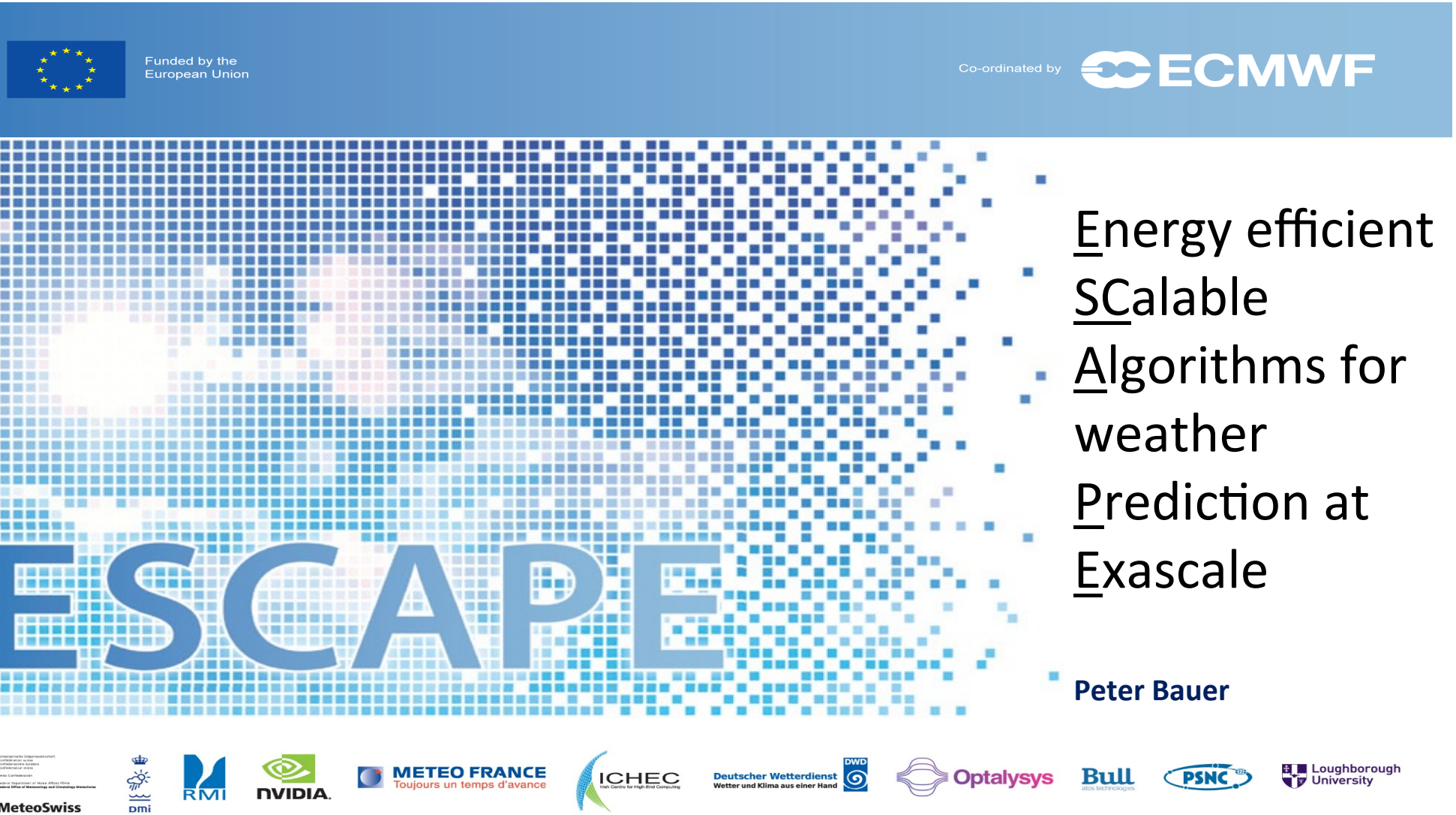


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 671627

Forecast production workflow: what is the challenge?

Funded by the European Union

Data acquisition

Forecast run

Product generation

Dissemination

RMDCN

Internet

Web services

Internet

Archive

Data Handling System

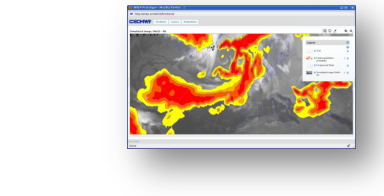
today: 10 TB
tomorrow: 300 TB
→ **f=30** per day in critical path

today: 60 million
tomorrow: 600 million
→ **f=10** per day

today: 10 millio
100 vert
10 progr
50 enser
tomorrow: 500 milli
200 vert
100 prog
100 ensem
→ **f=2000** per time step

today: 20 TB written
20 million fields
85 million products
tomorrow: 500 TB written
500 million fields
2 billion products
→ **f=25** per day in critical path

today: 100 TB
tomorrow: 10 PB
→ **f=100** per day



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What is the challenge?

