Challenges for weather and climate prediction – a UK perspective

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Outline

- The Unified Model – where we are now
- The need for change
- ENDGame
- GungHo!
- Summary

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 …

Operational NWP Models

Global

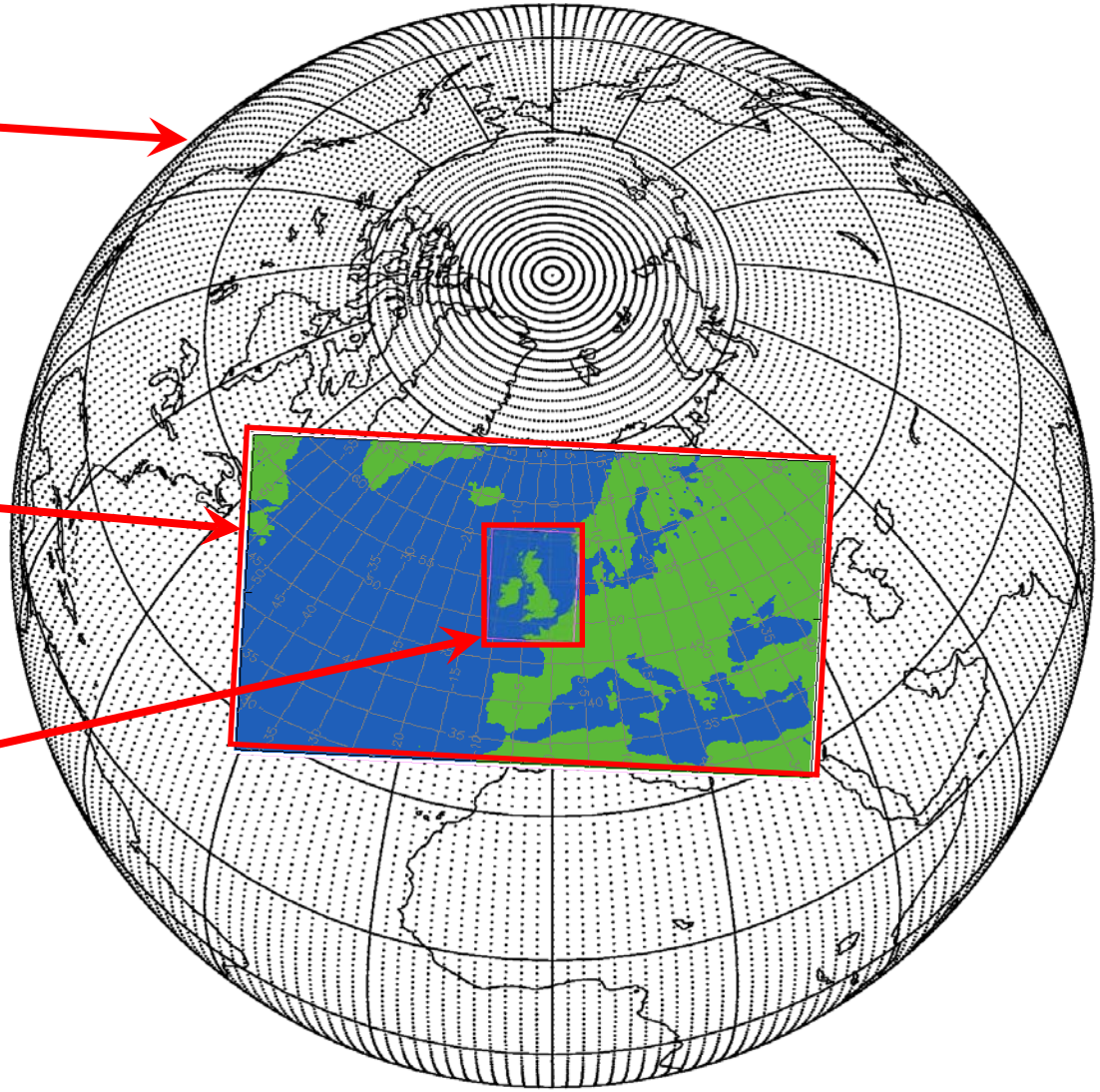
- 25km 70L
- 4DVAR – 60km
- 60h forecast twice/day
- 144h forecast twice/day
- *+24member EPS at 60km 2x/day*

NAE

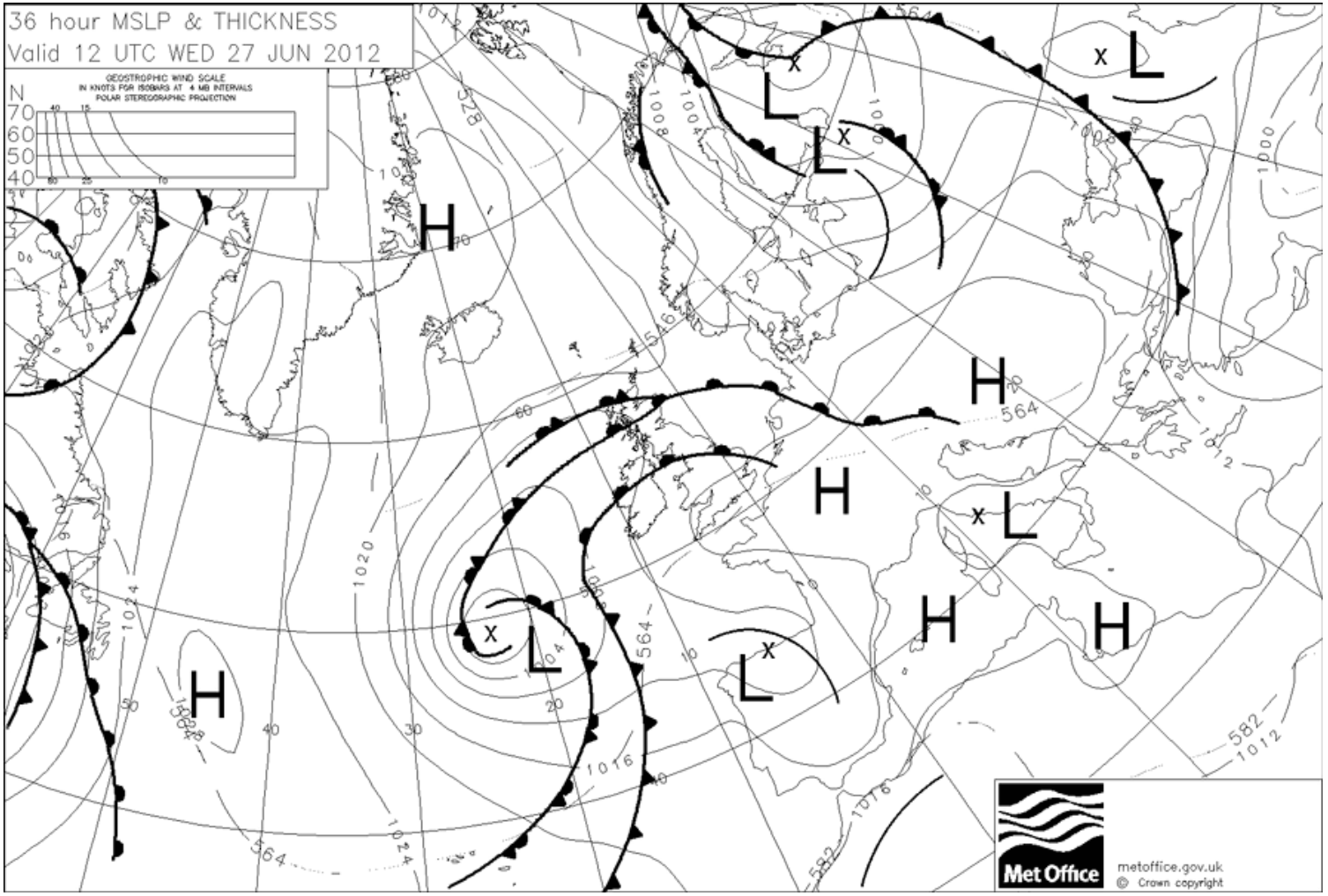
- 12km 70L
- 4DVAR – 24km
- 60h forecast
- 4 times per day
- *+24member EPS at 18km 2x/day*

