Multi-millennial simulations of the climate of the late Holocene

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The CSIRO Mk3L climate system model

- Low-resolution version of the CSIRO Mk3 climate system model
- Atmosphere:
  - Spectral general circulation model
  - Resolution is R21 18L ($\Delta \lambda \approx 5.6^\circ, \Delta \phi \approx 3.2^\circ$)
  - Dynamic-thermodynamic sea ice model
  - Land surface model (static vegetation)
- Ocean:
  - $z$-coordinate general circulation model
  - Resolution is R21 21L (same horizontal grid as atmosphere model)
  - Gent-McWilliams eddy diffusion
- Flux adjustments applied
- $\sim$5 model years/day (3GHz Pentium 4)
The pre-industrial climate

- Control simulation follows PMIP2 experimental design:
  - CO$_2$ concentration = 280 ppm
  - Solar constant = 1365 Wm$^{-2}$
  - “Modern” orbital parameters (AD 1950)
- Integrated for 2000+ years
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NADW formation: power spectrum
EOF1 of annual-mean sea surface temperature (°C) – 22.3%
El Niño: model versus observed

<table>
<thead>
<tr>
<th></th>
<th>Mk3L</th>
<th>Observed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation of Niño 3.4 SST anomaly (°C)</td>
<td>0.48</td>
<td>0.71</td>
</tr>
<tr>
<td>Average period (years)</td>
<td>7.8 ± 0.5</td>
<td>~3–6</td>
</tr>
<tr>
<td>Average duration (months)</td>
<td>17.2 ± 0.6</td>
<td>~12</td>
</tr>
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The climate of the mid-Holocene

- Equilibrium simulation conducted for 6ka BP
- PMIP2 experiment
- Orbital parameters for 6ka BP
- Atmospheric CO$_2$ concentration reduced from 280ppm to 277ppm
  - equivalent to a reduction in the atmospheric CH$_4$ concentration from 760ppb to 650ppb
- Initialised from year 100 of control simulation
- Integrated for 1200+ years
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Difference in August surface air temperature (°C)
El Niño: control versus 6ka BP

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<th>6ka BP</th>
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<tr>
<td>Standard deviation of Niño 3.4 SST anomaly (°C)</td>
<td>0.48</td>
<td>0.42</td>
</tr>
<tr>
<td>Period (years)</td>
<td>7.8 ± 0.5</td>
<td>8.8 ± 0.9</td>
</tr>
<tr>
<td>Duration (months)</td>
<td>17.2 ± 0.6</td>
<td>16.6 ± 1.0</td>
</tr>
</tbody>
</table>
The climate of the late Holocene

- Transient simulations from 6ka BP to the present day
- Initialised from year 1000 of the mid-Holocene simulation
- Orbital parameters varied, using the acceleration technique of Lorenz and Lohmann (2004)*
- Acceleration factors of 1, 5, 10 and 20
- Other boundary conditions unchanged

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Difference in annual precipitation over North Africa (mm)
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Conclusions

- The CSIRO Mk3L climate system model is a useful tool for studying past, present and future climate variability and change.
- Lorenz-Lohmann acceleration enables orbital effects on very long timescales to be studied.
- Simulations suggest a gradual strengthening of ENSO during the late Holocene.