FINDING SUITABLE ORBIT OPTIONS FOR JASON1'S EXTENSION OF LIFE

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1 - Abstract

The ageing of Jason1 and the risk to lose control of the satellite and the collision risk with TOPEX/Poseidon (still in orbit, and no longer manoeuvrable) initiated a collective reflexion on the so-called "Extension of Life phase" or EoL phase.

This work intends to assess the consequences (degradation vs. the tandem configuration), to find good EoL candidates (for mesoscale, sea state and geodesy applications), and to quantify the impact of changing both the sampling capability and the error budget (new ground track, loss of the repeat track analysis).

2 – Extension of Life and Consequences

The EoL configuration has various side effects:

- New ground track uncharted (no repeat track, gridded MSS only)
- Not possible to keep a 10 day cycle with 254 tracks (Figure 2)
  - ➔ Moiré patterns created by the interaction of EoL and Jason2
  - ➔ Temporal desynchronisation process is 30 to 100+ day long
- Base ground track geometry is almost the same
  - ➔ if Jason1 and Jason 2 overlap, it is on thousands of kilometers
- The sampling propagation direction (W/E) can be cyclic as shown in Figure 1 (aliasing risk)

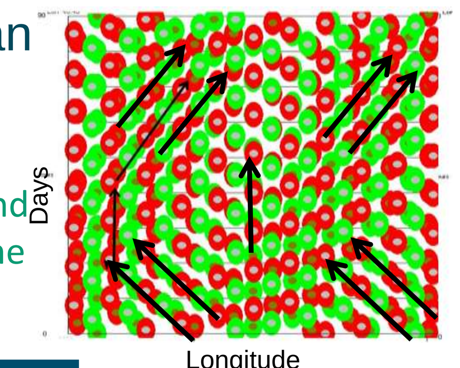


Figure 1: Example of propagation direction from the 14+6/11 and Jason2 duo. Dots show tracks position in the longitude (x) & time (y) plane for a 3000km scene over 90 days. The propagation exhibits a westwards/eastwards cycle of 70 days.

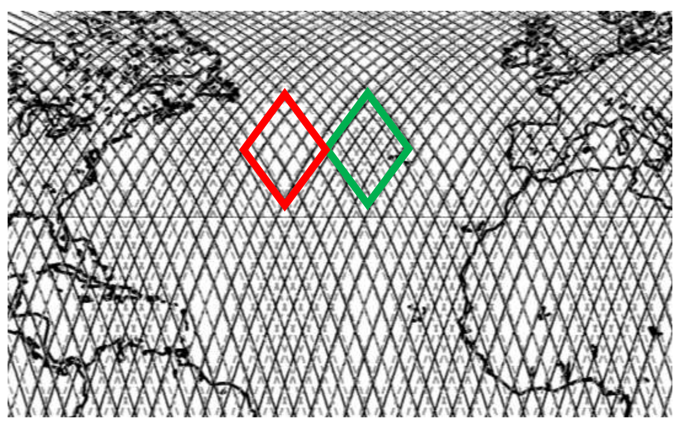


Figure2: Moiré pattern for the 12+9/11 EoL option (dashed, gray) and Jason2 (black, plain). The green diamond highlights one random zone where both satellites are locally optimally interleaved. The red diamond highlights one random zone where both satellites duplicating on the same track.

