Climate and Oceans Support Program in the Pacific

The Climate and Oceans Support Program in the Pacific (COSPPac) works to enhance the accessibility of essential ocean and climate information for Pacific Island nations. Through initiatives like wave climate reports, sub-seasonal to seasonal forecasts and ocean data tools, COSPPac strengthens ocean services across the region. The updated wave climate reports, based on hindcast data spanning 1979 to 2023, offer insights into regional wave climatology. These reports aim to support informed decision-making and resilience planning.

Wave Climate Report
Labasa Channel

Fiji

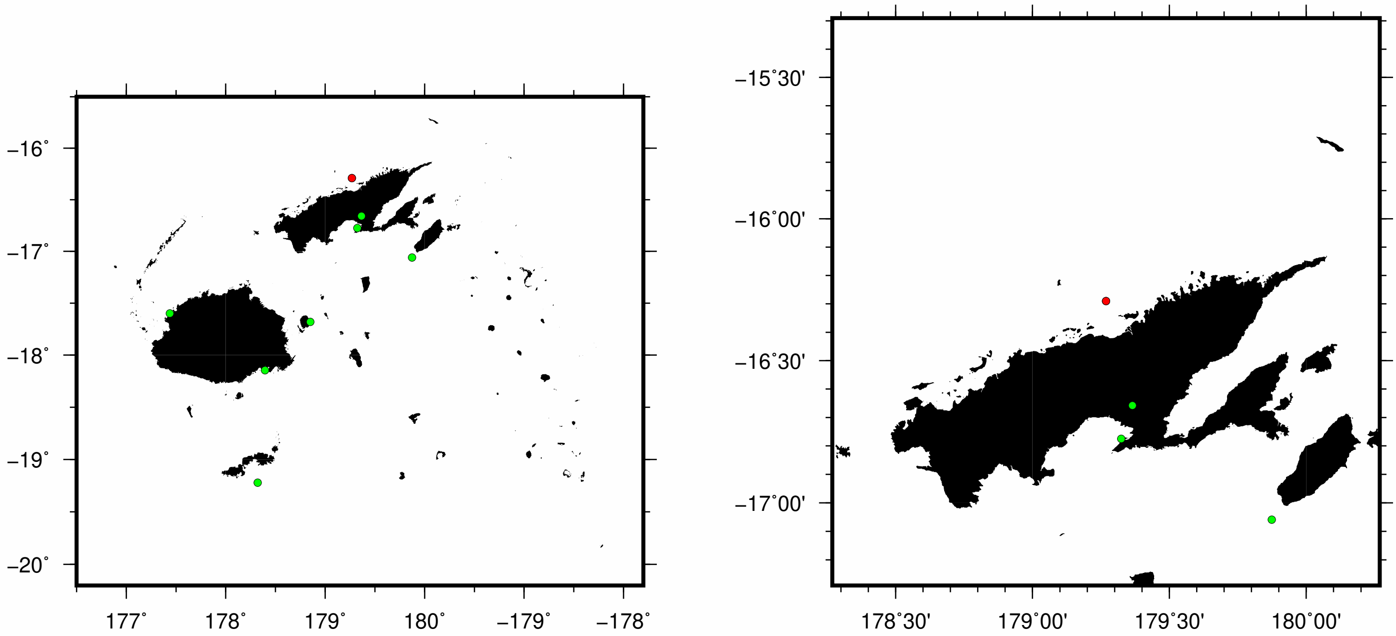

Figure 1. Location maps of the site. The map on the left shows the region. The map on the right shows the island and its surroundings. The red point shows the actual site and green points (if present) indicate other available wave climate reports in the region.

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I. General Wave Climate

I.1 General Introduction

This wave climate report presents wave information for **Labasa Channel** in Fiji. This report contains information about wind-generated surface gravity waves, often called wind waves and swell. The wave climate is defined here as the statistics of waves conditions over a 44 year period. The report details the average wave condition (page 2 and 3), the variability of wave conditions (page 4 and 5), severe and extreme waves (page 6 to 9) and characterises the wave energy resource(Page 10). Similar wave climate reports are available for more than 200 locations around the Pacific, near important ports, large settlements, tide gauge locations and areas where the wave climate is of particular interest. Other locations in Fiji are shown in Figure 1 (Previous page). Because little wave data exists for the Pacific, the information presented here was derived from a computer model: a regional wave hindcast.

The wave hindcast evaluated the wave conditions in the region between 1979 and 2023. The hindcast was produced by the Centre for Australian Weather and Climate Research, and updated by the Bureau of Meteorology (Australia) since 2013 onwards and focusses on the central and south Pacific with a resolution of 10 to 4 arcminutes (~20 to 8km) and therefore is accurate for offshore wave conditions. The model was constrained by the best available data and thoroughly verified against waves measurements. In the Pacific region, the wave hindcast produced resonably good results with an average skill of 0.85 (skills between 0.8 and 0.9 are considered good, above 0.9 is considered excellent, see Table 1). For more information about the regional wave hindcast, readers should refer to Durrant et al. (2014) and Smith et al. (2020). This report was generated by a computer program created at SPC-Geoscience which analysed the output from the wave hindcast and summarised the findings. Therefore, despite our best effort, this report may contain errors and ommissions and should be used with caution.

