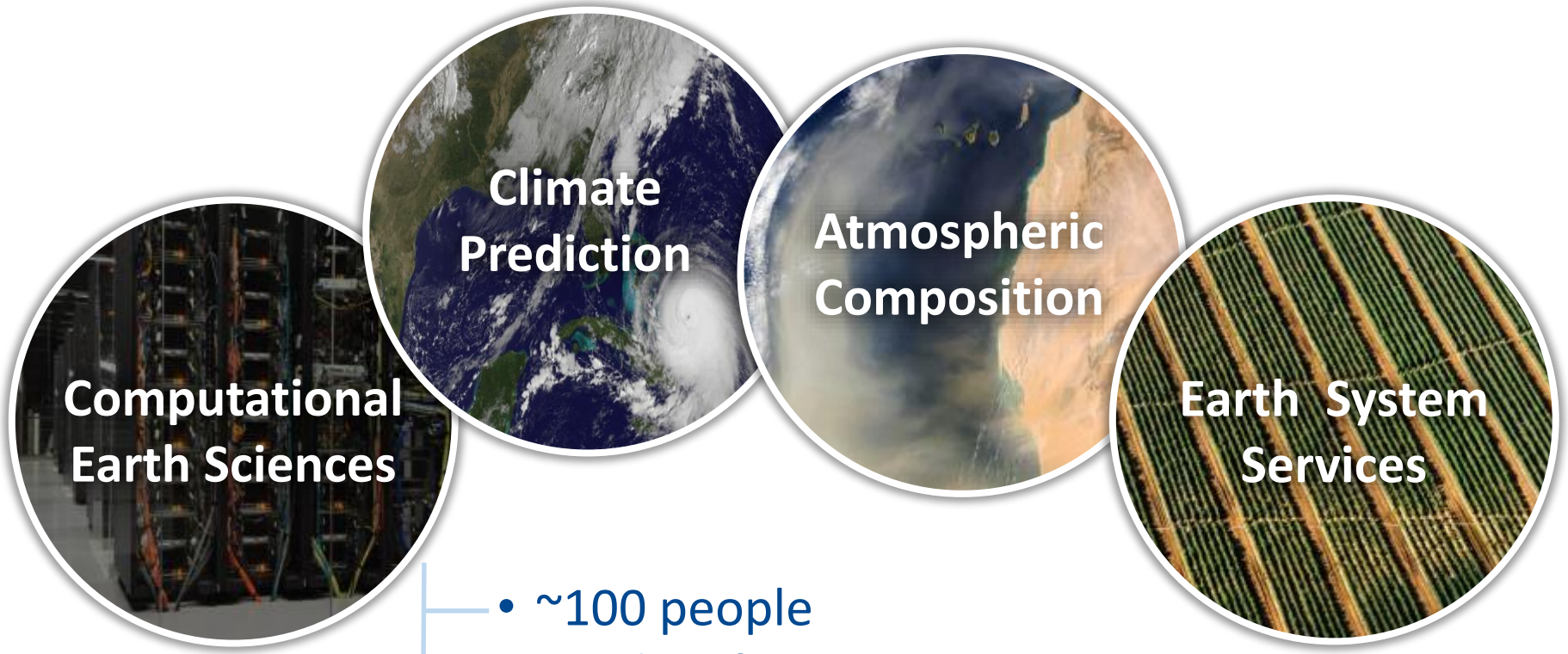
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Earth Sciences Department

Earth Sciences Department

Environmental modelling and forecasting using process-based and artificial intelligence models, with a particular focus on weather, climate and air quality. This includes transferring solutions to support the main societal environmental challenges through data applications



- ~100 people
- Funding from EC, Copernicus, private sector, ESA, Spanish and regional governments

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Objectives

Mission:

Performing research on and developing methods for environmental forecasting, with a particular focus on the atmosphere-ocean-biosphere system. This includes managing and transferring technology to support the main societal challenges through models and data applications in HPC and Big data solutions.

Objectives:

Develop an **online chemical weather model** from global to urban scales to understand and predict the chemical composition of the atmosphere.

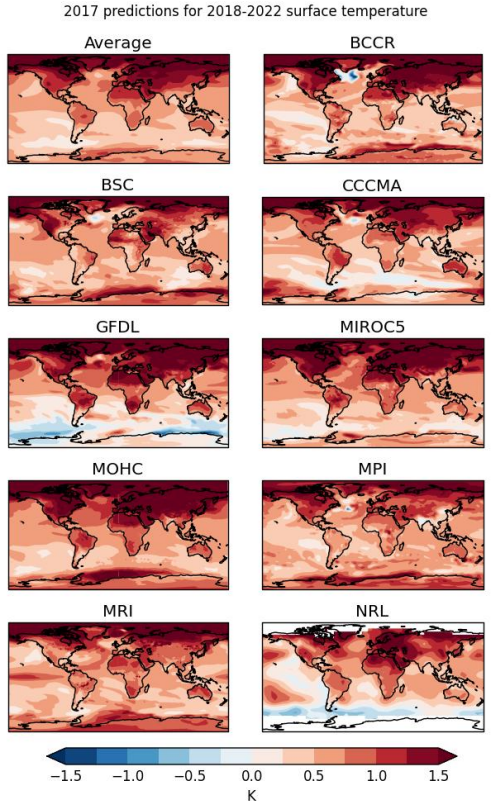
Implement the most reliable and skilful global **climate prediction system to cover time scales ranging from a month to three decades**.

Investigate the impact of weather/climate and atmospheric composition on socio-economic sectors through the development of **user-oriented services**.

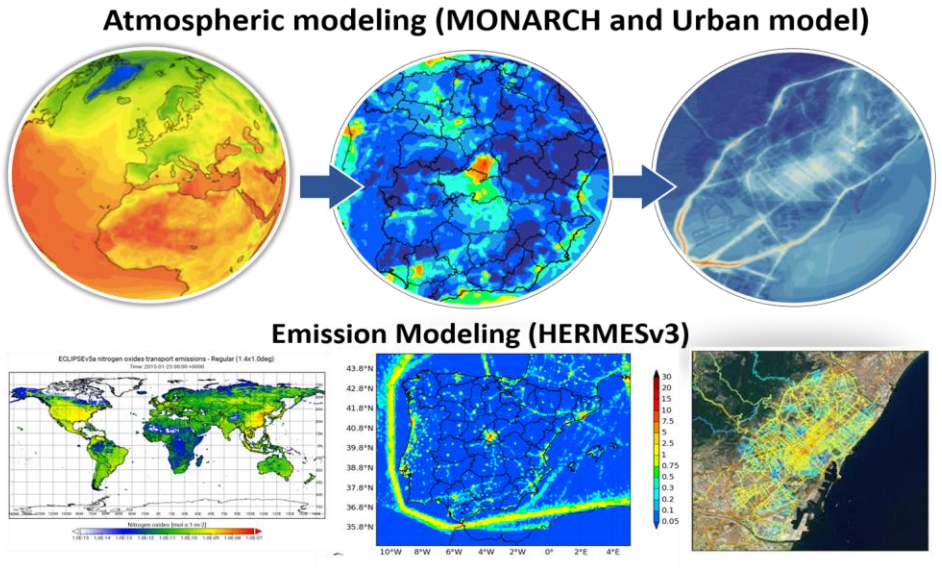
Make **optimal use of cutting-edge HPC and big data technologies** to increment the efficiency, portability and user-friendliness of Earth system models, including the pre- and post-processing of environmental data.

