GLONASS phase bias products in the bias-SINEX format at Wuhan University: Differential code-phase bias

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1 Abstract

- GLONASS double-differenced ambiguity resolution (DD-AR) is hindered by the presence of inter-frequency phase biases (IFPBs) due to its FDMA (Frequency Division Multiple Access) signal system.
- Although IFPB model is effective for GLONASS DD-AR at most time and has been prevalently recognized by GNSS community, it's not theoretically rigorous and is potentially problematic. Actually, IFCBs are in essence the outcome of differential code-phase biases (DCPBs).
- We recommend that DCPBs should estimated for specific station (combination of receiver, antenna and firmware) rather than for receiver types, since DCPBs can differ up to tens of ns even among homogenous receivers.
- In this study, we estimate DCPBs per station in a global IGS network by directly resolving ionosphere-free DD ambiguities of ~5.3cm wavelength. Temporal and spatial variation characteristics of estimated DCPBs along with GLONASS DD-AR fixing rate with these DCPBs products are analyzed.

2 Method

DCPBs are defined with respect to receivers as biases between pseudorange and carrier-phase measurements. DCPBs can be divided into the digital signal processing (DSP) derived and the hardware (HW) derived parts. According to the studies of J.-M. Sleewaegen, the DSP parts are dominant and the difference of HW parts on different channels are neglectable. So DCPBs can be generally written in the form of single difference between two stations with respect to satellite i, such that

$$\begin{cases} \Delta P_g^i = \Delta\rho^i + c\Delta t_g \\ \Delta L_g^i = \Delta\rho^i + c\Delta t_g + c\Delta B_g^i + \lambda\Delta N_g^i \end{cases} \qquad (1)$$

$$\begin{cases} \Delta t_g = \Delta t_P + \Delta b_{P,g} \\ \Delta B_g^i = \Delta B_{DSP} + \Delta B_{HW,g}^i \\ \Delta B_{DSP} = \Delta t_L - \Delta t_P \\ \Delta B_{HW,g}^i = \Delta b_{L,g}^i - \Delta b_{P,g} \end{cases} \qquad (2)$$

$$\Delta B_g f_q^i - \Delta B_g f_q^j = \Delta B_g \left(h^i - h^j\right)\Delta f_q \qquad (3)$$

where Δ means single difference between stations; g represents frequency; $\Delta\rho^i$ is the difference of geometry distances between two stations and satellite i; Δt_P denotes pseudorange clock error; $\Delta b_{P,g}$ means average hardware delay of pseudorange; ΔB_g denotes the DCPB while ΔB_{DSP} and $\Delta B_{HW,g}$ are DSP and hardware induced DCPBs, respectively.

