Supplementary Information

**A systematic review of climate change science relevant to Australian design flood estimation**

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**Table S1.** Systematic review search terms.

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| --- | --- |
| Search Terms | Number of Articles |
| Flood frequency analysis | |
| TITLE-ABS-KEY (Australia AND “flood frequency” AND change) | 76 |
| Continuous simulation | |
| TITLE-ABS-KEY (Australia AND downscaling AND flood AND change) | 10 |
| TITLE-ABS-KEY (Australia AND “flood frequency” AND projection) | 6 |
| TITLE-ABS-KEY (Australia AND “bottom up” AND flood) | 8 |
| TITLE-ABS-KEY (Australia AND “scenario neutral” AND flood) | 0 |
| TITLE-ABS-KEY (Australia AND “decision scaling” AND flood) | 0 |
| TITLE-ABS-KEY (Australia AND downscaling AND flood AND change) | 10 |
| TITLE-ABS-KEY (Australia AND “flood frequency” AND projection) | 6 |
| TITLE-ABS-KEY (Australia AND “bottom up” AND flood) | 8 |
| Rainfall intensity |  |
| TITLE-ABS-KEY (Australia AND “heavy rainfall” AND change) | 79 |
| TITLE-ABS-KEY (Australia AND “heavy rainfall” AND projection) | 9 |
| TITLE-ABS-KEY (Australia AND “heavy rainfall” AND trend) | 32 |
| TITLE-ABS-KEY (Australia AND “extreme rainfall” AND change) | 144 |
| TITLE-ABS-KEY (Australia AND “extreme rainfall” AND projection) | 34 |
| TITLE-ABS-KEY (Australia AND “extreme rainfall” AND trend) | 54 |
| TITLE-ABS-KEY (Australia AND “extreme precipitation” AND change) | 64 |
| TITLE-ABS-KEY (Australia AND “extreme precipitation” AND projection) | 10 |
| TITLE-ABS-KEY (Australia AND “extreme precipitation” AND trend) | 12 |
| TITLE-ABS-KEY (Australia AND “heavy precipitation” AND change) | 22 |
| TITLE-ABS-KEY (Australia AND “heavy precipitation” AND projection) | 7 |
| TITLE-ABS-KEY (Australia AND “heavy precipitation” AND trend) | 29 |
| TITLE-ABS-KEY (Australia AND “Clausius-Clapeyron”) | 20 |
| Probable maximum precipitation |  |
| TITLE-ABS-KEY (Australia AND “probable maximum precipitation” AND change) | 7 |
| Temporal and spatial patterns |  |
| TITLE-ABS-KEY (Australia AND “temporal pattern” AND change AND “rainfall”) | 25 |
| TITLE-ABS-KEY (Australia AND “temporal pattern” AND change AND “design storm”) | 2 |
| TITLE-ABS-KEY (Australia AND “design burst” AND change) | 0 |
| TITLE-ABS-KEY (Australia AND “design rainfall” AND “temporal pattern” AND change) | 2 |
| TITLE-ABS-KEY (Australia AND “areal reduction factor” AND “change” AND rainfall) | 3 |
| TITLE-ABS-KEY (Australia AND spatial AND change AND “design rainfall”) | 6 |
| TITLE-ABS-KEY (Australia AND spatial AND change AND “design rainfall”) | 0 |
| TITLE-ABS-KEY (Australia AND spatial AND “design burst”) | 0 |
| TITLE-ABS-KEY (Australia AND “correlation structure” AND rainfall AND change) | 2 |
| TITLE-ABS-KEY (Australia AND “spatial dependency” AND rainfall AND change) | 2 |
| TITLE-ABS-KEY (Australia AND “rainfall intensification” AND spatial) | 0 |
| TITLE-ABS-KEY (Australia AND “rainfall intensification” AND temporal) | 0 |
| TITLE-ABS-KEY (Australia AND “extreme rainfall” AND spatial AND change) | 33 |
| Antecedent wetness |  |
| TITLE-ABS-KEY (Australia AND flood AND “antecedent conditions”) | 16 |
| TITLE-ABS-KEY (Australia AND flood AND “continuing loss”) | 12 |
| TITLE-ABS-KEY (Australia AND flood AND “infiltration loss”) | 3 |
| TITLE-ABS-KEY (Australia AND flood AND “proportional loss”) | 3 |
| TITLE-ABS-KEY (Australia AND flood AND “initial loss”) | 18 |

