The modelling infrastructure and strategy at ECMWF: Recent advances & future challenges

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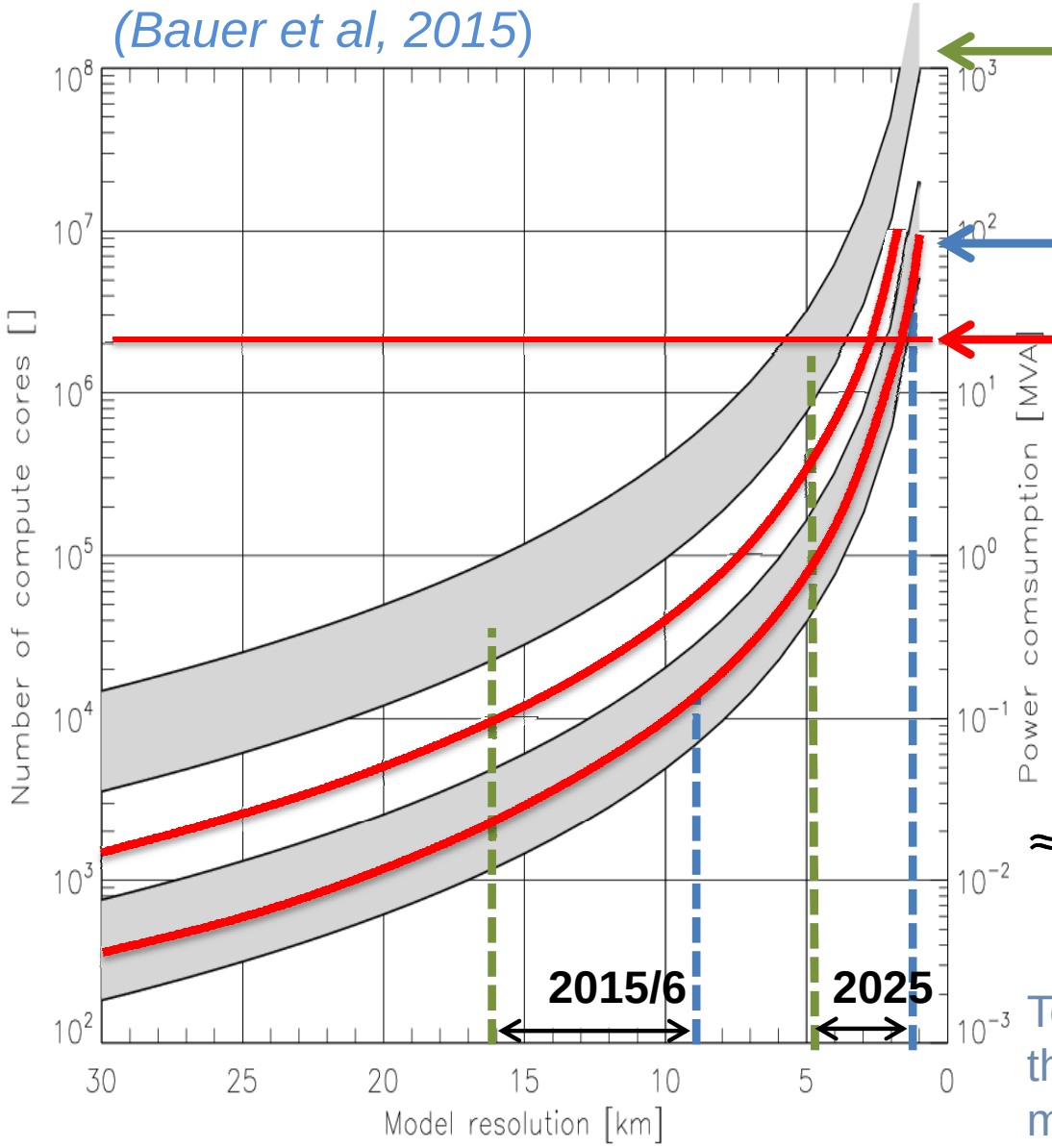
Presented by Richard Forbes

European Centre for Medium Range Weather Forecasts

Affordability – the art and cost of computing

(Bauer et al, 2015)



50 member ensemble

1 member

Hard limit for entire HPC ~20MW ?

