

# **Benchmarking estimates of Intensity-Frequency-Duration (IFD) design rainfalls for the Current Climate Regime**

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## **Abstract**

*The new Intensity-Frequency-Duration (IFD) design rainfall estimates provided by the Bureau of Meteorology (the Bureau) were derived for the current climate regime. The Australian Rainfall and Runoff Revision (ARR) Rainfall IFD Relationships under Climate Change Project sought to provide more definitive advice on the impacts of climate change on the new ARR2015 IFDs. However, in order to ensure that the advice for future climate regimes was relevant, the Bureau's ARR2015 IFDs served as the reference curves against which the IFD curves for the current climate produced using different regional climate models and alternative statistical methods were benchmarked.*

*The benchmarking of the rainfall IFD curves was undertaken by comparing the rainfall IFD curves derived from the Conformal Cubic Atmospheric Model (CCAM) and Weather Research and Forecasting (WRF) climate model based simulations and those derived using the Bayesian Hierarchical Modelling (BHM) framework for the current climate to the Bureau of Meteorology's new rainfall IFD curves. In undertaking the benchmarking comparisons for both the Greater Sydney Region and the Southeast Queensland Region were made between the gridded ungauged locations rather than gauged locations. This was to be consistent with the ARR2015 IFDs which are gridded, regionalised values rather than at-site values.*

*The benchmarking of the BHM derived rainfall IFD curves against the Bureau's ARR2015 IFDs showed that the BHM depths are most different to the ARR2015 IFD depths for the shortest and longest durations. In addition, the BHM depths are lower in the flatter and more data sparse areas and higher in areas of more topographic complexity. However, overall there was reasonable correspondence of the BHM derived rainfall IFD curves to the Bureau's ARR2015 IFDs. In contrast, the CCAM and WRF derived IFD depths showed large differences to the Bureau's ARR2015 IFDs – both positive and negative – across durations and probabilities but without any obvious causal reason for the differences.*

## **1. INTRODUCTION**

The new Intensity-Frequency-Duration (IFD) design rainfall estimates provided by the Bureau of Meteorology are for the current climate regime. However, for infrastructure whose design life is longer than 30 or so years, it will be necessary to incorporate climate change into the new IFDs. Previously, climate change has not been incorporated in a consistent manner with different states adopting different approaches (Green and Johnson, 2014). In order to develop a consistent, scientifically rigorous approach Engineers Australia commissioned research into Rainfall Intensity-Frequency-Duration (IFD) Relationships under Climate Change.

This research involved the deriving IFD curves for the current climate using:

- Conformal Cubic Atmospheric Model (CCAM) simulations at 2 km resolution driven by the Australian Community Climate and Earth-System Simulator (ACCESS 1.0) climate model,
- bias corrected Weather Research and Forecasting (WRF) simulations at 2 km with CSIRO Mk3.5 GCM as the driving climate model, and

- a Bayesian Hierarchical Modelling (BHM) framework which is an alternate method for deriving IFDs using a spatial Bayesian approach for estimating rainfall distribution parameters.

The resultant IFD curves were then benchmarked against the Bureau's ARR2015 IFD curves. This paper presents results from the benchmarking component of this research; further details on the models and research can be found in Engineers Australia (2015).

## 2. BENCHMARKING FOR CURRENT CLIMATE

For assessment of the climate models performance for the current climate, IFDs have been created at grid points. These were derived by extracting the grid point annual maxima series (AMS) for the model period, calculating L-moments (Hosking, 1990) and applying a generalised extreme value (GEV) distribution following which depths for a range of probabilities can be estimated by the quantile function  $Q_y$  :

$$Q_y = \xi + \frac{\alpha \left( 1 - \left( -\log \left( 1 - \frac{1}{y} \right) \right)^k \right)}{k} \quad (1)$$

