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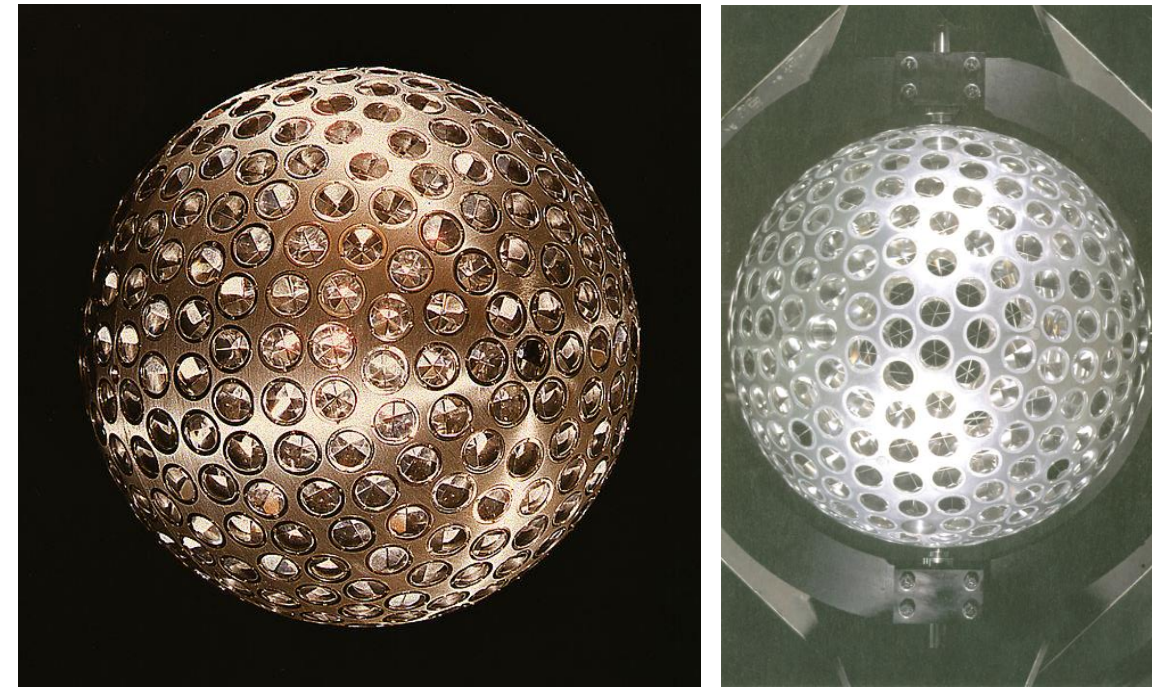
Abstract

Korea Astronomy and Space Science Institute (KASI) has developed two SLR systems. One of them was constructed and registered as the ILRS SLR tracking station SEJONG (SEJL, 73942601) in October 2015. The station SEJL was added to the EDC (EUROLAS Data Center) stations database in May 2016. Through the ILRS evaluation and validation process, it became an active station in July 2016 and has been providing SLR Normal Point (NP) data. KASI SLR team has performed SLR data process for LAGEOS-1/2 precise orbit determination (POD) and performance analysis of the station SEJL for normal operation. In this paper, the preliminary performance analysis for the station SEJL using LAGEOS-1/2 NP data is presented in terms of the POD RMS and station bias stability results.

Precise Orbit Determination of LAGEOS

LAGEOS-1 Geodetic Satellite

| | LAGEOS-1 | LAGEOS-2 |
|-----------------------|------------------|-------------------------|
| Sponsor: | United States | United States and Italy |
| Primary Applications: | geodesy | geodesy |
| COSPAR ID: | 7603901 | 9207002 |
| Launch Date: | May 4, 1976 | October 22, 1992 |
| RRA Diameter: | 60 cm | 60 cm |
| RRA Shape: | sphere | sphere |
| Reflectors: | 426 corner cubes | 426 corner cubes |
| Orbit: | circular | circular |
| Inclination: | 109.84 degrees | 52.64 degrees |
| Eccentricity: | 0.0045 | 0.0135 |
| Perigee: | 5,860 km | 5,620 km |
| Period: | 225 minutes | 223 minutes |
| Weight: | 406.965 Kg | 405.38 kg |