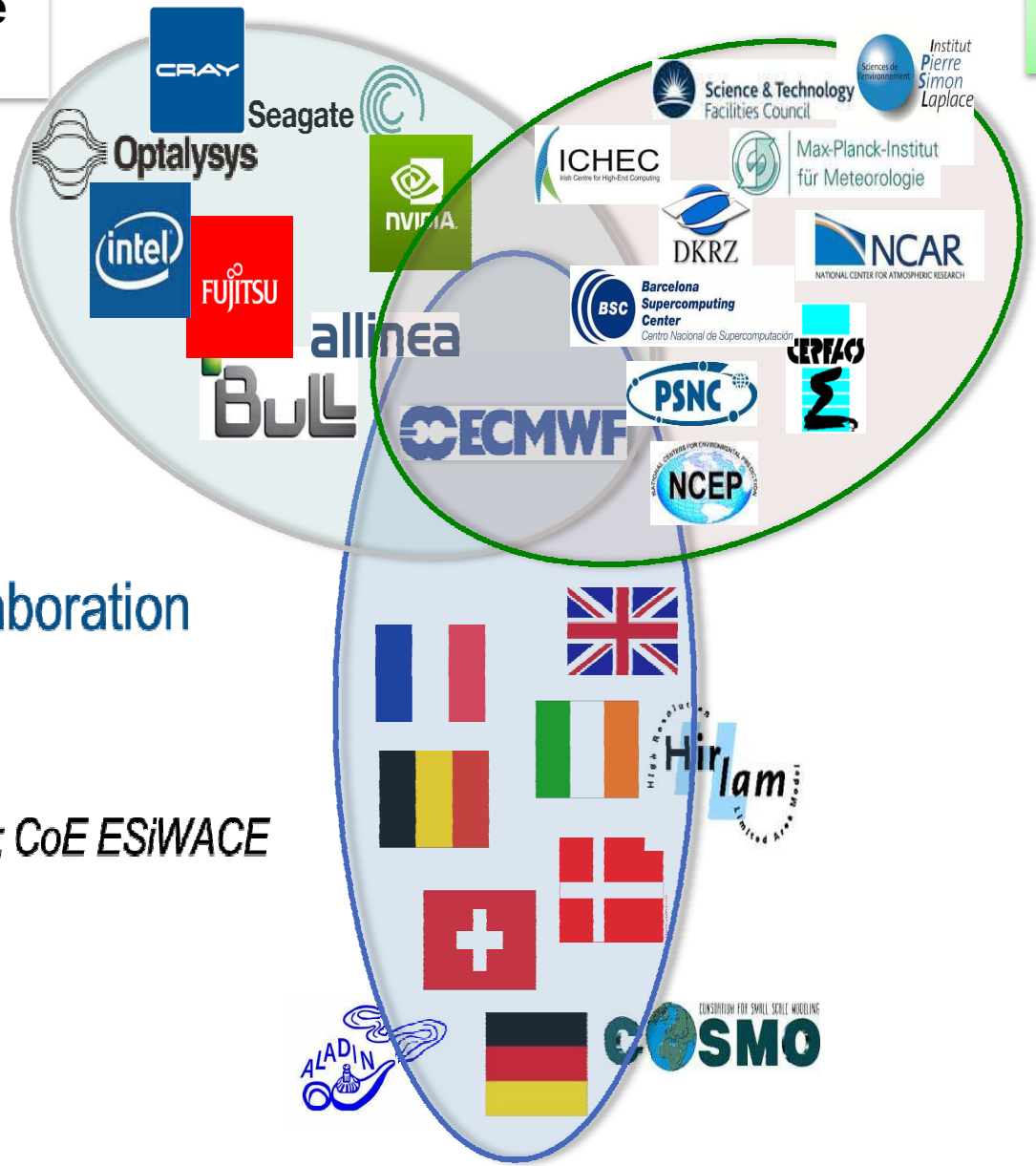
≈ M€ electricity/year

Technology advances may move the energy scale by one order of magnitude, so we need to be ready! *(Aurora 180PF, HPCwire April 2015)*

Scalability Programme needs Partnership

Hardware vendors

International Community



International collaboration

Horizon 2020

ESCAPE; NextGen-IO; CoE ESiWACE

European Commission

ECMWF Member States

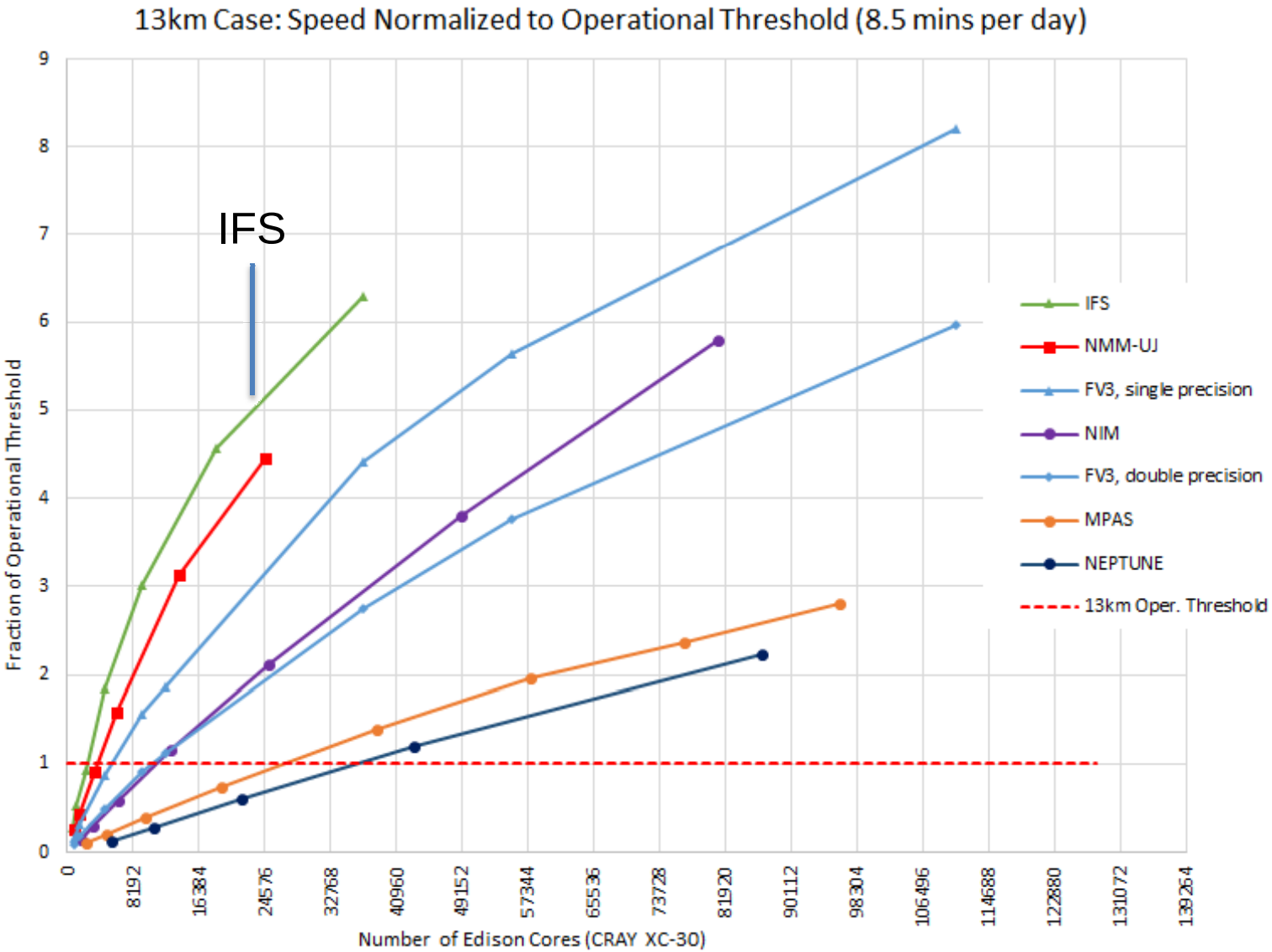
ECMWF

Outline

- The integrated forecasting system (IFS)
  - *Assets and the need for development*
  - *Developments at other Centres*
- A flexible, scalable and sustainable model infrastructure
  - *Scalability, discretization and numerical methods, equations, physics-dynamics coupling, tangent linear and adjoint model, uncertainty quantification, Earth-System complexity*
- Roadmap 2015 - 2025

