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

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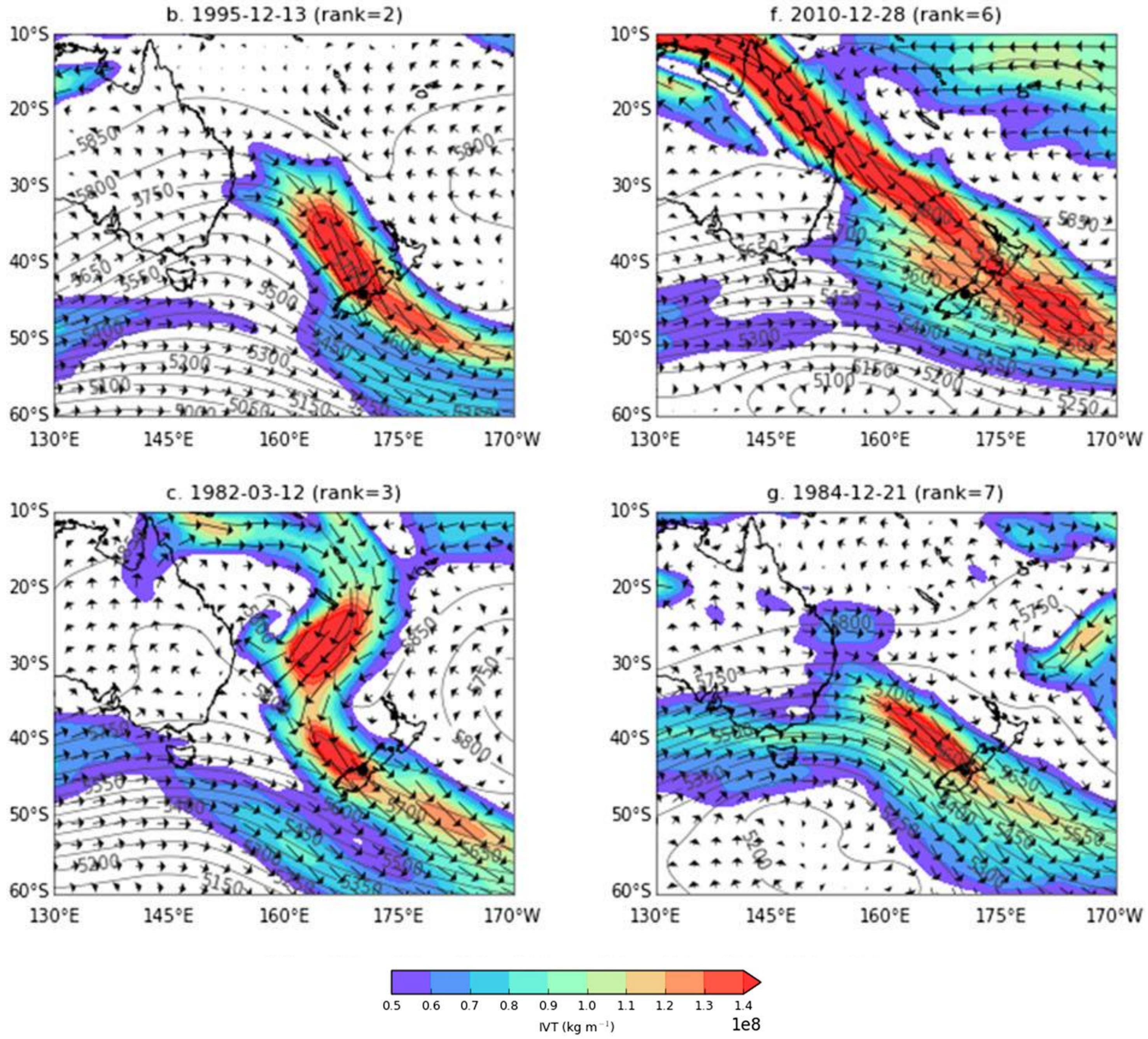

SCIENTIFIC BRIEFING

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

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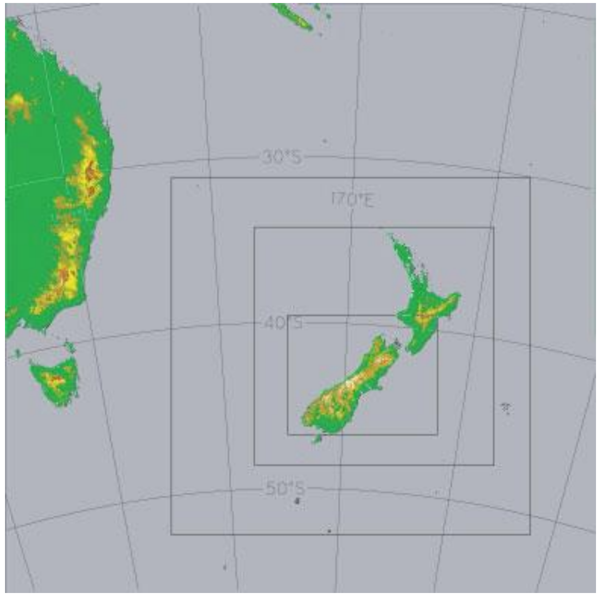
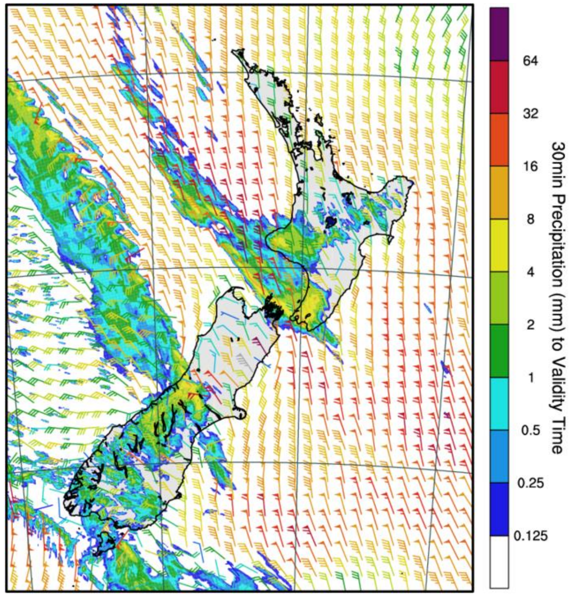
Abstract

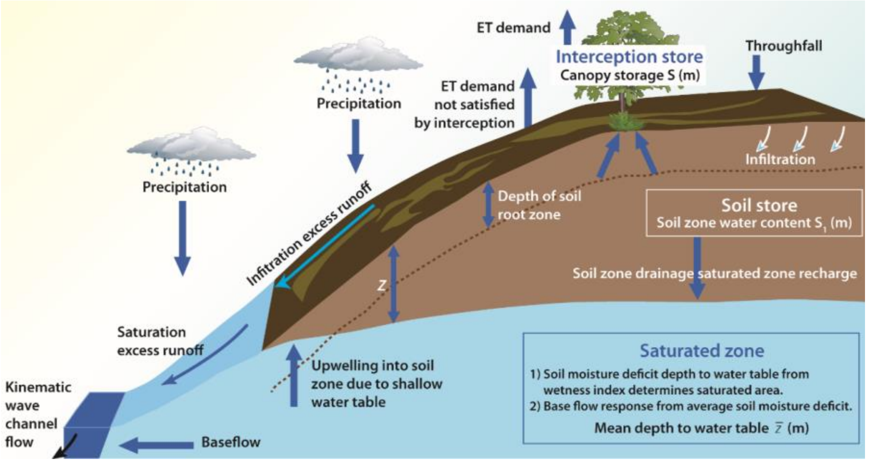
Extremely high precipitation occurs in the Southern Alps of New Zealand, associated with both orographic enhancement and synoptic-scale weather processes. In this study, we test the hypothesis that atmospheric rivers (ARs) are a key driver of floods in the Southern Alps of New Zealand. Vertically integrated 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

