

Introduction to NorESM



Mats Bentsen^{1,2}

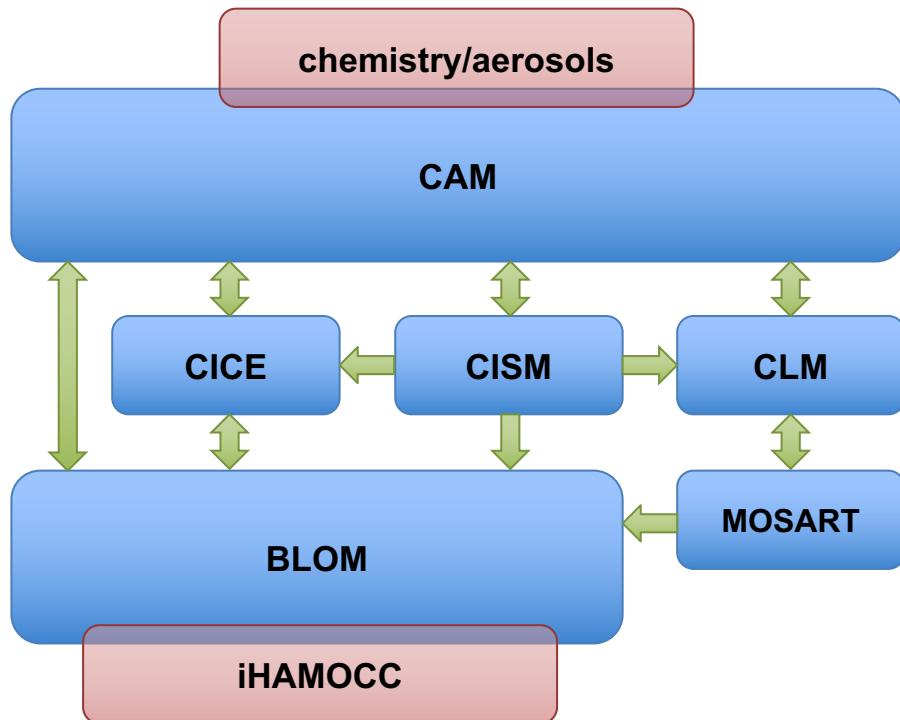
¹ NORCE Norwegian Research Centre

² Bjerknes Centre for Climate Research

Outline

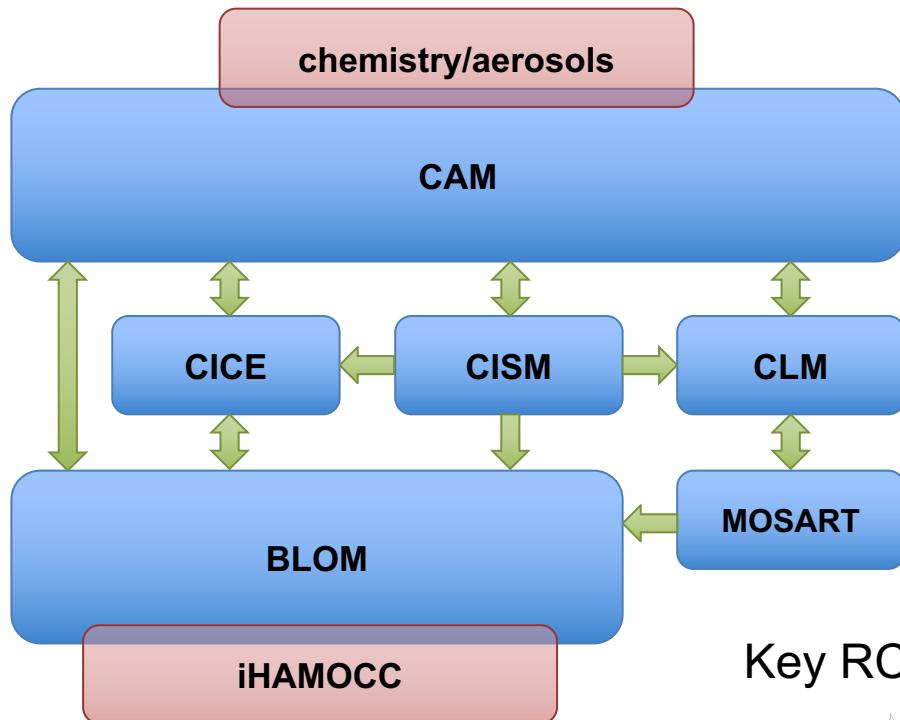
- NorESM overview and differences to CESM
- Some dynamical and physical characteristics
- Scientific updates in NorESM2 compared to NorESM1
- CMIP6 status
- NorESM infrastructure
- Plans for further NorESM development

Norwegian Earth System Model (NorESM)



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

Norwegian Earth System Model (NorESM)



Consortium:



Key RCN projects:



(2007-2010)



(2011-2014)



(2014-2018)



(2018-2021)



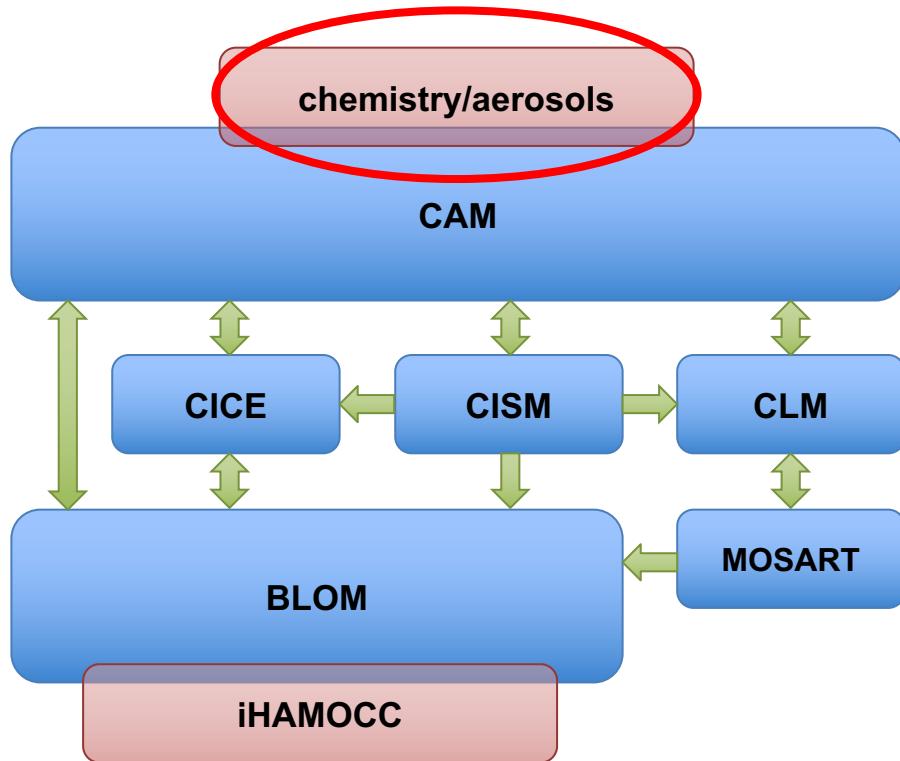
(2019-2023)



Norwegian Earth System Model (NorESM)

Specific NorESM additions to CESM:

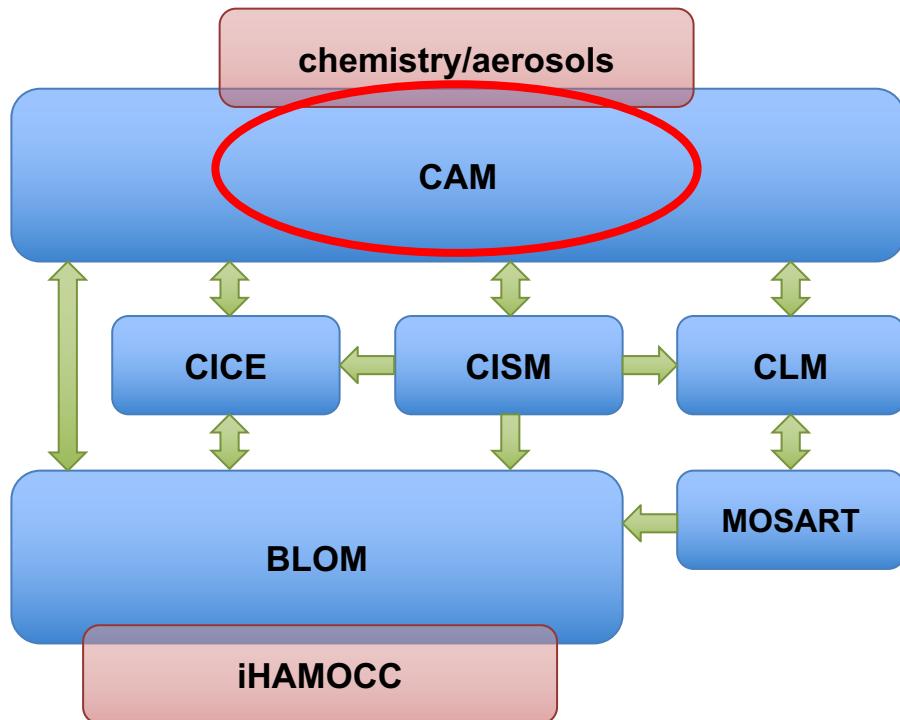
- Atmospheric chemistry/aerosol/cloud module



