Exploring Drivers of Coastal Flooding Uncertainty in New Zealand via Global Sensitivity Analysis

Charline Dalinghaus, Pablo Higuera, Giovanni Coco

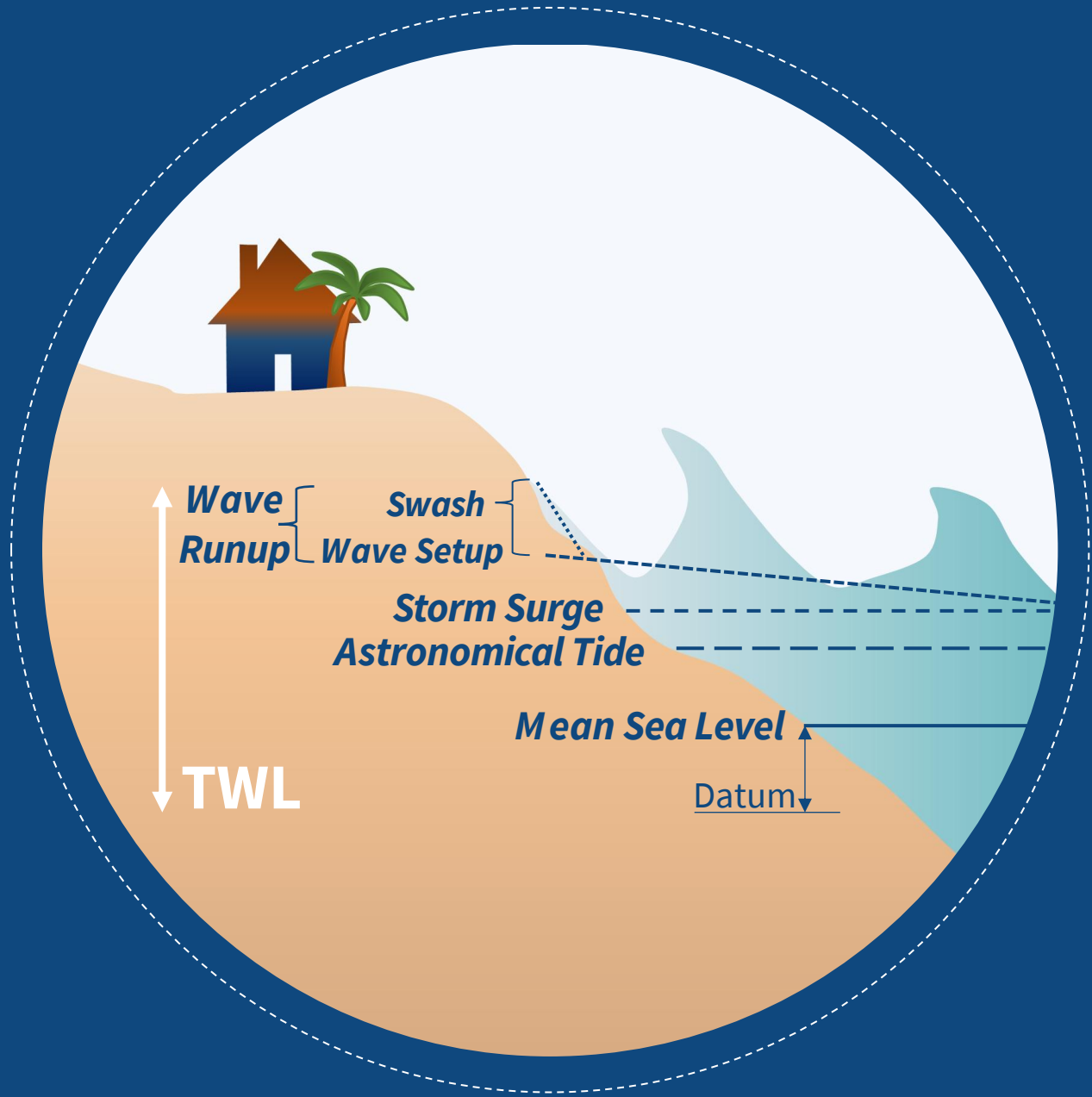
Coast and Ocean Collective

TE AO HURIHURI : TE AO HOU
OUR CHANGING COAST

NZ SEA RISE
TE TAI PARI O AOTEAROA

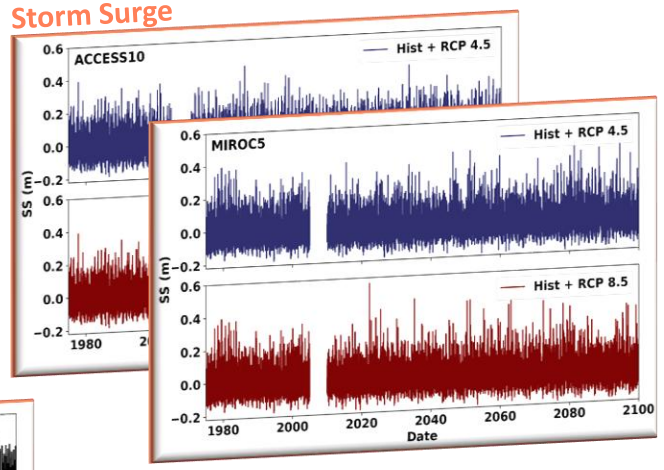
Coastal Flooding

$$TWL = MSL + AT + SS + Ru$$

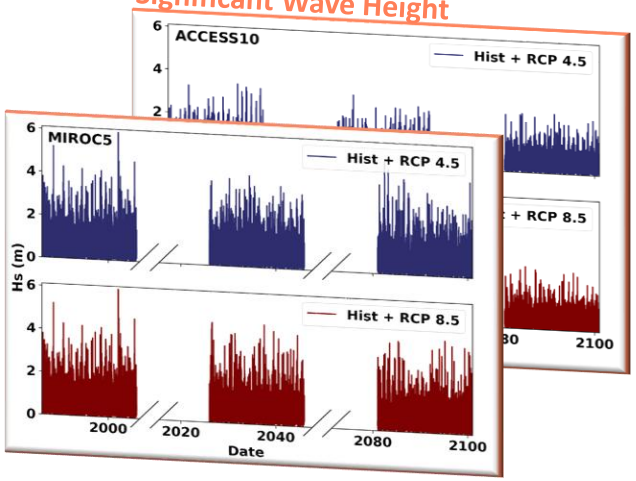


Datasets

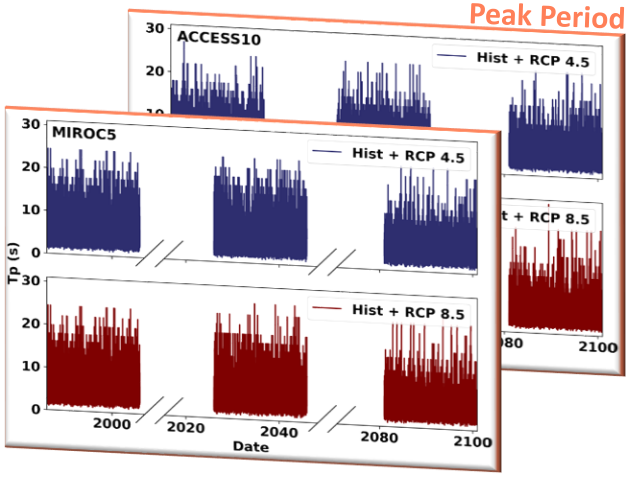
Storm Surge



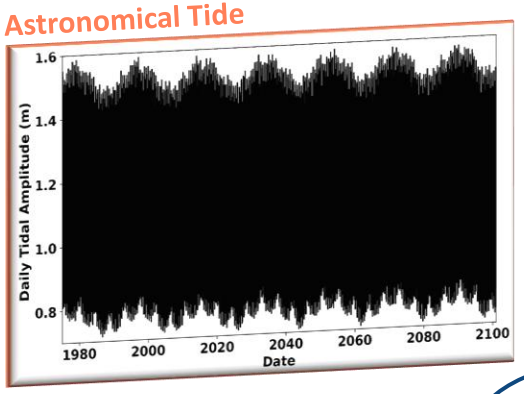
Significant Wave Height



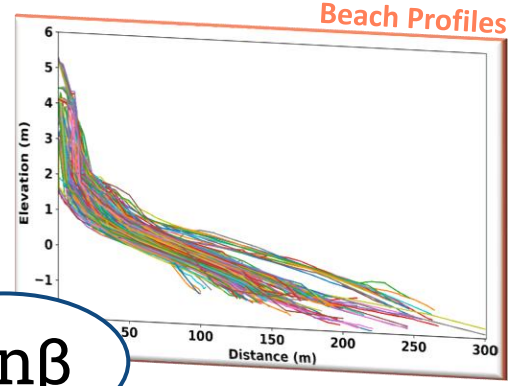
Peak Period

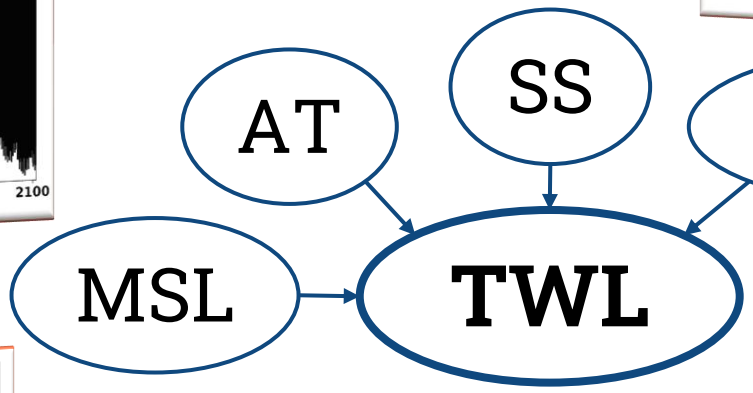


Astronomical Tide

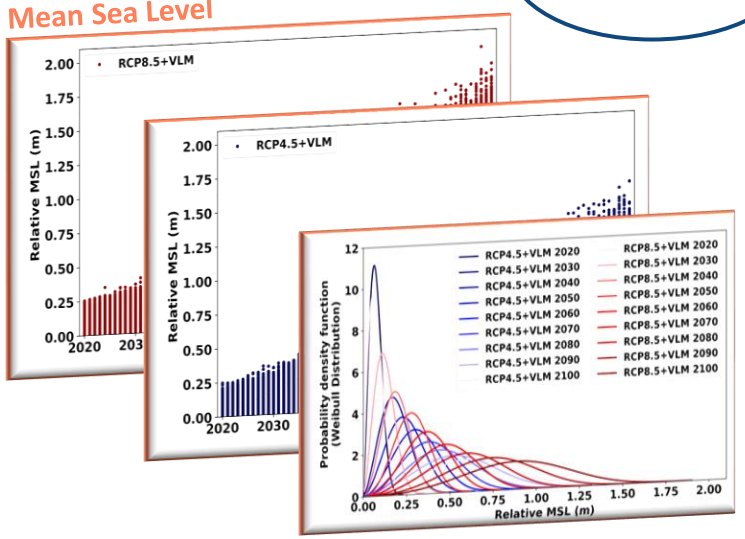


Beach Profiles





Mean Sea Level



$$\bar{\eta}_M = 0.355 H_{s0} {\xi_0}^{0.5}$$

$$\bar{\eta}_M = 0.220 {\beta_f}^{0.538} H_{s0} \left(\frac{H_{s0}}{L_0}\right)^{-0.371}$$