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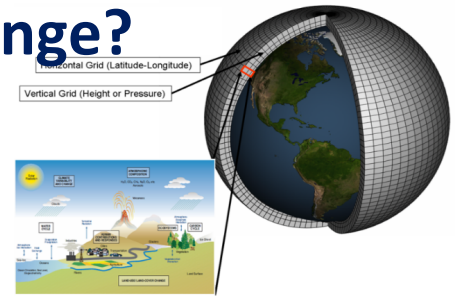


		Observations	Models
Today:	Volume	20 million = **2 x 10^7**	5 million grid points 100 levels 10 prognostic variables = **5 x 10^9**
	Type	98% from 60 different satellite instruments	physical parameters of atmosphere, waves, ocean
		Observations	**Models**
Tomorrow:	Volume	200 million = **2 x 10^8**	500 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 <u>time step</u>**

**(10-day forecast today = 1440 time steps,
but more time steps with increased resolution)**

Traditional science workflow

Funded by the European Union

Mathematical description

$$\text{Wind } \rho\dot{\mathbf{v}} = -\nabla p + \rho\mathbf{g} - 2\Omega\times(\rho\mathbf{v}) + \mathbf{F}$$

$$\text{Pressure } \dot{p} = -(c_{pd}/c_{vd})\, p\nabla\cdot\mathbf{v} + (c_{pd}/c_{vd}-1)Q_h$$

$$\text{Temperature } \rho c_{pd}\dot{T} = \dot{p} + Q_h$$

$$\text{Water } \rho\dot{q}^v = -\nabla\cdot\mathbf{F}^v - (I^l + I^f)$$

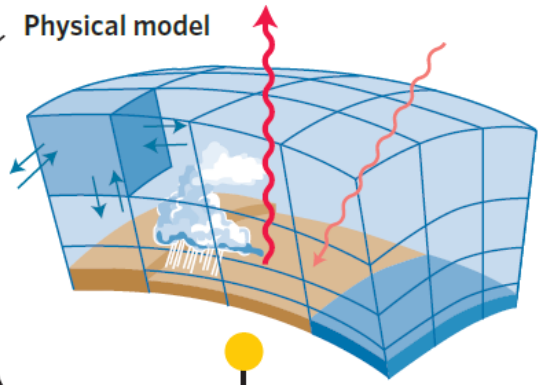
$$\rho\dot{q}^{l,f} = \nabla\cdot(\mathbf{P}^{l,f} + \mathbf{F}^{l,f}) + I^{l,f}$$

$$\text{Density } \rho = p[R_d\,(1+(R_v/R_d-1)\,q^v - q^l - q^f)\,T]^{-1}$$

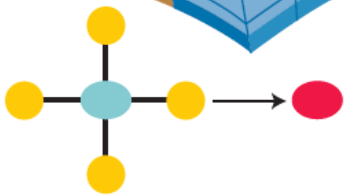
Domain science and applied mathematics

```
lap(i,j,k) = -4.0 * data(i,j,k) +
    data(i+1,j,k) + data(i-1,j,k) +
    data(i,j+1,k) + data(i,j-1,k);
```

Physical model

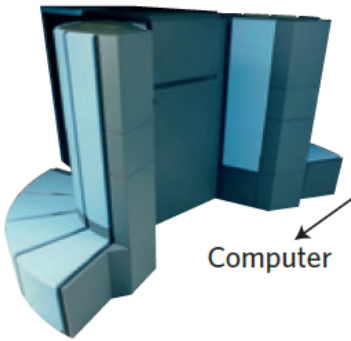


Algorithmic description



Imperative code

Compilation



Computer

Computer engineering

[Schulthess 2015]

NATURE PHYSICS

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Future science workflow

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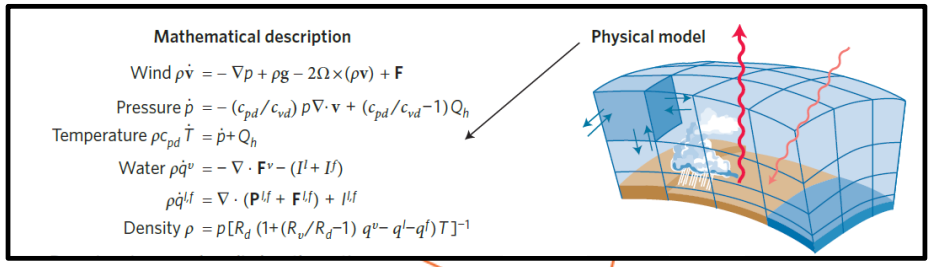

