esiwace

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

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Deutsches Klimarechenzentrum (DKRZ)

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DKRZ
DEUTSCHES KLIMARECHENZENTRUM

HPC for weather and climate:

A big success story …

… and a big and growing challenge

1985: Control Data Cyber-205

- 1 processor
- 0.2 Gigaflops
- 0.03 Gigabyte memory

1988: Cray 2S

- 4 processors
- 2 Gigaflops
- 1 Gigabyte memory

1994: Cray C-916 „Sea“

- 16 processors
- 16 Gigaflops
- 2 Gigabyte memory
- 128 Gigabyte disc space
- 10 Terabyte tape archive

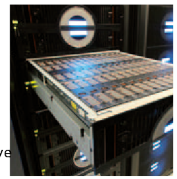
1985 — 1988 — 1994 — 2000

2002: NEC SX-6 „Hurrikan“

- 192 processors
- 1.5 Teraflops
- 1.5 Terabyte memory
- 60 Terabyte disc space
- 3.4 Petabyte tape archive

2009: IBM Power6 „Blizzard“

- 8500 processors
- 158 Teraflops
- 20 Terabyte memory
- 6 Petabyte disc space
- 60 Petabyte tape archive

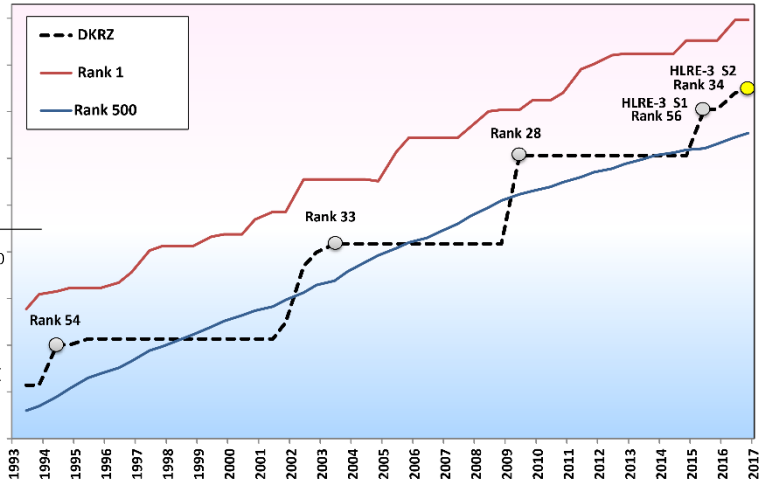


2015/16: bullx B700 DLC „Mistral“

- 36000 - ca 80000 processors
- 1.5 - 3+ Petaflops
- 120 - 240 Terabyte memory
- 20 - 50 Petabyte disc space
- up to 500 Petabyte tape archive

