NCAR UCAR

Update on Water Isotope-enabled CESM

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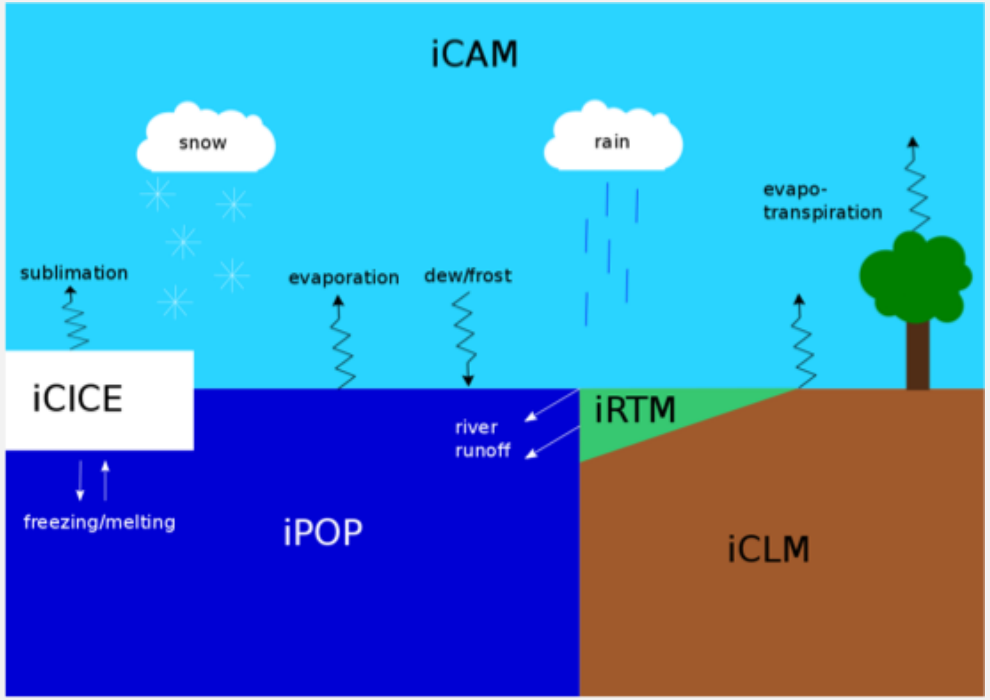
CGD

Water isotopes in CESM



iCESM1.2&1.3

iCAM5.3
Nusbaumer et al. 2017

iCLM4.0
Wong et al. 2017

iCICE4
Isotope enabled in ‘tag’ version

iPOP2
Water isotopes in development tag, Carbon in Trunk

iRTM
Implementation in development tag

FV 1.9x2.5: iCAM, iCLM
Gx1v6: iPOP, iCICE

Last Glacial Maximum (21 ka)
iTrace (19 ka -> 11 ka)

Eocene (~53 – 51 Ma)
Late Paleozoic (~300 Ma)

Last Millennium (850AD-2005AD)
(Solar, Orbital, GHG, Volcanic Aerosols, LULC)

Simulated $\delta^{18}O_{precip}$ vs GNIP Obs.

