MAURITIUS RESEARCH COUNCIL

A STUDY TO DETERMINE THE PROSPECTS FOR WAVE ENERGY DEVELOPMENT AROUND ENERGY

Final Report

May 2013

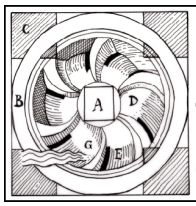
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NUMERICS WAREHOUSE

computer simulations of the natural environment

A Study to Determine the Prospects for Wave Energy Development Around Mauritius

Supported by the Mauritius Research Council under their Unsolicited Research Grant Scheme

By Marcel Curé

10th May 2013

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1.0 Introduction

This is a research project to investigate the wave energy resource to be found around Mauritius. The search for alternatives to fossil fuel generated power production is an issue to be approached with renewed urgency. As the need for power increases, and as the costs escalate, we also seek to reduce our effect on the environment by reducing greenhouse gases and the acidification of the oceans.

Mauritius has a proud heritage in wave energy. It was one of the first countries to seriously examine how to implement a realistic wave energy system back in the 1960's through the efforts of an engineer called Bott, who was the General manager of the CEB. His work was scuppered by political considerations in the UK, where nuclear power was in the ascendency, but perhaps the time has now come for wave energy to be seriously examined again. In the last few years there has been a preponderance of new wave energy devices, with an explosion in the number of patents and the development of prototypes. Only a few of these will ever be used in production, but it is hoped that by investigating the wave energy resource around Mauritius here, and by actively promoting itself as a project partner, Mauritius will be one of the first locations to develop power production through wave energy conversion.

Numerics Warehouse Ltd. is a small R&D led consultancy based in the west of Ireland and specialising in the simulation of the environment on supercomputers. During its 4 years of operation it has undertaken successful numerical modelling contracts for the Marine Institute of Ireland, for the Sustainable Energy Authority of Ireland (Ocean Energy Development Unit), INFOMAR and the Geological Society of Ireland. The company has worked with some of the leading ocean energy companies, such as Vattenfall and OpenHydro (several projects). We have conducted joint research projects with the University of Porto and INTECMAR in Spain. The range of the numerical modelling work we have been involved in has spanned oil dispersion, shellfish growth, Harmful Algal Bloom development, sediment transport, wave energy climatology, tidal stream resource analysis and mathematical variational data assimilation. We are also a project partner in an EU FP7 project called ASIMUTH. We are technical experts in numerical modelling of the atmosphere, oceans and waves. Our background is in physical oceanography.

In this study it was the intention to rigourously describe the wave climate around Mauritius by employing High Performance Computers and statistical tools. The format of the data outputs should be familiar to wave energy developers. The idea is to make it easier for designers and engineers to see how their products could be a part of an ocean renewable energy powered island economy for the future.

The results of the computer simulations are used to recommend further actions to be taken and to suggest where future wave energy parks might be situated in the seas around Mauritius.

1.1 Approach

This is a study of the wave climate of the Mascarene Islands and in particular Mauritius. The approach adopted here is to mathematically model, or simulate the generation, travel and dissipation of ocean waves as they are affected by the surface wind and as they interact with other waves and eventually dissipate. Ocean wave models have reached a level of sophistication that they are now routinely used by most meteorological agencies to forecast waves. Their results have an excellent correlation with measured data. The models used in this study are freely available as source code. They are the product of the work of many scientists collaborating. The two models that are employed in this study are WaveWatch 3 (http://polar.ncep.noaa.gov/waves), which is used for wide area models and SWAN (http://www.swan.tudelft.nl), which is a specialised model designed for coastal and shallow water applications.

It is expensive and complicated to maintain wave buoys, which is why long datasets are not usually available, and anyway they only provide data from individual locations. Satellite sensor derived wave parameters do not have the spatial resolution required, and the results are unreliable close to the coast. There is substantial inter-annual variability of wave energy (as borne out in this study) and to come to meaningful conclusions at least a decade of data is needed. Recent advances in numerical wave models, cheap storage for high volumes of data, and in particular supercomputer power has meant that it is now feasible to conduct very high resolution wave climate simulations using a series of model nests which can include the wave climate in a whole ocean basin.

The models are based on solving the evolving wave action density spectrum over model grids. The spectral wave energy is transported between grid cells, various parts of the spectrum interact and energy is increased by wave growth through wind stress acting on the sea surface and energy is removed through wave breaking or through sea bed shear stress. The source of the wind forcing for the modelling conducted here was the European Centre for Medium Range Weather Forecasting ERA-Interrim data product, which is defined on a 0.5 degree grid.

The approach adopted in this study has been to downscale spectral wave numerical models from a sufficiently large scale so that the effect of all weather systems and waves which traverse ocean basins are properly accounted for in the coastal areas around Mauritius. The model grid scales and the time steps are sufficiently fine enough to resolve temporal and spatial scales of motion that matter, but the wider model domains are sufficiently large so that the even those long swell waves which travel thousands of kilometres across the ocean to arrive in Mauritius are accounted for. The sequence of models ranging from the wide area to the local scale are designed in their choice of scale and frequency subdivision to transmit the wave directional spectra of physical features across their mutual boundaries without losing the essential details of the wave systems. The models themselves are used by many research and operational forecasting agencies around the world.

Numerics Warehouse has invested a considerable time prior to this project in applying the wave models used in this study to other studies in the Atlantic. The model results in the Atlantic have proven to be accurate compared to measurements from wave buoys there. Although we do not have access to any measured wave data of any duration here, we leave the validation of the models as a future exercise to be conducted when such data becomes available.

In addition to the raw data from the model runs, which cover the years 2002 to 2011

inclusive (a ten year climatology), the data has been combined to produce summary statistical data showing extremes and means, which are designed to show the inter-annual variability and the seasonal effects. The location of 23 stations along transects starting in deep water and ending in shallow water, have been chosen for more frequent output. The transects are ranged around the coast of Mauritius. In the broader Mascarene area, some additional stations have been chosen close to the three islands Reunion. Rodrigues and Mauritius so as to compare their wave energy and other statistics. Station data has been used to create directional wave sector plots, weekly average time series, power exceedence diagrams, wave height vs. wave period scatter plots, and extreme wave return periods and persistence duration statistics. These are considered the forms of data output most useful to potential wave energy producers.

Once the raw data from the model runs was collected, a series of post-processing routines was applied to convert the data to compact formats and then using a library of statistical routines developed by Numerics Warehouse for its other clients, some standard wave statistical climatological outputs were generated which are suitable for assessing the various needs of wave energy producers.

Taken as a whole this report and the associated database can be considered as a start to describing the physical oceanographic environment for new wave farms around Mauritius. This modelling effort does not however include the effect of tides and currents on the wave spectra, nor does it address the ultra high resolution diffraction and wave reflection effects that might be locally important. A more extensive study might combine hydrodynamics (and sediments) and wave modelling, together as a series of coupled models so that we can explore the feedbacks between them.

Once the detailed planning for larger scale wave farms is being considered, the interaction between Wave Energy Converters (WEC's) and their combined effect on the environment will have to be addressed, and numerical modelling should be included at an early stage to evaluate the impact and to help in the licensing of developments.

1.2 Overall Methodology

This report continues below by describing the wave models developed for this study, including the bathymetry and model grids in section 2. The models are used to generate data on grids, like maps, as well as at stations, or individual locations where we desire more information. The various grids and stations are described. The stations around Mauritius are organised into transects leading from shallow water to deep water. In this way we can learn how the proximity to the coast affects some key wave statistics. The stations and transects are described in section 3. The parameters estimated by the models are defined in section 4. The passage of a cyclone is modelled and described in section 5. This is also used as an illustration of how the model downscaling works. Most of the wave energy arrives in Mauritius during the winter. In section 6 we investigate how that energy is generated and how it comes to Mauritius. Following on we describe the wave climatology of the SW Indian Ocean (section 7), the climatology of the Mascarene Islands and an inter-comparison of the wave climate around the main islands (section 8), and of Mauritius (section 9). In section 9 we also use wave statistical products to further investigate how variable is the wave energy and how extreme the wave climate could be. In addition we look at the transects and use them to determine the best locations in the seas around Mauritius for wave farms. No formal validation of the wave models was planned for this study, but in section 10 we touch upon this by comparing some satellite

radar wave data with the model data. Finally in section 11, some conclusions and suggestions for further work are made.

2.0 Bathymetry Definitions for Mascarene and Mauritius Models

The source of all bathymetry for the models was the worldwide collection of data, GEBCO (www.gebco.org), which is defined on a 0.5 degree grid. In addition the freely available National Geophysical Data Center NOAA coastline database was used to define the shoreline. It had been hoped to use SWATH bathymetry collected by the National Indian Oceanography Institute and the inshore dataset kept by the Mauritius Oceanography Instutute, but having asked for them, these were not made available to us (reasons remain unclear). The modelling study would almost certainly have been more accurate with the inclusion of these higher resolution modern datasets and it is regretable that that these data, which after all were collected with public money, were kept from inclusion here.

There were three models defined, denoted WW3_SW_Indian, SWAN_Mascarene and SWAN_Mauritius. The final bathymetries for these models are shown in figures 1, 2 and 3.

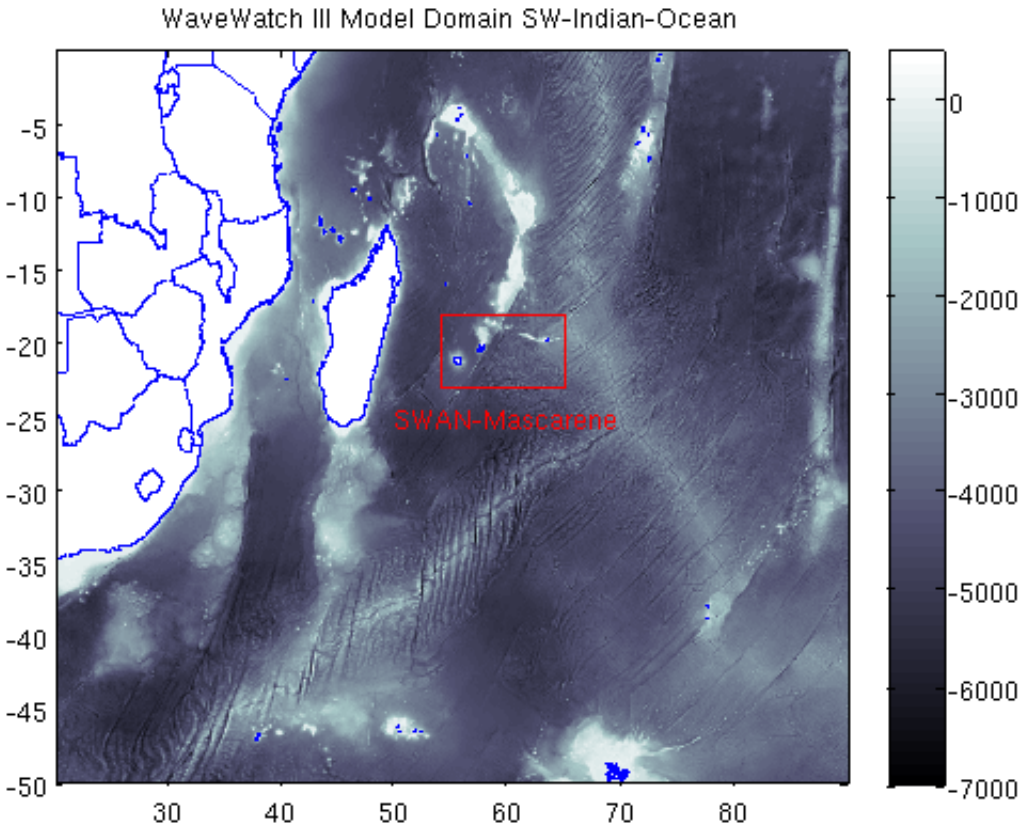


Figure 1. WW3_SW_Indian model domain and bathymetry, showing the nested domain SWAN_Mascarene.

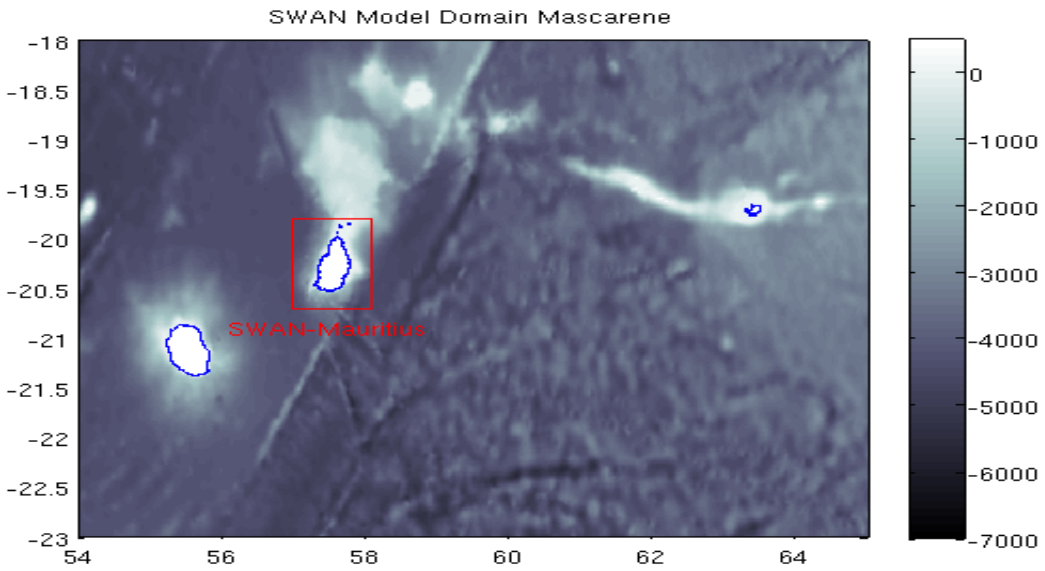


Figure 2. SWAN_Mascarene model domain and bathymetry, showing the nested model SWAN_Mauritius.

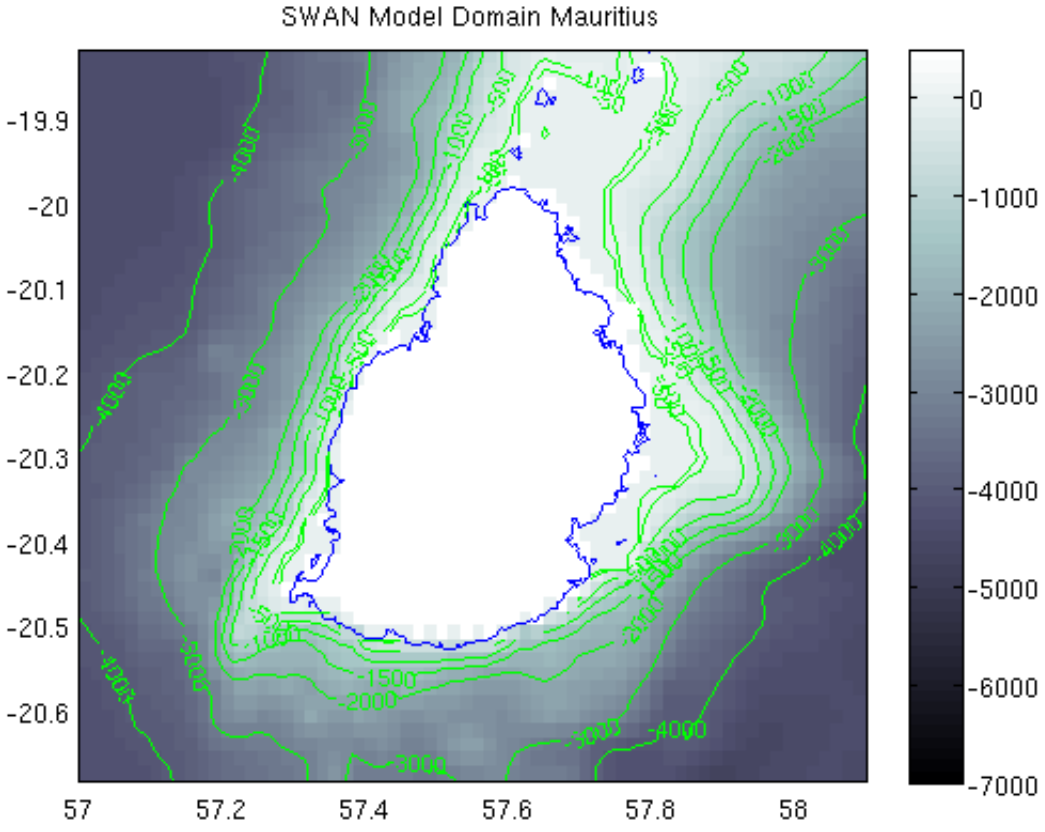


Figure 3. SWAN_Mauritius model domain and bathymetry.

The grid dimensions for each of the models are shown in Table 1, with nx and ny being the number of grid cells in the longitudinal and latitudinal directions and dx and dy being the respective grid sizes.

Table 1

Model	Longitude	Latitude	nx	ny	dx	dy
WW3_SW_Indian	22.0 to 89.5 E	50.0 to 5.0 S	270	180	0.250	0.250
SWAN_Mascarene	54.0 to 65.0 E	23.0 to 18.0 S	440	200	0.025	0.025
SWAN_Mauritius	57.0 to 58.1 E	20.7 to 19.8 S	550	450	0.002	0.002

3.0 Station and Transect Outputs

The models periodically output gridded datasets (every 12 hours for SWAN_Mascarene and every 3 hours for SWAN_Mauritius) with data at each of the grid points shown in Table 1, but they were also configured to output more frequent data from stations which are considered important positions. These stations are sometimes organised into transects so that we can see how the wave statistics vary with depth.

For the Mascarene model, data was output from stations on the 3 islands, Reunion, Rodrigues and Mauritius at positions where it was felt that the most wave energy on the respective islands would result. The data was output every 3 hours for the ten years between 2002 to 2011. Their positions in 200 m depth of water are shown in figure 4 and Table 2.

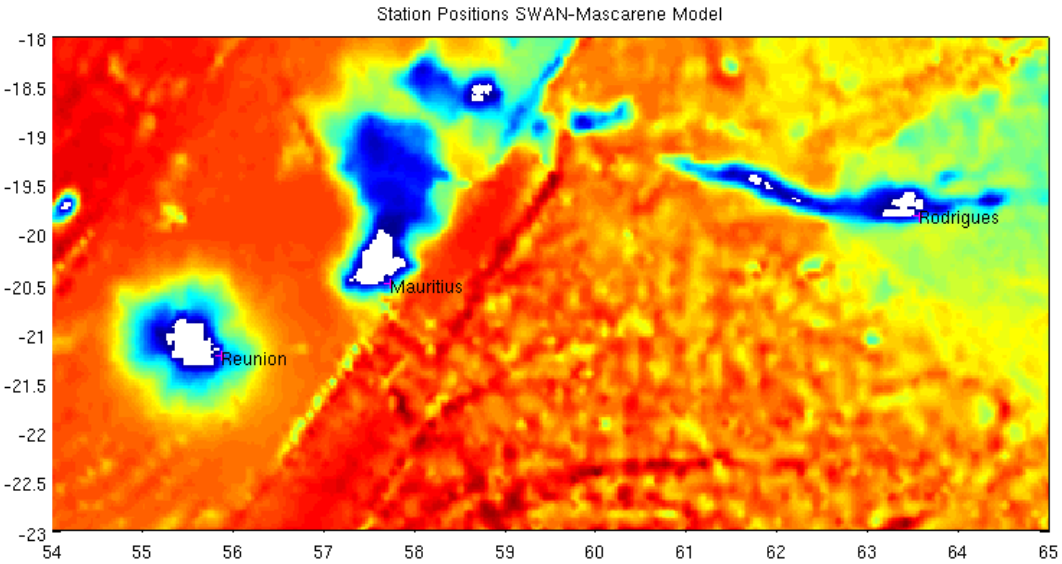


Figure 4. Station positions in SWAN-Mascarene model are shown as magenta crosses.

Table 2.

	Longitude	**Latitude**
Mauritius	57.720 E	20.500 S
Reunion	55.865 E	21.225 S
Rodrigues	63.560 E	19.820 S

For the Mauritius model, the 23 selected stations were chosen to lie along transects. The data from each of the stations was output every 20 minutes for the 10 year model run. The transect lines numbered 1 through 7 are shown in figure 5.

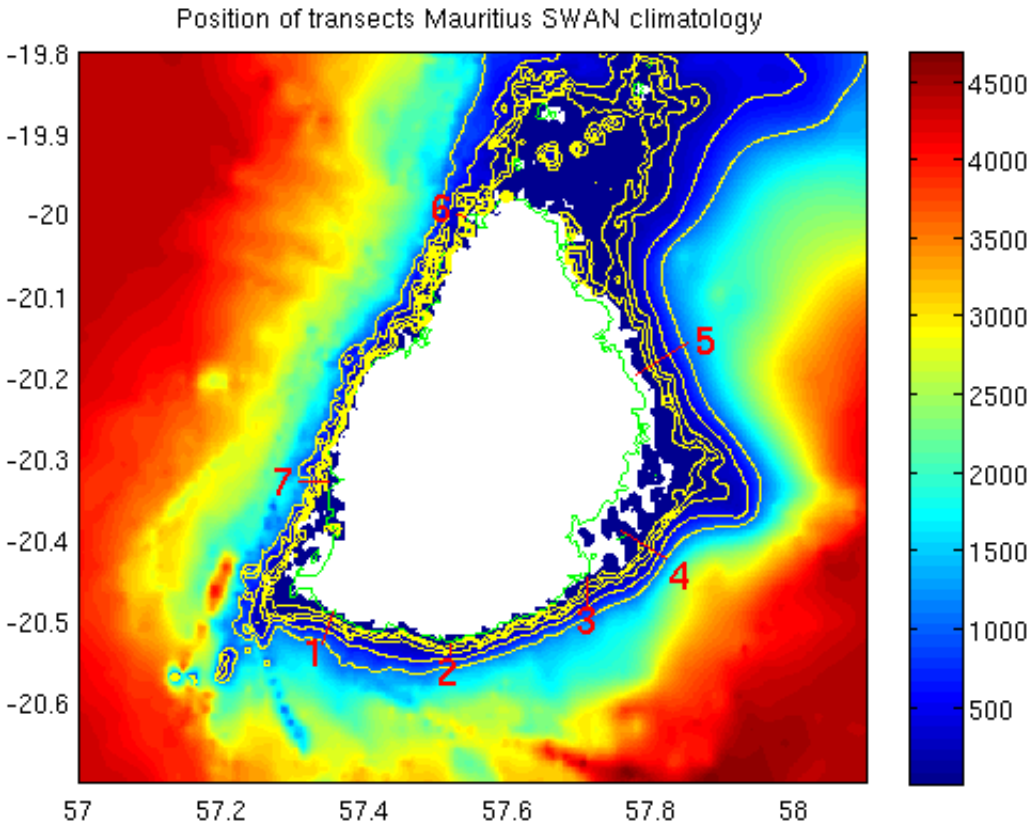
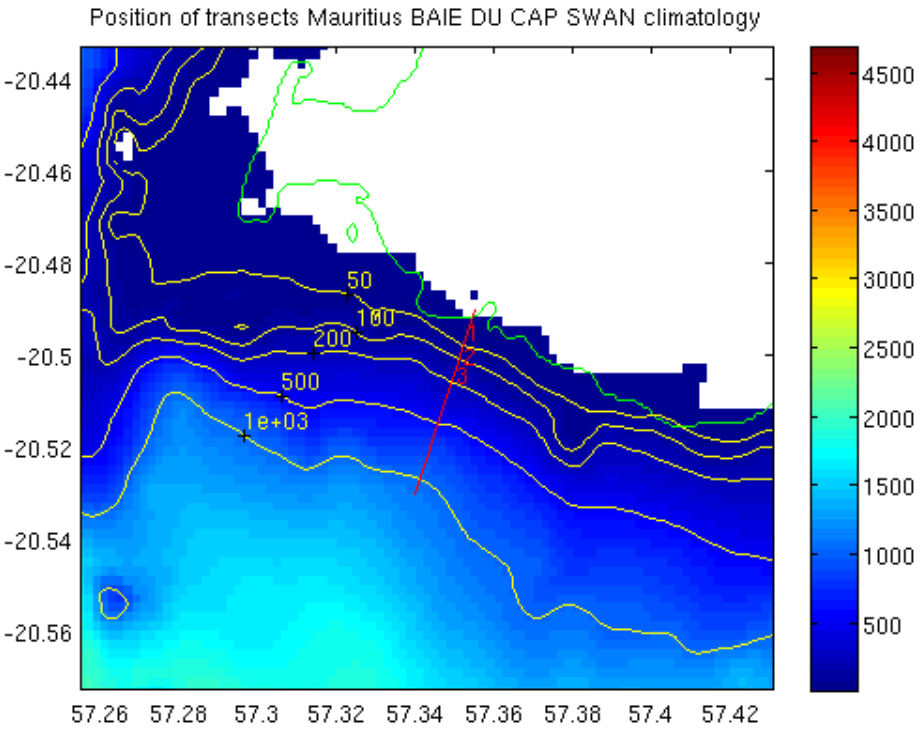
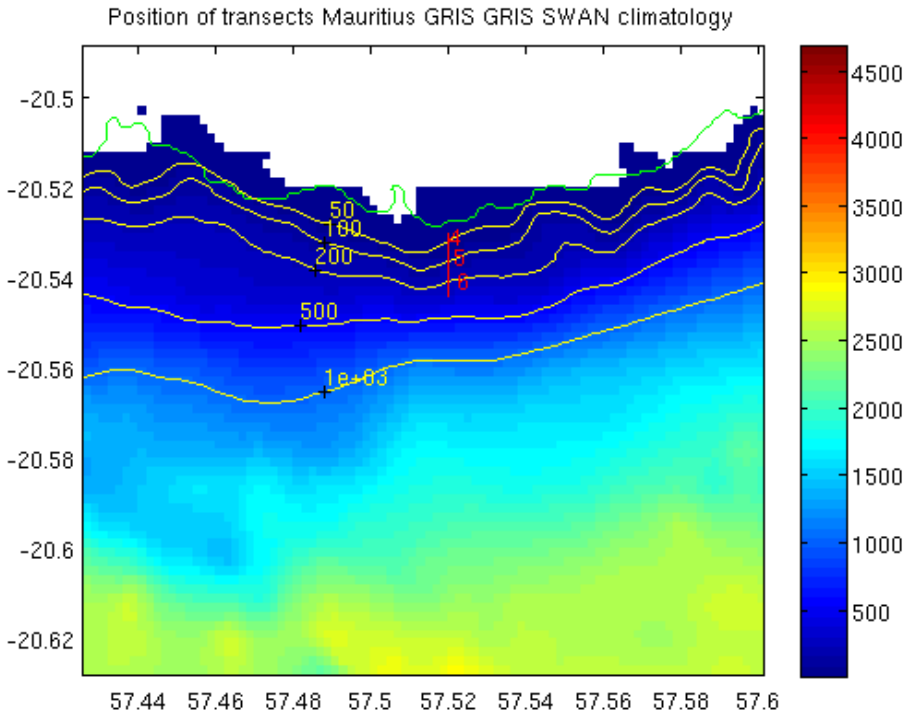


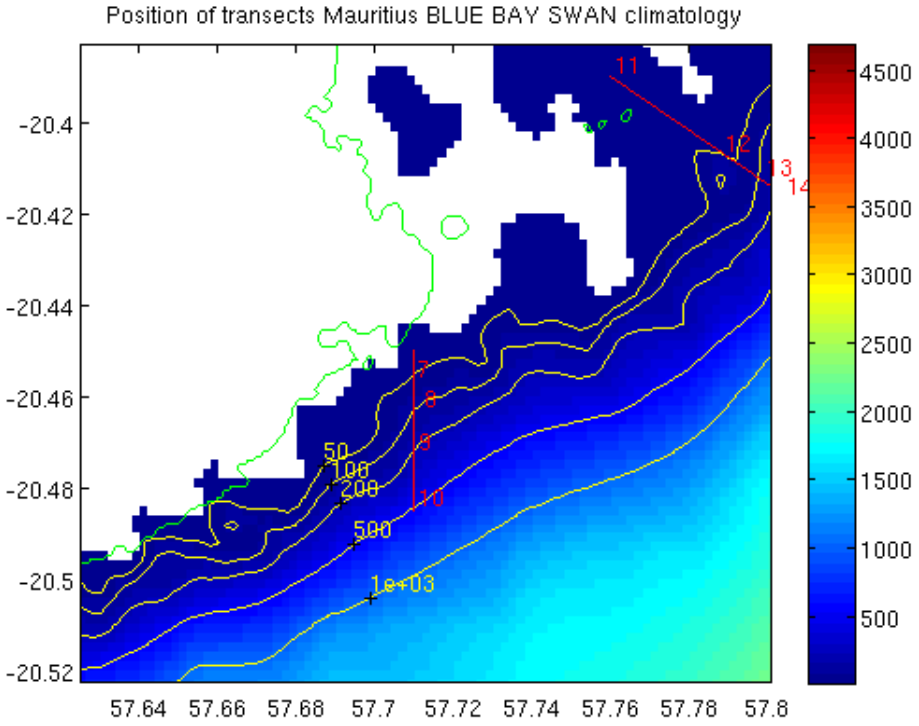
Figure 5. Transect lines chosen for detailed study around the coastline of Mauritius.

