A Bayesian framework for emergent constraints: case studies of climate sensitivity with PMIP

Paper in review in Climate of the Past: https://www.clim-past-discuss.net/cp-2019-162/

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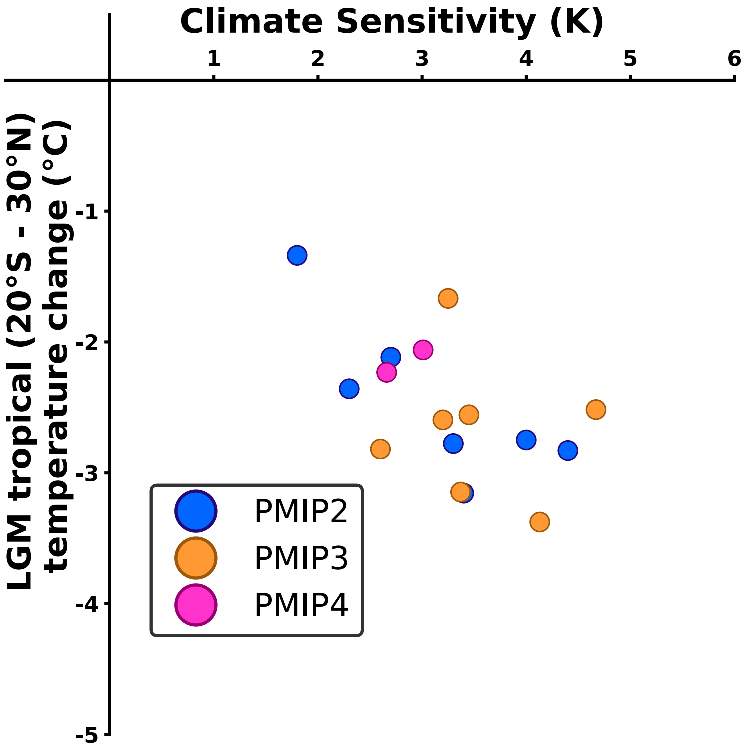
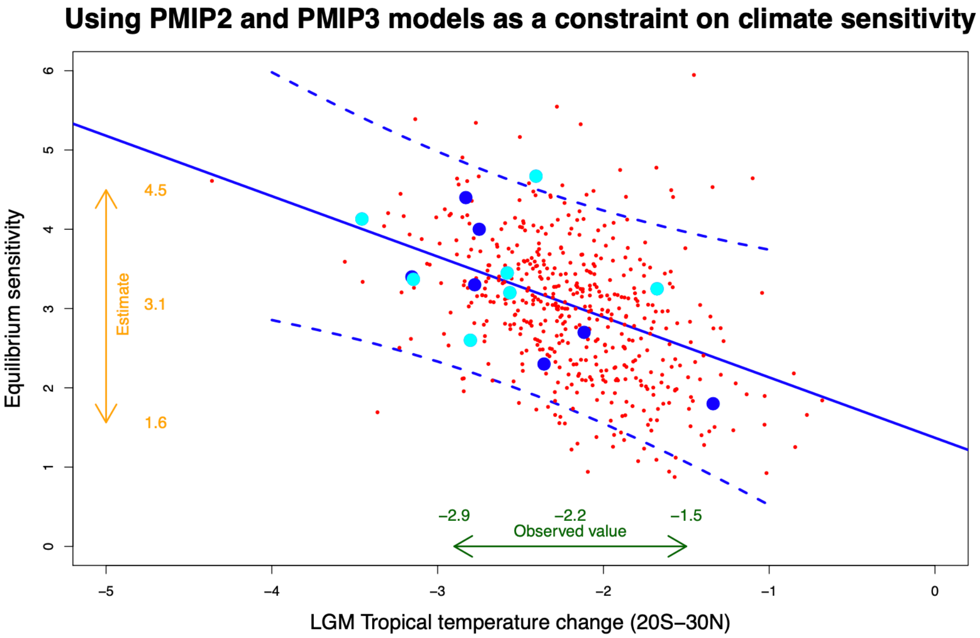
The emergent constraint theory



- Finding a physically plausible relationship between 2 variables of the climate system, i.e. tropical temperature and climate sensitivity
- Using an ensemble of climate models to infer ECS using an observation of tropical temperature

The emergent constraint theory



- Done in the past with PMIP2+PMIP3 models and ordinary least squares regression
- But what are the assumptions? What does the estimate mean? Which variable should be the predictor? How to control the parameters of this framework?

A Bayesian framework

$$P(S|T_o) \propto P(S) \times P(To|S)$$

- A belief that a relationship in the ensemble of models can be used to update a prior assumption on S into a posterior, knowing an observed value of temperature (T_o).

