Calibration strategies for distributed hydrological models using qualitative knowledge of spatially variable process characteristics

Hilary McMillan[1], Martyn Clark[1], Richard Ibbitt[1]

[1] National Institute of Water and Atmospheric Research Ltd. (NIWA), New Zealand.

Contact: h.mcmillan@niwa.co.nz

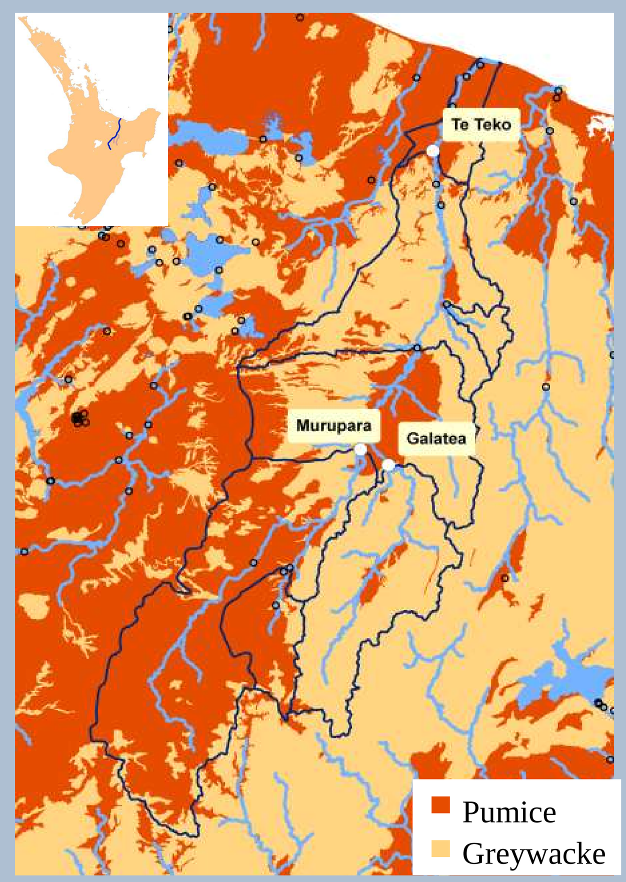
A catchment of two halves…

Rangitaiki River in NZ North Island

- Length 155 km, Mean Flow 25 m^3s^{-1}
- 378 sub-catchments (3rd order streams) of size approx. 10 km^2
- Geology of West half: Quaternary volcanic, thick pumice and tephra sequences
  - High stable baseflow regime with subdued flood peaks
- Geology of East half: Greywacke
  - Fast, peaked runoff response

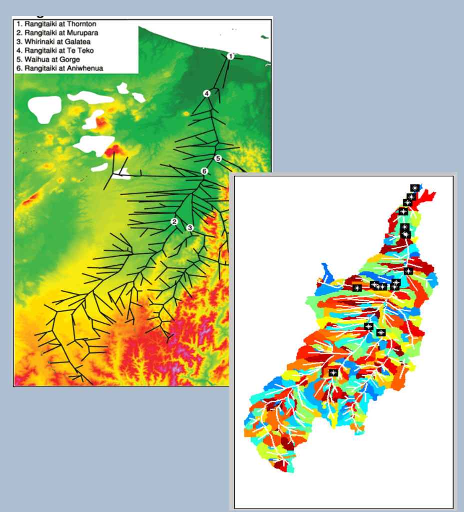
Can we model the contrasting behaviour of the two halves with only qualitative knowledge of heterogeneous geology?

