Orbit determination and prediction accuracy of TOPEX with a priori solar radiation force derived from photometrics and laser ranging data

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Australian Government
Department of Industry, Innovation and Science
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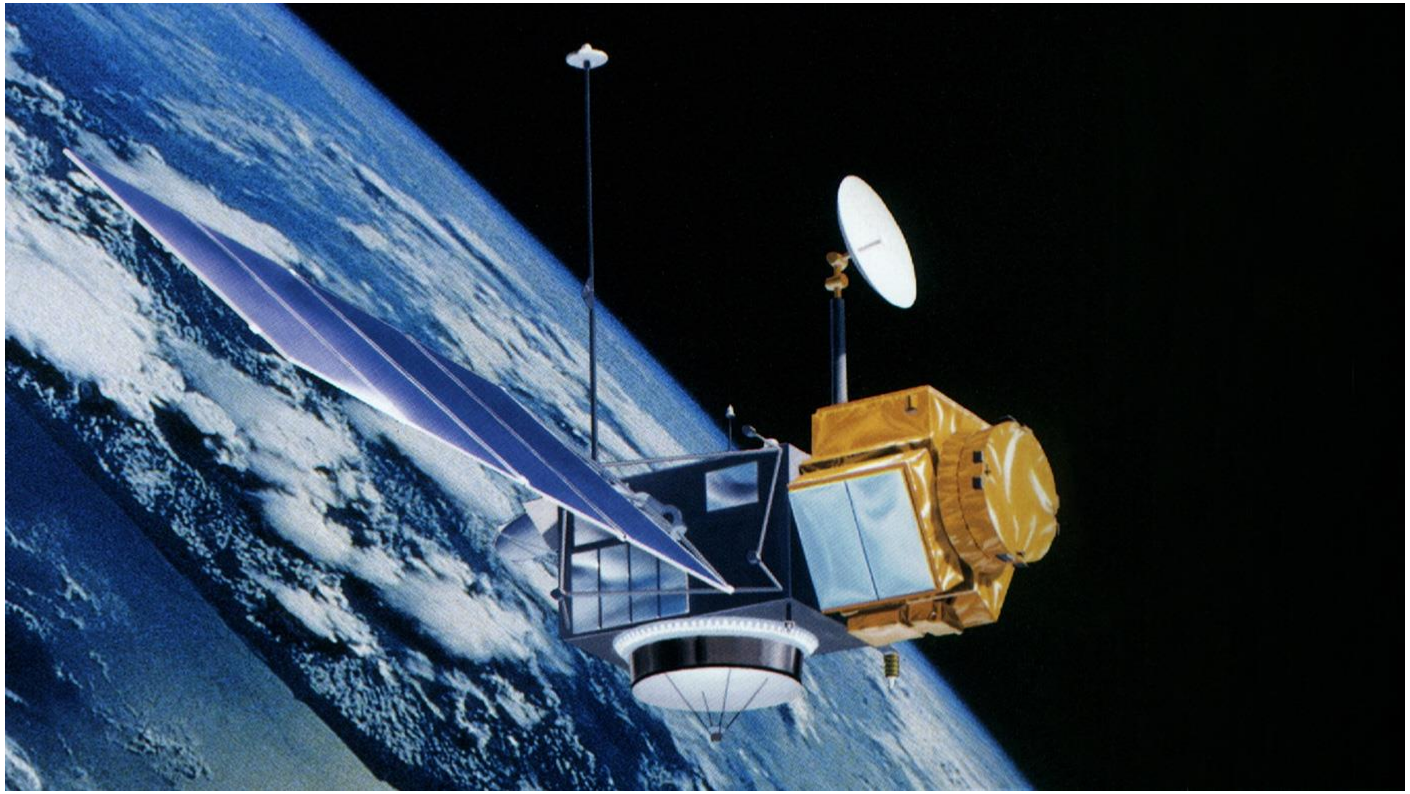
Revisiting the Topex/Poseidon (T/P) Mission



- T/P was a joint mission between NASA and CNES to map ocean surface topography
- Launched in 1992, T/P was one of the first oceanographic satellite which revolutionized oceanography
- A malfunctioning pitch momentum wheel lead to its mission ending in 2006

