The Final Frontier for Satellite Laser Ranging: Antarctica

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In 2015, the United Nations General Assembly adopted the UN resolution on Global Geodetic Reference Frame for Sustainable Development where the importance of geospatial information and observation infrastructure was highlighted. Modern high-precision geodesy largely relies on space geodetic techniques, such as VLBI (Very Long Baseline Interferometry), SLR (Satellite Laser Ranging), GNSS (Global Navigation Satellite System), DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) and other satellite missions and terrestrial observations. In early days these techniques were developed and operated tottally independently, but they are nowadays regarded as an integrated system. Geodetic products can be provided to the various fields in science and society, which should be actively promoted by the worldwide community. These are why GGOS (Global Geodetic Observing System) was established as a flagship component of IAG (International Association of Geodesy) in 2007 (Plag and Pearlman, 2009). The goal of GGOS is set to 1 mm and 0.1mm/year quality measurements in the Earth scale to satisfy the scientific objectives, such as requirements from sea surface height measurements and crustal monitoring, but we have not reached these levels yet.

One of the early space geodesy facilities was brought to Syowa in 1989, which is realised by the VLBI system that has been operational up to now. Gravimeters, DORIS and GNSS were later installed in Syowa, and it is now the best equipped geodetic site in Antarctica. Syowa still needs SLR to become a GGOS Core Station that is defined as a fully equipped site at least with all of GNSS, VLBI, and SLR. While GNSS, VLBI and DORIS use microwave wavelength, SLR uses optical wavelength and it has a great advantage in precisely modeling the propagation delay. SLR is the only two-way measurement technique in which a clock error will not be a major error source. As shown in Fig. 1, there are no SLR stations below 37 degrees of latitude south. As a result, artificial satellites, especially at low Earth orbits, can not be tracked by anyone when it flies over the high latitude region in the southern hemisphere.

A simulation analysis is conducted to assess the effectiveness of the location of a new station (Otsubo et al., 2016). This study is made of two steps: generating simulation datasets and running POD (precise orbit determination) simulation. In the first step, realistic numbers of observations for a new station are numerically simulated, based on the actual data acquisition statistics of the existing stations. In the second step, the space geodesy analysis software 'c5++' is used in its simulation mode

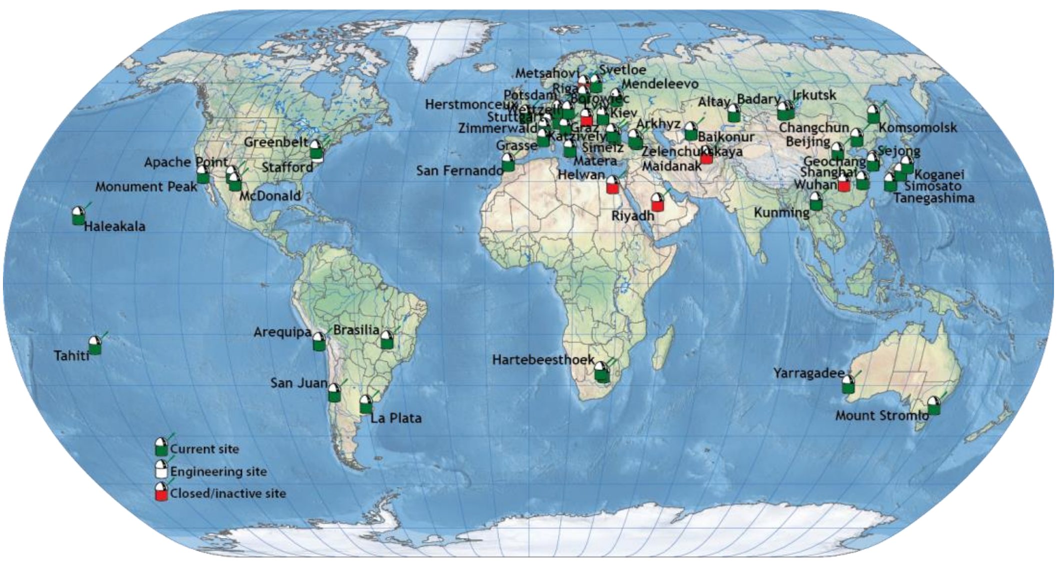

Fig. 1. Current SLR station network (https://ilrs.cddis.eosdis.nasa.gov/).