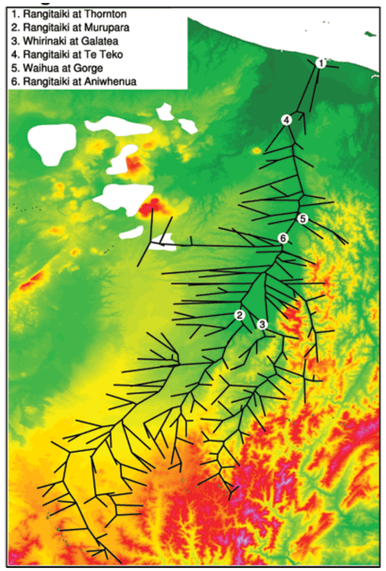
Forecasting System



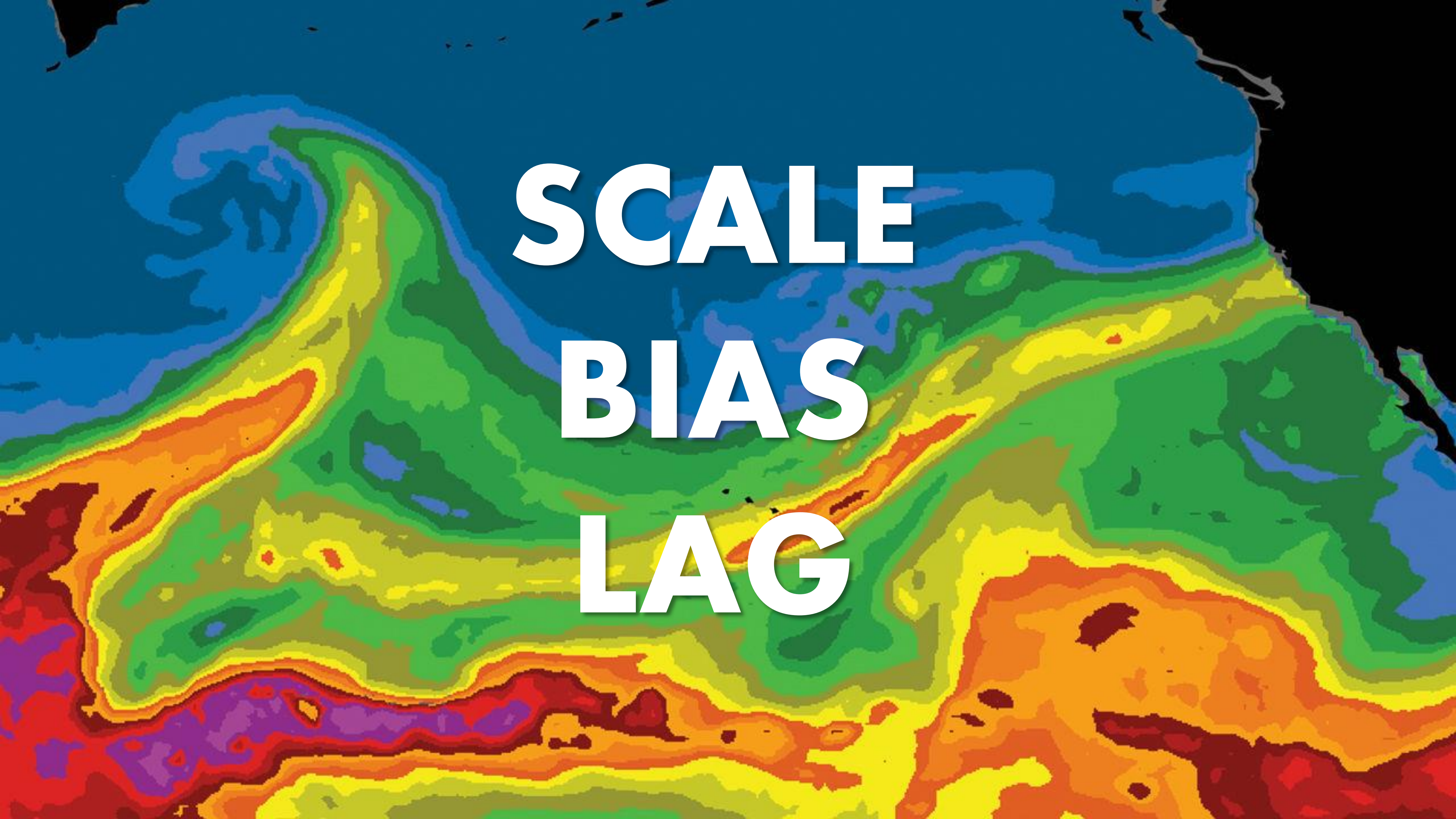


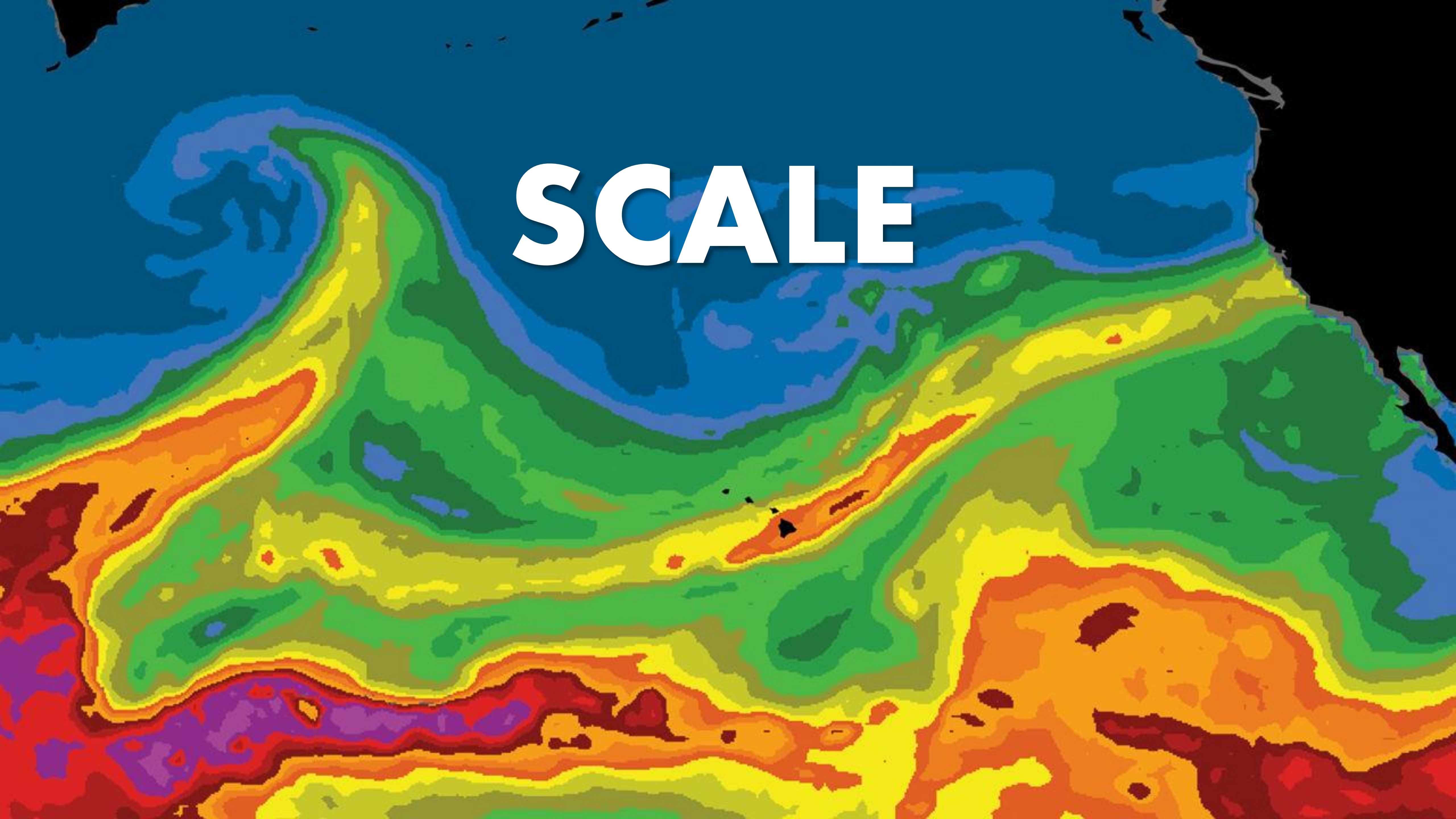
NWP model at 12km / 1.5 km



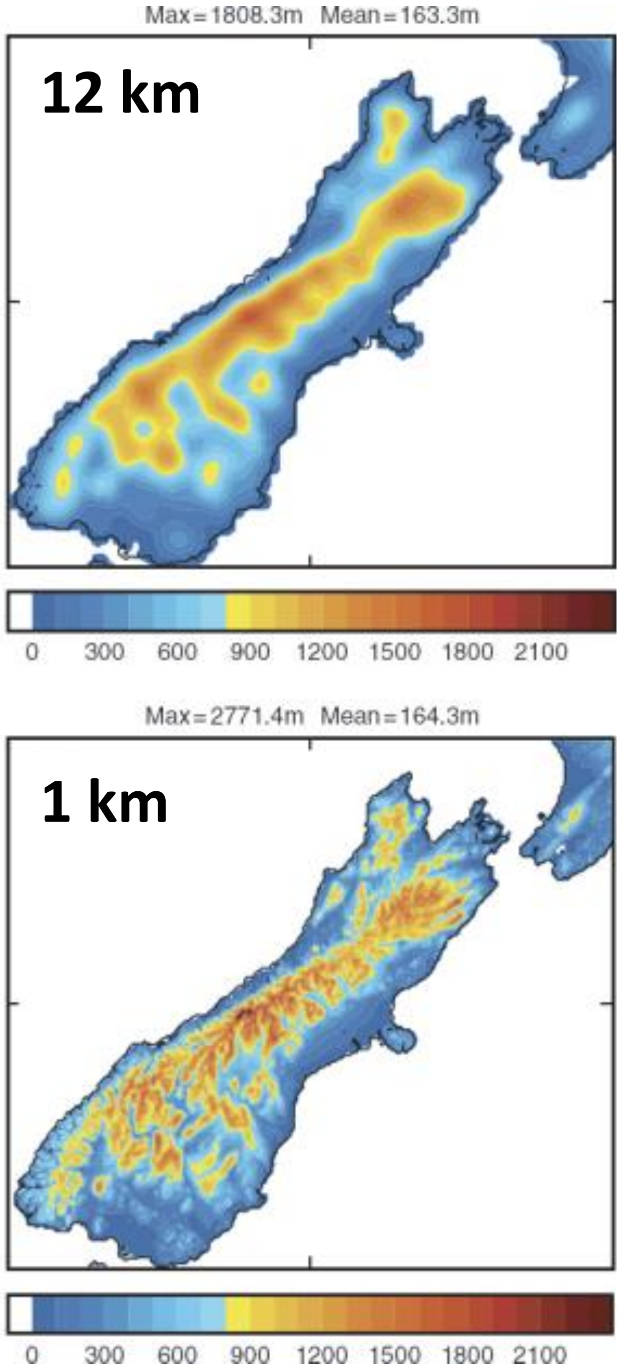


Distributed hydrologic model

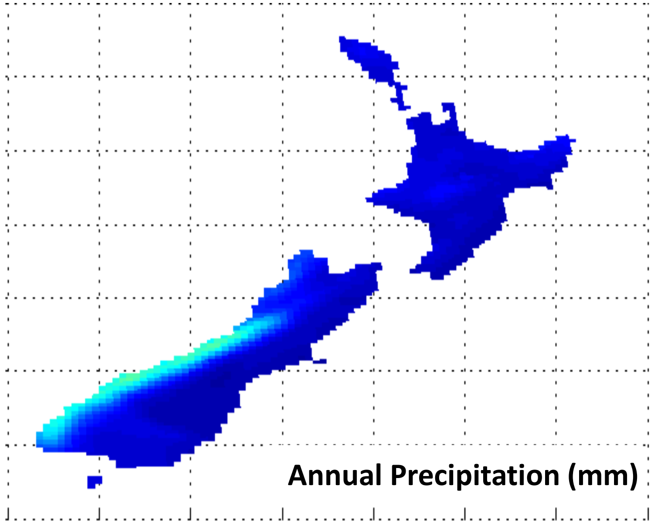

SCALE
BIAS
