THE MLRO 2007 RANGE BIAS PROBLEM
ANALYSIS AND SOLUTION

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Introduction

Starting from the second half of February, 2007, SLR solutions from the ILRS analysis centers have been showing an anomalous behaviour in the MLRO data, as clearly illustrated in the graph below which shows MLRO Up, East and North residuals with respect to the ITRF as computed in the ILRSA combined solution.

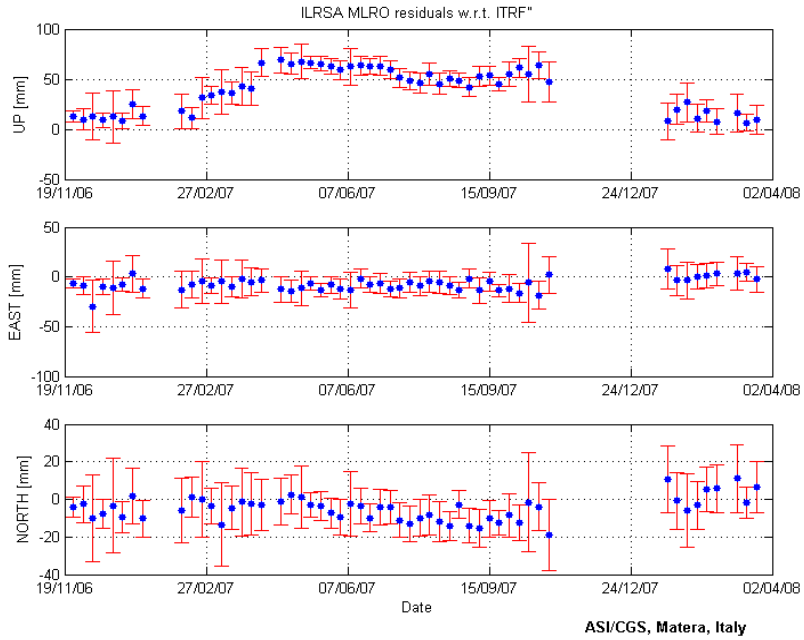

Fig. 1: ILRSA MLRO residuals w.r.t. ITRF

The very significant misbehaviour in the "Up" component was clearly caused by a non zero range bias, non properly modelled in the system calibration. The graph below shows the MLRO range biases derived from Lageos-1 and Lageos-2 (thanks to T. Otsubo, Hitotsubashi University, hereafter Hit-U) as a red curve, while the blue dots represent the single system delay values plotted with an arbitrary zero point.

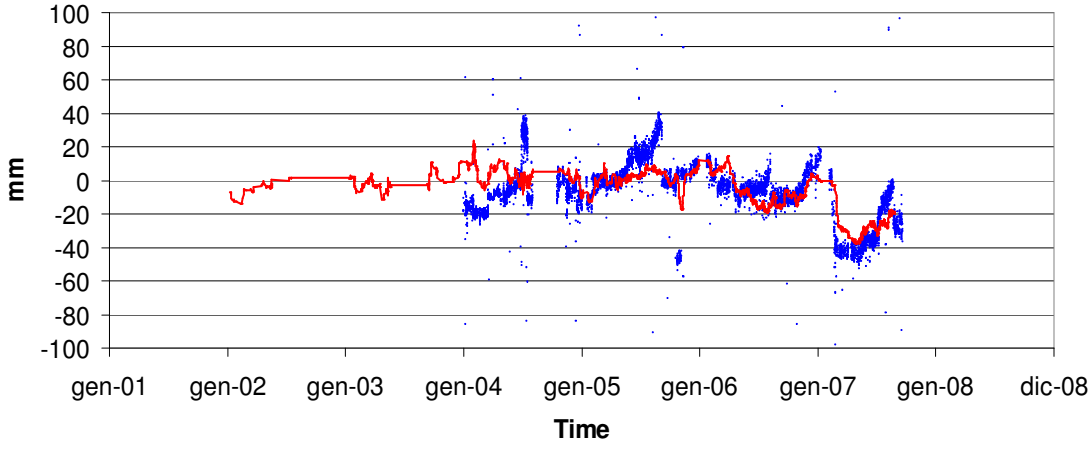

Fig. 2: L1/L2 MLRO range bias vs. system delay

Calibration scheme screening

It is clear that, for some reason, at a certain point in time the system calibration routine became unable to properly compensate the system delay variations, which are clearly mapped into the solved-for bias values. At a first glance, nothing was changed in the MLRO calibration scheme, so this prompted us to thoroughly review the whole procedure.

The first finding has been a strong dependence of the System Delay from the received pulse energy.

