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HYBRID DOWNSCALING APPROACH FOR NEARSHORE WAVE CLIMATE ANALYSIS IN ROATAN, HN
IMPACTS OF SEA LEVEL RISE

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FSBPA 2025 CONFERENCE

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AGENDA

1. Introduction and Available Data

2. Wave Climate Hybrid Downscaling

3. Sea Level Rise Impact Assessment

4. Conclusions

1. INTRODUCTION AND AVAILABLE DATA

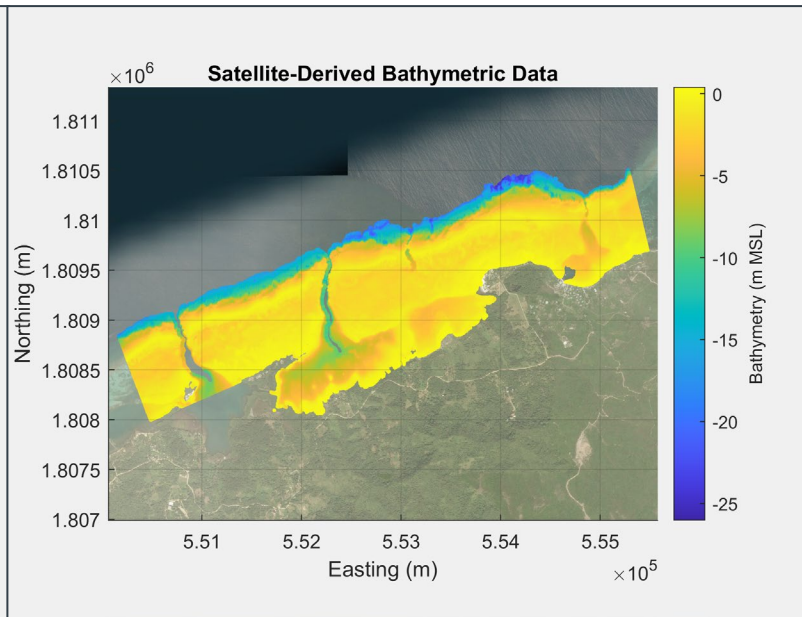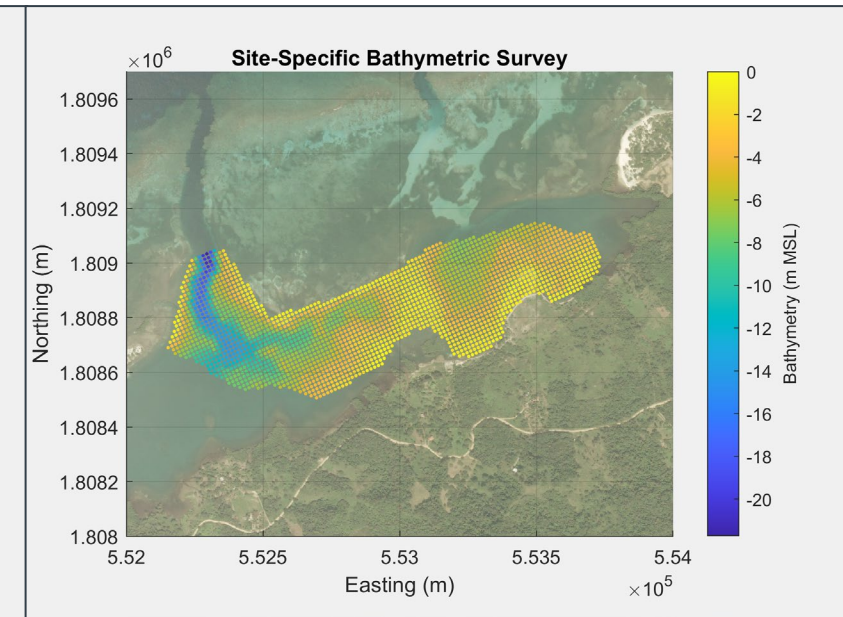# PROJECT LOCATION & OBJECTIVES

BATHYMETRIC DATA
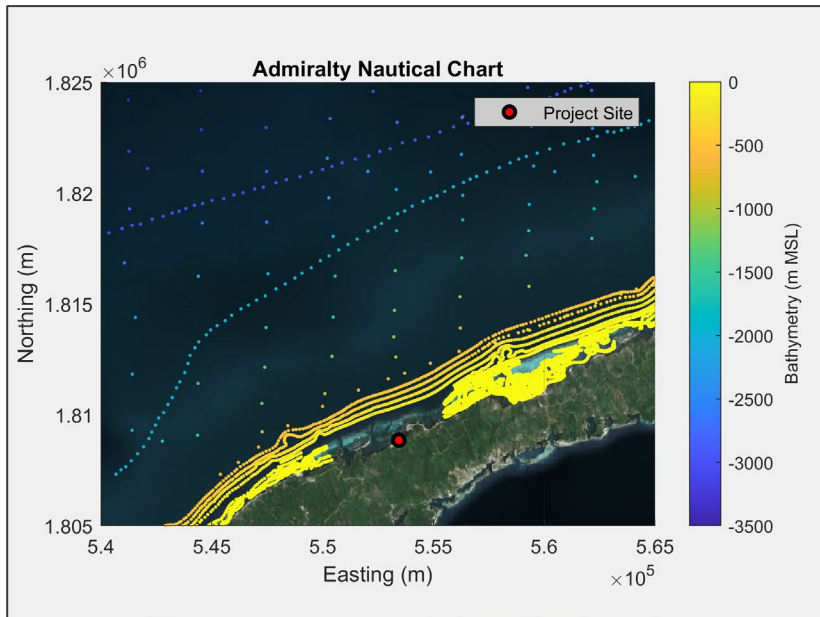
Offshore area
- Digitized UKHO Admiralty Nautical Chart #513

Nearshore area
- Satellite-Derived Bathymetry
- 2 m spatial resolution
- From 0 to -25 m MSL