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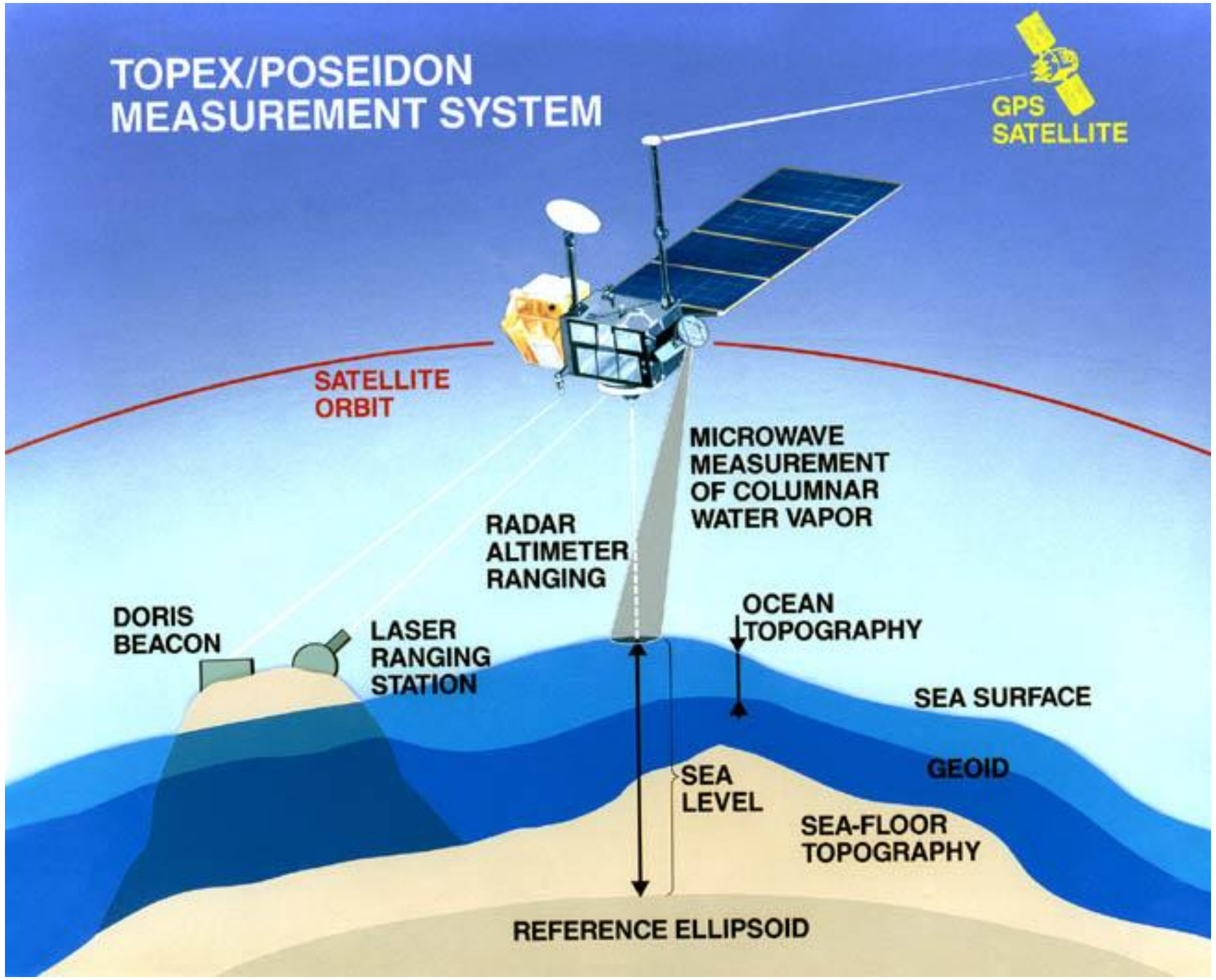


- From 1336 km above Earth T/P measured ocean height to 4-5 centimetres
- Achieved through subtracting Radar Altimeter ranging with T/P altitude determined via POD
- Primary tracking system consisted of 10-20 SLR stations and DORIS tracking data using 50 ground-based beacons measuring Doppler shift
- NASA (experimental) GPS receiver also provided continuous tracking

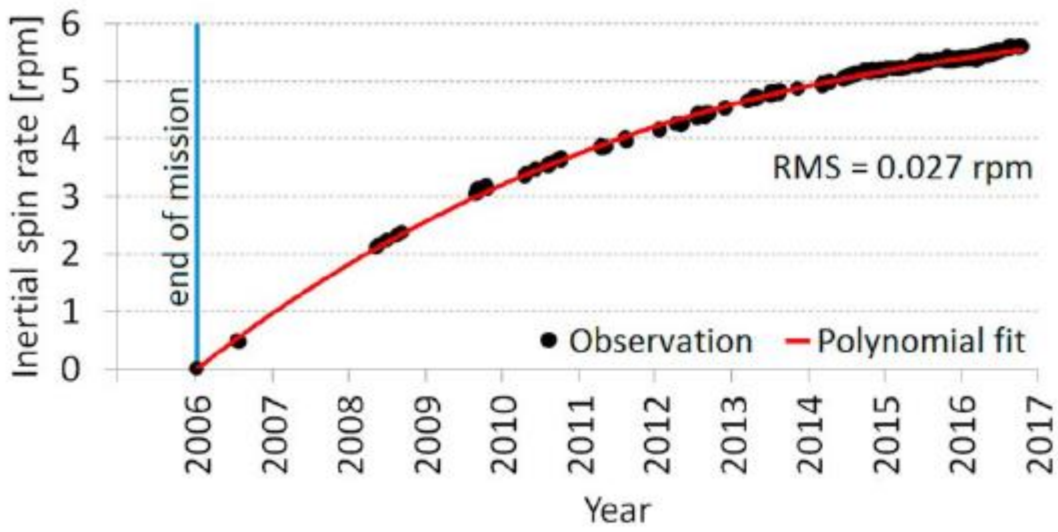
https://web.archive.org/web/20090730205052/http://sealevel.jpl.nasa.gov/technology/technology.html

SLR and Light Curve measurements of Defunct T/P

- SLR tracking of defunct T/P was reinitiated in 2014 by the Graz SLR station (Austria)
- Followed by the (ILRS) Space Debris Study Group in 2015 (data is publically available on the Graz Space Debris Server ftp://sddis.oeaw.ac.at)
- The Odessa photometric system has acquired light curves of T/P since it was decommissioned
- The Odessa system measures the intensity of the reflected sunlight from the satellite surfaces towards the ground station

Spin-Up of T/P

- During its mission, T/P was Nadir stabilized
- However, by combining SLR ranging and photometric data collected by the Odessa system, D. Kucharski et al., determined that T/P is gaining rotational energy



