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Co-ordinated by



Energy efficient Scalable Algorithms for weather Prediction at Exascale

Peter Bauer



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?

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Data acquisition

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



Forecast run

Product generation

today: 10 million
100 vert
10 progr
50 ens
tomorrow: 500 milli
200 vert
100 progr
100 ens
→ **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: 10 TB
tomorrow: 300 TB
→ **f=30** per day in critical path

Dissemination

RMDCN

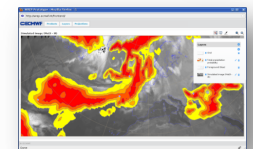
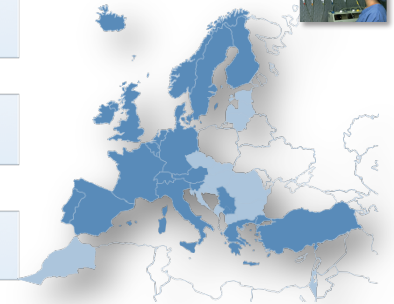
Internet

Web services

Internet

Archive

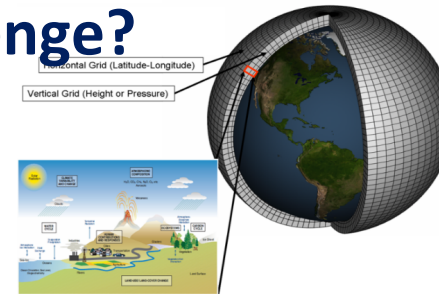
Data Handling
System





What is the challenge?

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Today:

	Observations	Models
Volume	20 million = 2×10^7	5 million grid points 100 levels 10 prognostic variables = 5×10^9
Type	98% from 60 different satellite instruments	physical parameters of atmosphere, waves, ocean
	Observations	Models
Volume	200 million = 2×10^8	500 million grid points 200 levels 100 prognostic variables = 1×10^{13}
Type	98% from 80 different satellite instruments	physical and chemical parameters of atmosphere, waves, ocean, ice, vegetation

