Technical note on the new PyFES tide prediction algorithm, used for FES2022b prediction

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2 prediction codes: libfes and pyfes

- **Libfes** = reference prediction code used for FES2022b tidal solution
  - Available on CNES github : https://github.com/CNES/aviso-fes/tree/2.9.7
  - Official version for FES2022b is **2.9.7**

- **PyFES** = new prediction code developed for the SWOT KaRIn needs (optimization of the computation for large databases & allows the use of finite element atlases)
  - Several modifications and corrections have been implemented in the code compared to Libfes
  - Code is also available on the same github : https://github.com/CNES/aviso-fes/tree/main
  - Minimum version to used for FES2022b prediction is **v2025.2.0**

- We compare the use of both codes for the tidal prediction of FES2022b solution.

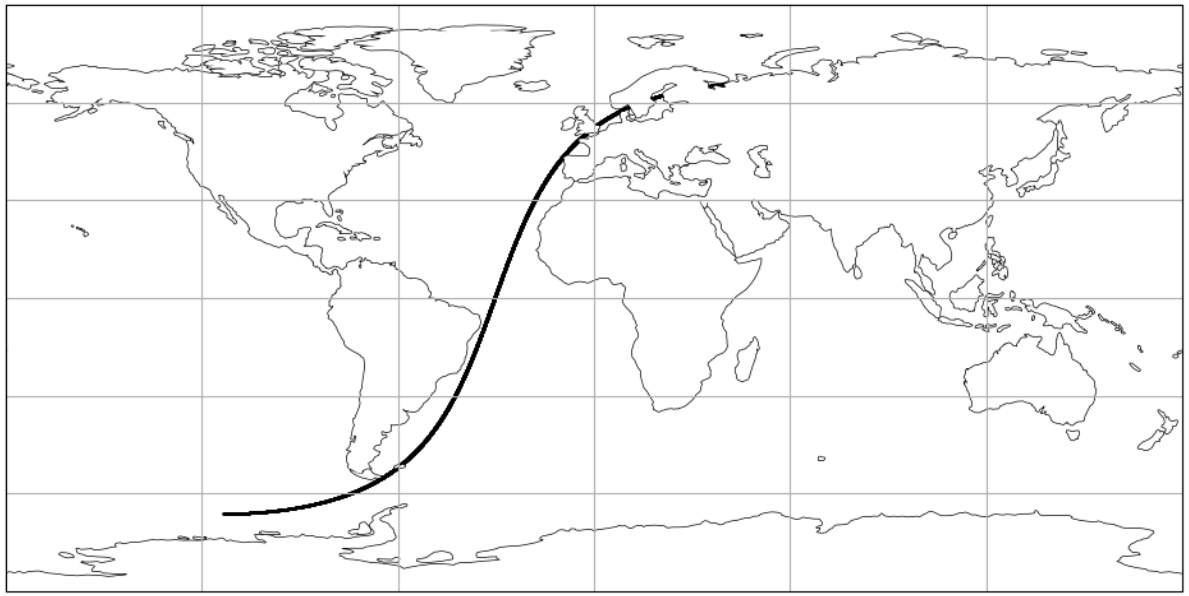
Key differences between libfes and pyfes

Code	Libfes (version 2.9.7)	Pyfes (Pyfes version 2025.2.0)	impact
Atlas input grids	Cartesian	Cartesian / Finite Element	cf in following slides
Astronomical argument coefficients	Schureman (1st order)	Schureman (3rd order, **default**) or Meeus (4th order), IERS (same as GOT)	Not estimated
Astronomic angles computation	lpe_minus_n_waves() and astronomics() compute slightly different angles	**correction of lpe_minus_n_waves()** for consistency with the routine astronomics()	$\pm 6\times10^{-5}$ mm
Angles i and w for Schureman	Angle rounded to 1×10^{-3}°	No rounding	$\pm 2\times10^{-2}$ mm
Nodal corrections	Calculation every 24 hours	Calculation every time step	Not estimated
Number of input tidal constituents	34 (max 75 including inferred)	34 (max 75 including inferred) – new waves to come in future versions	-
Number of inferred waves	19 defined	19 defined – new waves to come in future versions	-
Coastal extrapolation	None in the code - Use the cartesian extrapolated grids	Nearest point (default = 0km, but can be changed in the parameters)	Not shown here
Code maintenance and development in future	no	yes	-

Information on Versions: https://github.com/CNES/aviso-fes/releases
PyFES Documentation: https://cnes.github.io/aviso-fes/pyfes.html#example

