

Updates from NCAR and Plans for CMIP6/PMIP4 with the CESM2

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CESM Paleoclimate Working Group

Univ. Texas/Austin

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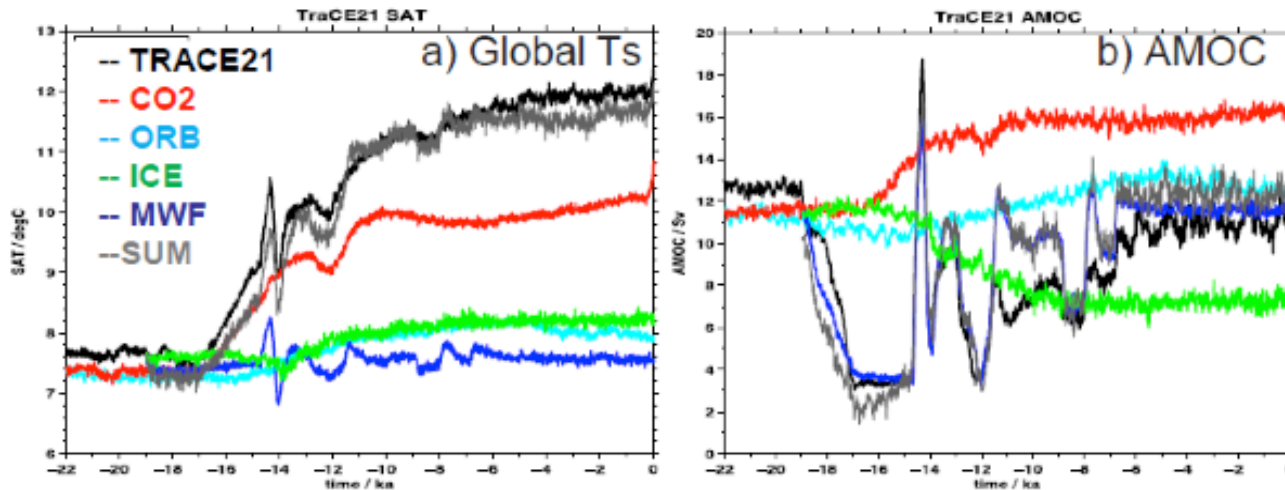


Outline

- NCAR Activities
 - Ongoing Projects:
 - iTRACE
 - Last Millennium Ensemble
 - New Pliocene Simulations (PlioMIP1)
- PaleoWG plans for CMIP6/PMIP4 (CSL)
- First steps with CESM2
 - Half-CO₂ sensitivity test run
- Update on iCESM2

TRACE-21ka

- Simulation of deglacial climate evolution from 22ka to PD
 - T31x3 CCSM3
 - Transient Forcing (GHG, Orbital, Ice sheet, Land/ocean mask; Meltwater)
 - Full forcing, and Single forcing runs
- Liu et al. Science, 2009; Otto-Bliesner et al. Science, 2014; He et al Nature, 2013

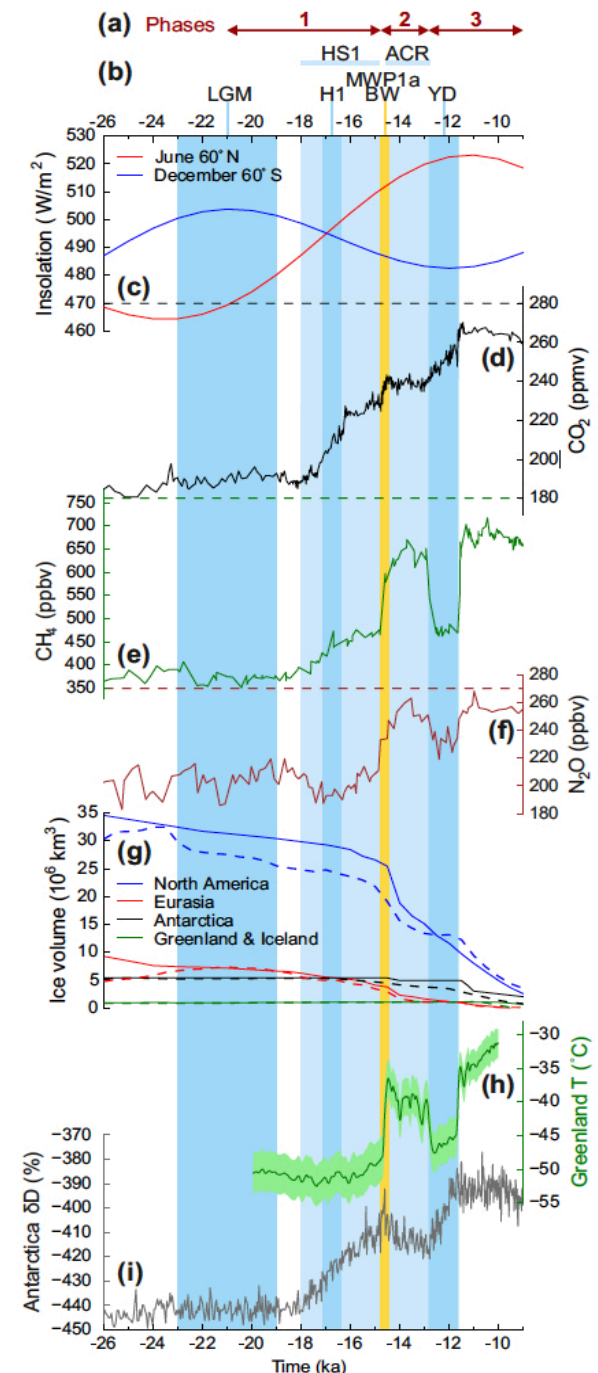


<https://www.earthsystemgrid.org/project/trace.html>

iTRACE: Last Deglaciation Experiment with iCESM

- iTRACE: NCAR/Ohio State/OSU NSF-funded collaboration (Otto-Bliesner, Liu, Clark)
 - Spin up for 21ka conditions,
 - Transient simulation (20ka -> 14ka)
- PMIP4 Forcings: from *Ivanovic et al. Geosci. Model Dev., 9, 2563–2587, 2016.*
- Isotope-enabled, multi-geotracer enabled CESM1.3

