Orbit Determination and Analysis for STSAT-2C

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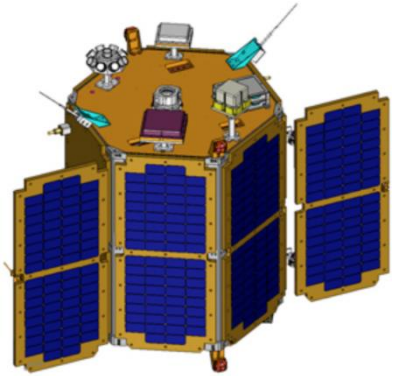
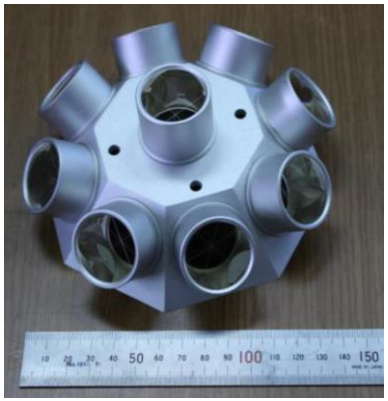
Outline

Overview of STSAT-2C (1/2)

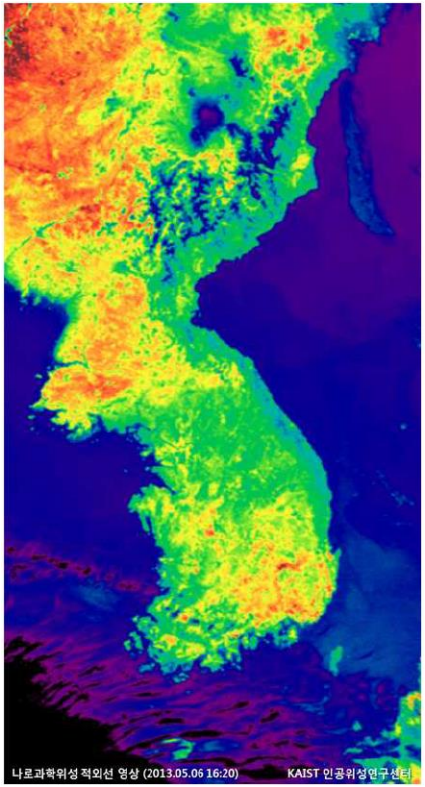
- **STSAT-2C**
  - Science and Technology SATellite 2C (Naro-science Satellite)
  - Launched by **KSLV-1**(Korea Space Launch Vehicle)
  - **First SLR Satellite of Korea**

Parameter	Specification
Sponsor	MEST, KAIST
Primary application	Spacecraft development
Primary SLR application	Precise orbit determination
Launch date	30 Jan. 2013
Expected life	1 year
Orbit	Elliptical
Inclination (deg)	80
Perigee (km)	300
Apogee (km)	1500
Weight (kg)	100





9 corner cubes LRA



IRA(Infra-Red Sensor)

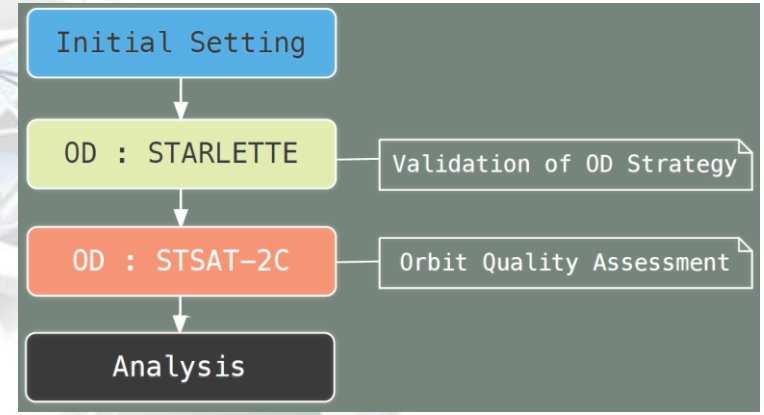
Overview of STSAT-2C (2/2)

- **ILRS Mission Supports**
  - SLR Tracking : 2013/03/29 ~
  - Tracking Stations : 12 Stations (~ 2013/10)
    - Changchun, Grasse, Graz, Greenbelt, Herstmonceux, Katzively, Kiev, Matera, Monument Peak, Mount Stromlo, Simeiz, Yarragadee
- **CPFs for STSAT-2C**
  - KAI (KAIST)
    - 2013/03/21 - Current
  - SGF/NSGF (NERC Space Geodesy Facility)
    - 2013/08/30 – 2013/09/25
- **Characteristics of STSAT-2C Orbit**
  - **Inaccurate CPF Information**
  - Source of OD : S-band Tracking
  - **Bad Observability**
    - Sparse and insufficient measurements condition

Poor Condition for Orbit Determination ➡ **Enhance OD accuracy using SLR**

Orbit Determination for STSAT-2C (1/5)