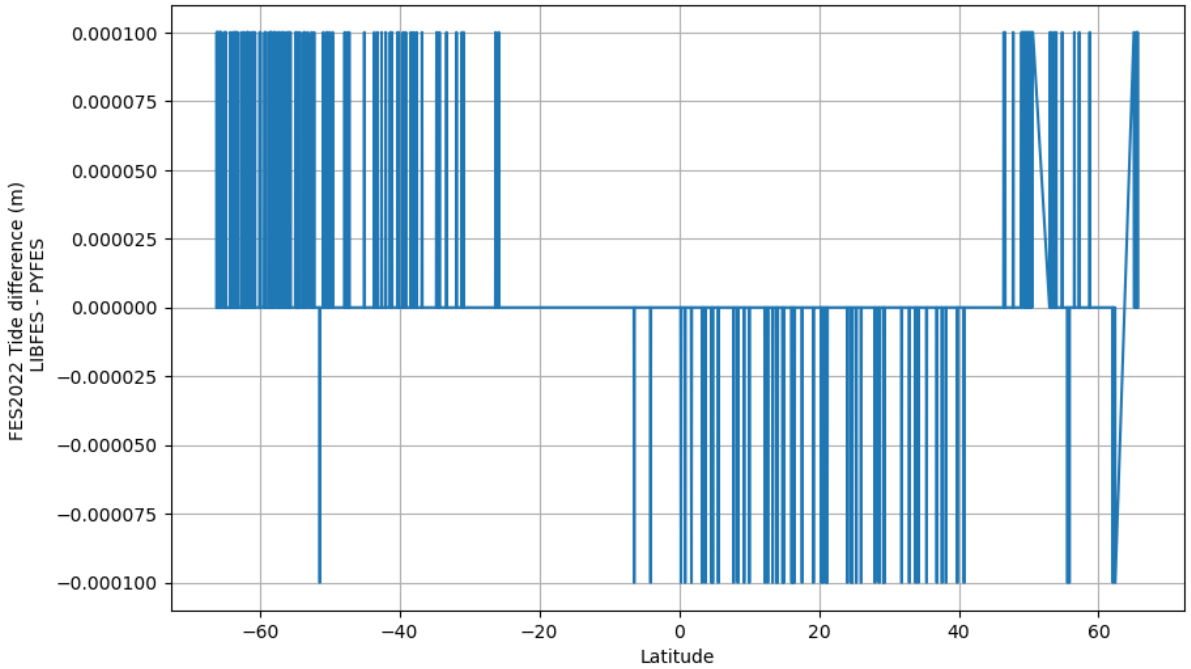
Comparison of tide estimates along a J3 altimetric track

