A new global ocean barotropic tide model: **FES2022**

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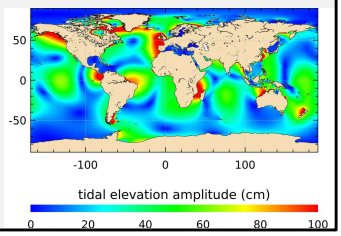
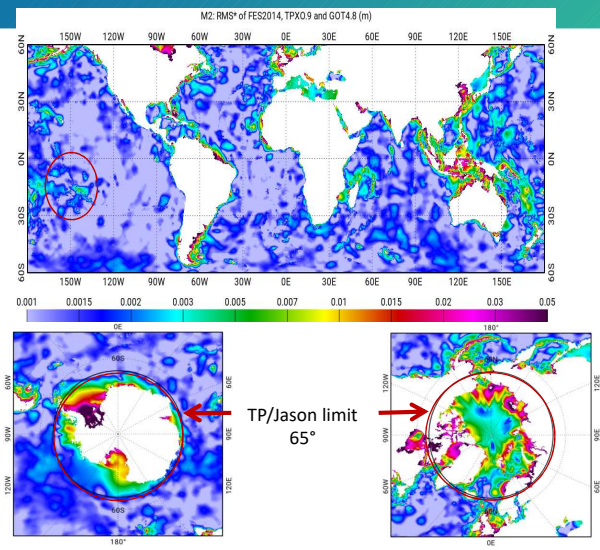


A new project funded by CNES has just been launched this year, in collaboration with LEGOS, NOVELTIS and CLS : FES2022.

Outline

1. Objectives of the new global ocean tide model FES2022
2. New bathymetry and mesh
3. Assimilation
4. Loading and Self-Attraction effects
5. Validation
6. Dissemination

Global atlases dispersion: uncertainty estimate



RMS of FES2014b, TPXO9 and GOT4.8 models for M2 wave (m)

Today M2 atlases convergence:

- 2 mm level in deep ocean
- 3 cm on shelves

Convergence mostly achieved in TP/Jason deep ocean coverage

Persisting challenges are:

- Shelf seas
- Polar seas
- Large meso-scale dynamics regions
- Large internal tide generation regions

The global atlases dispersion gives an estimation of the tidal model uncertainty.

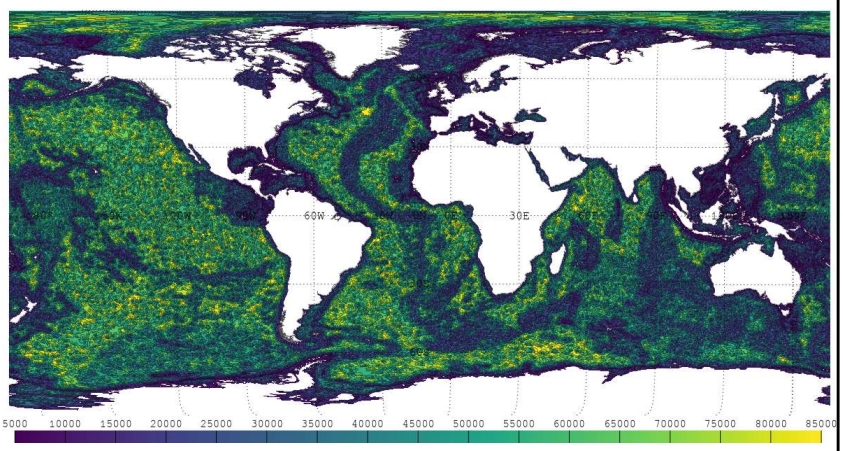
Objectives of new FES2022

- Atlas ready for beginning of 2022, just for the launch of SWOT
- Barotropic tide model only (baroclinic part is modeled separately by other teams)
- Improving the tidal atlas quality for :
  - Coastal regions / continental shelves, and focus on the SWOT/Calval estuarian areas if possible, but we'll be limited by the availability of accurate bathymetry databases …
  - High latitudes : Arctic, Antarctic, Hudson bay, Baffin bay …
  - For the main tidal components, secondary waves, non linear waves, long period waves
  - Coherency between Tides and DAC corrections for altimetry
- Provide tidal elevations and currents
- Include a tidal estimation error in the products
- Some external collaborations envisionned about high-latitudes, filtering of residual internal tide signals, data for validation, and validation of the atlas

