EC-Earth and CMIP6

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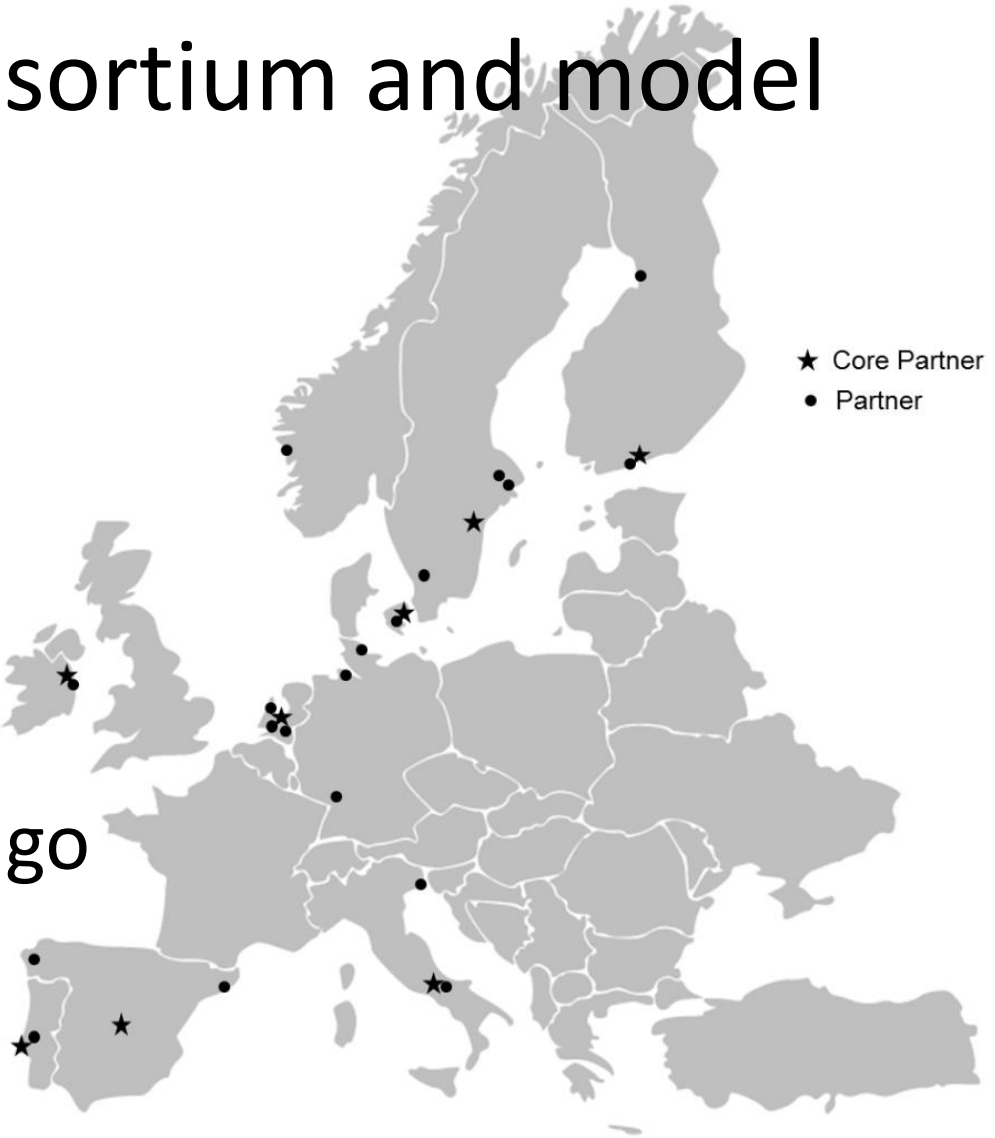
Outline

- The EC-Earth model
- Quick intro to CMIP6
- First EC-Earth results for CMIP6
  - Model performance
  - Climate change
  - Climate sensitivity
- The future: EC-Earth4

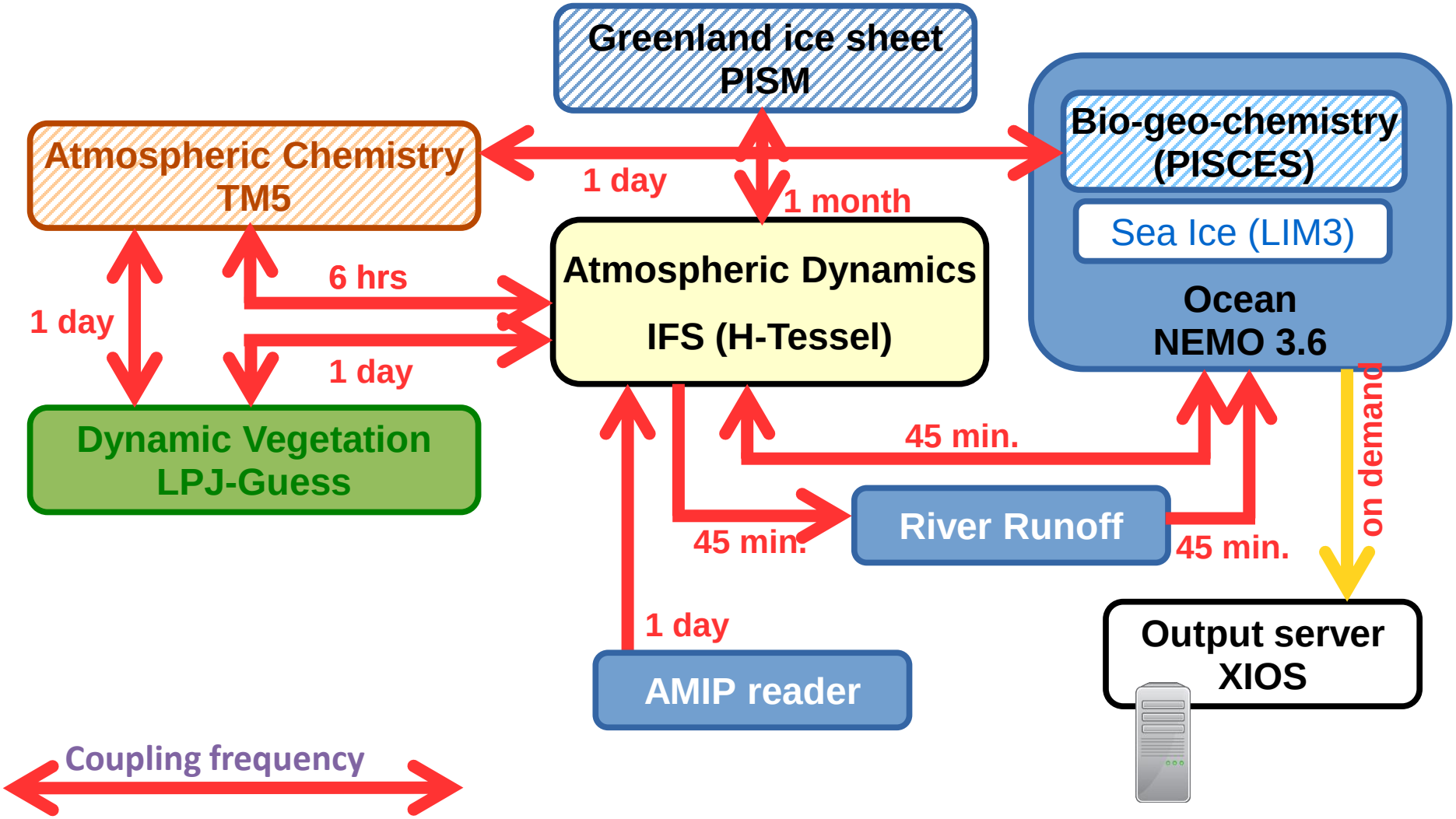
The EC-Earth consortium and model

EC-Earth model:

- jointly developed by members of the EC-Earth consortium
- has started from S3 more than 10 years ago
- was/is used for CMIP5 and CMIP6



EC-Earth ambition: towards a coupled ESM



Courtesy Philippe LeSager, KNMI

The EC-Earth3 model

Atmosphere: IFS cy36r4 (as S4)
- Enable long runs
- Coupling interface
- CMIP6 specific forcing
- Mass and energy conservation

Ocean: NEMO 3.6_stable
- LIM3 with 5 sea-ice categories

Vegetation: LPJ-Guess

Ocean: bio-geochemistry PISCES

Atmospheric chemistry: TM5

Greenland ice sheet model: PISM

Overview of model configurations and planned simulations

Configuration		EC-EARTH3	EC-EARTH3P	EC-EARTH3P-HR	EC-EARTH3-HR	EC-EARTH3-LR	EC-EARTH3-CC	EC-EARTH3-GrIS	EC-EARTH3-AerChem	EC-EARTH3-Veg	EC-EARTH3-Veg-LR
Description		IFS cy36r4 NEMO 3.6 LIM3	P version for standard resolution used as entry card for HighResMIP	P version	EC-EARTH3 at high resolution	EC-EARTH3 at low resolution	EC-EARTH3 with coupled carbon cycle	EC-EARTH3 with coupled Greenland ice sheet model	EC-EARTH3 with interactive aerosols and atm. chemistry	EC-EARTH3 with interactive vegetation module	EC-EARTH3 with interactive vegetation module at low resolution
Resolutions	atm	T255L91	T255L91	T511L91	T511L91	T159L62	T255L91	T255L91	T255L91	T255L91	T159L91
	oce	ORCA1 L75	ORCA1 L75	ORCA025 L75	ORCA025 L75	ORCA1 L75	ORCA1 L75	ORCA1 L75	ORCA1 L75	ORCA1 L75	ORCA1 L75
	TM5						2 x 3 deg L34		2 x 3 deg L34		
	LPJ-Guess						as atm.			as atm.	as atm.
	PISCES						as oce.				
	PISM							5 x 5 km			
Application		CMIP, DCPP, LS3MIP, PAMIP, RFMIP, ScenarioMIP, VolMIP, CORDEX, DynVarMIP, SIMIP, VIACSAB	CMIP*, HighResMIP*	HighResMIP	DCPP, HighResMIP	CMIP, PMIP	CMIP, CDRMIP, C4MIP, LUMIP, OMIP	CMIP, ISMIP6, PMIP	CMIP, AerChemMIP, ScenarioMIP*	CMIP, CDRMIP, LUMIP, LS3MIP, ScenarioMIP	CMIP, PMIP, ScenarioMIP

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Description		IFS cy36r4 NEMO 3.6 LIM3	P								
Resolutions	atm	T255L9									
	oce	ORCA1 L75									
	TM5										
	LPJ-Guess										
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	PISM										
Application		CMIP, DCPP, LS3MIP, PAMIP, RFMIP, ScenarioMIP, VolMIP, CORDEX, DynVarMIP, SIMIP, VIACSAB									

Support for different configurations with components switched on/off

Support for different resolutions

- T255L91-ORCA1L75
- T159L62-ORCA1L75
- T511L91-ORCA025L75
- T1279L91-ORCA012L75

EC EARTH 4

SMHI

CMIP

The World Climate Research Programme's
Coupled Model Intercomparison Project

The history of climate change modeling was first characterized in the 1980s by a number of distinct groups developing, running, and analyzing model output from their own models with little opportunity for anyone outside of those groups to have access to the model data. This was partly a consequence of relatively primitive computer networking and data transfer capabilities, along with the daunting task of collecting and storing such large amounts ▶

1995, in preparation for CMIP3

"…to improve our understanding of processes and simulation capabilities in global coupled models "

Meehl, 1995

2016, in preparation for CMIP6

"…to better understand past, present, and future climate change arising from natural, unforced variability or in response to changes in radiative forcing in a multi-model context."

