esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Joachim Biercamp, Philipp Neumann
and the ESiWACE team

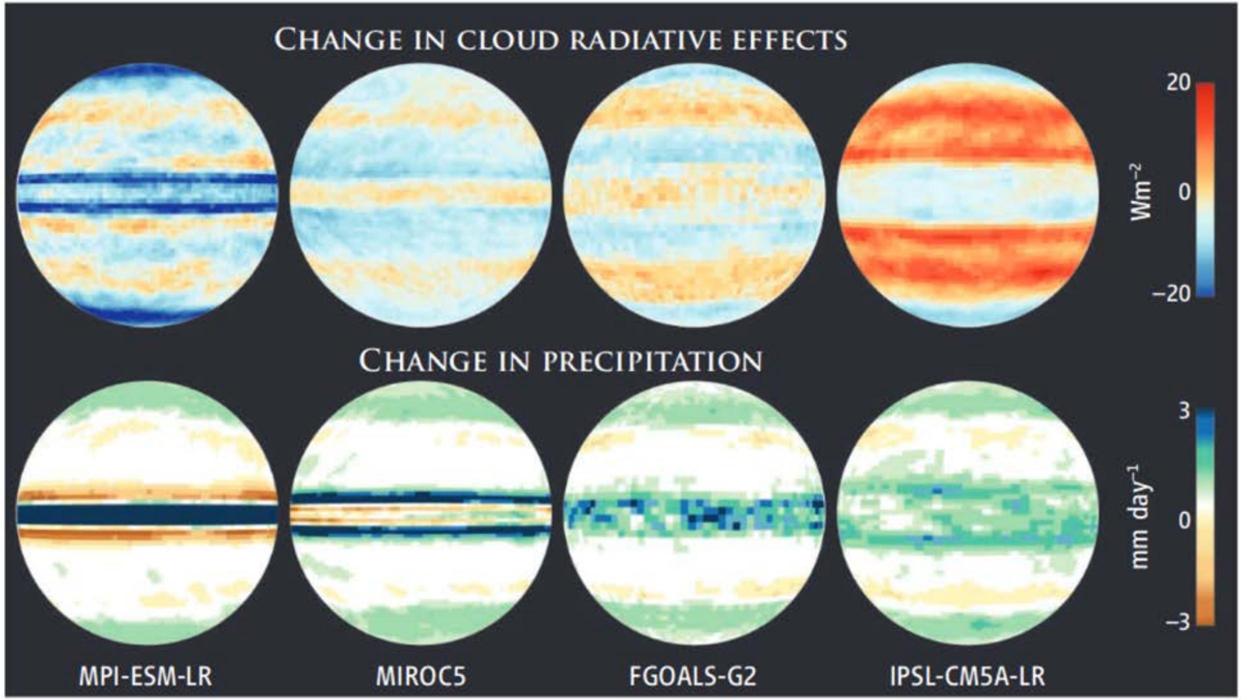
The ESiWACE2 project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 823988

DKRZ
DEUTSCHES KLIMARECHENZENTRUM

How good are current operational climate models

Parametrizations are a problem (in particular clouds and precipitation)

Stevens and Bony, Science, 2013.

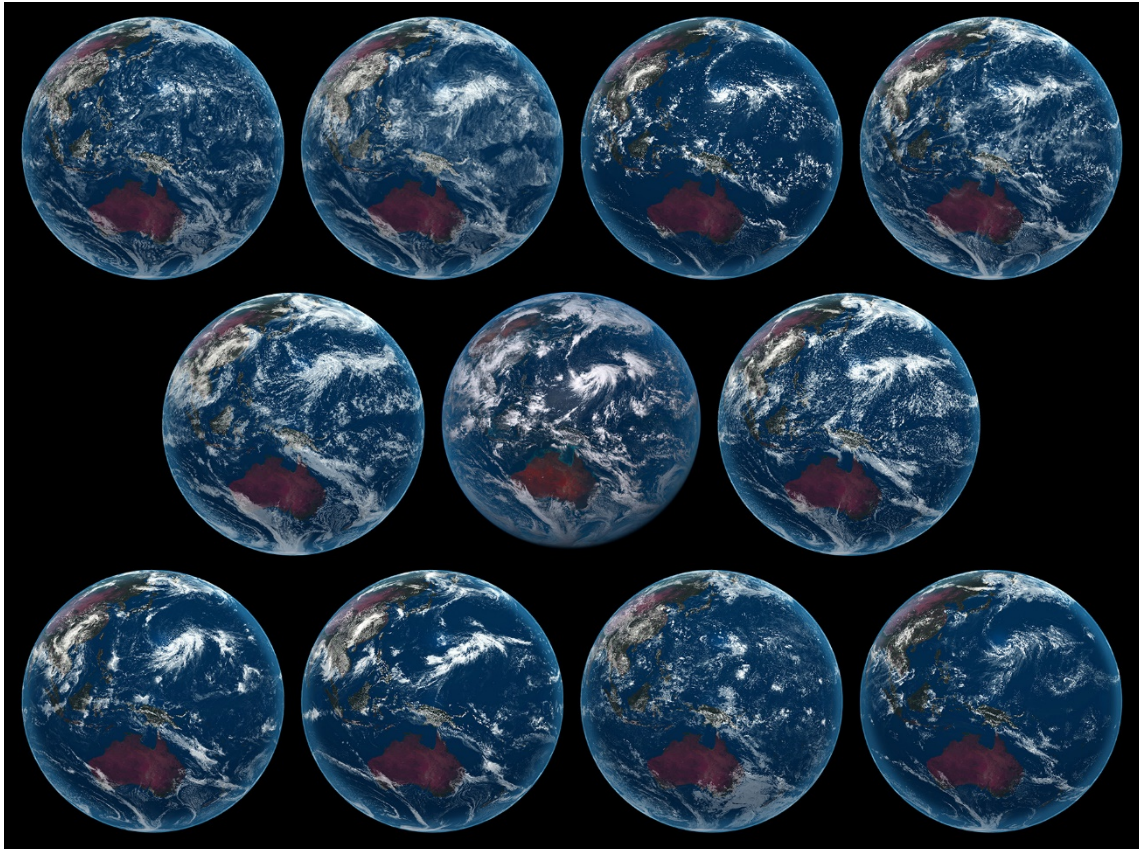


The response pattern of clouds and precipitation for to uniform warming (4) of five climate models for a simple model configuration (aqua planet with prescribed surface temperature)

