The Met Office Dynamical Core

Present and Future perspectives

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Outline

- ENDGame (Operational since July 2014 [Global])
- GungHo Project: Collaboration with:
  - Met Office
  - NERC: Bath, Exeter, Imperial, Leeds, Manchester, Reading, and Warwick Universities
  - STFC/Hartree Centre
- LFRic: A new UM infrastructure

Met Office Dynamical Core Past and Present

- ENDGame is an evolution from ND (Previous Model: 2002-2014)
- ENDGame shares many features with ND
- But ENDGame contains many new and improved features

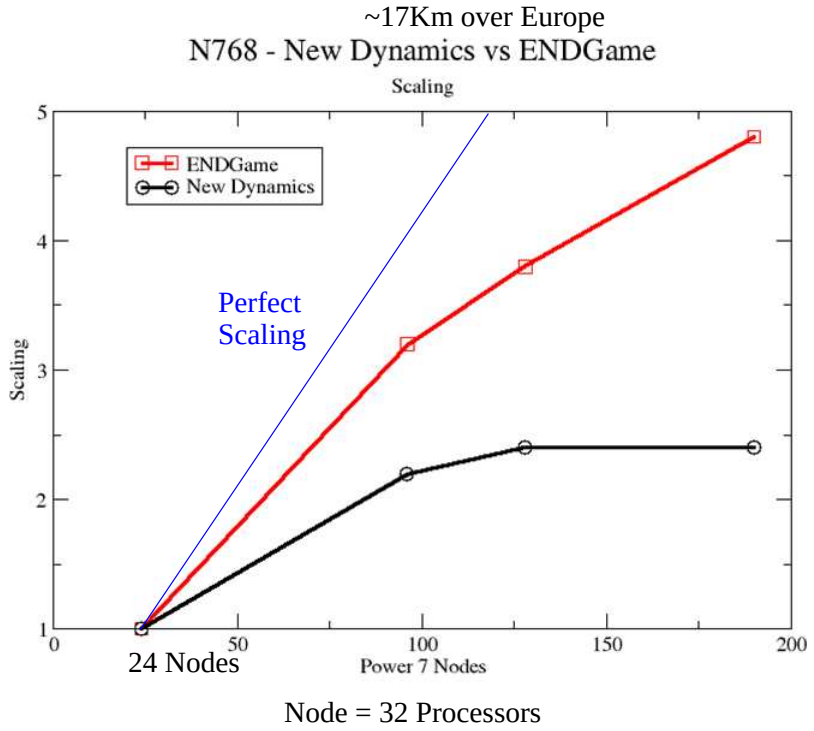
ENDGame-ND common features

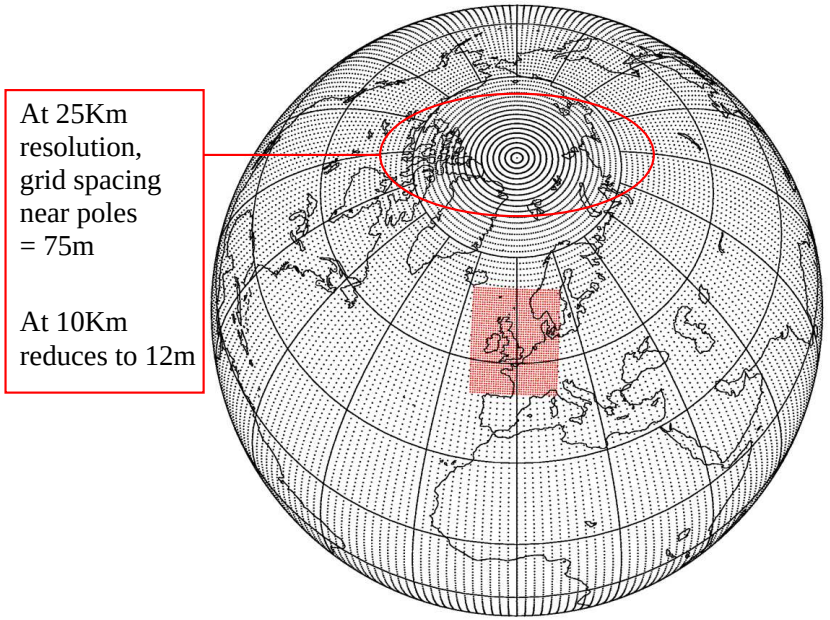
- Same set of deep non-hydrostatic atmospheric equations
- Same Longitude-Latitude grid
- Same C-Charney-Phillips variables/grid staggering
- Semi-Implicit semi-Lagrangian scheme

ENDGame main new features

- A consistent semi-Lagrangian scheme for the advection of all fields
- Iterative scheme instead of predictor-corrector approach
  - Improved stability
  - Reduced off-centring ($\sim$ centred scheme)
- v at poles instead of pressure
  - Improved conditioning of the Helmholtz problem
  - Fast convergence
- A simplified Helmholtz problem
- An efficient BiCGStab with Black & Red SOR Preconditioner
- A better conservation approach
- No polar filtering or horizontal diffusion