LAG

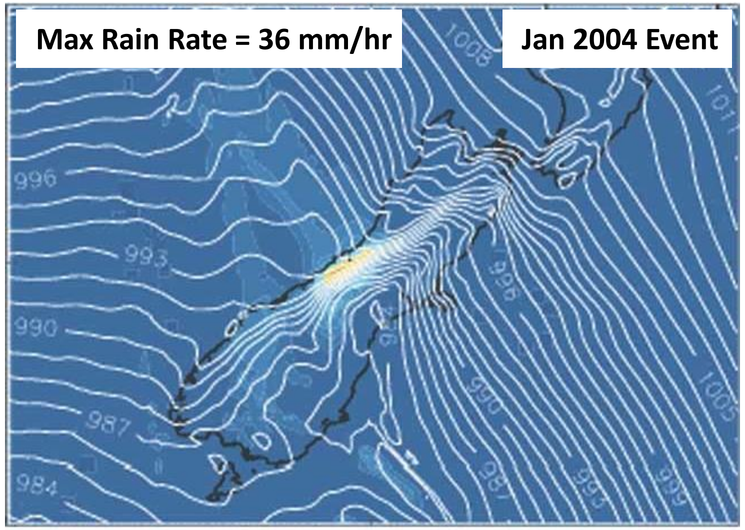

SCALE

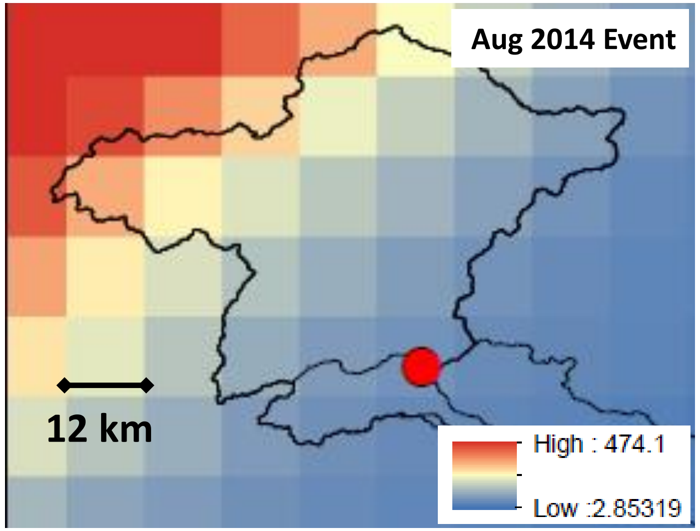
Weather model resolution of 1-2km is needed to resolve topography and storm systems



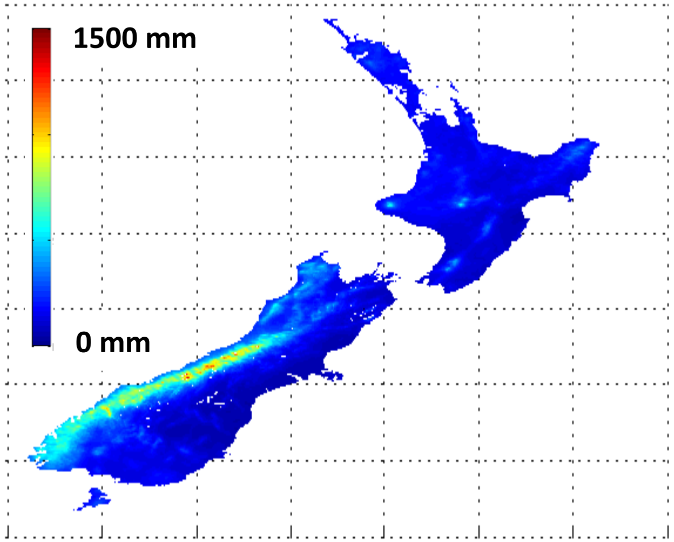
12 km

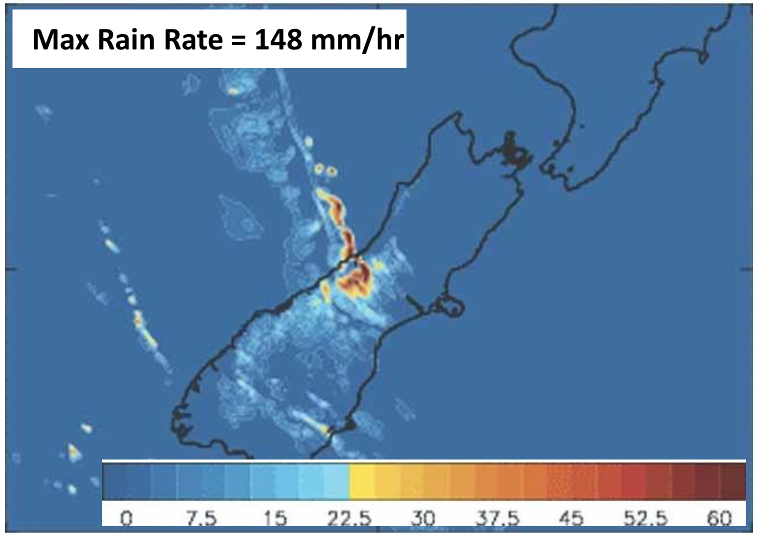

Annual Precipitation (mm)