Eyring et al., 2016

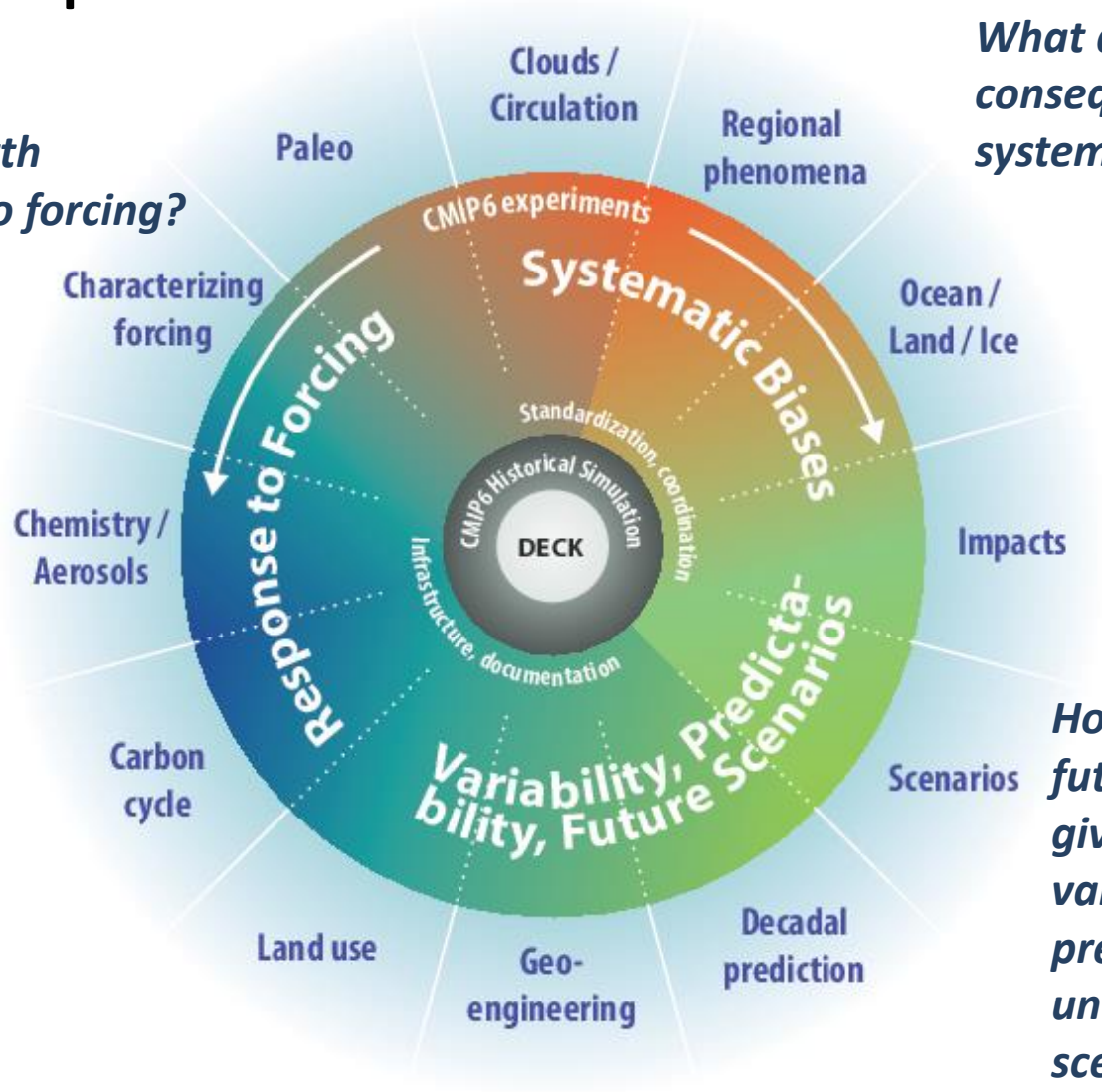
WCRP CMIP6
World Climate Research Programme

SMHI

CMIP6 will address 3 broad scientific questions…

How does the Earth system respond to forcing?

What are the origins and consequences of systematic model biases?



How can we assess future climate changes given internal variability, predictability and uncertainties in scenarios?

WCRP CMIP6
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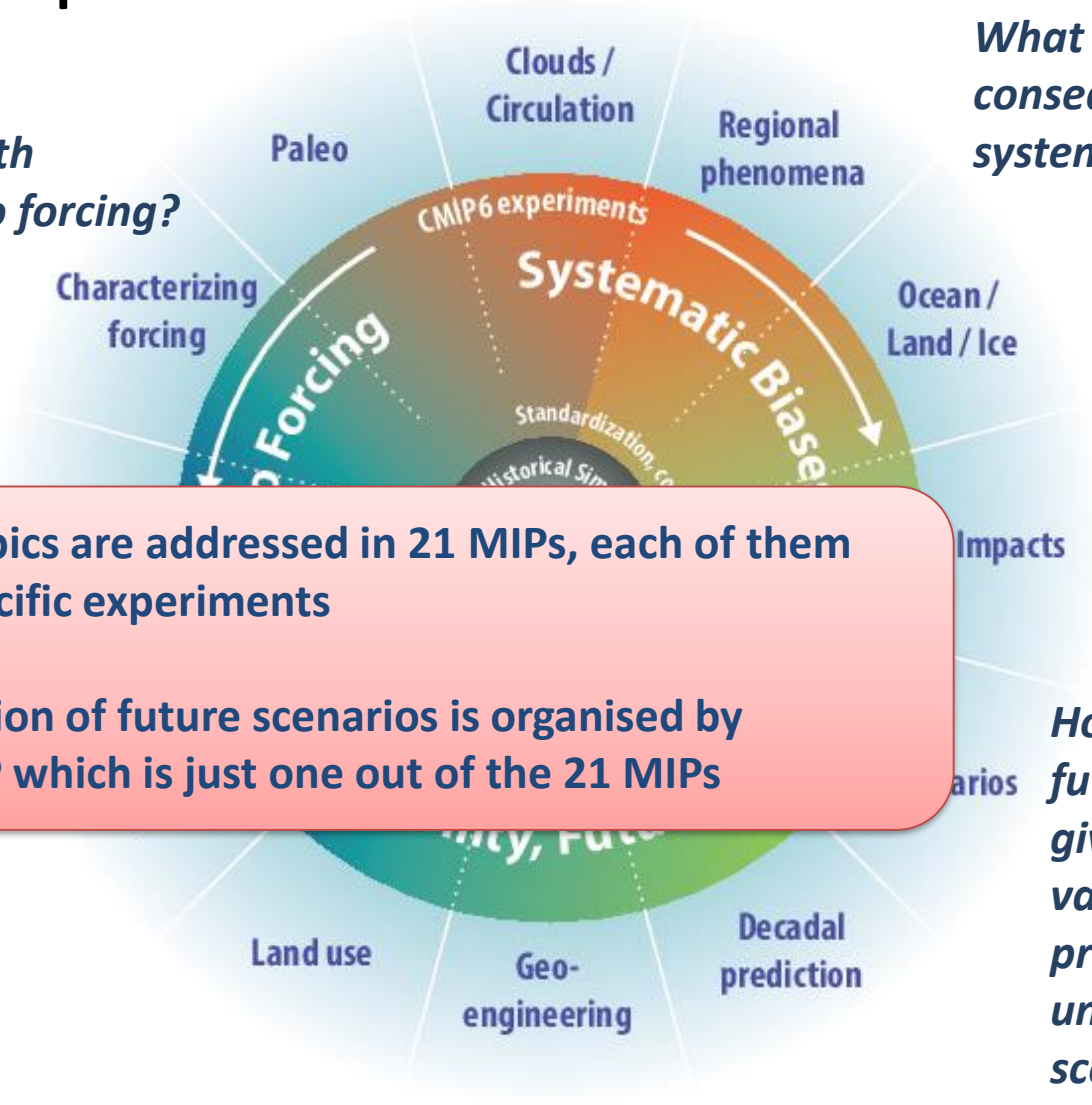


Scientific topics are addressed in 21 MIPs, each of them defining specific experiments

The production of future scenarios is organised by ScenarioMIP which is just one out of the 21 MIPs

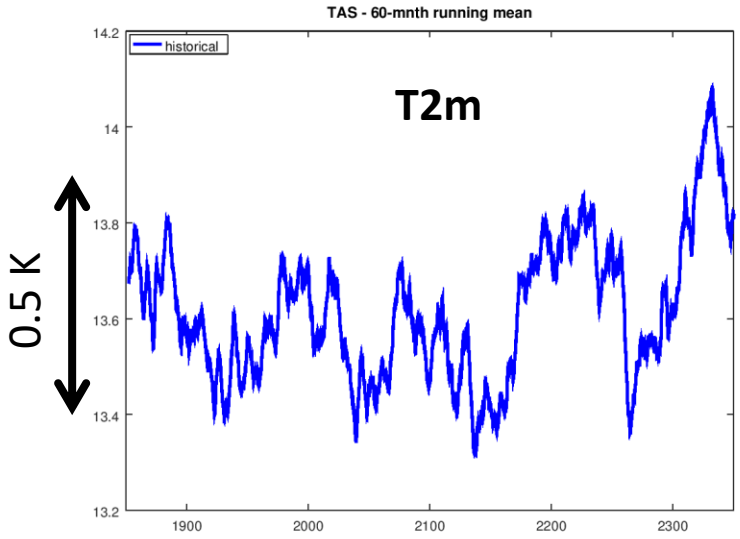
… and help to evaluate and compare global models (GCM or ESM)

