

Introduction to NorESM



Mats Bentsen^{1,2}

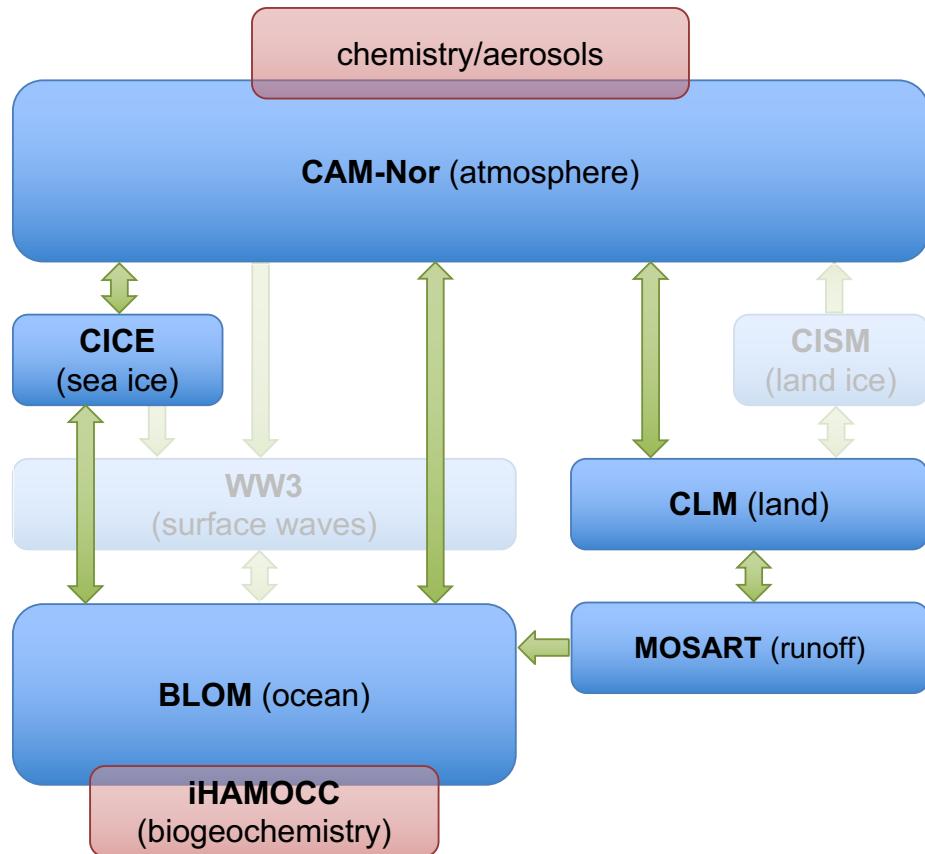
¹ NORCE Norwegian Research Centre

² Bjerknes Centre for Climate Research

Outline

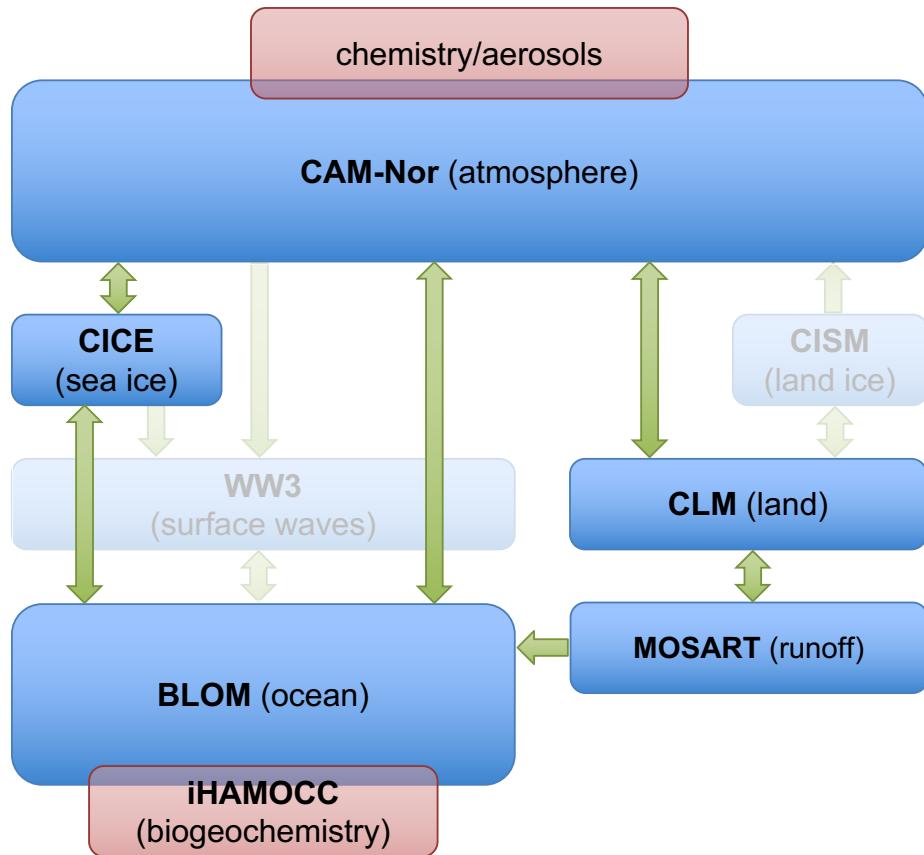
- NorESM overview and differences to CESM
- Some dynamical and physical characteristics
- Scientific updates in NorESM2 compared to NorESM1
- CMIP6 status
- NorESM infrastructure
- Plans for further NorESM development
- Workshop agenda

Norwegian Earth System Model (NorESM)



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

Norwegian Earth System Model (NorESM)



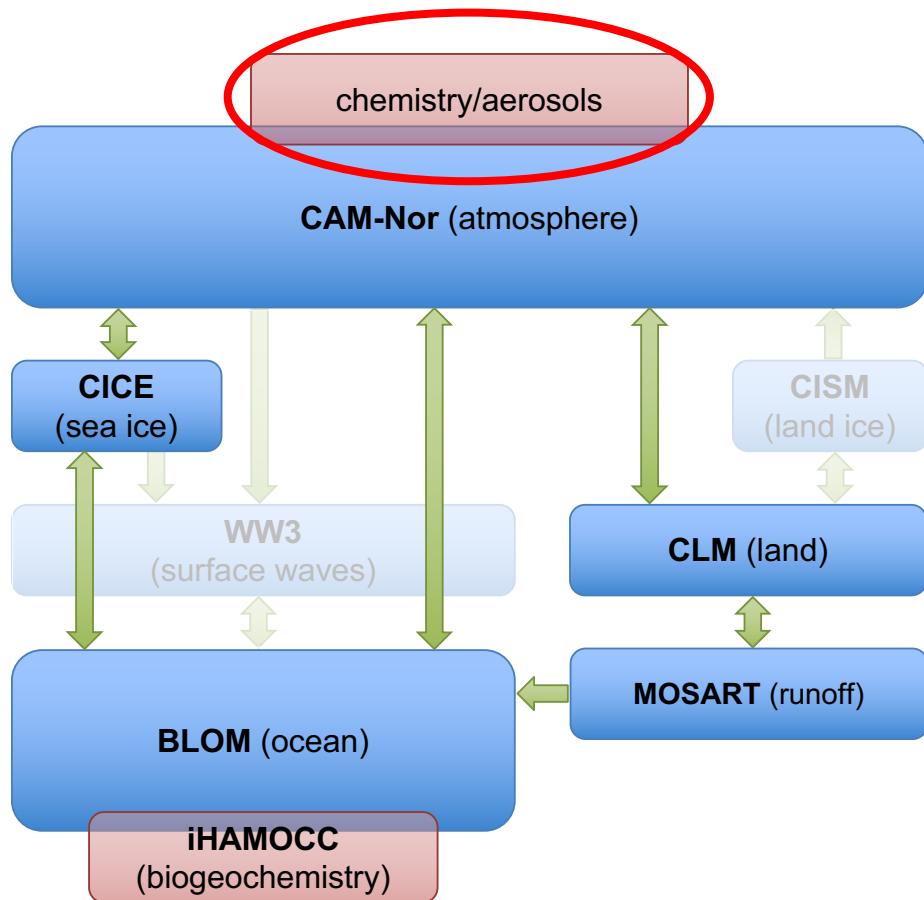
Consortium:



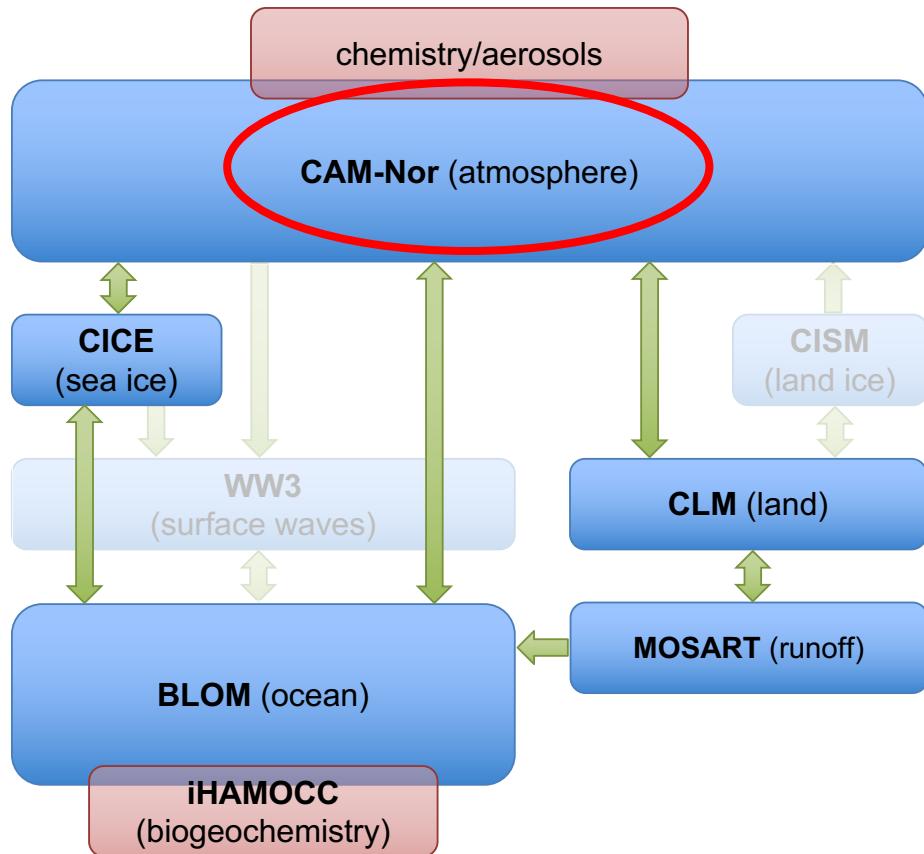
Norwegian Earth System Model (NorESM)

Specific NorESM additions to CESM:

- Atmospheric chemistry/aerosol/cloud module



Norwegian Earth System Model (NorESM)

