

Forecasting Across Scales at NIWA

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Abstract

NIWA undertakes to forecast Aotearoa/New Zealand's weather and climate across spatial scales ranging from individual locations to trans-Tasman Sea domains and temporal scales from a few hours ahead to seasonal outlooks and beyond. This is done using a variety of approaches, including traditional Numerical Weather Prediction (NWP), Machine Learning (ML) and analogue techniques. Here we describe these workflows and some of their applications.

Acknowledgements

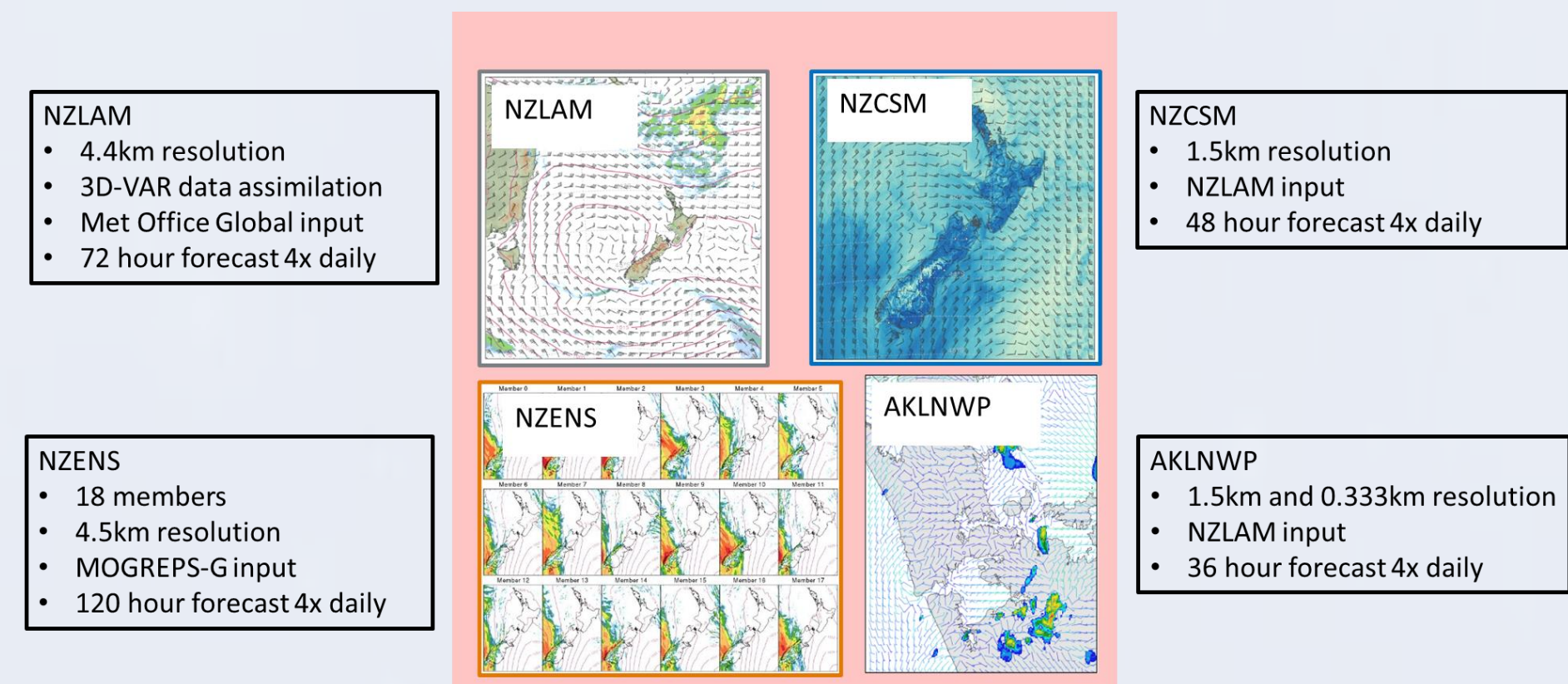
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References

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Nowcasting and Optimal Seamless Forecasting