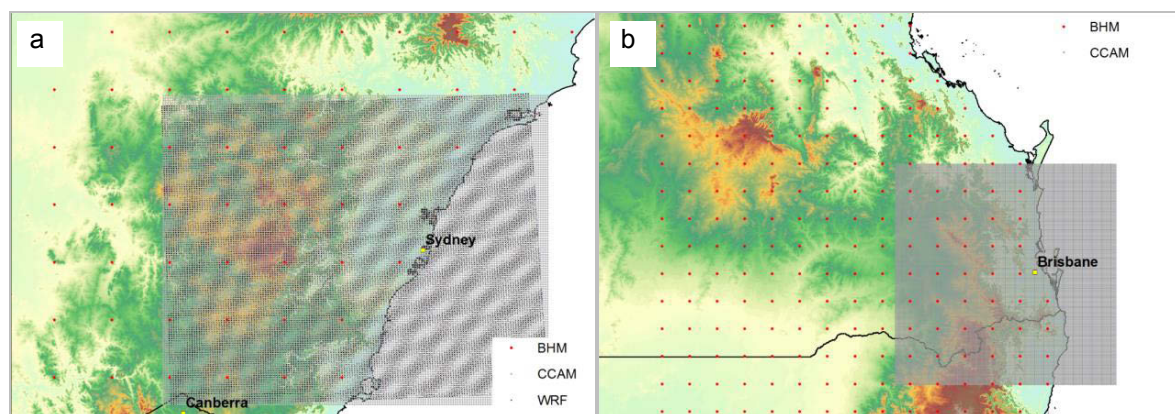
Where  $\xi$  is the location parameter,  $\alpha$  the scale parameter,  $k$  the shape parameter and  $y$  is given by:

$$y = k^{-1} \log \left( 1 - k \left( \frac{x - \xi}{\alpha} \right) \right) \quad (2)$$

This method is similar to that used to create the ARR2015 IFD depths (Green *et al*, 2012), however there is no regionalisation or additional gridding procedure incorporating information about topography or nearby sites. IFDs for the WRF model have been derived from rainfall modelled for the 1990 to 2009 period and for the CCAM for the period 1986 to 2005. This represents a much smaller sample of the climate record compared with the ARR2015 IFD dataset which included all available rainfall data up to 2012 (Green *et al*, 2012).

Benchmarking has also been undertaken for the current climate BHM data as an alternative statistical method for deriving IFDs. The BHM IFDs are based on available gauged continuous rainfall data for the period 1959 to 2009. Comparisons have been made at ungauged gridded locations as that most consistent with the ARR2015 IFD data.

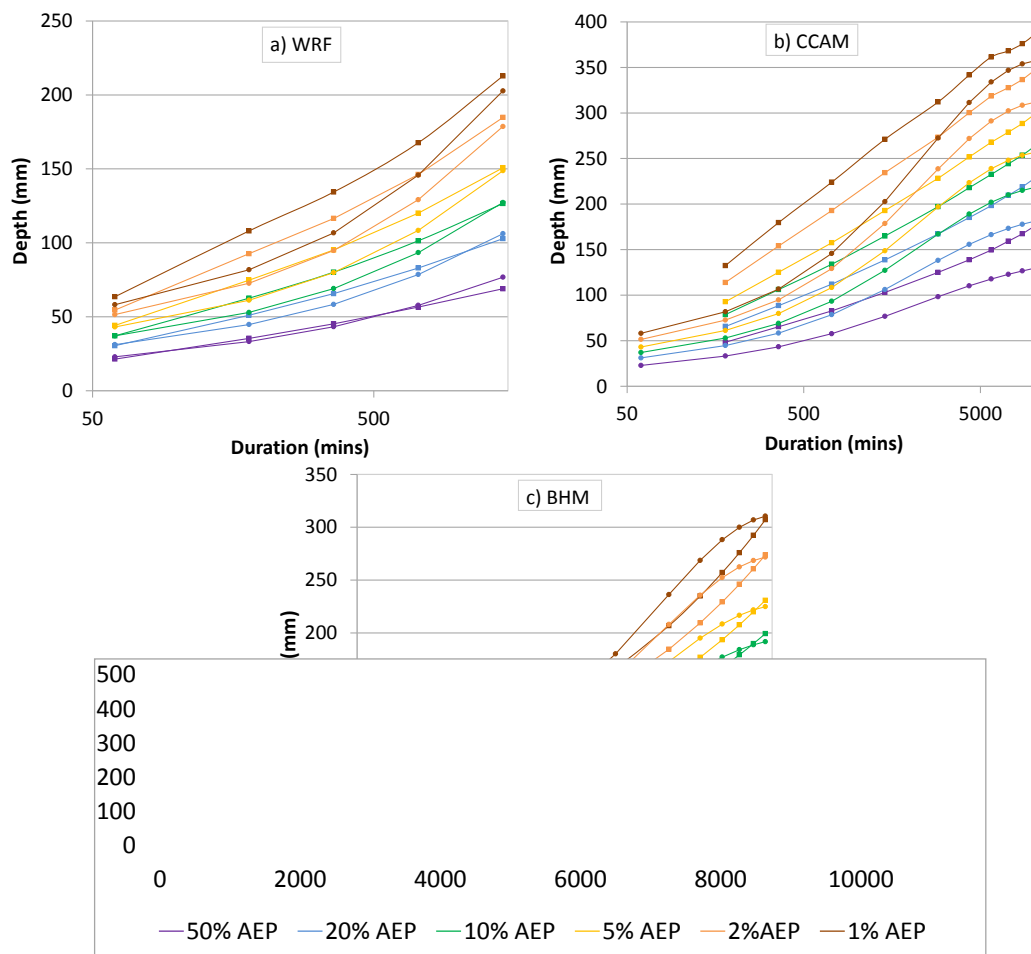
Figure 1 shows the relative grid coverage and resolution of the BHM, CCAM and WRF model for the Sydney and South-east Queensland (SEQ) study areas noting that WRF covers the Sydney area only. For the purposes of assessing the ability of the methods to reproduce similar current climate IFD depths, some analyses have been provided below.