- Calibrate model using outlet flow gauge only
- Check performance using internal gauges at Murupara (pumice subcatchment) and Galatea (greywacke subcatchment)



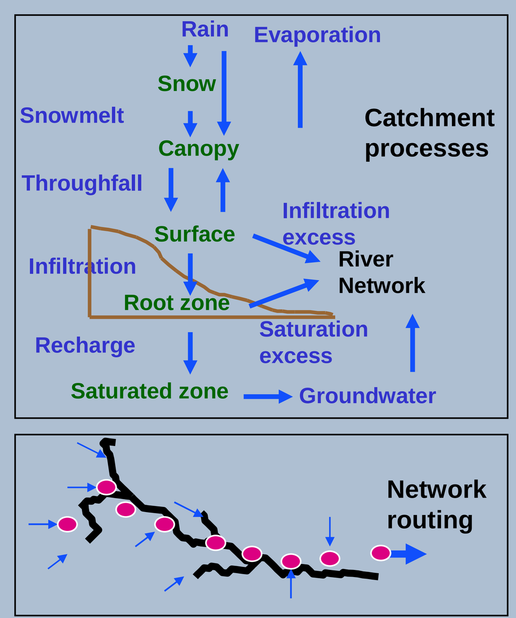
Geological map of Rangitaiki catchment showing flow gauge locations

Hydrological Model



TopNet Model:
Water balance model of sub-basins
+ kinematic network routing model

7 parameters per sub-basin
- Soil and vegetation parameters from catchment maps
- Other parameters set at default constant value

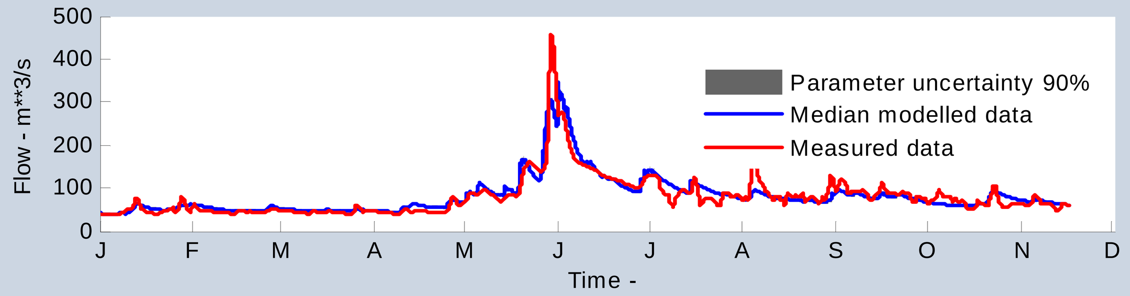


Uncertainty Estimation: Markov Chain Monte Carlo

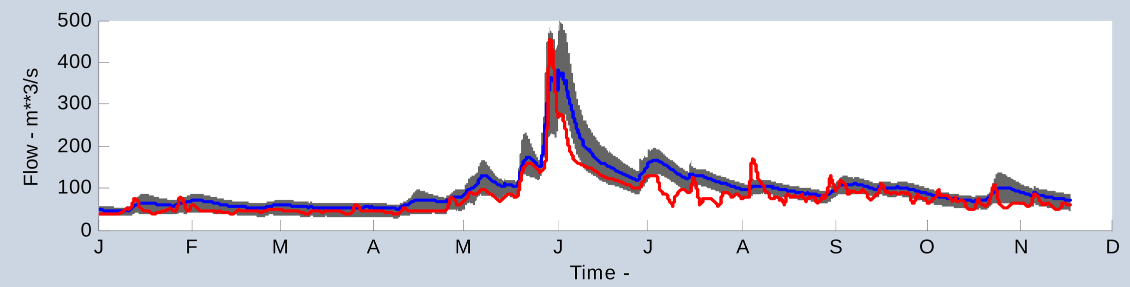
- The model is a simplification of nature and does not include all processes occurring in the catchment. Hence different model parameter sets may give equally good (or bad) predictions.
- MCMC is used to sample the parameter space, sampling more frequently where model performs well (see details of performance measure right →)
- Sample sets produced are interpreted as a median prediction + confidence intervals

Informal Likelihoods

- Where formal Bayesian likelihood (performance) measures are used, response surface is very peaked and predicts very narrow uncertainty bounds



- Using the Extended Nash-Sutcliffe as an informal performance measure, the confidence bounds more accurately reflect the uncertainty from many sources including model structural errors

