RIVER FLOW PROJECTIONS TO SUPPORT CLIMATE ADAPTATION

What do we know about how river flow will change under climate change?

What data are available?

Which data are most appropriate for us to consider?

What are the limits of these data?

What types of analysis could be conducted?

What can they be used for?

Fresh water is central to our natural environment, economy and way of life. We rely on our rivers for our livelihoods; to supply drinking water, to generate electricity, to irrigate our food producing land, and to sustain ecosystems and taonga species. Climate change is changing the amount, and timing, of water flowing through our rivers.

This data infosheet is for anyone interested in how climate change is expected to impact river flow in Aotearoa New Zealand. If, for example, you are interested or involved in water services planning, water infrastructure, drinking water availability or research into the impacts of climate change on our freshwater environments and species, this data infosheet will help you navigate data produced by the Deep South Challenge and other research programmes, and identify if and how it may be of use to you.

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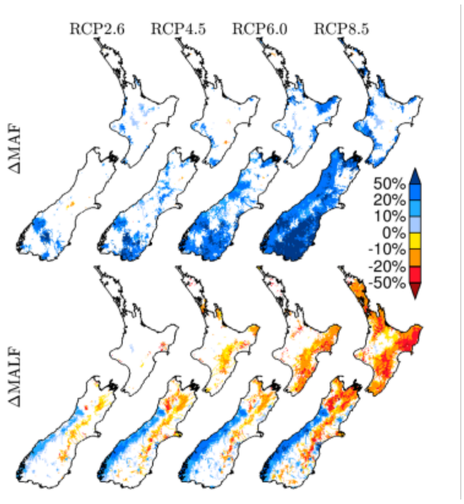
RIVER FLOW PROJECTION DATA FOR CLIMATE ADAPTATION

DEEP SOUTH CHALLENGE RESEARCH DISCUSSED: › Christian Zammit (NIWA) and Daniel Collins (Pūtahi Research) "Climate impacts on the national water cycle": https://deepsouthchallenge.co.nz/research-project/climate-impacts-on-the-national-water-cycle/

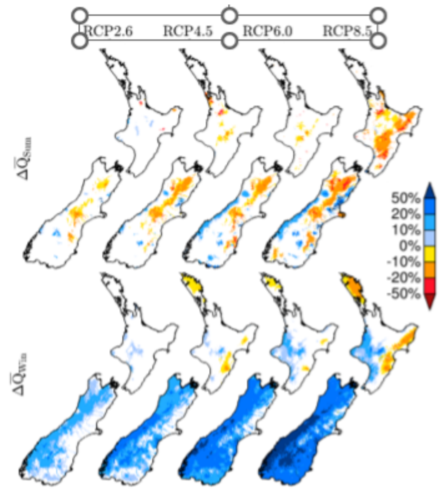
This data infosheet primarily focusses on projections of natural river flow due to climate change only; however, there are range of sources of information for other aspects of water and climate change in New Zealand.

CLIMATE HYDROLOGY PROJECTIONS

To understand how climate change will affect river flow into the future, this research uses 2013 IPCC climate projections (Representative Concentration Pathways, or RCPs) that have been modelled at a regional level for New Zealand and couples them with the national surface hydrology model TopNet. What results is a picture of how natural river flows are expected to change under different emissions scenarios. (Collins, 2020)



Reproduced from Collins (2020). Figure 5. Late century percentage changes in MAF and MALF across four RCPs relative to the reference period. White indicates statistically insignificant differences.



Reproduced from Collins (2020). Figure 4. Late-century percentage changes in mean summer and winter flows across four Representative Concentration Pathways (RCPs) relative to the reference period. White indicates statistically insignificant differences.

HOW COULD I APPLY THESE DATA?

