Bathymetry Improvement and High Resolution Tidal Modelling around Australia

Etienne Sahuc[1], Mathilde Cancet[1], Ergane Fouchet[1], Florent Lyard[2], Gérald Dibarboure[3], Nicolas Picot[3]

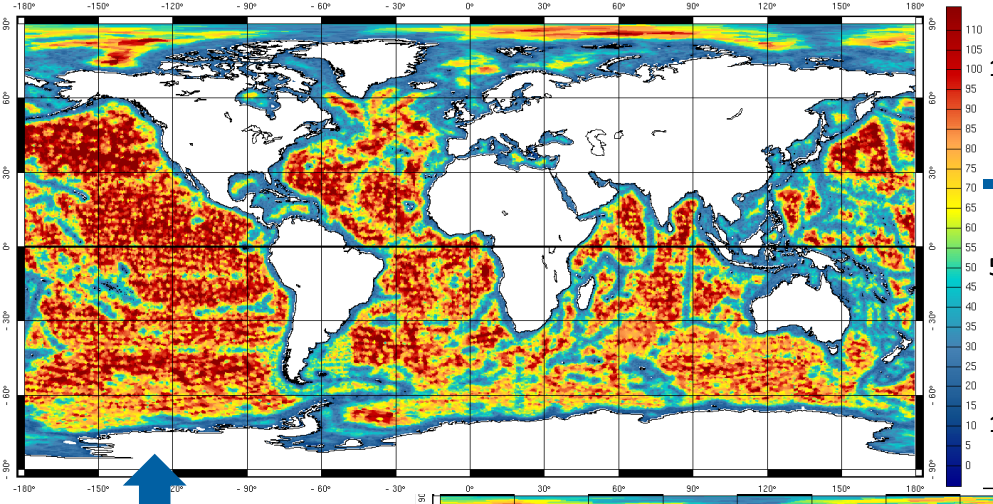
[1] : NOVELTIS [2] : LEGOS [3] : CNES

Context

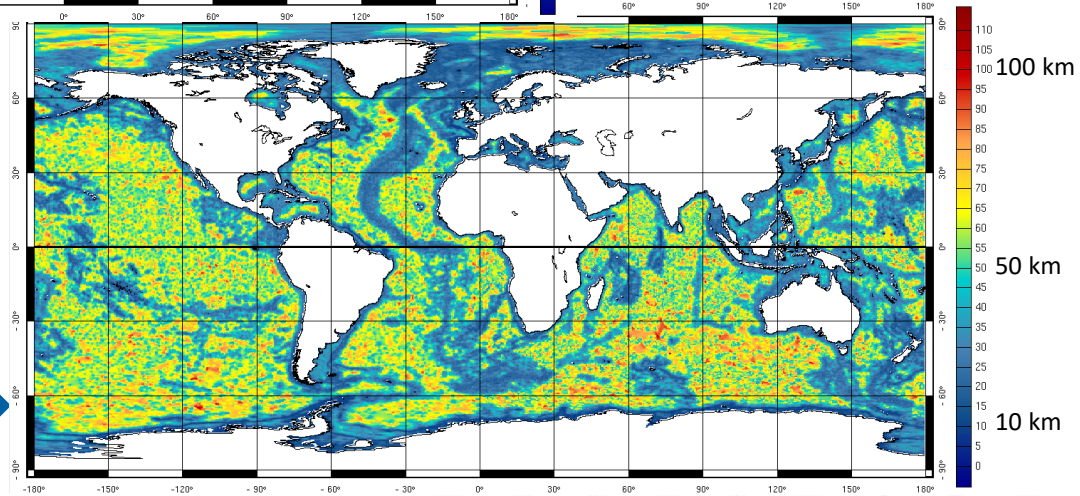
- **Global tidal modelling**
  - Significant improvement in the last 10 years
  - Large errors (> 10 cm) remain on shelves, where tides are stronger and more complex
  - The global tuning of the model may not represent local specificities