Project area
- Multibeam hydrographic survey
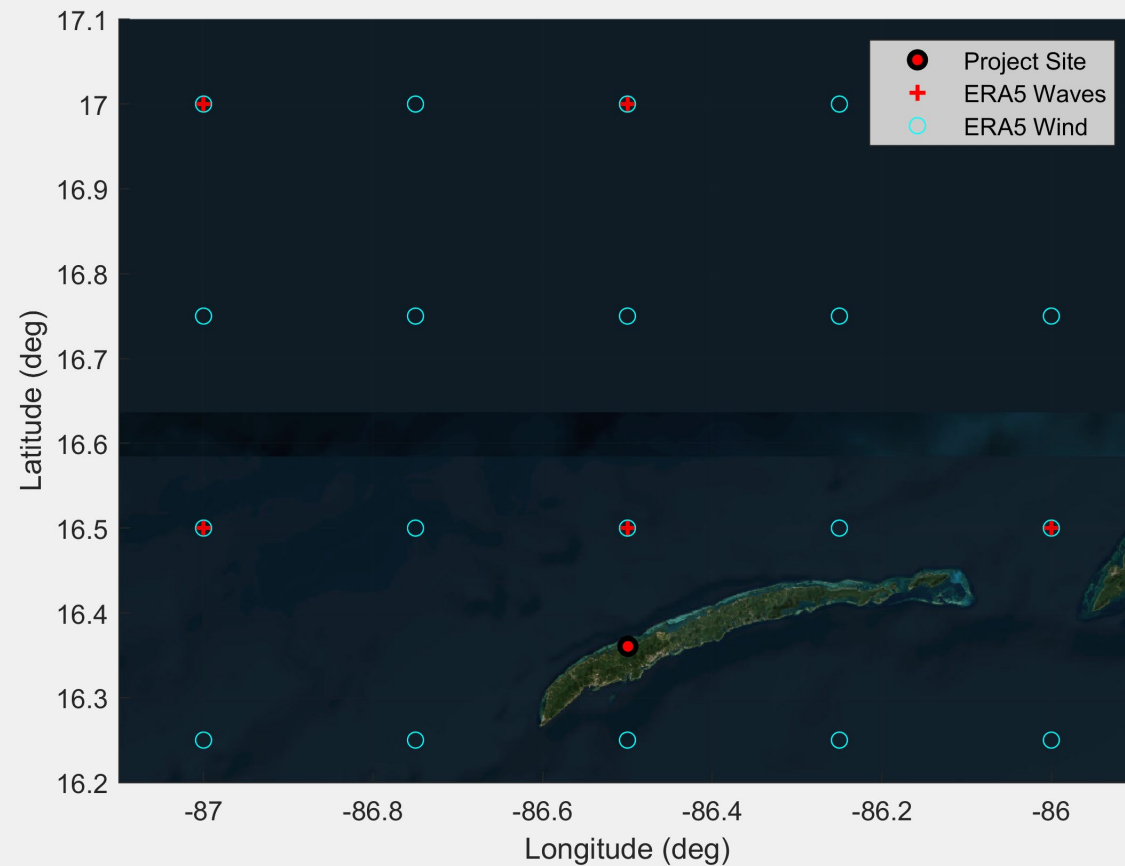
REANALYSIS METOCEAN DATA

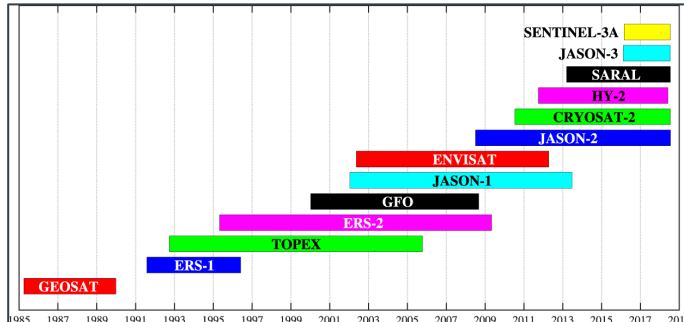- ECMWF ERA5 Reanalysis Global Model
- 84 years (1940-2024)
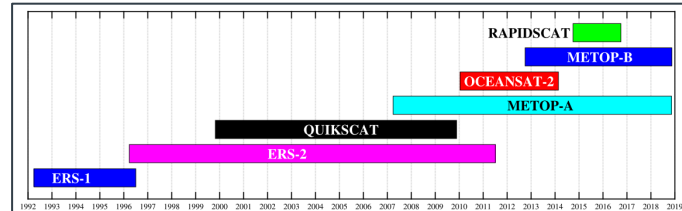- 1h interval

- 0.5° by 0.5°
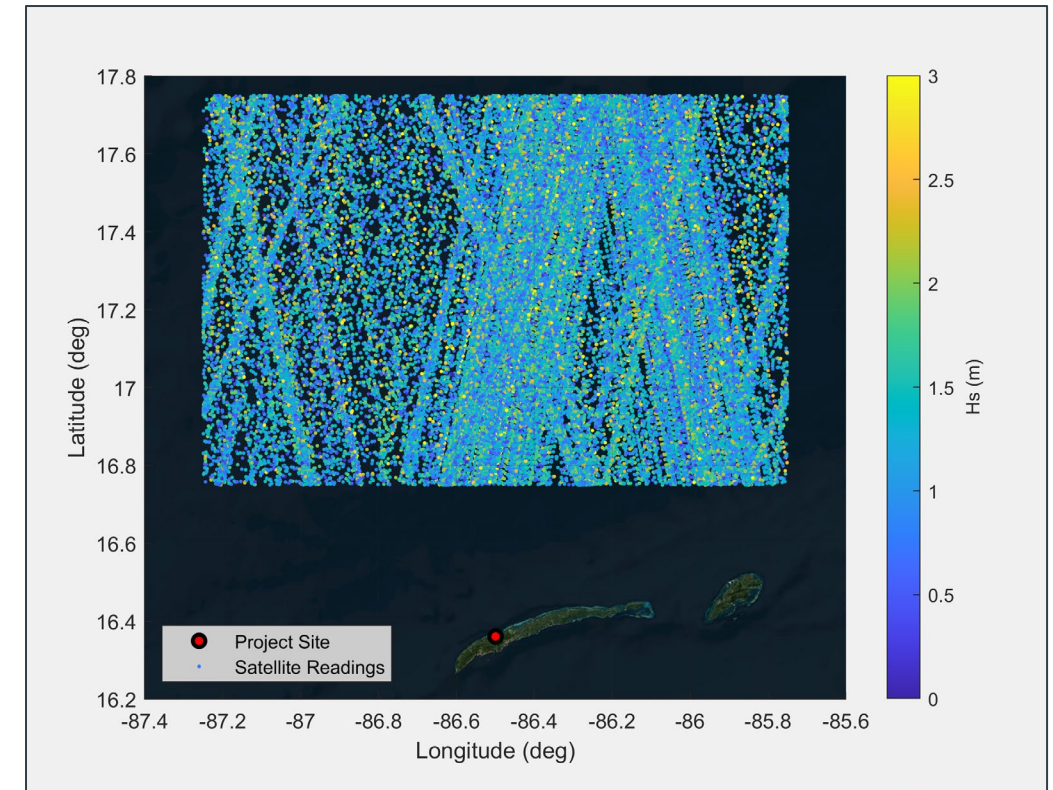- Hs, Tp, MWD

- 0.25° by 0.25°
- Wind Speed, Wind Direction

- Altimeter data
- Hs, Tp, MWD
- 39 years (1985-2024)
- 13 satellite missions

- Scatterometer data
- Wind Speed, Wind Direction
- 32 years (1992-2024)
- 7 satellite missions

2. WAVE CLIMATE HYBRID DOWNSCALING
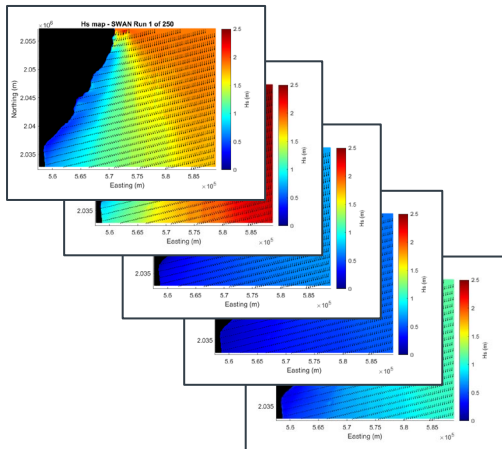
HYBRID DOWNSCALING METHODOLOGY

A hybrid efficient method to downscale wave climate to coastal areas

Paula Camus, Fernando J. Mendez [*], Raul Medina

Environmental Hydraulics Institute IH Cantabria, Universidad de Cantabria, Spain

Dynamical downscaling

Based on real-time numerical modelling

Statistical Downscaling

Based on empirical formulation

- $K_R K_S$
- Neural Networks

Hybrid Downscaling

Transfer function (statistical downscaling) obtained by

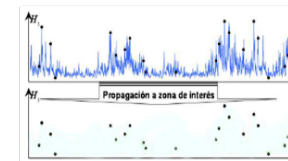numerical propagation of a number of sea state conditions (dynamical downscaling)