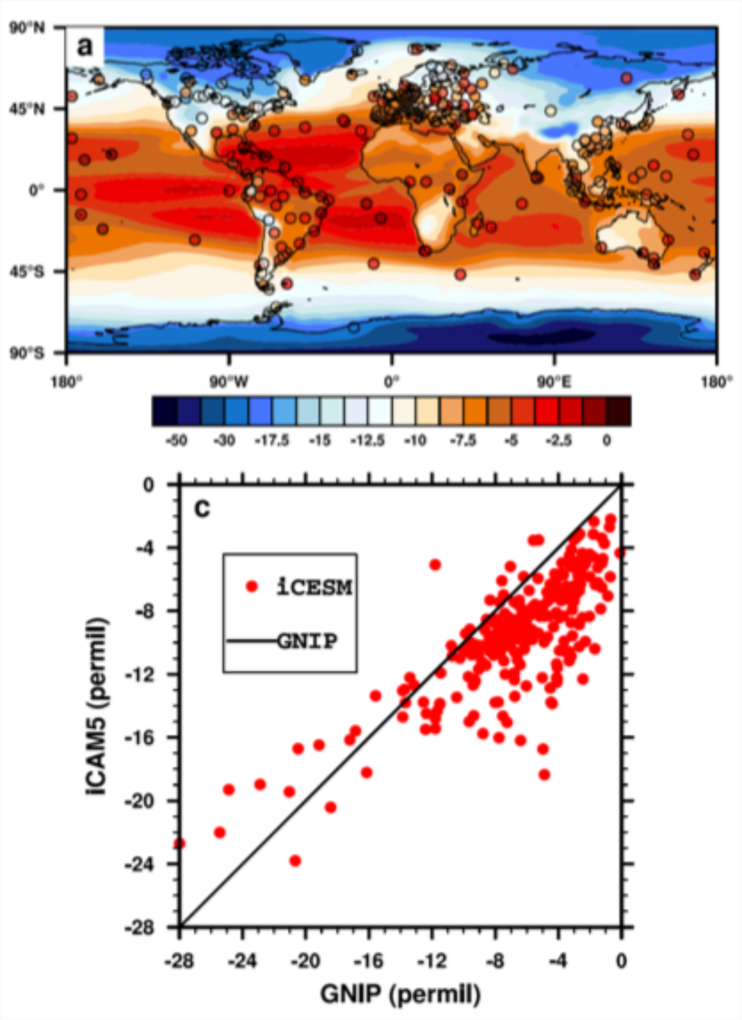
<u>Results: 20th Century portion (1950-2005AD)</u>

iCESM captures the isotopic signal observed in Precipitation:

Low in Polar Regions and Interior of large continents due to "rainout"

Higher in regions where E > (P+r) ~subtropics

ITCZ – Local Minima (amount effect)



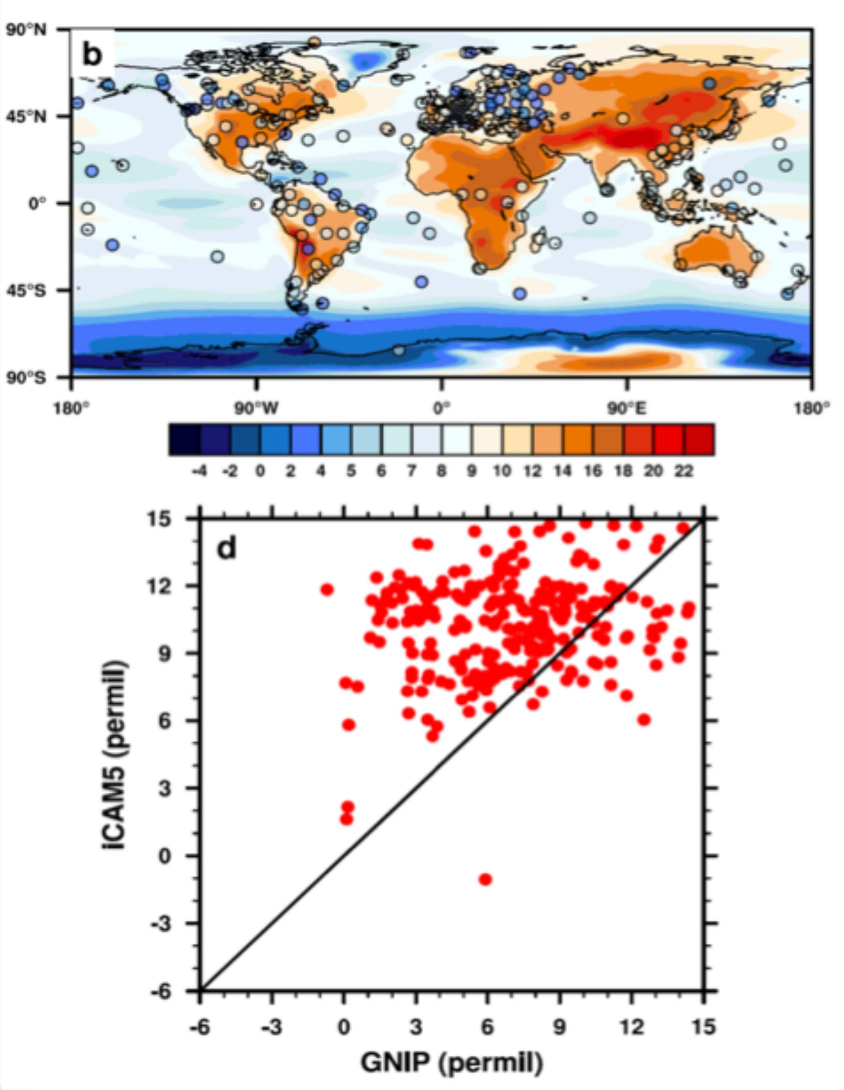
GNIP= Global **N**etwork of **I**sotopes in **P**recipitation (www.IAEA.org)

