Evaluating national-scale river flow forecasts for New Zealand

Céline Cattoën, Jono Conway, Andrea Mari, Kelsey Montgomery, Nava Fedaeff, Ude Shankar, Daniel Lagrava Sandoval and Trevor Carey-Smith

Background and aims

A national river flow forecasting system has the potential to increase flood hazard preparedness and response efforts, as well as aid hydropower operation, recreation, irrigation planning and regulatory/monitoring activities. The aim of the New Zealand flow forecasting system is to complement existing regional flood forecasting capability by providing decision-makers with consistent, NZ-wide, categorical river flow forecasts for all river reaches (Strahler order 3 and above).

Objective

Here we present a preliminary evaluation of categorical flow forecasts from October 2018 to August 2019 at 45 sites where data is available to NIWA in near-real time.

What we did

Ensemble model framework – from weather data to river flows

- National-scale river flow forecasts are produced by coupling NZ Water Model – Hydro to high-resolution weather model output and climate station data (Figure 1).
- Forecasts are reported in categories based on hourly flow %iles from a 40-year model climatological simulation using Virtual Climate Station Network (VCSN) climate input (see Table).

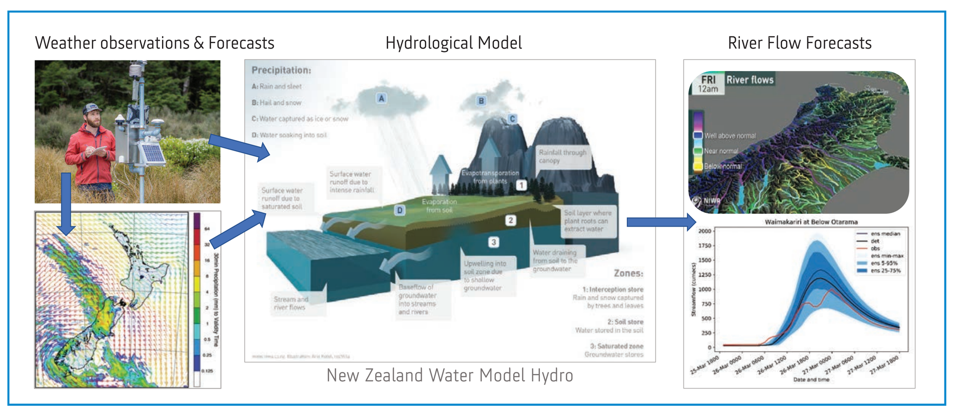


Figure 1: New Zealand river flow forecasting system.

Hourly flow %ile	Flow category
>99%th	Extremely high
90–99%th	Well above normal
66–90%th	Above normal
33–66%th	Normal
10–33%th	Below normal
0–10%th	Well below normal

Ensemble hydrographs

An ensemble of 50 different forecasts is created using spatial and temporal variations in rainfall, soil moisture and baseflow.

The deterministic forecast is a single forecast with no perturbations. Despite the large variability in absolute flow forecasts (Figure 2a), all ensemble members forecast the extremely high flow conditions that occurred on 27 March 2019 (Figure 2b).

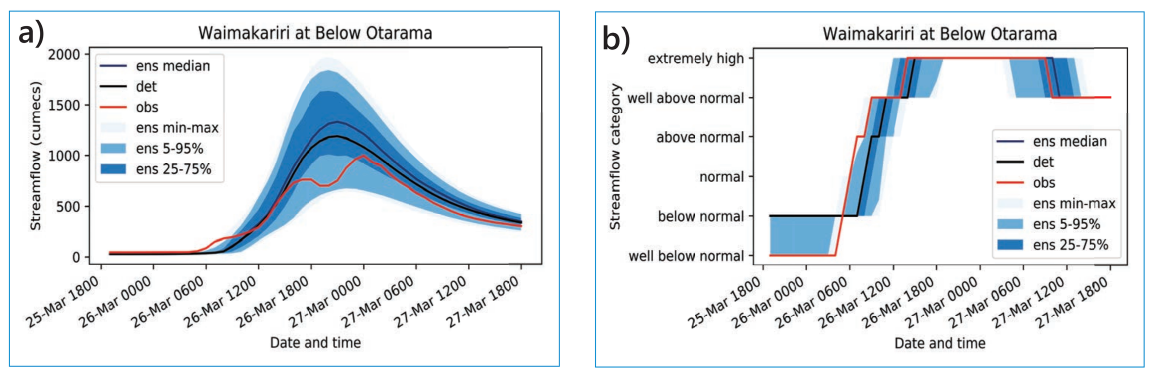
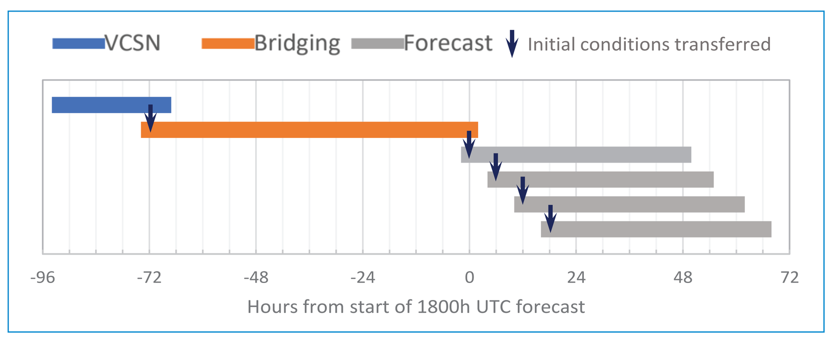


