An overview of GungHo:

Its origins, inception, organisation and aims

Nigel Wood, UK Met Office

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Outline

- The Unified Model – where we are now
- The need for change
- GungHo!
- Issues and progress
- Summary

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Met Office's Unified Model

Unified Model (UM) in that *single* model for:

- Operational forecasts at
  - Mesoscale (resolution approx. 12km → 4km → 1km)
  - Global scale (resolution approx. 25km)
- Global and regional climate predictions (resolution around 100km, run for 10-100 years)
- Seasonal predictions
- + Research mode (1km - 10m) and single column model
- 21 years old this year

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Current Unified Model

"New Dynamics"

Davies et al. (2005)

Dynamics:

- Regular lat/lon grid.
- Non-hydrostatic dynamics with a deep atmosphere.
- Semi-implicit time integration with 3D semi-Lagrangian advection.
- Atmospheric tracer advection

Physics:

- Spectral band radiation
- Diagnostic or prognostic cloud
- Mixed-phase ppn
- Mass flux convection
- Boundary layer
- Gravity wave schemes

Coupling possible to non-atmospheric components:

- Land surface model
- Ocean model
- Sea ice model
- Chemistry/aerosol model …

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Operational NWP Models: Jun 2011

Global

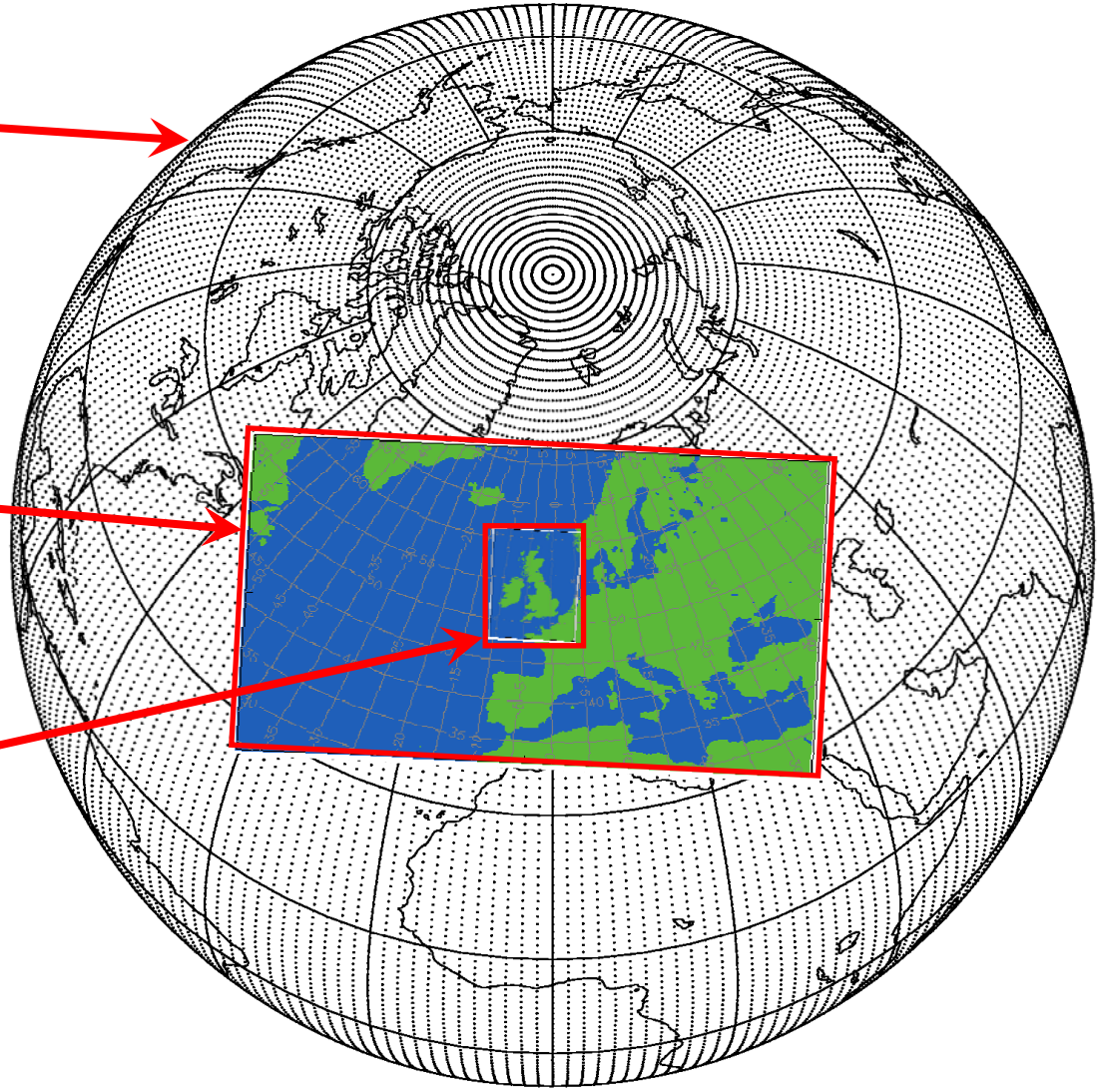
- 25km 70L
- 4DVAR – 60km
- 60h forecast twice/day
- 144h forecast twice/day
- *+24member EPS at 60km 2x/day*

NAE

- 12km 70L
- 4DVAR – 24km
- 60h forecast
- 4 times per day
- *+24member EPS at 18km 2x/day*

