Beyond iCESM1

The Latest Model Developments and Roadblocks for Improving Water Isotope Simulations at NCAR

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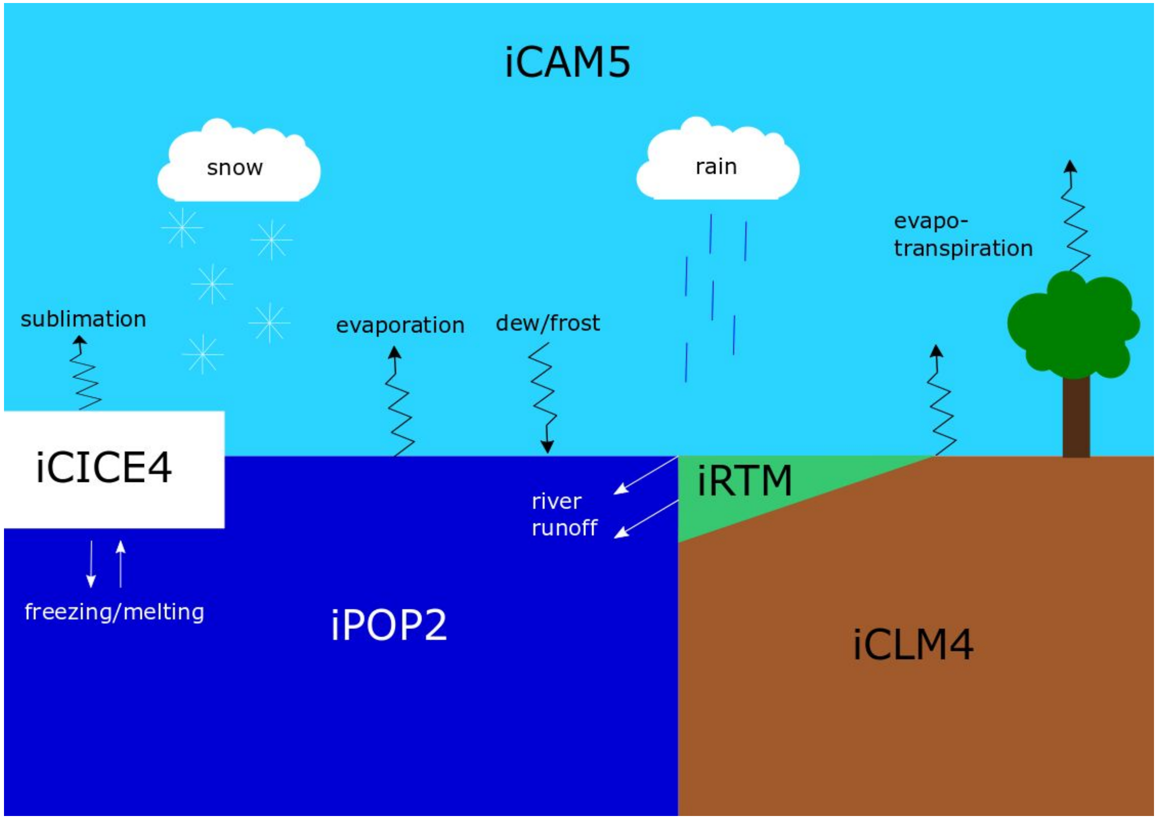
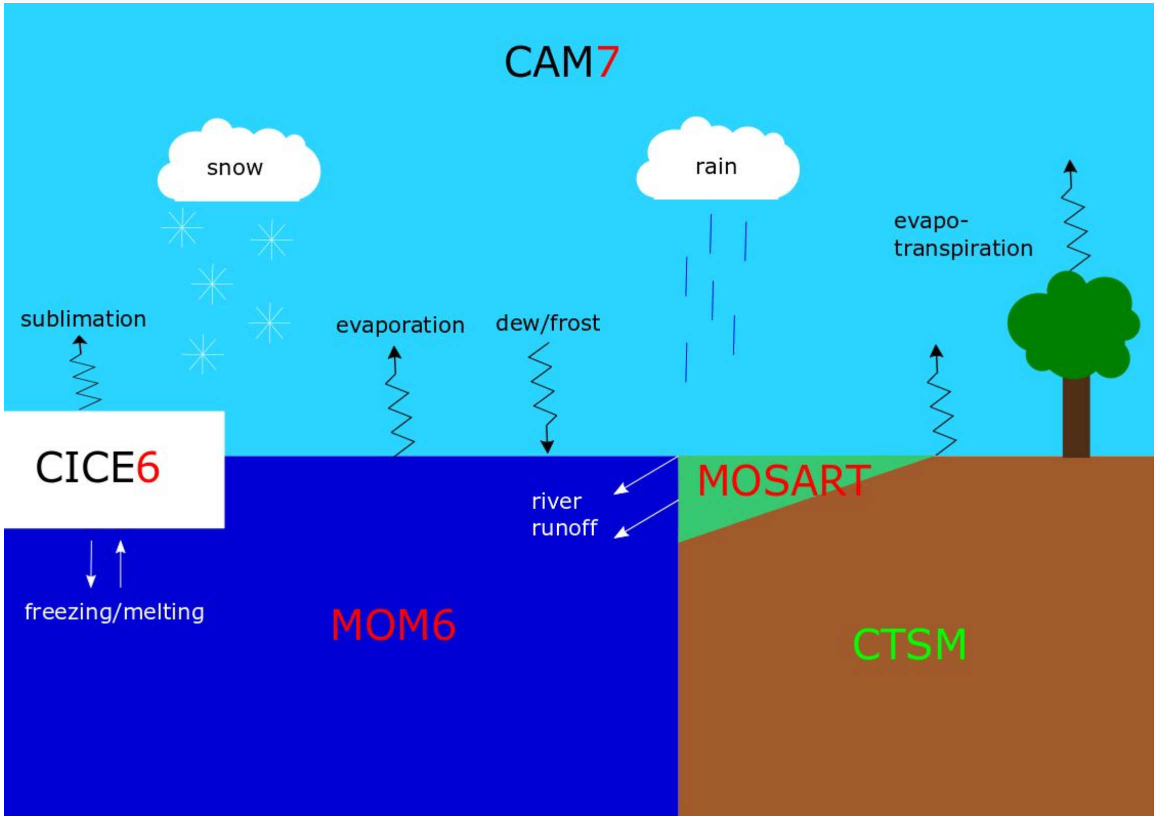
iCESM1.2



