Expectations towards Exascale: Weather and Climate Prediction

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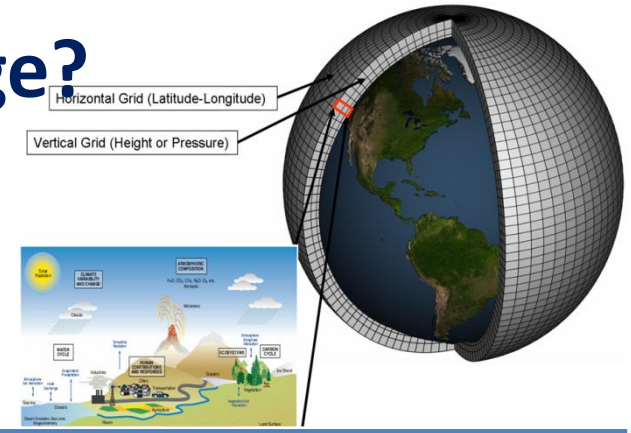
supported by 34 member
and cooperating states

What is the challenge?



Today:

	Observations	Models
Volume	20 million = **2 x 10^7**	5 million grid points 100 levels 10 prognostic variables = **5 x 10^9**
Type	98% from 60 different satellite instruments	physical parameters of atmosphere, waves, ocean

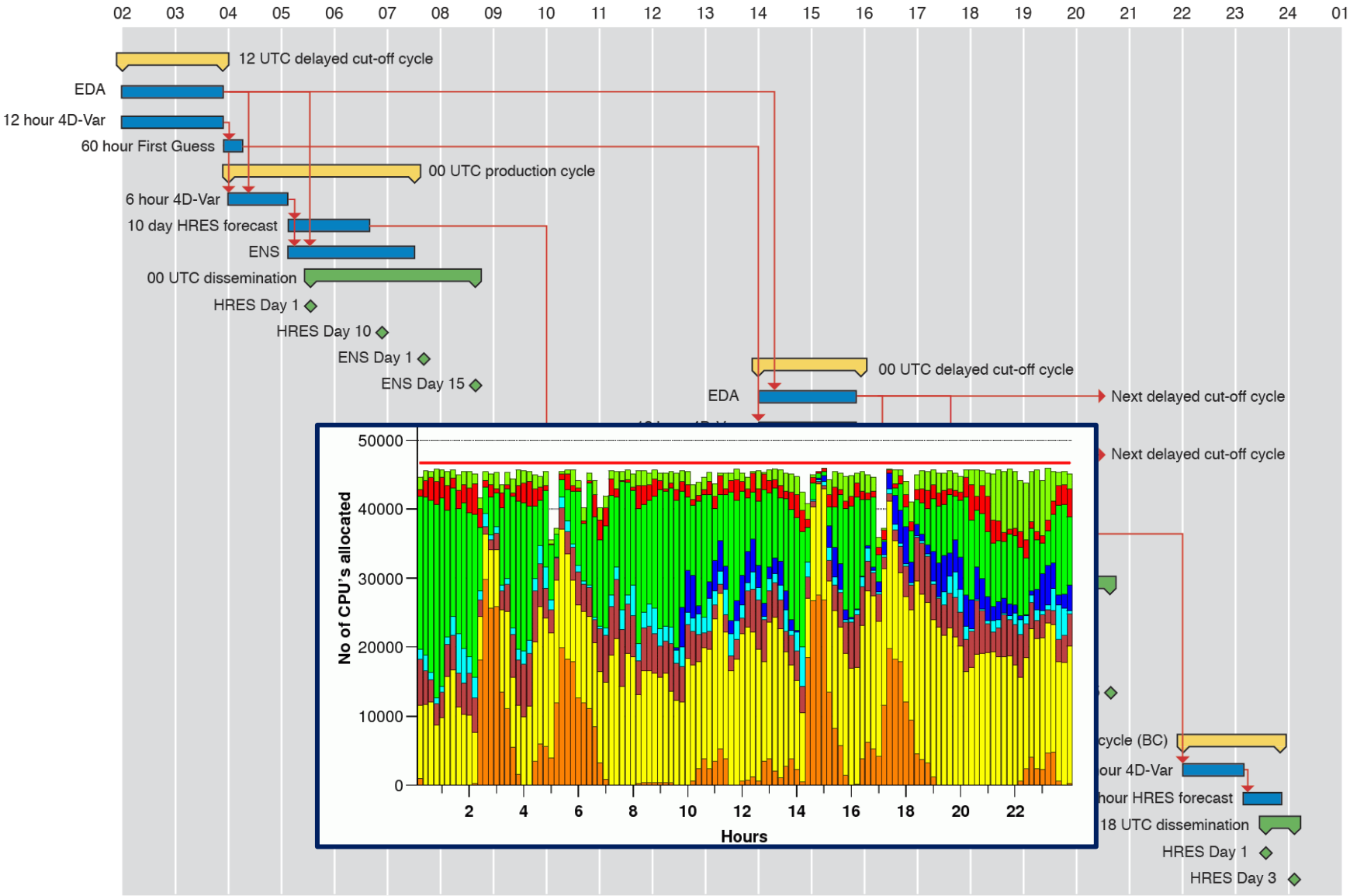
Tomorrow:

	Observations	Models
Volume	200 million = **2 x 10^8**	500 million grid points 200 levels 100 prognostic variables = **1 x 10^{13}**
Type	98% from 80 different satellite instruments	physical and chemical parameters of atmosphere, waves, ocean, ice, vegetation

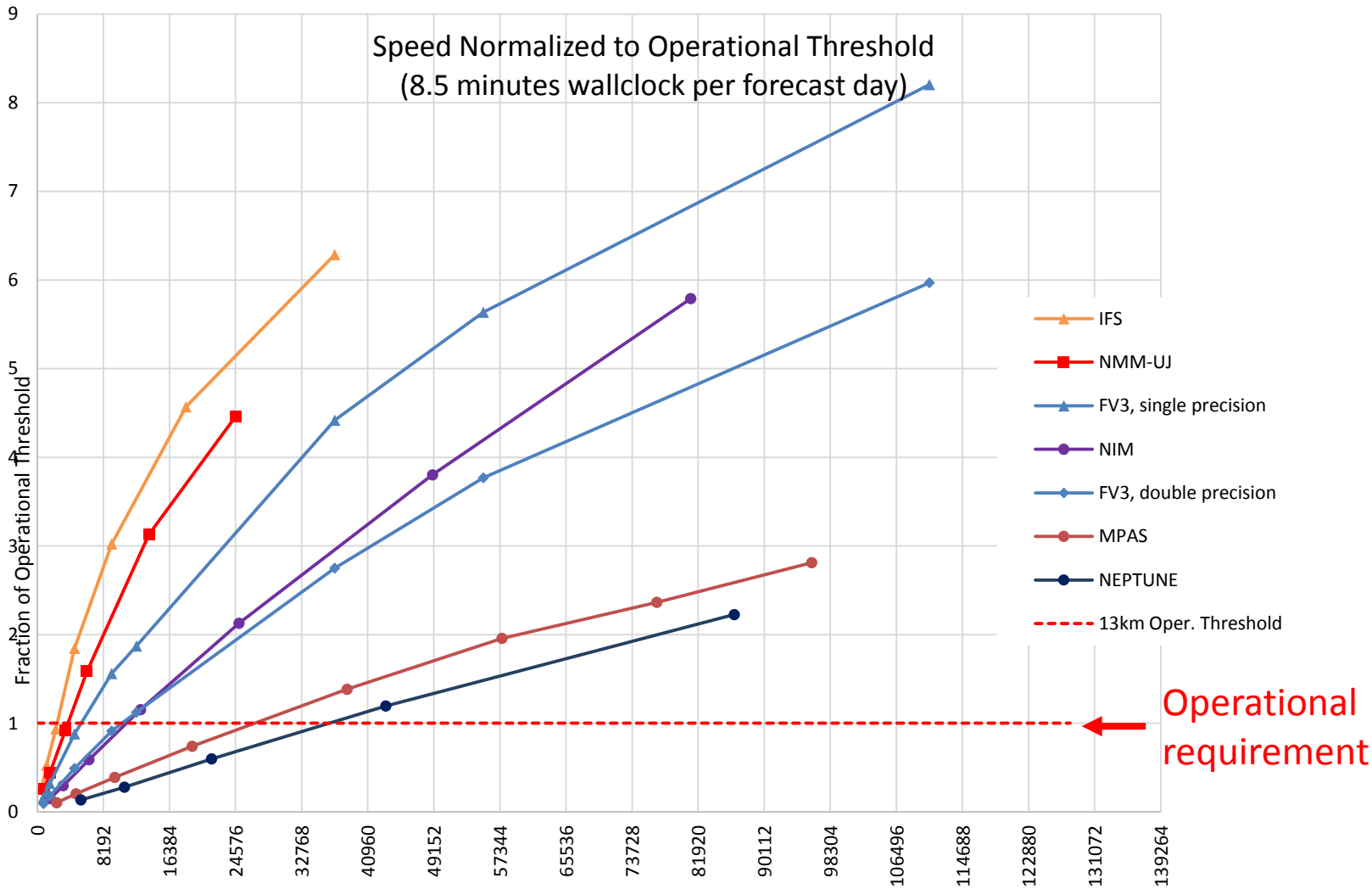
Factor 10 per day

Factor 2000 per time step