J3 Track 61 in November 2020



Total Geocentric Tide

LIBFES – PYFES: ± 0.1 mm

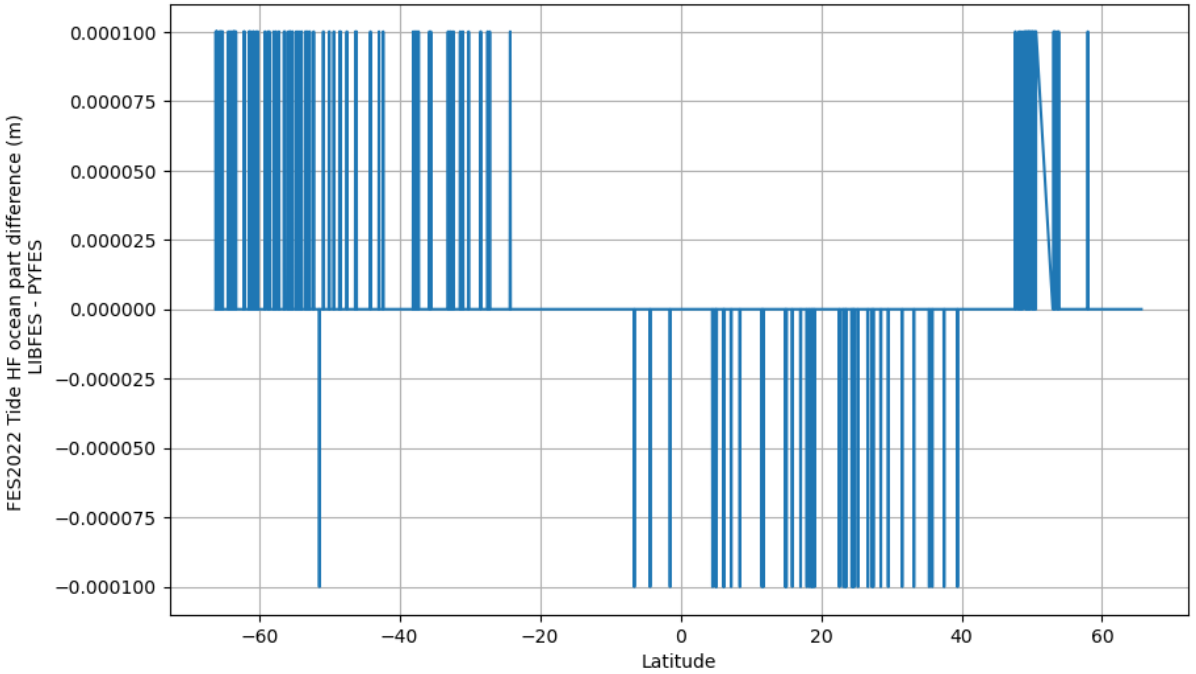


Difference is very weak : ~of the order of the storage accuracy

Comparison of tide estimates along a J3 altimetric track

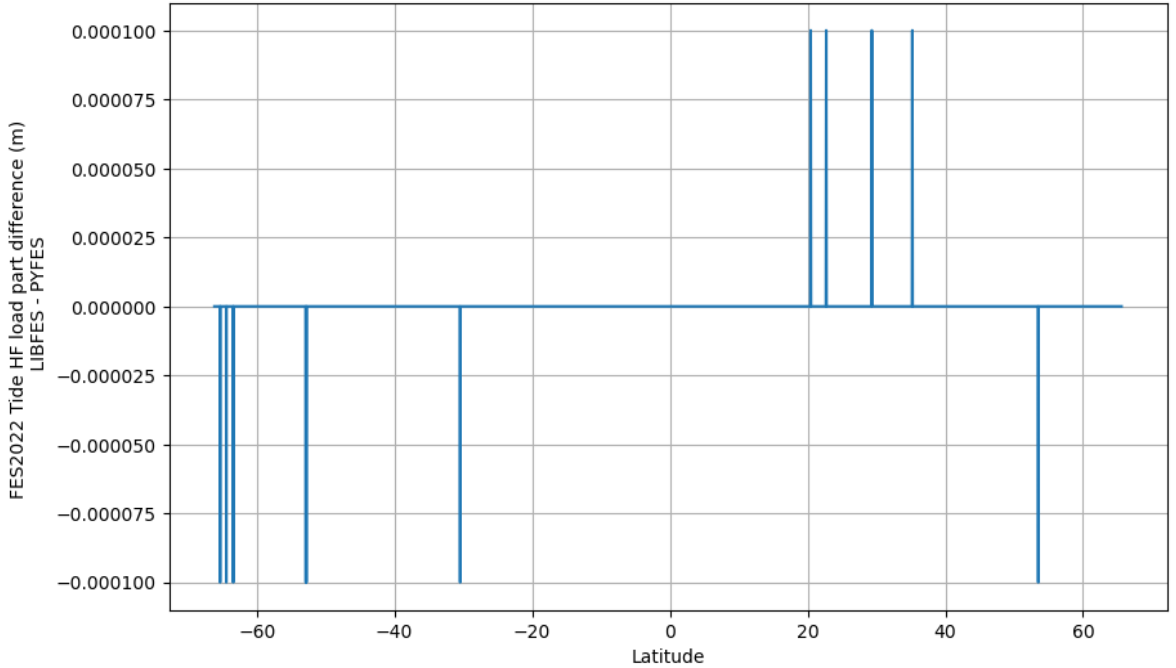
