UCF COASTAL
NATIONAL CENTER FOR INTEGRATED COASTAL RESEARCH

USGS
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PREDICTING DUNE EROSION WITH COMBINED PROCESS-BASED AND MULTIVARIATE STATISTICAL MODELS

Credit: USGS

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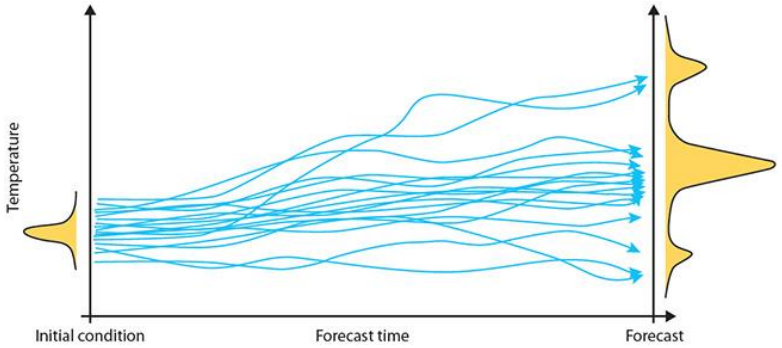
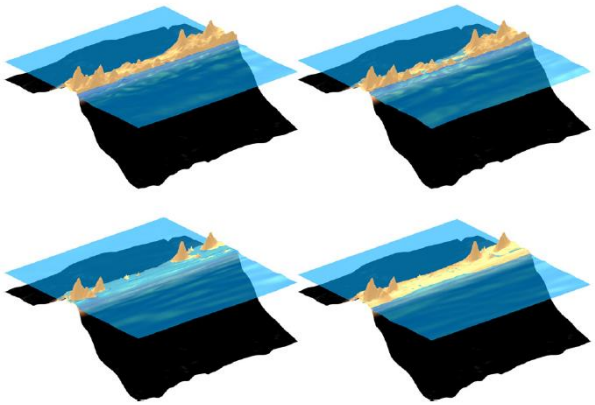
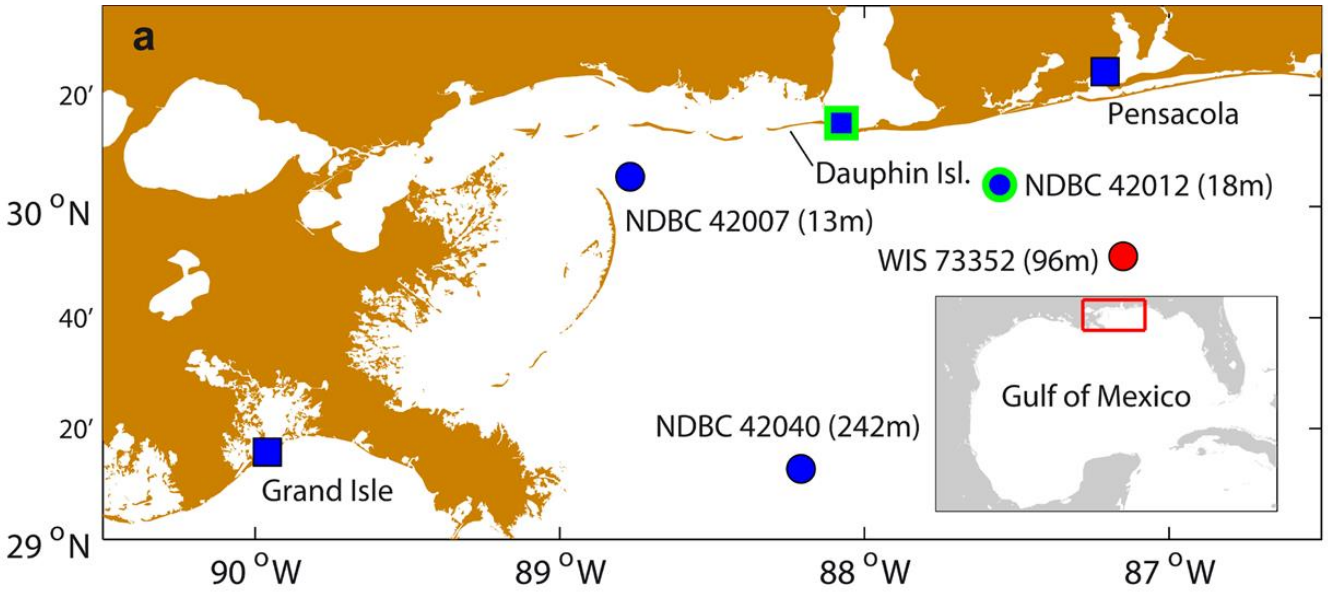
Motivation

- Dune erosion during extreme events leaves coastal communities vulnerable to flooding
- Ensemble forecasting systems for storm surges and waves are widely applied
- Translating the information into dune response is hampered by high computational cost of numerical models (e.g. XBeach)
- Our goal is to develop and test surrogate models to mimic XBeach, but at very low computational cost