KUCHARSKI ET AL., SPIN-UP OF TOPEX, AGU 2017

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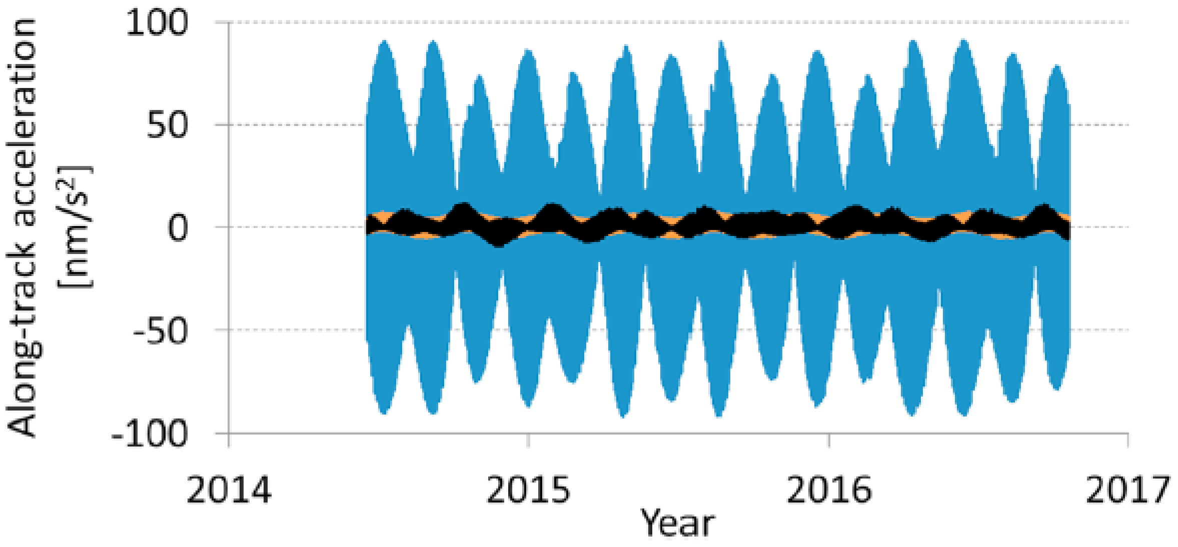
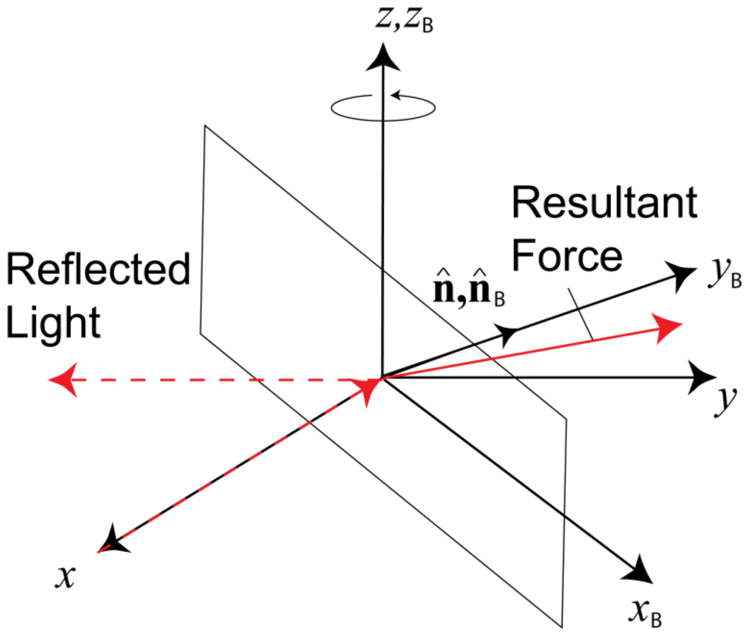
What is driving the spin-up of T/P?

- The mechanism driving the spin-up was demonstrated to be due to torques arising from solar flux interacting with the surfaces of T/P
- The BDRF model used to calculated the solar radiation force and hence the torque was that of Milani et al (1987):

$$d\bar{F} = -\frac{\Phi}{c}\left[(1-\rho)\hat{\boldsymbol{R}} + 2\left(\frac{\delta}{3} + \rho\cos\beta\right)\hat{\boldsymbol{n}}\right] dS|\cos\beta|$$



KUCHARSKI ET AL., SPIN-UP OF TOPEX, AGU 2017



- Light blue - direct solar radiation pressure – total force varies between 65 – 228 μN
- Dark blue and orange are the earth albedo and irradiation forces, respectively

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Orbit Determination Settings and Forces

OD/OP spans:

- 10 days OD, 7 days OP
  (between 02 Nov- 07 Dec 2015)

Integrator

- 11th order Störmer-Cowell predictor-corrector
- Step-Size: 30 Seconds

Forces

- Earth Gravity (70×70 EGM 96)
- Earth Tides
- Lunisolar & planetary gravity (JPL Planetary Ephemeris DE200)
- General relativity
- Drag Density Model (NRLMSIS-00)

Apply atmospheric drag (cannon-ball model):

$$\boldsymbol{a}_{drag} = -\frac{1}{2} C_D \frac{A_D}{m} \rho {v_{rel}}^2 \frac{\boldsymbol{v}_{rel}}{|\boldsymbol{v}_{rel}|}$$

Apply cannon-ball solar radiation pressure model - as benchmark:

$$\boldsymbol{a}_{SRP}^{(sph)} = -\nu C_R \frac{A_\odot}{m} p_{srp} \frac{\boldsymbol{r}_{\oplus\odot}}{|\boldsymbol{r}_{\oplus\odot}|}$$

Apply 3-constant solar radiation pressure model:

$$\boldsymbol{a}_{SRP}^{(3-C)} = -\nu \frac{p_{SRP}}{m} \left[A_1 \widehat{\boldsymbol{U}} + A_2 \widehat{\boldsymbol{V}} + A_3 \widehat{\boldsymbol{W}}\right]$$

where

$$\widehat{\boldsymbol{U}} = -\frac{\boldsymbol{r}_\odot}{|\boldsymbol{r}_\odot|}, \widehat{\boldsymbol{W}} = \cos\boldsymbol{\phi}\, \widehat{\boldsymbol{Z}} - \sin\boldsymbol{\phi}\, \widehat{\boldsymbol{Z}} \times \widehat{\boldsymbol{U}}, \widehat{\boldsymbol{V}} = \widehat{\boldsymbol{W}} \times \widehat{\boldsymbol{U}}$$

and

$$A_1 = \overline{\boldsymbol{a}}_{srp}^{(spin)} \cdot \widehat{\boldsymbol{U}}, A_2 = \overline{\boldsymbol{a}}_{srp}^{(spin)} \cdot \widehat{\boldsymbol{V}}, A_3 = \overline{\boldsymbol{a}}_{srp}^{(spin)} \cdot \widehat{\boldsymbol{W}}$$

