The ILRS Standard Products: A Quality Assessment

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Abstract

In June 2004 the Space Geodesy Center (CGS, Matera, Italy) of the Agenzia Spaziale Italiana (ASI) has been selected by the International Laser Ranging Service (ILRS) as its Primary Official Combination Center for station coordinates and Earth Orientation Parameters.

From the beginning, the CGS has been providing the weekly operational combined ILRS solutions (SSC/EOP), also supporting the IERS B Bulletin production; moreover, CGS has produced the official ILRS contribution to ITRF2005, by combining the weekly solutions, from 1993 to 2005, submitted by the contributing ILRS Analysis Centers.

The CGS combination methodology relies on the direct combination of loosely constrained solutions. This methodology has been implemented and tested to handle site coordinates, site velocities, EOP, LOD coming from the same and/or different techniques.

The whole set of weekly combined solutions, those produced in support of ITRF2005 as well as the operational ones, is analyzed in detail in this contribution, to show the coherence and robustness in terms of global parameters as well as station coordinates.

Introduction

Soon after the establishment of the ILRS a strong need was felt to coordinate the work and combine the results of the various SLR data Analysis Centers (AC's) in order to define and distribute a series of "certified" ILRS products to the users community.

In 1999 the ILRS Analysis Working Group, chaired by Ron Noomen (TU Delft), outlined two Pilot Projects for the estimation of site coordinates and EOP, separately, from different AC solutions; the year after the two Pilot Projects were joined and the first results discussed. In 2003 the ILRS issued a formal Call for Participation for the generation of ILRS products,

In 2004 the ILRS AC structure was finalized and official delivery of standard products started; the CGS was selected as the Primary Official Combination Center, referred to as ILRSA, while DGFI was selected as Backup Official Combination Center or ILRSB.

In 2005 the ILRS contributed to the definition of ITRF2005 with its official time series.

The ILRS Standard Products

Presently, the following six AC's regularly contribute to the production of the ILRS standard products by means of weekly solutions:

ASI, Agenzia Spaziale Italiana, I

BKG, Bundesamt fuer Kartographie und Geodaesie, D
DGFI, Deutsches Geodatisches Forschungsinstitut, D
GFZ, GeoForschungsZentrum Potsdam, D
JCET, Joint Center for Earth System Technology, USA
NSGF, NERC Space Geodesy Facility, UK

Those ACs have been recognized after passing the benchmark tests as requested by the AWG. Other institutes are now under test and on the way to become official ILRS Analysis Centers.

The standard weekly ILRS combined solutions (either the primary and the backup) are made available each Wednesday at CDDIS and EDC, together with the single contributing AC solutions. The complete time series, starting from 1993, is available at CDDIS and EDC. A backwards extension of the time series, back to 1980, in now under construction.

A complete description of standards and methods adopted in the combination is given in [Bianco et al, 2003].

The ILRS coordinate solution in the ITRF 2000 and ITRF 2005

The first quality assessment has been done comparing the ILRS coordinate solution with the ITRF2000 as well as with the newly issued ITRF2005.
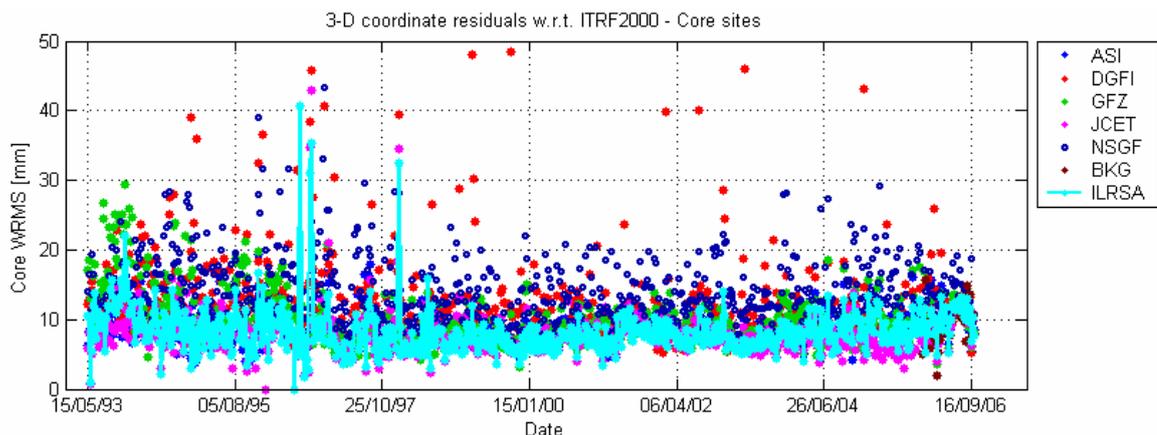

