# A national flood awareness forecasting system for ungauged catchments in New Zealand

*Shaping a more resilient tomorrow*

SPC & NIWA learning exchange

31st August 2021

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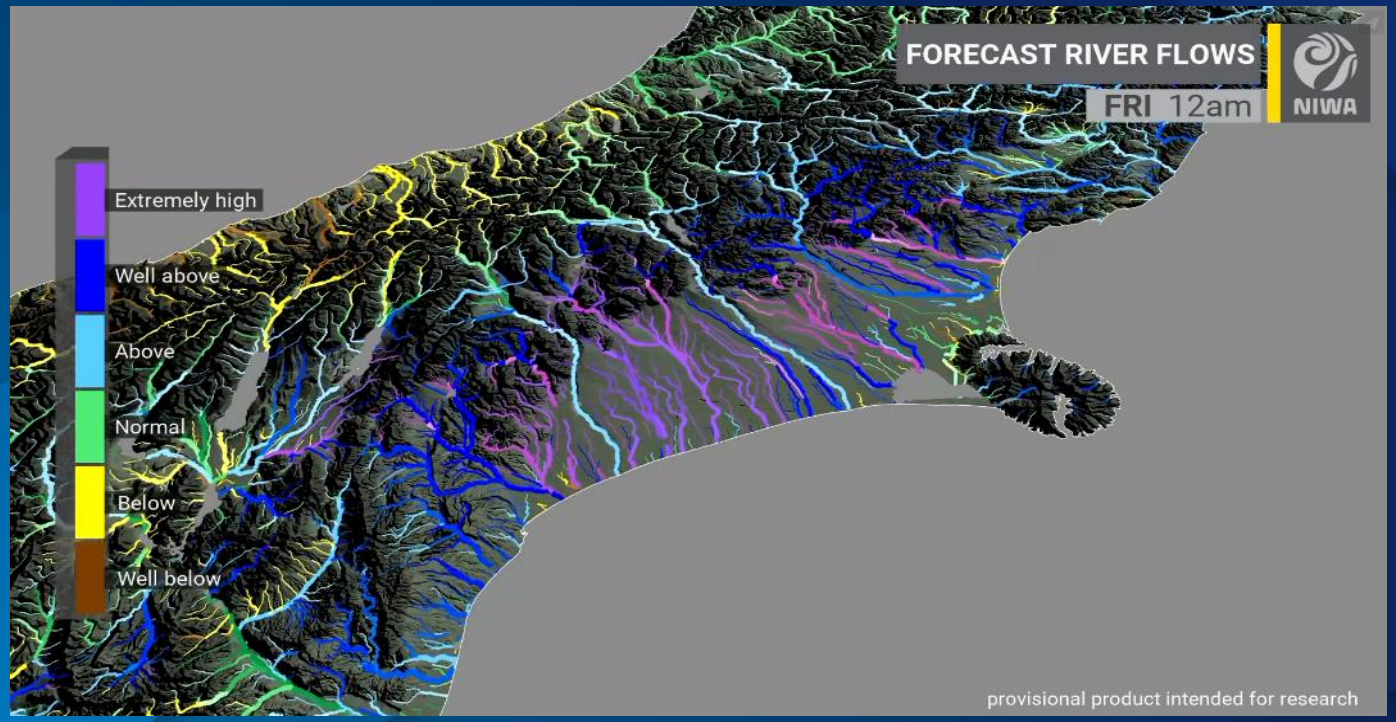


https://sv-se.facebook.com/NIWAWeather/videos/canterbury-flooding/229162631972248/

Conway, J., Montgomery, K., Fedaeff, N., Lagrava Sandoval D., Mari, A., Carey-Smith, T., Moore S., Steinmetz, T. Shankar, U, Blackett P., Mohan, S., Luttrell J.
Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi

# NZ river flow forecast project – key contributors

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Hydrological Forecasting Scientist

**Kelsey Montgomery**
Hydrological Modelling Technician

**Dr Trevor Carey-Smith**
Climate Scientist

**Dr Stuart Moore**
Meteorologist

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Forecaster/Science Communicator

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Hydrological Forecasting Scientist

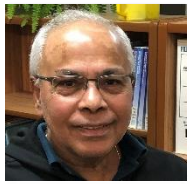
**Dr Paula Blackett**
Environmental
Social Scientist

**Jordan Luttrell**
Environmental
Social Scientist

**Dr Daniel Lagrava Sandoval**
Research Software Engineer

**Andrea Mari**
Research Software Engineer

**Stacy Mohan**
Communication
Leads – Climate
Science



**Dr Ude Shankar**
GIS Specialist

**Dr Tilmann Steinmetz**
GIS Data Analyst & Administrator

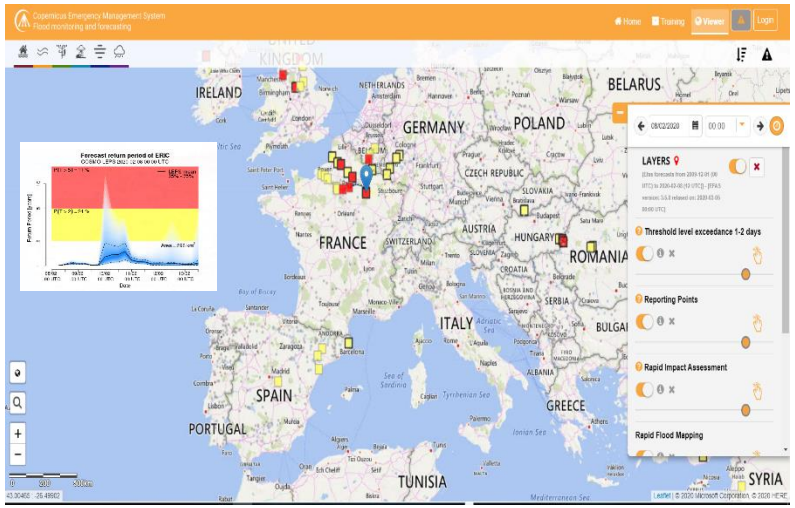
https://niwa.co.nz/climate/research-projects/river-flow-forecasting

# Outline

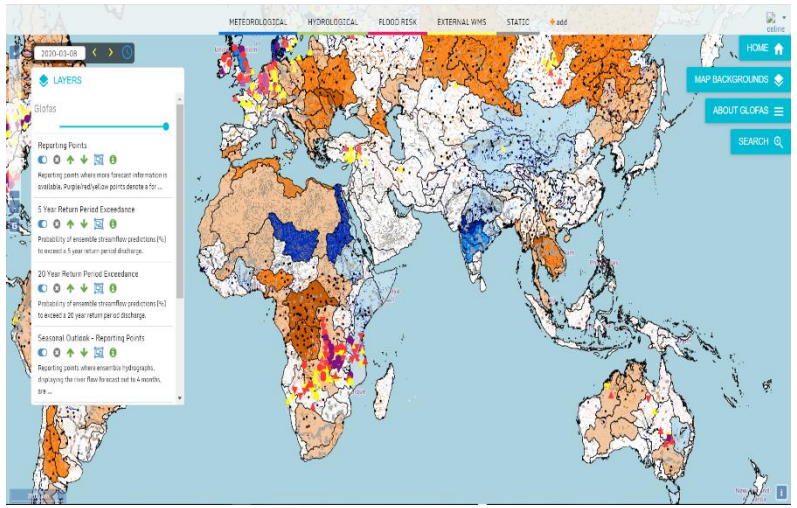
1. Ensemble flood forecasting – towards national and global scale
2. Hydrometeorological and flood context in NZ
3. New Zealand river flow forecast prototype: consultation process, data, models, implementation.
4. Forecast communication
5. Evaluation of NZ river flow forecasting system
6. Challenges and perspectives

# Ensemble flood forecasting – towards national and global scale

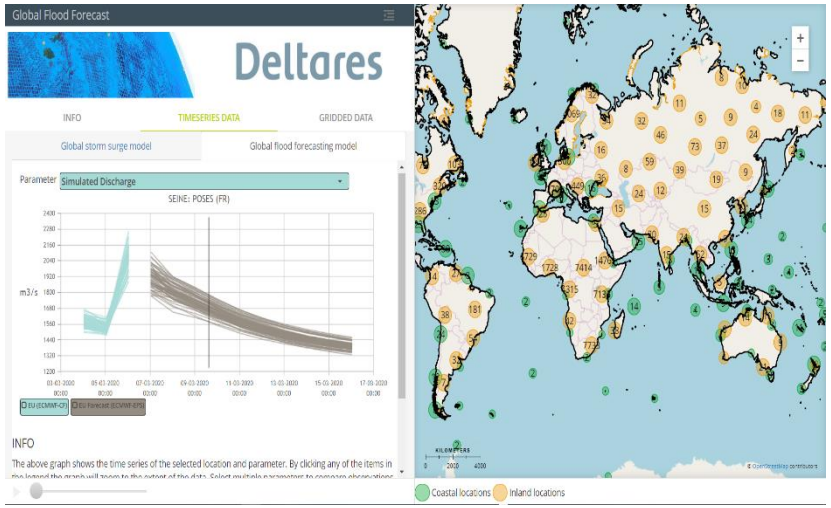
**European Flood Awareness System (EFAS)**



