Opportunities for Using Variable Resolution (VR) CESM in Paleoclimate Research

Winter Paleoclimate Working Group Meeting 2023

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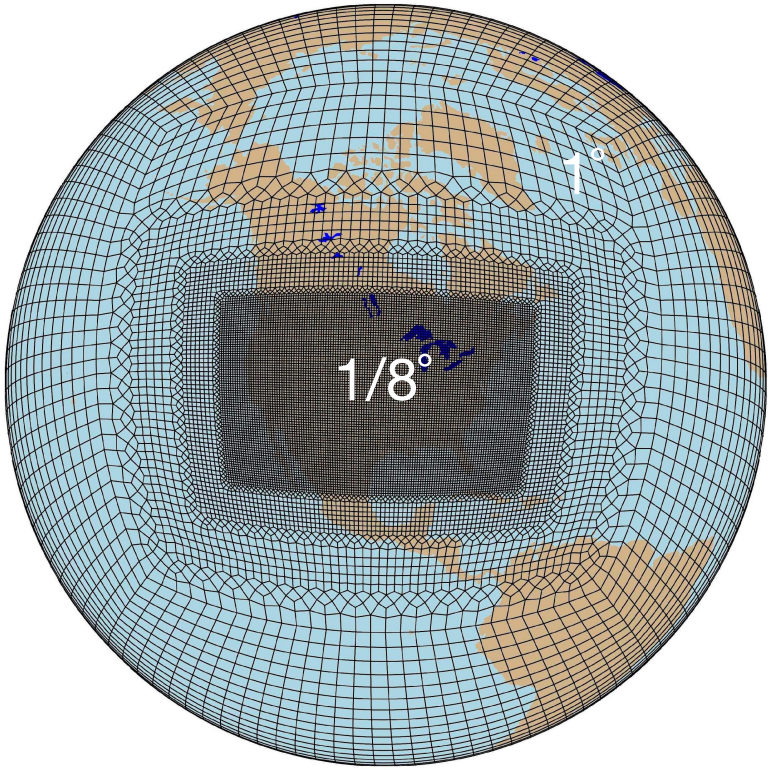
Outline

- Currently supported VR grids
- Why use VR
- Common challenges with VR
- Hierarchy of opportunities to use VR for paleoclimate

Out-of-the-box VR functionality in CESM2.2+

CONUS



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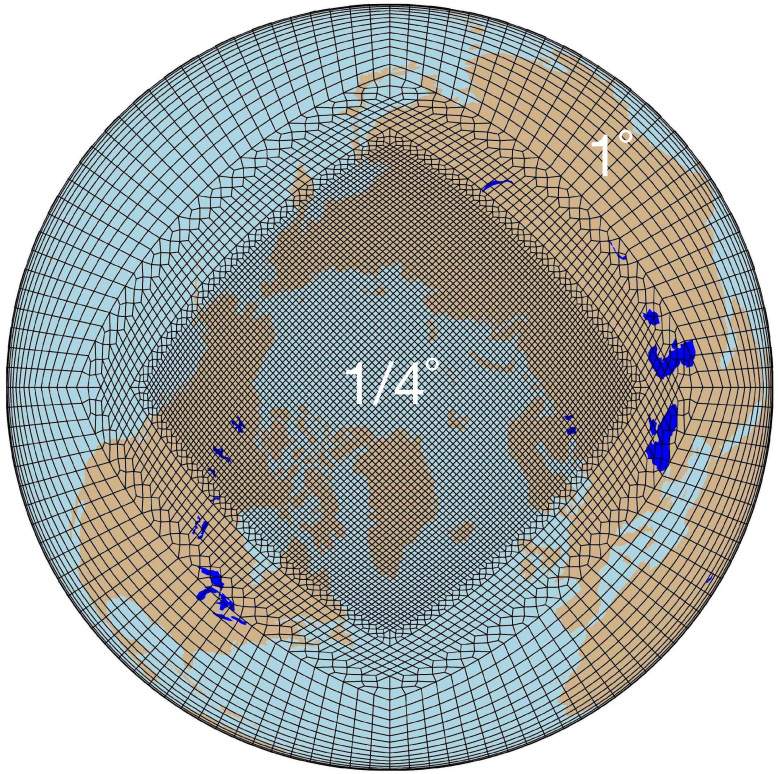