A Bayesian framework

$$P(S|T_o) \propto P(S) \times P(To|S)$$

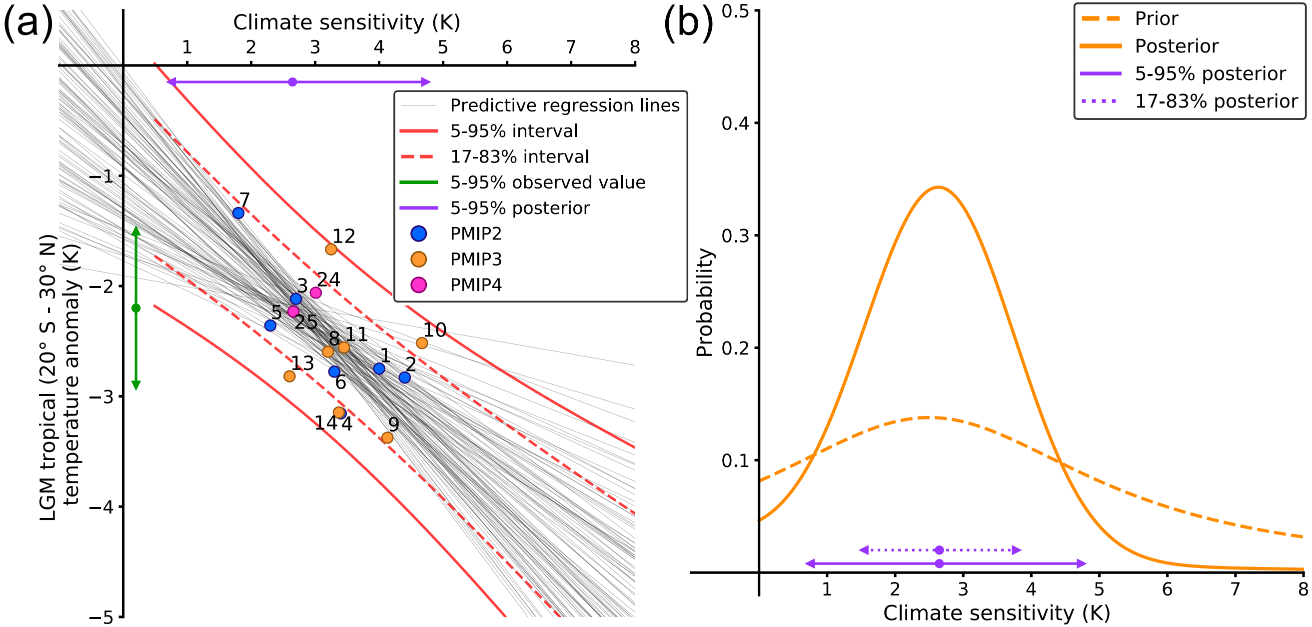
Prior on S for a flexible and explicit control of its value to its updating into a posterior

Likelihood is integrated over S for the unknown parameters α, β and ε, part of the linear relationship between T_{models} and S_{models}

$$T_{models} = \alpha \times Smodels + \beta + \varepsilon \quad \varepsilon \sim N(0, \sigma^2)$$