Oslo

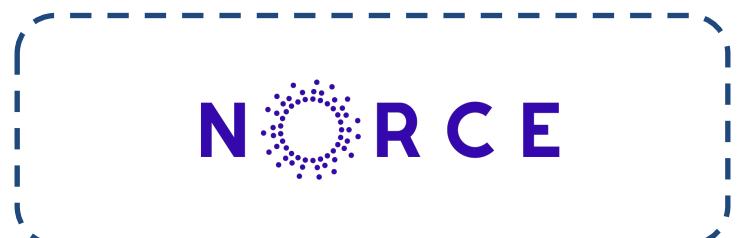


Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

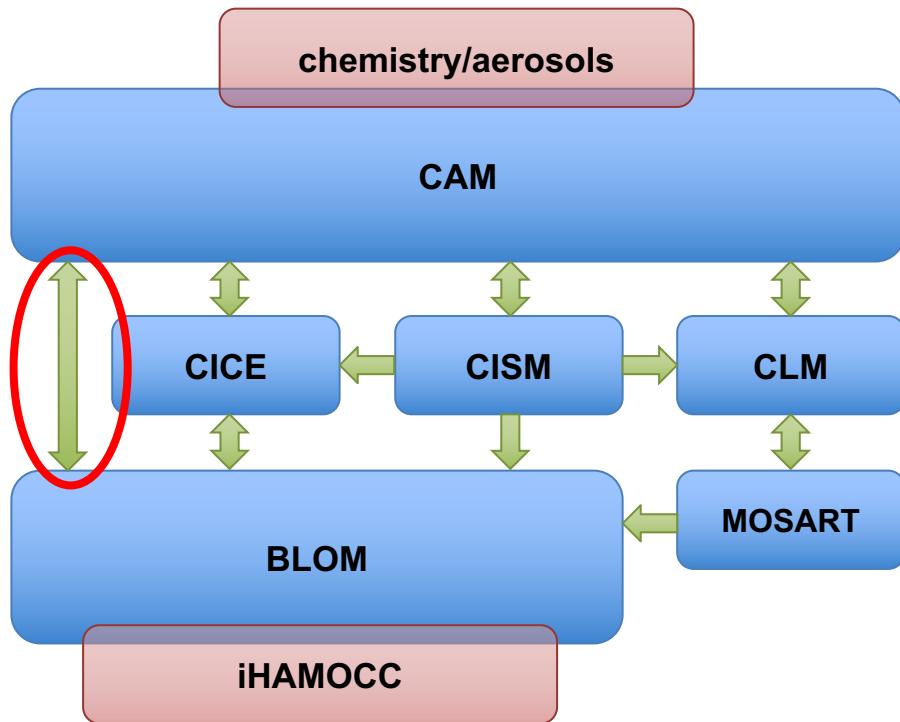
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics:
Improved conservation of energy and angular momentum



Bergen

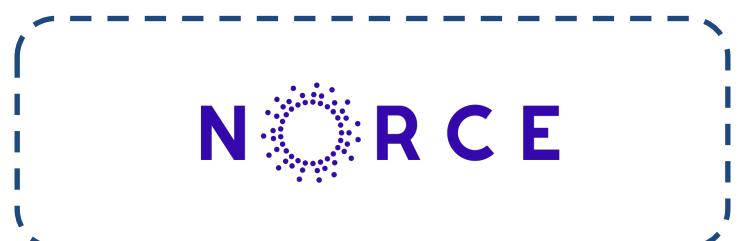


Norwegian Earth System Model (NorESM)

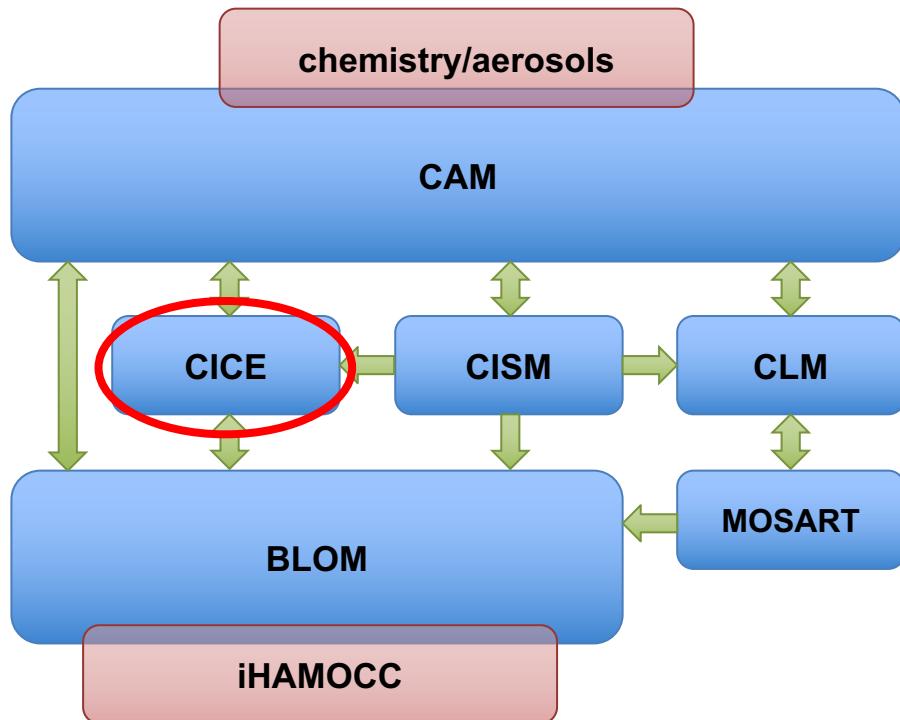


Specific NorESM additions to CESM:

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



Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

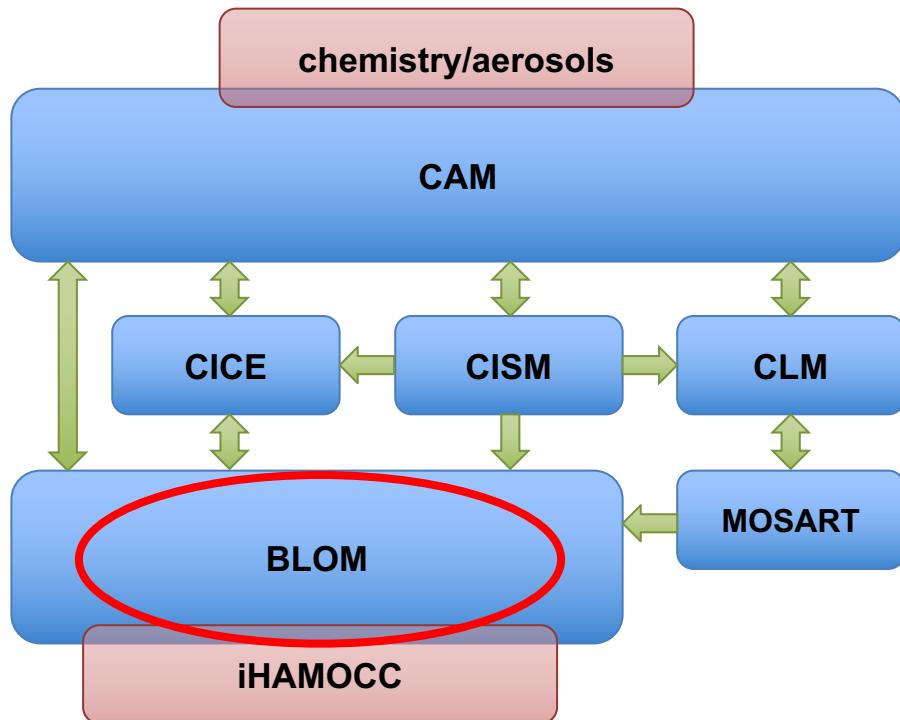
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes
- Wind drift of snow



Bergen



Norwegian Earth System Model (NorESM)



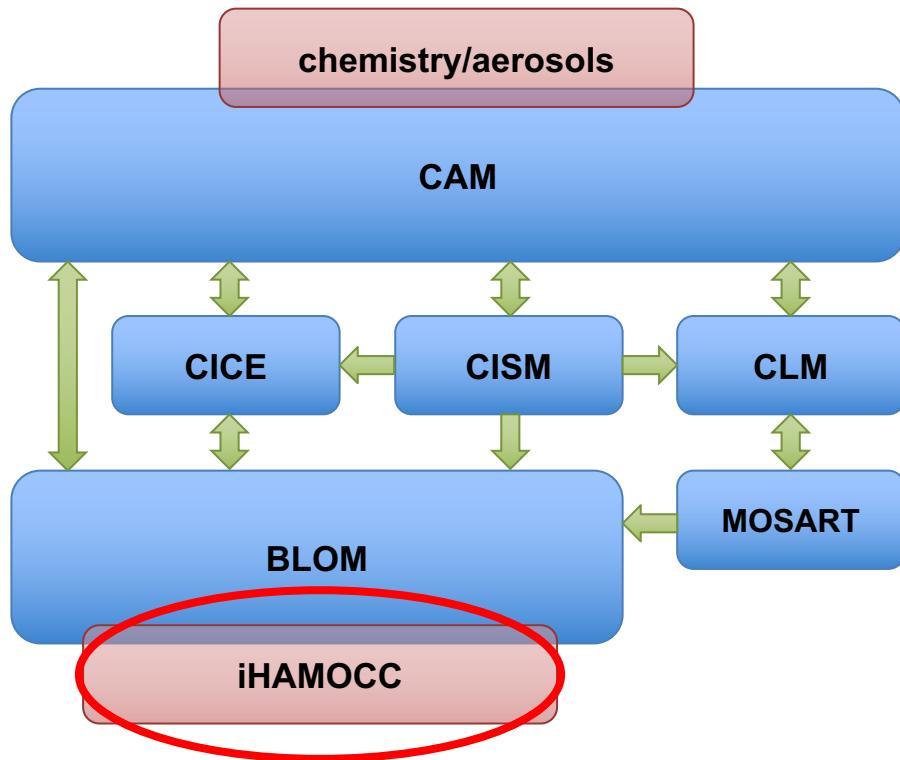
Specific NorESM additions to CESM:

- 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



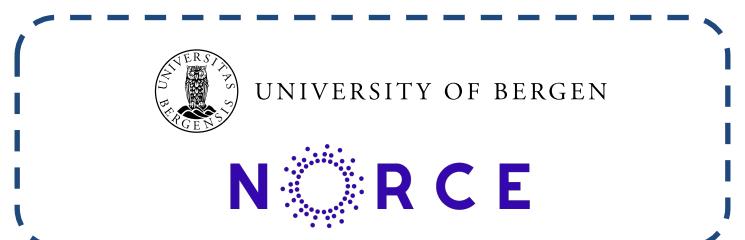
Bergen

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

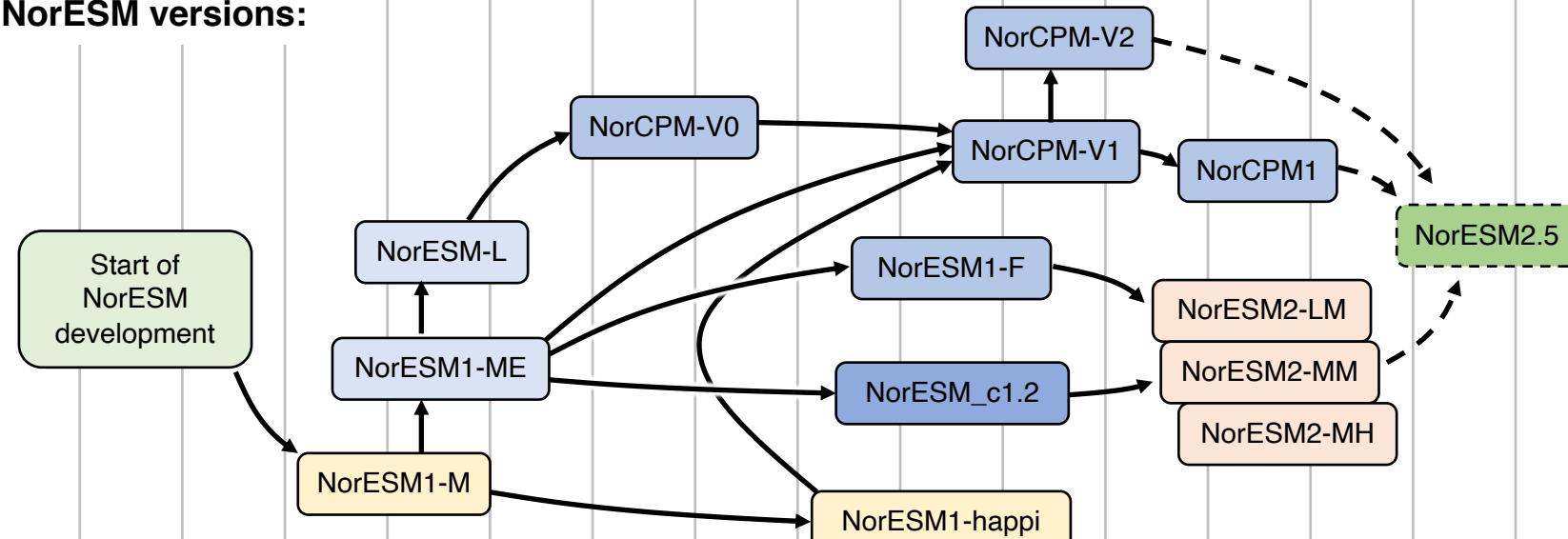


NorESM genealogy

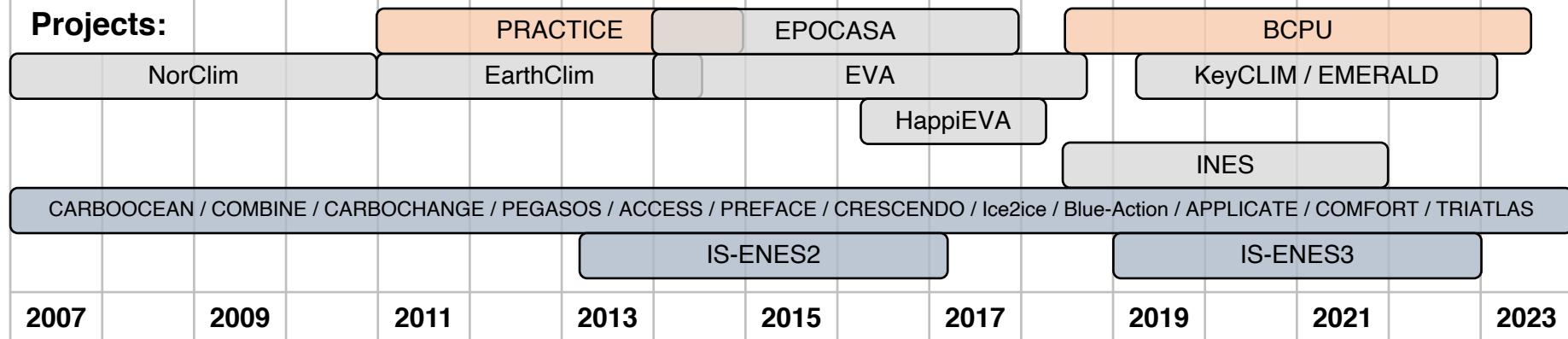
CCSM/CESM versions:



NorESM versions:



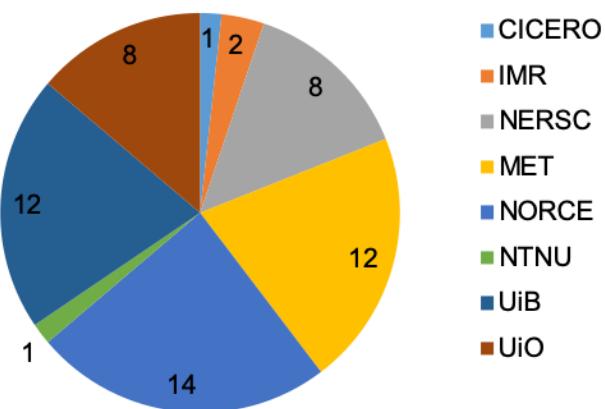
Projects:



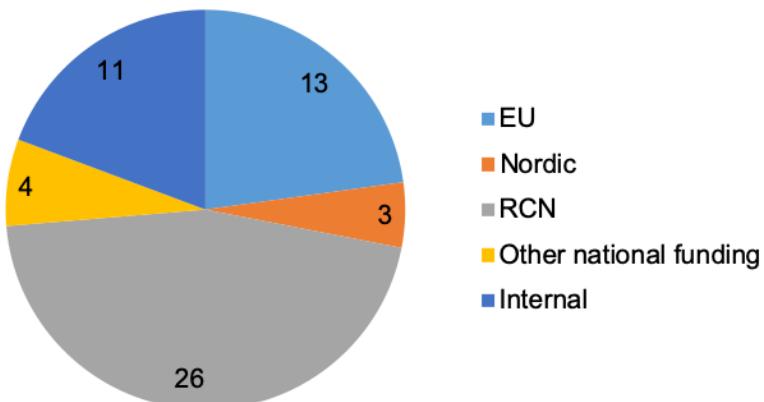
Users and developers of NorESM

Based on a survey in February 2020.

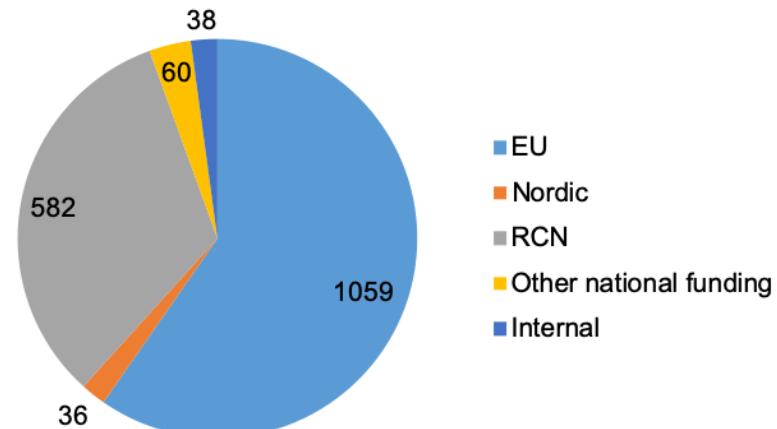
Participants



Number of projects



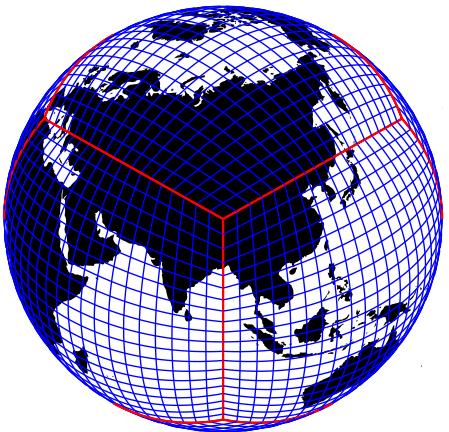
Total grant size (MNOK)