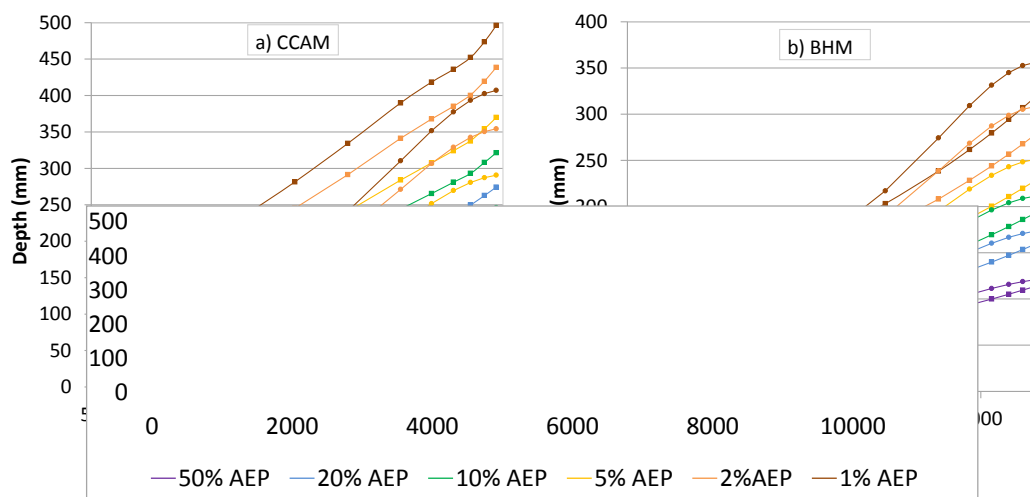
**Figure 1 Model grid point coverage for the a) Sydney and b) South-east Queensland study areas shown over topography.**

Figures 2 and 3 compare average growth curves for the Sydney and SEQ study areas respectively. They have been derived by averaging all of the grid cells for which depth data is available within the grid extent and therefore may include data influenced by boundary effects. In each figure, the solid

lines represent the ARR2015 IFD curves and the dashed lines those derived using the nominated approach. The WRF curves are shown for durations from 1 hour to 24 hours; the CCAM curves for durations from 3 hours to 168 hours; and the BHM curves for durations from 1 hour to 168 hours.



