The Impact of Model Resolution on Climate in NorESM3

...

Results from a Mini Perturbed Parameter Ensemble (PPE)
Using CAM7 at 2-degree resolution

Ada Gjermundsen, Johannes L. Fjeldsjå, Steve Goldhaber, Dirk Olivié, Kjetil S. Aas
+ the NorESM team

What is the Norwegian Earth System Model (NorESM)?

- Developed since 2008 as a consortium effort.
- Contributed to CMIP5 and CMIP6.
- More than 60 national users/developers, using NorESM in ~50 projects.
- Constraints: limited long-term basic funding, HPC and storage costs included in project budgets.

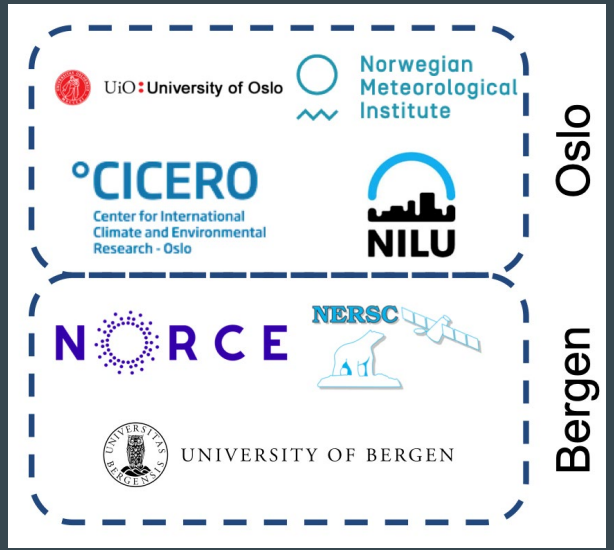
Versions used in CMIP:

- **NorESM1-M, NorESM1-ME** (CMIP5)
- **NorESM2-LM:** 2° horizontal resolution for atmosphere and land, 1° for ocean and sea ice (CMIP6)
- **NorESM2-MM:** resolution similar to CESM2 (CMIP6)
- **NorCPM**: NorESM adaptation for EnKF data assimilation and climate prediction applications (CMIP6)

NorESM3:

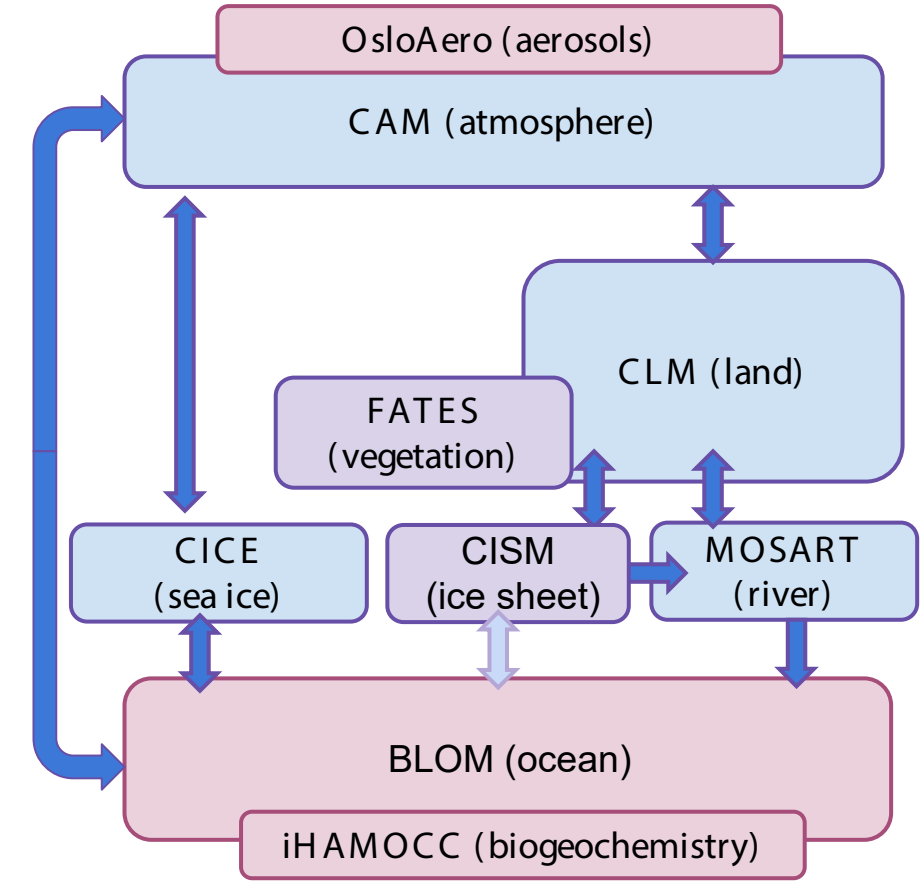
- Currently developing **NorESM3** for CMIP7.
- Model resolution similar to CESM3.
- Model “chill” on 15th of June.

