Supermodeling by combining imperfect models

SUMO

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SEVENTH FRAMEWORK PROGRAMME

EUROPEAN COMMISSION

THE SUMO PROJECT

- A novel computational strategy to combine existing models that give divergent climate change projections.
- A super model is an interconnected ensemble of existing imperfect models of a real, observable system.
- The connections between the models can be learned from observational data using methods from machine learning.
- New combination of insights from climate science, nonlinear dynamical systems, and machine learning.
- Supermodeling can potentially be applied to any collection of alternative real-time models of the same objective nonlinear process e.g. financial, ecological, or biological models.

ILLUSTRATION OF THE SUPERMODELING CONCEPT

The Lorenz equations are given by:

$$\frac{dx}{dt} = \sigma(y-x)$$
$$\frac{dy}{dt} = x(\rho-z)-y$$
$$\frac{dz}{dt} = xy-\beta z$$

	σ	ρ	β
Truth	10	28	8/3
Model 1	9	31	13/6
Model 2	8	30	19/6
Model 3	12	25	71/30

Three imperfect models are obtained by perturbing the parameters as indicated in the table. A supermodel is then formed by connecting the three imperfect models

$$\frac{dx^k}{dt} = \sigma^k(y^k-x^k) + \sum_{l\neq k} C_x^{kl}(x^l-x^k)$$
$$\frac{dy^k}{dt} = x^k(\rho^k-z^k)-y^k + \sum_{l\neq k} C_y^{kl}(y^l-y^k)$$
$$\frac{dz^k}{dt} = x^k y^k-\beta^k z^k + \sum_{l\neq k} C_z^{kl}(z^l-z^k)$$

With *k=1,2,3*

The connections are learned by minimizing a cost function over the average value of the imperfect models and the truth:

$$F(C) = \frac{1}{K}\sum_{j=1}^{K}\int_{t_j}^{t_j+\Delta t}\left((x_m(C,t)-x(t))^2+(y_m(C,t)-y(t))^2+(z_m(C,t)-z(t))^2\right)dt$$

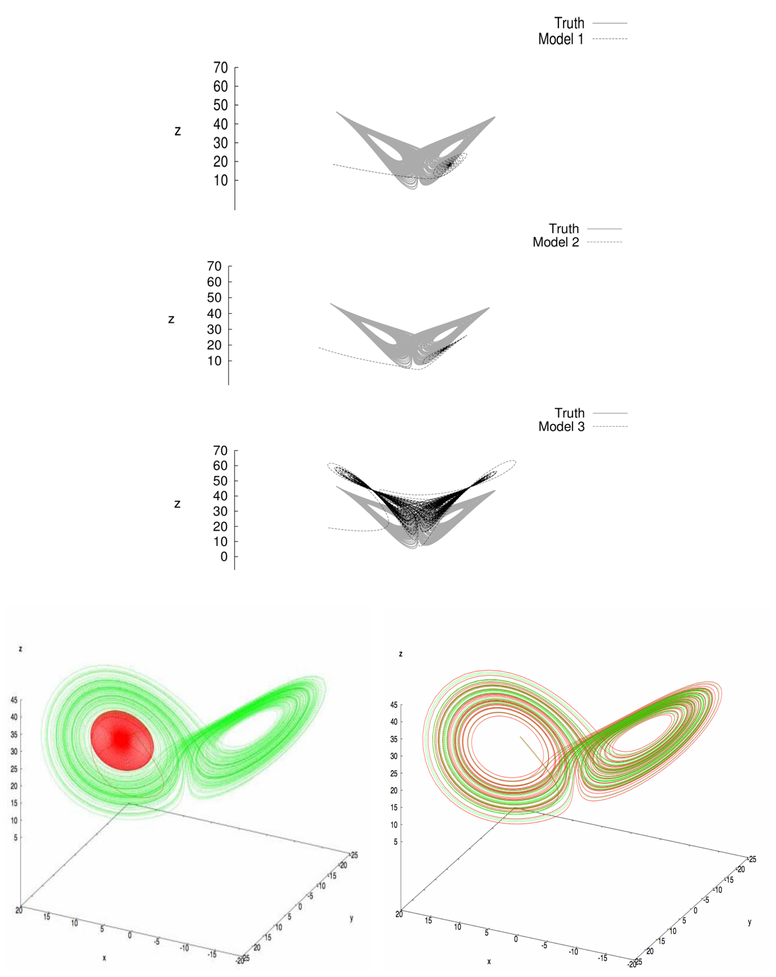
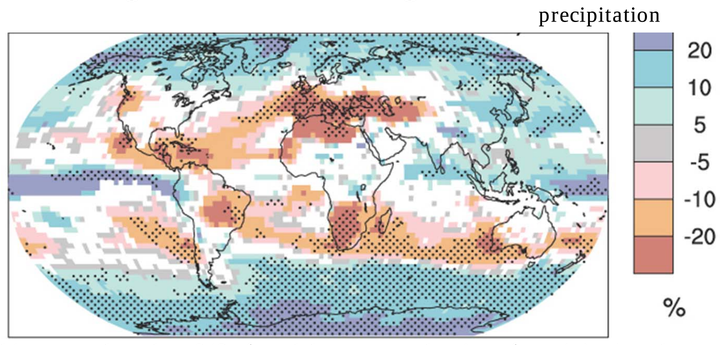


