High-Performance Computing | Environement

Philippe Segers

GENCI Head of European HPC projects
PRACE Board of Director
Thanks to Peter Dueben ECMWF, Bjorn Stevens MPI-Met, Marie-Alice Foujol IPSL, Francois Bodin Irisa, Emilie Germetz Neovia, Olivier Oldrini Amplisim, David Defour LAMPS

PRACE | members

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- Slovenia
- Sweden
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- United Kingdom

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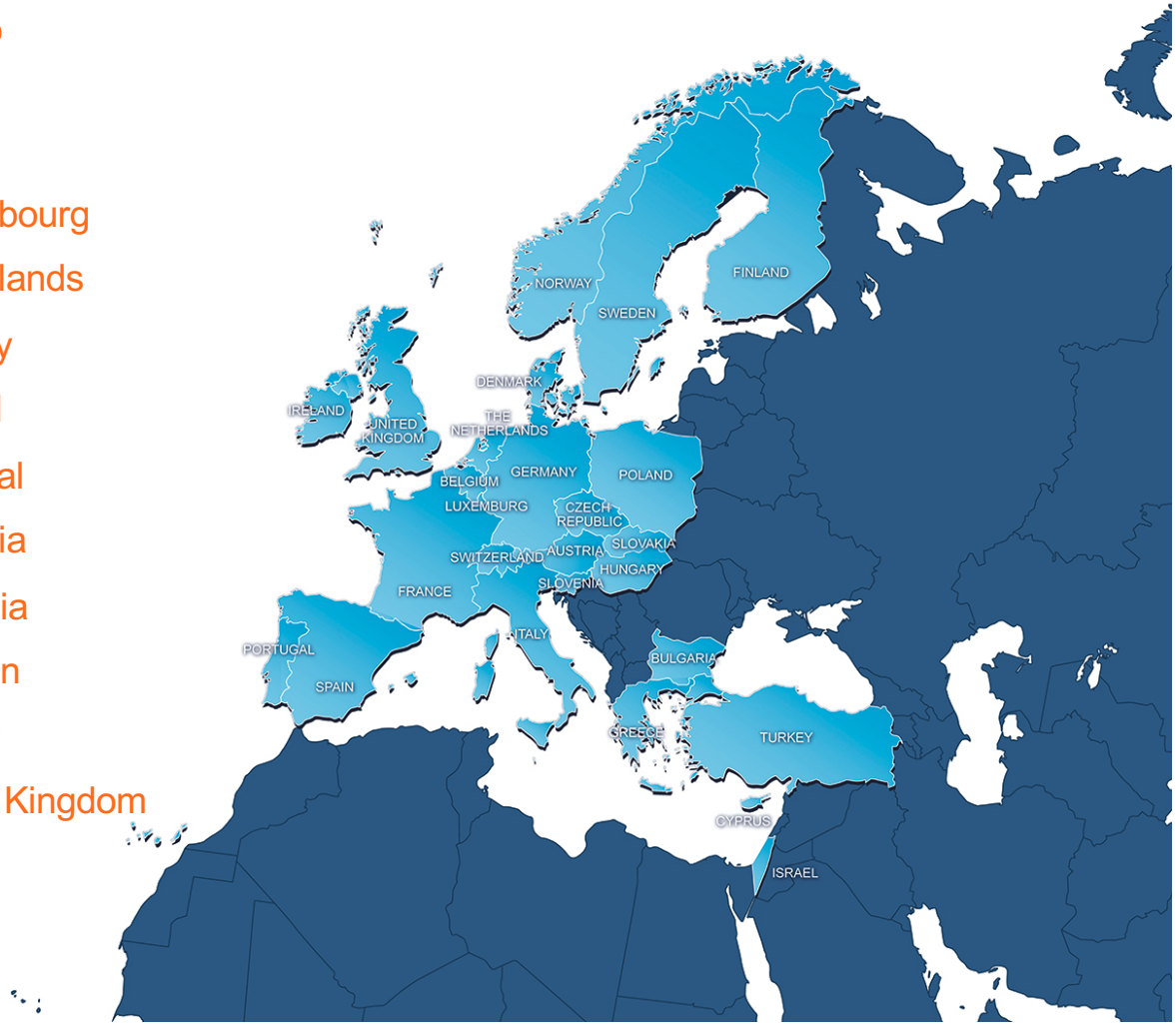
- Croatia
- Romania



PRACE | what we do

- Open access to world-class HPC systems to EU scientists and researchers
- Variety of architectures to support the different scientific communities
- High standards in computational science and engineering
- Peer Review at European level to foster scientific excellence
- Robust and persistent funding scheme for HPC supported by national governments and European Commission (EC)
- Support the development of intellectual property rights (IPR) in Europe by working with industry and public services
- Collaborate with European HPC industrial users and suppliers
- PRACE Ada Lovelace Award For HPC 2021- Nominations Are Now Open
- https://prace-ri.eu/nominations-are-now-open-for-prace-ada-lovelace-award-for-hpc-2021/

PRACE | Tier-0 Systems in 2020

MareNostrum: IBM
BSC, Barcelona, Spain
#38 Top 500

Piz Daint: Cray XC50
CSCS, Lugano, Switzerland
#10 Top 500

SuperMUC NG : Lenovo cluster GAUSS @ LRZ, Garching, Germany #13 Top 500

JUWELS (Module 1):
Atos/Bull Sequana
GAUSS @ FZJ, Jülich, Germany #39 Top 500

NEW ENTRY 2020
#7 in Top500 & #3 in Green 500 (Nov. 2020)
JUWELS Booster

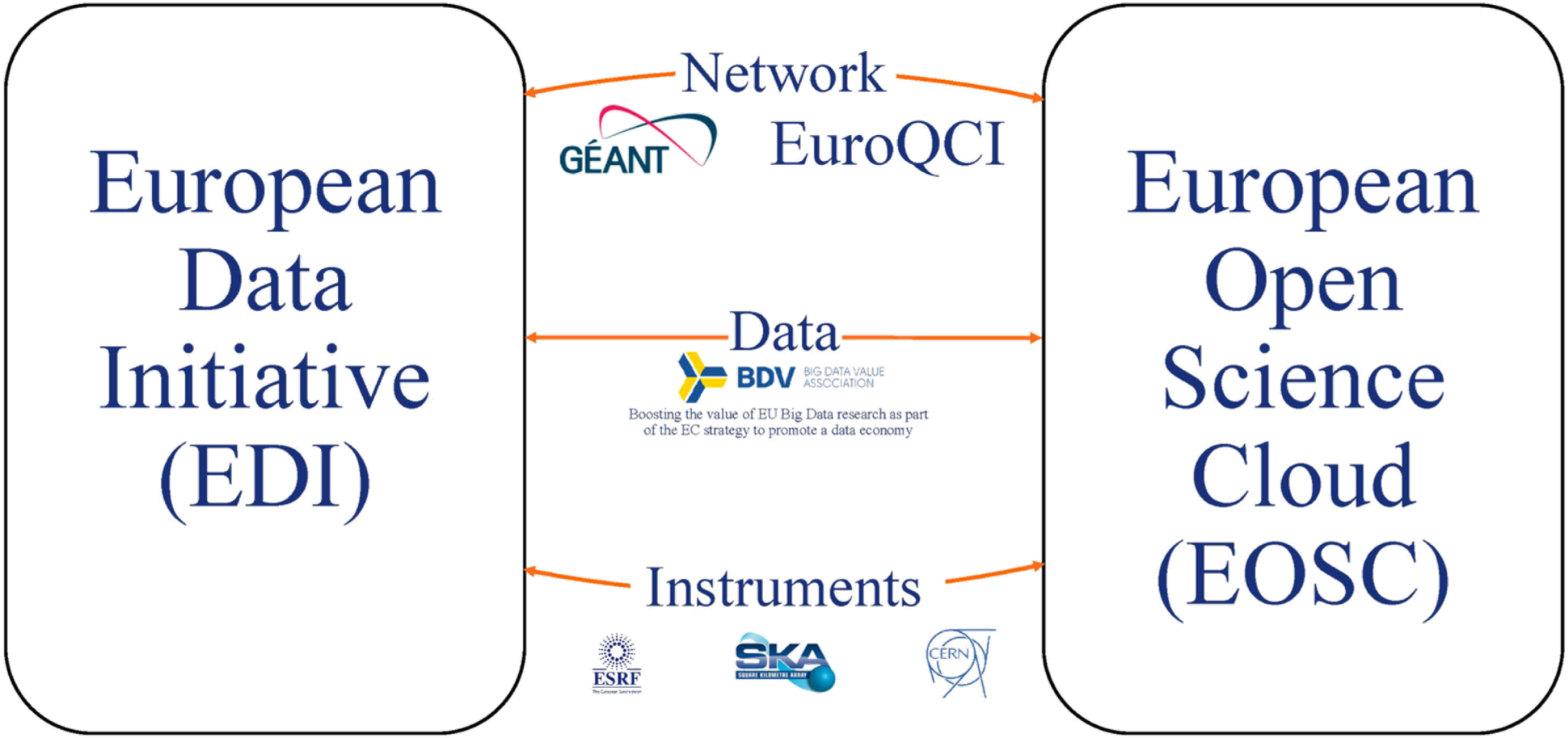
NEW ENTRY 2018
JOLIOT CURIE : Atos/Bull Sequana X1000; GENCI @ CEA, Bruyères-le-Châtel, France #34 Top 500

