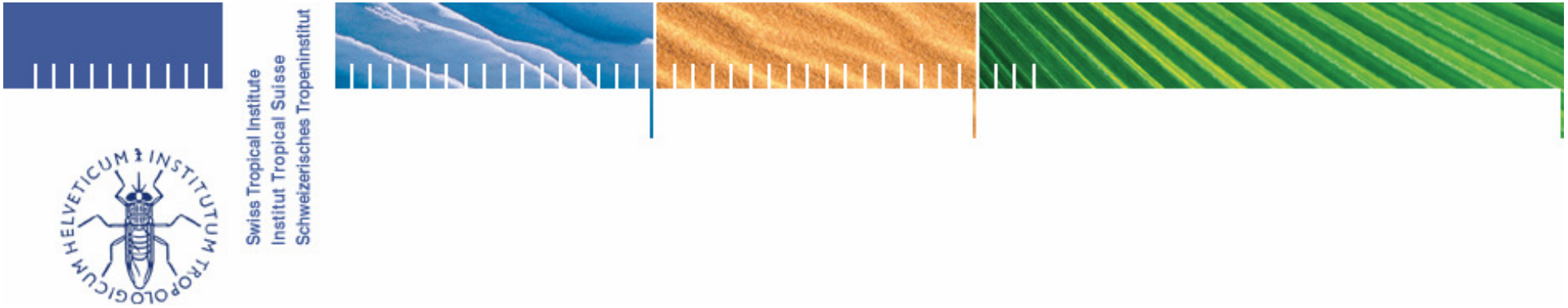

Estimating parameters for mathematical models of malaria epidemiology

Nicolas Maire
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malariacontrol.net

BOINC Workshop 09

Malaria and malaria models

- Malaria: a mosquito-borne disease caused by a parasite
- One to three million deaths per year
- Hundreds of millions of illness episodes per year, up to 40% of health expenditure
- Mathematical models have been a valuable decision making tool in public health
- Increasing demand for rational setting of priorities

