# CMIP6 debrief: climate sensitivity and centennial variability

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# Outline

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Introduction

Centennial variability

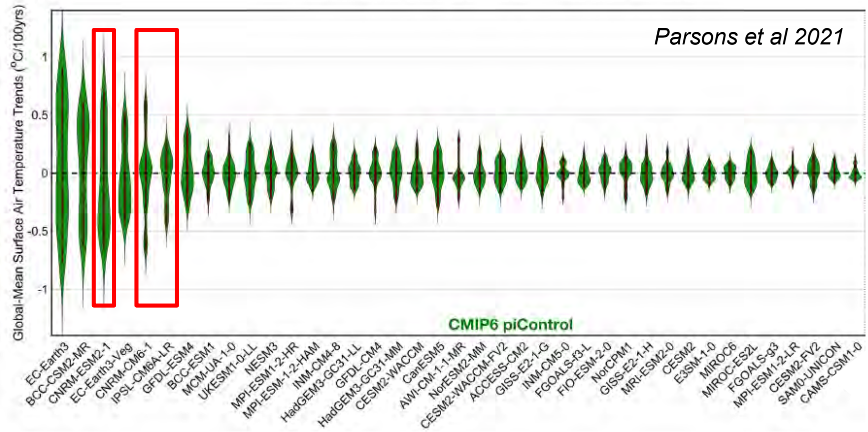
Equilibrium climate sensitivity

# Two main questions from the last Climeri workshop

What explains :

- a large internal centennial variability

of CNRM and IPSL climate models ?

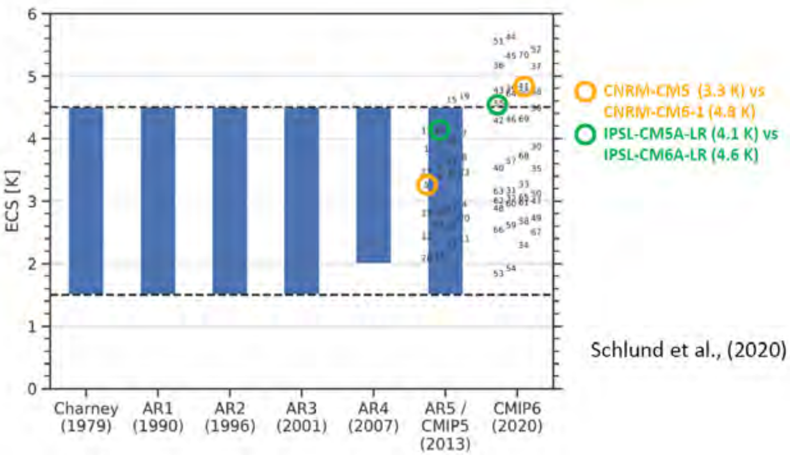


# Two main questions from the last Climeri workshop

What explains :

- a large internal centennial variability ;
- and a large equilibrium climate sensitivity

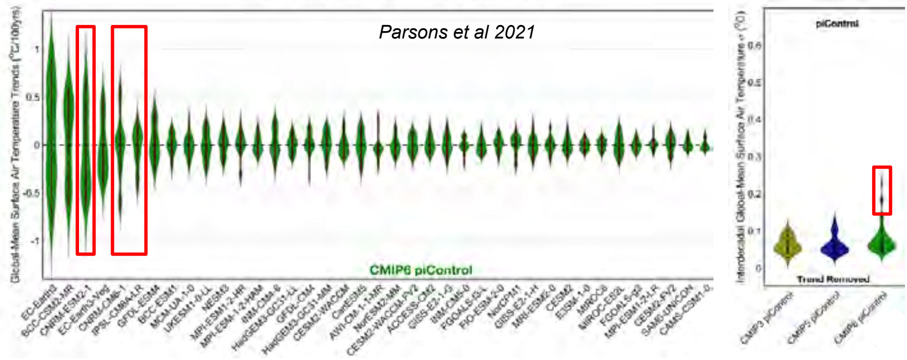
of CNRM and IPSL climate models ?




