Nearshore wave resources and wave climate analysis at American Samoa

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Summary

- The large amount of energy contained in the surface gravity waves in a large exclusive economic zone (EEZ) provides opportunities for stand-alone and grid-connected wave energy harvesting in the U.S. A detailed wave energy resource characterization with consistent methodology across regions is required for site identification, comparison, device design, leasing, etc.
- The U.S. Department of Energy is funding a high-resolution wave resource assessment which we are conducting by closely following the IEC-TS to cover all the U.S. EEZ. The assessment for American Samoa can be classified as class 2 per IEC-TS requirements (see Table 1).
- A high-resolution wave model was developed and validated against satellite-borne and in situ measurements. The model was used to generate a hindcast spanning 1979 – 2020.
- American Samoa has a multi-modal sea state receiving waves generated through most of the Pacific Ocean.
- American Samoa has modest energy density with the potential to provide energy with minor seasonal variability because of the availability of complimentary sources.

Class 2 Homologation Table (selected)		This Model
Minimum spatial resolution	500m	200 m
Minimum Temporal Resolution	3h	1h
Number of frequencies	25	34 0.03–0.70Hz
Number of directions	36	72
Spectral boundary conditions	Rec	Yes From WW3

Table 1. Requirements for a model-based wave energy resource characterization to meet the Class 2 IEC-TS. Rec: Recommended.

