Post-EPS altimeter mission orbit determination : test of potential orbits

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Introduction

The aim of the study is to suggest optimal orbit candidates for a Post-EPS (EUMETSAT Polar System) altimeter mission planned around 2020 and onward.
Optimising future altimeter missions is a complex problem: many conflicting requirements, constraints and issues must be taken into account. Particularly the aliasing of tides is a crucial issue: it was one of the drivers of the choice of the TOPEX/Poseidon-Jason's orbit. Nowadays tidal signals are well known in deep ocean. However some issues remain in coastal areas and for internal tides. Aliasing of tides by altimeter sampling remains a challenge as it may pollute other signal estimations, particularly in the aliasing band of 40-90 days and the semi-annual/annual band.
Some orbit candidates for Post-EPS altimeter mission have been selected and investigated within this context. Each post-EPS candidate is assessed in term of sampling capability (temporal and spatial), and the direct sampling effect of the orbit is investigated thanks to OSSE (for mesoscale variability of the ocean). 2-satellites constellations with Sentinel-3 (S3) are considered in the study and are compared to the well-known altimetric constellations (Jason-1/Envisat, J2/J1N).

1. Global recommendations from analysis of passed/planned altimeter missions (GFO, TP, Jason, Envisat, Sentinel3 …)

* Payload characteristics need to be optimised
* Raw recommendations for optimisation of orbit geometry
  - Altitude between 800 and 1400 km (Berthias 2008)
  - Air-drag and solar radiation exposure trade-off
  - Repeat cycle between 10 and 35 days (mesoscale observation + Long term continuity challenge)
  - High inclination to get more polar ocean observations
  - No sun-synchronous orbits because they do not allow aliasing of daily signals

⇒44000 possible orbit candidates for Post-EPS
⇒Need to define some selection criteria considering user/experts requirements : tides, climate, mesoscale, mission costs…

2. Post-EPS orbit selection criteria

* Tidal aliasing issues
  - No sun-synchronous orbits (to allow aliasing of daily signals)
  - Consider main tides + some non-linear tides
  - K1 alias is important
  - No aliasing at annual or semi-annual frequencies
  - No aliasing to very long period: good aliasing frequency is over 2 cpy
  - Good separability of major tides constituents
* Good mesoscale observability
  - Scales of ~150 km, ~15 days
  - 3-4 days subcycles are preferred
* Climate issues
  - Need to avoid the [4..9 cpy] aliasing band
  - No aliasing at annual or semi-annual frequencies + good separation with Sa Ssa
  - No aliasing close to 3 or 6 cpy (60 days climate signals)
* Low altitudes to reduce mission costs

All those criteria are very constraining. Trade-off and priorities are needed: two strategies have been followed, one based on purely tidal aliasing criteria, and a second one relaxing those criteria.

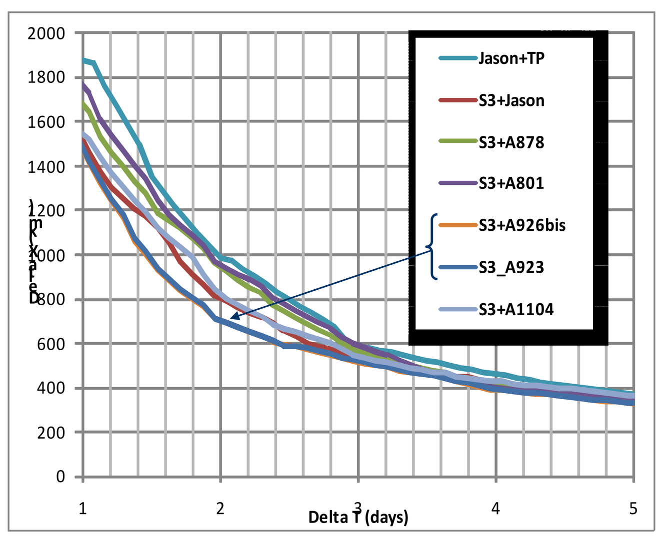
• **First strategy** : tide aliasing is a priority = most aliasing freq. > 2cpy + good separability criteria

