Extreme precipitation event analysis based on GCM daily data

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Introduction

Extreme event such as heavy rainfall can be serious treats to infrastructure, agriculture production, leading to substantial socio-economic damages. Hence, there is an increasing request from various stakeholders for the information on how the extreme event is going to change in future climate regimes. However, the climate change influence on climate variability, in particular its effects on extreme rainfall events, have not been adequately studied in climate change impact studies. One of the reasons is that the precipitation is generally not as well simulated as air temperature by General Circulation Models (GCMs), particular at the regional and local scales. Nevertheless, at global scale the recent GCM modeling indicates with confidence that each 1°C of surface warming, atmospheric precipitable water increase by ~9% and daily precipitation intensity increase by ~2%, whereas daily precipitation frequency decreases by 0.7%, which implies a likely tendency for an increase in daily heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease.

So far GCM is still the most reliable method in generating the future climate. Along with the advancing of climate science and the enhancing of the computer power, the GCM results have been improving. Since IPCC AR4, the daily simulation results from 12 GCMs for the selected future periods become publically available. Therefore, we proposed in this research a method for extreme rainfall event analysis based on these GCM daily simulation data.

Data and Method

The analysis was based on the Generalized Extreme Value (GEV) theory. Very extreme precipitation events are well described by the statistical formalism of the GEV distribution. The data used in this analysis were observed historical daily rainfall data, as well as the GCM simulation daily rainfall data. So far, the GCM daily simulation data is only available for 12 GCMs for baseline and 2 future sample periods (1981-2000, 2046-2065 and 2081-2100) under 3 SRES scenarios (A1B, A2 and B1). For a given GCM, the pattern scaling method was applied to process its simulation data to obtain the normalized change values for the following extreme rainfall events in terms of their return period interval (RPI): annual daily maxim rainfall of 5, 10, 20, 50 100 RPIs. The fundamental assumptions for such a method are 1) extreme rainfall events changes are linear to radiative forcing changes due to climate change; and 2) while the magnitude of extreme event value changes alter over time in proportion to the global warming, the pattern of change from the GCM remains constant.

For a given GCM, the key steps of the method for each grid box include:

1. Calculation the GEV functions for the baseline period (1981-2000);
2. Calculation the GEV functions for the future periods. As 2 future periods and 3 emission scenarios data is available, a total of 6 GEV functions were obtained;
3. Calculation of the extreme value for a given RPI from each GEV functions, including 1 for the baseline and 6 for the future periods;
4. Calculation the difference of the RPI values between the future and the baseline for each 6 future periods;

5. Calculation the global mean temperature change from the given GCM data for the 2 future periods compared to baseline, for all 3 emission scenarios;
6. Calculation the standardised value of an extreme rainfall event change by dividing individual change by its corresponding global mean temperature change, which produced 6 sample values ;
7. Calculation the normalised change value for an extreme rainfall event using linear least square estimate from the 6 samples;

A normalised pattern of an extreme rainfall event change can then be generated by repeating the above steps for each grid box. Essentially, the pattern indicated that how much an extreme rainfall value is going to change as per degree of global warming. Hence, if a global mean temperature change is known, the changed extreme event value can be deducted. In this study, the magnitude of global warming for a specified future year is based on various IPCC SRES estimates.

The same procedure was carried out for all 12 GCMs and for extreme values of RPI of 5,10,20,50 and 100 in order to develop database for climate change impact an extreme rainfall event analysis. The database was integrated into SimCLIM, an integrate climate change impact assessment software package, to provide an easy access of climate change impact on extreme rainfall evaluation with a user-friendly graphic interface.

Application and Results

The method was applied to analysis the extreme rainfall changes across Australia. A total of 11 observed stations were selected based on their good quality and long term daily rainfall records. The median value from the ensemble of the 12 GCM projections was used for demonstration. The ensemble results showed that the extreme event values were all increase in the future. Across Australia, in spite the spatial variation, the 20 RPI values are projected to have 14 – 26% increase under the A1B scenario with mid climate sensitivity by 2080. In general, large extreme rainfall events, such as 100 RPI event, tend to have larger relative change values than small event, such as 5 RPI event. The results are generally in accord with the hypothesis that the hydrologic cycle should intensify and become highly volatile with the greenhouse-gas-induced climate change, which is also supported by the up-to-date observations.

Discussion and future development

Only 20 years of GCM daily outputs were available for the given 2 future periods, which can barely satisfy the sample size requirement for GEV analysis. The method would benefit greatly if longer time daily GCM simulation results become available. In addition, there is no downscaling method involved in producing the normalized extreme value change patterns. The daily GCM precipitation outputs were analyzed in their original spatial resolution in order to retain the extreme precipitation change trend of GCMs. Downscaled GCM results, either from RCM or statistical downscaled GCM results, could very possibly improve the