UK-V *(& UK-4)*

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

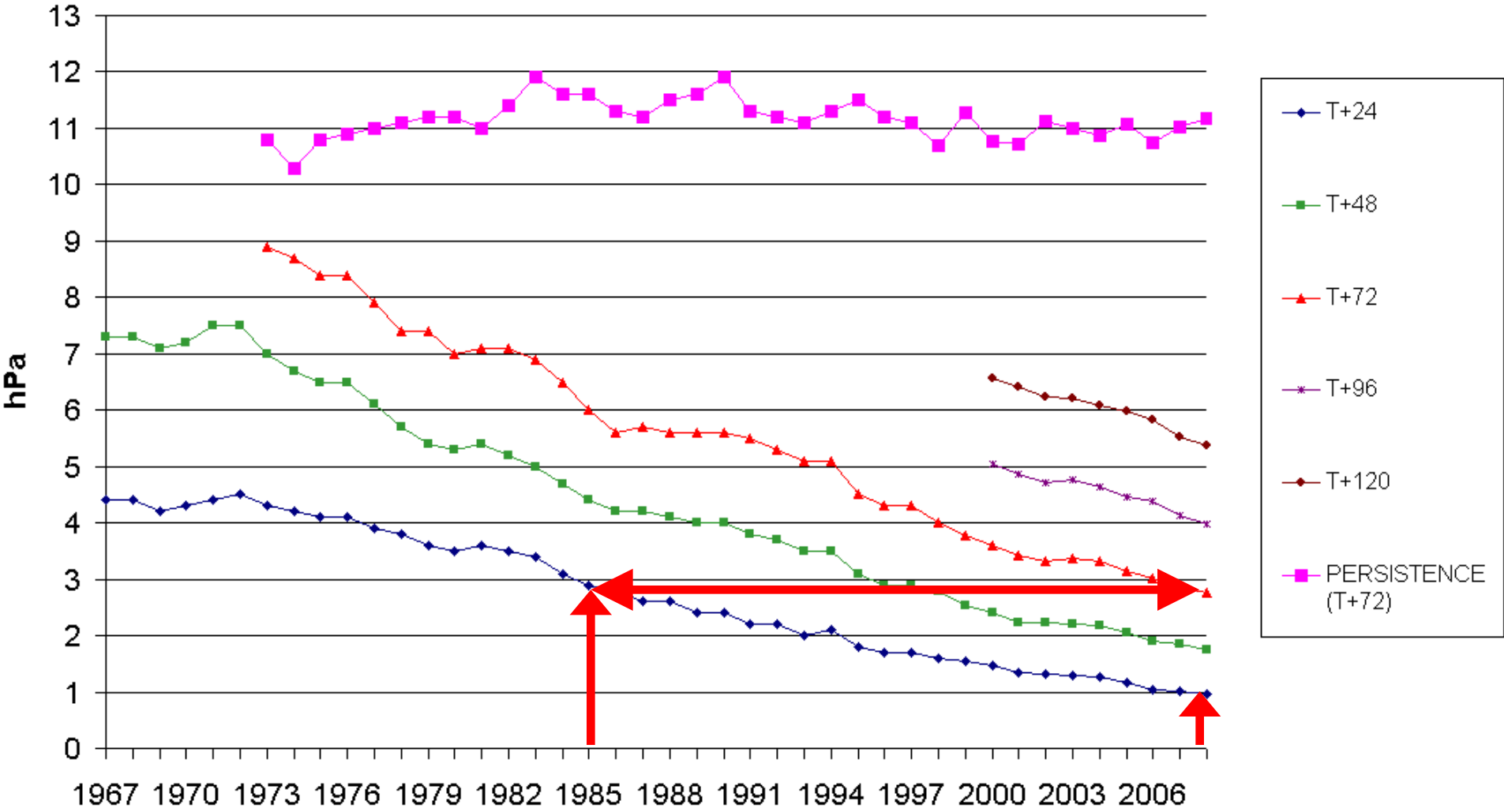


And the forecast for today...