New bathymetry, mesh, hydrodynamic simulation

Global tidal model FES2014

- FES2014 mesh counts 1 464 500 elements => will serve as V0 for FES2022 configuration
- FES2014 used a global LEGOS bathymetry based on etopo1



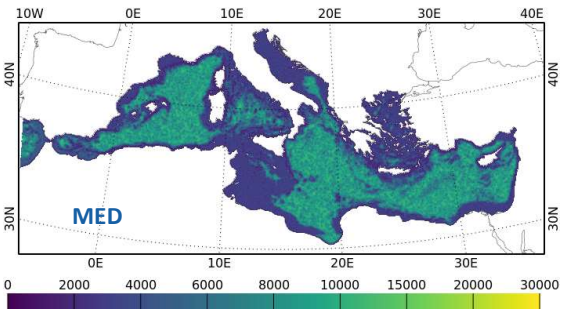
FES2014 mesh resolution (m)

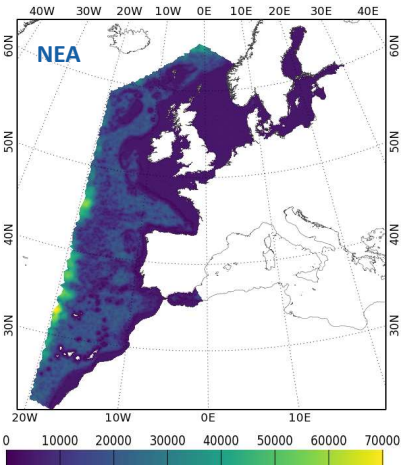
New bathymetry, mesh, hydrodynamic simulation

Integration of the regional models implemented in BATHY-CNES project (cf M. Cancet presentation)

- High resolution regional meshes
- Improved bathymetry, validated through hydrodynamic modelling

Regional meshes resolution (m)

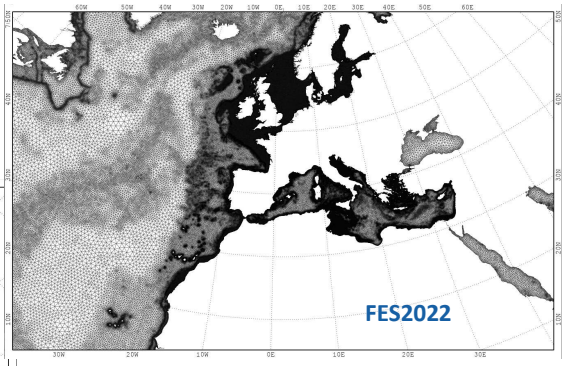


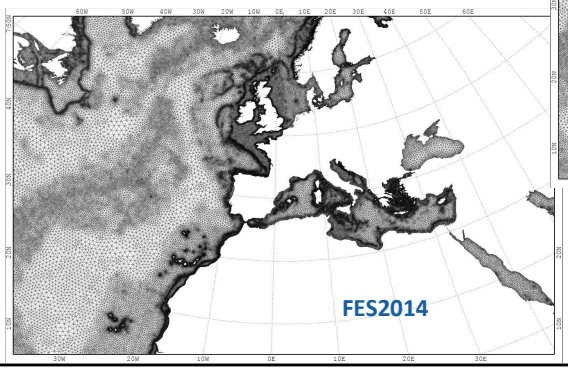


New bathymetry, mesh, hydrodynamic simulation

Integration of the NEA and MED regional meshes/bathymetry in the global FES2022 configuration as is