Making a difference in environmental services

- Unique capability to contribute to the decadal prediction of global climate, offering a outstanding tool for better mitigation and adaptation.

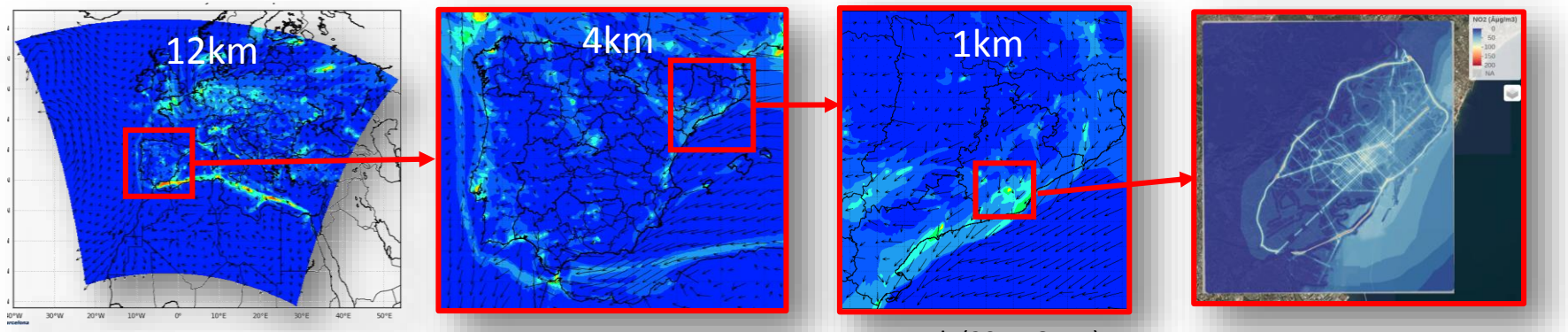


- In-house Multiscale Online Nonhydrostatic Atmosphere CHemistry model (MONARCH): gas phase and aerosol schemes, scale interactions.
- Reference model of the WMO Specialized Sand and Dust Storm Forecast Centre (with AEMET).
- Unique Spanish contributor to the Copernicus Atmosphere Monitoring Service regional production.



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Air quality forecasting at the BSC



Pay et al. (2011; 2012 AE) | Baldasano et al. (2012 AE) | Pay et al. (2014 GMD) | Benavides et al. (2019 GMD)

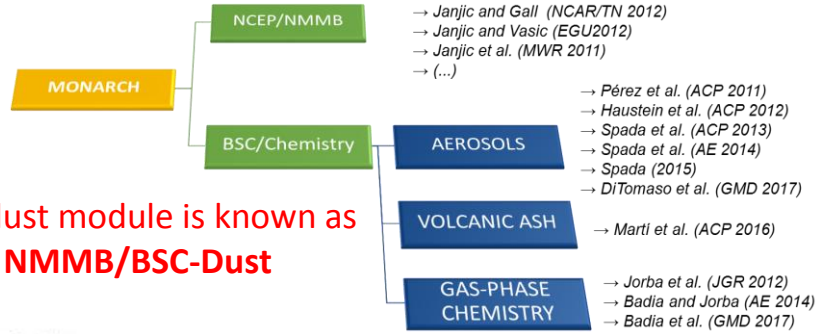
CALIOPE system: air quality forecasts from regional to local scales

In-house model developments

MONARCH model

Multiscale Online Nonhydrostatic Atmosphere Chemistry model

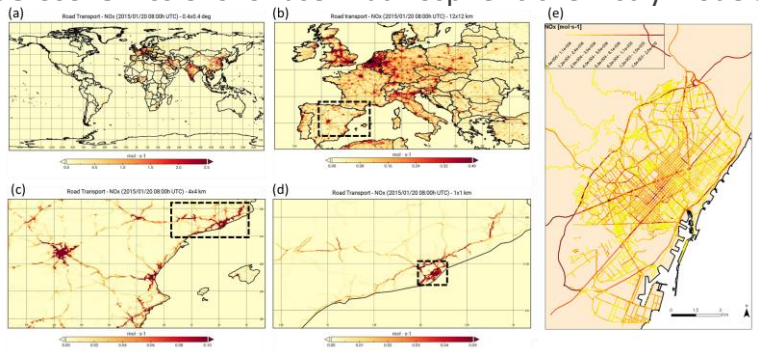
- **Multiscale**: global to regional (up to 1km) scales allowed
- Fully **on-line** coupling: weather-chemistry feedback processes allowed
- Enhancement with a **data assimilation** system and machine learning techniques



The dust module is known as **NMMB/BSC-Dust**

HERMESv3 emission model

A **python-based, open source, parallel and multiscale** emission modelling framework that **processes and estimates gas and aerosol emissions** for use in atmospheric chemistry models.



