MERCATOR OCEAN INTERNATIONAL

Toward a community global 1/36° configuration based on NEMO

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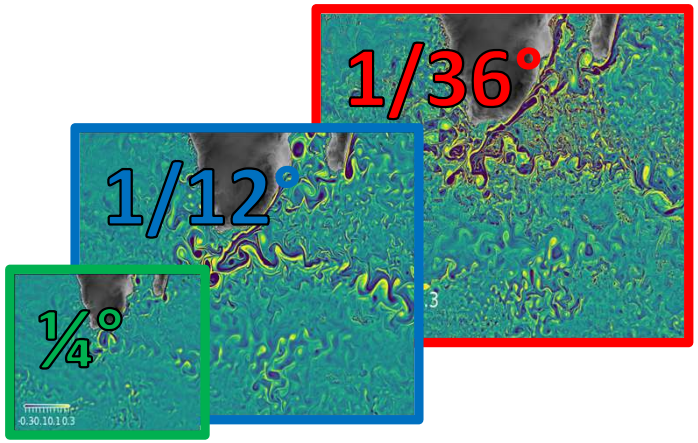
mercator-ocean.eu/marine.copernicus.eu

1. Context

Context: future CMEMS/MOI global forecasting system



20-25 km	6-9 km	2-3 km
Since 2005: PSY3, GLORYS2, GREP,…	Since 2009: PSY4, GLORYS12,…	

IMMERSE project:

→ efficient, stable and scalable NEMO reference code with improved performances

→ delivering ocean state estimates and forecasts describing ocean dynamics and biogeochemistry at kilometric scale

→ IMMERSE-WP6: the global 1/36° “ORCA36” configuration is the global high-resolution configuration used as a demonstrator for the projects

1/36° resolution:

→ ~ 2 km

→ Resolve the **1st Rossby radius at the global scale** (away from continental shelves)

→ **Sub-mesoscale permitting**

→ Most of the energy transferred from external to **internal tides** resolved

Why including tides ?

→ Broad impact on energy content from meso to sub-mesoscales

→ Produce realistic internal tides fields and prepare upcoming observing systems (SWOT)

→ Better modelling/understanding of deep mixing (impacts MOC)

immerse
IMPROVING OCEAN MODELS FOR THE COPERNICUS PROGRAMME

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 821926.

2. Model description and simulation performed

Model description and simulation performed

Numerical model based on NEMO 4.2 OGCM

Horizontal grid: tripolar ORCA grid, 2-3 km
→ 12960 * 10850 points

Vertical grid: 75 Z-levels, 1 meter at surface

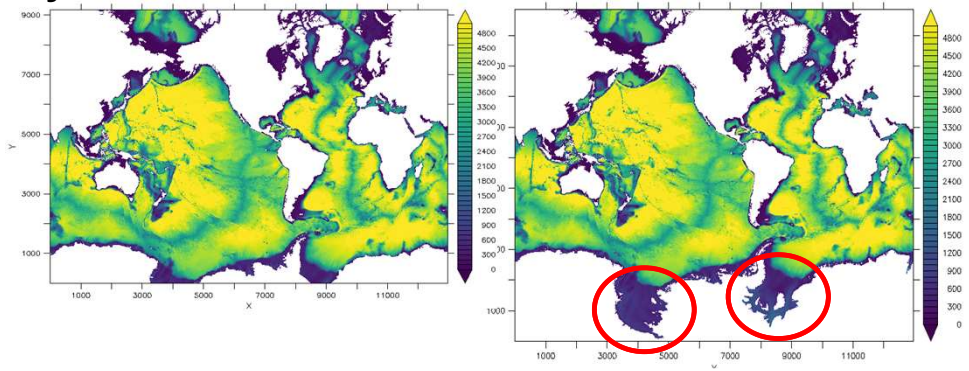
Tidal forcing: O1, K1, M2, S2, N2 + Self Attraction Loading

Forcing dataset: ECMWF/IFS resolution (1 hour frequency and 1/14° resolution)