MARCONI-100: IBM
CINECA, Bologna, Italy
#9 Top 500

NEW ENTRY 2020
HAWK: HPE Apollo
GAUSS @ HLRS, Stuttgart, Germany

More than 220
Petaflops of peak performance

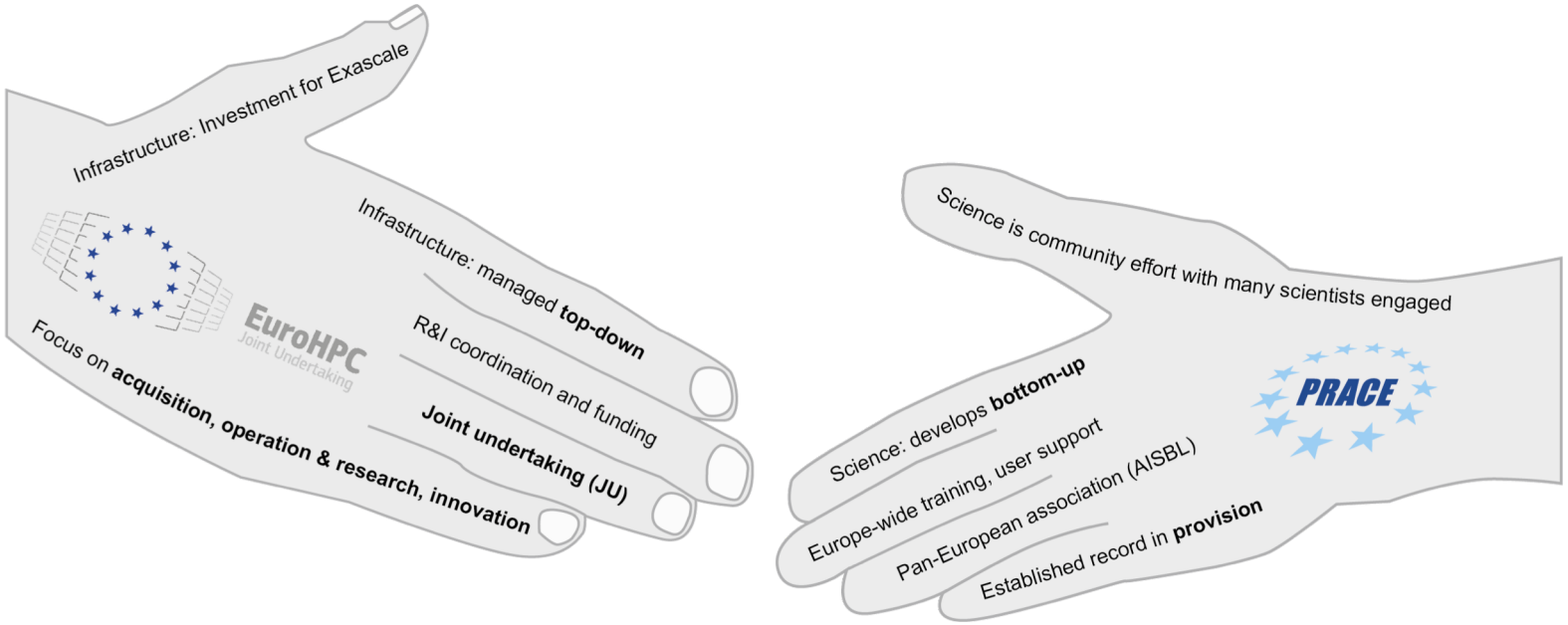
European Cloud Initiative



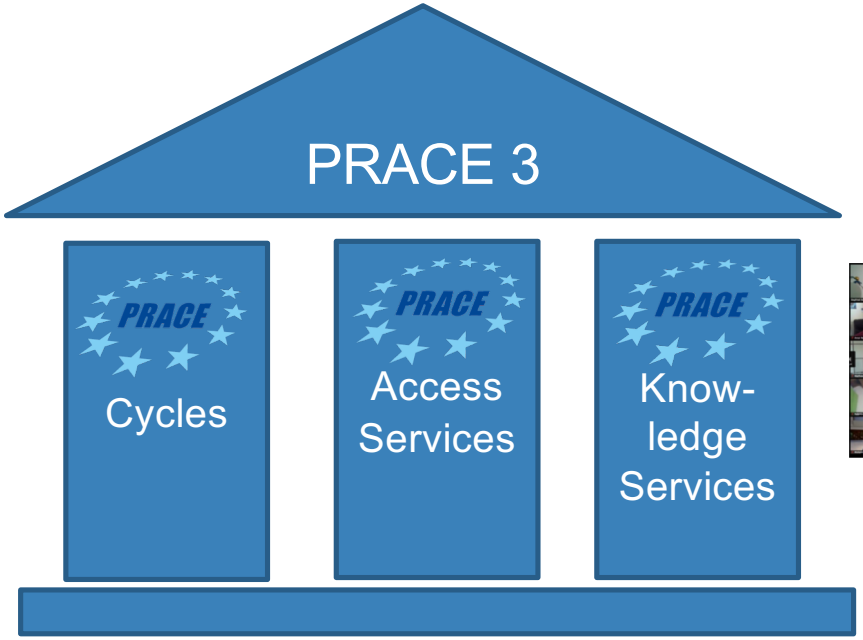
Enhancing European Science, Economy and Society

PRACE | in the EuroHPC era

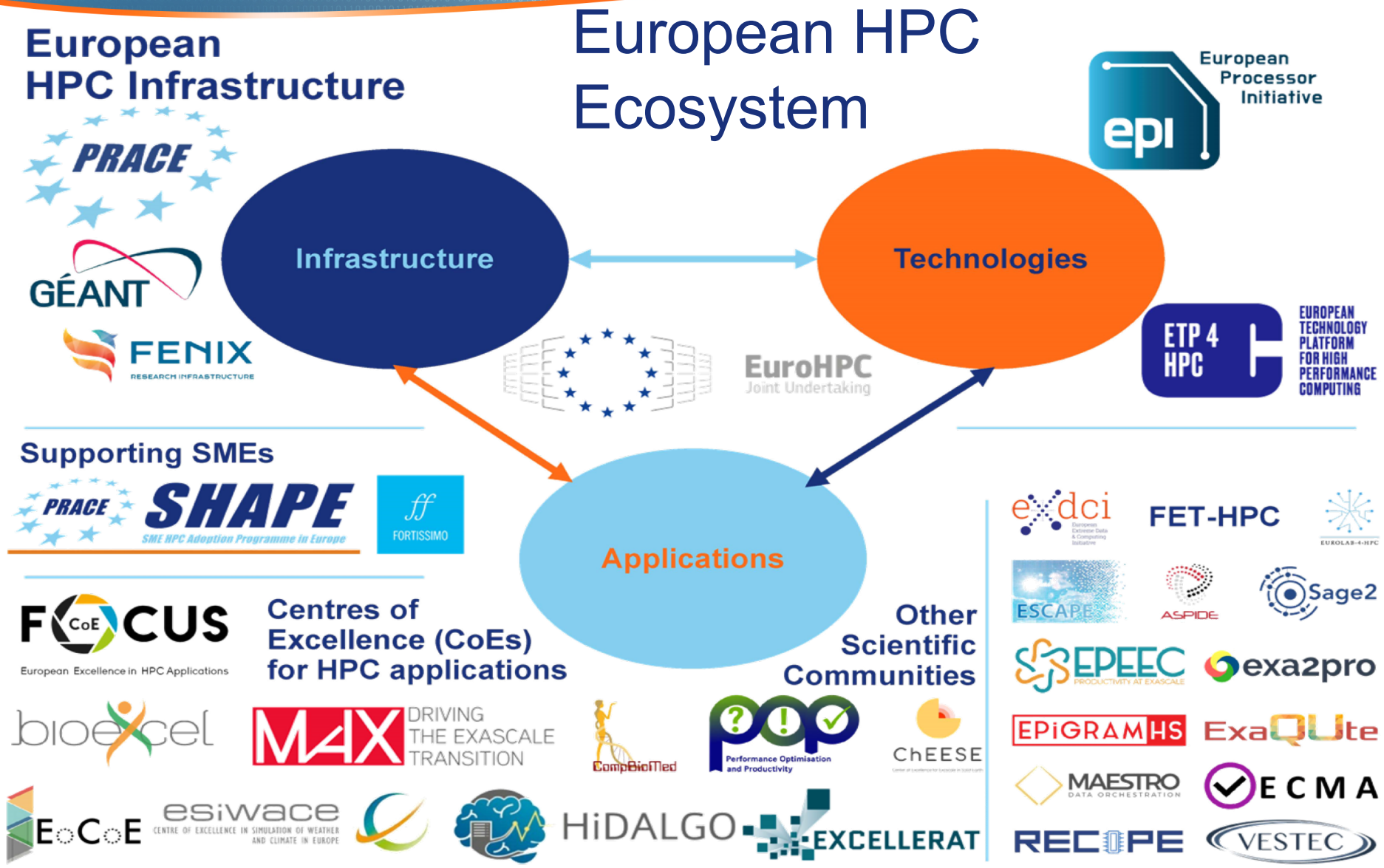
- PRACE position paper **PRACE in the EuroHPC era** published (Jan 2019)
  - Offer to provide processes and activities as a partner of EuroHPC
  - Future Services towards EDI: Data, Industry, GÉANT, new HPC services