• **Second strategy** : tide aliasing is **not** a priority as tides already well known + climate purposes are a priority (good separability criteria with Sa+ Ssa + less alias in [4-9 cpy] as possible) + mesoscale observation is a priority (3-4 days sub-cycles only)

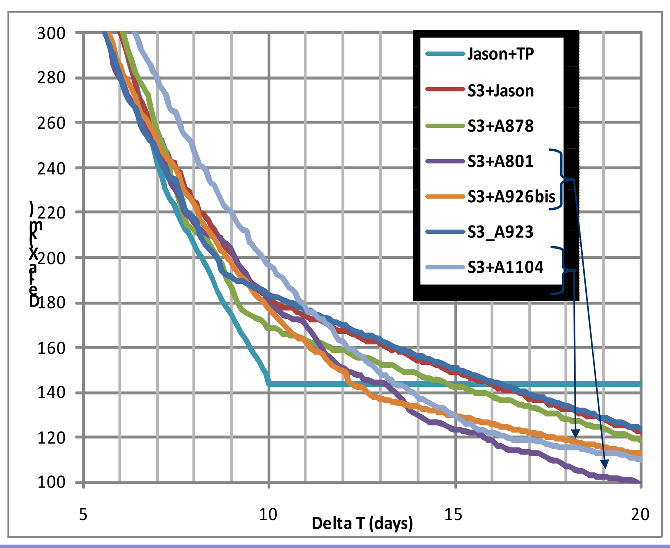
Description of the five first orbits selected

	Altitude (km)	Inc (deg)	Cycle (days)	Exact repeat cycle (days)	Tide Aliasing	Tide separ. (years)	Sub-cycle (days)	S1 aliasing (days)
A878_i66_c10	878.781	66	10	9.901936	K1<2cpy	3.5 y	1	100.97
A801_i71_c22	801.913	71	22	21.810438	K1<2cpy	6 y	7	115.05
A1104_i76_c16	1104.802	76	16	15.89562	K1<2cpy	-	3	152.3
A923_i67_c9	923.365	67	9	8.915522	K1>2cpy	-	4	105.53
A926_i67_c13	926.487	67	13	12.87810	K1>2cpy	-	4	105.64

3. Geometrical analysis of the proposed orbits



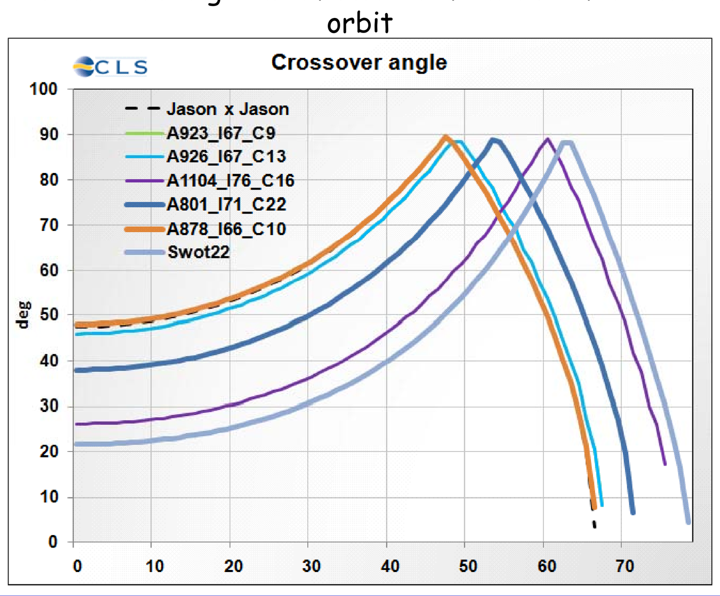
Approximate space/time scales resolved with post-EPS candidates (2-satellites constellations with S3)



