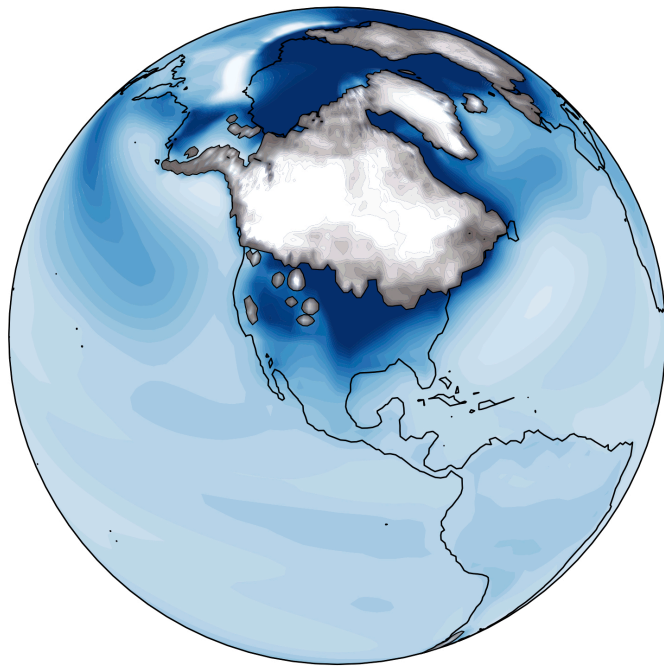


# Update on the simulation of the Last Glacial Maximum using CESM2



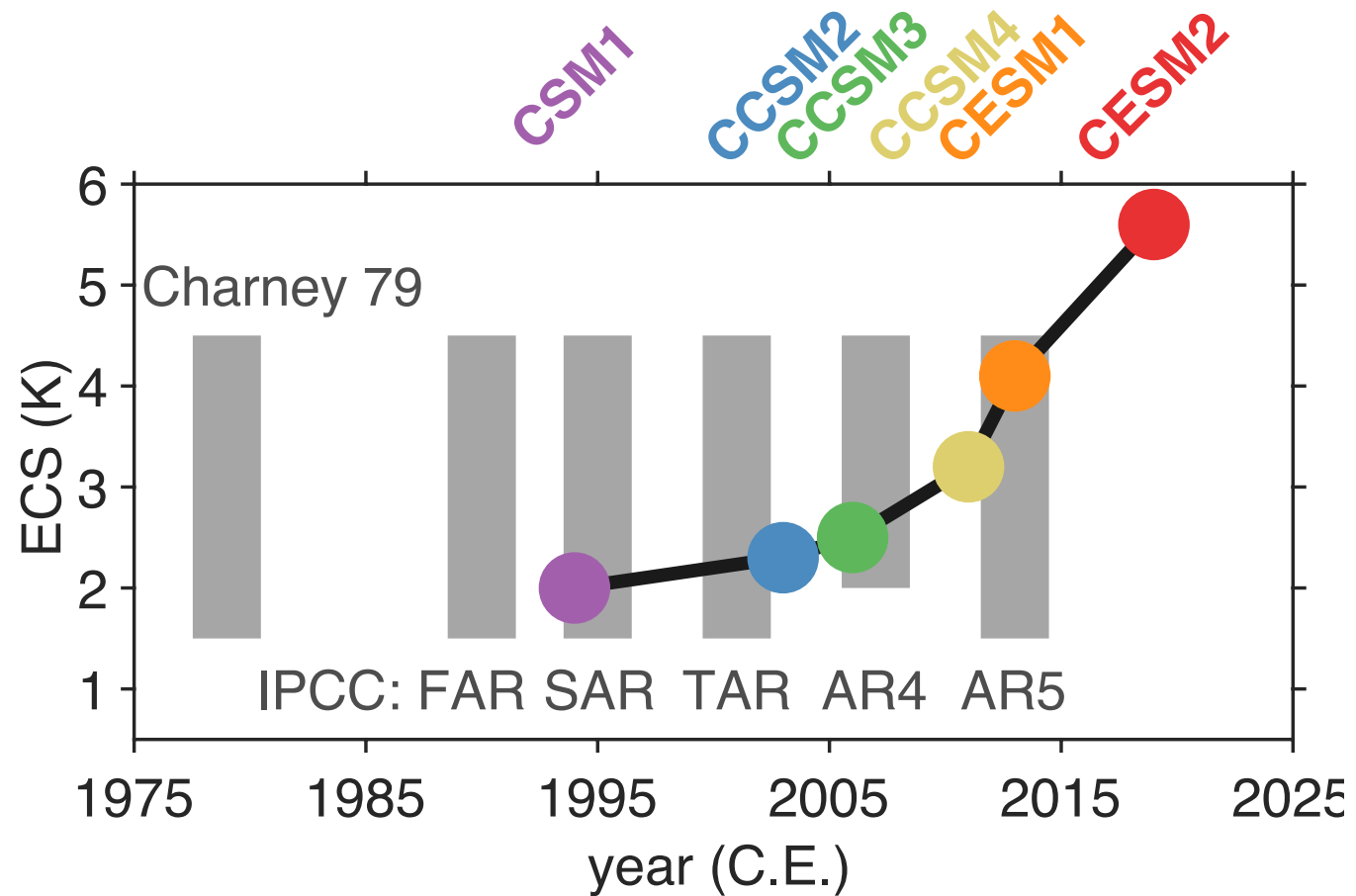
*Credit: J. Tierney*

**Jiang Zhu**

Collaborators: B. Otto-Bliesner, E. Brady, C. Poulsen,  
J. Tierney, M. Lofverstrom, P. DiNezio

Acknowledgements: AMWG, LMWG, ...

