

Introduction to NorESM



Mats Bentsen^{1,2}

¹ NORCE Norwegian Research Centre

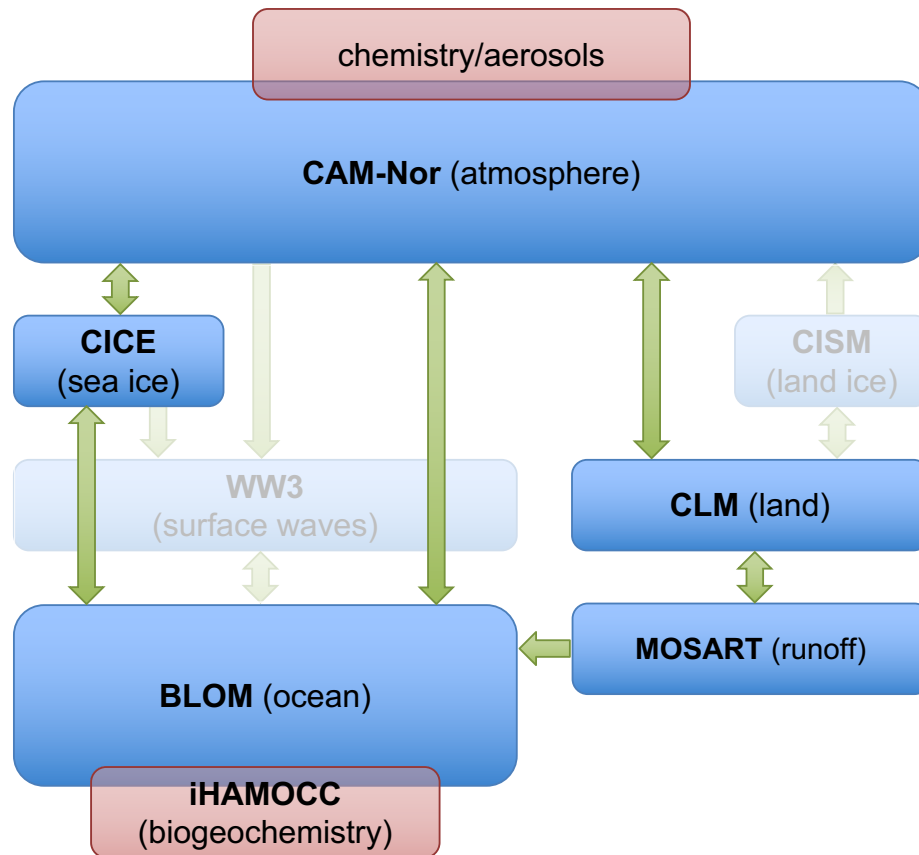
² Bjercknes Centre for Climate Research

Outline

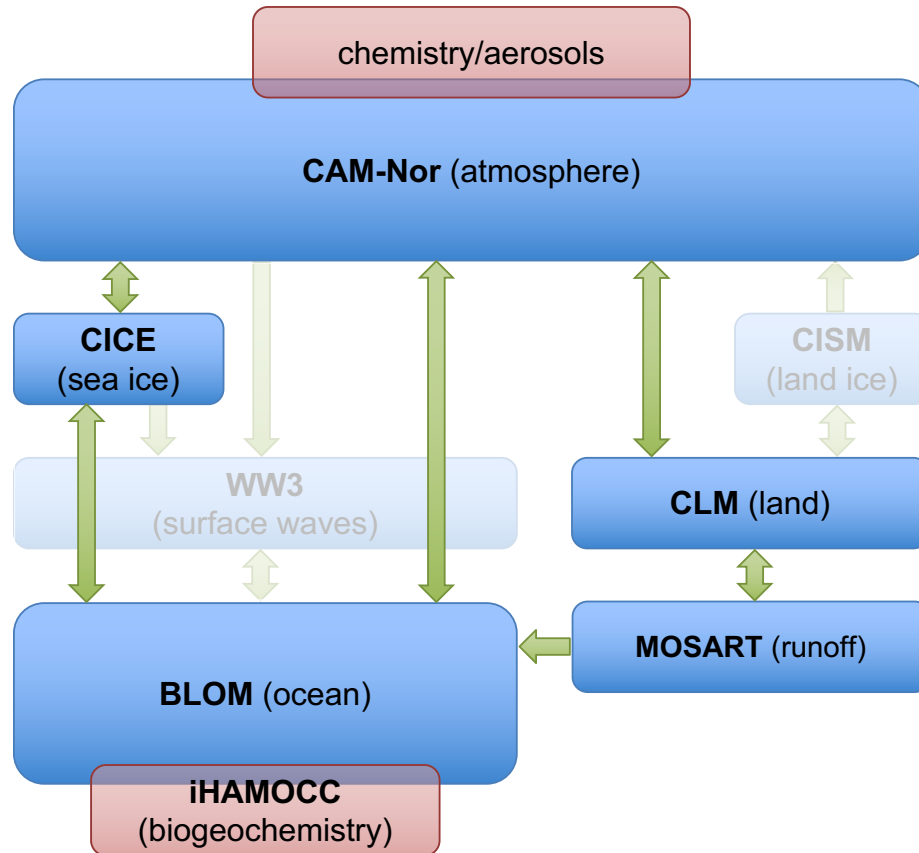
- NorESM overview and differences to CESM
- Some dynamical and physical characteristics
- Scientific updates in NorESM2 compared to NorESM1
- CMIP6 status
- NorESM infrastructure
- Plans for further NorESM development
- Workshop agenda

Norwegian Earth System Model (NorESM)

Based on Community Earth System Model (CESM) of NCAR, Boulder, USA.



Norwegian Earth System Model (NorESM)



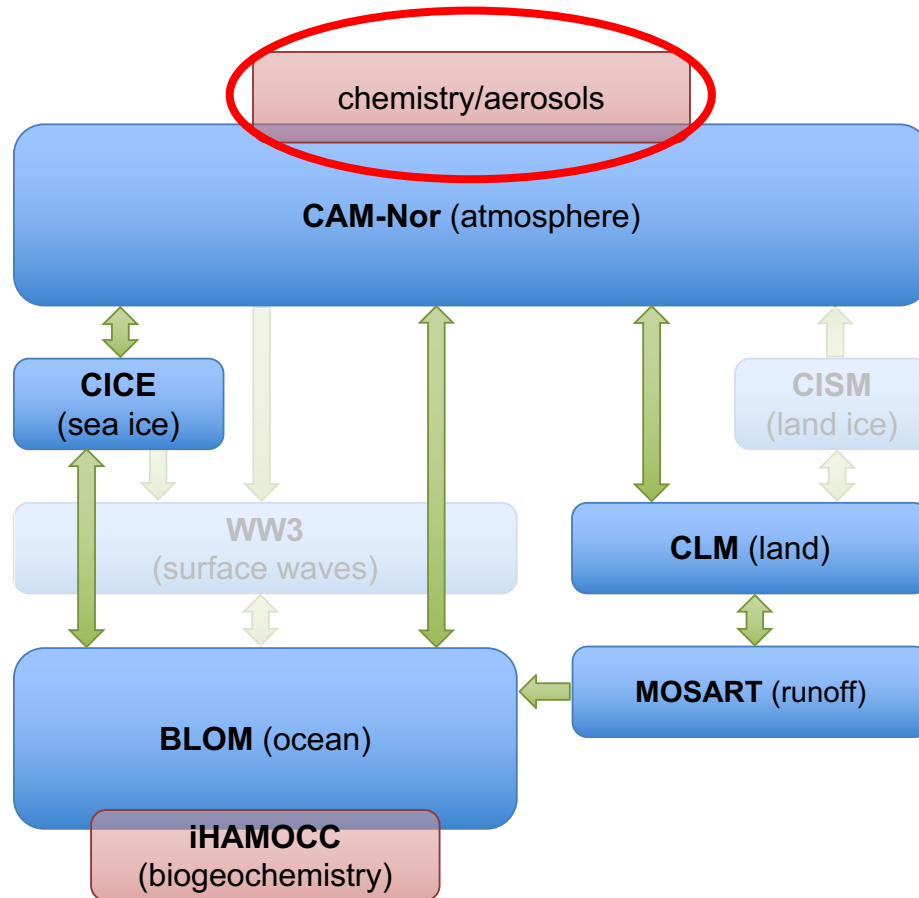
Consortium:



Norwegian Earth System Model (NorESM)

Specific NorESM additions to CESM:

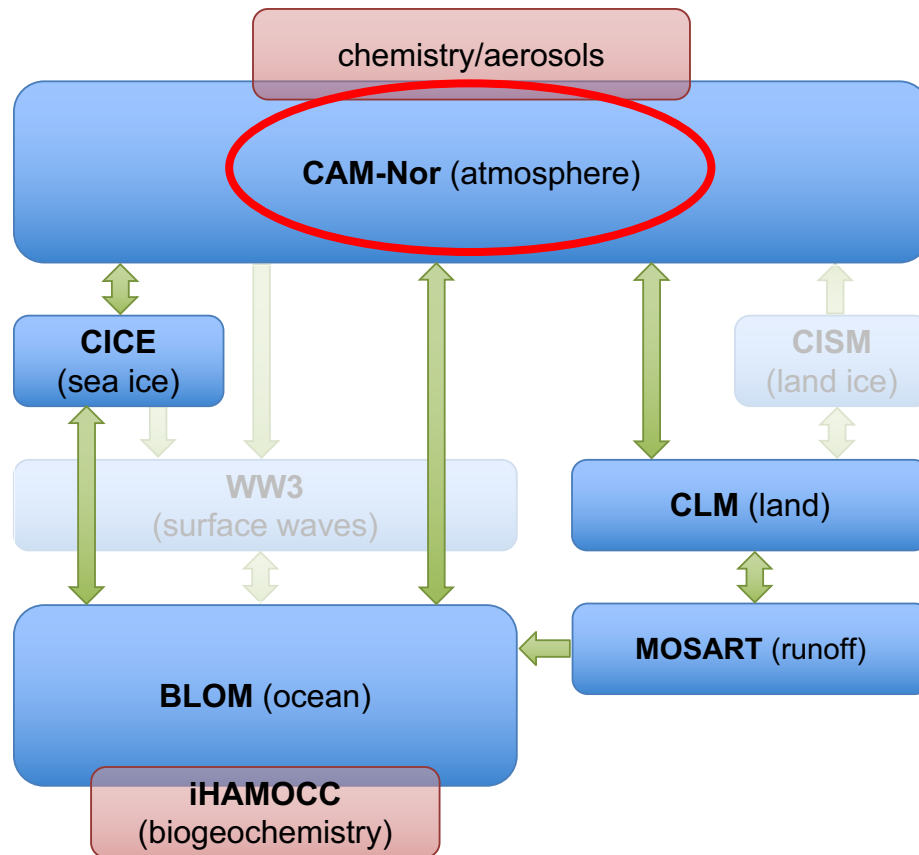
- Atmospheric chemistry/aerosol/cloud module



Oslo



Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

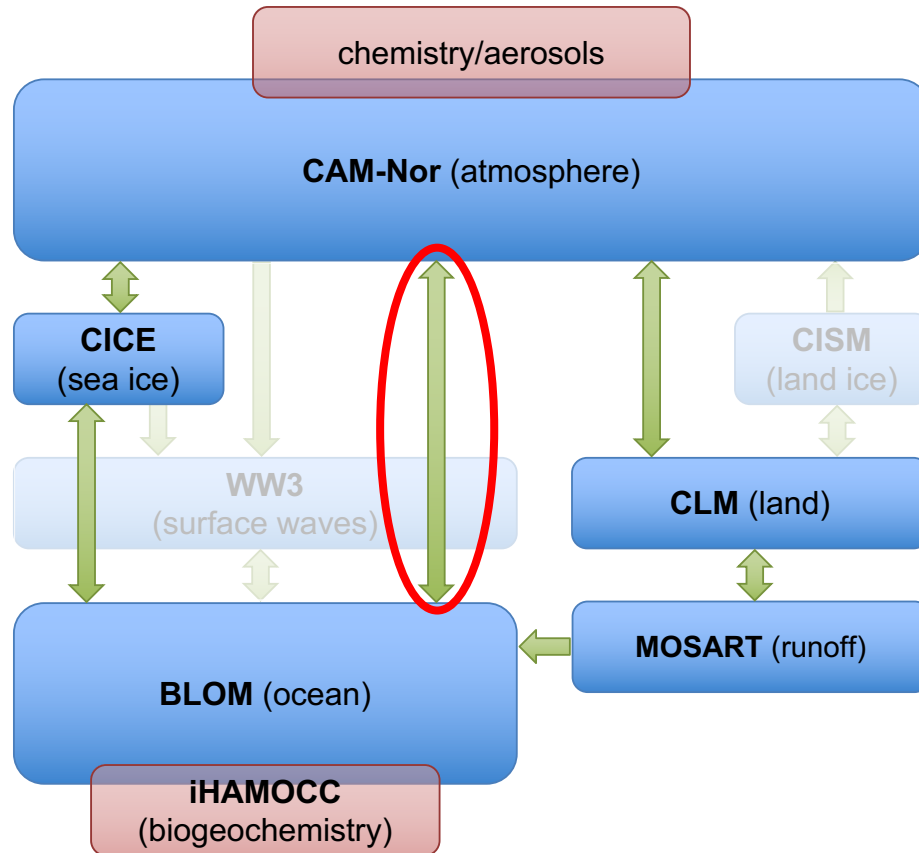
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum



