# (new) FES2022 Tidal atlas

L. Carrere, F. Lyard, M. Cancet, D. Allain, E. Fouchet, M. Dabat, M. Tchilibou,

R. Ferrari, Y. Faugère

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# Introduction & context

The last release of the global tidal model FES2014b is distributed since mid-2016 & used in alti GDRs

FES2014b is characterized by :

- An increased unstructured mesh resolution in areas of interest like shallow waters and on the slope of the continental shelves
- Improved bathymetry in some regions
- The error of the pure hydrodynamic ocean solution has been divided by a factor of 2 compared to previous version (FES2004)
- But some errors still remain locally, due to uncertainties on compound tides and bathymetric errors (in shelf/coastal seas), seasonal sea ice effects and lack of available data for assimilation (in the high latitudes)

To address the reduction of these errors and face the new challenges of the tide correction for HR altimetry, in particular the forthcoming SWOT mission, the new project FES2022 has started in 2020.

The objective is to produce a more accurate global tidal solution, particularly for shallow waters and high latitudes.

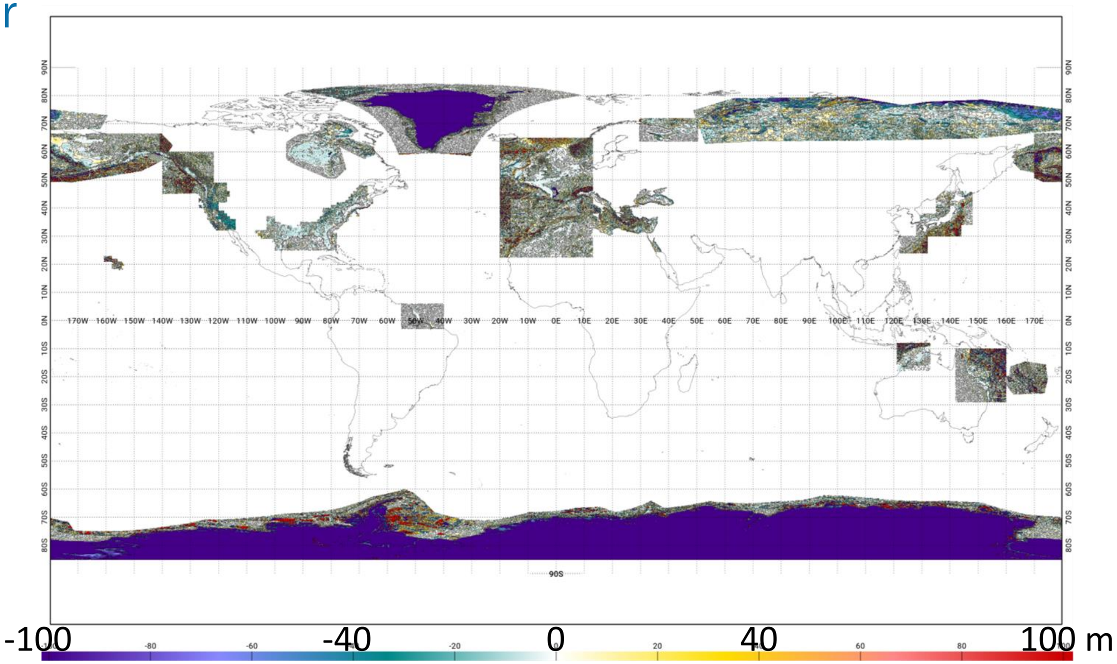
# FES2022 bathymetry

GEBCO 2020 database is taken as the reference bathymetry for FES2022

Methodology = combining many local or regional bathymetric databases collected (and/or re-processed) or developed within the framework of the Bathy-CNES project

We selected the bathymetry modifications that improve the overall accuracy of the test simulations (primarily for the M2 and K1 waves, and then for S2, N2, K2, O1 and Q1)

*Thanks to all teams who provided some local bathymetry databases !*




Difference between GEBCO 2020 and the FES2022 composite bathymetry (m)

# FES2022 HR mesh

The generation standard values for FES2022 global mesh were set as follows:

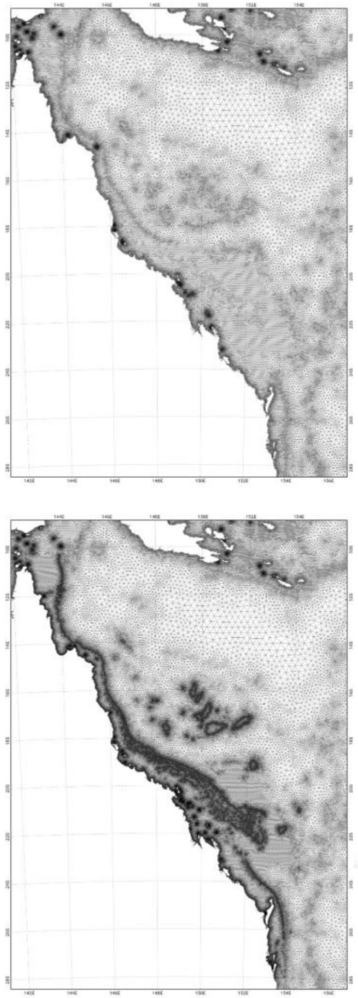
- Offshore resolution : 30 km
- Shelf resolution : 10 km
- Resolution at the continental slope : 6 km
- Coastal resolution: 4 km

Then a local/regional refinement stage was performed, guided by:

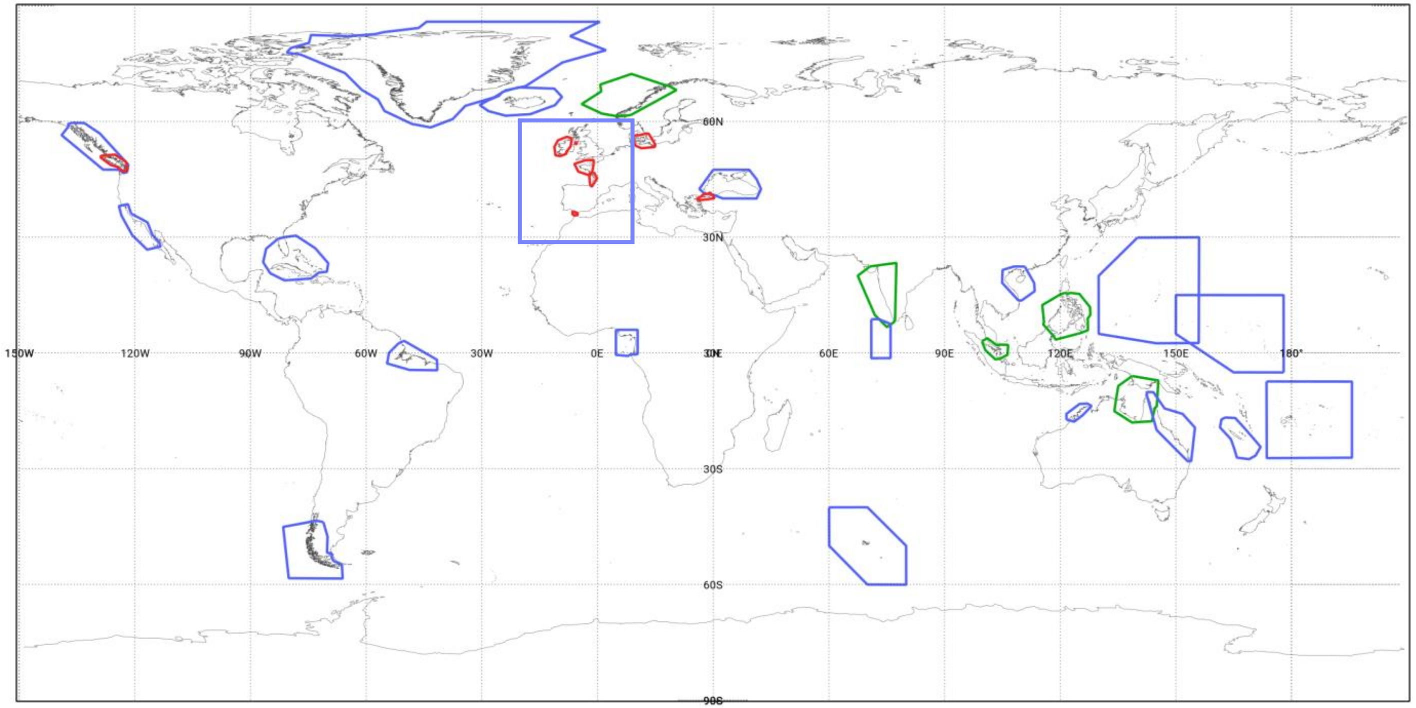
- coastline complexity (Norway, Tierra del Fuego, etc.)
- sensitivity of tidal modelling in certain critical areas
- local bathymetry accuracy
- the existence of scientific worksites (SWOT validation sites …)

