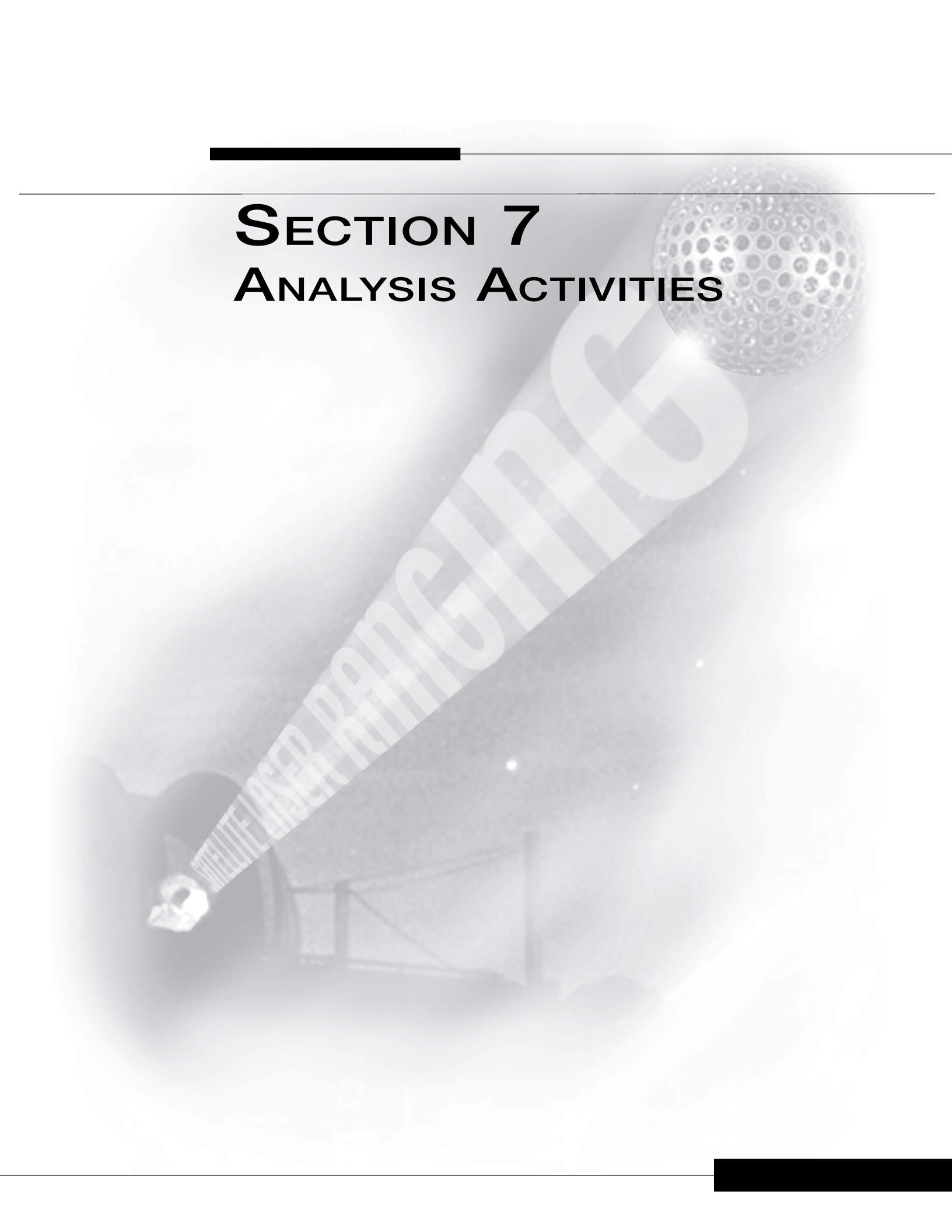
Section 7
Analysis Activities



SECTION 7

ANALYSIS ACTIVITIES

Erricos C. Pavlis/JCET, Vincenza Luceri/e-GEOS S.p.A., Centro di Geodesia Spaziale

Introduction

The ILRS is an official Technique Service in the International Earth Rotation and Reference Frame Service (IERS). To fully exploit the unique aspects of the SLR observations, the ILRS Analysis Working Group (AWG) addresses various issues of SLR products, such as quality control, the estimated parameter group, the satellite data to be used, and format definition/use, optimization, and (the development of) an official combination product on the basis of the individual AC contributions. Additional products being considered are evaluated through a number of so-called pilot projects, with several initiated during the past few years, some of them successfully completed and others still ongoing. This contribution to the ILRS 2007-2008 Report presents an update on the status and the results of these efforts. General information on AWG activities, membership and more detailed information on the pilot projects can be found on the relevant ILRS webpages (*http://ilrs.gsfc.nasa.gov/working_groups/awg/index.html*).

