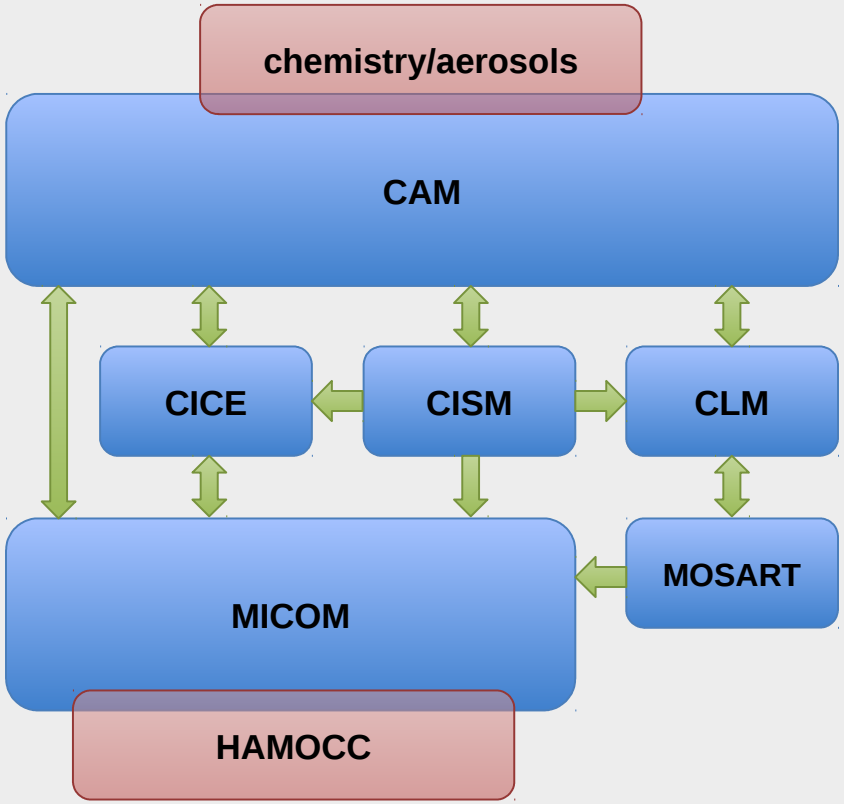
Norwegian Meteorological Institute

Tuning NorESM at 1 and 2 degree resolution

Øyvind Seland, Thomas Toniazzo, Dirk Olivié, Mats Bentsen, Alf Kirkevåg, Jerry Tjiputra

Partners:

Overview of NorESM2 within the CESM2 framework



Due to limited amount of computer resources but many research interests we need a low resolution version as well:
Standard grids are f09_tn14 and f19_tn14: Tests with f09_tn02

NorESM2 changes and developments CAM/CLM

- **CAM**: **Modified energy conservation; angular momentum fixer; deep convection modifcations; 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**: **Modified handling of freezing surface water.**

NorESM2 developments

- **CICE: Wind drift of snow.**
- **MICOM: *k-ε* model for vertical mixing; improved tracer conservation; modified GM and eddy diffusivity parameterization; higher ocean coupling frequency (1/day->1/hour); improved mixed layer physics; realistic channel widths; more options for SW absorption.**
- **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.**

The CAM-Oslo aerosol scheme

Aerosol BC, OM (including SOA), dust, sea-salt, sulphate

Gas-phase precursors

DMS, SO_2, H_2SO_4, H_2O_2

isoprene and monoterpenes $\rightarrow$ $SOAG_{LV}$ and $SOAG_{SV}$ ($\rightarrow$ SOA)

Condensation : H_2SO_4 and $SOAG_{LV}/SOAG_{SV}$

Distinction between background aerosol and condensate/coagulate/aqueous-phase-produced

NMR	Background	Condensate		Aq. phase			Coagulate
0.024	BC						
	↓						
0.024	BC	SO_4	SOA				
	↑						
0.062	BC						
0.040	BC/OM						
	↓						
0.040	BC/OM	SO_4	SOA				
0.012	SO_4/SOA	SO_4	SOA				
0.075	SO_4	SO_4	SOA	SO_4	BC	OM	SO_4
0.220	dust	SO_4	SOA	SO_4	BC	OM	SO_4
0.630	dust	SO_4	SOA	SO_4	BC	OM	SO_4
0.048	sea salt	SO_4	SOA	SO_4	BC	OM	SO_4
0.300	sea salt	SO_4	SOA	SO_4	BC	OM	SO_4
0.750	sea salt	SO_4	SOA	SO_4	BC	OM	SO_4

Aging

Loop-up tables : to estimate new NMR and σ after growth

Oxidants climatologies : OH, HO_2, O_3 and NO_3

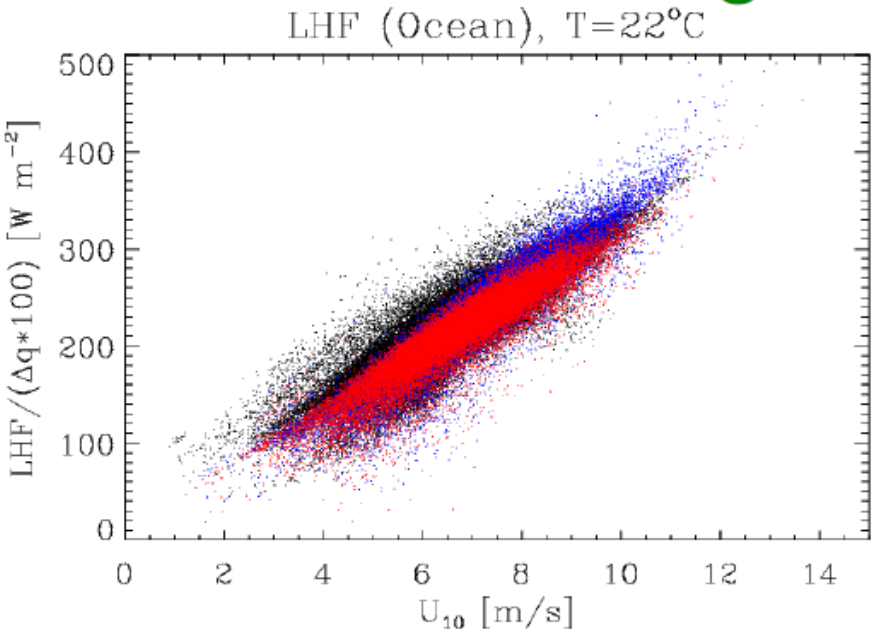
Number concentration : not a prognostic variable

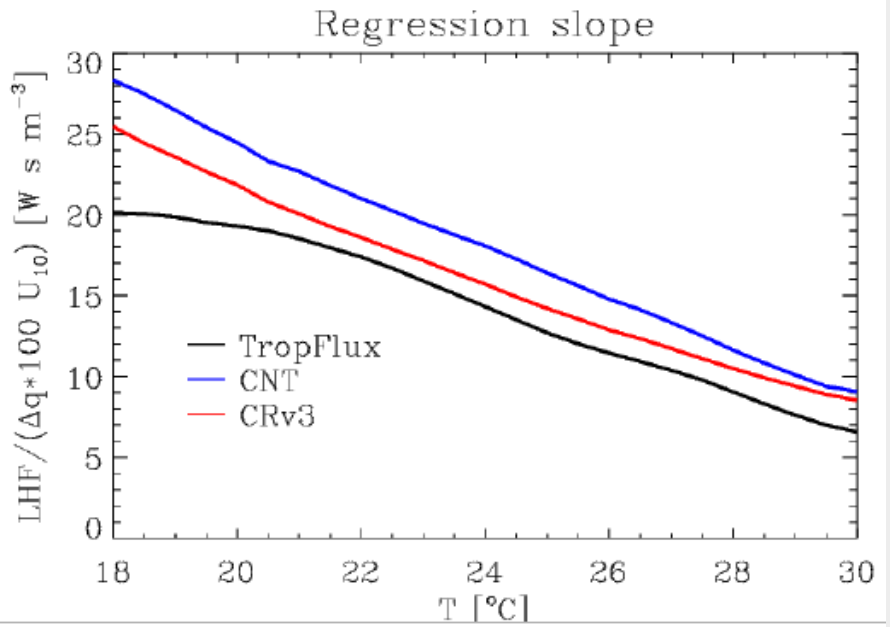
GMD: Kirkevåg et al 2018
Tested in NorESM1.2