Precise Orbit Determination (POD) System Configuration & Strategy

Dynamic, measurement models/parameters, and reference frame for POD

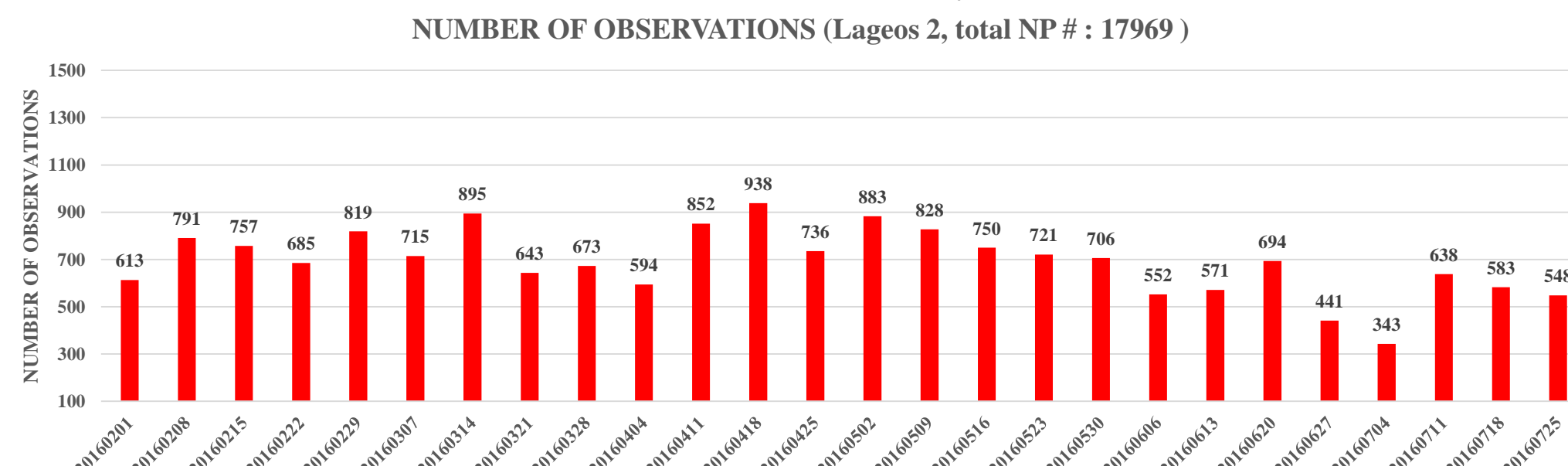
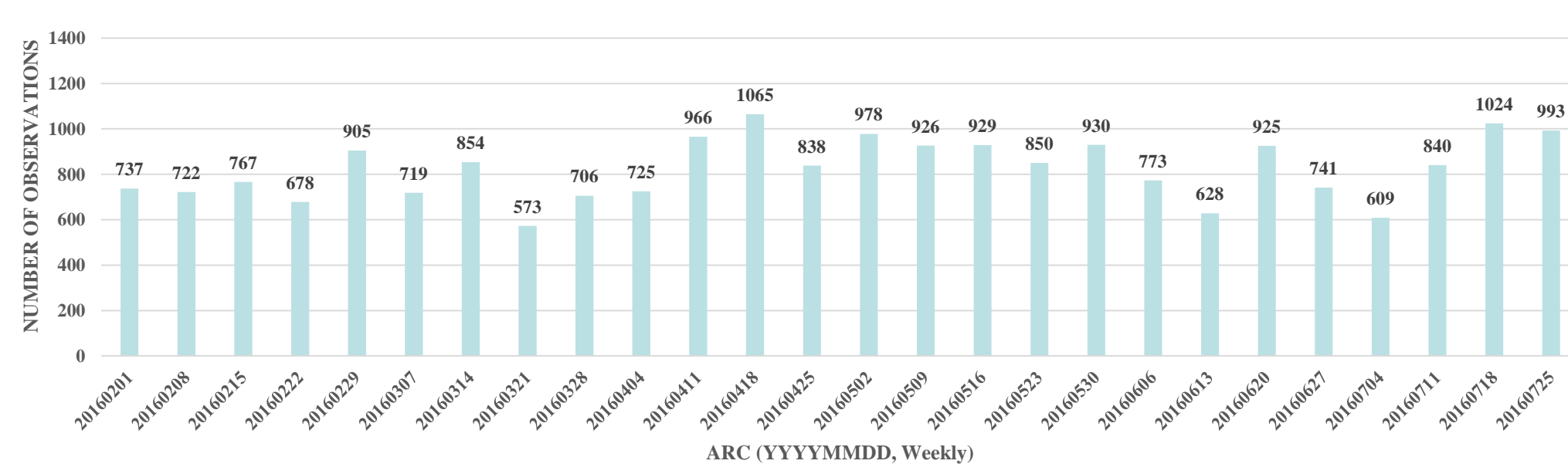
| | MEASUREMENT MODELS | ESTIMATED PARAMETERS (APRIORI VALUES & SIGMAS) |
|--------------------------------------|--|---|
| Measurement | Satellite Laser Ranging (SLR): round-trip travel time speed of light : 299792458 m/s wavelength : 532.0, 423.0, 847.0 & 694.3 nm elevation angle cutoff : 3 degrees weighting : 1.0 m to 10 m (3 levels) range biases : est/d for some stations time biases : modeled in some stations tropospheric biases : not modeled/estimated 3.5 sigma editing | weighted least-squares adjustment Orbital parameters Initial position and velocity: estimated for each satellite (unconstrained) Solar radiation pressure: CR kept fixed at 1.13 Empirical accelerations (unconstrained) a priori values: SLRF2008 a priori standard deviation: 1 m not estimated definition: x-pole, y-pole, (UT1-UTC) and LOD epoch: at noon of each day frequency: daily a priori values: IERS Bulletin A a priori standard deviation: 1 m equivalent for some (non-core) stations a priori value: 0 m a priori standard deviation: 100 m loose constraints (1 m, and equivalent for EOP) |
| Data editing | Mendes - Pavlis zenith delay model Mendes - Pavlis mapping function not modeled/estimated | Stations |
| Troposphere | Ionosphere scale: LET (TT time scale) effects: light time corrections | Troposphere EOP |
