HyWaves: A hybrid method to downscale swells in small Pacific Islands

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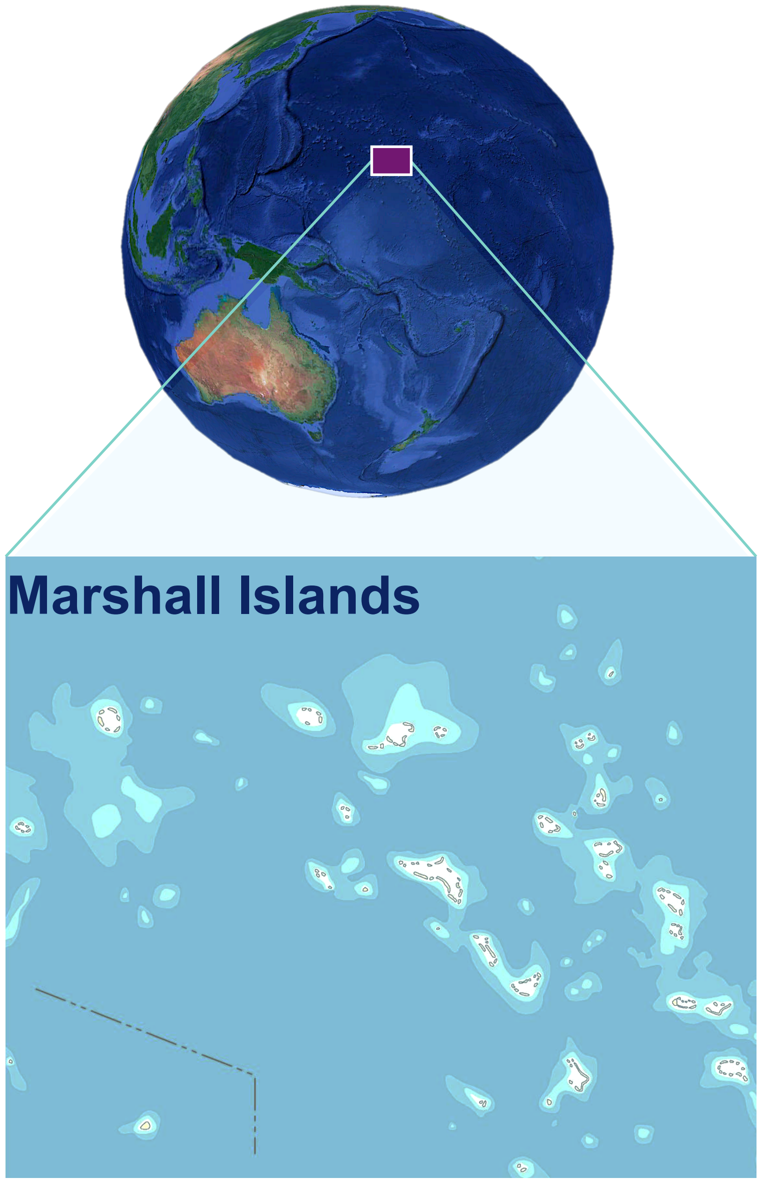
MOTIVATION



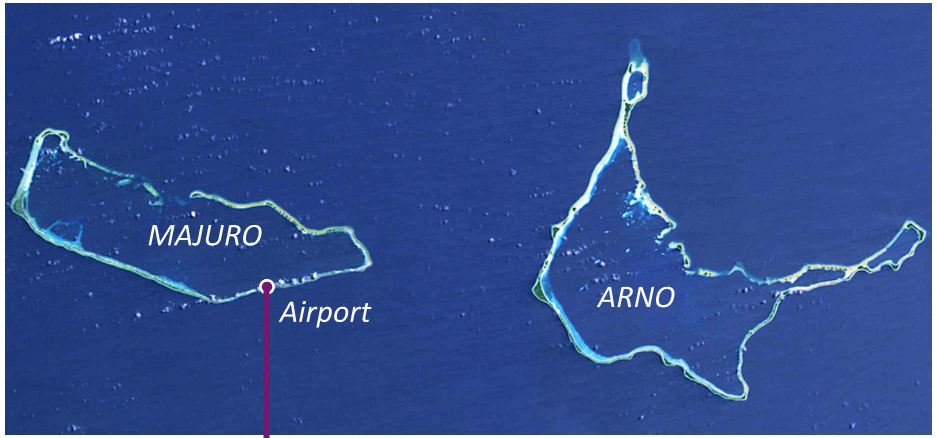
Hoeke et al,. 2013

Vulnerable to a large number of hazards

DISTANT-SOURCE WIND WAVES
TROPICAL CYCLONES
SEA LEVEL RISE

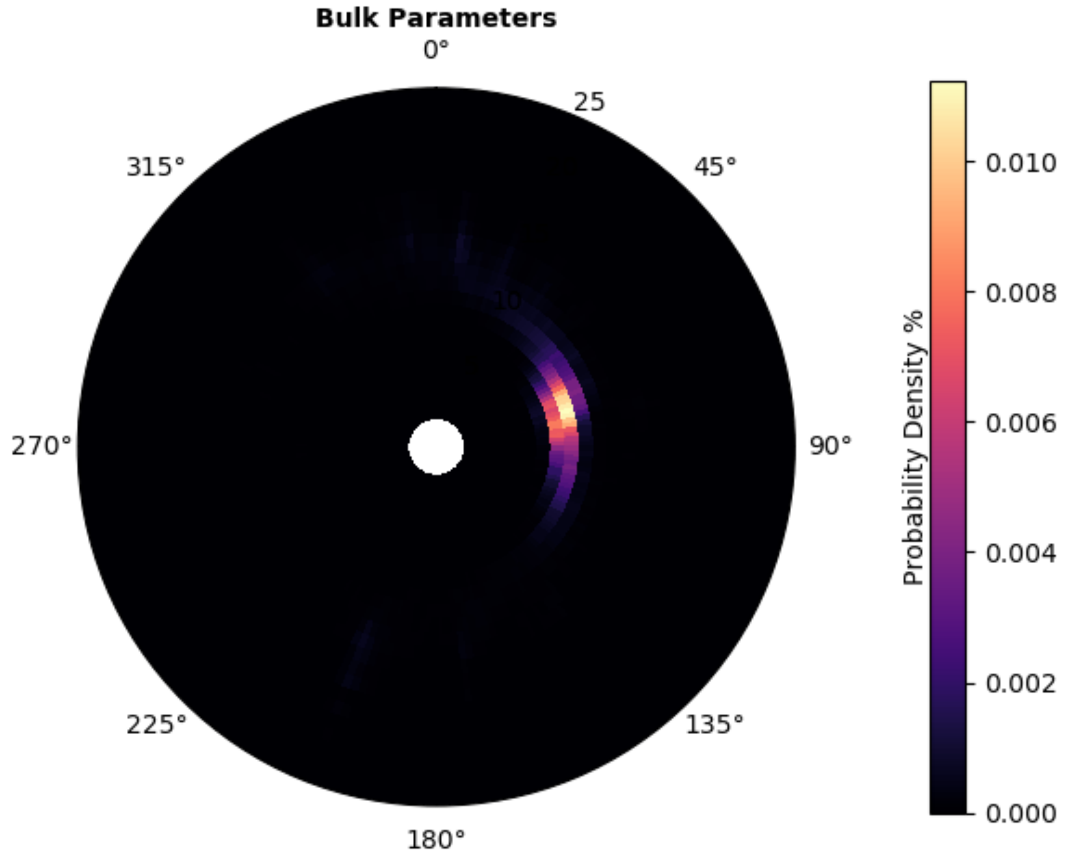
MOTIVATION

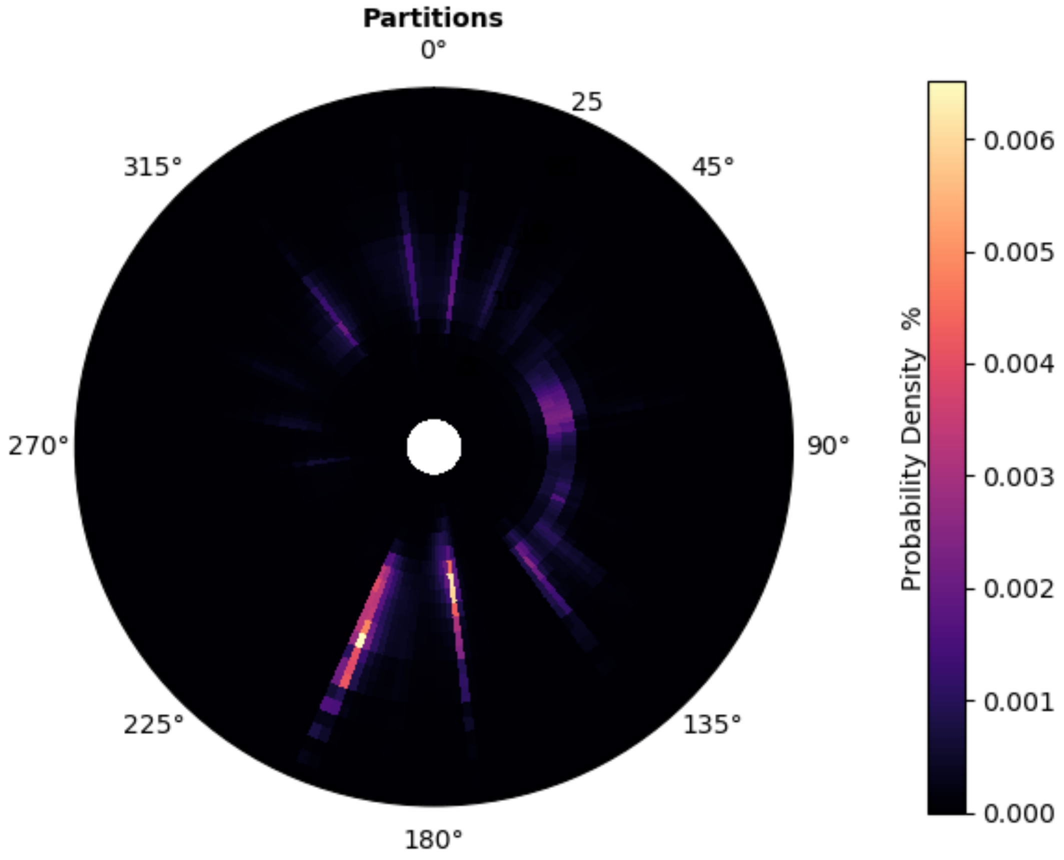
(Source: Dr. Murray Ford, the University of Auckland, New Zealand)