The problem was finally traced in a wrong value of a few parameters, which had changed after the MCP/PMT replacement but had not been correctly written into the configuration files. Those parameters are the PMT Gate Start Bias and, consequently, the CFD Gate Start Bias. The correct figures have been finally computed for the three operational MLRO configurations, i.e. Ground Target, Internal calibration and Satellite Ranging, and written into the relevant configuration files.

Once the parameters have been adjusted to the proper values, the MLRO range bias has returned to a zero value, as illustrated in the following graph in which MLRO Lageos' range bias computed by T. Otsubo (Hit-U) are plotted as a function of time.

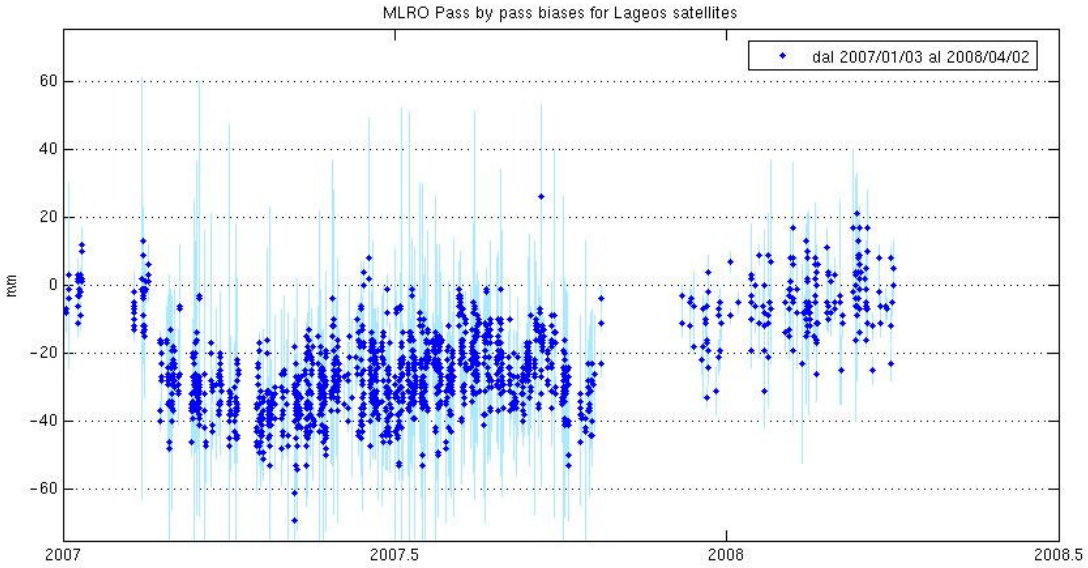

Fig. 3: L1/L2 MLRO range bias (HIT-U estimates)

Correction of 2007 data

All MLRO observational data taken in the period between February 16th, 2007 and October 22nd, 2007 are affected by a negative range bias which we have quantified by crossing the time series of system delay measurements with all significant system change events. It's important to note that this process has been kept independent from SLR solutions.

Fig. 4 shows the system delay starting from January 2007.
As stated before, the fictious jumps in the system delay, causing the bias, are due to erroneous values in the gating configuration, all the others are real system delay jumps and should not be considered.
A mean value of the system delay has been computed whenever a change in the Gate Start parameters was introduced (see previous paragraph). During 2007 MLRO was continuously under test trying to figure out the problem of the bias and those system changes were correctly reflected in the system delay. The hard job is to distinguish between real and false variations. Sometimes real jumps occurred soon after false jumps; in these cases the mean system delay values can be computed only using a few values.

The colours in Fig. 4 highlight the different intervals between changes in the gating parameters. The system delay variations in the red period, after the first jump on February 22nd , are real (see also Fig. 5) system delay variations.
The trend in the light green period has an engineering explanation: the run-down battery. For this reason, the value for the period has been computed soon after the start diode battery replacement (the last days) and just before another change in the gating configuration. The first days of the period cannot be considered because the two events occurred contemporaneously.
The same problem started to occur at the end of 2007 and the battery was soon replaced.

A reference system delay (dotted magenta) has been computed using the values of the system delay soon after the bias correction, October 22nd , 2007. Only a few system delay measurements have been considered to compute the reference value because, after the gating correction, MLRO stopped its operation for laser replacement and other upgrades. The system delay after this period cannot represent the period before.

The difference between this value and the reference system delay has been considered as the actual bias.

