TECHNISCHE UNIVERSITÄT DRESDEN

Estimation of absolute group delay variations of GNSS satellite antennas

Susanne Beer, Lambert Wanninger, Anja Heßelbarth, Geodetic Institute, School of Civil and Environmental Engineering, TU Dresden

Introduction

Code pseudorange signals of global navigation satellite systems (GNSS) are affected by group delay variations (GDV). Similar to phase center variations which affect phase observations, GDV are caused by direction-dependent properties of the satellite and receiver antennas. They are frequency-dependent and vary with nadir angle and elevation of the transmitted and received signal, respectively.

The correction of GDV can improve several applications based on GNSS code observations, e.g. single-frequency precise point positioning (PPP), ambiguity fixing with the so-called Melbourne-Wübbena linear combination, or the estimation of ionospheric total electron content (TEC).

Method

GDV of GNSS satellite antennas can be estimated from observations of terrestrial reference stations. Since GNSS code measurements contain both the GDV of the satellite and that of the receiver antenna, the exact separation of both parts is only possible if absolute GDV are available for one of the antennas.

Absolute GDV for a larger number of geodetic receiver antenna types were first published by Wübbena et al. (2019). We used the GDV of four receiver antenna types to correct the code observations of more than 80 globally distributed reference stations for their receiver antenna GDV. Then, by forming the code-minus-carrier (CMC) linear combination, we were able to extract the satellite antenna GDV, see Fig. 1.

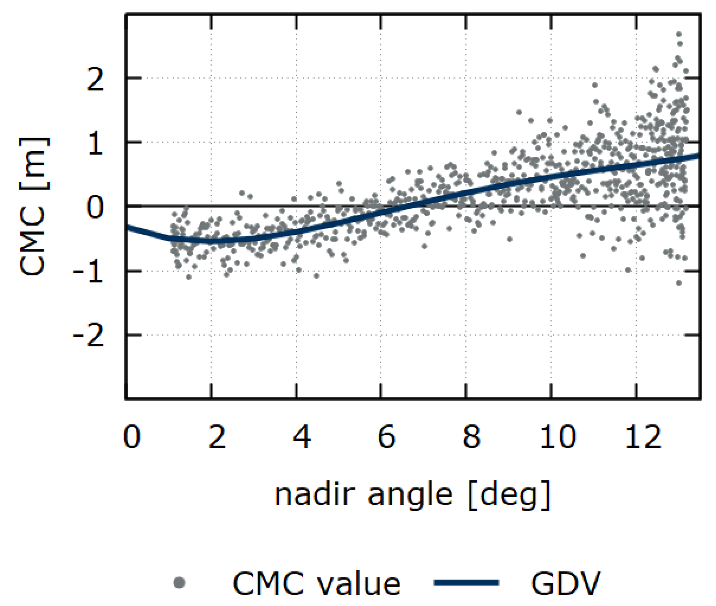

Fig. 1: Code-minus-carrier (CMC) linear combination and estimated group delay variation (GDV) for a BeiDou 2 satellite in medium earth orbit (MEO) on frequency band B1-2

Results

We present absolute nadir-dependent GDV for the satellite antennas of GPS, GLONASS, Galileo, BeiDou, and QZSS, see Fig. 2 (Beer et al. 2021). They were estimated based on observations of globally distributed GNSS reference stations which were corrected for absolute receiver antenna GDV. The results provide a cross-system overview and can be used as code corrections.

Most satellite antenna GDV amount to 1–2 decimeters and are similar for satellites of the same type or generation. The by far largest GDV with up to 1.6 m peak-to-peak are shown by the BeiDou-2 satellite antennas. GDV of the newer BeiDou-3 satellites show typical orders of magnitude as the other GNSS satellites.

While the GDV curves of the newest GPS IIIA satellites agree with those of the predecessor generation IIF at frequency bands L1 and L2, the GPS IIF and IIR satellites show the most pronounced satellite-to-satellite differences within the same constellation at frequency bands L5 and L1, respectively.

GDV of the newer GLONASS K1 satellites slightly differ from those of the GLONASS M satellites. Concerning frequency band G3, the GLONASS GDV show inhomogeneous curves, which may be caused by the significantly lower number of reference stations providing G3 observations and, thus, degrading the GDV estimation.

Except for frequency band E6, the GDV of the Galileo FOC satellites differ less than 10 cm and fit together well. The Galileo IOV satellites show larger differences among each other. The reason may be found in lower transmit power reducing the quality of the code measurements.