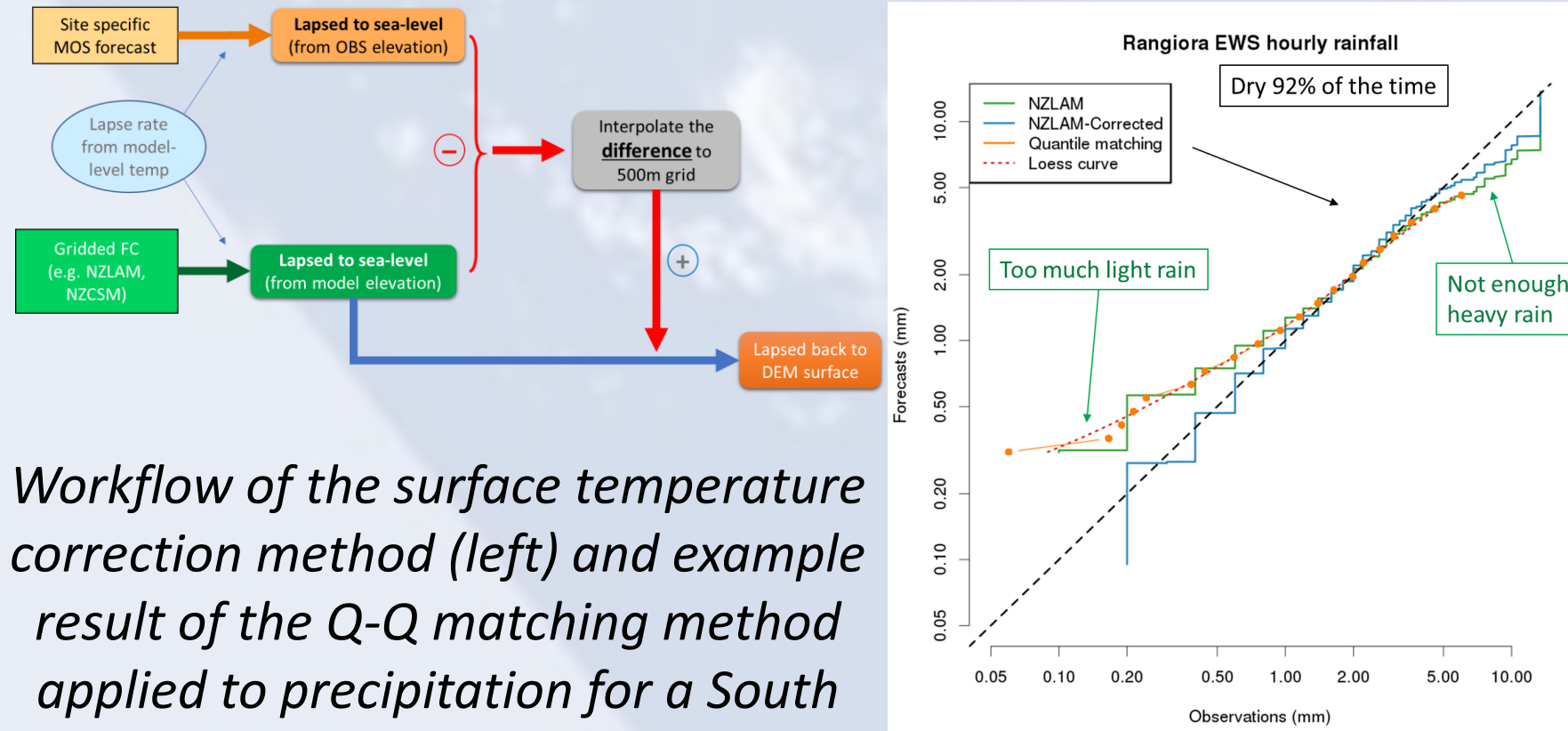
NIWA undertakes weather forecasting using a number of NWP models, designed to cover different regions and timeframes out to 10 days ahead. These include the 333m resolution Auckland Model, 1.5km resolution New Zealand Convective Scale Model (NZCSM), 4.4km New Zealand Limited Area Model (NZLAM) and 4.5km resolution New Zealand Ensemble (NZENS). All are configurations of the Unified Model.



Maps showing the geographic extent of NIWA's core NWP models.

Forecasts from these models are combined with data from available global models, including the Met Office Global Model and NCEP's GFS and GEFS, to create NIWA's Optimal Seamless Forecast (OSF). The OSF provides unified gridded weather forecast fields derived from a selection of different NWP models via a common API, including some lagged members, using different forms of weighted average depending on the variable. Higher resolution models and shorter lead times are given higher weights. Bias correction is applied to some variables before model averaging depending on the availability of relevant observations.