The flood event of 24th June 2013

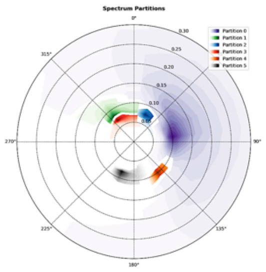
MOTIVATION: The importance of the directional spectra





METHODOLOGY

Global wave hindcast



Spectral partitioning

Sea

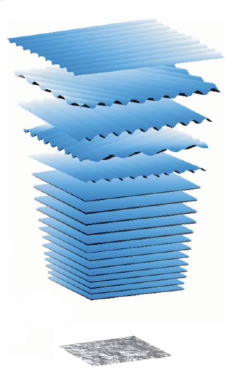
H_s, T_p, θ_m, σ, γ, W_{spd}, W_{dir}

MDA — SWAN — RBF

Swells

H_s, T_p, θ_m, σ, γ

MDA — SWAN — RBF



(Holthuijsen, 2007)

Reconstructio

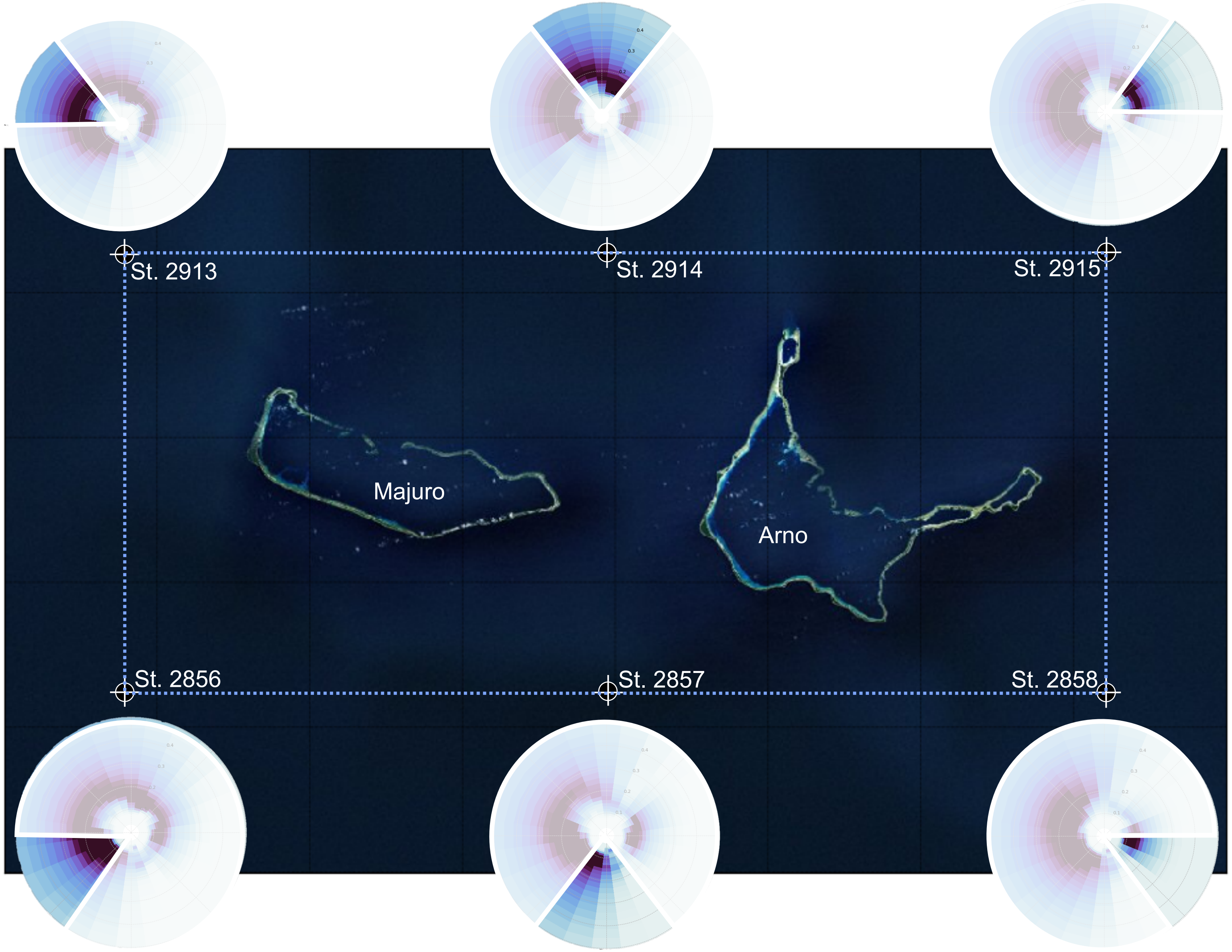
$S_t(f,\theta)=\sum_{i=1}^{n} W_{wave\ systems}$