J. W. McMahon & D. J. Scheeres, JGCD. 38-8, 2015

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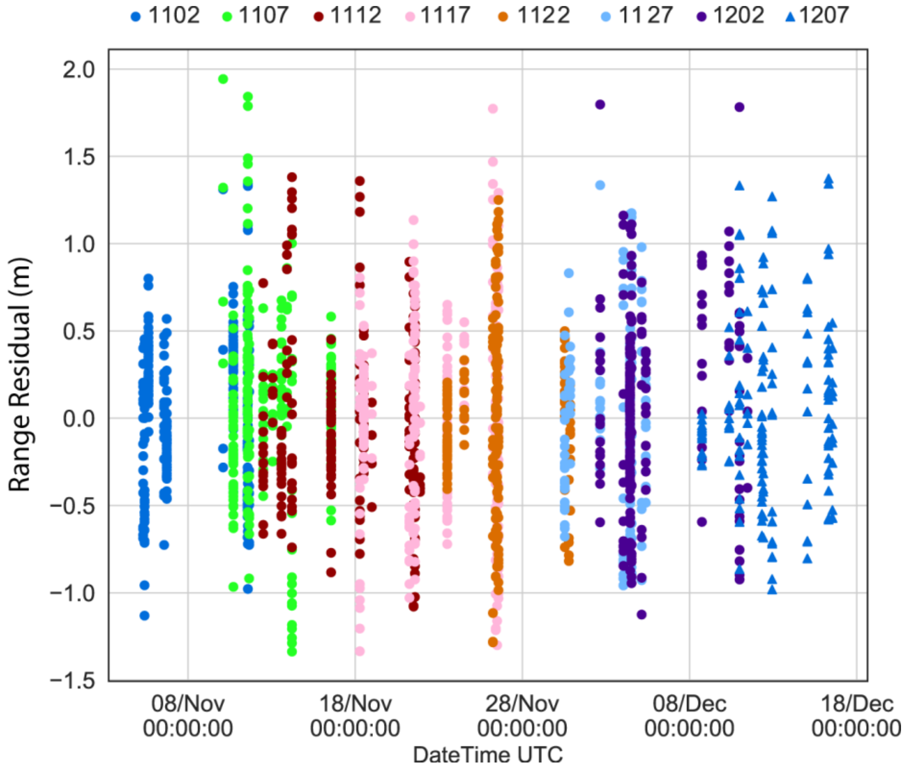
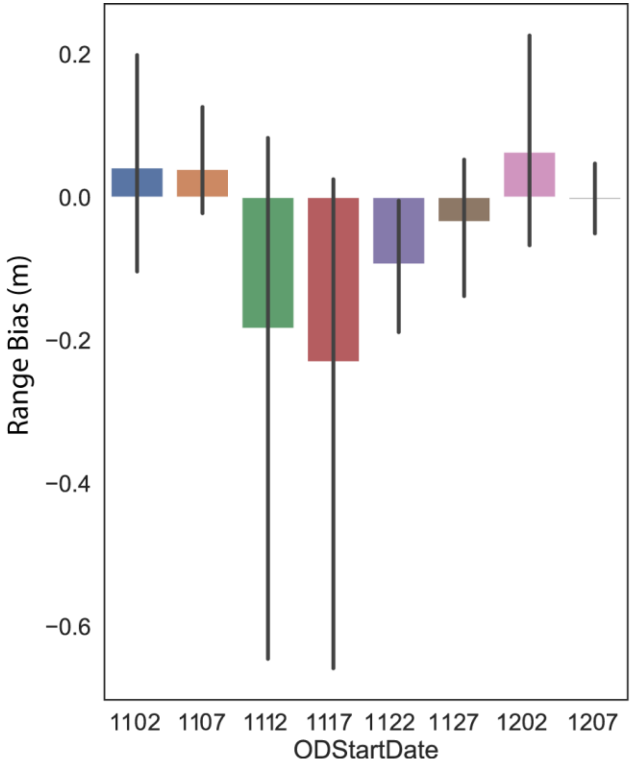
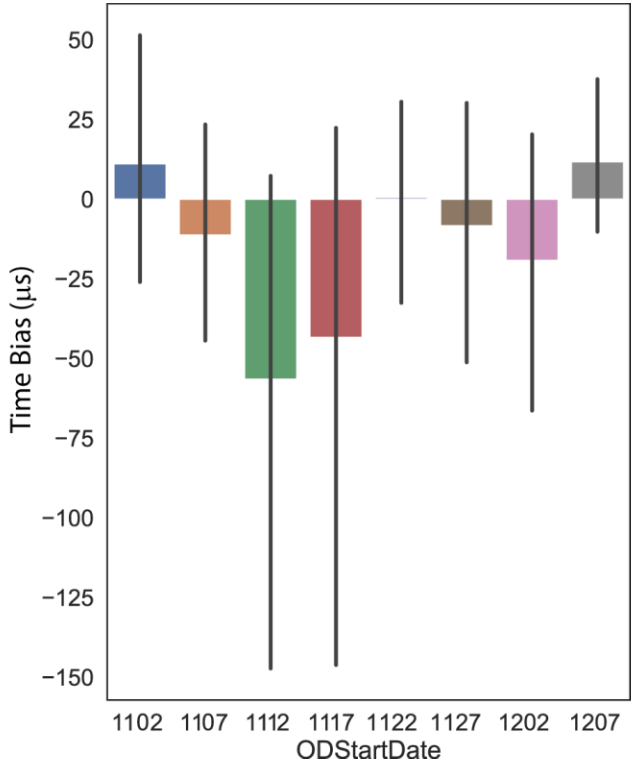
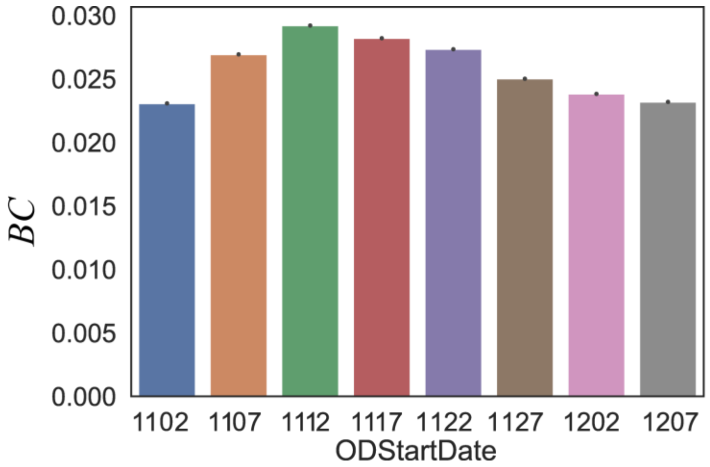
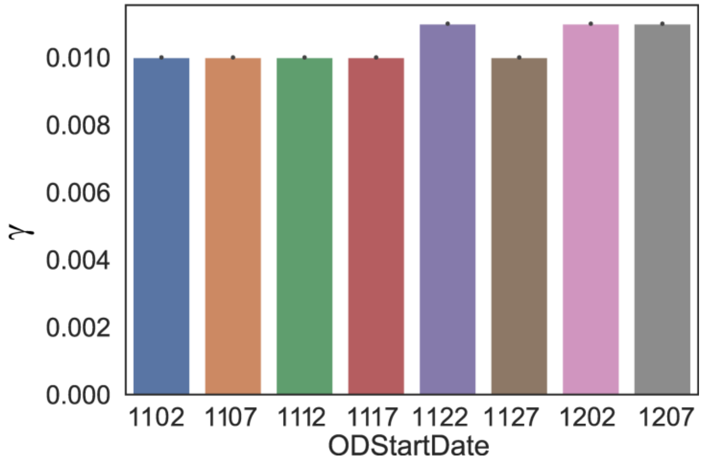
Orbit Determination Results – Cannon Ball Model











