Intelligent Model Calibration using Multi-objective Optimization

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Motivation

- Model calibration: numerical and physical Models might have lots of parameters that need to be tuned to get desired outputs
- Huge search space due to continuous value for each parameter
  10 tuning parameters with 100 search steps per parameter=100^{10} search steps
- Model might have multiple outputs to be optimized
- Limitation of traditional method for multi-outputs
  Multi-output-->Single output: $Output_1*W_1+Output_2*W_2+...Output_n*W_n$

Intelligent model optimizer

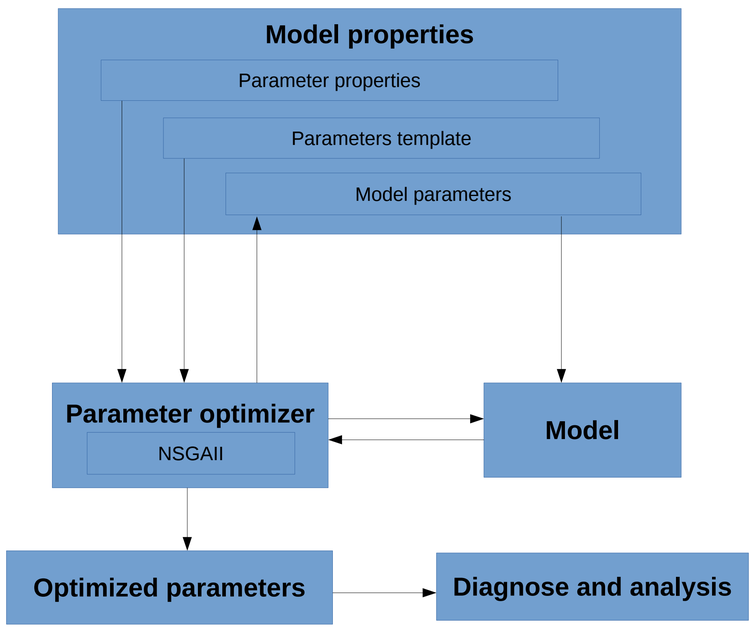


Figure 1. Framework of intelligent model optimizer

NSGAII: GA+Non-dominated Sorting

- **GA**: Biological evolution is a process of change and development of individuals, generation by generation, following the principle of “survival of the fittest”. Genetic algorithm (GA) loosely simulates the natural evolution to solve optimization problems.

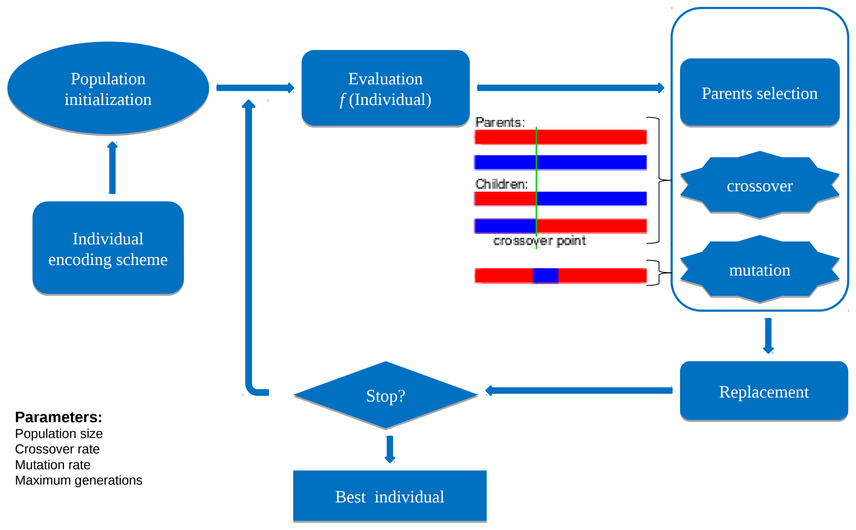
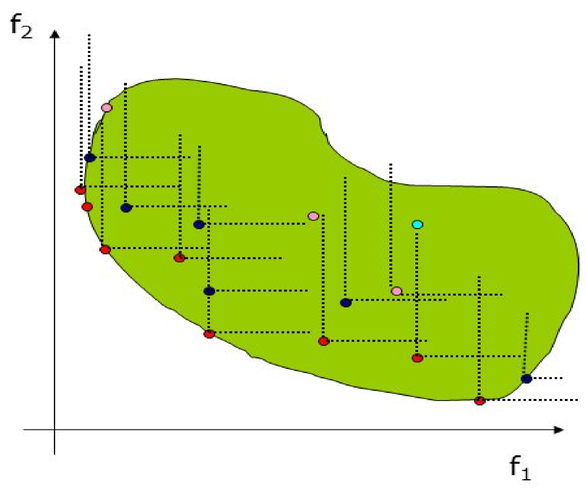


Figure 1. Framework of genetic algorithm

- **Non-dominated sorting**

Definition 2.1 (Pareto Dominance) The individual x Pareto dominates the individual y (denoted by $x \preceq y$) if and only if the fitness vector of x is less than the fitness vector of y, i.e. $(\forall i \in \{1, \cdots, k\}, fit_i(x) \le fit_i(y)) \wedge (\exists i \in \{1, \cdots, k\}, fit_i(x) < fit_i(y))$, where k is the number of objectives and fit_i is the fitness function for the ith objective.