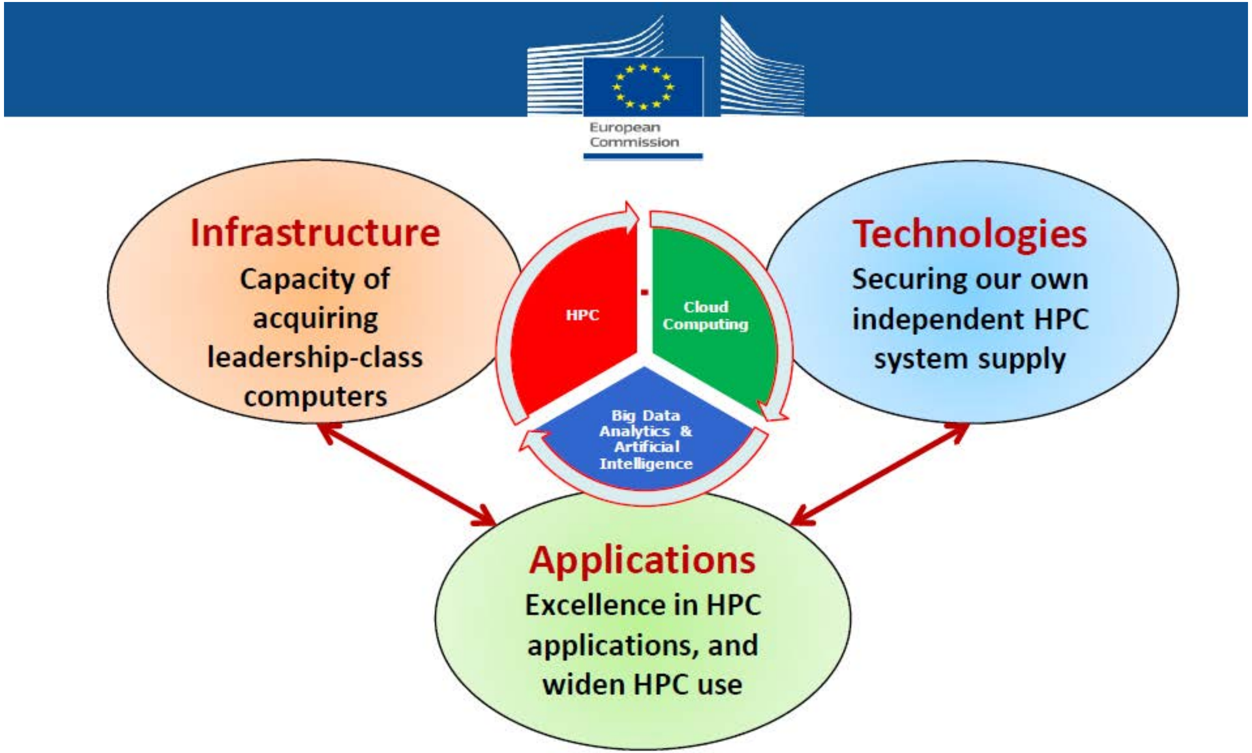
The "Palmer-Touring-Test"

There is hope and evidence that global cloud resolving models will allow significant improvements.

e.g. for deep convection, gravity waves, meso-scale eddies

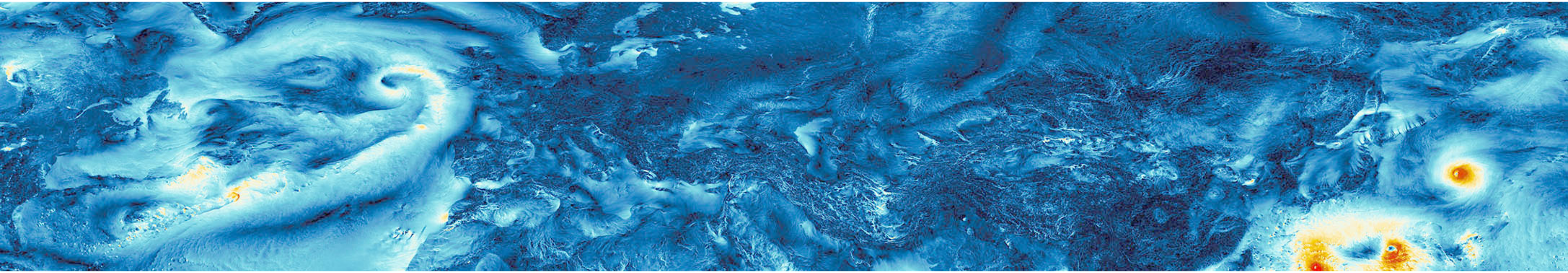


Stevens et al., DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains.
Progress in Earth and Planetary Science, accepted (2019/07/26).



Build a thriving European HPC Ecosystem
(hardware, software, applications, skills, services…)

Key objectives of ESiWACE



Evolution: Enable leading European weather and climate models to leverage the available performance of pre-exascale systems with regard to both compute and data capacity in 2021.

Revolution: Prepare the weather and climate community to be able to make use of exascale systems when they become available.

esiwace

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Funded from European Union; Horizon 2020;
Research agreement No 675191
Duration Oct. 2016 – Sept. 2019
Funding: ca 5 Mio €

allinea DWD

DKRZ DEUTSCHES KLIMARECHENZENTRUM · ECMWF · Sciences de l'environnement Institut Pierre Simon Laplace · Max-Planck-Institut für Meteorologie · BSC · SMHI · Met Office · ICHEC

Bull atos technologies · cmcc Centro euro-Mediterraneo sui Cambiamenti Climatici · SEAGATE · National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL · Science & Technology Facilities Council · CERFACS