Context

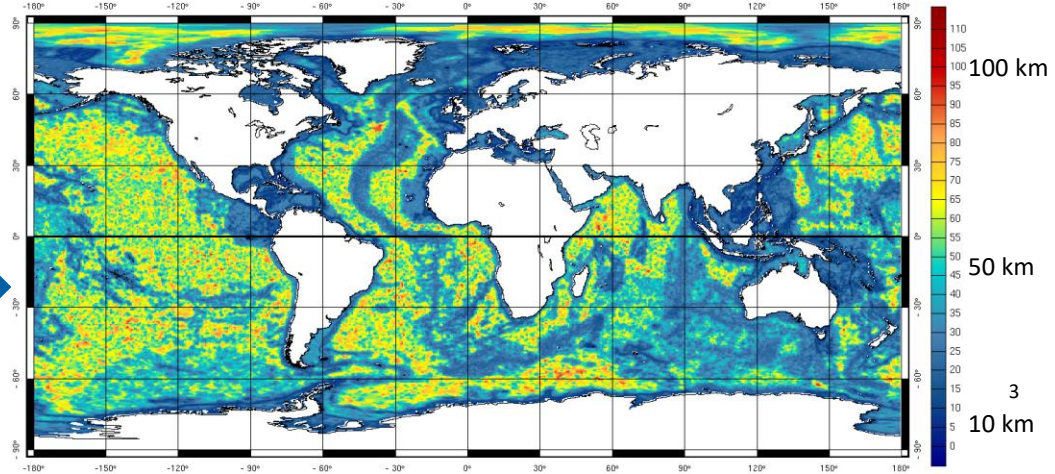
Increase in the global mesh resolution



FES2004
247 354 vertices



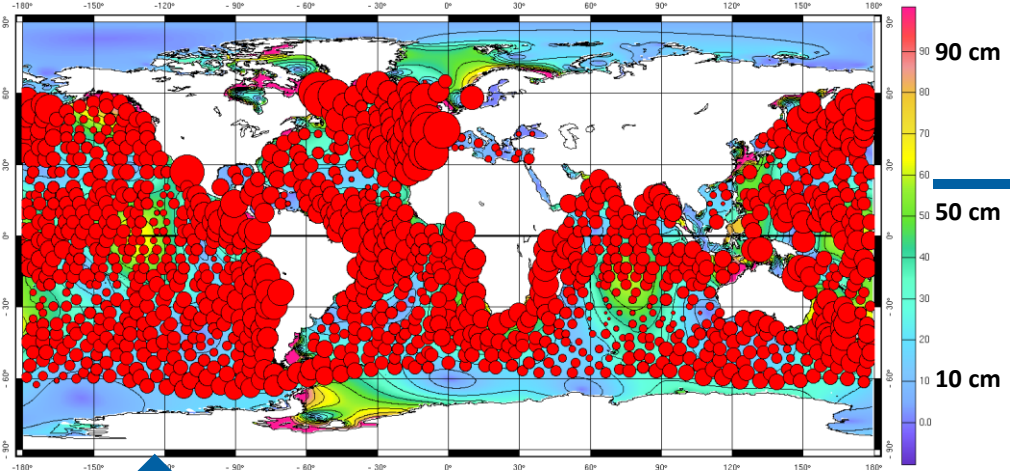
FES2012
389 737 vertices



FES2014
757 755 vertices

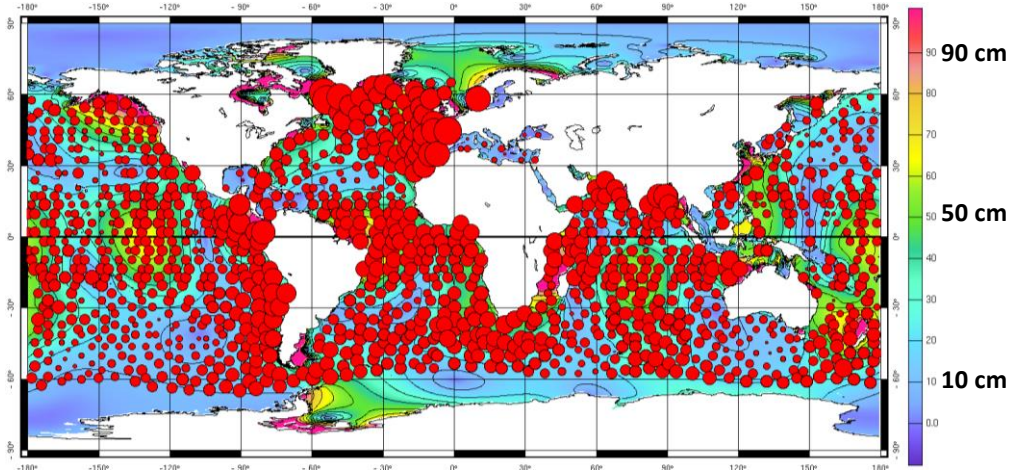
Context

Improvement of the hydrodynamic models (no data assimilation)



FES2004

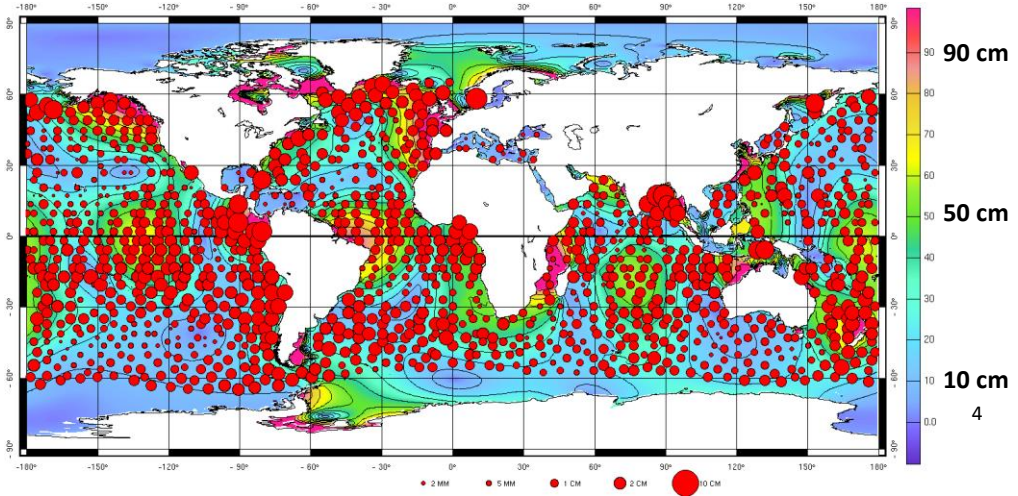
FES2012



Vector differences between hydrodynamic solution and TP/J1/J2 crossover points (M2).

The size of the red dots is proportionnal to the vector difference.

FES2014

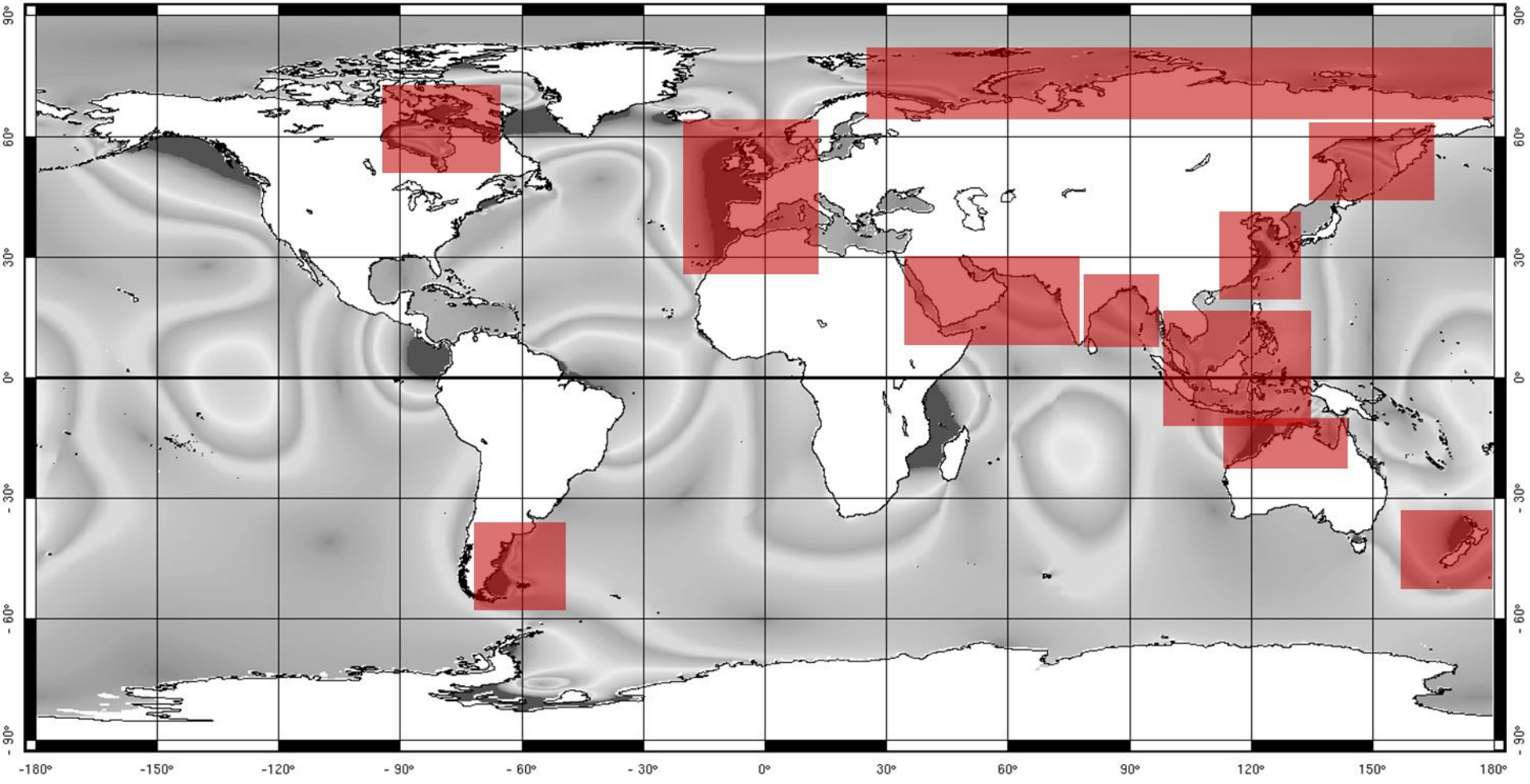


Context

- **Global tidal modelling**
  - Significant improvement in the last 10 years
  - Large errors (> 10 cm) remain on shelves, where tides are stronger and more complex
  - The global tuning of the model may not represent local specificities
  - Future developments, including increased resolution, are limited by computing capabilities
- **Regional tidal modelling**
  - **Smaller domain** allows **higher resolution**
  - Regional tuning easier to implement
  - Needed for current and future satellite altimetry missions (SAR alti, SWOT)
  - But **still limited by the quality of the ocean bathymetry** that plays a key role in tidal dynamics, especially in shallow coastal waters and estuaries

