The Precise Data Processing in MCC Analysis Center

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1. Introduction.

Precise data processing in the MCC Analysis Center is based on more than 30 years of experience in radiometric and SLR data processing. Components of this processing include:

- Terrestrial reference frame realization based on the adustment of permanent network station coordinates, and an assesment of the station data quailty (range bias, time bias, weighted rms etc.)
- Description of the precise force and measurement models used.
- Choice of a specific set of estimated parameters contingent upon a detailed mission analysis (adjusted coefficients, empirical accelerations etc.)
- Detailed evaluation and filtering of the tracking data
- Evaluation of data products and comparison with independent results.

2. Data processing methodology.

The following model components and computational methodology are used in the SLR and radio tracking data processing at MCC:

Force models:

- JGM-3 gravity field coefficients through degree and order 70. Different values of the Earth's GM are used for the two body term and harmonics. Secular changes in $C_{(2,0)}$, $C_{(2,1)}$ and $S_{(2,1)}$ are modeled.
- Inelastic deformation due to the Earth rotation*.
- Solid tides through degree and order 4 *.
- Ocean tides (either Schwiderski or CSR/Topex3.0 models).
- Third body gravitational perturbations from the position of any planet plus Sun and Moon as provided by the DE403 planetary ephemeris.
- Spacecraft shadowing can be calculated either by a conic or by a cylindrical model
- Solar pressure model accounting for atmospheric refraction and spacecraft shape; currently lunar shadowing is not implemented.
- Atmosphere drag using a spacecraft shape model (Russian model of atmosphere is used which depends on daily and 90 day mean values of solar flux and geomagnetic index).
- Indirect Lunar $C_{(2,0)}$ acceleration.
- Earth infrared radiation.
- Latitude dependent Earth albedo model.

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* from IERS standards

- Empirical accelerations depending on spacecraft orbit, shape and attitude.
- Relativity (optional).

Common models:

- IAU1976 precession;
- IAU1980 nutation with celestial pole corrections applied;
- Siderial time from IERS1997 applying UT1-UT1R correction to UT1-UTC.

Measurement model:

- Marini-Murray tropospheric refraction correction;
- Solid Earth tidal motion of station coordinates according to inelastic Earth model [*];
- Ocean loading site displacement for all stations from H.-G. Scherneck (Onsala Observatory);
- Station tectonic plate motion from the NUVEL NNR-1A model for stations for which velocities have not yet been determined;
- Rotation deformation due to polar motion[*];
- Time, range, and scale measurement corrections as reported by stations;
- Spacecraft center of mass correction and any required attitude dependence;
- Relativity (optional).

Model interpolation:

To reduce orbit determination computation time polynomial interpolation is used for some of the models. Usually lost of numerical accuracy due to the interpolation does not affect the orbit determination by more than 1 cm in position. The computational savings from interpolation varies from the tens of percents to the tens of times. The following use Hermite interpolating polynomials:

- Nutation model
- Siderial time model
- Solid Earth tidal model
- Ocean tidal model
- Solid Earth tidal station coordinates variation
- UT1R calculations
- Daily and sub-daily polar motion corrections

3. Mission preparation

The MCC goes through the following steps to prepare and implement models for a new mission:

- Force model investigation;
- Selecting and testing of the perturbations to be taken into account;
- Simulations of the orbit determination process;
- Comparison of the orbits built with different models;
- Choice of a preliminary orbit determination integration step size;
- Preparation of solar pressure and atmosphere drag force models;

[*] from IERS standards

- Obtaining a detailed spacecraft description (normally reflectivity, adsorption and diffusion coefficients for each surface element of spacecraft);
- Spacecraft model by simple geometric figures (cylinder, cone, sphere, plane);
- Update software to implement new solar pressure and atmosphere drag force models;
- Determine the initial setup for the new spacecraft;
- Change some database and files to include the new spacecraft;
- Chose an empirical acceleration model for the new spacecraft by determining the direction and period of three empirical linear accelerations;
- Make required changes in the software (e.g. use of telemetry in Meteor-3M mission).

