esiwace

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Joachim Biercamp
Deutsches Klimarechenzentrum (DKRZ)

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

DKRZ
DEUTSCHES KLIMARECHENZENTRUM

1. Introduction
2. ESiWACE selected results
3. ESiWACE2 plans

The weather & climate community has a “nearly infinite“ need for computing capability and computing capacity:

- **We could and would do better science if we had faster (better) HPC**

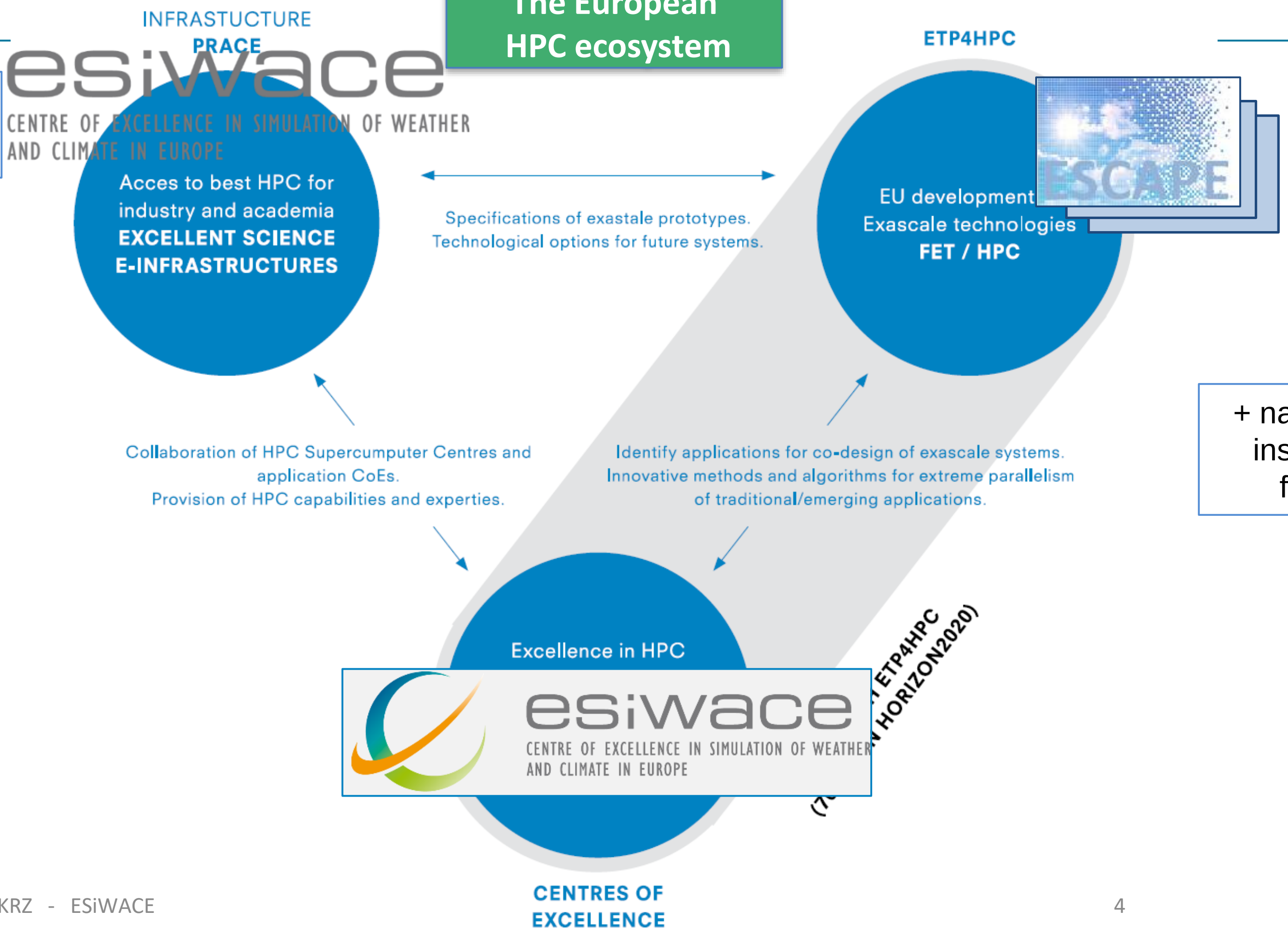
This community has a growing problem with HPC

- **Systems get broader not faster (in fact the may get slower)**
- **It is increasingly difficult to make progress in leveraging new systems**
- **The market is driven by cell phones and deep learning**

The European HPC ecosystem

dedicated machines
(Top500 rank, June 17)

Met Office	#11
ECMWF	#25 #26
DKRZ	#38



+ national and institutional funding

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

esiwace2

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Funded from European Union; Horizon 2020;
In grant preparation (ready for signature)
Duration Jan. 2019 – Dec. 2022
Funding: ca 8 Mio €

New Partners:

ESIWACE (phase 1) objectives

- ESiWACE will substantially improve the efficiency and productivity of numerical weather and climate simulation on high-performance computing platforms.

- ESiWACE will support the end-to-end workflow of global Earth system modelling for weather and climate simulation in high performance computing environments.