From Brady et al., 2019

iCESM1.2 is the current “officially-released” version of water isotope-enabled CESM, although a slightly-different, iCESM1.3 version may eventually become the new “official” version.. Still, these are the only model versions we have that contain a fully-coupled isotopic system.

CESM3



Model development at NCAR is currently focusing on CESM3, which has components that are several versions ahead of CESM1.2, as well as a new ice sheet component (CISM, not shown).

What is iCESM1.2 missing?

- New model features (MARBL, FATES, physics nudging, etc.)
- New dycores and grids (SE, MPAS, etc.)
- New default boundary conditions and forcing datasets (more relevant for modern validation)
- Better model physics and bug fixes
- Currently no plan to port to the new NCAR machine (Derecho)

Isotope-enabled CAM6

- Updated microphysics (MG1 -> MG2), which includes prognostic precipitation.

- Updated PBL/shallow convection scheme (UW -> CLUBB).

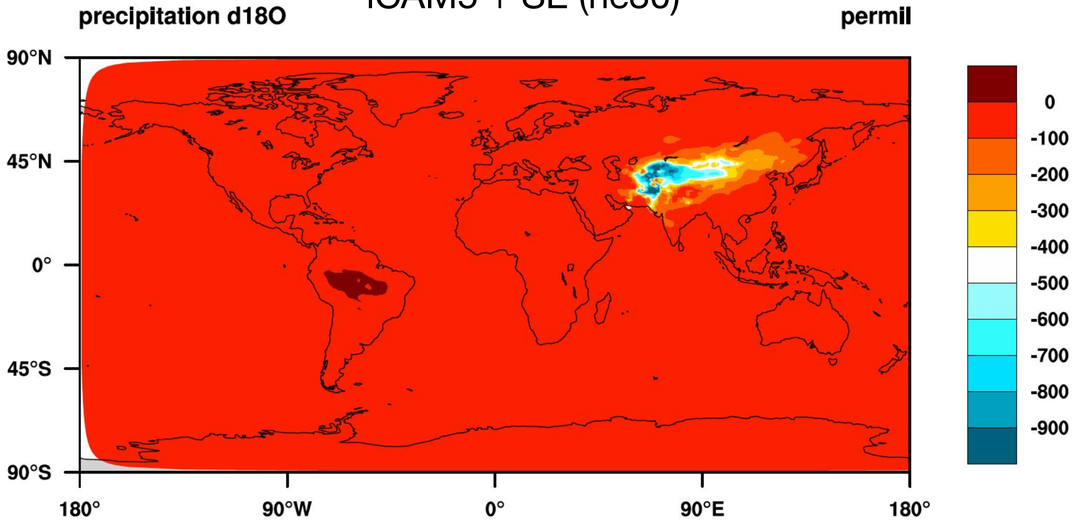
- Can use the SE-CSLAM dycore configuration.

