ACCESS-S2 Coupled Climate System
Reanalysis and Hindcasts

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Australian Community Climate and Earth System Simulator- Seasonal v1 (ACCESS-S1)

- Current BoM operational seasonal and multi-week prediction system
- Based on the UKMO Global Coupled model v2 (GC2)
  - Unified Model v8.6 atmospheric model: N216 (0.8° lat by 0.5° lon), 85 vertical levels
  - NEMO ocean model v3.4: 25km grid, 75 vertical levels
  - JULES land model: N216 (0.8° lat by 0.5° lon), 4 soil levels
  - CICE sea-ice model v4.1: 25km grid
- Using UKMO ocean initial conditions (NEMOVAR)
- Atmosphere initialised using BoM NWP fields (ACCESS-G2)
- BoM ensemble generation using scaled random atmospheric field perturbations
- Operational mid-2018
- Daily forecasts of 11 members to 9 months and 22 members to 6 weeks
Rainfall (mm/day) climatology for spring (SON)

Observations

ACCESS-S1

POAMA

Debbie Hudson, BoM
ACCESS-S1

3-month mean bias in climatology (all seasons, 1-month lead)

ACCESS-S1

POAMA

Debbie Hudson, BoM
ACCESS-S1

• Issues:
  • Climatological soil initialisation
  • Ocean initialisation shock
  • Only 23 year hindcasts, only 11 member ensembles
  • Ozone updated on 360 day calendar
ACCESS-S2

• Based on the same coupled GC2 model from the UK Met Office
• Perturbation scheme same as ACCESS-S1
• BoM-designed coupled assimilation: Ensemble Optimal Interpolation (EnOI)
• Soil and ice initialised indirectly by assimilation
• Many more hindcasts: 37 year, 27 member ensemble hindcasts
• Ozone updated by Gregorian calendar
• Due in operations late 2020
ACCESS-S2 Coupled Assimilation

Fast track version of BoM/CSIRO Coupled EnKF-C software (Pavel Sakov)

- Ensemble OI in ocean
  - Static ensemble calculated from 184 member semi-lagged NEMOVAR ensemble filtered for seasonal and longer variability
- Direct replacement of atmos basic variables from ERA-interim (U, V, T, specific humidity)
- Weakly coupled through daily model cycle
- Land surface and sea-ice indirect initialisation through coupling
- Strong nudging of SST (1 day relaxation coefficient)
- T/S profiles only, no SST, SSS or SLA yet
- Multi-variate – ocean current updated by cross-covariance
ACCESS-S2 Coupled Reanalysis

Single member 1981-2016 re-analyses completed in 4 ten-year continuous runs.

- Run on Raijin
- Approx. 800,000 cpu hours
- 110 TB daily climate output data

Preliminary results show a significant increase in the accuracy of initial conditions over the UKMO fields.

- 2 year ocean re-analyses analysed
- T and S very similar
- Velocities much improved
- Could have significant positive impact on ENSO/IOD skill (and SST biases)
- Equatorial currents important for oceanic Kelvin wave mode

Yonghong Yin, BoM
Preliminary results show a Ocean bias reduction. Planning to be made available on NCI for research and analysis.

Yonghong Yin, BoM

- Designed to be as close as possible to forecast ensemble
- Running on Bureau Australis SC.
- Originally planned for 32,542 model years.
  - ~300 million cpu hours.
- Reduced to 14,560 model years.
  - ~130 million cpu hours.
- Estimated to finish end 2021 depending on SC upgrade
- Ensemble enables 27-member lagged ensembles for seasonal and multi-week timescales.
- ~1+EB of raw data:
  - ~1.5PB of reduced output data:
  - ~600TB planned to be transferred to NCI
Preliminary results indicate good skill.

Plan for the data set to be made available on NCI for research and analysis once verified.

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Sharmilla Sur, BoM
Preliminary results indicate good skill.

Plan for the data set to be made available on NCI for research and analysis once verified.

ACCESS-S2 Aug start dates for 1982 – 2014

<table>
<thead>
<tr>
<th></th>
<th>30 day O2</th>
<th>Monthly O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASO</td>
<td>0.643413</td>
<td>0.705454</td>
</tr>
<tr>
<td>SON</td>
<td>0.636642</td>
<td>0.780583</td>
</tr>
<tr>
<td>OND</td>
<td>0.495705</td>
<td>0.838057</td>
</tr>
<tr>
<td>NDJ</td>
<td>0.217039</td>
<td>0.640535</td>
</tr>
</tbody>
</table>
ACCESS-S2 Optimisation

• GC2 was optimised for the UKMO Cray SC.
• ACCESS-S1 was not optimised for the Bureau Cray SC.
• The delay in the SC upgrade has raised the priority of ACCESS-S2 resource efficiency.
• UM and NEMO are MPI applications.
• Jules and CICE are integrated directly into the UM and NEMO source code.
• Default is 320 CPUs and 1280GB RAM for a model instance.
• Approx. one year of forecast per 1.25 days runtime: problem for daily forecasts
ACCESS-S2 Optimisation

UM Optimisation:

- Intel compiler versions and options tested
- Dr. Hook profiler
- Fast transcendentals
- Cubic lagrange optimisation
- Changes to improve memory access related to the coeff_z array
- Changes made in convection algorithm
- Memory reduction as well as memory contention in the large scale precipitation routines.
- Optimal block size in the large scale precipitation routines tested
- Sandbridge vs. Haswell configurations tested and defined explicitly per source file
- 11% reduction in coupled model runtime
ACCESS-S2 Optimisation

