# Case Study 1: A simple univariate Gaussian

## Problem

* What is the best estimate of the parameter combining prior knowledge and observation with associated uncertainties?
* How to communicate the estimates to inform a decision?

## Given

* Prior knowledge about a univariate parameter (e.g., mass of an electron, gravity constant, height of a person, temperature of a person. oil temperature in an airplane engine, fuel level in an airplane)
  + Gaussian
  + Uniform
  + Ignorant
* Single observation
  + Gaussian with know mean and standard deviation
  + Gaussian with subjective estimate of uncertainty
  + Empirical with subjective uncertainties

## Approaches

* Analytical solution
* Kalman Filter
* Precalibration
* Grid search
* MCMC

## Learning Objectives

* Understand Bayesian framework and how it differs from a Frequentist approach
* Set up a computational environment for perform simple Bayesian analyses
  + Github
  + Google Collab
  + R
  + R-Studio
* Implement and compare different approaches
* Diagnose numerical convergence
* Run a positive control check

## Background Reading / Codes

* Qian, S. S., Stow, C. A., & Borsuk, M. E. (2003). On Monte Carlo methods for Bayesian inference. Ecological Modelling, 159(2-3), 269–277.
* …

## Github Repository

# Case Study 2: Sea-level hindcasts and projections

## Problem

* How to hindcasts and produce probabilistic projections of a time series   
  (in this case, global mean sea-level rise)
* What are best, median, modes, and tails of hindcasts and projections?
* How to communicate the estimates to inform a decision?

## Given:

* Observed time series of model forcing and model response
* Autocorrelated and heteroscedastic residuals
* Nonlinear model

## Approaches

* Bootstrap
* Precalibration
* MCMC
* Residual analysis
* Likelihood functions accounting for autocorrelation
* Prior predictive checks
* Probabilistic inversion

## Learning Objectives

* Diagnose numerical convergence
* Run a positive control check
* Refined model diagnosis

## Background Reading / Codes

* Ruckert, K. L., Wong, T. E., Guan, Y., Haran, M., & Applegate, P. J. (n.d.). A Calibration Problem and Markov Chain Monte Carlo. In V. Srikrishnan & K. Keller (Eds.), Advanced Risk Analysis in the Earth Sciences.
* Ruckert, K. L., Wong, T. E., Guan, Y., & Haran, M. (n.d.). Applying Markov Chain Monte Carlo to Sea-Level Data. In V. Srikrishnan & K. Keller (Eds.), Advanced Risk Analysis in the Earth Sciences.
* Ruckert, K. L., Wong, T. E., Lee, B. S., Guan, Y., & Haran, M. (n.d.). Bayesian Inference and Markov Chain Monte Carlo Basics. In V. Srikrishnan & K. Keller (Eds.), Advanced Risk Analysis in the Earth Sciences.
* Ruckert, K. L., Guan, Y., Bakker, A. M. R., Forest, C. E., & Keller, K. (2017). The effects of time-varying observation errors on semi-empirical sea-level projections. Climatic Change, 140(3-4), 349–360. <https://doi.org/10.1007/s10584-016-1858-z>
* Ruckert, K. L., Shaffer, G., Pollard, D., Guan, Y., Wong, T. E., Forest, C. E., & Keller, K. (2017). Assessing the Impact of Retreat Mechanisms in a Simple Antarctic Ice Sheet Model Using Bayesian Calibration. *PloS One*, *12*(1), e0170052. https://doi.org/10.1371/journal.pone.0170052

Github Repository

# Case Study 3: Storm-surge risk analysis and link to decision-making

## Problem

* How to hindcasts and produce probabilistic projections of a extreme value functions (in this case high water levels due to storm surges)

## Given

* Observed time series of model forcing and model response
* Nonlinear model
* What are best, median, modes, and tails of hindcasts and projections?
* How to understand, characterize, and communicate deep uncertainties
* How to communicate the estimates to inform a decision?

## Approaches

* MCMC
* Residual analysis
* Prior predictive checks
* Probabilistic inversion
* Probabilistic scenarios
* Bayes factors, Bayesian Model Averaging
* Expert elicitation

## Learning Objectives

* Understand the concepts, being able to reproduce and expand a complex analysis

## Background Reading / Codes

* Ruckert, K. L., Srikrishnan, V., & Keller, K. (2019). Characterizing the deep uncertainties surrounding coastal flood hazard projections: A case study for Norfolk, VA. *Scientific Reports*, *9*(1), 11373. <https://doi.org/10.1038/s41598-019-47587-6>
* Ceres, R. L., Forest, C. E., & Keller, K. (2017). Understanding the detectability of potential changes to the 100-year peak storm surge. Climatic Change, 145(1), 221–235. <https://doi.org/10.1007/s10584-017-2075-0>
* Lee, B. S., Haran, M., & Keller, K. (2017). Multidecadal Scale Detection Time for Potentially Increasing Atlantic Storm Surges in a Warming Climate. *Geophysical Research Letters*, *44*(20), 10,617–10,623. https://doi.org/10.1002/2017GL074606
* Srikrishnan, V., Alley, R. B., & Keller, K. (2019). Investing in Science and Using the Results to Improve Climate Risk Management. *EOS*. Retrieved from https://eos.org/opinions/investing-in-science-to-improve-climate-risk-management
* Wong, T. E., Klufas, A., Srikrishnan, V., & Keller, K. (2018). Neglecting model structural uncertainty underestimates upper tails of flood hazard. Environmental Research Letters: ERL [Web Site], 13(7), 074019. https://doi.org/10.1088/1748-9326/aacb3d

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