UKESM-hybrid: focusing resolution where it’s most needed

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Which atmospheric sciences benefit most from high resolution?

Core Dynamics (Jung et al, 2012)

Convection (Tao and Chern, 2017)
Which sciences have the greatest share of the computation?

2/3rd of total computation is required for Aerosol and Chemistry (4 years ago it was 4/5th of the computation).
Should we run the sciences at different resolutions?

Benefits of higher resol’

High

Convection

Core dynamics

JULES & Boundary layer

Radiation

Microphysics

Aerosol

Chemistry

Low

Convection

Core dynamics

Microphysics

Radiation

ONLY RUN AT LOW RESOLUTION

JULES & Boundary layer

Computational expense

Low
Except XIOS, all coupling and re-mapping are done with the OASIS3-MCT coupler.
We tried just reducing the resolution of UKCA

Problems

- Coupling ~200 3D fields
- How do you degrade integer and logical fields?
UKESM-hybrid N216 N96
ORCA025 ORCA075

JULES
UM N216 (Snr)

Dynamical core fields

Aerosol & chemistry

JULES
UM N96 (Jnr)

UKCA

CICE
NEMO ORCA025

We’re trying this with DEGRAD

XIOS

MEDUSA ORCA075
Coupling frequency between Snr and Jnr

![Diagram showing coupling frequency between Snr and Jnr. The diagram illustrates the model time (vertical axis) and real time (horizontal axis). The UKCA timestep for Jnr is highlighted with a purple and blue shaded area. Coupling timesteps occur every hour.](Image)
Locking the physical atmosphere of Jnr to that of Snr

Which dynamical core fields from Snr should overwrite those over Jnr?
• Definitely: $U$, $V$ and $\theta_{vd}$
• Maybe: moisture fields, $W$, $D\eta/Dt$ and $\pi$.
• Definitely not: $\rho_d$ (ruins mass conservation in Jnr)

Which JULES fields?
• Probably: soil moisture and temperature

How we’re measuring success of locking?
• Trying to minimise drift of all dynamical core fields
• Minimise energy errors in Jnr’s atmosphere
• Using the standard evaluation tools, e.g. valnote
The feedbacks from Jnr to Snr

Fields passed from Jnr to Snr are remapped to the higher resolution with the OASIS3-coupler, they will be a slightly smudged version of the lower resolution field.

These 49*3D fields are

• 44 GLOMAP-mode fields for RADAER (optical properties for radiation)

• \( \text{O}_3, \text{N}_2\text{O} \) & \( \text{CH}_4 \) to calculate gas mixing ratios for radiation

• Total number of activated aerosol particles (for calculating cloud droplet number concentration)

• \( \Delta q \) (UKCA has a feedback on the moisture)
Comparing UKESM AMIP N216 vs UKESM-hybrid AMIP N216 N96 vs UKESM AMIP N96

Absolute annual mean TOA Outgoing Longwave Radiation (left column) and bias in TOA OLR against CERES observations (right column).
## Speed of UKESM-hybrid

### UKESM vs UKESM-hybrid with the same nodes

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Nodes</th>
<th>Speed (model years/day)</th>
<th>% faster</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKESM AMIP N96</td>
<td>20</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>UKESM-hybrid AMIP N96 N48</td>
<td>20 (10 for Snr; 10 for Jnr)</td>
<td>3.73</td>
<td>67%</td>
</tr>
<tr>
<td>UKESM N96 ORCA1</td>
<td>25 (20 for Atm; 5 for Ocn)</td>
<td>2.14</td>
<td></td>
</tr>
<tr>
<td>UKESM-hybrid N96 N48 ORCA1</td>
<td>25 (10 for Snr; 10 for Jnr; 5 for Ocn)</td>
<td>3.48</td>
<td>63%</td>
</tr>
<tr>
<td>UKESM AMIP N216</td>
<td>60</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>UKESM-hybrid AMIP N216 N96</td>
<td>60 (36 for Snr; 24 for Jnr)</td>
<td>1.82</td>
<td>65%</td>
</tr>
</tbody>
</table>

For the same resources, hybrid model is about 65% faster
# Speed of UKESM-hybrid II

Top speeds on two OpenMP threads

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Nodes</th>
<th>Speed (model years/day)</th>
<th>% faster</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKESM AMIP N216</td>
<td>242</td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td>UKESM-hybrid AMIP N216 N96</td>
<td>207 (130 for Snr; 77 for Jnr)</td>
<td>3.72</td>
<td>72%</td>
</tr>
<tr>
<td>UKESM N216 ORCA025*</td>
<td>191 (160 for Atm; 31 for Ocn)</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>UKESM-hybrid N216 N96 ORCA025*</td>
<td>242 (98 for Snr; 77 for Jnr; 67 for Ocn)</td>
<td>2.85</td>
<td>71%</td>
</tr>
</tbody>
</table>

*Run without MEDUSA, otherwise MEDUSA would limit speed

Top speed of hybrid model is about 71% faster
Options to improve speed of hybrid model

• Reduce the resolution of Jnr

• Move more science out of Snr, such as
  ❑ RADAER (optical properties of radiation)
  ❑ Radiation

• Reduce the domain of Snr
  ❑ Reduce the computation in Stratosphere for Snr
    ◦ Radiation column needs thinking about (we could apply BC on radiation or just reduce the vertical levels in Snr’s stratosphere)
  ❑ Run Snr(s) as a limited area model (LAM)
Next phase is developing UKESM-hybrid N96 N48 ORCA1

Reasons

• N96 N48 ORCA1 is computationally cheap – possible to run many long simulations

• It can be compared with UKESM (a model we know well)

What needs doing?

• Finish developing UKESM N48 ORCA1

  ❑ It did have too much cloud and was too warm
Summary

- 2/3\textsuperscript{rd} of computation for UKESM is for Aerosol and Chemistry

- Compared to running everything at the higher resolution
  - The hybrid model is about 65% quicker
  - Produces similar results (at least up to about 5 years)