FES2022 mesh has about 11 000 000 elements = x8 more than the FES2014 grid

Example on the Great Barrier Reef : initial FES2022 mesh, and then refined on the reef patterns



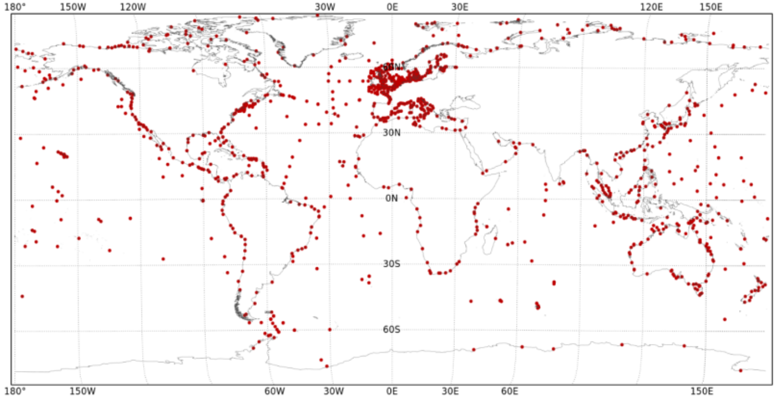
# FES2022 new HR mesh

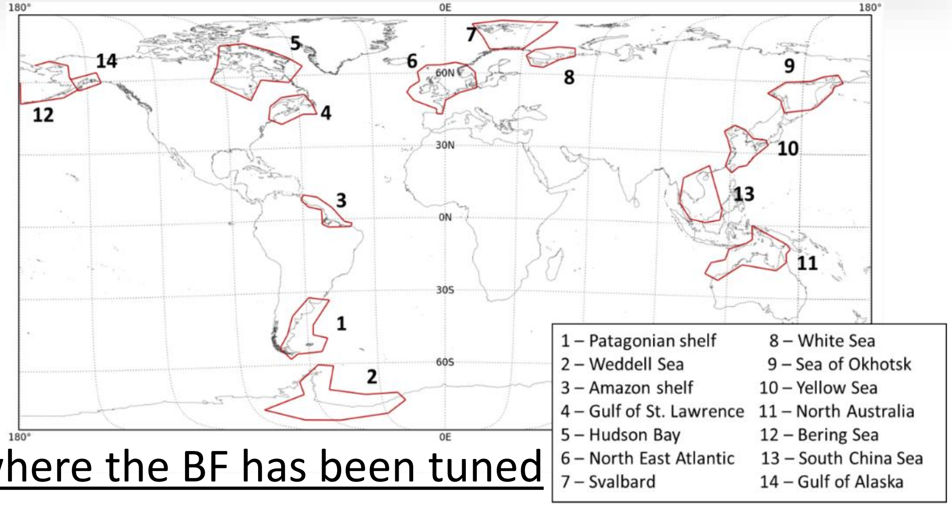



Coastal refinement areas: 3km (green), 2km (blue), 1km (red), 500m (magenta)

# Adjusting hydrodynamic solution

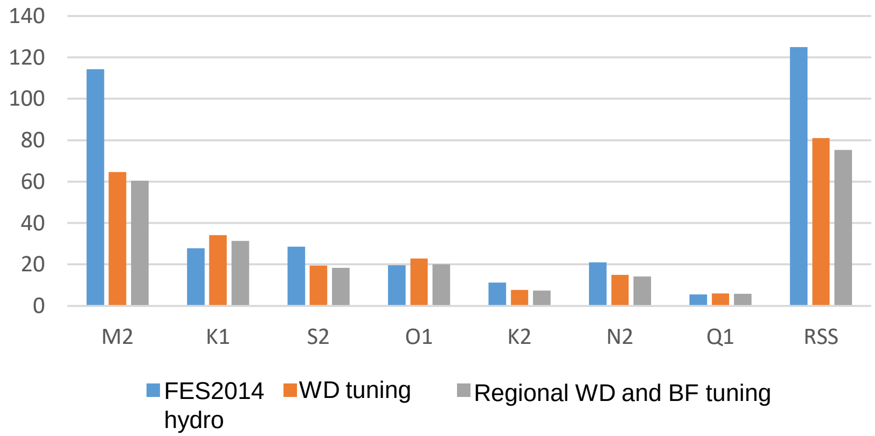
## Fine tuning of different parameters : BF and wave-drag




Regions where the BF has been tuned

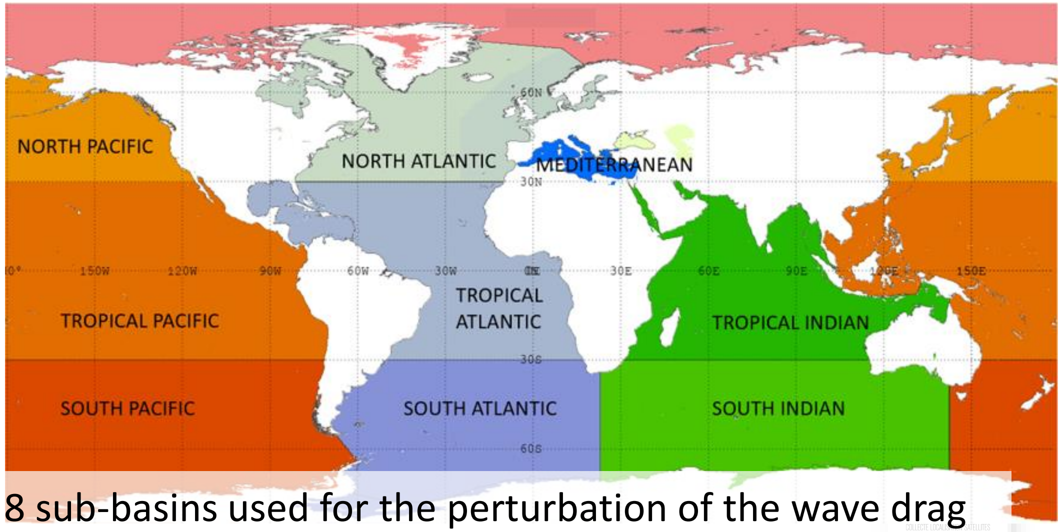
Validation to shelf crossovers : vector difference (mm)




Regional tuning improves the global RSS to shelf xovers :

**-9.2 mm** compared to global tuning

**-49 mm** compared to FES2014 hydro.




8 sub-basins used for the perturbation of the wave drag coefficient – Mediterranean Sea excluded

# FES2022 altimeter database on global ocean - repetitive tracks

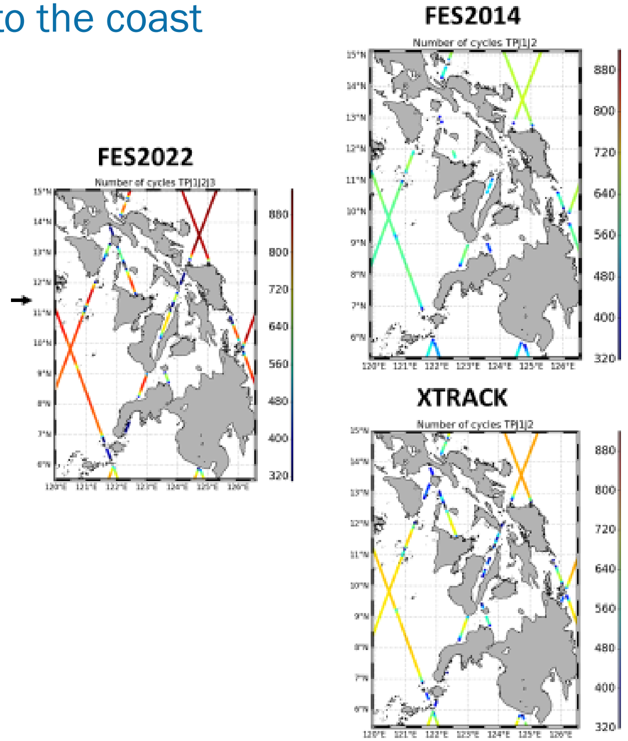
On the entire altimeter era : **TP-J1-J2-J3, TPN-J1N-J2N and ERS-EN-AL**