# CESM2 has an ECS > 5°C



*Kiehl et al., 2006; Bitz et al., 2011; Gettelman et al., 2012, 2019;  
Danabasoglu et al., 2020; Bacmeister et al., 2020; Bjordal et al., 2020*

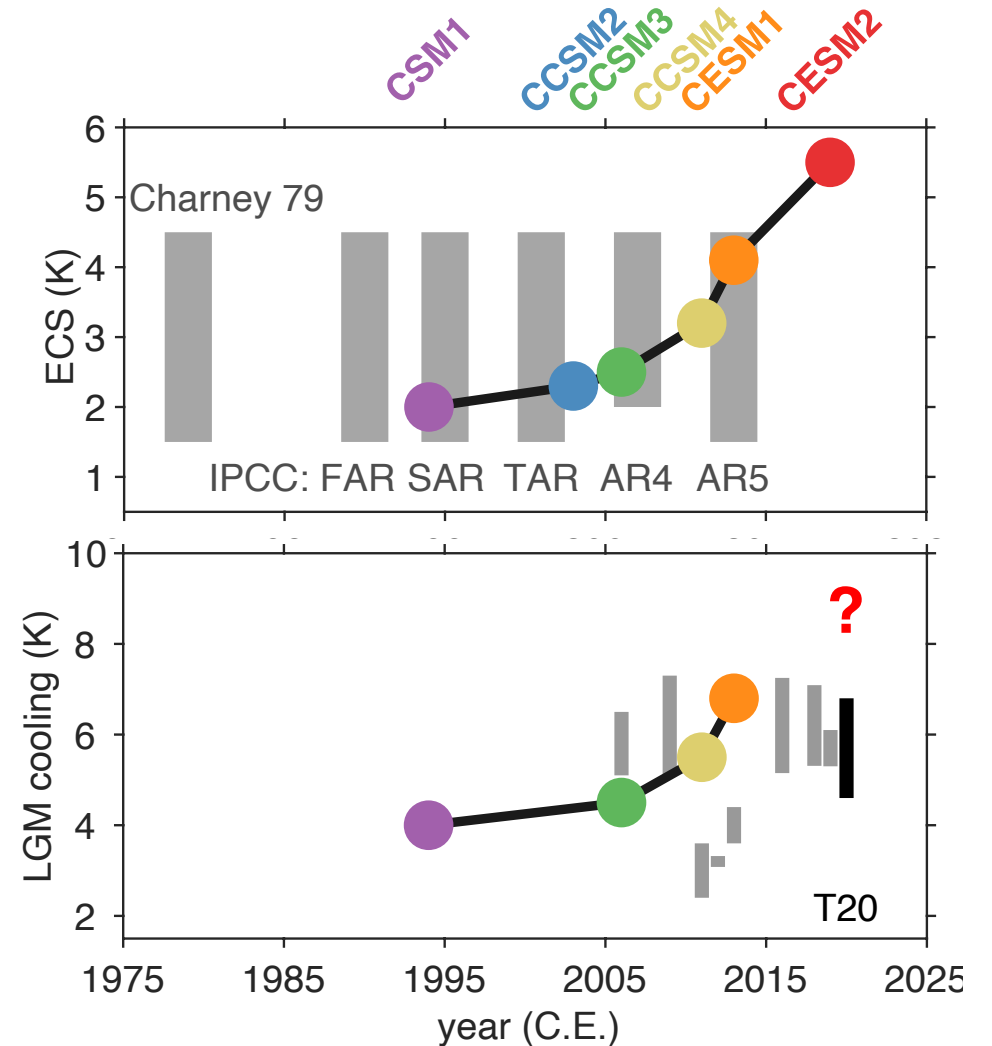
# Constraining ECS using the Last Glacial Maximum (LGM)

- LGM global cooling correlates with ECS

(*Shin et al., 2003; Otto-Bliesner et al., 2006; Brady et al., 2013; Zhu et al., 2017, 2020*)

- The latest LGM global cooling:  $\sim 6^{\circ}\text{C}$

(*Tierney et al., Nature, 2020*)



- CESM2 (≈CMIP6 configuration)
  - BGCs off; No-Anthro; RTM; ...
  - PI climate and ECS not impacted
- Boundary conditions
  - Lower GHGs
  - Land ice sheets: topography, land surface properties & shelf exposures
  - PI aerosol, vegetation & tidal mixing
- Initial condition: CESM1 LGM

