Understanding how climate change affects the tropical rain belt over Africa and its variability

Dr John Marsham (SEE), Dr Dave Rowell (Met Office), Prof Doug Parker

Contact email: J.Marsham@leeds.ac.uk

The tropics cover 40% of Earth's area, include 36% of its land, and are home to 40% of its people. Africa is the continent with the largest tropical land mass, and its rapidly growing population includes many of the people who are most vulnerable to climate change. Rainfall in the tropics is dominated by the tropical rain band (Figure 1) that encircles earth. To first order the rain-band moves to follow the solar heating, to reach its northernmost extent in the northern hemisphere summer, and its southernmost extent in northern hemisphere winter. As a result this movement, rainfall from the tropical rain-band directly affects not only the lush tropical forests of the Congo, but regions such as the southern reaches of the Sahara. The rain-band's movement leads to the annual West African monsoon rains on which populations in the Sahel depend, and the bi-annual rains of East Africa, which vary enormously across the region from the highlands of Ethiopia to the deserts of Somalia. This PhD will use a range of state-of-the-art models and observations to understand how climate change affects the tropical rain-belt, with a focus on Africa, using and developing models of global change, together with regional models.

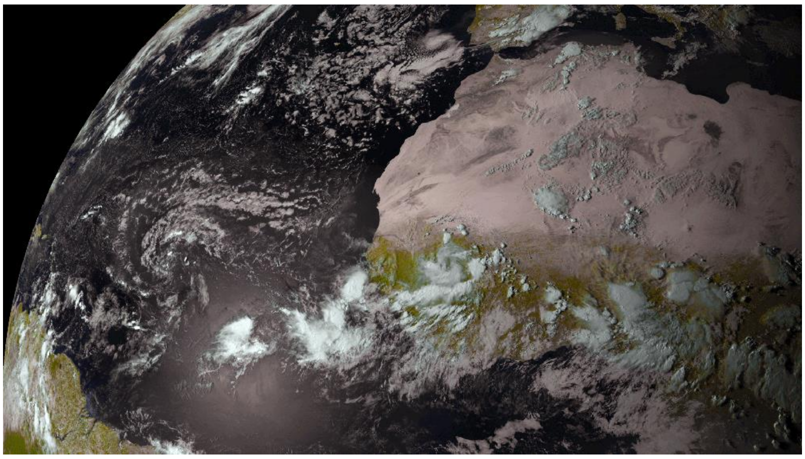

Figure 1: The tropical rain belt over West Africa and the Atlantic (image credit: NOAA NWS National Hurricane Centre).

Rain ascends in the tropical rain band, causing clouds and rain, and descends further north or south, causing the great deserts of the world, including the Sahara (the "Hadley circulation"). There is a diverse response of this rain belt from anthropogenic climate change in idealised models, exemplified in Figure 2, but also seen in simulations of the real world (e.g. Dunning et al., 2018). Understanding these changes and the processes governing them is made much more challenging by the fact that the cumulonimbus storms that generate the rainfall and provide the ascent in the rain-band are sub-grid in global models, which have grid-spacings of approximately 100km, so must be represented by simplifications known as parametrisations. Recently the £20 million Future Climate for Africa (FCFA) programme has run the first simulations, referred to as "CP4A", that have a small enough grid-spacing (approximately 4km) to explicitly capture these storms (Stratton et al., 2018). This fundamentally changes the representation of convection and rainfall, and so provides a unique opportunity for new understanding. This PhD will examine a range of observations and models, to generate new understanding of observed and modelled changes in the tropical rain band.

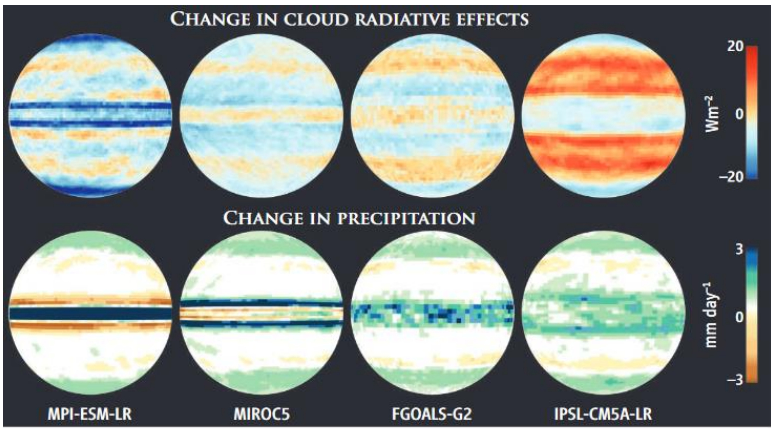

Figure 2: "The response patterns of clouds and precipitation to warming vary dramatically, depending on the climate model, even in the simplest model configuration. Shown are changes in the radiative effects of clouds and precipitation accompanying a uniform warming (4°C), predicted by four models from Phase 5 of the Coupled Model Intercomparison Project (CMIP5) for a water planet with prescribed surface temperatures" (from Stevens and Bony, 2013).

