COSMIC-2 Precise Orbit Determination

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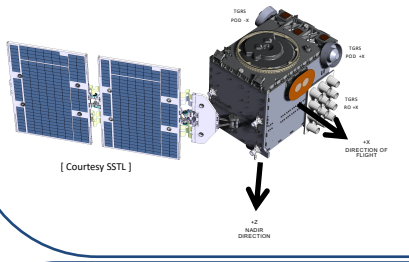
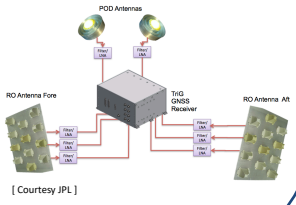
Abstract

We present initial results for post-processed GNSS orbit and clock estimation for the FORMOSAT-7/COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere, and Climate) constellation. The six COSMIC-2 satellites launched on June 25, 2019 into a 24 deg inclination, ~725 km circular orbit. The primary Tri-GNSS Radio-occultation Receiver System (TGRS) payload tracks GPS and GLONASS signals on two upward looking precise orbit determination (POD) antennas. We evaluate three GPS and GPS+GLONASS POD solutions applied at the COSMIC Data Analysis and Archive Center using the Bernese GNSS Software. The obtained results are very consistent for the six satellites. Orbit precision estimates are below the 10 cm and 0.1 mm/s 3D position and velocity requirements, respectively. A test case applying carrier phase ambiguity resolution indicates this technique may support the generation of more precise orbits in the future.

Introduction

- COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere, and Climate) launched into a 24 deg inclination orbit on June 25, 2019
- FM 1 was lowered to its operational ~525 km orbit altitude in August 2019
- FMs 2-6 remain in ~725 km initial orbit during study period
- The mission objective is to provide an operational constellation for the continuous and uniform collection of atmospheric and ionospheric data for input to daily near-real-time weather forecasts, space weather research, and climate change studies
- COSMIC-2 is a partnership between National Oceanic and Atmospheric Administration (NOAA, USA) and National Space Organization (NSPO, Taiwan)
- Primary payload is the JPL Tri GNSS Radio-occultation System (TGRS) for precise orbit determination (POD) and atmospheric radio occultation (RO)
  - Two upward looking choke-ring antennas for POD and ionospheric sensing (data rate 1 Hz), facing velocity and anti-velocity directions
  - Two high-gain phased arrays for RO measurements (data rate 50/100 Hz)
  - Data types:
    - Pseudorange, carrier phase, signal-to-noise ratio
    - GPS L1C/A, L2P, L2C
    - GLONASS L1C/A, L2C/A





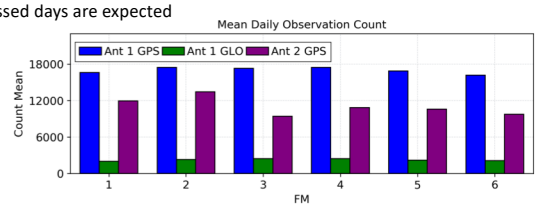
POD Strategy

- Evaluating post-processing POD solutions for data collected October 1-31, 2019
- Three solution sets are evaluated
  - 1) Antenna 1 (rear), GPS data only
  - 2) Antenna 1 (rear), GPS + GLONASS data
  - 3) Antenna 2 (forward), GPS data only
- The POD strategy is summarized in the following table

Category	Key Parameters
Observation data	L1 and L2 pseudorange and carrier phase
GNSS orbit/clocks	CODE final product
Orbit arc	24 hours
Data interval	30 sec
Antenna calibrations	Transmitter: IGS14 standard applied LEO: offsets only, phase center variations not considered
Apriori LEO orbit	Dynamic fit pseudorange only kinematic solution
Dynamic orbit solution estimated parameters	Epoch state Constant and 1/rev acceleration in radial, cross-track, along-track
Reduced dynamic orbit solution estimated parameters	Epoch state Constant and 1/rev acceleration in radial, cross-track, along-track Stochastic acceleration in radial, cross-track, along-track every 10 min, with apriori sigma 5 nm/s² Carrier phase data only
Receiver clock	White noise stochastic estimated every 30 sec