Consortium members:



The Norwegian Earth System Model

NorESM =



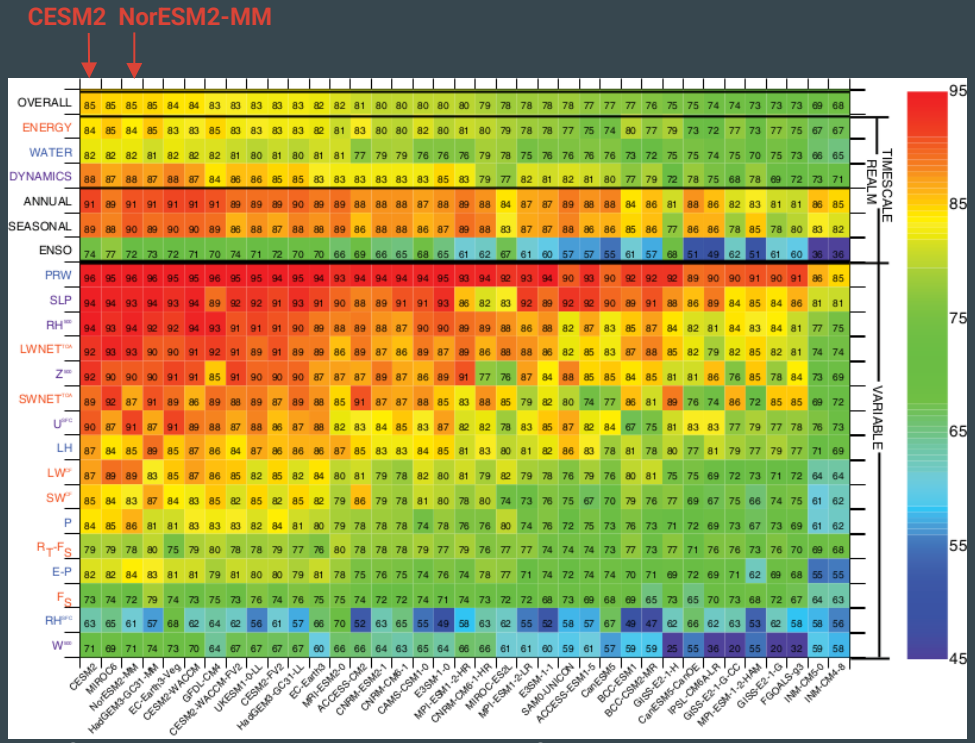
CESM-based component

Unique to NorESM

Joint development efforts

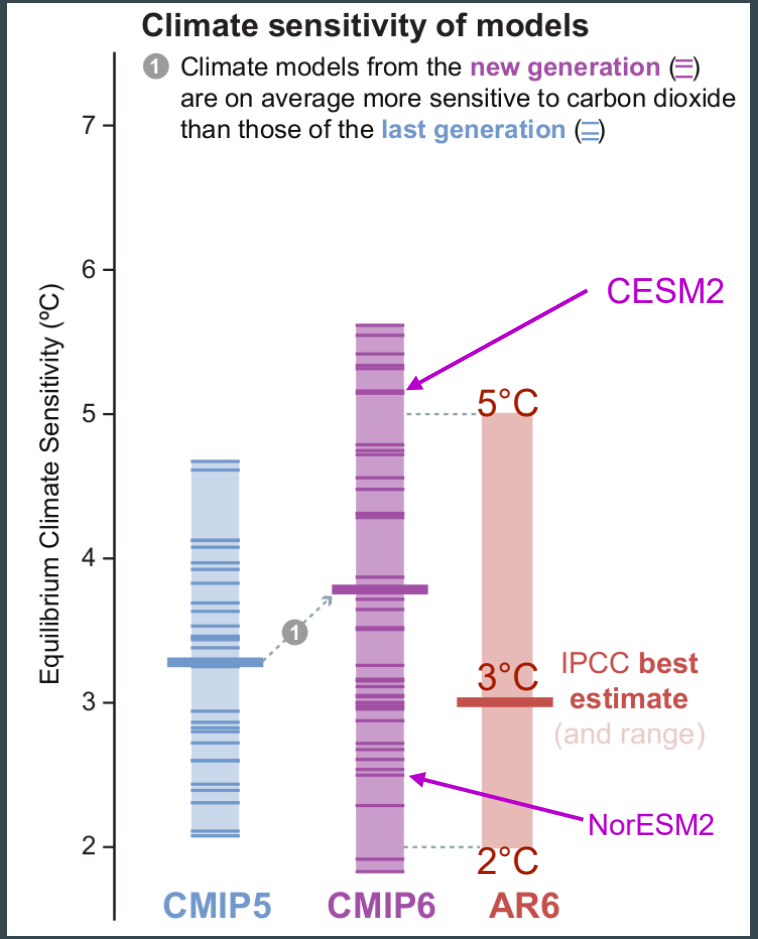
CMEPS

CESM2 and NorESM2



Performance across CMIP6 models for historical simulations

Source: Fasullo 2020, GMD



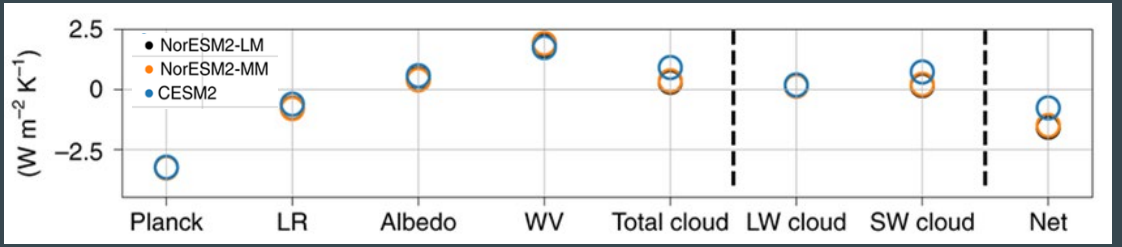