3 – Using sub-cycles to pick the best Jason-1 EoL options

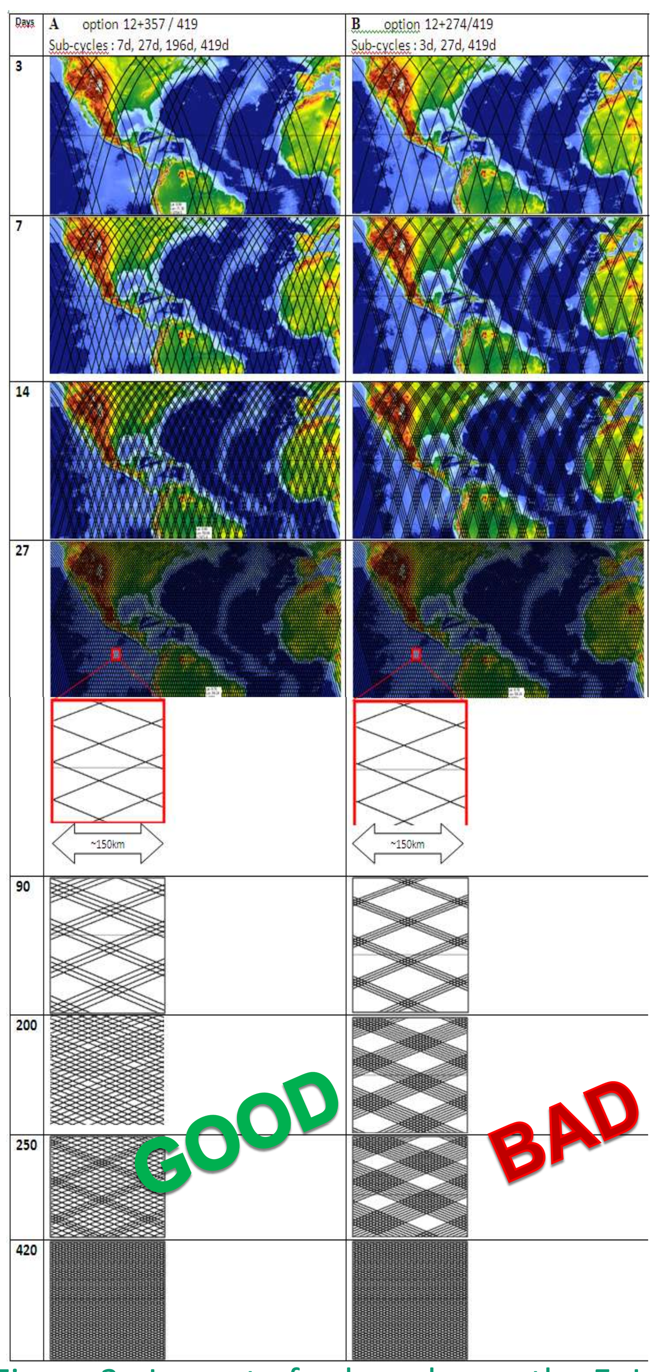
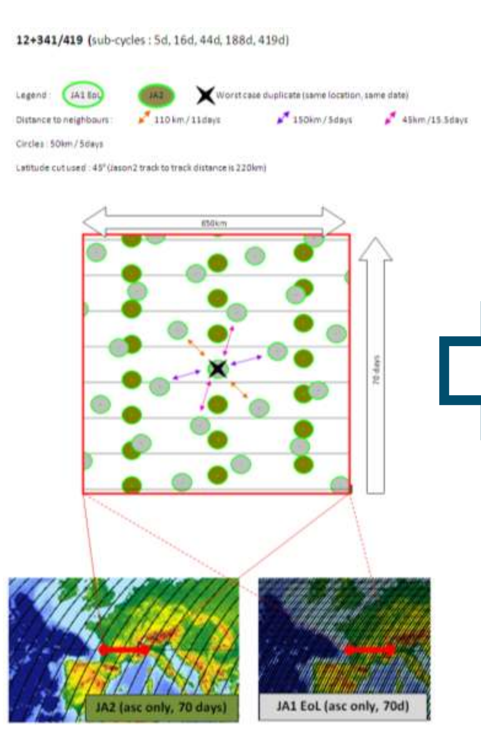


Figure 3: Impact of sub-cycles on the EoL sampling. Interleaved mesoscale or geodetic patterns and apparent sampling drift. Homogenous geodetic datasets are preferred for ~200 and ~400days

There are more than 17.000 orbits that can be considered for the Jason1 EoL with a large diversity of sampling patterns dictated by the number (2-5) and value (2-200d) of sub-cycles. To automate the screening process, the following rationale was used:

- Altitude must be compatible with EoL constraints: 1250-1420km minus the 1300-1360km forbidden zone
- Geodetic cycle (if any) must be as large as possible but inferior to EoL maximum duration ➔ 350 to 450d (Figure 3)
- Last pseudo-cycle must be as large as possible, and inferior to Jason1's most likely lifespan ➔ 120d -180d (Figure 3)
- Data from Jason1 EoL must be as decorrelated from one another, and as decorrelated with Jason2 data as possible