## Geophysical Research Letters

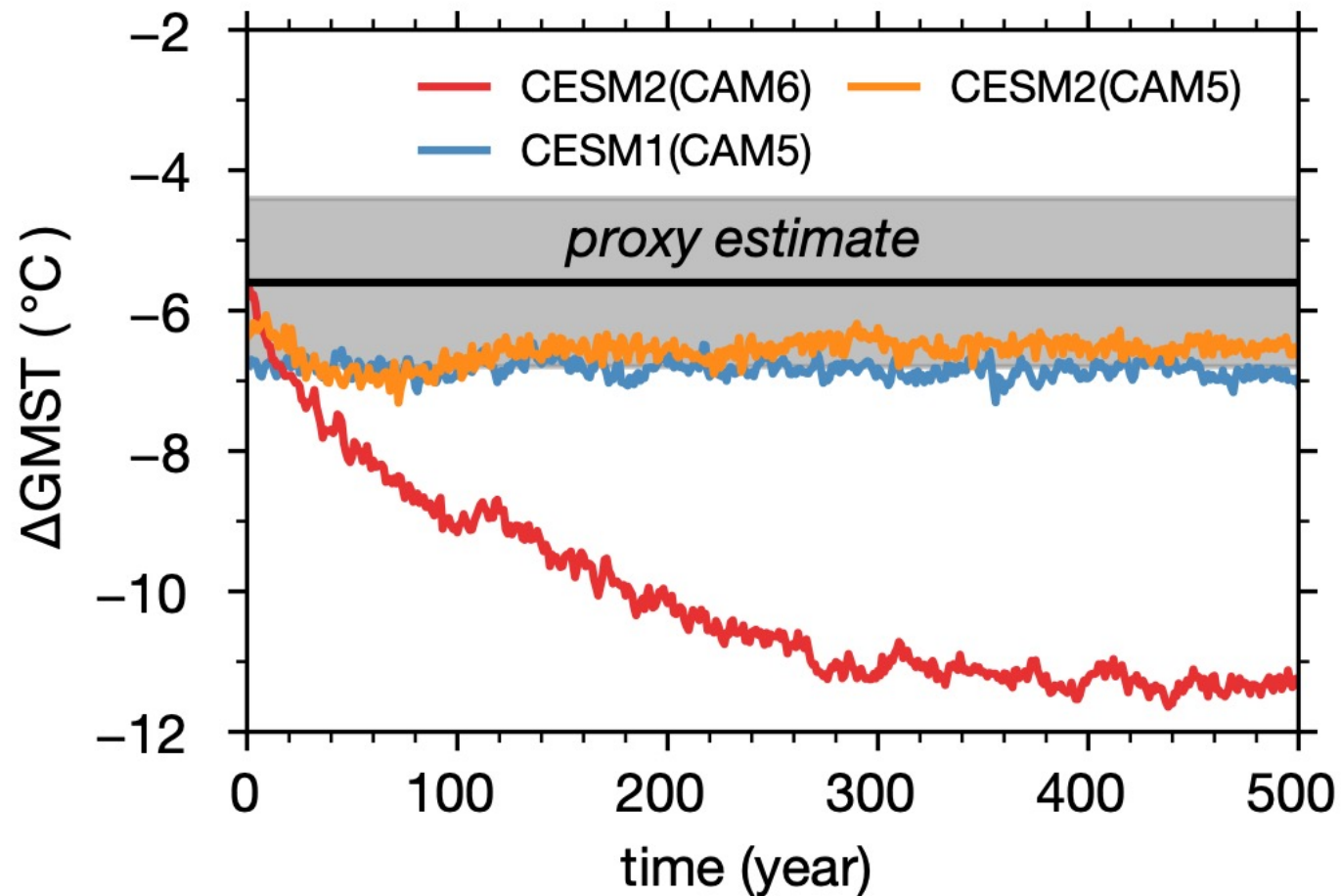
RESEARCH LETTER  
10.1029/2020GL091220

Special Section:  
Community Earth System  
Model version 2 (CESM2)  
Special Collection

