



**Barcelona
Supercomputing
Center**
Centro Nacional de Supercomputación



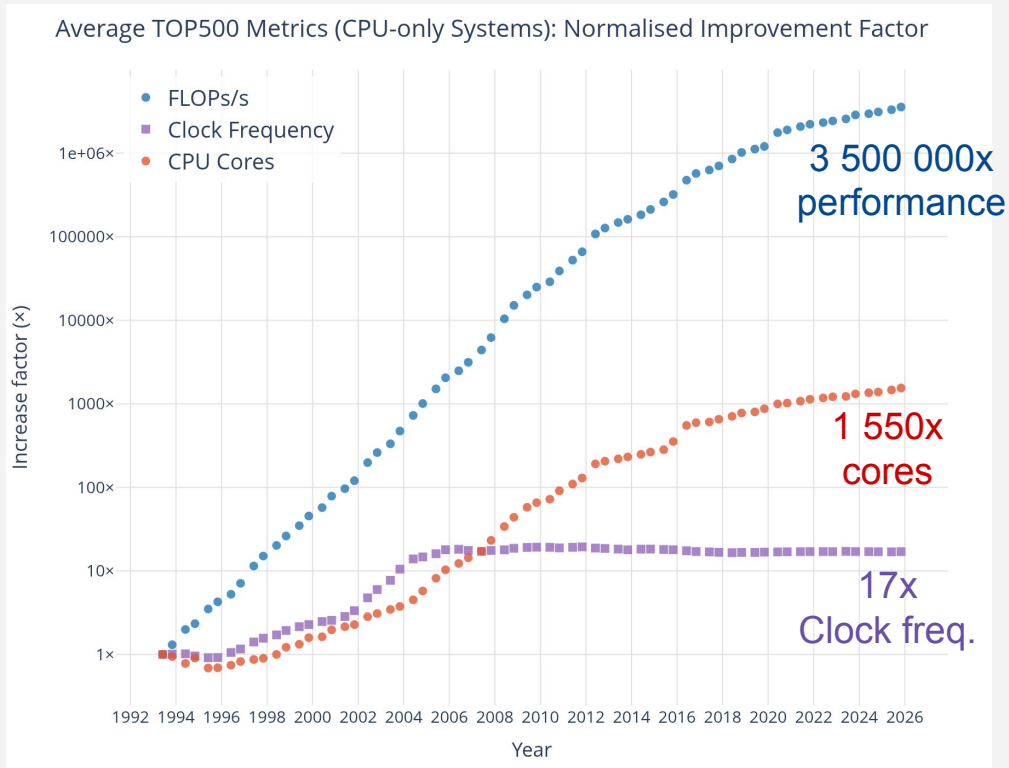
CMIP WIP

WCRP 

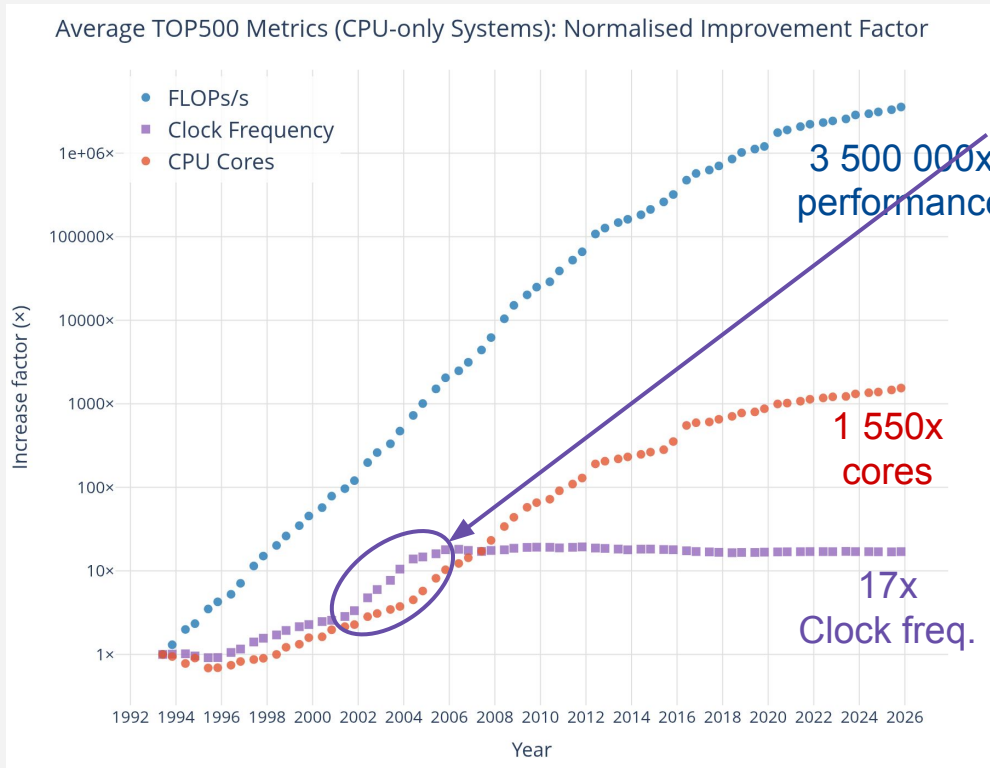
Computational and Energy consumption for climate sciences: Lessons from CMIP6

Sergi Palomas, Mario Acosta, Frédéric Bonou, Pierre-Antoine Bretonnière, Sophie Valcke and Paul Smith

