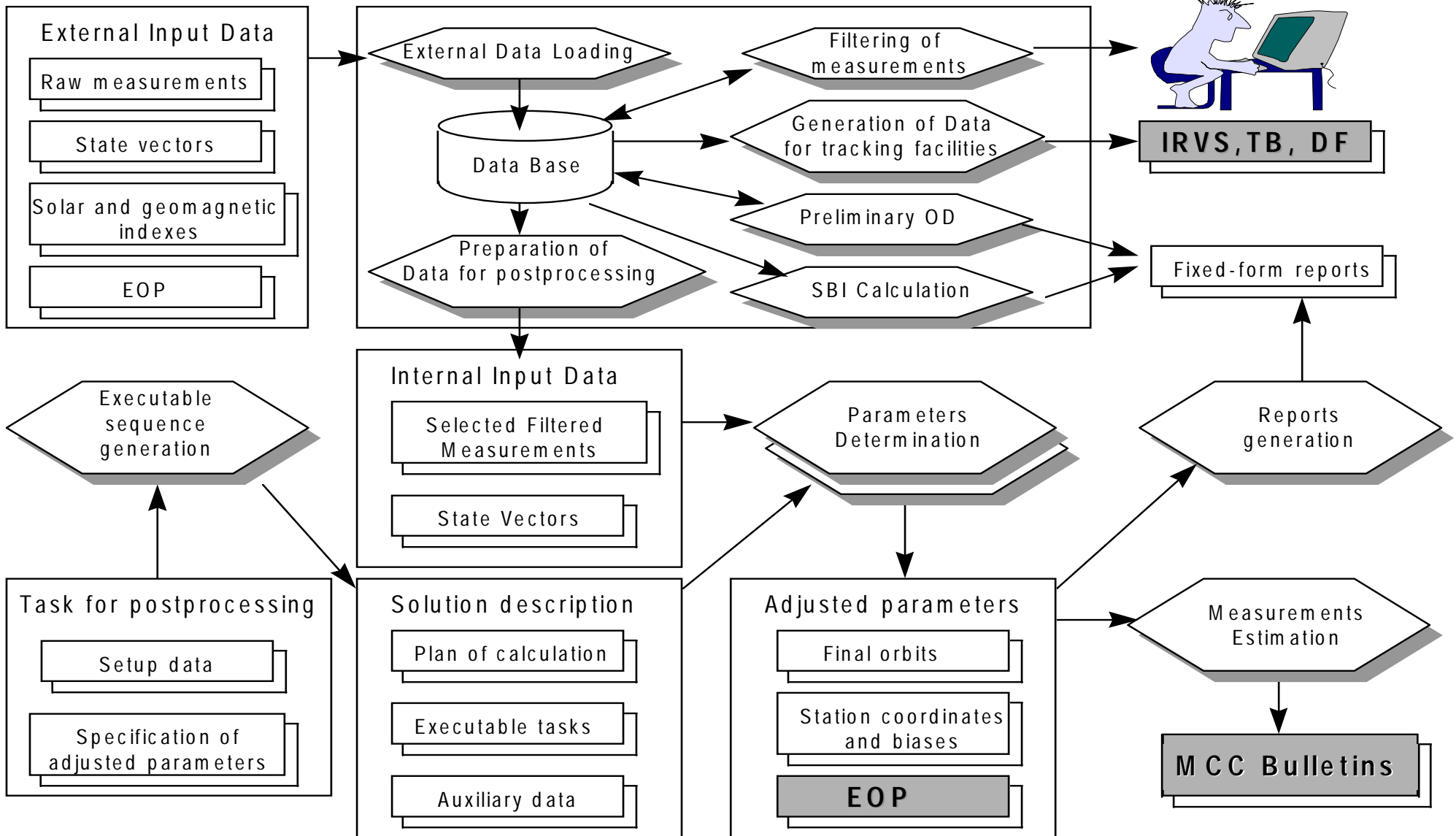11 Laser Workshop

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The Operational Procedure Of The SLR Data Quality Analysis in MCC