These data could be used (additional analysis may be required):

- To understand impact of climate change on environmental flows to inform water allocation decisions.
- To develop water supply and demand planning scenarios in order to plan for future augmentations or efficiency interventions.
- To assess future riverine flood risk to explore with residents, or inform the upgrade of flood protection infrastructure.
- To estimate the change in the frequency of low flows or high flows (e.g. for species survival, Te Mana o te Wai).
- To understand the impact of climate change on municipal water supplies
- To understand the impact of climate change on natural land surface recharge at regional level (annual and seasonal).
- To simulate impact of climate change on hydrological regimes as input to downstream models (e.g. local surface water/groundwater models in coastal areas).
- To understand river overtopping during periods of high flow (to convert this to local flooding extent would require additional modelling).

WHAT DATA ARE AVAILABLE?

This is a national dataset. The data are produced using version 2.3 of the digital river network associated with the third version of the land cover database (LCDB3), soil hydrological characteristics provided by the Fundamental Soil Layer database (FSL), and aggregated to Strahler 3 stream order at an average catchment size resolution of 7 km2. Flow data are assumed to represent natural flow, free of any man-made manipulations.

As hindcast projections are "free-running", they represent a "plausible past climate" rather than the actual past climate. **As such, these data are appropriate to be provided as relative or percentage changes in distributions of hydrological statistics due to climate change, rather than absolute values.** Local analysis (e.g. flood protection schemes) requiring absolute values will likely require local model to be developed and driven by climate projection data.

These data are most robust when considering changes to mean flows.

SCENARIOS AND CLIMATE INPUTS.

Hydrological projections have been run for the historical period (1986 – 2005) and then continued using four Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6.0 and RCP8.5; 2006- 2100).

The hydrological projections are based on the climate projections of six global climate models using the Regional Climate Model. Hindcast climate simulations were bias corrected to ERA5 (25km resolution) reanalysis of precipitation and temperature (ECWMF). All climate variables were downscaled to the VCSN with precipitation and temperature being further bias corrected to better represent New Zealand climatology. Details of these climate projections can be found here: [Climate Projections for New Zealand](#) (2018).

Data and analysis can be provided for a single global climate model or as a pool of all global climate models, or both.

TEMPORAL RESOLUTION.

Raw model data exist at daily resolution, however, post processed data and analysis can be provided using:

- 20-year centered time slices (assuming stationarity)
- Data within a time period from 2006 to a future time horizon
- Data within a time period from the start of the hindcast period (1985) to a future time horizon.

These three methodologies can be useful to offer a better measure of potential uncertainty, particularly for rarer events. Analysis for future time periods assumes "stationarity", i.e. that the climate is not changing during the time period of interest.

SPATIAL SCALE

Though data are aggregated to Strahler 3 stream order, analysis is most appropriate at the subregional or catchment scale, rather than reach specific. Reach-specific analysis is possible, and described below, but it will come with significantly higher uncertainty.

POST-PROCESSED VARIABLES OR ANALYSIS:

- Watershed riverine hydrological fluxes, for example:
  - Seasonal flow
  - Mean annual flood
  - Mean annual low flow
  - Seven-day mean annual low flow
  - Fre3 - Annual number of events over 3x the long-term average median flows
  - Q5 – 20th percentile of low flows calculated for 5-year return period
- Watershed average cryospheric (snow/ice) and hydrological fluxes (including snowfall), noted below as Topnet model variables.
- Watershed average storage for snow, vegetation, soil and "groundwater"

Characterisation of a change in the annual probability of "moderate" flood, can be investigated with these data using the Peak over Threshold method. However, due to the small number of model runs available, these data are not suitable for analysis of climate events rarer than 5% annual exceedance probability. Rare event metrics are likely to be influenced strongly by events outside of natural climate variability and, possibly, atmospheric movement not represented withing the individual global climate models (e.g. ex-tropical cyclones). For rarer, more intense

TOPNET MODEL VARIABLES:

events, large ensemble data such as Weather@Home (noted at end) is needed, though uncertainties become much larger.