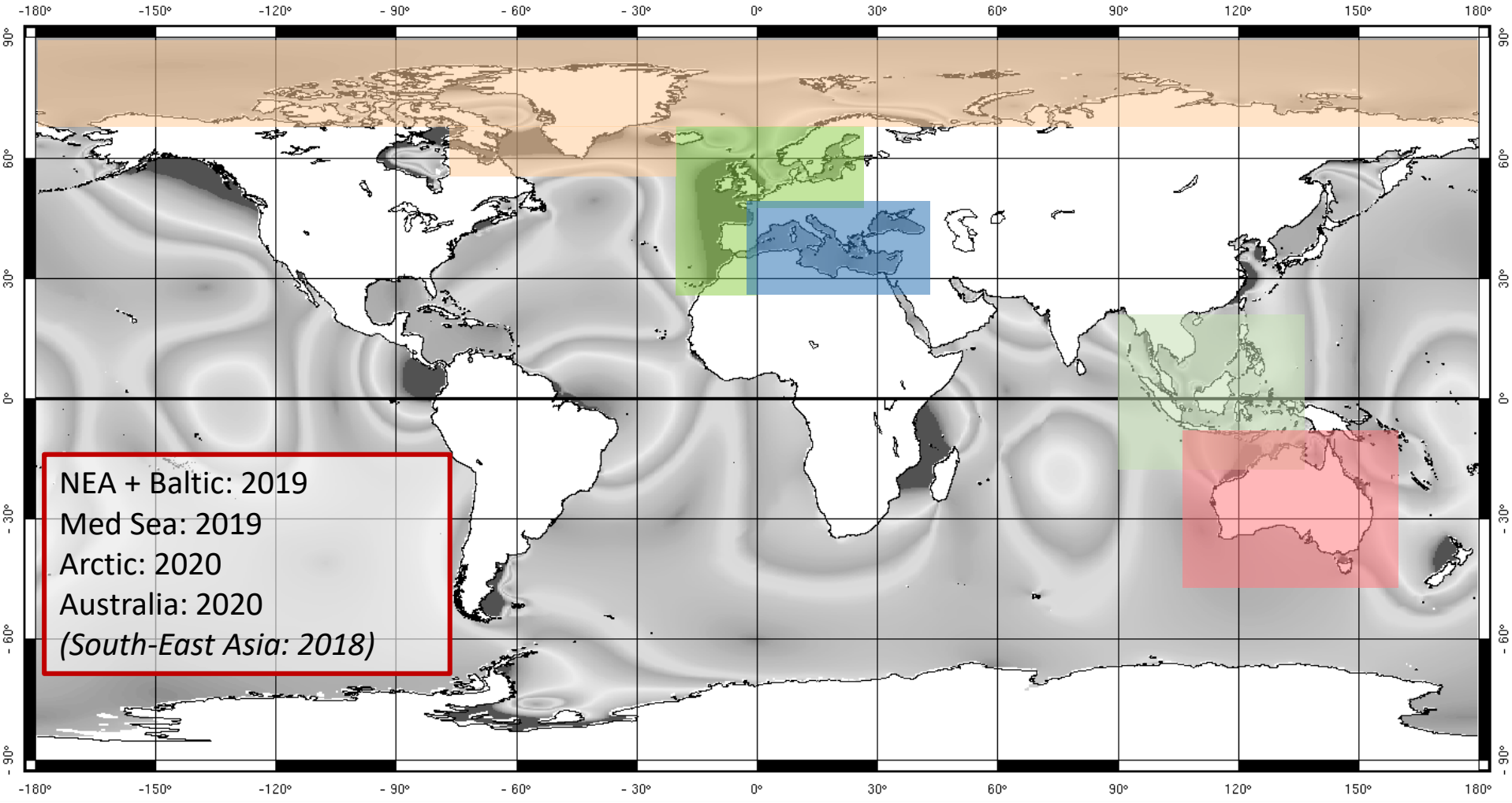
Context

- **A number of macro-tidal regions with bathymetry improvement potential have been identified**



Context

- **Selection of five regions (CNES project, 2018 - 2020)**



Methodology

- **Inventory** of existing / freely available bathymetry datasets
  - Raw data from single-beam or multi-beam soundings
  - Digital Elevation Models (DEM)
- **Integration** of these bathymetry datasets into the global database and visual assessment
- Implementation of a **regional tidal model** (hydrodynamic modelling) in the region of interest
- **Validation** of the tidal model with altimetry and tide gauge observations, assessment of the new bathymetry (iterative process)
- **Assimilation** of tide gauge and altimetry observations in the new regional tidal model

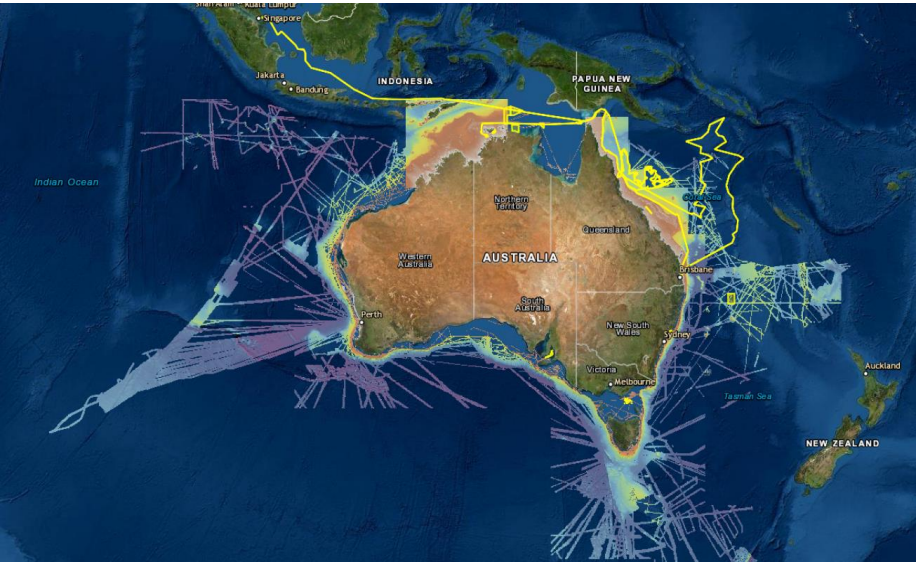
➔ **The resulting regional tidal model is consistent with FES2014 at the boundaries**

➔ **Work performed in preparation of the upcoming global FES2022 model**

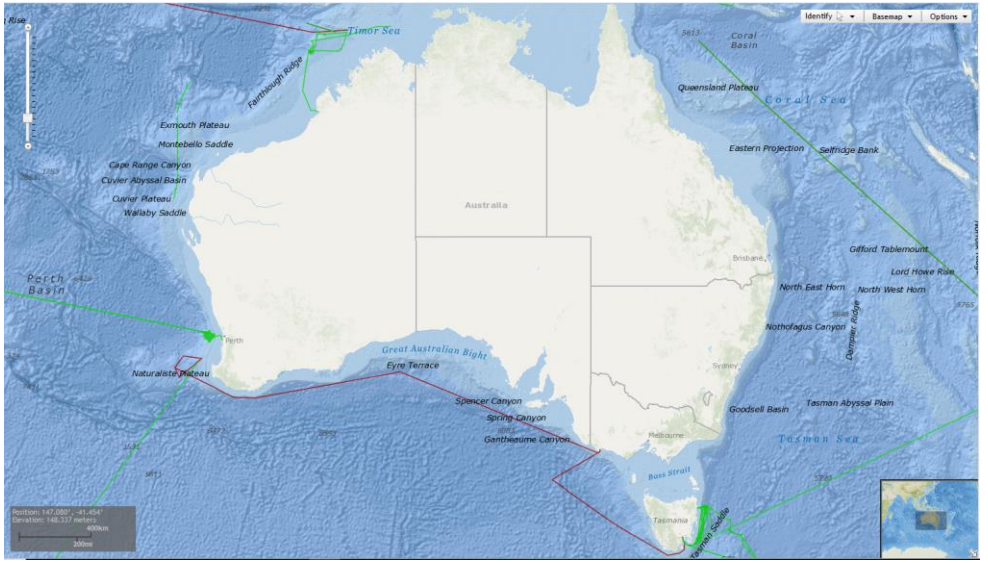
High-resolution tidal modelling in Australia