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SLR Processing in MCC

Precise Measurement Filtering and Tracking Data Evaluation Equations

Precise data filtering: N - number of measurements in a tracking session.

$$\min \sum_{i=1}^{N} (\Delta\gamma_i - \Delta\gamma_s - \Delta t_s \cdot \dot{\gamma}_i - \Delta h_s \cdot \tilde{\gamma}_i)^2; \quad \Delta\gamma_i = \gamma_0 - \gamma_c; \quad \dot{\gamma}_i = \frac{d\gamma_c}{dt}; \quad \tilde{\gamma}_i = \frac{d\gamma_c}{dh}$$

$$\Delta\gamma_s = \frac{\sum \Delta\gamma_i - \sum \dot{\gamma}_i \cdot a_t - \sum \tilde{\gamma}_i \cdot a_h}{N + \sum \dot{\gamma}_i \cdot b_t + \sum \tilde{\gamma}_i \cdot b_h} \qquad - \quad \text{session bias}$$

$$\Delta t_s = a_t + b_t \cdot \Delta\gamma_s \qquad\qquad - \quad \text{session time shift}$$

$$\Delta h_s = a_h + b_h \cdot \Delta\gamma_s \qquad\qquad - \quad \text{height shift}$$

$$a_t = \frac{1}{M}(\sum \tilde{\gamma}_i^2 \cdot \sum \Delta\gamma_i\dot{\gamma}_i - \sum \dot{\gamma}_i\tilde{\gamma}_i \cdot \sum \Delta\gamma_i\tilde{\gamma}_i); \quad a_h = \frac{1}{M}(\sum \dot{\gamma}_i^2 \cdot \sum \Delta\gamma_i\tilde{\gamma}_i - \sum \dot{\gamma}_i\tilde{\gamma}_i \cdot \sum \Delta\gamma_i\dot{\gamma}_i)$$

$$b_t = \frac{1}{M}(\sum \tilde{\gamma}_i \cdot \sum \Delta\dot{\gamma}_i\tilde{\gamma}_i - \sum \tilde{\gamma}_i^2 \cdot \sum \dot{\gamma}_i); \qquad b_h = \frac{1}{M}(\sum \dot{\gamma}_i \cdot \sum \Delta\dot{\gamma}_i\tilde{\gamma}_i - \sum \dot{\gamma}_i^2 \cdot \sum \tilde{\gamma}_i)$$

$$M = \sum \dot{\gamma}_i^2 \cdot \sum \tilde{\gamma}_i^2 - (\sum \dot{\gamma}_i \cdot \sum \tilde{\gamma}_i)^2$$

For the evaluations Δt_s and $\Delta\gamma_s$ are estimated from the final orbit:

$$\min \sum (\Delta\gamma_i - \Delta\gamma_s - \Delta t_s \cdot \dot{\gamma}_i)^2$$

$$\Delta h_s = 0; \quad \tilde{\gamma}_i = 0 \quad \text{in all equations}$$

Processing Method for Biased Data

$$\Delta\overline{q} = (WB_0^{-1}W^T)^{-1}WB_0^{-1}\Delta\overline{\gamma} = (WW^T)W\varDelta\overline{\gamma} = F_0^{-1}V \qquad - \quad \textbf{LSM}$$

$$\overline{\gamma} = \gamma_1, \ldots, \gamma_N \qquad - \quad \text{vector of measurements}$$

$$\Delta\gamma_i = \gamma_i^0 - \gamma_i^c$$

$$F_0 = \sum \overline{\omega}_i^T \cdot \overline{\omega}_i; \qquad \omega_i = \frac{\partial\gamma_i}{\partial\overline{q}} \cdot \frac{1}{\sigma_i^0}; \qquad \sigma_i^0 - \text{passport error}$$

$$V = \sum \overline{\omega}_i^T \cdot \varDelta\gamma_i; \qquad \varDelta\gamma_i = \Delta\gamma_i \cdot \frac{1}{\sigma_i^0}$$