ECMWF production workflow



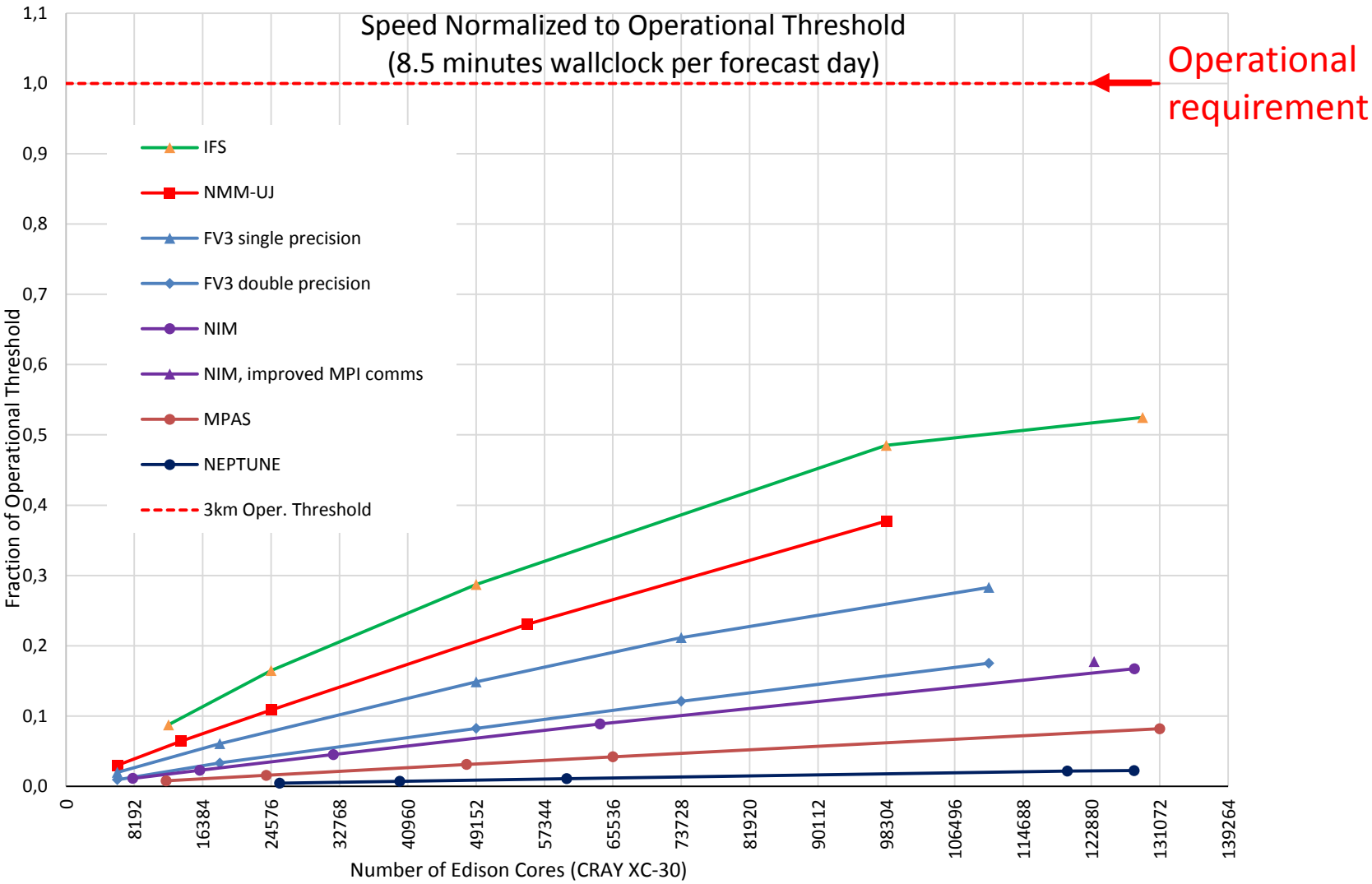
Current forecast models: 13km



[Michalakes et al. 2015: AVEC-Report: NGGPS level-1 benchmarks and software evaluation]

Number of Edison Cores (CRAY XC-30)

Future forecast models: 3km



[Michalakes et al. 2015: AVEC-Report: NGGPS level-1 benchmarks and software evaluation]