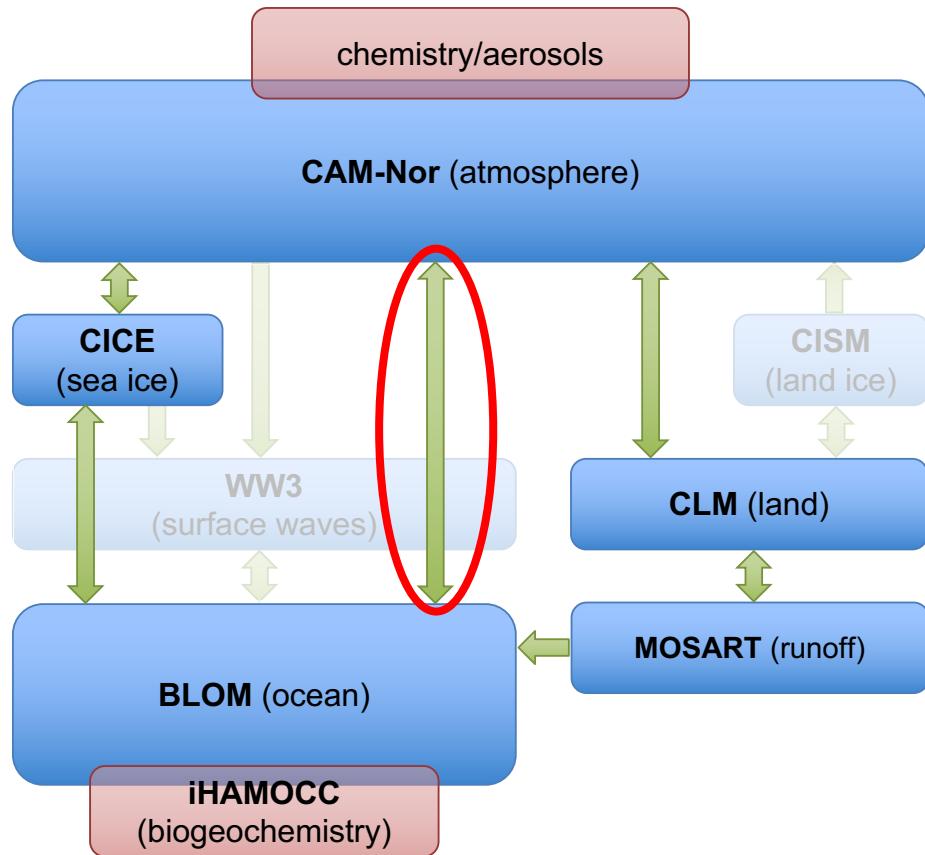


Specific NorESM additions to CESM:

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



Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

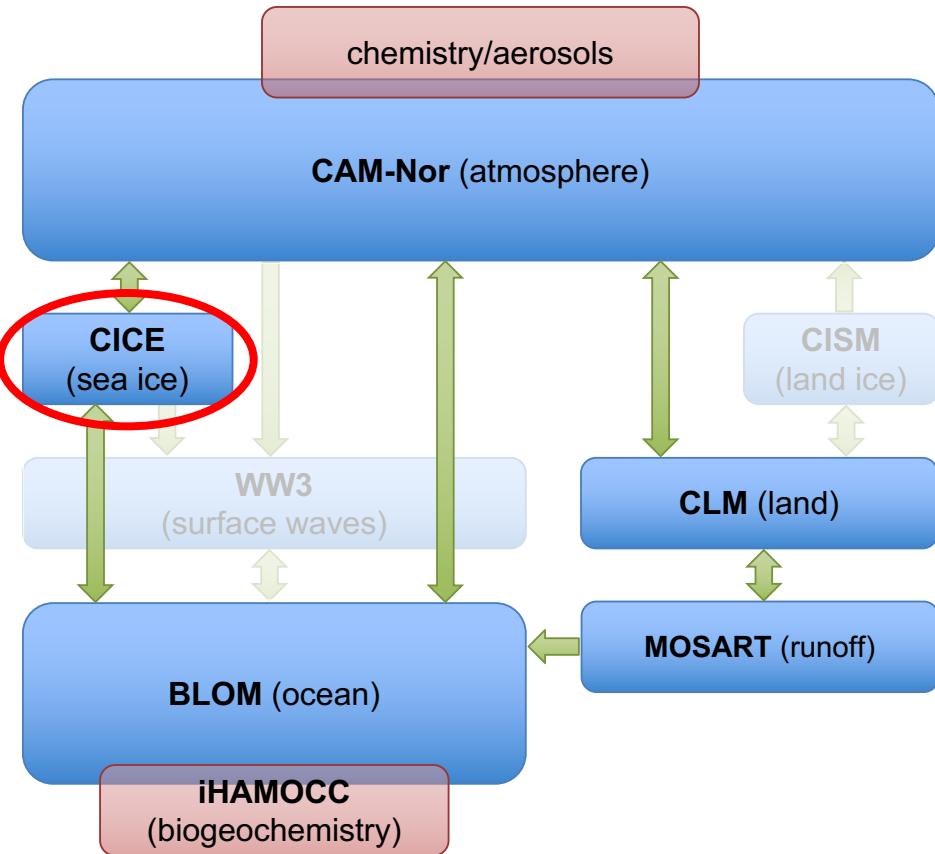
- Atmospheric chemistry/aerosol/cloud module
- Atmospheric dynamics/physics: Improved conservation of energy and angular momentum
- Parameterization of turbulent air-sea fluxes

NORCE

Bergen



Norwegian Earth System Model (NorESM)



Specific NorESM additions to CESM:

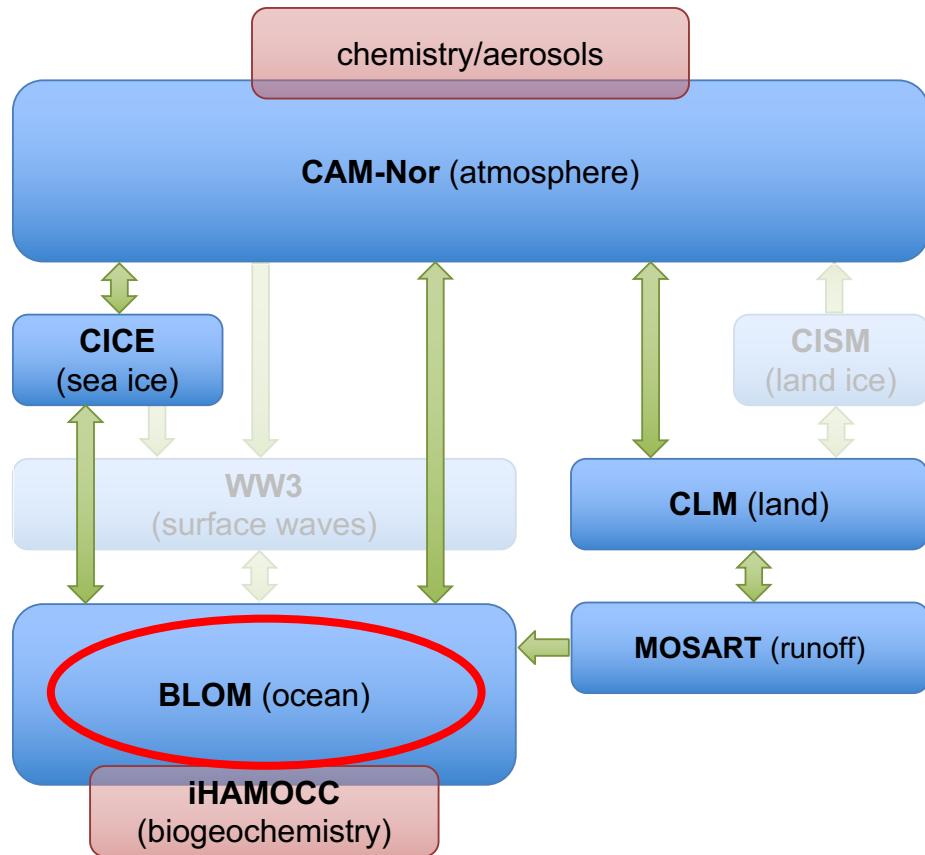
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Bergen



Norwegian Earth System Model (NorESM)



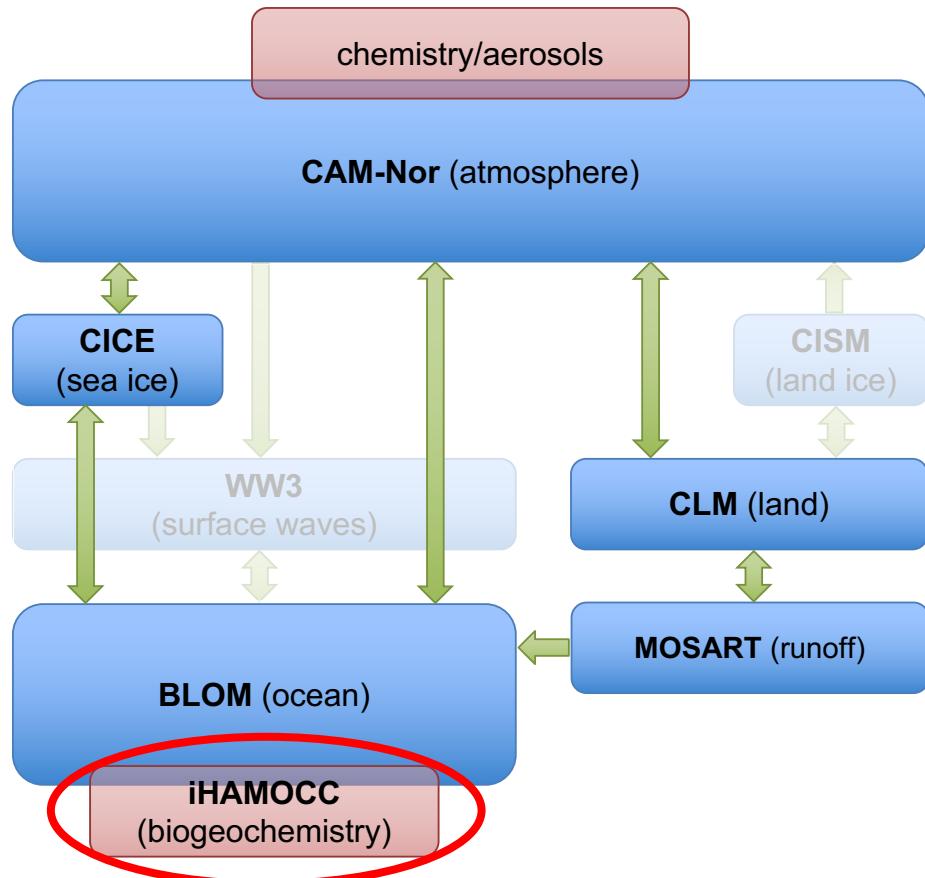
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- Ocean component with isopycnic vertical coordinate



Bergen

Norwegian Earth System Model (NorESM)



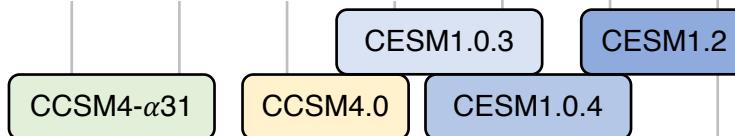
Specific NorESM additions to CESM:

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

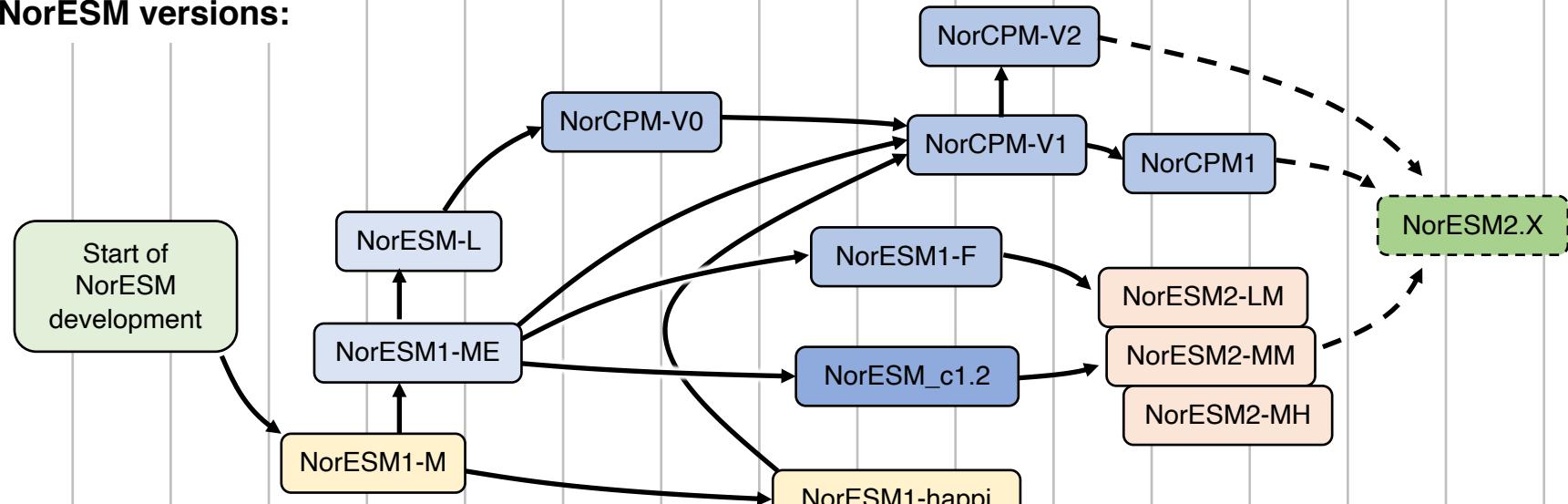


NorESM genealogy

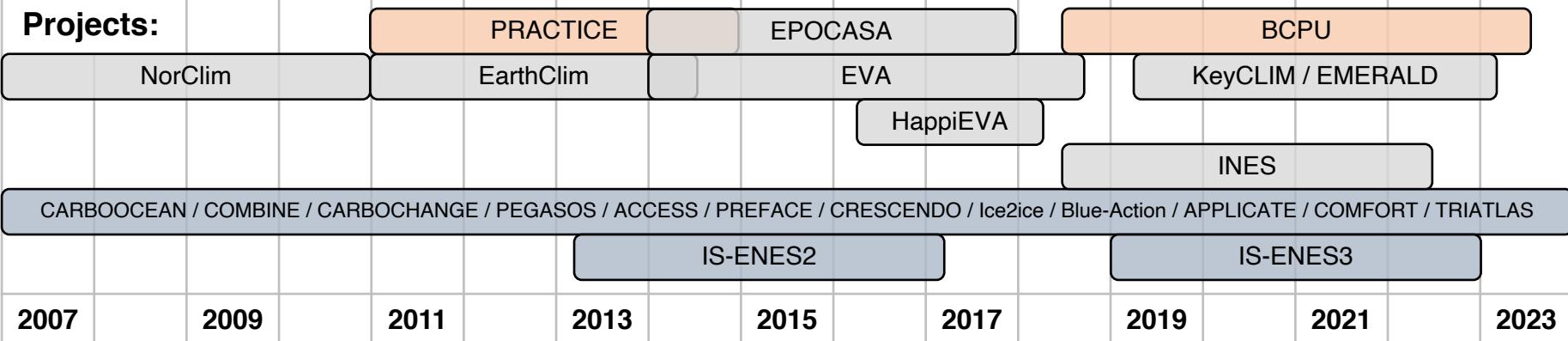
CCSM/CESM versions:



NorESM versions:

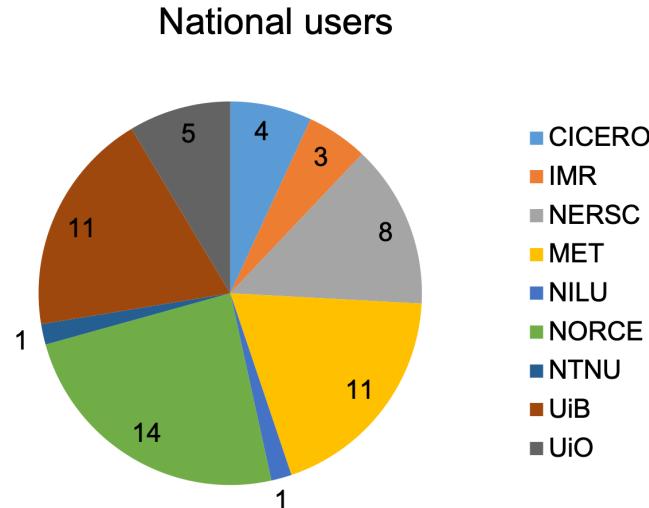


Projects:

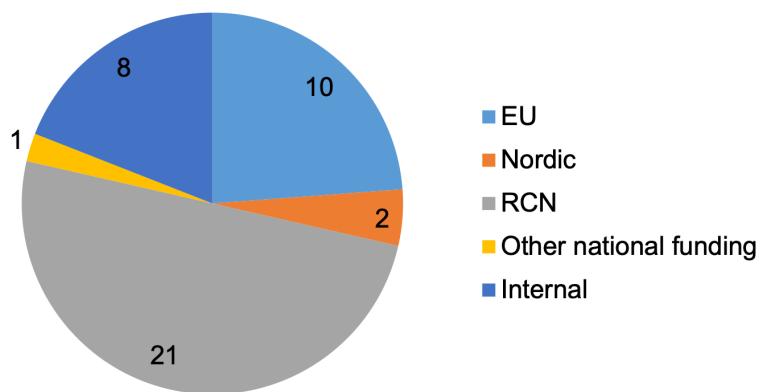


Users and developers of NorESM

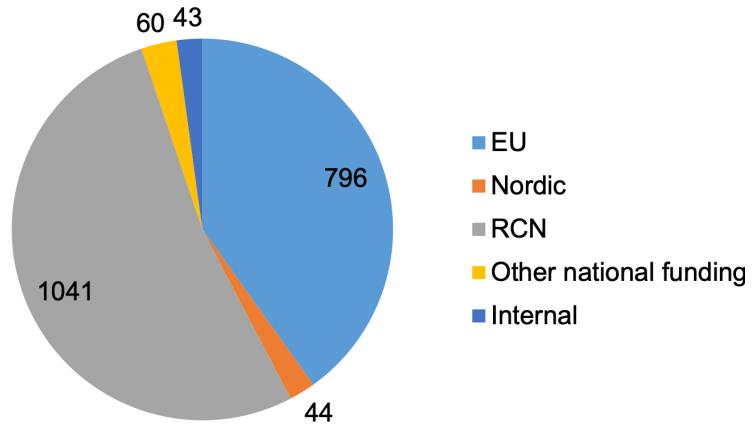
- Based on a survey from February 2021.
- In total 58 national users and developers of NorESM in 2020.



Number of projects



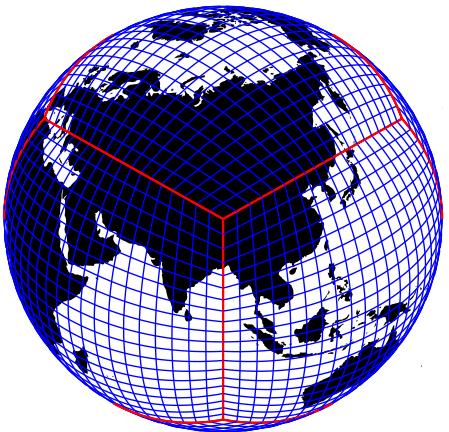
Total grant size (MNOK)