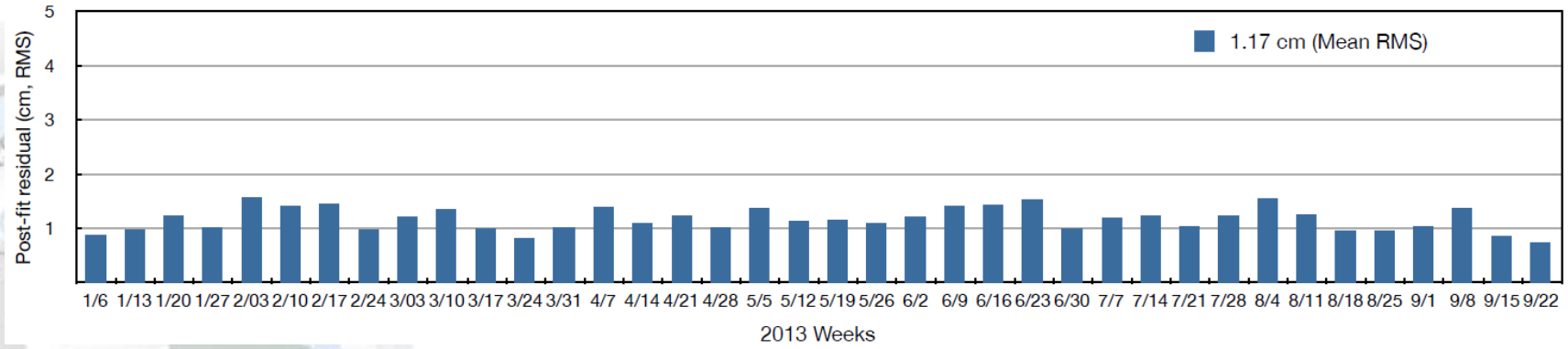
- **OD Strategy**
  - S/W : NASA/GSFC GEODYN II
  - Satellites : STSAT-2C
  - Estimation Parameters
    - Position/Velocity of satellite
    - Position/Velocity of stations
    - Drag coefficients C_D
    - General acceleration (GA) coefficients
    - Measurement biases (by pass)
  - Orbit Quality Assessment
    - Post-fit residual check
    - Orbit overlaps



Model/Parameter	Description
Earth gravity	JCET_RL04 180X180
Planetary ephemeris	JPL DE-1403
Precession/nutation	IAU2000
Atmospheric density	MSIS-86
Earth tide	IERS Conventions 2003
Ocean tide	GOT00.2
Solar radiation	Cannonball
Tropospheric refraction	Mendes-Pavlis
Station coordinates	ITRF 2005 SLR Rescaled
Numerical integration	11th Cowell method (step = 60s)

Orbit Determination for STSAT-2C (2/5)

- **OD Results of Starlette**
  - **<u>Validation Works for OD of STSAT-2C</u>**
  - Arc : 2013/01/06 – 2013/09/28 (Q1,Q2,Q3)
  - Weekly-based OD, 8h-based coefficients (C_D, GA) estimation
  - SLR Measurements : Normal Points by 23 ILRS Stations
    - KOML, SIML, RIGL, KTZL, MDOL, YARL, GODL, MONL, HA4T, THTL, CHAL, BEIL, SJUL, HARL, ZIML, SHA2, SFEL, STL3, GRZL, HERL, POT3, GRSM, MATM, WETL
  - Mean RMS of Post-fit Residuals : **<u>1.17 cm</u>**
    - 2013 Q1 : 1.16 cm
    - 2013 Q2 : 1.24 cm
    - 2013 Q3 : 1.11 cm