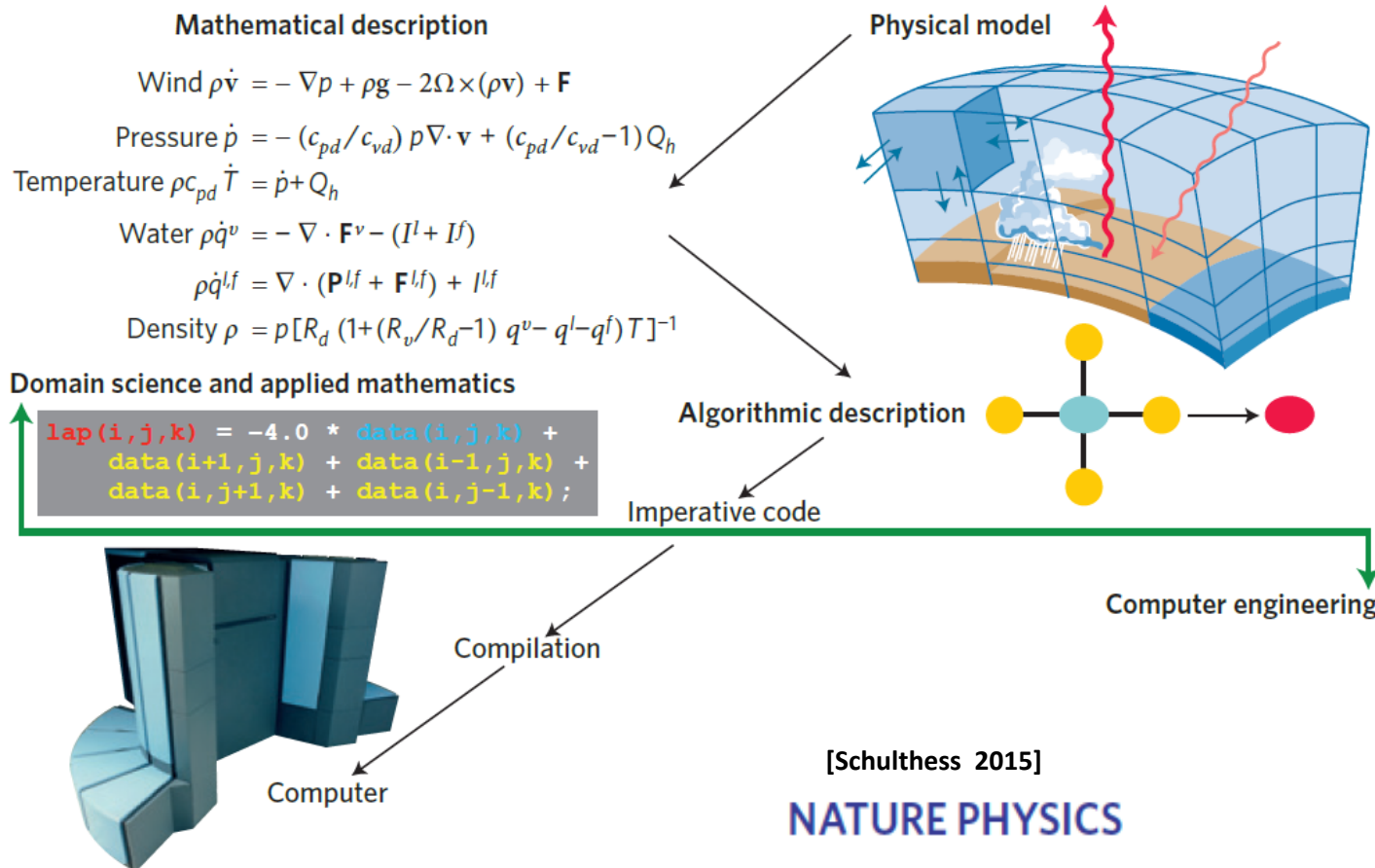
→ **Factor 10 per day**

→ **Factor 2000 per time step**

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



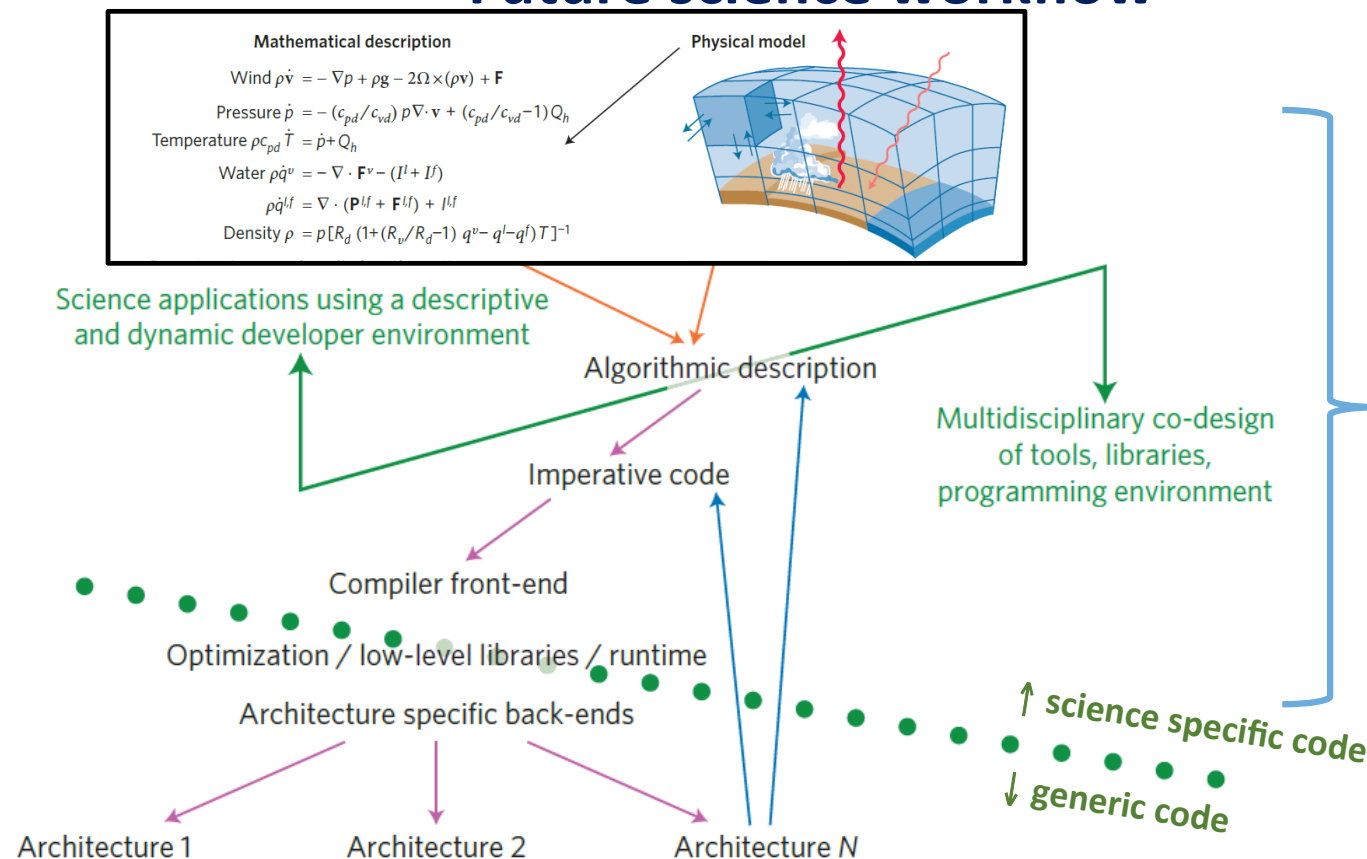
Traditional science workflow





Future science workflow

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Energy efficient
Scalable Algorithms for
weather Prediction at
Exascale
→ www.hpc-escape.eu