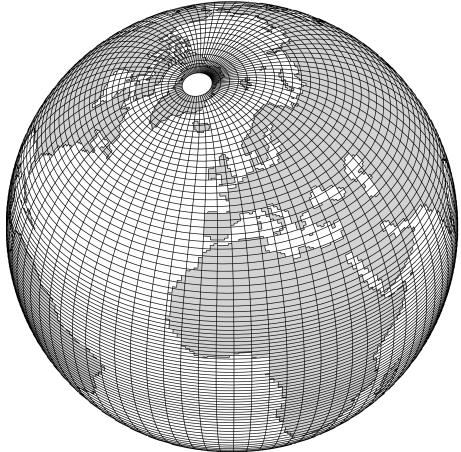
Component discretization



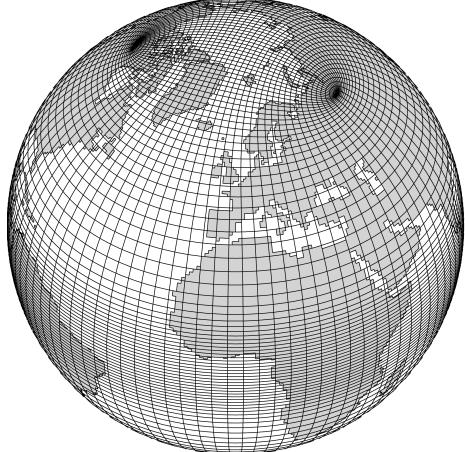
CAM finite volume



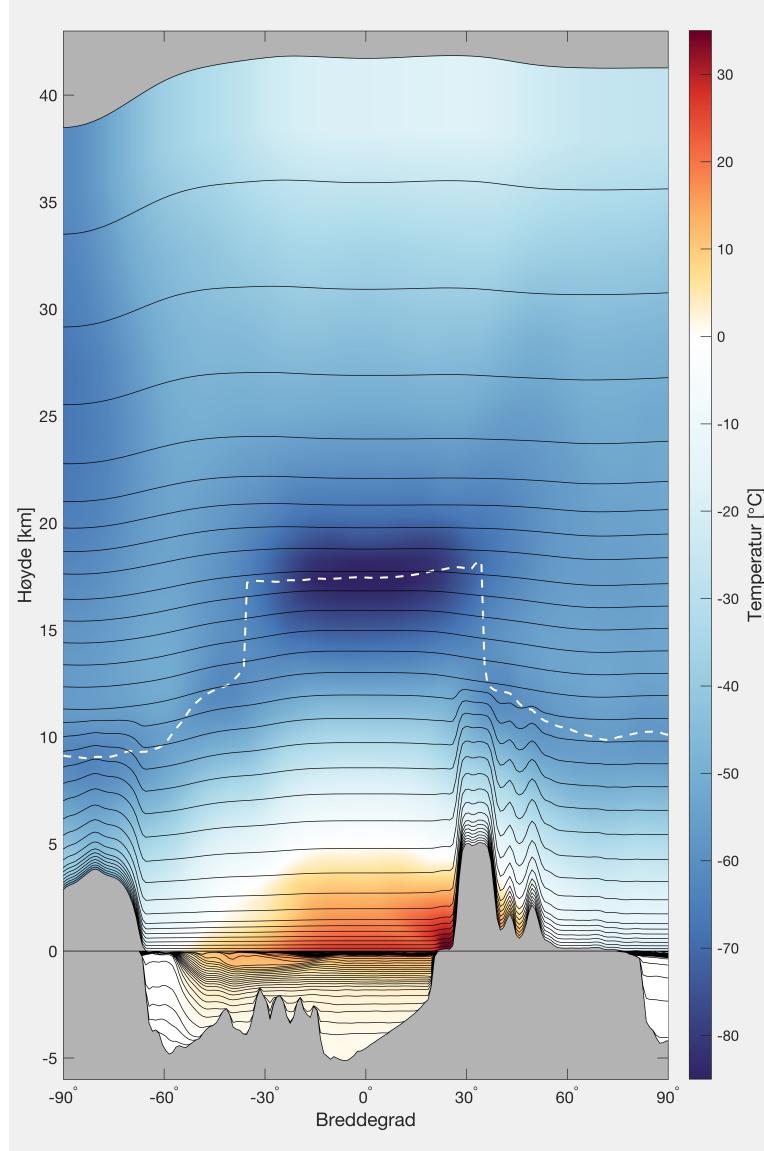
CAM spectral element



BLOM/CICE bipolar

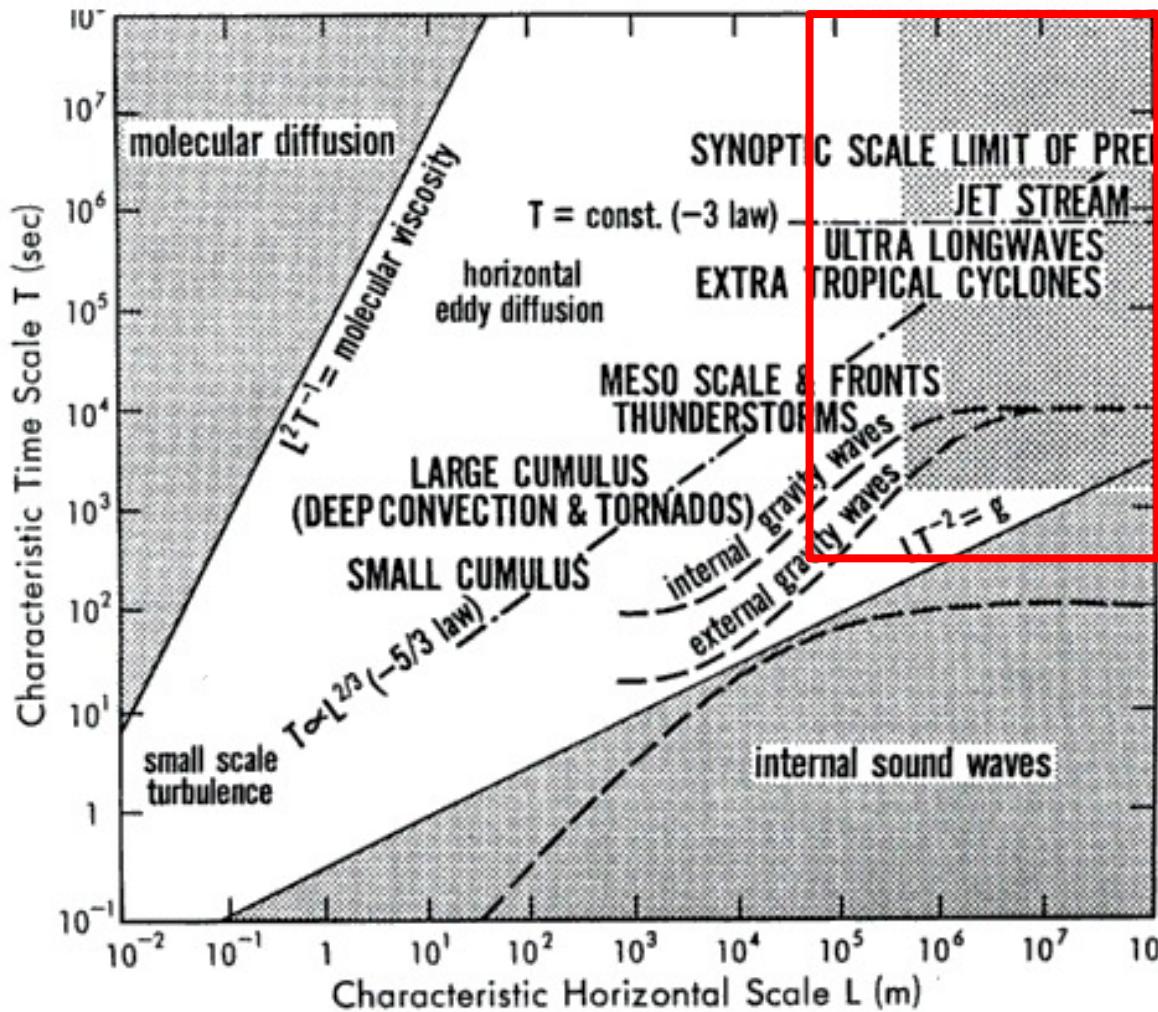


BLOM/CICE tripolar



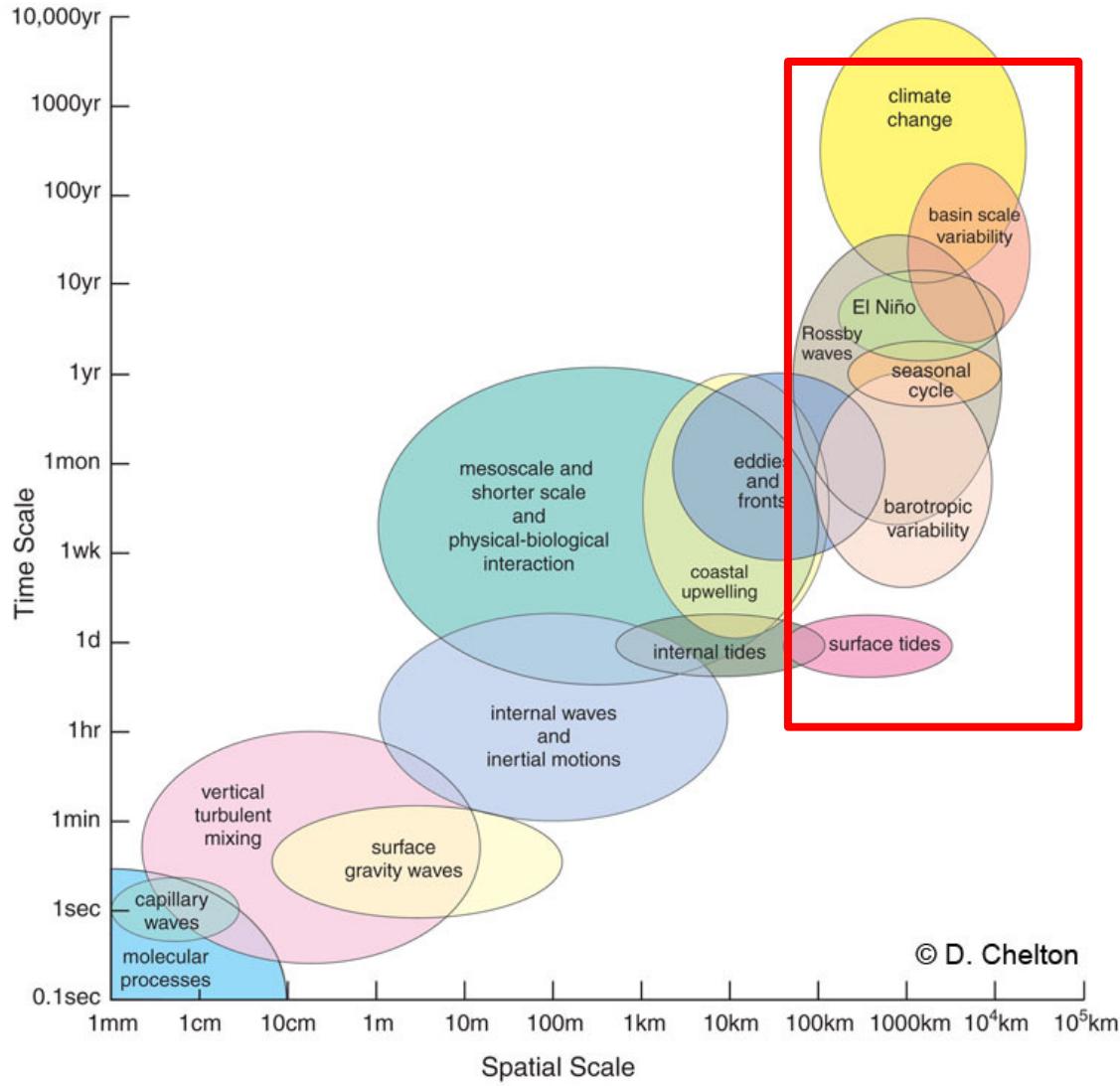
April temperature of
NorESM2 along 87.5°E

Spatial and temporal scales of the atmosphere



Courtesy: Smagorinsky (1974).

Spatial and temporal scales of the ocean



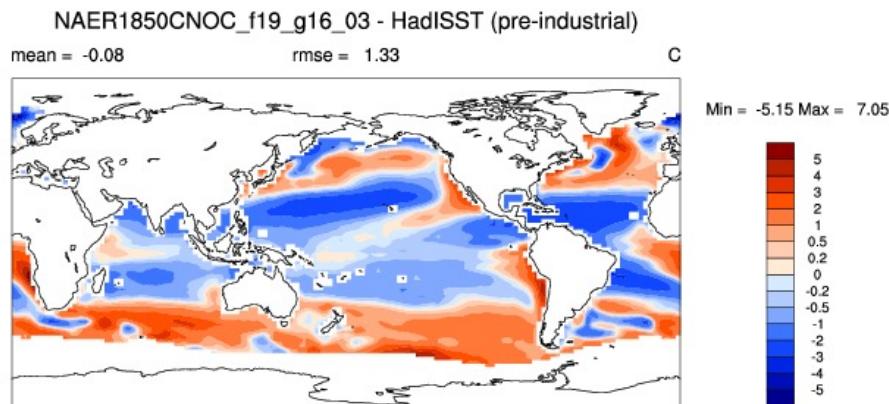
CESM2/NorESM2 developments

- **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.**

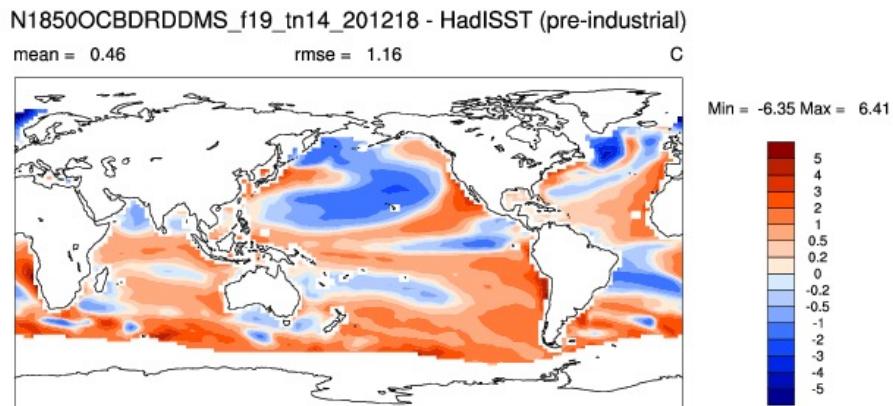
CESM2/NorESM2 developments

- **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.