Fig 1 Time series of weekly 3-D coordinate residuals w.r.t. ITRF2000 for ILRS core sites from individual AC solutions as well as from the combined ILRSA solution.

Generally speaking, the plot in Fig. 1 shows that the combined solutions represents a real improvement, in terms of consistency and dispersion, with respect to the individual AC solutions. The average 3-D residuals with respect to ITRF2000 are consistently at or below the 1 cm level, as confirmed by the plot in Fig. 2, which shows the 3-D coordinate residuals WRMS as a function of time.

It shows very clearly the fundamental role of the so called "core" sites (i.e., SLR stations with a consolidated tracking history in terms of data quantity and quality). The behavior of the total network worsens after year 2000 due to the introduction of several new observing sites which are not properly modeled in ITRF2000.

As expected, the situation improves with the ITRF2005, as shown if the plots in Figures 3 and 4 below. In particular, the new stations appear properly accounted for; moreover, the 3-D coordinate residuals for the "core" stations behave remarkably well, with an average value constantly below the 1 cm level.
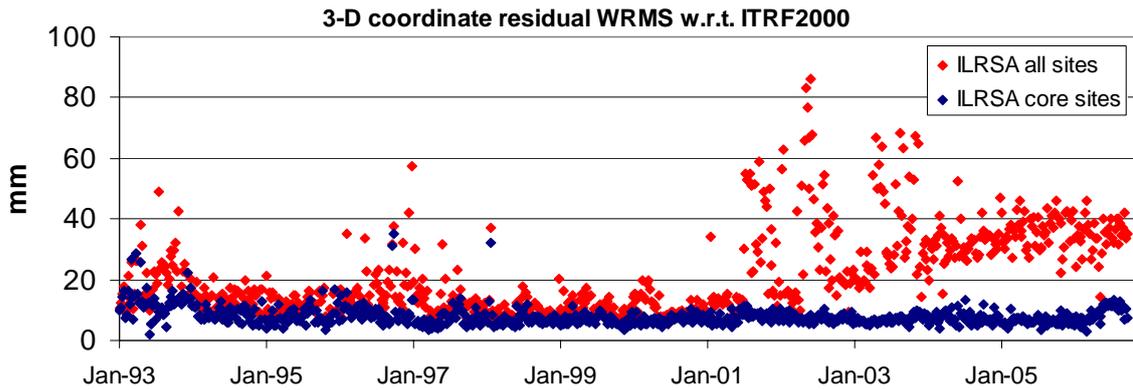
Fig. 2 *Time series of weekly 3-D coordinate residuals WRMS with respect to ITRF2000*
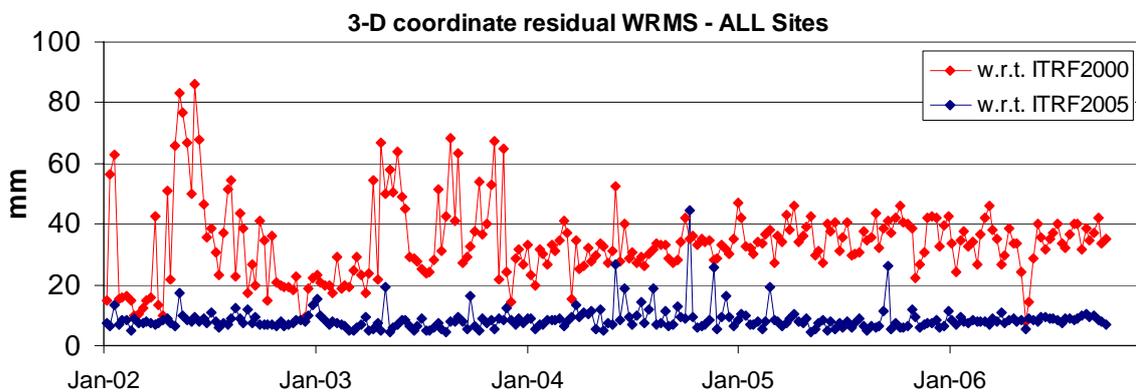

