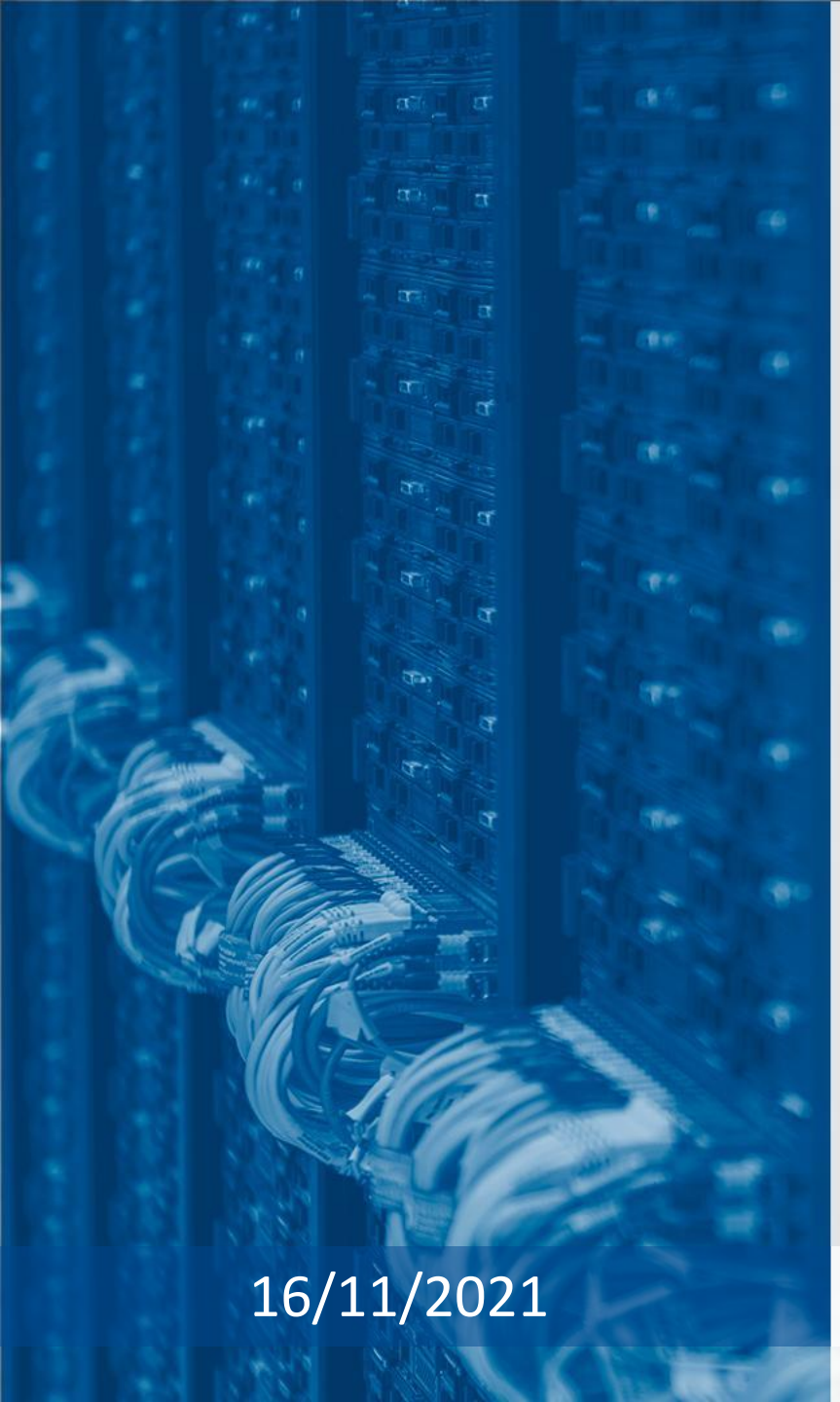

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The new very-high resolution EC-Earth 4 climate demonstrator

M. Castrillo, M. Acosta, T. Arsouze, I. Ayan, V. Lapin, G. Montané, S. Palomas, S. Paronuzzi, K. Serradell, O. Tintó, X. Yepes

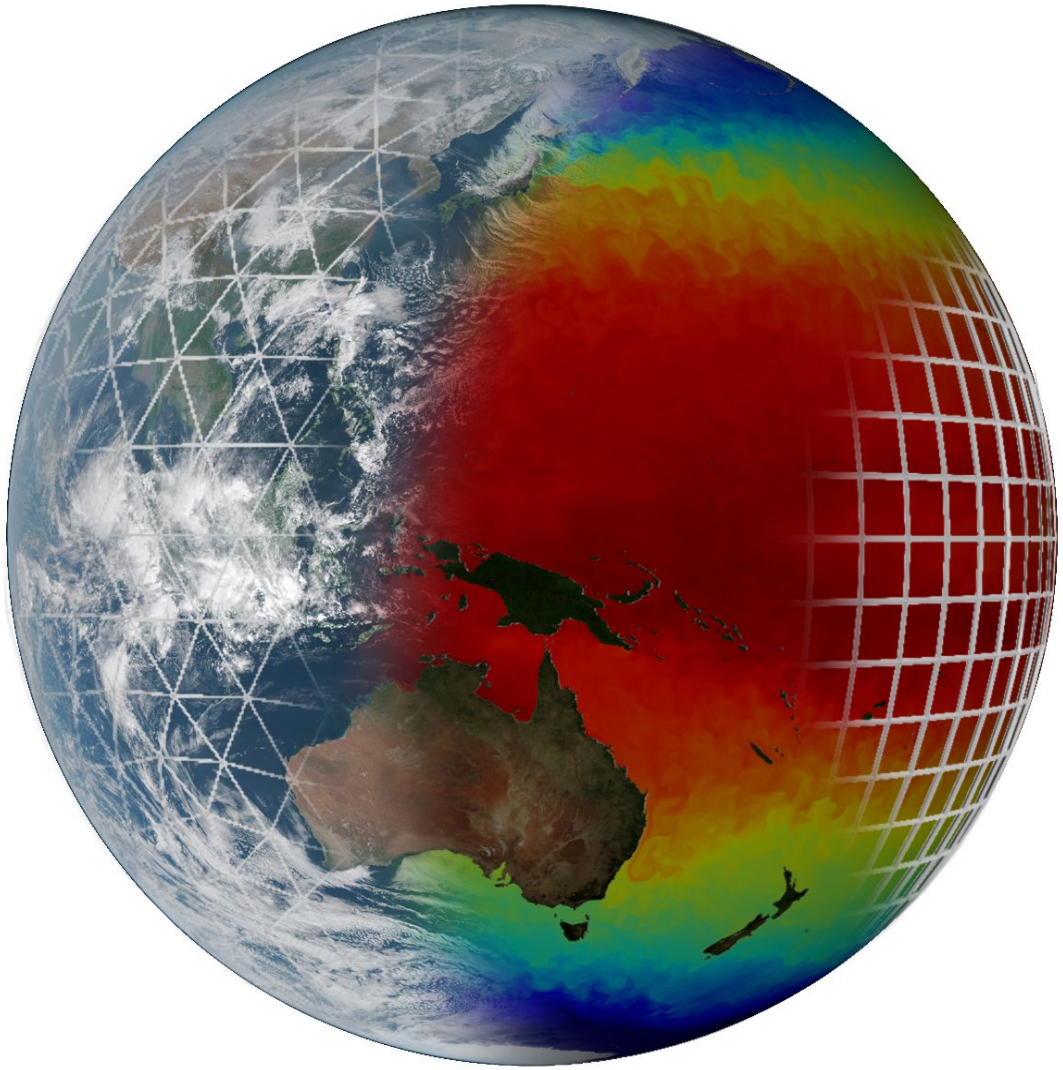
16/11/2021

EC-Earth Consortium General Assembly

Outline

- **EC-Earth**
- The **coupled pre-Exascale demonstrator**
- The **new** pre-Exascale VHR-GCM configuration

