Performance Assessment of Geodetic SLR Stations

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SLR station performance requirements depend on the application of the tracking data: orbit determination tasks are less demanding than individual station positioning, and horizontal positioning is less demanding than vertical. The ability to resolve whole Earth gravity and dynamics is mostly affected by errors at a station with similar spectral characteristics to the physical phenomenon to be monitored, and so effects with no known time variation require the most accurate and consistent instruments. We present an assessment of the performance of the stations in the Global Laser Tracking Network from recent range observations to Etalon 1 and 2, LAGEOS 1 and 2, Starlette, Stella and TOPEX. Each of these targets is useful for a different set of applications, and an appropriate assessment must consider any feature at a station adversely affecting the relevant observing capability, and these are caused by various Earth, satellite and instrument characteristics.

Station Characteristics

The signal which arrives at a station's receiving telescope is a convolution of the optical transfer function with the laser pulse shape. The finally measured return distribution will be affected by the laser pulse width and the response characteristics of the photo-detector. Systems operating at the multi-photon return level generally use a detector, such as a micro channel plate, which is sensitive to return pulse shape. The measured time-of-flight is typically defined by the triggering of a discriminator at the pulse's leading edge. A system which is calibrated with a similarly detected measurement from a terrestrial target at a known distance will produce accurate observations with a noise level of a few millimeters. The evolution of future systems such as SLR2000 will take a different emphasis and will rely on low light-level, eye-safe instruments, which must detect a much weaker return signal.

Single photon systems detect returns with a probability proportional to the density profile of the reflected pulse, and so individual range observations will be influenced by the satellite signature. The noise level of the resulting measurements is higher than those from the high-energy instruments, but consistent performance can be maintained by calibrating with terrestrial measurements collected at the same energy level as the satellite returns. Accuracy can be achieved in these systems if any difference in the satellite and ground target data distribution is accommodated in the computation of the final, 'normal' measurements. The formation of normal points from the full-rate observations is prescribed by a process which effectively takes the mean of the data distribution as the normal range.

Earth and Orbit Model

All observations between January 1992 through December, 1997 from the global laser tracking network were employed in the analysis, based on a fixed tracking complement of station positions, together with a compatible Earth orientation series. SLR observations from the LAGEOS I, LAGEOS II, ETALON I, ETALON II, Starlette and Stella satellites were analysed with a comprehensive solution parameter model. A ten-day orbital arc length was selected, except for the ETALON satellites, for which a thirty day span was needed to obtain a strong enough solution with their limited tracking coverage. The solution parameters were based on a speed of light of 299792.458 km/sec; a comprensive geopotential model was adopted and full Earth and Ocean tidal models were employed. Third body perturbations from Sun, Moon, and Mercury through Neptune were included and the effects of general and special relativity were modeled, together with Earth albedo. Ocean loading and solid earth tides were modeled at each station and tidally coherent diurnal and semi-diurnal geocenter and EOP motions were applied for fourteen tidal frequencies.

Force model parameterization was satellite dependent. LAGEOS I and LAGEOS II had along-track and once-per-revolution along-track accelerations estimated at 5 day intervals and the solar radiation coefficient held at 1.13. ETALON I and ETALON II had along-track and once-per-revolution along-track accelerations estimated at 15 day intervals, but the solar radiation coefficient was held at 1.21 for ETALON 1 and 1.25 for ETALON II. Starlette and Stella had no generalized accelerations adjusted, the solar radiation coefficient adjusted once per arc, and a coefficient of atmospheric drag adjusted daily.