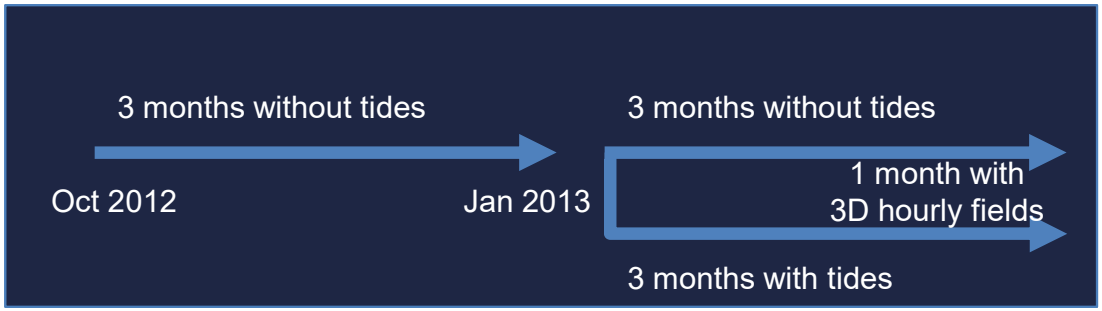
Numerics:

- **Non-linear free surface (z* coordinate)**
- **High-order advection schemes:**
  - 4th order FCT for tracers
  - 3rd order UBS for dynamics
- Split implicit/explicit vertical advection (for efficiency), from Shchepetkin (2015)
- k-epsilon vertical mixing.
- **No** internal wave drag parameterization
- Time step (baroclinic): 120 s

Bathy: based on GEBCO 2019 and Bedmachine 2 Antarctica



Domain extension and bathymetry without (left) / with (right) Antarctica ice cavities



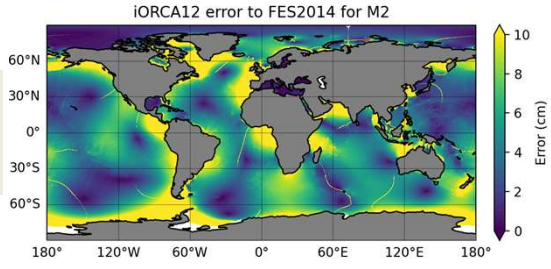
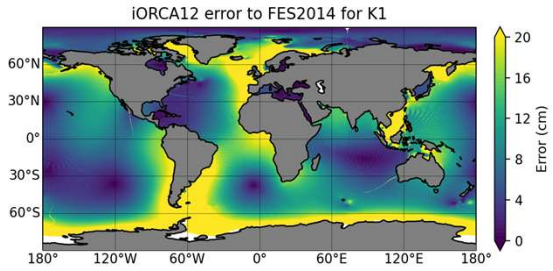
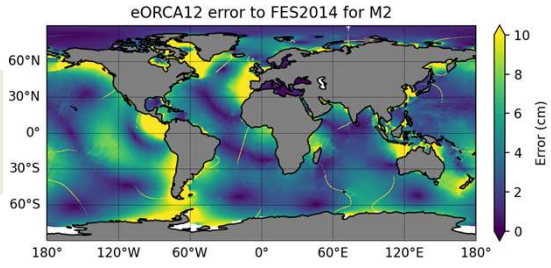
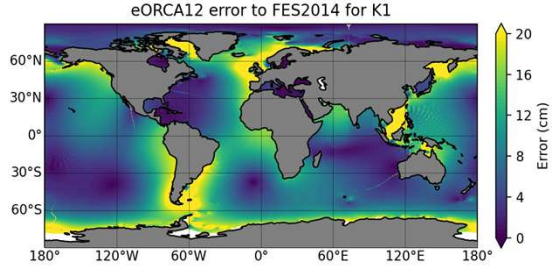
This run can be compared to the previous global 1/4° and 1/12° runs, without and with tides

3. Barotropic tides

Impact of southern cavities on barotropic tides

- Tests done with global 1/4° & 1/12° configurations
- Hindcasts produced with tidal forcing, one without cavity and one with cavities

