CESM Load Balancing Development

Optimizer Study

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OUTLINE

- Introduction
- Project Goals
- Optimizer study
- Case Study
- Results
- Conclusions & Future Work
Coupled Simulation

**Coupled versus standalone approach:**

- Time scales
- Mesh requirements
- Numerical methods
- Use of legacy codes

Modeling the climate system-Karl and Trenberth 2003.
Community Earth System Model (CESM)
Challenges

Reaching high performance is challenging with CESM:

- Size of the problem
- Multi-component nature
- Scientific requirements
Motivation

Saves lots of core hours!!!
1) Getting benchmarking data.

Subject to layout specific constraints:

\[ N[\text{atm}] + N[\text{ocn}] = \text{TotalTasks} \]
\[ N[\text{ice}] + \sum N[i] + N[\text{wav}] = N[\text{atm}] \]
\[ T[\text{ice}] \leq T[1] \quad (T[1] = \max(\text{ice}, \text{ind}, \text{wav})) \]
\[ T[\text{ind}] \leq T[1] \]
\[ T[\text{wav}] \leq T[1] \]
\[ T[1] + T[\text{atm}] \leq T \]
\[ T[\text{ocn}] \leq T \]
\[ NB[c] \geq 1 \quad \text{for } c \in [\text{ice}, \text{ind}, \text{ocn}, \text{wav}, \text{atm}] \]
\[ N[c] = \text{blocksize} \times NB[c] \quad \text{for } c \in [\text{ice}, \text{ind}, \text{ocn}, \text{wav}, \text{atm}] \]
Study the potential automatic load balancing capability for CESM.

- Get timing data.
- Study the existing and potential optimizer.
- Implement and test optimizers.
- Run the case study with the new layout.
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Mixed Integer Linear Programming (MILP)
Optimizer Options

- Selected open source optimizers:

  1) PuLP
     - COIN-OR - (CBC) - Branch and Cut
     - GNU Linear Programming Kit (GLPK) – Branch and Bound

  2) SciPy
     - CVXOPT - (GLPK) - Branch and Bound
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### Case Study

#### 5-day Runs

<table>
<thead>
<tr>
<th>Compset</th>
<th>Scientific Grid</th>
<th>Mesh Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1850</td>
<td>f09_g17</td>
<td>1deg ATM = 192 x 288 x 32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1deg OCN = 320 x 394 x 60</td>
</tr>
</tbody>
</table>
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Performance Curves

B1850-1degATM/1degOCN (5 day run)
### Optimizer Layouts

- **B1850-1degATM/1degOCN (5 day run)**

<table>
<thead>
<tr>
<th>Total Number of Processors</th>
<th>288</th>
<th>576</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCN</td>
<td>72</td>
<td>144</td>
</tr>
<tr>
<td>ATM</td>
<td>216</td>
<td>432</td>
</tr>
<tr>
<td>LND</td>
<td>144</td>
<td>322</td>
</tr>
<tr>
<td>ICE</td>
<td>39</td>
<td>75</td>
</tr>
<tr>
<td>WAV</td>
<td>33</td>
<td>35</td>
</tr>
</tbody>
</table>

**Diagram:**

- CESM Component Layout (time vs. mpi tasks)

  - ND
  - ATM
  - OCN
  - ICE
  - W

- CESM Component Layout (time vs. mpi tasks)

  - ND
  - ATM
  - OCN
  - ICE
  - W
Comparison with Baseline

- B1850-1degATM/1degOCN (5 day run)

<table>
<thead>
<tr>
<th></th>
<th>288</th>
<th>576</th>
<th>720</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time (s)</td>
<td>1.94</td>
<td>1.06</td>
<td>1.00</td>
</tr>
<tr>
<td>Cost/year</td>
<td>0.78</td>
<td>0.85</td>
<td>1.00</td>
</tr>
</tbody>
</table>

576-core vs 720-core
40.23 secs/day vs 38.04 secs/day
6% slower but 15% more efficient!
Layouts

- B1850-1degATM/1degOCN (5 day run)

![Unbalanced Layout](image1)

![Balanced Layout](image2)
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Conclusions and Future Work

✓ Researched and implemented candidate optimizers.
✓ Benchmarked the different optimizers for a typical and widely used compsets.

Future Work

✓ Use the Load balancer and optimizer on more cases.
✓ Add other components (GLC and River) to the optimization problem.
✓ Research on more accurate algorithms for creating scalability curves.
✓ Try modeling the optimization problem as a non-linear problem.
ACKNOWLEDGMENT

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THANK YOU!!

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