3 Global Network Data

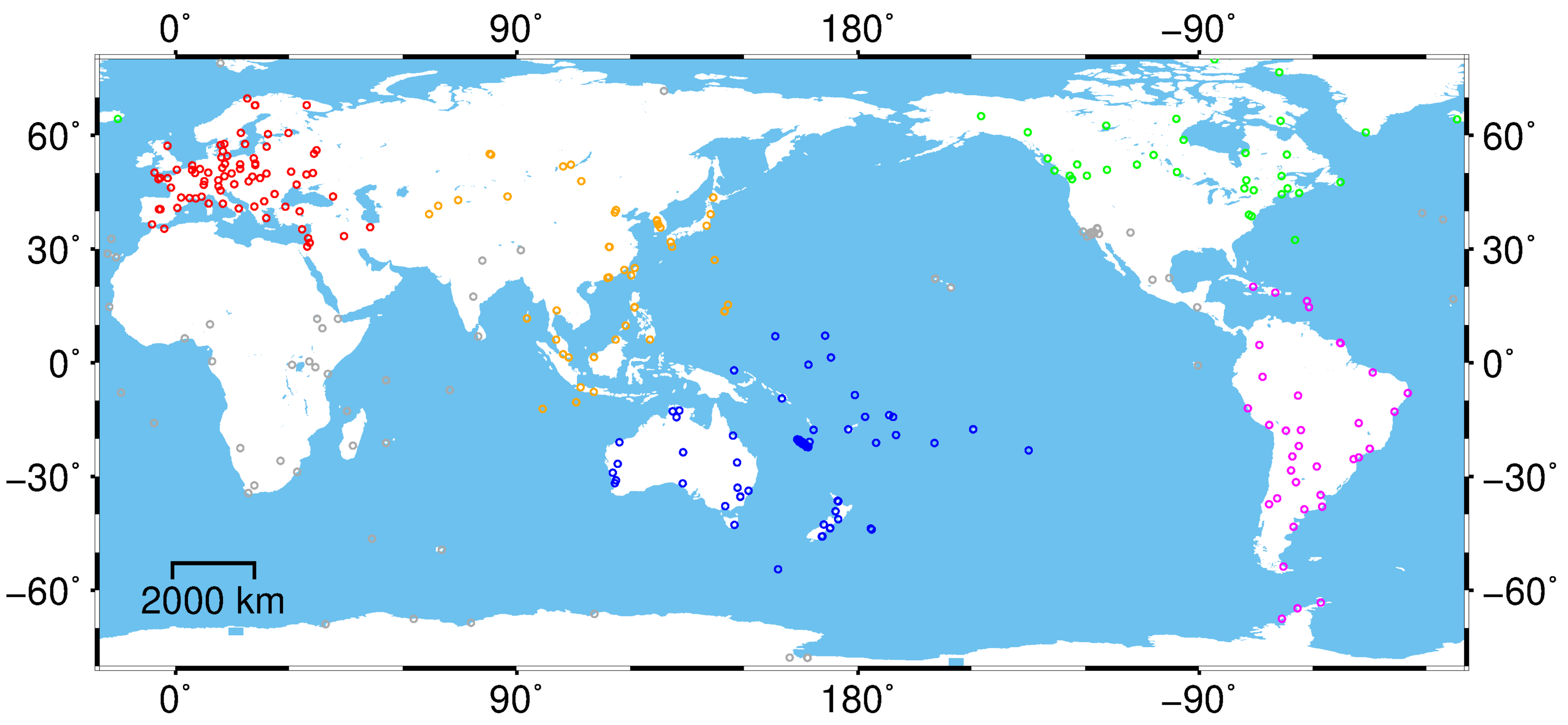

Figure 1 Global distribution of dual-GNSS capable IGS stations. Different colors represents 5 independent DCPBs estimation sub-networks.

We collected GPS/GLONASS data spanning 6 years (2012-2017) from about 300 IGS global stations. Due to the short wavelength of GLONASS ionosphere-free ambiguities, DD ambiguities are sensitive to orbit or atmosphere errors. GLONASS baseline lengths were mandated to less than 1200km to try to minimize the adverse impact of GLONASS orbit errors and also to maximize the AR performance across the entire network.

Due to the sparsity of IGS dual-GNSS capable stations, we divide the whole global network into 5 parts: i.e. Europe, Asia, Australia, North America and South America, in order to obtain reliable DD-AR solutions. Double-difference AR and DCPBs estimation were carried out independently in each sub-network. All DCPBs estimations were finally aligned to a common datum exploiting the consistency and stability of DCPBs among all LEICA receivers (Figure 2).