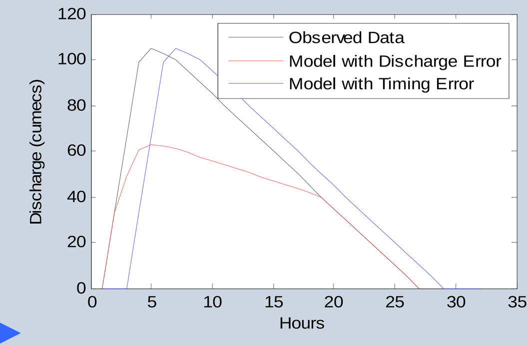


Performance Measure: Improving on Nash-Sutcliffe Efficiency

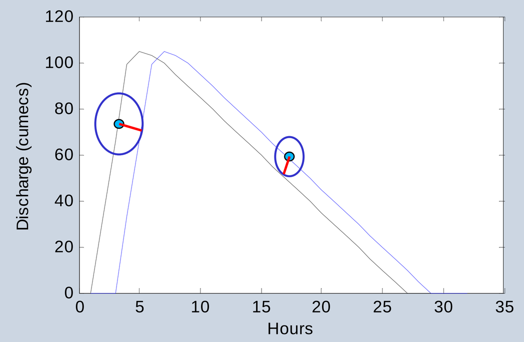
The popular Nash-Sutcliffe measure is based on the sum of squared errors

$$NSE = 1 - \sigma_\varepsilon^2 / \sigma_o^2$$

Where:
σ_ε^2 = sum of squared errors
σ_o^2 = observed series variance



This measure favours discharge (magnitude) errors over timing errors, illustrated by these synthetic hydrographs where the red simulation is graded more highly than the blue simulation.



Our suggested **Extended Nash-Sutcliffe** recognises a combination of discharge and timing errors

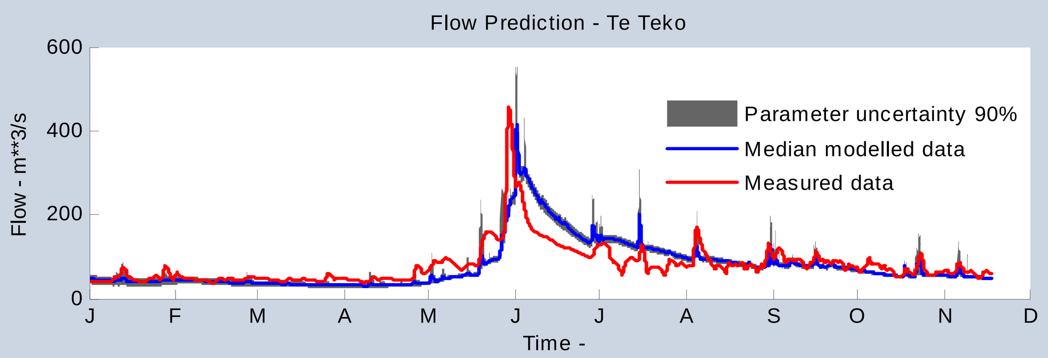
The modeller's judgment on relative importance of discharge and timing errors determines shape of oval search window

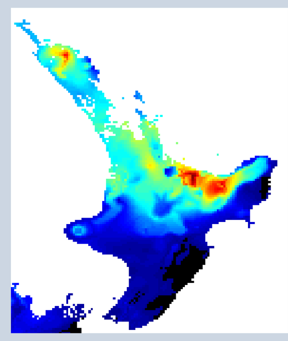
Standard NS appears as a special case when timing errors are considered infinitely worse than discharge errors (oval becomes vertical line)

