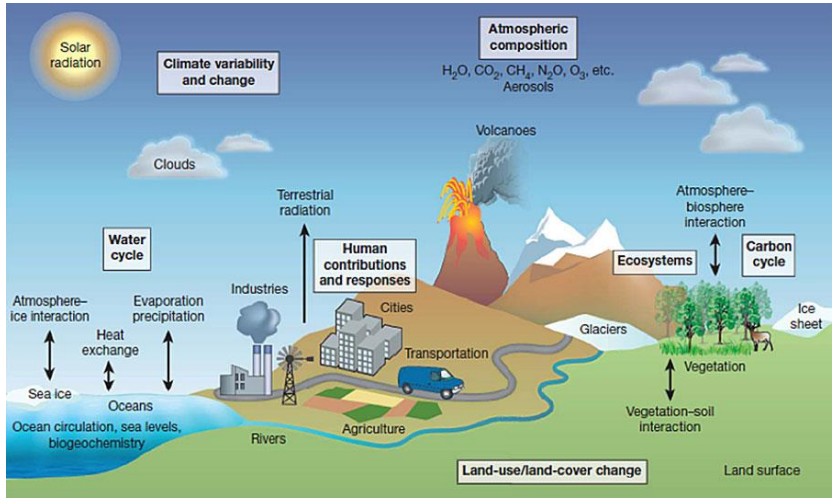
Water Isotope Modeling

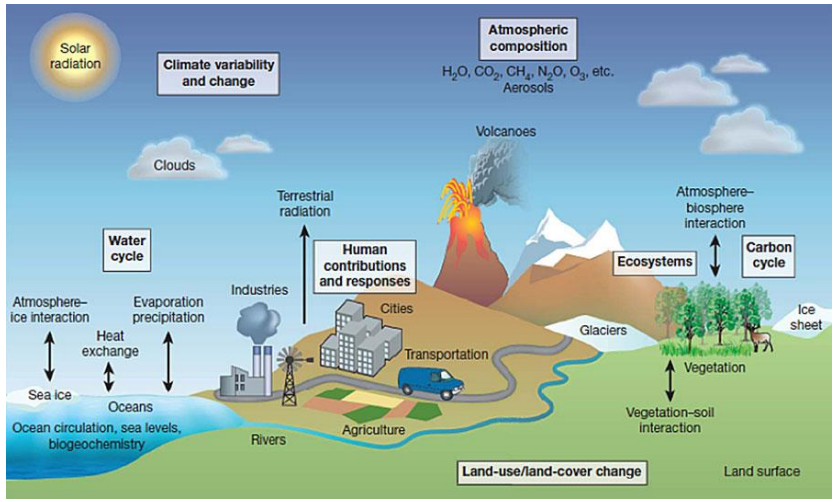
Why isotope-enabled models?

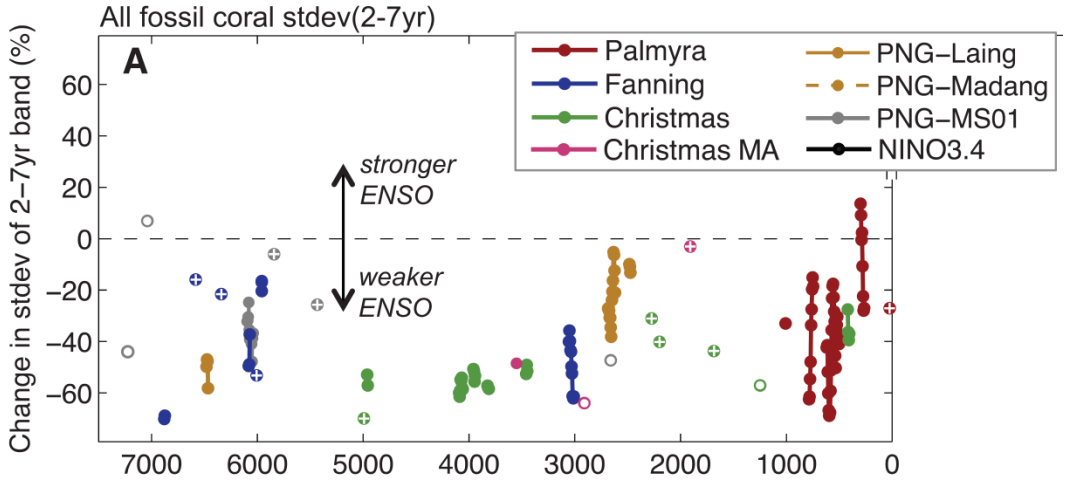
- Water isotopes can be used to identify, constrain, and improve issues in climate model physics, chemistry and biology.



