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Microarticle

Variability of GPS/GLONASS differential code biases

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ABSTRACT

While estimating ionospheric total electron content (TEC) using both pseudorange and phase GPS/GLONASS data, there occurs a systematic error caused by the difference in processing times of L1 and L2 signals through radio frequency paths of satellites and receivers, known as differential code biases (DCBs). A 1-ns DCB causes an ~2.9 TECU error in TEC estimation. Along with systematic DCB variations, seasonal variations, most likely related to variations in the receiver environment (temperature, humidity), also exist for some receivers and can reach in some cases up to ~20 TECU.

Along with navigation and precise time applications, Global Navigation Satellite Systems (GNSS) are widely used nowadays to remotely sense the ionosphere in equatorial, mid-latitude and arctic regions [1]. Ionospheric TEC can be estimated using dual-frequency code and phase measurements of pseudo ranges between a satellite and a receiver [2]. While estimating absolute TEC using the code and phase measurements simultaneously, a satellite and receiver dependent systematic error occurs. This error is associated with the different, frequency dependent processing times of L1 and L2 signals in RF paths, both for satellites and receivers. Due to these biases (known as DCBs), TEC, in some cases, can obtain even non-physical negative values. For example, a 1-ns DCB causes an ~2.9 TECU error (2.85 TECU for GPS and 2.92 TECU for GLONASS frequencies) in TEC estimation. Thus, one should take DCBs into account for precise absolute TEC estimations [4,5]. It is especially important for the analysis of long period TEC datasets obtained not only from GPS/GLONASS data but also from geostationary SBAS data [3]. Long period TEC datasets obtained from geostationary SBAS can have systematic change with time caused by DCB changing. This systematic change can be mistaken for ionospheric TEC changing. The complexity of evaluating DCB for geostationary SBAS data should be noted, since the elevation angle of geostationary satellites varies slightly and it is very difficult to separate the DCB from real TEC changes.

In this work, for the first time, we analyze DCBs dynamics and errors in TEC estimations associated with satellites and receiver DCBs for 2000–2014. For such estimates, we used the CODE laboratory data (ftp://ftp.unibe.ch/aiub/CODE/) based on the measurements at the world wide IGS network (International GNSS Service) (http://igscb.jpl.nasa.gov/) of GPS/GLONASS receiving stations. All the results of DCB estimations shown below are presented in TEC units (1 TECU = 10^{16} electrons/m^2).

Fig. 1 shows an example of the dynamics (variability) of DCB dependent mean along all IGS station errors of TEC estimations for two satellites, GLONASS 04 and GPS PRN03. Note the systematic variability of the TEC estimation errors associated with DCBs, which is about ~1 TECU/year for the GPS satellite and three times greater (~3 TECU/year) for the GLONASS satellite. Note also significant variations in TEC errors for GLONASS 04 satellite with amplitude up to ~5 TECU compared to rather small variations for GPS PRN03. Such a significant difference between the GLONASS and GPS systems also occurs for other satellites.

We believe that the mentioned effects are not associated with a zero-mean reference on the DCB estimates of all satellites in each individual system. When a satellite is retired or a new satellite is launched, estimated DCBs of other satellites and receivers change to a value that is equal to DCB of this satellite divided by the number of satellites (to satisfy zero-mean condition). The evaluated shift is about 1 TECU, which is significantly less than the observed DCB variations. Moreover, the shift should occur for all satellites, but this shift is not observed. Also, the zero-mean reference cannot lead to continuous systematic dynamics because satellite launches are not regular.

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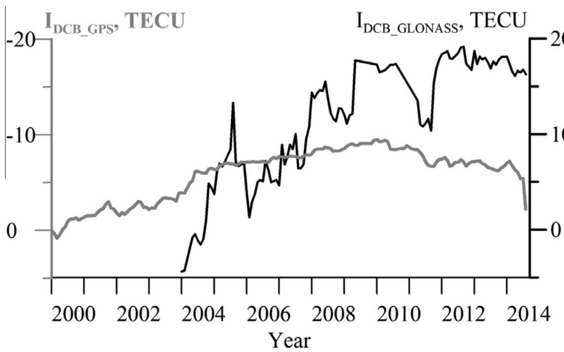

Fig. 1. Dynamics of TEC estimation error caused by DCB of GLONASS04 (black line, right scale) and GPS PRN03 (gray line, left scale) satellites.

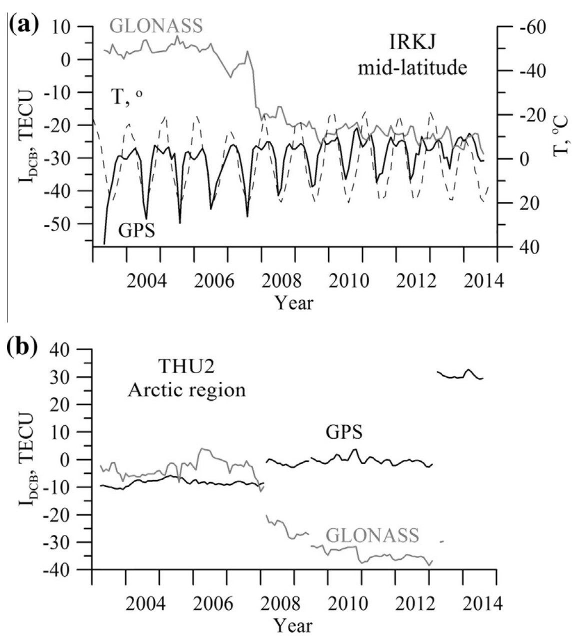

Fig. 2. Dynamics of TEC estimation error caused by DCB of receiver GLONASS (gray line) and GPS (black line) channels: (a) IRKJ station (mid-latitude); (b) THU2 station (arctic region). Dashed line marks temperature (°C).

We also analyze the receiver DCB variability (both for GPS and GLONASS frequencies) for several stations of IGS network. Fig. 2 presents DCB variability for mid-latitude and arctic stations. Summarizing, receiver DCBs for the GLONASS frequency range can reach up to ~17.5 ns, leading to TEC errors up to ~50 TECU, for the GPS frequency range – ~21 ns and ~60 TECU, respectively. These results agree with the 20-ns DCB estimates for receiver RF paths and 10 ns for satellites RF paths provided by [6].

Systematic DCB change both for GLONASS and GPS frequency channels is observed significantly varying depending on station. For the GLONASS and GPS frequency channels, seasonal variations in estimated TEC errors (up to ~20 TECU) associated with DCBs are observed (see Fig. 2a). Such strong variations could be associated with variations in the receiver environment, especially meteoparameters, such as temperature and humidity. It is not just receiver hardware problems because such variations are not observed for the other receivers of the same type. In Fig. 2a, we show temperature from the weather station next to IRKJ receiver (http://www.ncdc.noaa.gov/cdo-web/). The maximum of temperature seasonal variation corresponds to the minimum of DCB seasonal variation. This proves our hypothesis.

Taking into account systematic change in DCB dependent TEC estimation errors, it is impossible to estimate absolute TEC without continuous calibration of the receiver data, which can be implemented based on continuous DCB estimations both for receivers and satellites.

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