Inventory of Bathymetry datasets

- Several datasets of **Digital Elevation Models** and **raw multibeam surveys**



Datasets collected on Geoscience Australia : 50m DEM + 30m DEM

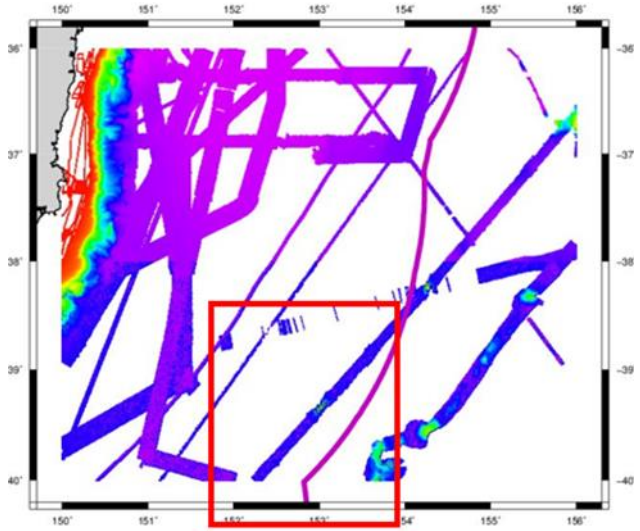


Datasets collected on NOAA : Multibeam bathymetric surveys (from 2015)

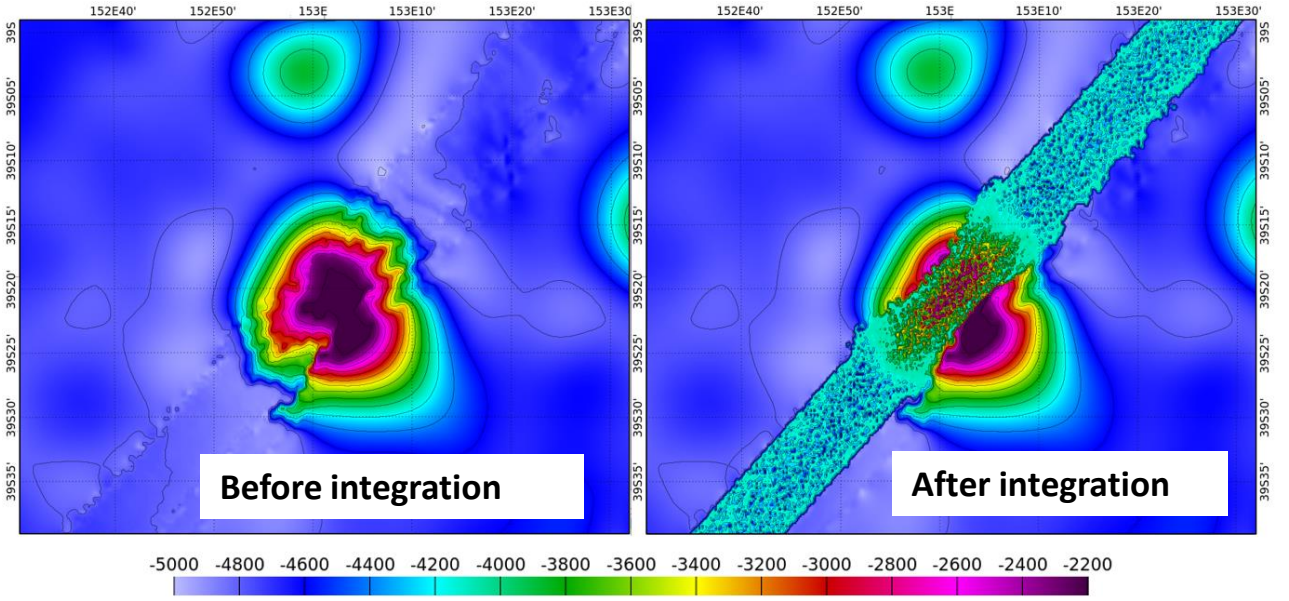
- **Global bathymetry datasets**
  - GEBCO2019, GEBCO2020
  - SRTMv1
  - SRTMv2
  - FES2014 composite bathymetry based on ETOPO (LEGOS)

Integration of collected datasets

- Integration of bathymetry datasets can lead to artefacts :

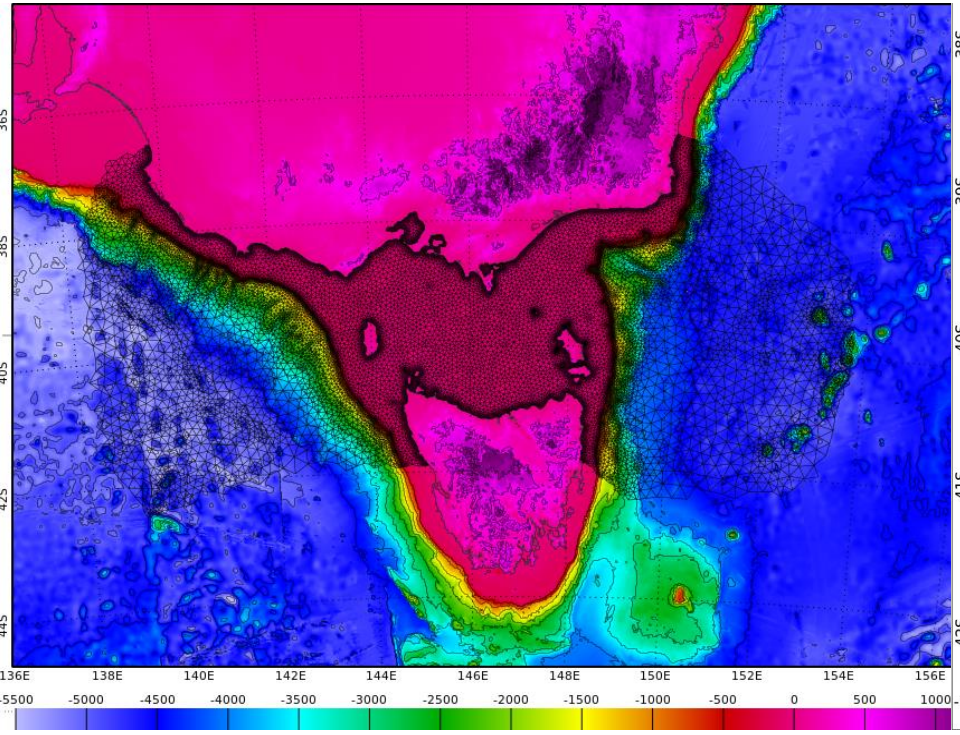


Tiles of the DEM50m from Geoscience Australia are composed of discontinuous bathymetric surveys.
In some cases, artefacts appear when integrating some of the DEM50m tiles in the initial bathymetry.
Although the DEM50 dataset is more recent than the initial bathymetry, some tiles were discarded from the integration.