Results of Performance Assessment

The orbital information derived for the ETALON and LAGEOS satellites as part of the performance assessment process is shown in the first four figures. The overall RMS of fit and mean residual for the full network is presented as a time series for each satellite, as well as the number of passes and the number of participating stations every thirty days for the ETALON satellites and every ten days for the LAGEOS satellites. The main data quality measure for a viable station assessment is the mean range residual determined from independent arcs from each satellite. The successful establishment of the continuity in performance of the Greenbelt station (GGAO) is demonstrated in the final three figures. The figure labeled GREE777 shows the mean residual levels for the MOBLAS-7 station for six satellites using observations taken between 1993 and 1999. GREE6666 shows the same time period and satellite results for MOBLAS-6, which was collocated with MOBLAS-7 in 1994, 1995, 1996 and 1997. The period of winter 1995 and spring 1996, during which time MOBLAS 7 was undergoing an up-grade, was covered by MOBLAS 6, and the continuous data flow allowed GGAO to remain as a fiducial point in the SLR reference frame. The plot labeled GREE9999 shows the total accumulation of data from the two sites, in which strict editing based on the final orbit fit and data concentration was implemented. The relatively seamless transition phase seen in GREE9999 is due to the rigorous site definition at GGAO, although large RMS orbital fits are observed from Starlette and Stella, as well as biased residuals in the Stella observations. The Survey Table 1 provides the details of the last few occupations of MOBLAS-7 at GGAO, as well as the MOBLAS-6 occupations.

Conclusions

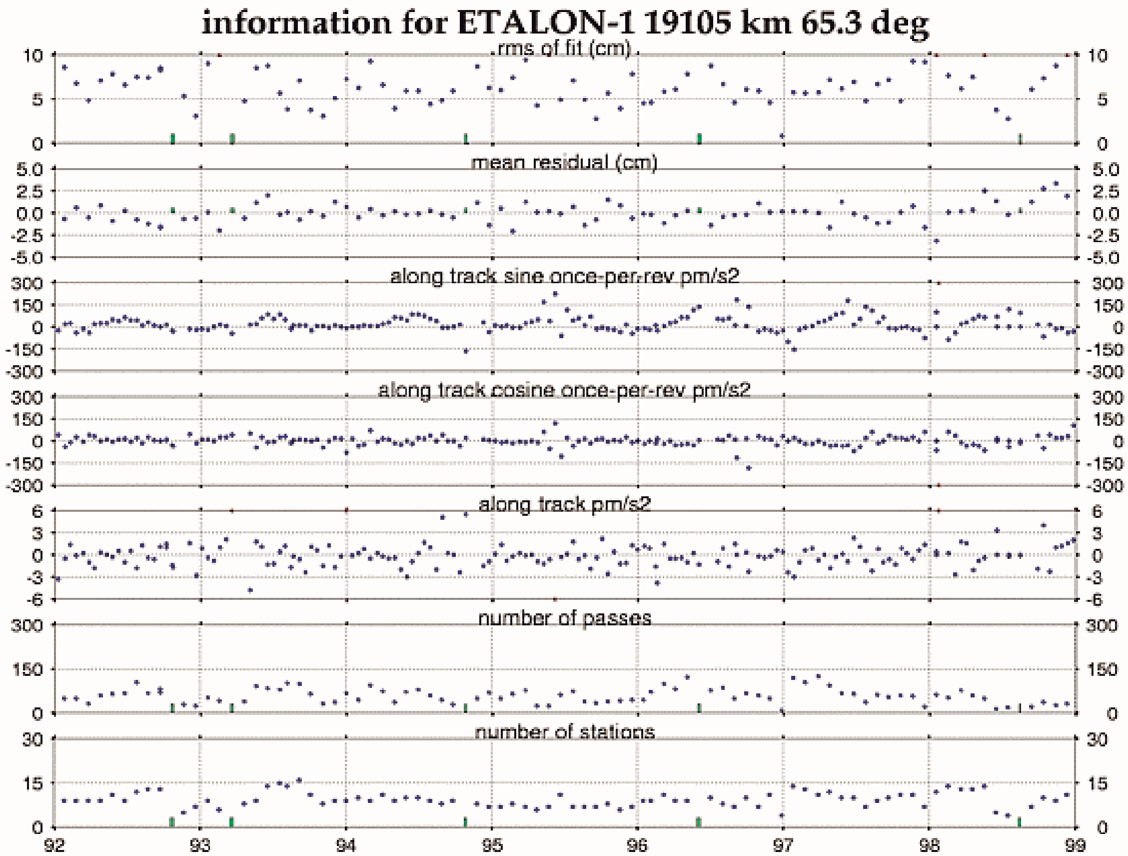
We have assessed the performance of geodetic GLTN stations tracking Etalon 1 and 2, LAGEOS 1 and 2, Starlette, Stella and TOPEX . The time period considered was 1993 to present, and the measure of data quality was chosen to be the mean range residual determined from independent arcs from each satellite. This measure confirms the general integrity of the major contributors to the Global Tracking Network, but suggests that the force model and satellite model for low Earth orbiting satellites can be improved. The analysis of collocated sites in Greenbelt indicates that the accuracy of the local survey between pads is critical to the ability of the SLR instruments to accurately define the reference system at the centimeter level.

