Absolute and Relative Range Bias Detection Capabilities

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Abstract: The computed orbit is the final yardstick in accessing ILRS data quality. The absolute accuracy of orbit determination depends ultimately on the quality and quantity of data, but is a trailing (not leading) indicator of 'true' network performance. In order to successfully monitor improvements is laser ranging technology, analysis techniques continually need to be enhanced. This is mandatory for the ILRS is to achieve its vision of mm level accuracy.

Orbital analysis techniques (i.e. collocation, short arc, long arc) have their own inherent strength and weaknesses and will be characterized in terms of absolute and relative range bias detection capabilities. Some new bias detection techniques will be explored and evaluated.

INTRODUCTION:

Below in Table 1 are a list of bias detection techniques and their capabilities. System characterization *[Pearlman 1984]* is a methodology for conducting **on-site** special engineering tests (i.e. counter calibrations *[Gibbs 2002]*, amplitude tests, cube corner maps, stability tests) that fully characterize, by sub-system, the random and systematic error sources in the SLR system hardware and software. Currently, this is still the best approach for identifying error sources at the 1mm level. The next two best techniques are the Portable Pico-second Event Timer (PPET) calibration standard developed by our Czech colleagues *[Hamel 1999]* and collocation *[Husson 1996]*. Collocations are rare events, because they require a sizeable commitment of time, money, and coordination.

Orbital techniques have several limiting factors in absolute bias detection capabilities which include but are not limited to station coordinates, network distribution, network data quantity and quality, satellite signature models, GM, tropospheric models and geocenter modeling. Different orbital analysis techniques (simultaneous arc, short arc, position/bias estimation) will be explored in more detail in the rest of this document.

Table 1. Bias Detection Techniques

Technique	Detection Capability	Detection Level(mm)			Orbit Required?	Simultaneity Required?	Station Coordinates
		Pass	Month	Year			
System Characterization	Absolute	≤1			NO	NO	NO
Portable Calibration Standard	Absolute	≤1			NO	NO	NO
Collocation	Relative	2 to 4	1 to 2	1	NO	YES	Relative
Simultaneous Arc	Relative	10 to 15	5 to 10	3 to 5	YES	YES	Fixed
Short Arc (2-3 days)	Relative	30 to 50	10 to 15	5 to 10	YES	NO	Fixed
28-Day Position/Bias Estimation	Absolute	20 to 70	10 to 30	2 to 4	YES	NO	Estimated

SIMULTANEOUS ARC ANALYSIS:

Simultaneous arc analysis *[Appleby 1996, Husson 2000]* is very similar to collocation analysis except the sites do not have to be in close proximity. The prime requirement is quasi-simultaneity of the data from the sites be evaluated. The main disadvantages of simultaneous arc analysis relative to collocation analysis are:

1. A short arc orbit (part of 1 satellite revolution) is required.
    a. Site biases can corrupt the orbit.
2. Station coordinates (and their associated fixed velocities) are an error source.
    a. There is NO conventional survey tie between the sites.
    b. Local site perturbations (i.e. atmospheric or station position motions) will influence the results.

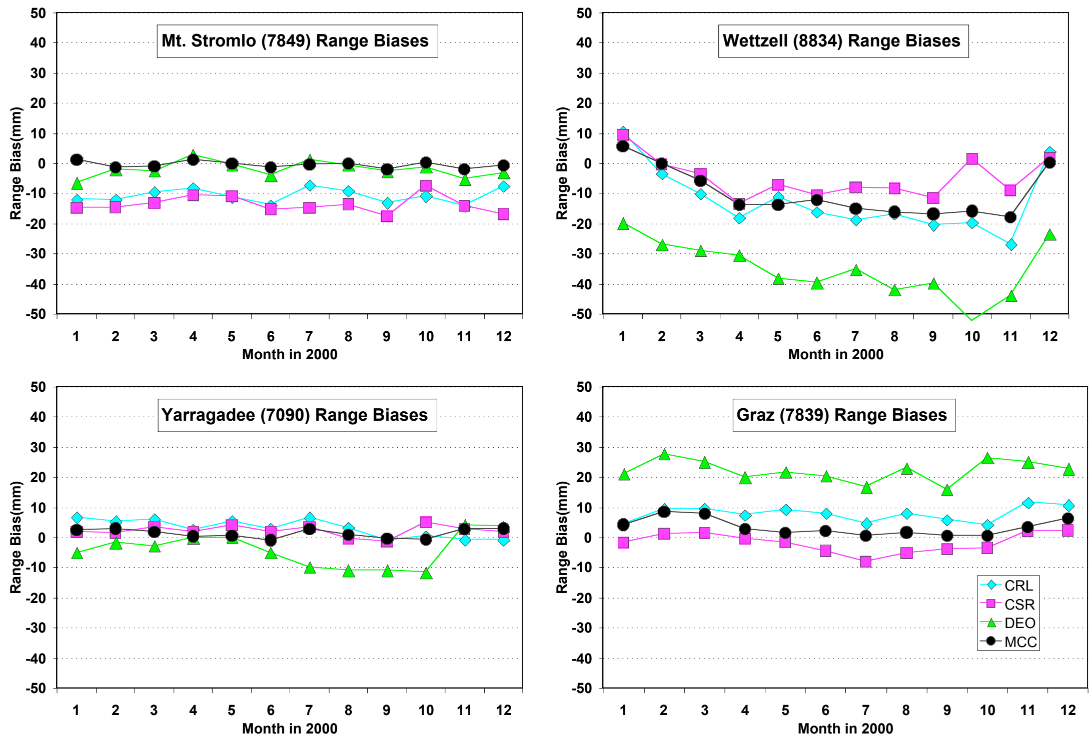
From this technique, relative biases on the order of 10-20 mm are easily detectable from a single pass. If there are three or more sites tracking simultaneously, then the bias can be isolated to a single system. A precise set of site positions (e.g. ITRF2000) can improve the detection capability perhaps to the 5-10 mm level.