Performance limits

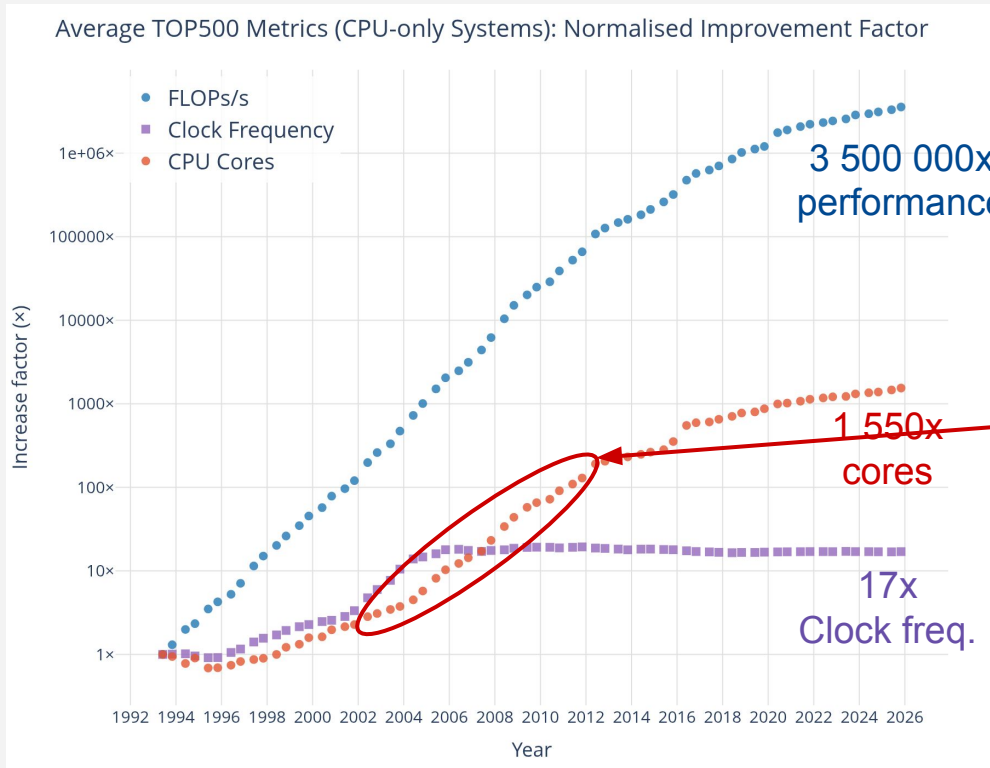


Power limits



Free clock Frequency scaling ->
Not anymore!

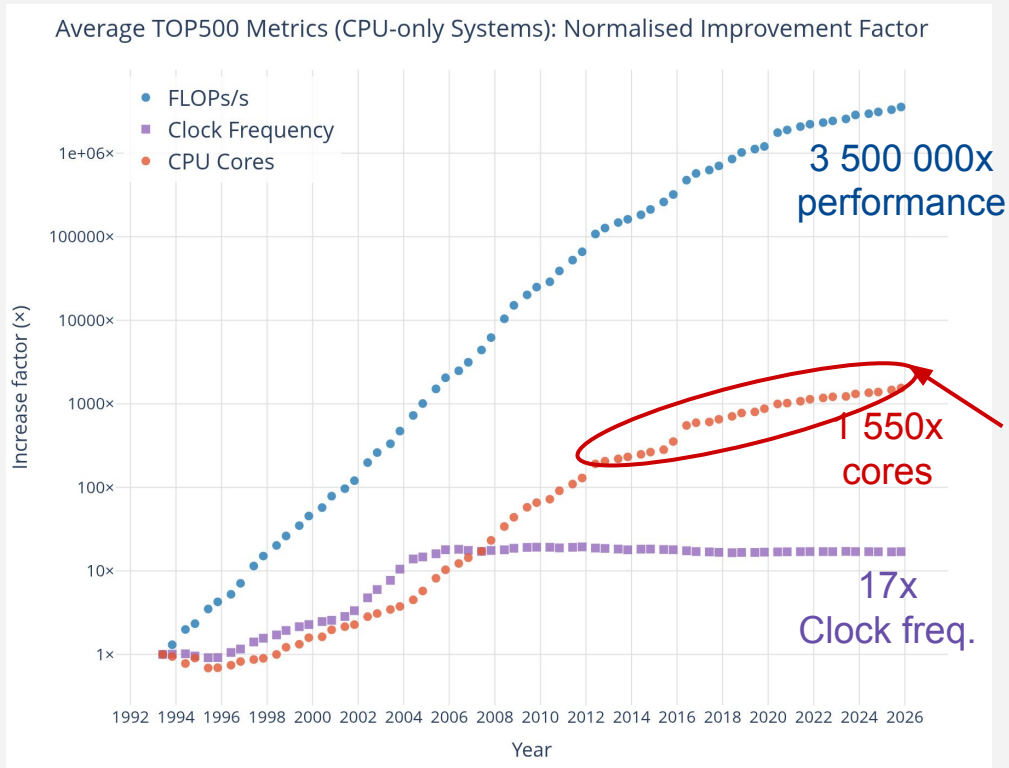
Power limits



Free clock Frequency scaling ->
Not anymore!

