International Workshop on Laser Ranging 2018, Canberra, Australia
Session 1 Summary

"SLR Contribution to Global Geodetic Observing System – A 2020 Perspective"

Session Chairs: Mike Pearlman (CfA), Richard Gross (NASA JPL), and Mathis Bloßfeld (DGFI-TUM)

The Session included eight oral presentations and two posters. The contributions covered a broad variety of topics ranging from SLR contributions to the Global Geodetic Observing System (GGOS) to inter-technique comparisons and synergies of SLR with other space geodetic techniques. The session was structured into two blocks; the first being dedicated to SLR in the context of GGOS, and the second to other geodetic space techniques and local ground surveys.

Richard Gross presented "**GGOS and essential geodetic variables**", a general overview of GGOS as a component of the International Association of Geodesy (IAG). GGOS is structured to provide a strong interface with the measurement Services and external organizations, to develop standards, and to help incubate new products. GGOS represents the IAG within the Group on Earth Observations (GEO) and the Global Earth Observation System of Systems (GEOSS). Richard Gross highlighted the advantages of Digital Object Identifiers (DOIs) for geodetic observations and data products. Currently, DOIs for scientific publications are well established and widely used by scientists to uniquely link to their publications. It was pointed out that DOIs for geodetic data are beneficial for both, data users and data providers. In the second part of the presentation, the work of the GGOS Bureau for Products and Standards (BPS) committee on essential geodetic variables (EGVs) was presented as a means of developing two-way traceability between basic observations (data) and final scientific products as an example for a definition. Essential polar motion variables were presented as an example.

Mathis Bloßfeld emphasized in his talk "**The role of laser ranging for the Global Geodetic Observing System GGOS**" that GGOS aims the integration of gravimetric and geometric aspects with 1 mm accuracy for positions and 0.1 mm/yr accuracy for motions. A prerequisite for such an integration of the so called "three pillars" of modern space geodesy are highly accurate reference frames and satellite orbits. Due to numerous correlations between the parameters, non-common standards and inter-technique biases as well as the inhomogeneous station distributions on ground, SLR could serve as a tool to realize GGOS because of the high sensitivity of SLR to parameters of every pillar. In the presented study, SLR was used to realize a multi-satellite multi-parameter solution where significant de- correlations between the parameters could be achieved. This study supports the GGOS goal of a multi- technique multi-parameter solution where the potential of all techniques and their combination on ground and in space will be fully exploited.

The presentation on "**The synergy of Satellite Laser Ranging (SLR) and DORIS as space geodesy techniques**" was given by Frank Lemoine. After a brief overview of the International DORIS Service (IDS) and the current DORIS space- and ground-based infrastructure, it was highlighted the current on- orbit Ocean (& Cryosphere) radar altimeter satellite constellation comprises seven satellites equipped with DORIS antennas and laser retro-reflector arrays. For these missions, a joint SLR and DORIS precise orbit determination (POD) can be performed. The combined POD provides superior performance to each technique individually, as measured by altimeter crossovers. SLR and DORIS data are used on the reference missions for altimetry to measure the global mean sea level (GMSL) rate and its acceleration. They provide a vital validation and verification of radial orbit accuracy and stability (8-10 mm). Moreover, SLR and DORIS data can individually and jointly be used to study geophysical parameters other than the reference frame (e.g. time-variable low degree gravity field, geocenter). It was finally concluded that SLR significantly contributes to identify/calibrate/overcome systematics in other geodetic space techniques.

Daniela Thaller discussed in her presentation named "**SLR tracking of GNSS constellations - Many synergies to be explored**" the large amount of SLR data to GNSS satellite (up to 70 satellites are currently tracked by the ILRS) and how these synergies can be explored. SLR data is used to validate

the orbit modelling for GNSS, to investigate inconsistencies and biases between SLR and GNSS, to validate laser retro-reflector arrays, to validate microwave satellite antenna offsets and finally to improve reference frame products. Moreover, it was presented that satellite co-locations provide an additional connection to strengthen the inter-technique combinations. As an outlook, it was finally stated that more data from space-geodetic stations can be included in reference frame computation since beside the ground-based co-locations (local ties), also space ties can be used to tie different space techniques together.

Carey Noll presented in her talk "**ILRS: Current status and future plans**" the work of the ILRS Central Bureau (CB). Within the ILRS, the following current trends were identified: (i) SLR systems are going to measure with lower energy and higher repetition rates, (ii) shorter NP intervals and faster slewing for increased pass interleaving will be performed and (iii) in the near future, the ILRS will face to track more than 100 satellites in parallel. This significant increase of space targets increases the need of optimal GNSS tracking scenarios which still need to be defined. One scenario could be that the different constellations may select 4 – 8 GNSS satellites for higher priority with three segments of tracking requested per pass.

