Monsoon-ocean interactions in a changing climate

University of St Andrews, Earth and Environmental Sciences

In partnership with Durham University

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Overview

Monsoons are summertime weather systems that deliver water to half of the world's population (Figure 1). Monsoon rainfall is essential for agriculture and water resources in many densely populated regions. Monsoons have changed in the past — Asian monsoon rainfall, for example, has fallen by 5% over the last 50 years — and are expected to change dramatically in future decades because of global warming. However, exactly how monsoons will respond to climate change is unclear: State-of-the-art climate models struggle to accurately simulate monsoons and predictions of future monsoon behaviour are highly uncertain. This uncertainty remains stubbornly large, despite the development of more complex and higher-resolution climate models, making it impossible for monsoon regions to prepare for the impacts of climate change.

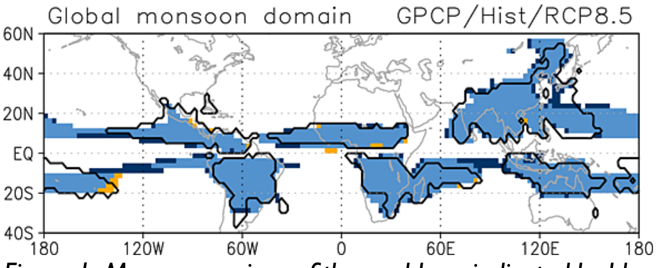

Figure 1: Monsoon regions of the world are indicated by blue shading (from Kitoh et al [2013]).

During this project, you will take an entirely new approach to reducing uncertainty in the monsoon response to climate change. Instead of relying on imperfect state-of-the-art climate models, you will instead use novel idealised simulations to transform our fundamental understanding of monsoon-ocean interactions and their role in shaping the response of monsoons to future climate change.

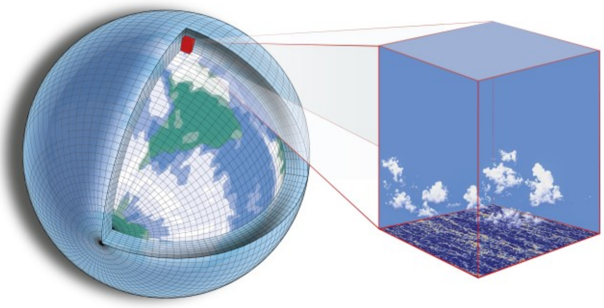

Figure 2: Schematic of a global climate model. This project will use novel climate simulations to better understand how oceans influence monsoons. Graphic courtesy of Prof. Tapio Schneider at Caltech.

Methodology

Monsoons are strongly connected to the oceans through exchanges of heat, water, and momentum, and are dynamically tied to the sea-surface temperature distribution. However, despite these intimate physical connections, the role of oceans in the monsoon response to climate change is largely unknown and has not been systematically investigated. The objectives of this project are:

1. To transform our physical understanding of monsoon-ocean coupling using novel idealised climate-model simulations focused on key coupling processes including wind-driven Ekman transport, wind-induced surface heat exchange (WISHE), and buoyancy-driven ocean circulations.

2. To apply new insights into monsoon-ocean interactions to narrow the large uncertainty in future monsoons projections from state-of-the-art CMIP5 and CMIP6 climate models.

For objective 1, the student will perform novel climate simulations using the Community Earth System Model (CESM). These simulations will be designed to investigate how individual atmosphere-ocean coupling processes affect monsoons and their response to climate change. For objective 2, the student will analyse monsoon rainfall and circulation dynamics in state-of-the-art climate simulations from the CMIP5 and CMIP6 data archives, with the aim of narrowing the large uncertainty in future monsoon changes.

Timeline

Year 1 will involve a literature review to allow the student to develop their understanding of monsoon dynamics and physical aspects of climate change. The student will also start using the CESM climate model and setting up the simulations to examine monsoon-ocean coupling. The student will attend a training course on how to run the CESM model at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

Year 2 will focus on (a) running the set of idealised climate simulations to investigate monsoon-ocean coupling and (b) analysing the results. The student will draft a research article on this portion of the project and will present the key results at the American Geophysical Union's annual meeting in San Francisco.

Year 3 will involve applying the insights into monsoon-ocean coupling developed in Year 2 to state-of-the-art climate simulations from the CMIP5 and CMIP6 archives. This will involve substantial Big-Data analyses with the objective of narrowing the large uncertainty in future monsoon projections. The student will attend and present their research at an international conference on monsoon dynamics.

Year 3.5 will focus on writing the PhD thesis and drafting a research article on the analyses conducted during Year 3.

Training & Skills

The student will be trained on several aspects of physical climate science including atmosphere & ocean dynamics, air-sea coupling, and climate change. The student will also be trained in highly sought-after technical skills in computational modelling, high-performance computing, and Big-Data analyses. The student will attend a training course on using the CESM climate model at NCAR in Boulder, Colorado.

References & Further Reading

[1] Kitoh et al. (2013): *Monsoons in a changing world: A regional perspective in a global context.* Journal of Geophysical Research: Atmospheres (doi: 10.1002/jgrd.50258)
[2] Turner & Annamalai (2012): *Climate change and the South Asian summer monsoon.* Nature Climate Change (doi: 10.1038/nclimate1495)
[3] Bordoni & Schneider (2008): *Monsoons as eddy-mediated regime transitions of the tropical overturning circulation.* Nature Geoscience (doi: 10.1038/ngeo248)
[4] Codron (2012): *Ekman heat transport for slab oceans. Climate Dynamics* (doi: 10.1007/s00382-011-1031-3)

Further Information

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