**Table S2.** Final set of articles included in systematic review.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Authors | Year | Title | Journal | Volume | Pages/Article Number |
| Alexander, L.V., Arblaster, J.M. | 2017 | Historical and projected trends in temperature and precipitation extremes in Australia in observations and CMIP5 | Weather and Climate Extremes | 15 | 34-56 |
| Ali, H., Fowler, H.J., Lenderink, G., Lewis, E., Pritchard, D. | 2021 | Consistent Large-Scale Response of Hourly Extreme Precipitation to Temperature Variation Over Land | Geophysical Research Letters | 48 | e2020GL090317 |
| Ayat, H., Evans J.P., Sherwood, S.C., Soderholm, J. | 2022 | Intensification of subhourly heavy rainfall | Science | 378 | 655-659 |
| Bao, J., Sherwood, S.C., Alexander, L.V., Evans, J.P. | 2017 | Future increases in extreme precipitation exceed observed scaling rates | Nature Climate Change | 7 | 128-132 |
| Barbero, R., Westra, S., Lenderink, G., Fowler, H.J. | 2018 | Temperature-extreme precipitation scaling: a two-way causality? | International Journal of Climatology | 38 | e1274-e1279 |
| BoM and CSIRO | 2015 | Climate Change in Australia | <https://www.climatechangeinaustralia.gov.au/en/communication-resources/reports/> | - | - |
| Bureau of Meteorology | 2022 | Assessment Reports | https://awo.bom.gov.au/about/overview/assessment-reports#regionsandreports | - | - |
| Bruyère, C.L., Done, J.M., Jaye A.B., Holland, G.J., Buckley, B., Henderson, D.J., Leplastrier, M., Chan, P. | 2019 | Physically-based landfalling tropical cyclone scenarios in support of risk assessment | Weather and Climate Extremes | 26 | 100229 |
| Bui, A., Johnson, F., Wasko, C. | 2019 | The relationship of atmospheric air temperature and dew point temperature to extreme rainfall | Environmental Research Letters | 14 | 74025 |
| Chen, H., Sun, J., Chen, X. | 2014 | Projection and uncertainty analysis of global precipitation-related extremes using CMIP5 models | International Journal of Climatology | 34 | 2730-2748 |
| Chen, Y.-R., Yu, B., Jenkins, G. | 2013 | Secular variation in rainfall and intensity-frequency duration curves in Eastern Australia | Journal of Water and Climate Change | 4 | 244-251 |
| Chevuturi, A., Klingaman, N.P., Turner, A.G., Hannah, S. | 2018 | Projected Changes in the Asian-Australian Monsoon Region in 1.5°C and 2.0°C Global-Warming Scenarios | Earth's Future | 6 | 339-358 |
| Contractor, S., Donat, M.G., Alexander, L.V. | 2018 | Intensification of the Daily Wet Day Rainfall Distribution Across Australia | Geophysical Research Letters | 45 | 8568-8576 |
| Coppola, E., et al. | 2021 | Climate hazard indices projections based on CORDEX-CORE, CMIP5 and CMIP6 ensemble | Climate Dynamics | 57 | 1293-1383 |
| Dey, R., Gallant, A.J.E., Lewis, S.C. | 2020 | Evidence of a continent-wide shift of episodic rainfall in Australia | Weather and Climate Extremes | 29 | 100274 |
| Dey, R., Lewis S.C., Arblaster, J.M., Abram, N.J. | 2019 | A review of past and projected changes in Australia's rainfall | Wiley Interdisciplinary Reviews: Climate Change | 10 | e577 |
| Du, H., et al. | 2019 | Precipitation From Persistent Extremes is Increasing in Most Regions and Globally | Geophysical Research Letters | 46 | 6041-6049 |
| Evans, J.P., McCabe, M.F. | 2013 | Effect of model resolution on a regional climate model simulation over southeast Australia | Climate Research | 56 | 131-145 |