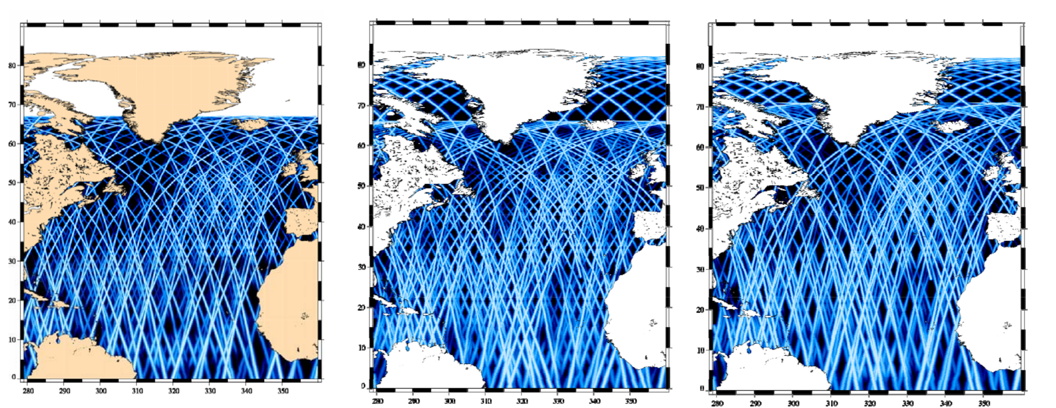
The orbit geometry determines the geographical coverage, the space/time sampling by the altimeter measurements and thus the type of applications that can be addressed. Left hand figures show that:
- A926 and A923 can resolve smaller scales for 1-5 days time scales;
- A926, A801 and A1104 can resolve smaller scales (< 140 km) for longer period >12-13 days, thus they are better suited to observe mesoscale structures;
- Constellation with A1104 is the worst constellation case for periods between 5-11 days;
- A878 is good for 9-11 days periods, but not as good as the reference T/P-J1 case.

The crossover angle (or track angle to equator plane) has a strong impact on geostrophic velocity observations : 45° tracks (=90° crossovers) allow an isotropic velocity obsvervation and lower cross angles create better observations on U and worse on V (EN vs S3). A878, A923 and A926 are equivalent to J1 with an ~orthogonal angle at 40-50° latitudes (geostrophic velocities of western boundary currents) and A801 in the 45-60° range (the circumpolar current). A1104 has orthogonal angles around 60°, too high to observe the large oceanic currents.

