Climate of the Indo-Pacific warm pool during the LGM simulated by CESM1

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New Simulations of LGM climate performed with CESM1.2:
  – 2 deg FV CAM5
  – 1 deg POP2
  – Timeslice (snapshot) simulations
    • Full LGM climate
    • Single forcing
  – Boundary conditions defined by PMIP3
    • New sea level boundary conditions

Evaluated against proxy synthesis

Two experiments designed to isolate:
  • Exp1: Response to GHGs vs. icesheets vs. sea level
  • Exp2: Effect of glacial sea level on tropical climate
Simulations evaluated against proxy synthesis of LGM hydroclimate:

- Drying of the warm pool center
  - Dry northern Australia
  - Not much of a signal towards the edges of the warm pool
- Wetter equatorial east Africa
Experiment 1: Full LGM climate

- 21ka BP timeslice run until deep ocean equilibrates
  - Ocean IC from CCSM4 PMIP3 LGM simulation

- Full glacial boundary conditions:
  - Sea level (shelves, ITF, other passages, tidal mixing)
  - Icesheets (topography + albedo)
  - Overflows
  - Greenhouse gases
  - Orbital

- All boundary conditions/forcings applied globally

- Single forcing experiments
  - Each forcing applied separately
LGM changes in warm pool rainfall simulated by CESM1

ΔP (mm/day)

Change in rainfall at the LGM
(LGM minus pre-industrial)
The new LGM simulation the best agreement with the proxies

12 models participating in PMIP2 and PMIP3 + new CESM1 LGM simulation

Stippling = 1σ statistical significance
κ = 1 means perfect agreement
κ = 0 means no agreement

Adapted from DiNezio and Tierney 2013
Break down of the LGM response

Full LGM

Greenhouse gases + Orbital

Icesheets

Sea level
Experiment 2: Warm pool response to glacial sea level

- Mechanisms whereby a 120 m sea-level drop influences tropical climate:
  - Shelf exposure
  - Closure of some key passages of the Indonesian Throughflow
  - Changes in tidal mixing over the Banda Sea
- Glacial boundary conditions applied over the Maritime Continent region:

- All other boundary conditions (GHGs, icesheets, orbit) set to pre-industrial values.

DiNezio et al. 2015
Sea level response simulated by CESM1.2

Response to the following boundary conditions:

- Exposure of Sunda and Sahul shelves
- Raised sills of key Indonesian Throughflow passages
- Altered tidal mixing

Proxy-inferred changes:

- LGM hydroclimate
  - Drier
  - No Change
  - Wetter
  - Not robust

DiNezio et al. 2015
How does the response to sea level work?

Rainfall change

- Anomalous easterlies
- Stronger SST gradient

Indian ocean response:

Bjerknes feedback?

SST change
The response is initiated by shelf exposure...

atmosphere-only response

and amplified by the Indian Ocean

Response due to coupled ocean-atmosphere dynamics
Break down of the sea level response

Sunda shelf exposure

Sahul shelf exposure

Indonesian Throughflow

Tidal mixing
Breakdown of the agreement with the proxies:

Stippling indicates statistical significance

$\kappa = 1$ means perfect agreement
Conclusions

• Sea level and icesheets are key drivers of changes in warm pool hydroclimate at the LGM.
  – Sea level dominates in the southern part of the warm pool
  – Icesheets dominate in the northern part
• GHG response is generally of opposite sign
  – Tendency towards wetter Maritime Continent.
  – Consistent with a stronger Walker circulation (opposite response than to Global Warming).
  – Can be detected?
Conclusions

• Exposure of both the Sunda and Sahul shelves is the key driver of changes in IPWP climate.
  – Coupled ocean-atmosphere dynamics amplifies the response
    • Akin to Bjerknes feedback.
    • The Indian Ocean becomes more like the Pacific, i.e. a cold tongue develops in the eastern side of the basin.
  – ITF and tidal mixing play a secondary role
    • Tidal mixing: Banda Sea and NW Australia shelf.
    • ITF: negligible effect.
Thank you!
Role for ocean dynamics?

Zonal current change

- anomalous eastward currents

Upwelling change

- stronger equatorial upwelling
Sunda shelf hypothesis:

- Centers of atmospheric deep convection over the Indo-Pacific warm pool are sensitive to exposure of the Sunda shelf

Geography of the Maritime Continent after a 120 m sea level drop
Representing shelf exposure in CAM5

CAM5’s 2x2 deg land-sea mask

(a) Present day

(b) LGM

atmosphere model land fraction (%)
Effect of lower sea-level on POP’s bathymetry

POP2’s 1x1/3 deg bathymetry

present day

LGM

(c)

(d)

ocean model depth (m)

Sunda

Sahul
ITF shutdown can have a large impact on warm pool climate

Fig. 4. Changes in precipitation due to closure of the throughflow in mm day$^{-1}$. Increase of rainfall is shown by solid lines, decreases are indicated by a dashed line, and the zero contour is omitted for clarity. Shading highlights changes that are significant at the 95% level.
Tidal mixing over the Banda Sea can influence IPWP climate

SST (contour lines: 0.2°C), precipitation (color intervals: 0.2 mm day⁻¹)

Jochum and Potemra 2008
Effect of lower sea-level on tidal mixing

present day

LGM

vertical diffusivity due to tidal and background mixing (cm$^2$/s)

DiNezio et al. 2015
Linear: sea level + ghg + orbital + icesheets

Full LGM