Concurrent metocean data analysis for holistic marine energy design and resource assessments

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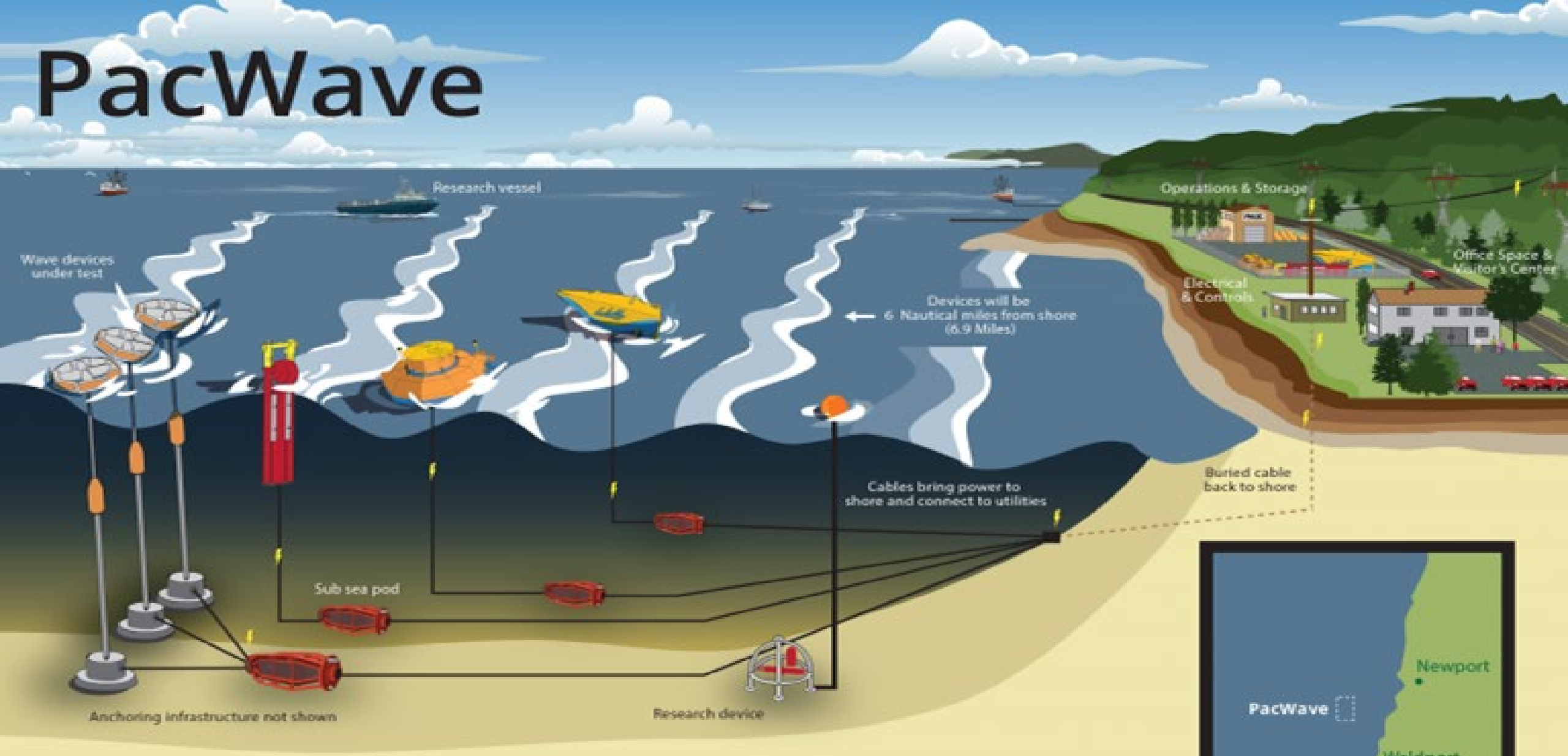
August 8th, 2024