High-Frequency Ocean Tide

LIBFES – PYFES: ± 0.1 mm



High-Frequency Loading Tide

LIBFES – PYFES: ± 0.1 mm

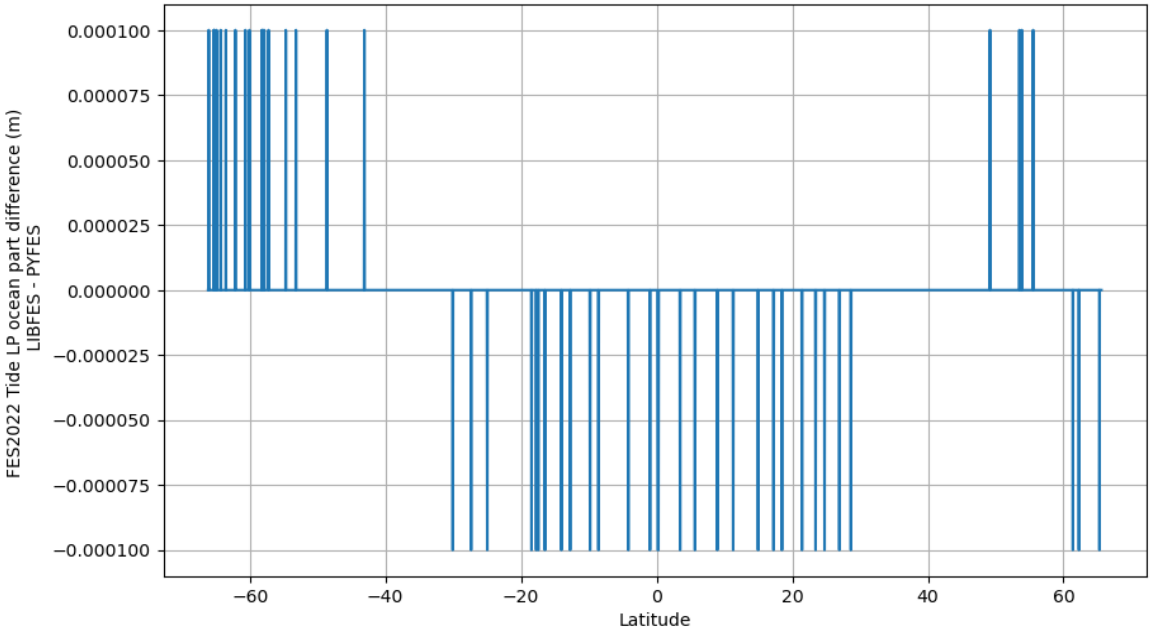


Difference is very weak : ~of the order of the storage accuracy

Comparison of tide estimates along a J3 altimetric track