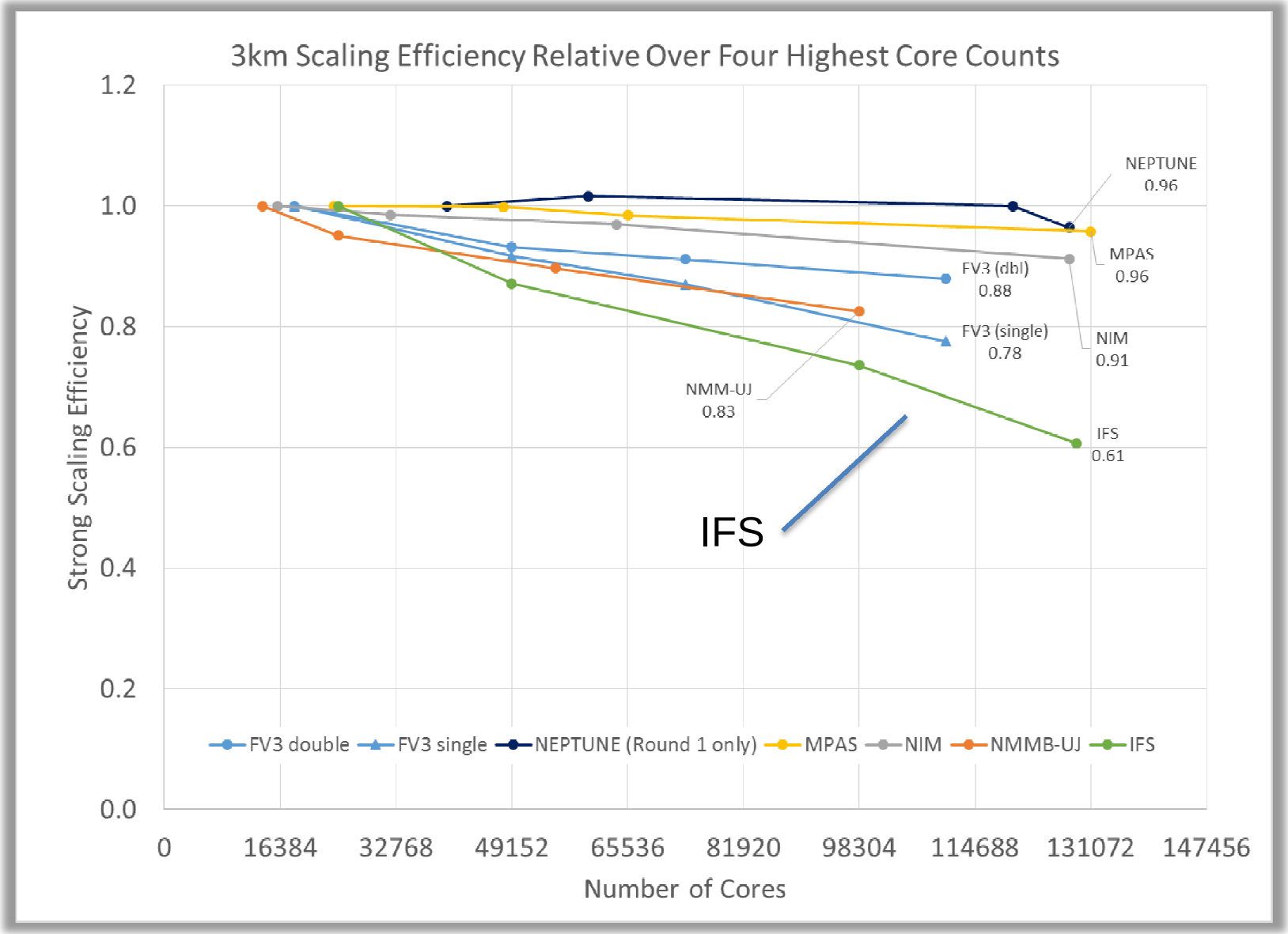
Wedi et al., 2015: The modelling infrastructure of the Integrated Forecasting System (IFS): Recent advances & future challenges, *Technical Report* **760**, Eur. Cent. For Medium-Range Weather Forecasts, Reading, UK.

Time-to-solution at 13km



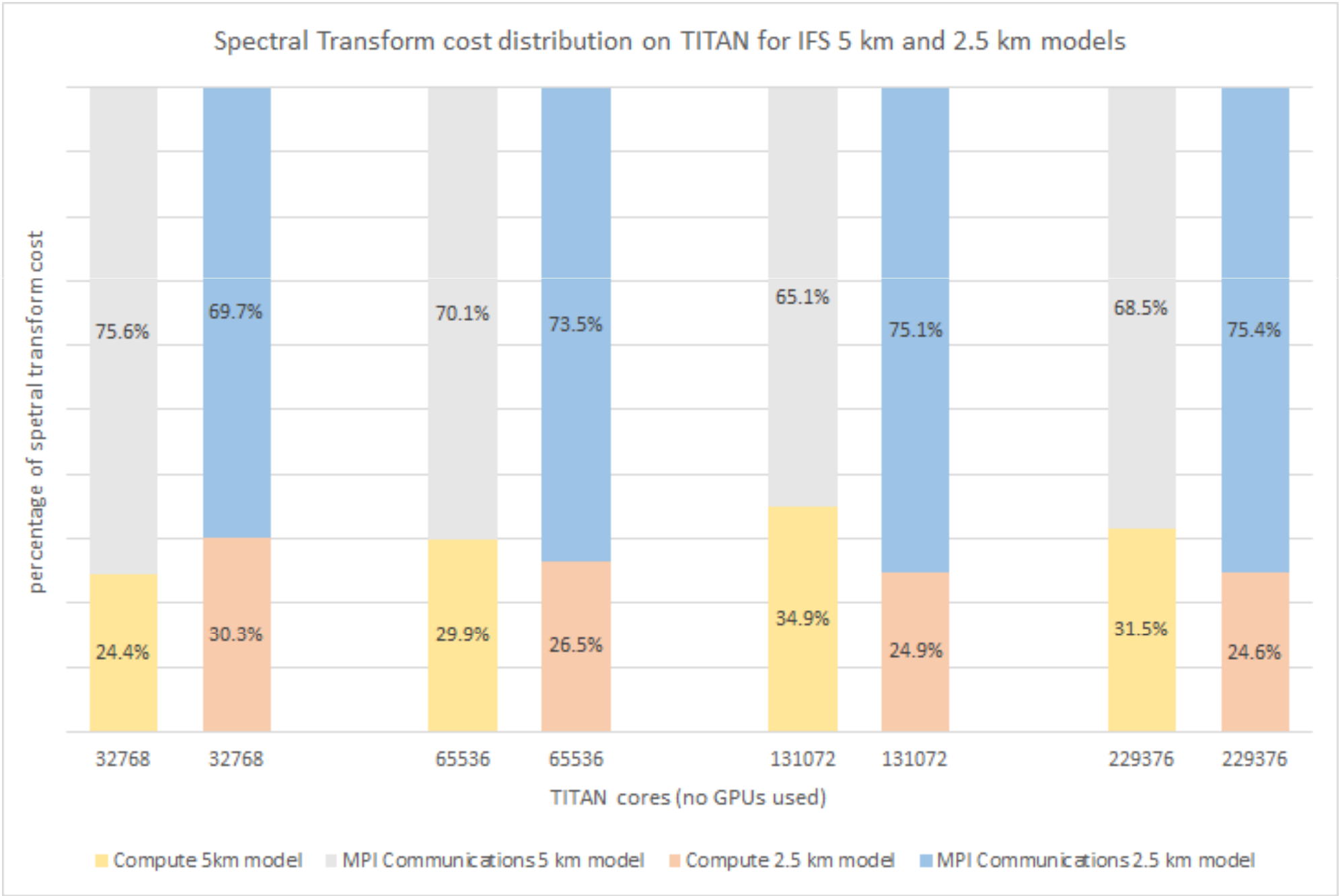
(Michalakes et al, NGGPS AVEC report, 2015)