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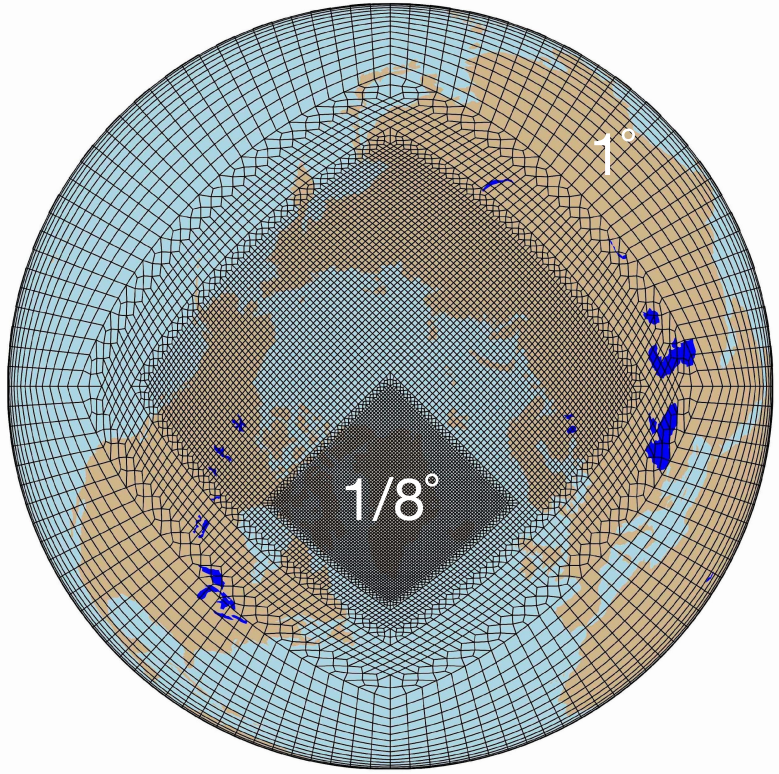
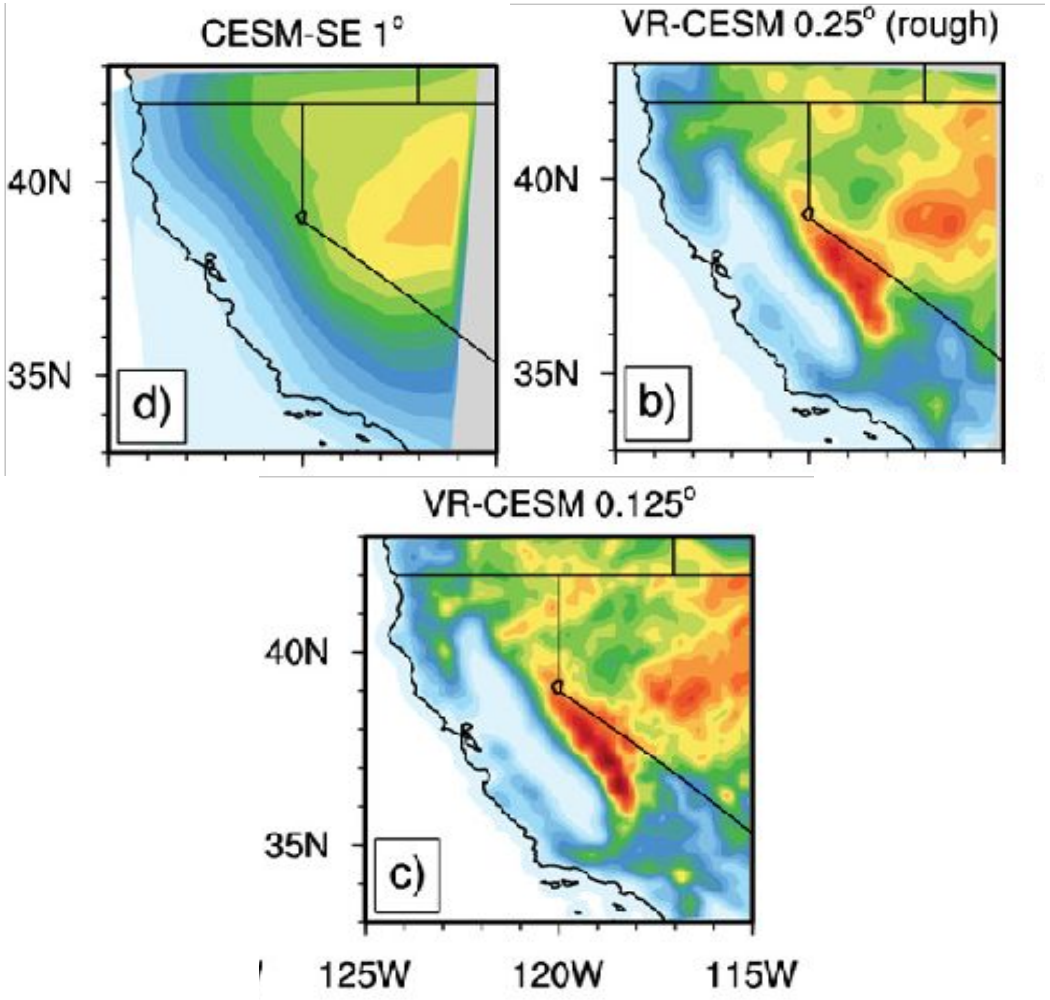
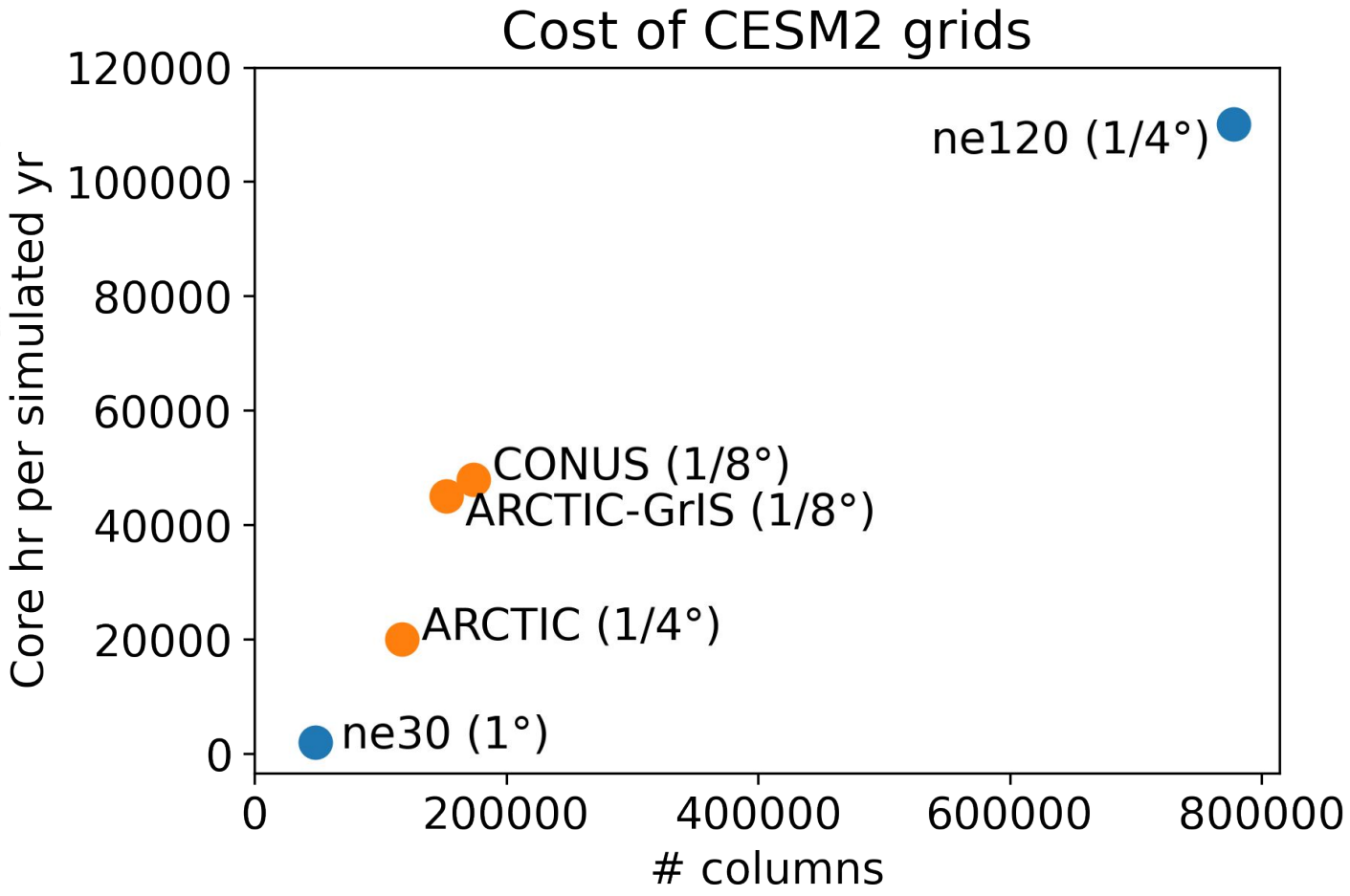