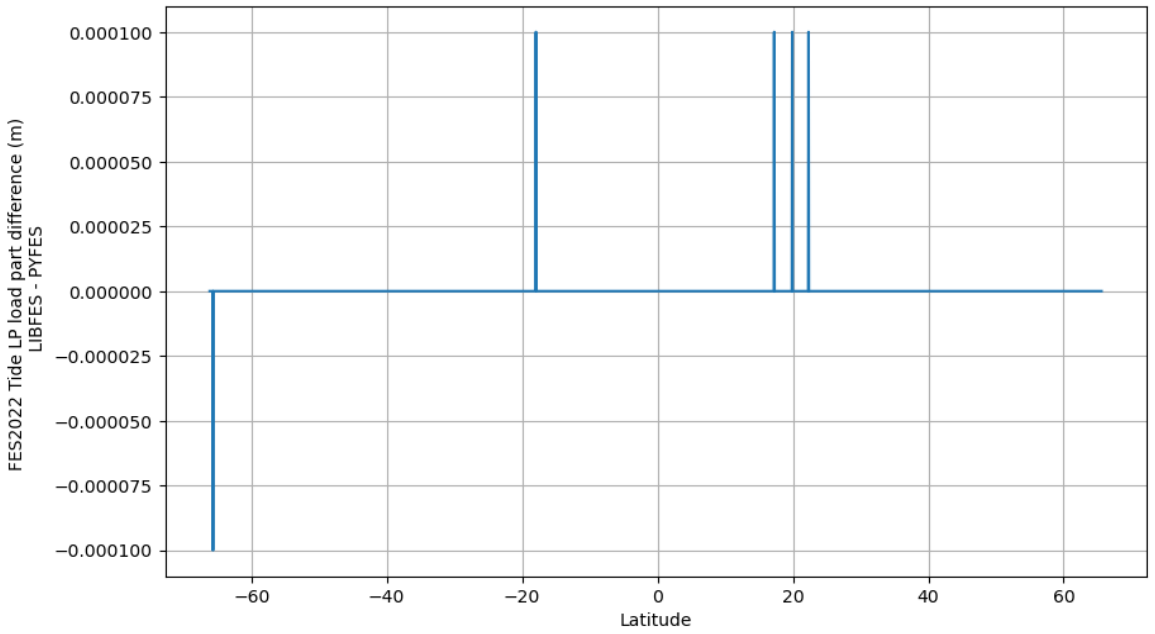
Long-Period Ocean Tide

LIBFES – PYFES: ± 0.1 mm



Long-Period Loading Tide

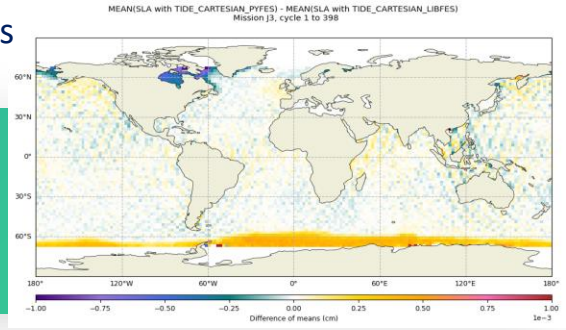
LIBFES – PYFES: ± 0.1 mm



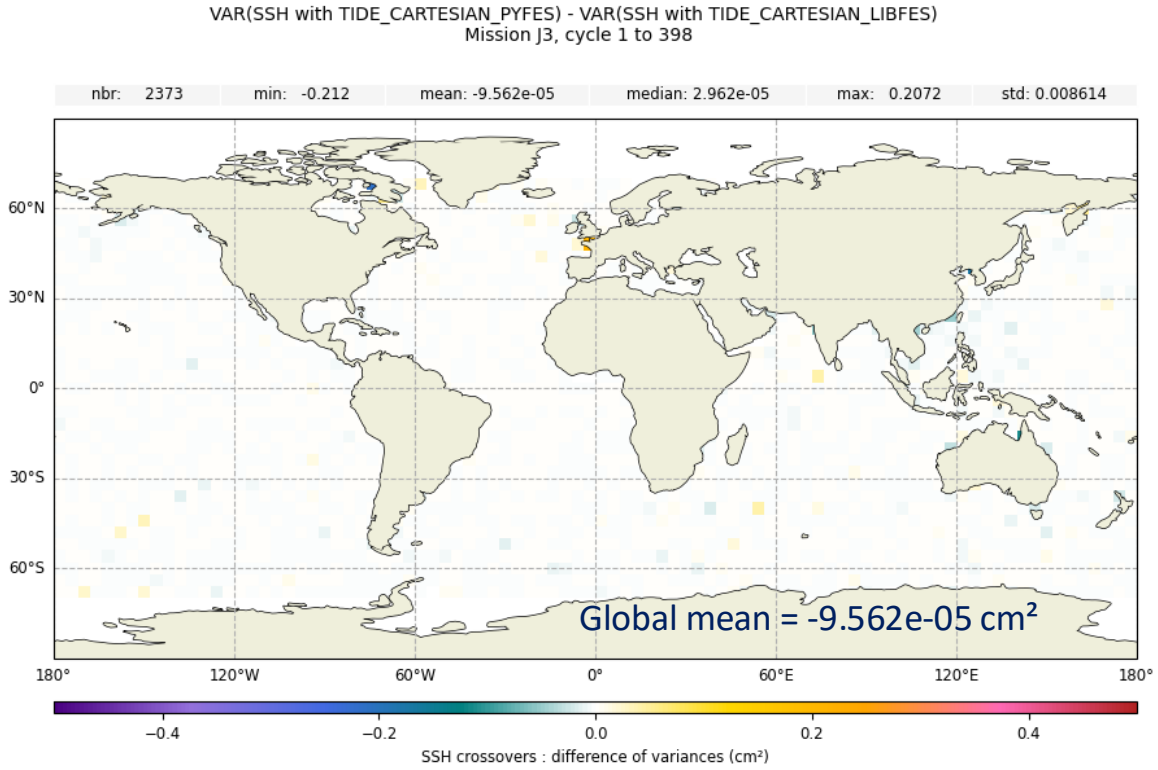
Difference is very weak : ~of the order of the storage accuracy