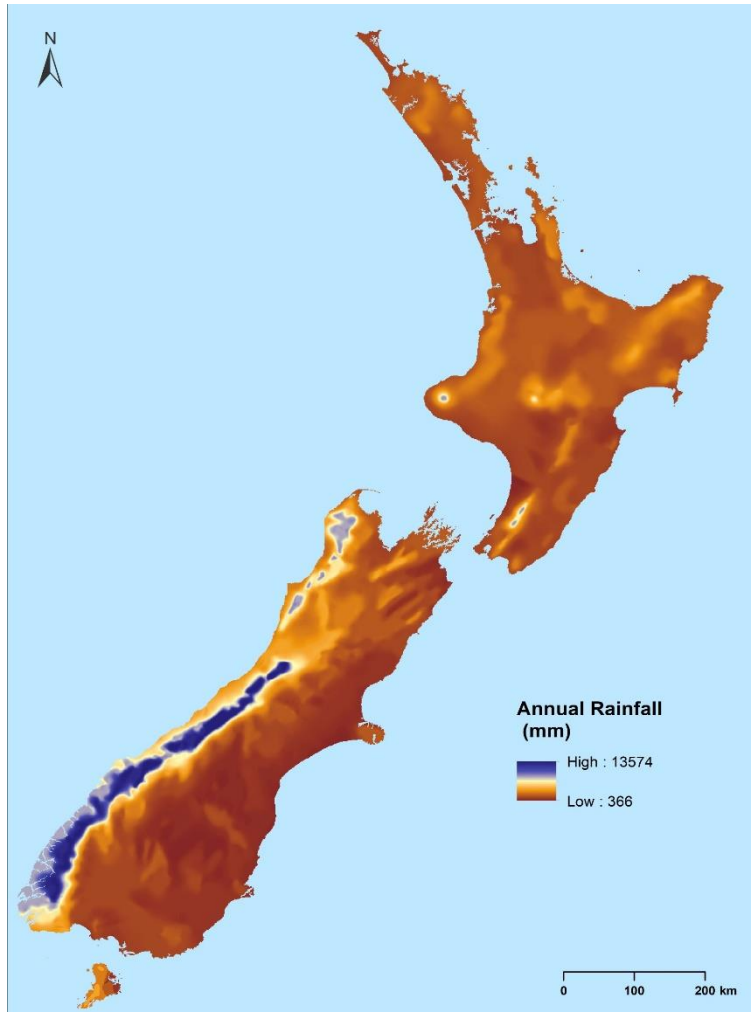

**Global Flood Awareness System (GLOFAS)**

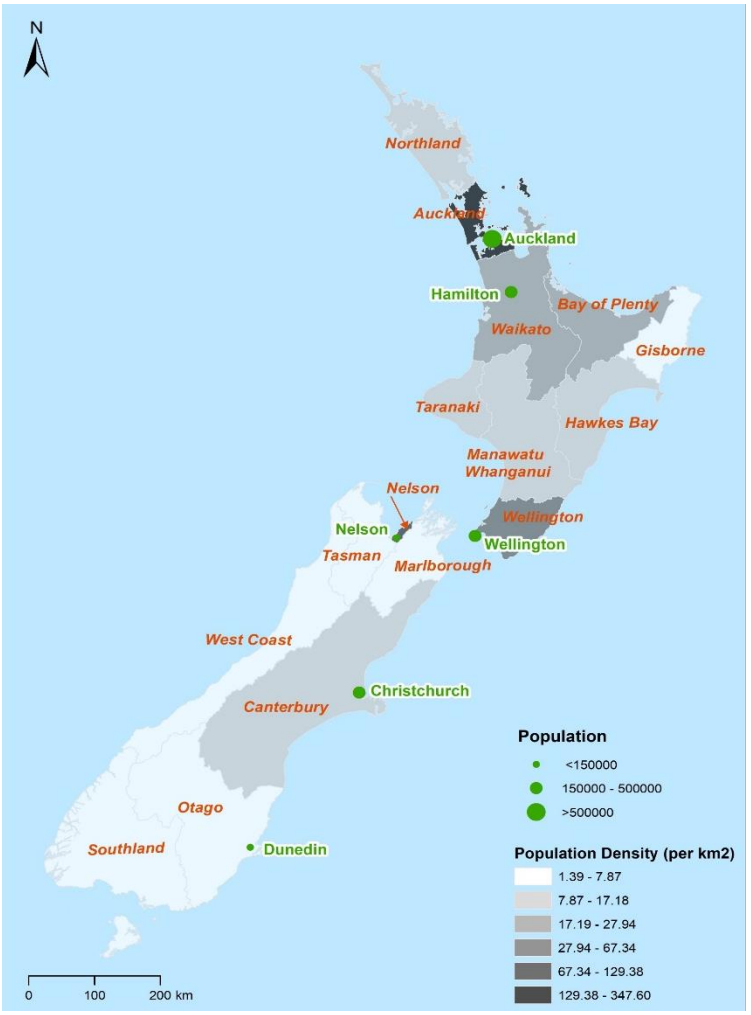



**GLObal Flood Forecasting Information System (GLOFFIS)**



# Hydrometeorological and flood context in New Zealand


**Insurance Costs[1] :**

<u>Between 1996-2014:</u>

$442 Million (NZD)

<u>2017-2019</u>:

>$350 Million (NZD), 6 ex-cyclones

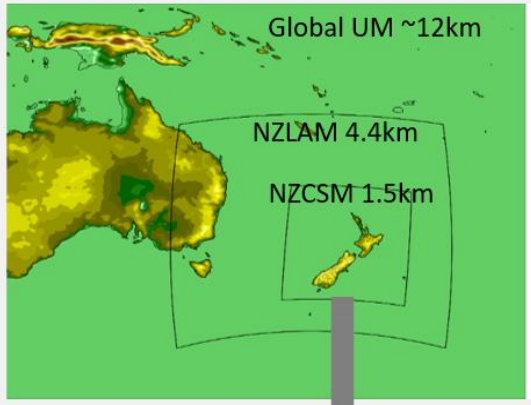
**Responsibilities for floods:**

Local authorities - primary agents responsible for civil defence emergency management (CDEM)

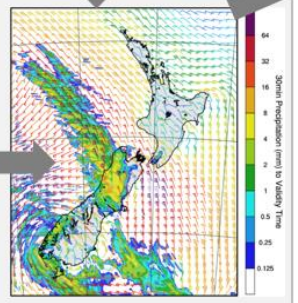
[1]Reference: Insurance Council of New Zealand (ICNZ)

# National scale river flow forecasting system for New Zealand

## Meteorological forcing



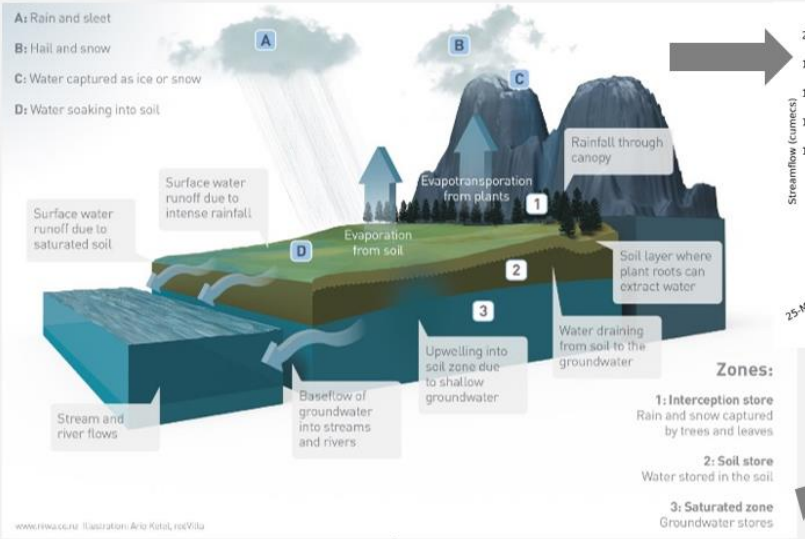

Observations

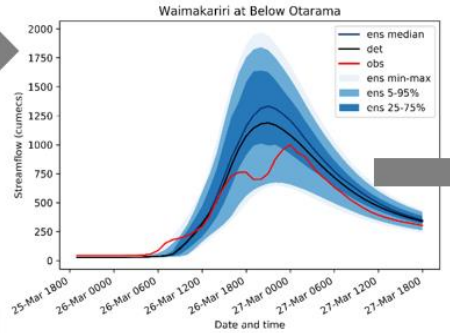


NZCSM forecast 1.5km

## Hydrological forecasts

New Zealand Water Model (NZWaM)




Geofabric dataset
Topography, river network, soil type, land use, lakes

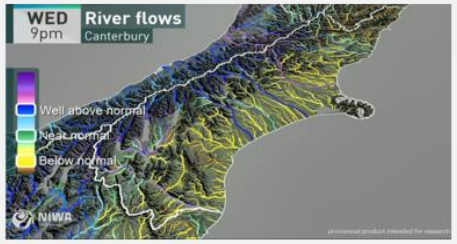
Hydrological initial conditions
Climate data (VCSN)+ followed by concatenated NZCSM forecast up to cycle time T (bridging observational gap) forced through NZWaM

## Post-Processing

Reference flow climatology
40 years simulations from climate observations

Exceedance thresholds
Percentile thresholds computed from reference flow climatology

River flow categories




## Forecast Communication



NIWA
Taihoro Nukurangi

# Why developing a national scale system for New Zealand?

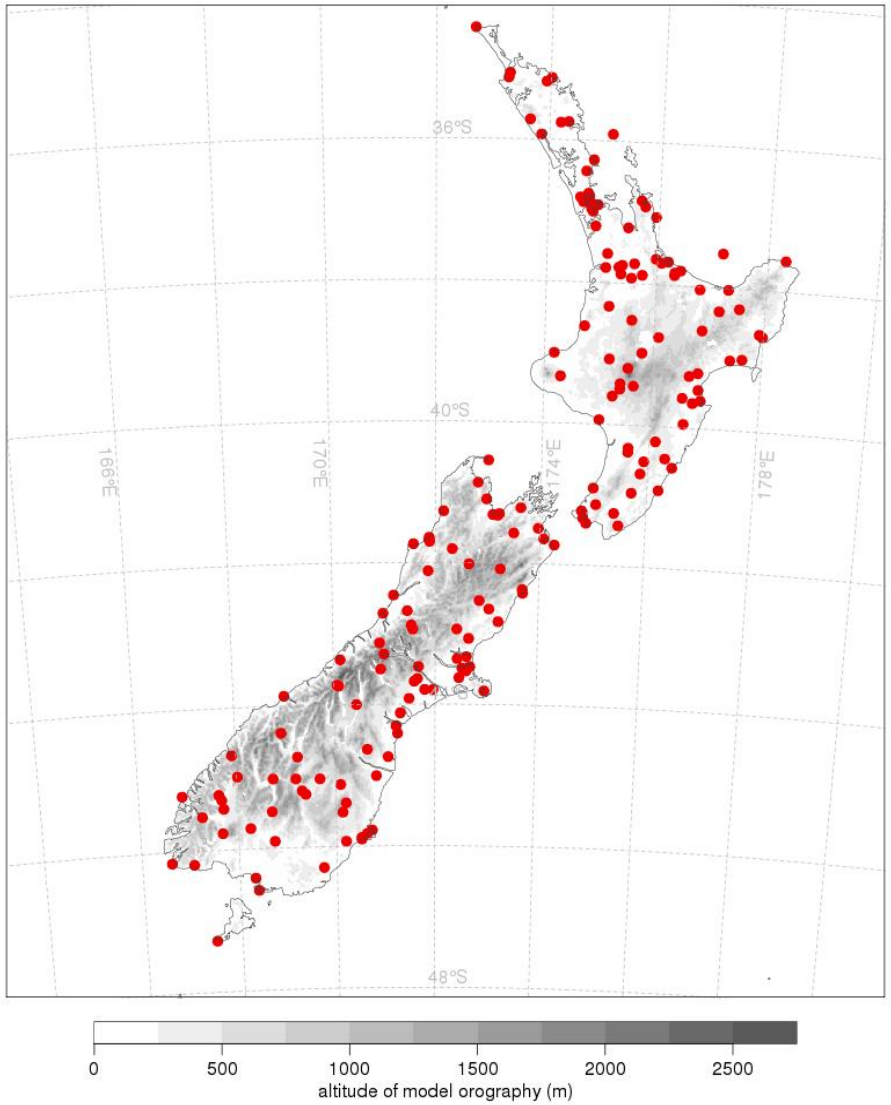
## Shaping a nationwide approach for New Zealand's river flow forecasts