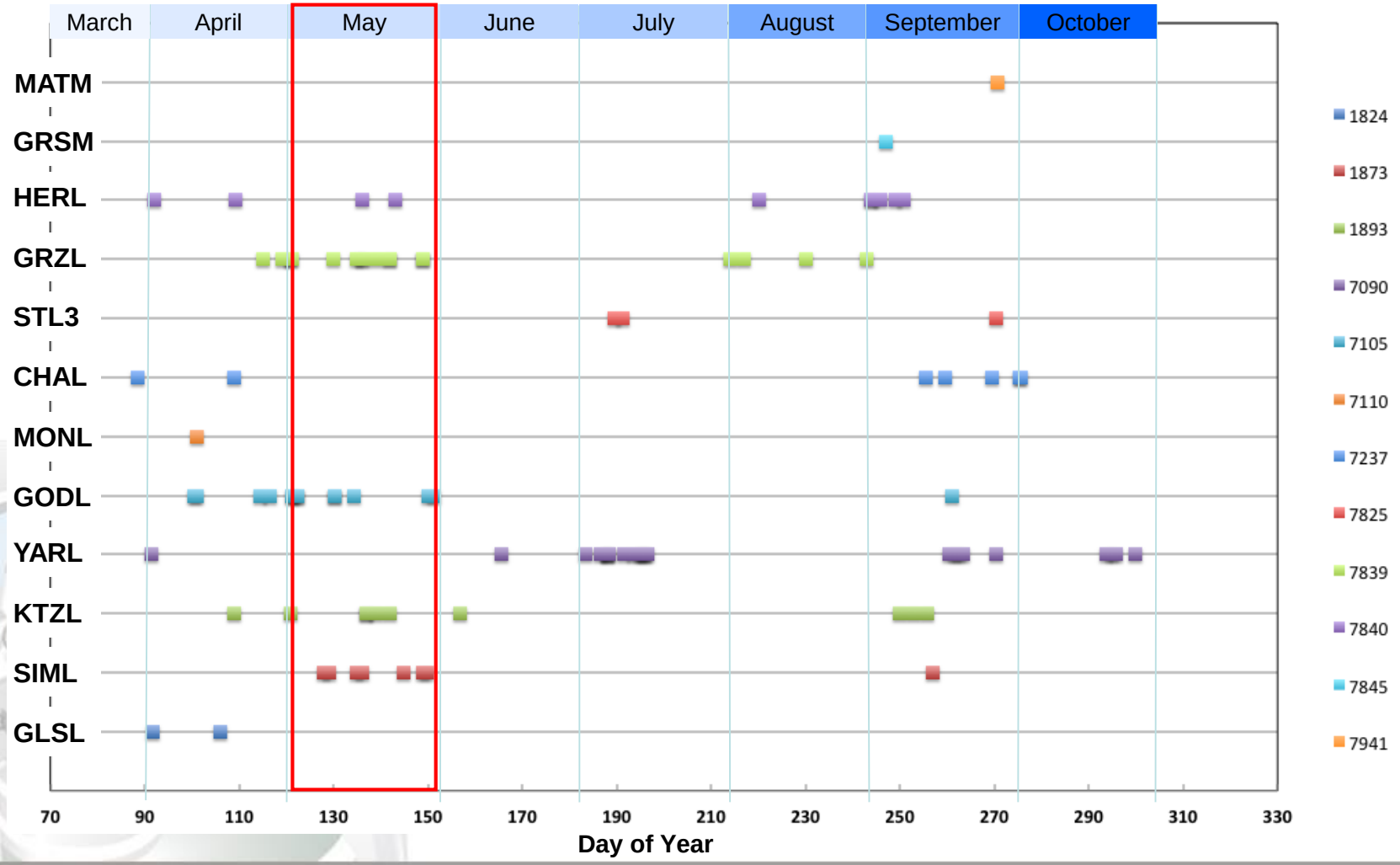
Orbit Determination for STSAT-2C (3/5)

- **Tracking Status of STSAT-2C (~2013/10)**

Station Name	Station	Start Date	End Date	No. Passes	No. NP
Changchun	7237	03/29 12:24:55	10/02 12:18:33	7	31
Grasse	7845	09/03 22:26:07	09/03 22:26:07	1	14
Graz	7839	04/25 00:52:24	08/30 21:00:56	17	246
Greenbelt	7105	04/10 09:33:33	09/18 00:14:12	14	229
Herstmonceux	7840	04/01 21:05:28	09/07 21:59:02	10	100
Katzively	1893	04/19 01:01:02	09/12 19:42:12	10	89
Kiev	1824	04/01 17:37:58	04/16 00:58:41	2	10
Matera	7941	09/27 17:56:31	09/27 17:56:31	1	10
Monument Peak	7110	04/11 02:12:54	04/11 02:12:54	1	13
Mount Stromlo	7825	07/08 09:20:09	09/27 08:57:07	3	11
Simeiz	1873	05/08 00:57:46	09/13 19:34:57	8	118
Yarragadee	7090	04/01 12:10:50	10/26 20:01:08	24	255

Orbit Determination for STSAT-2C (4/5)

- **Tracking Status of STSAT-2C (~2013/10)**

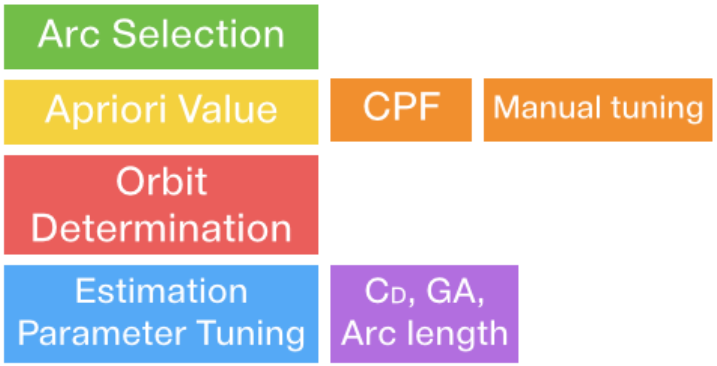


Orbit Determination for STSAT-2C (5/5)

- **The Configurations of OD for STSAT-2C**
  - Arc : 2013/05/01 – 2013/05/18
    - Selection : 2 passes per day at least
    - **Arc of length : determined for each arc**

Arc	Start date and time	End Date and time	#NP	Arc length	Station
1	05/01 00:51:28	05/02 07:53:54	96	2 Days	7105,7839
2	05/10 00:47:52	05/10 07:54:19	57	1 Day	7105,7839
3	05/14 06:01:08	05/18 23:08:03	172	5 Day	1873,1893,7105,7839,7840