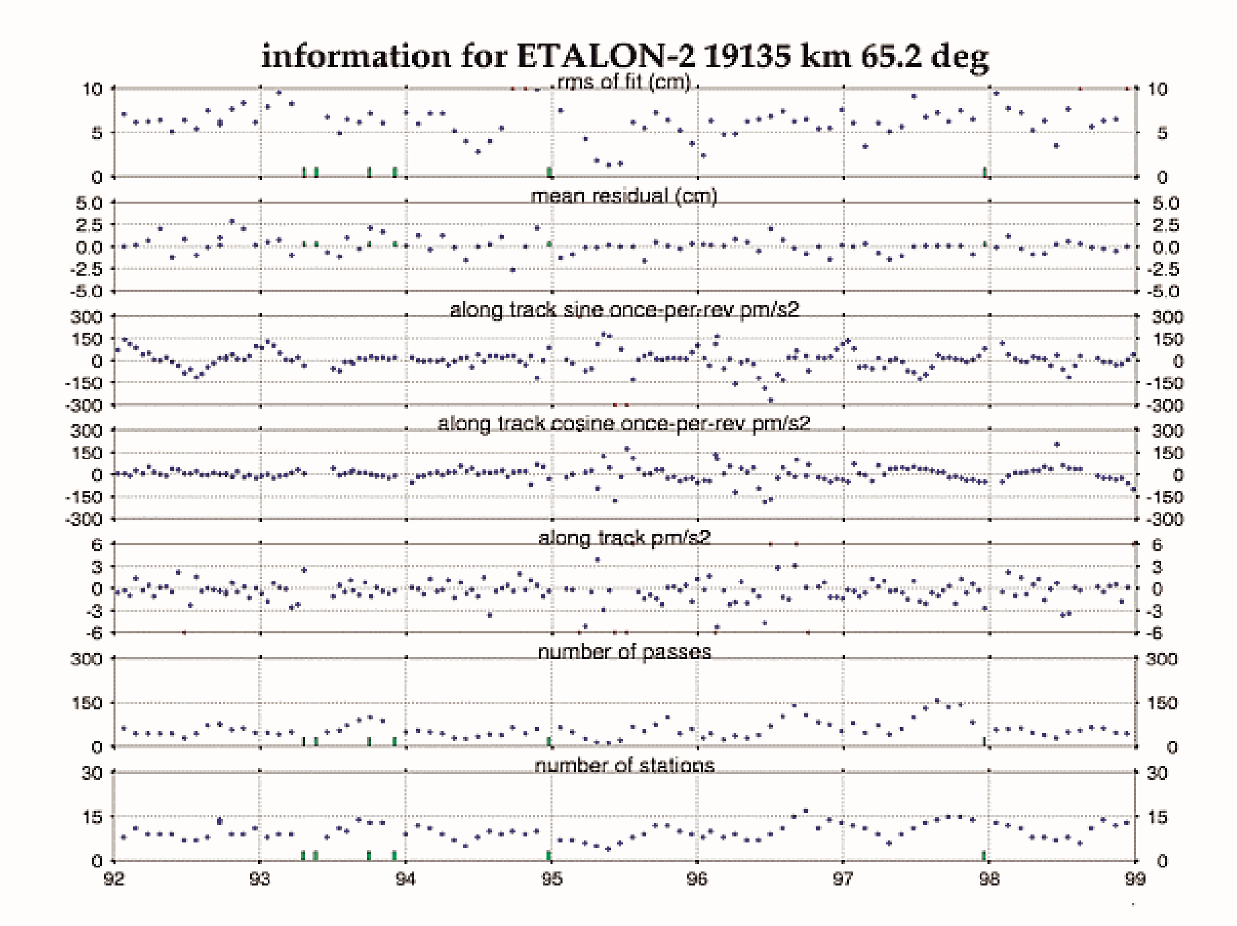
TABLE 1: Optical Axis Eccentricities at GGAO

