ARTIFICIAL SATELLITES, Vol. 46, No. 4 – 2011
DOI: 10.2478/v10018-012-0004-z

INTERNATIONAL SLR SERVICE

Stanisław Schillak
Space Research Centre, Polish Academy of Sciences
Astrogeodynamic Observatory, Borowiec
e-mail: sch@cbk.poznan.pl

ABSTRACT

The paper presents the current state of the International Laser Ranging Service (ILRS): distribution of the SLR stations, data centers, analysis centers. The paper includes also the information about the last International Workshop on Laser Ranging in Bad Koetzting, 16-20 May, 2011. The problems of quality of the SLR data are presented. The list of parameters which can be used for estimation of the accuracy of the SLR data for each station is given. Results of determination of the station position stabilities over long term period (from 1994 up to 2008) for the selected few main stations are presented in the five years blocks. The results show slight deterioration of accuracy observed for the last several years and the reasons for this effect are indicated.

Keywords: satellite geodesy, satellite laser ranging, ILRS, orbital analysis

1. INTERNATIONAL LASER RANGING SERVICE

http://ilrs.gsfc.nasa.gov/

The International Laser Ranging Service (ILRS) (Pearlman et al., 2002) organizes and coordinates Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) to support programs in geodetic, geophysical, and lunar research activities and provides the International Earth Rotation and Reference Frame Service (IERS) with products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF), (ILRS Report, 2009).

"The role of ILRS is to:
- coordinate activities of the international network of SLR stations;
- develop the standards and specifications necessary for product consistency;
- develop the priorities and tracking strategies required to maximize network efficiency;
- collect, merge, analyze, archive and distribute satellite and lunar laser ranging data to satisfy user needs;
- provide quality control and engineering diagnostics to the global network;

• work with new satellite missions in the design and construct retroreflector targets to maximize data quality and quantity;
• work with scientific programs to optimize scientific data yield;
• encourage the application of new technologies to enhance the quality, quantity, and cost effectiveness of data products." (ILRS Report, 2009).

These tasks are realized by SLR stations, Data Centers and Analysis Centers:

SLR stations (Fig. 1): EUROLAS – 18 stations
West Pacific Laser Tracking Network (WPLTN) – 17 stations
NASA - 8 stations
Data Centers: NASA Crustal Dynamics Data Information Centre (CDDIS)
EUROLAS Data Center (EDC)
Analysis Centers: 8 SLR + 4 LLR
Associate Analysis Centers: 17
SLR satellites: 27