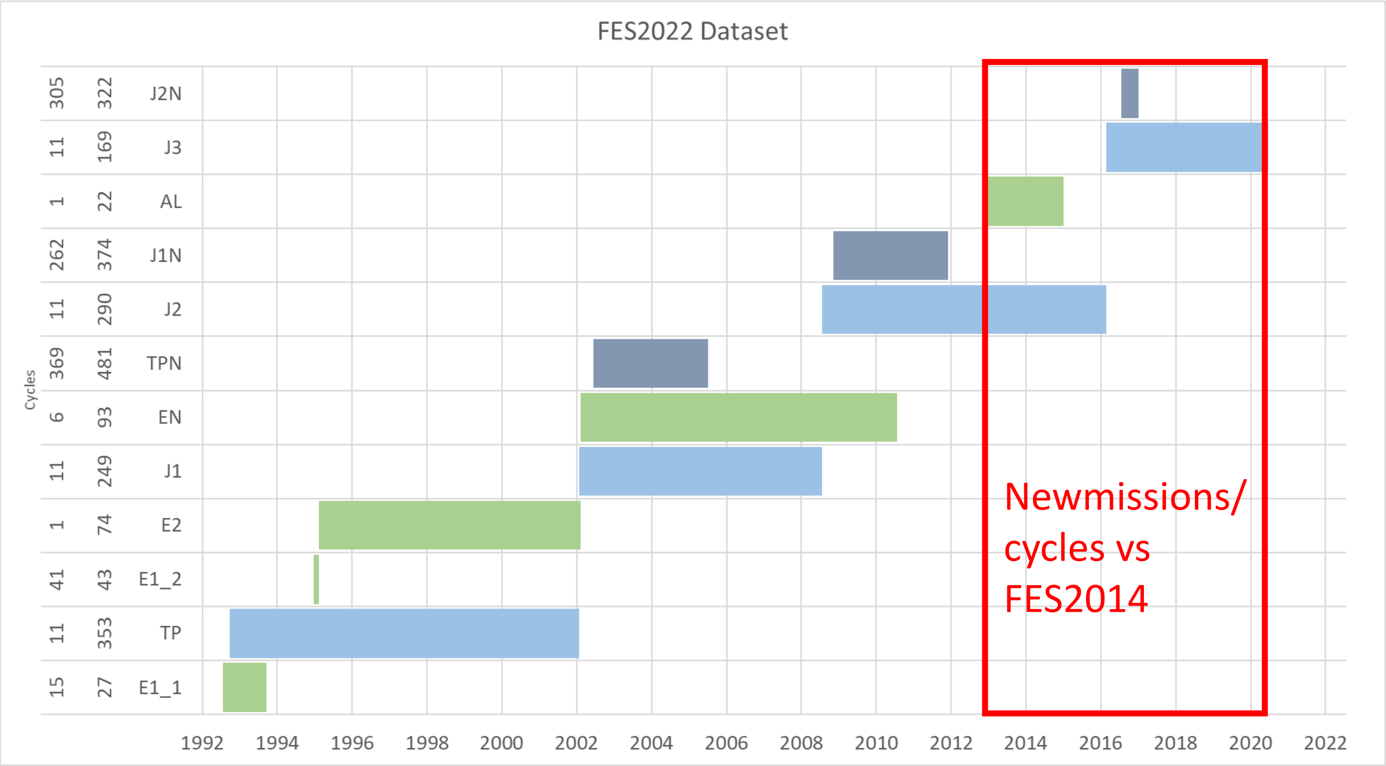
Includes new standards for instrumental and geophysical corrections (L2P 2021), including Zaron IT correction (2019)

⇒ Better quality of the tidal estimations

⇒ More points estimated

⇒ Get closer to the coast



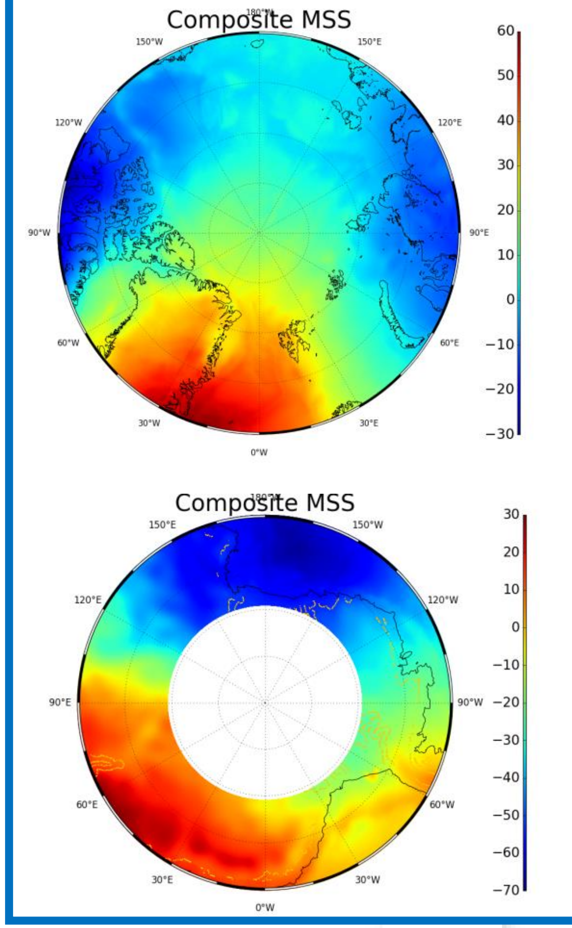



# FES2022 altimeter database for polar regions

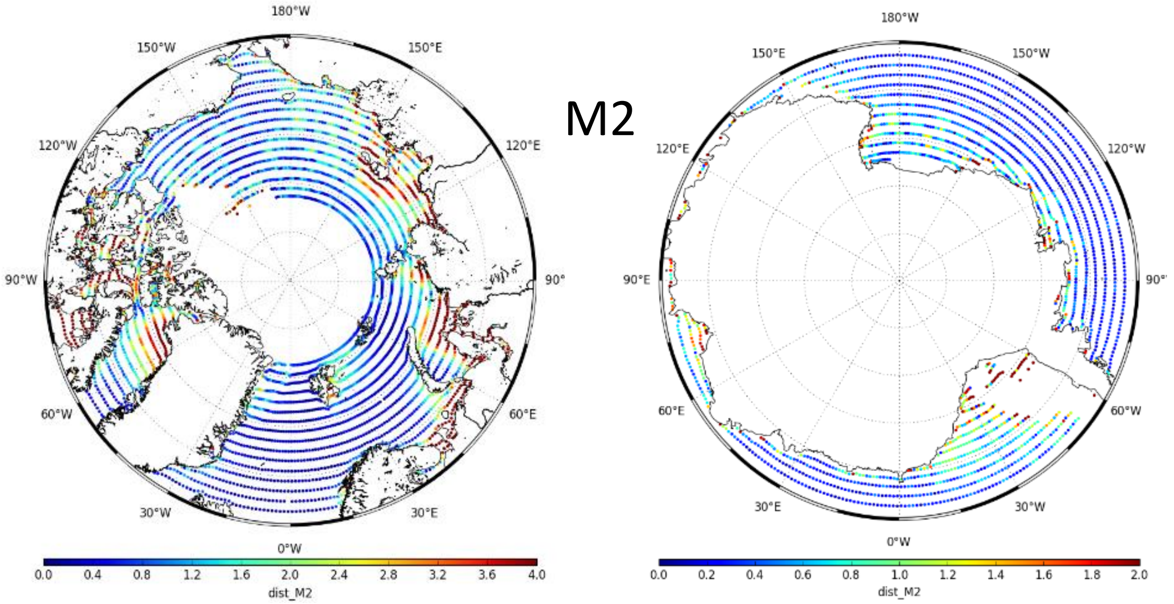
The reference missions are not available in these regions. => **construction of a specific database for |LAT| > 66° using all available altimeter missions combined in small boxes**

- Same corrections/processing as the **L2P 1Hz** database used on the global ocean
- Use the composite MSS for drifting orbits + recent missions and PM for repetitive tracks

Composite MSS = mix of SCRIPPS, CNES15, DTU15




Observed tide – FES2014 (cm)