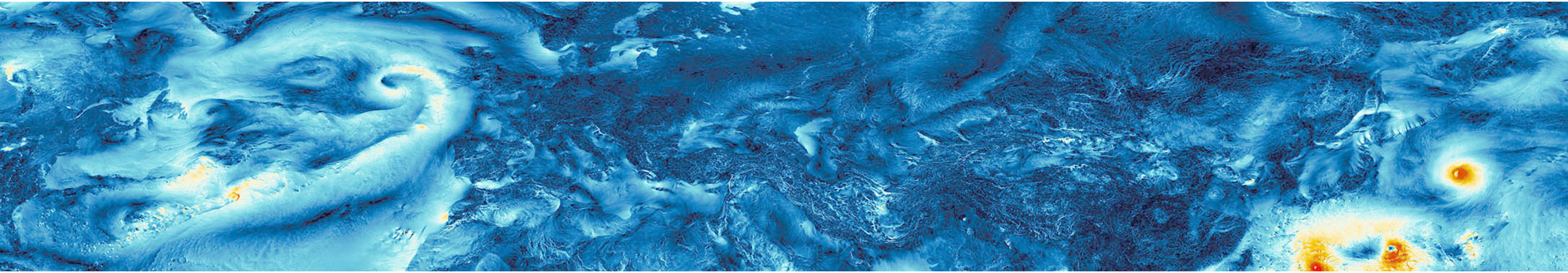
esiwace2

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Funded from European Union; Horizon 2020;
Research agreement No 823988
Duration Jan. 2019 – Dec. 2022
Funding: ca 8 Mio €

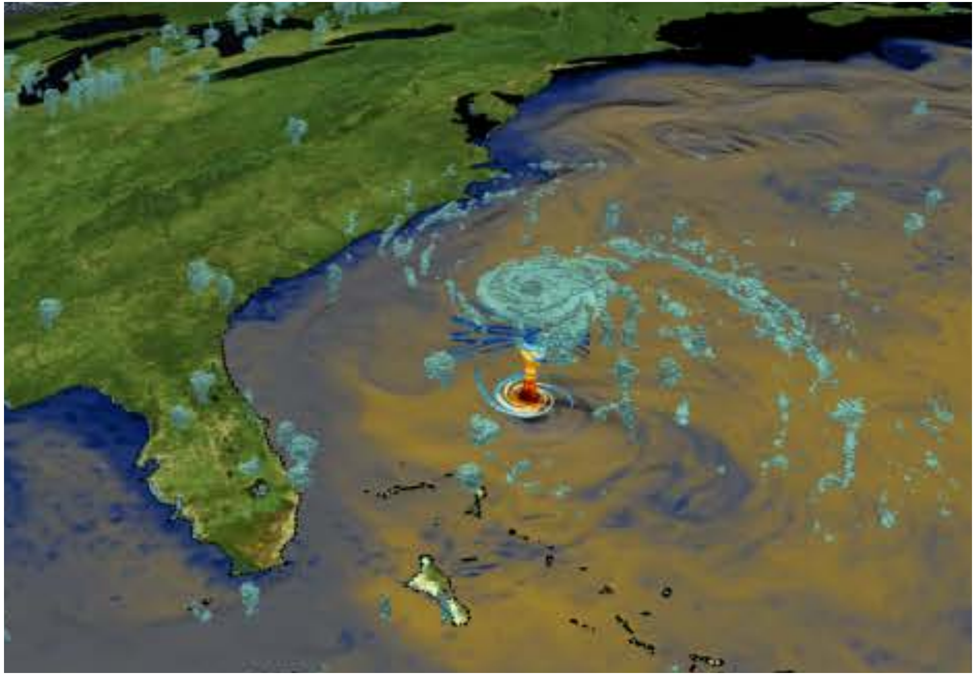
New Partners: eScience center · MeteoSwiss · CSCS · University of Reading · DDN STORAGE · MERCATOR OCEAN INTERNATIONAL

ESiWACE 2 work packages



WP1	Cutting Edge Resolution in Earth system modelling
WP2	Establish and watch new technologies for the community
WP3	HPC services to prepare the weather and climate community for the pre-exascale
WP4	Data Handling at Scale
WP5	Data post-processing, analytics and visualisation
WP6	Community engagement and Training
WP7	Coordination, Management and Dissemination

WP1 will develop coupled weather and climate models in unprecedented technical quality and performance as well as the organisational framework to assess their scientific performance.



WP2: Establish and watch new technologies for the community

WP2 will establish, evaluate and watch new technologies to prepare climate and weather simulation for the exascale era.

Lead: Rupert Ford, STFC; Carlos Osuna, MeteoSwiss

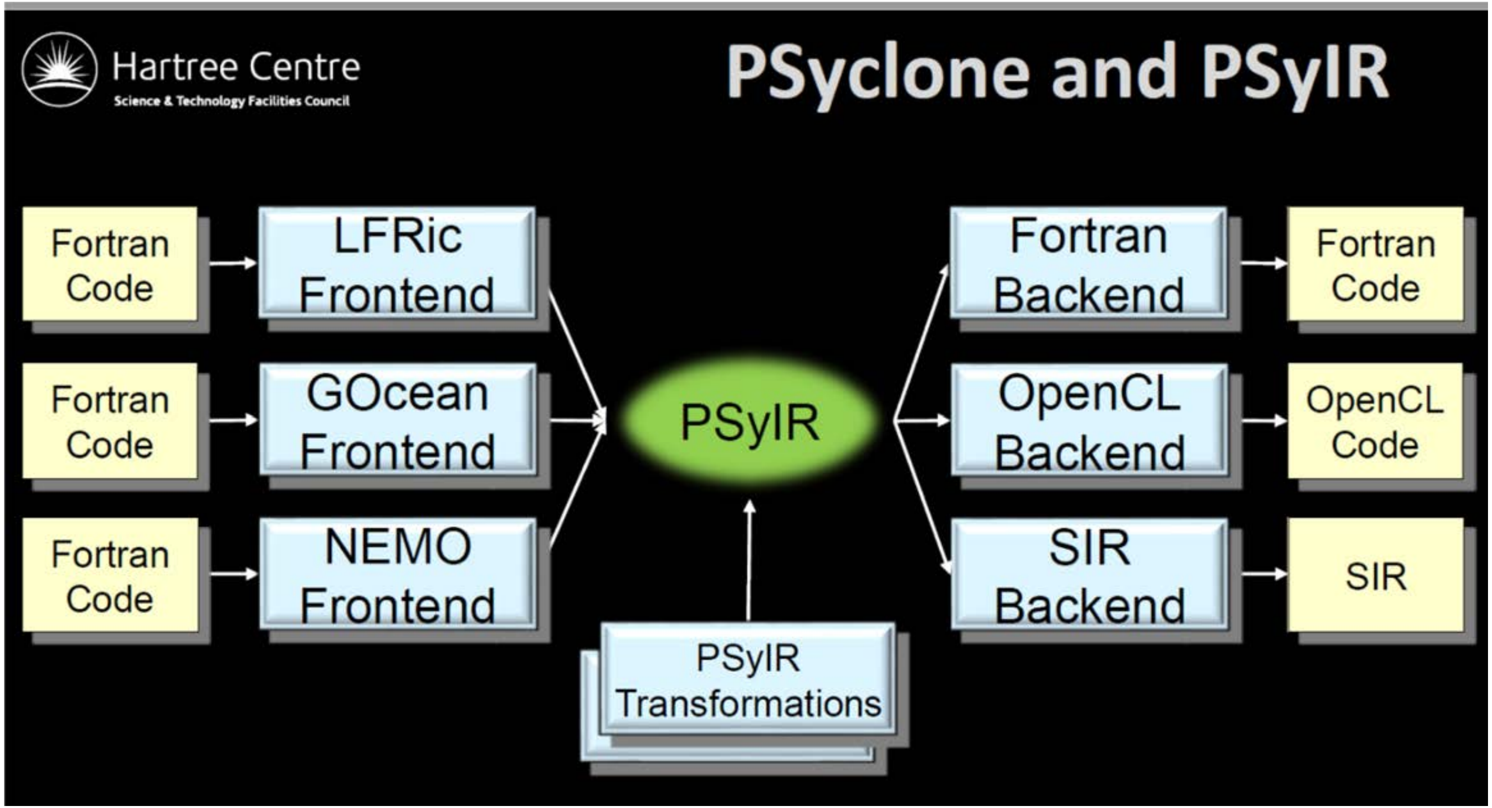
- Establish DSLs in the community
- Evaluate Concurrent Components to improve performance
- Evaluate Containers to port Earth system models to new hardware
- Watch emerging technologies (e.g. via Oxford machine learning workshop)