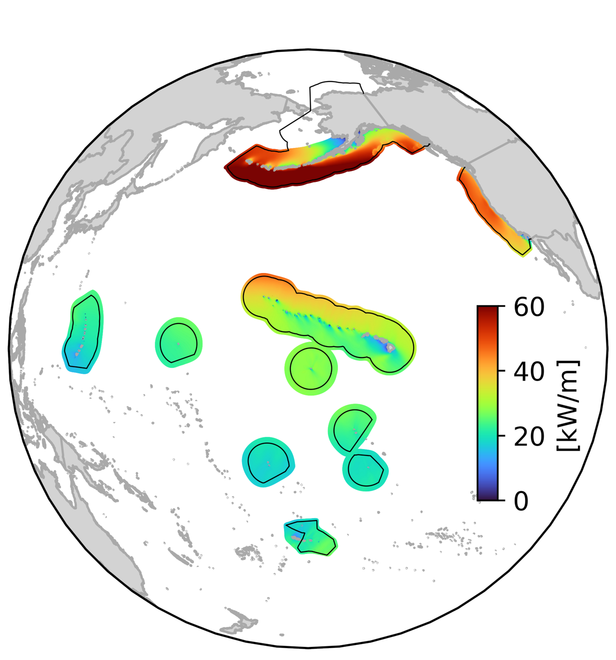


Fig 1. Average wave power at US Pacific EEZ

Study Area: American Samoa

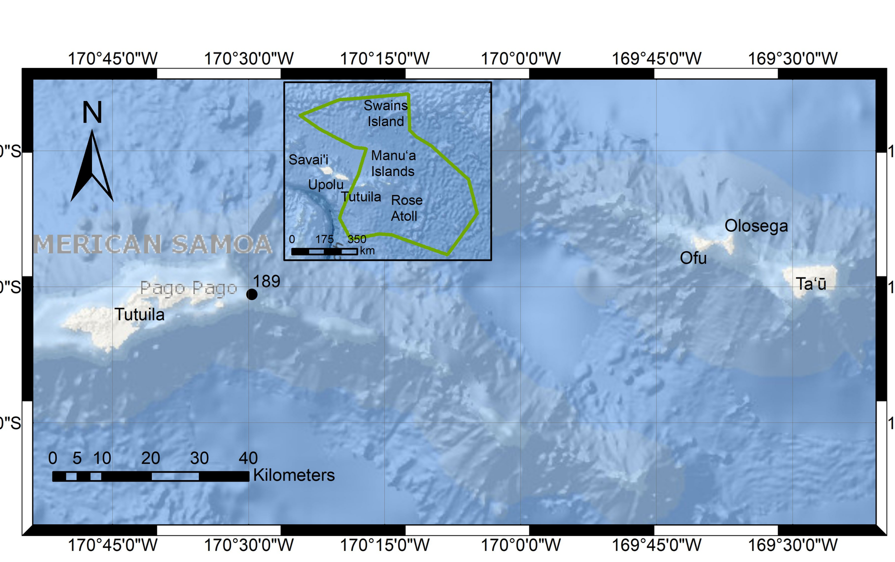


Fig 2. American Samoa is located in the South Central Pacific Ocean. The U.S. Territory comprises 7 islands and atolls.

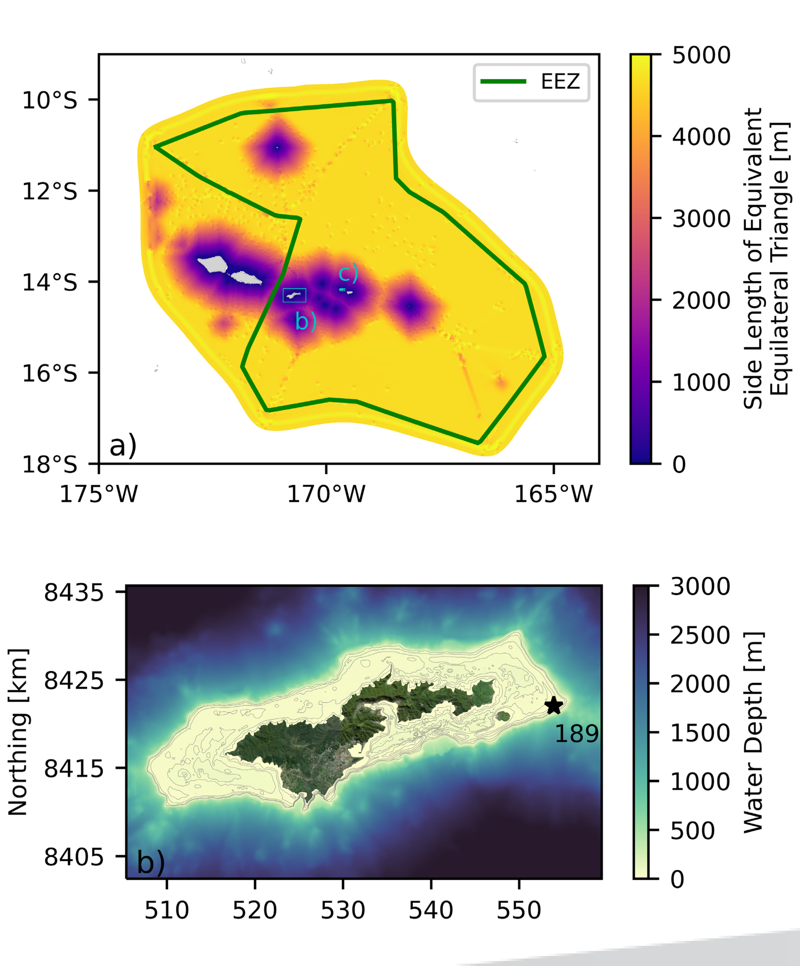


Fig 3. a) Resolution of the unstructured mesh for SWAN 41.10. Element size depends on water depth, distance from shore, and 10% maximum area change in adjacent elements. b) Bathymetry around Tutuila. PACIOOS buoy 189 was used for model-data comparison.

