Australian Government
Geoscience Australia

Impact of empirical parameters on GNSS orbit prediction through numerical integration

Thomas D. Papanikolaou[1], Michael Moore[1]

[1]Geoscience Australia, Australia

Abstract

Satellite orbit prediction is a major objective underlying in all real-time GNSS applications. The accuracy of the GNSS predicted orbits is critical in the case of high precision approaches such as the Precise Point Positioning (PPP) method. The current study focuses on GNSS orbit propagation based on full force model and the use of empirical parameters estimated over previous orbit arcs.

In particular, we apply dynamic orbit determination considering the estimation of empirical forces such as bias and one cycle-per-revolution accelerations introduced in the three directions of the orbital frame i.e. radial, along-track and cross-track components. The orbit prediction is performed based on numerical integration of the Equation of Motion and the use of the previously estimated parameters i.e. the initial state vector and the empirical parameters of the force model (bias and cycle-per-revolution terms) .

We investigate the strength of these parameters in terms of orbit accuracy and arc length. The study aims at quantifying the impact of the empirical parameters on the GNSS orbit propagation over following arcs.

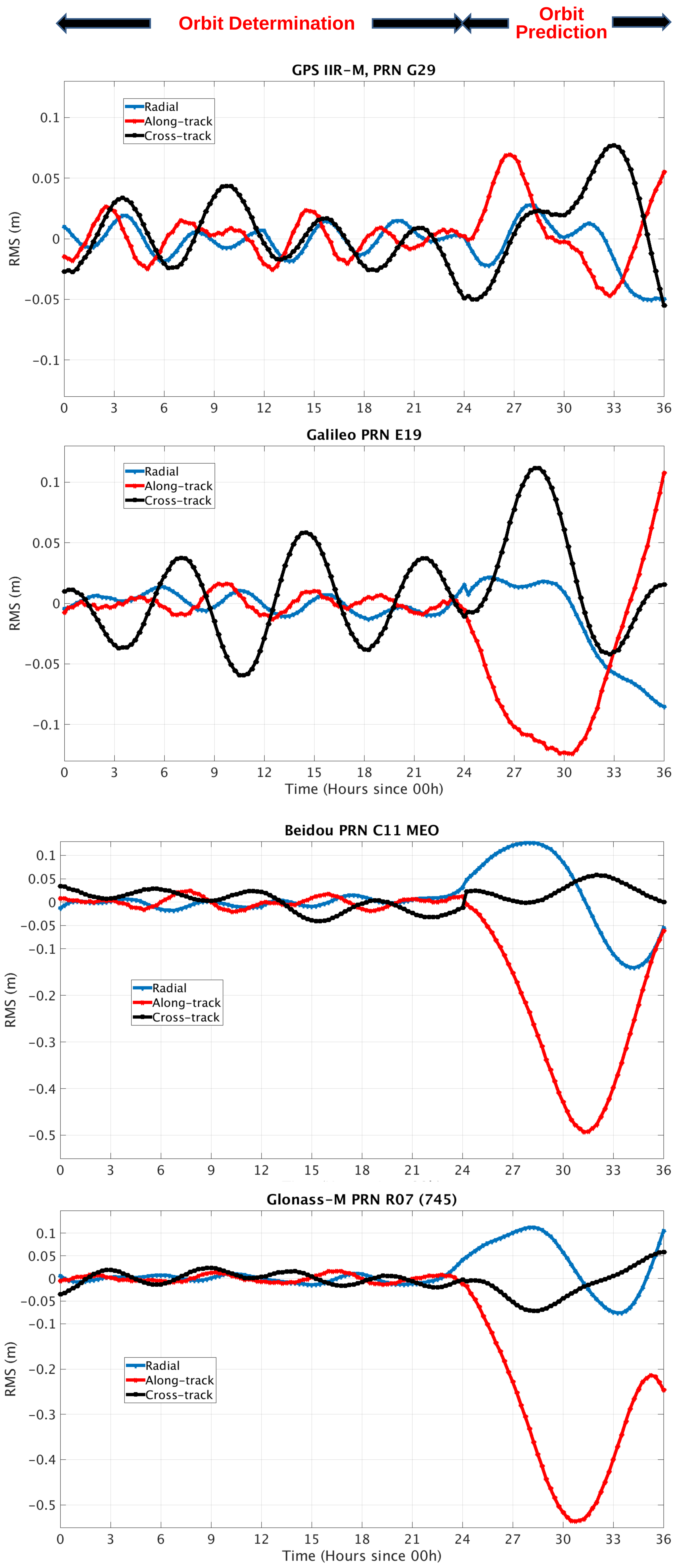

Figure 2. GNSS orbit residuals discrepancies during the 18-19 July 2018 based on the numerical comparison between the estimated/predicted orbits and available precise orbits provided by the IGS MGEX project. Orbit determination is applied for daily orbit arcs while the orbit prediction scheme is applied for the following 12 hours orbit arc.

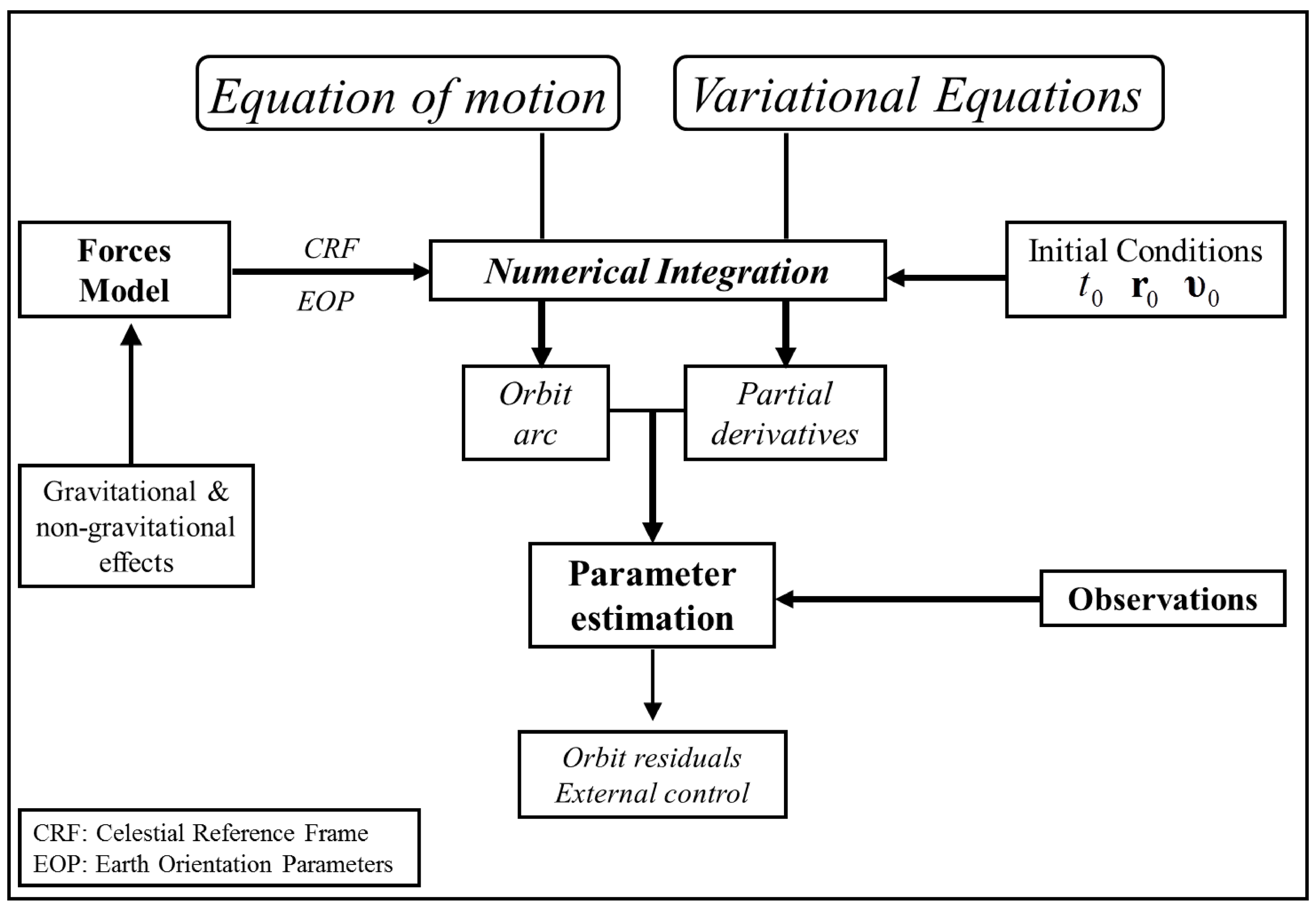

Figure 1. *Objectives of dynamic orbit determination (Papanikolaou and Tsoulis 2013) as applied in the current orbit analysis scheme*