Establish DSLs in the community

- **Enable community use** of the two main European DSLs for weather and climate:
  - **gtclang toolchain** (based on GridTools) for irregular grids (ICON & IFS)
  - **Psyclone-CLAW** for NEMO
- **Benchmark** extraction from WP1, adaptations to DSL, demonstration of usability and performance evaluations
- **Performance optimizations** for benchmarks from DSL
- **Interoperability** via High-level Intermediate Representation (HIR)

STFC, MeteoSwiss, DKRZ, ECMWF, UNIMAN, ICHEC, CMCC, METO, UREAD

Establish DSLs in the community



Courtesy Rupert Ford (STFC)

WP3: HPC services to prepare the W&C community for pre-exascale

WP3 will develop and provide services to improve performance and portability of climate codes with respect to existing and upcoming tier1 and tier0 computers..

Lead: Ben van Werhoven, NLeSC; Erwan Raffin, Bull/ATOS

- Open call for service requests to organise support for existing Earth system models that target the European pre-exascale systems planned for 2021
  - Model portability and refactoring
  - Coupling, IO and workflows
- Weather and climate benchmarking
  - “*HPCW*” (V1.0 developed by ESCAPE-2)

Call for Proposals

Collaborations to prepare Europe's Weather and Climate Models for pre-exascale systems (ESiWACE-S1)

2019-2020

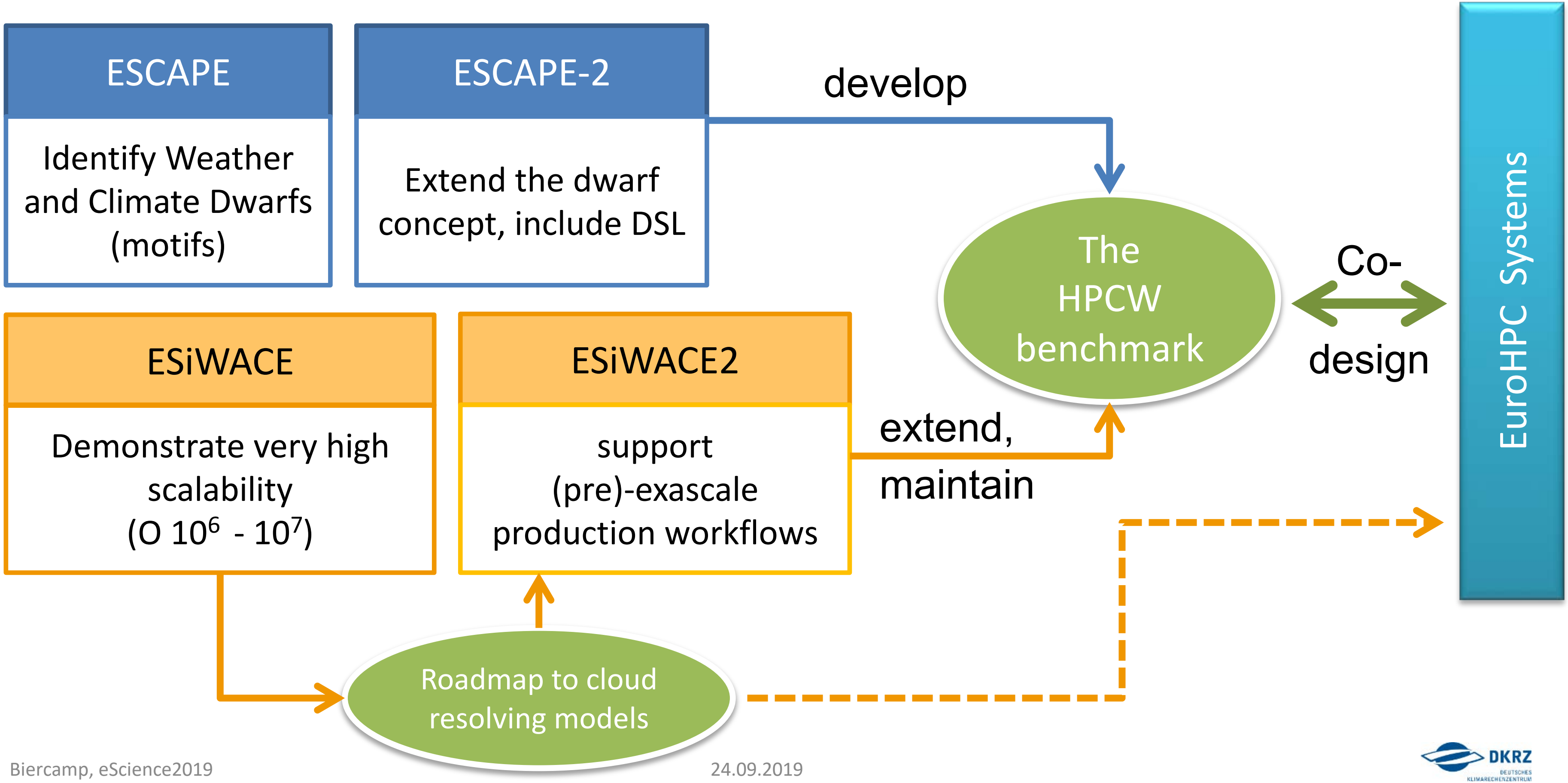
A joint call for proposals by the Netherlands eScience Center and Atos-Bull

Part of the Services provided by the ESiWACE2 Center of Excellence in Simulation of Weather and Climate in Europe

https://www.esiwace.eu/services/hpc-userservices

Deadline: November 1st 2019, 14:00 CET .