The simultaneous data requirement greatly limits the number of opportunities for performance comparison. Short arc analysis does not have this weakness.

SHORT ARC ANALYSIS:

Short arc analysis of LAGEOS (1&2) is routinely performed by a number of ILRS analysis centers. LAGEOS short arcs are typically 2-3 days and have RMS fits of 10-20 mm. Figure 1 contains a set of monthly range bias estimates in 2000 from the different Analysis Centers (AC). The four ACs are Center for Space Research (CSR), Mission Control Centre (MCC), Communication Research Laboratory (CRL), and Delft Earth Observation Space Research (DEO).

Figure 1. Range Bias Estimation from Different Analysis Centers



In general, the trends for each site and analysis center are similar, but there can be a few centimeter differences in the magnitude of the bias. The major source of these differences can be attributed to the different coordinate solutions used in the analysis. CSR used their CSR95 coordinate solution, MCC used their MCC2000 coordinate solution, DEO used their DEO93 coordinate solution and CRL used ITRF97. If the apparent absolute monthly range biases between ACs can differ by a few centimeters, then individual LAGEOS pass-by-pass results can and will differ by several cm or more.

Figure 2 below is a range bias time series of Zimmerwald and Graz from CSR short arc analysis. Please note that the monthly range bias estimates from each site have trends, which track each other nicely up until May 2002, when Zimmerwald fixed a 14.5mm range bias error. Graz appears to have ***absorbed*** a portion of Zimmerwald's bias change in the opposite direction. If we difference the monthly range biases from two sites in the same geographic region, we can better determine the ***relative*** bias change (see Figure 3). This is an improvement upon conventional short arc analysis and is similar in nature to collocation analysis without having the requirement of simultaneity.

