

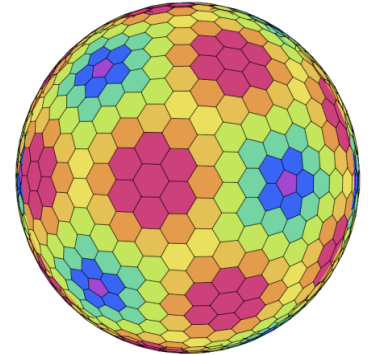
G8 ICOMEX: ICOSahedral-grid Models for Exascale Earth System Simulations

Japan, UK, France, Germany, Russia

Lead PI: **Günther Zängl**, Deutscher Wetterdienst, Germany

Objective: Prepare 4 advanced Earth system models based on icosahedral grids but *differences in numerics and grid structure*

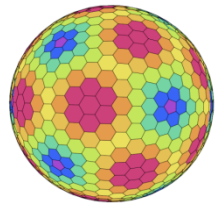
- **NICAM**, Structured hexagonal A-grid
- **ICON**, Unstructured triangular C-grid
- **MPAS**, Unstructured hexagonal C-grid
- **DYNAMICO**, Structured hexagonal C-grid
- Exascale computing required



Basic strategy

- Address selected key problems on the way to exascale and derive generic solutions
- WPs focus on optimization of computational performance and parallelization of I/O
- Complemented by a regular model intercomparison exercise

Intercomparison and evaluation of models

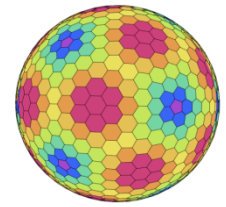


Goal: Model intercomparison on K computer

Lessons learned:

- Porting the model codes to K computer turned out to be difficult
 - Non-standard software stack (e.g. MPI library)
 - Initially, remote memory access did not work
 - OpenMP is not supported, instead the compiler supports auto-parallelization
 - Using the available auto-parallelization requires code refactoring at a level that is not feasible for the non-Japanese groups
- *Thus, only a limited performance comparison could be conducted so far*

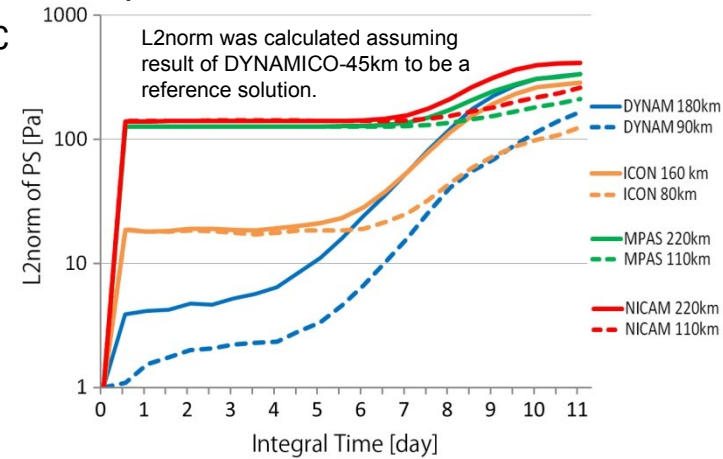
Intercomparison and evaluation of models



Deterministic Test (Jablonowski and Williamson 2006)

→ All four models show improvement of error assessed in surface pressure.

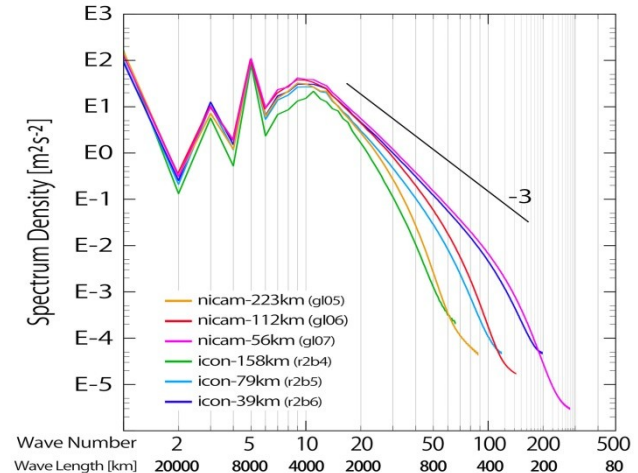
- Error rises just after an integration start in non-hydrostatic models; the degree of error is different among models.
- Most of the initial error can be solved by refinement of a vertical grid; it has been checked by changing number of vertical layers and its level.
- ICON model shows smaller error than that of the other non-hydro models; vertical discretization in ICON model seems to work well in this experiment.



Statistical Test (Held and Suarez 1994)

→ An energy peak is found at wave number 7-10; both models simulated waves reasonably.

- An energy slope obtained in higher horizontal grid-space is similar k^{-3} power spectra.
- An advantage of grid-space on ICON seems to be little comparing among same grid-levels (i.e. gl06 and r2b6).