Jason2 and EoL will necessarily overlap (Moiré+desynch). Good options are orbits for which the overlap is not systematic nor recurring frequently, and orbits that blend well with Jason-2 (Figure 4)



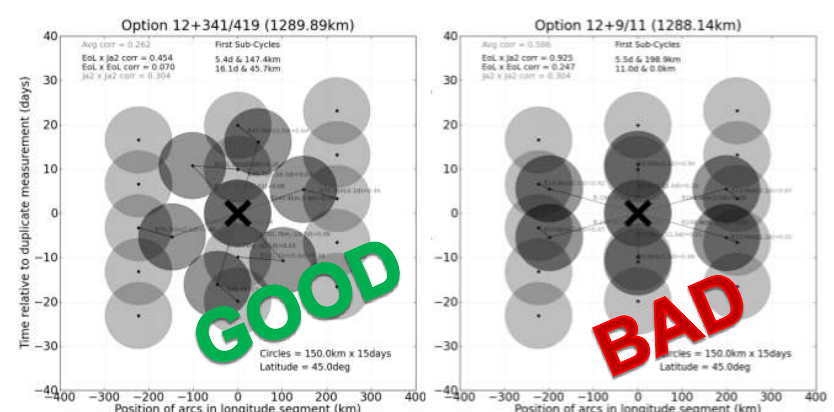


Figure 4: Positions and correlation circles of Jason2 (light gray) and Jason1 EoL (dark gray) measurements in the longitude (abscissa) and time (ordinate) plane. Units are km and days, relative to a Jason2/EoL duplicate measurement (black cross). Two configurations are compared: left is 12+341/419 (altitude of 1289.9km), and right is 12+9/11 (altitude of 1288.1km)

The best EoL options are all located in a handful of altitude bands (Figure 5, prefix A to F) about 1 to 3 km wide. Each band contains both repetitive (suffix r) and geodetic (suffix g) options associated by family (suffix number, e.g. Bg2).

Code	Altitude (km) Avg	Delta Alt	Alt Range	Rge with Repetitive	Best Geodetic options in range	Repetitive Options in range	Large SubCycles (days) 120 to 200	300 to 450	Neighbour Measurements #1 (SC)	#2 (SC)	#3
A	1268.5	-68	1	1	Ag1 : 12+361/416	Ar : 12+13/15	121	416	7.5 d 130 km west	15d 35km east	7.5d 165km east
					Ag2 : 12+316/365		150	365	7.5d 130km east	15d 30km west	7.5d 155km west
B	1287.5	-49	3	4	Bg1 : 12+365/444	Br1 : 12+14/17 Br2 : 12+13/16 Br3 : 12+9/11	163	444	5.6d 143km west	16.8d 54km west	11d 90km east
					Bg2 : 12+341/419		188	419	5.4d 147km east	16.1d 46km east	10.7d 101km west
C	1301.5	-35	1	1	Cg : 12+341/435	Cr : 12+11/14	198	435	4.6d 169km west	13.8d 54km west	9.2d 115km east
D	1359.5	23.5	1	4	Dg : 12+257/401	Dr1 : 12+11/17 Dr2 : 12+9/14 Dr3 : 12+7/11	181	401	2.8d 172km west	13.9d 63km west	11.1d 109km east
E	1405	69	2	5	Eg1 : 12+209/390	Er1 : 12+8/15 Er2 : 12+7/13 (Er3 : 12+6/11) (Er4 : 12+9/17)	181	390	2.2d 160km east	12.9d 74km west	15.1d 86km east
					Eg2 : 12+237/443		199	443	2.1d 160km east	15d 57km east	12.9d 103km west

Figure 5: Recommended EoL altitude bands with repetitive and geodetic options and their characteristics

4a – Impact on mapping

To quantify the degradation associated with the EoL phase, an impact study (OSSE) was carried out with DUACS multi-mission software. The rationale was to:

- ✓ Take an eddy-resolivng model output as the ocean « truth » (Mercator 1/12)
- ✓ Simulate along-track measurements with realistic errors (with or w/o the MSS error)
- ✓ Apply DUACS crosscal & mapping
- ✓ Reconstruct an « observed » ocean SSH (SSH, geostrophic velocities) in NRT

The difference « truth » - « observed » gives the observation error. All results are normalized to the error of the current J2/J1 tandem in NRT.

