Tide desaliasing within a wide-swath SSO context: results with 3 WISA orbits

L. Carrere, C. Busche, Y. Faugère (CLS) - lcarrere@groupcls.com
F. Lyard, D. Allain (LEGOS), C. Cheymol, G. Dibarboure, N. Picot (CNES)

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Introduction

The accuracy of tidal models has been much improved during the last 25 year (Stammer et al. 2014), but some tidal errors still remain mainly in shelf seas and in polar regions where availability of new databases is still worthful for the development of future tide models.
In this context and knowing that the tides and tidal currents are a predominant signal in shallow and shelf regions which have critical applications and societal interests, we analyse the interest of new satellite missions for the observation of tidal signals.
It is well-known that sun-synchronous orbits (SSO) do not sample properly the tidal signal, leading to bad aliasing frequencies of most tidal waves, and some solar waves are not even observable (S1 and S2).
As some of future SSO will benefit from wide-swath measurements of SSH (WISA, SWOT …) or even surface currents (SKIM, not shown here), we propose an estimation of the observability of tidal signals while taking into account the local multiple sampling allowed by the wide-swath of those SSO missions. Three different WISA-orbits constellations are investigated here. The analysis is based on an OSSE experiment using the IBI36 regional simulation of the North-East Atlantic Ocean (Mercator-Ocean); IBI36 includes the tidal signal as well as other realistic oceanic variability which may prevent a proper tide estimation from satellite measurements due to crossed aliasing issues. Results of this tidal desaliasing analysis are presented here.

Orbits tested

Three different WISA orbits are tested within a one and two satellites constellation:

- **Orbit-A** : 17 days revisit cycle, SSO, orbit optimal for mesoscale sampling
- **Orbit-G** : 39 days revisit cycle, SSO, favorable for hydrology
- **SWOT orbit** : 20.86 days revisit cycle, *non-SSO*, more favorable for mesoscale and tide observation
- **METOP orbit** (29 days cycle, SSO), has also been tested for the sampling of ocean surface currents (SKIM), but results are not shown here.

Tide separation problems

Orbit-A:
-M2-Q1 : 503 days
-M2-MS4 : +inf
-K1-P1 : +inf
-K1-Sa : not separable
-N2-Mf : 3.6 y

Orbit-G:
-Q1-Mf :+inf
-K1, P1-Sa : not separable
-N2-M6 : not separable
-K2-Ssa : not separable

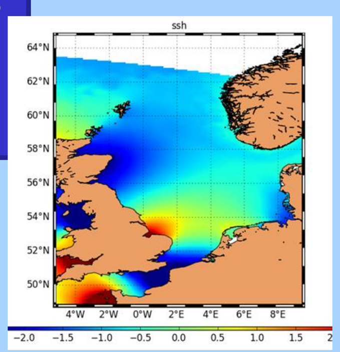
SWOT :
- M4-Q1 : > 11 years for separation

Aliased frequencies for each WISA orbit and for the main tidal waves

WAVE	Alias freq orbit-A (days)	Alias freq orbit-G (days)	Alias freq orbit SWOT
M2	112	108	66,02
S2-S1	+inf	+inf	77-154
N2	73	687	47
K1	365	365	266
O1	85	154	52
Q1	91	238	57
M4	56	137	56
K2	182	182	133
P1	365	365	108
Mf	69	268	44
Mm	44	93	85

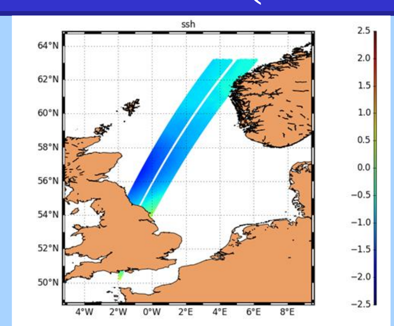
Methodology for tide desaliasing estimation: OSSE experiment

Reference model : IBI36 free simulation including tide+atmospheric forcing, 1/12°, 5 years available with 1-hour sampling: 2011-2015

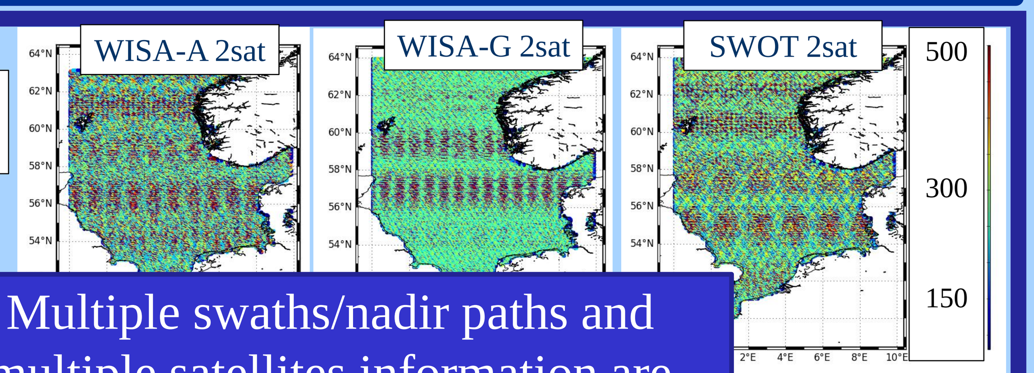


Satellites groundtracks information

Model's SSH is sampled on the satellites groundtracks: sat1, sat2, … + noise can be added (not done here)