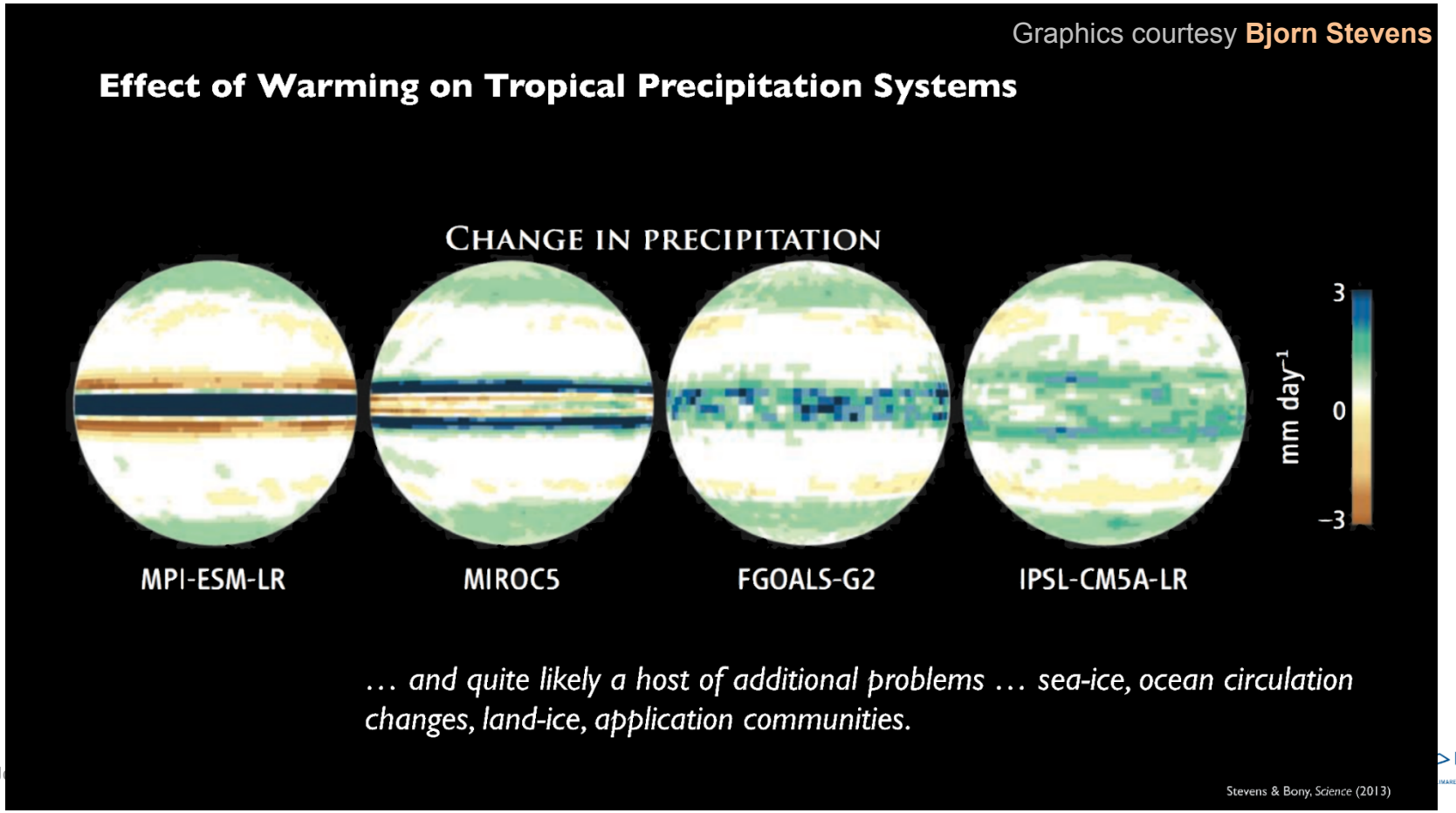
2002 — 2009 — 2015 — 2016

Increase in LINPACK performance within the TOP500 and at DKRZ



… but still, ESMs are far from being perfect

Graphics courtesy **Bjorn Stevens**



Slide courtesy Bjorn Stevens
(EGU Vienna, 2018)

Conventional approaches have brought us far, … but we are feeling their limits

Empiricism ⟵ // ⟶ Physical principles

EMICs C79 $CMIP_n$ $CMIP_{n+1}$ NWP

Quasi 2D;
Parameterized spatial coupling

Quasi 3D:
Parameterized vertical coupling

Slide courtesy Bjorn Stevens
(EGU Vienna, 2018)

Conventional approaches have brought us far, … but we are feeling their limits

Empiricism

Physical principles

EMICs C79 $CMIP_n$ $CMIP_{n+1}$ NWP NICAM, ICON

Quasi 2D;
Parameterized spatial coupling

Quasi 3D:
Parameterized vertical coupling

Fully 3D:
Resolved vertical energy transport

… its time to take the next great leap

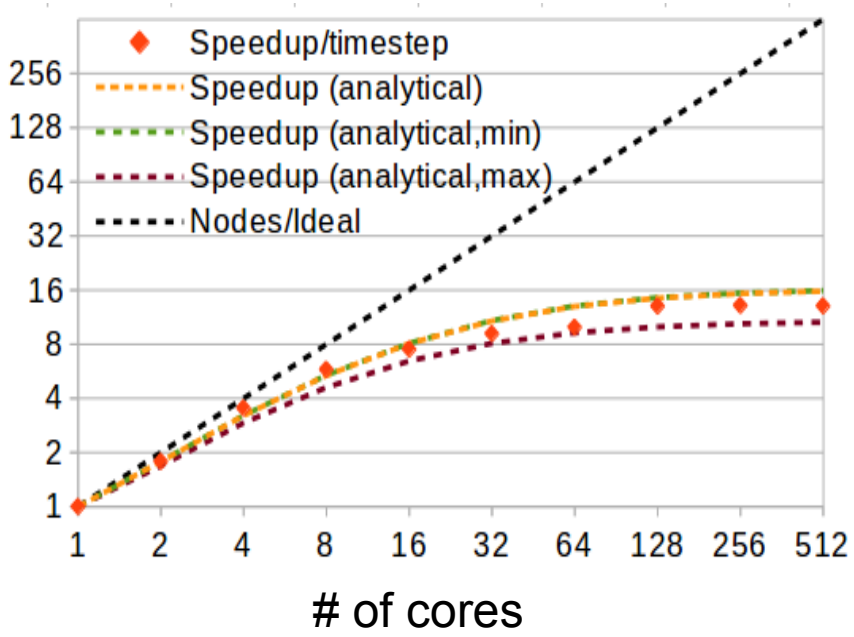
Bjorn Stevens at EGU 2018:

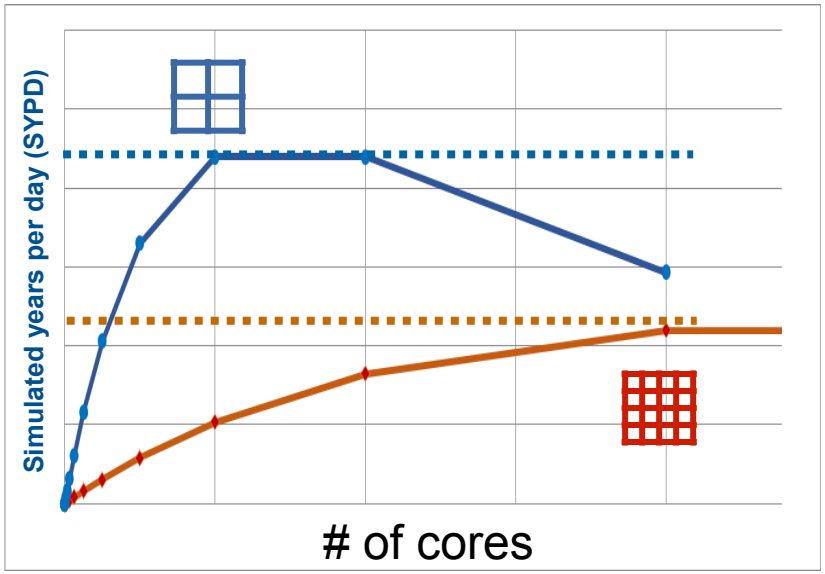
Top Ten Reasons … why 1 km coupled is a great leap