| Fu, G., Chiew, F.H.S., Post, D.A. | 2023 | Trends and variability of rainfall characteristics influencing annual streamflow: A case study of southeast Australia | International Journal of Climatology | 43 | 1407-1430 |
| Gu, X., Zhang, Q., Li, J., Liu, J., Xu, C.-Y., Sun, P. | 2020 | The changing nature and projection of floods across Australia | Journal of Hydrology | 584 | 124703 |
| Guerreiro, S.B., Fowler, H.J., Barbero, R., Westra, S., Lenderink, G., Blenkinsop, S., Lewis, E., Li, X.-F. | 2018 | Detection of continental-scale intensification of hourly rainfall extremes | Nature Climate Change | 8 | 803-807 |
| Gutierrez, J.M., et al. | 2021 | IPCC AR6 WG1 interactive atlas | http://interactive-atlas.ipcc.ch/ | - | - |
| Hajani, E., Rahman, A. | 2018 | Characterizing changes in rainfall: A case study for New South Wales, Australia | International Journal of Climatology | 38 | 1452-1462 |
| Han, X., Mehrotra R., Sharma A., Rahman A. | 2022 | Incorporating nonstationarity in regional flood frequency analysis procedures to account for climate change impact | Journal of Hydrology | 612 | 128235 |
| Han, X., Mehrotra, R., Sharma, A. | 2020 | Measuring the spatial connectivity of extreme rainfall | Journal of Hydrology | 590 | 125510 |
| Herath, S.M., Sarukkalige, P.R., Nguyen, V.T.V. | 2016 | A spatial temporal downscaling approach to development of IDF relations for Perth airport region in the context of climate change | Hydrological Sciences Journal | 61 | 2061-2070 |
| Herold, N., Downes, S.M., Gross, M.H., Nishant, R., Macadam, I., Ridder, N.N., Beyer, K. | 2021 | Projected changes in the frequency of climate extremes over southeast Australia | Environmental Research Communcations | 3 | 11001 |
| Ho, M., Nathan, R., Wasko, C., Vogel, E., Sharma, A. | 2022 | Projecting changes in flood event runoff coefficients under climate change | Journal of Hydrology | 615 | 128689 |
| Ho, M., Wasko, C., O’Shea, D., Nathan, R., Vogel, E., Sharma, A. | 2023 | Changes in flood-associated rainfall losses under climate change | Journal of Hydrology | 625 | 129950 |
| Jayaweera, L., Wasko, C., Nathan, R., Johnson, F. | 2023 | Non-stationarity in extreme rainfalls across Australia | Journal of Hydrology | 624 | 129872 |
| Ju, J., Wu C., Yeh, P.J.-F., Da,i H., Hu, B.X. | 2021 | Global precipitation-related extremes at 1.5 °C and 2 °C of global warming targets: Projection and uncertainty assessment based on the CESM-LWR experiment | Atmospheric Research | 264 | 105868 |
| Kamruzzaman, M., Beecham, S., Metcalfe, A.V. | 2016 | Estimation of trends in rainfall extremes with mixed effects models | Atmospheric Research | 168 | 24-32 |
| Laz, O.U., Rahman, A., Yilmaz, A., Haddad, K. | 2014 | Trends in sub-hourly, sub-daily and daily extreme rainfall events in eastern Australia | Journal of Water and Climate Change | 5 | 667-675 |
| Li, J., Wasko, C., Johnson, F., Evans, J.P., Sharma, A. | 2018 | Can Regional Climate Modeling Capture the Observed Changes in Spatial Organization of Extreme Storms at Higher Temperatures? | Geophysical Research Letters | 45 | 4475-4484 |
| Li, J., Wasko, C., Johnson, F., Evans, J.P., Sharma, A. | 2018 | Can Regional Climate Modeling Capture the Observed Changes in Spatial Organization of Extreme Storms at Higher Temperatures? | Geophysical Research Letters | 45 | 4475–4484 |
| Liu, J., Qiao, S., Li, C., Tang, S., Chen, D., Feng, G. | 2021 | Anthropogenic influence on the intensity of extreme precipitation in the Asian-Australian monsoon region in HadGEM3-A-N216 | Atmospheric Science Letters | 22 | e1036 |