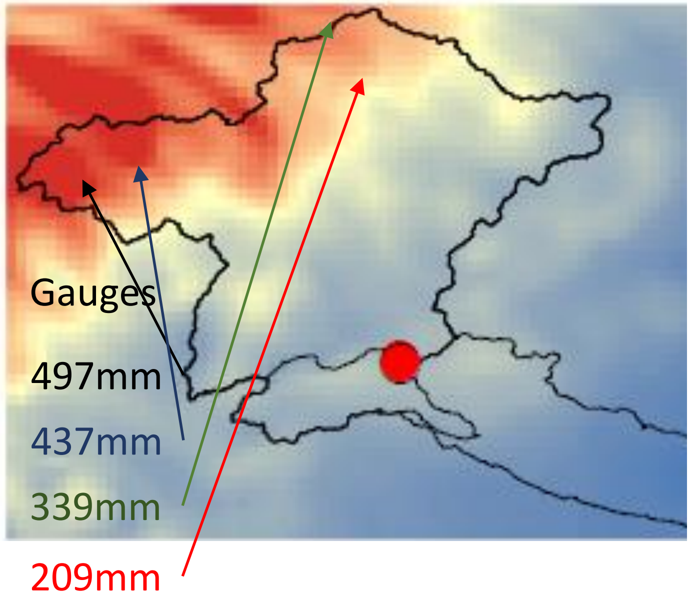

Max Rain Rate = 36 mm/hr
Jan 2004 Event
996
993
990
987
984

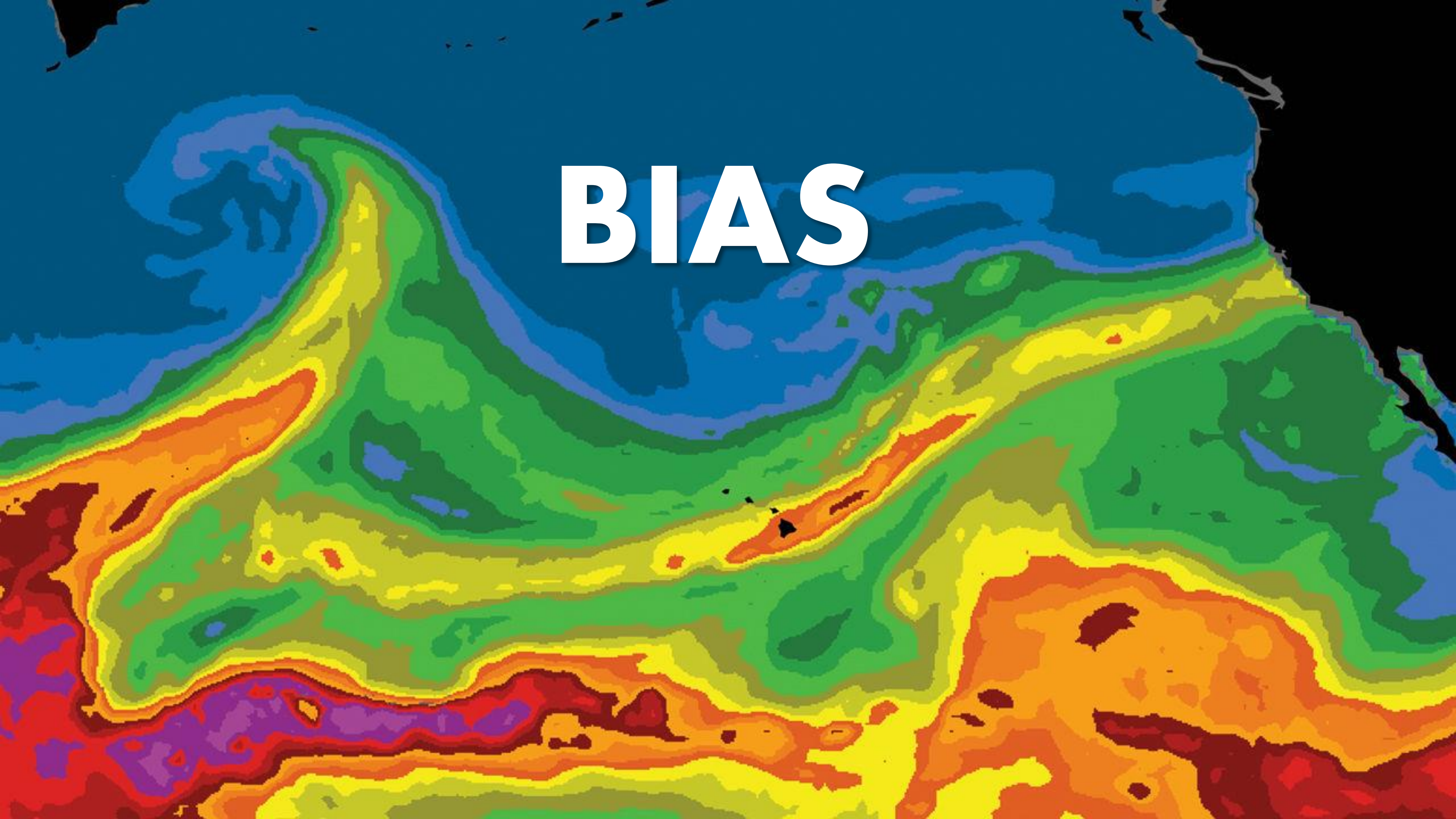

Aug 2014 Event
12 km
High : 474.1
Low :2.85319

1.5 km

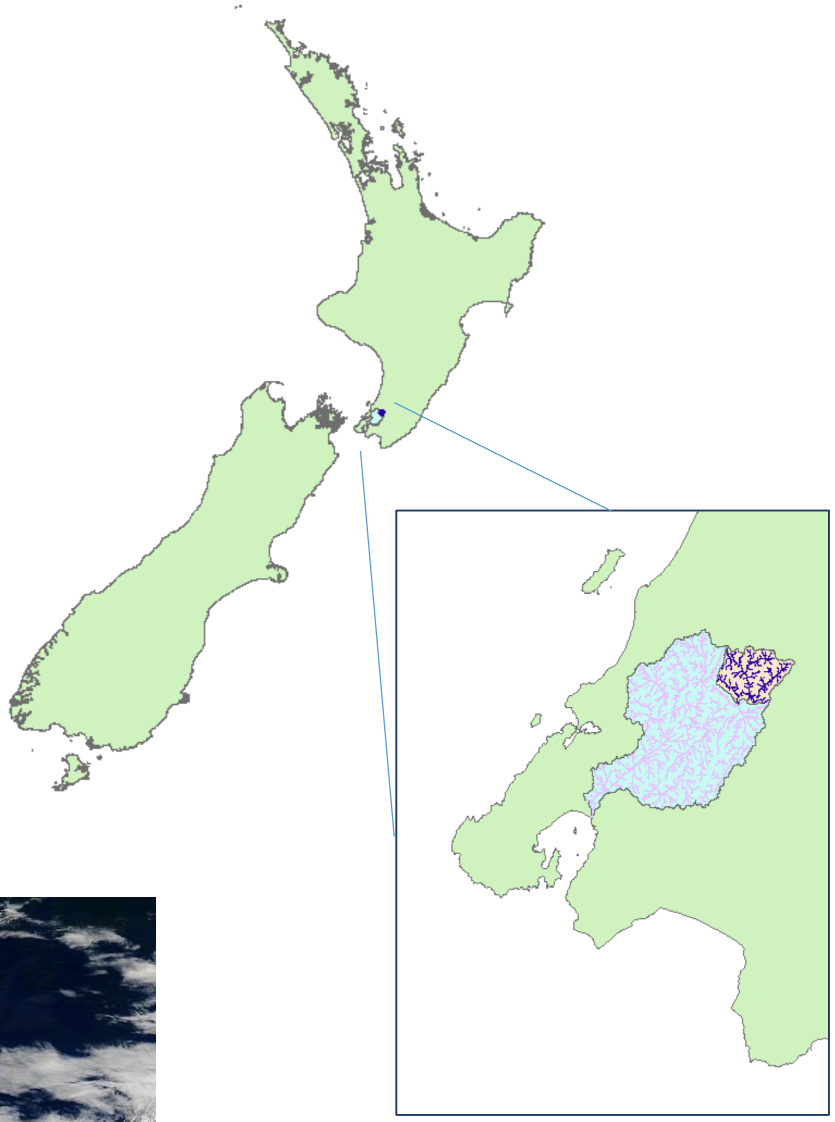

1500 mm
0 mm

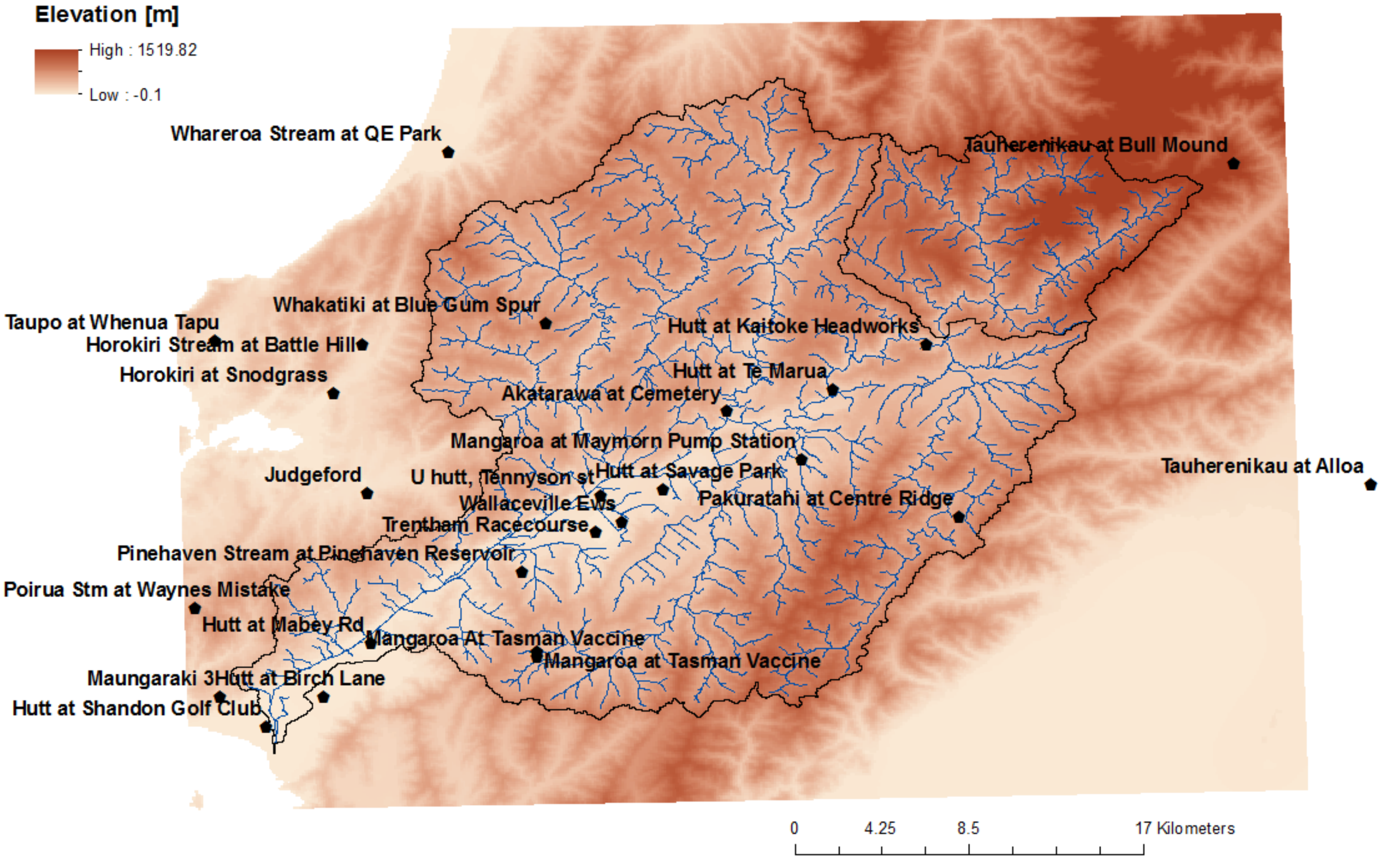

Max Rain Rate = 148 mm/hr
0
7.5
15