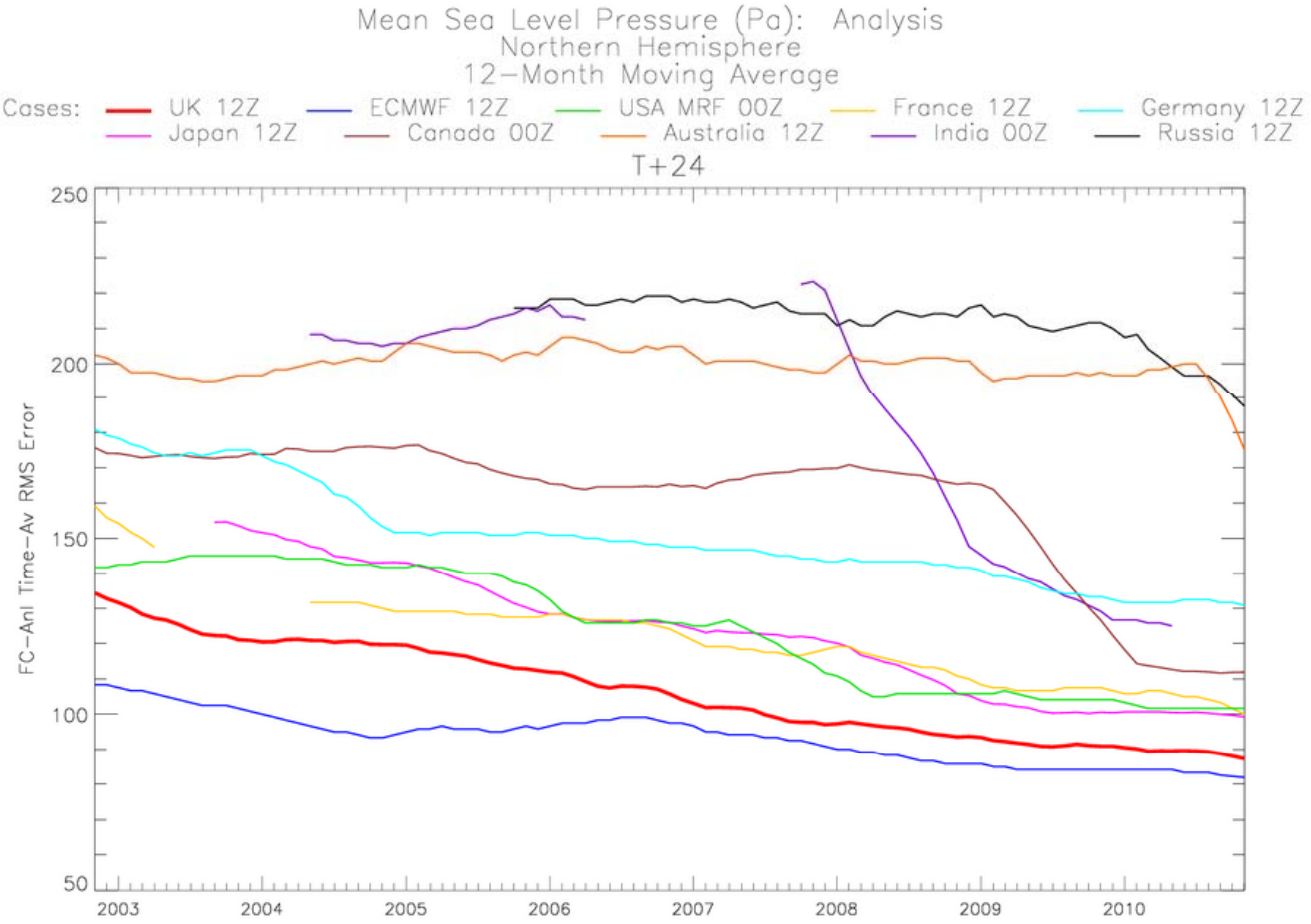
UK-V *(& UK-4)*

- 1.5km 70L
- 3DVAR (3 hourly)
- 36h forecast
- 4 times per day



Relative performance

RMS surface pressure error over the Northern Hemisphere



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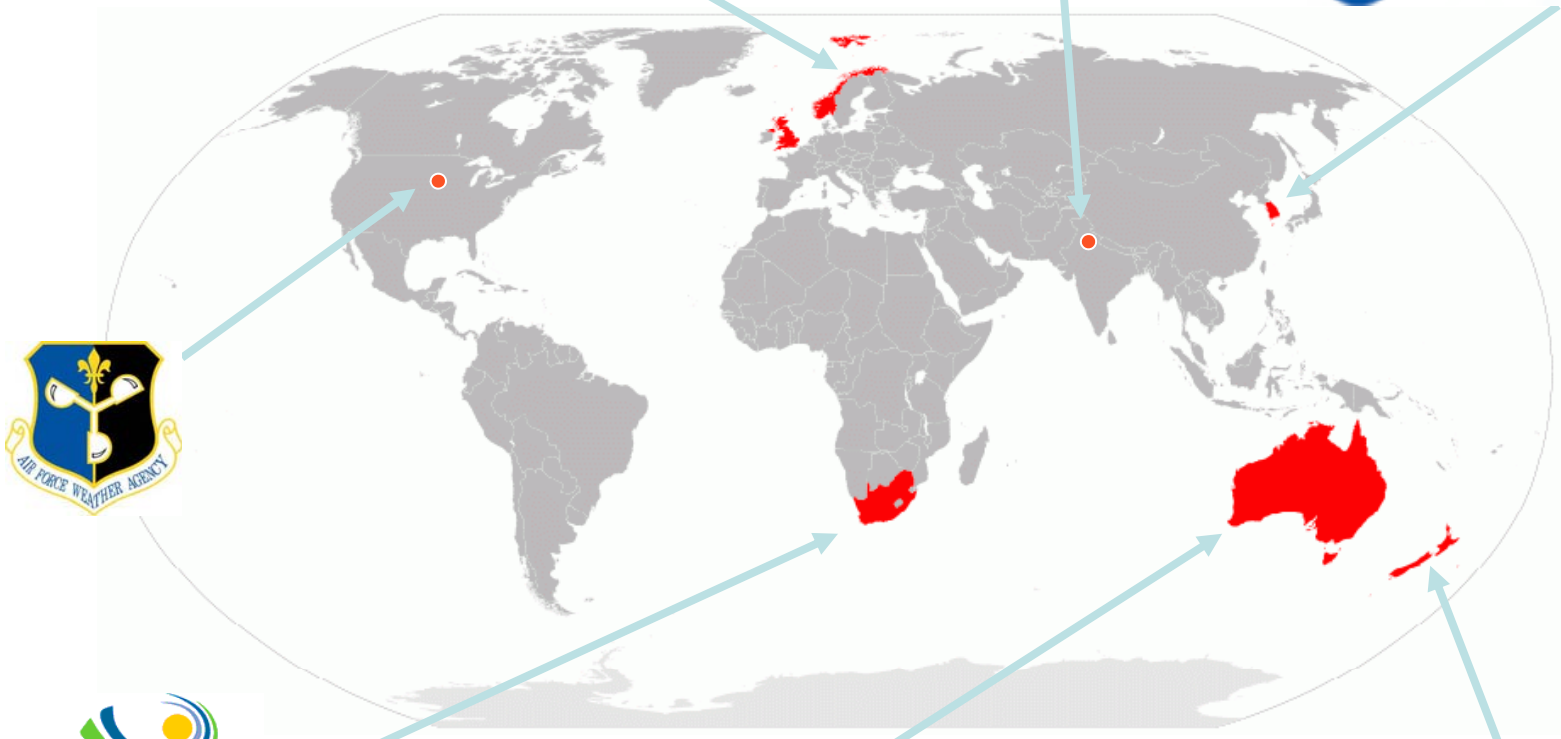
Operational users 2011