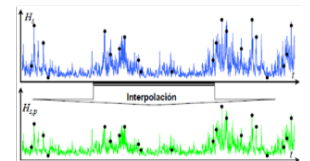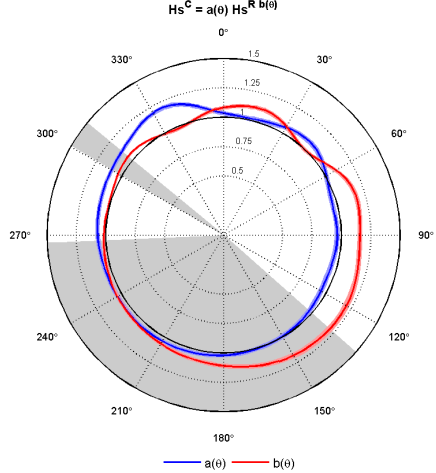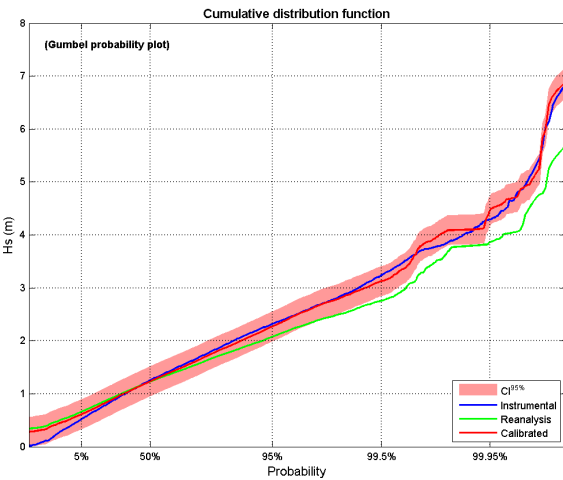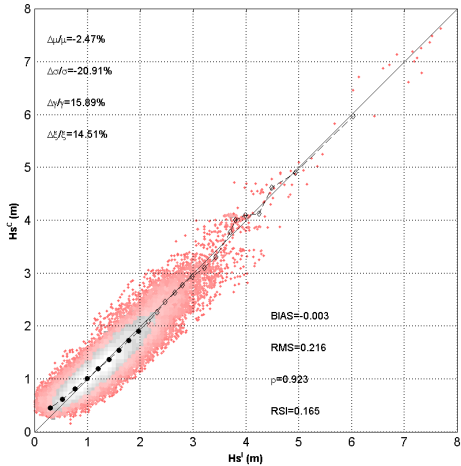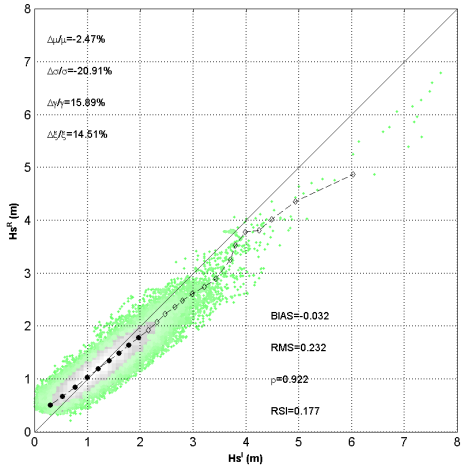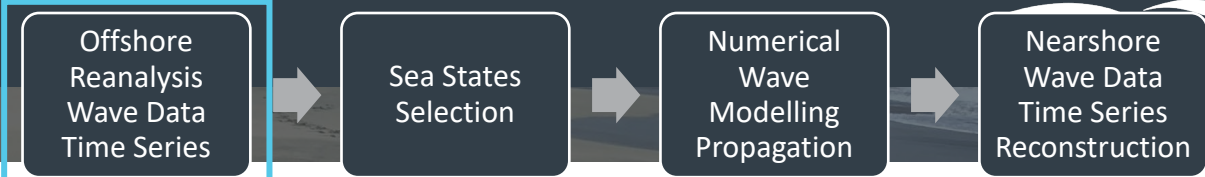| Offshore Reanalysis Wave Data Time Series | → | Sea States Selection | → | Numerical Wave Modelling Propagation | → | Nearshore Wave Data Time Series Reconstruction |

OFFSHORE WAVE DATA DIRECTIONAL CALIBRATION

ATM

Directional Calibration of Wave Reanalysis Databases Using Instrumental Data

R. MÍNGUEZ, A. ESPEJO, A. TOMÁS, F. J. MÉNDEZ, AND I. J. LOSADA

Environmental Hydraulics Institute "IH Cantabria," Universidad de Cantabria, Campus Internacional, Cantabria, Spain

(Manuscript received 13 January 2011, in final form 25 March 2011)

| Offshore Reanalysis Wave Data Time Series | → | Sea States Selection | → | Numerical Wave Modelling Propagation | → | Nearshore Wave Data Time Series Reconstruction |

Parameter	Before Calibration	After Calibration
Bias (m)	-0.032	-0.003
RMS (m)	0.232	0.216
ρ (-)	0.922	0.923
RSI (-)	0.177	0.165

OFFSHORE WIND DATA DIRECTIONAL CALIBRATION

Directional Calibration of Wave Reanalysis Databases Using Instrumental Data

R. MÍNGUEZ, A. ESPEJO, A. TOMÁS, F. J. MÉNDEZ, AND I. J. LOSADA

Environmental Hydraulics Institute "IH Cantabria," Universidad de Cantabria, Campus Internacional, Cantabria, Spain

