Kinematic RPP approach concept:

- Kinematic RPP offers the possibility of evaluating the yaw angle completely independently of the POD yaw attitude model/estimate. The technique is described in [2].
- The technique is obviously only applicable to satellites exhibiting sufficiently large XY phase center offsets.

For this study:

- 15.5 years of satellite yaw maneuvers (January 2002 until August 2018) were reanalyzed by means of kinematic RPP with a 120-station ground network, using orbits and clock products from JPL’s latest GPS data reprocessing campaign [4].
- 34 satellites were analyzed in total (22 Block II/IIA and 12 IIF): currently only one block II satellite is still transmitting regularly.
- The yaw attitude model for Block II/IIA satellites dates back to 1995 (GMM95 [3]). So far, it has never been revised due to a lack of RPP data from the earlier years.
- Block IIF satellite benefits from recent upgrades to their yaw attitude model by Kuang et al. [1].

Reverse Point Positioning Technique and Reanalysis Overview

- Kinematic RPP processes.
- New yaw angle models.
- In order to generate a consistent set of results for GPS Block II, IIA and IIF satellites, we have reanalyzed 15.5 years of GPS satellite maneuvers using the most recent GPS data reprocessing campaign conducted at JPL. Based on these long-time-series of RPP and POD derived yaw angles we document discrepancies observed during yaw maneuvers, particularly in the vicinity of zero beta angle.

Satellite Yaw Attitude Geometry

- $\psi$ is the elevation of the Sun above the orbital plane.
- $\mu$ is the geocentric orbit angle between the satellite and the orbit midnight, measured along track.
- $\alpha$, the nominal yaw angle, is defined as the angle between the nominal body-fixed x-axis and the instantaneous direction of the spacecraft’s velocity vector and is described as:
- $\alpha = \arctan(\tan(\beta), \sin(\mu))$ such that $\sin(\alpha) = \sin(\beta)$.
- The satellite is near Earth eclipse when: $-14.5^\circ \leq \psi \leq 14.5^\circ$.

Reprocessing Analysis

The quality of the yaw attitude models is first assessed by counting the number of times a wrong decision is made when performing a noon/midnight turn maneuver over the entire time period processed, focusing on the satellite-days when $|\psi| > 14.5^\circ$. Figure 1 displays the number of satellite-days for which the modeled and estimated directions of the turn agree and the number of satellite-days when the wrong decision is being made by the model. Discrepancies between modeled/estimated (POD) and kinematic (RPP) yaw angles are coarsely defined as satellite-days when yaw angle differences larger than 90° are detected. Both yaw attitude models exhibit a low rate of “wrong turns”; in particular, the block IIF yaw attitude model performs remarkably well, with discrepancies between modeled and estimated yaw angles being detected less than 1% of the time.