Science applications using a descriptive and dynamic developer environment

Algorithmic description

Multidisciplinary co-design of tools, libraries, programming environment

Imperative code

Compiler front-end

Optimization / low-level libraries / runtime

Architecture specific back-ends

↑ science specific code

↓ generic code

Architecture 1 | Architecture 2 | Architecture N

[Schulthess 2015]

NATURE PHYSICS

Energy efficient SCalable Algorithms for weather Prediction at Exascale

→ **www.hpc-escape.eu**

This project is funded by the European Union

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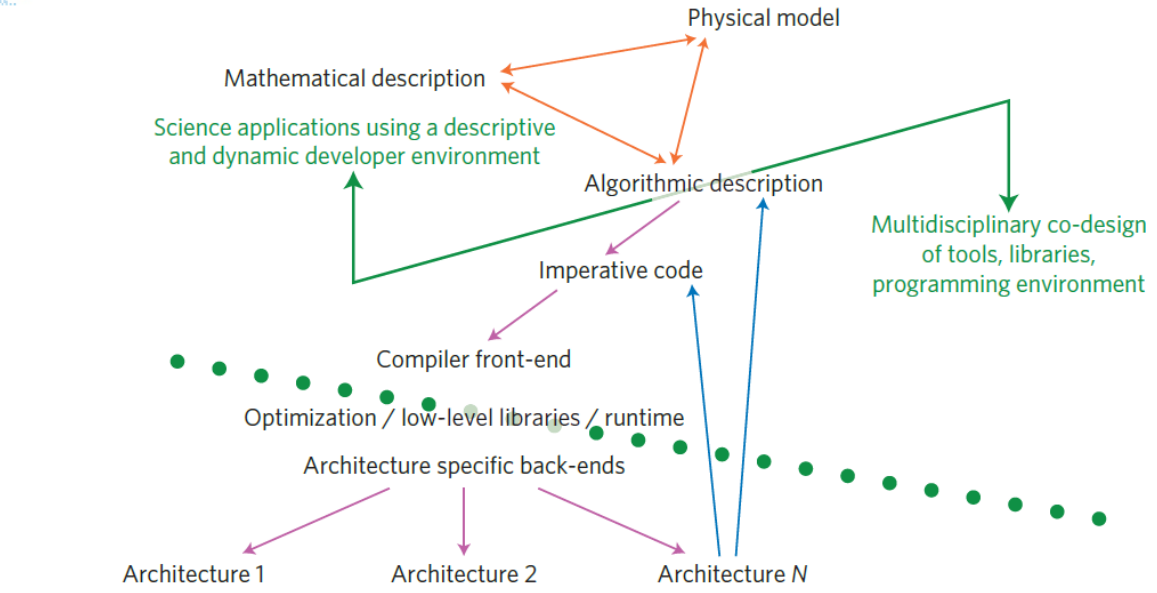
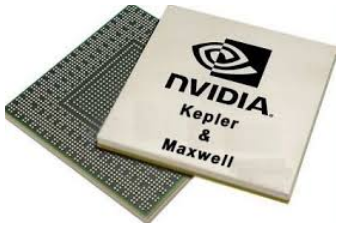
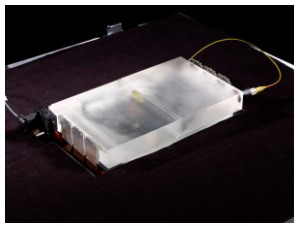
Energy efficiency

Funded by the European Union







.. aiming at minimizing Watts per forecast

BULL an atos company

NVIDIA

Optalysys

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ESCAPE key objectives

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- Define fundamental **algorithm building blocks** ("*Weather & Climate Dwarfs*") to co-design, advance, benchmark and efficiently run the next generation of NWP and climate models on energy-efficient, heterogeneous HPC architectures.

- Combine frontier research on **algorithm development** and extreme-scale, high-performance computing applications with **novel hardware technology**, to create a flexible and sustainable weather and climate prediction system.

- Foster the **future design of Earth-system models** and commercialisation of weather-dependent innovative products and services in Europe through enabling open-source technology.

- Pairing **world-leading NWP** with **innovative HPC solutions**.