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Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

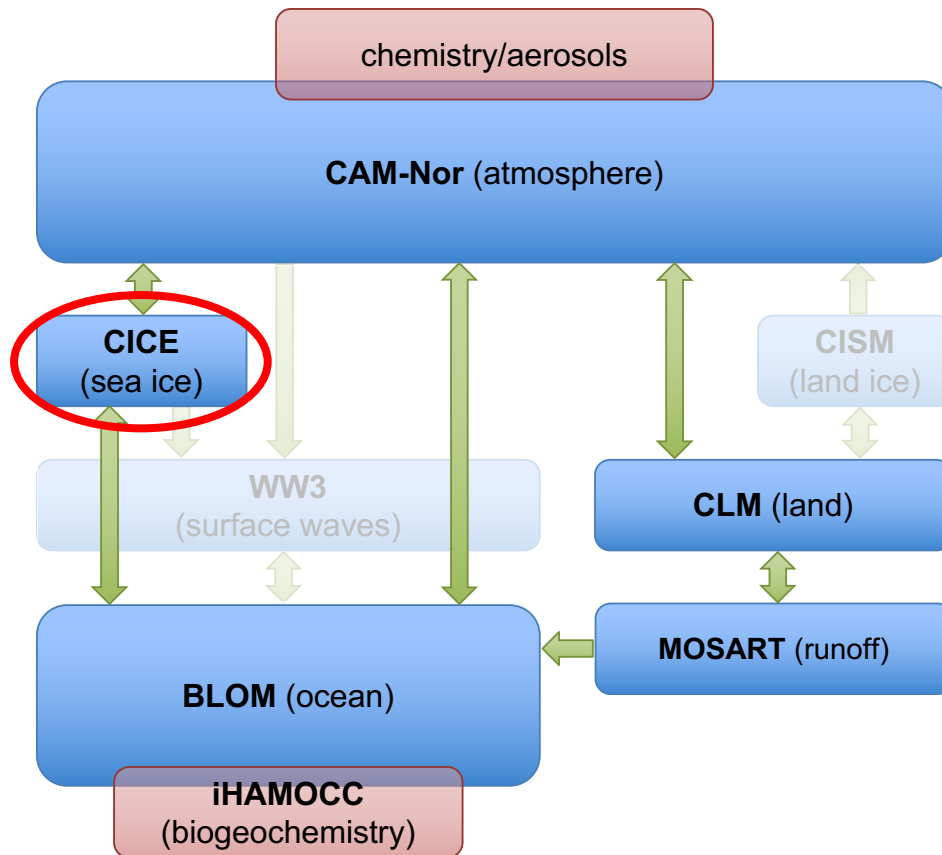
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes



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Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

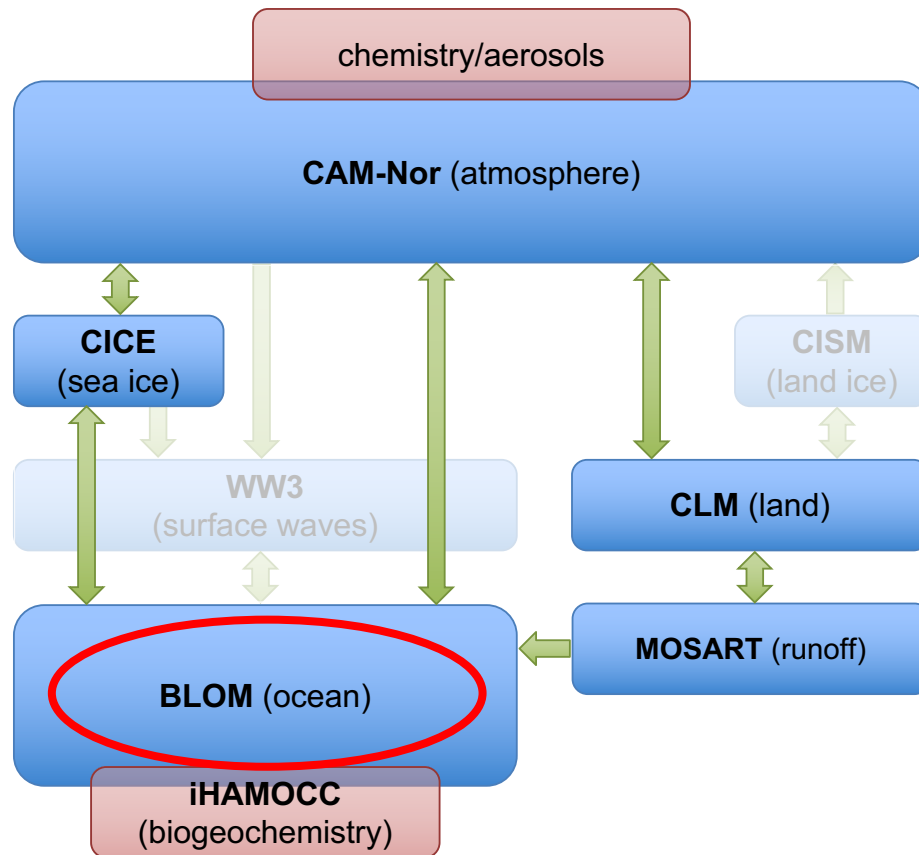
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes
- Wind drift of snow



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Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

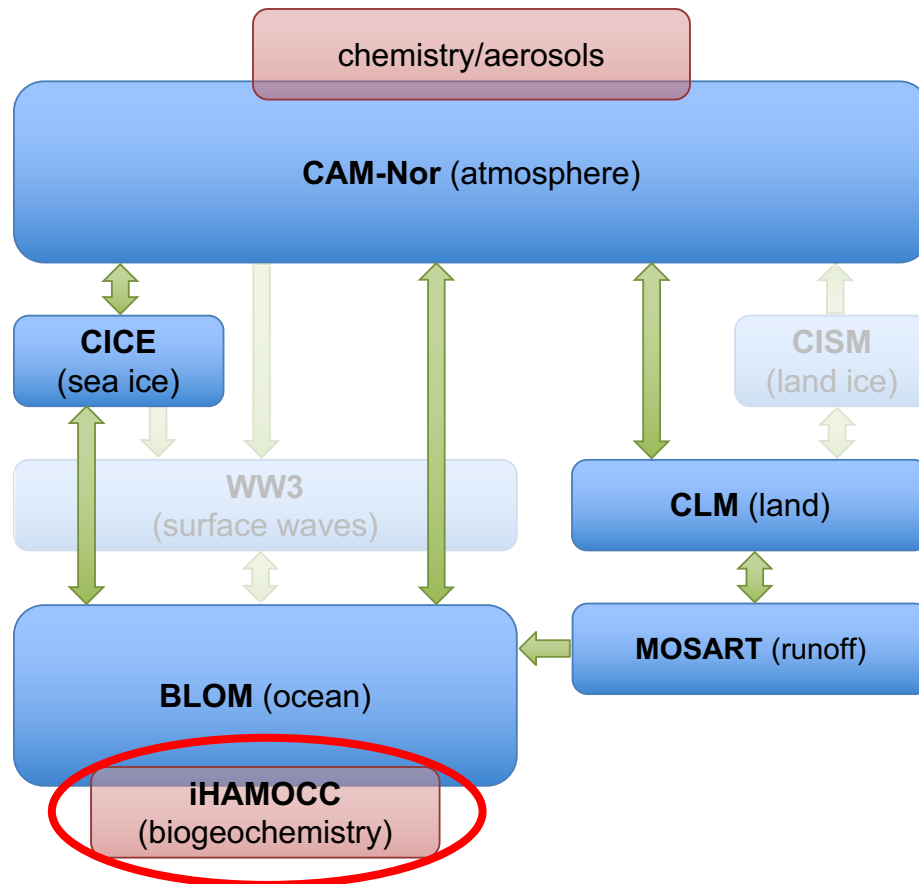
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes
- Wind drift of snow
- Ocean component with isopycnic vertical coordinate



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Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes
- Wind drift of snow
- Ocean component with isopycnic vertical coordinate
- Hamburg Model of Ocean Carbon Cycle (HAMOCC) adopted for use with isopycnic ocean model and further developed



UNIVERSITY OF BERGEN

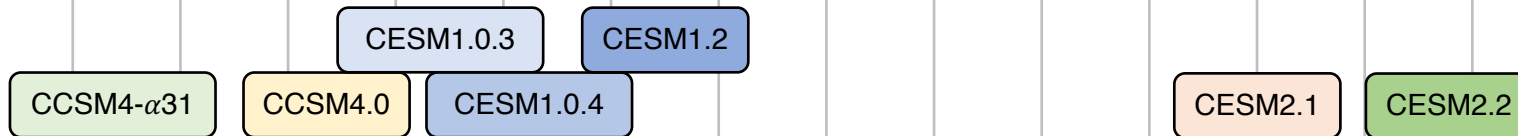
NORCE

Bergen

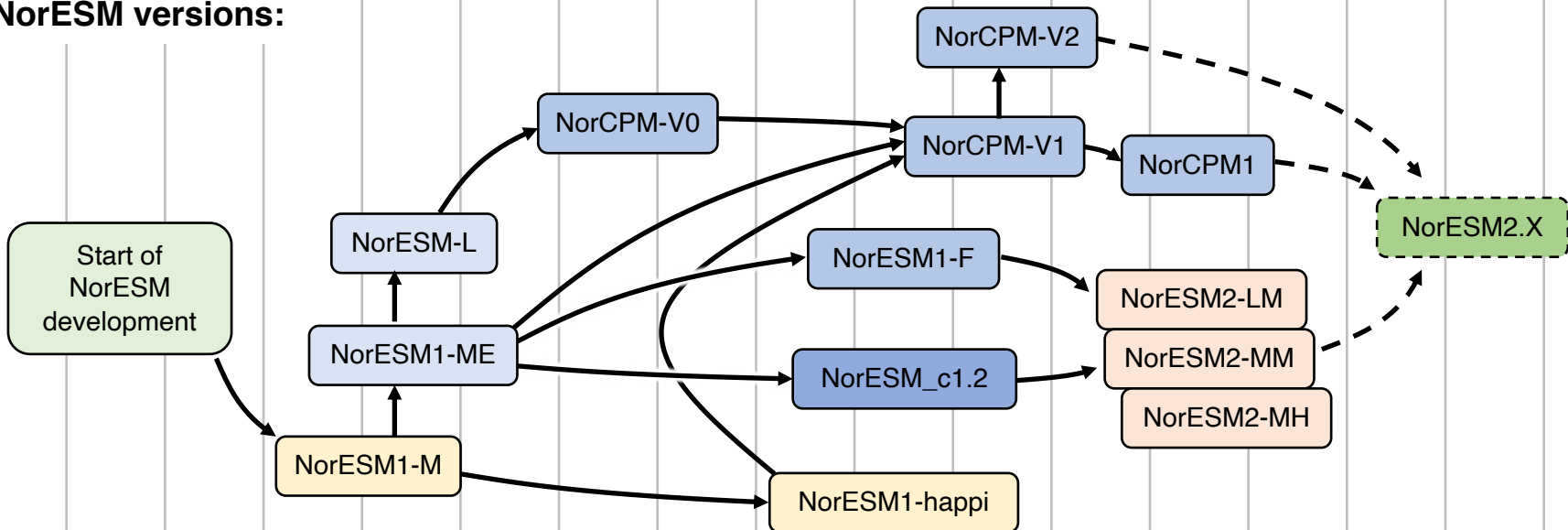


NorESM genealogy

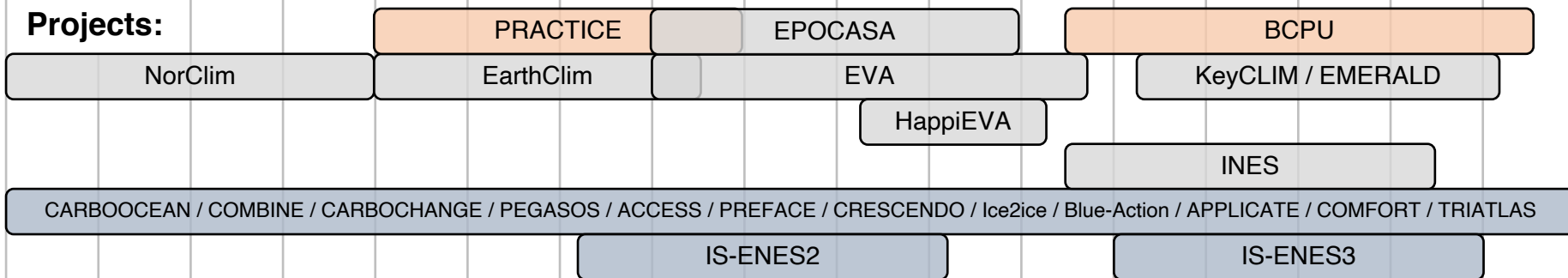
CCSM/CESM versions:



NorESM versions:



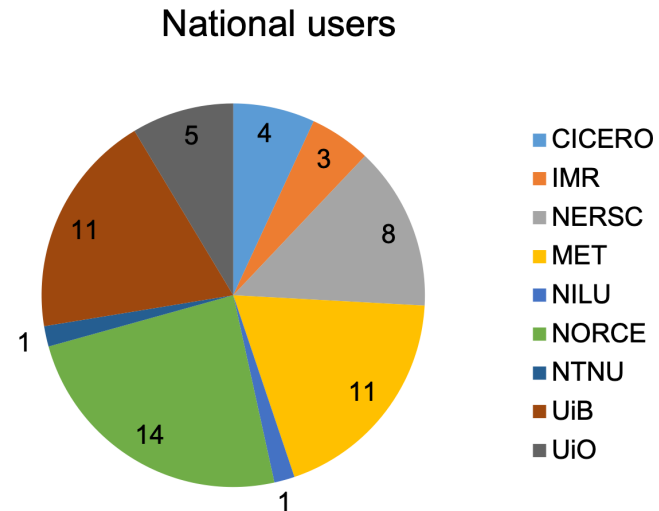
Projects:



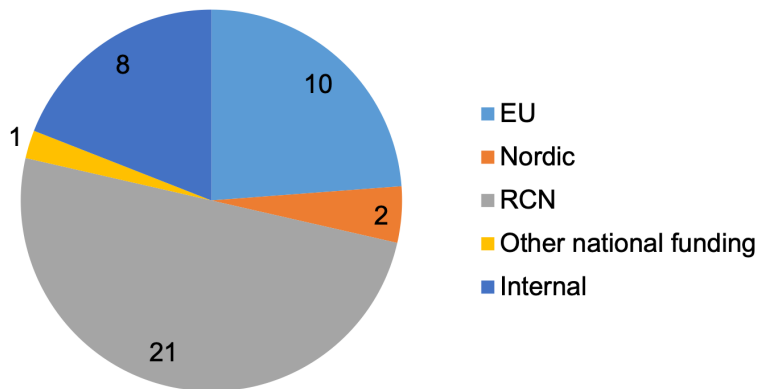
2007 2009 2011 2013 2015 2017 2019 2021 2023

Users and developers of NorESM

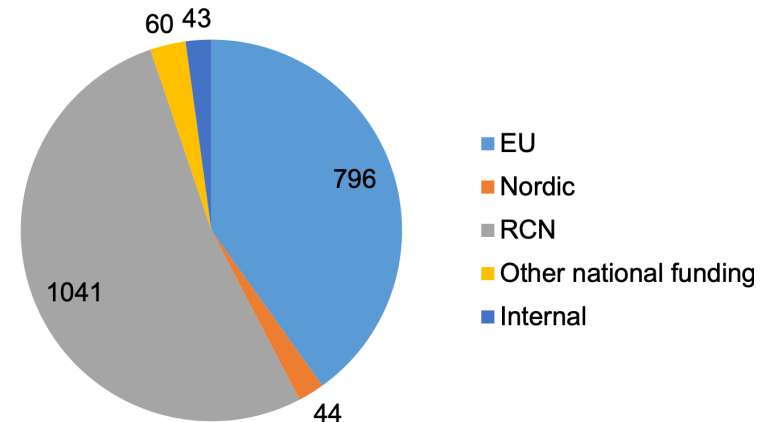
- Based on a survey from February 2021.
- In total 58 national users and developers of NorESM in 2020.



Number of projects



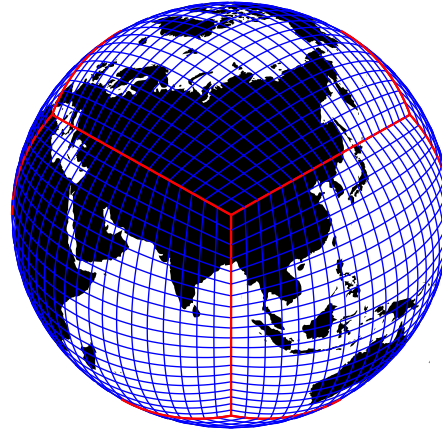
Total grant size (MNOK)