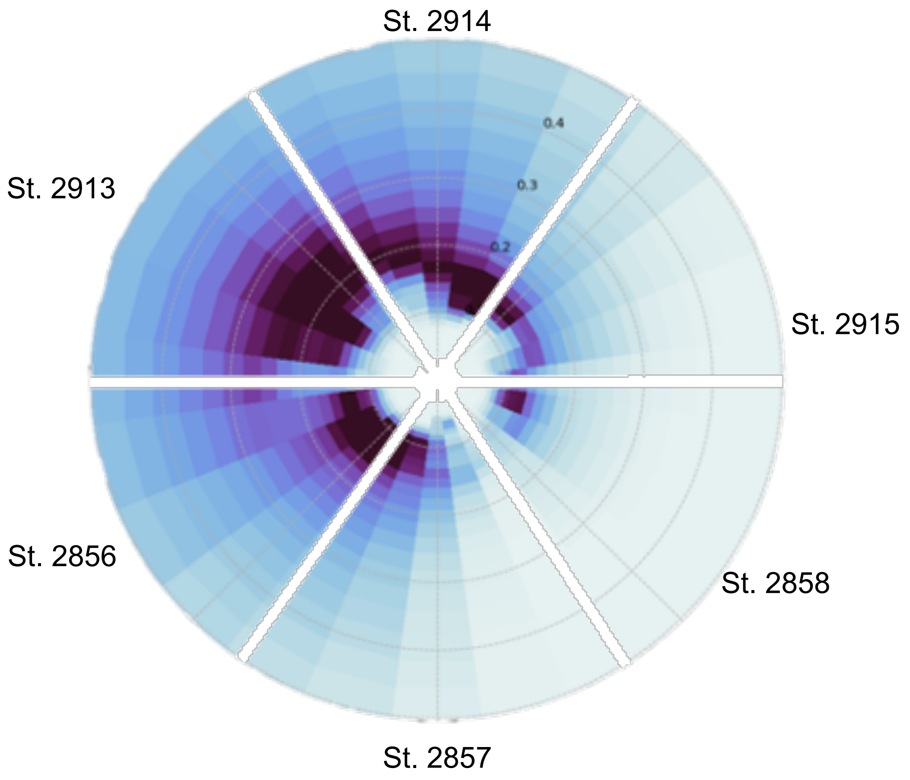
Validation

Inundation forecast

Early Warning Systems

METHODOLOGY: Super-Point

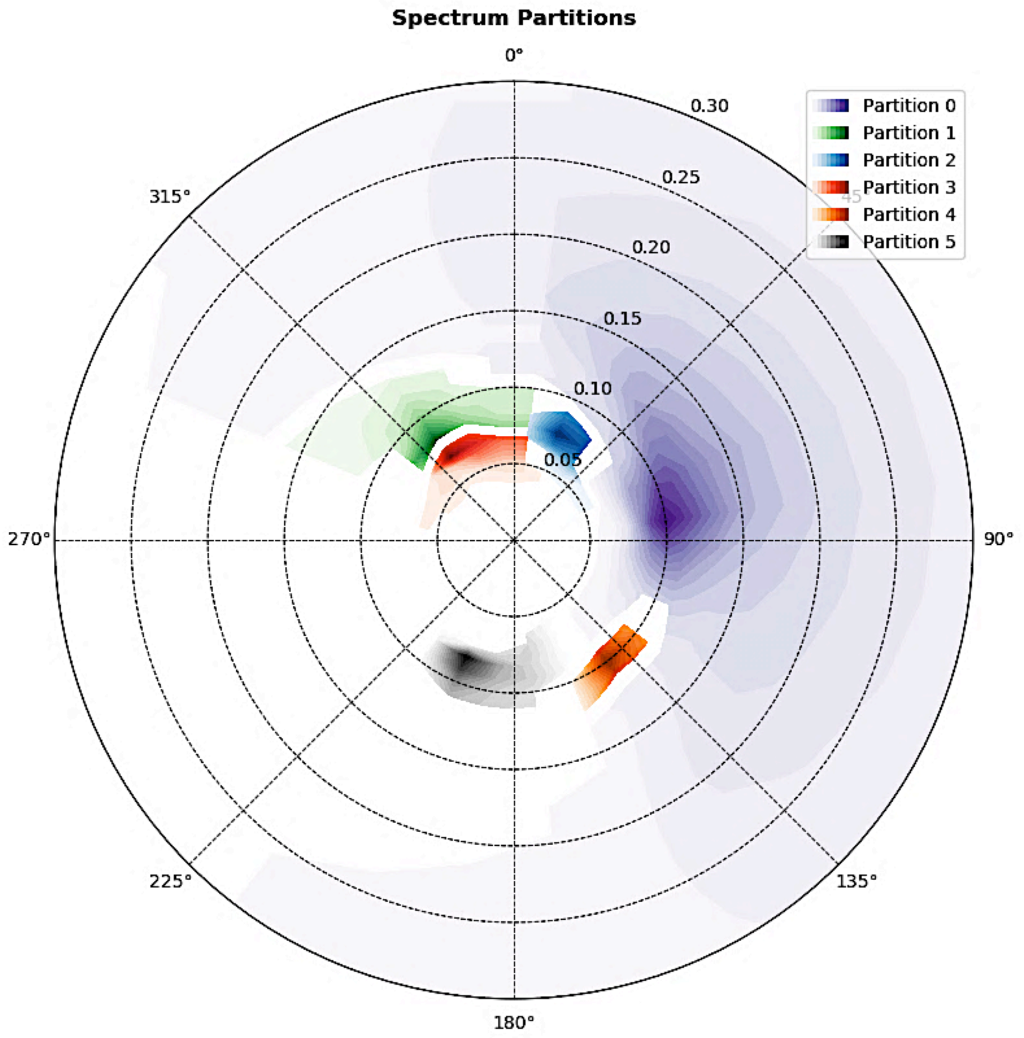




CSIRO stations
CAWCR Wave Hindcast 1979-201

$S_\eta(f,\theta)$

METHODOLOGY: Spectral Partitioning



Wavespectra Library

Developed by MetOcean Solutions

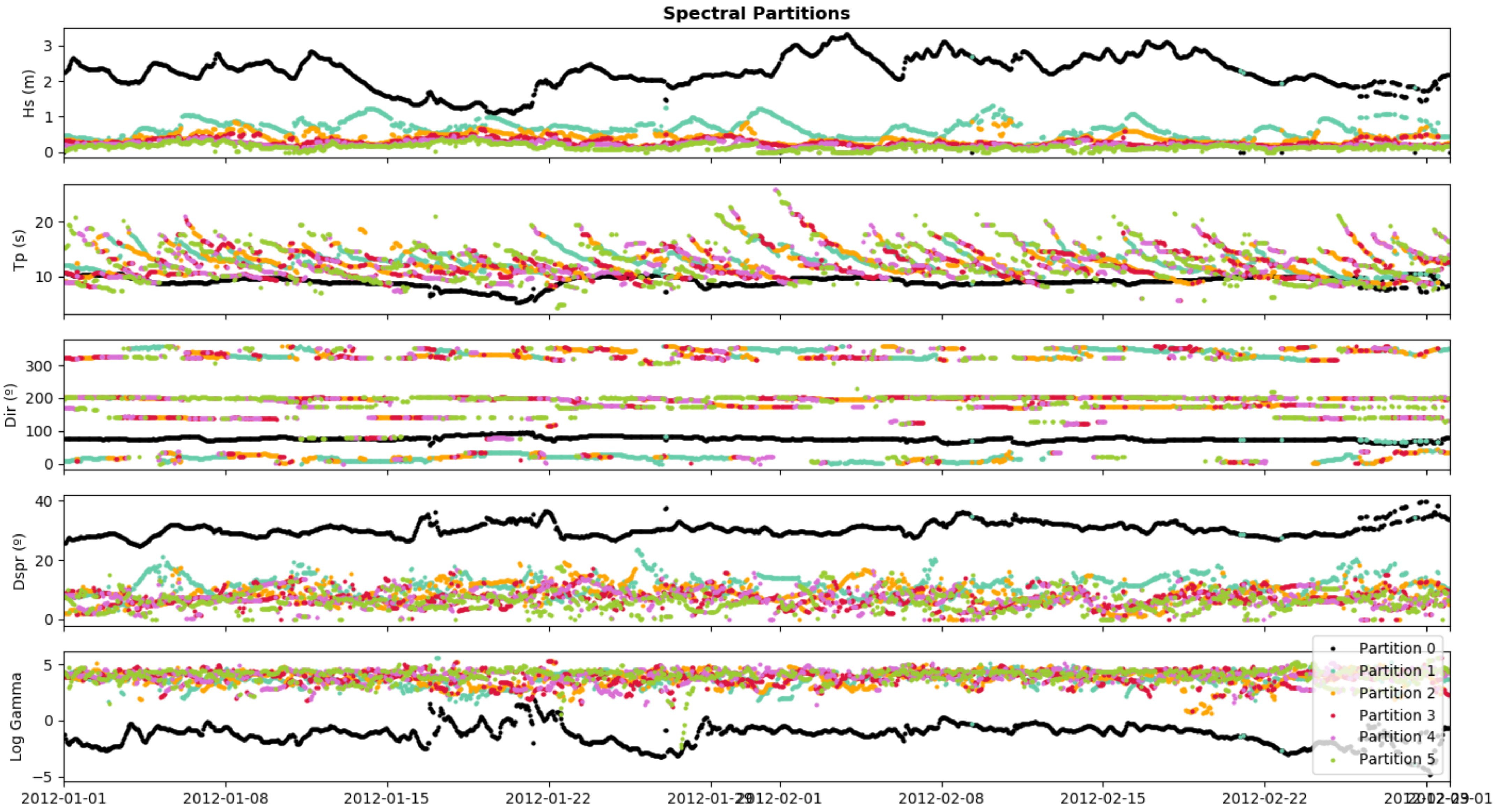
Physically-based techniques to identify swell trains

Watershed Method

(Hanson and Philips, 2001)

Max number of Swells = 5
Wave age = 1.7
Minimum energy in partitions
Minimum distance between peaks