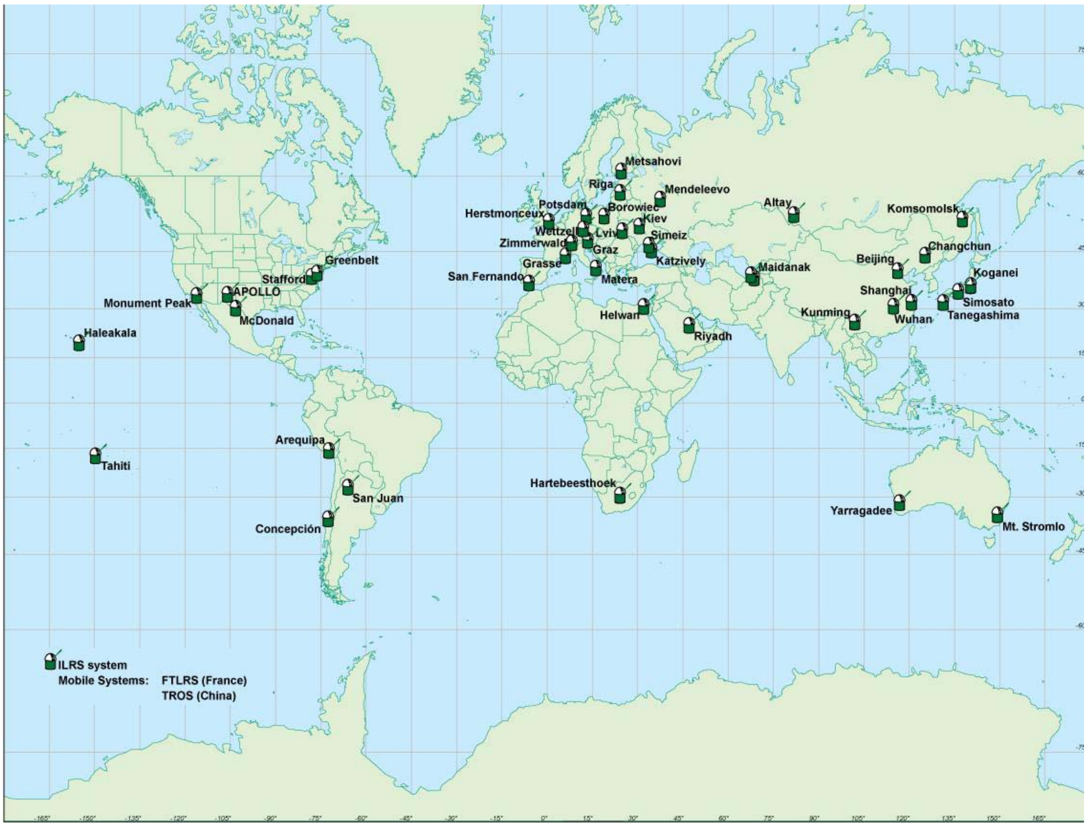

Fig. 1. SLR Network (ILRS)

2. 17TH INTERNATIONAL WORKSHOP ON LASER RANGING

The Bundesamt fuer Kartographie und Geodaesie (BKG) (Geodetic Observatory Wettzell and TIGO), the Research Group Satellite Geodesy of the Technische Universitaet Muenchen (TUM) and the International Laser Ranging Service (ILRS) organized the 17th International Workshop on Laser Ranging in Bad Kötzting, Germany in the week of May 16-20, 2011. The theme of the Workshop was "Extending the Range". Over 140 people participated in the workshop, whose programme included 88 oral and 50 poster presentations on scientific achievements, applications and future requirements, system hardware and software, operations, advanced systems, and analysis (Proceedings). Various ILRS-related meetings were held in relation to the workshop, including the 23rd General Assembly of the ILRS, the ILRS Governing Board, and various ILRS Working Groups. A trip to the Geodetic Observatory Wettzell was arranged and an introduction to the TWIN VLBI project was presented.

The Workshop Sessions:
Science Session
Operations: Spatial and Temporal Coverage
Atmospheric Refraction Correction: Hardware and Modelling
SLR Techniques
Modeling and Bias issues
Improving Ranging Accuracy, Calibration and Local Ties
Improving support for GNSS and Other Challenging Missions
Satellite Subsystems: Retroreflector Arrays
Interaction between Data-User and Stations
New Laser Ranging Technologies and Capabilities that must be Developed to Support Future Missions
Lunar Laser Ranging
In-Sky-Laser Safety
System Automation
Wettzell Observatory

The most important news:
10 kHz SLR system in Graz
New kHz two-color SLR system in Wettzell
Two new Korean SLR stations
kHz stations in China
Mount Stromlo SLR station automation
LARES – relativity satellite
Spin of AJISAI and BLITS
BLITS – zero signature satellite
Laser Ranging to NASA's Lunar Reconnaissance Orbiter (LRO)
European Laser Timing Experiment (ELT) to the International Space Station
Combined GNSS and SLR analysis
COMPASS navigation system

The next 18th International Workshop on Laser Ranging will be held in Tokyo in 2013.

3. QUALITY OF THE SLR DATA

One of the most important tasks of the satellite laser ranging (SLR) is estimation of the accuracy of SLR measurements. The analysis centers use several parameters to assess the accuracy, based on the differences between observed and computed values (O-C). The orbits are determined from all or the best SLR stations. The list of the parameters which can be used to estimate the accuracy of SLR measurements includes:

- Long term bias stability – variation in the one month range biases
- Short term bias stability – variation in the one satellite pass range biases
- RMS of fit per station
- NP residuals per one arc – graphic presentation
- Station position stability (3D) -> 1 mm

- N, E, U deviations of the station position - graphic presentation (GPS results also should be included)

From the list of these parameters the most reliable seems to be the station position stability in 3D form. The future work of SLR should be planned on the basis of careful consideration of the following problems: what is the current accuracy of data provided by SLR stations and how much it differs from 1 mm, what can be done to improve the accuracy of measurements at the best stations, what factors limit the observation accuracy and computation accuracy. The excellent work of ILRS Analysis Working Group (AWG) has provided responses to some of the above questions. Another important problem is the analysis of the long-term changes in SLR accuracy pattern, looking for answers to the following questions: has accuracy of the stations' data been really improving with time, what are the changes in the accuracy over long periods of time and what are the reasons for such changes.