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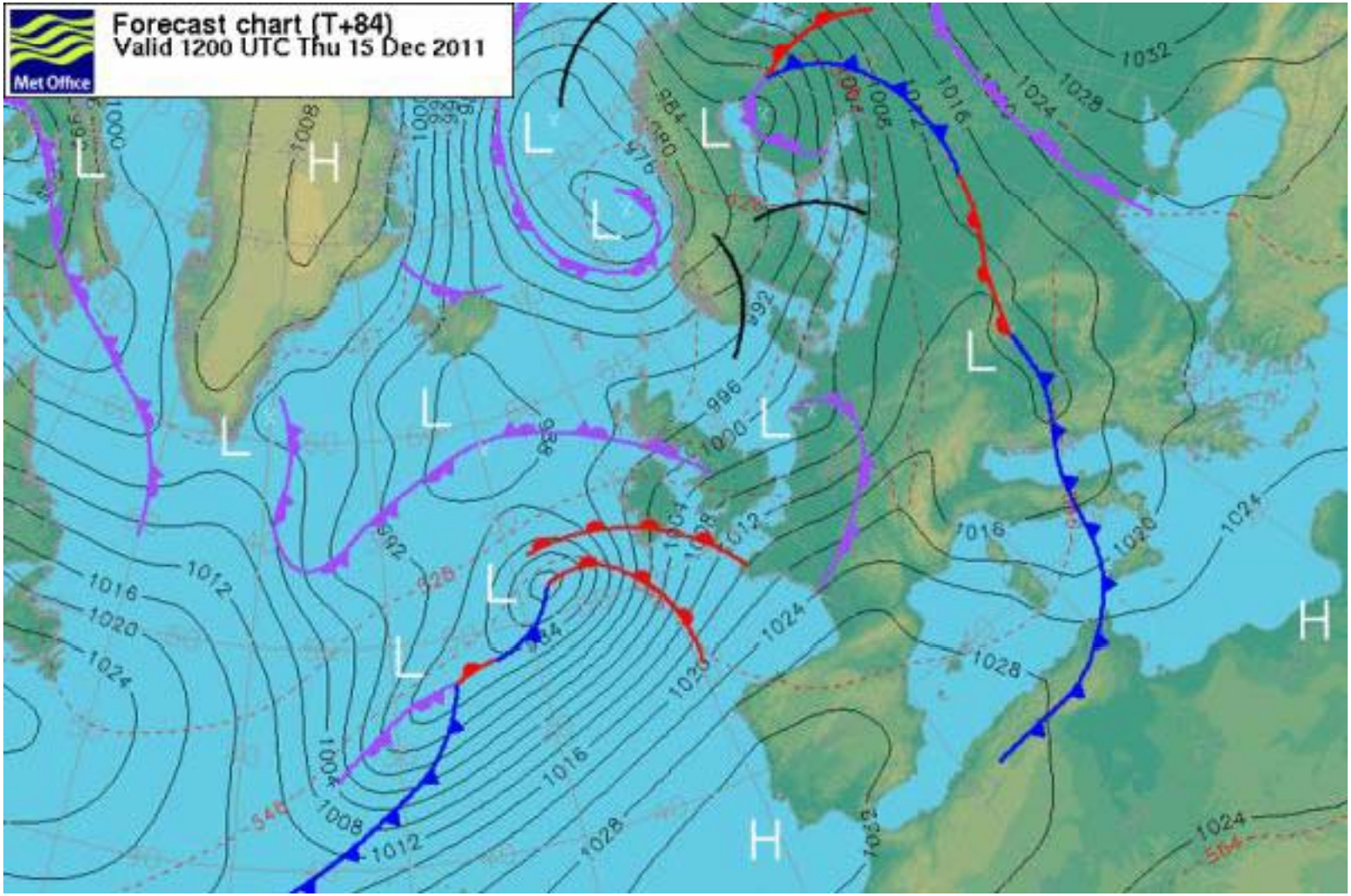
And today's weather…



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The need for change…

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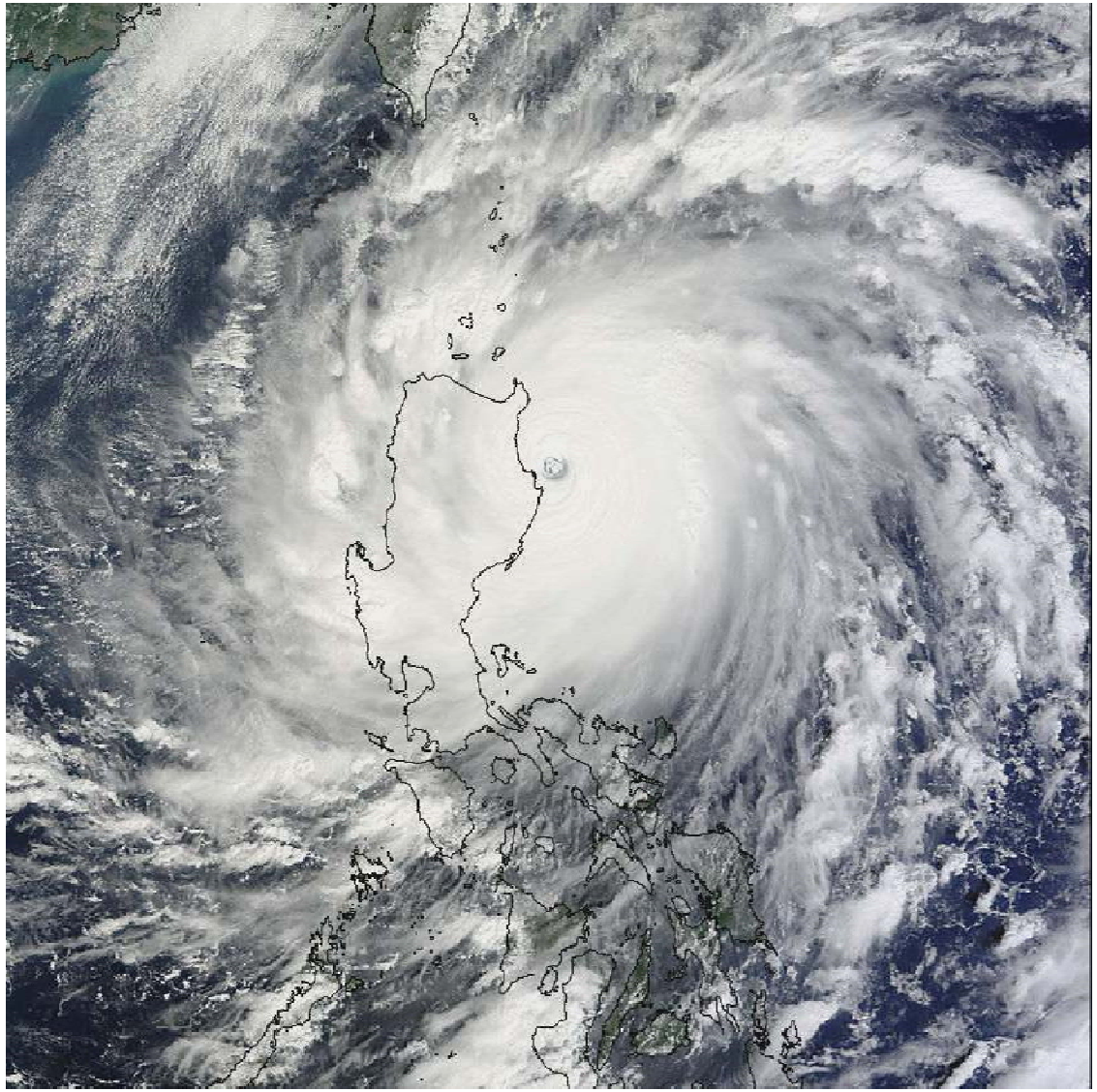
Super-typhoon Megi

Stuart Webster

- Made landfall in the Phillipines on October 18th 2010
- Lowest recorded central pressure for 20 years :– 885hPa
- Image to right captured by Terra satellite just prior to landfall
- 1.5km nested simulation