The EC-Earth GCM model



Atmosphere:

IFS

ECMWF

Ocean - ICE:

NEMO - LIM

Coupler:

Oasis

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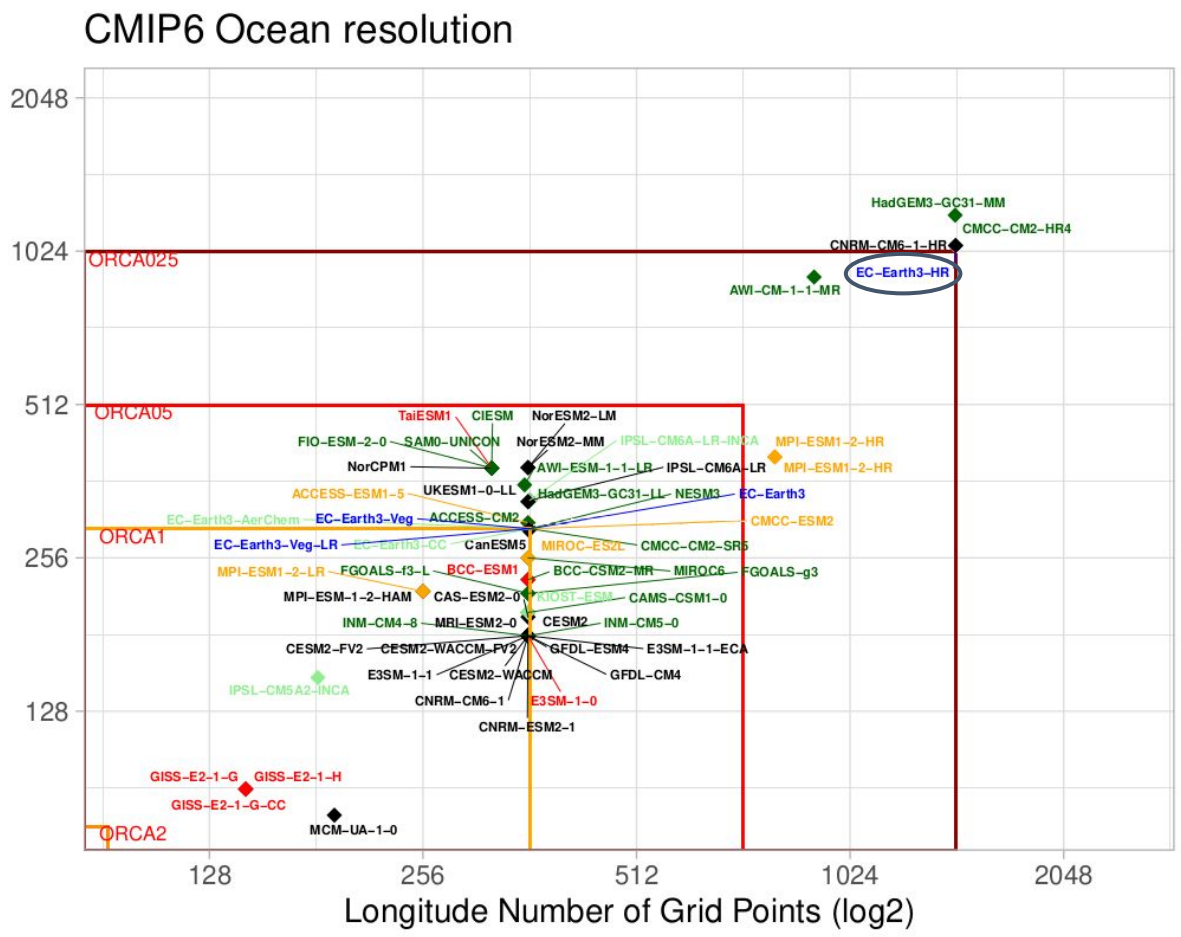
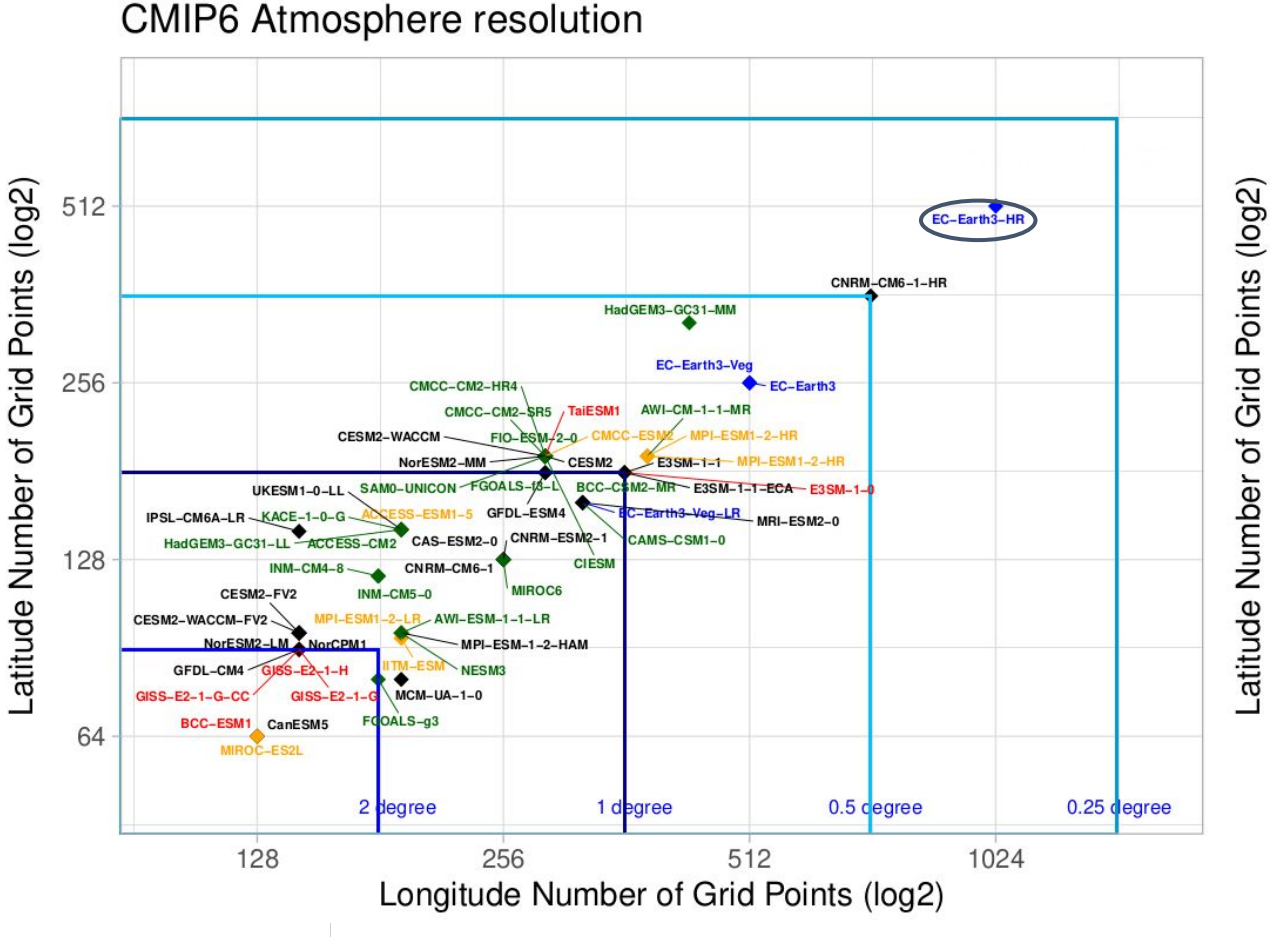
Resolution in climate models





