What sets Bayes apart?

ESS 575 Models for Ecological Data

N. Thompson Hobbs

January 16, 2017

What sets Bayes apart?

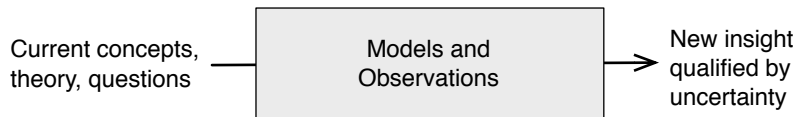ESS 575 Models for Ecological Data

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Today

- Some motivation for learning
- A high elevation view of Bayesian modeling

What sets statements of scientists apart from statements made by journalists, lawyers, and logicians?

Goals

Current concepts, theory, questions → Models and Observations → New insight qualified by uncertainty

Some notation

- y data
- θ a parameter or other unknown quantity of interest
- $[y|\theta]$ The probability distribution of y conditional on θ
- $[\theta|y]$ The probability distribution of θ conditional on y
- $P(y|\theta) = p(y|\theta) = [y|\theta] = f(y|\theta)$, different notation that means the same thing.

Bayesian models are stochastic.

- ▶ A model is a mathematical function that returns a quantity (or quantities) given parameters and inputs.
- ▶ A deterministic model returns a scalar (or sometimes a vector or matrix) for any given set of parameters and inputs.
- ▶ A stochastic model returns a *probability distribution* for any given set of parameters and inputs.
- ▶ Probability distributions characterize the behavior of *random variables*.[1].
- ▶ In Bayesian analysis, we seek to understand the probability distributions of random variables of interest using data, models, and prior information (including limited prior information).

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[1]A random variable is a quantity whose behavior is governed by chance.

What do we do in Bayesian modeling?

- ▶ We divide the world into things that are observed (y) and things that unobserved (θ).
- ▶ The unobserved quantities (θ) are random variables . The data are random variables before they are observed and fixed after they have been observed.
- ▶ We seek to understand the probability distribution of θ using fixed observations, i.e., $[\theta|y]$.
- ▶ Those distributions quantify our uncertainty about θ.

# Bayesian modeling is a procedure for updating knowledge.

An unobserved quanity (θ)

| Current knowledge | → | New data | → | Updated knowledge |
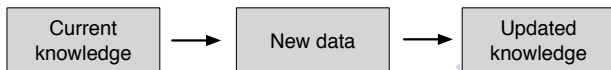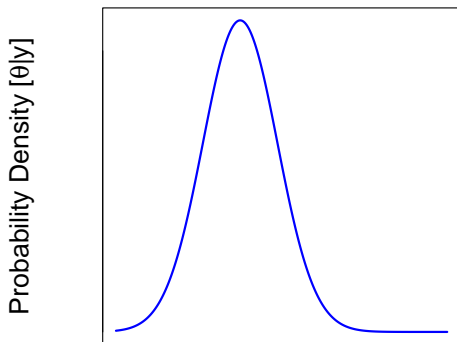
Updating knowledge

Show updating process in R

One approach applies to many problems

- An unobservable state of interest, z
- A deterministic model of a process, $g\left(\boldsymbol{\theta}, x\right)$, controlling the state.
- A model of the data
- Models of parameters

$$y \quad \text{Data}$$

$$z \quad \text{Process}$$

$$\boldsymbol{\theta}_p, \sigma_p^2 \quad \boldsymbol{\theta}_d, \sigma_d^2 \text{ Parameters}$$
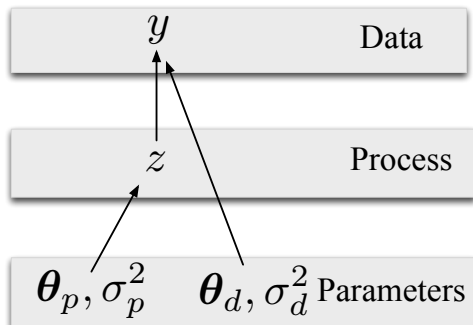
You can understand it.

- ▶ Rules of probability
  - ▶ Conditioning and independence
  - ▶ Law of total probability
  - ▶ Factoring joint probabilities

- ▶ Distribution theory
- ▶ Markov chain Monte Carlo

Current concepts, theory, questions → Model of process / Observations of process / Model of observations → New insight qualified by uncertainty