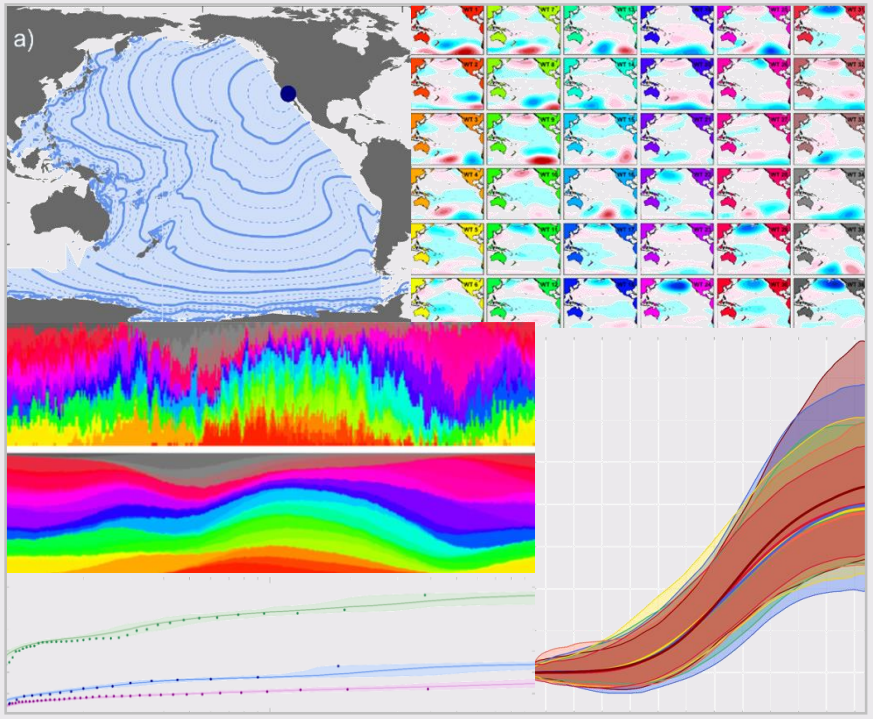


A CLIMATE-BASED WAVE AND STORM SURGE EMULATOR FOR LONG-TERM ANALYSIS OF COASTAL FLOODING AND EROSION

Laura Cagigal, Ana Rueda, Dylan Anderson, Peter Ruggiero, Mark A. Merrifield, Jennifer Montaño, Giovanni Coco, Fernando Méndez

Coast and Ocean Collective

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

UC UNIVERSIDAD DE CANTABRIA

NC STATE UNIVERSITY

OSU Oregon State University

SCRIPPS INSTITUTION OF OCEANOGRAPHY

The problem

Methodology

The emulator

Applications

Summary

The problem

Methodology

The emulator

Applications

Summary

MOTIVATION

SHORESHOP, NEW ZEALAND 2018
(Montaño et al., Submitted)

Need to generate synthetic time series of wave climate to evaluate shoreline evolution

Shoreshop
NZ 2018

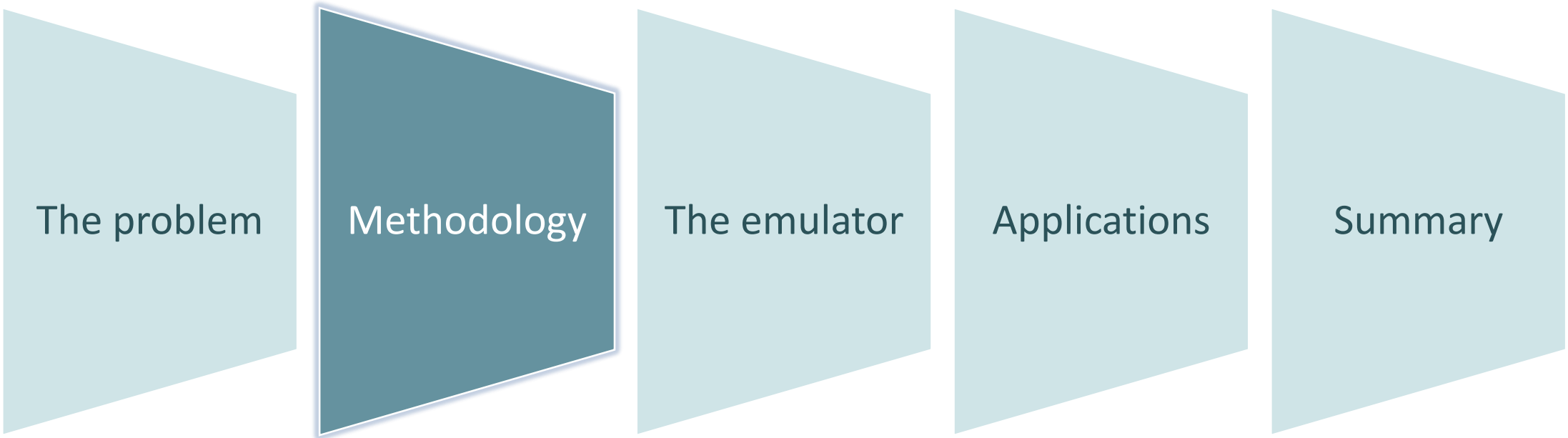
MOTIVATION

Why is it needed?

- Probabilistic **shoreline** evolution
- Estimate the **predictions uncertainty** by means of wave ensembles
- **Flooding** probabilistic risk assessments

Why is it difficult?

- Needs to provide a **continuous** and **long** time series of wave conditions
- Needs to preserve **chronology** at different time scales from inter-annual to intra-storm
- Needs to be **worldwide** transferable
- **Individual storms** need to have realistic shapes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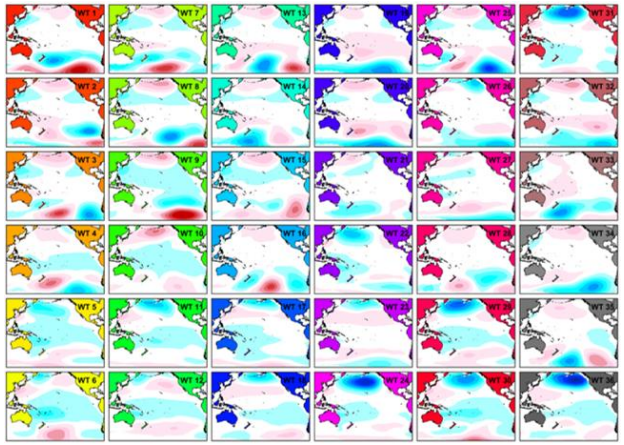
METHODOLOGY

1 DAILY WEATHER TYPE CLASSIFICATION



Daily weather patterns

METHODOLOGY

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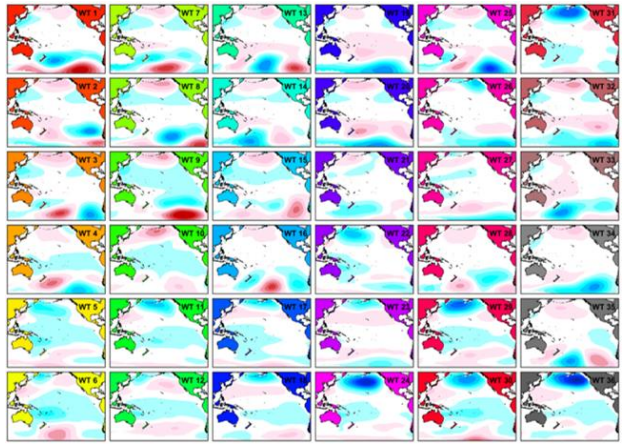

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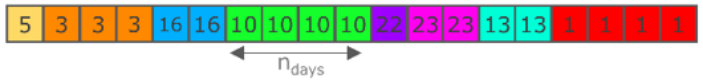
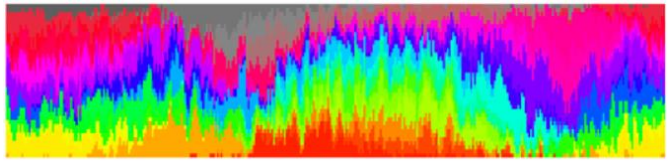


2 CHRONOLOGY MODEL AT A DAILY SCALE

- Probability of occurrence
- Persistence
- Transition probabilities
- Intra-seasonal variability
- Inter-annual variability



Obtain synthetic DWT sequences

METHODOLOGY

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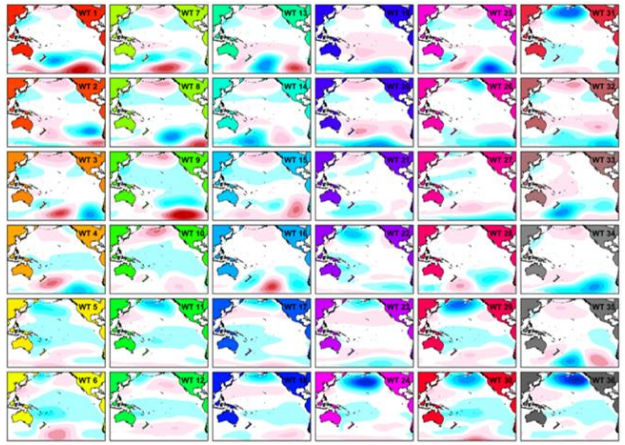

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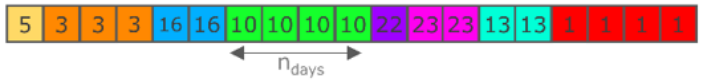

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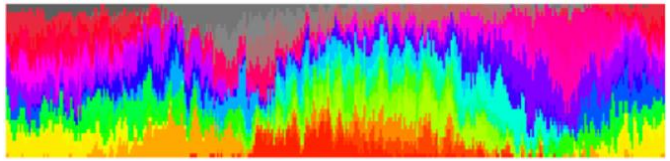
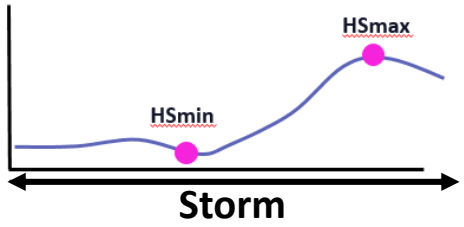


Obtain synthetic DWT sequences

3 STORM WAVE AND SS PARAMETERS



Hs^{max}, Hs^{min}, Tm^{max}, Tm^{min}, Dir^{mean}, SS^{mean}

METHODOLOGY

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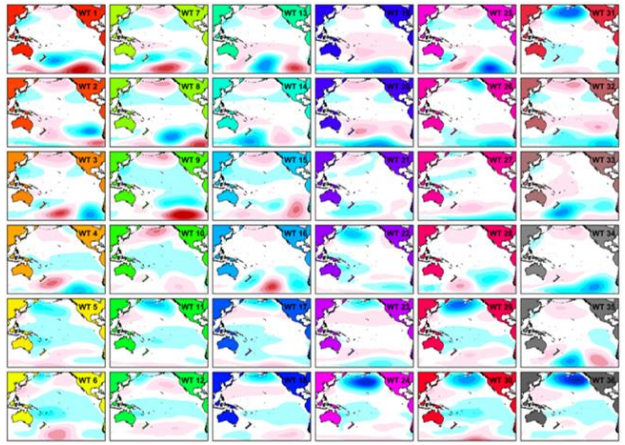

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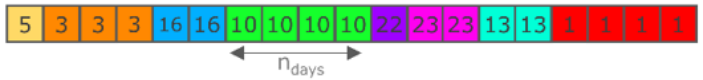

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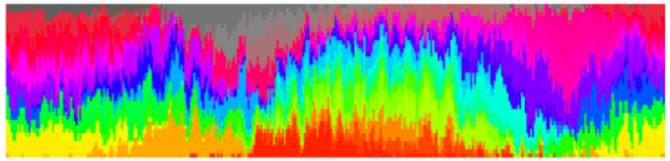

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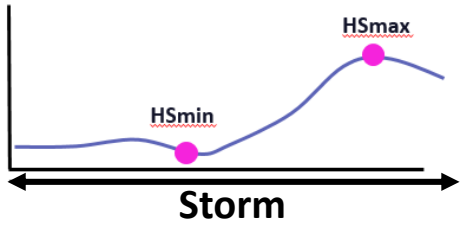
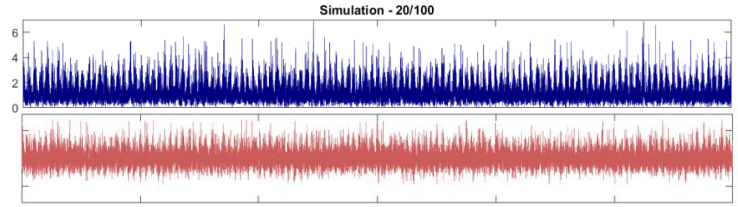


Hs^{max}, Hs^{min}, Tm^{max}, Tm^{min}, Dir^{mean}, SS^{mean}

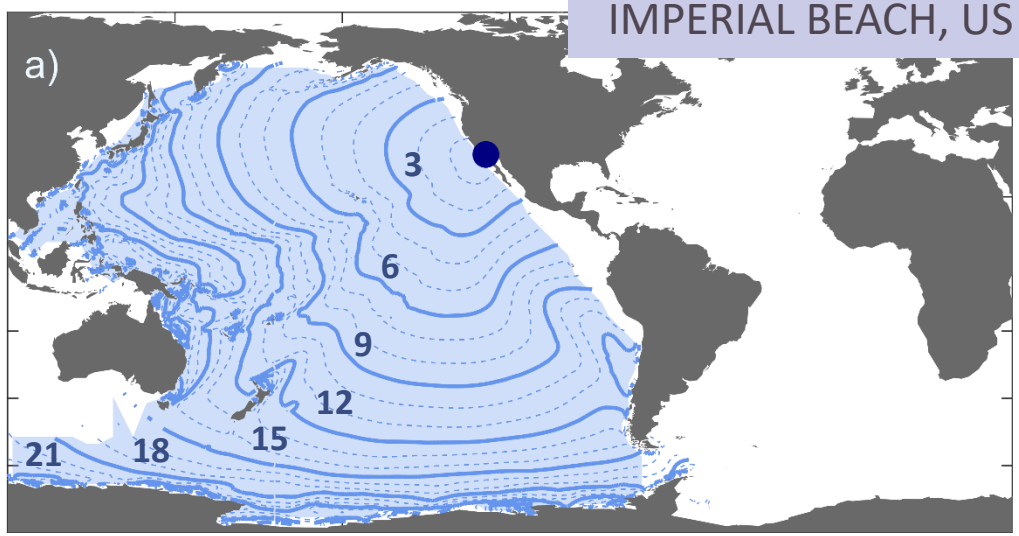
4 MONTECARLO SIMULATION

Synthetic time series of waves (Hs, Tm and Dir) and SS

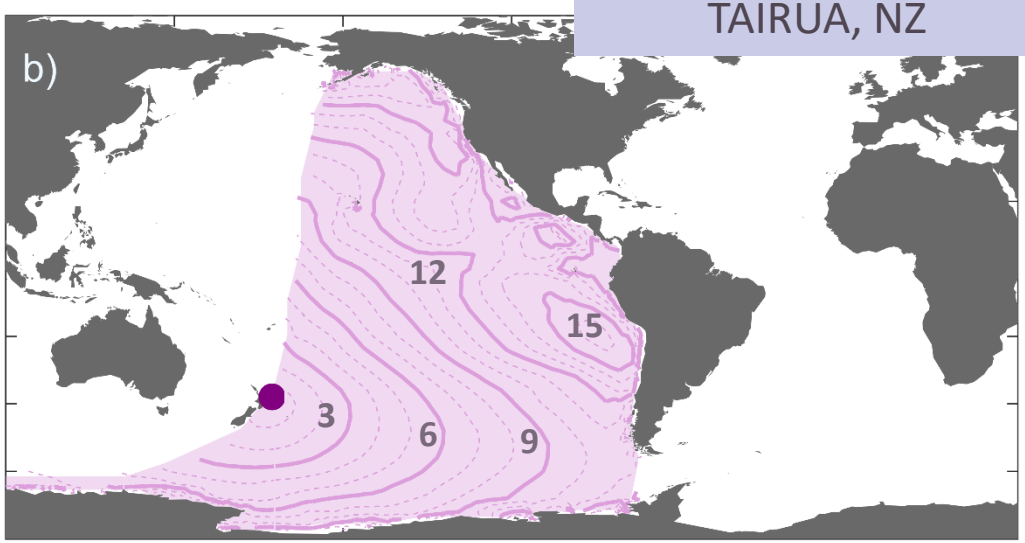


STUDY SITES

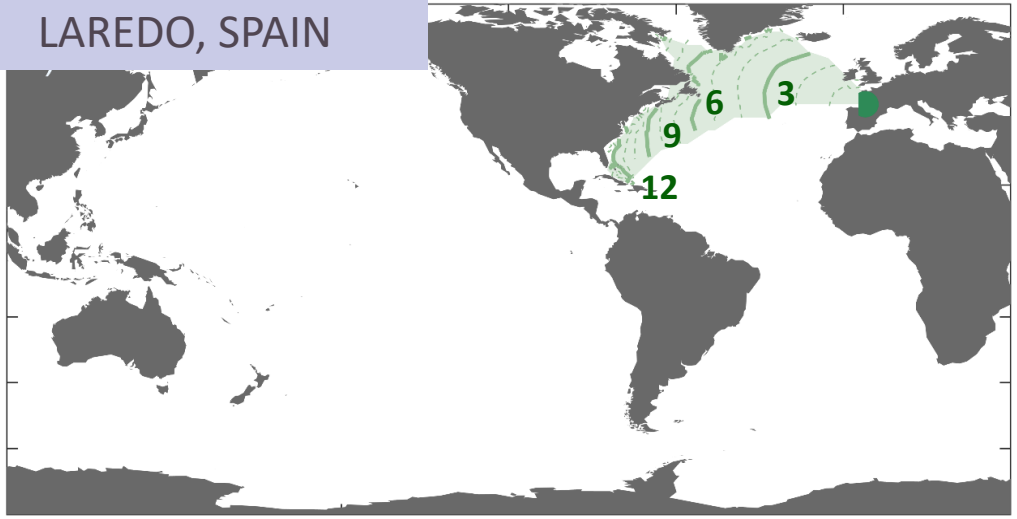
IMPERIAL BEACH, US



TAIRUA, NZ



LAREDO, SPAIN



	WAVE DATA	STORM SURGE DATA
IMPERIAL BEACH	BUOY	TIDAL GAUGE
TAIRUA	High Res. Wave Hindcast (SWAN)	REANALYSIS (DAC, Carrere & Lyard 2003)
LAREDO	BUOY	REANALYSIS (GOS, Cid et al., 2014)