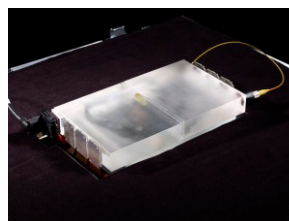
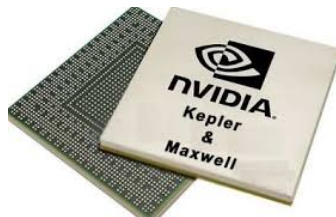
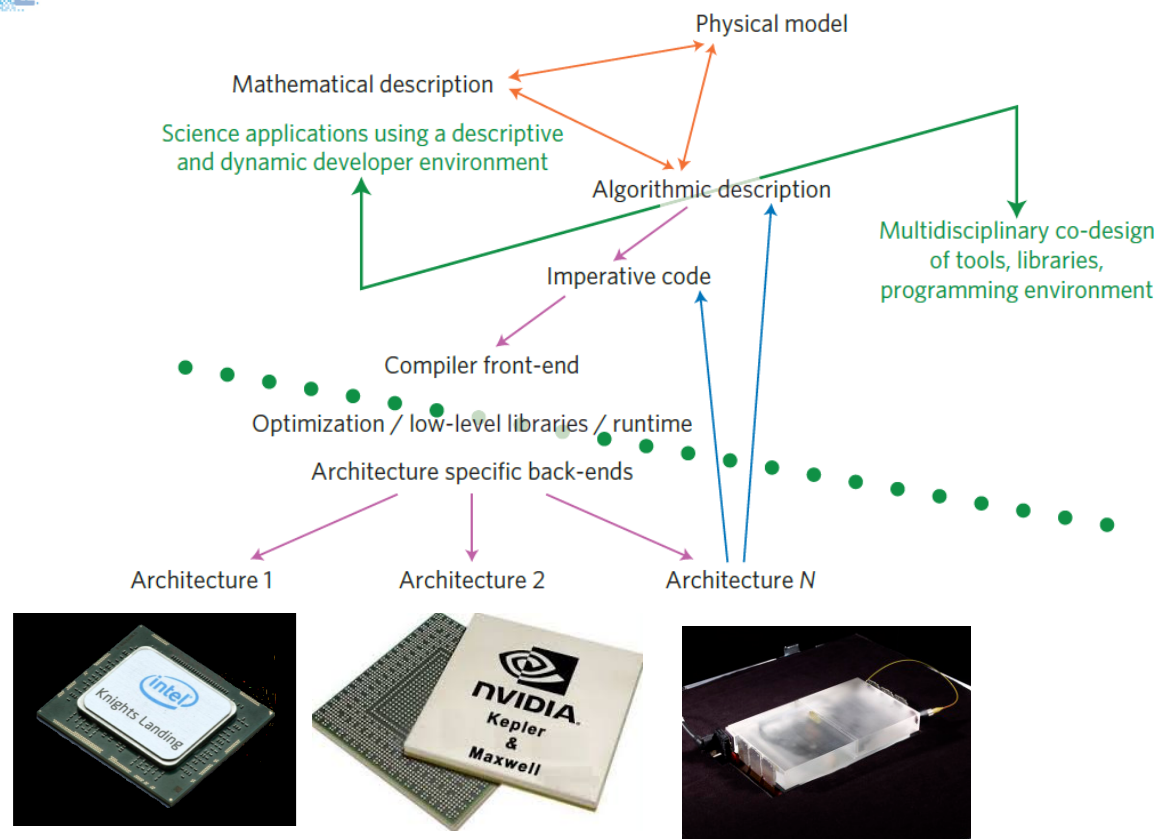
This project is funded
by the European Union

[Schulthess 2015]

NATURE PHYSICS



Energy efficiency



.. aiming at minimizing
Watts per forecast





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**.



