Analysis of the January 2011 extreme precipitation event in the Brisbane River Basin

A CLIMsystems Technical Report

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Executive Summary

Australia is experiencing extreme climatic events of many types: rainfall and associated floods, drought and associated bush fires, extreme temperatures and associate health risks are just three prominent examples. Underlying all extreme climatic events is the climate data. In the case of extreme rainfall events there are very few examples of examination of multiday extreme precipitation events applying both historical data and future General Circulation Model projections of climatic change. The recent Brisbane flood event of early January 2011 offered the opportunity to assess a multiday extreme precipitation event. The planning and decision making as an outcome of the floods makes the analysis of such multiday events critical so as to inform the process.

The flooding event of January 2011 is viewed in light of the 1974 flood event as it led to a risk assessment and the investment in infrastructure, the Wivenhoe dam, to limit the risk of a similar event. In fact, the Somerset dam, built in 1953 was also designed to reduce the risk of flooding. The assessment of the seven day rainfall of the recent flood exemplifies the trend toward greater magnitude rainfall events with the passage of time. The analysis also points to a shift in extreme rainfall regime from the pre-1980 period to a post-1980 period and when general circulation models are applied the trend toward more intense extreme precipitation events into the future is reinforced. The shortening of return periods for extreme precipitation events and greater intensity of such events has implications for planning and decision making of durable infrastructure along with emergency services planning, landuse regulation and building codes. This relates not only to possible flood mitigation strategies such as the potential need for additional flood mitigating infrastructure but also for the current built environment. The outputs generated through the application of SimCLIM modeling of extreme rainfall events can be integrated with hydrological and flood models so that risk scenarios can be constructed for future time periods. The risk posed by extreme rainfall events is clearly evident socially, economically and environmentally. A climate and climate change assessment as exemplified in this report can provide the foundation for other sectoral risk assessments.

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1.0 Introduction

The Brisbane 2011 floods have garnered international attention. Each year extreme rainfall events cause significant flood damage in the highly urbanized regions along Australia's eastern coastline. Information about extreme rainfall intensity and frequency for event-durations ranging from hours to multiple days is essential for flood impact, design and mitigation applications. Flood impact models also rely upon information about how rapidly the average rainfall intensity increases with decreasing area, i.e. depth-area curves. These relationships are likely to be altered by climate change.

The extreme precipitation for various durations and recurrence intervals in the last 100 years have varied significantly in Australia and are strongly effected by ENSO cycles (Haylock and Nicholls, 2000; BOM, 2005; Fu *et al*. 2010). Climate change is also likely to affect extreme rainfall in southeast Queensland (Abbs *et al*. 2007, CSIRO, 2007, Queensland Government, 2010). Projections indicate an increase in two-hour, 24-hour and 72-hour extreme rainfall events for large areas of southeast Queensland (Abbs *et al*. 2007).

The recent floods have led to considerable damage and are the result of multiple day events, however there is a paucity of studies on multiple day scale extreme precipitation event analysis (Nicholls, 2008), both for historical analysis and future projections with the application of multiple General Circulation Models (GCMs).

This report aims to provide an investigation of the characteristics and change trends of multiple day extreme precipitation events during the historical period and to future projections due to climate change for the Brisbane River Basin.

2.0 Study area, Data and Methodology

2.1 Brisbane River Basin

The Brisbane River forms in the Brisbane and Cooyar Ranges of the Great Divide, meanders through the Brisbane Valley and drains into Moreton Bay. The City of Brisbane straddles the river near its mouth. The river is fed by numerous tributaries, the principal ones being the Stanley and Bremer Rivers and Lockyer Creek in the middle reaches, and Oxley, Moggill, Bulimba, Enoggera and Breakfast Creeks in the lower reaches, within the Brisbane metropolitan area (Figure 1). The rainfall catchment for the Brisbane River comprises about 13,400 km^2, divided into six sub-catchments: the Stanley, Lockyer, Bremer, Upper Brisbane, Middle Brisbane (between Esk and Mt Crosby) and metropolitan sub-catchments.