Nb of points/box for each constellation

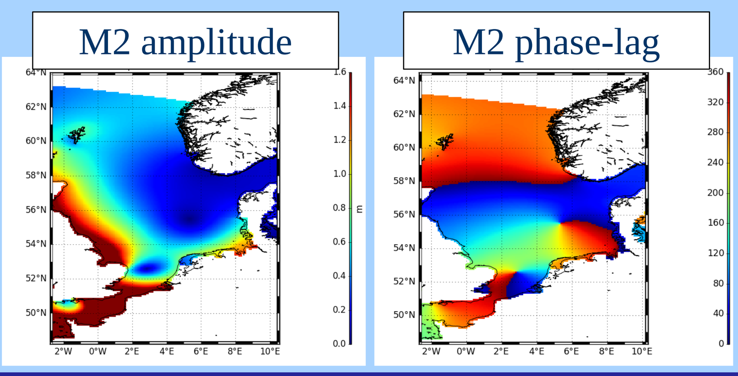


Multiple swaths/nadir paths and multiple satellites information are binned in observation boxes (0.05°)

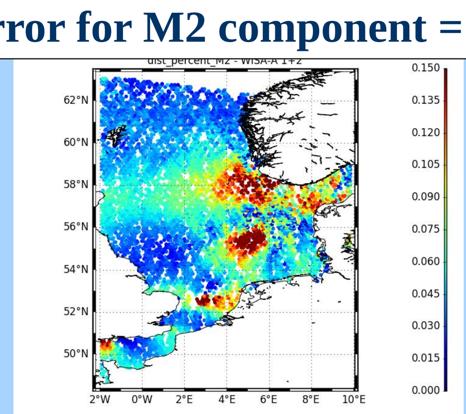
Harmonic analysis

Harmonic analysis

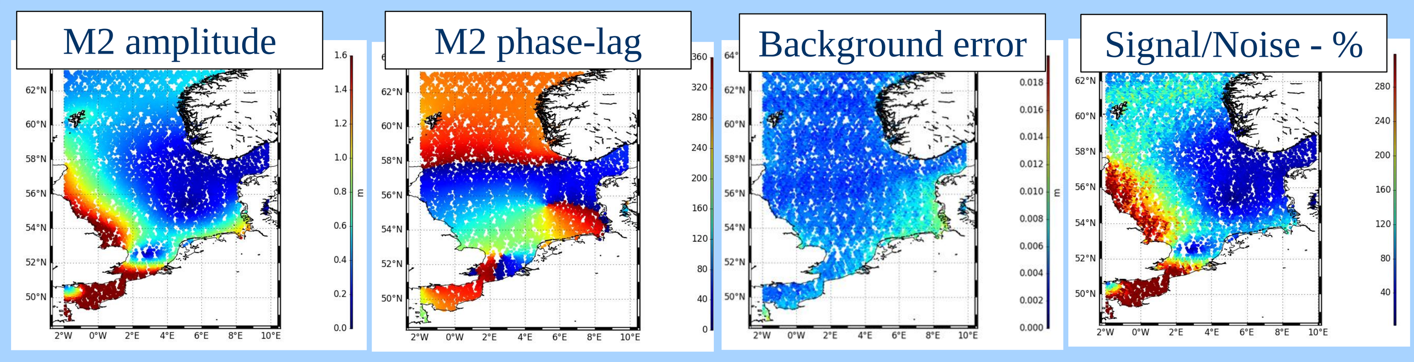
Reference tide spectrum



Comparison between ref and obs tide spectrum : % of observation error for M2 component = (obs- ref) /obs