Funded by the European Union

ESCAPE

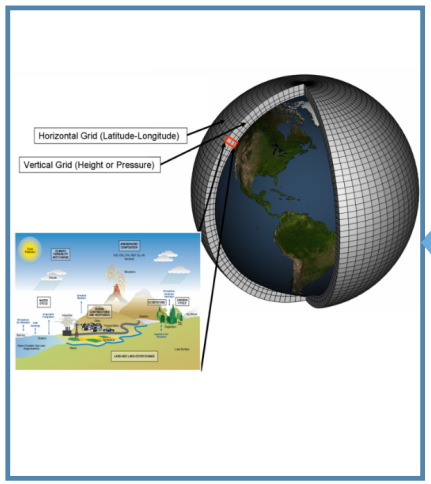
Energy efficient **SC**alable **A**lgorithms for weather **P**rediction at **E**xascale

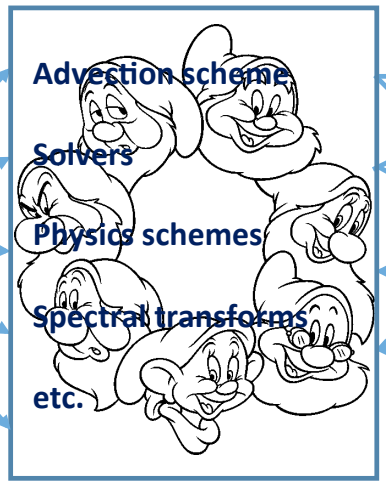
Disassemble …
NWP models

Extract, redesign…
key components

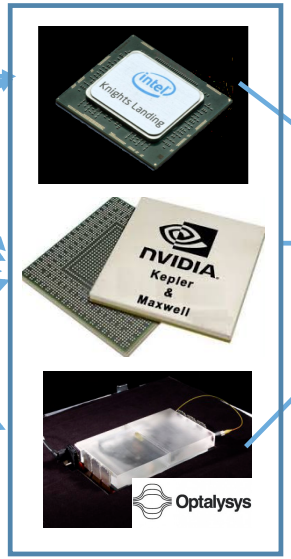
Optimize for energy…
efficiency on new hardware

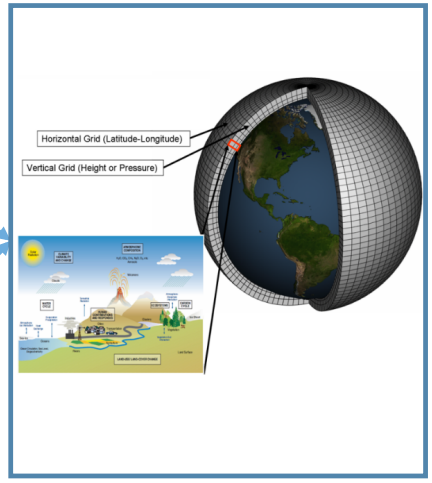
… Reassemble
NWP models





(memory, communication, compute intensity)





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What is a dwarf?

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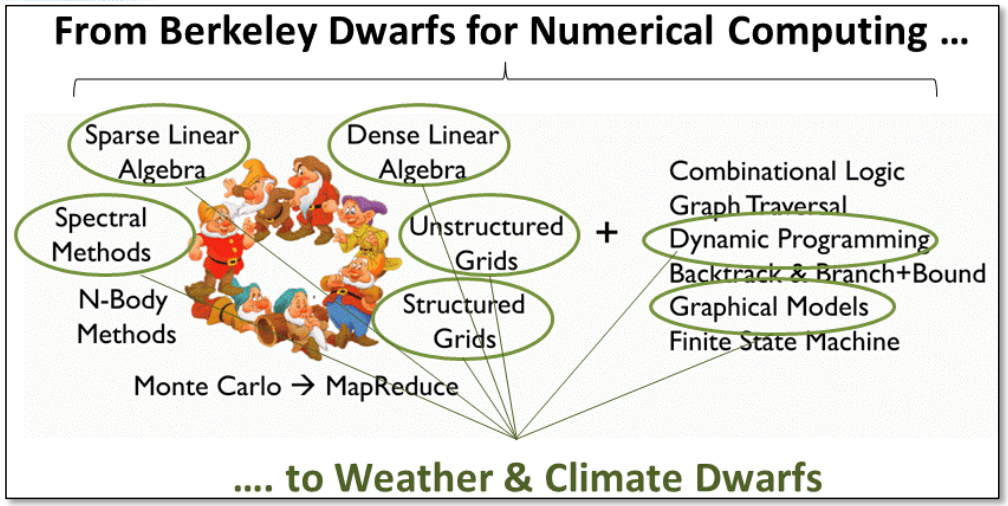


