



Impacts of El Niño Southern Oscillation on flood risk and insured losses in New Zealand

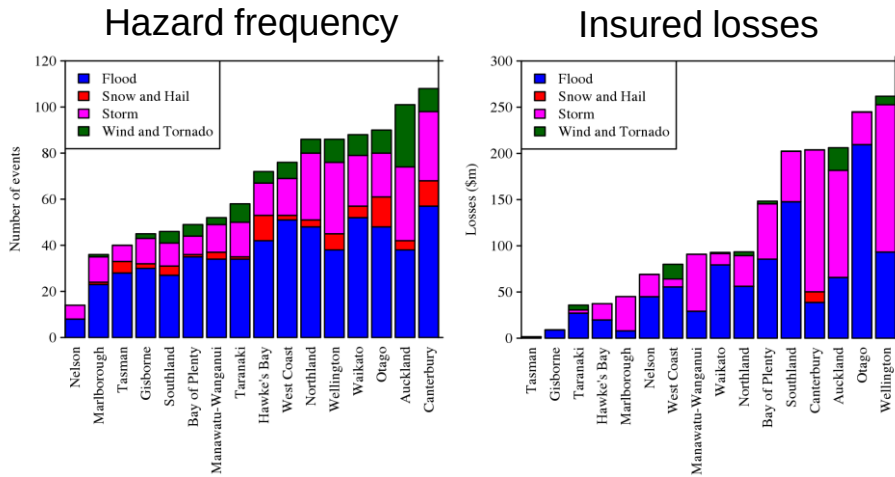
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Risk Management Solutions Inc

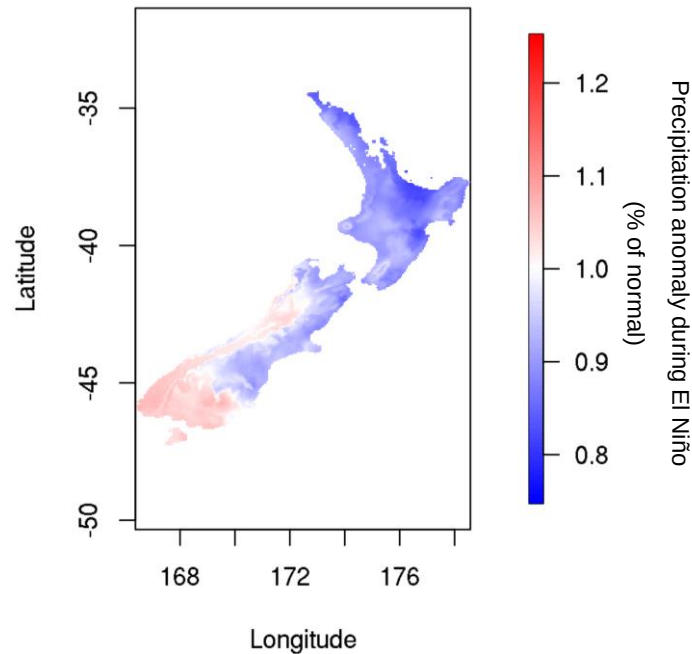
Introduction

WHAT WE KNOW:

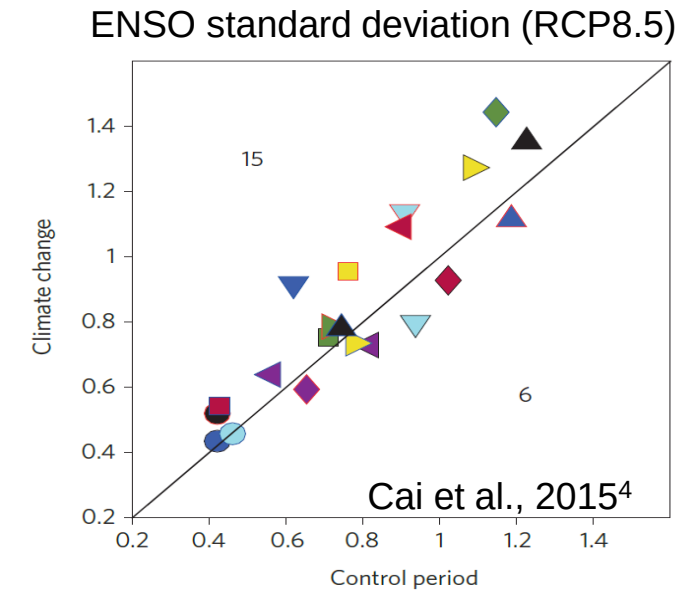
- ❑ Inland flooding is frequent in New Zealand and causes large insurance losses



- ❑ ENSO is a control on precipitation in New Zealand.



- ❑ Studies¹⁻⁵ showed that climate change may increase ENSO variability.



OUR QUESTIONS:

- ❑ What is the effect of ENSO on flood risk?
- ❑ What are the potential implications of climate change for flood risk?

Hazard methodology

PRECIPITATION MODEL

- ☐ Stochastic model
- ☐ Spatial / temporal correlations
- ☐ Correlation with ENSO



STREAMFLOW MODEL

- ☐ Multi-objective calibration
- ☐ Antecedent conditions
- ☐ Runoff and streamflow



INUNDATION MODEL

- ☐ Pluvial flooding
- ☐ Fluvial flooding
- ☐ 2D shallow water equations



Input data

WEATHER DATA

Daily precipitation maps are available for the observation period 1960-2018, at countrywide level. Station data is interpolated onto a regular 5km grid. Source : [NIWA](#)