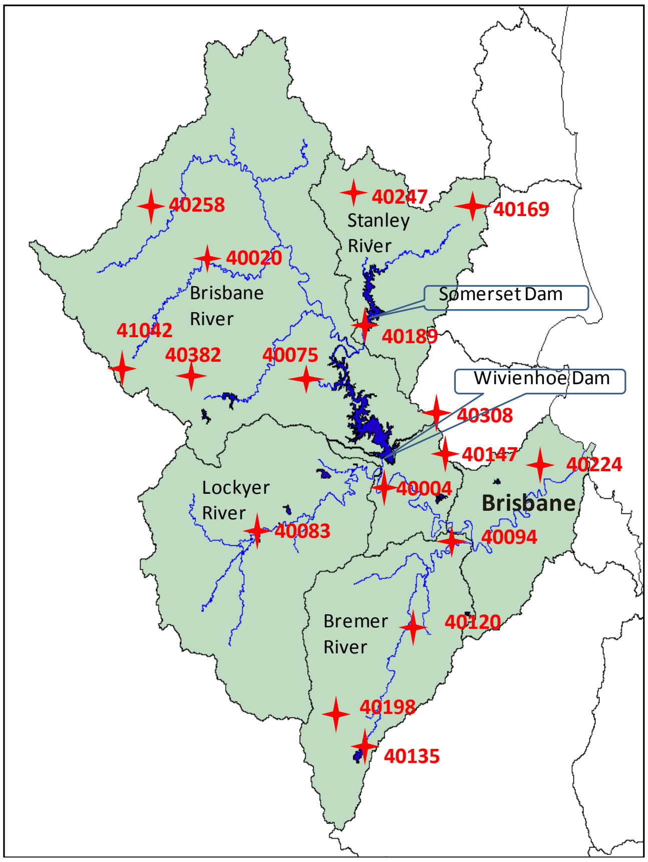


Figure 1. Key features of the Brisbane River catchment including sub-catchments, location of key rainfall stations and dams.

2.2 Precipitation data

The Brisbane catchment and the main observation stations for the analysis in this study were derived from the Bureau of Meteorology daily rainfall database (http://www.bom.gov.au/climate/data/). We acknowledge that these data are yet to be checked and officially released by BOM. Seventeen stations with long term and most complete records were selected for the analysis. Seven stations extend back to the late 1880s. Many of the remaining stations date from the first half of the 20th century. All the station data used in this analysis extend beyond the recommended minimum annual maximum event study which is 30 years. The list of stations, their locations, names and year in which record keeping began are listed in Table 1.

Table 1. Station numbers, location, name and date of initiation for the primary stations used in this analysis.

Station No.	Lat.	Long.	Name	Start year
40004	-27.63	152.71	AMBERLEY AMO	1941
40020	-26.88	152.10	BLACKBUTT POST OFFICE	1900
40075	-27.24	152.42	ESK POST OFFICE	1887
40083	-27.54	152.30	GATTON ALLAN STREET	1894
40094	-27.81	152.67	HARRISVILLE POST OFFICE	1897
40120	-27.46	152.57	LOWOOD DON ST	1887
40135	-28.03	152.55	MOOGERAH DAM	1917
40147	-27.40	152.79	MT NEBO POST OFFICE	1947
40169	-26.84	152.88	PEACHESTER WOODFORD RD	1915
40189	-27.12	152.56	SOMERSET DAM	1936
40198	-27.98	152.51	TAROME	1911
40224	-27.42	153.00	ALDERLEY	1899
40247	-26.84	152.58	LINDFIELD	1928
40258	-26.84	151.98	YARRAMAN POST OFFICE	1913
40308	-27.33	152.77	MT GLORIOUS FAHEY RD	1933
40382	-27.27	152.06	CROWS NEST	1893
41042	-27.22	151.88	HADEN POST OFFICE	1926

2.3 Methodology

In order to investigate the characteristic of the extreme precipitation in the study basin, the historical data is divided into three period: 1) the whole period from station record start to Jan 2011 (P1, hereafter), 2) the period from station record start to 1980 (P2, hereafter), and 3) the period 1981 to 2011 (P3, hereafter).