SYSTEM	START	END	SOD	SURVEY	ECCENTRICITY(M)		
MOBLAS-7	18-Oct-91	08-Dec-91	71050722	01-Jun-90	N-0.014	E-0.033	UP 3.153
MOBLAS-7	09-Dec-91	22-Jun-92	71050723	01-Jun-90	N-0.014	E-0.033	UP 3.153
MOBLAS-7	10-Jul-92	today	71050724	31-Jul-92	N-0.011	E-0.030	UP 3.138
MOBLAS-6	21-Apr-93	22-Jun-94	79180608	18-Mar-94	N-1.216	E-1.504	UP 3.100
MOBLAS-6	26-Sep-94	today	79180609	26-Sep-94	N-0.968	E-1.252	UP 3.168

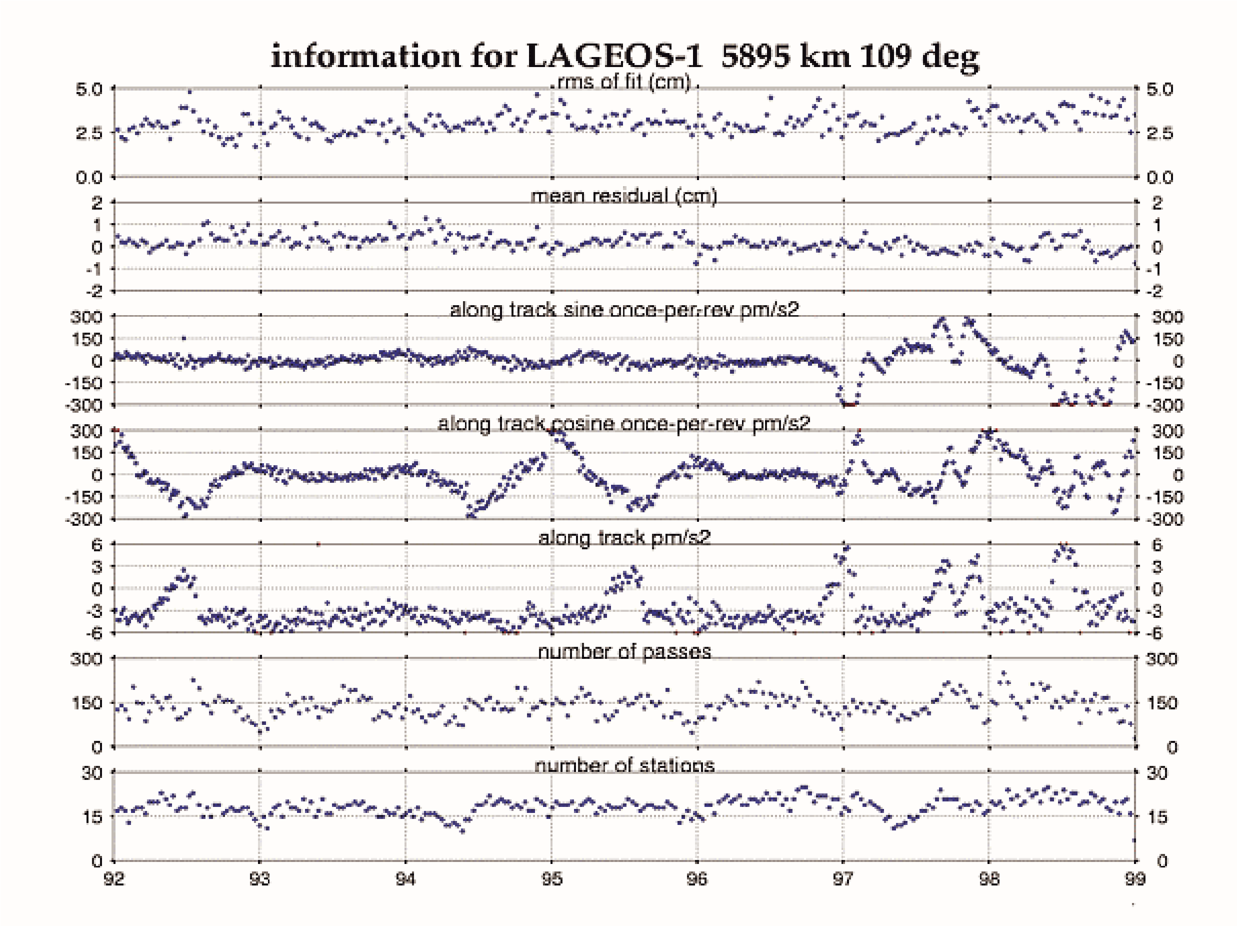
LOCAL SURVEY PAD DIFFERENCES

	DX	DY	DZ	DN	DE	DUP
7105-7918	-14.419	5.137	9.457	12.565	-12.869	-0.486

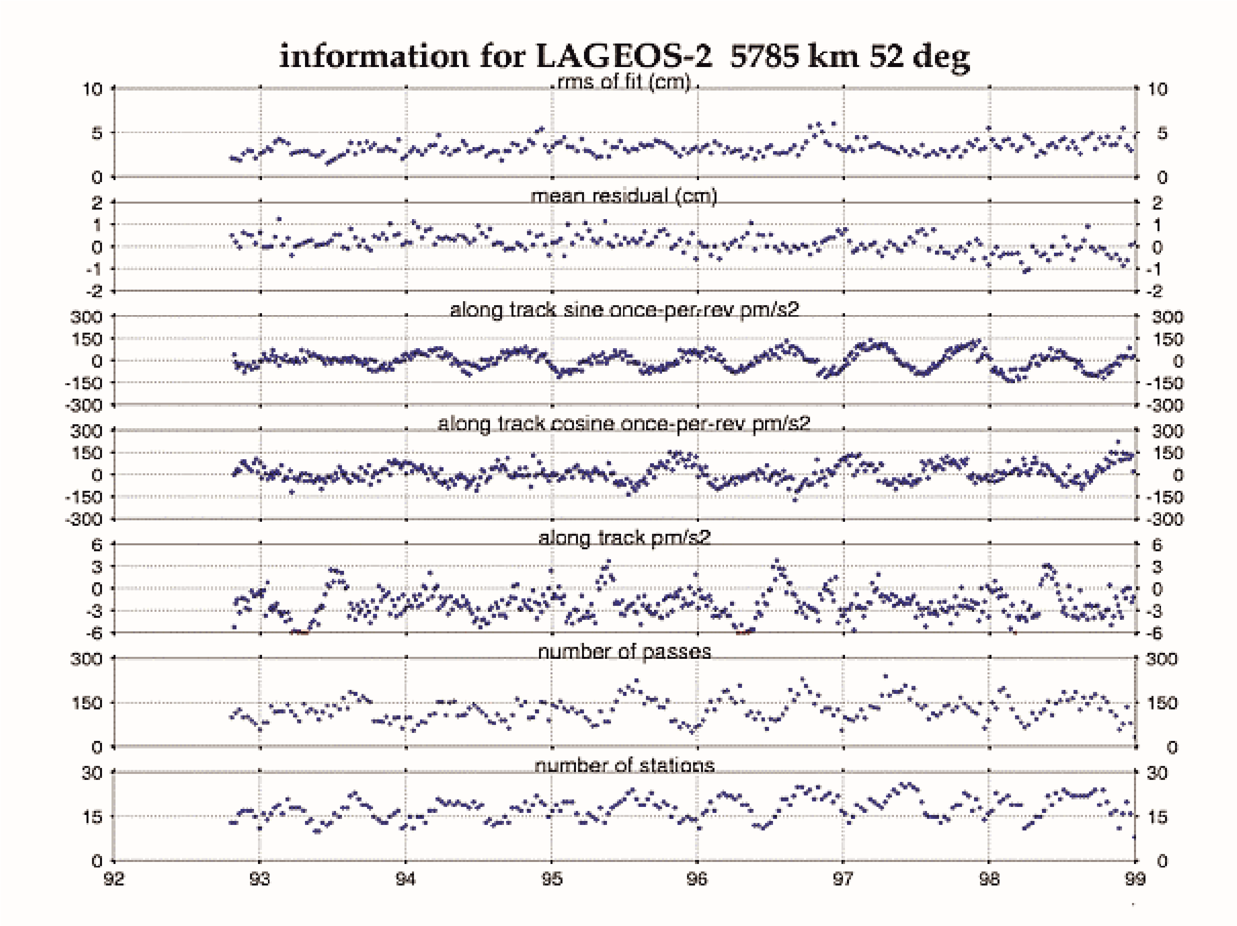

information for ETALON-1 19105 km 65.3 deg
rms of fit (cm)
mean residual (cm)
along track sine once-per-rev pm/s2
along track cosine once-per-rev pm/s2