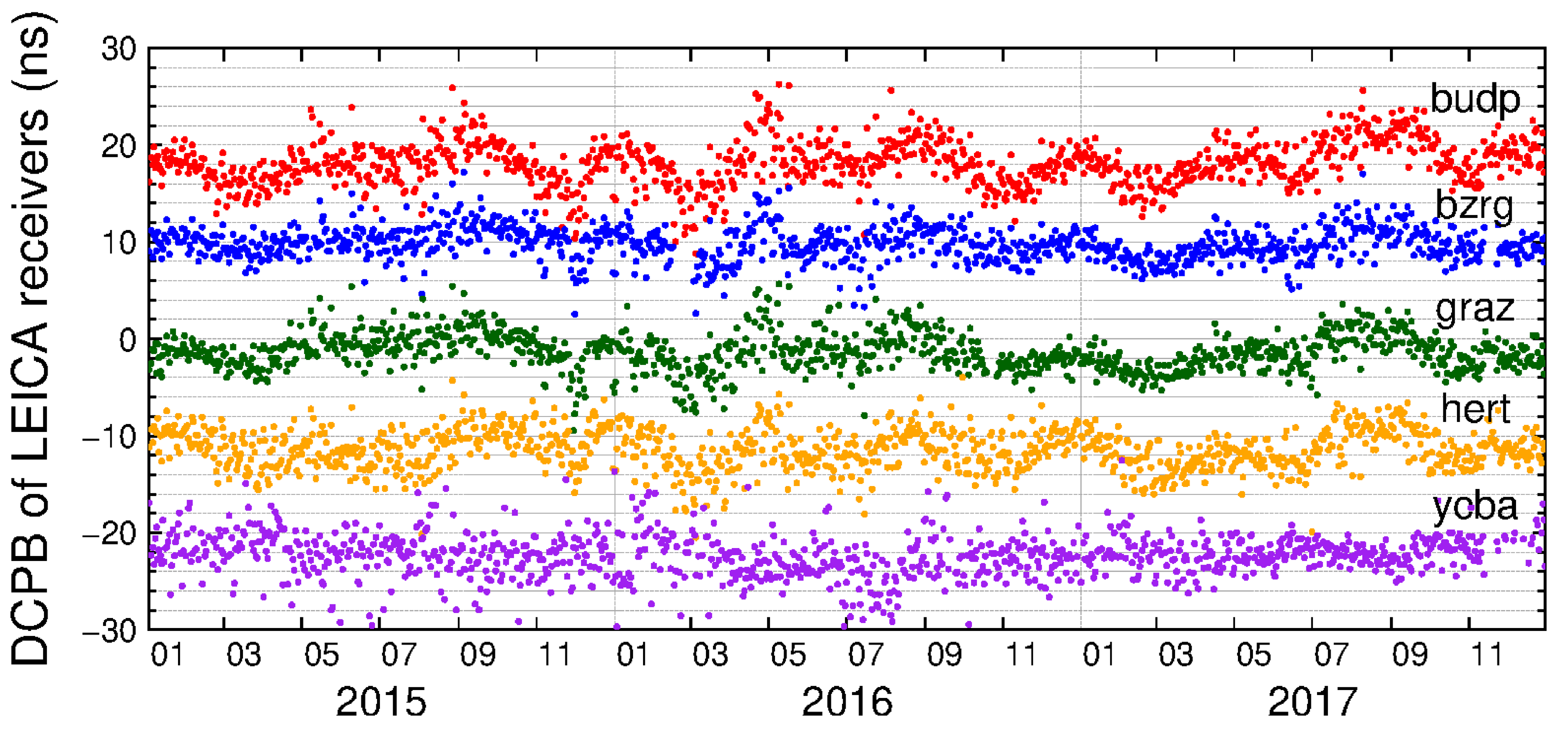

Figure 2 Time series of DCPBs estimations for 5 stations with LEICA receiver during year 2015-2017. Scatters, which originally all possess zero means, are shifted evenly to avoid overlap.