Figure 1. The solution for the true Lorenz equations is plotted in green in both panels. In the left panel the red trajectory denotes the solution of the supermodel with connections set to unity and in the right panel with connections learned

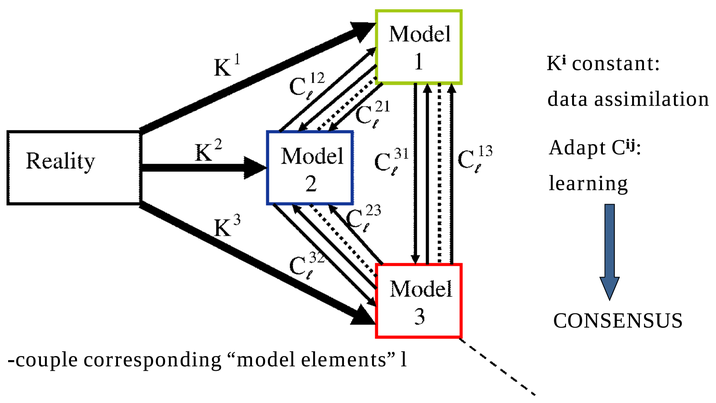
PROBLEM AND POTENTIAL SOLUTION

Problem: IPCC-class models give widely divergent predictions . Example is the divergent model projections of regional climate change:



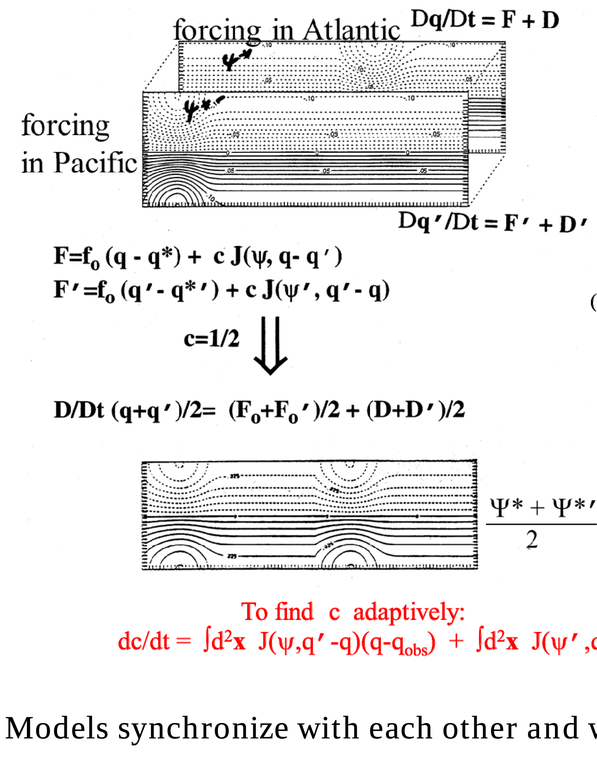
White areas: less than 2/3 of models agree on the sign of precipitation change.
Stippled areas: more than 90% of models agree on the sign

Potential solution: Take the synchronization view of data assimilation and allow models to form a consensus (synchronize) by assimilating data from one another.