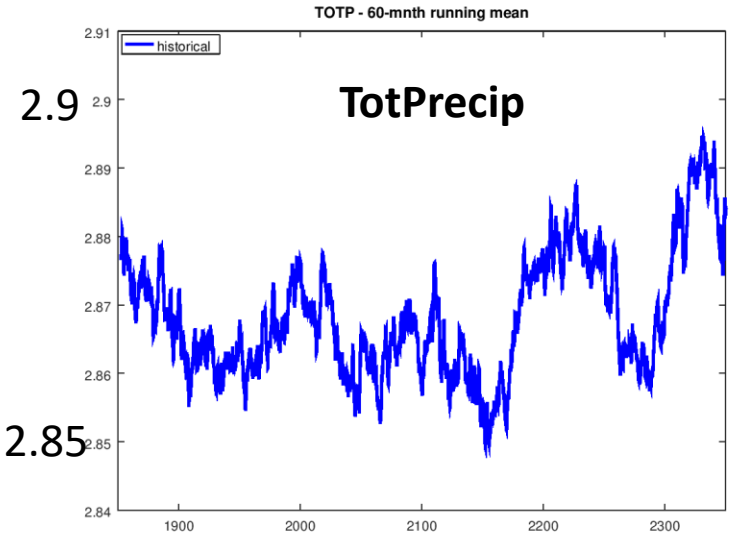
DECK = Description, Evaluation and Characterisation of Klimate

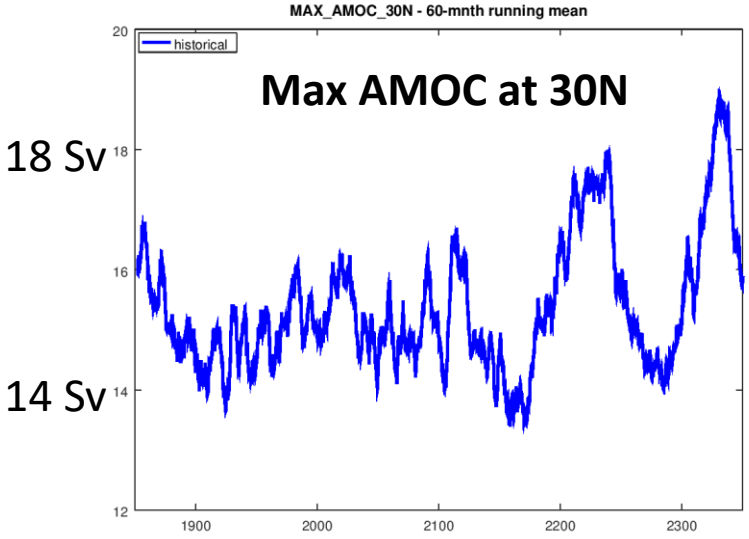
- piControl
- AMIP (atmosphere-only)
- 4xCO2 instantaneous
- 1% increase of CO2

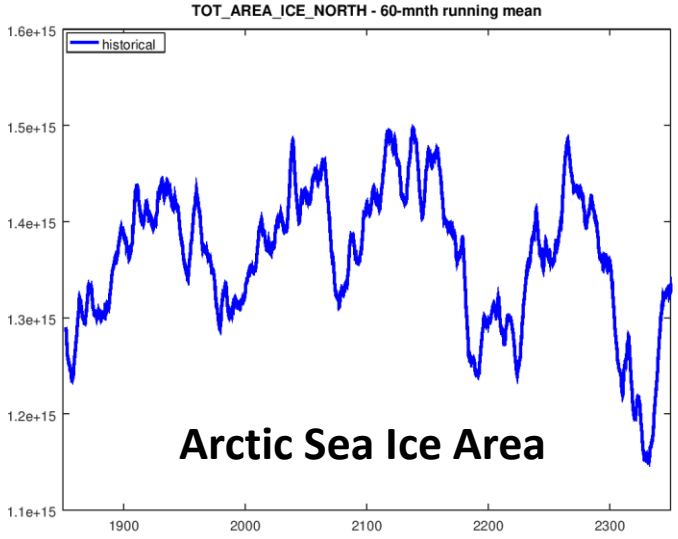
Historical experiment 1850-2014

piControl (500 years)