  - 8h-based C_D , 24-based GA coefficients estimation
  - SLR Measurements : 325 NPs by 5 ILRS Stations
    - GRZL, GODL, SIML, HERL, KTZL
  - No Data Editing
  - Observation Weighting
    - Same as Starlette
  - Pass by Pass Bias Estimation
  - **A priori Value of Satellite Orbit**
    - First arc : **CPF + Manual tuning**
    - Others : Prediction from previous arc

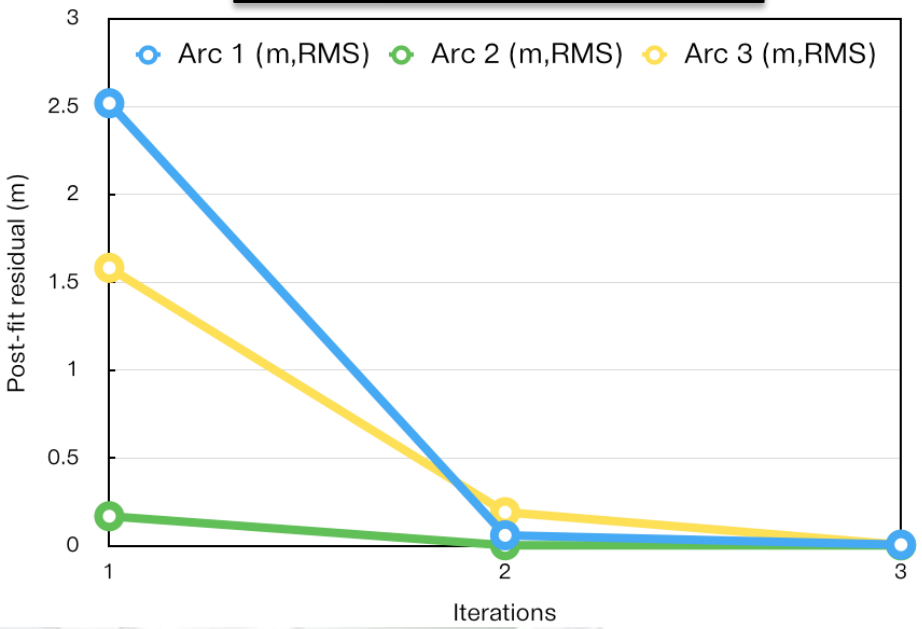


Orbit Quality Assessment (1/5)

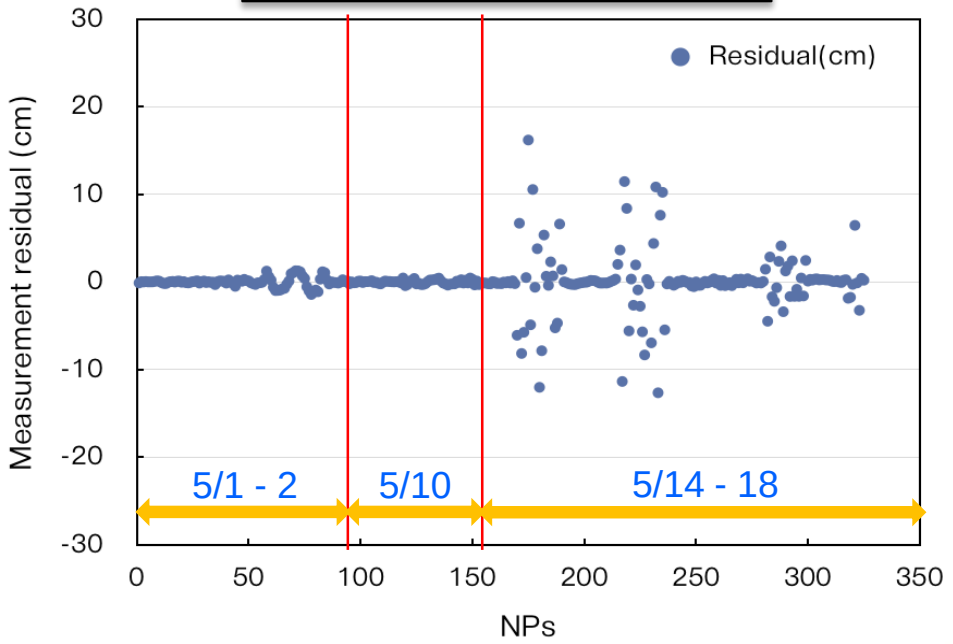
- **Orbit Quality Assessment 1 : Post-fit residuals**
  - RMS of Post-fit Residual