For surface temperature, this is done by first lapsing NIWA's site-specific MOS forecast and matching raw forecasts to sea-level. Hourly fields approximating the model error are found by interpolating the difference between these two point variables onto a grid. This error is then added back onto the sea-level NWP temperature before being lapsed back to the true elevation using a high resolution DEM.



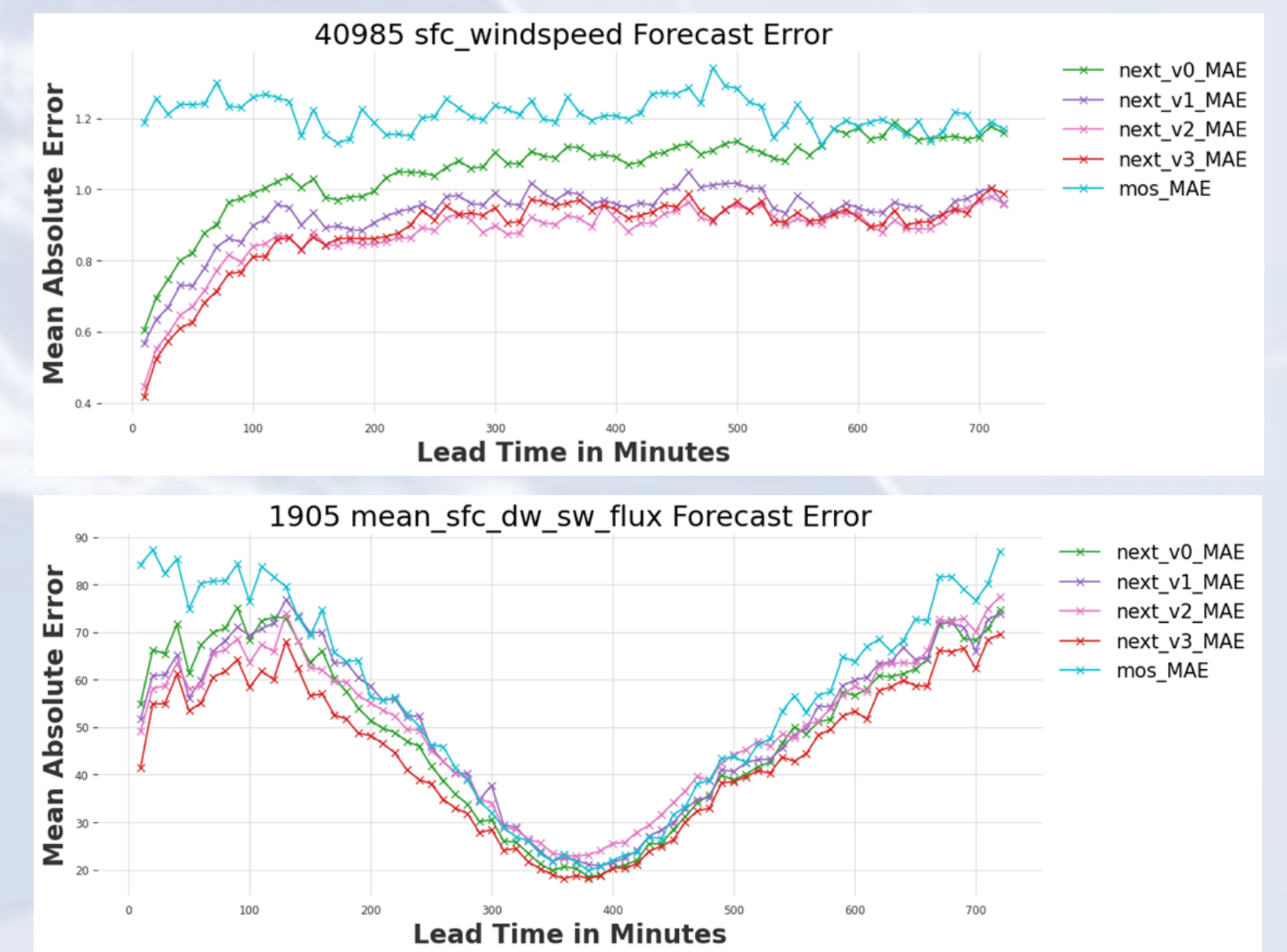
Workflow of the surface temperature correction method (left) and example result of the Q-Q matching method applied to precipitation for a South Island weather station.