Source: IPCC AR6 (2021), WG1 Chapter 7

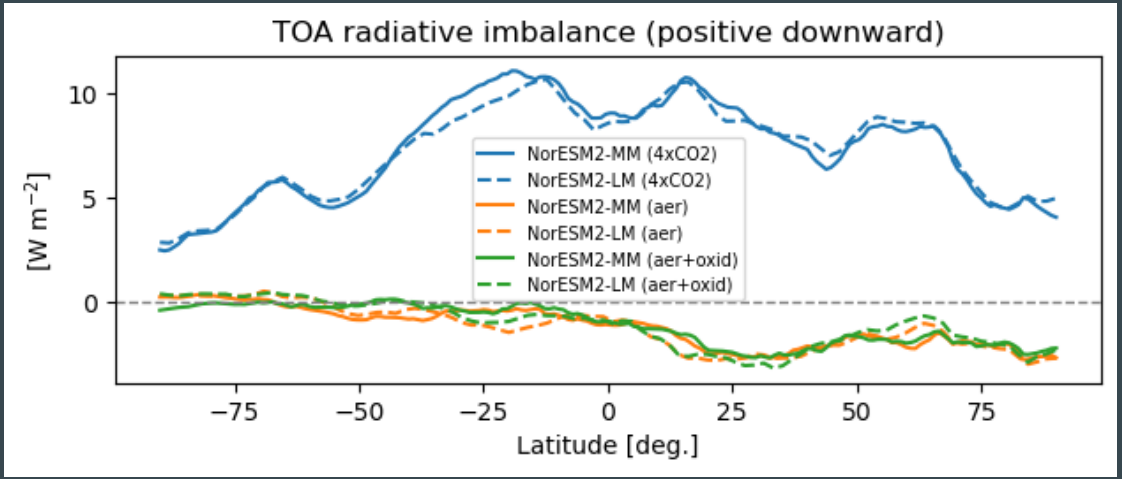
Experience from the CMIP6 versions of NorESM

Radiative forcing, feedbacks, and climate sensitivity are similar across model resolutions

- **NorESM2-LM:** 2° horizontal resolution for atmosphere and land, 1° for ocean and sea ice (CMIP6)
- **NorESM2-MM:** resolution similar to CESM2 (CMIP6)