$$\bar{\eta}_M = 0.35 \beta_f (H_{s0} L_0)^{0.5}$$

$$S = 146.737(\beta_f)^2 + \frac{T_p {H_{s0}}^2}{5.8 + 10.59 {H_{s0}}^2} - 4397.838(\beta_f)^4$$

$$S = 2.14 \tanh(0.4 H_{s0})$$

$$S = \sqrt{(0.06\,(H_{s0} L_0)^{0.5})^2 + (0.75 \beta_f (H_{s0} L_0)^{0.5})^2}$$

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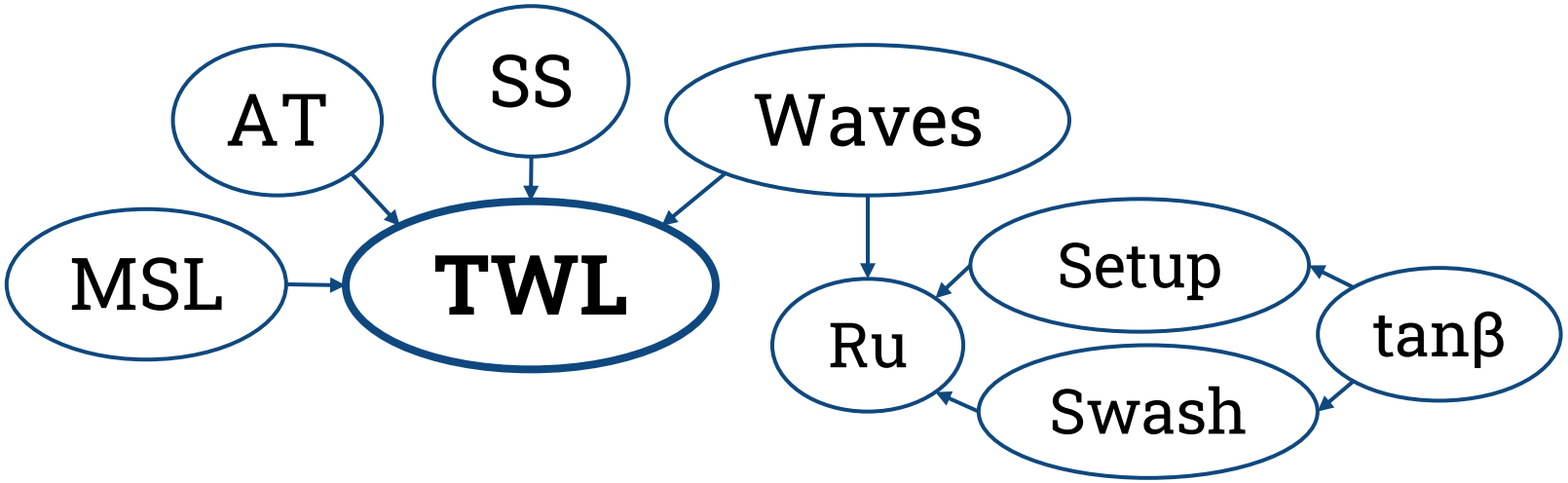

Datasets

1986 – 2100
NIWA Taihoro Nukurangi
Predicted tides

1975 – 2004
2010 – 2099
Coast and Ocean Collective
ACCESS 1.0
MIROC 5

1986 – 2005
2026 – 2045
2081 – 2100
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2020 – 2100
NZ SEA RISE TE TAI PARI O AOTEAROA
RCP 4.5 + VLM
RCP 8.5 + VLM

AT
SS
Waves
MSL
TWL
Ru
Setup
tanβ
Swash

Dalinghaus et al. (2023)
Ji et al. (2018)
Stockdon et al. (2006)

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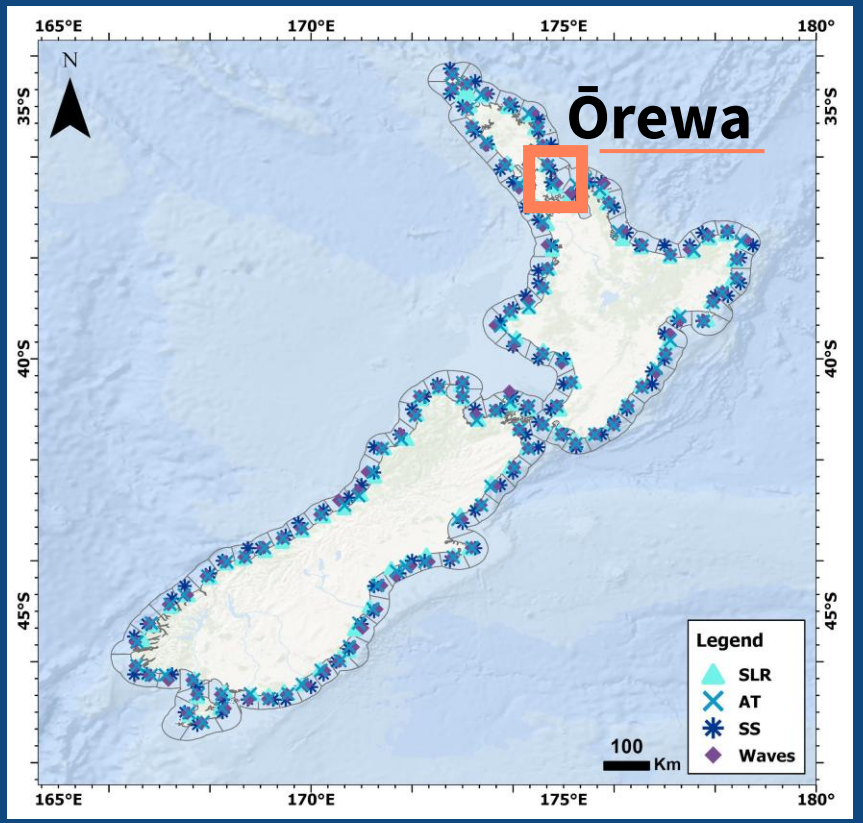
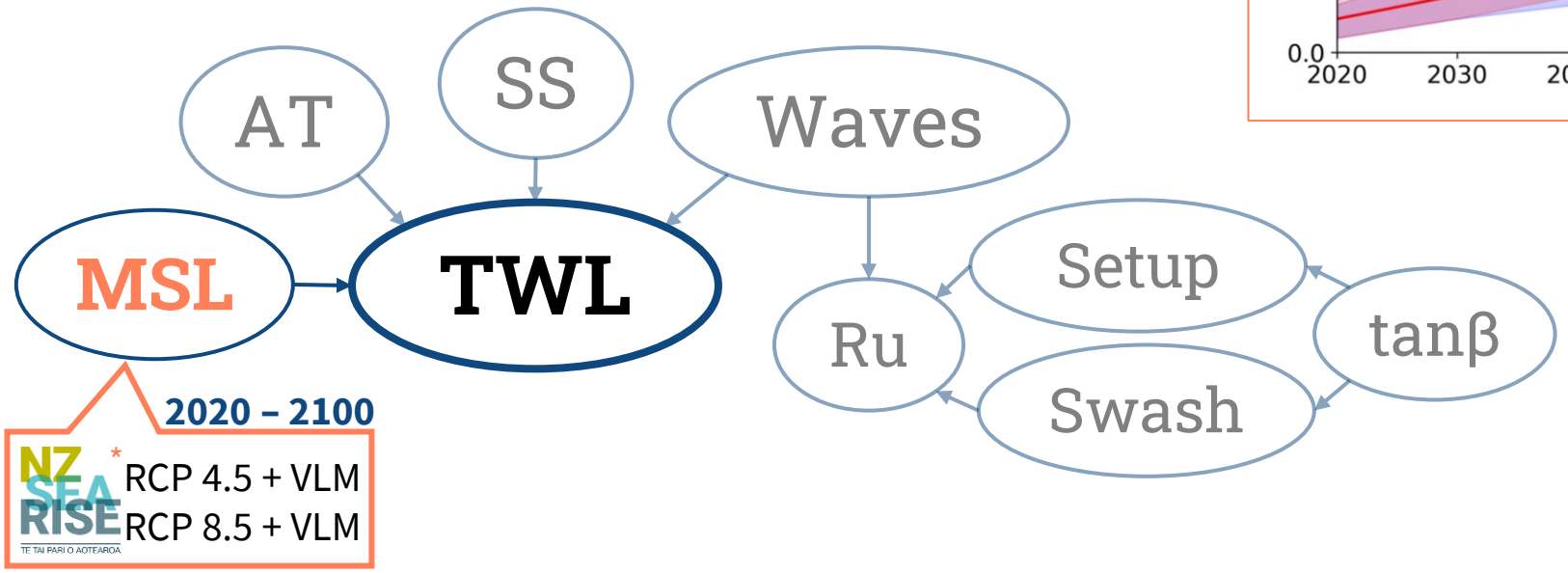
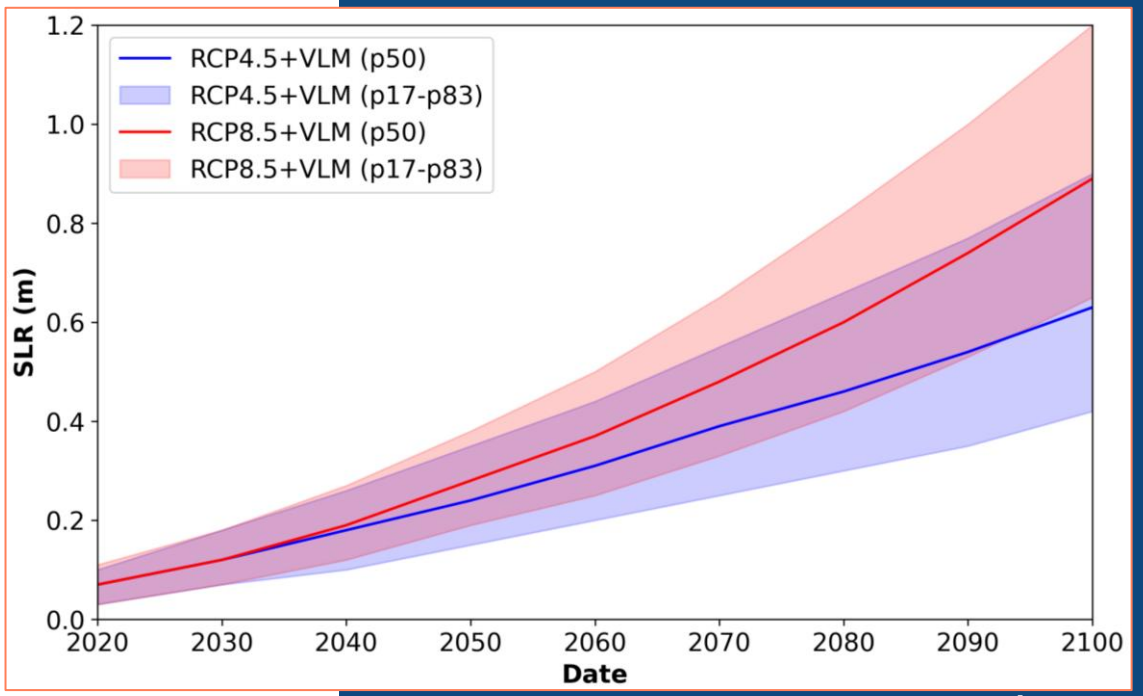


