Appendix A.1.1: Comparison of SWH from wave buoy data and EraInterim for cyclonic events

The wave buoy which collected wave data was located in waters of 46.2 m depths off the coast of Roches Noire, on the North east coast of Mauritius.

Cyclonic event 1 – Edilson

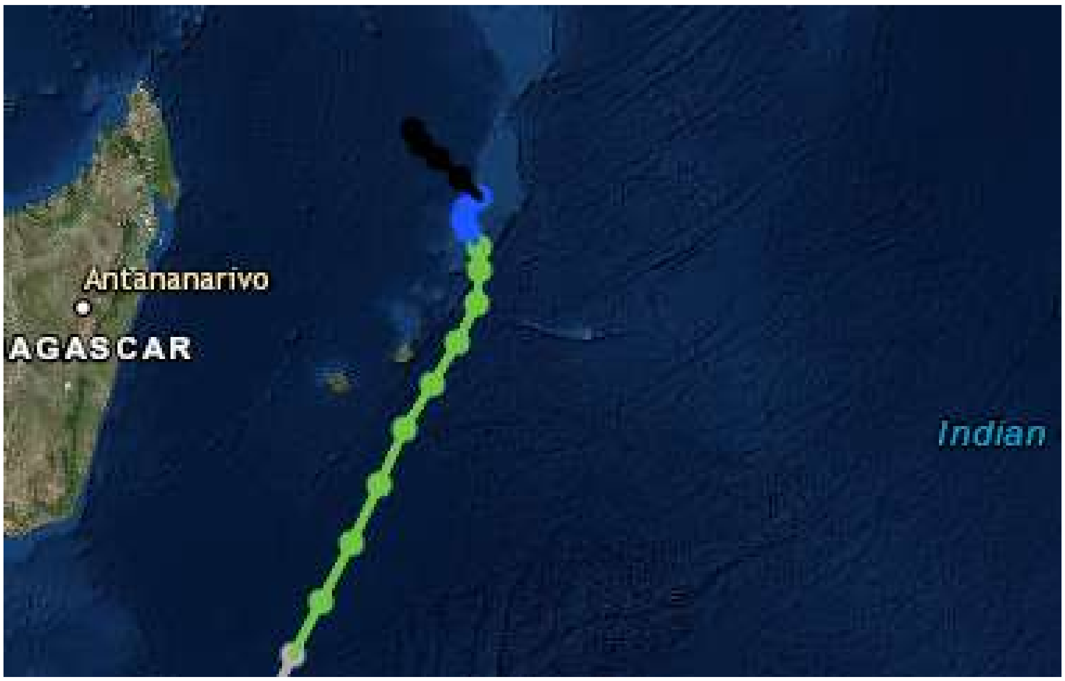
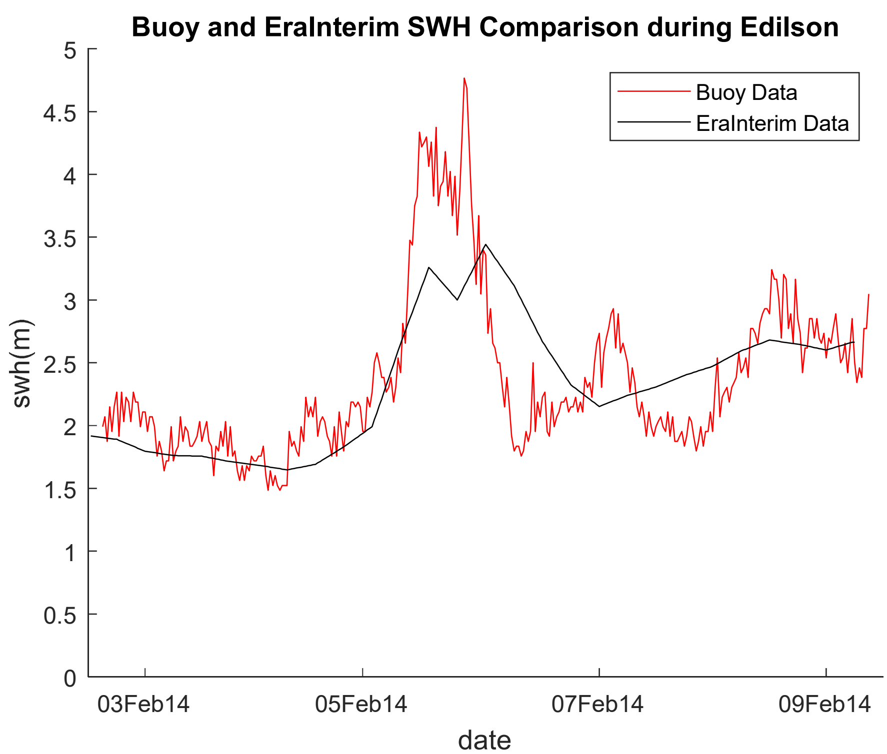


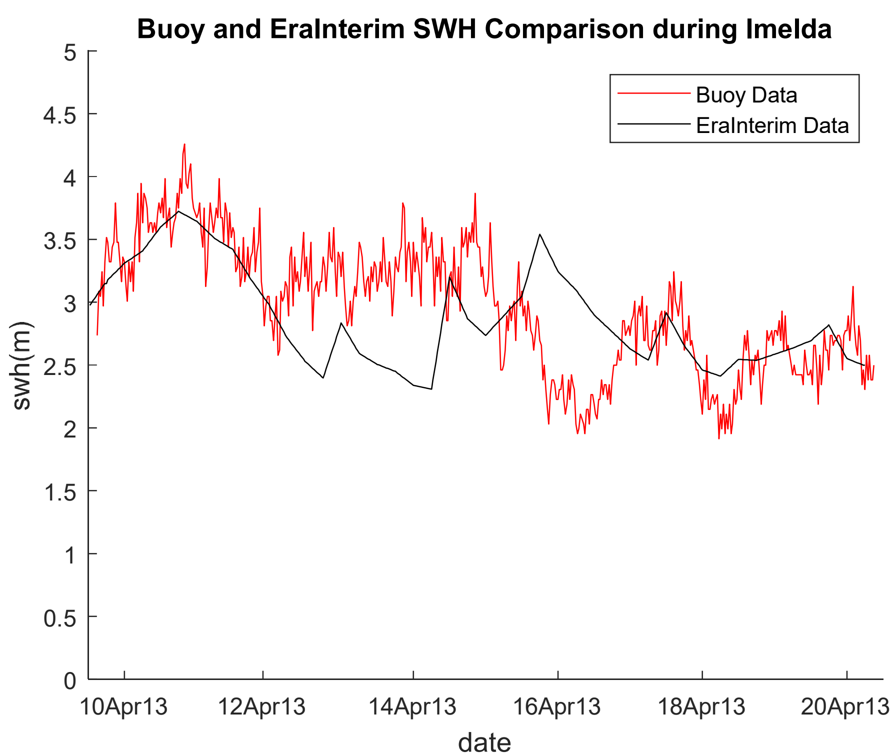
Figure: Cyclone trajectory of Edilson from NOAA (https://coast.noaa.gov/hurricanes/)



Appendix A.1.2: Comparison of SWH from wave buoy data and EraInterim for cyclonic events

Cyclonic event 2 – Imelda – April 2013

Figure: Cyclone trajectory of Imelda from NOAA (https://coast.noaa.gov/hurricanes/)



Appendix A.1.3: Comparison of SWH from wave buoy data and EraInterim for cyclonic events