**Figure 2 Growth curves for the Sydney study area (duration on log-scale) – ARR2015 = solid line, model = dash line**

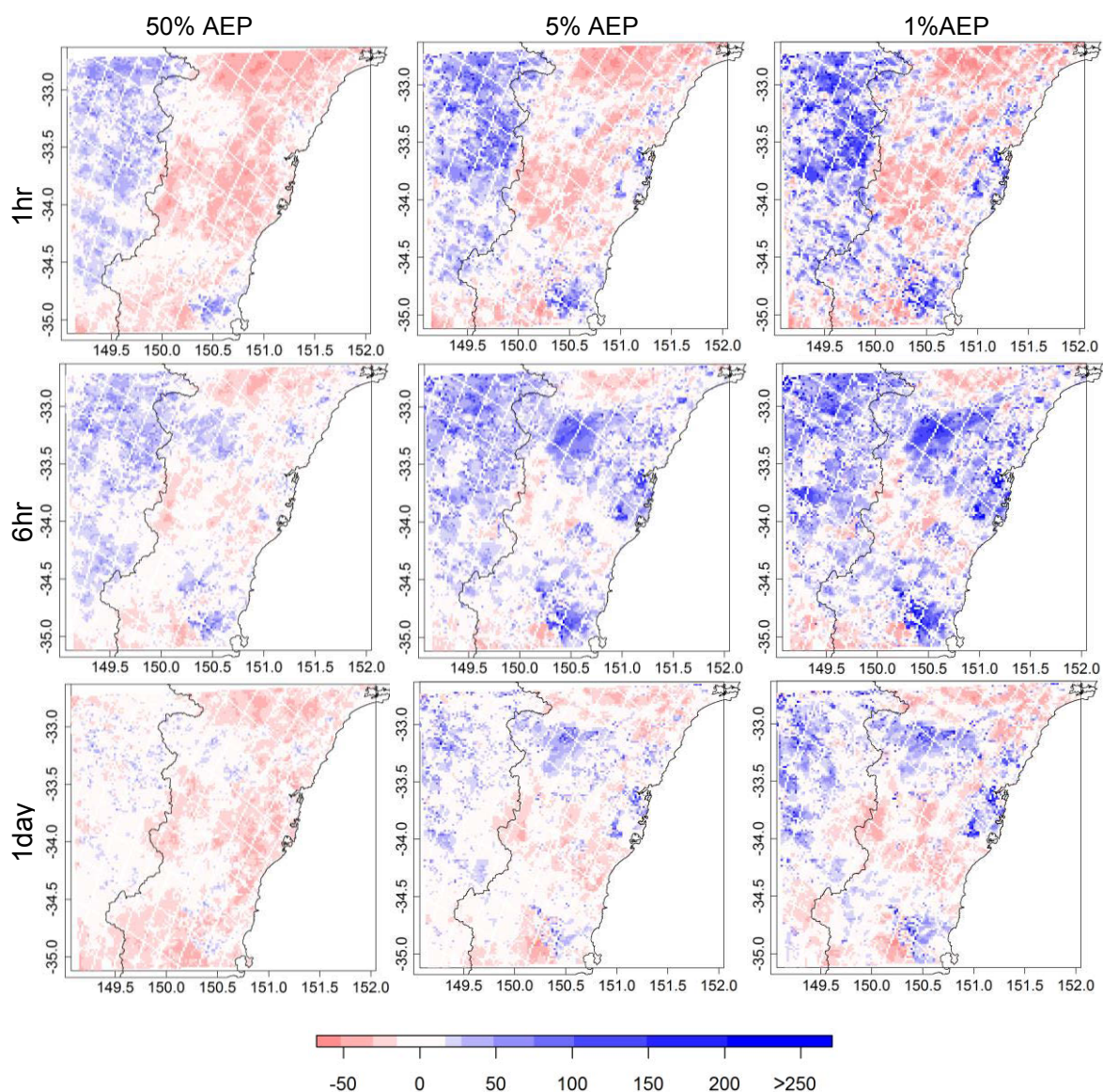


**Figure 3 Growth curves for the SEQ study area (duration on log scale) – ARR2015 = solid line, model = dash line**

These overall study area comparisons indicate that the curves derived from the WRF 1hr to 1 day AMS are similar to the ARR2015 IFD curves for the higher probabilities and 1hr and 1day durations. The WRF curves suggest a net overestimation of IFDs for the 3 to 12hr durations and lower probability

events across the Sydney study area. The CCAM curves for both study areas suggest an overall overestimation of current climate IFD depths. The BHM based on historical gauged data compares quite well with ARR2015 IFD depths for both study areas, particularly for durations less than 1day and higher probabilities. For the 2day to 6day durations, the curves indicate that the BHM approach produces an overall underestimation of IFD depths.

However, a summary figure for the study areas does not provide an adequate assessment for benchmarking due to the spatial variation across the regions. The percentage difference between model IFDs and the ARR2015 IFD depths ( $(\text{model IFD} - \text{ARR2015 IFD}) / \text{ARR2015 IFD}$ ) have been mapped in Figures 4 to 8 to represent the model performance across the study areas. These have been calculated at the centre of the grid cell. The CCAM and WRF grid resolution are slightly smaller but comparable with that of the ARR2015 IFD grids. However, the BHM grid cells are significantly larger and therefore the difference maps only provide an indication of difference at the centre of the grid cell and do not reflect variation that may exist in the ARR2015 IFD over the BHM grid cell area. Drainage division boundaries have been overlayed to indicate the location of major topographical divides.