Selected results

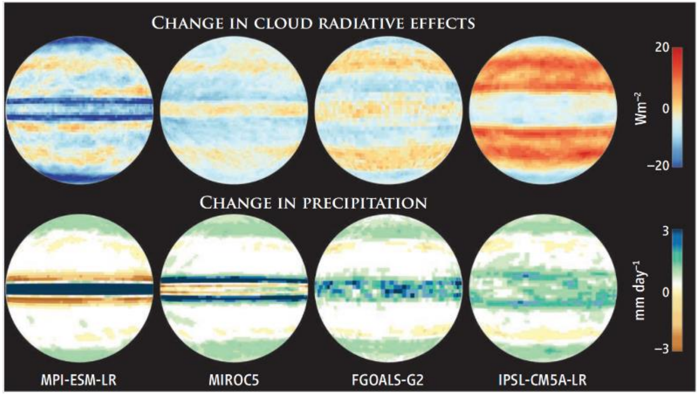
Scalability: The ESiWACE demonstrators

Global high-resolution model demonstrators:

- Demonstrate computability of:
  - 1km global Atmosphere, IFS, 2017
  - 1km global Atmosphere, ICON, 2017
  - 1km global Ocean, NEMO, 2019
  - at least 10km global, coupled ESM, EC-EARTH, 2019
  - target 1km global, coupled ESM, ICON-ESM, 2019
- Demonstrate that size and communality of the problem justifies a coordinated approach and strategic investment

Developing the next generation of climate and weather codes and related environments for exascale is a long-standing issue, beyond what ESiWACE can do in 4 years, but to which ESiWACE will help paving the way.

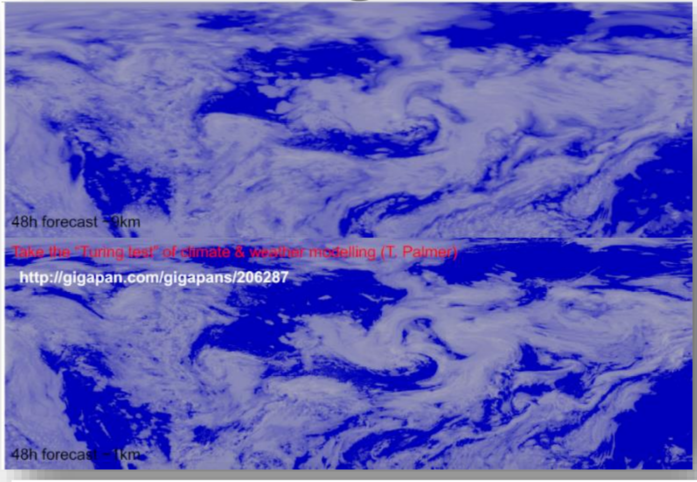
ICON-APE @1.25km and IFS @1.3km



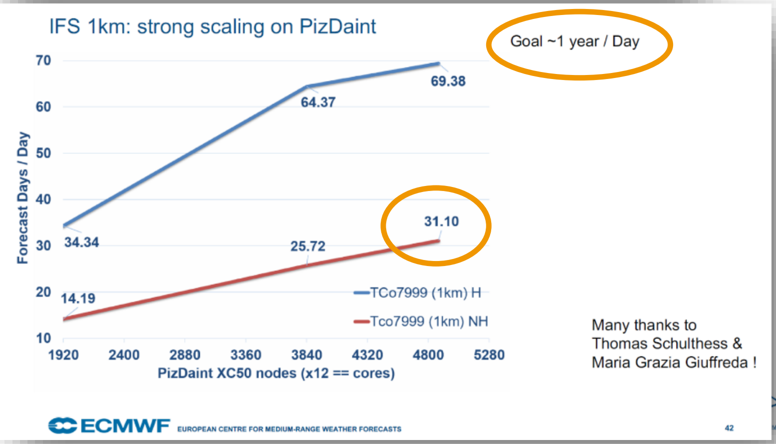
Aqua planet simulations:
From Stevens, Bony (2013). Science 340 (6136), 1053-1054

- **1.25km resolution,**
  335 544 320 horizontal cells, 45 vertical levels
- **1408 nodes, hybrid 2MPI x 18 OpenMP configuration**
  -> ca. 50.000 cores
- **throughput: 1.8 simulated days per day** (no IO)

benchmark (160km - 5km) available at:
https://redmine.dkrz.de/projects/icon-benchmark/wiki/



Wedi, Pasc 18, Basel



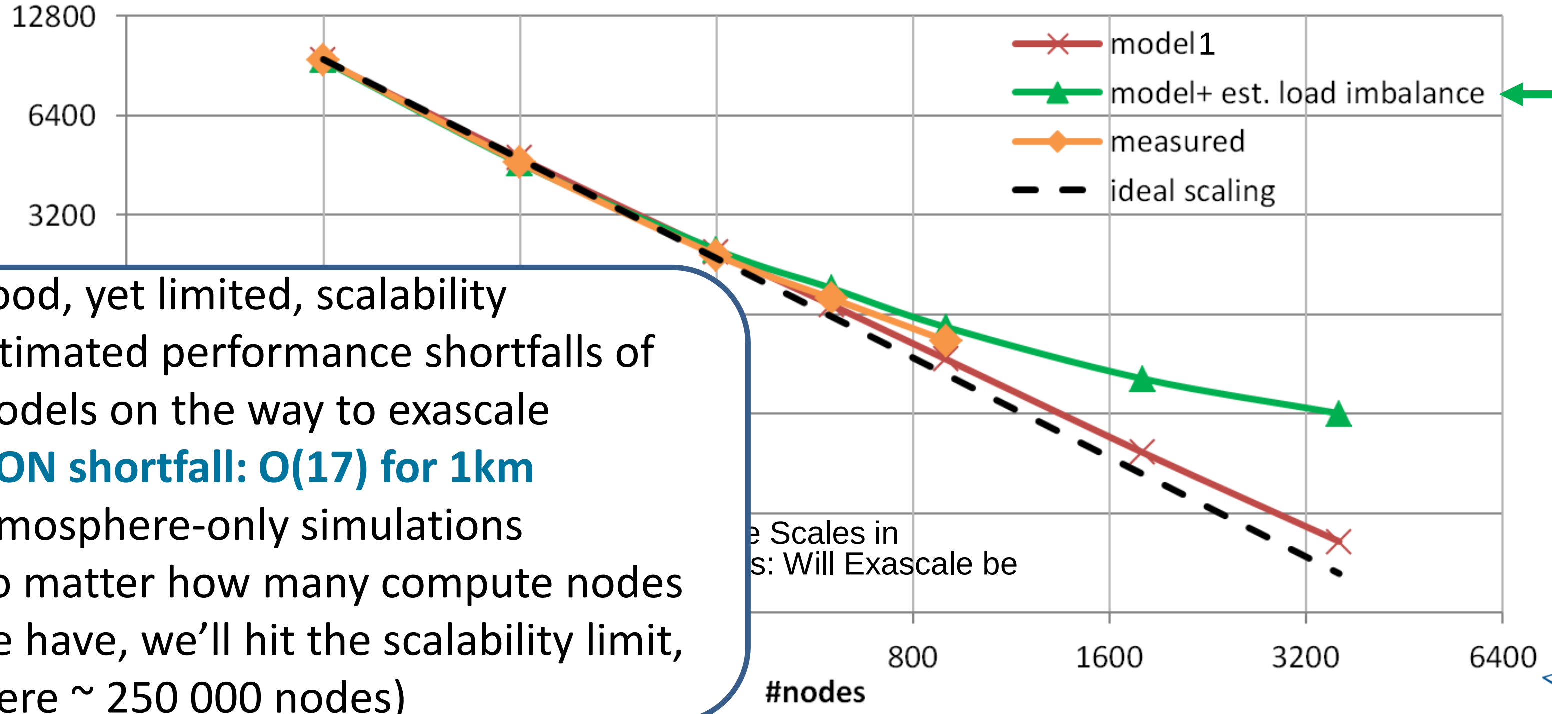
Performance Models for Scalability Predictions at Exascale