Cyclonic event 2 – Giovanna – February 2012

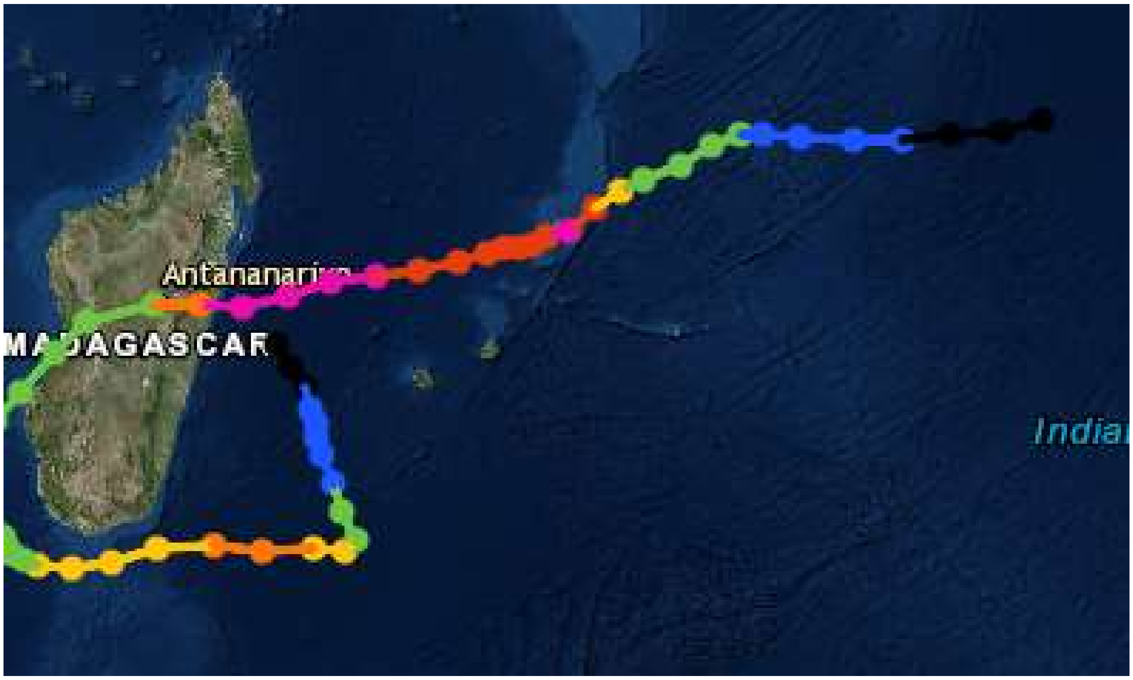
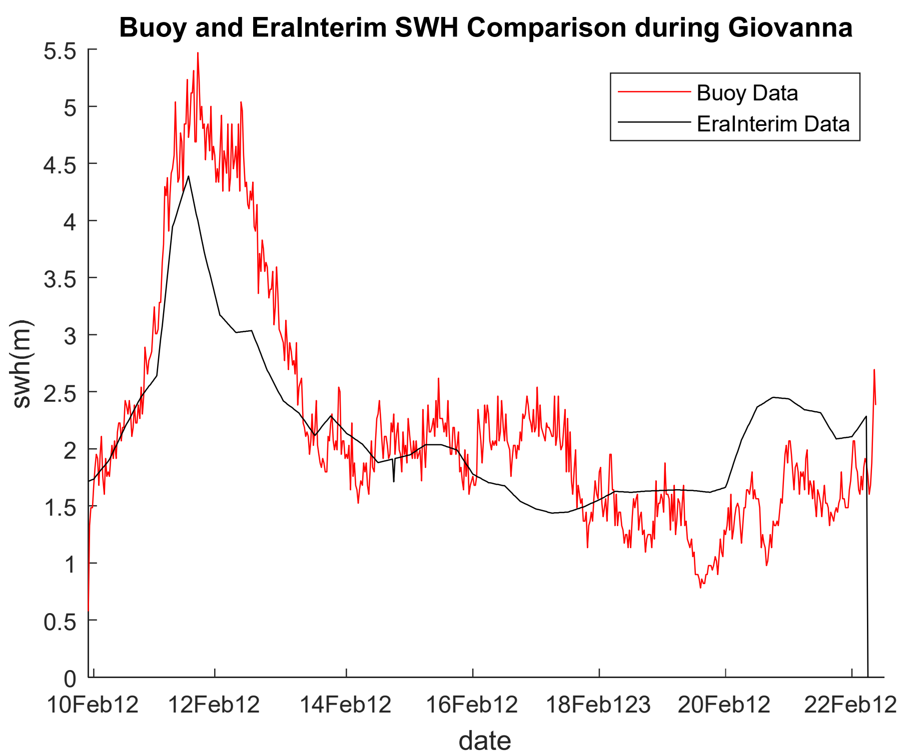


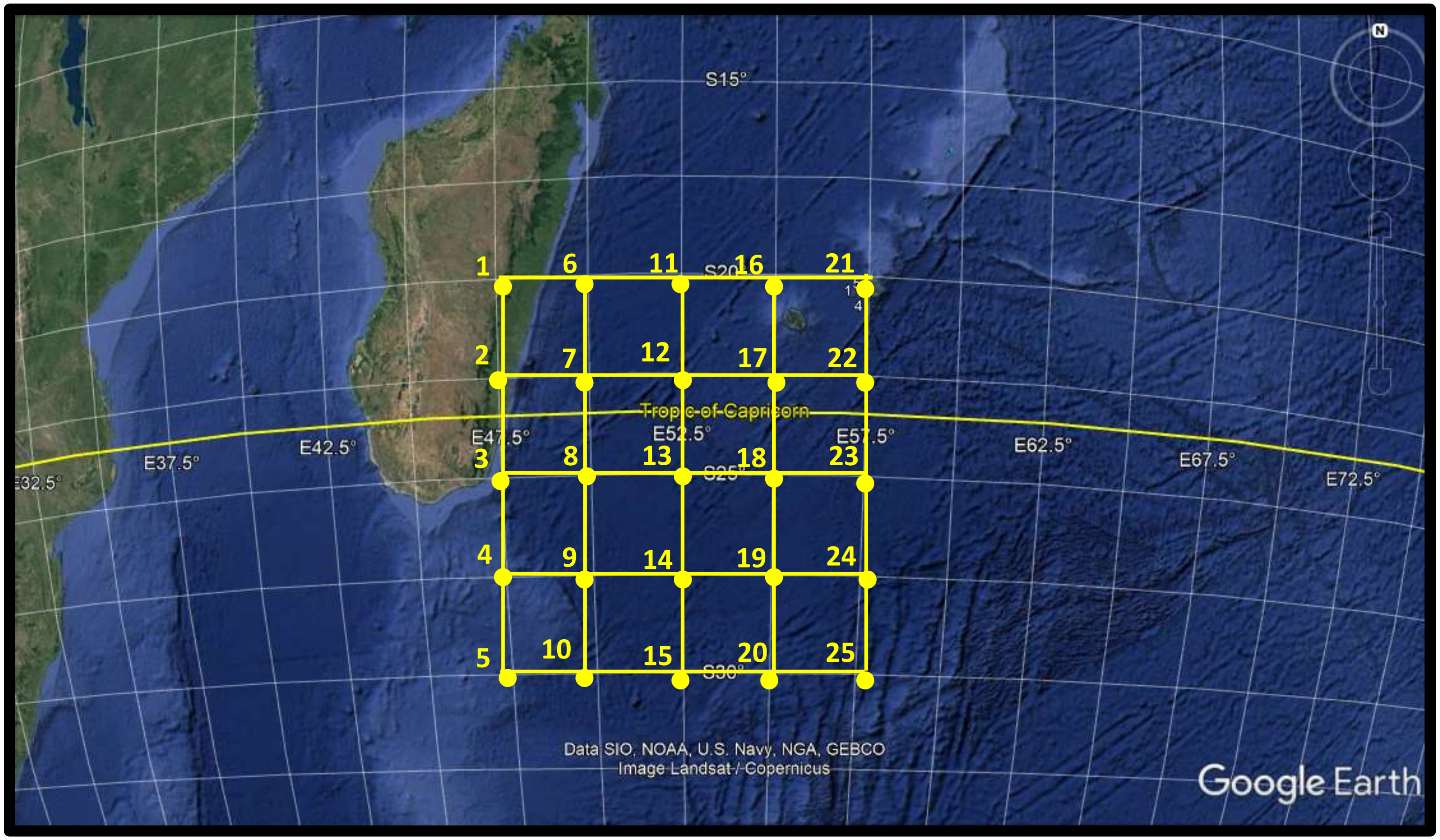
Figure: Cyclone trajectory of Giovanna from NOAA (https://coast.noaa.gov/hurricanes/)