Arc	Weighted-RMS (cm)
05/01 – 05/02	0.71
05/10	0.30
05/14 – 05/18	0.60

Convergence Characteristics

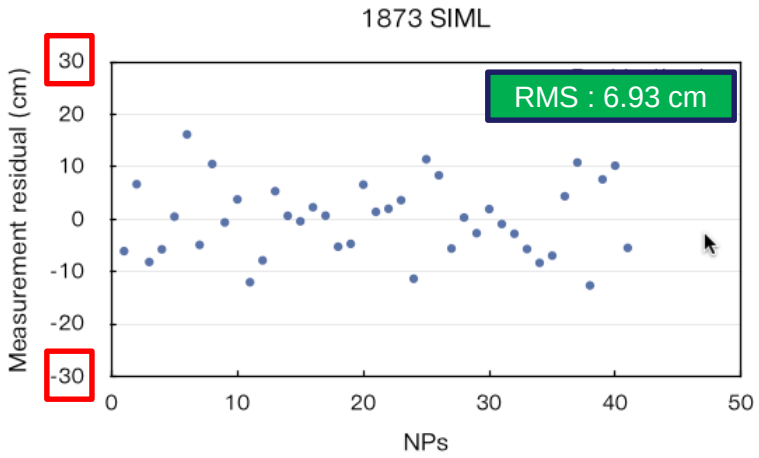


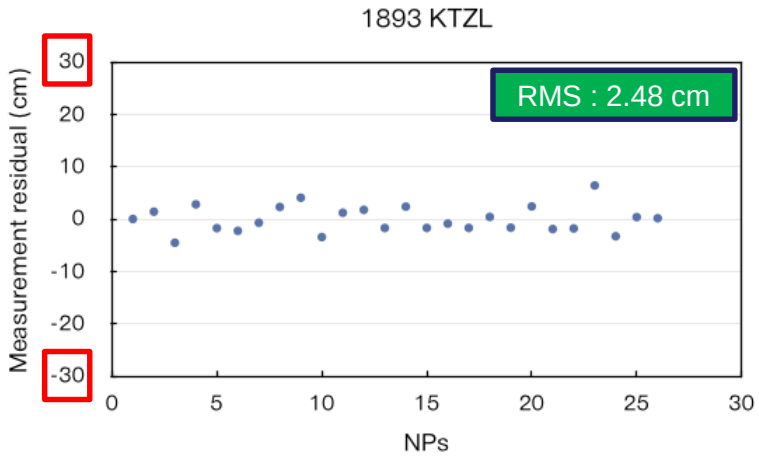
Measurement Residuals

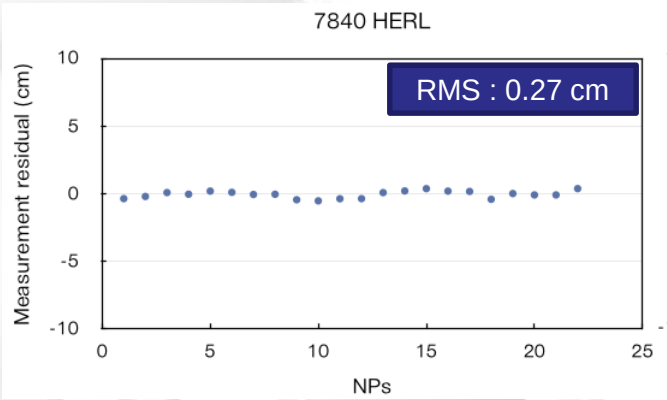


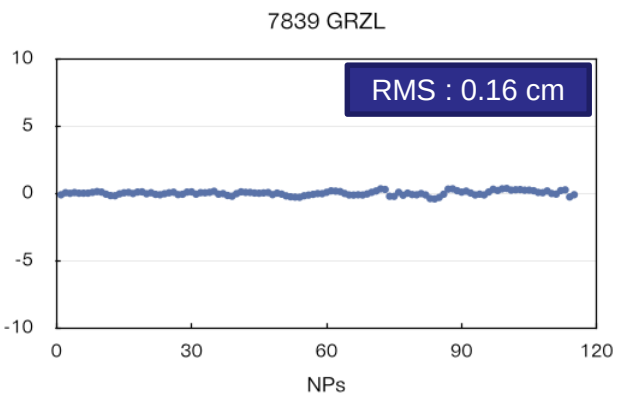
Orbit Quality Assessment (2/5)

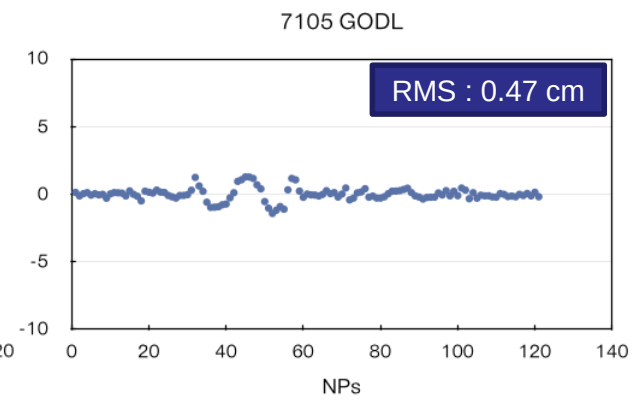
- **Orbit Quality Assessment 1 (Post-fit residual)**
  - Measurement residuals of each station (No weighting)