The HPCW – Benchmark



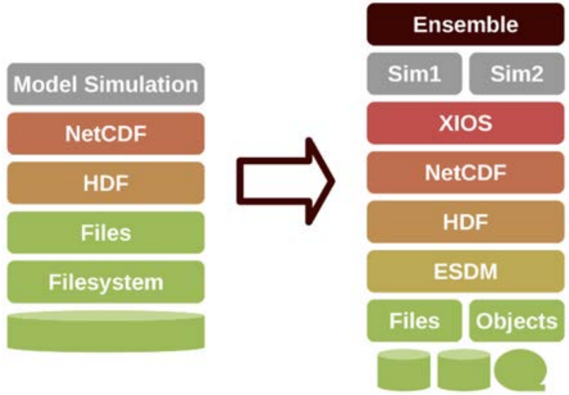
WP4 and WP5: Data Handling at Scale

WP4 will provide the necessary toolchain to handle data
at pre-exa-scale and exa-scale, for single simulations, and ensembles

Lead: Bryan Lawrence, UREAD; Julian Kunkel, UREAD

WP5 will enhance the tools to analyse and visualise these data

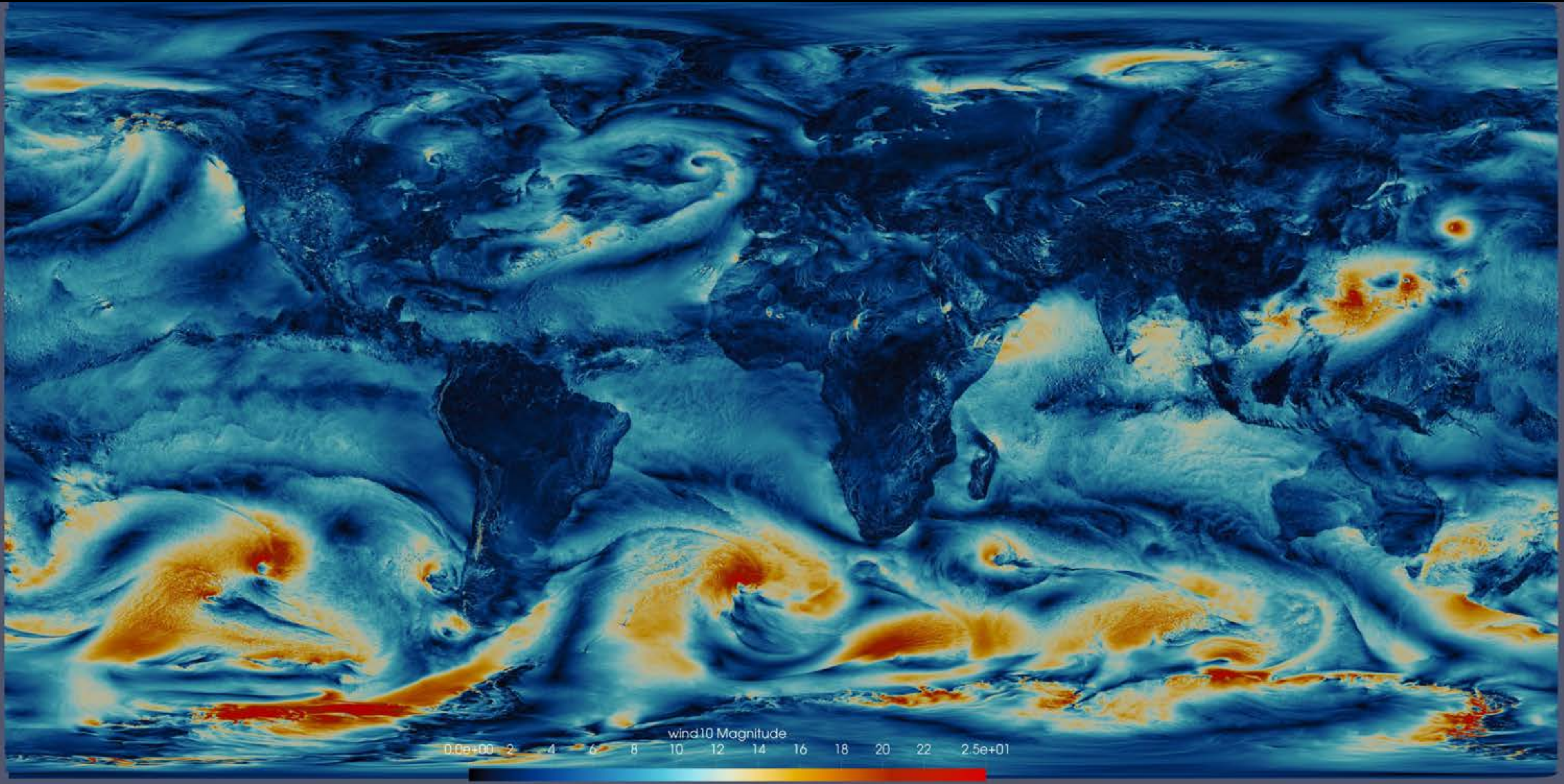
Lead: Sandro Fiore, CMCC; Niklas Röber, DKRZ



Control Workflow via CYLC Meta-scheduler

Handle data via Earth-System-Data Middleware (ESDM, non POSIX)

In-situ and asynchronous approaches to analytics and visualisation


wind10 Magnitude
0.0e+00 2 4 6 8 10 12 14 16 18 20 22 2.5e+01

WP6 will link ESiWACE2 to the weather and climate community and the European HPC ecosystem