Model 1:
compute
+communication

ICON-DYAMOND

5km Performance

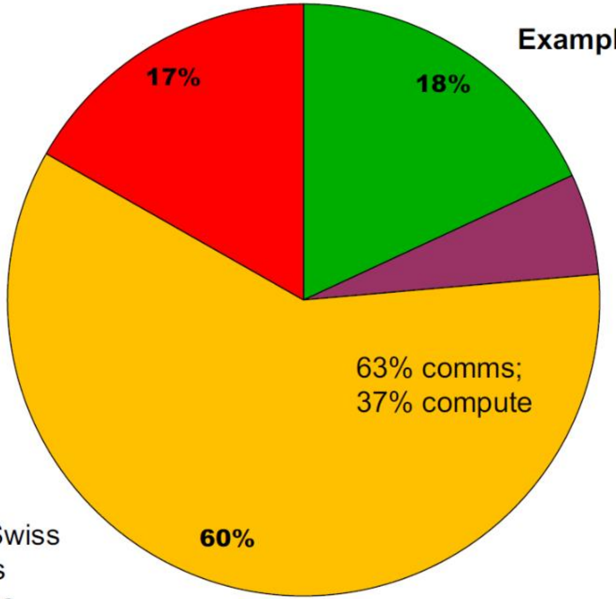
Model 2:
compute
+communication
+load imbalance (extrapolated)



- Good, yet limited, scalability
- Estimated performance shortfalls of models on the way to exascale
- **ICON shortfall: O(17) for 1km** atmosphere-only simulations
- No matter how many compute nodes we have, we'll hit the scalability limit, (here ~ 250 000 nodes)

The cost profile of a 1.25km (non-hydrostatic) IFS atmosphere simulation Piz Daint