This analysis deploys the GEV tool in SimCLIM, a product of CLIMsystems Ltd. The features of the SimCLIM GEV tool enable annual maximum of one day or multiple day extreme precipitation event analysis, including climate change impact assessment based on change scenarios generated from GCMs. This tool is based on fitting the historical annual maximum values to the Generalized Extreme Value (GEV) distribution. The climate change impact assessment is based on the extreme precipitation change patterns derived from the daily precipitation output of 12 IPCC AR4 GCMs applying an ensemble pattern scaling approach. Kolmogorov-Smirnov Goodness-of-Fit Test (K-S test) was used for an L-moments GEV distribution fitting test.

The possible implications of climate change for extreme rainfall events in the future were explored using the ensemble median of the 12 GCMs under different SRES emission scenarios and future time periods. Details on the methodologies can be found in SimCLIM documentations.

3.0 Results

3.1 1974 and 2011 analysis of extreme precipitation

The 1974 flood event is often cited as a benchmark flood event with which the 2011 event is compared. The flood of 1893 was also substantial but the data needed for analysis is not adequate. Tropical cyclone 'Wanda' played a major part in the generation of the 1974 flood event because, in addition to providing the initial rain that saturated the Brisbane River catchment, it forced the monsoonal trough southwards to Brisbane itself. Here the trough persisted for several days and small oscillations in its movement and intensity resulted in several periods of very intense rainfall (BOM, 1974). Due to its cyclonic origin, the rainfall of the 1974 event was concentrated on fewer days than the 2011 event for most area, as can be seen in Figures 2 and 3. The rainfall on day one of the 1974 event was greatest in the eastern third of the catchment. On day two and three the rainfall became more widespread but was still greatest in the eastern-most portion of the catchment. By day five the rain had stopped. As depicted in the total five-day rainfall in Figure 3, the amount of rain that fell across the catchment was between slightly over 200 mm in the western third to a small area of around 1250 mm in an isolated eastern portion of the catchment.

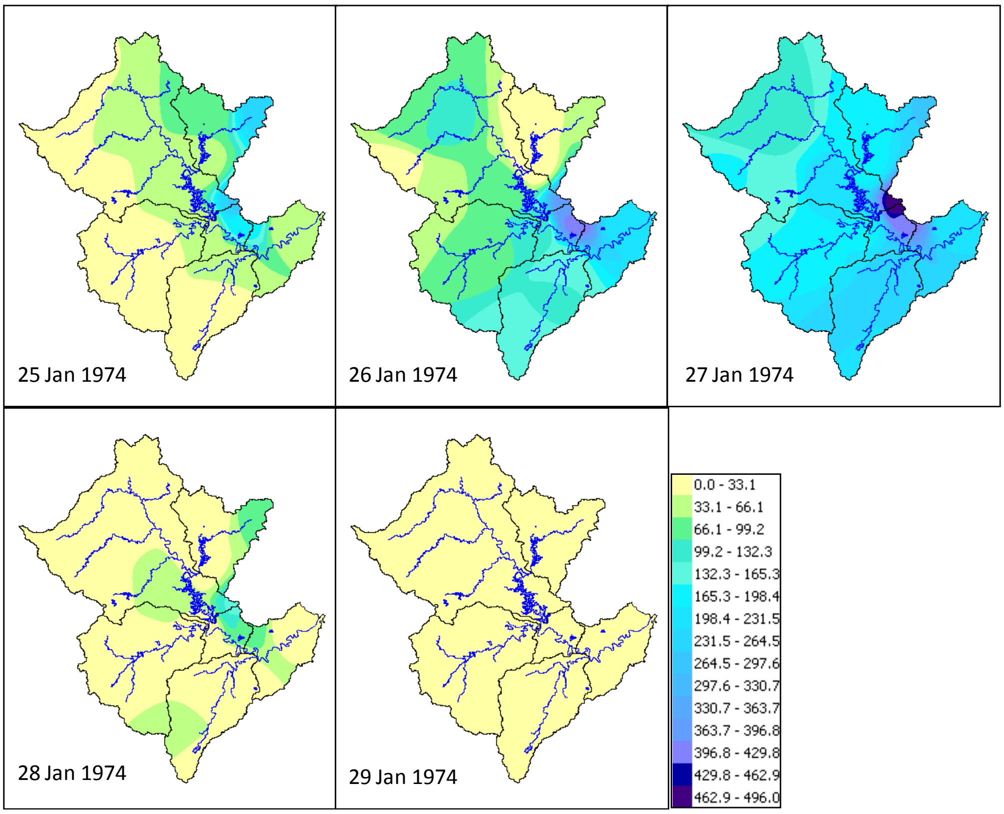


Figure 2. 1974 flood event day by day precipitation (in mm) from 25 to 29 January (17 stations were used for interpolation).

