A New Set of Recipes for CESM3 for Near-Modern Paleoclimate Applications

& Wrap-up Discussion

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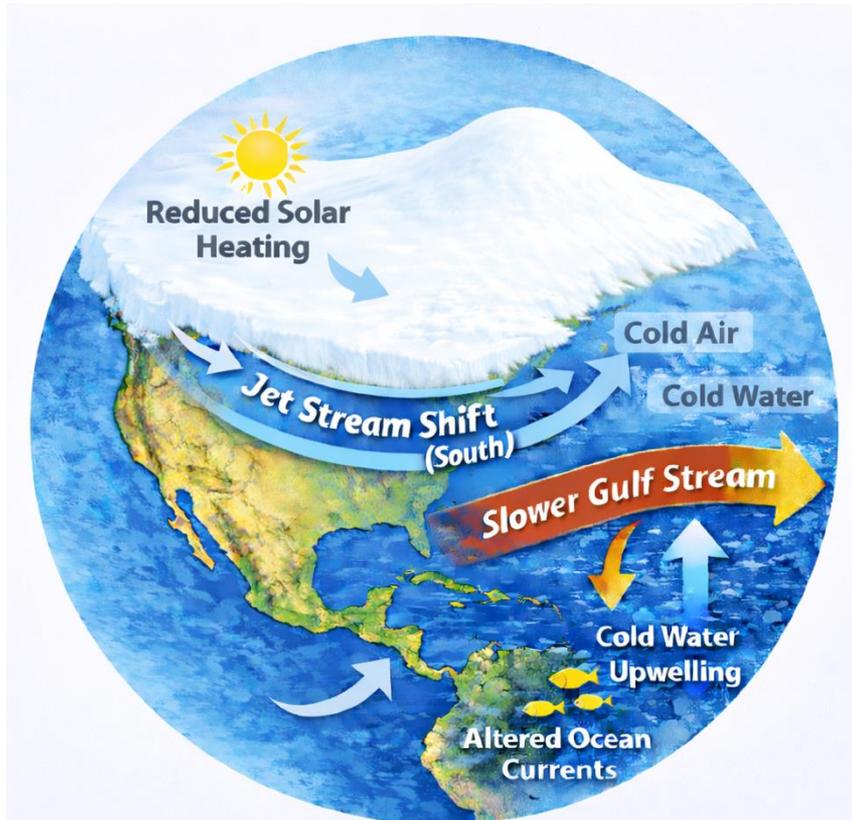
Why Recipes for Paleo Boundary Conditions?

"Give a man a fish, and you feed him for a day; teach a man to fish, and you feed him for a lifetime"