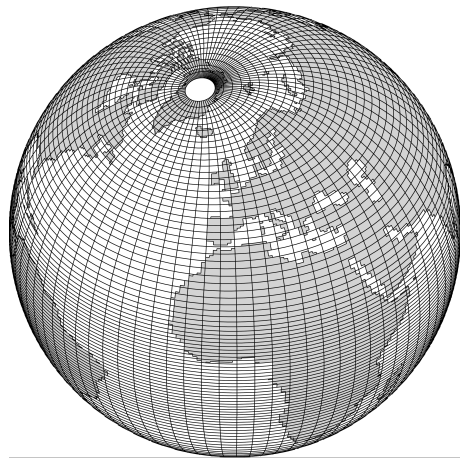
Component discretization



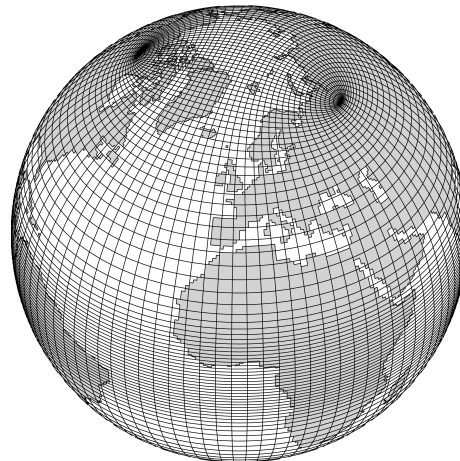
CAM finite volume



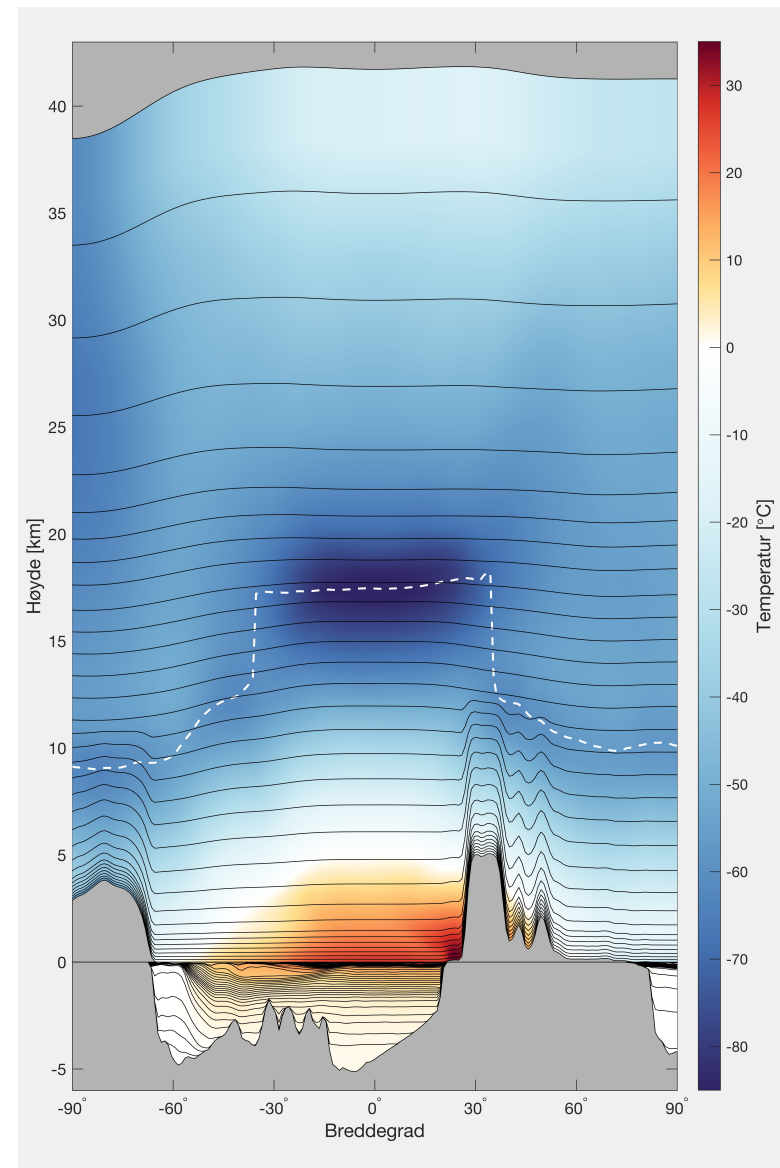
CAM spectral element



BLOM/CICE bipolar

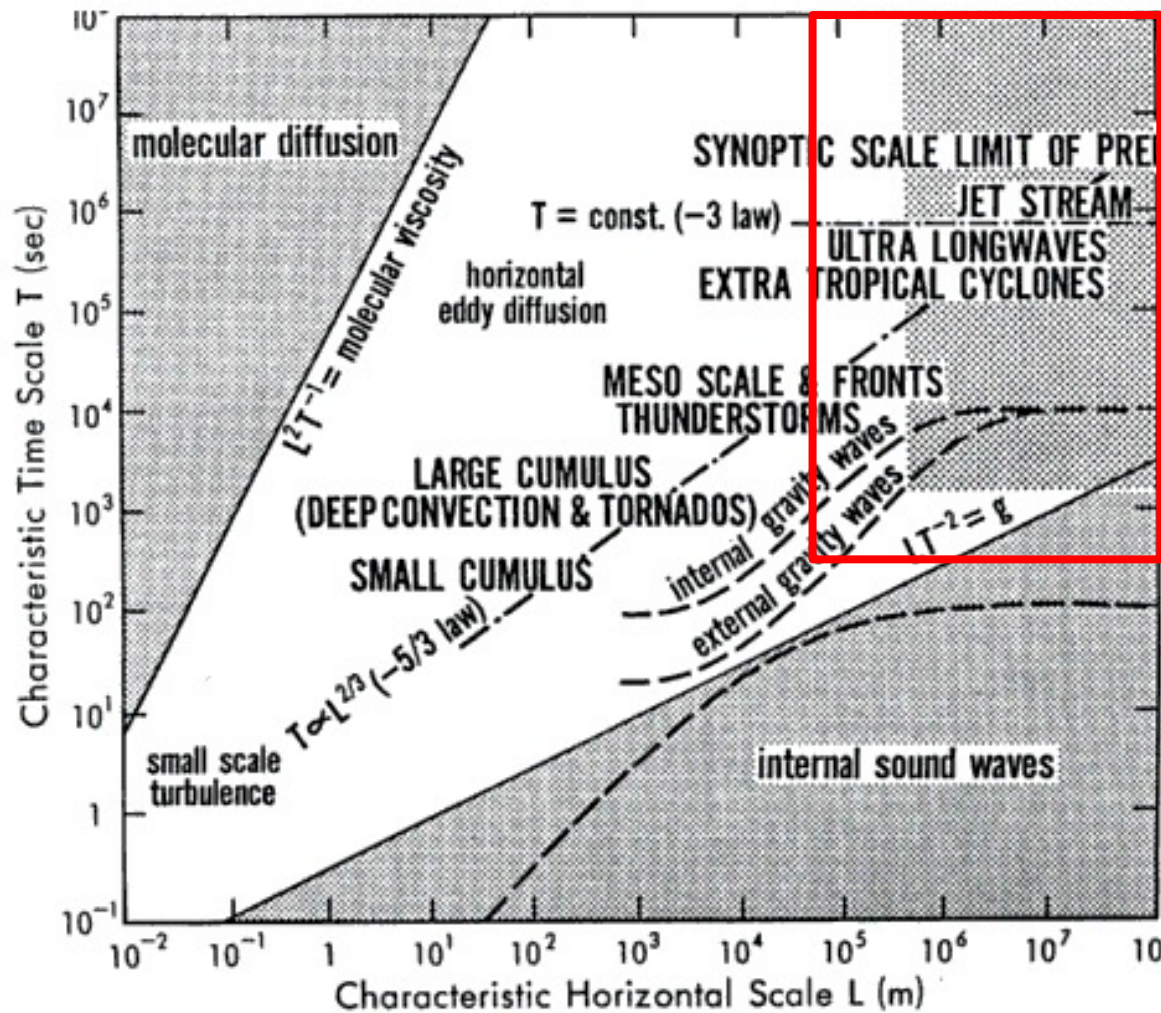


BLOM/CICE tripolar



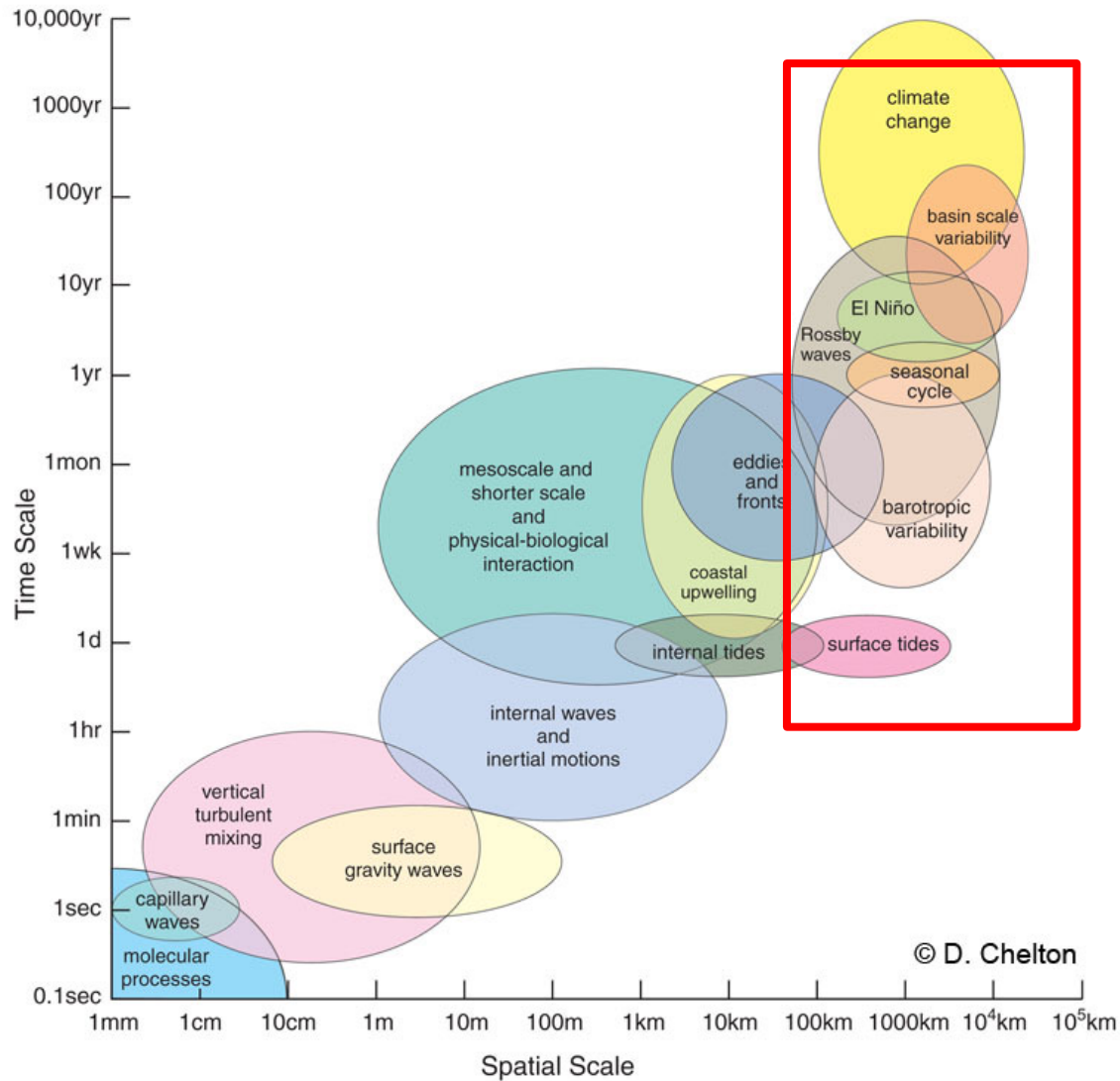
April temperature of
NorESM2 along 87.5°E

Spatial and temporal scales of the atmosphere



Courtesy: Smagorinsky (1974).

Spatial and temporal scales of the ocean



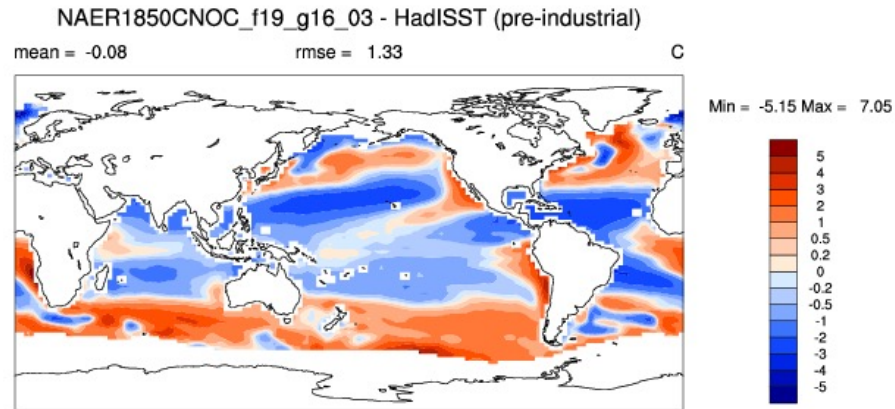
CESM2/NorESM2 developments

- **CAM:** CLUBB for PBL, shallow convection and macrophysics; RRTMG radiative transfer model; MG2 replacing RK for microphysics; modified subgrid orographic drag; **improved energy and angular momentum conservation; deep convection improvements; CAM-Oslo aligned with the new MAM; improved aerosol handling; new sea-salt emission parameterization; online emissions of mineral dust; improved heterogeneous ice nucleation treatment; coupling of DMS.**
- **CLM:** Revised photosynthesis scheme; improved soil and plant hydrology; MOSART river module; prognostic wetland distribution; new lake model; improved snow parameterization; new crop model; new C-N coupling; new plant hydraulic stress routine; dynamic land units and updated PFT-distribution; **modified handling of freezing surface water.**

CESM2/NorESM2 developments

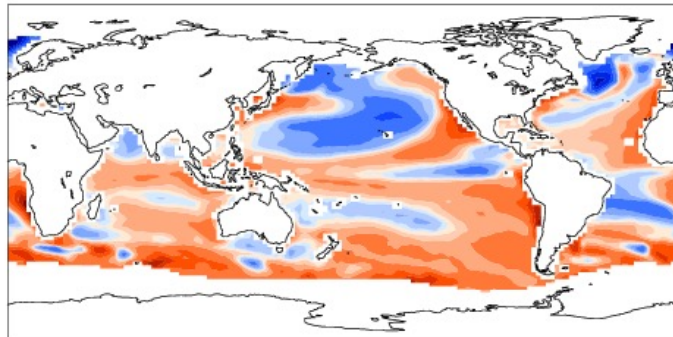
- **CICE:** Mushy-layer thermodynamics scheme; added prognostic salinity to the thermodynamic calculations; a level melt pond scheme accounting for ice surface roughness for melt pond fraction; **wind drift of snow**.
- **BLOM:** k - ϵ model for vertical mixing; improved tracer conservation; modified GM and eddy diffusivity parameterization; more options for SW absorption; higher ocean coupling frequency (1/day->1/hour); realistic channel widths; improved mixed layer physics; additional upper ocean mixing processes.
- **HAMOCC:** Coupling of DMS; improved nitrogen cycling; improved particle flux parameterization; carbon isotope tracers; riverine inputs; added preformed and natural tracers.
- **CIME:** Added COARE3 air-sea turbulent flux scheme.

Annual mean sea surface temperature



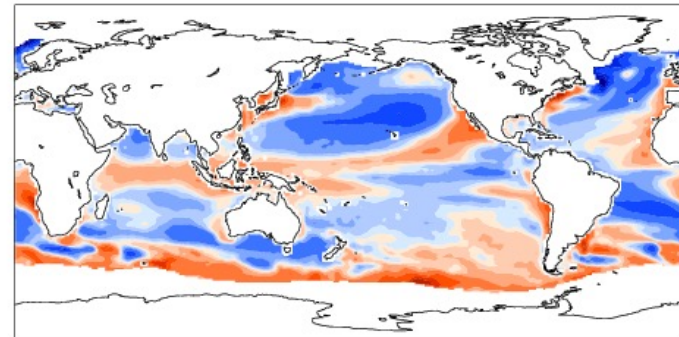
NorESM1-M

N1850OCBDRDDMS_f19_tn14_201218 - HadISST (pre-industrial)
mean = 0.46 rmse = 1.16 C



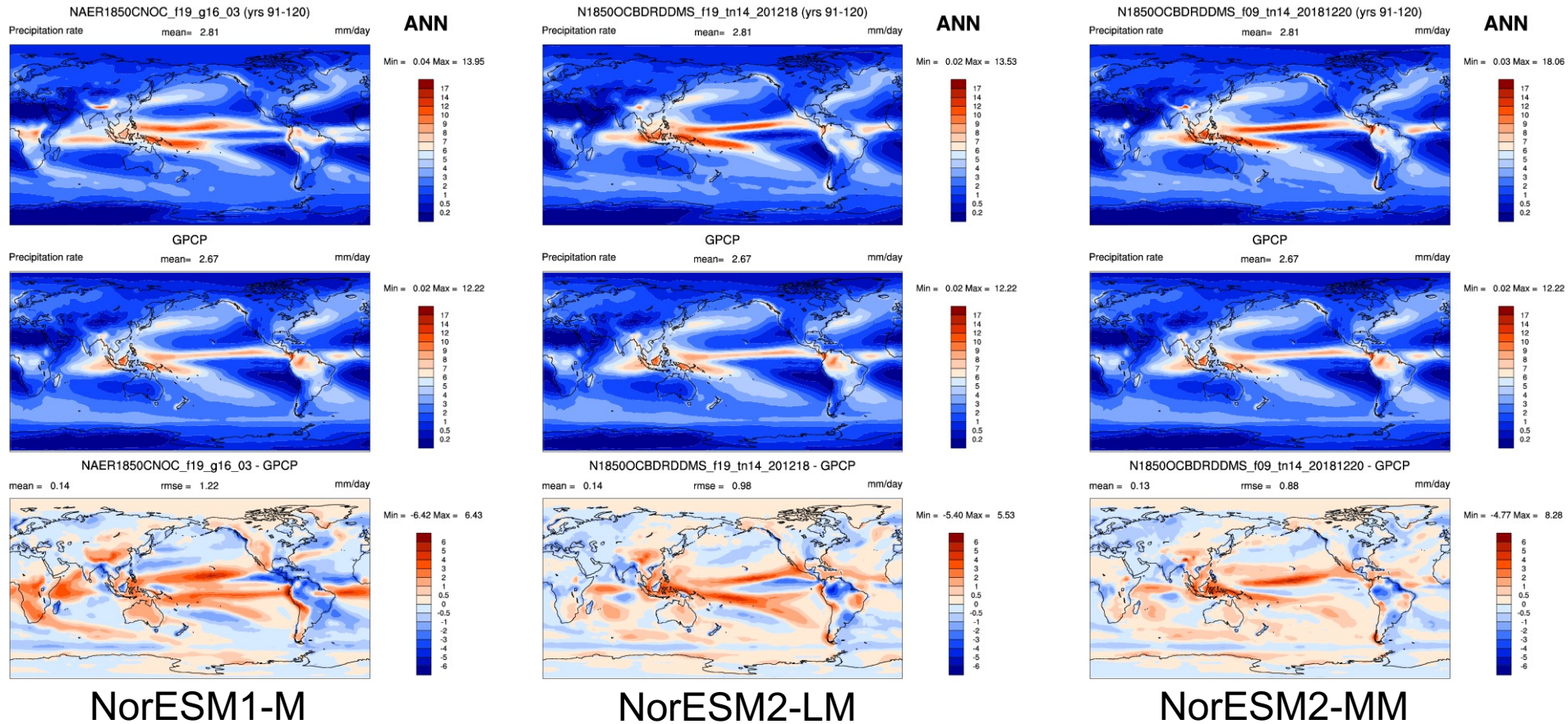
NorESM2-LM

N1850OCBDRDDMS_f09_tn14_20181220 - HadISST (pre-industrial)
mean = -0.15 rmse = 0.98 C