A dwarf encapsulates a relevant characteristic or required functionality of an weather/climate prediction model and it is meant to be a **runnable** and **verifiable mini-application**

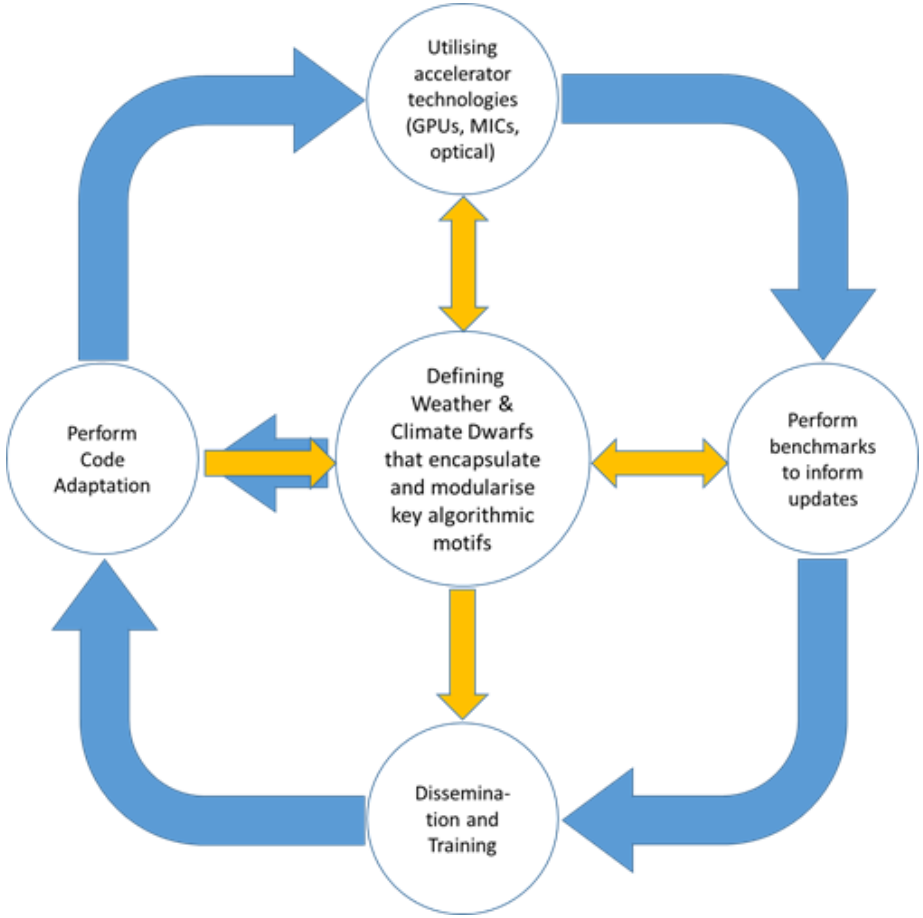
Candidates:

- Spectral transforms (FT/LT and bi-FT): very memory and communication bandwidth intensive, possibly limited scalability
- 2 & 3-dimensional elliptic solver: new, compute and communication latency intensive, possibly limited scalability
- Semi-Lagrangian advection: communication intensive, possibly limited scalability
- Cloud physics parameterization: expensive computation, scalable
- Radiation parameterization: expensive computation, scalable