Lead: Sylvie Joussaume, CNRS-IPSL; Sophie Valcke, CERFACS

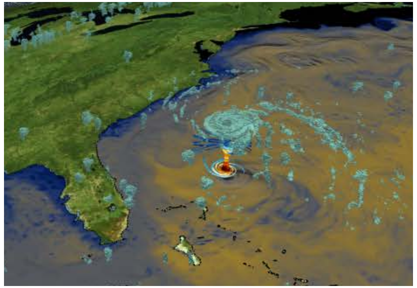
- Community engagement
  - HPC Workshops
  - HPC task force
  - Interface to PRACE

- Training and Schools
  - IO and HPC awareness
  - DSL
  - C++ for HPC
  - OASIS3-MCT
  - High performance Data Analytics
  - Container Hackathon
  - Summer school in HPC for weather and climate

WP1 will develop coupled weather and climate models in unprecedented technical quality and performance as well as the organisational framework to assess their scientific performance.

Lead: Peter Dueben ECMWF; Kim Serradell, BSC

- Extend the ESiWACE 1km demonstrator approach to production type configurations: For fixed SYPD (=1) + full IO **push resolution** as high as technically feasible. Tentative goal:
  - **EC-Earth: 16 km (TL1279) atmosphere coupled to a 1/12 degree (~8 km) ocean**
  - **ECMWF: 5 km (TCo1999) atmosphere coupled to a ¼ degree (25 km) ocean**
  - **ICON-ESM: 5 km atmosphere coupled to a 5 km ocean, aiming at higher resolutions for the ocean**
  - **The IPSL model: 10 km atmosphere coupled to a 1/12 degree (~8 km) ocean**
- Reach out to global hi rez community (via DYAMOND); provide the necessary infrastructure for light weight model intercomparison



The IFS 1 km demonstrator

Slide courtesy Peter Düben, ECMWF

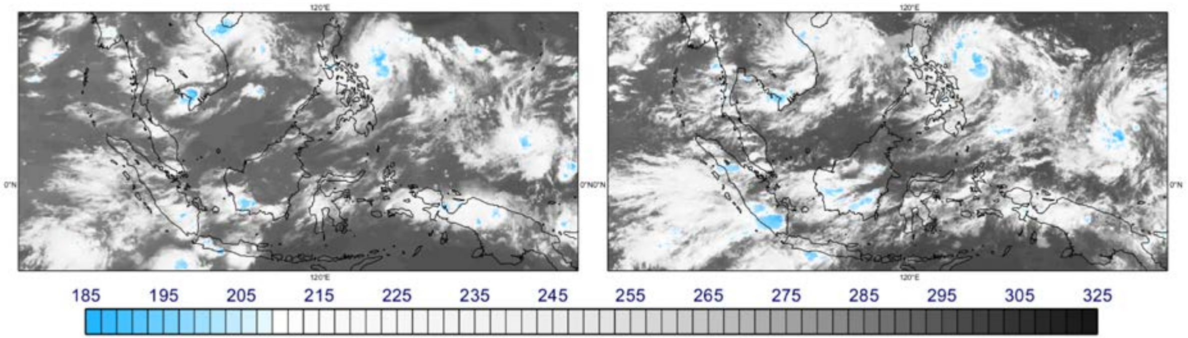
Model configuration:

- Full model complexity (high resolution topography, full physical parametrisation schemes except for deep convections which is switched off at <5km resolution).
- 62 or 137 vertical levels.
- No wave model or ocean model coupled.
- Both hydrostatic and non-hydrostatic simulations.
- Semi-implicit semi-Lagrangian timestepping scheme that allows very long timesteps: 450/240/120/120 seconds for 9/6/3.0/1.45 km resolution.
- The model is running in single precision.
- VERY limited IO.

ECMWF

Infrastructure developments:

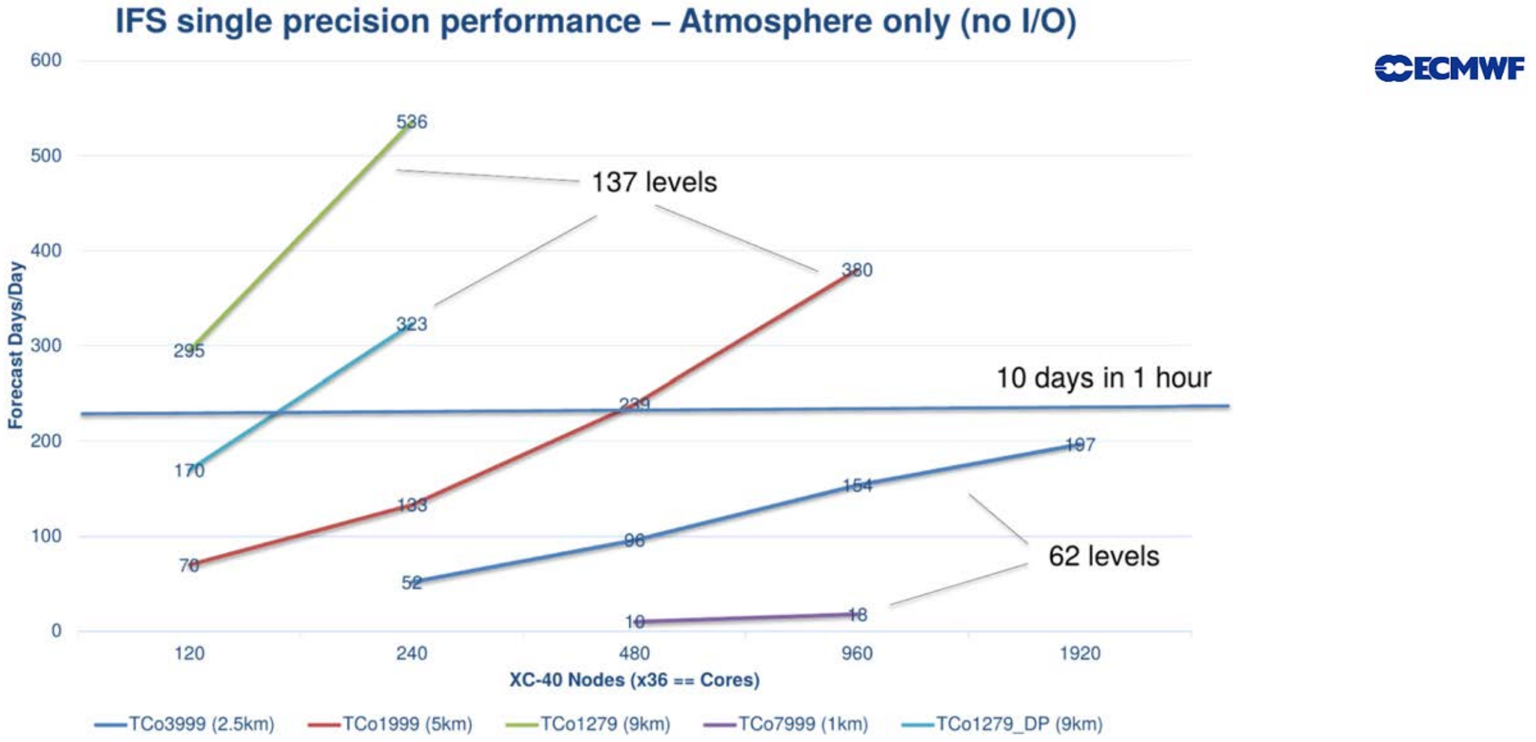
- We enable single precision to run at high resolution.
- We enable our data system to handle large files (MARS/MIR).
- We reduce memory consumption for large scale integrations.
- We improve the non-hydrostatic model