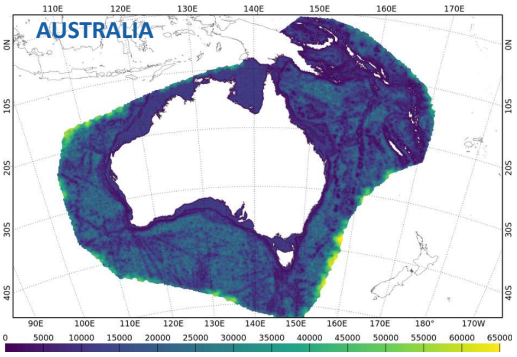
→ Hydrodynamic modeling first results are promising

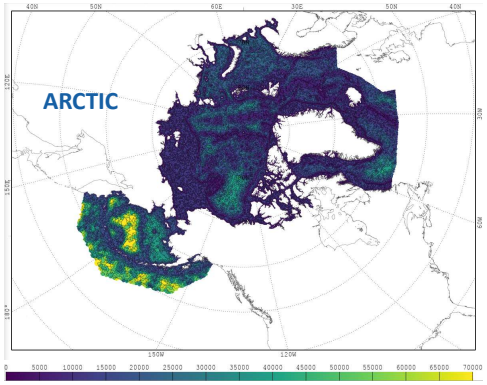




New bathymetry, mesh, hydrodynamic simulation

Integration of the regional models over Australia, Arctic Ocean, Indonesian and China seas, after lowering the resolution, because these are large domains and include too many nodes compared to global configuration and the global FES2022 mesh size objective

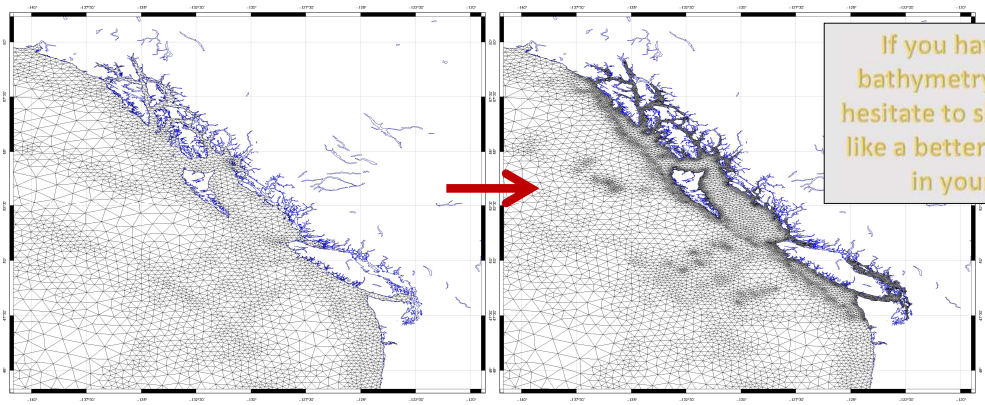




Regional meshes resolution (m)

New bathymetry, mesh, hydrodynamic simulation

Example of coastline and mesh refinement on the North-East Pacific coastline



If you have regional bathymetry data do not hesitate to share it if you'd like a better tidal solution in your area ☺

FES2014: 15 km element coastal resolution
(~7,5 km numerical resolution)

FES2022 : 5 km element coastal resolution
(~2,5 km numerical resolution)

~20 000 additional elements (over 1 500 000)

We give an example of coastline and mesh refinement done for FES2022 on the North-East Pacific coastline. Such refinement will be performed in many regions of the ocean at the condition we can get some accurate bathymetry databases.