Objectives

Using observations and a range of models, including global analyses, idealised global aqua-planet simulations, AMIP (Atmospheric Modelling Intercomparison Project) simulations of past global climate and CMIP (Coupled Model Intercomparison Project) simulations of past and future global climate, with unique new regional CP4A simulations to understand and quantify:

(1) How climate change affects the tropical rain-band in models, especially over Africa, and how this depends on internal atmospheric processes, and coupled processes such as land and ocean change;
(2) How an explicit representation of convection affects these changes;
(3) How changes seen in models relate to those observed in reality, and whether this can be used to constrain the diverse predictions from models.

Further objectives could include: (i) the role of non-greenhouse gas forcings such as aerosols and land-use change, (ii) changes in inter-annual, or intra-annual, variability, in mean rainfall or extremes.

Potential for high impact science

Changes in the tropical rain band are fundamental to regional climate change projections, and uncertainty in these projections is a limiting factor for long-term planning. The coupling of convection with circulation under climate change is highlighted as a grand challenge in the "Clouds, Circulation and Climate Sensitivity" Grand Challenge of the World Climate Research programme (WCRP). There is a lack of fundamental understanding of what controls change in the rain-band as highlighted by Stevens and Bony, 2013. Factors such as aerosol and land-use add further unknowns. The emerging signal of climate change in Africa (Taylor et al, *Nature*, 2017) and the convection-permitting runs of CP4A both provide new opportunities to understand change.

Training, Supervision and the Research Environment

You will join a large and dynamic team at Leeds, who have a strong record of highly cited publications, with opportunities to visit collaborators overseas, and potential for also gaining fieldwork experience. You will work under the supervision of Dr John Marsham who has published 84 papers in 13 years, and has recently been promoted to Associate Professor. He manages a large group working across African climate, weather, dust, moist atmospheric convection and associated fields, and his past PhD students have strong records of peer-reviewed publication. Co-supervisor at the Met Office, Dr Dave Rowell, is an expert in large-scale modelling of climate change and variability in the tropics, with a particular focus on the African climate system. Co-supervisor Leeds-Met Office Prof Parker is an expert in atmospheric dynamics and tropical meteorology, who has extensively studied the African climate system.

You will be working in a diverse institute (Institute of Climate and Atmospheric Science, ICAS) with dynamical meteorologists, aerosol modellers, chemists, climate scientists, and climate-impact specialists. The wider school (School of Earth and Environment, SEE) includes social scientists, and Leeds hosts the Priestly International Centre for Climate Change, water@leeds and the National centre for Atmospheric Science, enabling you to maximise inter-disciplinary opportunities, the reach of your research, and your own learning.

You will be encouraged to travel to share your findings and learn from other environments, including possible fieldwork on related projects (e.g.in Indonesia). Leeds is one of four Universities in the Met Office Academic Partnership, and ICAS has a formal partnership the Karlsruhe Institute of Technology (KIT, Germany), facilitating visits there, but there are also opportunities further afield, e.g. France and Australia. Projects such as GCRF Africa-SWIFT (https://www.ncas.ac.uk/en/swift-project) provide opportunities to engage with researchers and practitioners across the UK and Africa, e.g. in project meetings, forecast test beds and summer schools.

Environmental and atmospheric modelling is growing field and this PhD project will provide hands on experience with a world-leading models, and access to appropriate training, for handling the data and with the potential for running models as required for the research, as well as in wider skills (http://www.emeskillstraining.leeds.ac.uk/).

Student profile:

You will have a degree in a mathematical, physical or environmental science, and have some, but perhaps limited, familiarity with scientific programming, as the project will involve writing computer codes for data analysis. You will be interested in weather and climate, and the interface between them: a background in meteorology is useful but not essential, and excellent lecture courses in meteorology are available at Leeds University.

You will bring enthusiasm, the ability to learn how to use state-of-the art meteorological models and observational data, and the potential to understand some of the most pressing research questions in meteorology and climate science.

References

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