NorESM2-LM was used extensively for CMIP6 production runs and research projects due to its high efficiency and lower computational cost.





Radiative forcing [W m^{-2}] (global mean)		
	NorESM2-MM (1 degree)	NorESM2-LM (2 degree atm + lnd)
4xCO2	8.39±0.06	8.23±0.07
Aerosols	-1.26±0.07	-1.37±0.06
Aerosols + oxidants	-1.11±0.08	-1.23±0.06

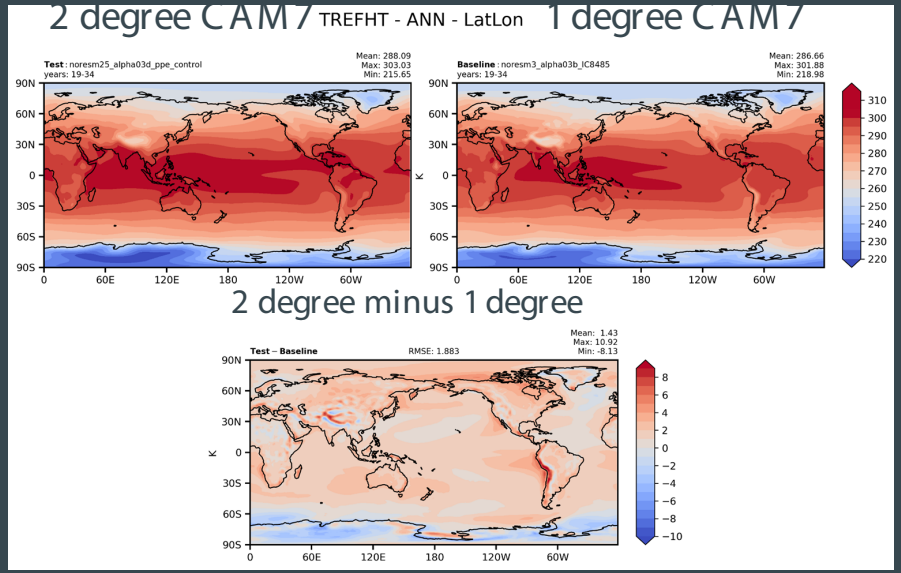
Courtesy: D. Olivié, Gjermundsen et al. (2021)