Historical (1986 – 2004) | Near Future (2026 – 2045) | Long-term Future (2081 – 2100)

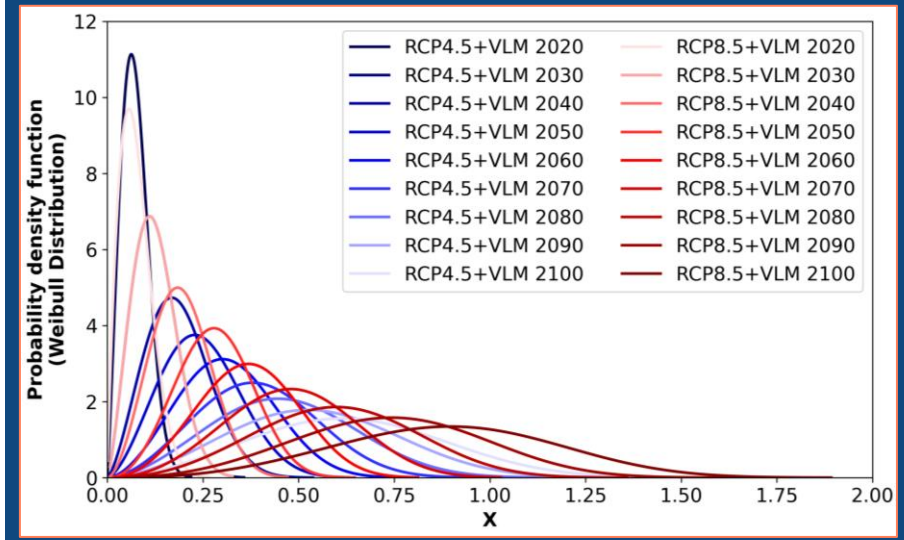
Ōrewa

Datasets





VLM = -0.46 mm/year



*https://www.searise.nz/

Ōrewa

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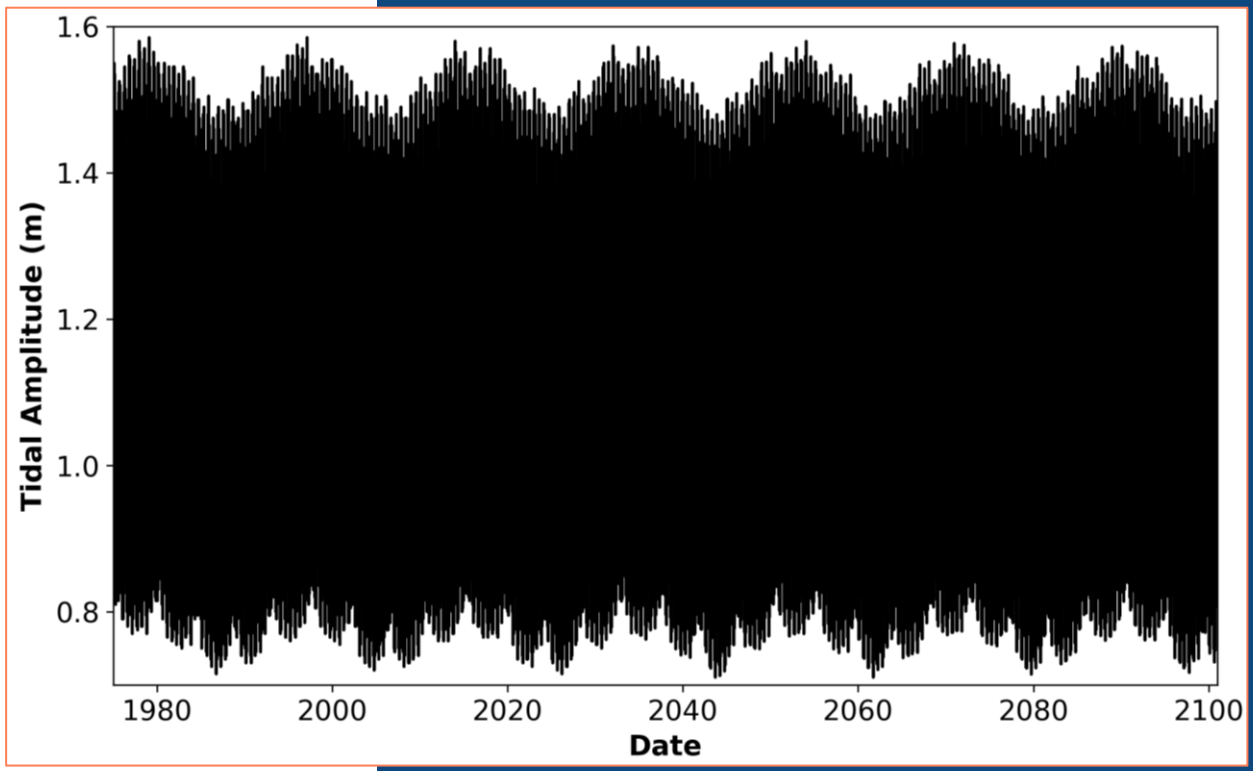

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Ōrewa

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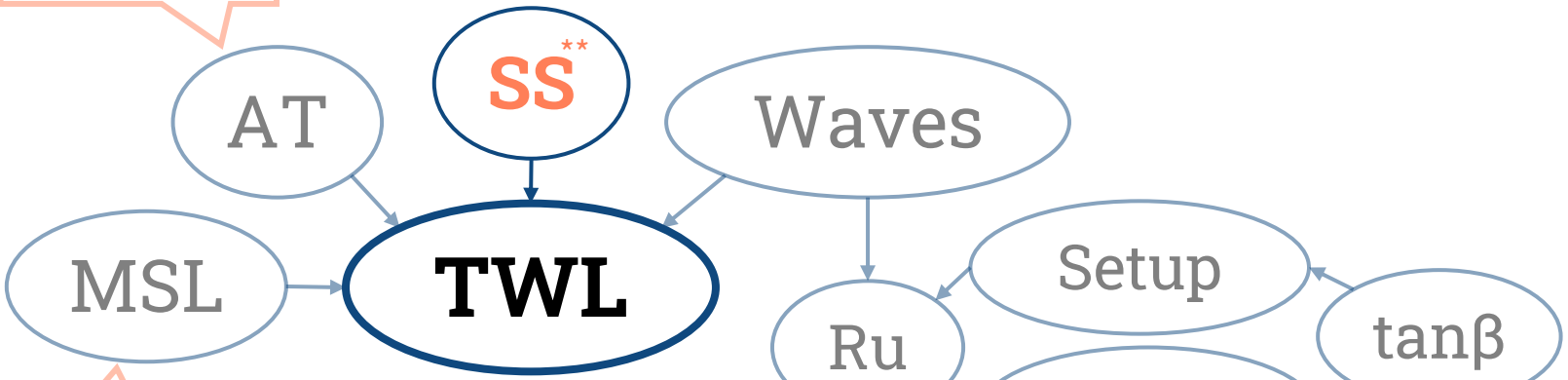