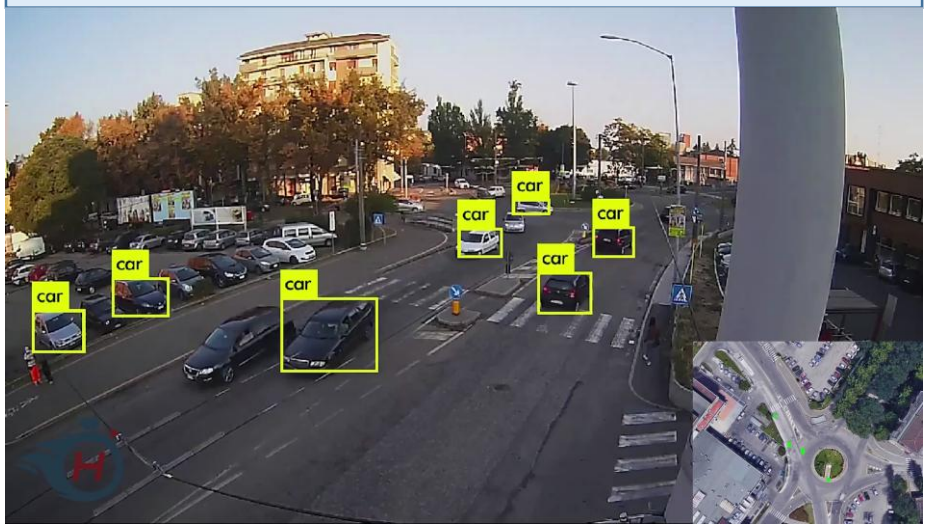
Guevara et al. (2019, 2020)

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Frontier in pollution emission modelling

Maritime high-resolution emission modelling and prediction from GPS (AIS) data and fog computing data using convolutional neural networks.

Artificial intelligence for smart cities: mining urban activity data from the increasing number of cameras for emission and air quality modelling and forecasting.

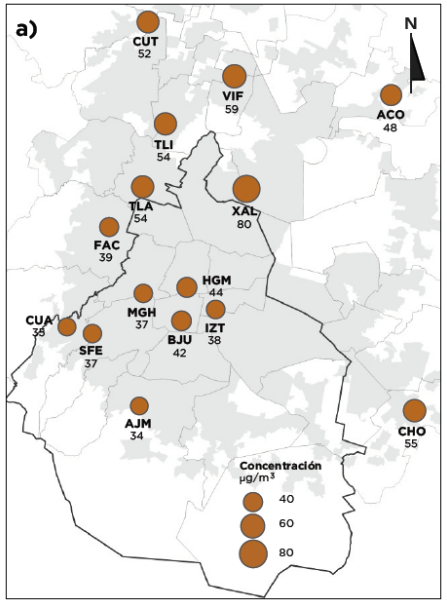


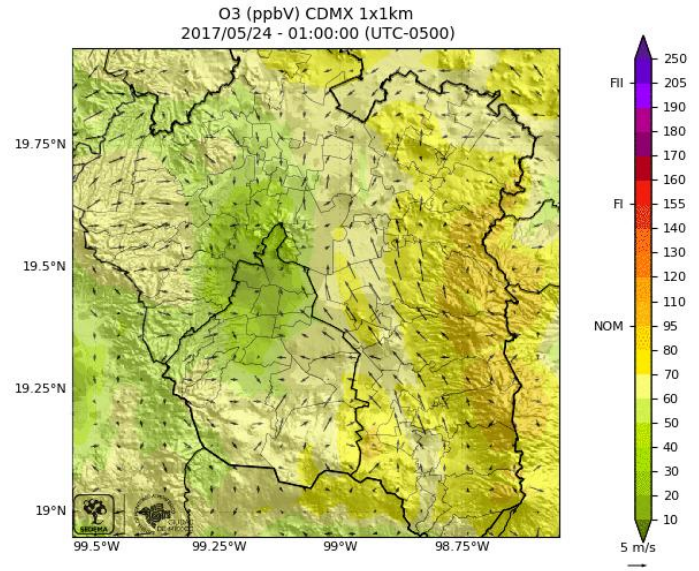
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Collaboration beyond Europe

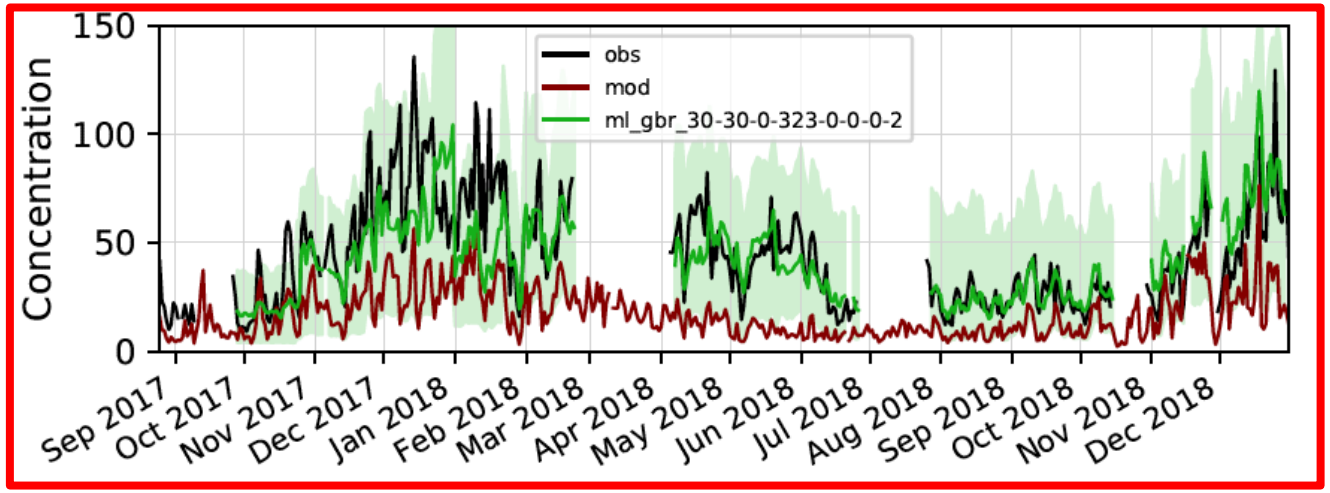
Mexico DF surface ozone: observations and forecasts for 2017

http://www.aire.cdmx.gob.mx/pronostico-aire





Data-driven artificial intelligence models to improve air quality forecasts provided by process-based models



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

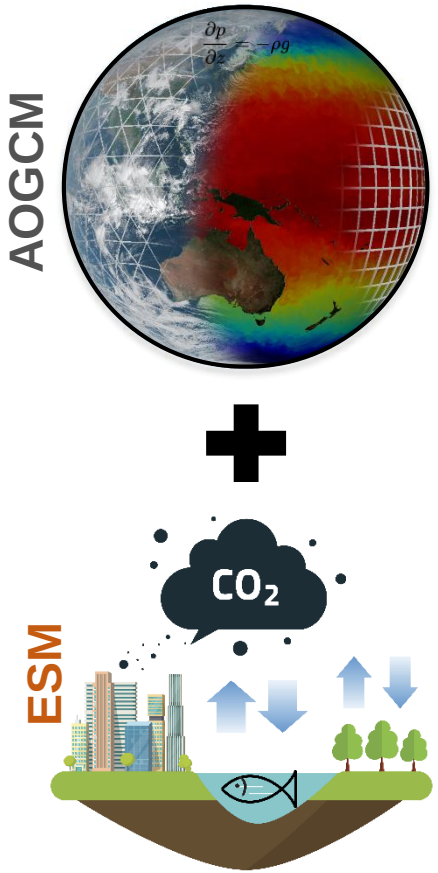
Climate modelling

- Developers of a global high-resolution Earth system model with a high-resolution configuration (10 kms).
- The objective is to understand and predict global climate in time scales of one month to 100 years
- ...and how carbon fluxes will evolve (to inform future actions regarding the Paris Agreement)
- Explore the effectiveness of natural-based climate mitigation strategies, such as reforestation.