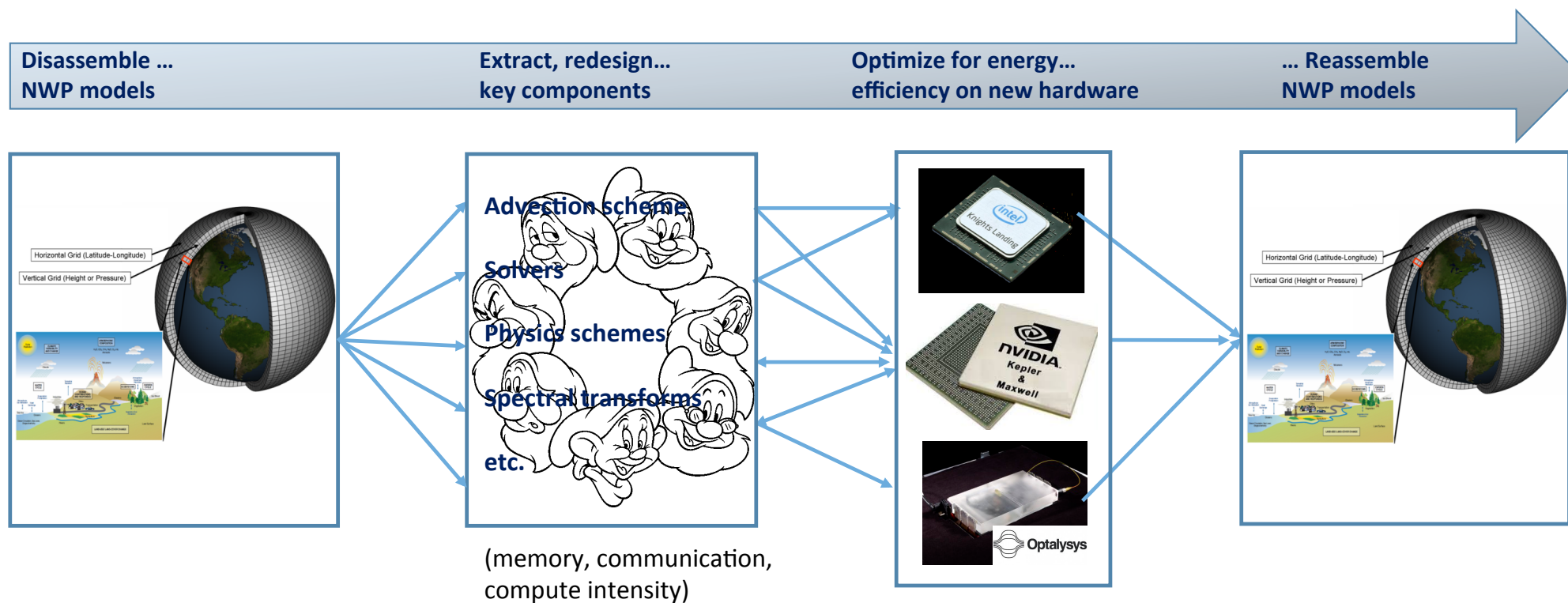


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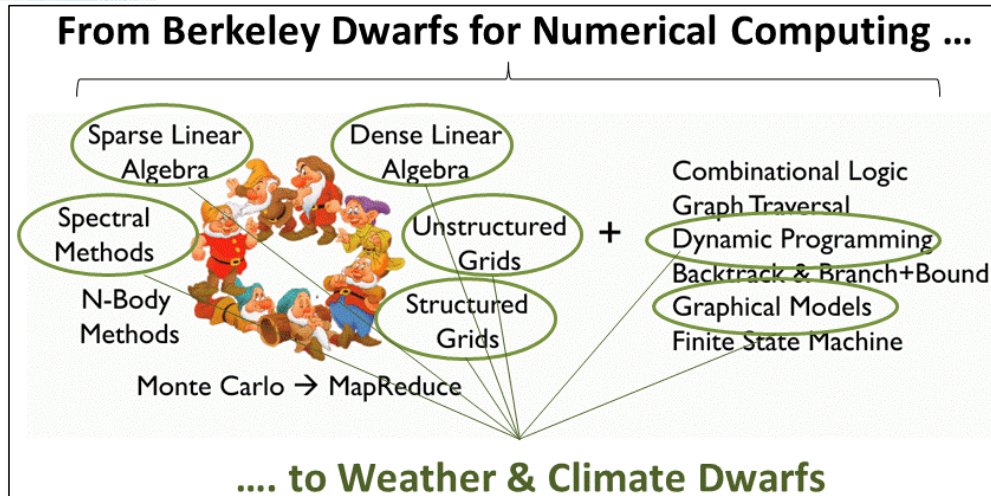


ESCAPE

Energy efficient Scalable Algorithms for weather Prediction at Exascale



What is a dwarf?



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:

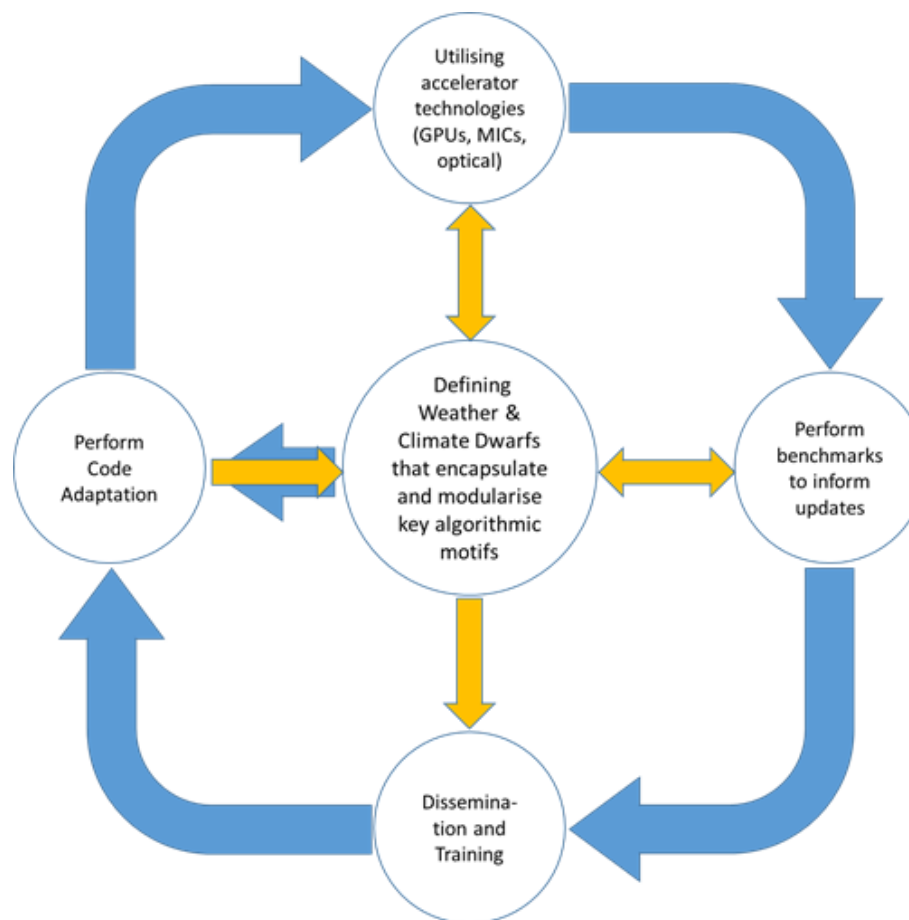
- Spectral transforms (FT/LT and bi-FT): very memory and communication bandwidth intensive, possibly limited scalability
- 2 & 3-dimensional elliptic solver: new, compute and communication latency intensive, possibly limited scalability
- Semi-Lagrangian advection: communication intensive, possibly limited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