Scaling efficiency at 3km

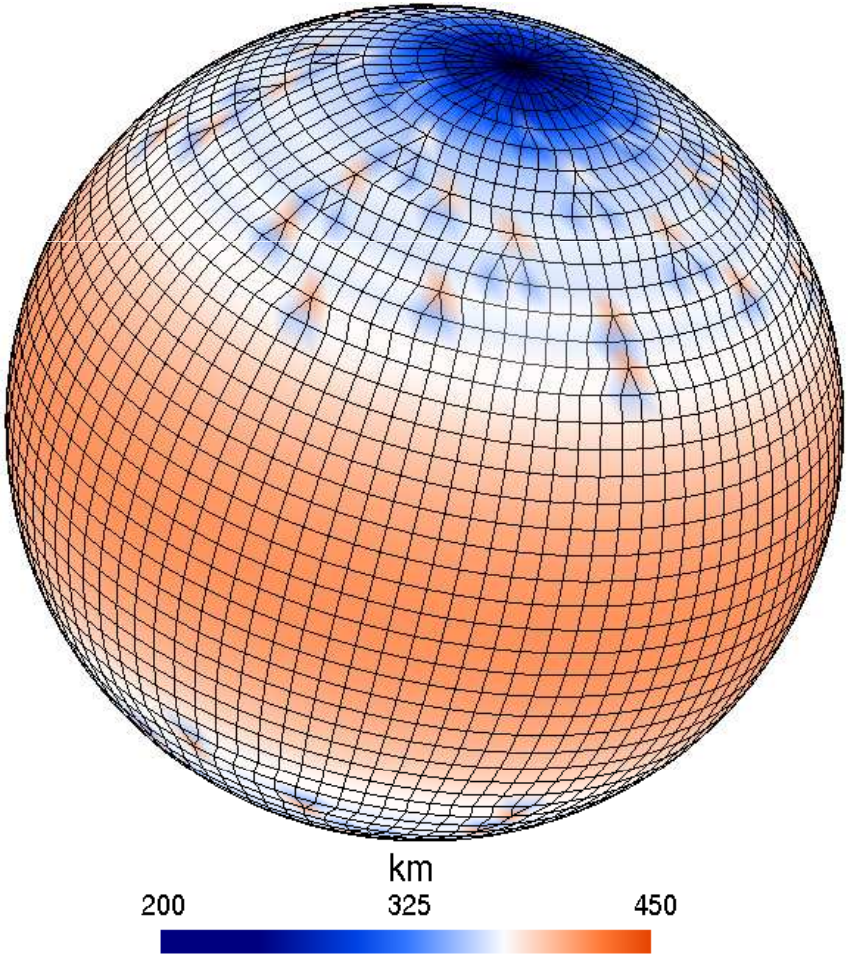


(Michalakes et al, NGGPS AVEC report, 2015)

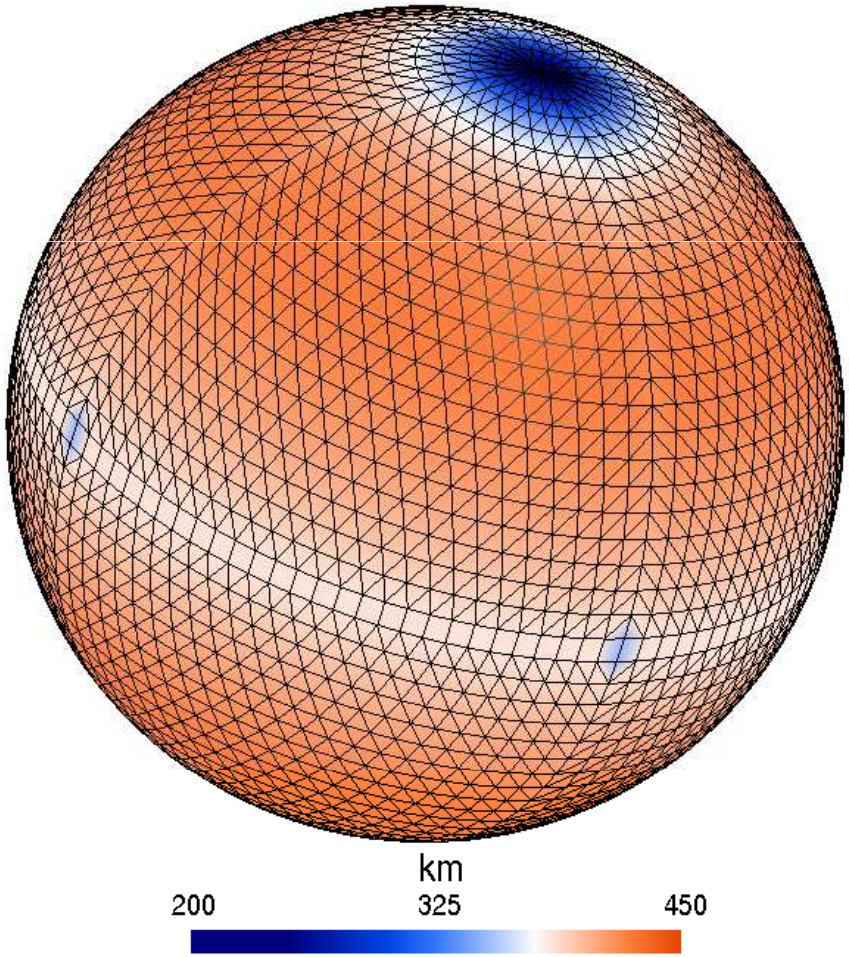
MPI communication cost at large core counts …