| Liu, J., Wu, D., Li, Y., Ren, H., Zhao, Y., Sun, X., Zhang, H., Ji M. | 2022 | Spatiotemporal variation of precipitation on a global scale from 1960 to 2016 in a new normalized daily precipitation dataset | International Journal of Climatology | 42 | 3648-3665 |
| Magan, B., Kim, S., Wasko, C., Barbero, R., Moron, V., Nathan, R., Sharma, A. | 2020 | Impact of atmospheric circulation on the rainfall-temperature relationship in Australia | Environmental Research Letters | 15 | 94098 |
| Mantegna, G.A., White, C.J., Remenyi, T.A., Corney, S.P., Fox-Hughes, P. | 2017 | Simulating sub-daily Intensity-Frequency-Duration curves in Australia using a dynamical high-resolution regional climate model | Journal of Hydrology | 554 | 277-291 |
| Osburn, L., Hope, P., Dowdy, A. | 2021 | Changes in hourly extreme precipitation in victoria, Australia, from the observational record | Weather and Climate Extremes | 31 | 100294 |
| Pepler, A.S., Dowdy, A.J. | 2022 | Australia’s Future Extratropical Cyclones | Journal of Climate | 35 | 4195-4210 |
| Pfahl, S., O'Gorman, P.A., Fischer, E.M. | 2017 | Understanding the regional pattern of projected future changes in extreme precipitation | Nature Climate Change | 7 | 423-427 |
| Roderick, T.P., Wasko, C., Sharma, A. | 2020 | An Improved Covariate for Projecting Future Rainfall Extremes? | Water Resources Research | 56 | e2019WR026924 |
| Salas, J.D., Anderson, M.L., Papalexiou, S.M., Frances, F. | 2020 | PMP and Climate Variability and Change: A Review | Journal of Hydrologic Engineering | 25 | 03120002 |
| Shields, C.A., Kiehl, J.T., Meehl, G.A. | 2016 | Future changes in regional precipitation simulated by a half-degree coupled climate model: Sensitivity to horizontal resolution | Journal of Advances in Modeling Earth Systems | 8 | 863-884 |
| Sillmann, J., Kharin, V.V., Zwiers, F.W., Zhang, X., Bronaugh, D. | 2013 | Climate extremes indices in the CMIP5 multimodel ensemble: Part 2. Future climate projections | Journal of Geophysical Research Atmospheres | 118 | 2473-2493 |
| Smith, I., McAlpine, C. | 2014 | Estimating future changes in flood risk: Case study of the Brisbane river, Australia | Climate Risk Management | 6 | 6-17 |
| Tolhurst, G., Hope, P., Osburn, L., Rauniyar, S. | 2023 | Approaches to Understanding Decadal and Long-Term Shifts in Observed Precipitation Distributions in Victoria, Australia | Journal of Applied Meteorology and Climatology | 62 | 3-19 |
| Visser, J.B., Kim, S., Wasko, C., Nathan, R., Sharma, A. | 2022 | The Impact of Climate Change on Operational Probable Maximum Precipitation Estimates | Water Resources Research | 58 | e2022WR032247 |
| Visser, J.B., Wasko, C., Sharma, A., Nathan, R. | 2021 | Eliminating the Hook in Precipitation Temperature Scaling | Journal of Climate | 34 | 9535-9549 |
| Visser, J.B., Kim, S., Wasko, C., Nathan, R., Sharma, A. | 2022 | The Impact of Climate Change on Operational Probable Maximum Precipitation Estimates | Water Resources Research | 58 | e2022WR032247 |
| Visser, J.B., Wasko, C., Sharma, A., Nathan, R. | 2023 | Changing storm temporal patterns with increasing temperatures across Australia | Journal of Climate | - | 10.1175/JCLI-D-22-0694.1 |
| Wasko, C., Guo, D., Ho, M., Nathan, R., Vogel, E. | 2023 | Diverging projections for flood and rainfall frequency curves | Journal of Hydrology | 620 | 129403 |
| Wasko, C., Lu, W.T., Mehrotra, R. | 2018 | Relationship of extreme precipitation, dry-bulb temperature, and dew point temperature across Australia | Environmental Research Letters | 13 | 74031 |