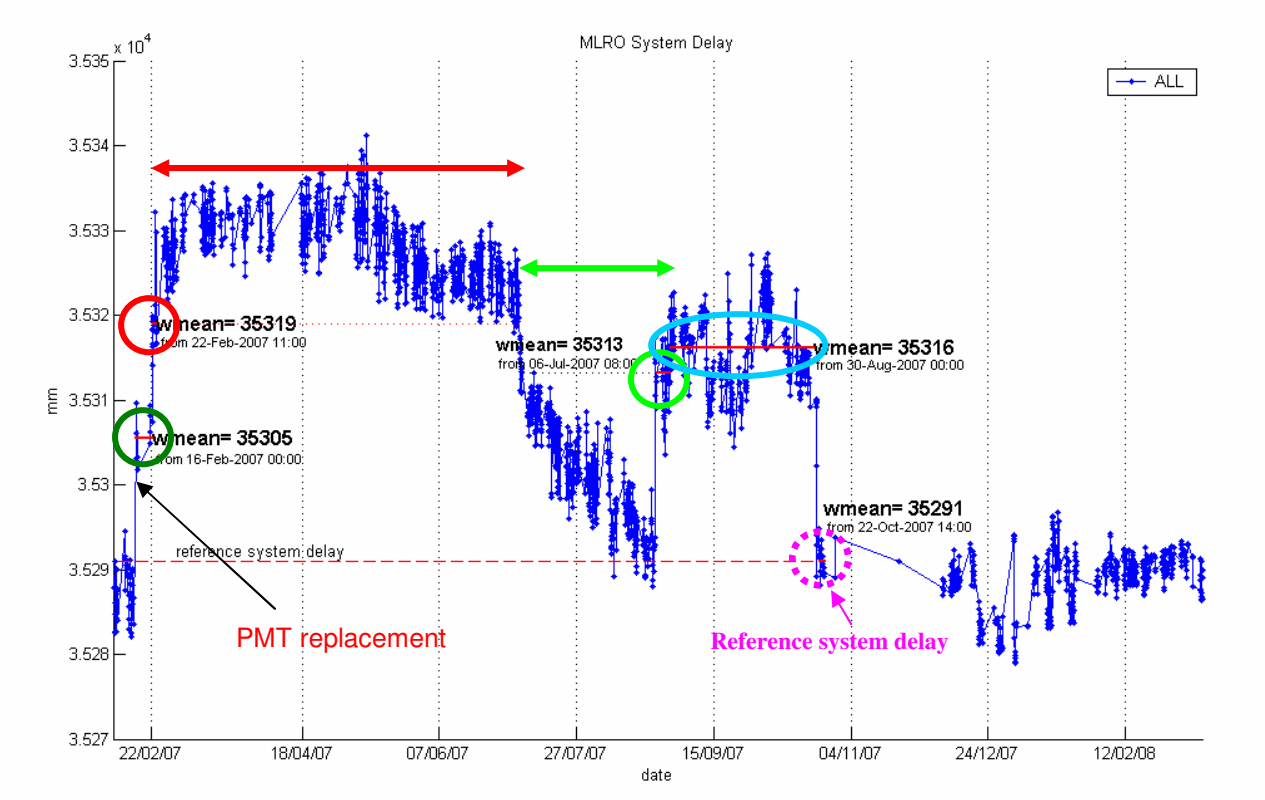

Fig. 4: MLRO system delay

The result is the following table which gives the computed MLRO range bias values for a few relevant time intervals.

Start (UTC)	Stop (UTC)	MLRO range bias (mm)
16/02/07 00:00	22/02/07 11:00	-14 +/- 2
22/02/07 11:00	06/07/07 08:00	-28 +/- 2
06/07/07 08:00	30/08/07 00:00	-22 +/- 3
30/08/07 00:00	22/10/07 14:00	-25 +/- 3

NOTE: These biases must be subtracted from the one-way ranges to obtain the correct value.

Fig. 5 shows HIT-U biases (blue), computed bias (red line) and the system delay minus reference delay with sign reversed. A running average is added to the biases and the system delay to have an evidence of their behaviour. The scatter in the HIT-U biases is high and that's why the system delay values have been used to compute the mean biases. It is clear that the additional system delay variation in 2007 after February 22nd to June 7th is real and not reflected as a higher bias.
From December 2007 on, after the gating correction, the Lageos bias seems to be stable, around 5 mm, but cannot be compared with the previous time series because the HIT-U reference coordinates were replaced with SLRF2005.