GP_DYNAMICS SI_SOLVER SP_TRANSFORMS PHYSICS+RAD

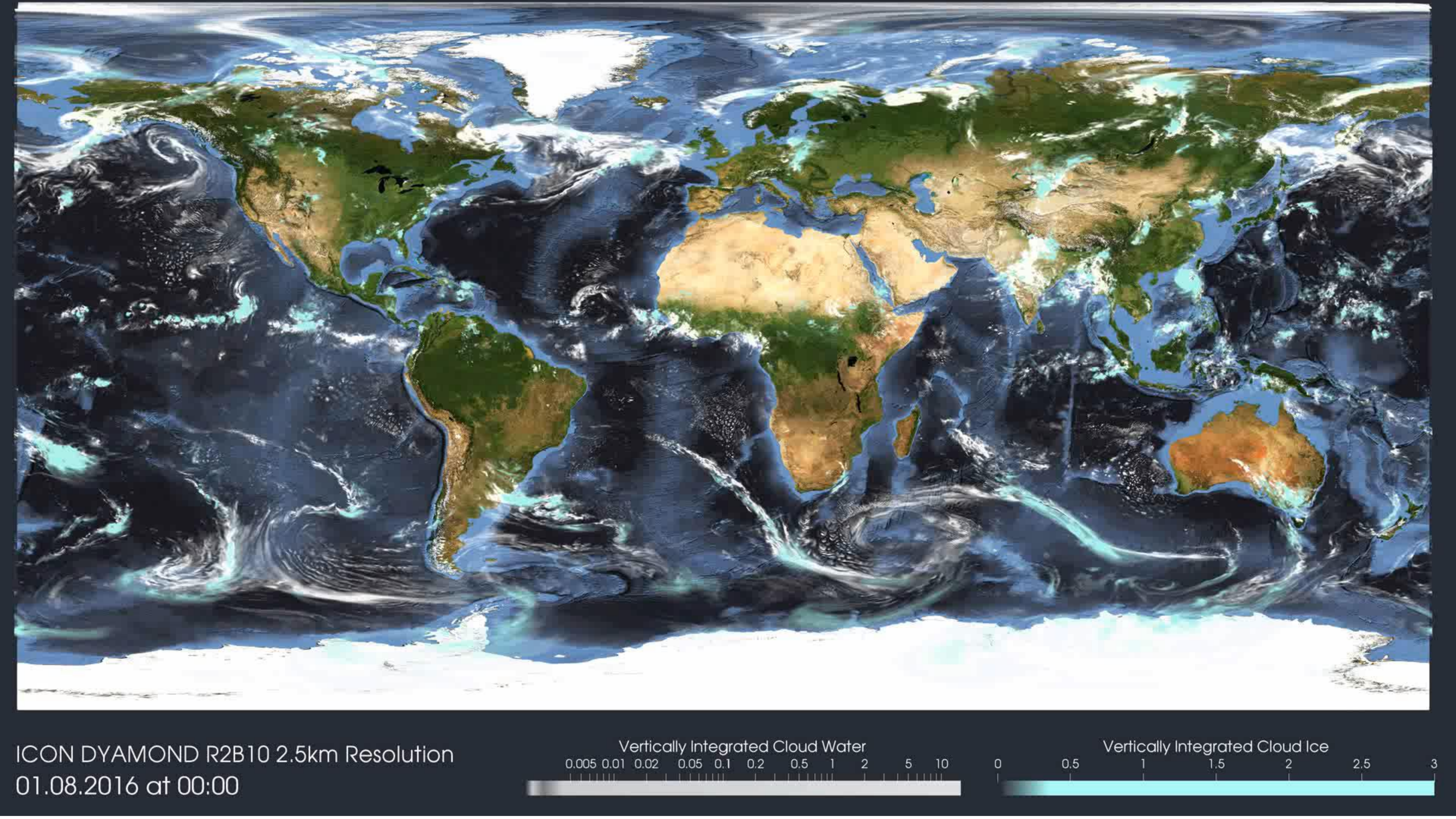


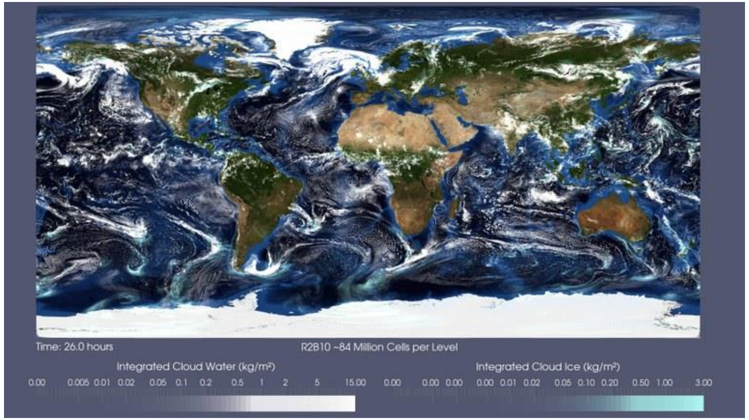
Example: TCo7999 L62 (~1.25km)

4880 MPI tasks x 12 threads
32 FC/day ~ 0.088 SYPD
single precision / FLT
~191.74 MWh / SY

Based on the Piz Daint, Swiss Cray XC50 Haswell, Aries interconnect, ~5000 nodes total

Nils Wedi, Pasc 18, Basel


ICON DYAMOND R2B10 2.5km Resolution
01.08.2016 at 00:00
Vertically Integrated Cloud Water
0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10
Vertically Integrated Cloud Ice
0 0.5 1 1.5 2 2.5 3



DYAMOND

DYnamics of the
Atmospheric general circulation
Modeled On
Non-hydrostatic Domains

Identifying **similarities and differences that emerge at storm resolving scales (1 km to 5 km)** as **compared to traditional** (hydrostatic-scale) representations of the atmospheric circulation;

Open to all interested international groups
Technical support through ESiWACE

https://www.esiwace.eu/services/dyamond

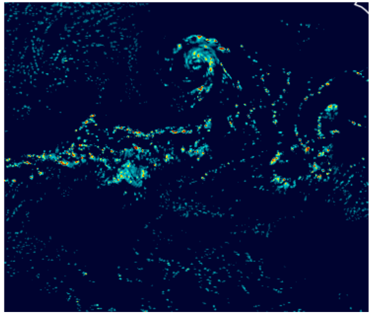
DYAMOND: Currently available data @DKRZ

Model	Horizontal Resolution	Vertical level	Model top	#columns	data	
SAM	4km	74	37km	42,467,328	38TB	✓
FV3	3.25km	75	3hPa	56,623,104	62TB	✓
ICON	2.5km	90	75km	83,886,080	132TB	✓
ICON (varying/fixed SST)	5km	90	75km	20,971,520	8/28Tb	✓
NICAM	3.5km	78	50km	41,943,042	28TB	
NICAM	7km	78	50km	10,485,762	7TB	

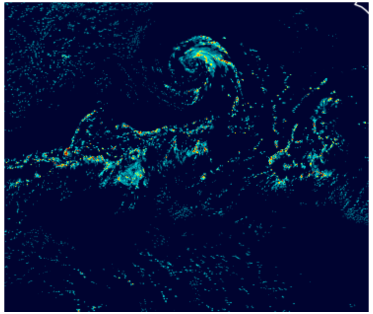
✓ = highest resolution of that model and all 40 days transferred to DKRZ