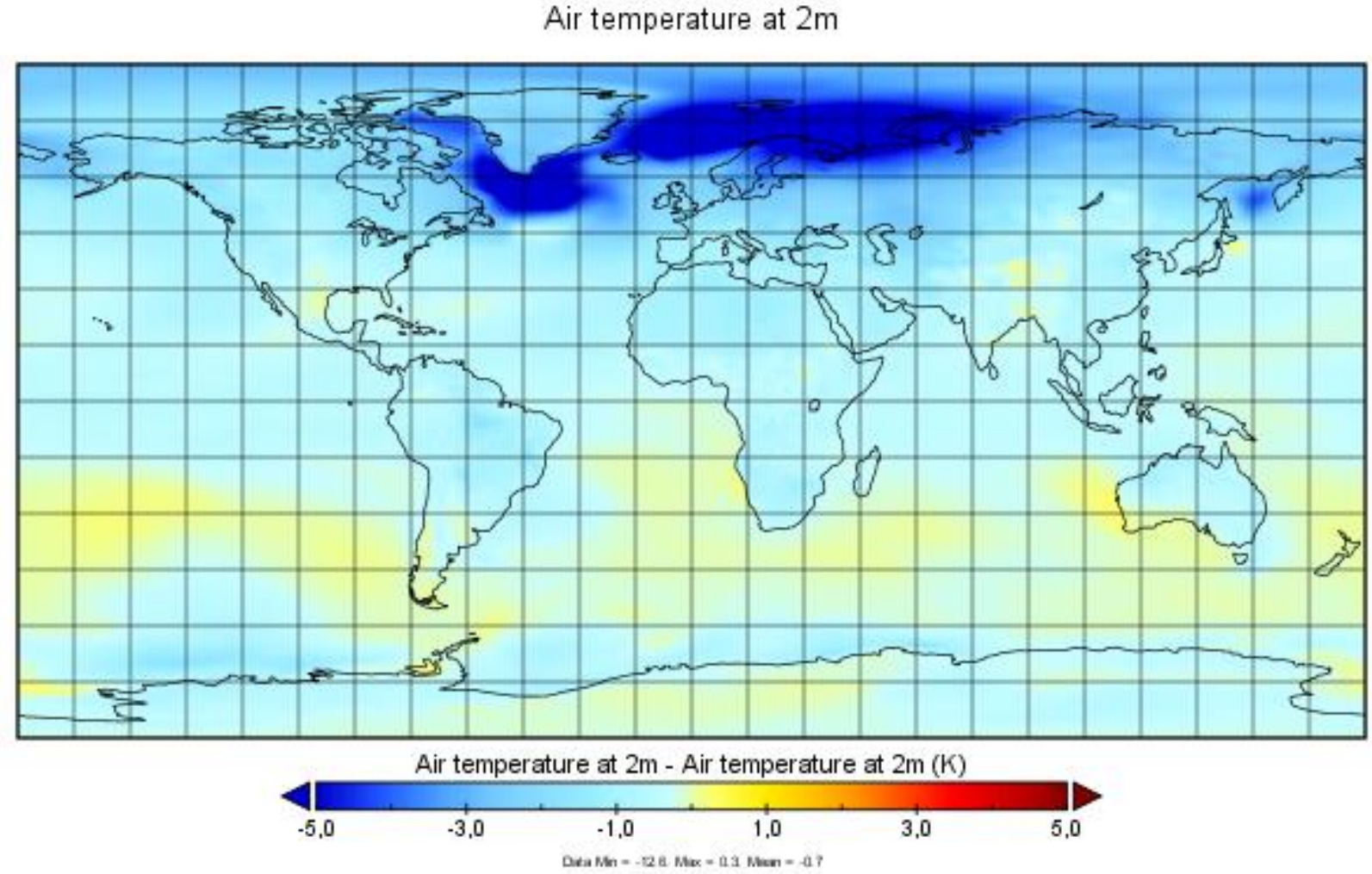




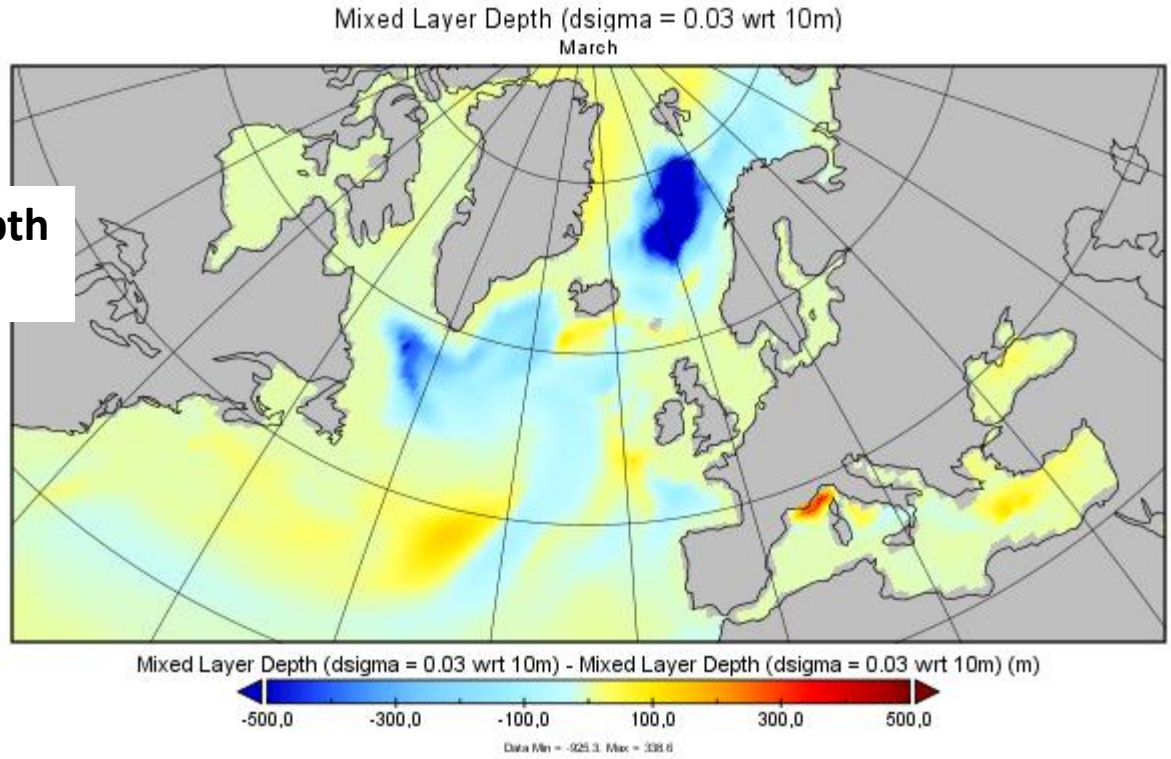




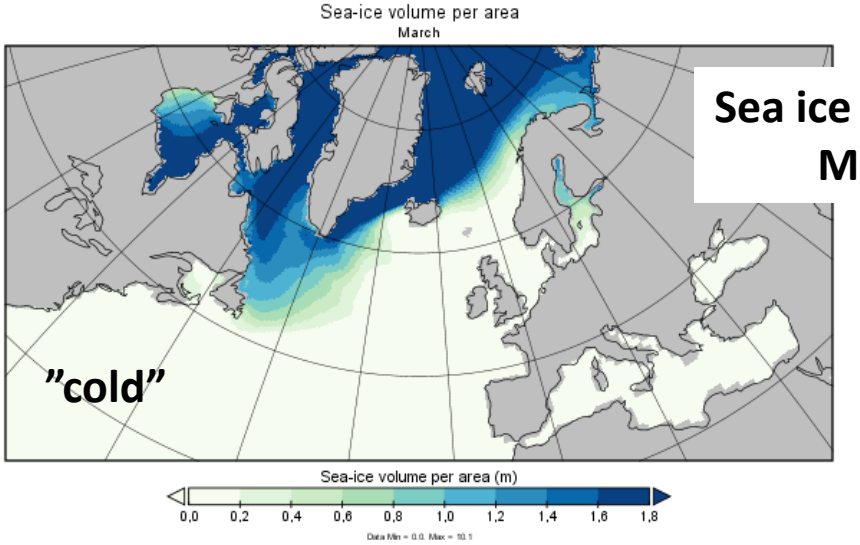
piControl: ”cold” – ”warm” composite

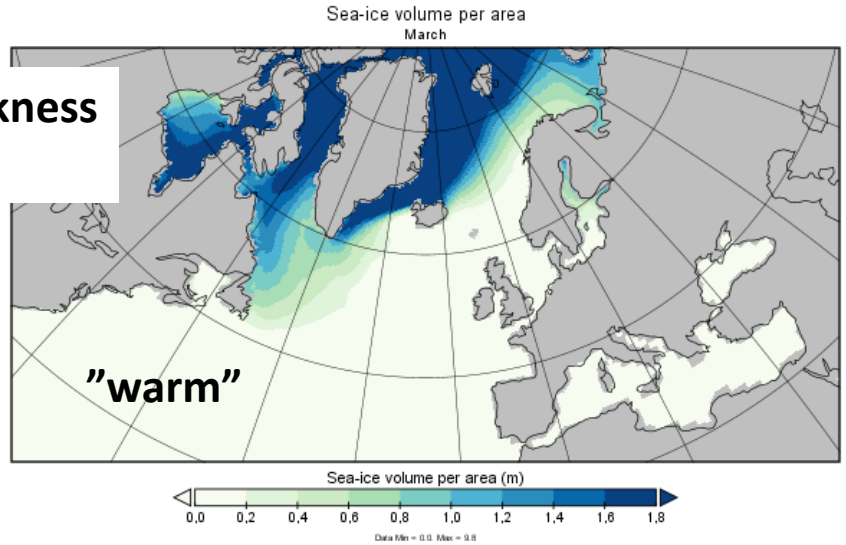


Difference in mixed layer depth
March

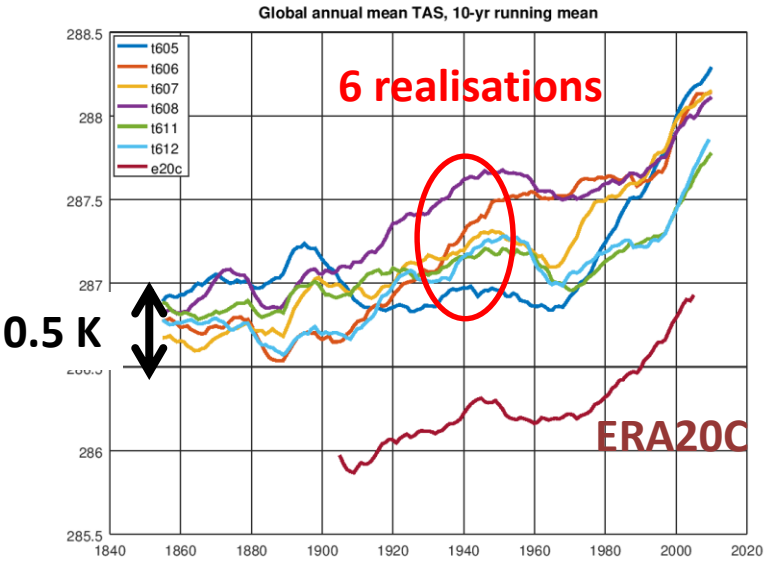


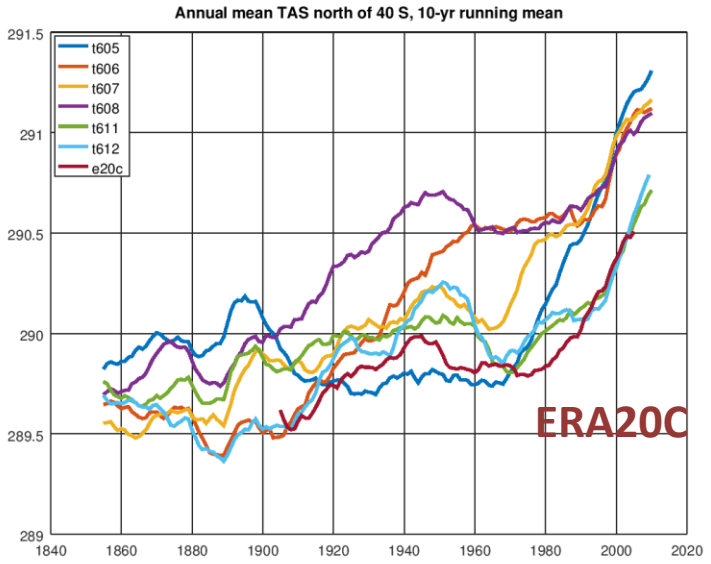
Sea ice thickness
March

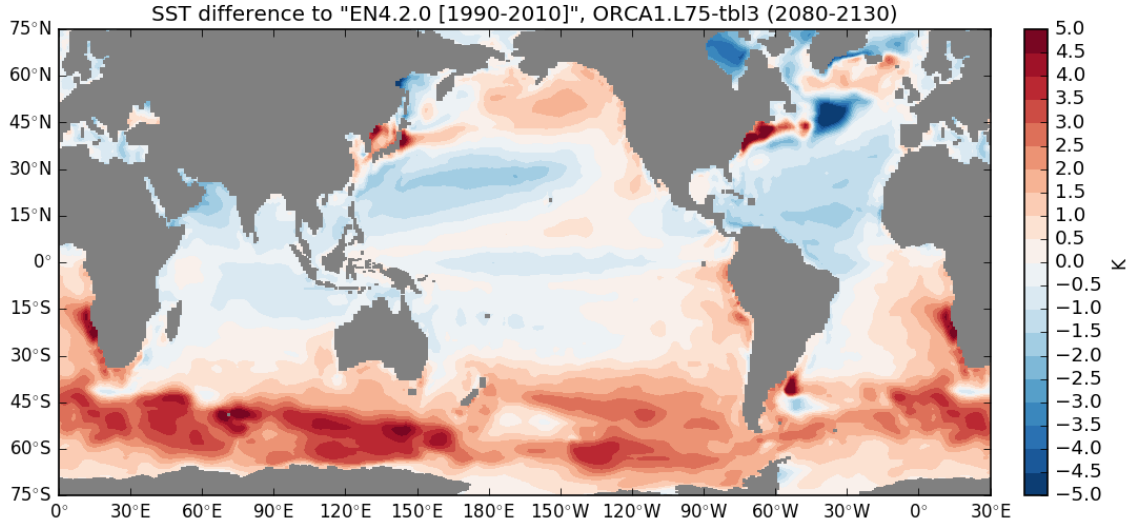