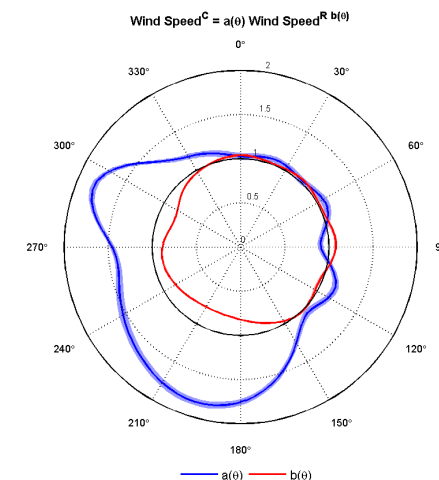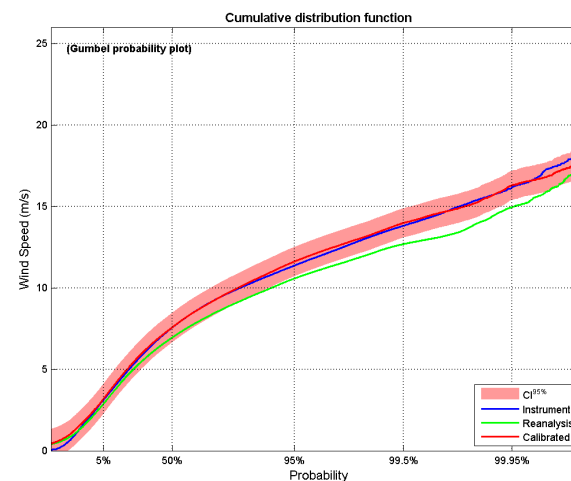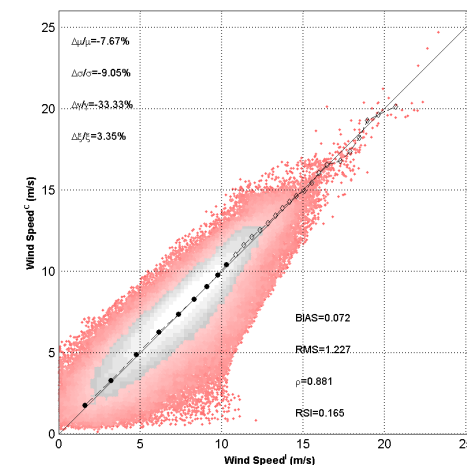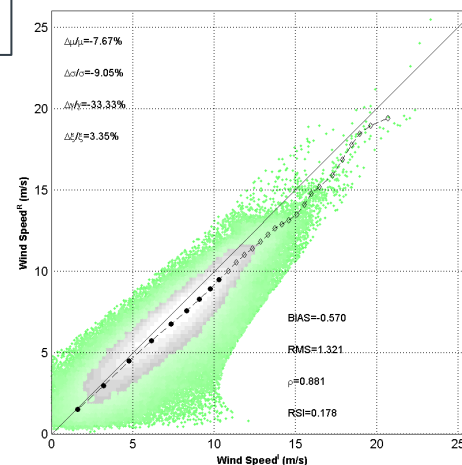(Manuscript received 13 January 2011, in final form 25 March 2011)

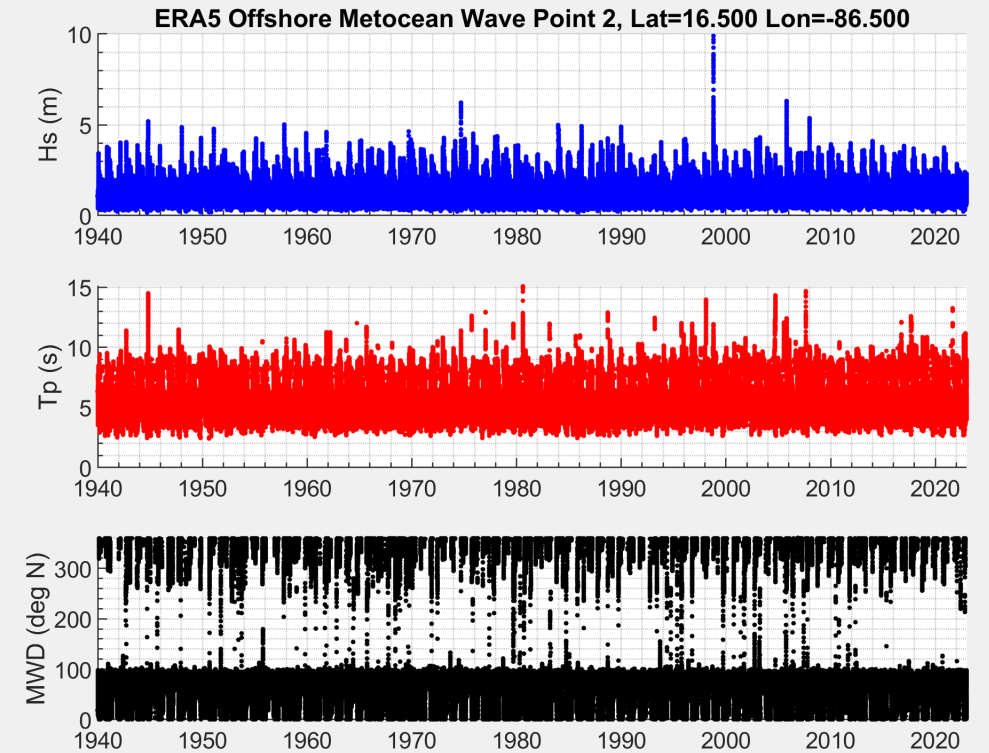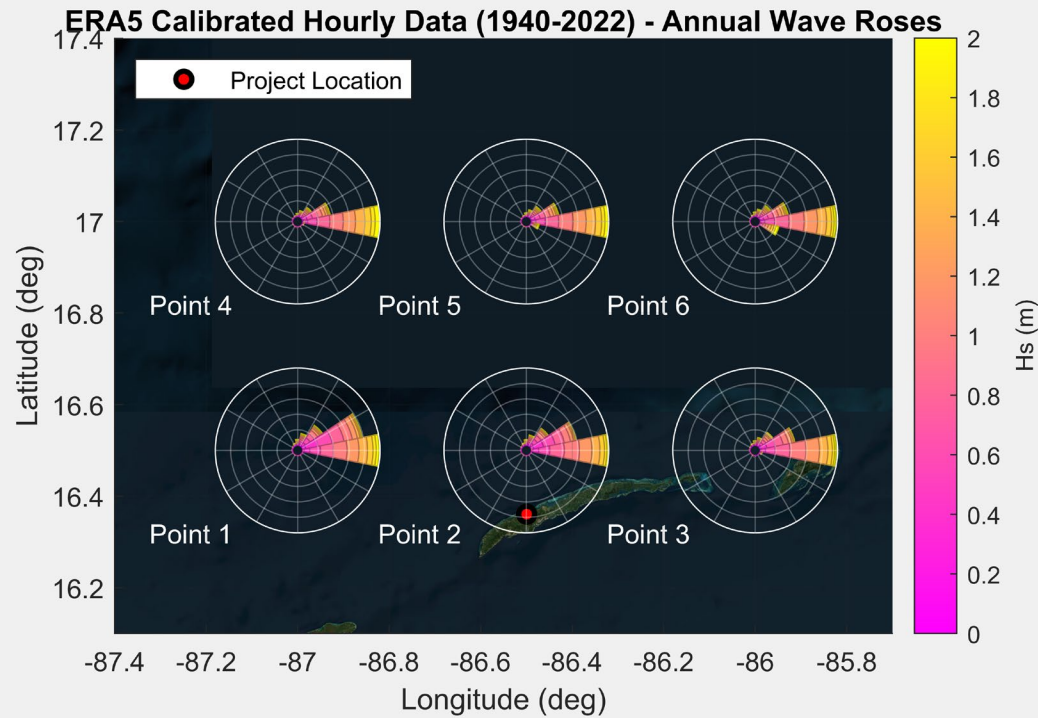| Parameter	Before Calibration	After Calibration
Bias (m/s)	-0.570	0.072
RMS (m/s)	1.321	1.227
ρ (-)	0.881	0.881
RSI (-)	0.178	0.165

