Severe weather over Southeast Asia: fieldwork and modelling

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Met Office CASE eligible

Science background

The Maritime Continent in Southeast Asia is a key region in the global weather and climate system. Its complex island geography and position among the warmest oceans on Earth lead to a multi-scale concoction of severe atmospheric convective and dynamical weather systems (Figure 1). The atmospheric response to this heating affects weather and climate across the Earth.

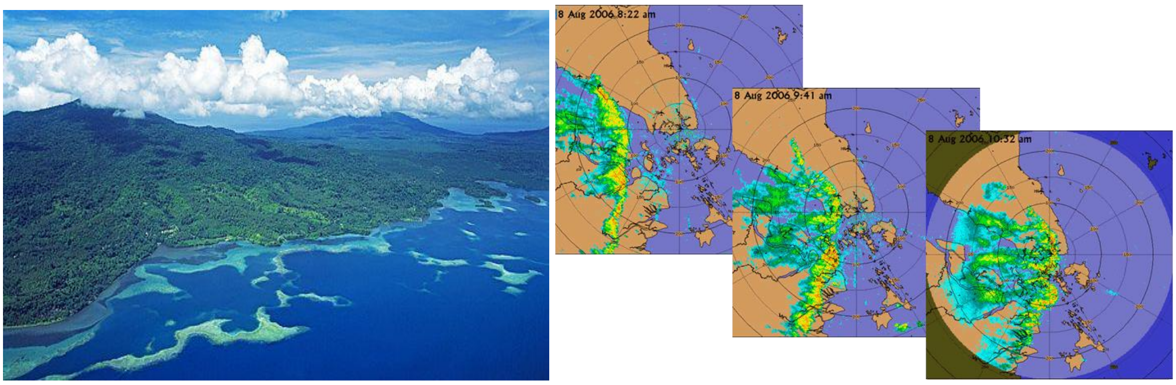

Figure 1: Typical landscape of Java, Indonesia (left) and radar imagery of a squall line over Singapore on 8 August 2006 (right).

The diurnal cycle is the fundamental building block of organised convection over the Maritime Continent. Conceptual models suggest that convection is initiated inland of the coastlines during the late afternoon due to upslope mountain winds and sea breeze convergence. During the night, a combination of downslope mountain winds, the land breeze and gravity waves causes the convection to propagate offshore and become more organised (Mori et al., 2004; Qian, 2008), producing a distinct diurnal cycle that is common to many of the islands. These conceptual models have not been tested using detailed observations, and the interplay between the processes is not well understood.

There are major knowledge gaps in our understanding of the processes within this multi-scale system due to difficulties modelling the tropical atmosphere and ocean over such complex geography, and a dearth of suitable observations against which to evaluate models. This lack of understanding is a significant limitation to regional weather forecasting, medium-range forecasting of the mid-latitudes and climate projections. Figure 2 shows the observed mean precipitation for the southern hemisphere monsoon season (November-April) and the regions were the Met Office climate model error is greater than 2 mm/day (up to 25% of the total rainfall).

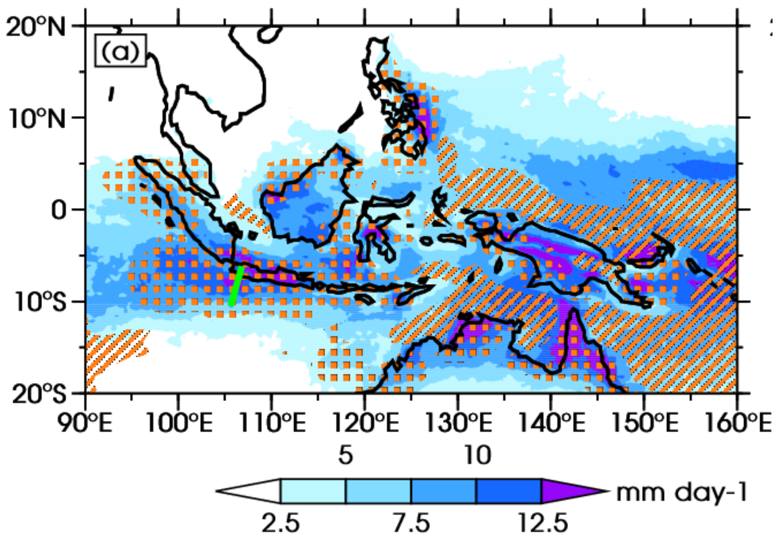

Figure 2: Observed mean precipitation for November-April (shading) and Met Office climate model error (squares below –2 mm day-1, diagonal shading above +2 mm day-1).

Fieldwork

There is a unique opportunity for the student to participate in and use the data from a major international field campaign on Java, Indonesia and Christmas Island between November 2019 and February 2020. The 5 year NERC-funded research programme "TerraMaris: The Maritime Continent – Driver of the Global Climate System" will make the field observations as a contribution to the major international initiative "[Years of the Maritime Continent]". There will be two ground-based supersites on Java and Christmas Island (NCAS X-band Radar, 3 hourly radiosondes, flux towers, radiometer, lidar etc) and oceanography measurements in the ocean between the two sites (Figure 3b). The [BAe146 FAAM research aircraft] will be based in Jakarta on Java and will make measurements between there and Christmas Island (Figure 3b). TerraMaris is a collaborative project between UK Universities, the Met Office and the Indonesian Weather Service (BMKG).

