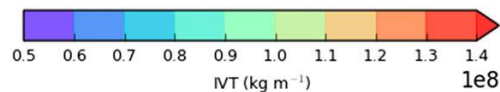
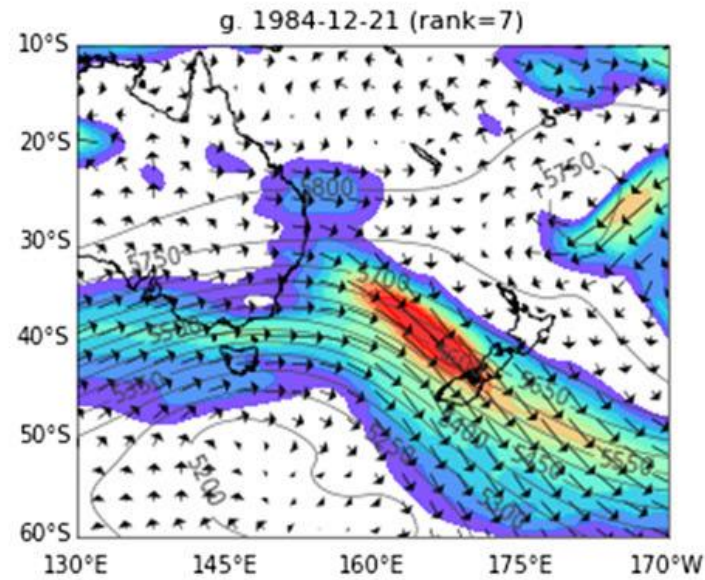
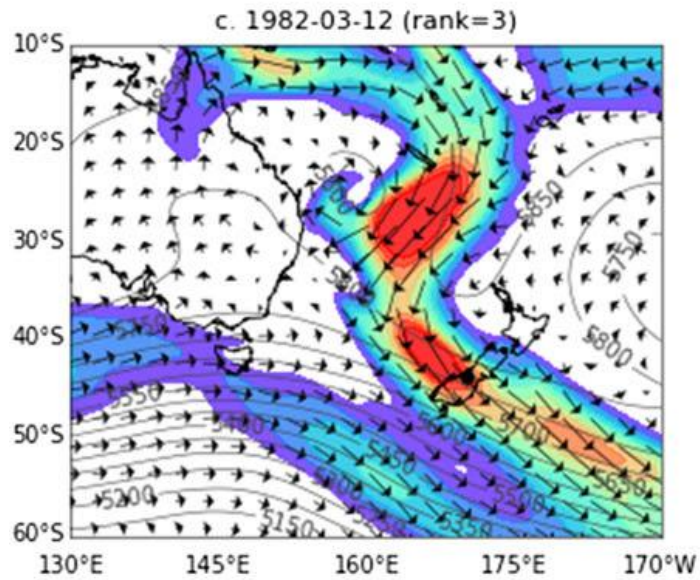
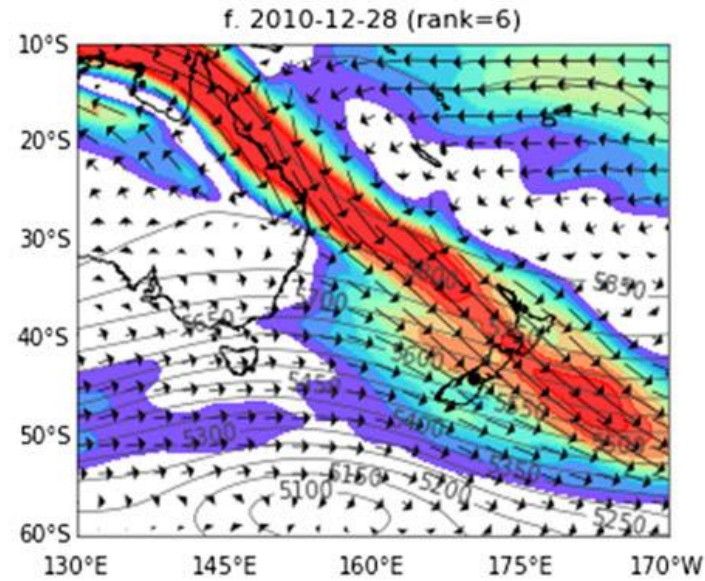
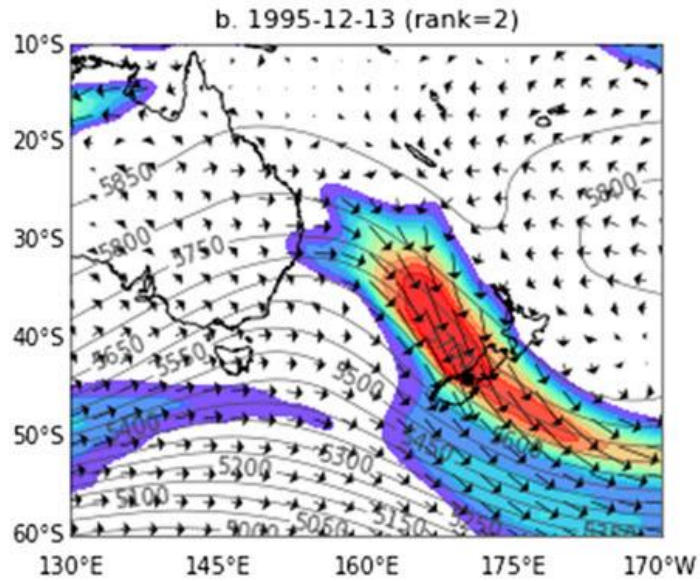


***Lessons Learned** from coupling a high-resolution weather model with a hydrologic model for flood forecasting*



Hilary McMillan

Associate Professor, Dept of Geography, San Diego State University



SCIENTIFIC BRIEFING

HP
TODAY

HYDROLOGICAL PROCESSES

Hydrol. Process. **30**, 5063–5070 (2016)

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Floods in the Southern Alps of New Zealand: the importance of atmospheric rivers

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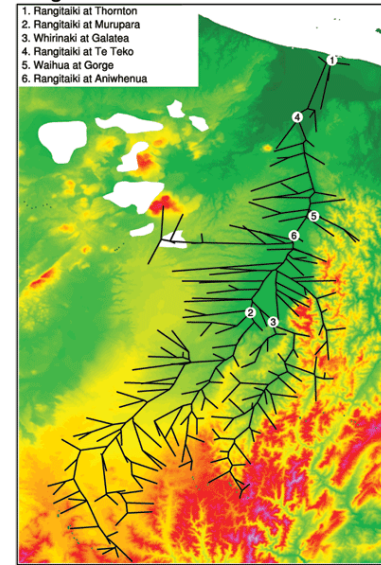
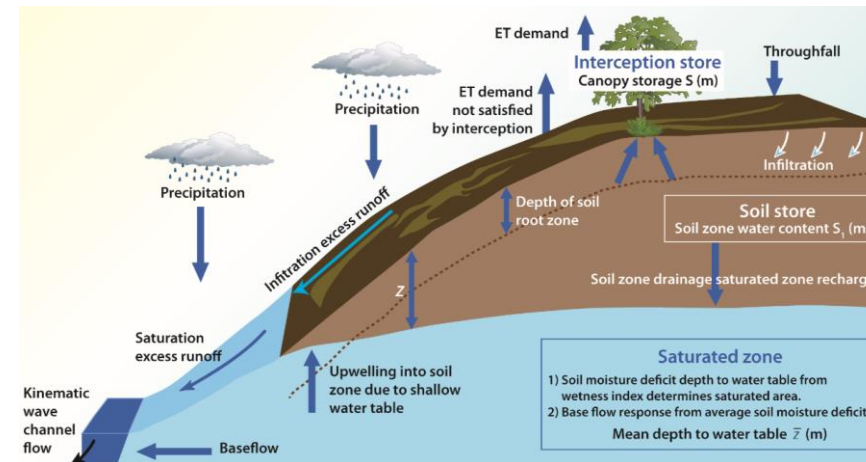
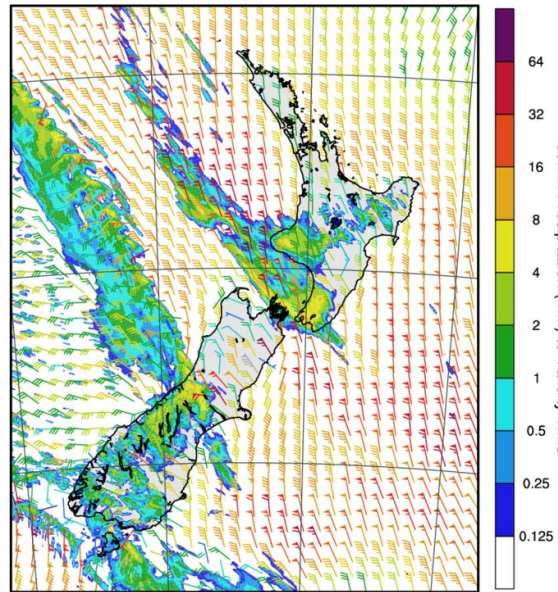
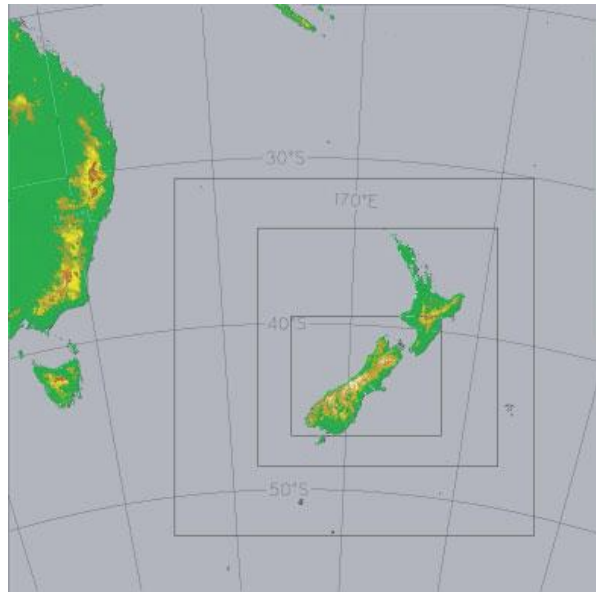
Abstract