… more to follow

ESCAPE work flow

Funded by the European Union



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ESCAPE European impact map

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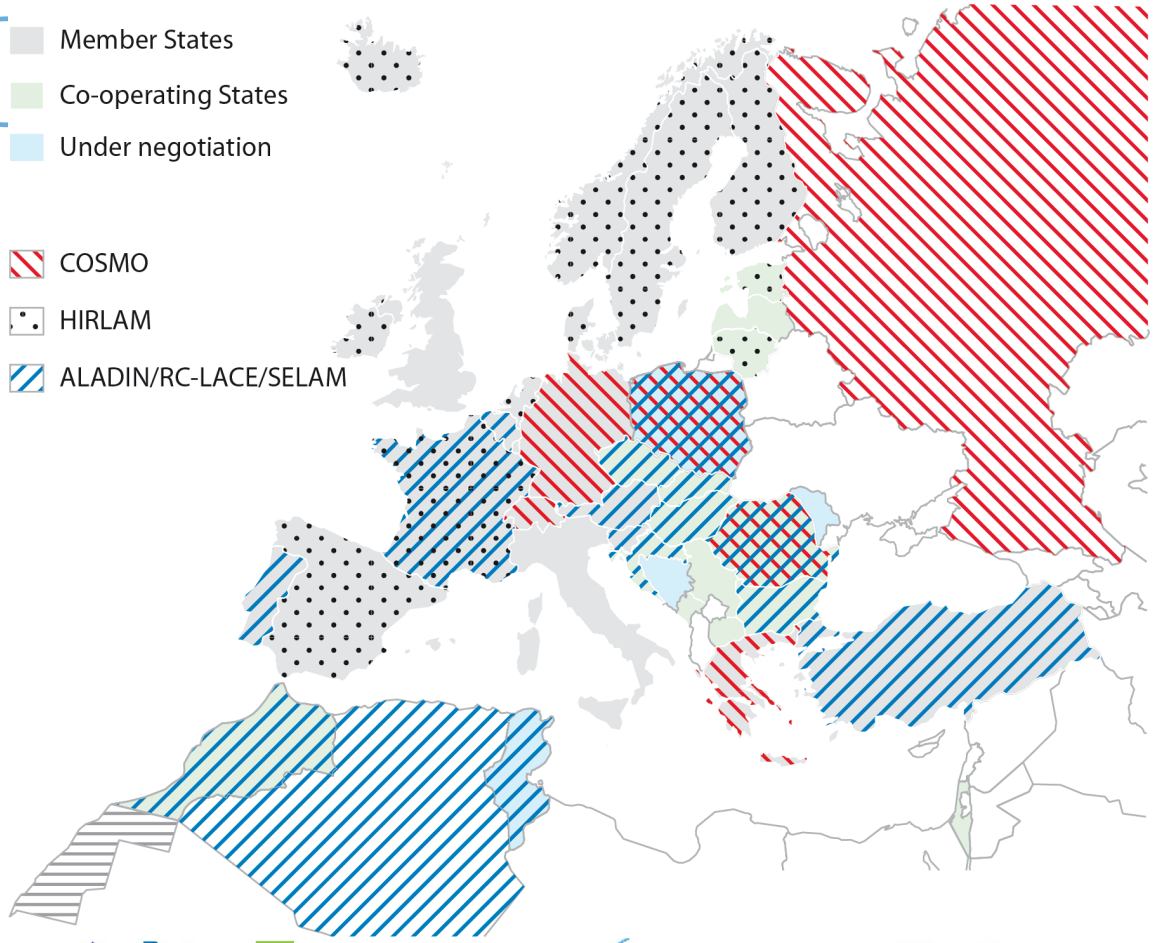
34 countries

Member States
Co-operating States
Under negotiation

7 countries
11 countries
16 countries

COSMO
HIRLAM
ALADIN/RC-LACE/SELAM



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ESCAPE partners & expertise

Funded by the European Union

Global operational NWP
Petaflop data centre
Numerical methods, parallel computing

Regional operational NWP
Numerical methods

Key technology development
Parallel computing

Regional operational NWP
Teraflop data centre
Physical processes

Numerical methods
Teraflop data centre
Parallel computing

Teraflop data centre
Parallel computing
Performance modelling

Teraflop data centre
Parallel computing

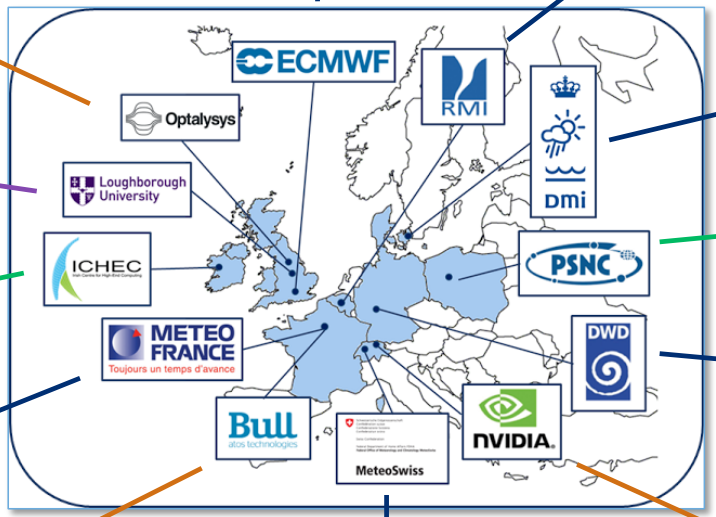
Global/regional operational NWP
Teraflop data centre
Numerical methods

Global/regional operational NWP
Petaflop data centre
Numerical methods

Key technology development
Parallel computing

Regional operational NWP
Petaflop data centre
Parallel computing

Key technology development
Parallel computing



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http://www.hpc-escape.eu

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And finally, the weather forecast