Figure 2. Zimmerwald and Graz Range Biases from CSR Short Arc Analysis

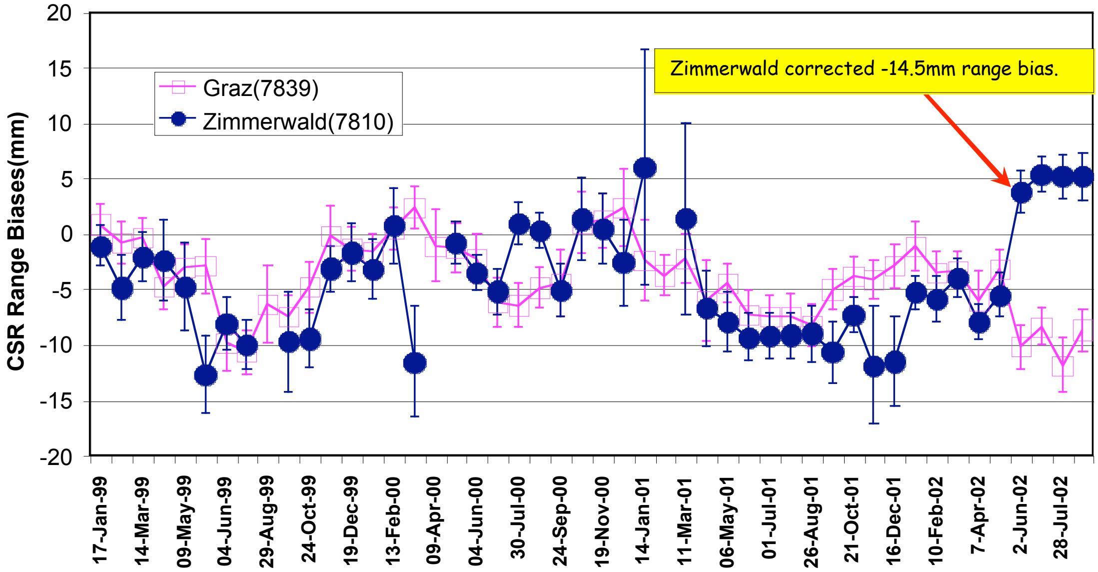
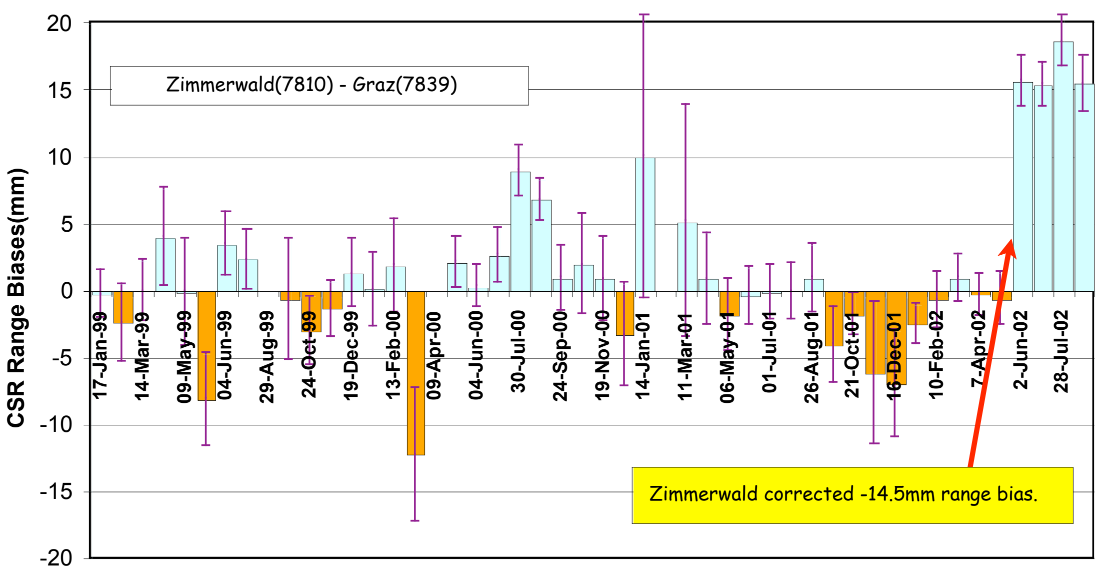


Figure 3. Collocated CSR Short Arc Analysis (Zimmerwald – Graz)



COORDINATE ESTIMATION:

Analysis centers have been generating 28-day coordinate solutions with range bias estimation in support of the ILRS Analysis Working Group Pilot Project on station position determination. Twenty-eight days *may not* contain enough LAGEOS data to adequately separate changes in station height from changes in range bias. Figure 4 is an example where changes in range bias are not separated from height, while Figure 5 is an example where bias was successfully decoupled from height.