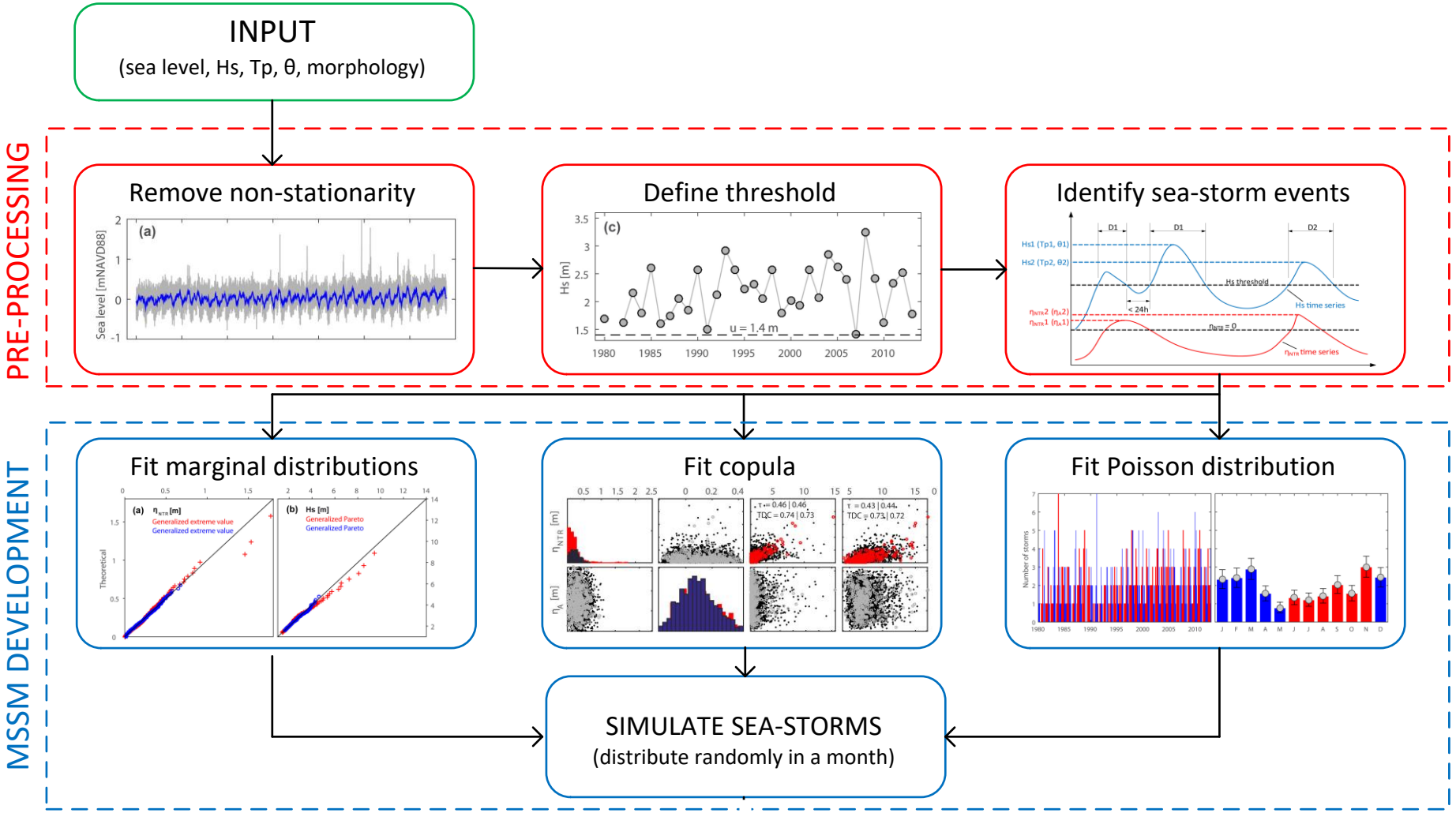




McCall et al., 2010

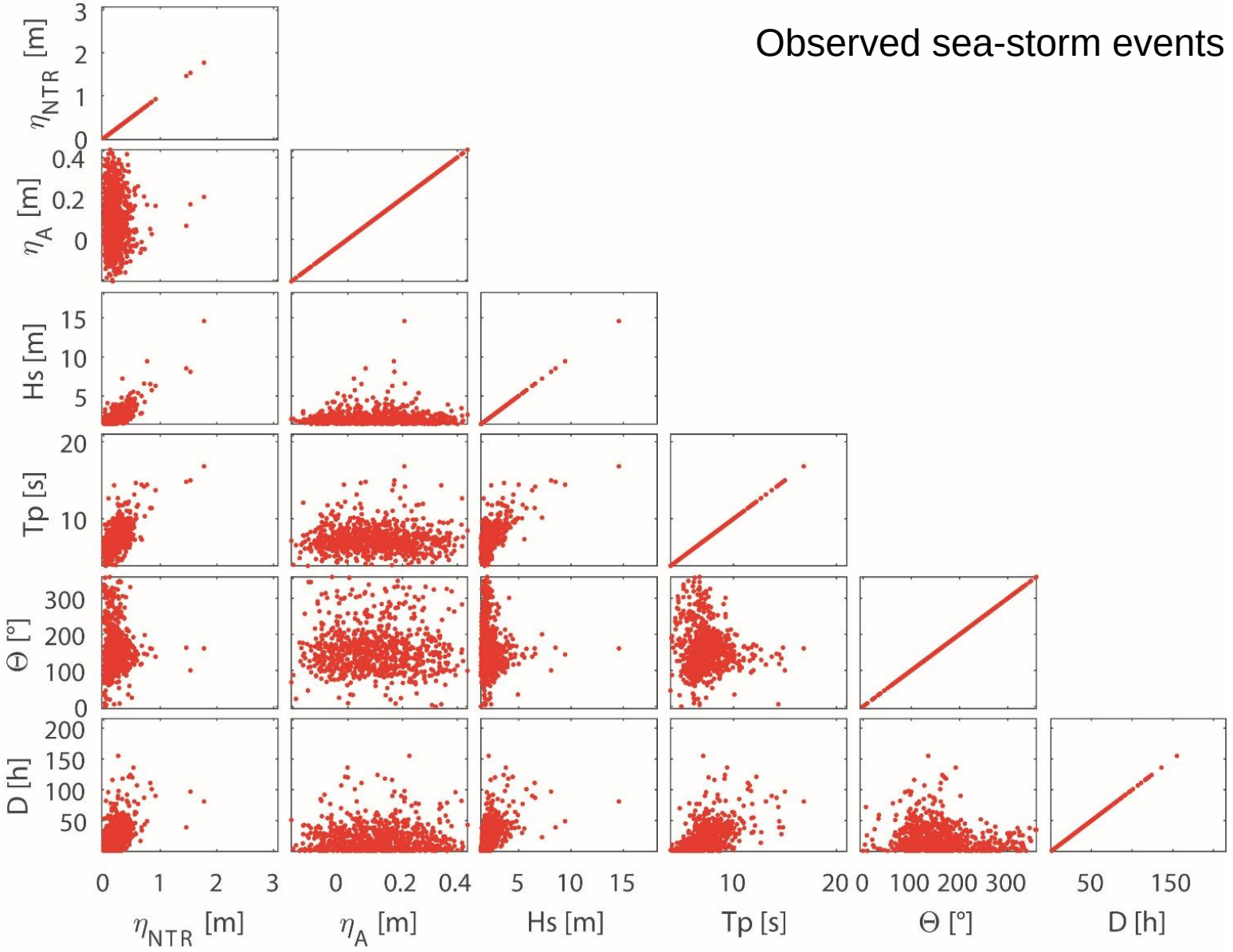


Continuous **34-year** long records of hourly sea level (tide η_A+ surge η_{NTR}), significant wave height Hs, wave peak period Tp, wave direction Θ.