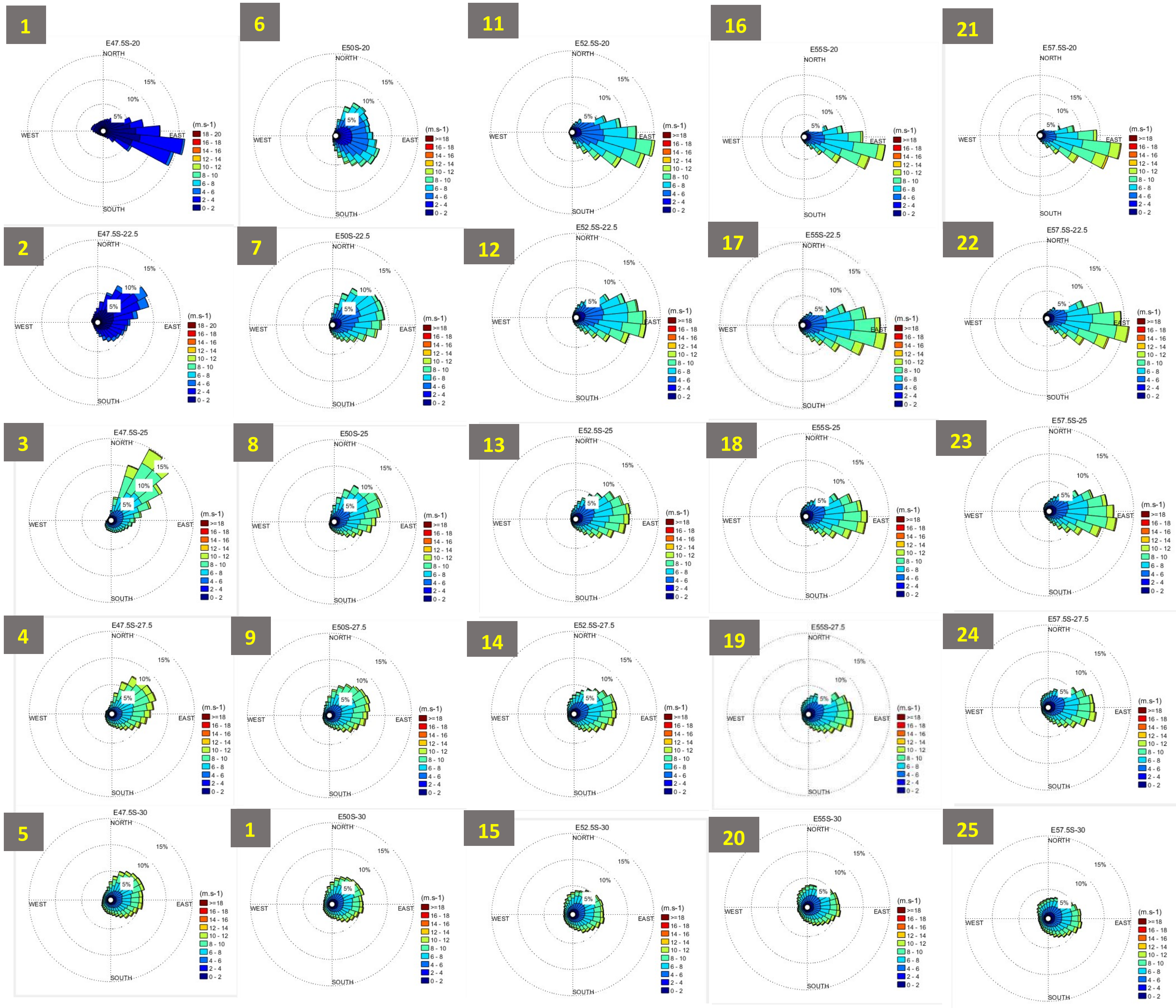


Appendix B1: Wind roses at 25 locations in the Indian Ocean from EraInterim reanalysis atmospheric models

Grid of locations of wind roses below.

Type:	Wind	Timespan:	39years – (1979 – 2017)
Coordinates:	-20/47.5 -30/57.5	Interval	2.5deg /2.5deg





1
E47.5S-20
6
E50S-20
11
E52.5S-20
16
E55S-20
21
E57.5S-20
2
E47.5S-22.5
7
E50S-22.5
12
E52.5S-22.5
17
E55S-22.5
22
E57.5S-22.5
3
E47.5S-25
8
E50S-25
13
E52.5S-25
18
E55S-25
23
E57.5S-25
4
E47.5S-27.5
9
E50S-27.5
14
E52.5S-27.5
19
E55S-27.5
24
E57.5S-27.5
5
E47.5S-30
1
E50S-30
15
E52.5S-30
20
E55S-30
25
E57.5S-30
NORTH
SOUTH
EAST
WEST
5%
10%
15%
(m.s-1)
>=18
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2

Appendix B.2: Tables of frequencies of occurence

Wave climate frequencies of occurrence sorted in significant wave height and mean periods bins for directions affecting Flic-en-flac beach (in percentage %)

The tables below indicate the frequencies of occurrence of each bin which is used in the SWAN model for the mean wave climate analysis. The X represents cases which have a frequency of occurrence lower than 2hr/yr and were not used in the SWAN runs.