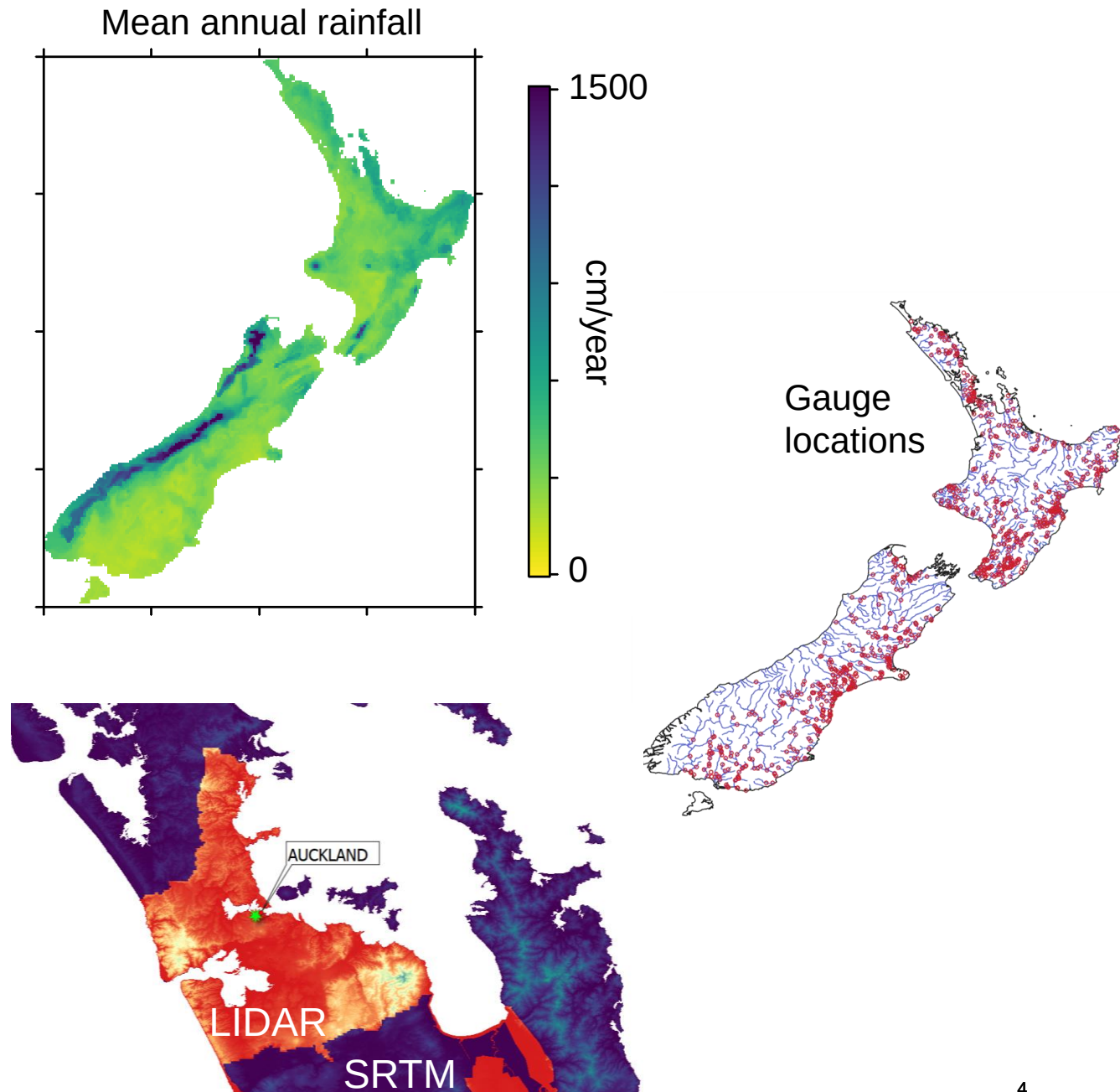
DIGITAL TERRAIN MODEL

	SRTM	LIDAR
Capture method	Spaceborne RADAR	Airborne LIDAR
Resolution	~ 30 m	1 m
Coverage	Global	Partial NZ

Extensive QA, artifacts removal

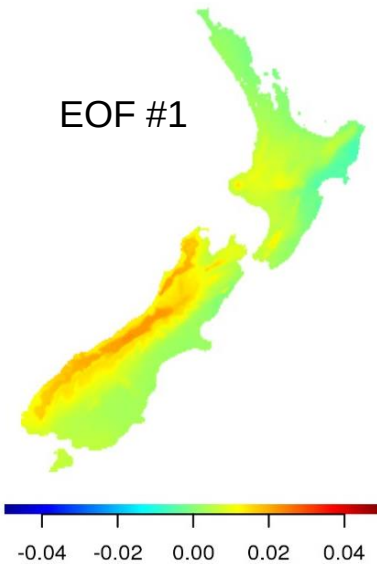
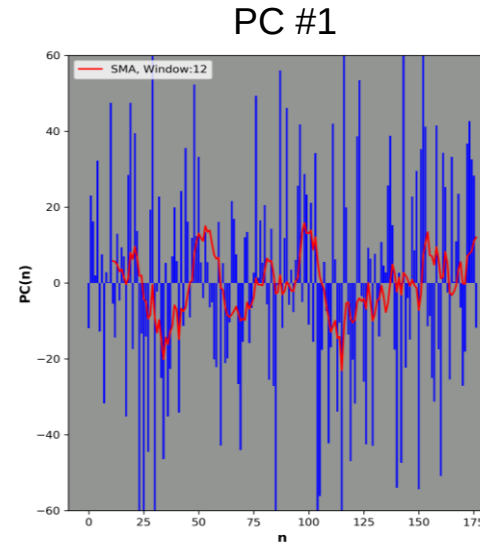
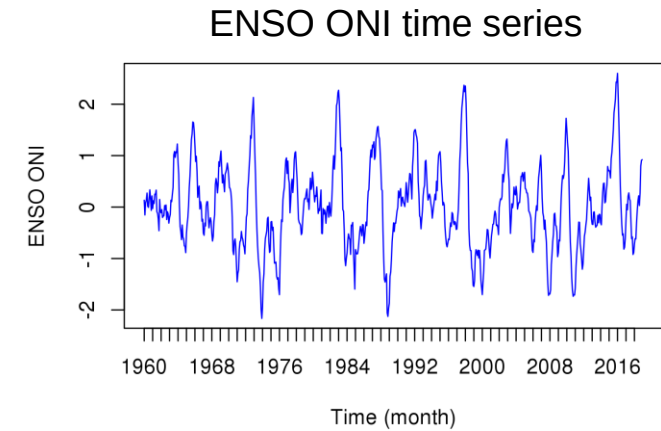
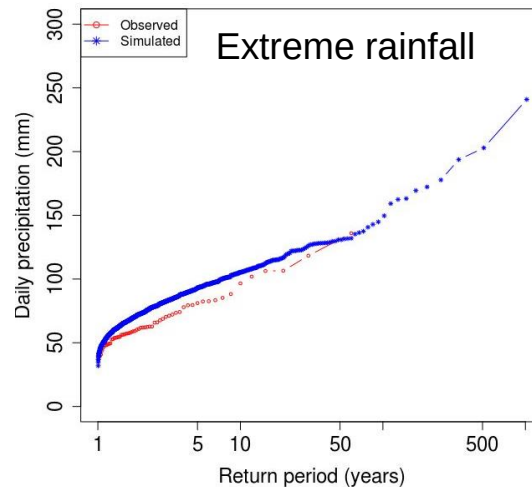
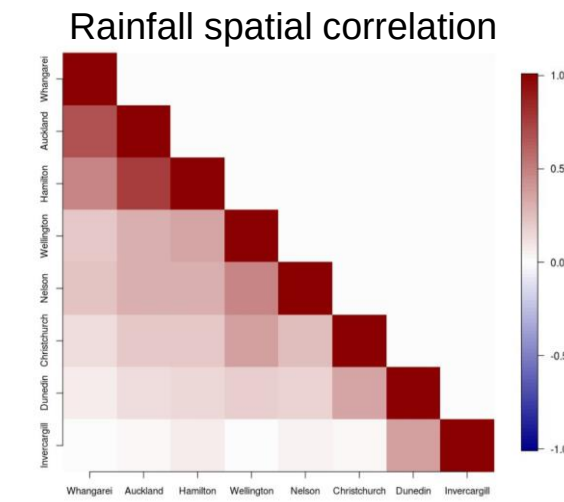
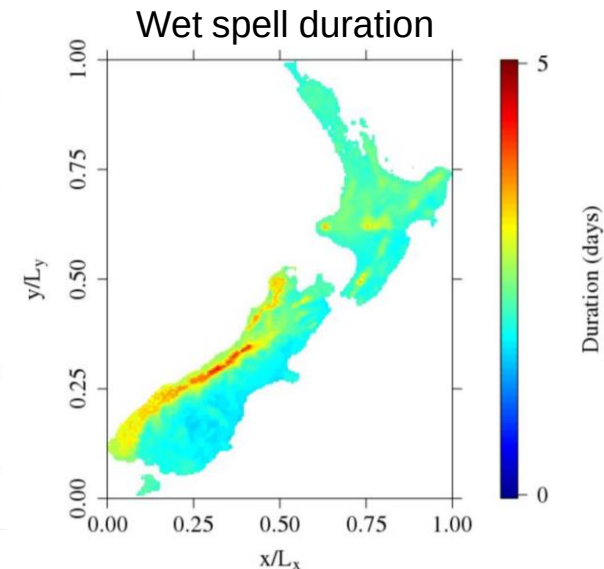
STREAMFLOW DATA