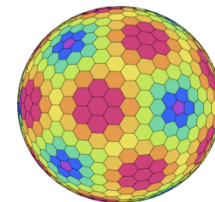


Aqua Planet Experiment (Neale and Hoskins 2000)

→ Equatorial Kelvin waves were simulated reasonably in ICON model and NICAM.

- In Hovmoller diagram of OLR, one or two clear line per one month (eastward propagation of cloud system) can be found in NICAM without CP.
- In ICON model, many lines can be found; it would be a characteristic of models with CP.

Abstract model description scheme



Goal: Improving portability of computational efficiency and productivity

- Development of a source-to-source compiler
- Abstraction of memory datatypes (and loop structures)
- Prototype available adapting the memory layout to a given computing platform
- For the ICON dynamical core, changing the memory layout from (cells, levels, blocks) to (levels, cells, blocks) yields a speedup between 11% and 17% on IBM Power 6 and Intel Westmere

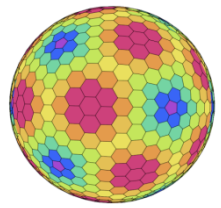
Ongoing: Assessing potential of using accelerators

- Uses DYNAMICO code as work base; OpenACC directives will be considered

Lessons learned:

- Limited tool support for Fortran code (that works on non-toy examples)
 - Workarounds for source-to-source compiler (Rose) required
- Application/analysis even on a (stripped) climate model too time consuming
- Current stage: Bottom-up approach to investigate kernels with alternative memory layout to derive best-practices for the model development and DSL requirements

Implicit solvers for massively parallel computing platforms



Goal: Development of an implicit Multigrid Helmholtz solver

Implicit solver avoids global communication and does not inhibit bit-reproducibility

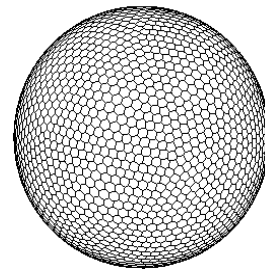
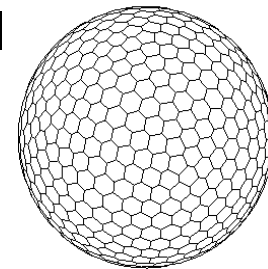
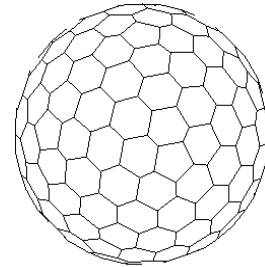
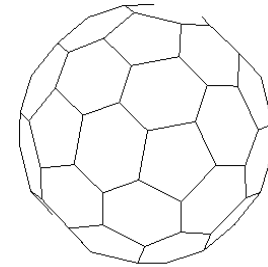
→ Results from Gung-Ho project indicate competitive computational performance and scaling

→ Development of a semi-implicit version of MPAS

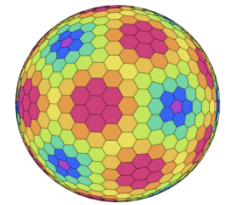
- Grid generation code has been adapted to build and write the multigrid hierarchy.
- Restriction/prolongation operators for the Hex C-grid have been tested in 2D.
- A semi-implicit time integration scheme has been formulated and the Helmholtz problem derived.
Coding in MPAS is under way.

Lessons learned:

- Working remote from the core developers is suboptimal
 - Face-to-face speeds up development



Parallel I/O and internal postprocessing



Parallel internal postprocessing

Goal: Extend the XIOS I/O servers to support unstructured grids

- A second-order accurate, conservative, scalable and efficient remapping scheme for arbitrary grids has been developed and successfully tested

I/O benchmarking and optimization

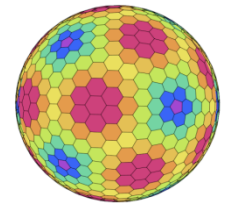
Goal: Analyze and suggest improvements for the (parallel) I/O scheme

- Analysis revealed performance degradation due to interactions between I/O libraries and file system (Blizzard + NFS)
 - A patch circumventing the NetCDF cache speeds up serial write by a factor of 3
 - MPI-IO layer on DKRZ supercomputer (IBM Power 6) required major performance fix
 - Embarrassingly parallel output (one file per task) continues to be fastest (A patch for HDF5 has been developed in the WP)
- Abstract I/O schemes and implied performance model have been developed

Lessons learned:

- Performance loss due to suboptimal interactions between file systems and I/O layers
- A generic performance optimized interface is needed to reduce optimization effort!

Lessons learned during the project



- International communication and coordination is important
 - Huge potential to share/re-use approaches and results
 - Unfortunately, this did not work perfectly for ICOMEX
 - Potential reason: the loose coupling of WPs in the proposal and late starts of several WPs
- Interdisciplinary effort involving computer science is helpful
- Challenges to overcome
 - Code portability
 - Performance portability
 - Inefficiencies in deployed software stack
 - Appropriate abstraction to formulate models
- Opportunities
 - Joint international development of standards avoiding redundancy

Disclaimer: The views of the speaker do not necessarily reflect the views of the consortium.