The computations of the station positions were performed in Borowiec Observatory by NASA Goddard's GEODYN-II orbital program (Schillak, 2011). The positions were determined only for the stations which had been working continuously over the last 15 years and provided high quality of measurements. These stations are presented in table 1. The stations Potsdam and Orroral-Mount Stromlo had two and three different SLR systems in the time of study.

Table 1. SLR stations 1994-2008

STATION	Station No	First – Last Point	Number of points
McDonald	7080	94-01 – 08-12	179
Yarragadee	7090	94-01 – 08-12	178
Greenbelt	7105	94-01 – 08-12	170
Monument Peak	7110	94-01 – 08-12	175
Graz	7839	94-01 – 08-12	179
Herstmonceux	7840	94-01 – 08-12	179
Wettzell	8834	94-01 – 08-12	171
Potsdam	7836–7841	94-01 – 08-12	172
Orroral-Mt.Stromlo	7843-7849-7825	94-01 – 08-12	154

The final results of the computations contain station geocentric coordinates for the first day of each month transformed to the common epoch 2005.0, standard deviation of the coordinates determination, stability of each component and 3D coordinates stability for three five years periods: 1994-1998, 1999-2003, 2004-2008.

The station positions stabilities for the all nine stations are given in Fig. 2.

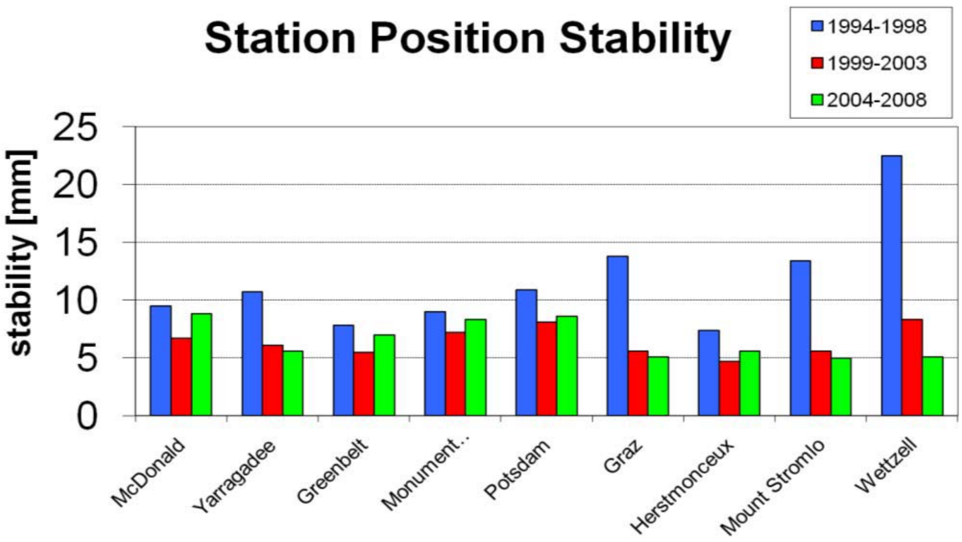

Fig. 2. Station position stability 1994-2008

At all stations a significant improvement in stability was achieved between the first (1994-1998) and the second (1999-2003) periods. When comparing the results of the second period (1999-2003) with those collected in the next period (2004-2008), better results have been only achieved at four stations with the most significant improvement observed for Wettzell, while the stability of five stations has deteriorated. The worse stability of McDonald station (Fig. 3 - deterioration in the positions determined in 2004-2008 is visible in all components), Greenbelt and Monument Peak is the effect of a significant decrease in the number of normal points in the period 2004-2008. The worse stability of Herstmonceux in the last period is a result of a jump in the vertical component in February 2007 (Fig. 4) caused by a replacement of the Time Interval Counter to the Event Timer. Potsdam station used a different SLR system since 2003. These results are also confirmed by SLR analysis centers (Evaluation and monitoring of ILRS AWG products).