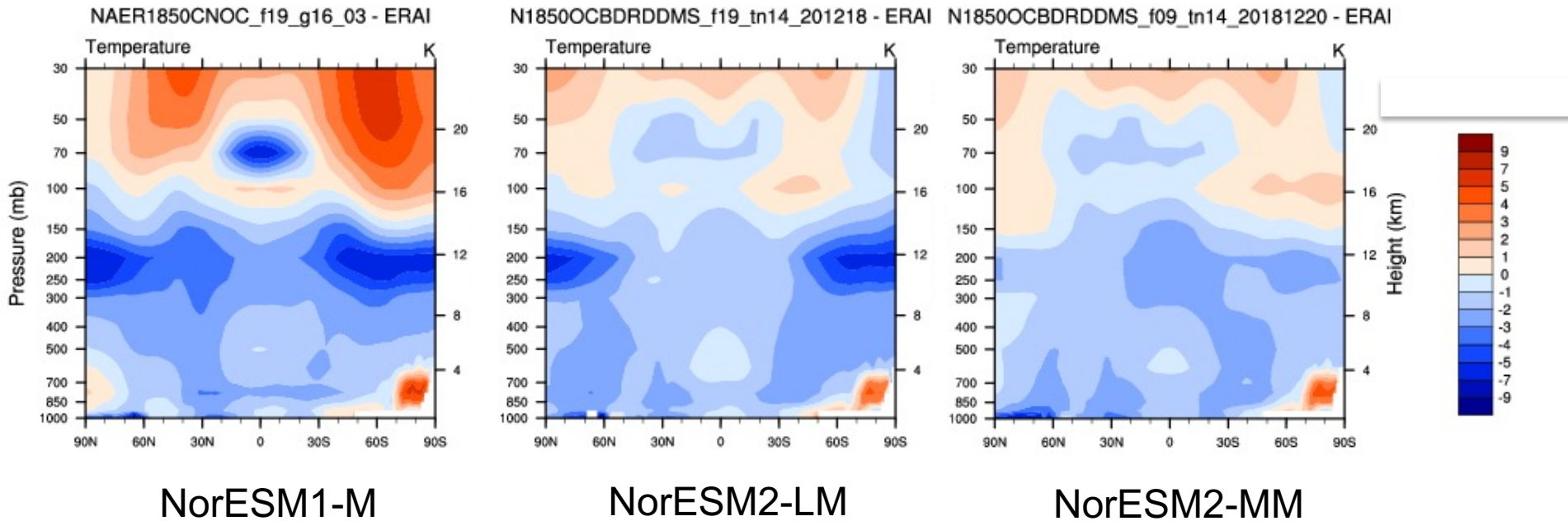


NorESM2-MM

Annual mean precipitation



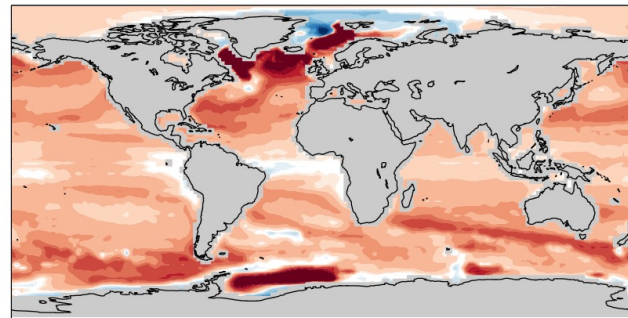
Annual zonal mean temperature bias



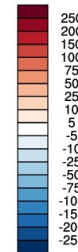
Annual mean ocean mixed layer bias

NAER1850CNOC_f19_g16_03 - de Boyer Montegut et al. (2004)

mean = 48.33 rmse = 86.48 m



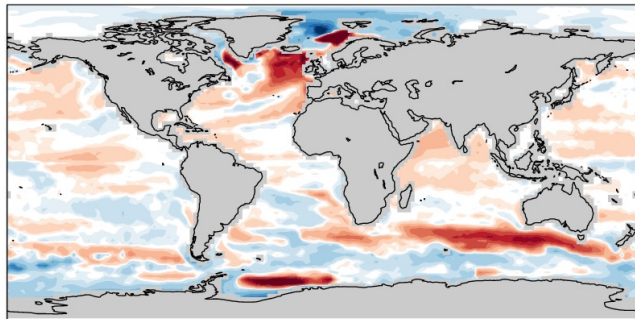
Min = -417.40 Max = 1263.89



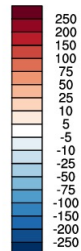
NorESM1-M

N1850OCBDRDDMS_f19_tn14_201218 - de Boyer Montegut et al. (2004)

mean = 7.10 rmse = 41.86 m



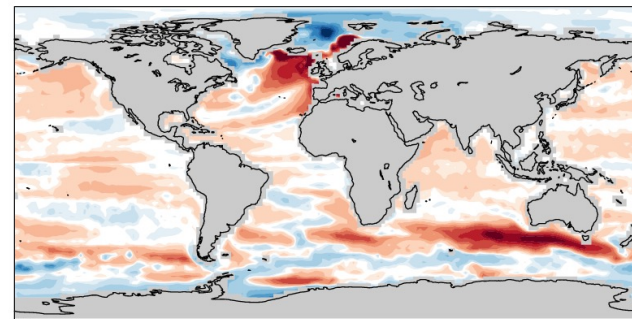
Min = -441.44 Max = 1072.42



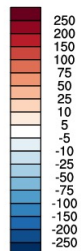
NorESM2-LM

N1850OCBDRDDMS_f09_tn14_20181220 - de Boyer Montegut et al. (2004)

mean = 13.27 rmse = 48.29 m

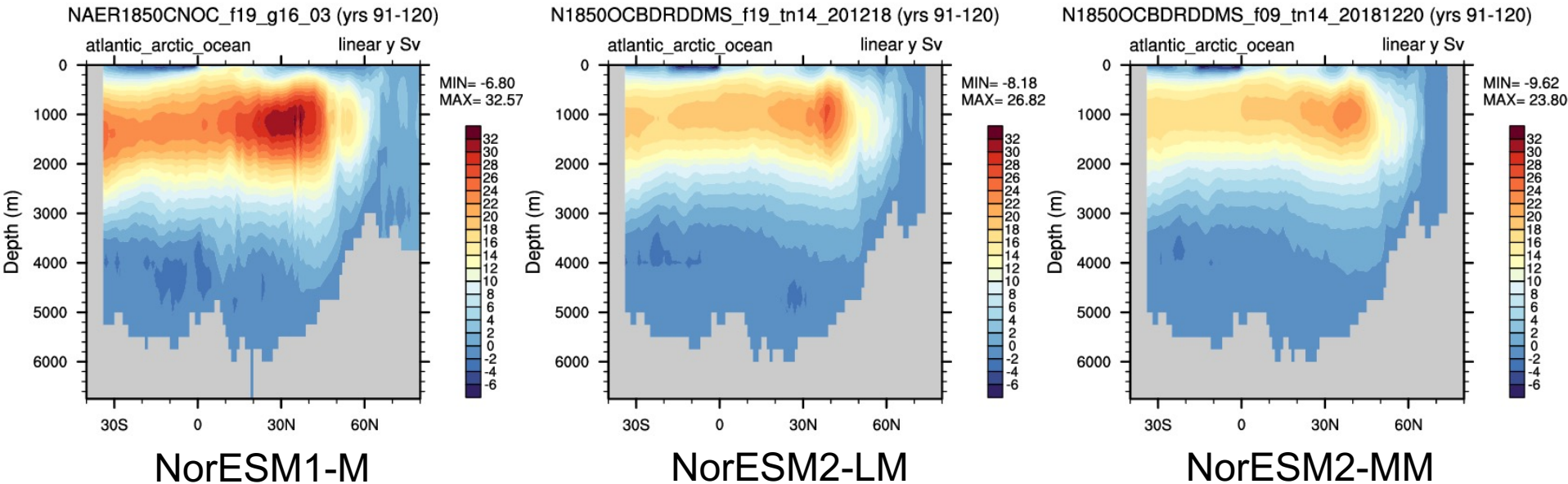


Min = -466.67 Max = 1398.97

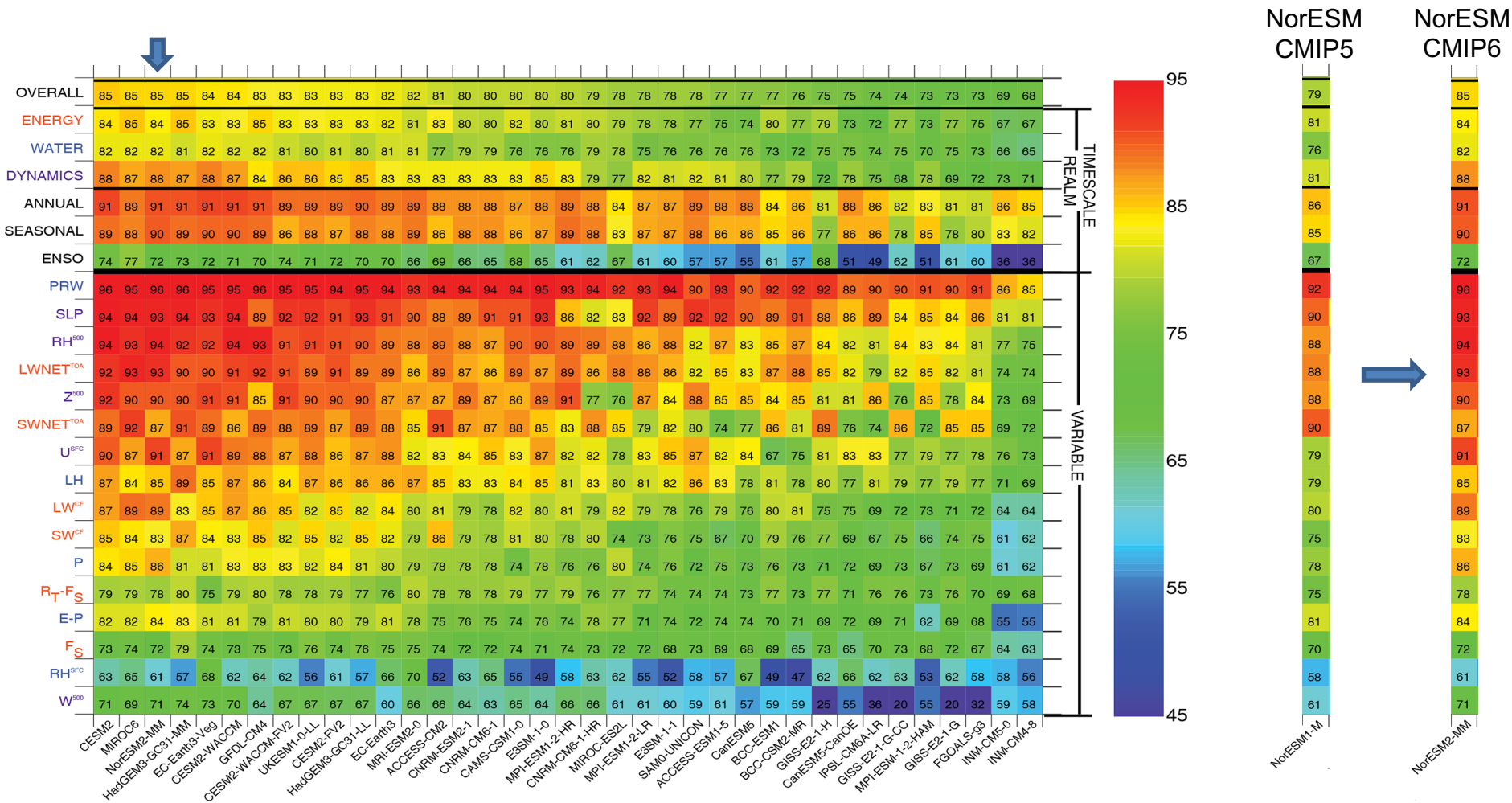


NorESM2-MM

Atlantic meridional overturning circulation



CESM2/NorESM2 developments



Courtesy: Fasullo (2020).