Assimilation

1. Improvement of assimilation databases
   - altimeter database
   - in-situ database
2. Generation of the pertubation ensembles
   - Bottom friction
   - Wave drag
   - Bathymetry
   - Loading tide…
3. Improvement of assimilation code
   - To take into account the small tidal horizontal scales and any inhomogeneous data collection due to land mask effect
   - Optimisation of the code to be able to deal with 2-3 times more nodes than FES2014
4. Data assimilation of a selection of the altimetry and tide gauges datasets

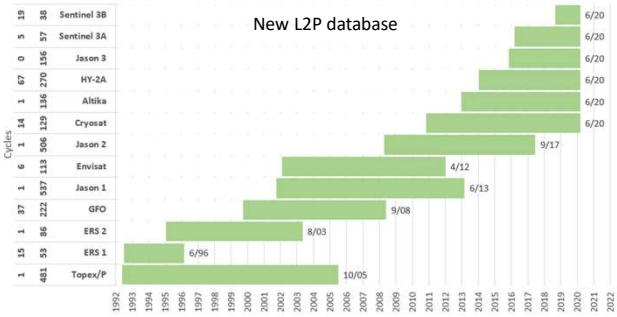
Altimetry database

1Hz databases – synergy with DUACS-DT2021 project (see M. Lievin et al. presentation)

- The new global L2P 1Hz DT2021 database is being computed and includes :
  - processing of all altimeter missions, on the entire altimeter era : TP, J1, J2, J3, ERS, EN, AL, C2, HY2A, S3
  - Includes FES2014b tide model, Zaron19 internal tide solution, DAC-ERA5 correction for the all missions until the Jason-3 launch
  - + Other updated instrumental/geophysical corrections

Production of a specific database for high-latitudes |LAT| > 65°

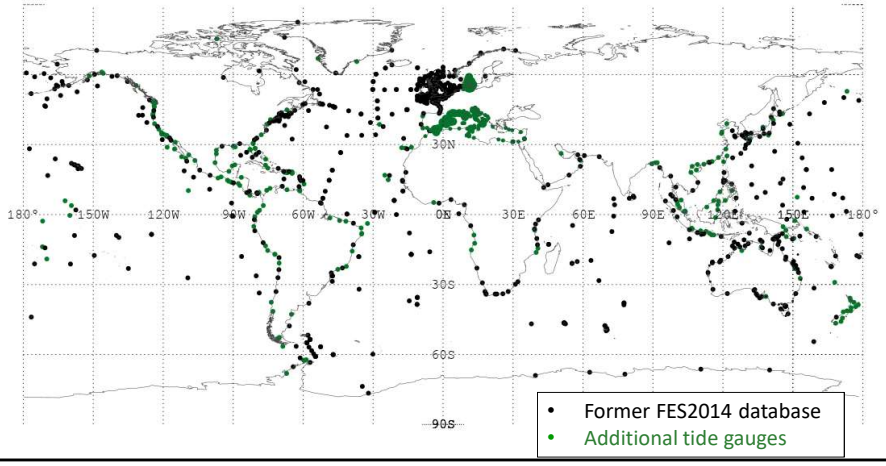
- Missions available = ERS, EN, AL, C2, HY-2A, S3-A
- Use same corrections/processing as the L2P 1Hz + specific MSS
- Specific boxes processing
- Improvement of the tide estimation



In situ database

Verification and update of the tide gauge database

- General evaluation of the historical databases used for FES2012 and FES2014
- Identification of newly available stations, update of time series and analyses



Loading and Self-Attraction effects

1. **Computing the LSA effects**

   Present FES2014 configuration:

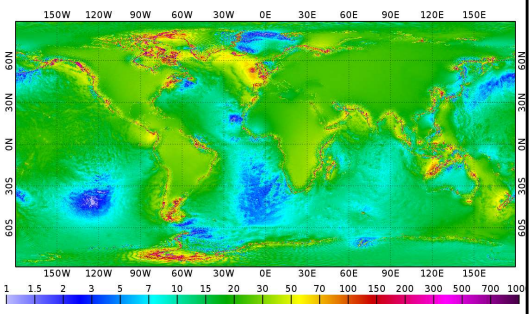
   - LSA atlas computed on a regular grid from a re-projected ocean tidal atlas (1/16th)
   - LSA atlas interpolated on the FE mesh in T-UGOm (derivation done on FE grid)
   - Atmospheric pressure LSA not included (mostly S2, S1)