Data Volume

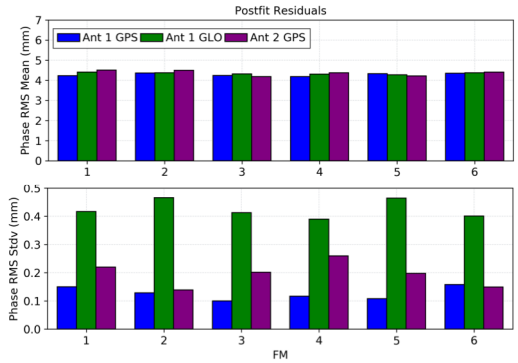
- The figure below shows the average daily number of of 30 sec phase observations by antenna and GNSS
- Due to operational or POD processing issues, solutions are not generated on all days, as summarized in the table; fewer observations are scheduled on antenna 2, so fewer processed days are expected



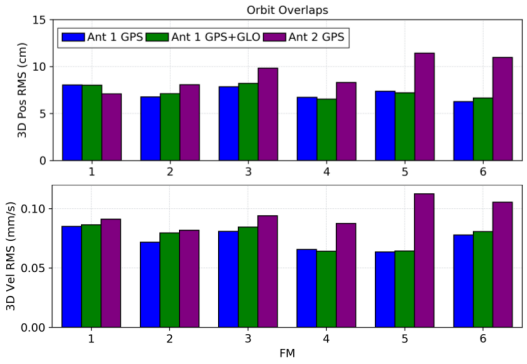
FM	1	2	3	4	5	6
Number of days antenna 1	31	31	30	31	30	27
Number of days antenna 2	28	25	20	23	24	16

Results

- The average and std. dev. of the daily phase residual RMS are given below
- In general, all solutions are very consistent in terms of mean RMS, while GLONASS and antenna 2 GPS residuals show more variation (~0.4 mm and ~0.2 mm 1-σ, respectively)

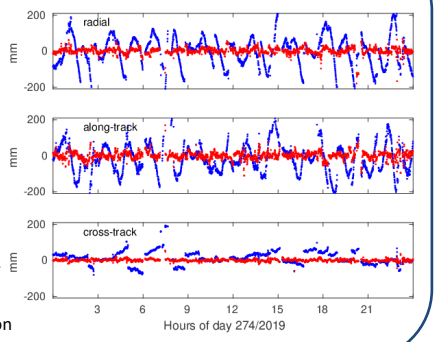


- Single point (so pessimistic) internal orbit overlaps are computed across the month and summarized by their RMS value
- Position and velocity results for antenna 1 are below the 10 cm and 0.1 mm/s mission requirements for post-processed solutions
- The standalone antenna 2 solutions are generally a bit worse, as expected due to the lower data volume



Ambiguity Resolution Test

- Data from Oct. 1 for FM 1, antenna 1, are processed with carrier phase ambiguity resolution
- Using a recently released CODE GNSS product
- Comparing the reduced dynamic and kinematic estimated orbits processed with (red) and without (blue) ambiguity resolution yields much better agreement with ambiguity resolution
- This demonstrates the feasibility of applying ambiguity resolution for COSMIC-2 to improve orbit precision



Summary and Future Work

- All six satellites perform consistently in terms of data volume collected, postfit residual statistics, and orbit precision metrics
- Mission requirements for orbit determination are already met
- Further improvements expected from
  - Tuning of reduced dynamic estimation strategy
  - Use of phase center variation calibrations
  - Ambiguity resolved processing
  - Combined processing of the antenna 1 and 2 data (currently under evaluation)
  - Improved antenna reference point offset vectors (potential mismodeling in radial direction under investigation)