From ENDGame to GungHo then LFRic

Replacing the Met Office Unified Model

Steve Mullerworth

ECMWF Exascale workshop. 14th April 2014

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Summary – the perspective from a Computational Scientist point of view

- Where are we now
- What are Gung Ho and LFRic
- LFRic plan to replace the Met Office Unified Model
- Description of our approach to some aspects of the project

It’s still early days – so no LFRic scalability plots!

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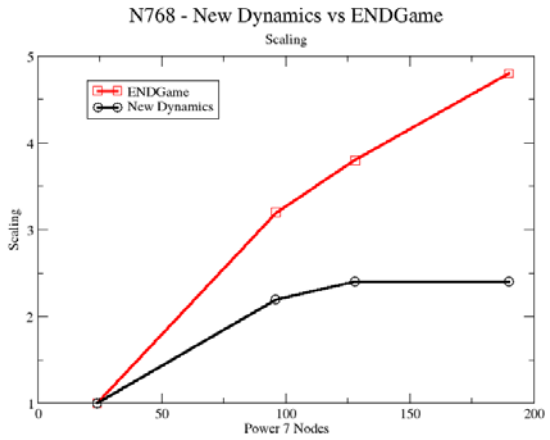
ENDGame

- Latest update to the Unified Model
- Currently undergoing operational trials
- Should (hopefully) deliver scalable performance for at least the next 10 years (two more supercomputers)
- The UM still has plenty of life and will continue to be developed



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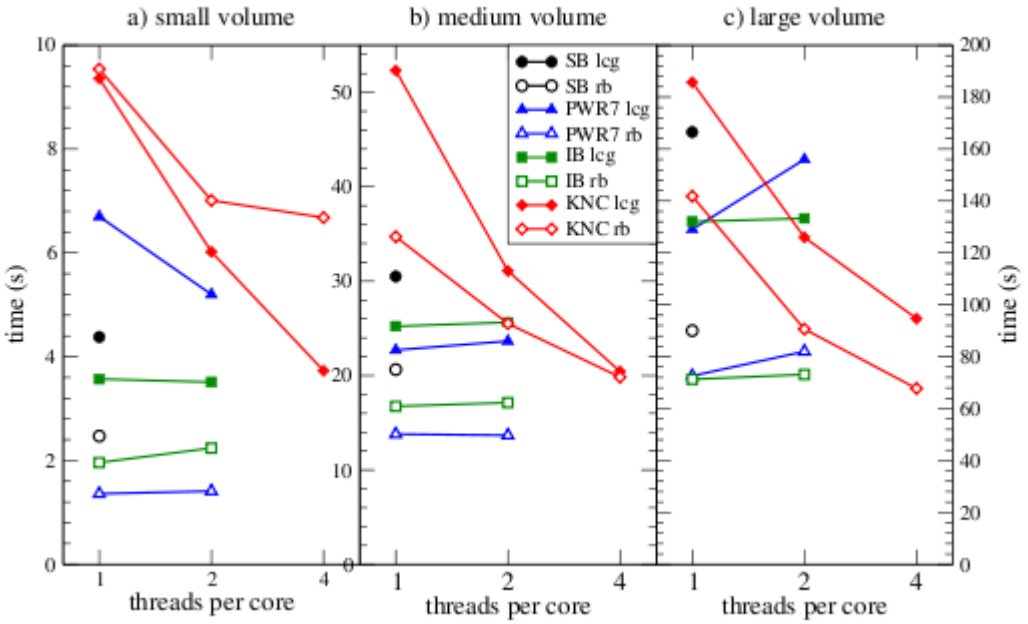
Assessment of Xeon Phi