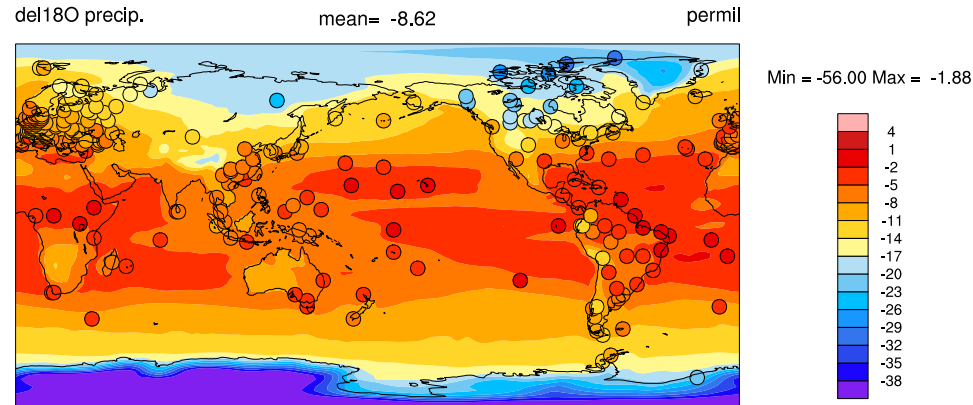
Fig. from Ivanovic et al. GMD, 2016.



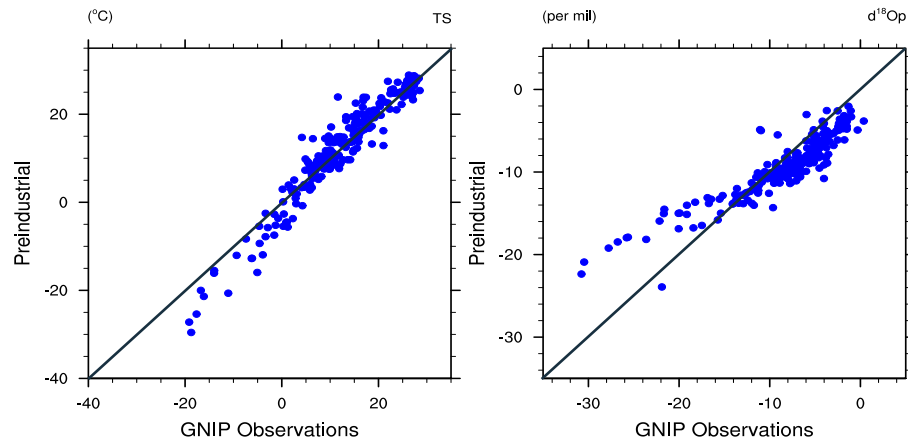
iTRACE Design

- Multiple GeoTracers
 - Stable water isotopes (Atmosphere, Land, ocean, sea ice, runoff)
 - Abiotic radiocarbon and 'bulk' C (ocean only, A. Jahn)
 - Abiotic Protactinium, Thorium (ocean only, S. Gu)
 - Neodymium isotopes (ocean only, S. Gu)
- Improved resolution vs. TraCE-21 (T31x3):
 - FV1.9x2.5 CAM5.3
 - gx1 POP2, 60 vertical levels, Greenland grid
- New Deglacial Forcings from PMIP4 design protocols
- Improved LGM Boundary Conditions
 - LGM land/ocean mask and KMT from Dinezio et al. *Paleoceanog.* 2016
 - ICE-6G ice sheets (Peltier et al. 2015, PMIP4 protocols)
- Forcing 'Factorization' simulations:
 - Transient Ice Sheet "ice" from ICE-6G (Peltier et al. 2015)
 - Ice+orbital
 - Ice+orbital+ghg
 - Ice+orbital+ghg+meltwater flux

Model $\delta^{18}\text{O}$ in Precipitation vs. GNIP obs



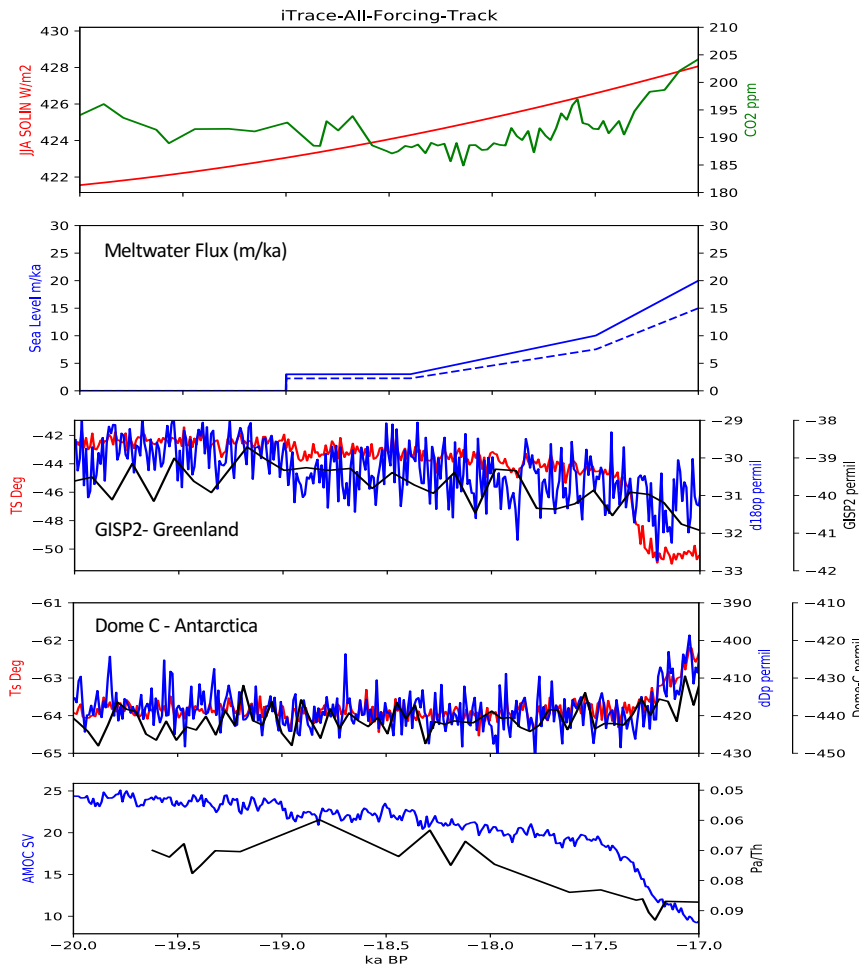
Iso-AMWG diagnostics
(Anne-Katrine Faber,
2016)