Multi-cores over single-core

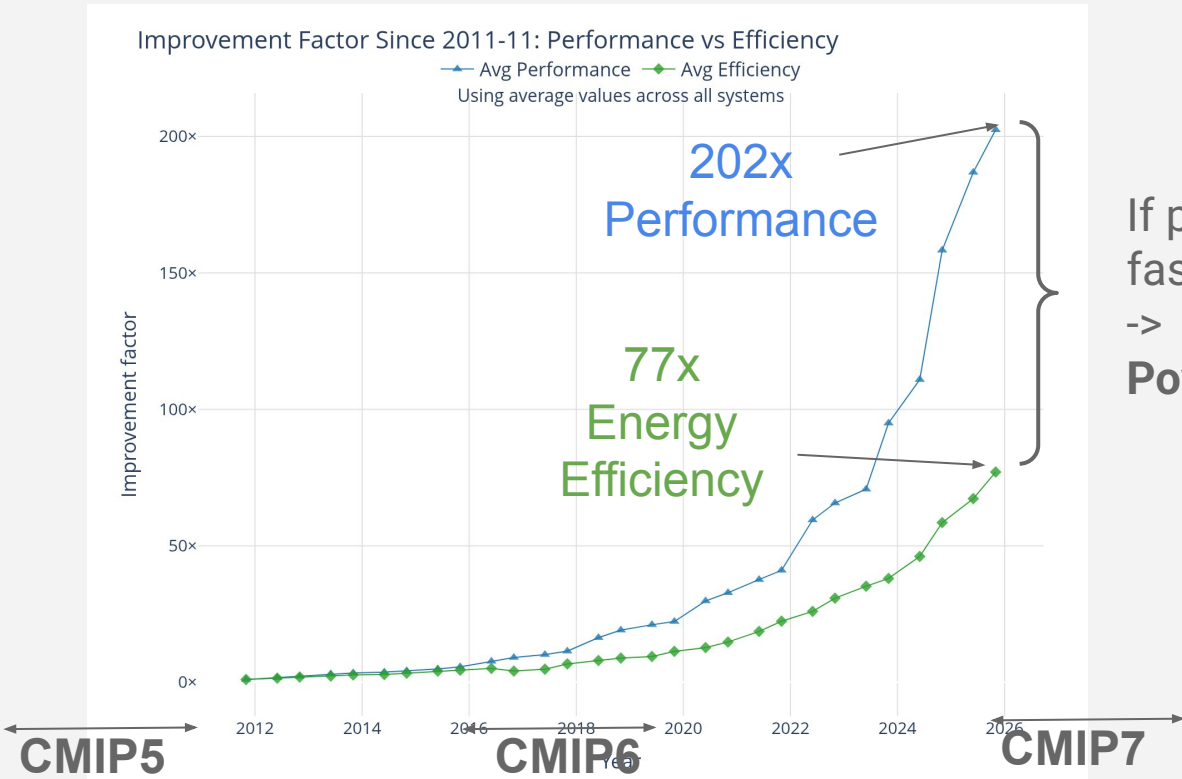
Power limits



Free clock Frequency scaling -> **Not anymore!**

Many-cores over single-core (i.e. accelerators)

Performance vs Efficiency



If performance grows faster than efficiency
 ->
Power must increase





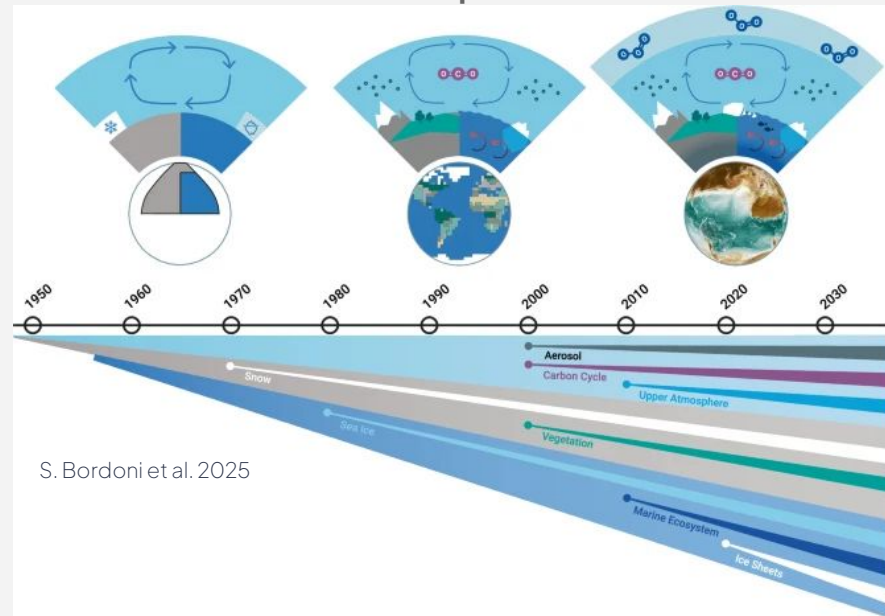
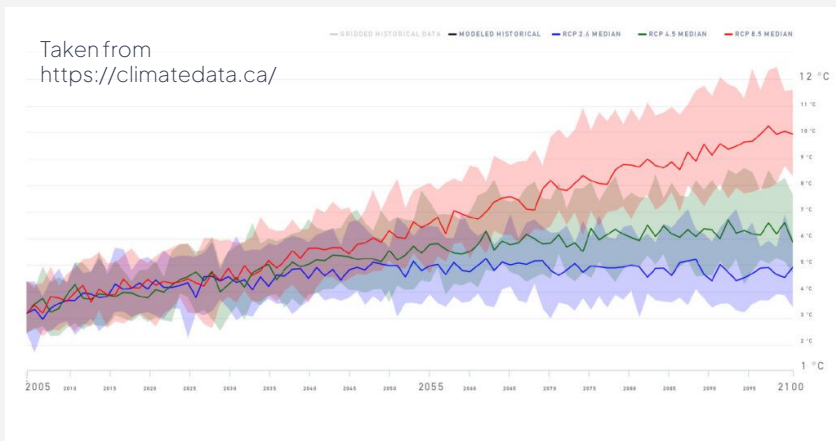
Compared to CMIP5, do ESMs now run **200× faster**?

