Updating the IGS processing standard: new GLONASS satellite antenna corrections for igs08.atx

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Introduction

In view of the forthcoming introduction of a new terrestrial reference frame ("IGS08") and a new consistent antenna phase center model ("igs08.atx") into the processing standards of the International GNSS Service (IGS), the IGS analysis centers (ACs) at the European Space Agency's Operations Centre (ESA/ESOC) and the Center for Orbit Determination in Europe (CODE) have reprocessed several years of multi-GNSS tracking data in order to provide an up-to-date set of consistent satellite-specific antenna phase center offsets (PCOs) and variations (PCVs) for the GLONASS space segment. Both AC solutions were generated according to a rigorously combined multi-GNSS processing scheme ensuring full consistency between the GPS and the GLONASS system. Thereby, the PCOs and PCVs for all receiving antennas as well as for the transmitting antennas of all GPS Block II/IIA/IIR satellites were fixed to their igs08.atx values. The reference frame was aligned to ITRF2008/IGS08. Further processing details are given below (see Table 1).

Background: Why updating the GLONASS satellite antenna corrections?

- individual z-PCOs for the majority of GLONASS-M satellite antennas missing in "igs05.atx" due to modernization of the GLONASS space segment in recent years
- ~1-ppb scale difference between ITRF2005 and ITRF2008 impacts z-PCOs
- the fact that two ACs (rather than only one) are involved in the reprocessing provides enhanced redundancy
- increased global availability of tracking sites (Fig. 1) and GLONASS-specific receiver antenna corrections ensure better modeling accuracy

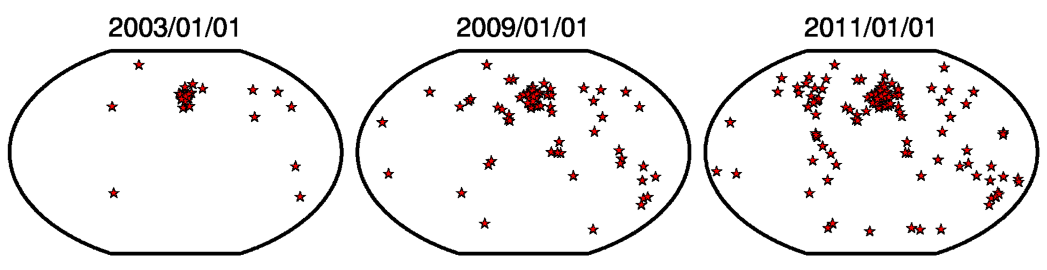

Fig. 1 Evolution of the GLONASS tracking network of the IGS

Phase center z-offsets

- adequate agreement between the two AC solutions (Fig. 2); common bias of 7 cm, most likely due to different troposphere/albedo/infrared modeling
- significant deviations from igs05.atx values; mean z-shift of +15 cm, mainly due to terrestrial scale change (Fig. 3)