The 2011 rainfall event had two major differences from the 1974 event. First it was of longer duration and hence the catchment's soils that were saturated early in the event led to considerable runoff as the event endured and intensified (Figure 3). Secondly, the rainfall was more concentrated in the northern two thirds of the catchment. Although the range in precipitation over the seven days for the entire catchment was lower than the 1974 event, Figure 6 shows that the percentage difference in precipitation for the total event is markedly greater in 2011 with all of the northern half of the catchment experiencing greater rainfall totals than the 1974 event with some sizable areas receiving greater than 40 percent more rainfall. That the 2011 was a more intense event in the northern half of the catchment is supported by the map of the stations depicting greater than 1 in 50 year events (Figure 5) with seven of eight stations in this area being of this category while only two of the nine stations in the southern half of the catchment experienced greater than 1 in 50 events year events. As can be seen the 1974 event was also extreme with 10 of the stations in the southern half of the basin experiencing greater than 1 in 50 return period precipitation. We also note that most of the extreme precipitation (greater than 1 in 50 year) of the 1974 event (except for two stations) fell to the south of the Wivenhoe dam which was constructed in 1980s.

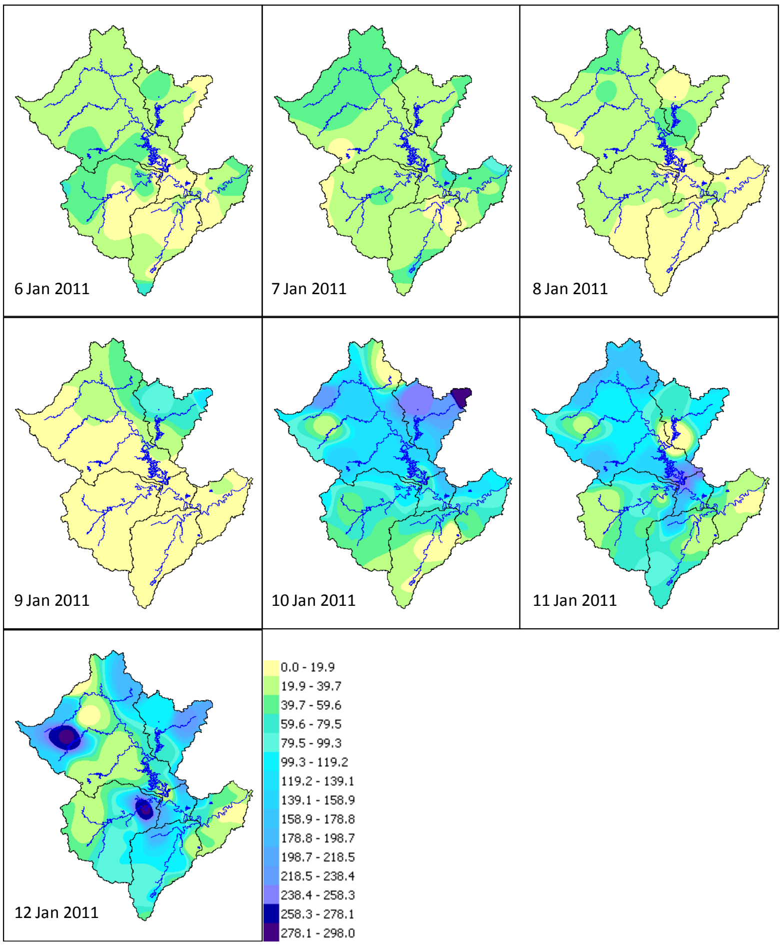
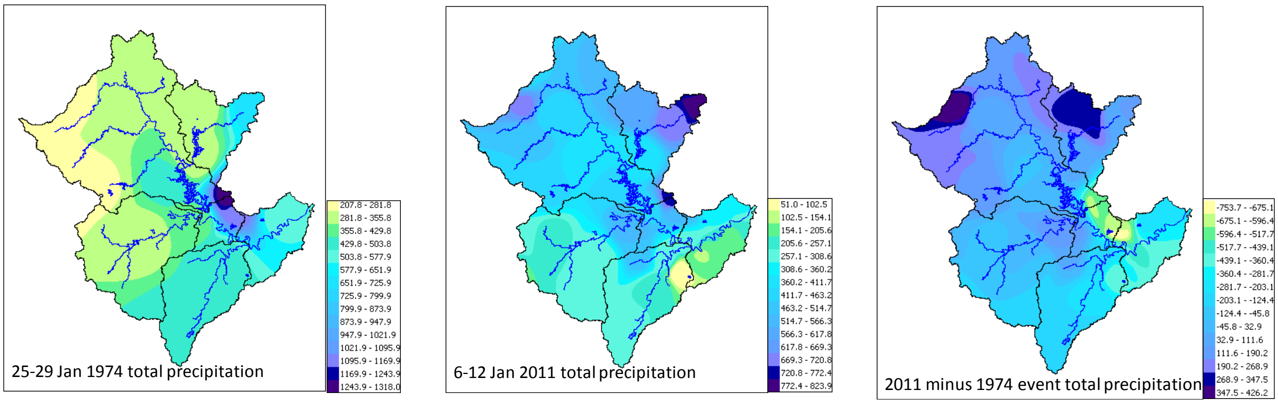