Direction: SbE

Significant Wave Height (m)	Mean Wave Period (s)							
	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0								
2.0 - 3.0					0.056%	2.597%	0.435%	
3.0 - 4.0					0.021%	2.929%	3.385%	0.030%
4.0 - 5.0						0.470%	1.030%	0.065%
5.0 - 6.0						0.030%	0.114%	0.021%
6.0 - 7.0							X	X
Number of selected cases for SWAN runs								13
Cumulative percentage of occurrence								11.18%

Direction: S

Significant Wave Height (m)	Mean Wave Period (s)							
	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	2.078%	0.790%	X	
2.0 - 3.0				X	1.911%	4.853%	0.151%	
3.0 - 4.0					0.205%	1.323%	0.198%	
4.0 - 5.0					0.028%	0.172%	0.051%	
5.0 - 6.0						X	X	
6.0 - 7.0								
Number of selected cases for SWAN runs								11
Cumulative percentage of occurrence								11.76%

Direction: SbW

Mean Wave Period (s)

Significant Wave Height (m)	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	1.260%	1.039%	X	
2.0 - 3.0				X	0.867%	5.328%	0.560%	
3.0 - 4.0					0.109%	1.118%	0.607%	
4.0 - 5.0					X	0.126%	0.093%	X
5.0 - 6.0						X	X	
6.0 - 7.0								
Number of selected cases for SWAN runs								10
Cumulative percentage of occurrence								11.11%

Direction: SSW

Mean Wave Period (s)

Significant Wave Height (m)	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	0.516%	0.809%	X	
2.0 - 3.0				X	0.347%	3.359%	1.246%	X
3.0 - 4.0					0.070%	0.579%	1.172%	0.068%
4.0 - 5.0					X	0.082%	0.137%	0.053%
5.0 - 6.0						X	X	X
6.0 - 7.0								
Number of selected cases for SWAN runs								12
Cumulative percentage of occurrence								8.44%

Direction: SWbS

Mean Wave Period (s)

Significant Wave Height (m)	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	0.172%	0.128%	X	
2.0 - 3.0					0.135%	0.746%	0.428%	X
3.0 - 4.0					0.028%	0.184%	0.474%	0.102%
4.0 - 5.0					X	0.021%	0.075%	0.081%
5.0 - 6.0							X	X
6.0 - 7.0								
Number of selected cases for SWAN runs								12
Cumulative percentage of occurrence								2.57%

Direction: SW

Significant Wave Height (m)	Mean Wave Period (s)							
	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	0.047%	X	X	
2.0 - 3.0				X	0.067%	0.056%	0.030%	X
3.0 - 4.0					X	0.035%	X	X
4.0 - 5.0						X		X
5.0 - 6.0							X	
6.0 - 7.0								
Number of selected cases for SWAN runs								5
Cumulative percentage of occurrence								0.24%

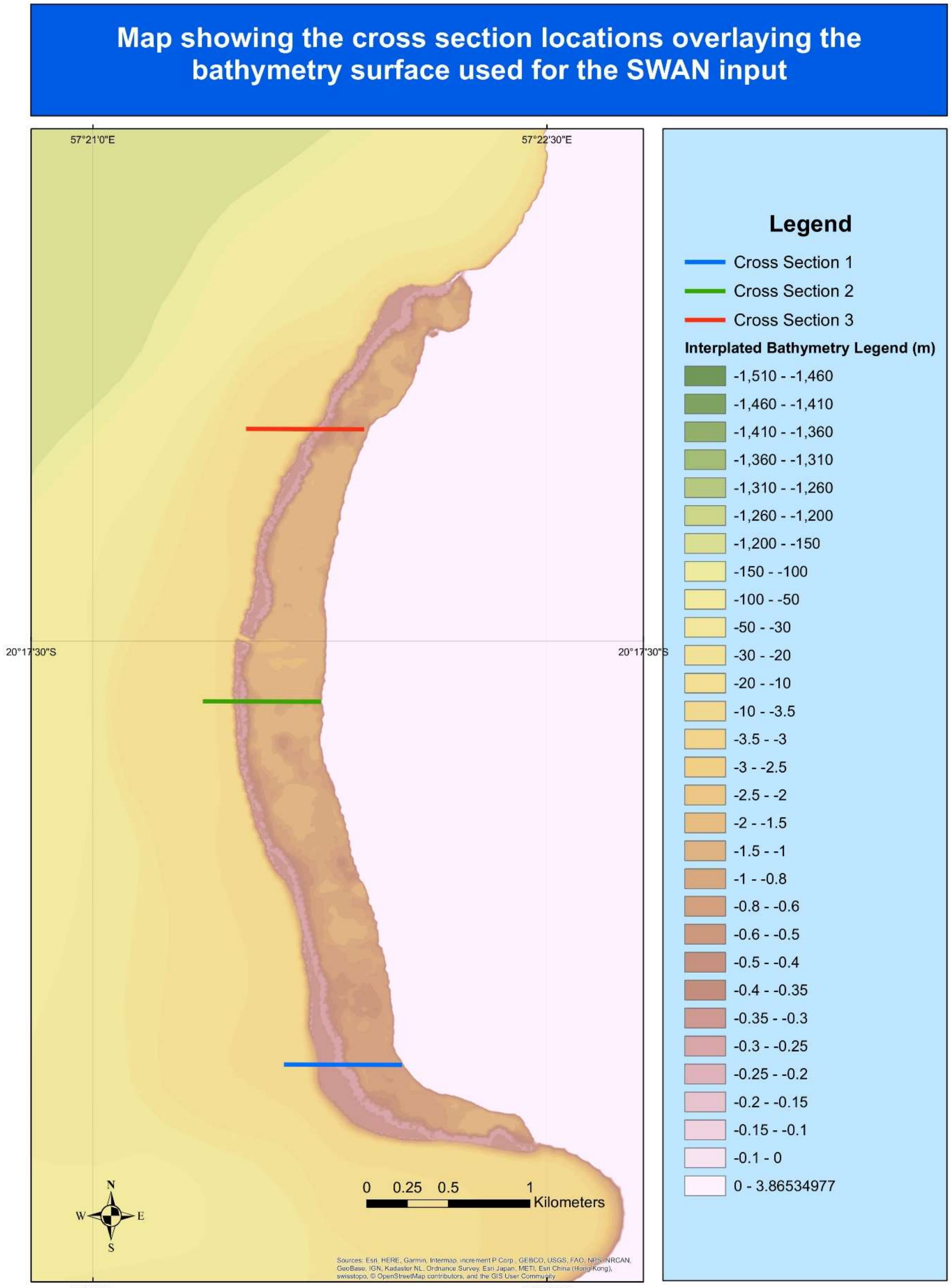
Direction: SWbW

Significant Wave Height (m)	Mean Wave Period (s)							
	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	0.030%	X		
2.0 - 3.0				X	0.058%	X		
3.0 - 4.0					X			
4.0 - 5.0								
5.0 - 6.0								
6.0 - 7.0								
Number of selected cases for SWAN runs								2
Cumulative percentage of occurrence								0.09%

Direction: SWbS

Significant Wave Height (m)	Mean Wave Period (s)							
	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.0	8.0 - 10.0	10.0 - 12.0	12.0 - 14.0	14.0 - 16.0
0.0 - 1.0								
1.0 - 2.0				X	X			
2.0 - 3.0					0.032%	X		
3.0 - 4.0					X	X		
4.0 - 5.0					X			
5.0 - 6.0								
6.0 - 7.0								
Number of selected cases for SWAN runs								1
Cumulative percentage of occurrence								0.03 %