Table 1 Validation of the Wave hindcast model used to evaluate the wave climate

Island (Country)	Longitude Latitude	Depth [m]	RMS [m]	Skill	Bias [m]
Efate (Vanuatu)	168.5500 -17.8750	285	0.419	0.905	0.309
Funafuti (Tuvalu)	179.2150 -8.52500	585	0.559	0.544	0.504
Kadavu (Fiji)	177.9567 -19.3067	356	0.355	0.910	-0.097
Rarotonga (Cook Islands)	200.2717 -21.2700	300	0.413	0.895	0.087
Tongatapu (Tonga)	184.7300 -21.2370	309	0.321	0.920	-0.039
Apolima St. (Samoa)	187.8000 -13.8800	104	0.394	0.871	0.241
Upolu (Samoa)	188.7800 -14.4150	850	0.347	0.883	0.146

I. General Wave Climate (Cont.)

I.2 Average Wave Conditions

Wave condition is usually defined by the significant wave height, the peak period and the peak direction. The significant wave height is defined as the mean wave height (from trough to crest) of the highest third of the waves and correspond to the wave height that would be reported by an experienced observer. The peak period is the time interval between 2 waves of the dominant waves. The peak direction is the direction the dominant waves are coming from. Note that this document uses the nautical convention and therefore reports the direction the waves (wind) are coming from, measured clockwise from geographic North.

This page provides information about the average wave climate of **Labasa Channel** in Fiji. The average sea state is slight, dominated by wind seas from the Northeast. The annual mean wave height is **0.95m**, the annual mean wave direction is **16**˚ and the annual mean wave period is **10.72s**. Table I.2 summarize the mean wave condition for Labasa Channel.

In the pacific, waves often comes from multiple direction and with different period at a time. In Labasa Channel, there are often more than 4 different wave direction/period components.

Wave conditions tend to be consistent, meaning that they vary little within a few hours. The mean annual and seasonal variability are reported in Table 2. For more information on the wave climate variability refer to page 5 and 6.

Table 2 Mean wave conditions calculated between 1979 and 2023 for Labasa Channel

Mean wave height	0.95m
Mean wave period	10.72s
Mean wave direction [˚ True North]	16 ˚
Mean number of wave components	4.22
Mean annual variability [m] (%)	0.05 m (5.2 %)
Mean seasonal variability [m] (%)	0.43 m (45.1 %)

II. Mean Wave Rose

II.1 Annual mean wave rose

The mean wave condition, does not describe the variety of wave height and direction that can occur in Labasa Channel. A better representation of the variety of waves is the wave rose (Figure 2). The annual wave rose shows where waves usually come from and the size of waves associated with each direction. It is a powerful illustration of the distribution of wave height and direction. The circles (polar axis) represents how often a wave direction/height happens (i.e. the percentage of occurrence); each circle shows the 10% occurrence with the outer circle representing 30% of the time. Each wedge represents a range of direction 20 degrees wide with the center direction of each wedge displayed on the outer circle. Wave heights are split into intervals of 0.25m. Each interval is associated with a colour on the scale right of the rose.

In Labasa Channel the wave come from many sources. The conditions are frequently slight, almost never calm and almost never rough. The principal direction, where waves North (20º).

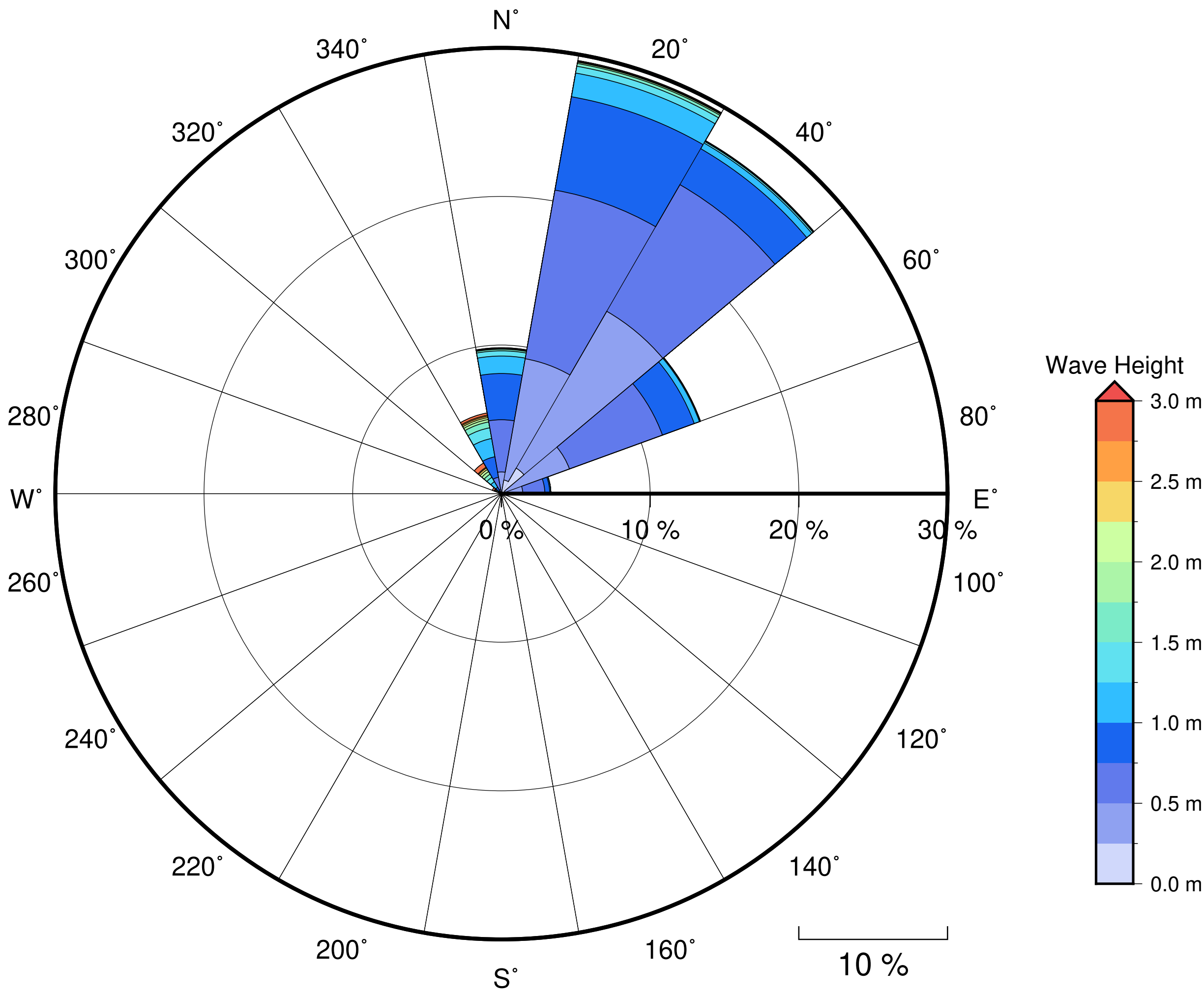

Figure 2 Annual wave rose for Labasa Channel. Note that direction are where the wave are **coming from**.