● MODEL ● INSTRUMENTAL

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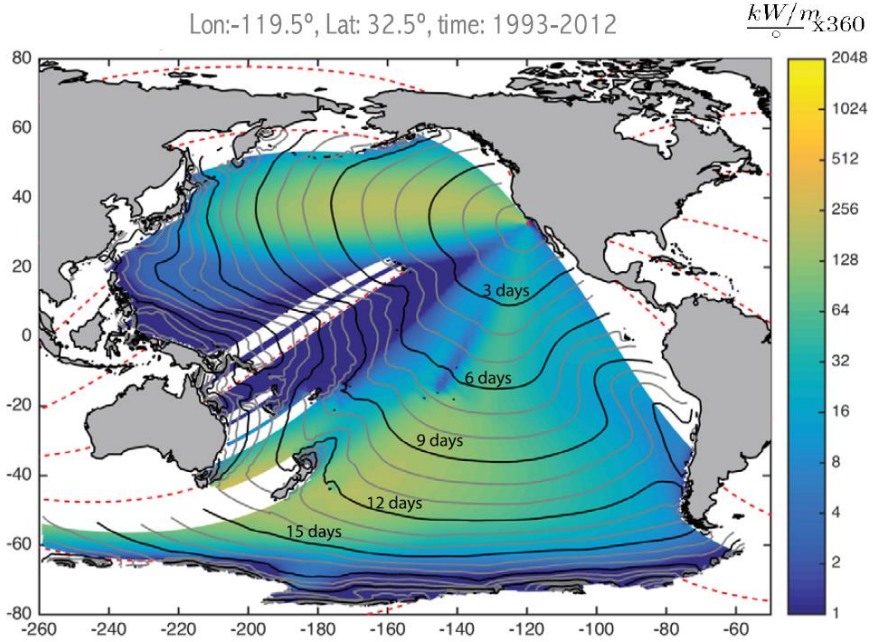
BUILDING THE EMULATOR: IMPERIAL BEACH

WAVE GENERATION AREA
(ESTELA, Perez et al., 2014)



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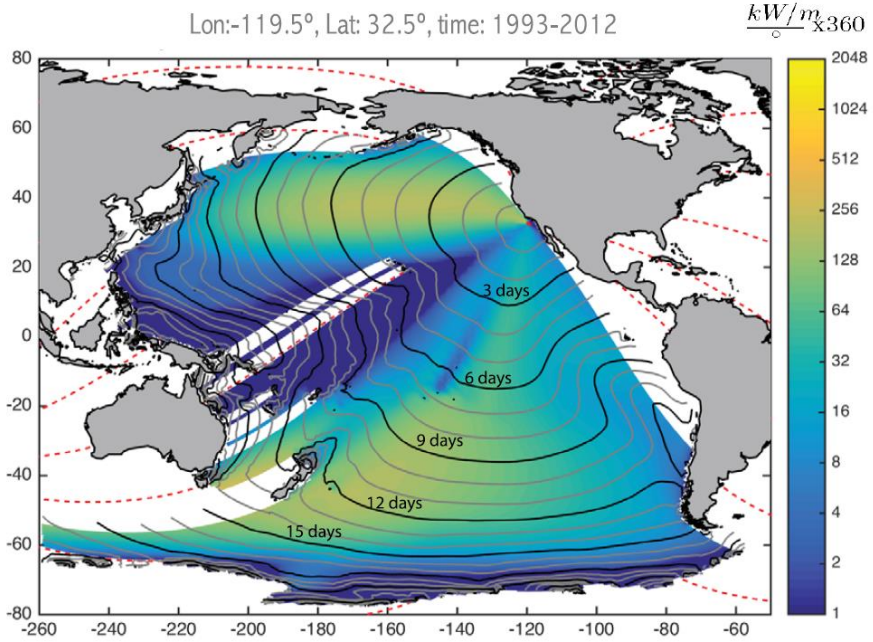
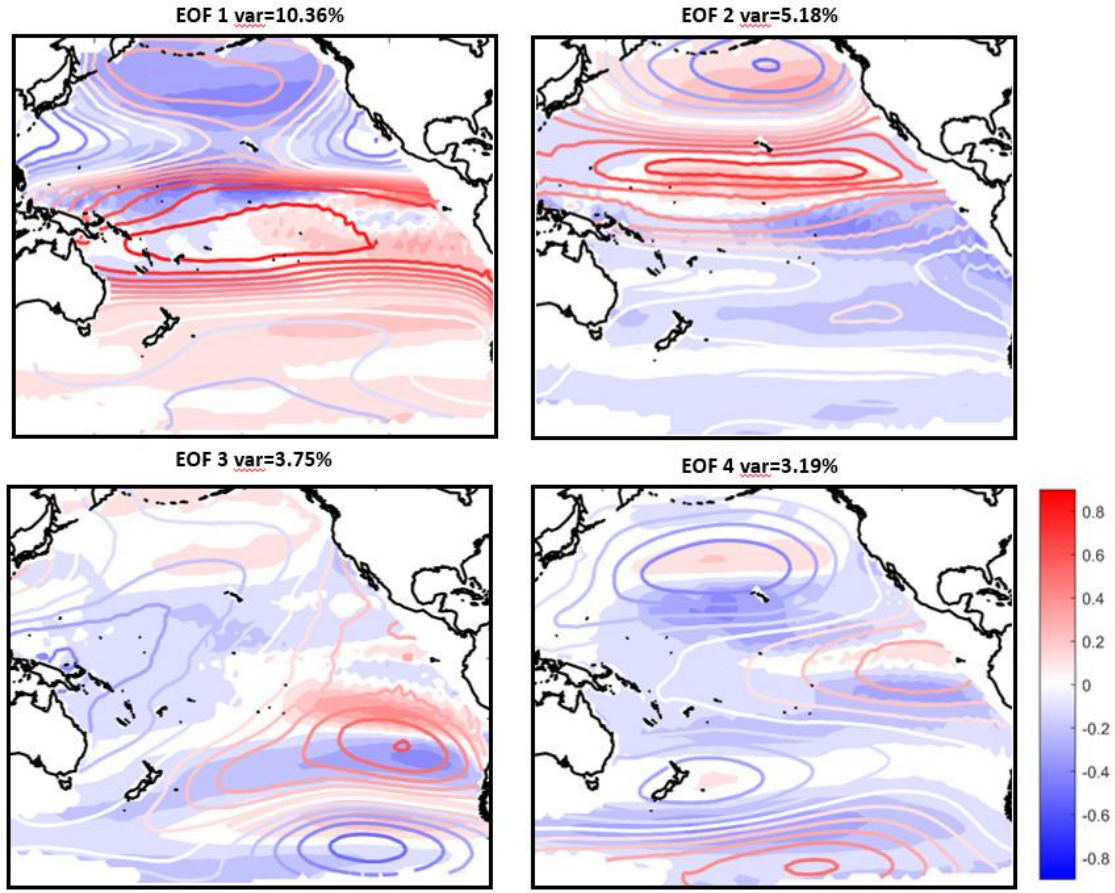


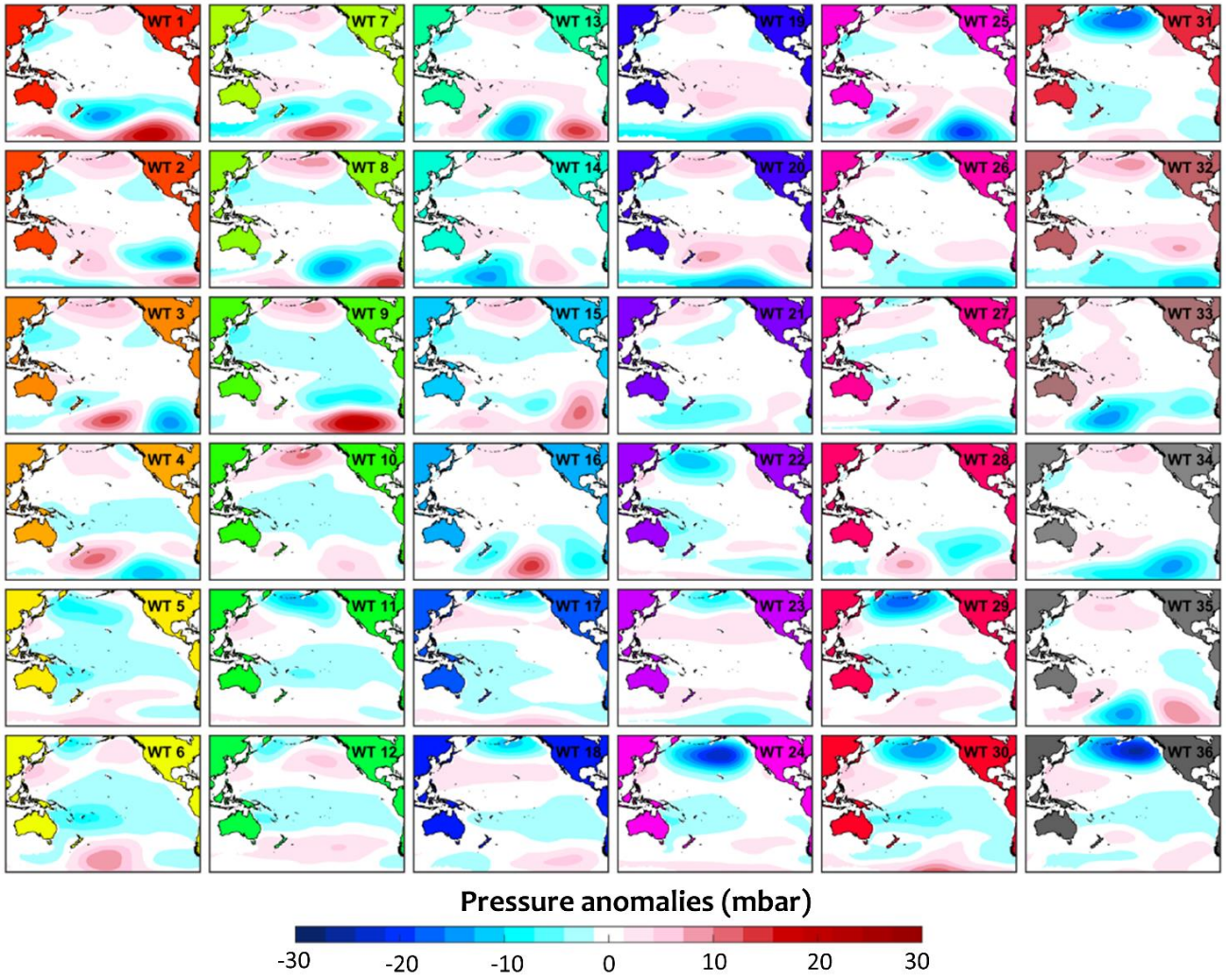
PRINCIPAL COMPONENT ANALYSIS
SLP and SLP Gradients



KEEP THE PCs EXPLAINING 95% OF THE VARIANCE

BUILDING THE EMULATOR: IMPERIAL BEACH

REGRESSION-GUIDED K-MEANS, Camus et al., 2016



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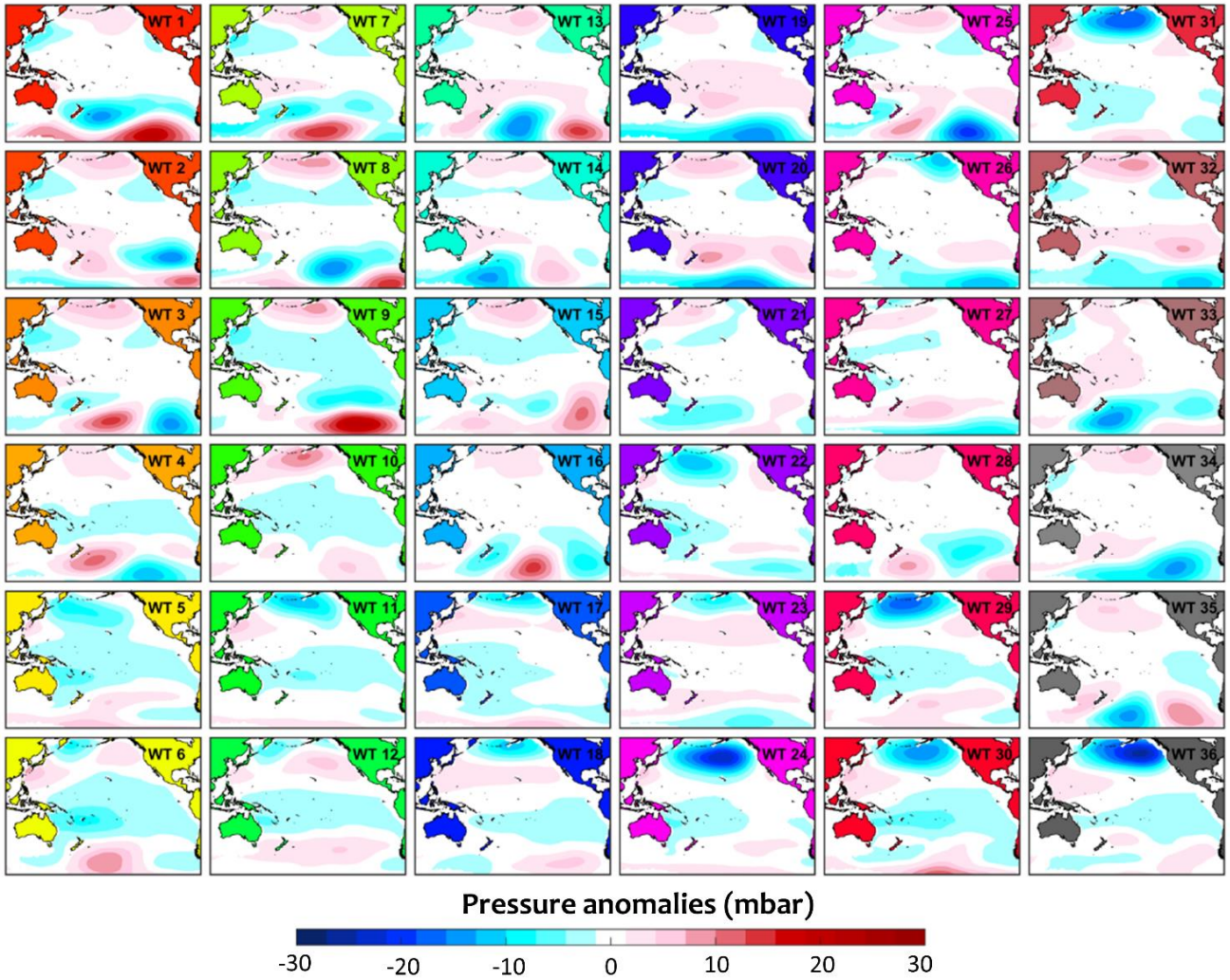
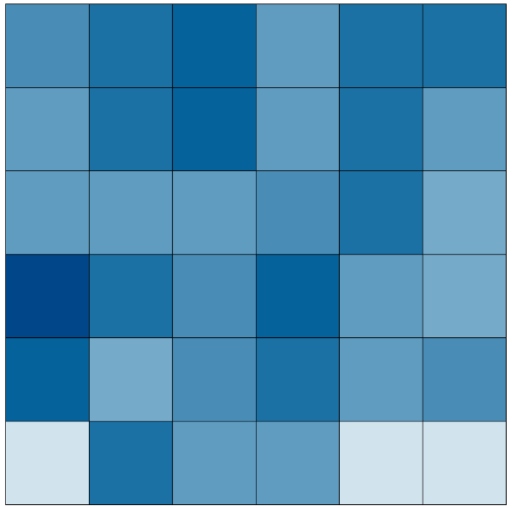
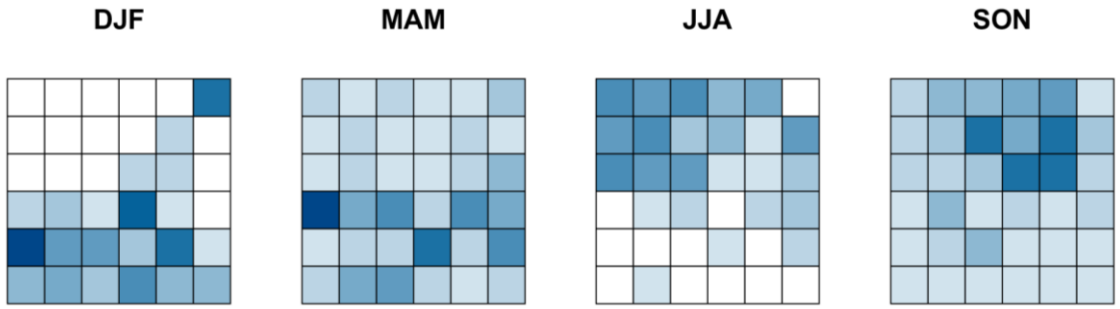