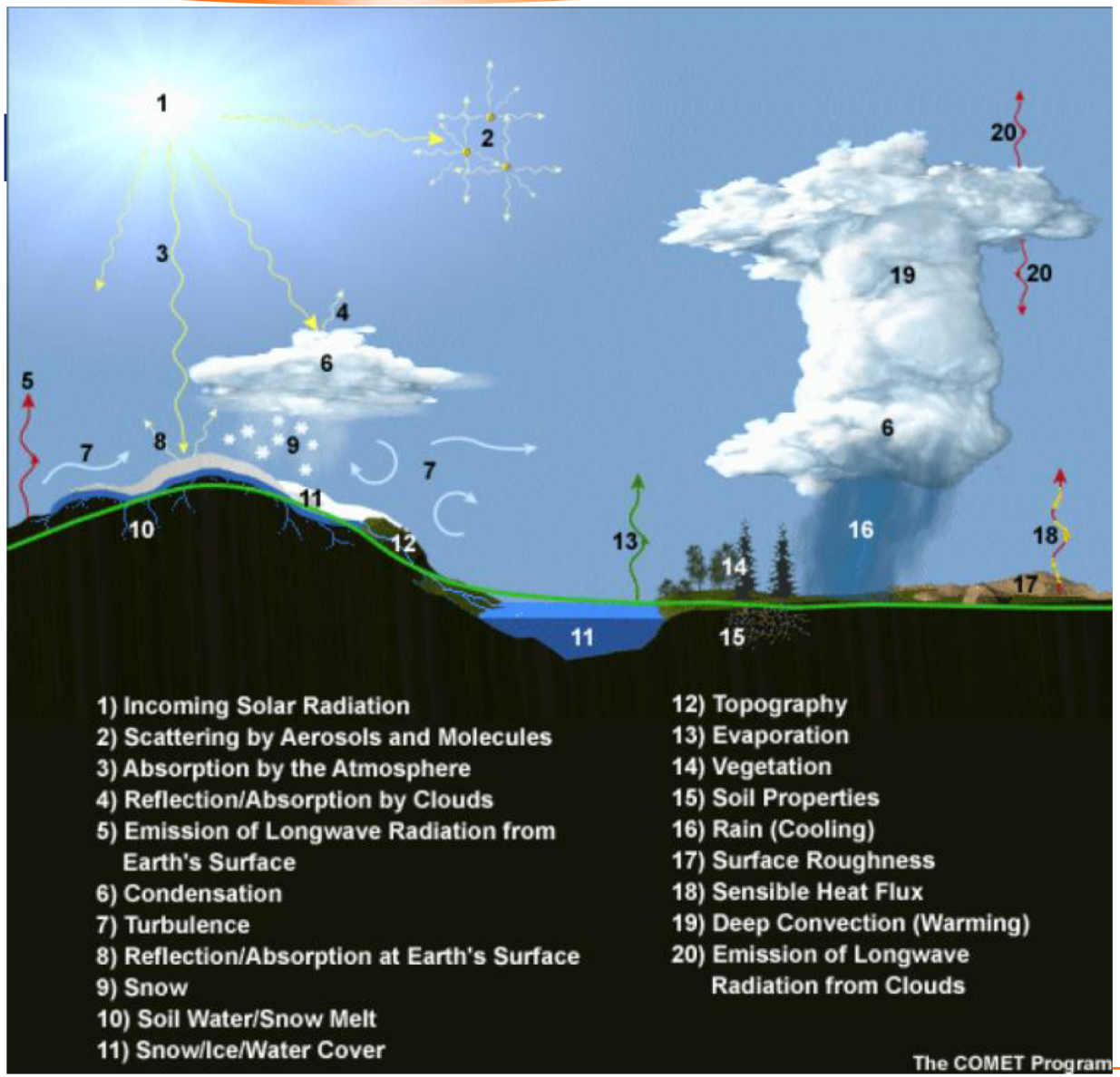
PRACE 3 | 3 Basic Pillars

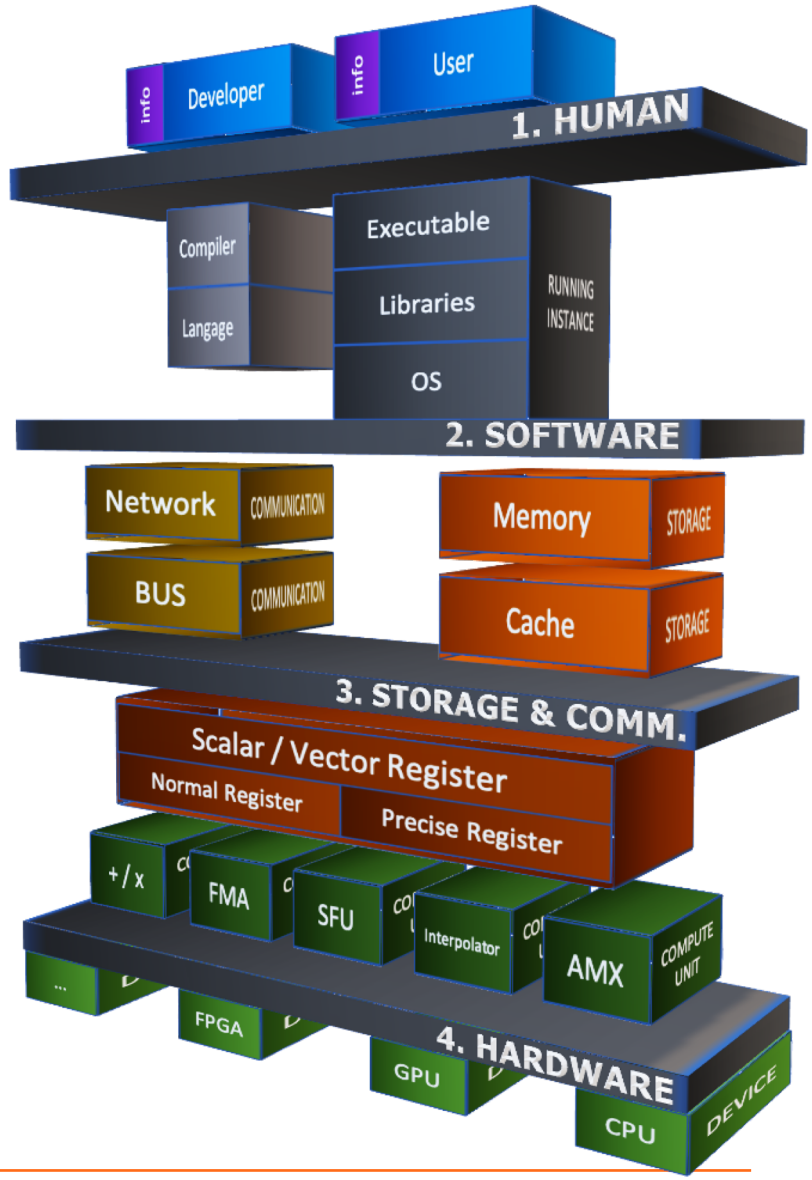


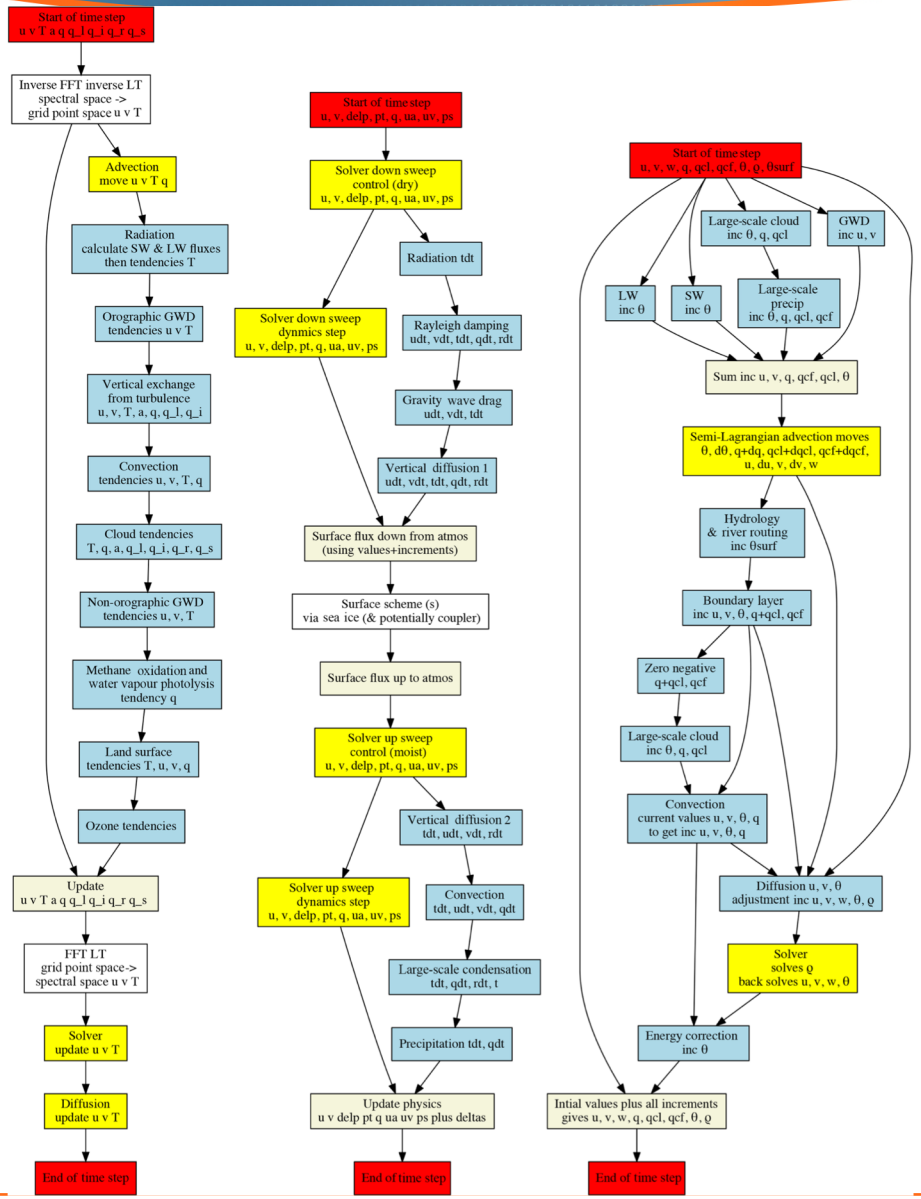
European HPC Ecosystem



The big picture | sustainable goals


1) Incoming Solar Radiation
2) Scattering by Aerosols and Molecules
3) Absorption by the Atmosphere
4) Reflection/Absorption by Clouds
5) Emission of Longwave Radiation from Earth's Surface
6) Condensation
7) Turbulence
8) Reflection/Absorption at Earth's Surface
9) Snow
10) Soil Water/Snow Melt
11) Snow/Ice/Water Cover
12) Topography
13) Evaporation
14) Vegetation
15) Soil Properties
16) Rain (Cooling)
17) Surface Roughness
18) Sensible Heat Flux
19) Deep Convection (Warming)
20) Emission of Longwave Radiation from Clouds
The COMET Program


info
Developer
info
User
1. HUMAN
Compiler
Langage
Executable
Libraries
OS
RUNNING INSTANCE
2. SOFTWARE
Network
COMMUNICATION
BUS
COMMUNICATION
Memory
STORAGE
Cache
STORAGE
3. STORAGE & COMM.
Scalar / Vector Register
Normal Register
Precise Register
+ / x
FMA
SFU
Interpolator
AMX
COMPUTE UNIT
FPGA
GPU
CPU
DEVICE
4. HARDWARE