PacWave



PacWave

Oregon State University

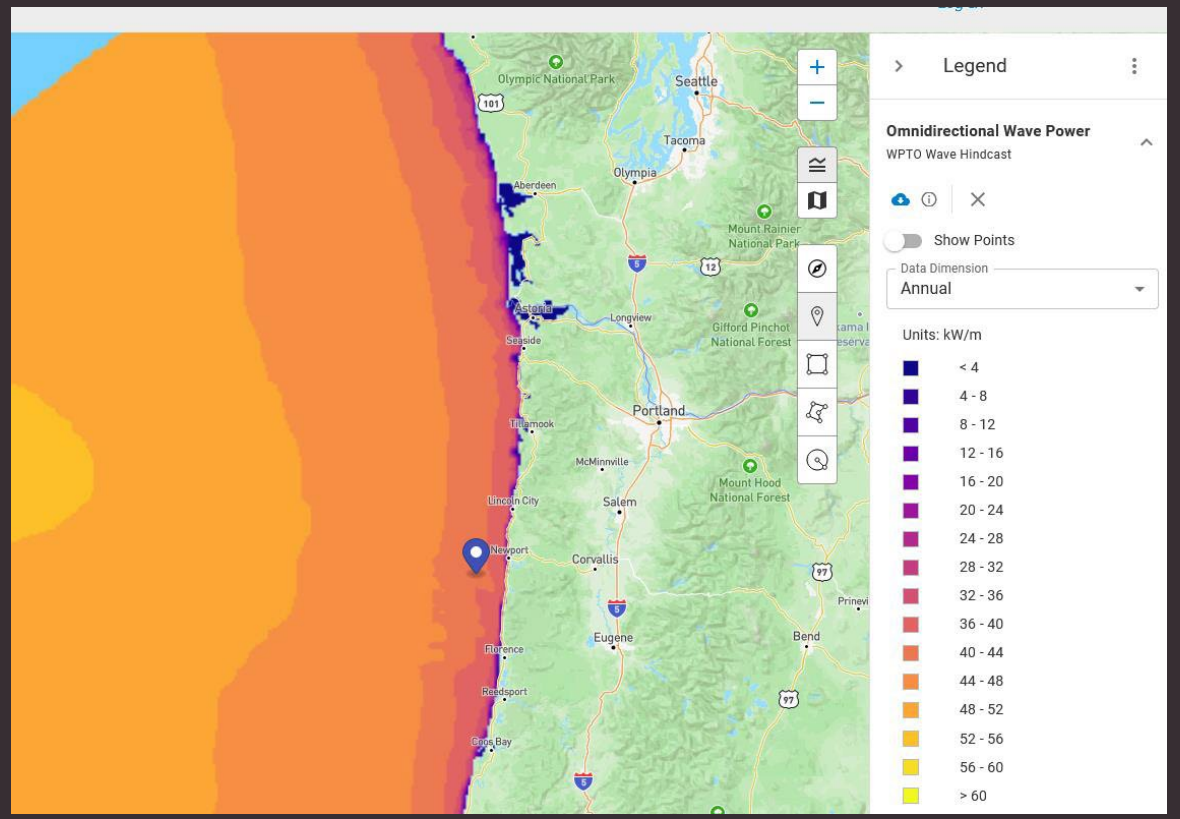
U.S. DEPARTMENT OF ENERGY

Wave Resource Assessment: PacWave

- NREL/PNNL/SNL Effort
  - Simulating WAves Nearshore (SWAN) Model
  - 1 and 3 hour resolution
  - 29 freq bins: 0.035 –0.505 Hz
  - Nominally, 24 directions @ 15º
    - 72 directional bins @ 5°(Alaska)
  - https://www.nrel.gov/water/wave-hindcast-dataset.html

