Who we are

- Macedonian Academy of Sciences and Arts
- Royal Netherlands Meteorological Institute
- Radboud University
- University of Bergen
- Institute Joseph Stefan
- Potsdam Institute for Climate Research
- University of Miami

Contact Us

Email: sumo@manu.edu.mk
Web: http://www.sumoproject.eu/

Supermodelling by combining imperfect models - SUMO

A GUIDE TO NOVEL STRATEGY FOR CLIMATE MODELLING
What is SUMO?

SUMO is a novel concept for improved modelling. It is also a project supported by EC, FP7 FET Open programme. It is a pilot project that served to demonstrate the great potential of supermodeling to improve global climate model simulations and lead to more reliable climate model projections.

Climate scientists are faced with the challenge to provide society with credible scenarios of future climate change. At a dozen or so institutes around the world, comprehensive climate models are being developed and improved. Over time, the capability of these models to simulate the observed climate has improved due to increased spatial resolution and better descriptions of unresolved processes, but large systematic errors remain and the models are still far from perfect. Nevertheless, these models are used to make climate change projections, which are used to inform policy.

How to combine the outcomes of these different models to get the most realistic estimate of climate change? Common practice is to form a weighted average of model outputs. It is a posteriori approach as the multi-model ensembles are constructed after performing the climate simulations or predictions. We put forward a different computational strategy that combines ideas from the machine learning, dynamical systems and climate science. SUMO proposes an interconnected ensemble of imperfect models of a real, observable system. The connections between the models are “learned” from observations to combine the strengths of the individual models and create a model that outperforms them. With SUMO is paved the way for creating improved climate models from an ensemble of state-of-the-art climate models trained to reproduce the observed, historical evolution of the climate system. SUMO combines the different models as the simulation or prediction evolves. It is thus a priori approach, and is unique and markedly different from the standard a posteriori approach.

Supermodel of global spectral quasi-geostrophic atmospheric model on the sphere. Mean fields are similar to unconnected ensemble mean while the standard deviation is improved in two versions of SUMO: connected SUMO and weighted SUMO.
SUMO has developed methods for computational scientific discovery that can learn supermodels (interconnected ensembles of models) of dynamical systems. This involves generation of diverse candidate models, selection of models for the ensemble, and selecting a method to combine the models and their predictions.

We have developed machine learning methods for learning ensembles of models, including candidate model generation, selection, and combination. The ensembles contain models with different structure and allow for making predictions of system behaviour.

### Interconnected ensemble of models

Learning the connections

For climate modelling one could assume: diverse candidate models are known (selected), selection of the models for the ensemble has been done, and the method to combine the models is selected (and it is linear algebraic equation). The next question is how to learn the coupling coefficients.

Both machine learning methods and strategies based on physical insight and mathematical arguments for leaning coupling coefficients have been developed.

For purely imperfect models (with smaller complexity than the ground truth) the supermodel shows skill improvement for short-term prediction when learning is also based on short-term prediction. However, for long-term statistics (e.g. the attractor) the results may deteriorate. Attractor learning may be necessary, but is tedious due to computational cost and local minima.

The climatology sea surface temperatures (SST, left panel, scale in °C) and precipitation (right panel, scale in mm/day) of observation (top), SUMO (middle) and models (bottom). SUMO offers improved SST and precipitation prediction over the equatorial region compared to the COSMOS model.
Supermodeling with climate models

A super climate model for the tropical Pacific was produced through partial synchronization of two Atmospheric Global Circulation Models (AGCMs) that were coupled to a single ocean model (i.e., an interactive ensemble). The model outperformed the individual coupled models, and the ensemble mean. The improvements appear related to better representation of ocean-atmosphere interaction. Performing historical simulations and developing a supermodel using a different climate model with higher model resolution showed the robustness of the strategy.

Climate change projections were performed and the results of the supermodel were shown to differ markedly over the tropical Pacific. The supermodel simulated a general weakening of the tropical circulation and an El Niño like warming. The individual models showed a La Niña like pattern and a shift tropical circulation.

A trans-Atlantic climate supermodel has started to be developed. The existing interactive ensemble for the National centre for atmospheric research (NCAR) family of models is enhanced so that multiple atmosphere, land and ice component models can be simultaneously coupled to a single ocean component model. Now, any AGCM (whether or not it includes an independent land or ice component model) can be incorporated into the interactive ensemble in a multi-model sense, and inclusion of the European AGCM ECHAM5 was tested.

Beyond Climate Modelling

In terms of predictive performance, interconnected ensemble of models perform clearly better than individual models as evaluated on several aquatic ecosystems.

Global surface temperature from observations and simulations with two Global Coupled Models COSMOS (T), COSMOS (N) and a supermodel (SUMO). The models are forced with greenhouse gas forcing following historical observations and the IPCC5 RCP8.5 scenario. **SUMO predicts an increase of 4.5° by the end of the century.**