- A co-design approach: we seek to complement and support existing local models and work together to shape research that is designed for decision-makers' needs and priorities

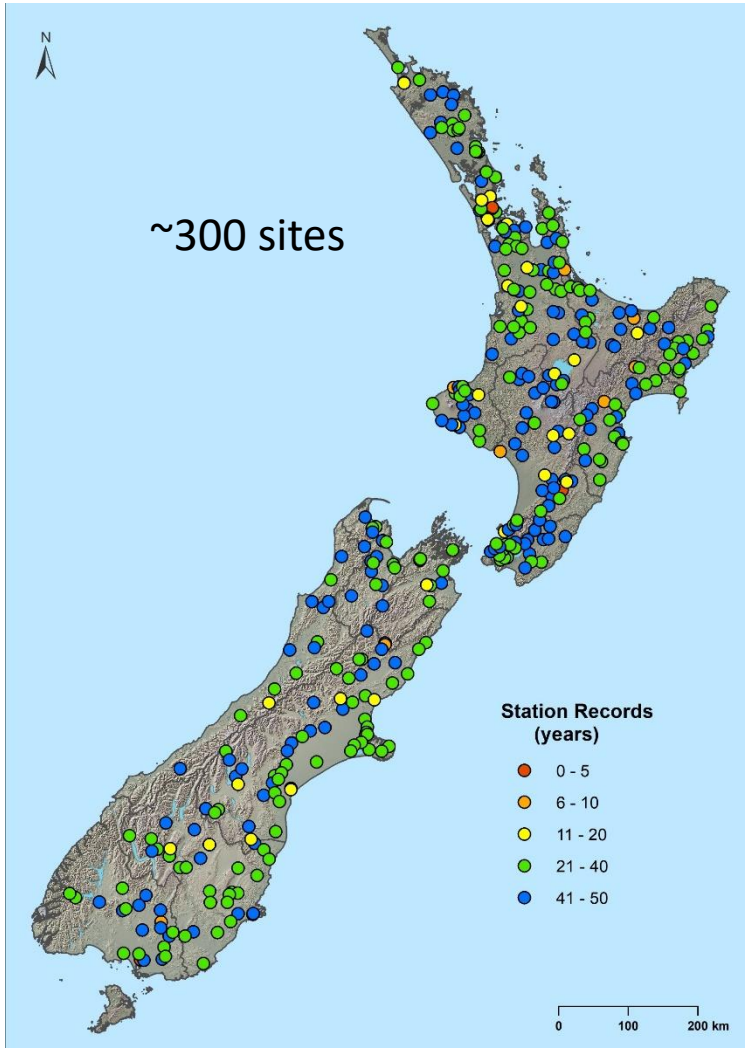
| Stakeholders | Format | Purpose and outcome | |
|---|---|---|---|
| 10 organisations central, regional gvt | presentations | Project awareness, formation user group, complementing strategy | 2017-2018 |
| 9 organisations regional gvt | workshops | Introduce methodology, improved user needs and priorities, data agreements | 2019, 2020 |
| Conference attendees | questionnaire | Stakeholder mapping and decision-making | Dec 2018 |
| 8 participants | interviews | Insight to aligned research and capabilities, feedback on tool | 2019 |

# Getting enough (long historical records) and real-time data is challenging

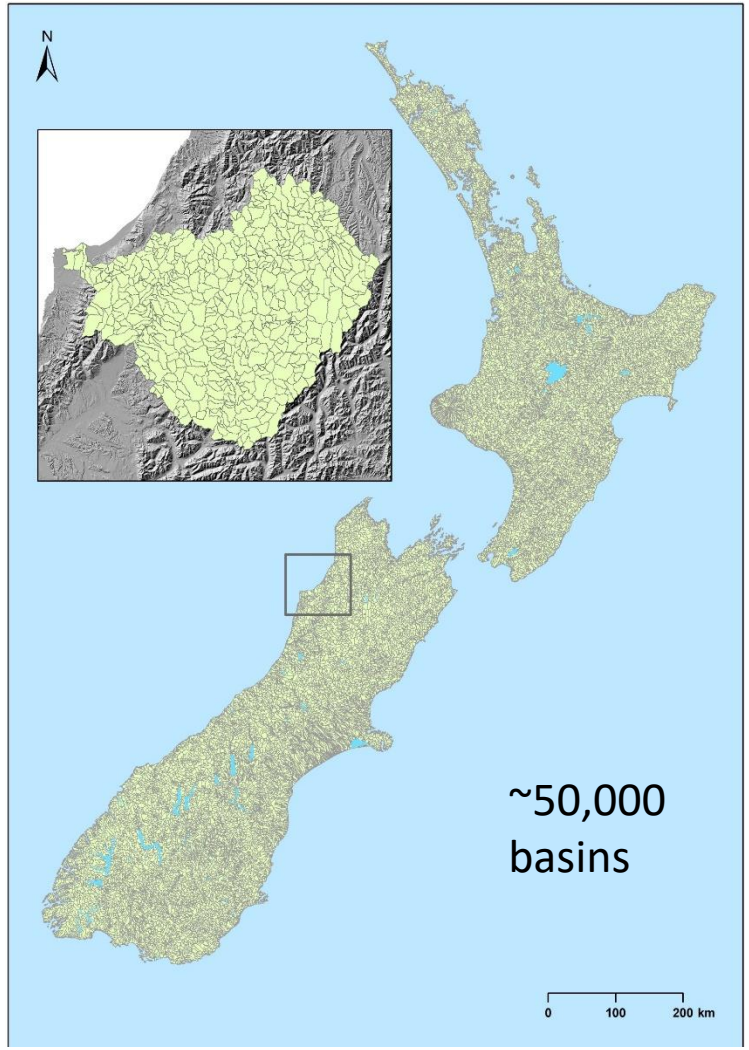
**Rain data at NIWA**




**Flow data: no national database**




**Modelled rivers**



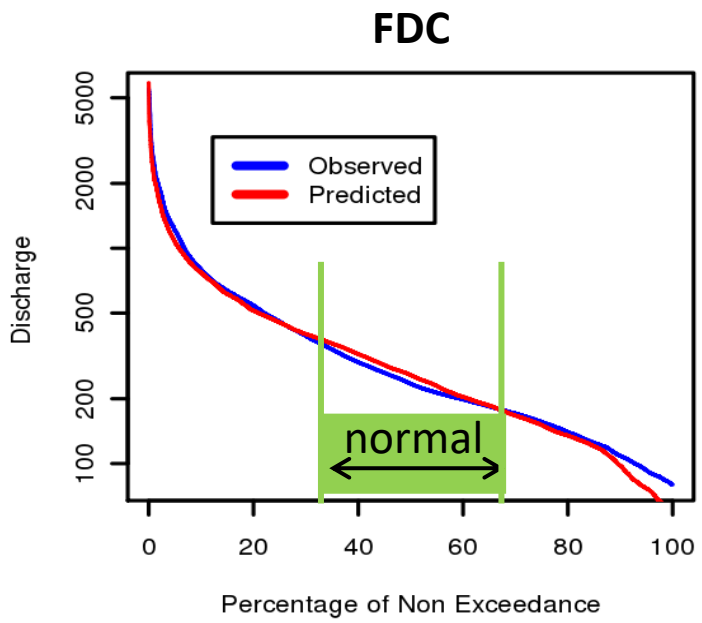
# The national scale approach produces forecast relative to a long-term modelled flow climatology at gauged and ungauged catchments

## Flow climatology

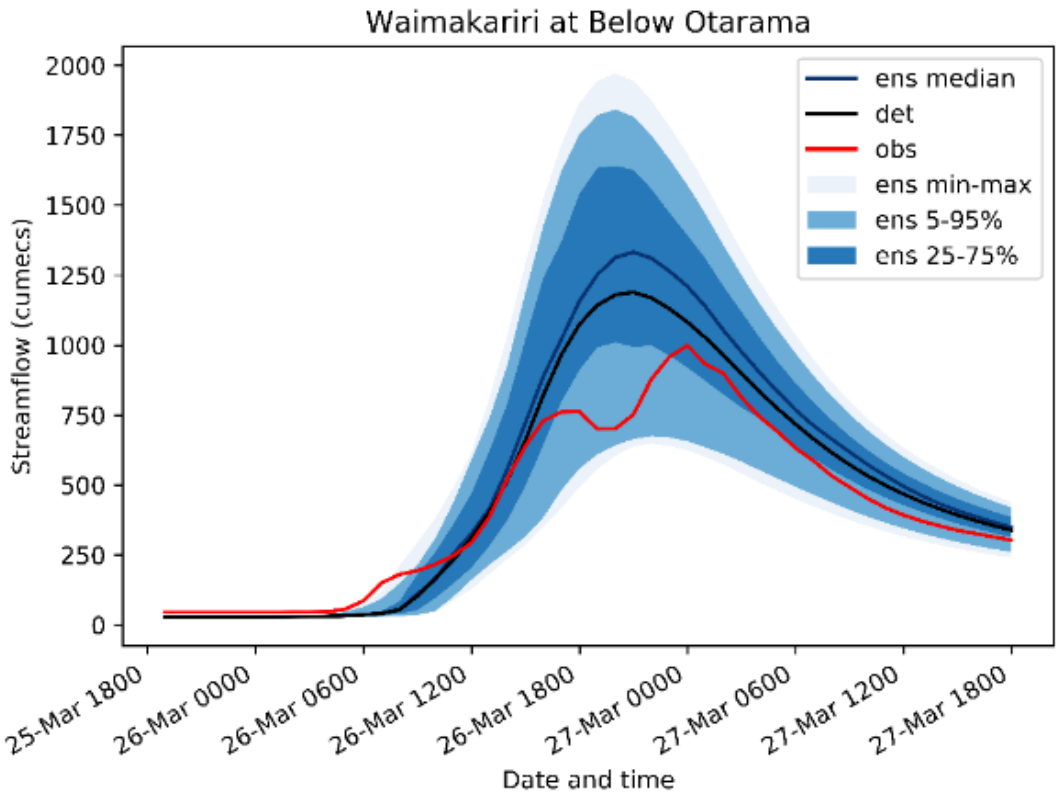
- 40 year model simulations using observed climate data (VCSN)
- Model flow statistics Flow Duration Curve (FDC) at ~50,000 basins