- More accurate default aerosol physics/chemistry (MAM3 -> MAM4).

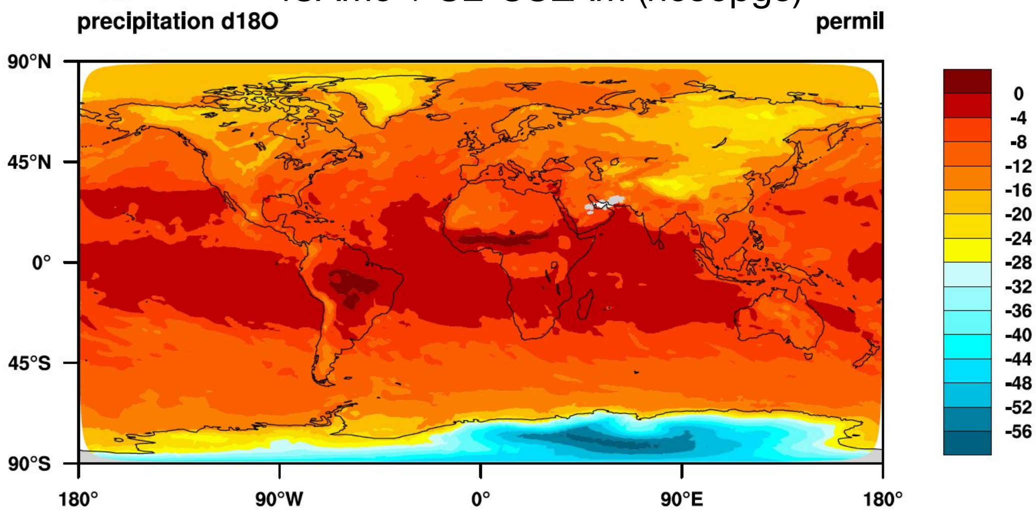
- Lacking isotope-enabled land model.

SE-CSLAM

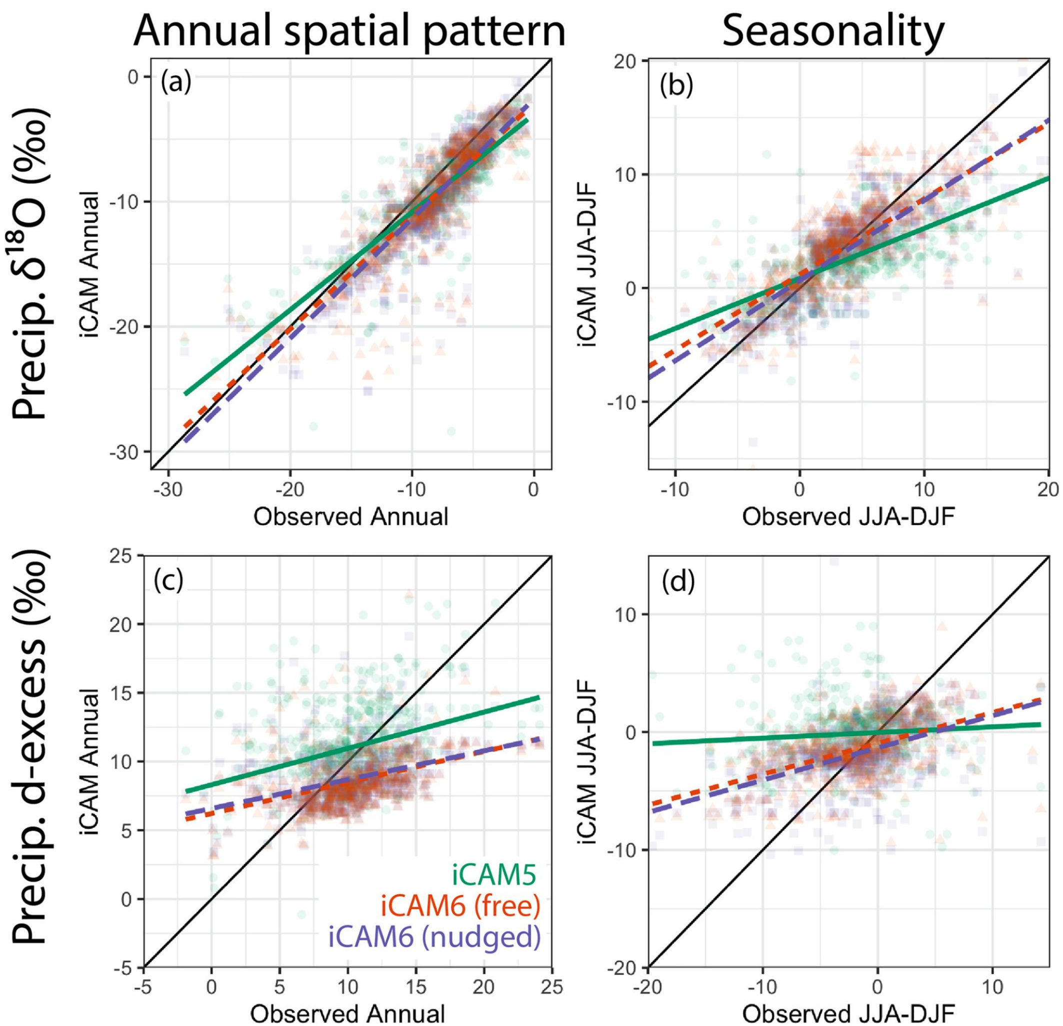
iCAM5 + SE (ne30)