Figure 4. CSR Range Bias and Height Determination for Borowiec

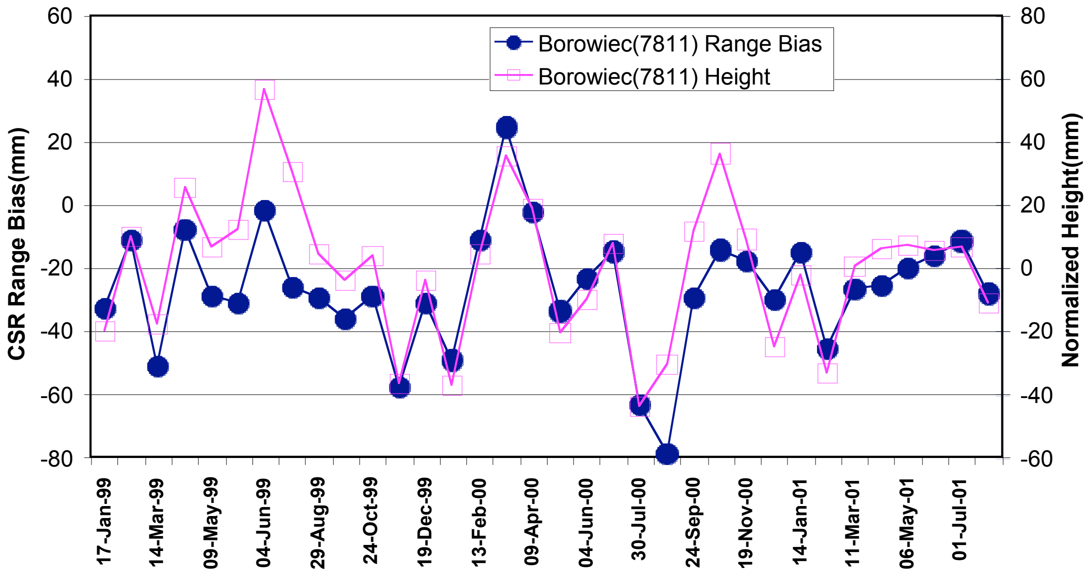
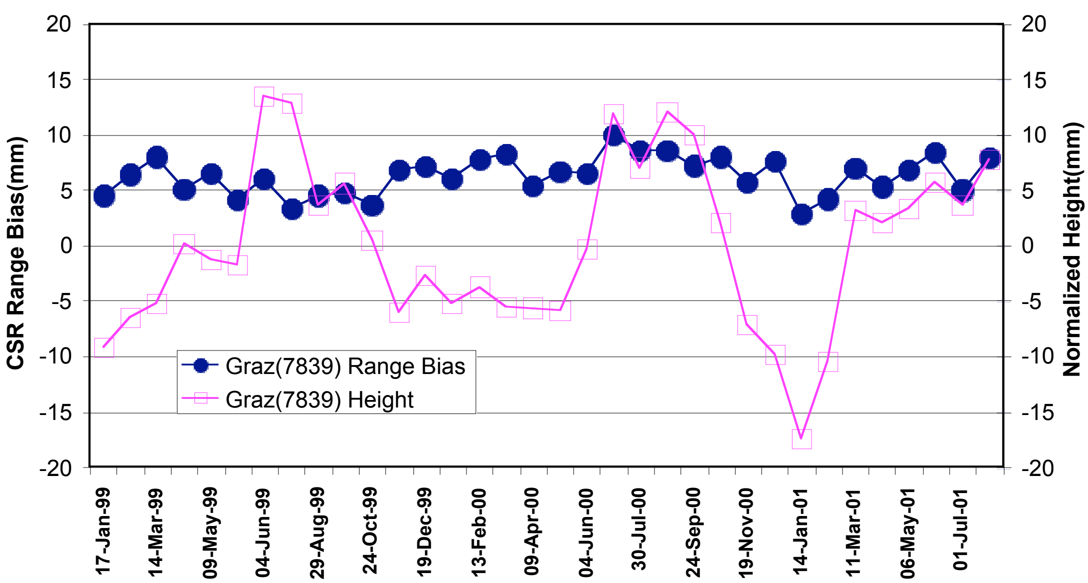


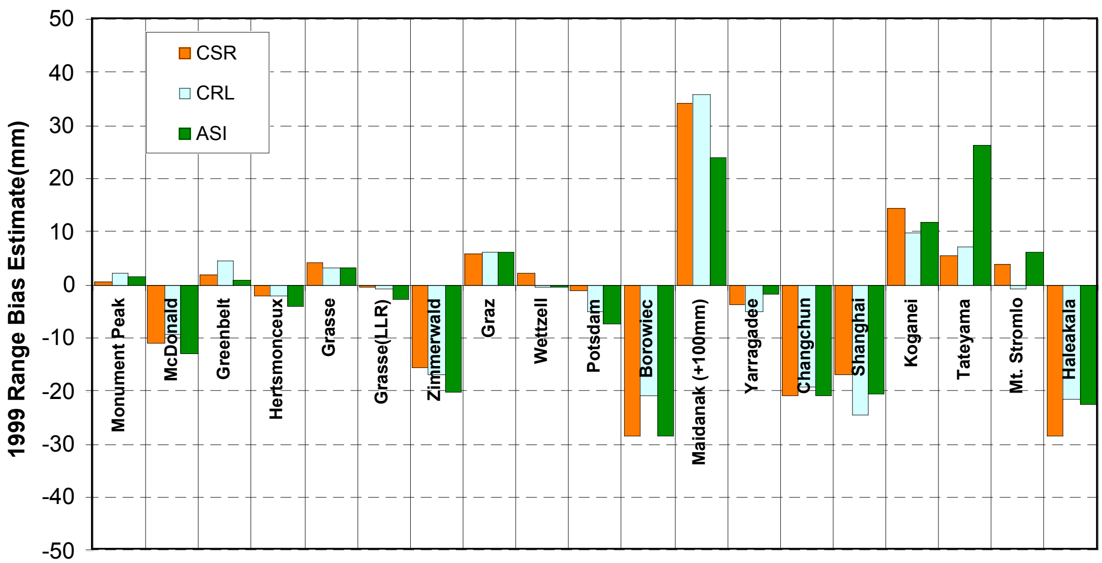
Figure 5. CSR Range Bias and Height Determination for Graz