III. Wave Variation

III.1 Introduction

The wave climate is rarely constant throughout the year and seasonal changes in wind patterns across the Pacific Ocean can greatly modify the wave conditions from one season to the next. This page provides a description of these variations in Labasa Channel. The monthly variability (or coefficient of variation) of the wave height is used to quantify these variations, in Labasa Channel the variability of the wave height is 45.1%. Typically, locations that are mostly exposed to trade winds show the smallest variation (less than 25%). Locations exposed to the Southern Ocean swell show more monthly variation (between 25 and 30%) and locations exposed to the North Pacific swell show the most monthly variation (>30%). The monthly variability gives an idea of how the wave condition changes from one month to the next but to better understand the seasonal changes requires to look at the seasonal wave roses (figure 3).

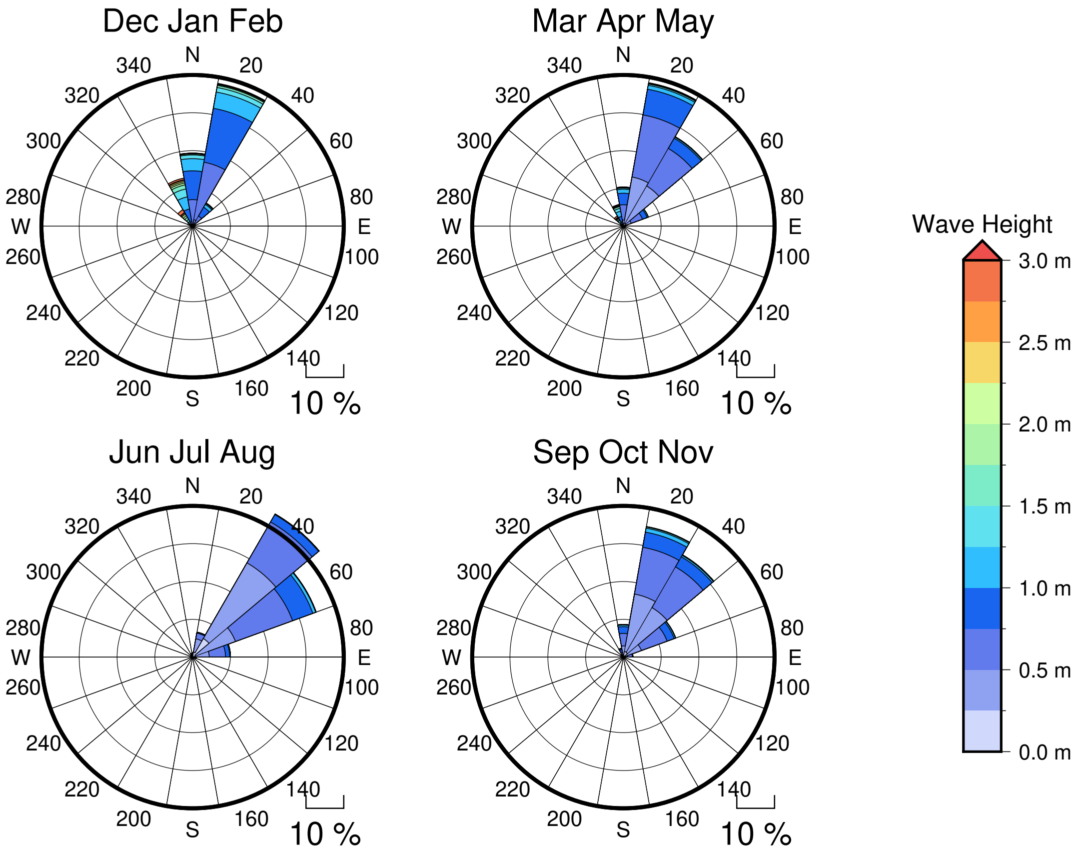

Figure 3 Seasonal wave roses for Labasa Channel

III.2 Seasonal wave rose summary

In summer the dominant wave condition (occuring often) is slight, the waves are almost never calm and almost never rough and the principal wave direction is from the North (20º). In autumn the dominant wave condition (occuring frequently) is slight, the waves are almost never calm and almost never rough and the principal wave direction is from the North (20º). In winter the dominant wave condition (occuring frequently) is slight, the waves are almost never calm and almost never rough and the principal wave direction is from the Northeast (40º). In spring the dominant wave condition (occuring usually) is slight, the waves are almost never calm and almost never rough and the principal wave direction is from the North (20º).

III. Wave Variation (Cont.)

III.3 Monthly wave height, period and direction

The monthly wave height, period and direction show the seasonal changes in the wave parameters with more details on the transition between seasons. The average wave height during calm periods (10% of the lowest wave height) and large swell events (10% of the largest wave heights) also changes with seasons. Figure 4 can help in finding the best month for servicing or installing offshore structures and moorings.