Appendix B.3: Plan view of bathymetry created and cross section 1 to 3 locations



Appendix B.4 – SWAN scripts

This is an example of a SWAN run for the Domain 1 – For wave conditions from SbE, 7s period, 1.5m wave heights

```
$-----------------------------------------------------------
$ START-UP
$-----------------------------------------------------------
$ (*) Start-up Commands
PROJECT 'Flic-en-flac' 'Domain1'
SET LEVEL = 0        SET NOR = 90.00
SET DEPMIN = 0       SET MAXMES = 1000
SET MAXERR = 3       SET GRAV = 9.81
SET RHO = 1025.00 SET INRHOG = 1
SET NAUT
MODE STAT TWOD
COORD SPHE
$-----------------------------------------------------------
$ MODEL DESCRIPTION
$-----------------------------------------------------------
$ (*) Computational Grid
CGRID 55.4 -21.6 0 2 1.4 399 279 CIRCLE 32 0.0400 1.0000 40
$ (*) Input Fields
INPGRID BOTTOM REG 55.4 -21.6 0 399 279 0.005 0.005
READINP BOTTOM -1 'Reu_Grid_400x280.txt' 4 0 FREE
$ (*) Boundary and Initial Conditions
INIT DEF
BOU SHAPE JON 3.3 MEAN DSPR DEGREES
BOUN SIDE S CCW CON PAR 1.5 7 168.75
BOUN SIDE W CCW CON PAR 1.5 7 168.75
BOUN SIDE E CCW CON PAR 1.5 7 168.75
$ (*) Output Spectral grid outline
POINTS 'NGRID001' FILE 'Outline_Reunion.txt'
SPEC 'NGRID001' SPEC2D ABS 'NEST001'
$-----------------------------------------------------------
$ PHYSICS
$-----------------------------------------------------------
OFF WINGROWTH
OFF WCAP
OFF QUAD
BREAKING BKD 1.09 0.94 7.59 -8.06 8.09
DIFFRAC 1
FRIC
$-----------------------------------------------------------
$ OUTPUT
$-----------------------------------------------------------
SPEC 'NGRID001' SPEC2D  ABS 'NEST001'
BLOCK 'COMPGRID' NOHEAD 'MRU.mat' LAY 3 XP YP HS BOTLEV RTP TM01 DIR
$-----------------------------------------------------------
$ LOCK-UP
$-----------------------------------------------------------
$ (*) Lock-up Input file
COMP
```

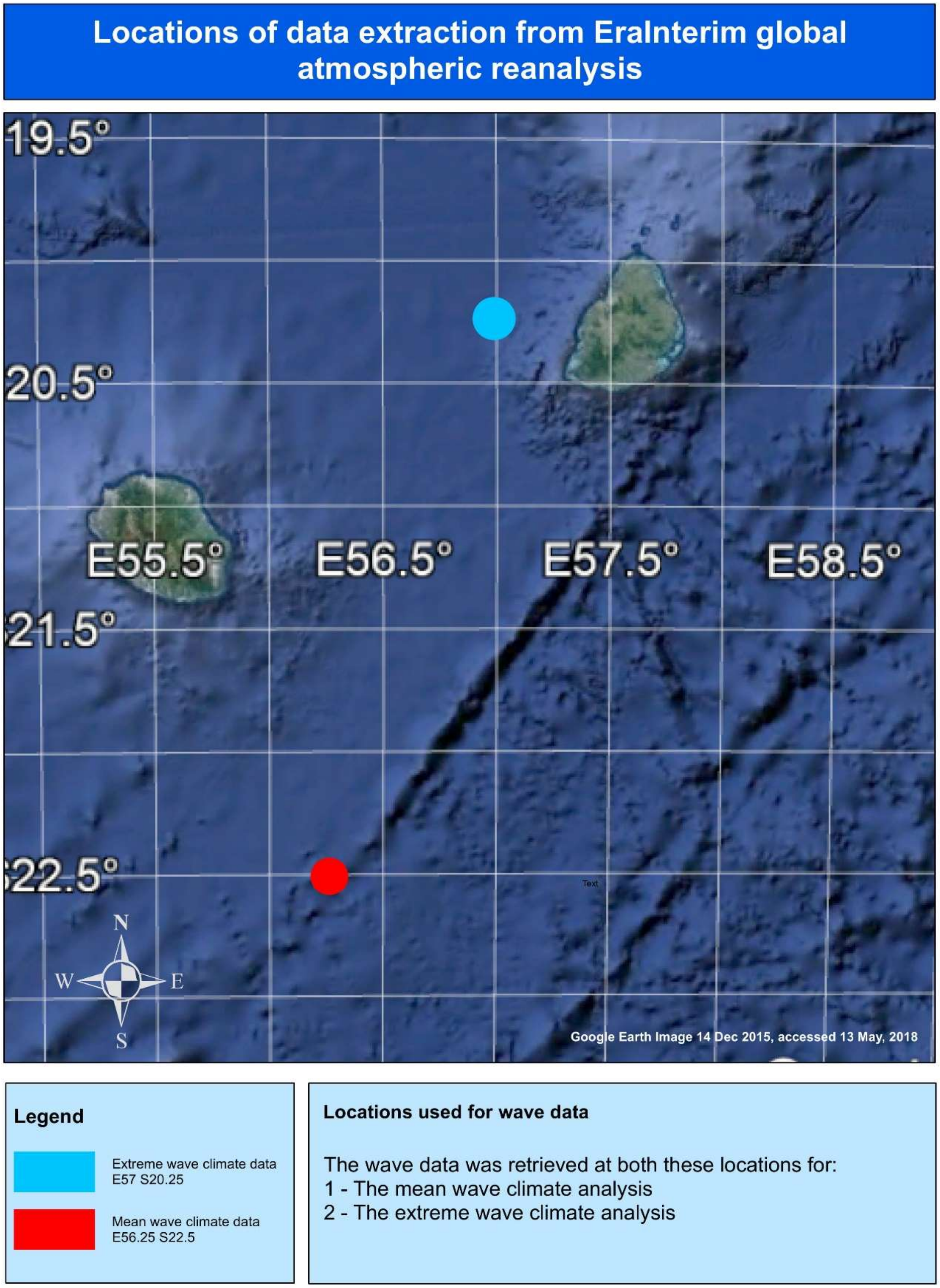
This is an example of a SWAN run for the Domain 2 – For wave conditions from SbE, 7s period, 1.5m wave heights

```
$------------------------------------------------------------
$ START-UP
$------------------------------------------------------------
$ (*) Start-up Commands
PROJECT 'Flic-en-flac' 'Domain2'
SET LEVEL = 0         SET NOR = 90.00
SET DEPMIN = 0        SET MAXMES = 1000
SET MAXERR = 3        SET GRAV = 9.81
SET RHO = 1025.00 SET INRHOG = 1
SET NAUT
MODE STAT TWOD
COORD SPHE
$------------------------------------------------------------
$ MODEL DESCRIPTION
$------------------------------------------------------------
$(*) Computational Grid
CGRID 57.23 -20.52 0 0.15 0.3 199 399 CIRCLE 32 0.0400 1.0000 40
$ (*) Input Fields
INPGRID BOTTOM REG 57.23 -20.52 0 199 399 0.00075 0.00075
READINP BOTTOM -1 'CGrid_200x400_M7.txt' 4 0 FREE
INPGRID FRICTION REG 57.23 -20.52 0 199 399 0.00075 0.00075
READINP FRICTION 1 'fw_C_19.txt' 4 0 FREE
$ (*) Boundary and Initial Conditions
BOU NEST 'NEST001' CLOSED
$ (*) Output Spectral grid outline
POINTS 'NGRID002' FILE 'outline_250x300_006_2.txt'
SPEC 'NGRID002' SPEC2D ABS 'NEST002'
$------------------------------------------------------------
$ PHYSICS
$------------------------------------------------------------
OFF WINDGROWTH
OFF QUADRUPL
OFF WCAP
FRICTION MADSEN
DIFFRAC 1
BREAKING BKD 1.09 0.94 7.59 -8.06 8.09
$------------------------------------------------------------
$ OUTPUT
$------------------------------------------------------------
SPEC 'NGRID002' SPEC2D  ABS 'NEST002'
BLOCK 'COMPGRID' NOHEAD 'MRU.mat' LAY 3 XP YP HS BOTLEV RTP TM01 DIR
$------------------------------------------------------------
$ LOCK-UP
$------------------------------------------------------------
$ (*) Lock-up Input file
COMP
```