METHODOLOGY: Wave System Parameterization



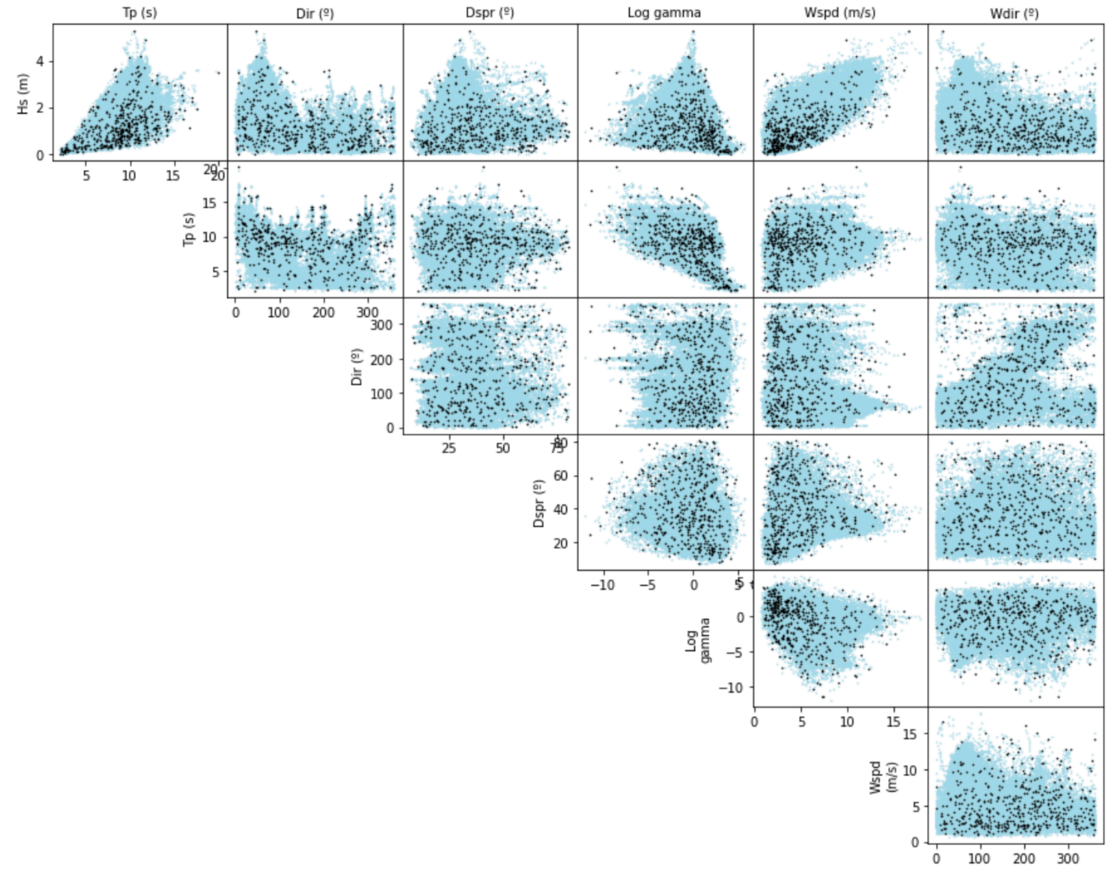
METHODOLOGY: MDA Selection

Maximum Dissimilarity Algorithm MDA *(Camus et al,. 2011)*

Subset N = 500 cases

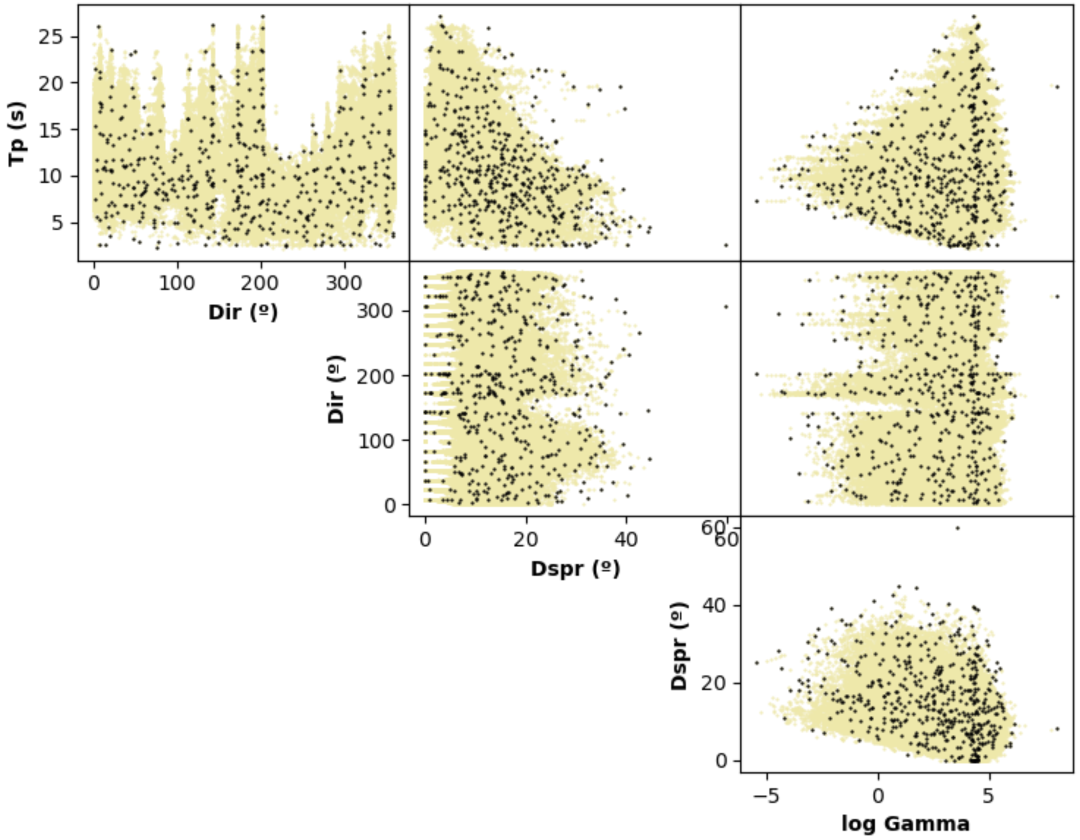
MDA – Sea

$H_s, T_p, \theta_m, \sigma, \gamma, W_{spd}, W_{dir}$



MDA – Swells (Hs = 1 m)

$T_p, \theta_m, \sigma, \gamma$



METHODOLOGY: Dynamical Downscaling

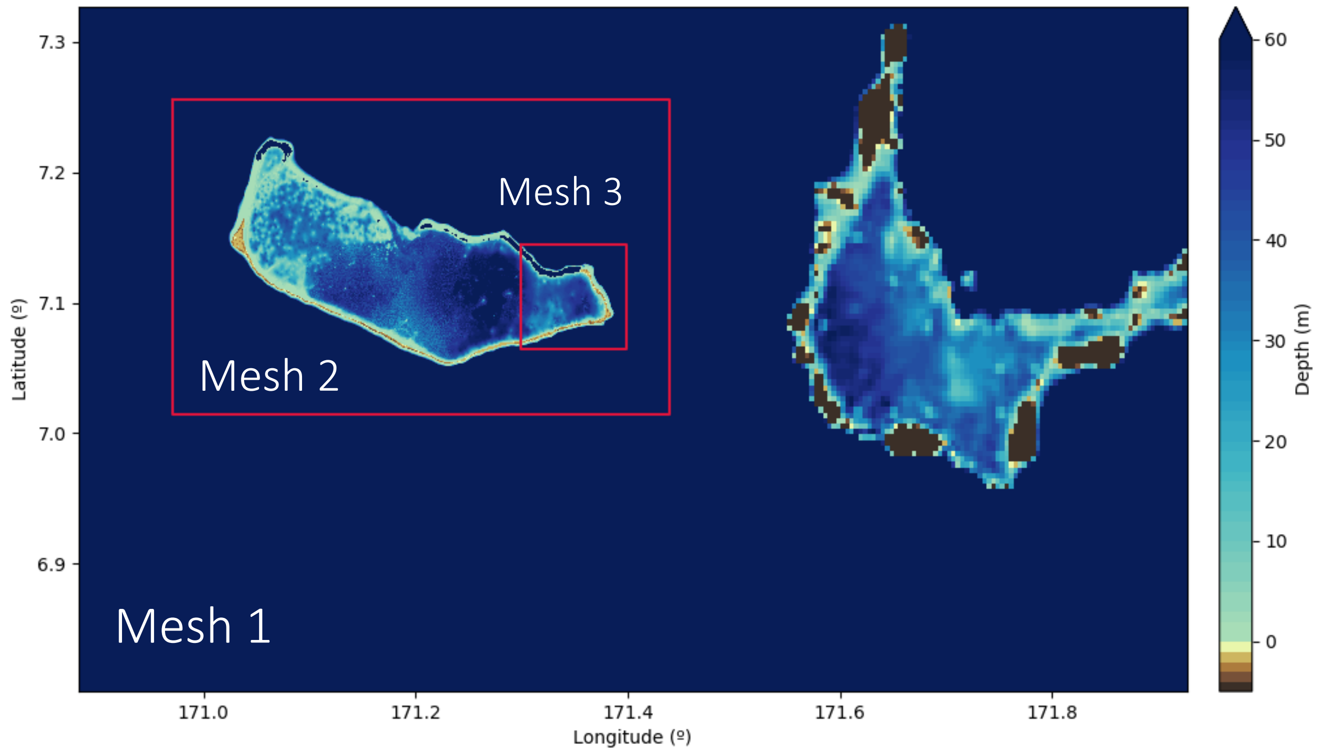
SWAN

Simulating Waves Nearshore
(Delft University of Technology)

(Booij et al., 1999)

Mesh 1 (bathymetry GEBCO) 1 km
Mesh 2 (bathymetry USGS) 200 m
Mesh 3 (bathymetry USGS) 50 m