GNIP = Global Network
of Isotopes in
Precipitation (IAEA.org)

iCAM5: Nusbaumer et al. JAMES 2017; iCLM4: Wong et al. JAMES 2017;
iPOP: Zhang et al. PNAS 2017; iCESM: Zhu et al. GRL 2017.

iTRACE: Response to Meltwater: ICE+ORB+GHG+MWF1

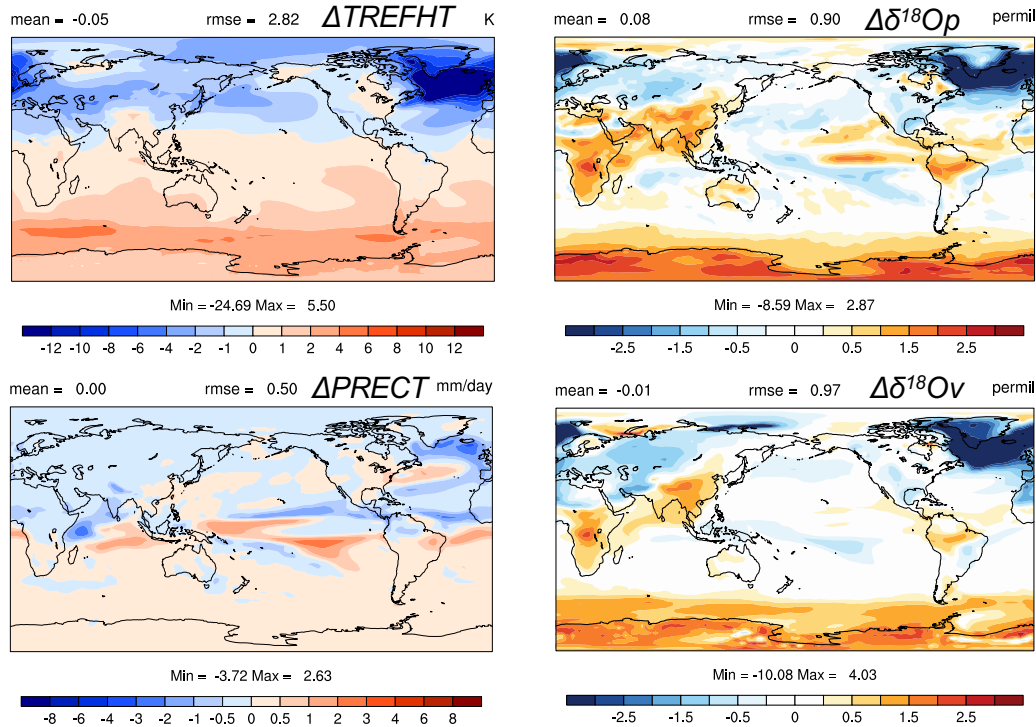


- *The response at GISP2, Greenland shows a similar slow reduction in $\delta^{18}O_p$ as compared to the icecore record, whereas temperature shows a rapid cooling response.*
- *At Dome C, Antarctica, the simulation of the isotopic content of precipitation compares well in timing and amount to the ice core data.*

Figure courtesy of C. He (OSU)

Effect of Meltwater forcing at 17ka

ICE+GHG+ORB+MWF1 – ICE+GHG+ORB



- NH Cooling/SH warming (bipolar seesaw) exhibited in $\delta^{18}O_p$ consistent with “temperature effect”
- Southward shift in ITCZ shown in $\delta^{18}O_p$ is consistent with “amount effect” over tropical oceans & S. America
- S. Asian/African Monsoon region response not consistent with local amount effect on annual timescale. Consistent with response in $\delta^{18}O_{vapor}$.

Last Millennium Ensemble (LME) Project



--A CESM "Community" Project

Goals: Investigate forced climate change and variability over the last 1000 years.

