Climate Sensitivity and Aerosols

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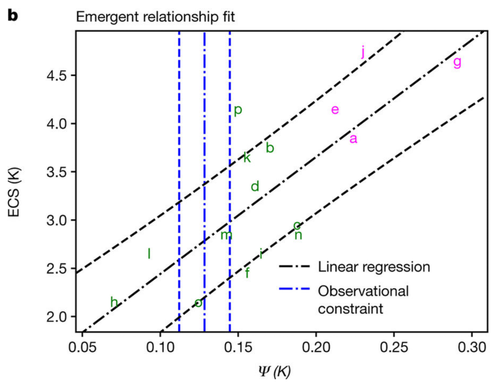
1 Introduction

The development of a theory of climate sensitivity needs a better understanding of the interaction of aerosols, clouds and circulation ([1]), in particular its impact on Equilibrium Climate Sensitivity (ECS) and Transient Climate Response (TCR).

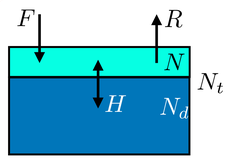
We show a close correlation between the warming from 1970—2005 and TCR, that is supported by the Forcing-Feedback Framework. Using the observed warming over this period we infer a TCR of 1.60 K.

2 Emergent Constrains

An emergent constraint is a mathematical relationship derived from model data between quantities: a non-observable and an observable. The estimation sets the values of the non-observable quantity consistent with reality (see figure below, from [2]).



The core assumption is that real world is a data point. The pitfall of emergent constraints is that they have no physical support by themselves. In this study, we propose a constraint supported by the Forcing-Feedback Framework.



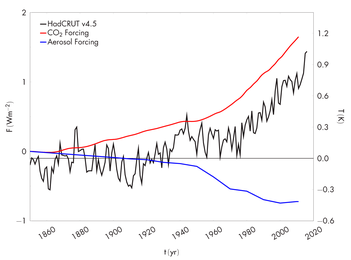
3 Forcing-Feedback framework

This is the principle of conservation of energy: Forcing plus feedback equate the net energy inside the system.

Earth system has (a) a low-heat-capacity mixed-layer encompassing the atmosphere, land and upper ocean and (b) a high-heat-capacity deep ocean. This is the Two-Layer Model (TLM) ([3]), with two limiting cases:

1) Mixed-Layer Model (MLM): Deep ocean as a heat sink. Forcing comparable to the mixed-layer heat capacity.

2) Zero-Layer Model (ZLM): Deep ocean as a heat sink. Mixed-layer heat capacity negligible in comparison to forcing.



4 Aerosol forcing

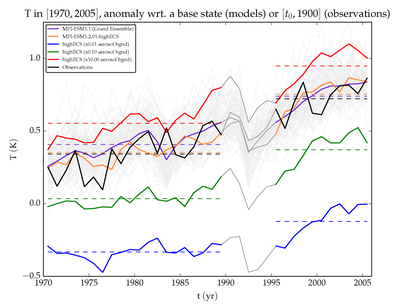
Aerosol forcing since 1970 has lesser increase in comparison to carbon dioxide. This suggests a better signal-to-noise relationship between warming and climate sensitivity.

We take the difference of the average temperatures of 1970—1989 and 1995—2005 to factor out Mount Pinatubo eruption. ZLM regime suggest a relationship to TCR given by:

$$\mathrm{TCR} = \frac{F_{2x}}{\Delta F}\Delta \mathrm{T} \qquad (1)$$

4.1 Observations

We used HadCRUT4, GISTEMP and NOAA GlobalTemp observations and we considered the MPI-ESM1.1 Grand Ensemble variability as an estimate of the variability of the observational estimate.



4.2 Models

We used data from 32 CMIP5 models and, in addition, the MPI-ESM1.1 100-member Grand Ensemble and MPI-ESM1.2.01-highECS in which we modified the tropical shallow convection ([4]) and mid-latitudes mixed-phase clouds to test if it can reproduce historical warming with the aid of aerosol indirect effect ([5]). TCR is calculated as the average of a 10-year period around year 70 of the 1pctCO2 experiments.

5 Results

The regression is statistically significant, as well as the slope. Although the y-intercept is greater than zero, it is not statistically significant

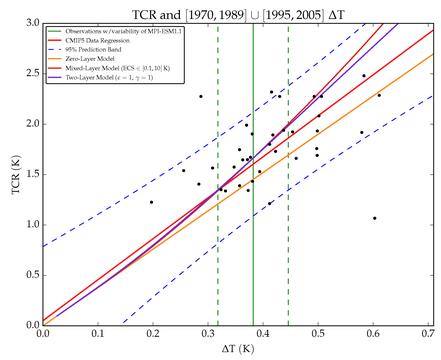
$$\mathrm{TCR} = (4.06 \pm 0.633)\Delta \mathrm{T} + (0.1 \pm 0.2)$$

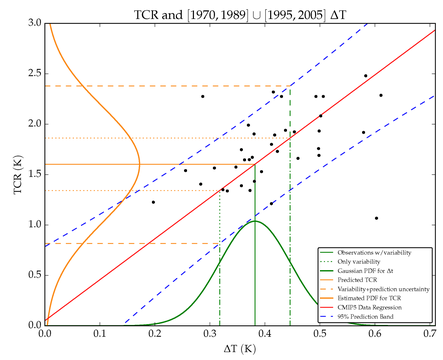
Considering (1) and the historical total forcing, we find that

$$\mathrm{TCR} = 3.8\Delta \mathrm{T}$$

6 Conclusions

From the regression, ZLM expression (1) and statistical significance tests we conclude that there is a robust emergent constraint for TCR in terms of the 1970-2005 warming. The emergent constraint gives a TCR of 1.60 K, 20% higher than 1.32 K from [6].





[1] Bony et al. (2015) *Clouds, Circulation and Climate Sensitivity*, **Nature Geoscience 8**, 261-268.
[2] Cox et al. (2018), *Emergent Constraint on Equilibrium Climate Sensitivity from Global Temperature Variability*, **Nature 553**, 319-322.
[3] Held et al. (2010), *Probing the Fast and Slow Components of Global Warming by Returning Abruptly to Preindustrial Forcing*, **J. Climate 23**, 2418–2427.
[4] Sherwood et al. (2014). *Spread in Model Climate Sensitivity Traced to Atmospheric Convective Mixing*, **Nature 505**, 37-42.
[5] Fiedler et al. (2017). *On the Sensitivity of Anthropogenic Aerosol Forcing to Model-Internal Variability and Parameterizing a Twomey Effect*, **JAMES 9**, 1325-1341.
[6] Mauritsen and Pincus (2017). *Committed Warming Inferred from Observations*, **Nature Climate Change 7**, 652-655