— Lao Tzu? Maimonides? Anne T. Ritchie

Credit: ChatGPT

For serious discussion, check out *Manabe and Broccoli, 1985, JGR Kutzbach and Guetter, 1986, JAS ...*
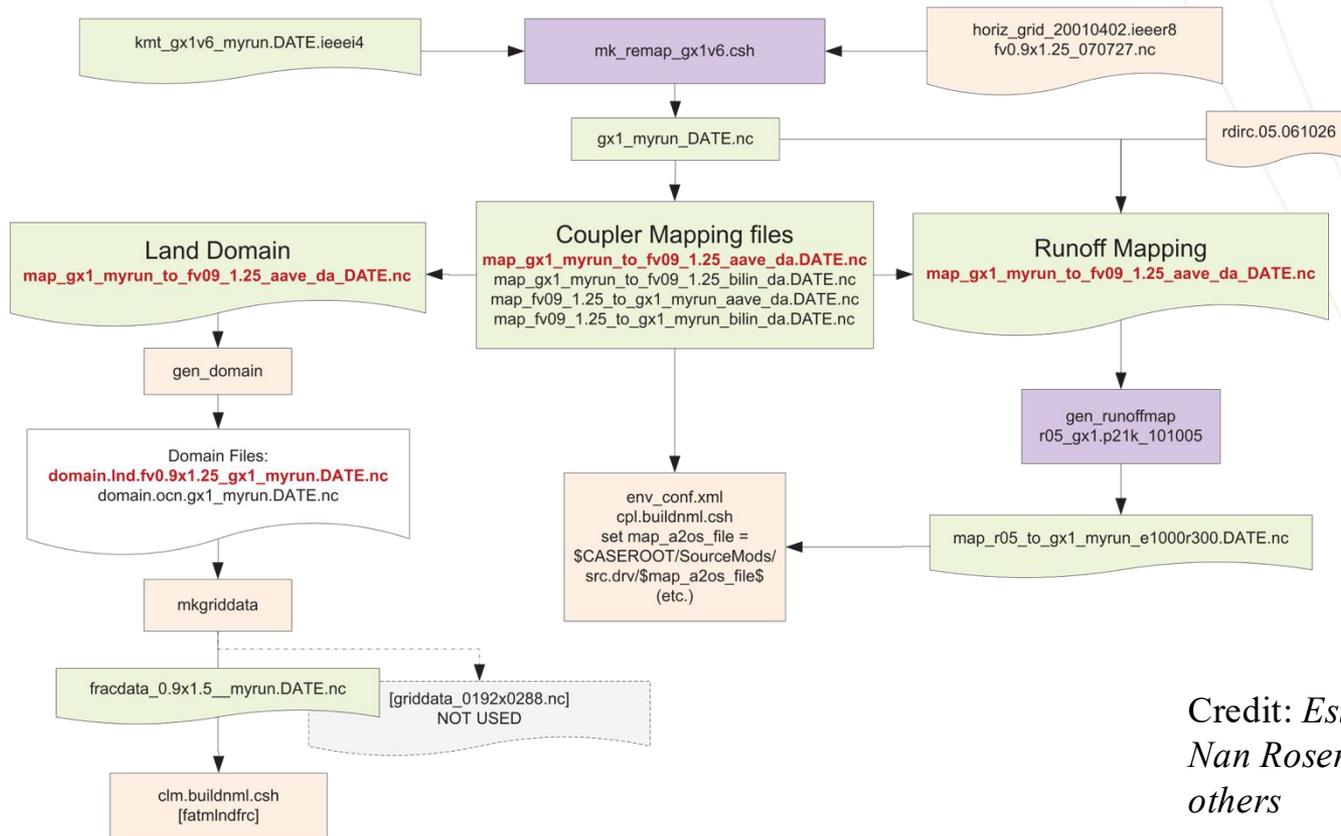
Old Recipes Need Updating

- o Designed for old coarse-resolution models (e.g., CCSM4 / CESM1)
  - Land surface data generation regrids raw data into 0.5°
  - Atmos. subgrid roughness is outdated, inconsistent, & lat–lon only (vs Lauritzen+2015)

- o Outdated protocols and practices
  - NCL is no longer being developed
  - SCRIP-based grids, while community is moving toward mesh-based workflow
  - Hard-wired resolution info (e.g., 0.5° river model)

- o Multi-language (Fortran, NCL, IDL, shell), complex dependencies, scattered steps

- o Sometimes lacks visualization, result checking, and documentation
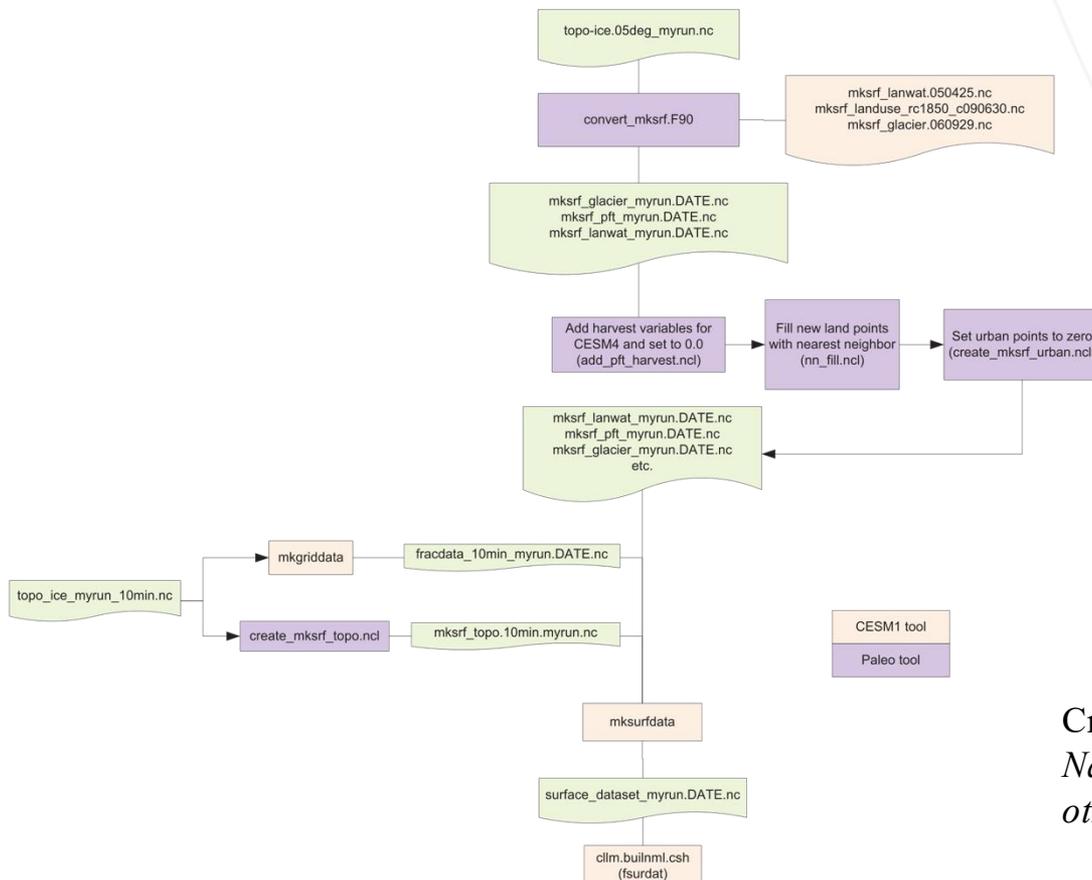
Old Recipes: Overview