Historical

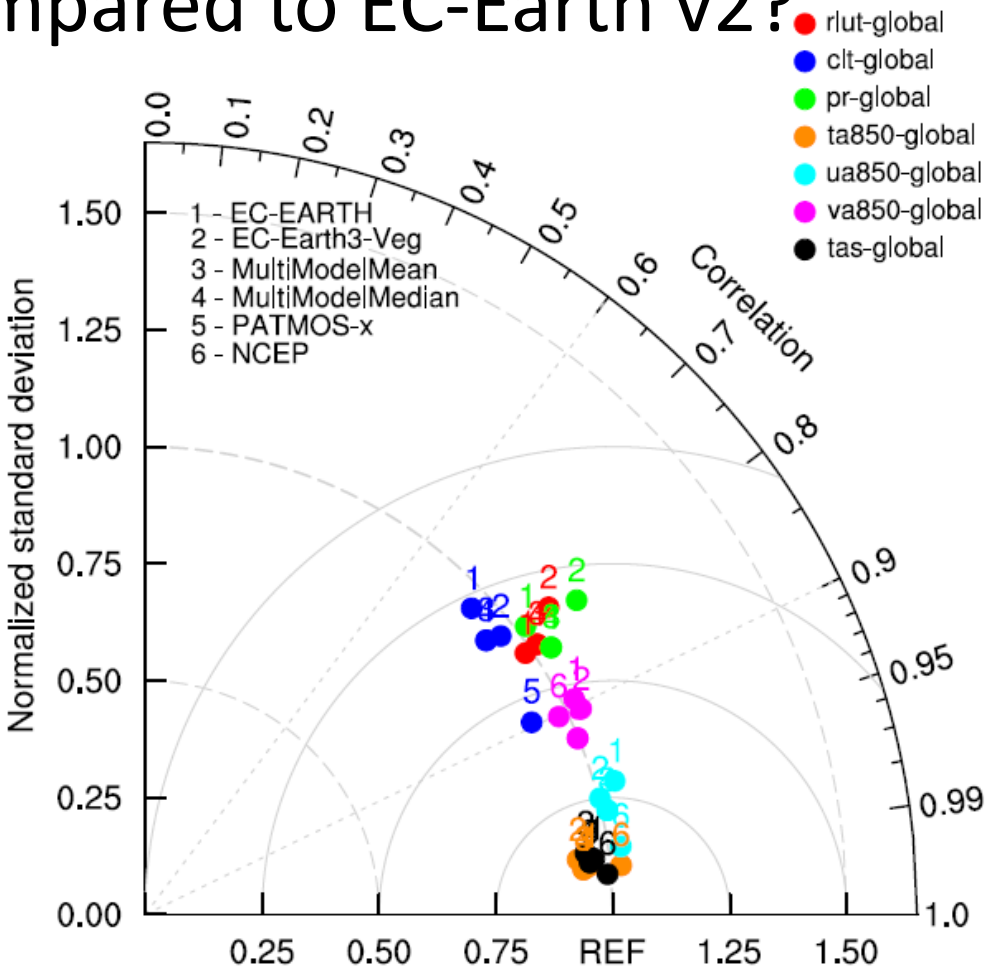


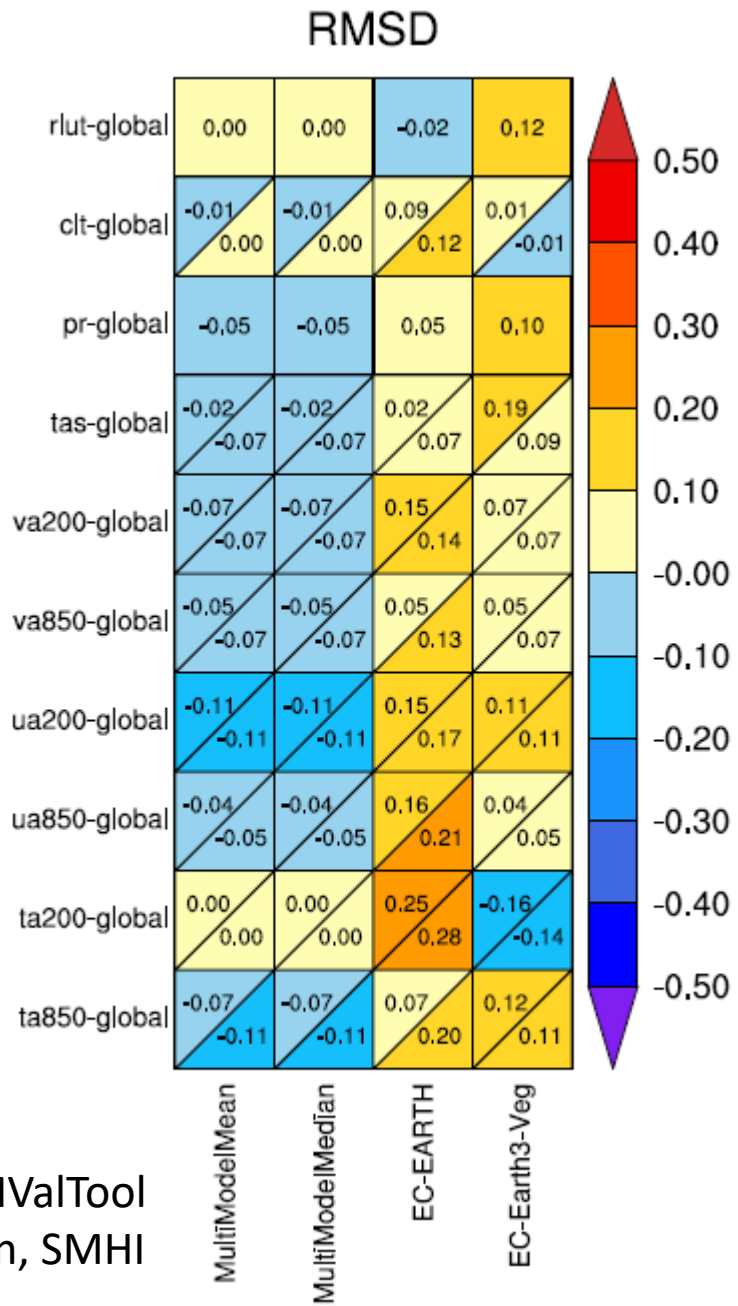




Huge warm bias in S Ocean (picture from piControl experiment)

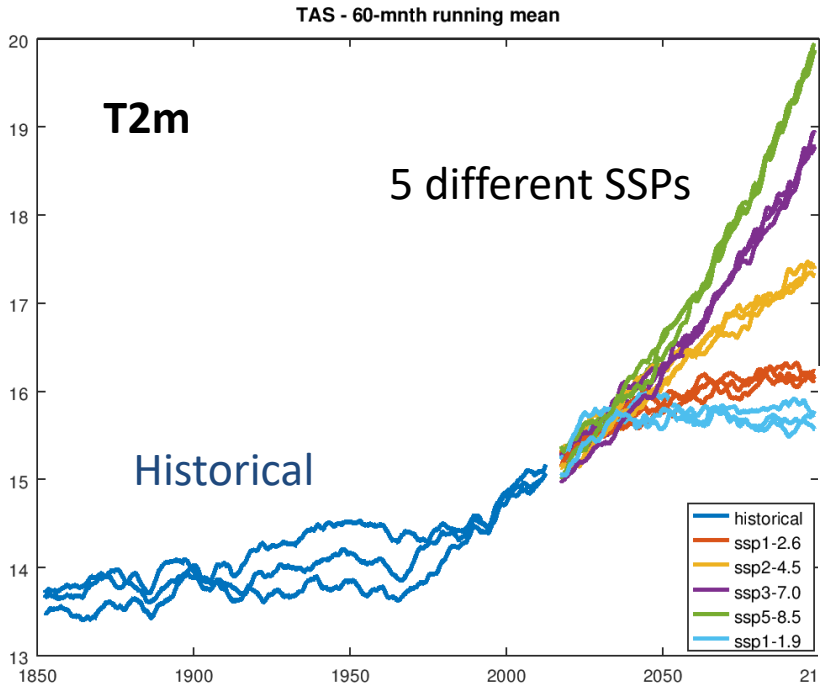
How good is EC-Earth3 compared to EC-Earth v2?

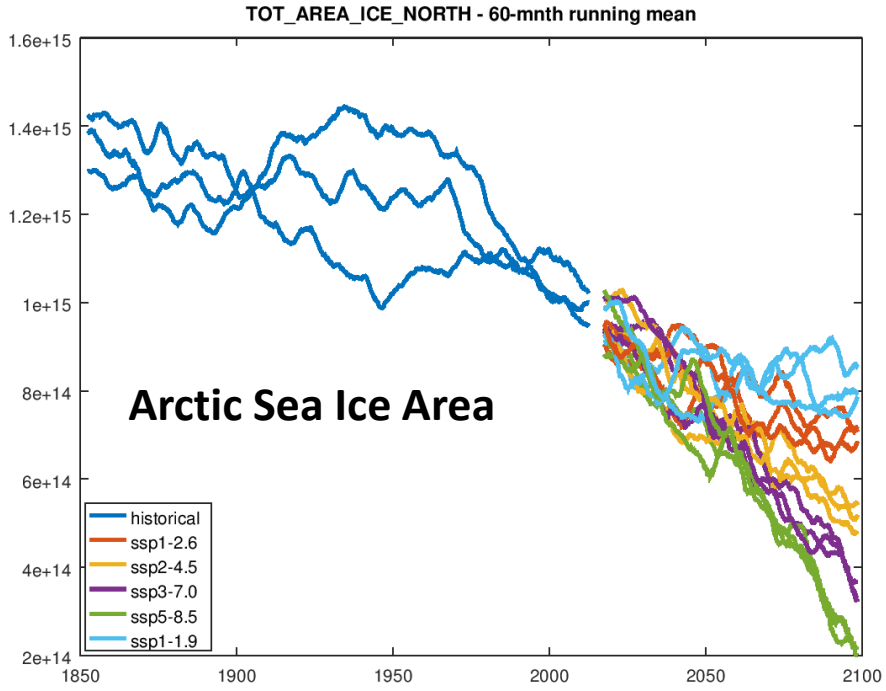




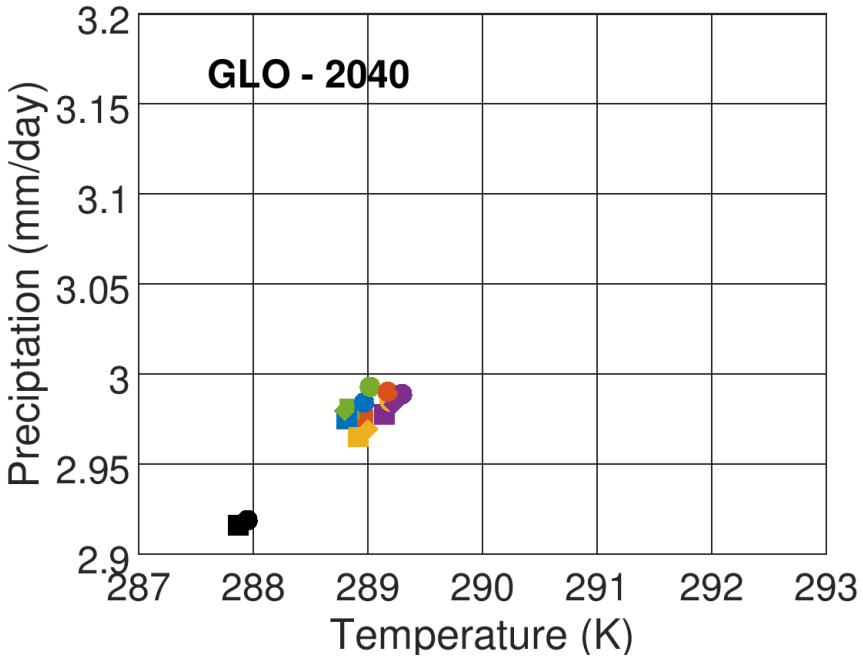
Performance indices from ESMValTool
Courtesy of Klaus Zimmermann, SMHI