CAM7-NOR at 2 degree resolution

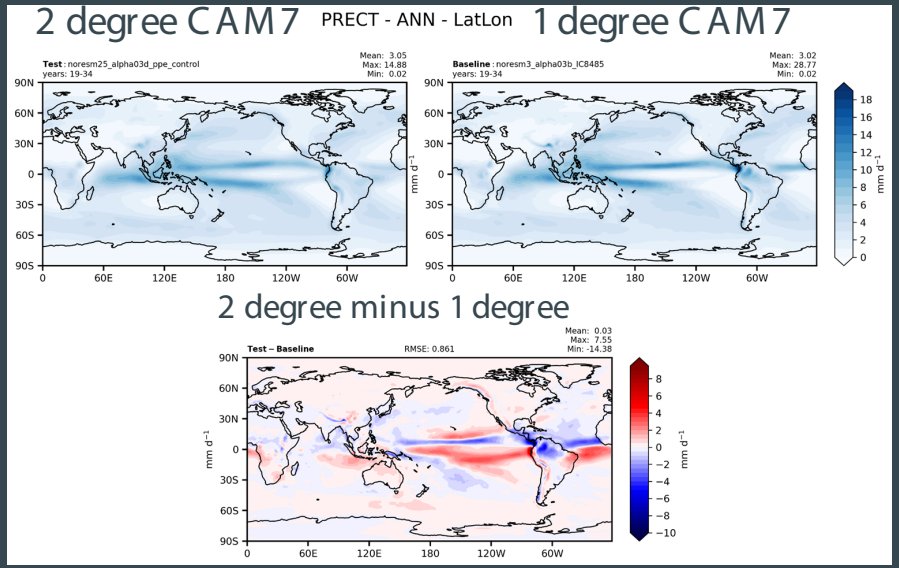
- **Motivation:** To develop a faster and more cost-efficient version of NorESM3, based on the one-degree configuration.
- CAM7 configuration for NorESM is similar to CESM/CAM. Some differences:
  - "Oslo Aero" module for aerosol physics and chemistry: independently developed module for the life cycle of particulate aerosols, and the representation of aerosol–radiation–cloud interactions
  - modified atm/ocn flux calculation
  - Different secondary ice scheme (RaFSIP from Georgakaki & Nenes)
  - Coupling to ocean (aerosols)
- Using ne16pg3_ne16pg3_mtn14 grid (ocean mask is different for NorESM)
- Using same files and settings as CESM for bnd_topo, SE dycore, drydep, etc. (compared to cam6_4_085)
- Currently using initial conditions spun up using the NorESM AMIP configuration

One-Degree vs. Two-Degree Resolution in NorESM3dev (Development Version)