Definition 2.2 (Mutual Non-Dominance) The individuals x and y are mutual non-dominated (denoted by $x \Diamond y$) if and only if the fitness vector of x is not less than the fitness vector of y and the fitness vector of y is not less than the fitness vector of x, i.e, $\exists i, j \in \{1, \cdots, k\}, x_i < y_i \wedge x_j > y_j$.



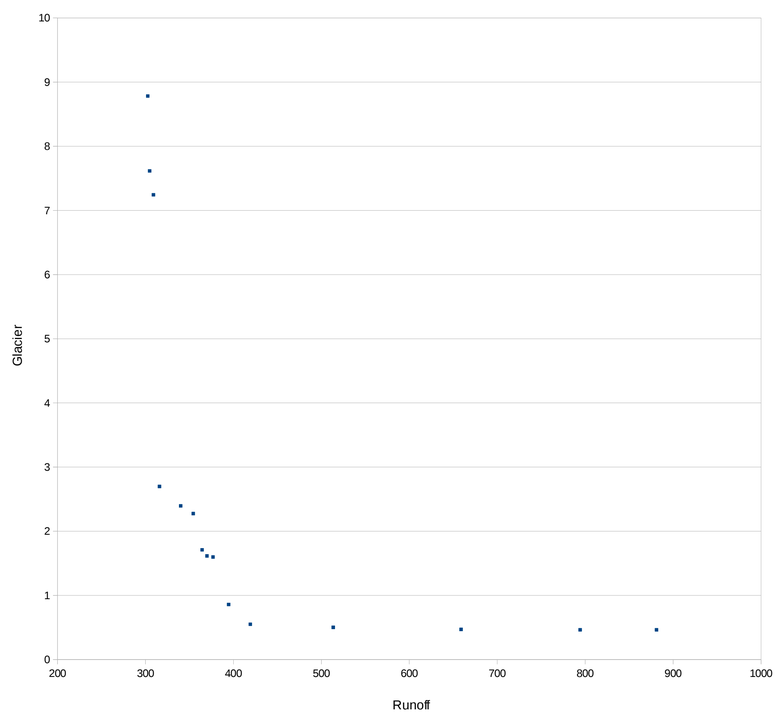
Application

- **Project**: Climate Change Impacts on Runoff in North-West India
- **Model Calibration**: Tuning 14 parameters of HBV model to optimize two model outputs: runoff and glacier

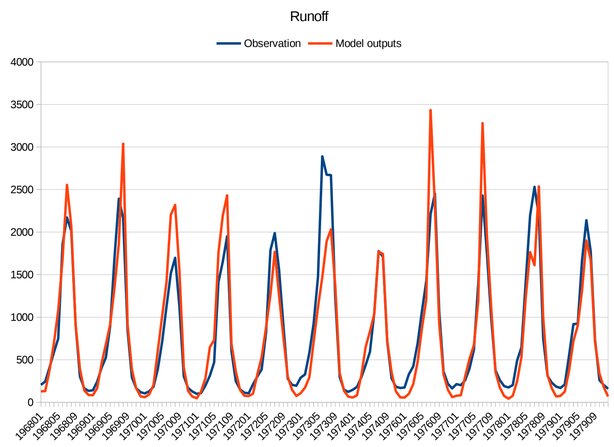
Optimization results

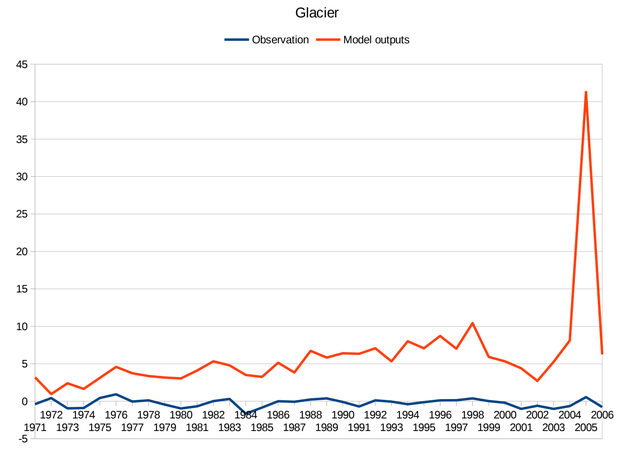
- Non-donimated solutions

RMSE	
Runoff	Glacier
881.10718	0.46393
302.60388	8.78283
315.91338	2.69842
309.02063	7.24462
658.97024	0.47046
513.47518	0.50232
794.27199	0.46503
419.23206	0.55033
394.55056	0.85876
304.6892	7.61554
376.80963	1.59864
354.29623	2.27536
340.08237	2.3964
364.38871	1.7105
369.96299	1.61552