along track pm/s2
number of passes
number of stations
92
93
94
95
96
97
98
99



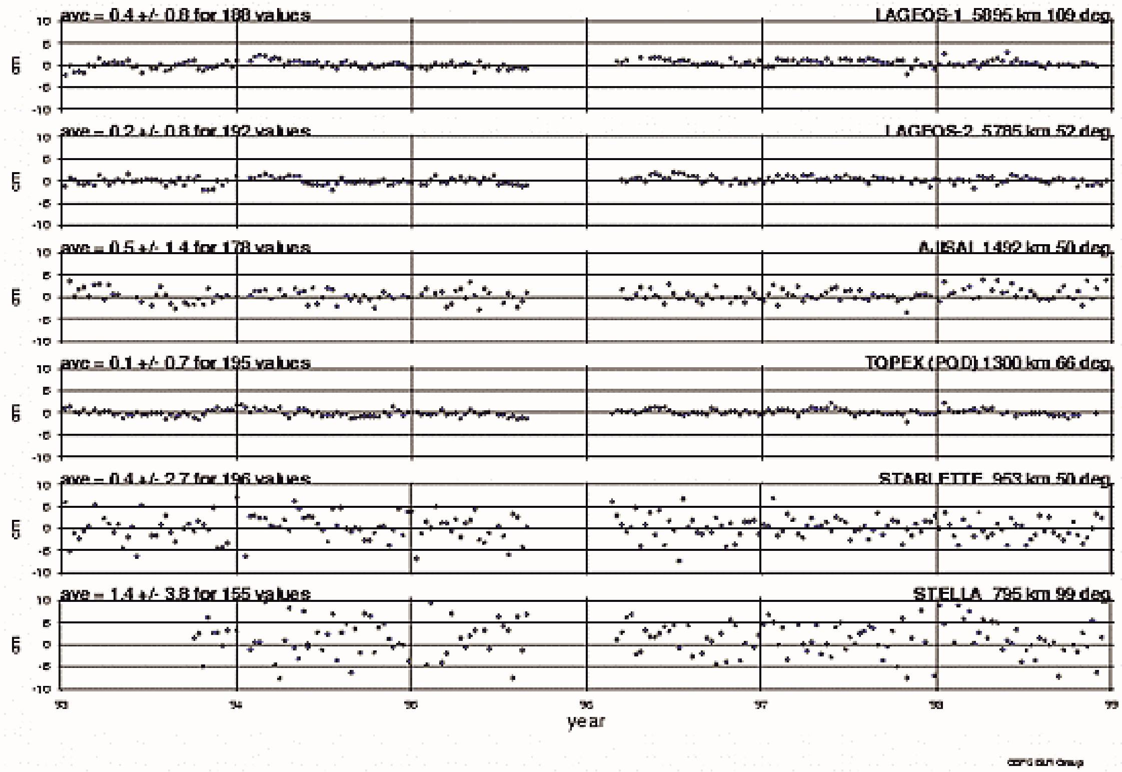
information for ETALON-2 19135 km 65.2 deg
rms of fit (cm)
mean residual (cm)
along track sine once-per-rev pm/s2
along track cosine once-per-rev pm/s2
along track pm/s2
number of passes
number of stations
92
93
94
95
96
97
98
99



