Title

Honours Research Project Proposal

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Abstract

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1 Introduction

The Earth system (including atmosphere, ocean and land) is distinguished both in its complexity and its influence on all terrestrial life. If the wellbeing of humanity in particular is to be preserved, it is difficult to overstate the importance of understanding and predicting this system's behaviour—both short-term weather and long-term climate. This understanding and predictive skill informs important decisions and government policies that have the potential to reduce our vulnerability to extreme events (e.g., floods, droughts, fires, tropical cyclones) and long-term climate change, and lessen negative human impacts (e.g., greenhouse gas emissions) to sustainable levels.

A significant part of our understanding and predictive skill is derived from numerical modelling of the Earth system. Like many other models, these aim to predict the time evolution of an initial state (e.g., pressure, temperature, wind velocity in the atmosphere) given a set of boundary conditions and external forcings. Unfortunately, there are many obstacles to accurate modelling. Arguably the most fundamental of these is chaos: even with a perfect model and unlimited computing resources, arbitrarily small differences in initial conditions grow exponentially. This constrains short-term predictability. Second, the Earth system comprises a vast number of interacting components, such as water in all three phases, solar radiation and clouds (just to name a few which are relevant to atmospheric modelling). In other words, the system is high-dimensional. Third, the dynamics occur on a wide spectrum of spatial and temporal scales. These range from large-scale, slowly-evolving motions such as ocean gyres and the atmospheric Hadley circulation, to mid-scale, transient weather systems (termed synoptic-scale) and ocean eddies, to small-scale wind gusts, tornadoes, water waves and turbulence. All scales and their cross-interactions influence the overall dynamics.

Atmosphere and ocean models solve the differential equations that govern fluid flow with a finite spatial and temporal resolution and are therefore only able to resolve behaviour whose scale is of the same order of magnitude as the resolution or larger. The achievable resolution is constrained by the capabilities, availability and cost of modern computing resources. A typical atmospheric global climate model has a spatial resolution on the order of 1° latitude/longitude, roughly corresponding to the size of the entire Greater Sydney area from Katoomba to Bondi. Sub-grid scale features, such as invidual clouds, cannot be explicitly resolved, but to ignore them completely would introduce unacceptable biases (inaccuracies, relative to observations) in the model output. The same is true for the numerous components of the Earth system that influence the fluid dynamics but are not directly predicted by the fluid equations, such as solar radiation and land interactions (e.g., moisture and heat fluxes from vegetation, soil and water bodies).

The process of using the information available in the model to estimate the effect of these unresolved processes on the coarse-scale variables is known as *parametrisation*, which will be the topic of the thesis. Traditional parametrisations are often based on heavily simplified conceptual models of the processes in question. For example, the Community Atmosphere Model (Neale et al. 2010) parametrises atmospheric convection by considering an ensemble of rising updraft plumes, making assumptions about their mass flux and initiation conditions (Zhang and McFarlane 1995). It is now known that these methods may under-predict the variance and extreme values of their outputs (e.g., precipitation). This is detrimental to predictions of future climate and climate extremes.

2 Proposed methods

3 Preliminary results