Analysis of sampling behavior of candidate SWOT satellite orbits
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Abstract
Current satellite altimetry cannot monitor global surface water variations well. The Surface Water and Ocean Topography (SWOT) mission addressed this deficiency. A careful repeat orbit design plays an important role in sampling the earth from the space by SWOT satellite. Choice an optimized repeat orbit is a key element for successful establishment of this mission. In this research we analyzed all possible repeat orbit scenarios with orbit height between 750 km and 1000 km and repeat periods less than 25 nodal days for inclination of 74° and 78°. We did this analysis at the presence of J2 effect via analytical solution for both phases of this mission.

Introduction
The Ka-band Radar Interferometer (KaRIN) mounted on SWOT platform contains two Ka-band SAR antennae at opposite ends of a 10 m boom with both antennae transmitting and receiving the emitted radar pulses along both sides of the orbital track. Look angles are limited to less than 4.5° providing a 120 km wide swath. The 200 MHz bandwidth achieves cross-track ground resolutions varying from about 10 m in the far swath to about 60 m in the near swath for an orbit height about 970 km. A resolution of about 2 m in the along track direction is derived by means of synthetic aperture processing.

Repeat orbit design
A repeat orbit mode βα occurs if satellite performs β revolutions respect to its ascending node in α nodal days. β and α are co-prime integer numbers. β = I + N. I is the integer part greater than 13 for SWOT and N is fractional part. In reality because of perturbing forces such as earth oblateness and atmospheric drag, satellite orbit has some perturbations and the exact repeat orbit is an instantaneous state therefor we can say the satellite passes thorough a βα repeat orbit. To have a repeat orbit close to reality we use the analytical formula, i.e. J2, the largest gravitational perturbing force effect due to earth oblateness, was considered. Under J2 effect we have following equations:

\[ \frac{\beta}{\alpha} = \frac{\mathbf{M} + \Omega}{\omega - \Omega} = \frac{T_A}{T_U} \]  

In which:

\[ \dot{\Omega} = \frac{3}{2} n J_2 \left( \frac{R_e}{a} \right)^2 \cos i (1 - e^2)^{-2} \]  

\[ \dot{\omega} = -\frac{3}{2} n J_2 \left( \frac{R_e}{a} \right)^2 (1 - 5 \cos^2 i)(1 - e^2)^{-2} \]  

\[ \mathbf{M} = n - \frac{3}{4} n J_2 \left( \frac{R_e}{a} \right)^2 (1 - 3 \cos^2 i)(1 - e^2)^{-2} \]  

\[ T_U = \frac{2 \pi}{\omega + \mathbf{M}} \]  

All possible scenarios
In the repeat orbit the following relationship between satellite mean motion, n, semi-major axis, a, and inclination, I, should be satisfied:

\[ n = \frac{\beta}{\alpha} \omega_0 \left( 1 - \frac{3}{2} J_2 \left( \frac{R_e}{a} \right)^2 (4 \cos^2 i - 1) \right) \]  

Where J2 = C22, \( \omega_0 \) is the angular velocity of the earth and Re is the earth radius. \( \alpha \) must be determined in an iterative way. According to Wagner’s algorithm:

\[ a_0 = \left\{ GM^2 \left( \frac{\alpha}{\beta} \right)^2 \left( \frac{1}{\omega_0} \right)^2 \right\}^{1/3} \]  

\[ a_{n+1} = a_0 \left( \frac{3}{2} \frac{R_e}{a} \left( \frac{1 - 3 \sin^2 i}{2} \right) \right)^{1/3} \times \ldots \left( 1 + \frac{3}{2} \frac{R_e}{a} \left( \frac{\beta}{\alpha} \right) \cos i - \frac{3}{4} (5 \cos^2 i - 1) \right) \]  

Candidate orbits
Candidate orbits were selected based on following criteria:

- **Sub-cycle**: Sub-cycle is a period of time less than the repeat orbit period after that satellite provides approximate homogeneous global sampling but sparser than that would do during the complete cycle of repeat orbit.
- **Coverage pattern**: Shows the ground tracks density along an arbitrary parallel, e.g. equator and is a useful graphical tool to represent relationship between spatial and temporal sampling.
- **Gap evolution**: To analyze spatial and temporal resolution gap evolution graph is used. This graph shows how fast an orbit is to sample unobserved gap.
- **Temporal and spatial sampling**: The more temporal sampling (corresponds to the shorter repeat orbit and the sparser ground tracks) the worse spatial sampling and vice versa. Therefore in the repeat orbit design making balance between temporal and spatial sampling is necessary.

Conclusion
Based on the gap evolution graph and coverage pattern as well as spatial-temporal resolution a few number of orbits (tables) were selected as the candidate orbits for this mission in the fast and nominal phases. An orbit with repeat mode, \( \beta = 343 \) and \( \alpha = 25 \), can be the best repeat orbit for nominal phase of SWOT mission.

There is no remarkable difference between all possible and candidate orbits with inclination of 78° and 74° other than coverage area.

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