4 Results and Discussion

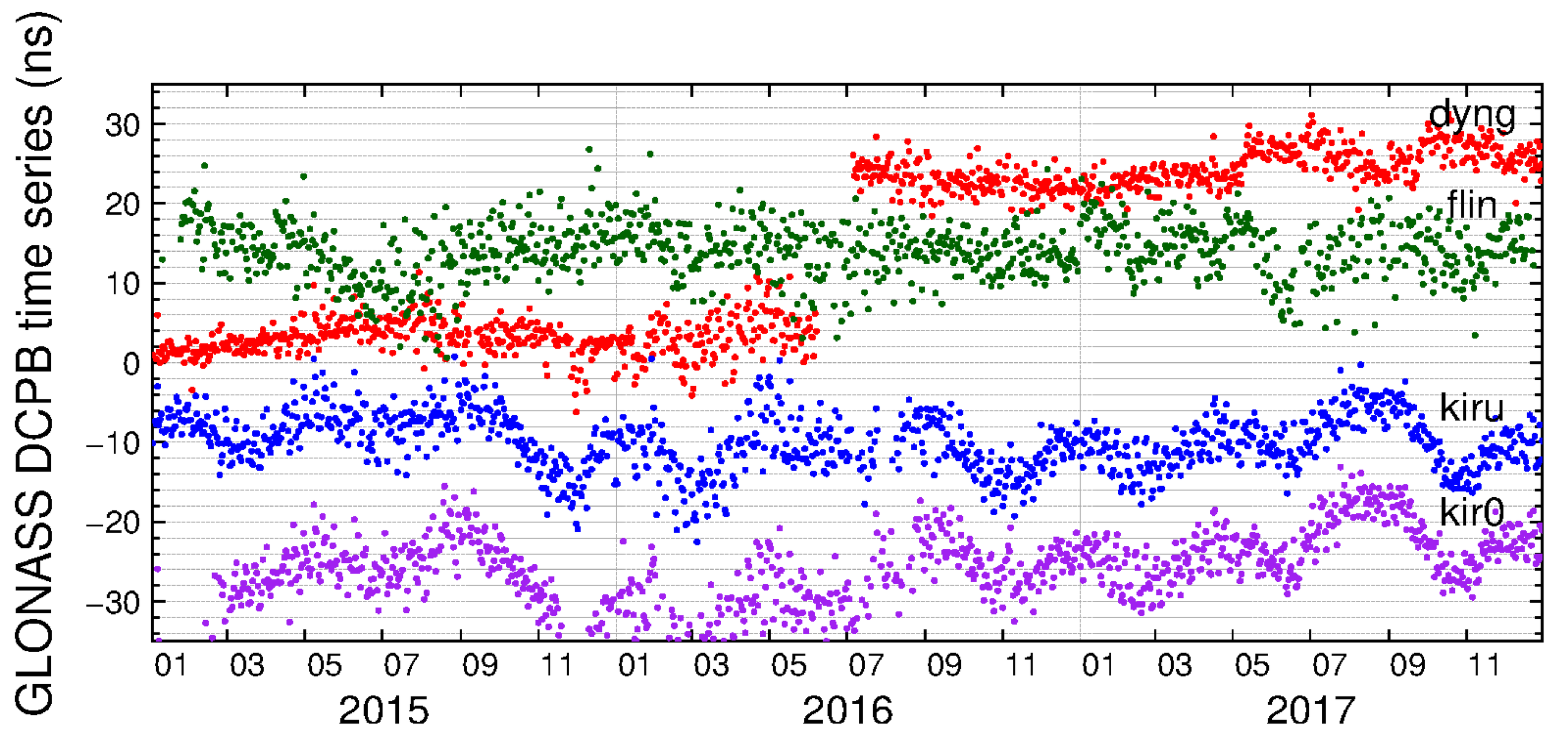

Figure 3 Representative DCPBs time series of 4 stations. All traces are shifted to a common regions, but the original scale is kept. KIRU are 4.5 km apart from KIR0.

From Figure 3. We can find that

- DCPBs would suddenly jump when station conditions change (receiver changed, firmware updated etc.), so one DCPB per station is desired.
- It's difficult to quantify the estimation errors only through time series. Common Mode Errors are examined in Figure 4.
- Alignment errors are even more hard to quantify since stations belonging to different continents can distanced up to 5000km-10000km and reliable DD-AR is tough. But these estimation errors and alignment errors of DCPBs products don't hinder DD-AR inside continent.
- DCPBs exhibit spatial correlation between close stations (blue and purple traces).