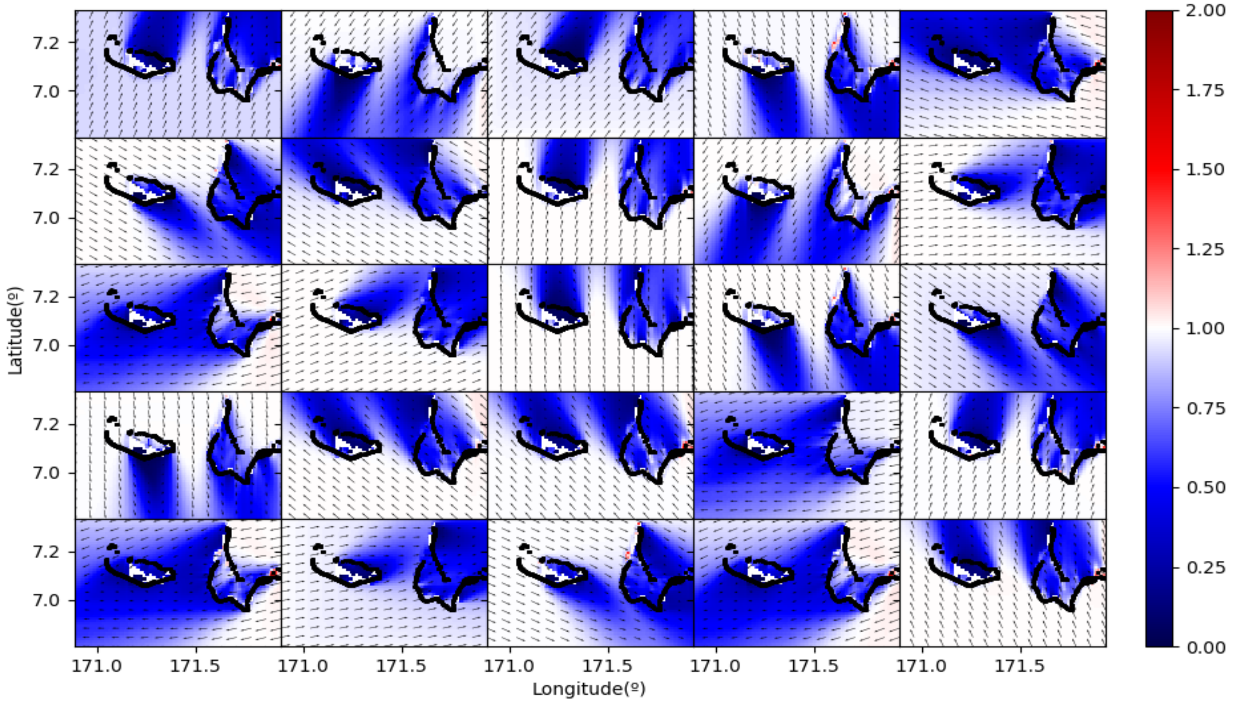
Stationary mode
Same forcing in boundaries
SL = 0 m



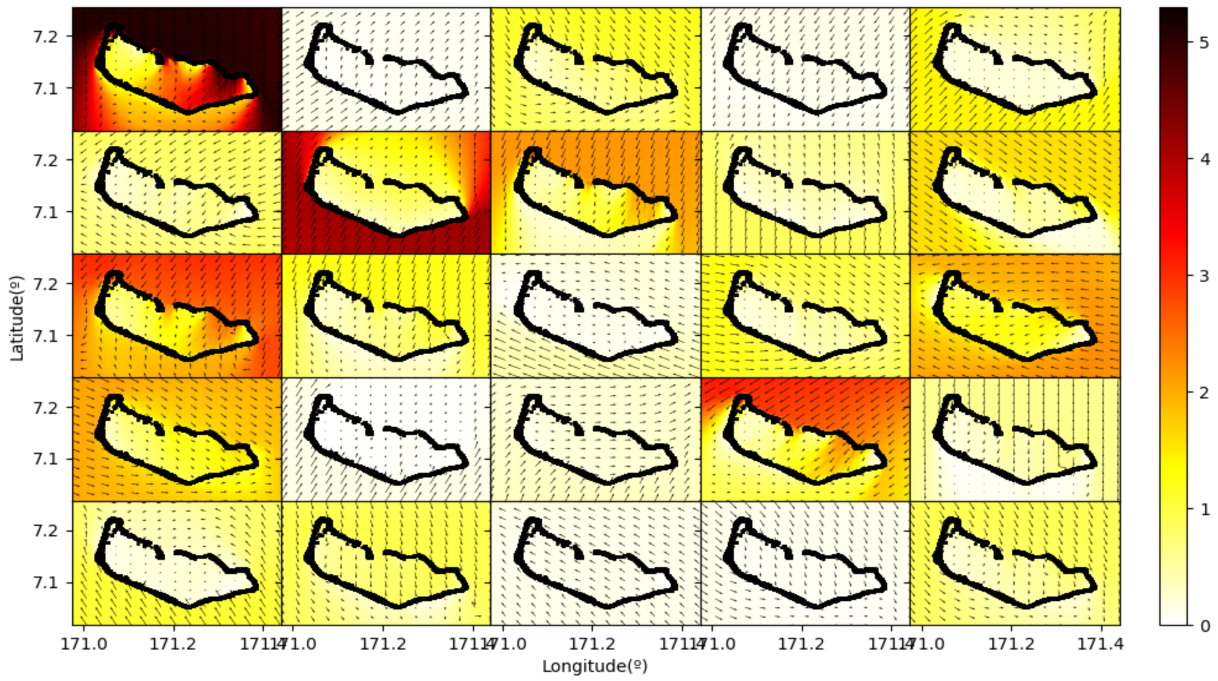
METHODOLOGY: Dynamical Downscaling

First 25 propagation maps from MDA

SWELLS
(Propagation Coefficient)



SEAS



METHODOLOGY: RBF Reconstruction

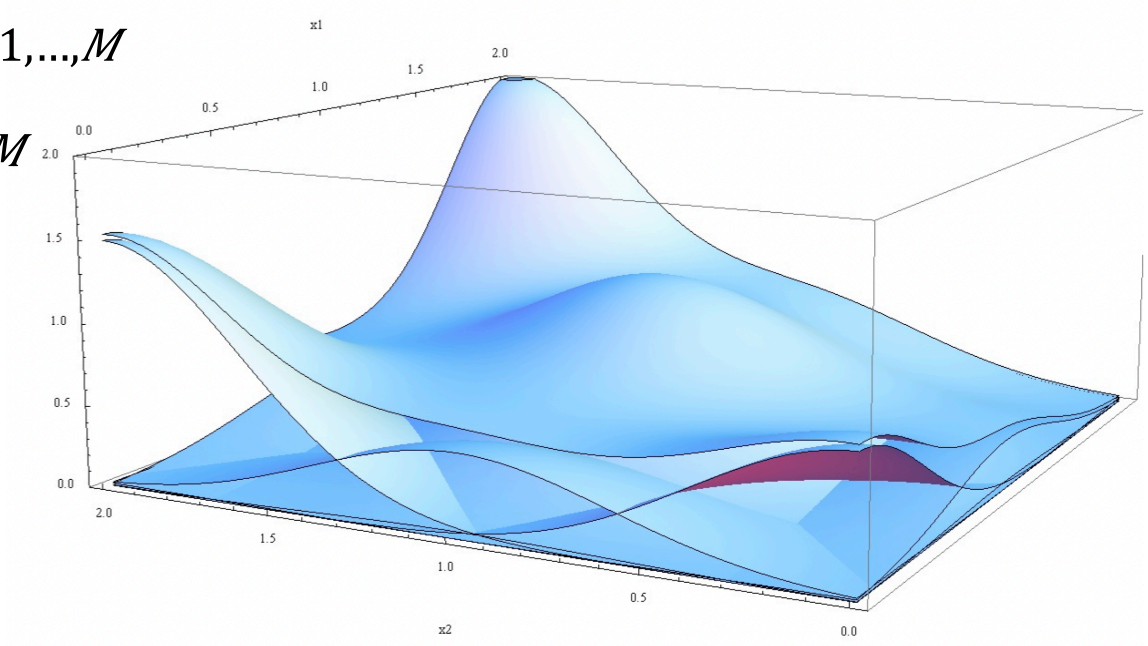
Radial Basis Function RBF

Interpolation Algorithm

(Rippa 1999)