| Wasko, C., Nathan, R. | 2019 | Influence of changes in rainfall and soil moisture on trends in flooding | Journal of Hydrology | 575 | 432-441 |
| Wasko, C., Sharma, A. | 2017 | Continuous rainfall generation for a warmer climate using observed temperature sensitivities | Journal of Hydrology | 544 | 575-590 |
| Wasko, C., Sharma, A. | 2014 | Quantile regression for investigating scaling of extreme precipitation with temperature | Water Resources Research | 50 | 3608-3614 |
| Wasko, C., Sharma, A. | 2015 | Steeper temporal distribution of rain intensity at higher temperatures within Australian storms | Nature Geoscience | 8 | 527–529 |
| Wasko, C., Sharma, A. | 2017 | Continuous rainfall generation for a warmer climate using observed temperature sensitivities | Journal of Hydrology | 544 | 575–590 |
| Wasko, C., Sharma, A. | 2015 | Changed Design Temporal Patterns with Higher Temperatures | 36th Hydrology and Water Resources Symposium: The Art and Science of Water. | Engineers Australia, Barton, ACT. | 1237–1244 |
| Wasko, C., Sharma, A., Westra, S. | 2016 | Reduced spatial extent of extreme storms at higher temperatures | Geophysical Research Letters | 43 | 4026–4032 |
| Watterson, I.G. | 2020 | Influence of Sea Surface Temperature on Simulated Future Change in Extreme Rainfall in the Asia-Pacific | Asia-Pacific Journal of Atmospheric Sciences | 56 | 349-366 |
| Westra, S., Evans, J.P., Mehrotra, R., Sharma, A. | 2013 | A conditional disaggregation algorithm for generating fine time-scale rainfall data in a warmer climate | Journal of Hydrology | 479 | 86-99 |
| White, C.J., McInnes, K.L., Cechet, R.P., Corney, S.P., Grose, M.R., Holz, G.K., Katzfey, J.J., Bindoff, N.L. | 2013 | On regional dynamical downscaling for the assessment and projection of temperature and precipitation extremes across Tasmania, Australia | Climate Dynamics | 41 | 3145-3165 |
| Yilmaz, A.G., Hossain, I., Perera, B.J.C. | 2014 | Effect of climate change and variability on extreme rainfall intensity-frequency-duration relationships: A case study of Melbourne | Hydrology and Earth System Sciences | 18 | 4065-4076 |
| Zhan, W., Buckley, S., Genova, P., Grobler, J., Redenbach, M., Eskola, K. | 2022 | Selecting and Processing High Resolution Climate Projections in Queensland Mine Water Planning and Hydrologic Assessment | Hydrology and Water Resources Symposium, HWRS 2022 | - | 518-533 |
| Zhang, W., Villarini, G., Wehner, M. | 2019 | Contrasting the responses of extreme precipitation to changes in surface air and dew point temperatures | Climatic Change | 154 | 257–271 |
| Zheng, F., Westra, S., Leonard, M. | 2015 | Opposing local precipitation extremes | Nature Climate Change | 5 | 389-390 |



**Figure S3.** Standardisation of initial loss parameter projections by global mean temperature change. Each boxplot represents the median change for each site in the Natural Resource Management Regions (CSIRO and Bureau of Meteorology, 2015), across the projections developed Australian Bureau of Meteorology (Srikanthan et al., 2022; Vogel et al., 2023; Wilson et al., 2022).



**Figure S4.** Standardisation of continuing loss parameter projections by global mean temperature change. Each boxplot represents the median change for each site in the Natural Resource Management Regions (CSIRO and Bureau of Meteorology, 2015), across the projections developed Australian Bureau of Meteorology (Srikanthan et al., 2022; Vogel et al., 2023; Wilson et al., 2022).