Daily river flow data for 490 station throughout the country



Precipitation model

- Input from 60 years of daily observed rainfall at 5km spatial resolution from NIWA
- Decomposition of observed monthly precipitation in empirical orthogonal functions (EOFs) and principal components (PCs)
- Correlation of monthly rainfall PCs with the Oceanic Niño Index (ONI)
- Generation of 50,000 years of stochastic monthly precipitation correlated with ENSO
- Stochastic disaggregation from monthly to sub-daily scale
- Validation against observed precipitation statistics



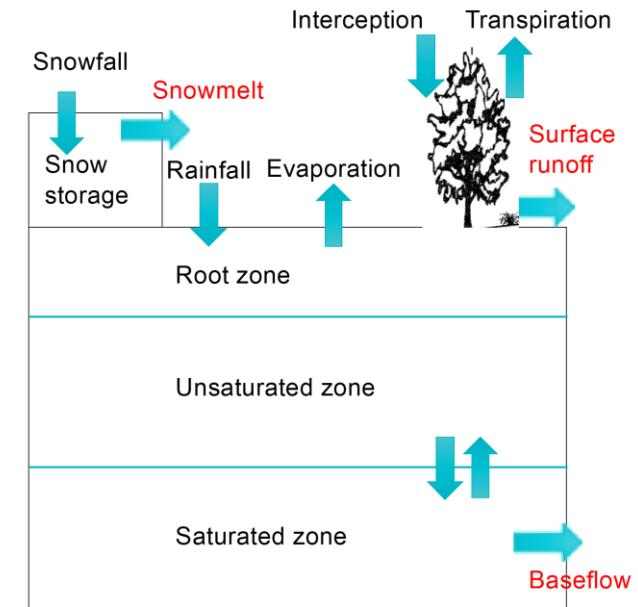
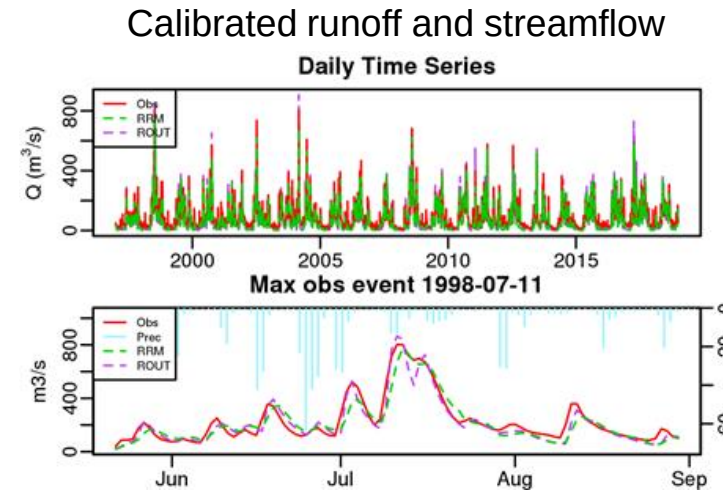
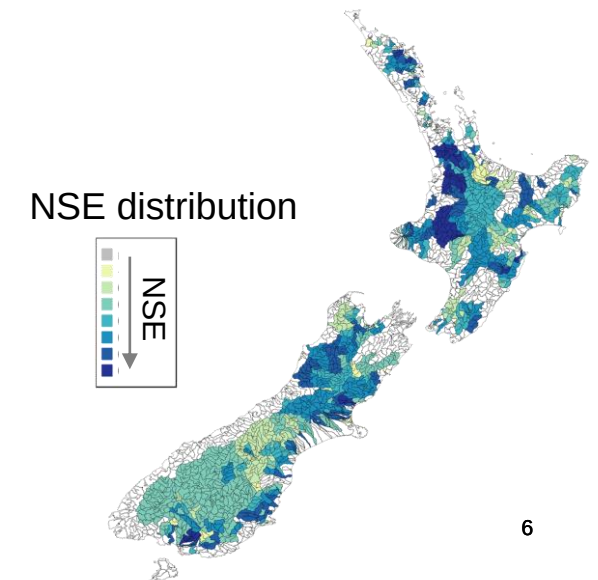
Streamflow model