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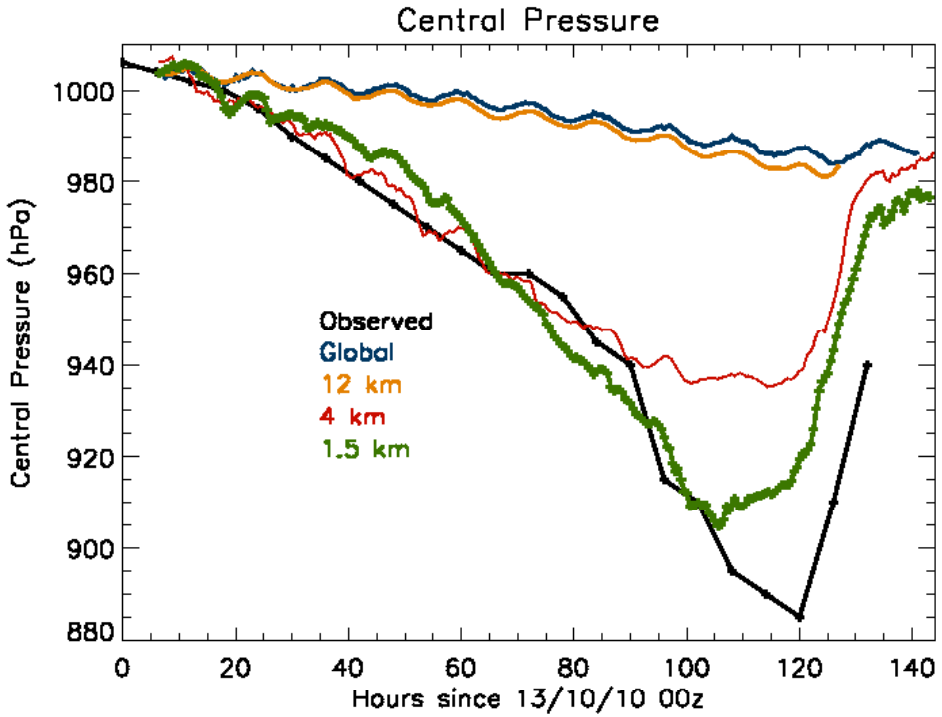
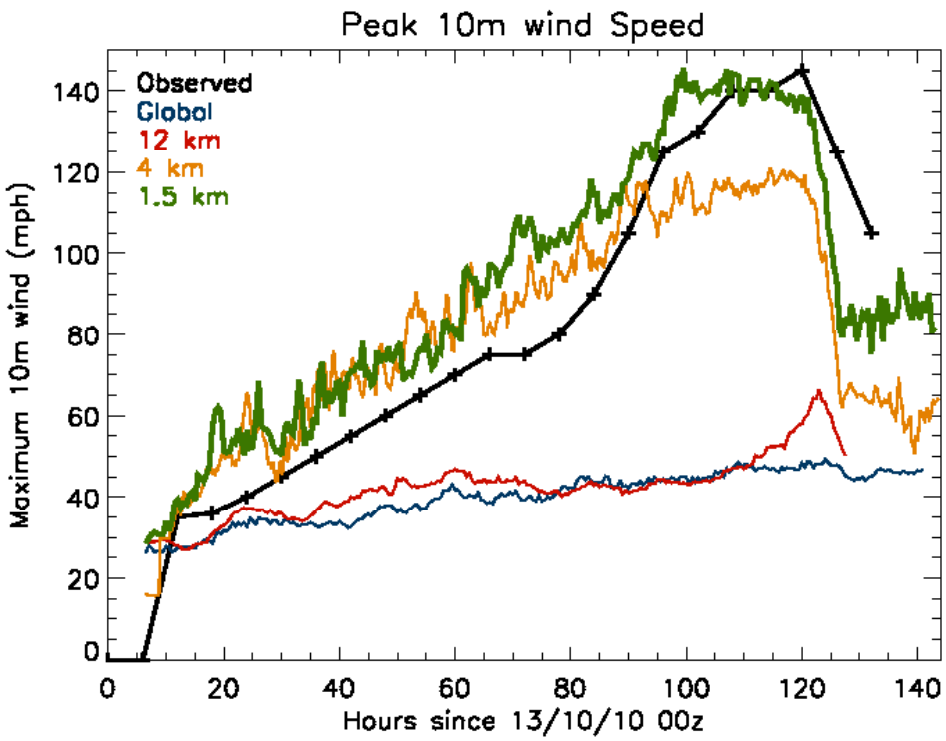
Resolution, resolution, resolution…





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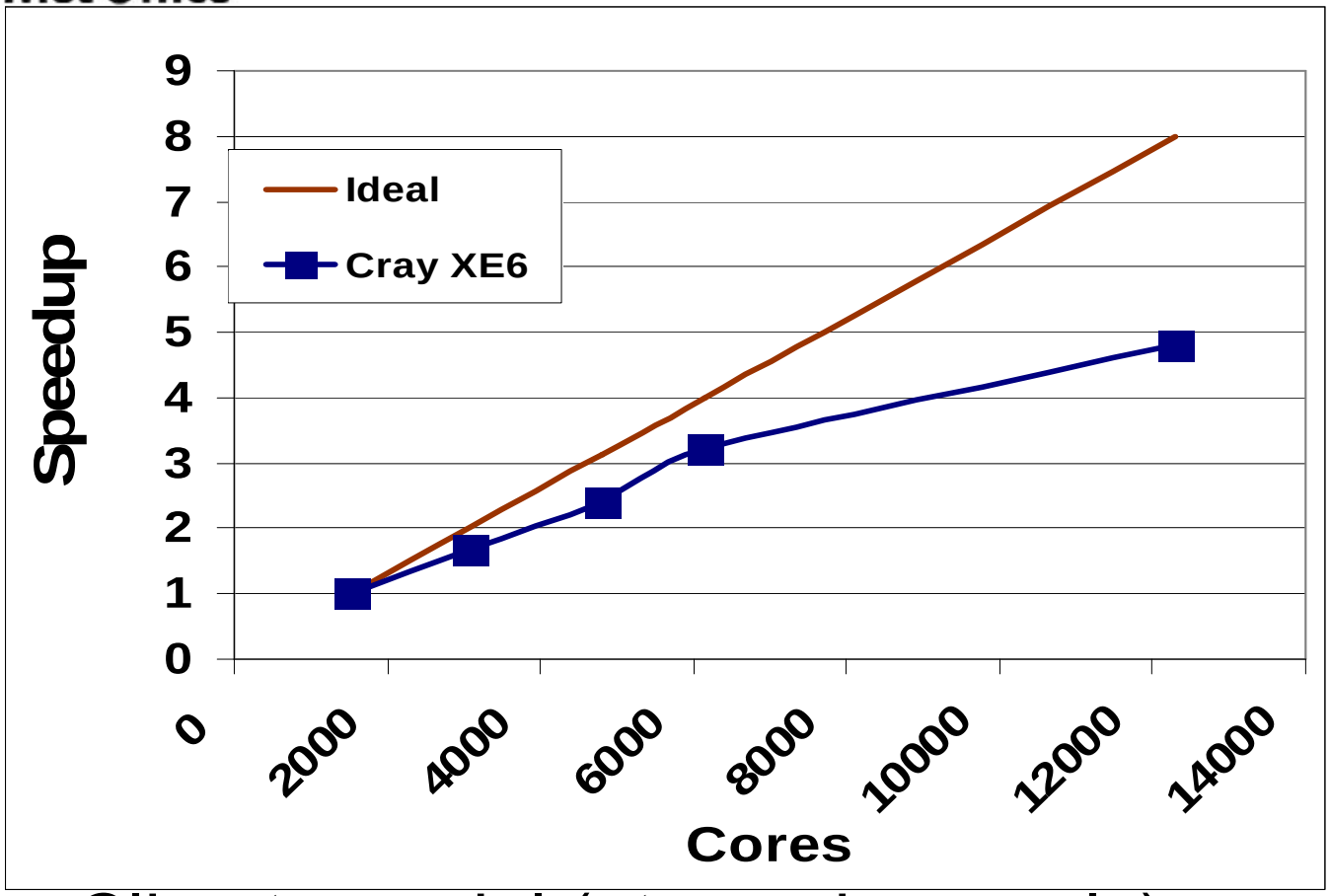
N512 scalability – Cray XE6