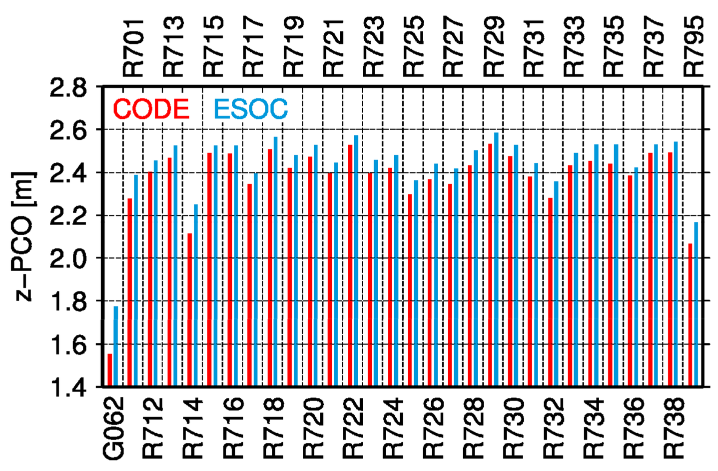

Fig. 2 z-PCOs from CODE and ESOC

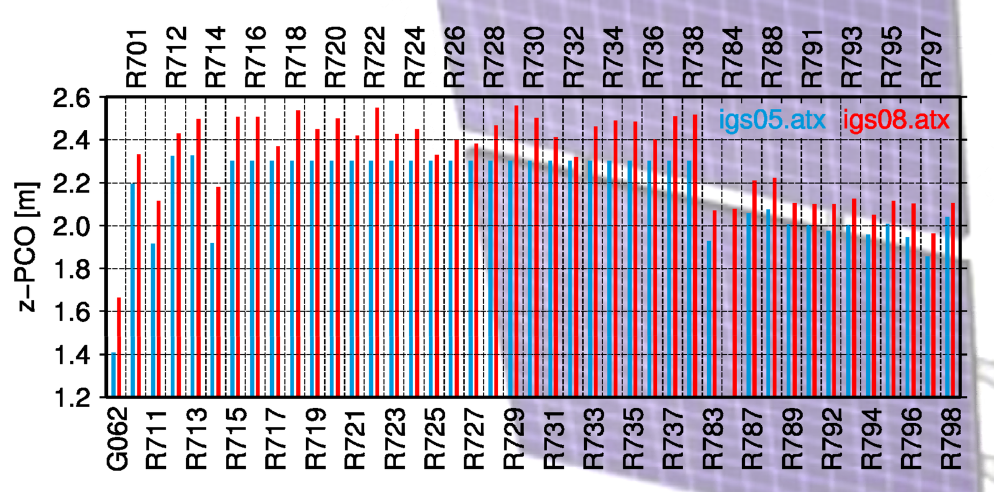

Fig. 3 Averaged z-PCOs for igs08.atx vs. igs05.atx values

References

Dach R, Schmid R, Schmitz M, Thaller D, Schaer S, Lutz S, Steigenberger P, Wübbena G, Beutler G (2011): Improved antenna phase center models for GLONASS. GPS Solut 15 (1): 49-65

Dilssner F, Springer T, Flohrer C, Dow J (2010): Estimation of phase center corrections for GLONASS-M satellite antennas. J Geod 84 (8): 467-480

Phase center variations

- excellent agreement between both AC solutions; differences below 1 mm (Fig. 4)
- exceptional PCVs for R714 due to anomaly in L2 signal (Dilssner et al. 2010)
- significant deviations from igs05.atx values; up to 4 mm for R714 (Fig. 5)