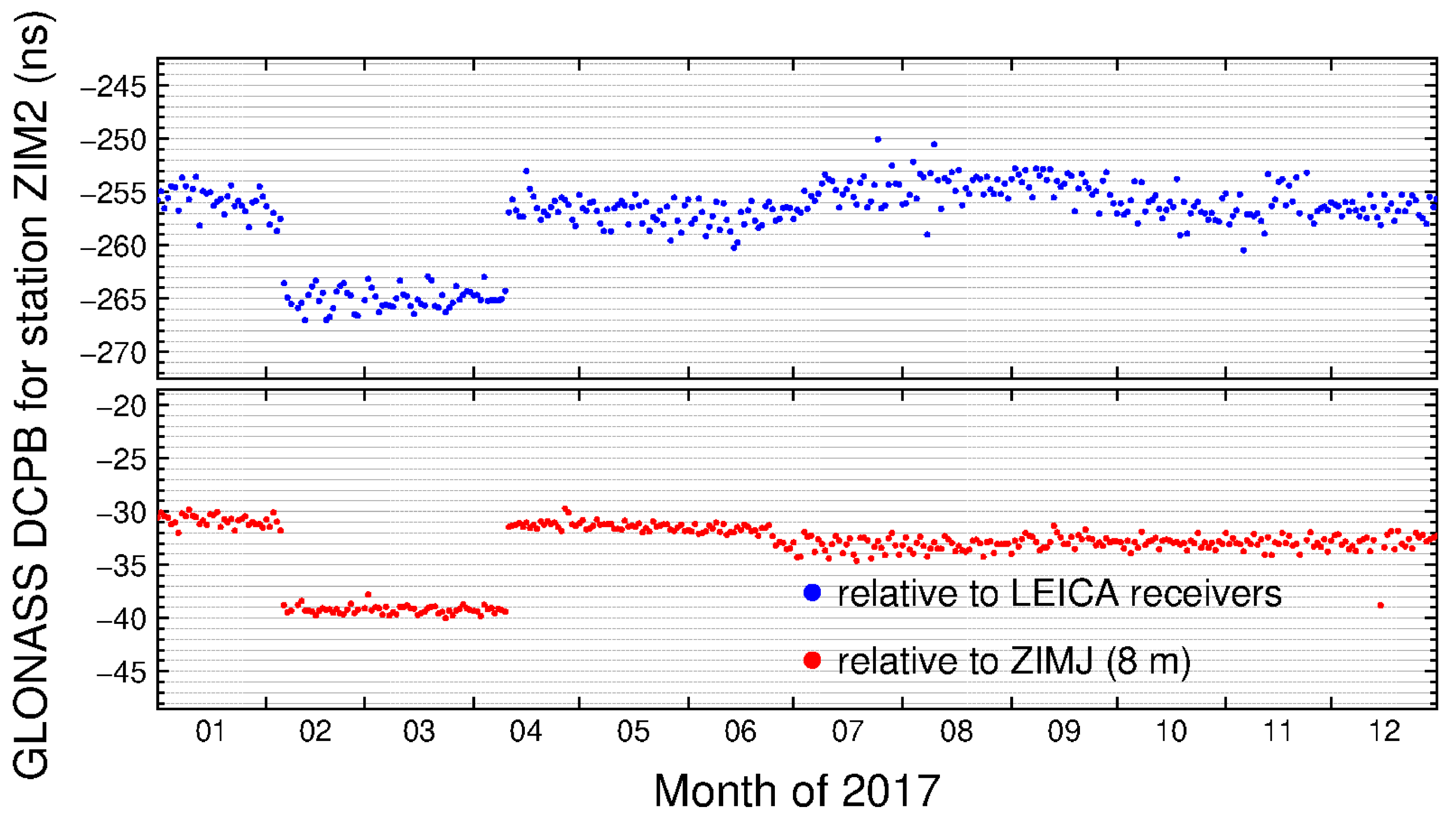

Figure 4 DCPBs time series of station ZIM2 relative to LEICA receivers median and station ZIMJ in up and bottom panels, respectively. ZIMJ is 8 m far away from ZIM2, thus Common Mode Error is expected between them.

5 Conclusion

- We estimated 6 years (2012-2017) of DCPBs products per station with median and long baselines in IGS network. Our DCPBs products display 1-2 ns daily variation for most of stations.
- DCPBs could differ up to tens of ns even between homogenous receivers. We recommend to estimate station specific DCPBs instead of receiver type of manufacturer specific DCPBs.
- With our estimated DCPBs products, GLONASS DD-AR fixing rate can reach beyond 96% between heterogeneous receivers distanced by even 1500 km. We stored those GLONASS phase bias products in the bias-SINEX format, in addition to GPS FCB (Fractional Cycle Bias) products, and can be freely accessed from the FTP of Wuhan University IGS analysis center.

[1] **Geng, J.**, et al. (2016) A review on the inter-frequency biases of GLONASS carrier-phase data. Journal of Geodesy 91(3): 329-340.
[2] **Sleewaegen JM**, et al. (2012). Demystifying GLONASS inter-frequency carrier phase biases. Inside GNSS 7(3):57–61.
[3] **Wanninger L** (2012) Carrier-phase inter-frequency biases ofGLONASS receivers. J Geod 86(2):138–148.