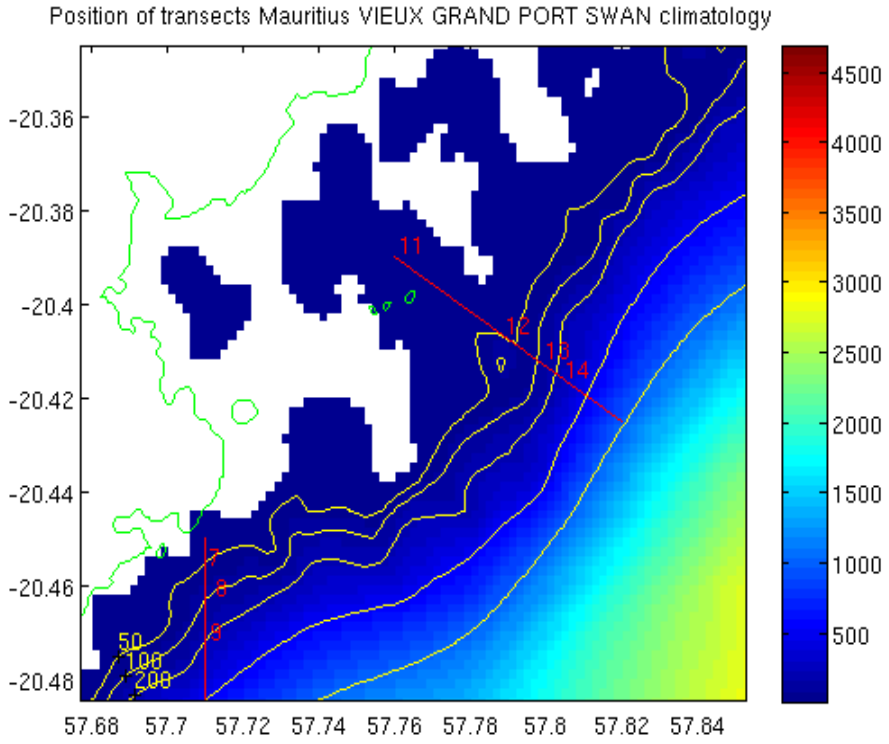
These transects were chosen to illustrate the variability of the main wave statistics around the coast and from deep to shallow water. It was clear that those transects on the west coast would not have a very high wave energy, but they are included to show the difference compared to the more promising locations on the south and east coasts.

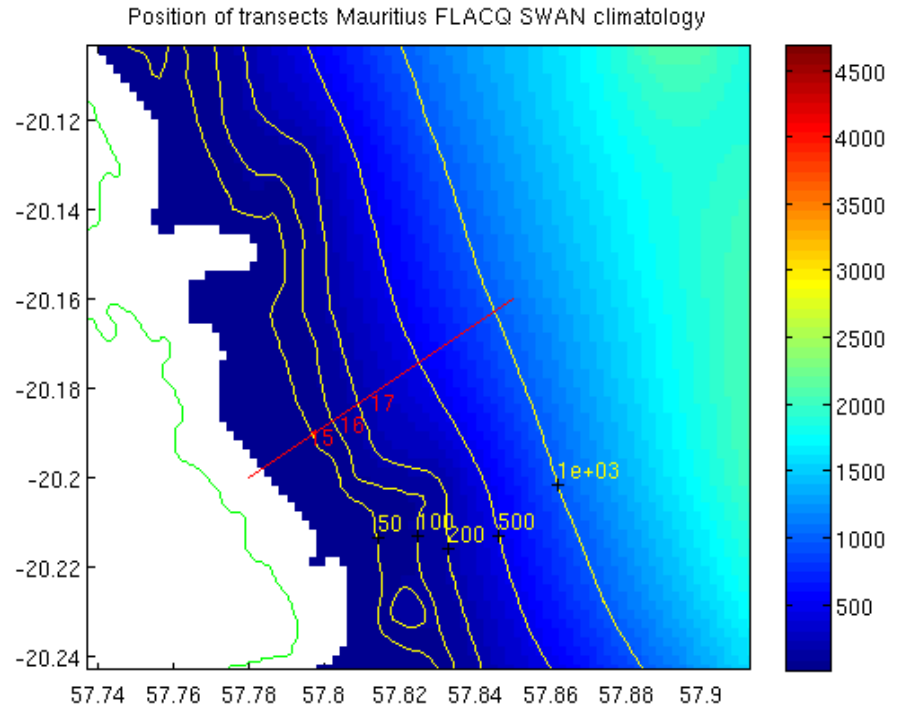
Each of the transects is shown in more detail in figure 6, with the positions of the stations.

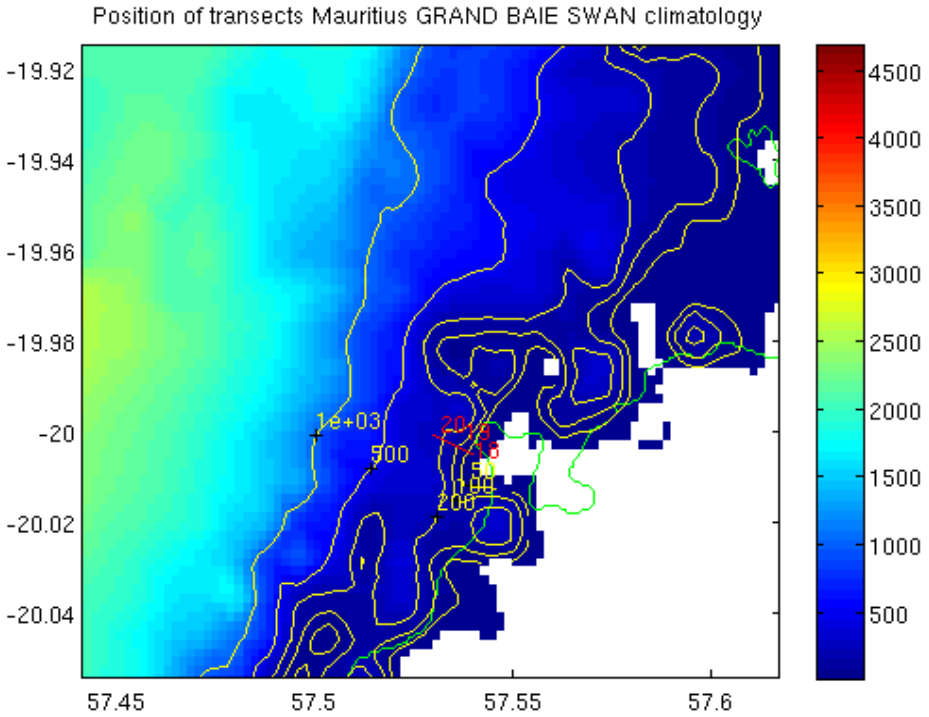

Position of transects Mauritius BAIE DU CAP SWAN climatology
-20.44
-20.46
-20.48
-20.5
-20.52
-20.54
-20.56
57.26
57.28
57.3
57.32
57.34
57.36
57.38
57.4
57.42
50
100
200
500
1e+03
4500
4000
3500
3000
2500
2000
1500
1000
500


Position of transects Mauritius GRIS GRIS SWAN climatology
-20.5
-20.52
-20.54
-20.56
-20.58
-20.6
-20.62
57.44
57.46
57.48
57.5
57.52
57.54
57.56
57.58
57.6
50
100
200
500
1e+03
4500
4000
3500
3000
2500
2000
1500
1000
500


Position of transects Mauritius BLUE BAY SWAN climatology
-20.4
-20.42
-20.44
-20.46
-20.48
-20.5
-20.52
57.64
57.66
57.68
57.7
57.72
57.74
57.76
57.78
57.8
11
12
13
14
7
8
9
10
50
100
200
500
1e+03
4500
4000
3500
3000
2500
2000
1500
1000
500


Position of transects Mauritius VIEUX GRAND PORT SWAN climatology
-20.36
-20.38
-20.4
-20.42
-20.44
-20.46
-20.48
57.68
57.7
57.72
57.74
57.76
57.78
57.8
57.82
57.84
11
12
13
14
7
8
9
50
100
200
4500
4000
3500
3000
2500
2000
1500
1000
500


Position of transects Mauritius FLACQ SWAN climatology
-20.12
-20.14
-20.16
-20.18
-20.2
-20.22
-20.24
57.74
57.76
57.78
57.8
57.82
57.84
57.86
57.88
57.9
4500
4000
3500
3000
2500
2000
1500
1000
500
1e+03
500
200
100
50
17
16
15


Position of transects Mauritius GRAND BAIE SWAN climatology
-19.92
-19.94
-19.96
-19.98
-20
-20.02
-20.04
57.45
57.5
57.55
57.6
4500
4000
3500
3000
2500
2000
1500
1000
500
1e+03
500
200
100
50
18
17

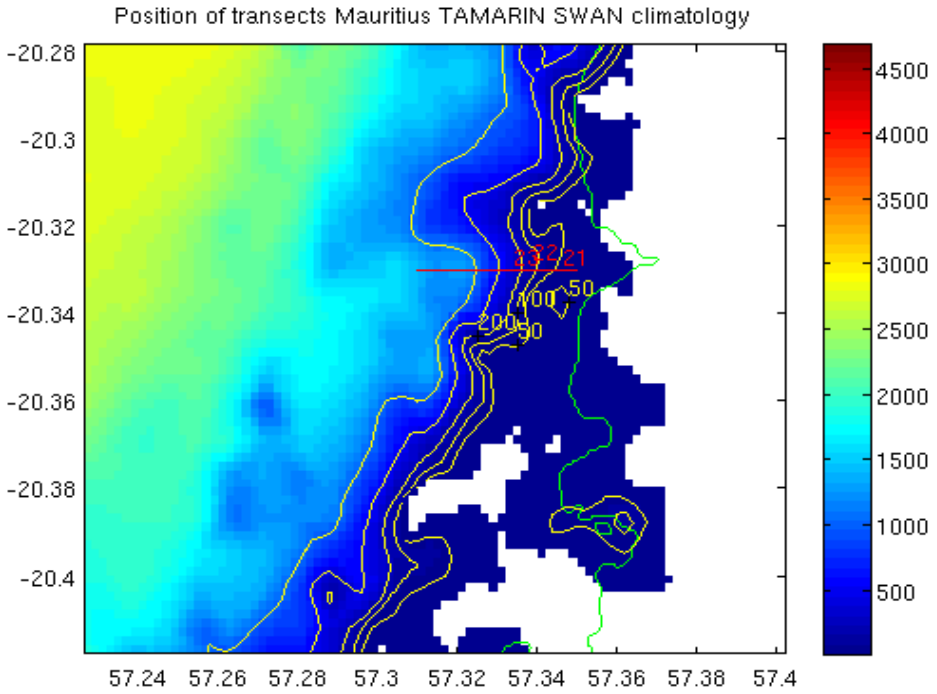


Figure 6. Details of the transects around Mauritius and the stations, which are numbered.

The positions of the stations are shown in Table 3. The variable data that was output from each station is shown in Table 4.

Table 3

	Longitude	**Latitude**	**Depth (m)**
Baie du Cap			
1	57.3520 E	20.4978 S	50
2	57.3510 E	20.5007 S	100
3	57.3492 E	20.5058 S	200
Gris Gris			
4	57.5200 E	20.5320 S	50
5	57.5200 E	20.5367 S	100
6	57.5200 E	20.5410 S	200
Blue Bay			
7	57.7100 E	20.4552 S	50
8	57.7100 E	20.4635 S	100
9	57.7100 E	20.4720 S	200
10	57.7100 E	20.4842 S	500
Vieux Grand Port			
11	57.7600 E	20.3900 S	20
12	57.7900 E	20.4080 S	50
13	57.7970 E	20.4120 S	100
14	57.8020 E	20.4150 S	200
Flacq			
15	57.7970 E	20.1910 S	50
16	57.8020 E	20.1880 S	100
17	57.8090 E	20.1840 S	200
Grand Baie			
18	57.5390 E	20.0045 S	50
19	57.5360 E	20.0035 S	100
20	57.5320 E	20.0020 S	200
Tamarin			
21	57.3440 E	20.3300 S	50
22	57.3390 E	20.3300 S	100
23	57.3350 E	20.3300 S	200

Table 4

Parameter name	Comment	Units
Time	ISO format, UTC	
U10	Eastward directed wind speed at 10 m height	ms^{-1}
V10	Northward directed wind speed at 10 m height	ms^{-1}
Hs	Significant Wave Height	m
mwd	Mean Wave Direction	Deg. East=0
rtp	Peak wave period	s
energy_x	Eastward directed energy transport	kWm^{-1}
energy_y	Northward directed energy transport	kWm^{-1}
tm01	Mean wave period	s
dspr	Directional spread of wave spectrum	Degs.
tm02	Zero crossing wave period	s

4.0 Wave Model Gridded Data Products

The parameters outlined in Table 5 were stored every 12 hours from SWAN_Mascarene and every 3 hours from SWAN_Mauritius for the entire 10 years between 2002 and 2011. The format of the data is the commonly used self describing netCDF.

Table 5

Parameter	Comment	Units
lat	Latitude	South of equator is negative
lon	Longitude	West of Greenwich is negative
time	Seconds since 1968-05-23 00:00:00 UTC	
Hs	Significant Wave Height	m
mwp, or tm01 (SWAN)	Mean Wave Period	s
zerop, or tm02 (SWAN)	Zero Crossing Period	s
pwp, or rtp (SWAN)	Peak Wave Period	s
mwd, or dir (SWAN)	Mean Wave Direction	degs. Cartesian sense. Due East = 0.0
pwd, or pdir (SWAN)	Peak Wave Direction	deg. Cartesian sense. Due East = 0.0
dspr	Directional Spread of waves	degs.
energy_x	Energy Transport towards East	kWm^{-1}
energy_y	Energy Transport towards North	kWm^{-1}

4.1 Definition of SWAN Parameters

Hs = $4\sqrt{\iint E(\sigma,\theta)\,d\sigma d\theta}$

tm01 = $2\pi\left(\frac{\iint \sigma E(\sigma,\theta)\,d\sigma d\omega}{\iint E(\sigma,\omega)\,d\sigma d\omega}\right)^{-1}$

tm02 = $2\pi\left(\frac{\iint \sigma^2 E(\sigma,\theta)\,d\sigma d\omega}{\iint E(\sigma,\omega)\,d\sigma d\omega}\right)^{\frac{-1}{2}}$

pdir = peak direction of $\iint E(\sigma,\theta)\,d\sigma$

dir = $\tan^{-1}\left(\frac{\int \sin\theta E(\sigma,\theta)\,d\sigma d\theta}{\int \cos\theta E(\sigma,\theta)\,d\sigma d\theta}\right)$

dspr is standard deviation of the directions

energy_x = $\rho g \iint c_x E(\sigma,\theta)\,d\sigma d\theta$

energy_y = $\rho g \iint c_y E(\sigma,\theta)\,d\sigma d\theta$

where σ is the discrete wave frequency, Θ is the discrete wave direction (Cartesian sense), E(σ, Θ) is the directional spectral wave energy (basic state variable of SWAN), c_x and c_y are the x and y components of the wave group velocity for discrete spectral components and ρ is the water density.

5.0 Modelling the Gamede Cyclone

One of the aims of this study was to examine in more detail the response of the wave field to the passage of a cyclone past Mauritius. Such conditions are likely to result in the most extreme waves that potential wave farms would have to endure. There was one notable cyclone that occurred during the period 2002 to 2011 that was simulated in this study. Cyclone Gamede passed to the north and then the west of Mauritius during February 2007.

The Mauritius Meteorological Service issued bulletins and weather charts as the cyclone developed. One of the charts and a polar orbiting satellite IR image is shown in figure 7.

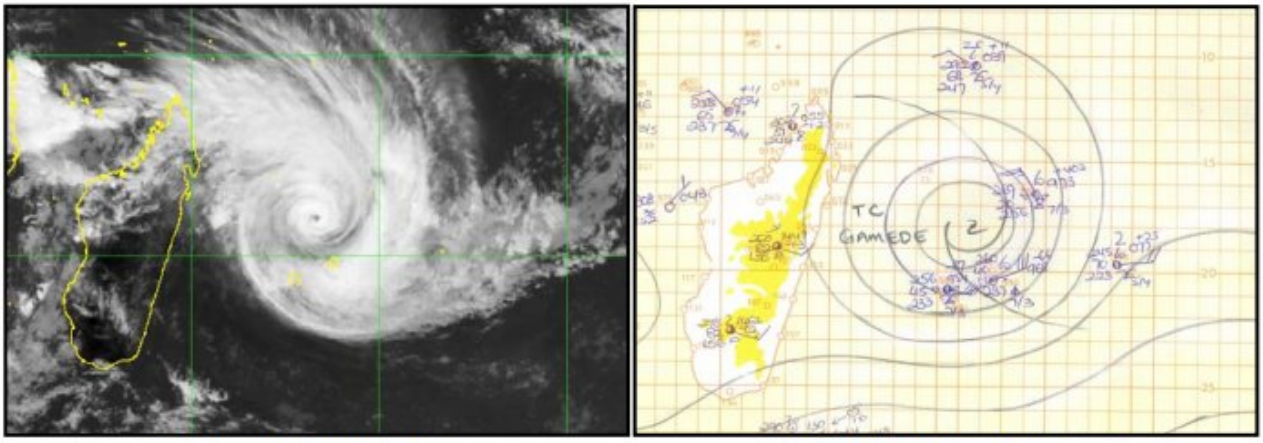
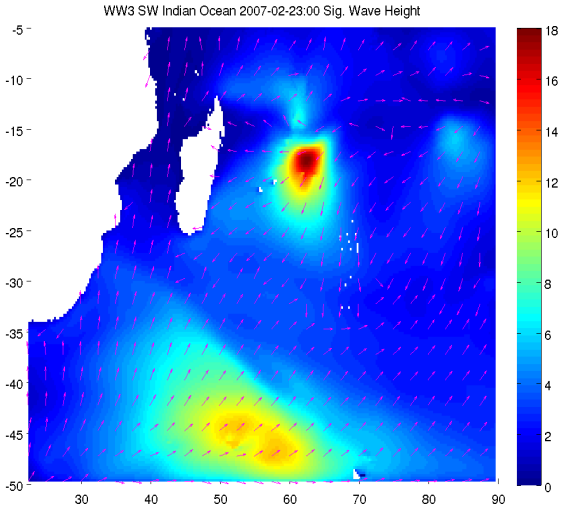


Figure 7. MMS report for cyclone Gamede at the time it was to the NW of Mauritius.

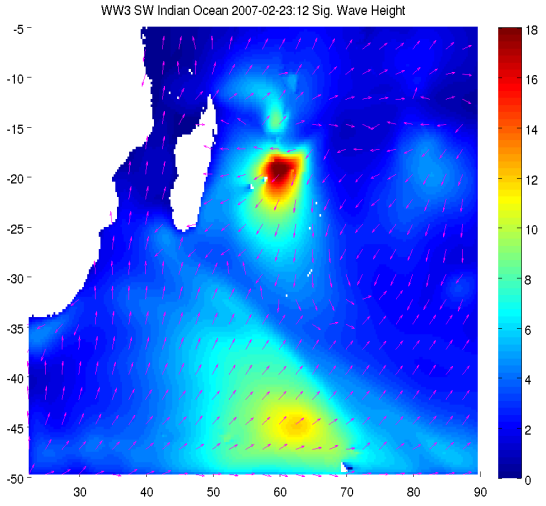
The MMS issued the Technical Report CS 28 The Cyclone Season in the SW Indian Ocean, 2006-2007. In it they state that there was a particularly strong ITCZ, with disturbed weather which was identified on 18th February near to 13.5 S and 79.5 E. This low pressure area deepened, moved west and then recurved SSW and headed towards Mauritius at a rate of 30 kmh^{-1}. It had a central 'eye' with a diameter of approximately 50 km. As it passed over St Brandon, gusts of 160 kmh^{-1} were recorded. At one point on the 26th February it became an intense tropical cyclone and gusts of 158 kmh^{-1} were recorded at Fort William. It was reported to have caused severe erosion along the northern and western coasts of Mauritius. By 3rd March it was subsiding having passed to the SW of Mauritius.

The modelling of Gamede serves to estimate the wave field response to a cyclone, but also to illustrate how the model downscaling functions. Figure 8 shows some snapshots of significant wave height and peak wave direction from the WaveWatch3 model.