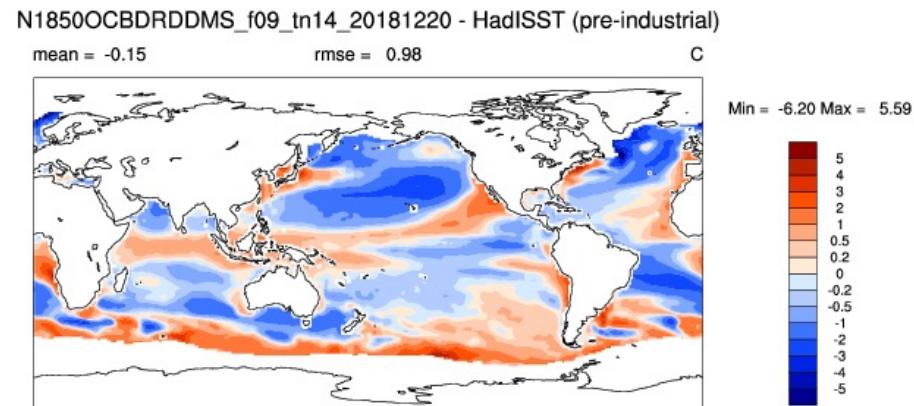
Annual mean sea surface temperature



NorESM1-M

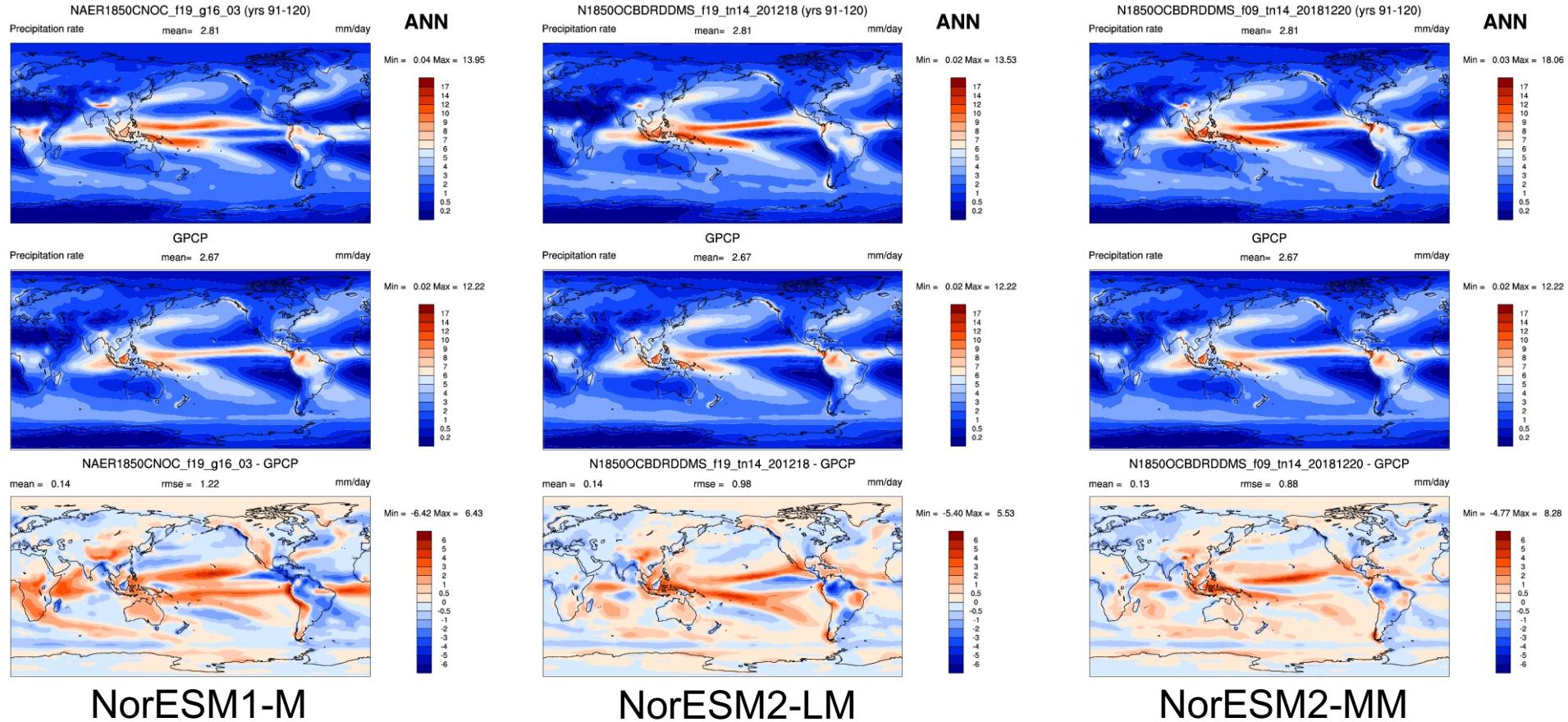


NorESM2-LM

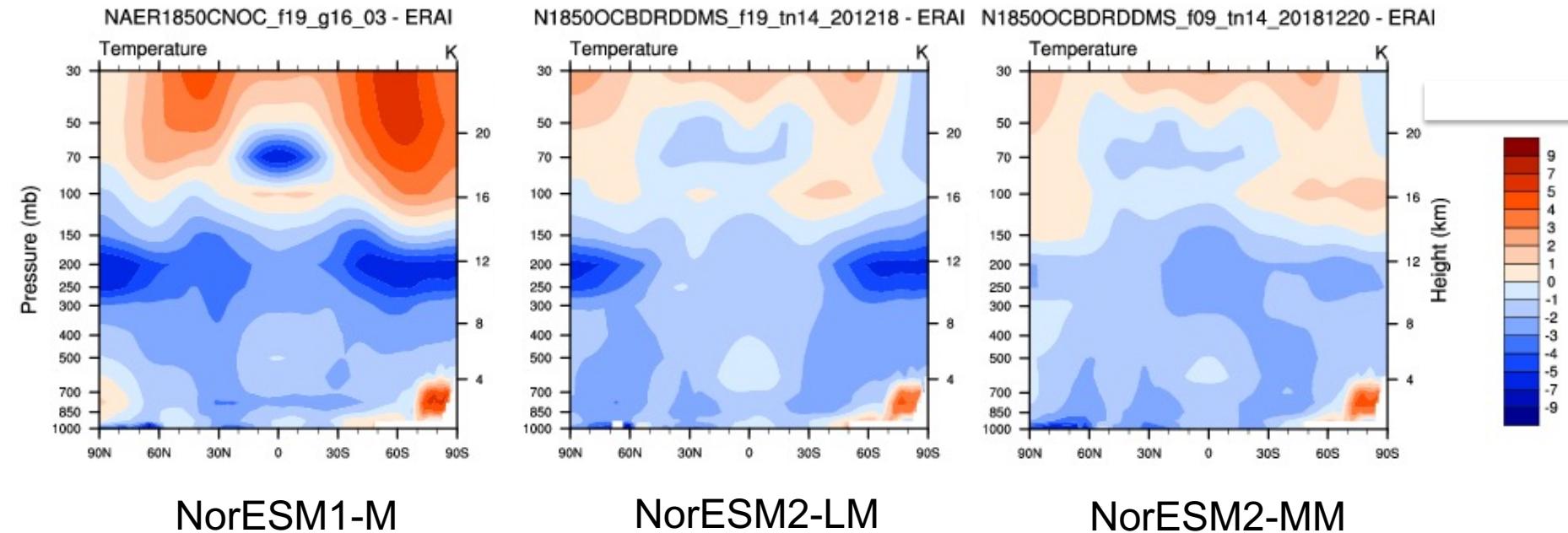


NorESM2-MM

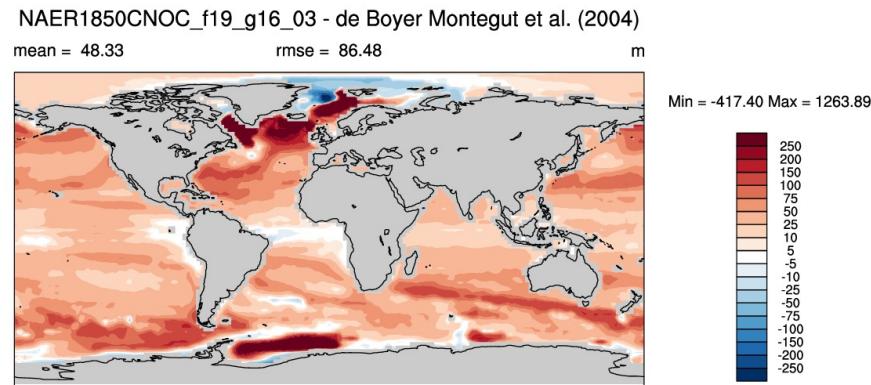
Annual mean precipitation



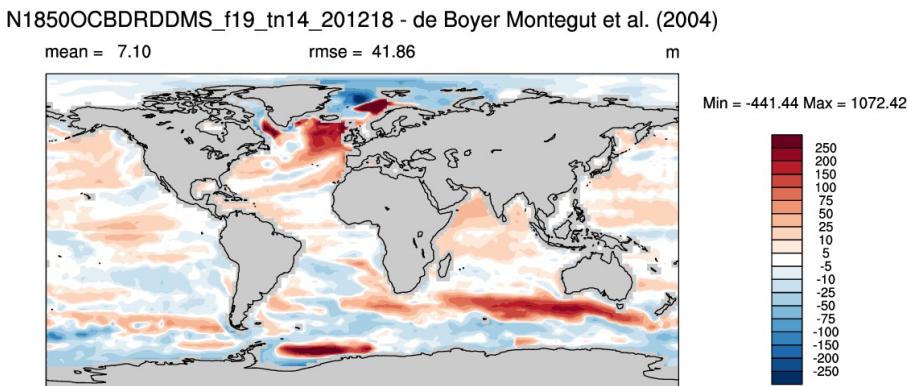
Annual zonal mean temperature bias



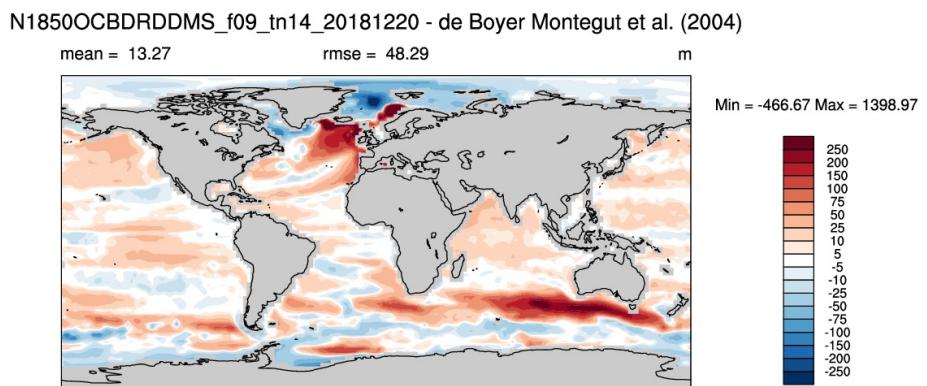
Annual mean ocean mixed layer bias



NorESM1-M

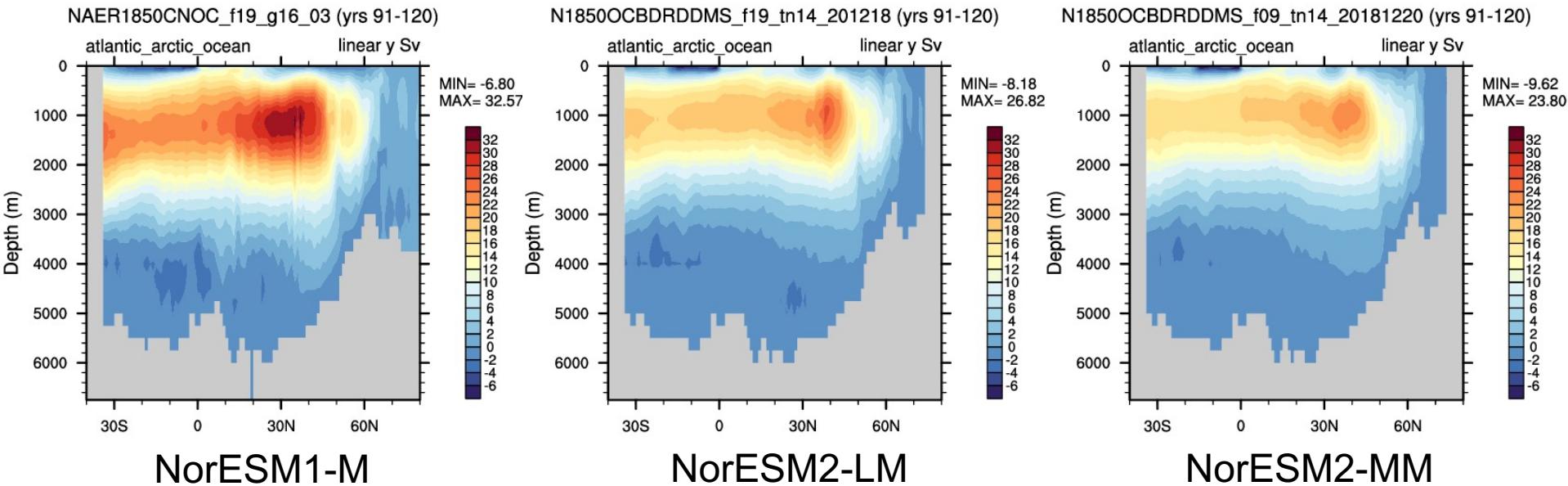


