July 10, 2026

2026 CESM Tutorial

Challenge Exercises: Lab Intro

Multiple Speakers
NCAR

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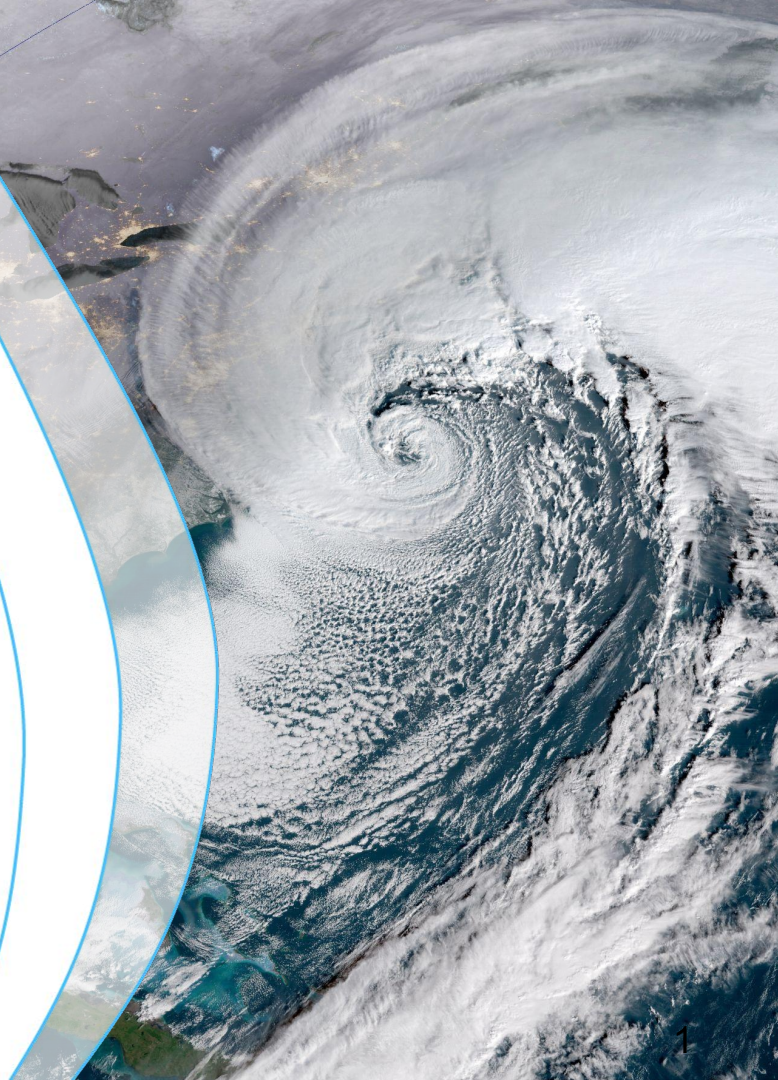
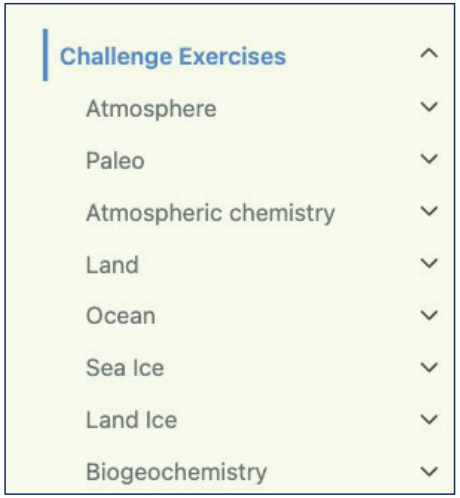
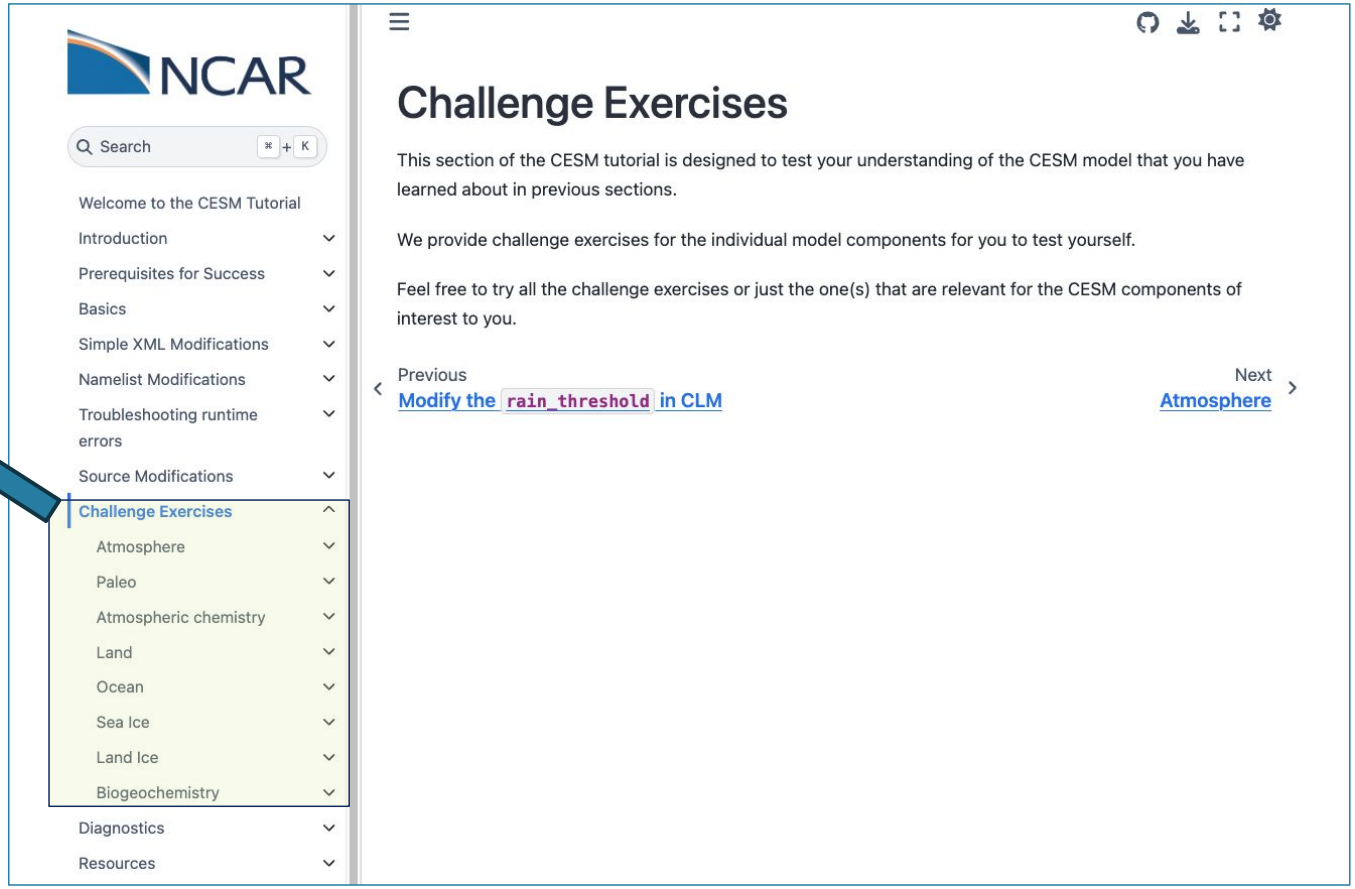