GNSS Orbit Determination: Parameterization and force modelling	
Orbit Parameter Estimator Observations	Least-squares method Pseudo-Observations based on IGS precise orbits
Orbit Integration method	RKN7(6)-8 (Dormand and Prince 1978)
Numerical Integration Step	900 sec
Earth Gravity Field	GOCO05s (Mayer-Gürr T. et al. 2015)
Planetary & Lunar perturbations	DE430 (Folkner et al. 2014)
Solid Earth Tides	IERS Conventions 2010 (Petit and Luzum 2010)
Ocean Tides	FES2004 (Lyard et al. 2006)
Solid Earth & Ocean pole tide	IERS Conventions 2010 (Update 19/06/2015)
Relativistic effects	IERS Conventions 2010 , Ch. 11, Eq. 10.12
Solar Radiation Pressure	Cannonball model
Empirical Parameters	Bias and One cycle-per-revolution accelerations (radial, along-track, cross-track)
Earth Orientation	IERS Conventions 2010 (Update 13/07/2011)
EOP	IERS C04
Earth Rotation tidal variations	UT1, Polar motion, LOD (IERS Conv. 2010, Ch. 8)
External Orbit comparison	IGS Precise Orbits MGEX

Table 1. GNSS orbit determination. Summary of force model and data.

Orbit residuals for GPS satellite PRN G29, IIR-M			
Orbit arc / RMS (cm)	**Radial**	**Along-track**	**Cross-track**
Orbit Determination			
1 Day	0.37	0.29	0.89
Orbit Prediction			
3 hours	1.50	4.15	2.65
6 hours	1.17	4.92	2.17
12 hours	1.38	7.81	3.08
24 hours	3.74	25.50	5.19

Table 2. GPS satellite G29 orbit determination and prediction residuals w.r.t IGS final precise orbits on 5/06/2011.

Conclusions

The combination of a dynamic orbit determination and propagation scheme has been applied to GPS, Galileo, Beidou and GLONASS satellites as a GNSS orbit prediction scheme. The current orbit determination approach leads to mm to few cm residuals over the estimation of daily orbit arcs. In the case of GPS and Galileo, the orbit propagation over following arcs up to 12 hours shows orbital differences within 10 cm. In the case of Beidou MEO and GLONASS satellites, the orbit residuals are increasing significantly in the along-track component that may reach 50 cm. The quantification of the orbit propagation accuracy provides an insight in the empirical forces strength. In the frame of our ongoing research, we should mention the consideration of additional orbital effects along with alternative empirical parameters estimation.

References

Dow J.M., Neilan R. E., Rizos C., (2009), The International GNSS Service in a changing landscape of Global Navigation Satellite Systems, *Journal of Geodesy,* 83(3-4):191-198.

Mayer-Gürr T., et al. (2015). The combined satellite gravity field model GOCO05s. Presentation at EGU 2015, Vienna, April 2015.

Montenbruck O., Steigenberger P., Prange L., Deng Z., Zhao Q., Perosanz F., Romero I., Noll C., Stürze A., Weber G., Schmid R., MacLeod K., Schaer, S. (2017), The Multi-GNSS Experiment (MGEX) of the International GNSS Service (IGS) – Achievements, Prospects and Challenges, *Advances in Space Research* 59(7):1671-1697.

Petit G., Luzum B. (2010). IERS Conventions 2010, IERS Technical Note No.36, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main.

Papanikolaou T.D., Tsoulis D. (2013). Dynamic orbit parameterization and assessment in the frame of current GOCE gravity models, Presented at the IAG Scientific Assembly, 1-6 September 2013, Potsdam, Germany.

IGS INTERNATIONAL GNSS SERVICE

IGS Workshop 2018
29 October – 2 November 2018, Wuhan, China