iCAM5 + SE-CSLAM (ne30pg3)



iCAM6



From Fiorella et al., 2021

iCAM6 has a better seasonal cycle relative to iCAM5, but may have a possibly worse d-excess bias.

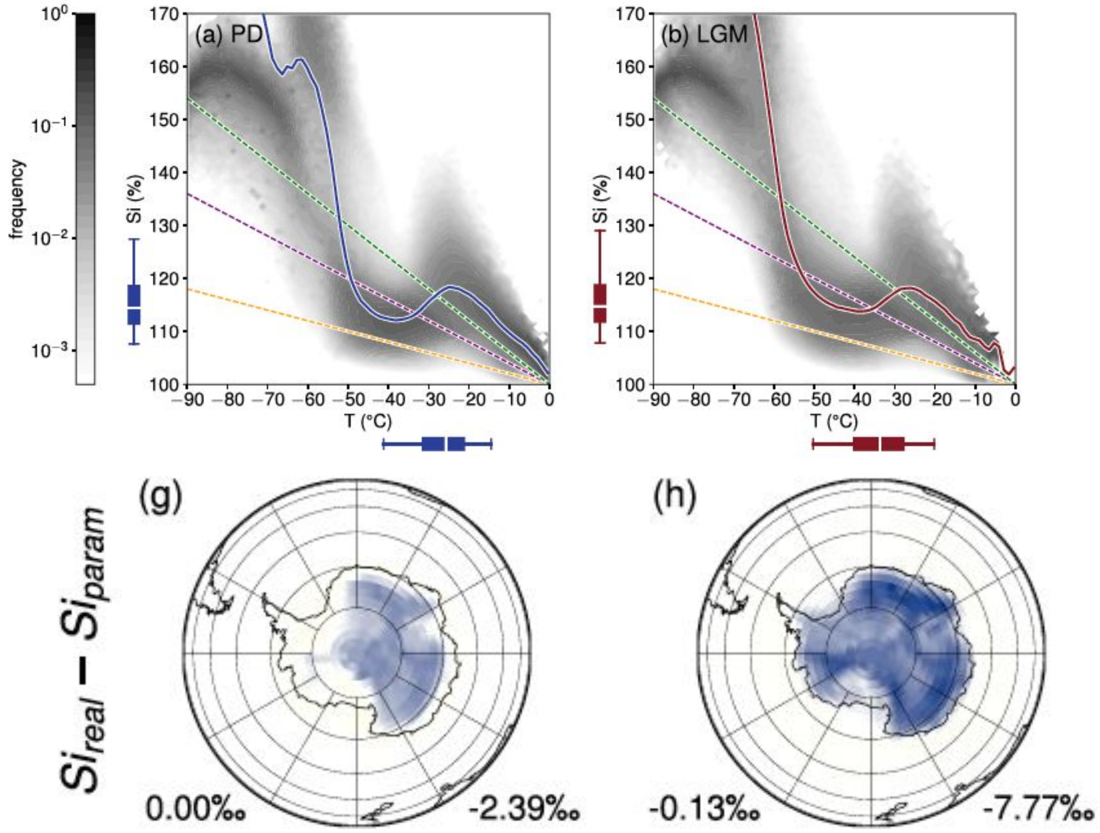
Isotope bug fixes

- Allow water isotopes to be read from a CAM IC (ncdata) file. This removes the need to cold-start the isotope values in CAM whenever one does a start-up or hybrid run.

- Bug fix where mass fixer was being applied incorrectly after rain evaporation in the deep convection scheme.

- Fixed bug that appeared when running with the SE dycore.