Activities in 2007 and 2008

An important instrument for contacts and discussions among SLR/LLR analysts proves to be the AWG workshops. During the period covered by this ILRS report, five such workshops were organized: the seventeenth AWG meeting was held on April 14, 2007, during the spring EGU meeting in Vienna, Austria, the eighteenth on July 10, 2007, during the IUGG meeting in Perugia, Italy, the nineteenth on September 24, during the Fall ILRS Workshop in Grasse, France, the twentieth meeting was held on April 12, 2008, during the spring EGU meeting in Vienna Austria, and the twenty-first meeting on October 12, 2008, during the 16th International Workshop on Laser Ranging in Poznan, Poland. AWG meetings are planned to take place on dates close to major geophysical meetings (EGU) or other (ILRS) venues, in order both to maximize AWG members' attendance and also encourage interaction with other scientists. In addition to these, the AWG participated with presentations and contributions to several position papers in the Unified Analysis Workshop of the Global Geodetic Observing System (GGOS), in December 2007, in Monterey, CA.

A main element of the AWG activities is the development of a unique, best-possible (in terms of quality) analysis product that can be used by the widest possible science community, e.g., station positions and EOP. An official solution for station coordinates and daily EOPs is generated by the Analysis Centers (AC) and Combination Centers (CC) on a weekly basis, and submitted to the IERS as an official ILRS contribution. These weekly results depend on high-quality laser range observations to LAGEOS-1, LAGEOS-2 and to the two Etalon satellites, and the ILRS network is encouraged to support this valuable work, ideally by tracking these satellites day and night, seven days a week. Two different products are distributed each week: a loose constrained estimation of coordinates and EOP and an EOP solution, derived from the previous product, fully constrained to an ITRF. The development of these products goes back to the very first days of the ILRS AWG. The currently operational products and the adopted analysis scheme were agreed upon by the AWG and have run continuously in an operational mode since 2003.

At this moment, eight different ACs support this activity and routinely provide this product: ASI, BKG, DGFI, GA, GFZ, GRGS, JCET, and NSGF. ILRS has also adopted two official CCs, the primary hosted by ASI and the backup at DGFI. These two CCs are responsible for combining the input solutions, and the delivery of the quality-checked and combined ILRS product to the IERS. In preparing the weekly combination of the individual solutions, these

combination centers follow a strict timeline and have to make sure that the products are of the highest possible quality. Official weekly ILRS products from the two combination centers are available in SINEX format each Wednesday at the CDDIS and EDC. All ACs are encouraged to improve the quality of their contributions further. It is noteworthy that a number of other institutes (ESA/ESOC, MCC, and NCL) are also in the process of being certified as official ACs in order to eventually contribute to the combination solutions.

During the period covered by this ILRS report, the procedures and analysis models have been scrutinized and documented thoroughly (in order to avoid artificial differences and inconsistencies between results). A major effort of the AWG was to determine a very complete and accurate set of station biases and corrections based on the reports of the stations and the analysis of long-term solutions that decorrelate the biases from the station height estimates. This effort led to a rather complete set of biases and corrections that were adopted and used by all ACs and will be published on the ILRS web pages for use by all SLR data users in the future, in order to ensure the best and most consistent results for any application. For ease of use, the compilation is put in a SINEX-like format that is machine-readable and allows the automatic use of the information in any analysis environment.

The AWG has also faced one problem of the latest reference frame ITRF2005. The input ILRS time series for ITRF2005 only covered the years from 1993 to 2005 and its shortness had two main effects in ITRF2005: the lack of the older SLR stations and poor estimates for those stations which stopped observing in the early 1990's. To overcome the problem, a new TRF was generated: SLRF2005. The terrestrial reference frame was obtained by combining ITRF2000, ITRF2005 rescaled, and a global SLR solution with data from 1993 to 2007 to add the new sites. SLRF2005 is a temporary reference frame until a new complete frame will be available. Currently, SLRF2005 is the ILRS reference frame.