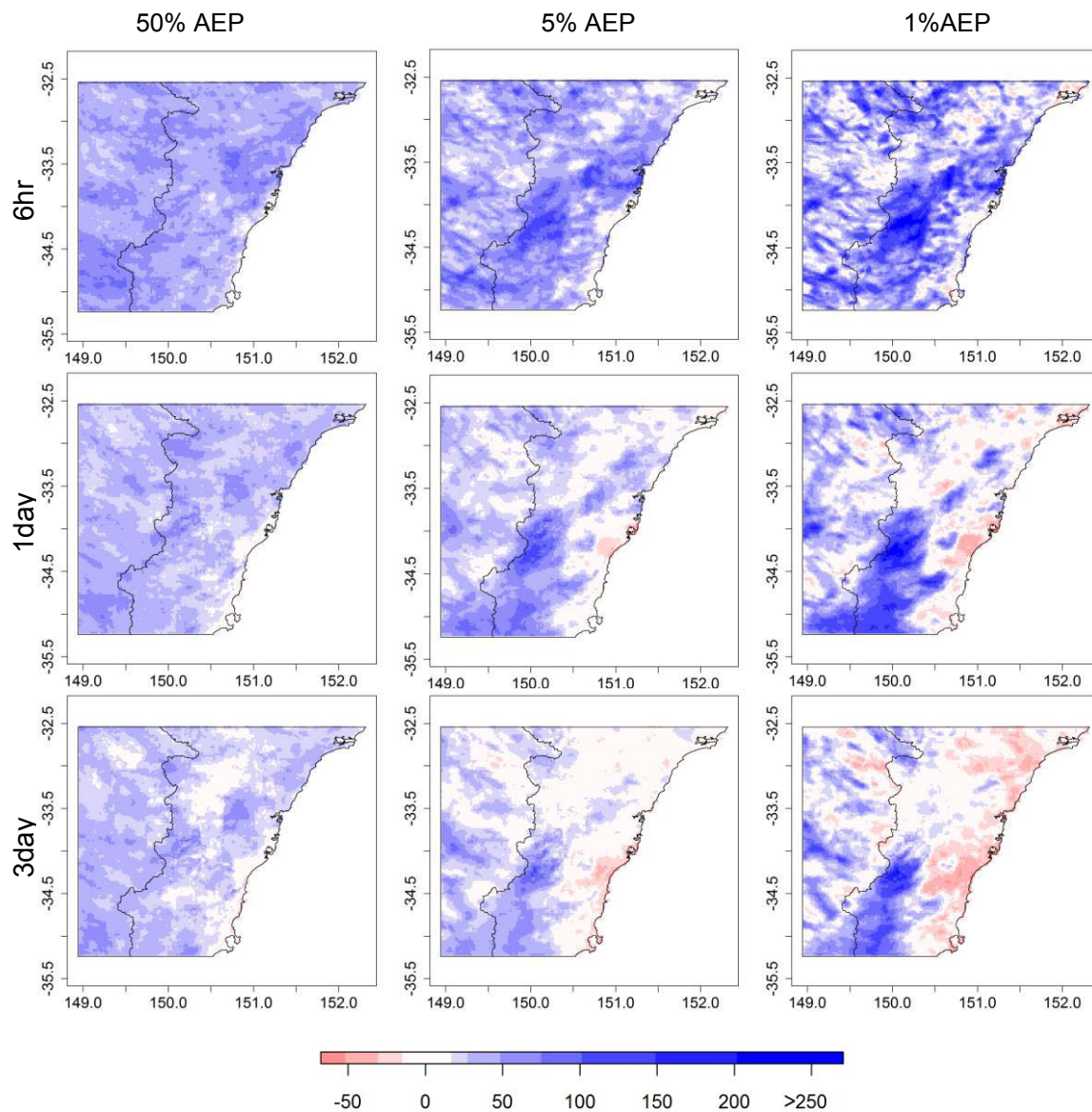


**Figure 4 Percentage difference between WRF and ARR2015s IFD for the Sydney study area**

The WRF difference maps for the Sydney area shown in Figure 4 indicate that the model produces closer estimates of large rainfall events for the higher probabilities and 1day duration. For the 1hr



depths, the WRF IFDs tend to underestimate compared with ARR2015 IFDs generally to the east of the Great Dividing Range and overestimate on the west, both more significant at lower probabilities and shorter durations. At 1day 50%AEP, there is tendency to moderately underestimate depths across the majority of the study area but overall, the 1day depths are closest to the ARR2015 IFDs. There are some areas of overestimation near the coast which are south of some east-west oriented topography.