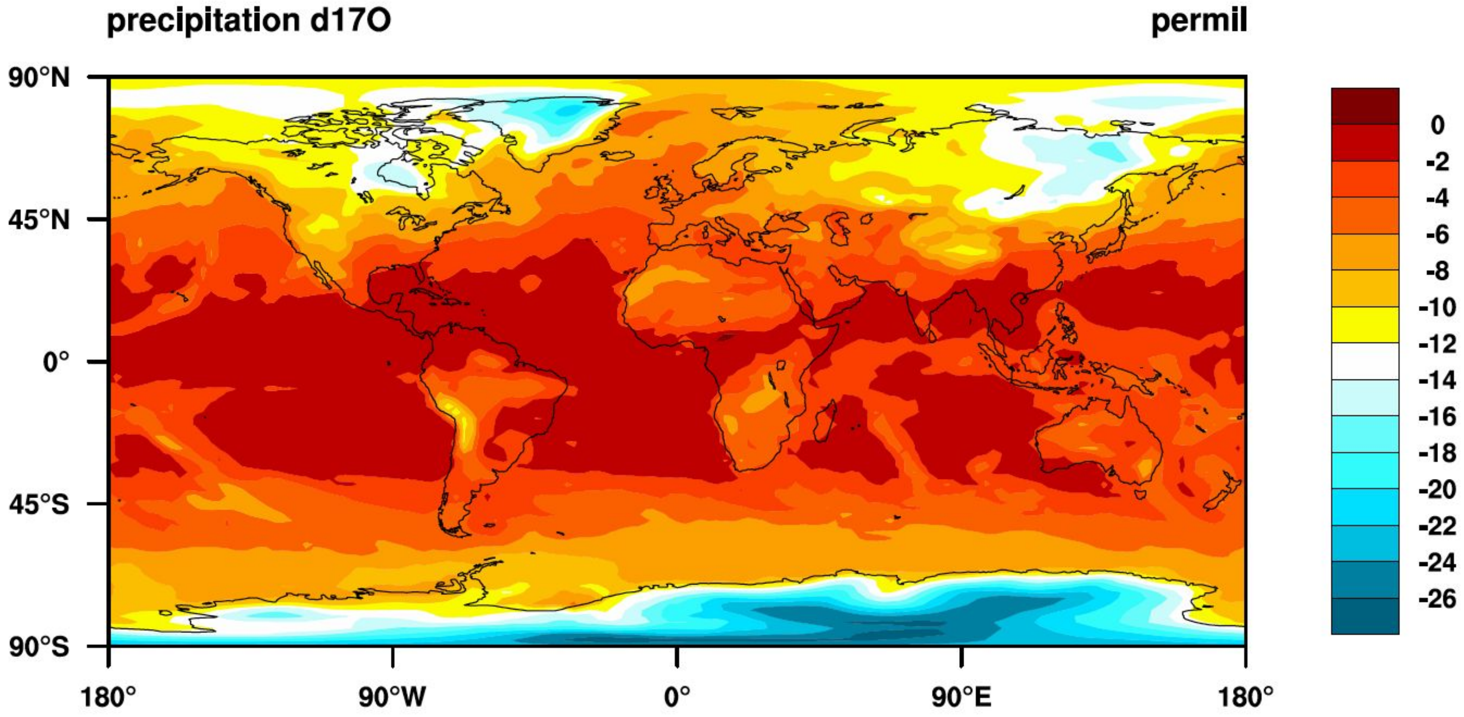
Model-predicted Supersaturation



From dütsch et al., 2019

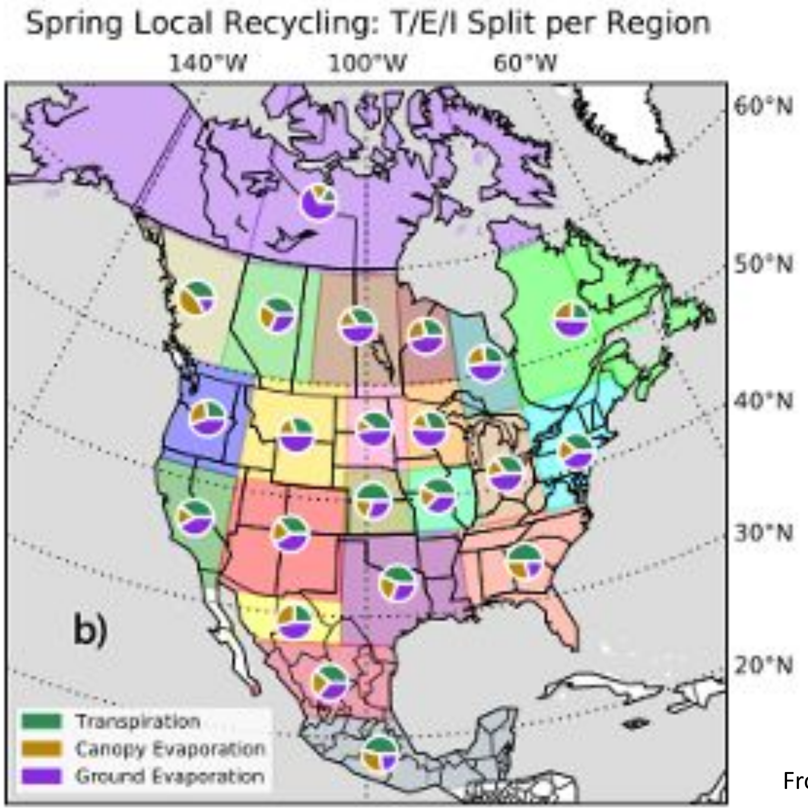
iCAM6 allows for one to use the model-calculated super-saturation, instead of using just the standard linear approximation based on temperature, and which can have a significant impact on isotope “excess” quantities.