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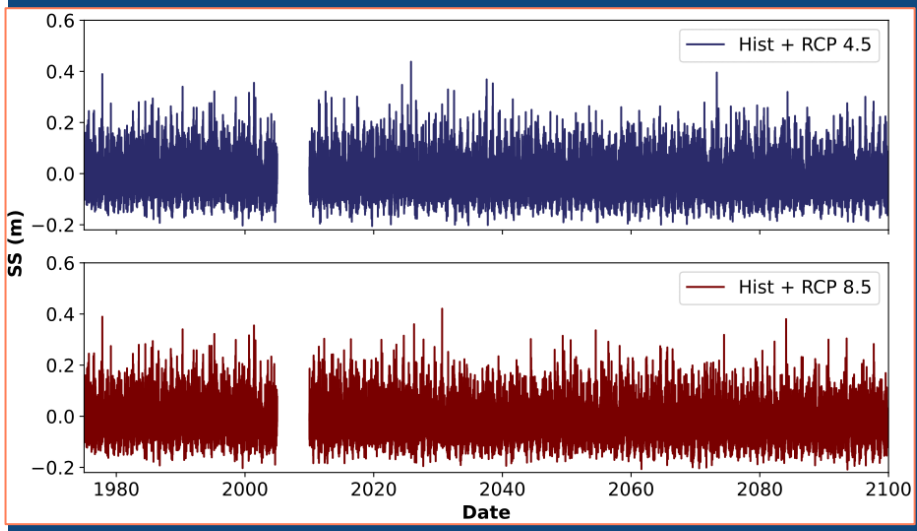
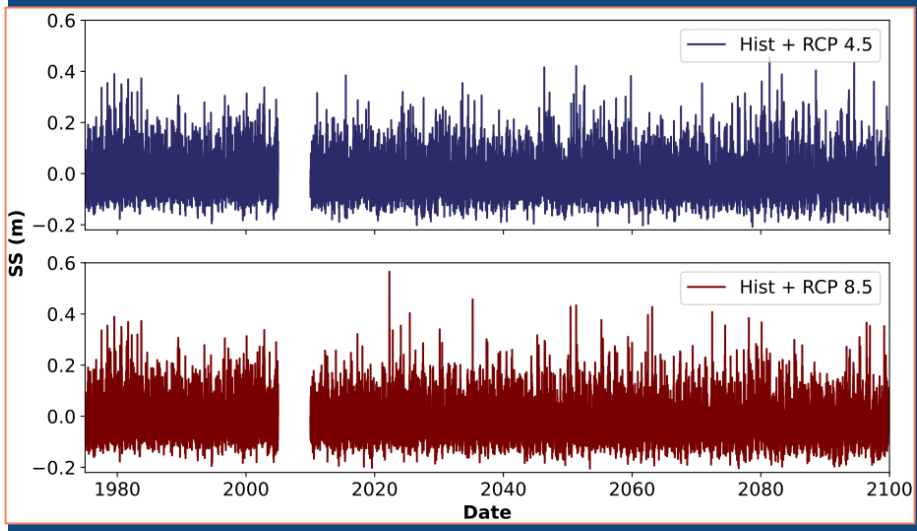


MIROC 5



* *https://coastalhub.science/data*

**Cagigal, L., Rueda, A., Castanedo, S., Cid, A., Perez, J., Stephens, S.A., Coco, G., & Méndez, F.J. (2020). Historical and future storm surge around New Zealand: From the 19th century to the end of the 21st century. Int J Climatol., 40, 1512–1525.

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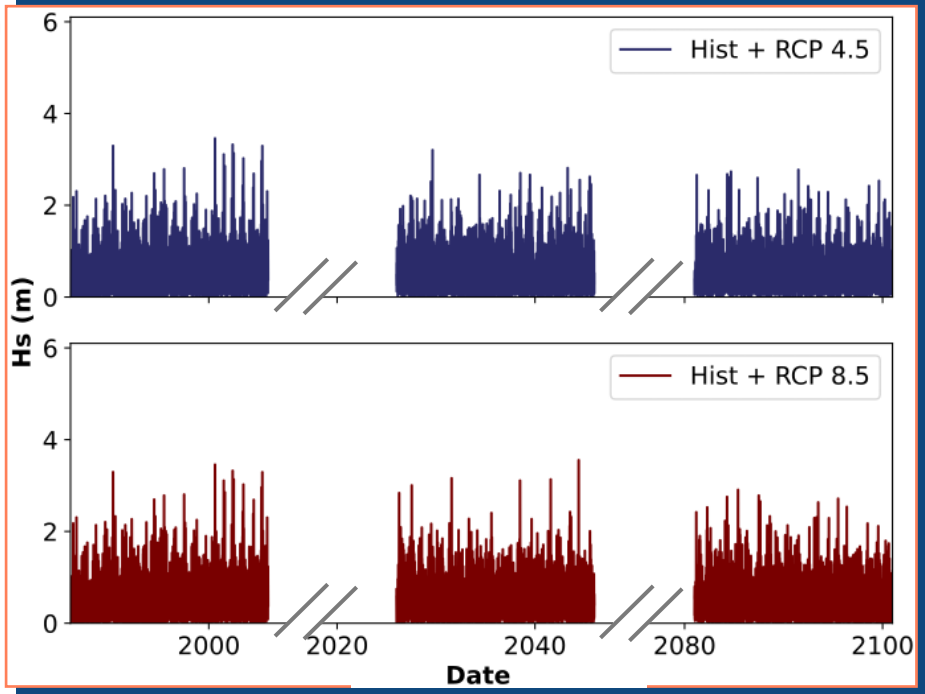

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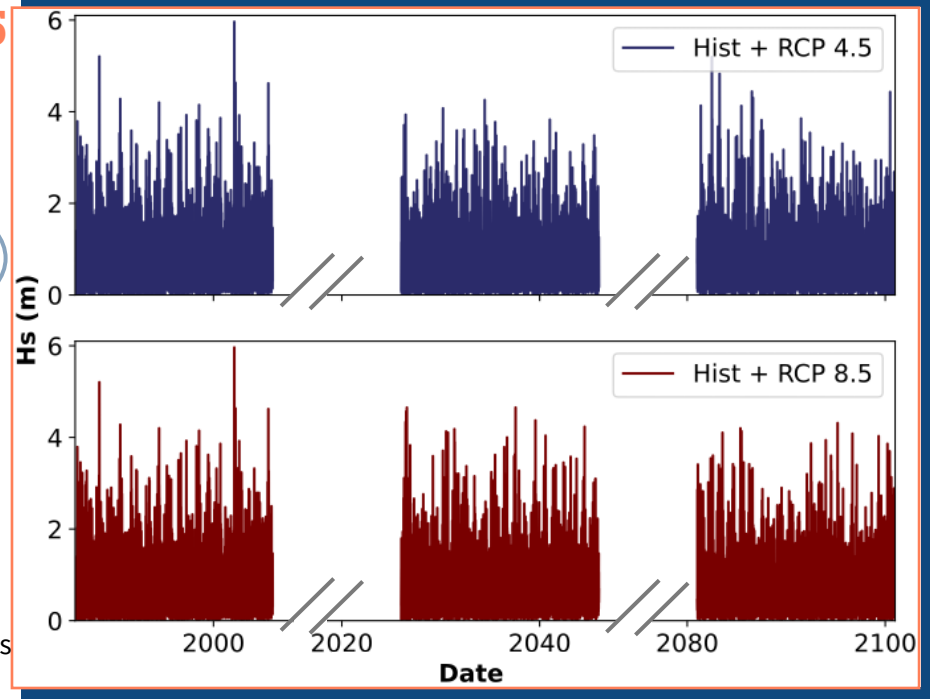

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**Albuquerque, J., Antolínez, J.A.A., Méndez, F.J. & Coco, G. (2022). On the projected changes in New Zealand's wave climate and its main drivers. New Zealand Journal of Marine and Freshwater Research.

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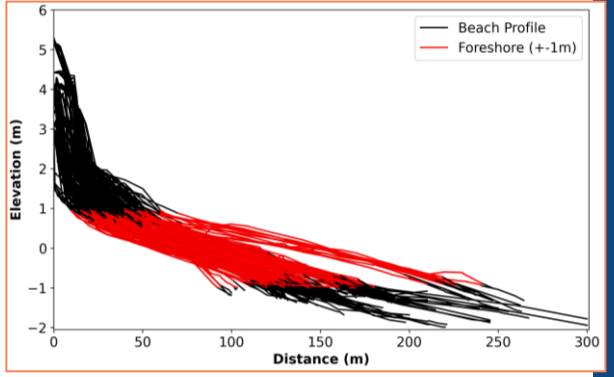