Thanks to Pier-Luigi Vidale, NCAS

- Climate model (atmosphere only)
- Preparation for real science on PRACE XE6

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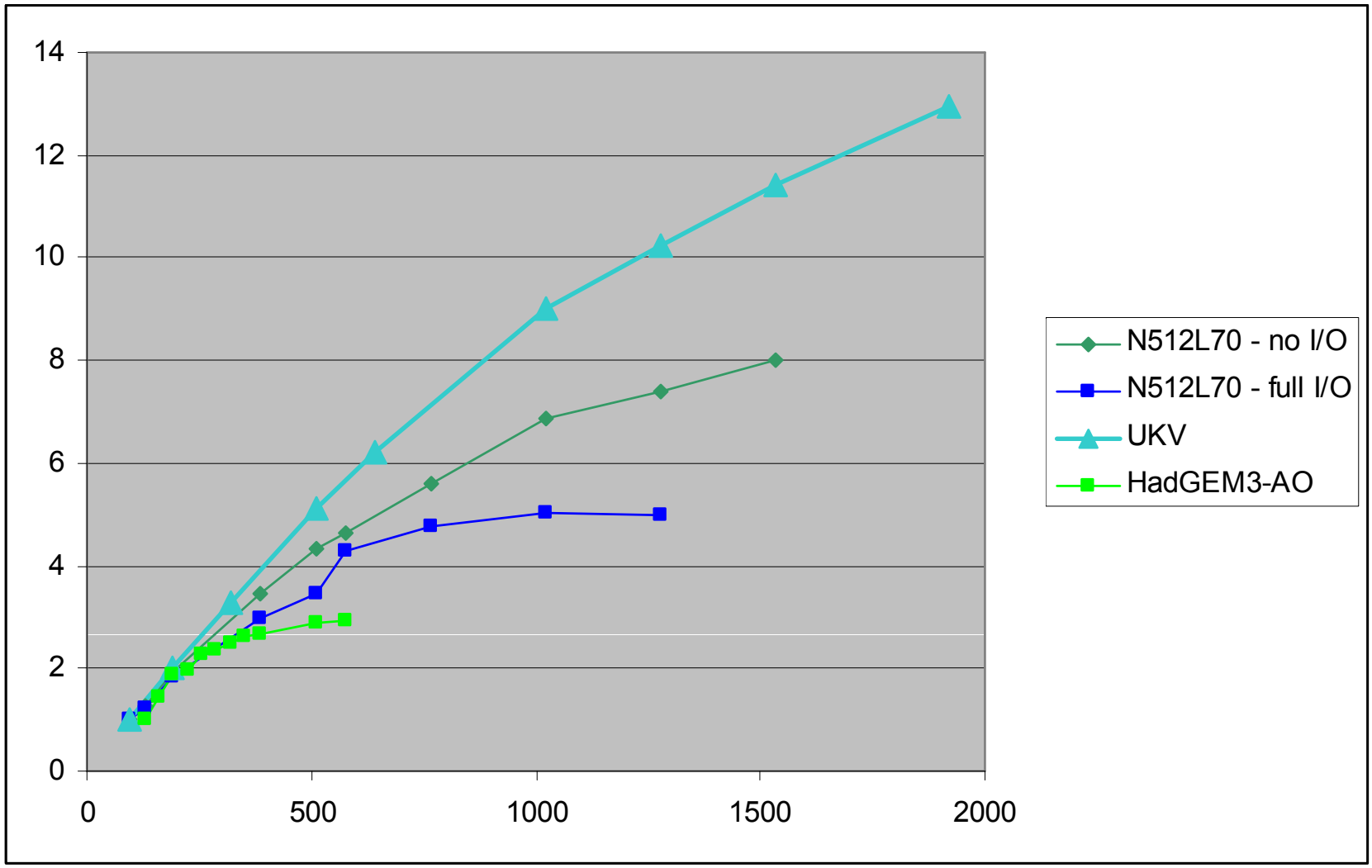
Scalability (March 2010)



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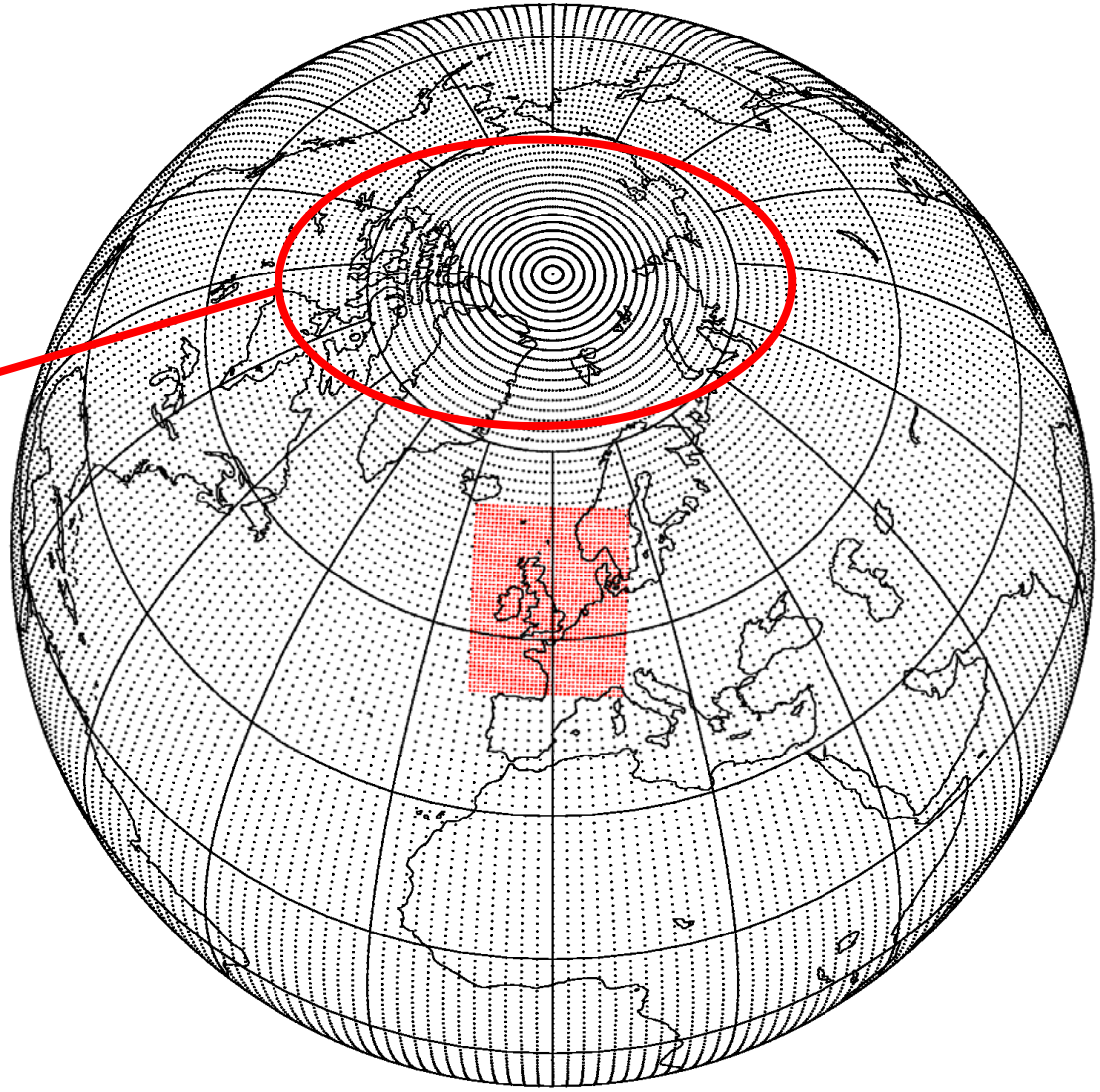
The finger of blame…