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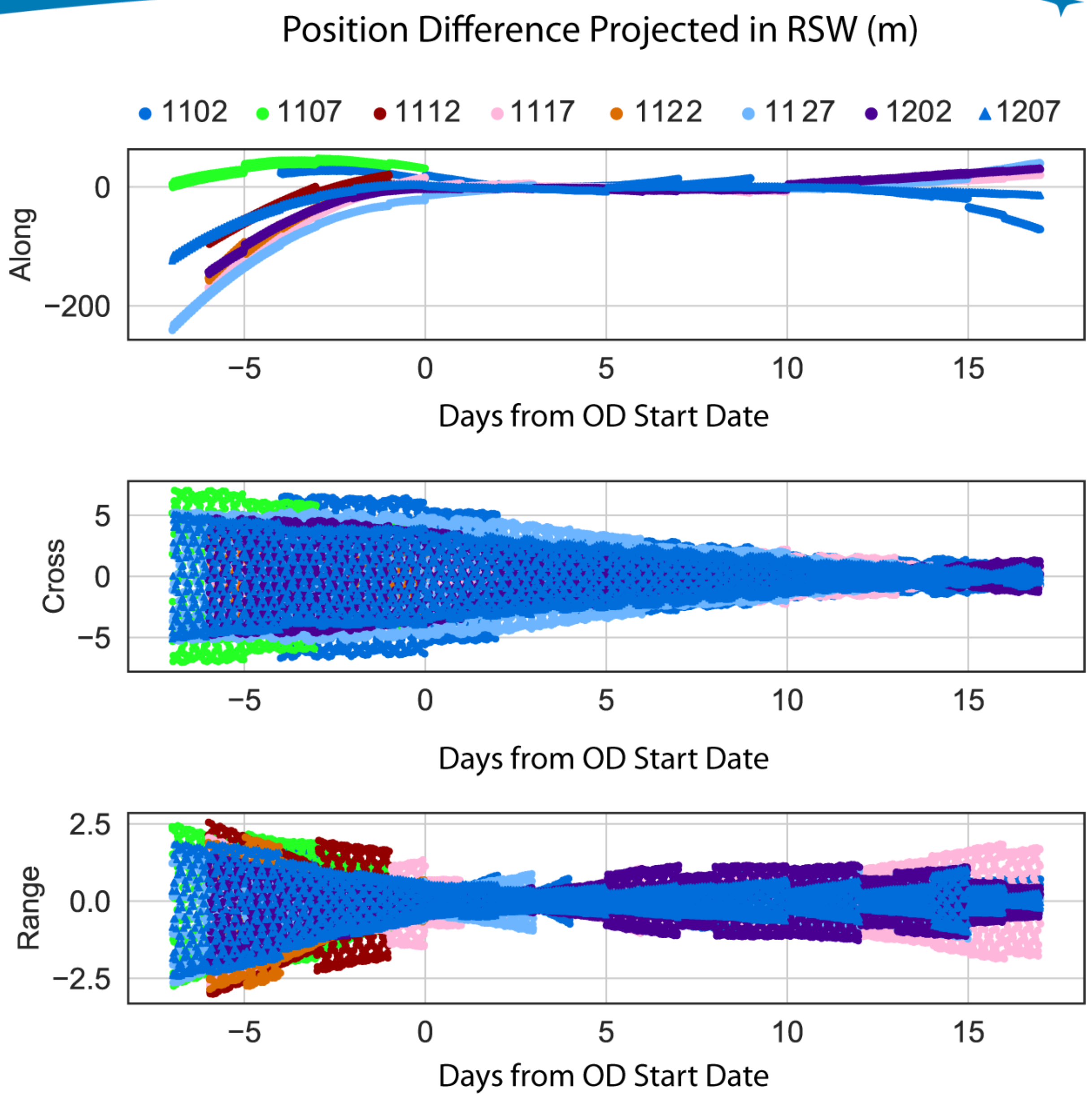
Orbit Prediction Accuracy – Cannon Ball Model