Legend
- Paleo tools
- CESM1.0 tools
- Required if using CLM restart files with new landcover

USER INPUT:
land-ocn.mask.1deg.nc
topo-ice.10min.nc

Step 1 — change_kmt.ncl or kmtEd → KMT.myrun

Step 2 — mk_remap.csh / mk_runoff_remap.csh / genrunoff → coupler mapping

Step 3 — gen_domain → ocn.domain.myrun / lnd.domain.myrun

Step 4 — mkgriddata → fracdata.myResolution / fracdata.10min.myrun

Step 5 — convert_mksrf.F90 or paleo_mkraw.csh → mksrf.myrun files

Step 6 — mksurfdata → surface_dataset.myrun

Step 7 — definesurf → bnd_topo.myrun

Step 8 — 5-day CESM → clm.r.new-paleo-map

Step 9 — interpinic → clm.r.spun-up-state mapped to new-paleo-map

Step 10 — Production CESM

Credit: *Esther Brady, Nan Rosembloom, and others*

Old Recipes: Mapping and Domain Files


```
kmt_gx1v6_myrun.DATE.ieeei4  →  mk_remap_gx1v6.csh  ←  horiz_grid_20010402.ieeer8
                                                          fv0.9x1.25_070727.nc

                                 gx1_myrun_DATE.nc  ─────────────  rdirc.05.061026
```

Land Domain
map_gx1_myrun_to_fv09_1.25_aave_da_DATE.nc

Coupler Mapping files
map_gx1_myrun_to_fv09_1.25_aave_da.DATE.nc
map_gx1_myrun_to_fv09_1.25_bilin_da.DATE.nc
map_fv09_1.25_to_gx1_myrun_aave_da.DATE.nc
map_fv09_1.25_to_gx1_myrun_bilin_da.DATE.nc

Runoff Mapping
map_gx1_myrun_to_fv09_1.25_aave_da_DATE.nc

gen_domain

Domain Files:
domain.lnd.fv0.9x1.25_gx1_myrun.DATE.nc
domain.ocn.gx1_myrun.DATE.nc

env_conf.xml
cpl.buildnml.csh
set map_a2os_file =
$CASEROOT/SourceMods/
src.drv/map_a2os_file
(etc.)

gen_runoffmap
r05_gx1.p21k_101005

map_r05_to_gx1_myrun_e1000r300.DATE.nc

mkgriddata

fracdata_0.9x1.5__myrun.DATE.nc

[griddata_0192x0288.nc]
NOT USED

clm.buildnml.csh
[fatmlndfrc]

Credit: *Esther Brady,
Nan Rosembloom, and
others*

Old Recipes: Land Surfdata

Credit: *Esther Brady, Nan Rosembloom, and others*

New Recipes for CESM3 LGM (& Near Modern)

- o Support CESM3 and future high-resolution applications
  - Backward compatibility maintained where possible

- o **Python on JupyterHub** using precompiled Fortran executables

- o **Streamlined workflow** organized into 8 ordered notebooks (01, 02, 03, …)

- o **Clear in-line documentation** explaining assumptions and choices

- o **Extensive diagnostics and visualization** including interactive hvPlot

o Paleo modeling is inherently complex, spanning all model components

- Requires familiarity with component-specific manuals and guides
- Research-driven for specific questions (not operational; *"learn how to fish"*)

o Paleo recipes must evolve as CESM becomes more complex

- Priority is clarity and transparent decision-making, not code elegance
- High-resolution workflows are memory intensive (~100 GB) and sometimes slow
- *No single perfect solution: many issues stem from inconsistent data & definitions*