$H_2{}^{17}O$ and HTO



iCAM6 has the capability to simulate $H_2{}^{17}O$ and HTO, as well as related quantities such as $\Delta^{17}O$-excess, although work is still needed for tuning and validation of these quantities.

More specific water-tagging capabilities

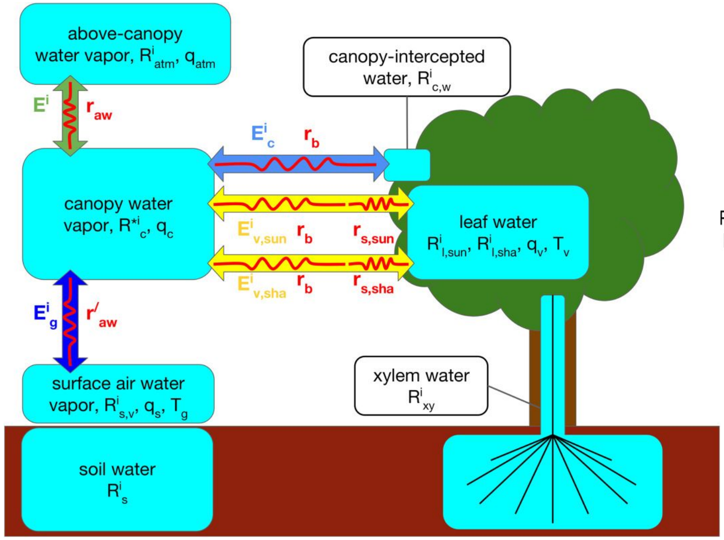


From Harrington et al., in review

The use of CLM5 (for the physical climate) simplifies the ability to split land surface moisture fluxes into their individual components when tagging.