Costs of interventions

Transmission Potential

Intervention package

Simulation model of malaria epidemiology and control

Costs of disease

Patterns of infection, morbidity & mortality without intervention

Intervention- modified patterns of Infection, morbidity & mortality

Burden of disease without intervention

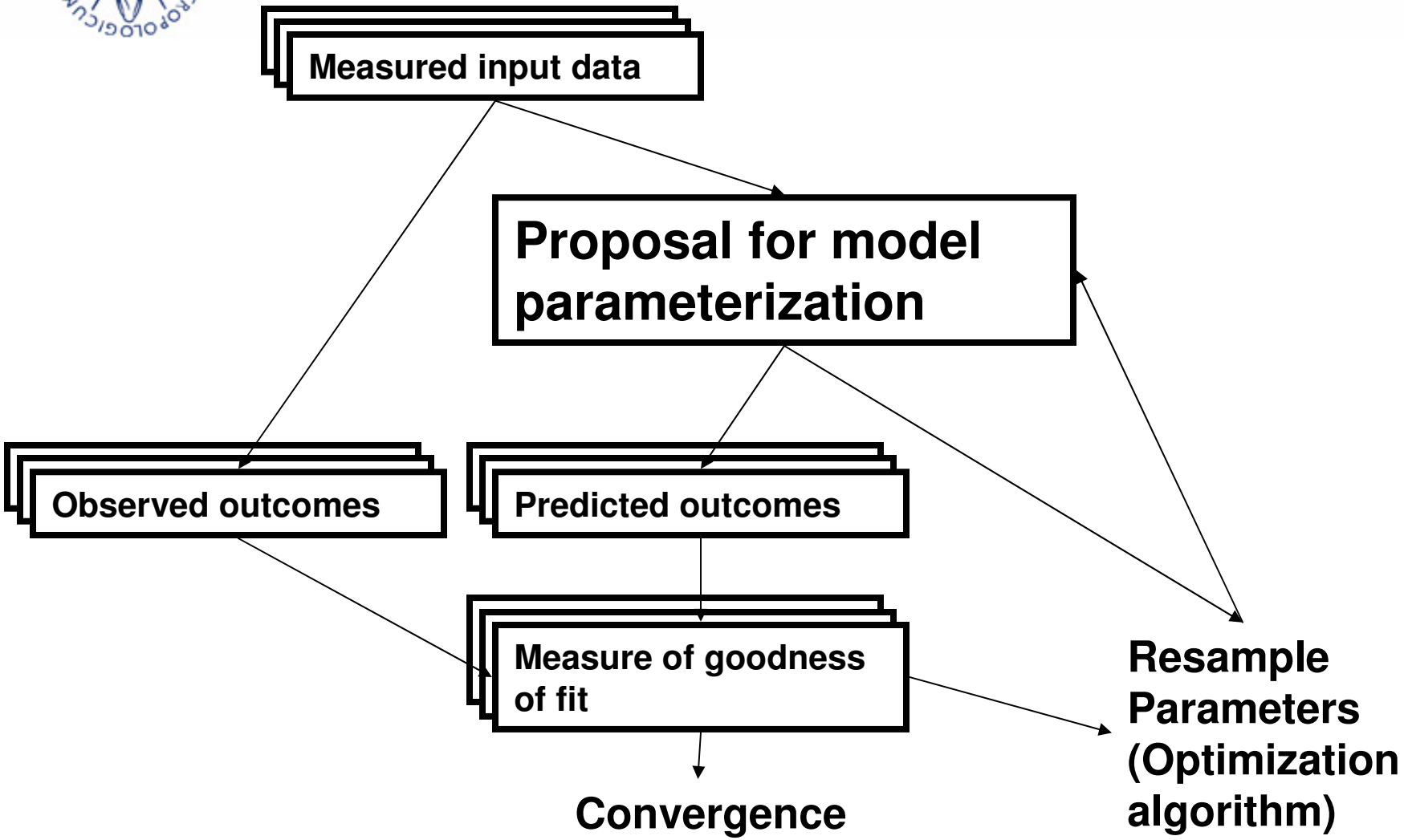
Intervention-modified burden of disease

Predicted intervention cost- effectiveness

Modeling approach

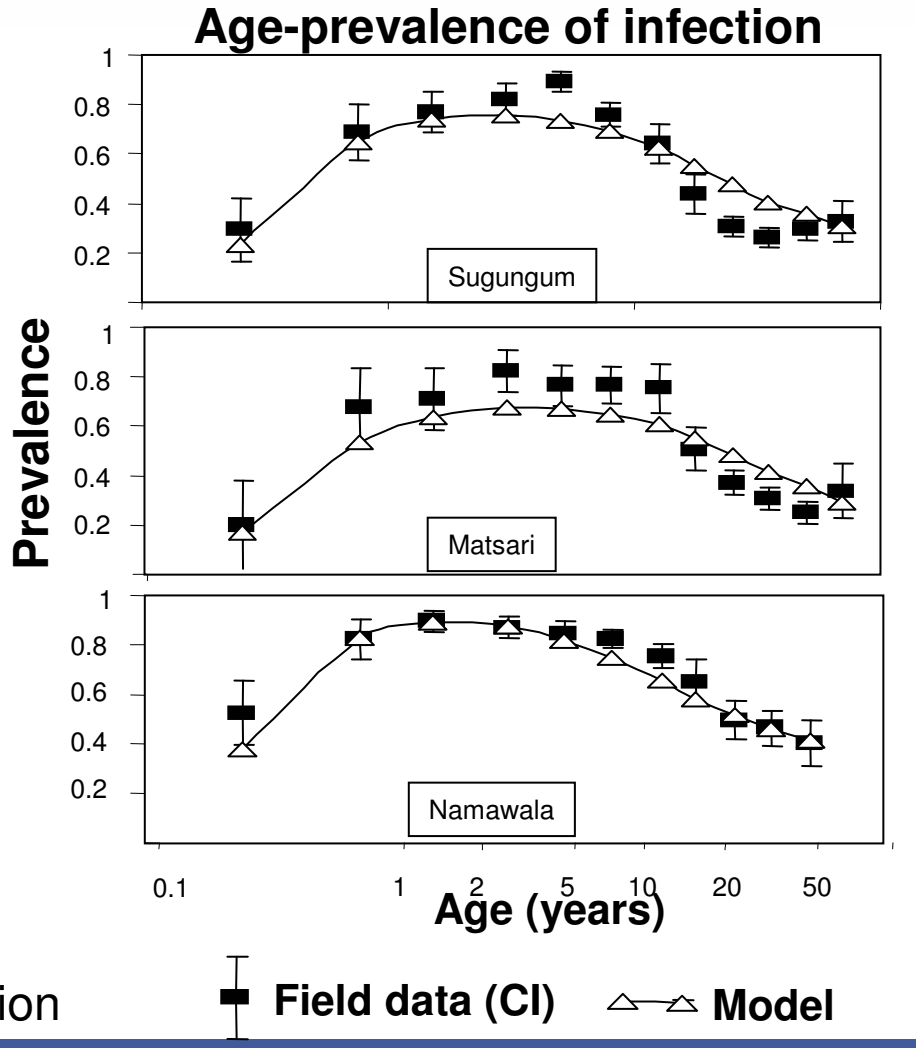
- Discrete time stochastic individual-based simulations
  - Human hosts are characterized by a set of state variables (age, parasitology, immune status,…)
- Models for the effect of acquired immunity on parasite densities, for transmission to the vector, for morbidity, and for mortality
- Fit model to data from field studies
- Predict impact of control strategies by comparing simulated interventions with baseline scenarios