$$D_j = \{H_j^D, T_j^D, \theta_j^D, W_j^D, \beta_j^D\}; j=1,\dots,M$$

$$D_{p,j}^* = \{H_{sp}^D, T_{mp}^D, \theta_{mp}^D\}; j=1,\dots,M$$



The historical wave climate can be reconstructed throughout the island

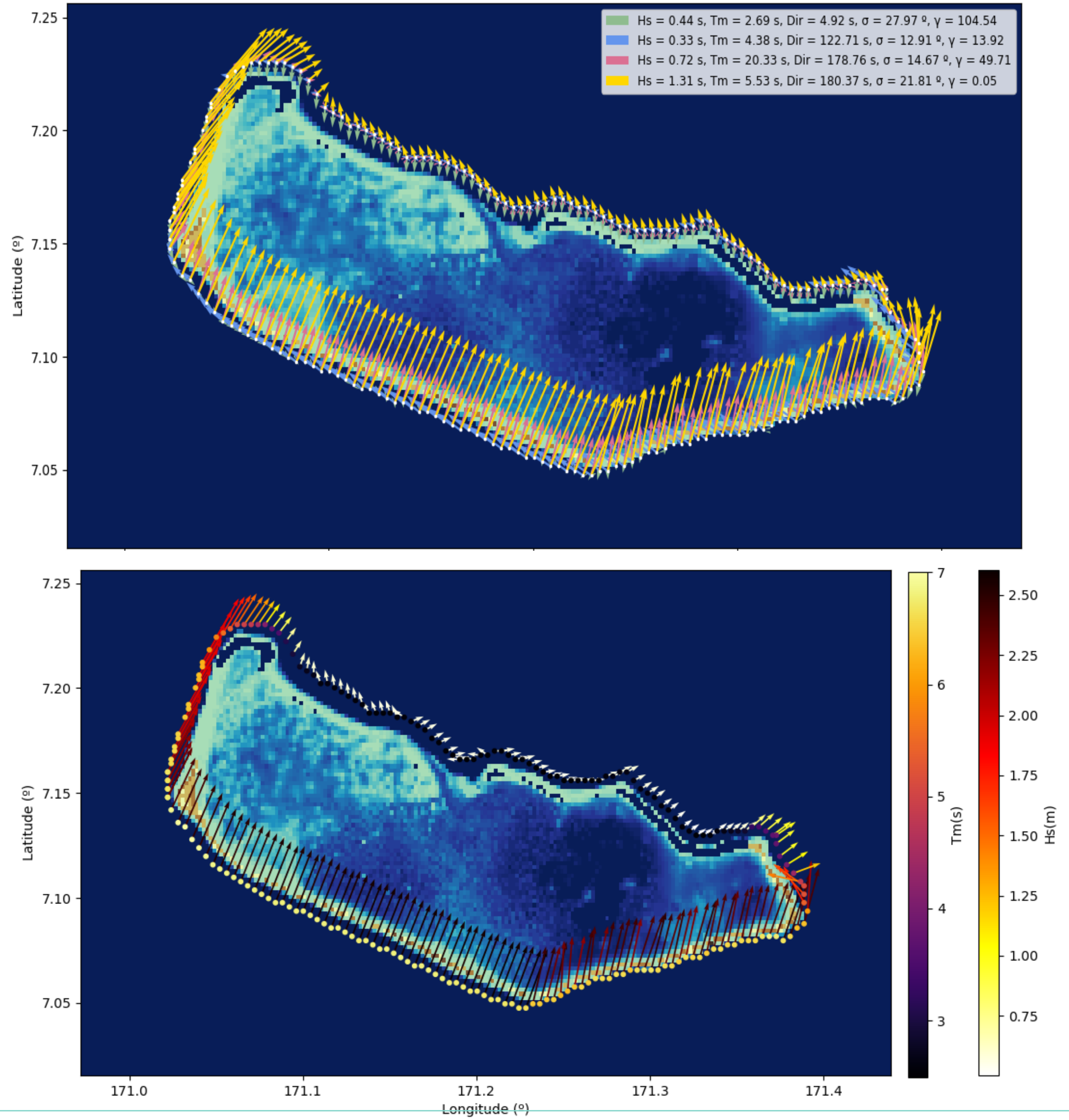
“a weighted sum of radial basis functions”

METHODOLOGY: Aggregation

Wave Systems Aggregation

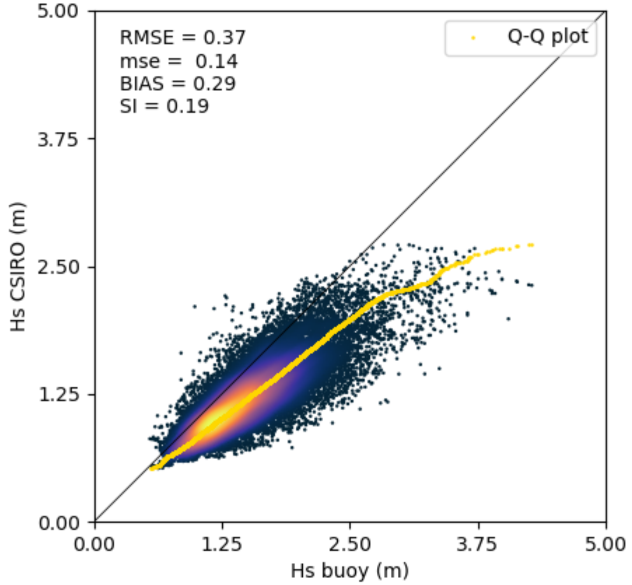
Linear Theory

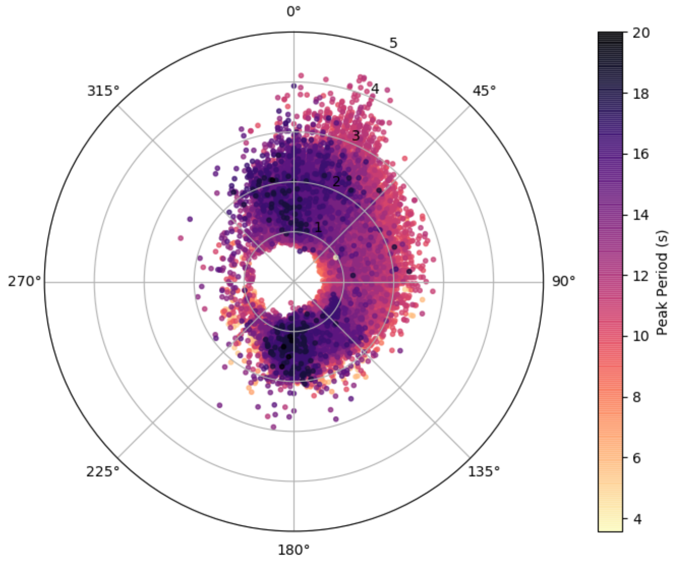
$$S_t(f,\theta)=\sum_{i=1}^{N_{wave\ systems}} S_i(f,\theta)$$