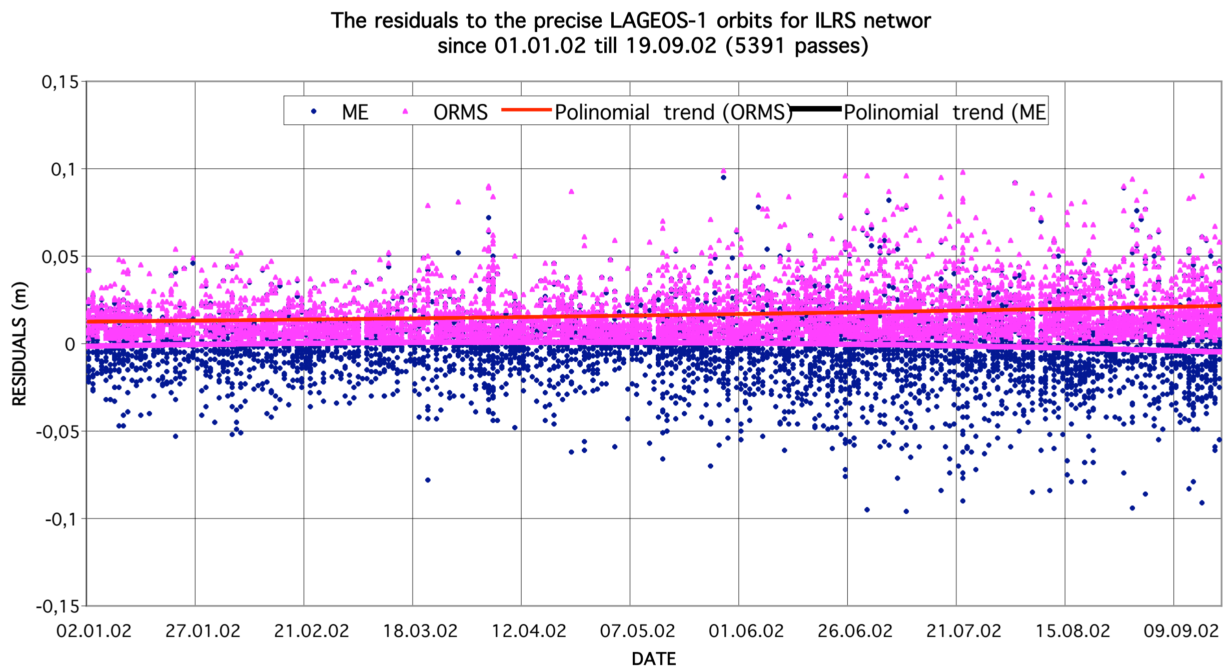
4. Software validation

Following are examples of the precise SLR data processing for several missions at the MCC Analysis Center:

- Sub-meter accuracy for Meteor-3 orbits by using SLR data;
- PRARE calibration onboard ERS-1, ERS-2 (in cooperation with GFZ and TimeTech);
- Estimation of the conditions for high precision orbit determination for low missions from analysis of Stella and GFZ-1 data;
- Precise orbit determination for WESTPAC (Australia) and Zeia (Russia) as the principle Analysis Center activity in the ILRS;
- Calibration of Maidanak, Komsomolsk and Shelkovo stations on the base of LAGEOS, LAGEOS-2, Etalon-1, Etalon-2 data (cooperation with Prof. Shargorodsky);
- Evaluation of high precision tracking system SATRE suited for geostationary spacecraft (cooperation with TimeTech);
- High precision orbit determination of GLONASS satellites since 1995 using both SLR and phase tracking data (in cooperation with IGEX/IGLOS-PP/IGS organizing committees; total: more than 20 000 passes of the SLR tracking data for GLONASS satellites);
- Routine EOP determination for use by the IERS Rapid Service/Prediction Center for EOP;
- Routine SLR data quality evaluation and calibration for the ILRS SLR stations.

4. Results

The following figures show some results of the SLR data precise processing at MCC:



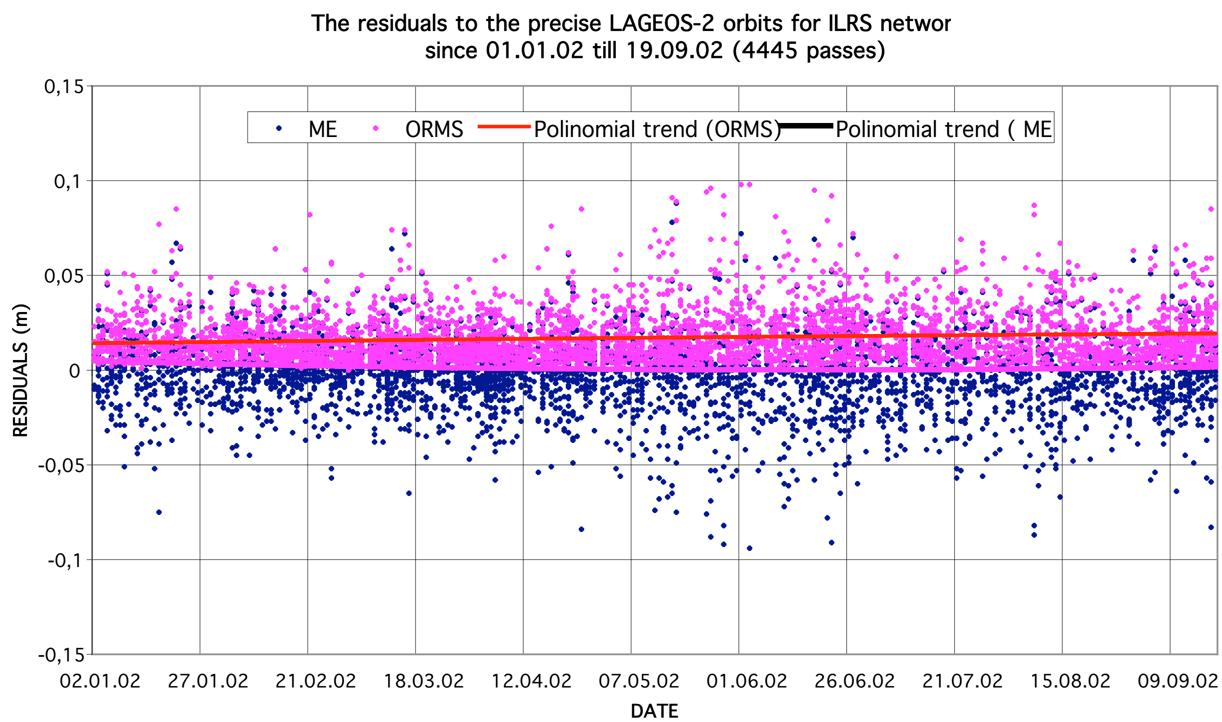


Figure 1. The residuals (ORMS and ME) to the precise LAGEOS-1 and LAGEOS-2 orbits for the all stations of the ILRS network (the time interval: 01/01/02 - 19/09/02; 5391 passes for LAGEOS-1 and 4445 passes for LAGEOS-2)