Model Performance

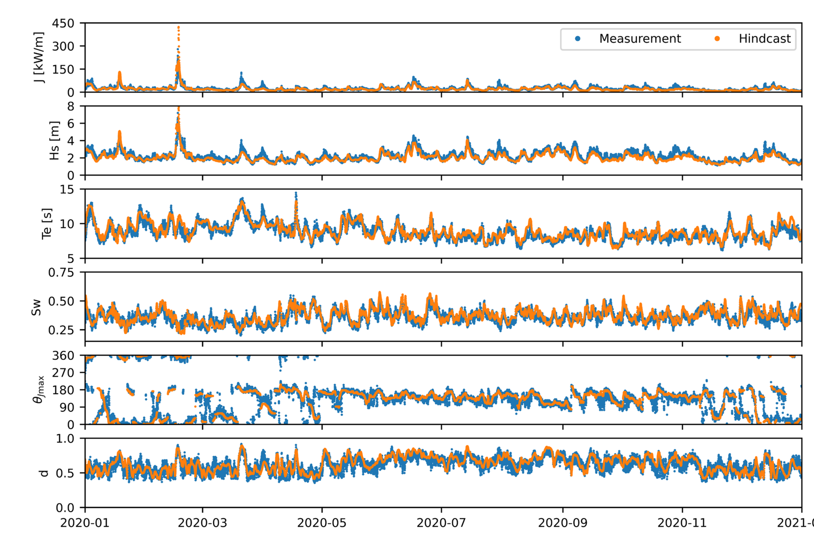


Fig 4. Model-data comparison during 2020 at station 189. From top to bottom: omnidirectional wave power, significant wave height, energy period, spectral width, direction of maximum directionally resolved wave power, and directionality coefficient.

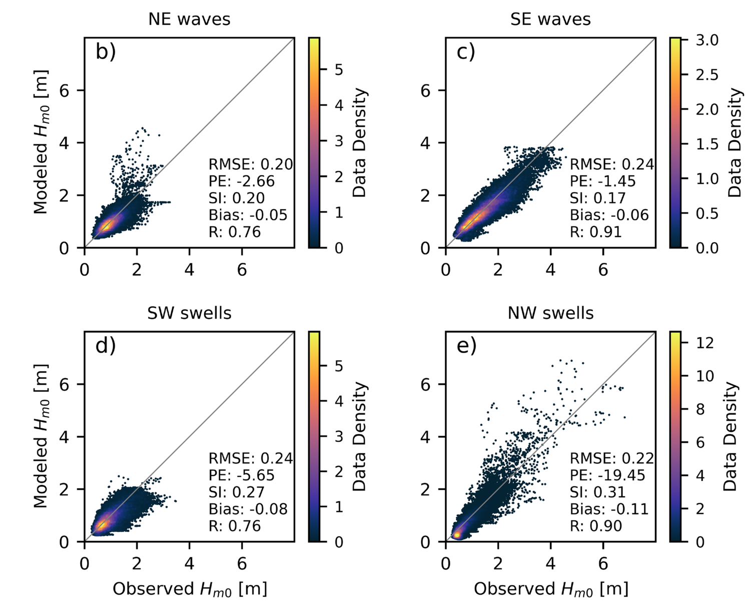


Fig 5. Modeled and observed wave height comparisons at the four main spectral partitions.

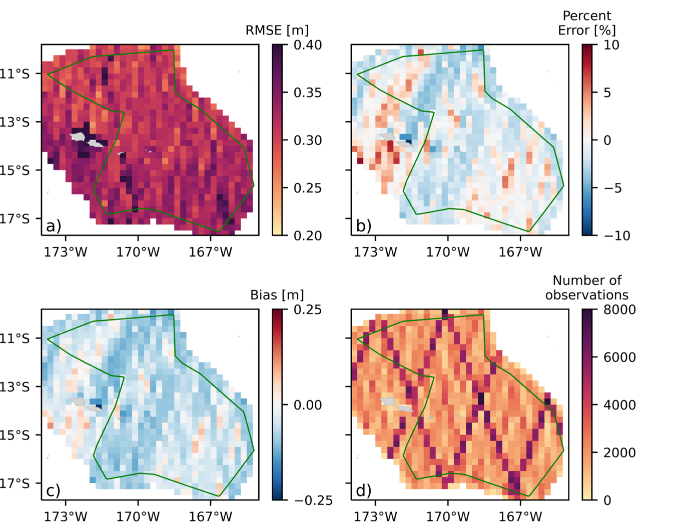


Fig 6. Significant wave height comparison between model and satellite based altimeters. Data were grouped by 0.25° x 0.25° bins to facilitate computation of error statistics.