Start of time step
u v T a q q_l q_i q_r q_s
Inverse FFT inverse LT
spectral space ->
grid point space u v T
Advection
move u v T q
Radiation
calculate SW & LW fluxes
then tendencies T
Orographic GWD
tendencies u v T
Vertical exchange
from turbulence
u, v, T, a, q, q_l, q_i
Convection
tendencies u, v, T, q
Cloud tendencies
T, q, a, q_l, q_i, q_r, q_s
Non-orographic GWD
tendencies u, v, T
Methane oxidation and
water vapour photolysis
tendency q
Land surface
tendencies T, u, v, q
Ozone tendencies
Update
u v T a q q_l q_i q_r q_s
FFT LT
grid point space->
spectral space u v T
Solver
update u v T
Diffusion
update u v T
End of time step
Start of time step
u, v, delp, pt, q, ua, uv, ps
Solver down sweep
control (dry)
u, v, delp, pt, q, ua, uv, ps
Radiation tdt
Solver down sweep
dynmics step
u, v, delp, pt, q, ua, uv, ps
Rayleigh damping
udt, vdt, tdt, qdt, rdt
Gravity wave drag
udt, vdt, tdt
Vertical diffusion 1
udt, vdt, tdt, qdt, rdt
Surface flux down from atmos
(using values+increments)
Surface scheme (s)
via sea ice (& potentially coupler)
Surface flux up to atmos
Solver up sweep
control (moist)
u, v, delp, pt, q, ua, uv, ps
Vertical diffusion 2
tdt, udt, vdt, rdt
Solver up sweep
dynamics step
u, v, delp, pt, q, ua, uv, ps
Convection
tdt, udt, vdt, qdt
Large-scale condensation
tdt, qdt, rdt, t
Precipitation tdt, qdt
Update physics
u v delp pt q ua uv ps plus deltas
End of time step
Start of time step
u, v, w, q, qcl, qcf, θ, ϱ, θsurf
Large-scale cloud
inc θ, q, qcl
GWD
inc u, v
LW
inc θ
SW
inc θ
Large-scale
precip
inc θ, q, qcl, qcf
Sum inc u, v, q, qcf, qcl, θ
Semi-Lagrangian advection moves
θ, dθ, q+dq, qcl+dqcl, qcf+dqcf,
u, du, v, dv, w
Hydrology
& river routing
inc θsurf
Boundary layer
inc u, v, θ, q+qcl, qcf
Zero negative
q+qcl, qcf
Large-scale cloud
inc θ, q, qcl
Convection
current values u, v, θ, q
to get inc u, v, θ, q
Diffusion u, v, θ
adjustment inc u, v, w, θ, ϱ
Solver
solves ϱ
back solves u, v, w, θ
Energy correction
inc θ
Intial values plus all increments
gives u, v, w, q, qcl, qcf, θ, ϱ
End of time step


BOX TS.1, FIGURE 1
FIGURE TS.1
FIGURE TS.2
FIGURE TS.3
TFE.1, FIGURE 1
TFE.1, FIGURE 2
TFE.1, FIGURE 3
TFE.2, FIGURE 1
TFE.2, FIGURE 2
FIGURE TS.4
FIGURE TS.5
FIGURE TS.6
FIGURE TS.7
FIGURE TS.8
FIGURE TS.9
BOX TS.3, FIGURE 1
TFE.3, FIGURE 1
FIGURE TS.10
TFE.4, FIGURE 1
TFE.5, FIGURE 1
FIGURE TS.11
FIGURE TS.12
BOX TS.4, FIGURE 1
BOX TS.5, FIGURE 1
BOX TS.6, FIGURE 1
TFE.6, FIGURE 1
TFE.6, FIGURE 2
FIGURE TS.13
FIGURE TS.14
FIGURE TS.15
FIGURE TS.16
FIGURE TS.17
FIGURE TS.18
FIGURE TS.19
FIGURE TS.20
TFE.7, FIGURE 1
TFE.7, FIGURE 2
FIGURE TS.21
FIGURE TS.22
FIGURE TS.23
TFE.8, FIGURE 1
FIGURE TS.24
FIGURE TS.25
FIGURE TS.26
TFE.9, FIGURE 1

In 2010 world Data Center electricity use

- 450 billion kWh (equivalent to France)

Forecast in 2020 :

- 1031 billion kWh (equivalent to France + Germany + Canada + Brasil)

And a major carbon footprint

- 2002 : Global Data Center carbon footprint = 76 MtCO2e
- Forecast in 2020
  - ✓ 259 MtCO2e (best case with use of virtualisation and free cooling)
  - ✓ 533 MtCO2e (worst case)*

ICT global carbon footprint and localisation (data center=20%)

	Emissions 2007 $MtCO_2e$	Percentage 2007	Emissions 2020 $MtCO_2e$	Percentage 2020
World	820	100%	1430	100%
US and Canada	156	19%	215	15%
OECD Europe	115	14%	172	12%
Other developed countries	82	10%	100	7%
Economies in transition	98	12%	143	10%
China	189	23%	415	29%
Rest of the world	180	22%	386	27%

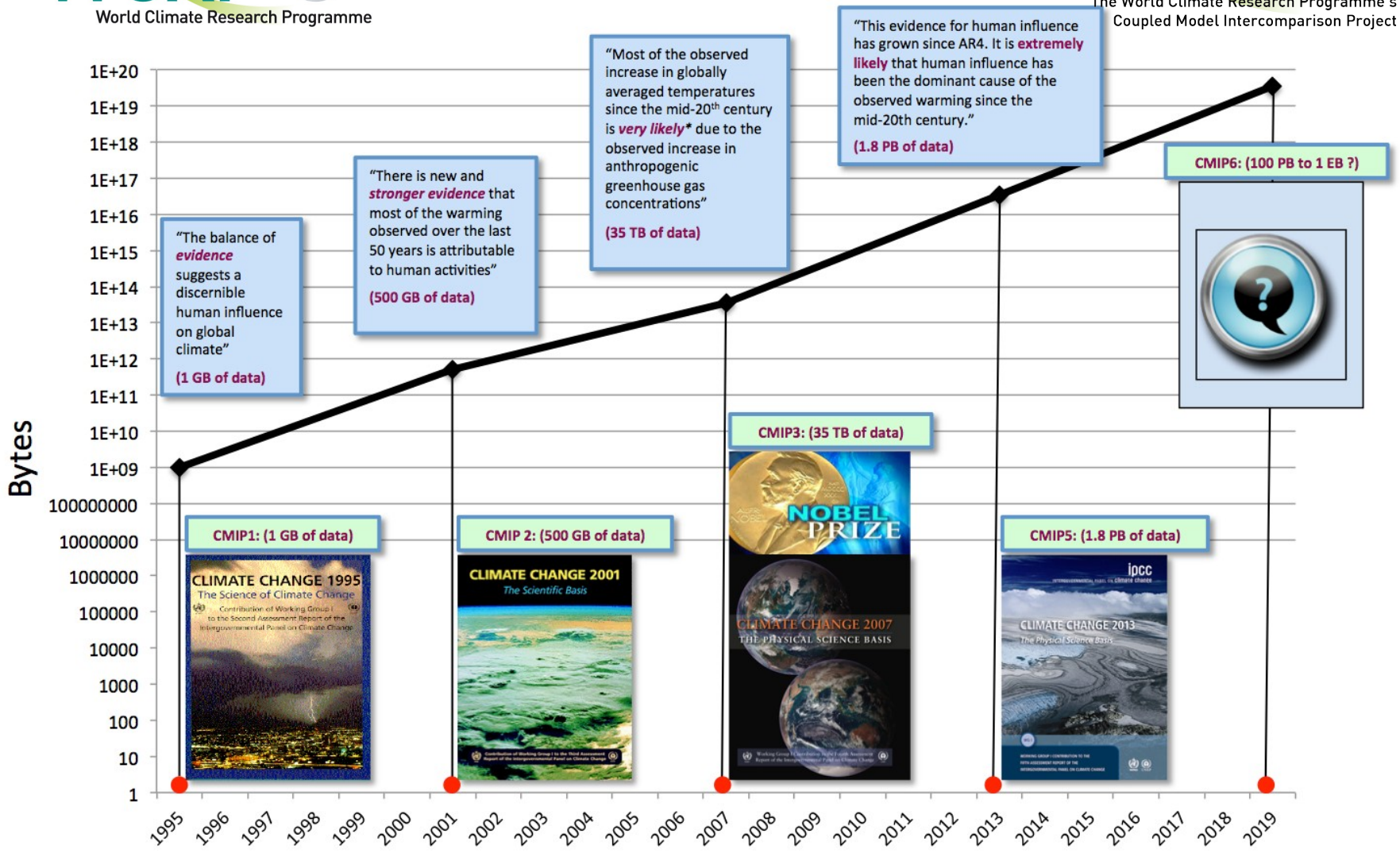
Source = SMART Global 2020
Make IT Green – Cloud Computing and its Contribution to Climate Change and International Energy Agency

Climate Sciences Programs

Institut Pierre Simon Laplace – Sciences de l'environnement

WCRP World Climate Research Programme

CMIP The World Climate Research Programme's Coupled Model Intercomparison Project



FAR SAR TAR AR4 AR5 SR15 MR AR6

IPCC – jointly established by **WMO and UNEP**

UNFCCC

Kyoto Protocol

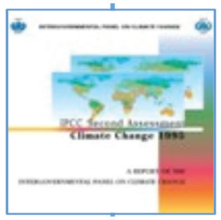
Adaptation

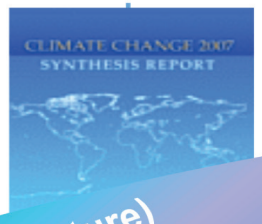
2 °C limit

Paris Agreement

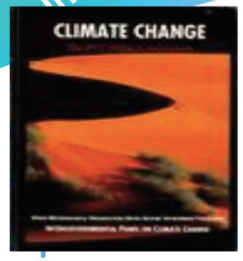
SROCC
SRCCL

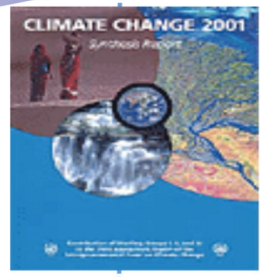
UNFCCC Global Stocktake



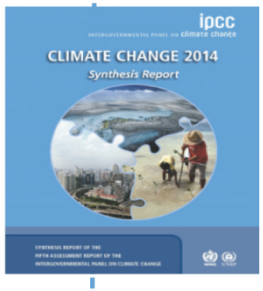


Science of climate change (peer-reviewed literature)
Growing public awareness
Involvement of various actors