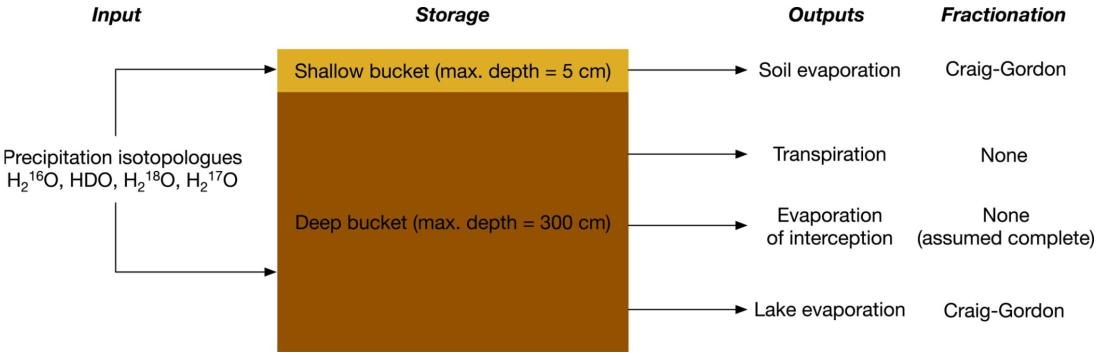
Challenges: CTSM

iCLM4



From Wong et al., 2017

CLM5 + Bucket

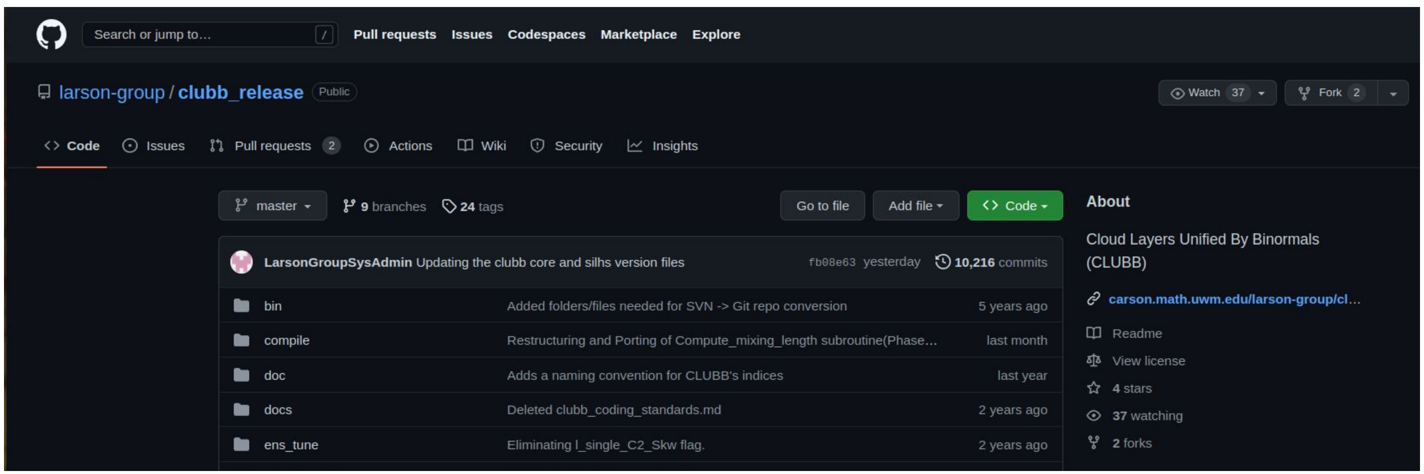


From Fiorella et al., 2021

There is currently no isotope-enabled version of CLM5 or CTSM, and it would take a significant amount of effort to develop one. Thus instead iCAM6 currently uses a two-layer bucked model for the isotopic fluxes.

Challenges: CLUBB

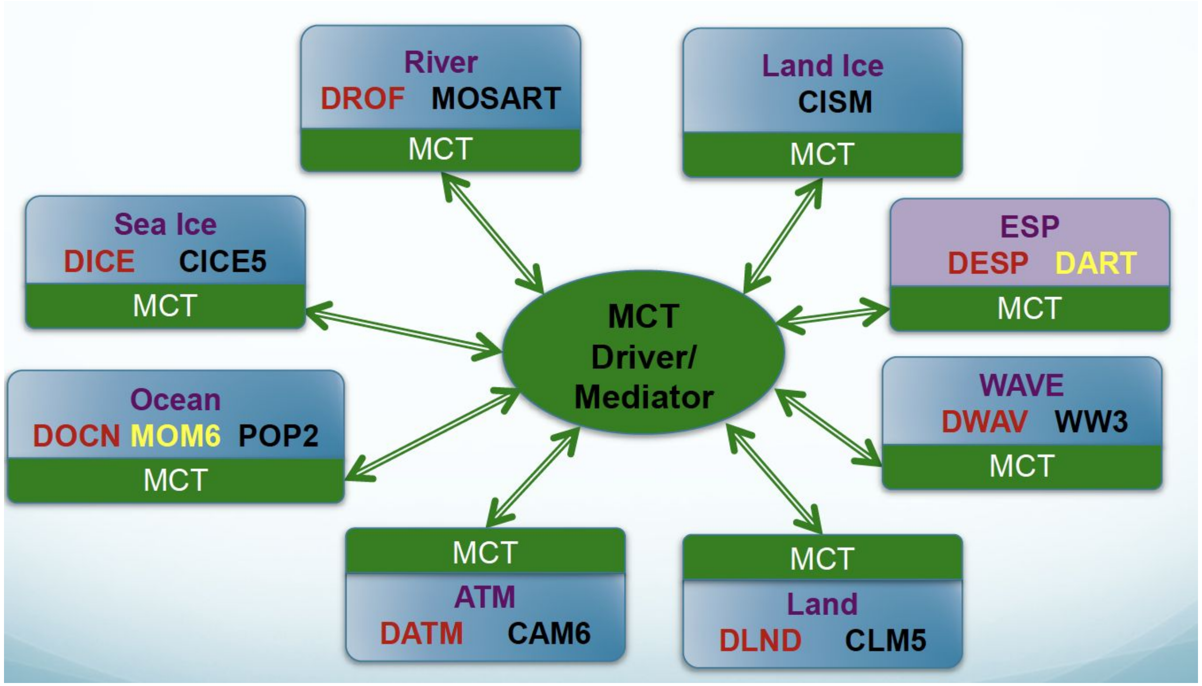
Physics	CAM5	CAM–CLUBB
Deep convection	Zhang and McFarlane 1995	Zhang and McFarlane 1995
Boundary layer	Bretherton and Park 2009	CLUBB
Shallow convection	Park and Bretherton 2009	CLUBB
Cloud macrophysics	Park (Neale et al. 2010)	CLUBB
Cloud microphysics	Morrison and Gettelman 2008	Morrison and Gettelman 2008
Radiation	Rapid Radiative Transfer Model for GCMs (RRTMG); Iacono et al. 2008	RRTMG; Iacono et al. 2008
Aerosols	Liu et al. 2012	Liu et al. 2012



