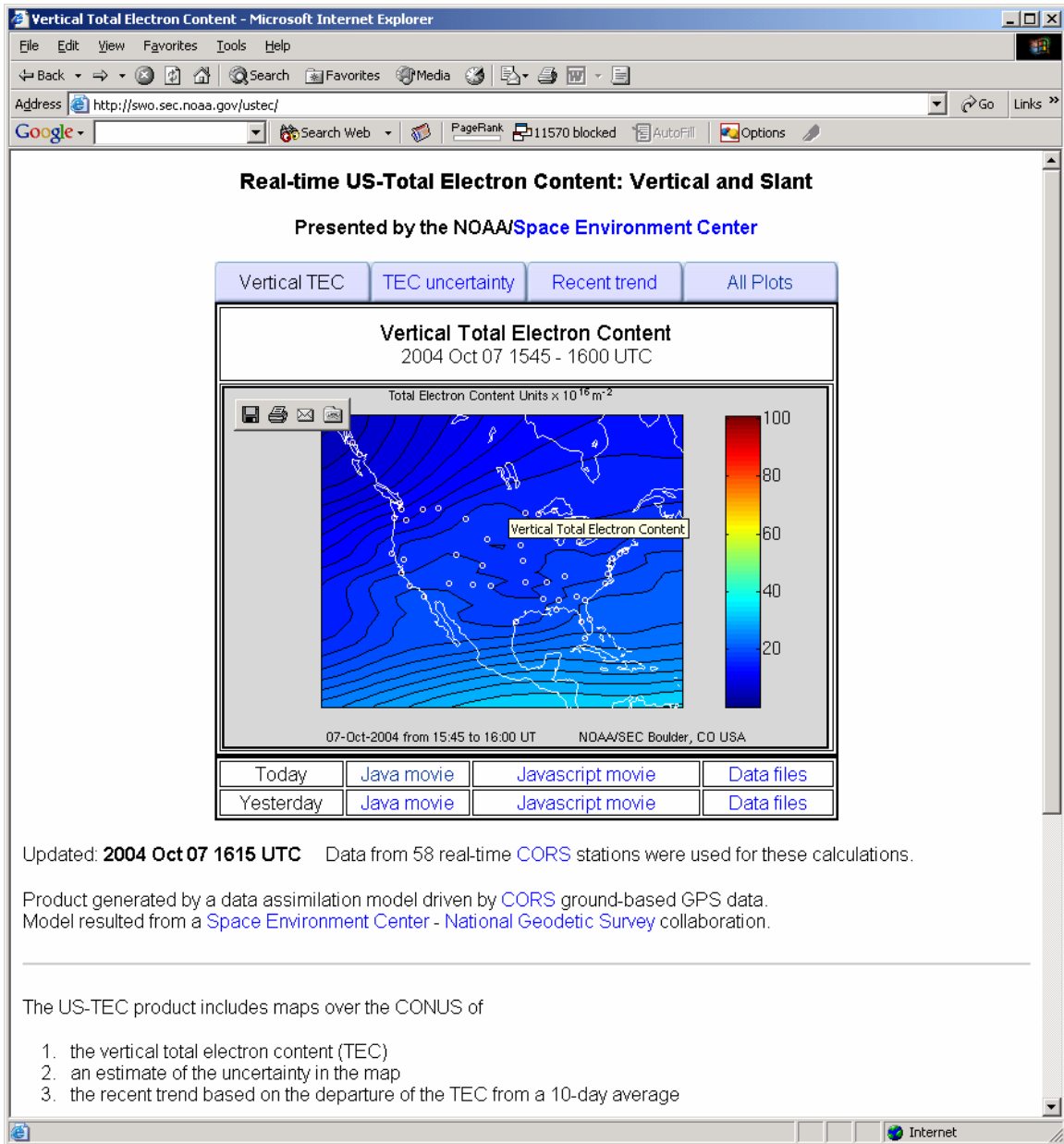


Figure 1. Vertical Total Electron Content graphic of the US-TEC experimental product.

b. Product Availability – The US-TEC product has new maps created every 15 minutes.