Dynamical Models - Purposes and Limits

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The term „model" is used in most disciplines, but often with a rather different meaning. Here, "dynamical models" refer to mathematical systems which allow to determine the temporal change conditional upon the state and upon constraints/forcing.

Dynamical models are simplified representations of a real world system; they vary in complexity and with respect to the represented and non-represented components of the full system. Models are constructed as a means to add knowledge about the real world. In that sense, models are mostly not "models of" but "models for".

The two major purposes of models are "**experimental**" and "**explanatory**". The former are complex, often of maximum complexity given the computational resource. Complex CMIP-type climate models are in this group. They are used for numerical experimentation, simulation of variability, reconstructing past changes, forecasts, scenarios but also for extending limited observational evidence (data assimilation). The latter are simple, often of minimum complexity with very few variables, of the "back-of-the envelope"-type. The simple mathematical set-up of such a model itself constitutes knowledge and understanding about the dominant dynamics of the considered system.

The signal-to-noise model as well as energy-balance models belong to this group.

"Experimental models" are engineering devices, which do not directly generate understanding about the modelled system, but only numbers. However, with suitable processing of the output, by projecting on explanatory (often statistical) models, such understanding can be constructed. Thus, the full power of such models is obtained only if explanatory models are employed for analyzing the output.

"Explanatory models" reduce the complexity of the system by considering only a few components, often mere two. They do not return detailed descriptions of observable change but describe the interaction between dominant processes

and their significance for change. Such models may be used to construct hypotheses, which later may be tested with “experimental” models.

However, “experimental” models cannot strictly prove anything about the real world (apart of computational issues). Demonstrating the validity of dynamical models must be done by attempted falsification. The falsification can aim at the structure of an “experimental “model, and try to determine contradictions in the choice of variables, and in the unavoidably parameterizations. However in most cases, the falsification consists of comparing the model output (simulation) with the observed record. In that case it is not the model which is falsified, but the simulation, which is based on both the model and the experimental set-up. When significant inconsistences of the model’s output and observations are found, which are of relevance for the modelling purpose (the intended added value), the experimental set-up is considered an invalid image of reality.

Even though sometimes people consider a model as an “objectively derived” mathematical object, derived by adequate numerical methodology from a set of differential equations, most models are the result of subjective decisions, in particular with respect to the selection of processes, which are a parameterized, and the details to the chosen parameterizations. Also, attempts of falsification are also based on subjective choices.

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