The problem has grown

Bigger ensembles



More complex ESMs

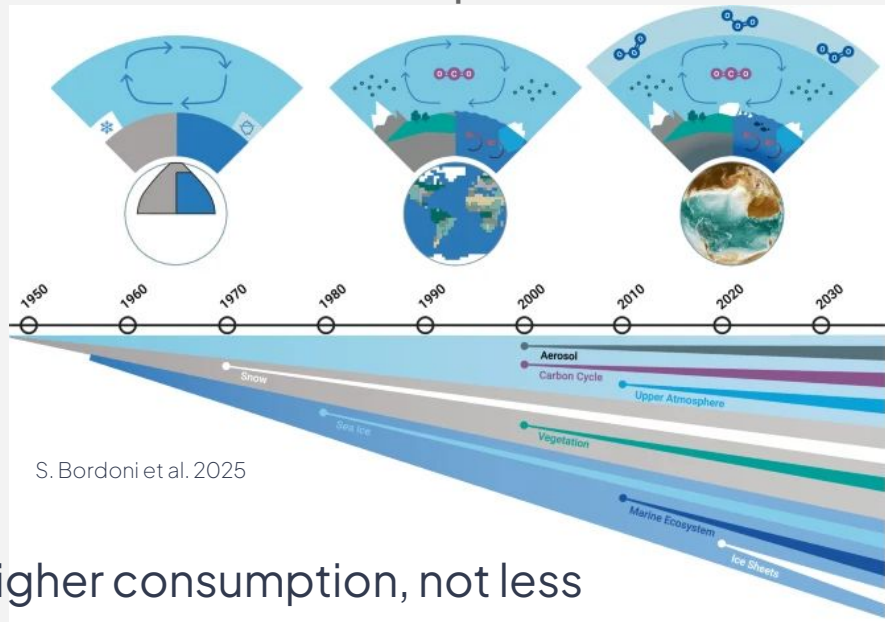
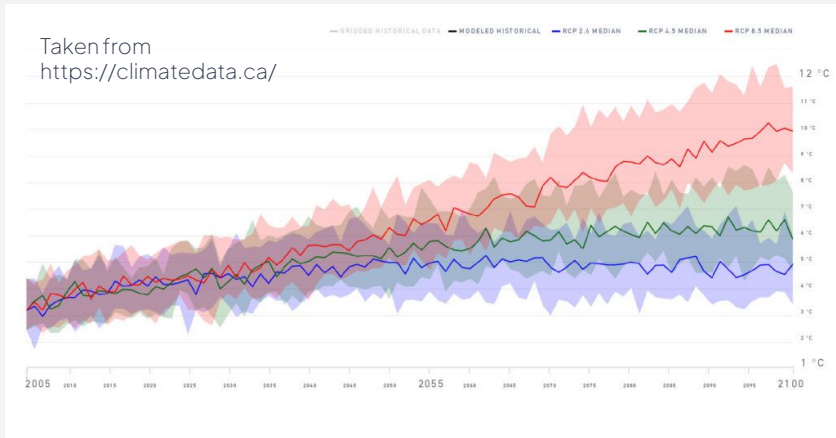


The problem has grown

Bigger ensembles



More complex ESMs

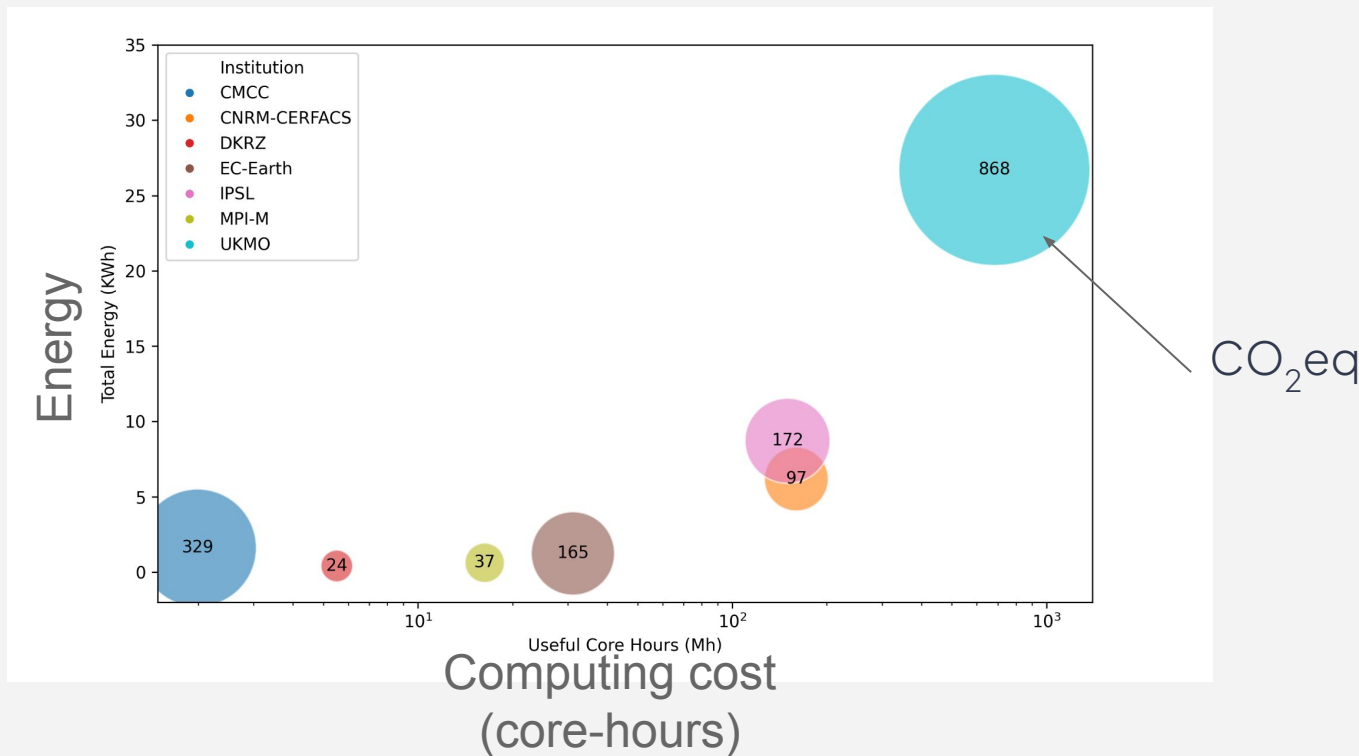


Jevons' Paradox ->

Increased efficiency of a resource lead to higher consumption, not less



Measuring computing costs: CMIP6



Measuring computing costs: CMIP7

[Home](#) / [CMIP Task Teams](#) / Energy Consumption and Carbon Footprint Task Team