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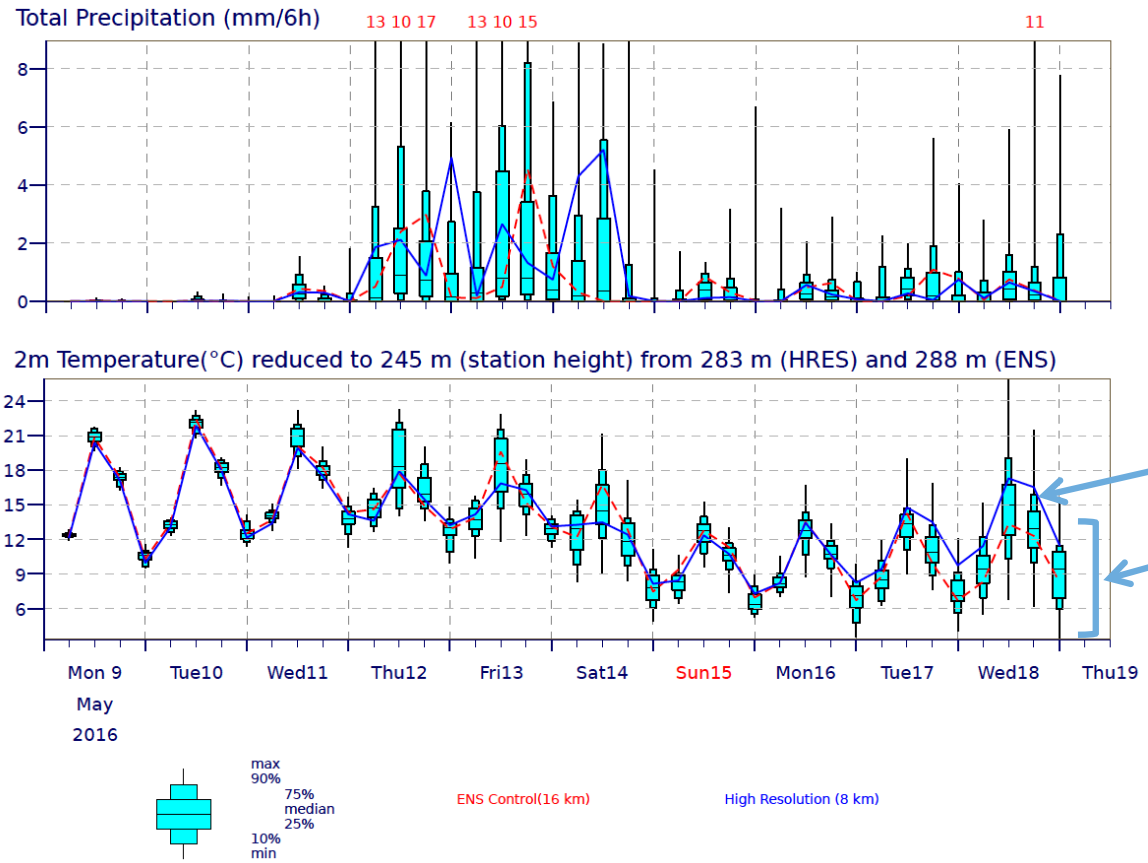