NEMO Optimisation:

- Cray Pat Lite
- Compiler options tested
- Array initialisation and fusion of several loops in the theta2t routine
- 1.5% reduction in coupled model runtime
• Decomposition testing of the coupled model provided a 3% speed-up by reducing the NEMO CPUs to provide more for the UM
• Rough scaling of the coupled model shows small non-linearity
• To be done:
  • Test cray compilers
  • Partially committed nodes
  • In-depth scaling
# ACCESS-S Future Plans

<table>
<thead>
<tr>
<th>System Configurations</th>
<th>ACCESS-S1</th>
<th>ACCESS-S2</th>
<th>ACCESS-S3</th>
<th>ACCESS-S4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic Model</td>
<td>UKMO GC2</td>
<td>UKMO GC2</td>
<td>UKMO GC4/5</td>
<td>UKMO GC5/6</td>
</tr>
<tr>
<td>Local updates</td>
<td>None</td>
<td>Remove inland lakes, Update tree height dataset (tbc)</td>
<td>Initial improvements from NACP and R&amp;D profit Extremes projects + other local improvements</td>
<td>Final improvements from NACP and R&amp;D profit Extremes projects + other local improvements, Inclusion of enhanced resolution over Australia from LFric Project</td>
</tr>
<tr>
<td>Model Uncertainty</td>
<td>Basic stochastic Physics</td>
<td>Basic Stochastic Physics</td>
<td>Advances stochastic Physics in the atmosphere</td>
<td>Inclusion of ocean stochastic Physics</td>
</tr>
<tr>
<td>Biases</td>
<td>Significant Biases</td>
<td>Significant Biases</td>
<td>Reduced Biases</td>
<td>Small Biases</td>
</tr>
<tr>
<td>Atmosphere Resolution</td>
<td>60km</td>
<td>60km</td>
<td>60km</td>
<td>60km with enhanced resolution around Australia to about 20km</td>
</tr>
<tr>
<td>Ocean Resolution</td>
<td>25km</td>
<td>25km</td>
<td>25km</td>
<td>25km</td>
</tr>
<tr>
<td><strong>Assimilation</strong></td>
<td></td>
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<tr>
<td>Ocean</td>
<td>Download Ocean from UKMO</td>
<td>Coupled ocean assimilation system (excludes altimeter data)</td>
<td>Weakly Coupled EnKF assimilation system includes ocean/atmos/land/ice in one coupled system</td>
<td>Strongly Coupled EnKF assimilation system includes ocean/atmos/land/ice in one coupled system</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>ACCESS-G realtime, ERA-Interim hindcasts</td>
<td>Coupled assimilation directly nudged to ACCESS-G realtime, ERA-Interim hindcasts</td>
<td>Include altimeter data, Investigate inclusion of sea ice data</td>
<td>Include sea ice assimilation, Includes surface salinity assimilation from satellite</td>
</tr>
<tr>
<td>Ice</td>
<td>Downloaded from UKMO from ice assimilation system using ice data, as part of ocean initial conditions</td>
<td>From coupled assimilation (no direct use of ice observations)</td>
<td>Perturbations directly from coupled assimilation system (optimised)</td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>Climatology</td>
<td>From coupled assimilation system</td>
<td>Basic coupled Perturbations directly from assimilation system (not optimised)</td>
<td></td>
</tr>
<tr>
<td>Ensemble Perturbations</td>
<td>Static perturbations developed locally</td>
<td>Retuned static perturbation scheme</td>
<td></td>
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<tr>
<td><strong>Hindcast System</strong></td>
<td></td>
<td></td>
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<tr>
<td>Target ensemble size</td>
<td>11</td>
<td>27</td>
<td>&gt; 27</td>
<td>&gt; 27</td>
</tr>
<tr>
<td>Target lead time</td>
<td>6 months</td>
<td>5 years</td>
<td>5 years</td>
<td>5 years</td>
</tr>
</tbody>
</table>
• ACCESS-S2 = de-bugged, optimised ACCESS-S1 coupled model + BoM weakly coupled assimilation.

• Early indications of extended seasonal skill in the hindcasts.

• Reduced project scope means no hindcasts or forecast beyond 9 months are planned.

• Extensive climate reanalysis and hindcast data set to be made available on NCI.

### ACCESS-S1

#### Cost:
- 7000 model years - Small but expensive model

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#### Skill Assessment
- 11 ensembles over (ok for median but not extremes) \( \sqrt{x} \)
- 23 years (not enough for regional skill - only for large scale) \( x \)
- Can be done 4 times per month (Very Good - more than necessary) \( \sqrt{\sqrt{\sqrt{}}} \)

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#### Bias Correction/Calibration
- 11 ensembles (more than enough) \( \sqrt{\sqrt{}} \)
- 23 years (not enough for calibration) \( x \)
- Can be done 4 times per month (compromised due to big gap) \( \sqrt{x} \)
ACCESS-S2

Skill Assessment
- 27 ensembles (Excellent for median and ok for extremes) ✓✓
- 37 years (OK) ✓
- Only once month (acceptable compromise) ✓ (X only for case studies)

Bias Correction/Calibration
- 3 ensembles (minimum possible for 37 years) ✓
- 37 years (OK) ✓
- 6 times per month (Excellent) ✓✓

Cost: 13,000 model years - Modest for benefits, but expensive model