Crossovers angle as a function of latitude for each orbit

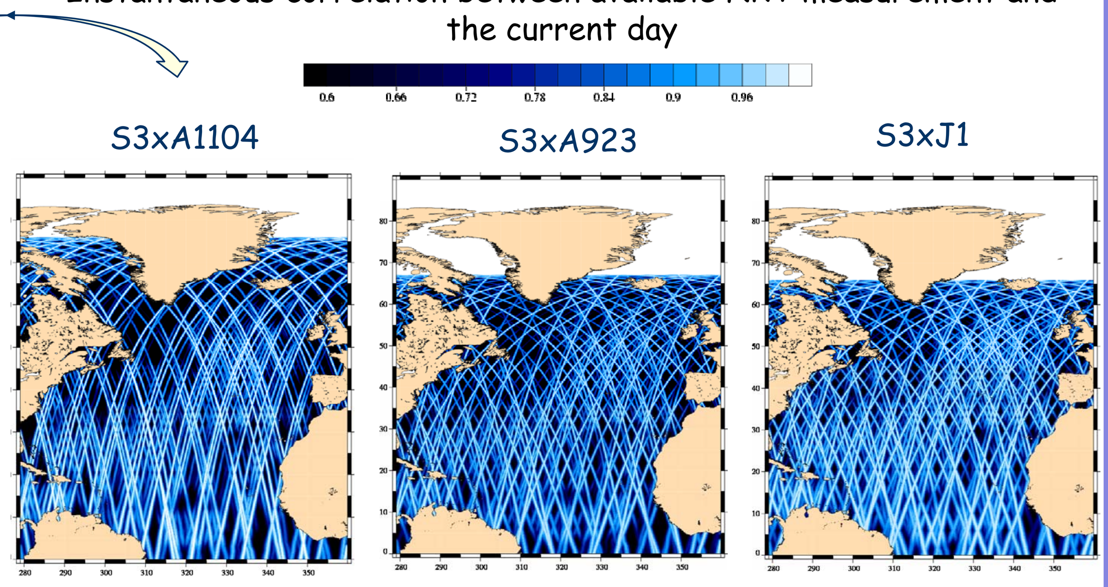


S3xA926 S3xA878 S3xA801



Instantaneous correlation between available NRT measurement and the current day

S3xA1104 S3xA923 S3xJ1

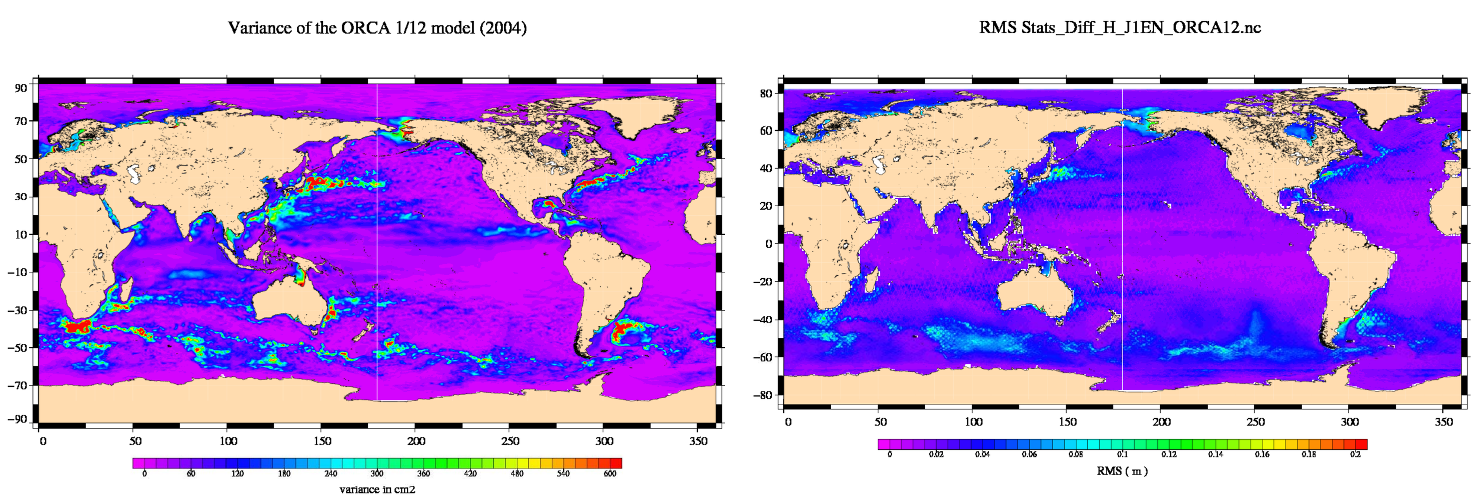


For each time step, we compute a map of the best correlation between observation and the grid point. The maps' space/time variations give info about the space/time sampling homogeneity of the constellations. S3+A878 has a good homogeneity in time, but a poor homogeneity in space. S3+A801 has a better spatial homogeneity than A878 (long repeat cycle once multiple sub-cycles have been completed): not-redundant sampling equivalent to S3+J1 or J1+EN. S3+A1104 is not a good candidate due to many blind spots. S3+A923 and S3+A926 have very good space sampling homogeneity, resp. similar/better than S3+J1, and also better time sampling homogeneity than S3+J1 likely due to their 4 days sub-cycle.