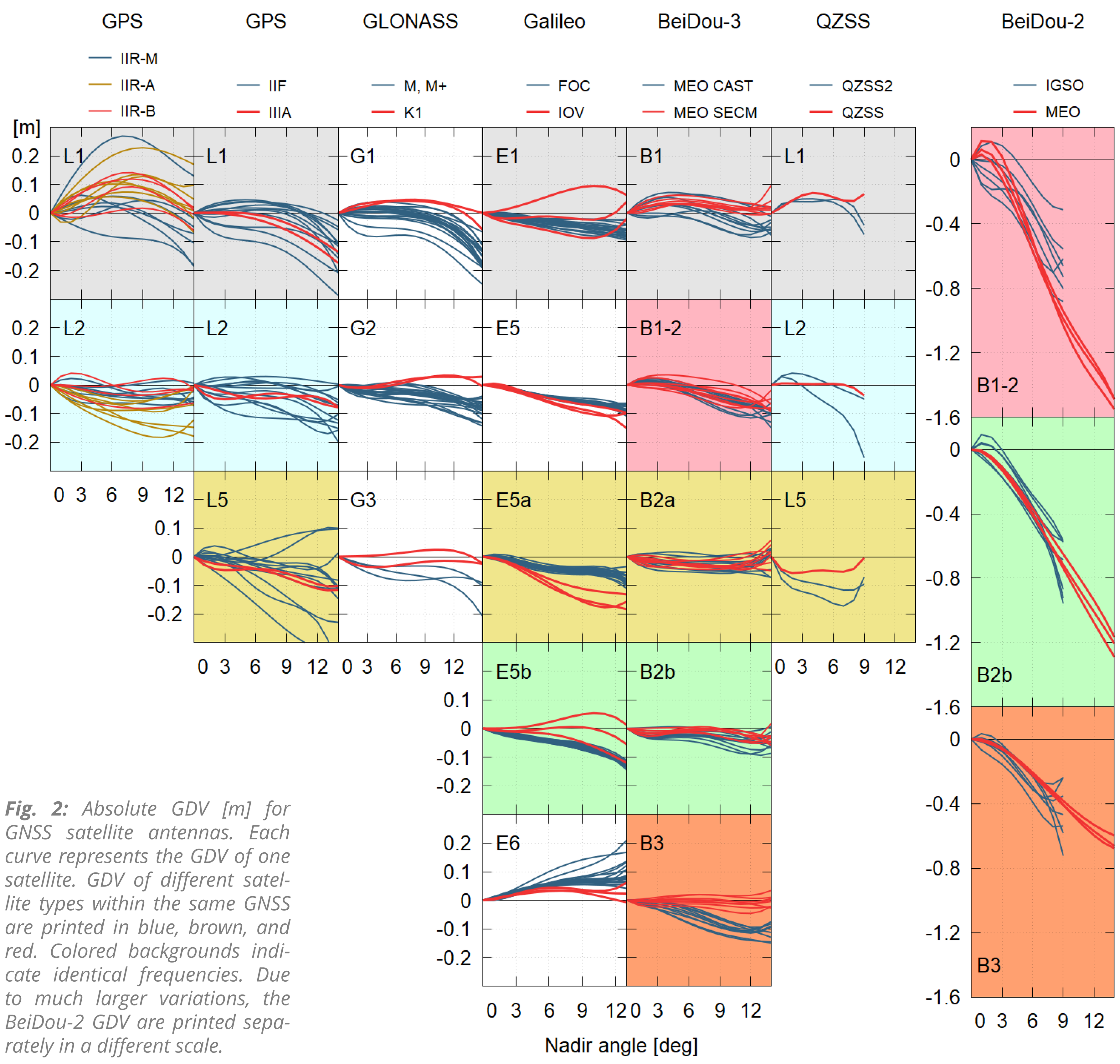

Fig. 2: Absolute GDV [m] for GNSS satellite antennas. Each curve represents the GDV of one satellite. GDV of different satellite types within the same GNSS are printed in blue, brown, and red. Colored backgrounds indicate identical frequencies. Due to much larger variations, the BeiDou-2 GDV are printed separately in a different scale.

References:

Wübbena, G., Schmitz, M., and Warneke, A. (2019) Geo++ absolute multifrequency GNSS antenna calibration. EUREF AC workshop, Warsaw, Poland. http://www.geopp.com/pdf/gpp_cal125_euref19_p.pdf

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www.tu-dresden.de/gi/gg

susanne.beer@tu-dresden.de