EC-EARTH3

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

International climate contributions



DECK: 1 x picontrol / 15 x historical
ScenarioMIP: 15 x SSP2-4.5
DCPP–Component A: 1 x Decadal Prediction Set
HiResMIP (2 resolutions): 1 x control1950 / 1 x hist1950+highres-future
C4MIP: 1 x picontrol / esm-picontrol / 1pctCO2 / hist / esm-hist
Tier 1: 1 x 1pctCO2-bgc / esm-ssp585
AerChemMIP: Tier 1: 1xhist/hist-piNTCF/ssp370/ssp370-lowNTCF
Tier 2: 1 x piClim-2xdust
DCPP–Component A: 1 x Decadal Prediction Set

Shared publicly via the **BSC ESGF node**

EC-EARTH

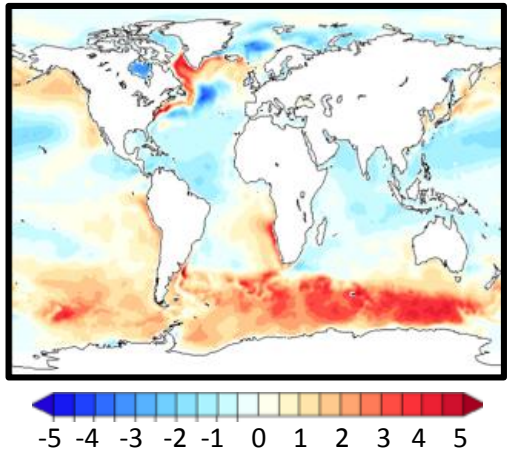
WCRP CMIP6
World Climate Research Programme

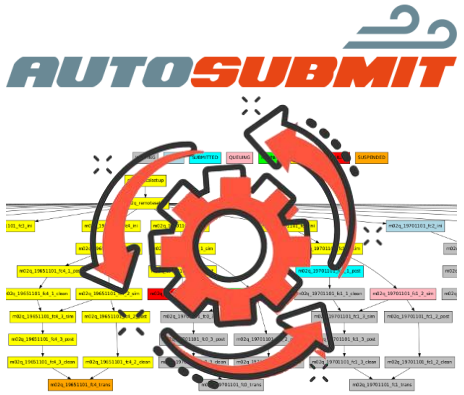
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Improving and using climate models

Implementing an adaptive workflow with **AUTOSUBMIT** for improving model systematic biases in the tuning process by better exploring the space of tuning hyper-parameters.

SST Bias in **EC-Earth3-HR**



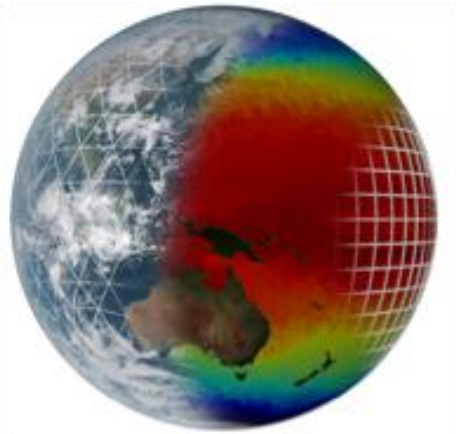


ADAPTIVE WORKFLOW

ARTIFICIAL INTELLIGENCE

LATEST OBSERVATIONS (e.g. ESA-CCI)

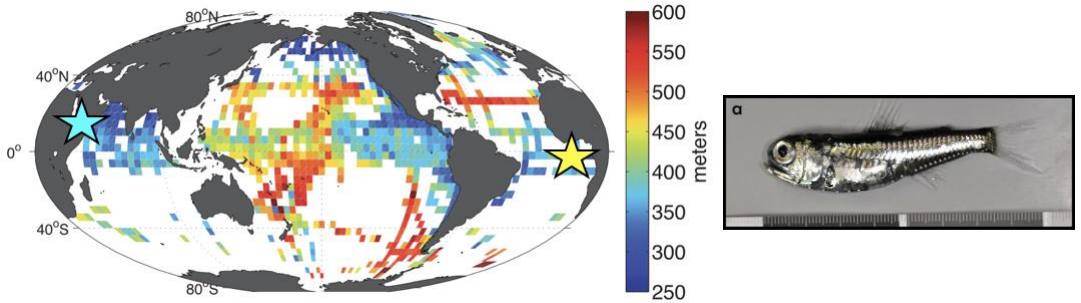
Optimised climate model



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EC EARTH 3

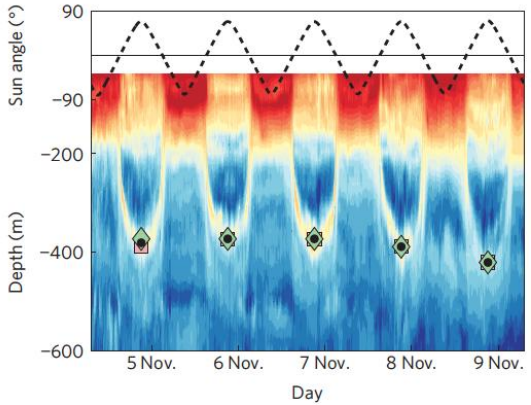
Characterising the twilight zone ecosystems



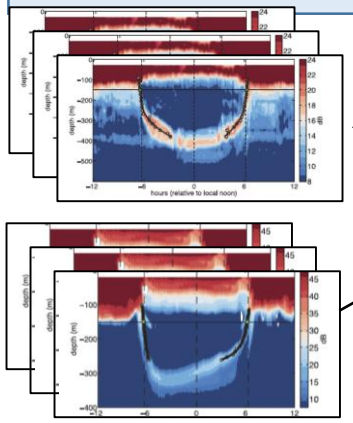
Bianchi et al, 2013

The twilight zone is:

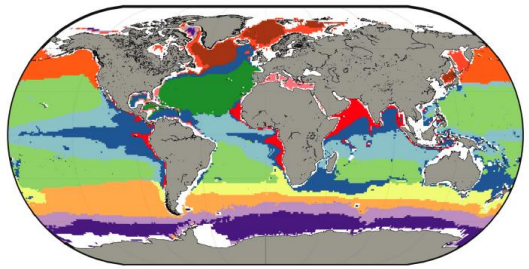
- potential source of nutrients
- potential commercial exploitation
- but is it sustainable?
- strategic resource



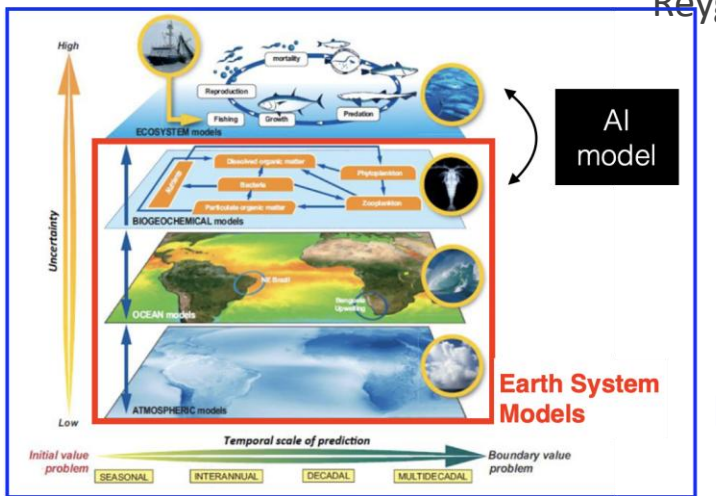
AI-based image classification



Environmental characterisation



Reygondeau et al, 2018



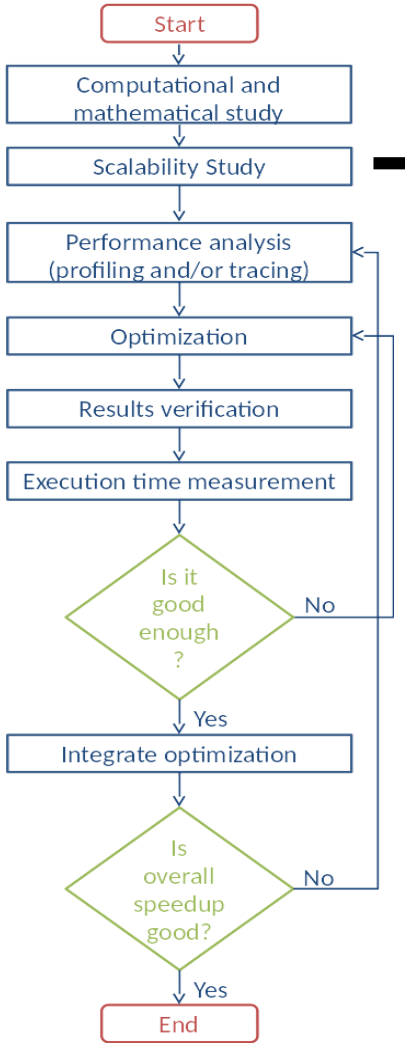
Hybrid model

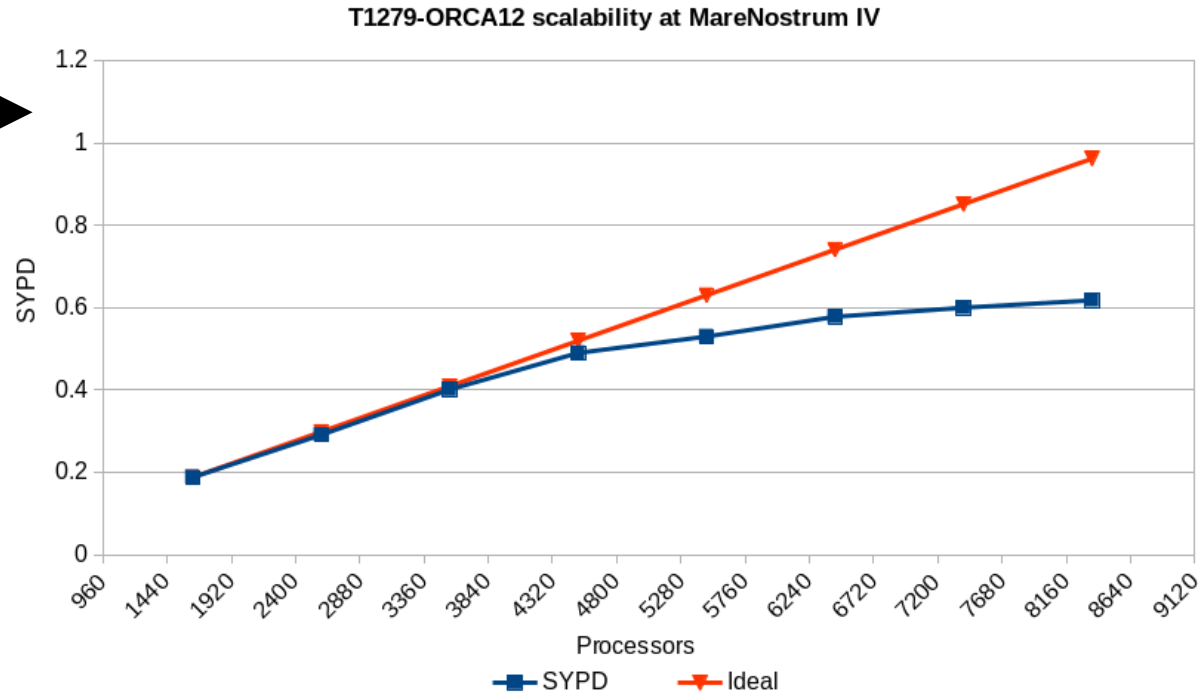
In collaboration with

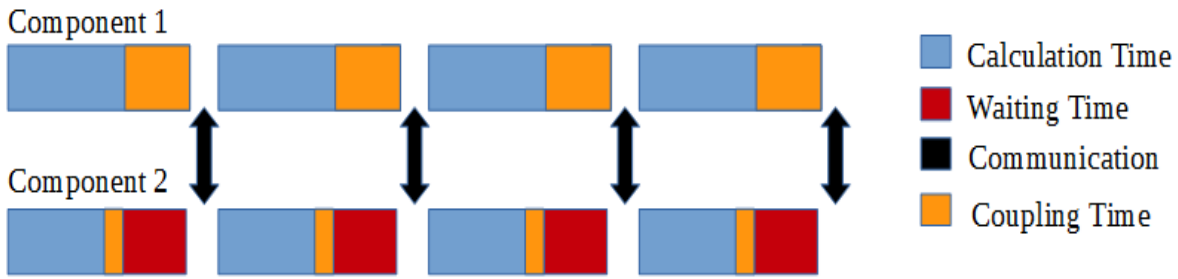
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Computational efficiency of climate models

Load balance of components of an Earth system model.