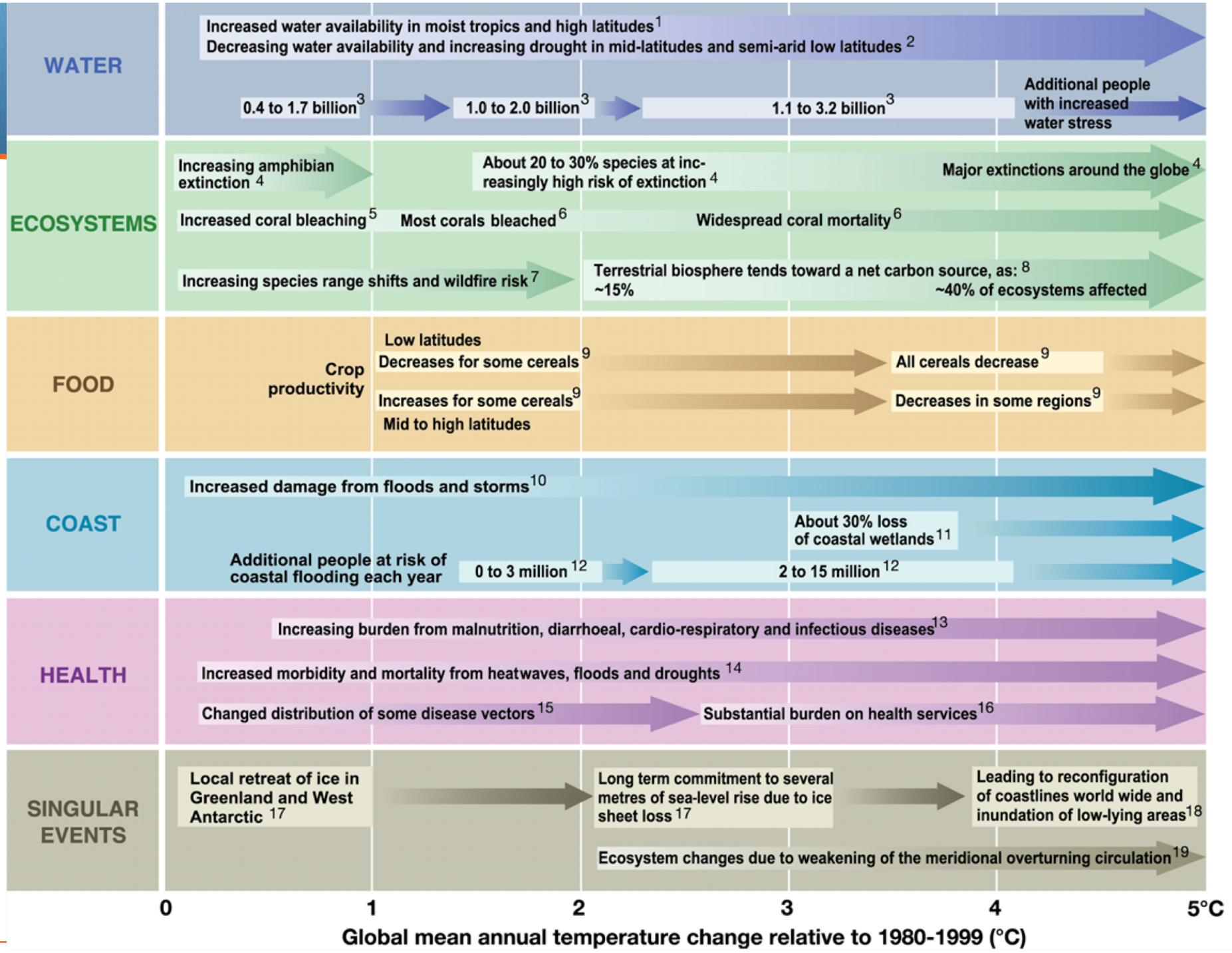


Nobel Peace Prize



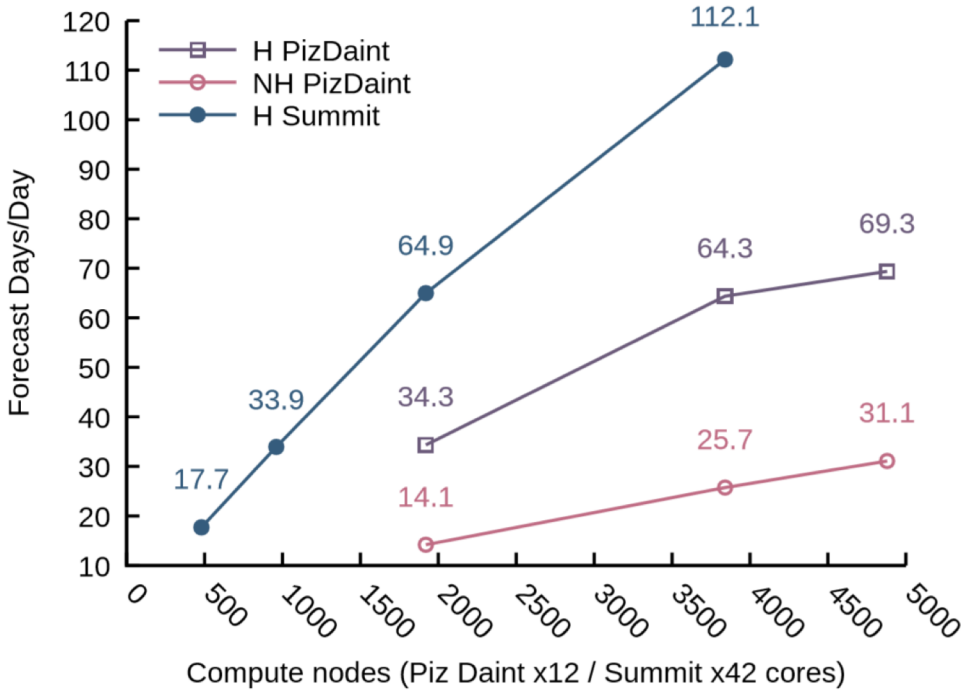
1988 1995 2007 2018 2019 2023

1970s-1980s 1990 2001 2013/2014 2016-2022

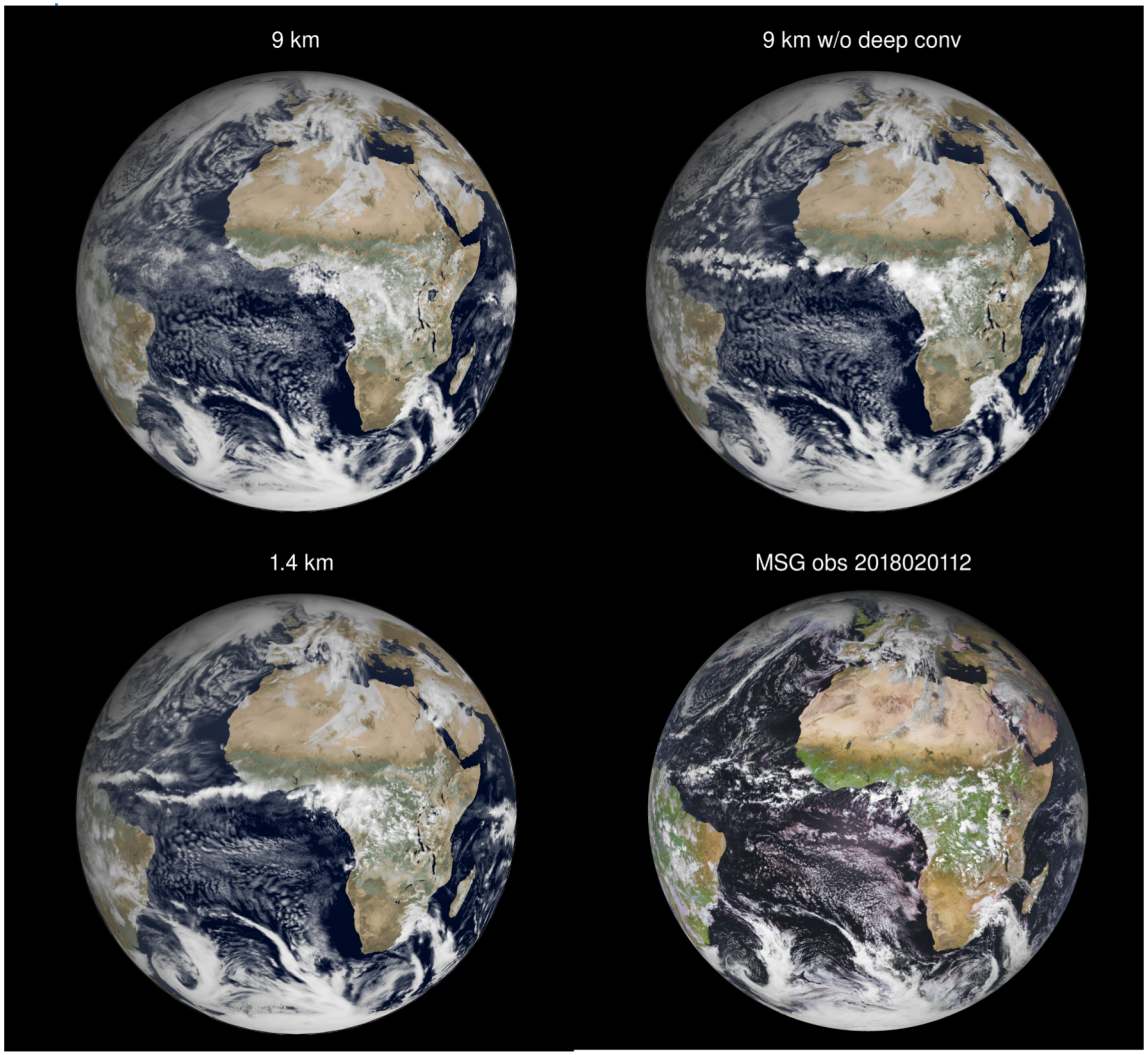

WATER
Increased water availability in moist tropics and high latitudes 1
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes 2
0.4 to 1.7 billion 3
1.0 to 2.0 billion 3
1.1 to 3.2 billion 3
Additional people with increased water stress
ECOSYSTEMS
Increasing amphibian extinction 4
About 20 to 30% species at increasingly high risk of extinction 4
Major extinctions around the globe 4
Increased coral bleaching 5
Most corals bleached 6
Widespread coral mortality 6
Increasing species range shifts and wildfire risk 7
Terrestrial biosphere tends toward a net carbon source, as: 8
~15%
~40% of ecosystems affected
FOOD
Crop productivity
Low latitudes
Decreases for some cereals 9
All cereals decrease 9
Increases for some cereals 9
Mid to high latitudes
Decreases in some regions 9
COAST
Increased damage from floods and storms 10
About 30% loss of coastal wetlands 11
Additional people at risk of coastal flooding each year
0 to 3 million 12
2 to 15 million 12
HEALTH
Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases 13
Increased morbidity and mortality from heatwaves, floods and droughts 14
Changed distribution of some disease vectors 15
Substantial burden on health services 16
SINGULAR EVENTS
Local retreat of ice in Greenland and West Antarctic 17
Long term commitment to several metres of sea-level rise due to ice sheet loss 17
Leading to reconfiguration of coastlines world wide and inundation of low-lying areas 18
Ecosystem changes due to weakening of the meridional overturning circulation 19
0
1
2
3
4
5°C
Global mean annual temperature change relative to 1980-1999 (°C)