Calibration Method

Too many parameters to adjust individually so…

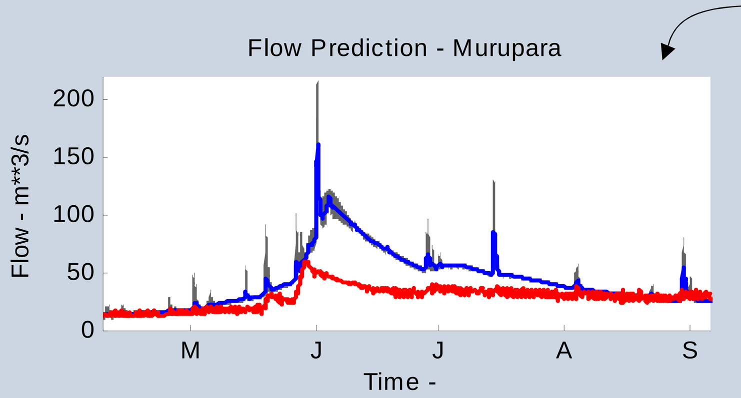
Assume the spatial distribution of model parameters is reasonable, and identify a set of parameter multipliers that adjust the magnitude of model parameters for the basin as a whole.

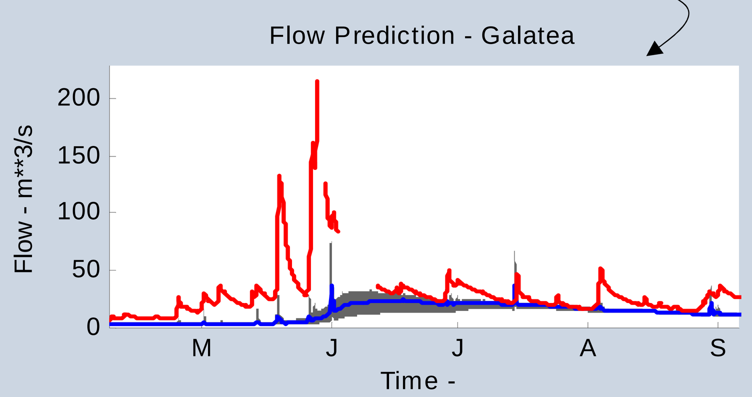




Weather data from 1998 including large flood event

Parameters for 'Average' Geology give poor results for Pumice or Greywacke

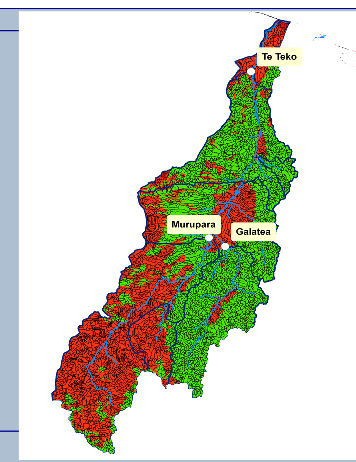




Calibration using qualitative Geological information

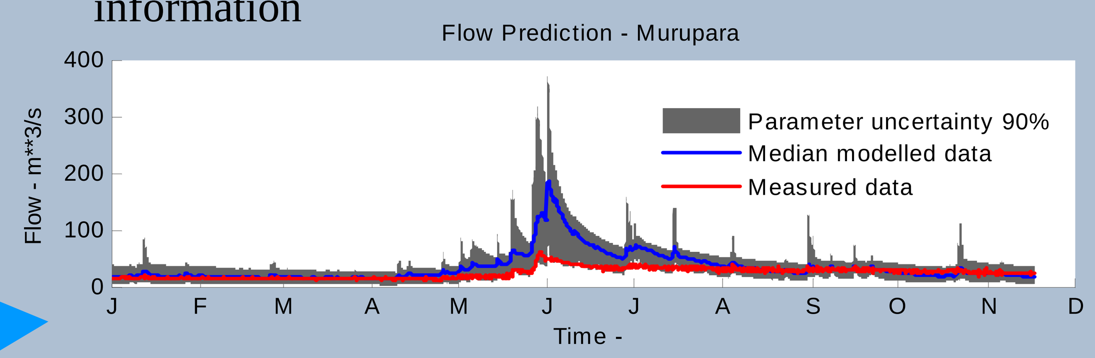
Each catchment is classified as
- 'Permeable' i.e. pumice, or
- 'Impermeable' i.e. greywacke/hard volcanics

