ILRS contribution to the geophysical investigation: the December 26, 2004, earthquake effects on the terrestrial reference frame as determined by SLR observations

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The International Laser Ranging Service (ILRS) contributes to the maintenance of the terrestrial reference frame by providing weekly combined SLR global solutions, containing SLR station positions and daily Earth Orientation Parameters (EOPs; x- and y-pole and excess Length-Of-Day (LOD)). This official ILRS combination product is produced by ASI-CGS (Matera, Italy) by combining individual, high-quality SLR solutions for the aforementioned parameters, using SLR observations on the LAGEOS-1, -2 and Etalon-1 and –2 satellites. These solutions are provided by several ILRS Analysis Centres (ASI, DGFI, GFZ, JCET, NSGF) and are made available to the International Earth rotation and Reference frame Service (IERS) and other users with a four day latency.

All ILRS combined solutions are available through ftp-as SINEX files at

- cddis.gsfc.nasa.gov/pub/slr/products/eop (EOP, ITRF2000-framed)
- cddis.gsfc.nasa.gov/pub/slr/products/pos+eop (EOP and site positions "quasi-observations")

The accuracy of the ILRS combined solution is better than 0.3 mas for x- and y-pole, which allows for the detection of geophysical signals in the EOP time series of unpredictable events characterised by extremely big releases of energy, such as the most recent disruptive Sumatra earthquake.

It is known (e.g. "The Earth's Variable Rotation", K. Lambeck, Cambridge University Press, 1980) that large earthquakes cause variations of the Earth shape, a shift of the rotation axis and a modification of LOD. It is expected that scientific investigations will better quantify the effect of this latest earthquake (see the already available calculations from B. Chao (NASA/GSFC) and R. Gross (NASA/JPL) at

http://science.nasa.gov/headlines/y2005/10jan_earthquake.htm?list44106).

The ILRS community has used its official combined global solution to measure the effect of the earthquake on the pole coordinates.

The daily x- and y-pole determinations have been analysed for the period November 28, 2004 – January 1, 2005, covered by five published weekly ILRS combined solutions (labelled at the ILRS ftp-site as 041204, 041211, 041218, 041225, and 050101).

To detect an anomalous behaviour, a first comparison is made with respect to the IERS EOP values. To avoid meaningless comparisons, the reference EOP values must not contain the effects of the earthquake, but instead provide estimated values as close as possible to December 26, with predicted values from December 26 onwards. With this objective, the EOP "rapid" values from the USNO "finals.daily" file, providing estimated values up to December 24 included, have been used as the reference. In this case, the predictions for December 26 should be in close agreement with the real values, provided no abrupt event has happened. In general, predictions loose their significance as time goes by, but, for the period under consideration, the predominant behaviour of y-pole in the period is more linear than that of x-pole, leading to more reliable predictions for y-pole.

Figure 1 below shows the differences between ILRS estimated values and USNO "finals.daily" as described above; a jump in the y pole coordinate on December 26, 2004, of about 2 mas is clearly evident, while the behaviour of x-pole becomes rather erratic.