ENDGame solver pre-conditioner performance

C. Maynard

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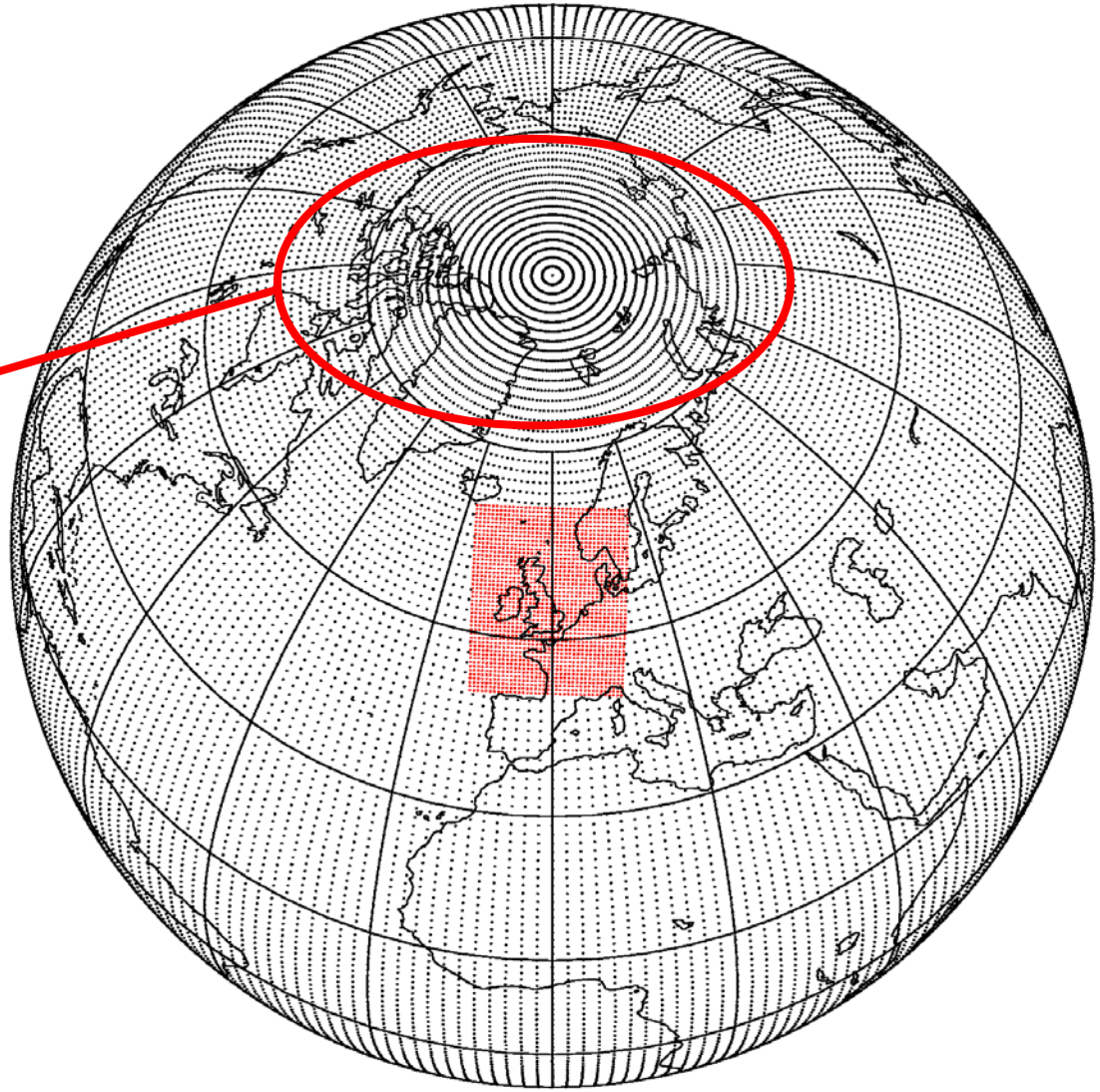
Choice of grids has to avoid this…

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



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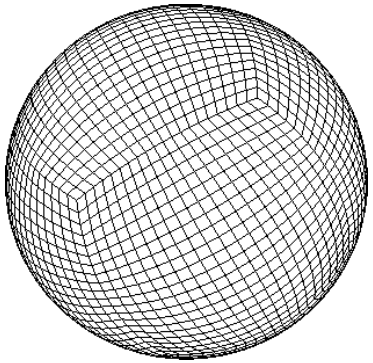
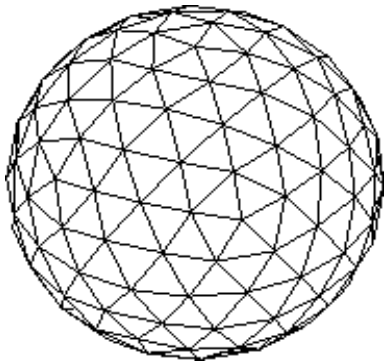
Gung Ho – 2011-2016

- Met Office, NERC, STFC partnership involving
  - Imperial College, STFC, Universities of Bath, Exeter, Manchester, Leeds, Reading and Warwick
- Develop a dynamical core that is
  - Scientifically as good as ENDGame
  - Scales on future architecture
  - Used for future dynamics research
- Gung Ho will probably:
  - Use finite element methods (FEM)
  - Support a “higher order” schemes
  - Support cubed-sphere or triangles