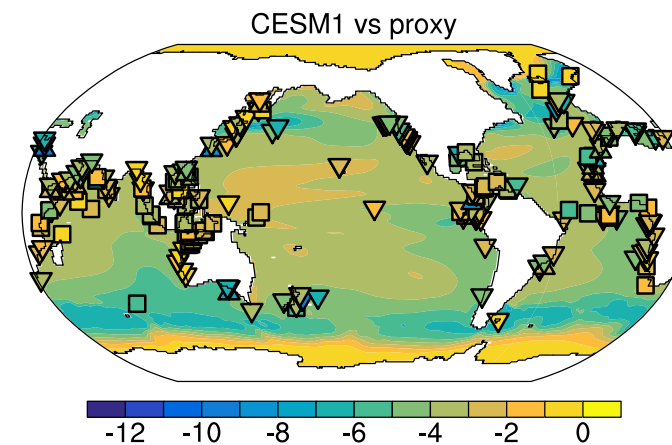
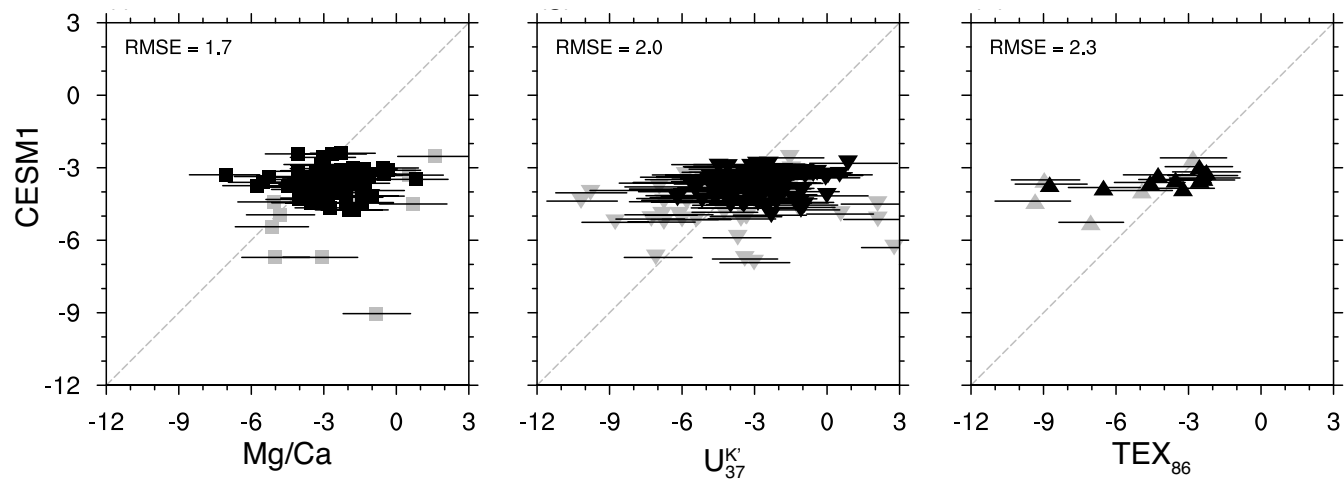
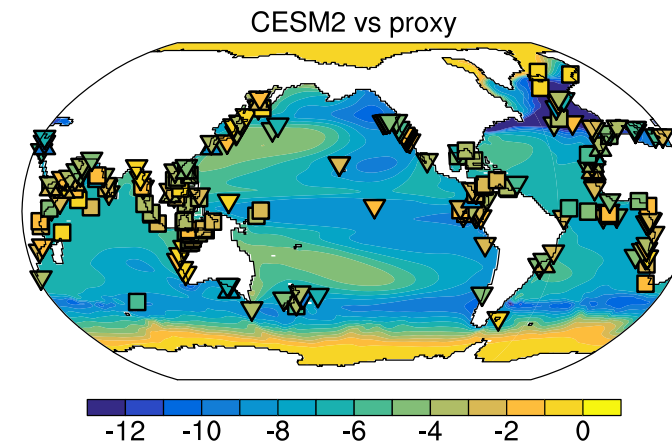
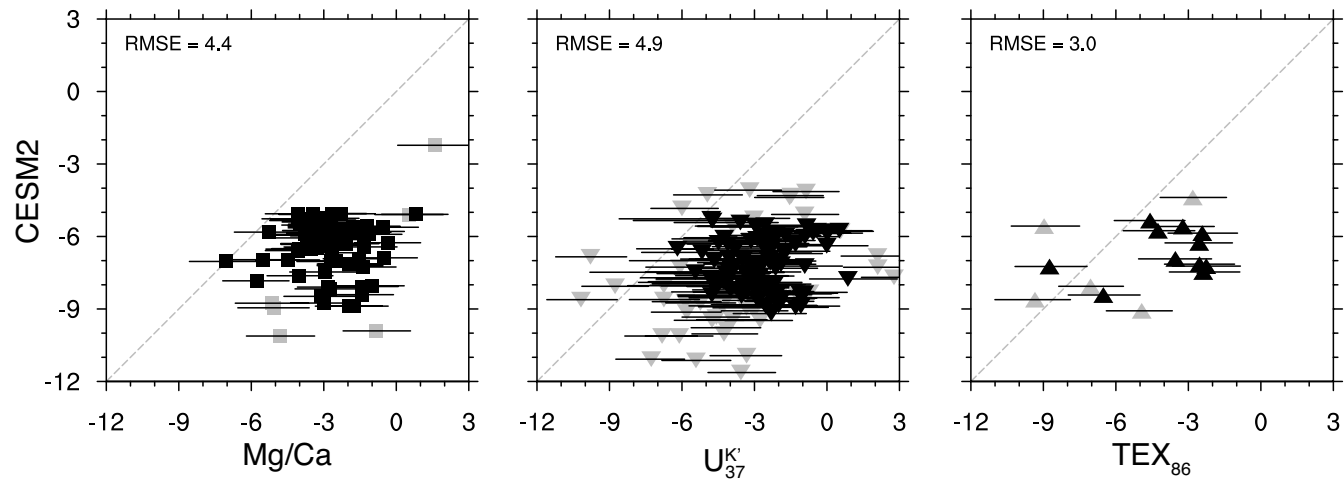
### Assessment of Equilibrium Climate Sensitivity of the Community Earth System Model Version 2 Through Simulation of the Last Glacial Maximum