Improving forecast accuracy

RMS surface pressure error over the NE Atlantic

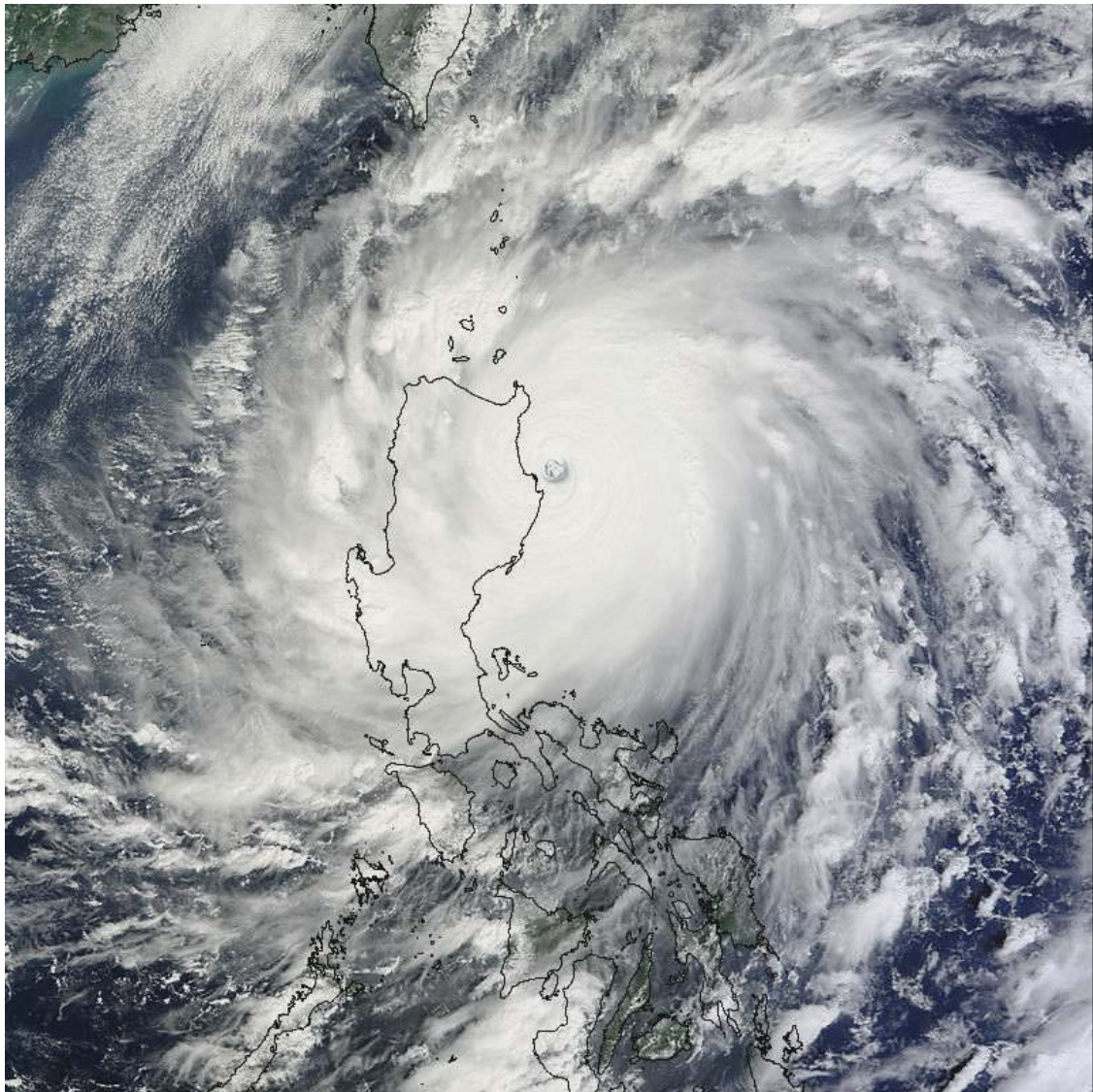


The need for change…

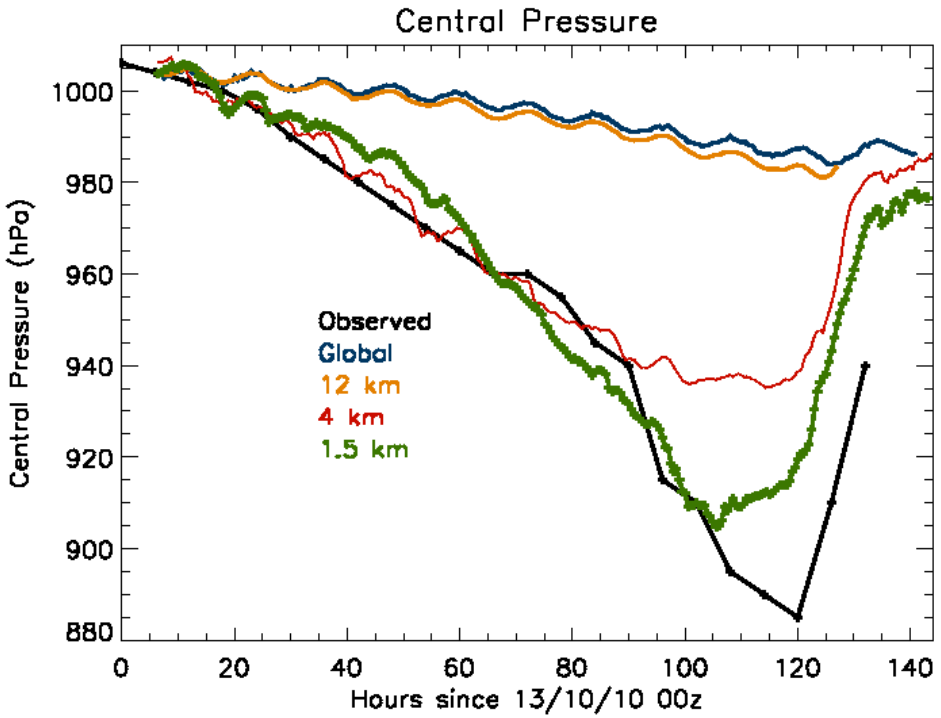
Super-typhoon Megi

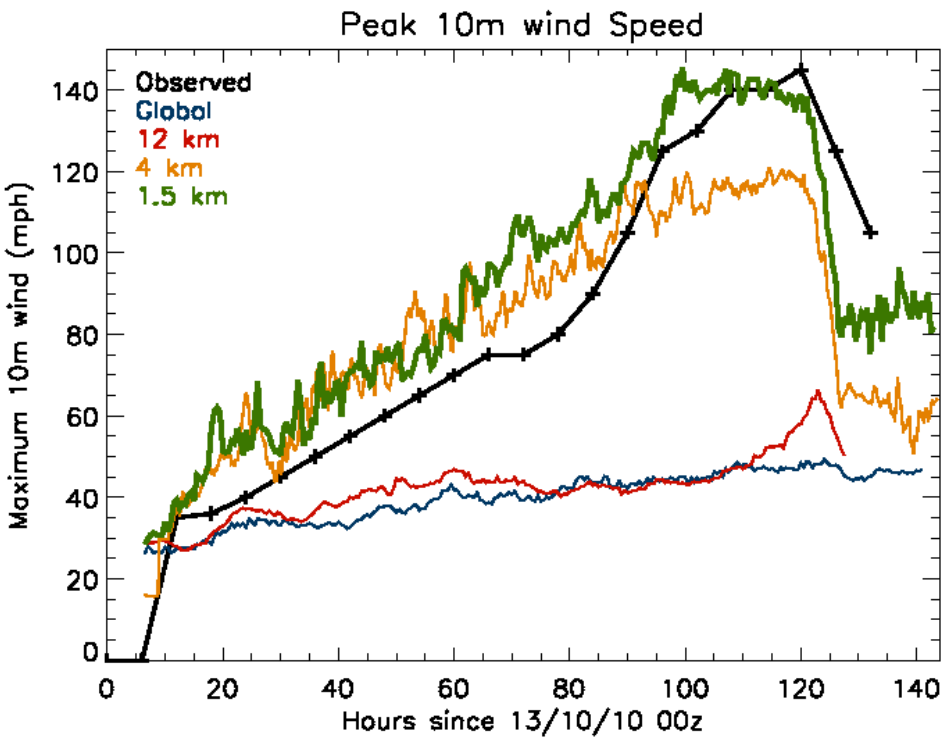
Stuart Webster

- 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



Resolution, resolution, resolution…





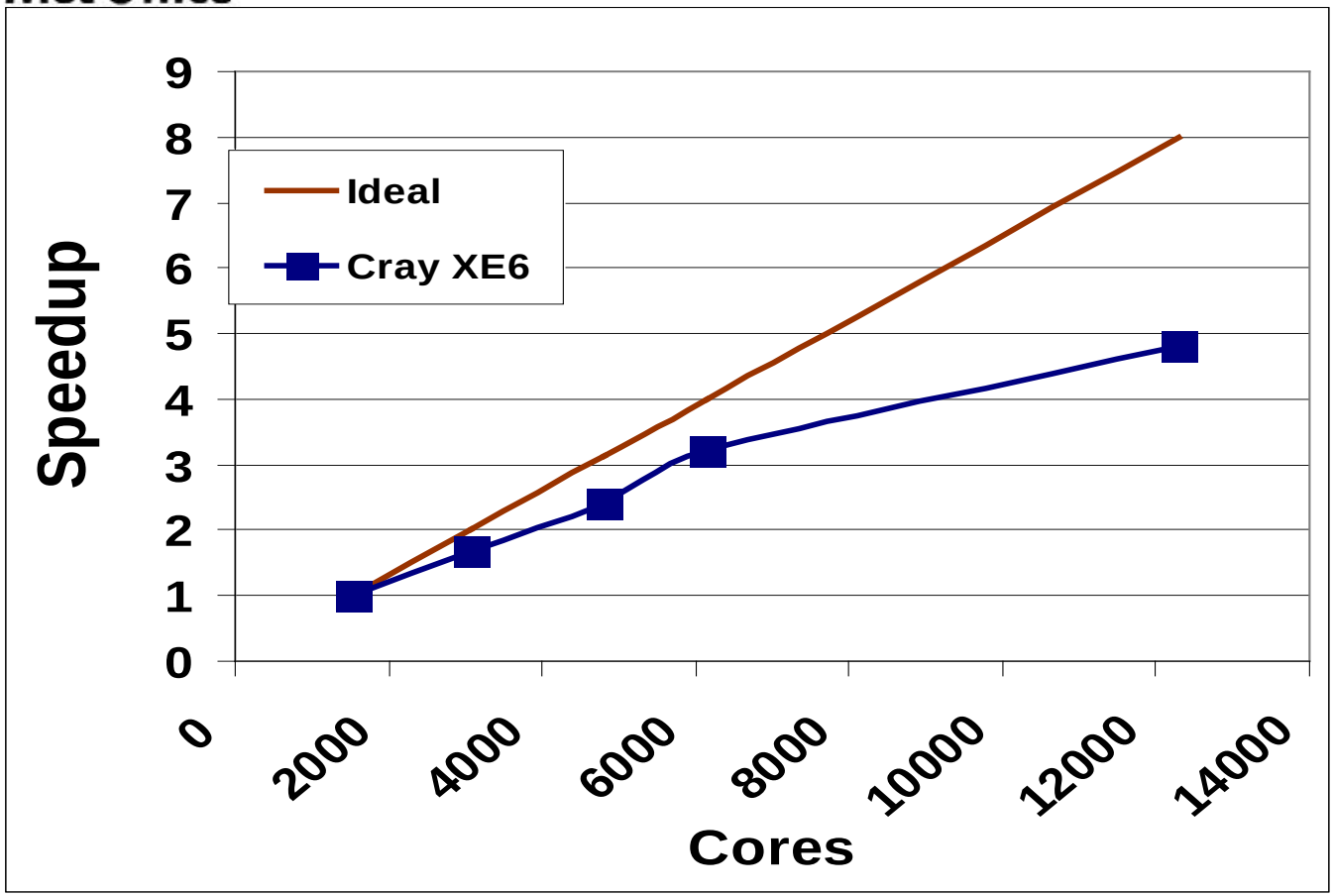
Computational performance critical

Global 25km model:

- Forecast to: 7 days 3 hours
- Timestep: = 10mins $\Rightarrow$ 1026 time steps
- Resolution 1024 × 768 × 70 = 55M grid points
- To run in 60 minute slot, including data assimilation and output

36 ($\approx 2^5$) times bigger than running 5 years ago

N512 scalability – Cray XE6



Thanks to Pier-Luigi Vidale, NCAS

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

Short term…

Where next after New Dynamics?

