Precise estimation of total electron content by double-shell model using local receiver network

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The total electron content (TEC) derived from the differential group delay of the code signals of GNSS on two frequencies has been a basic parameter in ionospheric studies. In most applications, the thin-layer approximation is used to convert the measured slant TEC to vertical TEC at the ionosphere pierce point. Usually the thin-layer height is assumed to be constant regardless of the location and time, which is unrealistic and can be a source of error in TEC estimations. This is a serious problem at low latitudes where the ionospheric height greatly varies by the action of the vertical EXB drift due to the zonal electric field and field-aligned transport due to the meridional neutral wind drag. In this paper, we parameterized the ionosphere by two thin-layers (double-shell model) at 250 and 1100 km to avoid this inconvenience. The variation of partial electron content related to each layer was approximated by the spherical harmonics expansion to minimize the error of slant TEC between the measurements and the sum of contribution from the two layers. In the harmonics expansion calculation, the longitude parameter was the sun-fixed longitude or the local time measured in angle. Thus data obtained in a whole day were used.
Another problem with the conventional technique is the leveling procedure, where phase measurements with a small noise are leveled to the noisy code signal data. Therefore, noises and multipath effect on the code delay are not resolved by the leveling. To avoid this inconvenience, the leveling to the code data was not applied in our study. Instead, the total bias including instrumental (satellite and receiver) code biases and phase ambiguity for each arc (i.e., total arc bias) was determined in conjunction with TEC.
The technique was applied to datasets obtained by a local receiver network near the magnetic equator. Results were compared with those of the conventional (single) thin-layer model. A significant difference was found in the ratio of TECs at the equatorial anomaly crests and trough. The double-shell model captured the equatorial anomaly more correctly than the conventional method. Another outcome of the double-shell model was the different patterns of TEC variations at the two heights, as expected. Equatorial anomaly crests and the evening TEC bite-out at the equator were prominent in the lower shell. The TEC peak at the higher shell appeared later than the lower shell. Two shells exhibited different features of north-south asymmetry of TEC, depending on the local time. These results provide information on the ionospheric dynamics, such as the ionosphere-thermosphere coupling through the field-aligned transport and variations of the evening enhancement of zonal electric field.

Keywords: TEC, double-shell model, equatorial anomaly