RUNOFF MODEL:

- ❑ Mass and energy balance equations in 2,071 catchments (snow dynamic, canopy interception, evapo-transpiration, soil moisture dynamics)

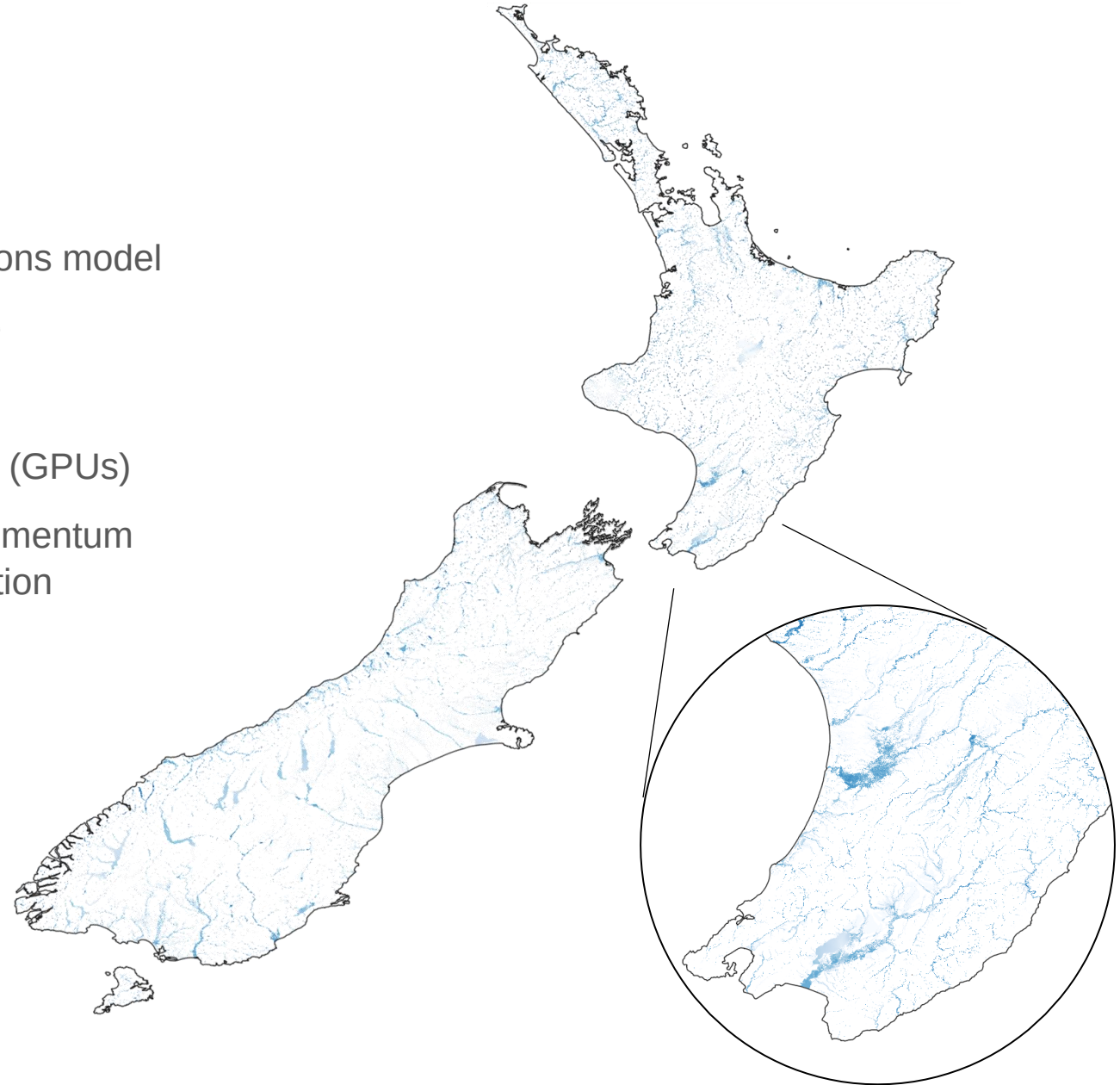
RIVER ROUTING MODEL:

- ❑ 27,000 km of modeled rivers
- ❑ Described with a 1d advection-diffusion equation
- ❑ Calibrated against gauge data using a genetic algorithm
- ❑ 50,000 years of continuous runoff and streamflow simulations

