

SIMENV -

A FLEXIBLE FRAMEWORK FOR SENSITIVITY AND UNCERTAINTY ANALYSES OF LARGE-VOLUME MODEL OUTPUT



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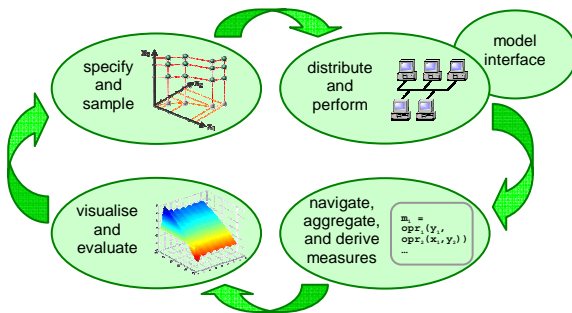
MOTIVATION

Development and investigation of integrated models are challenges in global and climate change research. Such heterogeneous models generate multi-dimensional, large-volume output with high computational costs. They require a structured and integrated approach for verification, validation, sensitivity and uncertainty analyses.

APPROACH

Integration of techniques in a flexible and open framework for the sample-based evaluation of a model M and its outputs $\{y\}$ in a factor space $\{x\}$: $y = M(x)$. Support for

- high-dimensional factor spaces;
- multi-dimensional, large-volume model output;
- multi-programming language models.



SimEnv system design

EXPERIMENT DEFINITION

Pre-formed experiment type templates represent different sampling plans for the factor space $\{x\}$. They are equipped by the user with numerical information.

Experiment types and examples of sampling plans in a 2-dimensional factor space $\{x\} = (\text{sub-})\text{sample}$ $\circ = \text{default factor value}$

	GLOBAL SENSITIVITY ANALYSIS qualitative factor ranking (Morris method) for determination of most sensitive factors to focus on in subsequent investigations
	DETERMINISTIC SCREENING with flexible strategies for factor sub-spaces for one-factor-at-time experiments, (fractional) factorial experiments, and response surfaces
	LOCAL SENSITIVITY ANALYSIS in the local neighbourhood of the default factor value for local first order sensitivity measures
	MONTE CARLO ANALYSIS probabilistic random or Latin hypercube sampling for determination of statistical measures
	UNCERTAINTY ANALYSIS orthogonal variance decomposition of $\{y\}$ by Monte Carlo re-sampling for first order and total effects (Saltelli et al.)
	OPTIMIZATION applying a simulated annealing strategy (Ingber) for model fitting and control design

MODEL AND DATA INTERFACES

C/C++, Fortran, Python, Matlab, Mathematica, and GAMS models can be coupled to SimEnv by minimal source code modifications to forward factor values to the model and to export model output. Appropriate interfaces are also available at shell script level and for ASCII files. For experiment and post-processor output NetCDF, IEEE compliant binary, and ASCII format are supported.

EXPERIMENT LOAD DISTRIBUTION

Factor value sampling in experiment preparation allows for dynamically distributing simulation load on a cluster of workstations during experiment performance and/or running the experiment in parallel.

EXPERIMENT POST-PROCESSING

Analysis of multi-dimensional, large-volume model output on multi-dimensional factor spaces and determination of sensitivity and uncertainty measures demand efficient strategies for navigation, dimension reduction and processing. Chains of built-in and user-defined operators can be applied to experiment output, factors, and reference data to derive multi-dimensional measures m from secondary experiment output g : $m = m(g(y, x, \text{data}))$.

MODEL OUTPUT:

```
pmsl = pmsl(lat,lon,time)
```

POST-PROCESSOR OUTPUT:

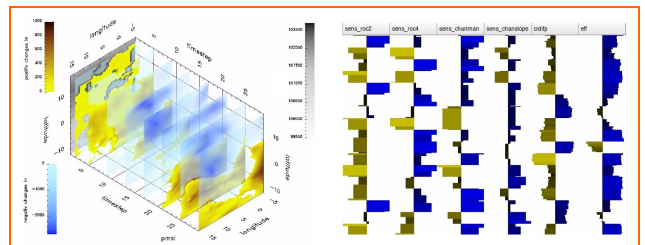
```
m(g) = μmorrisabs<factor>(lat,lon,time) =
```

```
clip('* , * , * , <factor> , 1' , morris(abs(pmsl)))
```

Example of an operator chain for a global sensitivity analysis

VISUAL EVALUATION

To efficiently interpret and communicate experiment and post-processed output, visualisation modules provide interactive methods for data sets with spatio-temporal and abstract experiment dimensions.



left: Global sensitivity analysis - parallel slices visualisation of differences in time for one factor of a regional climate model
right: Deterministic screening - four factors (sens_*) and two aggregated model outputs of an integrated soil - water model

APPLICATIONS

The system has proved its applicability in a number of case studies, ranging from conceptual qualitative models to large-scale earth system models of intermediate complexity. SimEnv is available for Unix and Linux operating systems.