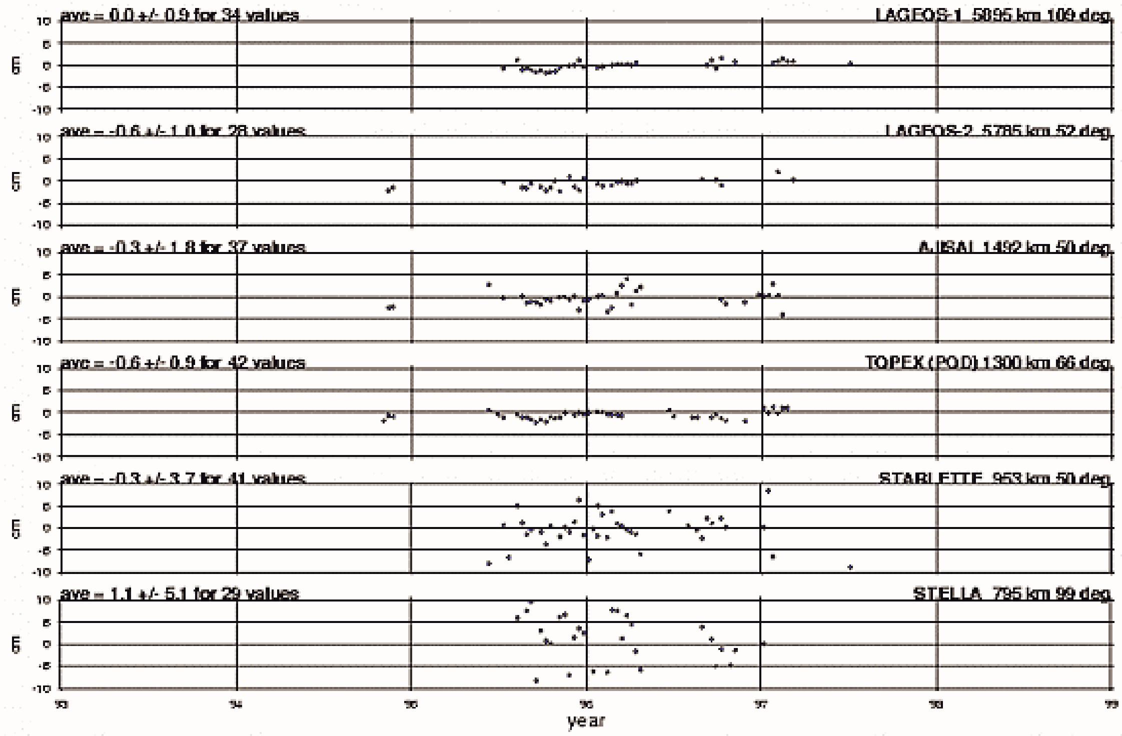
information for LAGEOS-1 5895 km 109 deg
rms of fit (cm)
mean residual (cm)
along track sine once-per-rev pm/s2
along track cosine once-per-rev pm/s2
along track pm/s2
number of passes
number of stations
92
93
94
95
96
97
98
99