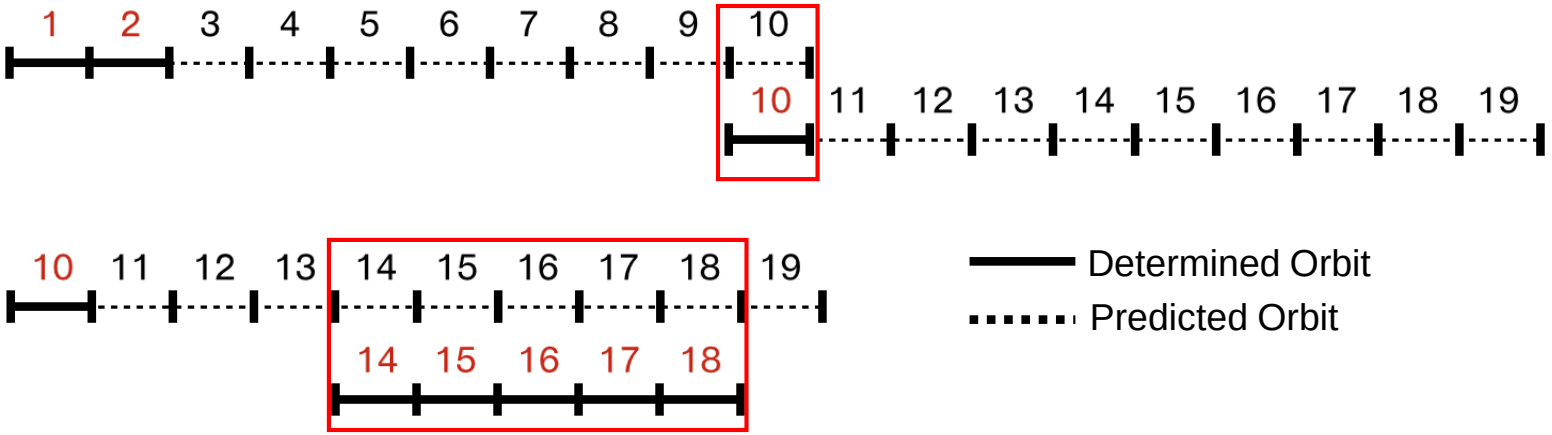




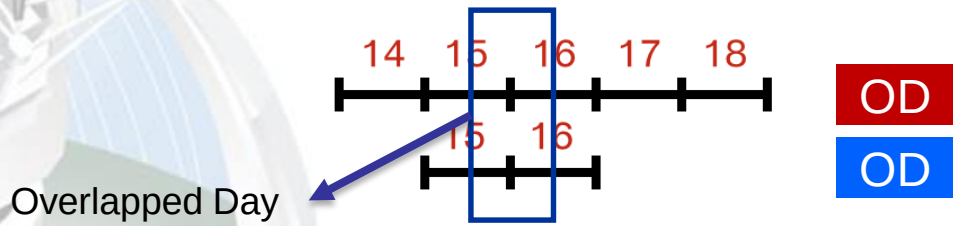


Orbit Quality Assessment (3/5)

- **Orbit Quality Assessment 2 (Orbit Overlaps)**
  - General Orbit Overlaps Comparison



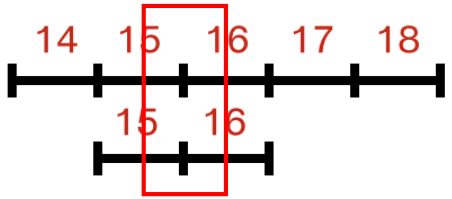
    - No overlap period
    - Low accuracy of period by orbit prediction
  - Orbit Overlaps

