# The Impact of Model Resolution on Climate in NorESM3

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

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## 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:





## CESM2 and NorESM2

#### CESM2 NorESM2-MM



Performance across CMIP6 models for historical simulations

**Climate sensitivity of models**  Climate models from the new generation (Ξ) are on average more sensitive to carbon dioxide 7. than those of the last generation  $(\equiv)$ 6 CESM2 Sensitivity (°C) 5°C 5 Equilibrium Climate IPCC best 300 estimate 3 NorESM2 2 2°C CMIP6 CMIP5 AR6

Source: IPCC AR6 (2021), WG1 Chapter 7

Source: Fasullo 2020, GMD

## 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 <sup>-2</sup> ] (global mean) |                       |                                 |  |  |  |  |  |
|--|-----------------------|---------------------------------|--|--|--|--|--|
|  | NorESM2-MM (1 degree) | NorESM2-LM (2 degree atm + Ind) |  |  |  |  |  |
| 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 (<u>RaFSIP from Georgakaki & Nenes</u>)
  - 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





## Preliminary PPE Results for NorESM3dev at 2 degree resolution

Member 1 is the reference case, with identical setup as the 1degree 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)

|                  |    |       | Rank of | NRMSE - | normalize | d by PPE | variance, | per Varia | ble and E | Insemble | Member |        |            |         |
|------------------|----|-------|---------|---------|-----------|----------|-----------|-----------|-----------|----------|--------|--------|------------|---------|
| Member 1 -       | 12 | 6     | 5       | 15      | 3         | 19       | 2         | 2         | 1         | 16       | 1      | 22     | 4          | - 25    |
| Member 2 -       | 7  | 24    | 6       | 24      | 11        | 9        | 9         | 8         | 6         | 18       | 7      | 19     | 9          |         |
| Member 3 -       | 20 | 22    | 11      | 10      | 17        | 13       | 18        | 18        | 15        | 12       | 20     | 16     | 20         |         |
| Member 4 -       | 19 | 9     | 9       | 6       | 22        | 7        | 22        | 22        | 20        | 13       | 15     | 11     | 18         |         |
| Member 5 -       | 2  | 3     | 19      | 9       | 7         | 14       | 10        | 10        | 14        | 6        | 14     | 1      | 5          |         |
| Member 6 -       | 1  | 14    | 3       | 14      | 5         | 24       | 4         | 4         | 4         | 23       | 2      | 25     | 7          | - 20    |
| Member 7 -       | 18 | 19    | 13      | 20      | 20        | 21       | 21        | 21        | 22        | 24       | 18     | 7      | 24         |         |
| Member 8 -       | 3  | 25    | 10      | 16      | 10        | 25       | 13        | 13        | 7         | 25       |        | 21     | 17         |         |
| Member 9 -       | 13 | 15    | 25      | 22      | 23        | 10       | 20        | 20        | 21        | 20       | 16     |        | 22         |         |
| Member 10 -      | 9  |       | 12      | 17      | 14        | 22       | 14        | 14        | 19        | 17       | 23     | 2      | 14         | rst)    |
| ັອຼ Member 11 -  | 14 | 11    | 16      | 7       | 19        | 5        | 19        | 19        | 18        | 5        | 22     | 12     | 15         | - 15 နိ |
| Member 12 -      | 23 | 23    | 24      | 8       | 25        | 6        | 25        | 25        | 25        | 19       | 19     | 13     | 25         | 25 =    |
| ے Member 13      | 11 | 5     | 1       | 3       | 4         | 3        | 6         |           |           | 1        |        | 15     | 3          | est,    |
| E Member 14 -    | 6  | 1     | 8       | 19      | 1         | 11       | 1         | 1         |           | 2        |        | 5      | 1          | ă<br>I  |
| မို့ Member 15 - | 22 | 13    | 14      | 4       | 15        | 15       | 16        | 15        | 10        | 7        | 13     | 17     | 12         | ć (1    |
| Member 16 -      | 16 | 20    | 21      | 21      |           |          |           |           | 12        | 8        | 12     | 10     | 10         | - 10 gu |
| Member 17 -      | 15 | 2     | 7       | 12      | 12        | 18       | 11        | 11        | 16        | 15       | 17     |        | 8          |         |
| Member 18 -      | 21 | 16    | 22      | 13      | 24        | 1        | 24        | 24        | 24        | 11       | 25     | 14     | 23         |         |
| Member 19 -      |    | 12    | 4       | 5       | 6         | 23       | 5         |           | 3         | 21       | 3      | 24     | 6          |         |
| Member 20 -      | 10 | 8     | 2       | 2       | 2         | 8        | 3         | 3         | 2         | 3        |        | 18     | 2          |         |
| Member 21 -      |    | 17    | 18      | 23      | 18        | 2        | 15        | 16        | 17        |          | 24     |        | 16         | - 5     |
| Member 22 -      | 25 | 18    | 17      | 1       | 16        | 20       | 17        | 17        | 11        | 14       | 11     | 23     | 19         |         |
| Member 23 -      |    |       | 23      | 25      | 9         | 17       | 7         |           | 13        | 9        | 21     | 3      | 11         |         |
| Member 24 -      | 24 | 10    | 20      | 11      | 13        | 16       | 12        | 12        |           | 10       |        | 20     | 13         |         |
| Member 25 -      | 17 | 21    | 15      | 18      | 21        | 12       | 23        | 23        | 23        | 22       | 10     | 6      | 21         |         |
|                  | тs | PRECT | LHFLX   | UIO     | SWCF      | LWCF     | FSNTOA    | FSUTOA    | FSNS      | FLNT     | FLNS   | CLDTOT | Total Rank |         |

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## 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.



## 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.
- NorESM hub: <u>https://github.com/NorESM hub</u>
- NorESM3dev: <u>https://github.com/NorESMhub/noresm3\_dev\_simulations</u>
- If you have questions, please email me: <a href="mailto:adag@met.no">adag@@geo.uio.no</a>