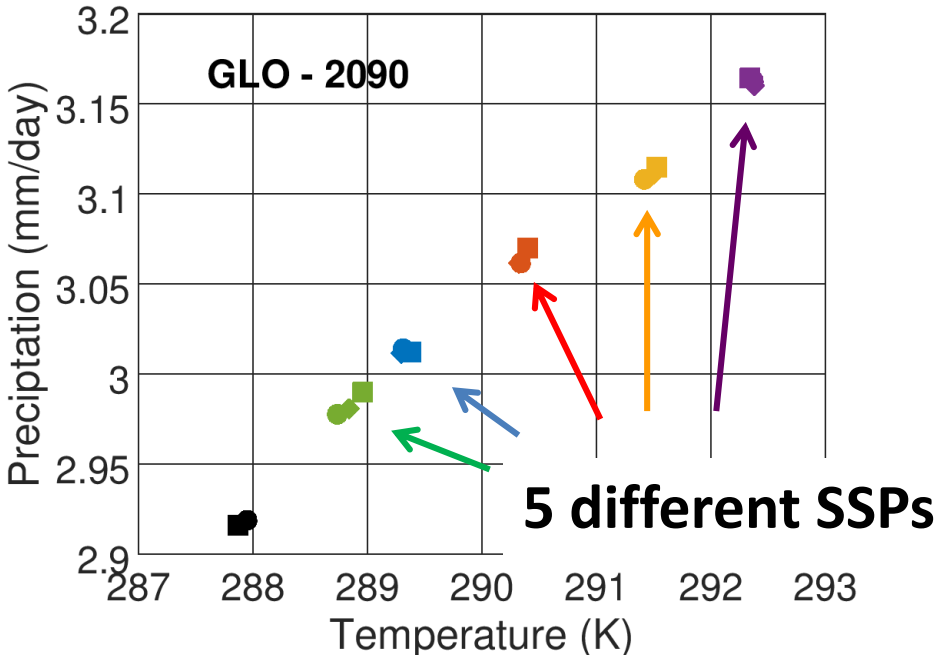
Historical + scenarios

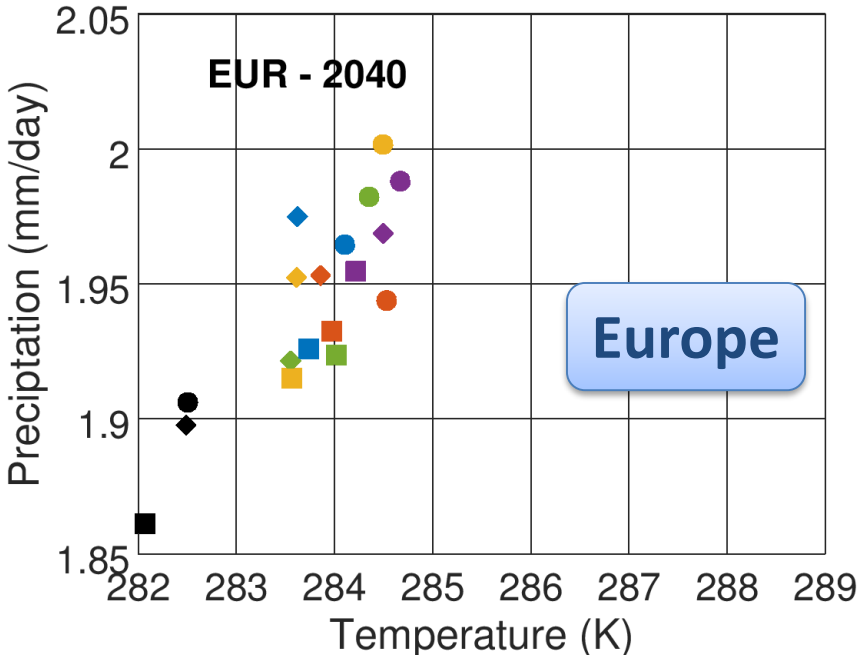


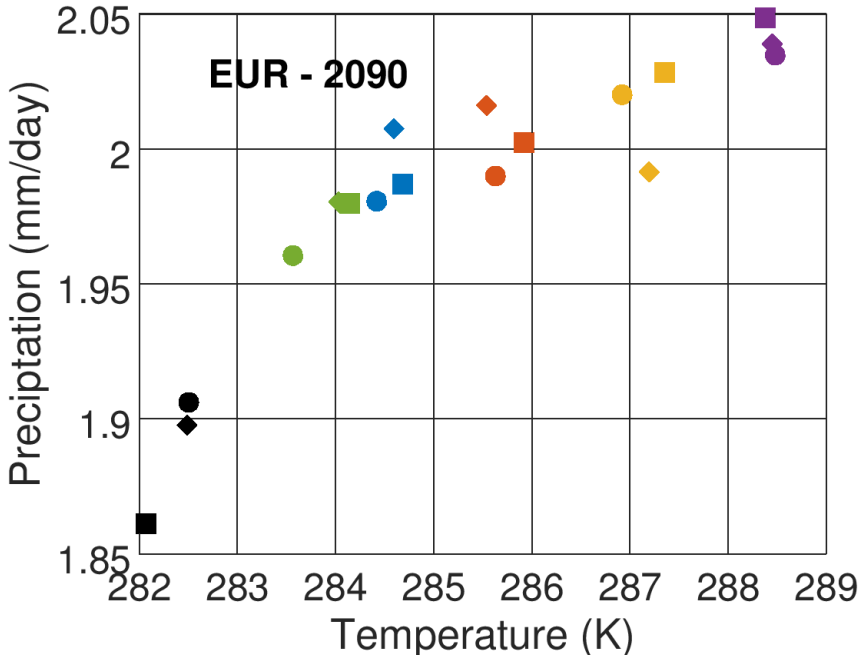


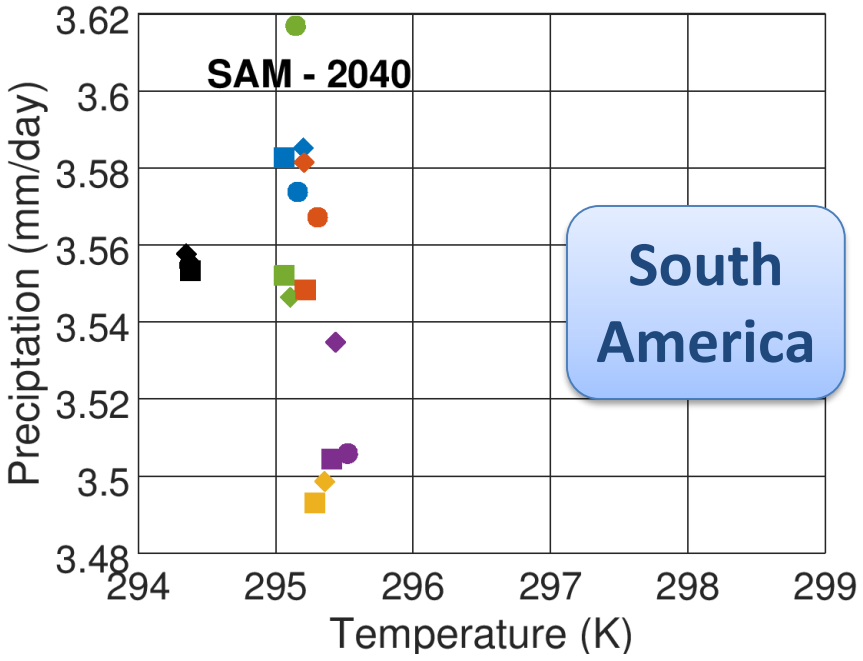
Adressing climate change

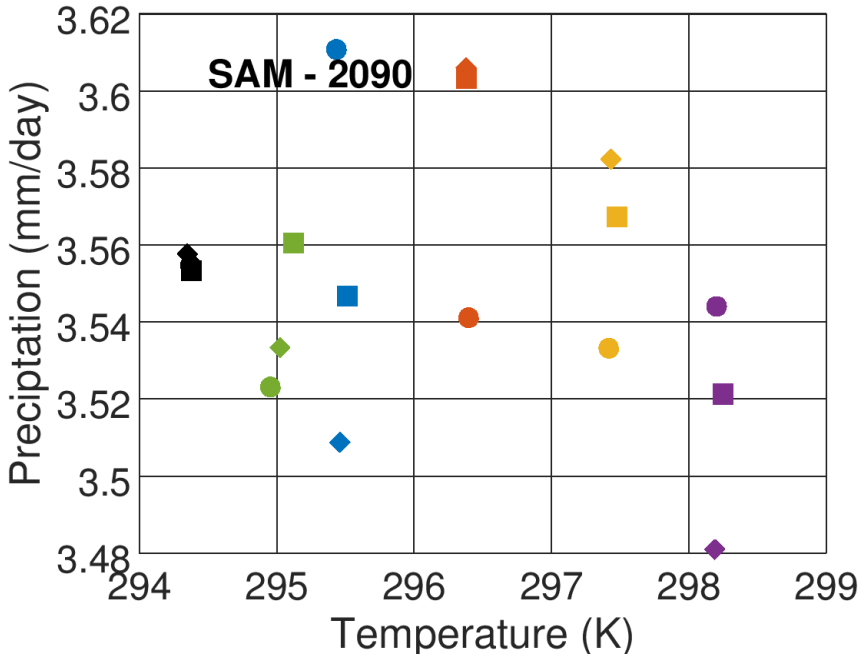





EUR - 2040
Europe
Preciptation (mm/day)
2.05
2
1.95
1.9
1.85
282 283 284 285 286 287 288 289
Temperature (K)


EUR - 2090
Preciptation (mm/day)
2.05
2
1.95
1.9
1.85
282 283 284 285 286 287 288 289
Temperature (K)