Challenge Exercises

https://ncar.github.io/CESM-Tutorial/README.html





Breakout leads for challenge exercises

Cecile Hannay
Atmosphere

Jiang Zhu
Paleo

Gunter Leguy
Land Ice

David Bailey
Sea Ice

Charlie Becker
Machine Learning

Kristen Krumhardt
Biogeochemistry

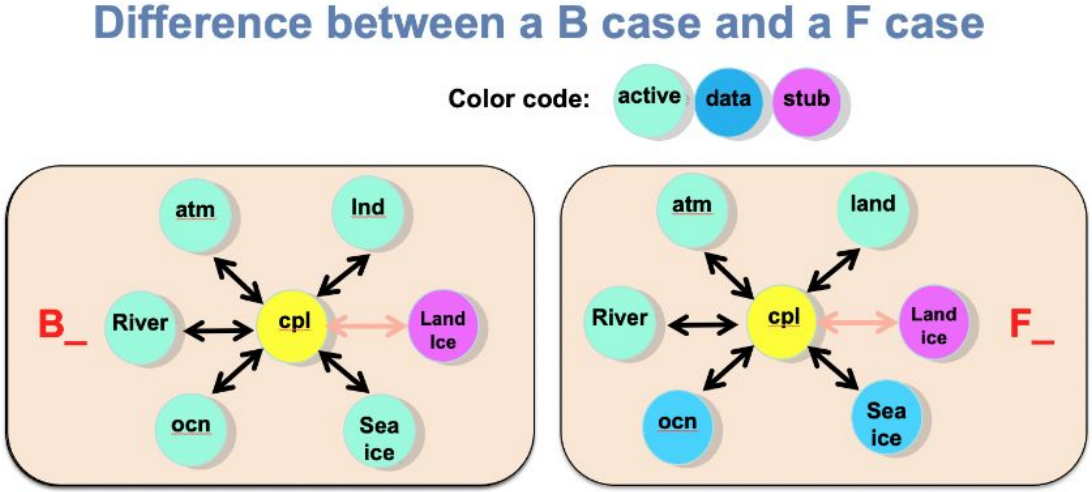
William Xu
Ocean

Rebecca Buchholz
Atmospheric Chemistry

Erik Kluzek
Land (SE)

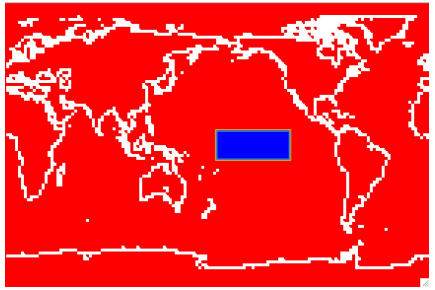
You are welcome to do exercises from different topics

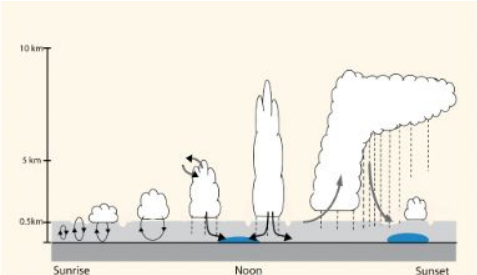
Difference between a B case and a F case



Proposed exercises

- Control: Use historical SSTs/forcings
- Use fixed pre-industrial forcing
- Change run starting date
- Modify sea surface temperature in the tropics
- Increase the triggering threshold for deep convection over land



