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Multiobjective tuning of GENIE Earth system models

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In order to simulate at the multi-decadal time scale and beyond, climate models rely heavily on parameterisations of physical processes that occur on comparatively small time and spatial scales. A key concern in climate modelling is therefore to find appropriate values for these parameters so that a reasonable climatology is simulated. This is of particularly importance within the GENIE modelling framework where component codes, that are often developed independently, are coupled together to form new Earth system models. In order to produce stable and sensible model output it is almost always necessary to re-tune the parameters of the coupled system. However, as with many design problems, the nonlinear response of a model to its parameters and the often conflicting tuning objectives make this a difficult problem to solve.

The general problem of optimising a set of model parameters in order to improve a number of possibly conflicting design objectives is typically approached in one of two ways. One can create a single objective measure of design quality by computing a weighted sum of the individual objectives and seek to find the set of variables that minimise or maximise this measure. Many sophisticated algorithms can be applied to a single objective problem but the weighting factors can be critical in the performance of the optimisation. Alternatively, multiobjective methods can be employed to seek a Pareto set of non-dominated solutions; designs that are superior when all objective measures are considered but that may be inferior when a subset of those objectives are considered. Such a solution set can inform the user of competition in the design goals and allows domain expertise to be applied to select the most appropriate parameter sets for further study.

We present the results of applying a multiobjective Non-dominated Sorting Genetic Algorithm (NSGA-II) to tune two models from the GENIE framework. The genie-eb-go-gs (3D frictional geostrophic ocean model, 2D energy moisture balance model and 2D sea-ice) and genie-ig-fi-fi-ml (3D atmosphere, 2D fixed ocean and sea-ice and land surface) models are tuned to appropriate target data sets by minimising multiple measures of model-data mismatch across different physical fields. Grid computing is exploited to perform the large number of concurrent simulations that comprise the generations of the algorithm. Recent advances in the method use Response Surface Modelling (RSM) to provide surrogate models of the underlying objective functions. These RSMs can be searched much more cheaply and extensively to provide considerable performance improvements in the optimisation.