# Assimilated solution FES2022A

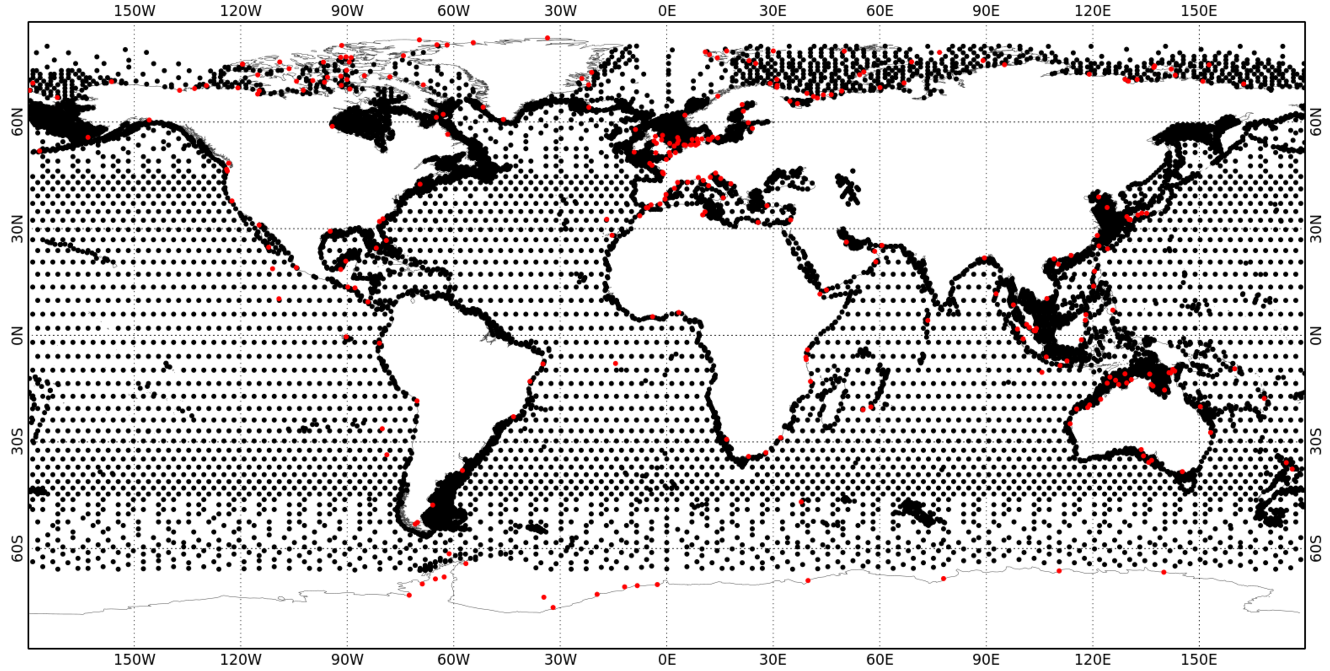
16 waves assimilated => 2N2, E2, K1, K2, L2, La2, M2, Mu2, N2, Nu2, O1, P1, Q1, S2, M4, J1

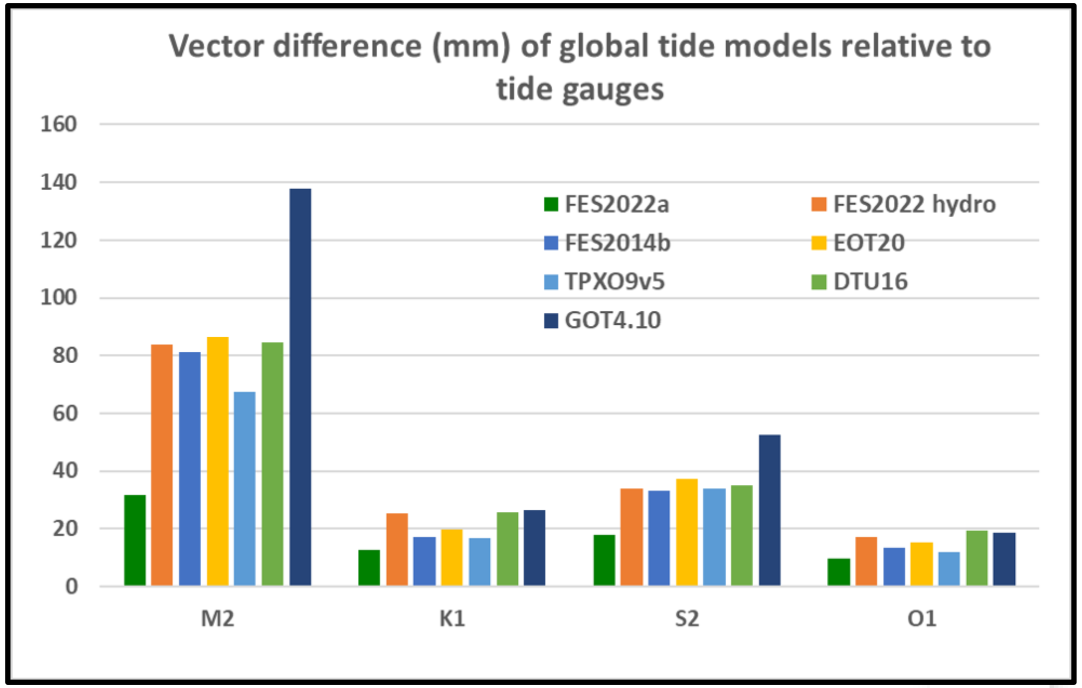
FES2014 waves to complete spectrum => 34 waves in FES2022 atlas

2 min x 2 min grid resolution

| Assimilated data | FES2014b | FES2022 |
|---|---|---|
| Altimetry points | 12 022 | 13 489 |
| Tide gauges | 600 | 295 |

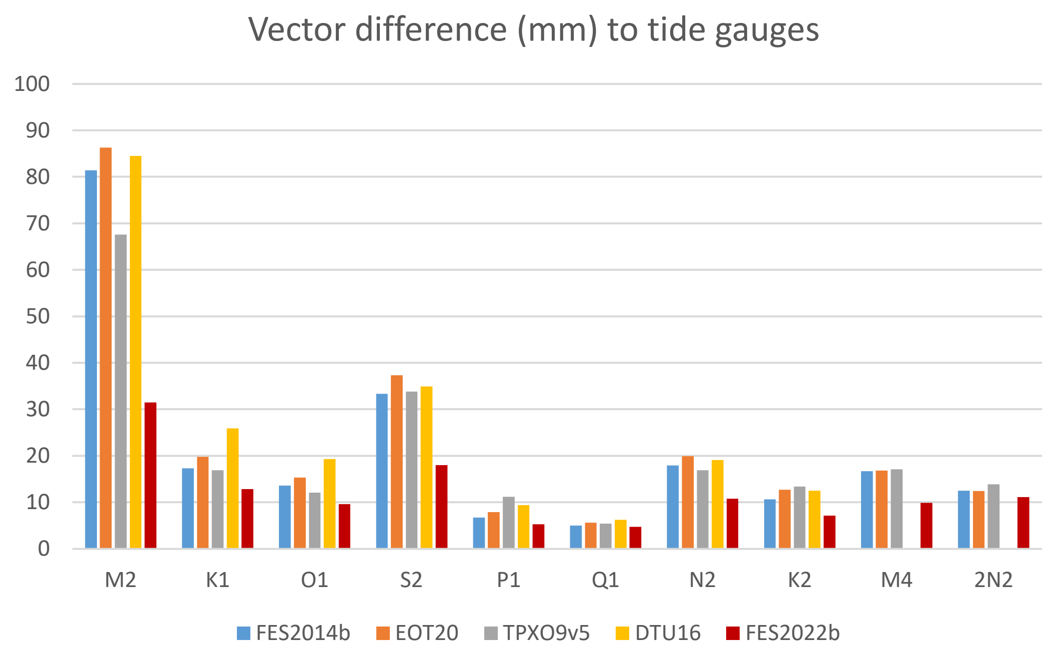
**Assimilated observations in FES2022 (altimetry and tide gauges)**

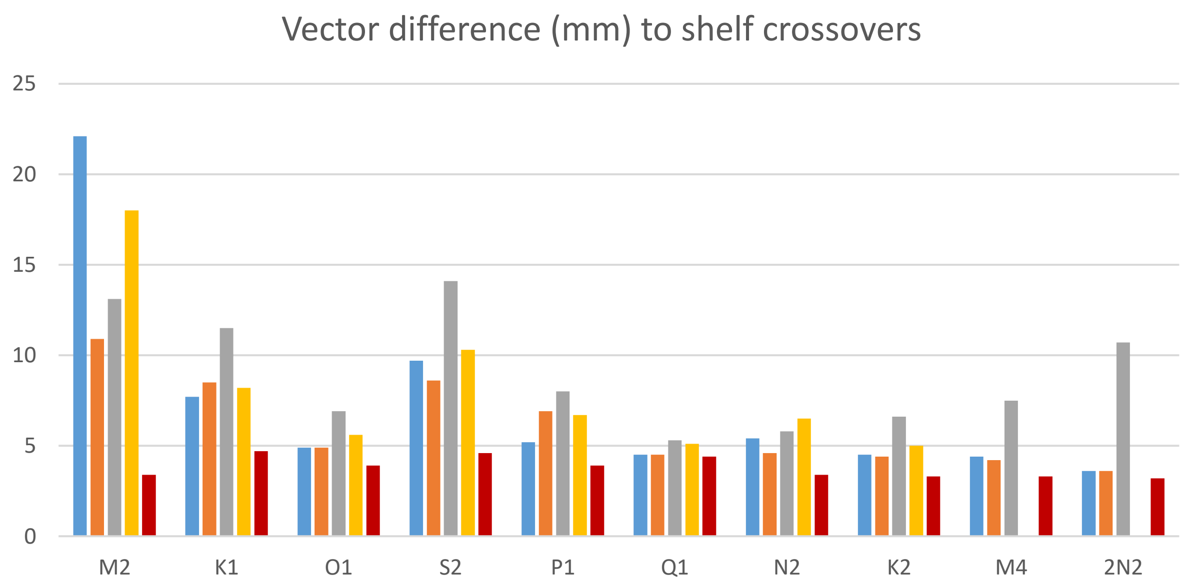


# FES2022 Loading Tide

FES2022 loading tide has been computed on the FES grid => new computation code developed