Figure 2: Observed (red) and forecast (deterministic in black and ensemble in blue) absolute flow (a) and categorical flow (b) during a ~2.5-year return period flood event.

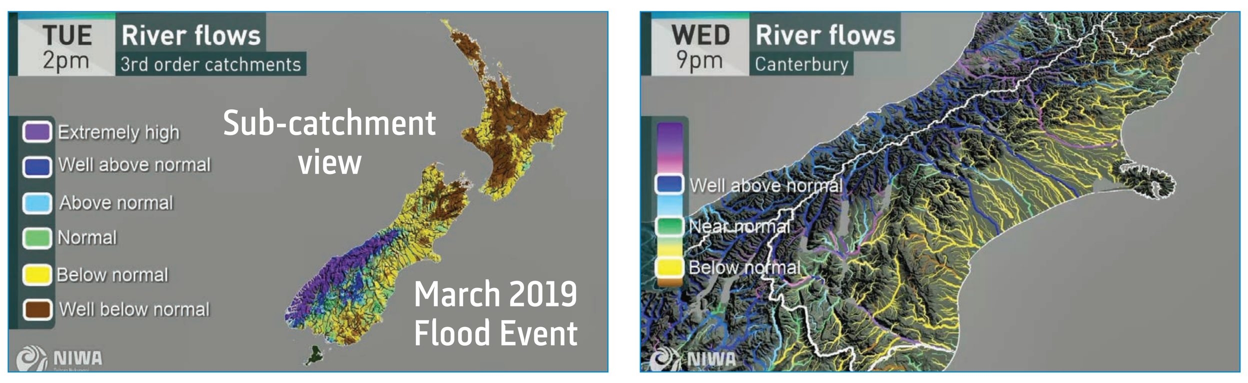
Bridging the gap between observed data and forecast

Figure 3: Observed climate data (VCSN) is used to create the initial model conditions (flow, soil moisture, baseflow, etc.,) that are passed to the Forecast simulations. As VCSN is not available for 2-3 days, a 'Bridging' simulation is made using rainfall from previous NZCSM forecasts.



Visualisation of categorical river flow forecasts

Figure 4: Videos of categorical forecasts (snap-shots right) are currently being tested by a group of stakeholders – Please contact us if you would like to be involved.



Preliminary results

Forecast compared to observed flow

- Most sites have reasonable forecast error (Figure 5a), while a few sites have much larger errors. Note that all sites are considered here, including sites with managed river flow and/or water abstractions.
- At most sites forecasts are slightly lower on average than observed (Figure 5b), except NW of South Island where forecasts usually higher.

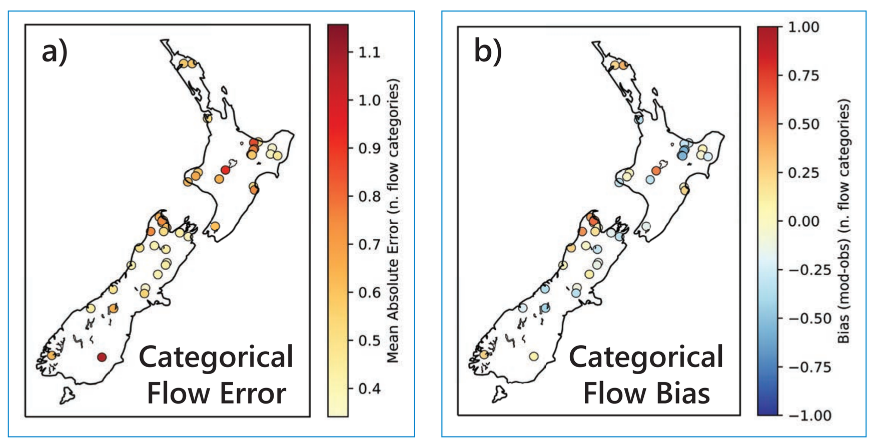


Figure 5: Average error and bias Oct 2018–Aug 2019.