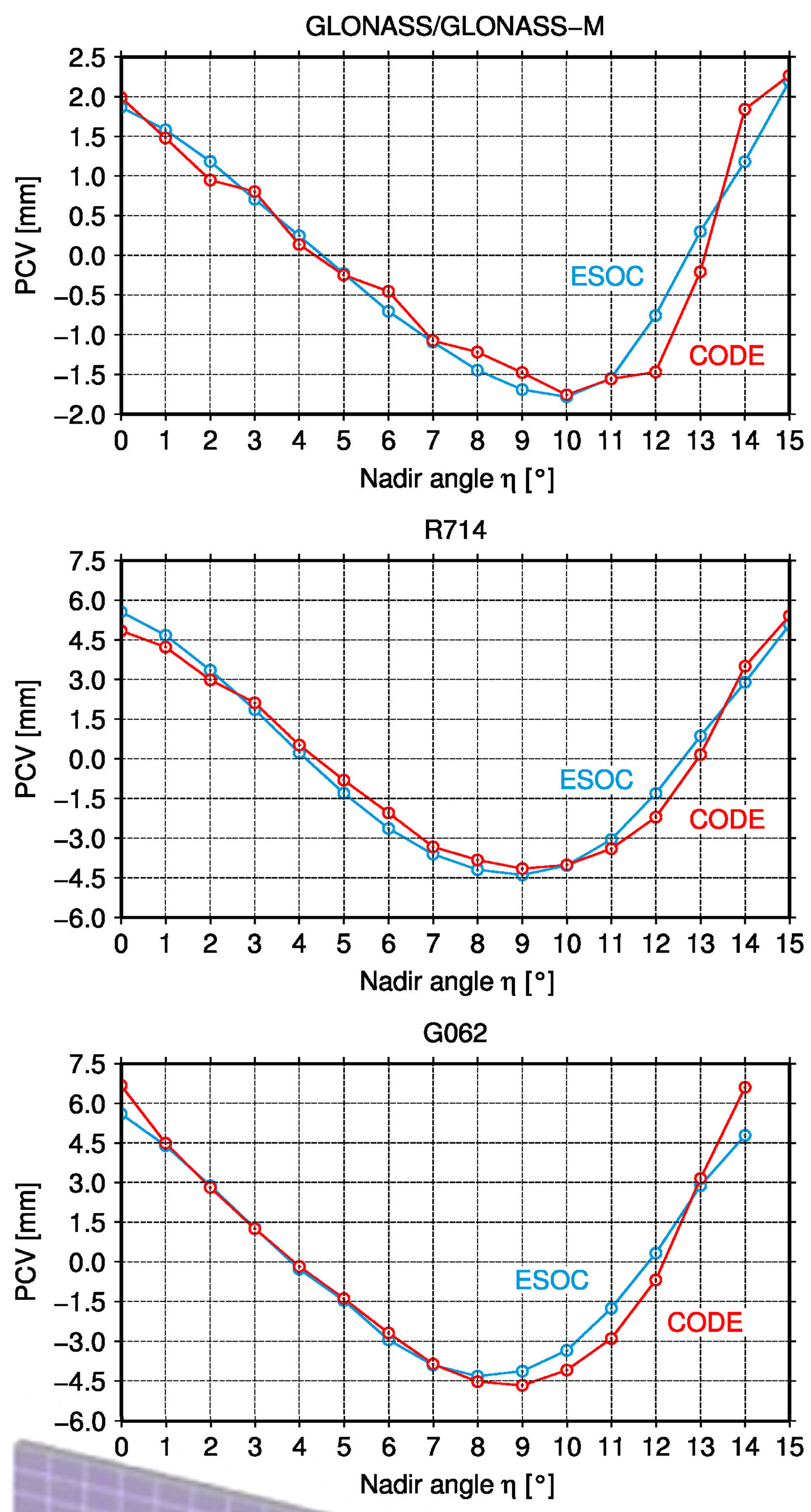

Fig. 4 Estimated PCVs from CODE and ESOC

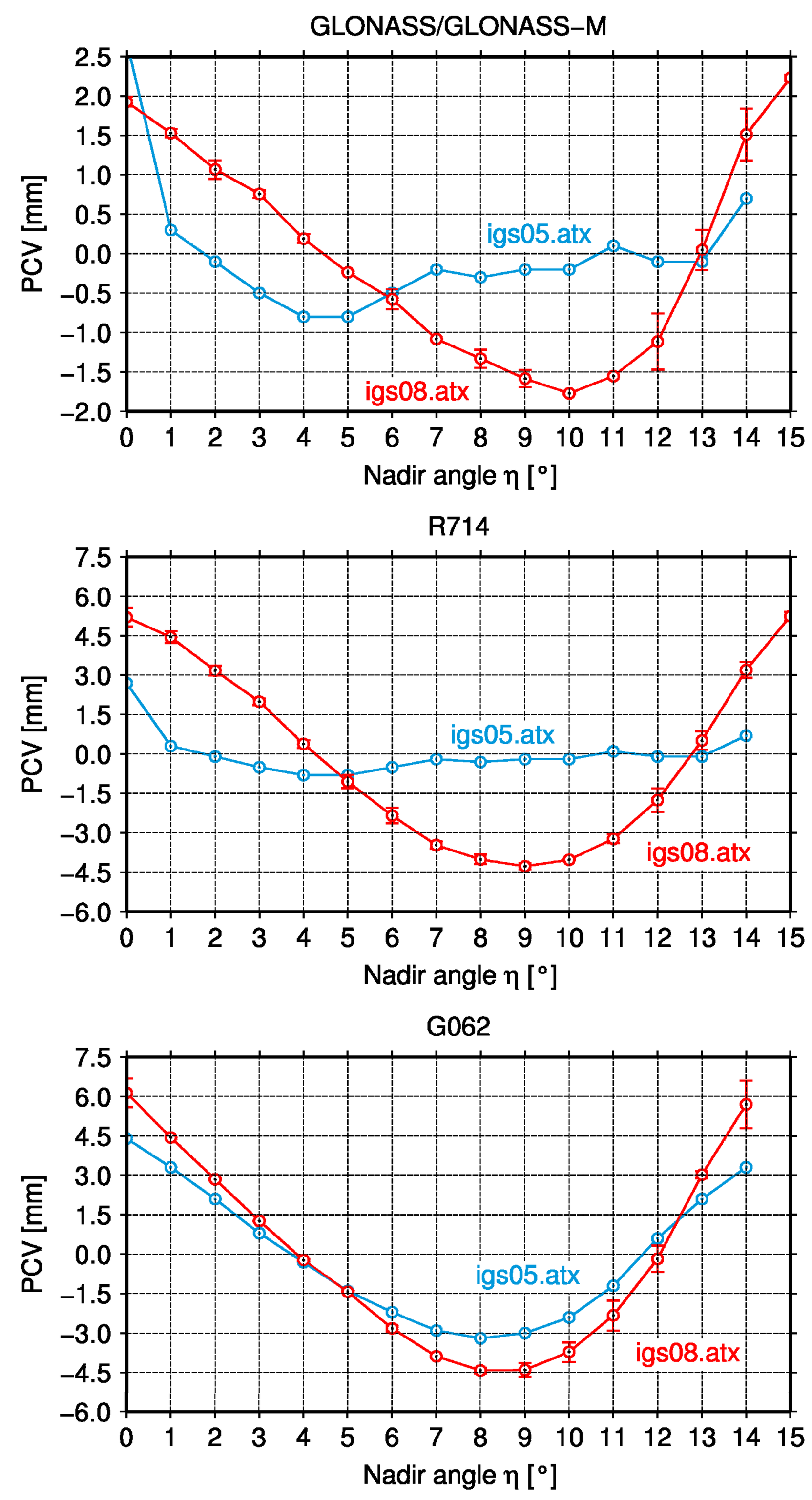

Fig. 5 Averaged PCVs for igs08.atx with error bars indicating the difference between CODE and ESOC compared to igs05.atx values

Validation

- inherent scale inconsistency in igs05.atx between GPS and GLONASS z-PCOs; results in "terrestrial inter-system scale bias" of 1 ppb (Dilssner et al. 2010); bias smaller than 0.2 ppb when applying igs08.atx (Fig. 6)
- improvement of internal orbit consistency when using IGS08 + igs08.atx (Fig. 7)