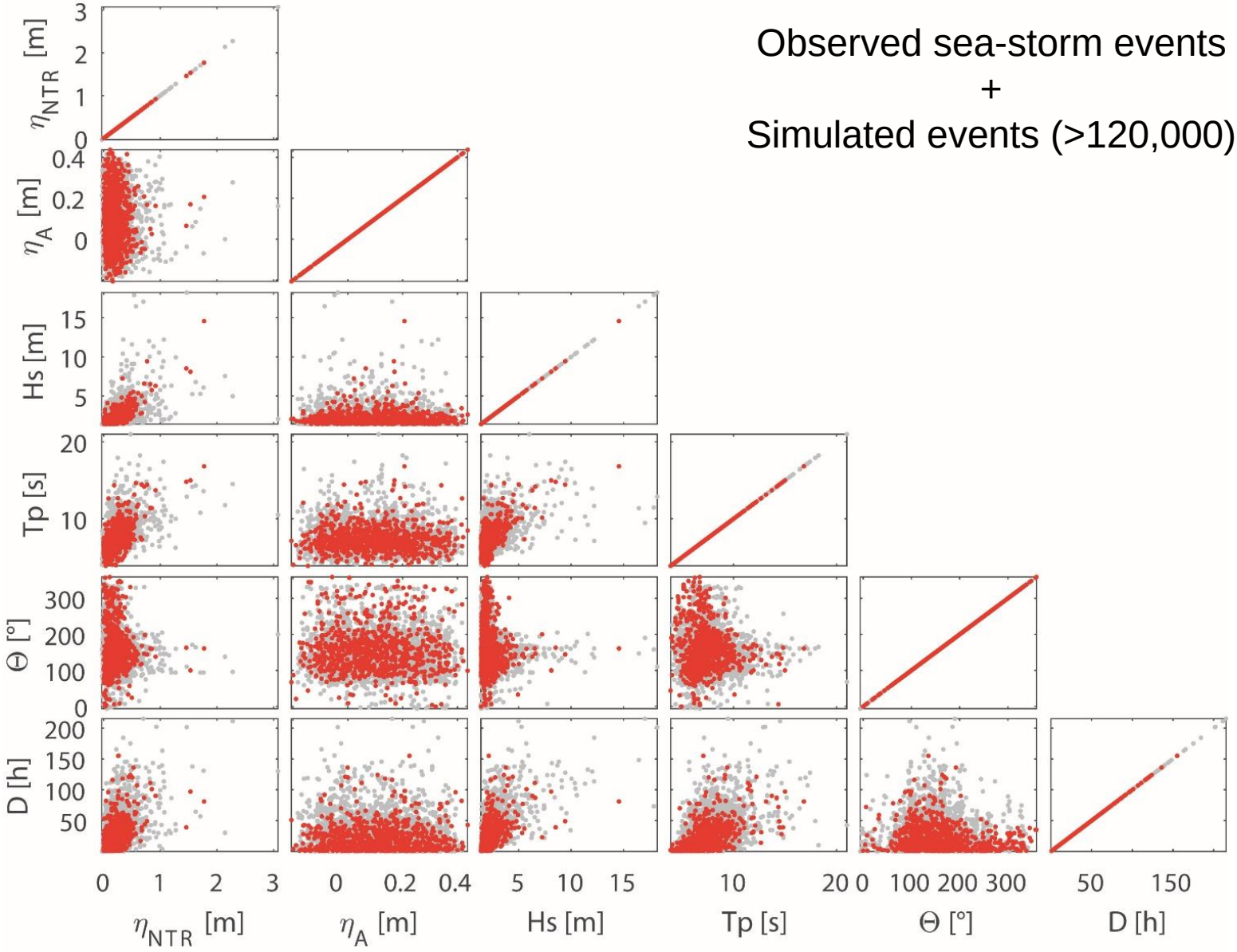


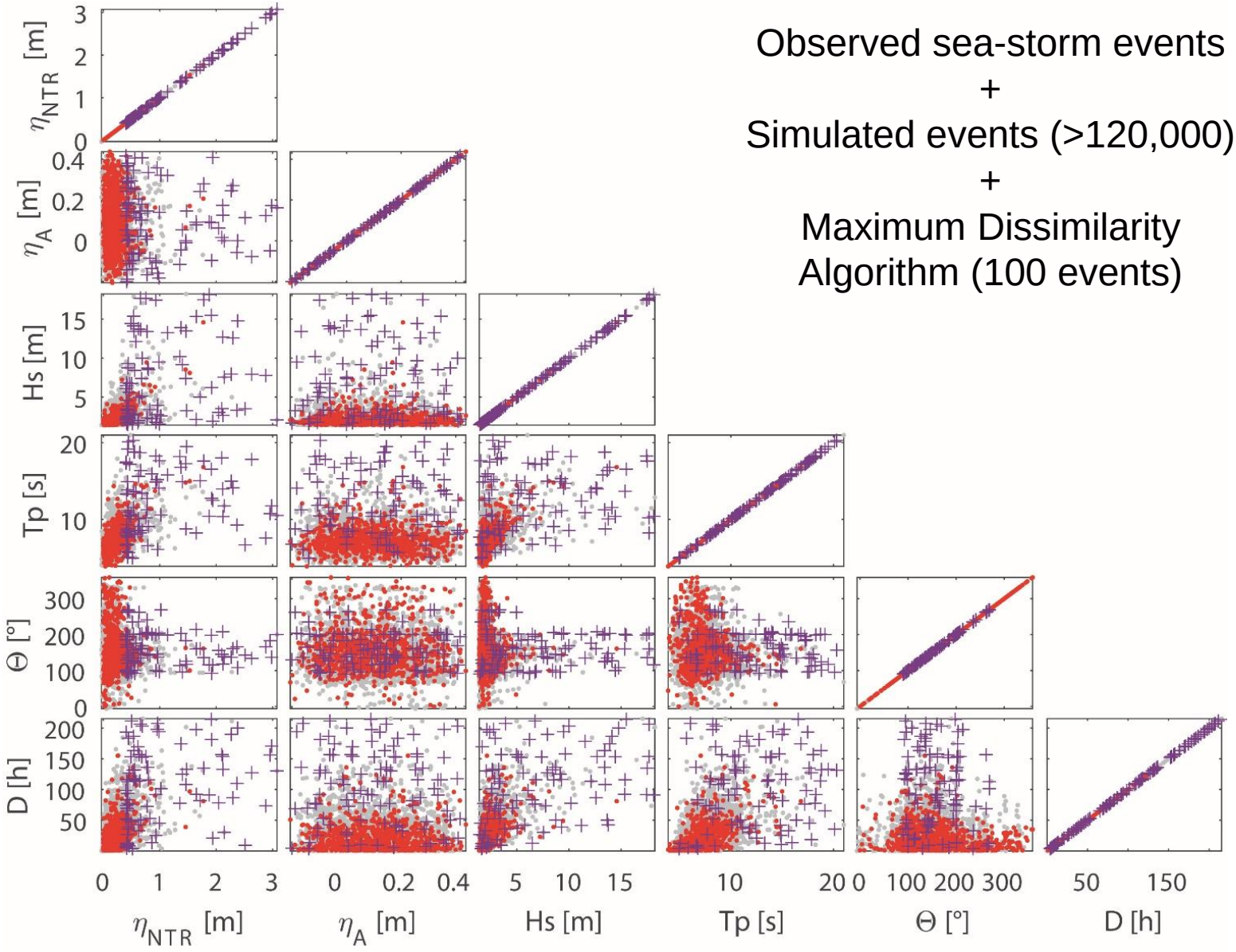
Wahl, T., Plant, N.G., Long, J.W. (2016). Probabilistic assessment of erosion and flooding risk in the northern Gulf of Mexico, *Journal of Geophysical Research Oceans*, 121, 3029–3043