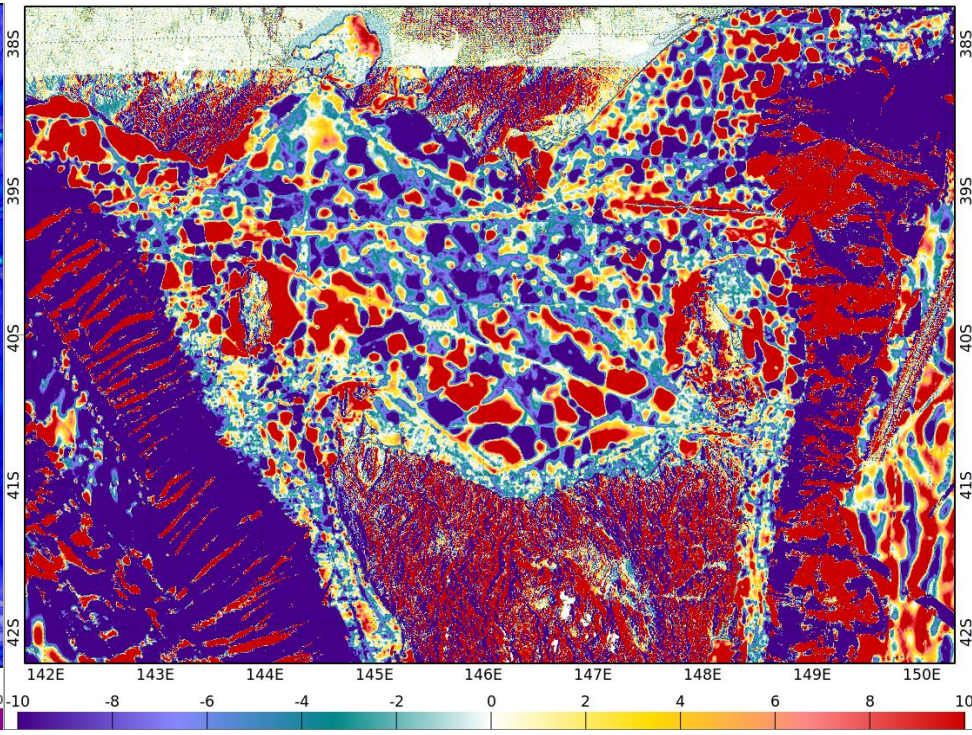


Integration of collected datasets

- **The necessity of mesh resolution improvement on shelves requires a relevant high resolution bathymetry**
  - Issues found on the **Tasmanian shelf** with divergent bathymetry datasets
  - A local hydrodynamic model has been developed to explore the various bathymetry datasets and build a local composite bathymetry as a trade-off.



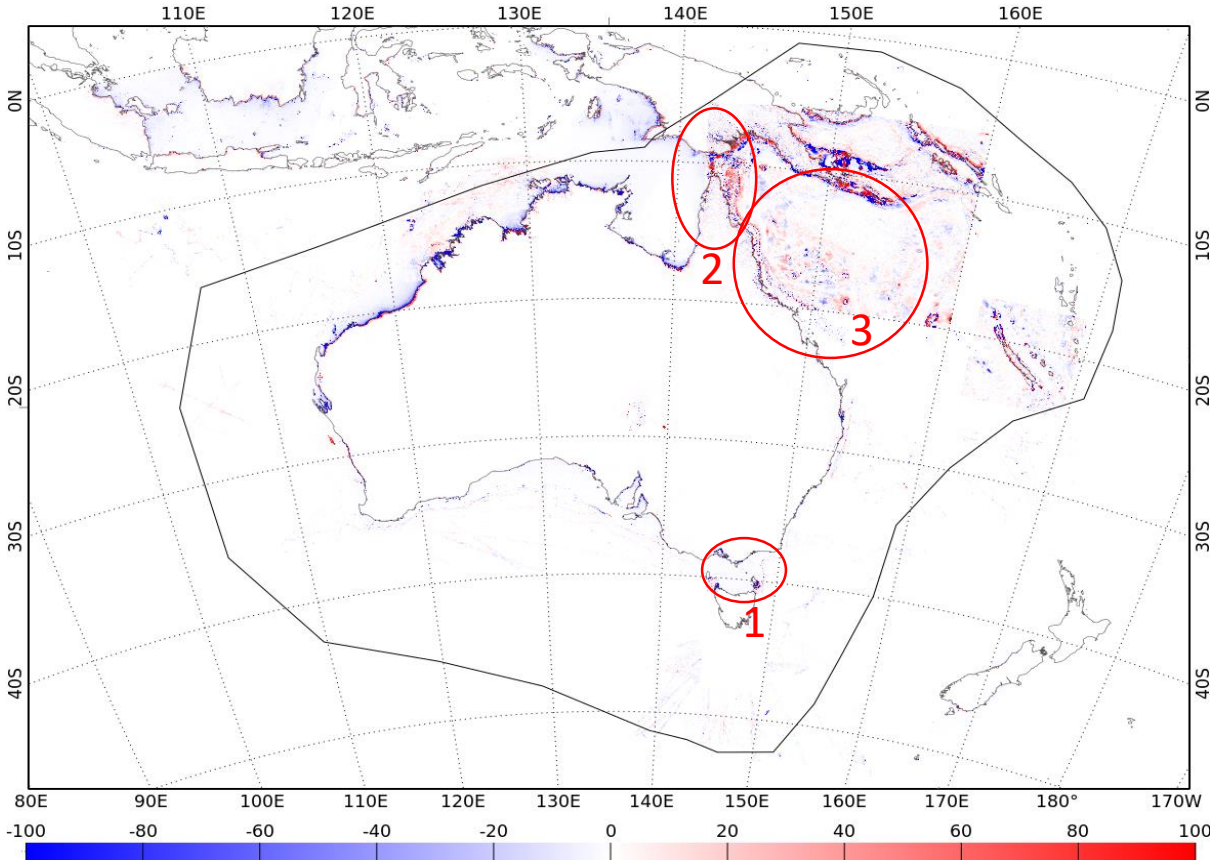
Mesh of the local model around Tasmania in black / Bathymetry in color (m).



Absolute difference (m) between initial bathymetry and SRTMv1 global bathymetry shows major differences on the Tasmanian shelf (30-50m on depth of about 100m)