Energy Consumption and Carbon Footprint Task Team

On this Page

Challenge

Objectives and Deliverables

Members

Activities

FAQs

Co-lead: Mario Acosta (BCS)

The primary purpose of the Coupled Model Intercomparison Project (CMIP) Energy Consumption and Carbon Footprint (ECCF) Task Team, is to evaluate the energy consumption and carbon footprint of CMIP, develop appropriate target setting and monitoring procedures, and identify potential actions for reducing impact.

Objective

1. Quantify emissions related to computing the **simulations** (CO₂eq)

$$\text{CO}_2\text{eq} = \text{Energy} \times \text{PUE} \times \text{Conversion Factor}$$

- Energy from running experiments only
- Dynamic Energy i.e. without idle

- PUE = HPC efficiency
- Conversion Factor from Joules to gCO₂

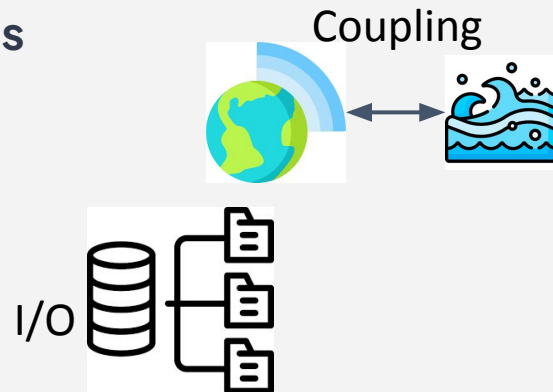
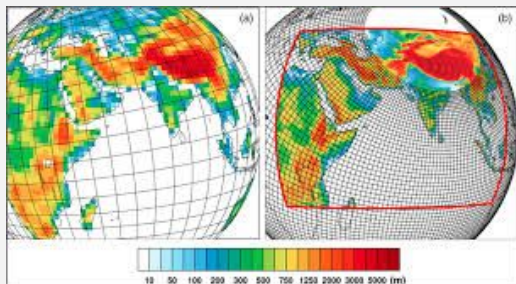
Objective

1. Quantify emissions related to computing the **simulations** (CO₂eq)

$$\text{CO}_2\text{eq} = \text{Energy} \times \text{PUE} \times \text{Conversion Factor}$$

2. Collect basic **computational performance** from **ESMs**

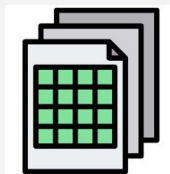
Resolution



Methodology

Each Modelling Centre will receive:

- Private spreadsheet to fill-in



N:N

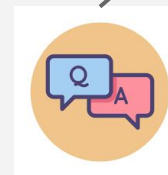
Task team provides:

- Guidelines
- Shared FAQ/Q&A
- Direct support (mail)

Modelling centres

<p>AER</p> <p>Associated institutions AER - Verisk Atmospheric and Envi...</p> <p>General contact emlawer@aer.com</p> <p>CMIP6 Models LBRM-12-B, RRMG-LW-4-91, RR...</p> <p>Associated ESGF Nodes ...</p> <p>Country USA</p>	<p>AS-RCEC</p> <p>Associated institutions AS-RCEC - Research Center for Env...</p> <p>General contact ...</p> <p>CMIP6 Models HIRAM-SIT-HR, HIRAM-SIT-LR, TaiE...</p> <p>Associated ESGF Nodes esgf/rceci.sinica.edu.tw</p> <p>Country Taiwan</p>	<p>AWI</p> <p>Associated institutions AWI - Alfred Wegener Institute, H...</p> <p>General contact ...</p> <p>CMIP6 Models AWI-CM-1-1-HR, AWI-CM-1-1-LR, A...</p> <p>Associated ESGF Nodes ...</p> <p>Country Germany</p>	<p>CAMS</p> <p>Associated institutions CMA - China Meteorological Admi...</p> <p>General contact ...</p> <p>CMIP6 Models CAMS-CSM1-0</p> <p>Associated ESGF Nodes esgf.cma.cn</p> <p>Country China</p>
<p>CAS</p> <p>Associated institutions CAS - Chinese Academy of Sciences</p> <p>General contact ...</p> <p>CMIP6 Models CAS-ESM2-0, FGOALS-F3-H, FGOAL...</p> <p>Associated ESGF Nodes esgf.lasp.ac.cn</p> <p>Country China</p>	<p>CCCR-ITM</p> <p>Associated institutions ITM - Indian Institute of Tropical M...</p> <p>General contact itlm-esm@tropmet.res.in</p> <p>CMIP6 Models ITM-ESM</p> <p>Associated ESGF Nodes esgf-cccr.tropmet.res.in</p> <p>Country India</p>	<p>CSIRO-ARCCSS</p> <p>Associated institutions ARCCSS - Australian Research Cou...</p> <p>General contact ...</p> <p>CMIP6 Models ACCESS-CM2, ACCESS-ESM1-5</p> <p>Associated ESGF Nodes esgf.ncl.org.au</p> <p>Country Australia</p>	<p>CSIRO-COSIMA</p> <p>Associated institutions CSIRO - Commonwealth Scientific ...</p> <p>General contact ...</p> <p>CMIP6 Models ACCESS-CM2, ACCESS-CM2-Q25</p> <p>Associated ESGF Nodes esgf.ncl.org.au</p> <p>Country Australia</p>
<p>DWD</p> <p>Associated institutions DWD - Deutscher Wetterdienst</p>	<p>E3SM-Project</p> <p>Associated institutions LLNL - Lawrence Livermore Nation...</p>	<p>ECMWF</p> <p>Associated institutions ECMWF - European Centre for Med...</p>	<p>FIO-QLNM</p> <p>Associated institutions FIO - First Institute of Oceanograpp...</p>