Observed sea-storm events

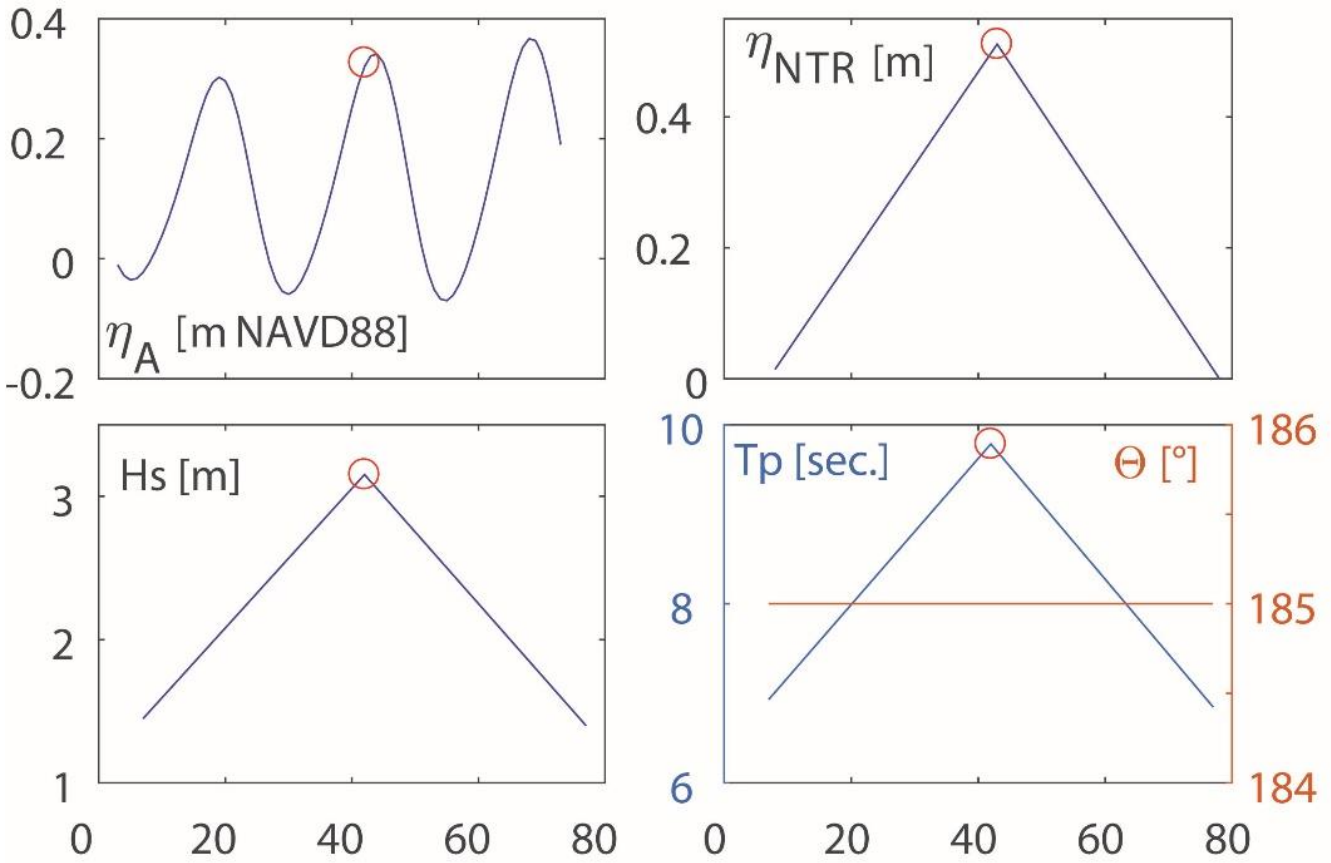


Observed sea-storm events
+
Simulated events (>120,000)