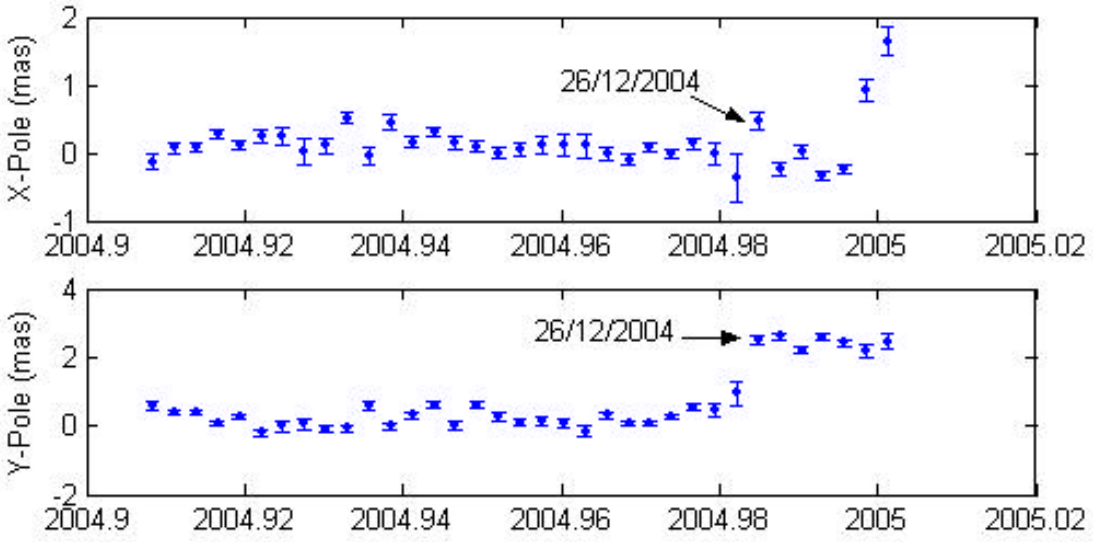

Figure 1 – Residuals of ILRS combined solution w.r.t. finals.daily (041224)

The predominantly linear behaviour for the y-pole coordinate in the period under consideration provides another way to make the "y" jump evident, avoiding the need to refer to a-priori EOP values. A weighted low-degree polynomial fit of the estimated y values up to December 25, allows us to draw a line to predict values which are probably more realistic than the "finals.daily" predictions for the next few days (**Figure 2**). Under 'normal' conditions, the solutions after December 25 should depart from the almost straight-line prediction approximately as much as the ones for earlier dates. Instead the discrepancy, about 1.5 mas, is again clearly much higher.