Surface (2 m) air temperature



Precipitation

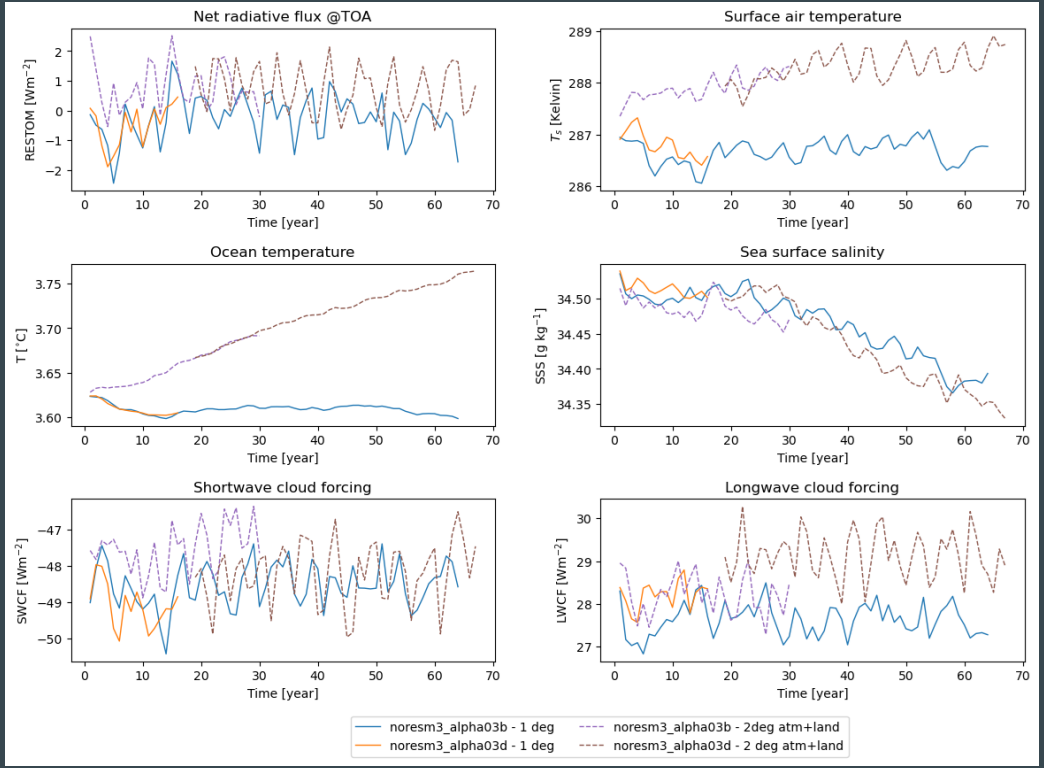


One-Degree vs. Two-Degree Resolution in NorESM3dev (Development Version)

Compared to the one-degree version (solid line), the two-degree version (dashed line):

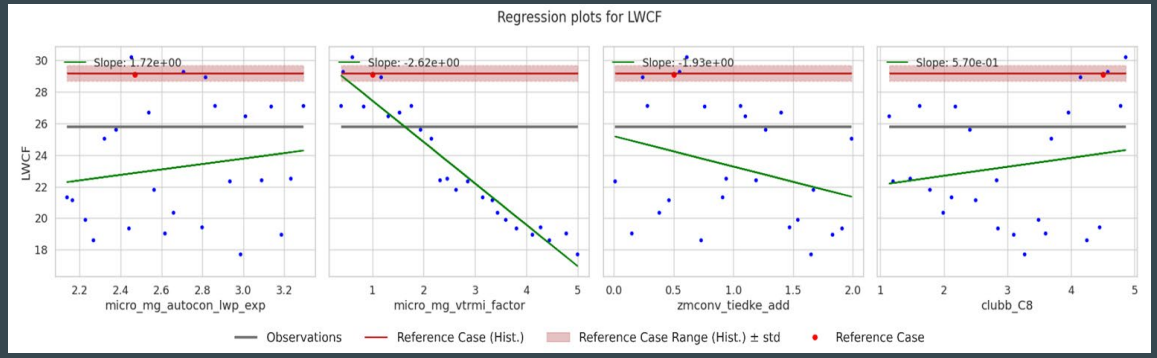
- Exhibits a positive RESTOM
- Is warmer at the surface and continues to warm
- Has a more positive longwave cloud forcing (LWCF)
- Shows similar drift in sea surface salinity (SSS)
- Has similar shortwave cloud forcing (SWCF)