Probability





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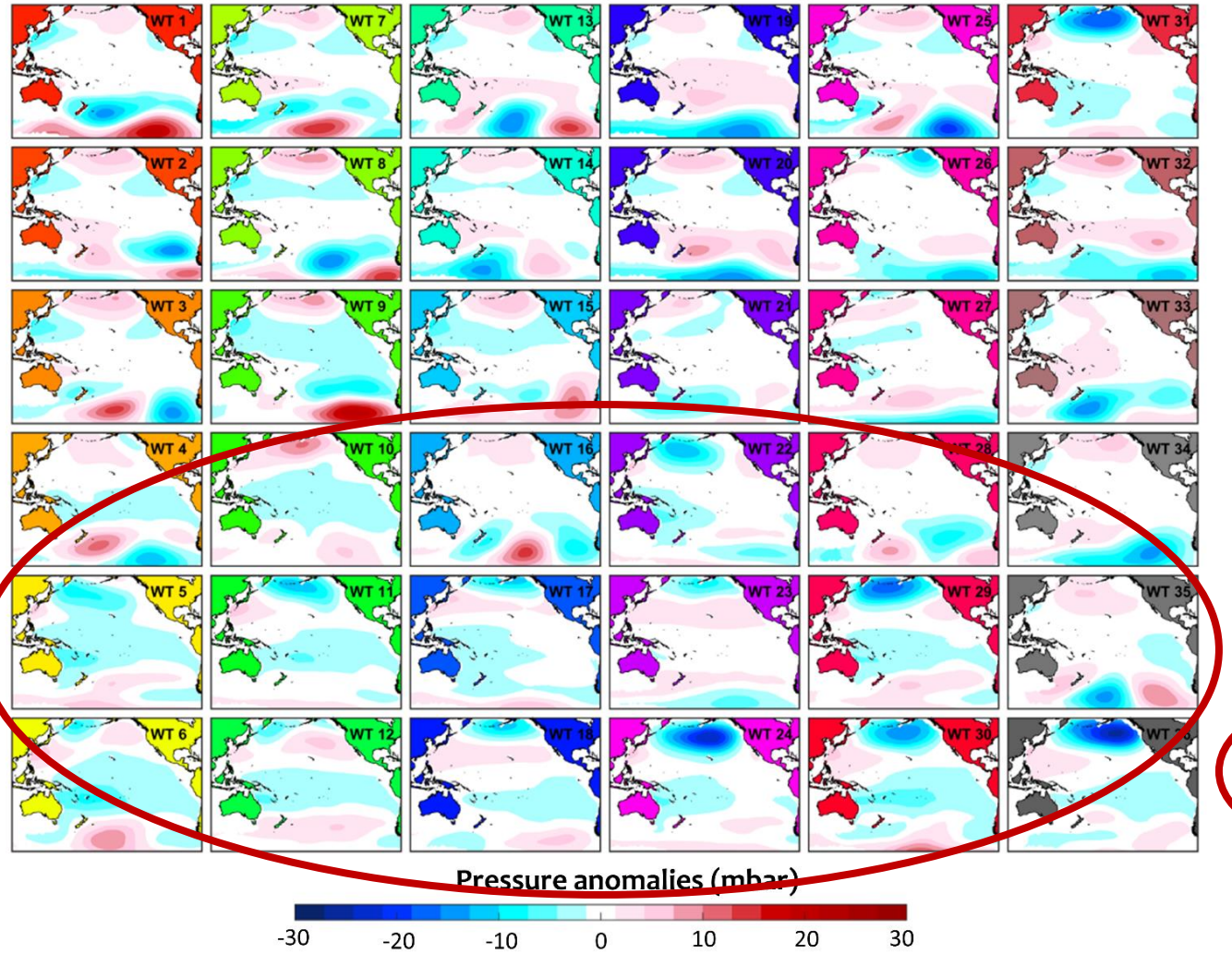

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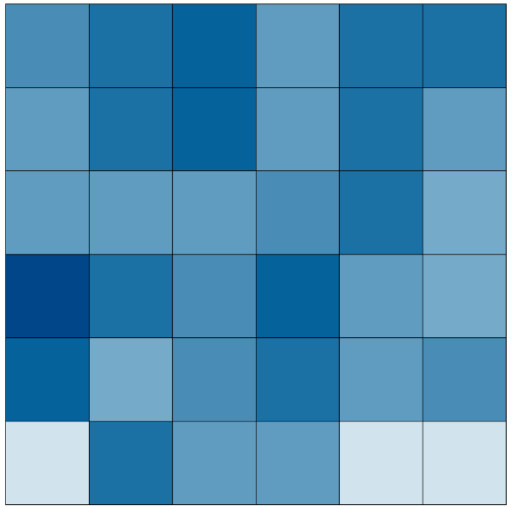

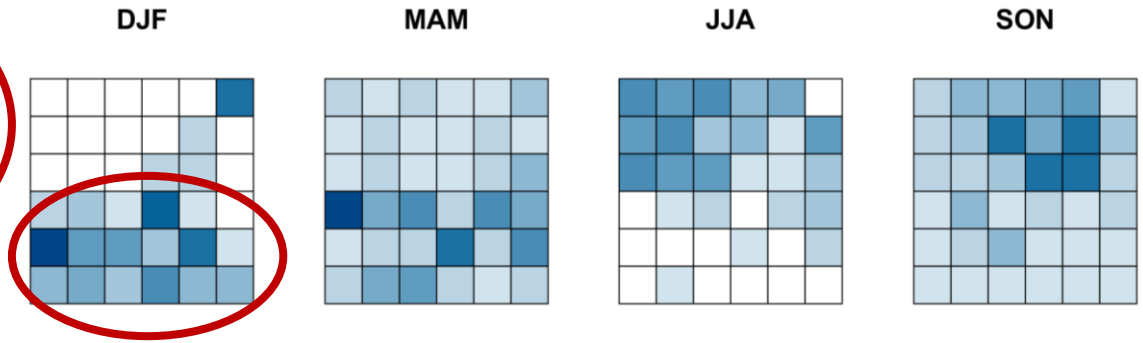

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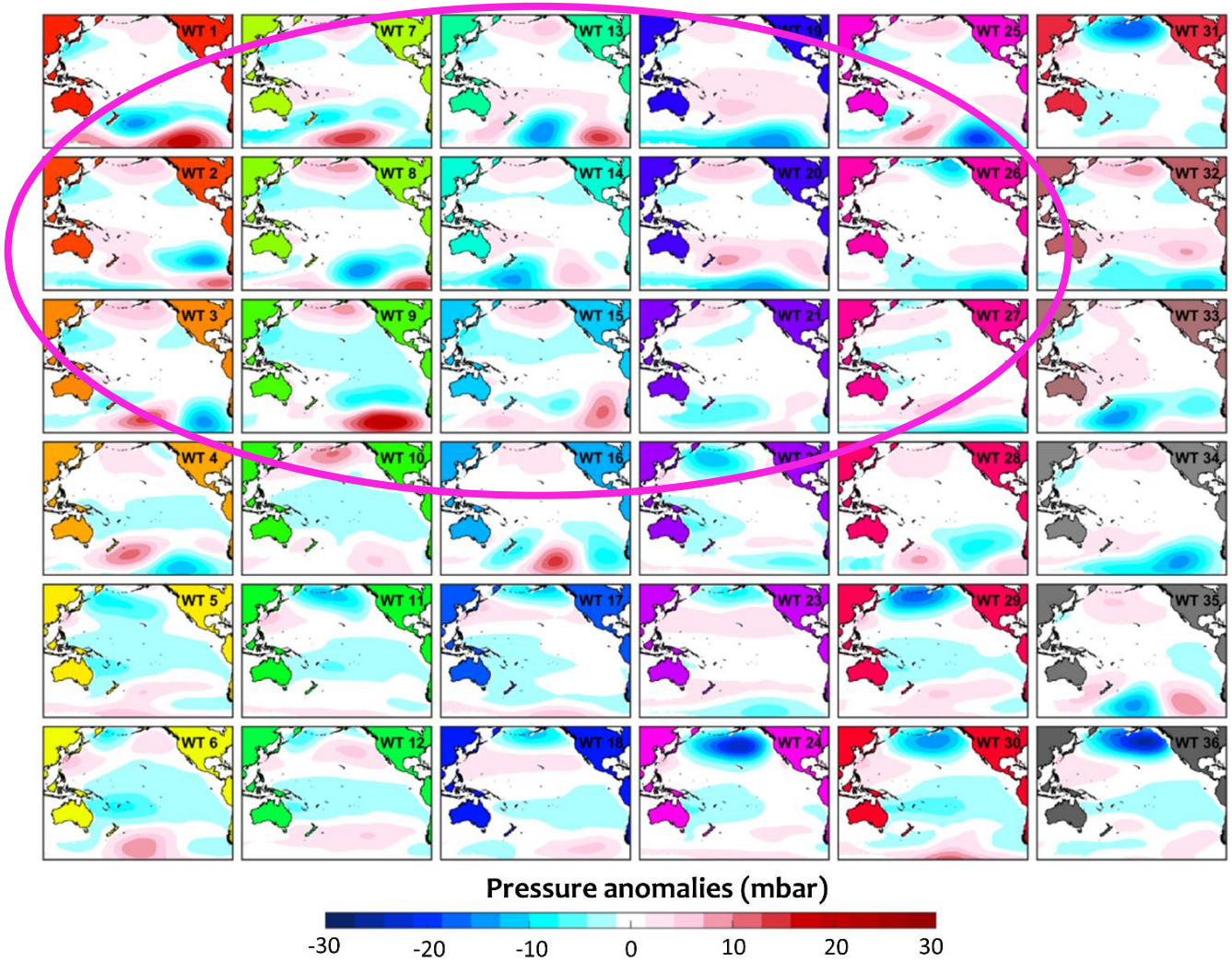

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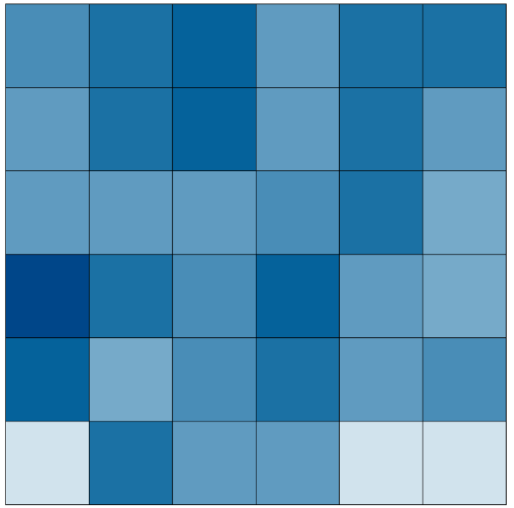
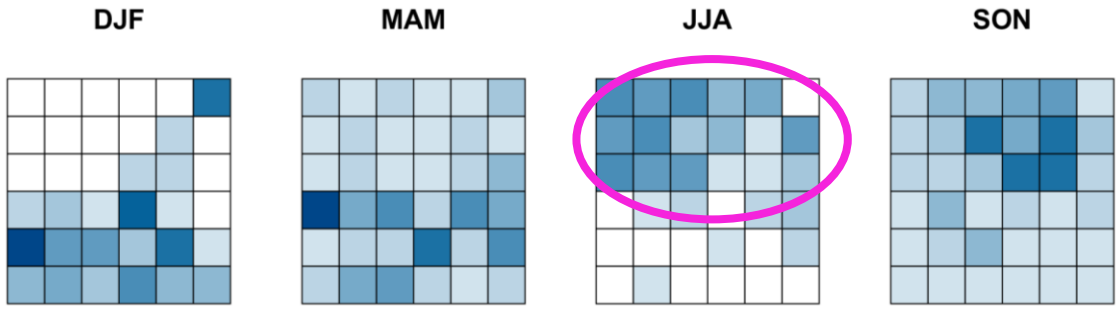
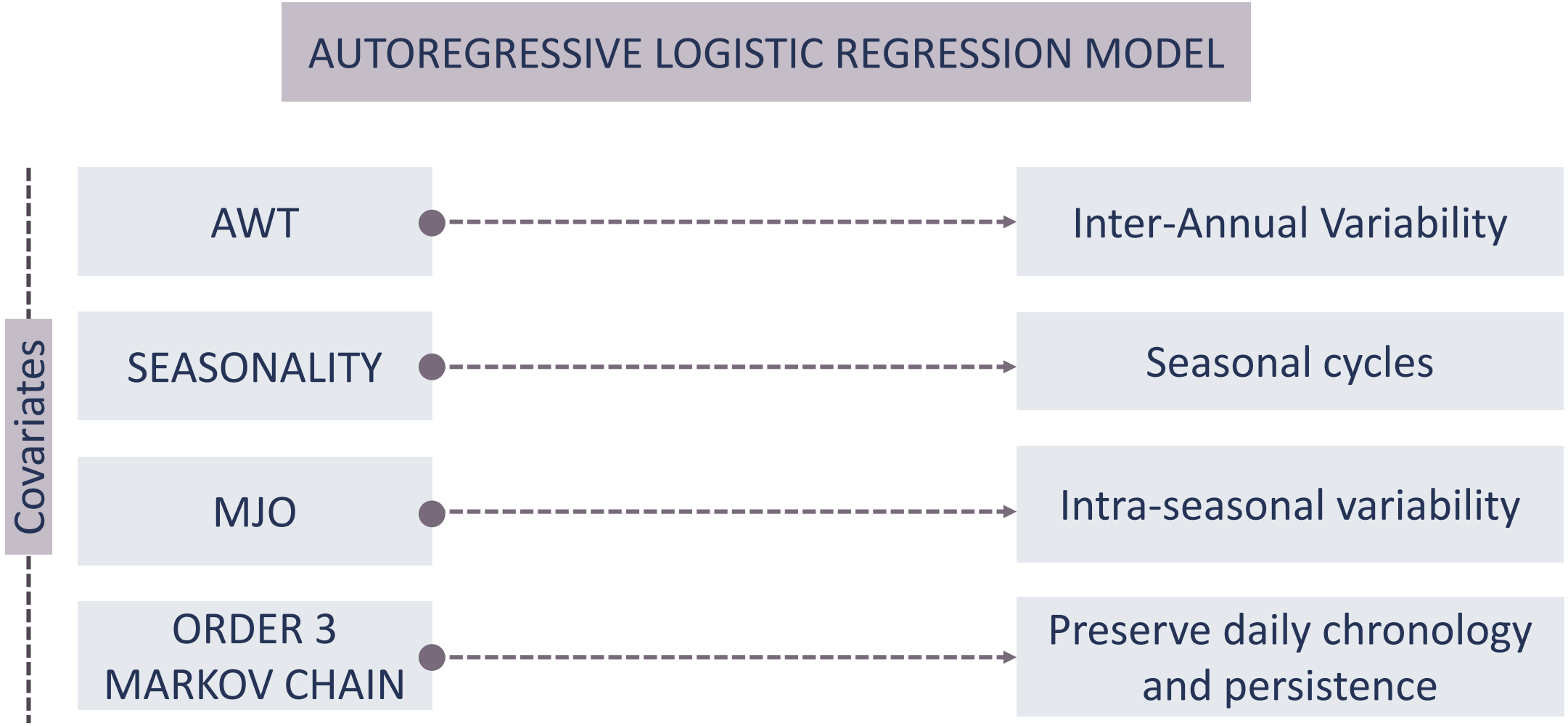