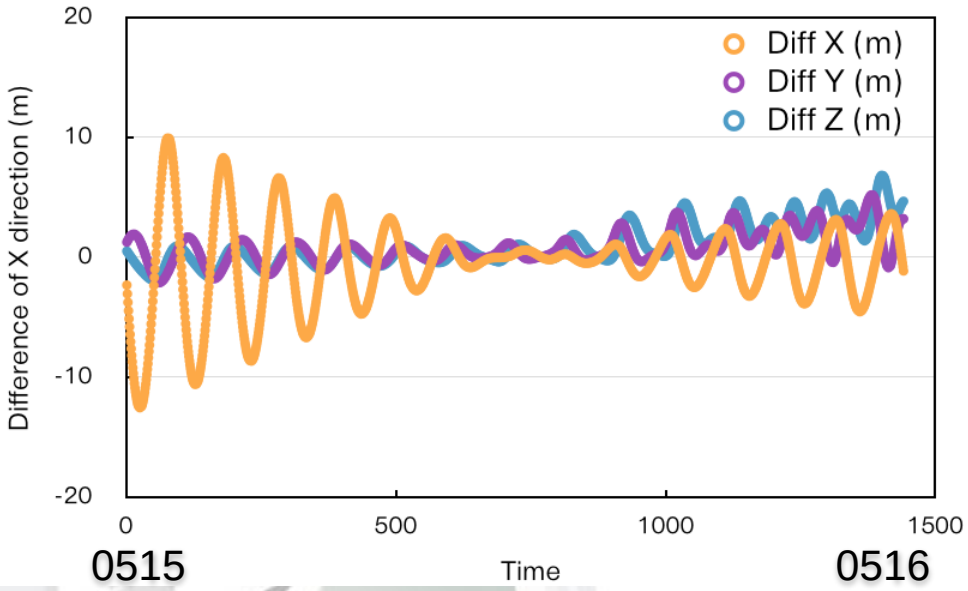


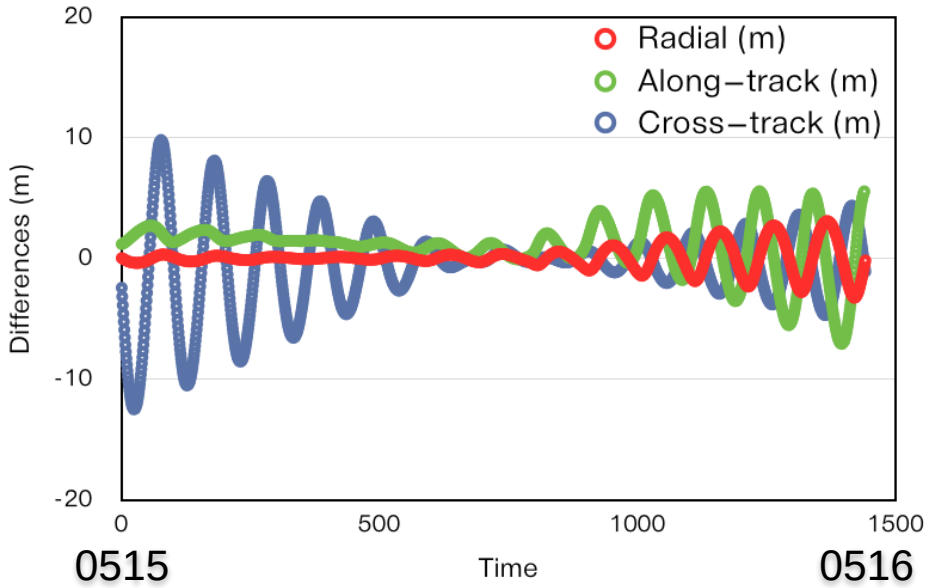
Orbit Quality Assessment (4/5)

- **Orbit Quality Assessment 2 (Orbit Overlaps)**
  - Overlapped Day (5/15 12h – 5/16 12h)

Arc	Post-fit residual (cm)
05/14 – 18	0.60
05/15 – 16	0.59



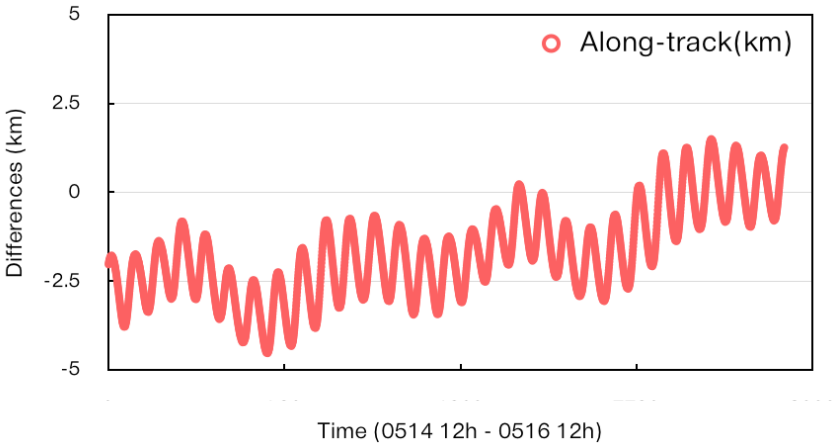


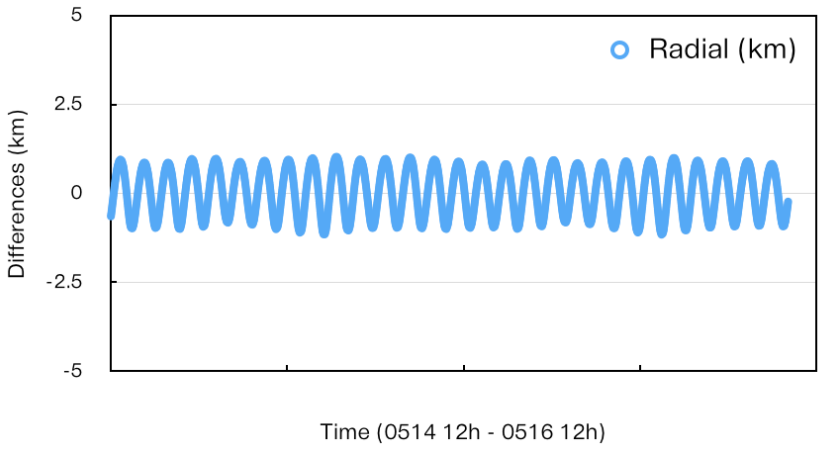


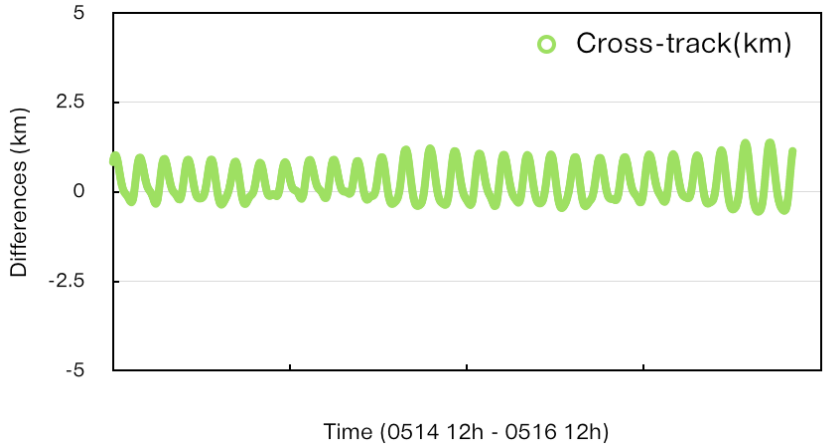
Orbit Quality Assessment (5/5)