22.5
30
37.5
45
52.5
60


Gauges
497mm
437mm
339mm
209mm


BIAS

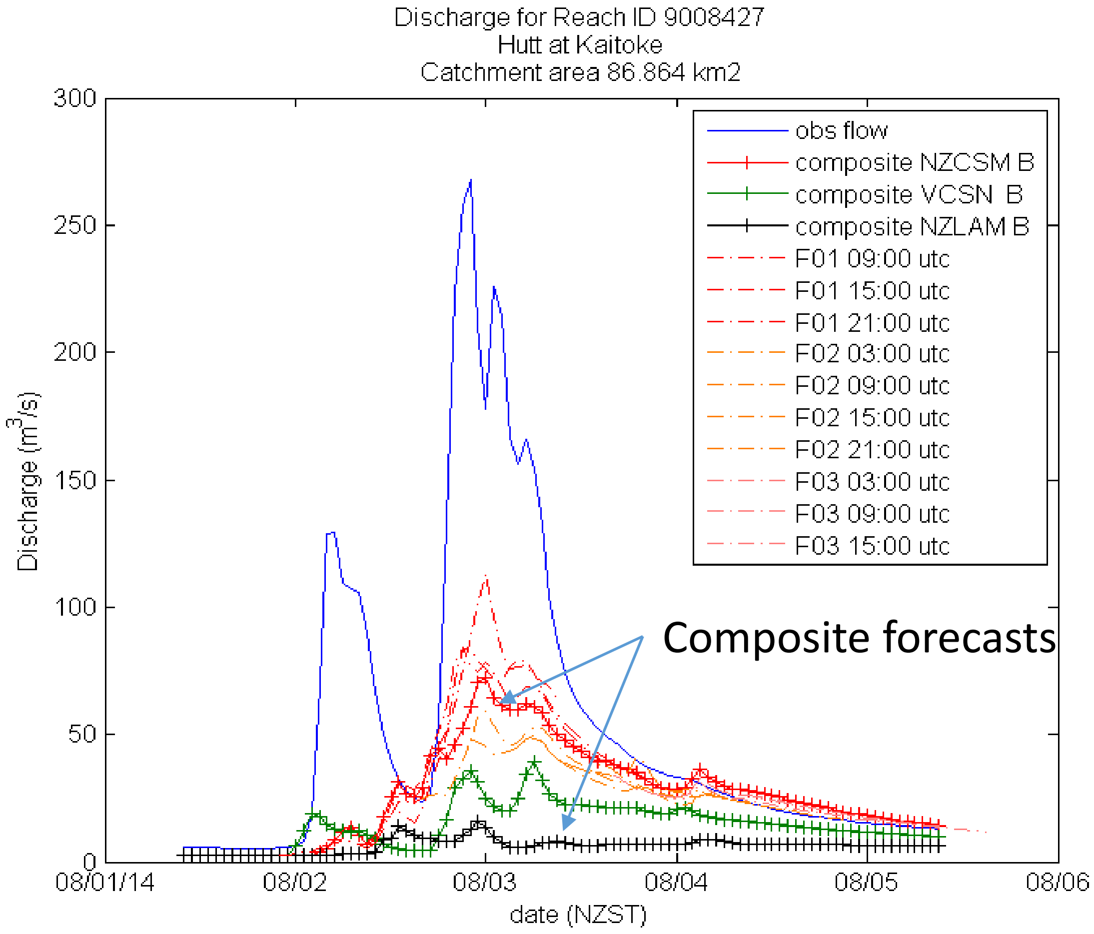
Case Study: Hutt catchment



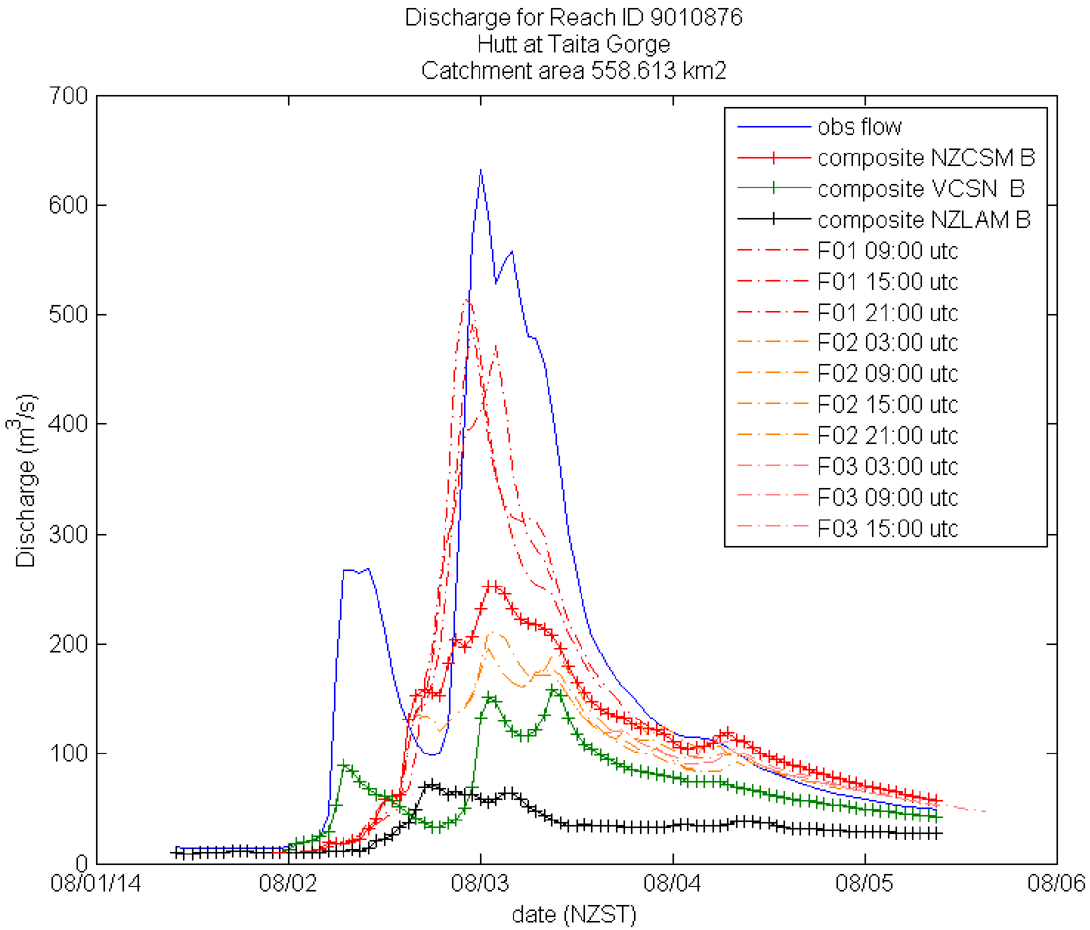


Low Bias: 1.5 km Weather Model and (worse) 12km Model

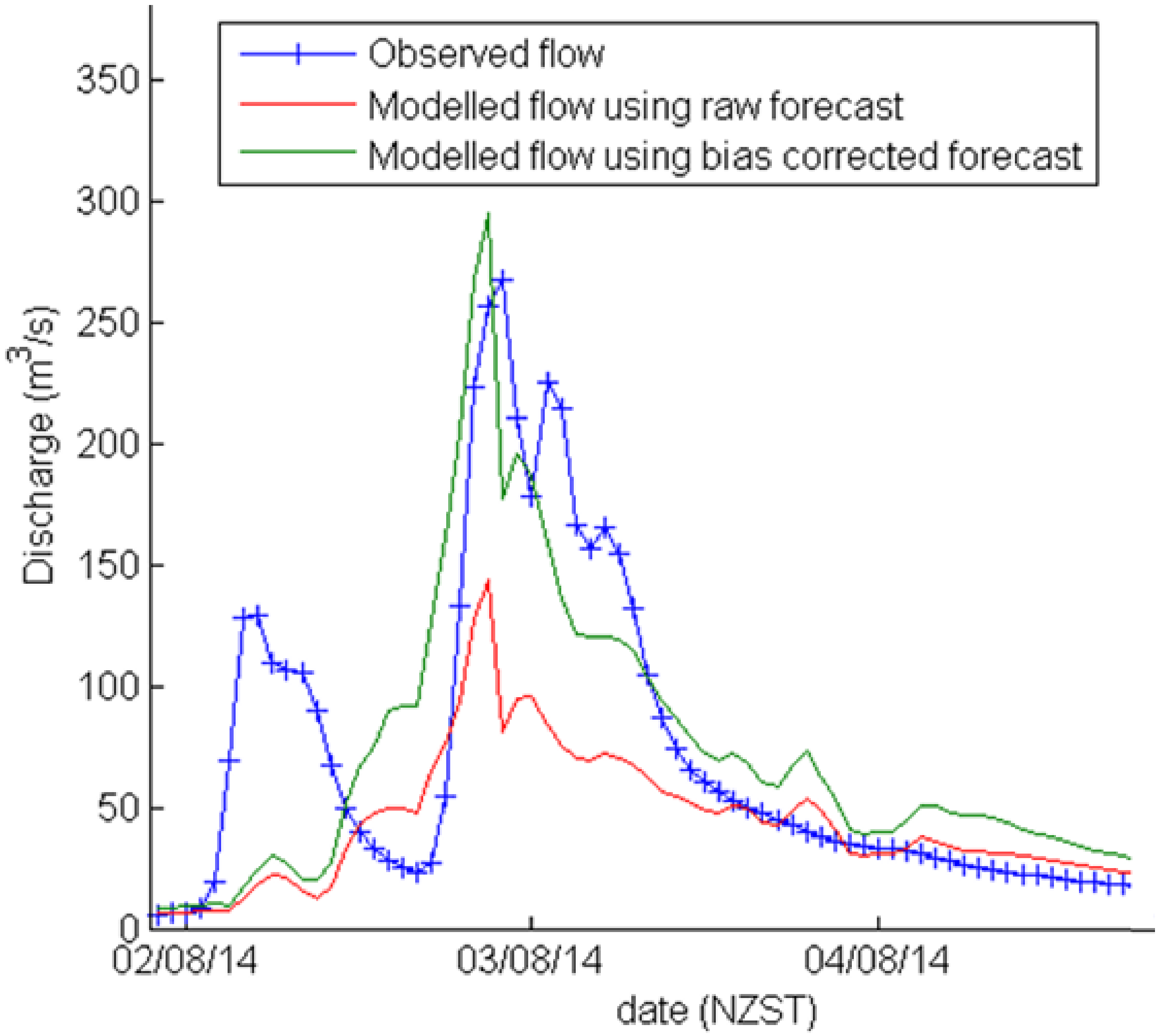
Small Hutt catchment (86km2)



Large Hutt catchment (558km2)