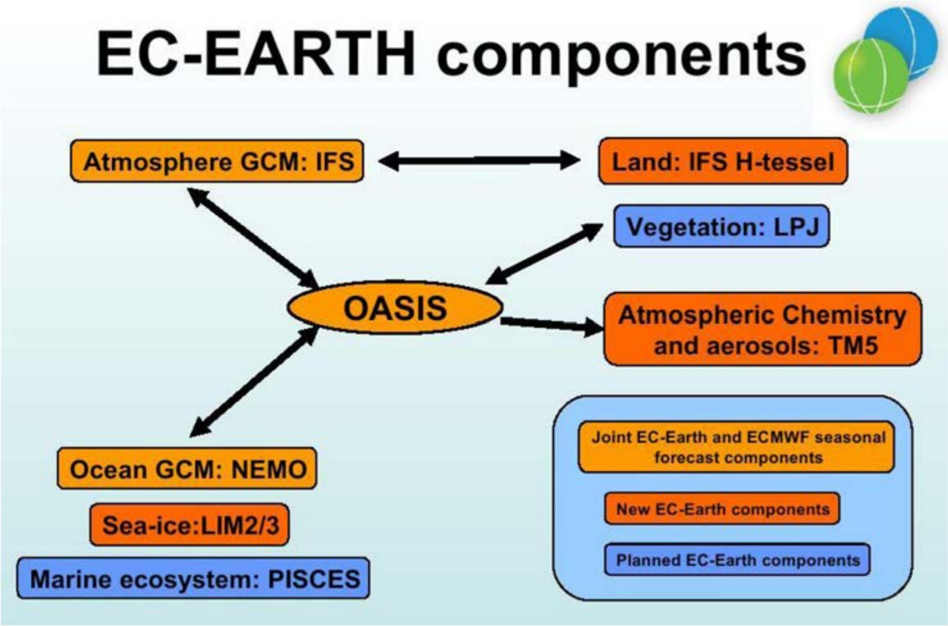
DKRZ DEUTSCHES KLIMARECHENZENTRUM

Scaling on CRAY@ECMWF

Slide courtesy Peter Düben, ECMWF



EC-Earth (II)



Slide courtesy Kim Serradel, BSC

29 partner institutes

8 core partners
KNMI, AEMET, DMI, Met Éireann, FMI, IPMA, CNR-DTA, SMHI

Workgroups
Technical
Tuning
Atmospheric Composition and Land
Ocean
Millennium scale studies
CMIP6

EC-Earth T1279-ORCA12 in MareNostrum4

Operational global, coupled ~10 km simulations (T1279 - ORCA12):

- EC-Earth 3.2 (IFS36r4 + NEMO 3.6 + OASIS3-MCT)
- 5,040 MPI tasks - 0.44 SYPD, 160 SDPD
  - 3,209 NEMO
  - 1,584 IFS
  - 69 XIOS
  - 1 runoff mapper
- MareNostrum4 @ BSC

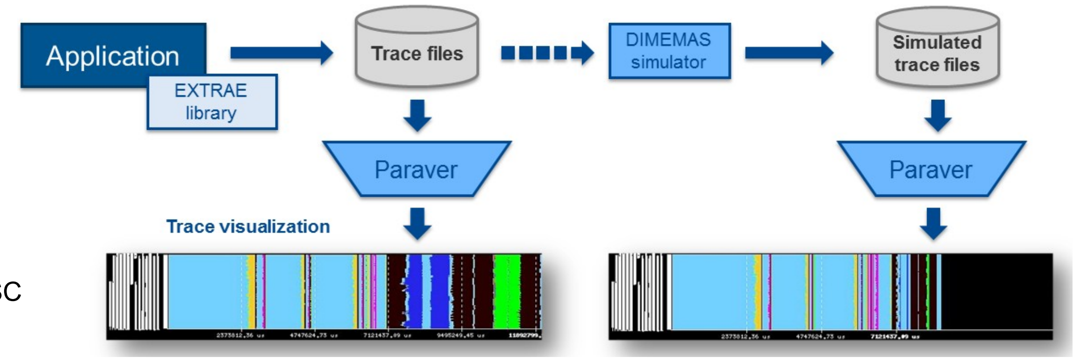
100 year exp
~40M ch !!!