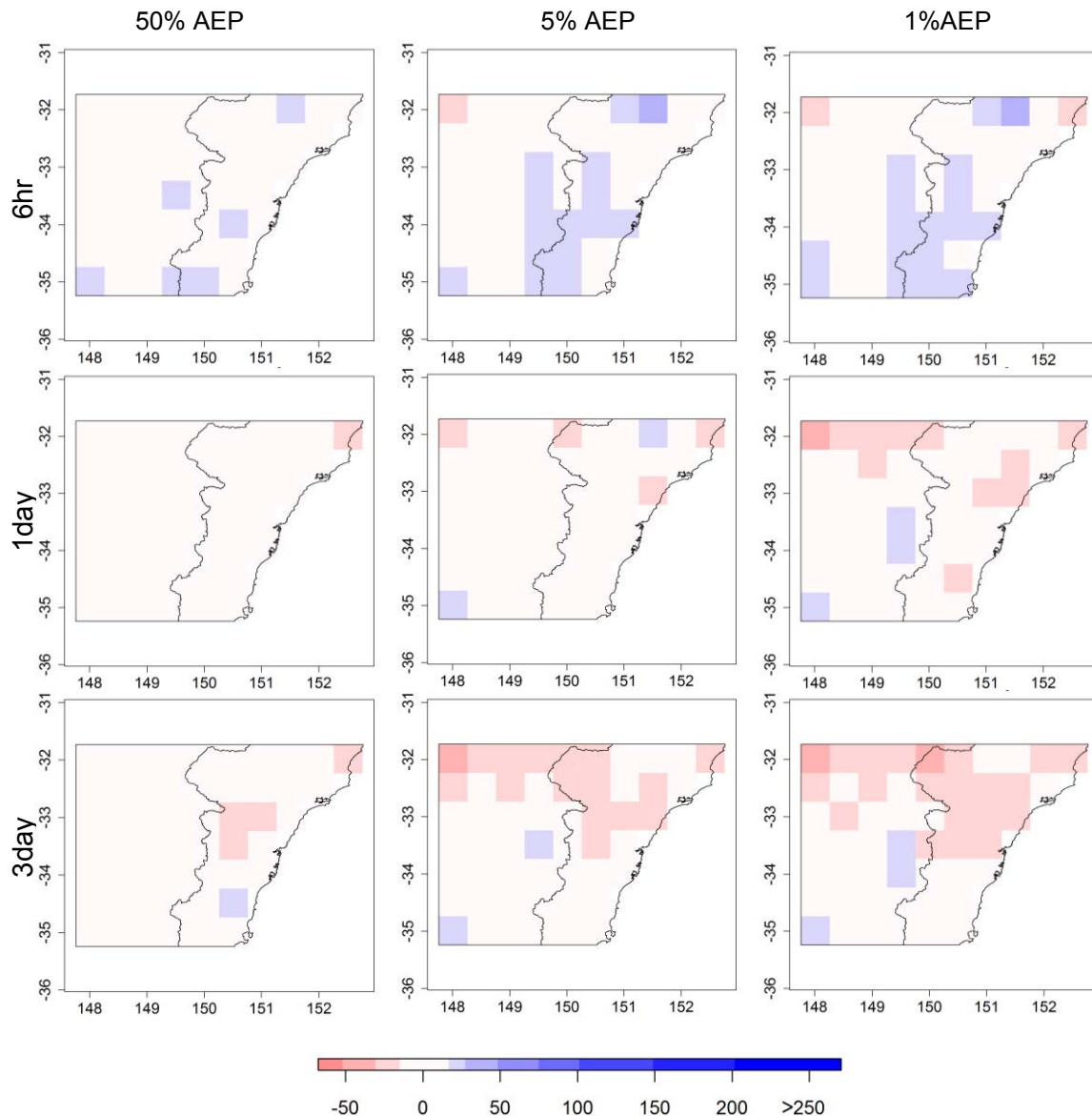


**Figure 5 Percentage difference between CCAM and ARR2015 IFDs for the Sydney study area**

The CCAM Sydney study area maps (Figure 5) show a general tendency for the model to produce overestimates of IFD depths for higher probability events over most of the domain. For longer durations, there is an area of underestimation along the coast, particularly around the greater metropolitan Sydney region. For less frequent events, the differences increase significantly in magnitude with some relatively large areas of overestimation. The estimates in the north east of the study region are improved for longer durations. There is an area of significant overestimation to the south of Katoomba corresponding with a valley with a narrow mouth.

Figure 6 shows the comparison between the IFDs derived using the BHM approach and the ARR2015 IFD depths for the Sydney area. It can generally be noted that the BHM produces comparable results with less than 15% difference over the majority of the area. Larger differences tend to still be within 50% and mostly under 30%. They are their highest at lower probabilities. At shorter durations, the BHM generally generates higher IFD depths, particularly around the area in the Blue Mountain ranges where topography peaks. In the north-west of the study area where gauges are sparse, the BHM

tends to underestimate and as duration increases, the area of underestimation extends across the top of the study area.