Wave Setup

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Monte Carlo Sampling

Ōrewa

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2020 – 2100
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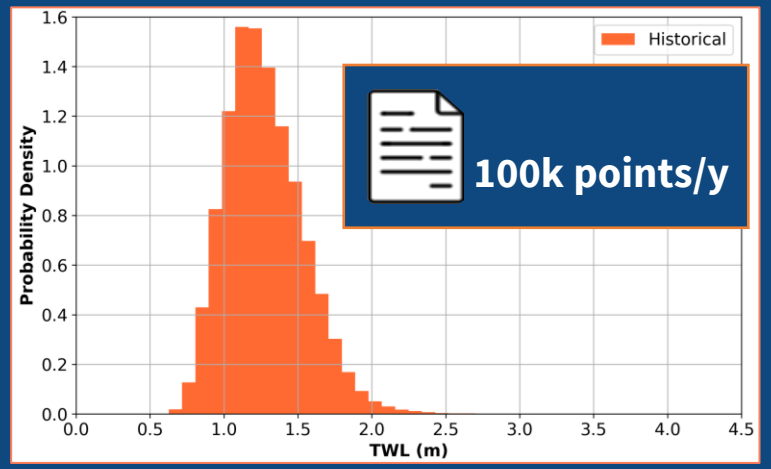
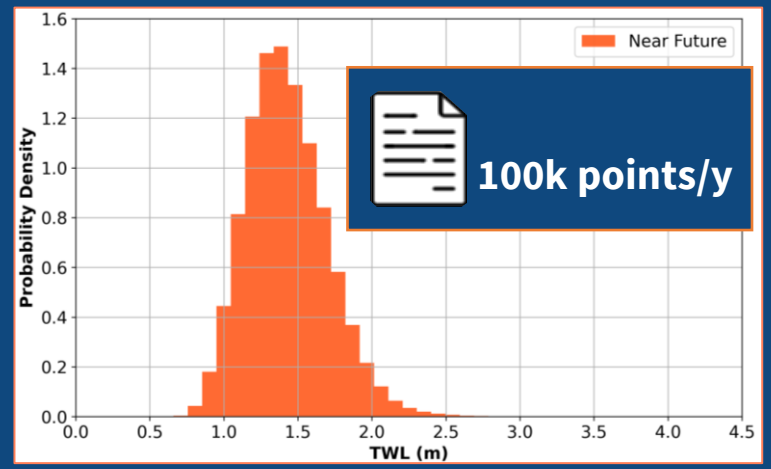
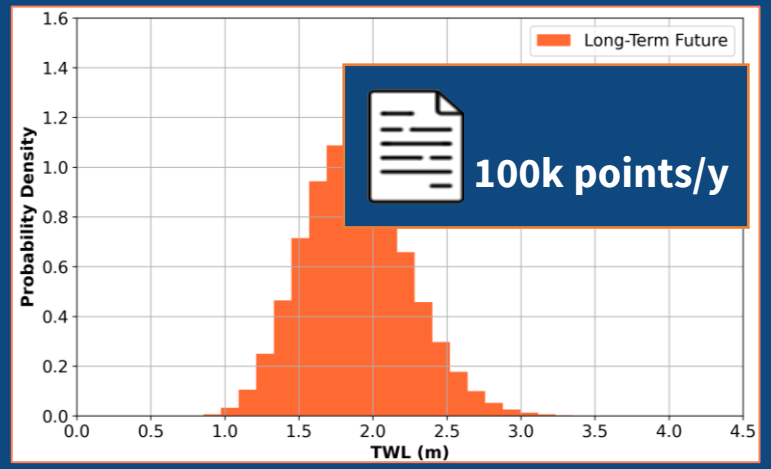


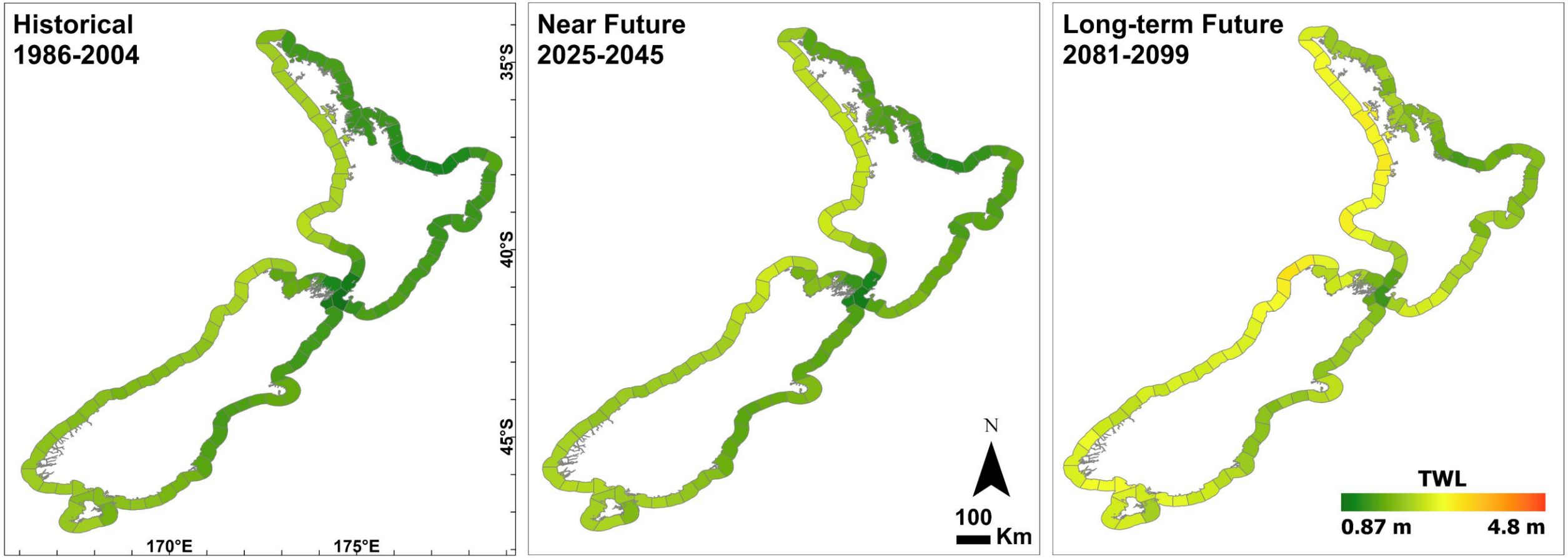




Results:

Total Water Level - AVERAGES

$$TWL = MSL + AT + SS + Ru$$



Results:

Total Water Level - EXTREMES

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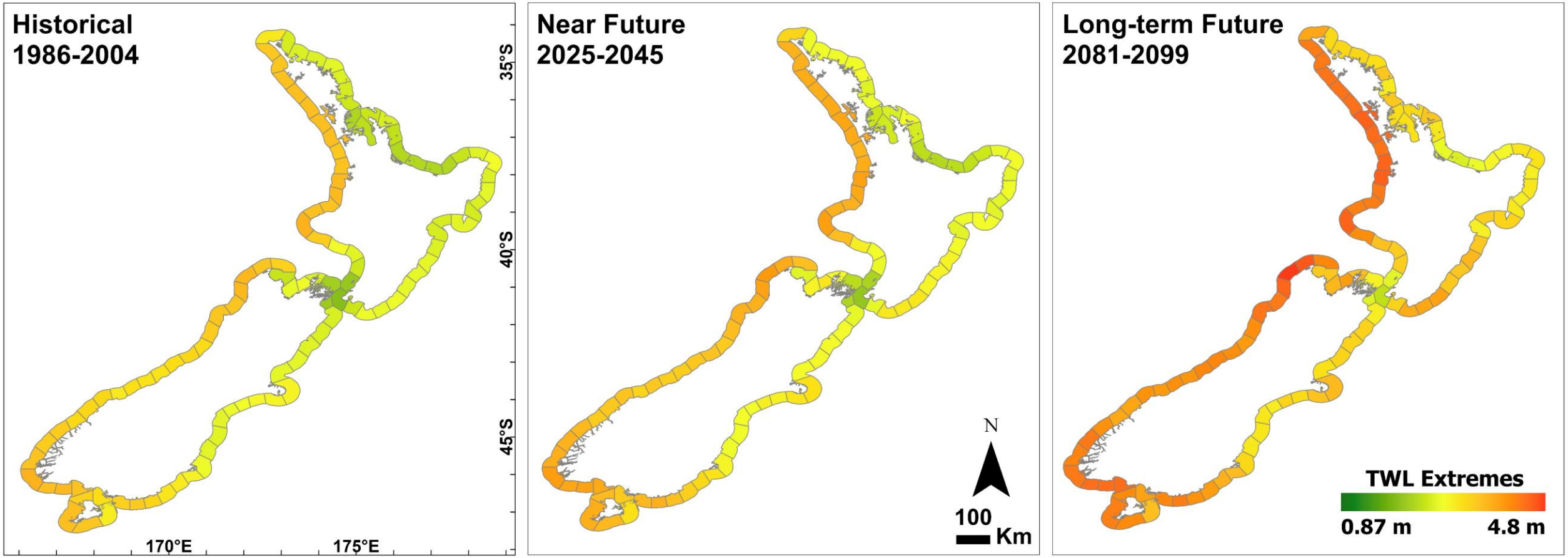
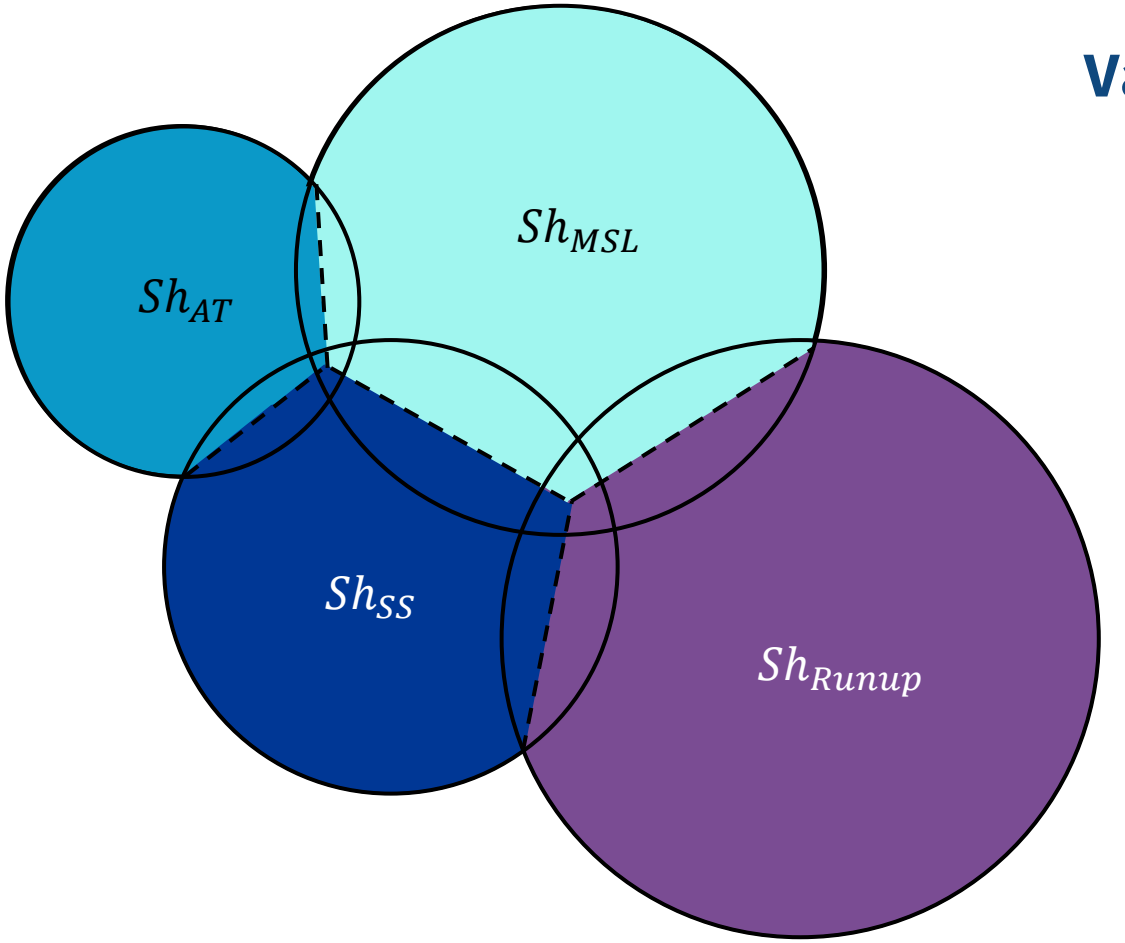