Schlund et al., (2020)

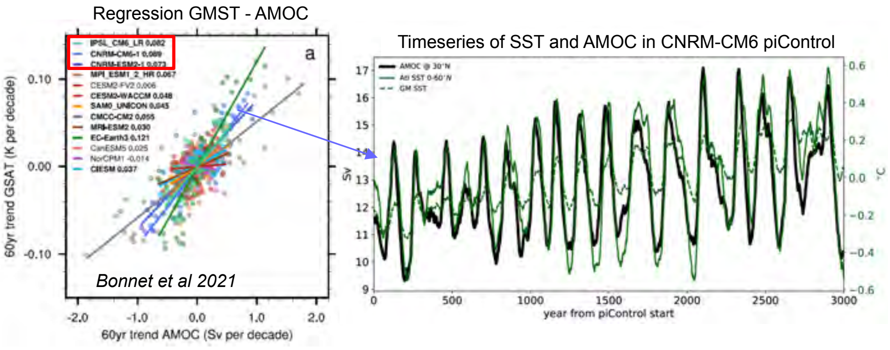
# Outline

# Two groups of low-frequency variabilities among CMIP6



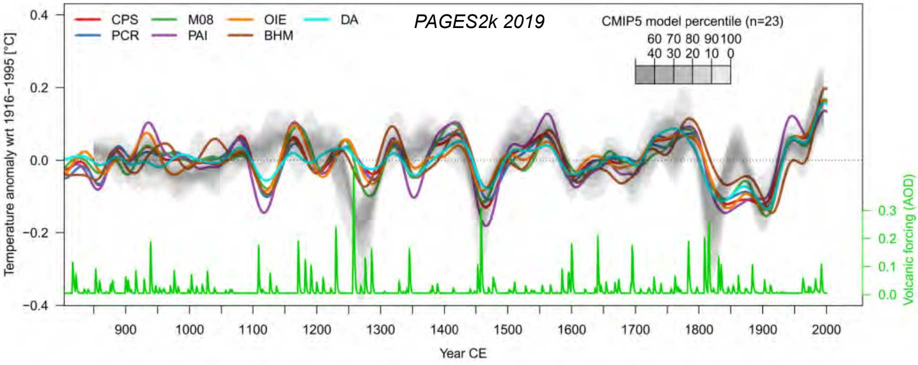

- Most models with large low-frequency variability use NEMO v3.6 at nominal 1° - 75-level resolution
- However, most CMIP6 models do not share this behaviour
- The CMIP6 ensemble shows larger interdecadal variance of GMST than previous CMIP ensembles

# A centennial variability driven by the AMOC



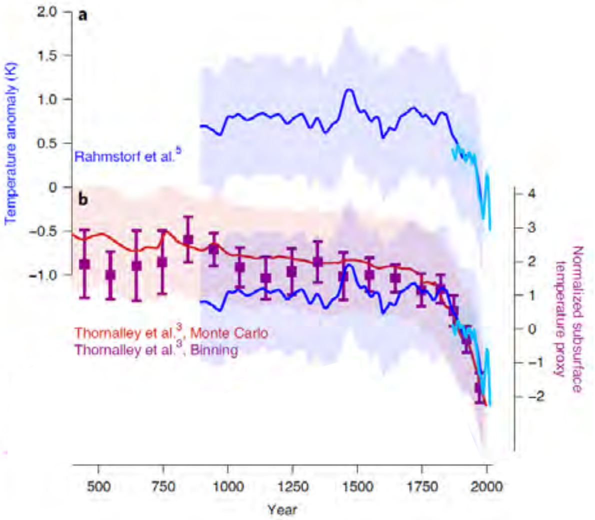

- The AMOC explains most of the low-frequency GMST variance in models with large low-frequency variability
- It causes an intense cycle of SST variability, most intense in the North Atlantic

# Observational evidence of such variability




- No such large GMST variability in the 30–200-year frequency range over the last two millenia
- A significant fraction of it is forced by volcanic emissions, which are constant in piControl runs !