Wave Climate

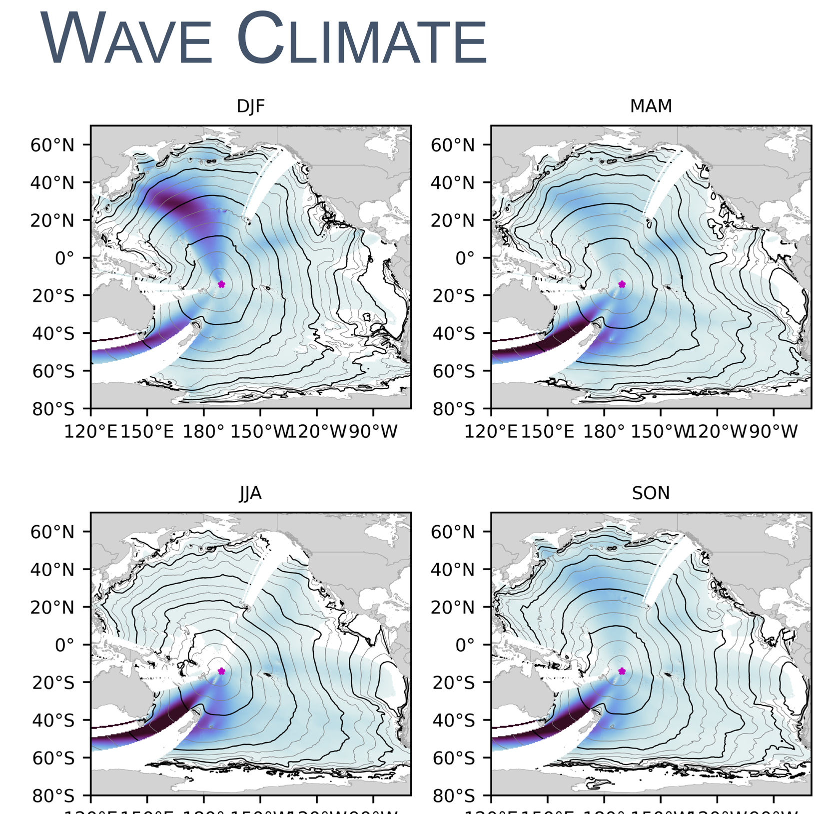


Fig 7. Sources of energy reaching Buoy 189. Contour lines indicate time of travel in days. DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November.