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LFRic

- Named in honour of Lewis Fry Richardson
- A Met Office project to completely replace our Unified Model Atmosphere
- Using the Gung Ho dynamical core
- Three phases of development
  - 2016: Gung Ho dynamics with a computational infrastructure
  - 2019: First version of the atmosphere model
  - 2022: Operational deployment

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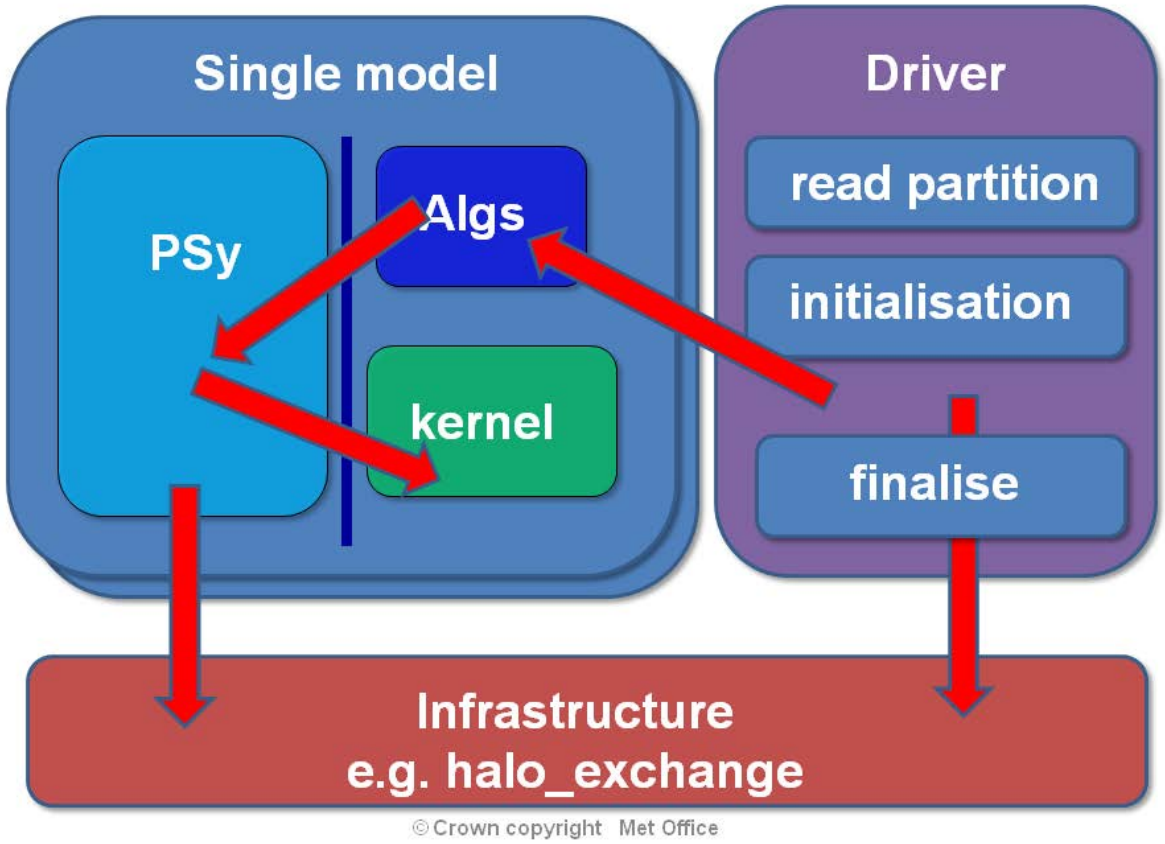
Single model Architecture



Ref: Computational Science Recommendations: Ford et al. Met Office Tech. Report 587

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PSyKAl

- Separation of concern between
  - **P**arallel **S**ystems (the PSy layer), and
  - **Al**gorithms and **K**ernels.
- Algorithms act on “fields”

```
call invoke_v3_solver_kernel(pressure_density,rhs)
```

- Algorithm “code” *could* look like equations
  - Auto-generation of algorithm code generates Fortran

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PSyKAl - Kernels

- Kernels loops over levels in a column
  - Cost of neighbour look-up in loop is balanced by efficient solve of a column…hopefully

```
! compute the LHS integrated over one cell and solve
do k = 0, nlayers-1
  do df1 = 1, ndf
     do df2 = 1, ndf
        do qp1 = 1, ngp
           do qp2 = 1, ngp
              do qp3 = 1, ngp
                 f(qp1,qp2,qp3) = v3_basis(df1,qp1,qp2,qp3,1) * &
                                  v3_basis(df2,qp1,qp2,qp3,1)
              end do
           end do
        end do
        mass_matrix_v3(df1,df2) = gq%integrate(f)
     end do
     rhs_e(df1) = rhs(map(df1)+k)
  end do
  call matrix_invert(mass_matrix_v3,inv_mass_matrix_v3,ndf)
  x_e = matmul(inv_mass_matrix_v3,rhs_e)
  do df1 = 1,ndf
    x(map(df1)+k) = x_e(df1)
  end do
end do
```