For precipitation, forecasts from each upstream model are bias corrected to gauge observations using a Q-Q matching procedure with steps as follows:

- At-gauge wet/dry proportion
Corrected by thresholding the forecast so the dry proportion matches gauge at forecast temporal resolution
- Model biases vary depending on rain rate
Corrected using quantile matching
Curve fitting to minimise noise, relaxed to 0 above 98%ile
- Gauge-based correction parameters interpolated to grid
Corrections applied to all model (land-based) points

For the shortest of timescales, NIWA has developed the NEXT nowcasting system. NIWA NEXT blends NIWA's NWP data and locally retrieved satellite data with Transfer Learning data science techniques to create site-specific predictions of solar and wind power at 10-minute increments out to 12 hours, and updating every 30 minutes.

NIWA NEXT (versions 2 and 3) use a Time-series Dense Encoder method, an improvement over the original Temporal Fusion Transformer method used (versions 0 and 1). NIWA NEXT now also uses a single model per variable for all forecast sites.



Plots showing evolution of NIWA NEXT mean absolute error as a function of forecast lead time for wind speed (upper panel) and solar radiation (lower panel) across all NIWA NEXT versions.

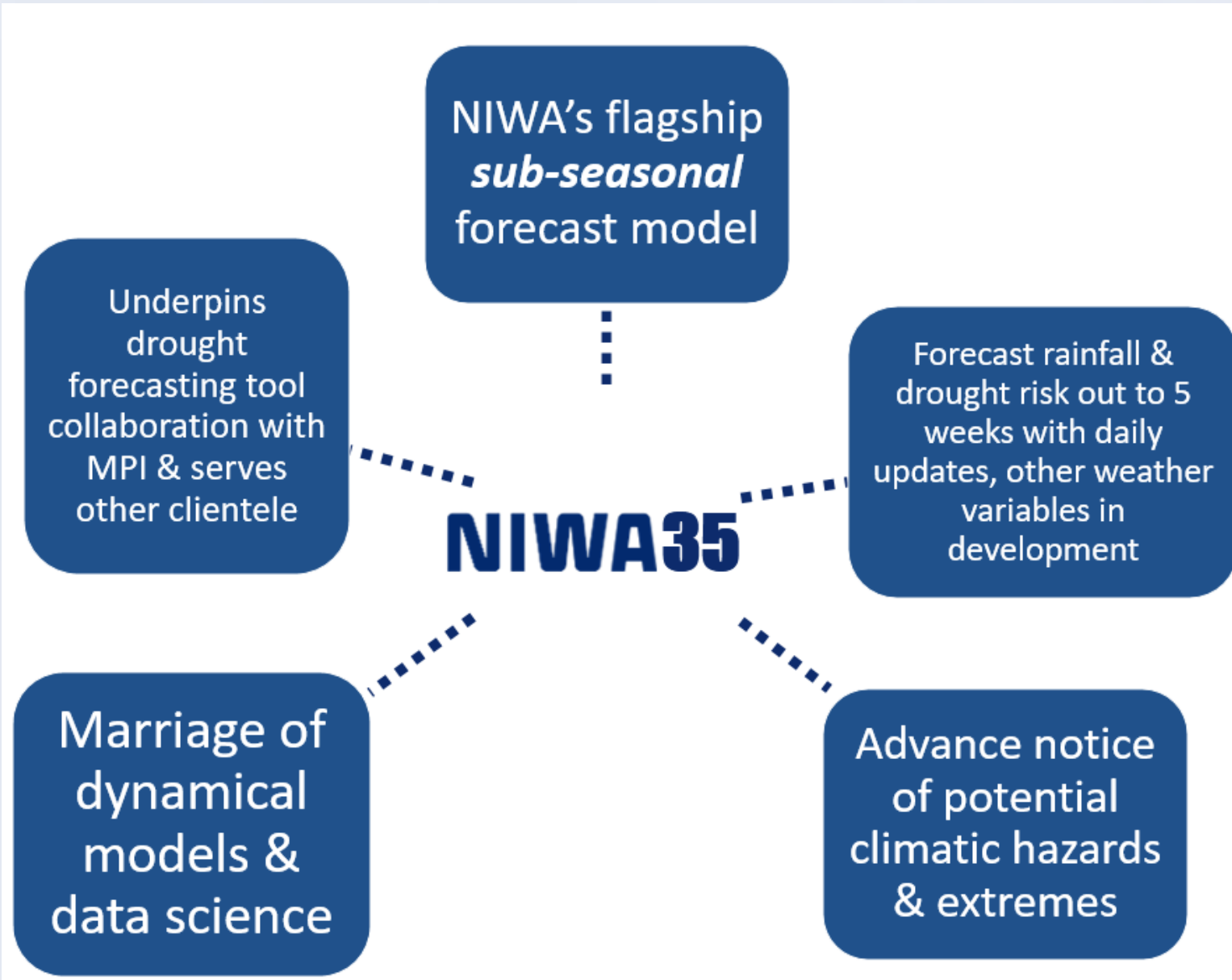
Weather
Hours to 10 days

Sub-seasonal
10-35 days

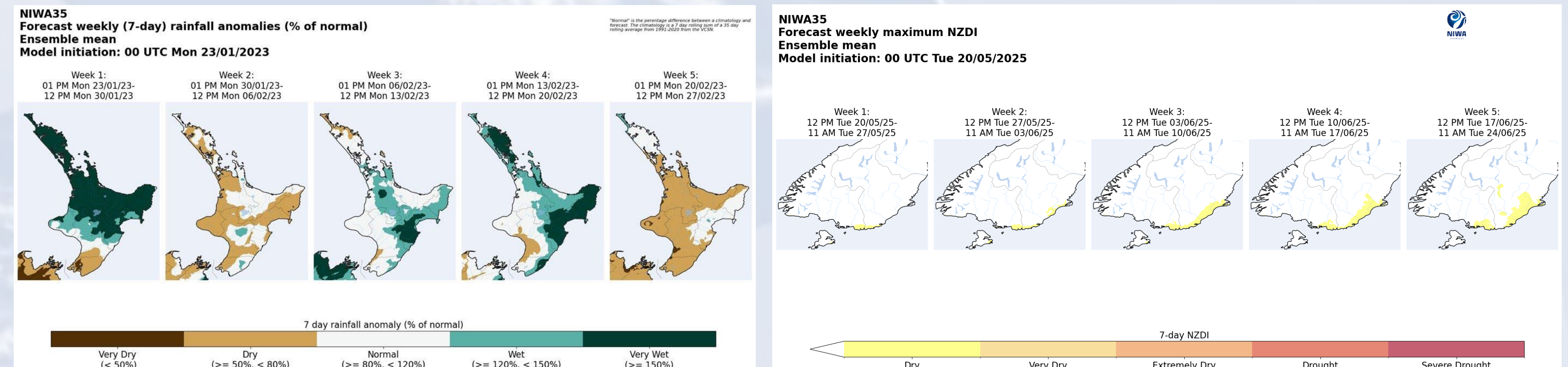
Seasonal
1-6 months

Climate
Years

NIWA35



NIWA35 is a sub-seasonal forecast model that combines extended range NWP forecasts with Machine Learning to produce high-resolution downscaled forecasts of rainfall and drought conditions. The key output is the New Zealand Drought Index used in government and agricultural sectors. Future developments of NIWA35 will see expansion to include wind and temperature forecasts.



