climate extremes
ARC centre of excellence

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A new global picture of compounding weather and climate hazards

ARC Centre of Excellence for Climate Extremes Special Briefing Note on Compounds Events 2

- The ARC Centre of Excellence for Climate Extremes has performed a global assessment of the occurrence of coincident weather and climate extremes under current climate conditions and has examined future changes in these compound events in simulations from the latest generation of global climate models.
- The research by the ARC Centre of Excellence for Climate Extremes points to some types of compounding weather and climate extremes occurring much more frequently in the future, presenting a material change in risks associated with these events.
- With careful interpretation, some currently available climate models can provide some information on the changing hazard posed by compound events. However, further development of climate models could yield more useful information to businesses and governments seeking to address compound event risks.

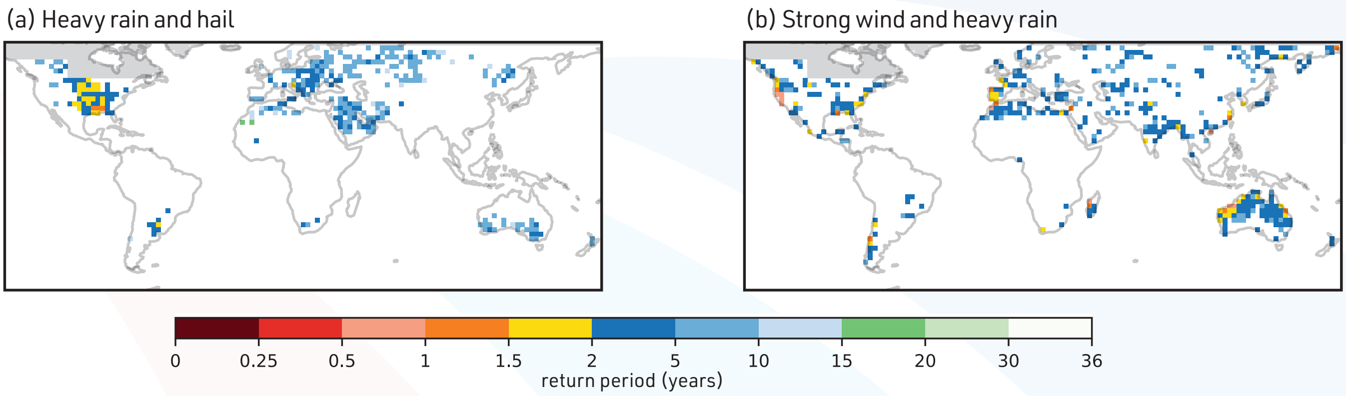
What relevant research is being done by the ARC Centre of Excellence for Climate Extremes?

Compound events (CEs) are weather and climate events that result from multiple hazards or drivers with the potential to cause severe socio-economic impacts[1]. The ARC Centre of Excellence for Climate Extremes (CLEX) has embarked on a program of research focused on CEs specifically because risks associated with them are still largely unknown even under current climate conditions. Further, we want to determine whether climate change will bring major changes to the contribution of CEs to socio-economic risks.

CLEX's CE research program has begun by examining the occurrence of multivariate compound events across the globe under current climate conditions. A multivariate event occurs when several hazards affect the same region at the same time[1]. For example, each of the individual fires occurring during the Australian Black Summer bushfires of 2020/21 qualifies as a multivariate CE as it was caused by the simultaneous occurrence of several hazards including high temperature, low humidity, dry conditions leading up to the event, and strong winds in the same region.