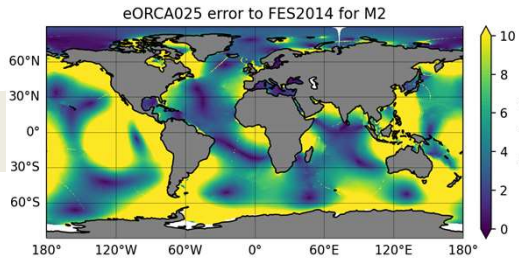
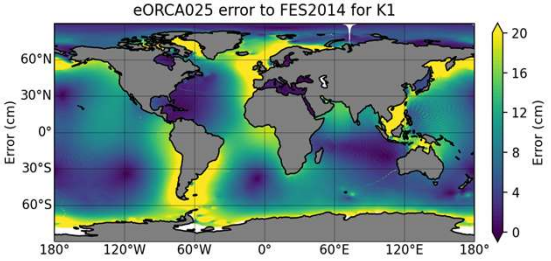
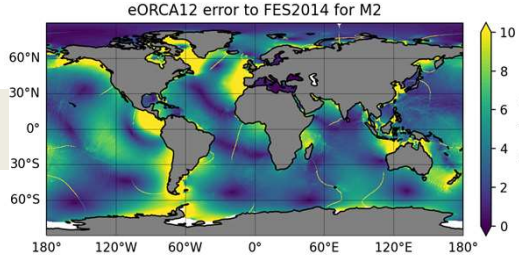
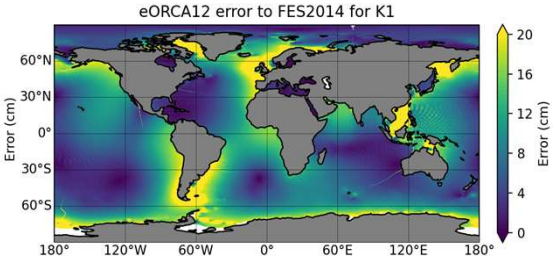
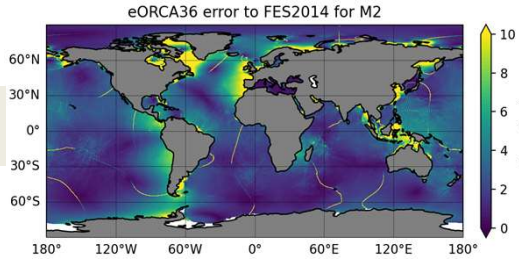
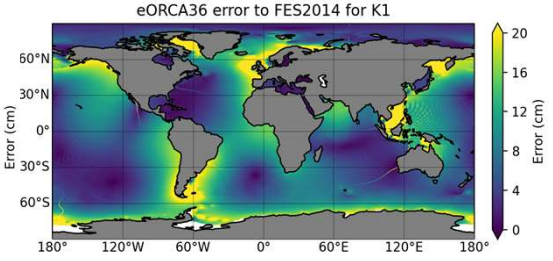
- Compare tidal solution with FES2014: $E^2 = \frac{1}{2}\left\|A_{NEMO}e^{i\varphi_{NEMO}} - A_{FES2014}e^{i\varphi_{FES2014}}\right\|^2$

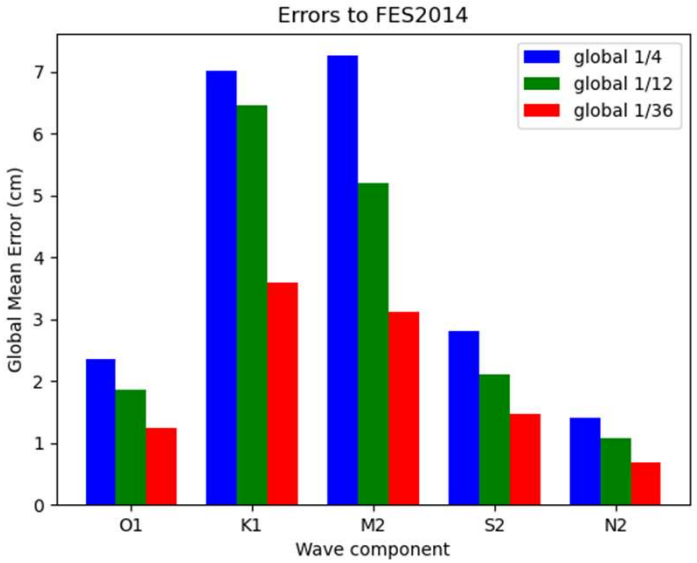
	M2	K1
ORCA12 without cavity		
ORCA12 with cavities		

⇒ Adding southern cavities improves tidal solution at global scale for all components