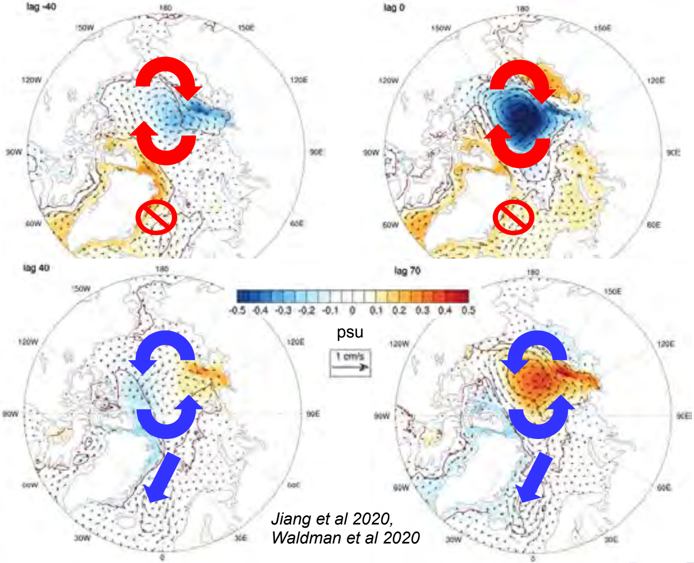
# Observational evidence of such variability




- AMOC proxies show no clear evidence of a strong centennial variability, but given the uncertainty such behaviour cannot be discarded (Caesar et al 2021).

# Mechanism : freshwater advection from the Arctic

Regression top 150m velocities (arrows) and salinity (shades) onto AMOC PC1 - IPSL-CM6




*Jiang et al 2020,*
*Waldman et al 2020*

# Causes of this variability

Sensitivity :

- To initial conditions : sustained variability after 3,000 years of piControl run in CNRM-CM6
- To forcings : when forcings cause a weak mean AMOC (river runoff in CNRM-CM6 or strong GHG forcings in all models), centennial variability largely damped
- To physics : inconclusive experiments on main differences with CM5 (tidal mixing) and HadGEM3 (namelist parameters)
- To grid-bathymetry : variability typical of NEMOv3.6 1$^\circ$ -75 level configuration