Fig. 3 *Time series of 3-D coordinate residual WRMS for all ILRS sites with respect to ITRF2000 and ITRF2005, as computed in the ILRSA combined solution*
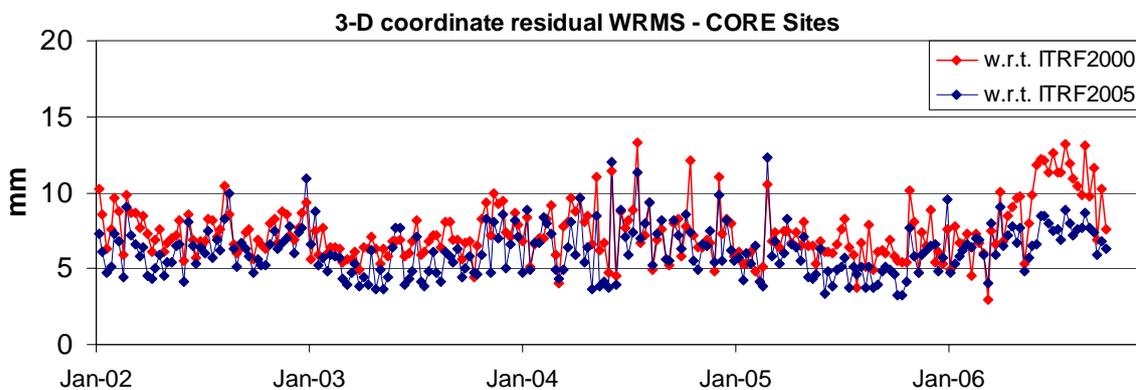

Fig. 4 *Time series of 3-D coordinate residual WRMS for ILRS "core" sites with respect to ITRF2000 and ITRF2005, as computed in the ILRSA combined solution*

ILRS TRF origin with respect ITRF 2000/2005 origins

Another quality assessment has been done by looking at the time series of the 3-D distances of the ILRS Terrestrial Reference Frame origin with respect to another ITRF origin. Each TRF realized by the SLR stations in a loose solution places naturally its origin in the center of mass of the Earth: its Cartesian coordinate offsets from a conventional origin describe the geocenter location. This time series, often referred to as "geocenter motion", is particularly interesting since it can be proposed as a new standard ILRS product.