Global variance difference for J3 mission

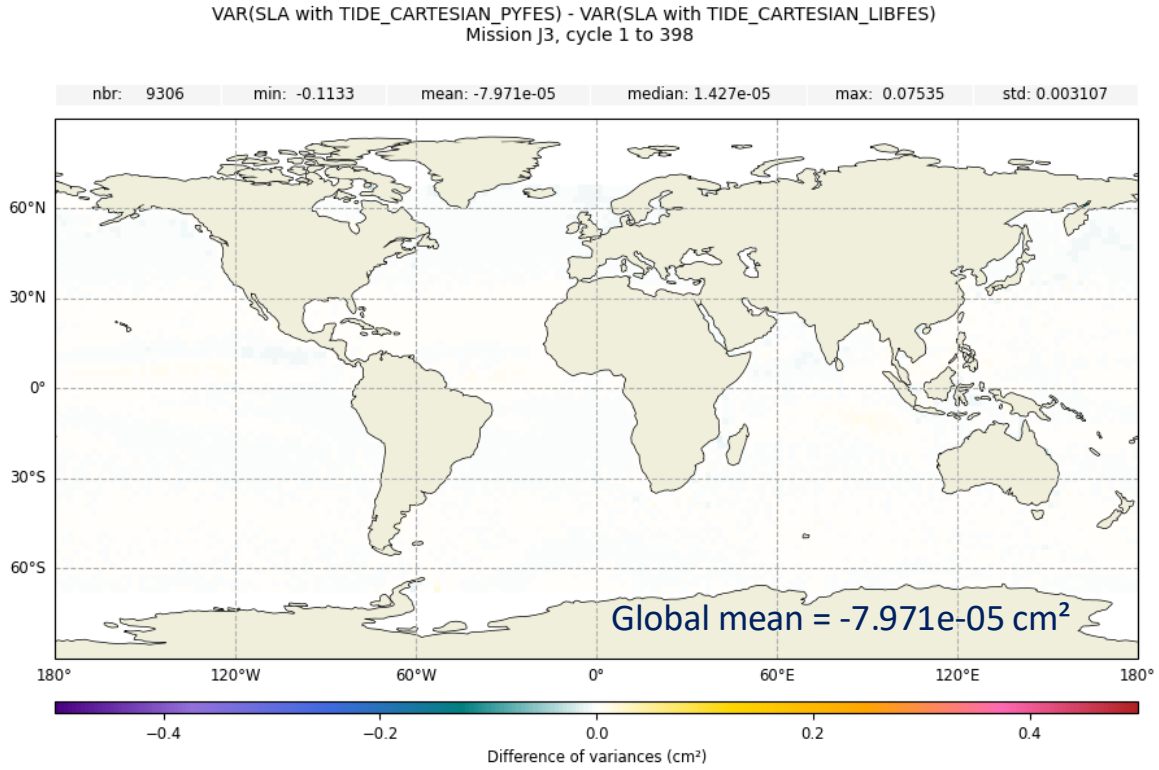
Mean differences



Variance difference at cross-over points when using Pyfes instead of Libfes with FES2022b cartesian grids (cm²)



Variance differences for the SLA along the tracks, when using Pyfes instead of Libfes with FES2022b cartesian grids (cm²)

