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Coordinate Systems MGE-05 WS2122

Exercise 1

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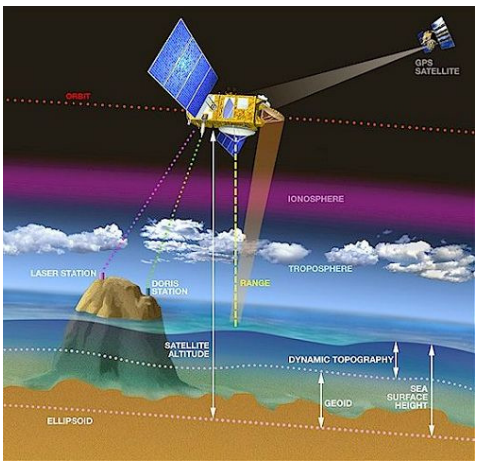
Introduction

Radar altimeter satellites such as Jason-2, -3, Saral/Altika, Cryosat-2, Sentinel-3, etc., measure the range from the spacecraft to the sea surface. The ellipsoidal sea surface height (SSH) is then obtained as the satellite's height above the ellipsoid minus the measured range. Typical measurement accuracy is 2-3 cm, but by averaging many measurements one achieves mm-accuracy and better. The satellites' 3D positions are obtained from precise GNSS tracking. Altimetric SSH can be compared to SSH determined at tide gauges provided they are equipped with GNSS. In radar altimetry it is common to use the Topex/Poseidon (T/P) ellipsoid.



Radar altimetry principle (image credit: Aviso)

Task 1.1

Given are the Cartesian coordinates in [m] of a satellite at time t,

$$X_{sat} = 4831342.4634 \;\; Y_{sat} = 2833965.0779 \;\; Z_{sat} = 5289590.6351$$

and the ellipsoidal longitude, latitude and height [m] of a nearby (few km) tide gauge station

$$\lambda_{tg} = 30.329000100^\circ \;\; \phi_{tg} = 43.592000088^\circ \;\; h_{tg} = 30.888 \; .$$

1. Compute ellipsoidal coordinates of the satellite w.r.t. the T/P ellipsoid.
2. What would be the (exact) difference in height if we were to use the GRS80 ellipsoid instead?
3. How far, in [m], is the altimeter footprint (sub-satellite point on the ellipsoid) located from the tide gauge?
4. How big is the distance between the footprints expressed in [m], if we were accidentally to compute the spherical latitude instead of the ellipsoidal one? Hint: use haversine formula to calculate the distance.

Task 1.2

The satellite orbit has, at time t, an inclination of $i = 66.036006500^\circ$, right ascension of ascending node (RAAN) of $\Omega = 335.188990200^\circ$ and argument of perigee $\omega = 289.450123600^\circ$. We assume here the orbit is perfectly circular, and the revolution time is $T = 110.0000$ min. Range measurements are provided every $\delta t = 1$ sec.

1. Compute both spherical and ellipsodial coordinates of the satellite footprint for one whole revolution, i.e. for times $t' = t + \delta t$.
2. Plot both footprints of the satellite for the whole revolution on a global map. Your plot should also contain coastlines, axis labels, title, legends etc.

Formal Regulations

Your solution must include

- step-by-step explanation of the way of solving (what equations are used)
- all intermediate results
- all results must be provided with (the correct) units
- all results must be provided with the relevant number of digits
- all the above must be in a machine-readable format (i.e. not as scanned hand-written text)
- the codes that you used