Geophysical Research Abstracts, Vol. 9, 10361, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-10361

A Realtime Laboratory Observatory for Data Assimilation Research

S Ravela, J Marshall, S Stransky, A Wong, C Hill
Massachusetts Institute of Technology

Motivated by the state estimation problem in meteorology and oceanography, we build an observatory for a laboratory analog of planetary circulation. The well-known analog of planetary circulation is a thermally-driven unstable rotating flow. A rotating annulus with a cold center (core) and warm periphery (exterior) forms an unstable flow with a circulation that is dynamically similar to the mid-latitude circulation in the atmosphere.

Our observatory has (A) Sensors to take measurements of the evolving physical system, (B) a numerical model trying to forecast this physical system, and (C) inference algorithms that can constrain the model. The challenges in the laboratory system are similar to the large-scale problem in at least four ways. Nonlinearity: The dynamics are nonlinear and the numerical model is the same as planetary simulations. Dimensionality: The size of the model-state is of the same order as planetary simulations. Uncertainty: The initial conditions are unknown, and the model is imperfect relative to the physical system. Realtime: Forecasts must be produced in better than realtime.

The apparatus consists of a perspex annulus placed rigidly on a rotating table. The annulus has inner radius 8cm, outer radius of 30cm, and is filled with water 15cm high. A robotic arm by its side moves a periscopic mirror arrangement to illuminate a horizontal sheet of the fluid at any depth of the fluid with laser light. An Imperx camera acquires 12-bit quantized, 1Kx 1K images and this data is transported out of the rotating frame using a fiberoptic rotary joint (FORJ).

The physical simulation is begun with fluid homogenized by neutrally buoyant particles. We then spin the rotating platform, with a rotation period of 0.6 seconds. After some time the fluid entrains itself to the rotation and enters into solid body rotation. Then we add ice to the inner core, which is usually a metal coffee-can with some dead-weight to hold it down. Within minutes the circulation starts to form.

A system acquires particle images and ships them to two processors that compute velocity in parallel, in realtime. Flow vectors are passed to an assimilation program that combines them with forecasts to estimate new states. These estimates become new initial conditions for the models. Both model and assimilation is in realtime. We use the MIT-GCM and a two-stage assimilation scheme that produces useful estimates in realtime. The assimilation method uses a novel scheme presented separately in this venue and builds on one presented last year; it combines a scale-spase ensemble filter with time snapshots of model states to generate ensembles.

We believe that this successful demonstration of realtime data-assimilation is the first of its kind, building on previously presented incremental progress at this venue. It is immediately useful to study assimilation issues, sans the necessity for toy-models or other identical twin experiments. Because the issues in the laboratory analog are so similar to the large-scale problem, we believe that this testbed will be a useful data-source for other researchers.

There are other exciting possibilities that open up with the proposed observatory. As the numerical model faithfully tracks the physical system, properties of the fluid that cannot easily be observed can be studied using the model including tracer transport and effective diffusivity. For weather prediction state estimation algorithms, characterizations of model error, targeting observations can all be studied and results reported will be credible.