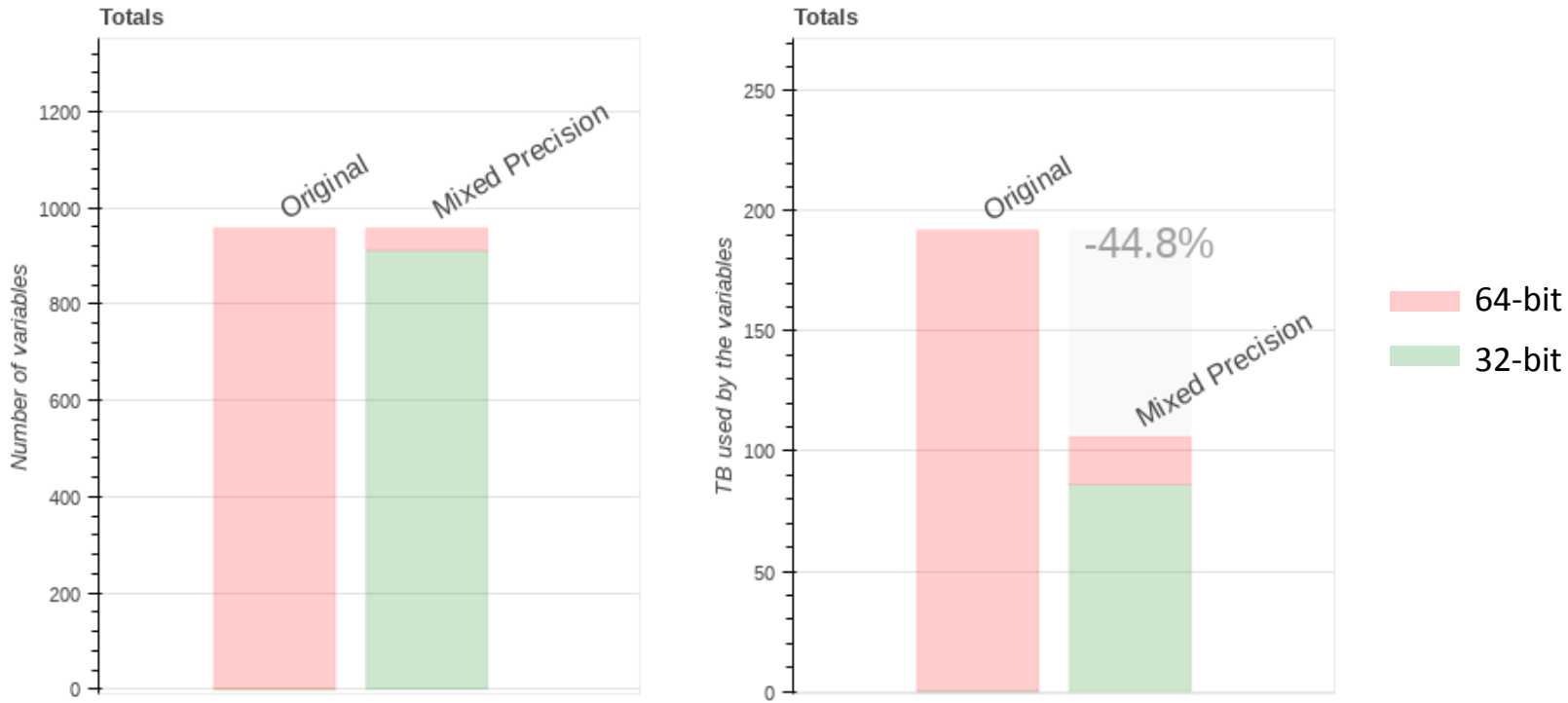
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Collaboration with Jesús Labarta

Mixed precision in environmental models

A method has been developed to adjust the numerical precision of climate models to minimize the resources used maintaining the accuracy of the simulations by identifying which variables require higher precision and which ones can effectively use less precision.

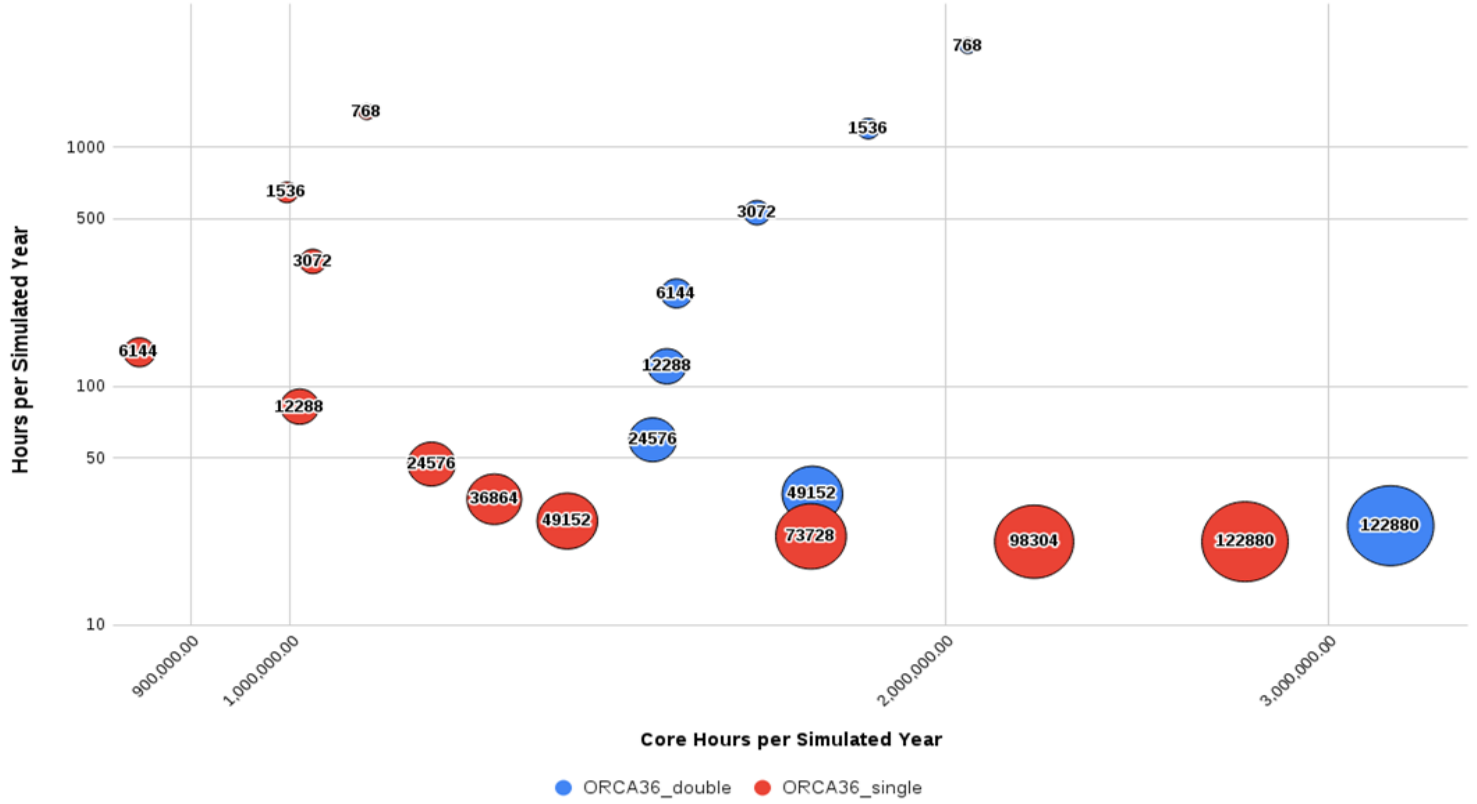
Impact estimation for the NEMO ocean model at 1 km grid



