Research Report

Earthquake Research Institute, the University of Tokyo

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General Description of Work:

I was a short-term visiting scholar to the Earthquake Research Institute (ERI), the University of Tokyo from July 24 to August 27, 2023 to collaborate with Prof. Yosuke Aoki on very early postseismic deformation of large earthquake using kinematic GNSS. During the visit, we discussed how to improve kinematic GNSS positioning precisions to recover slight motions after an earthquake or preceding a volcano eruption event, and especially, the role of multi-GNSS multipath mitigation in reducing noise of epoch-wise GNSS displacements. On August 10, we visited together to Geospatial Information Authority of Japan (GSI) in Tsukuba, and I gave a talk on the IGS activities at Wuhan University. We had a good talk with Dr. Hiroshi Munekane, Dr. Basara Miyahara, Dr. Yusaku Ohta, Dr. Kyohei Akiyama, et al. and they talked about the MADOCA software, the GSI GEONET as well as the application of high-precision GNSS in earthquake/tsunami early warning. On August 18, we talked to Prof. Akimichi Taketa on the GNSS time synchronization for Hyper-Kamiokande. On Friday seminars, I also talked to the speakers Philippe Lognonné, Vladimir Vukobratovic and Zefeng Li on the potential of GNSS and its combination with seismic sensors in studying structural vibrations and earthquake deformations.

Research Project:

After the rupture of large earthquakes, the fault activity does not stop immediately, and a series of afterslip and structural evolution (*e.g.*, poroelastic and viscoelastic relaxation) will continue, especially in the very early phase which shows dramatically different ground deformation signatures from those taking place days later. While seismometers can hardly register slow deformations at DC, kinematic GNSS can well capture both transient and permanent ground motions, and can continuously observe the dynamic rupture process and the slow deformation before and after an event. Therefore, kinematic GNSS provides a good perspective to studying the transition from co- to post-seismic processes of target events.

I have been devoted to high-precision multi-GNSS data processing. Compared to GPS-only solutions, multi-GNSS augmented by advanced multipath suppression techniques can effectively improve the positioning precision thanks to more visible satellites and stronger geometry. It is highlighted that multi-GNSS data lead to a substantial reduction of 30-60% for the high-rate displacement noise. We further applied this technique to postseismic studies. Kinematic GNSS was applied to analyze the coseismic and postseismic deformation of the 2015 Illapel Mw8.3 earthquake in central Chile. It was found that the very early postseismic deformation was very significant and cannot be ignored. The early deformation was dominated by afterslip, while the impact of the poroelastic rebound was almost negligible. Different from the long-term post-seismic deformation, the very early post-seismic deformation obeys power function decay better, rather than the conventional exponential and logarithmic models. It was found that the distribution of coseismic slip and the early afterslip were spatially complementary, and the relationship between the spatial distribution of the early aftershocks and the spatiotemporal evolution shows that early aftershocks may be dominated by early afterslip.

At the moment, my main work at ERI is to investigate the possibility of combining multi-GNSS constellations to improve the multipath hemisphere maps (MHMs) with the goal of improving kinematic GNSS positioning precisions. We used data from the Sakurajima event associated with a failed eruption on August 15, 2015. However, the data were sampled at 30 s and only GPS/GLONASS dual-frequency data were available. In Fig. 1, we plotted the satellite tracks in the hemisphere sky plot. The upper plots show the tracks recorded by 30-s data and the lower plots the tracks by 1-Hz data. From left to right, the panels show the accumulated tracks based on one, three and five days of data. We can clearly see some "holes" in the upper plots compared to the lower plot, which means that 30-s data can hardly produce an MHM eligible for sufficient multipath corrections. We then turned to the seismic swarm data in the Noto Peninsula continuing since November 20, 2020, and 1-Hz data will be available from the SoftBank. However, we contacted Prof Ohta from Tohoku University and waited for the response from SoftBank. This work will continue until we could find a geophysical event to validate our method.