| Relativity | Satellite center of mass LAGEOS: 0.251 m (0.245 m for 7840) | Range biases |
| Other | Stanford ET corrections applied to 7840 ONLY | Constraints |
| | ORBIT MODELS | REFERENCE FRAMES |
| Geopotential | GGM02C (30by30) | Inertial J2000.0 |
| Third-body | 8 planets, JPL DE403 | Terrestrial SLRF2008 |
| Solar radiation | IERS Conventions 2003 | NUVEL-1A NNR (2nd source for station velocities) |
| Pressure | direct, albedo, earth thermal radiation : applied reemitted radiation: not applied | tidal uplift: IERS 2003 Conventions ocean loading: GOT4.7 atmospheric pressure loading: not modeled/estimated geocenter motion: not explicitly modeled/estimated geocenter tidal frequencies: applied pole tide: IERS 2003 Conventions (incl. ocean PT) origin: C(1,0) = C(1,1) = S(1,1) = 0 orientation: loose constraints (1 m equivalent) |
| Satellite thermal thrust | modeled | Interconnection Precession, Nutation : IAU 2000 |
| thermal thrust | LAGEOS: estimation of empirical | Celestial pole: modeled using IERS C04 values Relationship between UT1 and GMST: UT1-UTC estimated Earth Orientation Parameters: estimated Tidal variations in UT1 and PM: sub-daily not modeled |
| Tidal forces | solid earth tides : IERS 2003 Conventions model Ocean tides: Ray GOT4.7 | |
| Atmospheric gravitational attraction | not modeled/estimated | |
| Dynamic polar motion | applied | |
| Relativity | point-mass accelerations, Lense-Thirring effect, Coriolis force | |
| Numerical integration | Cowell 11th order predictor-corrector integration step: LAGEOS: 150 s | |