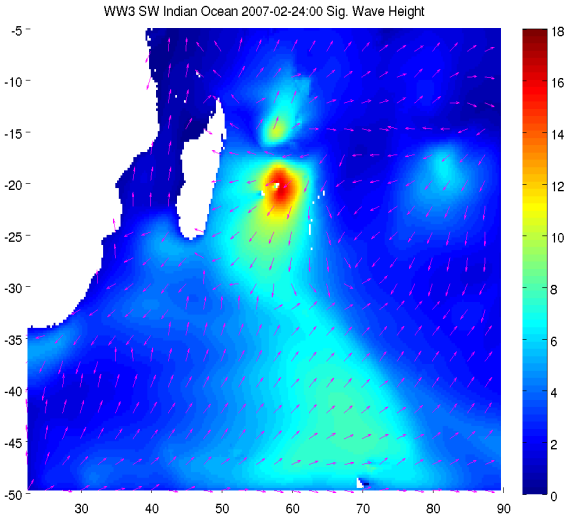
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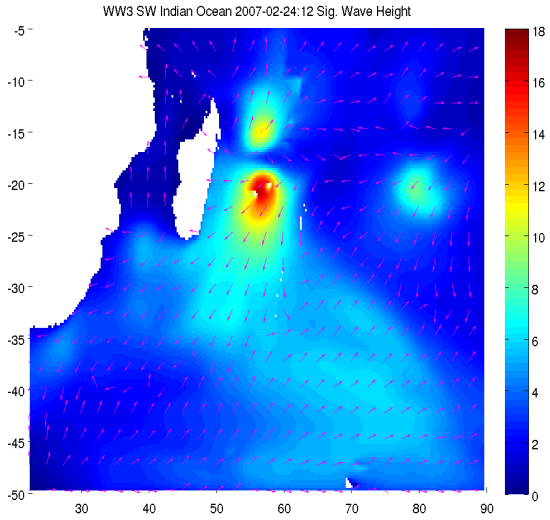
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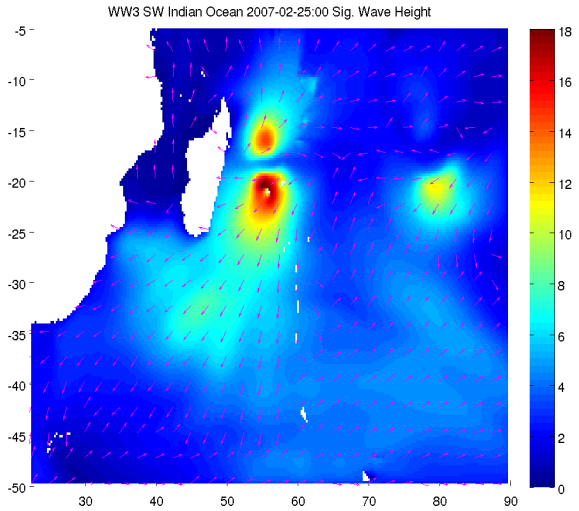
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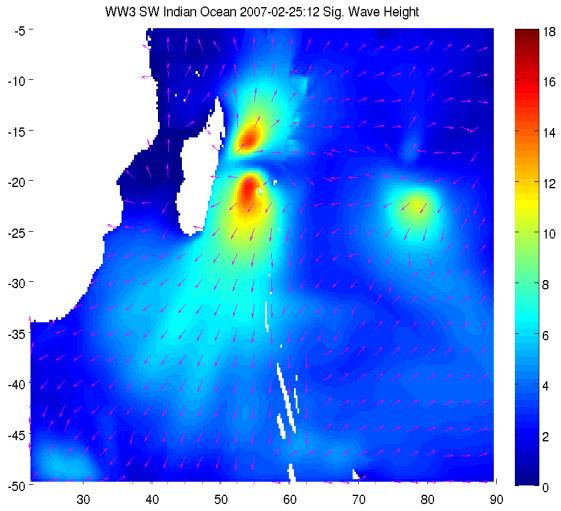
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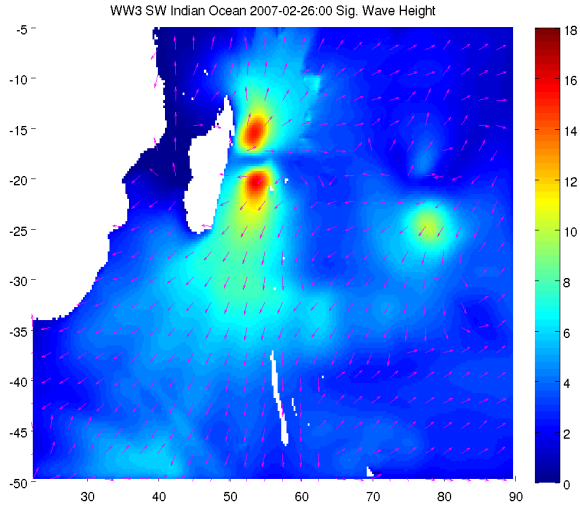
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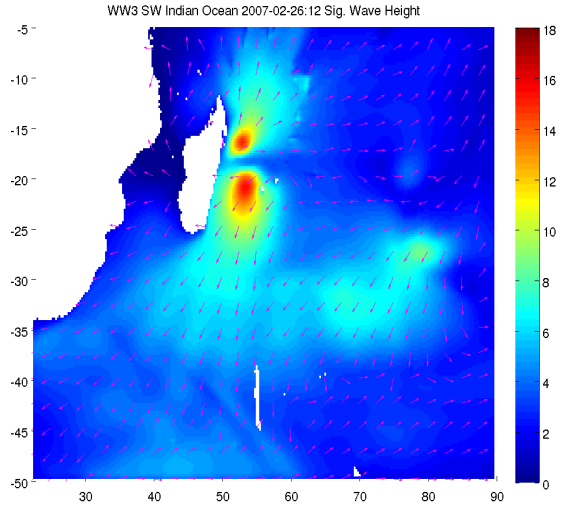


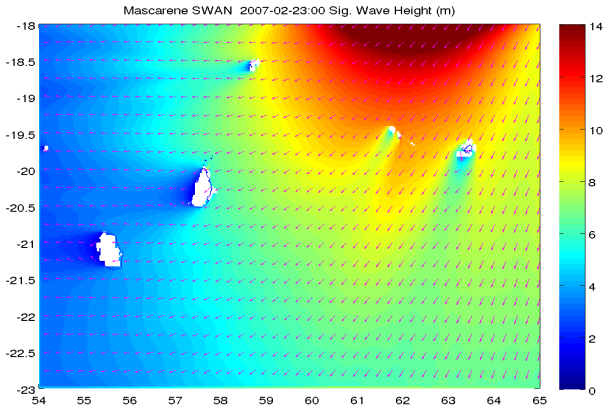
Figure 8. Significant wave height (m) and peak wave direction from WW3_SW_Indian model. Snapshots every 12 hours from during the Gamede cyclone passage.

It can be seen that the waves could be seen thousands of km ahead of the cyclone. These waves grew as the cyclone approached. The waves were highest (> 18 m) whilst Gamede was NE of Mauritius. They subsided somewhat on the 24th Febraury when the cyclone before building again and delivering the highest waves to Reunion on the 25th February. The model results show that the wave heights exhibit an interesting 'doublet' on a north-south axis.

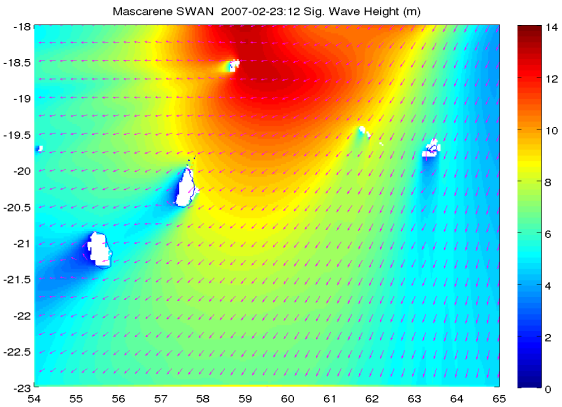
The evolution of Gamede shows that it was absolutely necessary to include as wide a model domain as was used here in WW3_SW_Indian in order to capture all of the dynamics.

The directional spectral data was transferred to the boundaries of the nested model SWAN_Mascarene. Snapshots from the significant wave height from this model are shown in figure 9.

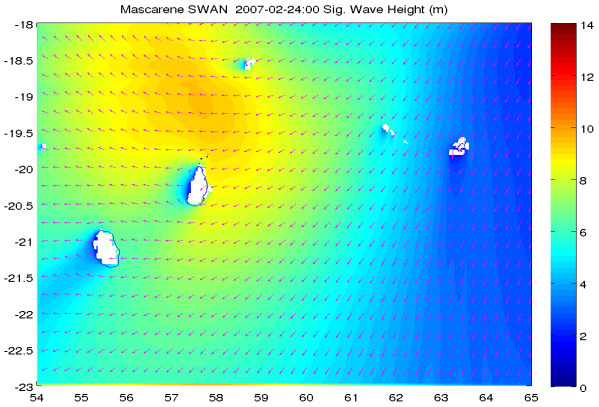
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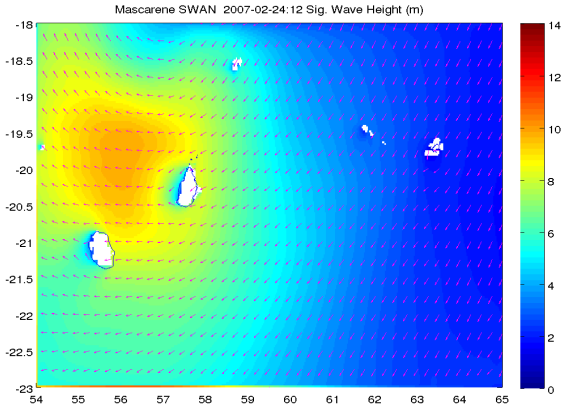
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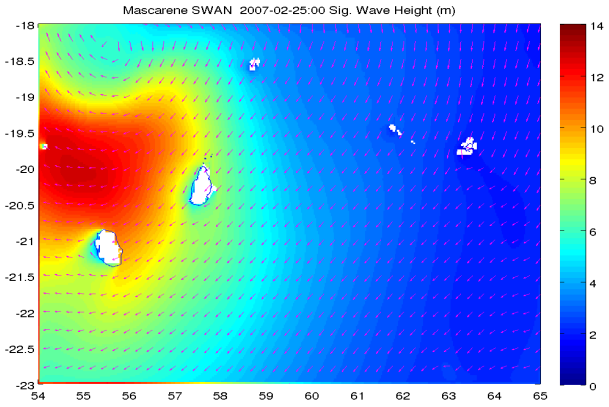
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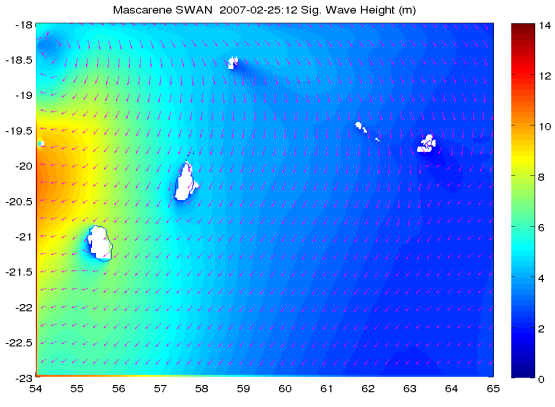
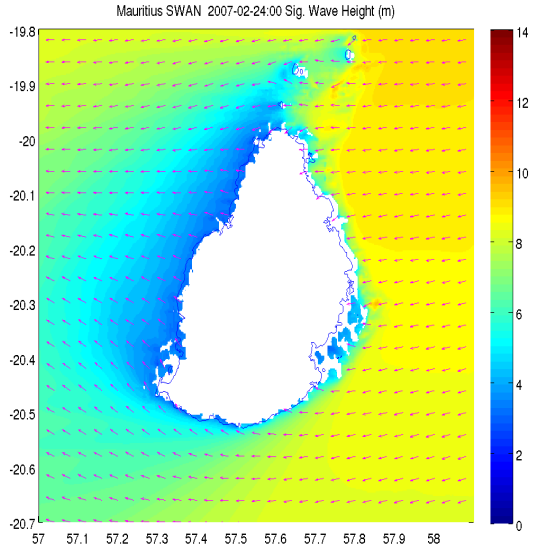


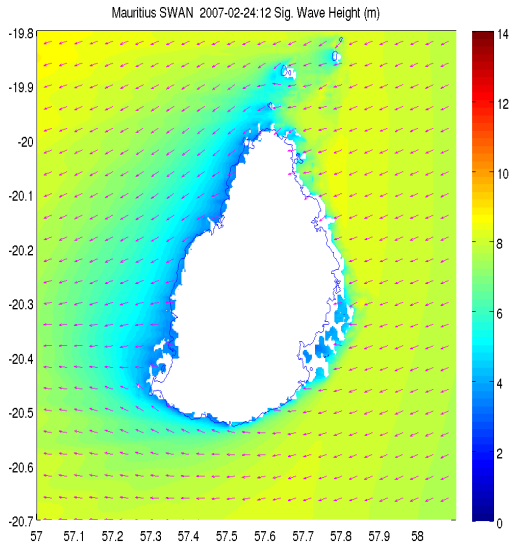
Figure 9. Significant wave height and peak wave direction from SWAN_Mascarene during cyclone Gamede.

The final level of model nesting for the SWAN_Mauritius model and the resulting significant wave height is shown in figure 10.

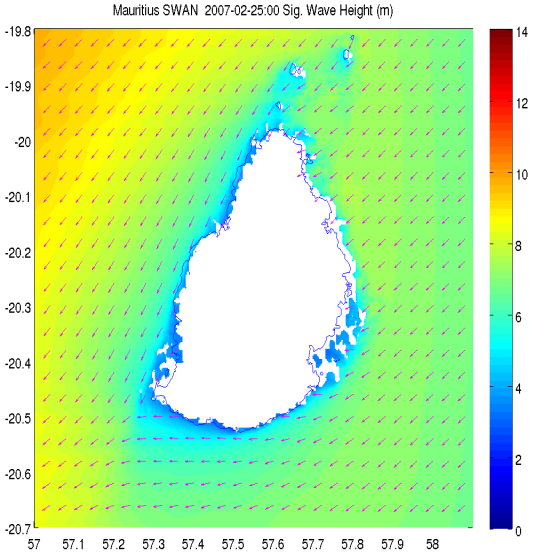
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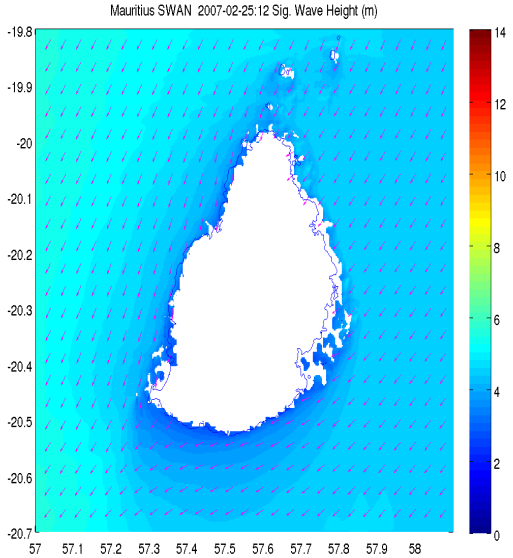


Figure 10. Significant wave height and peak wave direction from SWAN_Mauritius during cyclone Gamede.

The wave modelling shows that in fact Mauritius had a lucky escape during Gamede, with the worst of the waves missing the country. The highest significant wave height of approximately 9 m was to be found off of the NE coast. The wave energy flux at this time is shown in figure 11.

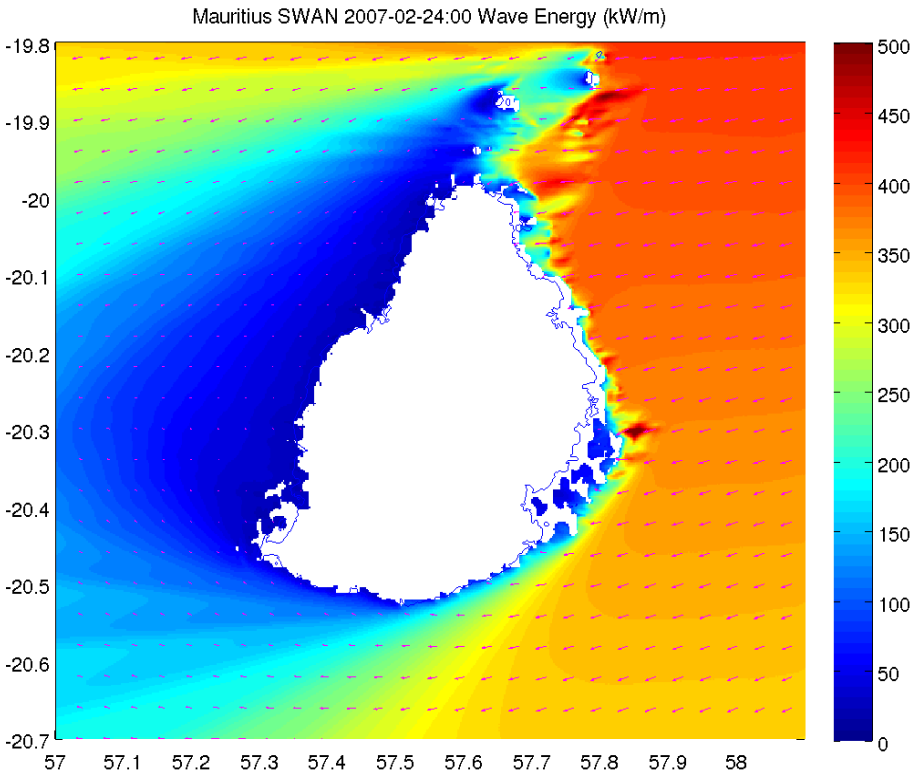


Figure 11. Wave energy flux on the 24th Feb. 2007 during cyclone Gamede.

It is interesting to note that the wave energy tends to be concentrated at certain locations, presumably due to wave refraction. This type of modelling shows how important it is to discover the best wave energy resource through modelling and how this has a high spatial variability.

The year 2006 was a fairly calm year in the seas around Mauritius, followed by 2007, which was had the roughest seas in the model hindcast period (2002 to 2011). Figure 12 shows time series of significant wave height and wave energy flux from station 13 (Vieux Grand Port, 100m depth) for these two years. As we shall see later, station 13 represents what might be one of the best locations to maximise wave energy production. We can see the cyclone Gamede and we can also see a few storms in the winter of 2007. One of these is examined in the next section.

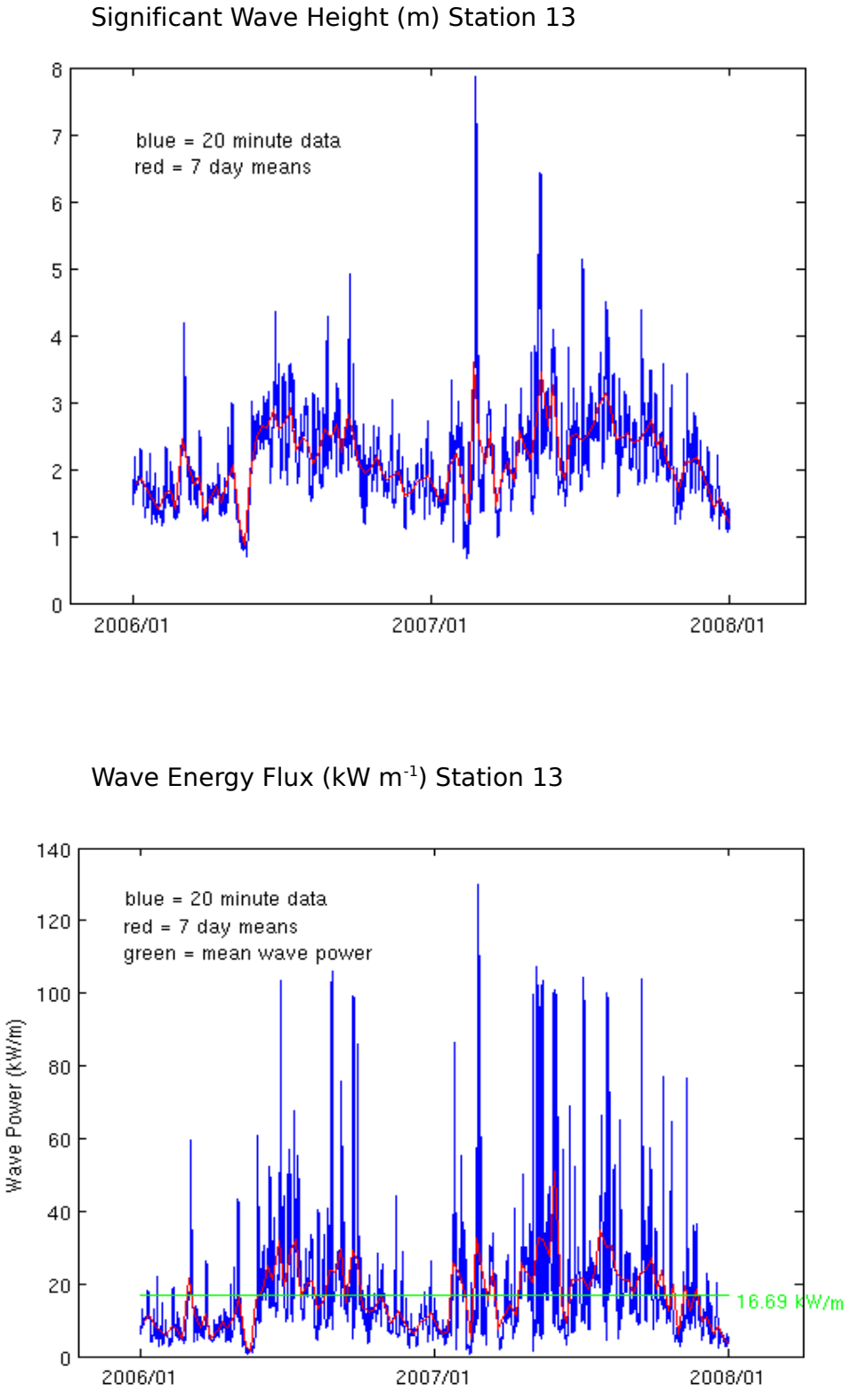
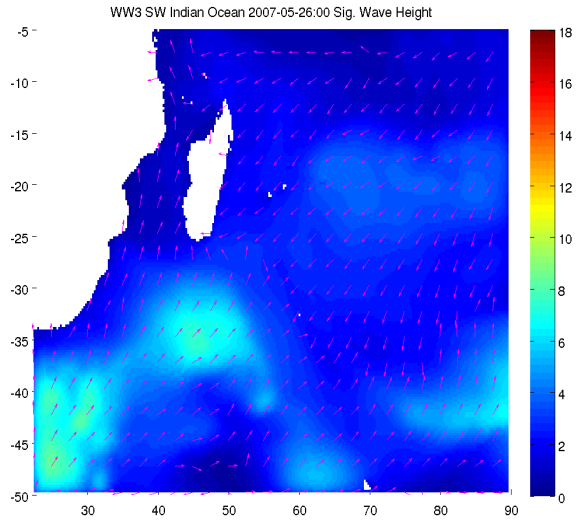


Figure 12. Significant wave height and wave energy flux for station 13 (Vieux Grand Port, 100 m depth).

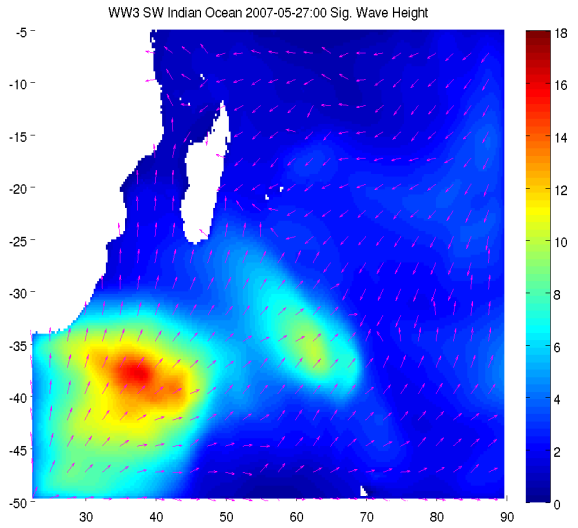
6.0 Modelling a Winter Storm Event

Whereas the most extreme waves around Mauritius are to be found during cyclones, the best wave energy resource occurs during the winter season, when sustained elevated wave conditions can persist. One such typical wintertime event is examined here from the end of May 2007 so as to better understand the meteorological progression that leads to large waves arriving in Mauritius. The WaveWatch3 snapshots from this period are shown in figure 13.

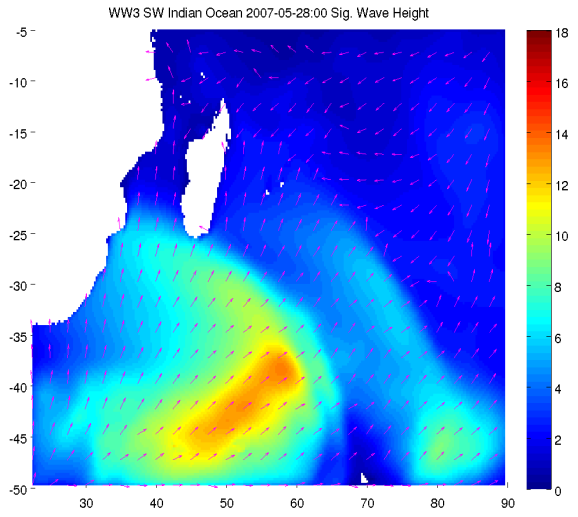
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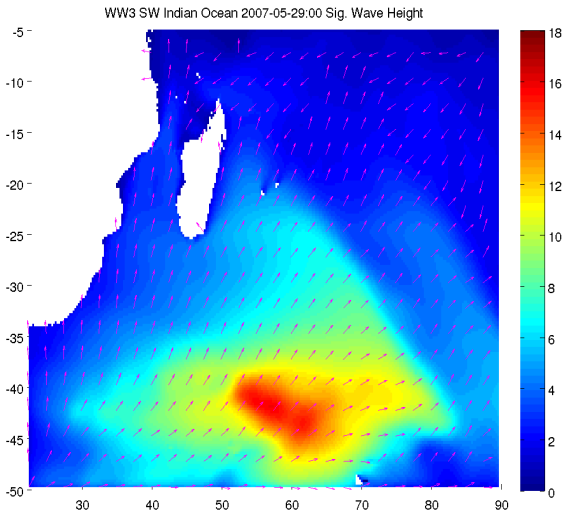
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2007/05/30 2007/05/31

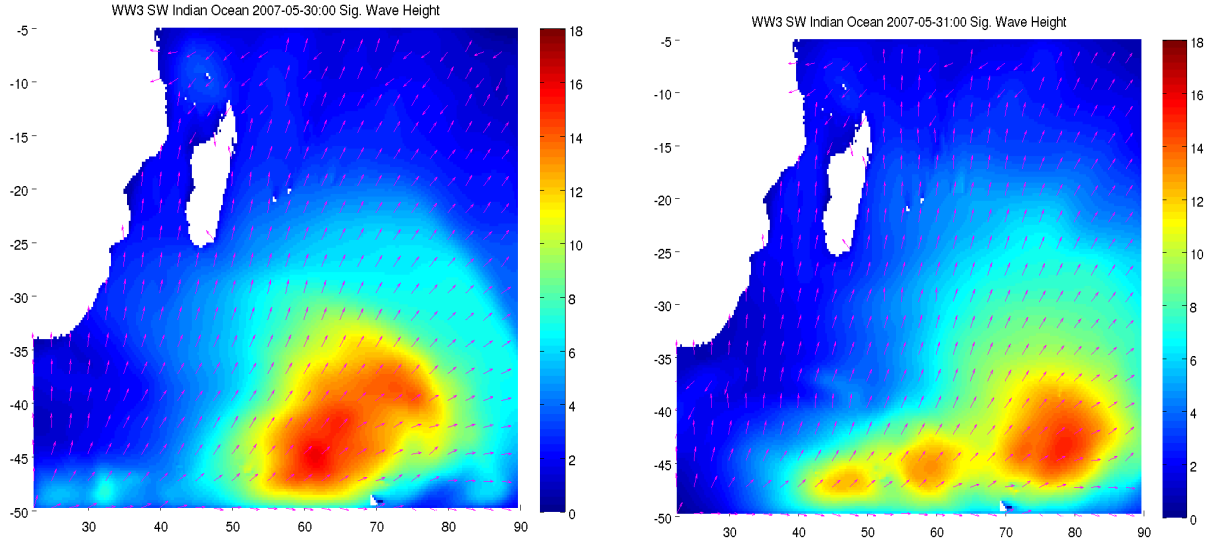


Figure 13. A typical progression of wintertime storms in the Southern Ocean that leads to waves arriving in Mauritius. WW3_SW_Indian model significant wave height results.