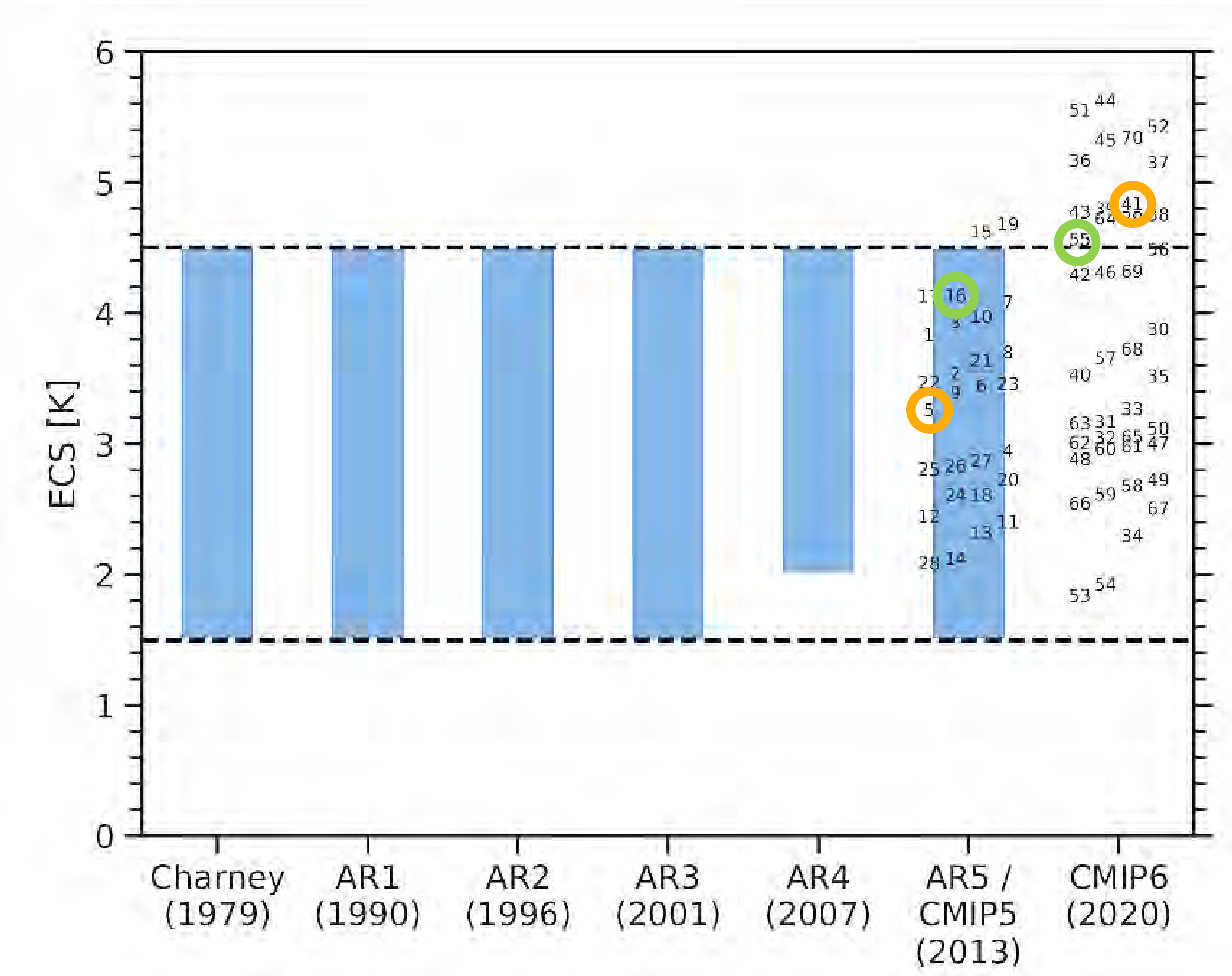
# Summary

All French low-resolution climate/Earth System models have :

- An intense low-frequency internal variability
- Shared with other CMIP6 models although it is in the upper end of the CMIP6 ensemble
- Not evident in paleoclimate reconstructions, although such behaviour cannot be discarded
- Driven by the AMOC variability, itself controlled by freshwater exchanges between Arctic and North Atlantic
- Specific of the NEMOv3.6 $1^\circ$ -75 level configuration