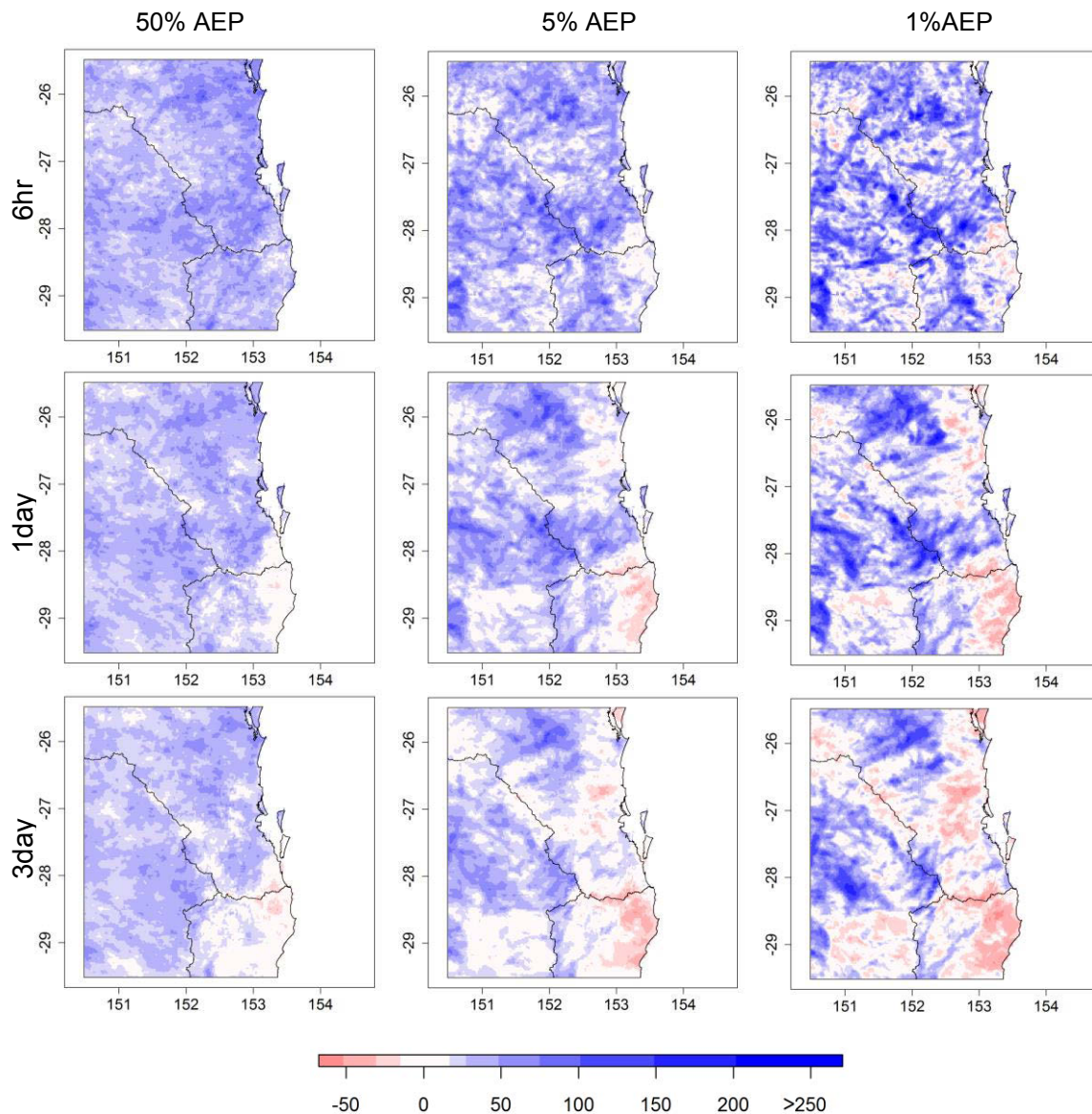
**Figure 6 Percentage difference between BHM and ARR2015 IFDs for the Sydney study area**

The results for the IFD depths derived from the CCAM data for the SEQ study area (Figure 7) show similar patterns to the Sydney area, with general overall overestimation increasing in magnitude as the probability decreases. As the duration increases, areas of underestimation are apparent along the coast.

The BHM differences for SEQ shown in Figure 8 are also similar in pattern to those of the Sydney study area. Differences are small for durations 1day or less. For shorter durations, there is a small area of underestimation in the south-east. As the duration increases, the BHM depths are less than the ARR2015 IFD depths along the coast.

## SUMMARY

IFD curves for Australia have recently been updated (ARR2015 IFDs) using a rigorous analysis of current data and methods and represent the best estimate of design rainfalls in Australia. IFDs derived from the CCAM and WRF annual maxima series have been compared with ARR2015 IFD depths.



**Figure 7 Percentage difference between CCAM and ARR2015 IFDs for the SEQ study area**

All results showed an increase in the magnitude of the differences with lower probability.