See Nusbaumer et al. [2017] for iCAM details

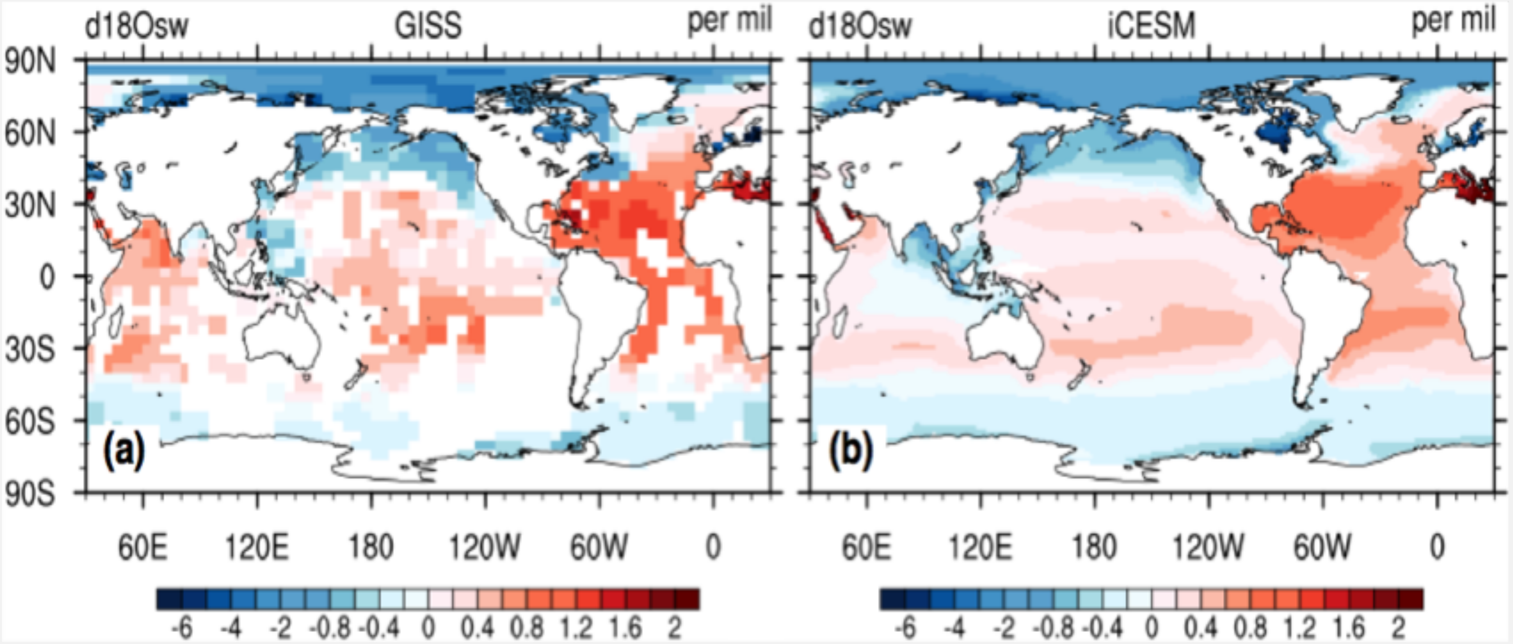
iCESM Deuterium-Excess (d) vs GNIP Obs.