I. COARE computation of air-sea exchange

Implementation of model and algorithm of COARE v3.0 (Fairall et al. 2003)

- consistent formulation in terms of parametrised z*
- first guess for stability branch, convergence iteration
- more commonly used self-similarity functions
- less evaporation per stress than Large et al. (1994)
  - → Weaker circulation
  - → Better zonal winds
  - • Positive impact on ENSO in F19





Main goals for tuning the model

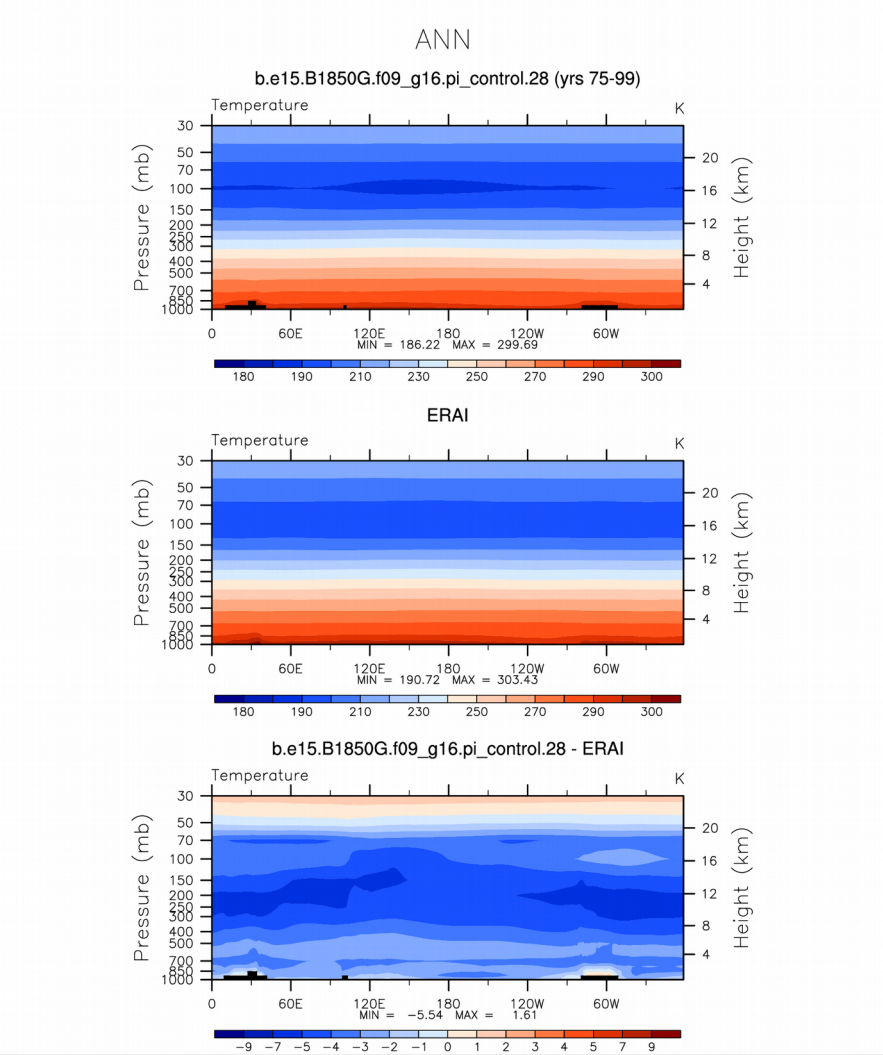
- Net radiative imbalance close to 0 W m^{-2}
- Keep ocean volume temperature close to observed estimates
  - Plots of ocean temperature often cleaner that TOA plots
- Reduce or not worsen model biases
- Reproduce 20th century warming
- Not creating a permanently frozen Labrador Sea
  - NorESM spin-up experiments have followed a very stable pathway. The Labrador Sea gets covered by sea-ice after 60-80 years and melts again after another 50-100 years.

NorESM need other parameter values than CESM2

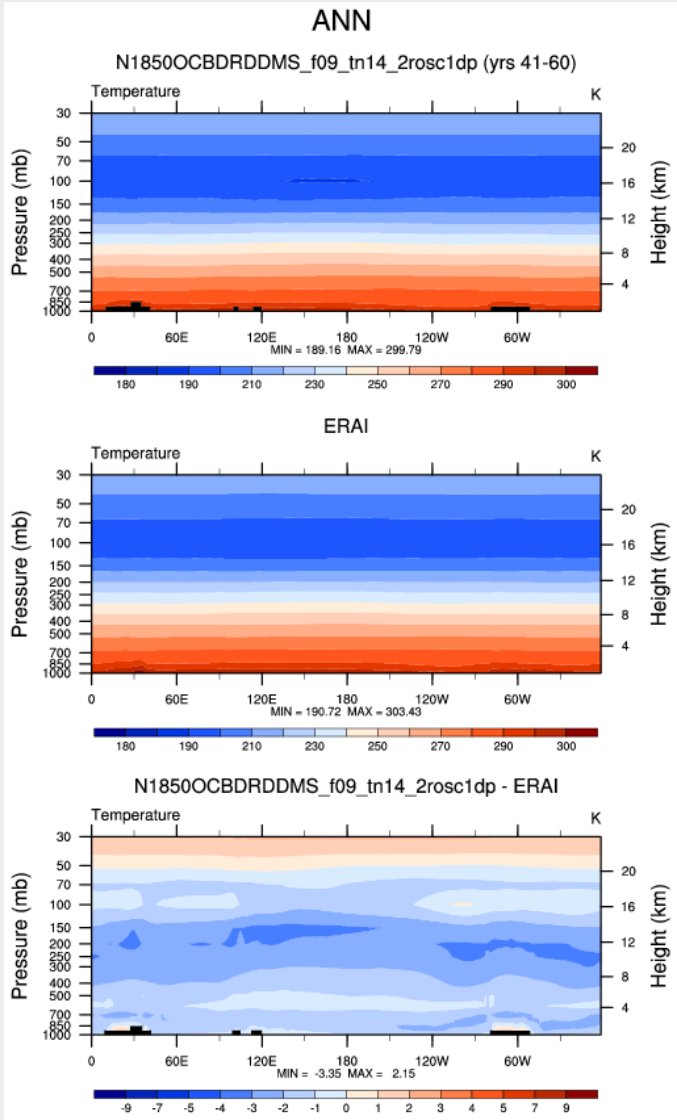
- Clubb gamma is a powerful tuning tool and can fix anything right ?