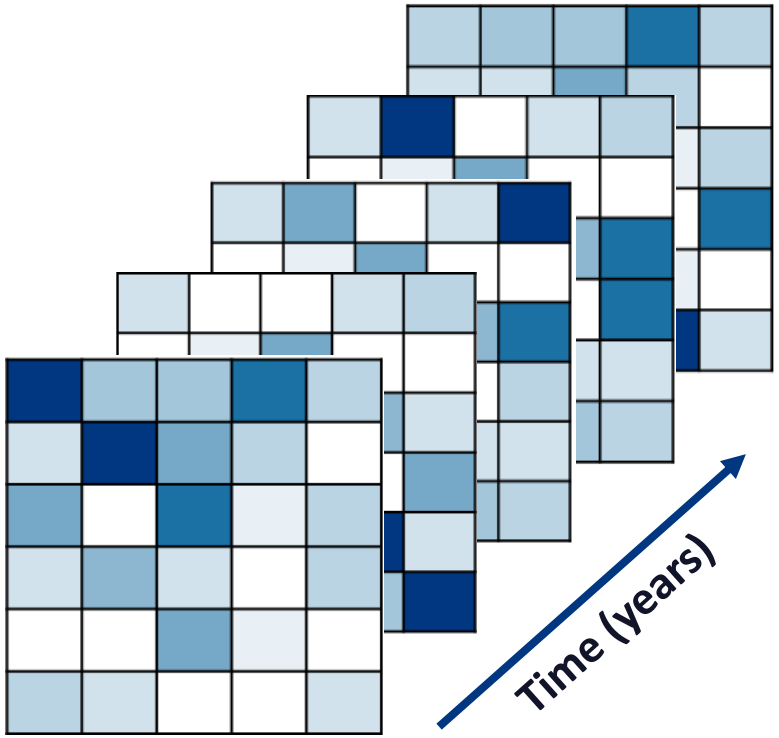


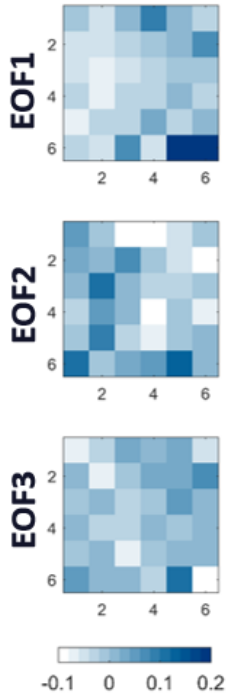
CHRONOLOGY MODEL

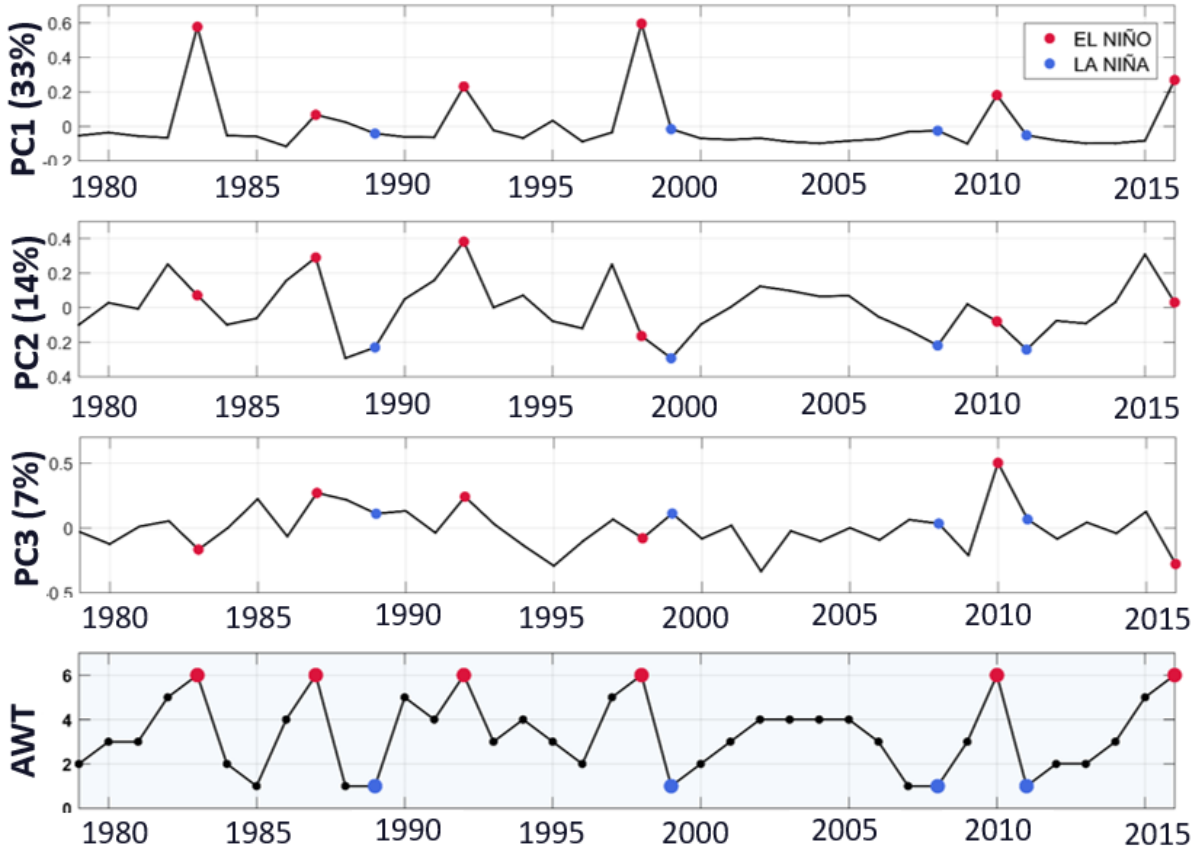


Anderson et al., 2019

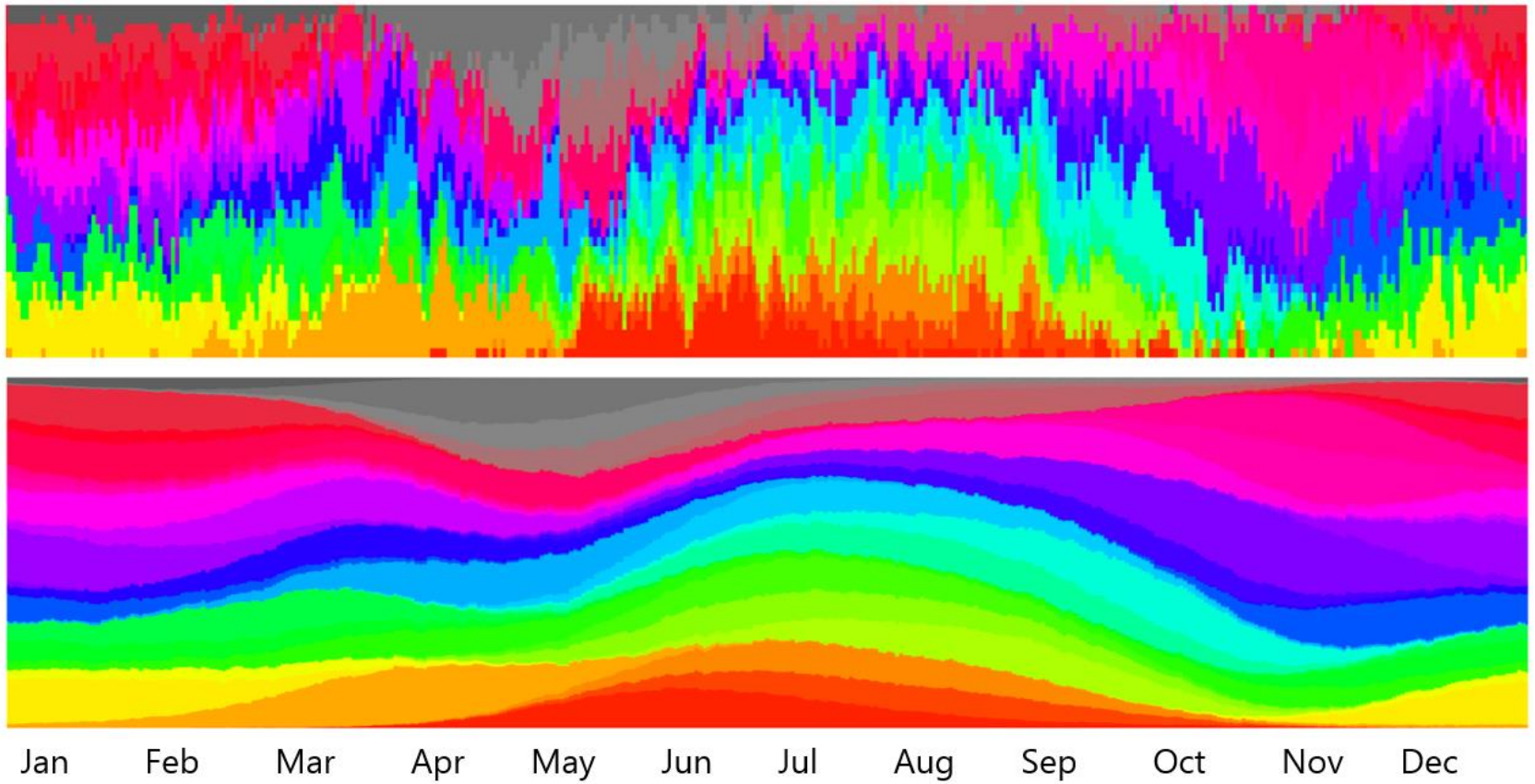
PREDICTORS : ANNUAL WEATHER TYPE

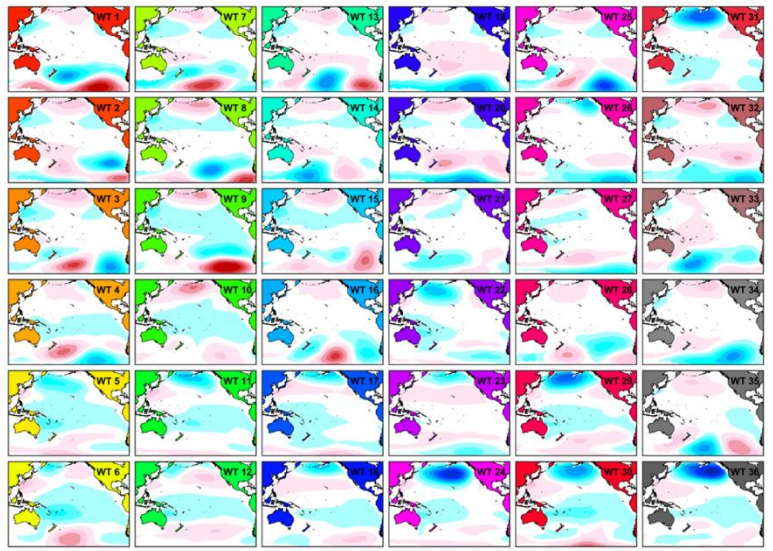






ALR : DAILY WT vs PERPETUAL YEAR





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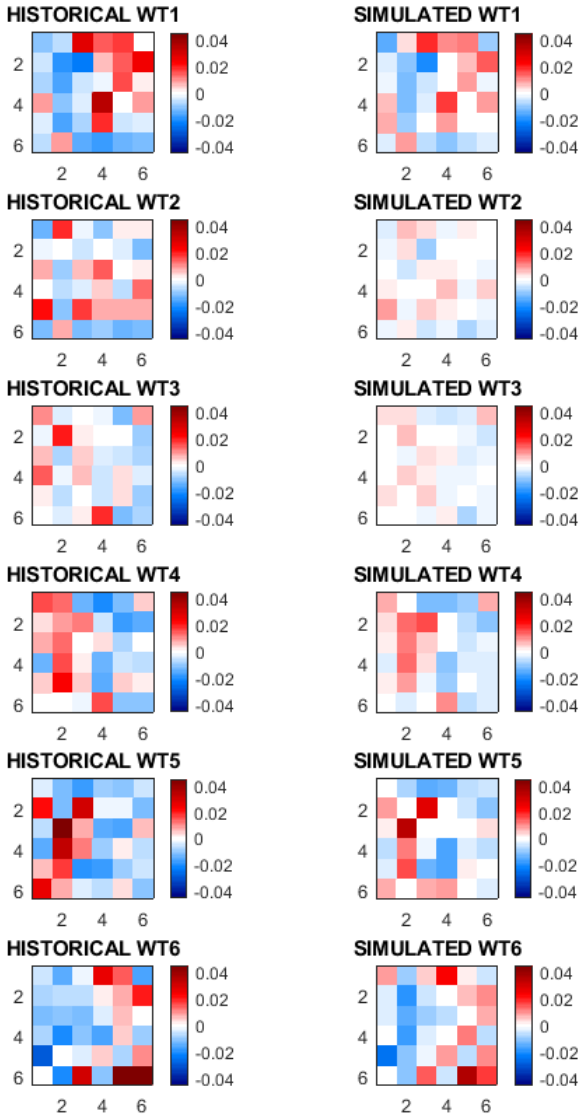