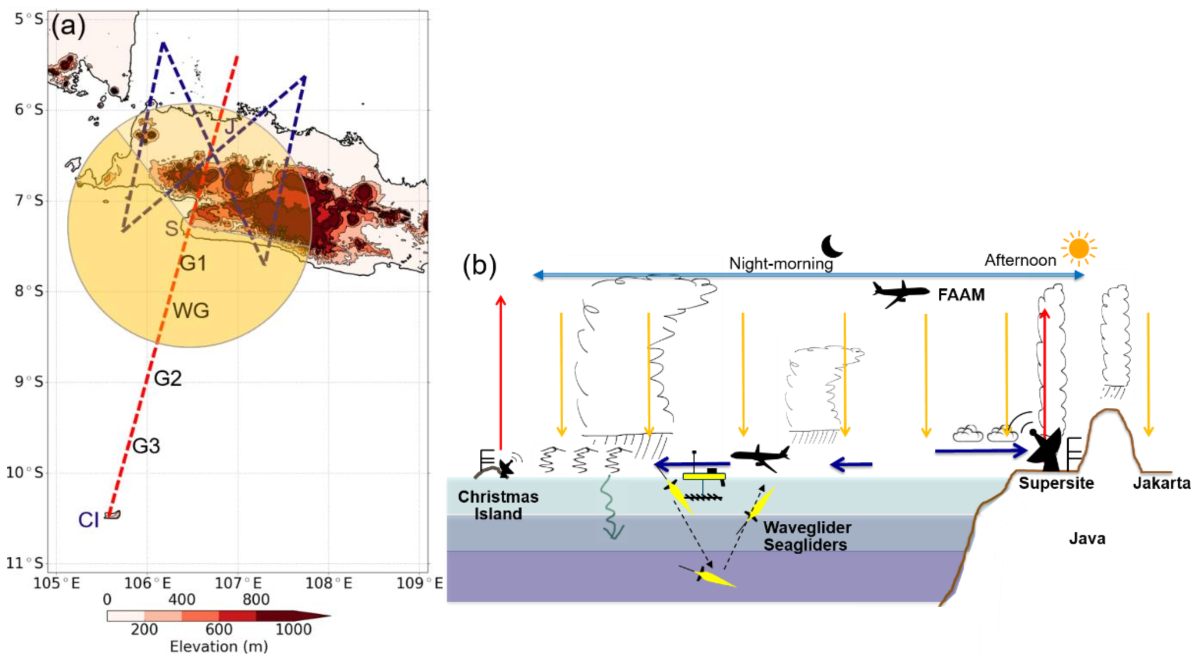

Figure 3: Outline of TerraMaris field campaign Nov 2019-Feb 2020 (a) Proposed flight path (red dashed line) for the BAe-146 research aircraft between Java, Indonesia and Christmas Island and

(b) the suite of observations on the Java to Christmas Island transect designed to measure the diurnal cycle of storm initiation and propagation.

Objectives

This PhD project provides a unique and attractive opportunity for a student to take part in a major international field campaign, develop understanding of convective processes and use the observations to evaluate and improve the suite of Met Office models. Specifically, the project will address the following science questions:

- What is the role of upslope mountain flows and sea-breeze convergence in initiating convection over the Maritime Continent islands?
- What is the relative role of land breezes, storm outflows, and gravity waves in controlling the offshore propagation of convective systems?
- How does the atmospheric boundary layer develop over land through the diurnal cycle? How does this interact with the maritime atmospheric boundary layer?
- How does propagating convection that originates over land interact with convection originating from the open ocean?
- How do low-frequency modulations of the background state (e.g. variability in wind, large-scale vertical motion, environmental stability and humidity, and cloud through the Madden-Julian Oscillation) impact the diurnal cycle of Maritime Continent convection?
- How well do numerical weather models of varying complexity represent important processes relating to the triggering, organization and propagation of convection?

Student profile

The student should have a strong interest in environmental problems related to meteorology and climate, a strong background in a quantitative science (math, physics, engineering, environmental sciences) and a flair for, or a good familiarity with, programming and scientific computing.

Training

The student will work under the supervision of Dr. Cathryn Birch, Dr John Marsham and Dr Ryan Neely within the Atmospheric Dynamics and Cloud group in the School of Earth and Environment at the University of Leeds. This project will build on the group's expertise in tropical dynamical meteorology, extreme weather, observations and modelling research.

The student will receive a high-level of training in:
(1) dynamical meteorology and climate science
(2) field observations: remote sensing (such as radar), ground-based and airbourne
(3) the use of state-of-the-art model simulations and observational data sets to understand atmospheric processes
(4) research skills within a major international field initiative
(4) a computer programming language (e.g. Python)
(5) effective written and oral communication skills.

There will be the opportunity for international travel to conferences and for research visits to other universities, such as Monash University in Melbourne, Australia and Karlsruhe Institute of Technology (KIT), Germany.

Met Office Partnership

The Met Office are a key partner in the TerraMaris field programme. The student will be jointly supervised by Dr. Stuart Webster, an expert in convective-scale numerical weather prediction and Dr Paul Barrett, an expert in airborne observations at the Met Office.

The project is CASE award eligible, which would provide funding in addition to the NERC student stipend. The student would spend periods of time (perhaps 4-6 weeks per year) working at the Met Office in Exeter, where the Met Office will provide model data, model expertise and guidance on the use observations for understanding atmospheric processes and analysing the simulations.

References and further reading

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