- 1. Convection is resolved (rainbands).
- 2. Surface orographic effects and gravity waves are resolved (storm tracks).
- 3. Shallow circulations (clouds and convection, feedbacks and forcing).
- 4. Ocean eddies are resolved (southern ocean stratification).
- 5. Tropopause dynamics are resolved (storm tracks and stratospheric water vapor).
- 6. Bathymetric effects on water mass formation are resolved (variability).
- 7. Allows a native representation of land surface (land use changes).
- 8. Remaining problems, such as microphysics & turbulence become tractable (parameterization).
- 9. Simulates observables (brings different science communities to the same table).
- 10. Direct link to impacts (connects directly to application communities).

Slide courtesy Bjorn Stevens
(EGU Vienna, 2018)

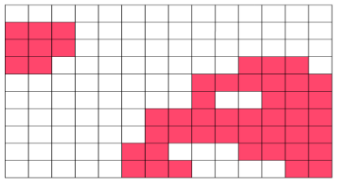
Very high resolution exposes the SYPD wall !

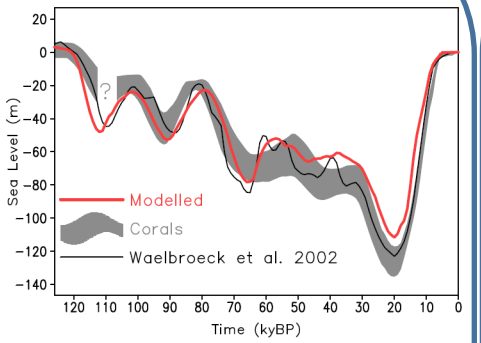




Very high resolution exposes the SYPD wall !

Paleo





Time scale: Millennia (up to 100,000 a)

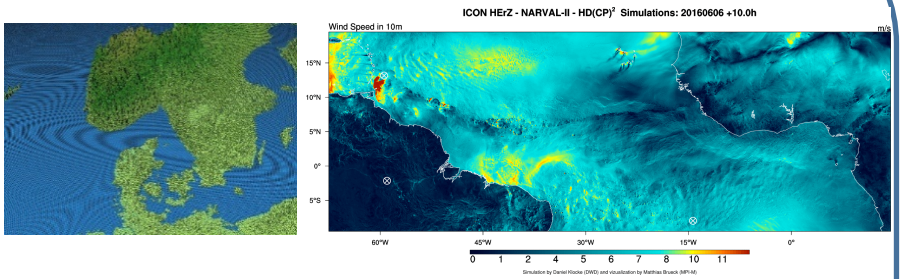
Resolution: ~ 500km

HPC: Need world class **capability** systems with low number of cores (e.g. the “good old vector”)

Per single experiment less then 10 TeraFLOPS (peak)
Wall clock: months or even years !

Using a 1 PFLOP machine you could run ensemble of size 100 but would still wait years for the results

Cloud resolving



Time Scale: a few years

Resolution: 1 km or lower

HPC: Needs „suitable“ exa-scale systems and new programming paradigms

Could fill an Exaflops system but limited to simulation periods of years to decades (if we work hard)