Herrington et al. (2022), *JAMES*

VR captures global climate and complex regional terrain at a low cost

TOPOGRAPHY





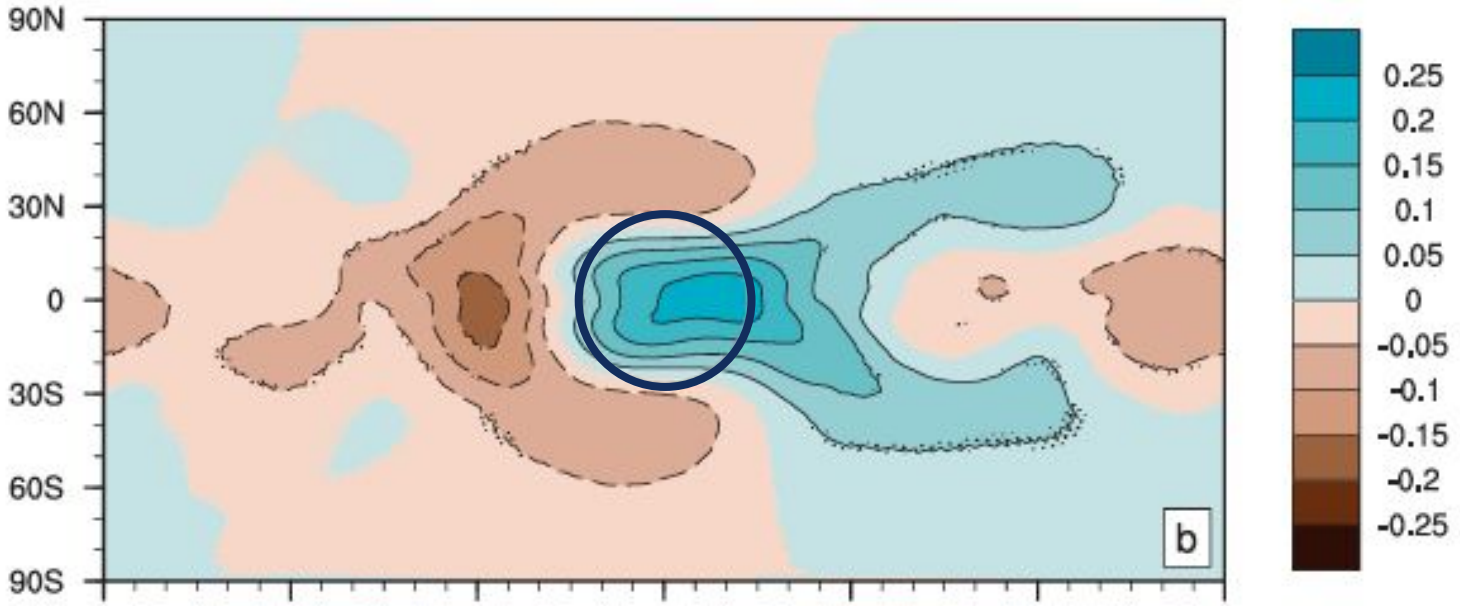
Rhoades et al. (2016), *JAMC*

Common Challenges with VR Grids

#1: Inadequate scale awareness

- Not much we can do but avoid refining regions with lots of diabatic forcing and vertical motion

200 hPa Velocity Potential

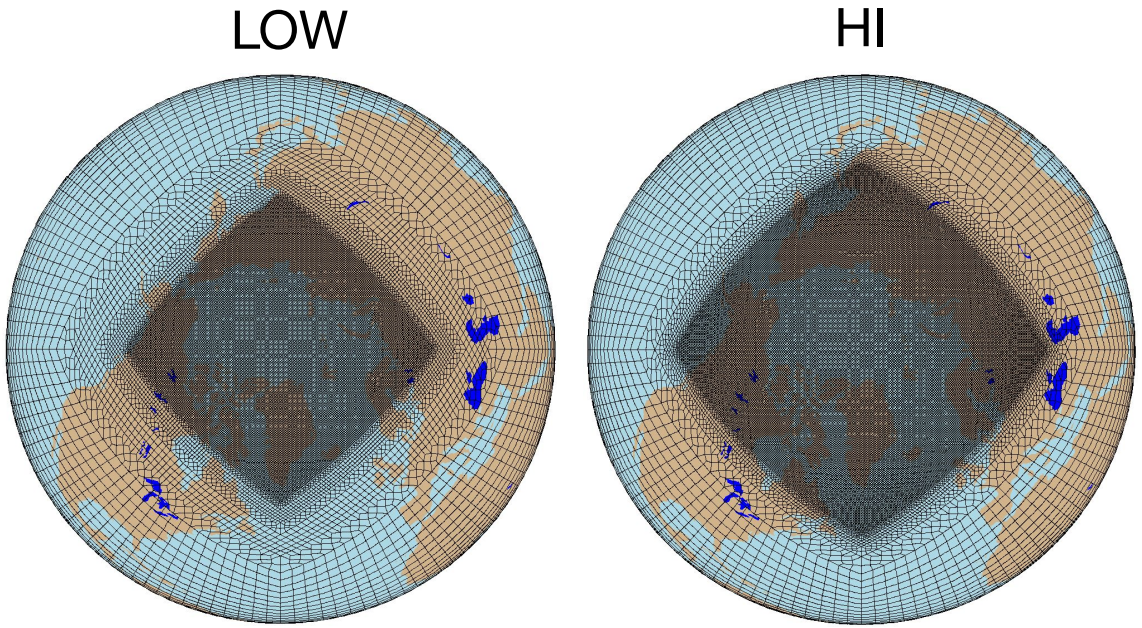


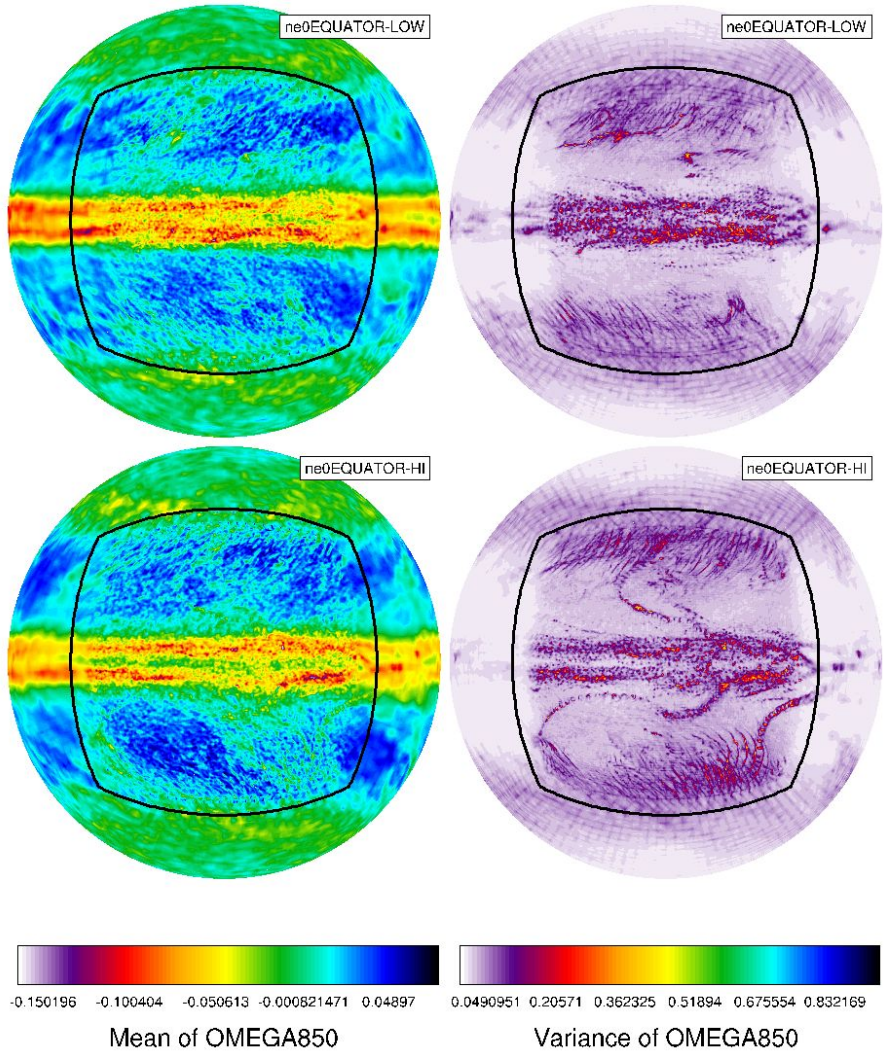
Rauscher et al. (2013), *Journal of Climate*

Common Challenges with VR Grids

#2: Grid refinement too abrupt

- Aggressive refinement can cause spurious circulation features
- Rule: 4 element buffer zone per halving of grid resolution