$d = \delta D - 8^* \delta^{18}O$ (second order effect)

- iCESM d shows less correlation with the GNIP and too large a mean bias
- Coupled d and d18Op biases are similar to that found in uncoupled iCAM+iCLM results (Nusbaumer et al. JAMES[2017]; and Wong et al. JAMES[2017])
- implying the biases are a product of CAM and CLM components alone



Model Surface δ^{18}Ow Compared to Data



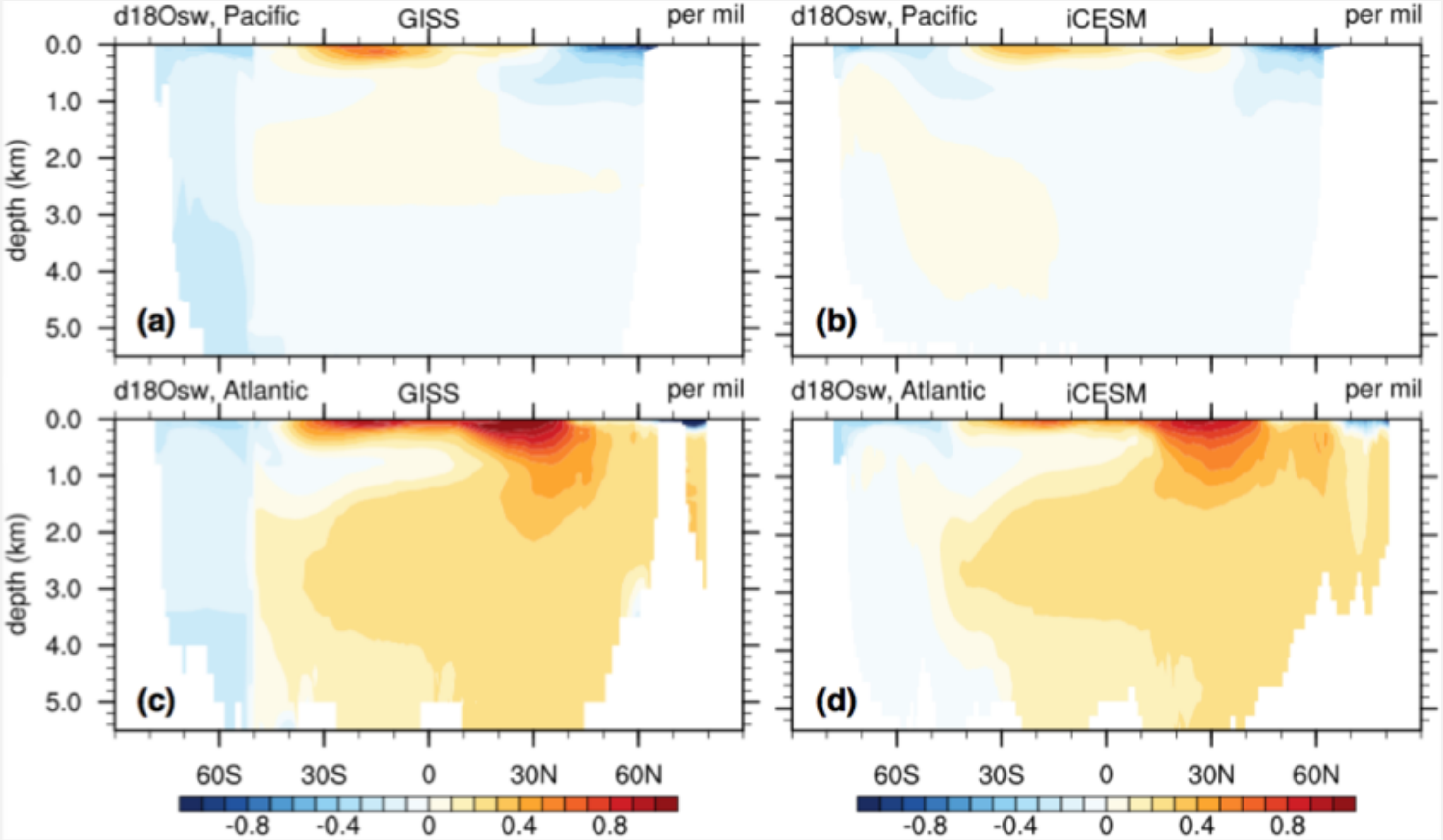
iCESM captures the overall features in the observations.