Intermediate summary

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**

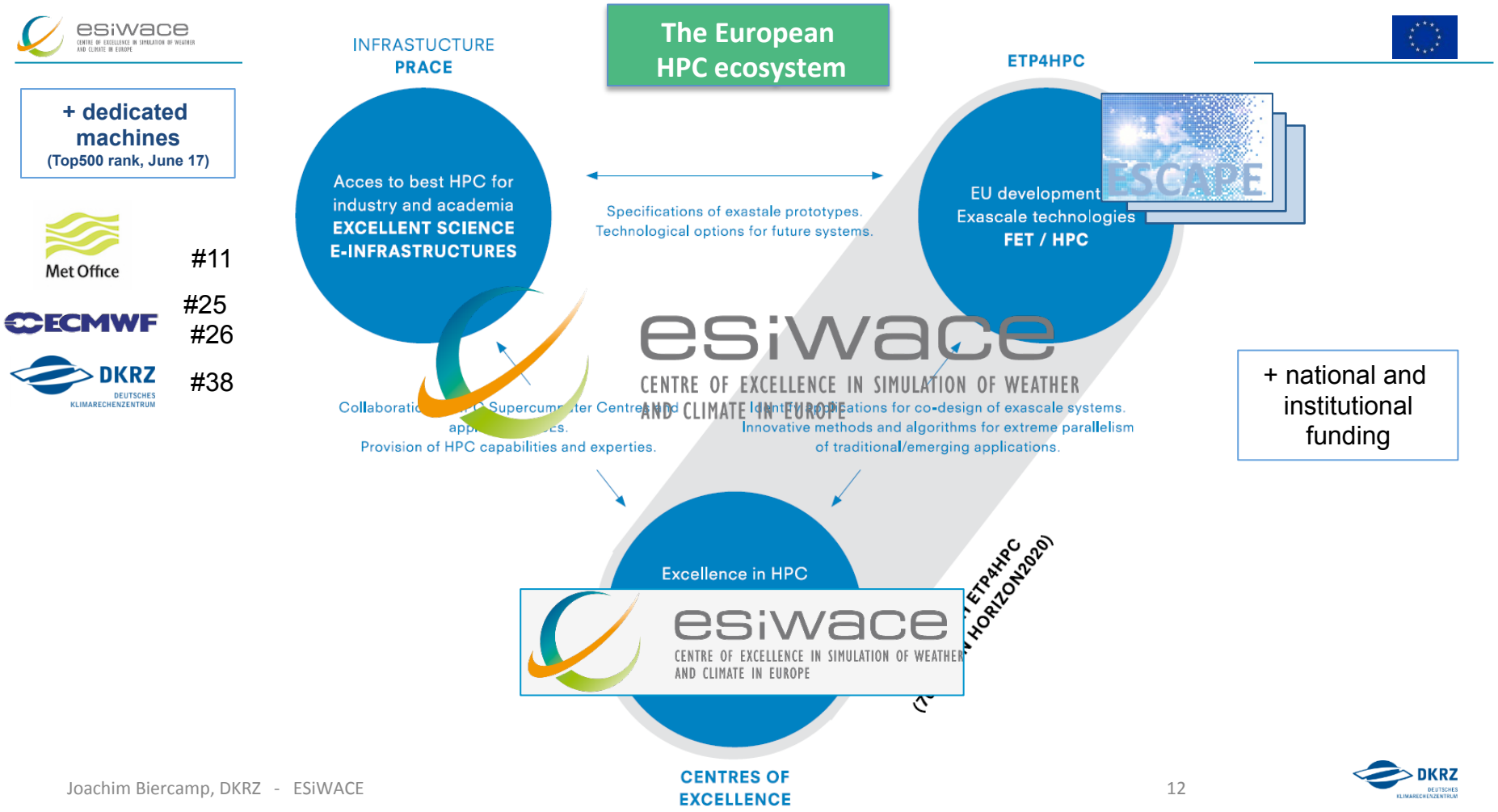
This community has a growing problem with HPC

- **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**

ESiWACE:

Linking climate and weather modelling to the European HPC ecosystem

Fostering co-design


esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE
+ dedicated machines
(Top500 rank, June 17)
Met Office
#11
ECMWF
#25
DKRZ
DEUTSCHES KLIMARECHENZENTRUM
#26
#38
The European HPC ecosystem
INFRASTUCTURE
PRACE
Acces to best HPC for industry and academia
EXCELLENT SCIENCE
E-INFRASTRUCTURES
Specifications of exastale prototypes.
Technological options for future systems.
ETP4HPC
EU development
Exascale technologies
FET / HPC
ESCAPE
Provision of HPC capabilities and experties.
Innovative methods and algorithms for extreme parallelism
of traditional/emerging applications.
esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE
+ national and institutional funding
Excellence in HPC
esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE
CENTRES OF EXCELLENCE

esiwace

CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

One of currently nine CoEs funded within H2020

16 partners:

Climate modelling **HPC industry**

Weather services **Computing centres**

Funded from European Union; Horizon 2020; research agreement No 675191

Duration Oct. 2016 – Sept. 2019

Funding: ca 5Mio €

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ESiWACE:

Technical focus

Scalability: The ESiWACE demonstrators

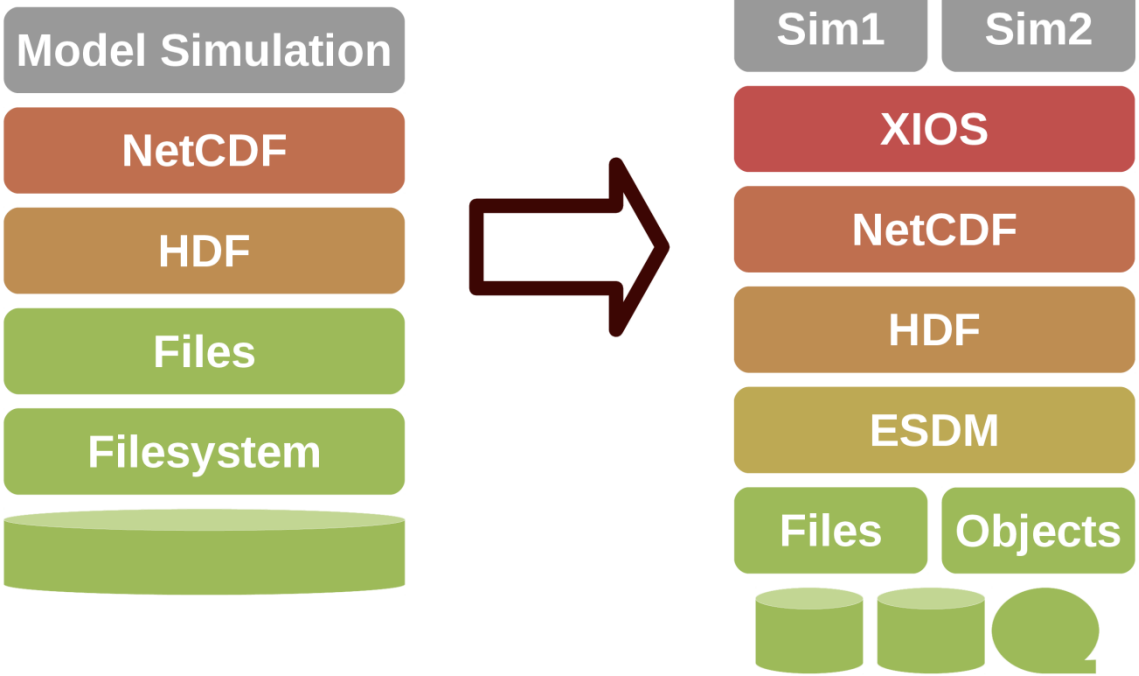
Global high-resolution model demonstrators:

- Demonstrate computability of:
  - 1km global Atmosphere, IFS, 2017
  - 1km global Atmosphere, ICON, 2017
  - 1km global Ocean, NEMO, 2019
  - at least 10km global, co
  - target 1km gl
- Dem… …mmunality of the problem justifies a c… …n and strategic investment

See Philipps talk this afternoon

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 pave the way.

Expoitability: Data centric workflow – fight the data deluge



ESiWACE approach:

Control Workflow via CYLC Meta-scheduler

Handle data via Eart-System-Data Middleware (non POSIX)

In-situ approaches to Analytics and visualisation

Community Building !

Community = Earth System Modelling Community

(Weather + Climate + HPC)

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**

ESCAPE, ESCAPE 2, MAESTRO DATA ORCHESTRATION, nextgenio, EuroEXA, EPiGRAM-HS

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**

esiwace, esiwace2

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

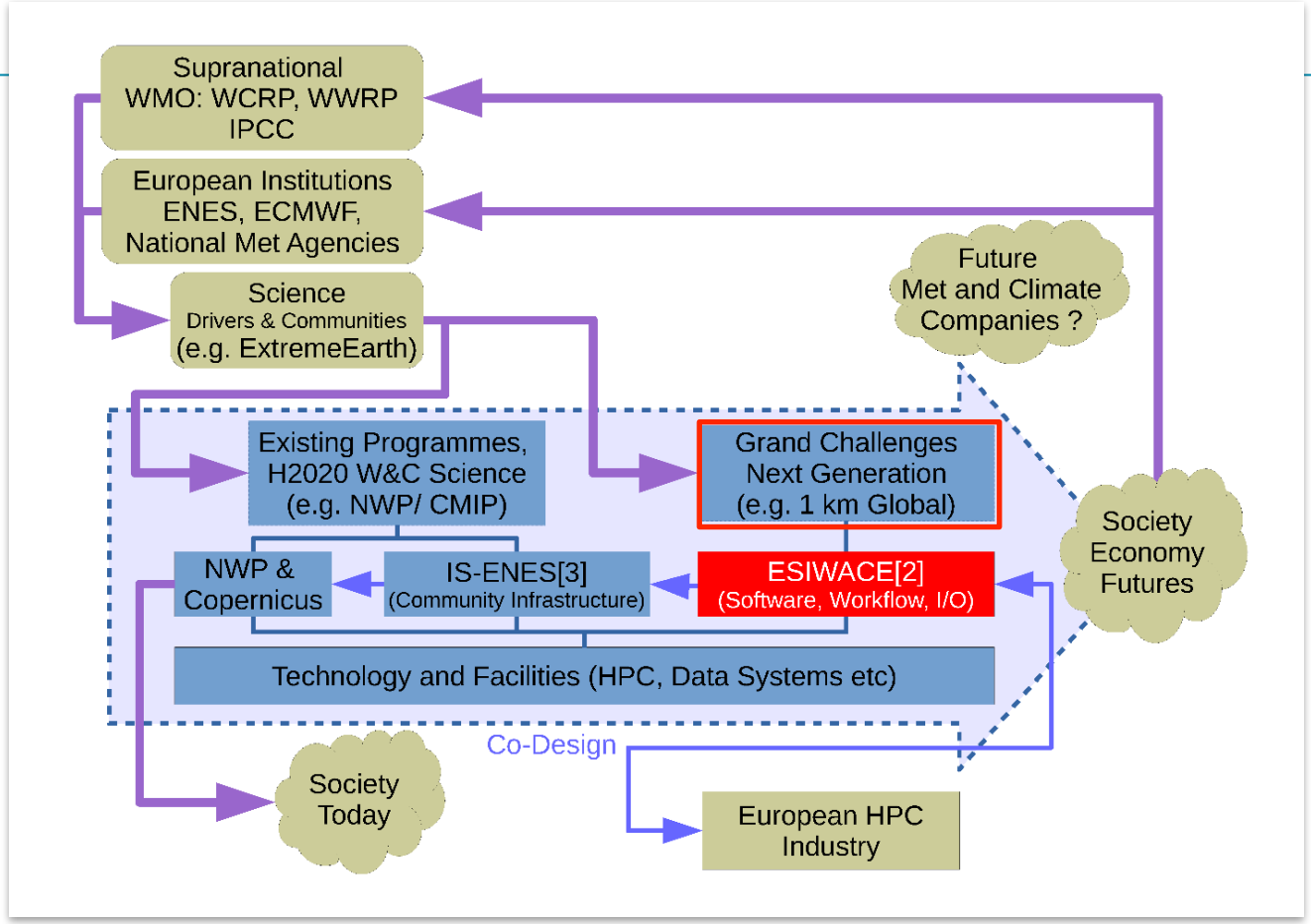
→ **Redesign entire prediction philosophy**