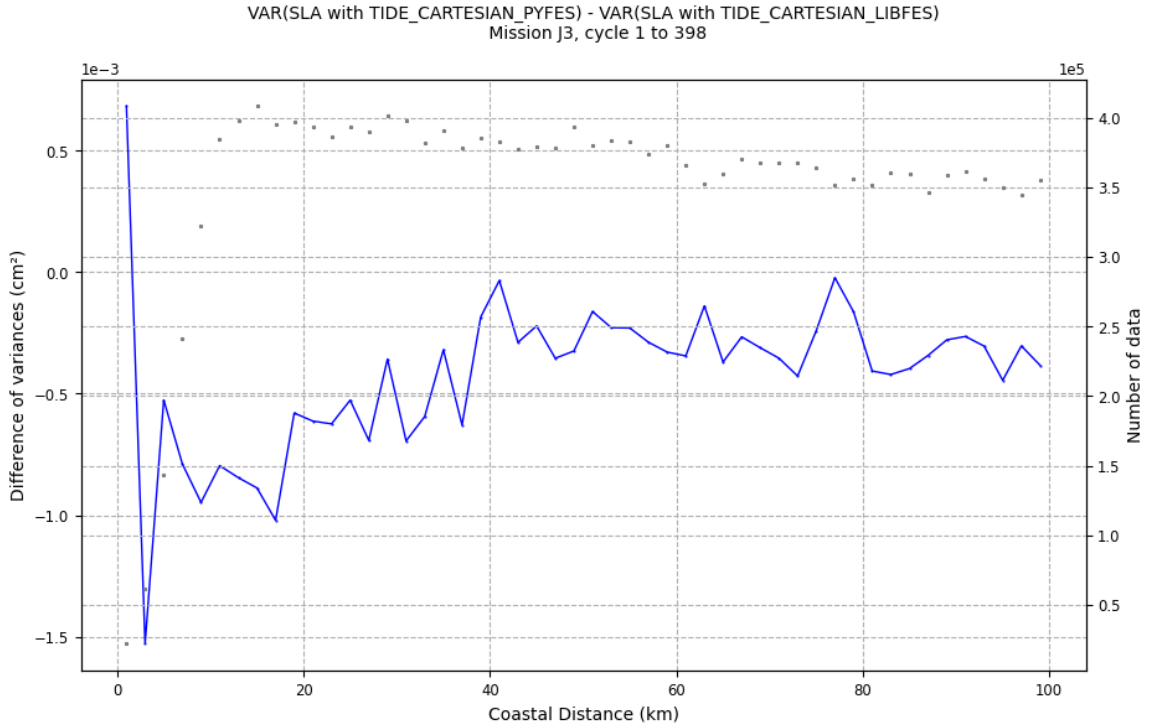


Difference is very weak for both crossovers and SLA.

SLA maps show large scale patterns following ocean currents: this is linked to cross-correlations between tide model and SLA, amplitude is very weak too

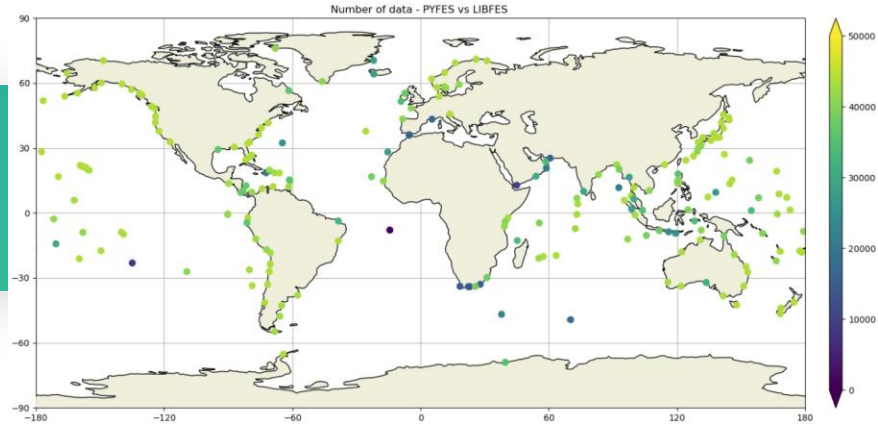
Variance differences relative to coastal distance for J3 mission

Mean variance differences for the J3 SLA along the tracks, when using Pyfes instead of Libfes with FES2022b cartesian grids, as a function of coastal distance



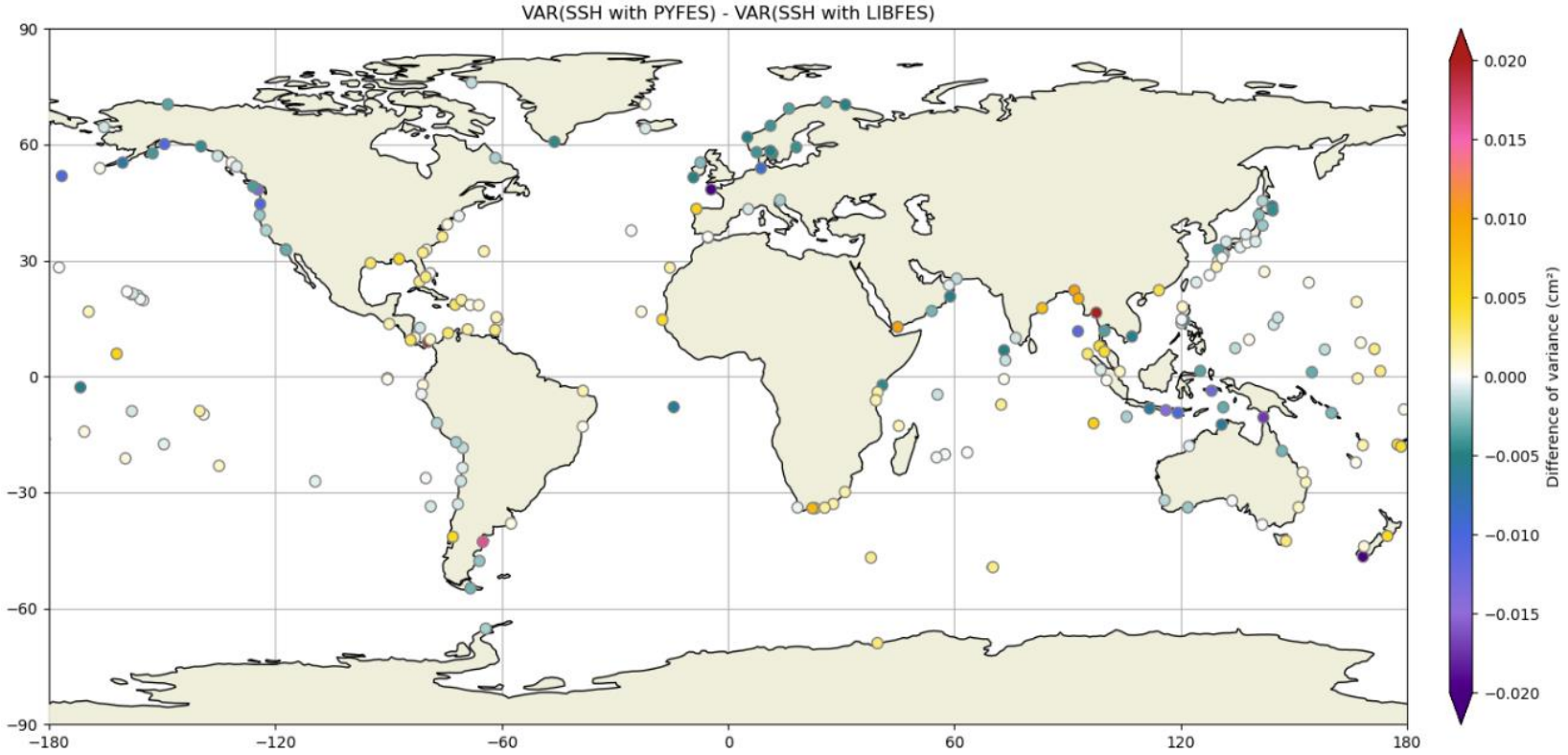
Difference is negligible (1e-3 cm^2) although slightly negative, so in favor of PyFES.