The results presented in Fig. 2 show also a limit of the station positions' stability on the level of 5 mm, which no station can exceed since 1999 despite the fact that in the last ten years the precision of SLR measurements has been significantly improved and many systematic biases have been eliminated. It means that there is some unknown effect which blocked further improvement in the SLR accuracy. It is probably the atmospheric correction whose uncertainty in the opinion of many analysts is estimated on the level of 5 mm. If this is the case, without two-colour ranging the improvement in the quality of the SLR results will be rather impossible.

On the other hand a step by step improvement in the station position stabilities has been observed as a result of the introduction of the new models in orbital programs. The difference between the same data computed in 2000 and presented in this paper is 2 mm. This is the effect of better models of the Earth gravity field (most important), ocean tides, or terrestrial reference frame. An important problem remains which part of the uncertainty in the station positions comes from observation errors and which from computations.

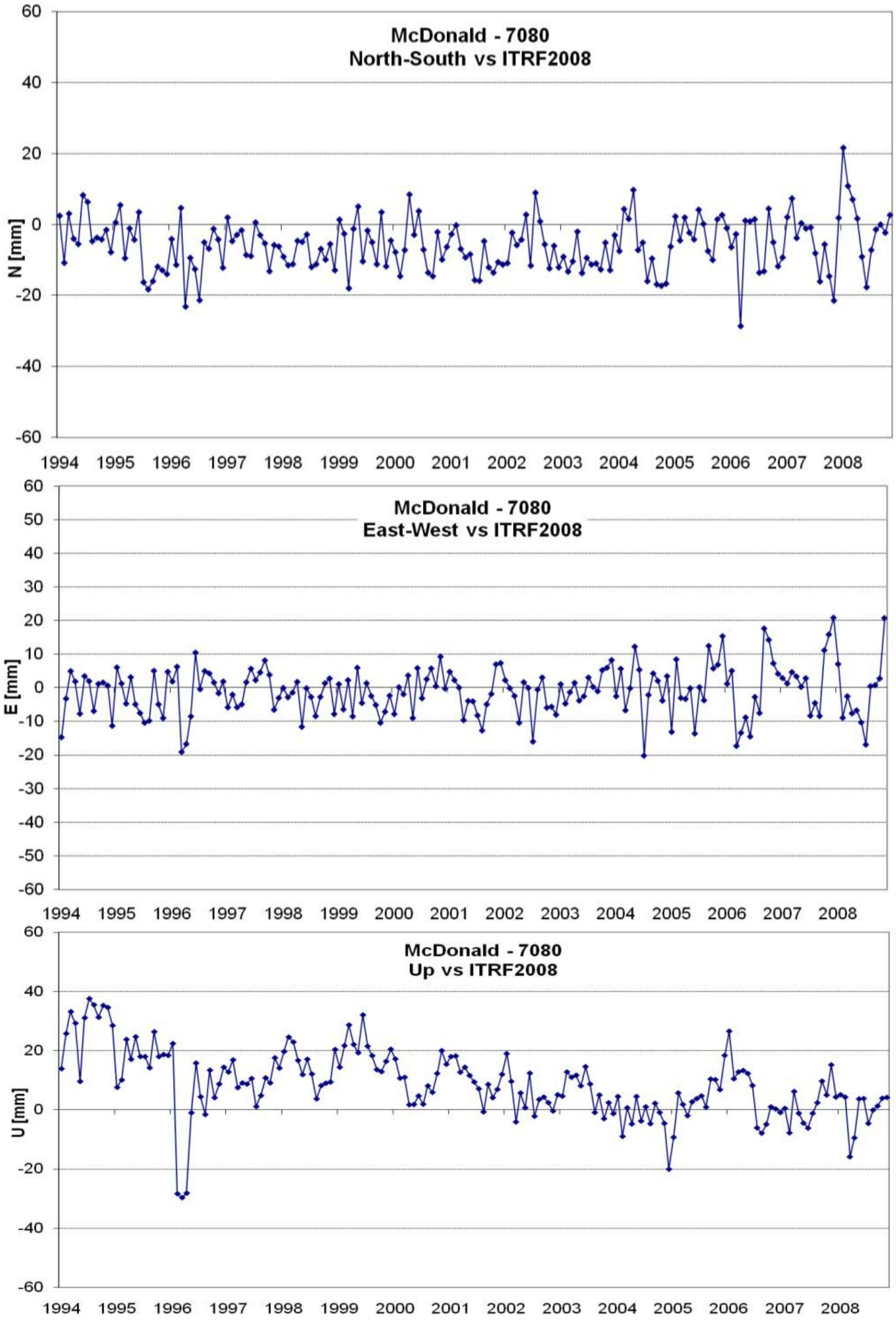

Fig. 3. Station McDonald – N, E, U components 1994-2008 in comparison to ITRF2008