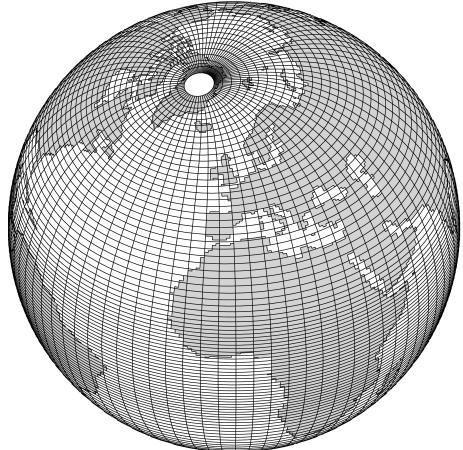
Component discretization



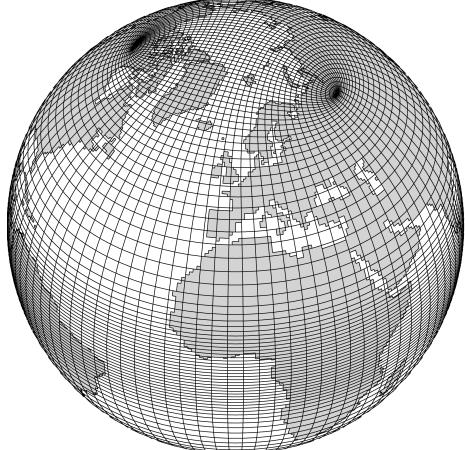
CAM finite volume



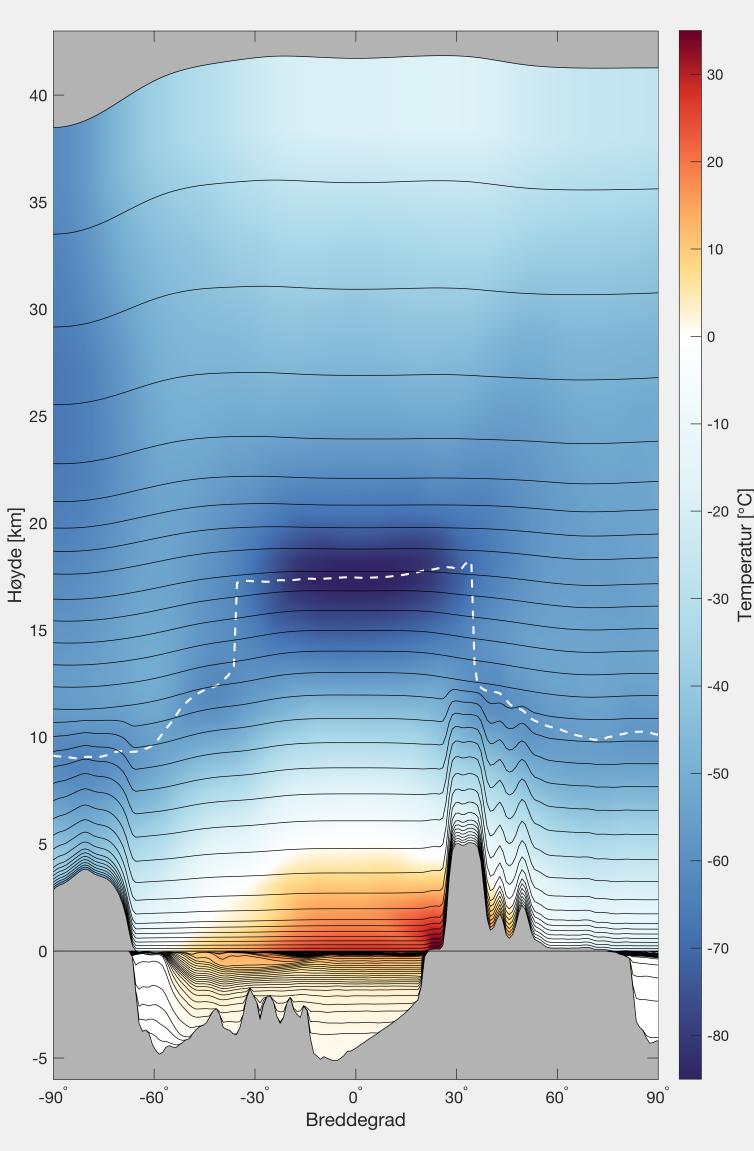
CAM spectral element



BLOM/CICE bipolar

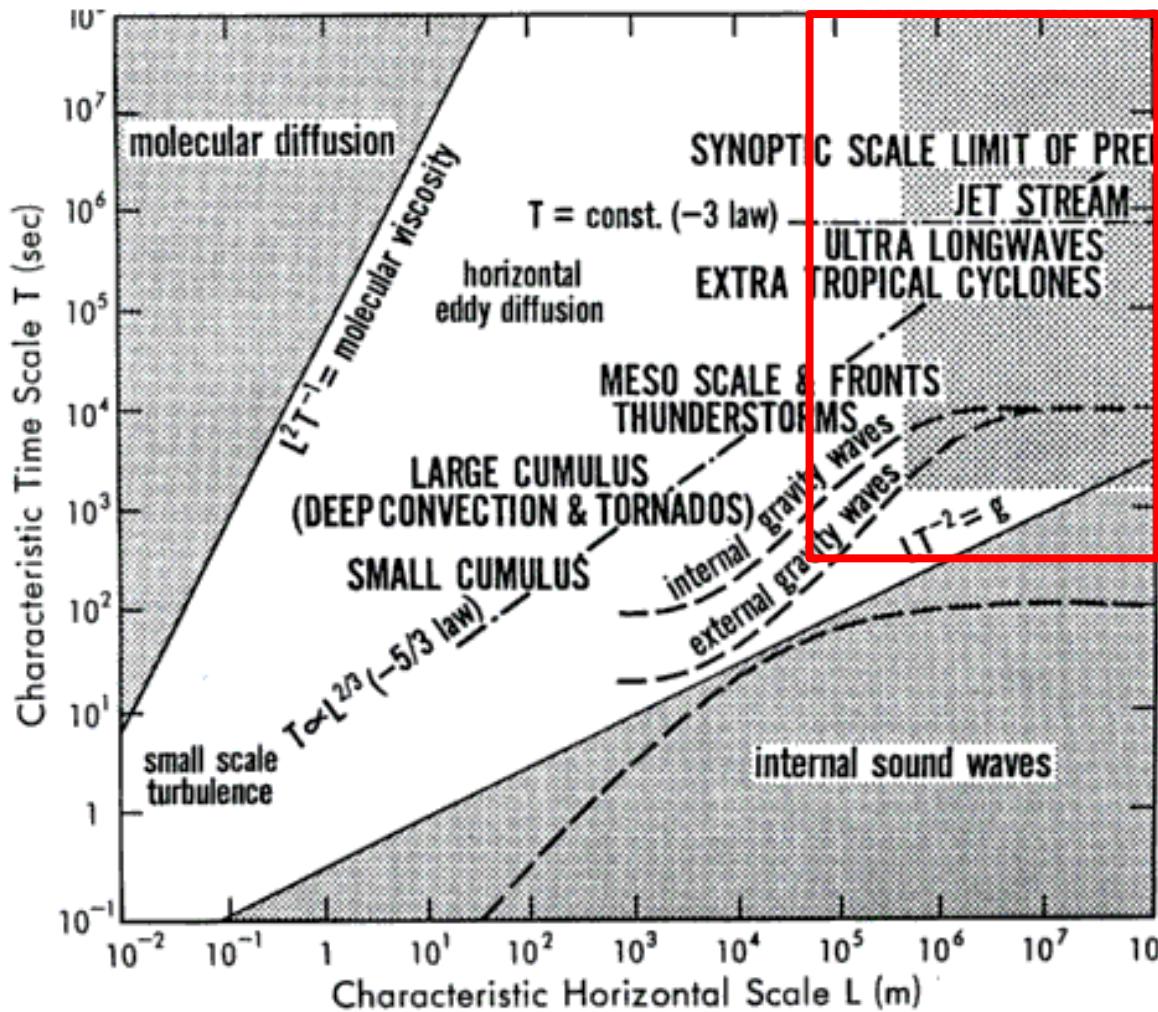


BLOM/CICE tripolar



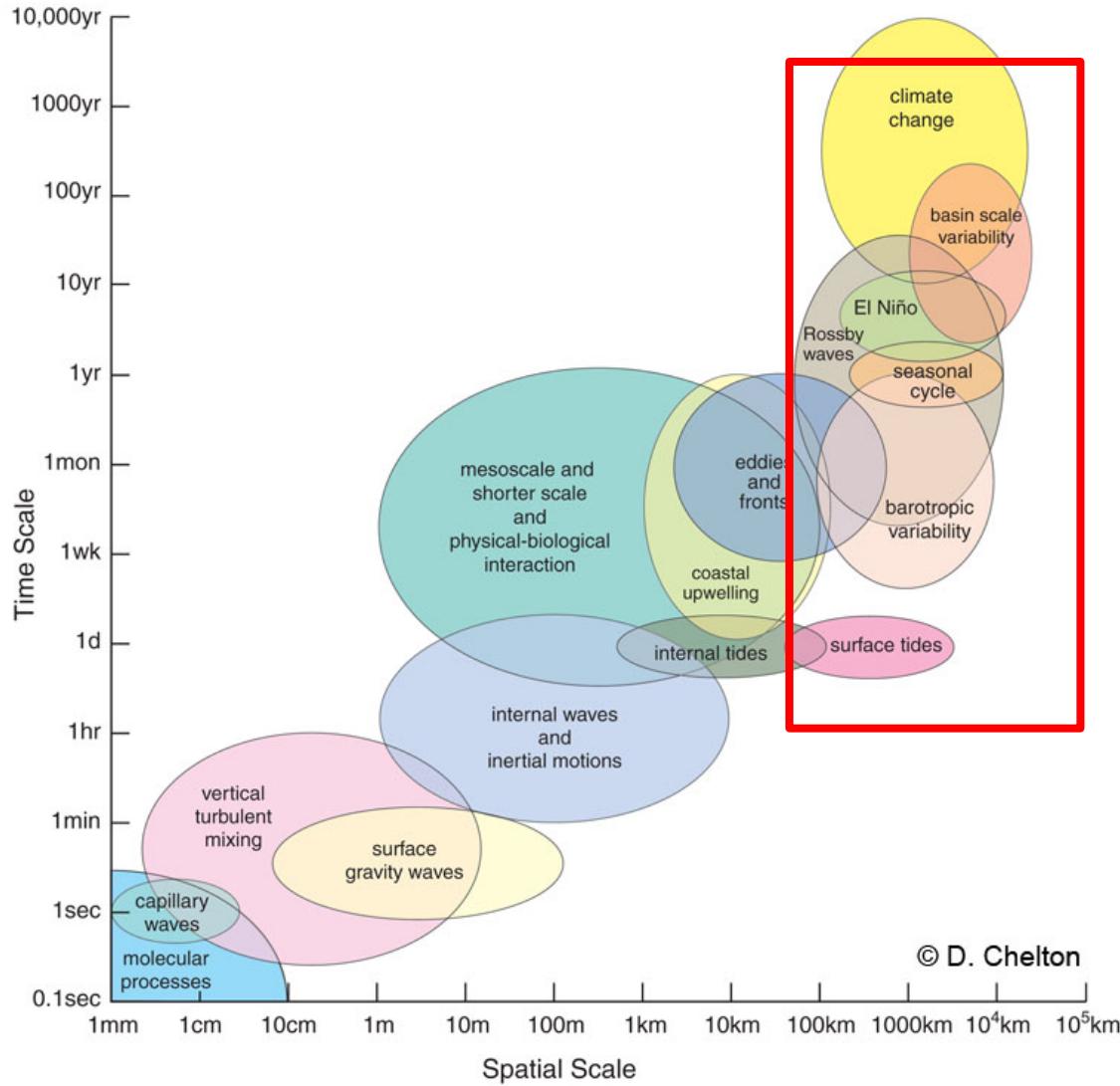
April temperature of
NorESM2 along 87.5°E

Spatial and temporal scales of the atmosphere



Courtesy: Smagorinsky (1974).

