PhD Proposal – Contrasting the response of extreme precipitation and drought to aerosols and greenhouse gases

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Background

Extreme precipitation and drought events have a significant impact on our society. Flooding can cause severe damage to infrastructure, loss of life and long-term economic problems, while drought is a huge problem for the agriculture industry. With a changing climate the frequency, strength and location of extreme events is expected to change (see Figure 1) (Collins et al. 2013). Understanding how extreme precipitation is changing and what we should expect in the future is of vital importance. However projected changes remain uncertain and the physical processes not fully understood, particularly at regional scales.

Extreme heavy rainfall events are expected to increase with anthropogenic warming of the climate, and the associated economic impacts to rise (Dottori et al. 2018). As the temperature of the atmosphere rises the water-holding capacity increases by around 7%/K following the Clausius-Clapeyron equation (Chou et al. 2012). The increased moisture availability can therefore fuel stronger extreme precipitation events (Trenberth 1999). Given this relation it has been suggested that extreme precipitation change is only dependent on the extent of future warming and not on the emissions scenario (Pendergrass et al. 2015). However, various studies have indicated that aerosols and greenhouse gases drive different extreme precipitation responses per degree of warming for more moderate extreme statistics (Lin et al. 2016). Understanding these differences is important for interpreting future projections and informing climate policy.

The Precipitation Driver Response Model Intercomparison Project (PDRMIP) provides an excellent opportunity to investigate the key climate drivers and processes which affect the hydrological cycle (Myhre et al. 2017). PDRMIP is an international collaborative project for which numerous modelling groups have performed targeted global climate model simulations in which single forcing agents have been perturbed. These simulations make it possible to isolate the processes which affect extreme precipitation for individual climate drivers, such as carbon dioxide, methane, sulphate, black carbon and solar forcing. There have already been a number of successful studies based on PDRMIP which have developed our understanding of precipitation change (Samset et al. 2016; Richardson et al. 2018). Most of the work has focused on changes in annual mean precipitation, which can be understood through analysis of the atmospheric energy budget. The energetic constraint on annual mean precipitation can be used to explain the differing responses to different forcing agents. However extreme precipitation is more affected by moisture availability and the differences between responses to aerosols and greenhouse gases less well understood.

Output from PDRMIP can be used to construct simple models which relate radiative forcing of individual drivers and surface temperature change to precipitation changes. This helps disentangle the importance of different drivers on observed changes and understand the implications of differing future emissions scenarios. This concept has been used for annual mean precipitation but could be extended to investigate extreme precipitation events. There is considerable potential for developing new understanding of extreme precipitation changes through analysis of responses to individual drivers.

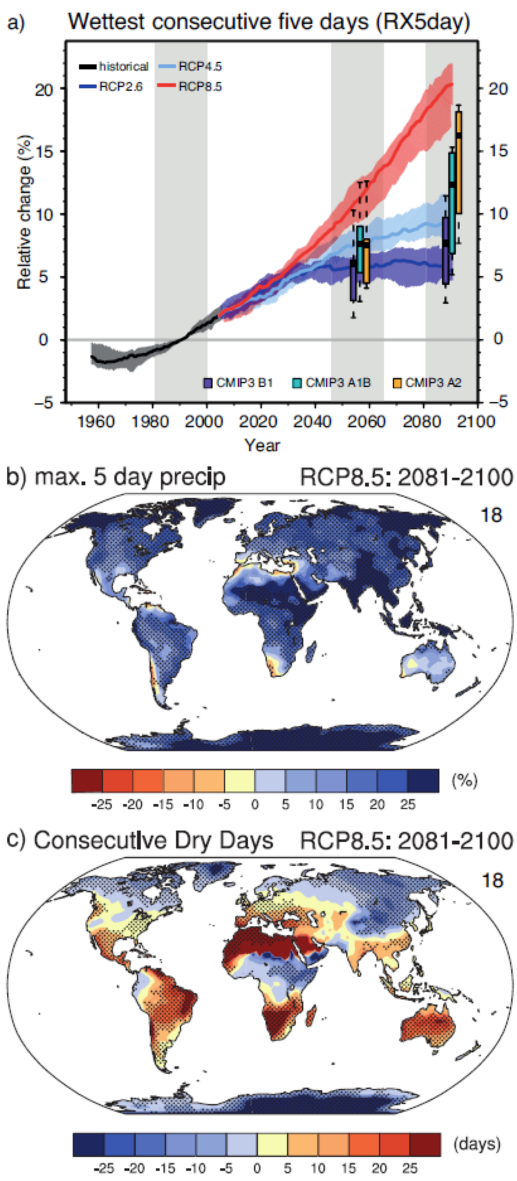

Figure 1: (a, b) Projected changes in the annual maximum five-day precipitation accumulation (RX5day) from the CMIP5 models. (a) shows the global average for land areas following different future emission pathways and shading represents the interquartile ensemble spread. (b) shows the spatial pattern of projected change for 2081-2100 following RCP8.5. (c) shows projected change in annual consecutive dry days (CDD) for 2081-2100 following RCP8.5. Stippling indicates where gridpoints are significant at the 5% level. Taken from IPCC AR5 (Collins et al. 2013).