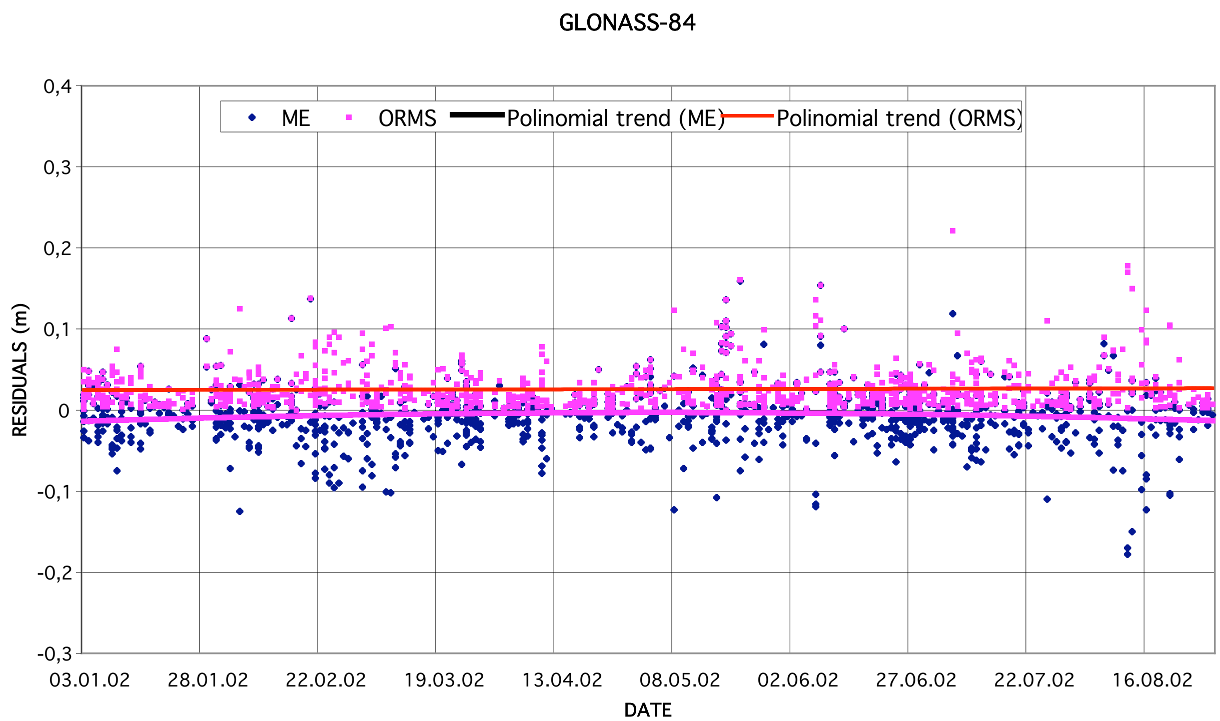


Figure 2. The residuals (ORMS and ME) to the precise GLONASS-84 orbits for the all stations of the ILRS network (the time interval: 03/01/02 - 30/08/02, 1091 passes)

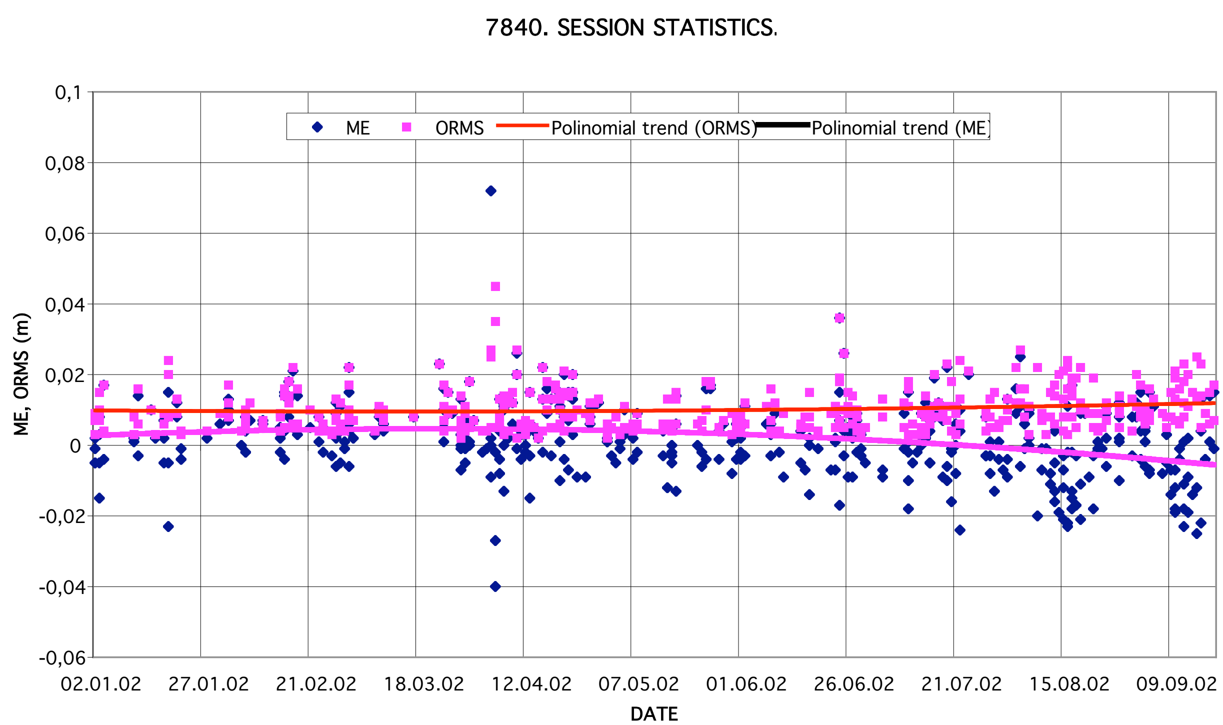


Figure 3. The residuals (ORMS and ME) to the precise LAGEOS-1 orbits for Herstmonceux station (the time interval: 02/01/02 - 19/09/02, 420 passes)