Global Sensitivity Analysis



Variance-based GSA approach: Shapley effects

$$Sh_i = \frac{1}{k} \sum_{A \subseteq K \setminus \{i\}} \binom{k-1}{|A|}^{-1} \left(S^{clos}_{A \cup \{i\}} - S^{clos}_{A} \right)$$

$$S^{clos}_{A} = \frac{Var\left(E(Y|\, X_A)\right)}{Var(Y)}$$

The Shapley value determines the fair contribution of each player to a game outcome, considering both their individual contribution and their interactions with other players.

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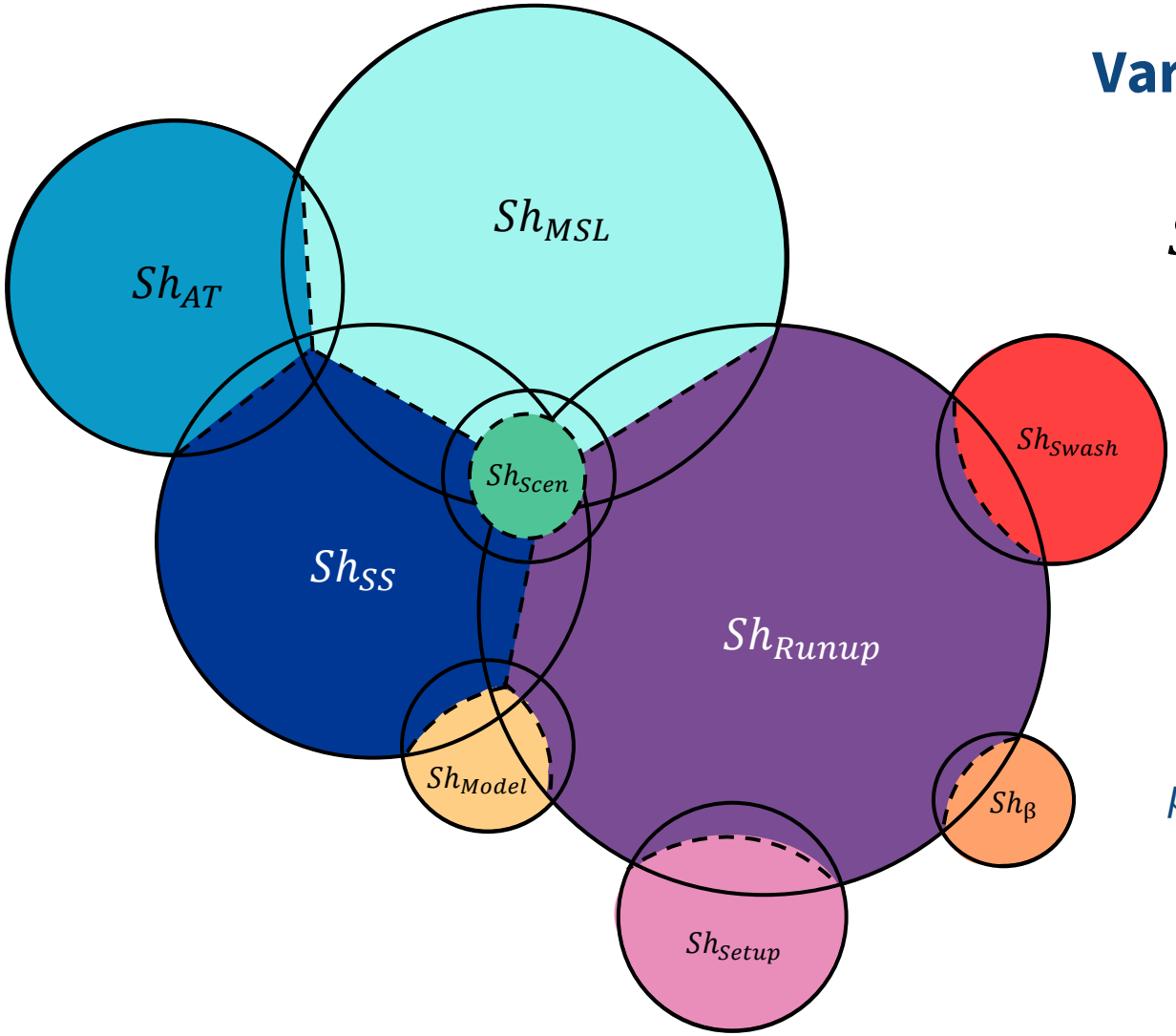

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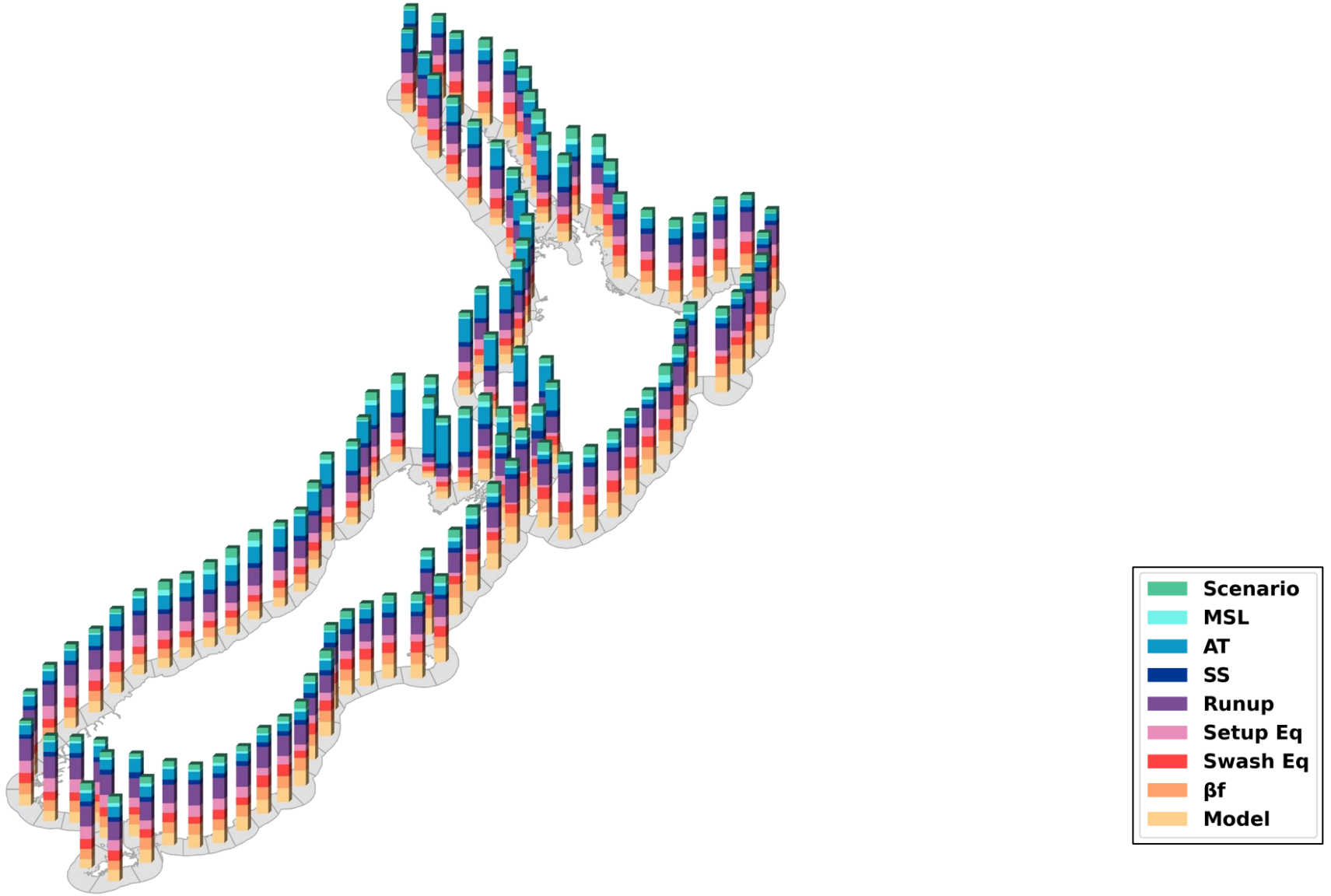
Global Sensitivity Analysis - TIME AVERAGED