- relatively enriched water (~0.5–1 ‰) in the subtropics (E>P+r),
- depleted water (<–1‰) in the Arctic,
- inter-basin contrast between the Atlantic and Pacific Ocean.

NASA-GISS
Global Seawater d^{18}O Database
(LeGrande and Schmidt, 2006)
http://data.giss.nasa.gov/o18data/

- Along the ITCZ, high precipitation totals give rise to locally low d18O values
- Overall negative bias in seawater δ^{18}O is consistent with the fresh bias in surface salinity

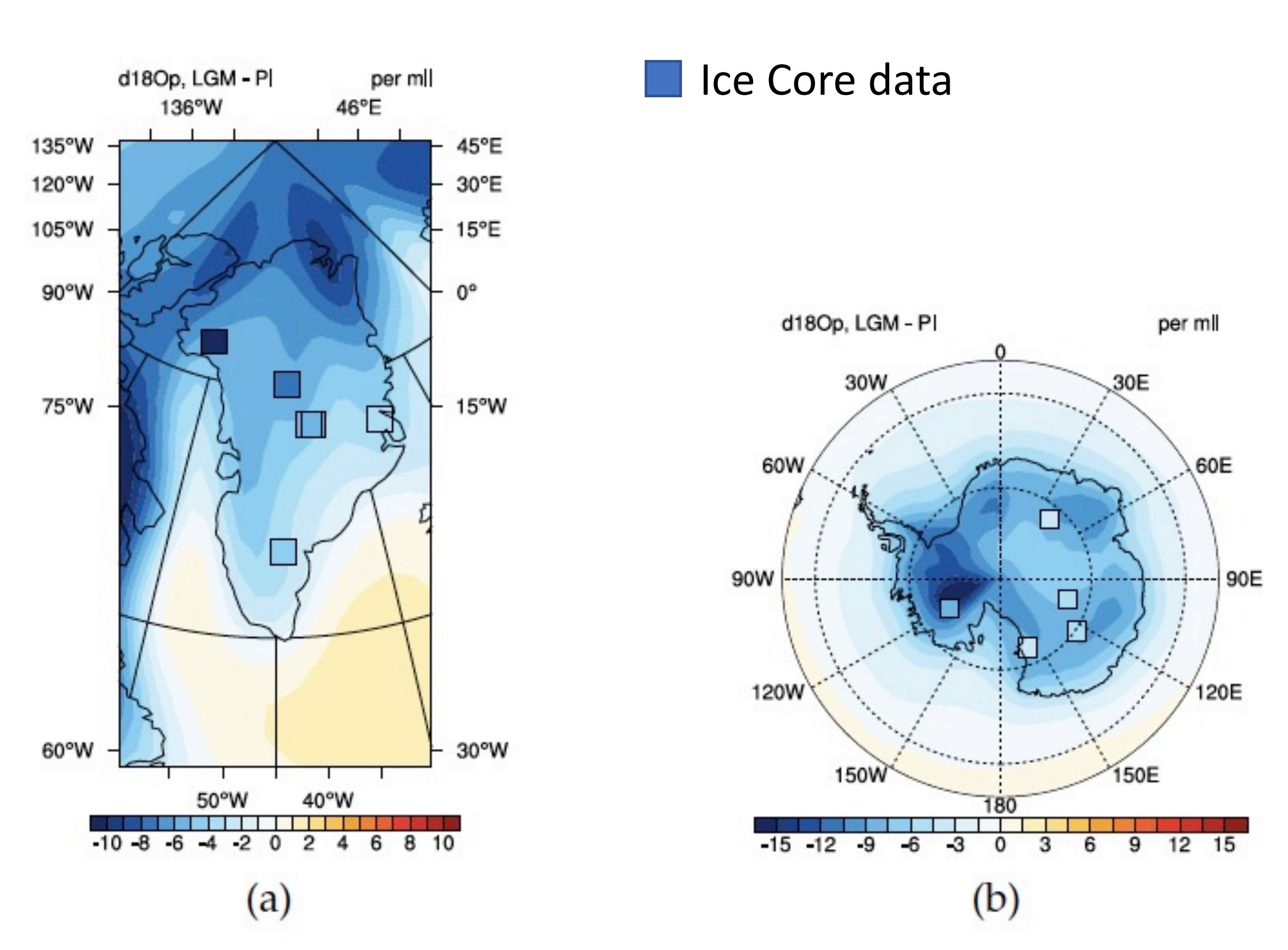
Zonal mean $\delta^{18}O_w$ vs Observations



iCESM reproduces the $\delta^{18}O$ signature of major water masses:

- Enriched North Atlantic Deep Water of ~0.2–0.4 ‰
- Depleted Antarctic Bottom Water and Antarctic Intermediate Water

Paleo Perspectives: LGM – PI $\delta^{18}O_{precip}$ vs. Ice Core Data

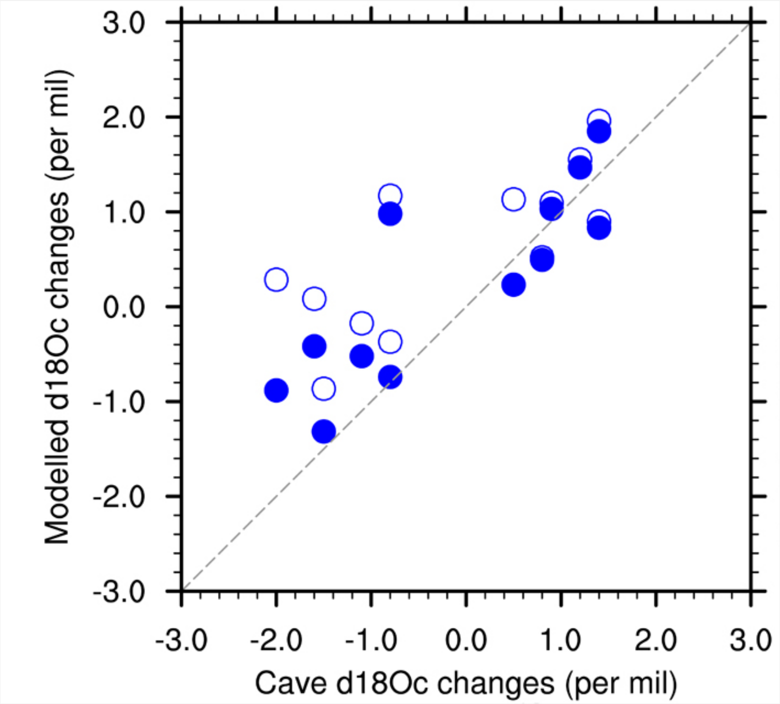


In Greenland, the greater depletion in $d^{18}Op$ towards the northwest from the Dye 3 and Renland to the Camp Century is well-simulated in iCESM.

In Antarctic, the model simulates the east–west contrast in $d^{18}Op$, but the model values are generally too depleted.

Courtesy, J. Zhu, 2017

Paleo Perspectives: Response during Heinrich Stadials



Magnitude and spatial features of proxy-reconstructed speleothem $\delta^{18}O$ changes during Heinrich events can be well-reproduced using idealized water hosing experiments in iCESM, i.e., injecting isotopically depleted and fresh meltwater into the northern North Atlantic as shown in Zhu et al. GRL (2017).

$\delta^{18}O$ signals in speleothems during Heinrich events have long been used to infer changes in monsoon intensities.

But, Zhu et al. (2017) show sensitivity experiments, suggest that a large portion of the $\delta^{18}O$ variations (e.g., 15–35% over eastern Brazil) can be directly related to the direct meltwater effect from the depleted meltwater, instead of changes in monsoon intensities.

Modeling of isotopic signals is critical for understanding the recorded oxygen isotope signal in paleoclimate archives.