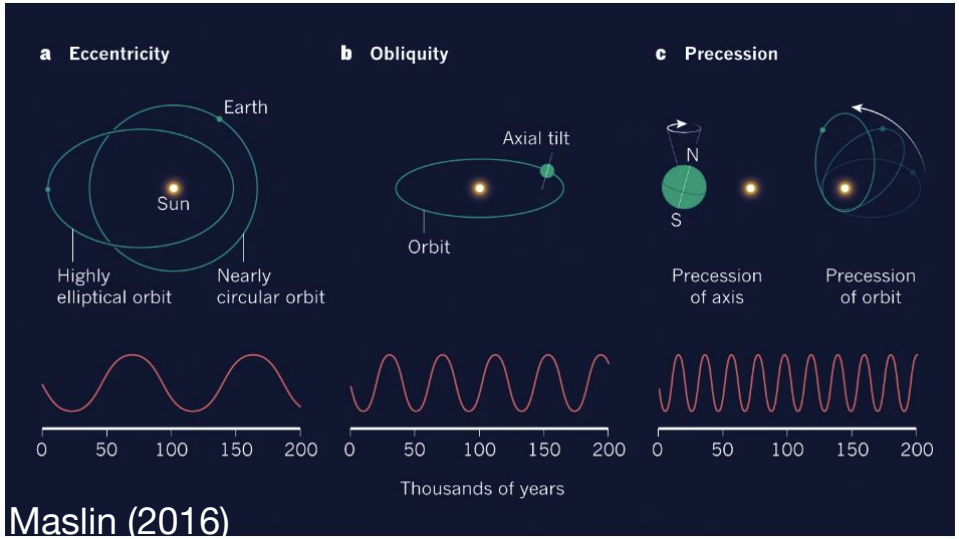


Paleo

Proposed exercises

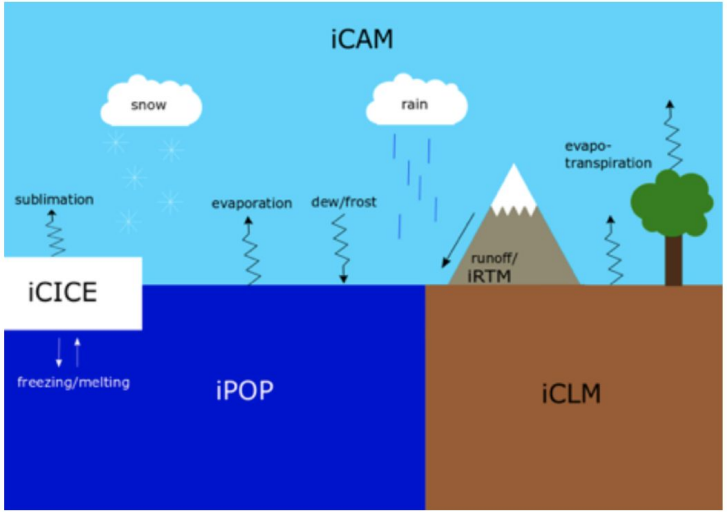
- How does Earth's orbit affect climate? —Recreate a mid-Holocene (~6 ka) paleo simulation inspired by the 1981 ***Science*** paper.

Kutzbach, 1981, Science
Otto-Bliesner & Kutzbach, 1982, JAS



Maslin (2016)

- Run a CESM simulation with water isotope tracers



Atmospheric Chemistry: CAM-chem or WACCM

Using F cases

Proposed exercises with the Low-Top model CAM-chem (FHISTC_LTt1s) or WACCM (FHISTC_WAt1ma)

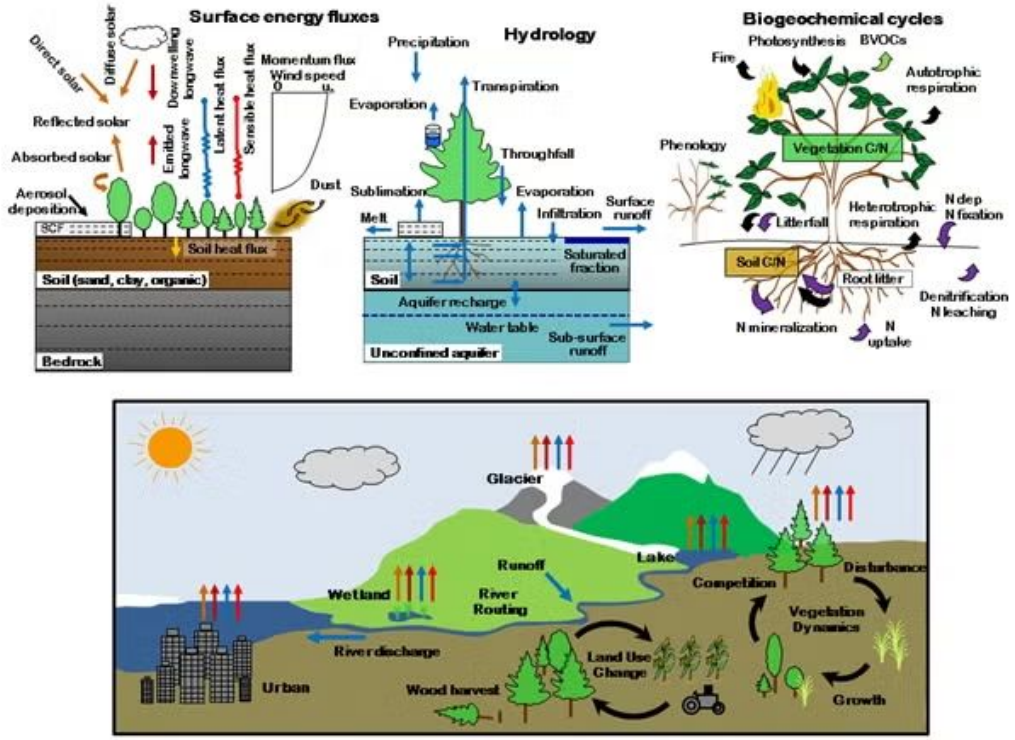
1. Run chemistry with daily output (control)
2. Change reaction rate in the chemical mechanism
3. Change emissions