Variance difference on tide gauges

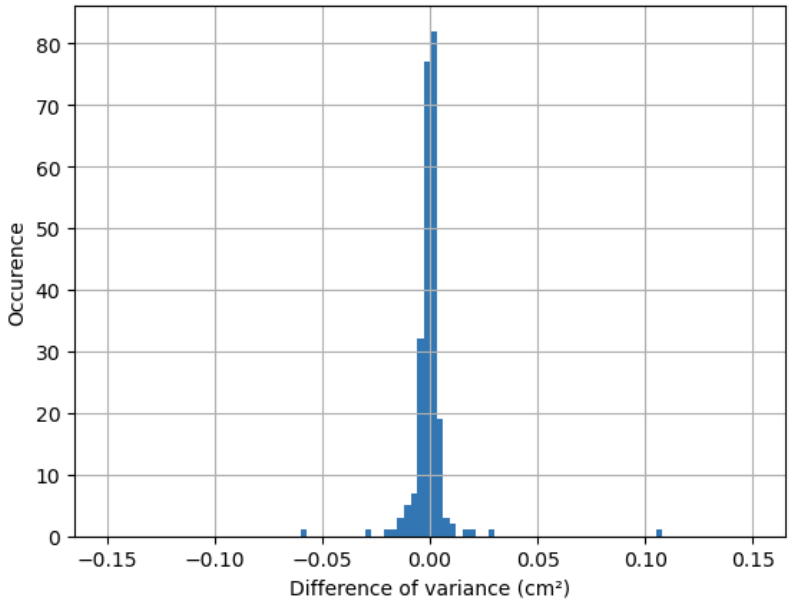


Comparison of FES2022b tidal predictions with Tide Gauge measurements from GLOSS-CLIVAR network (01/01/2017 to 01/01/2022)

=> variance differences are very weak and mostly slightly negative indicating a small improvement when using Pyfes instead of Libfes.



Number of Tide Gauges: 238
Mean: -0.00039 cm²
Median: -0.000176 cm²



Conclusions about the comparison of Pyfes and Libfes prediction codes

- Analysis shows minor differences between the use of the **libfes 2.9.7** and **pyfes 2025.2.0** tidal prediction codes on J3 altimetric data and also for tide gauges (<0.02 cm^2)

- The choice of prediction code has a negligible impact on the estimation of the total FES2022b ocean tide (geocentric ocean tide)

- Pyfes library (version 2025.2.0 and over) shall be used as official tidal prediction library for FES2022 and future FES20XX tidal solutions, both for cartesian and NS grids.

- Libfes library will no longer be maintained