Modelling the eruption processes of a large number of similar but not identical volcanoes

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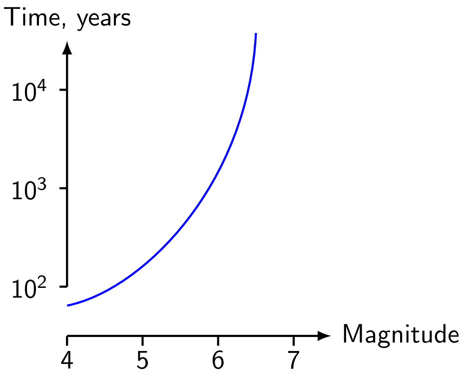
http://1.bp.blogspot.com/-BchmTrxUXZY/T3Vqs94irfI/AAAAAAAAAd-4/ikCA-i0Y0_U/s1600/mt+fuji.jpg

The return period curve

Shows the expected time in years between events of at least the specified magnitude: magnitude $= \log_{10}(\text{mass in kg}) - 7$.



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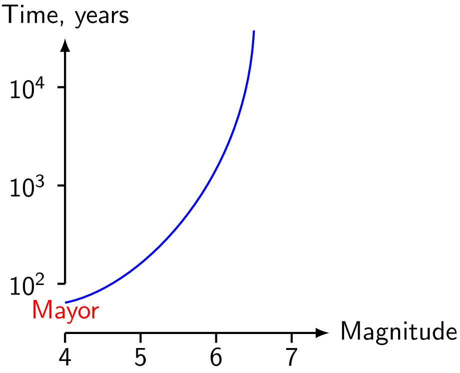

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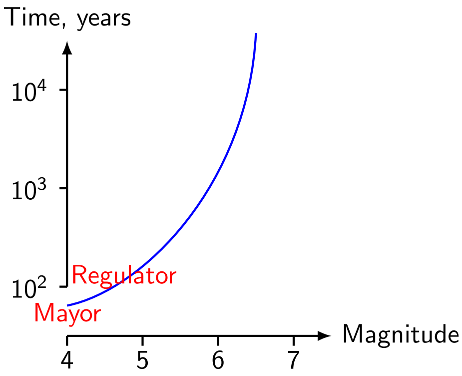

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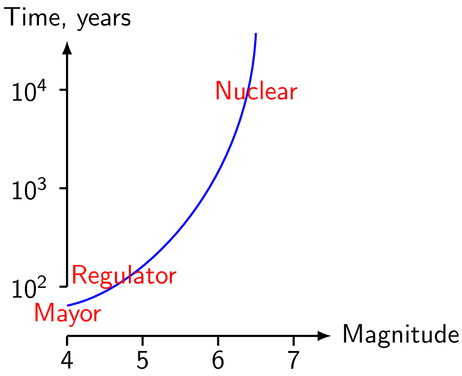

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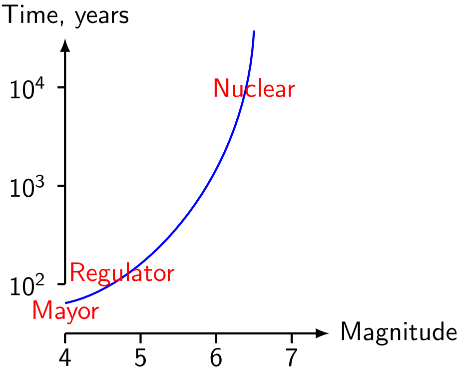
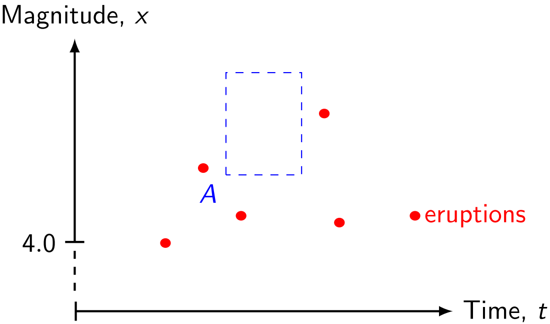


Caveat: Return periods are subtle; they are today's assessment, but look like they are a prediction about the future. This leads to lots of confusion.

The model for a single volcano



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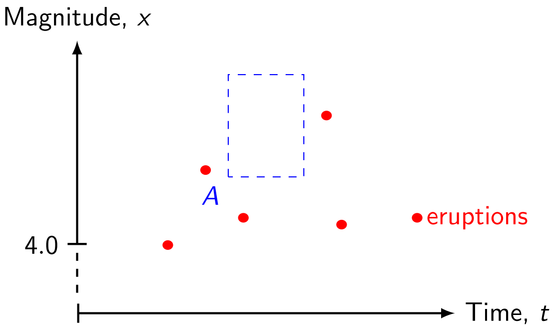

$$N(A) \sim \text{Poisson}(\lambda_A)$$

with the parametric form

$$\lambda_A = \iint_A \frac{1}{\sigma}\left(1 + \xi\frac{x-\mu}{\sigma}\right)_+^{-(1/\xi)-1} \mathrm{d}t\,\mathrm{d}x$$

The model for a single volcano (cont)

We make a change of parameters:

$$(\mu, \sigma, \xi) \mapsto (\kappa, \lambda, \xi)$$

where

κ	Maximum possible eruption magnitude (finite),
λ	Expected time between eruptions of mag $\geq$4.