Bette Otto-Bliesner, et al., BAMS, 2015

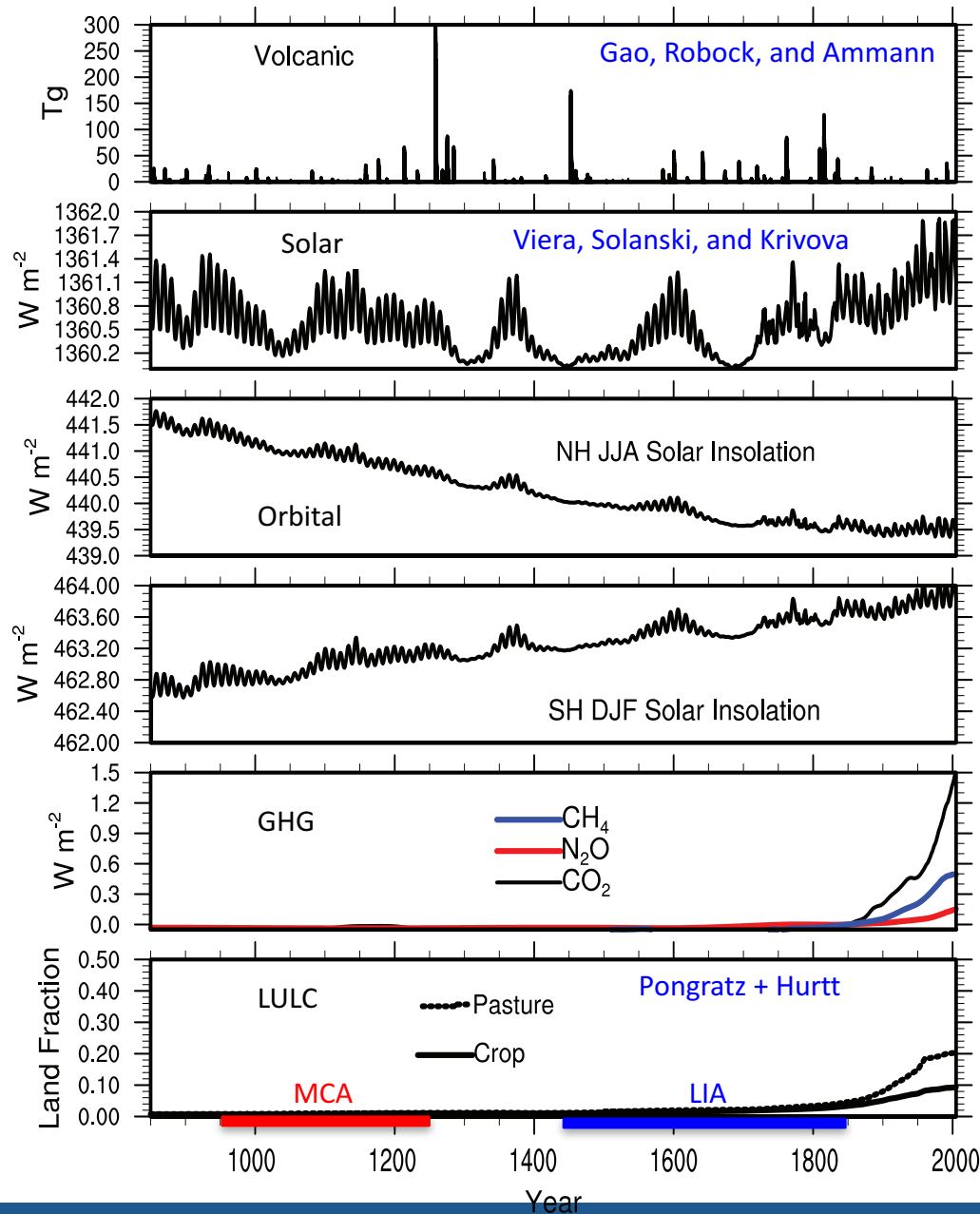
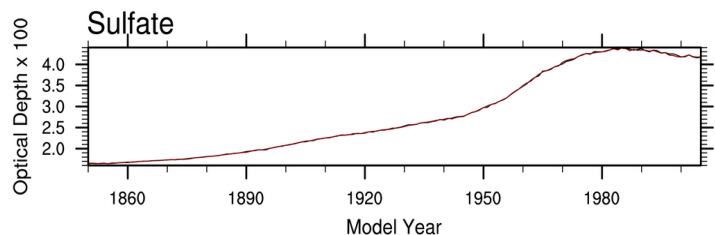
Esther Brady, Nan Rosenbloom, Andy Mai, Gary Strand, Samantha Stevenson, John Fasullo, Laura Landrum, Alexandra Jahn, Bob Tomas, and many others

Last Millennium Forcings (850-2005AD)

based on CMIP5/PMIP3 and LENS protocols

LENS="Large Ensemble": 1920-2100w/RCP8.5; Kay et al. BAMS 2015, www.cesm.ucar.edu/projects/community-projects/LENS/

CESM1.1.1-CAM5
Same model configuration as LENS
Except no OBGC & uses FV2_gx1v6



CESM1.1.1-Last Millennium Ensemble (30+ simulations)

Atmosphere: CAM5, 2-degree lat-lon resolution

Land: CLM4, 2-degree lat-lon resolution, prescribed vegetation

Ocean: POP2, Sea ice: CICE4: gx1v6

Expt	# runs	Solar variability	Volcanic eruptions	Land use	Greenhouse gases	Orbital changes	Ozone/aerosols
Full forcings	13	Transient 850-2005AD	Transient 850-2005AD	Transient 850-2005AD	Transient 850-2005AD	Transient 850-2005AD	Transient 1850-2005AD
Solar only	4 +2High	Transient 850-2005AD	None	*	*	*	1850AD
Volcanic only	5	*	Transient 850-2005AD	*	*	*	1850AD
Land use only	3	*	None	Transient 850-2005AD	*	*	1850AD
GHG only	3	*	None	*	Transient 850-2005AD	*	1850AD
Orbital only	3	*	None	*	*	Transient 850-2005AD	1850AD
Ozone Aerosol only	2	*	None	*	*	*	Transient 1850-2005AD

* Forcing kept constant at 850 AD value, **pertlim ...**

Full-forcing.002 extended to 2100 with RCP8.5 forcing

Full-forcing.007 with high temporal CAM output for forcing WRF and extremes analysis

Full-forcing.010 with abiotic radiocarbon in the ocean

For More Information

Project webpage:

<http://www.cesm.ucar.edu/projects/community-projects/LME/>

Data Access via Earth System Grid:

www.earthsystemgrid.org

Overview Paper:

Bette Otto-Bliesner, et al., BAMS, 2015; (doi: 10.1175/BAMS-D-14-00233.1)