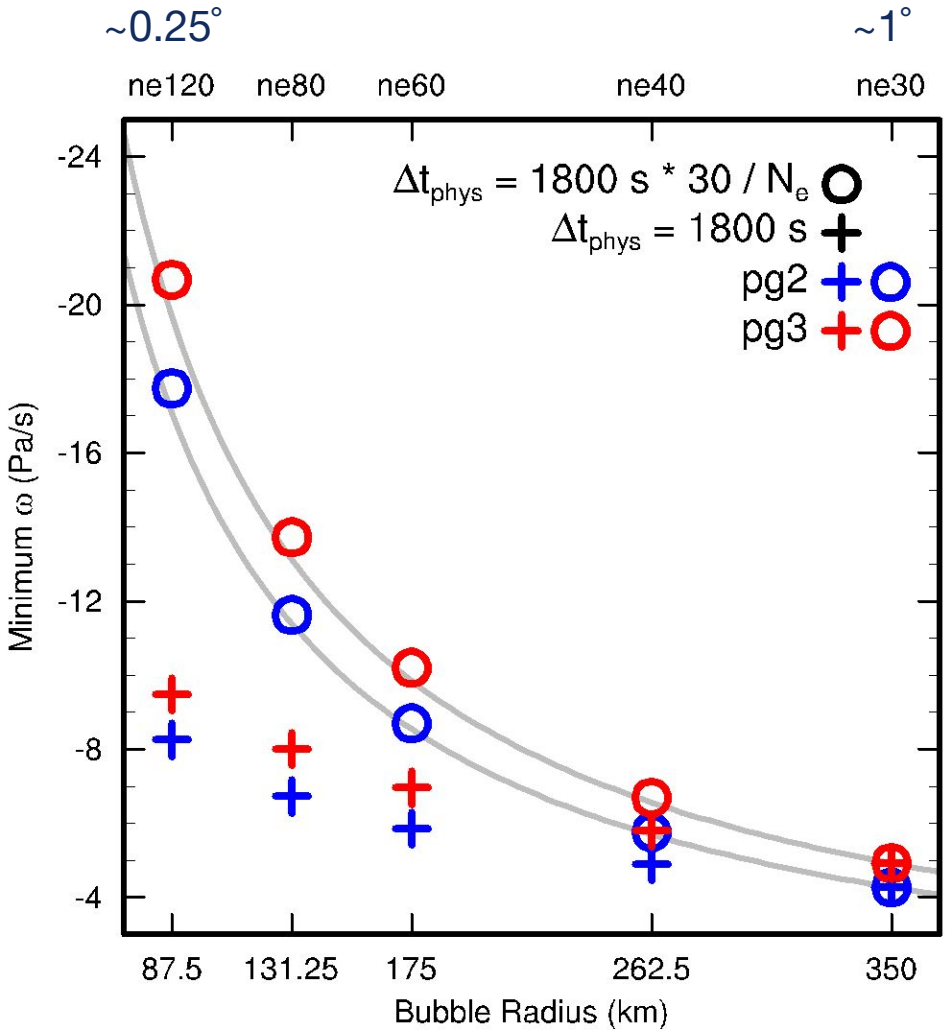
Common Challenges with VR Grids

#3: Large sensitivity to physics timestep

- Truncation errors arise when the physics timestep is too large and lead to substantial loss in solution accuracy

magnitude of vertical velocity scales like the inverse of horizontal buoyancy length scale

$$\frac{\omega_{\Delta x_1}}{\omega_{\Delta x_2}} = \frac{D_{\Delta x_2}}{D_{\Delta x_1}},$$

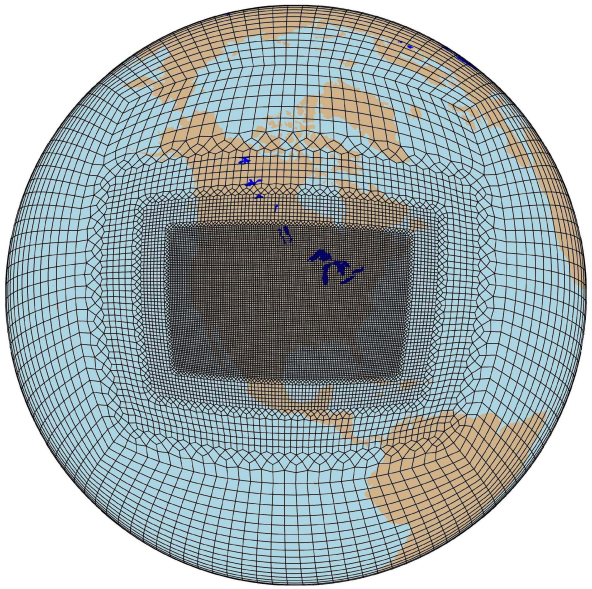


Herrington et al. (2019), *JAMES*

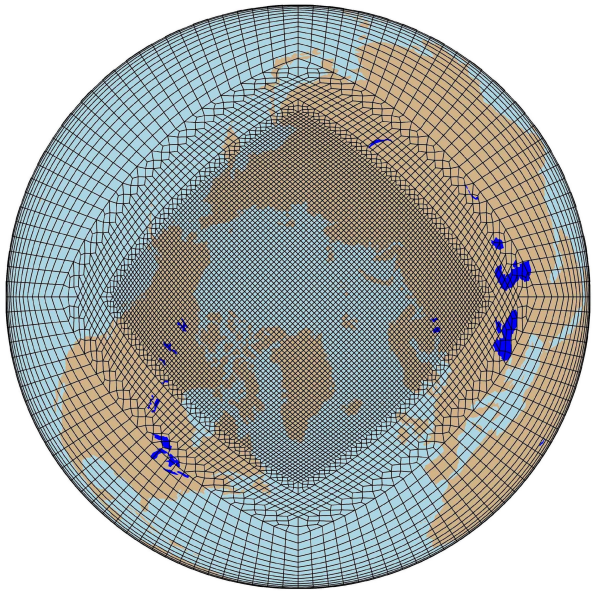
Hierarchy of opportunities to use VR for paleoclimate

Level 1: *Almost "out-of-the-box" DIY VR*

Modify only climate forcings (e.g., CO_2) of modern-day AMIP configuration (CESM2.2+) to learn about your paleoclimate interval of interest



ne0CONUSne30x8_ne0CONUSne30x8_mt12



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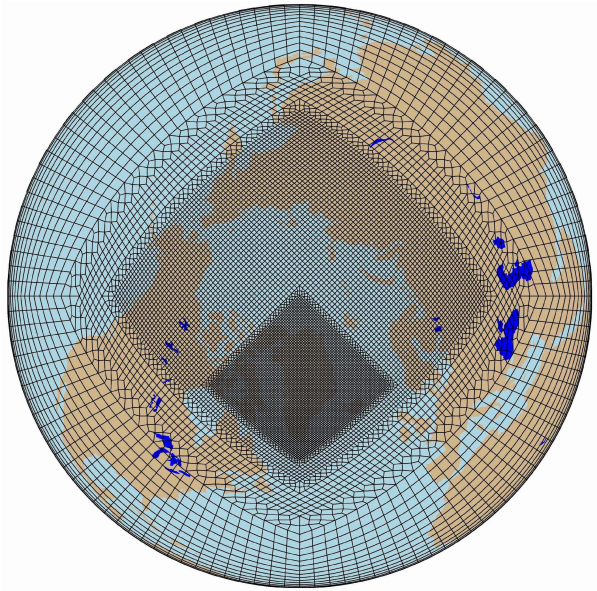