Transformation to New Measurement free of session systematic error $\delta\gamma$

$$\tilde{\gamma}_i = \gamma_i + \delta\gamma - \frac{1}{N}\sum(\gamma_i + \delta\gamma) = \gamma_i + \delta\gamma - \frac{1}{N}\sum\gamma_i - \delta\gamma = \gamma_i - \frac{1}{N}\sum\gamma_i; \quad \tilde{\omega}_i = \omega_i - \frac{1}{N}\sum\omega_i;$$

$$F_0 = \sum \omega_i^T\omega_i - \frac{1}{N}\sum\omega_i^T\sum\omega_i; \quad V = \sum\omega_i\varDelta\gamma_i - \frac{1}{N}\sum\omega_i\sum\varDelta\gamma_i$$

Factors affecting the result:
- range rate (orbit height, elevation),
- session duration,
- measurement noise,
- number of measurements.

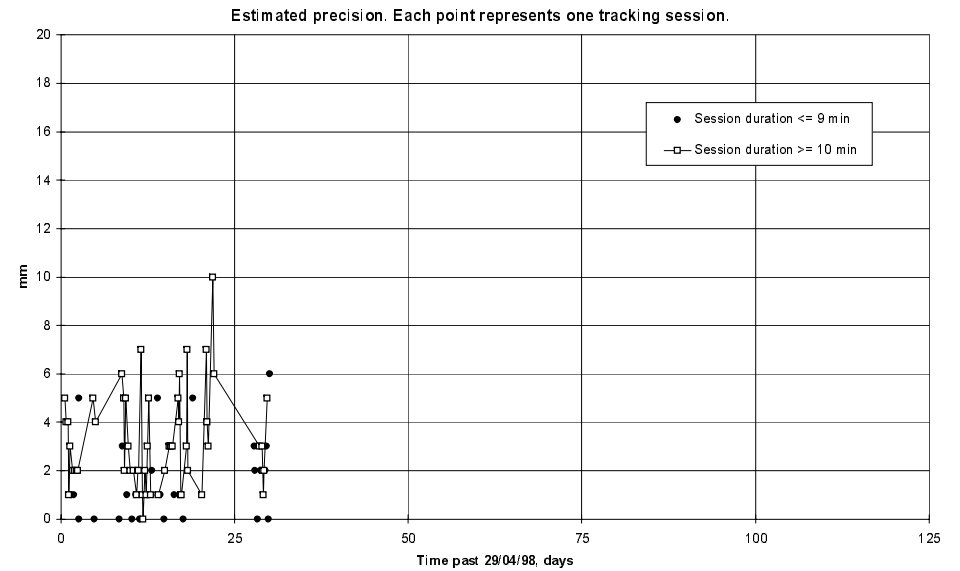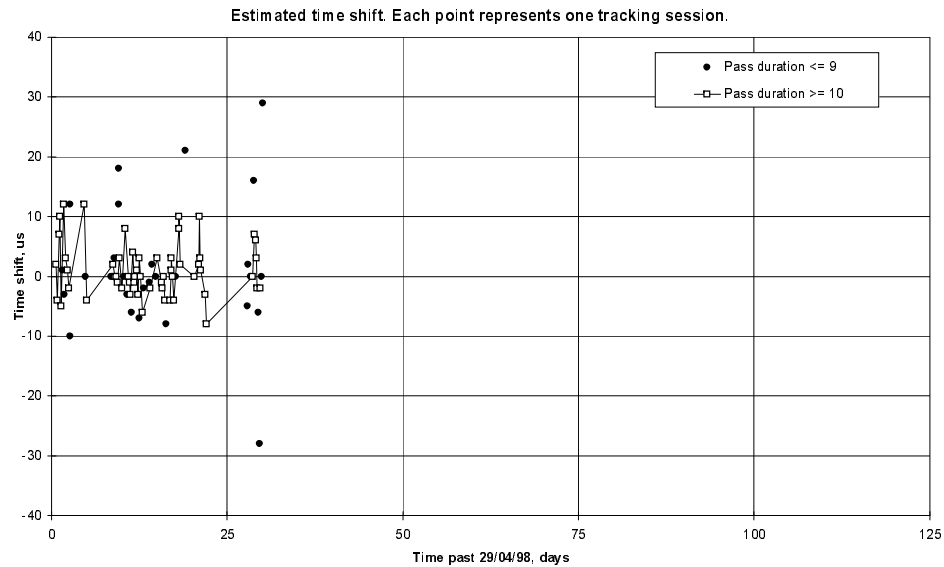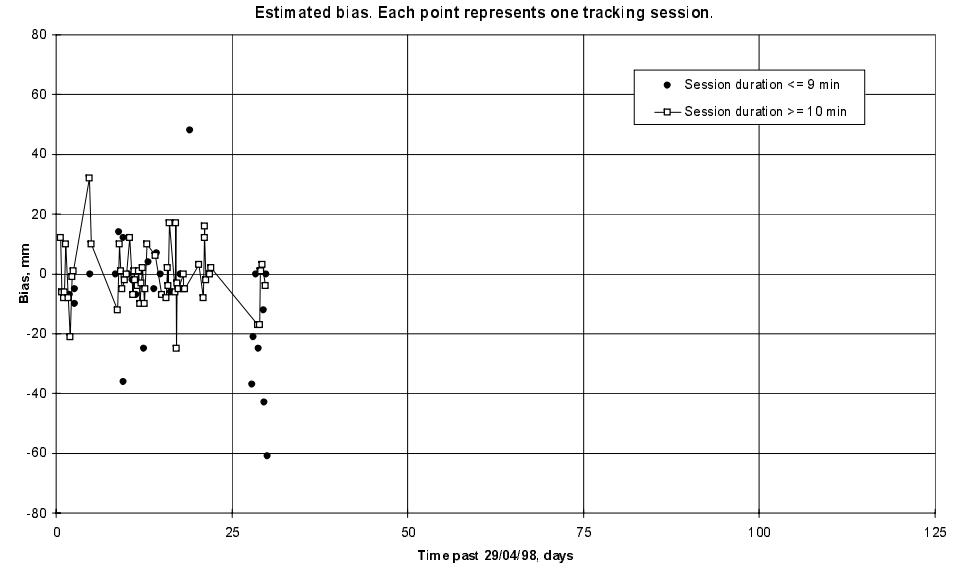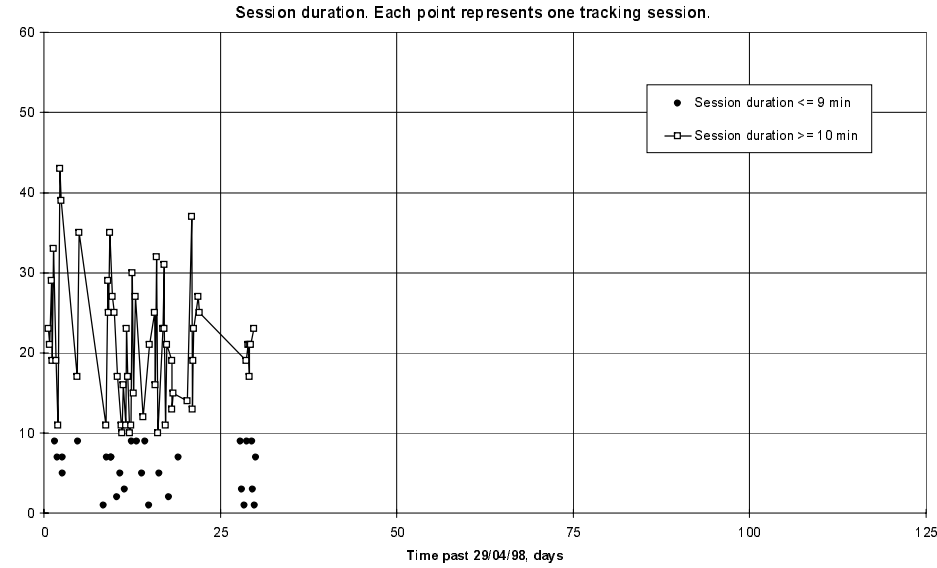The following stations had biased data processed without session ME: 1864, 1868, 1873, **1884**, 7249,**7847**,8834.