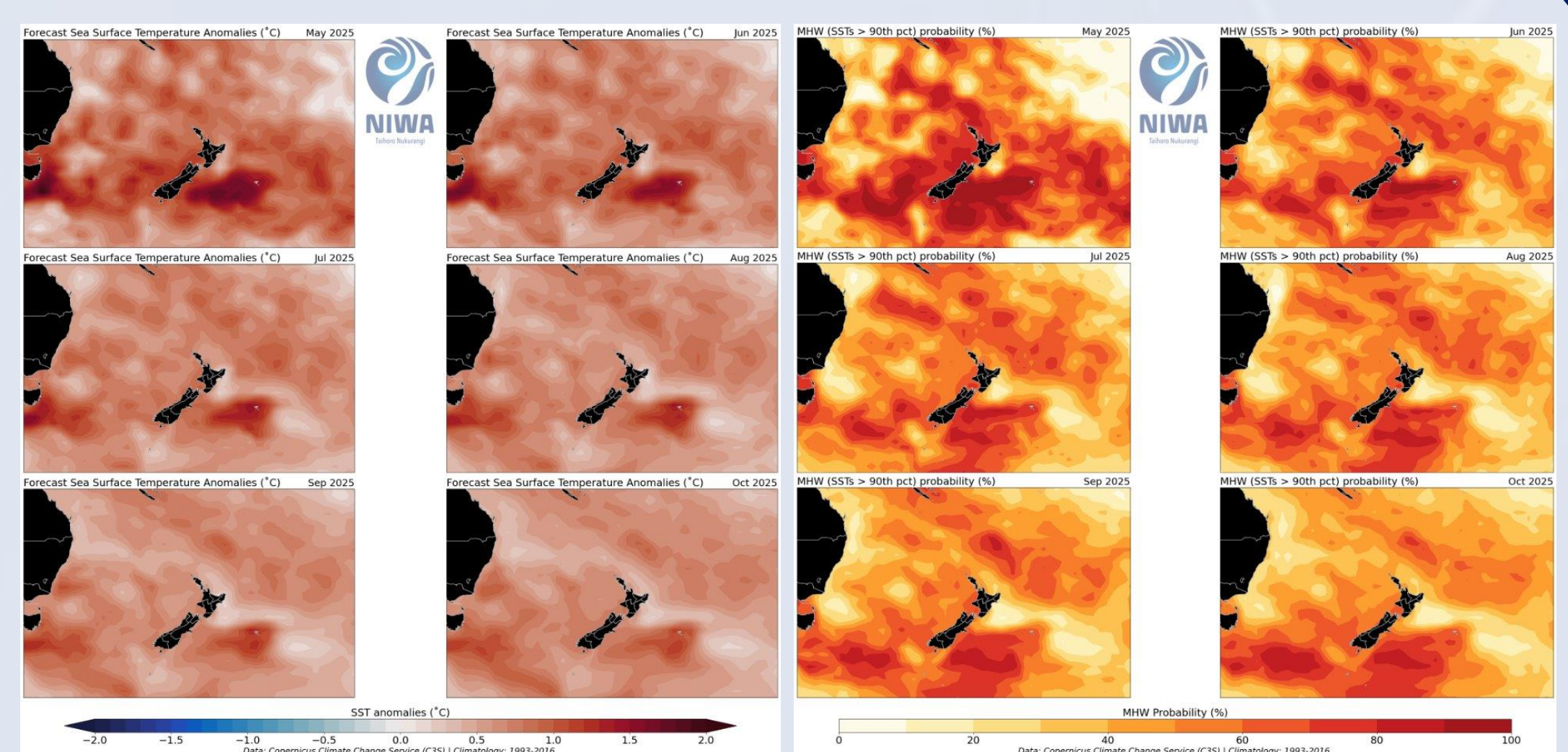
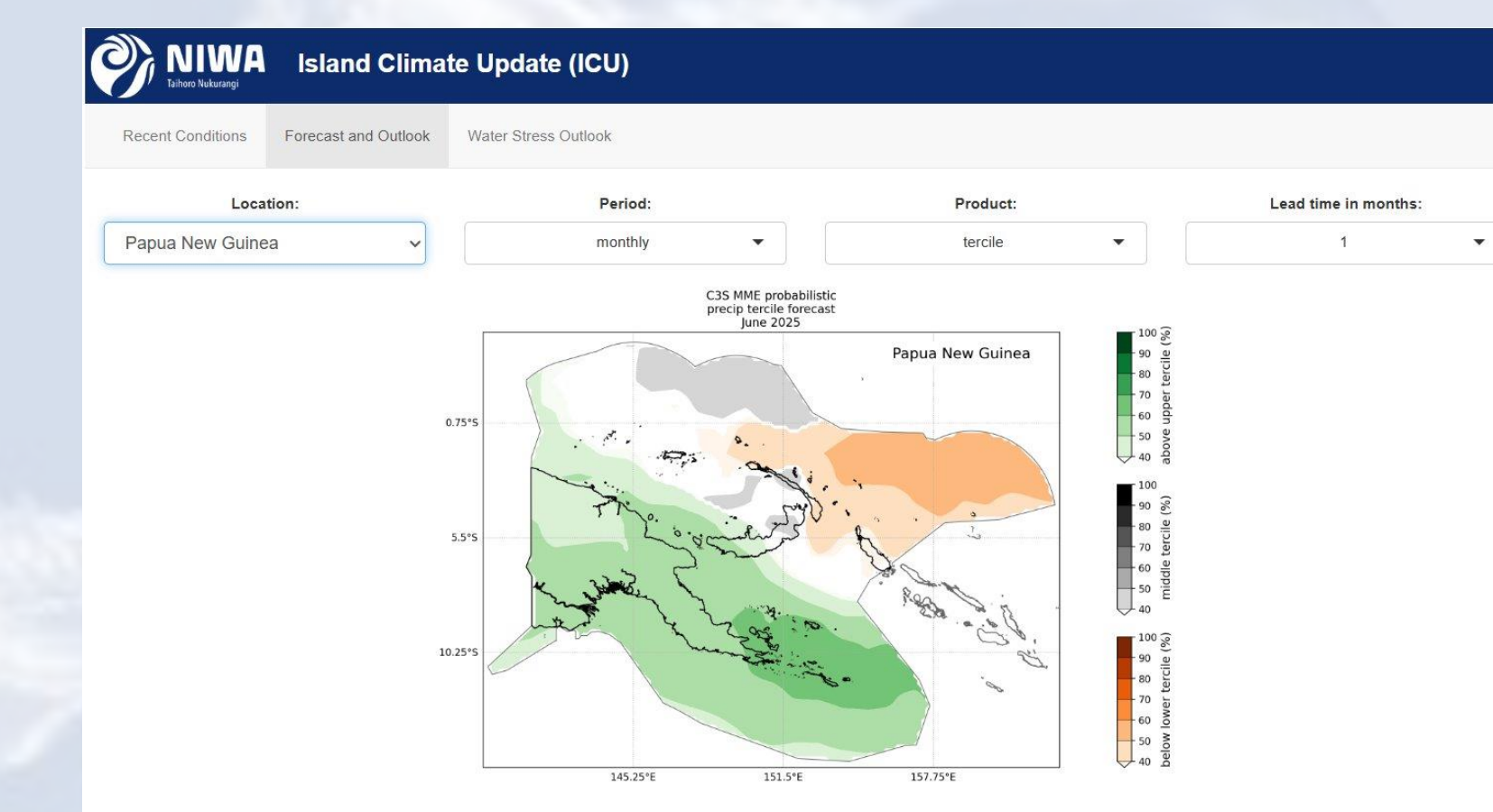
Example products from NIWA's Drought Forecasting Dashboard (<https://shiny.niwa.co.nz/drought-forecast/>).