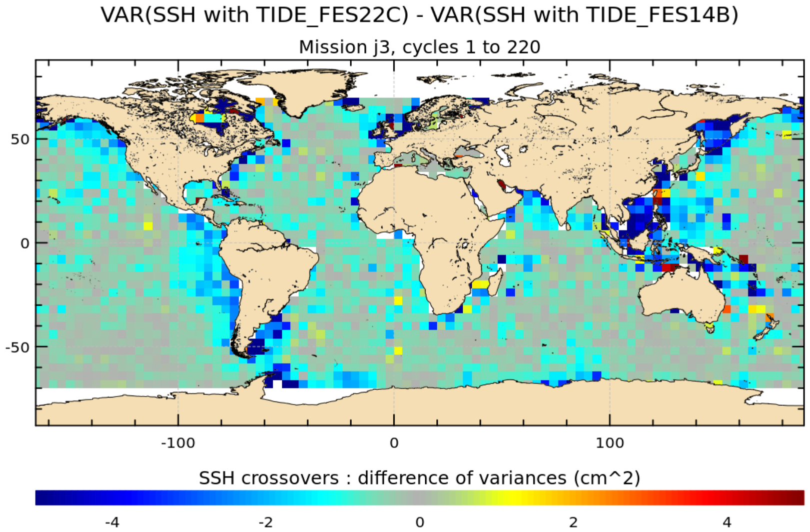


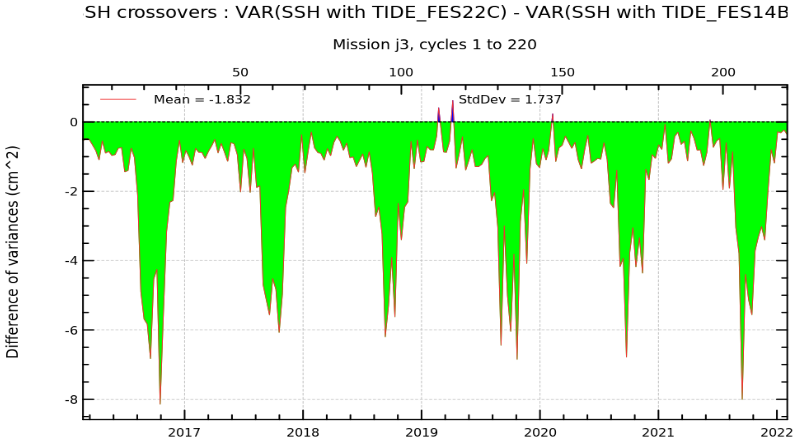




Globally FES2022 is better than all the global models to all the validation datasets and for all the tidal waves

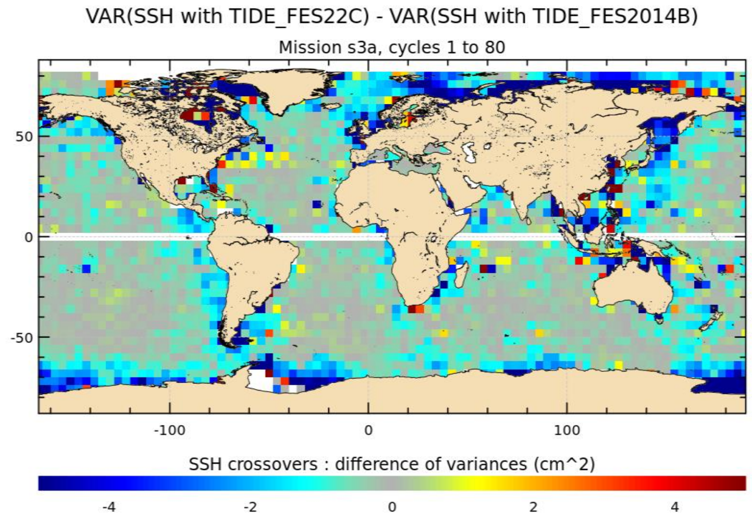
# Validation results of FES2022 atlas vs FES2014