The centre of the storms that are the source of the waves experienced in Mauritius in the winter are some 1,500 nautical miles distant to the south. They are carried along in the westerly winds of the 'roaring forties', but their waves and their energy travel as far as Mauritius. The wave energy that arrives on the south coast is shown in figure 14.

2007/05/28 2007/05/29

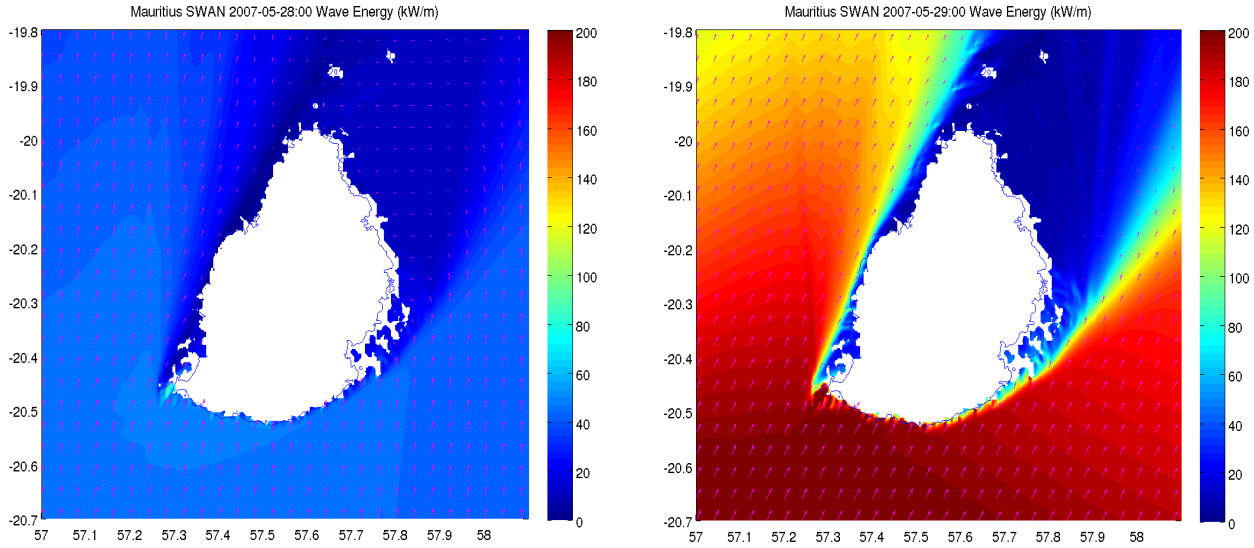


Figure 14. Wave energy flux (kW m^{-1}) and energy direction for a typical winter event.

7.0 Ten Year Wave Climatology SW Indian Ocean

We report here on the modelled wave height in the SW Indian Ocean over the ten year period 2002 to 2011. The data is compiled from the WaveWatch3 model output, which has was generated every 3 hours of the model run. Figure 15 shows the mean overall significant wave height.

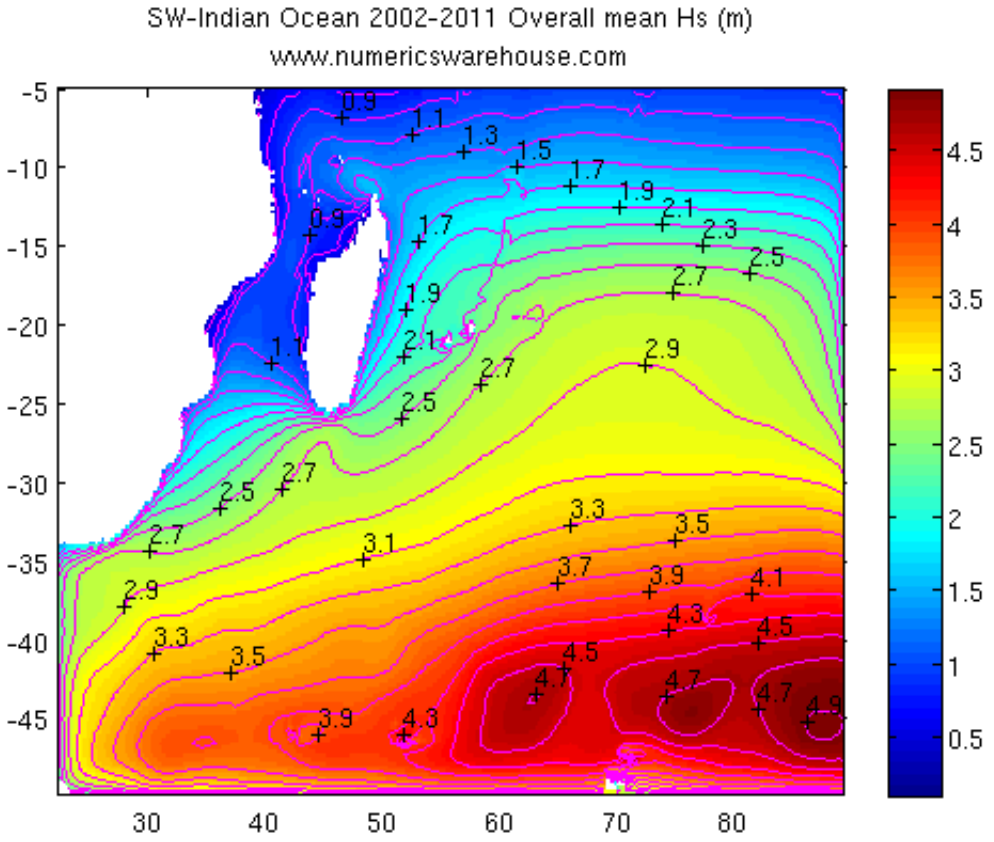


Figure 15. Overall mean significant wave height 2002 to 2011.

The significant wave height decreases towards the north and towards the west. The wave mean height near to Mauritius is similar to that found in Reunion and the south coasts of Madagascar and the Eastern Cape of S. Africa.

The difference in the mean significant wave height between summer and winter months is shown in figure 16. The height of the waves around Mauritius is less in the summer than the winter, but the overall spatial pattern is nor very different between the seasons.

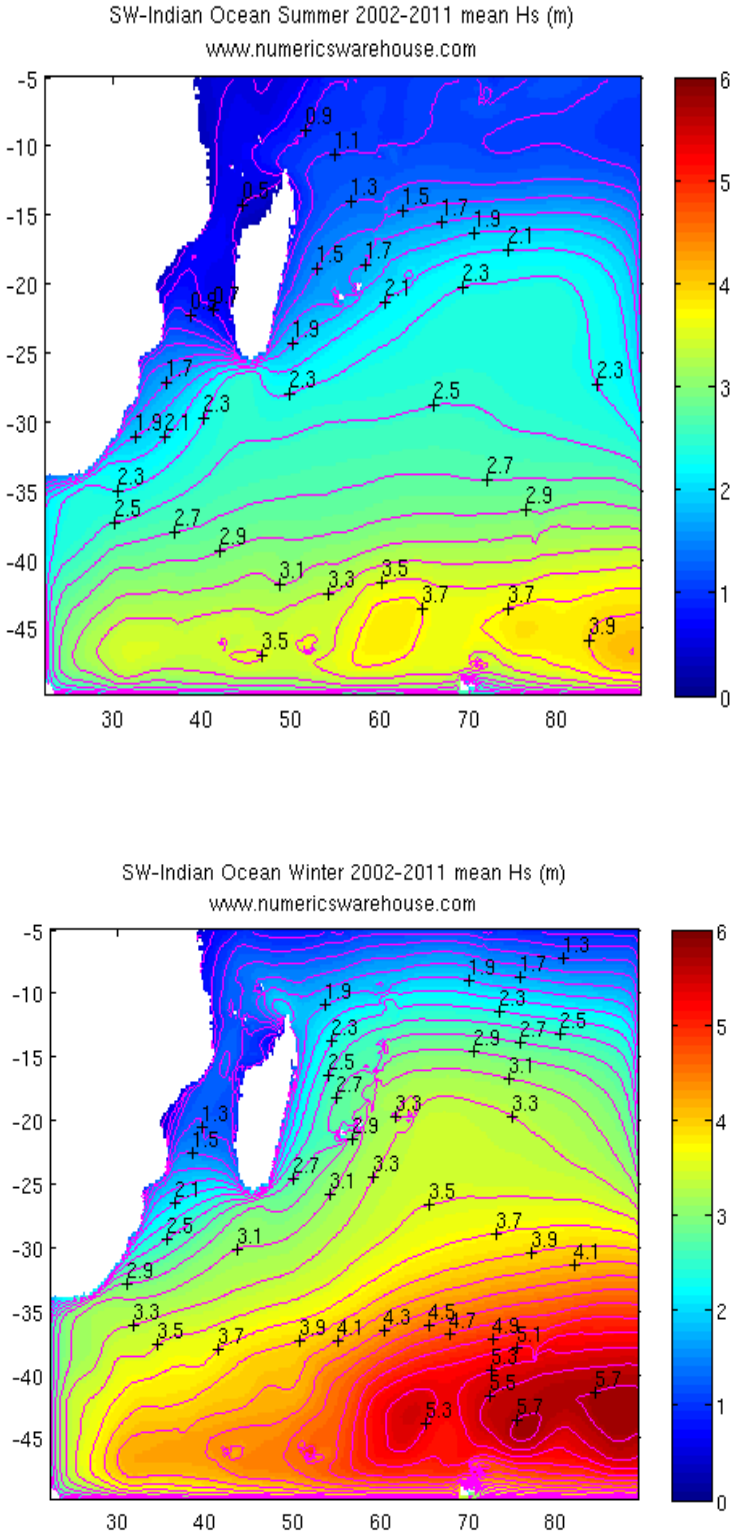


Figure 16. Mean significant wave height 2002 to 2011 during the summer (top) and the winter (bottom).

Figure 17 shows the highest 3 hour significant wave height value from the ten year model run.

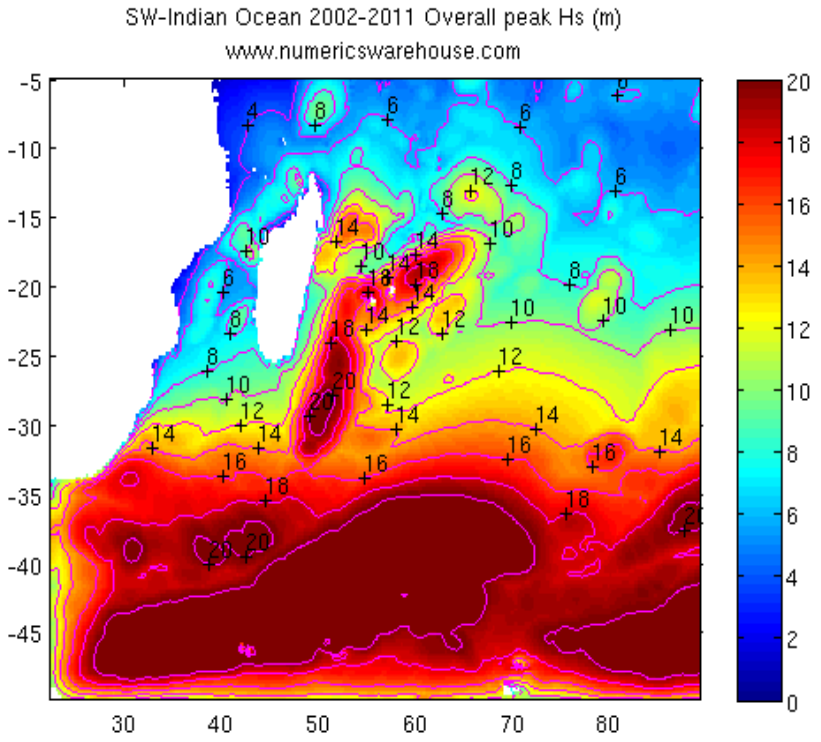


Figure 17. Peak value of significant wave height from the period 2002 to 2011.

Some of the peak wave height values modelled in the Southern Ocean are so high (> 20 m) that they may extend beyond the validated range of WaveWatch3. They should be regarded with some caution. The peak values in the latitudes of Mauritius are dominated by cyclone related wavefields. There appears to be a 'cyclone alley' from the ITCZ and extending over Mauritius towards the SW, but it is likely that much better statistics would result with a longer model run of perhaps 30 years, which would include more cyclones.

8.0 Ten Year Wave Climatology Mascarene Area

The mean overall significant wave height for the Mascarene area is shown in figure 18. The peak significant wave heights are shown in figure 19. The mean overall wave period and peak wave periods are shown in figures 20 and 21. The mean wave energy flux is shown in figures 22 and 23, with the later also showing the direction of energy transport with arrows. Figures 24 and 25 show the wave energy flux for the summer and the wintertime periods respectively.

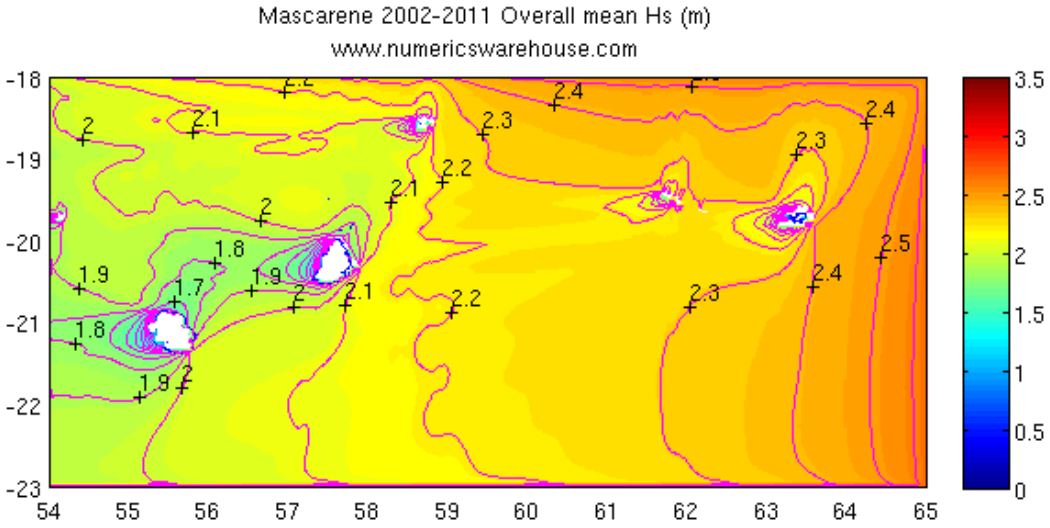


Figure 18. Mean overall significant wave height 2002-2011.

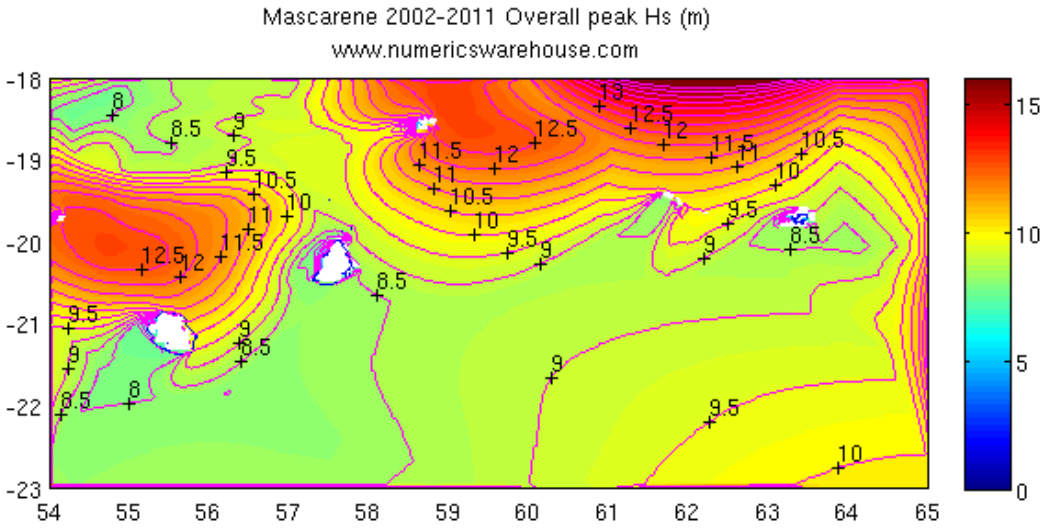


Figure 19. Peak significant wave height 2002-2011.

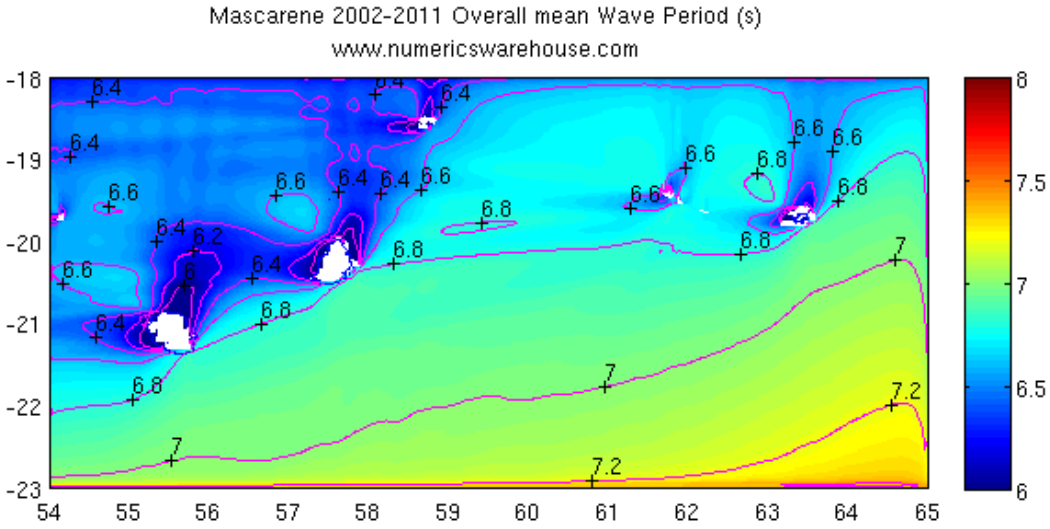


Figure 20. Mean overall wave period 2002-2011.

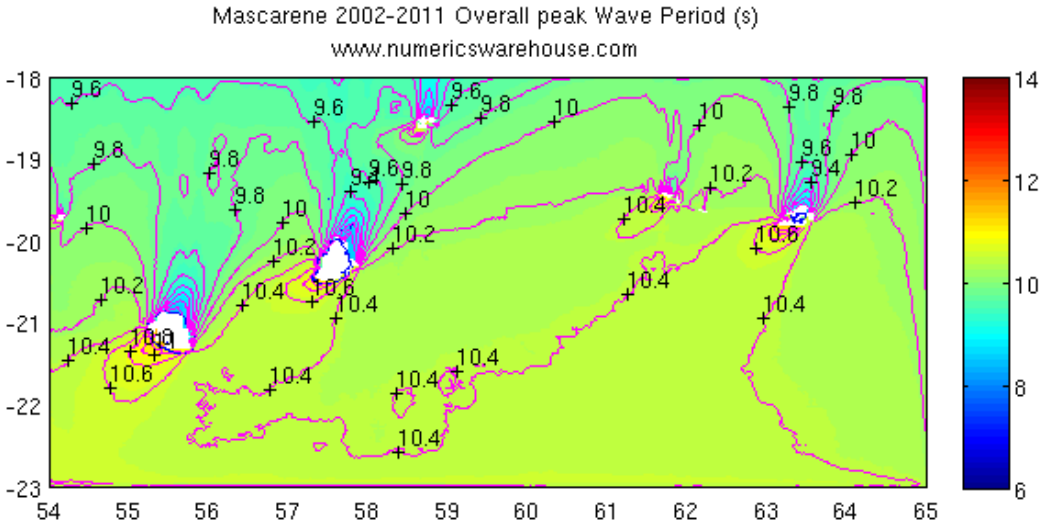


Figure 21. Mean overall peak wave period 2002-2011.

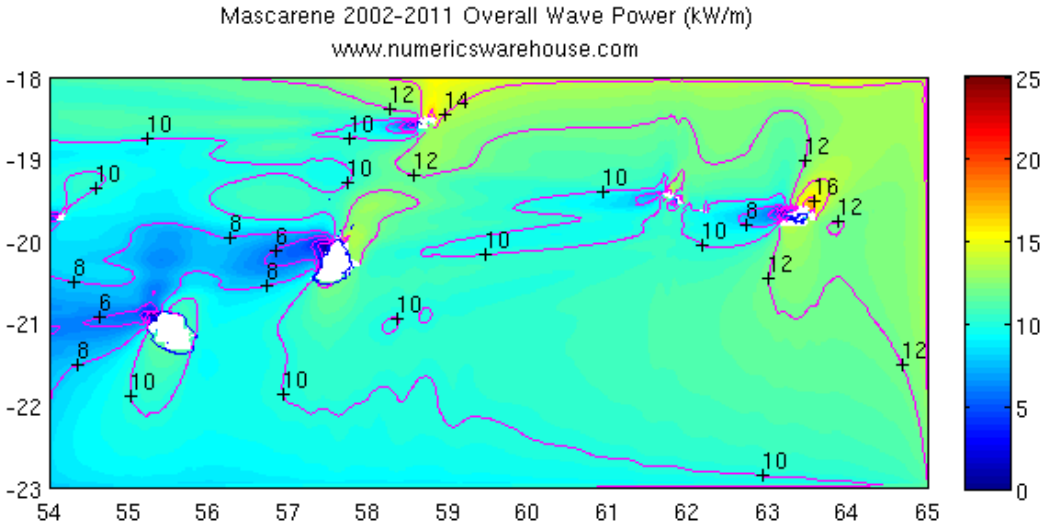


Figure 22. Mean overall wave energy flux 2002-2011.

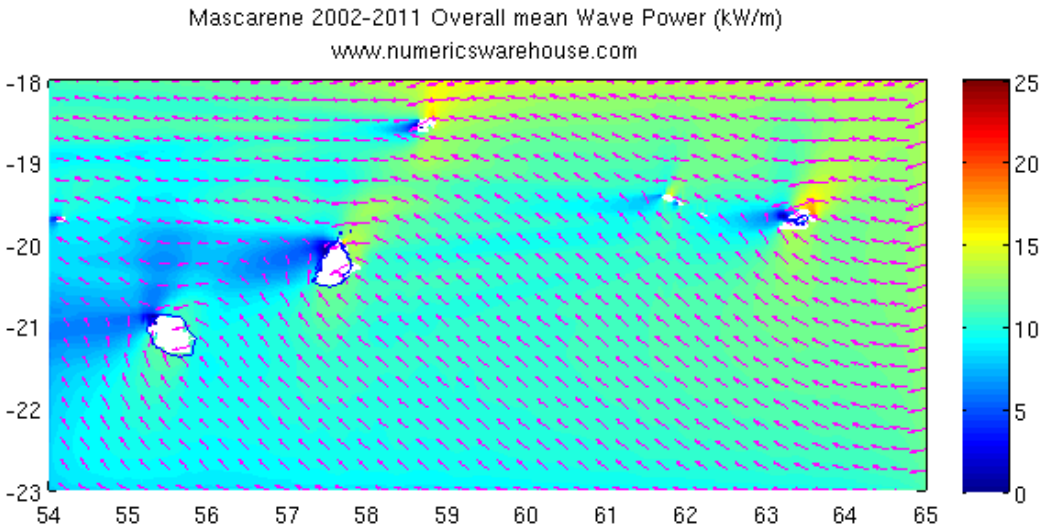


Figure 23. Mean overall wave energy flux 2002-2011, with wave energy direction.