Why isotope-enabled models?

- Water isotopes can be used to identify, constrain, and improve issues in climate model physics, chemistry and biology.
- Isotope-enabled models are useful tools for the interpretation of paleoclimate records.





Cobb et al. (2013)

SWING2

Table 1. Model Name, Key Reference, Resolution, and Simulations Considered in This Publication

Model	Key Reference	Simulations	Grid Resolution
CAM2	*Lee et al.* [2007]	Free	2.8° ×2.8°
ECHAM4	*Hoffmann et al.* [1998]	Nudged with ECMWF	2.8° ×2.8°
MIROC	*Kurita et al.* [2011]	Free	2.8° ×2.8°
GENESIS3	*Mathieu et al.* [2002]	Free	3.75° ×3.75°
LMDZ4	*Risi et al.* [2010]	Free and nudged with ECMWF	2.5° ×3.75°
GISS	*Schmidt et al.* [2007]	Free and nudged with NCEP	2° ×2.5°
GSM	*Yoshimura et al.* [2008]	Free and nudged with NCEP	1.9° ×1.9°
HadAM3	*Sime et al.* [2009]	Free	2.5° ×3.75°
HadCM3	*Tindall et al.* [2009]	Free (no SST forcing)	2.5° ×3.75°

From Conroy et al., 2013

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CAM5 [Nusbaumer et al., 2017]

ECHAM5 [Werner et al., 2011]

ModelE2.1 [Field et al., 2014]

GSM2 [Prasanna et al., 2018]

From Conroy et al., 2013

Multiple models have advanced since SWING2, indicating that an update to SWING may be needed.

Fully-coupled models

- “Fully-coupled” climate models are those that simulate all components of the climate system, specifically the atmosphere, ocean, land-surface, and sea ice (and occasionally land ice).

- Fully-coupled models are necessary for paleoclimate simulations.

- Over the past several years there has been a rapid increase in the number of isotope-enabled GCMs that are fully-coupled.

Fully-coupled models

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- GISS ModelE2.1 [e.g. Field et al., 2014]

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- GISS ModelE2.1 [e.g. Field et al., 2014]
- MPI-ESM (with ECHAM5) [Werner et al., 2016]
- CESM1 [Brady et al., 2019]

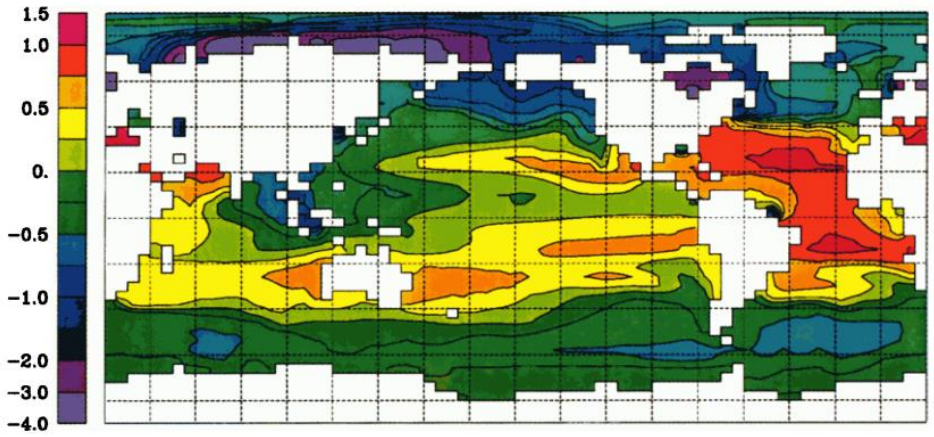
Additional models being worked on include:

  - IPSL
  - EC-Earth
  - GFDL

Isotope-enabled Ocean Models

Papers describing isotope-enabled ocean models:

- GISS (Russell) ocean model [Schmidt, 1999]
- MPI-OM [Xu et al., 2012]
- POP2 [Zhang et al., 2017]