In a first step, we ignore the additional MSS error to quantify the performance of the new sampling pattern only (Figure 6). Breaking the tandem adds 20 to 35% of additional error due to measurement duplicates (Moiré, section 4b). The best repetitive orbit is « Ar » (15-days). The best geodetic is « Bg2 » (pseudo 17-days). The worst Moiré effect is on 11-day orbits.

We then add the correlated MSS error to quantify its impact in addition to the sampling degradation (Figure 7). 3cm rms of error add +50% of mapping error wherever ocean variability is less than 12cm (75% of the globe).

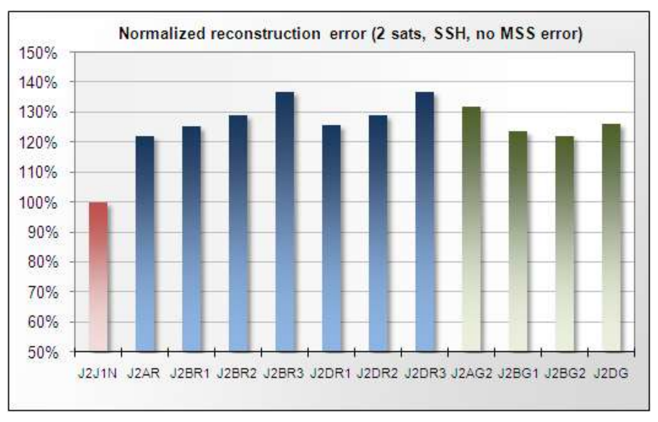


Figure 6: Normalized observation error for the current tandem (red), and various repetitive (blue) or geodetic options (green).

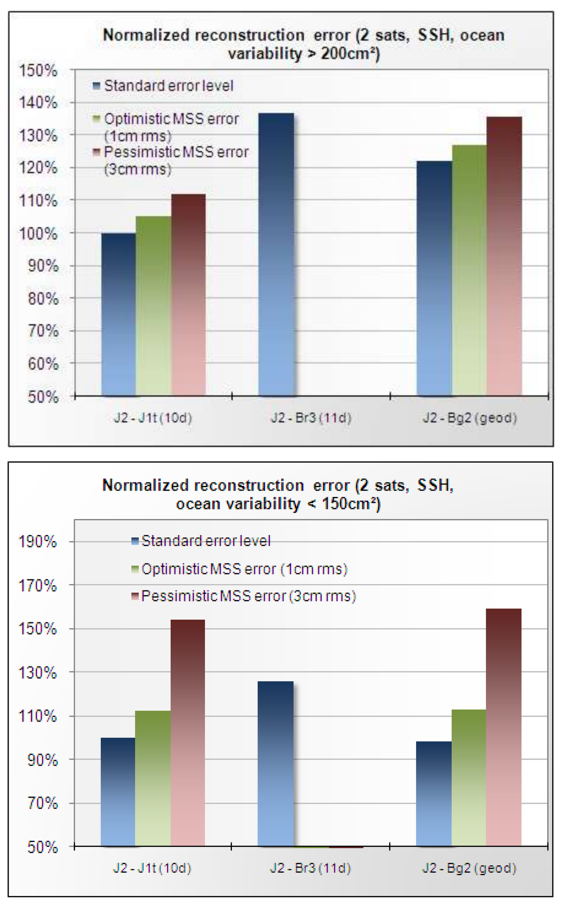


Figure 7: Normalized observation error for energetic areas (top) or variability < 12cm (bottom). Three error levels are used : standard (blue), 1cm MSS error (green) and 3 cm MSS error (red).

4b – Impact on sampling dynamics

Geometrical simulations (no MSS error) and animations were used to explore the dynamics of mixing Jason1 EoL and Jason2. E.g. ability to detect and to keep tracking sea state or mesoscale features in Near Real Time.

Blending well with Jason2 is mandatory to get a stable sampling capability from the tandem. The first sub-cycles impact sea state applications (Figure 8). Larger sub-cycles and cycles impact mesoscale sampling (Figure 9).