A new grid for ECMWF



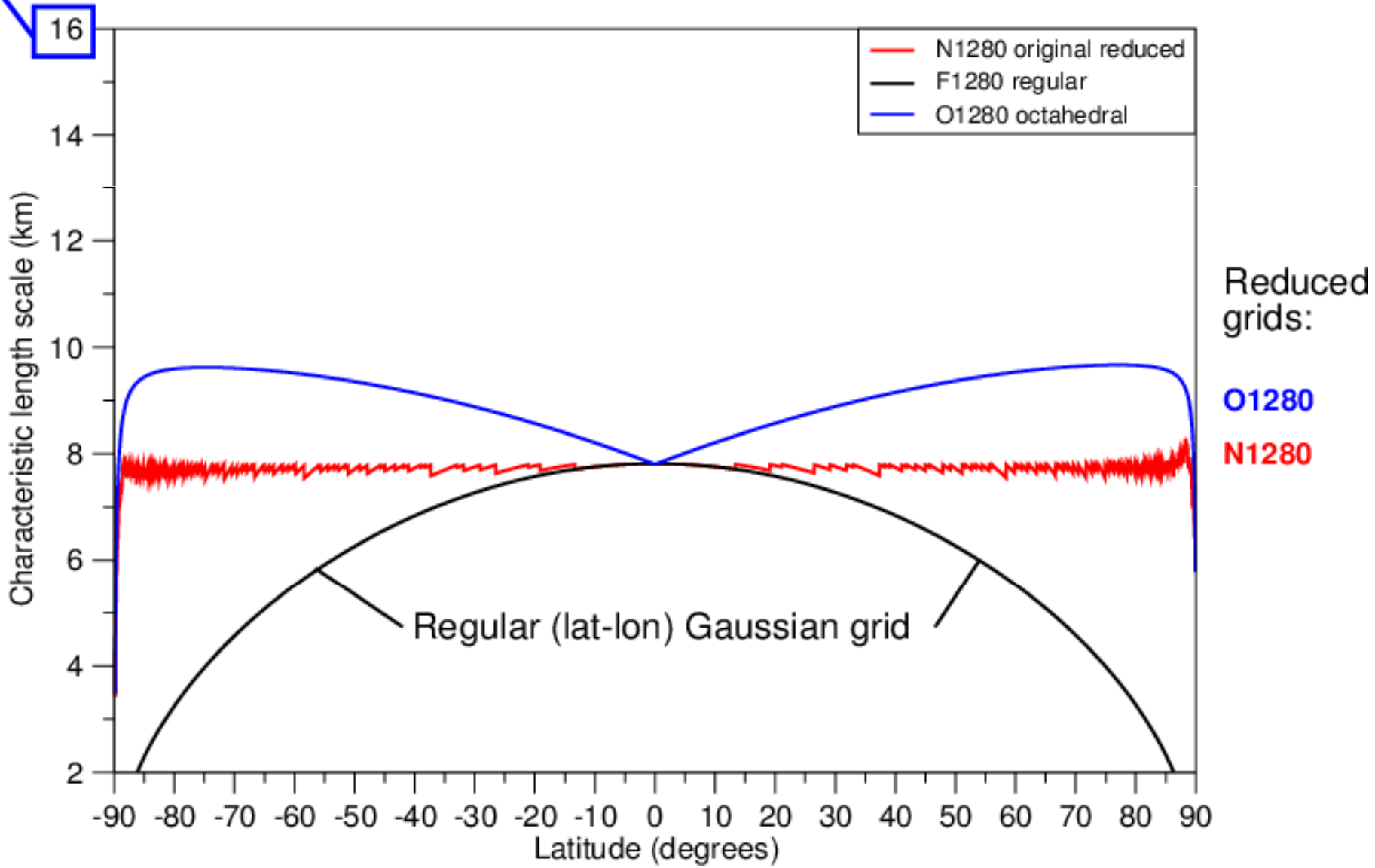
N24 reduced Gaussian grid



N24 octahedral Gaussian grid

Gaussian grids

current

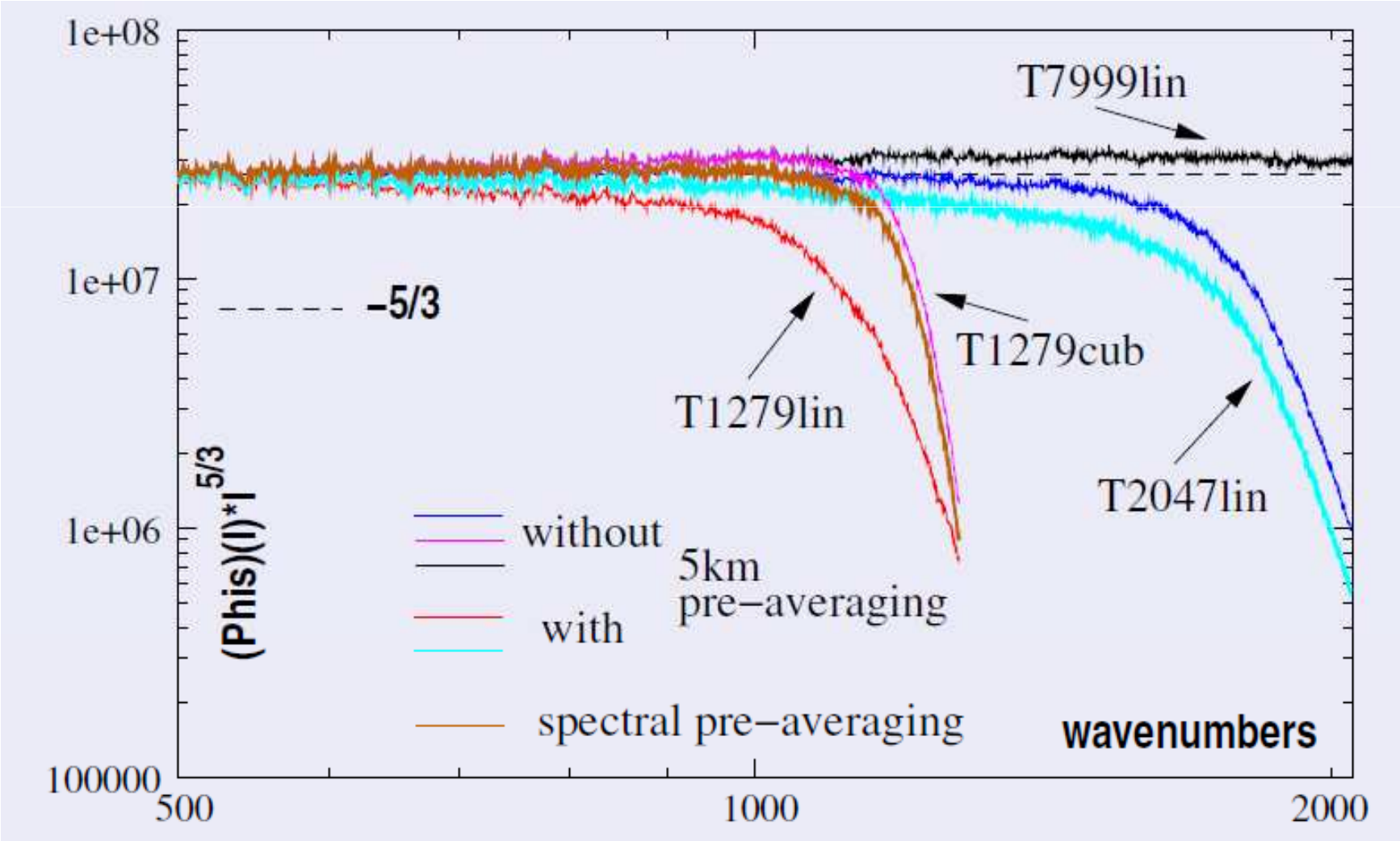


Reduced grids:

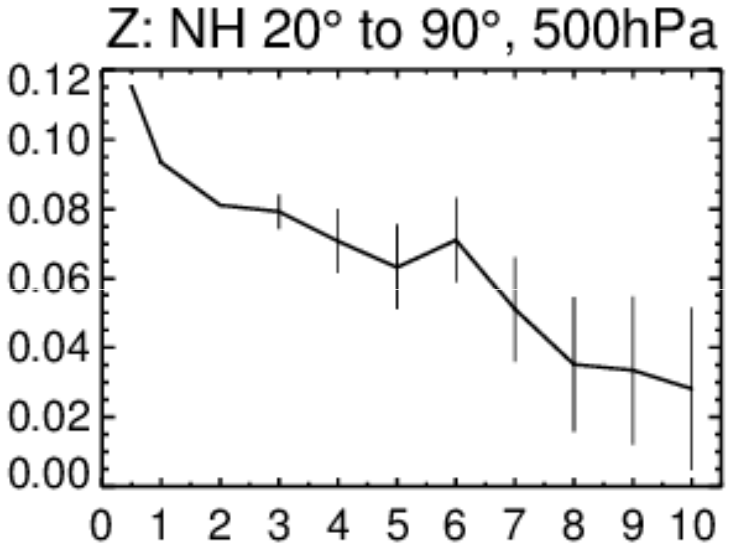
O1280

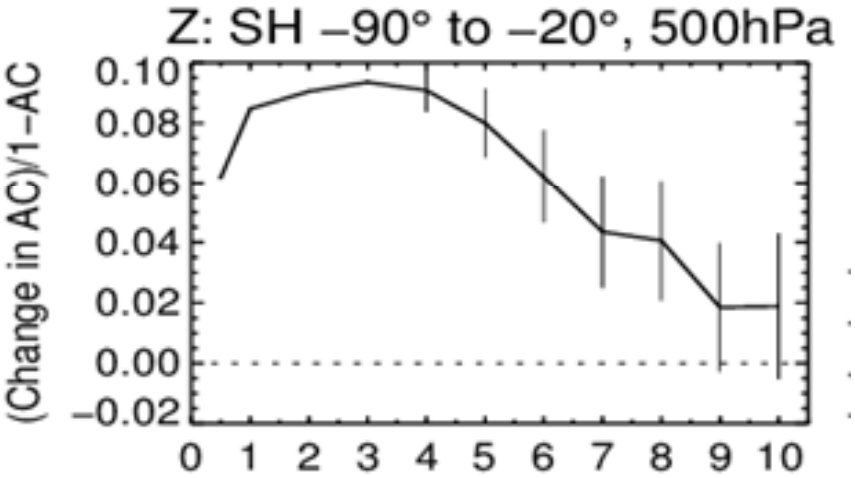
N1280

Orographic variance and truncation – TCo1279



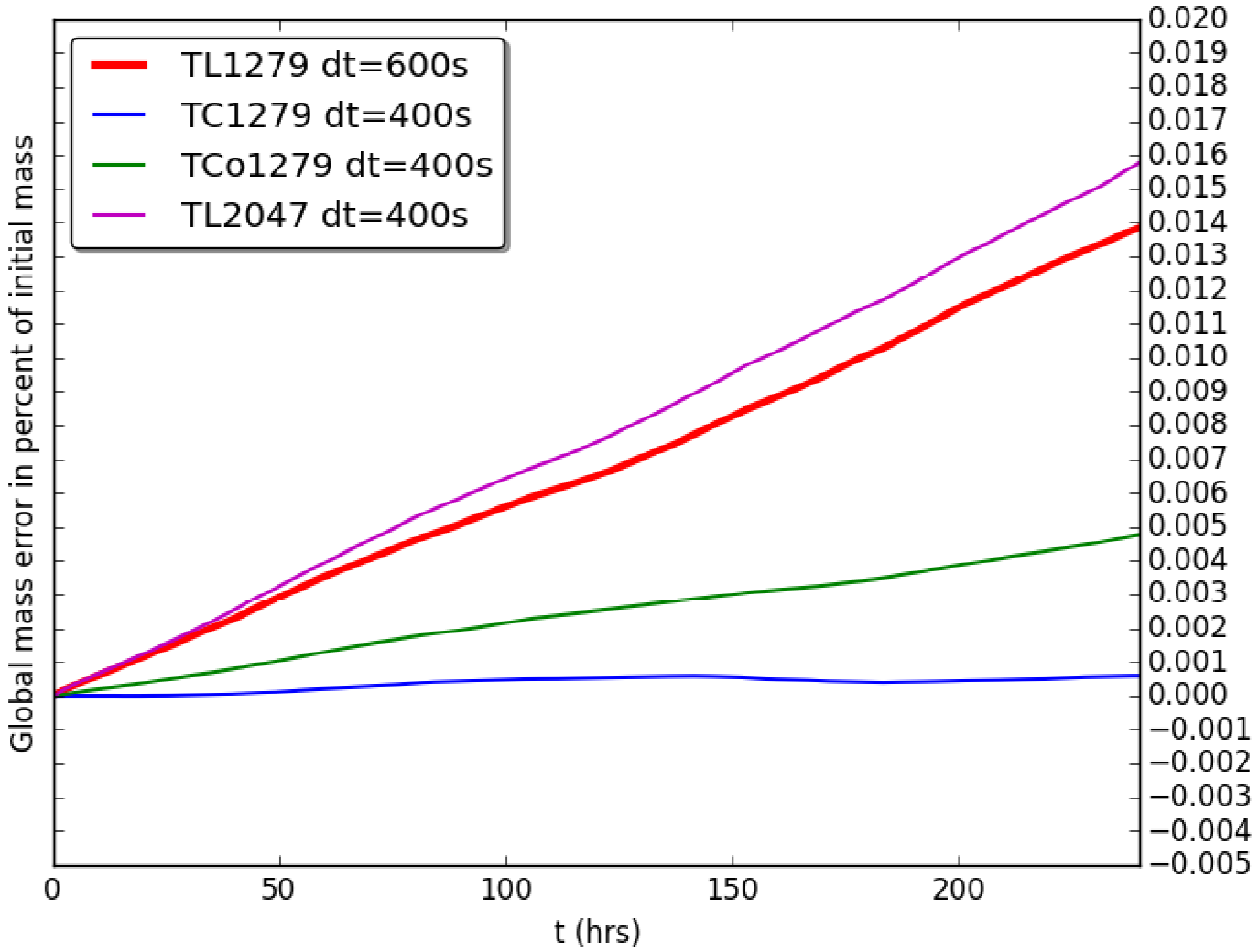
Increasing resolution makes a big difference!