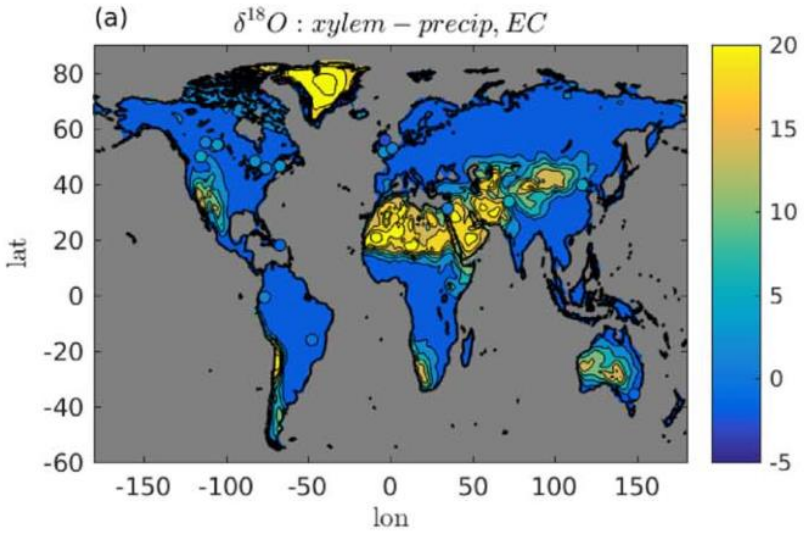
From Schmidt, 1999

Other ocean models include:

- HadCM3 ocean model [Tindall et al., 2009]
- NEMO [not sure if published yet?]

Land Surface models

- GISS LSM [Aleinov and Schmidt, 2006]
- MATSIRO [Yoshimura et al., 2006]
- HadCM3 LSM [Tindall et al., 2009]
- JS-BACH [Haese et al., 2013]
- ORCHIDEE [Risi et al., 2017]
- CLM4 [Wong et al., 2017]



From Wong et al., 2017

Several other isotope-enabled LSMs not (to my knowledge) associated with GCMs also exist, which are not listed here.

Expanded model capabilities

Additional model capabilities/advancements include:

- Single-column models (SCMs) [Bony et al., 2008; Risi et al., 2008].

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- Single-column models (SCMs) [Bony et al., 2008; Risi et al., 2008].
- High-top models [Eichinger et al.,2015]
- Water-tagging [Werner et al., 2001; Risi et al., 2010b; Lewis et al., 2010; Buenning et al., 2013; Nusbaumer and Noone, 2018]

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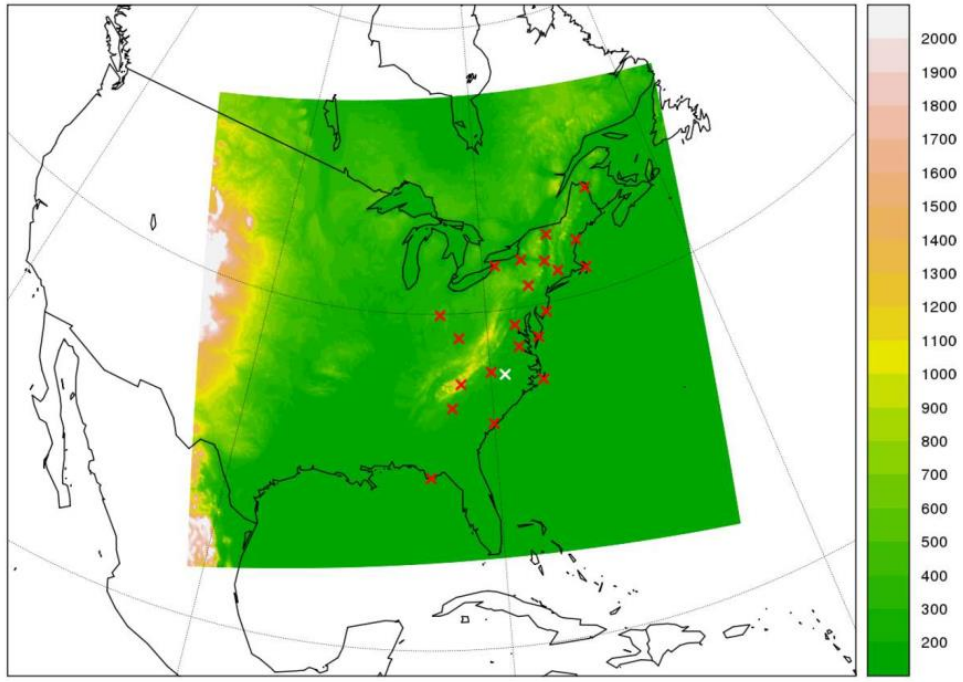
- They can be used to (dynamically) down-scale GCM results to a particular site location, including paleoclimate proxy sites.
- There is the potential to involve water isotopes in weather forecasting.