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PSyKAl – PSy-layer

- Works on a domain-decomposed field
- Breaks it down into columns
- Uses lookups to access stencil data (neighbours)
- Loops over columns to call kernels
- PSy layer could be auto-generated
  - Examples exist in the Finite element world
  - Field and kernel metadata is used to write correct code
  - Metadata is used also to write *optimal* code

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Code auto-generation

- PSy code auto-generated to help with:
  - Performance on different architectures: eg. divides up tasks according to thread size
  - Identifying and encoding loop fusion – running kernels in parallel
  - Maximising efficiency and timeliness of halo swaps according to choice and order of kernel calls
  - Providing choice of optimising level: bit comparison and test code, versus high performance code
  - Enabling flexibility of choice for different meshes, and different FEM schemes – same algorithms, different kernels

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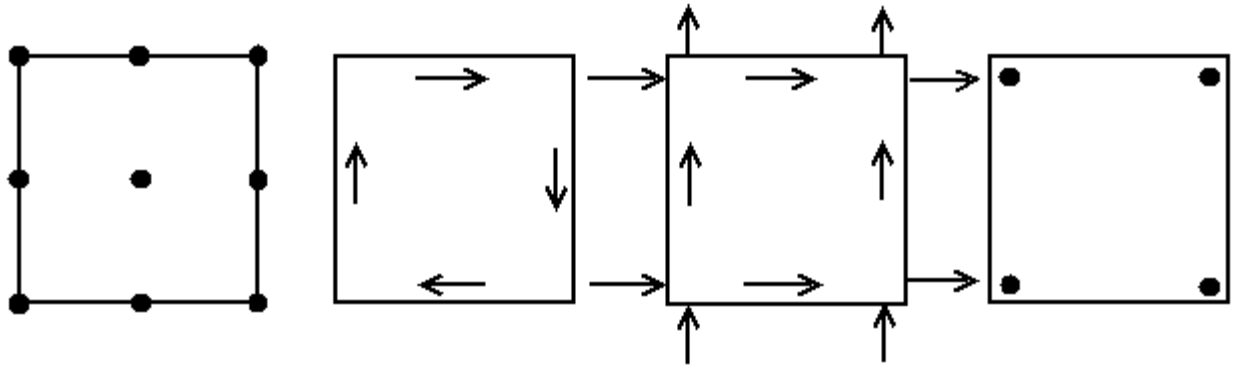
Higher order Finite Element Methods

- Fields represented by functions on mesh entities (cells and faces)
- Higher order implies multiple degrees of freedom per mesh entity
- Mixed finite element scheme



Potential temp. Vorticity Velocity Pressure

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ESMF

- ESMF (Earth System Modelling Framework) developed at NCAR
  - Will be used for Gung Ho infrastructure
  - For full functionality requires support for higher-order FEM to be added…
    - …we are not sure what the requirements are yet!
  - We are in productive discussions with ESMF

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Coupling to Physics Schemes

- Choices for physics are
  - To run as now on column by column basis
  - To take advantage of additional information in FEM
- Physics grid may be different from Gung Ho grid
  - May not make sense to use locations of dynamics dofs
  - Physics quantities can be computed from basis functions on evenly spaced grid
  - Tendencies from physics need to be “projected” onto dynamics fields – numerics to be solved

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Data formats & diagnostics

- Semi-unstructured data not dealt with by CF, for example
  - Regridding to lat-long is not ideal
- UGRID proposal exists as a potential basis
- What formats are required though?
  - Do we need to analyse higher order data, or
  - Will diagnostics be written out at lower order
- Tools for visualisation?

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Current status of development

- Developer framework
  - Subversion and Trac
  - Build, test (pfUnit) and documentation (Doxygen/Sphinx)
- Dynamo: A serial model infrastructure
  - Fortran 2003
  - Supporting preliminary implementation of GH science
  - Experience with handling FEM fields
  - PSyKAl-lite: Hand-coded PSy-layer
- PSyclone
  - Auto-generation of PSy-layer
- Distributed memory
  - Assessing ESMF
  - Exploring tools for handling unstructured meshes

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Still lots to learn and do!

- IO
- Coupling
- Performance analysis
- Novel architectures
- Data work flow
- ...

Questions…

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