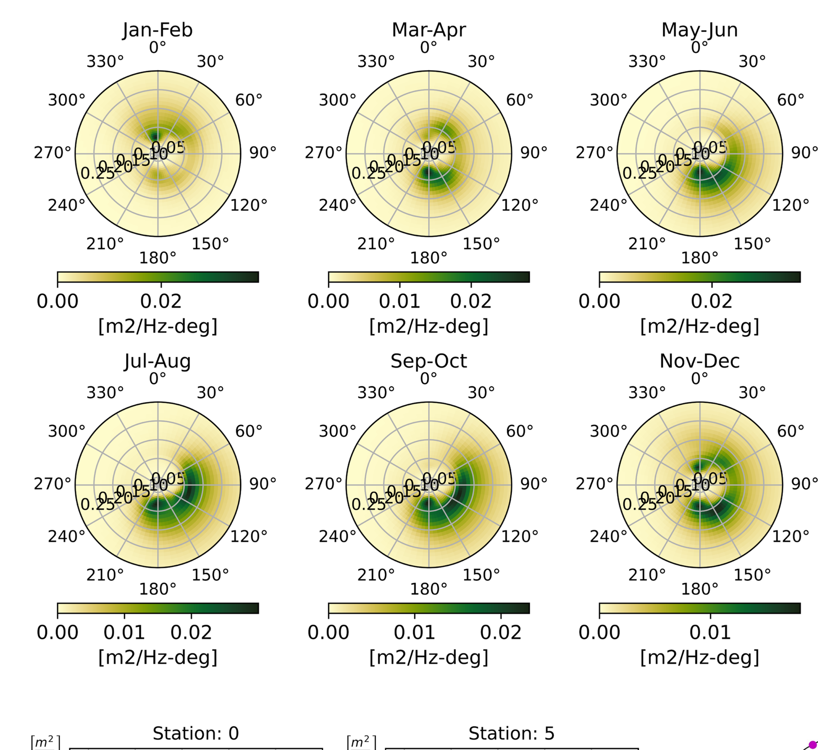
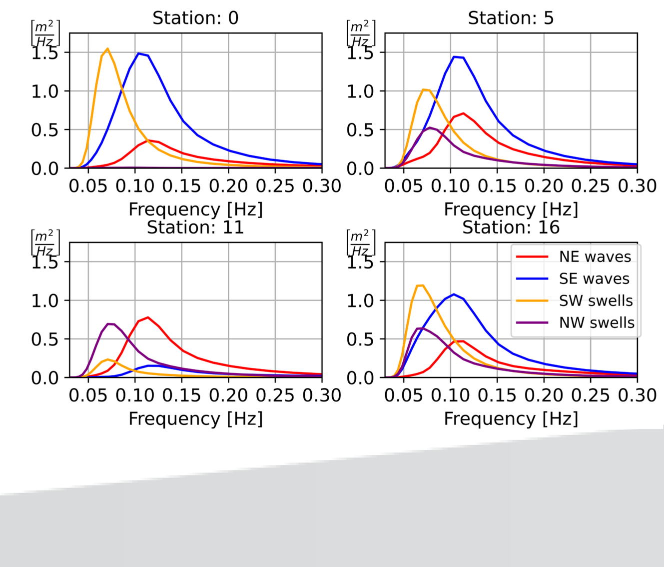


Fig 8. Bimonthly averaged wave spectra at Buoy 189. North swells are energetic during austral summer, south swells are dominant the rest of the year. Two shorter wave components from the northeast and southeast are active year-round but weaker during the austral summer.



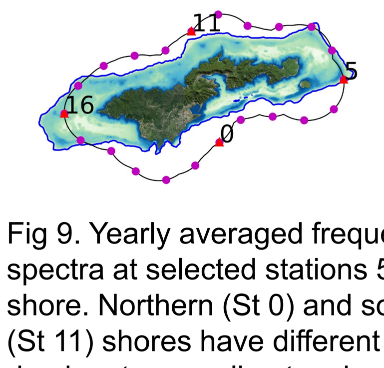


Fig 9. Yearly averaged frequency spectra at selected stations 5 km from shore. Northern (St 0) and southern (St 11) shores have different dominant wave climates due to sheltering from the island.