e.g. of super-simple chemistry mechanism

```
 SPECIES
      Solution
O3, O, O1D -> O, O2, O2_1S -> O2, O2_1D -> O2
      End Solution

      Fixed
M, N2
      End Fixed
 End SPECIES

 Solution Classes
      Explicit
       CH4, N2O, CO, H2, CH3CL, CH3BR, CFC11, CFC12
      End explicit
      Implicit
       O3, O, O1D, O2, O2_1S, O2_1D
      End implicit
 End Solution Classes

 CHEMISTRY
      Photolysis
[jo2_a] O2 + hv -> O + O1D
      End Photolysis

      Reactions
 [cph1,cph] O + O3 -> 2*O2       ; 8e-12, -2060
      End Reactions
END CHEMISTRY
```

https://ncar.github.io/CESM-Tutorial/notebooks/challenge/cam-chem_waccm/cam-chem_waccm.html#

Land


Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Reflected solar
Absorbed solar
Emitted longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
Dust
Aerosol deposition
SCF
Soil heat flux
Soil (sand, clay, organic)
Bedrock
Hydrology
Precipitation
Transpiration
Evaporation
Throughfall
Sublimation
Evaporation
Melt
Infiltration
Surface runoff
Saturated fraction
Soil
Aquifer recharge
Water table
Sub-surface runoff
Unconfined aquifer
Biogeochemical cycles
Photosynthesis
BVOCs
Fire
Autotrophic respiration
Phenology
Vegetation C/N
Litterfall
Heterotrophic respiration
N dep
N fixation
Soil C/N
Root litter
Denitrification
N leaching
N mineralization
N uptake
Glacier
Runoff
Lake
Wetland
River Routing
Competition
Disturbance
Vegetation Dynamics
River discharge
Land Use Change
Urban
Wood harvest
Growth

Introduction to land only cases ("I" compsets)

Control: SP (Satellite Phenology) big-leaf vegetation

Test 1: BGC (Biogeochemistry) big-leaf vegetation

Test 2: FATES-SP (Functionally Assembled Terrestrial Ecosystem Simulator)) Ecosystem Demography vegetation

Test 3: Change an input parameter for FATES-SP

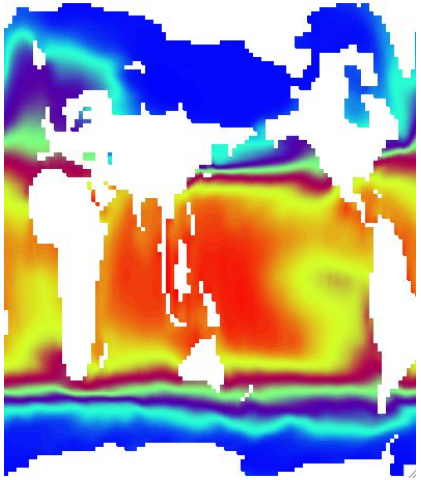
Proposed Exercise:

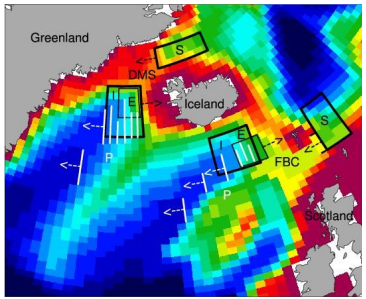
1. Run a control case: compset: I2000Clm60Sp at f19_f19_mt233
2. Run the experiment: compset: IHistClm60BgcCrop
3. Run the experiment: compset: I2000Clm60FatesSpCrujraRsGs
   a. Run without modifications
   b. Change an input parameter "VCMAX"
4. Compare case/results with control – what's different about them?
5. Compare and investigate FATES

Ocean

CESM-MOM6 exercise:

1. Run a G compset forced by JRA55 atmospheric data as a control case.
2. Turn off submesoscale parameterization to assess its impact.
3. Modify wind stress.
4. Turn on the ecosystem.