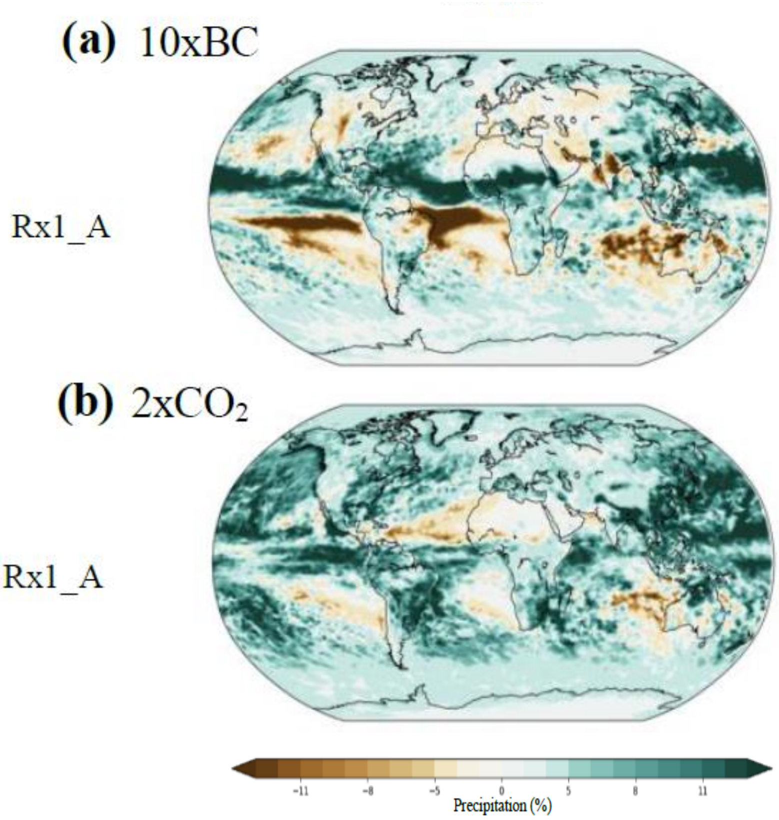

Figure 2: Change in annual maximum daily precipitation (RX1day) in response to (a) 10 times perturbation in black carbon emissions (10xBC) and (b) doubling of CO_2 ($2xCO_2$) using the HadGEM2 global climate model data from the Precipitation Driver Response Model Intercomparison Project (PDRMIP).

Project Objectives

- Analyse PDRMIP climate model data and identify regions where extreme precipitation/drought responses vary between different climate drivers

- Perform targeted climate simulations to investigate the physical processes which lead to different responses – in particular the effects of aerosols on extreme precipitation

- Construct a simple model to test the effects of different future emission scenarios on extremes

- Investigate links between observed trends in extreme precipitation/drought and aerosol emissions

Potential for high impact outcome

Extreme precipitation change is one of the most important aspects of climate change prediction, with huge societal implications. The students work will develop important new understanding of the key drivers of extreme precipitation change, and elucidate the consequences of different future emission pathways helping to inform climate policy. PDRMIP provides an excellent resource for precipitation research which has already produced significant output. There will also be the opportunity for international multi-disciplinary collaboration through the Priestley International Centre for Climate.

Training and research group

For this project you will work under the supervision of Professor Piers Forster, Dr Cathryn Birch?? and Dr Tom Richardson within the highly active and multi-disciplinary Physical Climate Change group. You will also be a member of the Priestley International Centre for Climate which brings together a wide range of expert scientists to deliver climate solutions. Through this project you will get the opportunity to participate in large international collaborative research projects such as PDRMIP.

During the project you will receive extensive training in climate science and dynamical meteorology, computer programming (e.g. Python), the use of state-of-the-art climate models and observational data, research and communications skills. You will have access to a wide range of training and support workshops provided by the Faculty (http://www.emeskillstraining.leeds.ac.uk/).

References and Further Reading

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