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Emulating regional temperature responses of short-lived climate forcers

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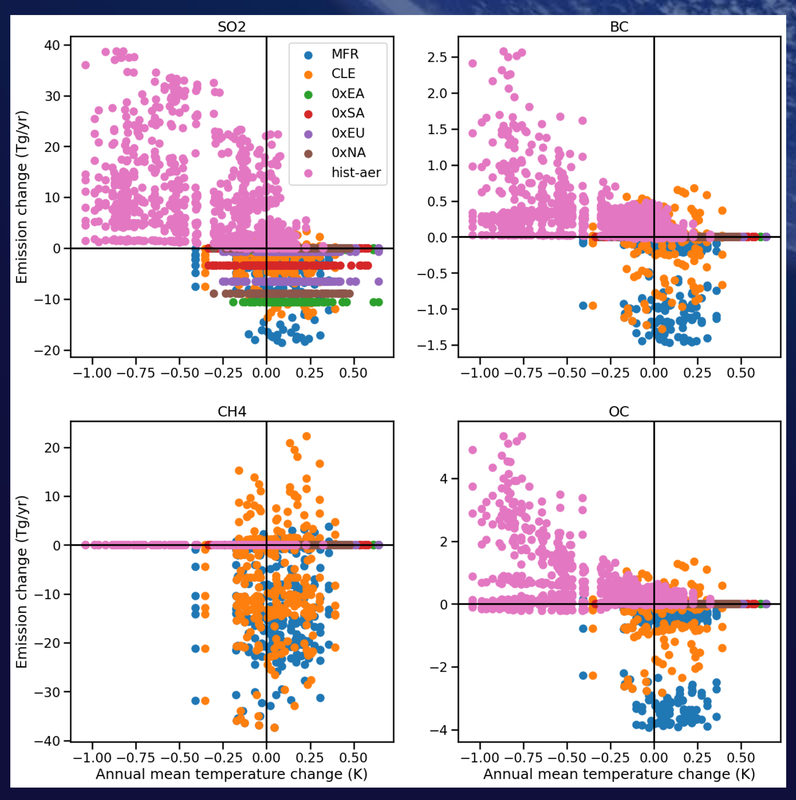
Motivation and Methods

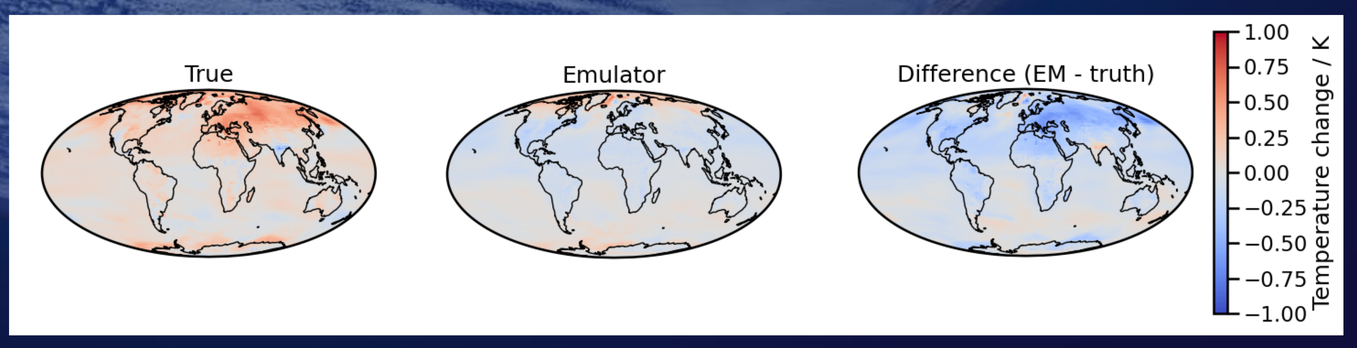
Short-lived climate forcers (**SLCFs**) are climatically important chemical species with atmospheric residence times much shorter than that of CO2. They impact climate via interactions with radiation, the background atmospheric structure, and cloud microphysics. Currently, the impact of potential emission reduction strategies are often evaluated by policy makers with simple linear factors for a pre-defined set of emission and impact regions, which we assume apply continuously.

Here we investigate the impact of **sulphate (SO_2), black carbon (BC), organic carbon (OC), and methane (CH_4)** emission perturbations on global temperature distributions using a Gaussian process emulator of NorESM, with the aim of developing a fast and flexible model for policy evaluation that is not constrained to linear behaviour.

Emission Perturbations:



Temperature response to 0xEU SO_2 test perturbation:



An example of preliminary testing results, showing the mean global temperature response in NorESM and emulator for the 0xEU SO_2 run, which was not see by the emulator during training.

The emulator captures the expected Arctic warming, and has a reasonable spatial distribution but globally is too cool, especially in the mid-latitudes

Currently policy tools are factors such as absolute regional temperature potentials (ARTPs), which are defined as the temperature change in some region as a function of the emission change in another, with units of Kelvin per Tg-yr^{-1}.

Here we compare ARTPS calculated from NorESM and the emulator.

The perturbation is relative to year 2000 emissions and is held constant for the duration of the model run.

	Arctic	NH Mid-Latitudes	Tropics	SH
0xEU SO_2 perturbation in NorESM	0.056	0.033	0.009	0.007
0xEU SO_2 perturbation in emulator	0.029	-0.011	-0.008	0.001

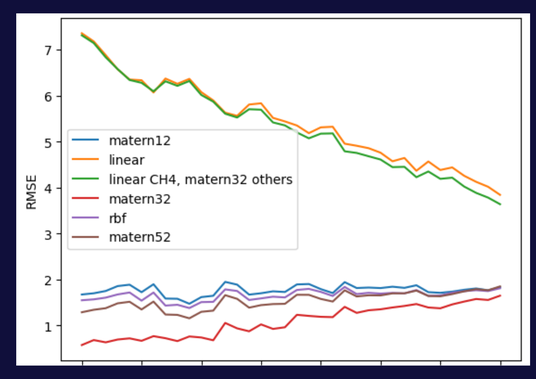
Emulator Design

A machine learning emulator is a (fast) statistical representation of a more complex, deterministic model. Here we are interested in learning the **temperature response** to aerosol and methane forcing in **NorESM** (the Norwegian Earth System model).

We use **Gaussian Process (GP)** emulation, which is a form of nonlinear and nonparametric supervised learning that assumes predictions are sampled from a multivariate normal distribution.

Training and testing data is developed from CMIP5&6, DAMIP, AMAP, and custom perturbation NorESM runs. Inputs are annual mean SLCF emissions in 8 regions (North America, South America, Europe, Africa, Russia, East Asia, South Asia, Australia). Outputs are annual mean native resolution temperature change maps. All cases have CO_2 influence removed.

We use a constant mean prior and Matern32 kernels for each input species, and hyperparameters are tuned independently for each emission species and region.



Ongoing Work:

1. Continue developing additional training data: CovidMIP, BC -, and CH4 - only perturbations.
2. Additional kernel testing (customized) and testing different priors, to increase extrapolation ability.
3. Development of user interface

Computations enabled by resources provided by the National Academic Infrastructure for Supercomputing in Sweden (NAISS) and the Swedish National Infrastructure for Computing (SNIC).
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