The results of the combination process are used as input for a number of products computed by others, e.g., the International Terrestrial Reference Frame (ITRF) 2008 solution, developed under the coordination of the IERS, and the IERS Combination Pilot Project (CPP) towards a unified GGOS product. As a result of the weekly combination process, the ILRS also maintains a time series of the similarity transformation parameters of the weekly product with respect to the current ITRF – SLRF2005 during this reporting period. For SLR, the weekly geometric offsets of the origin from the conventionally defined ITRF origin provide a measure of the motion of the geocenter due to mass redistribution in the Earth system. Similarly, the time series of the scale differences with respect to the current ITRF provide a measure of the stability of the SLR-defined TRF.

To improve the usefulness of the time series of combination solutions and the ancillary products, and thus improve its prospects for future utilization (reliability of resulting velocities, results on historical SLR stations, etc.), the ILRS AWG decided to extend the period covered by these solutions. In a first step, this was done by a full re-analysis of the LAGEOS-1 and -2 and Etalon data (where available) for the interval 1993–2008, with the same procedures and conventions as those applied in the operational product. Following that, the contributing ACs worked on a re-analysis of the LAGEOS data over the historical period 1983-1993; since the observations from this time frame are of an inferior quality and a single satellite (prior to the launch of LAGEOS-2), these analyses require a modified parameterization approach (e.g., biweekly arcs, consideration of additional bias adjustment, three-day EOP, etc.). Initial (preliminary) results were submitted to IERS for ITRF2008, in late 2008, which upon their preliminary analysis will serve as the basis for the final submission (later in 2009), taking into account the feedback from the ITRS. Figure 7-1 shows the three -month running average of the origin and scale components for the "historical" data period (1984-1992). This period is based on LAGEOS data alone and ground systems with much less accurate data than the present network, which are the reasons behind the large and often systematic behavior during this period.

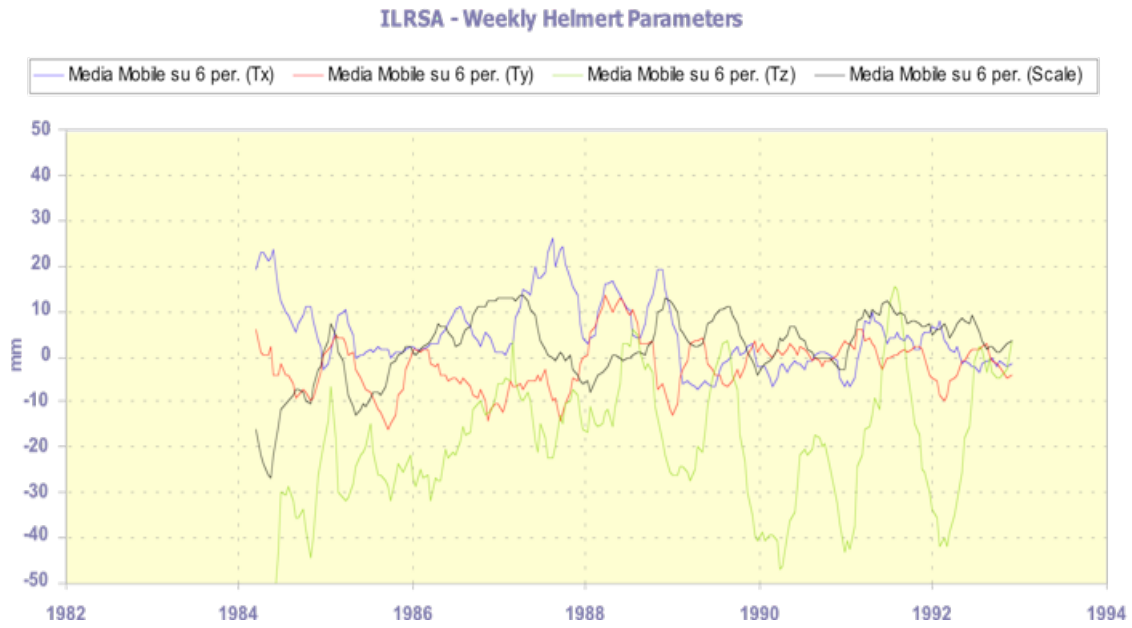


Figure 7-1. Time-series of X, Y, and Z offsets and scale factor averages (3-month boxcar smoothing) of the ILRS-A official combination origin with respect to the reference TRF (SLRF2005) origin (proxy for "geocenter" variations) and scale as observed by SLR (1984.0 – 1993.0).