11

OFFSHORE WAVE CLIMATE

Offshore Reanalysis Wave Data Time Series → Sea States Selection → Numerical Wave Modelling Propagation → Nearshore Wave Data Time Series Reconstruction

ERA5 Calibrated Hourly Data (1940-2022) - Annual Wave Roses

ERA5 Offshore Metocean Wave Point 2, Lat=16.500 Lon=-86.500

OFFSHORE SEA STATES SELECTION

Analysis of clustering and selection algorithms for the study of multivariate wave climate

Paula Camus [a,*], Fernando J. Mendez [a], Raul Medina [a], Antonio S. Cofiño [b]

[a] Environmental Hydraulics Institute "IH Cantabria", Universidad de Cantabria, Spain
[b] Santander Meteorology Group, Dep. of Applied Mathematics and Computer Sciences, Universidad de Cantabria, Spain
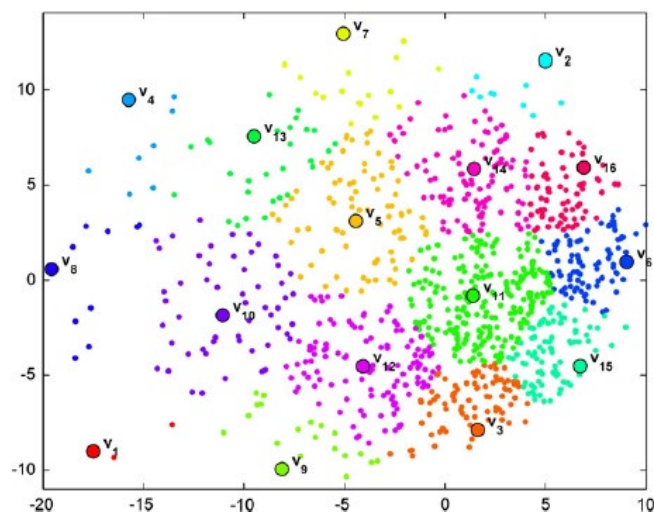
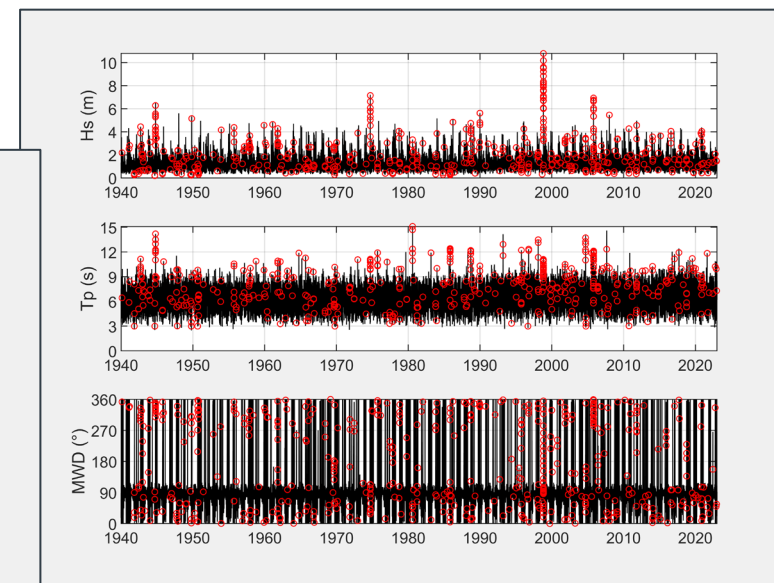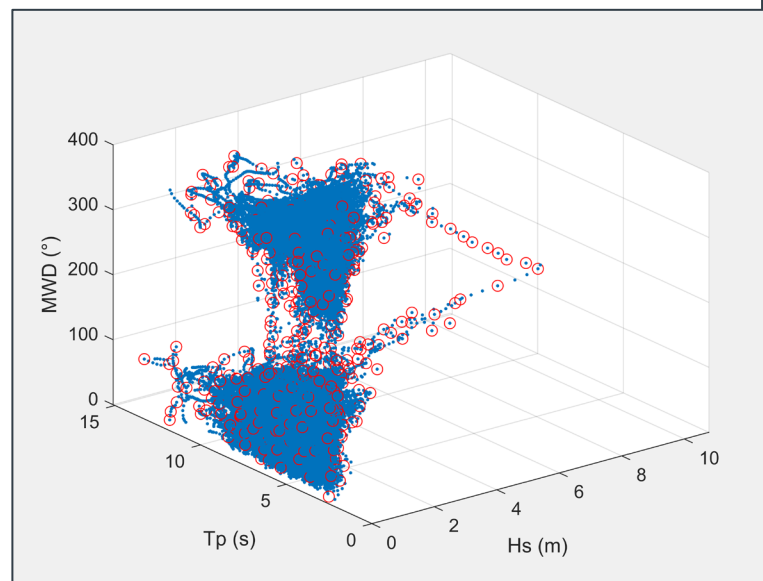Offshore Reanalysis Wave Data Time Series → Sea States Selection → Numerical Wave Modelling Propagation → Nearshore Wave Data Time Series Reconstruction
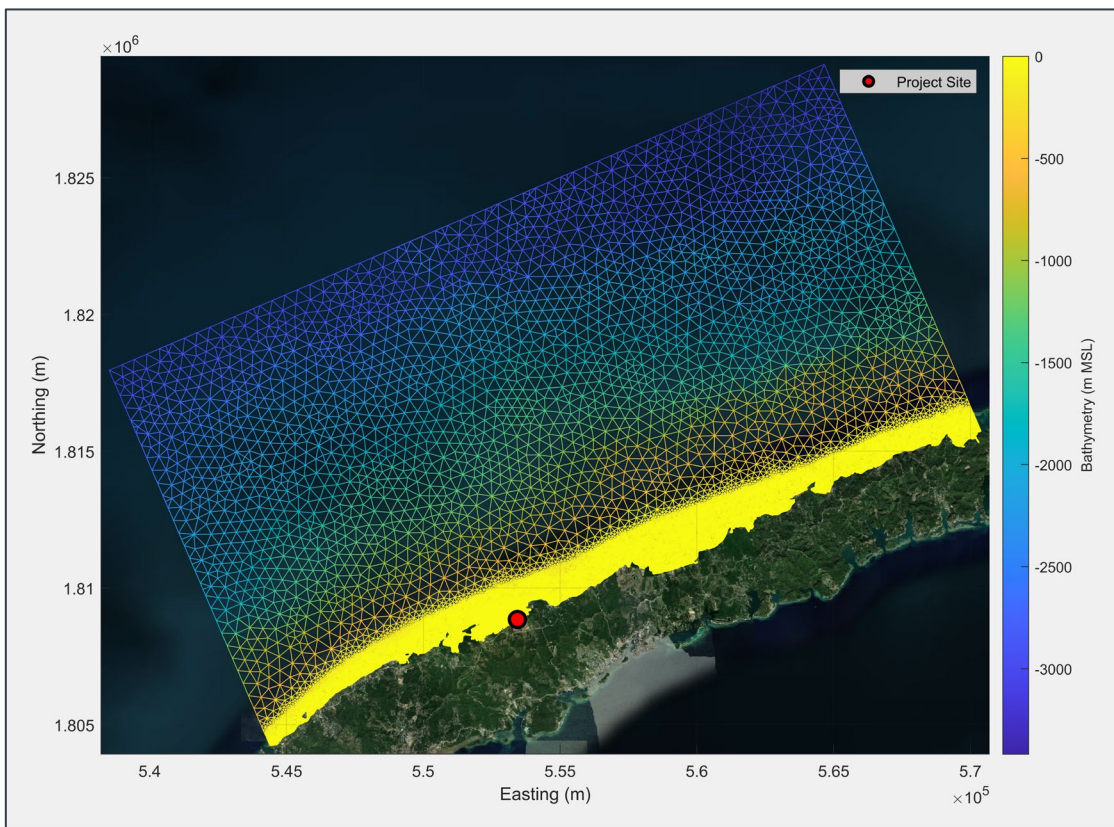
Selection of 500 cases based on 3-dimension cluster of offshore sea states