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P. Davini (CNR)

EC-Earth 3 coupled ~10 km

ESiWACE: EC-Earth ~10km coupled demonstrator

- **IFS** cycle 36r4 for atmosphere
  - T1279L91: ~16 km grid point distance, **2.1 M** grid points
- **NEMO-LIM3** v3.6 for ocean & sea-ice
  - ORCA12L75: ~9 km grid point distance, **13.2 M** grid points*
- Total 3D space points: **1,181kM vertices**

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* Including land points (up to 1/3 of the total)

EC-Earth 3 - T1279-ORCA12 in MareNostrum4

Operational global, coupled ~10 km simulations:

- **EC-Earth 3.2** (IFS36r4 + NEMO 3.6 + OASIS3-MCT)
- **4,512 MPI tasks** - 0.44 SYPD, 160 SDPD

100 year exp
~25M computing hours,
227 days

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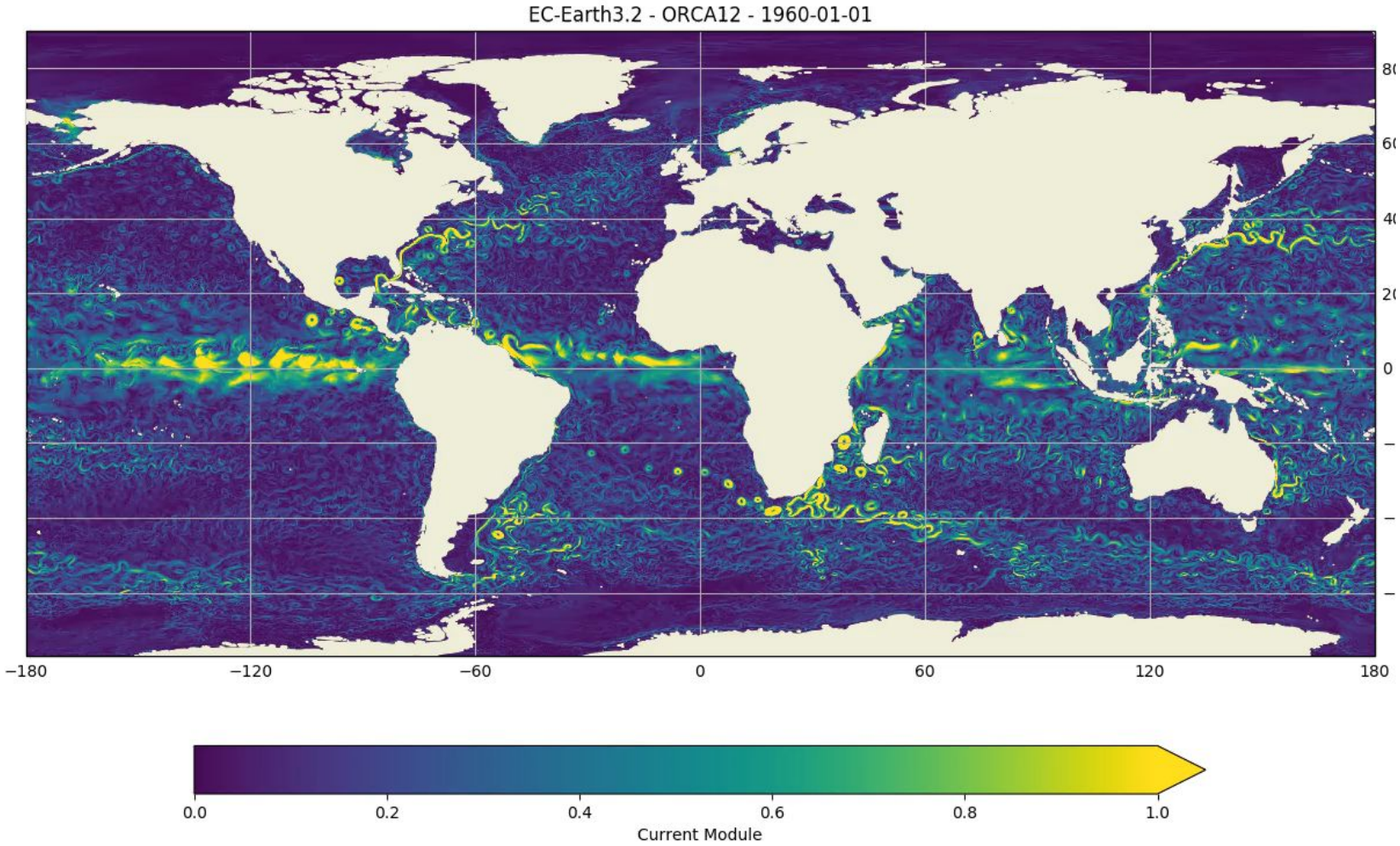
EC-Earth 3 - T1279-ORCA12: production runs

- **PRIMAVERA** is a **Horizon 2020** project which aims to develop a **new generation of advanced and well-evaluated high-resolution global climate models**, capable of simulating and predicting regional climate with **unprecedented fidelity**, for the **benefit** of governments, business and society in general.

- The **High Resolution Model Intercomparison Project (HighResMIP)** is a **CMIP6** endorsed MIP that applies, for the **first time**, a **multi-model approach** to the systematic investigation of the **impact of horizontal resolution**.

EC-Earth 3 - T1279-ORCA12: production runs



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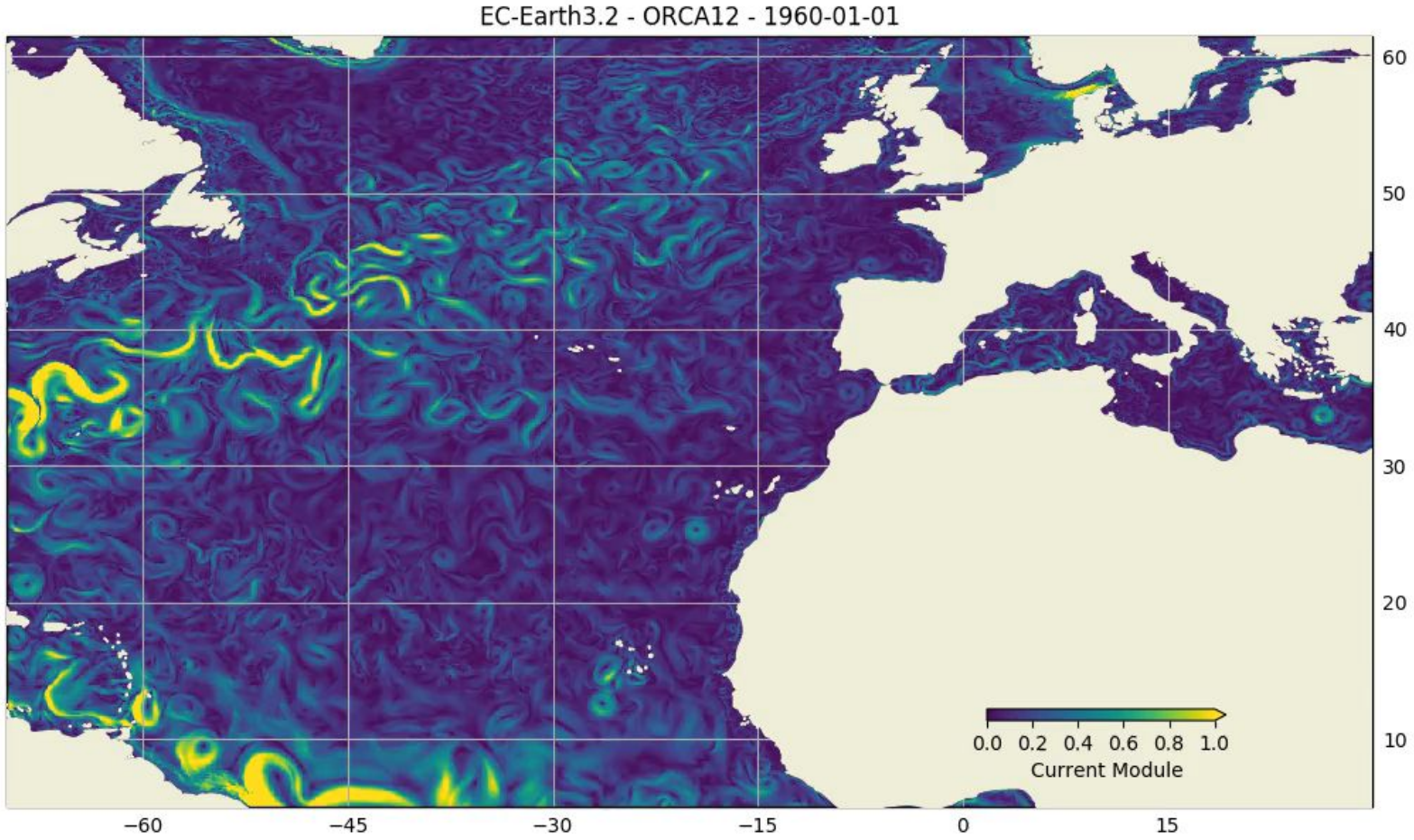
Courtesy of: Thomas Arsouze