E ven
N ewer
D ynamics for
G eneral
a tmospheric
m odelling of the
e nvironment

Raison d’être

- Build on foundations of New Dynamics
- Aims are:
  - Improved robustness
  - Improved accuracy
  - Maintain/improve conservation
- While maintaining/improving efficiency

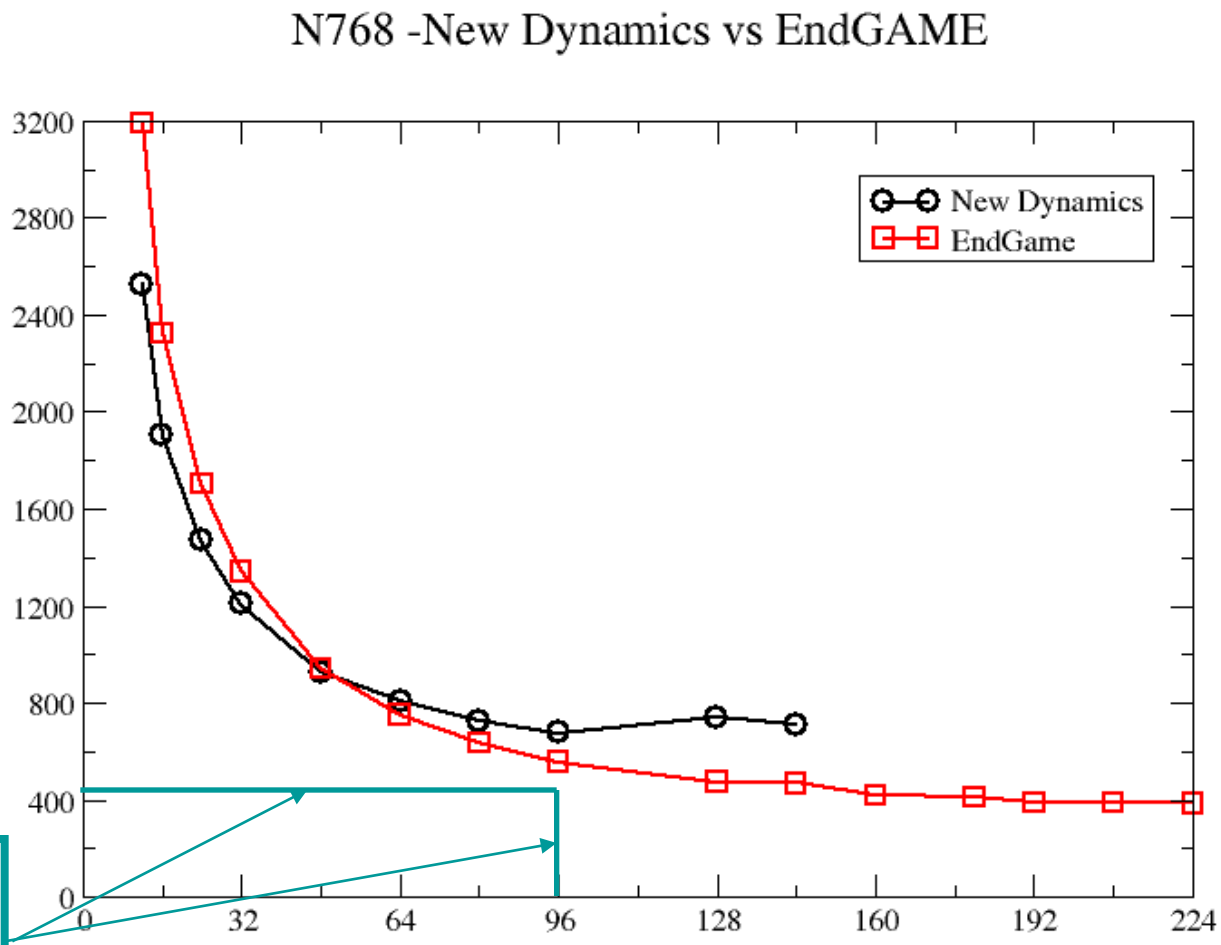
$\Rightarrow$ Accuracy/Robustness/Scalability

Main change

- Improved (iterative) solution procedure
  - More implicit, approaching second-order in time
- Resolves number of New Dynamics issues
- Iterated approach
  - Allows much simpler Helmholtz problem (7 point stencil cf. 45 point)
  - Much simpler (red/black) preconditioner ⇒ greatly reduced communications

⇒ Improved scalability

Improved Scalability (16km)