Figure 3. 2011 flood event day by day precipitation (49 stations were used for spatial interpolation).


25-29 Jan 1974 total precipitation

6-12 Jan 2011 total precipitation

2011 minus 1974 event total precipitation

Figure 4. 1974 event five day and 2011 event 7 day total precipitation, and the difference between 1974 and 2011 event.

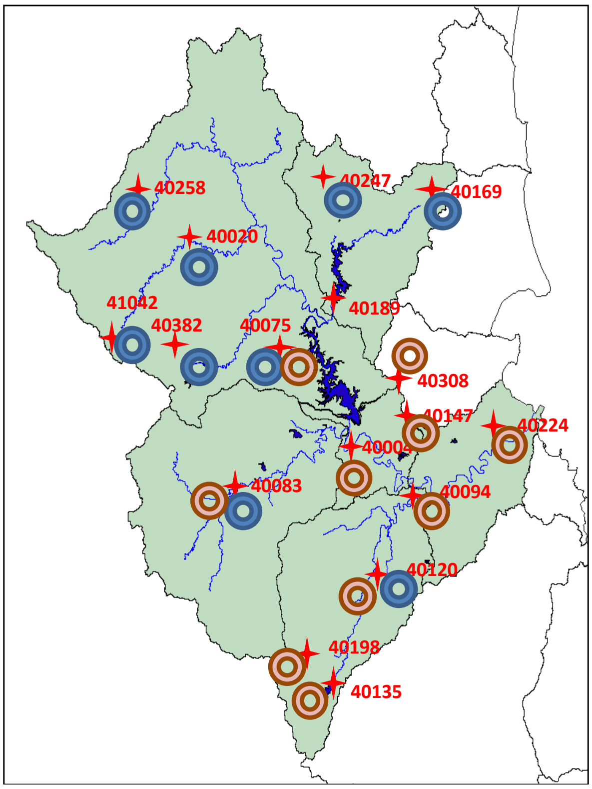


Figure 5. The stations with a blue circle have a significantly high precipitation (larger than 1 in 50 years) for the 2011 event and the red circles denote larger than 1 and 50 year precipitation in the 1974 event.

3.2 Generalized extreme values analysis

The first map in Figure 6 shows the rainfall amounts and spatial distribution for a 1 in 100 year event based on historical rainfall data from 17 stations in the Brisbane River basin. The range is considerable: from approximately 260 to 300 mm in the west and northwest to between 800 and nearly 1000 mm in basin's eastern boundary. The middle map in Figure 6 depicts the percentage change in the 1 in 100 year event for the period prior to 1981, in contrast with, the entire rainfall record for the basin. In some areas, notably the west and central portion to the south of Wivenhoe dam there is a reduction in the amount of rainfall that was received. This is the opposite of the 30 year period from 1981 to 2011 which is also compared with the entire length of record as shown in the final map on the right panel of Figure 6. In the last thirty years, the portion of the basin experiencing a decline in 1 in 100 year values is limited to the southern reaches of the Bremer River. Most of the basin shows an increase in 1 in 100 year values and these changes are considerable for the northern portion of the basin.