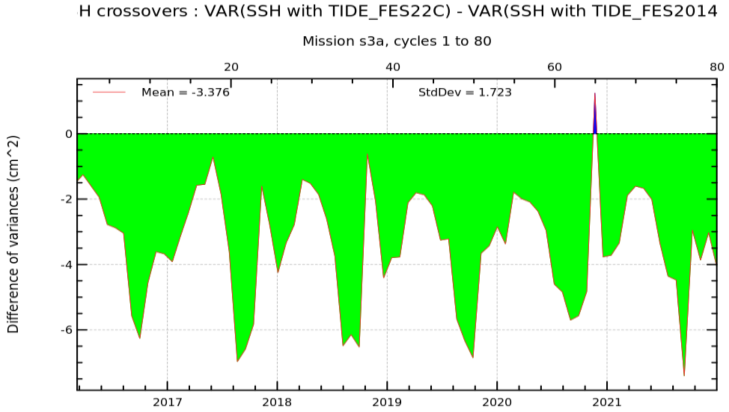
## XOVERS J3



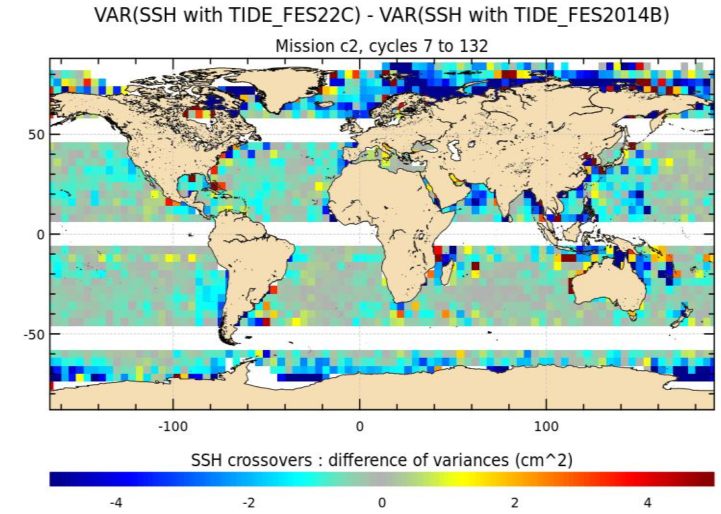



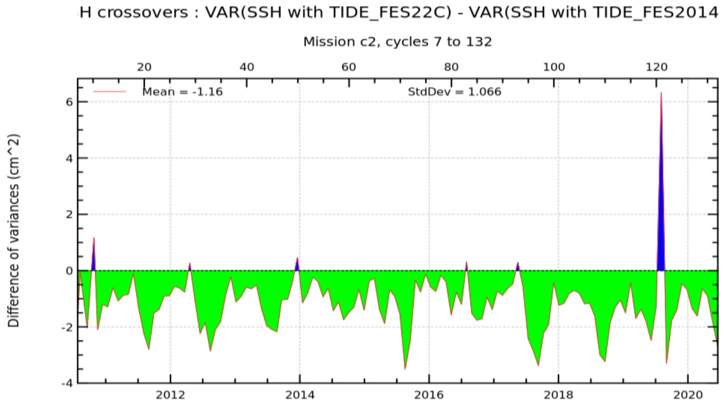

## XOVERS S3A




## XOVERS C2

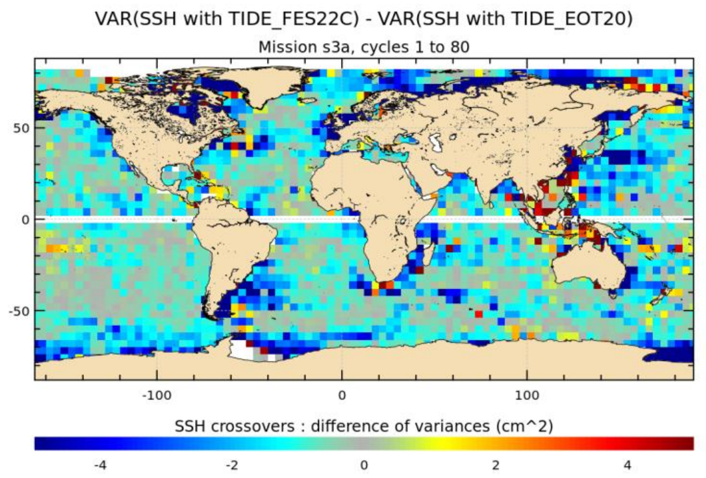


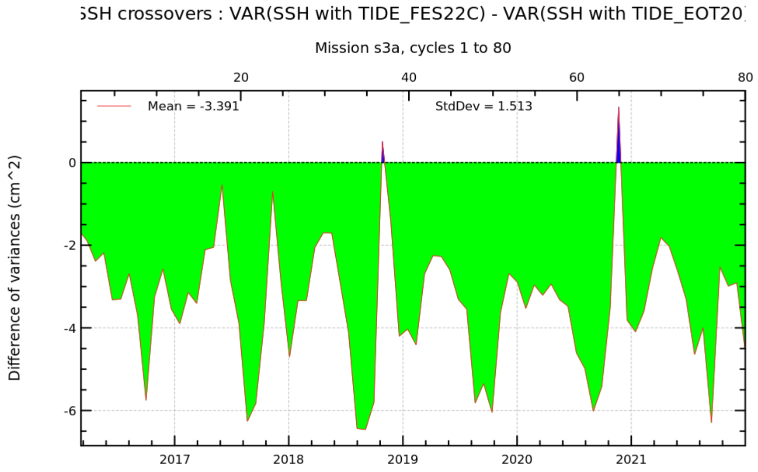



# Validation results of FES2022 atlas vs other models

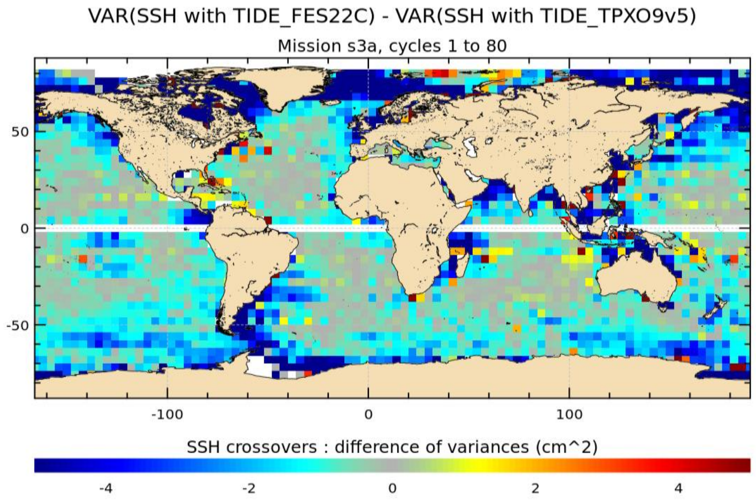
XOVERS S3A

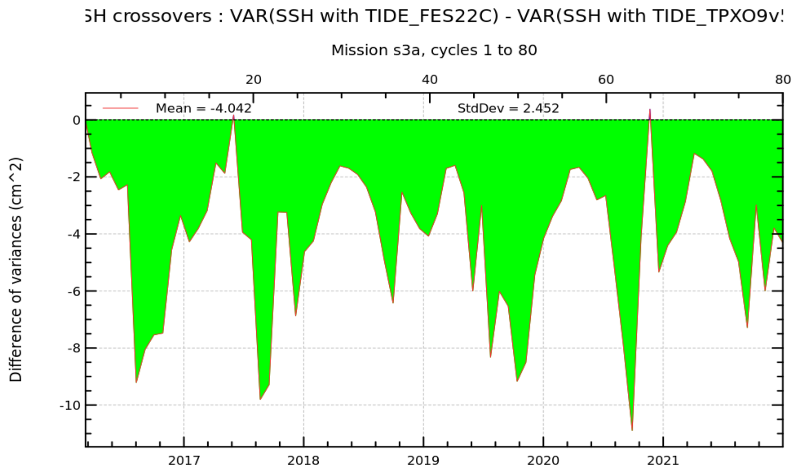
**EOT20** -> all EOT20 waves but no Sa and SSa waves



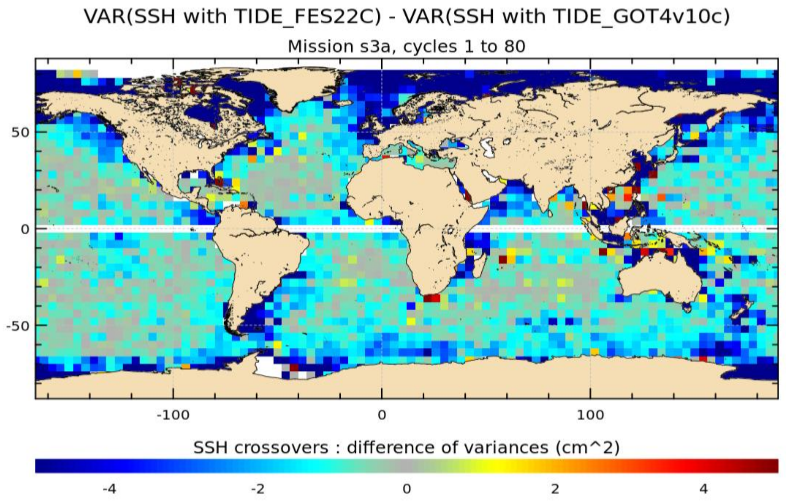



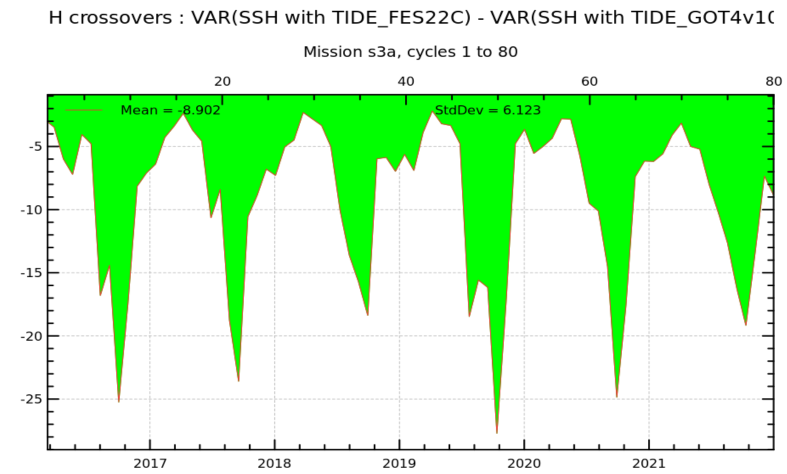

**TPXO9.v5** -> all TPXO9v5 waves




**GOT4.v10c** -> all GOT4.10 waves



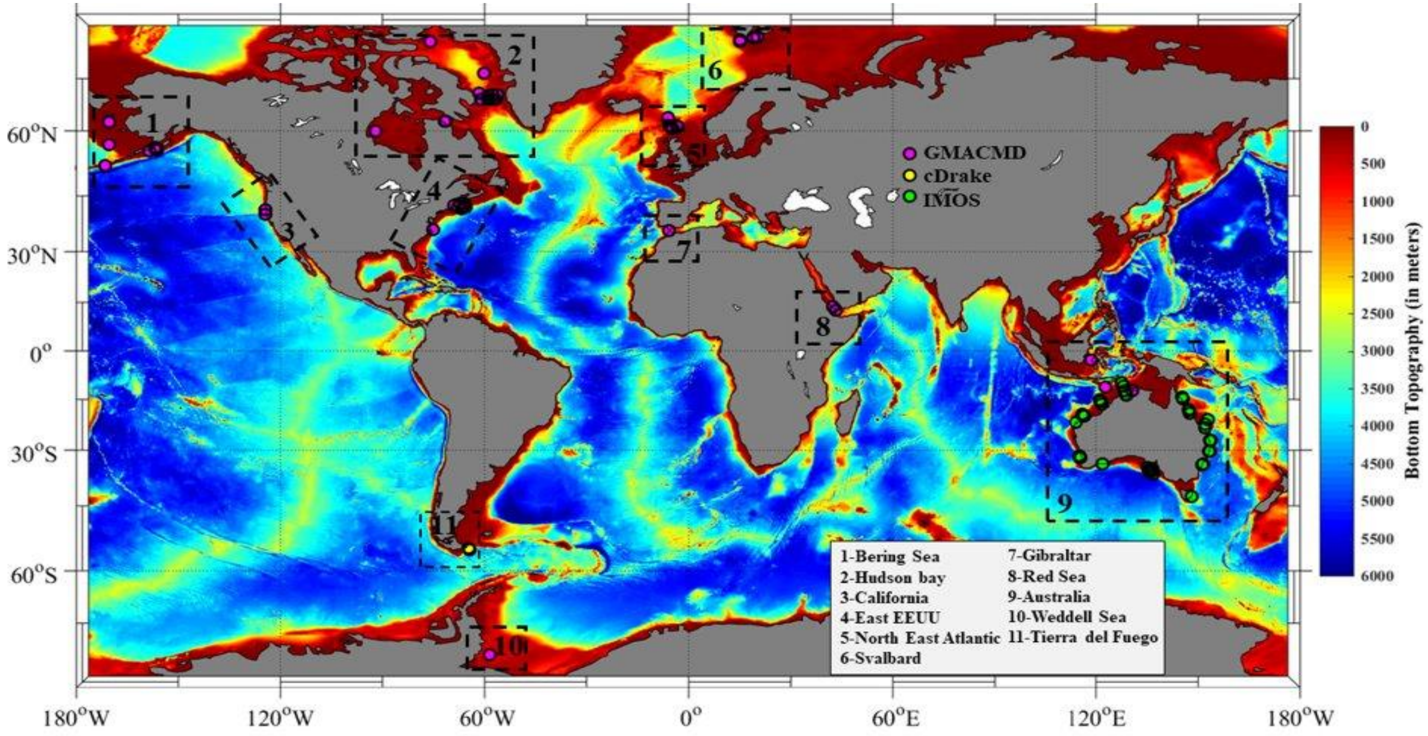



# Validation results of FES2022 currents vs other models

Discrepancies between different tidal models (FES2022, FES2014 and TPXO9v5) and current meters data

Current-meter data (119 stations distributed in 11 regions):

- Global MultiArchive Current Meter Database (GMACMD)
- 44 Acoustic Doppler Current Profiler (ADCP) stations around Australia (IMOS)
- A current-meter mooring from cDrake project (https://data.nodc.noaa.gov/) off Tierra de Fuego.