Extremely high precipitation occurs in the Southern Alps of New Zealand, associated with both orographic enhancement and synoptic-scale weather processes. In this study, we test the hypothesis that atmospheric rivers (ARs) are a key driver of floods in the Southern Alps of New Zealand. Vertically integrated water vapour and horizontal water vapour transport, and atmospheric circulation, are investigated concurrently with major floods on the Waitaki River (a major South Island river). Analysis of the largest eight winter maximum floods between 1979 and 2012 indicates that all are associated with ARs. Geopotential height fields reveal that these ARs are located in slow eastward moving extratropical cyclones, with high pressure to the northeast of New Zealand. The confirmation of ARs as a contributor to Waitaki flooding indicates the need for their further exploration to better understand South Island hydrometeorological extremes. Copyright © 2016





Forecasting System



**NWP model at
12km / 1.5 km**

**Distributed
hydrologic model**



SCALE

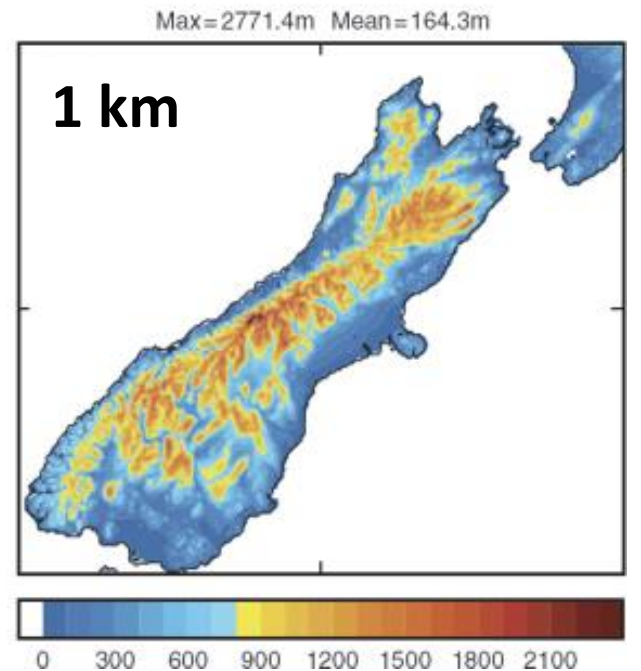
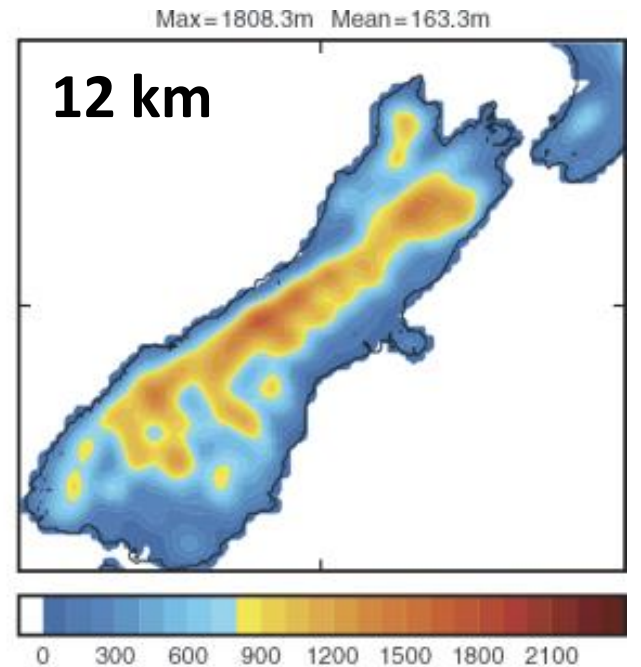
BIAS

LAG

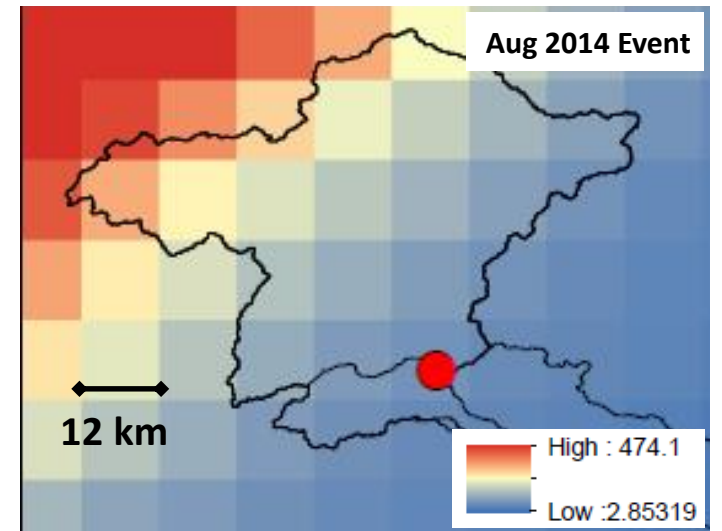
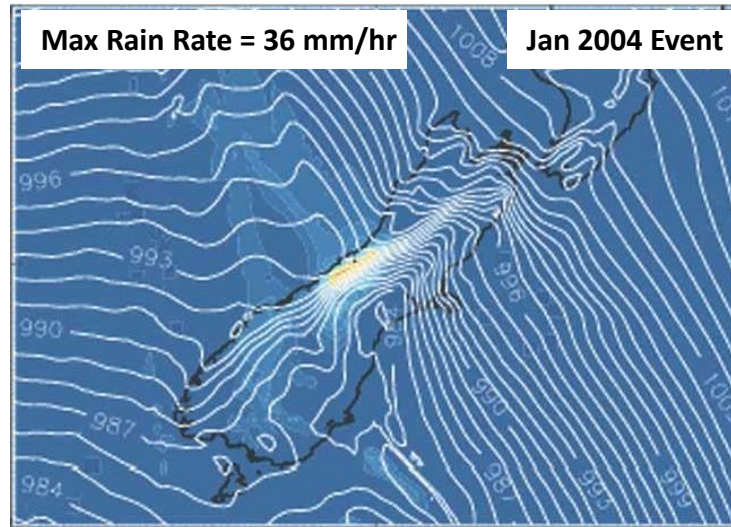
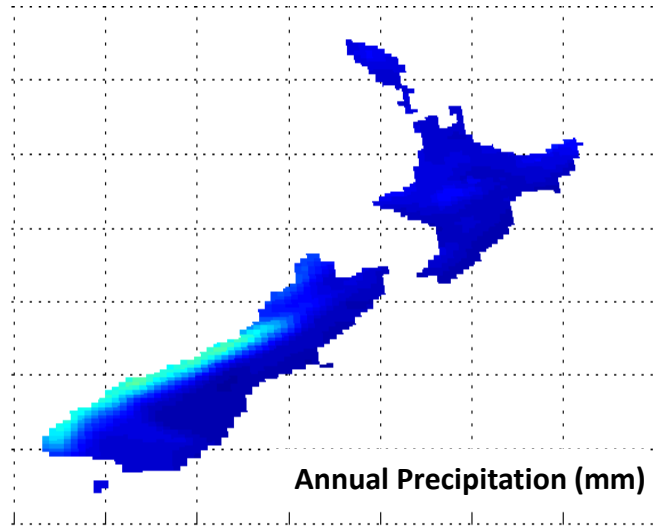
The image features a stylized, colorful map of the world. The colors are vibrant and somewhat abstract, with shades of blue, green, yellow, orange, and red. The map is centered on the Atlantic Ocean, with North and South America visible on the left and Europe and Africa on the right. The word "SCALE" is written in large, white, bold, sans-serif capital letters across the center of the map, positioned over the Atlantic Ocean. The overall aesthetic is modern and graphic.