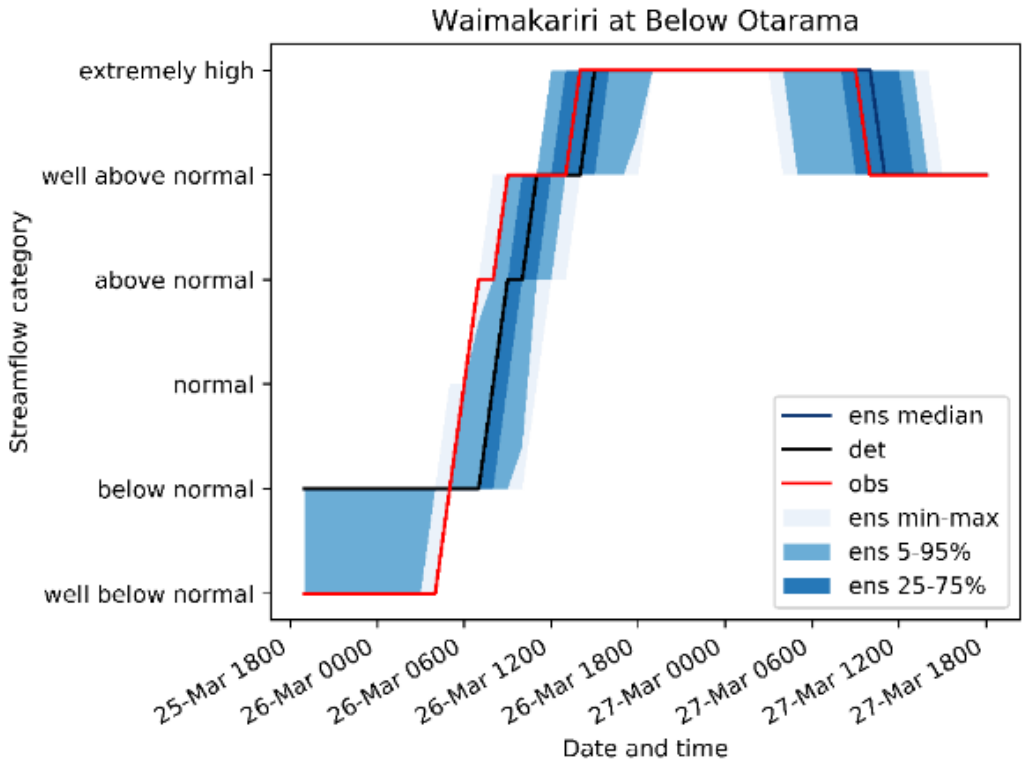
## Categorical flow forecasts

| | | |
|---|---|---|
| < 1 % | FDC | Extremely high |
| 2% - 10% | FDC | Well above normal |
| 10% - 33% | FDC | Above normal |
| 33% - 66% | FDC | Normal |
| 66% - 90% | FDC | Below normal |
| 90% - 100% | FDC | Well below normal |



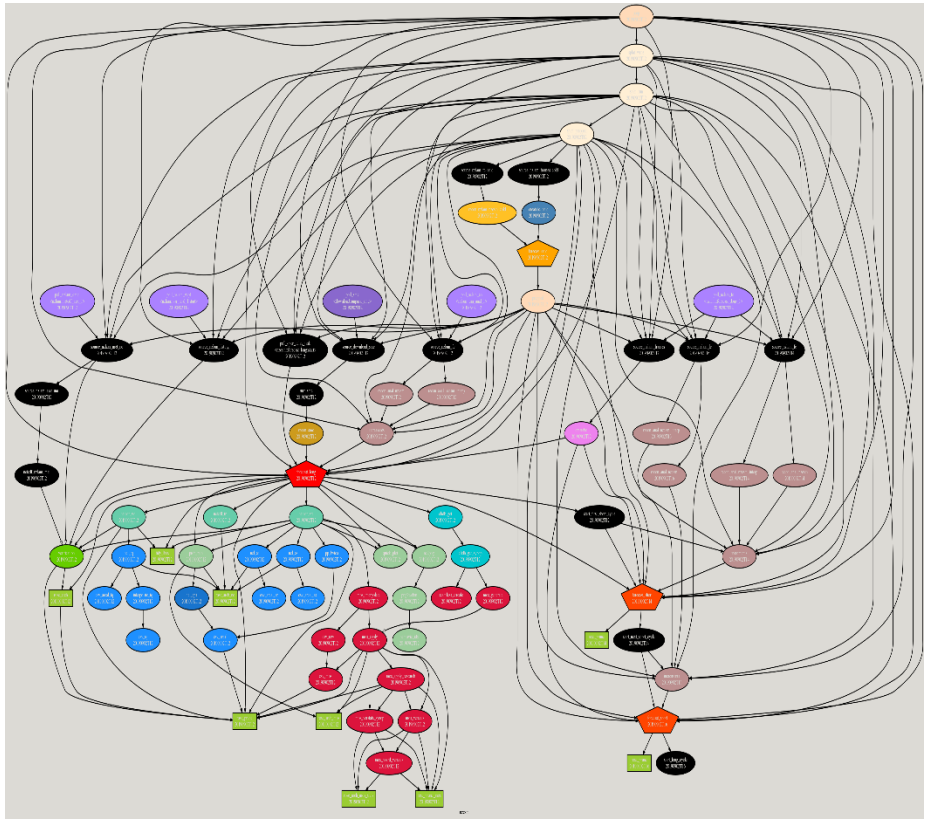
# Example absolute and categorical river flow forecasts for a flood event 26th March 2019



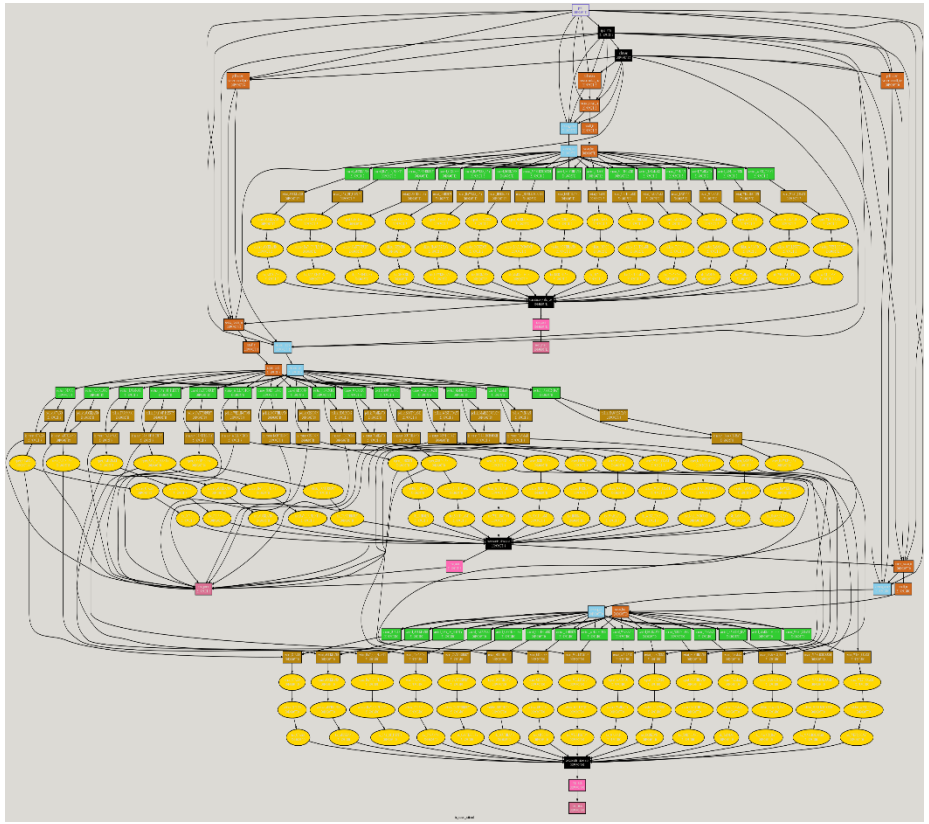



# The scientific workflow for operational forecasting is very complex

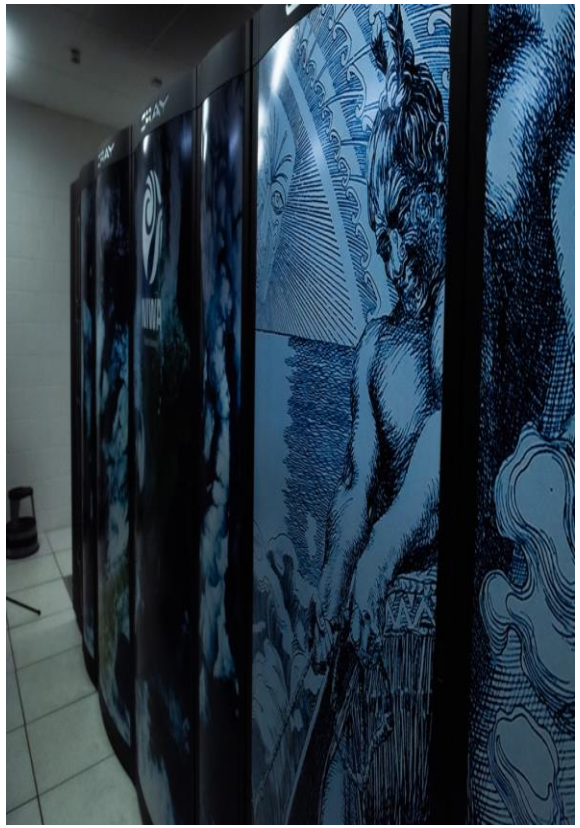
## Cylc (“Silk”)