Weather/Regional Climate models

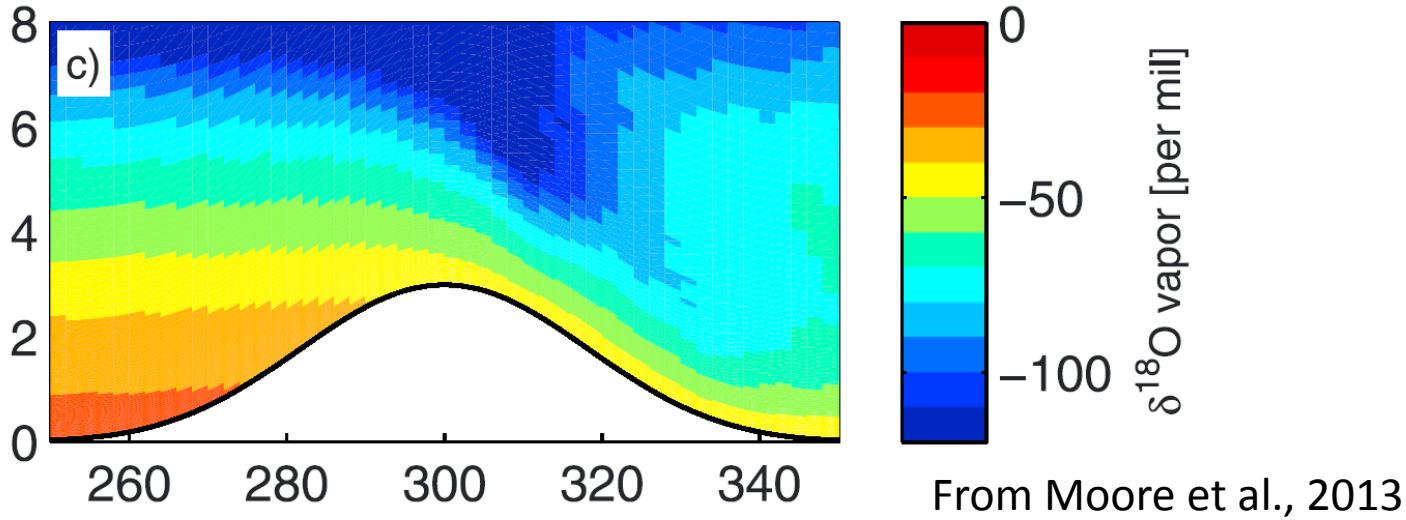
- REMOiso [Sturm et al., 2005]
- COSMOiso [Pfahl et al., 2012]
- IsoRSM [Yoshimura et al., 2010]



From Pfahl et al., 2012

Cloud-resolving models

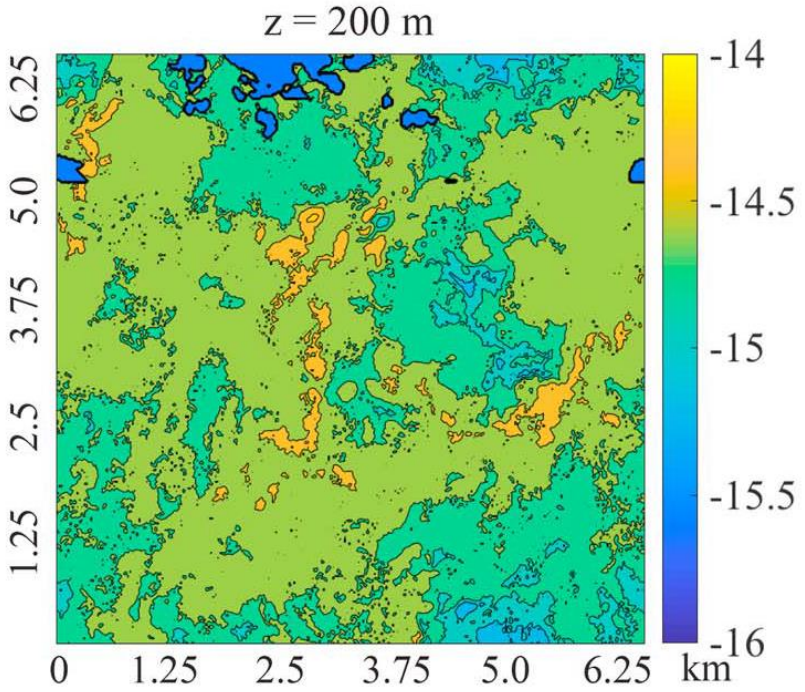
- REMOiso [Sturm et al., 2005]
- COSMOiso [Pfahl et al., 2012]
- IsoRSM [Yoshimura et al., 2010]
- Isotope-enabled SAM [Blossey et al., 2010]
- Isotope-enabled WRF [Moore et al., 2013]