Integration of collected datasets

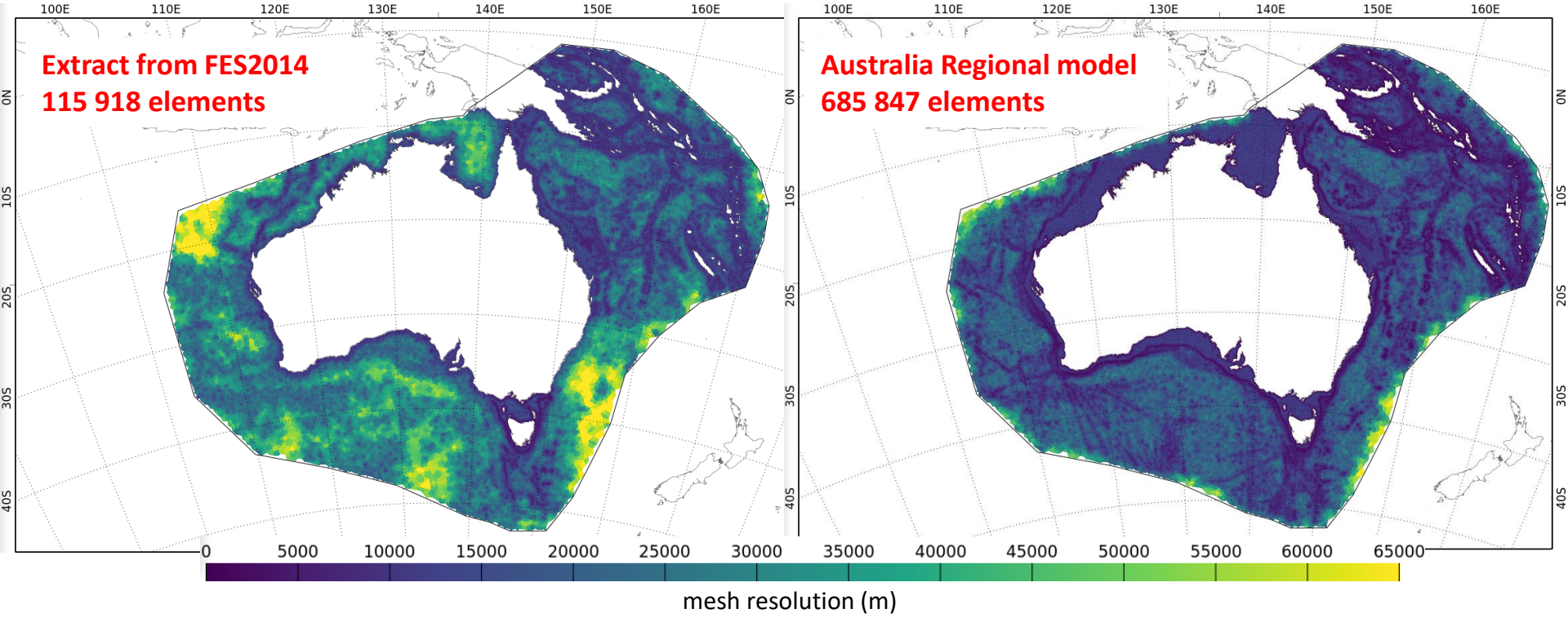
- The main regions where the choice of bathymetry is the most difficult are :
  - **Tasmanian shelf (1);**
  - **Torres Strait (2);**
  - **Coral Sea and Coastal waters of Great Barrier Reef (3).**



Relative difference (%) between the initial regional bathymetry and the final composed bathymetry over Australia

Hydrodynamic modelling

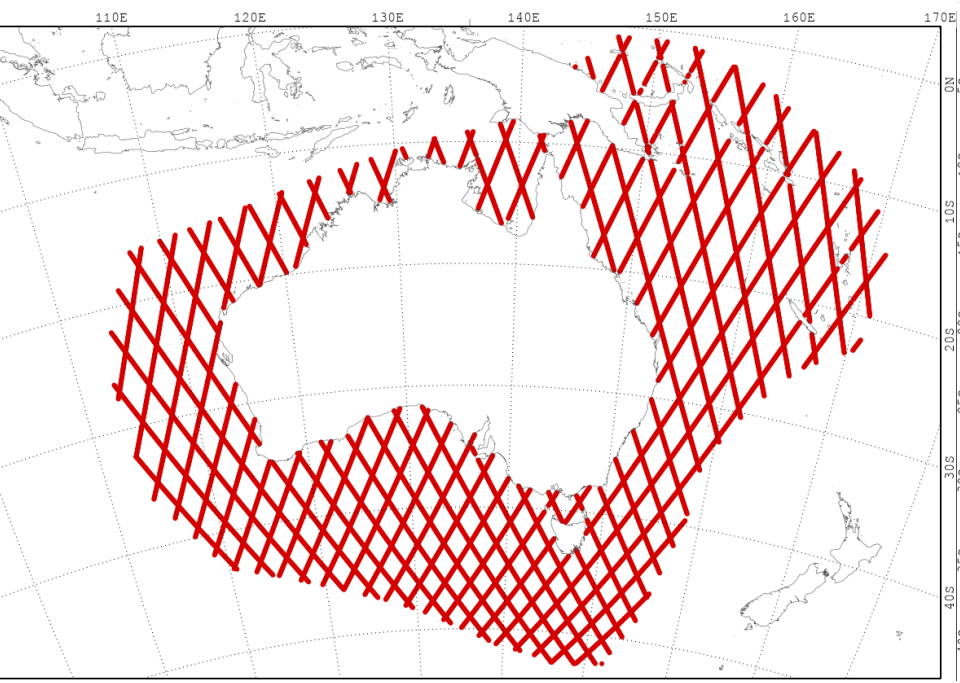
- The FES2014 original mesh has been extracted and **refined around Australia, mainly on shelves**.
  - This new configuration has **a 25km resolution** on the open ocean and **reaches a 2km resolution on shelves.**



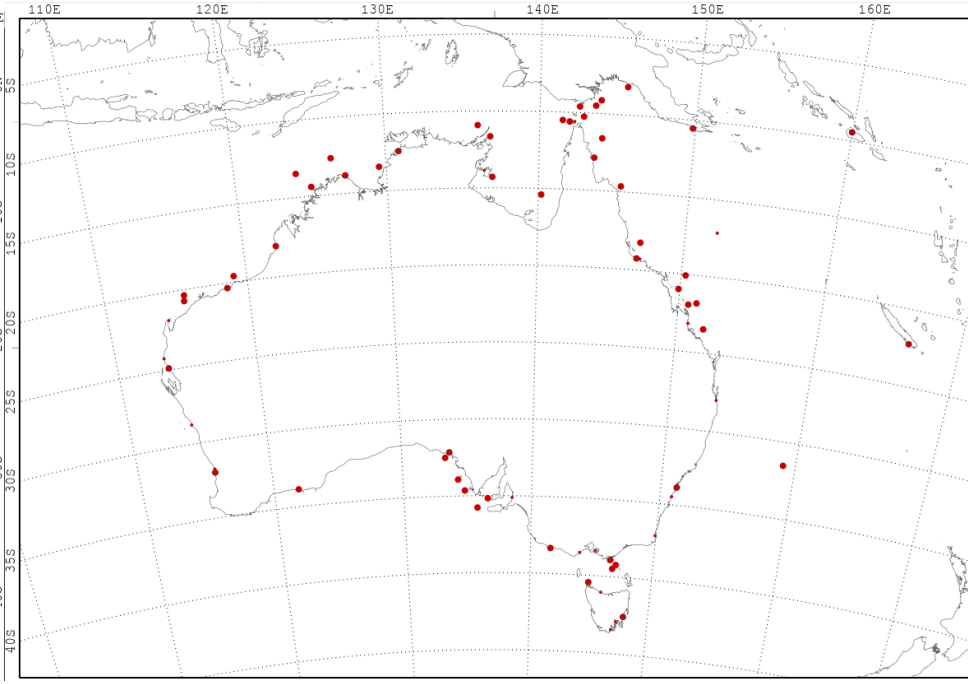
➔ The number of elements has been multiplied by 6 from FES2014 to the regional model around Australia

Hydrodynamic modelling

- Validation datasets :
  - Tidal harmonic constants extracted from alongtrack altimetry observations from the Topex/J1/J2 missions (from FES2014 project);
  - Tidal harmonic constants extracted from tide gauges time series collected and processed by NOVELTIS.