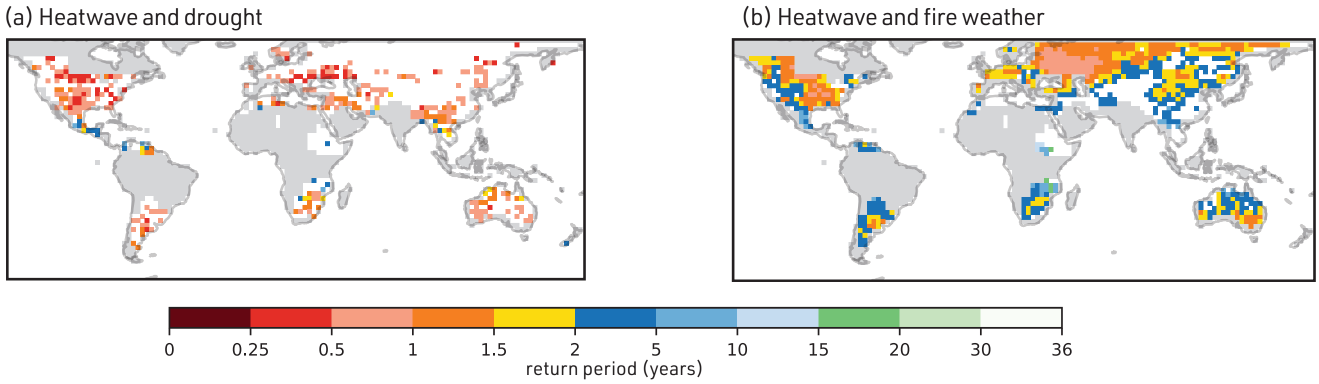
What is the compound event climatology in the present?

Motivated by the fact that the degree of coincidence of hazards was not known, an initial aim of CLEX's research was to determine the occurrence frequencies of a range of multivariate CEs in the recent past. For this, researchers analysed 27 hazard pairs (e.g., heavy rainfall and hail, strong winds and heavy rainfall, heatwaves and drought, drought and high fire danger weather) over the 1980–2014 period to provide the first spatial assessment of multivariate CE occurrences on a global scale[2]. Using a specifically developed statistical tool, they identified hotspots with a high incidence of multivariate events for several hazard combinations. For example, coincident heavy rainfall and hail occur annually over North America but are much less frequently elsewhere (see map). Hotspots for coincident strong winds and heavy rainfall include coastal regions of North America, Western Europe, and northwest Australia.



Likelihood of frequent rain-related compound events during 1980–2014

The research also examined hot and dry conditions. The results shown on the next page highlight high risks of coincident heatwaves and drought across North America, southern Europe, and Australia and high risk of coincident heatwaves and high fire danger weather in North America, Europe, Eastern and Western Australia.



