Summer Research Scholarship 2021-22

Simulation-Based Inference for Geothermal Models

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1 Background

- Geothermal model calibration involves adjusting parameters, including rock permeabilities and hot mass upflows, until the model temperatures and pressures match historical data.
- Bayesian model calibration begins with the *prior* distribution, which encodes one's beliefs in the values of the parameters prior to seeing data, then data is conditioned on to give the *posterior* distribution, which characterises the remaining uncertainty in the parameters.
- Accurately characterising the posterior of a geothermal model allows for better quality decisions to be made in terms of the management of the real geothermal system. Generally, linear approximations are used; however, simulation-based methods are potentially more accurate.

2 Methods

Two simulation-based methods were used to characterise the posterior of a synthetic geothermal model.

ABC (approximate Bayesian computation)

Description: models with parameters sampled from the prior are run, their fit to the data is evaluated, and parameters of the best-fitting models are used to characterise the posterior.

- 1000 models were run, and the best-fitting 5% were used to characterise the posterior.

Population ABC

Description: same as ABC, but populations of models are used; the first is sampled from the prior, but the rest are formed by modifying the best models in the previous population. This can be more efficient than ABC.

- After the first population, most models failed to converge. A decision tree was fit to determine why.

3 Results

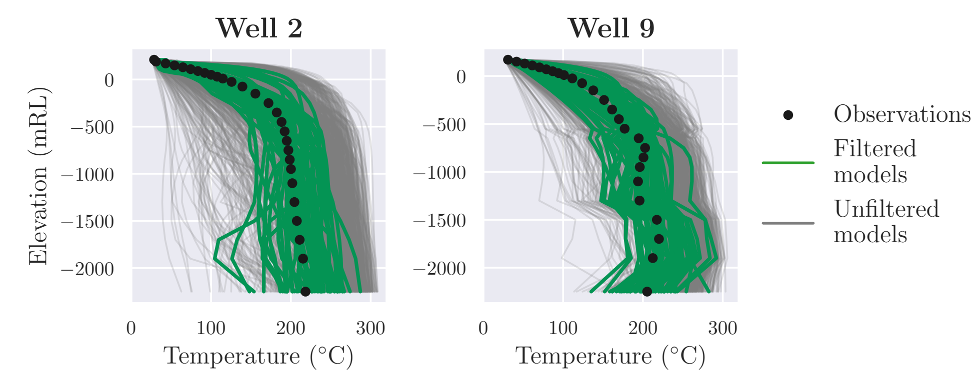

Figure 1. ABC model temperature predictions for selected wells.

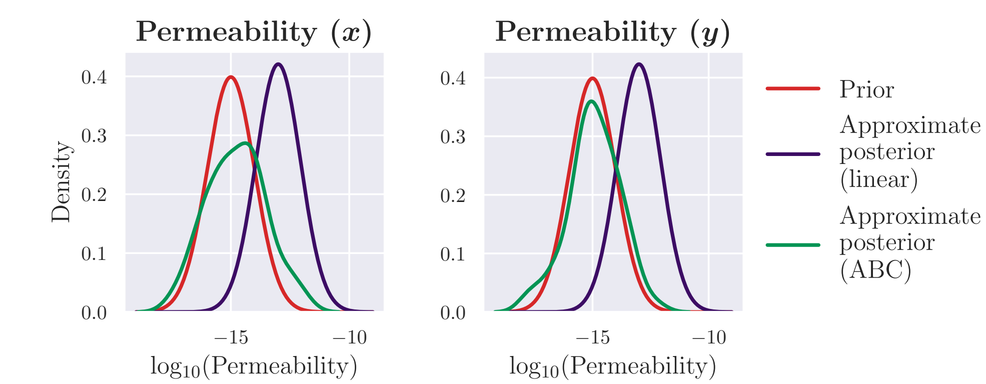

Figure 2. Prior *(red)*, and linear / ABC posterior distributions *(purple / green)*, for permeabilities of the IAC01 rock type.

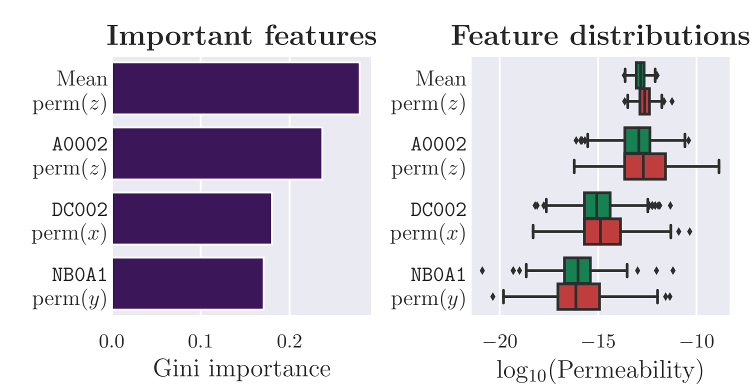

Figure 3. Most important features of decision tree *(left)*, and the distributions of these for successful / failed models *(right)*.

4 Conclusions

ABC

- Even the best-fitting models do not fit the data well (**figure 1**).
- Consequently, the ABC posterior is still similar to the prior, but very different to a standard linear approximation (**figure 2**).
- Unless a large number of models are run, which is unrealistic for most geothermal models, ABC will characterise the posterior poorly.

Population ABC

- The decision tree suggests a potential cause of the models failing is some of the permeabilities being too high (**figure 3**).
- Bounding the range of acceptable permeabilities reduces the failure rate significantly.
- The algorithm is currently being run with these additional constraints and will finish in the coming weeks.