Error and bias with lead time compared to different baselines:

Observed flow:
- Ensemble forecast error is smaller than deterministic error (Figure 8a).
- Most sites tend to under-estimate flow against observations (Figure 8c).

VCSN simulated flow:
- Ensemble forecast error grows slowly with lead time (Figure 8b).
- Flow tends to increase with lead time indicating NZCSM simulations are, in general, wetter than VCSN (Figure 8d).

Rainfall forecast errors are small compared to total model error, even at 48 hrs lead time (Figure 8a vs 8b).

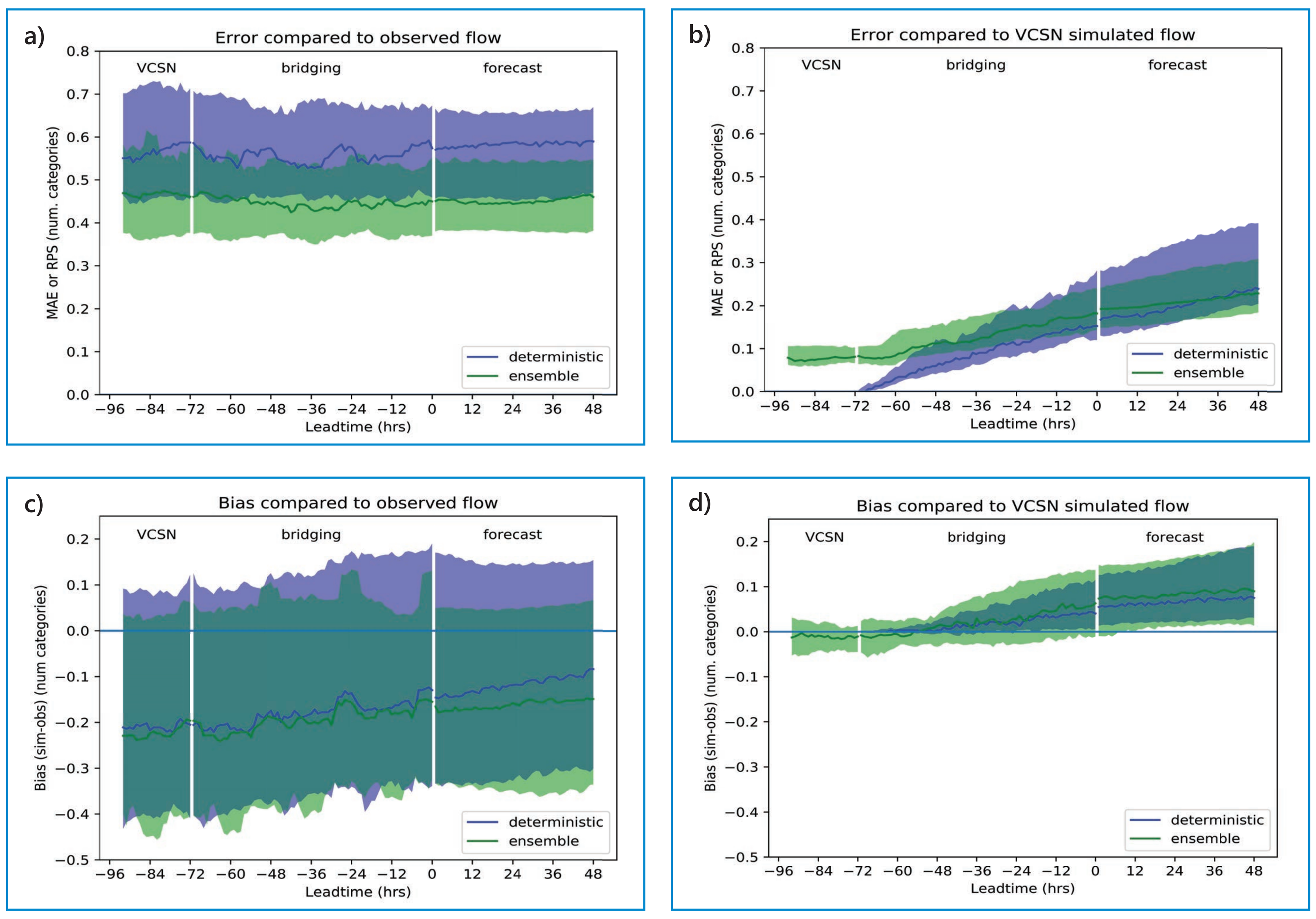


Figure 8: Error and bias vs lead time. Solid lines = median and shading = interquartile range of 39 sites.