SCALE

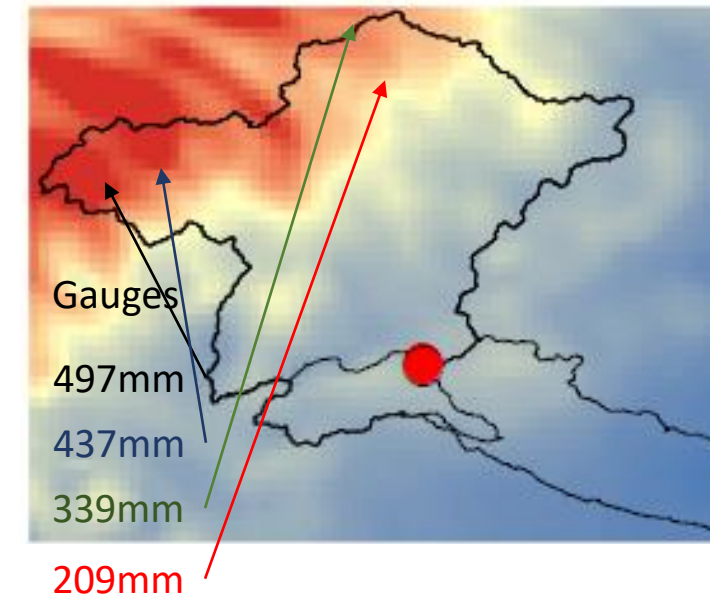
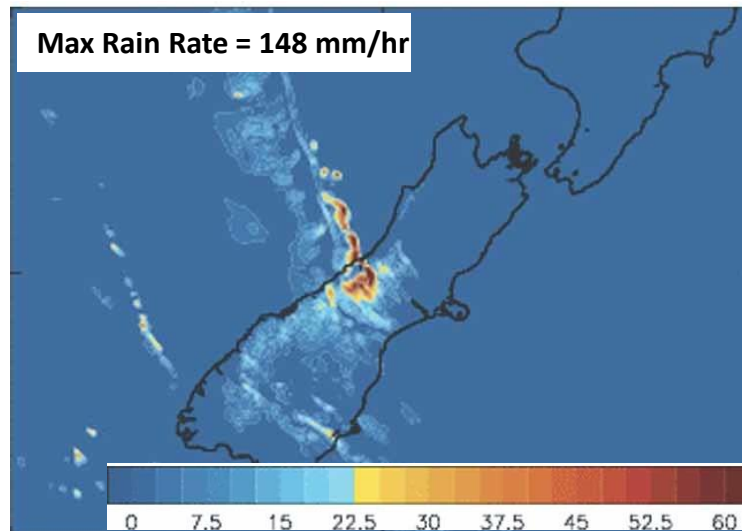
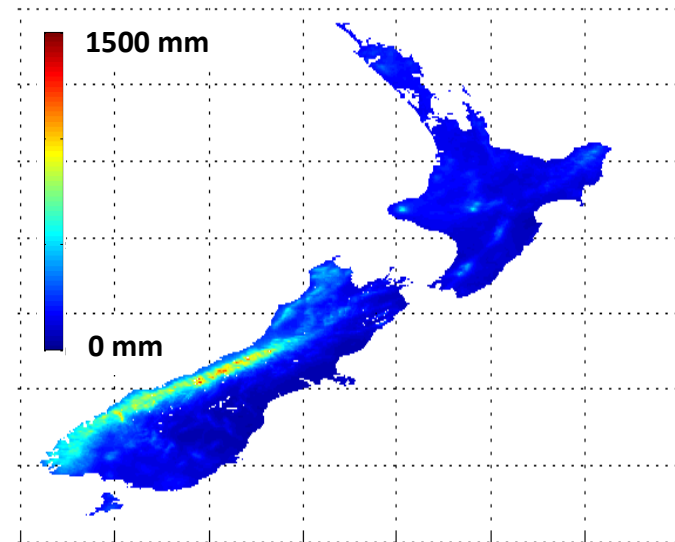
**Weather model
resolution of 1-2km is
needed to resolve
topography and
storm systems**



12
km



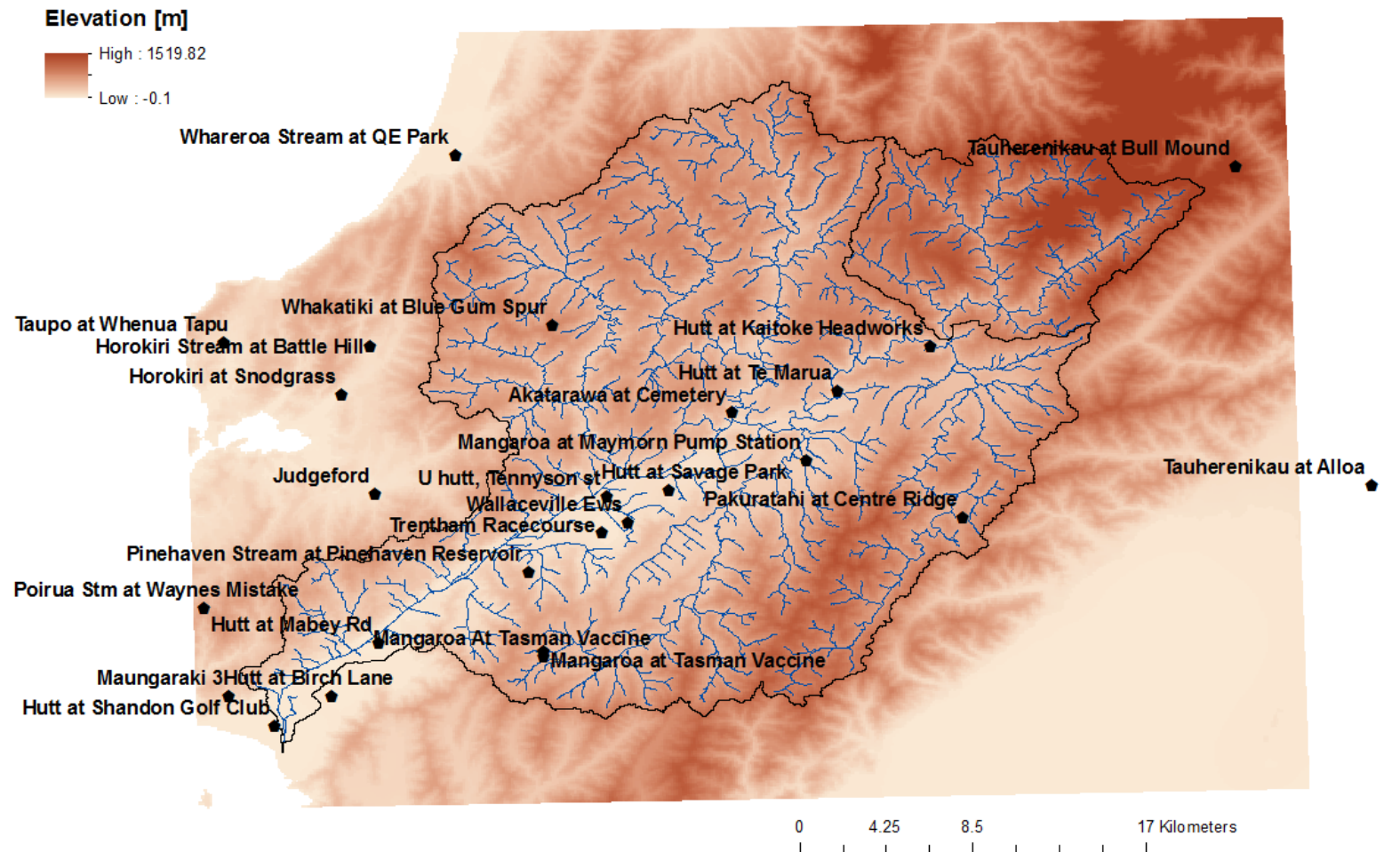
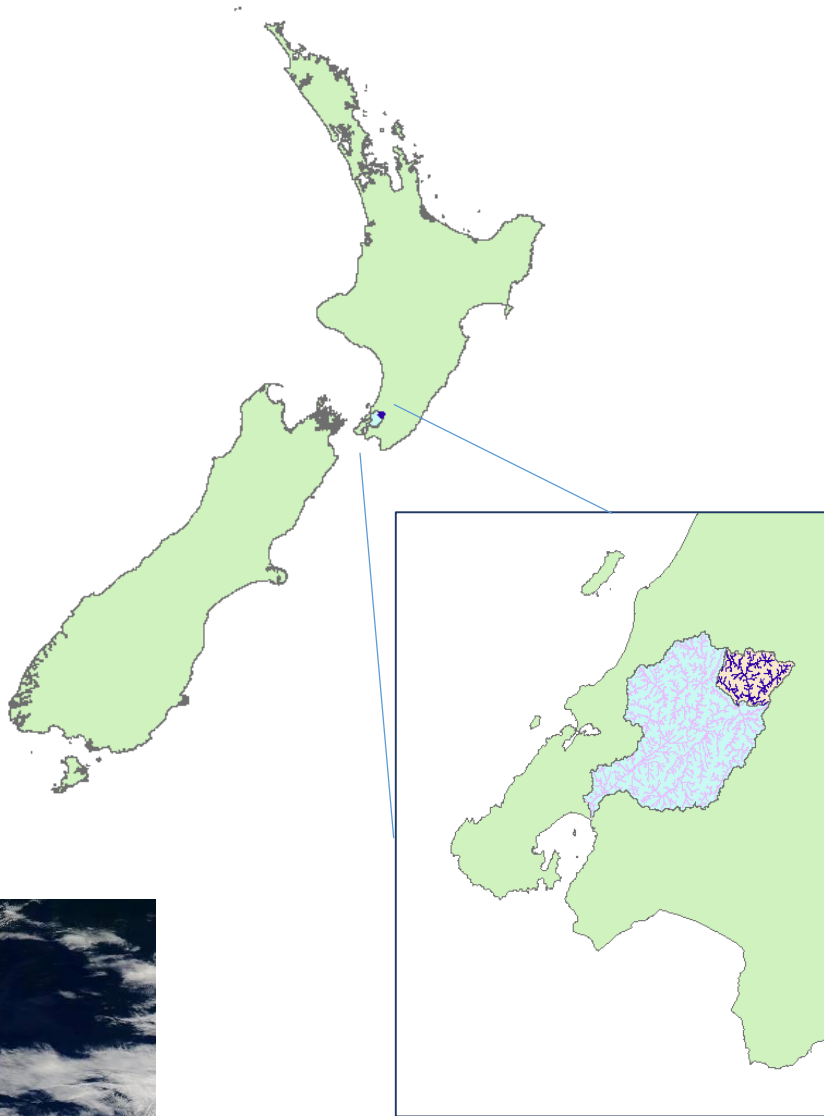
1.5
km