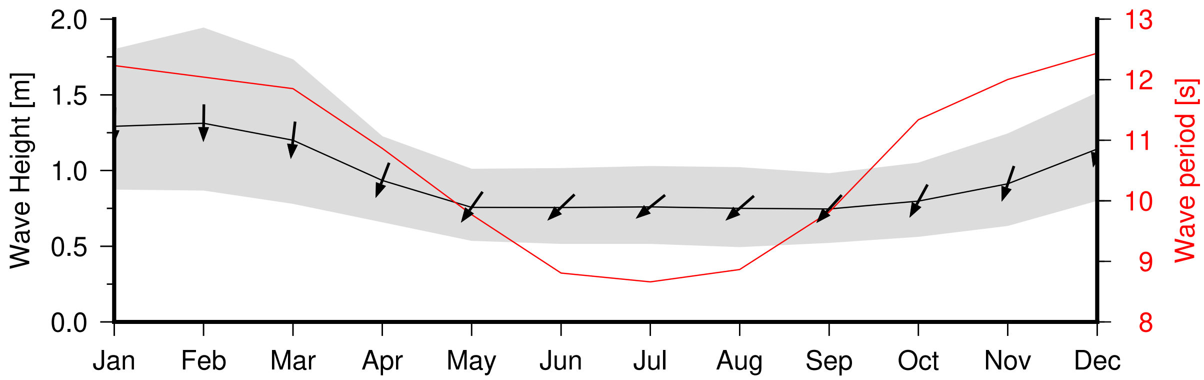

Figure 4 Monthly wave height (Black line), wave period (Red line) and wave direction (arrows). The grey area represents the range of wave height between calm periods (10% of lowest wave height) and large wave events (10% of highest wave height)

III.4 Annual wave height, period and direction

Waves change from month to month with the seasons but they also change from year to year with climate oscillations. Typically these changes are smaller than the seasonal changes but can be important during phenomenon such as El Niño. In Labasa Channel, the inter-annual variability (or coefficient of variation) for wave height is 5.2%, The Pacific average region variability in typically 7%. In Labasa Channel the mean annual wave height has remained relatively unchanged since 1979. The mean annual wave height in Labasa Channel is not significantly correlated with the main climate indicators of the region. The 1997/1998 El Niño greatly affected the wave climate in the Pacific region and in most islands a dramatric change in the wave patterns could be observed (Figure 5).

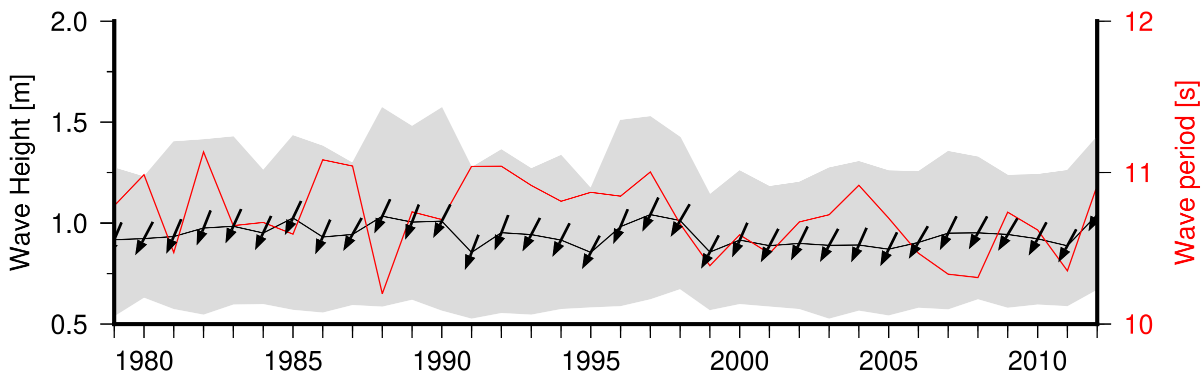

Figure 5 Annual wave height (Black line), wave period (Red line) and wave direction (arrows). The grey area represents the range of wave height between calm periods (10% of lowest wave height) and large wave events (10% of highest wave height)

IV. Large and Severe Waves

IV.1 Introduction

From time to time the waves become larger to a point where they can cause erosion of the beaches and inundation of the shore. Large wave are waves that exceed the 90th percentile of the wave height. In other words large wave occur 10% of the time (37 days in a year). Large wave are typically the largest event expected each month. Large wave rarely cause damage on the coast or inundation but water activities during large wave events can be hazardous. Large wave events do cause coastal inundation and erosion when they occur at the same time than large spring tide such as perigean spring tides (also called king tides). In Labasa Channel the threshold for large waves is 1.3m.

Severe waves are less common than large wave. They are the waves that occur less than 1% of the time (4 days in a year). Severe waves typically occur once or twice in a year. Severe waves can be associated with coastal erosion and inundation especially if they occur during spring tides and water activities are hazardous on the coast during these events. In Labasa Channel the threshold for severe waves is 2.7m.

Large and severe waves can be generated by different weather events such as, cyclones, distant extra tropical storms and fresh trade winds. The direction and period of the waves are telltale of the origin of the large waves. This information can be derived from the large, severe and extreme wave rose (Figure 6). In Labasa Channel, the dominant direction for wave height larger than 1.3m is from the Northwest (320º).