The significant differences observed when comparing the CCAM IFDs and WRF IFDs with the ARR2015 IFDs indicate the simulations for this study are currently unable to reproduce the annual rainfall extremes which give similar design depths when fitted with a GEV distribution.

IFDs created using the BHM approach have also been compared to assess the ability of this alternate method to produce similar to the ARR2015 IFD depths. Overall the BHM IFD depths compare reasonably well with the ARR2015 IFD depths, however in the study areas there is a tendency to produce higher estimates for shorter durations and lower estimates for longer durations.

### 3. ACKNOWLEDGMENTS

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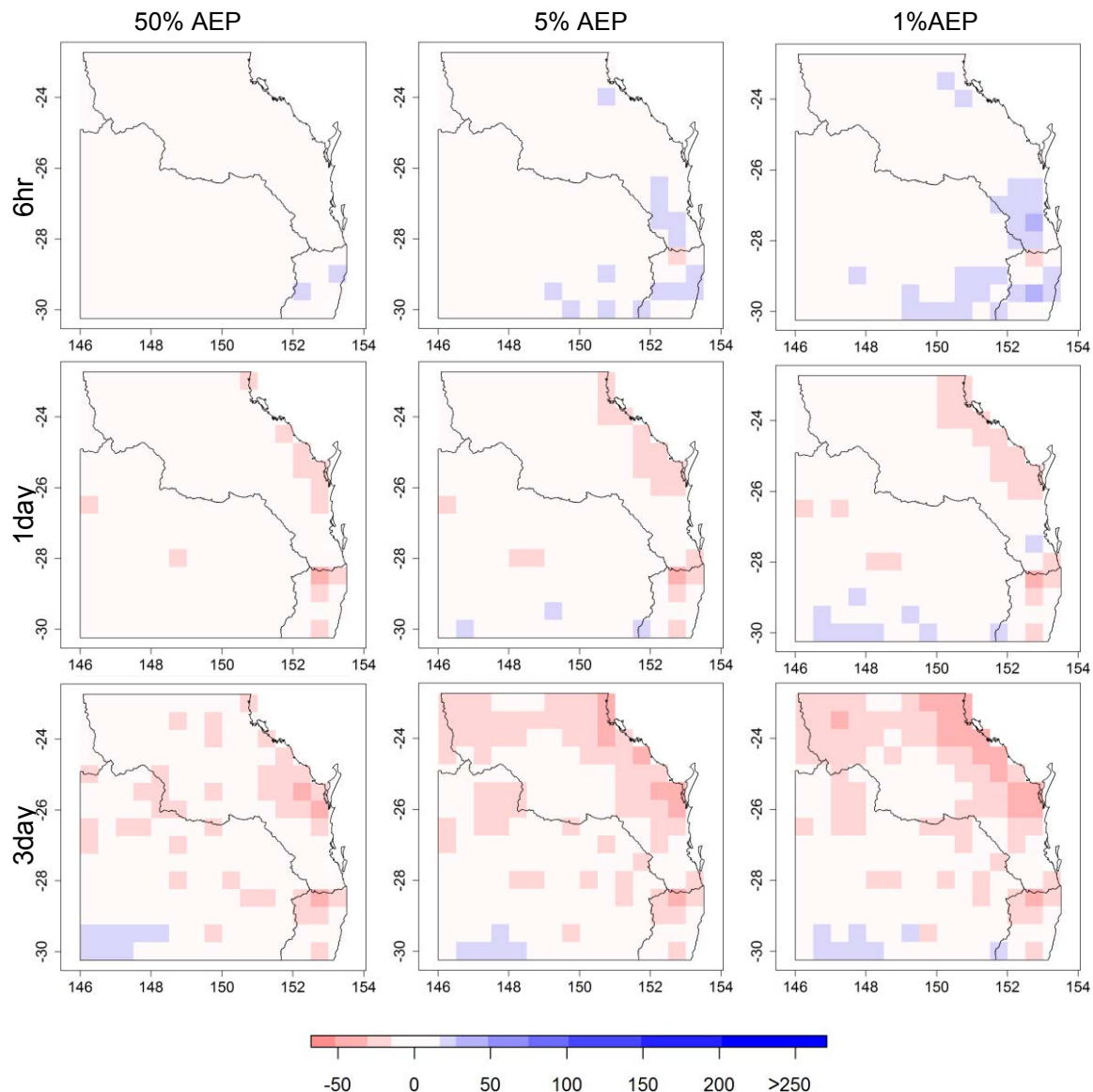


Figure 8 Percentage difference between BHM and ARR2015 IFDs for the SEQ study area

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