Jiang Zhu<sup>1</sup> , Bette L. Otto-Bliesner<sup>1</sup> , Esther C. Brady<sup>1</sup> , Christopher J. Poulsen<sup>2</sup> ,  
Jessica E. Tierney<sup>3</sup> , Marcus Lofverstrom<sup>3</sup> , and Pedro DiNezio<sup>4</sup> 

# CESM2 LGM is too cold in global mean surface temperature



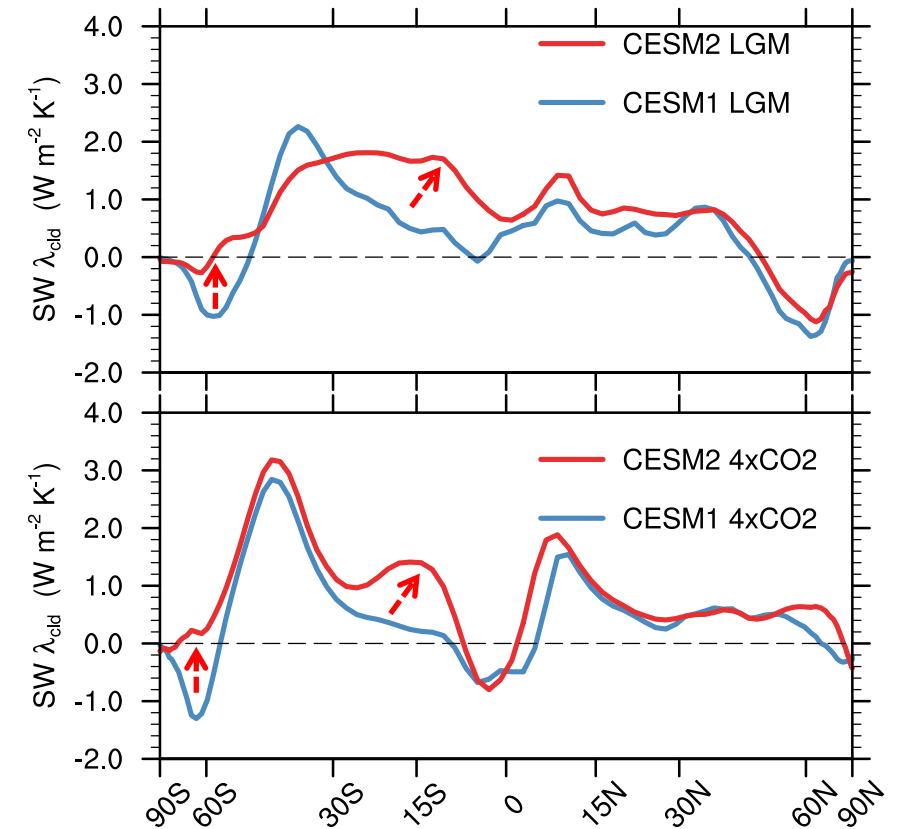
# CESM2 LGM is too cold in sea-surface temperature