Spatial and temporal scales of the ocean



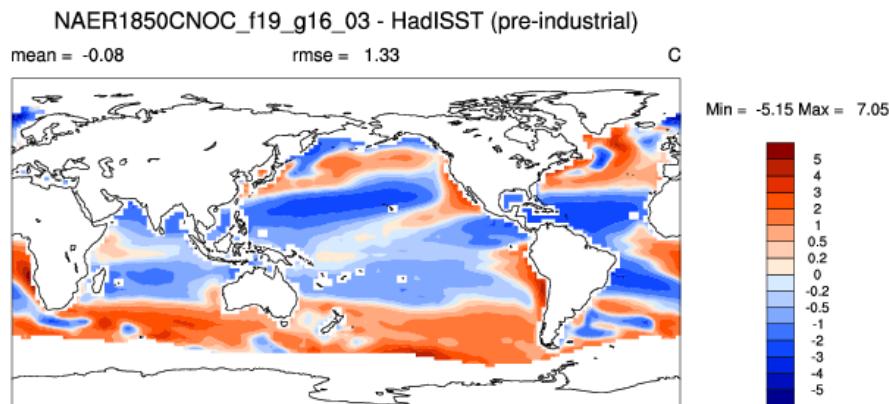
CESM2/NorESM2 developments

- **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.**

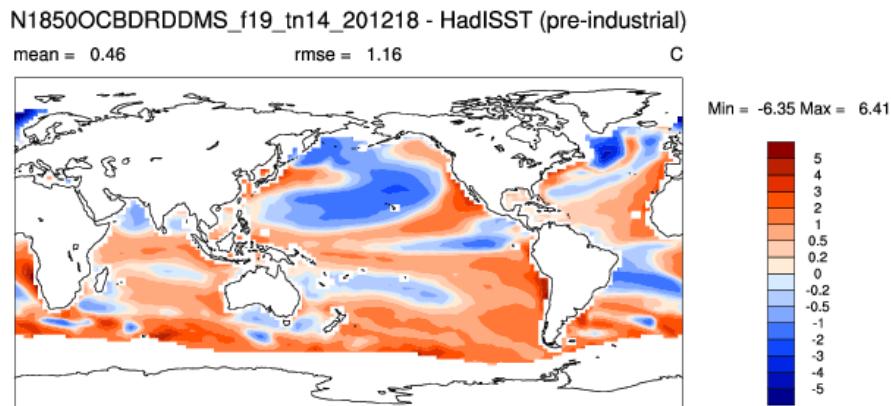
CESM2/NorESM2 developments

- **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**.
- **MICOM:** *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.

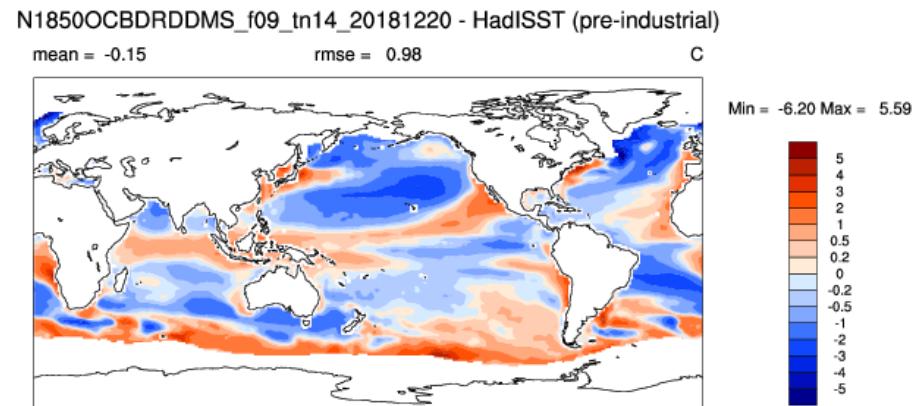
Annual mean sea surface temperature



NorESM1-M

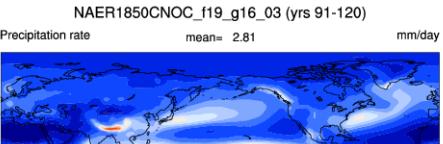


NorESM2-LM

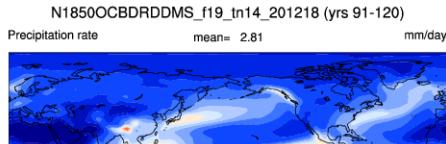


NorESM2-MM

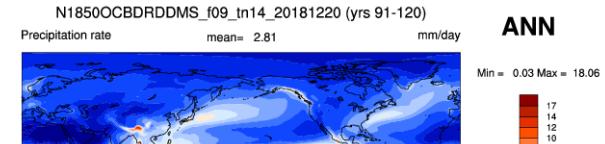
Annual mean precipitation



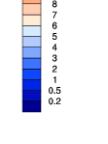
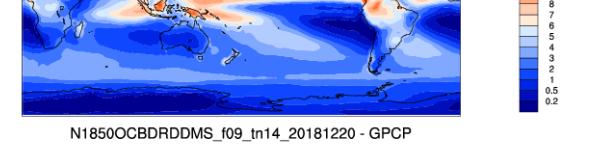
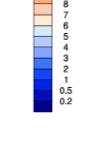
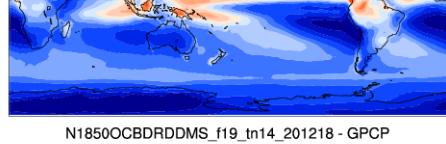
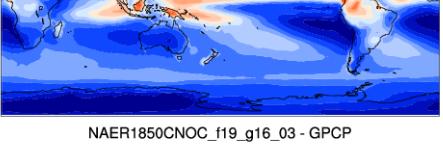
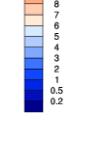
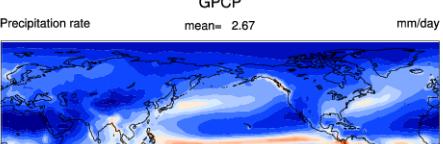
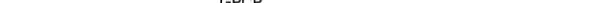
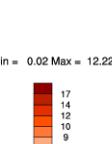
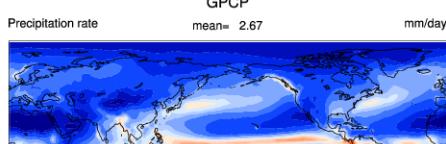
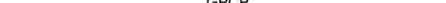
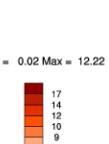
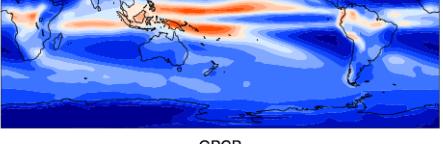
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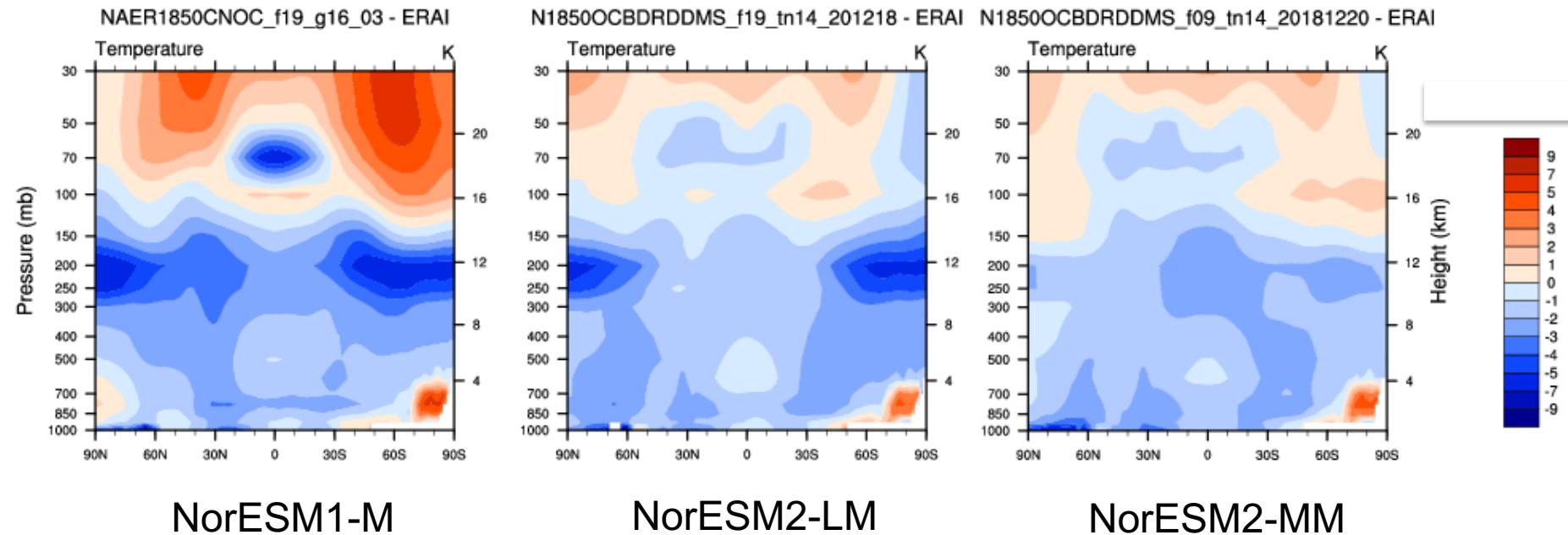


