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Using gradient descent with a perfect model of the rotating annulus

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The existence of *shadowing trajectories*, model trajectories consistent with a sequence of past observations of a system, is a desirable property of any predictive model. Techniques for finding such trajectories are, to some extent, understood in low-dimensional systems such as the Lorenz equations, and there is significant interest in their application to high-dimensional systems such as general circulation models (GCMs). Gradient descent of indeterminism is one such technique, and it is well-established for finding shadowing trajectories of low-dimensional analytical systems. It has also been used for state estimation in some limited experiments with an idealised quasi-geostrophic model (Judd et al. 2004, Physica D, 190, 153) and with the NOGAPS weather model (Judd et al. 2008, J. Atmos. Sci., 65, 1749). Its ability to find model trajectories that shadow observations for a long time in high-dimensional models of real systems is not yet well explored.

We apply gradient descent to a model of the thermally-driven rotating annulus laboratory experiment, a system intermediate in model complexity and physical idealisation between low-dimensional analytical systems and high-dimensional GCMs. We report on some preliminary results from applying gradient descent to the annulus under the controlled conditions of the perfect model scenario. Starting from a sequence of noisy observations combined with a model, our demonstration shows that a sequence of states close to the true system trajectory is recovered.

The laboratory setting allows investigation of the properties of gradient descent using a real physical system and a non-idealised model in a situation where the complexity of the flow can be controlled, the experiments can be repeated, and where there is potential for long-range observations under laboratory conditions. We hope to extend this work to laboratory data, which will allow us to determine how well models of the rotating annulus reproduce observations, and hence improve our fundamental understanding of this system. We also hope to inform the use of gradient descent with high-dimensional GCMs by determining whether it is a feasible method for finding shadowing trajectories in a real physical system.