EC-Earth 3 - T1279-ORCA12: production runs



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Courtesy of: Thomas Arsouze

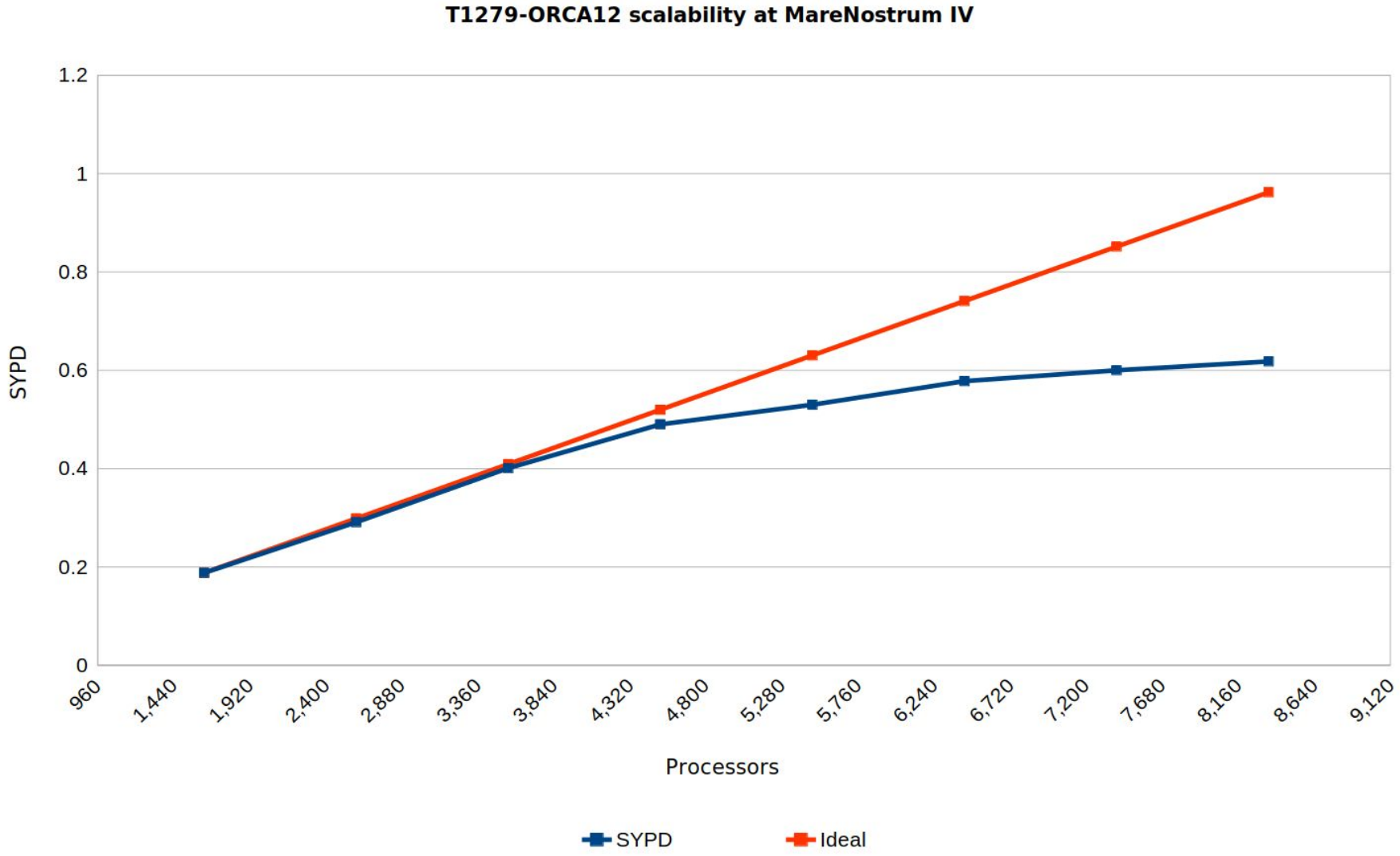
EC-Earth 3 - T1279-ORCA12 in MareNostrum 4

Benchmark scaling

Reduced output: ocean monthly means & 6-hourly atmospheric variables

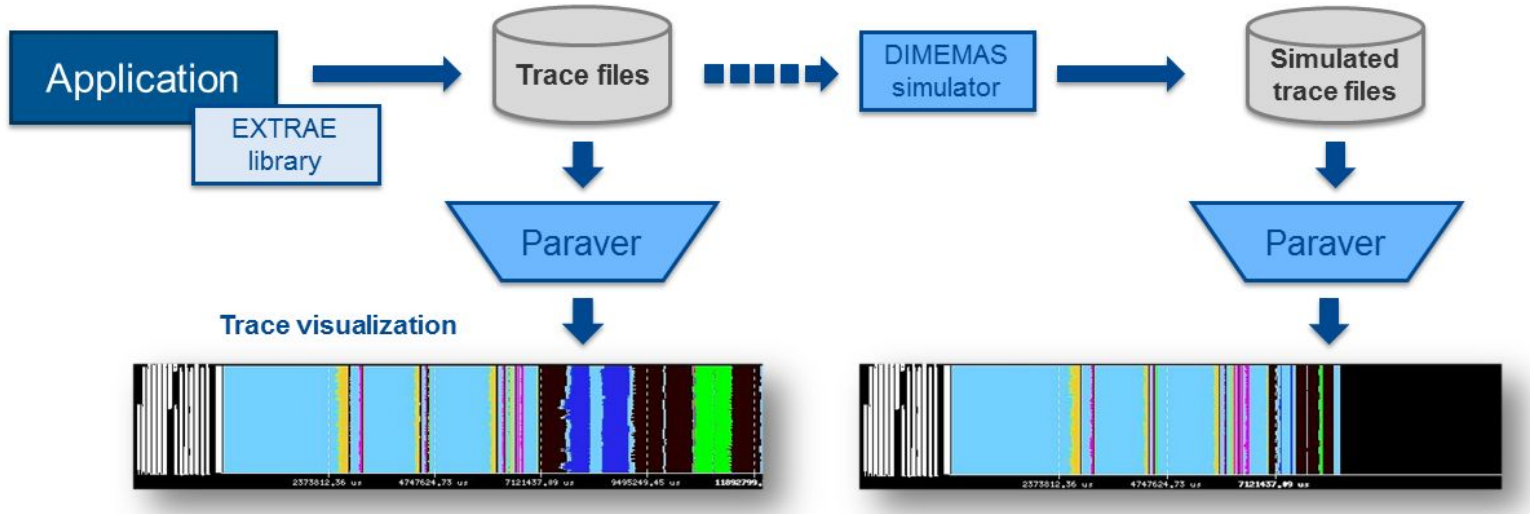
Timestep: 6 min. (atm. & oce.)