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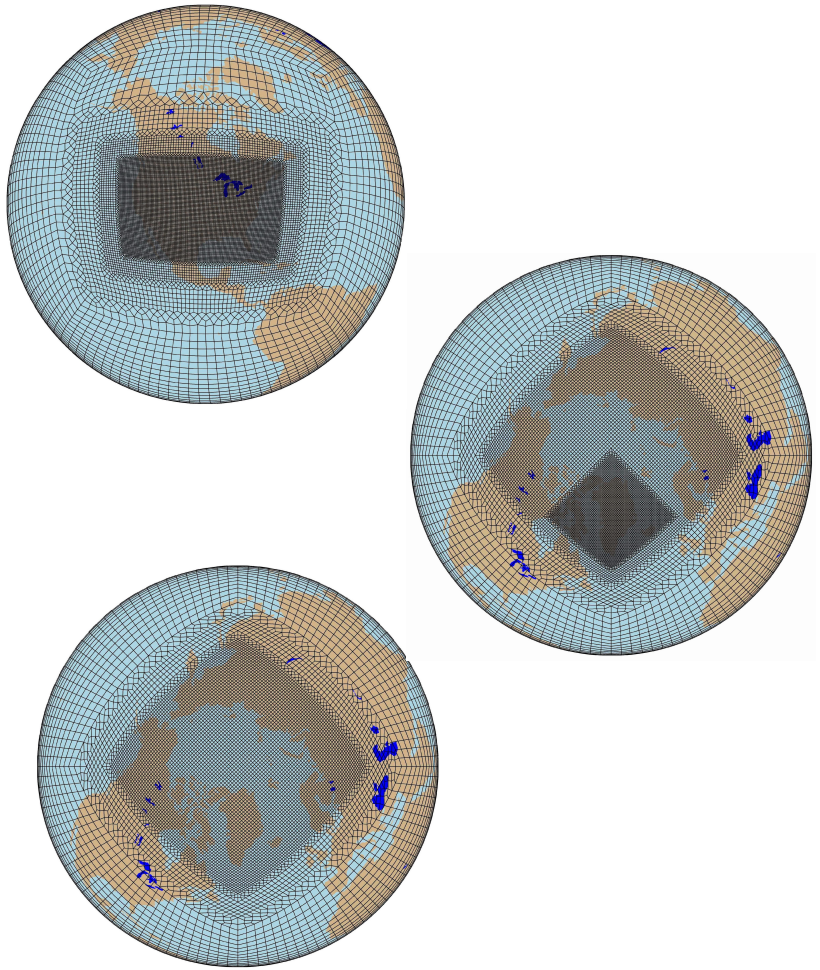

ncar.github.io/CAM

ncar.github.io/CAM/doc/build/html/users_guide/atmospheric-configurations.html#cam-developmental-compsets

camdoc documentation » CAM6.3 User's Guide »

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4. Atmospheric configurations (compsets)

There are a number of atmospheric models which can run within CESM. While CAM is the basic atmospheric model within CESM, there are several models with significant extensions to CAM which may also be run within CESM. The available atmospheric models in CESM2 are:

- **CAM**: Community Atmosphere Model
- **CAM-chem**: Community Atmosphere Model with Chemistry
- **WACCM**: Whole Atmosphere Community Climate Model
- **WACCM-X**: Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension

Each of these models have a number of atmospheric configurations provided to run them. These component sets known as **compsets** are used to supply both configure and namelist settings for predefined experiments.

The predefined compsets exist with one of three levels of support.

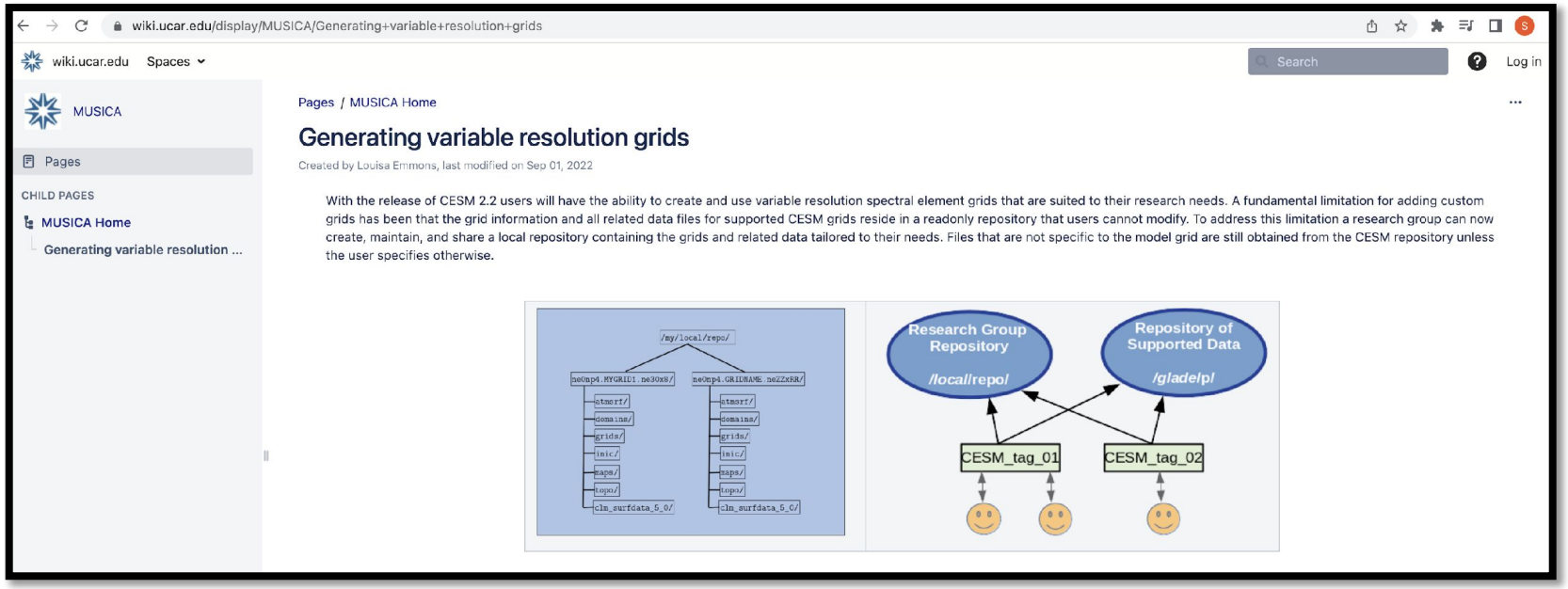
- **Scientifically supported**: Specific compset/resolution pairs which have had significant, multi-year runs made and have been studied scientifically. It is important to note that resolutions which are not listed, are not scientifically supported, have not had tunings performed and should not be used for scientific studies without careful examination of the results.
- **Developmental support**: Developmental configurations that are being evaluated. These are not fully scientifically supported in the sense of extensive tuning, testing and vetting.

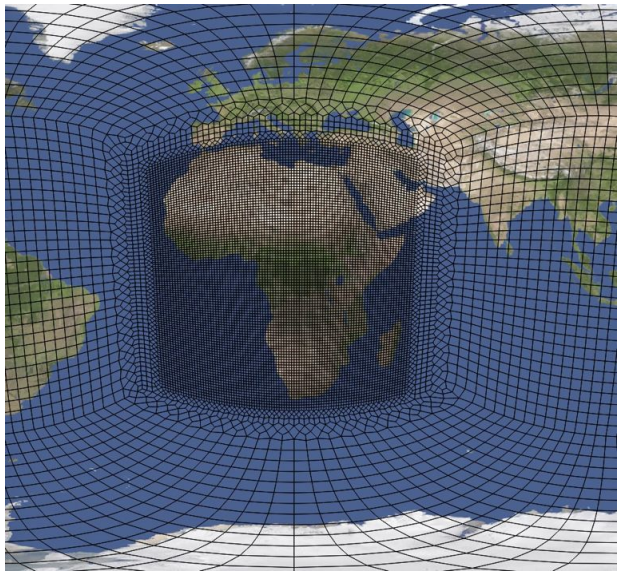
Hierarchy of opportunities to use VR for paleoclimate