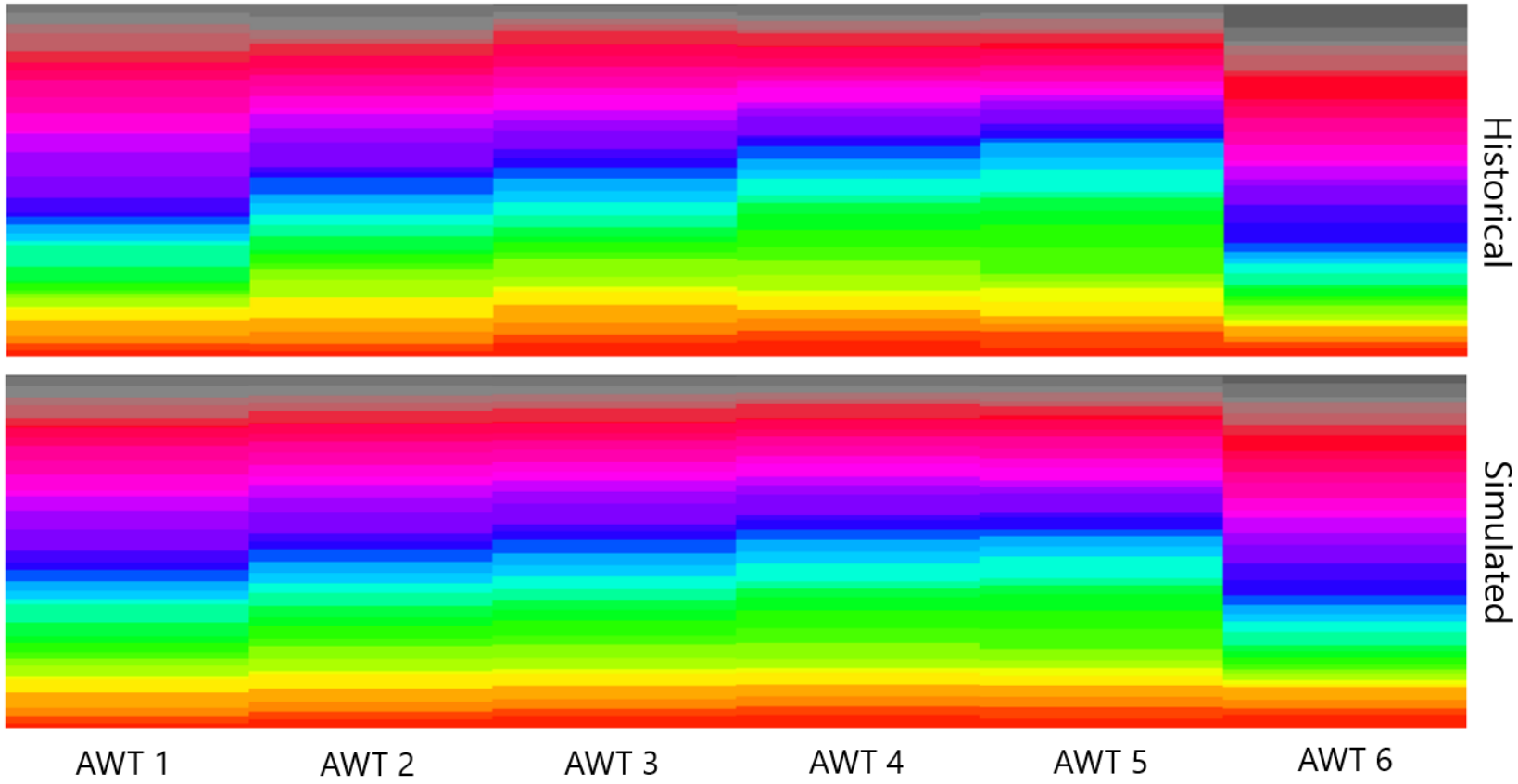

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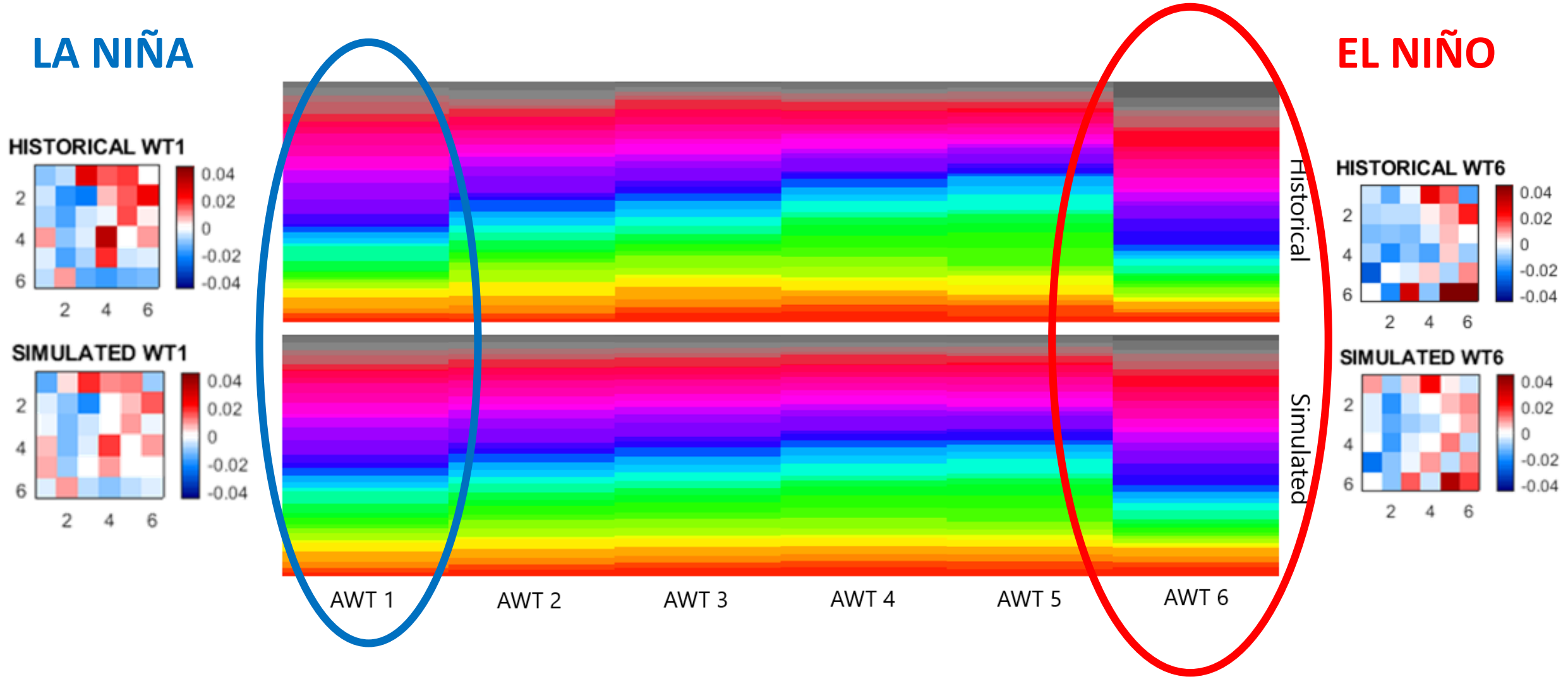
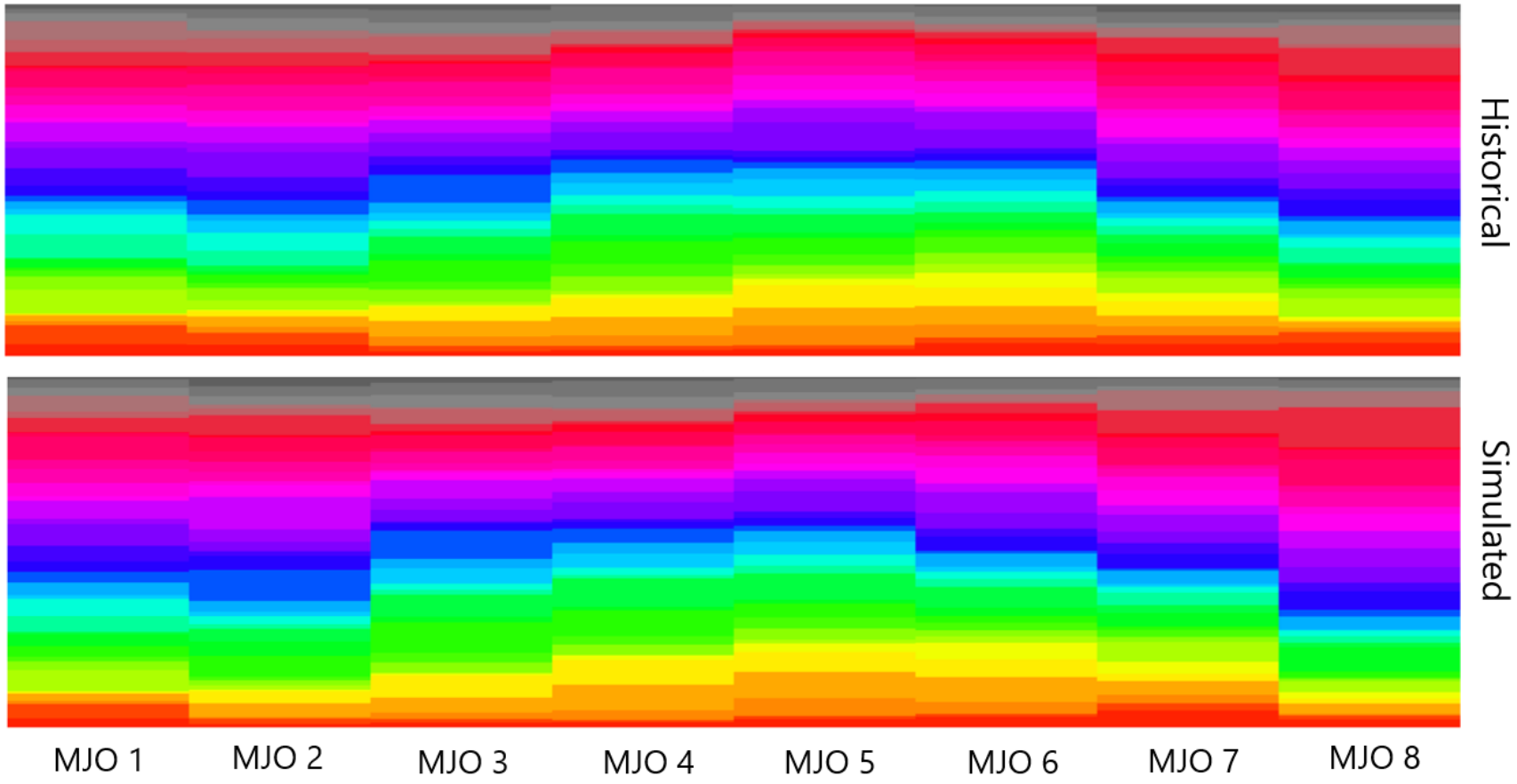
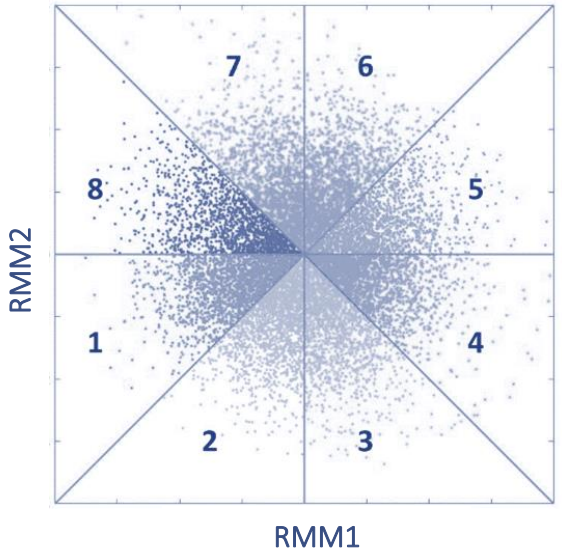
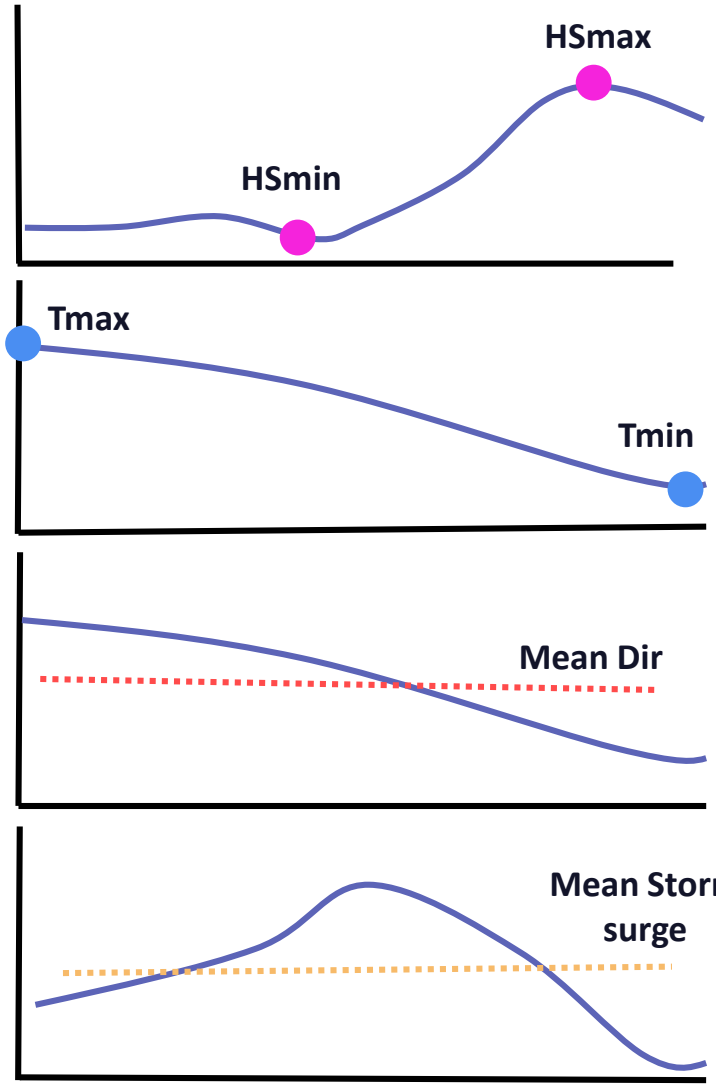