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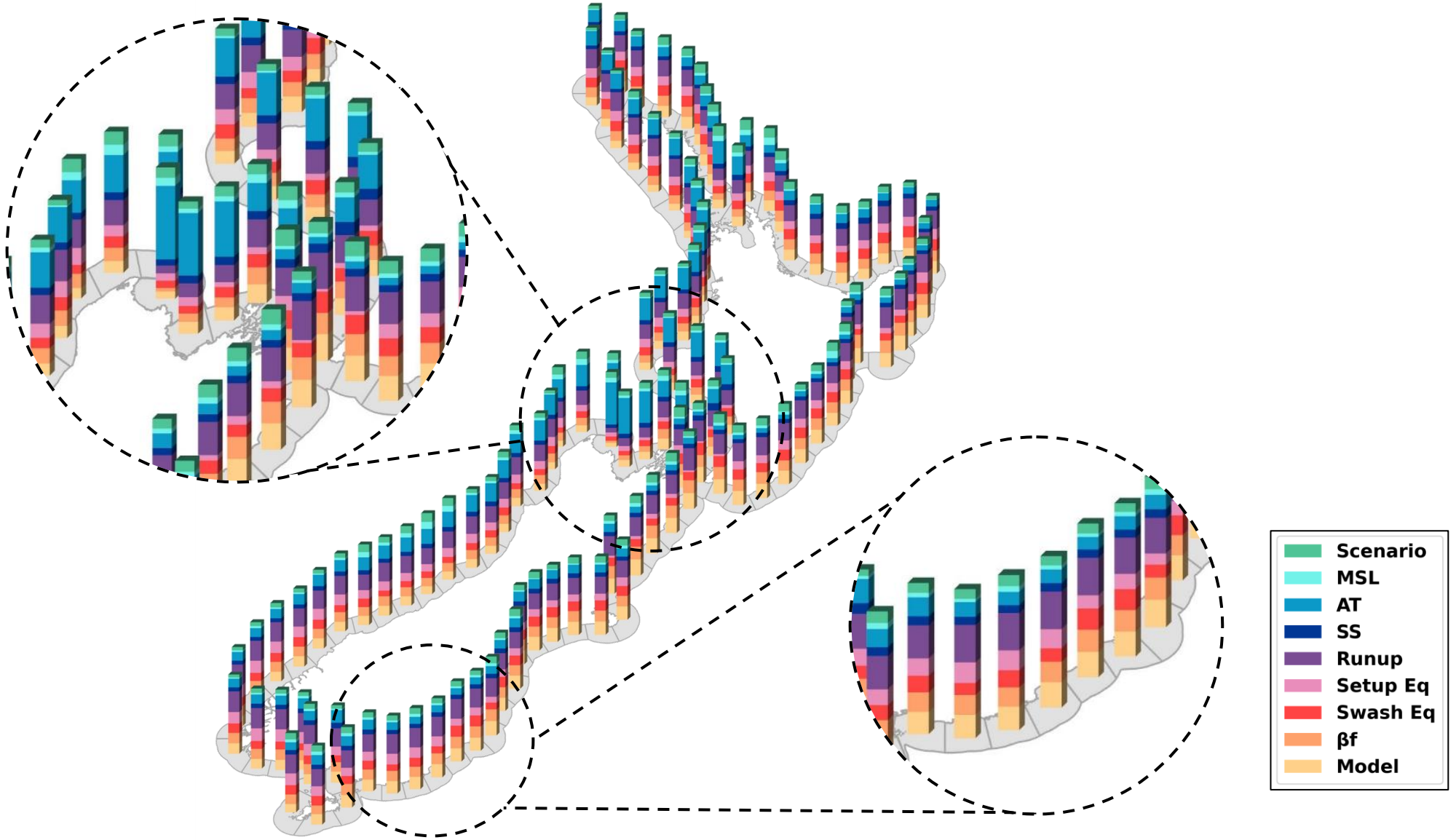
Global Sensitivity Analysis - TIME AVERAGED



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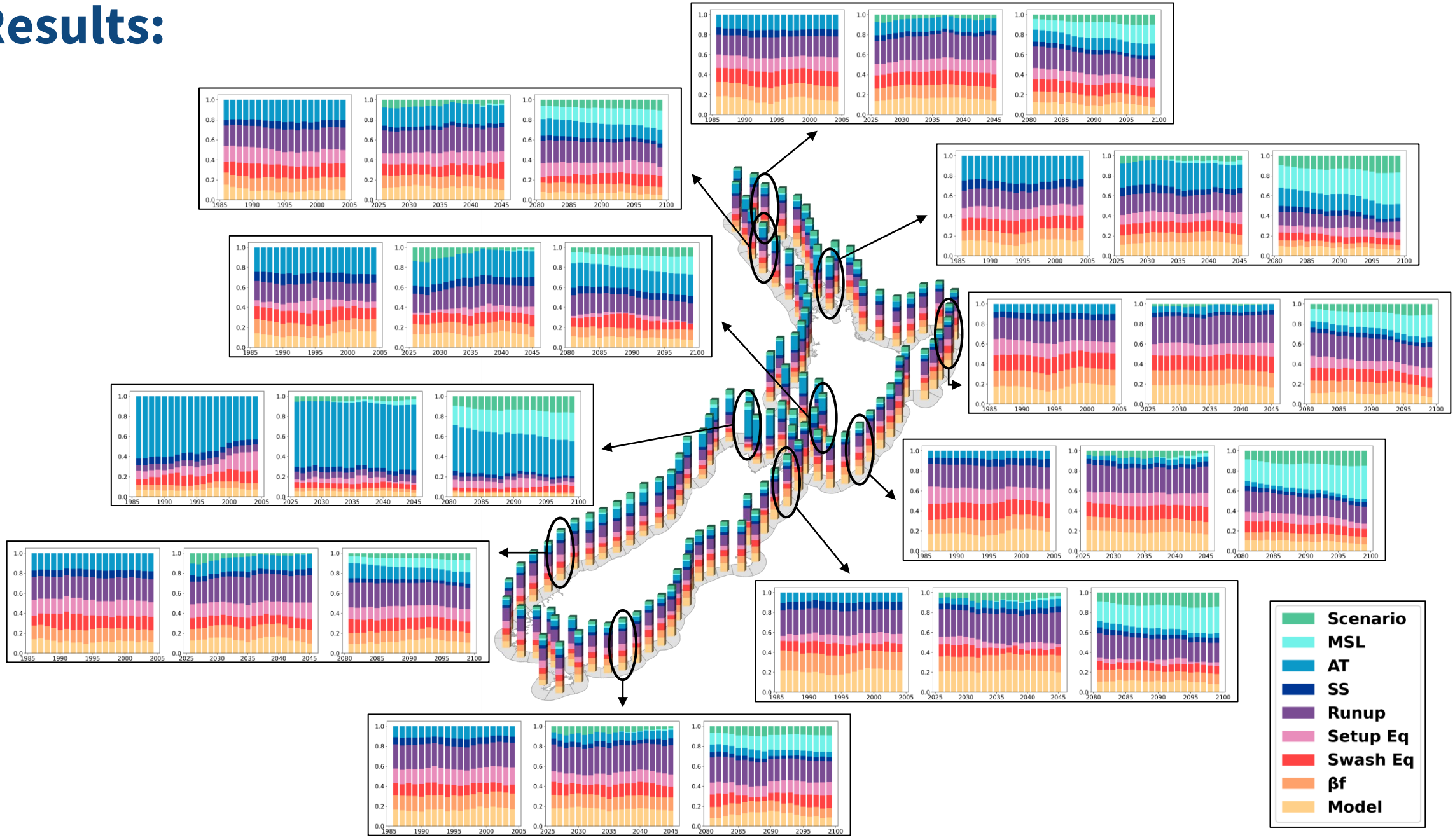

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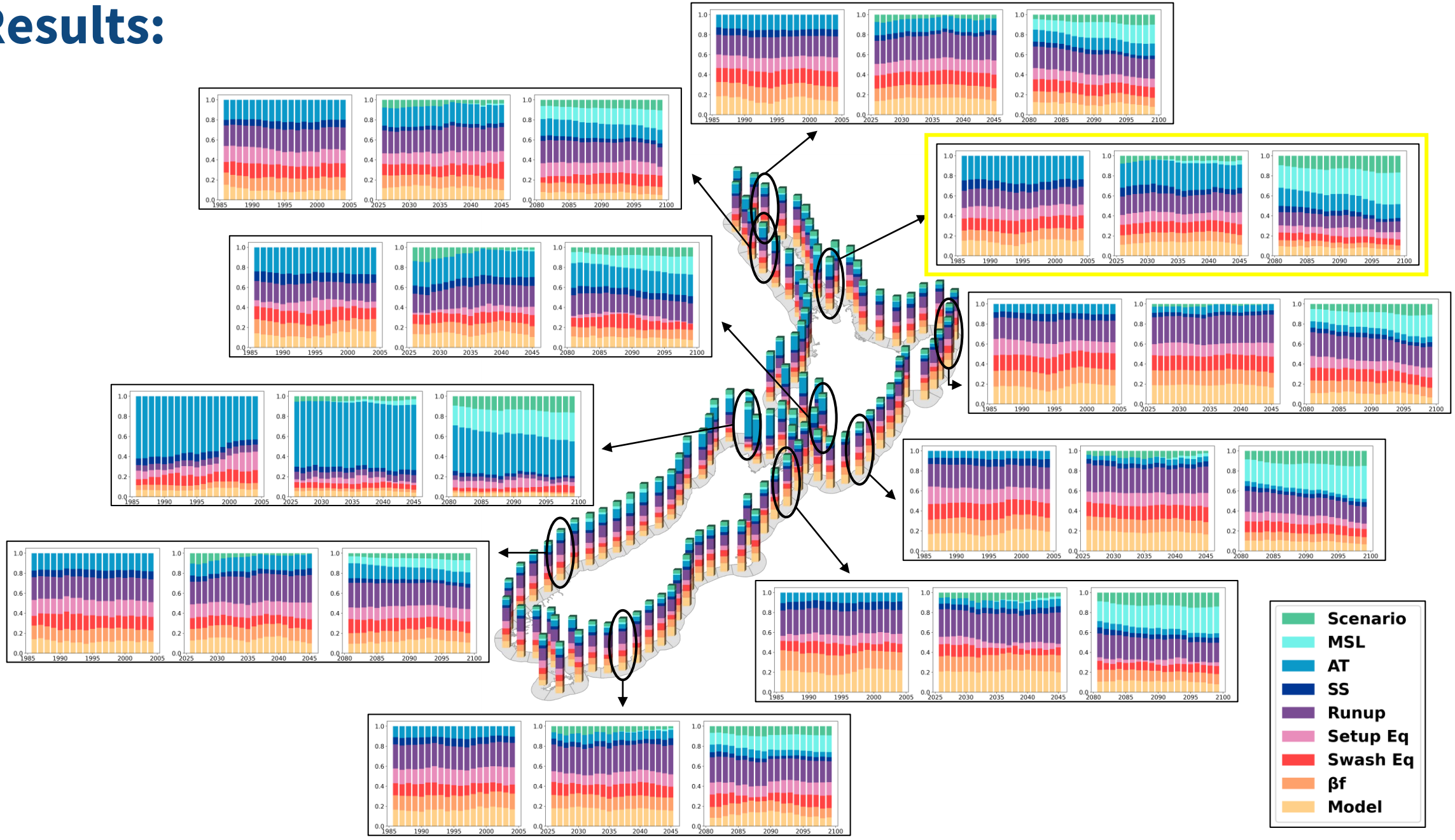