Seasonal Forecasting

NIWA leverages the Copernicus Climate Change Services (C3S) Multi-Model Ensemble (MME) for a range of applications, covering the seasonal forecasting timescales (one to six months).

The C3S MME comprises outputs from 10 different seasonal forecast Global Climate Models (GCMs). These GCMs come from the European Centre for Medium-Range Weather Forecasting (ECMWF), the UK's Met Office (UKMO), Météo-France, the Deutscher Wetterdienst (DWD), the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), the US National Centers for Environmental Prediction (NCEP), the Japan Meteorological Agency (JMA), Environment and Climate Change Canada (ECCC) and the Australian Bureau of Meteorology (BOM). In the May 2025 seasonal forecast, more than 690 model members were utilised in creating the seasonal outlooks.

The principal outlet for NIWA's seasonal climate forecasts are the Seasonal Climate Outlook service (SCO, <https://niwa.co.nz/climate-and-weather/seasonal-climate-outlook>) and the Island Climate Update (<https://niwa.co.nz/climate-and-weather/island-climate-update>).



Example anomaly plots (above) of Sea Surface Temperature and Marine Heat Wave occurrence for the Southern Hemisphere winter 2025 period, and a screenshot of NIWA's web-based Island Climate Update service (left).

Regional Climate

NIWA undertakes work on regional climate modelling using a convection permitting configuration of the Unified Model (CPM). Current objectives are to understand how future projections of NZ precipitation are represented in such a model and how hourly precipitation extremes over NZ will change in a warming climate.

Future changes shown here are for the 2081-2100 period relative to 1995-2014, forced by the New Zealand Earth System Model (NZESM) under a high emissions (SSP3-7.0) scenario. Air over New Zealand is around 3.7 °C warmer, the southwest of the country becomes wetter, and the north and east become drier, with more spatial detail in the nested regional climate models. CPM shows less windward enhancement and less lee drying than its 12km parent model. NZESM results show increases in sea level pressure and sea surface temperatures, consistent with higher risk of marine heatwave occurrence.