HYDROLOGY:

- River flow discharge at reach outlet
- Infiltration excess runoff
- Depth to water table
- Instantaneous discharge to stream
- Drainage from soil zone to saturated zone (land surface recharge)
- Instantaneous sub-basin averaged overland flow
- Instantaneous groundwater discharge

HYDROLOGY CONT:

- Saturation and Infiltration excess runoff
- Soil moisture content
- Canopy storage
- Large surface water storage (surface area larger than 1ha) inflow/outflow/volume/surface area/precipitation/evaporation treated as natural inland surface water bodies (i.e. not connected to local watershed scale groundwater store)

EVAPORATION:

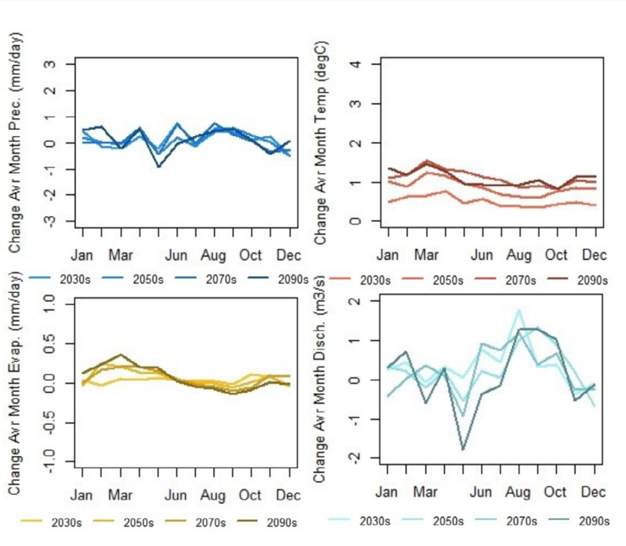
- Potential evapotranspiration
- Water evaporation from snow
- Water evaporation from soil
- Water evaporation from canopy

SNOW:

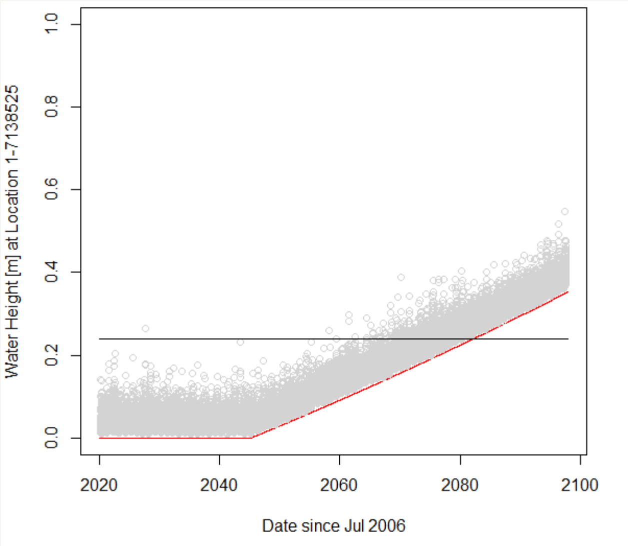
- Surface snow area fraction
- Snow accumulation
- Snow melt

HOW COULD I EXPLORE THESE DATA?

These data can be analysed in many ways, for example:



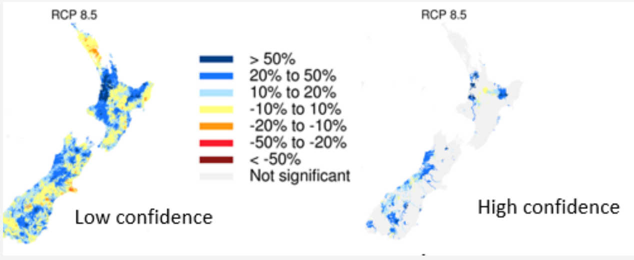
Reproduced from Smith et al. (2022). Figures 3-12 – 3-15. Simulated changes in average monthly precipitation, temperature, evaporation and river discharge for the Ōhau River, under RCP 4.5 for four 20-year centred periods.