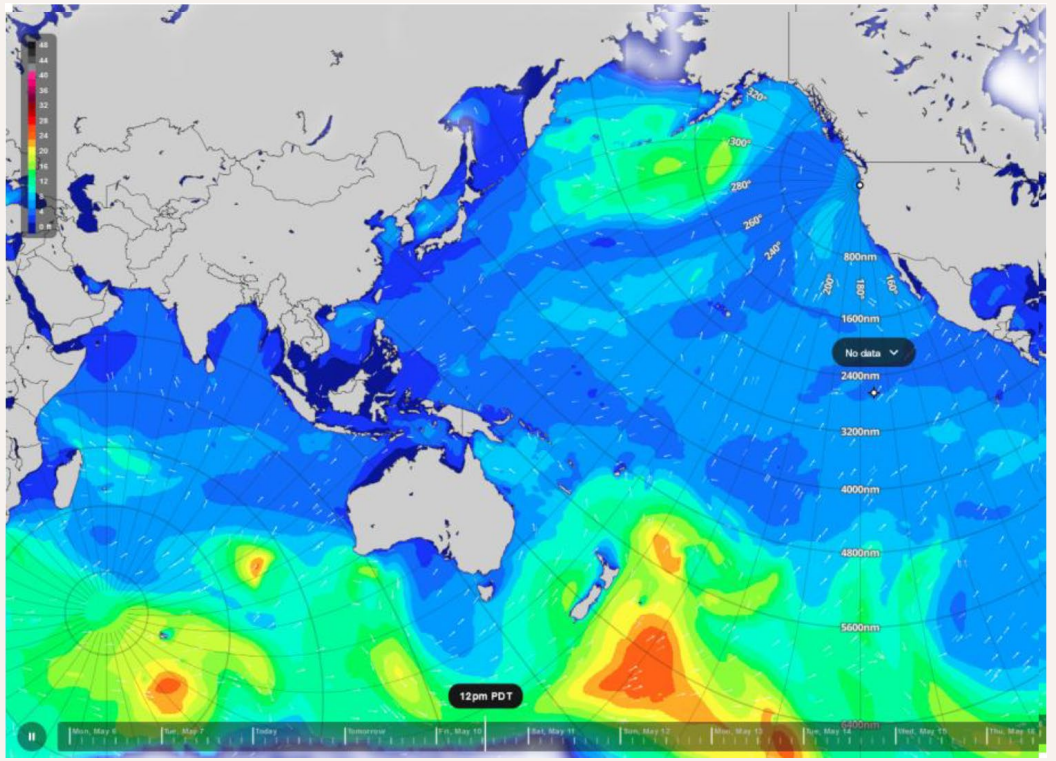
- PacWave South:

(43.489171,-125.152137)



Wave Model Realities

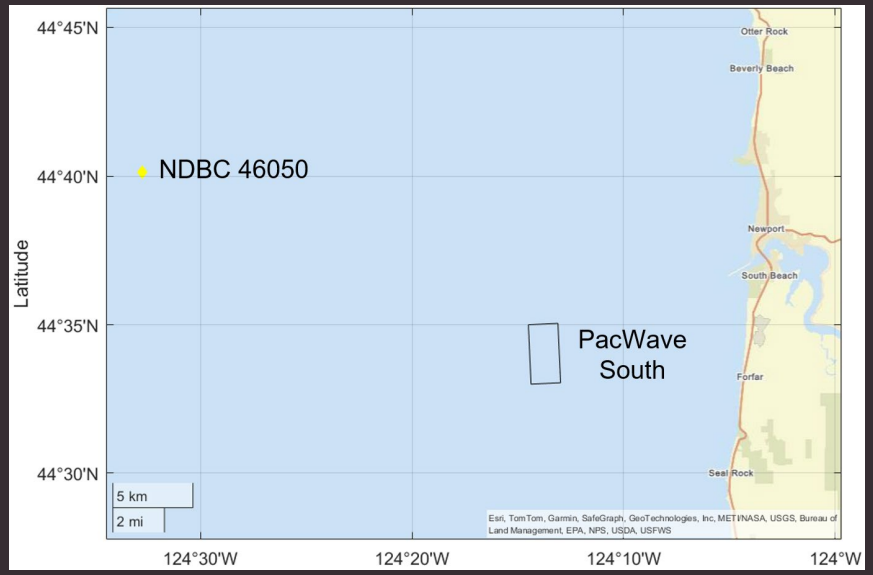
- Purely numerical and empirically derived coefficients and relationships
- Limited by time-resolution, frequency resolution, empirical relationship, processing and storage.
- Known to underestimate extremes and overestimate benign conditions