ALR : DAILY WT vs MADDEN JULIAN OSCILLATION



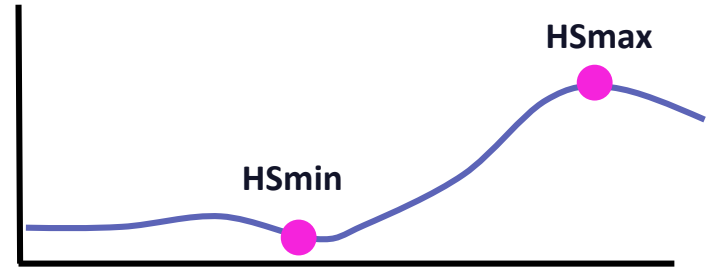


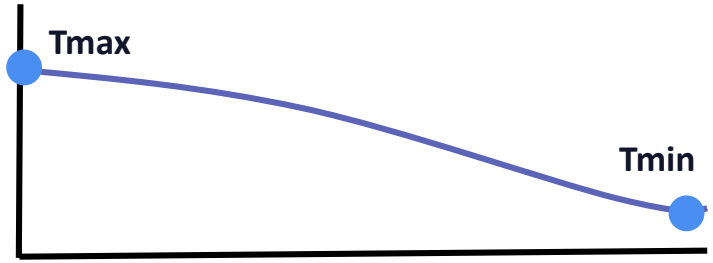
STRETCHING

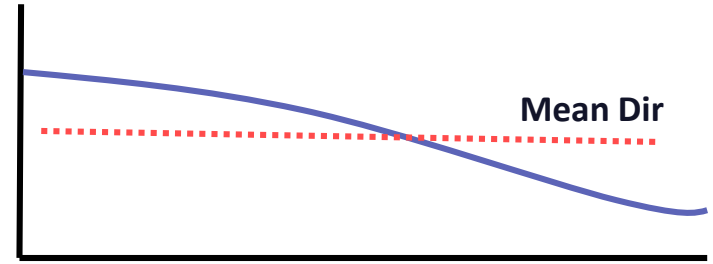


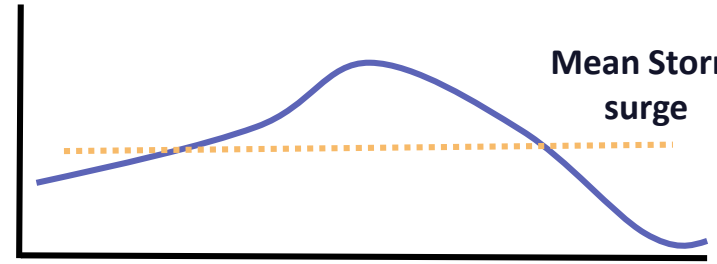
WT9	WT 1	WT1	WT1	WT1	WT15

STRETCHING



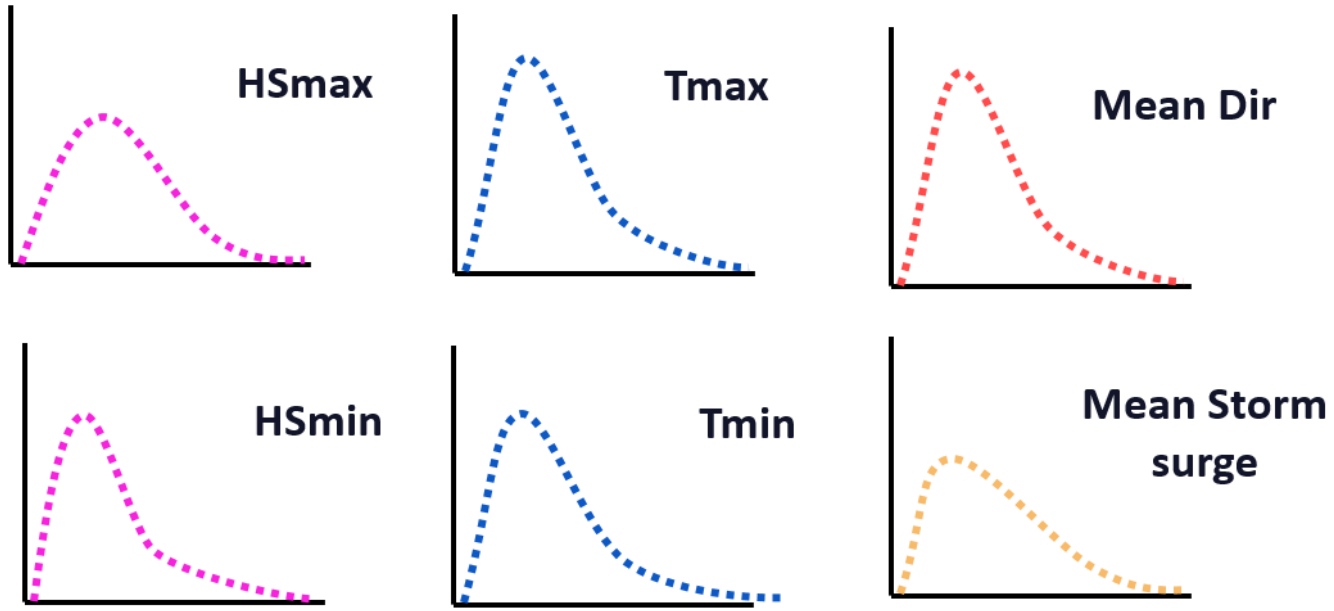




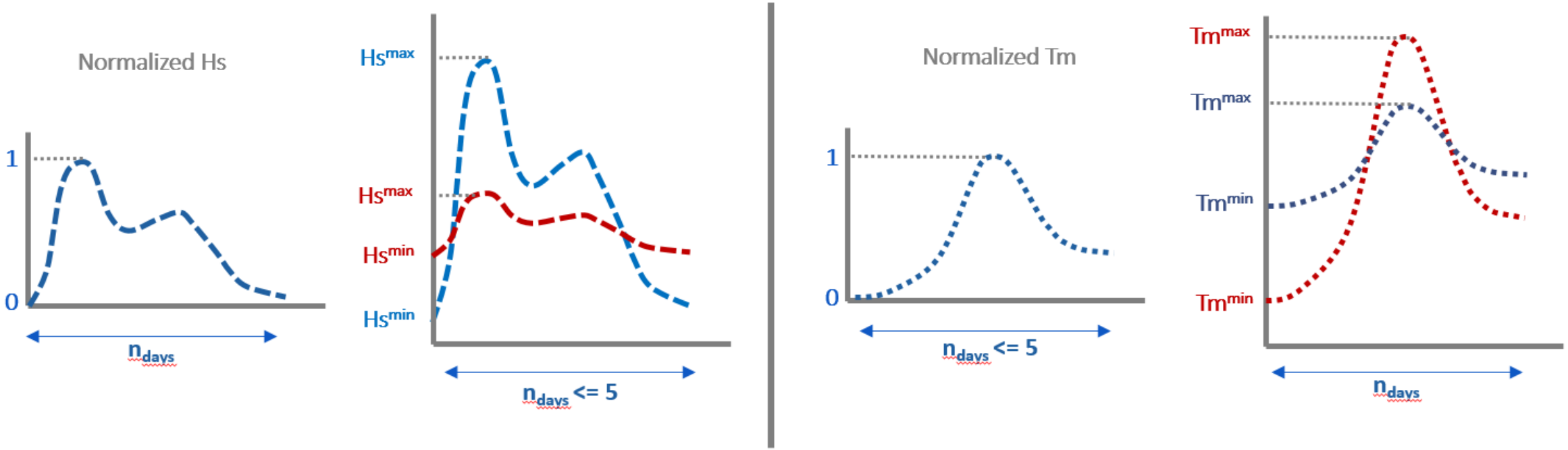


WT9	WT 1	WT1	WT1	WT1	WT15

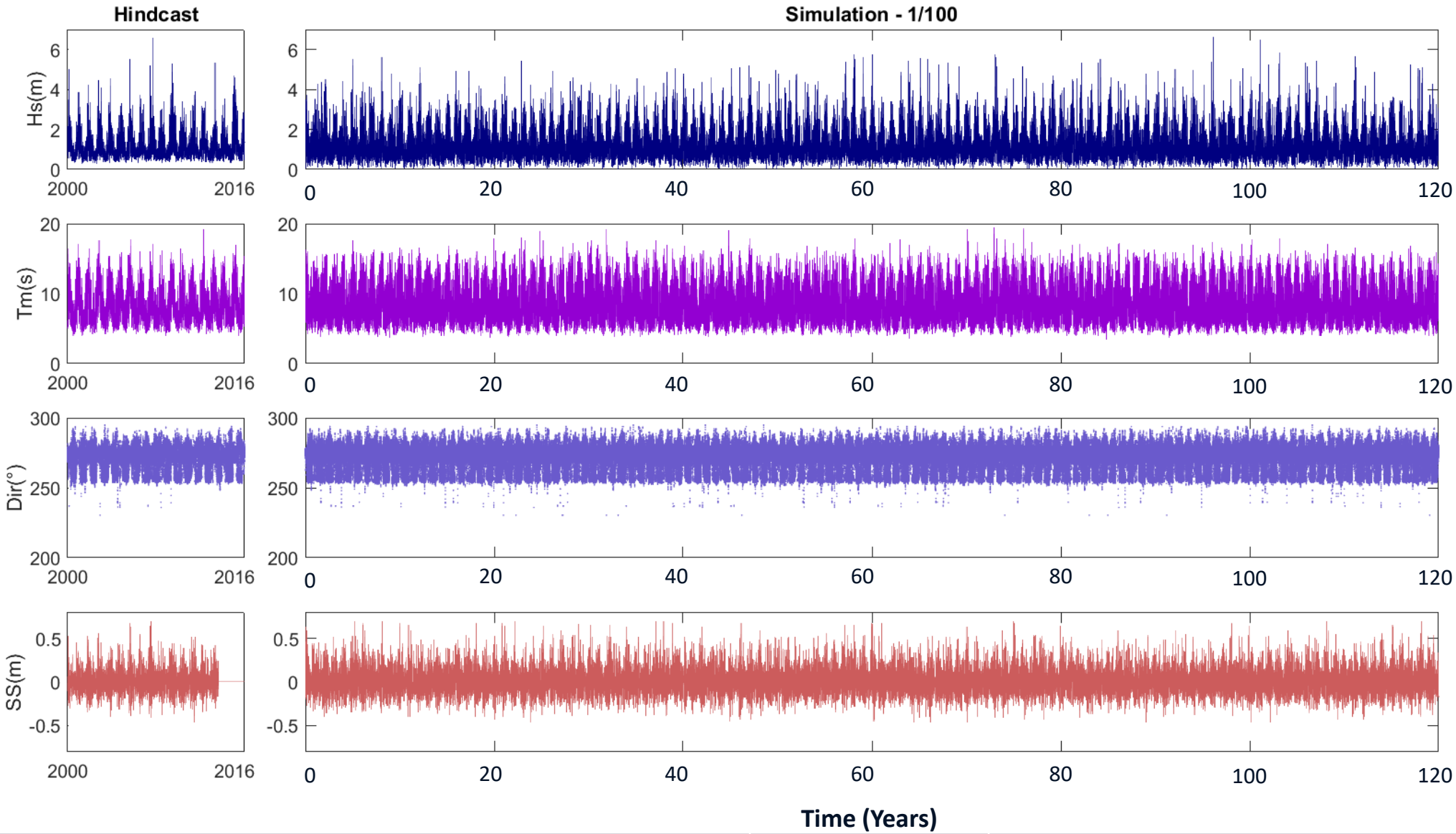
GAUSSIAN COPULA



MONTECARLO SIMULATION



EMULATOR : IMPERIAL BEACH



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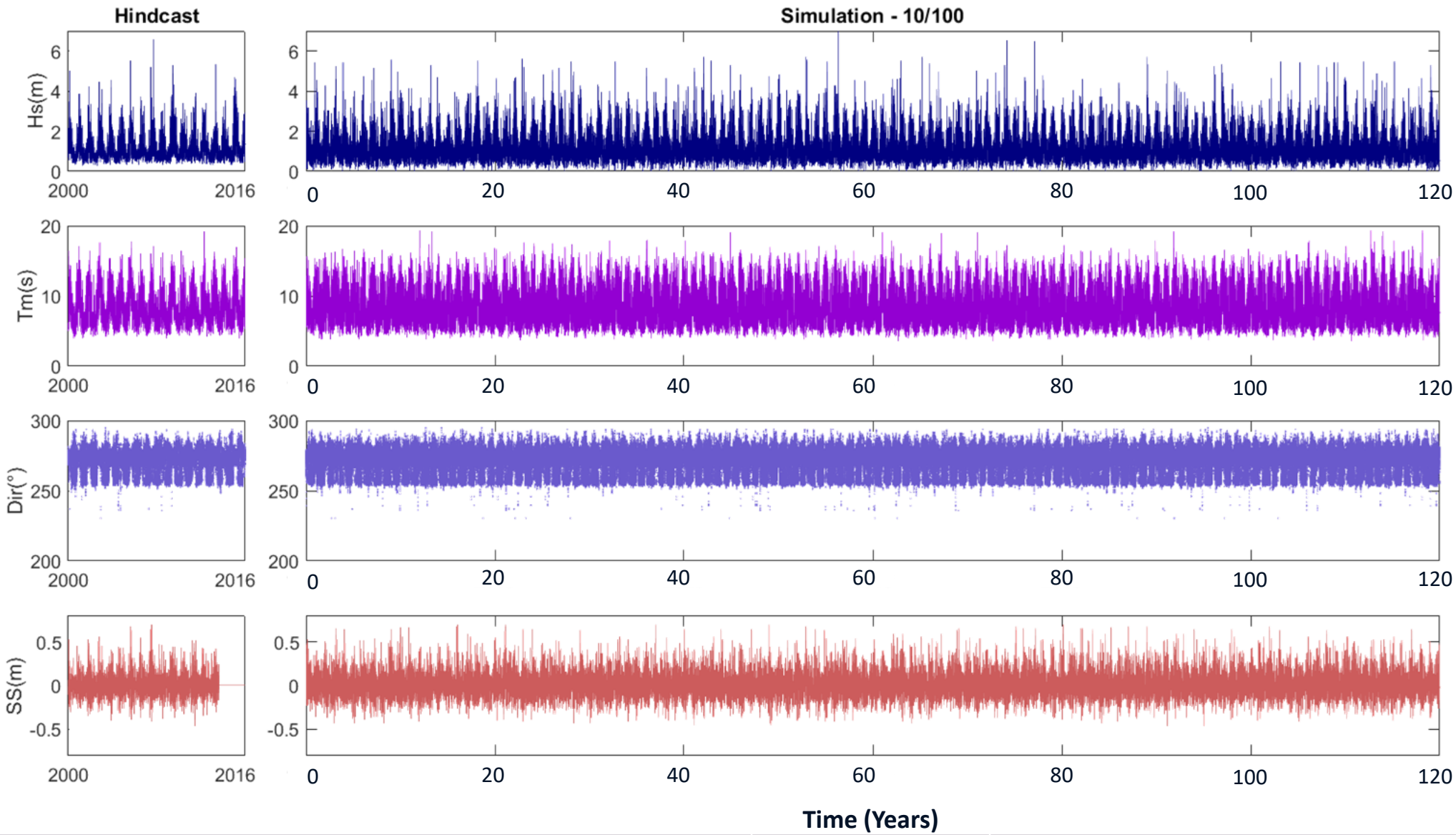

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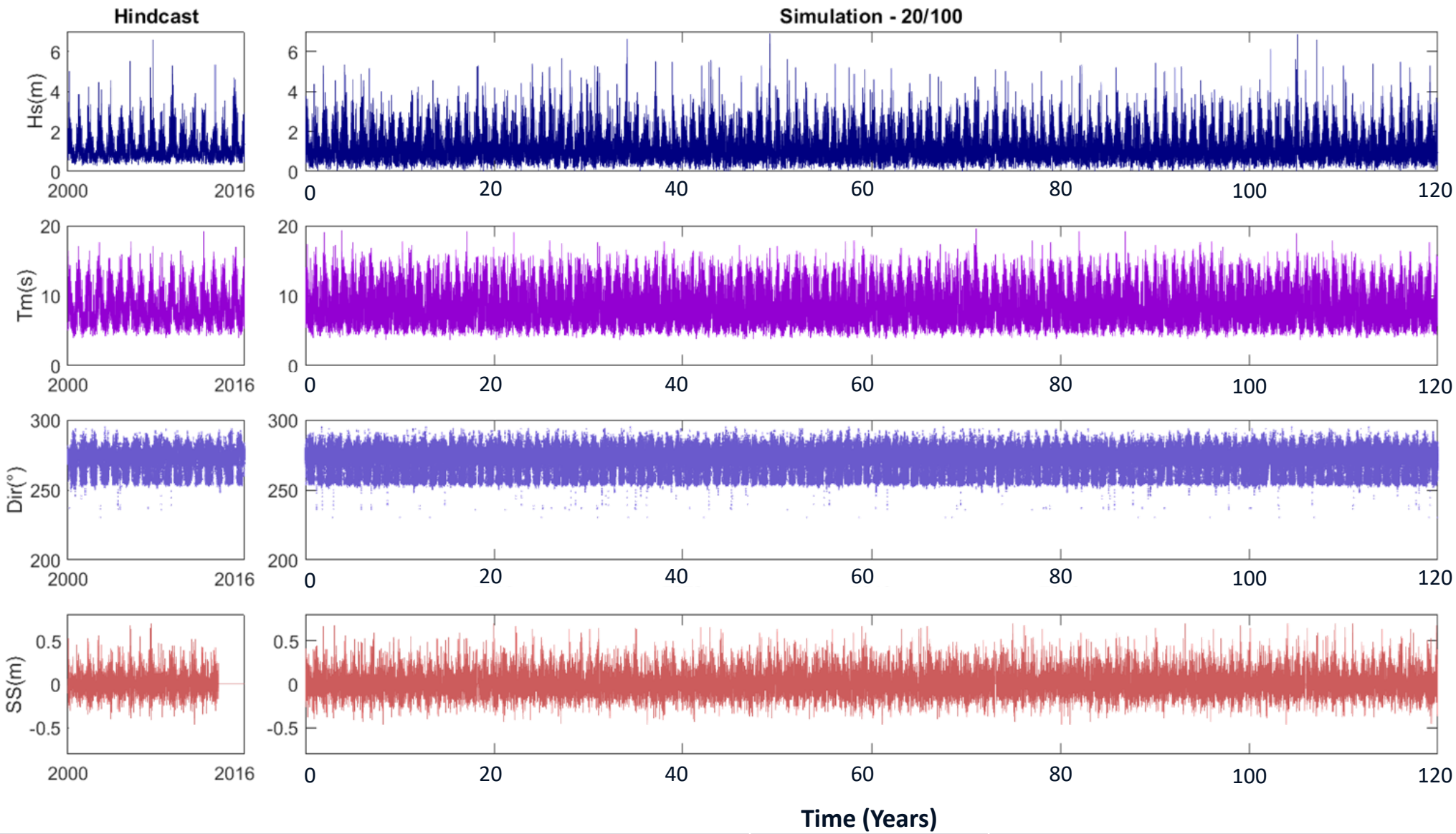
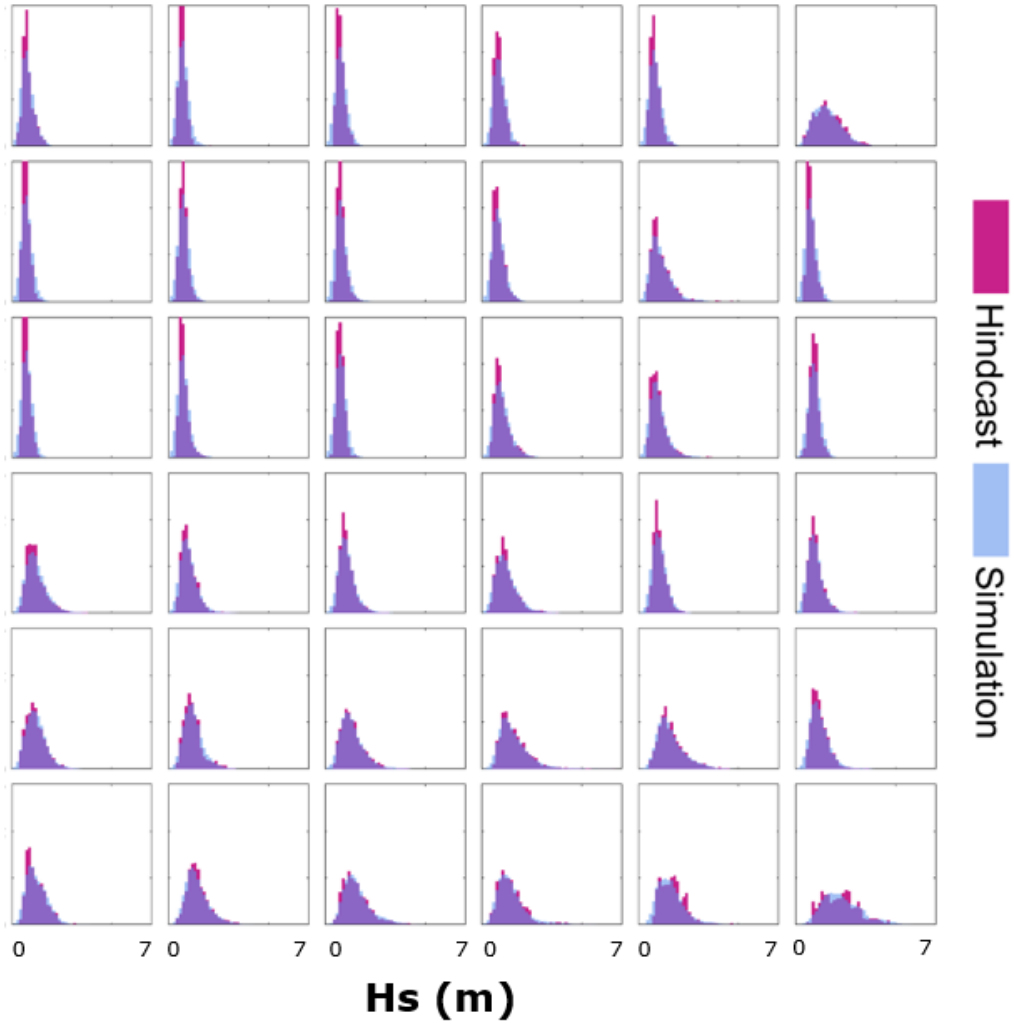
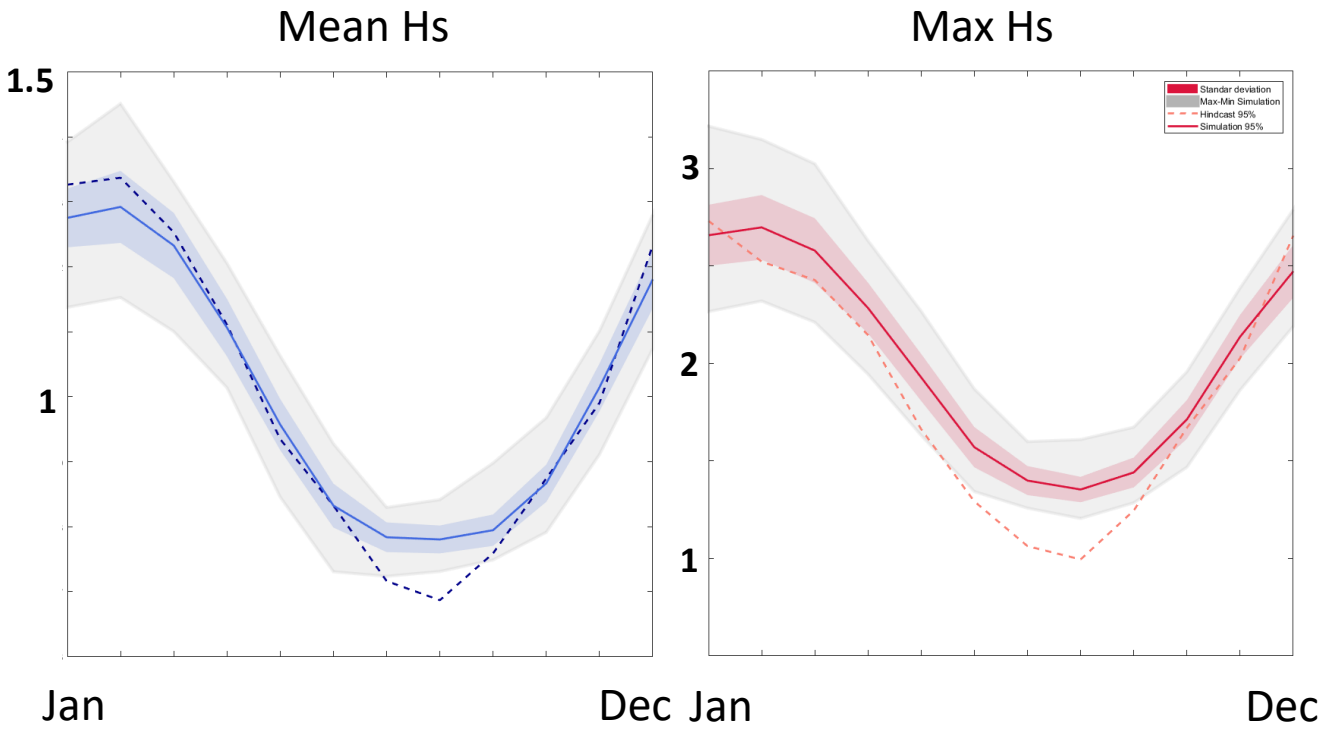
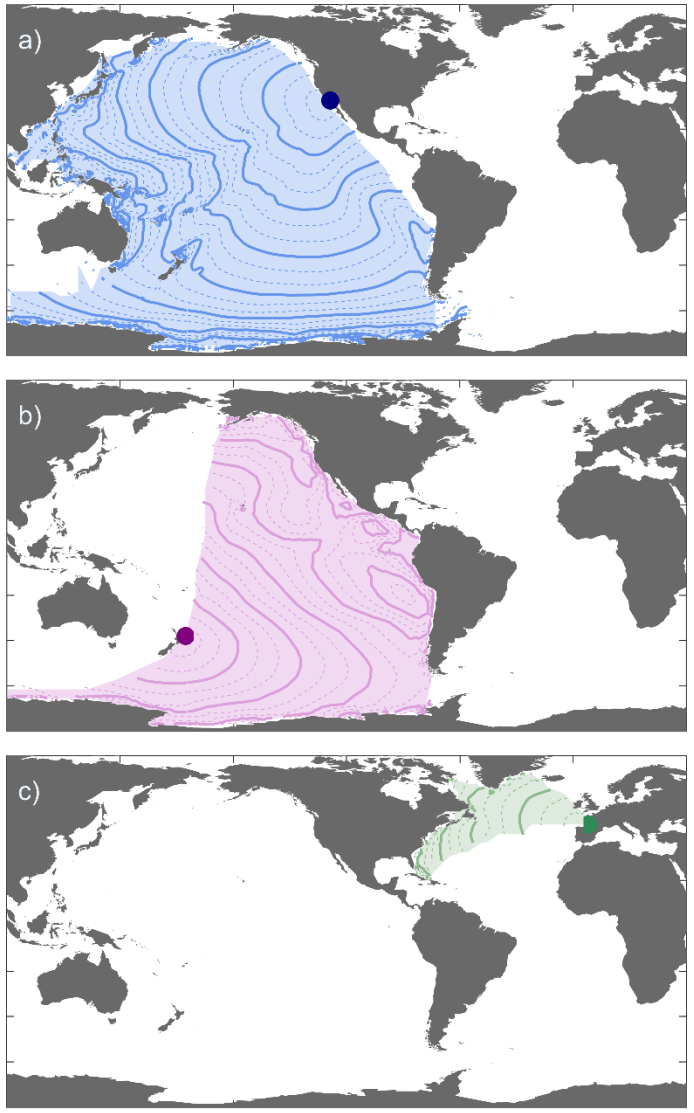