NorESM2-LM

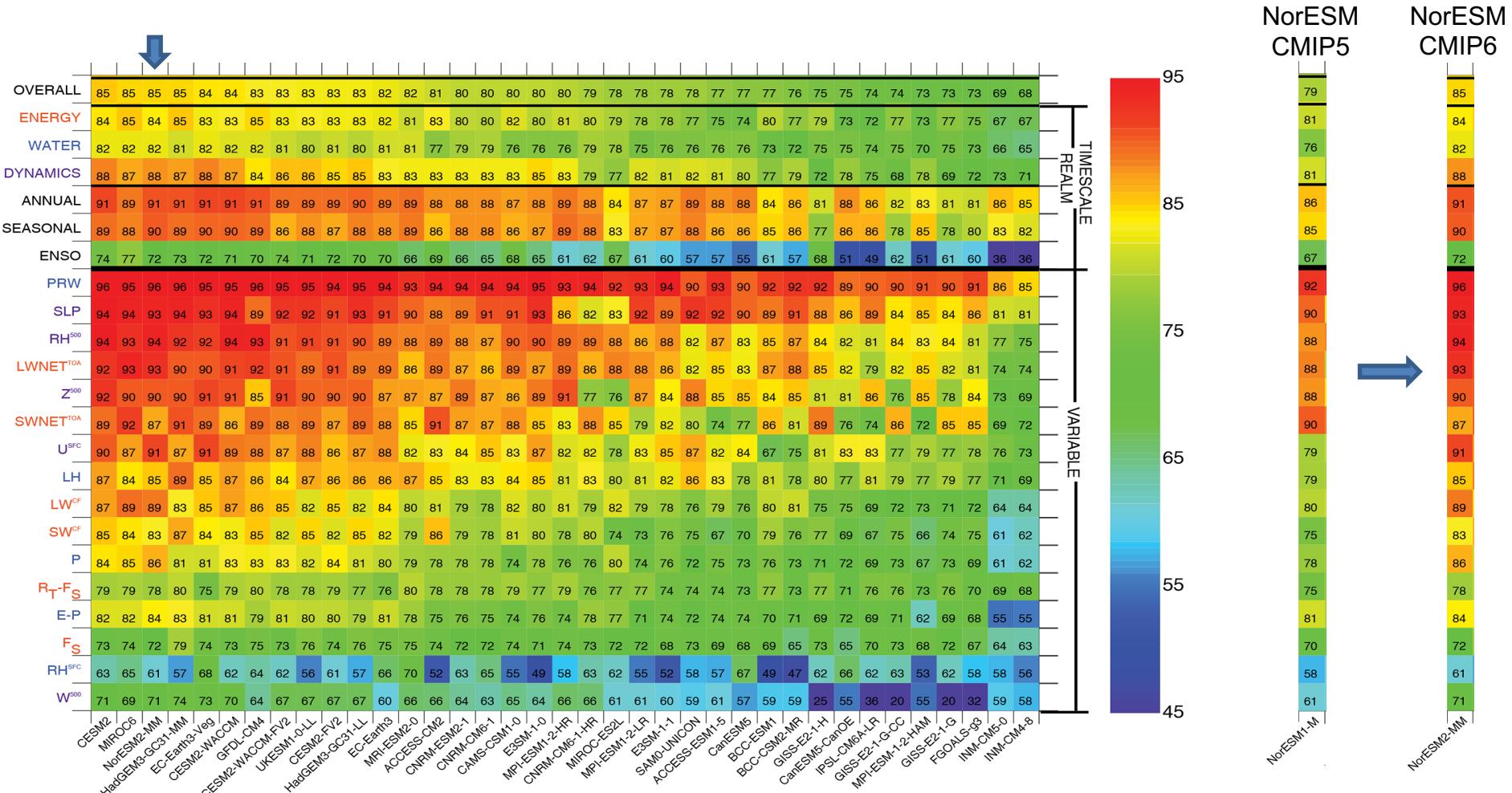


NorESM2-MM

Atlantic meridional overturning circulation



CESM2/NorESM2 developments

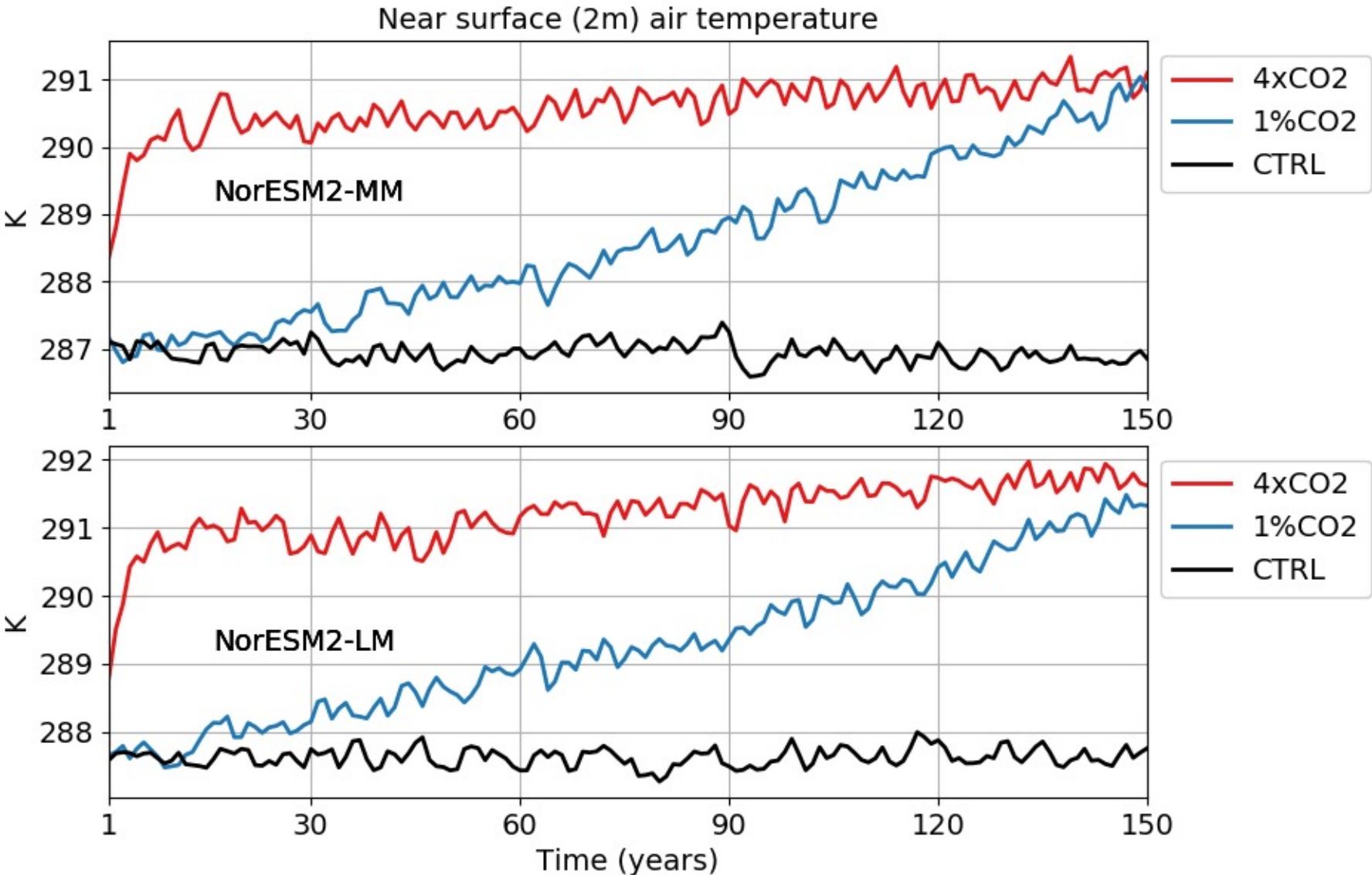


Courtesy: Fasullo (2020).

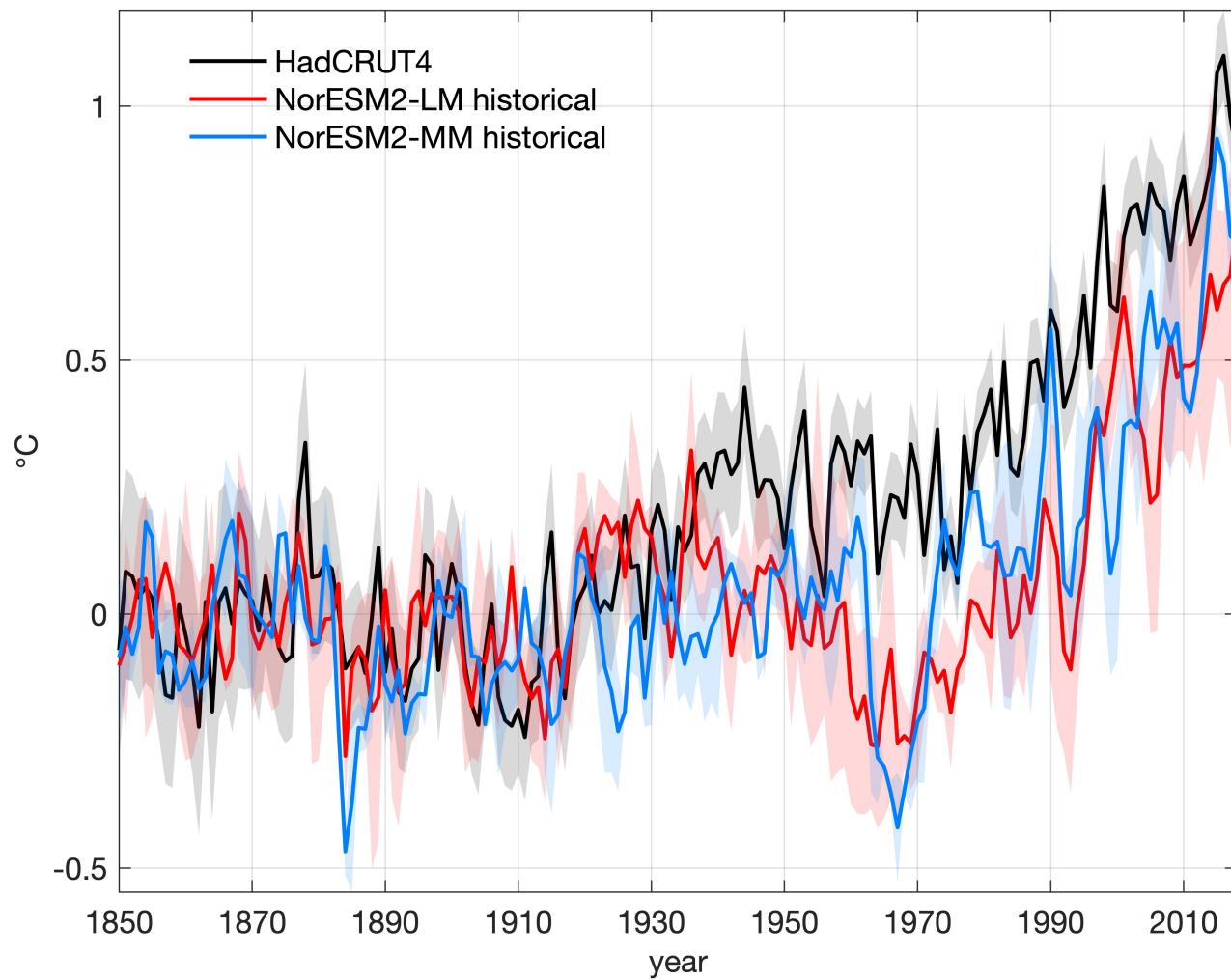
CMIP6 status

- 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, DCPP.
 - **NorESM1-F:** CMIP, PMIP.
- For development and production **200 million CPU hours** have been used and **3 PB** of data produced.