Threshold exceedance scores compared to observed

- Hit rate can be increased and event frequency improved (closer to observed) with only small increase in false alarms by requiring less ensemble members to exceed threshold for event.
- Ensemble probabilities can be optimised to trade-off between hit rate, false alarms and frequency.

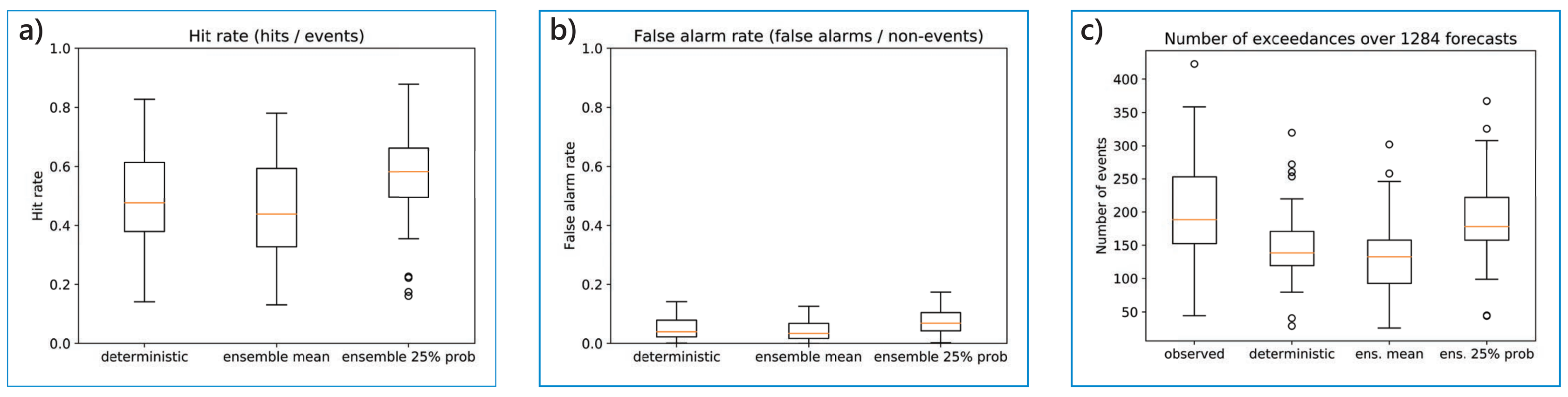


Figure 9: a) Hit rate, b) False alarm rate and c) Event frequency for threshold exceedance of 80th percentile flow. Box plots show performance of deterministic forecast along with using ensemble mean or 25% probability to calculate exceedance.

Current and future developments:

- Extend validation to sites operated by regional councils.
- Generate longer forecast archive to evaluate for flood events.
- Decrease time lag before observed rainfall is used.
- Increase forecast lead time by blending rainfall from several forecast models.
- Increase ensemble spread and reliability (i.e., so that ensemble always includes the observed flow) through better precipitation ensembles and including hydrological model uncertainty.
- Provide bias-corrected absolute flow forecasts using estimated flow-duration curves.

Summary

The NZ river flow forecasting system is a first attempt at producing and communicating national flow forecasts. Validation of the forecasts is a work-in-progress, but initial results indicate:

- Categorical forecasts have reasonable skill at most sites.
- Errors in short-term (<2 day) forecasts are dominated by hydrological, rather than rainfall errors.
- Ensemble method improves forecasts of high-flow exceedance.

As the operational archive grows and quality-assured observed flow data becomes available, evaluation of forecast performance will be undertaken at a larger suite of gauge stations, enabling reasons for good and poor performance to be properly diagnosed. In parallel, engaging with potential users and stakeholders to acquire critical feedback and refine the system's usefulness will continue to guide future development directions. For more information, please visit: https://niwa.co.nz/climate/research-projects/river-flow-forecasting

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