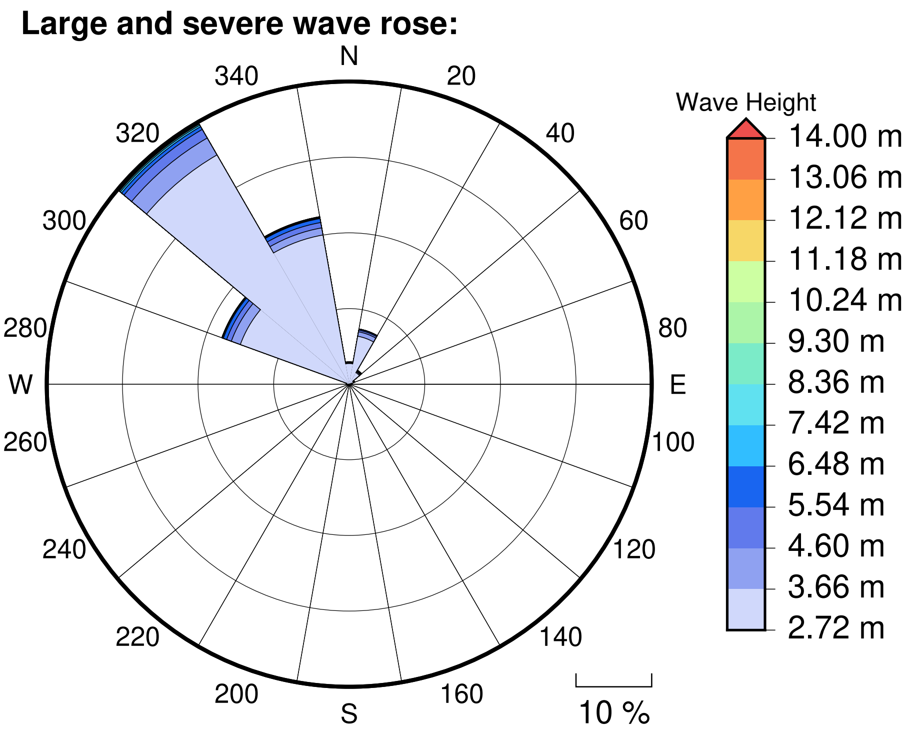

Figure 6 Large, severe and extreme wave roses for Labasa Channel

IV. Large and Severe Waves (Cont.)

IV.2 Large wave variability

Larger waves can be generated by different meteorological phenomena such as tropical cyclones, extra-tropical storm or fresh trade wind events. These meteorological events are very dependent on the seasons and so does the large waves. In Labasa Channel large waves are bigger in summer(Jan). Large waves are also present during other seasons and the monthly variability of the large wave threshold (90th percentiles) for Labasa Channel is 27% (Figure 7).As mean wave height varies from year to year so does the larger waves. In Labasa Channel the annual variability for the large wave threshold is 8% (Figure 8).

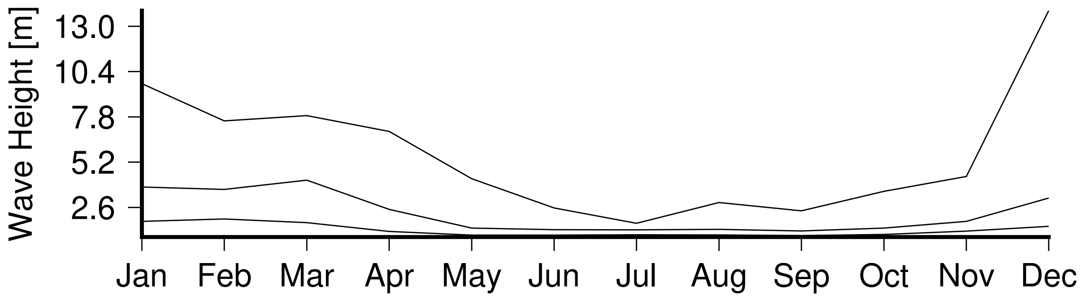

Figure 7 Monthly variation in large waves (90th percentile)(lower curve), severe waves (99th percentile) (middle curve) and the largest wave(upper curve) in Labasa Channel.

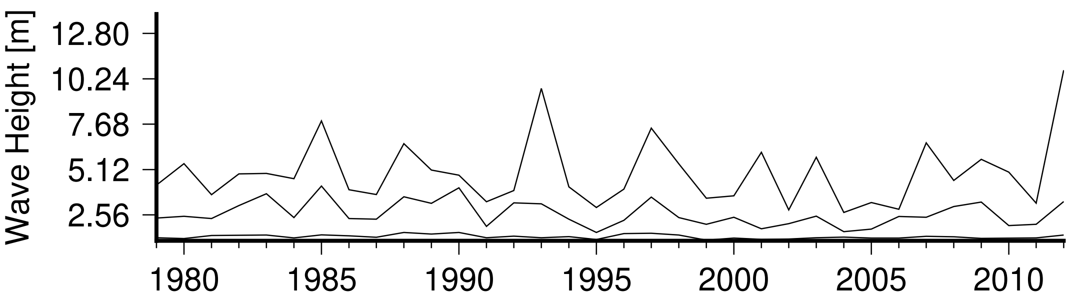

Figure 8 Annual variation in large waves (90th percentile)(lower curve), severe waves (99th percentile) (middle curve) and the largest wave(upper curve) in Labasa Channel.

V. Extreme waves

V.1 Largest events

A list of the 30 largest wave events is presented in table 3 with the ranking, the date (UTC time), wave height, wave period and direction at the peak of the event. The largest event that reached Labasa Channel since 1979 was on the 17-12-2020 and exceeded 14m which is considered high . All the listed events have a wave height higher than 4m which is considered rough . The list of the 30 largest events can be used to calculate the probability of occurrence of wave event larger than the average largest annual wave height. Such analysis, called an extreme wave analysis, is presented in the next page.

Table 3 List of the 30 largest wave events in Labasa Channel .

30 largest events				
Rank	Date	Height (m)	Period (s)	Dir. (˚)
1	17-12-2020	13.90	15	331
2	16-12-2012	10.73	13	7
3	02-01-1993	9.70	13	316
4	16-03-1985	7.87	16	317
5	20-02-2016	7.57	10	313
6	06-03-1997	7.45	12	33
7	01-02-2021	7.28	12	343
8	17-01-1985	7.22	13	308
9	08-04-2020	6.97	14	302
10	26-12-2019	6.75	12	10
11	04-02-2007	6.62	12	5
12	03-03-1988	6.58	13	309
13	12-03-2015	6.17	17	323
14	01-03-2001	6.10	13	295
15	09-03-2003	5.81	12	27
16	06-03-1985	5.78	13	315
17	13-12-2009	5.70	11	350
18	04-04-1980	5.46	10	341
19	07-01-1998	5.45	14	301
20	15-02-1989	5.09	10	320
21	14-03-2010	4.98	14	63
22	23-03-1980	4.92	10	355
23	28-02-1983	4.90	11	325
24	30-01-1982	4.88	12	315
25	10-04-2018	4.87	11	305
26	21-03-1990	4.80	11	331
27	18-03-1984	4.61	10	317
28	23-02-1983	4.55	11	5
29	28-01-2008	4.51	11	43
30	18-03-1990	4.50	12	17