This preliminary analysis of changes in rainfall amounts in multiple day events is broadly consistent with the changes modelled globally and regionally for this part of Australia for the relationship with changes in global and regional temperature and modelled increased rainfall.

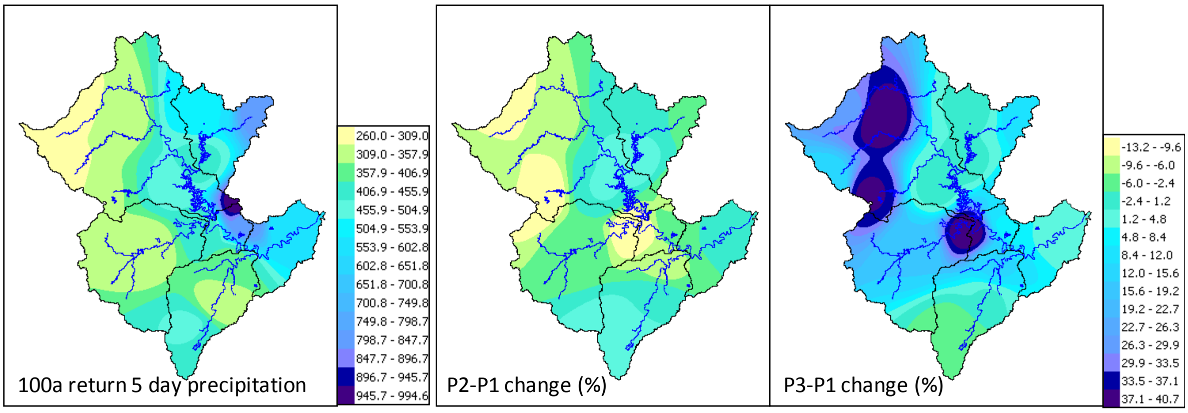


Figure 6. The 100 year return extreme precipitation values and changes. 1981 to 2011 period (P3) to the whole period (start to 2011, P1) and the before 1981 period (P2). All fitted GEV distributions passed a 95 % significant level K-S test (p>0.05).

The relationship between the pre-1981 period and post-1981 period is also depicted in Figure 7 that provides even greater detail for one, three, five and seven day rainfall events. As in Figure 6 the percentage change for most stations when the post-1981 period is compared to the entire record shows the trend toward increased rainfall for 25, 50 and 100 year return period values. The one day value in relation to the period prior to 1981 (lower panel of Figure 7) increased slightly with some stations showing an increase in percentage change and others a decrease. However with three, five and seven day events there is a strong indication that both the mean value for all stations and the individual values for stations have increased substantially for 25, 50 and 100 year return period events.

The results show that the return period for both the 1974 five day and 2011 seven day rainfall events has become more likely, for most stations across the catchment over the last 30 years in comparison with the total observation period to 1981, and often considerably so.