Estimating model parameters from field data



Calibration

- 61 datasets from field studies, different objectives*
  - Incidence of infection
  - Age-prevalence of parasitemia
  - Seasonality of parasitemia
  - Age-density of parasites
  - Age-incidence of clinical disease, hospitalisation and mortality



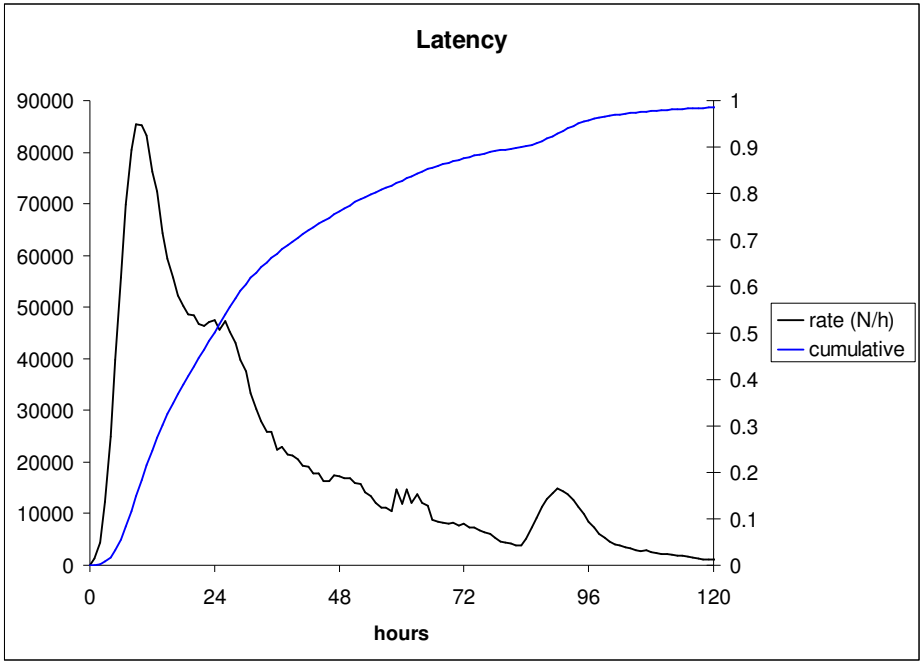
*all related to seasonal patterns of transmission