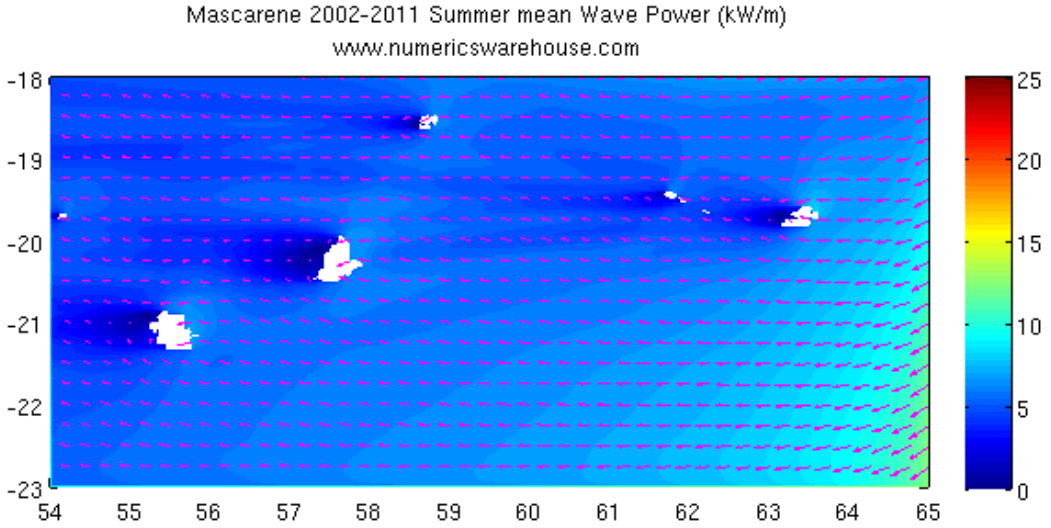


Figure 24. Mean summer wave energy flux 2002-2011, with wave energy direction.

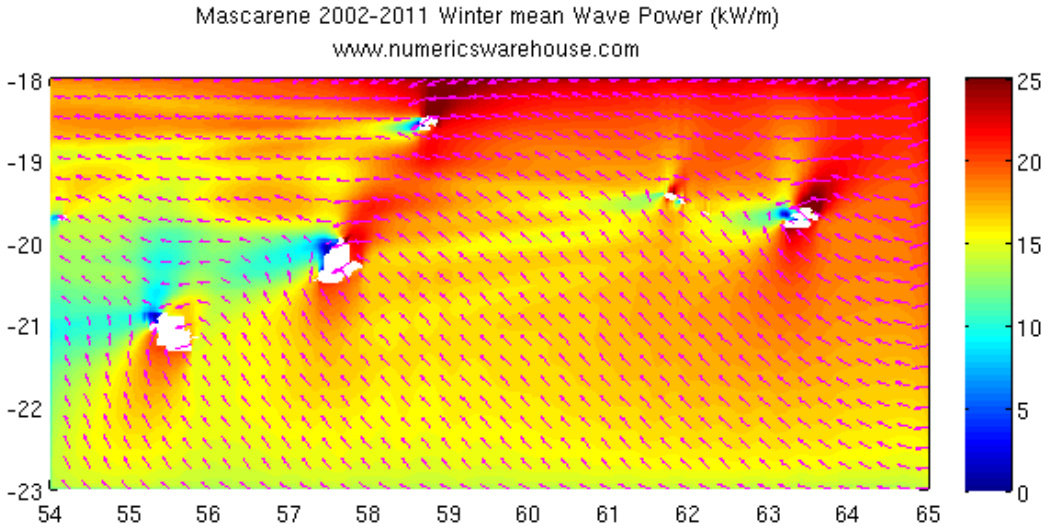


Figure 25. Mean winter wave energy flux 2002-2011, with wave energy direction.

The wave energy environment on the southern coast of Mauritius is very similar to that found to the south of Reunion. The wave energy on the west coast of Mauritius is similar to that found on the south coast. The wave energy in Rodrigues is superior to either Reunion or Mauritius. The mean wave period throughout the Mascarene region is not very different from the peak wave period indicating the predominance of wave fields with a peaked spectrum, notably with fairly long period waves which have travelled some distance. The peak wave direction overall is predominantly from the SE, which is the direction of the trade winds. When we split the wave energy into summer and winter seasons, we see that the wintertime wave energy is markedly higher than the summertime energy. The direction of transport in summer is mainly from the E, whereas in winter, it is from the SE.

8.1 The Mascarene Islands – a Comparison of Wave Statistics

We now examine some of the wave statistics from the stations identified in Table 2, in order to compare the wave climate in Reunion, Mauritius and Rodrigues. Figure 26 shows the Hs-Tp scatter diagrams for each of the islands. These diagrams show the number of 3 hour intervals during the 10 year model run that occur with waves binned by significant wave height and peak wave period. These statistics are important since wave energy device developers can use them to calculate the energy to be expected from a particular WEC, or to design the ideal WEC for a particular location. The green contours overlaid onto the diagrams show the theoretical deep water wave power to be expected for that Hs-Tp combination. The cyan-magenta shading shows the frequency of occurence within the range 0.0 to 1.0. See Section 9.2 for more details regarding Hs-Tp diagrams.

The diagrams illustrate that the wave energy variability for Reunion and Mauritius is similar, but that for Rodrigues, most of the energy is at slightly lower Tp, but higher Hs, leading to overall higher wave energy than for the other two islands.

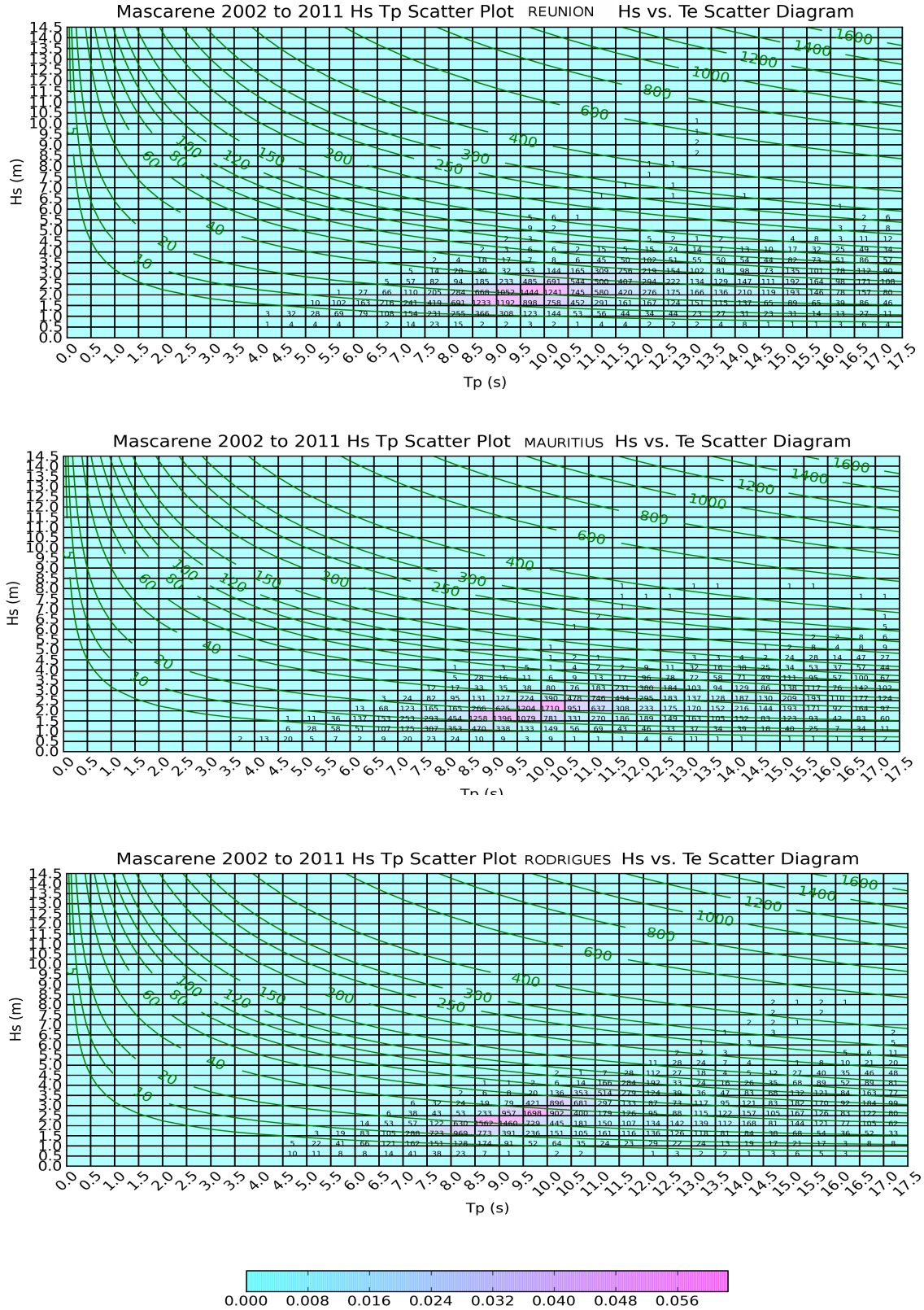


Figure 26. Comparison of the Hs-Tp diagrams for the Mascarene Islands

9.0 Ten Year Wave Climatology Mauritius

We begin by examining the spatial wave statistics of the seas around Mauritius. This section of the report is akin to an climatological atlas. We then show the statistical data from stations and transects.

9.1 Ten Year Wave Climatology Mauritius – Gridded Data

The significant wave height figures shown here are the overall mean wave height (figure 27), peak wave height (figure 28), mean summertime wave height (figure 29) and the mean wintertime wave height (figure 30). The mean overall significant wave height is highest offshore of Vieux Grand Port in the SW. It is also highest separately both during summertime and wintertime months. The peak wave heights are possibly dominated by the effects of just one cyclone:- Gamede and so caution should be used in interpreting this data.

The mean wave period figures are :- overall mean wave period (figure 31), summertime mean wave period (figure 32), wintertime mean wave period (figure 33). The corresponding peak wave period figures are 34-36.

The wave energy flux data is shown as the overall mean with contours and also directions (figures 37 and 38) and the same for summertime data (figures 39 and 40) and wintertime data (figures 41 and 42). These figures are some of the important results from this study. They show the locations of the best wave energy resource in Mauritius and how this varies between seasons. It seems that much of the south and west coasts would be suitable for wave farms, with perhaps the optimal solution being to use both coasts so as to smooth out the power input to the grid when waves arrive from different directions.

The final spatial maps shown are the standard deviation of the wave direction. The overall spread is presented in figure 43. The summertime and the wintertime data are shown in figures 44 and 45. Most of the south and west coasts have reasonably similar directional spreads. The waves are more variable in direction during the summer than the winter. The preferred location for a wave farm is one where the waves predictably arrive from the same direction, so that it can be seen from the data presented here that there is not much to choose between anywhere along either of the south or west coasts.