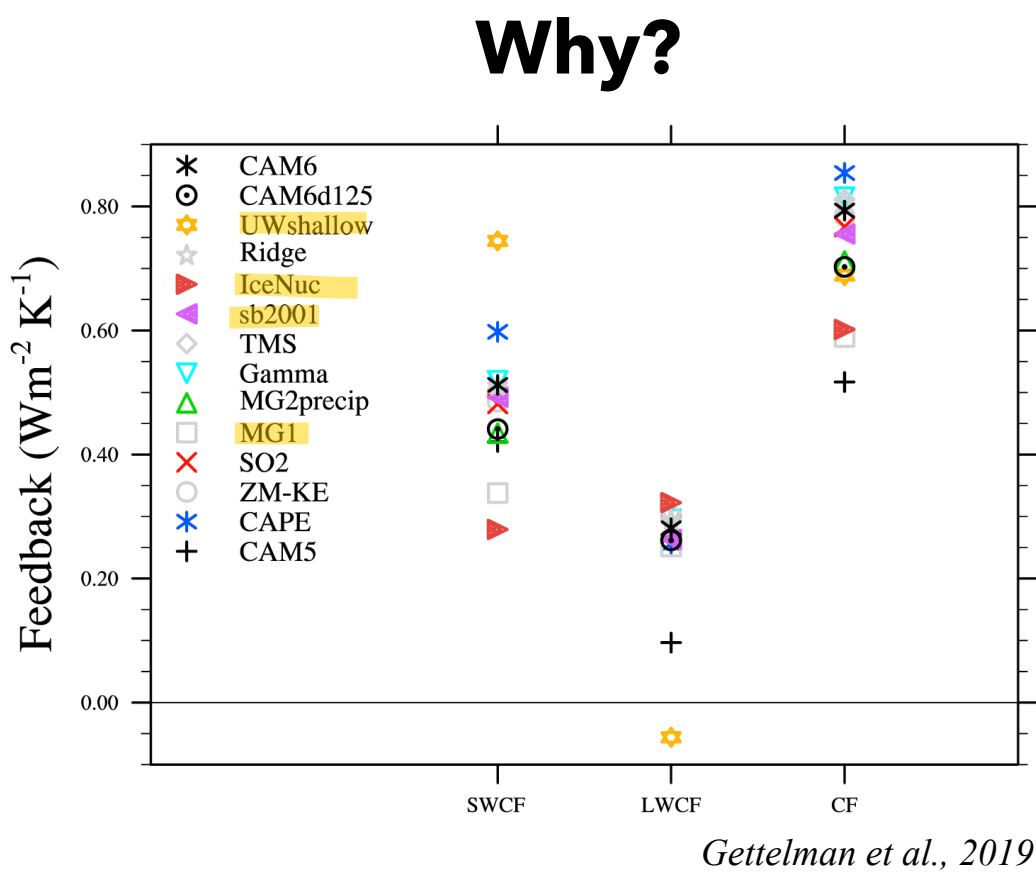
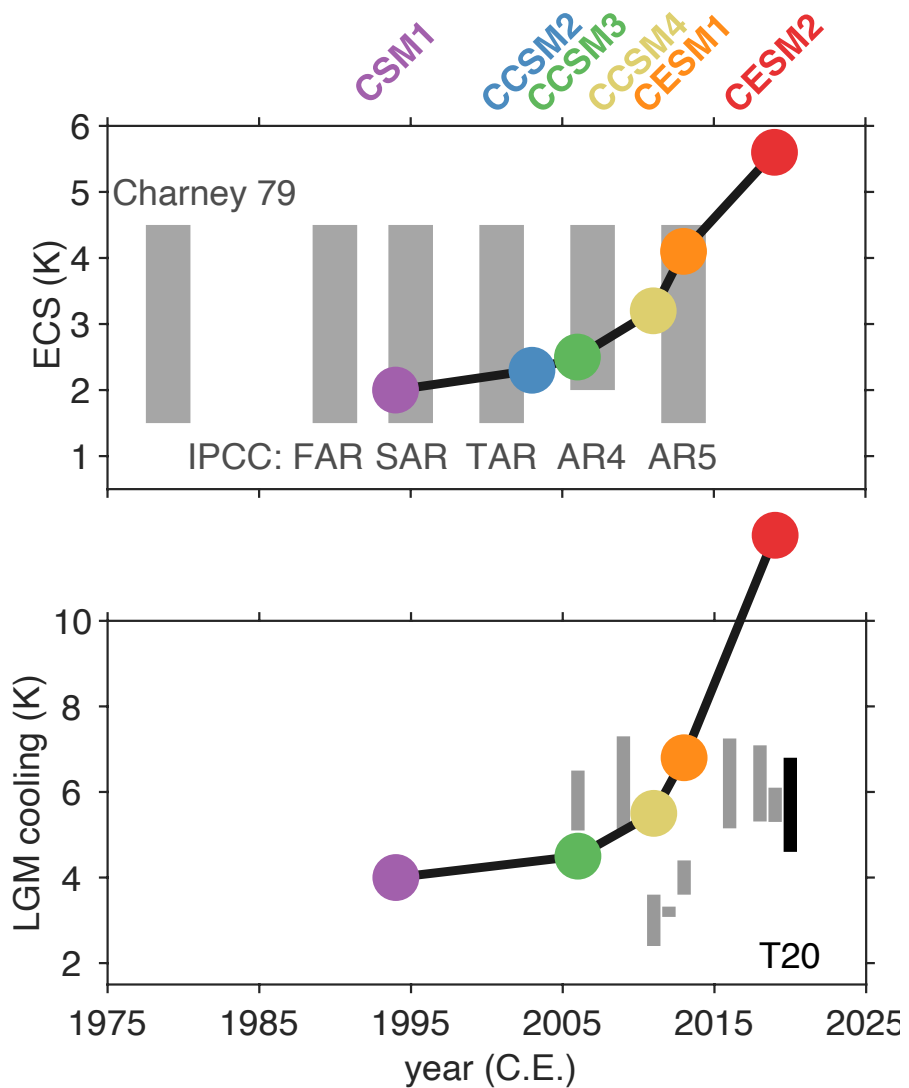
# SW cloud feedback explains the excessive LGM cooling in CESM2