This is an example of a SWAN run for the Domain 3 – For wave conditions from SbE, 7s period, 1.5m wave heights

```
$---------------------------------------------------------
$ START-UP
$---------------------------------------------------------
$ (*) Start-up Commands
PROJECT 'Flic-en-flac' 'Domain3'
SET LEVEL = 0
SET NOR = 90.00
SET DEPMIN = 0
SET MAXMES = 1000
SET MAXERR = 3
SET GRAV = 9.81
SET RHO = 1025.00
SET INRHOG = 1
SET NAUT
MODE STAT TWOD
COORD SPHE
$---------------------------------------------------------
$ MODEL DESCRIPTION
$---------------------------------------------------------
$(*) Computational Grid
CGRID REG 57.34 -20.325 0 0.04 0.06 249 299 CIRCLE 32 0.0400 1.0000 40
$ (*) Input Fields
INPGRID BOTTOM REG 57.34 -20.325 0 249 299 0.00016 0.0002
READINP BOTTOM -1 'NGrid_250x300_M07.txt' 4 0 FREE
INPGRID FRICTION REG 57.34 -20.325 0 249 299 0.00016 0.0002
READINP FRICTION 1 'NGrid_fw_250x300_006.txt' 4 0 FREE
$ (*) Boundary and Initial Conditions
BOU NEST 'NEST002' CLOSED
$---------------------------------------------------------
$ PHYSICS
$---------------------------------------------------------
OFF WINDGROWTH
OFF QUADRUPL
OFF WCAP
BREAKING BKD 1.09 0.94 7.59 -8.06 8.09
FRICTION MADSEN
SETUP
$---------------------------------------------------------
$ OUTPUT
$---------------------------------------------------------
BLOCK 'COMPGRID' NOHEAD 'MRU.mat' LAY 3 XP YP HS BOTLEV RTP TM01 DIR
$---------------------------------------------------------
$ LOCK-UP
$---------------------------------------------------------
$ (*) Lock-up Input file
COMP
```

Appendix B.5: Location of the EraInterim extraction points



Appendix B.6: SWAN fundamentals

SWAN fundamentals

SWAN (**S**imulating **WA**ves **N**earshore) is a third generation phase-averaged refraction wave model that simulates the evolution of the wave spectrum developed by Delft University of Technology. to solve the spectral energy balance equation.

The spectral energy balance is solved with no 'a priori' restrictions on the evolution of the wave growth. It uses implicit propagation schemes, which has proven to be more time effective and robust in solving shallow water wave propagation than the explicit one. (SWAN, scientific and technical doc).

It is a well suited software to solve wave propagation from deep to shallow waters, by considering the effects of spatial propagation, shoaling, refraction, diffraction, generation, dissipation and wave to wave interactions.

Since diffraction requires high computational effort, a phase decoupling refraction-diffraction approximation approach is used.

Physics:

SWAN deals with the action density spectrum N(σ,θ) rather than the Energy density E(σ,θ).The action density is equal to the Energy density divided by the relative frequency.

$$N(\sigma,\theta) = E(\sigma,\theta)/\sigma$$

And can be written in the Cartesian co-ordinate system in the following way:

$$\frac{\partial}{\partial \mathrm{t}}N + \frac{\partial}{\partial \mathrm{x}}c_x N + \frac{\partial}{\partial \mathrm{y}}c_y N + \frac{\partial}{\partial \sigma}c_\sigma N + \frac{\partial}{\partial \theta}c_\theta N = \frac{\mathrm{S}}{\sigma}$$

t	*- Time in (x,y)*	*(x,y)*	*- Cartesian coordinates*
(c_x, c_y)	*- Propagation velocities of wave energy*	*θ*	*- Wave direction*
σ	*- Wave frequency*	*S*	*- Sources*
(c_θ, c_σ)	*- Propagation velocities in the spectral space*		

Sources and sinks:

The physical processes of generation, dissipation and nonlinear wave-wave interaction that are implemented in swan are explained below.

$$S_{tot} = S_{in} + S_{nl3} + S_{nl} \; + S_{ds,w} + S_{ds,b} + S_{ds,br}$$

All terms in order, correspond to the wind growth by the wind, the nonlinear transfer of wave energy through three-wave and four wave interactions, wave decay due to whitecapping, bottom friction and depth induced wave breaking.

Bottom friction:

The bottom friction models chosen in SWAN include the Jonswap model, the drag law model of Collins, and the eddy viscosity model of Madsen et al.

Conventional bottom friction formulation:

$$S_{ds,b} = -C_b \frac{\sigma^2}{g^2 sinh^2 kd} E(\sigma, \theta)$$

k=wavenumber *d=water depth* *g=acceleration of gravity*

The conventional Jonswap model formulation, appropriate for swell dissipation over sandy bottoms

- Hasselmann et al (1973) : Cb= C_{JON} = 0.038m^2s^{-3}

The Madsen et al. formulation was used, since it includes the effects of hydrodynamics and bed roughness - the bottom friction is a function of the bottom roughness height and the actual wave conditions

- Madsen et al (1988) $C_b = f_w \frac{g}{\sqrt{2}} U_{rms}$

Urms=root mean square of orbital velocity *fw= non dimensional frictional coefficient*

Jonsson (1966) defined the formulation of f_w

$$\frac{1}{4\sqrt{f_w}} + log_{10}\left(\frac{1}{4\sqrt{f_w}}\right) = m_f + log_{10}(\frac{a_b}{k_n})$$

Wave breaking

The wave breaking process is defined by Battjes and Janssen (1978) estimation of energy dissipation. The same equation for a single breaking wave is combined to a portion of a Rayleigh distribution to estimate the bulk dissipation of random waves.

$$\varepsilon = -\frac{1}{4} \propto f Q_b \rho g {H_{max}}^2$$

f=mean wave frequency *ρ=density of water*
H_{max}= max possible wave height under breaking conditions
Q_b= the fraction of breakers