The talk "**Recent progress of VGOS and its role on GGOS**" was given by Takahiro Wakasugi from the International VLBI Service for Geodesy and Astrometry (IVS) Directing Board. Within the presentation, an overview of the new VGOS network and a description of technical designs of the new VGOS VLBI antennas was presented. It was emphasized that when the VGOS network is finally operational (after 2020), "mixed mode" observations will be performed in order to ensure consistency of the VLBI contribution to geodetic products. Moreover, it was pointed out the up to now, the correlation of VLBI observations with the VGOS setup is a bottleneck since all observations are correlated at Haystack. Finally, it was concluded that the expansion of the VGOS network and the correlators might advance the VGOS development rapidly.

Alexander Kehm gave the presentation named "**Extension of the SLR tracking network and its potential for the realization of Terrestrial Reference Frames**" and discussed the extension of the existing ILRS tracking network and how this extension would affect geodetic products. Based on simulation studies performed at DGFI-TUM, it was shown that under realistic error assumptions, an SLR network extended by the eight already planned stations can significantly improve the TRF datum realization (up to 20 %) and the realization of Earth orientation parameter (EOP; up to 5 %). It was also pointed out that a purely geometric approach omitting systematic errors in a-priori models confirms the assumption that the network at the southern hemisphere needs to be extended. Finally, it was emphasized that this study only covered the geometric improvement of the station network and not the improvement of the station performance.

In the last presentation of this session, Gary Johnston presented in his talk "**The role of ground Surveys in GGOS and recent advances in ground survey techniques**" the current space geodetic network operated by Australia with numerous co-location sites across the continent. It was pointed out that VLBI and SLR reference points located at the intersection of the rotation axis are only measureable via an indirect measurement approach using terrestrial observations (total station) which results in a highly over-determined ground network. A special focus was put on the fact that there is a substantial need for an improved alignment of local ground surveys to the ITRS Product Centre (PC) since currently, equal ties measured at different epochs are not reported to the ITRS PC.

Pablo Yanyachi presented on his poster "**New Horizons for the Latin American SLR Network**" the current situation of the Latin American SLR network. It is envisaged that the four SLR stations coordinate their work and connect the SLT network to the SIRGAS reference frame (a densification of the ITRF2014 for Latin America and the Caribbean). Since this region of the world is affected frequently by intense seismic events, laser observations to common space targets might be used to monitor the baseline between displaced stations on the western coast and non-displaced station on the eastern coast (short-arc approach). In future, it is also planned to establish a center for SLR data processing in South America.

Carey Noll's poster was focused on "**NASA CDDIS: Important Changes to User Access**". In 2018, more than 235.000 unique hosts had accessed the CDDIS archive. Up to now, users access CDDIS via anonymous FTP. Due to restrictions made by U.S. Government agencies, the anonymous FTP login at CDDIS will no longer be possible in the future. New access protocols (https and ftp-ssl) will require users to update scripts used for accessing the CDDIS data base.

Main take-away messages from the first session block:

- The GGOS BPS is in charge to define **essential geodetic variables (EGVs)**
- **DOIs for geodetic data** would be beneficial for all (users and data providers)
- GGOS aims the **integration of gravimetry and geometry**
- **SLR is a tool to realize GGOS** since parameter interactions can be studied (multi-satellite multi- parameter solution)
- Further research towards a **multi-technique multi-parameter solution** is required
- Unification/extension of **SLR activities in South America** (4 SLR stations available)

Main take away messages from the second session block:

- SLR significantly contributes to **identify/calibrate/overcome** systematics in other geodetic space techniques
- **Space ties** should be used to strengthen the connection between the techniques
- Current trends within the ILRS: lower energy (SLR systems), higher repetition rates, shorter NP intervals for **100+ SLR-tracked satellites** in 2018
- **"Mixed mode" observations** of VGOS/legacy network → continuity of products is ensured
- TRF improvements up to 20% and EOP improvements up to 5% can be achieved by **improving the network** (8 additional/planned stations simulated)
- **Improved alignment** of local ground surveys to the ITRF is necessary
- In future, anonymous FTP access to CDDIS **no longer possible**!

Mathis Bloßfeld, Mike Pearlman, Richard Gross