1:N



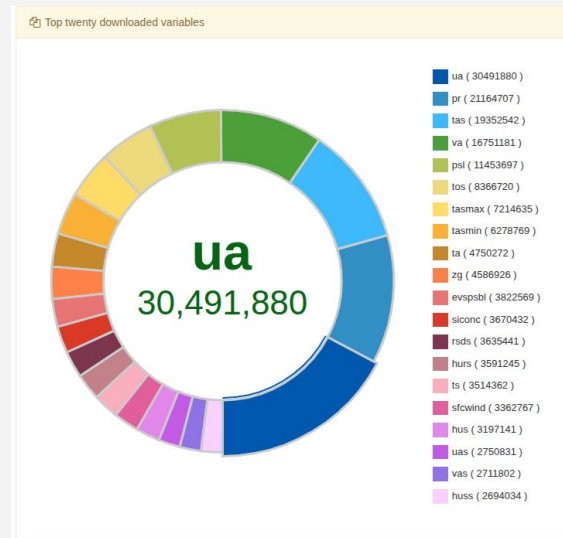
Outcome

Short term

- Peer-reviewed publication
- Dashboard (TBC, inspired by ESGF Data Statistics)

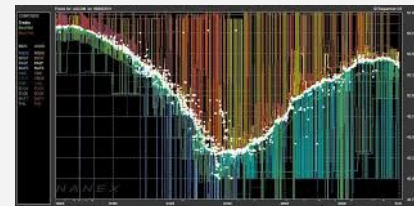
Long term

- Evolution of climate models CO2 footprint and performance
- Identify model and/or HPC bottlenecks



ESGF Data Statistics:
<https://esgf-ui.cmcc.it/esgf-dashboard-ui/cmip6.html>

Key takeaway





**Barcelona
Supercomputing
Center**
Centro Nacional de Supercomputación



CMIP WIP

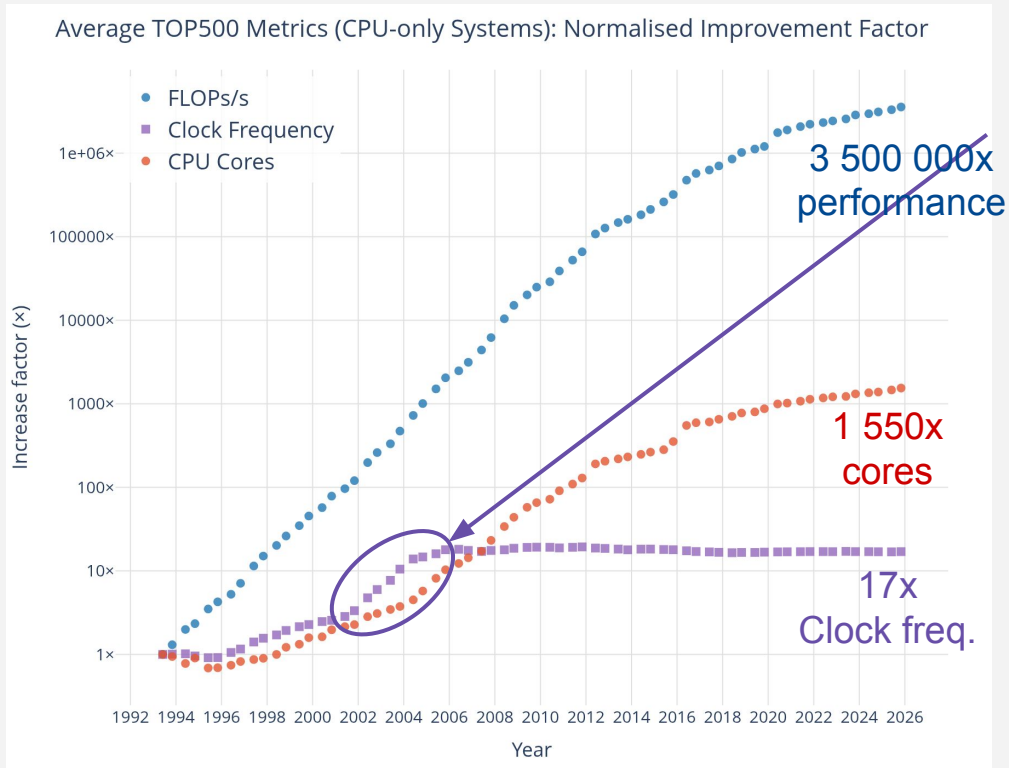
WCRP

Computational and Energy consumption for climate sciences: Lessons from CMIP6

Contact: sergi.palomas@bsc.es

Sergi Palomas, Mario Acosta, Frédéric Bonou, Pierre-Antoine Bretonnière, Sophie Valcke and Paul Smith