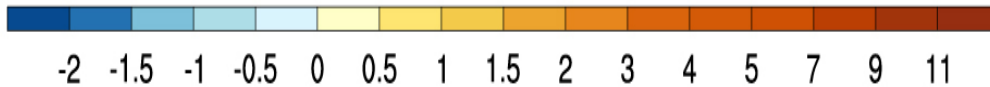
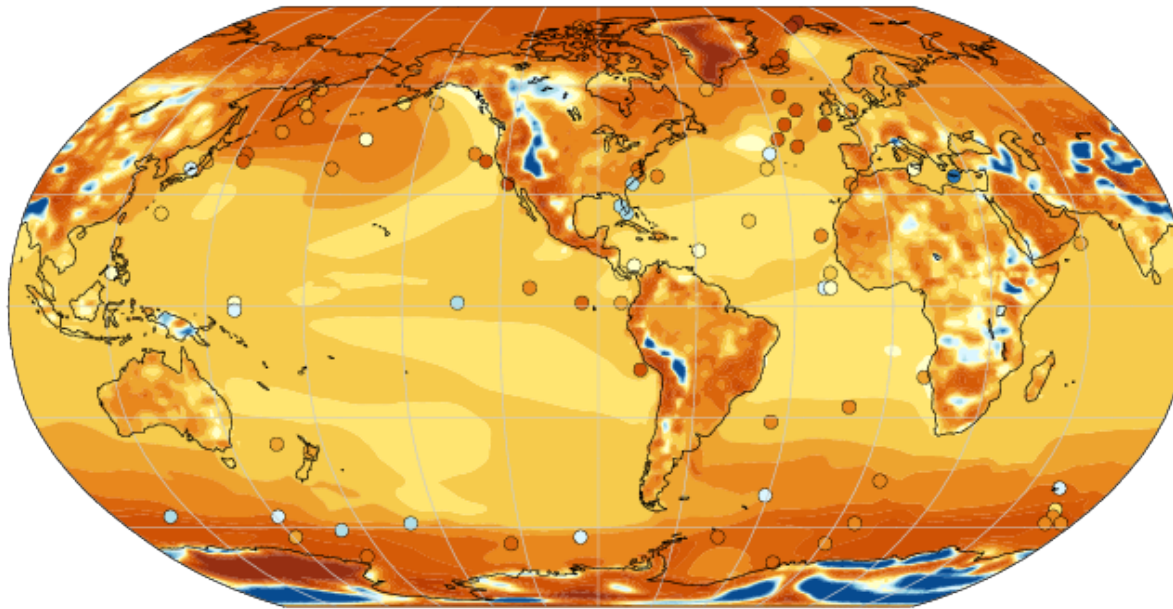
Publications (13 so far!); some downloads available:

<http://www.cesm.ucar.edu/projects/community-projects/LME/publications.html>

PlioMIP1 simulation (with modern land-ocean mask)

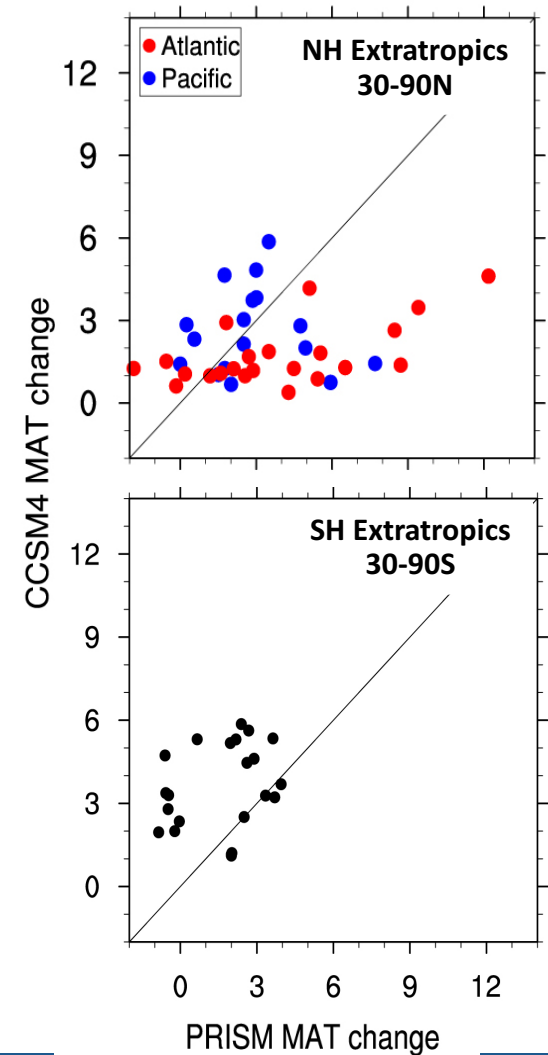
Otto-Bliesner, R. Feng (U.Conn), E. Brady, N. Rosenbloom

CCSM4 (MAT change - mPWP minus Modern)



Key Result: Not enough High Latitude NH Warmth vs PRISM3

Description paper: Rosenbloom et al. GMD 2013



New! Pliocene Runs Completed in Preparation for PlioMIP2

Goal: Evaluate the sensitivity to uncertainties in forcings over the mPWP Interval.

1) Gateway Runs:

- Closed Bering Strait
- Closed Canadian Archipelago
- Closed CAA&BS
- Open WAIS

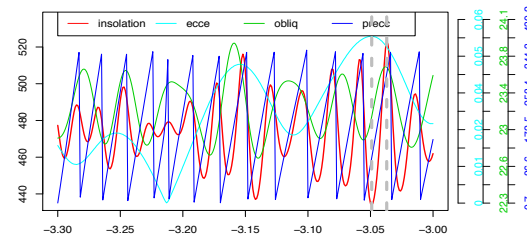
Otto-Bliesner et al. *GRL*, 44, 2016: Amplified North Atlantic warming in late Pliocene by changes in Arctic gateways,.