Math. Expectation of residuals from GZ98L02 solution for station 8834.
Each point represents ME of one Lageos or Lageos-2 tracking session.
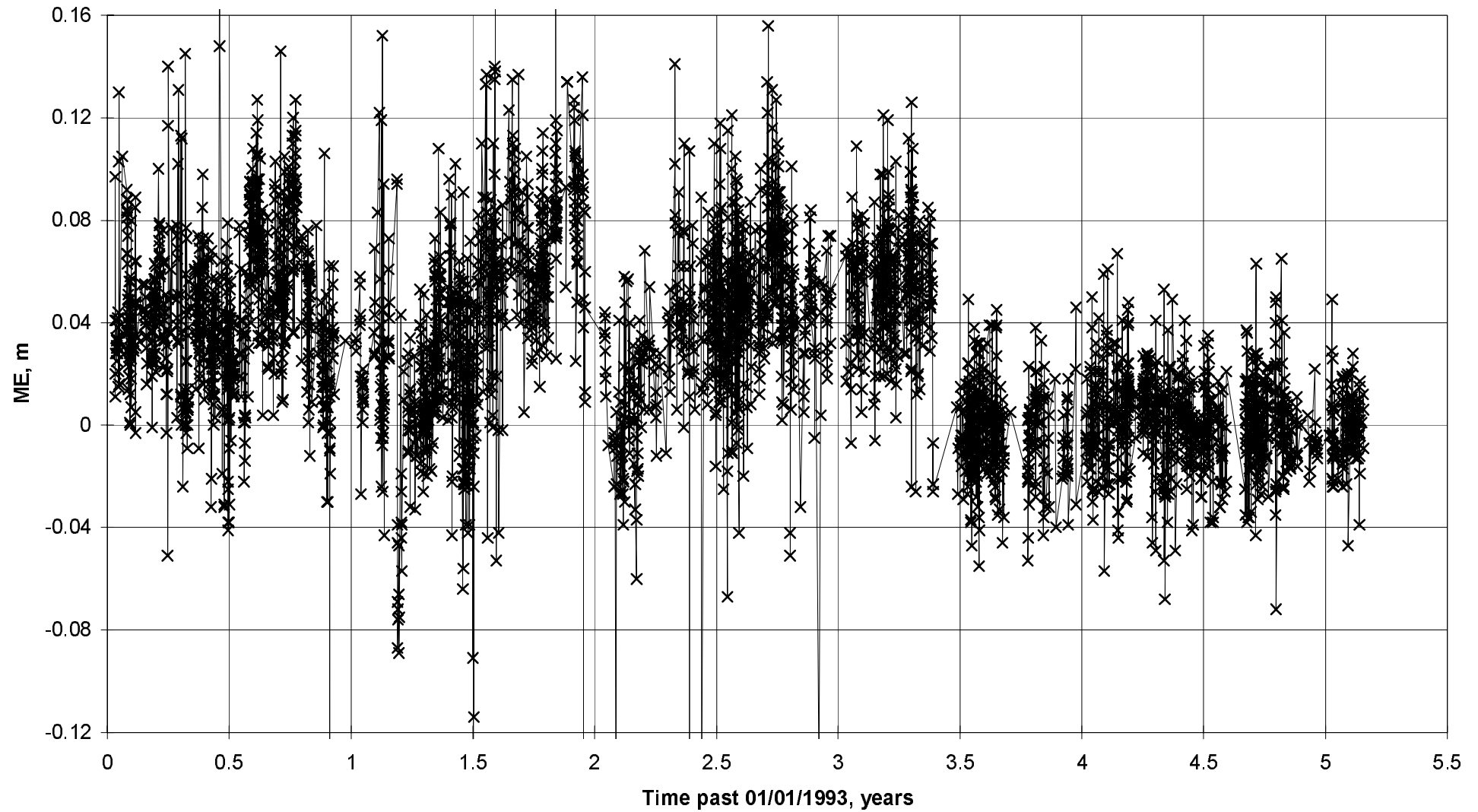
Operational SLR Data Processing

