Evaluation of the CMIP5 palaeo-simulations

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Why palaeo-evaluation?
**PMIP boundary conditions: MH**

<table>
<thead>
<tr>
<th>Mid Holocene (6000 years BP)*</th>
<th>eccentricity = 0.018682 obliquity = 24.105° perihelion-180° = 0.87°</th>
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<tr>
<td>Insolation</td>
<td><strong>CO2</strong> = 280 ppm Or 280/345*Ccont CH4 = 650 ppb N2O = 270 ppb CFC = 0 O3 = not considered</td>
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<td>Trace gases</td>
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</tr>
<tr>
<td>Vegetation and land surface</td>
<td>Prescribed to be the same as modern vegetation</td>
<td>Either prescribed to be the same as modern vegetation or computed using a dynamical vegetation module</td>
<td>Computed using a dynamical vegetation module, Or prescribed as in PI, with phenology computed for models with active carbon cycle or prescribed from data</td>
</tr>
<tr>
<td>Carbon cycle</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Interactive, with atmospheric concentration prescribed and ocean and land carbon fluxes diagnosed as recommended in CMIP5</td>
</tr>
</tbody>
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*In this experiment ice-sheet, coastline, solar constant and aerosols are prescribed as in the PI simulation.*
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<tr>
<th></th>
<th>PMIP1</th>
<th>PMIP2</th>
<th>PMIP3</th>
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<td><strong>Last Glacial Maximum (21000 years BP)</strong> *</td>
<td>* In this experiment solar constant and aerosols are prescribed as in the PI simulations.</td>
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<td><strong>eccentricity</strong> = 0.018994 obliquity = 22.949° perihelion-180° = 114.42°</td>
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<td>Trace gases</td>
<td>CO2 = 200 ppm or 200/280) * Ccont CH4 = 350 ppb N2O = 190 ppb CFC = 0 O3 = same as in PI</td>
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<tr>
<td>Ocean</td>
<td>SST prescribed from CLIMAP (1981) Or SST computed using a slab ocean model</td>
<td>3D Ocean model and sea-ice</td>
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</tr>
<tr>
<td>Land-sea mask</td>
<td>- 105 m sea level</td>
<td>Prescribed following Peltier (2004) land-sea mask -120 m</td>
<td>Prescribed from the blended ice-sheet land-sea mask</td>
</tr>
<tr>
<td>Freshwater</td>
<td>Excess LGM freshwater added to the ocean in 3 different regions</td>
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<td>Ice sheet ice streams</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Not considered</td>
</tr>
<tr>
<td>River runoff</td>
<td>Not considered</td>
<td>As in CTRL or river pathway modified</td>
<td>As in PI or river pathway modifier according to PMIP protocol</td>
</tr>
<tr>
<td>Mean ocean salinity</td>
<td>Not considered</td>
<td>Not considered</td>
<td>+1 PSU everywhere</td>
</tr>
<tr>
<td>Carbon cycle</td>
<td>Not considered</td>
<td>Not considered</td>
<td>Interactive, with atmospheric concentration prescribed and ocean and land carbon fluxes diagnosed as recommended in CMIP5 For PCMIP: fully interactive with atmospheric concentration computed by the model</td>
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Palaeo-benchmarking

Mid-Holocene

LGM

Land - Pollen

- America (90W - 40W)
- Africa (2W - 50E)
- Indonesia, Pacific (105E - 109W)
- MARGO data

Ocean - all proxies
Quantitative climate reconstructions: MH and LGM

Mean Annual Temperature (MAT) Anomalies 21 ka

Mean Annual Temperature (MAT) Anomalies 6 ka

Ocean reconstructions: MARGO Project Members, 2009, Leduc et al., 2010;
Land reconstructions: Bartlein et al., 2011
OTHER TYPES OF RECONSTRUCTIONS

- BIOME 6000 project
  Prentice et al., 2000
  Prentice et al., 2011

- GPWG charcoal database
  Power et al., 2009
  Daniau et al., unpub.

- GLSDB
  Kohfeld and Harrison, 2000

- DIRTMAP database
  Kohfeld and Maher, unpub.
Peat records: Charman et al., subm.  Charcoal records: GPWG database
Evaluation: land-sea contrast

Future ratio: 1.36-1.84

Palaeo-ratio: same ballpark!

Braconnot et al., subm.
Evaluation: polar amplification

Braconnot et al., subm.

polar amplification ✔

Antarctic cooling underestimated
Evaluation: MH monsoons

Mean Annual Precipitation

red: obs mean
purple: model mean

Obs
Model
Climate sensitivity

Ballantyne et al. (2005) LGM data, 1σ limits

using spatial explicit data set

median = 2.3K

1.7–2.6 K 66% prob

>6K IMPLAUSIBLE

Edwards et al., 2009

Schmittner et al., in press, Science
Magnitude errors: LGM

Models underestimate regional cooling
Magnitude errors: MH
Discrimination: LGM oceans

Adkins et al., 2002, Science

Analyses courtesy of Bette Otto-Bleisner
Discrimination: continental aridity

- monsoon too extensive, limited aridity
- wetting/drying too zonal
- continent-wide aridity
“There’s more to life than temperature reconstructions, Brian”
Transient evolution of fire

Outputs from ECBILT-CLIO simulation, in response to orbital, ice sheet & GHG forcing, can reproduce observed zonal fire responses.
Other PMIP3 experiments

- other warm periods
  - orbitally driven (LIG, 125ka)
  - CO$_2$ driven (mid-Pliocene, 3-3.3Ma)
- other cold periods
  - Greenland stadials
- transient simulations – rapid climate changes
  - deglaciation/YD
  - D-O cycles

Additional experiments broaden scope of PMIP contribution to CMIP5

- additional tests of mechanisms in LGM, MH and LM simulations
- assess model capacity to reproduce the amplitude, timing and nonlinear feedbacks
Example data sets: time-slice

Salzmann et al., 2008; CAPE Project Members, 2006; Tilberg, 2011
Example data sets: transients

Harrison & Sanchez Goni, 2010; Daniau et al., 2010
Take-home messages

• Palaeo-world presents opportunities to evaluate climate change mechanisms
• PMIP has data sets and evaluation tools
• PMIP has shown that models can reproduce first-order signals – it makes sense to use models to simulate future climate change!
• PMIP has shown that models fail to capture magnitude of responses
• PMIP has shown that feedbacks important but still poorly captured in models