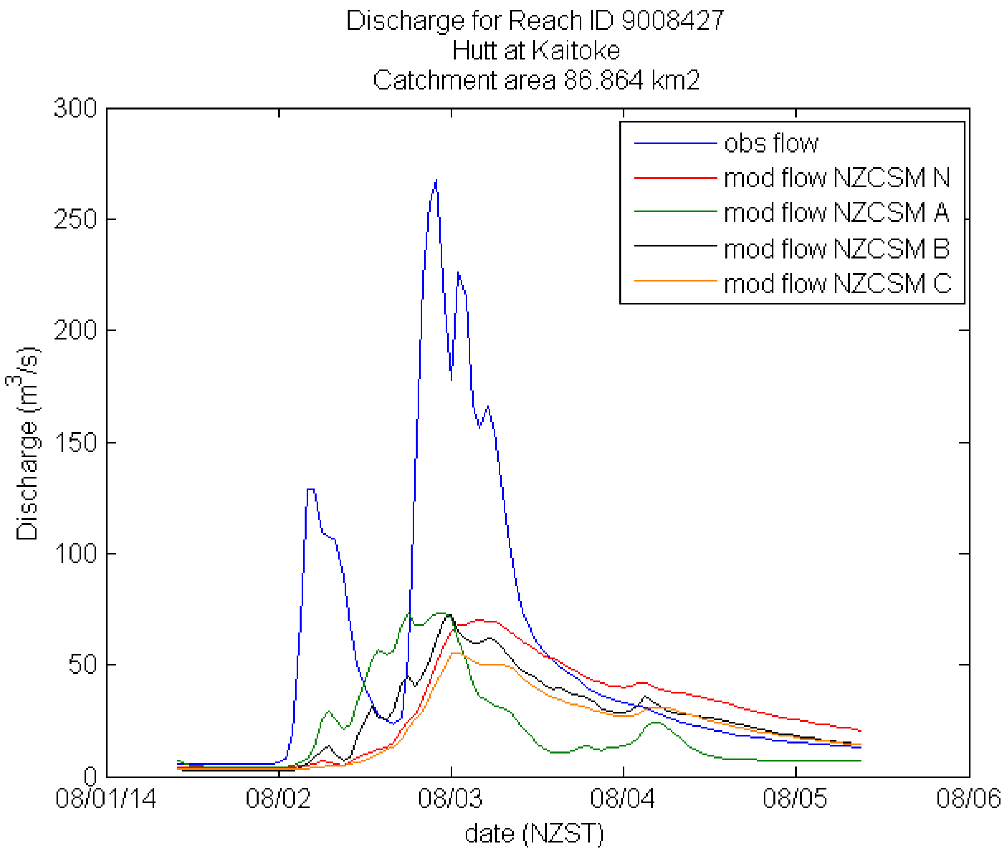


Bias correction of NWP shows significant improvement (drizzle removal; quantile correction)



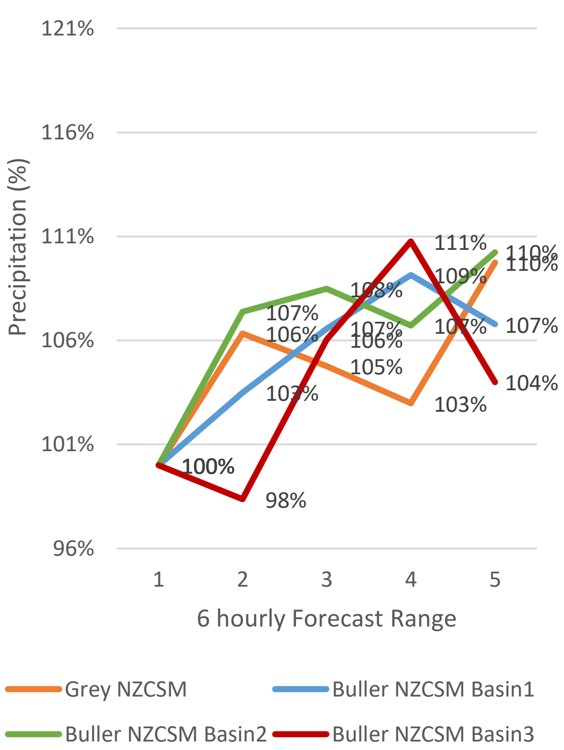
Other sources of uncertainty / bias

- Uncertainty due to hydrologic model parameters is small

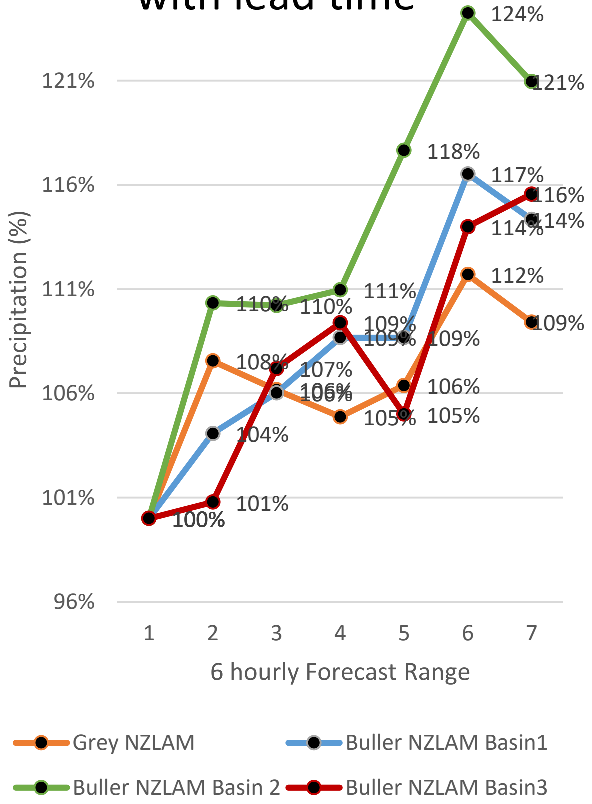


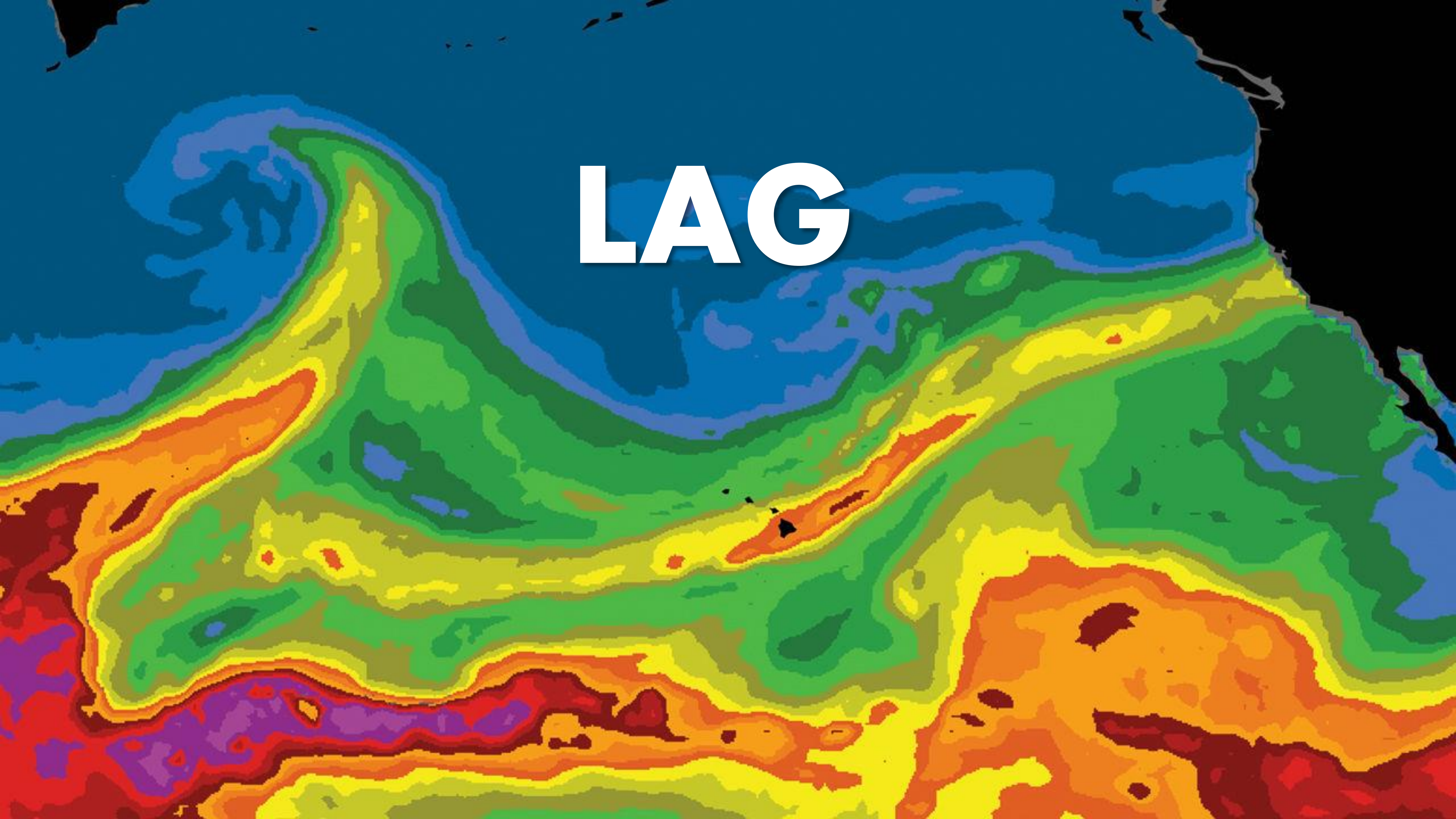
- Bias in rainfall totals due to forecast lead time