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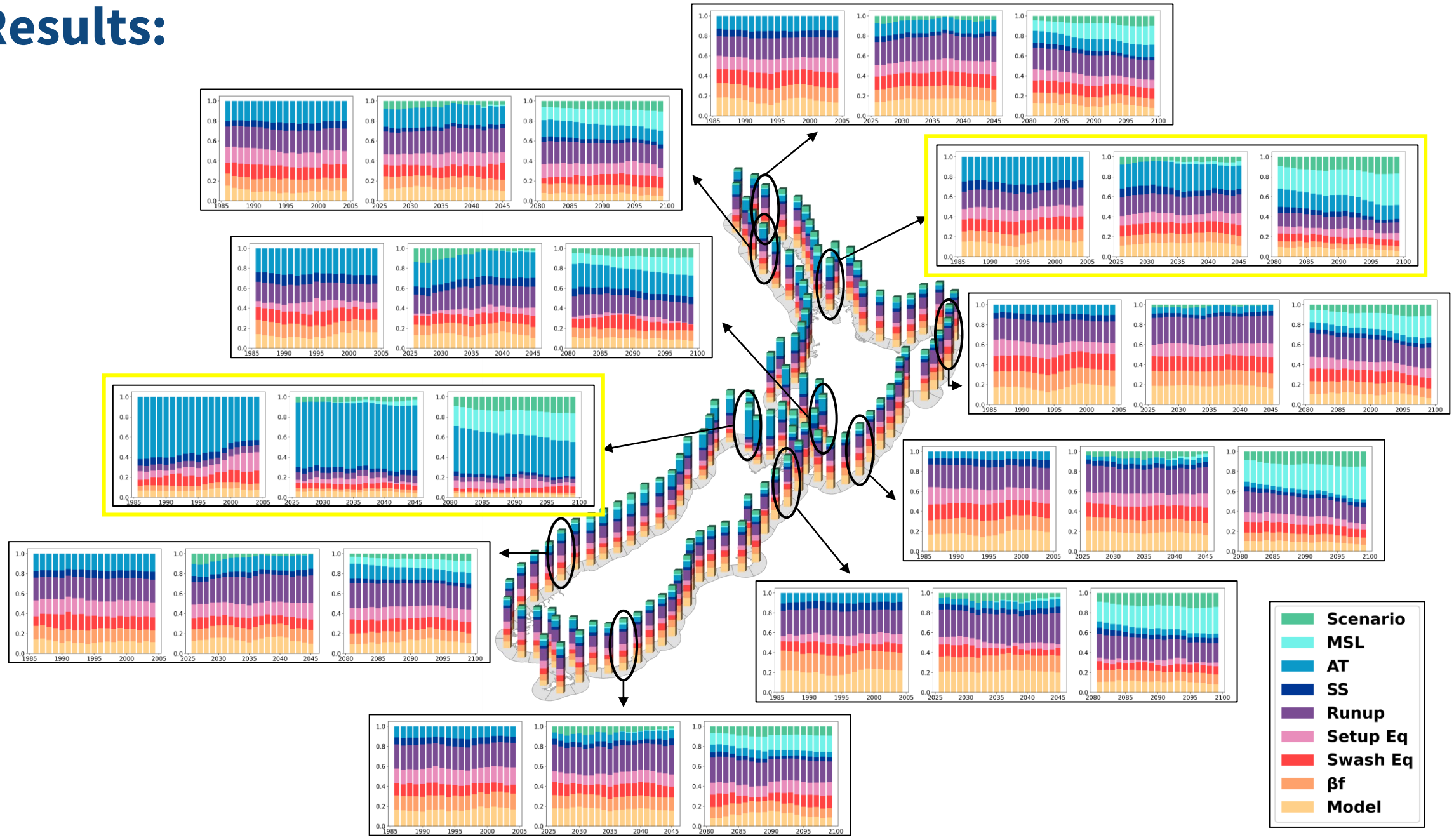

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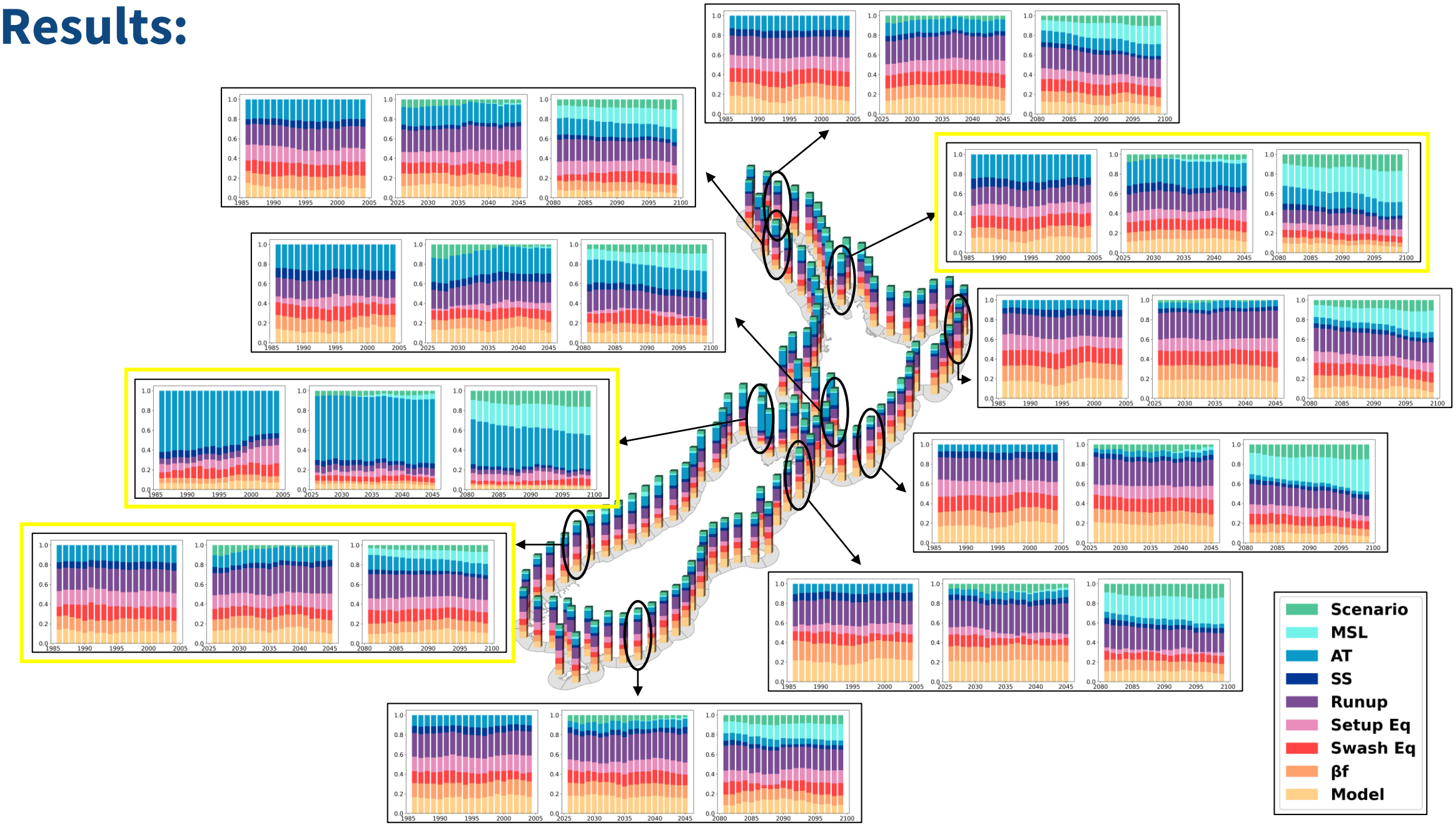

Summary

Time evolution of TWL (and associated uncertainty) is site-specific

Relative role of processes on uncertainties changes with time

SLR not a major driver of uncertainty in the *near* future

SLR (often) the major driver of uncertainty in the *far* future

Inevitably, there are uncertainties in how we deal with uncertainties…

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Pablo Higuera

SLR & VLM (R. Levy & T. Naish)

Waves (Joao Albuquerque)

Storm Surge (Laura Cagigal)

Legos (F. Mendez)

Research funded by:

UNIVERSITY OF AUCKLAND Waipapa Taumata Rau NEW ZEALAND

TE AO HURIHURI: TE AO HOU
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We acknowledge the following for providing the data used in this study:

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https://coastalhub.science/data

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Coast2Cast

A podcast on coastal science

with Ana Vila-Concejo, U. Sydney

COastal MOrphodynamics and Machine LeArning: Building an Inclusive International Network of Scientists

with Kristen Splinter, UNSW

www.coastalhub.science

Results: probability distributions of TWL & individual variables