# Outline

# CMIP6 vs previous estimations of ECS



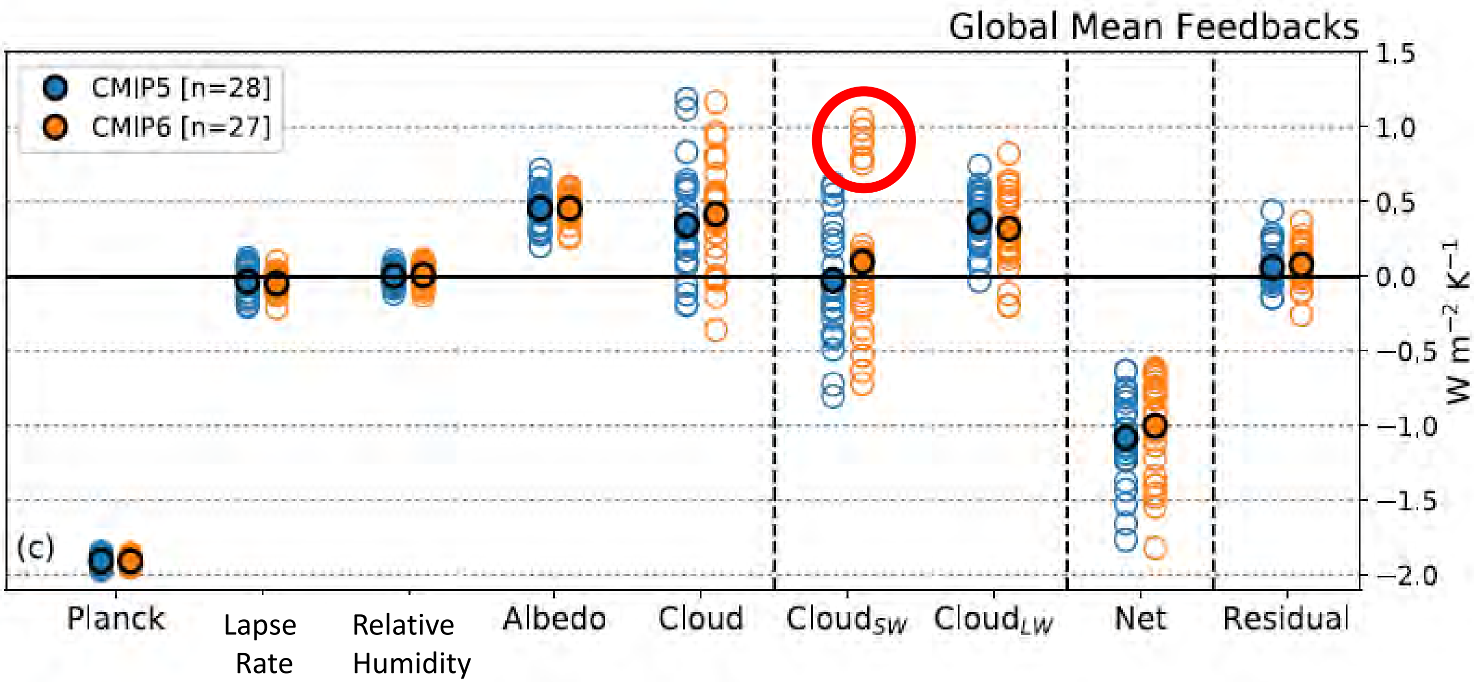

CNRM-CM5 (3.3 K) vs CNRM-CM6-1 (4.8 K)

IPSL-CM5A-LR (4.1 K) vs IPSL-CM6A-LR (4.6 K)

Schlund et al., (2020)

→ Increase in multi-model ECS mean and intermodel spread in comparison to CMIP5 and older estimations

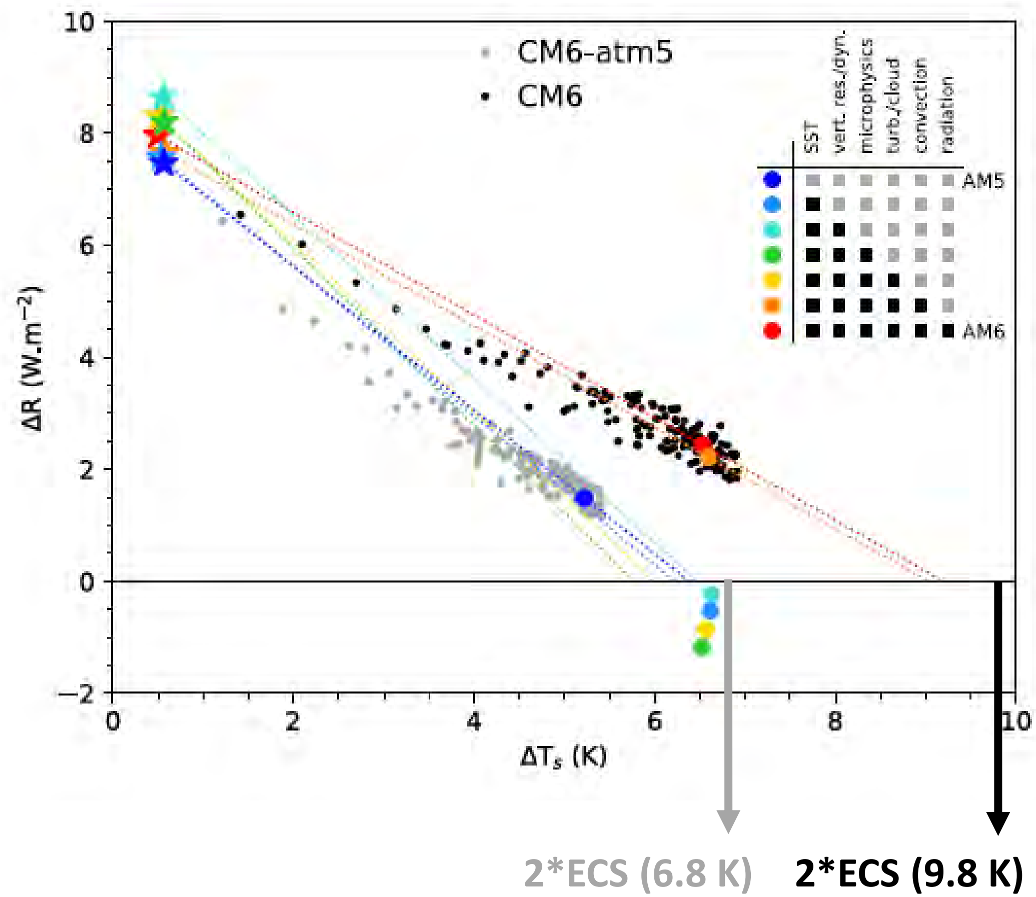
# Causes of this change in the multi-model mean