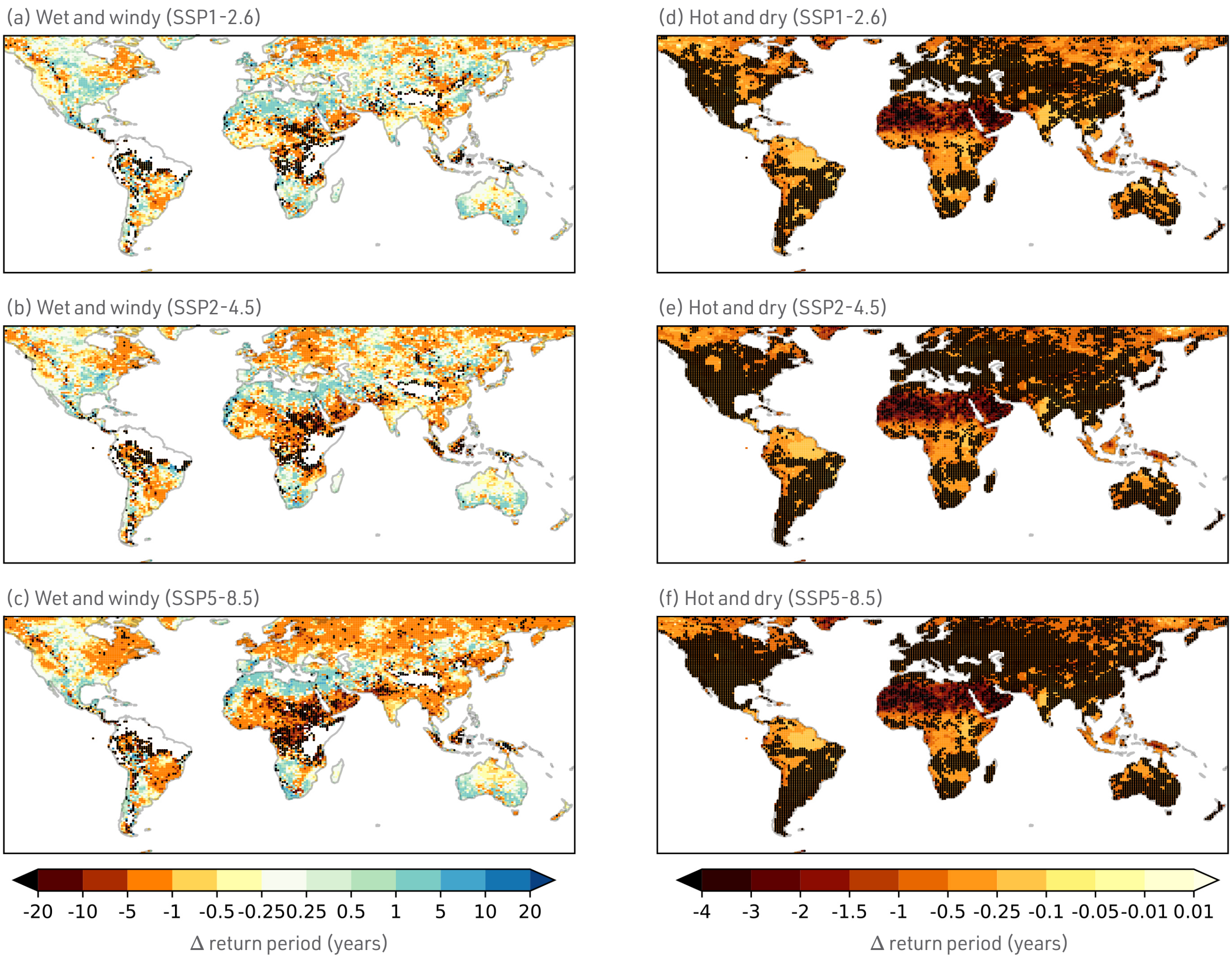
Likelihood of frequent heat-related compound events during 1980–2014

How well do climate models represent compound events?

As well as telling us which areas are at risk under present-day climate conditions, analyses of this kind provide a basis for assessing the global climate models used to project future climate. CLEX has used this climatology to examine the skill of the latest generation of such models, the CMIP6 models[3], to reproduce selected CEs[4]. Briefly, they found that some of the CMIP6 models do simulate the co-occurrence of strong wind and heavy rainfall and heatwaves and drought quite well, particularly over North America, Europe, and Eurasia. Unfortunately, they perform less well over Australia. This is likely due to problems with simulating tropical cyclones, and other important weather phenomena, such as East Coast Lows. That said, if the CMIP6 ensemble is used with care we can begin to explore what these models tell us about CEs in the future.

What do climate models say about what will happen to compound events in the future?

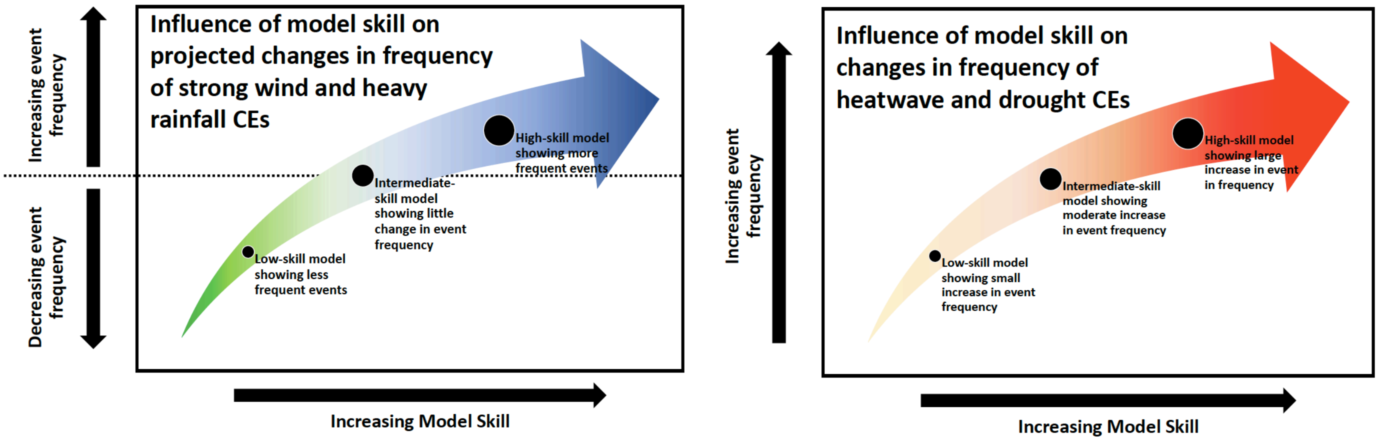
Building on both the creation of a global climatology and the evaluation of CMIP6 models, CLEX research[5] has examined how the occurrence of selected CEs could change in the future. The maps below summarise changes in the occurrence frequency of CEs by the end of the 21st century (2066–2100).The maps combine the results across all available CMIP6 model simulations of a mid-range scenario for future greenhouse gas emissions, consistent with global warming of 2.1-3.5°C above pre-industrial temperatures by the end of the century.



