SURROGATE-BASED OPTIMIZATION OF PARAMETERS IN A MARINE ECOSYSTEM MODEL

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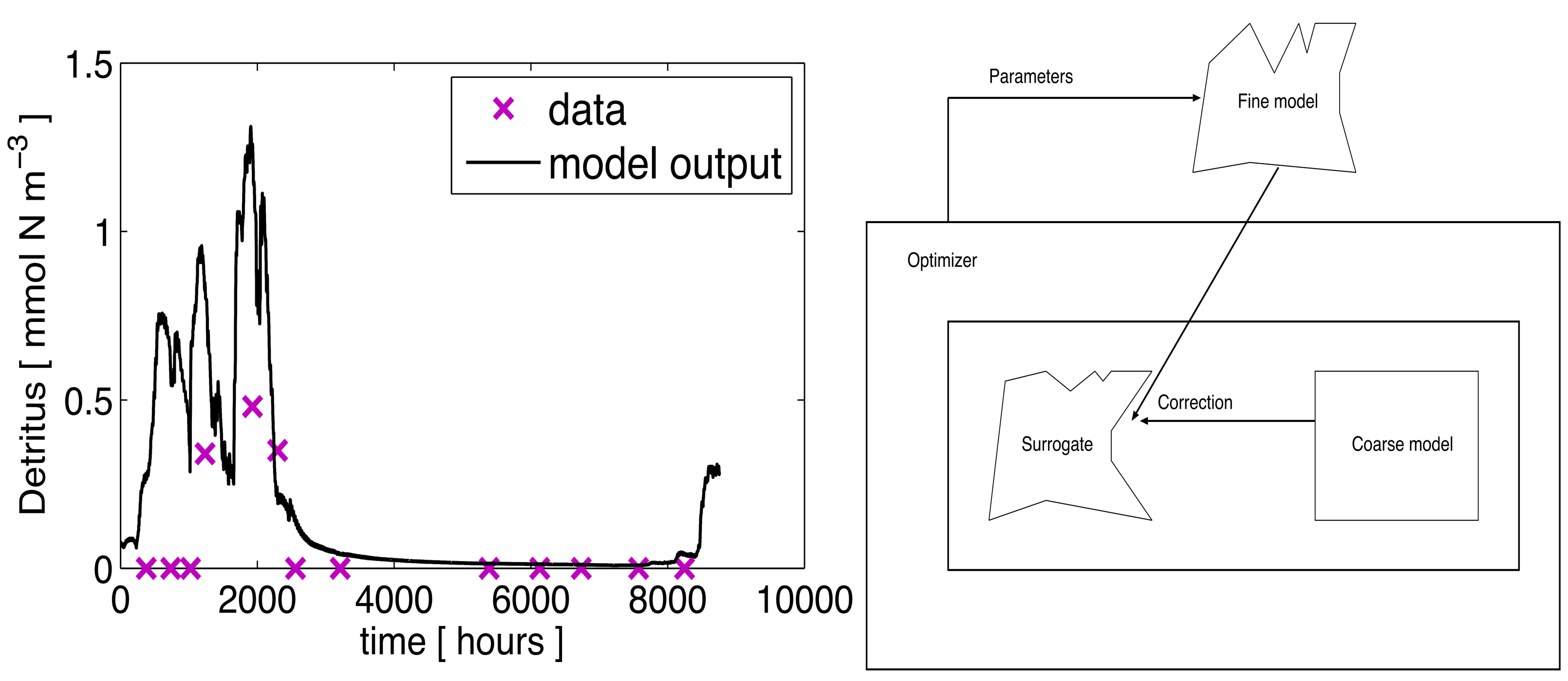
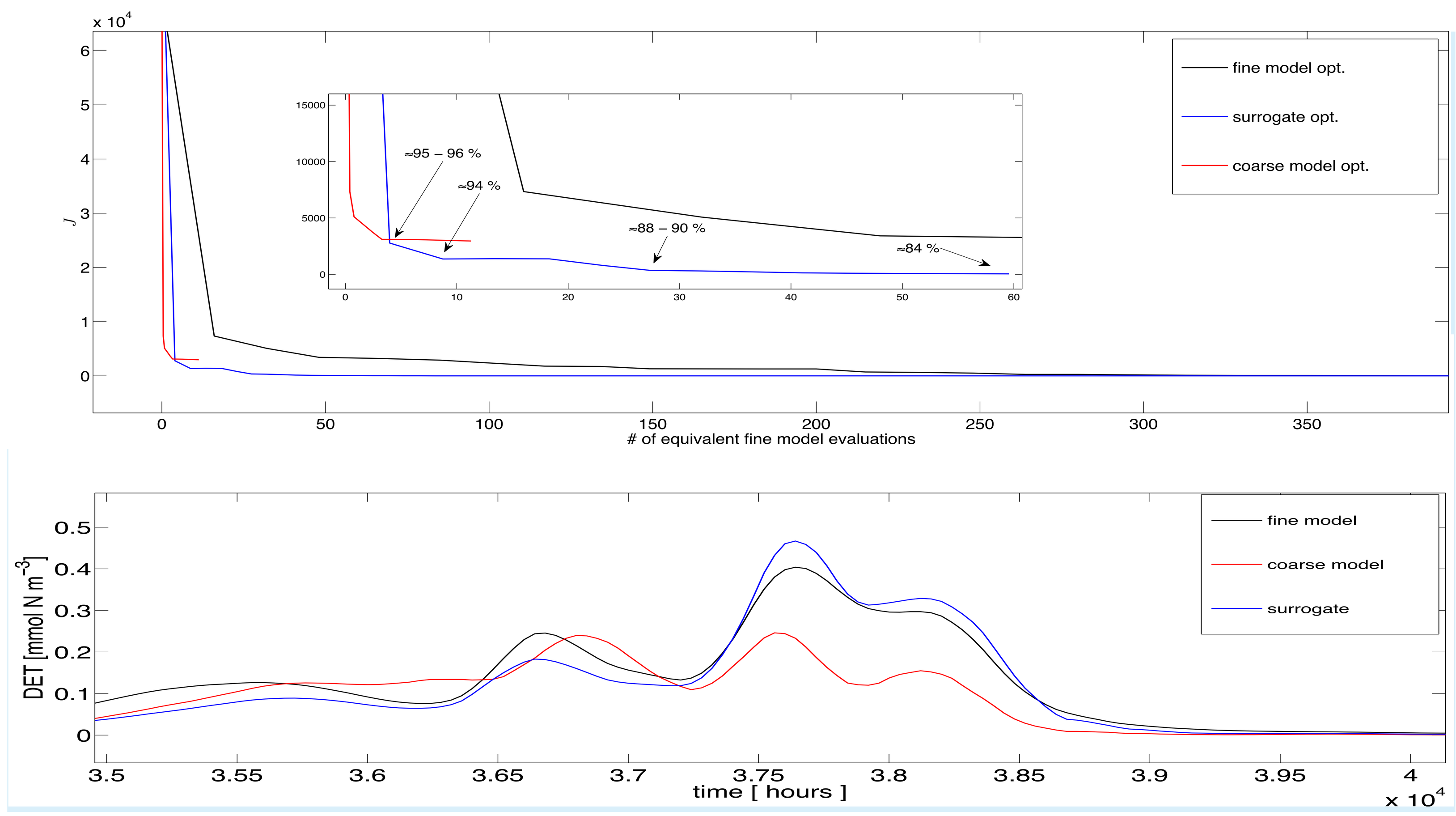
Simulating the marine ecosystem is important for the investigation of the global carbon cycle. Marine ecosystem models describe biogeochemical processes (e.g. photosynthesis) in the ocean. The models consist of transport equations for tracers as nutrients, phyto- and zooplankton etc., driven by the ocean circulation.
For a reliable prediction, the models have to be calibrated, i.e., their parameters have to be optimized in order to obtain a reasonable fit of the model output to available observation data.