Maximum Dissimilarity Algorithm (MDA) selected points are maximally dissimilar to each other

WAVE MODELLING PROPAGATION

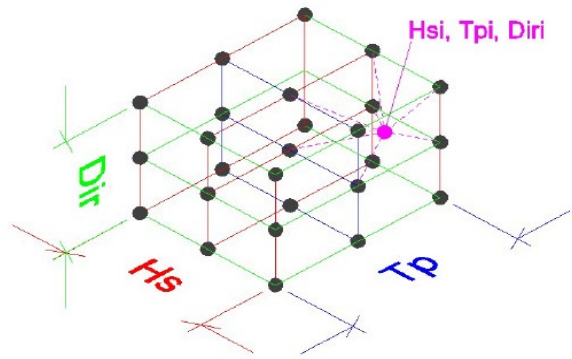| Offshore Reanalysis Wave Data Time Series | → | Sea States Selection | → | Numerical Wave Modelling Propagation | → | Nearshore Wave Data Time Series Reconstruction |

- MIKE21 SW Flexible mesh of 58,334 elements
- Stationary spectral wave propagation of the 500 selected cases
- Under constant water level and 0.37 m of SLR (Approximation for 50 years of SLR under SSP5-8.5)
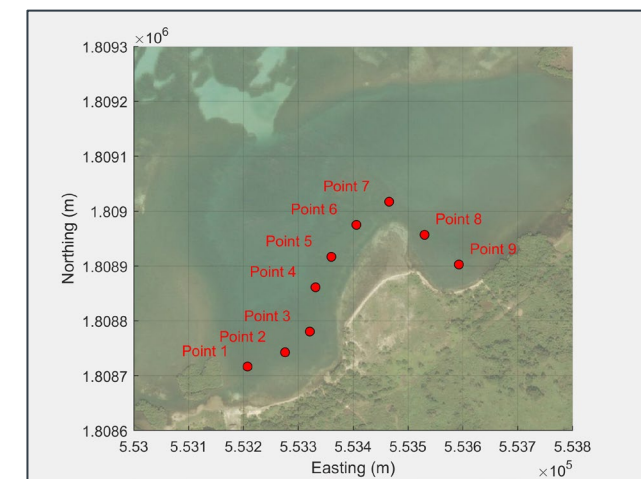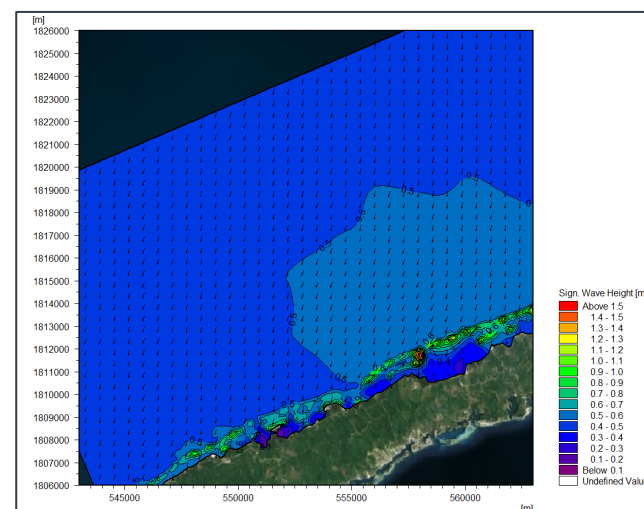
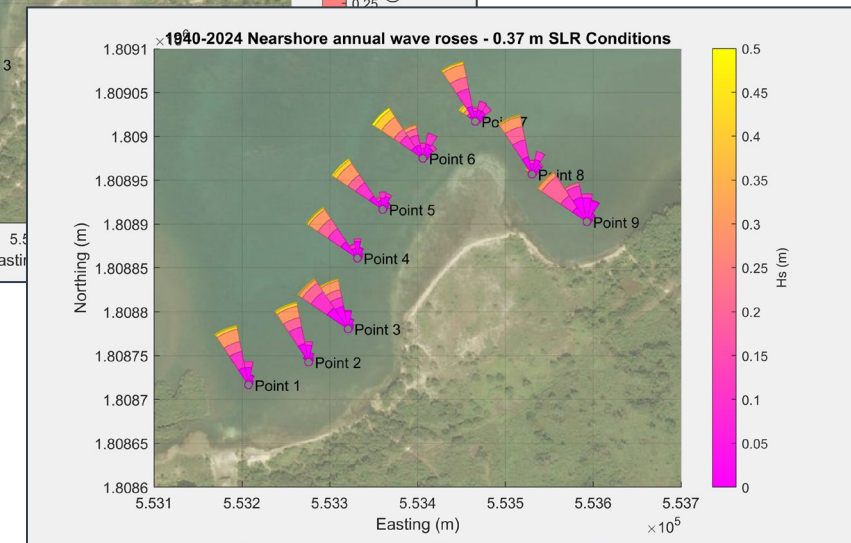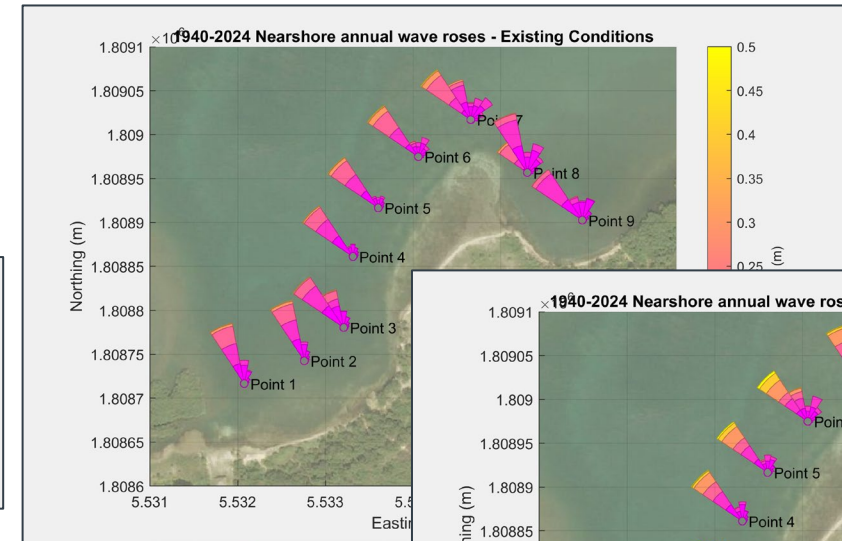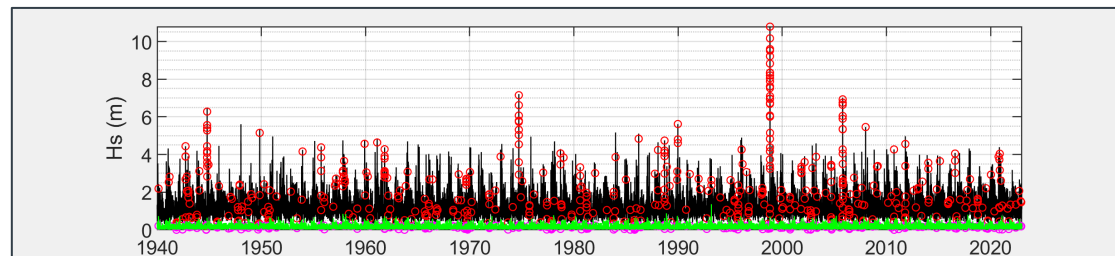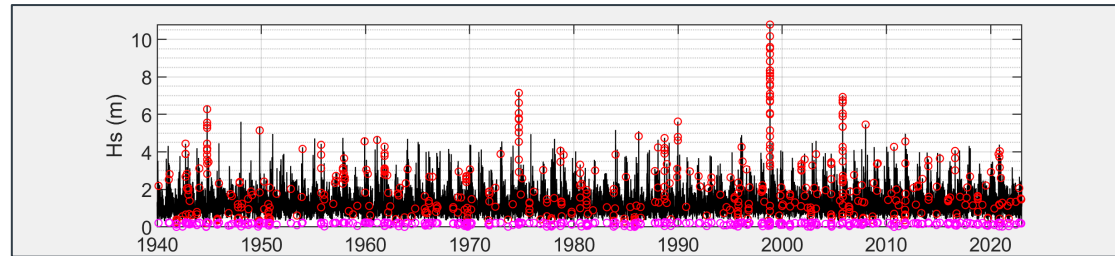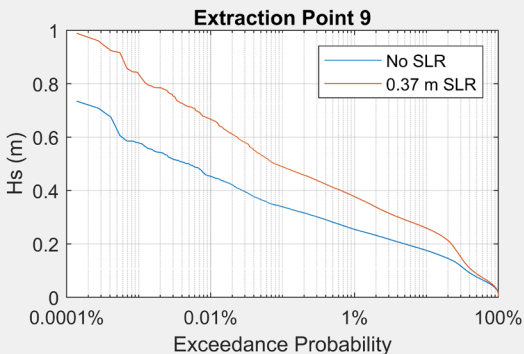# NEARSHORE TIME SERIES RECONSTRUCTION

