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Climate Change and The Trillion-Dollar Millenium Mathematics Prize Problem

Abstract: Climate change has been referred to as the defining issue of our age. Formulation of international policy to mitigate climate change and national strategies to adapt to climate change, each depends critically on reliable predictions of climate over the coming century, both globally and regionally. For example, how will climate change affect the frequency and intensity of drought, flood and storms. Collectively, climate change is a trillion-dollar problem?

From a mathematical point of view, climate is a very large dimensional chaotic system comprising the partial differential equations associated with the basic physics of a turbulent multi-phase fluid, interacting with representations of specialised biogeochemical processes. Many of the uncertainties in predicting large-scale climate change are associated with the amplification of the direct radiative forcing from increased anthropogenic emission of greenhouse gases with small-scale cloud processes associated with individual kilometre-scale weather systems. Examples will be shown.

These small-scale weather systems are only poorly simulated in the current generation of climate models. However, increasing the resolution of models in order to simulate such systems well would require dedicated multi-petaflop computing facilities. In order to make the case for governments to invest in such dedicated computing facilities, climate scientists need to quantify how simulations of climate converge to truth as the resolution of the climate models increases.

As will be discussed, the Clay Mathematics Navier-Stokes Prize Problem indicates that our theoretical understanding of the convergence of solutions of three-dimensional fluid equations is still poor. Indeed, in view of the finite-time upscale propagation of error associated with scaling arguments applied to the 3D Navier-Stokes equations, there is a strong case for developing explicitly stochastic mathematical models of climate. Examples will be discussed.