Weather forecast suite



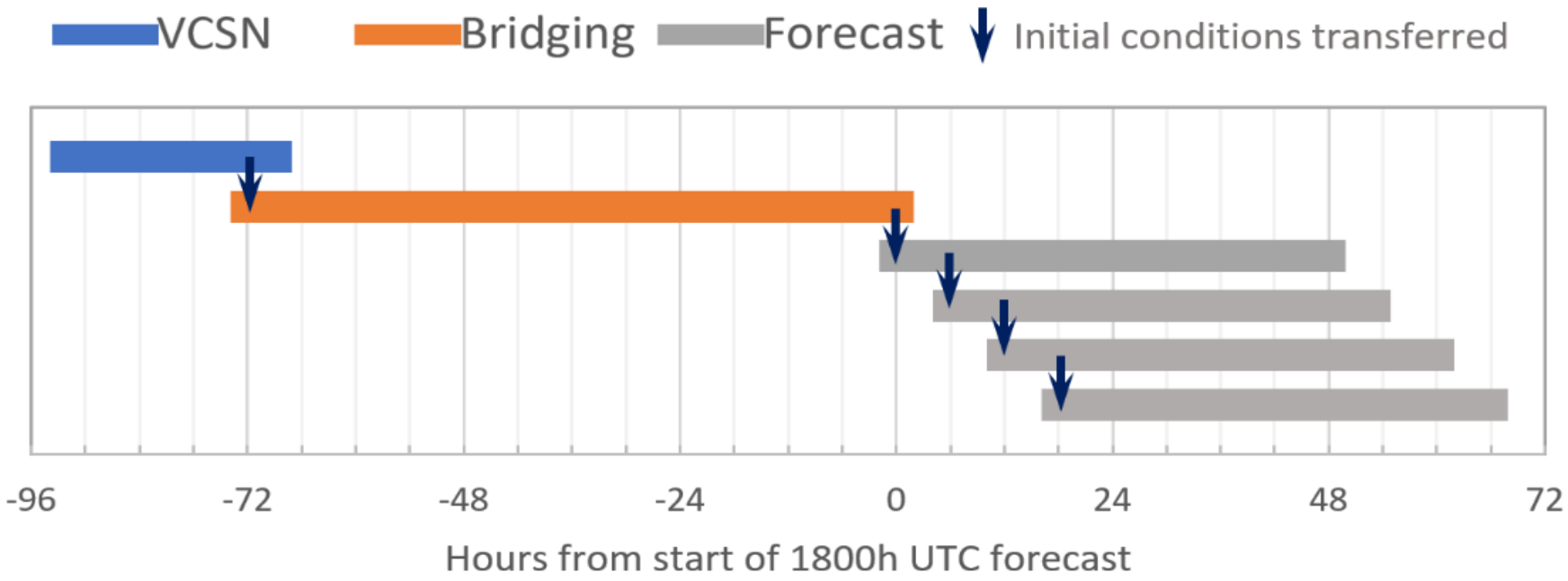
National River flow forecast suite



High Performance Computing

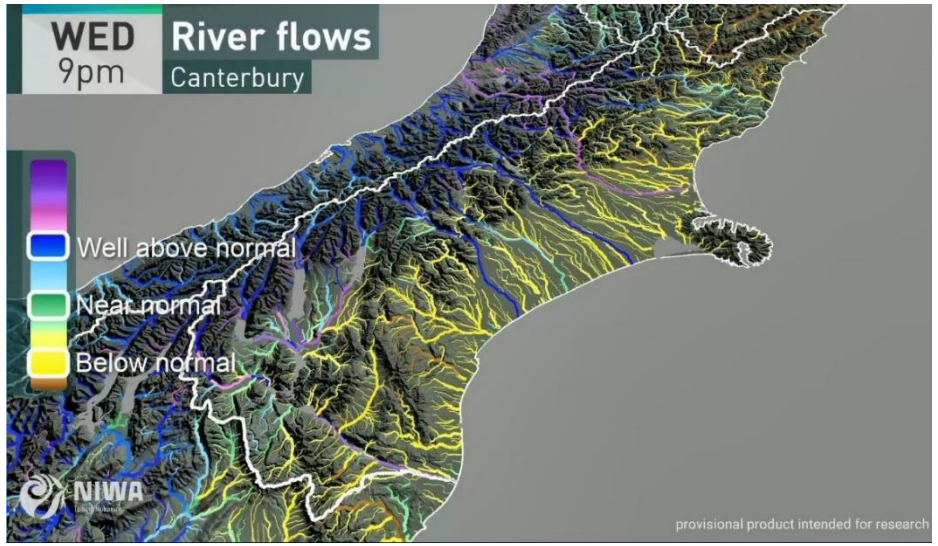
H. Oliver, *et al.*,"Workflow Automation for Cycling Systems" in *Computing in Science & Engineering*, vol. 21, no. 04, pp. 7-21, 2019.
doi: 10.1109/MCSE.2019.2906593