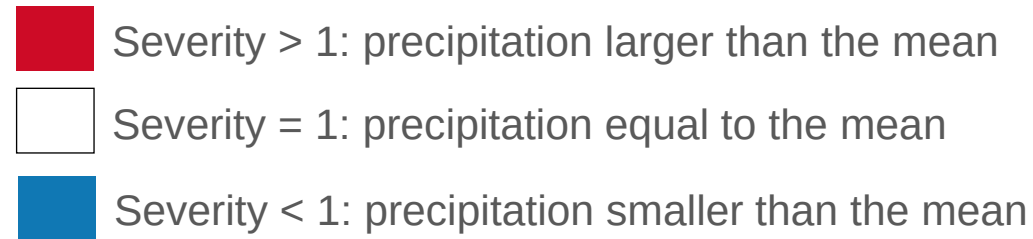


Inundation model

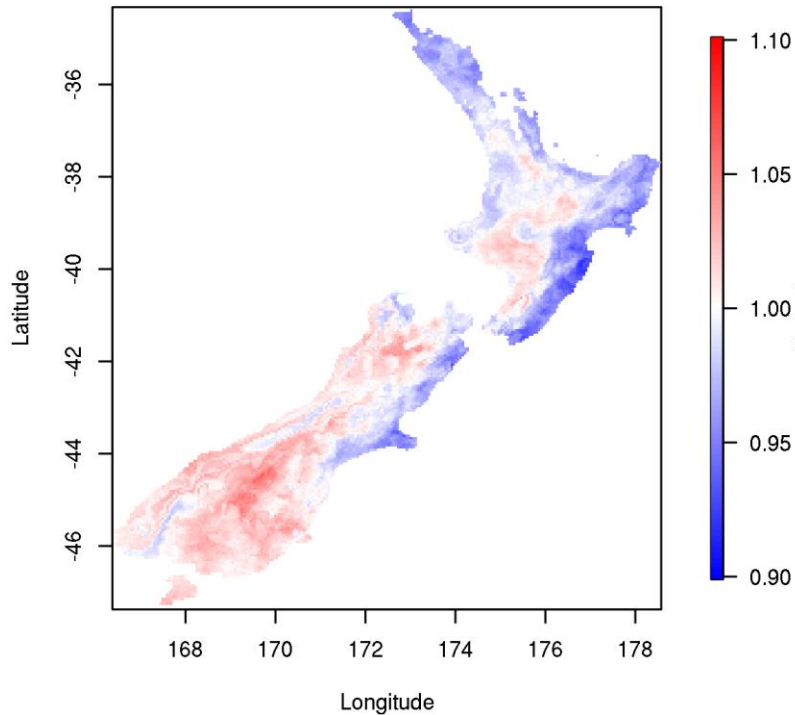
- ❑ Fluvial and pluvial inundation
- ❑ In-house bi-dimensional Shallow Water Equations model
 - Very fast, second order, numerically stable
 - Extensively benchmarked
 - Running on RMS cluster of graphics cards (GPUs)
- ❑ Finite-volume solution of the continuity and momentum equations on a 2-D regular grid at 20 m resolution
- ❑ Undefended inundation maps
- ❑ Validation against authority defenses



