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Framework for deriving future hazard layers from future climate data for physical climate risk assessments

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Abstract: This study presents a framework for translating standardised IPCC climate model outputs, particularly under suitable scenarios and associated global warming levels, into localised hazard metrics relevant to infrastructure and asset risk. By integrating downscaled climate data with metrics calculations or physical modelling for hazards such as flooding, bushfires, extreme winds and landslides, the framework enables comprehensive multi-hazard risk assessments aligned with national climate risk endeavours.

Keywords: *Physical risk assessment, future hazards, future climate, computational modelling*

1. INTRODUCTION

As climate-related risks intensify across sectors and geographies, the need for robust, forward-looking frameworks to assess physical climate risk is becoming more urgent. In response, governments including Australia are moving towards mandatory climate-related financial disclosure defined in AASB S2 (Australian Accounting Standards Board, 2023) or equivalent, requiring large businesses and institutions to quantify and report their exposure to future climate hazards. This demands methodologies that go beyond historical trends and incorporate projected climate scenarios grounded in the latest science.

The Intergovernmental Panel on Climate Change (IPCC) provides the scientific foundation for such assessments, particularly through its Coupled Model Intercomparison Project (CMIP) (Eyring et al., 2016). CMIP6 (the latest collection of models), offers standardised global climate projection data under a range of shared socioeconomic pathways (SSPs). However, translating these General Circulation Model (GCM) large-scale outputs into actionable, localised risk metrics for different assets and infrastructure types remains a challenge.

Traditionally risk is defined using consequence and likelihood (Risk = Likelihood × Consequence), representing the expect annual losses (direct and indirect) of a particular hazard on assets or infrastructure. Alternatively, the IPCC considers climate risk (Section 1.3.1, Pörtner et al., 2022) as a complex interplay between three elements – the climate hazard, the level of exposure to the hazard and the vulnerability of the affected system (Risk = Hazard × Exposure × Vulnerability). In both cases, physical risk calculations need information of relevant hazards like extreme heat, extreme cold, extreme wind, extreme precipitation, flooding (pluvial, fluvial and coastal inundation), bushfires and landslides. For present day climate risk calculations these can just use observational data and statistics from the recent past to model extreme scenarios. However, for future risk assessments the hazards information must be derived from the future climate projections. Some of these hazards (temperature extremes, precipitation extremes and wind extremes) can be derived directly from the future climate projections. Other hazards like flooding and bushfires require further physical modelling to determine their future severity (consequence) and likelihood. Once these relevant datasets have been obtained, multi-hazard risk assessment frameworks like Lin and Jarrett (2010) can be used for comprehensive physical risk assessments. This study explores a standardised framework for determining future hazard information from future climate projections. Section 2 outlines the methodology and some results whilst Section 3 contains the conclusions.

2. METHODOLOGY AND RESULTS

2.1. Climate scenario, models selection and downscaling

The model intercomparison project (MIP) coordinated by the IPCC ensures different climate models are run under standardised scenarios – allowing the model results to be compared and uncertainties to be quantified. Depending on the local region being considered, a subset of the GCMs which most accurately reflects relevant local historical climate data should be selected.

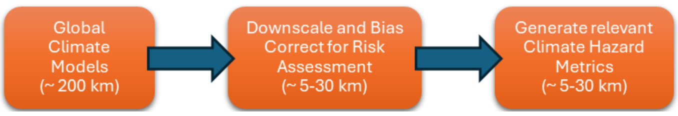

Figure 1 Process for downscaling global climate models (GCMs)

Figure 1 shows the steps required to downscale the chosen climate models. Climate projections from GCMs are statistically/dynamically downscaled to the resolution of historical gridded data. These downscaled projections are bias corrected using historical reference data to remove modelling biases and subsequently transformed into climate hazard metrics. The outputs of the final step can include metrics usable directly in climate risk assessments including extreme heat, heatwaves, extreme cold and extreme rainfall.

Scenario selection should be tailored to the application. To satisfy Australia's AASB S2 requirements of a physical risk assessment it is recommended to use the CMIP6 based SSP3-7.0 scenario (known as "Regional Rivalry") for a plausible future scenario. For Australia's National Climate Risk Assessment (Jakob et al., 2025) the CMIP6 SSP3-7.0 scenario was considered for global warming levels (GWLs) of +1.2°C (baseline), +1.5°C, +2.0°C and +3.0°C.

2.2. Hazard layer generation

Some future hazards are determined through post-processing (into diagnostics) or through physical modelling:

- **Coastal inundation**: Ocean modelling included in the AOGCMs provides prediction of the future sea level rise (SLR) which is spatially varying. However these models do not adequately resolve localised extremes in the total water levels (TWLs) with contributions from astronomical tides, storm surge, etc. Baseline statistics for total water levels can be obtained from historical analysis of tide gauge datasets. Coastal inundation modelling can then be run for scenarios with extreme water levels which combine the TWL and SLR values.
- **Pluvial flooding:** Rainfall based flooding scenarios can be modelled using the local rainfall statistics. For example a scenario of 1% AEP (annual exceedance probability) daily rainfall amount falling in 1 hour and allowing the runoff to be modelled for the rest of the day to obtain the flood layer extents.
- **Fire hazard:** Fire hazard can be obtained by determining the statistics for number of days with locally dangerous weather for fires (e.g. Forest Fire Danger Index) from the climate data. This can then be combined with information on the local fuel loads to derive a local fire hazard.
- **Severe convective wind hazard:** This hazard represents the potential for convective storms through a metric derived from temperature, specific humidity and pressure.
- **Landslide hazard:** The landslide hazard (triggered by rainfall) is developed through two key steps - landslide susceptibility mapping and critical rainfall threshold calculation.

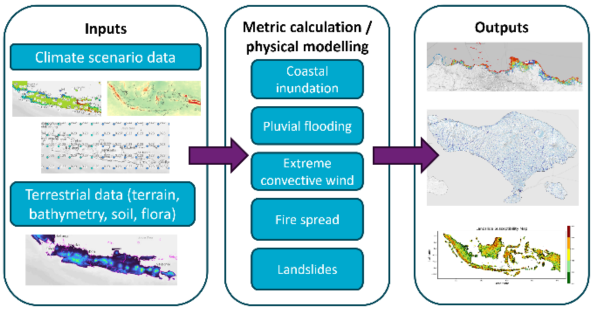

Figure 2 Process for generating hazard outputs from climate inputs

Alternatively, if it is not practical to run physical modelling for the future hazard scenarios, it may be possible to update the hazard likelihood instead. For example a 1% AEP baseline rainfall amount (e.g. 89 mm) which causes a pluvial flooding hazard currently can have its likelihood calculated for the same rainfall amount (89 mm) and flooding event in a future epoch. The resulting likelihood might change to, for example, 5% AEP rather than 1% AEP. This will still provide sufficient information for future climate risk calculations. Examples of some of the output hazard layers from this process are shown in Figure 2.

3. CONCLUSIONS

This study demonstrated a practical framework for translating future climate projections into localised hazard metrics essential for physical risk assessments. By leveraging suitable scenarios and associated global warming levels, it enables more consistent, science-based evaluation of climate-related risks across sectors and geographies.

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