Too low gamma give a cold troposphere
Equatorial temperature profile

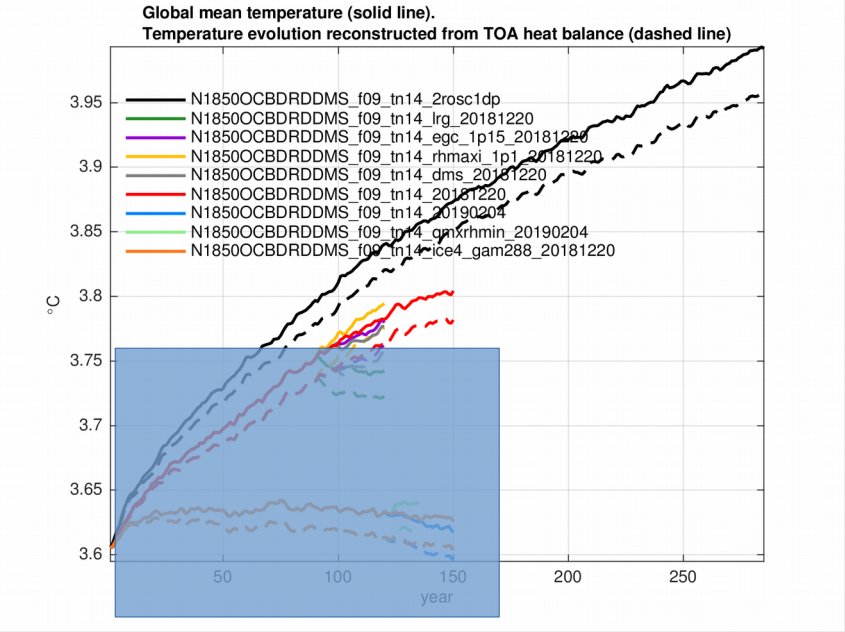
CESM1.5 simulation 28, gamma =0.287

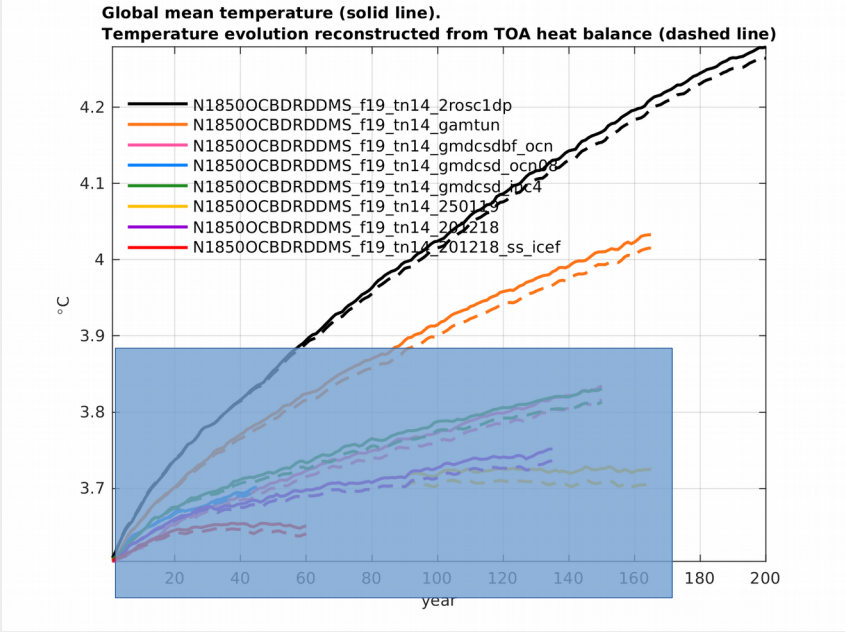


NorESM2 f09_tn14: gamma =0.283



All parameterisation changes in gamma=0.283
Is it possible to use the same tuning for the different resolutions?





Temperature profile along the equator: gamma=0.283

Simulation 0 (f09_tn14)

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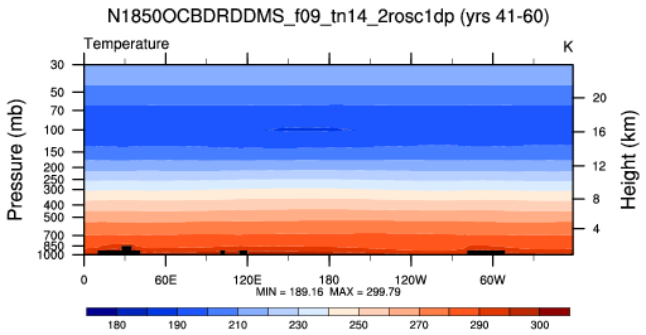
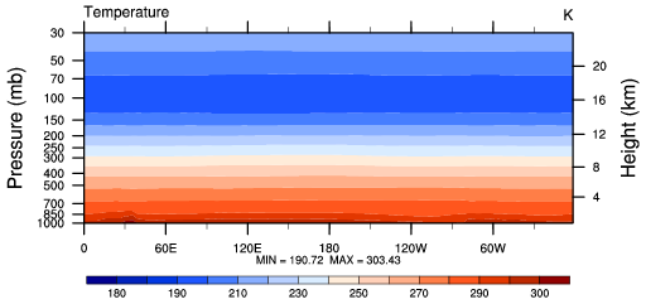
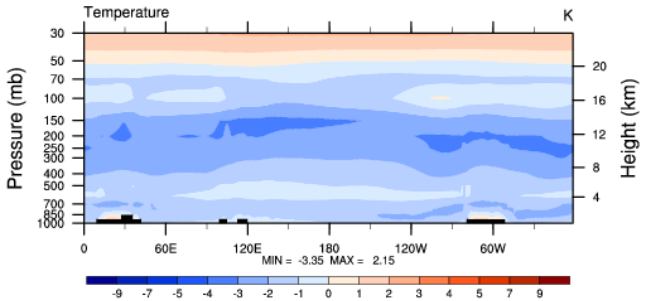


ERAI



N1850OCBDRDDMS_f09_tn14_2rosc1dp - ERAI



Simulation 1 (f19_tn14)

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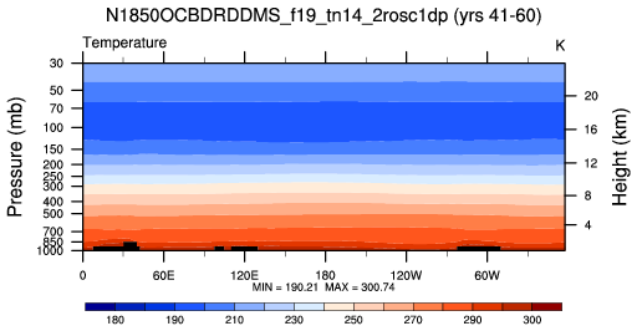

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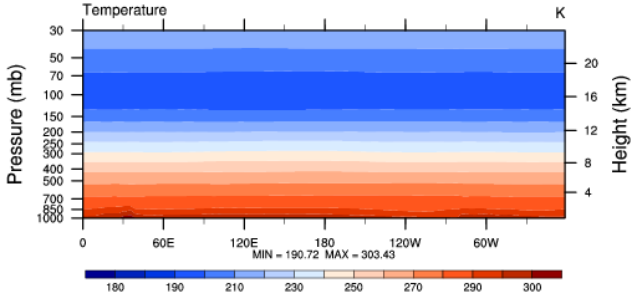
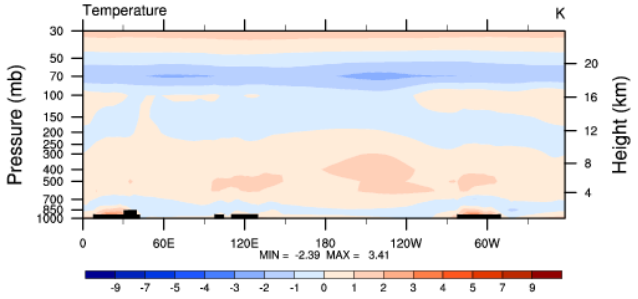