- At 25km resolution, grid spacing near poles = 75m
- At 10km reduces to 12m!



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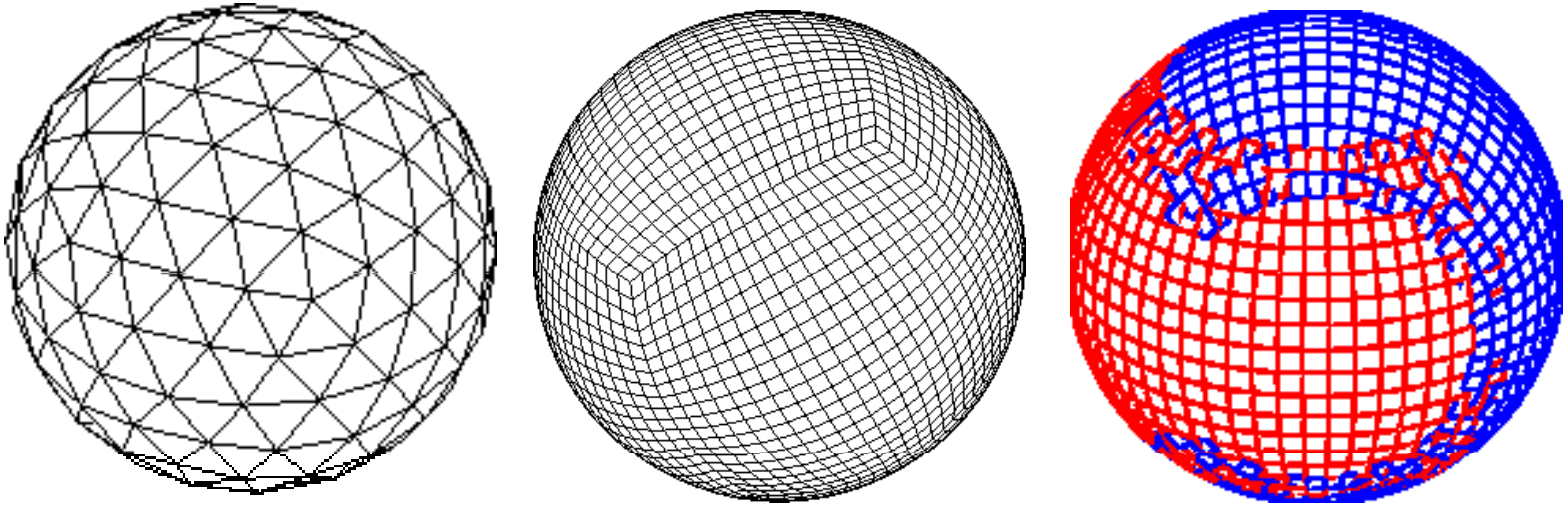
Challenges!

- Scalability – climate accelerating demand on model



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Challenges!

- Scalability – climate accelerating demand on model
- Speed – cannot sacrifice this for low resolution moderate core counts
- Accuracy – need to maintain standing of model
- Space weather $\Rightarrow$ 600km deep model…
- Danger:

  Everything to everyone…or
  Nothing to anyone?

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GungHo!

Globally

Uniform

Next

Generation

Highly

Optimized

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5 Year Project

- "To research, design and develop a new dynamical core suitable for operational, global and regional, weather and climate simulation on massively parallel computers of the size envisaged over the coming 20 years."
- To address (inter alia):
  - What should replace the lat-lon grid?
  - How to transport material on that grid?
  - Is implicit time scheme viable/desirable on such computers?
- Split into two phases:
  - 2 years "research"
  - 3 years "development"

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UK Collaboration of GFD, numerical and computational scientists

- 5 FTEs from Met Office (Dynamics Research & HPC Optimisation)
- 5 FTEs from NERC (Bath, Exeter, Imperial, Leeds, Manchester, Reading)
- 2 FTEs from STFC

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Working Together Harmoniously

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Organisation

- Executive board
  - Ned Garnett (NERC);
  - Andy Brown (MetO);
  - Mike Ashworth (STFC);
  - Pier-Luigi Vidale (NERC/NCAS);
  - Nils Wedi (ECMWF);
  - Nigel Wood (MetO)
- Regular one day focus meetings (IC)
- Regular two day plenary meetings

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GungHo Themes: Phase 1

- Quasi-Uniform Grids (icosahedral; kites/balanced triangles; cubed-sphere; Yin-Yang)
- Advection schemes (conservation, SL, ...)
- Time schemes (explicit vs. implicit)
- Test cases
- Computational science aspects

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GungHo Themes: Phase 2

- Refinement & testing of Phase 1 proposal
- Vertical aspects
  - Choice of variables
  - Grid & Staggering
  - Discretization
- Code development and testing

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Issues and progress…

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Quasi-Uniform Grids

- Review of options and pros & cons
  - ➢QJ Review paper on all things grid-like [Staniforth and Thuburn]
- Fundamental research on finite difference non-orthogonal C-grid

  [Thuburn and Cotter]
- Fundamental research for finite elements

  [Cotter]

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Quasi-Uniform Grids II

- Analysis of emerging spectral element scheme highlights shortcomings of scheme

  [Melvin, Staniforth, Thuburn]

- Yin-Yang version of ENDGame Shallow-water model written (plus efficient solution of elliptic solver for overset grids)

  [Zerroukat]

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Transport Schemes

- Work beginning to spin up
- Inherent conservation of tracers = key driver
- Is semi-Lagrangian scheme viable or desirable?
- Interaction with TRiSK scheme?