Turing test passed

Scalability for 62 vertical levels and without GPUs:



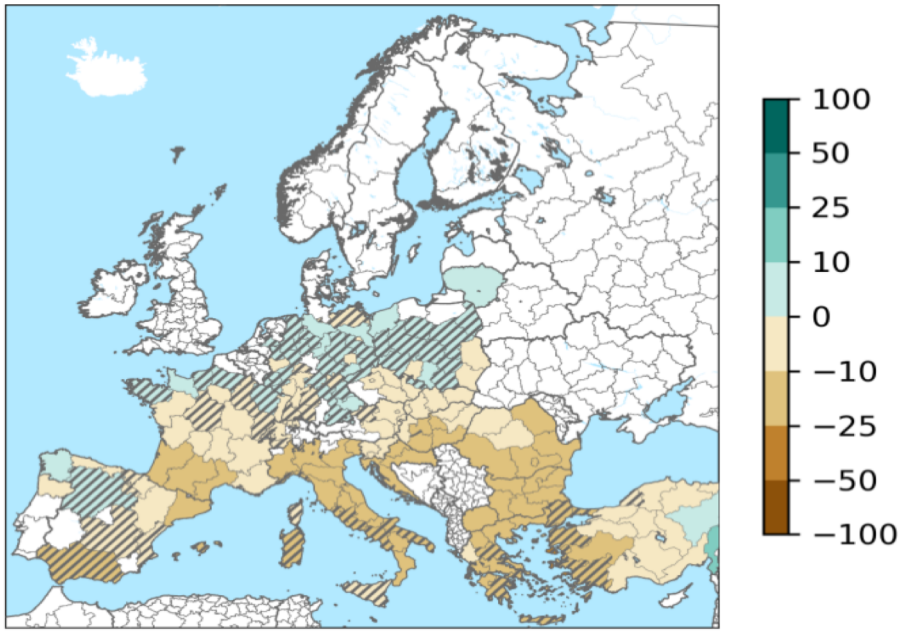
Summit is equipped with about 4600 liquid cooled nodes, each with 2 IBM Power9 (21 core) processors and 6 NVIDIA Volta100 GPUs.



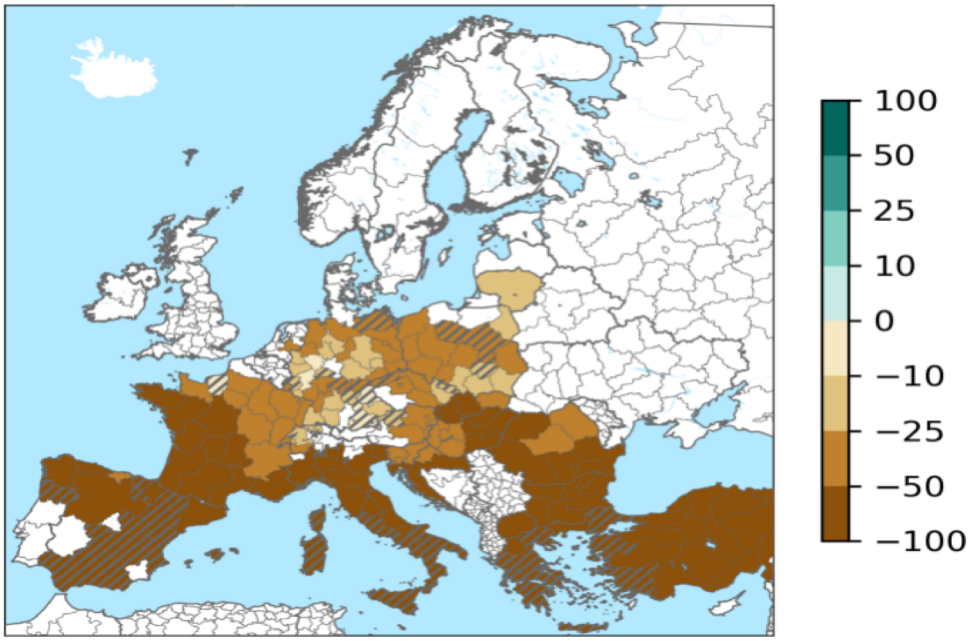
Climate change impact assessment on EU grain maize production potential (PESETA4)

- RCP8.5 2021-2050 vs 1981-2010 % yield change.
- 10 crops- example for grain maize.
- Water availability will be critical for growing maize in Southern Europe.

Graine maize- assuming irrigated conditions

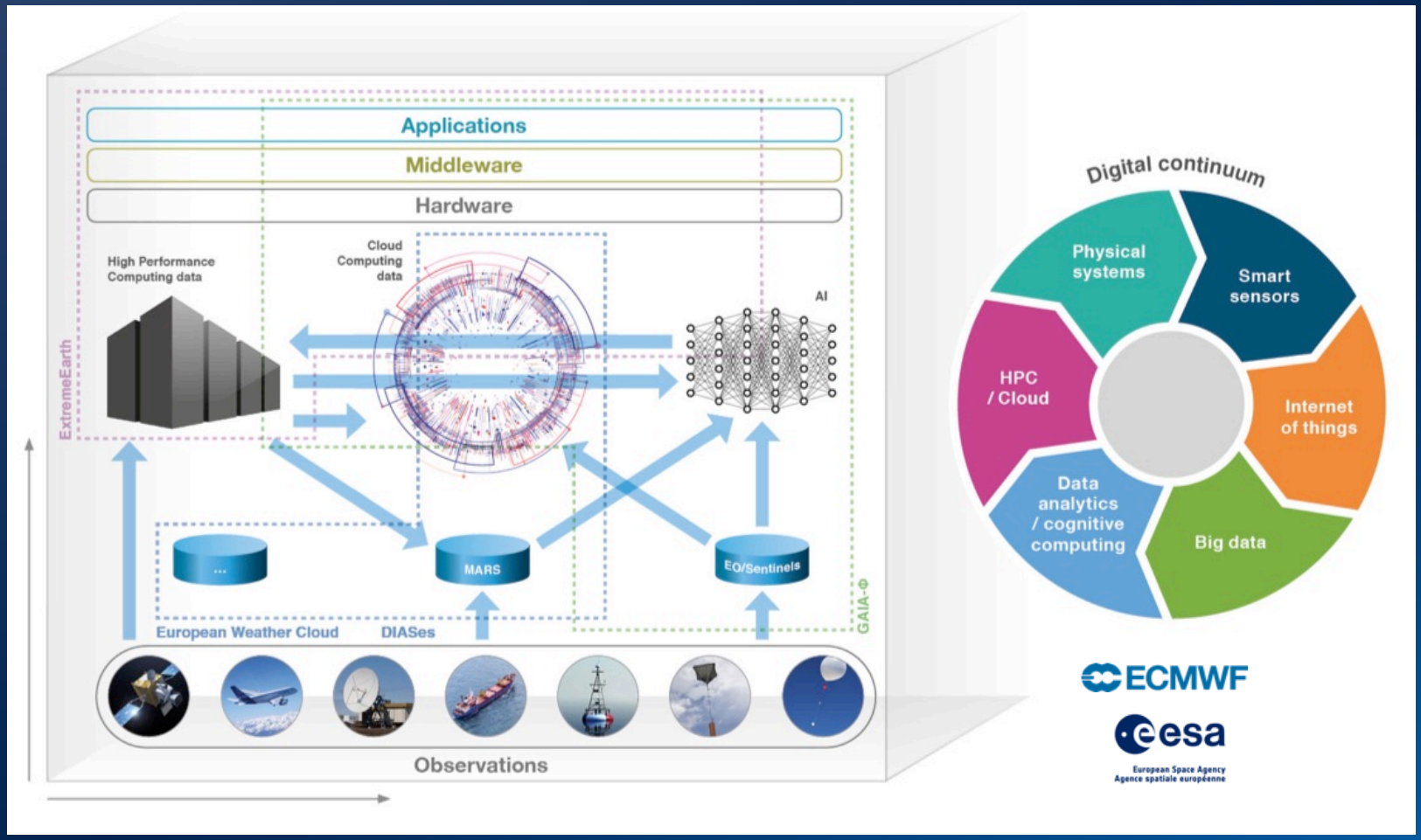


Graine maize- assuming rain-fed only conditions



A Digital Twin Earth HPC/Cloud Scenario

esa



European Space Agency

Assets, Competencies and Objectives

esa

ESA

- Earth Explorers and Third-Party Missions
- Copernicus Infrastructure and Operations for COM
- Platforms and Applications / DIAS
- Expansion of future EO Data Management and Operations

ESA and ECMWF

Moving forward together towards planetary-scale analytics, simulation, and modelling

= Digital Twin Earth

→ need for additional infrastructure to support common vision

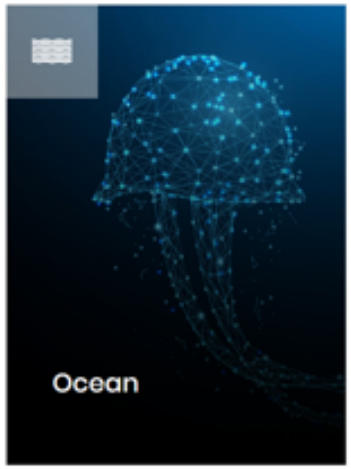
PHIDIAS
Prototype of HPC/Data Infrastructure for On-demand Services

- Connecting Europe Facilities PHIDIAS:
- Prototype of HPC / Data Infrastructure for On-Demand Services

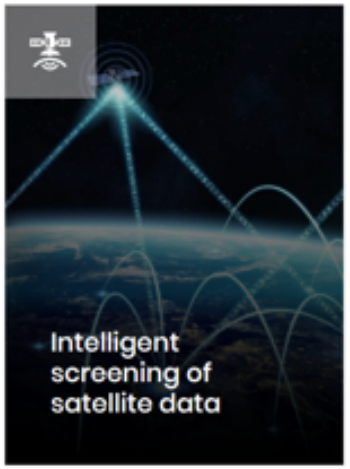
PHIDIAS goal is to build **a prototype for Data/High Performance Computing (HPC) services based on Earth sciences Satellite Data use cases**