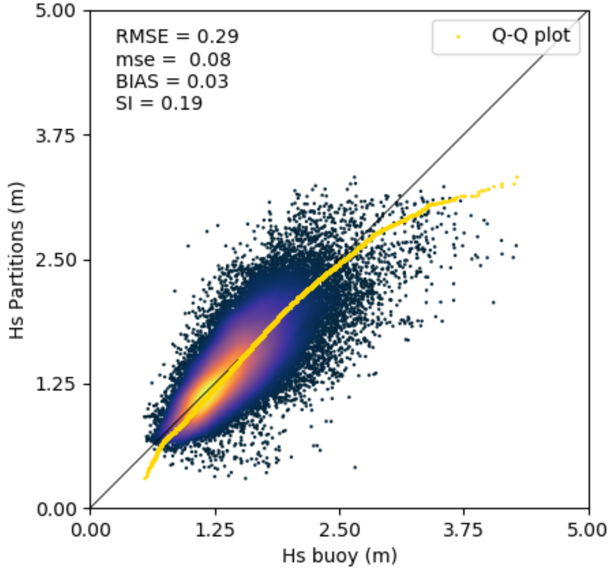
METHODOLOGY: Validation

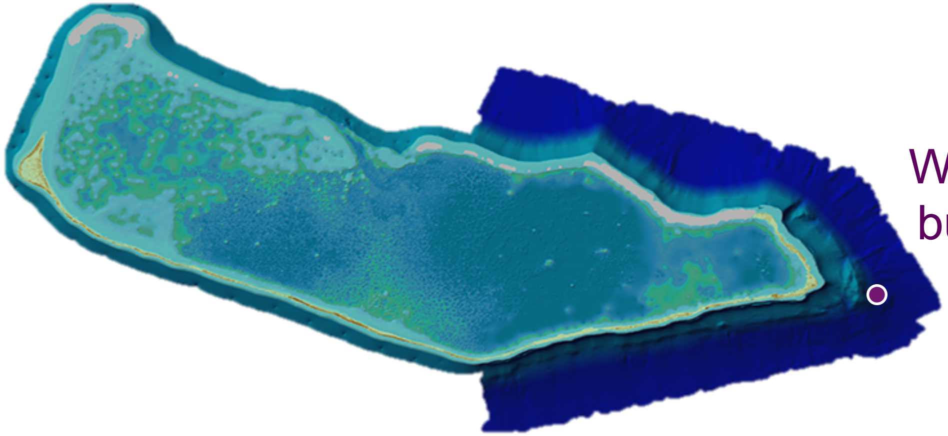
CSIRO hindcast





HyWaves



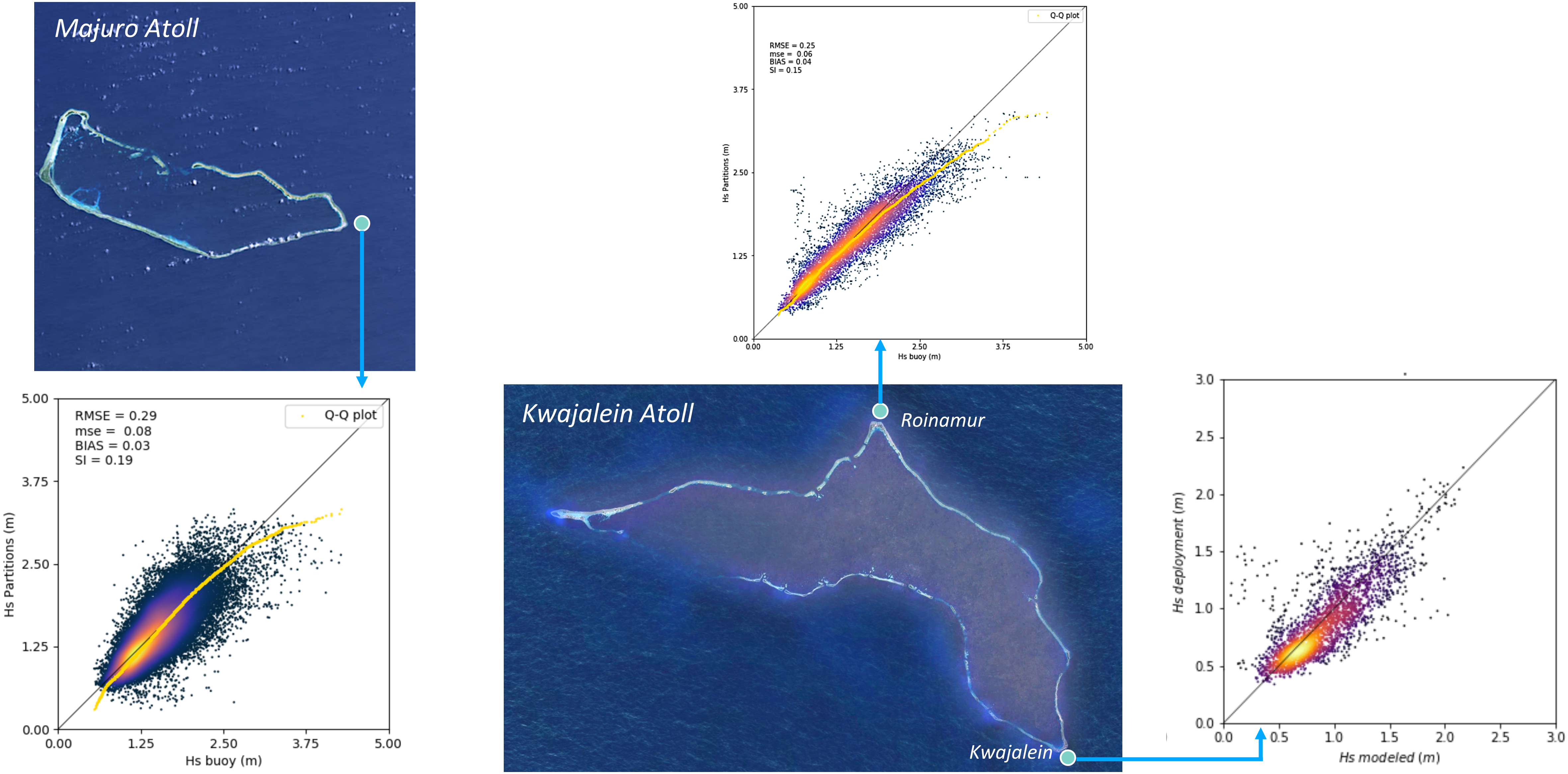


Wave buoy

PacIOOS (The Pacific Islands Ocean Observing System)
2010/04 – 2018/12

0.9 km E
540 m depth
Data every 30'
H_s, T_p, θ_m

METHODOLOGY: Validation sites



Spectral Wave Climate

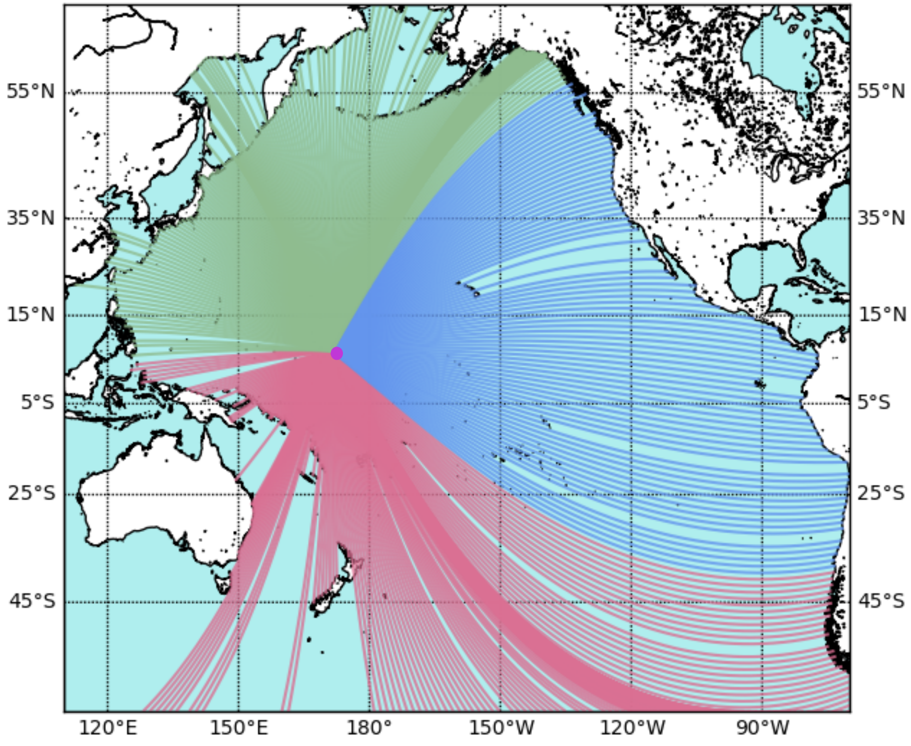
North Swells (270 – 30º)

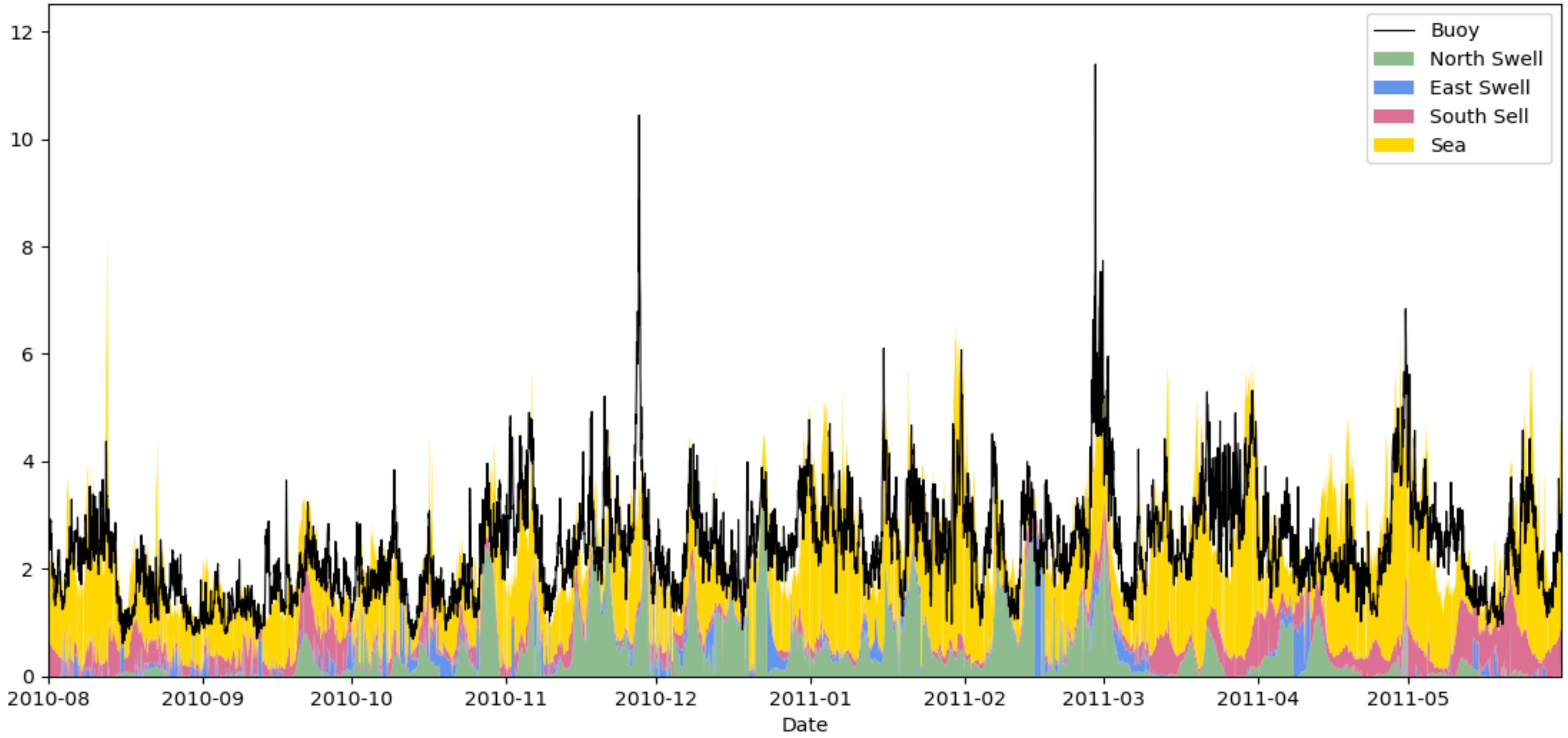
East Swells (30 – 130º)

South Swells (130 – 270º)