Model-simulated changes in the occurrence of compound events by 2066-2100. Note that the broad patterns of change shown here are potentially robust, but selecting very small regions or individual pixels is highly likely to be misleading.

The CMIP6 models suggest that strong wind and heavy precipitation CEs will occur more frequently in many regions. The combination of heatwaves and drought occur more frequently everywhere with the greatest increases in frequency in North Africa, followed by the mid-latitudes. Additional results suggest we are committed to more of these compound events even under a scenario in which keeps global warming at around 1.8°C above pre-industrial temperatures by the end of the century.

As mentioned previously, not all models perform equally well in reproducing current occurrences of CEs. Therefore, the researchers also examined results from individual models by comparing the future changes in the frequency of CEs simulated by individual models with the model's skill. They found that, overall, for strong wind and heavy precipitation CEs models with higher skill in simulating the CE climatology projected more frequent events. In contrast, the models with the lowest skill projected an overall decrease in events. For heatwave and drought CEs all of the models simulated an increase in event frequency, but the more skilful models simulated larger increases of event numbers.



Influence of model skill on changes in the occurrence of compound events by 2066-2100

What are the implications for climate modelling?

The difference in results between the high-skill and low-skill CMIP6 models highlights an urgent need to examine why some models work well and some don't, and, ultimately, improve those with weaknesses. In the near-term, the weaker CMIP6 models should be flagged to avoid misuse. For reasons that are unclear, in general the CMIP6 models perform poorly over Australia compared to regions of the Northern Hemisphere. However, one of the most skilled models is the Australian Community Climate and Earth System Simulator. This suggests Australia's strategic investment in this model is warranted. However, it is important to note that the CMIP6 global climate models are designed first and foremost to simulate climate trends at large spatial scales and they do not simulate the detail of our weather. CEs are weather phenomena and there is an urgent need for a program that pushes our climate modelling systems to far higher spatial detail such that they become "weather-resolving"[6], similar to the models currently used for weather forecasting.

What are the implications for government and business?

This CLEX research points to multivariate CEs occurring more frequently in the future. The scale of the changes suggests seriously material changes in CE risk. However, rigorous assessment of this risk is not straightforward. Governments and businesses seeking to address CE risk should use results from global climate models with considerable care. Some of the CMIP6 models, including those that perform well in terms of standard skill metrics (e.g., those based on seasonal average temperature and rainfall), fail to capture the statistics of compound events. Some of the models do seem to work well for CEs, opening up an opportunity to use the results from these models in some aspects of risk assessment (e.g., scenario planning, storyline development). However, we do not recommend taking data points from any of the analysis described and using them directly. This is not an appropriate use of climate model data. Any government or business interested in how specific types of CE might change in a particular region should undertake an appropriate analysis using carefully chosen data and models and understand the uncertainties associated with that analysis.

What follow-up research is the ARC Centre of Excellence for Climate Extremes doing?

CLEX is undertaking a more detailed analysis of multivariate CEs in Australia using CMIP6 data and detailed regional observations.

Created by:

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