PHIDIAS Goals

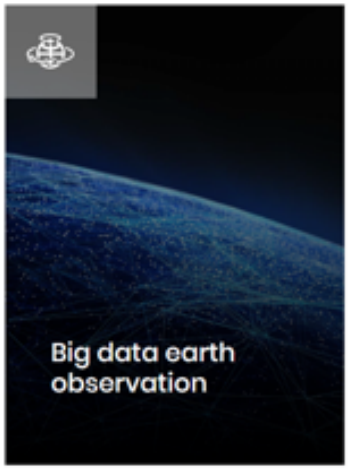
- Building a prototype for earth sciences satellite open data and HPC services
- Optimising and industrialising treatment workflows for extensive reusability
- Ensuring open access to standardised HPC services
- Improving FAIRisation processes, cross-use and open access
- Developing new data-processing models coupled with HPC capabilities
- Deploying data-processing methods as a service for scientific communities, public authorities, private entities and citizen science



Improve the use of numerical services for marine data management, service and processing, considering EOSC challenge and the DIAS



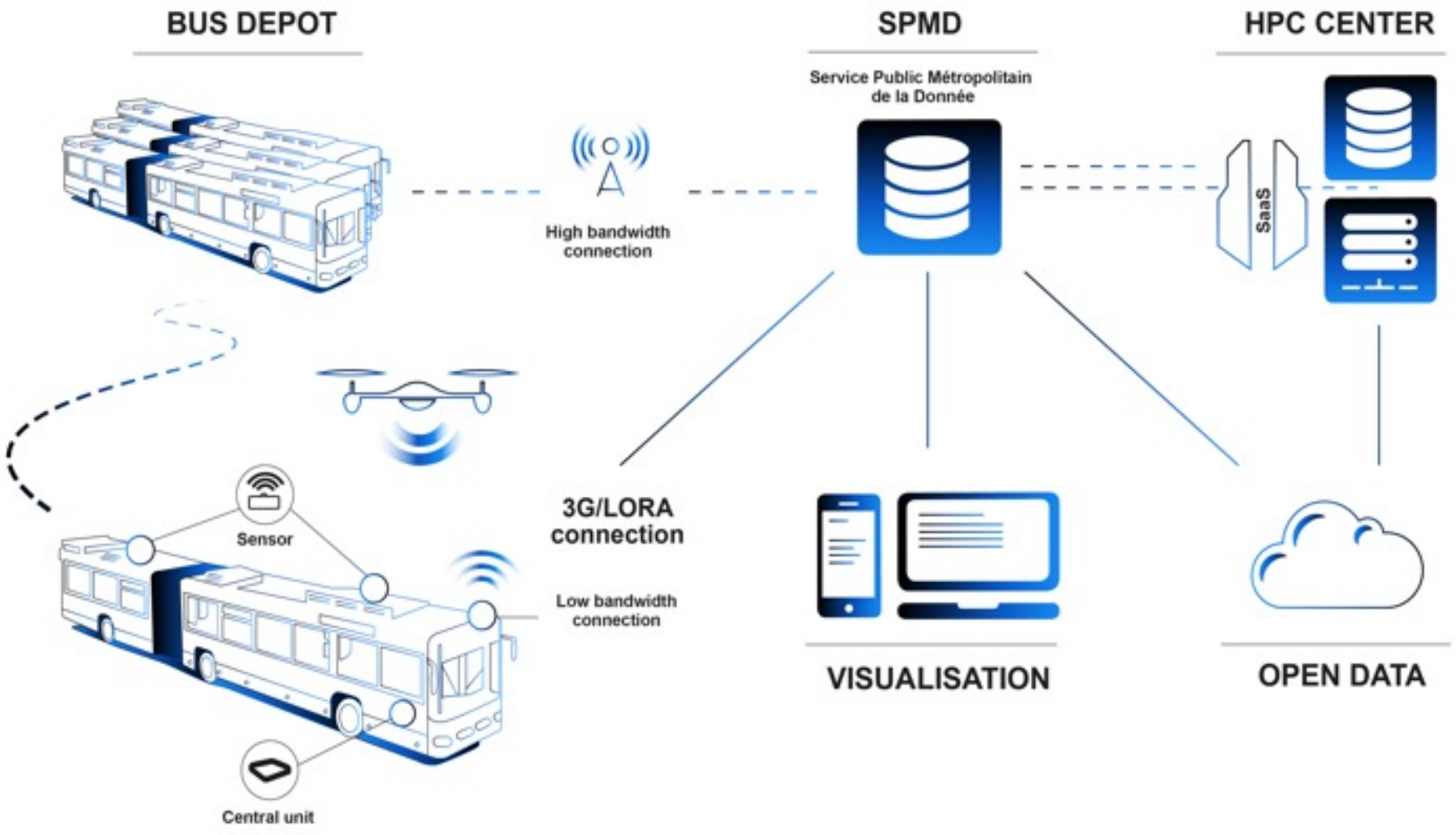
Improve efficiency and genericity of the intelligent screening of environmental satellite data



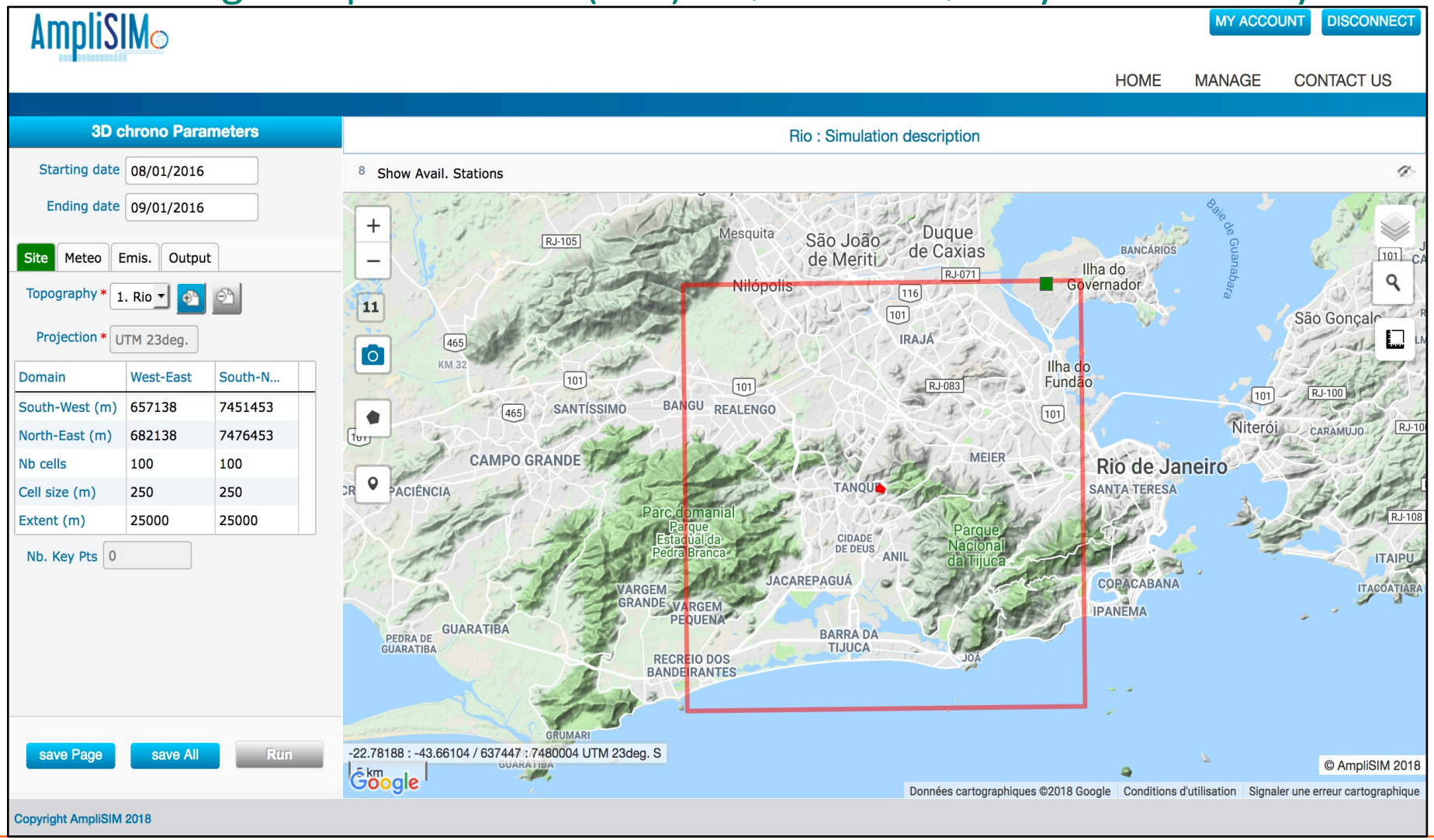
Enhance EO data processing chains scalability for environmental monitoring from the end-users needs of THEIA land data centre network

Enabling HPC and data capacities of the European Data Infrastructure for Scientists & Researchers