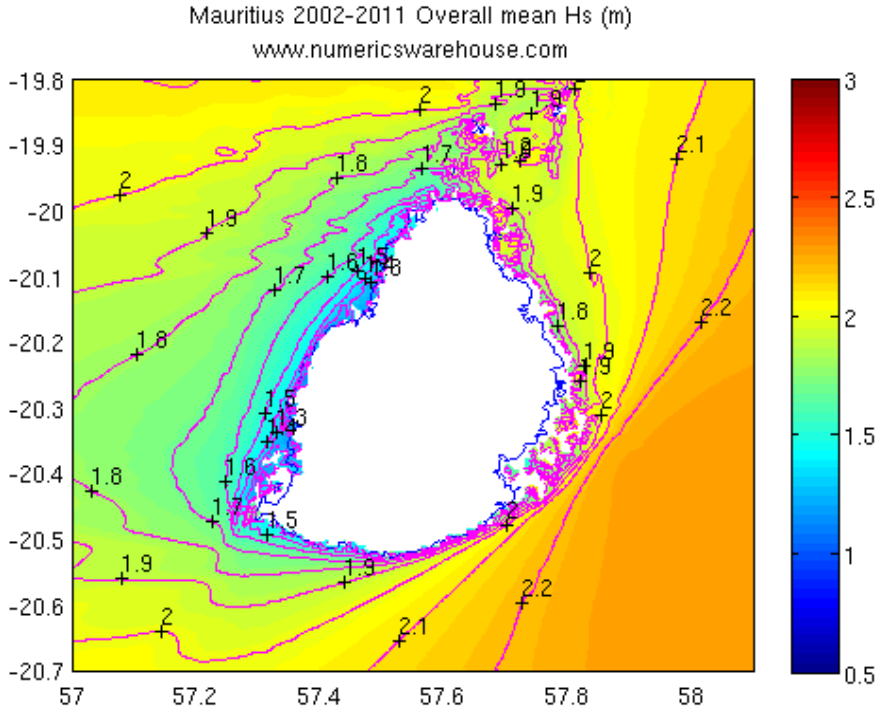


Figure 27. Mean overall significant wave height (m) 2002 to 2011

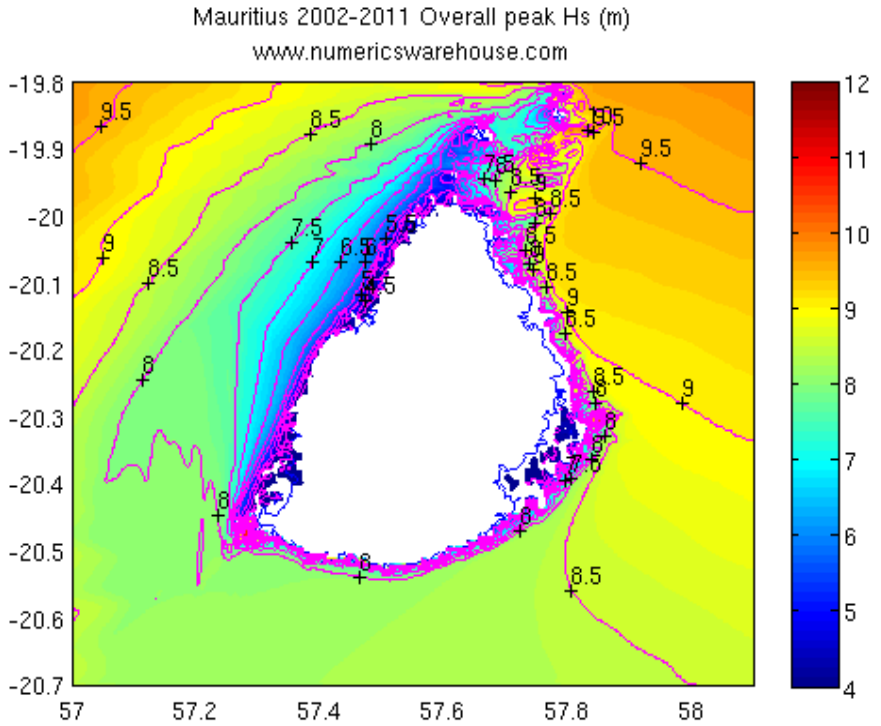


Figure 28. Peak significant wave height (m) in the interval 2002 to 2011

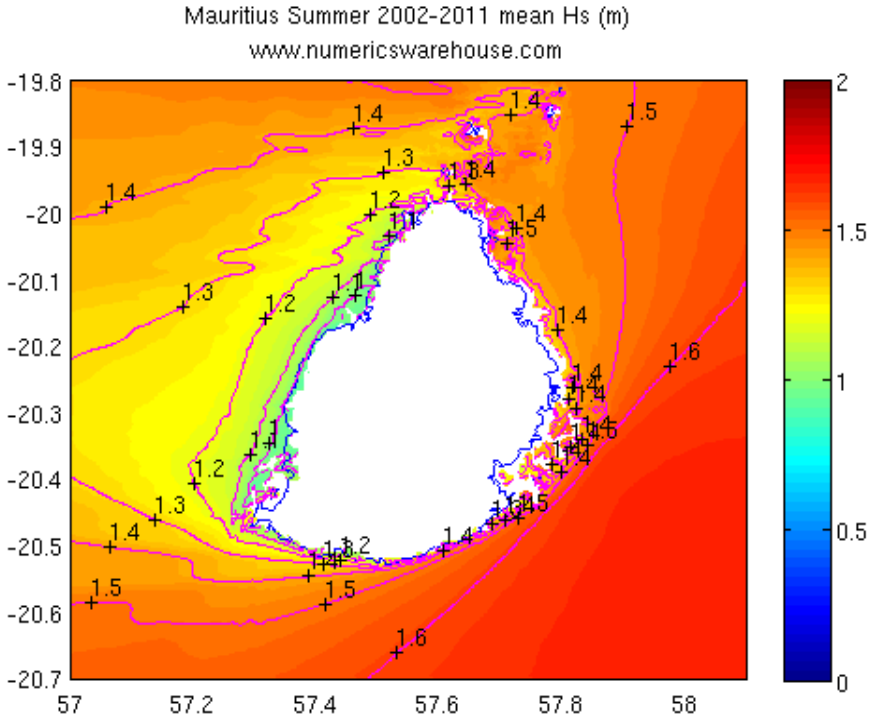


Figure 29. Mean summertime significant wave height (m) 2002 to 2011

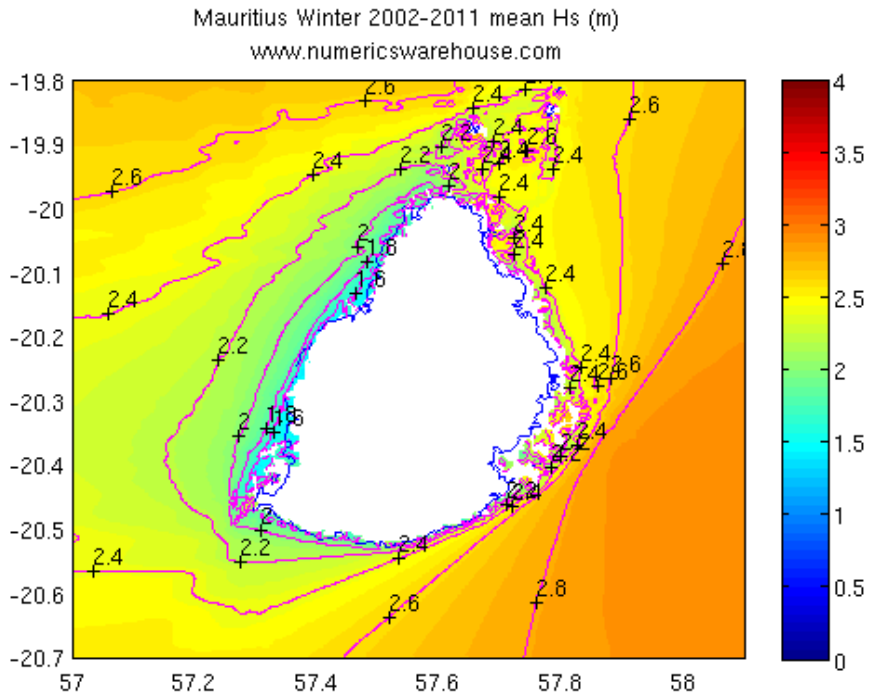


Figure 30. Mean wintertime significant wave height (m) 2002 to 2011

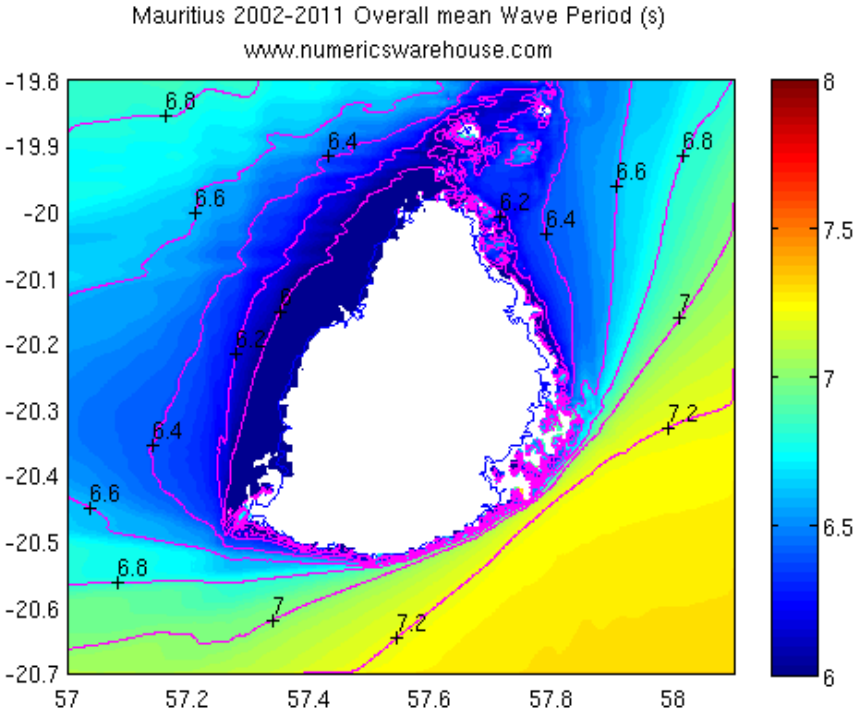


Figure 31. Overall mean wave period (s) 2002 to 2011

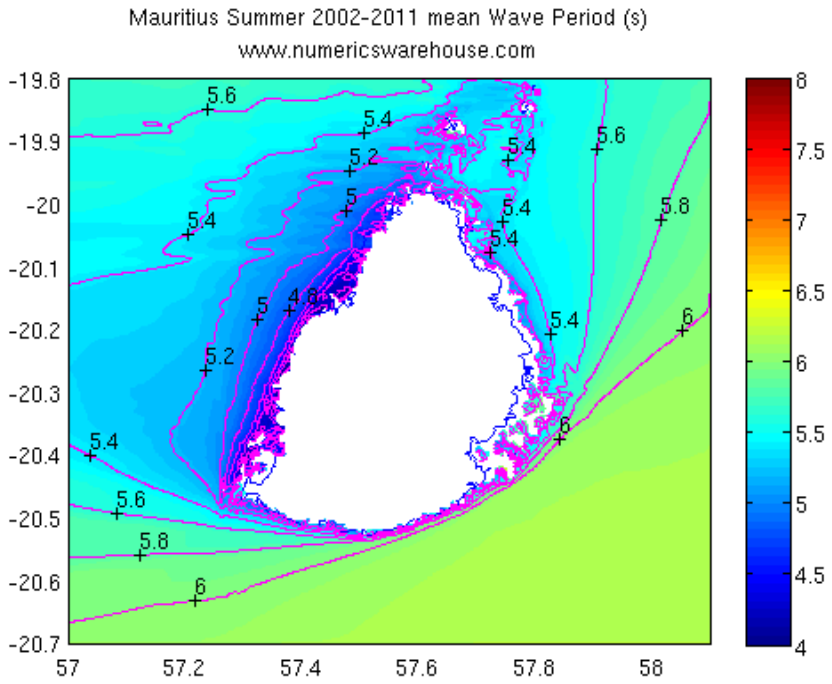


Figure 32. Summertime mean wave period (s) 2002 to 2011

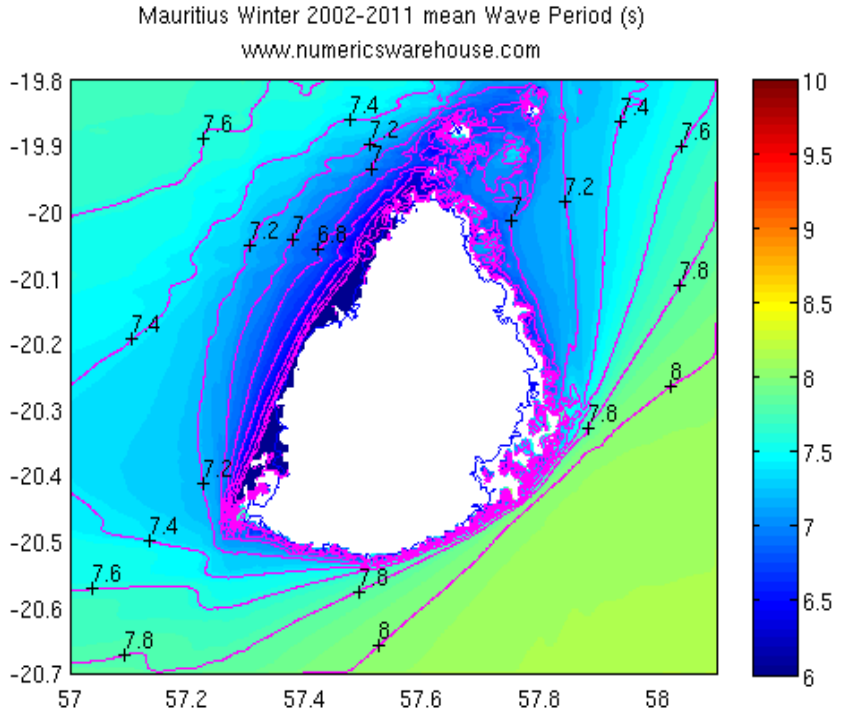


Figure 33. Wintertime mean wave period (s) 2002 to 2011

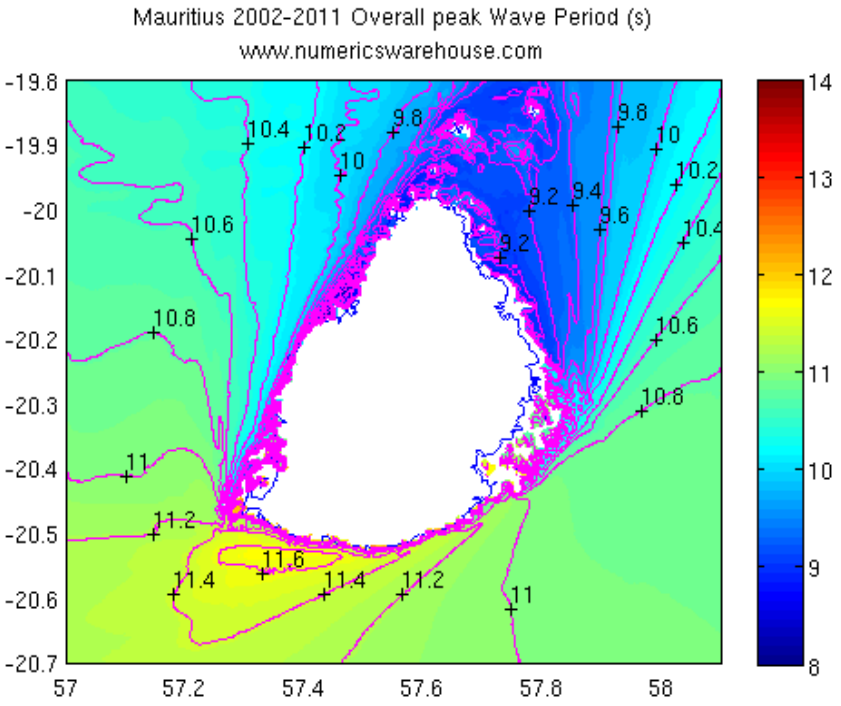


Figure 34. Overall peak wave period (s) 2002 to 2011

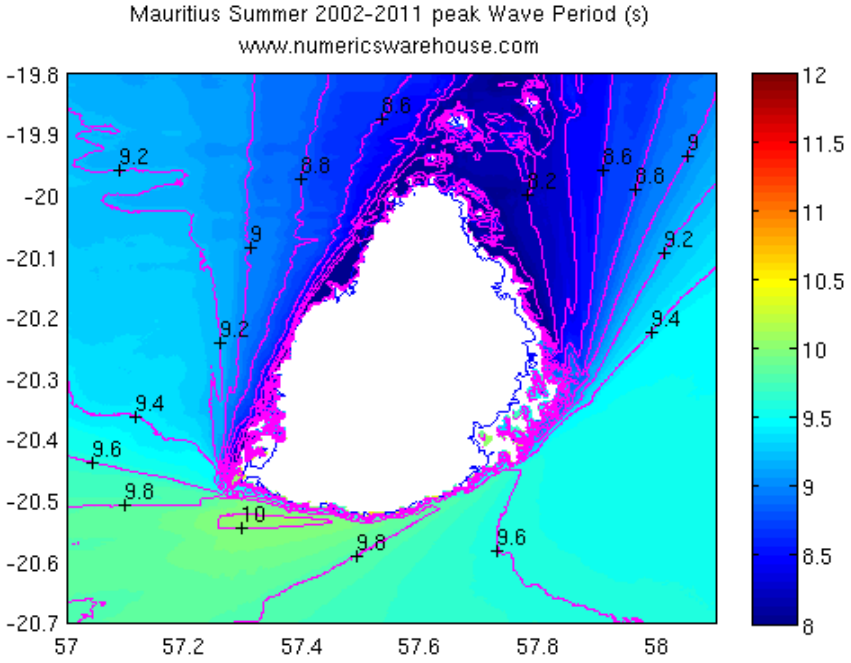


Figure 35. Summertime peak wave period (s) 2002 to 2011

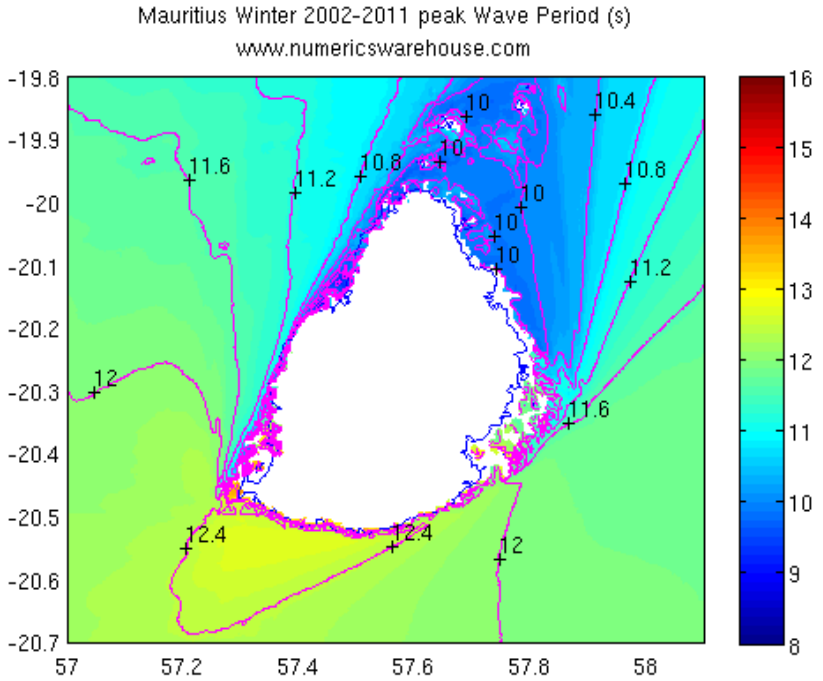


Figure 36. Wintertime peak wave period (s) 2002 to 2011

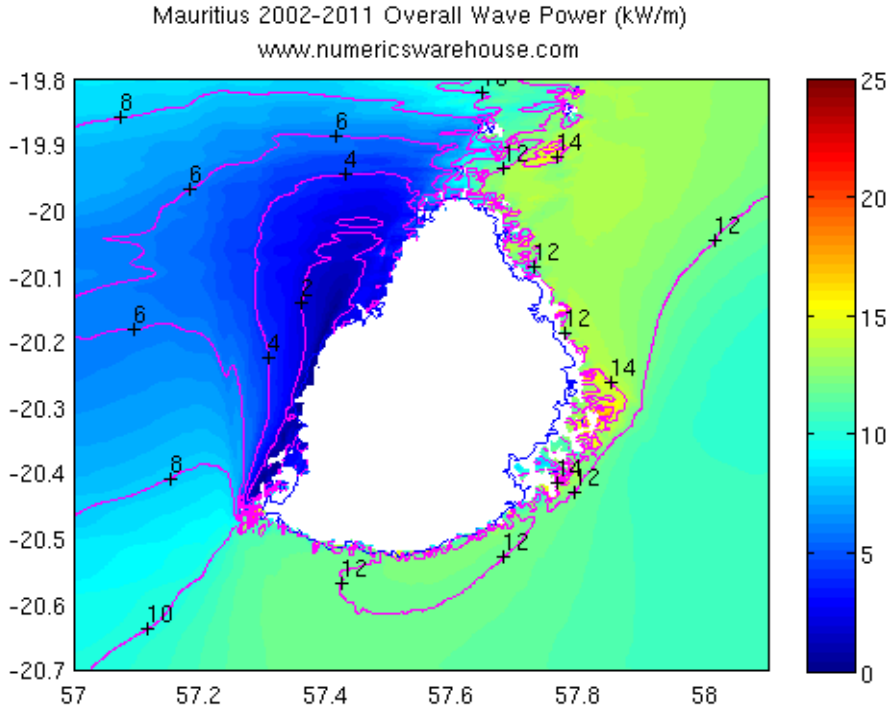


Figure 37. Mean overall wave power (kW m^{-1}) 2002 to 2011

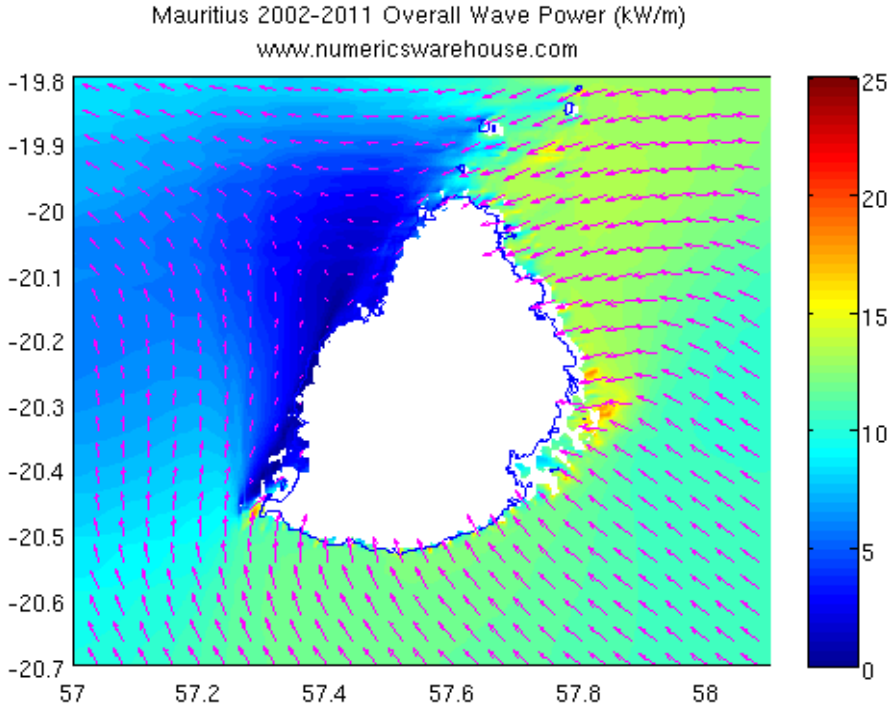


Figure 38. Mean overall wave power (kW m^{-1}) with mean energy direction arrows 2002 to 2011

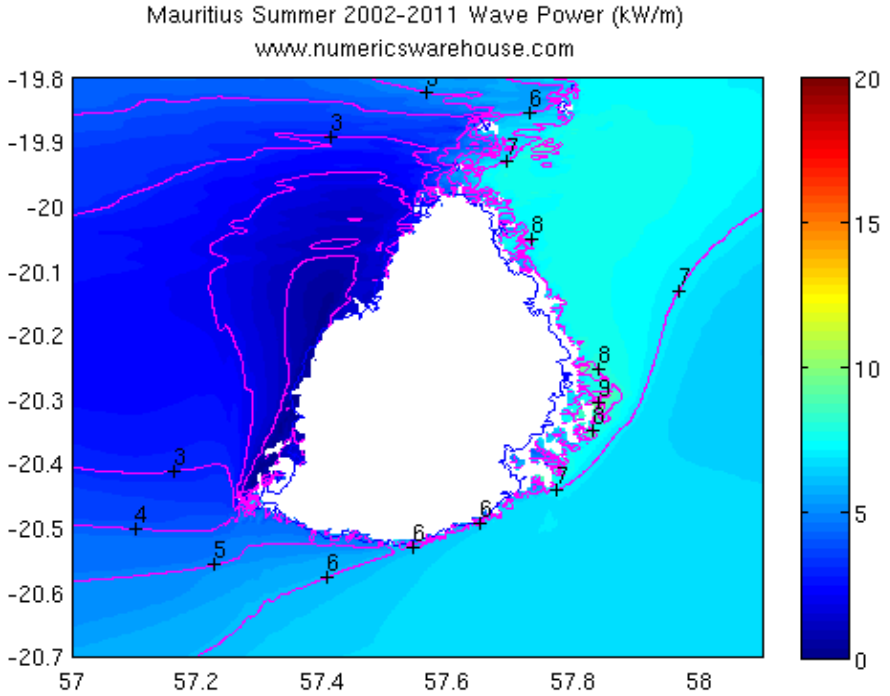


Figure 39. Mean summertime wave power (kW m^{-1}) 2002 to 2011

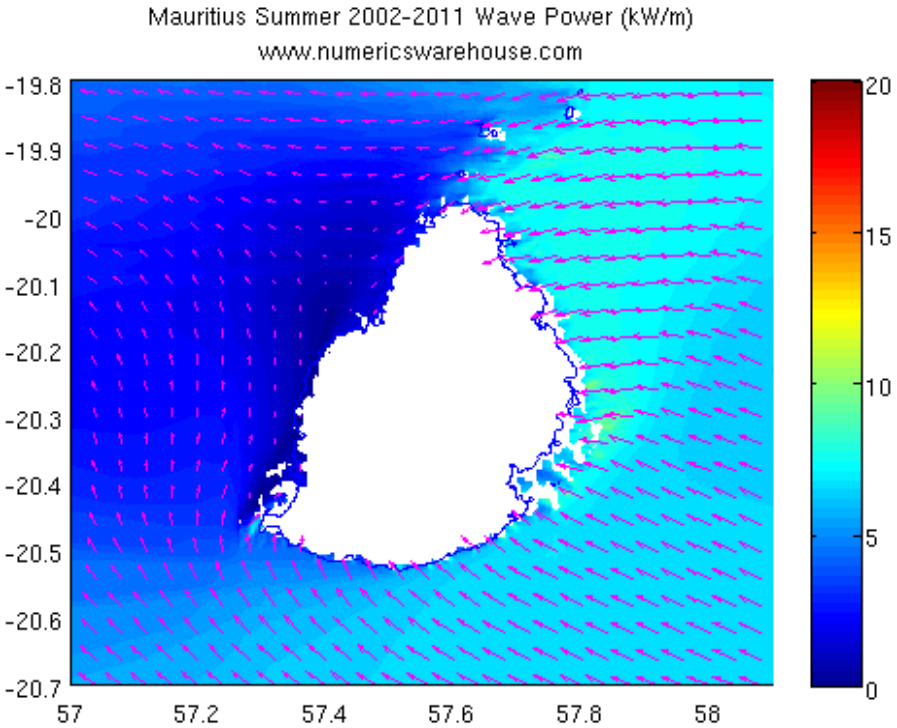


Figure 40. Mean summertime wave power (kW m^{-1}) with mean energy direction arrows 2002 to 2011

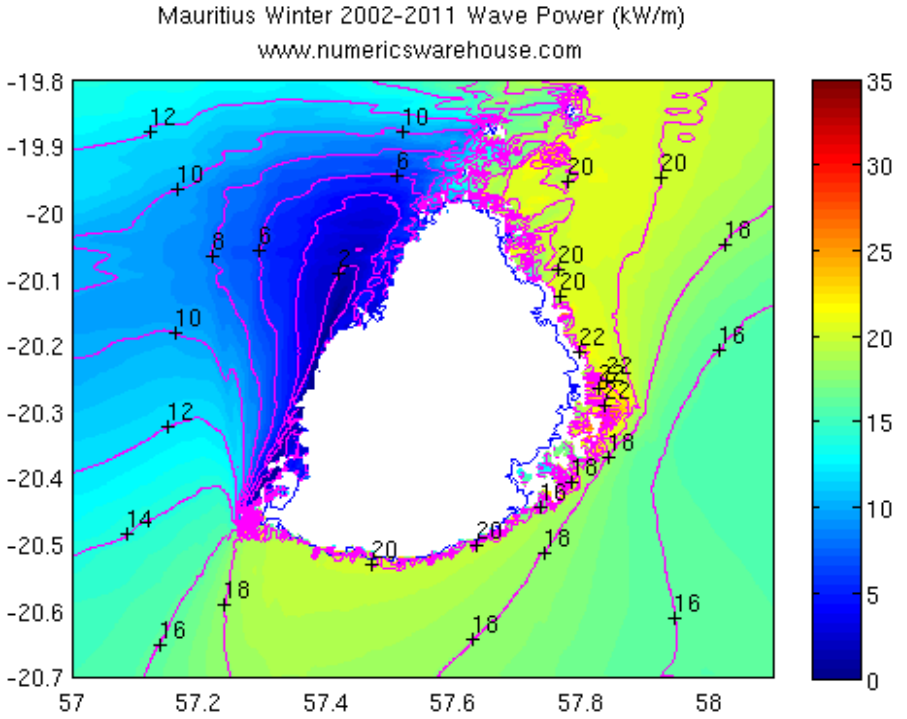


Figure 41. Mean wintertime wave power (kW m^{-1}) 2002 to 2011

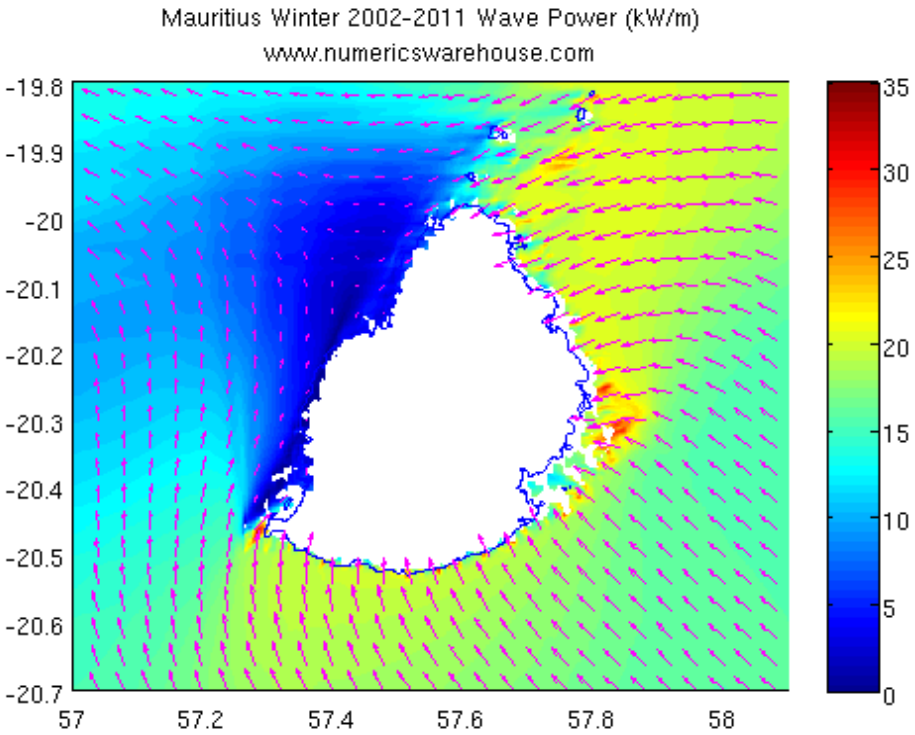


Figure 42. Mean wintertime wave power (kW m^{-1}) with mean energy direction arrows 2002 to 2011

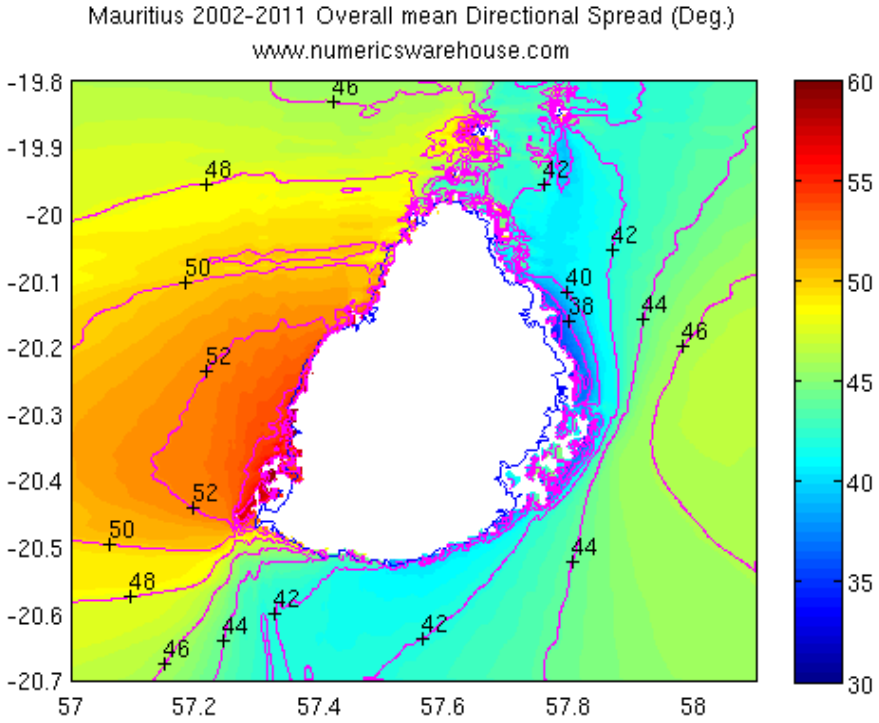


Figure 43. The overall mean value of the standard deviation of wave direction. 2002 to 2011

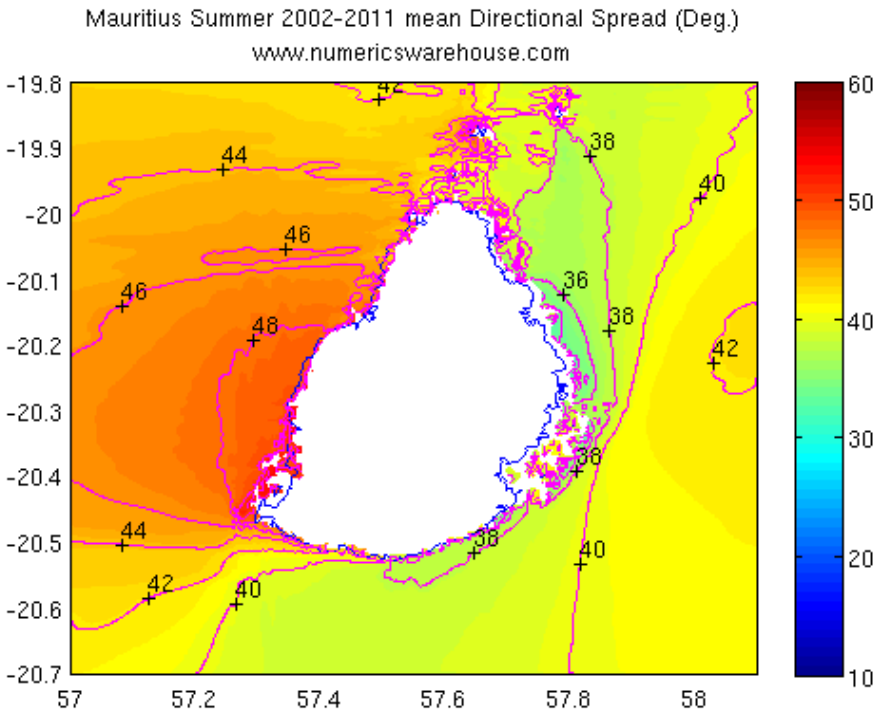


Figure 44. The summertime mean value of the standard deviation of wave direction. 2002 to 2011

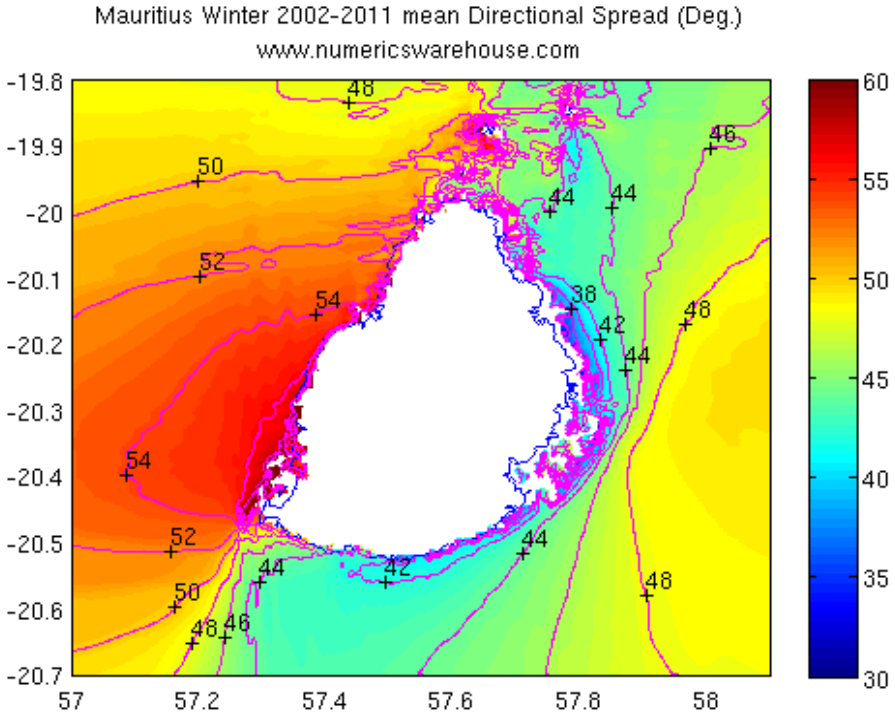


Figure 45. The wintertime mean value of the standard deviation of wave direction. 2002 to 2011

9.2 Ten Year Wave Climatology Mauritius – Station Data

There are too many stations (23, see Table 3) to display all of the data here, so some representative results are shown to illustrate the main points and conclusions. Data from all stations is available. We shall concentrate on station 13, which is offshore from Vieux Grand Port in 100 m depth. This probably represents a good location for an 'offshore' wave farm.

A standard set of statistical wave climate products has been produced as part of this study. These are described below. The statistics are produced from the 20 minute station data.

Power Weighted Wave Roses
These are designed to show the predominant directions to which the wave energy is directed. The power is split into 36 directions. The area of each petal is proportional to the percentage of the wave power which its direction represents. The roses clearly show whether there is a predominant wave direction, or whether there might be 2 such directions.

Exceedence of Wave Power
These curves show the proportion of the 30 minute wave power outputs that exceed threshold levels varying from 0.0 to 260 kwm^{-1}. The data has been shown as a total for each station for the full 10 year period, as well as taken by month of the year and also yearly. The results as a whole enable the user to evaluate how consistent the total power is and how this varies from year to year and with month of the year.

Weekly Mean Time Series
The data averaged over weeks shows clearly the seasonality and inter-annual variability of the power, wave height and other measures at each station.

Significant Wave Height vs. Peak Period Scatter Diagrams (Hs-Tp diagram)
The 20 minute data has been grouped into bins of Hs (every 0.5 m) and pwp (every 0.5 s). These are displayed as a grid which shows the average number of outputs per year for each bin. The grid is colour coded to show the percentage of the values in each bin. Also shown superimposed on the grid are contours in green of the theoretical wave power for linear deep water plane fronted waves, which has the following functional form for power in Wm^{-1} :-

$$\text{power} = \frac{\rho g^2}{64\pi} H^2 T$$

where ρ is the water density, g is the acceleration due to gravity, H is the wave height, taken as the significant wave height here, and T is the wave period, taken as the peak wave period here.

Extreme Wave Height Analysis
A standard Potential Over Threshold (POT) method has been used to identify significant storm events. Only those storms separated by at least 24 hours are counted (although it was found that using a 48 hour cutoff makes little difference to the statistics). The peak Hs values were then sorted into descending order and then the probability of exceedence Q and the number of events per year τ calculated and fitted to a 2 parameter Weibull curve :-

$$Q = 1/\left(\tau T_R\right)$$

$$H_{TR} = \gamma + \beta\left[\ln\left(1/Q\right)\right]^{1/\alpha}$$

where T_R is the expected Return Period, H_{TR} is the wave height expected with the Return Period and γ, β, and α are parameters to be determined by using a least squares fitting algorithm. The value of α with the highest R^2 value was selected after it was varied from 1.0 to 4.0, every 0.05. This covers all possible values. In all cases an R^2 of better than 0.95 was obtained.