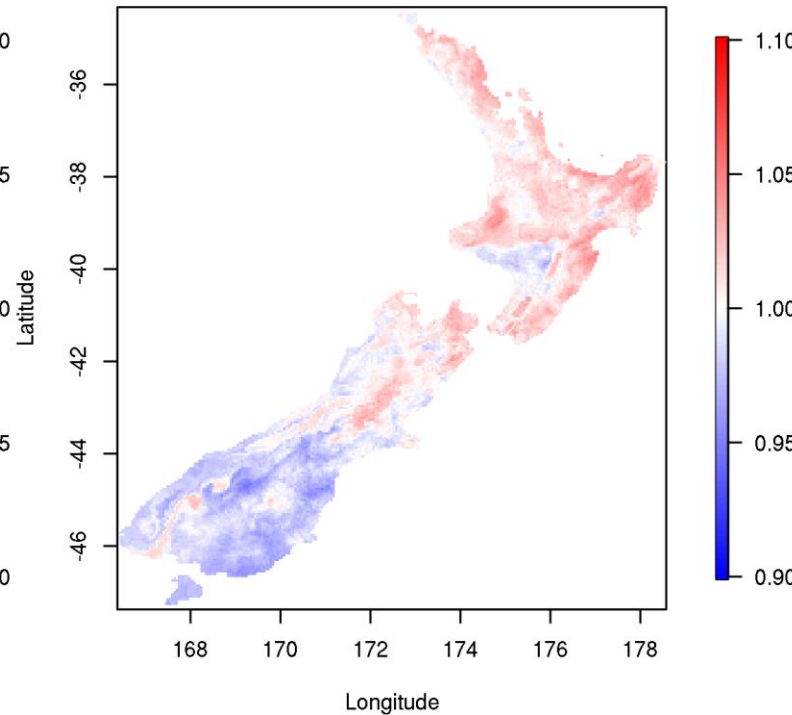
Results – Extreme monthly precipitation



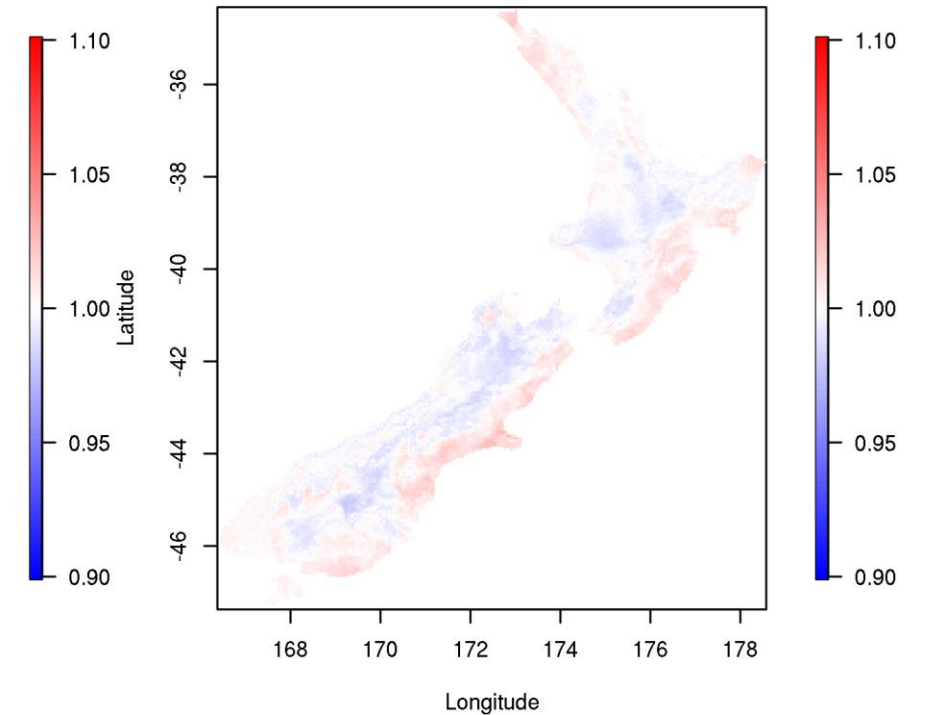
El Niño: ONI > 0.5



La Niña: ONI < -0.5



Neutral: -0.5 < ONI < 0.5

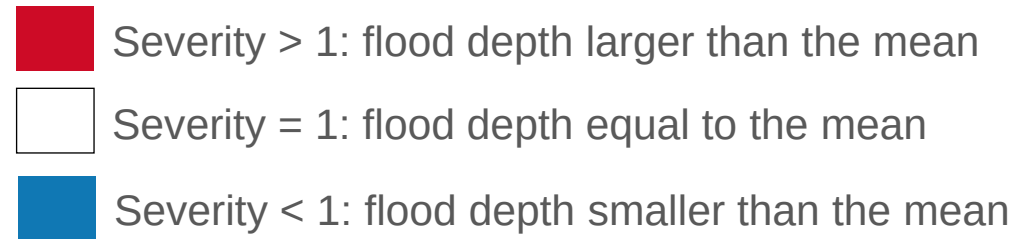


Results – Extreme monthly precipitation

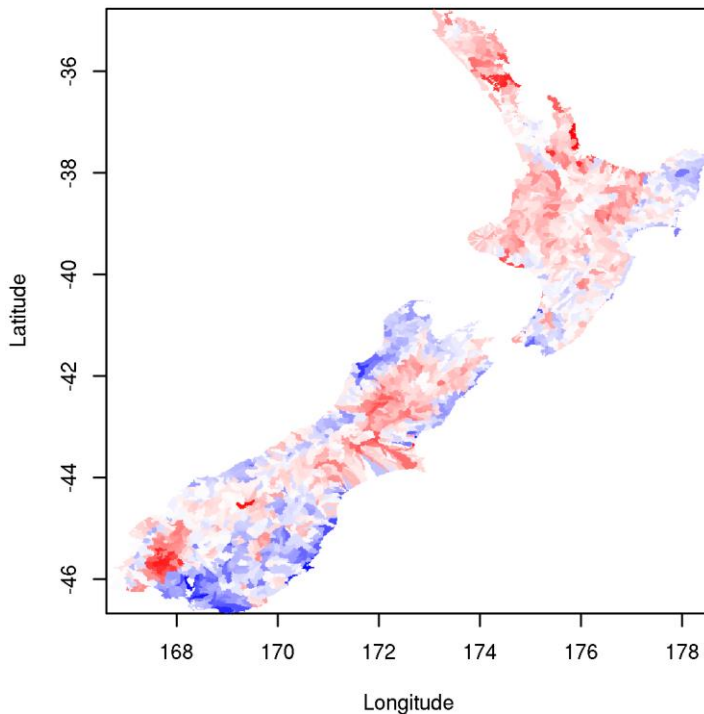
Key takeaways:

- El Niño periods tend to cause larger precipitation extremes in the south-west of the South Island. This is consistent with the observation that during El Niño, New Zealand tends to experience stronger or more frequent winds from the west in summer, which can encourage dryness in eastern areas and more rain in the west.
- La Niña periods tend to cause larger precipitation in the North Island. In fact, northeasterly winds tend to become more common during La Niña events, bringing moist, rainy conditions to northeastern areas of the North Island and reduced rainfall to the lower and western South Island.
- Neutral ENSO phases do not seem to be associated to larger-than-average precipitation events in New Zealand.