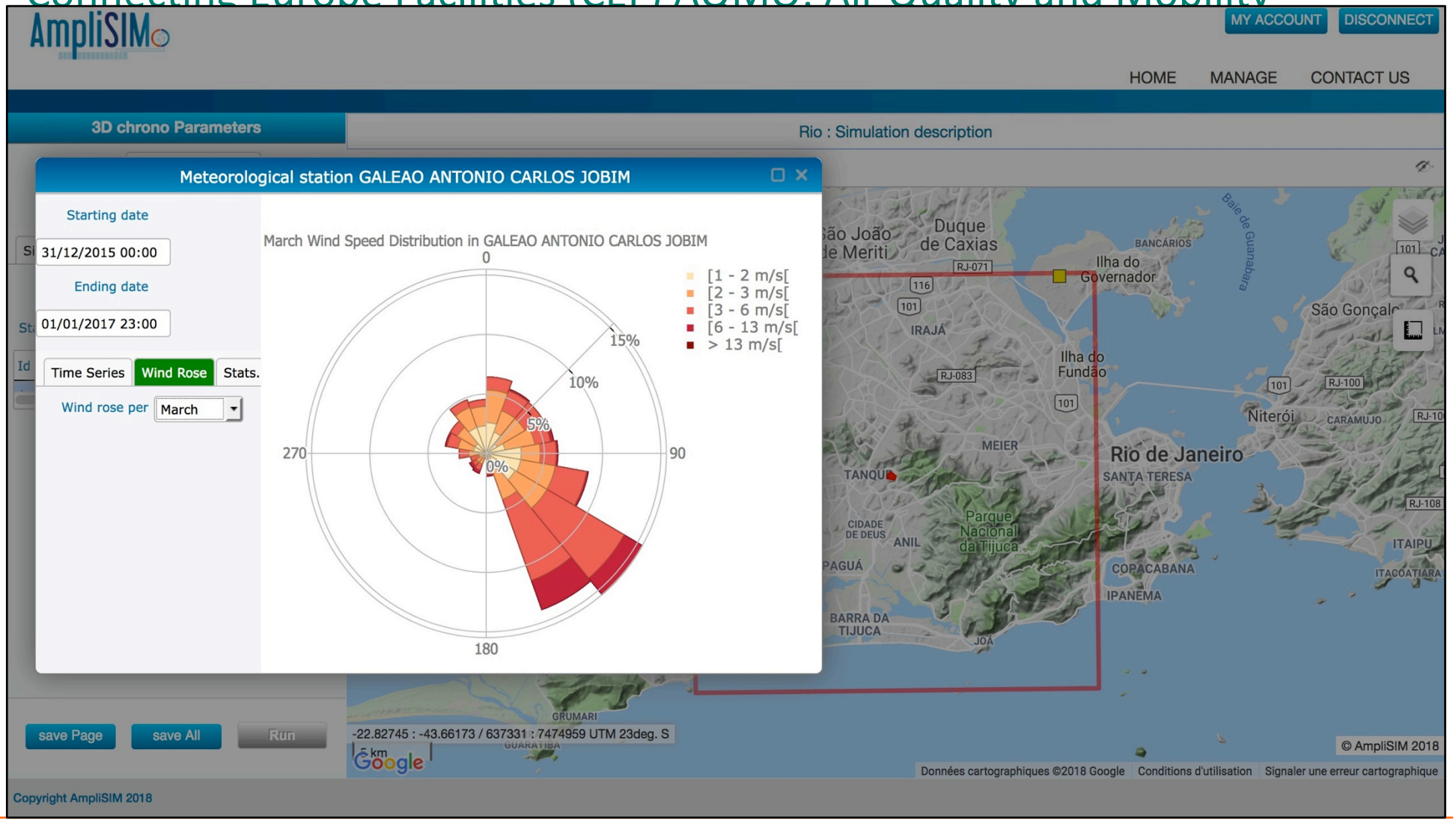
Connecting Europe Facilities (CEF) AQMO: Air Quality and Mobility



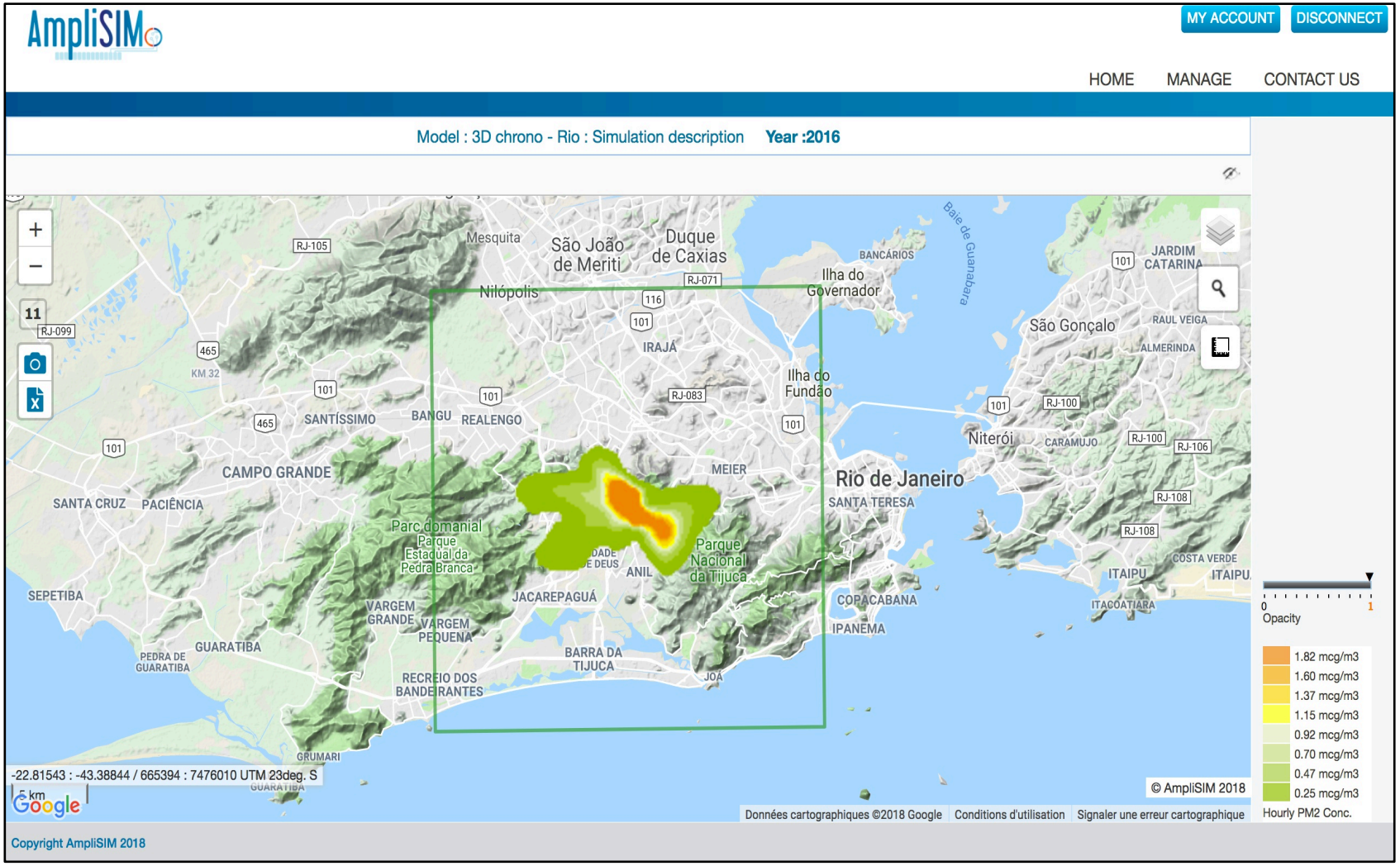
Connecting Europe Facilities (CEF) AQMO: Air Quality and Mobility



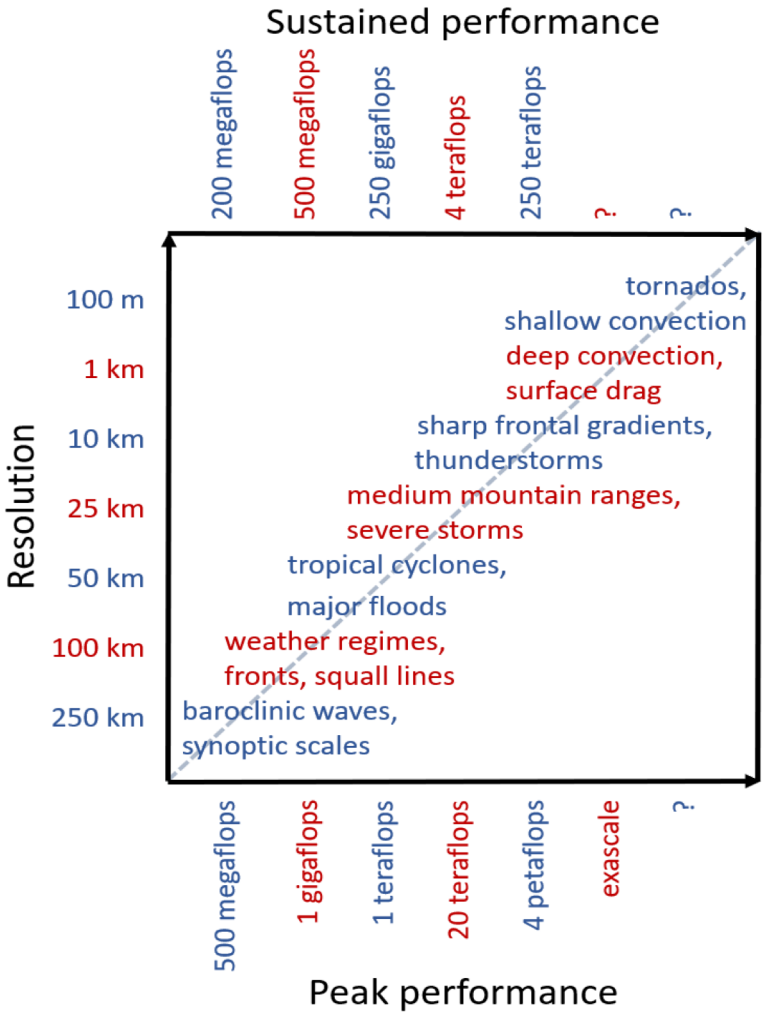
Connecting Europe Facilities (CEF) AQMO: Air Quality and Mobility



Connecting Europe Facilities (CEF) AQMO: Air Quality and Mobility



- Research in climate, weather and Earth sciences requires next-generation computational resources, along with new types of infrastructure capable of handling, analysing and disseminating vast amounts of data either measured or generated from simulations.
- The societal and financial impact of such research is immense and goes far beyond the cost of the infrastructure: computational models are critical to reducing the impact of climate change by finding the most appropriate and cost-efficient counter-actions, and better weather forecasting is of paramount importance e.g. in agriculture.
- The software in the field is diverse, and ranges from legacy codes in urgent need of modernisation and improved scaling to state-of-the-art GPU-accelerated extremely parallel programmes. However, both require continued investments to maintain, port, and optimise in addition to implementation of new algorithms.
- In addition to a few codes with exceptional scaling, there is an acute need for resources to enable large ensembles of independent runs with different parameters to quantify the uncertainty in models. The field will easily be able to use exascale computing, provided future infrastructure is organised to handle this type of ensemble simulation.



Adapted from Neumann, Dueben et al. Phil Trans A 2018

- Weather and climate simulations are HPC applications
- Quality depends on model resolution and model complexity
- Resolution depends on the performance of state-of-the-art supercomputers
- Hardware will be more heterogeneous
  → CPUs / GPUs / FPGAs / ASICs / (Quantum ?)
- We need more ensemble for Forecast and Climate
- We need longer simulation for Forecast and Climate
- Performance (energy consumption) will matter ever more
- Programability will matter ever more
- Usability will matter ever more
- This will not be smooth painless transition…

Strong need for skills to build Exascale systems
Strong need for skills to operate Exascale systems
Strong need for skills to use Exascale systems
Strong need for skills to translate Exascale systems (DT)
Strong need for skills to use/understand derivate Digital Twins
Strong need for basic science skills for policy maker
Strong need to believe what we know and act on it…


THANK YOU FOR YOUR ATTENTION
www.prace-ri.eu