Challenge of fitting these models

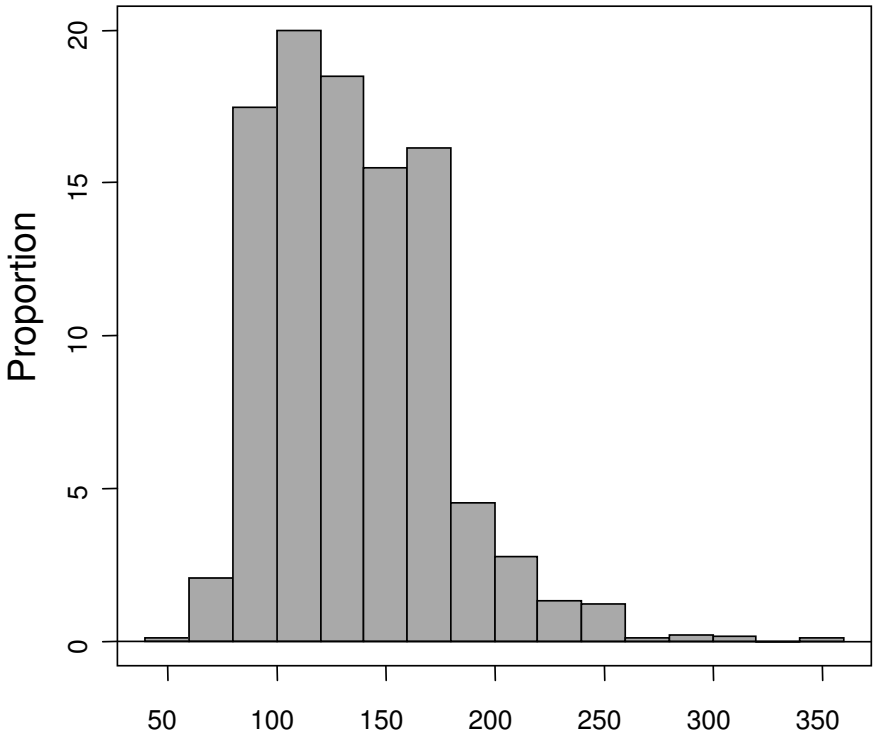
- Objective functions non-differentiable
- Loss function values are not reproducible because of stochasticity
- High-dimensional parameter space
- (Multi-objective)
- Computationally expensive
- *malariacontrol.net*
- Time to completion of results long and unpredictable