2) Radiative Forcing Runs:

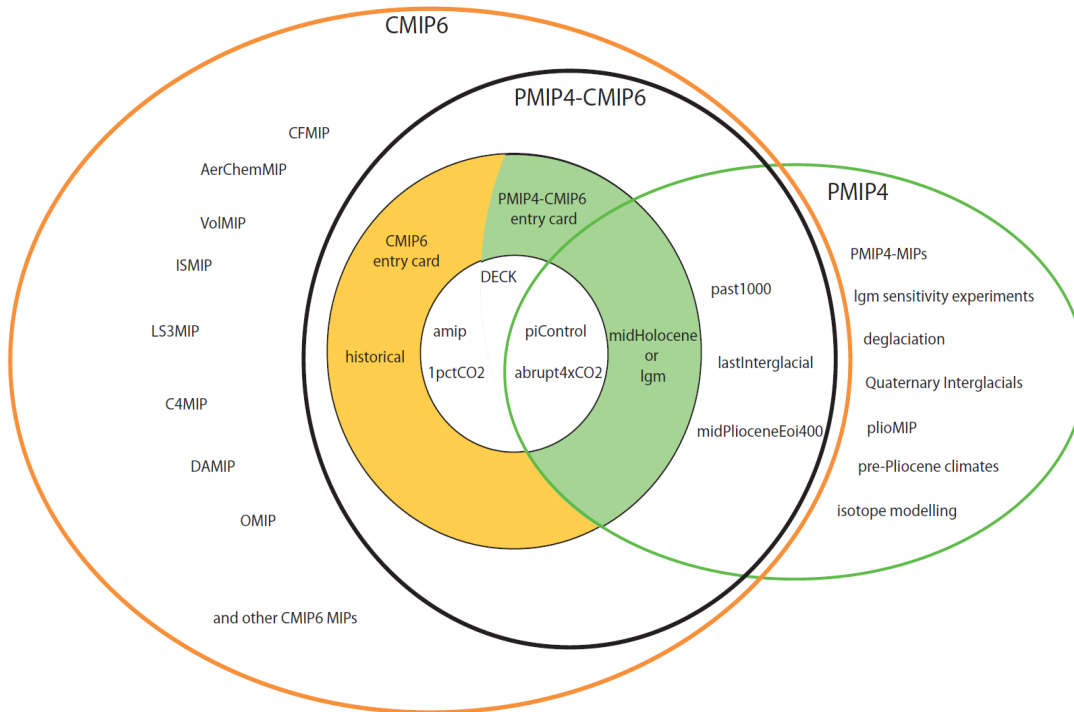
- High CO₂ (450ppm)
- Low CO₂ (350ppm)
- High NH Summer Orbit (3.037Ma)
- Low NH Summer Orbit (3.049Ma)
- High NH Annual Orbit (3.159Ma)

Feng, R. et al., *EPSL*, 466, 2017: Amplified Late Pliocene terrestrial warmth in northern high latitudes from greater radiative forcing and closed Arctic Ocean gateways.

All Sensitivity simulations run 200+ years from PlioMIP1



PMIP4-CMIP6 Experiments



Tier 1 experiments are within PMIP4-CMIP6

Tier 2 & 3 experiments are within PMIP4

For PMIP4-CMIP6:

Mandatory to perform:

- the CMIP6 DECK
- the CMIP6 entry card (i.e. historical simulation)
- one of the PMIP4-CMIP6 entry cards: lgm or mid-Holocene

For PMIP4:

Mandatory to perform:

- the CMIP6 piControl and abrupt4xCO2 runs
- one of the PMIP4-CMIP6 entry cards: lgm or midHolocene

Plans for PMIP4-CMIP6 with CESM2

NCAR Paleo CMIP6/PMIP4 builds off of

- CESM2 Deck Experiments (piControl, abrupt4xCO2)

NCAR-Paleo runs both PMIP4 Entry Cards:

- midHolocene
- lgm (last glacial maximum)

- Plus Tier 1 Simulations:
 - past1000 + historical
 - lig127 (last interglacial @127ka)
 - midPliocene-eo400 (for PlioMIP2 with R. Feng at UConn)

- Some Tier 2 & 3 simulations
 - Additional PlioMIP2 (E400 & Eo400) for linear factorization

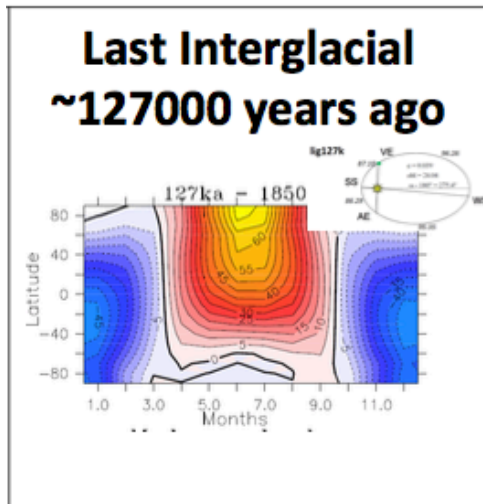
- Same Model Configuration and Resolution as CESM2 DECK (~1 degree & OBGC)

- Single variable timeseries output on Earth System Grid

lig127k & midHolocene

Goal: Explore climate model response to orbital and ghg and compare to paleoclimate and paleoenvironmental data

