CONSTRAINING CLIMATE SENSITIVITY:

TRANSIENT CLIMATE RESPONSE (TCR) AND EQUILIBRIUM CLIMATE SENSITIVITY (ECS)

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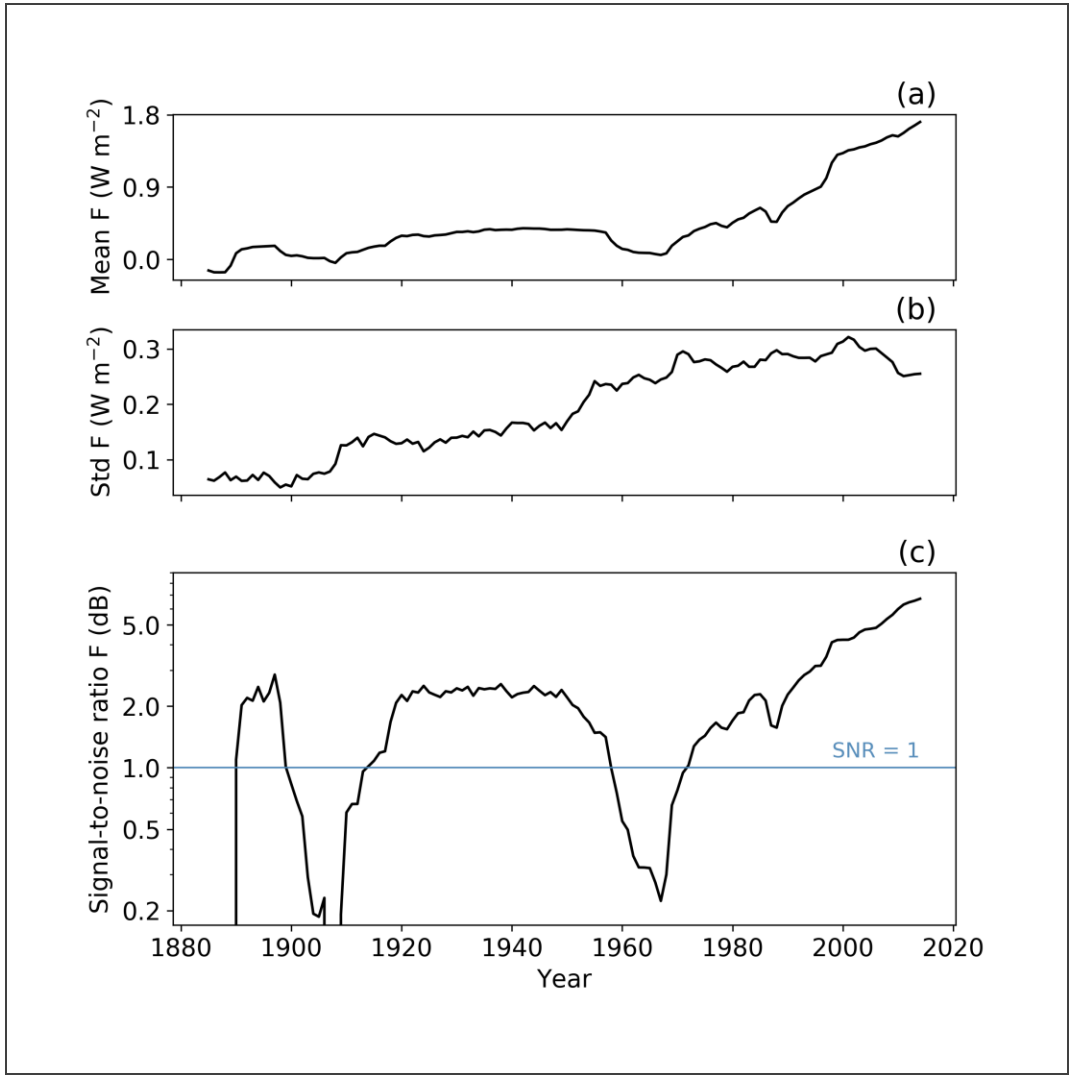


CMIP6 ensemble historical simulations.