- NASA GSFC GEODYN II (S/W)
- Pass-by-Pass estimation using NP data (weekly based), convergence criteria for POD (< 2%)
 - Stations and EOP are fixed
 - Outlier for range bias statistics : |50mm|
- Measurement data : NP data from 14 ILRS stations (2016.02.01 - 2016.07.31)
 - McDonald(7080), Yarragadee(7090), Greenbelt(7105), Monument Peak(7110), Sejong(7394), Zimmerwald@532(7810), Mount Stromlo(7825), Simosato(7838), Graz(7839), Herstmonceux(7840), Potsdam(7841), Matera(7941), Grasse(7845), Wettzell(8834)
 - All stations are same weight for pass-by-pass estimation

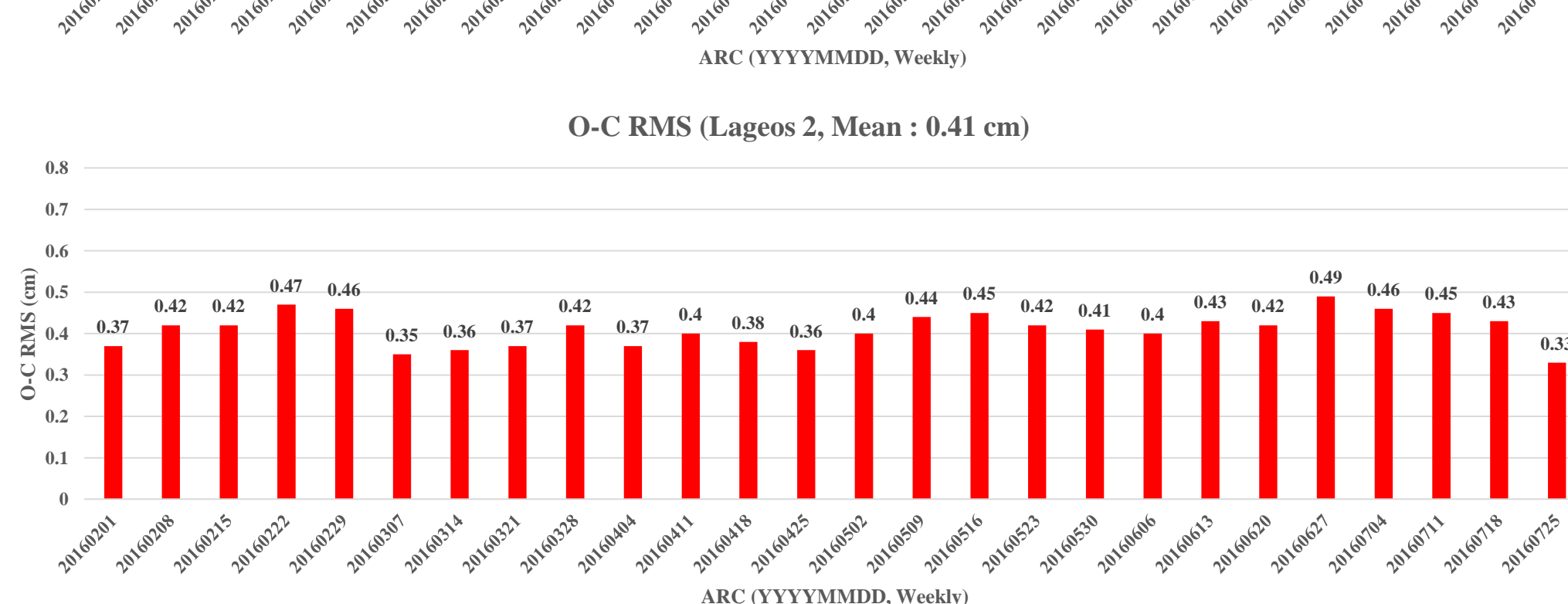
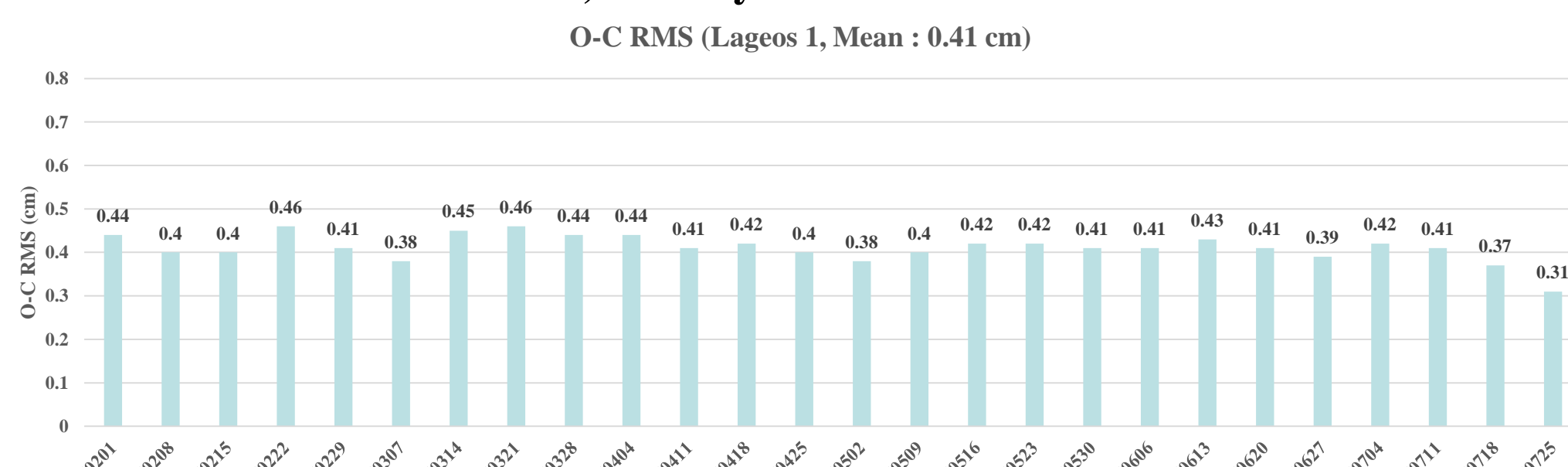
Precise Orbit Determination Results