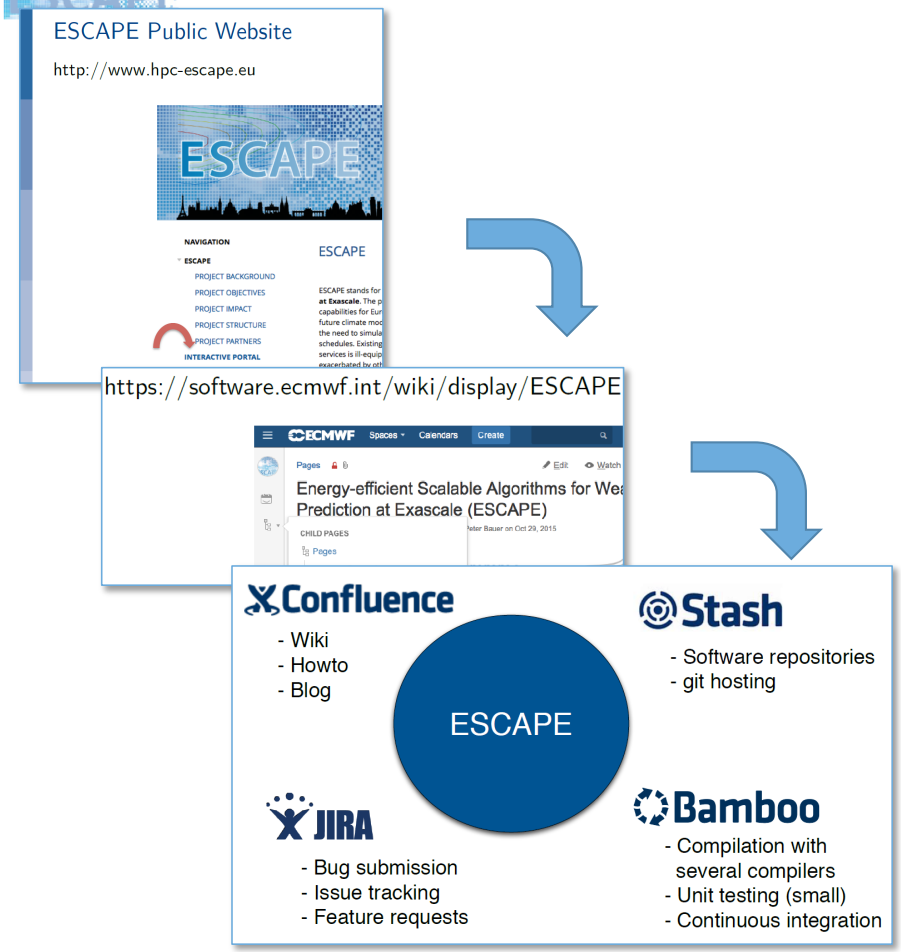
Operational forecasts:

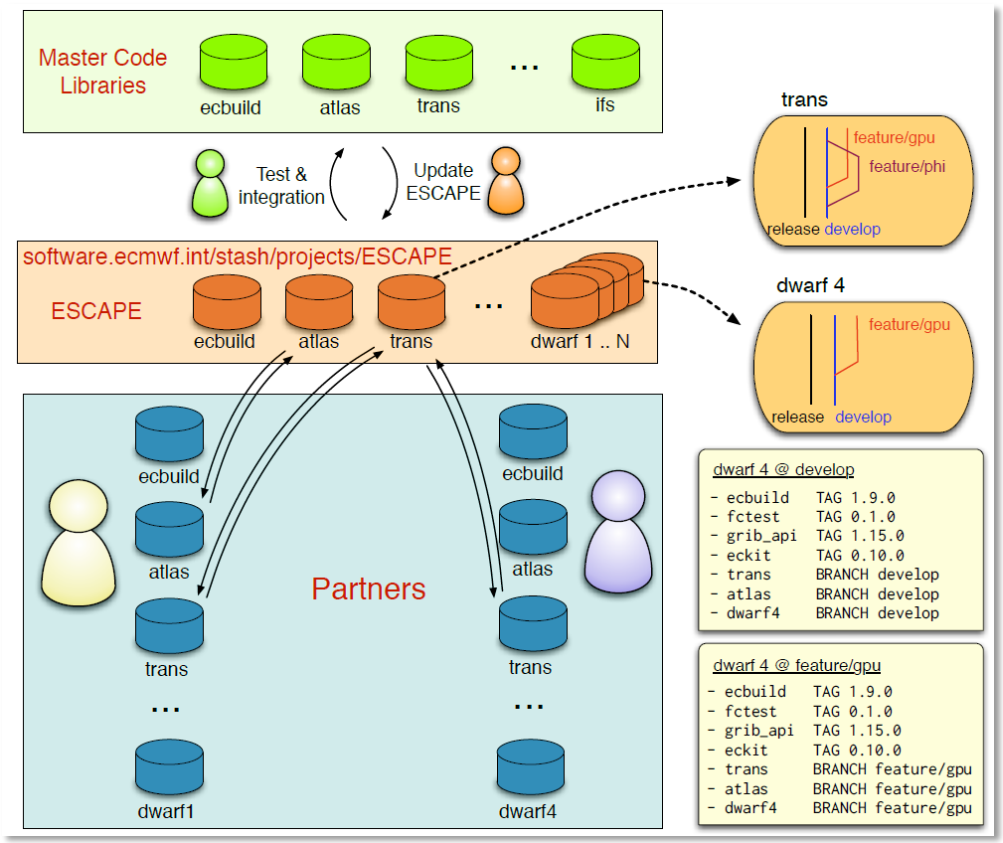
- **1x 10km forecast run on 352 nodes in 60'**
- **51x 20km forecasts run on 1632 nodes in 74'**
- **Post-processing run on 500 nodes in 30'**

Total about 2,500 nodes
(24 Ivybridge cores per node on Cray XC-30)

Software collaboration platform

Funded by the European Union





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Software stack

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