Coupling freq.: 12 min (atm-oce) and (oce-ice).

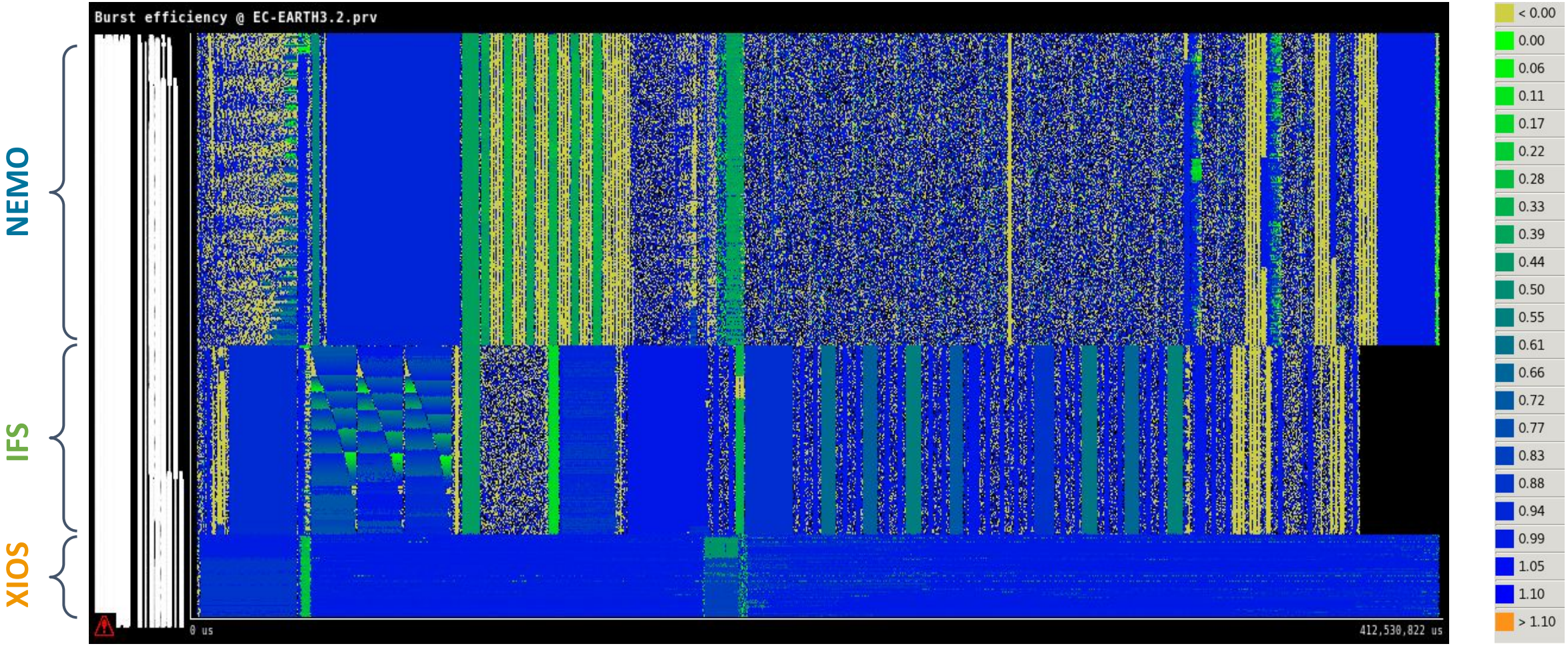


Performance analysis

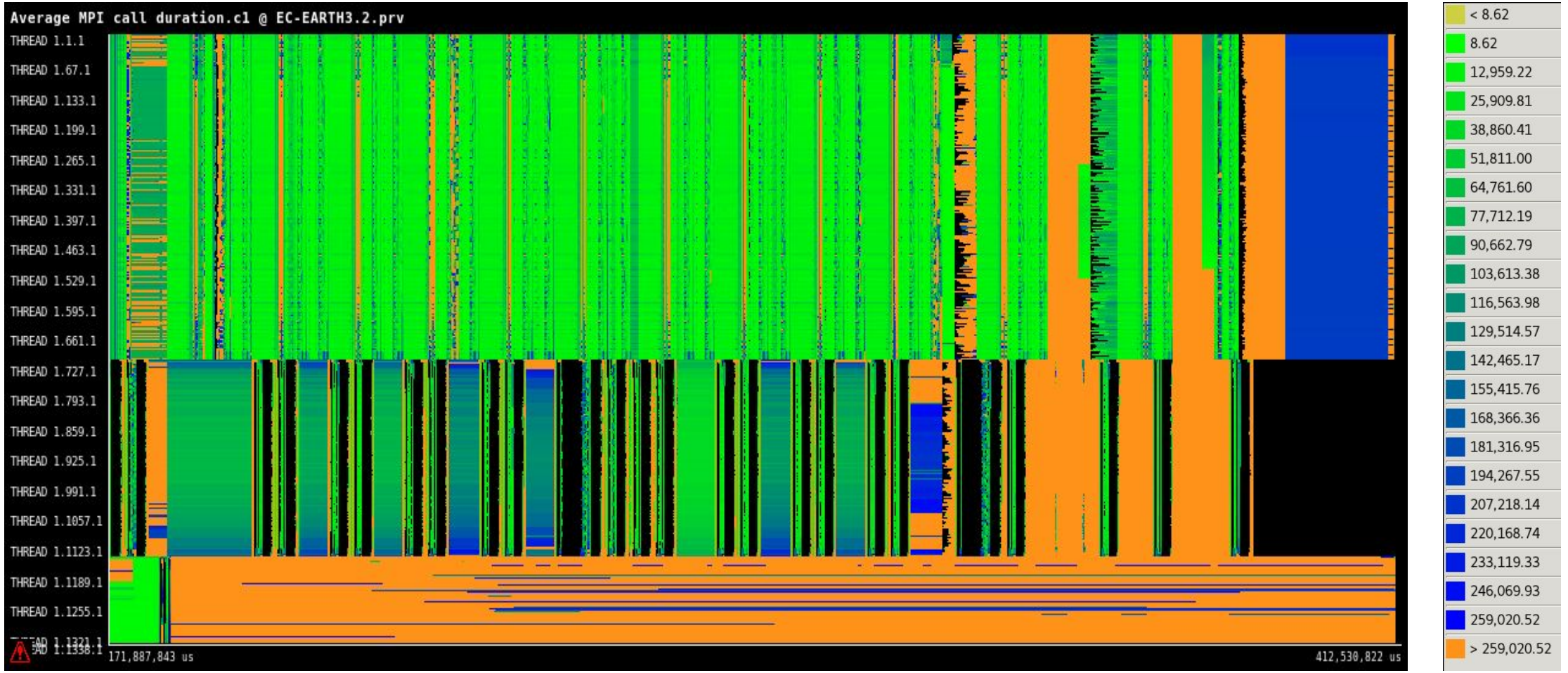
- **Extrae**: Library to **generate trace files**
- **Paraver**: Trace **visualization** and **analysis**
- **Dimemas**: Message passing **simulator**