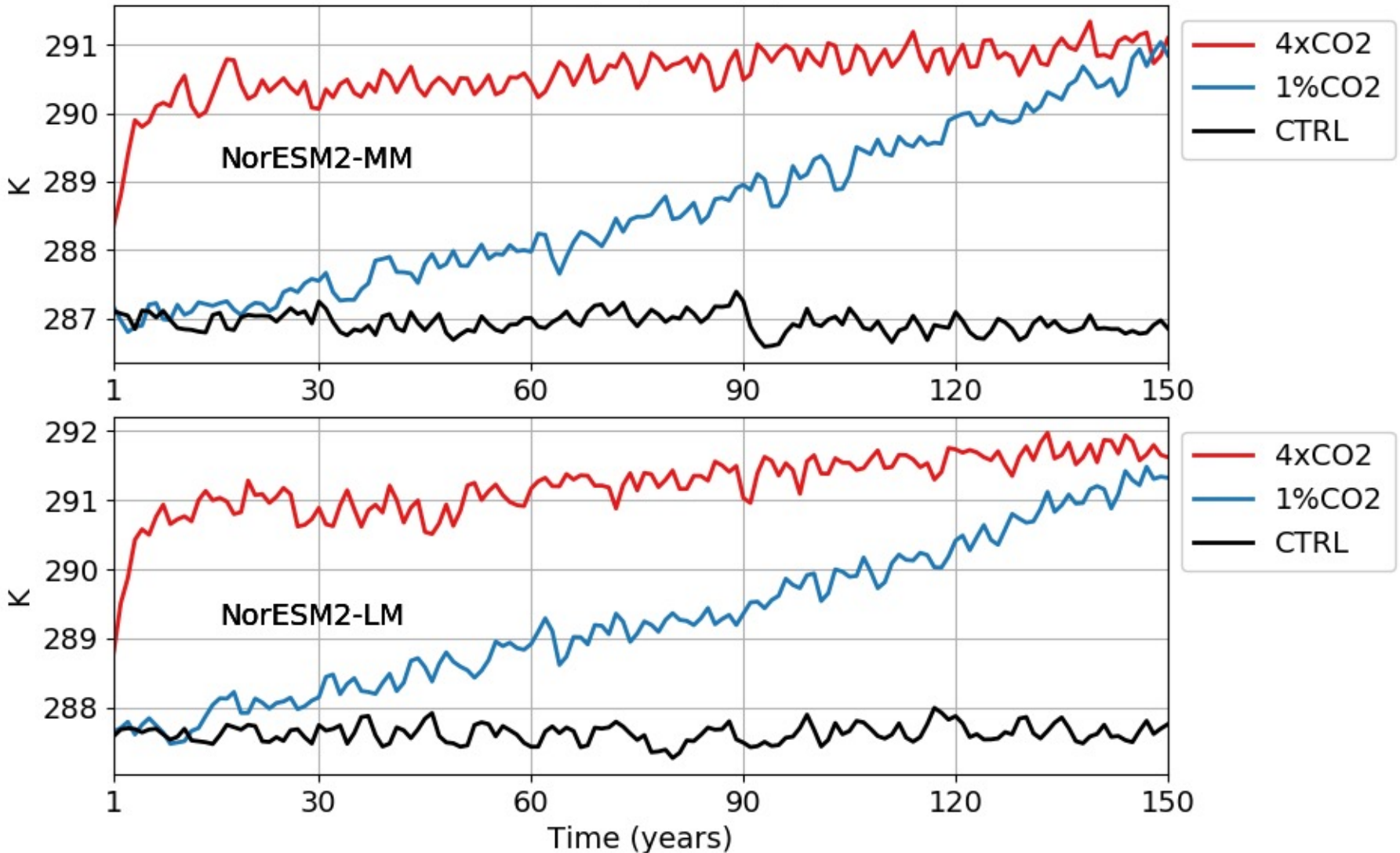


CMIP6 status

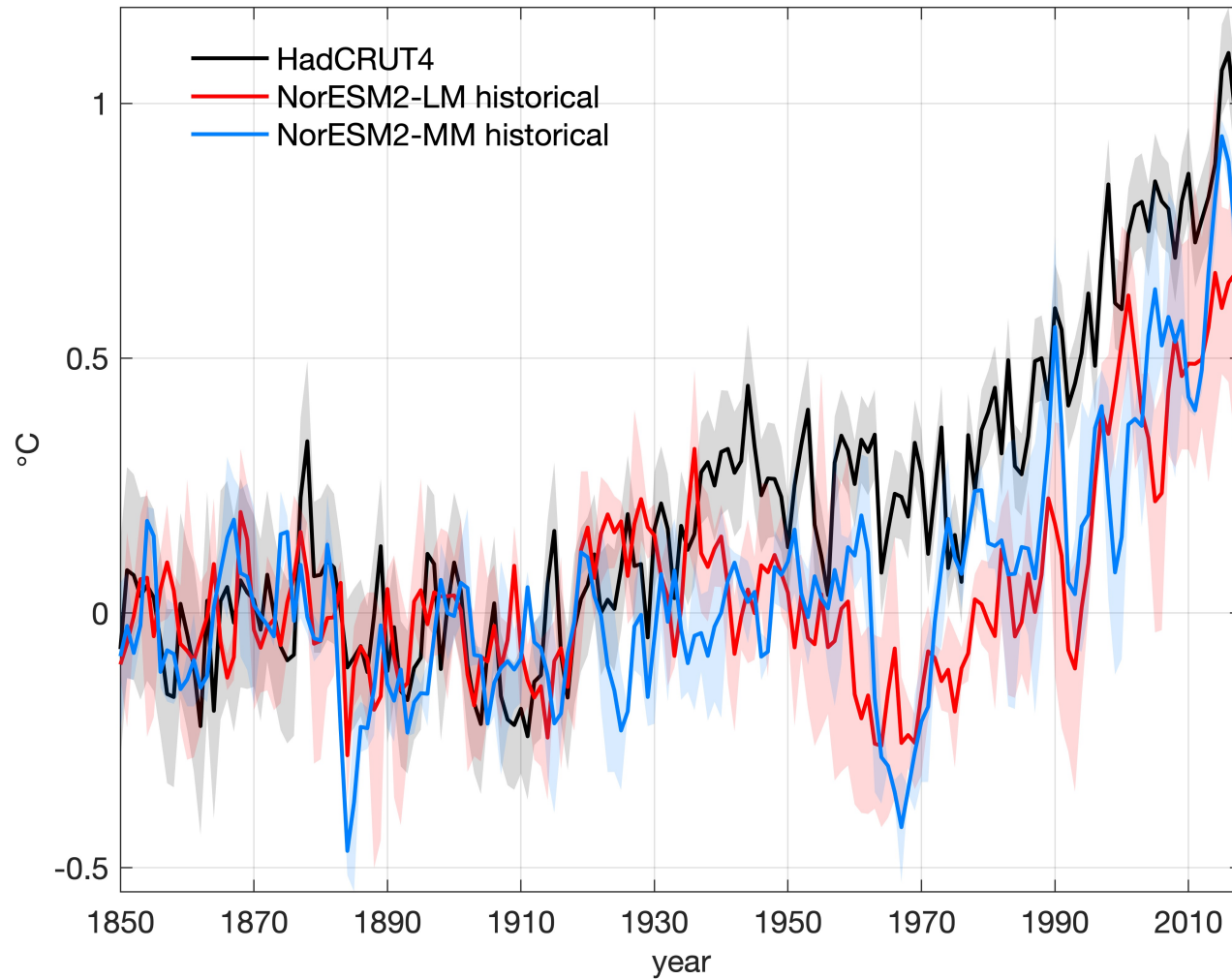
- Through ESGF there are currently **86** NorESM2-LM, **12** NorESM2-MM, **8** NorCPM1 and **4** NorESM1-F experiments available.
- The various NorESM configurations have contributed to the following MIPS:
 - **NorESM2-LM:** AerChemMIP, C4MIP, CDRMIP, CFMIP, CMIP, DAMIP, LUMIP, OMIP, PAMIP, PMIP, RFMIP, ScenarioMIP.
 - **NorESM2-MM:** AerChemMIP, CMIP, RFMIP, ScenarioMIP.
 - **NorCPM1:** CMIP, DCPD.
 - **NorESM1-F:** CMIP, PMIP.
- For development and production **200 million CPU hours** have been used and **3 PB** of data produced.