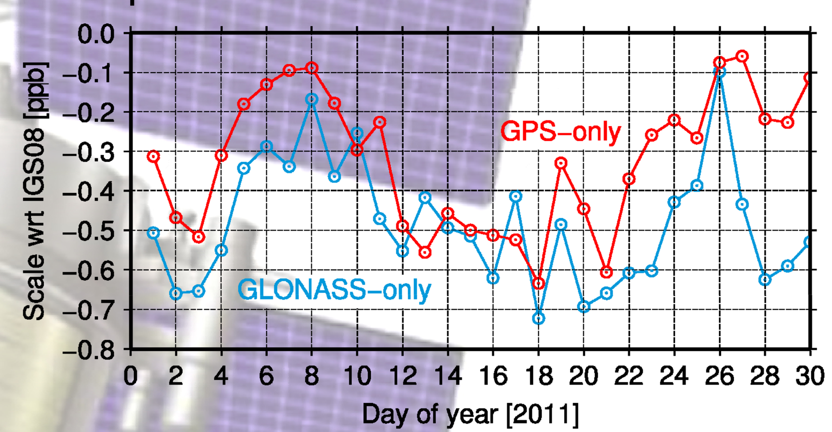

Fig. 6 Daily terrestrial scale bias wrt IGS08

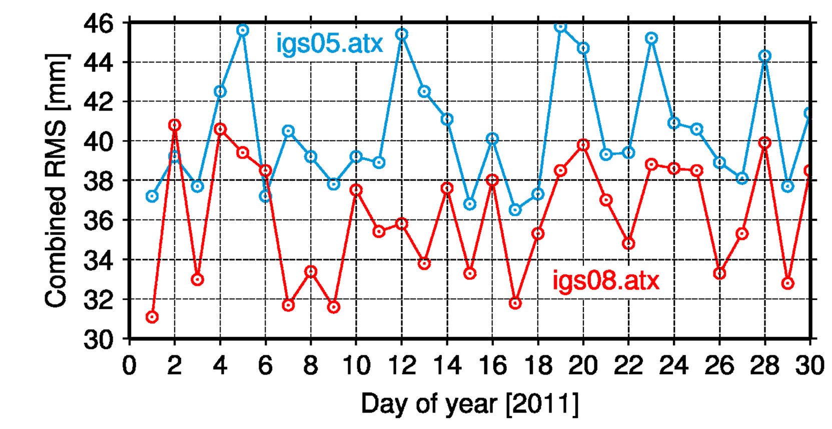

Fig. 7 RMS from GPS/GLONASS orbit overlaps

Table 1 Processing strategies of CODE and ESOC

AC	CODE	ESOC
GLONASS stations	30 to 40 in 2003, mainly in Europe; global coverage from 2007 onwards; 100 stations in 2008, 120 in 2010	
GLONASS satellites	R701, R711-738, R783-784, R787-789, R791-798 (# 42 SV)	R701, R712-738, R795 (# 29 SV)
Time interval	08 June 2003 - 30 January 2011	20 January 2008 - 26 February 2011
Software	Bernese GPS Software Version 5.1 (modified)	NAPEOS Version 3.6 (modified)
Data	double-difference GPS/GLONASS phase observations	zero-difference GPS/GLONASS phase and code observations
Sampling rate	3 minutes	5 minutes
Elevation cut-off angle	3º	10º
Weighting	elevation-dependent (weight w = $\cos^2 z$ with zenith angle z)	
Ambiguity fixing	GPS-only (85-90% per day)	GPS-only (68-80% per day)
Interfrequency biases	implicitly; assumption of constant value per day/station/satellite	estimated weekly for each station/satellite
Station coordinates	fixed to a coordinate/velocity solution generated beforehand using no-net-rotation condition for IGS08 sites	no-net-scale and no-net-rotation condition for IGS08 sites
Orbits	72-hour arcs; 6 initial osculating elements, 3 constant plus 2 periodic RPRs; pseudo-stochastic pulses at 12 UT	24-hour arcs; initial positions and velocities, 3 constant plus 2 periodic RPRs; 3 along-track CPRs; Earth albedo and infrared model
Earth rotation	piece-wise linear modeling; resolution of one day for ERPs	daily pole coordinates and drifts, UT1 and LOD are estimated
Ionospheric refraction	first-order effect eliminated by forming ionosphere-free linear combination; higher-order effects corrected (only CODE)	
Tropospheric refraction	a priori ZPDs computed with formula of Saastamoinen using GPT model; mapped into slant delays using hydrostatic GMF; ZPDs estimated at 2-h intervals as continuous piece-wise linear functions using wet GMF; horizontal gradients estimated with 24-h resolution (only CODE)	
Satellite antenna PCOs	satellite-specific z-offset estimation for GLONASS satellites and GPS IIF-1 (G062); x- and y-offsets fixed to manufacturer values; offsets of GPS Block II/IIA/IIR satellites fixed to igs08.atx values	
Satellite antenna PCVs	block-specific estimation (common parameters for GLONASS and GLONASS-M); satellite-specific estimation for R714 and G062; η_{max} = 14º for GPS, η_{max} = 15º for GLONASS; nadir-dependent, piece-wise linear modeling with 1º-resolution; sum condition to prevent the normal equation system from becoming singular; PCVs of GPS Block II/IIA/IIR satellites fixed to igs08.atx values	
Receiver antenna PCOs/PCVs	fixed to igs08.atx values; frequency-specific corrections for GLONASS applied, if available	