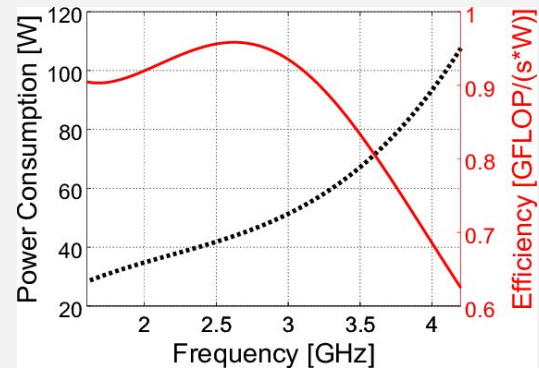
Power limits



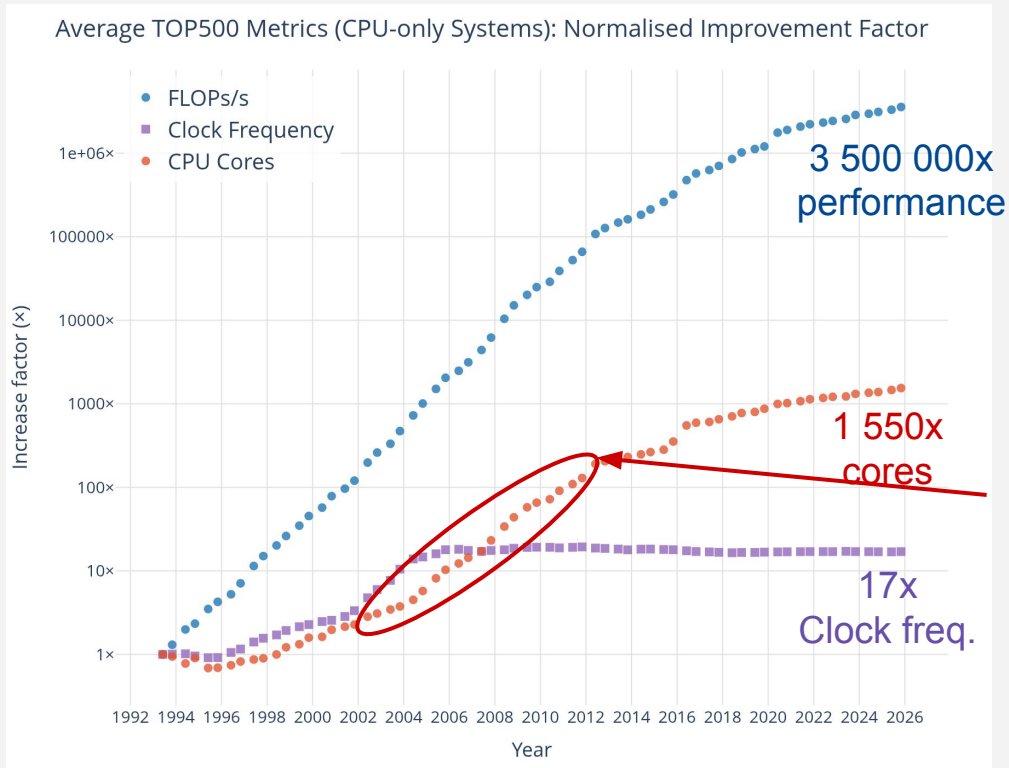
Free clock Frequency scaling ->
Not anymore!

$$P \propto CV^2 f$$

P is dynamic power
 V is voltage
 C is capacitance
 f is frequency



Power limits HPC design



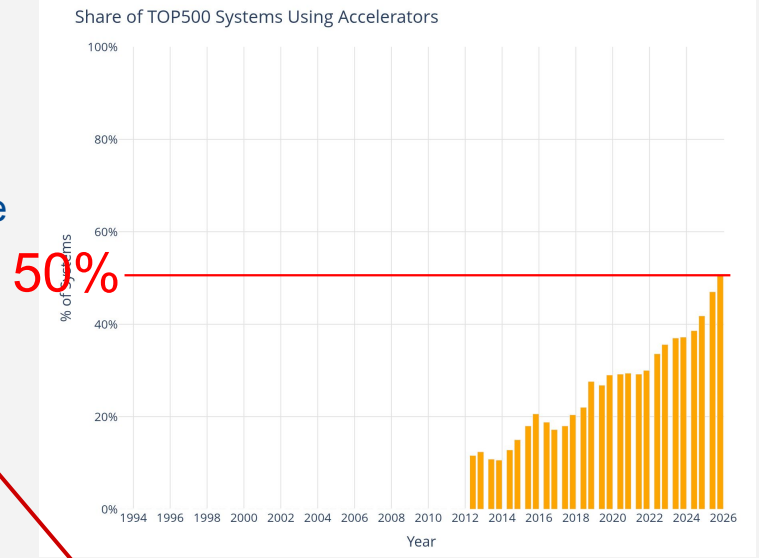
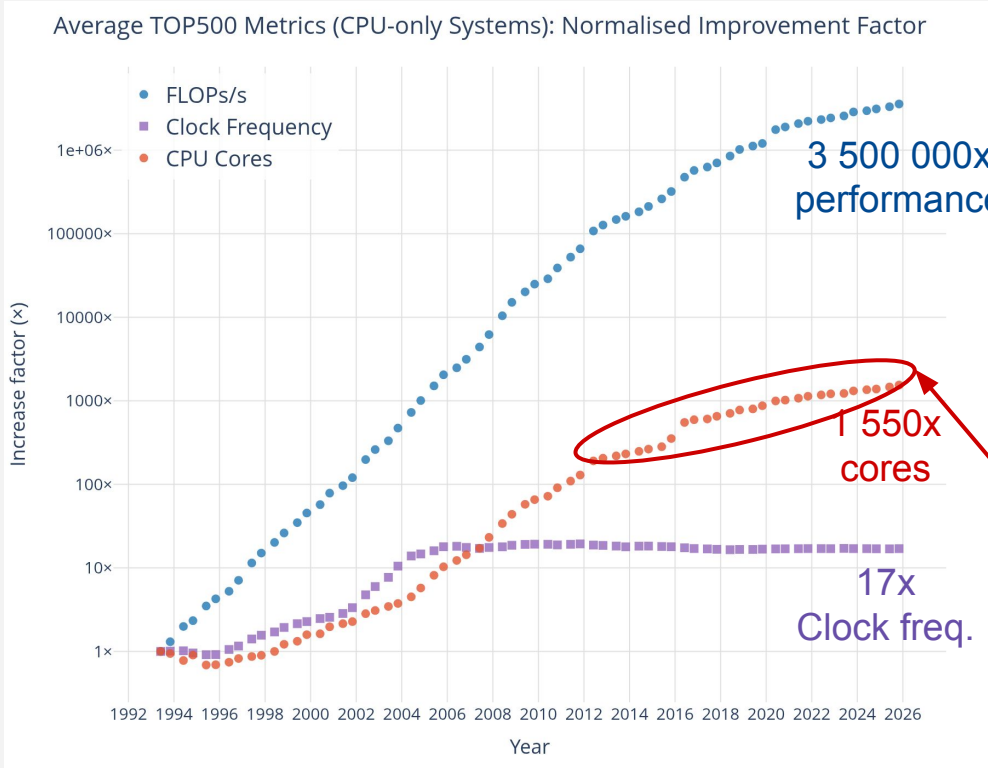
Free clock Frequency scaling ->
Not anymore!