# Streamflow forecast initialisation are constrained by operational data availability

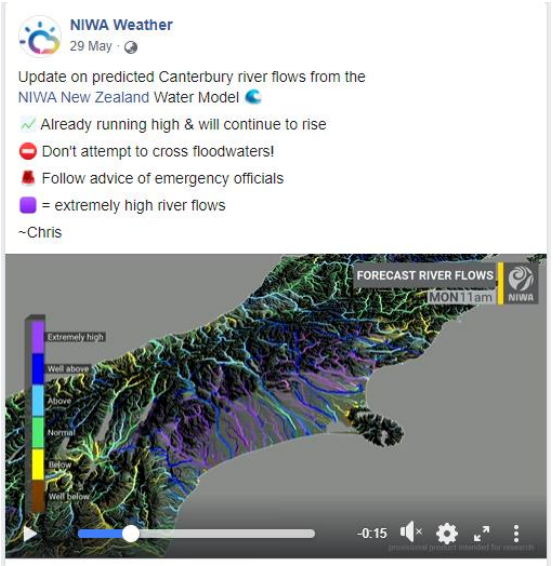


# Forecast visualisation and warning dissemination at national scale

Daily videos publicly available

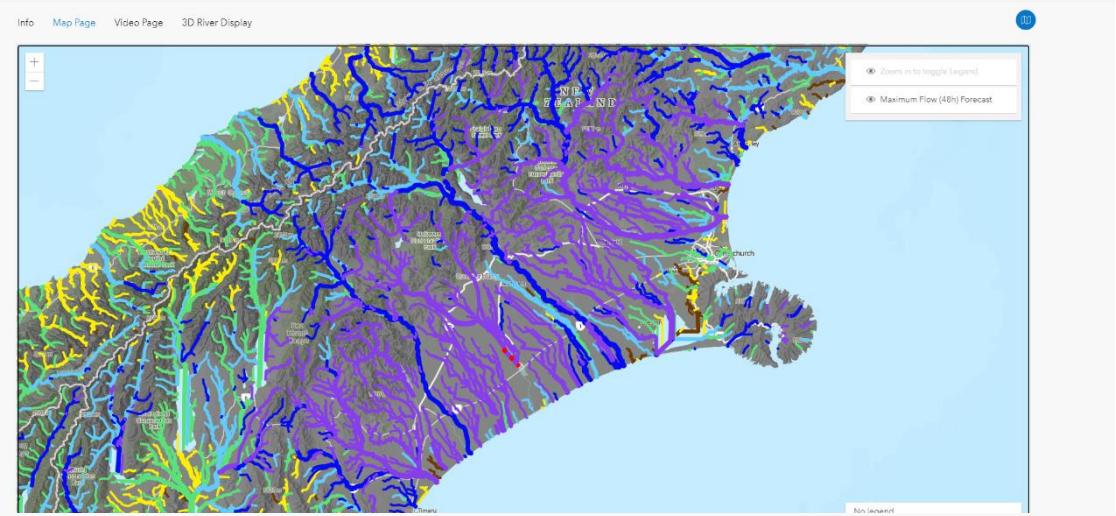


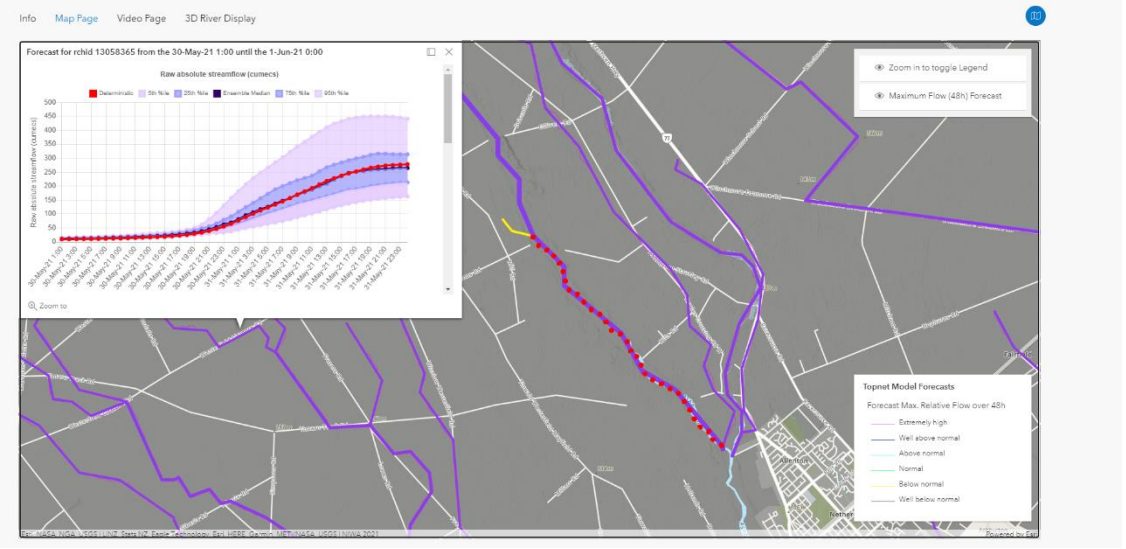





Dissemination via DOC national park forecast and social media

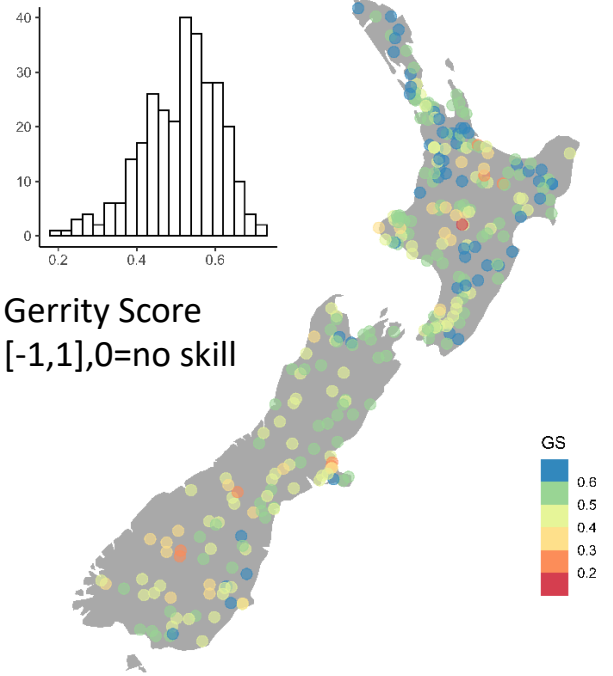
Website under construction: Webapp ESRI



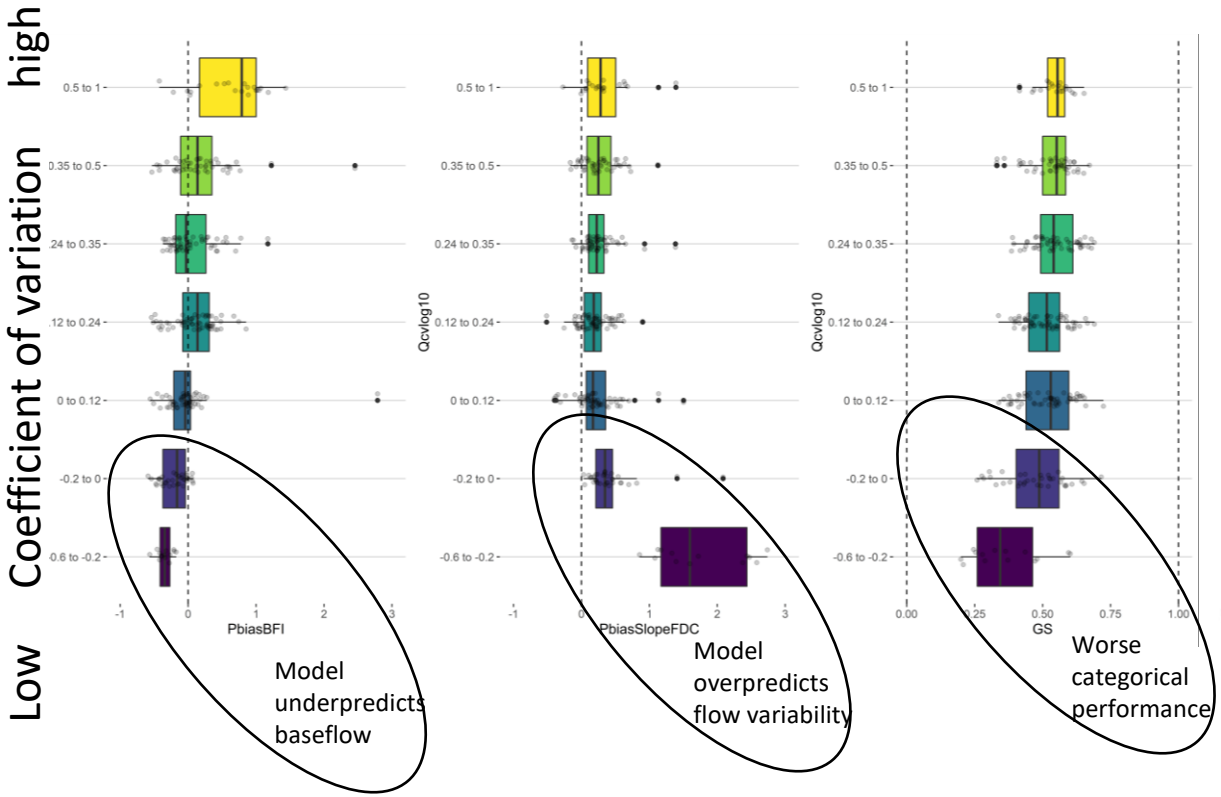



# Flow climatology evaluation: categorical flow (1975-2020)

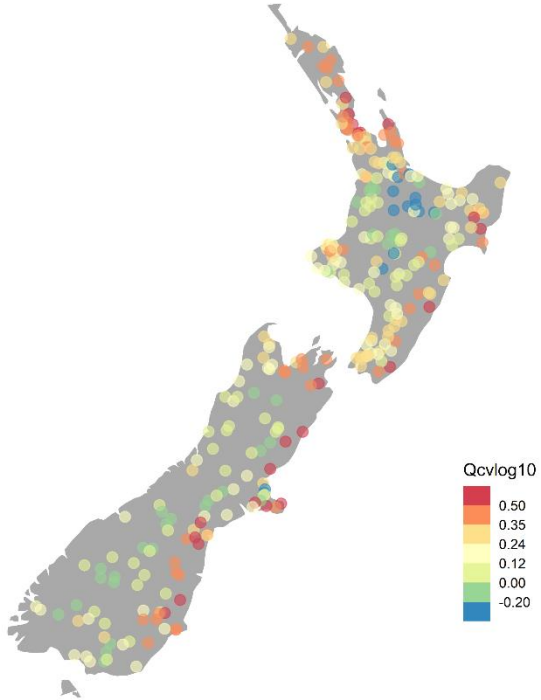
What was the accuracy of model in predicting the correct category, relative to that of random chance?




Gerrity Score
[-1,1],0=no skill





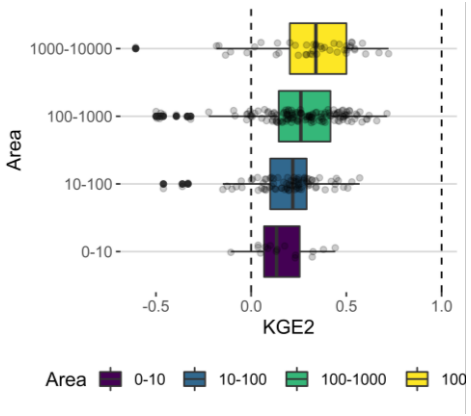



Categorical performance: Gerrity Score (GS) for 6 categories

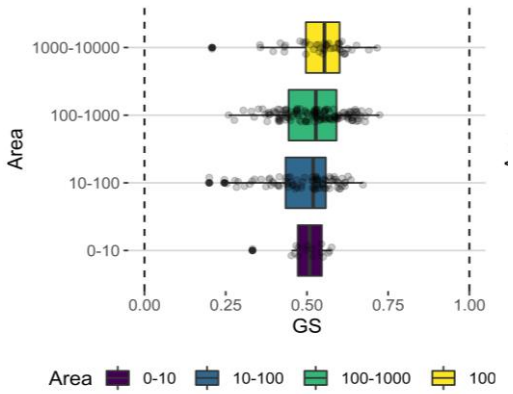
# Flow climatology evaluation: categorical flow (1975-2020)

What was the accuracy of model in predicting the correct category, relative to that of random chance?