- Data loading to DB with extra outliers filtering from predicted orbit.

- Preliminary Orbit Determination (7 parameters are adjusted on 3 days intervals separately for each satellite):
    - raw data filtering using Δt or $\Delta\gamma$ from their averaged values;
    - precise data filtering inside of the sessions (automatic and manual);
    - tracking sessions weights determination (automatic and manual);
    - storage of orbits and filtered measurements Data Base.

- Orbit prediction generation for measurements loading.

- IRVS, TB and DF generation.

- Preparation of the data for post-processing.

- Final orbit and EOP determination (all parameters are adjusted simultaneously):
    - 6 orbital parameters, along track acceleration for Lageos and Lageos-2,
    - PM and LOD.

- Analysis of results:
    - determination of sessions to be used in final OD;
    - estimation of orbit and EOP accuracy.

- Labeling of suspicious sessions in DB.

- Tracking data evaluation (independent sets of Δt_s, $\Delta\gamma_s$, Δh_s and Δt_s, $\Delta\gamma_s$ for each session).

- Forming of MCC Bulletin for ILRS and EOP message for IERS.

The operational procedure of the SLR data quality analysis in MCC

Impact of pass duration on estimated time shift and bias for 8834

Session duration. Each point represents one tracking session.

Estimated bias. Each point represents one tracking session.

Estimated time shift. Each point represents one tracking session.

Estimated precision. Each point represents one tracking session.

Long-term data processing

- Operational processing results evaluation (time shifts, biases, …).

- Individual solutions for each station to guarantee the use of correct data only:
    - application of WME method for estimation of possible biases;
    - various solutions with station velocities;
    - independent solutions reference frame on Lageos and Lageos-2 data.

- Determination of biases to be adjusted in common solution.

- Performing of common solution (4000-6000 parameters simultaneously):
    - 6-days SV for Lageos and Lageos-2;
    - 6-days along-track accelerations;
    - 24-days C_R;
    - Polar Motion;
    - station coordinates and velocities;
    - bias for selected stations.

- Determination of data weight (passport errors).

- Analysis of the obtained coordinates.

- Setting up new coordinates, velocities, biases and passport errors for operational processing.

- SINEX-file generation for IERS.

- Orbits accuracy, data distribution residuals plots creation for the annual report.