The image features a vibrant, multi-colored abstract pattern that resembles a topographic map or a weather system. The colors transition from deep blues at the top, through greens and yellows, to oranges and reds at the bottom. The pattern is characterized by swirling, wavy lines and irregular shapes, creating a sense of movement and depth. Overlaid on this pattern is the word "BIAS" in a bold, white, sans-serif font, centered horizontally and slightly above the vertical middle. The text is sharp and stands out against the darker blue background behind it.

BIAS

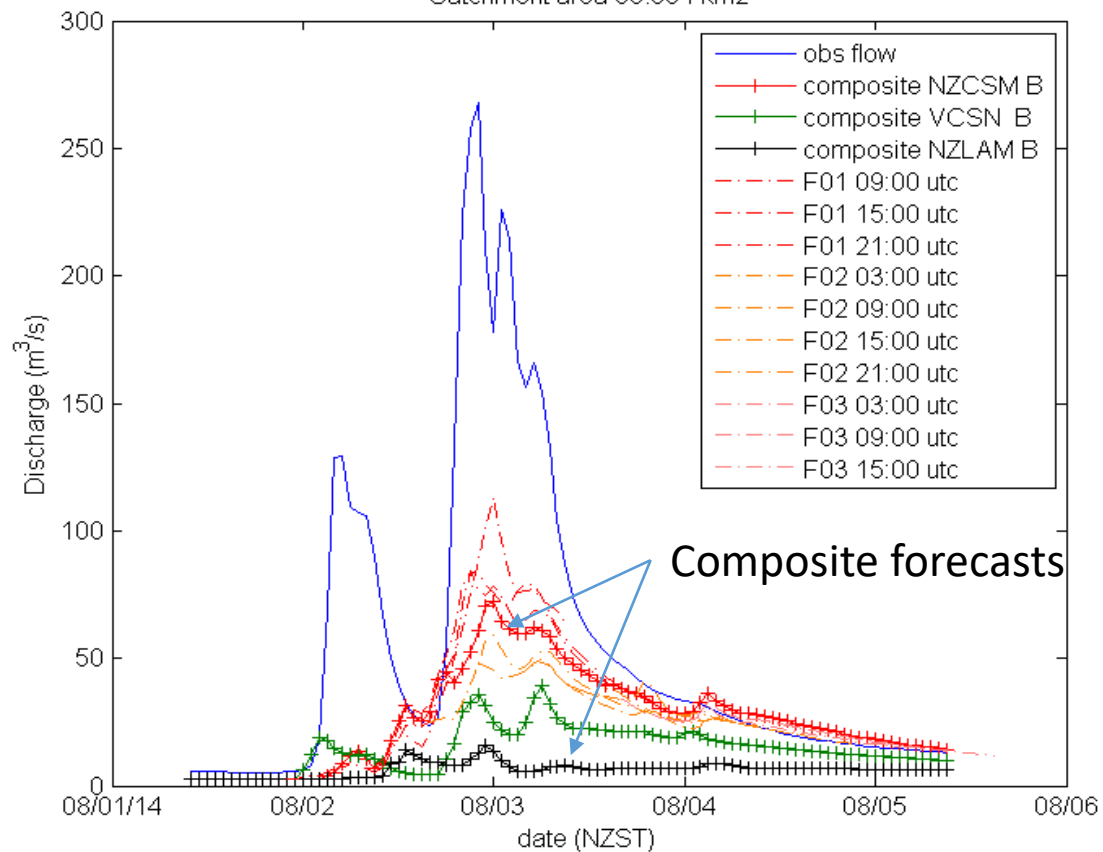
Case Study: Hutt catchment



Low Bias: 1.5 km Weather Model and (worse) 12km Model

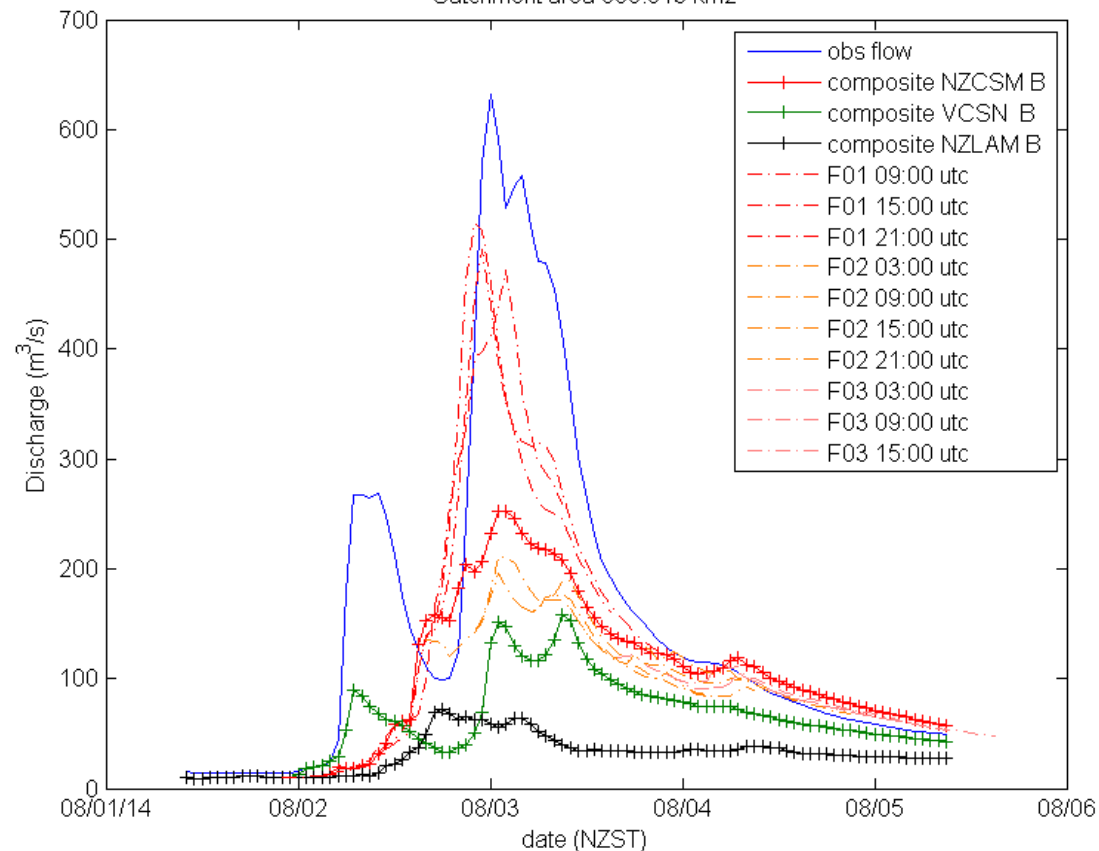
Small Hutt catchment (86km²)