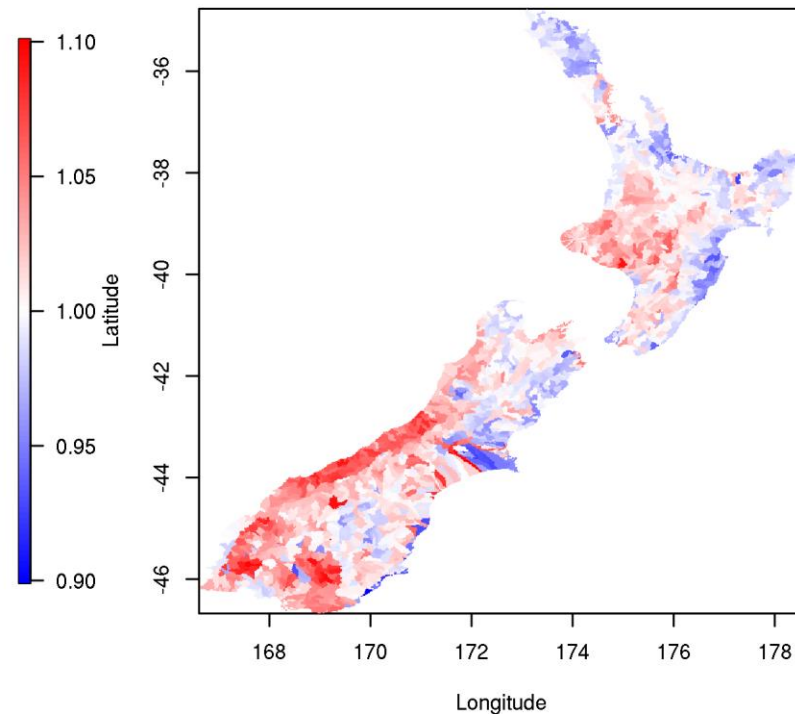
Results – (Undefended) Flood depth



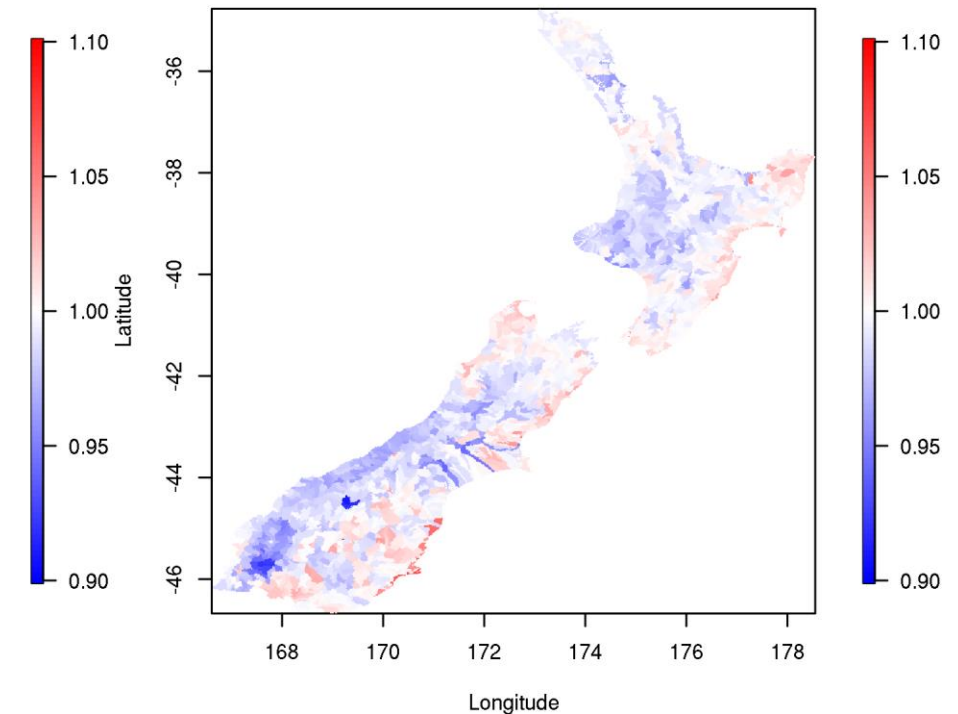
El Niño: ONI > 0.5



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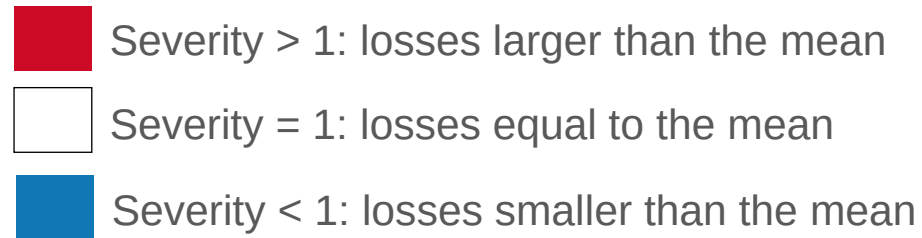
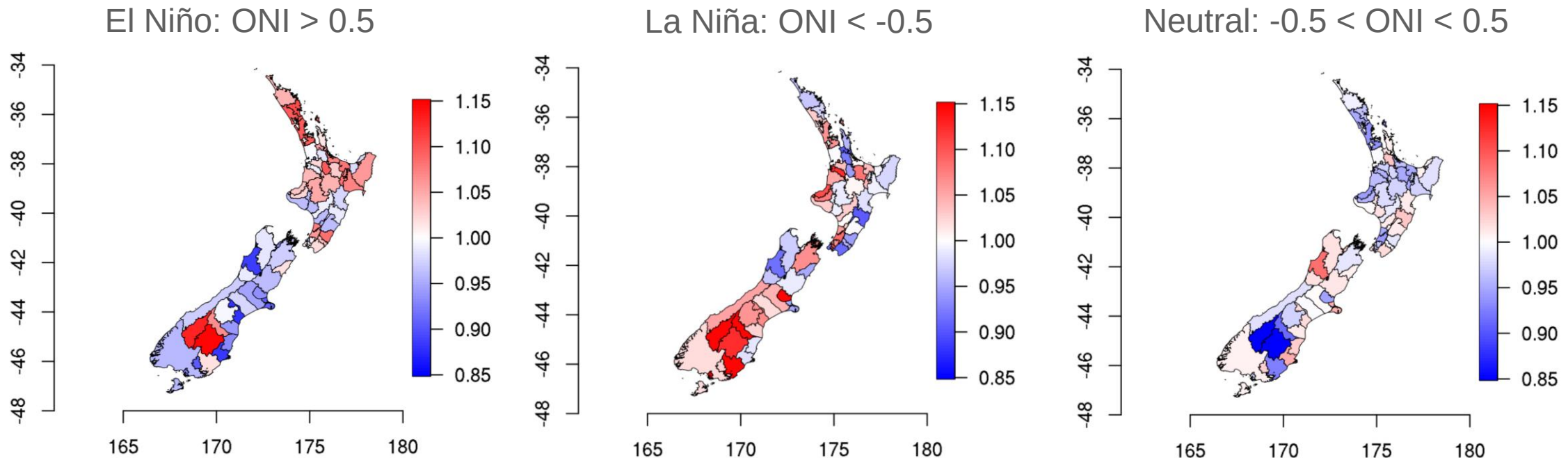


Results – (Undefended) Flood depth

Key takeaways:

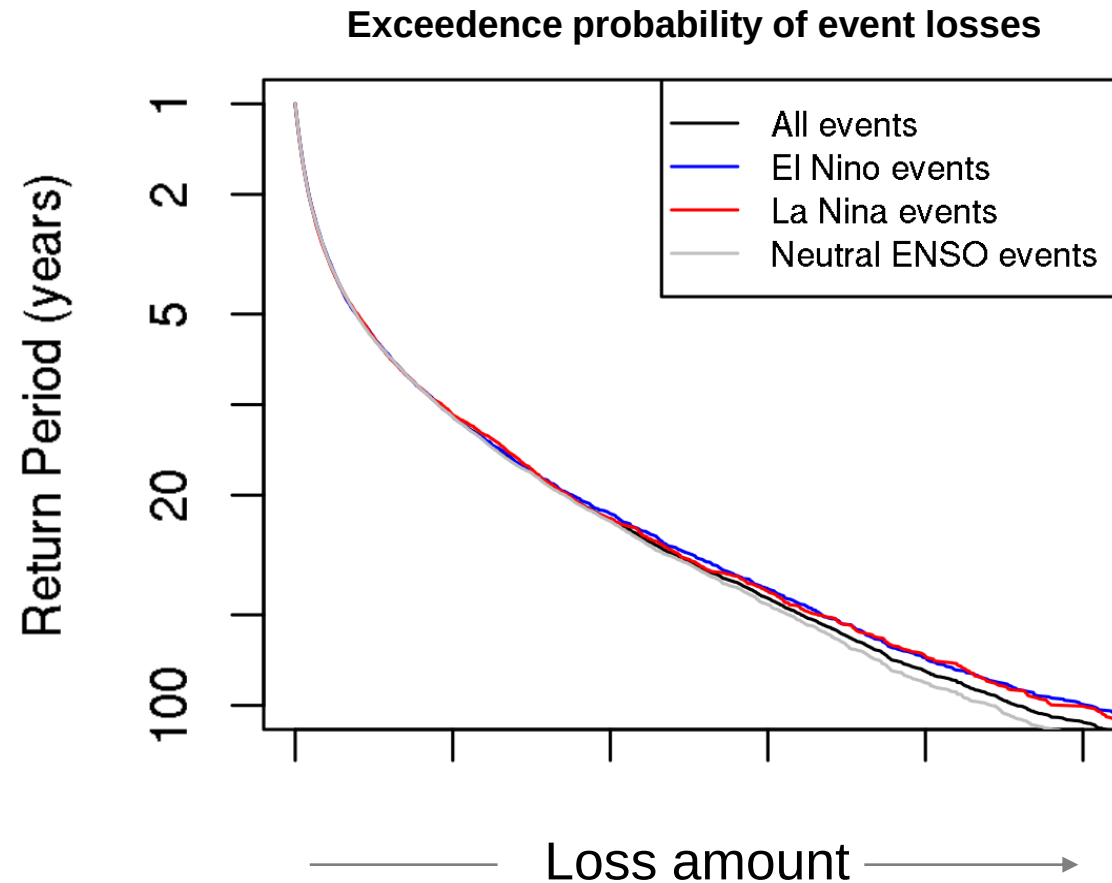
- El Niño periods tend to cause larger flood events in the North Island and in the north-east of the South Island.
- La Niña periods tend to cause larger flood events the south and west of the South Island.
- Neutral ENSO events tend to cause average or small-than-average events in the country.
- The flood severity patterns do not seem to closely match the monthly precipitation severity maps. This is because flood events in New Zealand are most often caused by sequences of intense daily rainfall. A critical role is therefore played by the stochastic temporal disaggregation methodology, which is based on seasonal disaggregation statistics.