Component	Data Sources	Resolution	Variable	Land-Sea-Lake mask	Processing
CAM6/7	USGS GTOPO30	~1 km	topo	LND = 1, OCN = LAK = 0	NCAR_Topo
MOM6	SRTM15_v2.4	~500 m	z	User defined	Avg., smooth, manual edits
ICE-6G	ETOPO2	~4 km	Topo & orog	LND (LAK) ∈ (0, 1), OCN ∈ (0, 1]	GIA modeling in 1°

Quick Demo

For now: **https://github.com/jiang-zhu/paleowg-recipes**

When released: **https://github.com/NCAR/paleowg-recipes**

o   MOM6 bathymetry generation

o   Topography generation for CAM7, CAM6, CAM5, and CAM4

o   Land surface datasets for CTSM5 (adaptable to CLM4 and CLM5)

Future Directions

o An LGM "compset" is planed for CESM3

o Deep-time workflow

- Create new grid for MOM6

- Aerosol modifications

- Subgrid roughness for CAM

- Land surface datasets (including vegetation)

o Contributions welcome!

CESM Updates

o CESM Tutorial (free to participants; July 6–10, 2026): apply by Feb 17

o CESM3 is planned for release in June 2026

- AGU Townhall update by David Lawrence: https://www.cesm.ucar.edu/news/development
- 2026 Winter Working Group Meetings (AMWG, OMWG, PWG, CVCWG, etc): https://www.cesm.ucar.edu/events/working-groups

o Reasons for switching to CESM3 for paleo

- **New capabilities enabling new science**: (1) wave-ocean-sea ice interactions; (2) ice sheet-climate interactions; future/better support on (3) machine learning, (4) high resolution, and (5) perturbed parameter ensemble, etc.
- **Improved physics (ECS=3.7K)**: microphysics, radiation, circulation, dust, etc.
- **Improved software**: runtime remapping & integrated post-processing/diagnostics
- (**Tradeoff**: significantly more expensive at ~3× CESM2)

Paleoclimate Working Group Updates

- CESM3 LGM simulations
  - Featured in David Lawrence's presentation at AGU 2025
  - My OMWG 2025 presentation (recording available)

- CESM3 PMIP participation
  - Jiang Zhu – LGM
  - Sophia Macarewich – Mid-Holocene & LIG
  - Ran Feng – Pliocene

- Resources & contact
  - Simulation diagnostics: https://www.cesm.ucar.edu/working-groups/paleo
  - Join the PaleoWG mailing list: cesm-paleoclimate@ucar.edu
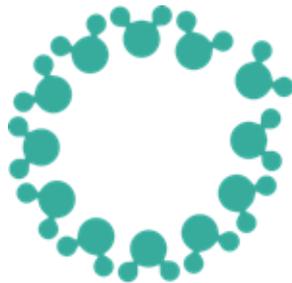
SCI-SWIM

Sustainable Community Infrastructure for Stable Water Isotope Modeling

Enabling Earth System Research

- Develop the next-generation water-isotope-enabled CESM using modern software design.

- Sustain long-term community use and co-development through open-source tools, clear documentation, and training.