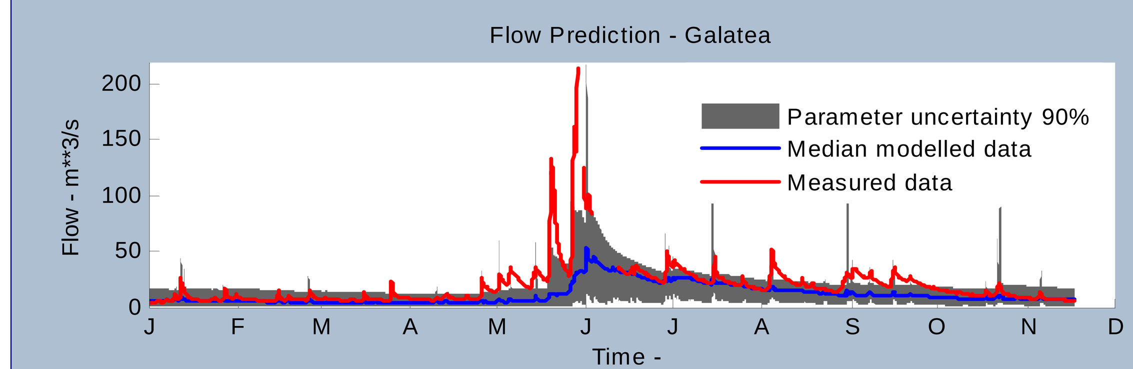
2 sets of parameter multipliers used, one for each geology type



Unconstrained Parameters

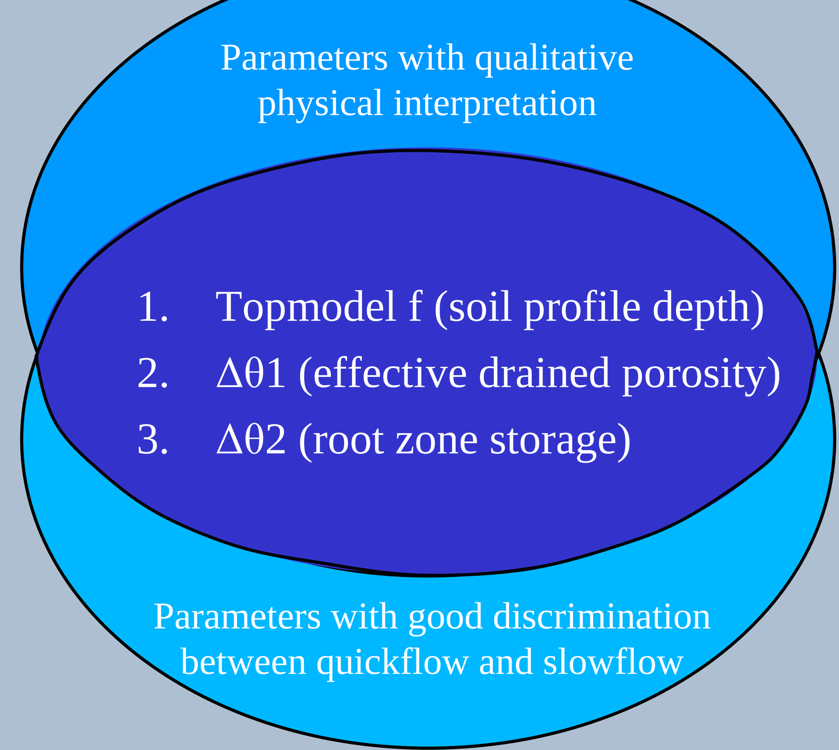
- Damped / flashy flow characteristics can be wrongly assigned to sub-catchments as long as total is correct
- Uncertainty bounds extremely wide, provides little information





Constraint Process

- Multiplier ranges modified for 3 out of 14 parameters



Constrained Parameters

- Accurate flow prediction in both subcatchments