The above formula was then used to estimate the expected value of significant wave height for each T_R in (1, 2, 5, 10, 50 and 100 years).

In practice the threshold significant wave height used in the POT method does influence the H_{TR} values found. For this reason a range of threshold wave heights has been used to show the range of extreme wave heights that result. The threshold values for each station

were determined by inspecting the time series of Hs. The users must judge for themselves which curve is most appropriate, but usually a number of curves will be roughly coincident and will be the most likely prediction. For conservative requirements however, the highest H_{TR} predictions should be used.

Also shown on the figures are the number of storm events per year for each threshold value to help the user choose the most appropriate curve.

Significant Wave Height Persistence Analysis
The 20 minute data were analysed and sorted into bins of the duration that the significant wave height was less than (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 m) for periods of more than (6.0, 12.0, 24.0, 48.0, 72.0 hours). The analysis was done for all 10 years of data, and then the average number of 20 minute periods per year in each of the bins calculated.

For station 13, we can see in figure 46 the time series of significant wave height for the 10 years, as weekly averages. Cyclone Gamede can easily be seen. There is a clear seasonal signal with the largest waves in the middle of winter.

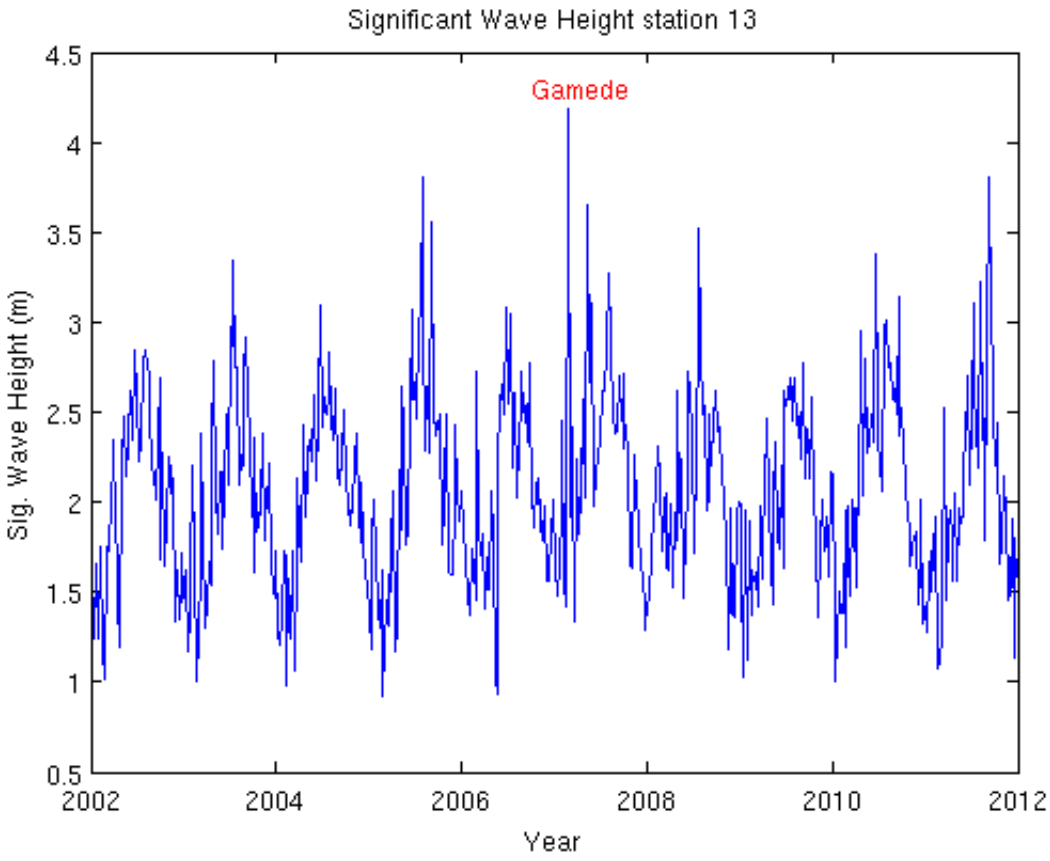


Figure 46. Time series of Significant Wave Height at station 13 (Vieux Grand Port, 100 m depth). The cyclone Gamede is indicated.

The seasonality can also be seen in the time series of wave energy in figure 47 for the same station. The wave energy is remarkably similar year to year.

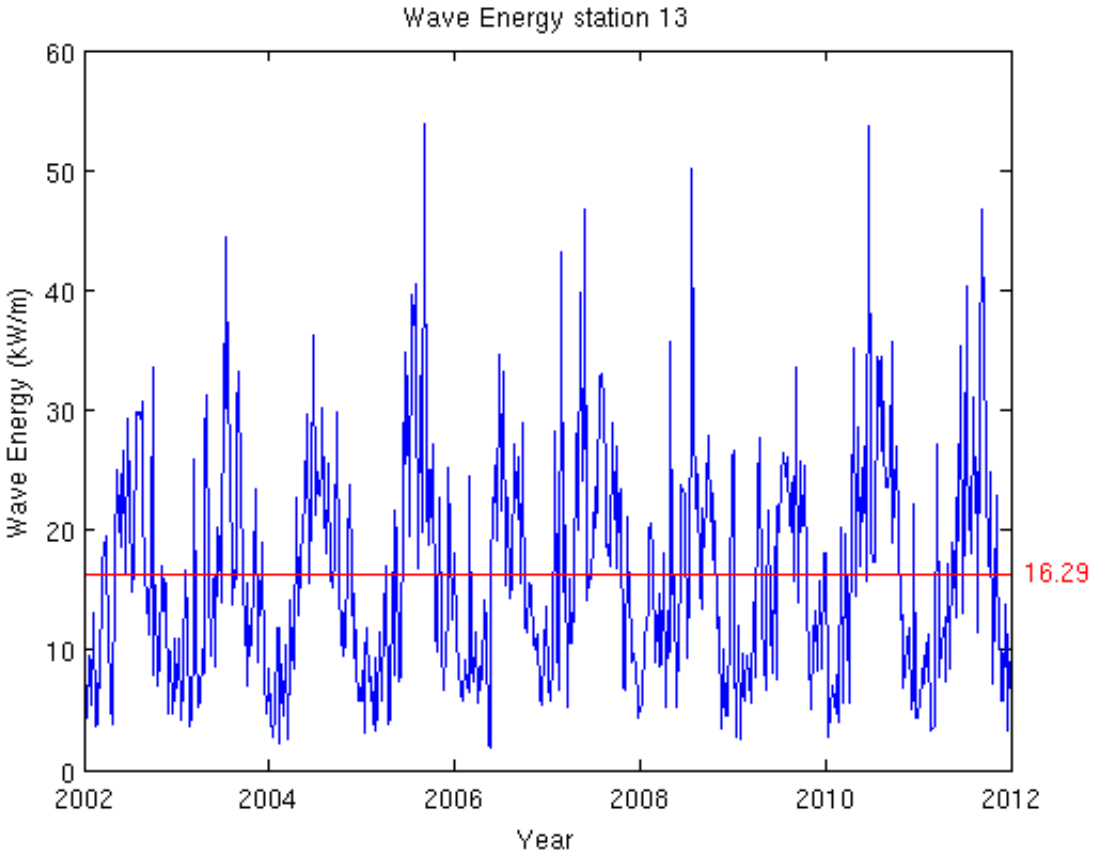


Figure 47. Time series of Wave energy at station 13 (Vieux Grand Port, 100 m depth). The horizontal red line shows the mean value for the ten year duration 2002 to 2011.

The Hs-Tp diagram for station 13 is shown in figure 48.The wave energy has a mode of 9.5 to 10.0 s and 2.0 to 2.5 m. This bin represents some 5% of all values. Quite a lot of the wave energy arrives through long waves with a peak period > 15 s. Even though the significant wave height of these waves might not exceed 2 m, they nonetheless contain a lot of energy. These may be the waves that arrive from the distant Southern Ocean.

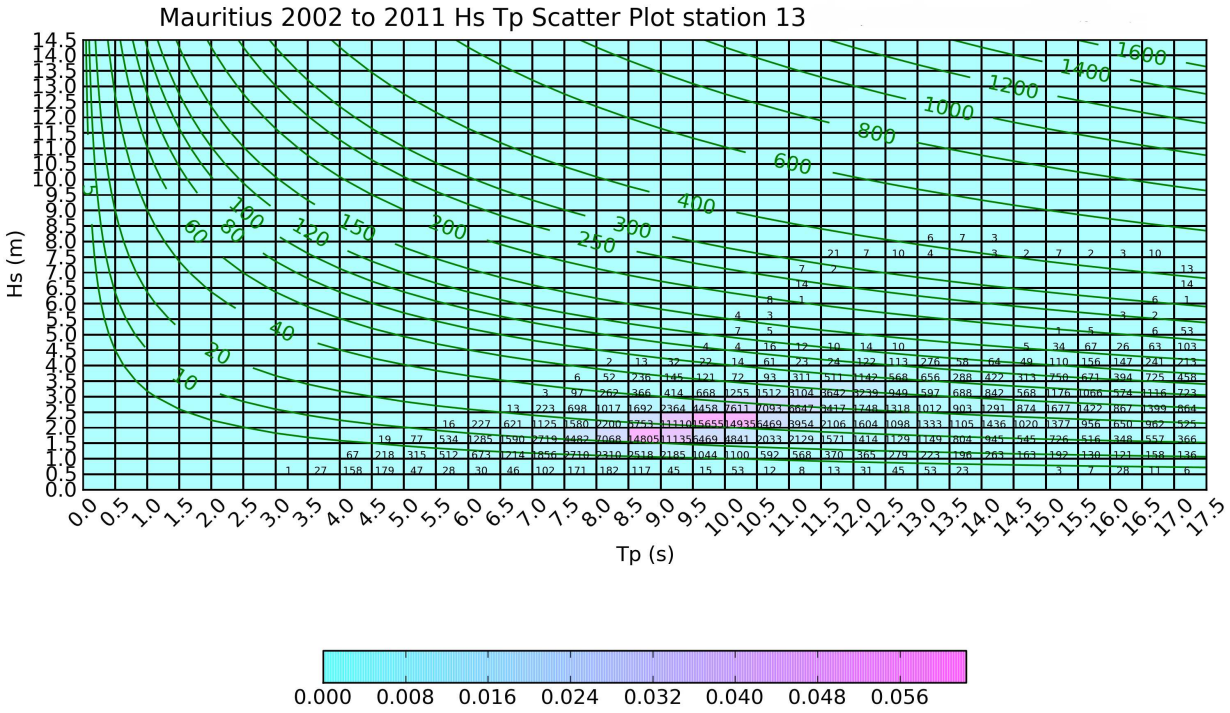


Figure 48. Significant wave height vs. Peak period scatter diagram for station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011

Another way of comparing the year to year variation of wave energy is to examine the exceedence plots. Figure 49 shows the overall exceedence diagram for station 13. We can see that approximately 5% of the time, wave energy exceeds 50 kW m^{-1}.

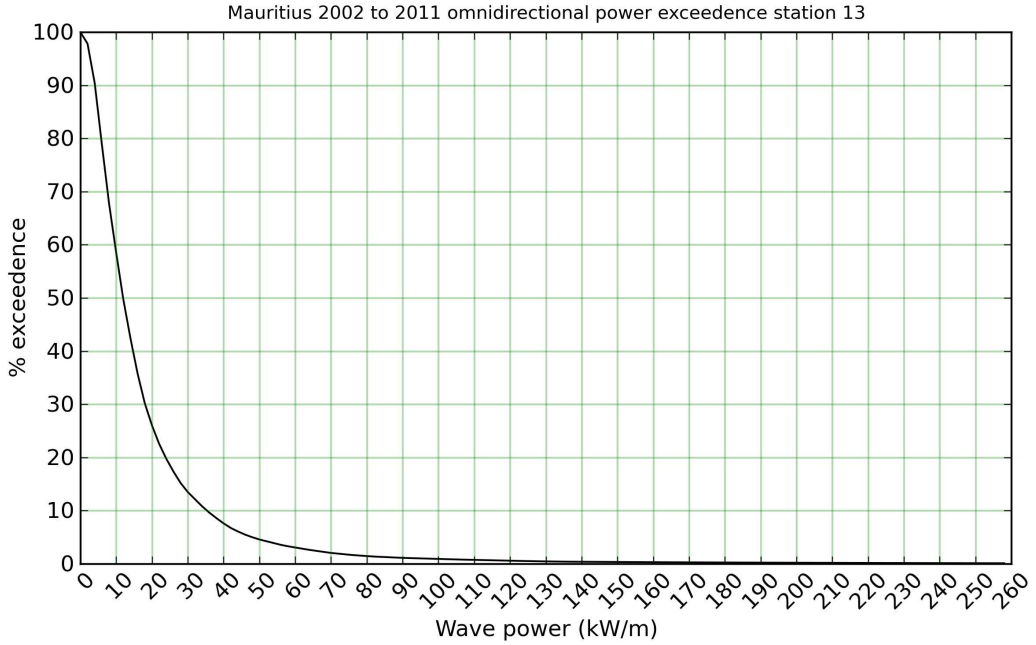


Figure 49. Overall wave energy exceedence, station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011.

If we separate the data into years, we can see that 2007 had a high wave energy (figure 50).

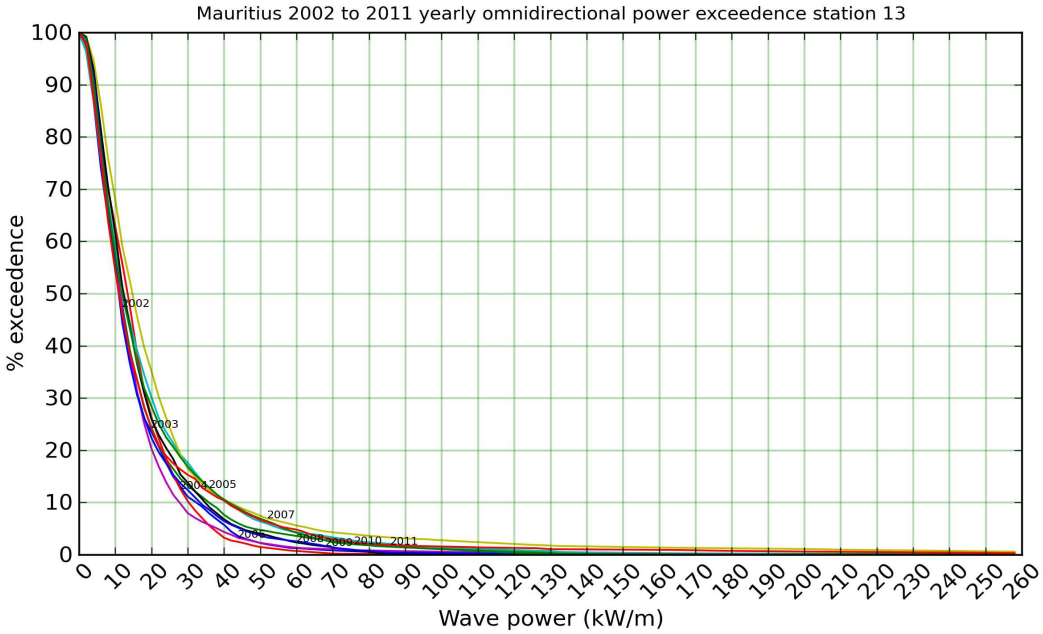


Figure 50. Yearly wave energy exceedence, station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011.

If we separate the data by month, it can be seen that July has the most wave energy and January the least (figure 51).

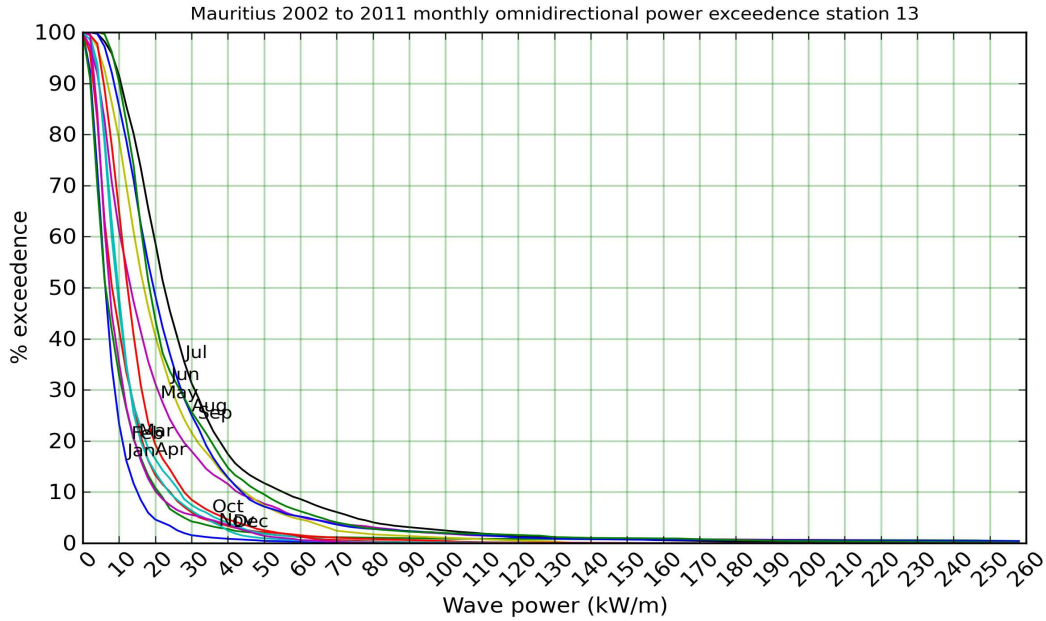


Figure 51. Monthly wave energy exceedence, station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011.

We can also look at the main directions for wave energy. Many WEC's have a preferred orientation and it is important to orient them for maximum efficiency. Figure 52 shows the wave rose diagram for station 13.

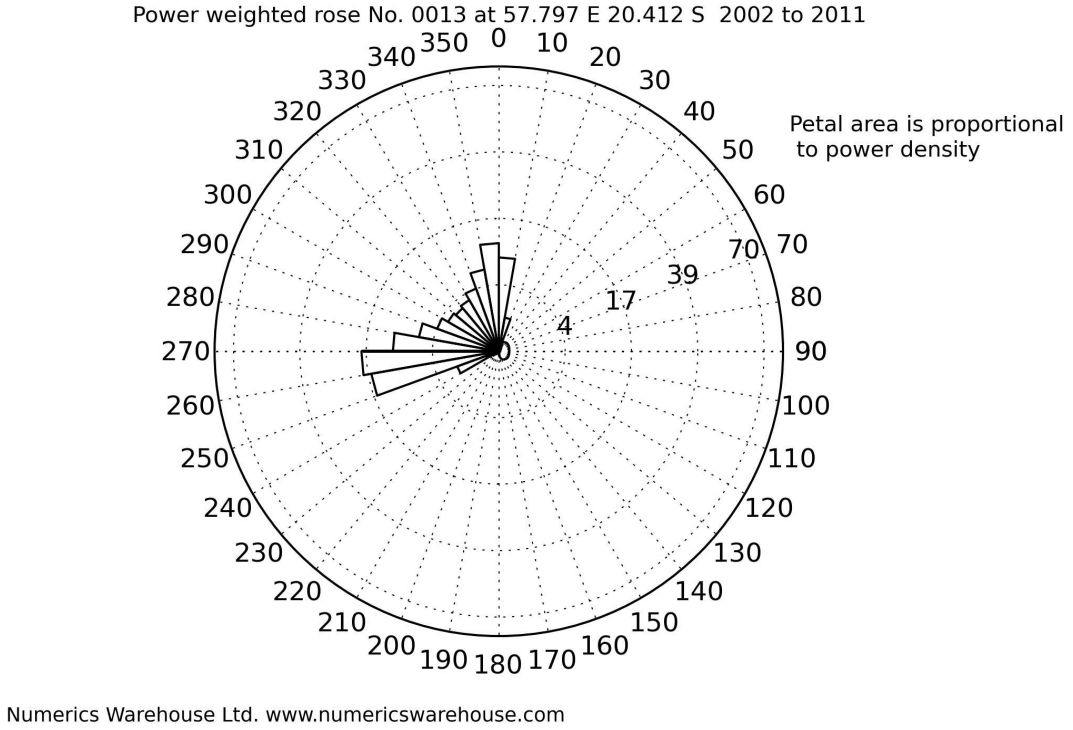


Figure 52. Power weighted wave rose diagram for station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011.

The direction spectrum is very strongly bipolar, indicating that most of the wave energy arrives either from the S or from the ENE, but rarely from the SE. Such a strong bipoarity is unusual and may cause some difficulty for designers of WEC's. Omnidirectional devices will be favoured here. At this location, the best wave energy arrives from the ENE. Waves heading into the directions between 250 and 270 degrees account for about 30% of all the wave energy.

Another important consideration for WEC developers is the survivability of the devices. The extreme significant wave height vs. The expected return period for station 13 is shown in figure 53. For this analysis, 4 different threshold wave heights were used to detect peaks. The statistical analysis shows the results to be similar for each, with an 8 m significant wave height returning every 100 years. It must be borne in mind when examining these results that no cyclone impinged directly on this station during the 10 years of the analysis and so we must exercise caution in using the answers. The low value of extreme wave height here will be well below what typical devices have been designed for in other parts of the world.

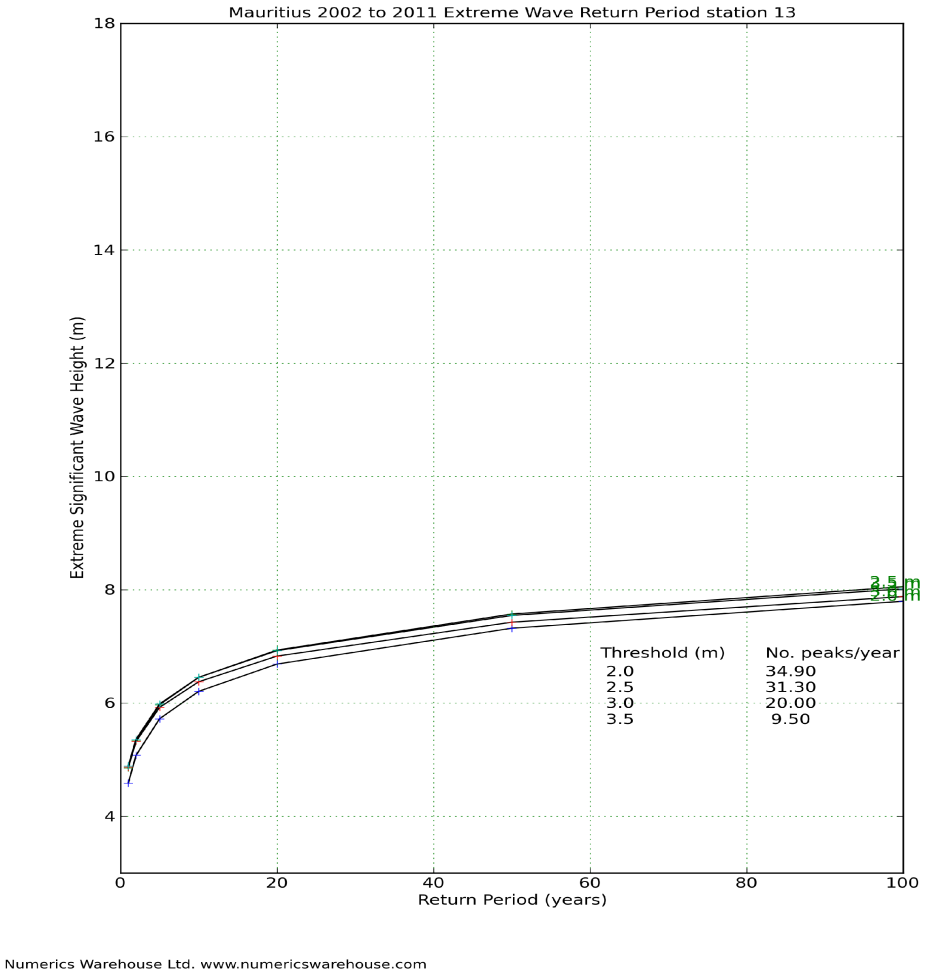


Figure 53. Extreme significant wave height vs. Return Period for station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011.

The final statistical approach presented in this section is the wave persistence analysis. This can be used to determine 'weather windows' for device installation or maintenance. Figure 54 shows the persistence analysis for station 13. Once again these figures are unlikely to trouble wave energy planners since even in July, there are a substantial number of periods when the waves do not exceed the significant wave height of 2.0 m for up to 72 hours.