... more to follow



ESCAPE work flow

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ESCAPE European impact map

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34 countries

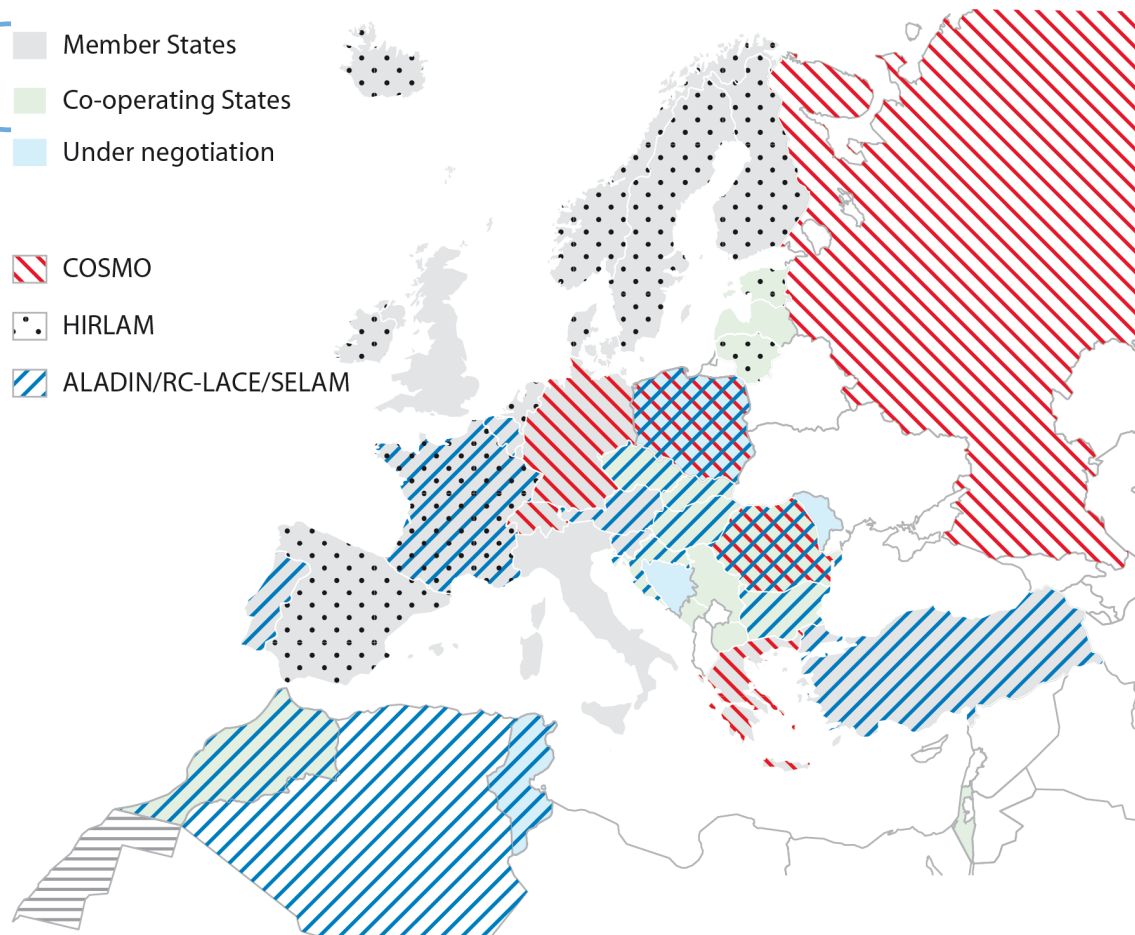
- Member States
- Co-operating States
- Under negotiation