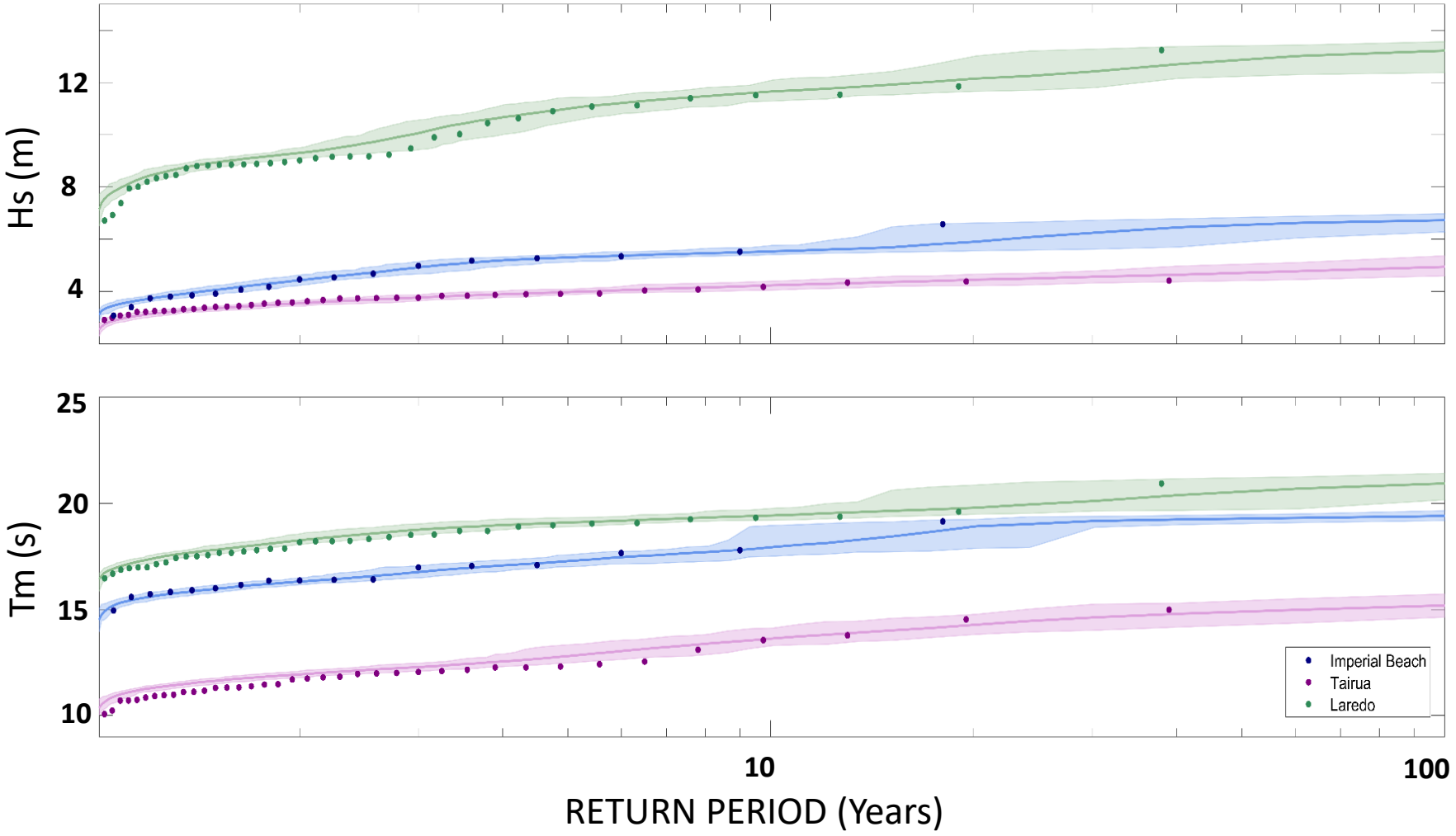
COMPARISON: MEAN REGIME





COMPARISON: EXTREME REGIME





The problem

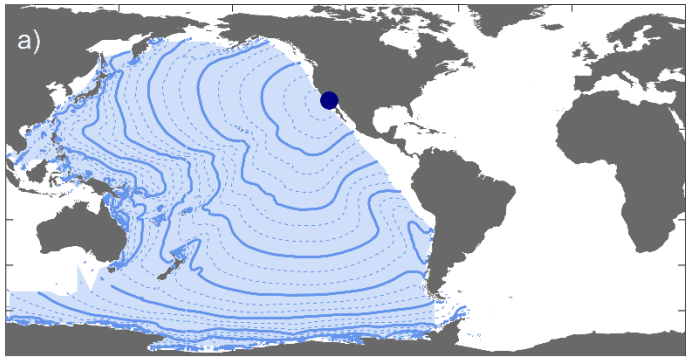
Methodology

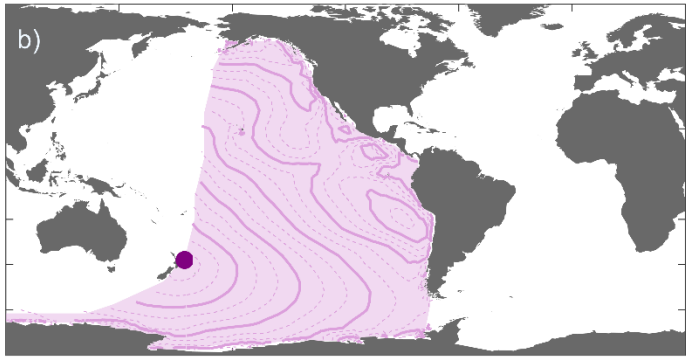
The emulator

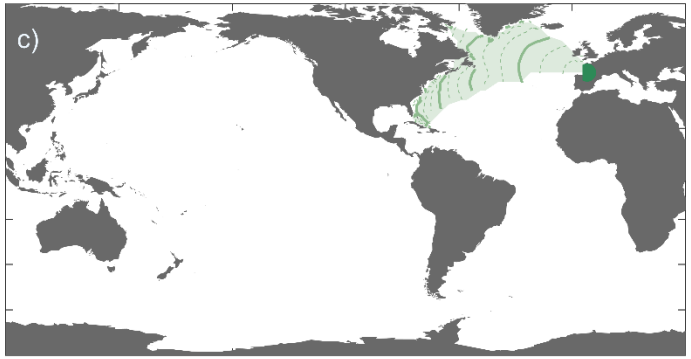
Applications

Summary

APPLICATIONS







LONG-SHORE WAVE POWER : IMPERIAL BEACH

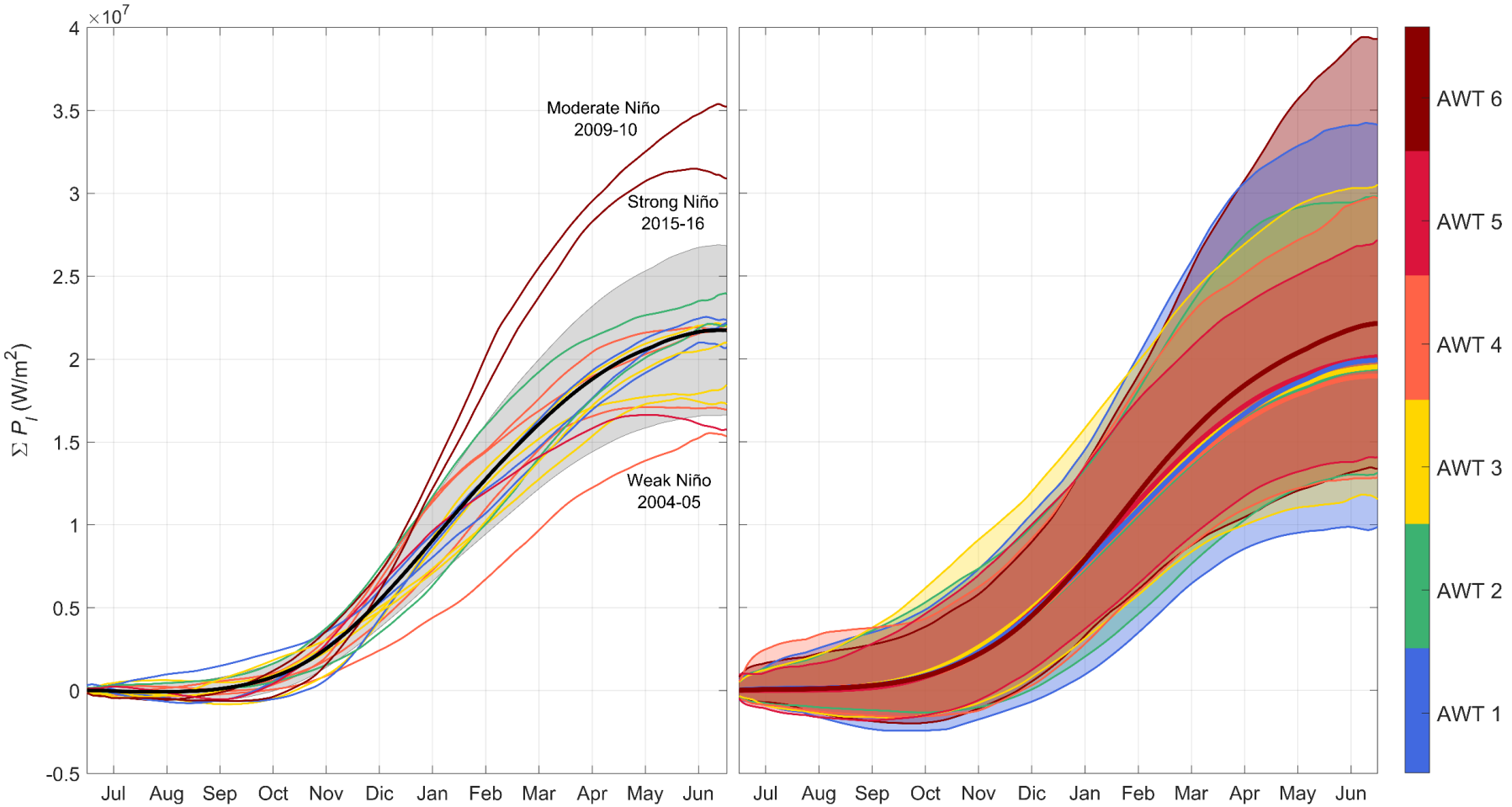
CROSS-SHORE EROSION : TAIRUA BEACH

BEACH ROTATION : LAREDO

LONG-SHORE WAVE POWER : IMPERIAL BEACH

CERC FORMULA (Komar, 1998)

$$P = ECn\sin(\theta)\,cos(\theta) = \frac{1}{8}\rho_w g H^2 Cn \sin(\theta)\,cos(\theta)$$



6° north shift on directions during El Niño 2009-2010 (Barnard et al., 2011)

Imperial beach highly eroded and flooded 2015-2016 (Young et al., 2018)

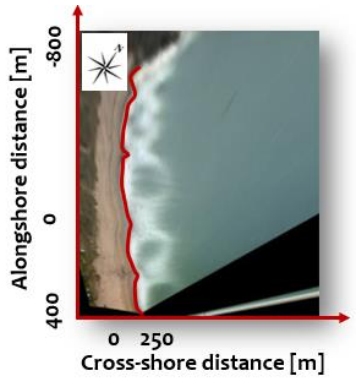
More southerly waves during La Niña

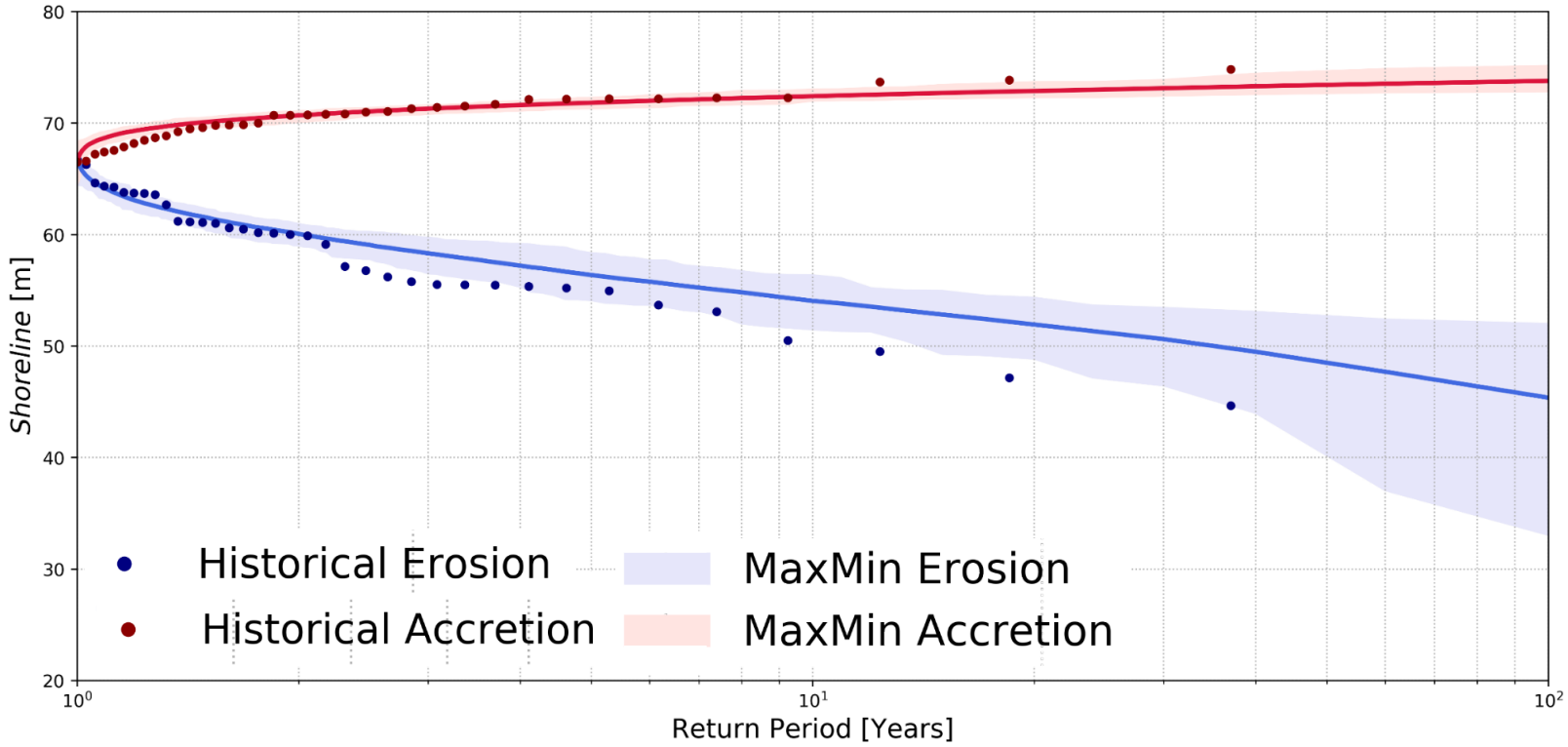
CROSS-SHORE EROSION : TAIRUA BEACH, NZ

Yates et al., 2009
Cross-Shore equilibrium model

$$\frac{dy}{dt} = C^{\pm}E^{1/2}\left(E - E_{eq}\right)$$

18 years of daily shoreline position from a camera system



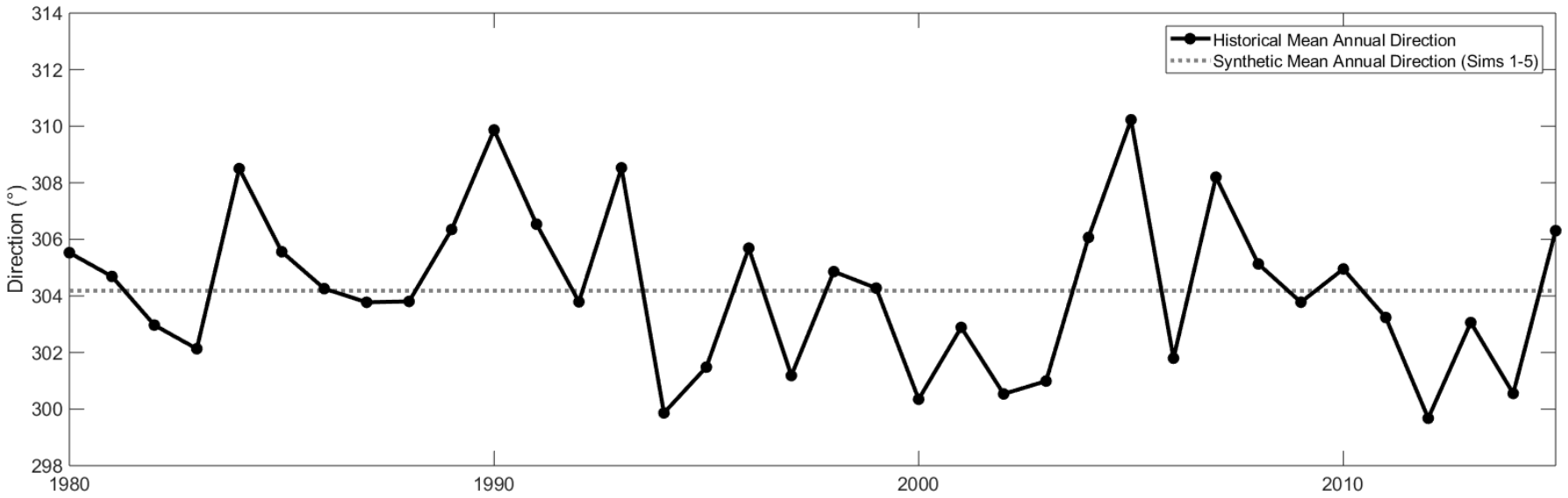


BEACH ROTATION : LAREDO, SPAIN

Shoreline change at seasonal to interannual scales

Triggered by changes on the mean wave direction

Annual mean wave direction proxy



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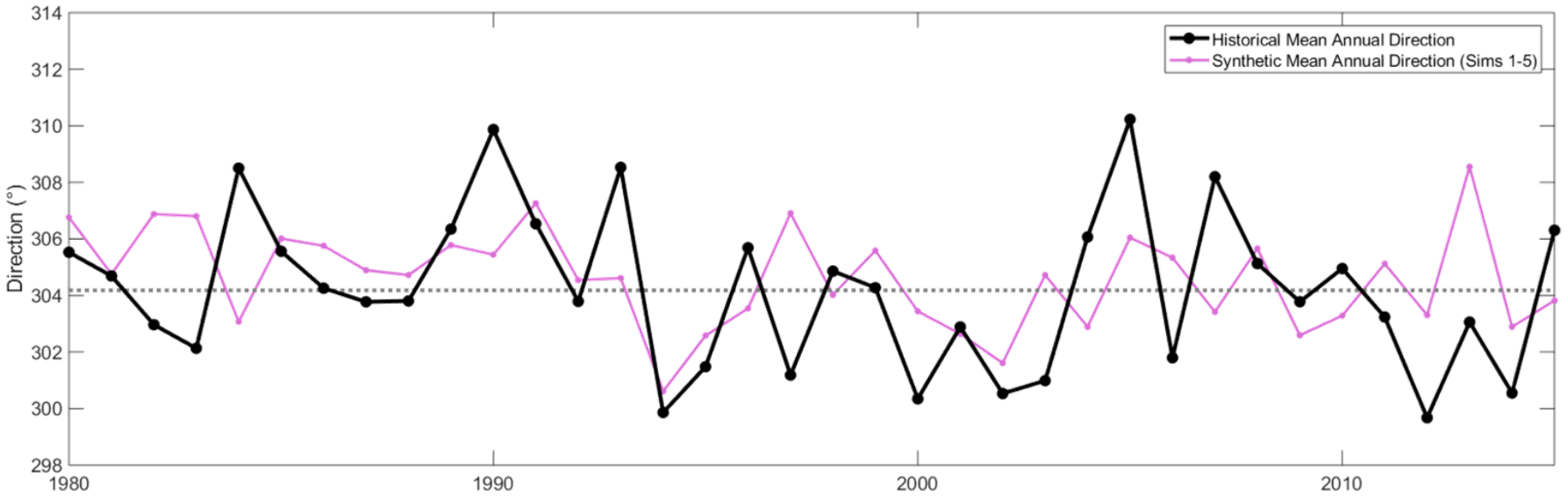