NorESM1-M

NorESM2-LM

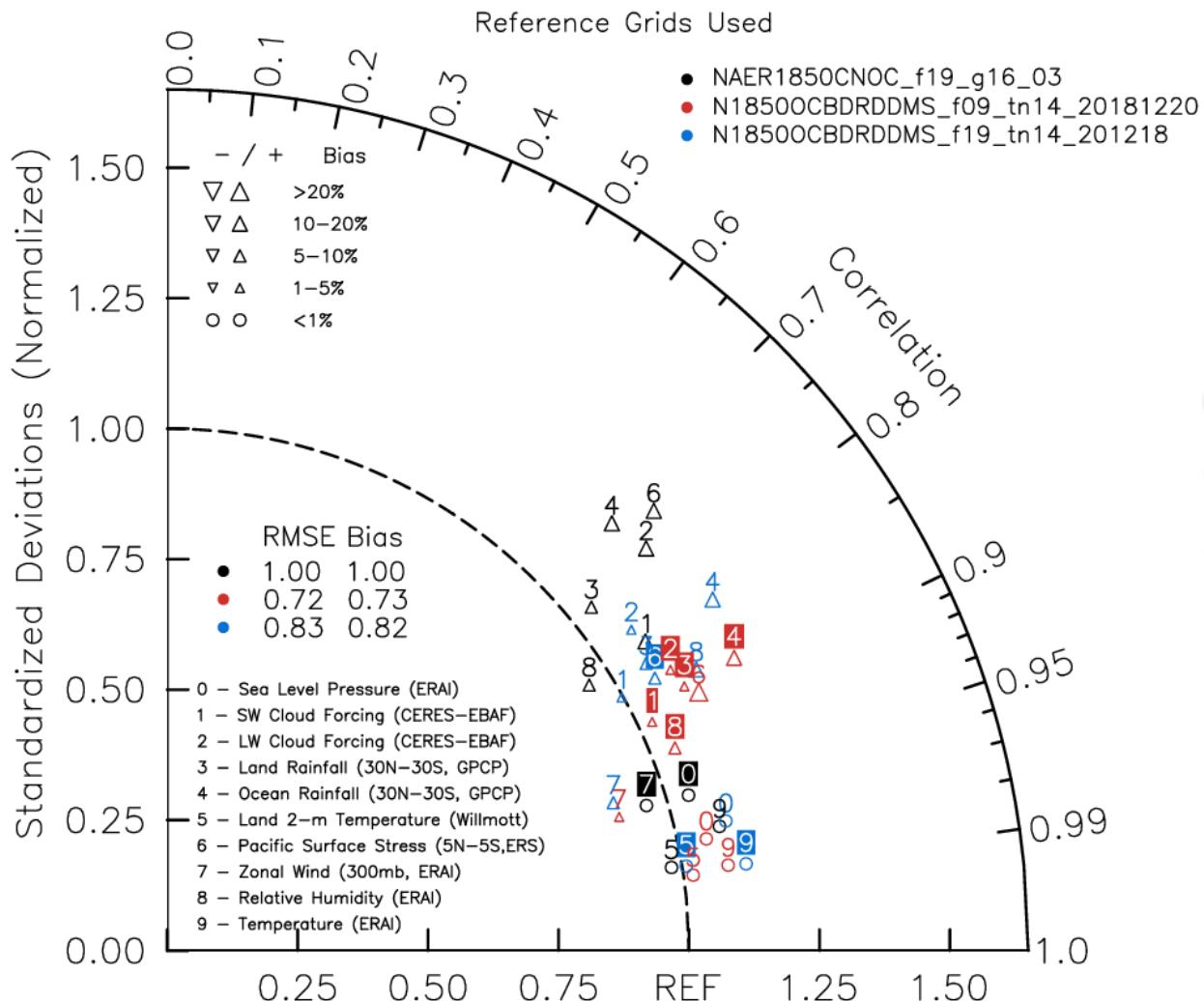
NorESM2-MM

Annual zonal mean temperature bias



CESM2/NorESM2 developments

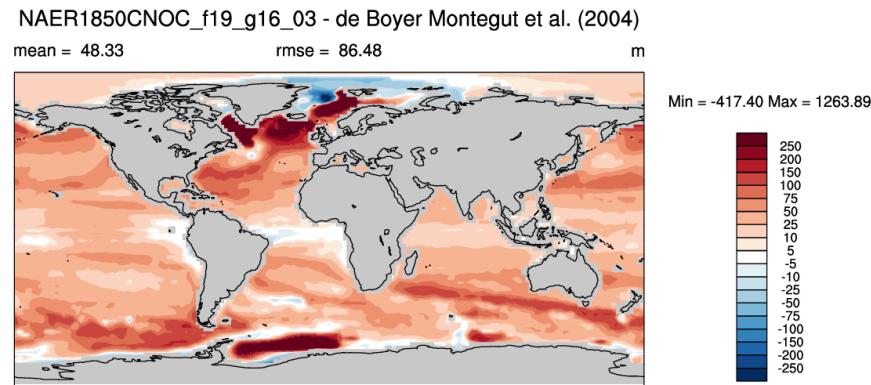
ANN: SPACE-TIME



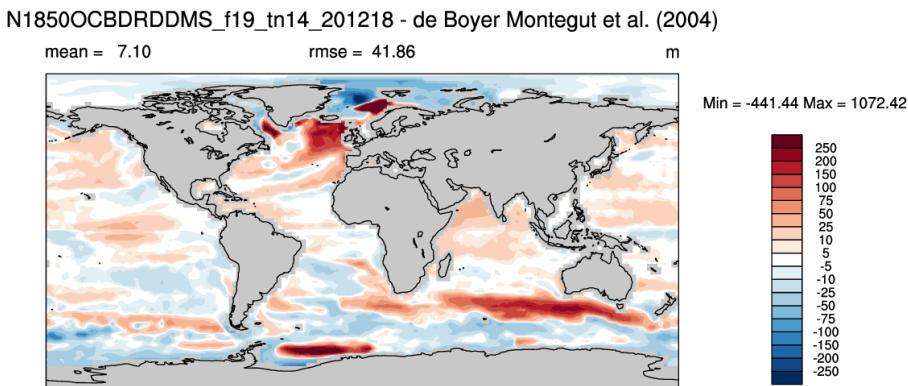
Statistical comparison with observations of