Zoom on tropical storm ‚Howard' after 36h forecast time

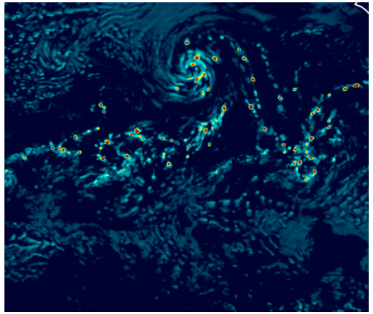
ICON 5 km



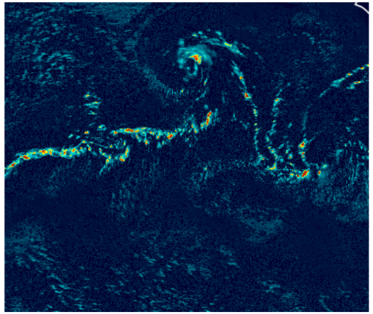
ICON 2.5 km



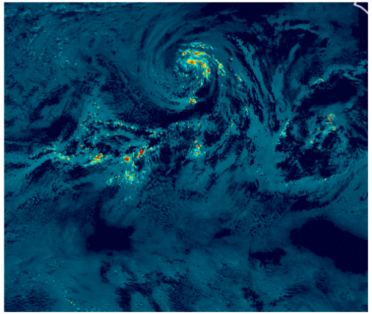
NICAM 7 km



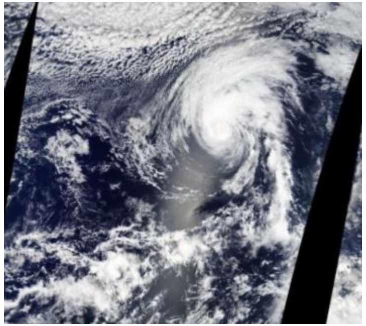
SAM 4 km



FV3 3.25 km



NASA worldview



Matthias Brueck (MPI)

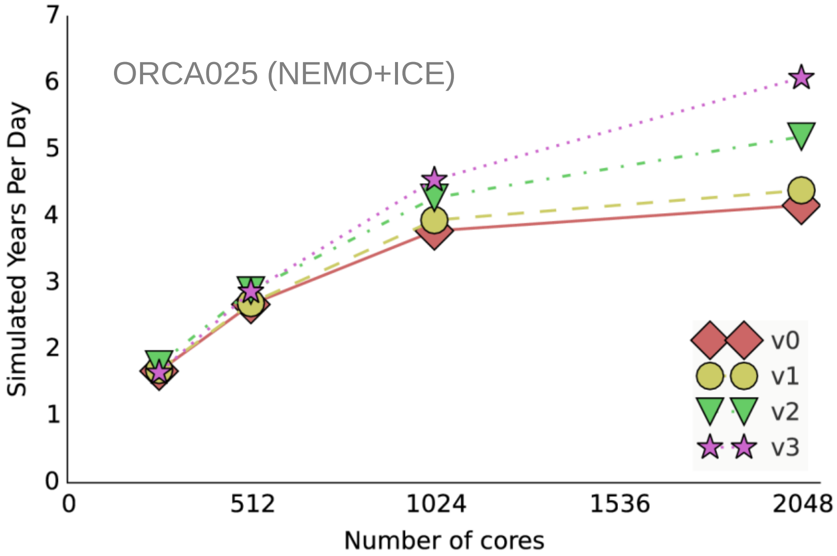
Finding, analysing and solving MPI communication bottlenecks in Earth System models

Journal of Computational Science

Oriol Tintó Prims, Miguel Castrillo, Mario C. Acosta, Oriol Mula-Valls, Alicia Sanchez Lorente, Kim Serradell, Ana Cortés, Francisco J.Doblas-Reyes

Highlights

- There was not a well established method to find MPI issues in Earth Science models.
- A performance analysis of ESMs can lead to productive and efficient optimizations.
- State-of-the-art ESMs still use algorithms not suitable for massive-parallel systems.



Slide:
Neil Massey, STFC, RAL

JDMA: a prototype tape library for advanced tape subsystems

- JASMIN Data Migration App(lication)
- A multi-tiered storage library
  - Provides a single API to users to move data to and from different storage systems
  - HTTP API running on webserver, database records requests and file metadata
  - Command line client which interfaces to HTTP API
- Multiple storage “backends” supported:
  - Amazon S3 (Simple Storage Solution) for Object Stores and AWS
  - FTP, also for tape systems with a FTP interface
  - Elastic Tape – a proprietary tape system based on CASTOR
- Backends have a “plug-in” architecture:
  - Extra backends can be added by writing the plug-in
- A number of daemons (scheduled processes) carry out the data transfer
  - Asynchronously
  - On behalf of the user