The plots in Fig. 5 represent respectively the X, Y and Z components of the distance between the ILRS weekly origin with respect to the ITRF2000 and ITRF2005 origins, computed by roto-translations ("geometric" method) in the period 2002-2006. A clear annual signature is visible in all three components. The two series look pretty similar, with a slightly more evident drift in the Z component with respect to the ITRF2005 origin.
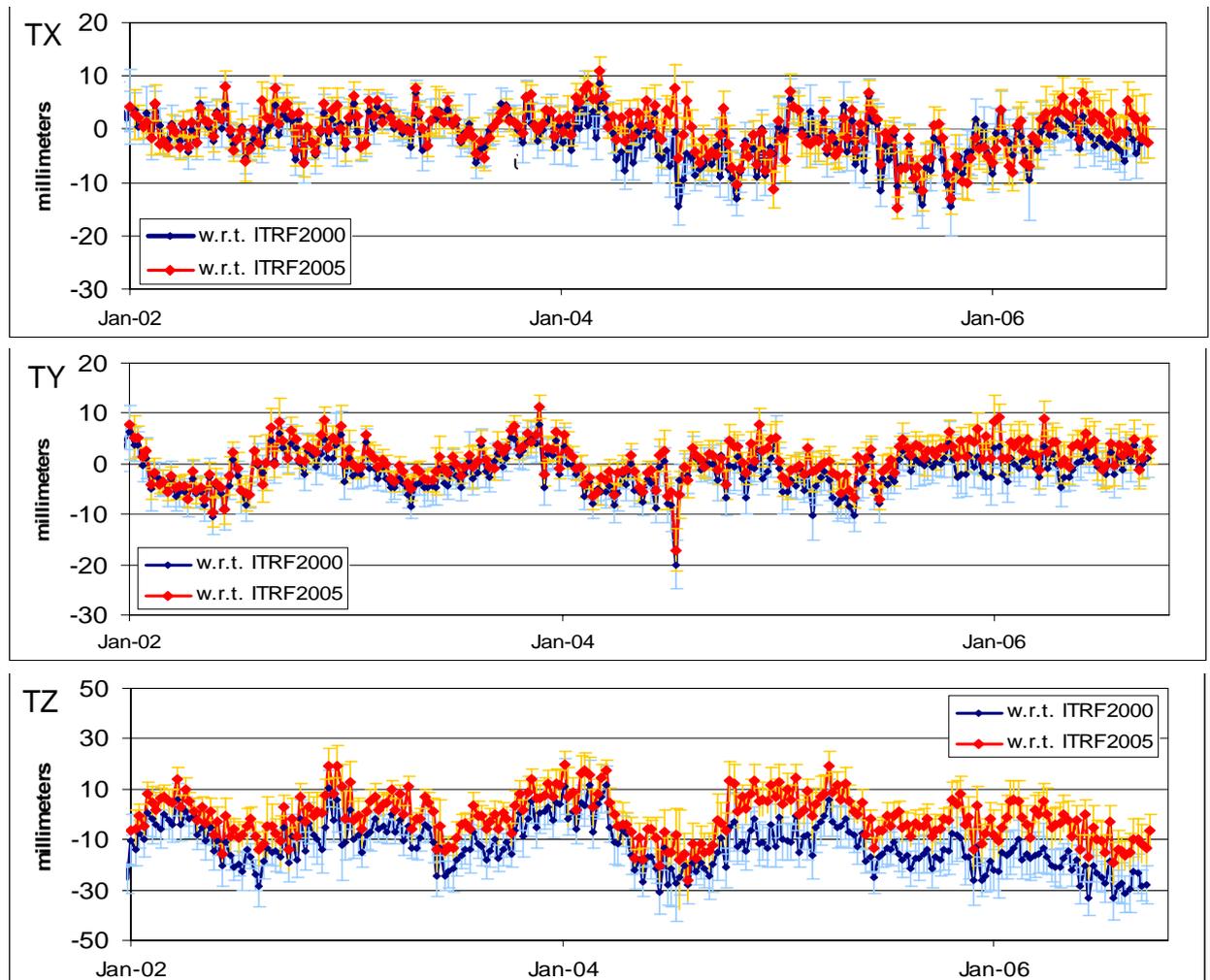

Fig. 5 *Time series of distance between the ILRSA geometric origin and the ITRF2000 and 2005 origins*

The translations of the ILRS TRF origin can also be obtained with a more rigorous data analysis strategy: through the estimates of the C_{10}, C_{11}, S_{11} geopotential coefficients, ("dynamic" method).

The plots in Fig. 6 show a direct comparison between the geometric and the dynamic ILRS TRF origin translations, with the latter obtained via the dynamic solution done by ASI. The behavior of the two time series is remarkably similar; the dynamic origin evolution looks smoother but the main features are present in both series.