Target configuration on Power 7

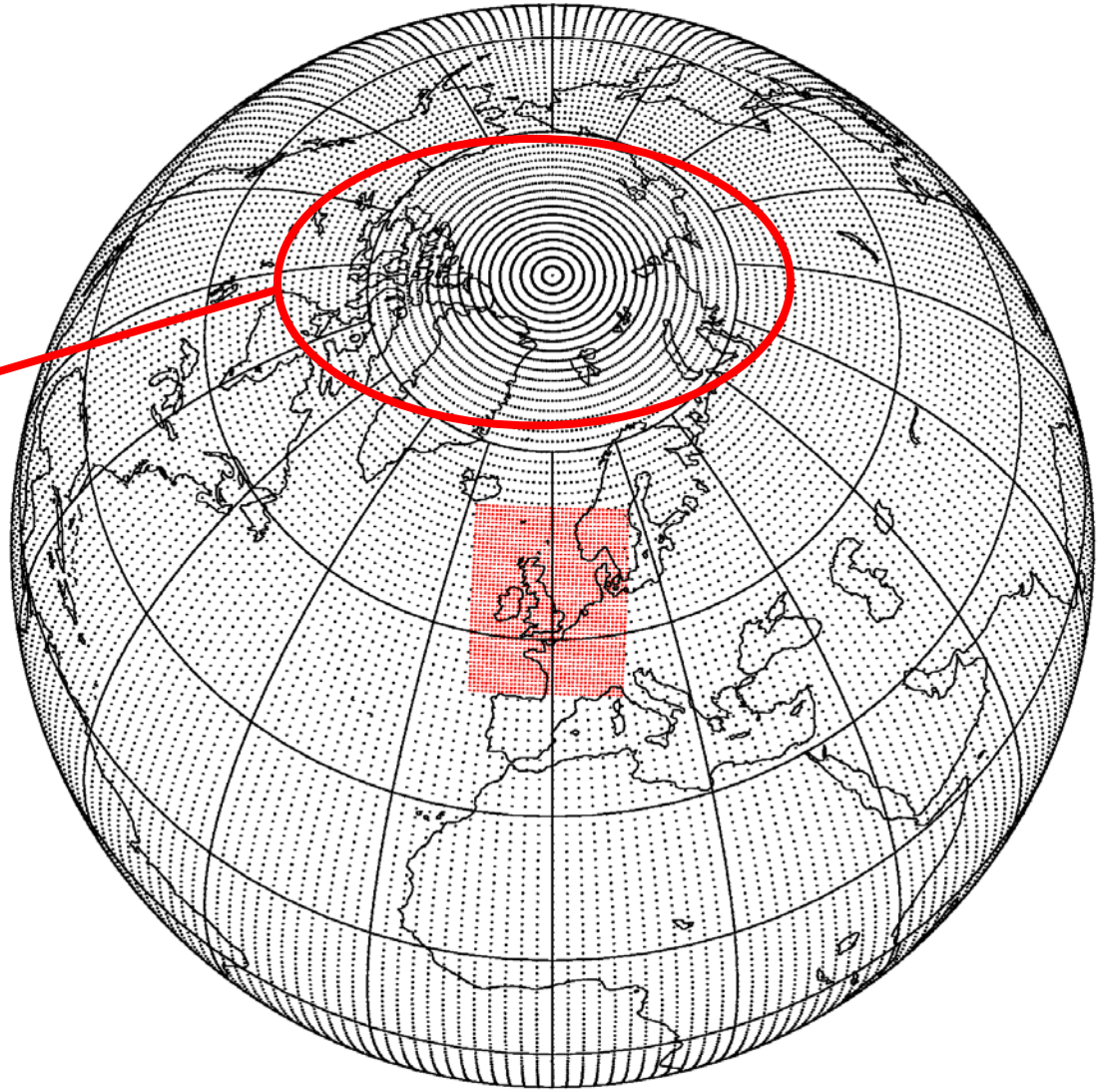
IBM Power 7

ENDGame with dt = 10 mins hits the target

Longer term…

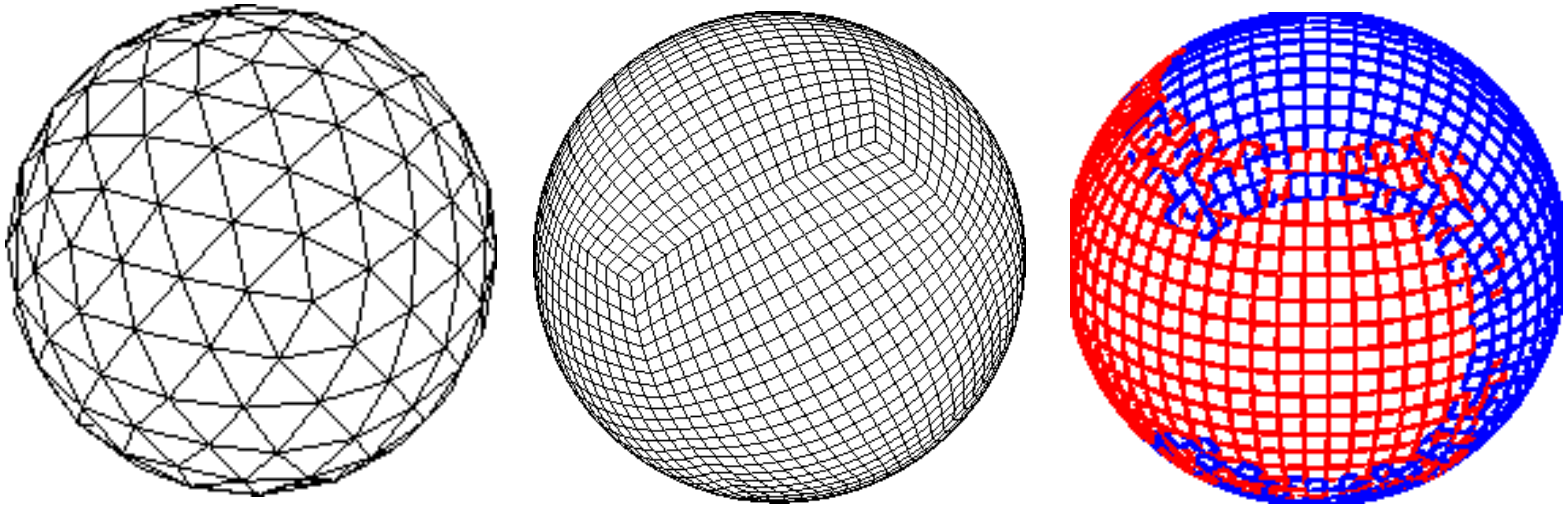
The finger of blame…

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



Challenges!

- Scalability – remove the poles!



Challenges!

- Scalability – remove the poles!
- 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?

GungHo!

Globally

Uniform

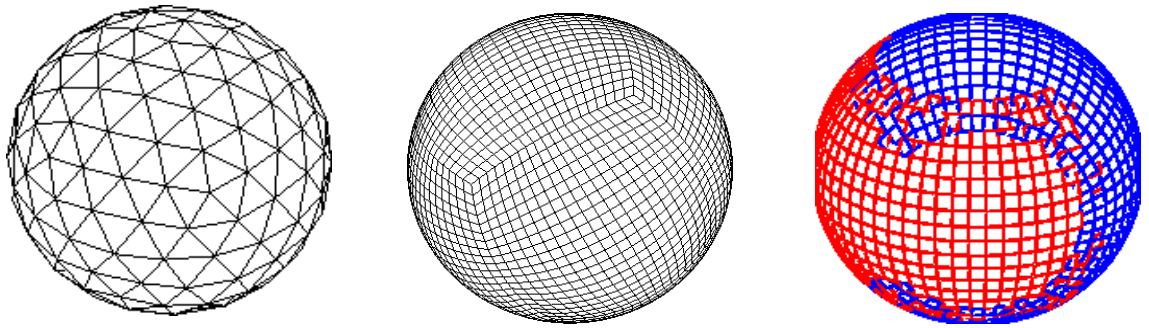
Next

Generation

Highly

Optimized

工合



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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

Progress

- Implicit schemes look viable
  - Multigrid = scalable algorithm + scalable implementations
- But developing HEVI approaches (Sarah-Jane Lock's talk)
- Initial focus of grids package was on pros and cons of different grids
  - Andrew Staniforth + John Thuburn review
  - Hilary Weller's experimentation