This makes it more appropriate for us to treat the parameters as *a priori* mutually independent, and we can use informative priors for each margin.

- It also opens up the possibility of incorporating lower-quality data from other volcanoes.

The model for multiple volcanoes

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2. Reduces the effective number of parameters below the actual number of parameters and so creates 'degrees of freedom'.

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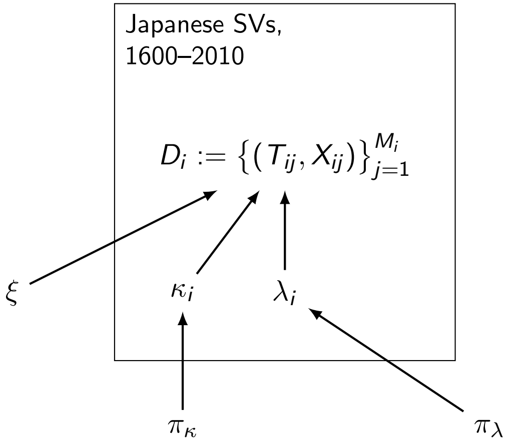

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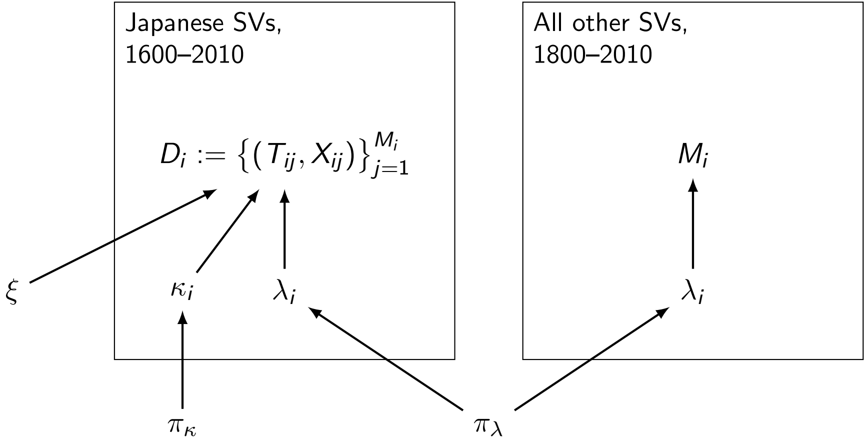

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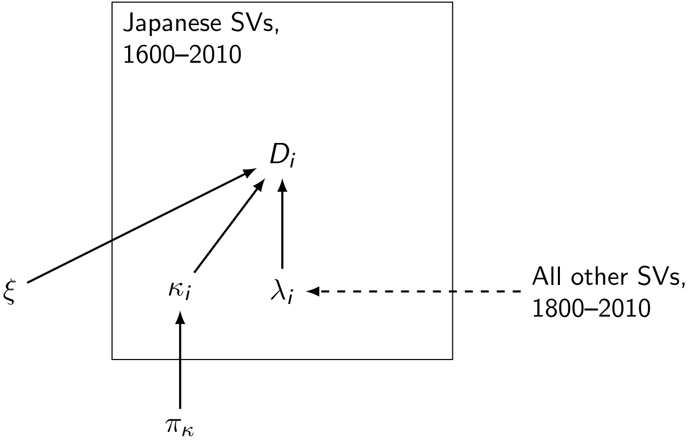
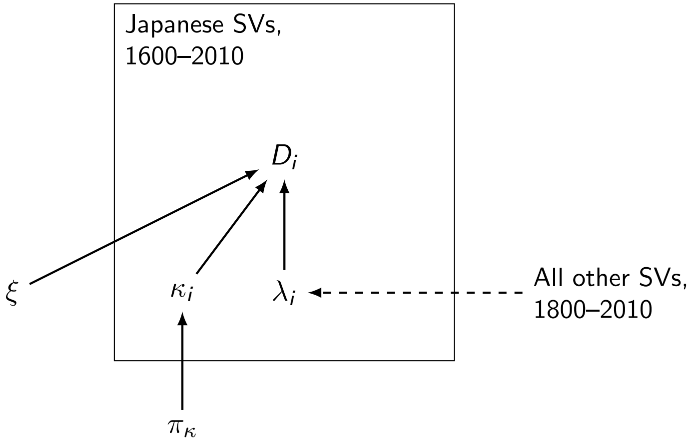
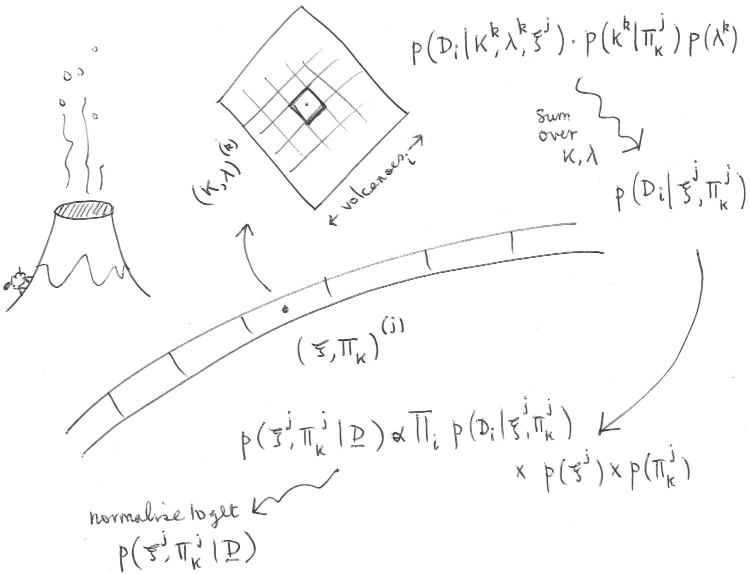