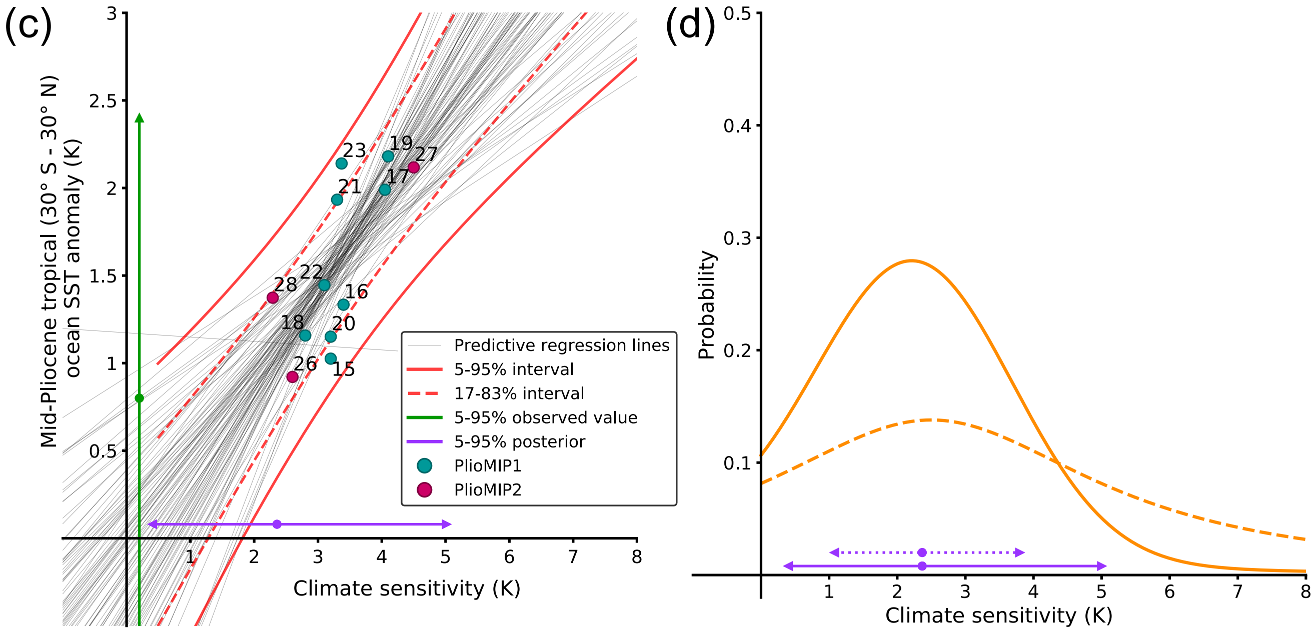
Example: The Last Glacial Maximum

- LGM: 19-23 ka, cold climate with low CO_2 and extensive ice sheets
- Posterior S is similar to past studies, but with explicit and adjustable assumptions



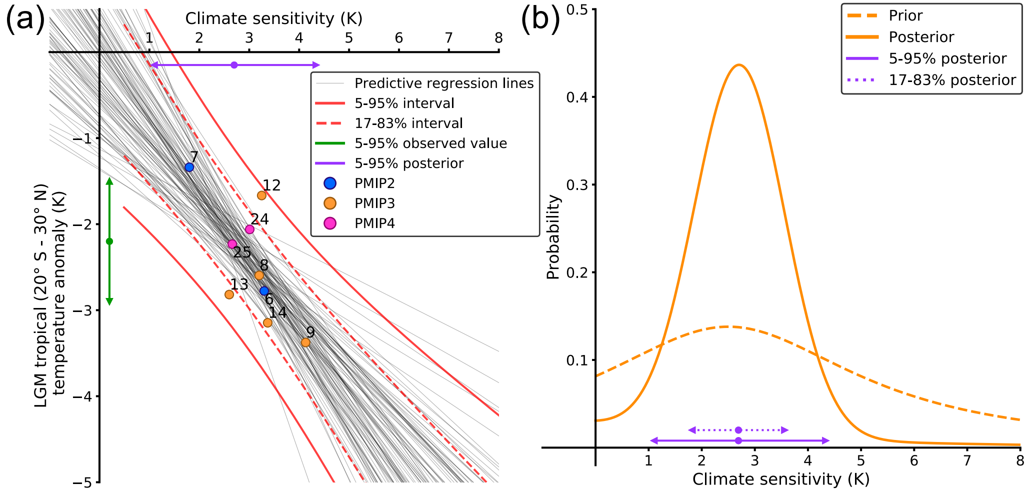
Example: The mid-Pliocene Warm Period

- mPWP: around 3.2 ma, 400 ppm CO_2 and warm climate
- Posterior S is also similar to past studies

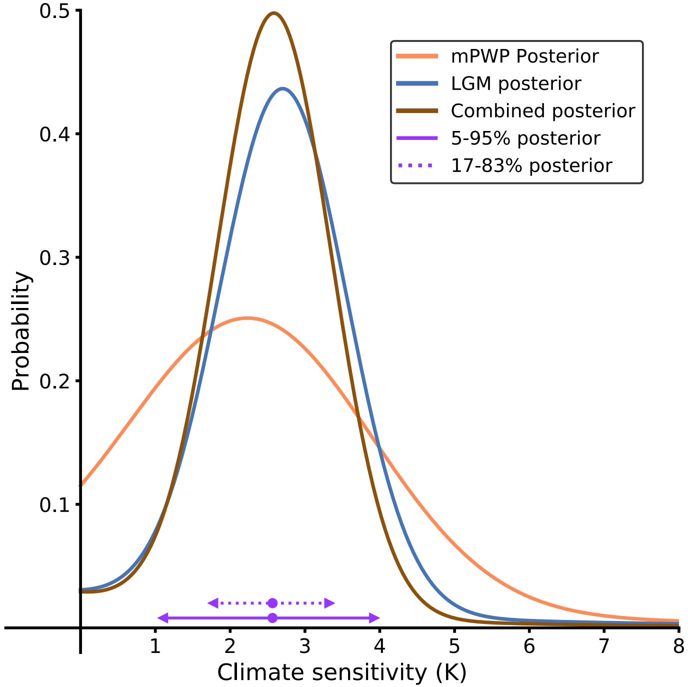


Multiple ensembles and combination of both LGM and mPWP!

Using only the latest version of LGM models



Using the LGM posterior as a prior for mPWP!



Summary

- A Bayesian Linear Regression to build the likelihood of a Bayesian model, with S as predictor
- The Bayesian model allows flexibility on the prior on S and can also combine multiple independent lines of evidence
- Considering (preliminary) structural uncertainties of model and other sensitivity to the different assumptions, we compute S as mostly below 5 K and never above 6 K.
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