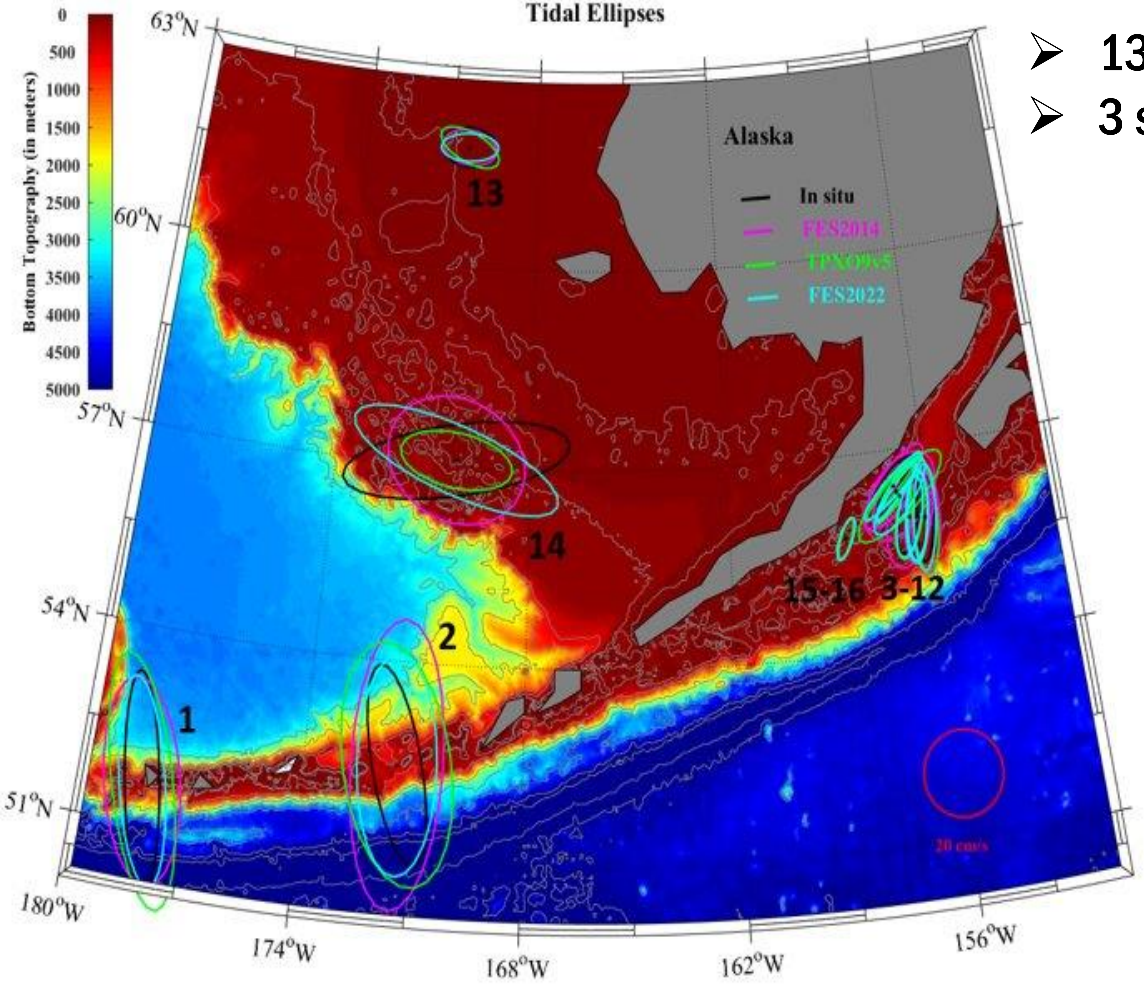



Data base chosen based on the following criteria:

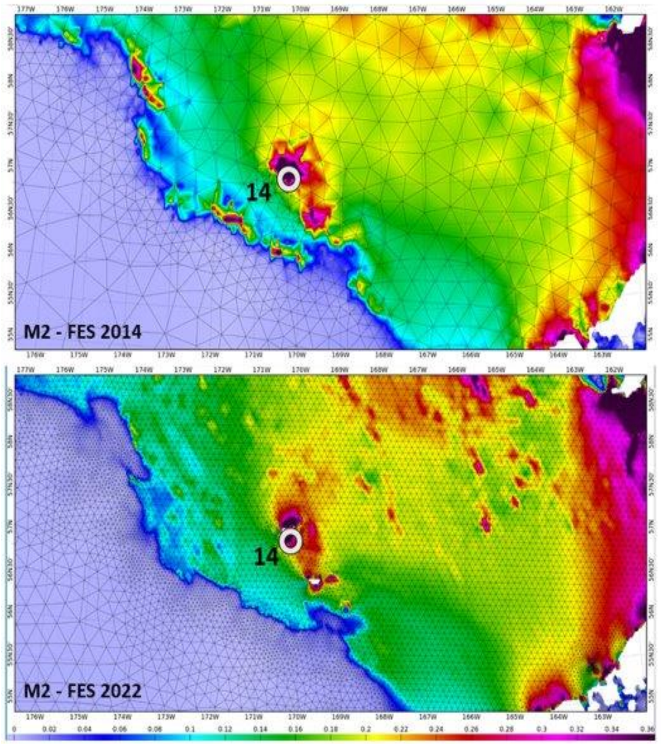
- High-frequency (time step < 1h)
- Current meters time series larger than 300 days and tidal amplitude > 10 cm/s
- Each raw time series of the velocity components has been submitted to several diagnoses in order to assess the accuracy and consistency of the selected records.

# Validation results of FES2022 currents vs other models

## Bering Sea region : 16 stations



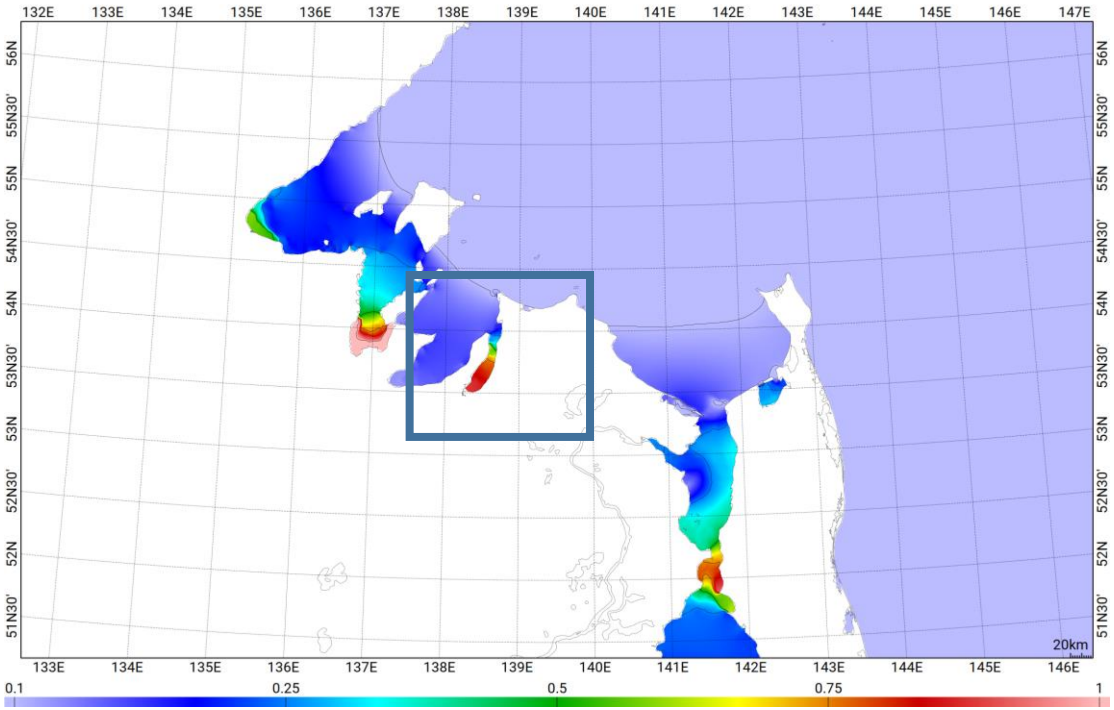

- 13 Stations: Small Differences ~ 5 cm/s (relative errors<15 %)
- 3 stations: Differences > 10 cm/s (FES2022 significantly improves)