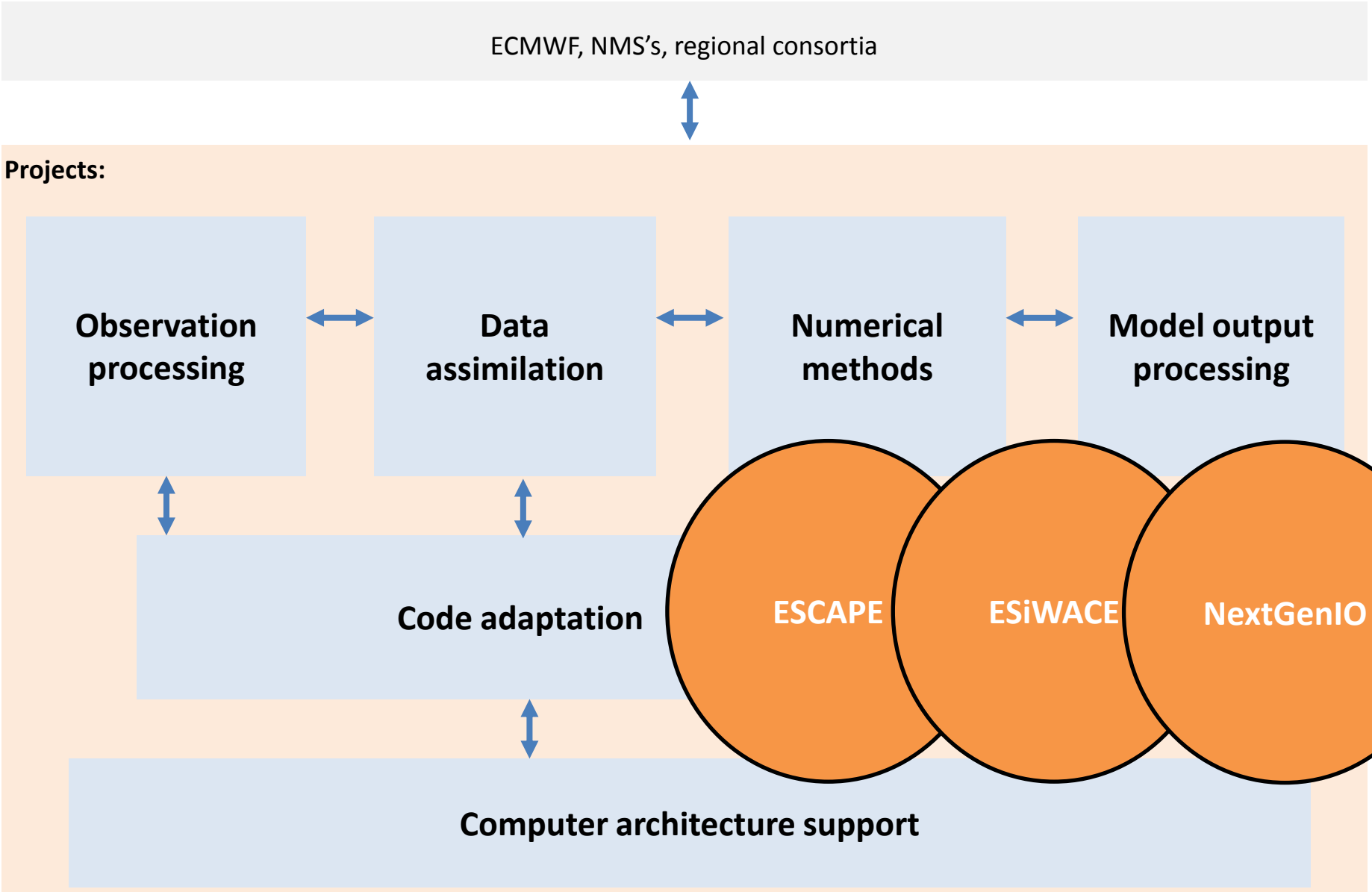
EESI2 recommendations

Conclusion:
Current mathematics, algorithms and hardware will not be sufficient (by far)

Way ahead:
NWP and Climate need to invest in all areas at the same time (e.g. numerical methods, solvers, programming models, couplers, data handling, resilience)
→ <u>we reach exabytes before exascale</u>!

- **Data**:
  - asynchronous data movement
  - post-processing of data where it is produced
  - data compression conserving information content
- **Computing**:
  - standardized, highly optimized kernels on specialized hardware
  - overlap of communication and computation
  - compilers/standards supporting portability