V. Extreme waves (Cont.)

V.2 Extreme wave analysis

Extreme wave analysis are used to assess the probability of occurrence of wave events larger than the severe wave height. It is often used to evaluate the vulnerability of communities to coastal inundation and to decide how high a seawall or a jetty needs to be built. Extreme wave analysis is a statistical analysis that looks at the distribution of past wave events and extrapolates (predict) the probability of occurrence of unusually large events that may have never been recorded. The probability of an event to occur within a year is often presented as an Annual Return Interval (ARI). The ARI is the probability of an event to occur within a year. For example the probability of a 100 year ARI event to occur within any given year is 1%. Similarly the probability of a 50 year ARI event to occur within any given year is 2%.

The analysis completed for Labasa Channel was done by defining a threshold of severe heights and fitting a Generalised Pareto Distribution (hereafter GPD). The optimum threshold was selected at 2.58m. In the 40 year wave hindcast 128 wave events have reached or exceeded this threshold. The GPD was fitted to the largest wave height reached during each of these events (Figure 9). Extreme wave analyses are a very useful tool but are not always accurate because the analysis is very sensitive to the data available, the type of distribution fitted and the threshold used. For example, this analysis does not accurately account for Tropical Cyclone waves. More in-depth analysis is required to obtain results fit for designing coastal infrastructures and coastal hazards planning.

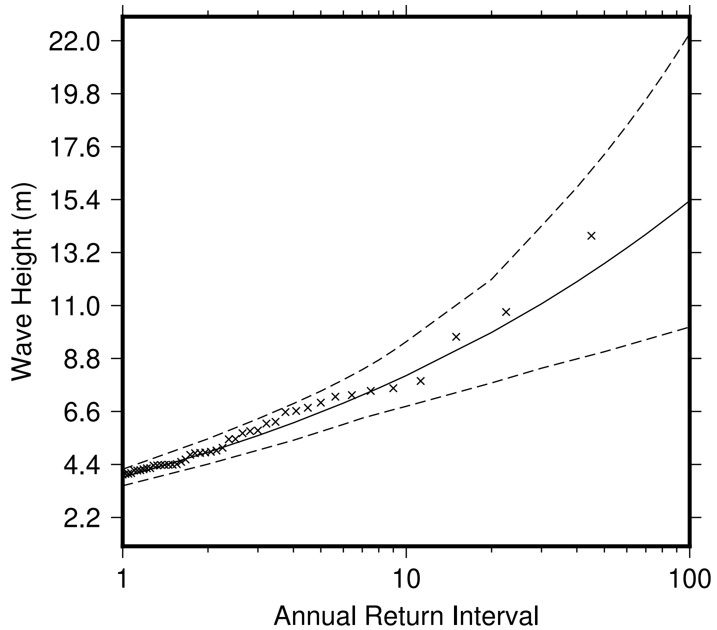

Figure 9 Extreme wave distribution for Labasa Channel. The crosses represents the wave events that occured since 1979. The plain line is the statistical distribution that best fit the past wave events. The dotted line show the upper and lower high confidence of the fit, there is a 95% chance that the fitted distribution lie between the two dashed lines.

Table 4 Summary of the results from extreme wave analysis in Labasa Channel .

Large wave height (90th percentile)	1.33 m
Severe wave height (99th percentile)	2.72 m
1 year ARI wave height	3.86 m
10 year ARI wave height	8.09 m
20 year ARI wave height	9.88 m
50 year ARI wave height	12.74 m
100 year ARI wave height	15.36 m

VI. Wave energy

VI.1 Introduction

Ocean waves are often cited as an appealing renewable energy resource because waves are a dense energy resource that is consistently present in some location. However, extracting wave energy is challenging because of the oscillating nature of waves and because of the harshness of the ocean environment. Yet some wave energy converters (e.g. Pelamis device) have reached a level of efficiency and reliability that is sufficient to generate electricity at a competitive cost if the resource is sufficient.

The wave energy resource is usually summarised by the mean annual wave energy flux (wave power). Typically locations with a mean annual energy flux above 7 kW/m should further investigate the feasibility of wave energy converters. In Labasa Channel the mean annual energy flux is 4.6kW/m.

Further site investigations should include a detailed assessment of the resource, environment and requirements for the most appropriate device for the site. The Pelamis device, a former prominent wave energy converter, can be used as a benchmark to compare between potential wave energy sites and between locations. In the Pacific, the total lifetime cost of a single device like the Pelamis is expected to be between $US6,318,000 and $US14,104,000.

In order to calculate the energy generated by a single device, similar to the Pelamis, the probability of occurrence of all sea states has to be calculated. This is done by calculating the percentage of time that a particular combination of wave height and wave period occur. The occurrence of sea states for Labasa Channel is presented in figure 10. This can then be combined with estimated power outputs from a Pelamis device for each of these sea states. In Labasa Channel the average annual energy output of a single device similar to the pelamis is expected to be 136MWh. Combined with the expected capital cost of a single device the cost of electricity generation of wave energy from a single Pelamis device in Labasa Channel is between 1855$US/MWh 4141$US/MWh.

Wave energy is unlikely to be a suitable renewable energy resource in Labasa Channel.

