**ESCAPE: Accelerating extreme-scale Numerical Weather Prediction**

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**Introduction**

- Numerical Weather Prediction (NWP) and Climate models contain decades of algorithmic developments for conventional CPU hardware architectures.
- Paradigm shift towards more parallel and energy-efficient many-core hardware architectures due to breakdown of Dennard scaling.
- Large impact on programming models expected in the near future.
- Rethink of design choices for future software frameworks:
  - Scalability
  - Flexibility in algorithmic choices
  - Energy efficiency
  - Maintainability

**ESCAPE (EU Horizon 2020)**

*Energy-Efficient Scalable Algorithms for Weather Prediction at Exascale*

- Combine scientific and computer-science expertise
- Define and co-design necessary steps towards affordable exascale HPC simulations of weather and climate

**Weather and Climate Dwarfs**

Weather and Climate Dwarfs are self-contained algorithms representing key functional blocks of a NWP & Climate model. They must be verifiable and possible to integrate in back in the model.

**Atlas, a library for NWP and Climate models**

ESCAPE dwarfs rely on Atlas, an object-oriented library for flexible parallel data structures for structured grids and unstructured meshes for both global and limited area models.

**Where are we heading?**

- Variety of hardware → variety of algorithm implementations
- Single source code for maintainability is crucial
- Separation of concerns:
  - Readable science code
  - Abstract hardware specific details
  - Abstract parallelisation, memory, data structure details
  - Abstract computational loops and programming models
- Domain specific languages provide a way forward: GridTools

**Atlas components showing support for both structured and unstructured grids, and hybrid unstructured meshes. Meshes hold connectivities between cells, edges and nodes.**

**Atlas code example (C++) for computing spherical harmonics spectral transforms.**

**Atlas code example (Fortran) for computing gradients using a finite volume method.**

**Coverage of ESCAPE Weather and Climate Dwarfs in ECMWF's operational integrated forecasting System (IFS). ESCAPE Dwarfs not covered by IFS: MPDATA advection, GRM (tropo solver), BRTF spectral transformed.**

**Figure 2:** The aim of ESCAPE is to (1) define and create a number of Weather and Climate Dwarfs, (2) optimise them, (3) adapt them to novel hardware technologies, and (4) measure and benchmark them both for performance as well as energy efficiency.