Resolution impact

- Tests done with global 1/4°, 1/12° & 1/36° configurations

	M2	K1
1/4°		
1/12°		
1/36°		



Tidal solution errors to FES2014 for a 3 months period

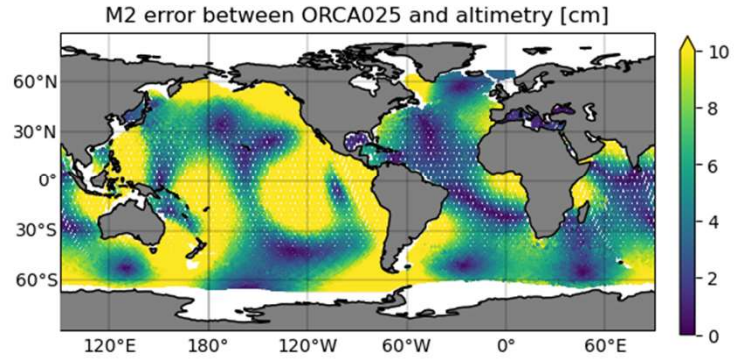
⇒ Resolution improves tidal solution in global configurations

⇒ Between 1/4° and 1/36°, errors to FES2014 are divided by 2

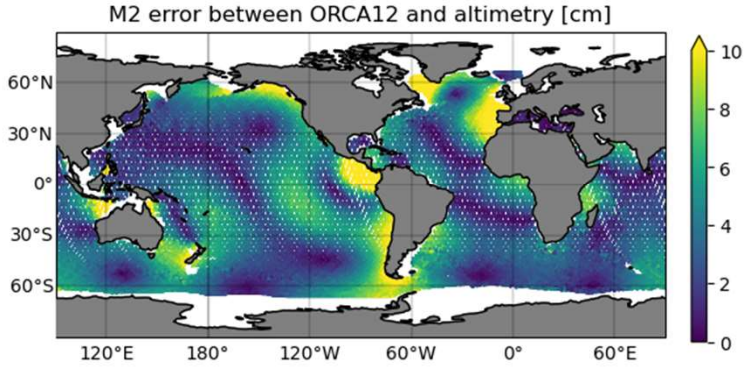
Resolution impact

- Tests done with global 1/4°, 1/12° & 1/36° configurations
- Comparison to along track altimetry (TOPEX, Jason 1 & 2)

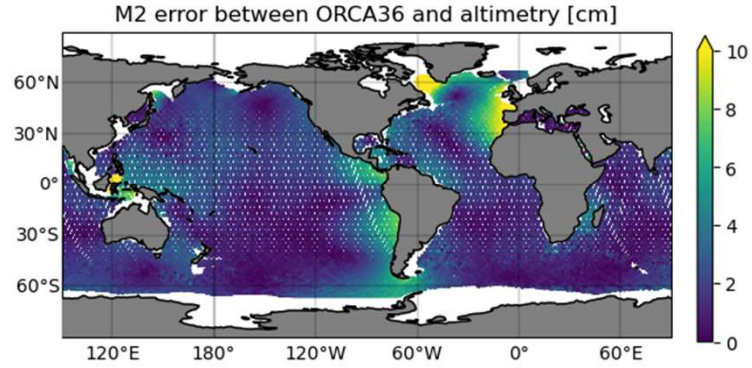
1/4°



1/12°



1/36°



⇒ Resolution improves tidal solution in global configurations

4. Internal waves

Internal waves – Modal decomposition

Using the theory for linear internal waves and assuming that vertical and horizontal motions can be decoupled leads to resolving the Sturm-Liouville problem :

$$\frac{d}{dz}\left(\frac{1}{N^2(z)}\frac{d\Pi_n}{dz}\right)+\frac{\Pi_n(z)}{c_n^2}=0 \quad \text{with} \quad \begin{cases} g\dfrac{d\Pi_n}{dz}+N^2(z)\Pi_n(z)=0 \quad \text{for} \quad z=0 \\ \Pi_n(z)=0 \quad \text{for} \quad z=-H \end{cases}$$

Corresponding modes for horizontal velocity and pressure are : $\Phi_n \propto \frac{d\Pi_n}{dz}$