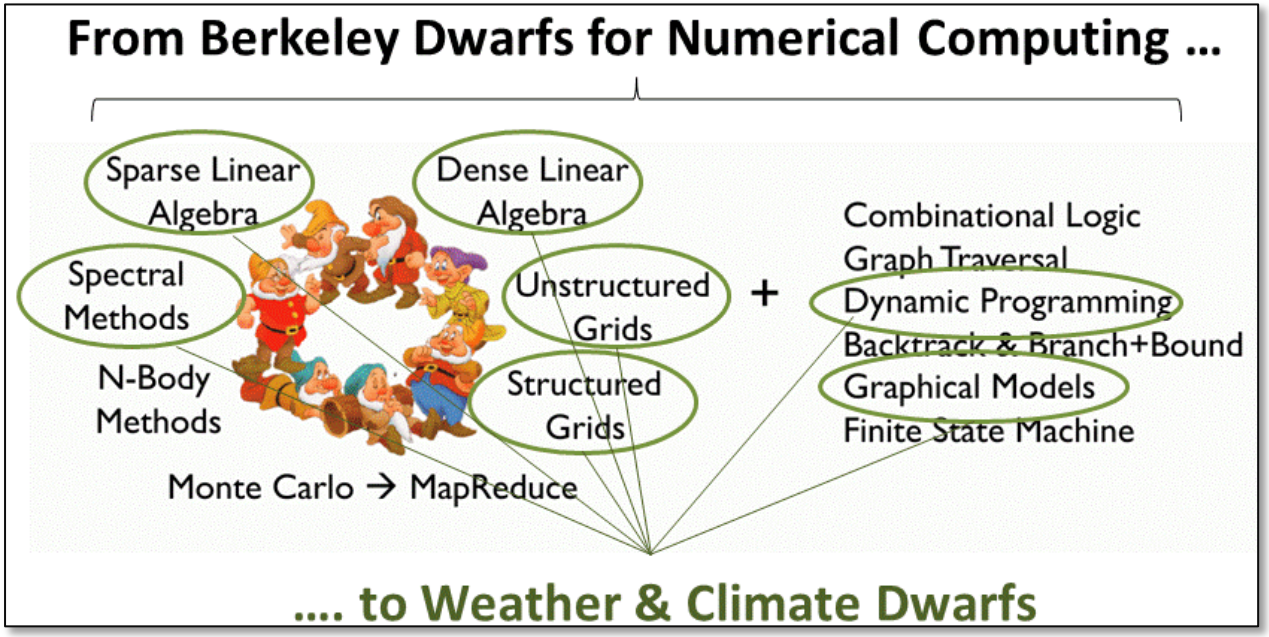
ECMWF Scalability Programme



Numerical methods – Code Adaptation - Architecture

ESCAPE*, Energy efficient SCalable Algorithms for weather Prediction at Exascale:

- Next generation IFS numerical building blocks and compute intensive algorithms
- Compute/energy efficiency diagnostics
- New approaches and implementation on novel architectures
- Testing in operational configurations



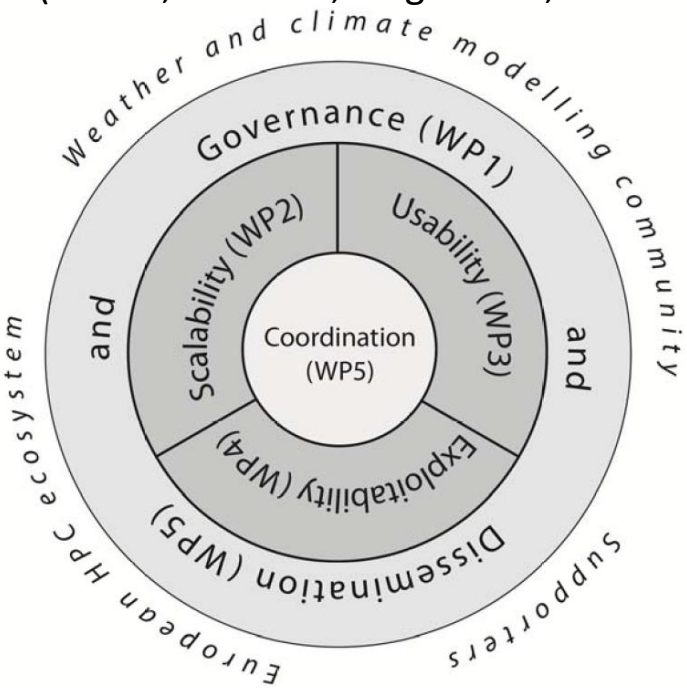
*To be funded by EC H2020 framework, Future and Emerging Technologies – High-Performance Computing; Partners: **ECMWF**, Météo-France, RMI, DMI, Meteo Swiss, DWD, Loughborough U, PSNC, Bull, NVIDIA, Optalysys

Numerical methods – Code Adaptation – Model output processing - Architecture

ESiWACE*, Excellence in Simulation of Weather And Climate in Europe:

- Join weather and climate communities to provide support, training, services
  - fostering community models, tools and software (NEMO, EC-Earth, diagnostics, couplers, I/O servers, ESM workflow, Cylc)
  - towards enhanced code performance (e.g. MPI/OpenMP, I/O, single-precision)
  - towards exascale (e.g. concurrency, knowledge compression)

- IS-ENES heritage, PRACE interface, ETP4HPC strategy, link to hardware providers

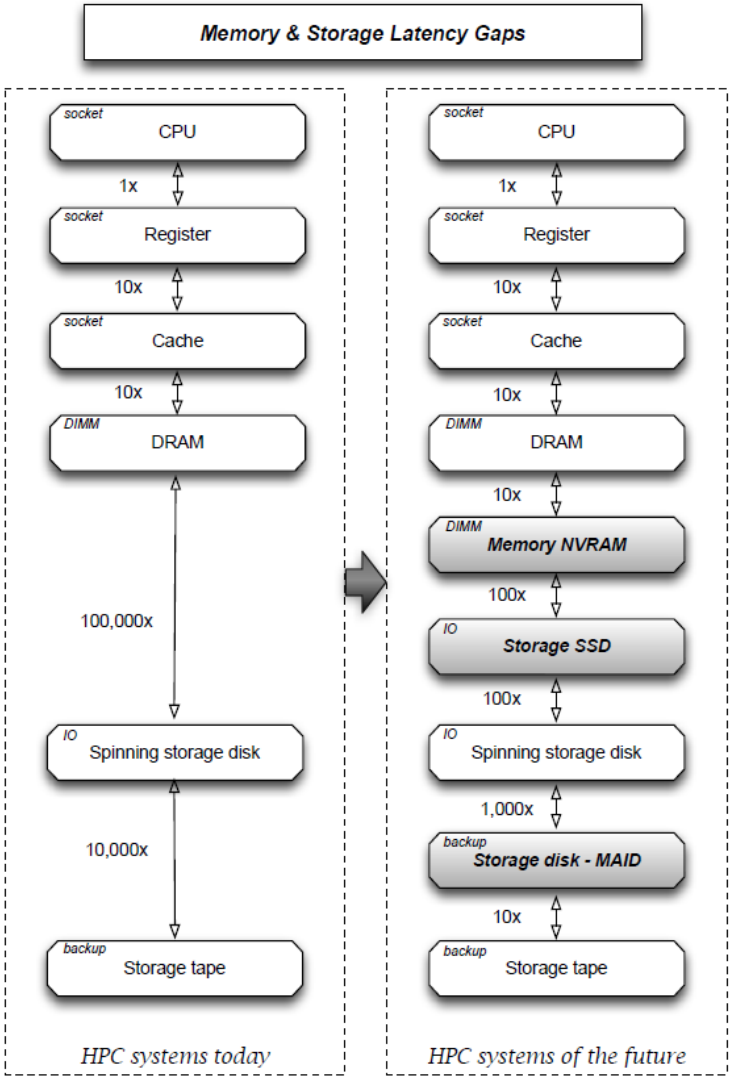


*To be funded by EC H2020 framework, e-Infrastuctures, Centres of Excellence for Computing Applications; Partners: **DKRZ**, ECMWF, CNRS-IPSL, MPG, CERFACS, BSC, STFC, Met Office, U Reading, SMHI, ICHEC, CMCC, DWD, Seagate, Bull, Allinea

Numerical methods - Model output processing - Architecture

NextGenIO*, Next Generation I/O:

- Define exascale I/O requirements across demanding applications
- Define hardware architectures
- Define data architecture
- Develop I/O workload simulators
- Develop support tools for NVRAM
- Develop necessary systemware
- Develop prototype hardware