3. SEA LEVEL RISE IMPACT ASSESSMENT

SLR IMPACT ON WAVE HEIGHTS
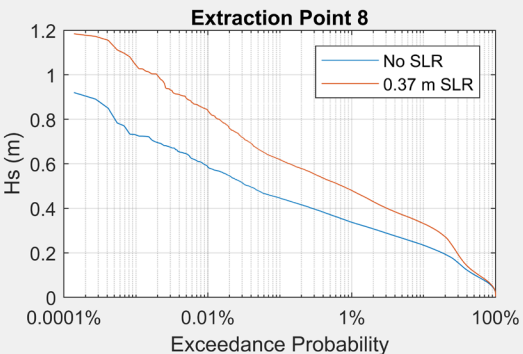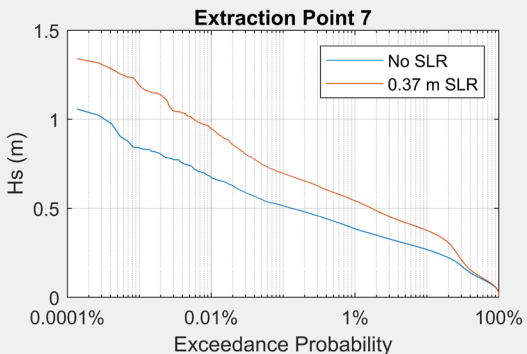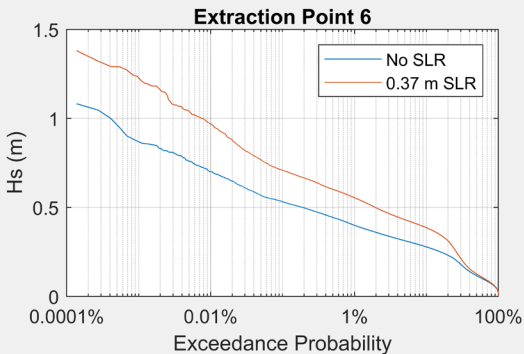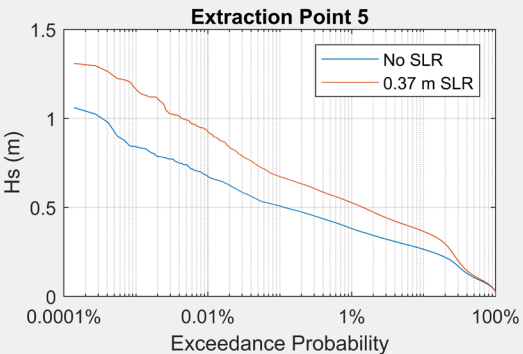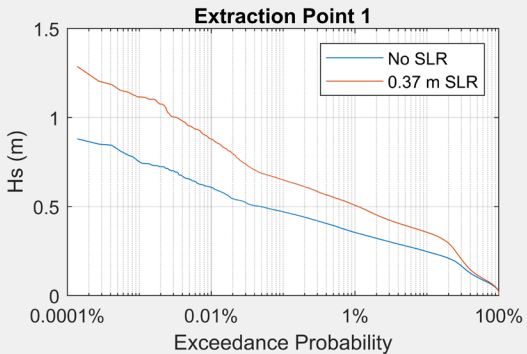
Freq. of exceedance	Ave. difference Hs (m)	Ave. difference Hs (%)
50%	0.01	11%
10%	0.10	40%
1%	0.14	40%
0.1%	0.16	36%
0.001%	0.25	40%
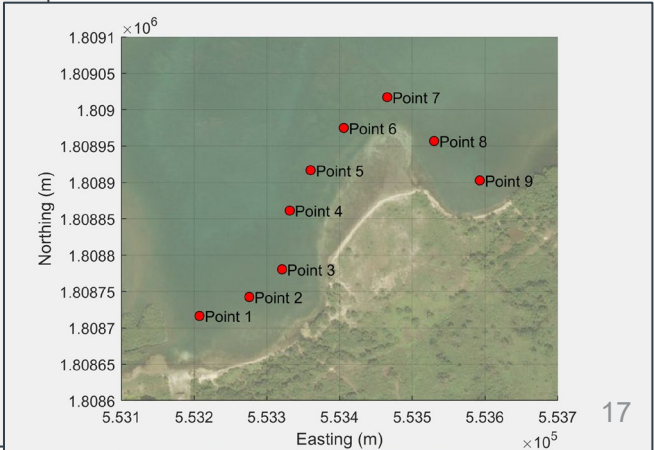
SLR IMPACT ON WAVE DIRECTION