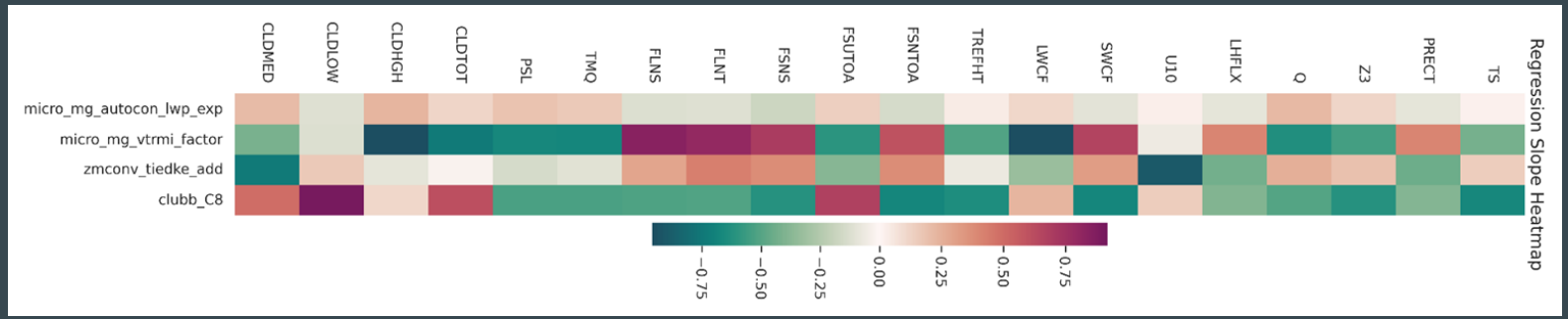
Globally Averaged Time Series



Preliminary PPE Results for NorESM3dev at 2-Degree Resolution

- Mini-PPE with 25 members
- Run in **coupled** configuration
- Four parameters adjusted: micro_mg_autocon_lwp_exp, micro_mg_vtrmi_factor, zmconv_tiedke_add, clubb_C8





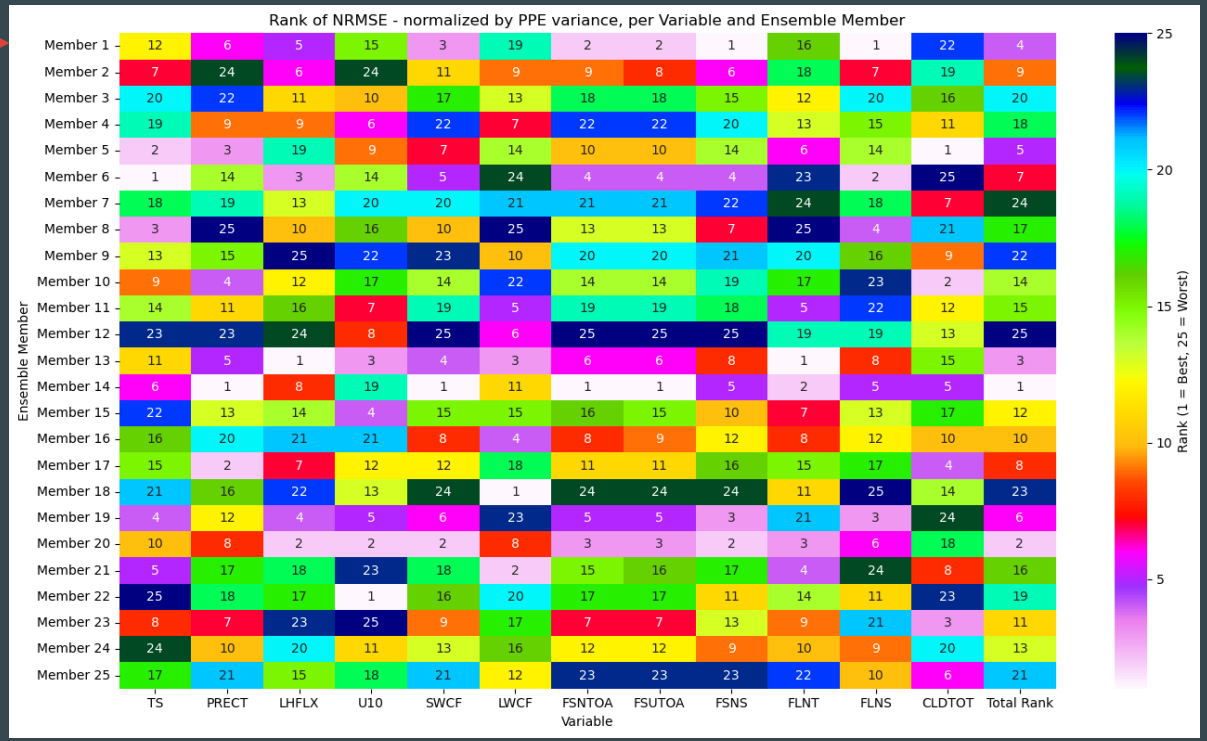
Courtesy: Johannes L. Fjeldsjå

Preliminary PPE Results for NorESM3dev at 2 degree resolution

Member 1 is the reference case, with identical setup as the 1-degree NorESM3dev version.