NorESM2 DECK simulations

Near surface (2m) air temperature

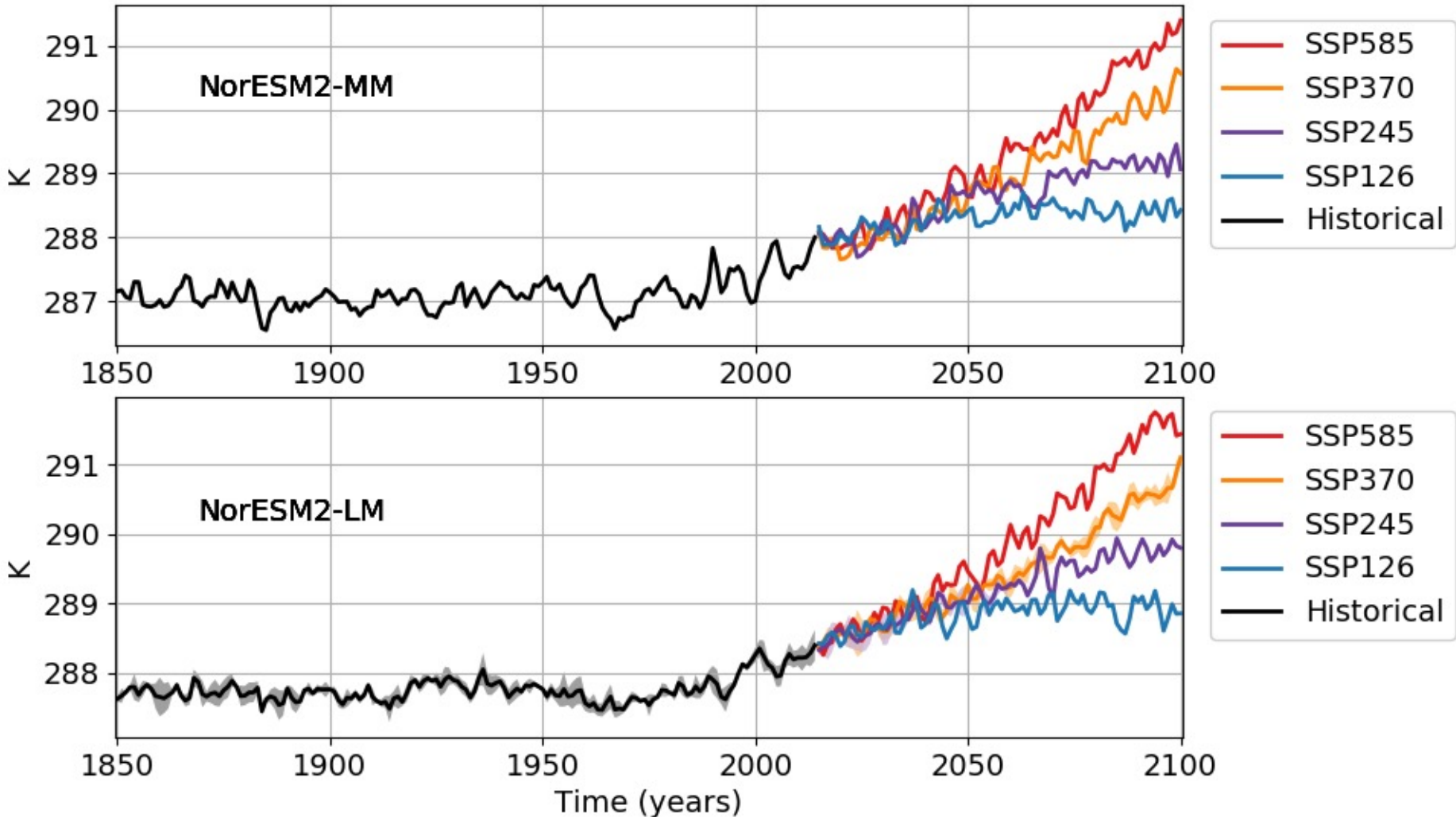


NorESM2 historical simulations

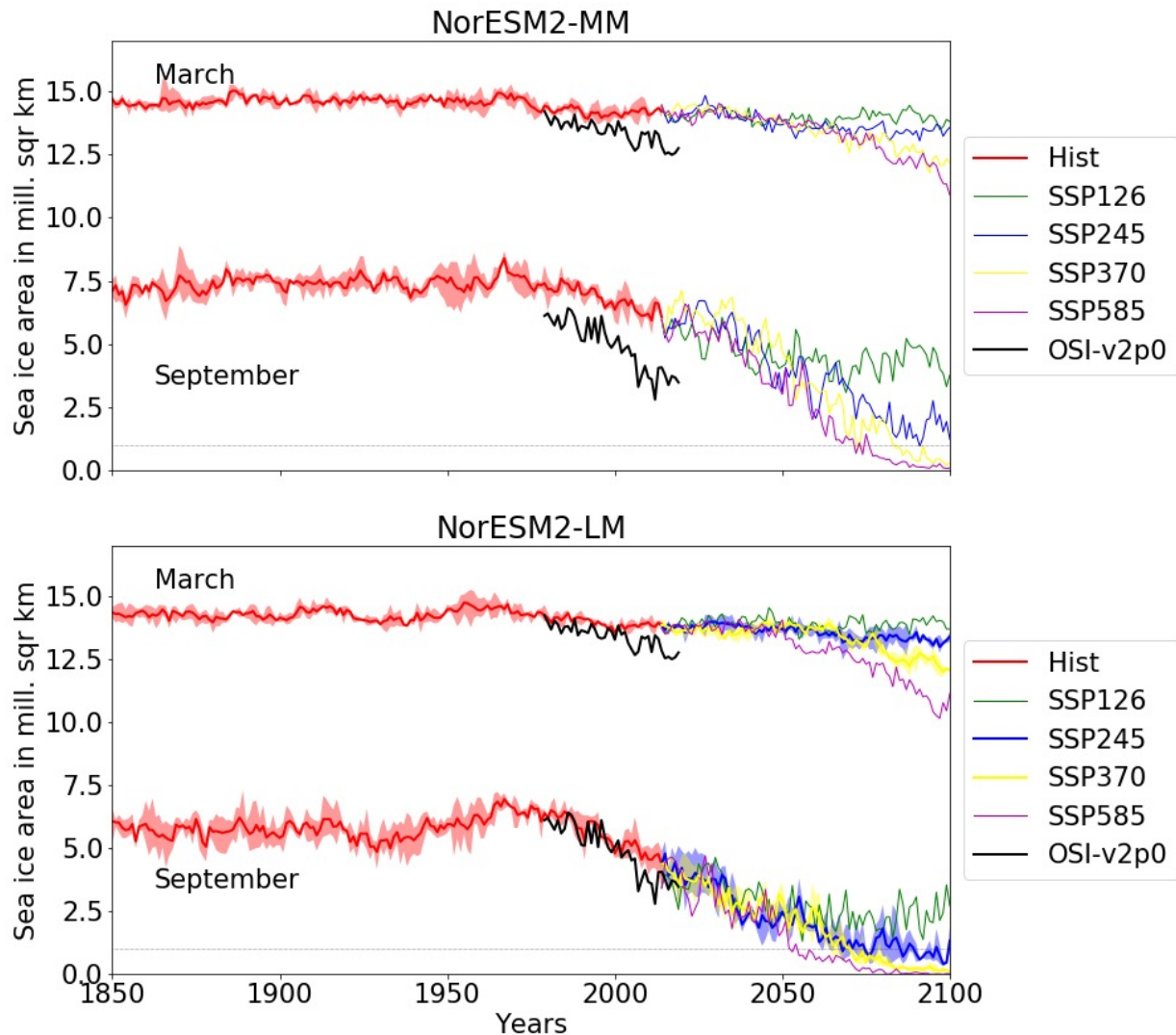


NorESM2 historical and scenario simulations

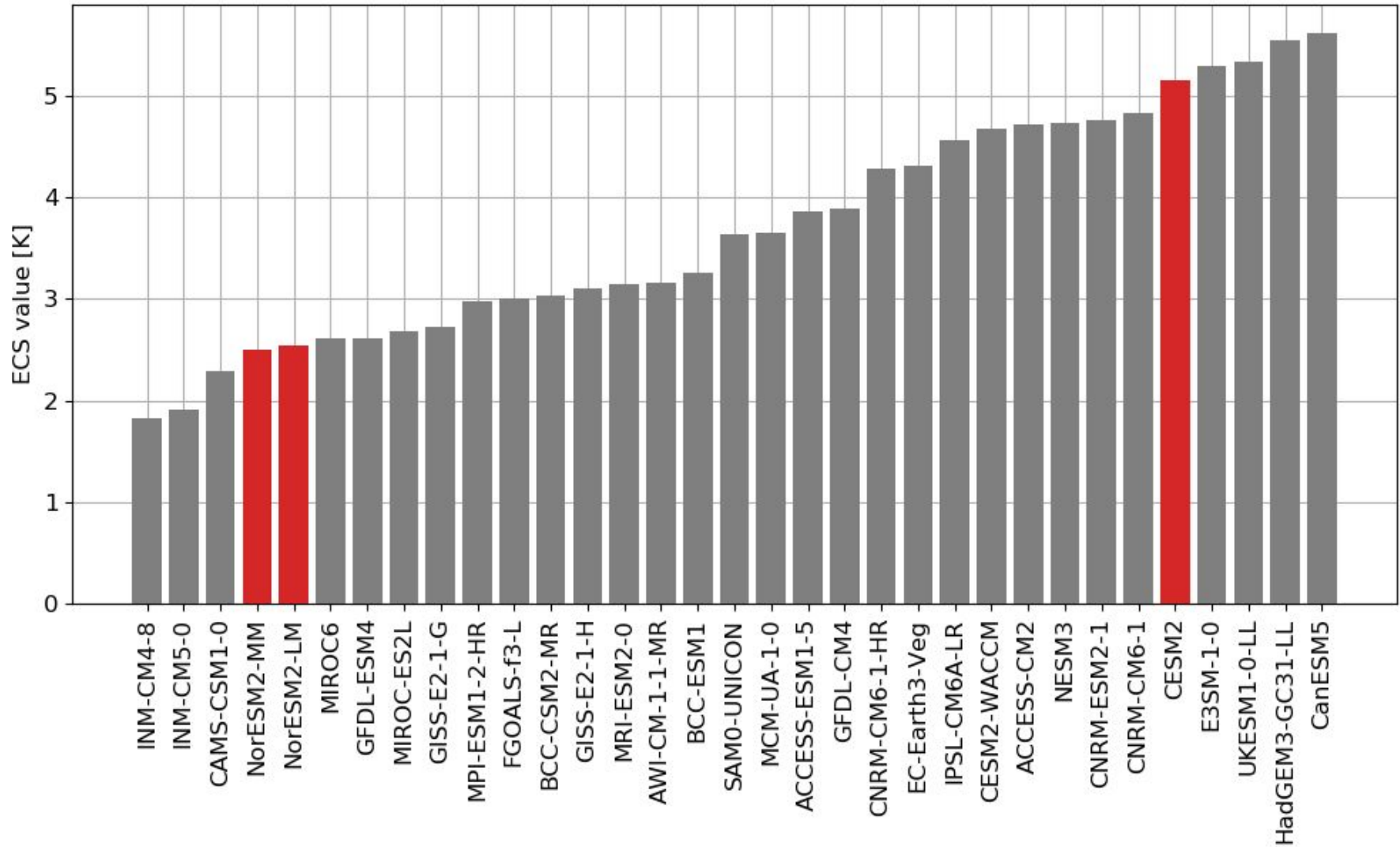
Near surface (2m) air temperature



NorESM2 historical and scenario simulations

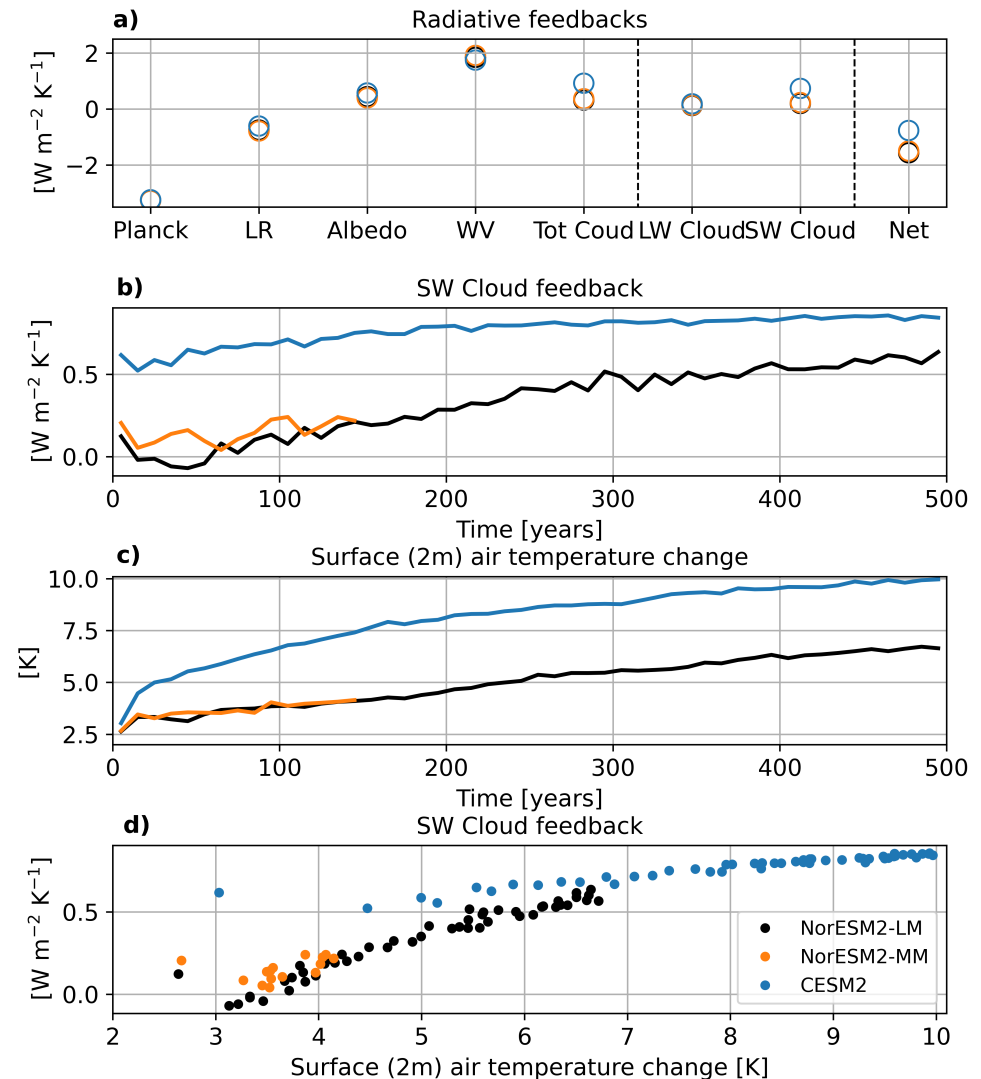


CMIP6 equilibrium climate sensitivity



CMIP6 equilibrium climate sensitivity

- Very different transient climate sensitivity between NorESM2 and CESM2.
- Caused by different depth distribution of heating in the Southern Ocean, subsequently impacting SST, clouds and radiation.