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

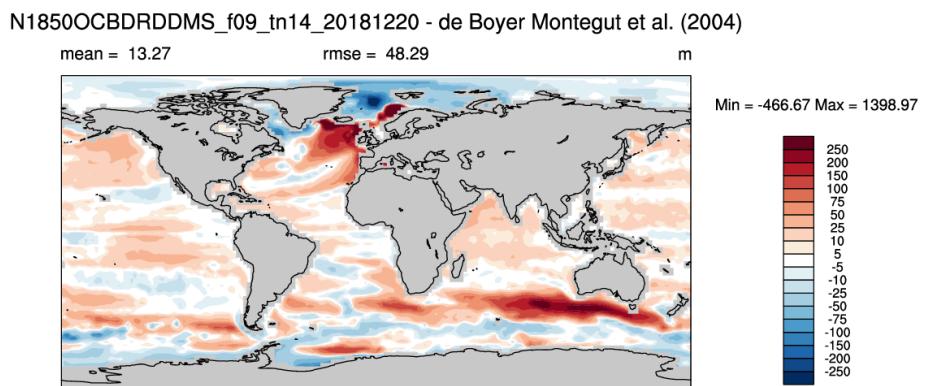
Annual mean ocean mixed layer bias



NorESM1-M

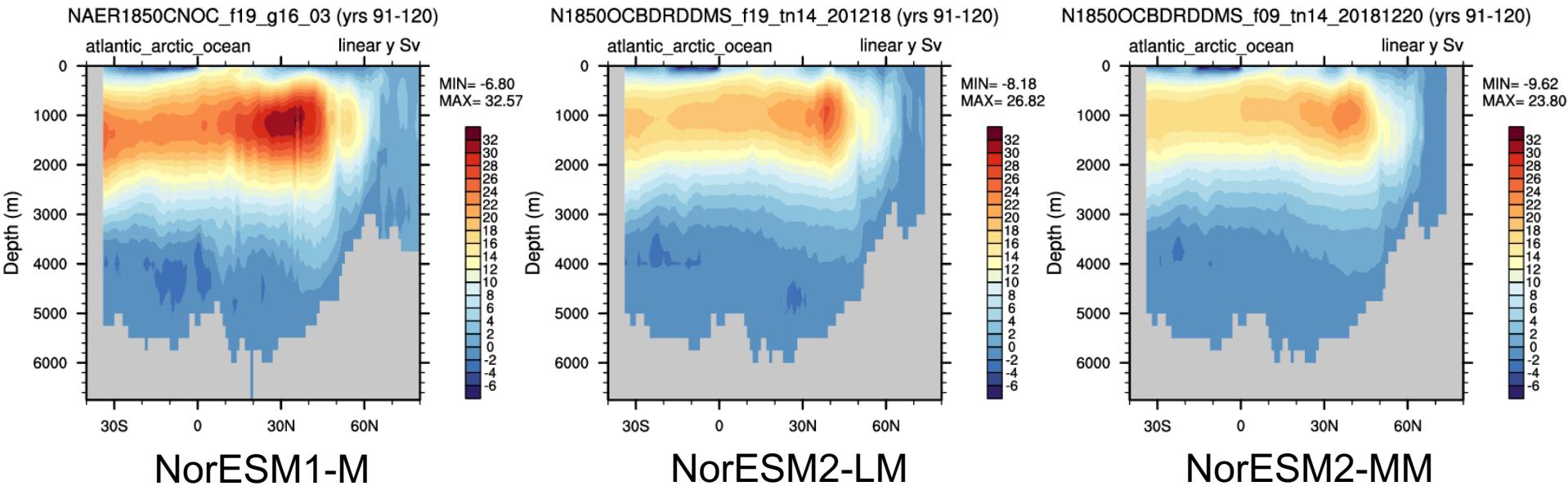


NorESM2-LM



NorESM2-MM

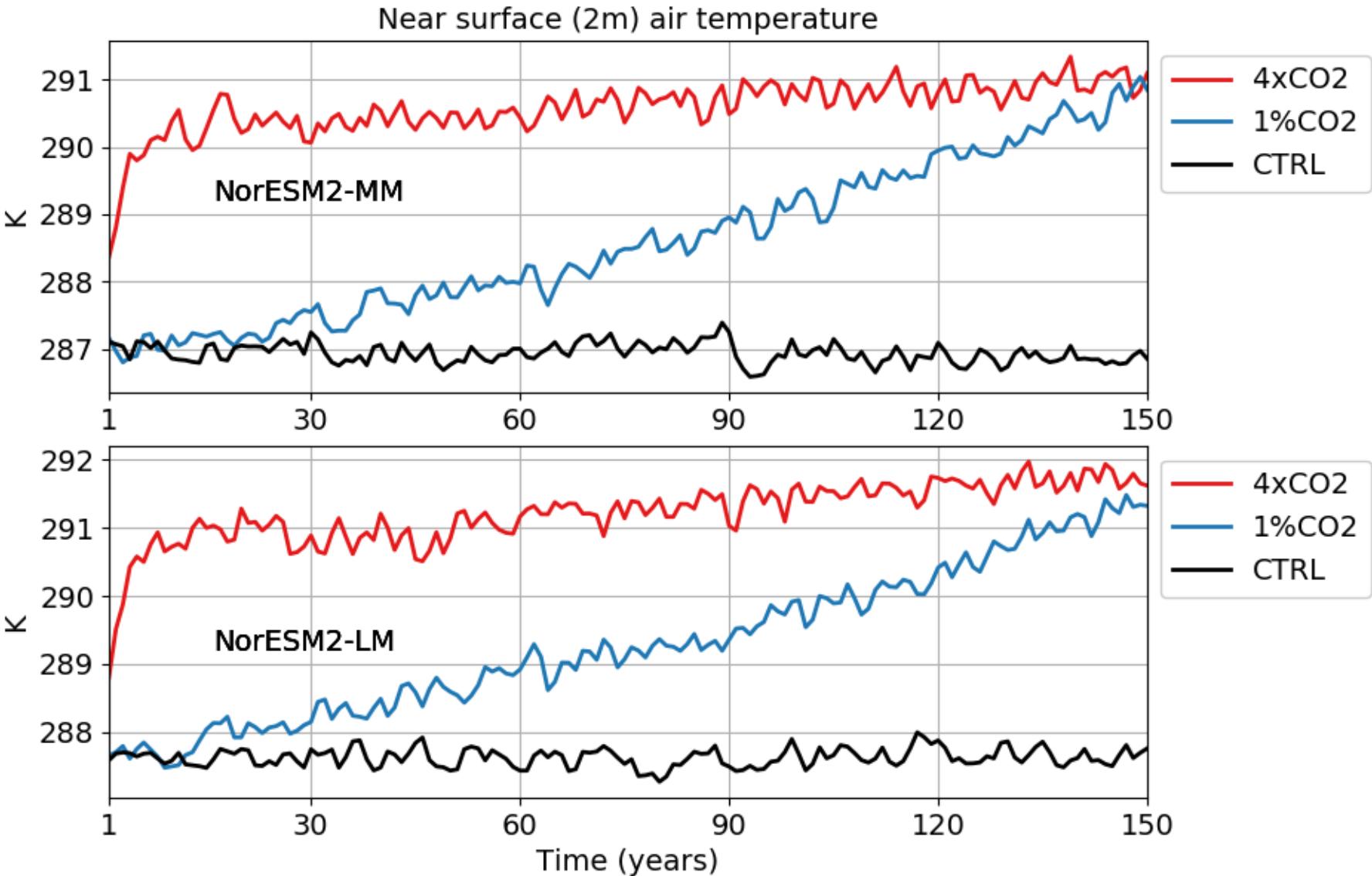
Atlantic meridional overturning circulation



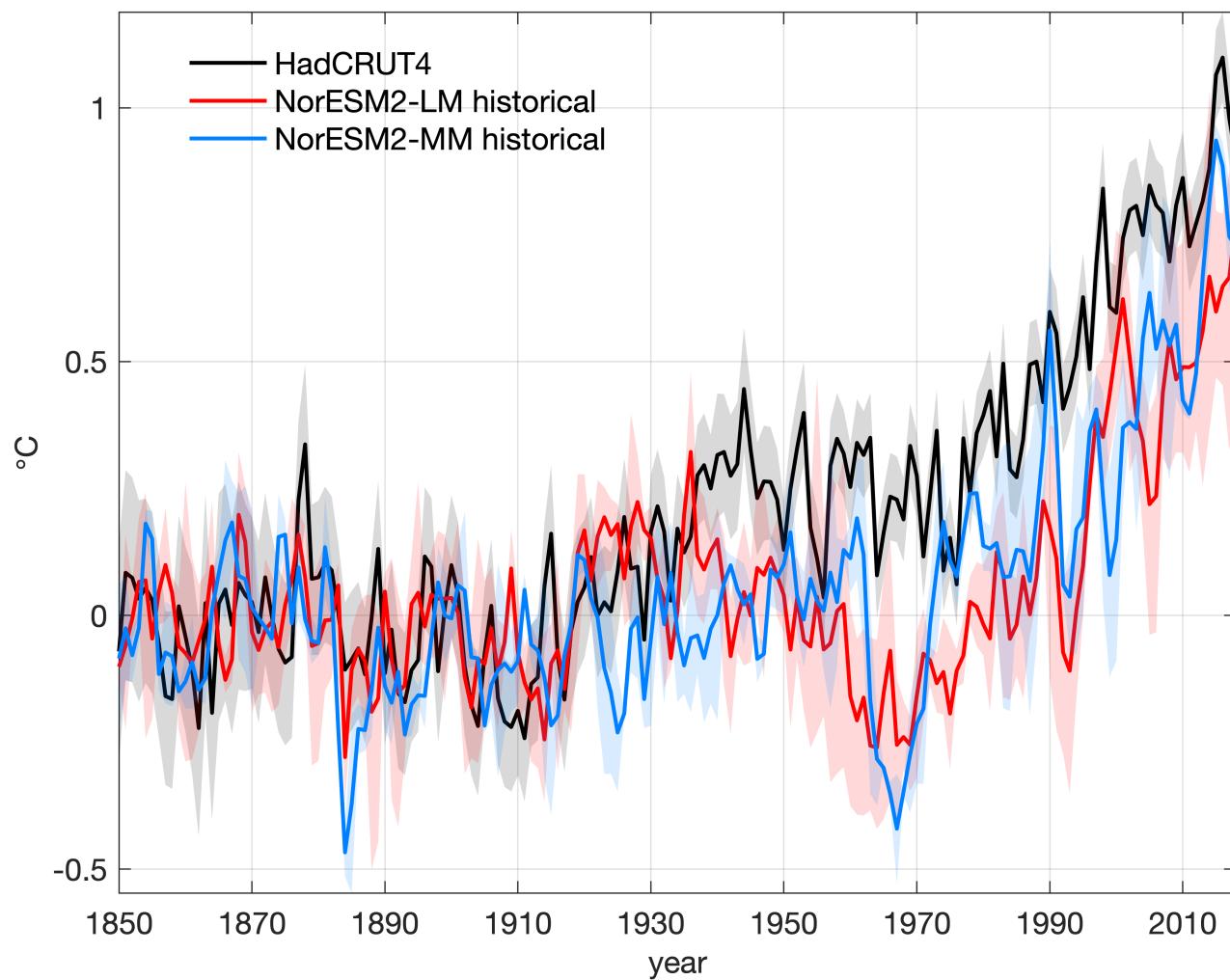
CMIP6 status

- Through ESGF there are currently **68** 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, CMIP, DAMIP, LUMIP, OMIP, PAMIP, PMIP, RFMIP, ScenarioMIP.
 - **NorESM2-MM:** AerChemMIP, CMIP, RFMIP, ScenarioMIP.
 - **NorCPM1:** CMIP, DCPP.
 - **NorESM1-F:** CMIP, PMIP.