Discharge for Reach ID 9008427
Hutt at Kaitoke
Catchment area 86.864 km²

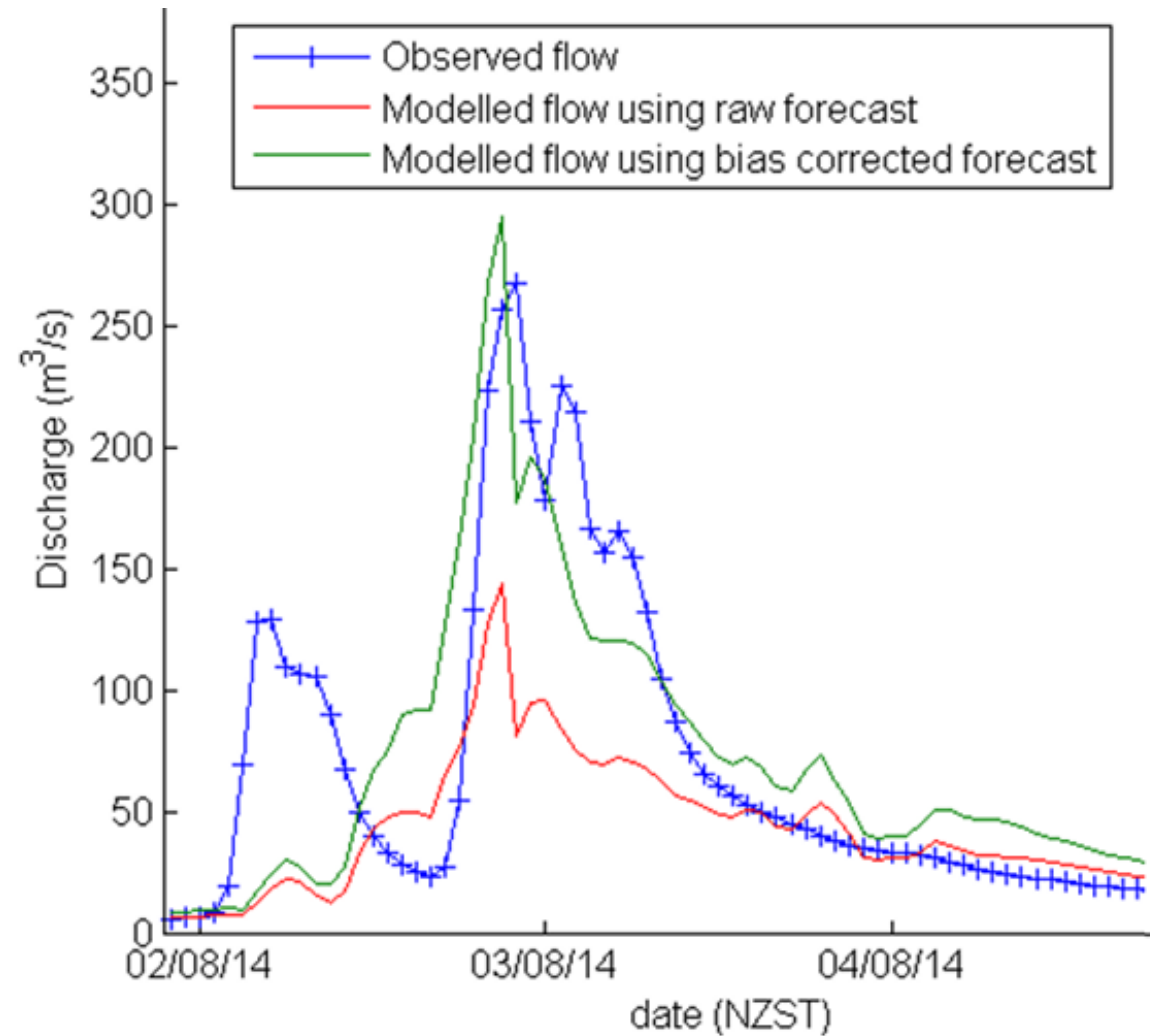


Large Hutt catchment (558km²)

Discharge for Reach ID 9010876
Hutt at Taita Gorge
Catchment area 558.613 km²

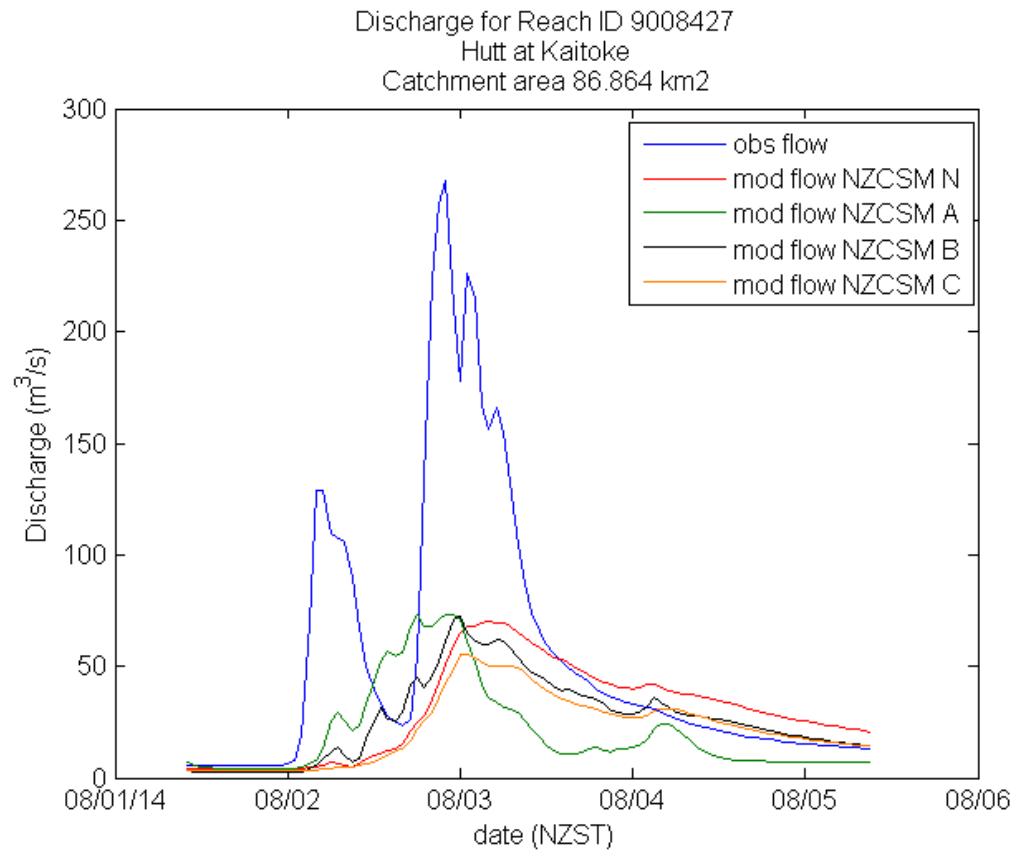


Bias correction of NWP shows significant improvement (drizzle removal; quantile correction)