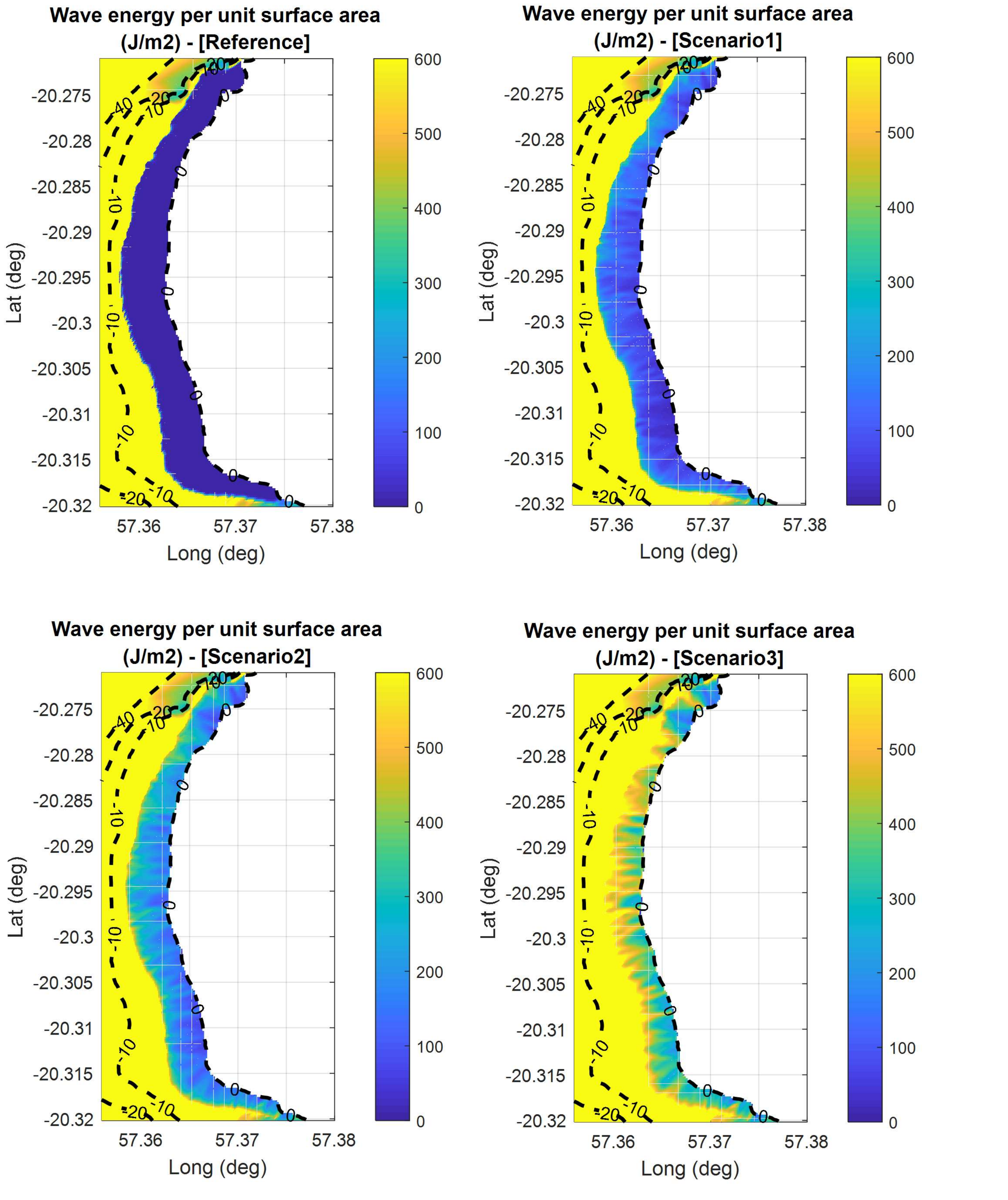
The fraction of breakers Q_b can be expressed in terms of H_{max} and H_{rms}

$$\frac{1 - Q_b}{lnQ_b} = -(\frac{{H_{rms}}^2}{H_{max}})$$

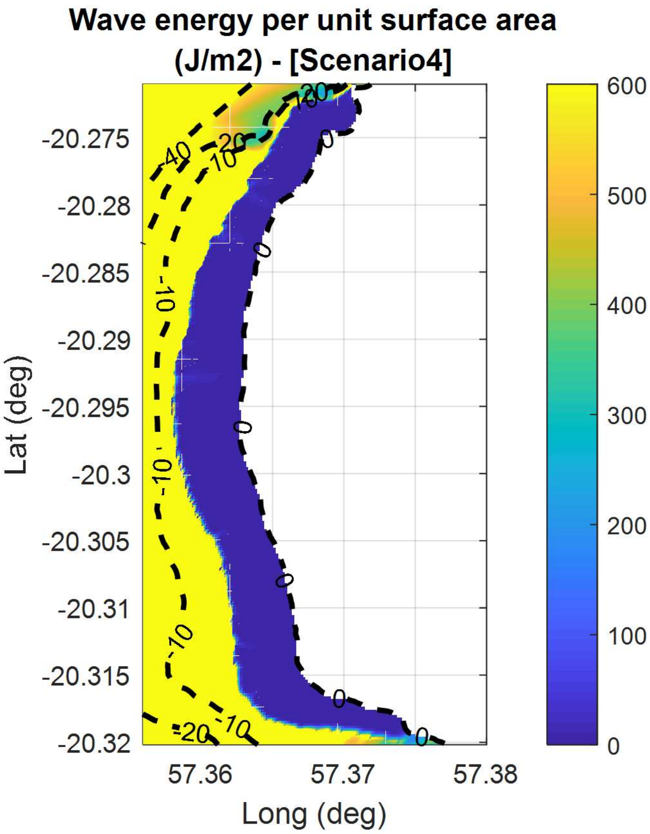
Refer to (Filipot & Cheung, 2012) for further description on the procedure for the determination of the breaking intensity (B) and breaker index (γ)

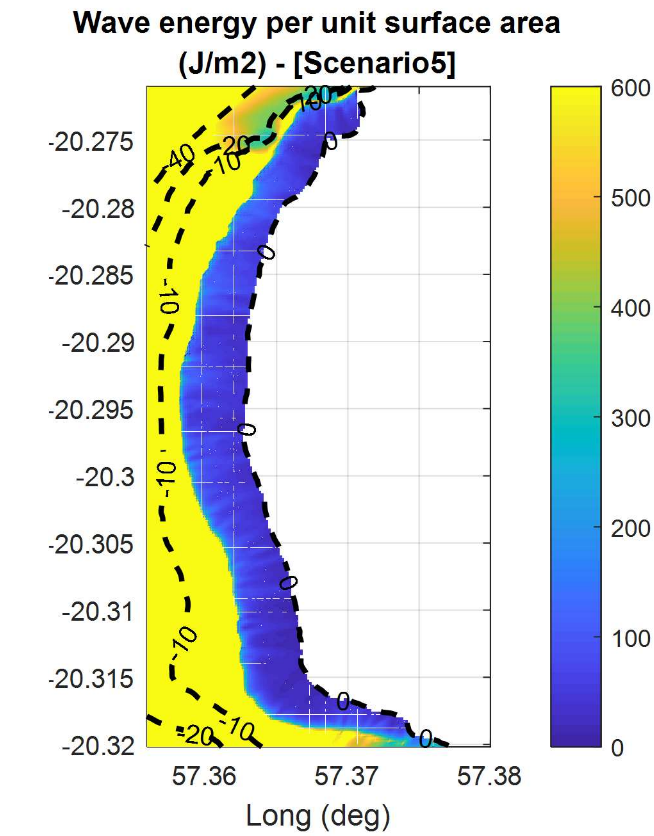
See the SWAN scientific and technical documentation for further clarification on the equations used to derive results from the model (Swan, 2009).