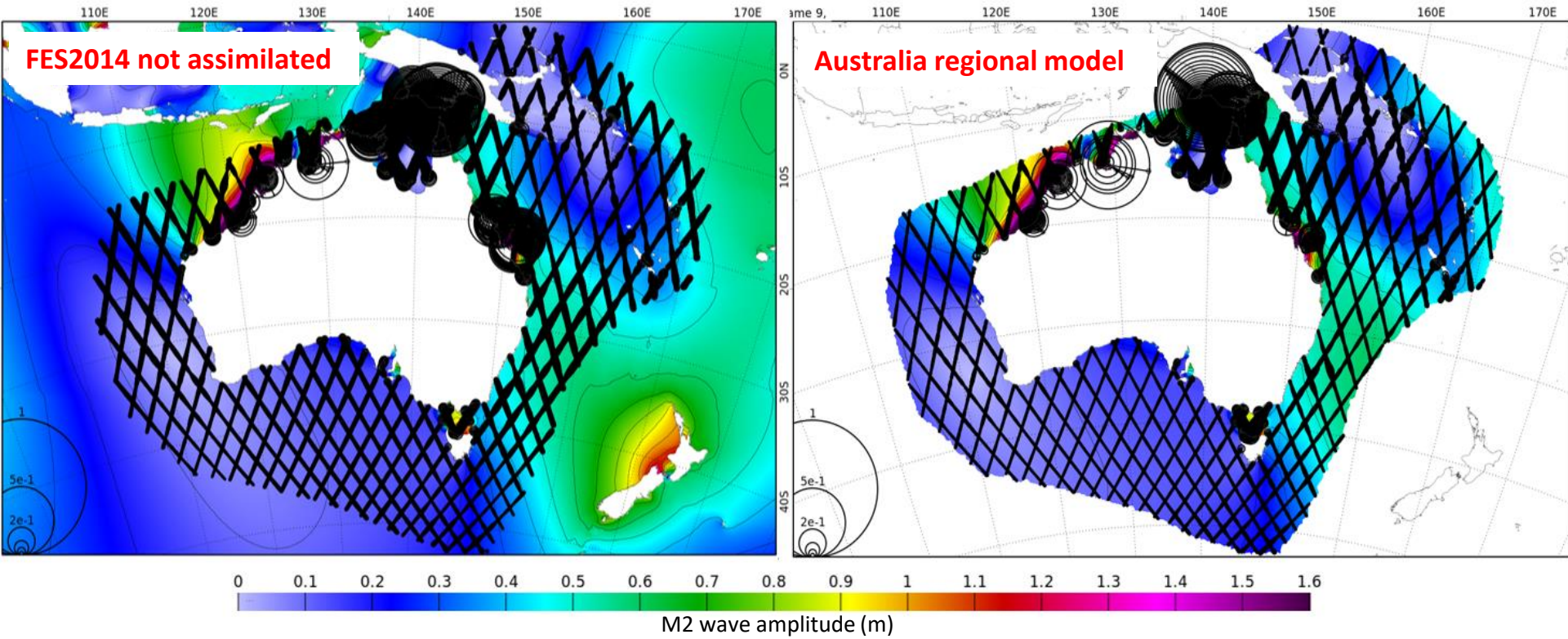
Altimetry points location for validation



Tide gauges points location for validation

Validation of regional model

- **Results :** vector differences between hydrodynamic solution and TP/J1/J2 alongtrack points



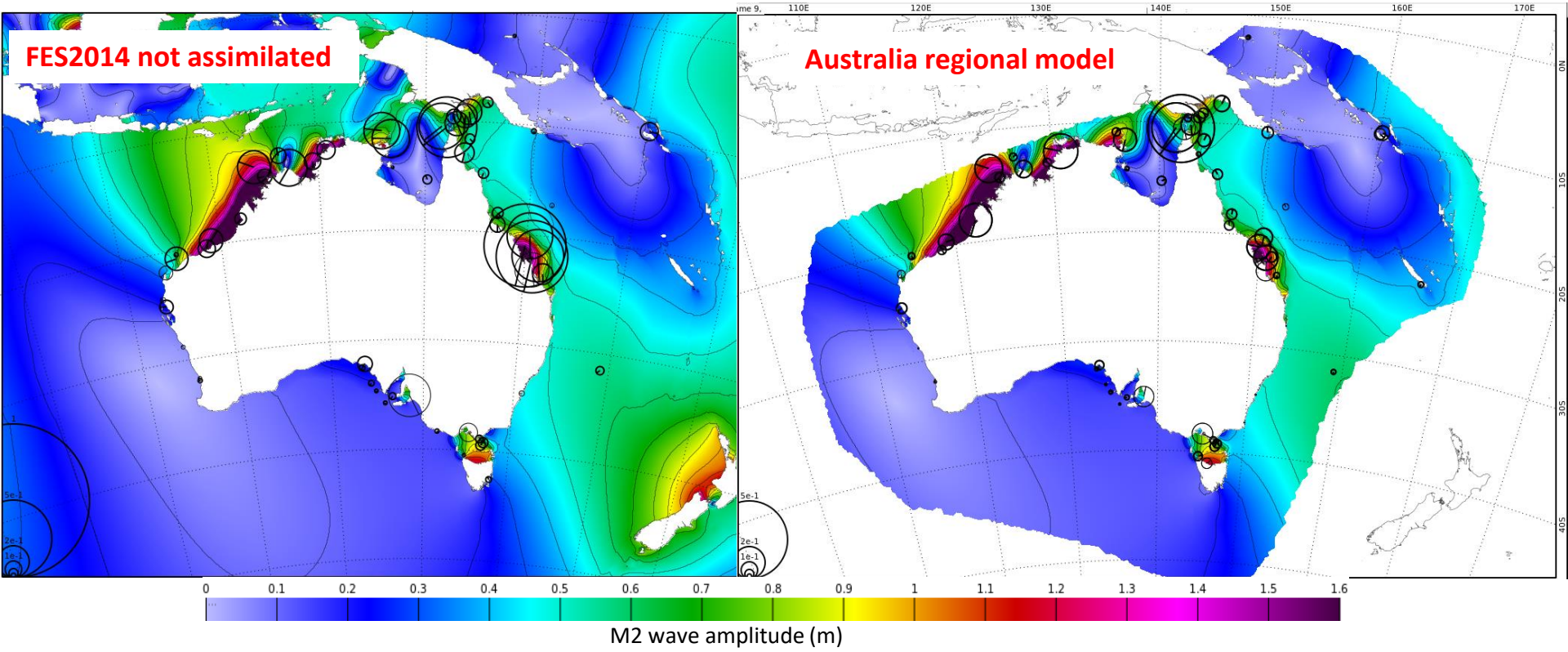
Wave	Altimetry	
	E rms regional (mm)	Diff E rms regional/FES2014 (mm)
M2	24.5	-6.7
S2	11.6	-3.8
K1	11.2	-11.5
O1	6.5	-8.6

General decrease of the complex error on altimetry points for all the main waves compared with FES2014 not assimilated.

6 mm improvement on M2 and more than 1 cm on K1.