7 countries

11 countries

16 countries

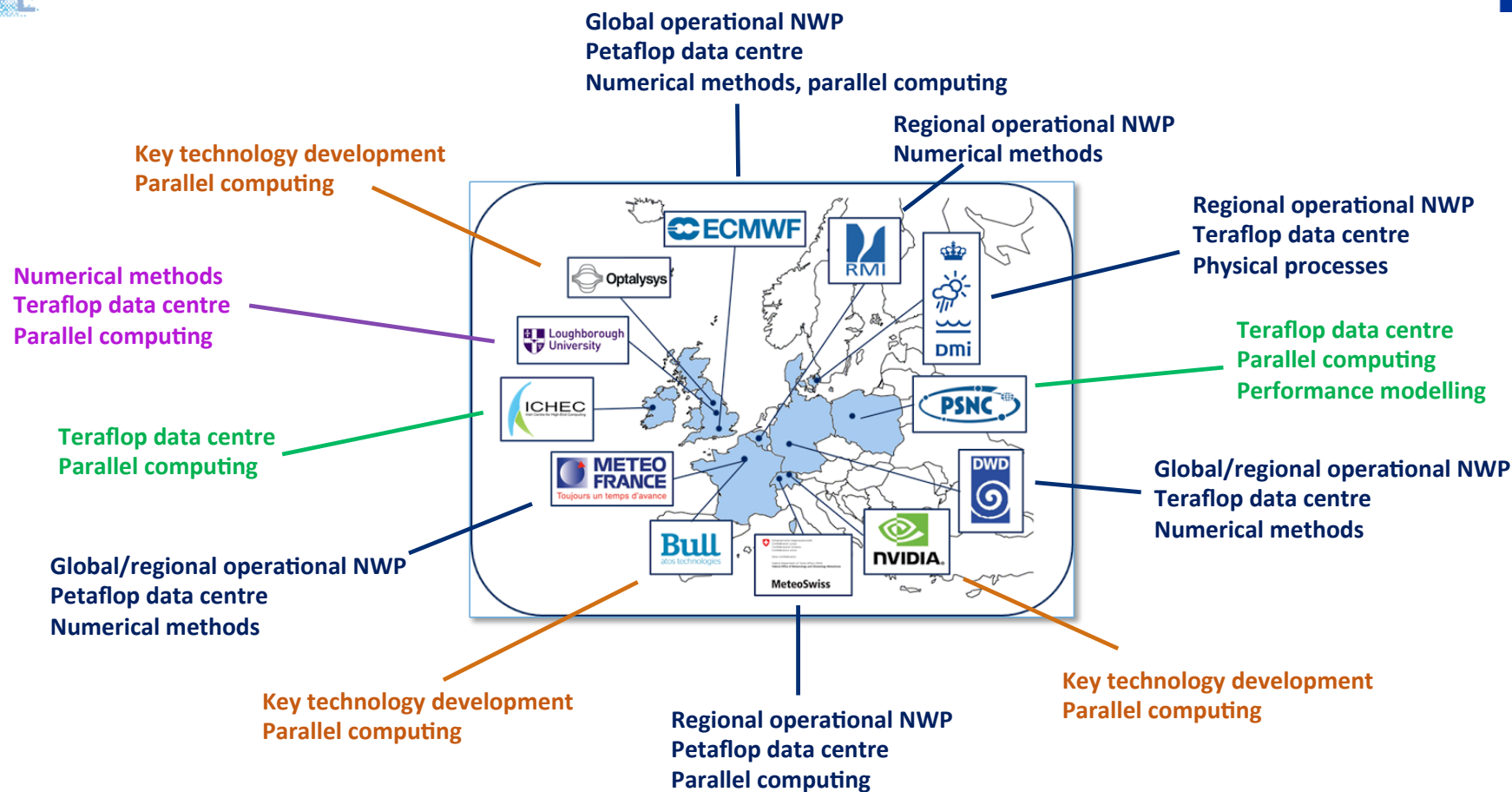
- COSMO
- HIRLAM
- ALADIN/RC-LACE/SELAM





ESCAPE partners & expertise

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<http://www.hpc-escape.eu>

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The screenshot shows the ESCAPE website interface. At the top, there's a navigation bar with a search box and a 'Search this site' button. Below the navigation bar is a large banner image featuring the word 'ESCAPE' in large, stylized letters, with a city skyline and a weather map in the background. To the right of the banner, there's a search box and a 'Search this site' button. Below the banner, the website is divided into two main sections: 'NAVIGATION' and 'ESCAPE'. The 'NAVIGATION' section on the left contains links to 'PROJECT BACKGROUND', 'PROJECT OBJECTIVES', 'PROJECT IMPACT', 'PROJECT STRUCTURE', 'PROJECT PARTNERS', 'INTERACTIVE PORTAL', 'MEDIA HUB', 'ESCAPE NEWS', 'ESCAPE EVENTS', 'ESCAPE PUBLICATIONS', 'CONTACT', and 'SITEMAP'. The 'ESCAPE' section on the right contains a detailed description of the project, its goals, and its partners. Below the description, there's a 'News and Events' section with two articles: 'NEW FORECAST MODEL AT ECMWF' and 'INVITATION AND CALL FOR CONTRIBUTIONS FOR 1ST ESCAPE DISSEMINATION WORKSHOP'.