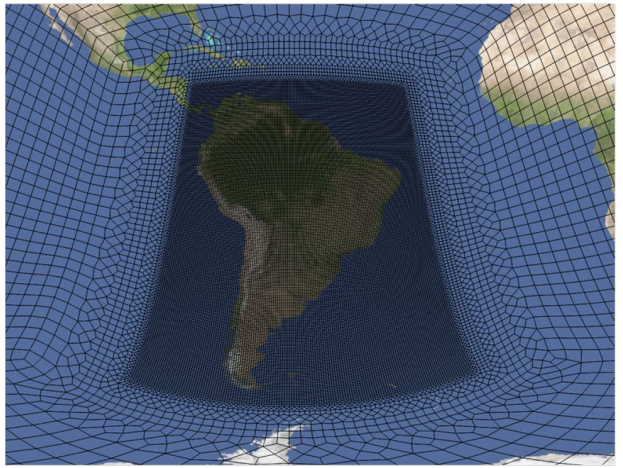
Level 2: *Need-to-put-in-work DIY VR*

- Generating your own VR grid (VR-toolkit) and/or modifying modern topography with CESM2.2+

wiki.ucar.edu/display/MUSICA



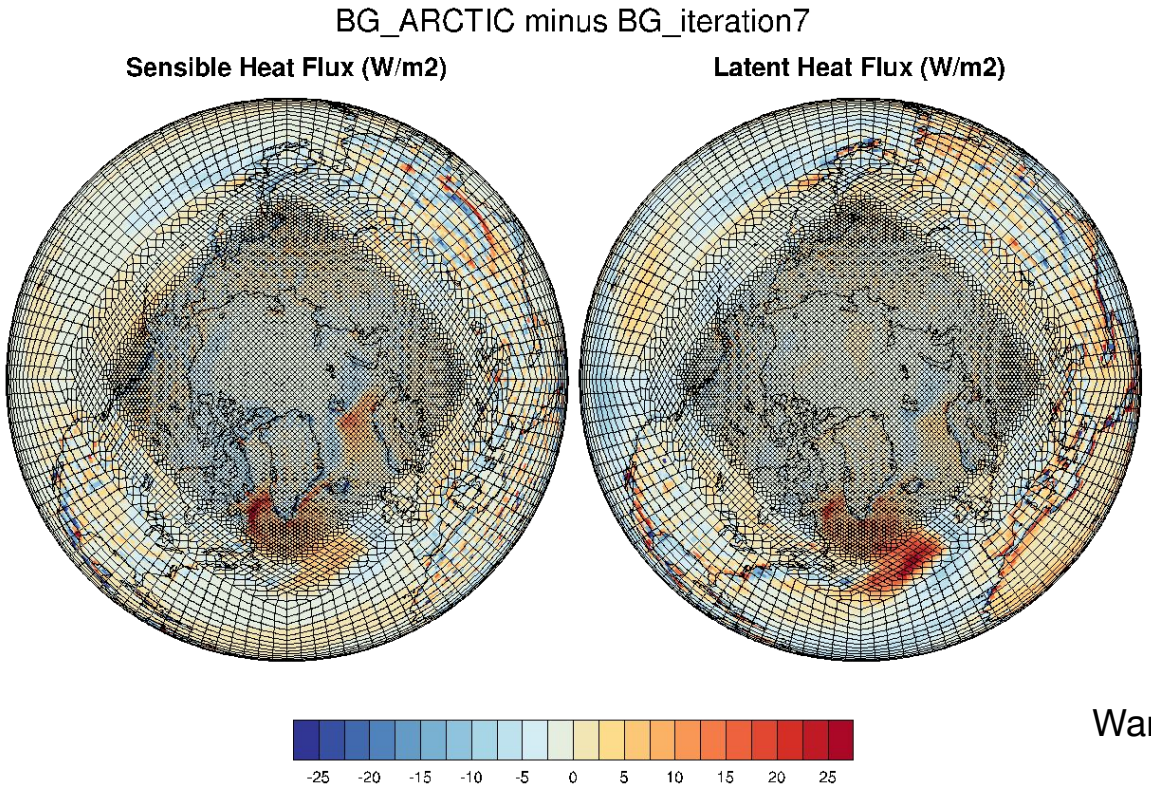


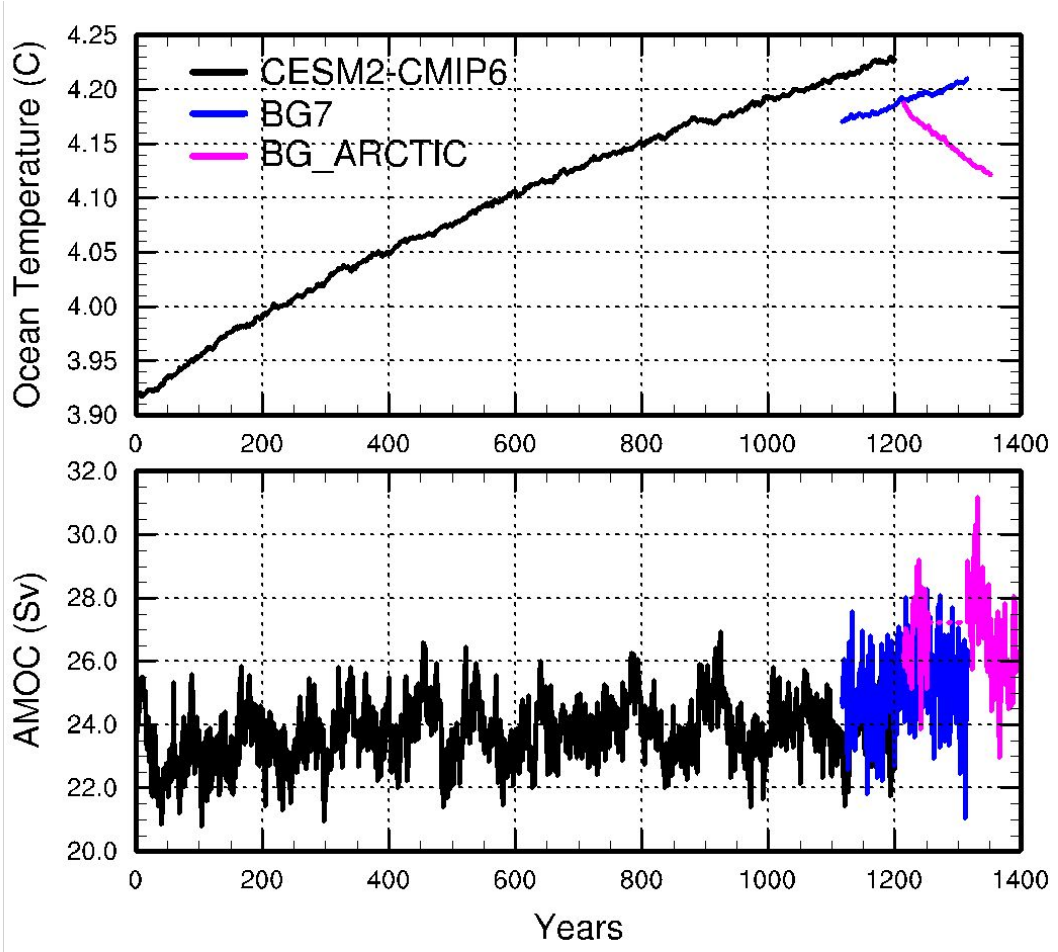


Hierarchy of opportunities to use VR for paleoclimate

Level 3: *Need-some-help VR*

- Coupling VR-CAM with POP2 in CESM2.2+