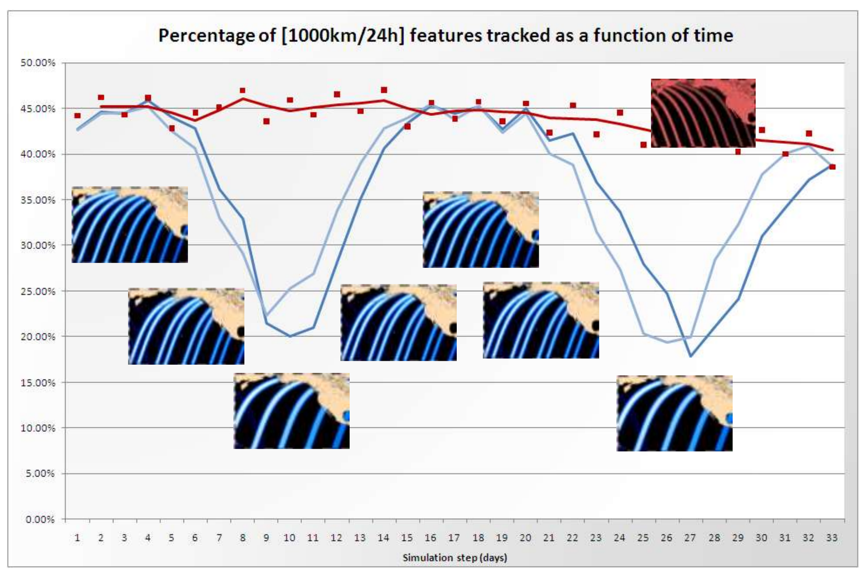
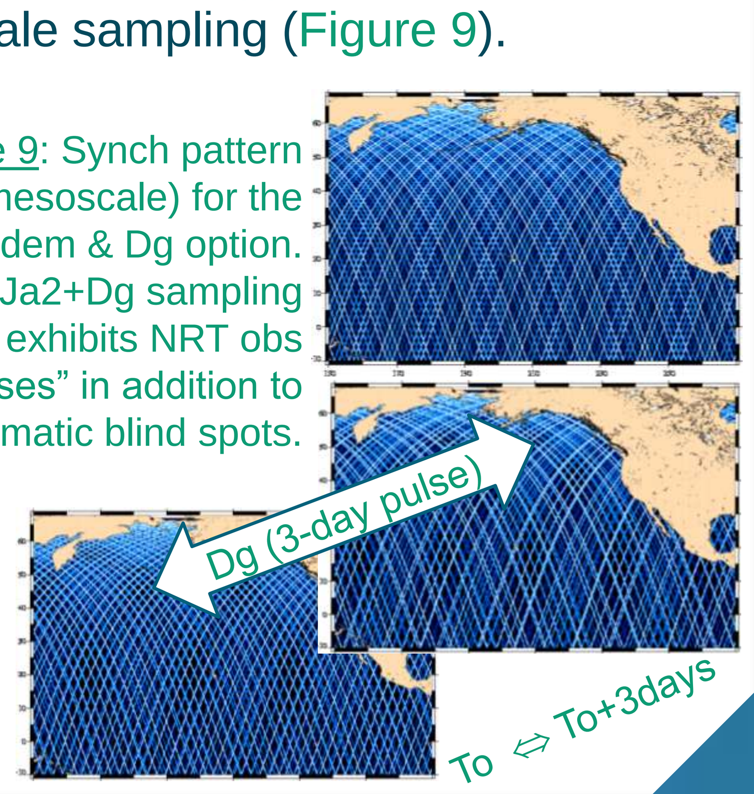


Figure 8: Synch pattern for Bg2, Br3 (blue) and current tandem (red) & impact on SWH or storm surge tracking

Figure 9: Synch pattern (mesoscale) for the tandem & Dg option. Ja2+Dg sampling exhibits NRT obs "pulses" in addition to systematic blind spots.



5 - Conclusions

All EoL are largely inferior to the current tandem with +30% mapping error from sampling alone. Furthermore, the MSS error adds again +20% to +50% error. Both losses degrade a coordinated sampling already barely sufficient in NRT.

If Jason1 is to be moved, the 11-day orbit Br3 should be selected if the EoL phase lasts for more than one year (MSS error can be minimized). If the EoL likely duration is less than 1 year (or unknown) the choice should be Bg2 for its sampling capability (but decent observations will be limited to strong currents).

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