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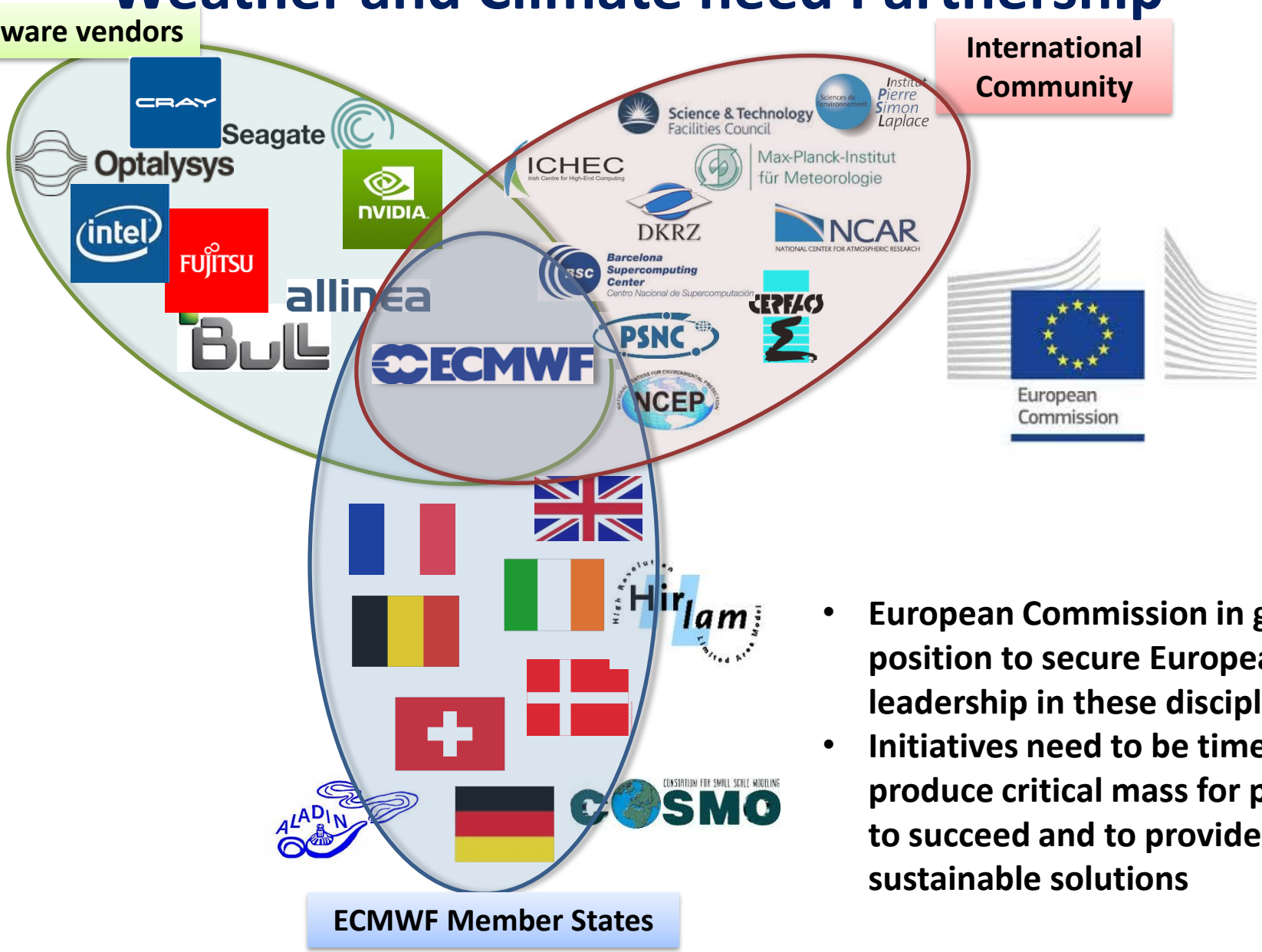
Weather and Climate need Partnership



- European Commission in good position to secure European leadership in these disciplines
- Initiatives need to be timely and produce critical mass for projects to succeed and to provide sustainable solutions