1.5 km averaged rainfall with lead time



12 km averaged rainfall with lead time

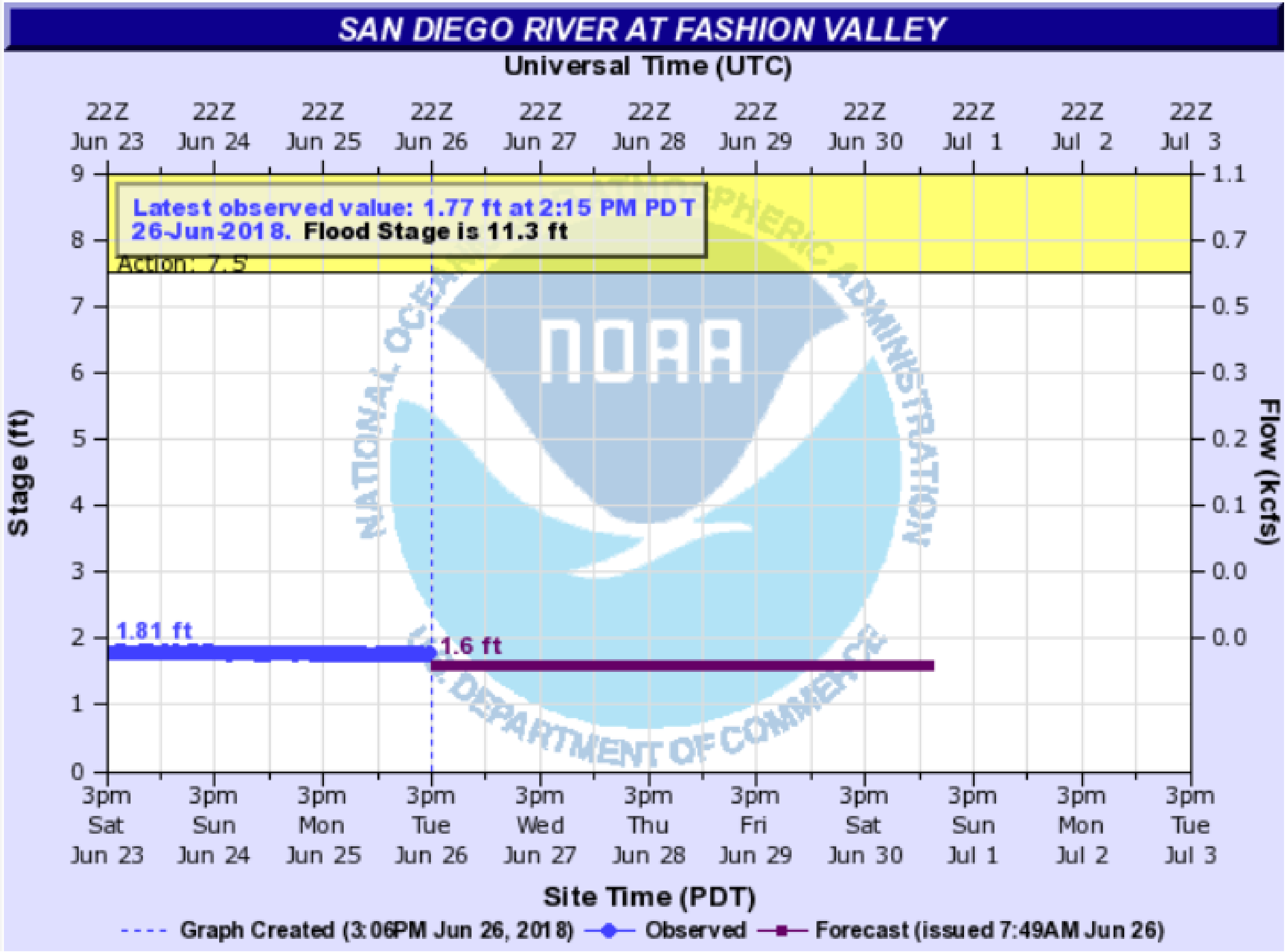



LAG

Data Assimilation by Kalman Filter

- Kalman Filter adju
  balance between

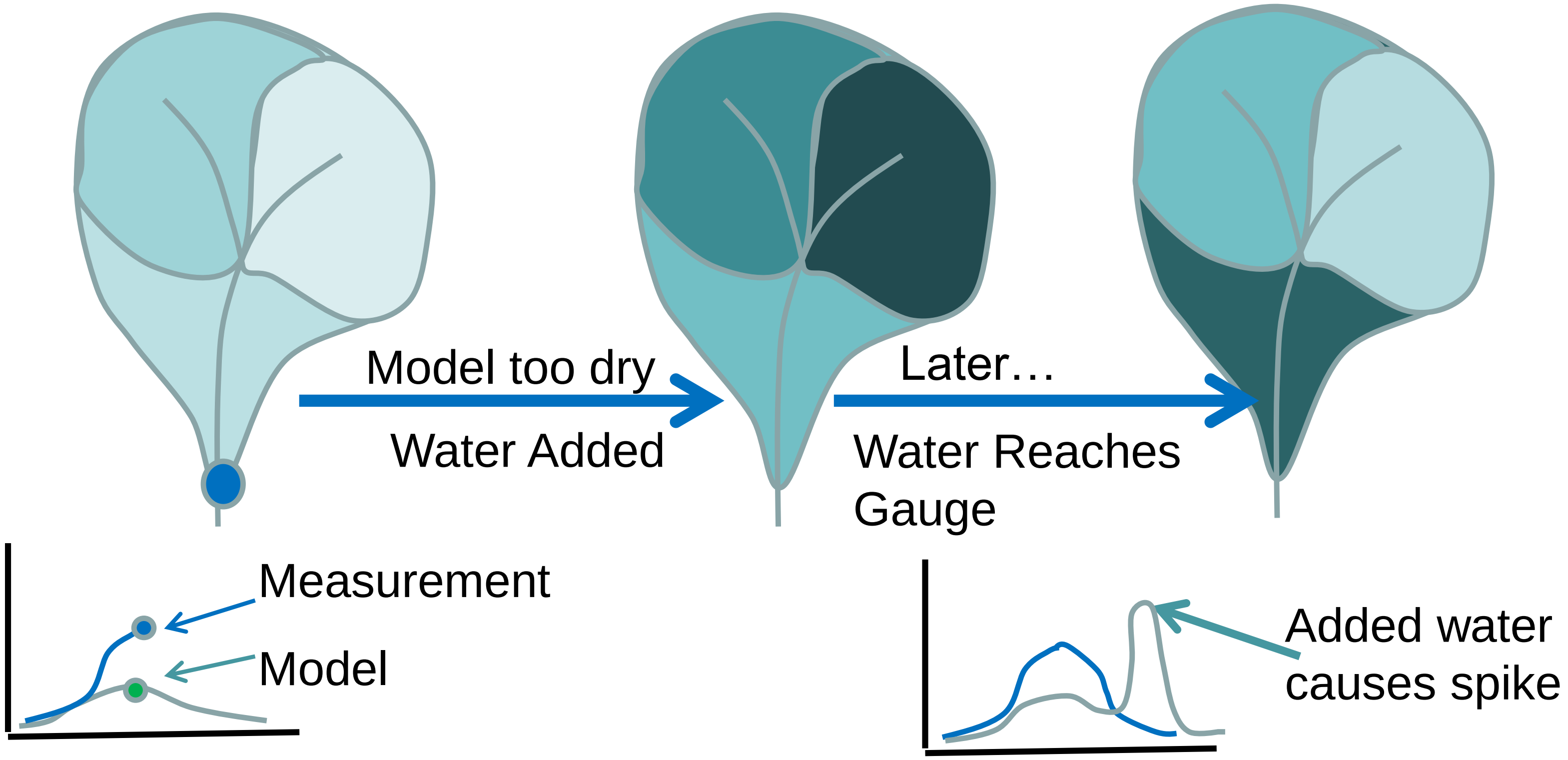
Example: If the model under-estimates streamflo it implies the basin is too dry, and water is added to the model