Horizontal velocity and pressure can be written in the general case :

$$\vec{u}(x,y,z,t)=\sum_{n=0}^{\infty}\overrightarrow{u_n}(x,y,t)\Phi_n(z) \quad \text{and} \quad p(x,y,z,t)=\sum_{n=0}^{\infty}p_n(x,y,t)\Phi_n(z)$$

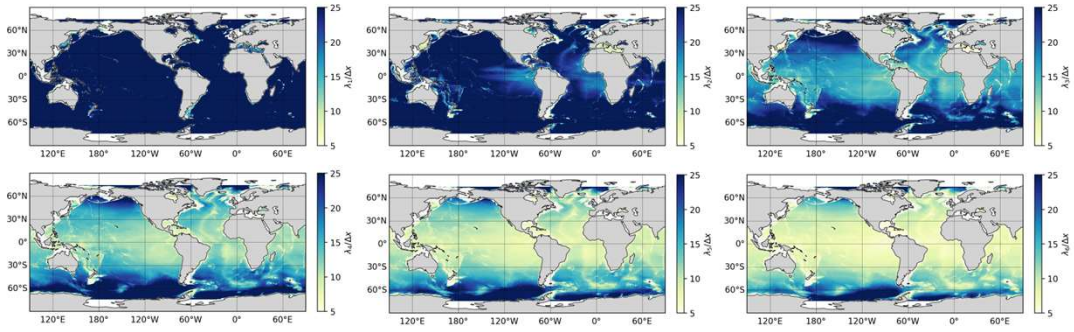
Ref: N. Lahaye, GitHub - NoeLahaye/ITideNATL: ongoing work for internal tide analyis in eNATL NEMO simulations

To determine the number of modes that can be resolved, comparison between

- the size of the horizontal resolution: $\Delta x = \max(dx, dy)$
- the M2 wavelength of the mode: $\lambda_n = \frac{2\pi c_n}{\sqrt{\omega^2 - f^2}}$

We consider that the mode is resolved if $\lambda_n/\Delta x > 5$.

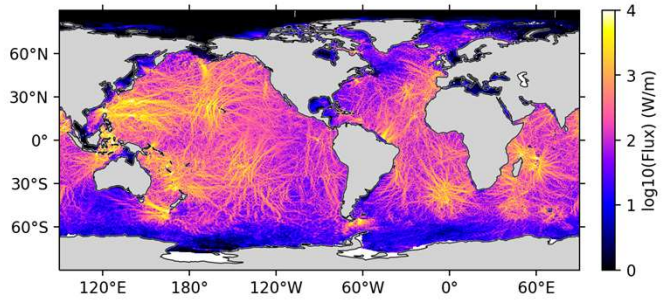
For ORCA36, we can resolve 6 baroclinic modes.



Internal waves – Baroclinic energy fluxes

Data filtered around the tidal frequency M2 (Butterworth bandpass filter)

1



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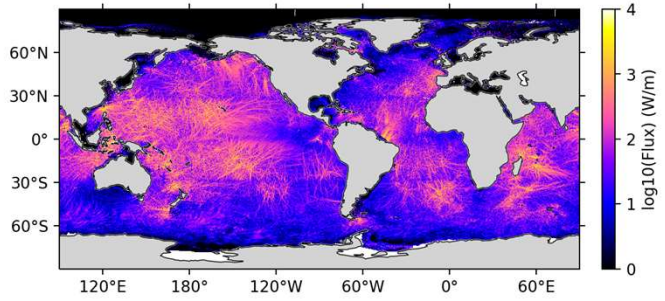

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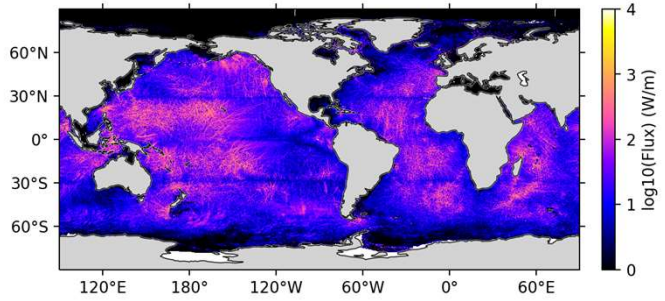