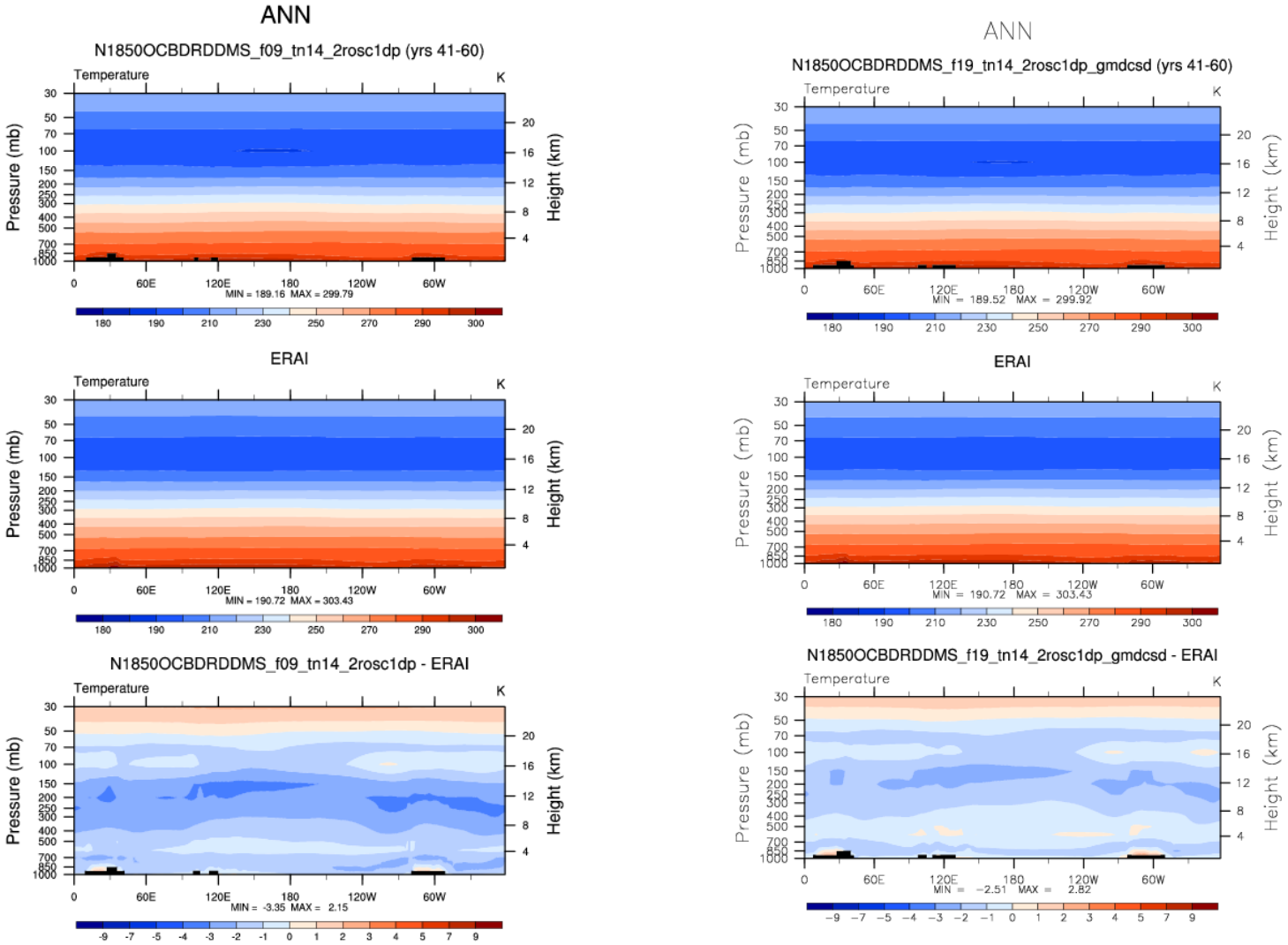
N1850OCBDRDDMS_f19_tn14_2rosc1dp - ERAI



May still reduce gamma in f19

f09_tn14: Gamma =0.283

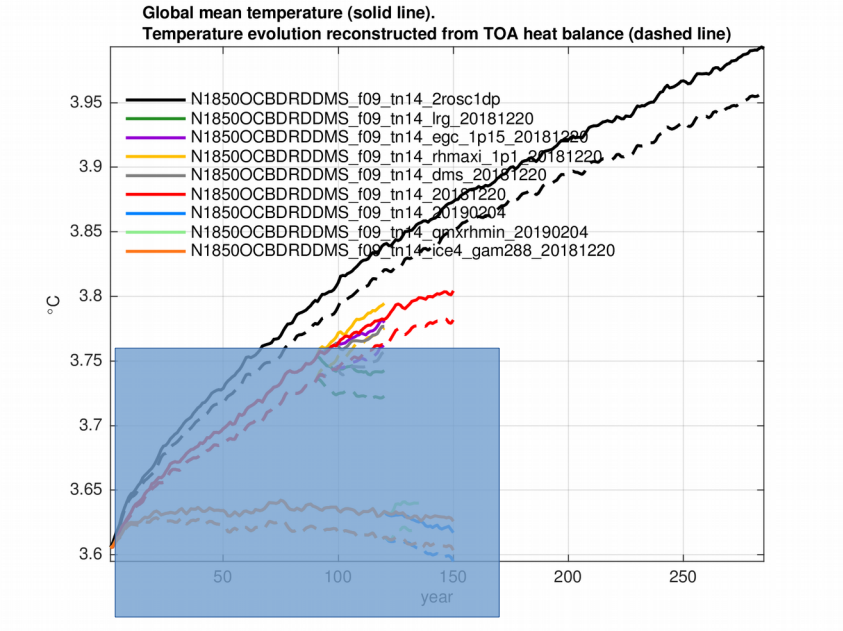
f19_tn14: Gamma=0.258



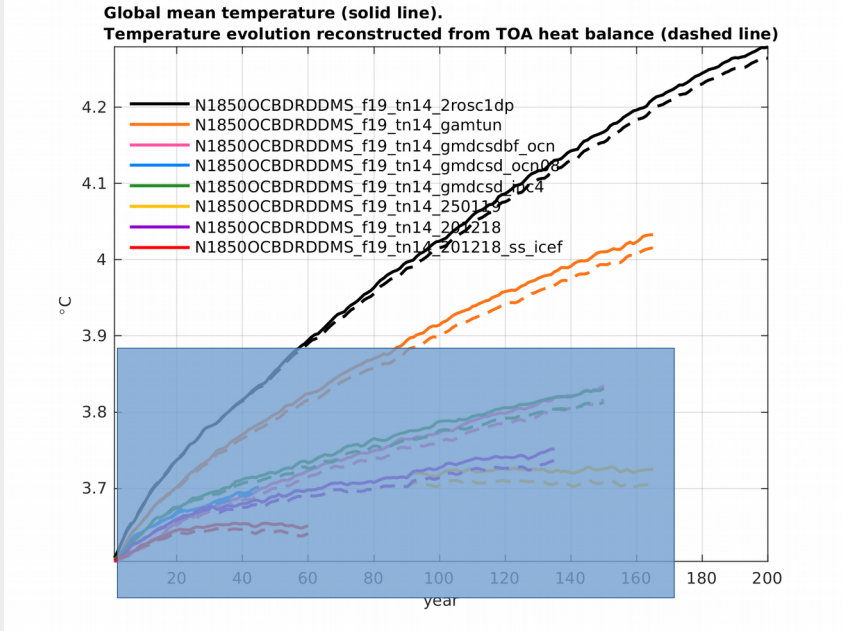
Gamma “saturates” with respect to the overall top of the model imbalance
A further reduction to gamma 0.230 gave a TOA reduction of 0.4 W m^{-2} in coupled simulations but SWCF was 4 W m^{-2} more negative

Changing gamma is not enough

0.3 - 0.5 W m-2 radiative imbalance



1 W/m2 radiative imbalance



Where is my rhminl: 0.5 W m-2 should be easy to get rid of.
A long process followed

- Accept heating of the average ocean temperature:
  - Unacceptable for ocean biogeochemistry
- Tune ocean parameters
  - Tried a lot of parameter changes: Degraded the climate: Retained tuning of background ocean mixing
- Increase aerosol or aerosol pre-cursor emissions
  - Homogenized emissions between f09 and f19
- Change ice-clouds: Non physical ice-cloud fraction
  - Parameters
  - Parameterisations : Should different model resolutions use different parameterisations?
  - Change of ice-cloud parameterisation had a larger impact on coupled simulations than AMIP

