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Models and Simulations in Geosciences

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In geosciences, since scientists can seldom intervene in their research objects, what can be experimented are limited. For example, intervention in past objects is impossible in principle, and intervention in macroscopic objects such as planets and the Earth's interior is (in most cases) technologically impossible. Such objects also can not be observed directly or their observational data are often insufficient. Therefore computer simulations play significant roles in geosciences.

Winsberg(1999) analyzed the processes in which simulationists construct the model of the phenomena from theory, and found that simulations are not simple deduction, have motley methodology, and do not admit full comparison with data from observations or experiments. He then stressed the importance of problems of why or when or to what extent simulation results are reliable, arguing for the need of "the epistemology of simulation" (after "the epistemology of experiment" of Franklin (1986)) as "the study of the means by which we sanction belief in the outcome of simulation studies".

In this presentation, we address this epistemology of simulation, and clarify the points simulationists should pay attention to and the tactics they use to justify their results.

We summarize the way geoscientists justify their simulation results. The justification has two steps; validation of models and verification of numerical computation. For validation of models, the points are such as (1) being formulated based on well-confirmed physical processes, and (2) grounded on past researches. As verification of numerical computation, simulationists use (1) agreement with strict solutions in simple cases, (2) high theoretical precision of numerical algorithms, (3) convergence to the extent that results do not change when the size of computational grid is reduced, and (4) agreement with other codes in benchmark computation. Justification which involves both is (1) consistency with observational results, (2) stability of results when parameters and initial conditions are changed.

We also analyze from case studies in geosciences, approximations and idealizations, or combination of simulations and observations, examining their implications to the problem "how should we consider the epistemological status of simulation (compared with observation and experimentation)?".

Keywords: philosophy of science, simulation, model