EC-Earth - T1279-ORCA12: Performance analysis



EC-Earth - T1279-ORCA12: Performance analysis



NEMO

IFS

XIOS

time

EC-Earth 3 - T1279-ORCA12: Main bottlenecks

- **I/O overhead** → Implement asynchronous I/O
- **Sea-ice scalability** → Reduce **global** communications
- **Legacy atmospheric model (2010)** → Update **IFS** to newest cycle, using octahedral grid

ESiWACE 2: EC-Earth coupled ~10 km production-mode

- **I/O overhead** ⟶ Implement asynchronous I/O
- **Sea-ice scalability** ⟶ Reduce **global** communications
- **Legacy atmospheric model (2010)** ⟶ Update **IFS** to newest cycle, using octahedral grid

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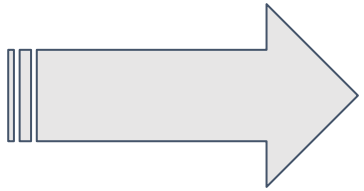
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE



> 1 SYPD

~~**0.45 SYPD**~~

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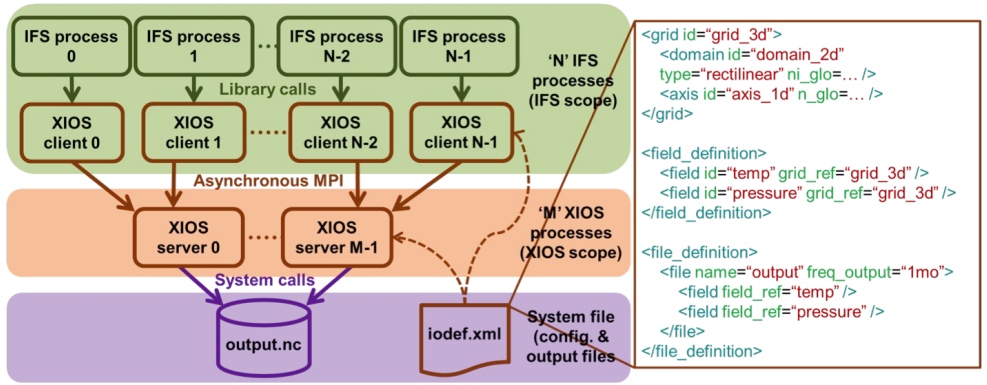
ESiWACE 2: EC-Earth coupled ~10 km production-mode

- Develop **infrastructure** for production-mode configurations

ESiWACE 2: EC-Earth coupled ~10 km production-mode

- Develop **infrastructure** for production-mode configurations
  - **Coupling** infrastructure **(OASIS)**
  - Improvement of **I/O (XIOS)**
  - **NEMO** for high-resolution
  - Infrastructure for **high-resolution data**



XIOS integration into OpenIFS (X. Yepes)

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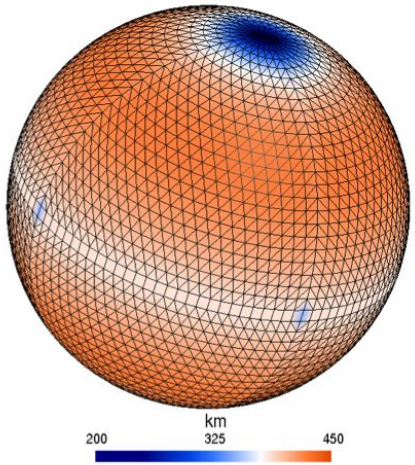
ESiWACE 2: EC-Earth coupled ~10 km production-mode

- Develop **infrastructure** for production-mode configurations
- Develop production-mode **configurations** 
- Port models to **pre-exascale** EuroHPC **systems**

EC-Earth coupled ~10 km production-mode

Main assets

- Brand **new ESM: EC-Earth 4**
  - **OpenIFS cycle 43r3** (2020)
  - **NEMO v4.0.2** (2019) (incl. **SI3** sea-ice model)
  - **OASIS3-MCT 4**
- **Common** asynchronous **I/O server** (XIOS v2.5)
- **Octahedral reduced** gaussian grid for OpenIFS
- Possibility to **switch** numeric **precision**



N24 octahedral Gaussian grid

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EC-Earth coupled ~10 km production-mode

ESiWACE2: EC-EARTH 4 VHR coupled demonstrator

- **OpenIFS** cycle 43r3 for atmosphere
  - Tco639L91: ~16 km grid point distance, **1.66 M** grid points
- **NEMO-SI3** v4 & SI3 for ocean & sea-ice
  - ORCA12L75: ~9 km grid point distance, **13.2 M** grid points*
- Total 3D space points: **1,141kM vertices**

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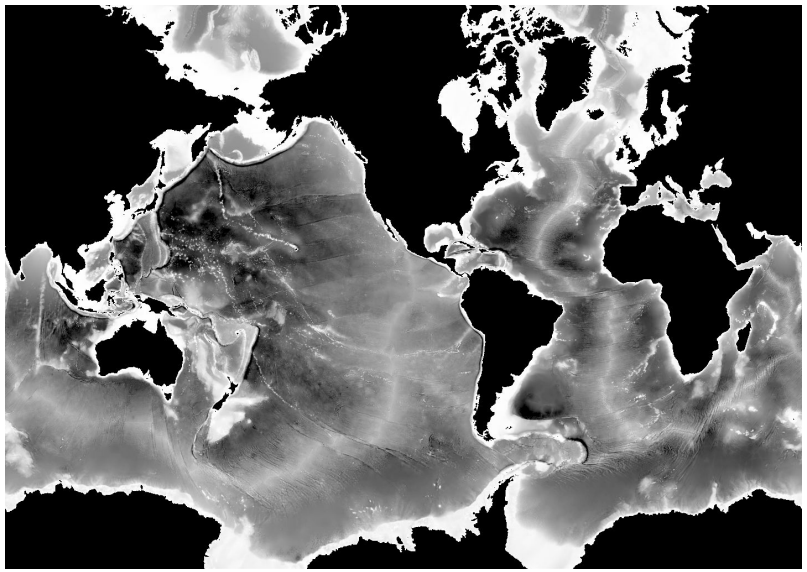
* Including land points (up to 1/3 of the total)

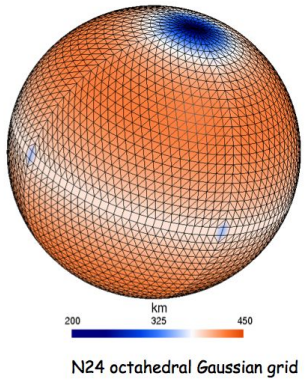
Tco639-ORCA12 configuration development

ORCA12 inspired from EC-Earth 3 T1279-ORCA12. Namelist "tuning" for NEMO4.



ORCA12 bathymetry

Tco639 configuration and **initial conditions.**



N24 octahedral Gaussian grid

OASIS coupler grids, masks and areas information using the **OCP**[1] tool.

OASIS remapping weights generated in parallel (OpenMP)[2].