Computation

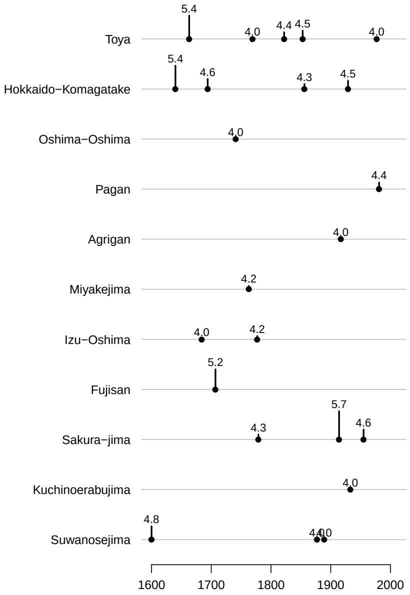


Computation

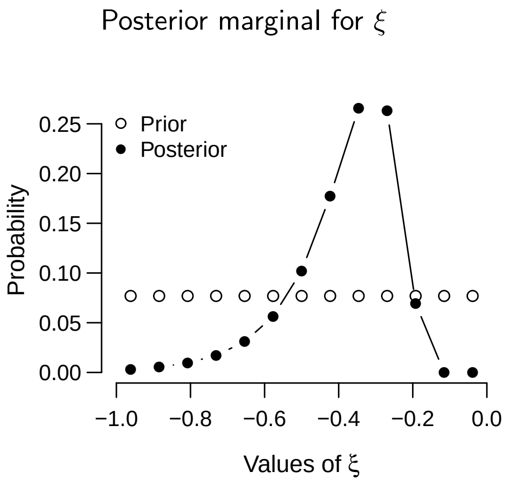
It's all done with napkins:



Japanese active stratovolcano dataset

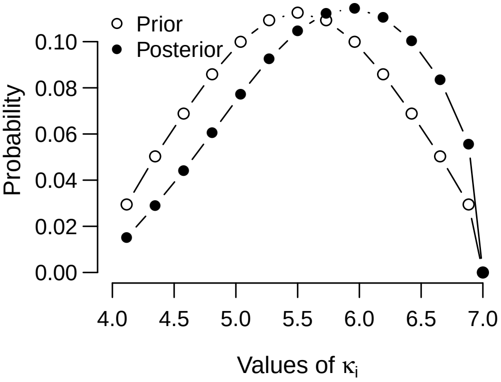


Posterior margins



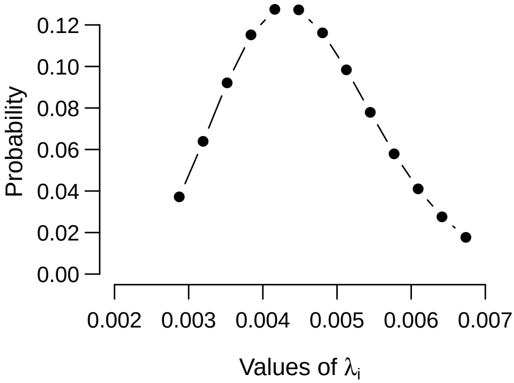
Posterior margins

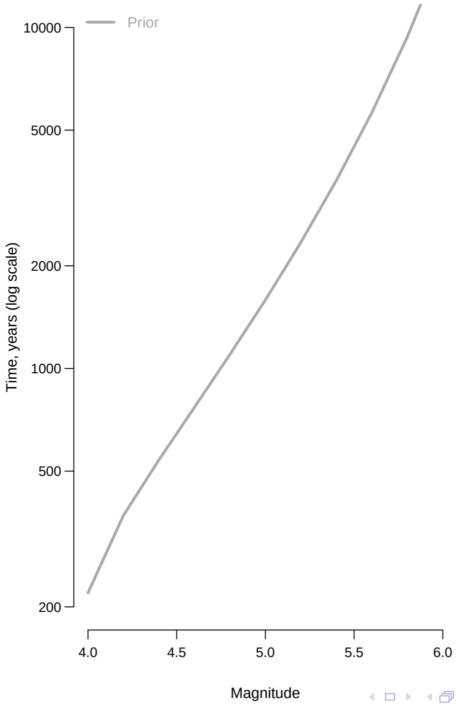
Posterior marginal for κ_i for a volcano not in the dataset.

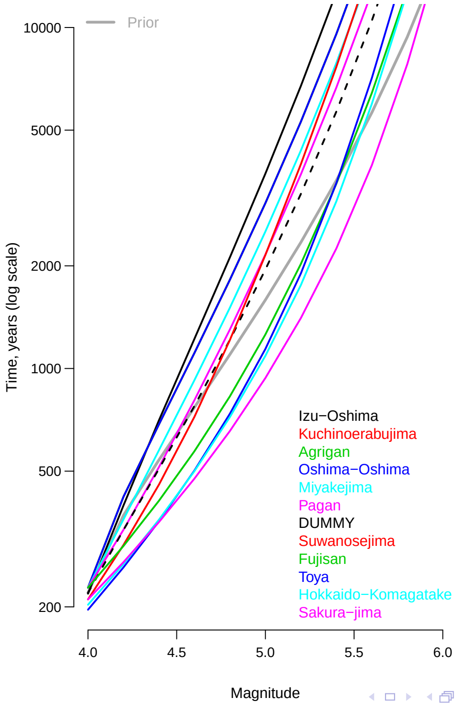


Posterior margins

Prior/posterior marginal for λ_i for a volcano not in the dataset.




Prior
10000
5000
2000
1000
500
200
Time, years (log scale)
4.0
4.5
5.0
5.5
6.0
Magnitude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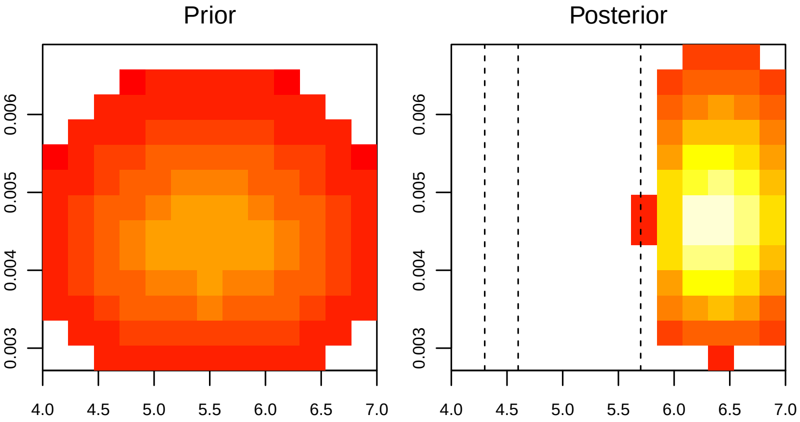
Izu−Oshima
Kuchinoerabujima
Agrigan
Oshima−Oshima
Miyakejima
Pagan
DUMMY
Suwanosejima
Fujisan
Toya
Hokkaido−Komagatake
Sakura−jima

Sakurajima

http://earthobservatory.nasa.gov/IOTD/view.php?id=80274

Sakurajima

Marginal distribution for (κ_i, λ_i).



The coloured region shows an approximate 95% high probability region. The dashed lines show the magnitudes of the three eruptions.

Sakurajima

Some further observations on this volcano:

- Sakurajima had a huge eruption in 1914 (mag 5.7). Since 1955 it has been erupting almost continually.

- Volcanoes can operate in one of two regimes: episodic (plugged conduit) and persistent (open). Many volcanoes are dominated by one regime, but it looks as though Sakurajima switched from plugged to open in 1955.

- If so, Sakurajima should drop out of our analysis at 1955, because it would no longer be exchangeable with the other (plugged) volcanoes.

This illustrates how a screening procedure works. A database plus some simple rules provides a first-cut. For any particular volcano, the results can be challenged by experts, allowing us to refine the rules, and to identify important missing fields in the database.