Abstract ID: **431503**

Relationship between decadal climate variability and climate sensitivity

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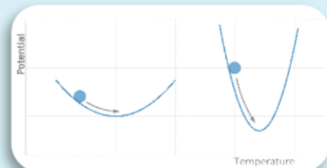
AGU 100 ADVANCING EARTH AND SPACE SCIENCE

Background

- Major question in climate science to determine "safe climate" is finding out climate sensitivity: How much does the earth warm under doubling of CO_2?
- But: safe climate also depends on climate variability. Here we examine them together.
- Decadal variability chosen as scale relevant to humans.

Why more sensitive systems have more variability



Sketch of a system of a high sensitivity (left) versus low sensitivity (right). Giving the left-hand system a small perturbation will lead to a big temperature change and a slow recovery rate.

Common model of Earth's temperature: Hasselmann model:

$$C\frac{dT}{dt} = -\lambda T + Q$$

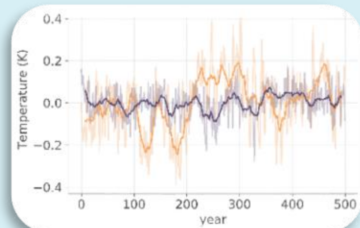
Here C is the heat capacity, T temperature anomaly, $\frac{1}{\lambda}$ proportional to Equilibrium Climate Sensitivity (ECS) and Q internal noise (forcing) and external forcing.

Methods

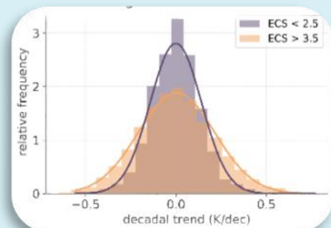
1. Use the control simulations of the CMIP5 model ensemble:
   (Control because of long record)
2. Compute all temperature trends of 10 years
3. Compute the standard deviation and fit a normal distribution
4. Combine this information with the background information of historical simulations and projections.

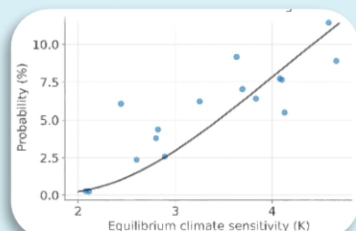
Results

Comparison of Global Mean Surface Temperatures (GMST) timeseries for control simulation. The orange is the HadGEM2-ES model with ECS = 4.6 K, while the purple is the GISS-E2-R model with ECS = 2.1 K. The high sensitivity has a larger typical decadal trend.

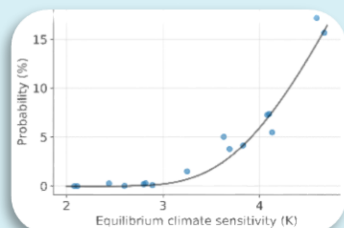


Histogram of decadal trends found in a set of climate models. Again, the high sensitive models show higher decadal variability. Overall, the Pearson's r between ECS and the standard deviation of decadal trends is 0.82.





Probability of a decade without warming. Here a background warming independent of ECS was assumed, which corresponds to a model ensemble that is tuned to match historical warming. Using a ECS-dependent background warming, the relationship becomes weaker. Each dot corresponds to one member of the CMIP5 ensemble.



Chance of a hyperwarming decade in the RCP8.5 scenario. Hyperwarming is defined here as >10 times the mean warming rate over the 20th century.

Possibility that one decade of 21st century warming equals entire 20th century's.

Discussion

Assumptions include:

- Internal noise generation (Q) independent of ECS
- Ocean internal variability not dominant
- Year-to-year variation in λ small and has same regulating mechanism as long-term climate sensitivity.[1]

Relation to historical measurements

- Historical measurements of decadal variability are consistent with ECS around 2.2 – 3.8 K, comparable to earlier work using variability.[2]

Conclusions

- Under RCP8.5 and with high climate sensitivity: 1 in 12 decades will be decades of hyperwarming. Virtually impossible in a low ECS world.

Cooling decade begin 21st century more likely in high ECS climate.

- Reducing uncertainty in climate sensitivity is critical for building resilience to climate variability.

Acknowledgements and References

- European Research Council (ERC) ECCLES project, grant number 742472 (F.J.M.M.N and P.M.C.)
- EU Horizon 2020 Research Programme CRESCENDO project, grant number 641816 (P.M.C. and M.S.W.)
- World Climate Research Programmes Working Group on Coupled Modelling, responsible for CMIP

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