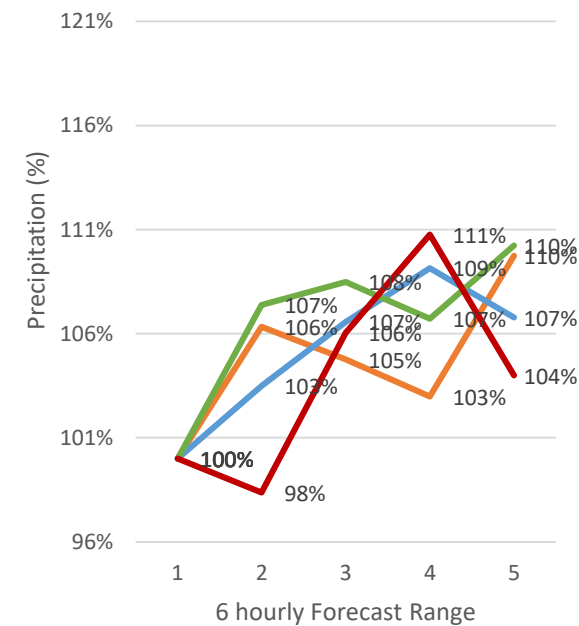


Other sources of uncertainty / bias

- Uncertainty due to hydrologic model parameters is small
- Bias in rainfall totals due to forecast lead time