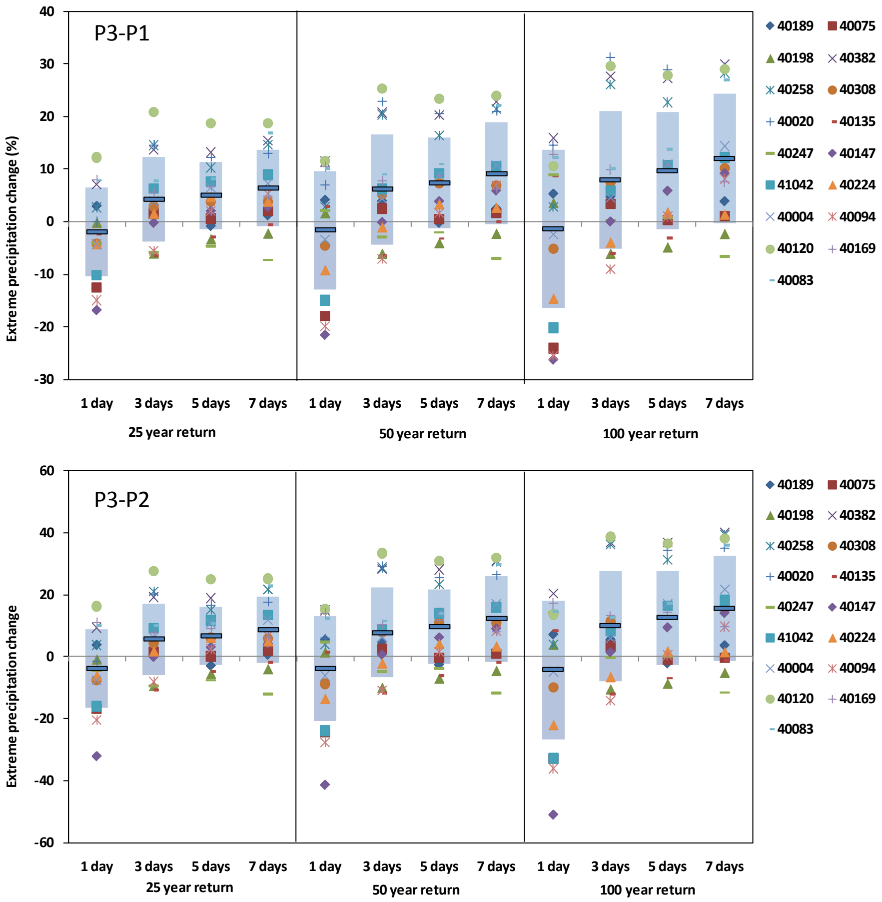


Figure 7. The difference of extreme precipitation for three return periods (25, 50 and 100 year) and 4 time scales (1, 3, 5, 7 days) 1981 to 2011 period (P3) compare to the whole period (start to 2011, P1) and the before 1981 period (P2). Each marker denotes a station, shaded boxes are the standard deviations and the dark lines in mid of the boxes are the mean for the 17 stations.

Table 2. 1974 and 2011 event total precipitation average return period calculated based on the start of recording keeping to 2011, and the 1981 to 2011 period. The red font denotes the return period becoming shorter in the 1981 to 2011 period in contrast to the start of record keeping to 2011, indicating that extreme events have become more frequent.

Station	1974 Event			2011 Event		
	5 day total rainfall	Return Period		7 day total rainfall	Return Period	
		Start-2011	1981-2011		Start-2011	1981-2011
40189	305.4	17.6	18.4	361.0	25.2	24.1
40075	448.8	87.5	86.5	426.8	57.6	53.7
40198	472.0	100.5	127.0	250.4	6.6	7.1
40382	276.4	32.6	20.3	449.6	200.2	58.2
40258	251.6	37.0	23.5	475.4	>500	117.7
40308	1318.0	337.3	176.8	648.4	14.7	14.2
40020	352.2	74.1	45.4	438.6	121.6	66.8
40135	436.9	74.5	170.0	285.2	12.3	12.0
40247	330.4	12.1	14.3	575.8	65.4	68.2
40147	1118.1	353.1	294.3	519.2	11.4	11.5
41042	207.8	25.0	17.2	269.0	96.7	45.0
40224	553.0	91.3	69.6	328.6	7.3	6.2
40004	480.5	295.1	146.2	282.2	14.8	12.8
40094	446.2	>500	>500	179.4	5.2	5.0
40120	391.4	75.1	31.1	549.8	258.3	69.2
40169	677.6	34.2	24.6	823.9	54.3	38.5
40083	322.2	88.2	49.1	339.4	61.7	26.3

4.0 Extreme Precipitation and Climate Change

The historical data shows a change in the ARI's for extreme rainfall events for the Brisbane Basin in the last 30 years (1980 to present) as compared to the complete observation period, representing up to 100 years of record. Scenarios of climate change are increasingly being considered in decision making for planning and policy making (Wilby and Dessai 2010). To express the range of possibilities for the changes in rainfall for daily and multiple day events, climate change scenarios are applied. Given the uncertainty inherent in future projections, a wide range of models, future emissions and sensitivity values for the climate system are advocated. For this preliminary report we applied patterns from twelve GCM that provide daily outputs. The GCM patterns are derived from model inter-comparison data of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. CLIMsystems can provide additional modelling details when required. An ensemble approach is taken so that the whole range of GCMs can be considered. For each degree of global warming, the median result of the models predicts a 2.5 to 3.5% increase in the extreme values of the 5-day event, and a 3.0 to 4.0% increase in the extreme values of the 7-day event. The ranges cover all 17 observation stations, and 25, 50, and 100 year return events. Table 3 expresses this for the two IPCC scenarios A1B (with medium climate sensitivity) and A1FI (with high climate sensitivity).