Radiative forcing: $N = F + \lambda T$.

- F : Radiative forcing
- N: Top of the atmosphere radiative imbalance
- T: Temperature anomaly
- λ: Climate feedback parameter

The model GHG signal was extremely weak compared to variance between 1960-1970 due to aerosols.

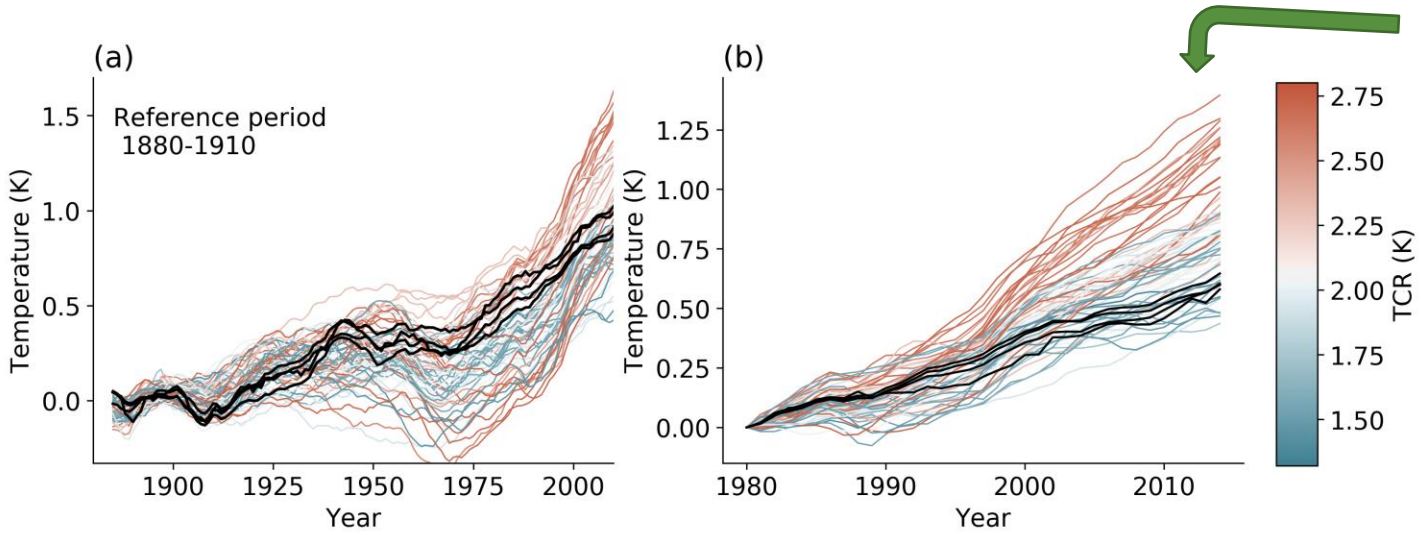
Temperature evolution

(a) Entire period: no clear pattern between warming and TCR

(b) Identified period: beautiful simplicity

Emergent constraint (EC)