   FES2022 configuration:

   - LSA atlas computed on a regular grid from the finite element (FE) ocean tidal atlas
   - Reduce the loss of coastal details/intensity due to the gradient operator
   - Include S2, S1 atmospheric pressure LSA

2. **Correction of the altimeter databases with the new FES2022 LSA effects for the assimilation step**
3. **Update the model solution taking into account the new LSA fields (update of hydrodynamic solution, and assimilation of the corrected altimeter database)**

Structured versus unstructured radial displacements computation (M2, micro-metres)



We will compute the new FES2022 LSA effects following 3 steps : first we'll compute the LSA effects from the FES2022 ocean tide atlas, secondly we will correct the altimeter database from these new LSA effects, and third we will update de FES2022 tidal atlas (update hydrodynamic solution and the assimilated one).

Validation of FES2022

Several validation steps are planned including:

- Intermediate validations during the assimilation task
- Internal validation of the final model (elevation and currents)
- External validation of the final model -> external collaborations TBD
- Specific validation for climate studies
  - Focus on climate signals and on 58.74 days aliasing period of S2 wave (cf Zawadzki et al. 2016)
  - Estimate impact on global and regional MSL, and also annual/semai-annual frequencies

Validation of tidal elevations

Comparison with state-of-the art global tide models : FES2014b, GOT, TPXO9, DTU ...

Validation diagnostics planned are:

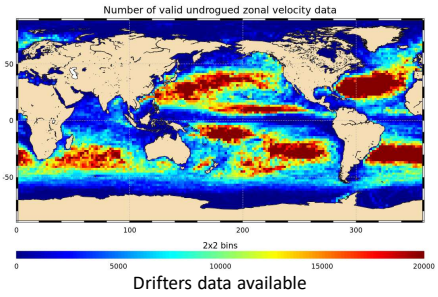
- Spectral validation
- Variance reduction analysis using altimeter and TG databases
  - Altimeter databases :
    - Use a reference mission + one mission sampling high-latitudes: Altika or C2 or S3 TBD
    - Compute statistics on SSH crossovers differences and along-track SLA
  - TG database including GLOSS-CLIVAR and other available databases
  - Use independent validation databases as much as possible

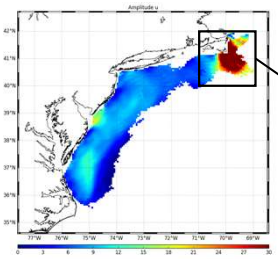
Validation of tidal currents

Comparison with TPXO9 and FES2014b currents

Validation diagnostics planned are:

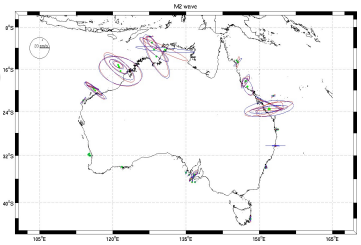
- Comparison to ADCP databases : Australia + global GMACMD ADCP database (IFREMER)
- Comaprison to HFR data : Iroise + Maracoos regions
- Comparison to drifters database





Above: M2 zonal tidal current from Maracoos HFR (cm/s)
Right: Comparison of FES2014 M2 tidal ellipses with HFR observations (blue = FES2014, red = HFR)

Comparison of FES2014 M2 tidal current ellipses with ADCP observations around Australia



Several validation of FES2022 tidal currents will be performed, using ADCP, HFR and drifters databases. FES2022 currents will be compared to other global tidal currents atlases available (TPXO9, FES2014b).

Dissemination of the atlas

- The new FES2022 tidal atlas should be disseminated to scientific users during 2022 (elevation and currents)
- Through AVISO+ website
- Likely both on cartesian grids and finite element grids
- Prediction code will also be available