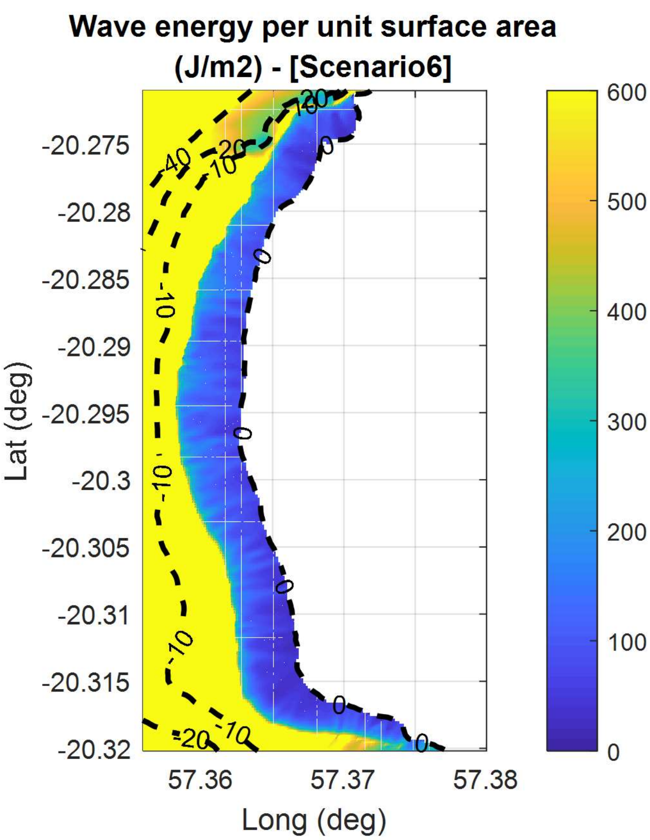
Appendix C1: Wave energy inside the lagoon for Reference and Scenarios 1-3

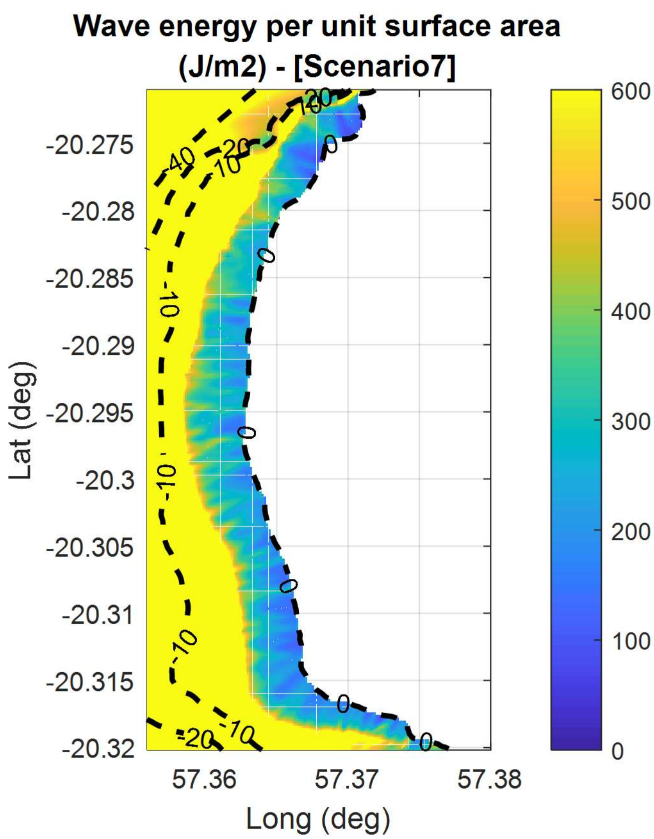


Appendix C1: Wave energy inside the lagoon for Scenarios 4-7

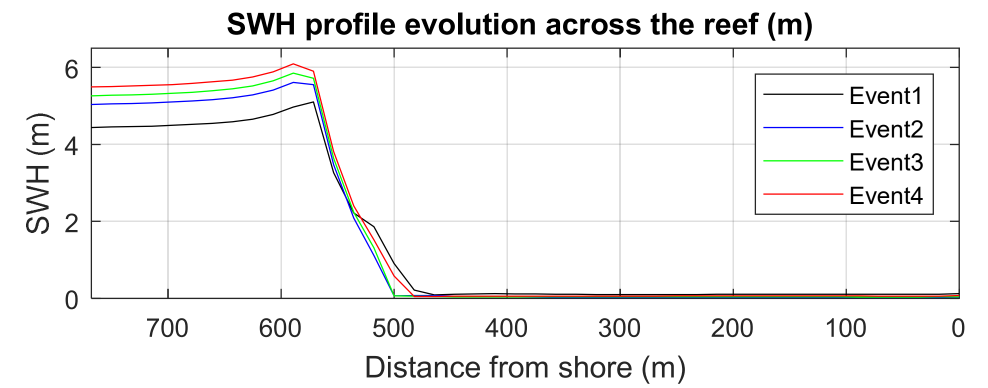


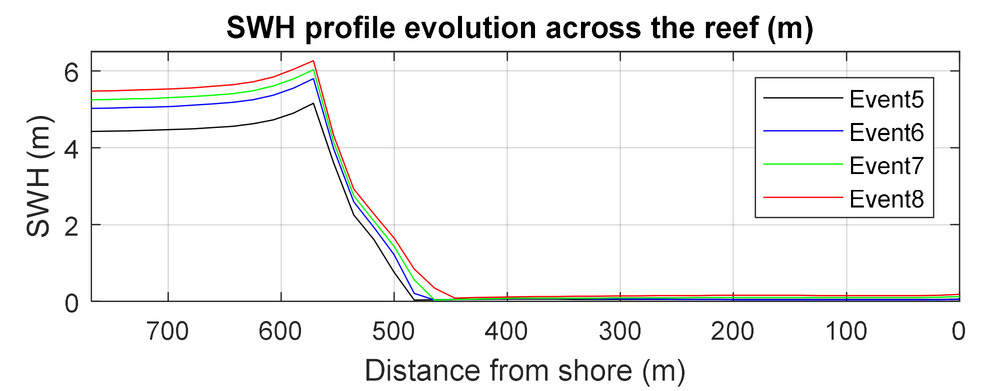


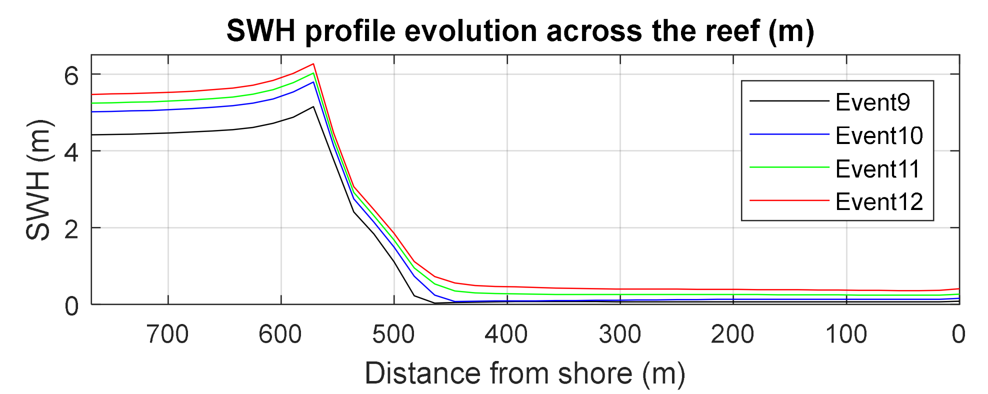


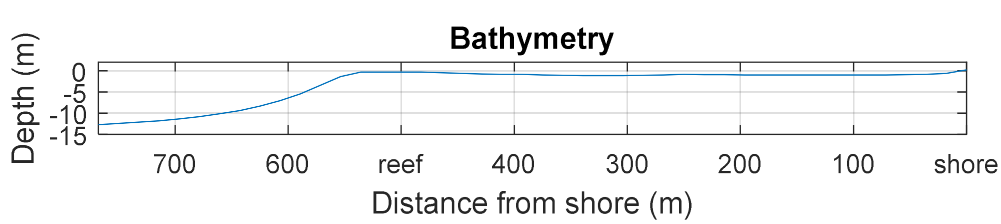


Appendix C.2 Significant wave across the reef at section 2 for each SLR condition









Appendix C2: Significant wave height across the reef at section 2 for all events graphed per return period