Wave Energy Resources

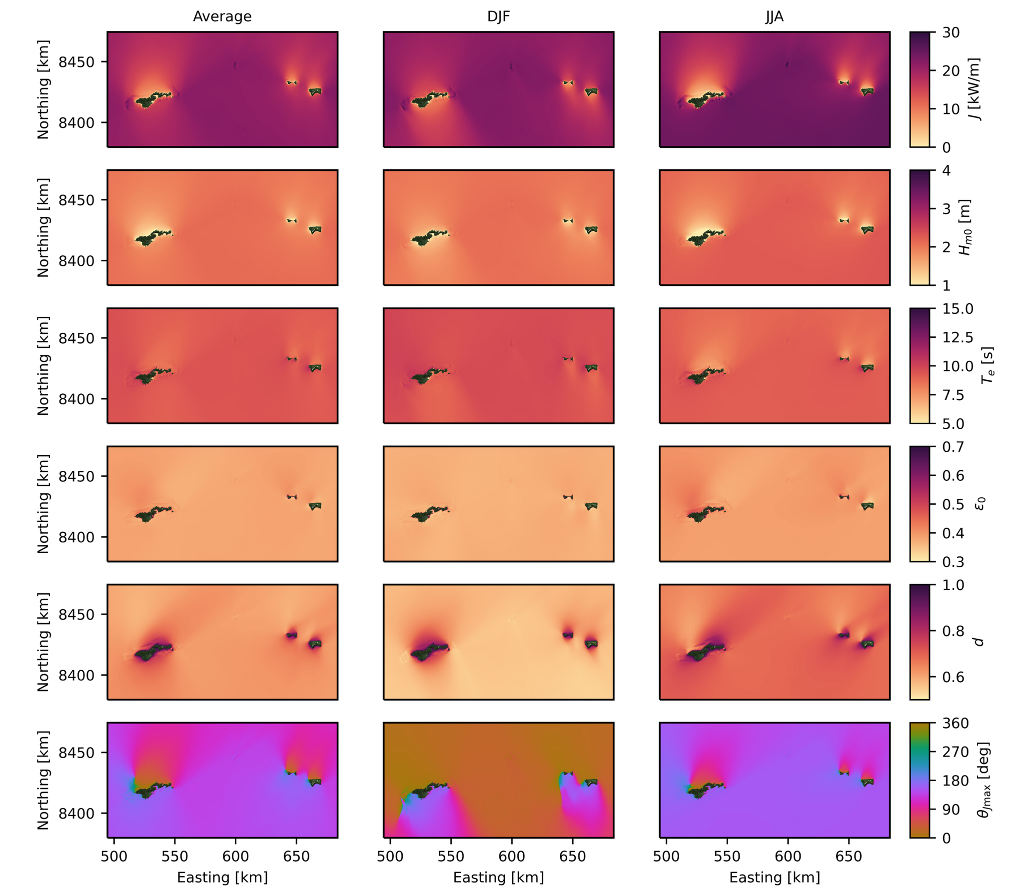


Fig 10. Wave energy resources characterization parameters averaged from 1979 – 2020 near Tutuila and the Manu'a Islands. Top to bottom: omnidirectional wave power, significant wave height, energy period, spectral width, directionality coefficient, and direction of maximum directionally resolved wave power. DJF: December, January, and February; JJA: June, July, August.

Omnidirectional wave power is greater east and west of the islands because north and south swells travel without being interrupted. More wave power in this region comes with a lower directionality coefficient. The most energetic conditions occur during the austral winter.