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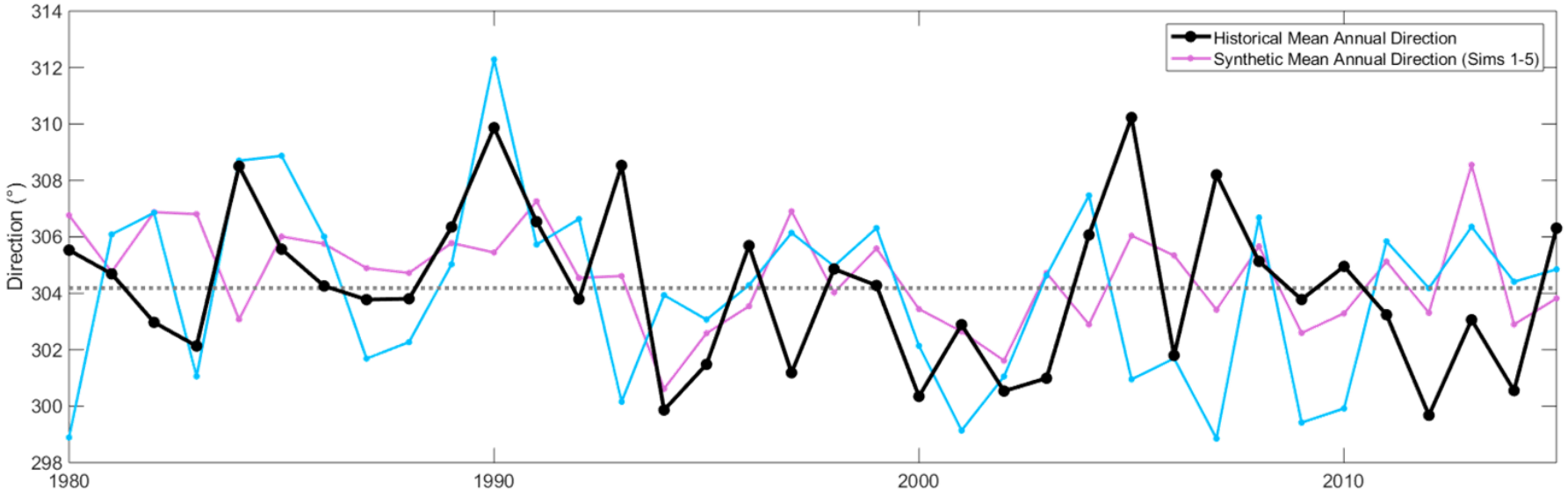

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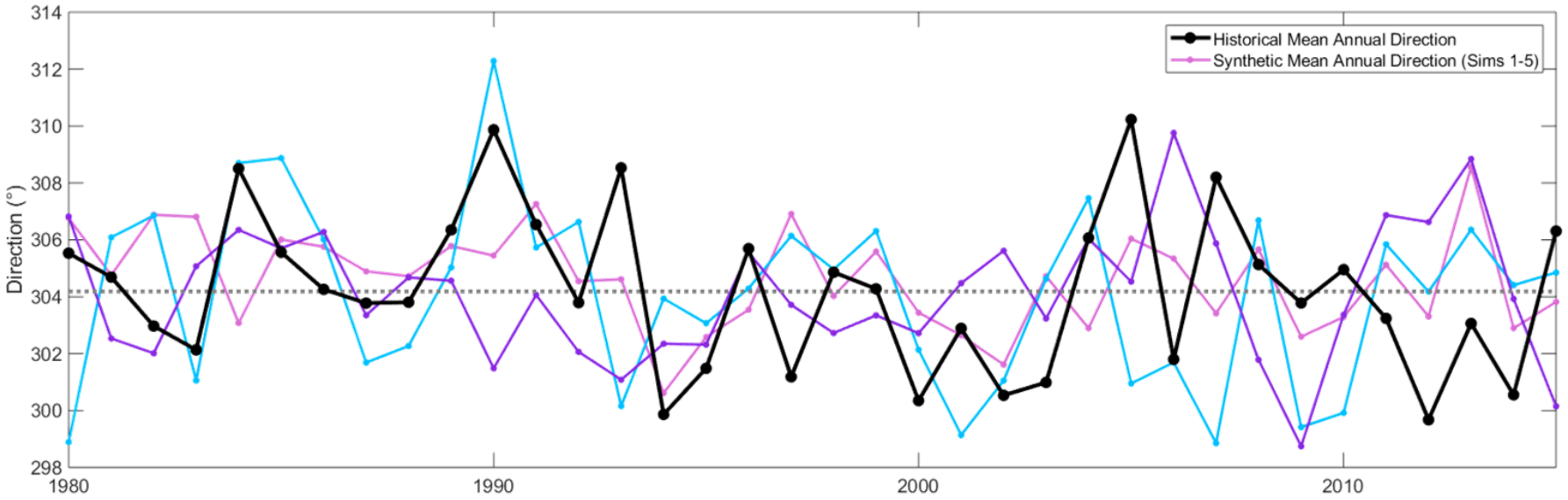

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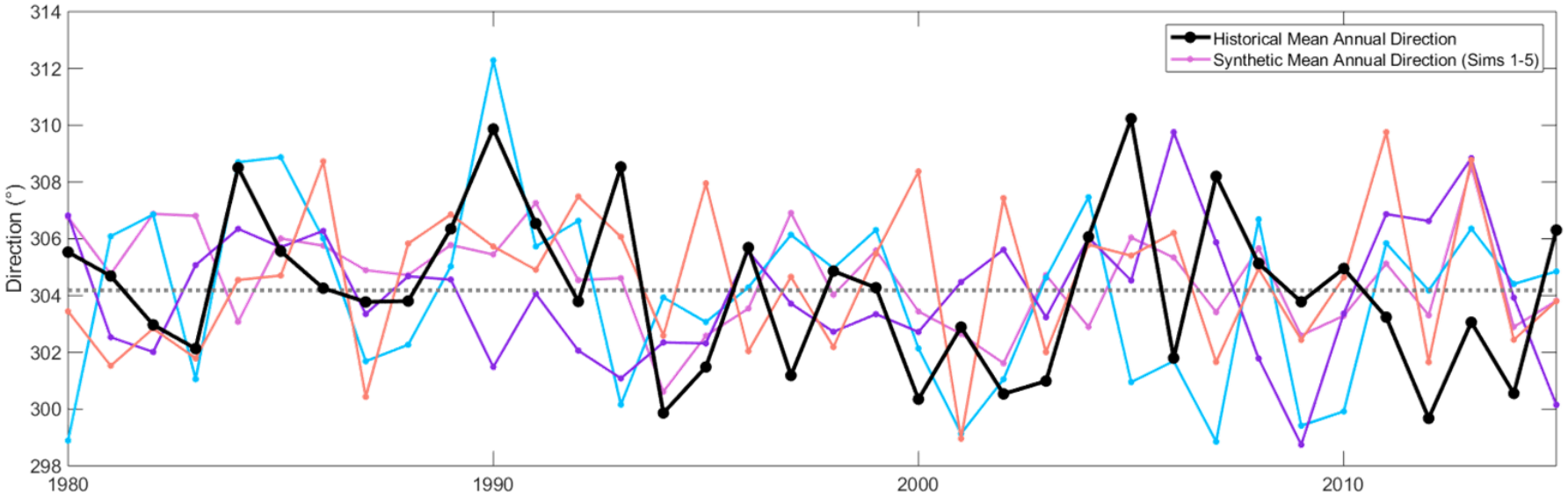

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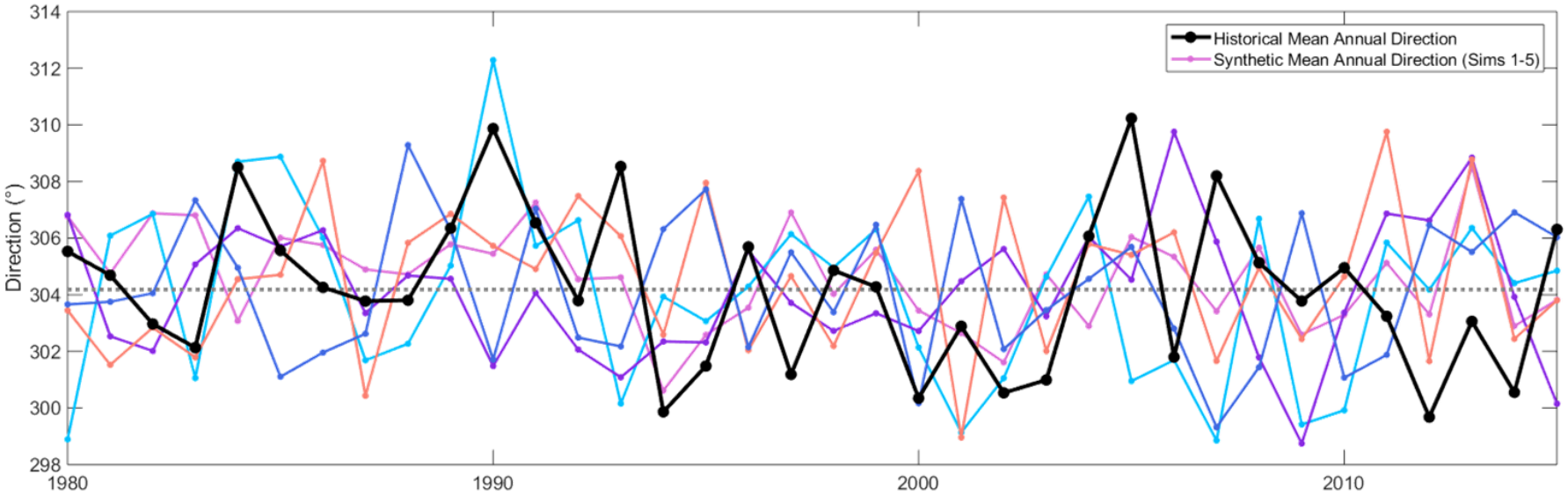

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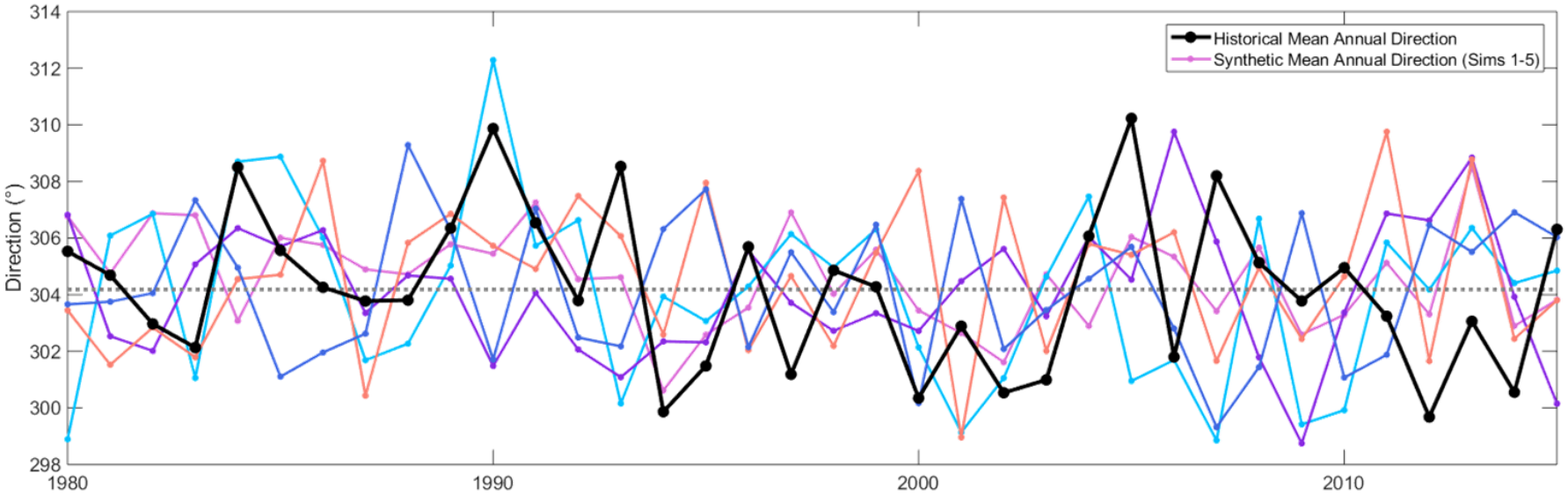

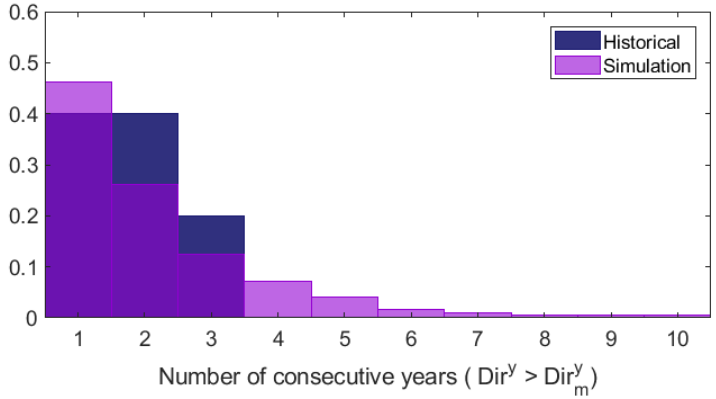

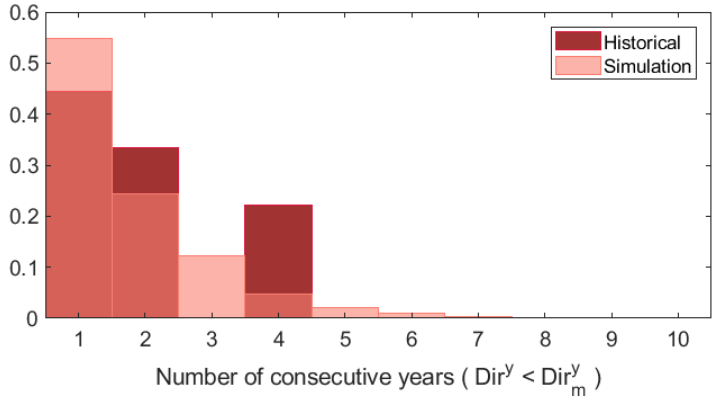

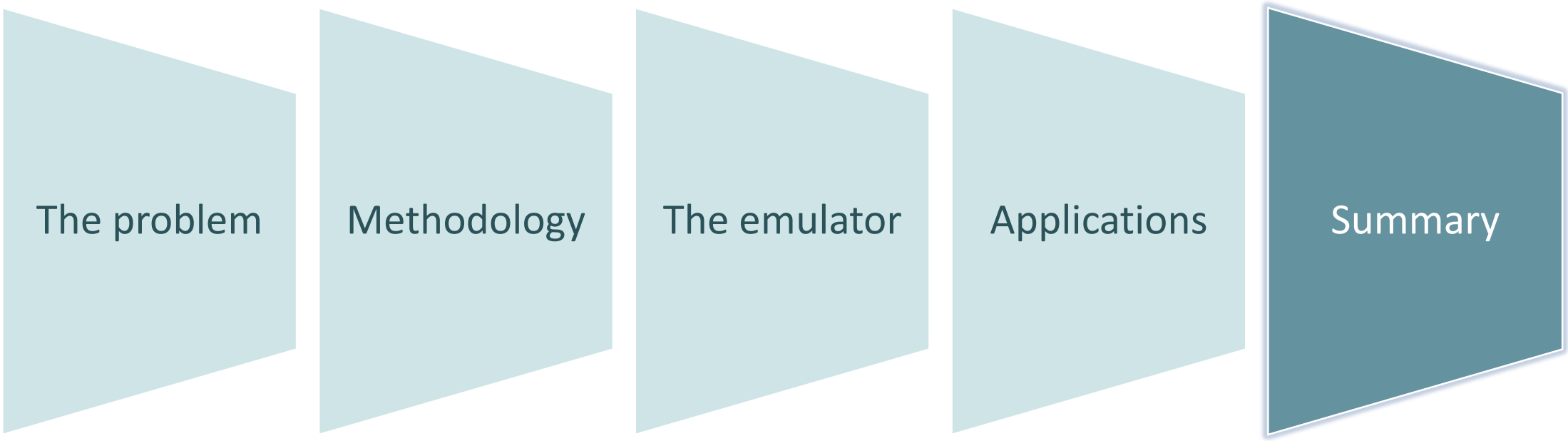
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Summary

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Synthetic generation of wave time series preserving chronology at different scales from intra-storm to inter-annual

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→ **Easy to link the most energetic conditions with large scale climatic patterns**

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→ **Worldwide transferable**

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Could be adapted to generate wave time series under climate change scenarios

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- Easy to link the most energetic conditions with large scale climatic patterns
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→ **Provides a probabilistic framework to assess the uncertainty in model parameters and wave conditions**

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- Provides a probabilistic framework to assess the uncertainty in model parameters and wave conditions

THANKS

Laura Cagigal, Ana Rueda, Dylan Anderson, Peter Ruggiero, Mark A. Merrifield, Jennifer Montaño, Giovanni Coco, Fernando Méndez

lcag075@aucklanduni.ac.nz

Coast and Ocean Collective

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

UC UNIVERSIDAD DE CANTABRIA

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