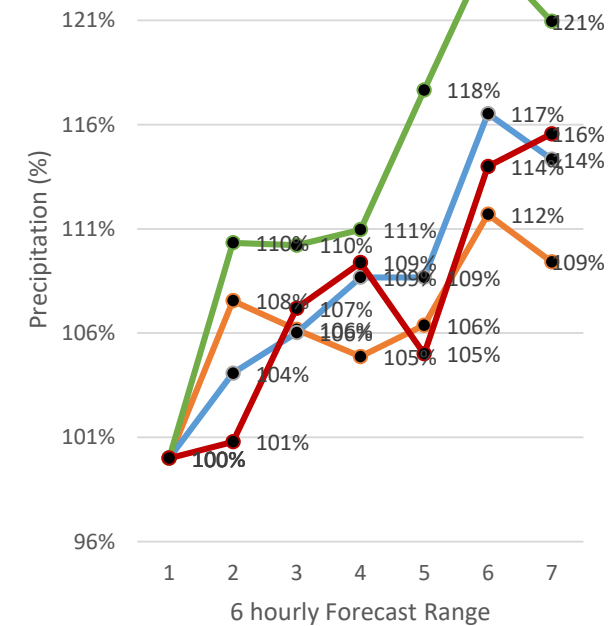


1.5 km averaged rainfall with lead time



Grey NZCSM Buller NZCSM Basin1
Buller NZCSM Basin2 Buller NZCSM Basin3

12 km averaged rainfall with lead time



Grey NZLAM Buller NZLAM Basin1
Buller NZLAM Basin 2 Buller NZLAM Basin3



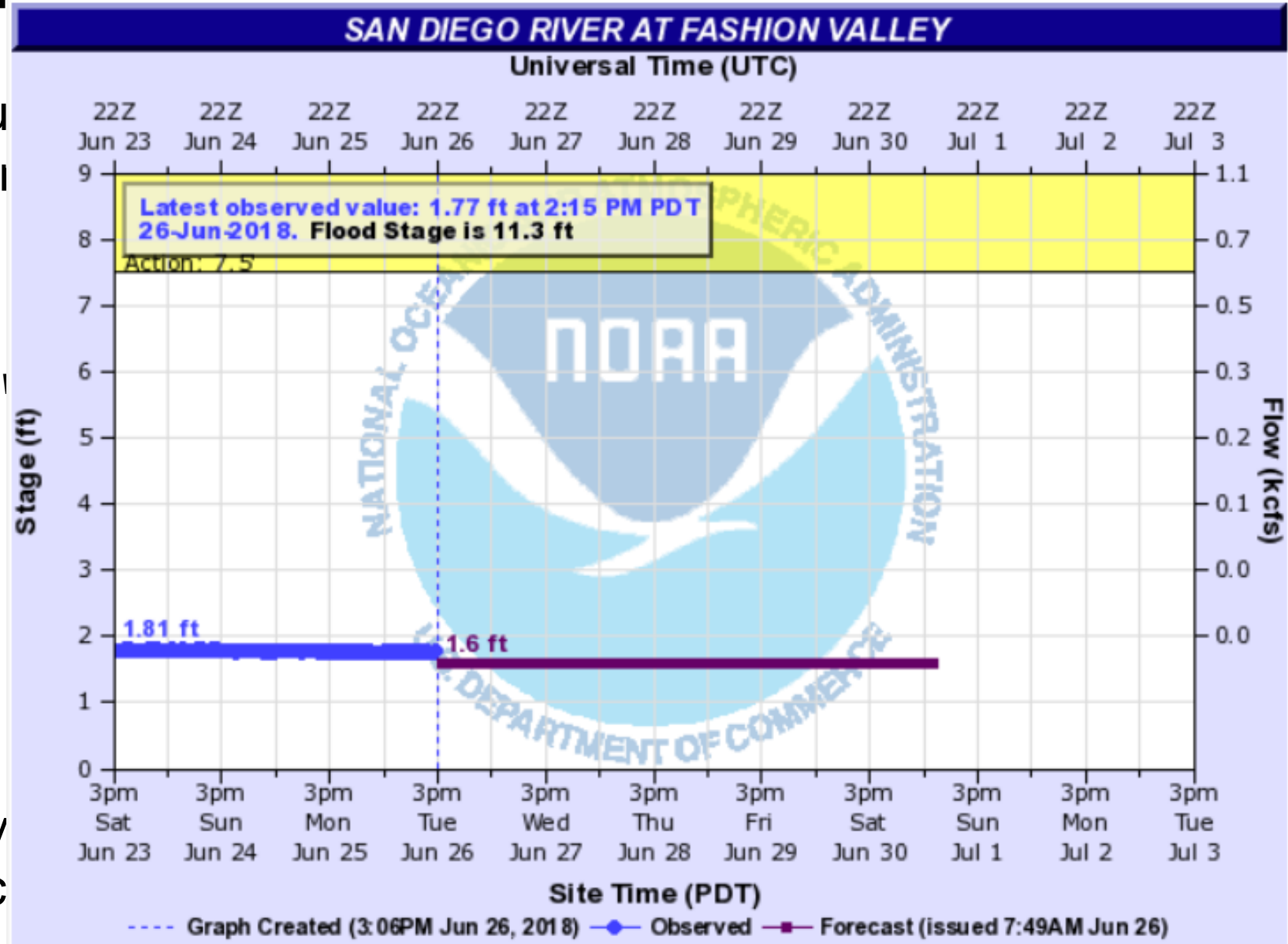
LAG

Data Assimilation by Kalman Filter

- Kalman Filter adjusts balance between model and measurement

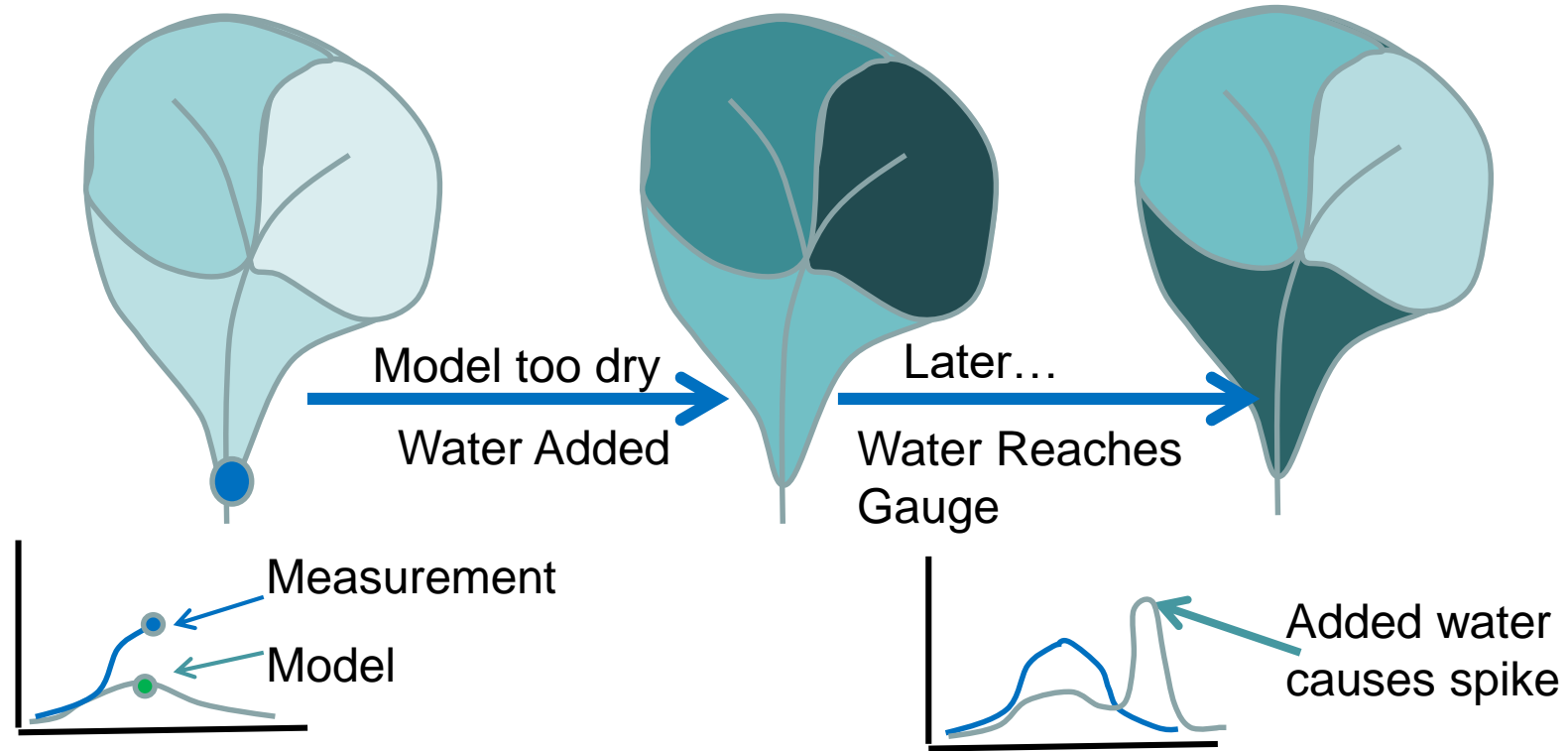
Example: If the model under-estimates streamflow it implies the basin is too dry, and water is added to the model

- Model Uncertainty
- Measurement uncertainty

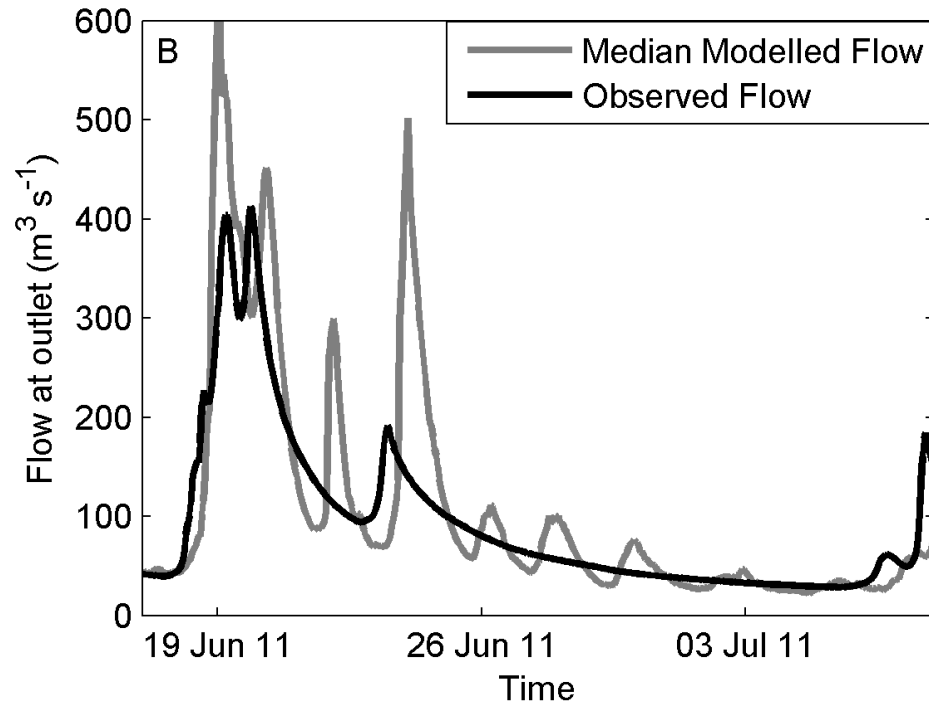


Kalman Filter may fail in hydrology

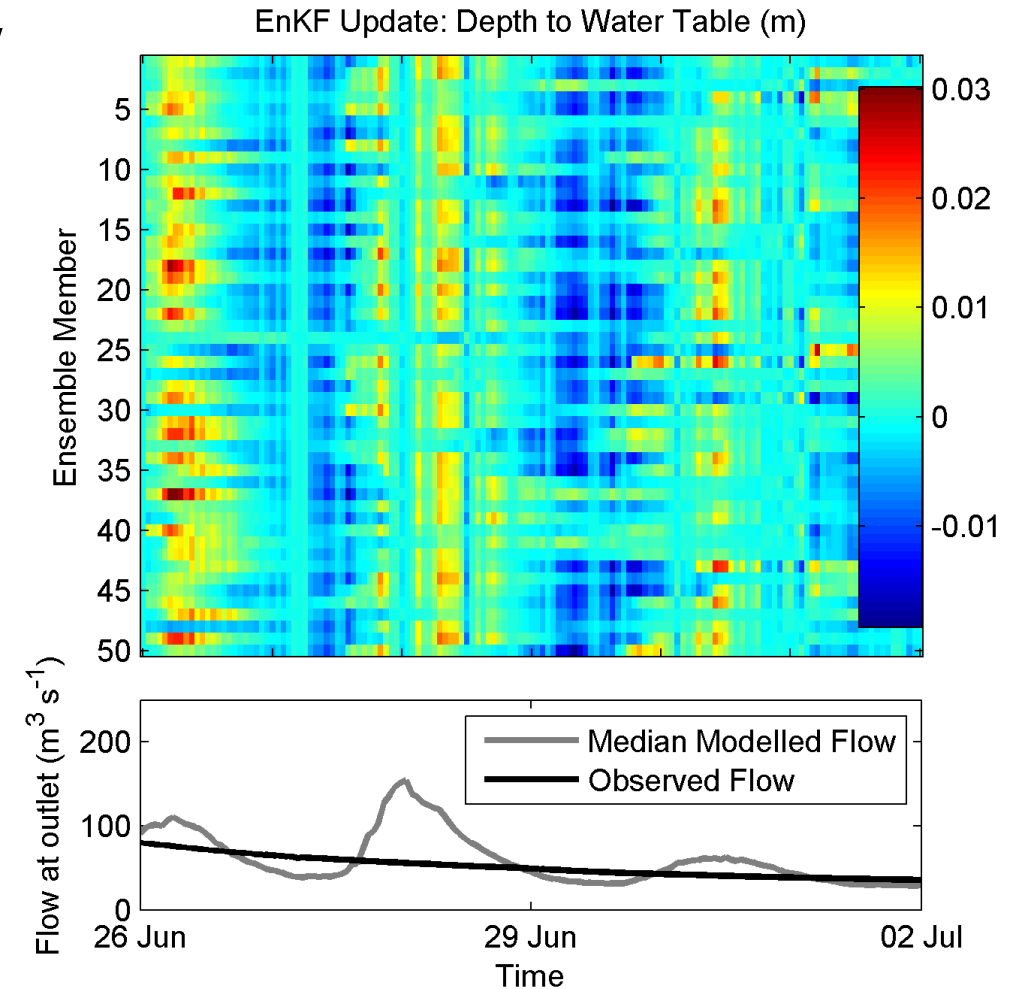
- Hydrology is a special case!
- The natural lag between rainfall in the catchment and streamflow response is not accounted for.