Courtesy: Gjermundsen et al., (2021)

NorESM infrastructure

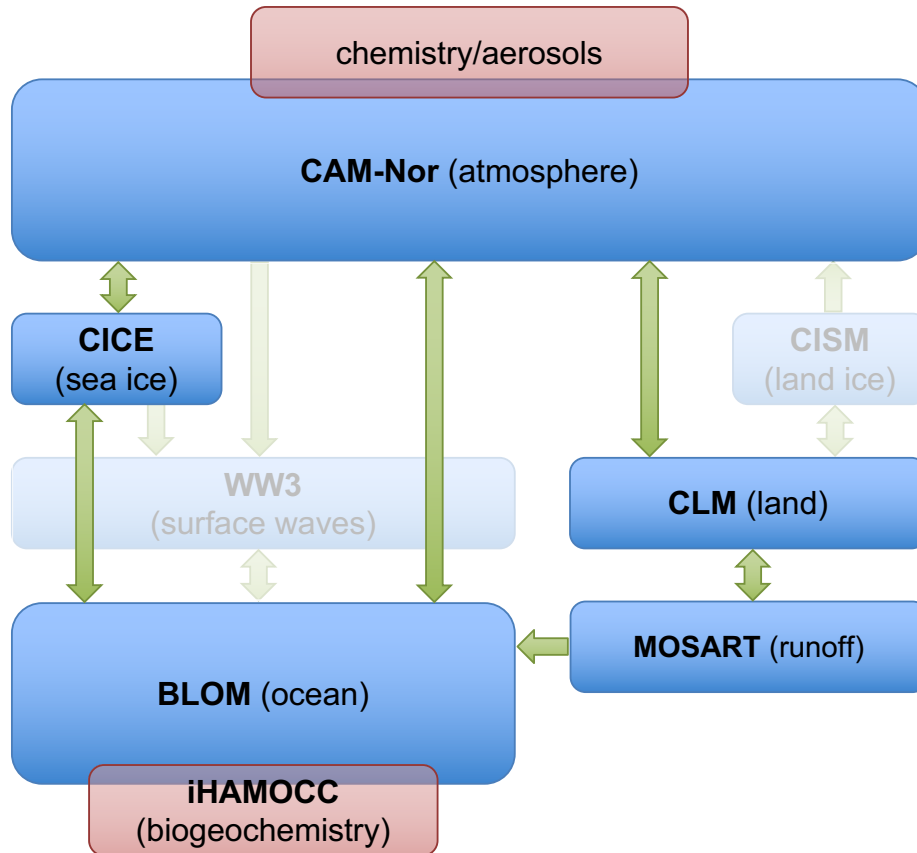
- Repository hub for NorESM code, documentation and tools:
<https://github.com/NorESMhub>
- NorESM2 User's Guide:
<https://noresm-docs.readthedocs.io>
- Time-invariant location of NorESM input data:
<https://www.noresm.org/inputdata>

Plans for further NorESM development

- Boundary layer processes, with particular emphasis on Arctic conditions.
- Conserving material-energy fluxes between model components.
- Ocean eddy parameterization.
- Realistic snow hydrology over sea ice.
- Interactive land ice.
- Understand and better constrain cloud phase.
- Improve interactive emissions in earth system components.
- Extend and improve representation of atmospheric aerosols and chemistry.
- Improve representation of high latitude terrestrial ecosystems and their climate interactions.
- Surface wave field coupling to atmosphere, sea ice and ocean.
- Increased horizontal and vertical resolution.

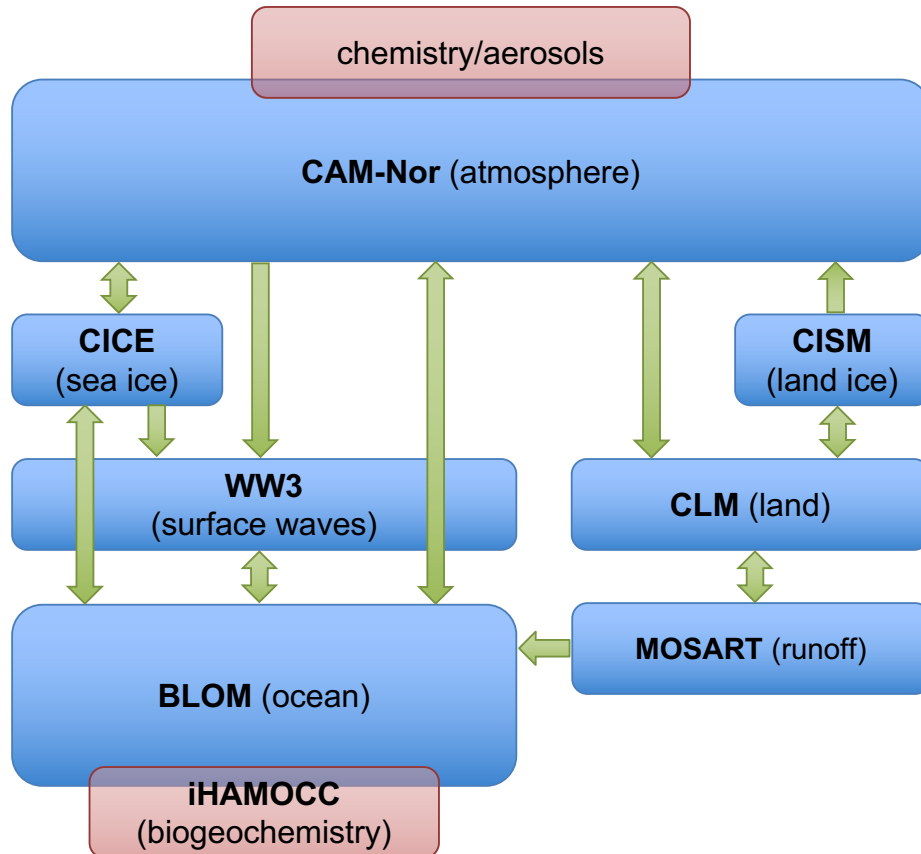
Norwegian Earth System Model (NorESM)

NorESM2



Norwegian Earth System Model (NorESM)

NorESM2.X



2021 (3rd) iNES NorESM User Workshop

Time: 10:00 15/Nov – 12:00 17/Nov.

Venue: Scandic Solli, Oslo

Zoom Link:

<https://uib.zoom.us/j/68752585635?pwd=UkVZDjJid01iV1ZSMkhVcSt1dkRwZz09>

Meeting ID: 687 5258 5635

Password: pH6VzUNZ

Agenda:

Day -1 (Monday, 15 November 2021)

10:00-10:30

- **Mats Bentsen** - *Introduction to NorESM and recent developments*

10:30-10:45

- Coffee break

10:45-11:30

- **Dirk Olivé and Ada Gjermundsen** - *Presentations on NorESM e-resources*

11:30-13:00

- **Ada G/Tomas Torsvik** - *hands-on session: download code and get familiar with NorESM; configuration and submit jobs*

13:00-14:00:

- Lunch

14:00-17:00

- **Ada G/Tomas Torsvik** - *hands-on session: advanced settings:- SourceMods, namelist, Debug, branch and Hybrid run, pecount (coffee break: 15:30-16:00)*

Day -2 (Tuesday, 16 November 2021)

9:00-12:00

- **Jean laquinta** - *Running NorESM in a container (coffee break: 10:15-10:45)*

12:00-13:00

- *Talks on the features of BLOM /recent developments/future plan*

13:00-14:00

- Lunch

14:00- 15:30

- *Meeting with experts (without presentations) and discuss solutions to the problems for your research (1.5 hours)*

15:30- 16:00

- Coffee break

16:00- 17:00

- More hands-on/troubleshooting for running NorESM

Day -3 (Wednesday, 17 November 2021)

9:00-11:30

- **Yanchun He** - *NorESM output and post-processing (coffee break: 10:15-10:45)*

11:30-13:00

- Lunch

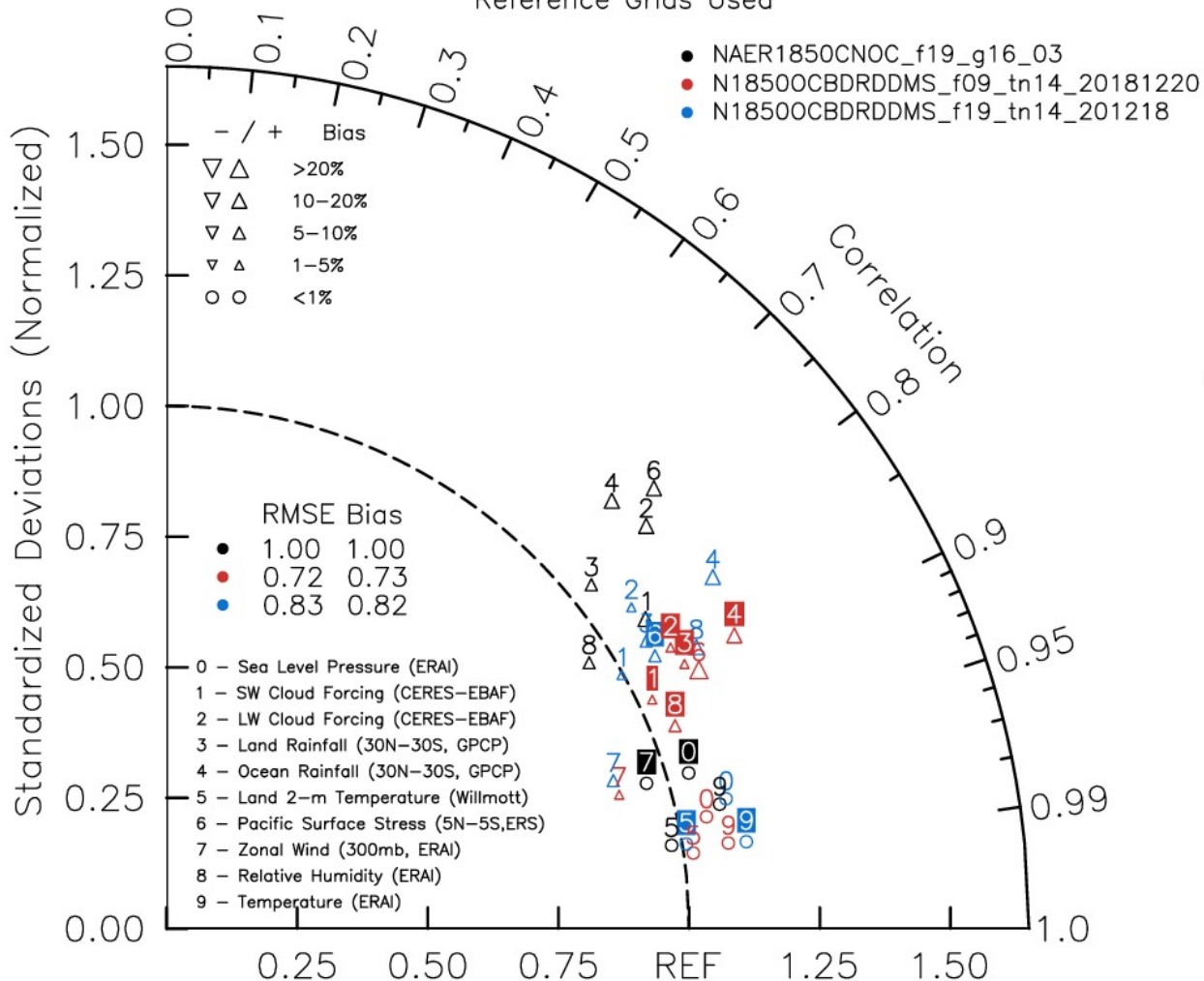
13:00-15:30

- Joint session with the INES annual meeting

CESM2/NorESM2 developments

ANN: SPACE-TIME

Reference Grids Used



Statistical comparison with observations of

- NorESM1-M
- NorESM2-MM
- NorESM2-LM