ExtremeEarth

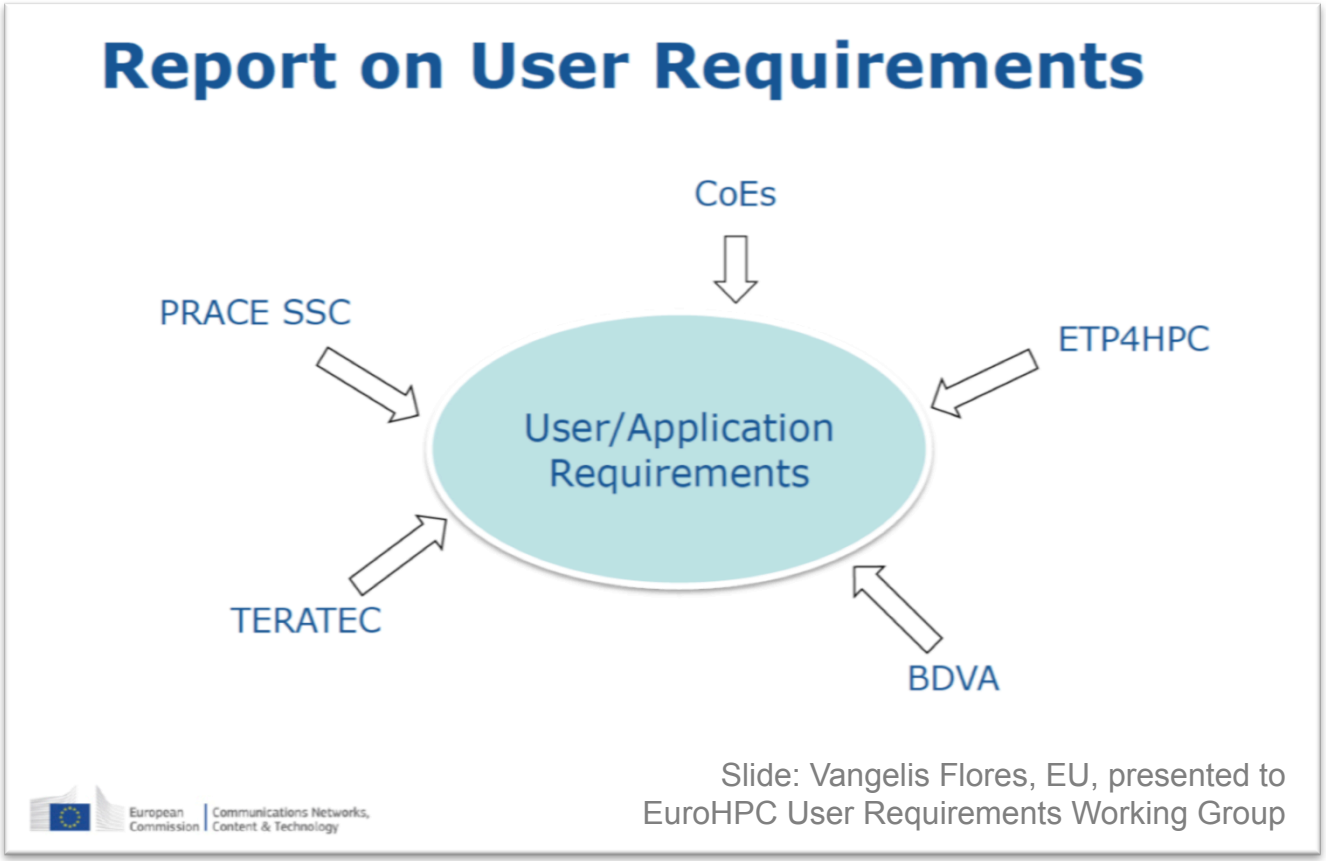
EuroHPC:

EuroHPC-1&2 pre-exascale

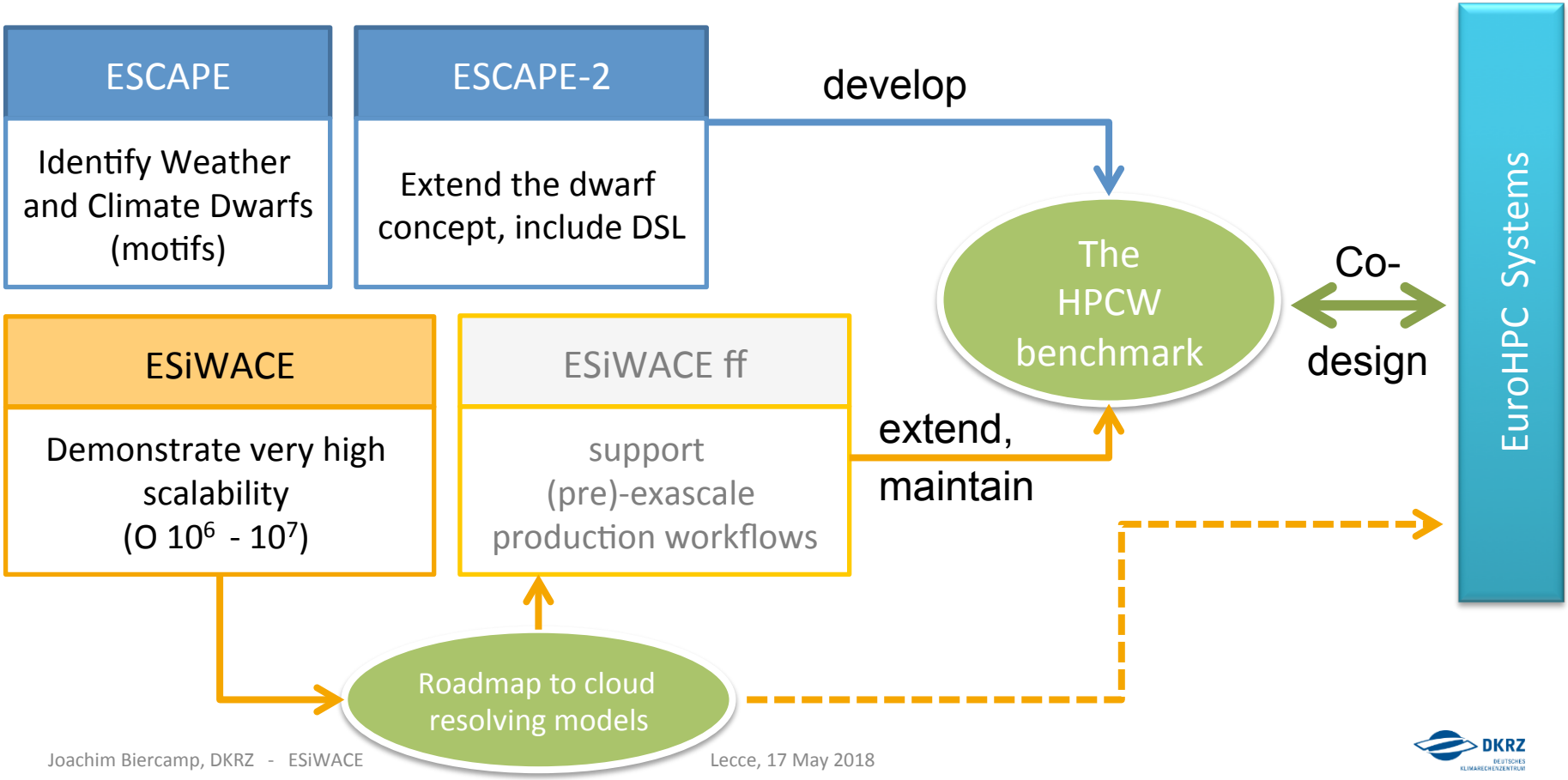
EuroHPC-3&4 exascale


Supranational
WMO: WCRP, WWRP
IPCC
European Institutions
ENES, ECMWF,
National Met Agencies
Science
Drivers & Communities
(e.g. ExtremeEarth)
Future
Met and Climate
Companies ?
Existing Programmes,
H2020 W&C Science
(e.g. NWP/ CMIP)
Grand Challenges
Next Generation
(e.g. 1 km Global)
Society
Economy
Futures
NWP &
Copernicus
IS-ENES[3]
(Community Infrastructure)
ESIWACE[2]
(Software, Workflow, I/O)
Technology and Facilities (HPC, Data Systems etc)
Co-Design
Society
Today
European HPC
Industry

Impact on EuroHPC, etc



The HPCW – Benchmark



Exchange and Collaborate

DYAMOND

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

See Philipps talk this afternoon

Identifyi… …at **emerge at storm resolving scales (1 km to 5 km)** as **comp**… …static-scale) representations of the atmospheric circulation;

Open t… …interested international groups
Technical support through ESiWACE

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

Exchange and collaborate

June 19-20, 2018: Teratec Forum, Palaiseau, France

June 24-28, 2018: ISC High Performance, Frankfurt, Germany

- Birds-of-a-Feather session "ESiWACE: What is Special about HPC Computing for Weather and Climate?“
- Presentation "Towards Cloud-Resolving Weather and Climate Prediction at Exascale" in session "Tornados, Disaster & Early Warnings“
- Project Poster "ESiWACE”

July 2-4, 2018: PASC, Basel, Switzerland

- Contribution to several mini symposia
- ESiWACE (Joachim, Philipp) will be chairing W&C track 2019; Peter did the same 2017

Sep 13-14, 2018: 3rd ENES Workshop on Workflows, Brussels, Belgium

Sep 24-28, 2018: 18th Workshop on HPC in Meteorology, Reading, UK

- Longer session on EU-projects dealing with scalability, etc

Oct 29-Nov 1, 2018: Weather & Climate Science in the Digital Era, Amsterdam, Netherlands

