Monitoring Ionospheric Total Electron Content Using the GPS Global Network and TOPEX/POSEIDON Altimeter Data

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Abstract

The results of a preliminary study to assess the accuracy of global ionospheric maps are presented, Global ionospheric maps, produced using dual-frequency data from the global network of GPS receivers, are "snapshots" of the Earth's vertical total electron content (TEC) distribution. These can be compared to the TEC measured by the dual-frequency altimeter onboard the TOPEX/POSEIDON ocean altimetry satellite, Computed root-mean-square differences between global ionospheric maps and TOPEX are 4 TECU (1 TECU = 1x10^{16} el/m^2) when the TOPEX ground track comes within 500 km of a GPS receiver. Comparisons along the entire TOPEX track generally yield larger RMS differences, indicating that the global maps become less accurate in regions far from GPS receivers.

1. Introduction

The GPS global network currently consists of about 50 high-precision dual-frequency global positioning system (GPS) receivers distributed around the. world. Data from this network has been used to produce global ionospheric maps (GIM) which are "snapshots" of the Earth's zenith total electron content (TEC) distribution [*Mannucci*, Wilson *et al.* 1993]. Global ionospheric maps are useful for monitoring the global TEC distribution for scientific studies, model development and calibration of ionospheric delay.

In addition to the GPS network, TEC measurements that cover a significant portion of the globe are available from instruments on board the TOPEX/POSEIDON ocean altimetry satellite. These instruments include a dual-frequency ocean altimeter and a dual-frequency range-rate device. The TOPEX data can be used to study the accuracy of the GPS-based global maps, or incorporated into the mapping algorithm to improve accuracy, In this paper, we present a preliminary assessment of the accuracy of the global maps by performing comparisons between the mapped TEC and the ionospheric measurements available from the dual-frequency altimeter,

First, we review the factors which affect the accuracy of the global maps (see *Mannucci et al.* 1993, for a more complete description of the technique). After a brief discussion of the altimeter data type, a preliminary study of the global map accuracy will bc presented, based on comparisons to the TOPEX data. Finally, we will summarize and indicate what follow-on studies are being pursued.

2. Factors affecting the accuracy of global ionospheric maps

The GPS receivers in the global network measure line-of-sight total electron content between a receiver and up to 8 GPS satellites simultaneously. To form a global map, the GPS measurements are converted to equivalent vertical values and a grid-based algorithm is used to interpolate between the individual TEC measurements. In some geographic regions, the nearest receivers are thousands of kilometers away (see figure 1). Therefore, the interpolation must work locally near each receiver and globally between receiver groups, and the accuracy of the maps are likely to vary with distance from the GPS receivers.

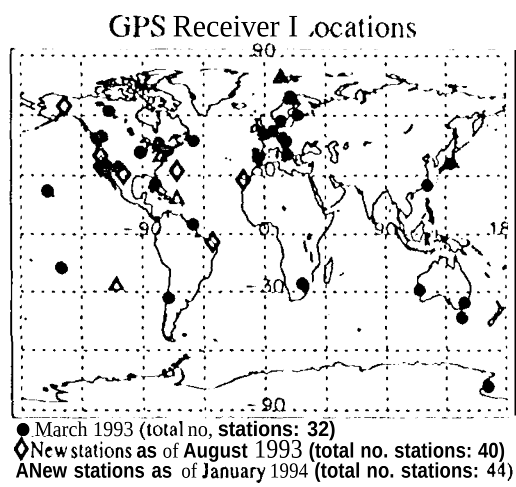

Figure 1: Locations for the GPS receivers in the global network.

The global mapping technique uses a linear least squares parameter estimation procedure. A linear relationship relating the "ionospheric state" to the GPS observable is formed. For global maps, the ionospheric state consists of specifying the TEC at a set of 642 pre-determined grid points on an "ionospheric shell" at a height of 350 km. The TEC values are related to a GPS observation as follows:

$$I_{rs}(t) = F(E)\sum_{i=1}^{3} W_i(\phi_{pp},\lambda_{pp})V_i + b_r + b_s \qquad (1)$$

where $I_{rs}(t)$ is the GPS line-of-sight measurement from receiver r and satellite s at time t, V_i is the value of the