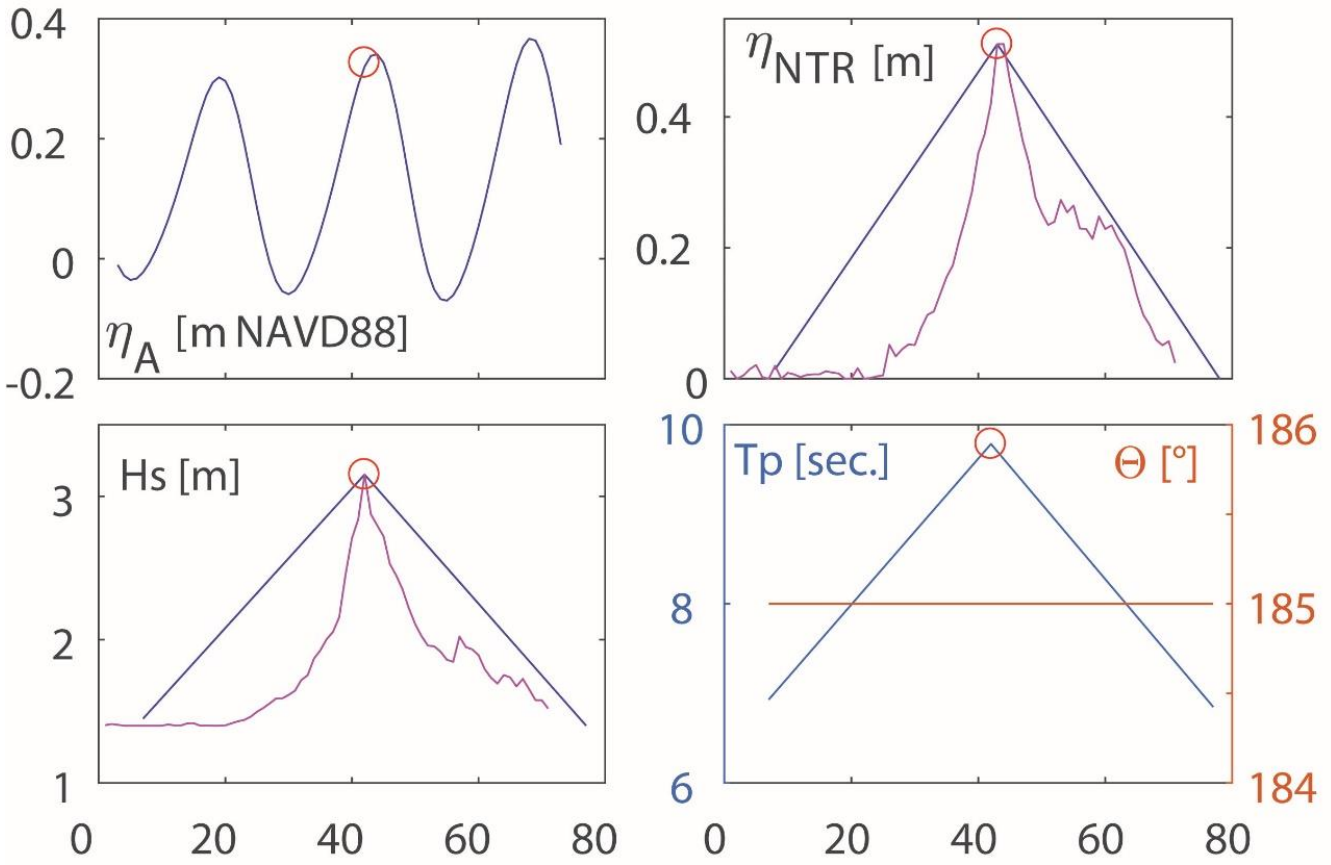



Observed sea-storm events
+
Simulated events (>120,000)
+
Maximum Dissimilarity Algorithm (100 events)
η_{NTR} [m]
η_A [m]
Hs [m]
Tp [s]
Θ [°]
D [h]

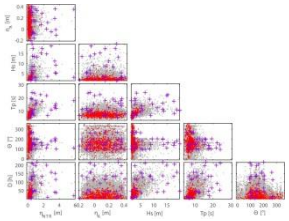
- Point estimates need to be transformed to continuous time series for XBeach simulations
- Surge, wave height and wave period are parameterized as triangular for extra-tropical events

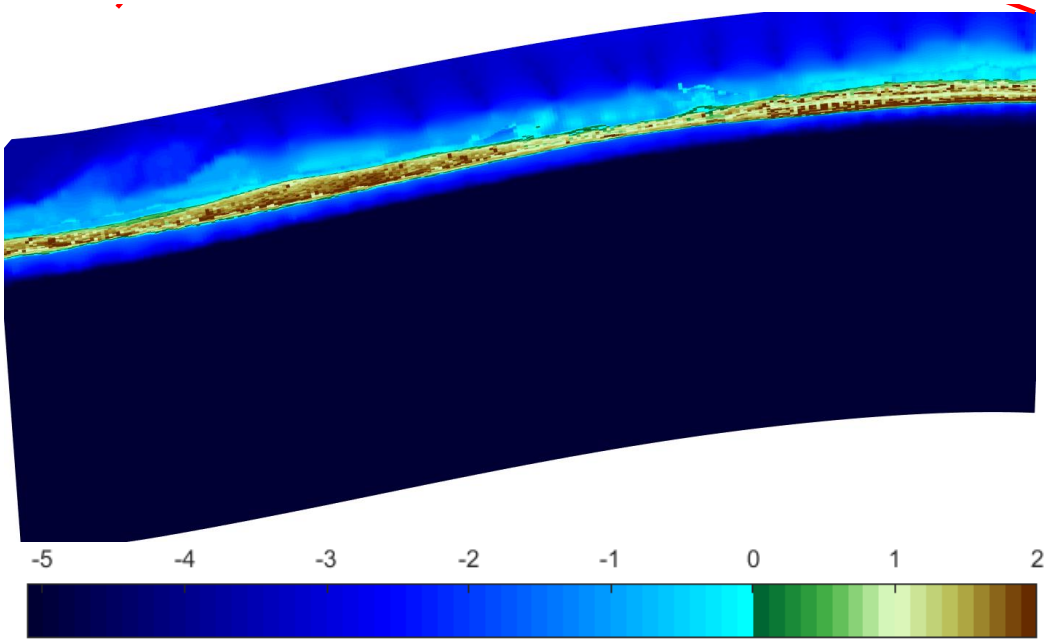


- Point estimates need to be transformed to continuous time series for XBeach simulations
- Surge, wave height and wave period are parameterized as triangular for extra-tropical events
- “Representative” curves are used for surge and wave height for tropical events



Sea-storm variables ⟶ **Simulator**





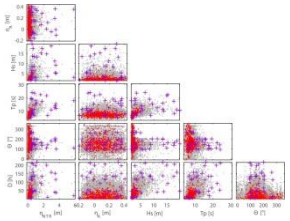
Cross-shore resolution: 2.5m (nearshore) – 12m (offshore)