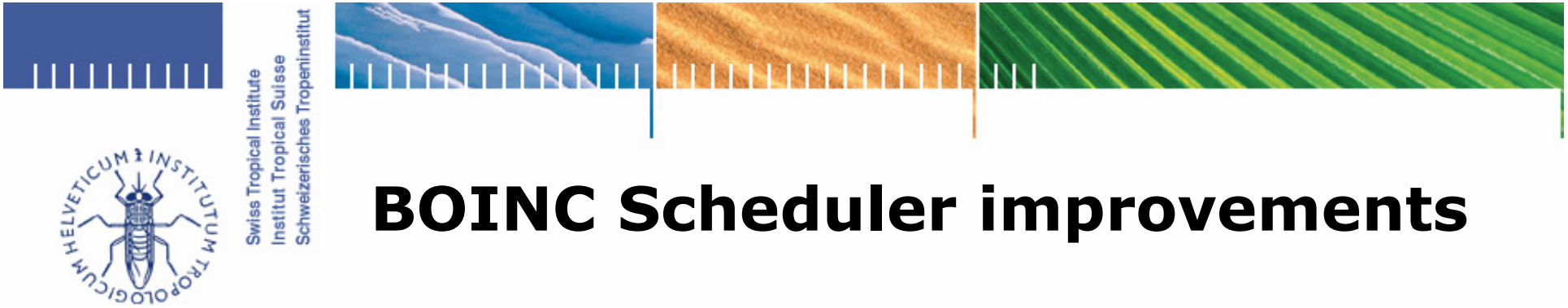
Latency

Workunits



Parameterizations





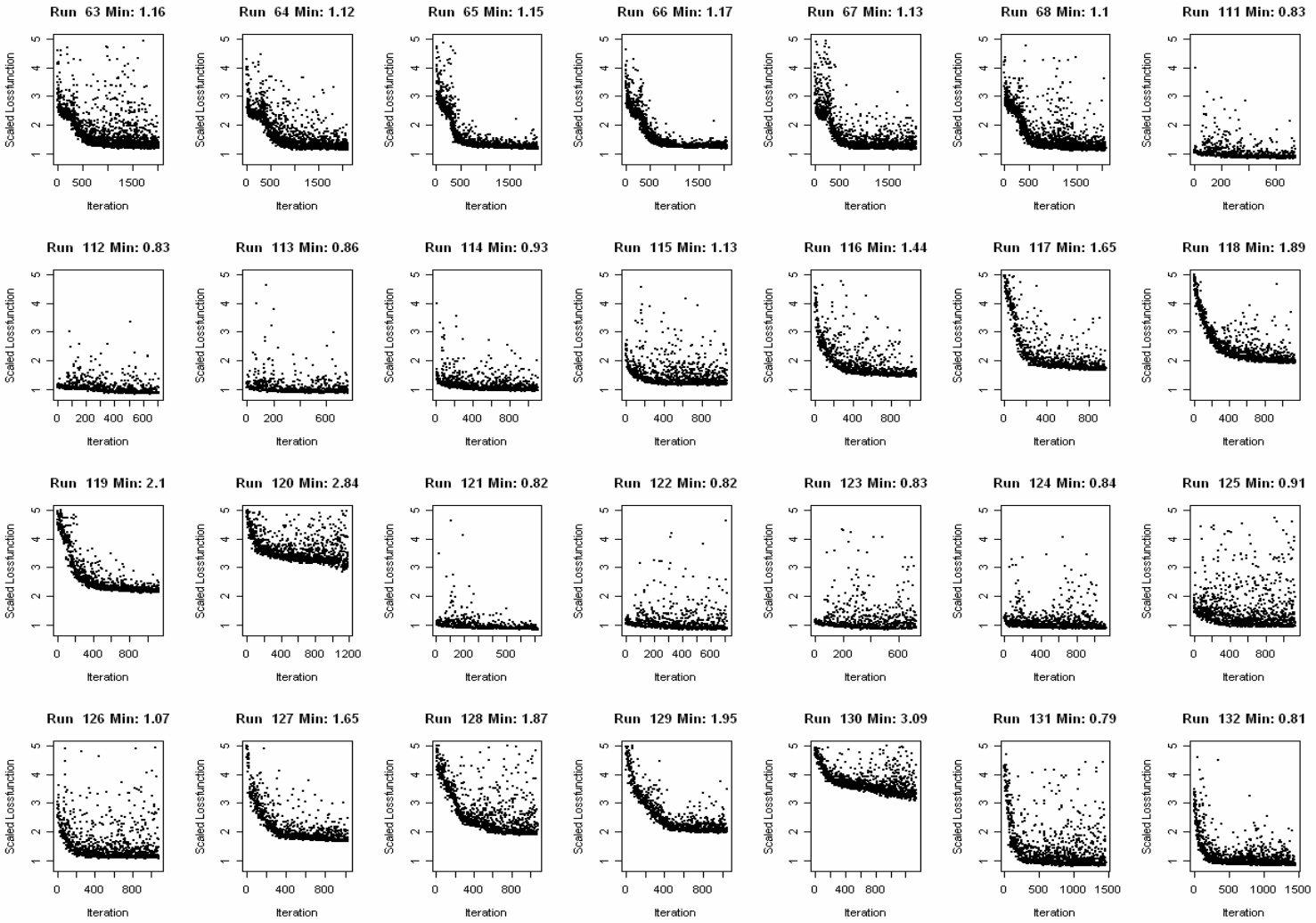
BOINC Scheduler improvements

- Reliable host scheduling
- Redundancy elimination (next release of mcdn science app)

Current strategy using Genetic Algorithm

- Truncating mating selection
  - Choose best n individuals
- Mutation
  - Sample around current parameter values
  - Adaptive sampling range
  - Adaptive mutation rate
- Overlapping generations
  - Work generator samples new parameterizations on demand