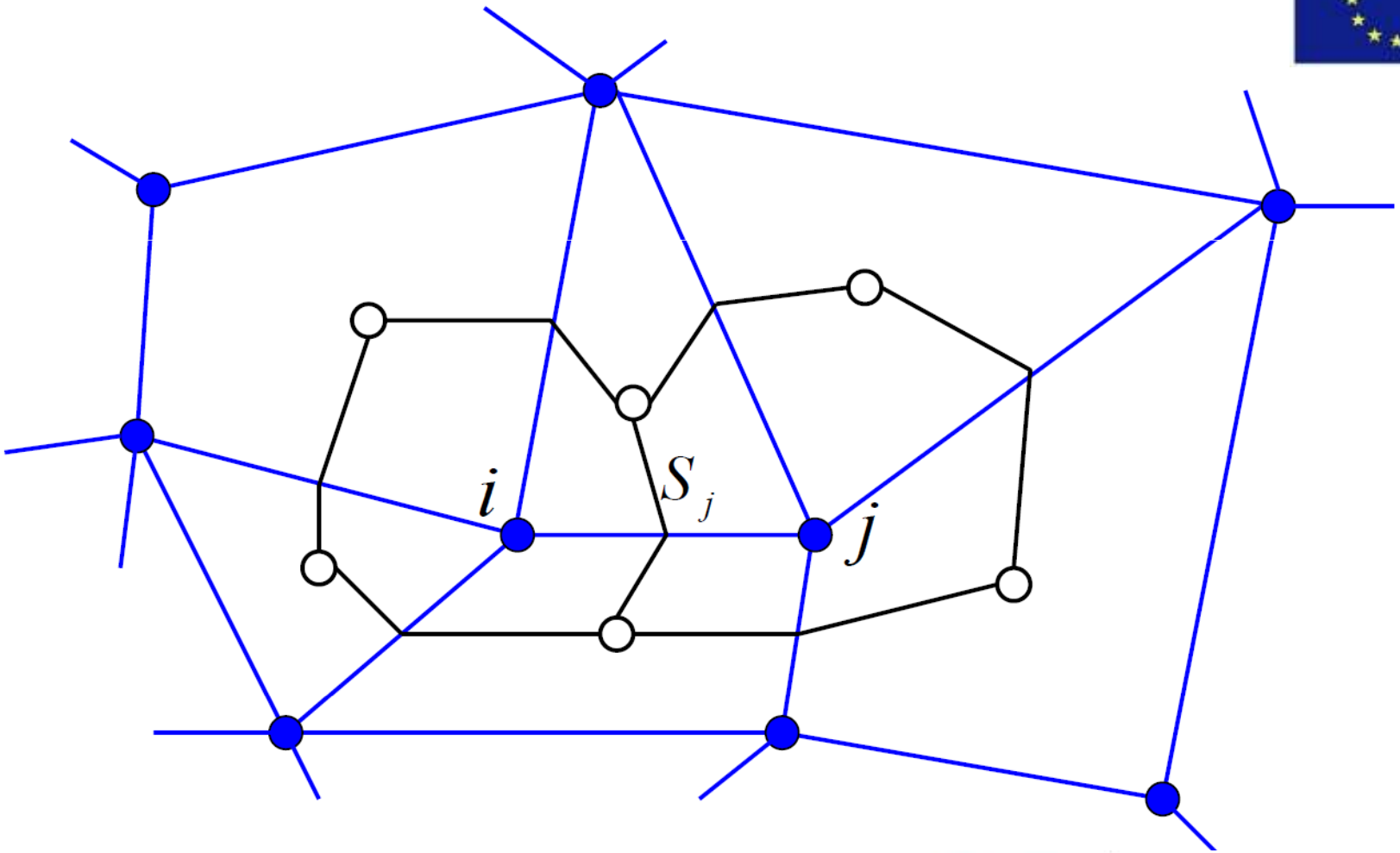


Significant change in anomaly correlation for southern hemisphere and northern hemisphere 500hPa, respectively, for 6 months of winter and summer cases, comparing the new analysis and forecast system TCo1279 (~9km) (TL399/TL319/TL255) cycle 41r2 with current operations at TL1279 (~16km)

Global mass conservation in IFS



“PantaRhei” – Non-hydrostatic Finite Volume Module (FVM) in the IFS: An unstructured median-dual mesh in 2D



(Szmelter & Smolarkiewicz, 2010; Smolarkiewicz et al, 2014, 2015)

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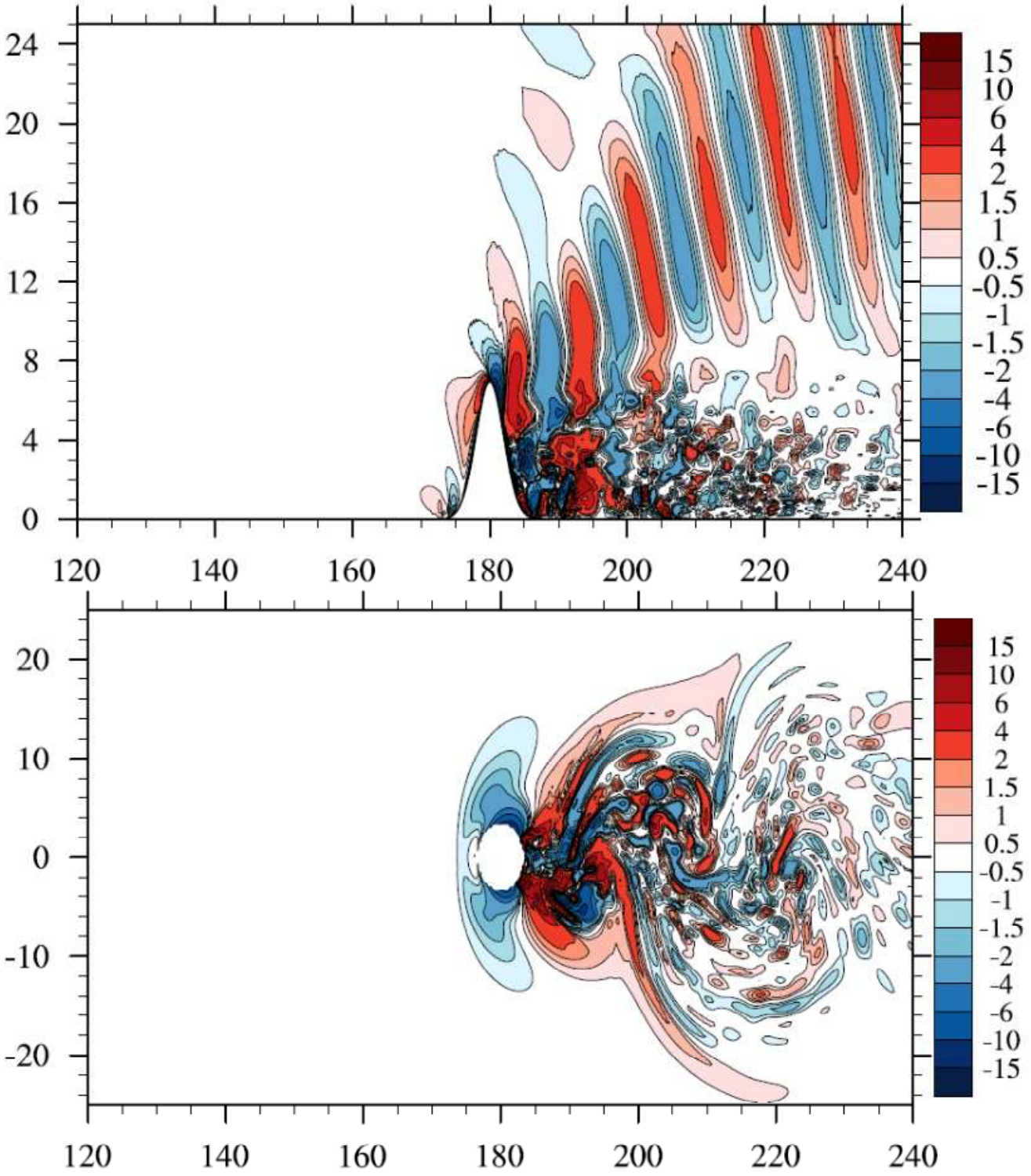
FVM
Vertical discretization