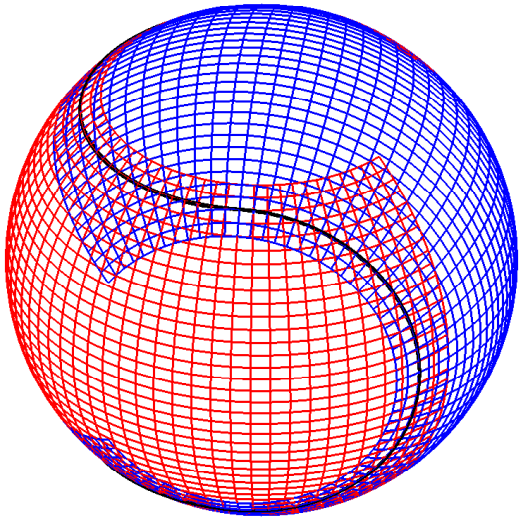
Long-Lat Grid: The End of the Road



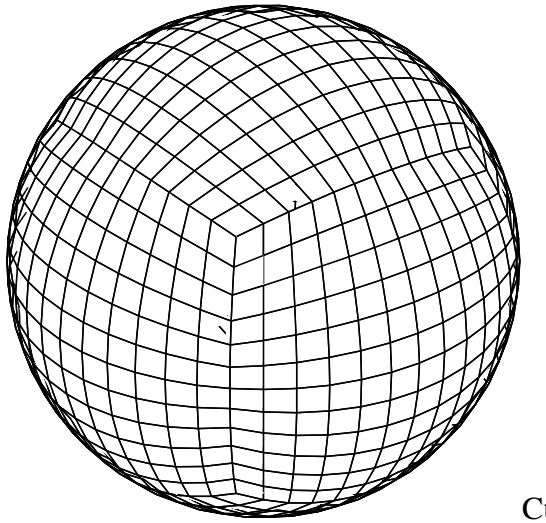


Grid Anisotropy → Stability → Timestep limitations→ Ill-conditioning → Increased Communications → Load imbalance → Performance Bottleneck

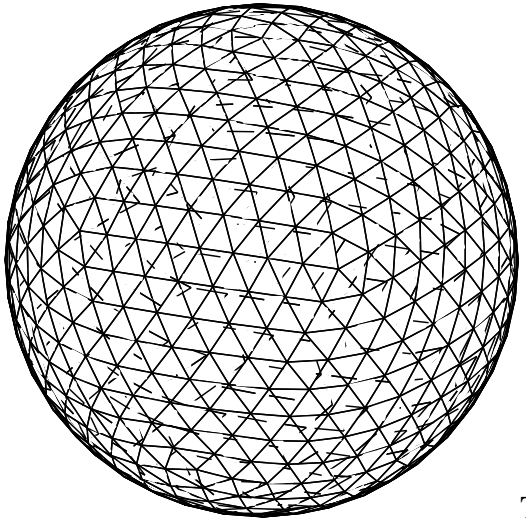
Alternatives to Long-Lat Grid



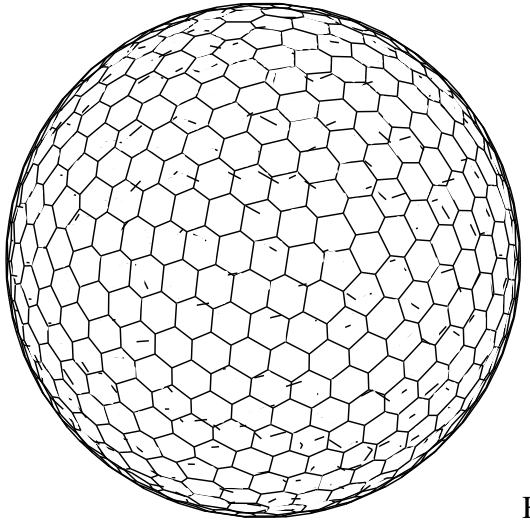
Yin-Yang



Cube-Sphere



Triangular



Hexagonal

GungHo Project: Objectives

- Highly Scalable model
  - Quasi-Uniform Grids (Hexagonal, triangles, cubed-sphere, Yin-Yang)
  - Minimum (or avoid global) communications
  - Key = Local Algorithms/Schemes
- Comparable performance and capabilities with the present model
  - Solve the same equation set
  - Maintain the Unified approach of Global/Limited Area/NWP/Climate configurations

Desirable properties for a dynamical core

- Mass conservation
- Accurate representation of balance and adjustment
- Accuracy at least approaching second order
- Absence of computational modes
- Consistent discretisation (maintain properties of continuous equations or converge to them in the limit of finer mesh-time)
  - Pressure gradient should not produce spurious vorticity
  - Energy conserving pressure and Coriolis terms
  - No spurious Rossby modes
  - Conservation of axial angular momentum

GungHo: The Road Map

- Mixed Finite Elements achieve most of the desired properties
- Finite Element framework allows various options to be pursued
- Actively pursuing 2 main approaches:
  - Quadrilateral elements: (equi-angular cubed sphere)
    - Lowest order approach (similar to C-grid method)
    - Higher order approach (to reduce grid imprinting)
  - Triangular elements:
    - Requires higher order to avoid computational modes
    - Has an unresolved dispersion problem
    - More uniform and flexible grid
- Multi-grid solver (Implicit) and Explicit options
- Flux form advection schemes for transport

GungHo: On going work and future directions

- Developed shallow water models to investigate the different methods
- Developed a 3D discretisation
- Developing a prototype 3D model in the LFRic framework
- Use 3D model to test vertical dicretisation options
- Incorporate the Multi-grid solver into the prototype model
- Physics Coupling:
  - How to couple FE with physics
  - What dynamics/physics splitting scheme to use
  - Impact of forcings on grid imprinting (e.g. cubed sphere corners)

LFRic

- A new flexible UM computational infrastructure
- To take care of:
  - Configurations
  - Coupling model's components
  - Parallelism
- Allow easy implementation of scientific developments
- Allow easy plug-and-play

”No” Questions Please