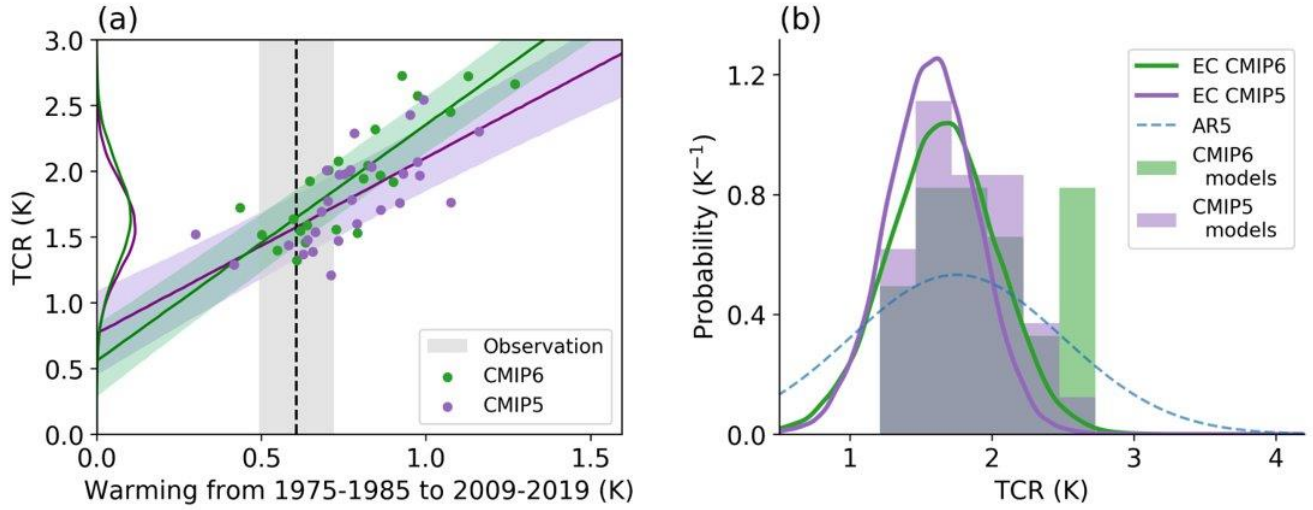
- Observational error includes estimate of internal variability
- CMIP6 more variable.
- **TCR: 1.68 [5-95%, 1.02 - 2.10]**



Extended to 2019 using SSP2-4.5

Emergent constraint: Each dot represents one model. Total of 24 CMIP6 models.

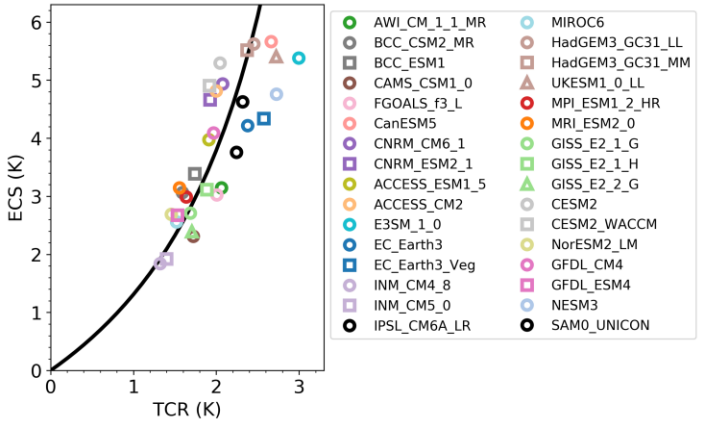
Internal variability explicit in observation. Estimated using model internal variability.



Emergent constraint on ECS: theory

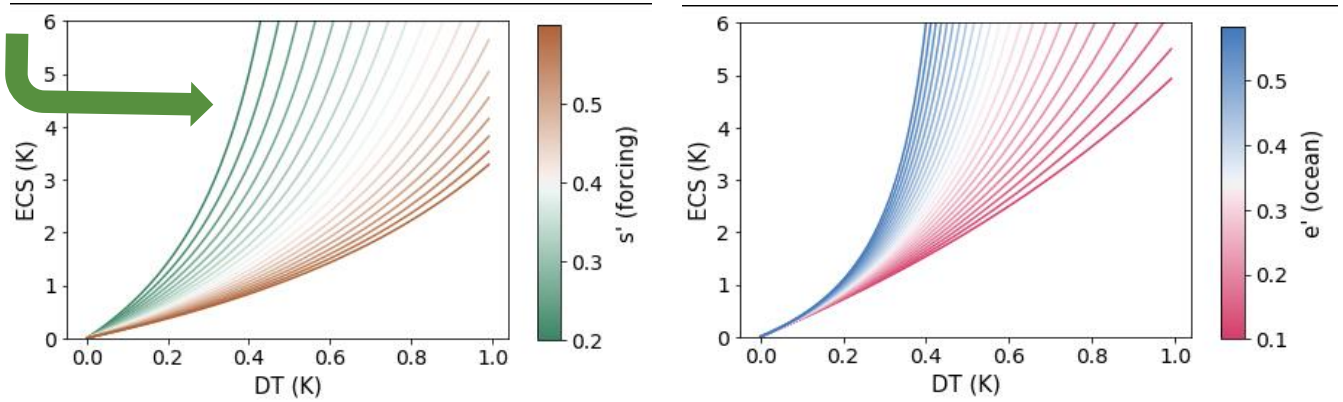
Approximation	Valid when	Equations
Full equations		$C\,dT/dt = -\lambda T + Q - \varepsilon\gamma(T - T_0)$ $C0\,dT0/dt = \gamma(T - T_0)$
No **deep ocean** warming	< century	Algebra
Upper ocean equilibrium	> decade	Algebra
	s': percentage doubling CO_2 e': ocean heat uptake	**ECS = ΔT / (s' - e' ΔT)***