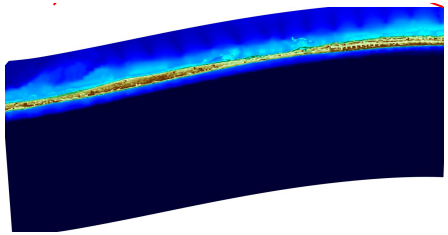
Alongshore resolution: 50m

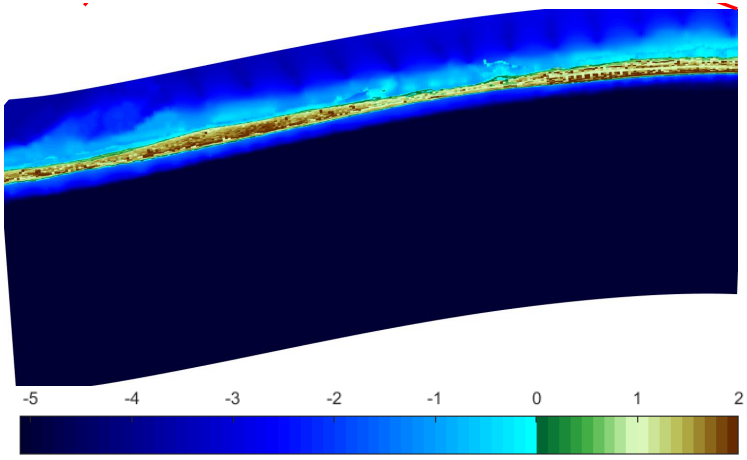
Elevation: compilation of pre-Ivan topo/bathy

Passeri et al. (2018) The influence of bed friction variability due to land cover on storm-driven barrier island morphodynamics, *Coast. Eng. 132, 82-94*.

Sea-storm variables → **Simulator** → **Structural variable(s)**



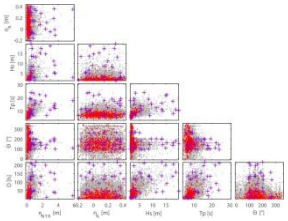


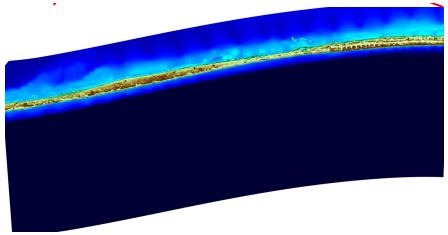


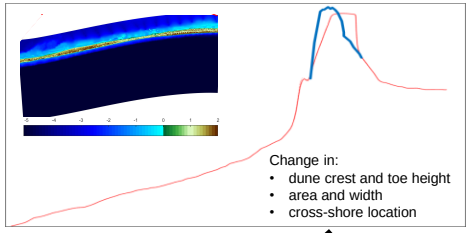
Change in:

- dune crest and toe height
- area
- width

Sea-storm variables → **Simulator** → **Structural variable(s)**







Surrogate models:

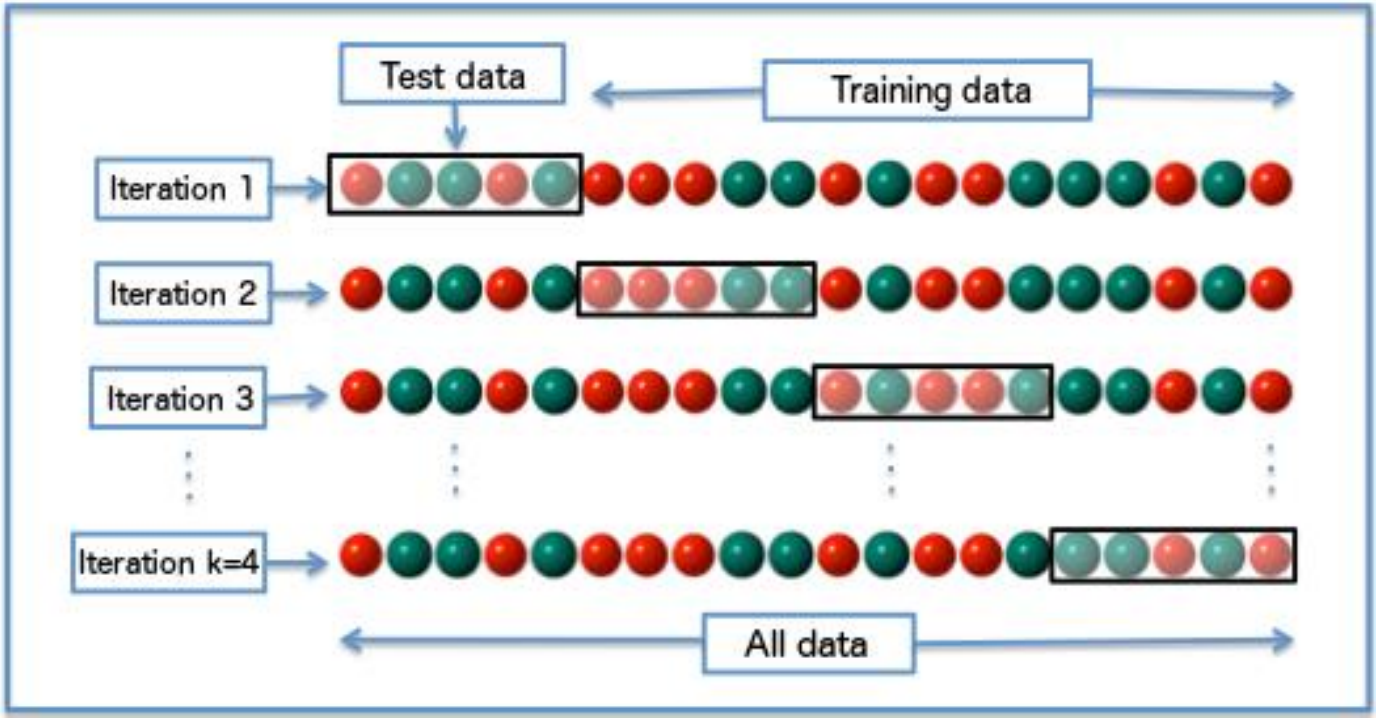
Multiple linear regression (MLRM)