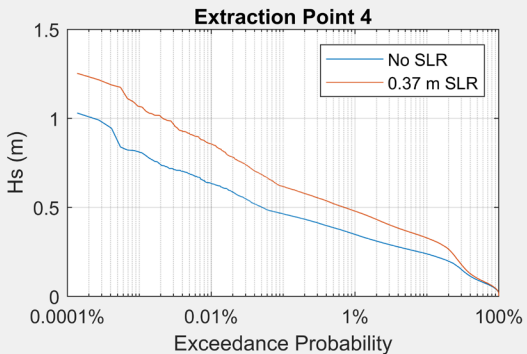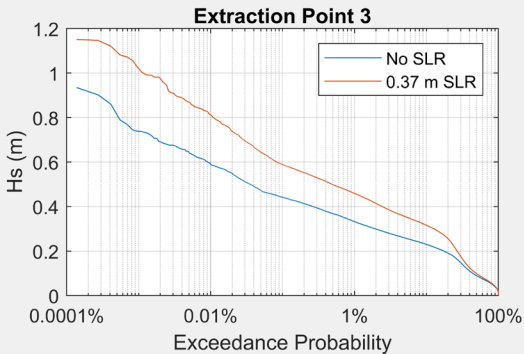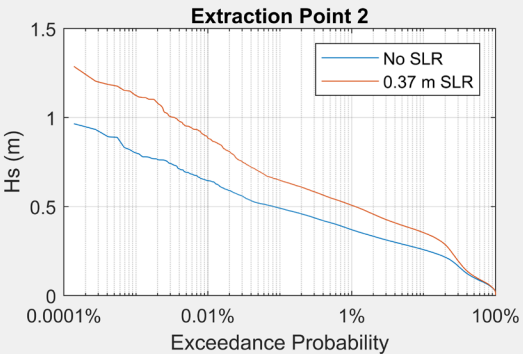**Wave Energy Flux Mean Direction**

Legend: No SLR, 0.37 m SLR
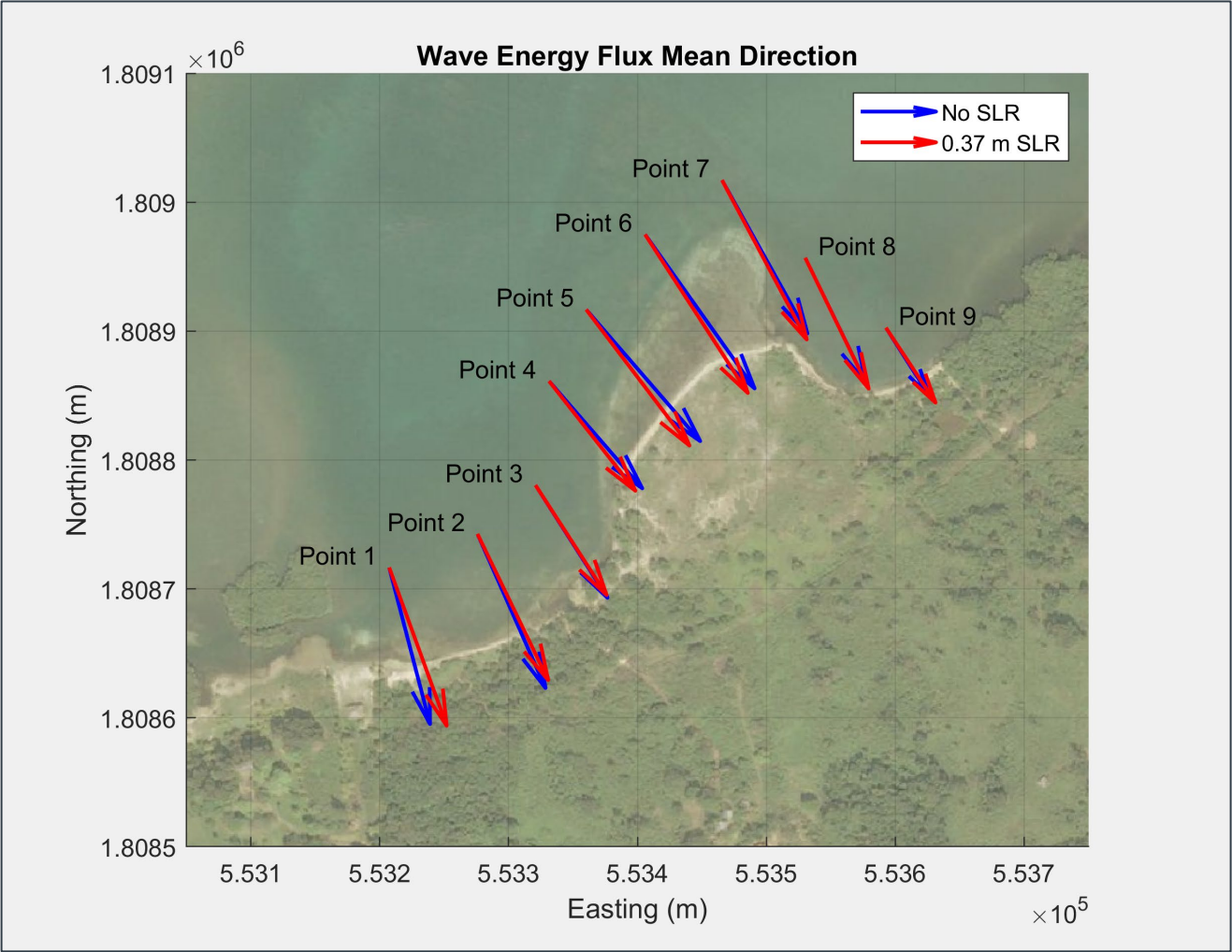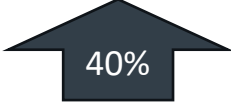
Point #	Direction change
1	-5.4°
2	-1.9°
3	-0.3°
4	2.8°
5	3.7°
6	2.5°
7	1.1°
8	0.1°
9	-1.1°
Absolute Ave.	*2.1°*

4. CONCLUSIONS AND FURTHER APPLICATIONS

CONCLUSIONS

- The shallow fringing reef provides a valuable natural protection against incoming swells.

- Increased wave heights under SLR conditions

  Hs exceeded 50% ⬆ 15%   Hs exceeded 10% ⬆ 40%

- Once the waves pass over the reef, the wave direction spreading is significantly reduced.

- The WEMFD rotates under the considered increased SLR scenario (2.1° on average, up to 5.4°).

- The rotation of the WEMFD can have multiple impacts on the shoreline such as:

  - reorientation of the equilibrium position of beaches
  - changes in littoral drift patterns
  - alterations in wave-driven currents

  - increased erosion or accretion in specific areas
  - shifts in nearshore bar and sandbank formations

APPLICATIONS

Case Study specific applications

- Resilient design of coastal infrastructure, and climate adaptation strategy.

Other applications

- Design of physical restoration of coral reefs (engineering analysis of Nature-based Solutions);

- Quantitative analysis for adaptation of coastal infrastructure to physical impacts of climate change;

- Detailed analysis of coastal impacts under different Sea Level Rise Scenarios, in coastal areas with irregular morphology, including shallow fringing reefs.

THANK YOU

Felix Juzgado, ME

Project Professional

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