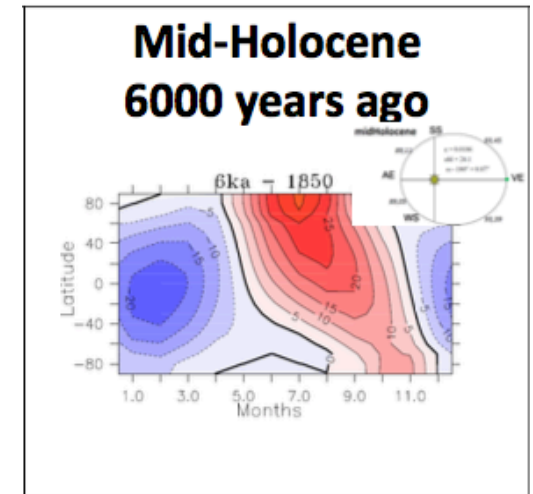
➤ midHolocene: PMIP4 entry card



Changes to orbital parameters

Different GHG concentrations

Ice sheets as modern



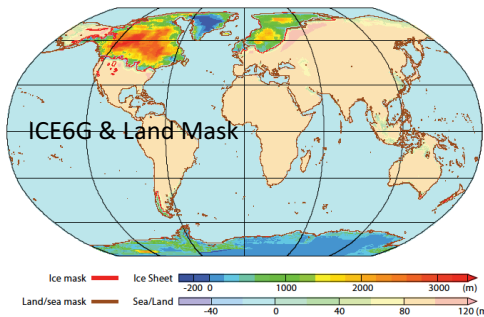
Tier2 Opportunities for collaborators: midHolocene-veg, lig127k-veg, lig127-ais, lig127k-gris, various meltwater events (8.5ka, H11) & Tier3: transient: past6k, lig127to121k

Otto-Bliesner et al. GMD, 10, 3979-4003, 2017.

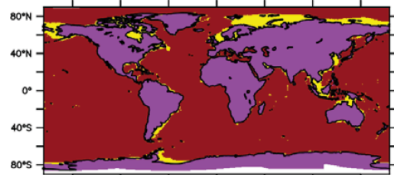
<https://www.geosci-model-dev.net/10/3979/2017/>

Last Glacial Maximum, LGM

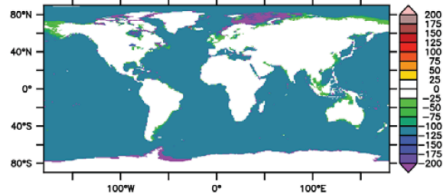
PMIP4 Entry Card



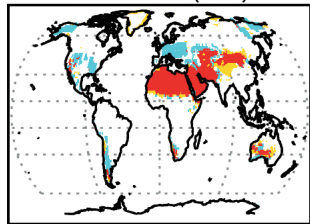
a) modern and LGM ocean masks



b) LGM – modern bathymetry



o. Dust sources (Albani)



- PI
- PI & LGM
- LGM

Large, negative radiative Forcing Conditions for 21,000 years ago.

- Ice sheet, land mask and bathymetry:
ICE-6G_C, PMIP3, GLAC-1D
- Prescribed Lowered GHG's, orbital parameters for 21ka
- Dust: interactive with LGM soil erodibility map available from PMIP
- Active Ocean Ecosystem, consistent with DECK, & biotic carbon isotope tracers

Tier 2: LGM-PI-ghg, LGM-PI-ice, LGM-PI-ghg_ice, could be done by collaborators

PMIP4 Pliocene: PlioMIP2

Goal: Earth System response to long-term CO₂ forcing analogous to modern with higher sea level, smaller ice sheets, altered Land-surface. Past as key to future...

New Boundary conditions: Eoi400

- Focus: Time slice: 3.205Ma– Near Modern Orbit
- PRISM4 expanding collection effort
- New Paleographic Reconstructions (Eoi400)
 - ocean bathymetry, Land&Ice topo, soils&lake data
 - 400ppm CO₂

NCAR (lead: Ran Feng UConn) to do CORE
(piControl: E280 + Eoi400)
and E400 & Eo400 to enable Linear Factorization

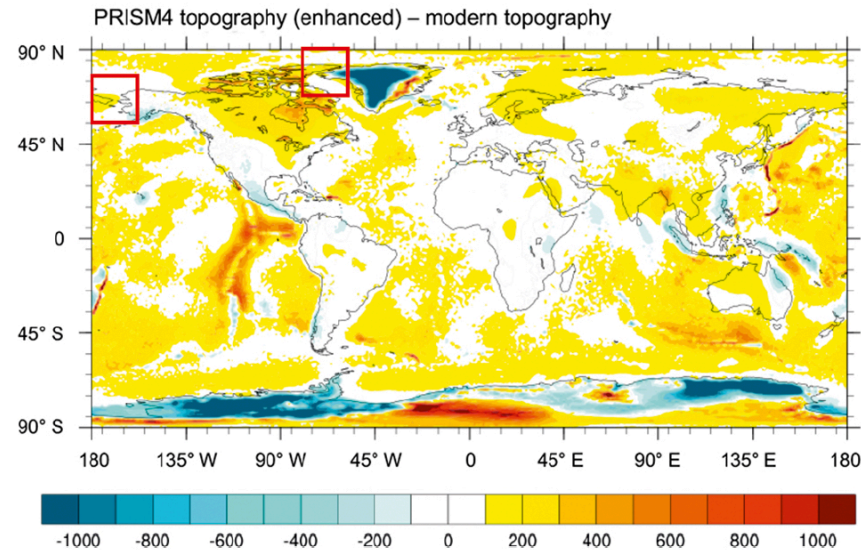
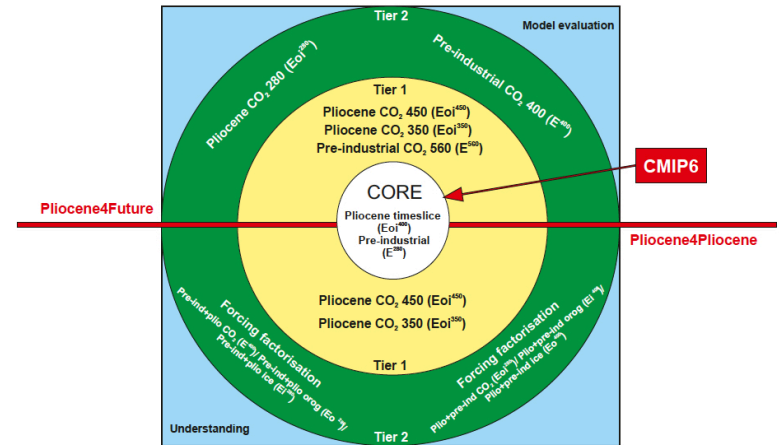
$$dT(\text{CO}_2) = E400 - E280$$