Fit by iteration for alternative models



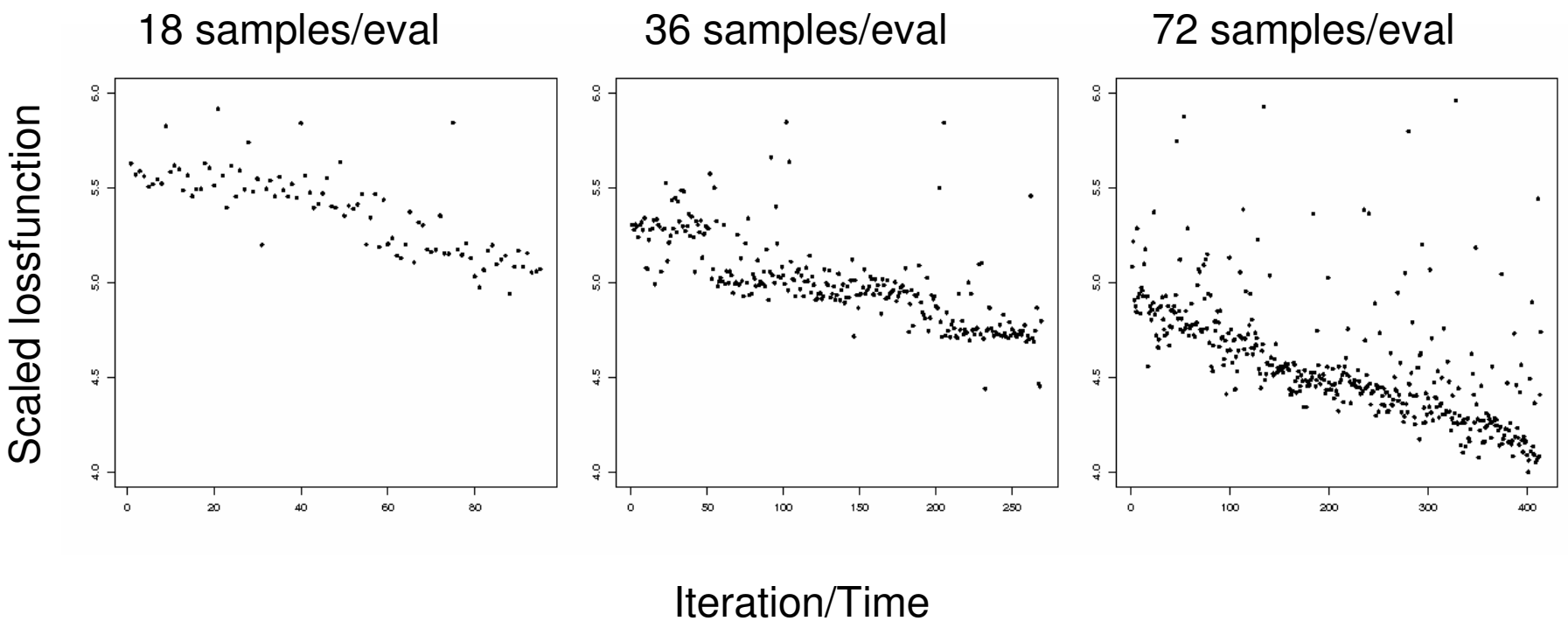
Questions

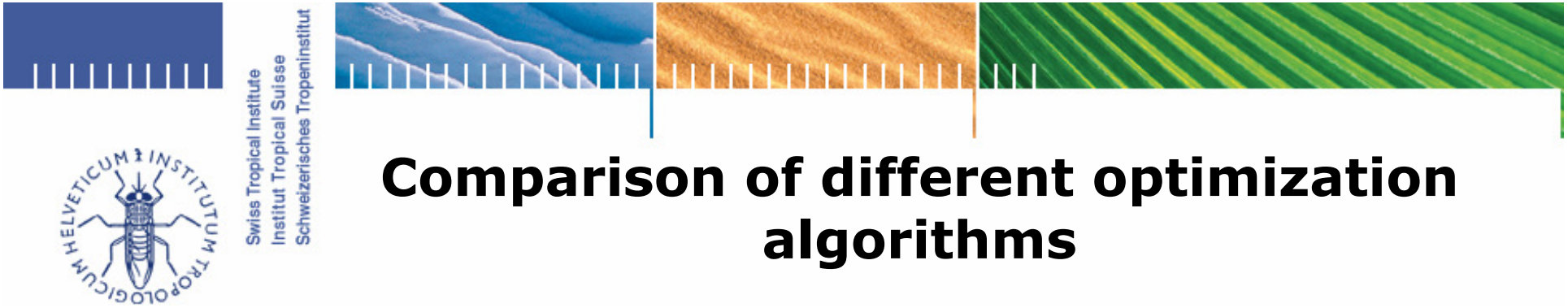
- How much do we gain by increasing the number of participating hosts?
- Which optimization algorithm works best?

Return on investment in additional hosts

- Simulate different volunteer population sizes by using different workunit generation priorities
- Compare optimization performance against number of participating hosts
- Metrics
  - Performance: Absolute time to convergence
  - Investment: Avg. number of parameterizations sampled per evaluation period

Preliminary results





Comparison of different optimization algorithms

- Design work generator for pluggable algorithms
- Mostly a wrapper for the backend database
- Abstract **Algorithm** class with sample method
  - `Parameterization sample(Population pop);`
- Core classes
  - Population
  - Parameterization

Population

- A collection of completed Parameterizations

- `vector<Parameterization> getParameterizations();`
- `string getProperties();`
- `string setProperties();`

Parameterization

- A collection of samplable parameters, a lossfunction, and optional properties
- `int getNumParameters();`
- `double getLossfunction();`
- `double getValue(int index);`
- `void setValue(int index, double value);`
- `string getProperties();`
- `void setProperties(string properties);`

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