SAM - 2040
South America
Preciptation (mm/day)
3.62
3.6
3.58
3.56
3.54
3.52
3.5
3.48
294 295 296 297 298 299
Temperature (K)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Temperature (K)

Equilibrium climate sensitivity (ECS)

Equilibrium climate sensitivity is likely in the range 1.5°C to 4.5°C (high confidence), extremely unlikely less than 1°C (high confidence), and very unlikely greater than 6°C (medium confidence)
IPCC AR5 SPM (2013)

However, the 'likely' range of ECS as stated by the Intergovernmental Panel on Climate Change (IPCC) has remained at 1.5–4.5 degrees Celsius for more than 25 years. […] Here we present a new emergent constraint on ECS that yields a central estimate of 2.8 degrees Celsius with 66 per cent confidence limits (equivalent to the IPCC 'likely' range) of 2.2–3.4 degrees Celsius.
Cox et al (2018), Nature

Early results suggest ECS values from some of the new CMIP6 climate models are higher than previous estimates, with early numbers being reported between 2.8C (pdf) and 5.8C. This compares with the previous coupled model intercomparison project (CMIP5), which reported values between 2.1C to 4.7C. The IPCC's fifth assessment report (AR5) assessed ECS to be "likely" in the range 1.5C to 4.5C and "very unlikely" greater than 6C.
Carbonbrief (2019)

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EC-Earth v2 3.3 K
EC-Earth v3 4.2 K

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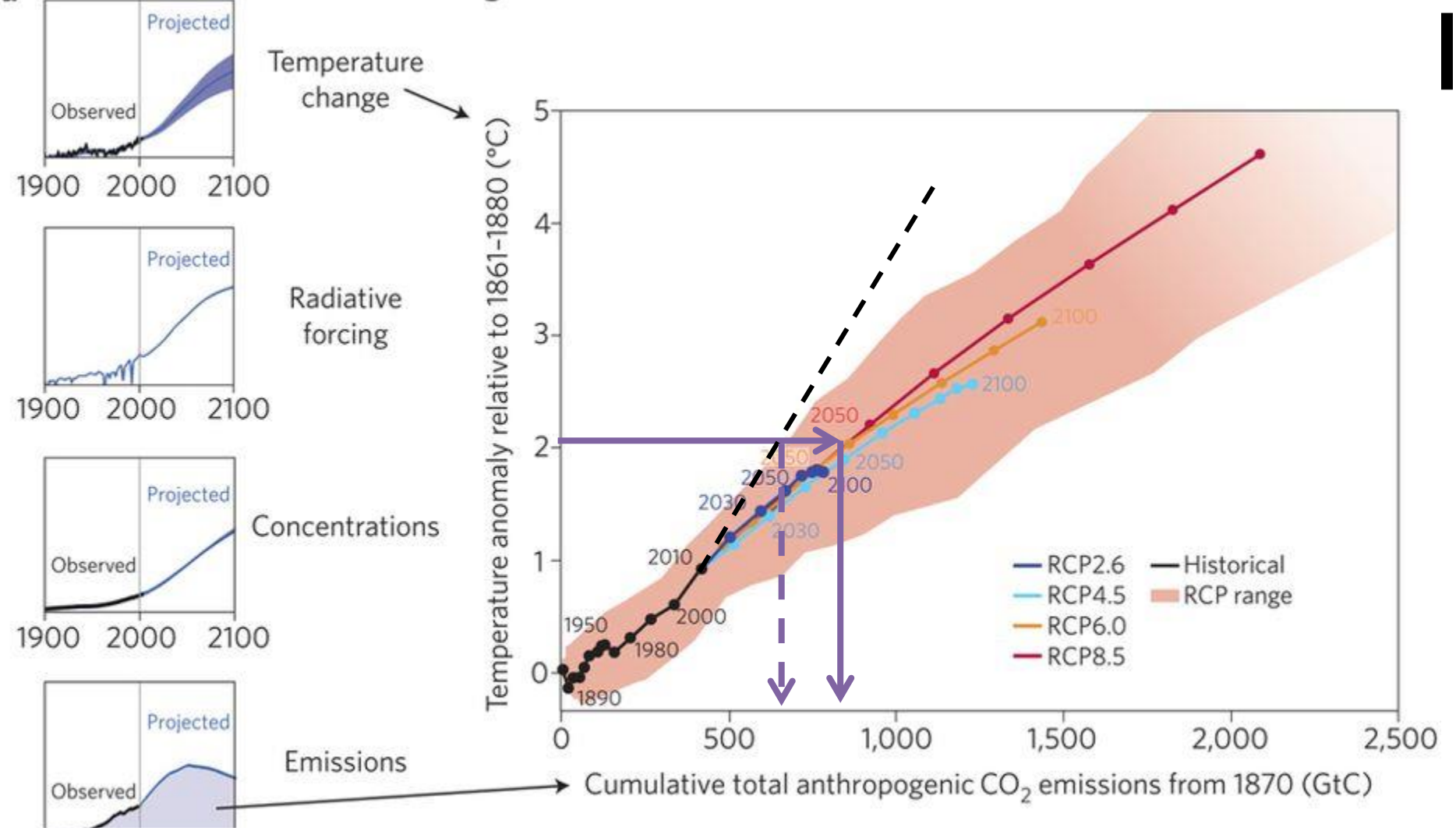
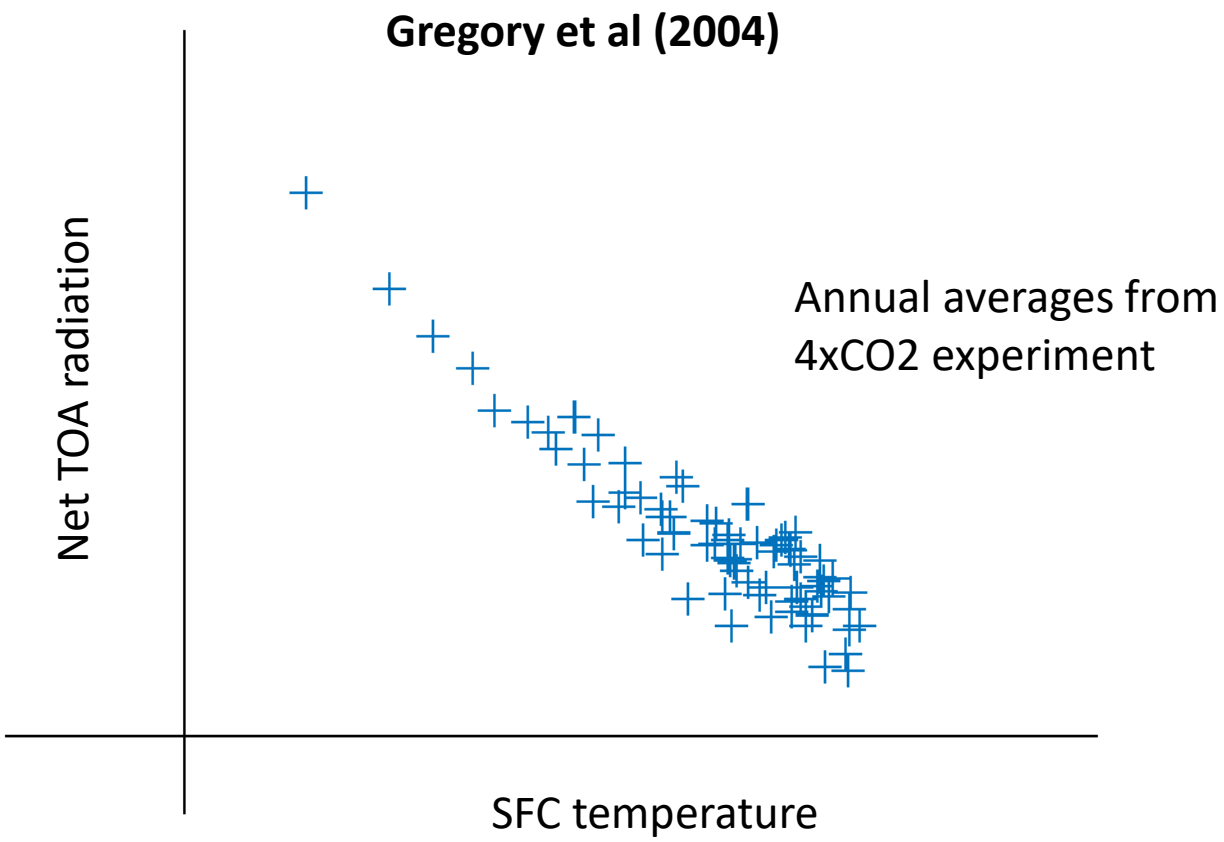