We will rank the members to identify which are most suitable for longer simulations.

This table needs some further work (and maybe a less intense colormap)



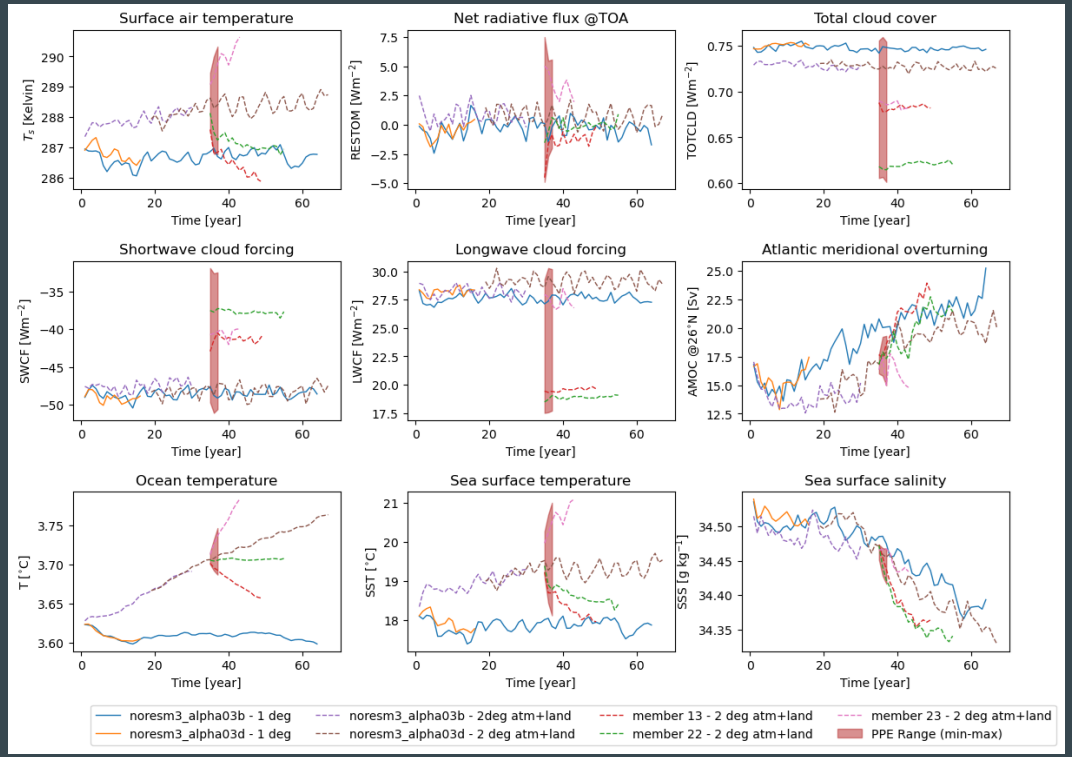
Preliminary PPE Results for NorESM3dev at 2 degree resolution

One-degree version (solid line),
Two-degree version (dashed line),
PPE range (shading)

Even with a mini-PPE, the ensemble spans a wide range of values.

We will continue a subset of members to investigate long-term behavior.

Globally Averaged Time Series



Outlook

- We need to further investigate whether the 2-degree version of NorESM3dev exhibits similar forcing and feedbacks as the 1-degree version.
- We hope to tune the CMIP7 version of NorESM3 (at 1-degree resolution) using results from the 2-degree version PPE in coupled mode.
- We aim to streamline the workflow—building, running, and analyzing the PPE—so it becomes straightforward for NorESM developers to use.
- NorESMhub: https://github.com/NorESMhub
- NorESM3dev: https://github.com/NorESMhub/noresm3_dev_simulations
- If you have questions, please email me: adag@met.no or adagj@geo.uio.no