Progress

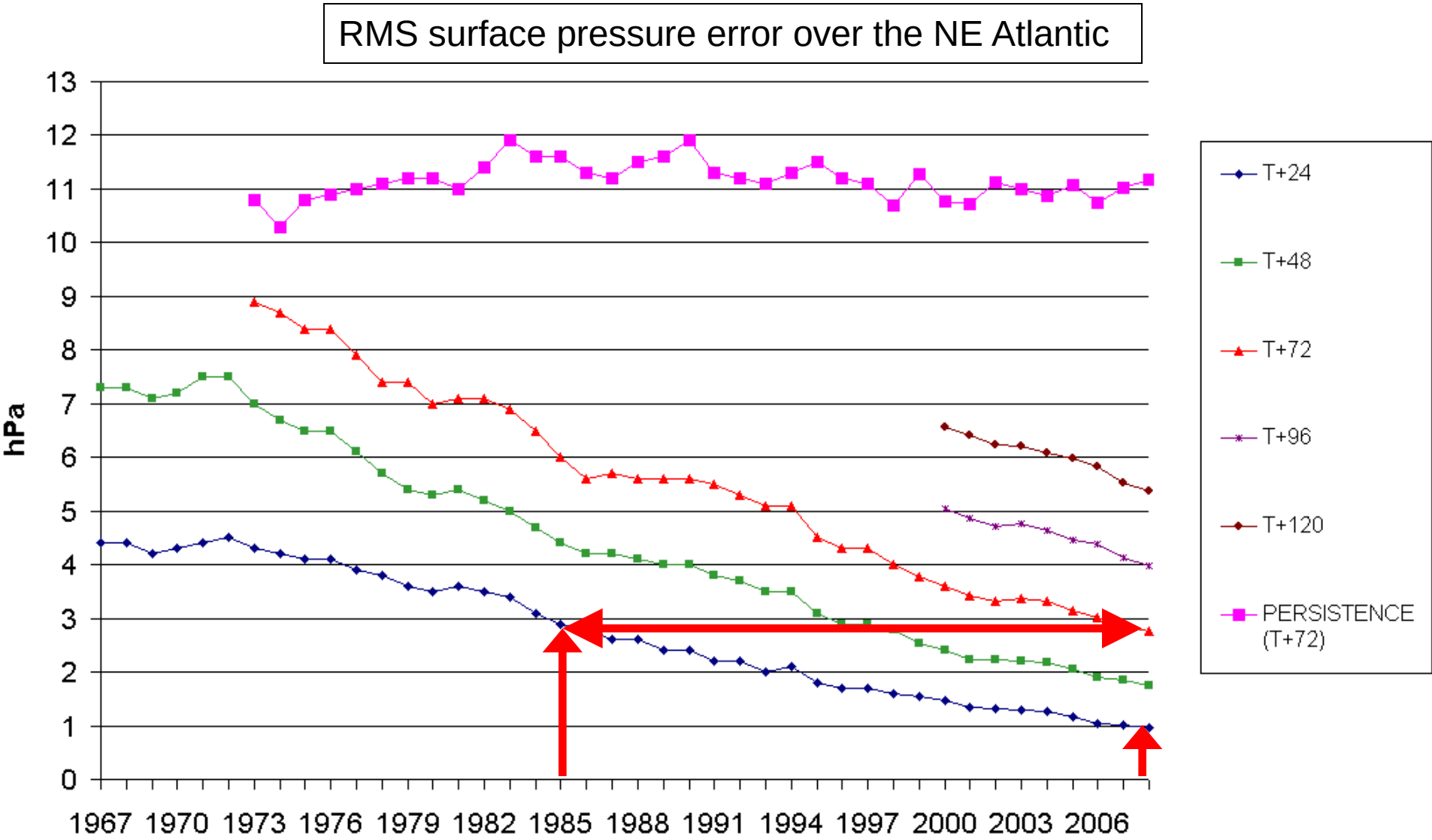
- However data model changes focus:
  - Grid choice secondary to choice of discretization (David Ham)
- Non-orthogonal finite-difference
  - TRiSK extension (John Thuburn)
- C-grid finite-element
  - Mixed elements (Colin Cotter)

GungHo Themes: Phase 2

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

Summary…

Continual Improvement…



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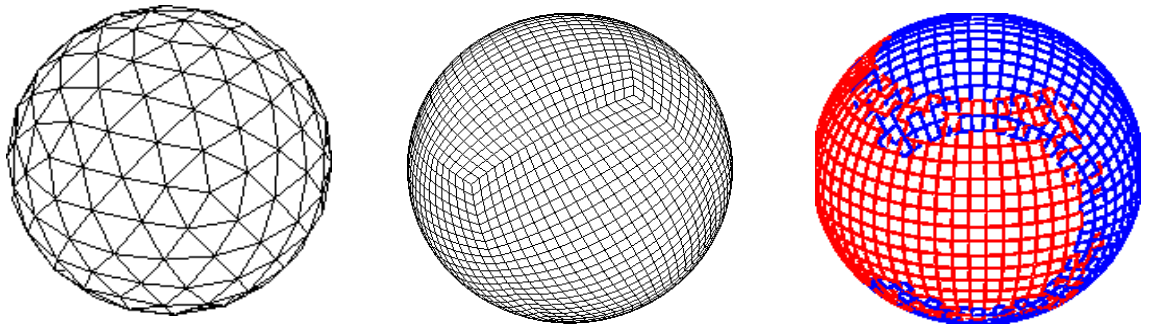

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Thank you!

Questions?

Super-typhoon Megi simulations (II).