Validation of regional model

- **Results :** vector differences between hydrodynamic solution and tide gauges

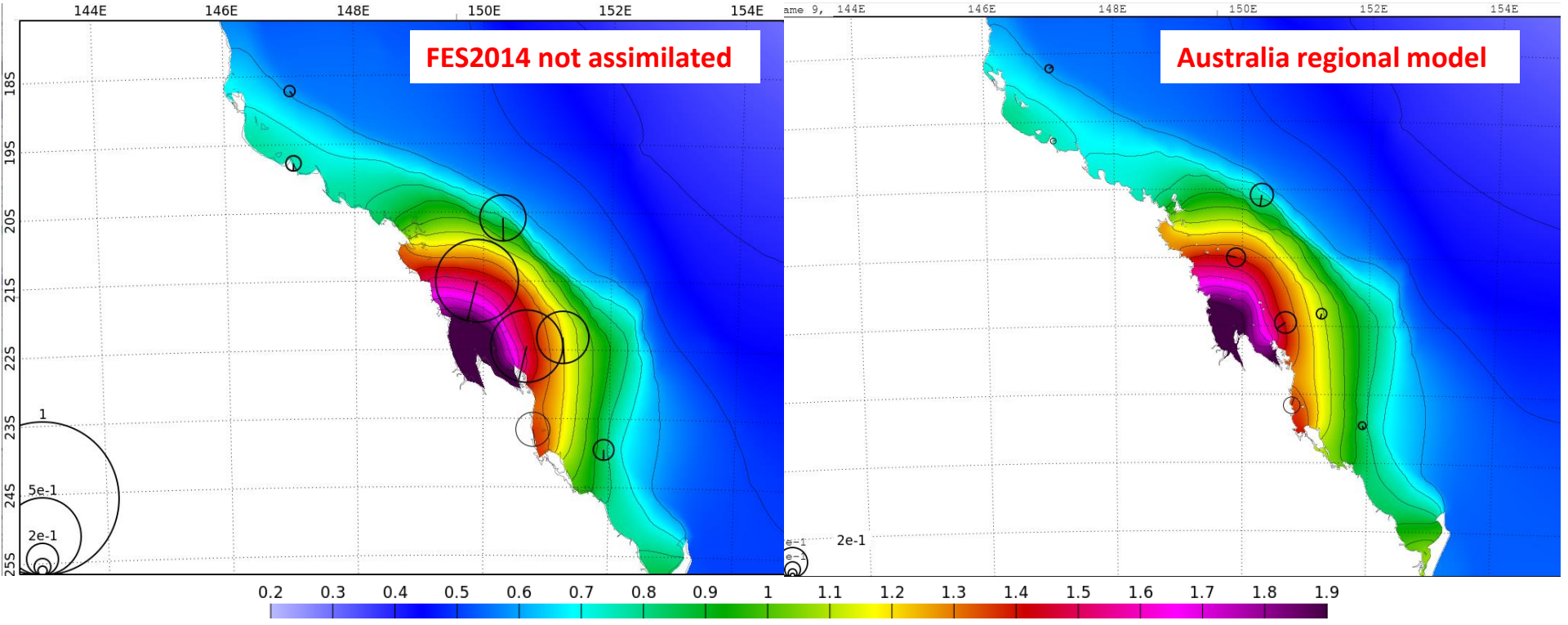


Wave	Tide gauges	
	E regional rms (mm)	Diff E regional rms/FES2014 (mm)
M2	63.6	-42.0
S2	38.3	-14.2
K1	29.8	-18.6
O1	21.7	-11.5

Dramatic reduction of the error to tide gauges on main waves compared with FES2014 not assimilated.
More than 4 cm on M2 and almost 2 cm improvement on K1

Validation of regional model

- Zoom in on coastal waters of the Great Barrier reef

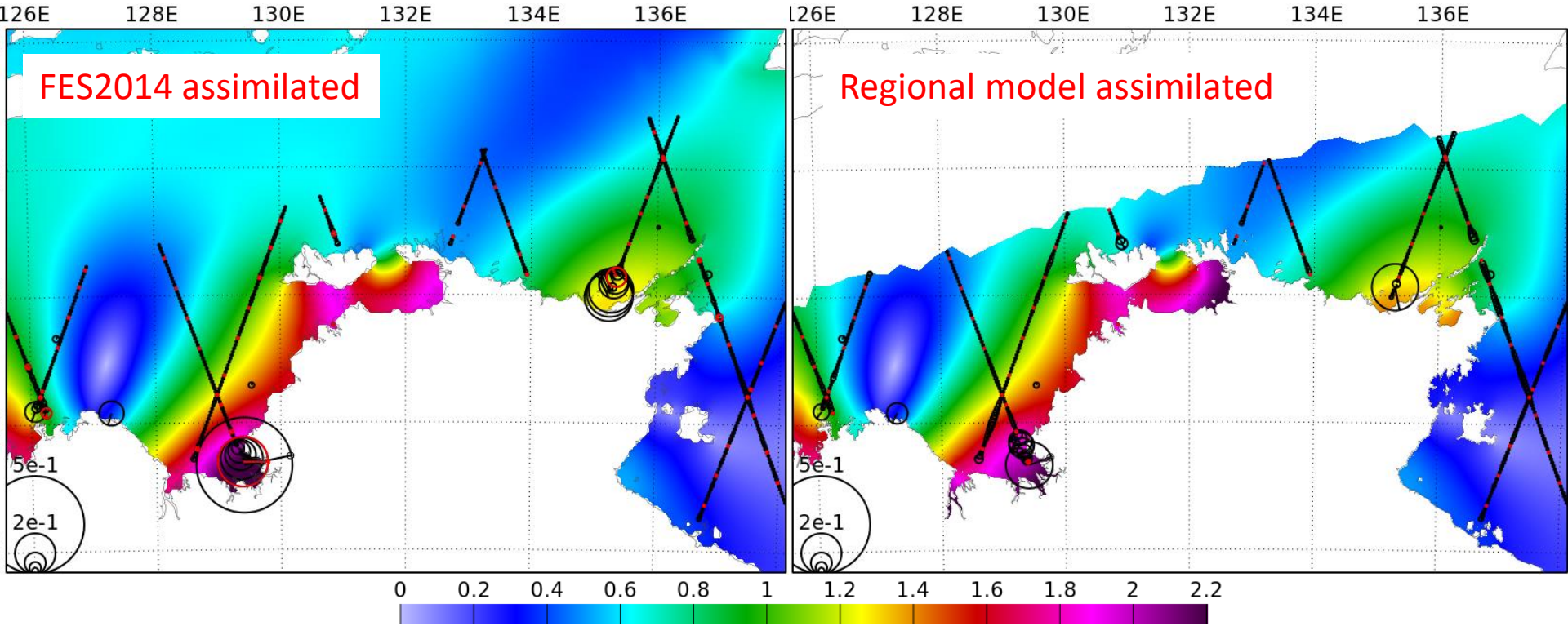


› Vector differences to tide gauges are **almost divided by two** on the southern coastal waters of the GBR for **the regional model compared to FES2014.**

› A **local tuning of the model parameters** and the integration **of relevant bathymetry patches** enabled to drastically reduce the model error on this shelf.

Assimilation of tidal observations into the model

- Assimilation tests are in progress.
  - Part of the **tide gauges**, **crossover** and **alongtrack** altimetry points are used (upon their quality) to improve the hydrodynamic model solution.



M2 wave amplitude (m), black dots show all available data and red dots show assimilated observations. The size of the dots is proportional to the vector difference between the model and the observation.

➔ First assimilation results show a good improvement of the model solution to observations on North West Australia.

Conclusion

- Very good performance and dramatic reduction of the errors of the regional hydrodynamic model, especially compared to tide gauges, thanks to :
  - **High-resolution mesh**
  - **Integration of relevant bathymetry datasets on shelves**
  - **Local tuning of the model**
- The first assimilation tests are **very encouraging** by improving the regional solution on critical areas (North-west bays, Coastal waters of the GBR, Coral Sea)

- This study enhances **the necessity of high-resolution, precise and relevant bathymetry data on shelf** where the model resolution model is refined
  - **The example of the Tasmanian shelf is a perfect demonstration.**
- With no bathymetry improvement, increasing the mesh resolution will not automatically give a better solution

- New methods for bathymetry detection **using satellite data (optic and/or SAR)** could also help improve bathymetry and tidal modelling in areas poorly covered by traditional in situ data.

- This regional work in different regions (NEA, MED, Arctic, Australia) will be integrated in the upcoming **FES2022 global tide atlas** (see L. Carrère et al. presentation in the same session).