POD Results of LAGEOS

- Total 39370 NP data (14 Stations, 2016.02.01-2016.07.31) used for POD (LAGEOS 1, 2)



Post-fit residual for LAGEOS, Pass-by-Pass Estimation



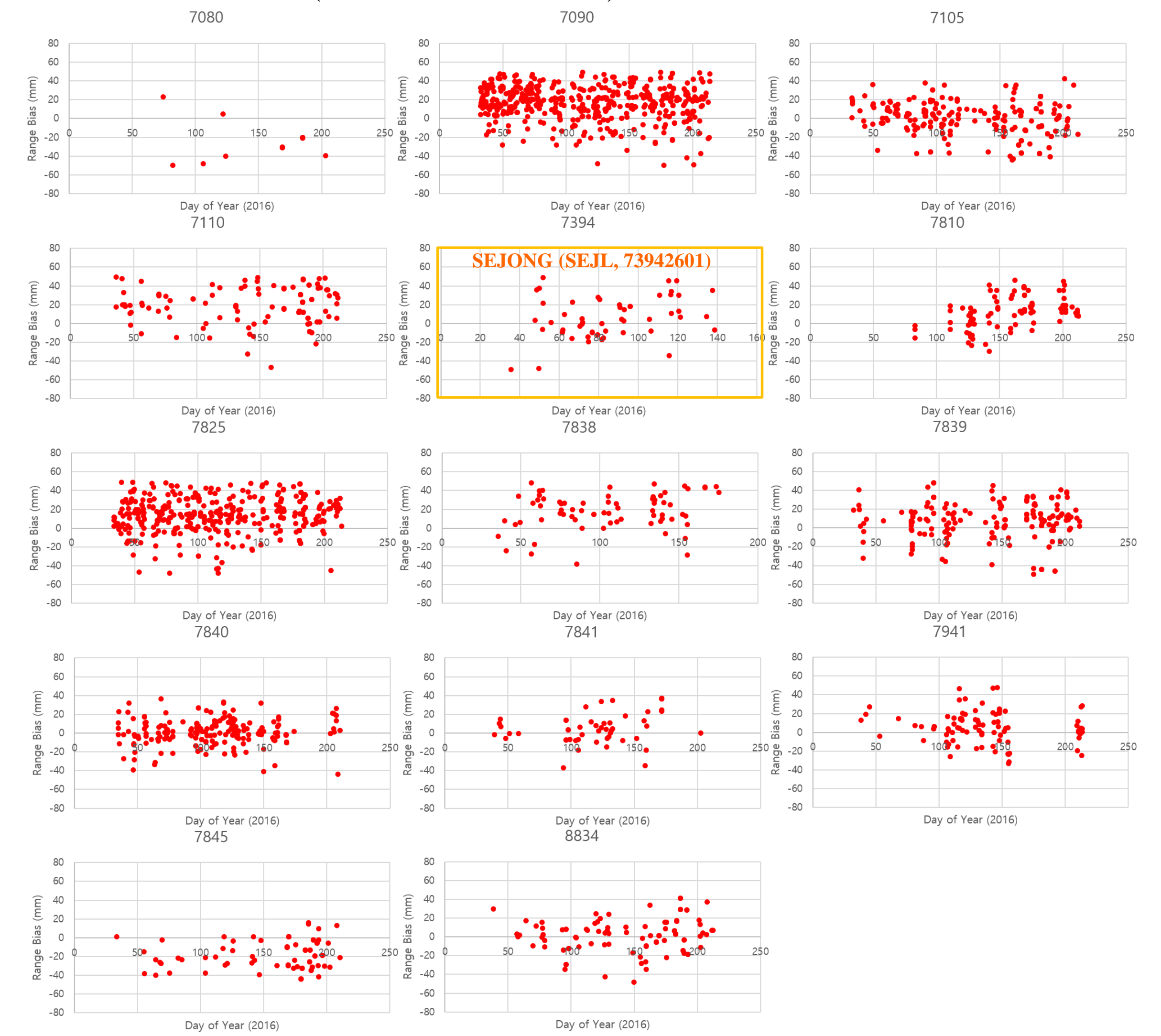
Range Bias Estimation Results

- Range Bias Estimation & Stability Analysis
 - Pass-by-Pass range bias estimation, stability (standard deviation) analysis of the station range bias
- Range Bias Estimation Results
 - LAGEOS 1 : Total 2751 Pass (2016.02.01 - 2016.07.31)



| Station# | Location | Mean (mm) | Bias Stability (mm) | Pass # |
|----------|---------------|-----------|---------------------|--------|
| 7080 | McDonald | -31.8 | 9.3 | 7 |
| 7090 | Yarragadee | 11.0 | 20.3 | 655 |
| 7105 | Greenbelt | -2.8 | 18.7 | 319 |
| 7110 | Monument Peak | 16.4 | 18.1 | 124 |
| 7394 | Sejong | 5.6 | 16.0 | 53 |
| 7810 | Zimmerwald | 6.3 | 17.3 | 169 |
| 7825 | Mt. Stromlo | 8.7 | 19.0 | 404 |
| 7838 | Simosato | 12.1 | 19.9 | 71 |
| 7839 | Graz | 4.5 | 16.7 | 187 |
| 7840 | Herstmonceux | 1.3 | 15.4 | 256 |
| 7841 | Potsdam | -5.3 | 17.0 | 146 |
| 7941 | Matera | 3.5 | 18.8 | 126 |
| 7845 | Grasse | -21.7 | 17.9 | 88 |
| 8834 | Wettzell | 4.4 | 15.1 | 146 |

LAGEOS 2 : Total 2300 Pass (2016.02.01 - 2016.07.31)