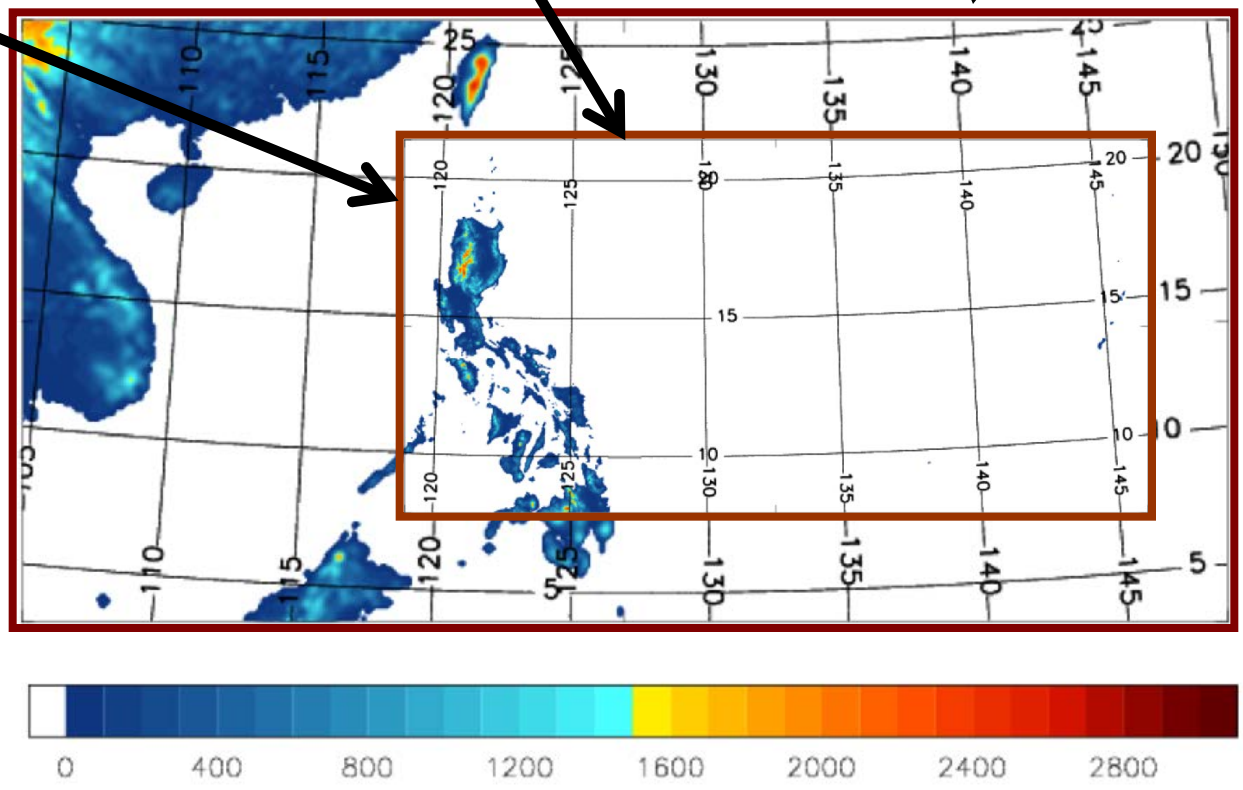
- Suite initialised using global analysis at 00z on 13/10/10
  - So about 120 hours before landfall
  - Observed central pressure at this time 1004 hPa.
- Global and 12 km simulations run for 6 days
  - Compared to 2 days previously
- 4km and 1.5 km simulations both:-
  - initialised using T+6 flow fields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

12km, 4km and 1.5 km domains

12km model
400x200x70
dt=60 s

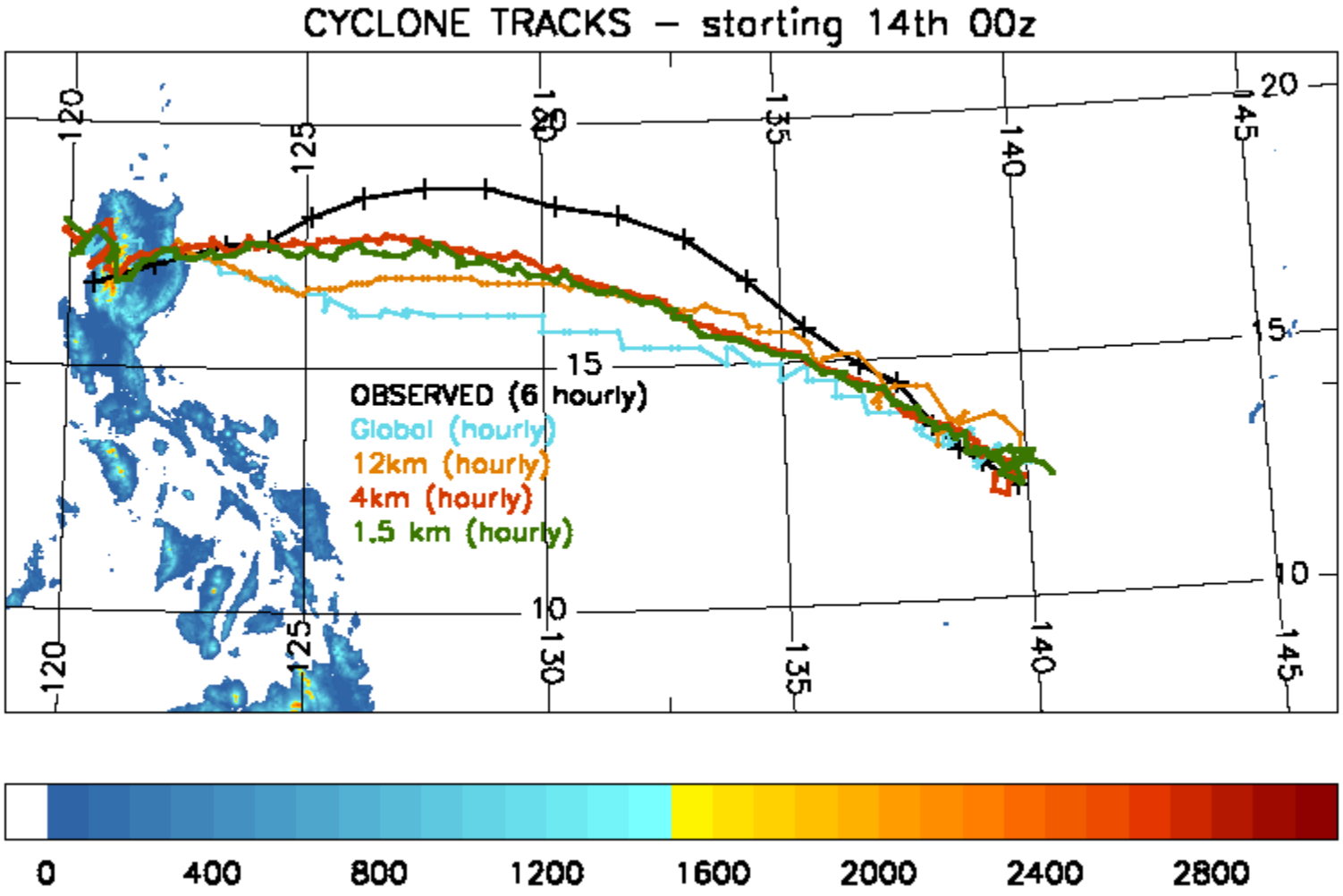
4km model
750 x 380 x 70
dt=30 s

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



- Area shown is 4800 km x 2400 km

Cyclone Tracks



Variable resolution grid structure