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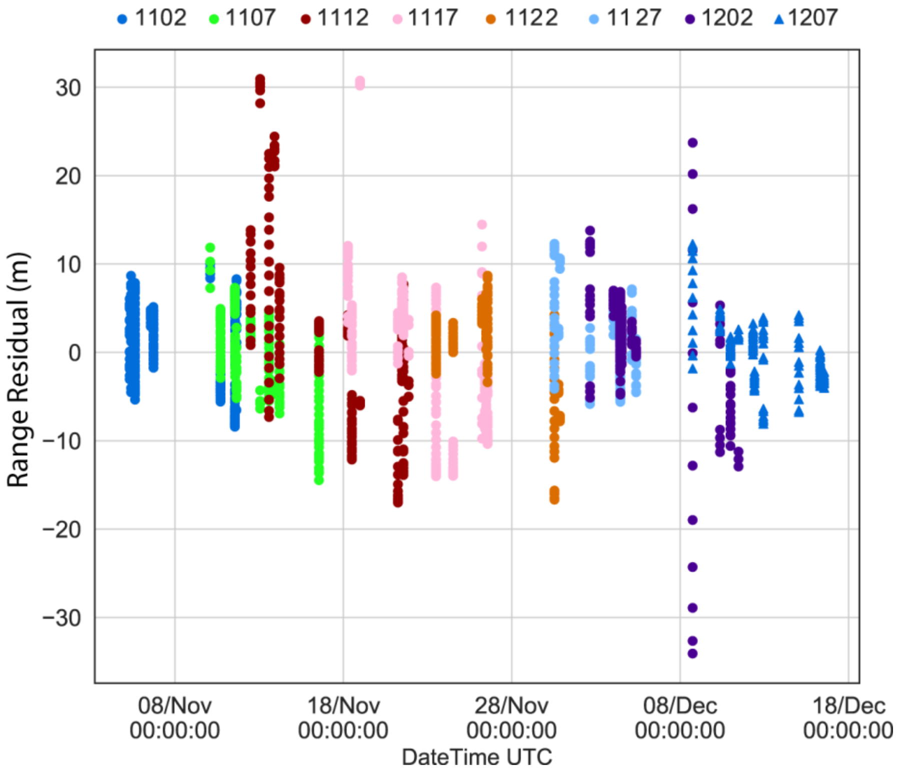
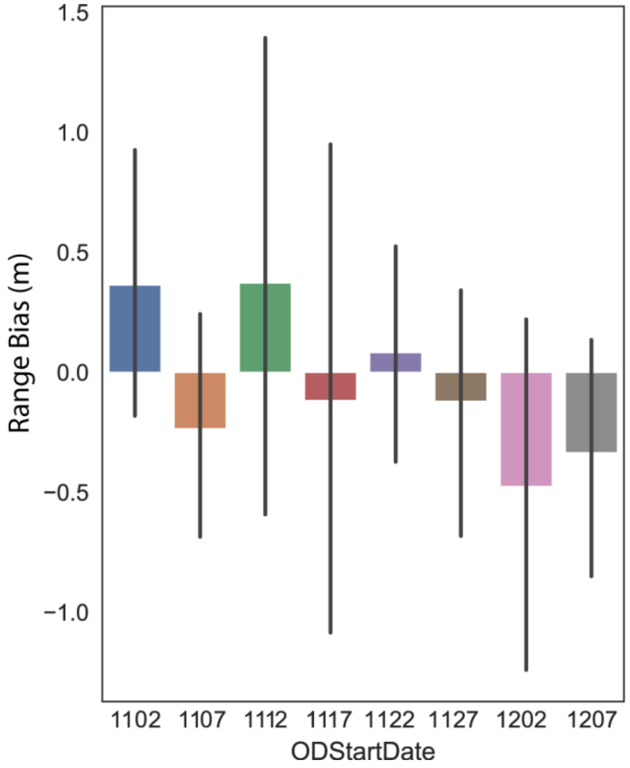
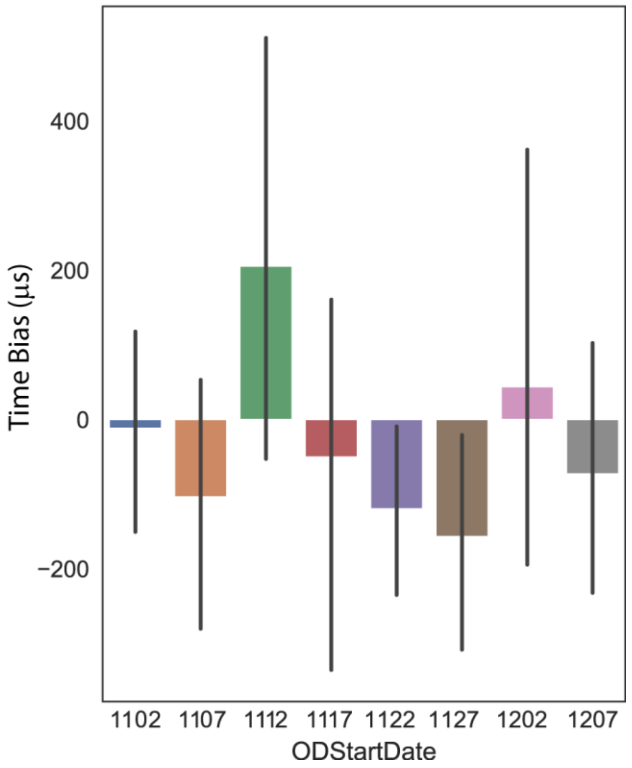
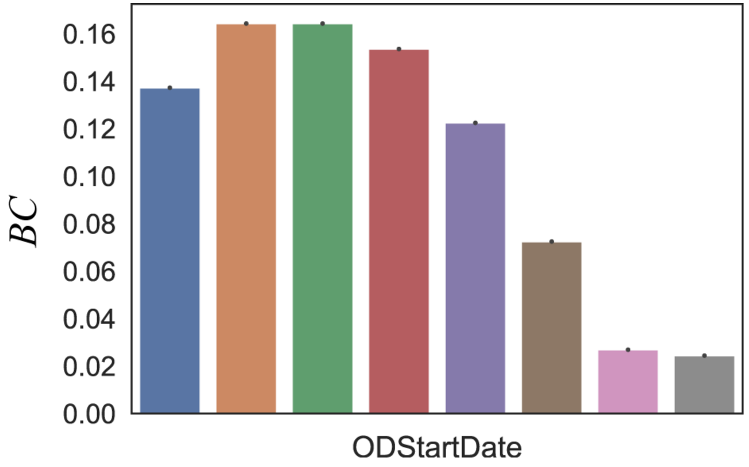
Orbit Determination Results – 3-Constant Model