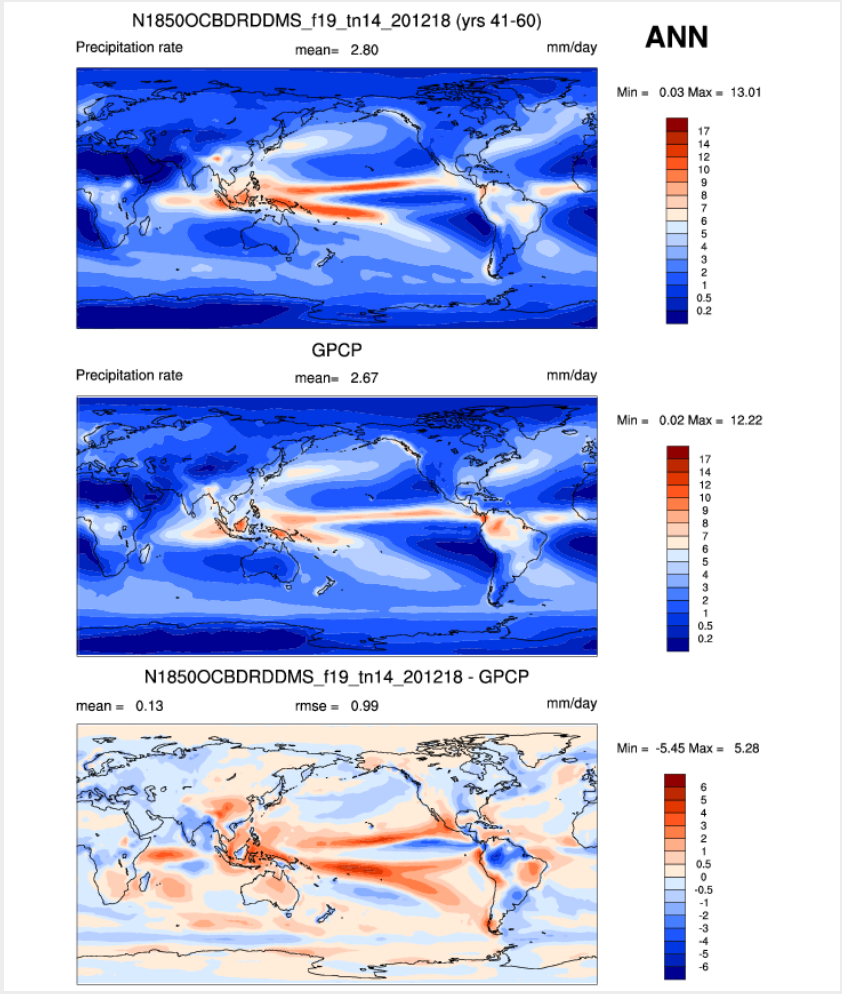
- I am not going to do a step by step comparison of all the tuning terms
- Would take way to much time
- The hpc vendor by accident deleted all our data, plots and made general havoc at the hpc and storage facilities so much of the information is unavaiable.

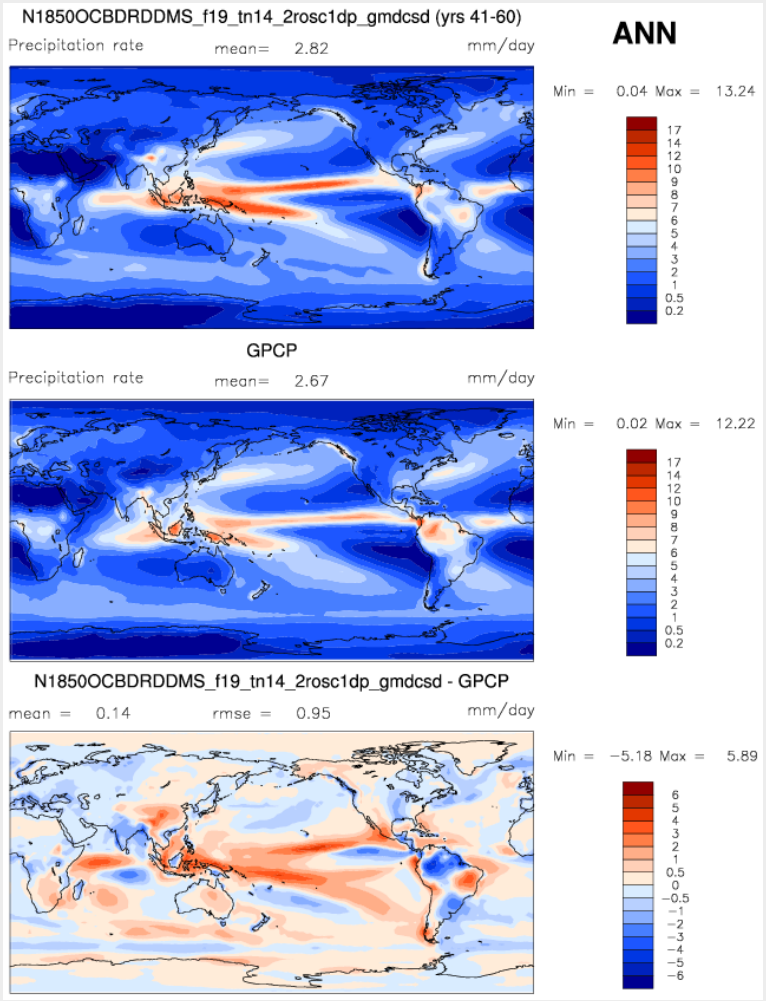
Final? Tuning: f09_tn14 vs f19_tn14

- Increase in DMS
- Increase in general ocean mixing
- Ice cloud parameterisation
  - Number 5 (default)
    - Increase rhmin to 0.9
    - Decrease qistmax to 2.5e-4
  - Number 4

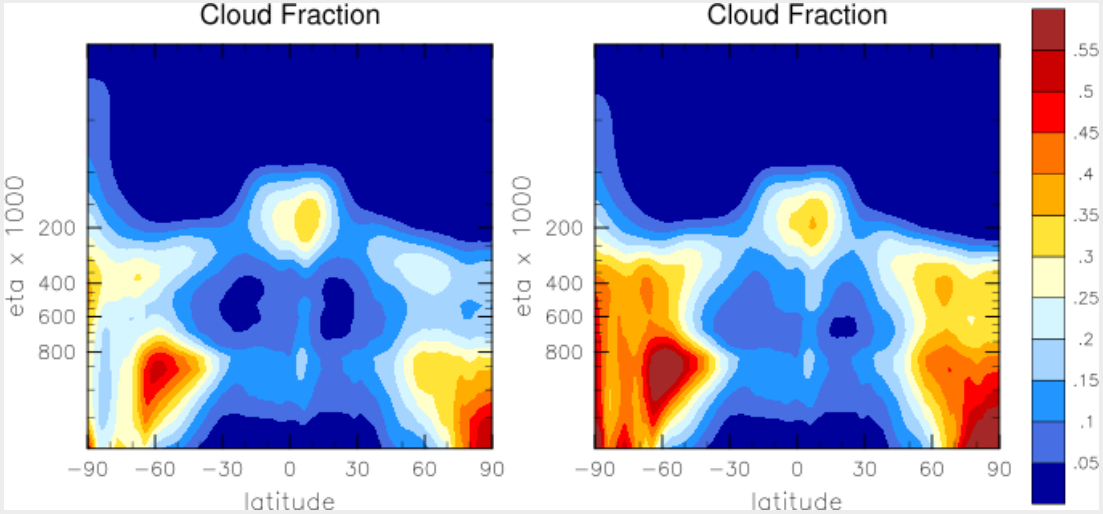
- Increase in DMS
- Increase in general ocean mixing
- Sea-salt emissions scaled to the emissions in f09 (10 % increase)
- Ice cloud parameterisation 4