Contribution of each wave system to the total Energy

$$E \sim H_s^2$$



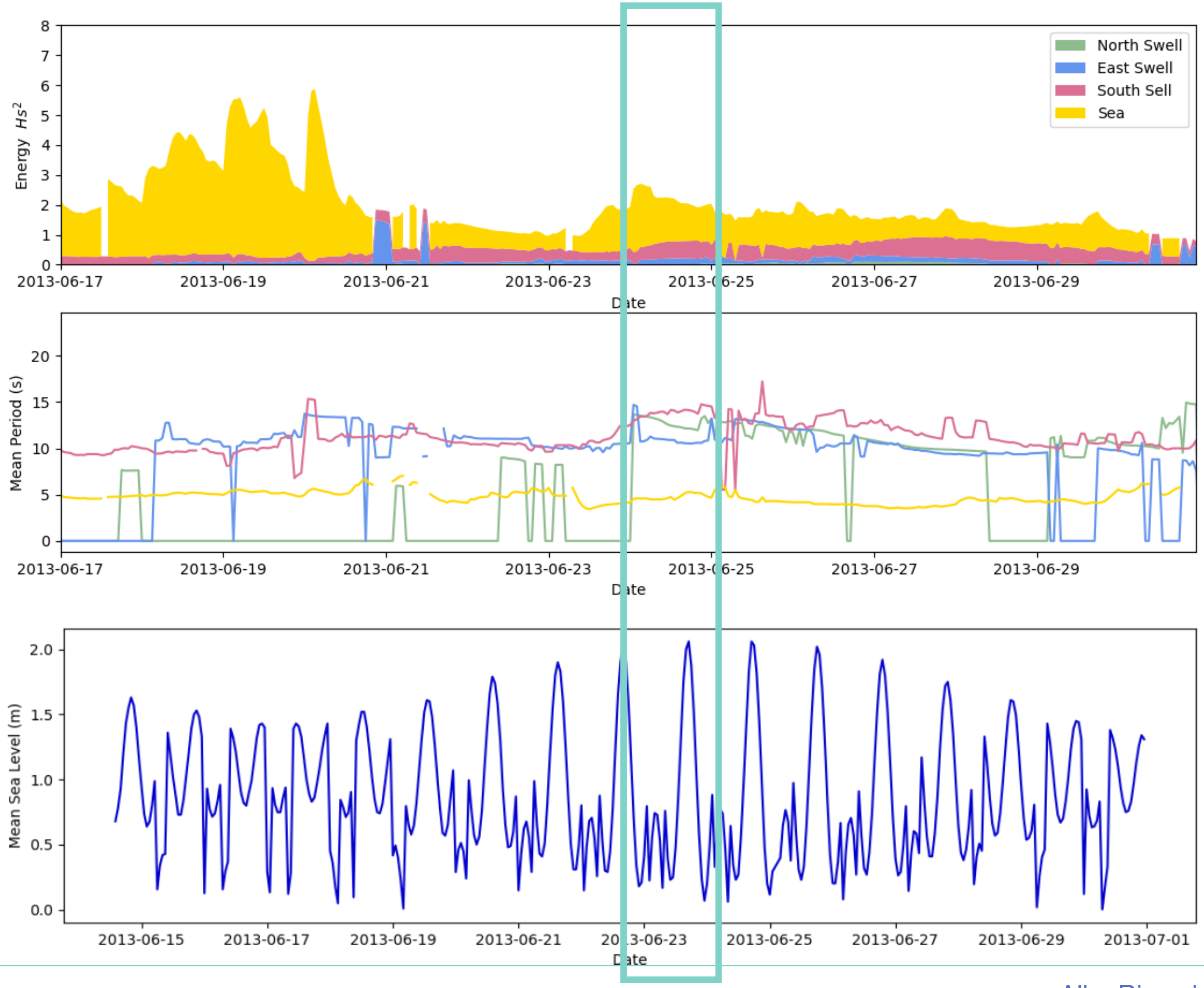


Spectral Wave Climate

Flooding Event
24th June 2013

Southern region (Airport)

La Niña ENSO phase
MSL ~ 2 m
Hs = 1 m
Tm = 15 s

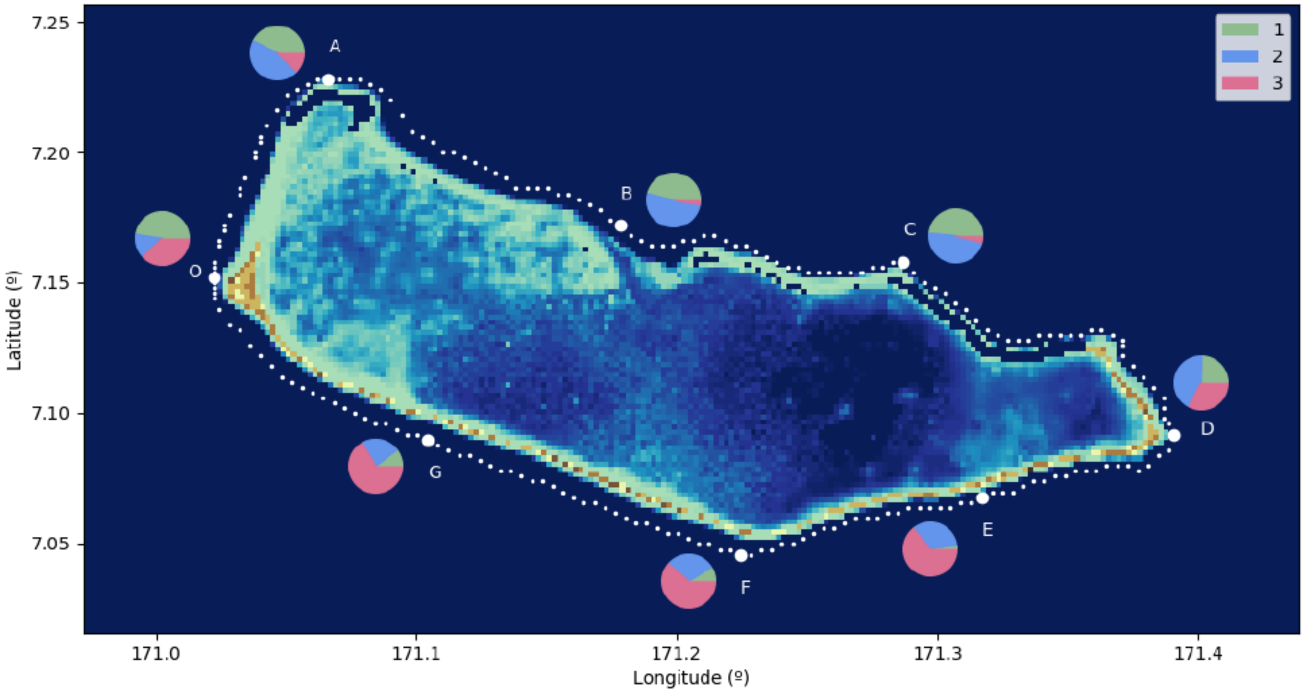


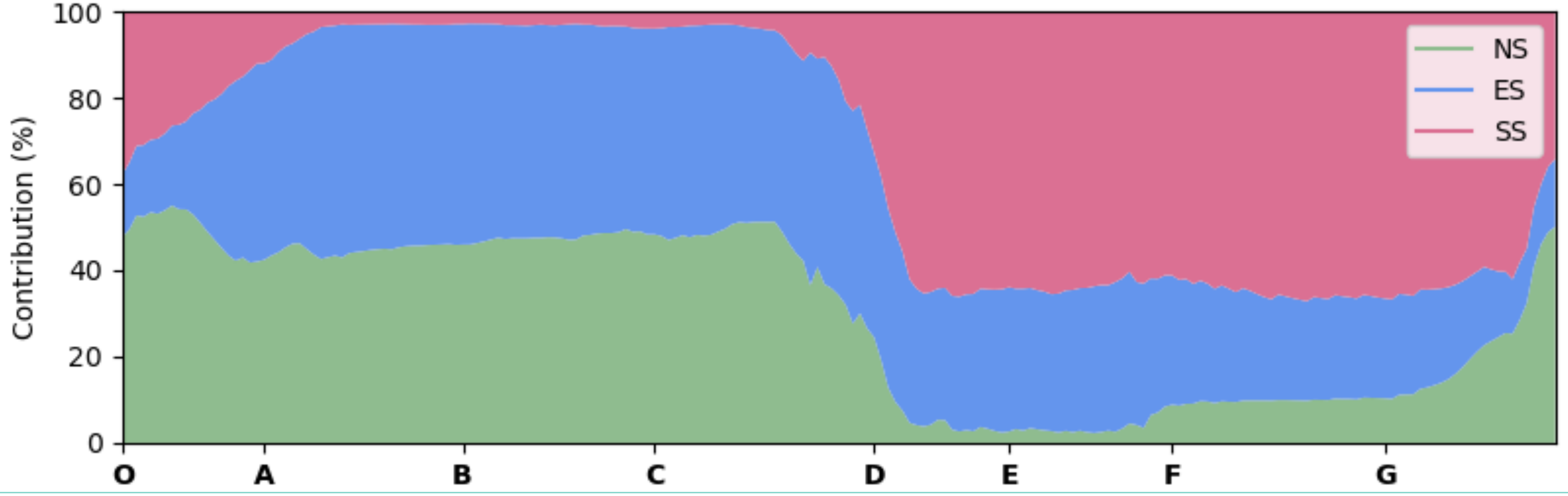
Spectral Wave Climate

Energy Flux Contribution

$$FE = H_s^2 \cdot T_p$$

Seasonality
Interannual variability
ENSO events





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Thank you very much for your attention

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