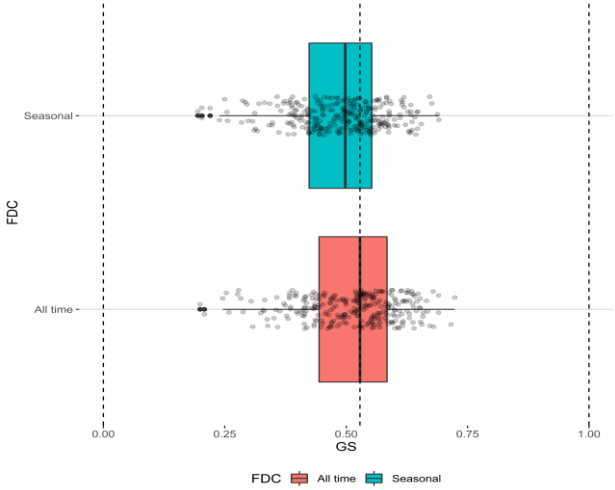
Absolute performance

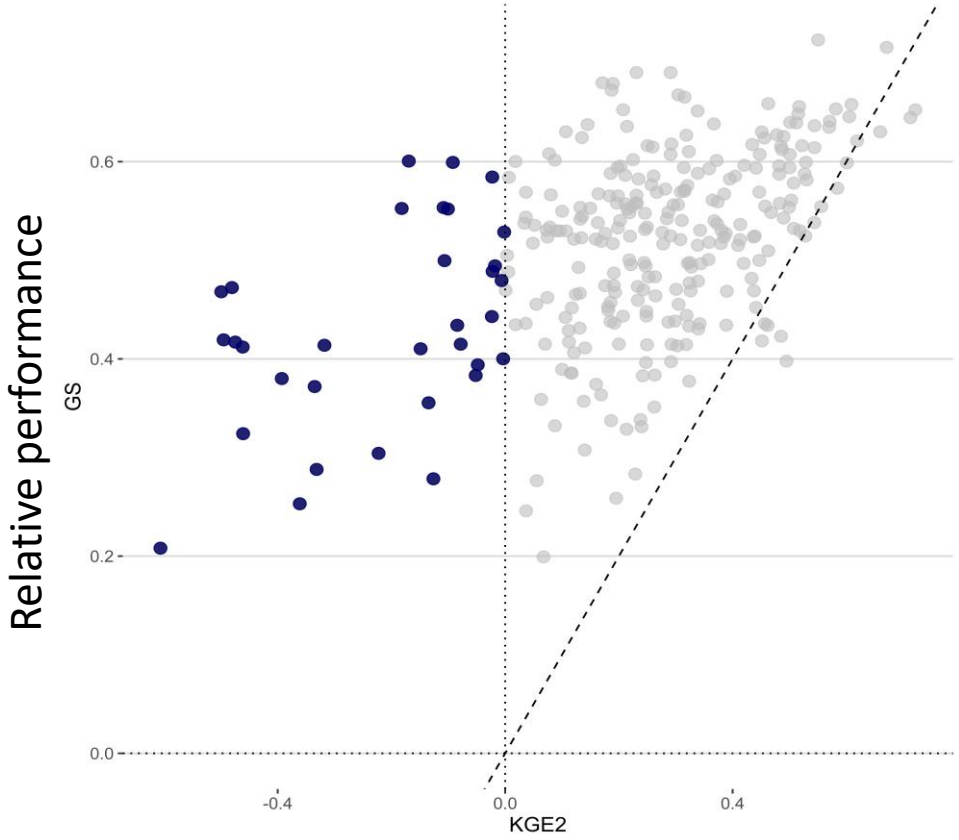



Relative performance




All time vs Seasonal FDC sampling

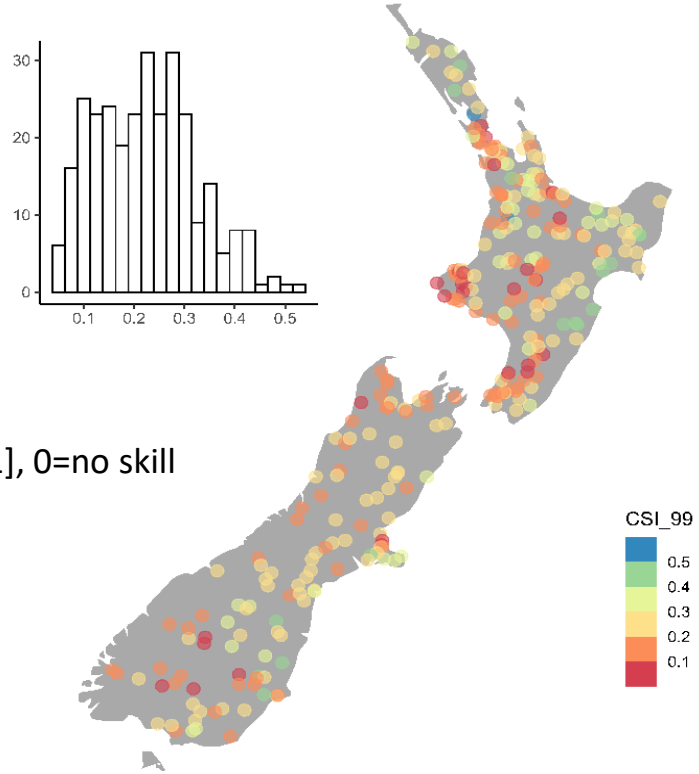



Absolute performance

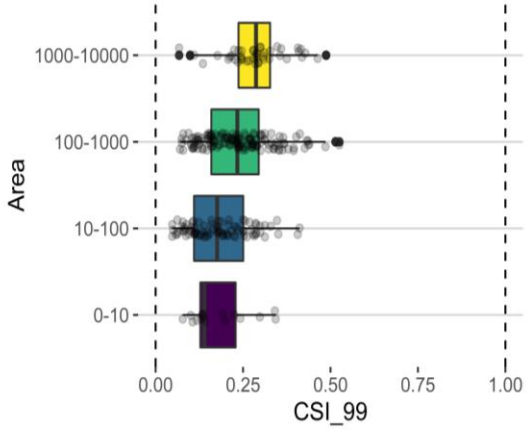
# Flow climatology evaluation: flood category (1975-2020)

How well did the “yes” flood event predicted correspond to the observed “yes” flood event?




CSI
[0,1], 0=no skill

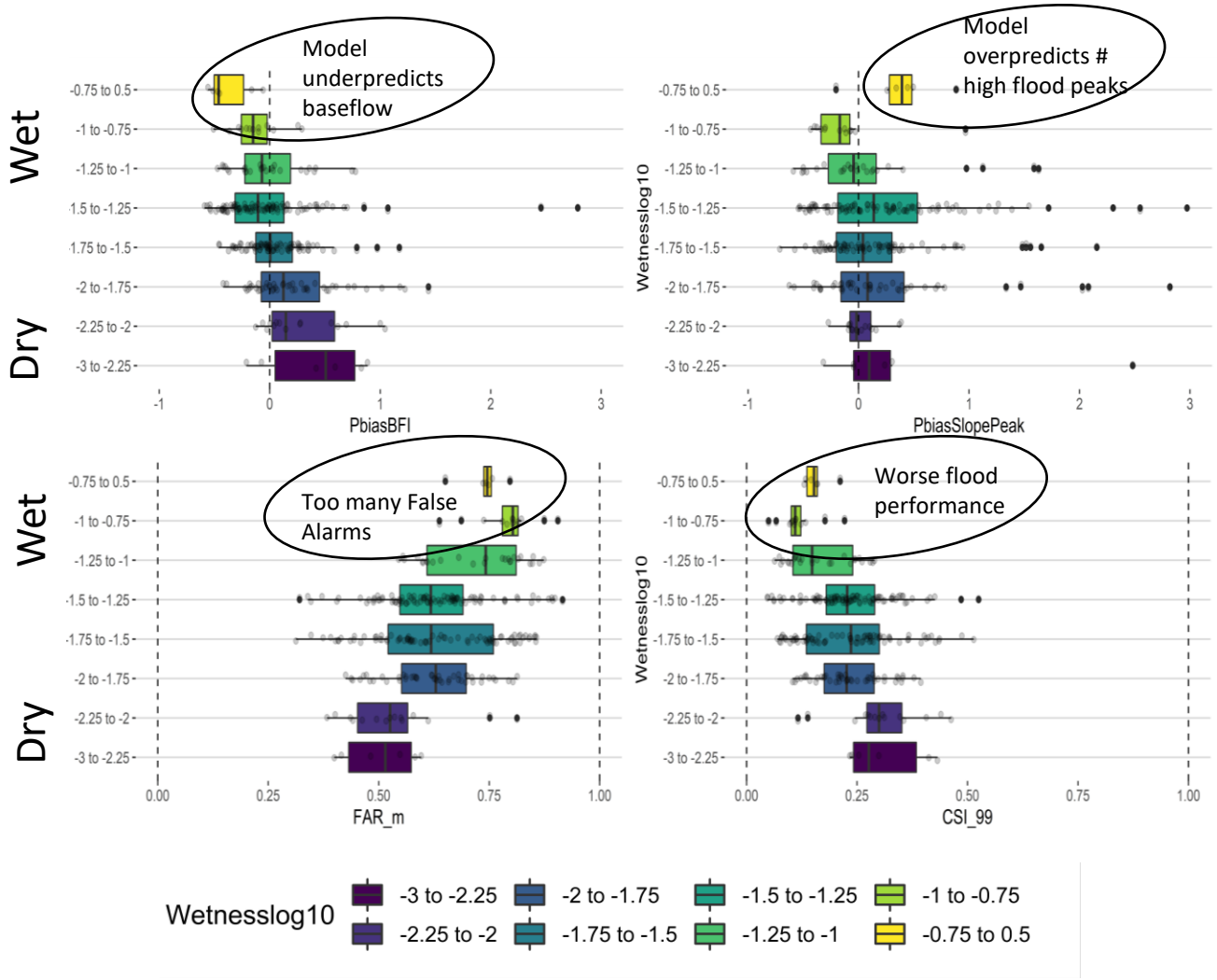
| Contingency table | Observed (True class) | |
|---|---|---|
| Simulated (Predicted class) | Hits | False Alarm |
| | Misses | Correct negative |




Flood performance: Critical Success Index (CSI) 99% threshold (>2yr)

# Flow climatology evaluation: flood category (1975-2020)

How well did the “yes” flood event predicted correspond to the observed “yes” flood event?

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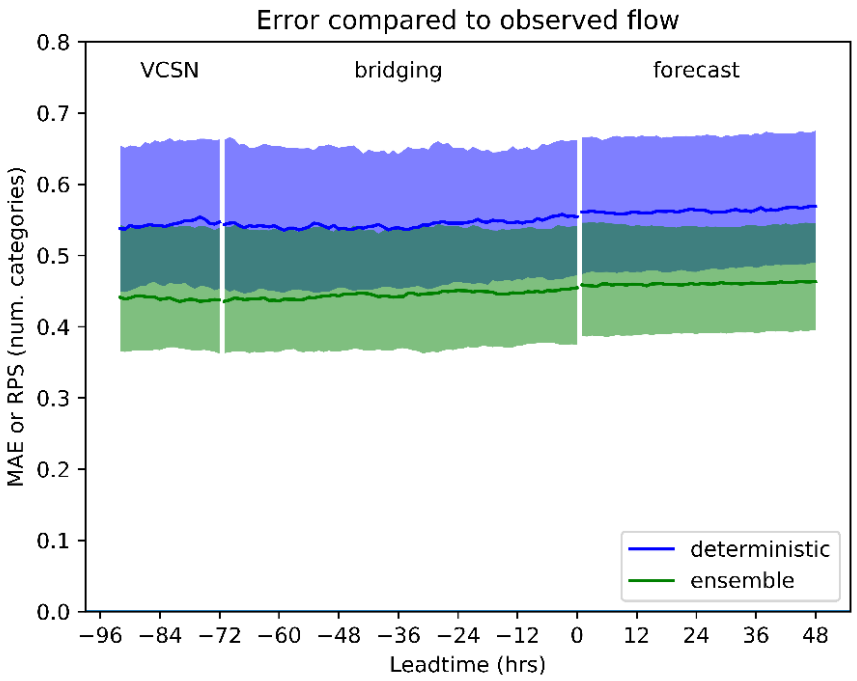
Flood performance: Critical Success Index (CSI) 99% threshold (>2yr)