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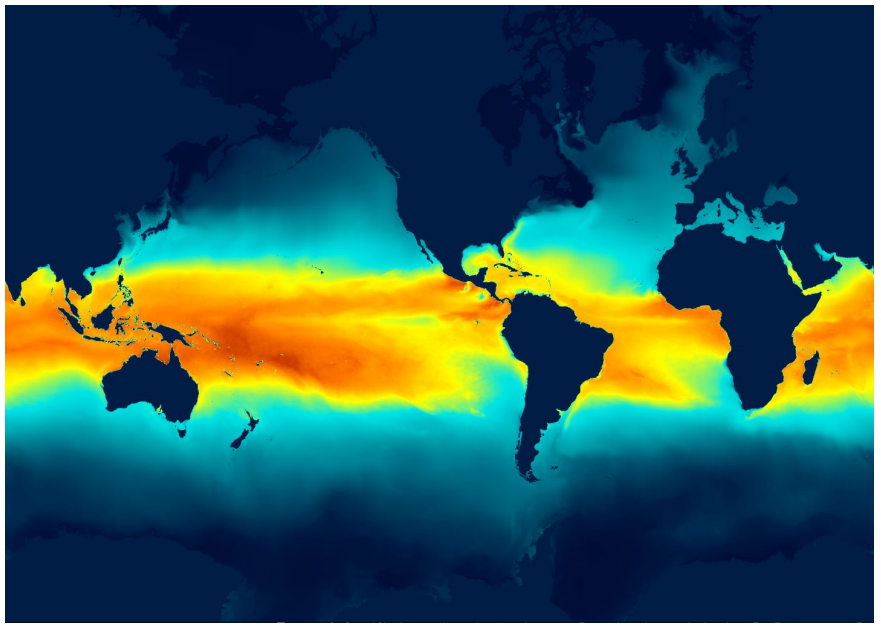
[1] https://github.com/JanStreffing/ocp-tool
[2] OASIS3-MCT4 new feature

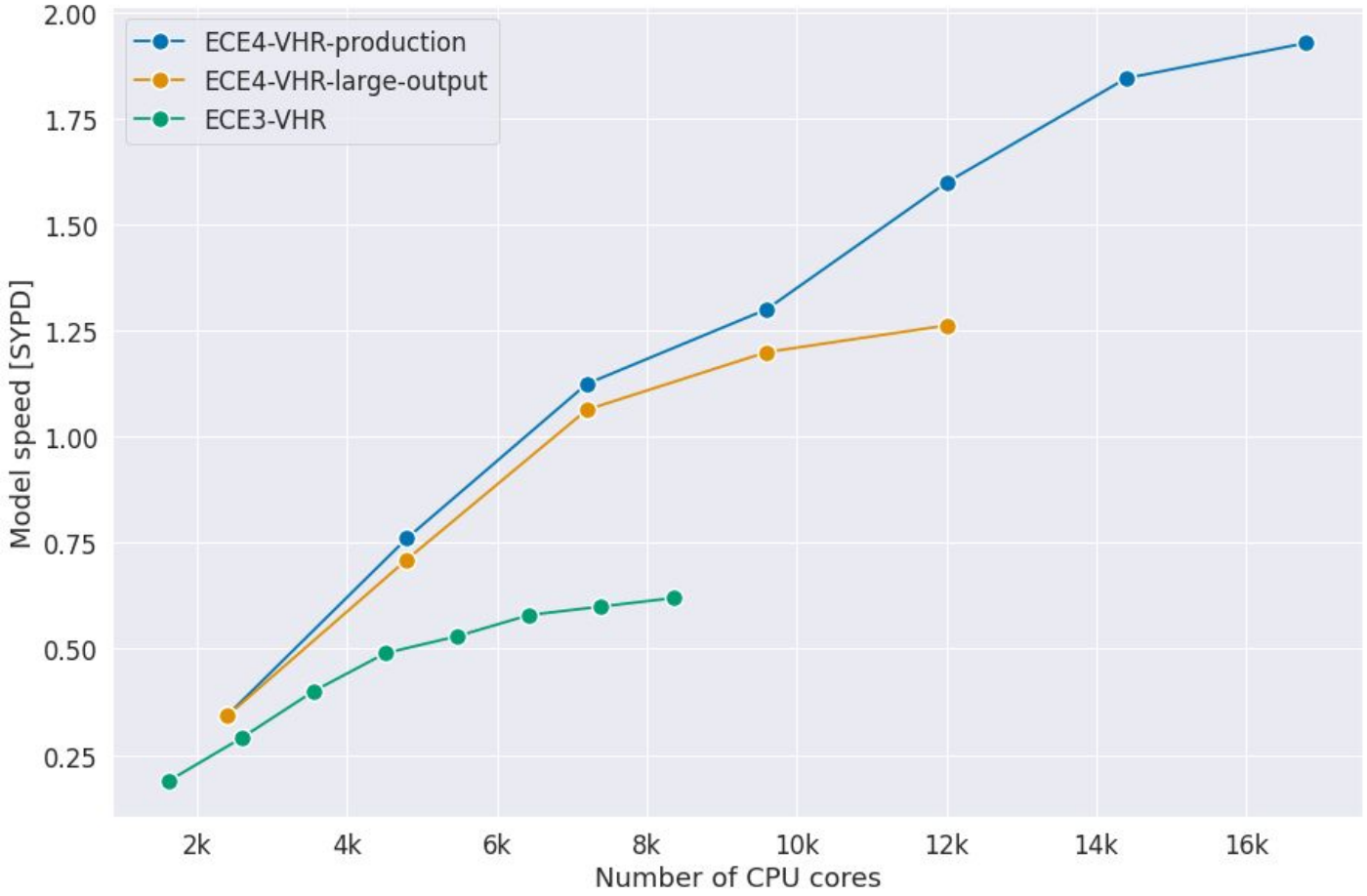
The creation process

- **Deployment** at the development and testing platform (MareNostrum4).
- NEMO (ORCA12) and OpenIFS (Tco639) **initial configurations**.
- Generation and testing of **coupling remapping weights**.
- **Test** runs. Test and **tune output** generation.
- **Fine tuning** of (Ocean) model parameters.
- **Spinup**, generation of initial conditions.
- Load **balance** and **scalability** exercise.
- **Performance** study + optimizations.
- **Final deployment** (pre-Exascale).



Sea-surface temperature after 1 month

Tco639-ORCA12 in MareNostrum 4



ECE3: TL1279-ORCA12

ATM: 360s, **OCE: 360s**, ICE: 720s, **CPL: 720s**

ECE4: Tco639-ORCA12

ATM: 360s, **OCE: 240s,** ICE: 720s, **CPL: 3600s**

- **Production: Monthly** output (6-hourly and daily averages)
- **Large output: 3-hourly** output