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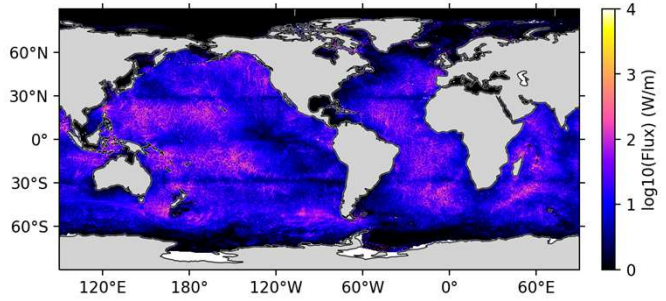

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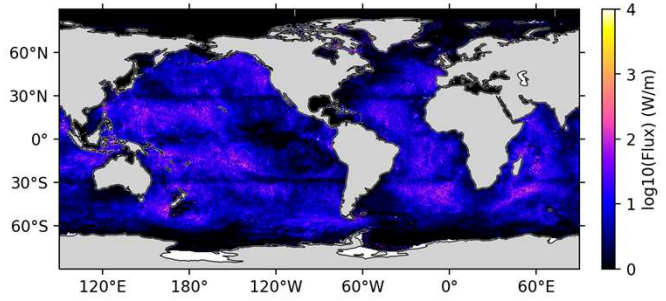

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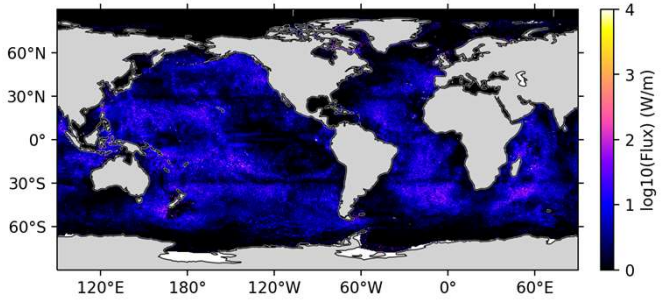


⇒ Lower modes: the energy propagates over thousands of km

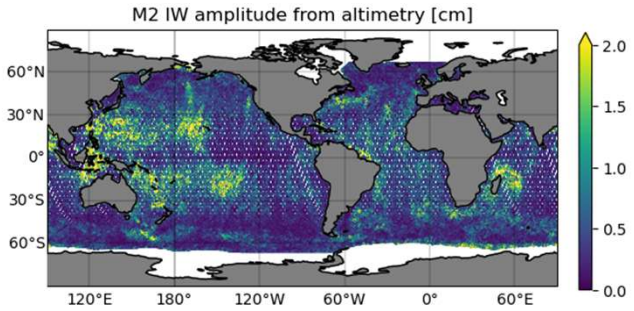
⇒ Higher modes: quickly dissipated

⇒ Interesting patterns around critical latitudes

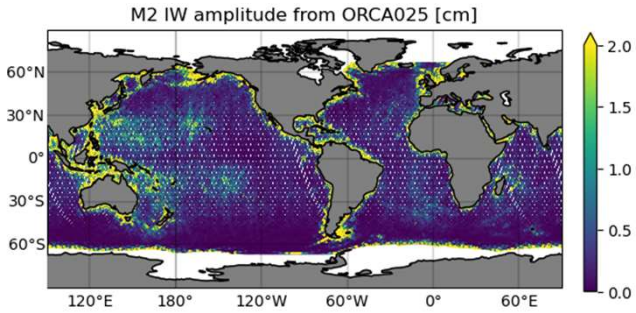
Internal waves – Surface signature

Comparison between along track altimetry (TOPEX, Jason 1 & 2) and the model at different resolutions