Mean residual from orbit in GZ98L01 solution
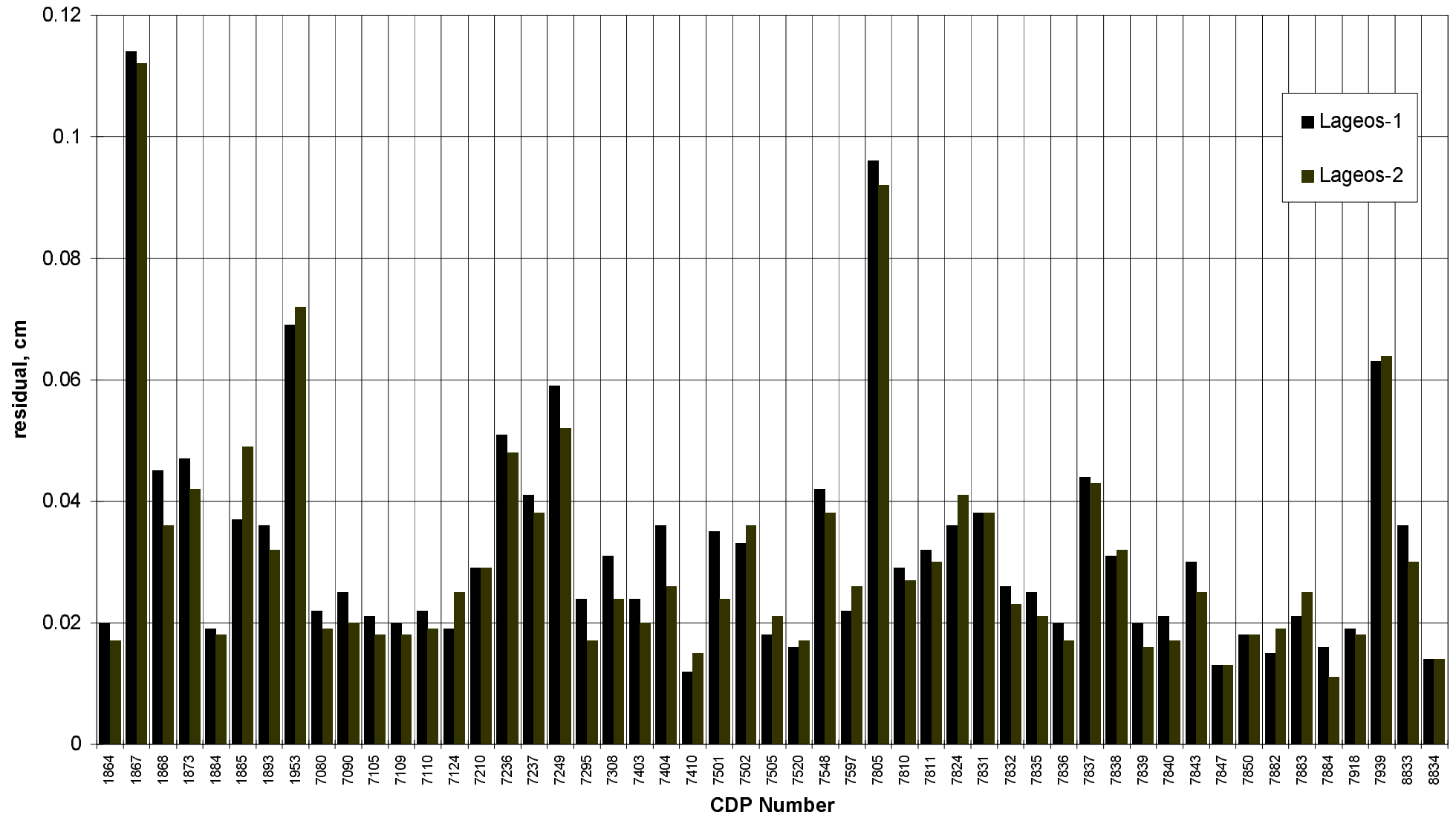
Conclusions and recommendations.

- Independent evaluation of SLR quality by different analysis centers.

- Common form of Lageoses (Stella, Westpac,…) SLR data evaluation report:
    - all data from CSR and MCC reports,
    - complete description of data used in OD.

- ILRS Web-site preparation and support:
    - all information about detected time shifts and biases in hardware (summarized CDDIS Bulletins and SLR Mail);
    - short description of the processing procedure;
    - data evaluation results from different analysis centers;
    - ground marker-to-intersection of axes correction to be used in data analysis;
    - station coordinates and biases used by different analysis centers;
    - final post-processing ILRS report based on different analysis centers results;
    - graphic presentation of pass residuals for low-accurate stations;
    - graphic presentation of range and time biases on long-term intervals (>1 month).

- Tracking recommendations for high-precision stations:
    - both ascending and descending branches tracking (especially for calibration);
    - min 10-minutes session duration for Lageoses and 5-minutes for low orbiters;
    - min 6 QLNP per one pass;
    - min 20 deg elevation.

- Tracking recommendations for other stations depends on their precision and generally concern to as much session duration as possible.