From Moore et al., 2013

Large Eddy Simulation models

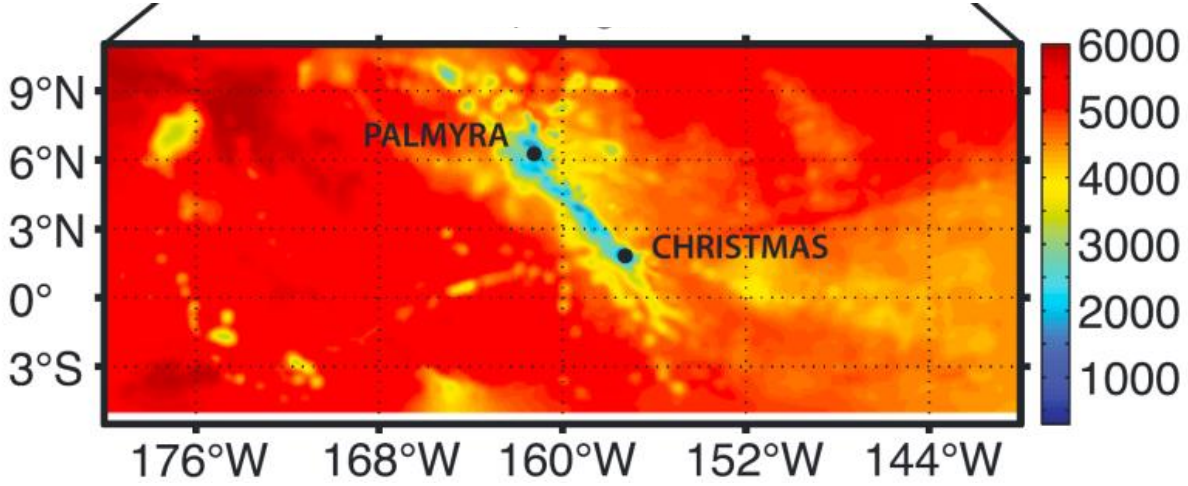
- REMOiso [Sturm et al., 2005]
- COSMOiso [Pfahl et al., 2012]
- IsoRSM [Yoshimura et al., 2010]
- Isotope-enabled SAM [Blossey et al., 2010]
- Isotope-enabled WRF [Moore et al., 2013]
- DHARMA [Smith et al., 2006]
- ISOLESC [Wei et al., 2019]



From Wei et al., 2019

Mesoscale Ocean models

- REMOiso [Sturm et al., 2005]
- COSMOiso [Pfahl et al., 2012]
- IsoRSM [Yoshimura et al., 2010]
- Isotope-enabled SAM [Blossey et al., 2010]
- Isotope-enabled WRF [Moore et al., 2013]
- DHARMA [Smith et al., 2006]
- ISOLES [Lee et al., 2012]
- isoROMS [Stevenson et al., 2015]



Future High-res models

- REMOiso [Sturm et al., 2005]
- COSMOiso [Pfahl et al., 2012]
- IsoRSM [Yoshimura et al., 2010]
- Isotope-enabled SAM [Blossey et al., 2010]
- Isotope-enabled WRF [Moore et al., 2013]
- DHARMA [Smith et al., 2006]
- ISOLES [Lee et al., 2012]
- isoROMS [Stevenson et al., 2015]
- Others in development (SP-CAM,NICAM,etc.)

General Issues

- Isotope-enabled models are almost always behind the regular model in terms of physics improvements/updates, or on their own “branch” such that it doesn’t always represent the latest version of the regular model.

- The modern isotopic records we currently have are not ideal for model development/validation (too sparse, too short, certain quantities not usually observed).

- The perception of water isotopes outside the geochem and paleo communities as too niche (i.e. why should we invest in isotopes when we can instead invest in <insert other model feature here>)?

Thanks for listening!

Questions?