As an example, for station 40020, the 7-day rainfall event in 2011 was 438.6 mm. This had an ARI based on the whole observation period of >500 years. For the last 30 years, this has increased to an ARI of 66.8 years. Under climate change, for 2050, with A1FI (high), this event could increase to 477 mm of rain.

Table 3. GCM projected extreme precipitation changes in Brisbane River Basin for the future.

Scenario (sensitivity)		**temp. inc 2010-2050**	**% change extreme**	**temp. inc 2010-2100**	**% change extreme**
5-day rainfall event	A1B (mid)	1.24 °C	3.1 - 4.4%	2.62 °C	6.5 - 9.2%
	A1FI (high)	2.20 °C	5.5 - 7.7%	6.27 °C	15.6 - 22.0%
7-day rainfall event	A1B (mid)	1.24 °C	3.7 - 5.0%	2.62 °C	7.8 - 10.5%
	A1FI (high)	2.20 °C	6.6 - 8.8%	6.27 °C	18.8 - 25.1%

5.0 Discussion and Implications

The aim of this report has been to stimulate discussion in the academic and more importantly the policy arena. In this technical report we investigated the characteristics and changes in the trend of multiple day extreme events during the historical period and provided a cursory examination of the application of multiple GCMs to the historical time series data currently available for the Brisbane River Basin. From this analysis we can make some preliminary conclusions:

1. The rainfall event of 2011 was different in its origins and characteristics when compared with the event of 1974. In general, the length of the event was different and the overall amount of rain that fell over the basin and where it fell was greater in 2011.

2. The trend in the rainfall data is towards more extreme multiple day events when examined at the basin level. Not all stations show the same trend or rate of change in intensity of rainfall but the general signal is towards an increase in extreme rainfall levels in the last thirty years compared to the period prior to 1980.

3. The cursory examination of the effect of climate change on multiple day rainfall events in this part of Queensland is consistent with Intergovernmental Panel on Climate Change modelling that links increases in temperature with more extreme rainfall events. This signal is seen in both the historical record with recent warming temperatures and in the corresponding increase in extreme rainfall events.

4. The implications of this change (what is likely to be a continued trend in increasing extreme rainfall values) highlights the need for consideration of the anticipated changing rainfall values and return periods for a wide range of development and rehabilitation plans. Although the specific ramifications for various sectors extend beyond the purpose of this preliminary technical report it is obvious that the impacts from the projected increase in extreme precipitation and decreased return periods should be considered in land use planning, infrastructure design, emergency management, agricultural practices, resource extraction and transport management.

Finally, CLIMsystems notes that this is a preliminary report. More emphasis needs to be placed on the modelling with the application of different General Circulation Models, storylines and different climate sensitivities. Moreover, the linkage of climate change extreme event scenarios with hydrological and flooding models would seem to be a logical exercise to begin to construct possible future risk scenarios for the Brisbane River Basin. The primary goal of any such modelling should therefore be the presentation of the range of possibilities for future rainfall/flooding regimes for the Brisbane River Basin. With this information, decision makers can begin to develop adaptation plans that are best informed with regard to future climate scenarios and extreme events.

CLIMsystem Ltd.

CLIMsystems is a New Zealand-based company that specializes in climate change risk assessments and modelling and maintains a staff of highly qualified climate scientists. The company has developed methods for examining extreme climatic events such as the rainfall associated with the recent floods in Southeast Queensland. As specialists in climate change risk and adaptation the company also has expert capacity for developing scenarios of climate change. The company is known for its innovative and cutting edge scientific approaches and the use of Intergovernmental Panel on Climate Change General Circulation Model outputs for practical application for policy and decision making.

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