- Several partners plan contributions

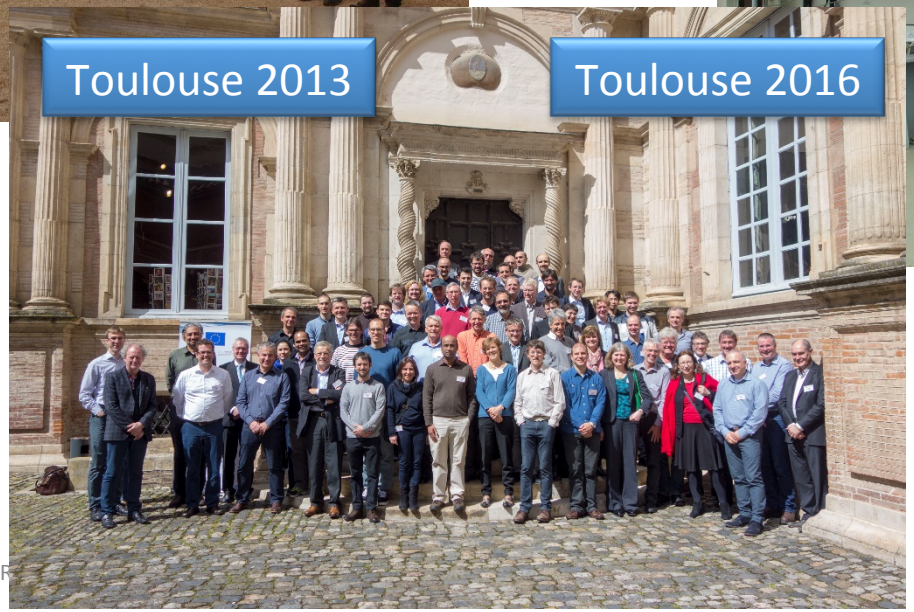
Exchange and collaborate: ENES HPC workshops

Lecce 2011

Hamburg 2014

Toulouse 2013

Toulouse 2016



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

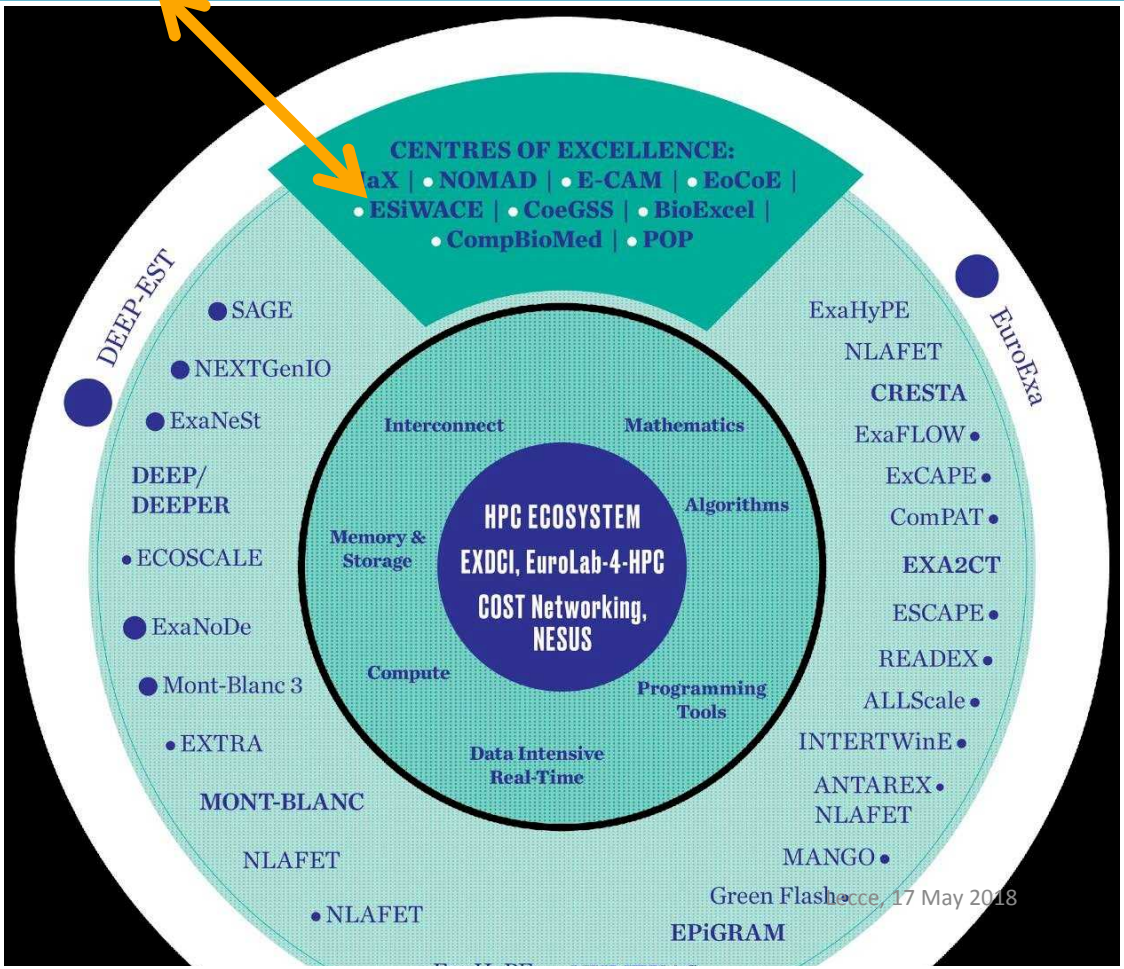
Lecce 2018

(Hamburg 2020)

(Barcelona 2022)

ENDE

The European HPC Ecosystem



FET:

Future and Emerging Technologies Projects

CoE:

Centers of Excellence on Application Performance

One of nine CoE is on climate and weather

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