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Mixed precision and frontier resolution

Mixed precision in the NEMO ocean model may allow to achieve 1 SYPD with 3 km global resolution on current architectures, but needs something close to exascale for production. Up to x1.9 speedup on memory bandwidth bound configurations. NEMO memory usage is not scaling though. Data is an issue: restarts of ~1 Tb.

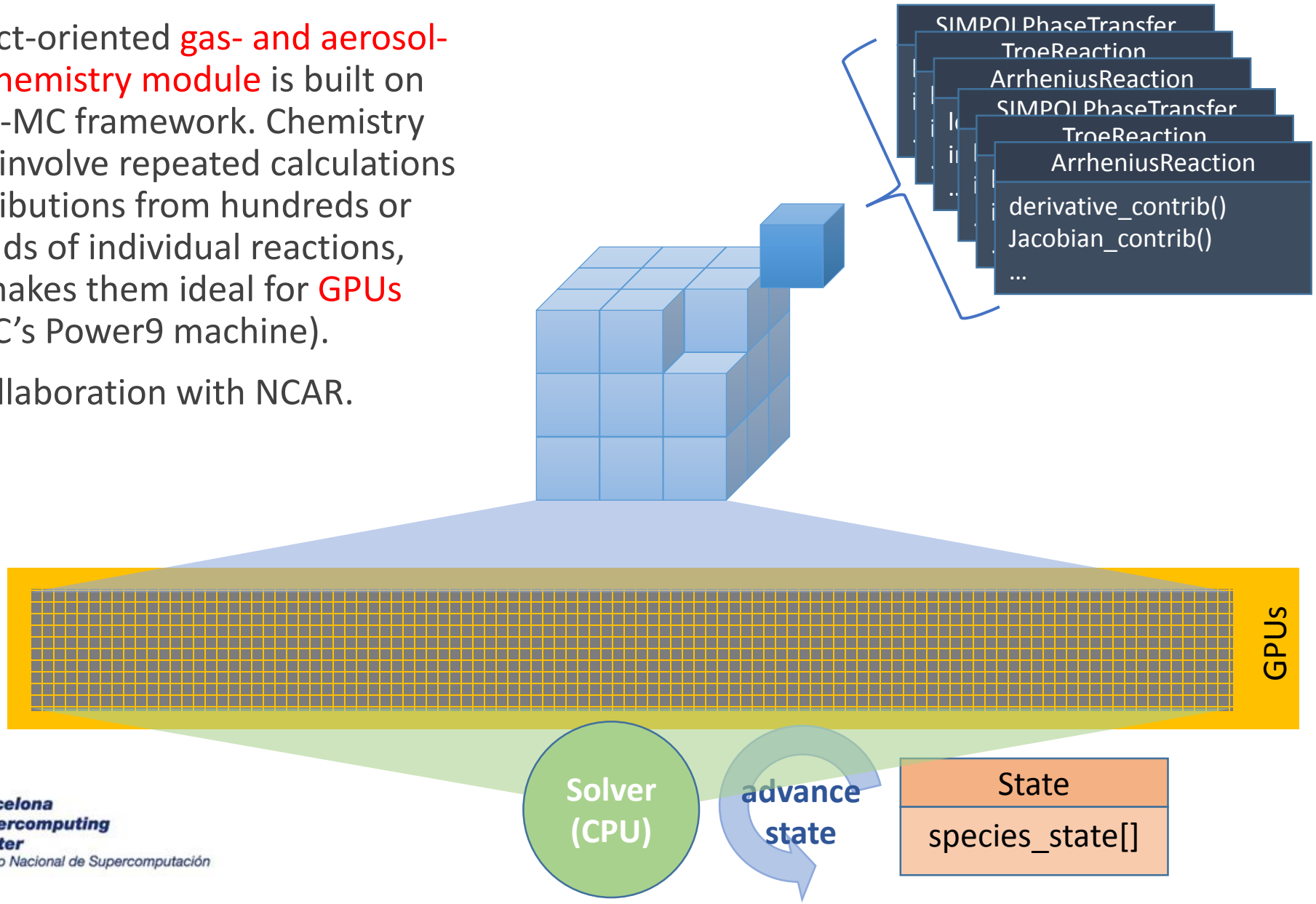


Barcelona Supercomputing Center
Centro Nacional de Supercomputa

Using accelerators

An object-oriented gas- and aerosol-phase chemistry module is built on the Part-MC framework. Chemistry models involve repeated calculations of contributions from hundreds or thousands of individual reactions, which makes them ideal for GPUs (e.g. BSC's Power9 machine).

Solid collaboration with NCAR.