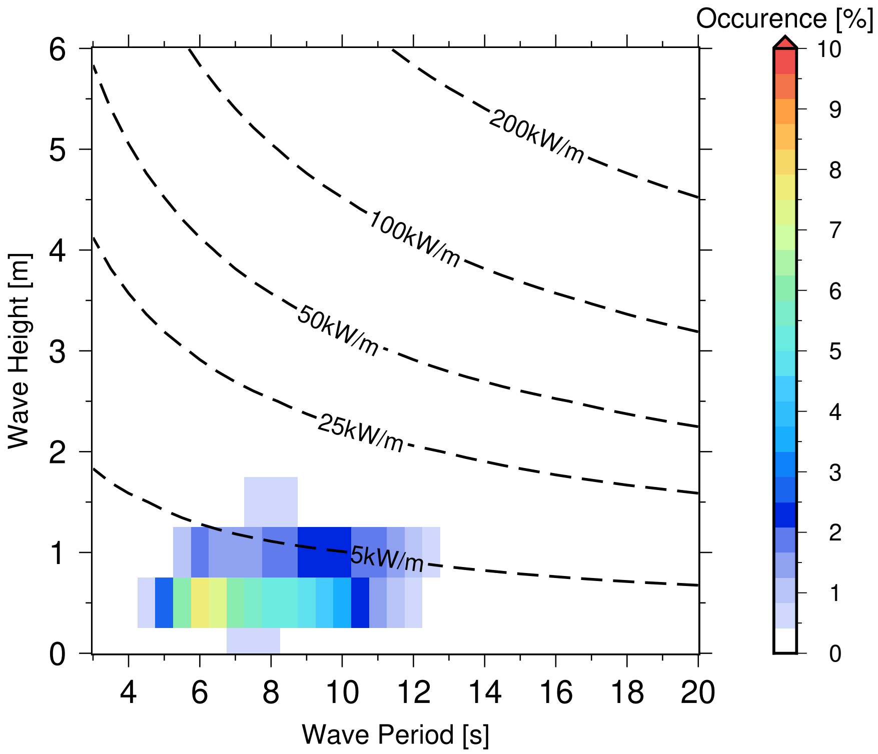

Figure 10 Occurences of sea states in Labasa Channel .

Read more:
http://wacop.gsd.spc.int/RegionalWaveEnergy.html

VIII. Wind

VIII.1 Introduction

Wind is the origin of all waves and although swells are created by distant wind events, local winds can significantly affect the local waves. In Labasa Channel the prevailing wind is dominated by South Easterly trade winds. with a mean wind speed of 4.53ms^{-1} (8.81knts) from the 106º. Figure 11 shows the wind rose for Labasa Channel and Figure 12 shows the monthly mean wind speed and direction. Note that the results presented here use the nautical convention: directions shown are the directions the wind is blowing from.

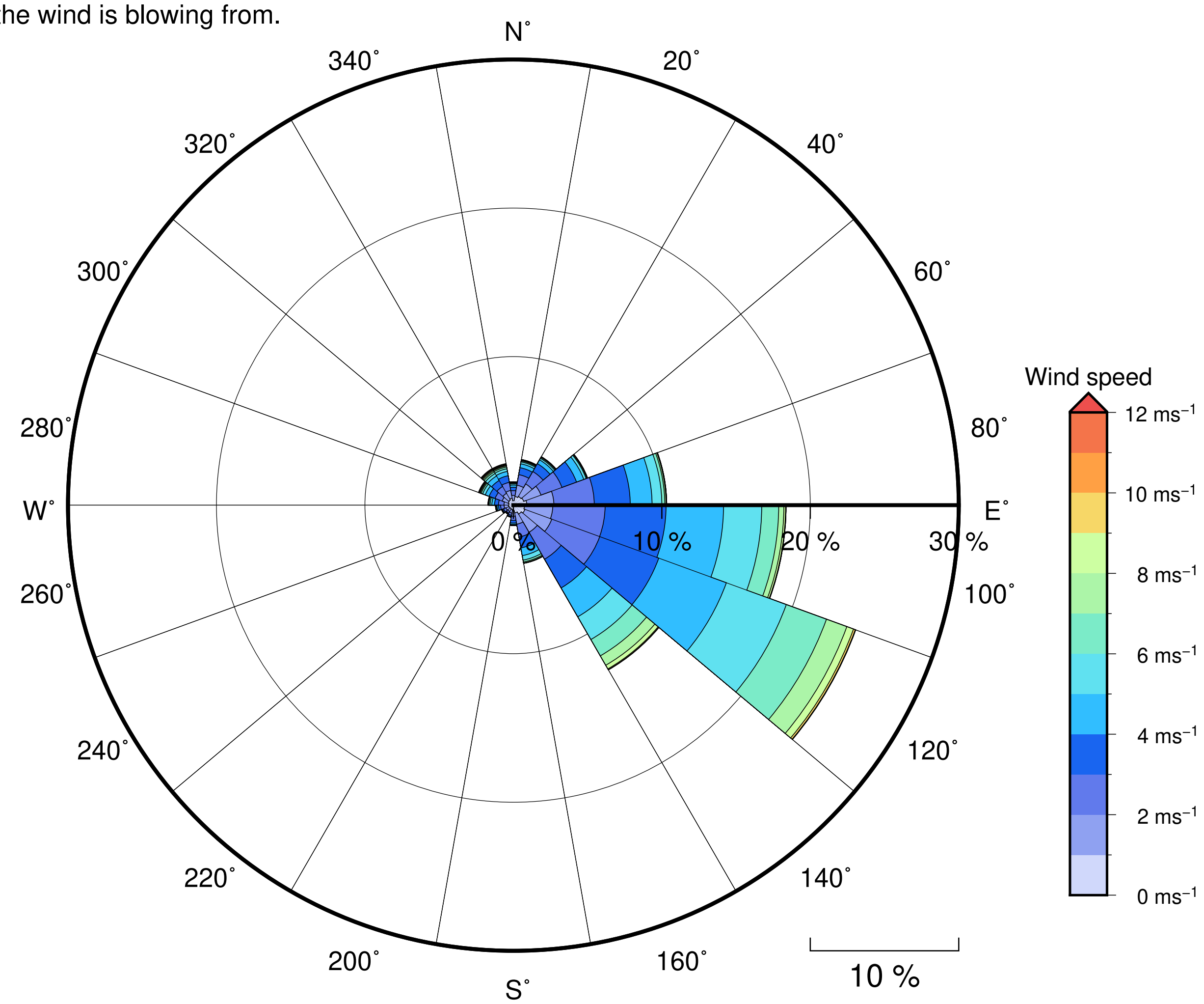

Figure 11 Annual wind rose for Labasa Channel. Note that directions are where the wind is **coming from**.