Want more? Adam Herrington @ AMWG 2023 on NCAR CGD Youtube

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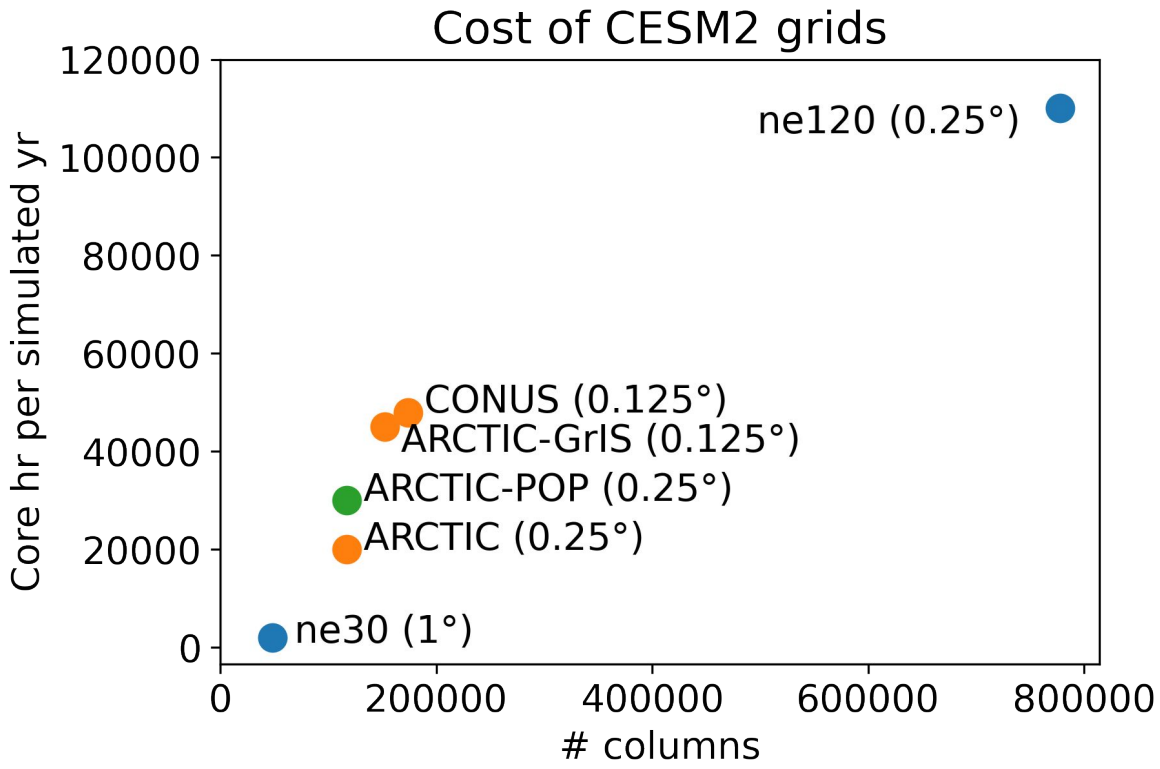
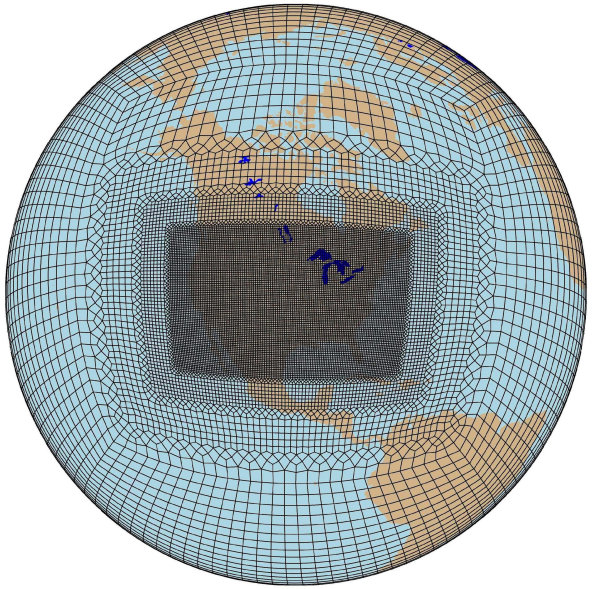
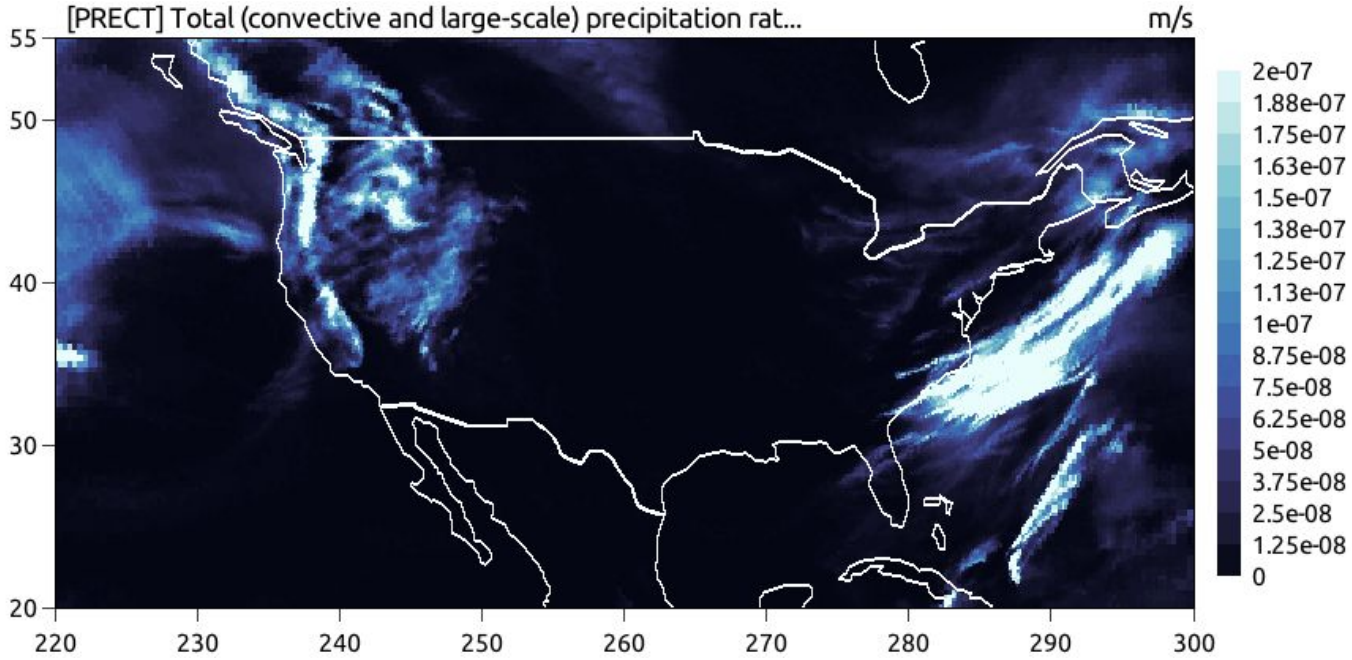


Hierarchy of opportunities to use VR for paleoclimate

Level 4: *"Wild west" of VR-CESM*

- VR-CESM with water isotope tracers (VR-iCESM1.3)