TCR vs ECS



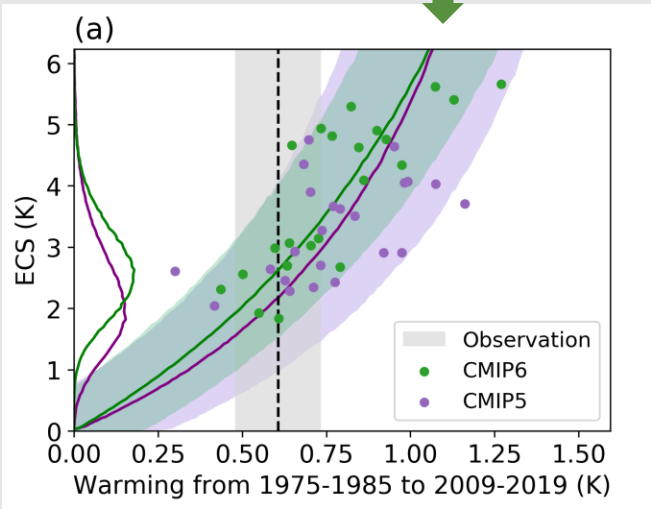
If emergent relationship steep: difficult to constraint ECS using obser-vations

Behaviour parameters



*Jiménez-de-la-Cuesta, D., & Mauritsen, T. (2019). *Nature Geoscience*, *12*(11)

Emergent constraint ECS



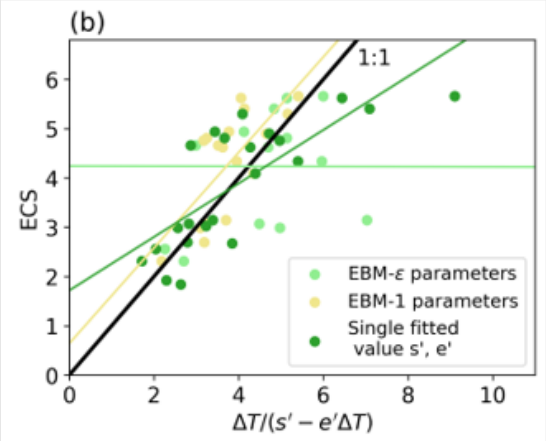
Similar lines; but not possible to estimate parameters accurately:

CMIP5: e': 0.233
s' : 0.420
CMIP6: e': 0.138
s' : 0.315

Model parameters:

CMIP6: e': 0.240
s': 0.200

Double check theory



If theory perfect, all points would be on 1:1 line.

Comparing two two-layer models; with and without ocean heat uptake efficacy.

The emergent constraint:

- Final ECS CMIP5 weaker than CMIP6.
- Consistent upper bound
- ECS: 2.62 K [5-95%, 1.51 - 4.04]

Checking with respect to theory.

1. Taking model DT
2. Fitted the ocean and forcing parameter per model.
3. Put in equation and compare real ECS

Very unlikely that ECS > 4.5 K and TCR > 2.5 K.

ECS can possibly be further restricted using ocean heat uptake, but theory may need refinement

Emerging consensus on ECS (Cox et al (2018), Goodwin (2016), Renault (2020))?

… and TCR (Jiménez-de-la-Cuesta (2019) and Tokarska (2020)?

Conclusions and Discussion