Slide courtesy Kim Serradel, BSC

Kim Serradel, BSC: A Major benefit created through ESiWACE: create a framework where different institutions can work together to technically improve a community model like EC-Earth

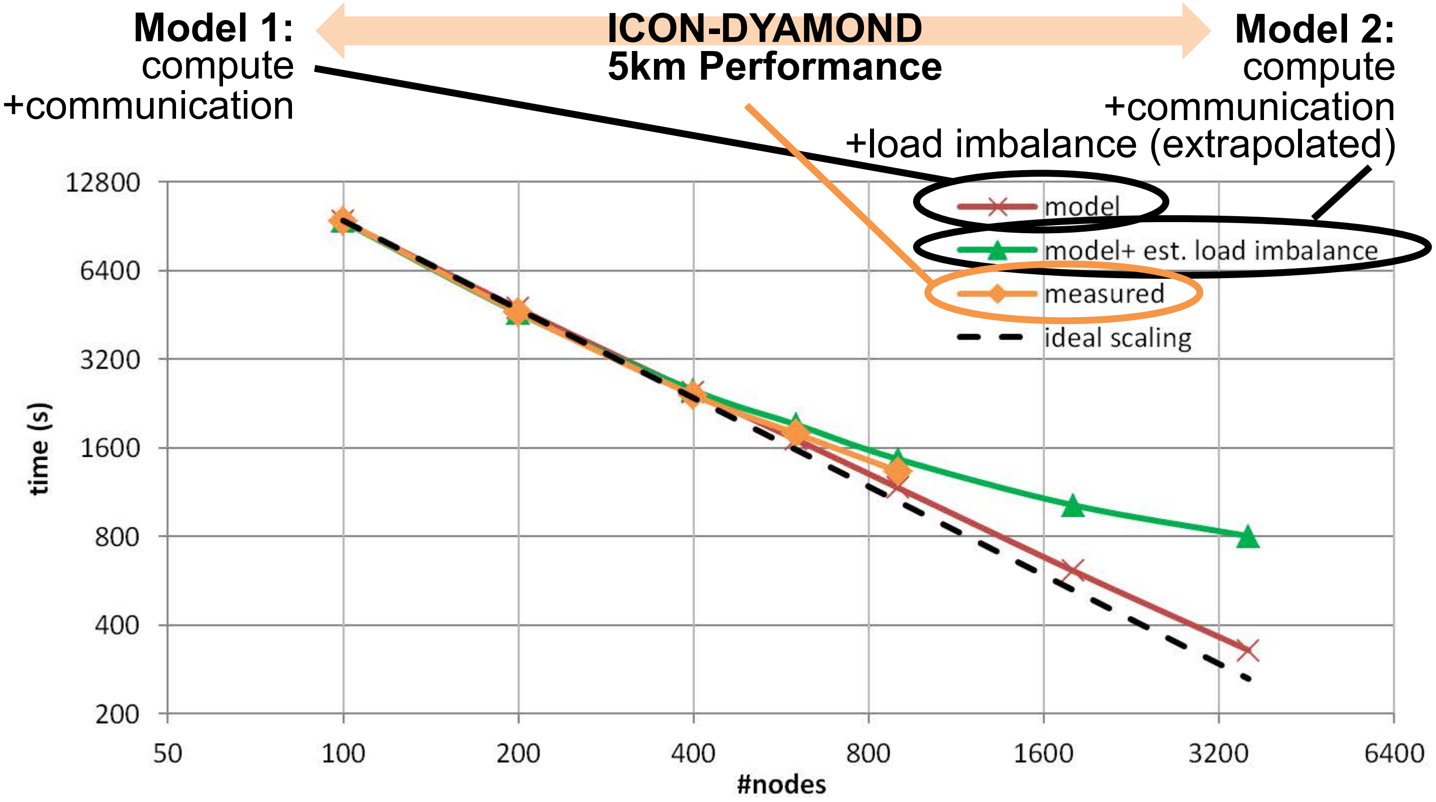
Performance analysis

- Since 1991
- Based on **traces**
- Open Source: https://tools.bsc.es
- **Extrae:** Package that generates Paraver trace-files for a post-mortem analysis
- **Paraver:** Trace visualization and analysis browser
- **Dimemas:** Message passing simulator



Slide courtesy Kim Serradel, BSC

Barcelona Supercomputing Center
Centro Nacional de Supercomputación



P. Neumann, P. Düben, et al. Assessing the Scales in Numerical Weather and Climate Predictions: Will Exascale be the Rescue? Phil Trans Roy Soc A, 2018

A roadmap to the Implementation of 1 km Earth System Model Ensembles

Joachim Biercamp, Peter Bauer, Peter Düben, Bryan Lawrence

Contributions by Sylvie Joussaume, Jochem Marotzke, Philipp Neumann, Erwan Raffin

ESiWACE Deliverable D1.2

https://zenodo.org/record/3361229#.XXc0aPxS_M0

Roadmap: Towards a new generation of models

We need to …

…make efficient use of millions of processing units in parallel;

…run efficiently on very different hardware (CPUs, GPGPUs, FPGAs, machine learning accelerators such as TPUs, embedded system/RISC hardware…) while keeping a single realisation of the source code which is easy to read by domain scientists;

…allow for energy aware executions that are maximising simulated years per Joule or throughput, depending on the requirements of runs;

…be fault resilient in a computing environment that can suffer from hardware faults or soft-errors;

…minimize model IO to disc/tape via trade-offs between re-computation and storage of model fields, online evaluation of model diagnostics, and the capability to perform output at different levels of resolution;

The way forward:…

- Refactoring, using domain specific languages and new programming models
- Performance modelling, data-flow and co-design
- Algorithmic developments
- Workflow management, dynamic allocation of compute nodes and test suites
- Machine learning
- Mixed precision
- Reduced resolution output
- Tiered storage
- On-the-fly diagnostics
- Ensemble analysis
- Active storage

- **100eds of person years**
- **international collaboration**

Selected weather/climate science and computational science projects funded by and proposed to the European Commission

2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |

1. Model assessment, initial conditions
2. Process understanding, interaction, teleconnections
3. Model improvements and transfer to operations

→ Science of prediction

PRIMAVERA, SPECS (Seasonal-to-decadal climate Prediction for the improvement of European Climate Services), APPLICATE, EUCP (European Climate Prediction system), CRESCENDO

1. Weather and climate benchmarks, and IO (HPCW)
2. Demonstration of novel programming models (DSL)
3. Hardware-software co-design

→ Feasibility of new concepts, computability

ESCAPE, nextgenio, EuroEXA, ESCAPE 2, MAESTRO (DATA ORCHESTRATION), EPiGRAM HS

1. Full-sized weather and climate models for EuroHPC
2. Community testing of new methodologies
3. Interface between and science & computing

→ Adaptation of leading models to (pre-)exascale; common strategies for community

esiwace, is-enes, esiwace2

1. Full-sized applications with required speed/volume and power footprint
2. Ingestion of downstream applications, all ensembles
3. Domain-specific, distributed computing capability, interactive workflows

→ Redesign entire prediction philosophy

ExtremeEarth

National and European HPC strategy programmes (e.g. EuroHPC)