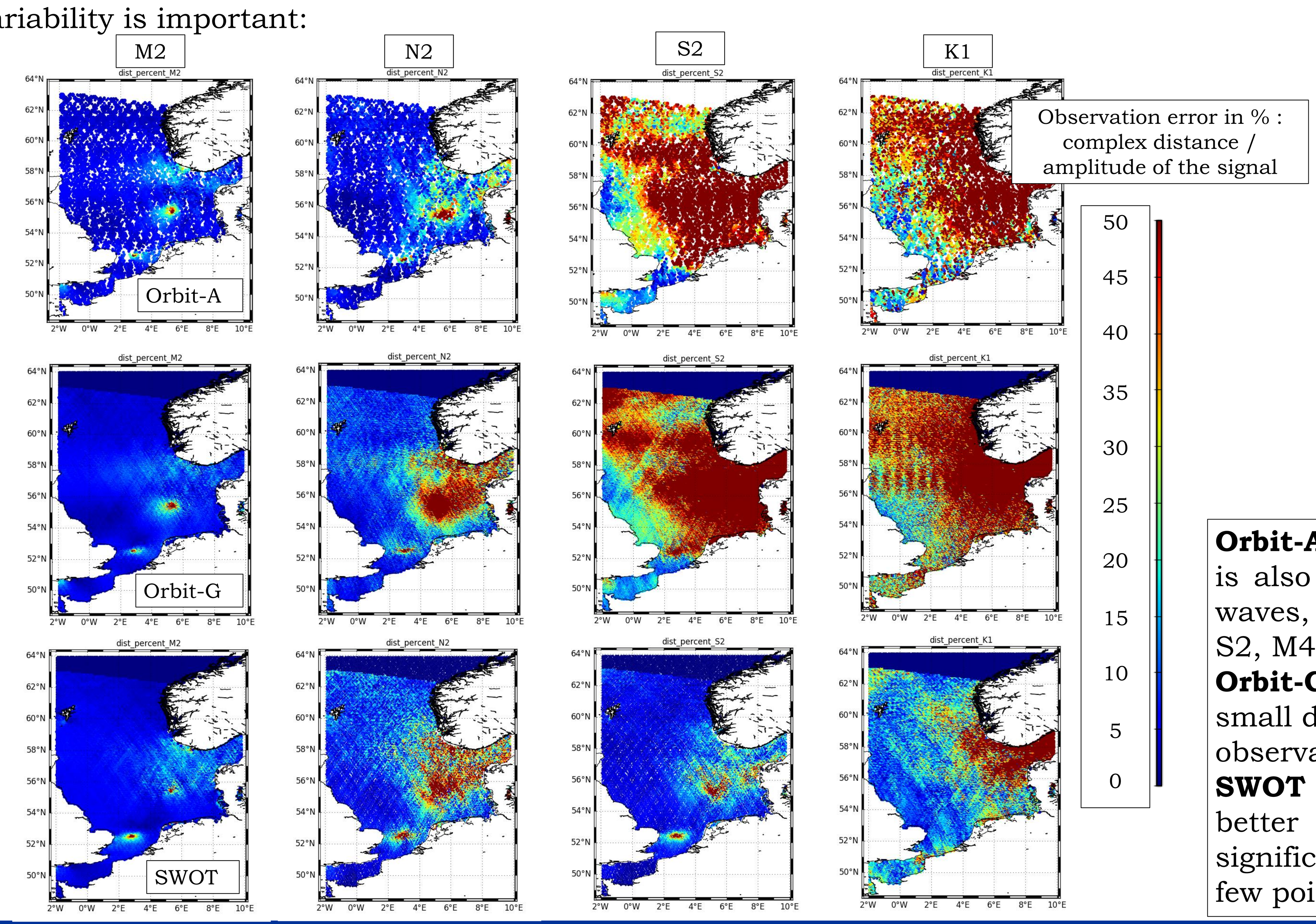


Observed tide spectrum for the satellites configuration tested



Results: tide observability for SSO or non-SSO constellations

The tide observability of each SSO/non-SSO constellation described above is investigated for the main tidal frequencies: M2, N2, K2, S2, K1, O1, P1 and the non-linear wave M4. The observation error of each constellation is computed for each tidal wave, focusing here on the Channel and the North Sea area where barotropic tide variability is important:



Mean observation error for each wave and each 2-satellites configuration: mean of errors < 15% in % and % of points concerned.

WAVE	WISA-A 2sat	WISA-G 2sat	SWOT 2sat
M2	**5,4 – 97%**	**4,9 – 97%**	**5 – 96%**
N2	**5,9 – 86%**	**6,3 – 70 %**	**6 – 71%**
S2	9,8 – 9 %	**3,9 – 21 %**	**5,1 – 87 %**
K1	10,2 – 7 %	**2,6 – 18 %**	**6,7 – 51 %**
O1	9,3 – 40 %	**6,6 – 41 %**	**5,9 – 35 %**
P1	10,5 – 7 %	**2,7 – 18 %**	**6,1 – 37 %**

Orbit-A: M2 and N2 are well observable on North Sea, with obs error < 6%; O1 is also observable on 42% of points but with stronger error (9,3%). For other waves, less than 10% of points are observable due to bad aliasing of K1, P1, K2, S2, M4.
Orbit-G: slightly better observation of most waves compared to **orbit-A**, but small degradation is noted for N2. S2, K1 are a bit improved with ~20% of points observable.
SWOT orbit: as expected due to its non-sun-synchronicity, SWOT orbit allows a better observation of most tidal waves compared to orbit-A and G including significant improvement for S2, K1 and P1. A small degradation is noted for a few points for N2, and M4 is not observable within 5 years.

Conclusion and perspectives

- This analysis shows the interest of using an OSSE methodology to estimate the tide observation error of a wide-swath satellites' constellation, even when considering SSO.
- As expected the SWOT non-SSO gives the more accurate results for tide observation, but the analysis also indicates that the SSO WISA-A and WISA-G orbits have some skills to observe M2 and N2 tides, and also diurnal tides for orbit-G, the studied area.
- Perspectives are to estimate the baroclinic tide observation error in deep ocean, to improve the estimation method (preliminar correction of HF signals …), and we can also envision testing the impact of the number/phasing of satellites of a constellation.

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