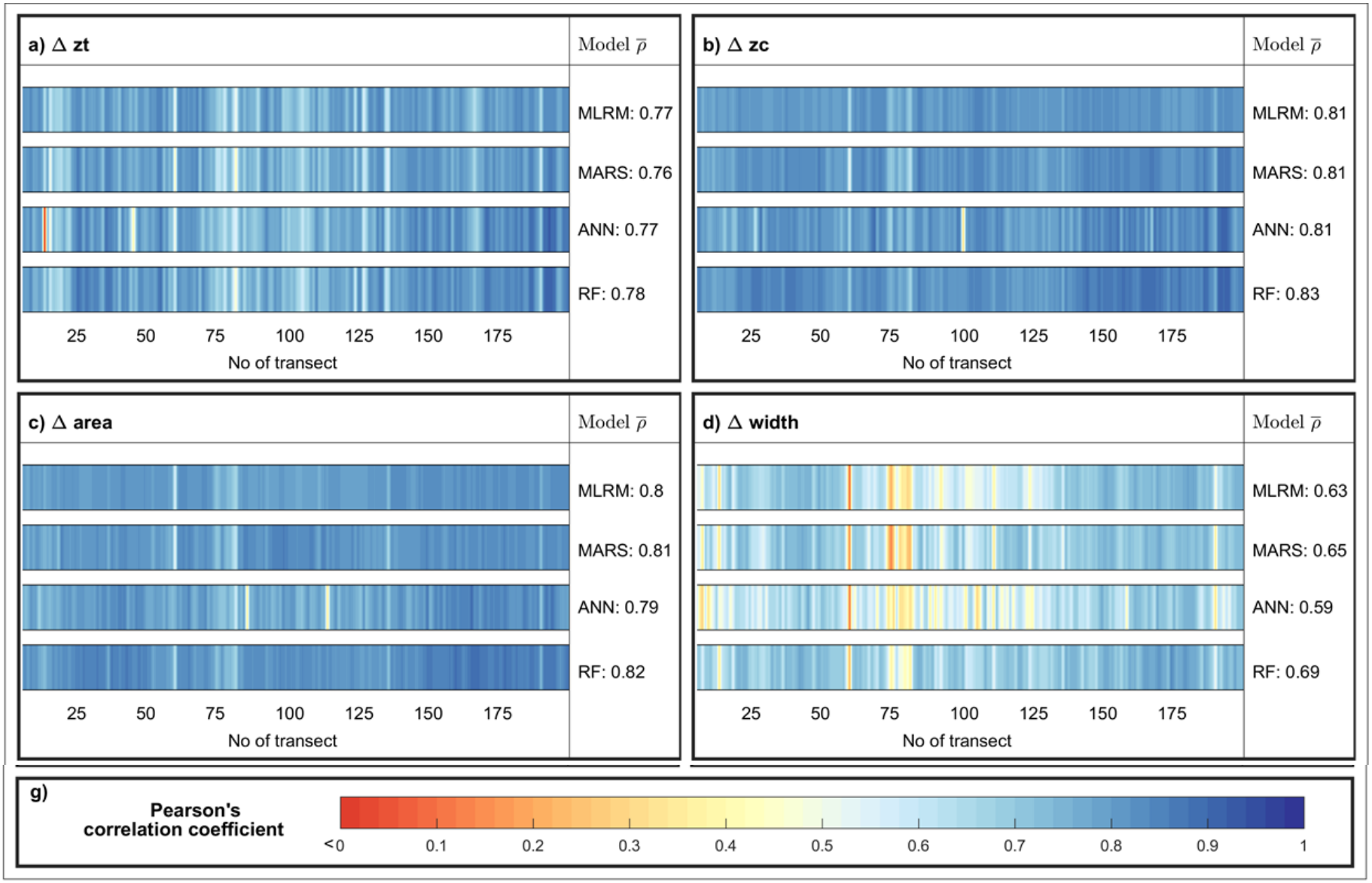
Artificial Neural Networks (ANN)

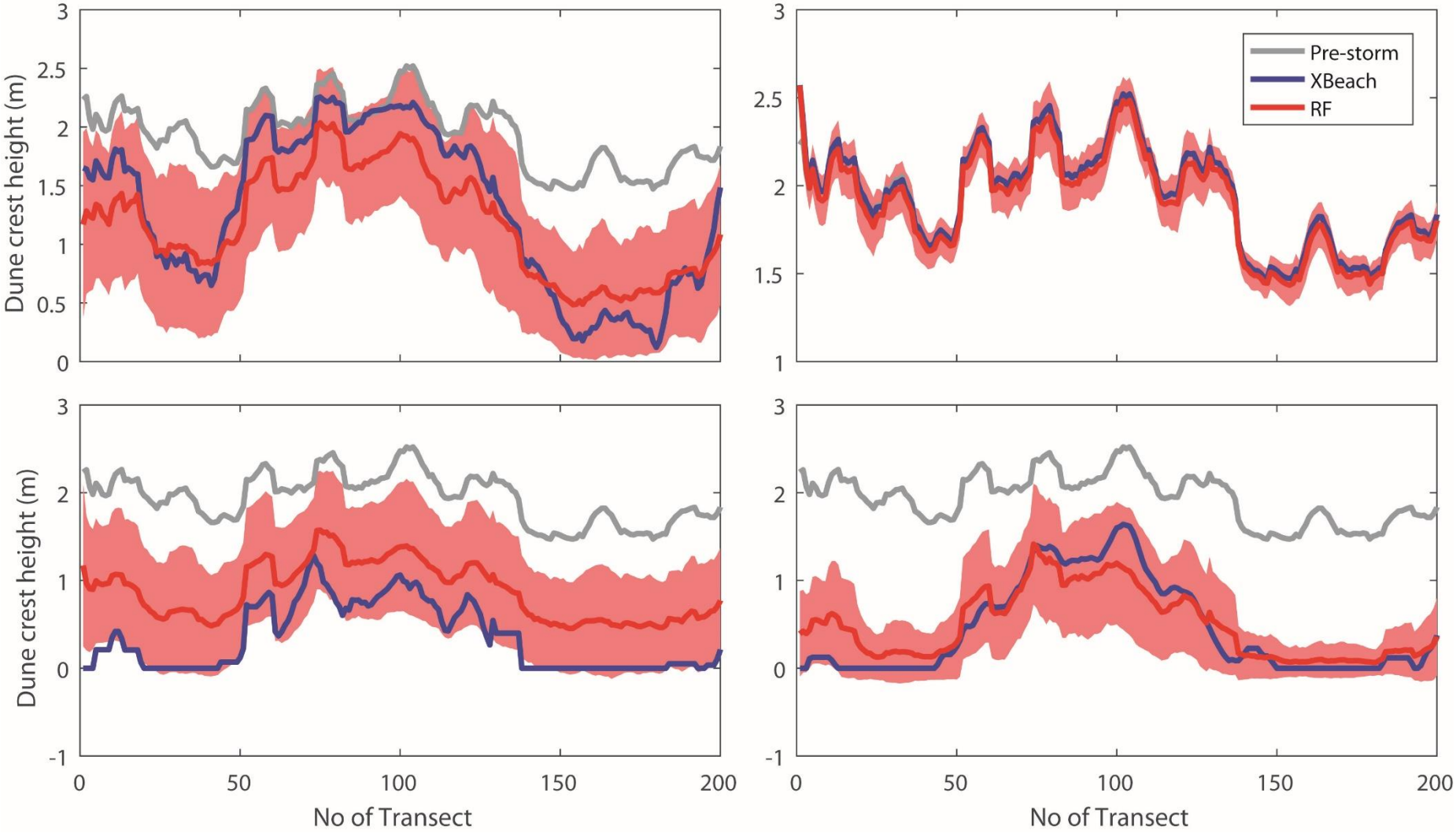
Multivariate Adaptive Regression Splines (MARS)