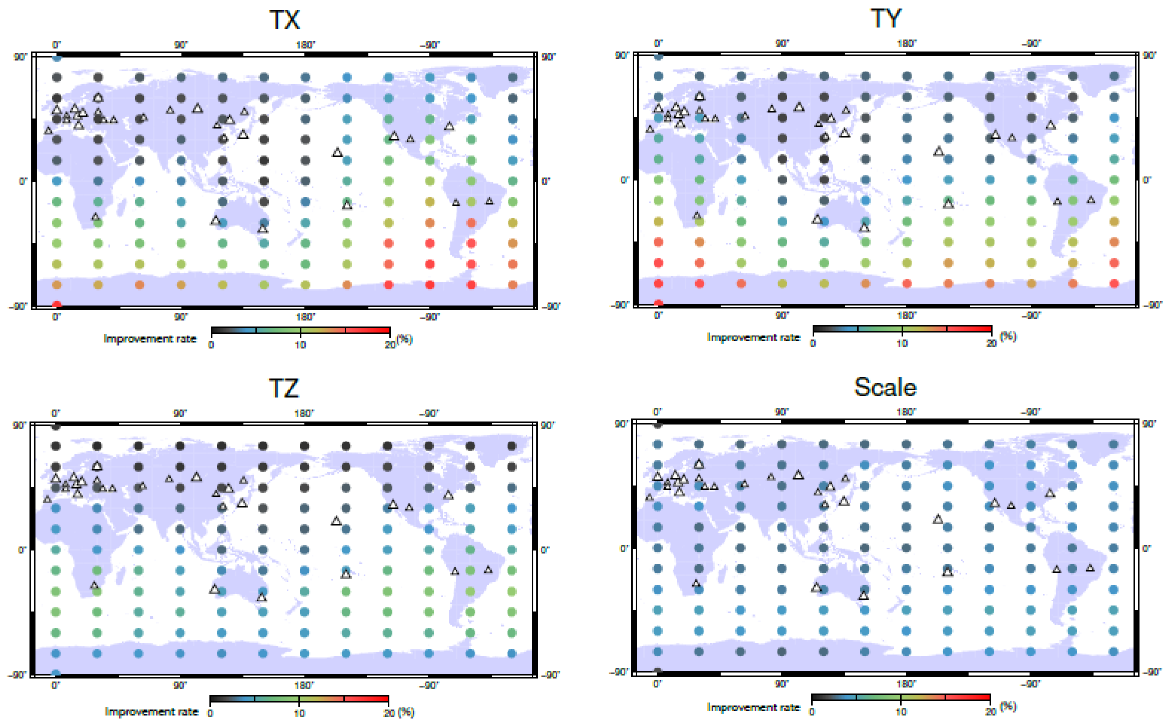

Fig. 2. Simulated improvement rate of three translation parameters and a scale parameter of a terrestrial reference frame when one laser-tracking station (one of the colored circles) is added to the existing laser-tracking network (white triangles; large ones are high productive stations) (Otsubo et al., 2016).

with six geodetic satellites, LAGEOS-1, -2, Ajisai, LARES, Starlette and Stella are used, and, with and without the new station, and the difference of the estimated error for each parameter is examined. The X and Y components of the geocenter and the sectoral terms of the Earth's gravity field are largely improved by a station in the polar regions. A middle latitude station best contributes to the tesseral gravity terms, and, to a lesser extent, a low latitude station best performs for the Z component of the geocenter and the zonal gravity terms. The expected improvement rates for the geocenter and the scale parameter are plotted in Fig. 2.

This simulation results clearly support the effectiveness of operating a new SLR station in Antarctica. Therefore, in January-February 2018 (JARE 59), we looked into possible station locations for SLR in Syowa and made an all-time all-sky camera operational for a year. SLR needs a clear sky and Syowa seems to provide satellite-tracking chances almost at the same level as the existing operational stations in Japan and Europe. We are pursuing a further opportunity for developing an SLR system and installing it in Syowa.

References

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