This confirms that the geometric offsets, as defined by the standard ILRS combined solution, could be used to properly represent the geocenter motion.
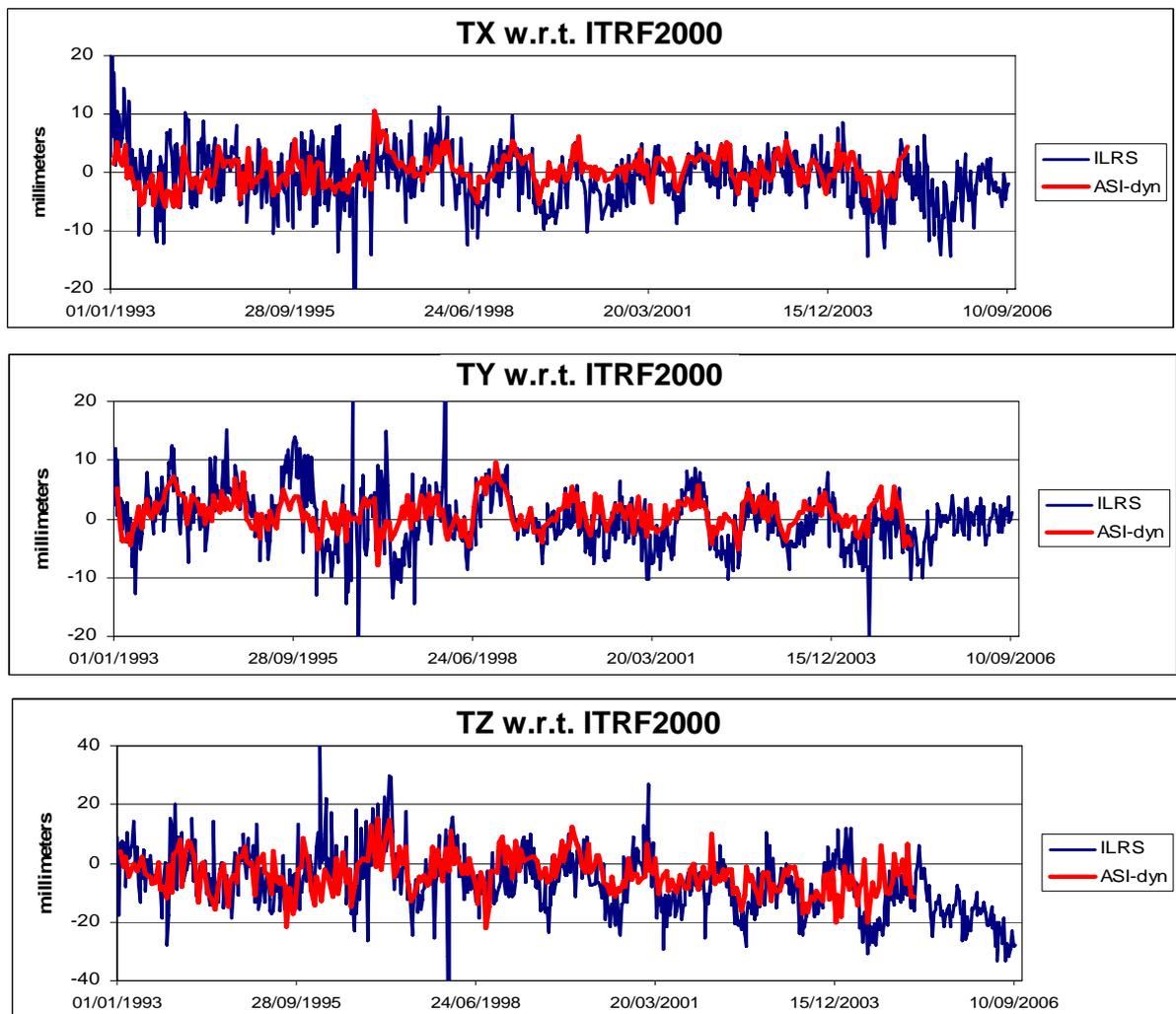
Fig. 6 *ILRSA geometric vs ASI dynamic geocenter motion.*

The scale factor

Much debate has been generated soon after the publication of the ITRF2005, whose scale has been defined without taking into account the ILRS contribution, due to an apparent strange behavior of the ILRS scale itself.

However, based on our work, we do not find evidence of any strange effect in the ILRS scale, as shown in the plots hereafter, covering the period January 2002 to mid 2006.

The ILRS scale with respect to the ITRF2000 is nicely flat, while a clear trend shows up in the scale time series with respect to the ITRF2005.