Mauritius 2002 to 2011 Wave Height Persistence Analysis station 13

Hs < 0.5

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	0	3	4	0	0	0	0	0	0	0	0	0
> 12 hours	0	0	4	0	0	0	0	0	0	0	0	0
> 24 hours	0	0	0	0	0	0	0	0	0	0	0	0
> 48 hours	0	0	0	0	0	0	0	0	0	0	0	0
> 72 hours	0	0	0	0	0	0	0	0	0	0	0	0

Hs < 1.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	146	241	113	21	61	9	0	0	0	2	16	12
> 12 hours	144	235	110	18	61	9	0	0	0	0	16	12
> 24 hours	122	240	96	18	61	9	0	0	0	0	11	7
> 48 hours	74	204	59	0	61	0	0	0	0	0	0	0
> 72 hours	45	160	59	0	45	0	0	0	0	0	0	0

Hs < 1.5

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	1028	907	800	419	341	76	22	37	0	189	361	684
> 12 hours	1023	897	796	412	334	66	22	36	0	185	361	683
> 24 hours	982	865	761	350	320	54	17	11	0	153	324	626
> 48 hours	942	854	694	251	227	39	17	0	0	109	219	486
> 72 hours	781	873	612	206	212	24	0	0	0	79	154	387

Hs < 2.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	1784	1439	1421	1339	927	505	257	402	304	952	1296	1550
> 12 hours	1781	1432	1418	1334	919	484	250	402	288	936	1292	1551
> 24 hours	1773	1398	1384	1289	875	450	237	369	244	851	1243	1521
> 48 hours	1734	1335	1339	1167	797	352	165	262	115	768	1204	1446
> 72 hours	1697	1317	1302	1069	716	286	149	213	80	592	1086	1456

Hs < 2.5

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	1987	1731	1833	1749	1449	1190	862	1075	1136	1689	1780	1903
> 12 hours	1987	1732	1832	1748	1445	1183	856	1067	1128	1695	1778	1904
> 24 hours	1985	1729	1820	1742	1426	1138	805	999	1100	1674	1765	1888
> 48 hours	1980	1710	1803	1732	1361	1044	690	910	1031	1647	1743	1881
> 72 hours	1967	1656	1788	1728	1264	945	576	824	908	1546	1743	1865

Hs < 3.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 6 hours	2020	1781	1968	1894	1776	1644	1508	1669	1592	1947	1931	2007
> 12 hours	2018	1781	1969	1895	1778	1641	1503	1670	1585	1948	1932	2007
> 24 hours	2023	1781	1968	1891	1776	1635	1465	1643	1577	1951	1931	2002
> 48 hours	2034	1773	1978	1891	1766	1604	1440	1647	1519	1952	1932	1991
> 72 hours	2034	1773	1978	1891	1728	1553	1386	1578	1435	1956	1932	1991

Numerics Warehouse Ltd. www.numericswarehouse.com

Figure 54. Persistence analysis for station 13 (Vieux Grand Port, 100 m depth). 2002 to 2011. The figures indicate the number of 20 minute samples that fall within the month and between the duration periods for a particular significant wave height criterion.

9.3 Ten Year Wave Climatology Mauritius – Transect Data

In this section we look at how the mean wave power over the 10 years varies along the 7 defined transects and how the 7 transects compare with each other. Figure 55 shows the results.

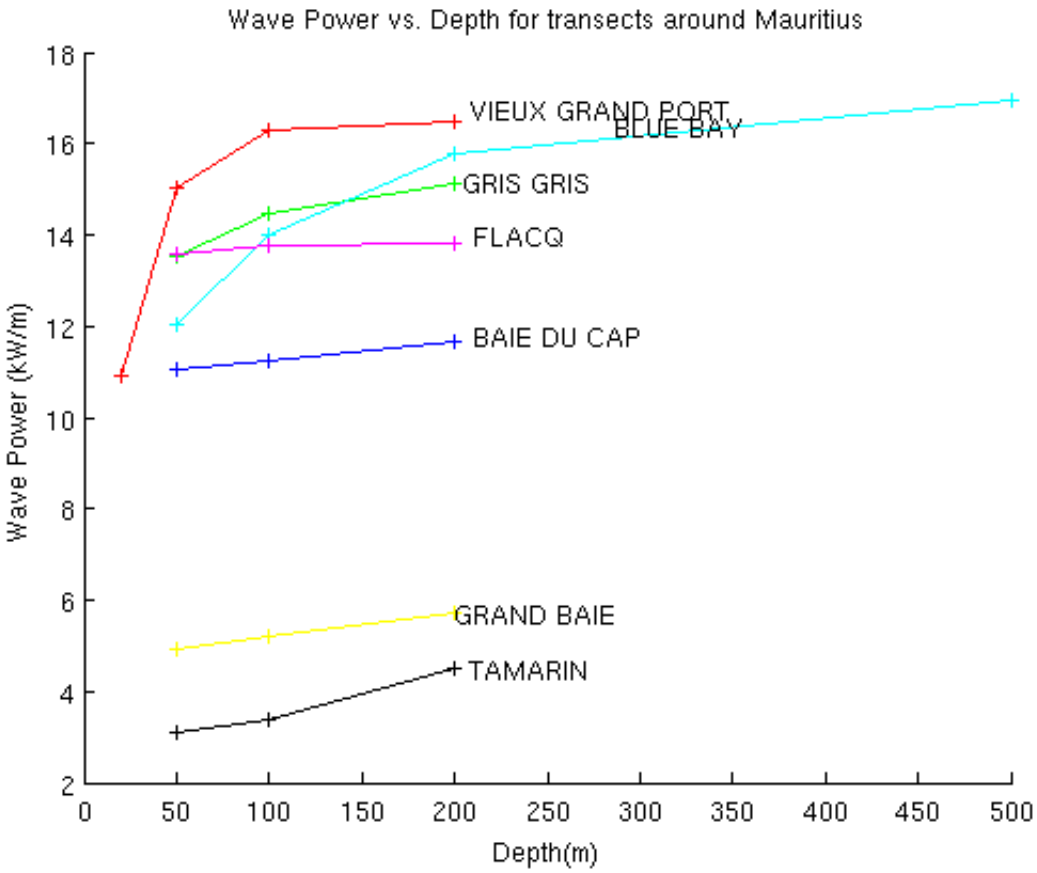


Figure 55. Mean wave power variation with depth for each of the transects around Mauritius. Data from 2002 to 2011.

The transect at Vieux Grand Port has the best wave energy resource. The wave energy does not improve in water deeper than 100 m, so cables would not have to be extended any great distance along the seabed to avail of the power. The transects on the south coast also have a good wave power, but only in the deeper water (> 200 m), although with such a steeply shelving seabed, this is no great distance. In fact each of the locations - Vieux Grand Port, Blue Bay and Gris Gris have an almost equally good wave energy resource and perhaps other considerations would determine where to situate a wave farm (access to electricity grid, sheltered port, communications etc.). The location on the east coast, Flacq also has a good wave energy resource, especially if we only compare the shallow water results. Several promising WECs are designed to work in 50 m water depth. The locations on the north and west coasts had a poor wave energy resource as expected.

10. Comparison of Satellite Radar Data with the Models

It was not within the scope of this study to validate the numerical model results. That was to be left to a further study. Some ARGOSS satellite radar wave data, however, became available from the MRC towards the end of the project and the results from this are shown alongside the model data. It should be noted that satellite radar does not work well close to coasts and usually a very wide area of open sea is required to develop meaningful statistics. The time of satellite data collection is different from the model hindcast period too. This means that it is not strictly valid to compare the different datasets here. The model data pertains to shallow water stations. The comparisons are presented here in figure 56, but it is hoped to be able to return to this at a later point.

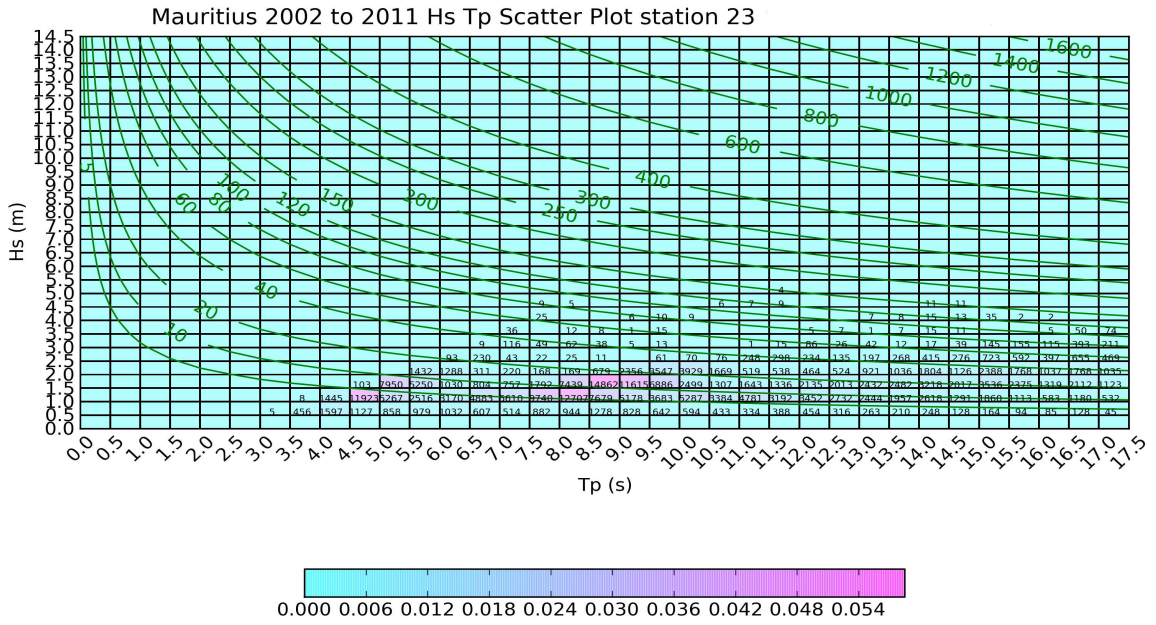
SW Mauritius

SOUTH WEST MAURITIUS

Percentage of occurrence of wave height (m) in rows versus peak wave period (s) in columns

	lower	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
lower	upper	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	1	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0.2
1	1.5	0	0	0.9	1.2	7.4	1.2	0.7	0.9	0.2	0.5	0	0	0.2	0	13.1
1.5	2	0	0.2	2.3	3	9.4	3.2	1.8	3.5	2.5	3	0	0.2	0.5	0	29.7
2	2.5	0	0	0.7	2.3	7.8	1.6	3.5	2.8	3	1.6	0	1.4	0	0	24.7
2.5	3	0	0	0	3	3	2.8	0.7	1.6	1.6	2.3	0	2.3	0	0	17.3
3	3.5	0	0	0.2	1.4	0.7	1.6	0.7	0.7	1.4	1.6	0	0.2	0	0	8.5
3.5	4	0	0	0	0.5	0.7	0.5	0.2	0.7	0.7	0.5	0	0.5	0	0	4.1
4	4.5	0	0	0	0	0	0.2	0	0	0.5	0	0	0.5	0	0	1.2
4.5	5	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2
5	5.5	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0	0	0.5
5.5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	6.5	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0.2
6.5	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5	8	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0.2
8	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	0.2	4.1	11.3	29.3	11.1	7.6	10.4	9.9	9.9	0	5.5	0.7	0	100

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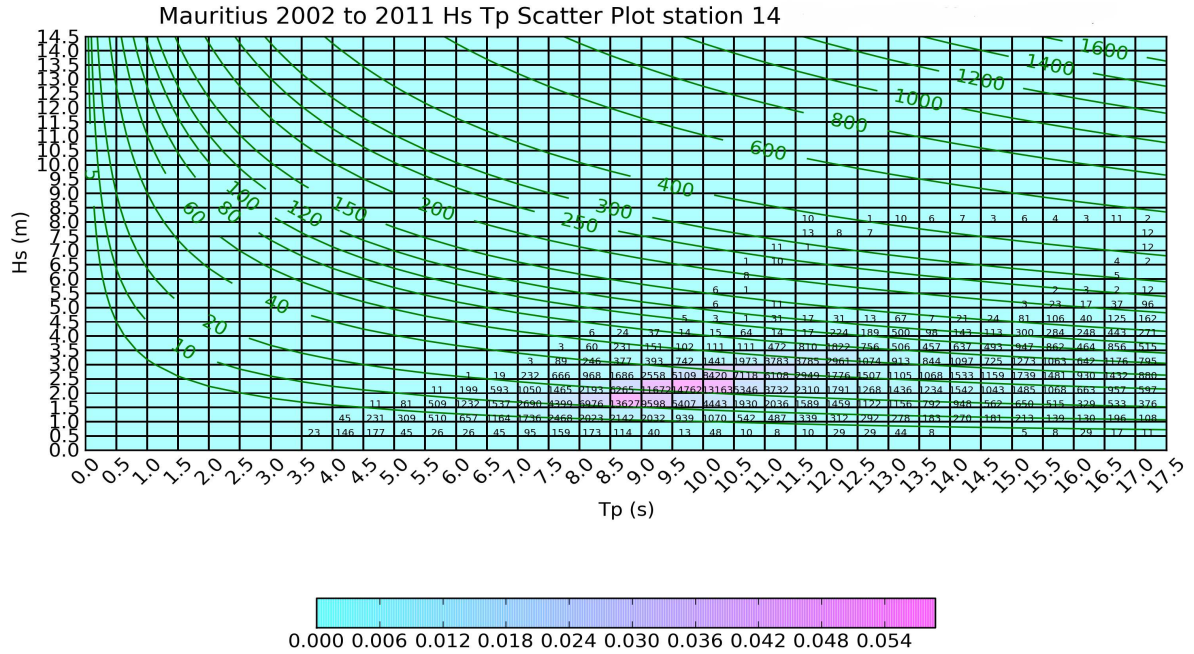
SE Mauritius

SOUTH EAST MAURITIUS

Percentage of occurrence of wave height (m) in rows versus peak wave period (s) in columns

	lower	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
lower	upper	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
0.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1.5	0	0	0.3	0.3	0.5	0.3	0	0	0	0	0	0	0	0	1.3
1.5	2	0	0.3	2.1	2.1	11.1	2.1	1.3	2.9	1.1	1.1	0	0	0.3	0	24.4
2	2.5	0	0	0.5	4	8.2	3.2	2.7	3.7	3.7	1.6	0	1.3	0.8	0	29.7
2.5	3	0	0	0.8	2.4	4.8	2.9	1.6	2.1	2.7	2.1	0	3.2	0	0	22.5
3	3.5	0	0	0.3	1.9	1.3	2.4	0.5	0.8	1.3	1.3	0	0.3	0	0	10.1
3.5	4	0	0	0	1.6	0.5	0.5	0.5	1.1	1.9	1.6	0	0.3	0	0	8
4	4.5	0	0	0	0	0.3	0.3	0	0.5	0.5	0.3	0	1.1	0	0	2.9
4.5	5	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0	0	0.5
5	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5	6	0	0	0	0	0	0	0	0	0	0.3	0	0.3	0	0	0.5
6	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	0.3	4	12.2	26.8	11.9	6.6	11.1	11.1	8.2	0	6.6	1.1	0	100

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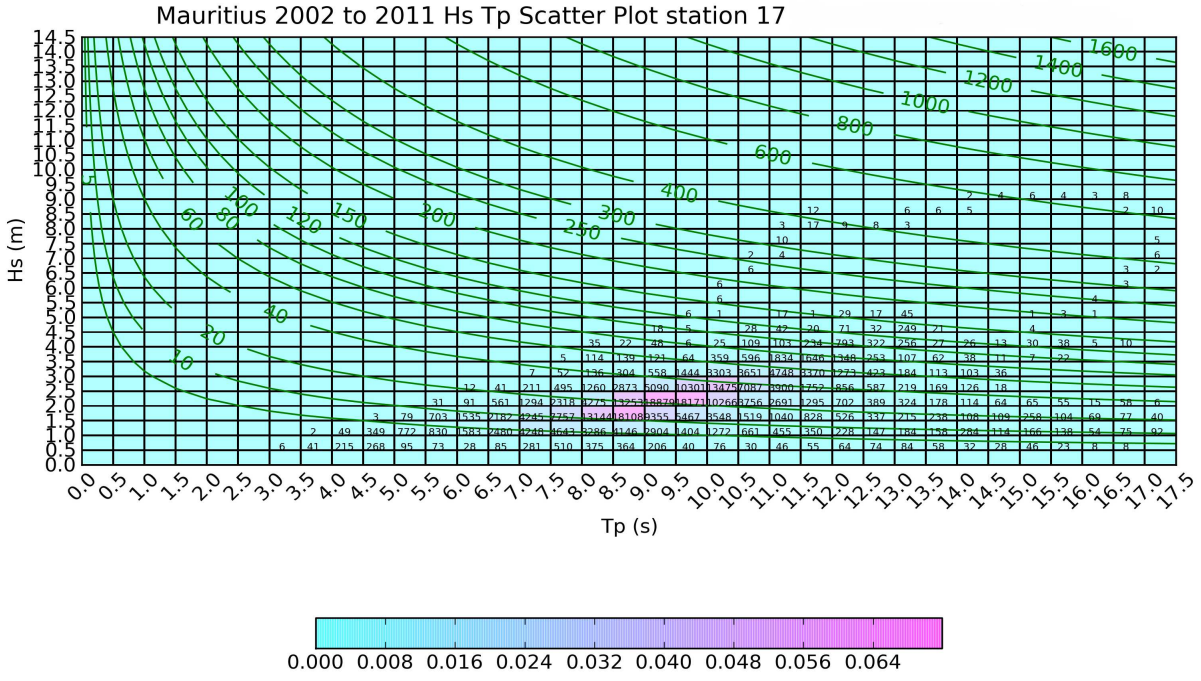
NE Mauritius

NORTH EAST MAURITIUS

Percentage of occurrence of wave height (m) in rows versus peak wave period (s) in columns

	lower	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
lower	upper	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	1	0	0	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0.5
1	1.5	0	0	1.1	1.9	6.5	1.6	0.8	0.5	0	0	0	0	0.3	0	12.7
1.5	2	0	0.3	2.4	3	9.2	2.4	1.6	3.2	1.3	1.6	0	0.5	0	0	25.6
2	2.5	0	0	0.8	4	8.1	1.9	3.5	2.4	2.2	1.9	0	1.1	0.5	0	26.4
2.5	3	0	0	0.5	1.9	3.8	2.7	0.8	2.4	1.6	1.9	0	2.2	0	0	17.8
3	3.5	0	0	0.3	0.5	1.9	2.4	0.8	1.3	1.1	0.8	0	0.5	0	0	9.7
3.5	4	0	0	0	1.1	1.3	0.5	0.3	0.5	0.3	0.8	0	0	0	0	4.9
4	4.5	0	0	0	0	0	0.5	0	0.5	0	0	0	0.5	0	0	1.6
4.5	5	0	0	0	0	0	0	0	0.3	0	0	0	0.3	0	0	0.5
5	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5	6	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.3
6	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	0.3	5.4	12.4	31	12.1	7.8	11.3	6.5	7.3	0	5.1	0.8	0	100

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NW Mauritius

NORTH WEST MAURITIUS

Percentage of occurrence of wave height (m) in rows versus peak wave period (s) in columns

	lower	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
lower	upper	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	1	0	0	0.5	0.5	0.5	0.3	0	0	0	0	0	0	0	0	1.9
1	1.5	0	0.3	4.1	3.5	16.3	3	1.9	1.9	1.4	1.6	0	0	0.3	0	34.2
1.5	2	0	0	1.1	4.1	11.4	1.9	4.6	4.3	2.4	3.3	0	1.1	0.3	0	34.5
2	2.5	0	0	0.3	1.6	3.8	2.7	1.4	1.6	1.6	1.9	0	2.4	0	0	17.4
2.5	3	0	0	0	1.6	1.9	1.6	0.8	0.8	0.5	1.1	0	0.5	0	0	9
3	3.5	0	0	0	0	0.3	0.8	0	0.3	0	0	0	0.3	0	0	1.6
3.5	4	0	0	0	0	0	0	0	0.3	0	0	0	0.3	0	0	0.5
4	4.5	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.3
4.5	5	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.3
5	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	6.5	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.3
6.5	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	0.3	6	11.4	34.2	10.3	8.7	9.5	6	8.4	0	4.6	0.5	0	100

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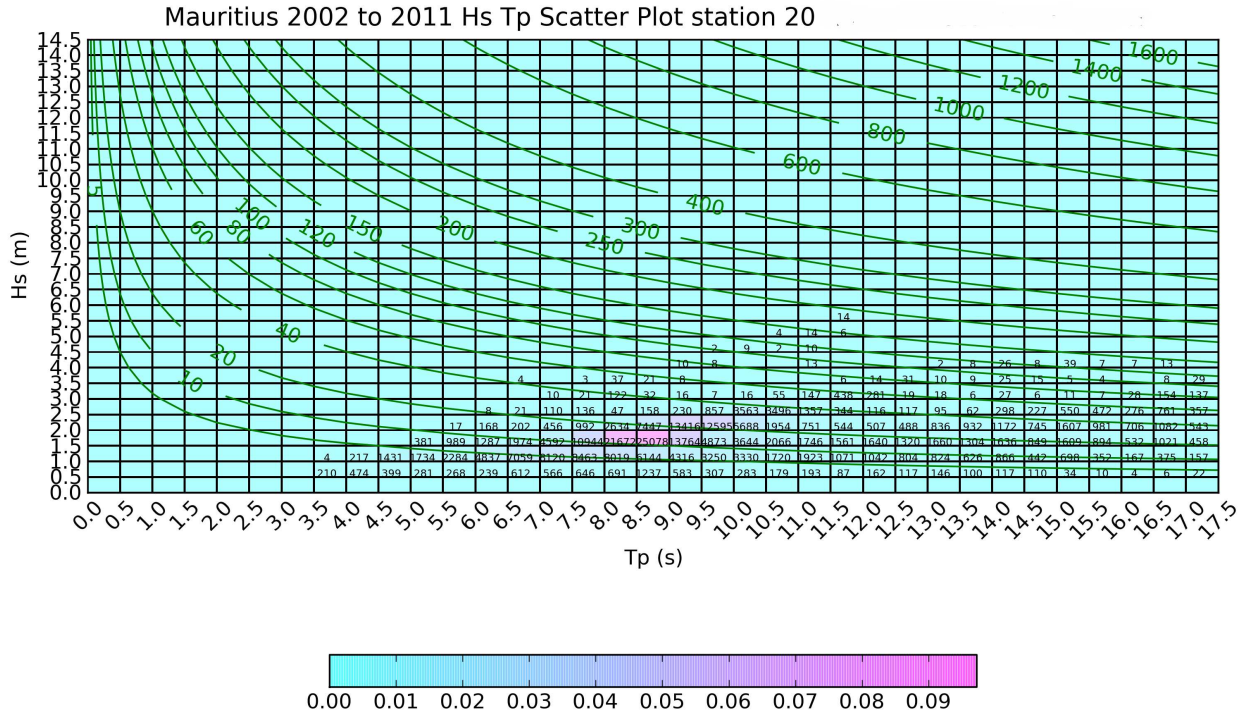


Figure 56. Comparison of ARGOSS satellite wave data with model data displayed as Hs-Tp diagrams. Please note that ARGOSS data has an inverted y axis (Hs) compared to the model data and that the model Tp bins are 0.5 s compred to the ARGOSS' 1.0 s. This means that the reader has to ADD the frequencies from adjacent bins in the model data so as to compare with the ARGOSS data.

It is felt that the data intercomparisons are promising since the Hs and Tp modes are very similar and so too are the absolute frequencies of occurence.

11.0 Some Conclusions

This study was meant to cover just the production of the raw data from numerical modelling of a 10 year wave hindcast period for the seas around Mauritius. It has achieved that and gone substantially beyond the stated aim so as to include a statistical analysis of the wave energy and other parameters around Mauritus and the other Mascarene islands. The major remaining task in the is to conduct a validation study of the models (if this is possible with the available data). The next step should also include an analysis of other factors relating to the ideal siting of wave energy farms and their potential effect on the environment.

Mauritius has a worthwhile wave energy resource – very similar to that found near to Reunion, where wave farms are currently being developed. The wave energy is not as substantial as for instance is to be found around the Orkney Islands in the UK, but considering the lack of hydrocarbon resources on the island and the rapid need for new energy production, it seems obvious to the author at least, that this natural resource should be exploited to the full.

Wave energy is complimentary to other types of renewable energy. In Mauritius it is frequently the case that there is a lot of wave energy when there is little wind – the energy is transported from storms 1,500 nautical miles to the south towards Mauritius at 50 knots (the speed of a deepwater wave with a period of 15 s). Wave energy, solar and wind energy taken together offer the prospect of smoothing out the peaks and the troughs of renewable energy production. A joined up strategey is advised. Numerical modelling of all the renewable energy sources together would help policy makers make decisions about the scale needed to substitute for fossil fuel generation and the standby generation capacity that would be needed to account for the variability of the power production.

Considering that there is a good harbour in Vieux Grand Port and that the wave energy is at least as good in the seas there as elsewhere, it would seem to offer itself as the ideal first location for a wavefarm. The area of seabed in and around 100 m depth would be suitable for 'deep water' wave energy converters. The area near to the mouth of the port, in about 20 - 50 m depth, would be very suitable for a wave energy test site and for reduced scale devices. It is advised that an environmental impact study and a strategic renewable energy assessment be conducted to decide what facilities, communications, grid access etc. would be needed for a wave farm in this area.

The impact of cyclone Gamede on the waves around Mauritius was analysed in this study. It was found that the significant wave height rose to more than 9 m on the NE coast during the approach of the cyclone. Wave energy developers are used to planning for operation in seas with much larger waves. For instance on the west coast of Ireland, waves with a significant wave height of 16 m and more are recorded every few years.

With an approximate wave energy of 15 kW m^{-1} (a year round figure determined in this study at a typical location) and a guess at the efficiency of wave energy conversion to power production at the shore of 60% it would require a wave farm stretching along a length of coastline of approximately 5 km to produce 40MW, or about 7% of current energy needs in Mauritius. This seems to be a realisable aim.

The wave energy around Mauritius has a low inter-annual variability. It is seasonal, but in quite a predictable way. These factors will help developers who require a degree of certainty in their financial projections.

The wave energy around Rodrigues is better than around Mauritius. It is recommended that a further study be conducted to assess the potential to develop wave energy there. With a relatively small population, wave energy could make a substantial contribution to power production there.

Finally, this study has produced a substantial dataset to be used to help wave energy developers who wish to invest in Mauritius. By funding this project, the government has signalling in a very real way that Mauritius is serious about wave energy and that it will support developers in the future.