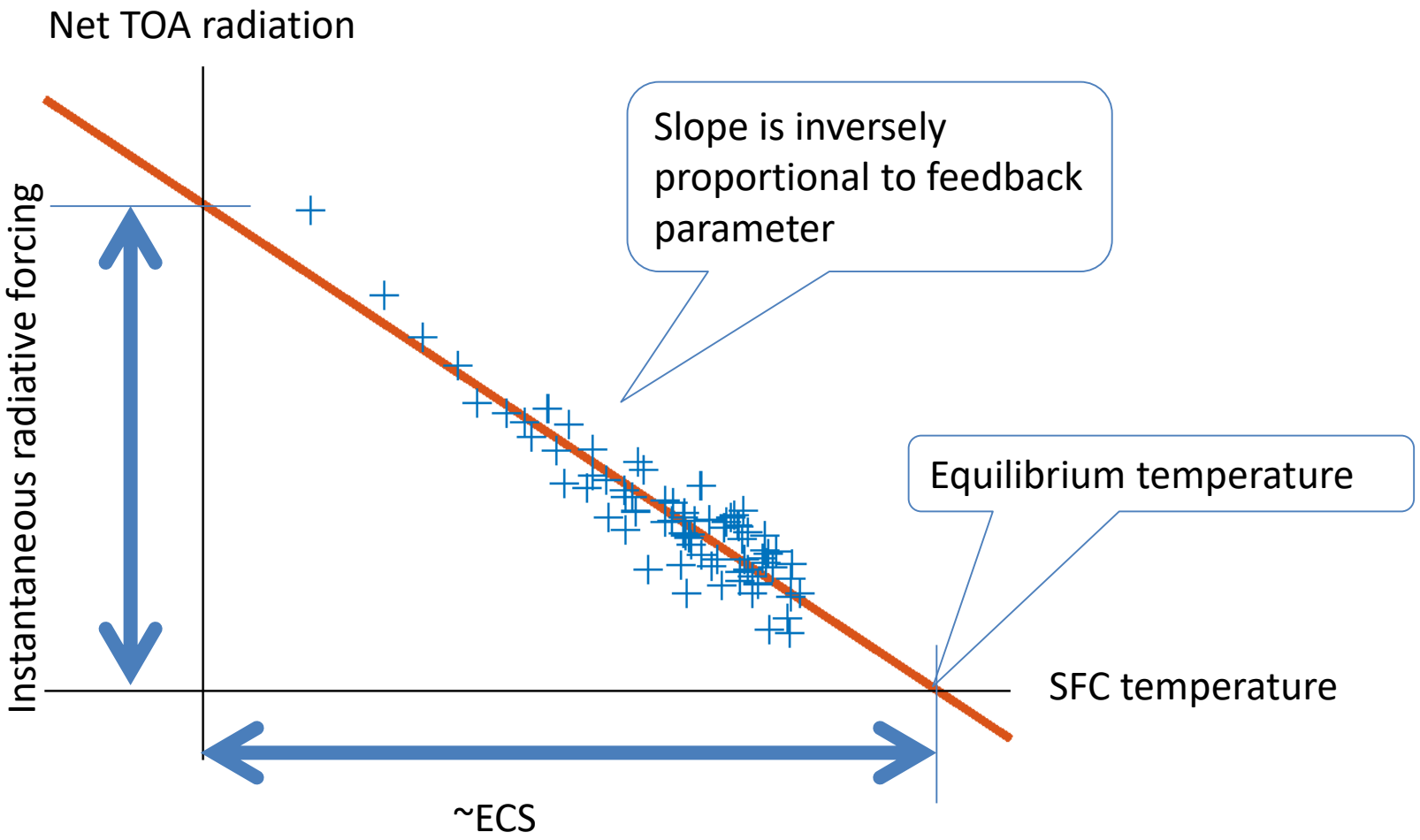
For any given temperature target, such as limiting the warming of global mean surface temperatures to 2 °C above preindustrial levels, there is a total amount of carbon dioxide that can be emitted into the atmosphere. […] Scientifically, this conceptual framework of a fixed carbon budget for a given temperature target has proved compelling and influential, and in principle it is also of strong relevance to policy.

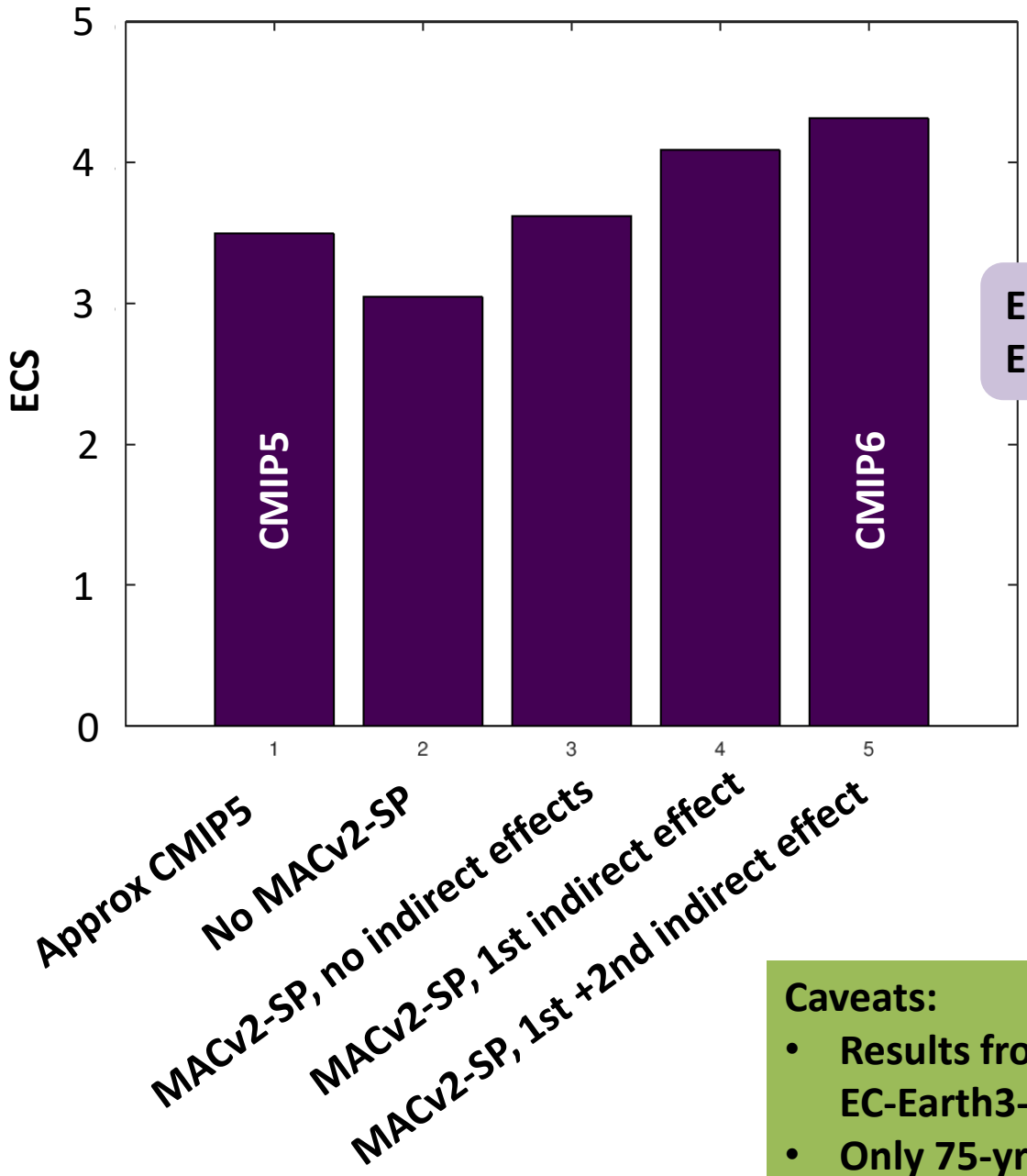
Frame et al (2014), Nature

Finding the ECS without running to equlibrium



Finding the ECS without running to equlibrium





EC-Earth v2	3.3 K
EC-Earth v3	4.2 K

Caveats:

- Results from <u>untuned</u> EC-Earth3-Veg-LR
- Only 75-yrs long experiments

Towards EC-Earth4

THE EC-Earth consortium has decided to replace IFS by OpenIFS in the next generation of the EC-Earth model because

- Connect to a wider community (e.g. universities, non-European groups)
- Ease upgrade path and reduce cycle lag
- Improve feedback loop with ECMWF
- Reduce code complexity (370kLOC vs. 1.4MLOC)
- Improve code quality

OpenIFS integration in EC-Earth4

Wait for upgrade to cy43r3, then

- Create OIFS vendor branch, incl. maintenance
- Build system adaptation
- Introduction of CPLNG to OIFS
- Interface for reading SST/SIC files (AMIP forcing reader)
- NEMO/LIM interface
- Prepare for making long runs (integer overflow, handling output)
- Implement CMIP6 forcing (if possible)
- Couple components for vegetation, chemistry, land ice, …

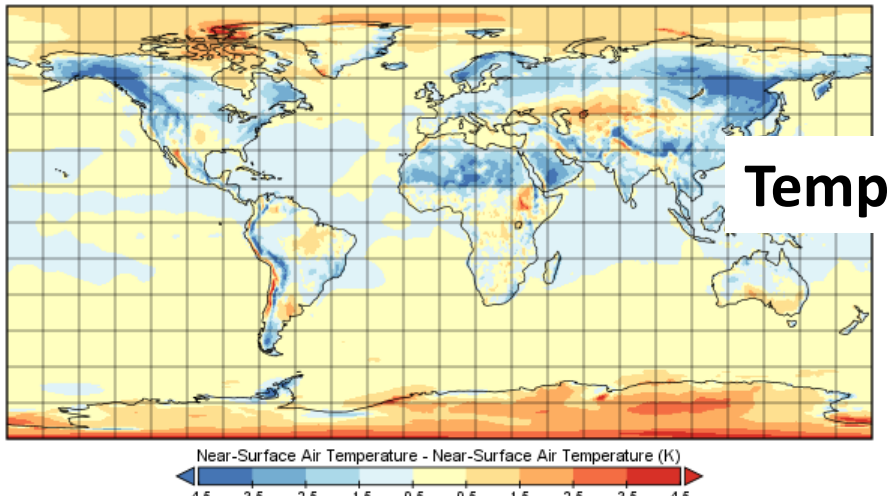
First results with EC-Earth4 (OIFS cy40r1)

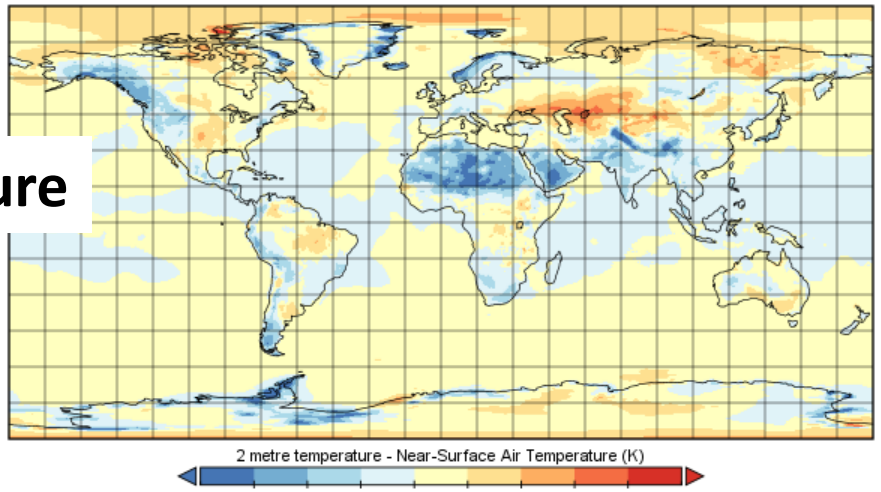
21-yr long AMIP runs (1990-2010)

ECE3 - ERA interim

ECE4 - ERA interim

Temperature





Precipitation