The selection of the core sites to be used when comparing different reference frames is crucial and can introduce artifacts.

Earth Orientation Parameters

In Fig. 8, ILRS X-pole, Y-pole and Length of Day (LOD) residuals with respect to the USNO "finals.daily" EOP time series, are plotted. The ILRS EOP products look pretty good and stable, with a WRMS of the residuals of the order of 0.25 milliarcseconds.

We've also made an external comparison between ILRS EOP's and those computed by other space geodetic services, namely IVS and IGS (CODE solution). The results for the Y component are shown in Fig. 9 below.
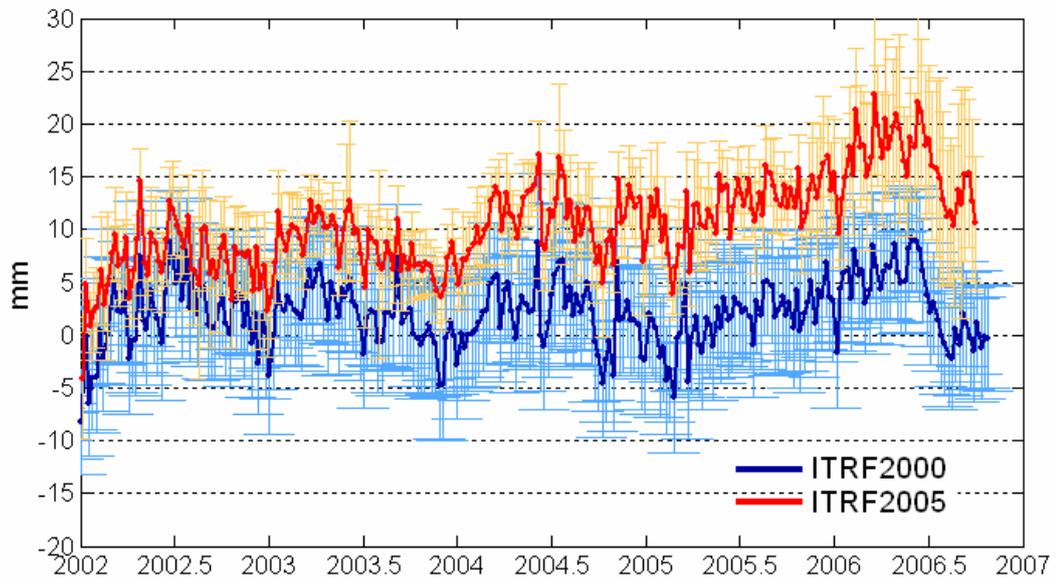

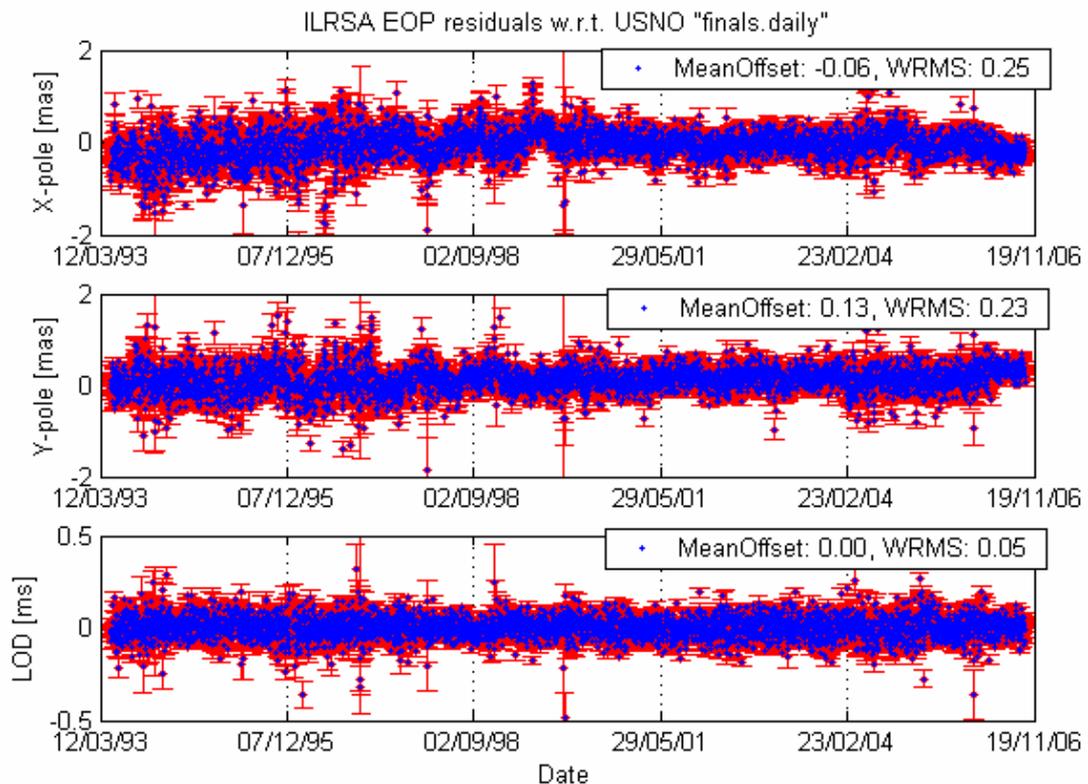**Fig. 7** *ILRSA scale with respect to ITRF2000 and ITRF2005*