From Bogenschutz et al., 2013

CLUBB is a relatively complex parameterization of shallow convection, turbulence, and cloud macrophysics that is a core part of CAM, but is owned by a research group external to NCAR.

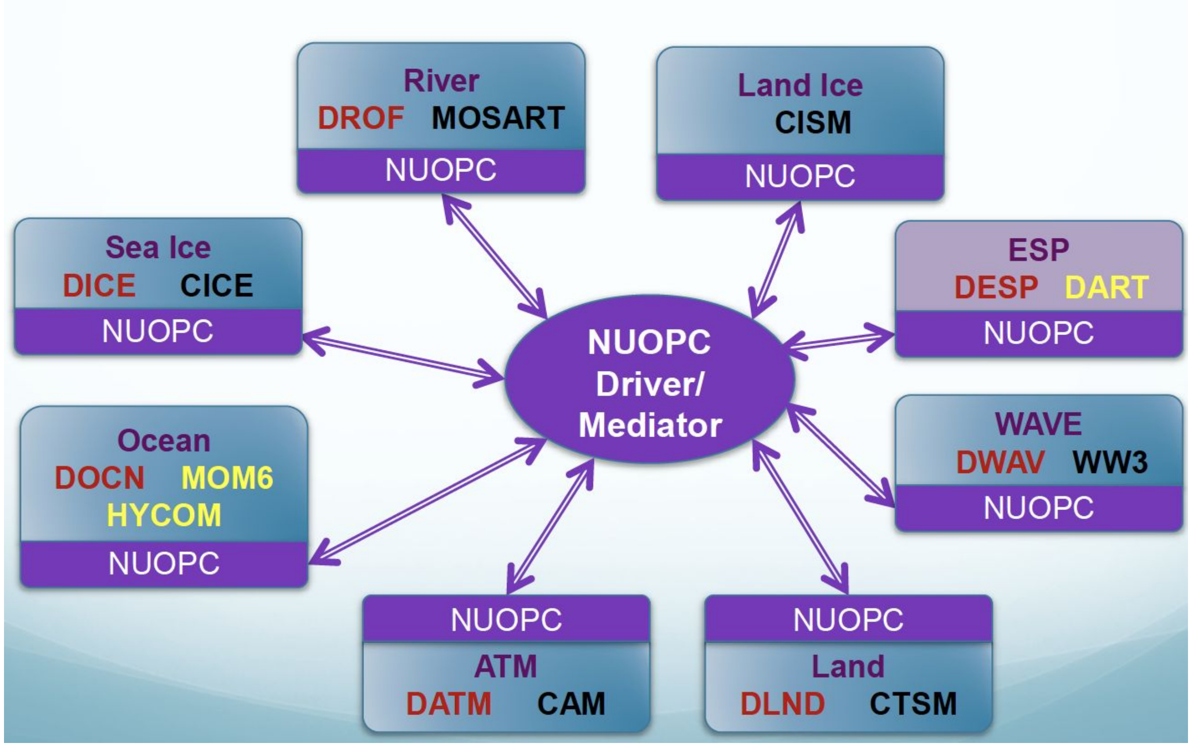
Challenges: NUOPC



From Mariana Vertenstein

iCESM1 uses MCT and CPL7 to couple the various model components together.

Challenges: NUOPC



From Mariana Vertenstein

However, CESM3 will use NUOPC and CMEPS to provide the coupling infrastructure, and although the water isotope fields have theoretically been ported, they have not been tested, and so likely will need additional work.

Possible discussion questions

- If we want isotopes (and water tracers) in CESM2/3, can we find the needed resources?

- Beyond CESM3, can we implement water isotopes in a way that is sustainable and more "future-proof"? Possible avenues:
  - Have the isotope physics completely outside the parameterization(s).
  - Create a water "object" that "owns" all fundamental water-related quantities and physics.
  - Emulate the water isotope results via machine learning

Questions

Thanks for listening!

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