	$\Delta\text{GMST}$	$\Delta N$	$F_{\text{eff}}$	$\lambda_{\text{eff}}$	LGM $\lambda_{\text{sw\_cld}}$	4×CO2 $\lambda_{\text{sw\_cld}}$
<b>CESM2</b>	-11.3	-0.2	-5.2	<b>-0.48</b>	<b>0.76</b>	<b>0.87</b>
<b>CESM1</b>	-6.8	0.06	-6.0	<b>-0.88</b>	<b>0.35</b>	<b>0.48</b>
<b>Diff.</b>				<b>0.4</b>	<b>0.4</b>	<b>0.4</b>

**LGM  $\lambda_{\text{sw\_cloud}} \propto 4 \times \text{CO}_2 \lambda_{\text{sw\_cloud}}$**

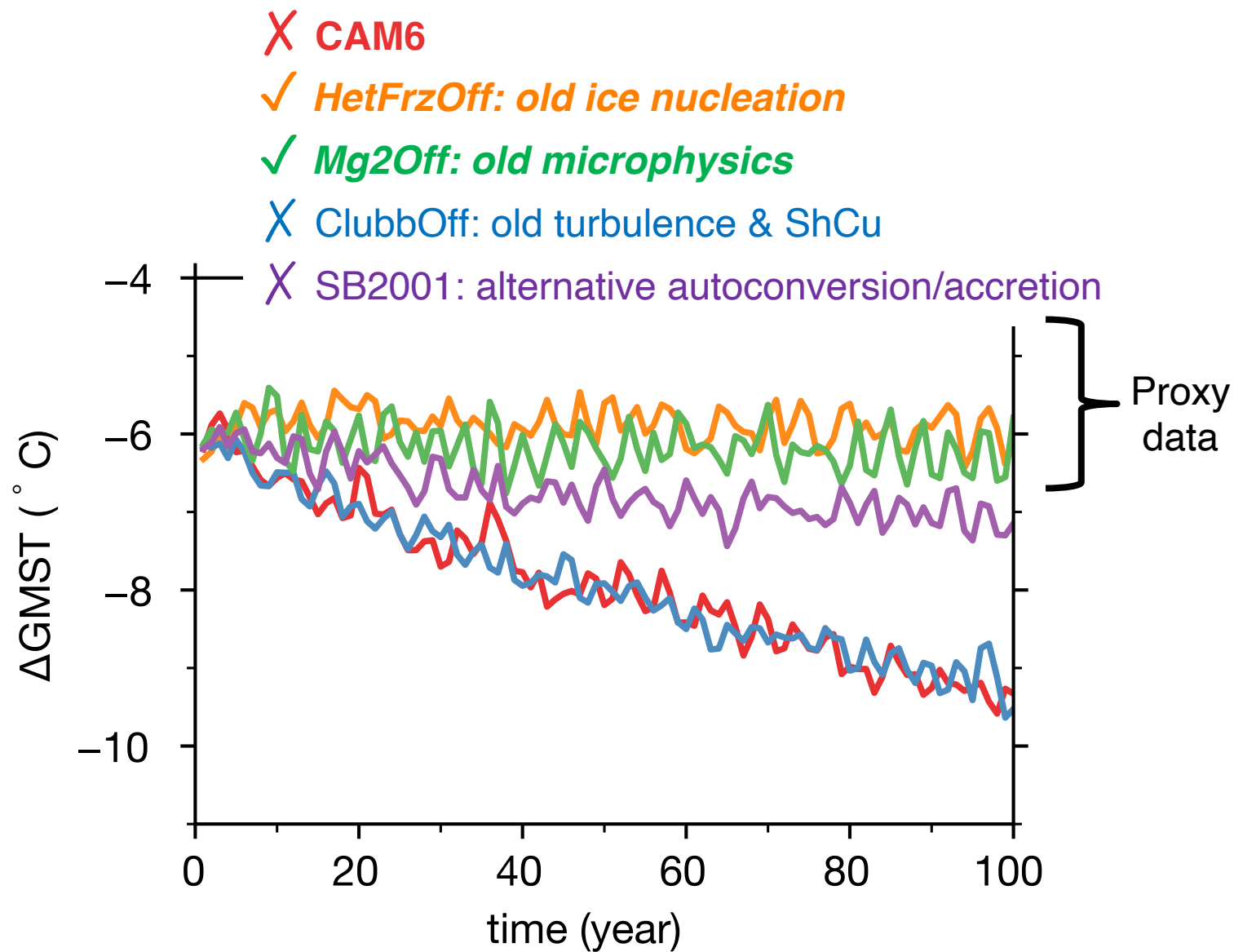


# CESM2 LGM is too cold, ECS is too high, and it's the cloud.





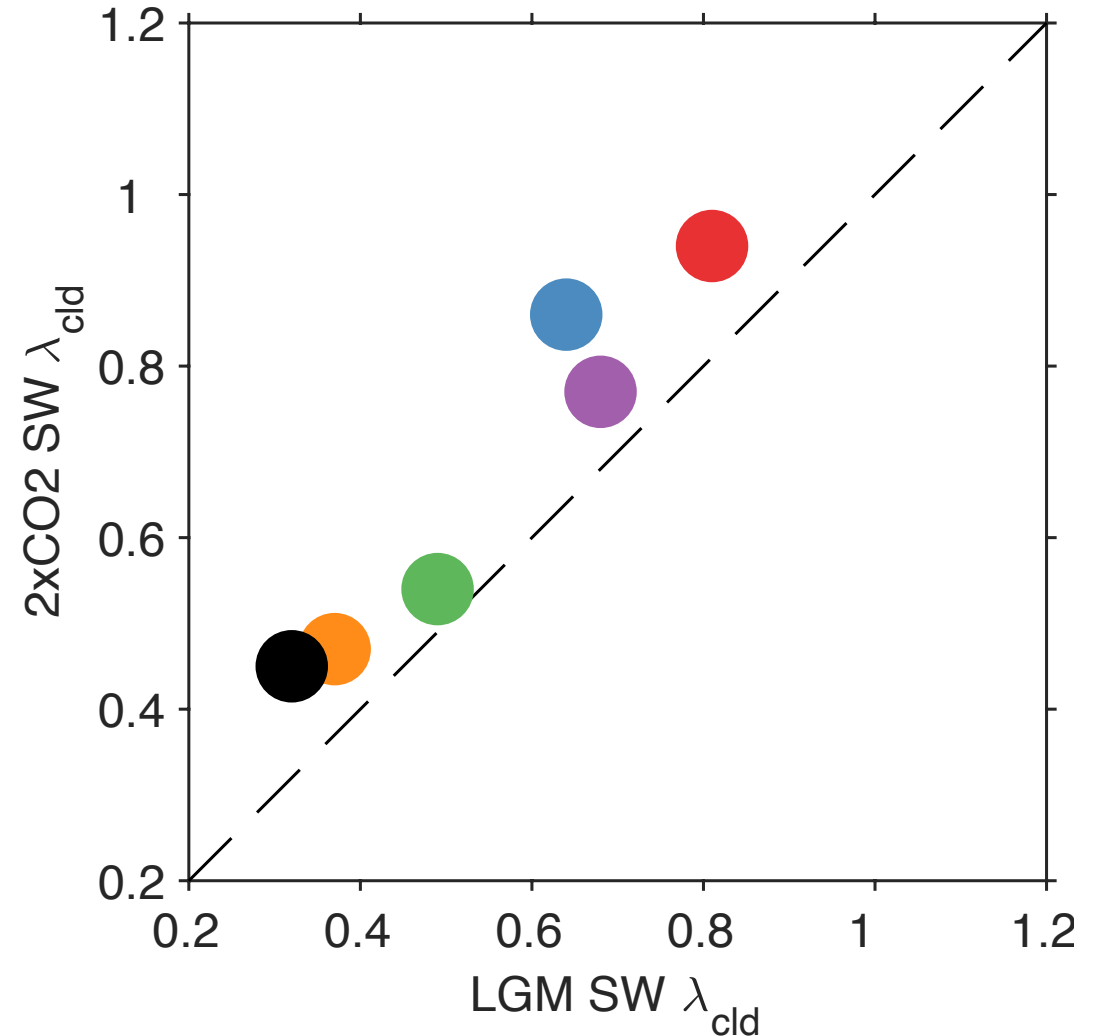