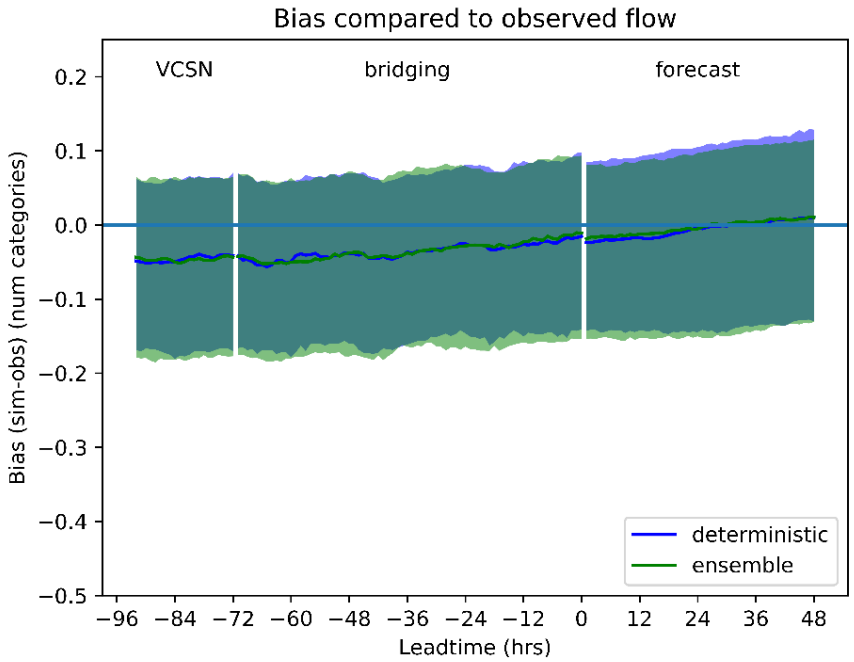
# Forecast performance: 2.5yr reforecast (2018-2020)

(ongoing work, recent flow data update)

## Flow forecasts (preliminary)



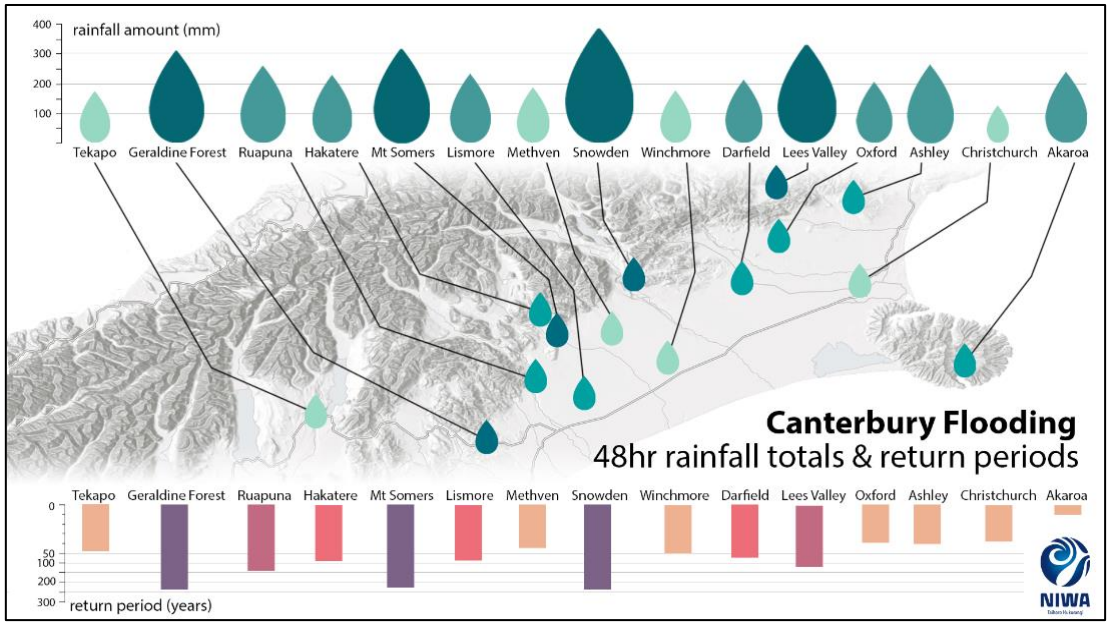

Ensembles improves performance, error on average by 0.5 of a category

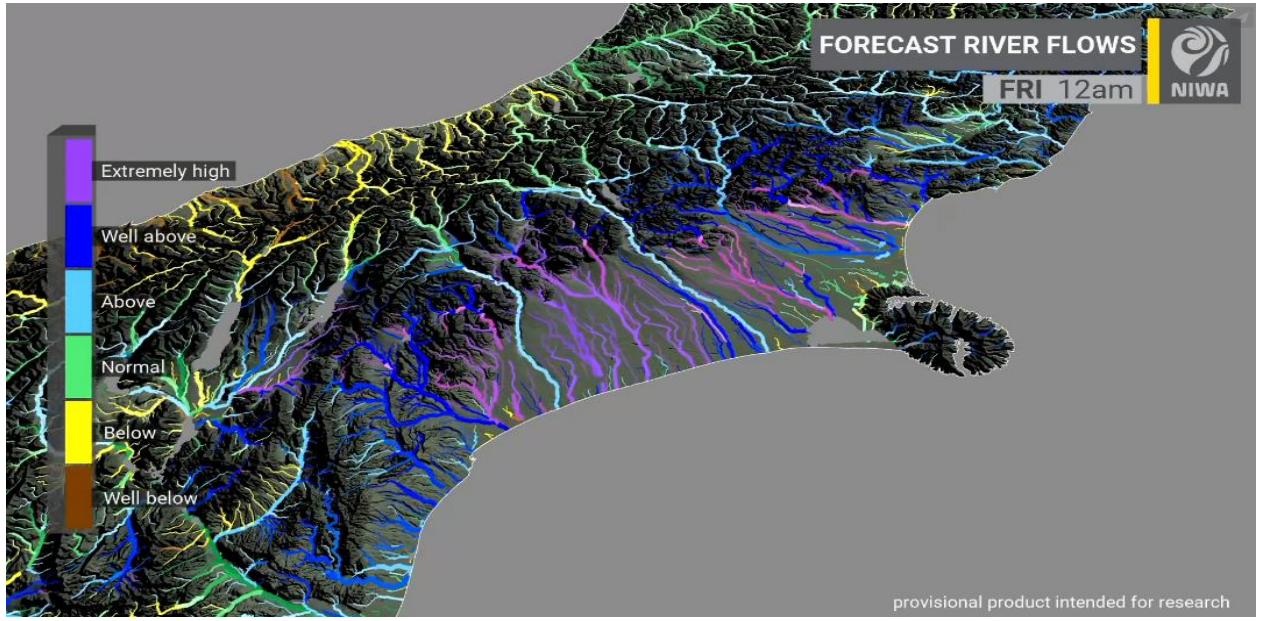



Slight wet bias between flow climatology and NZCSM forecasts


Conway, J., Cattoën, C., K. M. Montgomery, A. Mari, D. Lagrava Sandoval, N. Fedaeff, U. Shankar, and T. Carey-Smith (2020) *Preliminary evaluation of a national-scale river flow forecasts for New Zealand*, NIWA SSIF report , 2020250CH

# Canterbury flooding 29-31 May 2021



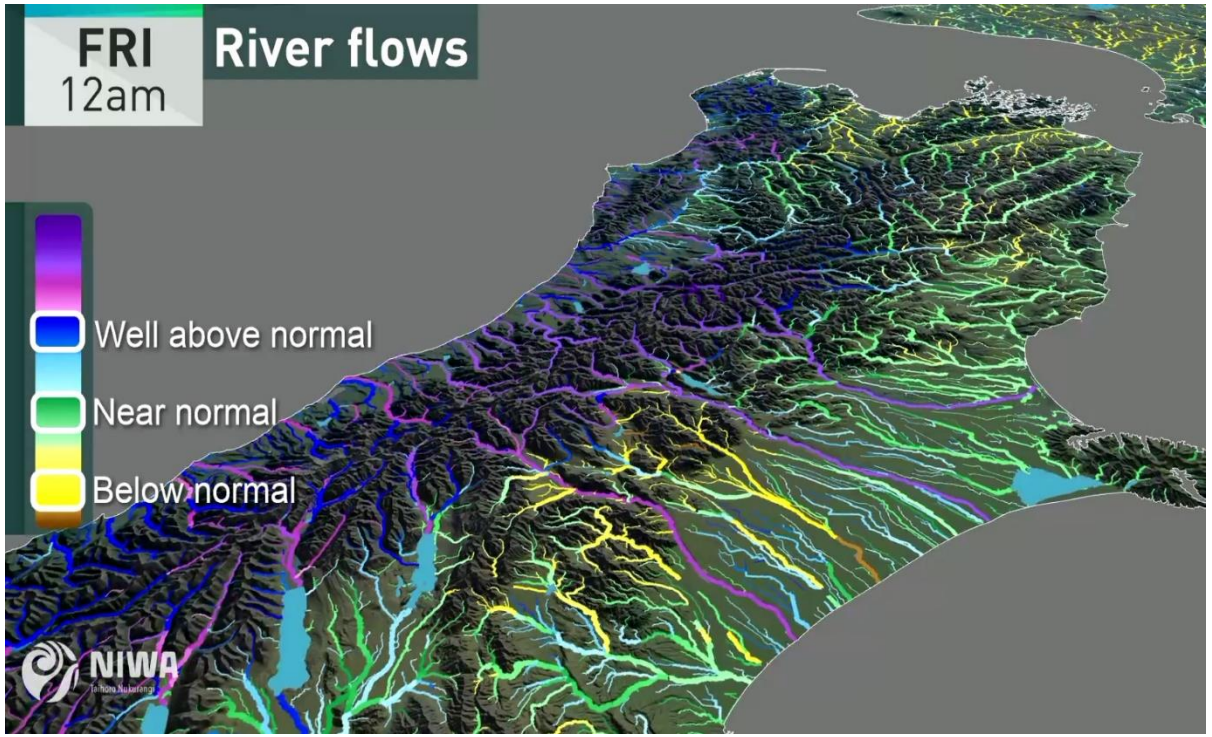

Full evaluation underway but forecast spatial pattern matched what occurred according to media reports and NIWA staff on the ground

# Challenges and Perspectives

- Real-time access to climate and flow data at national scale is problematic (24h embargo and no national flow database)
- Engagement with stakeholder shaped a co-design process and tool design
- Relative river forecasts provide more detailed information than rainfall forecast alone about which rivers will be affected by high flow and when
- Further model developments required for flood process representation
- Absolute flow forecasts: calibration or machine learning with bias correction
- Links to International community (e.g. HEPEX) critical
- Scientific feasibility proof of concept established for New Zeland

# Conclusion

**Shaping a nationwide approach for New Zealand's river flood forecasts**




- Proof of concept of a national scale river flow forecasting
- Models, data, HPC, machine learning and social science play a central role

## Thank you

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Climate, Freshwater & Ocean Science

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