Introduction
Sentinel-3 is a designated European Space Agency (ESA) Earth observation satellite formation devoted to oceanography and land-surface monitoring. Currently two identical satellites are flying at a circular sun-synchronous orbit with an altitude of about 800 km. Their prime onboard payload systems, e.g., radar altimeter, necessitate high-precision orbits, particularly in the radial direction. This can be fulfilled by using the collected measured data as from the onboard dual-frequency high-precision 8-channel Global Positioning System (GPS) receivers. The equipped laser retro-reflector allows for an independent validation to the orbits.

Non-gravitational Force Models
The non-gravitational forces profile used in Equation 1 can be given by:

\[ \vec{f}_{\text{forces}} = \vec{f}_{\text{ref}} + \vec{f}_{\text{Solar}} + \vec{f}_{\text{Improved}} + \vec{f}_{\text{Earth}} \]

where, \( \vec{f}_{\text{ref}} \) is the atmospheric pressure force; \( \vec{f}_{\text{Solar}} \) is the Solar radiation pressure (SRP), \( \vec{f}_{\text{Improved}} \) is the Earth electromagnetic (EM) force, and \( \vec{f}_{\text{Earth}} \) are the surface forces acting on the satellite. The research uses a description of the Sentinel-3 satellites in terms of an 8-plane macro-model (Montenbruck et al. 2018). SRP and AF are, scaled by factors \( S_{\text{SRP}} \) and \( S_{\text{AF}} \) that are co-estimated in POD.

Orbit Solutions
In BSW, a kinematic (KV) LEO orbit is depicted as an epoch-wise trajectory fully independent of force models, whereas a dynamic orbit heavily relies on them. A reduced-dynamic raw data-driven compromise and reduces the strength of force models using constant and/or periodic empirical accelerations, and the so-called pseudo-stochastic parameters, e.g., Piecewise Constant Accelerations (PCA) (Jaggi et al. 2008). The equation of motion for this nominal (NM) reduced-dynamic orbit is given by:

\[ \bar{r} = \bar{G} \bar{M} \bar{r} + \bar{f}(r, \bar{r}, \bar{Q}, \bar{P}, \bar{Q}_r, \bar{P}_r) \]

where, \( \bar{r} \) is the geocentric position vector of the satellite center of mass, \( \bar{G} \) represents the gravitational constant of the Earth; \( \bar{Q}, \bar{P} \) indicate dynamic parameters that are often set as constant accelerations in three directions; a total of 6 PCA \( \bar{f}(\ldots) \) are characterized by the a priori statistical properties, e.g., a priori variances \( \sigma^2 \) and spacing time \( \Delta t \), which is fixed to 6 mins in this research. In addition, non-gravitational force models will minimize the heavy dependence on those empirical parameters. The constant accelerations are completely replaced and the PCA can be more tightly constrained towards zero. The reduced-dynamic orbit based on non-gravitational force models is marked as NM.

Satellite Laser Ranging Validation
The independent Satellite Laser Ranging (SLR) measurements are used to validate our orbit solutions. Tab.3 and Fig.6 show that the SLR validation residuals decrease significantly after introducing integer ambiguities, and then the non-gravitational force modeling strategy in POD. The former adds more geometry constraints to the orbit, and the latter significantly improves the orbit particularly in the radial direction. The best possible orbit precision are at levels of sub cm for both satellites.

Conclusions
• The single-receiver ambiguity resolution provides significantly more geometry constraints to the orbit solutions.
• The non-gravitational force modeling orbit solution generates the superior orbit quality. In particular the orbit offset in the radial direction is almost mitigated.
• These LEO POD implementations obtain significantly better orbits and are supposed to be released in the new Bernese GNSS Software.

References

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