| Station# | Location | Mean (mm) | Bias stability (mm) | Pass # |
|----------|---------------|-----------|---------------------|--------|
| 7080 | McDonald | -25.4 | 19.7 | 14 |
| 7090 | Yarragadee | 16.8 | 17.6 | 545 |
| 7105 | Greenbelt | -0.6 | 18.0 | 236 |
| 7110 | Monument Peak | 18.9 | 18.9 | 120 |
| 7394 | Sejong | 6.2 | 22.1 | 52 |
| 7810 | Zimmerwald | 12.1 | 16.2 | 103 |
| 7825 | Mt. Stromlo | 14.3 | 18.4 | 425 |
| 7838 | Simosato | 18.8 | 19.2 | 73 |
| 7839 | Graz | 7.7 | 19.7 | 192 |
| 7840 | Herstmonceux | 0.9 | 13.7 | 204 |
| 7841 | Potsdam | 5.9 | 16.9 | 55 |
| 7941 | Matera | 5.0 | 16.5 | 95 |
| 7845 | Grasse | -18.4 | 15.8 | 83 |
| 8834 | Wettzell | 1.4 | 17.2 | 103 |

Summary and Future Work

- Summary
 - Pass-by-Pass Orbit Estimation for LAGEOS-1,-2 and Range Bias Analysis for ILRS stations
 - KASI SLR data processing - 14 ILRS stations including Sejong (7394, Korean SLR System) NP data
 - Preliminary performance analysis for the Sejong and ILRS stations using LAGEOS-1/2 NP data is presented in terms of the POD RMS and range bias stability results.
- Future Work
 - Long term SLR data processing
 - Considering more geodetic satellites/ILRS stations NP data
 - Global SLR Station Quality Assessment