Examples of Failures we saw



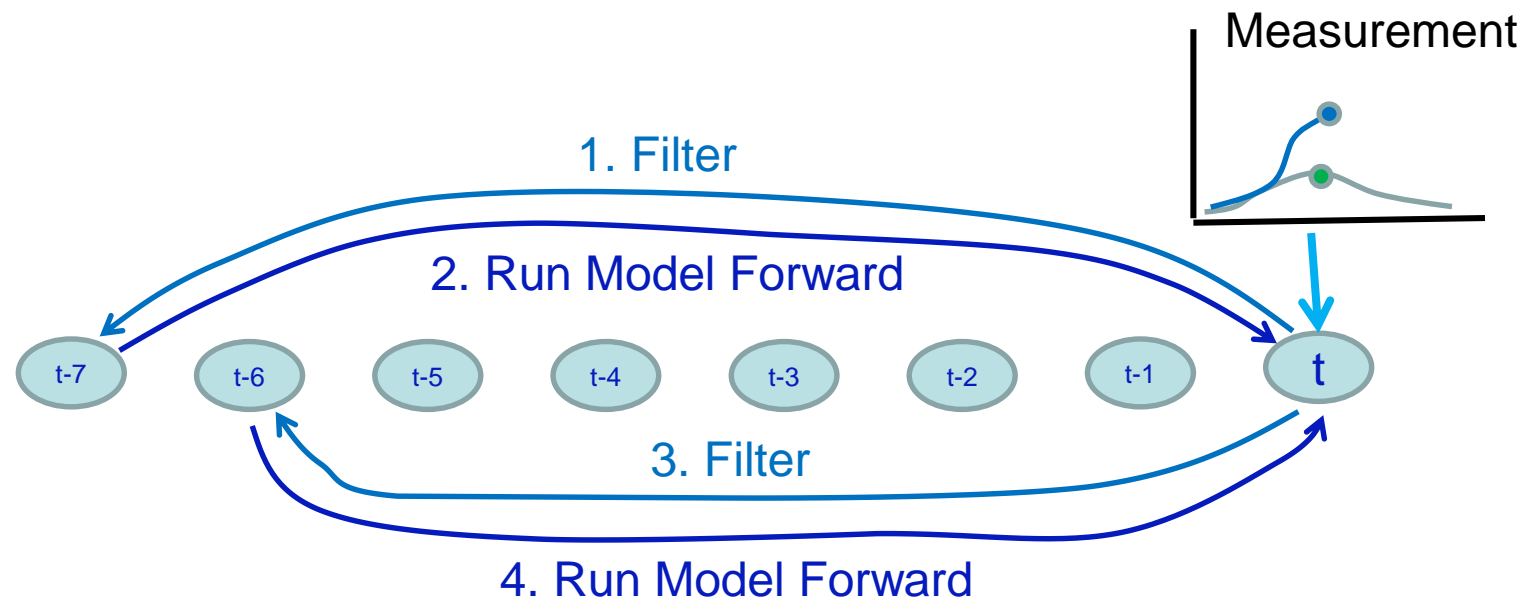
- Oscillations in forecast for Motueka River



- Model overcorrects and adds/removes water.
- Oscillations occur with a period similar to the concentration time of the catchment.

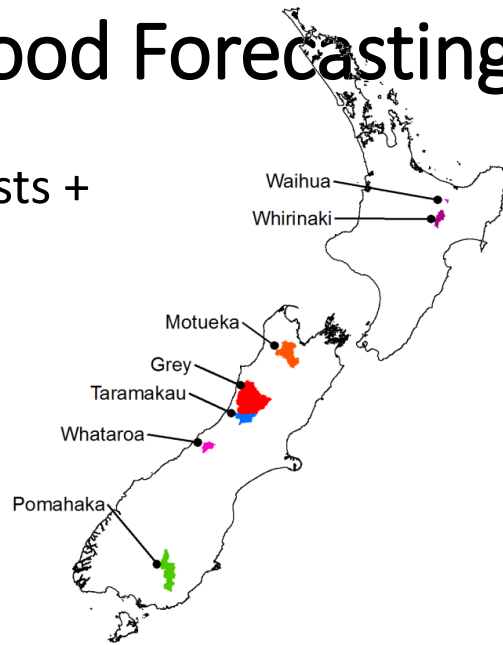
Solution: Allow for lag time

- The 'Retrospective Ensemble Kalman Filter' allows for the catchment lag time by iteratively updating water stores at prior timesteps

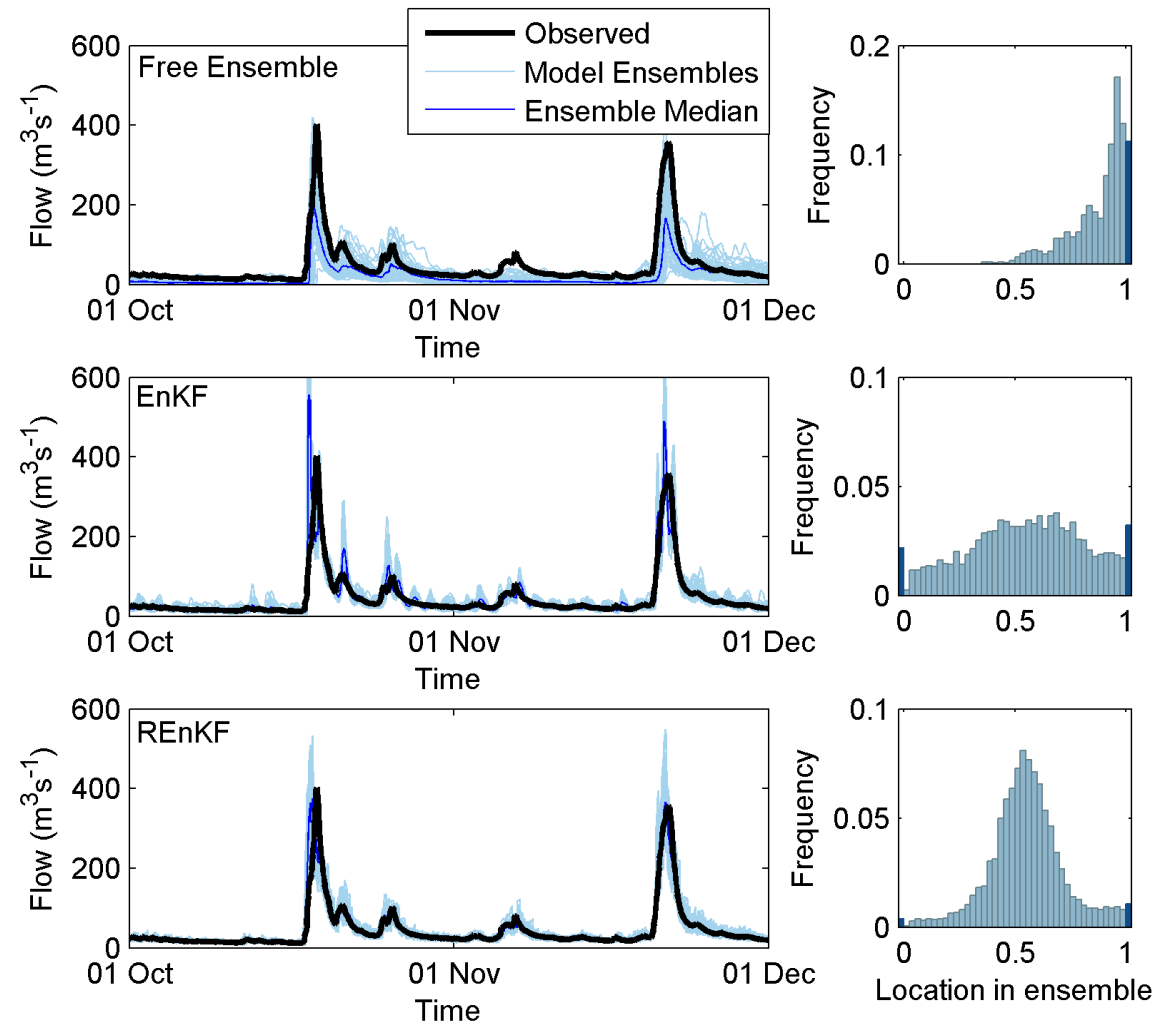


Coupled Model Flood Forecasting

- 12km NWP rainfall forecasts +
- Stream flow observations assimilation (REnKF) +
- Hydrological Model



Catchment	No Assimilation	EnKF median	REnKF median
Waihua	0.6167	0.8973	0.8251
Whirinaki	0.4277	0.9338	0.8307
Motueka	0.4379	-1.1640	0.8982
Grey	0.4747	0.7302	0.8828
Taramakau	0.3759	0.7970	0.8305
Whataroa	0.1499	0.5353	0.6649
Pomahaka	0.0836	0.7298	0.8583



NS Score: <0=random, 0=long term mean, 1 = perfect

Lessons Learned from coupling a high-resolution weather model with a hydrological model for flood forecasting

High-res Forecasts Correct Bias Use Lagged DA

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Cattoën, C., McMillan, H., Moore, S., 2016 Coupling a high-resolution weather model with a hydrological model for flood forecasting in New Zealand, *Journal of Hydrology (NZ)*, 55: 1-23.

McMillan, H.K., et al. 2013. Operational hydrological data assimilation with the recursive ensemble Kalman filter. *Hydrology and Earth System Sciences*, 17(1), p.21.