→ This increase in the ECS is due to a **stronger positive cloud feedback** associated with a **decrease in extratropical low cloud coverage and albedo** → representation of the mixed phase (liquid/ice) clouds

Zelinka et al., (2020)

# The case of CNRM-CM6-1



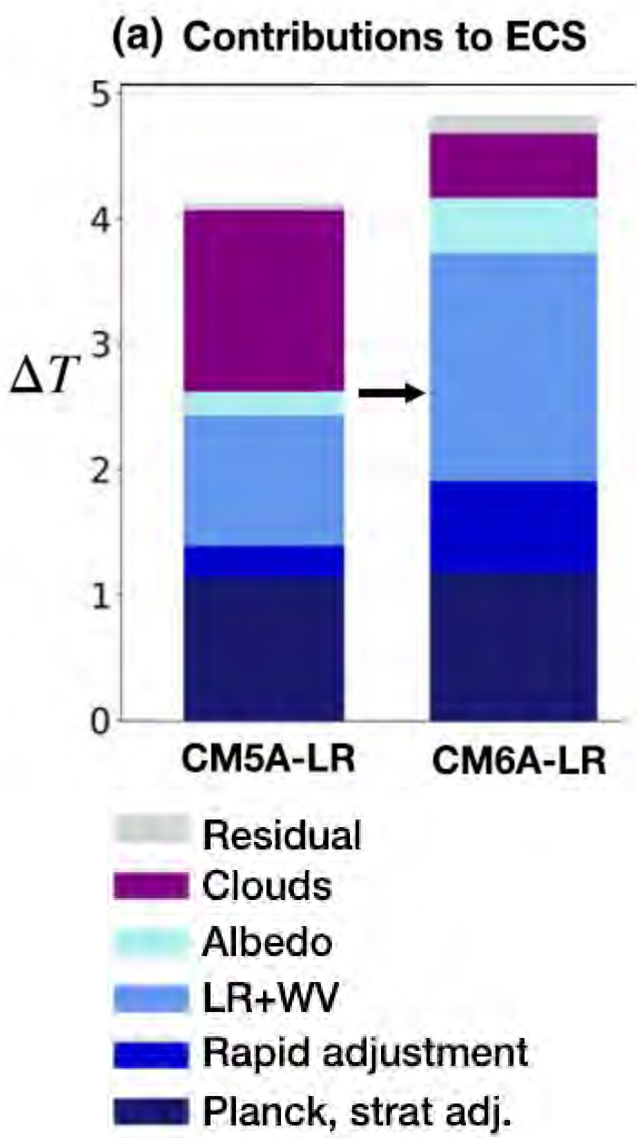

→ Sequentially replace AM5 modules or options until the final atmospheric model is identical to AM6

→ The climate sensitivity increase → change in the atmospheric component → convection scheme

→ Predominant contribution of high altitude tropical clouds + significant contribution of extratropical and tropical low cloud.