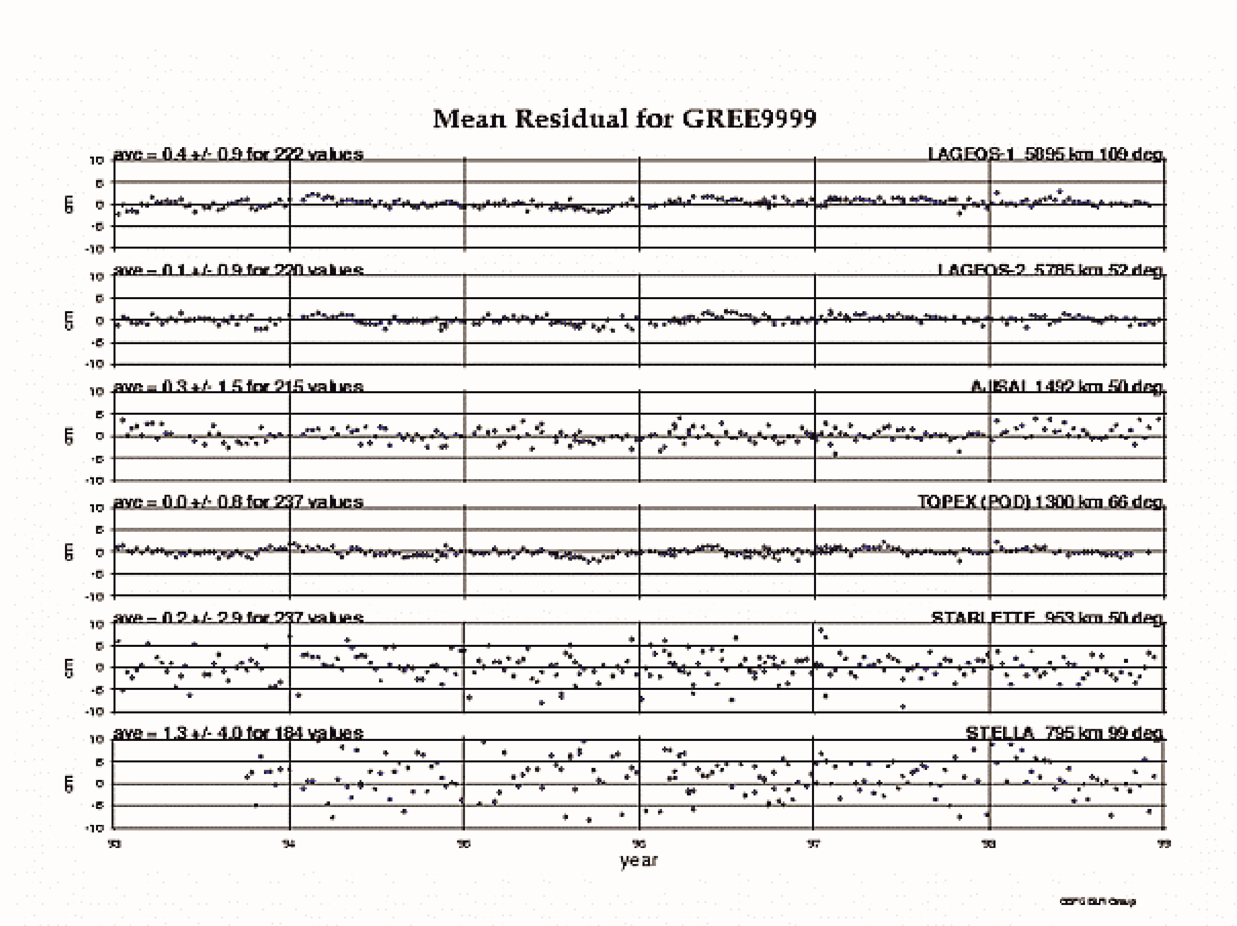

information for LAGEOS-2 5785 km 52 deg
rms of fit (cm)
mean residual (cm)
along track sine once-per-rev pm/s2
along track cosine once-per-rev pm/s2
along track pm/s2
number of passes
number of stations
92
93
94
95
96
97
98
99

Mean Residual for GREE7777



Mean Residual for GREE6666




Mean Residual for GREE9999
ave = 0.4 +/- 0.9 for 222 values
LAGEOS-1 5895 km 109 deg.
ave = 0.1 +/- 0.9 for 220 values
LAGEOS-2 5785 km 52 deg.
ave = 0.3 +/- 1.5 for 215 values
AJISAI 1492 km 50 deg.
ave = 0.0 +/- 0.8 for 237 values
TOPEX (POD) 1300 km 66 deg.
ave = 0.2 +/- 2.9 for 237 values
STARLETTE 953 km 50 deg.
ave = 1.3 +/- 4.0 for 184 values
STELLA 795 km 99 deg.
cm
93
94
95
96
97
98
99
year