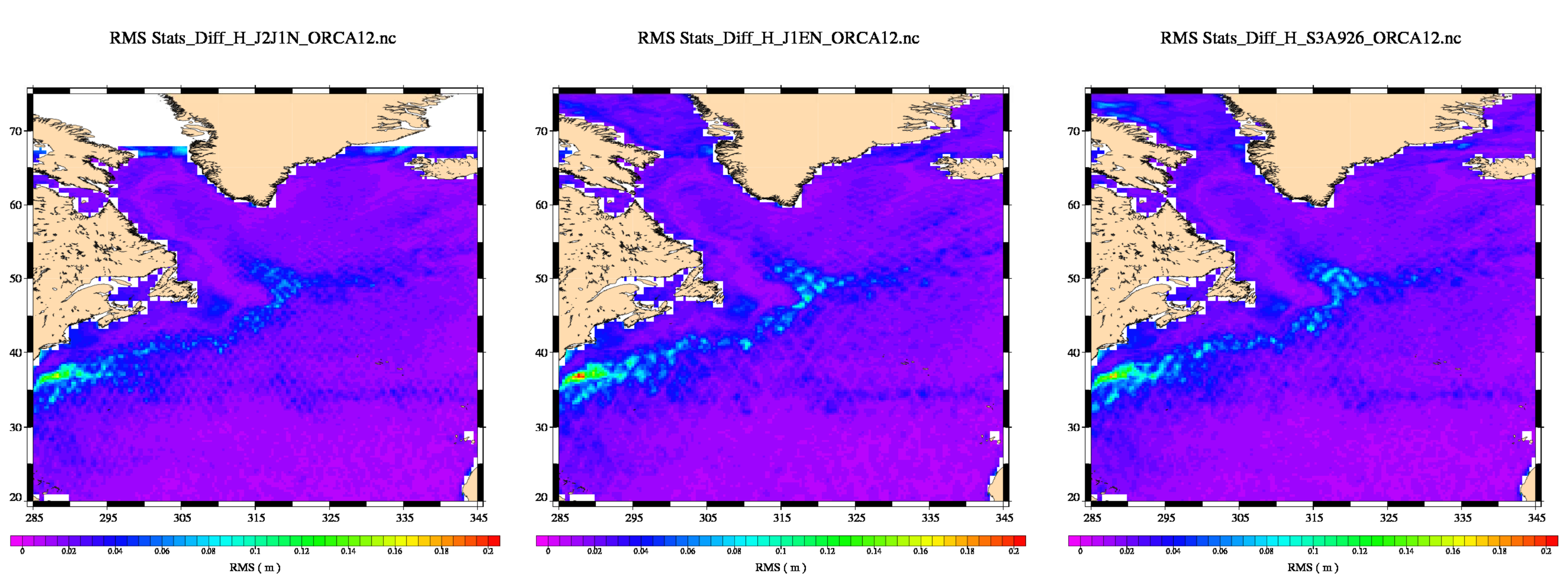
4. Mesoscale application performances (OSSE in a mapping context)

We focus on the ocean mesoscale signal which is modelled thanks to MERCATOR-OCEAN global 1/12° simulations (ORCA12 model: variance of the model is on right panel). We run OSSE in a mapping context for each orbit selected for post-EPS: 2-satellites constellations with Sentinel-3 have been studied and then compared to the other well-known constellations (J1-EN, J2-J1N, 4-satellites; *Le Traon and Dibarboure 2002*). Notice that the SWOT 22 days orbit (nadir configuration) has also been tested here.