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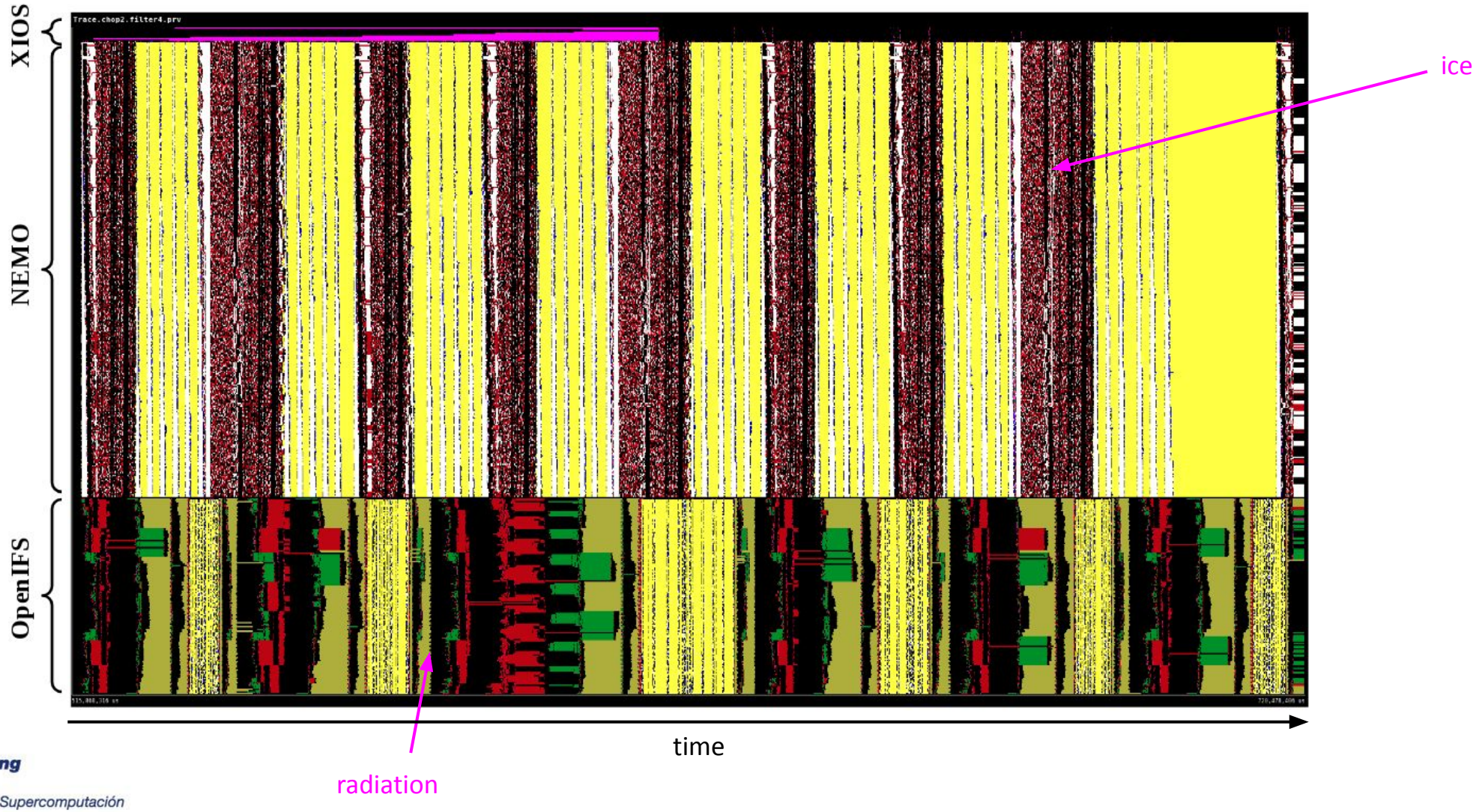
100 year experiment, **~16M** computing hours & **68** days

EC-Earth - Tco639-ORCA12 performance analysis



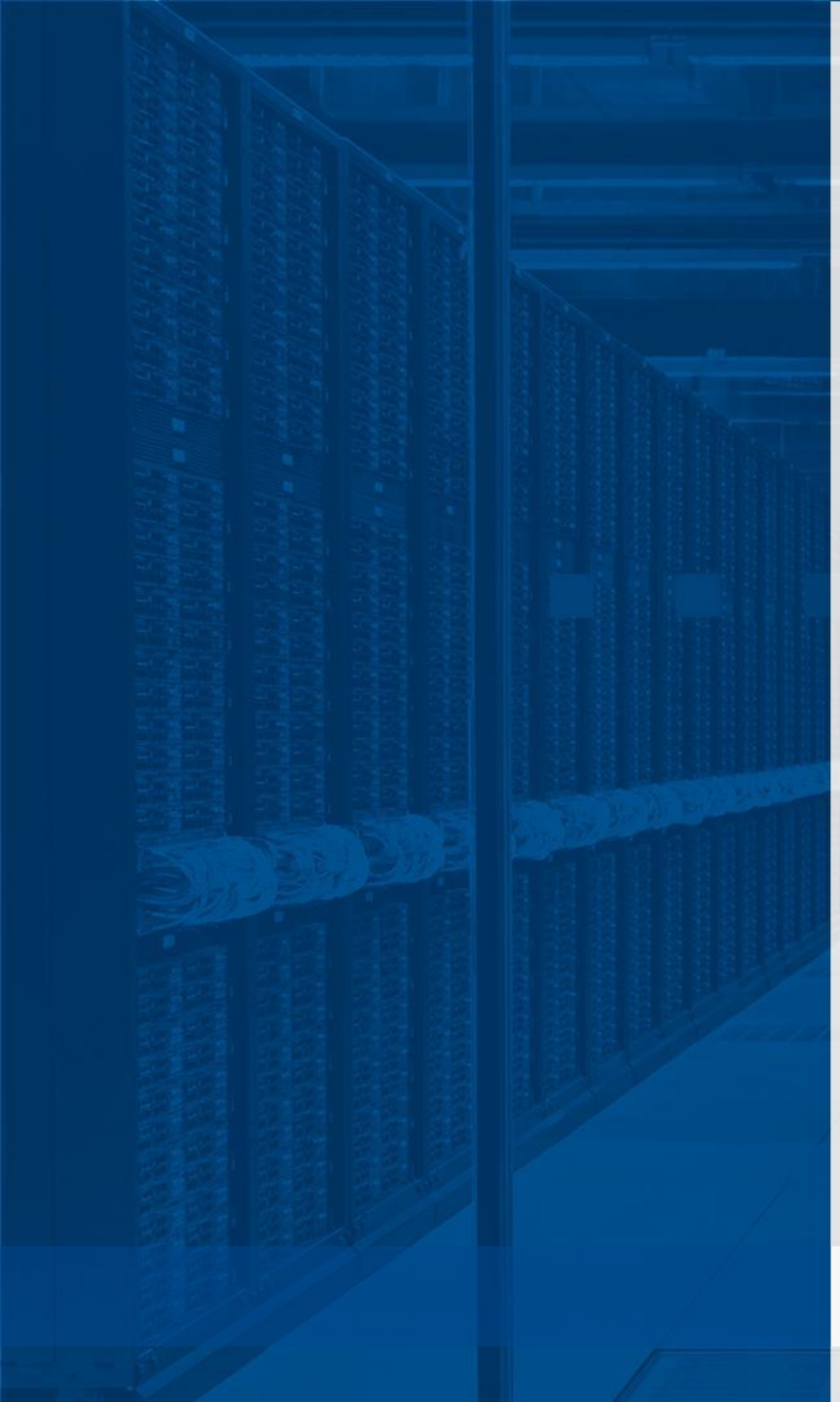
Technical take-home messages

- **Parallelizing** the **remapping weights** creation **saves** a lot of **time**.
  - **Independent** process for each pair of source-target grid.
- MareNostrum4 (OmniPath): **Open MPI** more **robust** than **Intel MPI**.
- XIOS: **parallel I/O** has a significant **overhead**. Multiple-file fairly efficient.
- OASIS: **Initialization** time increases with the number of processes (need to **tune** the remapping search method)
- NEMO: Using EN4 T&S. Need of a **spin-up** to **increase the timestep**.
- Properly **distributing** resources to handle **memory** needs.

Conclusions

- **First coupled ~10km** configuration developed within ESiWACE:
  - Developed and shared among **EC-Earth consortium** partners
  - **Deployed and tested** in the **BSC** HPC systems
  - Used in **production** for **different** projects
  - Used to investigate **very-high resolution scalability** for coupled systems

- **~10 km production-mode** configuration developed within ESiWACE2:
  - Solves the most important **bottlenecks**. Uses **updated** model components
  - Will be deployed and tested in the **pre-Exascale** EuroHPC systems
  - Will allow running **efficient** VHR simulations with a **production throughput**



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Thank you!

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The ESiWACE project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 675191

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Tco639-ORCA12 in MareNostrum 4