Slide:
Neil Massey, STFC, RAL

JDMA: a prototype tape library for advanced tape subsystems

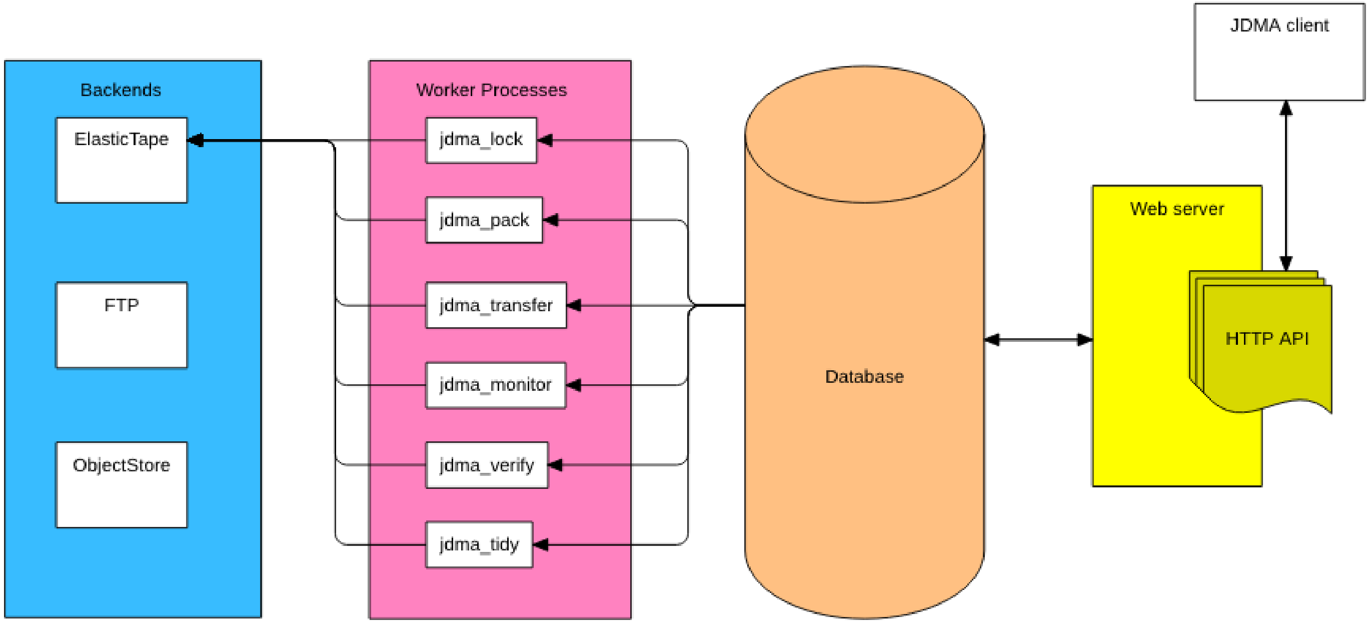


Figure 2: System structure of the JDMA showing the client, HTTP API residing on the webserver, the central database containing information about the migrations and requests, the worker processes which carry out the migrations and the storage backends.

Exchange and collaborate: ENES HPC workshops

Lecce 2011 & 2018

Hamburg 2014 & 2020

Toulouse 2013 & 2016

The Series of ENES HPC-workshops is co-organized by ESiWACE and IS-ENES with the ENES HPC task force

(Barcelona 2022)

ESiWACE2 plans

weather & climate computing as driver for HPC

EU funding programms

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

FETHPC:

1. Weather and climate benchmarks, and IO (HPCW)
2. Demonstration of novel programming models (DSL)
3. Data aware numerical methods

→ **Feasibility of new concepts, computability**

EINFRA:

1. Full-sized weather and climate models for EuroHPC
2. Community testing of novel programming models (DSL)
3. Data handling workflows, data analytics research

→ **Adaptation of leading models to (pre-)exascale**
→ **Strategy for achieving full-sized requirements**

Plus is-enes-3 via DG-reserach

FETFLAG:

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**

EuroHPC:

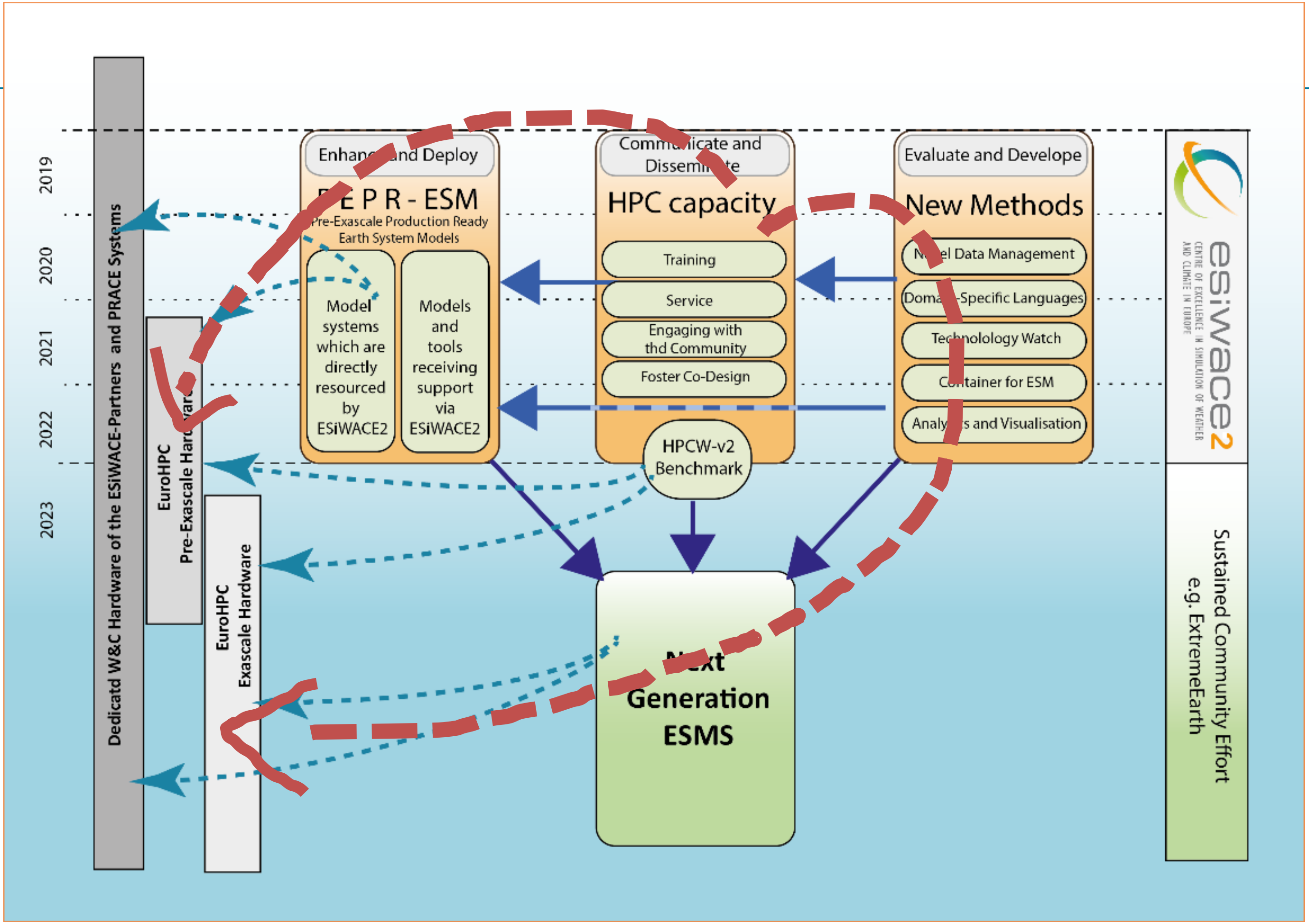
EuroHPC-1&2 pre-exascale

EuroHPC-3&4 exascale

ESIWACE2 objectives

1. 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.