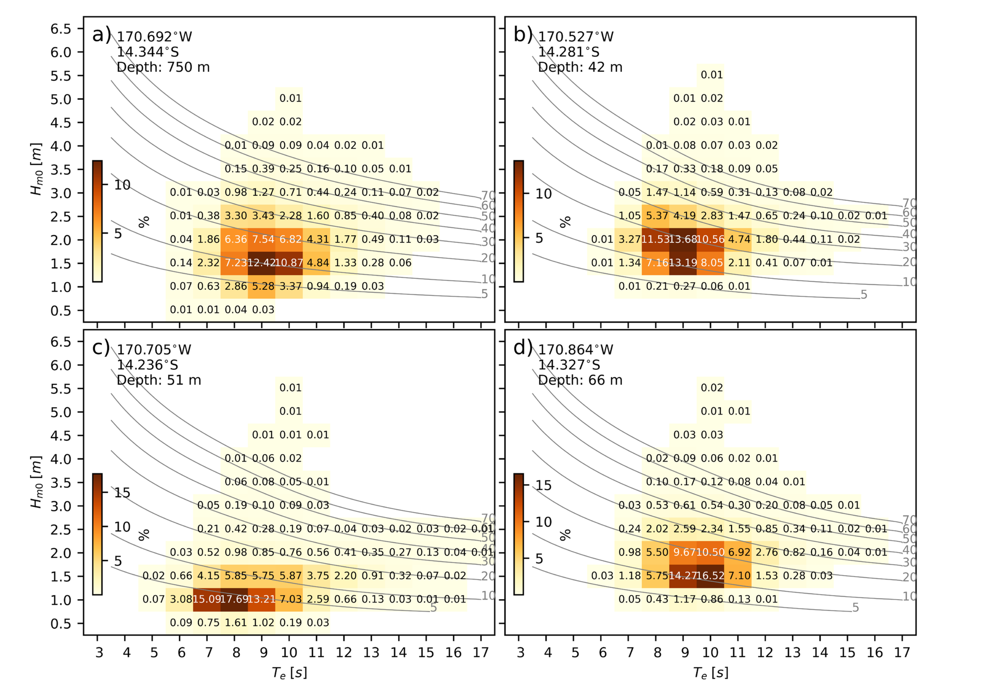


Fig 11. IEC-TS compliant, bivariate distribution of significant wave height and energy period at selected stations around Tutuila located (a) south, (b) east, (c) south, and (d) west.

Most of the waves in the southern shore have significant wave heights between 1.5 and 2.0 m, and energy period in the range between and 7 to 9 s. East and west significant wave heights are larger by 0.5 m and dominant periods around 2 s larger.

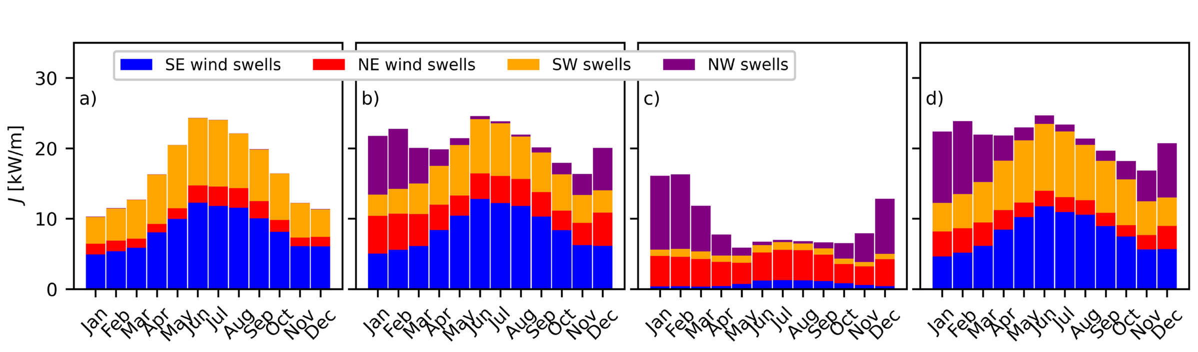


Fig 12. Average wave resources by sea state around Tutuila at stations located (a) south, (b) east, (c) south, and (d) west. Stations are the same as those in Fig 9.Monthly variability in the resource is larger in the north and south shore with but have opposite seasonality. East and west the resource is more consistent in time.

Region	30 km	15 km	10 km	5 km	2 km
Tutuila	15.1	8.4	6.3	4.5	3.5
Manu'a Islands	15.7	9.1	6.9	4.4	
Ofu and Olosega	-	-	-	-	1.5
Ta'ū	-	-	-	-	1.7
Rose Atoll	13.0	6.0	3.7	1.7	0.6
Swains Island	10.1	4.9	3.1	1.8	0.8

Table 2. Integrated wave energy resource crossing lines of equal distance from shore in TWh/yr.

Acknowledgements

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