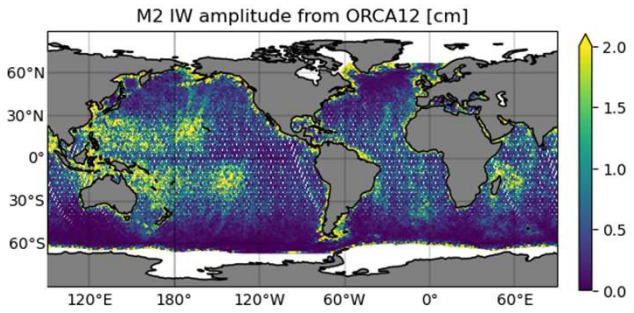
Altimetry



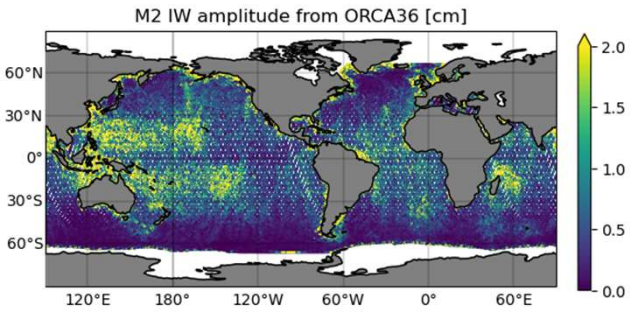
1/4°



1/12°



1/36°



⇒ 1/4° does not resolve the internal waves

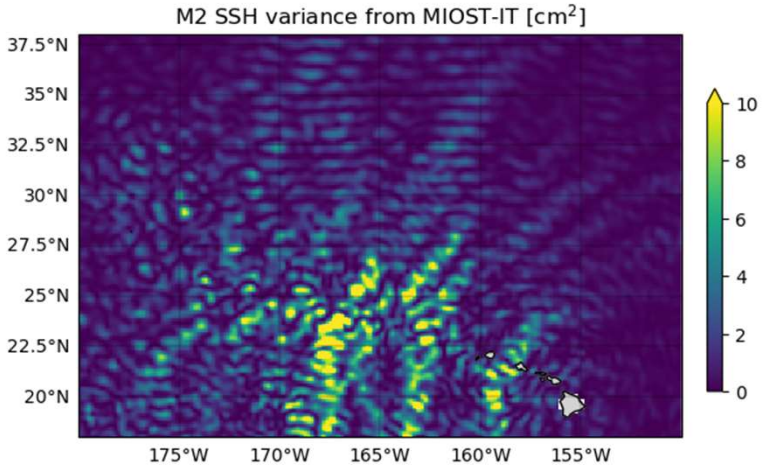
⇒ 1/12° and 1/36° seem to give the same results

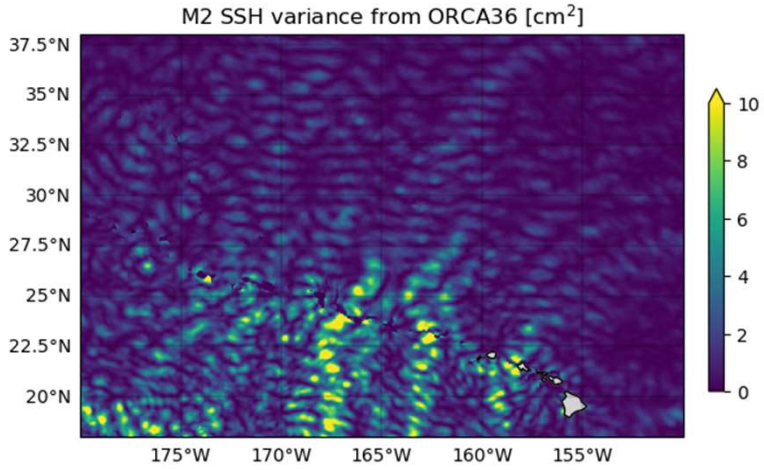
Internal waves – SSH variance

Regridded altimetry

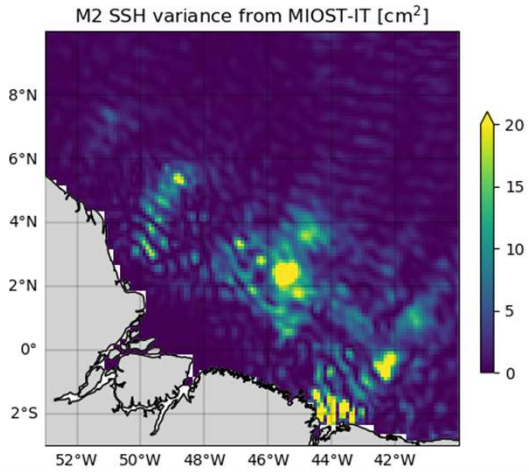
ORCA36 barotropic modes (mode 1 + mode 2)