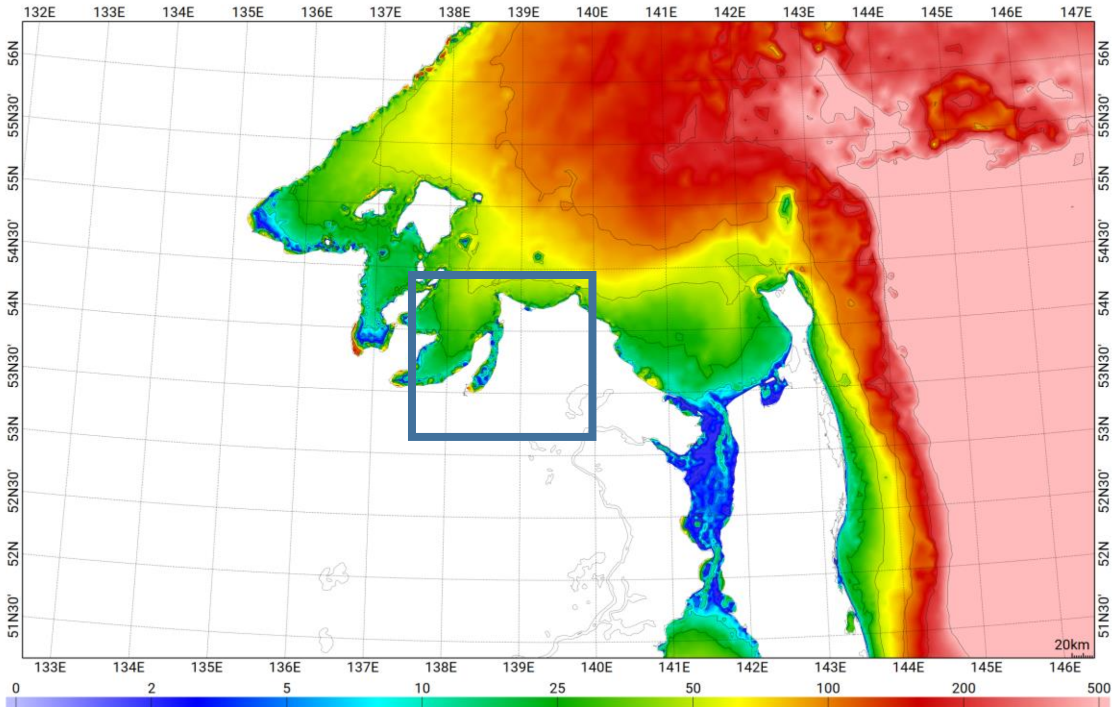



- Improvements of the mesh grid resolution for FES2022 in the vicinity of the stations 1, 2 and 14.
- Better representation of the along bathymetry variability component.

# Identified issues: bathymetry-related ensemble

Minimum depths: set to 10m in FES2014, 2m in FES2022 (to take profit of coastal bathymetry improvements)



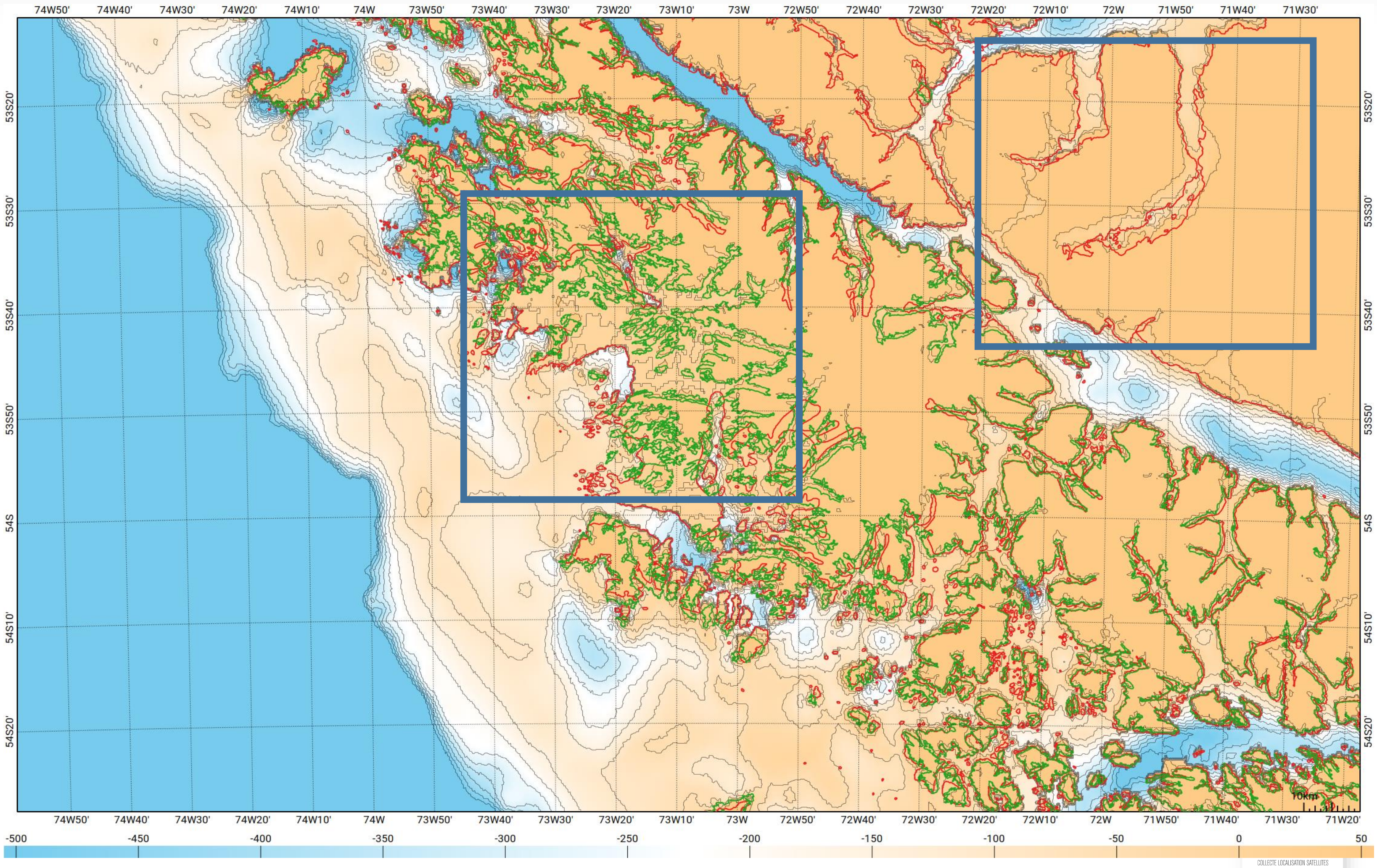

Minimum depths setting used to produce some members of the data assimilation ensemble
But… very shallow (erroneously) bathymetry can trigger ensemble unphysical variance “bloom”
In **absence of control data (assimilation)**, it can lead to very local anomalous tidal elevation

# Known issues: GSHHS shorelines

red=gshhs shorelines (last release)
green=global-Islands database

- GHHS used for mesh construction
- Numerous shifts observed in many places
- Errors can reach 20 km

A combined bathymetry/shorelines scrutiny now necessary because of the O(1km) coastal resolution in FES atlases



# Conclusion

1- FES2022 tidal atlas has been now finalized

2- FES2022 tidal elevations: validation shows significant improvement compared to FES2014b and other models

3- FES2022 tidal currents perform:

- better than **FES2014** at 19 stations (3 in Alaska, 11 on US coasts, 1 in the Weddell Sea, 2 in Svalbard and 2 in Australia)
- similarly (without significant differences) at 92 stations
- worse at only one station in the northern Faroe Islands (increase of resolution on suspect bathymetry).

4- FES2022 is SWOT resolution-friendly in coastal zone, but some issues still remain (shorelines, bathymetry)

5- *OSTST and SWOT tidal groups can have access to the atlas on demand for early assessment* (34 waves on 2min x 2 min grid)

# First user feed-backs (Emilie Lyard, Toulouse, independent advisor)

The new FES2022?

Fantastic !!!