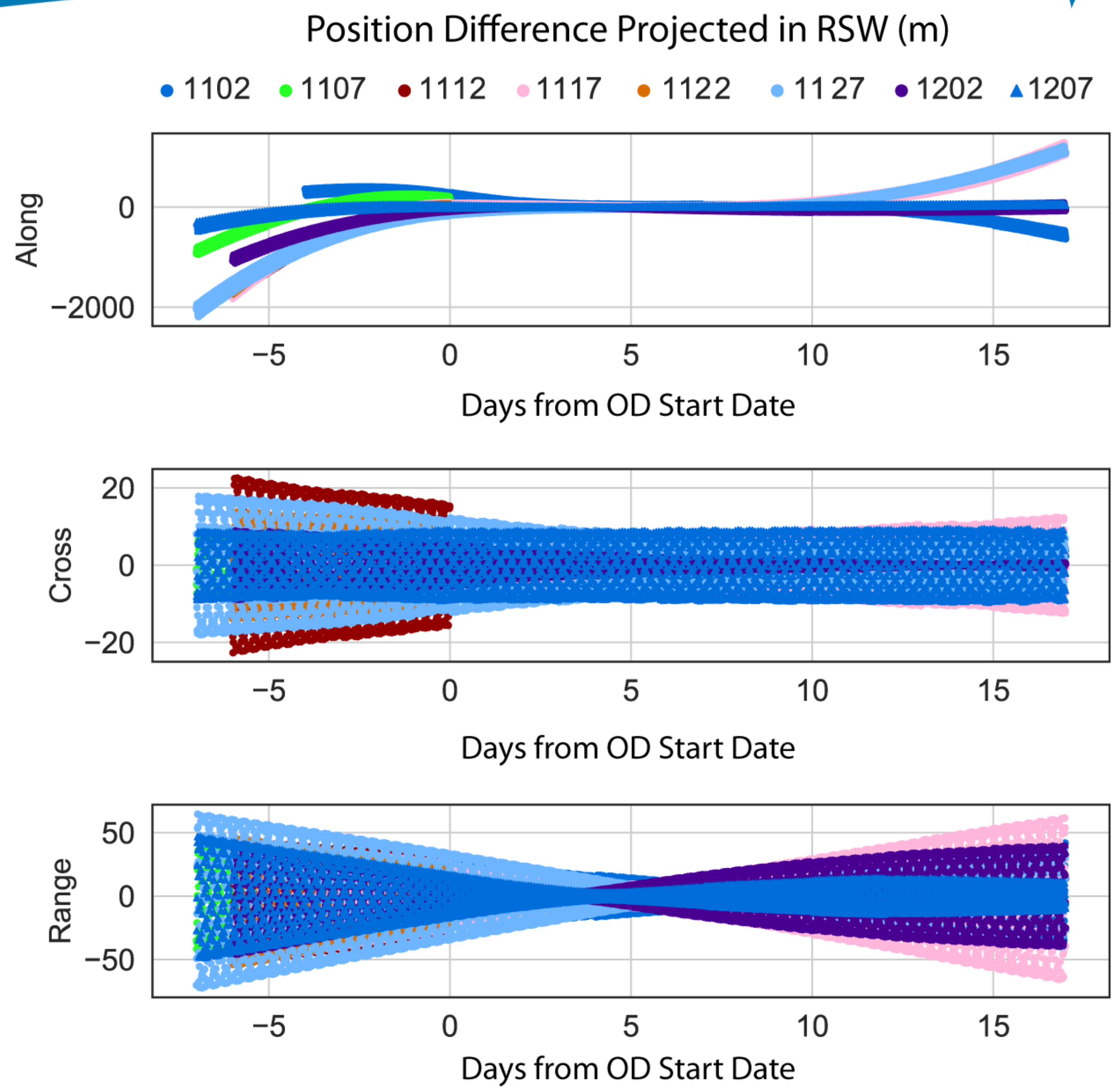








Orbit Prediction Accuracy – 3-Constant Model



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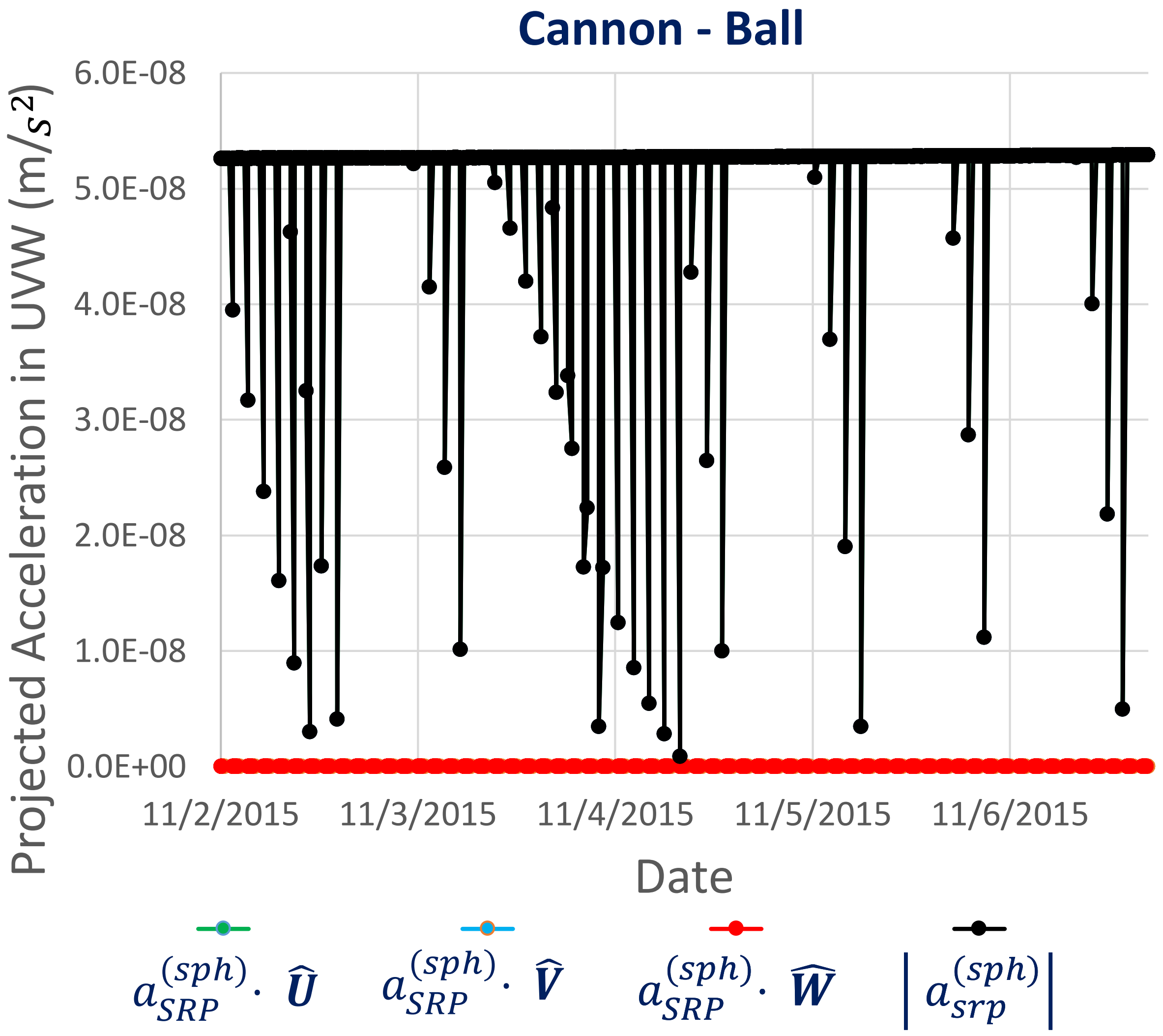
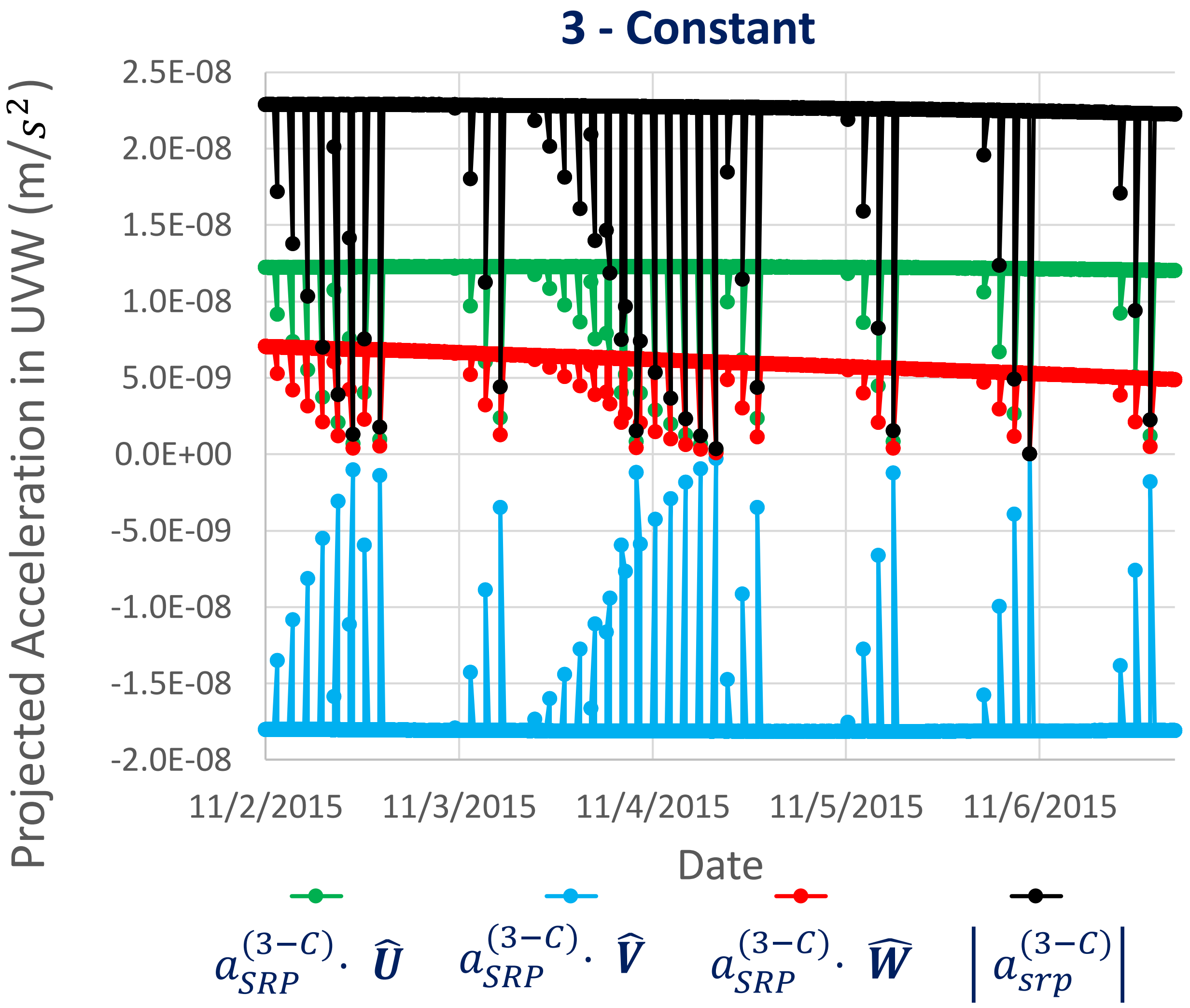
SRP Force projected in the UVW directions





Summary

- Proposed a 3-Constant Model to represent the averaged A priori SRP force derived from combining light curve and SLR data
- Surprisingly, the 3-Constant Model approach yielded worse results than the cannon-ball approach
- However, the magnitude of acceleration from the 3-Constant is smaller than that of the cannon-ball model, which requires further investigation

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Thank You

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