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


2019
2020
2021
2022
2023
Dedicatd W&C Hardware of the ESiWACE-Partners and PRACE Systems
EuroHPC
Pre-Exascale Hardware
EuroHPC
Exascale Hardware
Enhance and Deploy
P E P R - ESM
Pre-Exascale Production Ready Earth System Models
Model systems which are directly resourced by ESiWACE2
Models and tools receiving support via ESiWACE2
Communicate and Disseminate
HPC capacity
Training
Service
Engaging with thd Community
Foster Co-Design
HPCW-v2 Benchmark
Evaluate and Develope
New Methods
Novel Data Management
Domain-Specific Languages
Technolology Watch
Container for ESM
Analytics and Visualisation
Next Generation ESMS
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Sustained Community Effort
e.g. ExtremeEarth

ESiWACE2 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

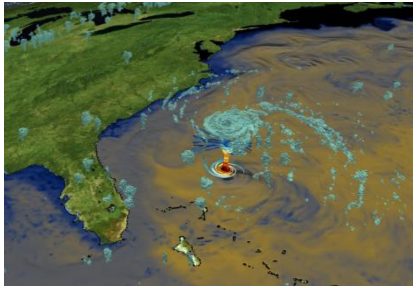
WP7 Coordination, Management and Dissemination

WP1: Cutting Edge Resolution in Earth system modelling

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 Bauer ECMWF; Joachim Biercamp, DKRZ

- Extend the ESiWACE demonstrator approach to production type configurations: For fixed SYPD (=1) **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
- Extend the DYAMOND idea and provide the necessary infrastructure



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

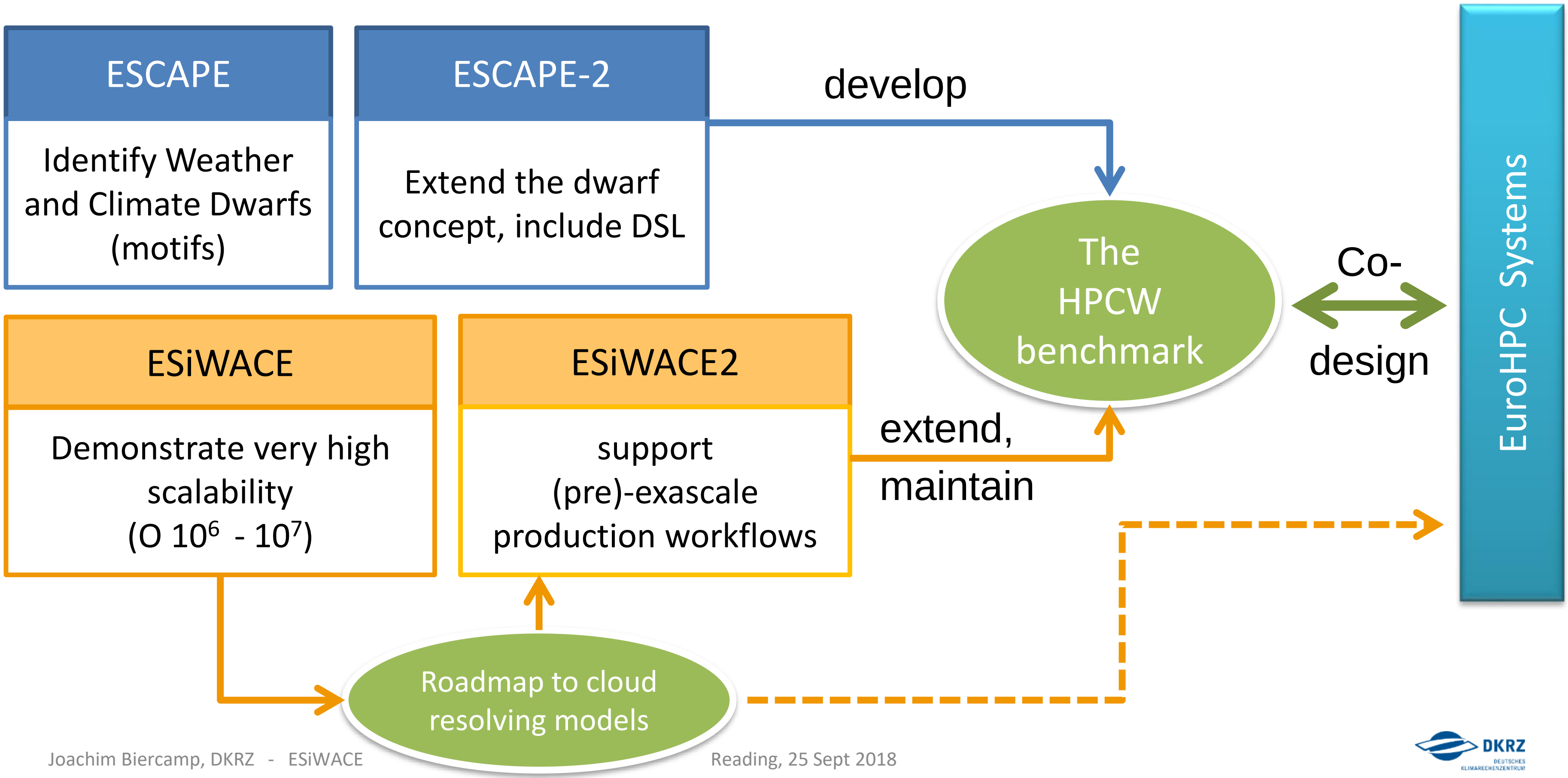
- Establish DSLs in the community
- Evaluate Concurrent Components to improve performance
- Evaluate Containers to port Earth system models to new hardware
- Watch emerging technologies