Fig. 8 *ILRSA EOP residuals with respect to USNO "finals.daily" EOP's*

EOP Y DIFFERENCES w.r.t. C04

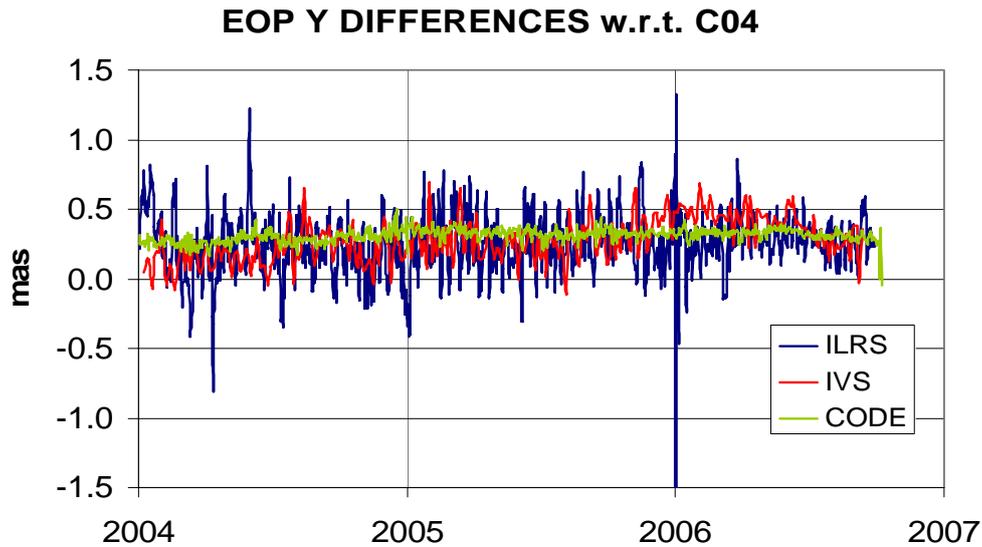***Fig. 9*** *ILRSA EOP differences with respect to IERS EOPC04*

Conclusions

After two years of continuous operations, the routine ILRSA combination production process is stable and reliable. The processing chain has been made almost completely automatic and has already demonstrated a high degree of dependability.

Other than for the definition of origin and scale, almost unique to SLR, the ILRS standard products are a very valuable monitoring tool for site coordinates and EOPs, with a very fast response time.

This work has also shown that the geocenter motion, geometrically derived from the weekly solutions, is reliable enough to be included among the future ILRS standard products.

References

[1] Bianco, G., Devoti, R., Luceri, V., 2003, Combination of loosely constrained solutions, Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids (Munich, 18-21 Nov 2002), IERS Technical Note 30, 107-109, 2003