NAVIGATION

- ESCAPE
- PROJECT BACKGROUND
- PROJECT OBJECTIVES
- PROJECT IMPACT
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- CONTACT
- SITEMAP

ESCAPE

ESCAPE stands for **E**nergy-efficient **S**calable **A**lgorithms for **W**eather **P**rediction at **E**xascale. The project will develop world-class, extreme-scale computing capabilities for European operational numerical weather prediction (NWP) and future climate models. The biggest challenge for state-of-the-art NWP arises from the need to simulate complex physical phenomena within tight production schedules. Existing extreme-scale application software of weather and climate services is ill-equipped to adapt to the rapidly evolving hardware. This is exacerbated by other drivers for hardware development, with processor arrangements not necessarily optimal for weather and climate simulations. ESCAPE will redress this imbalance through innovation actions that fundamentally reform Earth system modelling. ESCAPE addresses the [ETP4HPC](#) Strategic Research Agenda 'Energy and resiliency' priority topic, developing a holistic understanding of energy-efficiency for extreme-scale applications using heterogeneous architectures, accelerators and special compute units. The three key reasons why this project will provide the necessary means to take a huge step forward in weather and climate modelling as well as interdisciplinary research on energy-efficient high-performance computing are:

- Defining and encapsulating the fundamental algorithmic building blocks ('Weather & Climate Dwarfs') underlying weather and climate services. This is the prerequisite for any subsequent co-design, optimization, and adaptation efforts.
- Combining ground-breaking frontier research on algorithm development for use in extreme-scale, high-performance computing applications, minimizing time- and cost-to-solution.
- Synthesizing the complementary skills of all project partners. ECMWF and leading European regional forecasting consortia are teaming up with excellent university research and experienced high-performance computing centres, two world-leading hardware corporations, and one European start-up SME, providing entirely new knowledge and technology to the field.

ECMWF's partners in the project are Danmarks Meteorologiske Institut; Deutscher Wetterdienst; l'Institut Royal Météorologique de Belgique; Météo-France; MeteoSchweiz; Instytut Chemii Bioorganicznej Polskiej Akademii Nauk; Loughborough University; National University of Ireland, Galway; Bull SAS; NVIDIA Corporation; and Optalysys Ltd.

News and Events

NEW FORECAST MODEL AT ECMWF On 10 March 2016, ECMWF introduced a new version of its operational model that provides much enhanced horizontal resolution in both forecasts and analyses. The high-resolution single forecast is ...
Posted 11 Mar 2016, 06:19 by Daniel Thieme

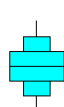
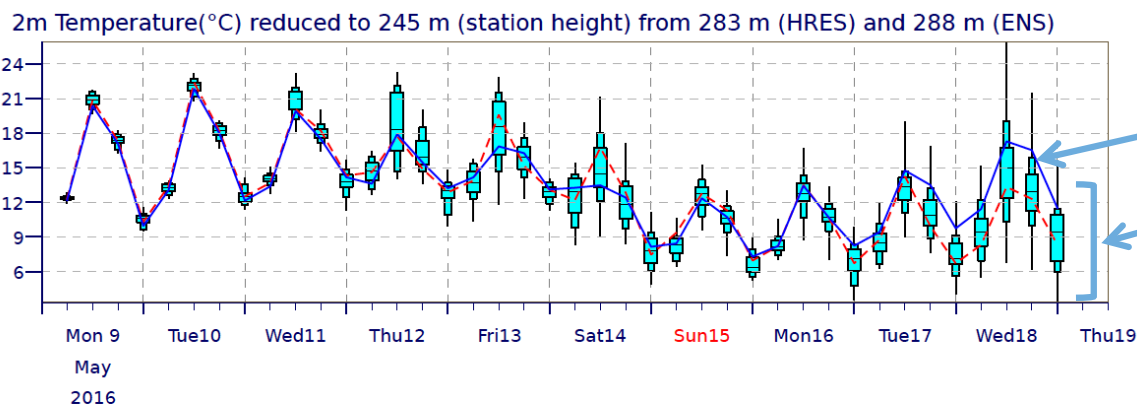
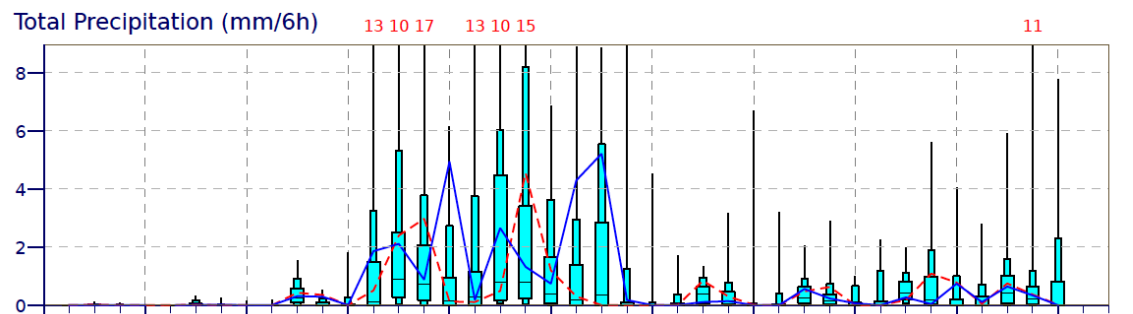
INVITATION AND CALL FOR CONTRIBUTIONS FOR 1ST ESCAPE DISSEMINATION WORKSHOP The ESCAPE project is organising its 1st Dissemination and Training Workshop from the 18th to the 20th October in Elsinore, Denmark. The invitation and call for contributions has now been...