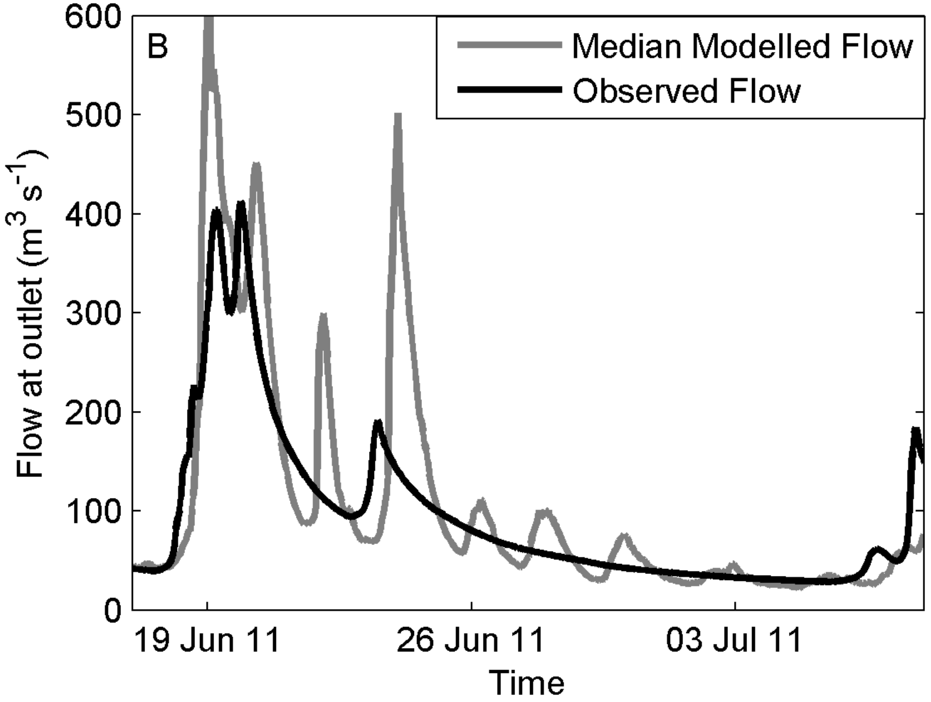
- Model Uncertainty
  Measurement unc

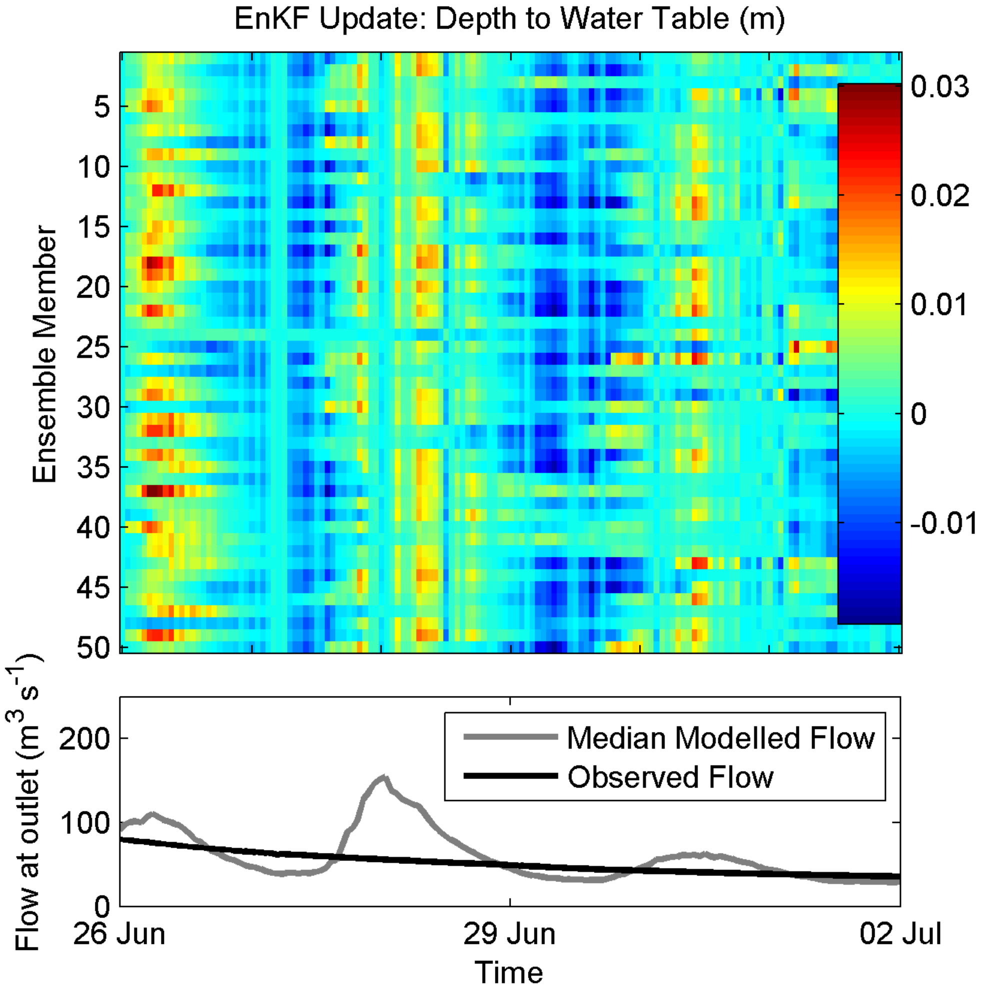
Kalman Filter may fail in hydrology

- 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



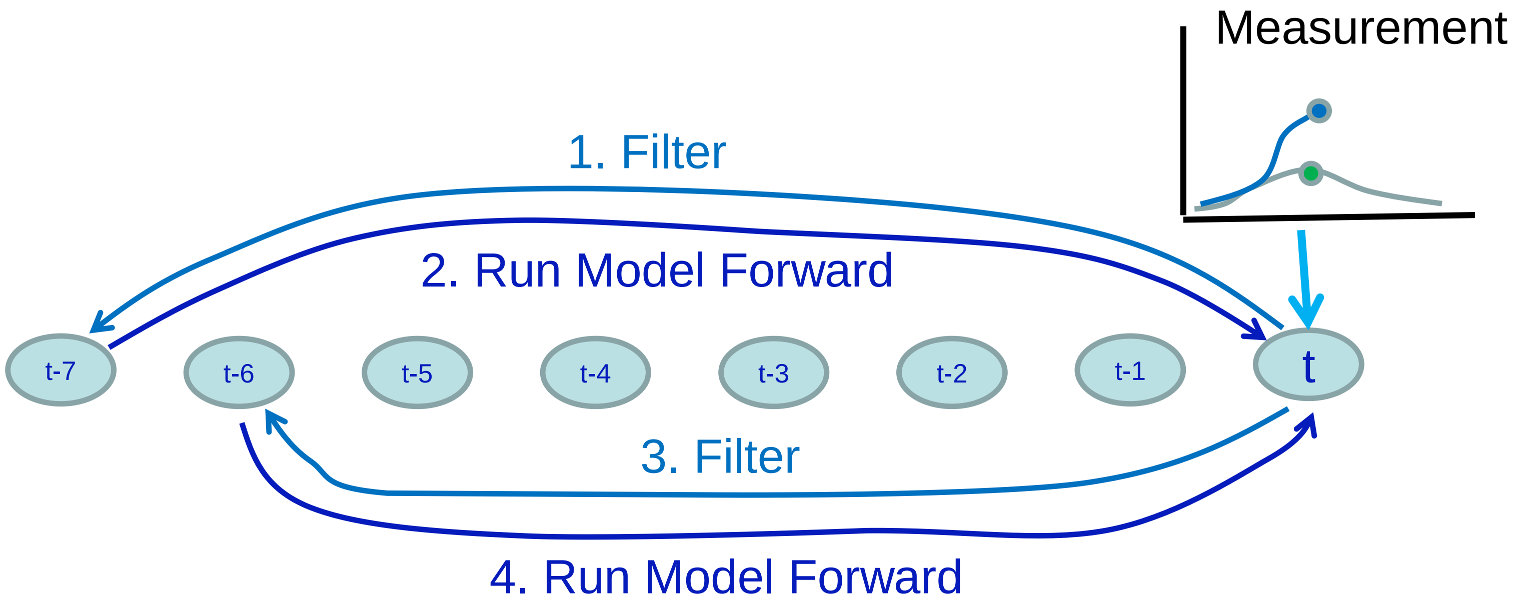


- Oscillations in forecast for Motueka River

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

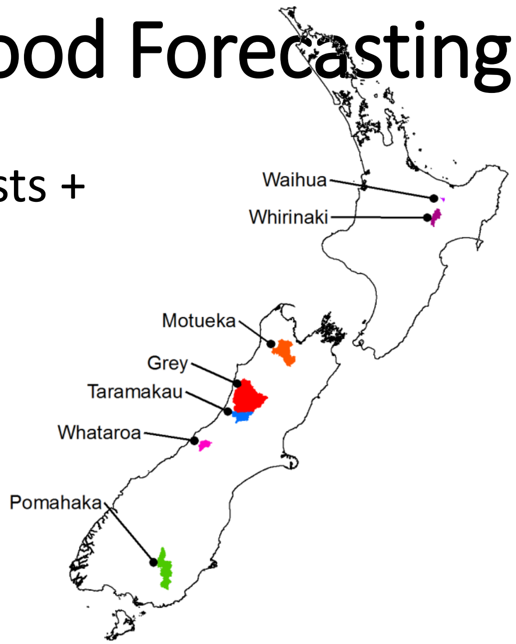
Solution: Allow for lag time

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



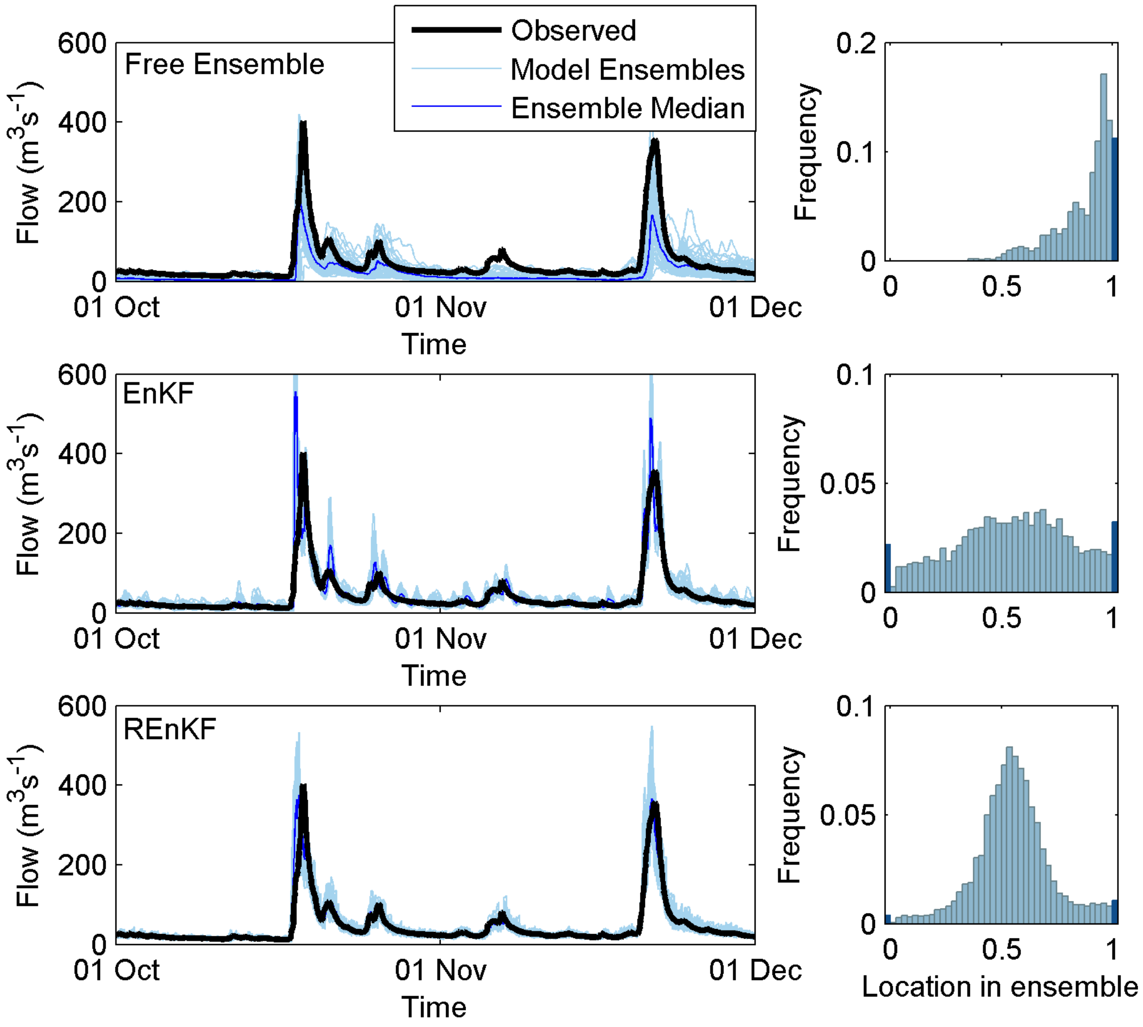
Coupled Model Flood Forecasting

- 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.

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