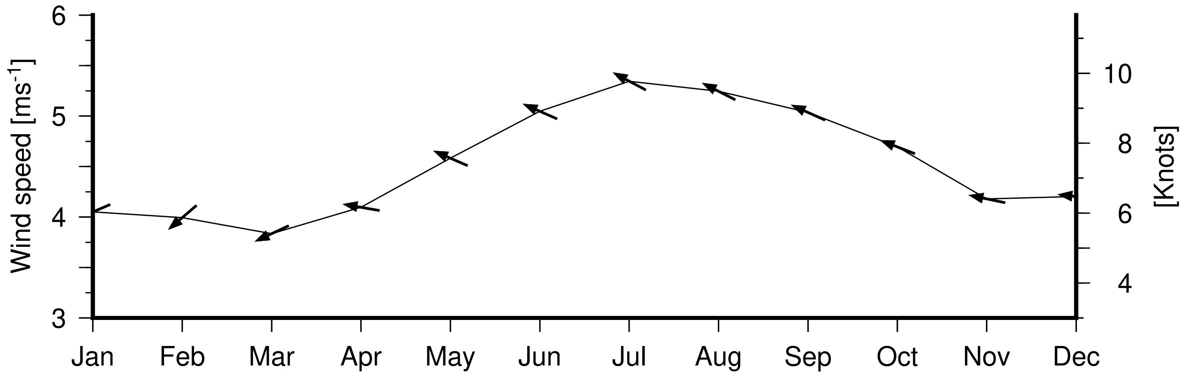

Figure 12 Monthly wind speed (Black line) and wind direction (arrows).

Glossary

Autumn
Autumn is the transition season between summer (wet season) and winter (dry season), best noticed by low wind speed and change in wind direction and warm seas. This is typically when the largest cyclone occur.

Climate oscillation
A climate oscillation or climate cycle is any recurring cyclical oscillation within global or regional climate, and is a type of climate pattern.

El Niño
El Niño events are large climate disturbances which are rooted in the tropical Pacific Ocean that occur every 3 to 7 years. They have a strong impact on the weather around the tropical Pacific, and some climatic influence on half of the planet.

Hindcast (wave)
The prediction of wave characteristics using meteorological information combined in a model, this is often used when measurements of these features are not available.

Mean number of wave components
Represents the mean number of wave events occurring at any given time. These values describe the complexity of the wave climate.

Mean annual variability
Is the standard deviation in annual mean wave height. In other word, it is the average changes in the mean wave height expected from one year to another.

Mean seasonal variability
Is the standard deviation in the wave height within a year. In other word it is the average changes in wave height from one season to another

Offshore Zone
Coastal waters to the seaward of the nearshore zone. Swell waves in the offshore zone are unbroken and their behaviour is not influenced by the seabed.

Spring
Spring is the transition season between winter (dry season) and summer (wet season) during which we see days getting longer, temperatures warming.

Summer
Time of year when part of the Earth receives the most daylight: In the Pacific. Summer is often associated with increase rainfall and often referred to as the wet season.

Swell Waves
Wind waves that have travelled far from the area of generation (fetch). They are often uniform and orderly appearance characterised by regularly spaced wave crests.

Glossary (Cont.)

Wave climate
Wave climate is the average wave condition in a given region over a long period of time, usually 30 years. It is the measure of the average pattern of variation in âŒ¨variablesâŒ, such as wave height, wave period, and wave direction. As an example, seasonal variability in significant wave height may be characterized by calculating the monthly mean significant wave heights from several years of measurements.

Wave Direction
The direction from which ocean waves approach a location (Following the nautical convention). Generally, the principal wave direction is represented by the direction of the principal wave component.

Wave Height
The vertical distance between a wave crest and the next trough. The significant wave height is defined as the mean wave height (from trough to crest) of the highest third of the waves and correspond to the wave height that would be reported by an experienced observer.

Wave Period
The time taken for consecutive wave crests or wave troughs to pass a given point. The peak period is the time interval between 2 waves of the dominant wave component.

Wave Power
The rate at which wave energy is transmitted in the direction of wave propagation. Normally expressed in kilowatts per metre of wave crest length.

Wave rose
The annual wave rose shows where waves usually come from and the size of waves associated with each direction. It is a powerful illustration of the distribution of wave height and direction.

Wind Waves
The waves initially formed by the action of wind blowing over the sea surface. Wind waves are characterised by a range of heights, periods and wave lengths. As they leave the area of generation (fetch), wind waves develop a more ordered and uniform appearance and are referred to as swell or swell waves.

Winter
Time of year when part of the Earth receives the least daylight. In the Pacific it is often associated with a decrease in rainfall and often refered to as the dry season.

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The data used in this report is from the hindcast model by Smith et al. (2020), Durrant et al. (2014) and Trentham et al. (2014):
Smith G.A., Hemer M., Greenslade D., Trenham C., Zieger S., Durrant T. (2020). Global wave hindcast with Australian and Pacific Island Focus: From past to present. Geosco. Data J. https://doi.org/10.1002/gdj3.104
Durrant T. H., Greenslade D. J. M., Hemer M. A., Trenham C. E. (2014). A global wave hindcast focussed on the Central and South Pacific. CAWCR Technical Report No. 070.
Trenham C. E., Hemer M. A., Durrant T. H. and Greenslade D. J. M. (2014). PACCSAP wind-wave climate : high resolution wind-wave climate and projections of change in the Pacific region for coastal hazard assessments. CAWCR Technical Report No. 068.
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