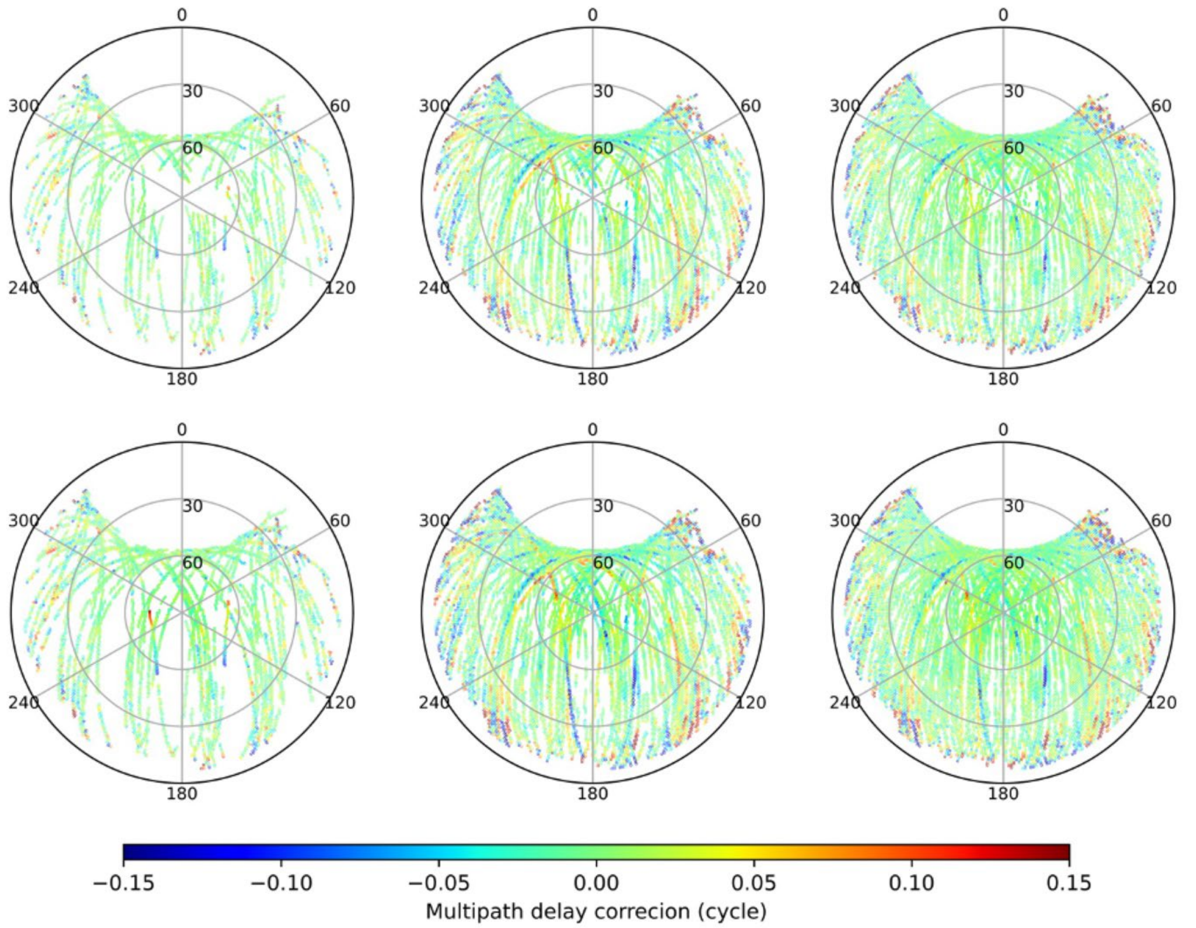

Figure 1. Satellite tracks color coded by multipath delays in cycles. The upper plots show the tracks recorded by 30-s data and the lower plots the tracks by 1-s data. From left to right, the panels show the accumulated tracks based on one, three and five days of data.

Acknowledgement:

I sincerely thank Prof. Aoki for his kindness in inviting me to ERI. We had really good discussions on several issues related to high-precision GNSS. I'm also grateful to Ms. Yuko Yamada for her assistance throughout my stay in Tokyo. I enjoyed my trip to Japan with my new friends, Dr. Yunmeng Cao, Dr. Zongchao Li, Mr. Jiaqing Wang and Prof. Zefeng Li.