$$P \propto CV^2 f$$

P is dynamic power
 V is voltage
 C is capacitance
 f is frequency

Multi-core over faster cores

Power limits HPC design

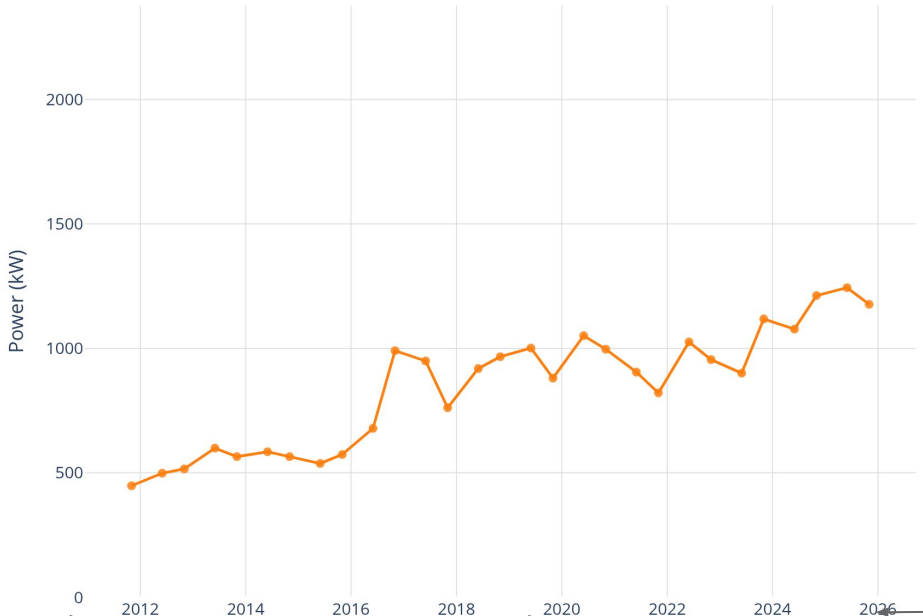


Rise of accelerators

Performance vs Efficiency

Implied Average Power per System from the Performance–Efficiency Gap

— Implied Power (Performance ÷ Efficiency)



$$\frac{\text{Performance (ops/second)}}{\text{Efficiency (ops/Watt)}} = \text{Power (W)}$$

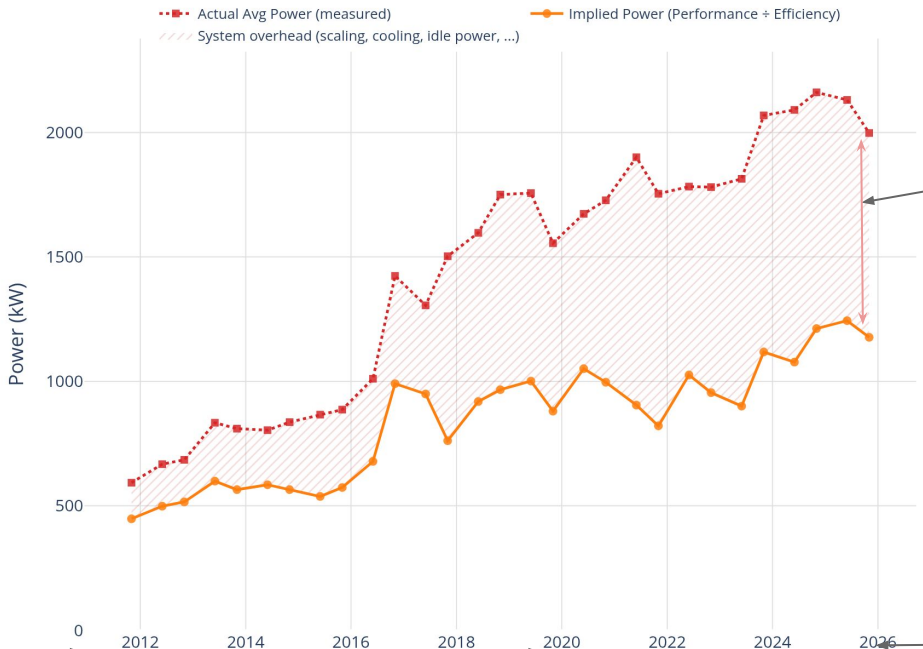
← CMIP5

← CMIP6

← CMIP7

Performance vs Efficiency

Implied vs Actual Average Power per System (kW)



+77% System overhead (scaling, cooling, etc.)

CMIP5

CMIP6

CMIP7

Performance (FLOPS) / Energy Efficiency (FLOP/Watt) Improvement Ratio Since 2011

