Performance Predictions for Storm-Resolving Simulations of the Climate System

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Global High-Resolution Simulations

- High level of detail → 100-1000m horizontal resolution
- Less parametrisation → In the limit, we know the equations!
- Challenges: very compute/memory/data intensive!
Overview

1. ESiWACE: Overview and Goals
2. ESiWACE, DYAMOND and Perspectives
3. Scalability, IO, Visualisation
4. Performance Prediction
5. Summary
ESiWACE: Overview

- ESiWACE = Centre of Excellence in Simulation of Weather and Climate in Europe
- Funded by H2020, e-Infrastructures „Centres of Excellence for computing applications“
- ESiWACE leverages two European networks:
  - European Network for Earth System Modelling (ENES)
  - European Centre for Medium-Range Weather Forecasts (ECMWF)
ESiWACE substantially improves efficiency and productivity of numerical weather and climate simulation on high-performance computing platforms by supporting the end-to-end workflow of global Earth system modelling.
ESiWACE, DYAMOND and Perspectives

- **ESiWACE1**: Establishment of global high-resolution simulations to demonstrate the computability of weather/climate predictions with (at least)
  - 1km resolution (atmosphere only)
  - 10km resolution (atmosphere-ocean)
  - Codes: IFS, NEMO, ICON, EC-EARTH
  - Explicit representation of deep convection, convective clouds, small-scale ocean eddies
  - Decreasing errors and uncertainties in weather and climate prediction
- **DYAMOND**: Intercomparison of global high-resolution models
- **ESiWACE2**
- **Long-term**: Extreme-scale robust high-resolution ensemble simulations at 1 simulated year per day (SYPD)
Scalability of ICON: Global High-resolution Simulations

- **IFS TCo 1279 (9km, 137 levels, double precision)**
- **IFS TCo 1279 (9km, 137 levels, single precision)**
- **IFS TCo 1999 (5km, 137 levels, single precision)**
- **IFS TCo 3999 (2.5km, 62 levels, single precision)**
- **ICON R2B8 (10km, 137 levels, double precision)**
- **ICON R2B9 (5km, 137 levels, double precision)**
- **ICON R2B9 DYAMOND (5km, 90 levels, double precision)**
- **ICON R2B10 (2.5km, 62 levels, double precision)**

**with async. IO:**
- 164GB per sim. day
- 682GB checkpoint
## I/O in Numbers: Outtakes from DYAMOND runs

<table>
<thead>
<tr>
<th>Nodes</th>
<th>No I/O procs</th>
<th>wrt_output (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>6</td>
<td>1091</td>
</tr>
<tr>
<td>300</td>
<td>6</td>
<td>1332</td>
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<tr>
<td>600</td>
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<td>1661</td>
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<td>600</td>
<td>11</td>
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<tr>
<td>900</td>
<td>15</td>
<td>749</td>
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</table>

→ How to determine optimal splitting?
### I/O in Numbers: Grib vs Netcdf (DYAMOND 5km)

900 nodes (Mistral, compute2), 15 IO procs, 1 simulated day, 2D/3D/rh,omega output every 15min/3h/15min

<table>
<thead>
<tr>
<th>filename</th>
<th>variables</th>
<th>grb (GB)</th>
<th>nc (GB)</th>
<th>ratio nc/grb</th>
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The Purpose of Simulation is Insight...

See, understand, learn, communicate ...

- Confirmatory visualisation
- Interactive visualisation
- Animations & stills for communication
Large Data Visualisation

in-situ Visualisation
(ParaView/Catalyst/Cinema)

Simulation
Adaptor
ParaView/Catalyst
Results

in-situ Compression
(Vapor)

Simulation
Decomposition
Vapor
Results

HPC System
Workstation
Towards Performance Prediction using Sparse Grids

- **Objective:** performance estimate for complex ESMs...
  - ...to gain insight into (wanted or unwanted) hotspots
  - ...to improve scheduling (relevant to workflows?)
- **Multi-parameter influence on computational performance**
  - → OpenMP/MPI decomposition, loop-blocking, vector lengths, ...
- **Approach:** *Regression on (potentially) high-dimensional parameter space via adaptive sparse grids*
Towards Performance Prediction using Sparse Grids

- Configuration: ICON R2B4 DYAMOND (160km global res.), no I/O
- Run times on single-node (dual-socket Broadwell)
- Parameters: number OpenMP threads/MPI tasks loop-blocking (nproma)
- Thanks to Paula Harder, DKRZ
ESiWACE – Joining forces to explore computability of extreme-scale weather and climate simulations

- ENES HPC Workshop, May 17-18 2018, Lecce/Italy
- Teratec Forum, June 19-20 2018, Palaiseau/France
- ISC, June 24-28 2018, Frankfurt/Germany
- PASC, July 2-4 2018, Basel/Switzerland

5km global resolution simulations incl. IO at O(45) forecast days/day → still some way to 1 SYPD...

Performance prediction with sparse grids delivers accurate run time estimates in various applications

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