Results – Insured Losses



Results – Insured Losses

- ❑ Flood events occurring during El Niño and La Niña periods cause larger than average country-wide losses, for equal return periods
- ❑ Events occurring during El Niño and La Niña events generate comparable losses, for equal return periods.
- ❑ Flood events occurring during neutral ENSO phases cause smaller than average losses.



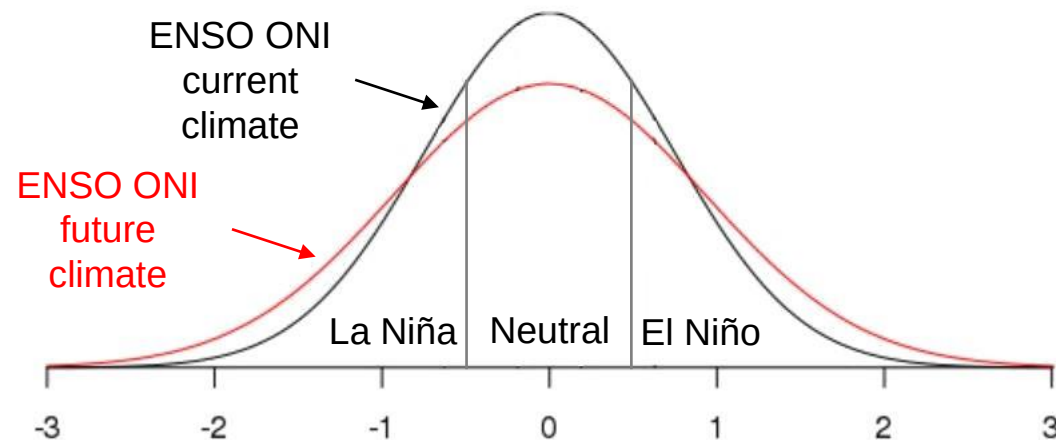
Results – Insured Losses

Key takeaways:

- El Niño periods generate overall higher losses in the North Island.
- La Niña events generate higher losses in the South Island and in part of the North Island.
- Neutral ENSO periods are characterized by overall average and lower-than-average losses throughout the country.
- The relation between flood depth and insured losses is non-trivial, given the importance of exposure location and flood defences in determining the loss distribution.

Conclusions

- ❑ ENSO effects precipitation, flood, and insured losses across New Zealand by as much as 15%
- ❑ El Niño periods cause higher monthly precipitation in the South Island, whereas La Niña periods cause larger monthly precipitation in the North Island
- ❑ Flood risk is overall higher in the North Island during El Niño periods and higher in the South Islands during La Niña periods. This pattern is loosely correlated to that of monthly precipitation because flood events in NZ are caused by sequences of intense daily precipitation.
- ❑ Insured losses are higher in the North Island during El Niño periods, and higher in the South Island during La Niña periods. At country level, El Niño and La Niña periods cause events 5-10% more costly than average, for equal return periods
- ❑ These results have potential implications for climate change



Future climate may cause:

- Less of neutral ENSO events
- More of El Niño / La Niña events

References

- ¹ Collins, M., An, S.I., Cai, W., Ganachaud, A., Guilyardi, E., Jin, F.F., Jochum, M., Lengaigne, M., Power, S., Timmermann, A. and Vecchi, G., 2010. The impact of global warming on the tropical Pacific Ocean and El Niño. *Nature Geoscience*, 3(6), pp.391-397.
- ² Fowler, A.M., Boswijk, G., Lorrey, A.M., Gergis, J., Pirie, M., McCloskey, S.P., Palmer, J.G. and Wunder, J., 2012. Multi-centennial tree-ring record of ENSO-related activity in New Zealand. *Nature Climate Change*, 2(3), pp.172-176.
- ³ Cai, W., Borlace, S., Lengaigne, M., Van Rensch, P., Collins, M., Vecchi, G., Timmermann, A., Santoso, A., McPhaden, M.J., Wu, L. and England, M.H., 2014. Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature climate Change*, 4(2), pp.111-116.
- ⁴ Cai, W., Santoso, A., Wang, G., Yeh, S.W., An, S.I., Cobb, K.M., Collins, M., Guilyardi, E., Jin, F.F., Kug, J.S. and Lengaigne, M., 2015. ENSO and greenhouse warming. *Nature Climate Change*, 5(9), pp.849-859.
- ⁵ Yan, Z., Wu, B., Li, T., Collins, M., Clark, R., Zhou, T., Murphy, J. and Tan, G., 2020. Eastward shift and extension of ENSO-induced tropical precipitation anomalies under global warming. *Science Advances*, 6(2), p.eaax4177.