Saint-Martin et al., (2020)

# The case of IPSL-CM6A-LR



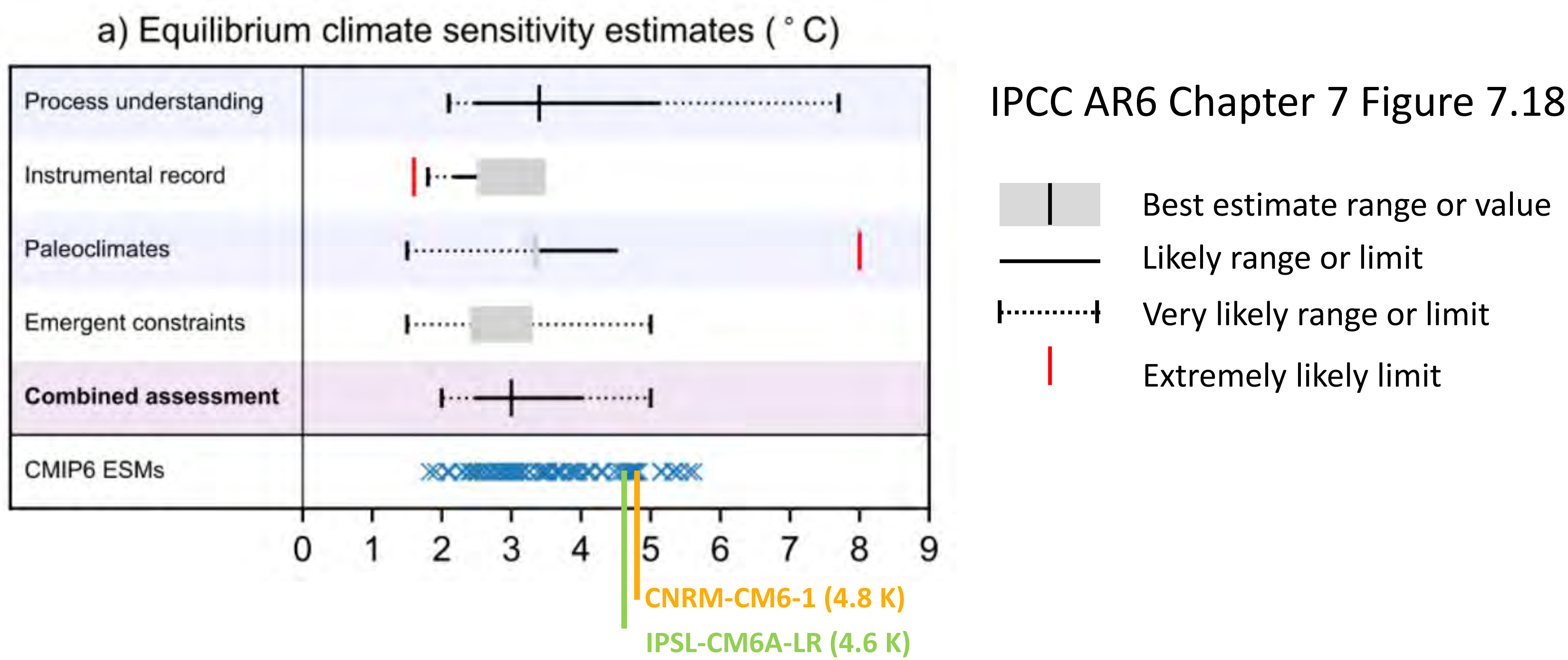

→ Main drivers of this larger ECS = more positive rapid tropospheric adjustment to CO2 + stronger combined lapse rate and water vapor feedback

→ Only partly compensated by less positive cloud feedbacks

→ **Hypothesis:** change in the physics convection (inclusion of thermal winds for shallow convection and stochastic triggering of deep convection) → if thermals wind are too weak to trigger deep convection → moisture accumulation in the lower-middle troposphere

Boucher et al., (2020)

# How credible are models with high ECS compared to other lines of evidence ?




→ Clear reduction in the spread of ECS by combining information from various sources (Sherwood et al., 2020; IPCC AR6 Chp 7)

→ French models are in the upper very likely range of the combined assessment

→ The mechanisms behind these higher ECS can differ from one model to another, although water vapor and cloud feedback seem generally involved