And finally, the weather forecast

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max
90%
75%
median
25%
10%
min

ENS Control(16 km)

High Resolution (8 km)

Operational forecasts:

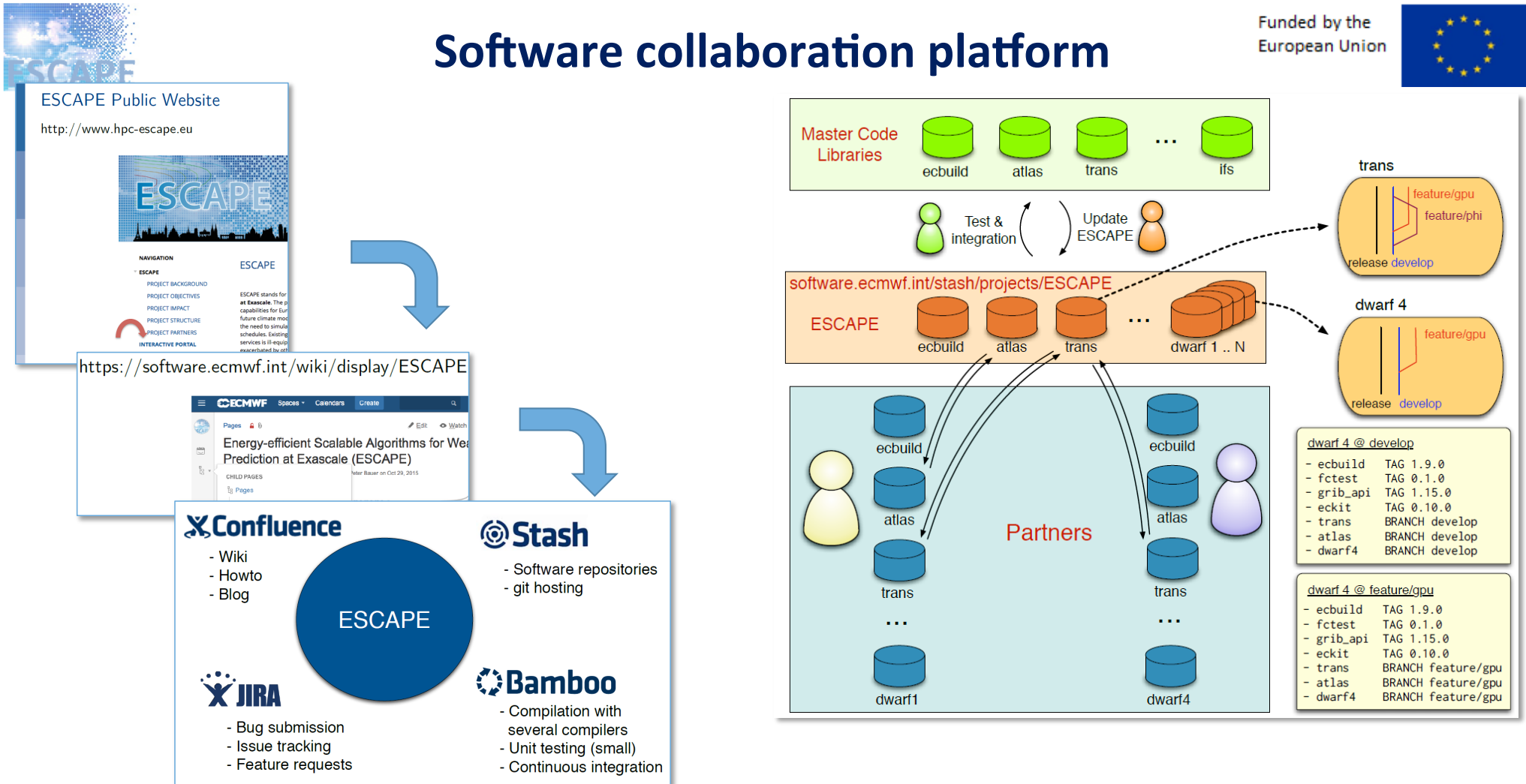
- 1x 10km forecast run on 352 nodes in 60'
- 51x 20km forecasts run on 1632 nodes in 74'
- Post-processing run on 500 nodes in 30'

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



Software collaboration platform

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Software stack