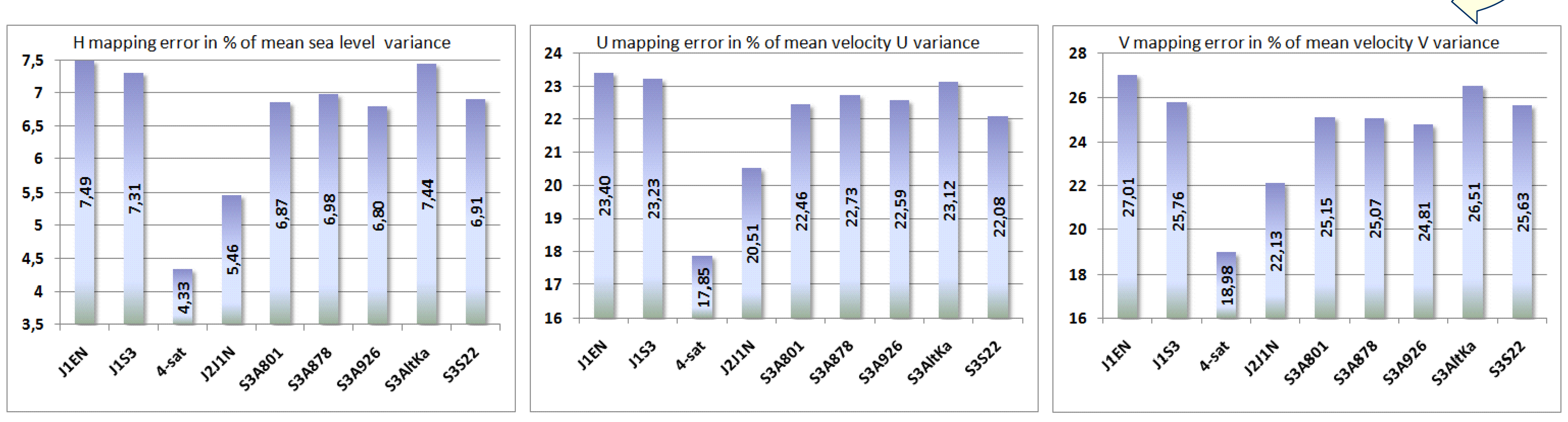
The RMS of the sea level mapping error (difference with instantaneous maps) for J1+EN configuration on the global ocean is given on right figure : as expected this error is correlated with the variability of the model, with strong errors in high variability areas, like great ocean currents but also south-east of Pacific and Indian ocean where there is a strong wind induced variabilty at high and low frequencies (*Webb and de Cuevas 2002, 2003*).



In order to validate the approach, we focused on the North Atlantic region which was already simulated by other authors. The mean mapping error is computed while averaging on the areas of variability greater than 15 cm and is given in percentage of model variance for H, U and V. Results corroborate other studies although this study has been performed with a different mesoscale model: **the 4-satellites constellation is the best with an error smaller by more than 42%. Concerning the 2-satellites constellations, the optimised J2-J1N has very good performances compared to non optimised ones, thanks to its 10-days repeat period and the 5 days phasing which almost provides a synoptic sampling of the ocean and makes it less sensitive to HF aliasing. The three post-EPS orbits have similar results, all better than old 2-satellites configurations, and A926 shows slighly better performances for H and V. SWOT orbit shows also similar performances.**



Mean and average for points with var > 15 cm



Conclusions – Perspectives

- Selection on tidal/climate considerations allowed proposing a few orbits candidates for Post-EPS
- Preliminary characterisation of the orbits has been made thanks to geometrical analysis of observable space/time scales : **A1104** is not a good candidate, **A926, A878, A801 are better suited.**
- OSSE analysis allowed the characterisation of each orbit in a mapping context for 2-satellites constellations with Sentinel-3 which will likely fly with Post-EPS:
  - Results are similar to previous studies which used different mesoscale models
  - The optimised 2-satellites constellation J2-J1N is widely better than other 2-sat. constellations
  - The proposed orbits have better scores than the other 2-sat. constellations (J1-EN, J1-S3, S3-EN, S3-Swot), but they are very similar
  - One orbit have slightly better scores : **A926.**
- Evaluation of post-EPS orbits candidates is ongoing for other applications (MSL, and climate variations of the ocean), mission costs, POD.