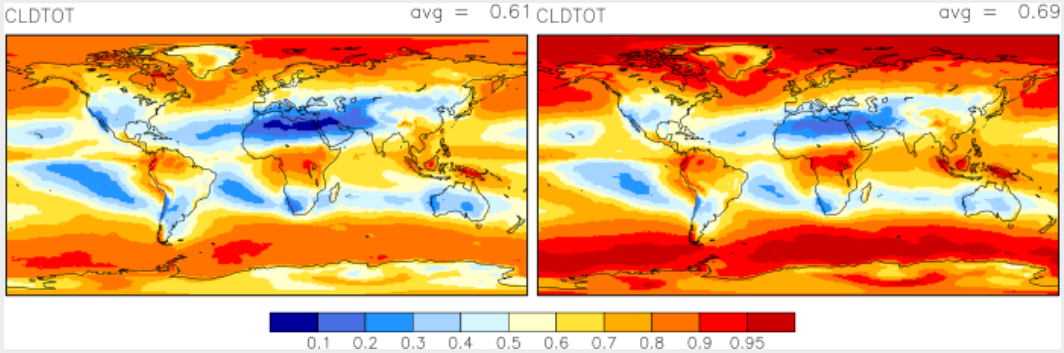
Switcing from ice-option 5 to ice-option 4 degrades the precipitation patterns
Bias not much affected





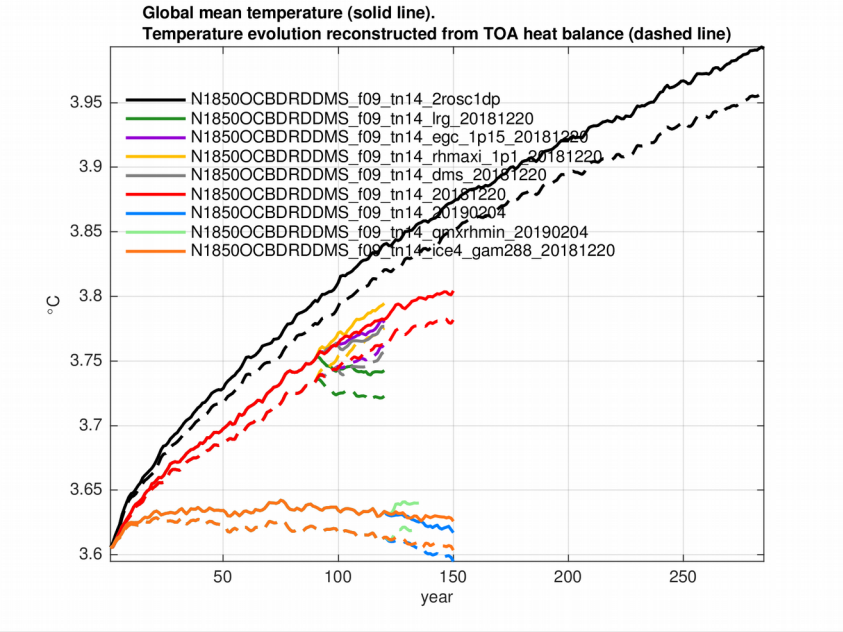
Switching from ice-option 5 to ice-option 4 reduces the cloud cover.
The bias of mid level clouds become worse.
Low level clouds are improved in the Arctic and slightly degraded elsewhere.