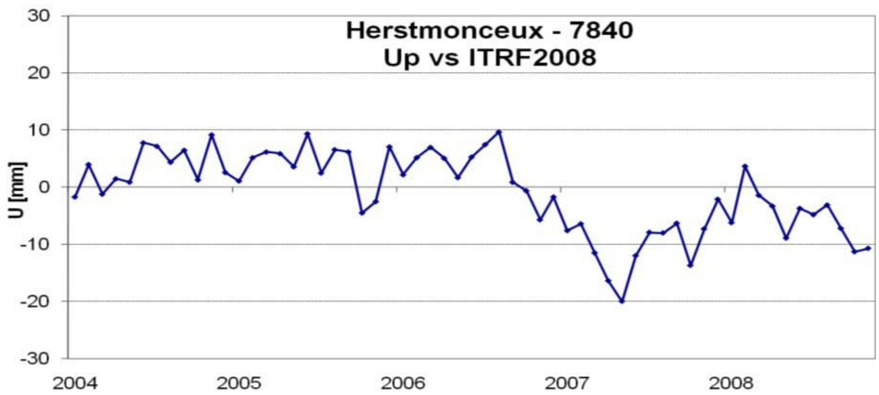

Fig. 4. Jump in vertical component (after February 2007), Herstmonceux station.

4. CONCLUSIONS

Analysis of the data provided by the best SLR stations over a period of 15 years shows the accuracy limit on the level of 5 mm, which can result from the atmospheric correction model. The new two-colour SLR system in Wettzell can verify this supposition. Very important for SLR accuracy improvement is the number of normal points per site. The SLR stations have to observe as many points of LAGEOS satellites as possible. Also detection of all significant jumps in results and their quick elimination by current control of the common SLR and GNSS results is very important. The problem of estimation of the errors sources in the observations and the computations has not been fully clarified yet. Deterioration in the SLR accuracy over the last years observed at several best stations is alarming. The control of data form the next five years 2009-2013 should answer if a further significant improvement in the SLR accuracy up to 1 mm will be possible in the next few years.

ACKNOWLEDGEMENT

The author wishes to thank the NASA GSFC for the consent to use GEODYN-II orbital program and ILRS stations for their continuous efforts to provide high-quality SLR data for this work. Special thanks are due to the Borowiec SLR team: Piotr Michałek and Stanisław Zapaśnik for their help in data analysis. This work has been supported by financial resources for science in 2010-2013 as a research project No. N N526 231839.

REFERENCES

Evaluation and monitoring of ILRS AWG products: http://geodesy.jcet.umbc.edu/ILRS_QCQA/

International Laser Ranging Service (ILRS): http://ilrs.gsfc.nasa.gov/

International Laser Ranging Service 2007-2008 Report, 2009, Ed. C.Noll, M.Pearlman, November 2009: http://ilrs.gsfc.nasa.gov/reports/ilrs_reports/ilrsreport_2007.html

Pearlman, M.R., Degnan, J.J., and Bosworth, J.M., 2002, The International Laser Ranging Service, *Advances in Space Research,* Vol. 30, No. 2, pp. 135-143, July 2002, DOI:10.1016/S0273-1177(02)00277-6.

Proceedings of the 17th International Workshop on Laser Ranging, 2011, Bad Koetzting, 16-20 May 2011: http://cddis.gsfc.nasa.gov/lw17/index.html

Schillak S., 2011, The estimation of the SLR data, *Proceedings of the 17th International Workshop on Laser Ranging,* Bad Koetzting, Germany, 16-20.05.2011, (in print).

Received: 2011-11-30,

Reviewed: 2012-12-08, by H. Mueller,

Accepted: 2012-02-23.