$$dT(\text{orog}) = Eo400 - E400$$

$$dT(\text{ice}) = Eoi400 - Eo400$$

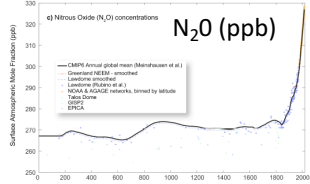
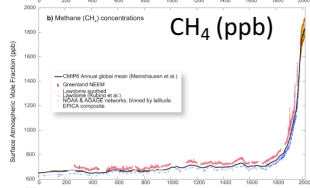
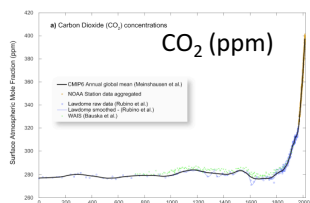
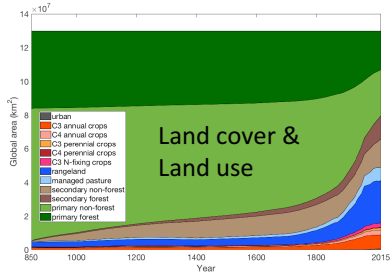
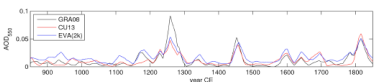
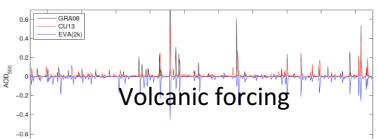
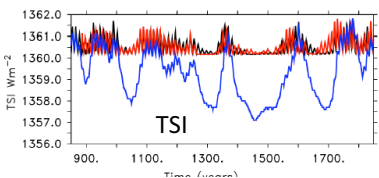
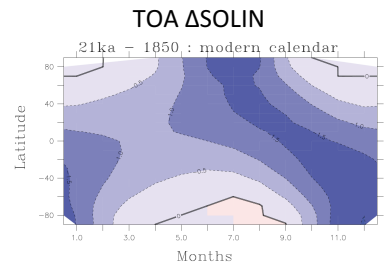
Tier2: E560, Eo280, Ei280, Ei400, Eoi450, Eoi350
could be done by others in collaboration

Haywood et al. CP12, 663-675, 2016
<https://www.clim-past.net/12/663/2016/>



Last Millennium (past1000 + historical)

Goal: Investigate response to Natural forcing in context of Modern background climate and its internal variability



- Same CESM2 config & resolution as DECK w/OBGC
- Transient: 850 to 1849 & 1850 to 2015 CE
- Forcing (should be seamless with CMIP6):
 - GHG's
 - Volcanic aerosols*
 - Solar variations
 - Land cover & use
 - Orbital
- Create an 850CE control for I.C.'s
 - Extend control through 2015 to have estimate of model drift in LM simulation

*Need to run 2° WACCM with new Volcanic emissions first!

Jungclaus et al. GMD 10, 4005-4033, 2017.

<https://www.geosci-model-dev.net/10/4005/2017/>

CMIP6/PMIP4 Papers & web links

- Overview *Kageyama et al GMD 2016*
<https://www.geosci-model-dev-discuss.net/gmd-2016-106/>
- Last Millennium *Jungclaus et al., GMD 10, 4005-4033, 2017*
<https://www.geosci-model-dev.net/10/4005/2017/>
- Interglacials *Otto-Bliesner et al. GMD, 10, 3979-4003, 2017.*
<https://www.geosci-model-dev.net/10/3979/2017/>
- LGM *Kageyama et al GMD 10, 4035-4055, 2017*
<https://www.geosci-model-dev.net/10/4035/2017/>
- Mid- Pliocene *Haywood et al. CP12, 663-675, 2016*
<https://www.clim-past.net/12/663/2016/>

PMIP4 index page:

<https://pmip4.lsce.ipsl.fr/doku.php/index>

First steps with CESM2.0

Half-CO₂ Simulation (R. Tomas)

Goals: Evaluate climate sensitivity to reduced CO₂ and the response of sea ice to colder climate state

CESM1.2 Half-CO₂ ->> $\Delta T = -4.8\text{K}$, $\Delta \text{RESTOM} = -0.36 \text{ W/m}^2$ ~1000 years

→ ECS_{2x} (estimated) ~ 5.3K > ECS_{2x} (CESM2) ~ 4K

May show greater sensitivity to reducing GHGs

Isotope-enabled CESM2

- CAM6 --- J. Nusbaumer, D. Noone, A. Gettelmann
- CLM6 --- B. Andre, D. Noone, J. Tang, W. Riley, A. Wong
- POP2 --- J. Zhang, E. Brady, J. Zhu
- CICE5 --- D. Bailey, J. Zhu
- MOSART --- H. Li, B. Andre
- CPL --- M. Vertenstein

- SEs: C. Craig, B. Andre, M. Vertenstein

- To Be Released as "CESM2.1"

Timeline for iCESM2

CESM1.2&1.3

CAM5.3
Nusbaumer et al. 2017

CLM4.0
Wong et al. 2017

CICE4
Isotope enabled in 'tag'
version

POP2
Water isotopes in
development tag,
Carbon in Trunk

RTM
Implementation in
development tag

Current Status

CAM6
Poster: Nusbaumer et al.
2017

CLM5
In Development

CICE5
Implemented,
On trunk

POP2
Testing/Evaluation,
added to trunk

MOSART
Implemented, to be
tested

CESM 2.1

CAM6

CLM5
Isotopes added

CICE5

POP2
EBM tested

MOSART

Thank You