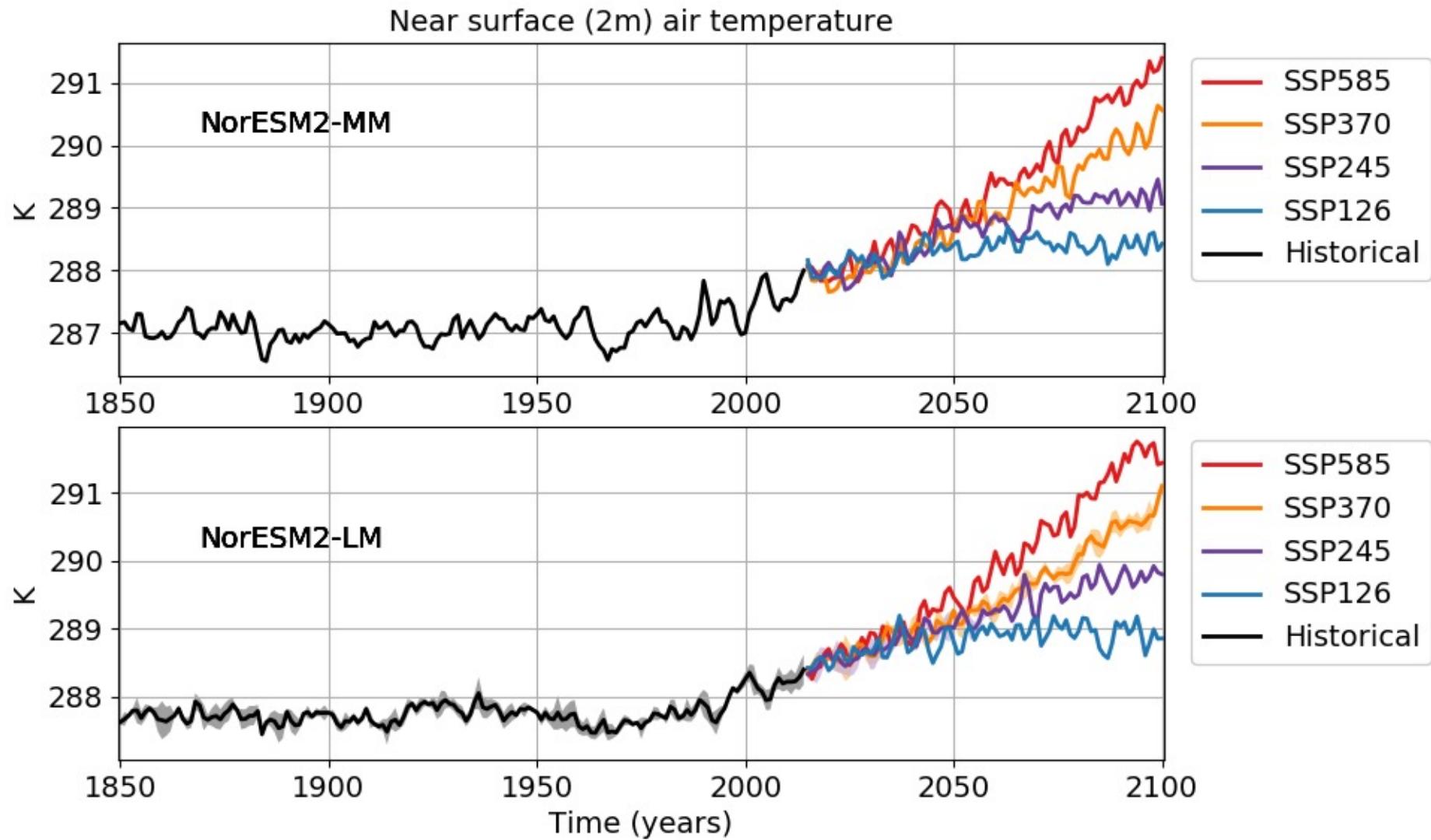
NorESM2 DECK simulations



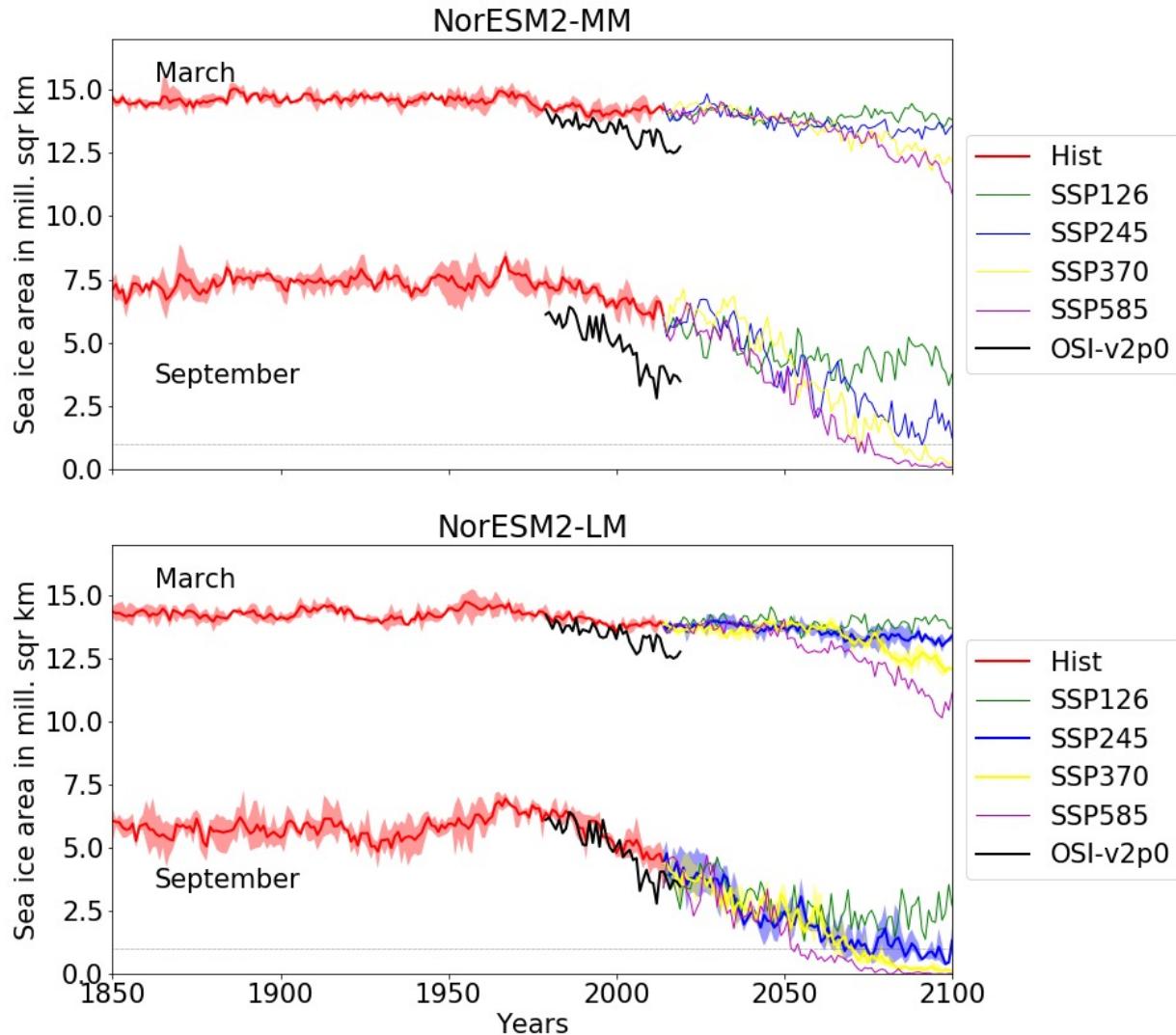
NorESM2 historical simulations



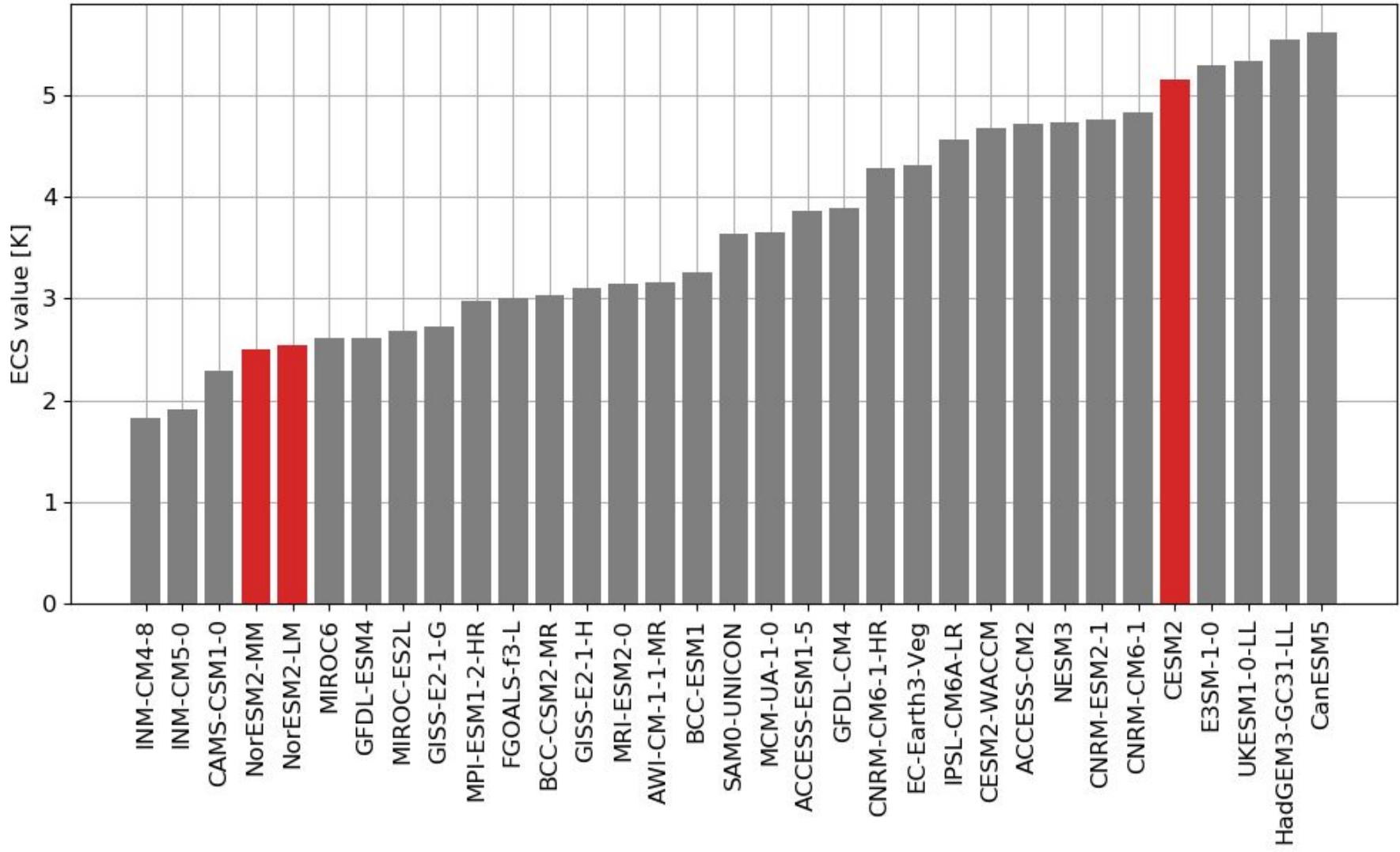
NorESM2 historical and scenario simulations



NorESM2 historical and scenario simulations

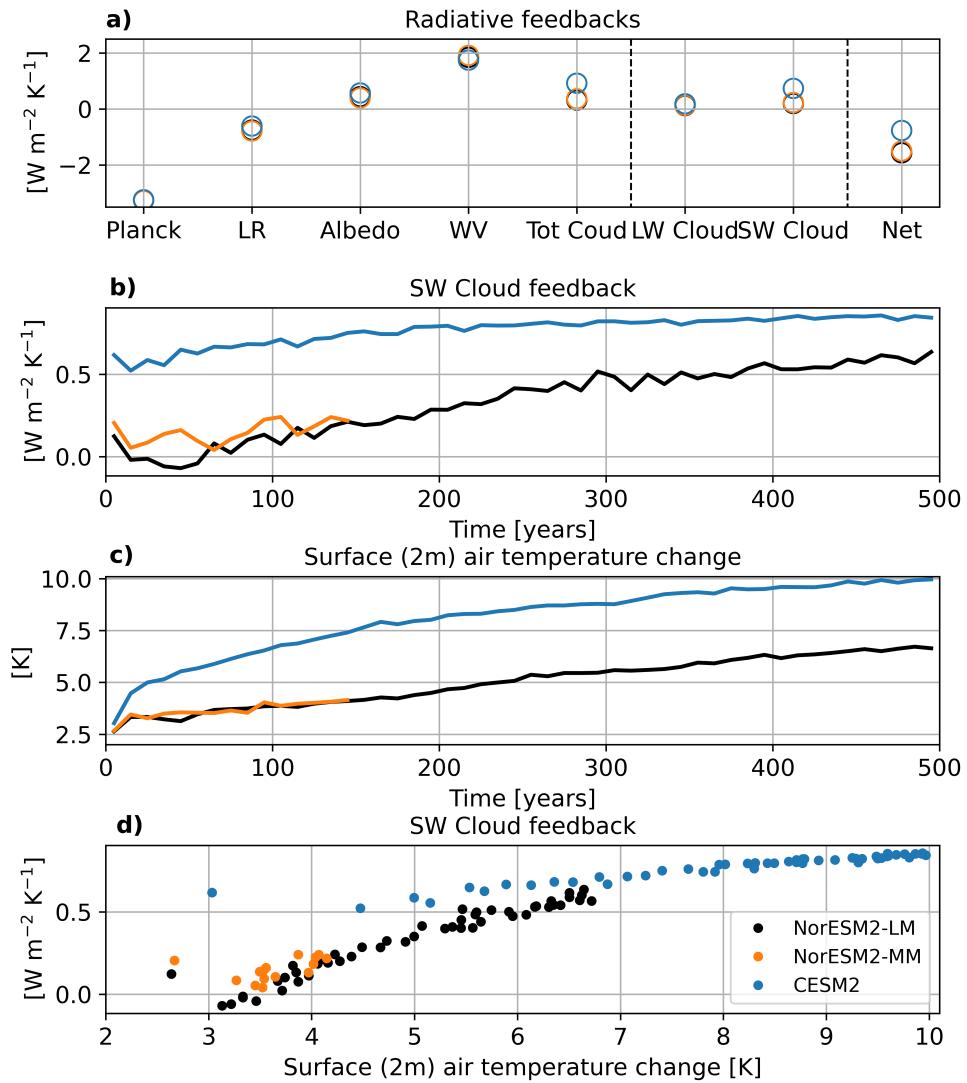


CMIP6 equilibrium climate sensitivity



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)