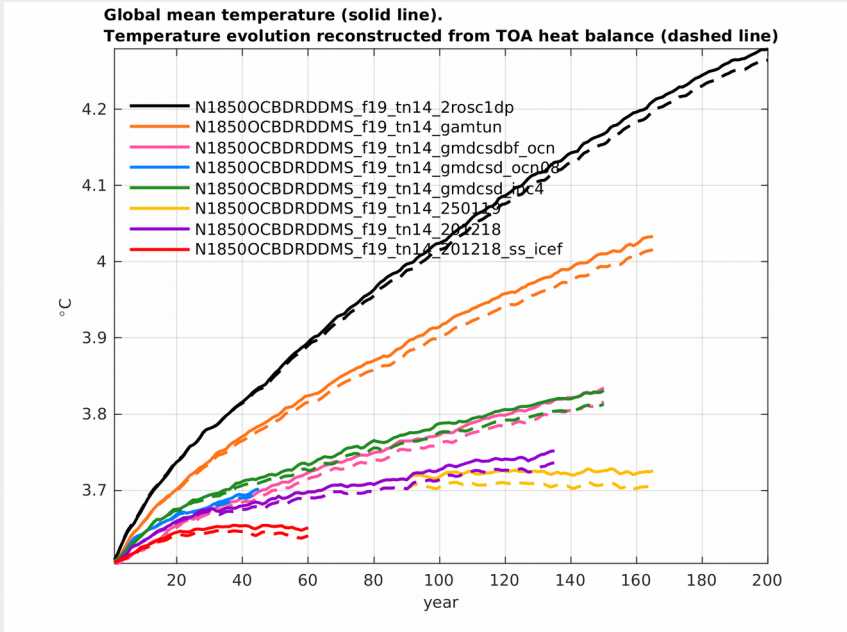


Finally stable models

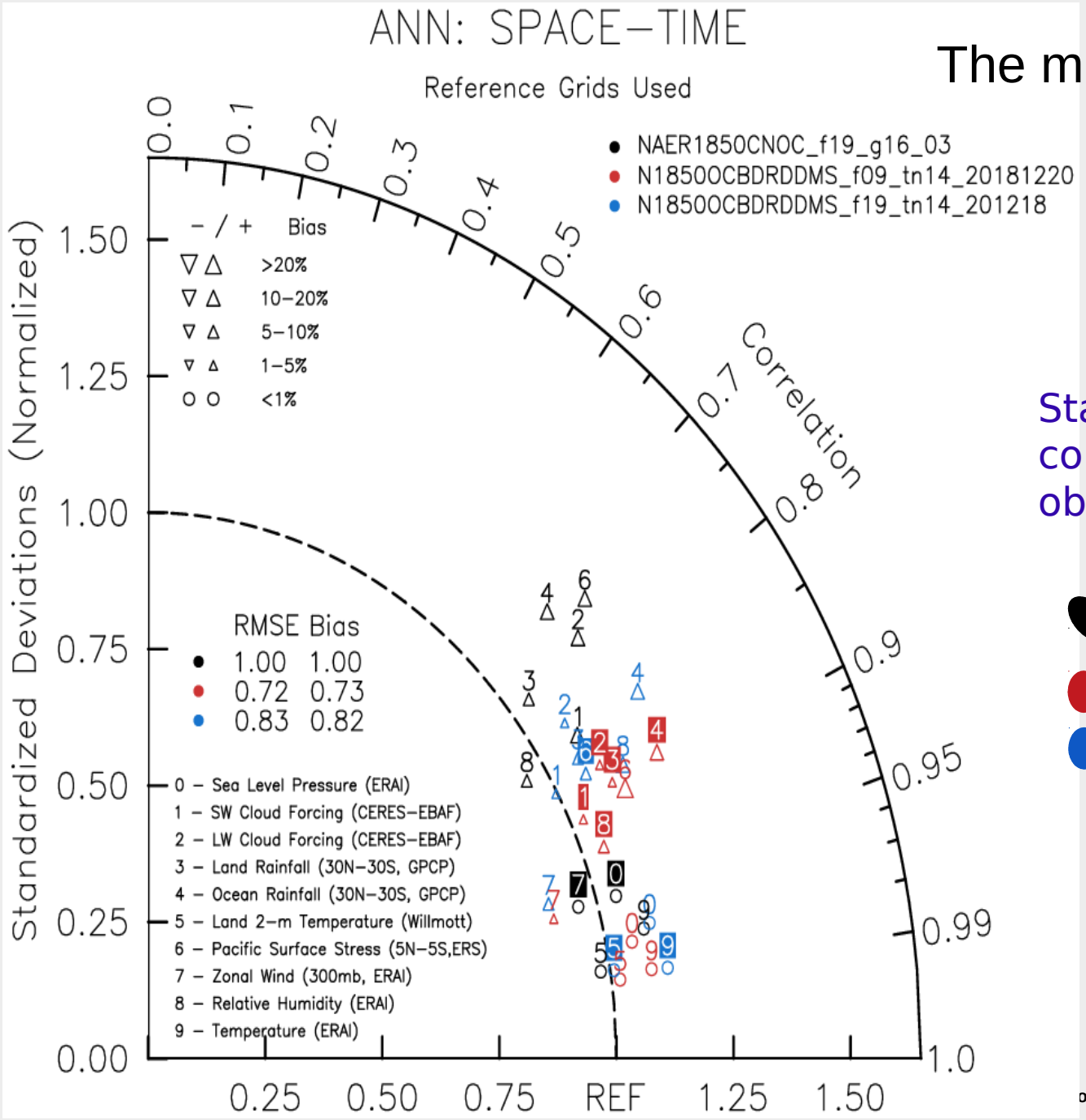
f09_tn14



f19_tn14



The model has improved



Statistical comparison with observations of

- NorESM1-M
- NorESM2-MM
- NorESM2-LM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Thank you for the attention.


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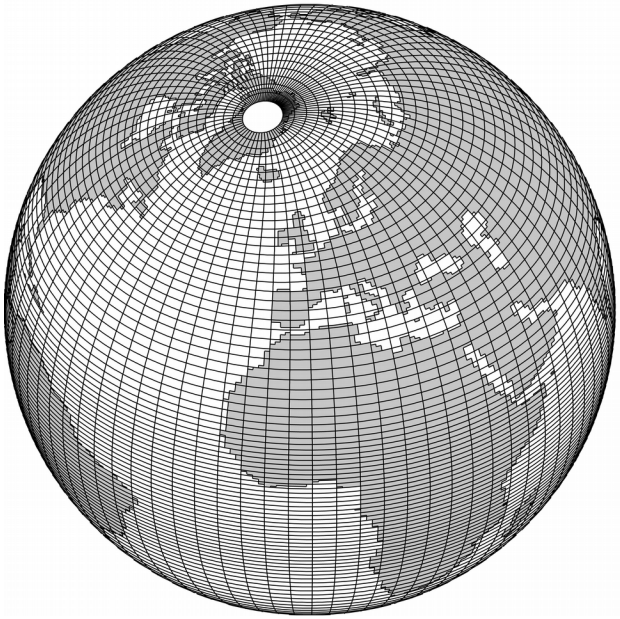
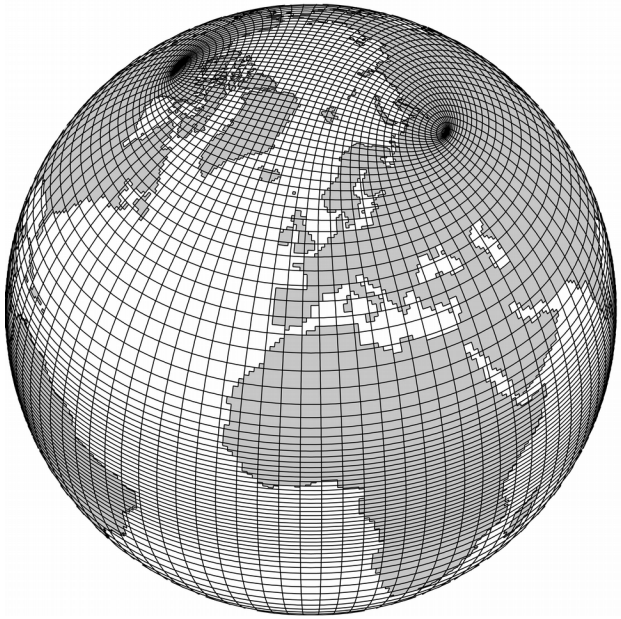
EXTRAS

Horizontal ocean/sea-ice grids



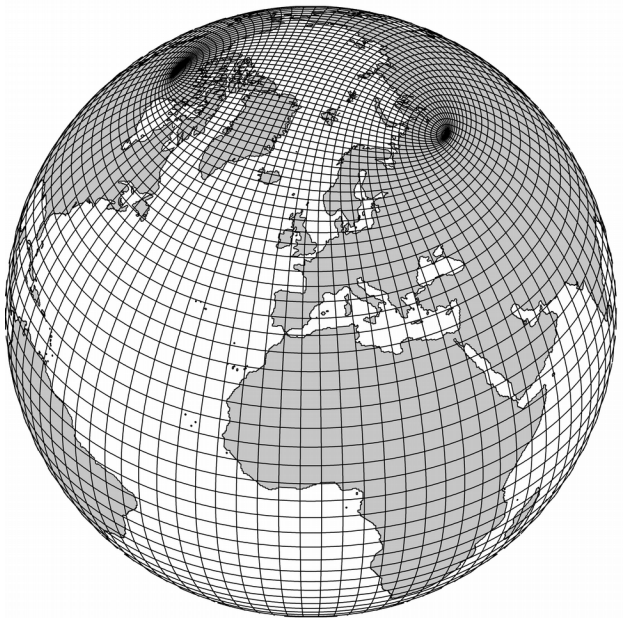
1.125° bipolar grid (every 4th grid line shown):

- NCAR gx1v6 grid.
- 320 × 384 grid cells.
- Used for the NorESM CMIP5 experiments.
- Enhanced meridional resolution near the equator (f_e = 1/4).



1° tripolar grid (every 4th grid line shown):

- NorESM tnx1v4 grid.
- 360 × 384 grid cells.
- Used for the NorESM-O CORE2 and CMIP6 experiments.
- Enhanced meridional resolution near the equator (f_e = 1/4).



0.25° tripolar grid (every 16th grid line shown):

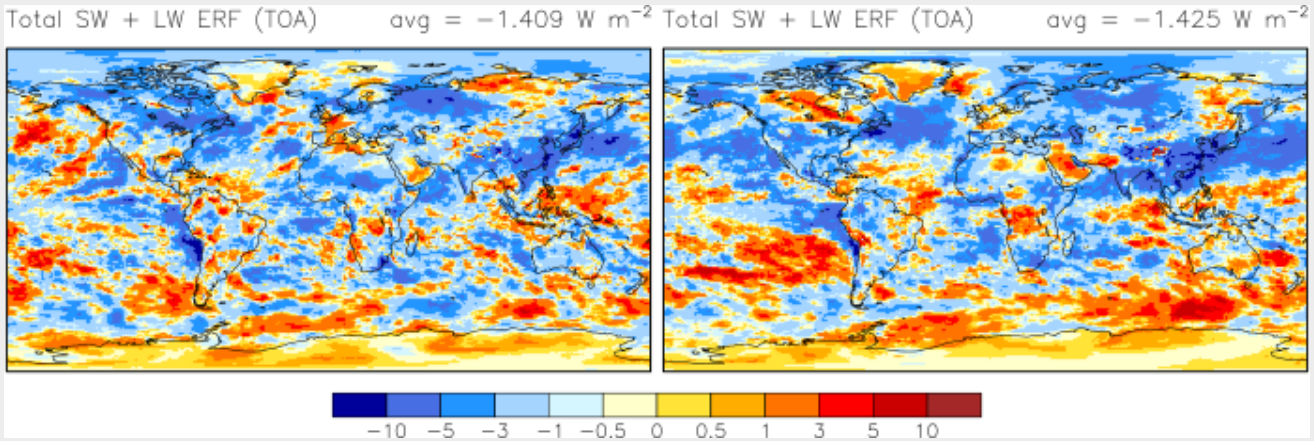
- 1440 × 1152 grid cells.
- Isotropic grid near equator.
- To be used for CMIP6 experiments (at least OMIP).