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Time Schemes: Explicit

- Split-explicit scheme ruled out – pros outweighed by cons
- Multi-*step* schemes (e.g. leapfrog) ruled out due to efficiency and accuracy issues
- $\Rightarrow$ Multi-*stage* schemes (i.e. Runge-Kutta)

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Time Schemes: Explicit II

- Vertical grid spacing makes explicit scheme in vertical too expensive

  $\Rightarrow$ **H**orizontally **E**xplicit **V**ertically **I**mplicit

- Work started on analysing such schemes to propose appropriate form

  [Lock, Smith, Staniforth, Thuburn, Wood]

- Interaction with implicit work…

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Time Schemes: Implicit

- Preferred approach (accuracy, stability) but scalability?
- Test problem defined and initial runs

  [Scheichl, Mueller, Allen, Pickles]

- Easier to say no than yes…
- …can we design a switchable scheme? (HEVI makes this more likely)

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Test Cases

- Collecting wide range of test cases

  [Weller, Staniforth, Thuburn]

- Identify impact of computational modes (spatial/temporal)?

- Impact of excessive diffusion

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Computational Science

- Scientists embedded within each theme

  [Ford, Gross, Ham, Malcolm, Pickles, Riley, Selwood]

- Profiling of any proposed approach
- Key to future-proof proposal
- Therefore design not linked to any specific architecture
- Abstraction… [hear David Ham's talk!]

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Summary…

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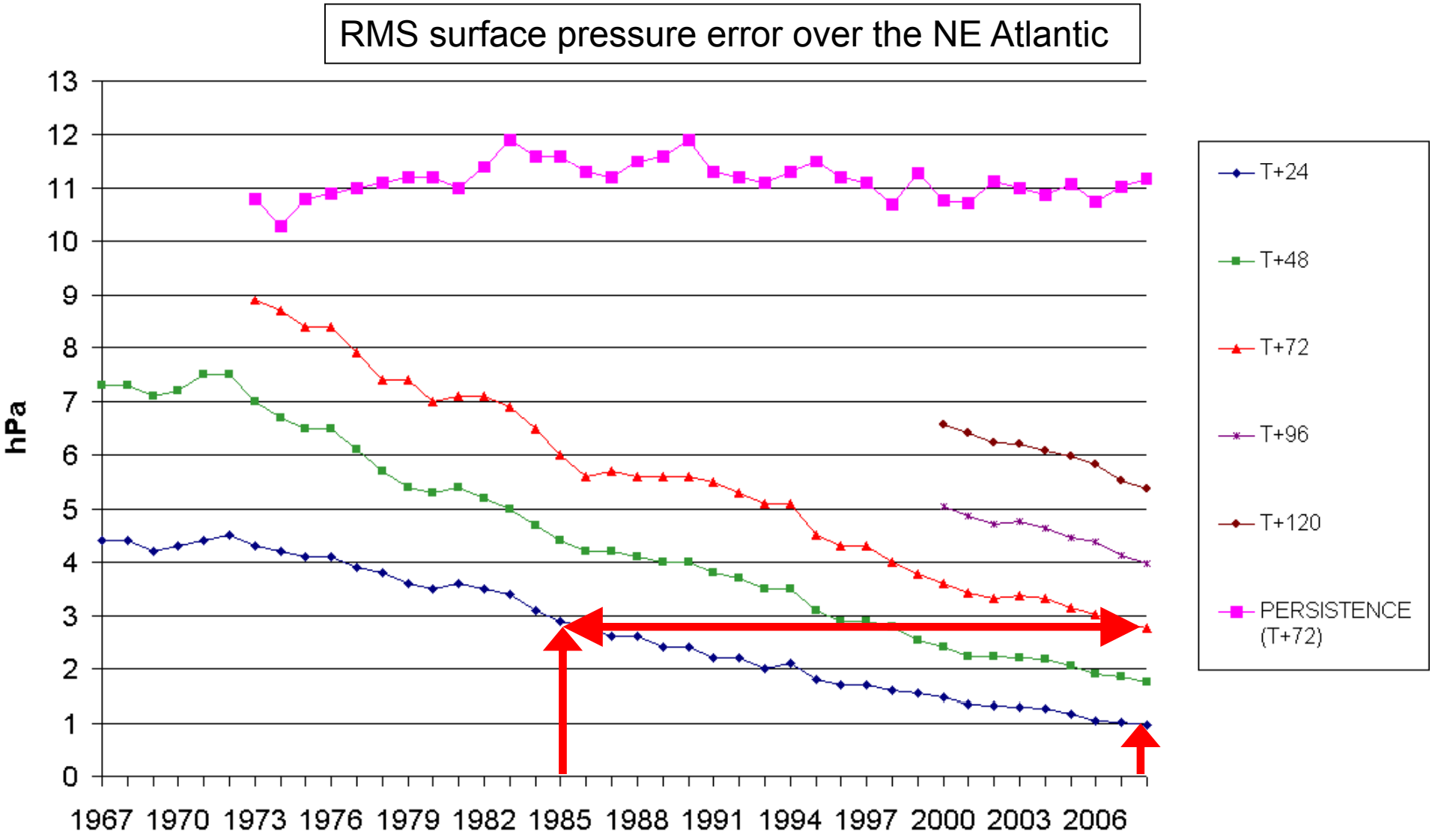
Continual Improvement…



GungHo!

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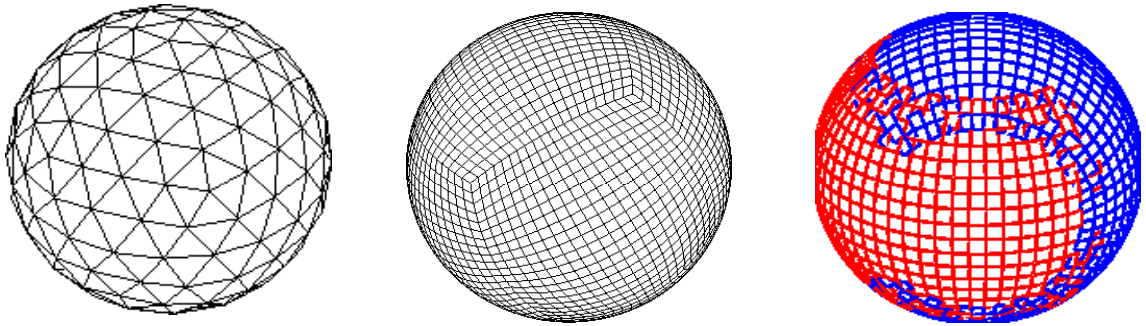

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Science & Technology Facilities Council

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Questions?

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Super-typhoon Megi simulations (II).

- Suite initialised using global analysis at 00z on 13/10/10
  - So about 120 hours before landfall
  - Observed central pressure at this time 1004 hPa.
- Global and 12 km simulations run for 6 days
  - Compared to 2 days previously
- 4km and 1.5 km simulations both:-
  - initialised using T+6 flow fields of 12 km simulation.
  - Both use LBCs derived from 12 km model.