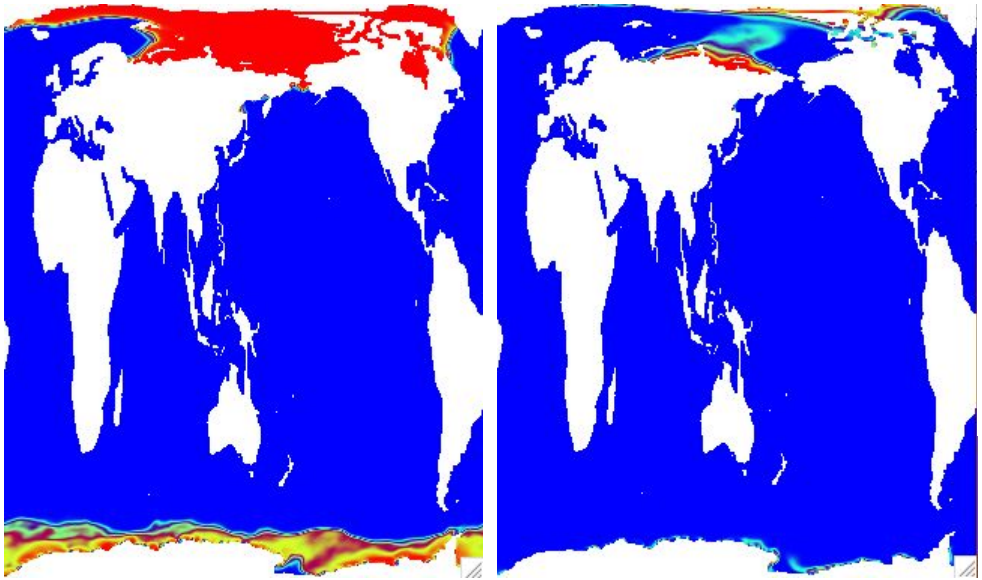


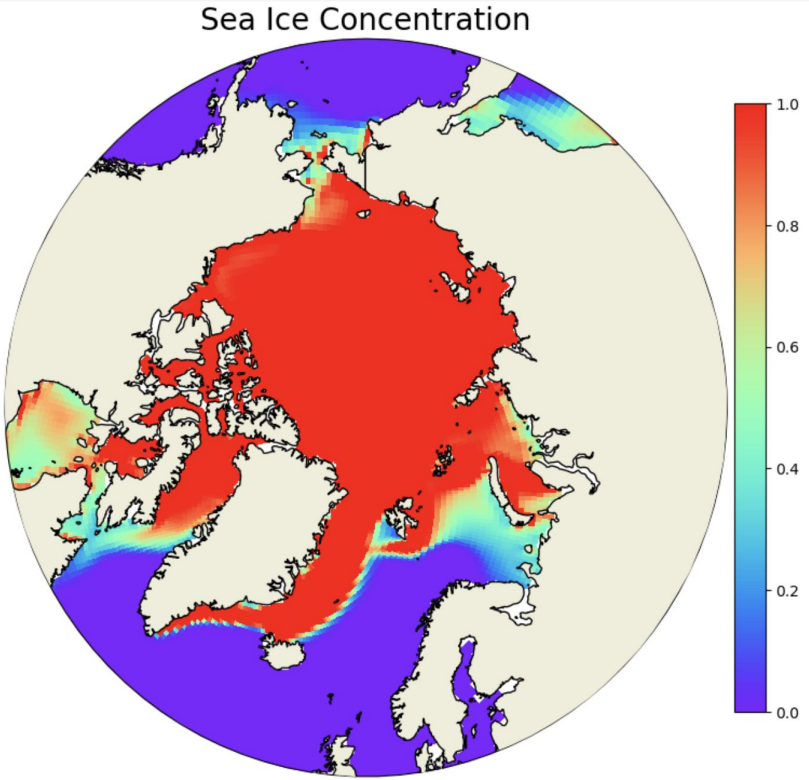


Sea ice

Proposed exercises

- Run a G compset with “normal year forcing”.
- Adjust the sea ice “albedo”.
- Modify the snow conductivity.