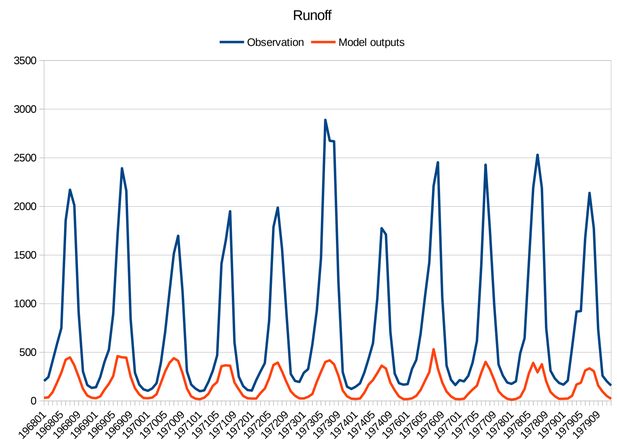


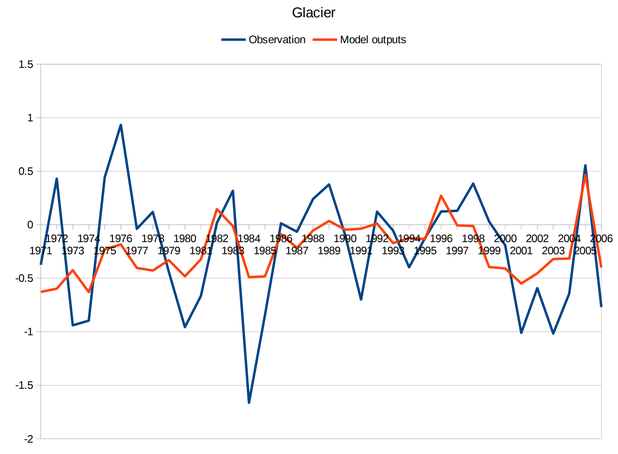
- Solution optimizes runoff



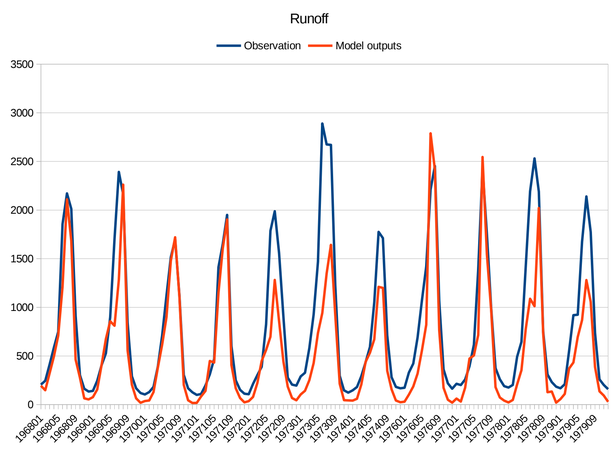


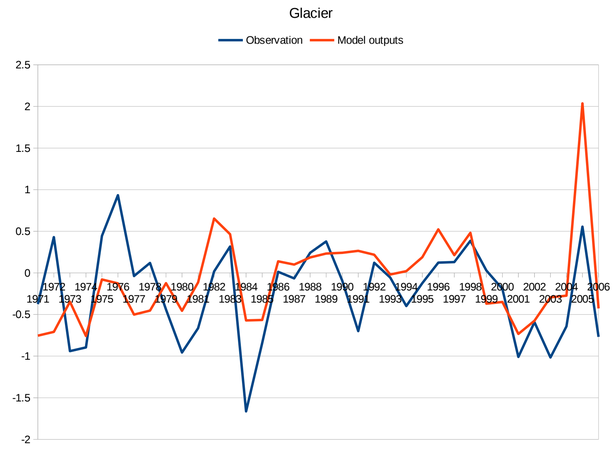
- Solution optimizes glacier





- Solution balances runoff and glacier





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2. The Norwegian Water Resources and Energy Directorate, Oslo, Norway