The corresponding components for the period 1993 to 2009 are shown in Figure 7-2. It is evident that the contribution of data from LAGEOS-2 during this period, and the Etalon-1 and -2 after 2002, are helping to considerably stabilize the series and the improved data quality results in the trend-free series, demonstrating only seasonal signals of geophysical origin. The IERS/ITRS uses the SLR solutions to exclusively determine the origin of the new ITRF2008 solution. Unlike the previous ITRF2005 solution, the scale for the 2008 realization will be determined through some combination of the SLR and VLBI contributions, similar to the way that was traditionally done in the past.

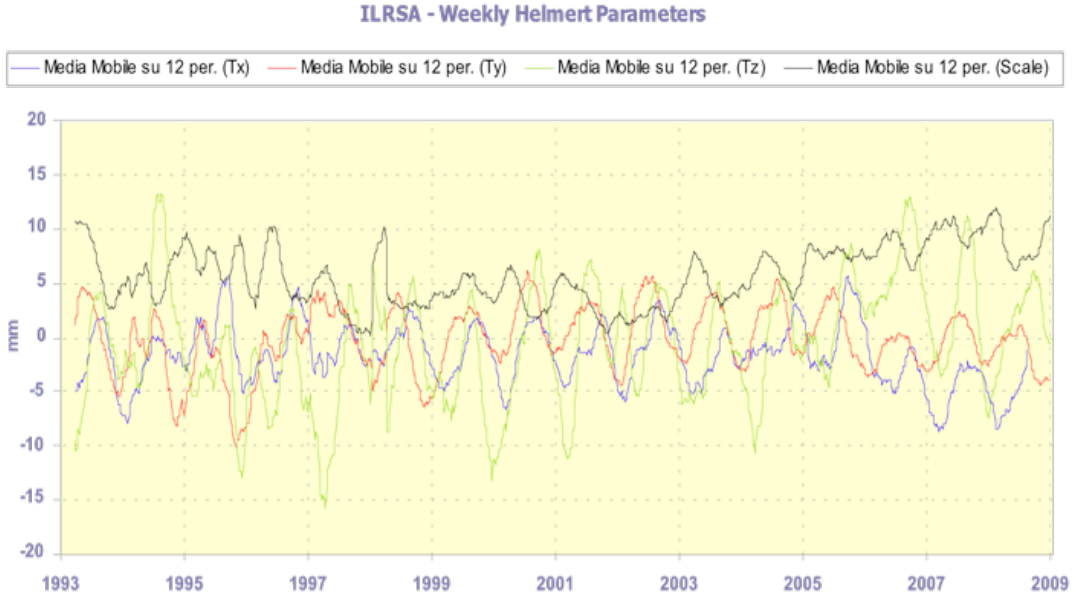


Figure 7-2. Time-series of X, Y, and Z offsets and scale factor averages (as in Figure 7-1) as observed by SLR (1993.0 – 2008.0).

The AWG is currently expanding its list of weekly products to fill a void in the area of routinely available precise orbits for the primary SLR targets, i.e., the two LAGEOS and two Etalon satellites. At present this is only a pilot project; however, it is expected that by 2009 these products will be delivered routinely on a weekly basis. In order to fulfill the need of NEOS for as "fresh" as possible EOP information, the ILRS AWG decided in late 2007 to develop a new "daily" product, based on a seven-day arc sliding by one day each day. The results of this analysis are available to NEOS within two days from the last observation in the analysis, and efforts are underway to further decrease the latency period. During 2007, three ACs (ASI, JCET, and NSGF) contributed to the pilot project for this daily product, by the end of 2008 two more ACs (BKG and GFZ) joined the group and it is expected that in the future more ACs will contribute. NEOS will evaluate the new product and the ILRS will decide whether to evolve this pilot project into an official product (replacing the weekly one), or to discontinue it.

Another ongoing activity of the AWG is the improvement of the quality control (QC) process in various semi real-time analysis results with a unique analysis report, which is made available to all customers (stations, satellite managers, ILRS). This effort reduced inconsistencies among the various previous reports. The results of the QC process are combined in a single report, which is available weekly at: *http://aiuas3.unibe.ch/ftp/slr/summary_report.txt*. A major improvement in the consistency of these results was the adoption the single set of high quality station coordinates given by SLRF2005. This TRF was used as the a priori one for the re-analysis that generated the ILRS contribution to ITRF2008.