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

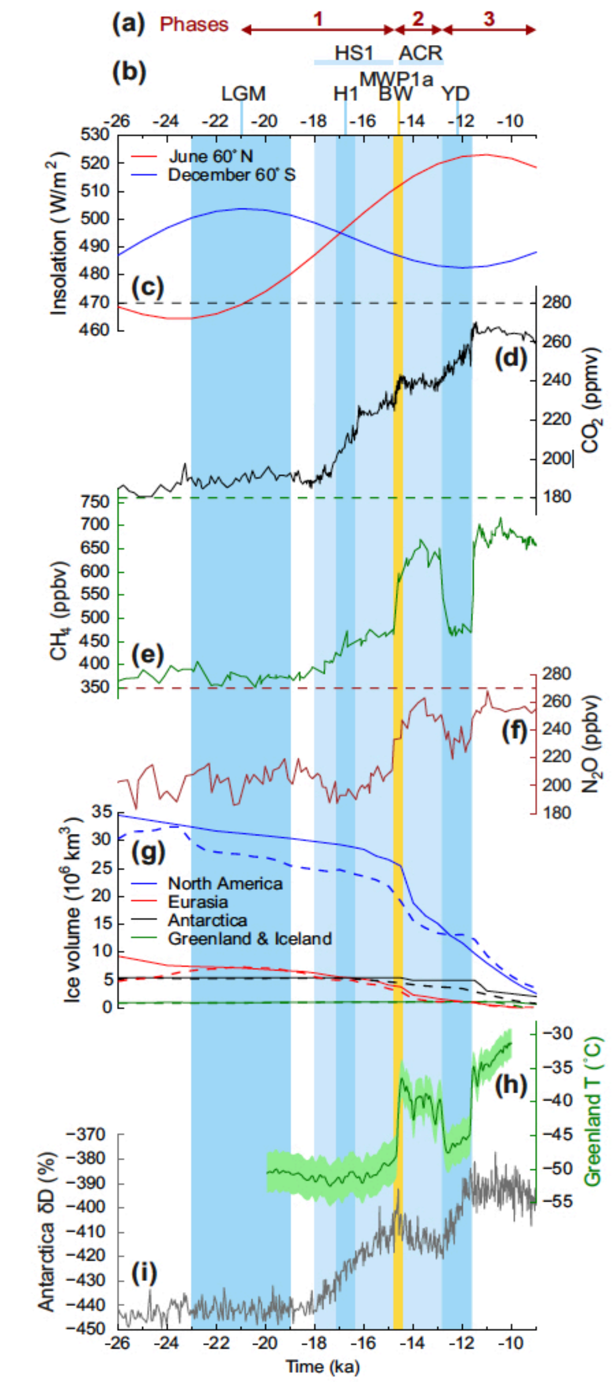
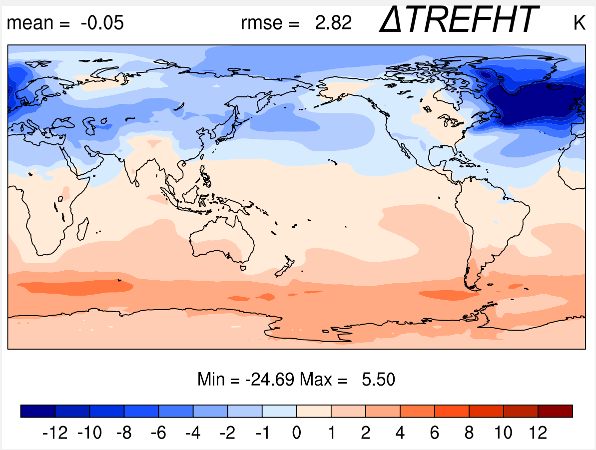
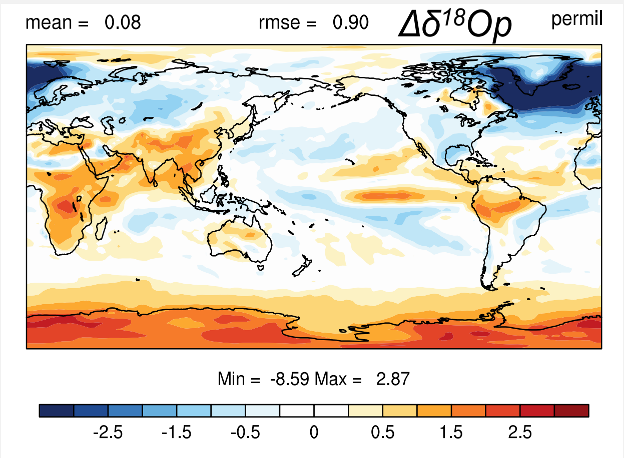