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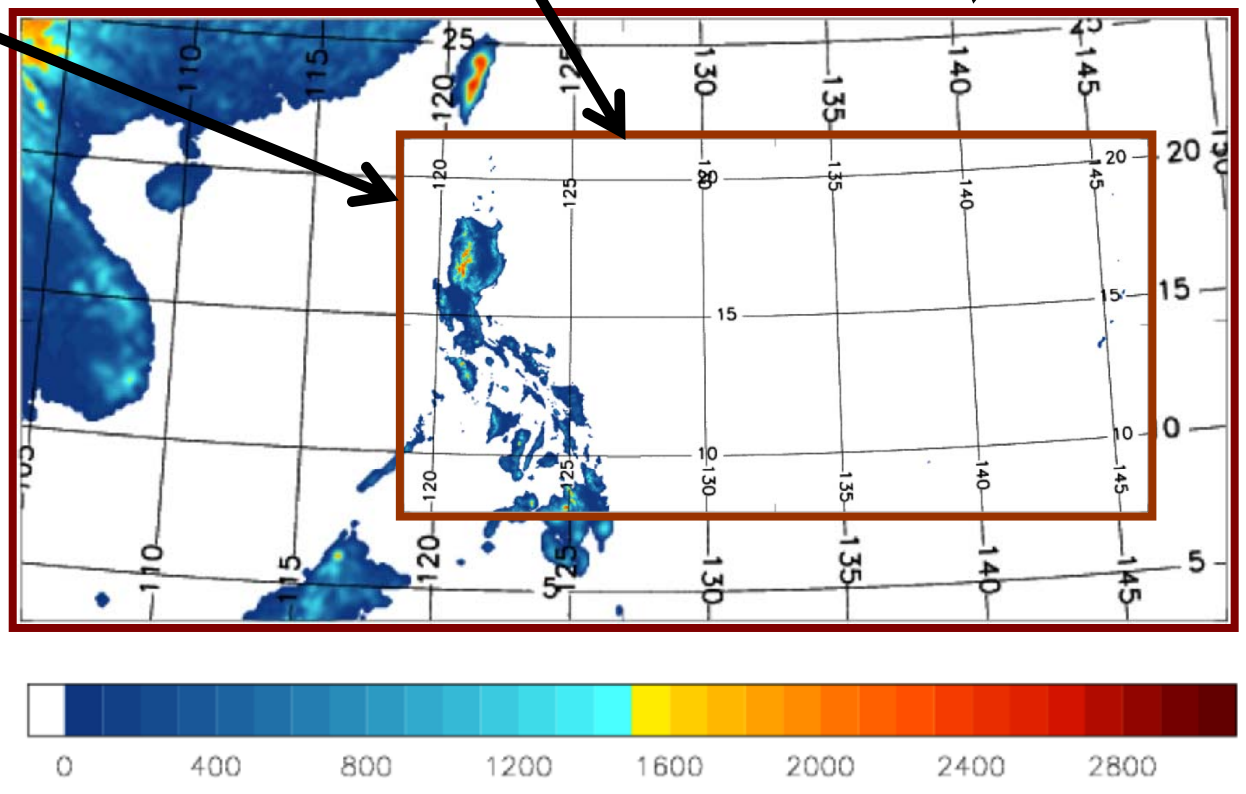
12km, 4km and 1.5 km domains

1.5km model
2000 x 1000 x 70
dt=10 s

4km model
750 x 380 x 70
dt=30 s

12km model
400x200x70
dt=60 s

- Area shown is 4800 km x 2400 km



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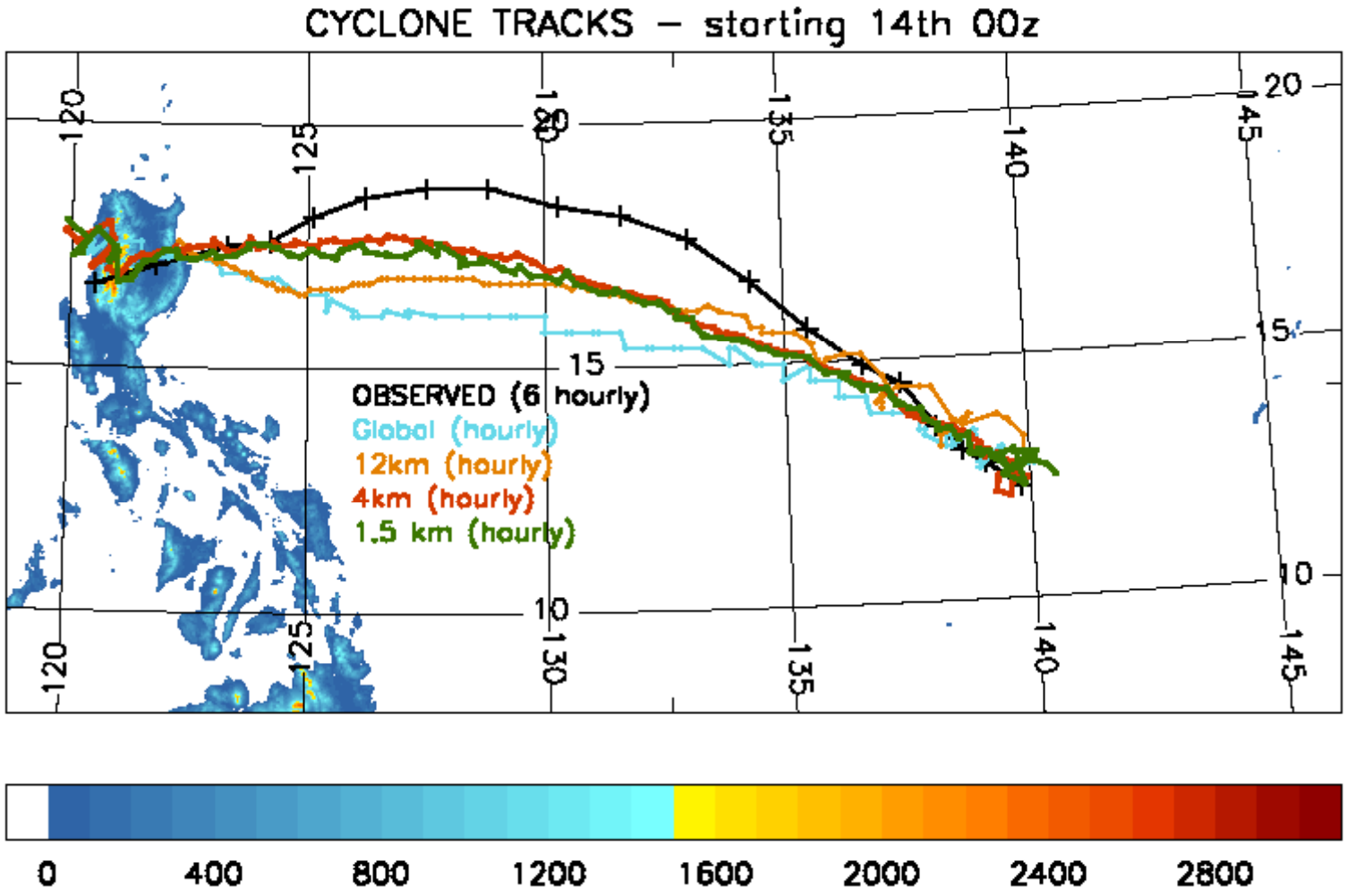
Cyclone Tracks



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