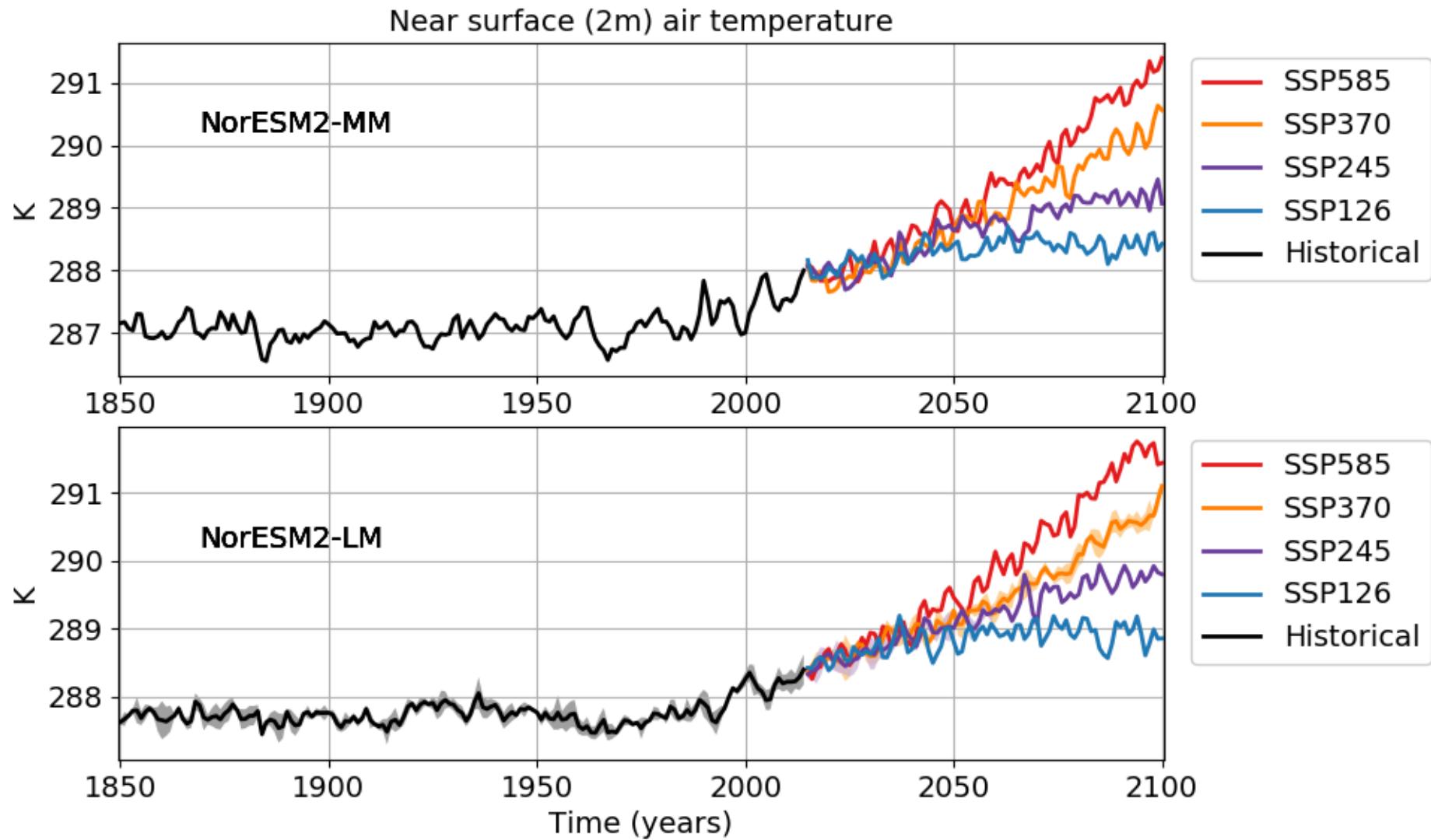
NorESM2 DECK simulations



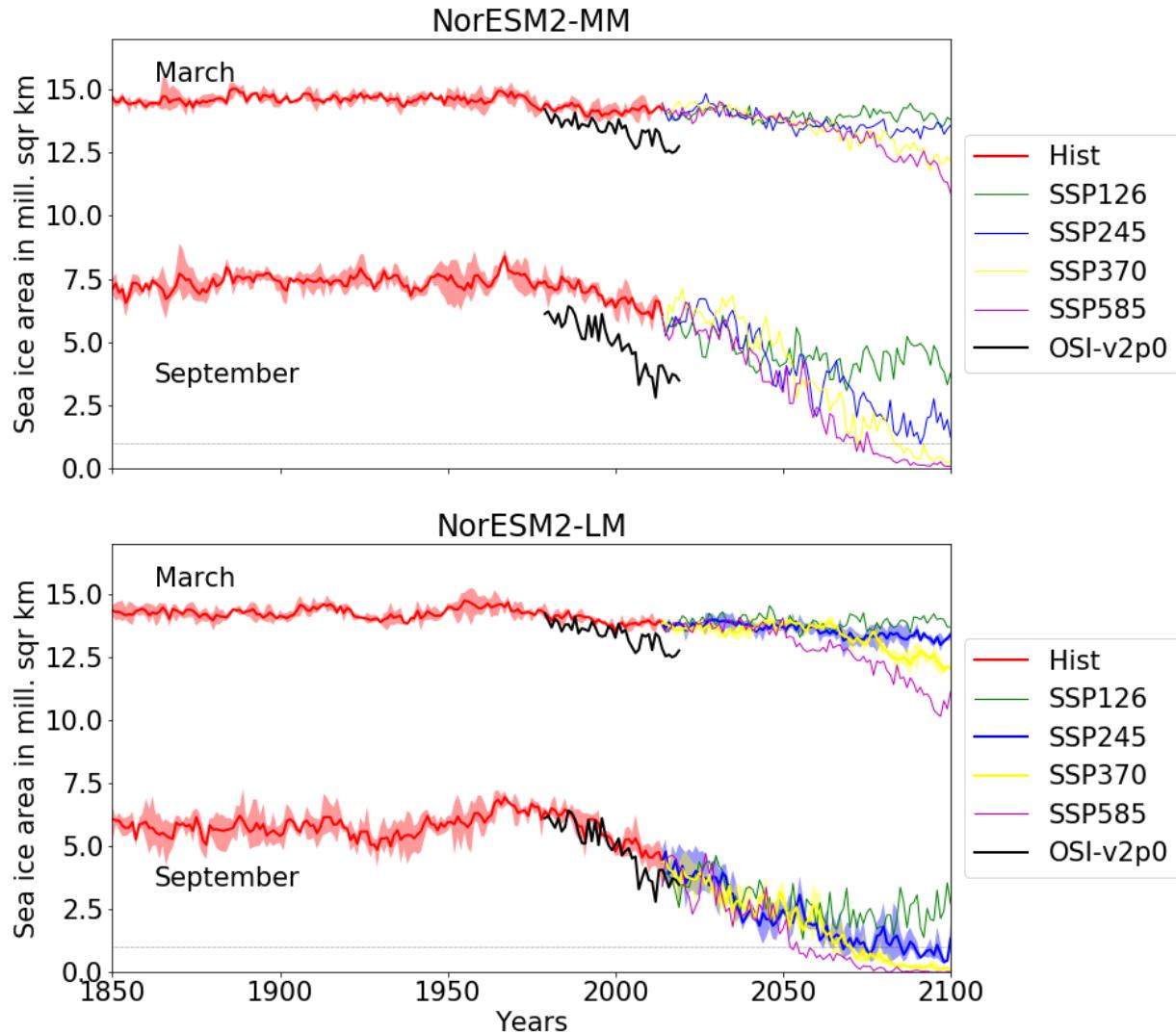
NorESM2 historical simulations



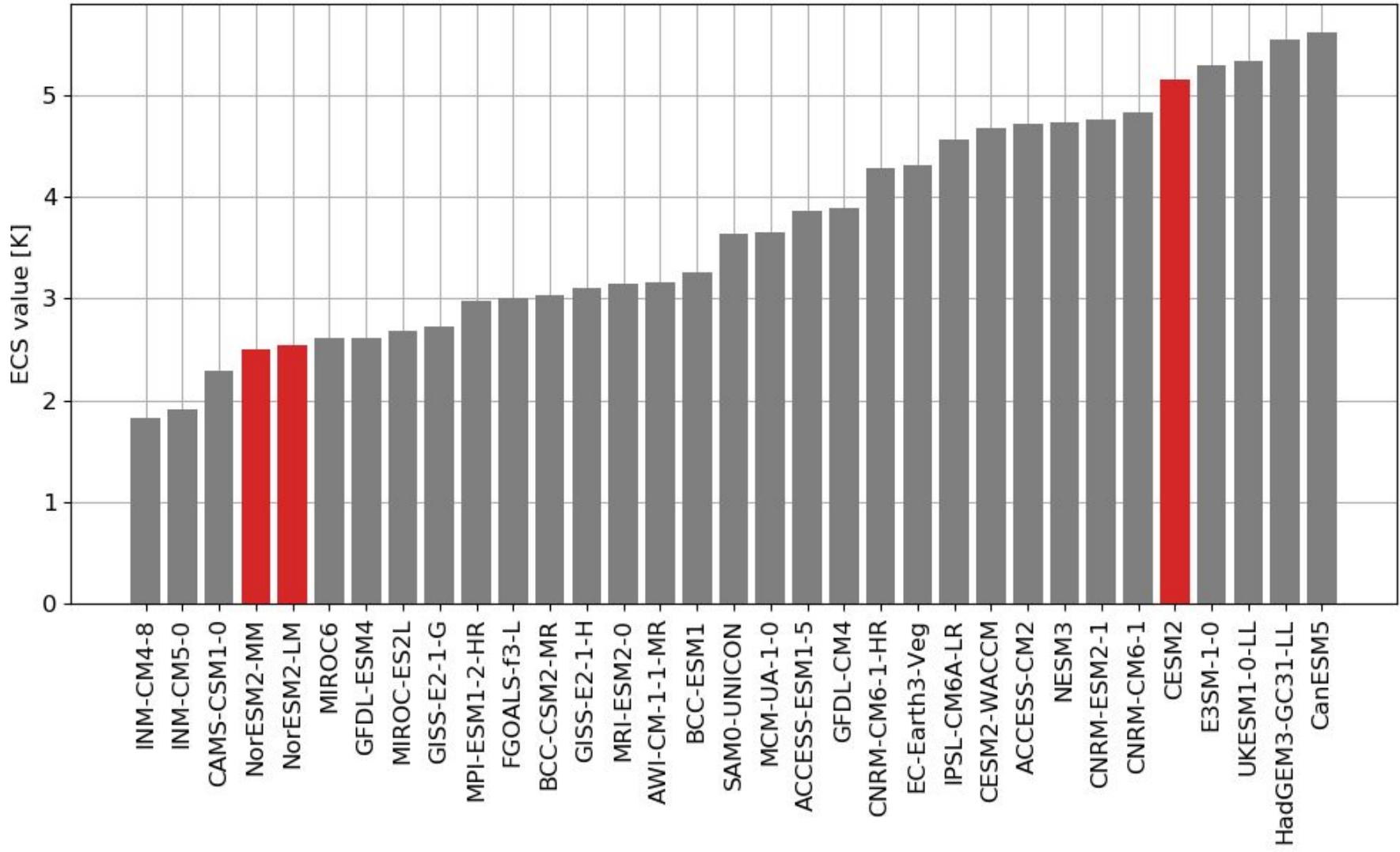
NorESM2 historical and scenario simulations



NorESM2 historical and scenario simulations



CMIP6 equilibrium climate sensitivity



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.noressm.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.
- Increased horizontal and vertical resolution.