- **Orbit Comparison (OD Results and CPF)**
  - OD Results (5/14 – 5/18)
  - CPF by KAI (5/14 – 5/16)
    - Stsat2c_cpf_130514_6341.kai
  - Period for Comparison
    - 5/14 12h – 5/16 12h

Direction	Differences (km, RMS)
Radial	1.675 km
Along-track	5.290 km
Cross-track	1.329 km





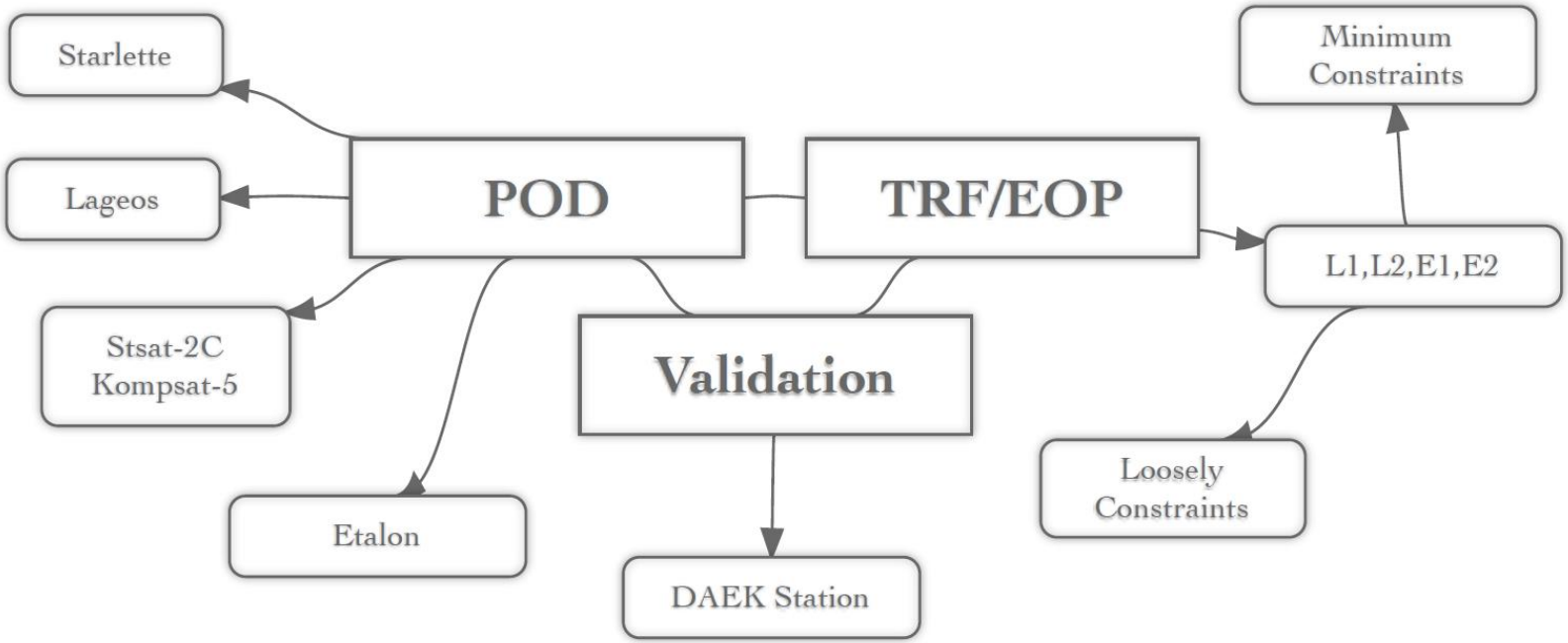


Summary

- **Characteristics of STSAT-2C Orbit**
  - Inaccurate CPF Information & Bad Observability
  - Poor Conditions for Orbit Determination
- **Orbit Determination for STSAT-2C**
  - S/W : NASA/GSFC GEODYN II
  - Arc : 3 Arcs (2013/05/01 – 05/18)
  - A Priori Value of Initial Orbit : CPF + Manual Tuning
- **Orbit Quality Assessment for STSAT-2C**
  - Post-fit residual : < 1 cm
  - Orbit Overlaps : < 10 m
  - Orbit Comparison
    - Differences between OD results and CPF : < 5 km

Future Works

- **Better CPF and More Tracking for STSAT-2C**
  - Long-term Orbit Analysis
  - Generation Enhanced CPF by Orbit Determination Using SLR
  - More Tracking by Global Stations
  - Support to Tracking Korea's SLR Satellites by DAEK Station
- **SLR Data Processing of KASI & DAEK Station**



Thanks for your attention !!!