When 28-day range bias estimates are aggregated over a period of a year, there is excellent bias estimate agreement between analysis centers (see Figure 6). Since the agreement is very good, this provides evidence that these observed biases are a representation of the absolute truth. However, there are some limits to the absolute determination of range bias from this technique. The limits are:

1. The tropospheric model,
2. The LAGEOS center-of-mass model, and
3. The gravitational constant (GM)

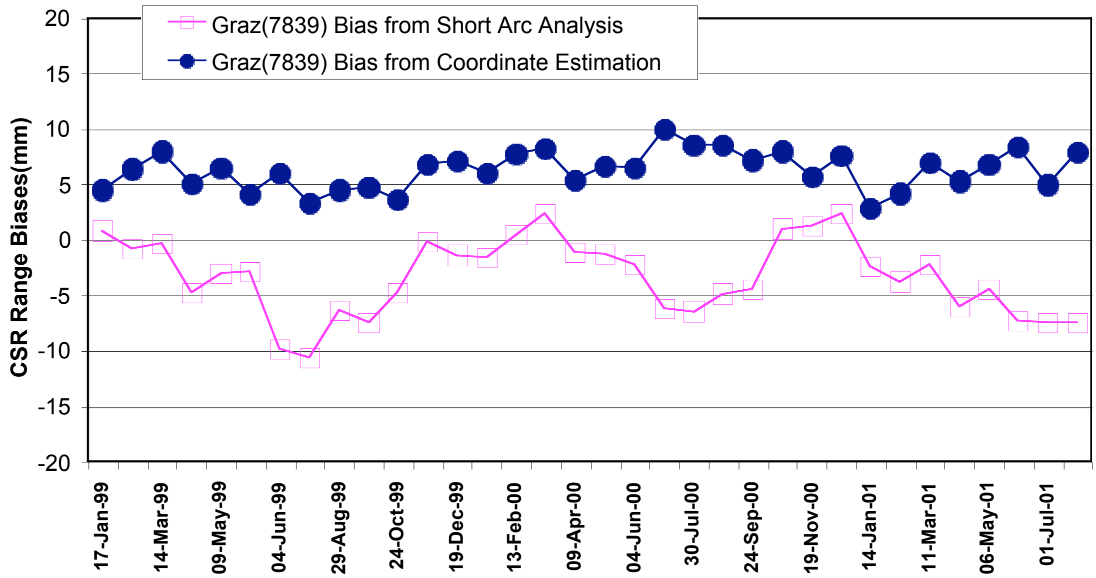
Figure 6. Aggregate 1999 Range Biases from Coordinate Estimation



COMPARISONS OF BIAS TECHNIQUES:

Figure 7 below contains a comparison of Graz range bias estimates from the short arc and the coordinate estimation technique. Please note the different magnitudes of the 2 sets of biases and also the seasonal structure in the short arc biases. The offset between the 2 biases is caused by the different station heights used in the analysis. In the short arc analysis, the station height is fixed (except for small linear height rate), while in the coordinate estimation technique Graz's height is dynamic and changes with the seasons (evidenced from Figure 5). The apparent seasonal bias trend in the short arc analysis is induced by constraining Graz's height.

Figure 7. Graz Range Bias Estimates from 2 Different Analysis Techniques



CONCLUSIONS:

Each orbital analysis technique has its limitations in absolute and relative bias determination. The short arc technique has been the primary orbital analysis method for bias detection for 2 decades. The technique is severely limited by the site coordinates and velocities used. In addition, a change in the bias of one site will be partially absorbed into neighboring sites.

Short arc analysis can be enhanced by differencing the biases from sites from the same geographic region (e.g. Europe, China, the United States). The apparent seasonal bias trends cancel and the full magnitude of a bias change in a site can be observed. This is an excellent technique for determining relative bias changes from a densely populated geographic region and when at least one site's long term performance is reliable (i.e. 'trusted') and can be used as a 'standard'.

Coordinate estimation is the BEST technique for determining absolute range biases, but can be limited by insufficient data. Current modeling can estimate absolute range biases to the few millimeter level given an adequate data set (a few months to a year).

ACKOWLEDGEMENTS:

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