Reproduced from Smith et al. (2022). Figure 3-18. Ensemble theoretical uniform flow March to September water level time series (grey dots), streambank full discharge water height (black line) and Mean Sea Level Rise (red line) under RCP2.6 (top left), RCP4.5 over the period 2006-2100 at location 1.

ASSUMPTIONS & LIMITATIONS

There are large uncertainties in the hydrological projections, due to small number of climate models and model runs available, model uncertainty, and natural climate variability. The level of confidence may need to be relaxed, depending on the decision-making process the data are informing.



Change in Mean Annual Flood versus modelled variability mid-century. "Confidence" is defined by the Wilcoxon Signed Rank test.

THE MODEL:

- The TopNet hydrological model (Clark et al., 2008) is mainly a surface water model, with elementary descriptions of groundwater and snow processes and conceptualisation. Flows are natural flows, devoid of any water takes.
- Streams are modelled as natural streams (no man-made structures such as stop banks) assuming a rectangular shape that overtops at the height of MAF flow.
- Land cover remains stable over the period of simulation. Land cover assumed in the current national dataset is based on version 3 of the Land Cover Database.

THE DATASET:

- Climate inputs to TopNet are those detailed in the Climate Change Projections for New Zealand (MfE, 2018). Due to the method of bias correction, any current bias in Virtual Climate Station Network observations will be present in the CMIP5 climate model hindcast simulations, and therefore, the hydrological hindcast simulations.
- The model is uncalibrated and parametrised for both hydrology and climate, based on nationally available datasets. Neither the climate nor hydrology models are constrained to match observations over the hindcast period (1985 – 2006), meaning the modelled past is not equivalent to the observed past, but a plausible past climate.
- Bias correction has occurred for hydrology for mean flow only, assuming all errors come from errors in precipitation, following Woods et al., 2006. No bias correction has been applied to match projections from 2006-present to observations.
- Validation of this national model (taken as the median across the six GCMs) has been carried out by comparison of hydrological characteristics calculated over ~400 natural streamflow stations in New Zealand. (Collins; 2020)

ADDITIONAL DATA AVAILABLE

Under both the Deep South Challenge (Modelling Future Extreme Weather) and Whakahura: extreme events and the emergence of climate change, large (multi-thousand member) ensembles have been run to better capture simulations of extreme events. This modelling is of lower spatial resolution (25-50 km) but due to the large number of model runs it is possible to more robustly analyse the statistics of extreme events. Research in Whakahura is exploring using this climate model data as input to the TopNet hydrological model. This model output can be used to, for example, characterise the change in service level associated with riverine and blue-green infrastructure.

WHO DO I CONTACT TO ACCESS THESE DATA OR ANALYSES?

Access to these data or to discuss project-specific analysis, contact Christian Zammit, NIWA hydrologist, or Kate Turner, Deep South Challenge Knowledge Broker. Due to size, this dataset is archived on NIWA's high performance computing facilities offline storage, and is not directly accessible, meaning there may be a delay to extract the data. There is no cost attached to the data itself, but there may be costs associated with required analysis or post-processing. Data and analysis are provided through a NIWA data access agreement.

- Christian Zammit (Hydrologist, NIWA): christian.zammit@niwa.co.nz
- Kate Turner (Climate Change Knowledge Broker, Deep South Challenge): kate.turner@niwa.co.nz

WILL THESE DATA BE UPDATED?

There is no funded update of these projections planned to date using CMIP6 Shared Socio-Economic Pathways. For information about how CMIP5 (currently used for hydrology) and CMIP6 projections differ for the projected climate of New Zealand, see the Aotearoa New Zealand Climate Change Projections Guidance.

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