Generalised curvilinear coordinates with optionally static or dynamic adaptivity

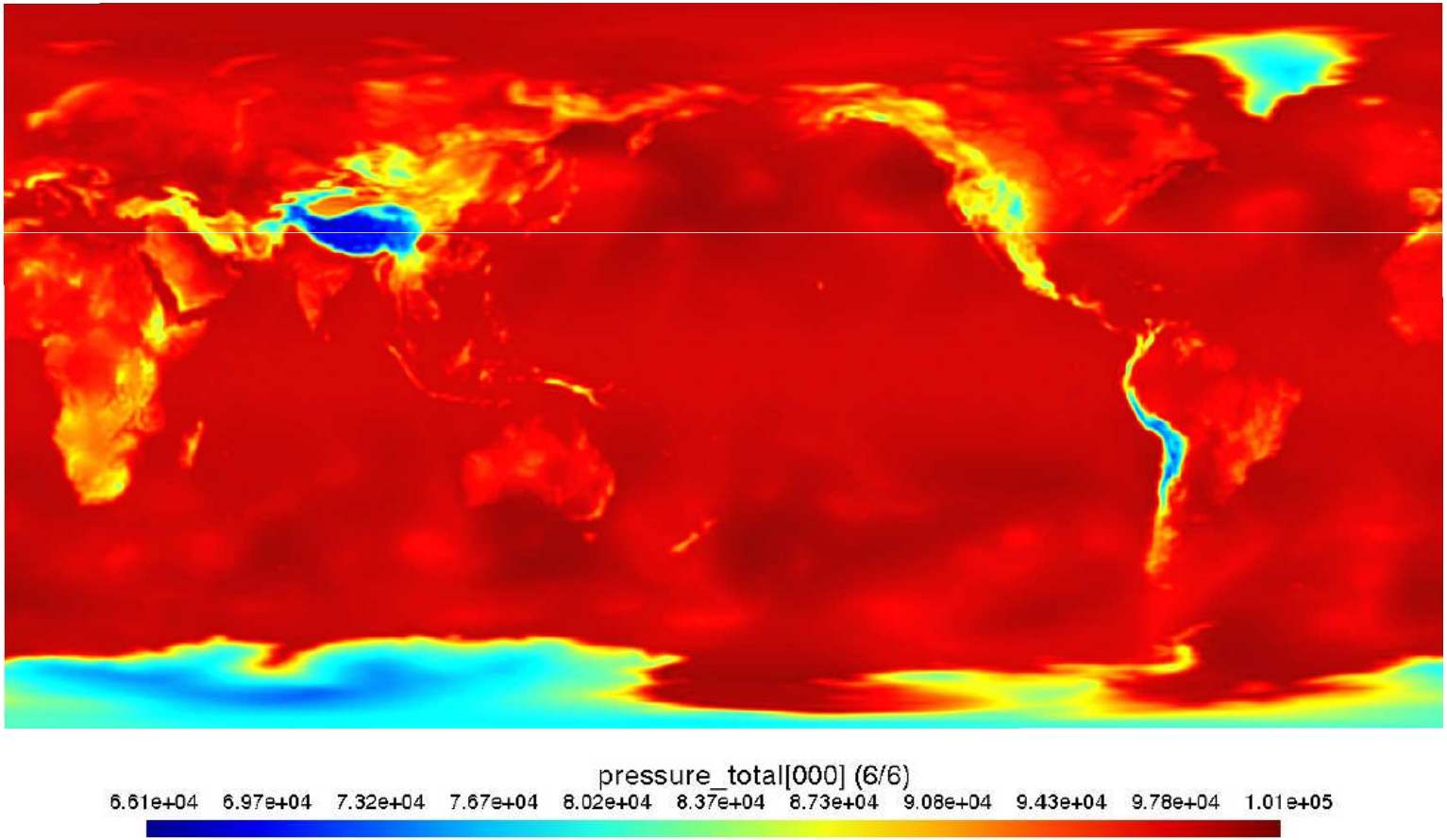
Different approach: time-independence in computational space (in contrast to current pressure coordinates)

Flow past 70° slope on the small planet



ECMWF

FVM simulation of a global circulation using realistic orography: surface pressure



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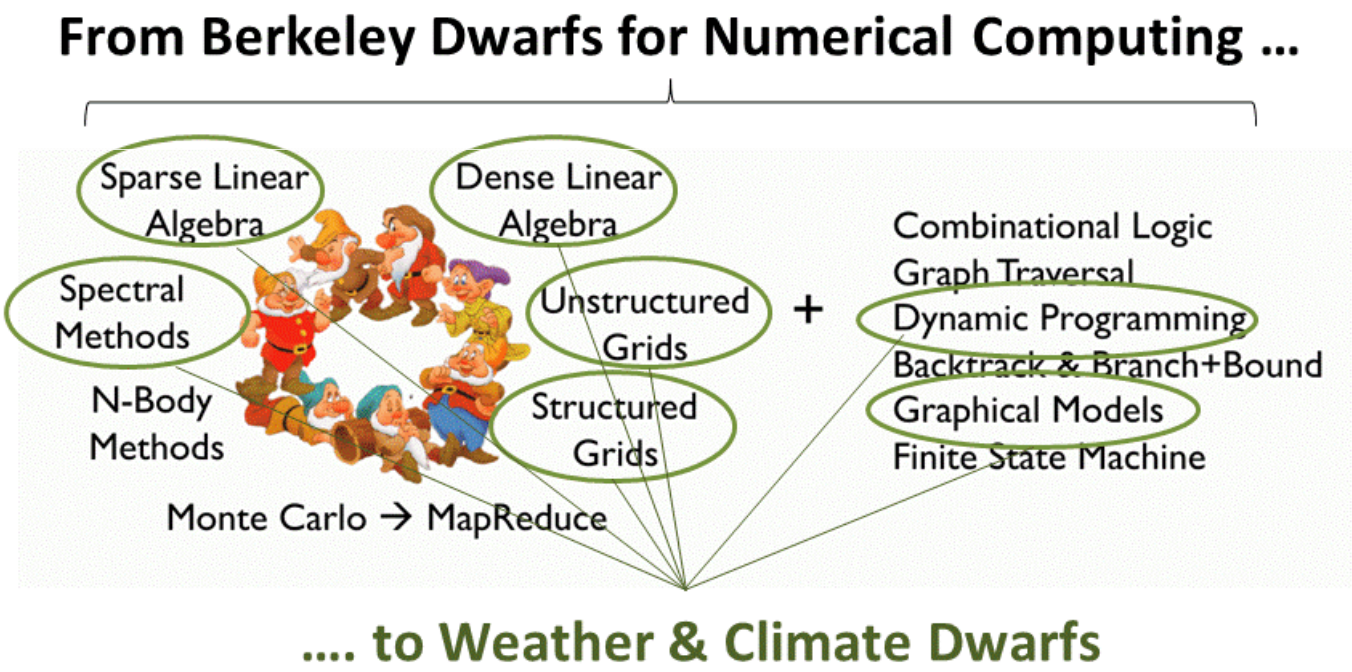
Scalability: ESCAPE

http://hpc-escape.eu

Energy-efficient Scalable Algorithms for Weather Prediction at Exascale



1. **Define fundamental algorithm building blocks** (hereafter called **"*Weather & Climate Dwarfs*"**) to foster trans-disciplinary research and innovation and to co-design, advance, benchmark and efficiently run the next generation of NWP and climate models on energy-efficient, heterogeneous HPC architectures.
2. **Map key NWP processes to energy-efficient, specialized compute units and novel accelerator technologies,** addressing performance portability, and by establishing in NWP novel data structures, mathematical algorithms and numerical methods encapsulated in new dwarfs.

Outlook

- Optimize *energy-to-solution* and *information density*
- Engage with EWGLAM consortia in *ESCAPE* on
  - Novel numerical techniques
  - Accelerator use
  - Open Source data structure, parallelisation and processing software (Atlas/MIR)

Roadmap for IFS model development