Random Forests (RF)

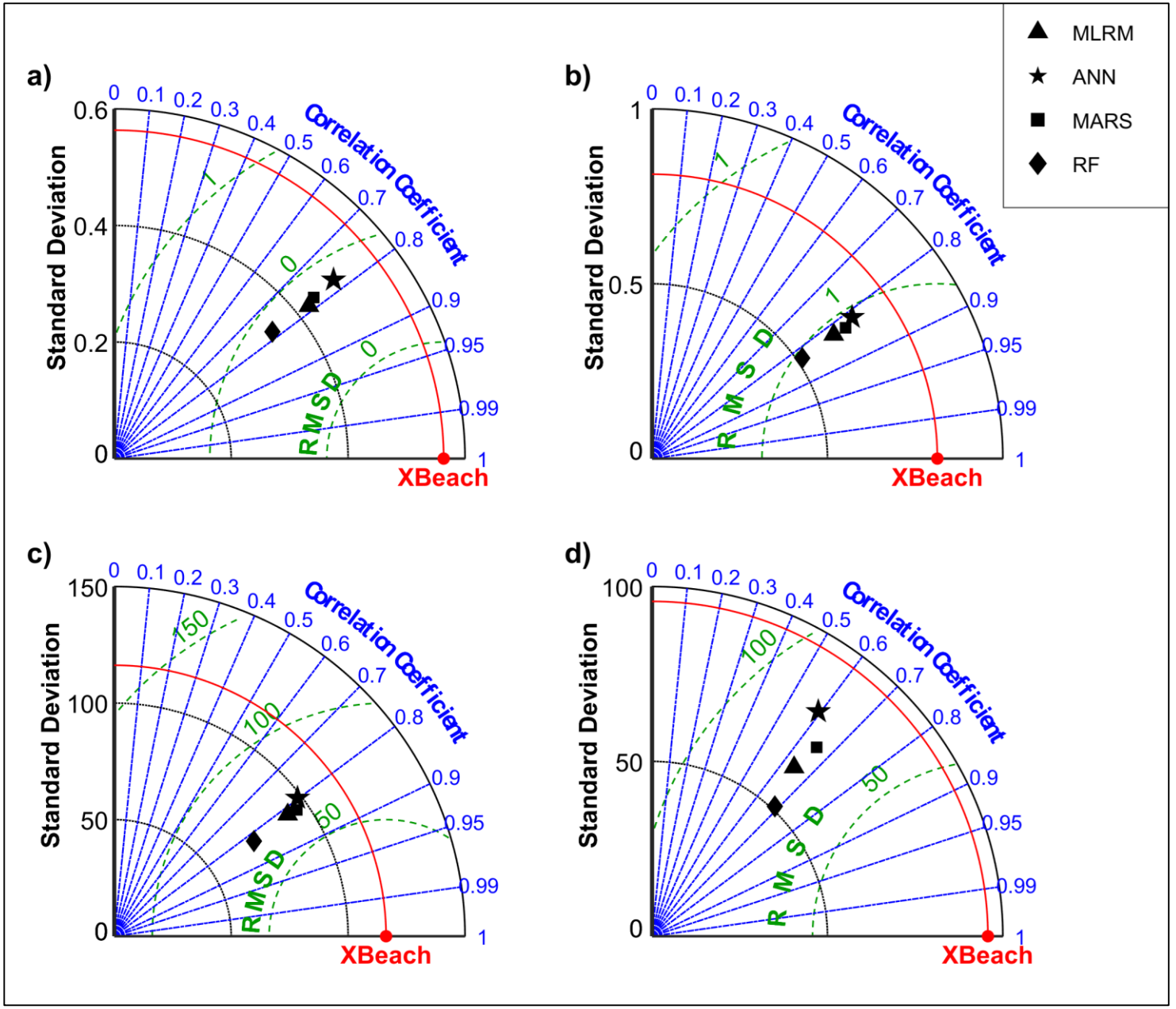
- Surrogate models are trained based on oceanographic drivers (predictors) and dune response (predictand)
- K-fold cross validation is performed (for different values of k)
- Performance indicators: Pearson correlation coefficient and root mean squared error




a) Δ zt
Model $\overline{\rho}$
MLRM: 0.77
MARS: 0.76
ANN: 0.77
RF: 0.78
25 50 75 100 125 150 175
No of transect
b) Δ zc
Model $\overline{\rho}$
MLRM: 0.81
MARS: 0.81
ANN: 0.81
RF: 0.83
25 50 75 100 125 150 175
No of transect
c) Δ area
Model $\overline{\rho}$
MLRM: 0.8
MARS: 0.81
ANN: 0.79
RF: 0.82
25 50 75 100 125 150 175
No of transect
d) Δ width
Model $\overline{\rho}$
MLRM: 0.63
MARS: 0.65
ANN: 0.59
RF: 0.69
25 50 75 100 125 150 175
No of transect
g)
Pearson's correlation coefficient
<0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


Dune crest height (m)
Dune crest height (m)
No of Transect
No of Transect
Pre-storm
XBeach
RF

Thank you for your attention!


a)
b)
c)
d)
MLRM
ANN
MARS
RF
Standard Deviation
Correlation Coefficient
RMSD
XBeach
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.99
1
0.6
0.4
0.2
0
0.5
150
100
50