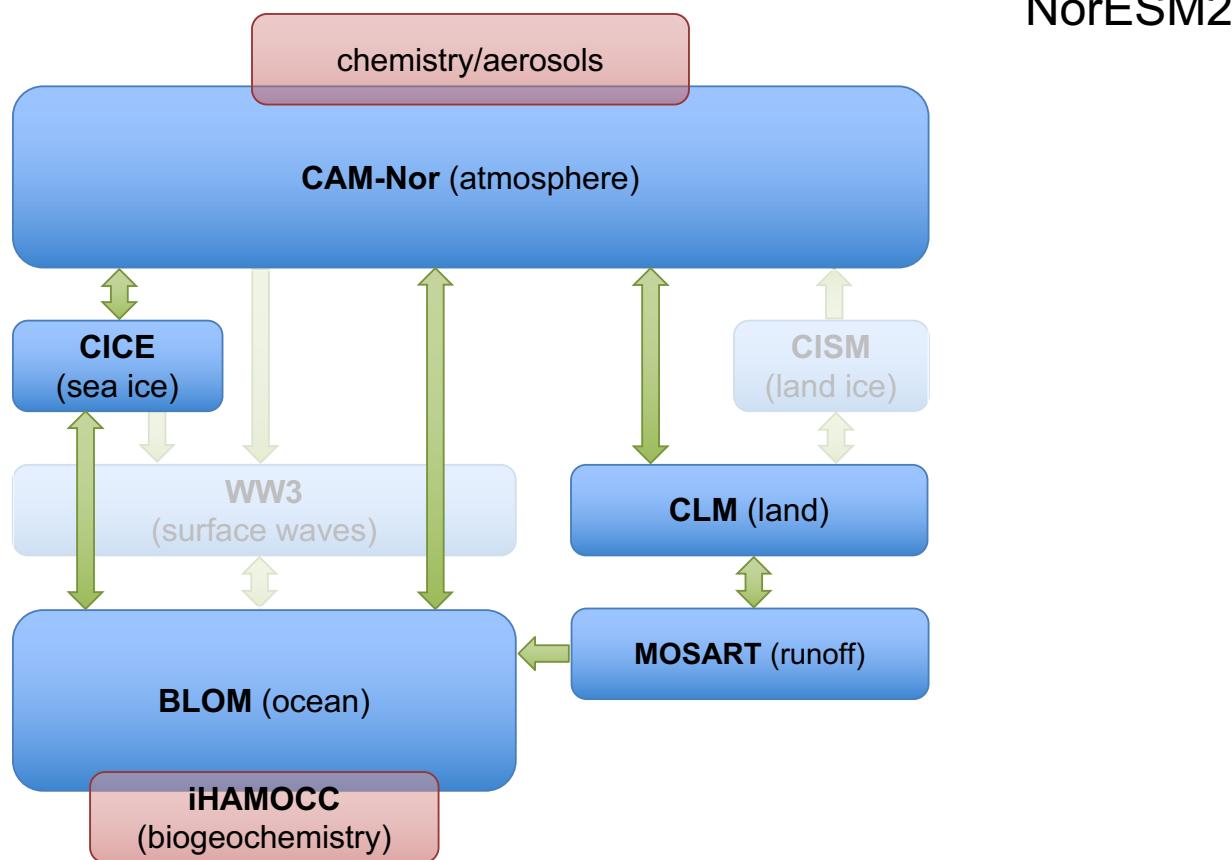
NorESM infrastructure

- 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.noressm.org/inputdata>

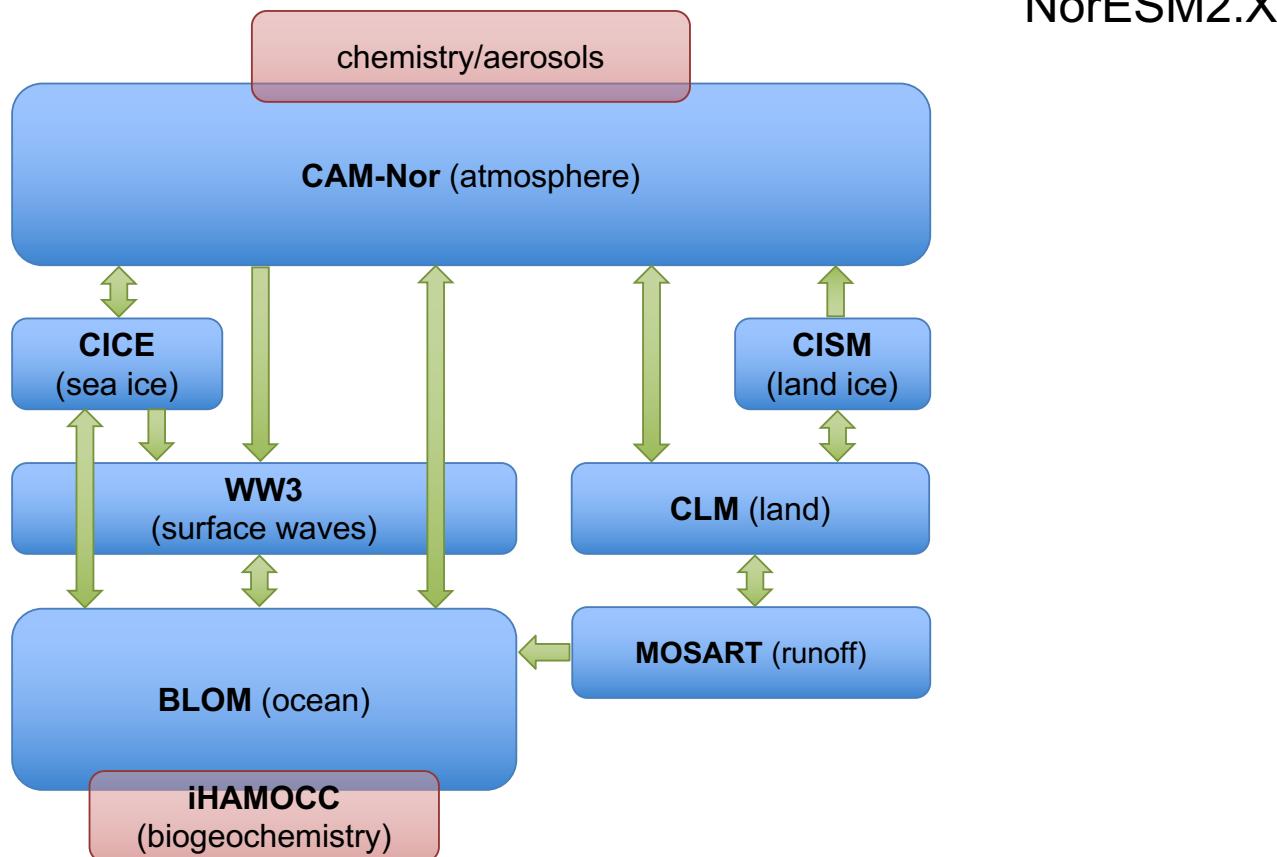
Plans for further NorESM development

- 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.
- Surface wave field coupling to atmosphere, sea ice and ocean.
- Increased horizontal and vertical resolution.

Norwegian Earth System Model (NorESM)



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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=UklVZDJid01iV1ZSMkhVcSt1dkRwZz09>

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 Iaquinta** - *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

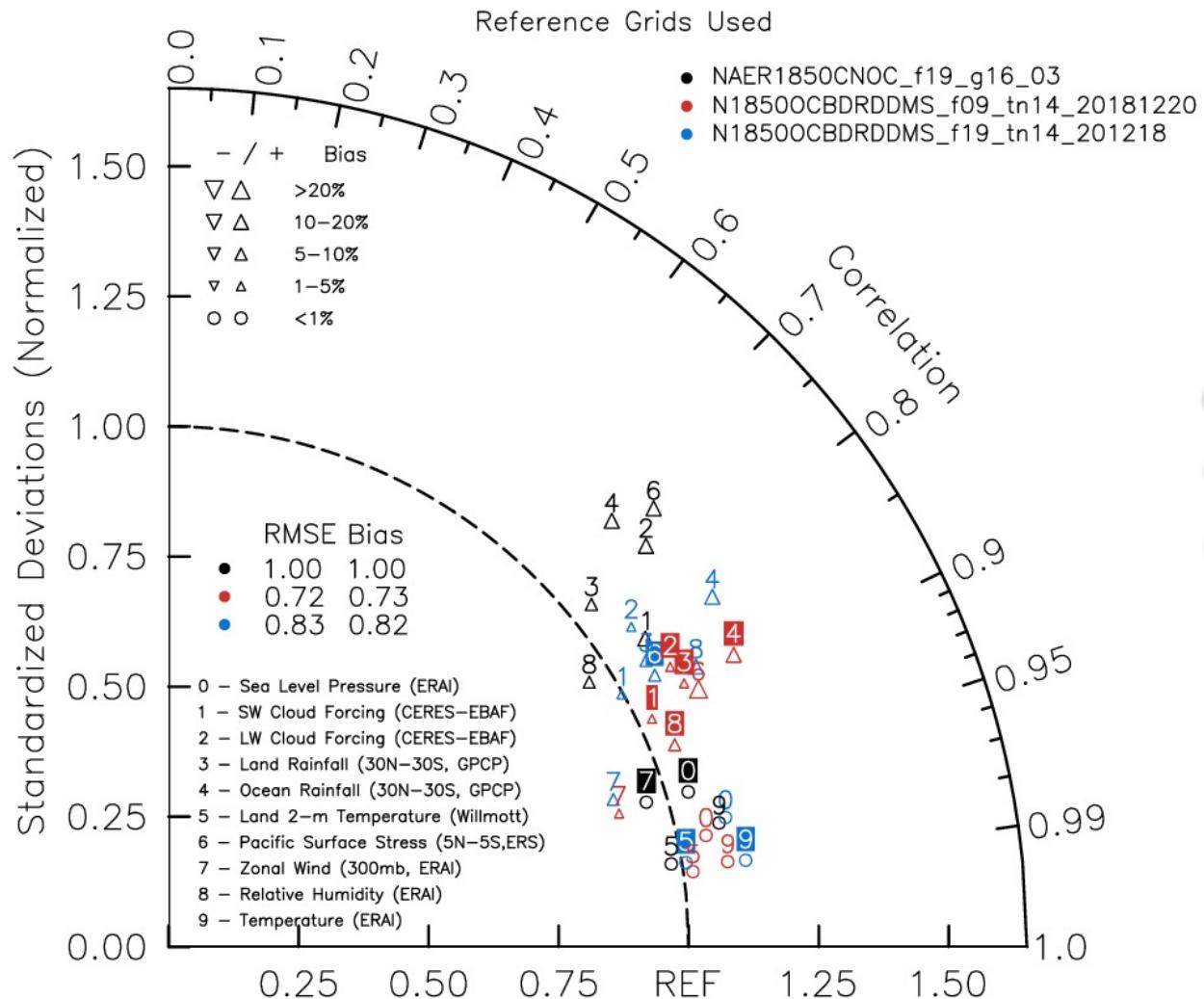
- Lunch

13:00-15:30

- Joint session with the INES annual meeting

CESM2/NorESM2 developments

ANN: SPACE-TIME



Statistical comparison with observations of

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