The First and Second Hackathons of the International CLIVAR C20C+ Detection and Attribution Project

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Extreme weather and climate events are a dominant contributor to overall climate-related risk, and there is a growing realisation that they may also play a major role in past, current, and future trends in climate-related risk in a world under the influence of human activities (Oppenheimer et al., 2014). In order to improve understanding of changes in extreme weather under climate change, the International CLIVAR Climate of the 20th Century Plus (C20C+) Detection and Attribution (D&A) subproject is producing a large number of climate model simulations within an experiment design configured specifically to diagnose the behaviour of extreme weather under climate change (Folland et al., 2014). In order to facilitate analysis by the broad climate research community, the project has held two week-long ``hackathons'' in which researchers from around the world can discuss the project and analyse output on the same machine on which the data portal is hosted.

C20C+ brings together researchers from around the world to develop understanding of variations and changes in the climate over periods up to the last 150 years, through analysis and comparison of observational and dynamical modelling data sets (Folland et al., 2014). Since 2010, C20C+ has been developing this interest into a capacity to understand extreme weather in the context of anthropogenic climate change, through the D&A subproject (http://portal.nersc.gov/c20c). C20C+ D&A is an international collaboration generating a large number of climate model simulations with relatively high resolution atmospheric models, with high frequency output distributed through a public data portal. Current archived output exceeds 3PB.

As part of an effort to facilitate research by the broader climate community, Lawrence Berkeley National Laboratory's CASCADE project and the National Energy Research Scientific Computing Center (NERSC) have hosted "hackathons" in Berkeley, California, during the week before the 2015 and 2016 Fall Meetings of the American Geophysical Union held across the bay. The aim has been to bring together researchers from around the world in order to:

- analyse large quantities of C20C+ D&A data on (and next door to) the machines which host the data portal;
- discuss the experiment design and implementation with researchers who are conducting the simulations;
- coordinate analyses and develop research plans.

Each hackathon involved about a dozen researchers from Africa, Asia, Australia, Europe, and North America, with most participants being early career researchers. The first day of each hackathon was dominated with presentations and discussions about the project, simulations, and NERSC computing systems. For the remaining days the researchers mostly worked on their own analyses on NERSC machines, with occasional spontaneous discussions and impromptu presentations on interesting results or issues, including on methods to estimate uncertainty in risk ratio-based (or fractional attributable risk-based) estimates of the role of anthropogenic emissions on extreme weather (C. Paciorek and colleagues, in preparation) and on the importance of experiment design for attribution assessment (Risser et al., 2017).

While the common and unifying theme of the research was "extreme climate events" and their attribution to human influence, the participants' analyses in both hackathons covered a large variety of different topics, including various simulated metrics and variables, spatio-temporal scales, and analysis methodologies. For example, the breadth of topics included the role and attributability of fire events in Australia, the role of atmospheric modes of variability in extreme events such as heat waves and intense precipitation, interannual

variability and attribution of flooding in Nigeria and southern Africa, and the effect of the land surface on extreme weather. Most of the researchers examined daily output from the climate model simulations, which would be more challenging outside of the hackathon venue.

Both hackathons ended on Friday afternoon with presentations of preliminary results and further analysis plans by all participants. Participants at the 2015 hackathon recommended an emphasis on participation by young researchers. Holding the event alongside the AGU Fall Meeting provides a synergy that is more effective for young researchers than for more mature researchers, who may be in the examination period and have other administrative responsibilities that preclude two weeks of travel. Obtaining travel funding for young researchers, also identified as a way of facilitating participation, helped the 2016 event.

While both hackathons thus far have been considered successful in stimulating and facilitating research, it may be beneficial to modify the approach in future by focusing meetings on specific topics. These could involve a regional focus, hosted anywhere with a high-speed connection to the NERSC portal or through organised staging of data through disk transfers, which would also facilitate travel for young researchers with limited funds in the selected region. There are also identified synergies with other activities which will be actively producing climate model output over the next couple of years, including the Half a degree Additional warming, Prognosis and Projected Impacts Project (HAPPI, Mitchell et al., 2017) (which shares the C20C+ D&A data portal), the Detection and Attribution Model Intercomparison Project (DAMIP, Gillett et al., 2016), Global Monsoons Modeling Intercomparison Project (GMMIP, Zhou et al., 2016), or High Resolution Model Intercomparison Project (HighResMIP, Haarsma et al., 2016), and thus joint hackathon events may be beneficial in facilitating multi-project research.

Participants of both hackathons, as well as the broader climate research community, are invited to submit publications to a special issue in Weather and Climate Extremes concerning "First results of the C20C+ Detection and Attribution Project" (submission deadline 30 June 2017). As with the hackathons, the special issue is intended as a venue to facilitate analyses of C20C+ D&A simulation output, and thus does not preclude publication elsewhere.

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Participants of the 2015 hackathon in front of NERSC's Cori supercomputer, then one week old.

Participants of the 2016 hackathon during a normal working moment, working on laptops, large screens, and writing on the wall. Images courtesy of M. Wehner and P. Kushner.

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