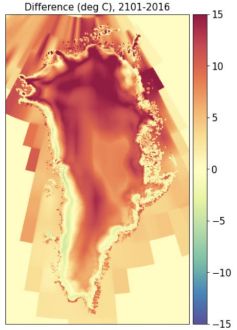


Land ice

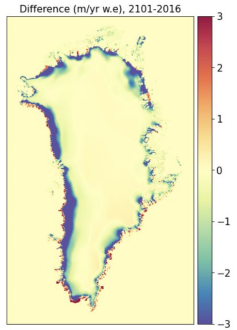
Proposed exercises

- Run a T compset and simulate the Greenland ice sheet evolution in CESM.
- Compute offline global sea level contribution from ice sheet.

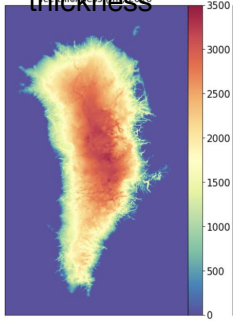
SMB



Temperature



Ice thickness



Difference between a B and a T case

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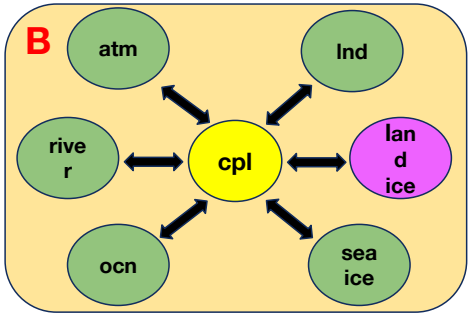
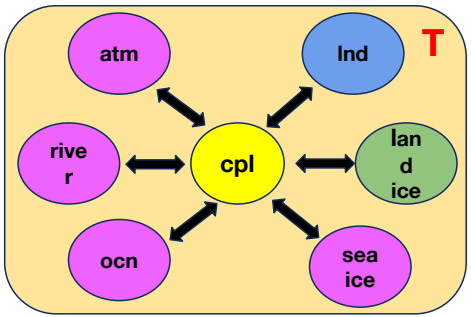
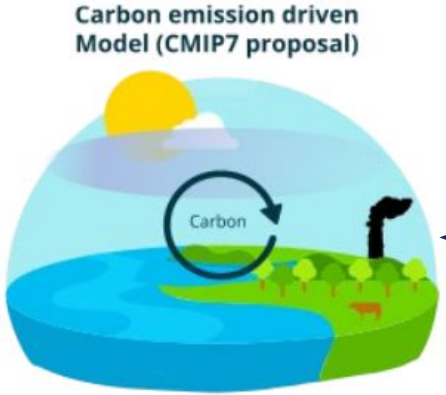




Proposed exercises

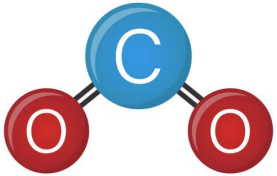
- Check out CESM2.1.5
- Set up two different BGC cases and compare case directories (you will **not** be running the model for this exercise)
- Compsets: B1850 and B1850_BPRP
- Both have f19_g17 resolution



Closed carbon cycle. CO_2 concentrations, aerosols and calculated as a function of human emissions and land use

Figure from Sanderson et al., 2023

Differences concern how CO_2 is handled:



Prognostic CO_2

- Compset = B1850_BPRP
- "Emission-driven"
- Predicted atmospheric CO_2 concentrations, computed from surface fluxes

Diagnostic CO_2

- Compset = B1850
- "Concentration-driven"
- Prescribed atmospheric CO_2 concentrations that are read from a file

See setup script and analysis notebooks:

https://github.com/NCAR/CESM-emission-driven-run-tutorial

Machine Learning