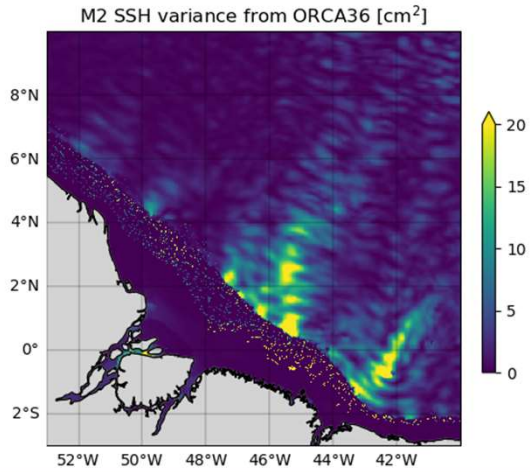
Hawaiian Ridge





Amazon Shelf





5. Conclusion and perspectives

Conclusion

Barotropic tides:

- Improved representation of barotropic tide thanks to resolution and Antarctic cavities in the domain

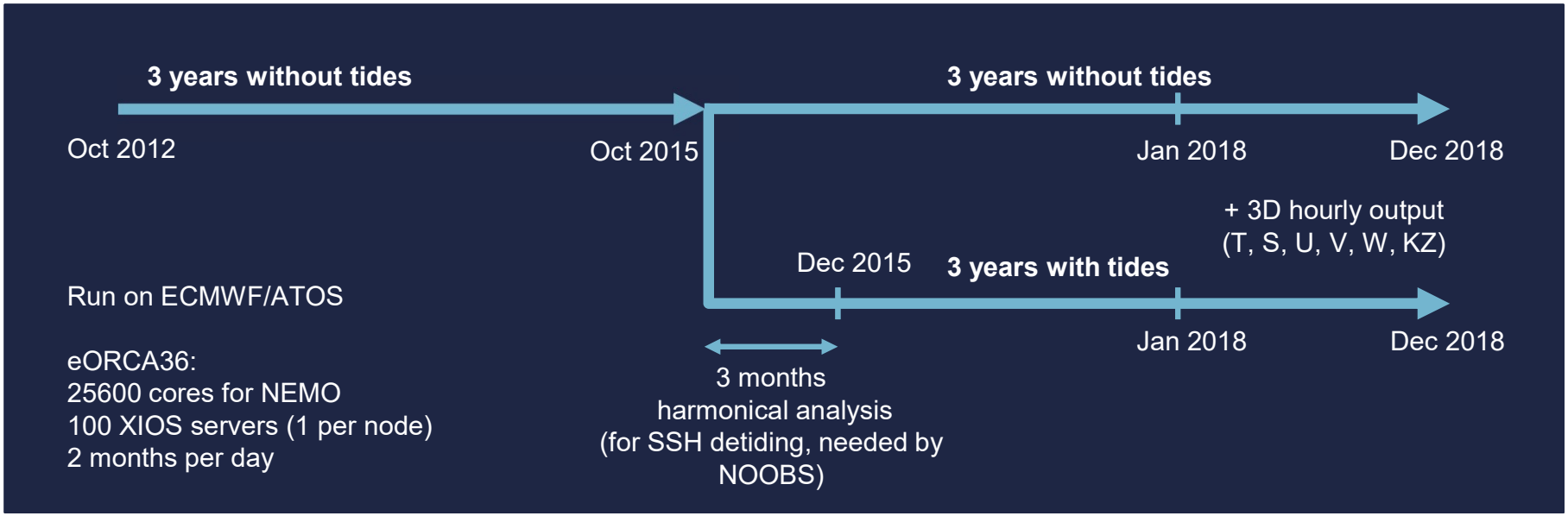
Baroclinic tides:

- amplitude appears reasonable
- energy diagnostics are in progress

Perspectives – 2022: multi-year hindcast production

- Product a multi-year hindcast for :
  - 1/4° : ORCA025, 18-20 km resolution
  - 1/12° : ORCA12, 6-9 km resolution
  - 1/36° : ORCA36, 2-3 km resolution
- Forced by ECMWF/IFS 14 km resolution/1 hour frequency

Status:
1/4° and 1/12° produced
1/36° with tides produced
1/36° without tides: production in the last year



Data will soon be available on WEkEO
ORCA36 will be the new forecasting model for Mercator Ocean in 2025

Thank you for your attention