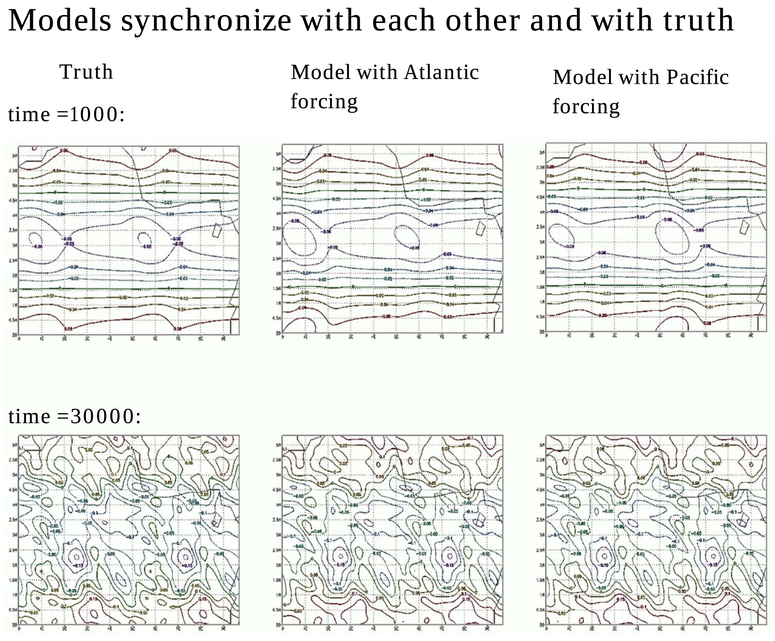


ADAPTIVE FUSION OF TWO DIFFERENT CHANNEL MODELS

If the parallel channels synchronize, their common solution also solves the single channel model with the average forcing.

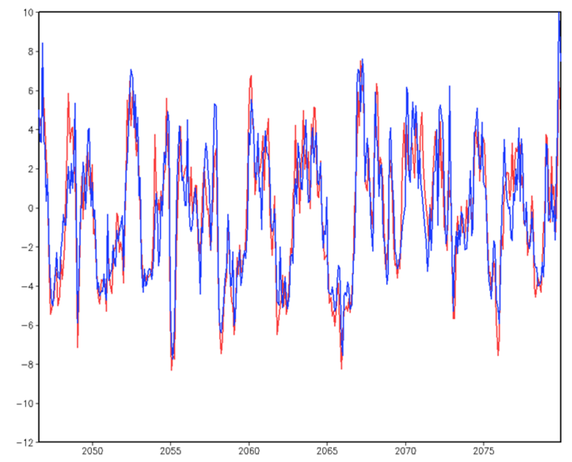


Models synchronize with each other and with truth

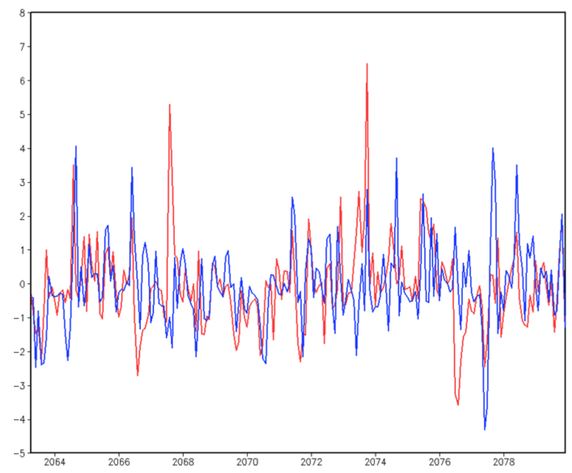


THIS CAN WORK FOR LARGE MODELS

Two atmospheric general circulation models (AGCMs) coupled to a common ocean model (OGCM) tend to synchronize remote precipitation patterns



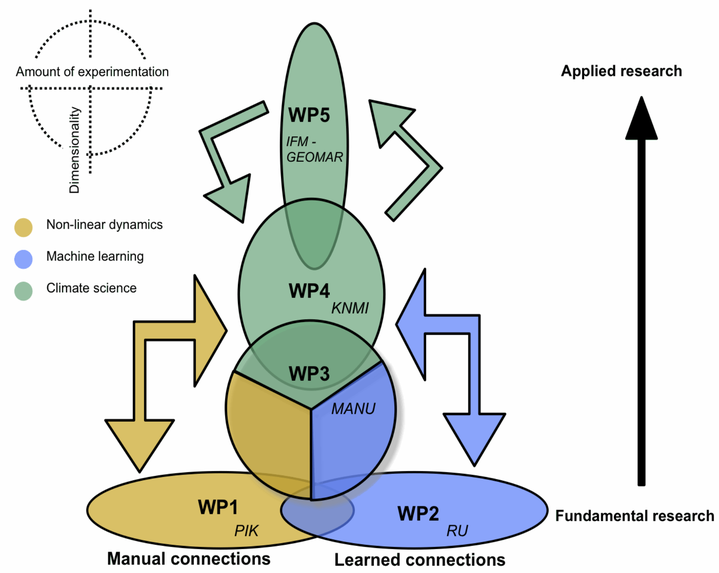
Pacific



Indian

OVERAL STRATEGY

In SUMO we adopt a hierarchical approach in the form of 5 work packages, as reflected in the graphical representation of the nature of interconnections between the five work packages.



- WP1—General theory of supermodeling with ODE systems
- WP2—Learning connection coefficients in ODE systems
- WP3—Learning of connection coefficients in PDE systems
- WP4—Supermodeling with intermediate complexity climate model
- WP5—Supermodeling large climate models

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www.sumoproject.eu

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