Configurations of NorESM2 for CMIP6.

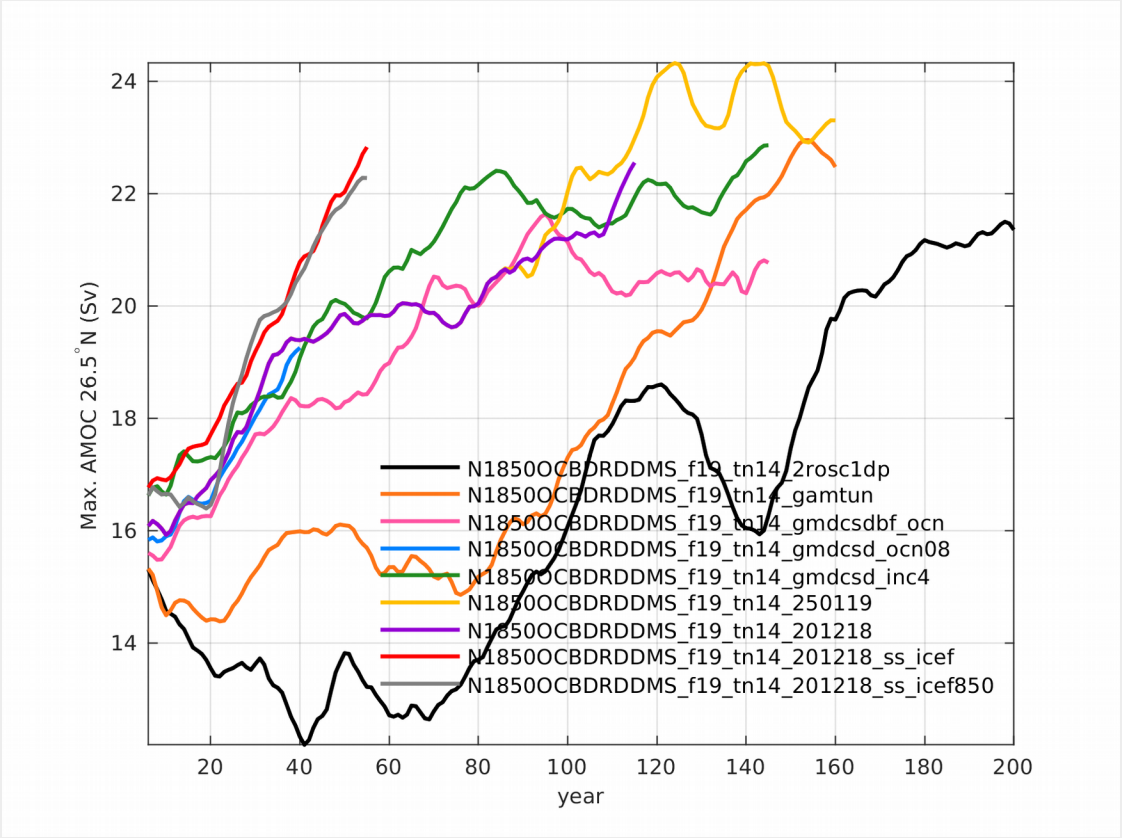
Low and **M**edium atmospheric and oceanic resolution.
Vertical resolution Ocean 53 levels: Atmosphere 32 levels.
Process complexity: **E**mission-driven GHG and atmospheric **C**hemistry.
.

NorESM2		_LM	_LME	_MM
RESOLUTION	Atmos. – Land	L: 1.9x2.5 deg.	L: 1.9x2.5 deg.;	*M: 0.9x1.25 deg.*
	Ocean - Sea-Ice	M: 1 deg.	M: 1 deg.	*M: 1 deg.*
PROCESSES	GHG	Concentration-driven	E: Emission-driven	*Concentration-driven*
	Aerosol	Emis-driven, Compl physics	Emis-driven, Compl physics	*Emis-driven, Compl physics*
	Atmos. Chem.	Simplified;	Simplified	*Simplified;*
	Ocean BGC.	ON	ON	*ON*
CMIP-DECK + CMIP6 Hist		AMIP, PreInd, Historic	ALL except AMIP	*ALL*
MIPs		• AerChemMIP • CFMIP • DAMIP • DCPP • LS3MIP • LUMIP • OMIP • PMIP • RFMIP • ScenarioMIP • VolMIP • SIMIP	• C4MIP • LUMIP • LS3MIP • OMIP	AerChemMIP • CFMIP • RFMIP • DAMIP • OMIP • ScenarioMIP • SIMIP

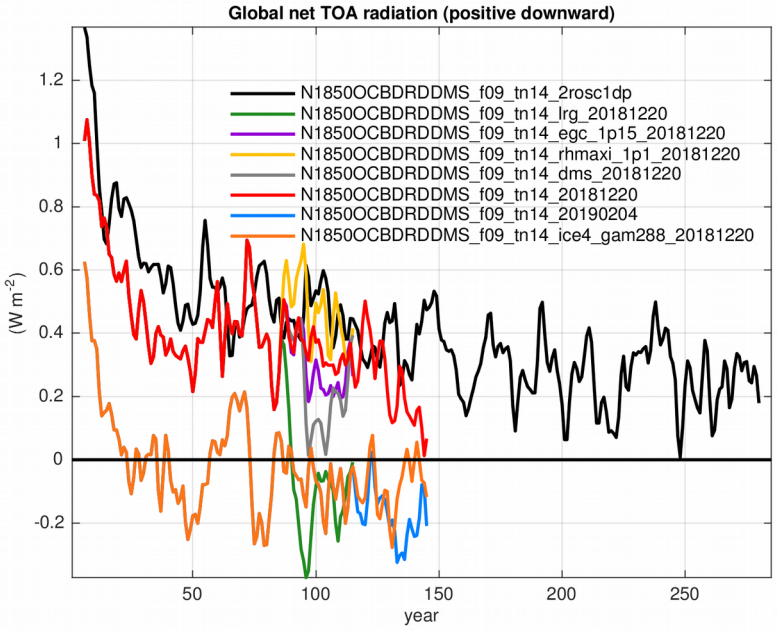
Aerosol radiative forcing

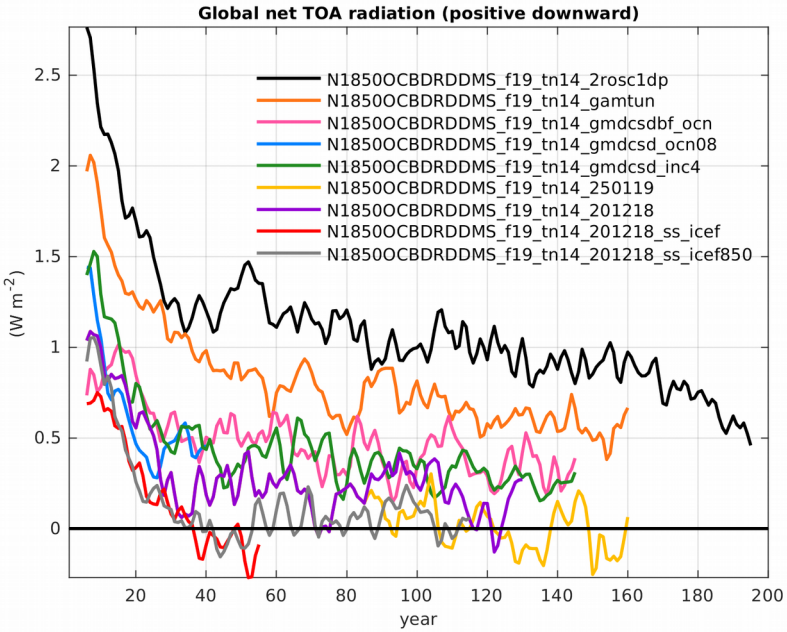


AMOC for different tuning parameters



Global net forcing





20th Century temperature development