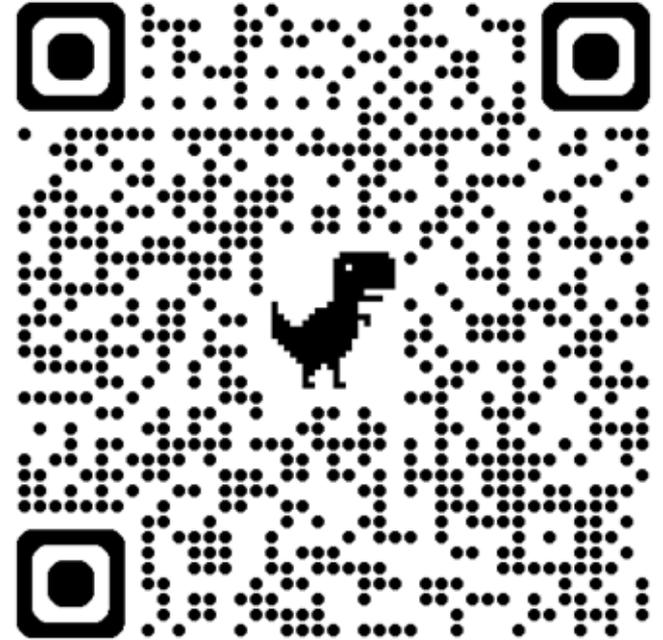- Replace the legacy iCESM1, which relies on physics more than a decade old.
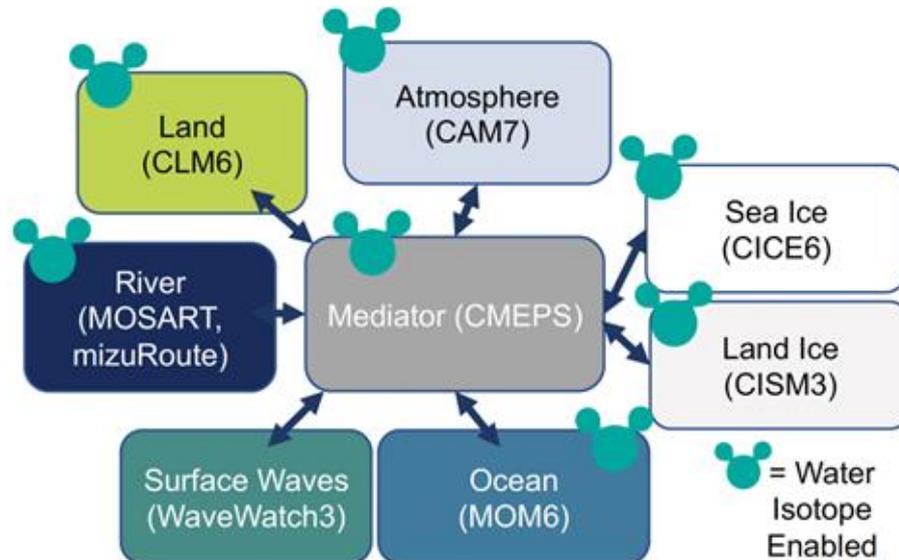
Please participate in this survey to help guide *iCESM development*, *validation*, and *user support*.

iCESM User Survey

https://forms.gle/gBftvVGEQeMWG2NGA
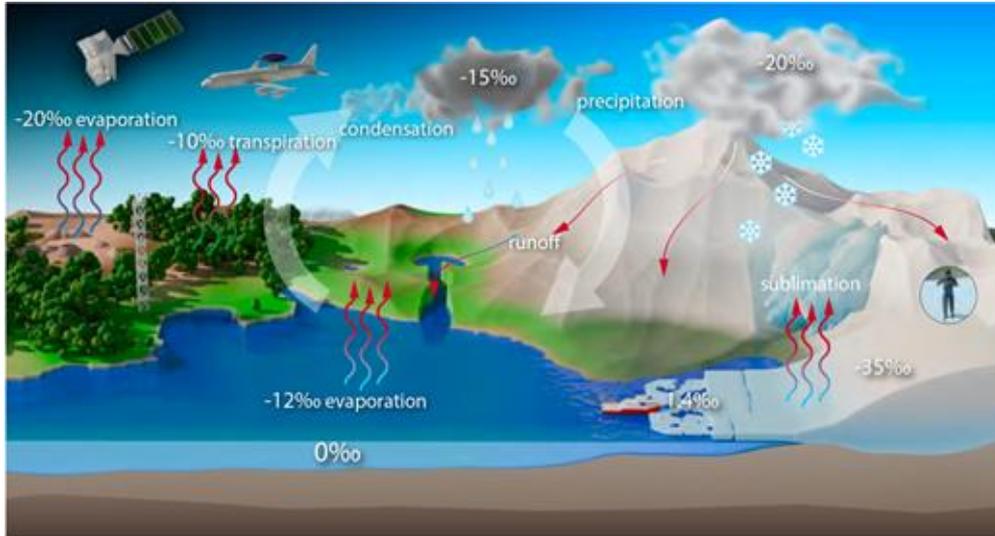
(Link also available in CESM Newsletter)

Summary

o **Modernized paleo recipes developed for CESM3 LGM**

- Extendable to other near-modern applications

- Ice sheet steps need to be added.

- Deep-time support still needed

o **CESM3 is planned for release in June 2026**

o **PaleoWG activities**

- LGM, Mid-Holocene, LIG, Pliocene, and beyond

- Co-leading iCESM development

o **Please complete the iCESM user survey**

Thank you!

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iCESM User Survey
https://forms.gle/gBftvVGEQeMWG2NGA
(Link also available in CESM Newsletter)