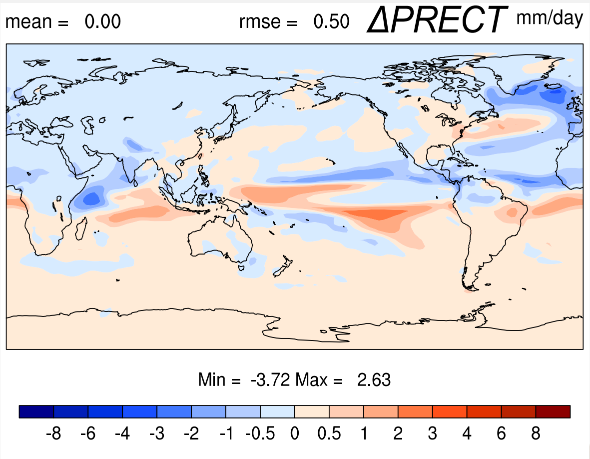
Fig. from Ivanovic et al. GMD, 2016.

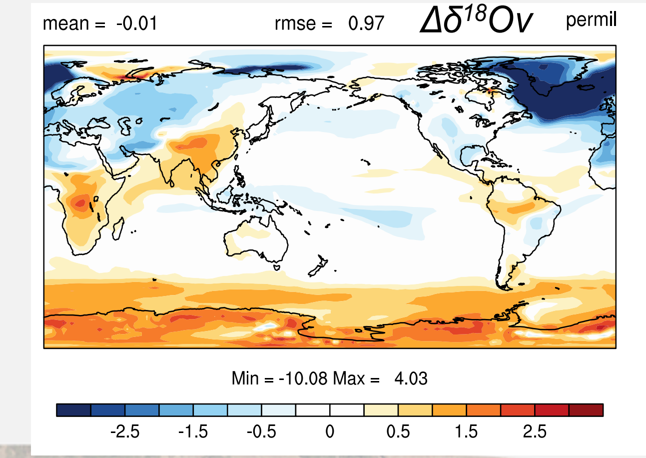
Effect of Meltwater forcing at 17ka

ICE+GHG+ORB+MWF1 – ICE+GHG+ORB









- NH Cooling/SH warming (bipolar seesaw) exhibited in δ^{18}Op consistent with "temperature effect"
- Southward shift in ITCZ shown in δ^{18}Op 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 δ^{18}Ovapor.

Timeline for iCESM2

CESM1.2&1.3	Current Status	CESM 2.3
CAM5.3 Nusbaumer et al. 2017	**CAM6** In development Nusbaumer et al. 2017	**CAM6**
CLM4.0 Wong et al. 2017	**CLM5** In Development	**CLM5** Isotopes added
CICE4 Isotope enabled in 'tag' version	**CICE5** Implemented, On trunk	**CICE5**
POP2 Water isotopes in development tag, Carbon in Trunk	**POP2** To be Tested, added to trunk	**POP2** EBM tested
RTM Implementation in development tag	**MOSART** Implemented, to be tested	**MOSART**

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Summary

When evaluated against isotopic observations, iCESM is shown to capture the broad qualitative features of precipitation isotopic patterns, albeit with a low bias in $\delta^{18}O$ values of precipitation.

iCESM well captures the large-scale structure of seawater $\delta^{18}O$, including subtropical enrichment, Arctic depletion, and interbasin contrasts between the Atlantic and Pacific;

The isotopic signatures of major water masses are also well captured by iCESM, although the tropical/subtropical upper ocean appears to be depleted relative to observations.

Interpretation of isotopic measurements from the calcium carbonate of speleothems and ice cores is one useful application of the coupled iCESM (Liu et al., 2014b; Tabor et al., 2018). The combination of iCESM with forward proxy models can provide valuable insights into how seasonal and annual isotopic variability translate into the paleoclimate records.

The availability of iCESM will enable investigation of a variety of modern and paleoclimate questions.

Thank you