# Cloud microphysics and/or ice nucleation produces unrealistic LGM

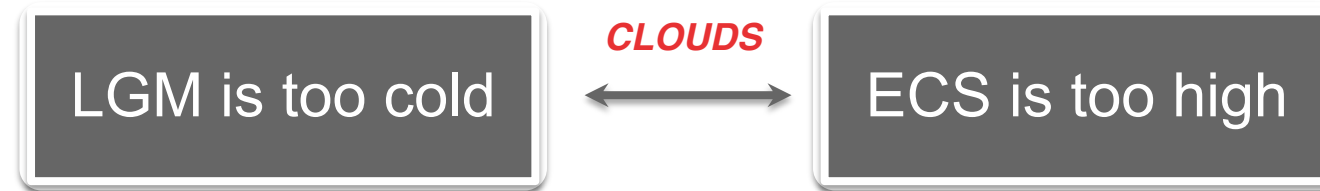


# Lower ECS in LGM constrained configurations

	$\Delta T_{\text{LGM}}$	ECS
CAM6	-9.0*	6.1
<i>HetFrzOff</i>	-5.9	3.8
<i>Mg2Off</i>	-6.3	4.3
ClubbOff	-8.9*	6.2
SB2001	-7.0*	5.2
CAM5	-6.5	3.7

\* Far from equilibrated





- Cloud microphysics and/or ice nucleation is not working well within CAM6
- Challenging to do it correctly
  - Simulate past cold & warm climates (e.g., Eocene)
  - Simulate present-day observation and historical warming
  - Agree with process understanding
- CESM2(CAM5): No WACCM5; Bad mean state mixed phase clouds