Hierarchy of opportunities to use VR for paleoclimate

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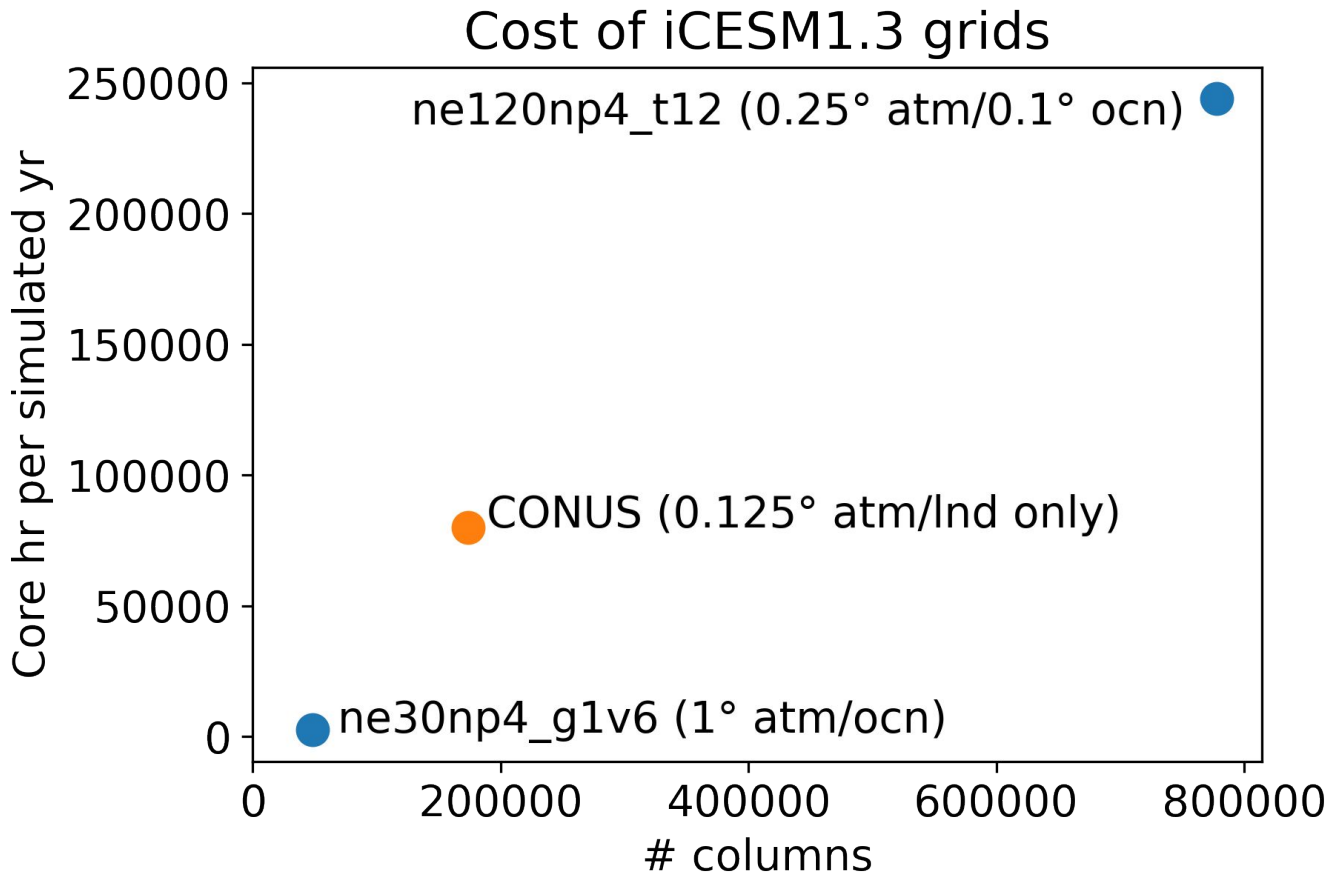
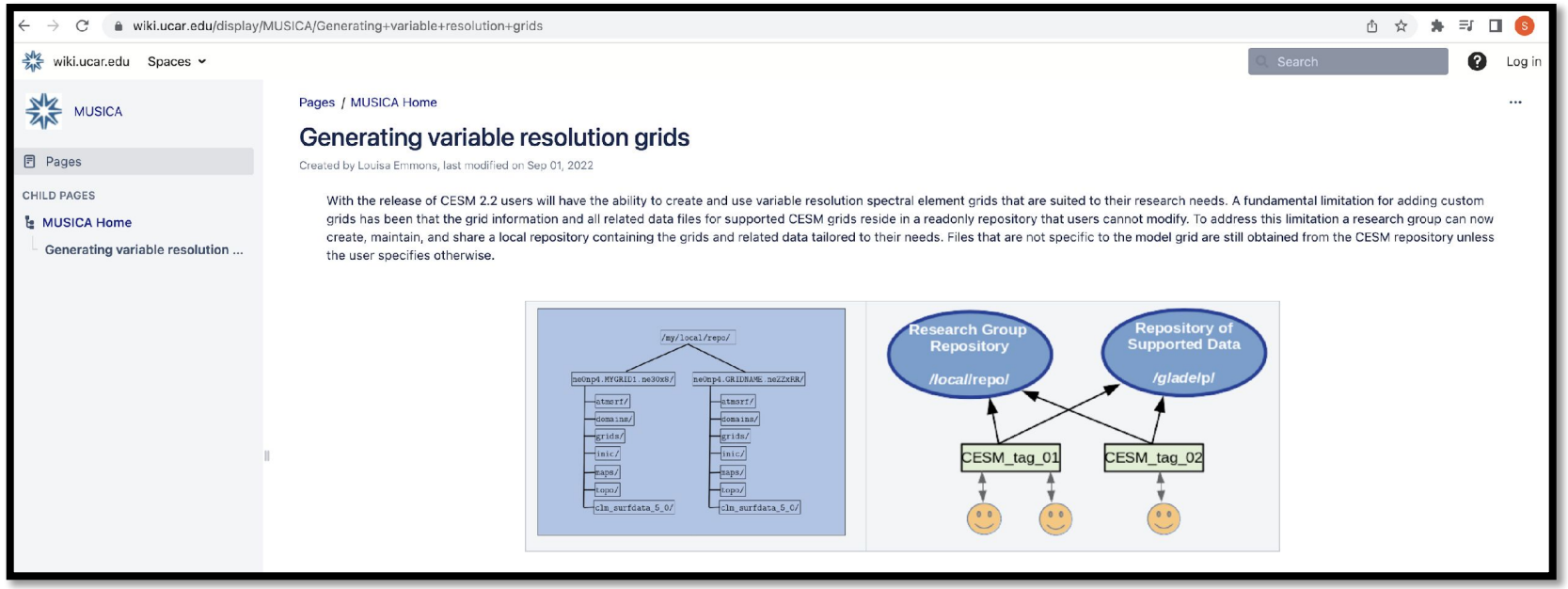


Hierarchy of opportunities to use VR for paleoclimate

Level 4: *"Wild west" of VR-CESM*

- Creating custom VR grid with paleogeography and/or using alternative versions of CESM

wiki.ucar.edu/display/MUSICA



Potential Paleo Edits:

- Need to create topography file for interval of interest (ne120 or 30 arc-sec resolution)

Conclusions & Summary

- Major advancements in accessibility, documentation, and "out-of-the-box" functionality of VR-CESM in recent years
- Using VR-CESM for paleoclimate research is currently limited, but there is lots of opportunity
  - DIY: Minor paleo adjustments to modern VR-CESM2.2+ & creating mesh on modern topo
  - More complicated: Coupling VR-CAM to POP2
  - Active development: VR-iCESM1.3 and workflow for custom VR grids on paleogeographic configurations

Email: macarew@ucar.edu

Supported VR grid documentation: Herrington et al. (2022), *JAMES*
Lots info on VR and creating grids: *wiki.ucar.edu/display/MUSICA*

Additional Slides

Where does VR fall on the spectrum of simulation cost

Grid	NCOLS	dt_dyn	Physics time step/dtime/delta p (s)	Core hours p/ sim. yr.
ne30 (global 1 deg)	48602	300 s	1800	2073
ne120 (global 1/4 deg)	777632	75 s	450	110000
ne120-POP (0.1 deg)				
ARCTIC	117398	75 s	450	20000
ARCTICGRIS	152390	37.5 s	225	45000
CONUS	174098	100 s	600	11000
ARCTICGRIS-POP	152390			
iHESP ne120-POP	777632			
iCONUS	174098	75 s	225	110000