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)

The HPCW – Benchmark



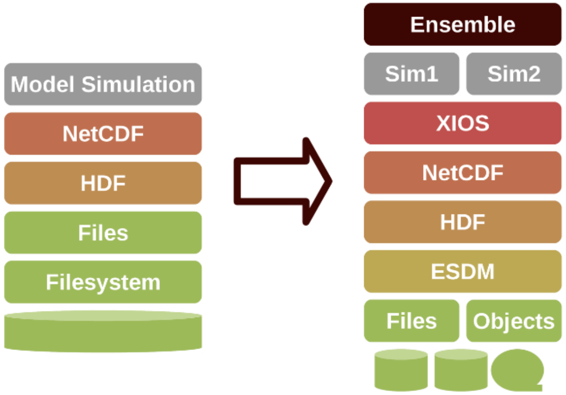
WP4 and WP5: Data Handling at Scale

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

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

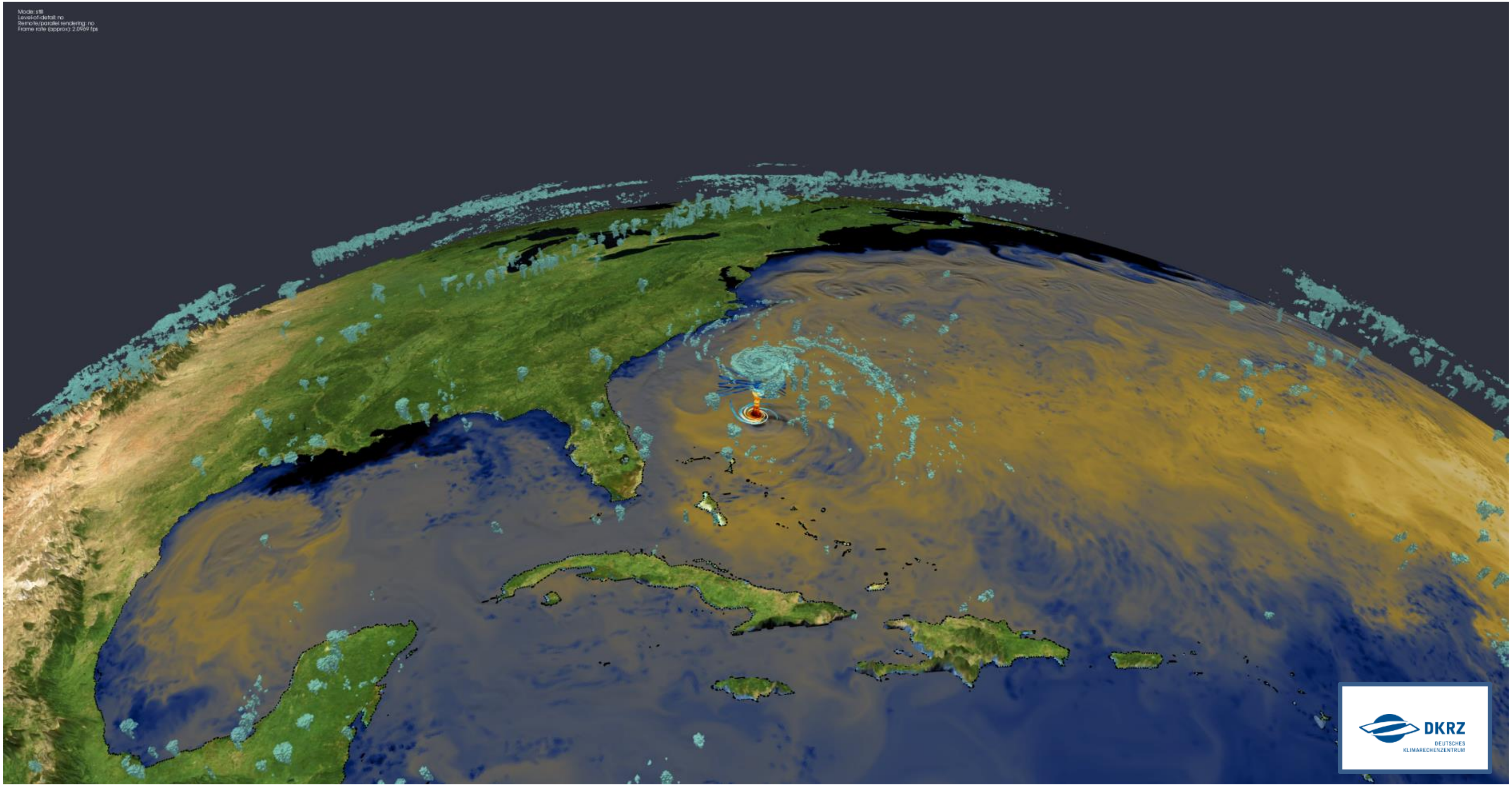
WP6: Community engagement and Training

WP6 will link ESiWACE2 to the weather and climate community it serves on the one hand and to the European HPC ecosystem on the other hand

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
  - Docker
  - Summer school in HPC for weather and climate


Mode: still
Level-of-detail: no
Remote/parallel rendering: no
Frame rate (approx): 2.0969 fps
DKRZ
DEUTSCHES KLIMARECHENZENTRUM


Coupled Cloud Resolving Earth System Model - DYAMOND++
Horizontal Resolution Atmosphere & Ocean 5km, 15min Interval
September 4, 2013
Thank you for your attention

ENDE