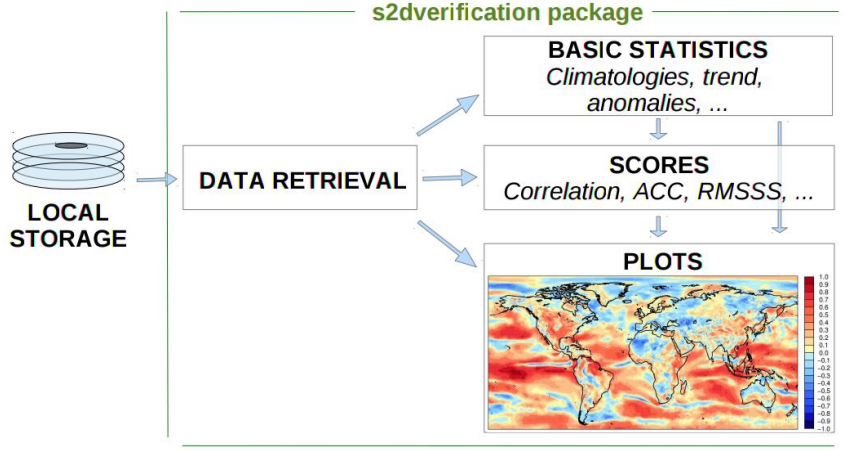
Workflows and data analysis

Models and workflows:

- Workflow solutions for transparent environmental experiments (Mare Nostrum 4, PowerPC, ARM)
- Support to a wide range of climate experiments
- Fostering the development of workflow managers (Autosubmit)

Data and diagnostics

- Accelerating with GPUs and multicore solutions (e.g. chunking, I/O optimisation)
- Data infrastructure for internal curation and public dissemination
- Core contribution to ESMValTool
- Metadata, curation, quality control and provenance



Evaluation and quality control

BSC is responsible of the development of the evaluation and quality control (EQC) function of the climate data store (CDS) of the Copernicus Climate Change Service (C3S) to:

- Provide a user-led overarching EQC service for the whole CDS
- Provide an independent quality assessment

- CDS datasets: provide information about the technical and scientific quality and fitness-for-purpose, and an assessment of the datasets
- CDS toolbox: assessment of maturity and fitness for purpose of the software provided to explore the datasets
- CDS service: performance assessment of the CDS infrastructure (e.g. speed, responsiveness, system availability)
- CDS users: user requirement assessment to measure users' satisfaction with the CDS. Map evolving user needs into viable user requirements to ensure a user-oriented evolution of the CDS

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

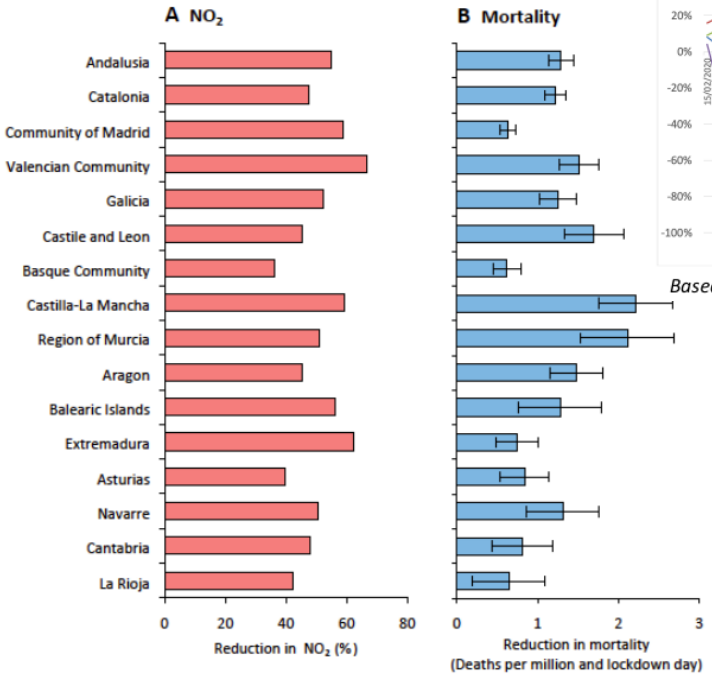
Copernicus Europe's eyes on Earth

Climate Change Service

COVID-19

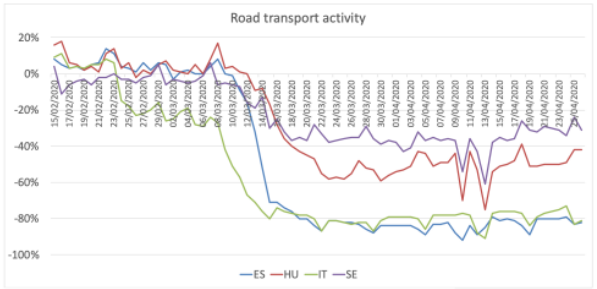
In a department strongly coordinated like ours working from home has an important impact. However, apart from staff members with dependent responsibilities, no major difficulties were found.

Associated reduction in attributable mortality due to reductions in NO2



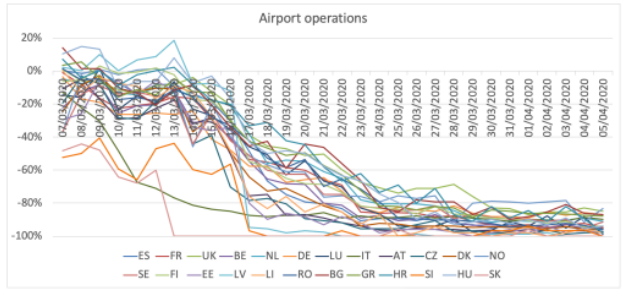
Development of a European country and sector emission reduction factors

Road Transport



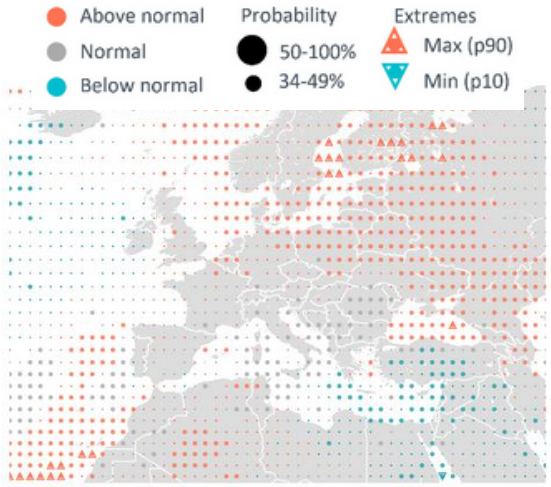
Based on the Google Community Mobility Reports

Aviation



Based on the flightradar24 airport statistics

Global real-time subseasonal heat wave prediction to support early warming systems during confinement periods



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Barcelona Supercomputing Center

Centro Nacional de Supercomputación