Specifically in three space dimensions, optimization of such time-dependent systems is a non-trivial and computationally elaborate task.
We present a method that allows to reduce the computational effort in the optimization by up to 95%.
To evaluate this cost reduction and to show the validity of the obtained optimal parameters, we applied the method to a one-dimensional version of the Oschlies-Garcon NPZD model. However, the method is applicable to a quite general class of models.



Left: Typical parameter optimization problem: Aim is to minimize the misfit between model output and data. Right: Basic scheme of the surrogate-based optimization method.



Top: Reduction of model-data misfit J during an optimization of coarse, fine and surrogate model. Numbers indicate the amount of run-time saving.Bottom: Different model trajectories.

Model

We study as example the nitrogen-based NPZD pelagic model (Oschlies Garcon, Global Biogeochem. Cycles 1999) for the tracers nitrate, phyto-, zooplankton and detritus, driven by circulation data from the OCCAM global ocean model.

Model Calibration/Parameter Identification

The aim is to minimize the model-data misfit between the aggregated NPZD model variables/tracers and given data, e.g. from the BATS data set.

Fast Optimization using a Surrogate

Surrogate-based optimization is a method to efficiently optimize complex models that require substantial computational effort already for a model evaluation. This is especially important in 3-D models. In the optimization algorithm, the original ("fine") model is replaced by a surrogate. The surrogate is created by employing a computationally cheaper, "coarse" model which is iteratively corrected or aligned by using only evaluations of the fine model.

Coarse Model

Here we use a coarse model with a time step increased by a factor of 40, while still remaining numerically stable. In general, it is also possible to use a coarser spatial discretization or simpler model equations.

Model Alignment

In every grid point, we apply a multiplicative correction to ensure that the surrogate exactly reproduces the fine model output in the point of alignment, i.e., the current parameter values in the optimization. It is assumed that this alignment still holds when the parameters are changed locally in the optimization.

Validity and Effectiveness Check

We show results performed with attainable, synthetic data and compare them to those obtained by a fine model optimization. They show a reduction in computing time of up to 95% while producing a reasonable optimal solution. For BATS data that are far from being attainable by the model, results are similar; a coarse model optimization already gives a comparable fit.

The authors would like to thank Andreas Oschlies.

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