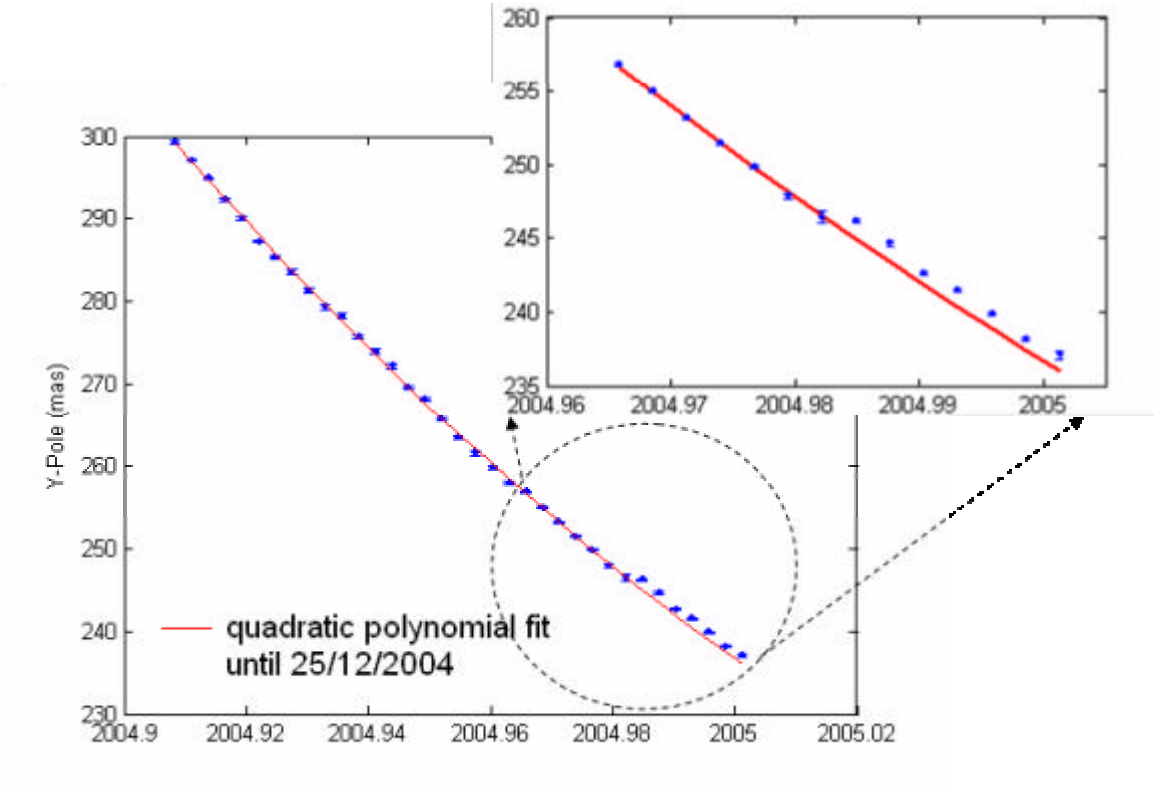

Figure 2 – Low degree polynomial fit of ILRS combined solution

The jump is even clearer when looking at the fit residuals of the y values. Fitting two straight lines to the residuals for the weeks immediately before and after December 26 (**Figure 3**) provides a quick, but statistically meaningful, estimate of the jump: 1.5 mas.

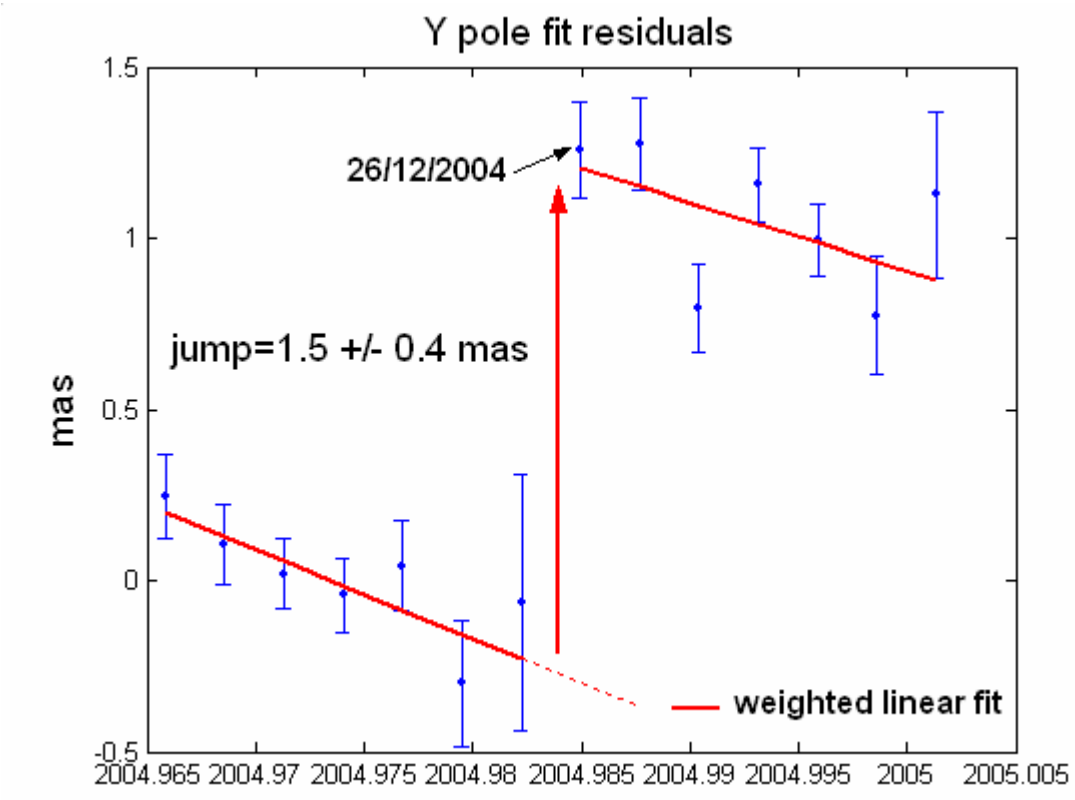

Figure 3 – Fit of residuals

A similar behaviour is also observed by other space-geodetic techniques, such as the rapid EOP solution provided by CODE (U. Hugentobler) based on GPS observations, as shown by the plot in http://www.aiub.unibe.ch/code/dec26_pole_xy.gif.
Although it is good to see such an agreement, it must be stressed, however, that the complete numerical characterization of the earthquake impacts on the terrestrial reference frame will deserve a rigorous mathematical treatment and a deep geophysical interpretation.