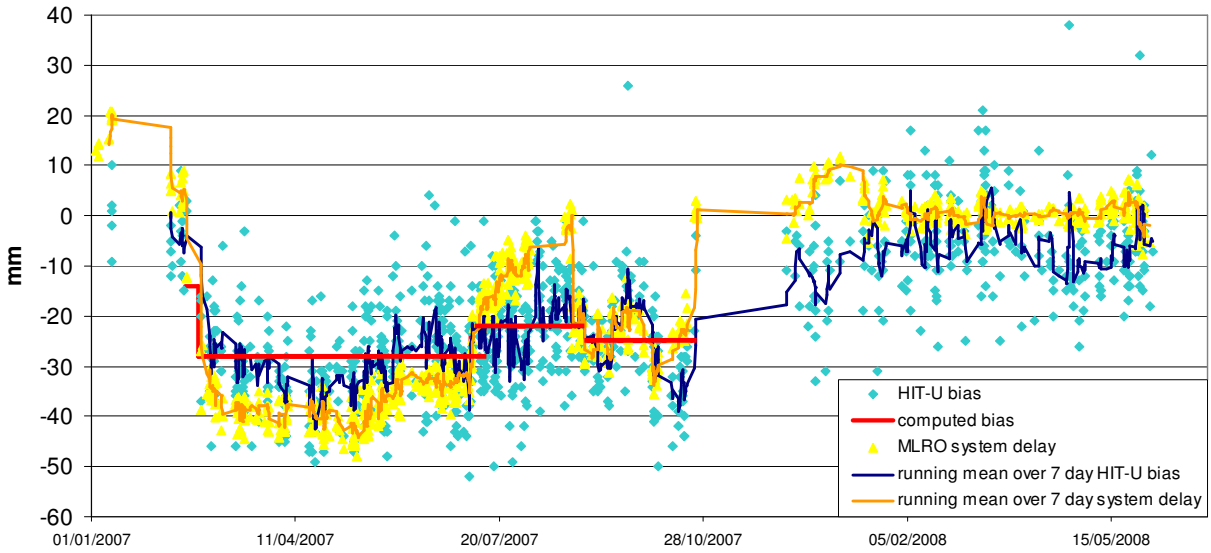

Fig. 5: L1/L2 MLRO range bias (HIT-U estimates) and system delay

The following graph shows the MLRO coordinate residuals computed before (cyan) and after (blue) the corrections (ASI SLR solution). The improvement is readily apparent and brings the MLRO back to the ILRS core station quality standard.

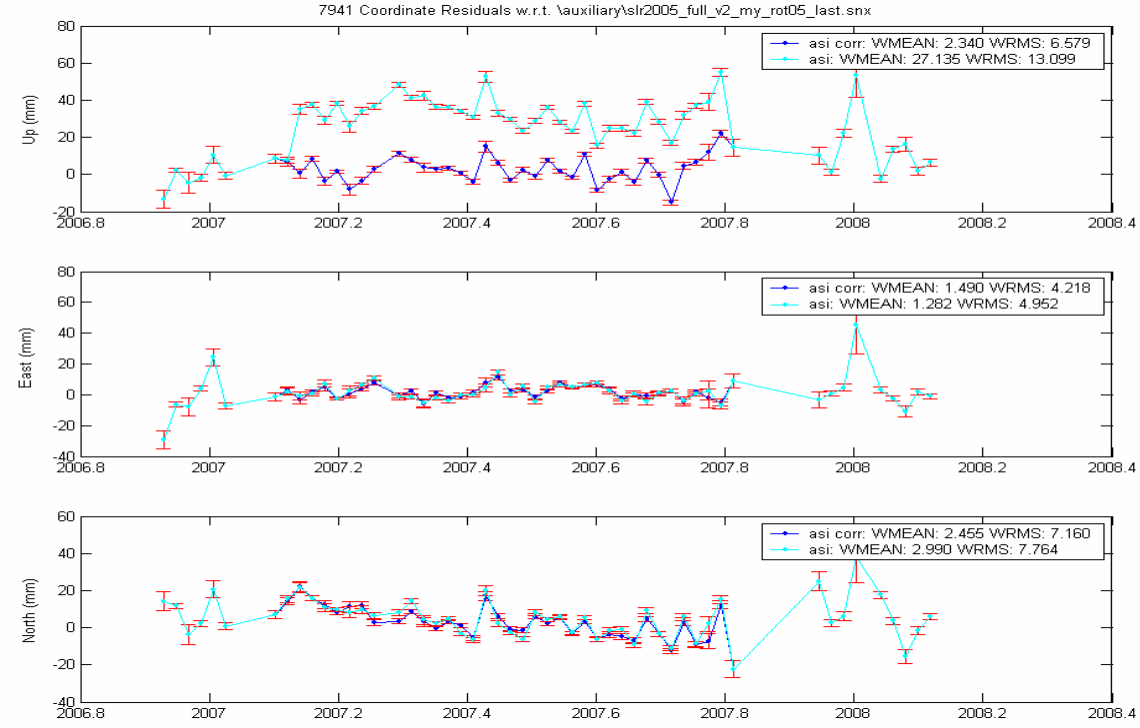

Fig. 6: ASI MLRO residuals w.r.t. SLRF2005, before and after bias application