Still the best method to predict long-duration, large-domain wave and metocean conditions

Wave Resource Assessment: PacWave

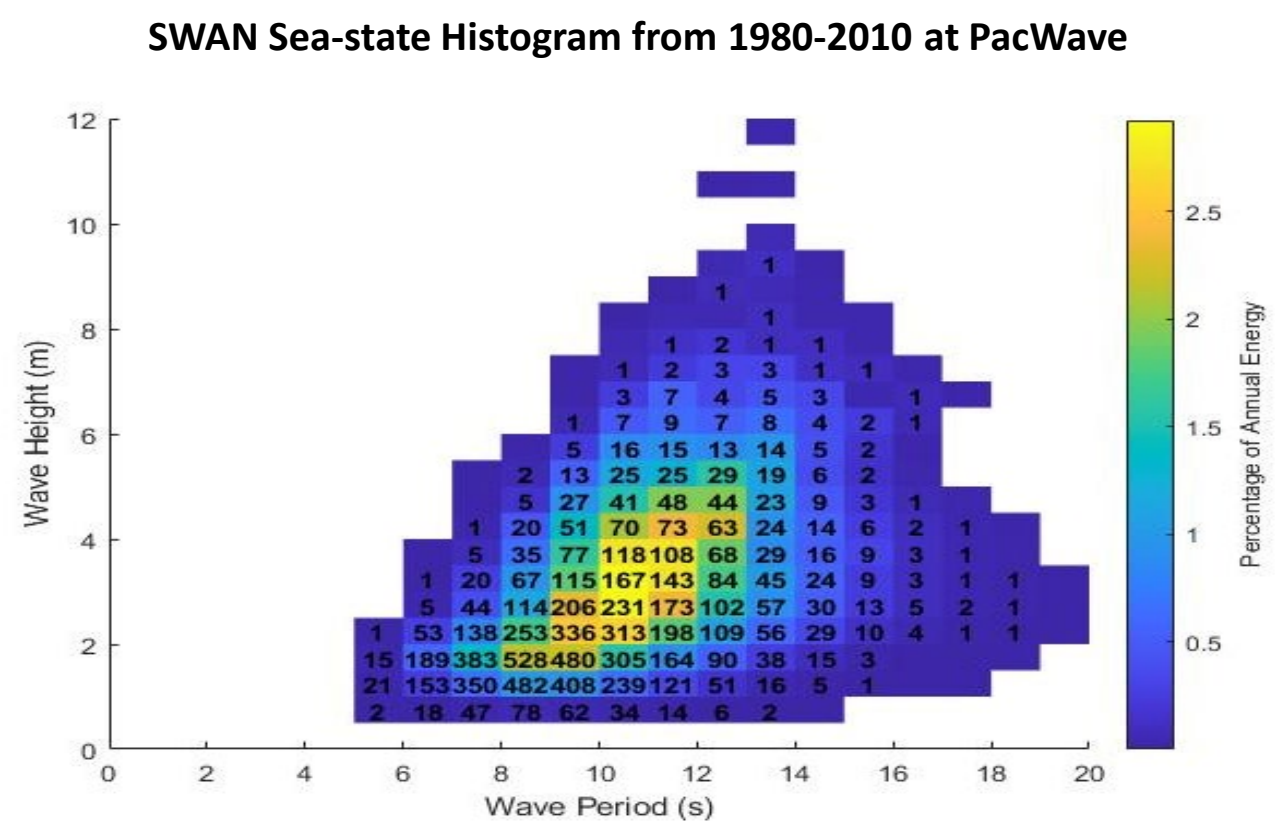
- NDBC Stonewall Banks Buoy
  - Station 46050 (1991-)
  - 30-60 min resolution



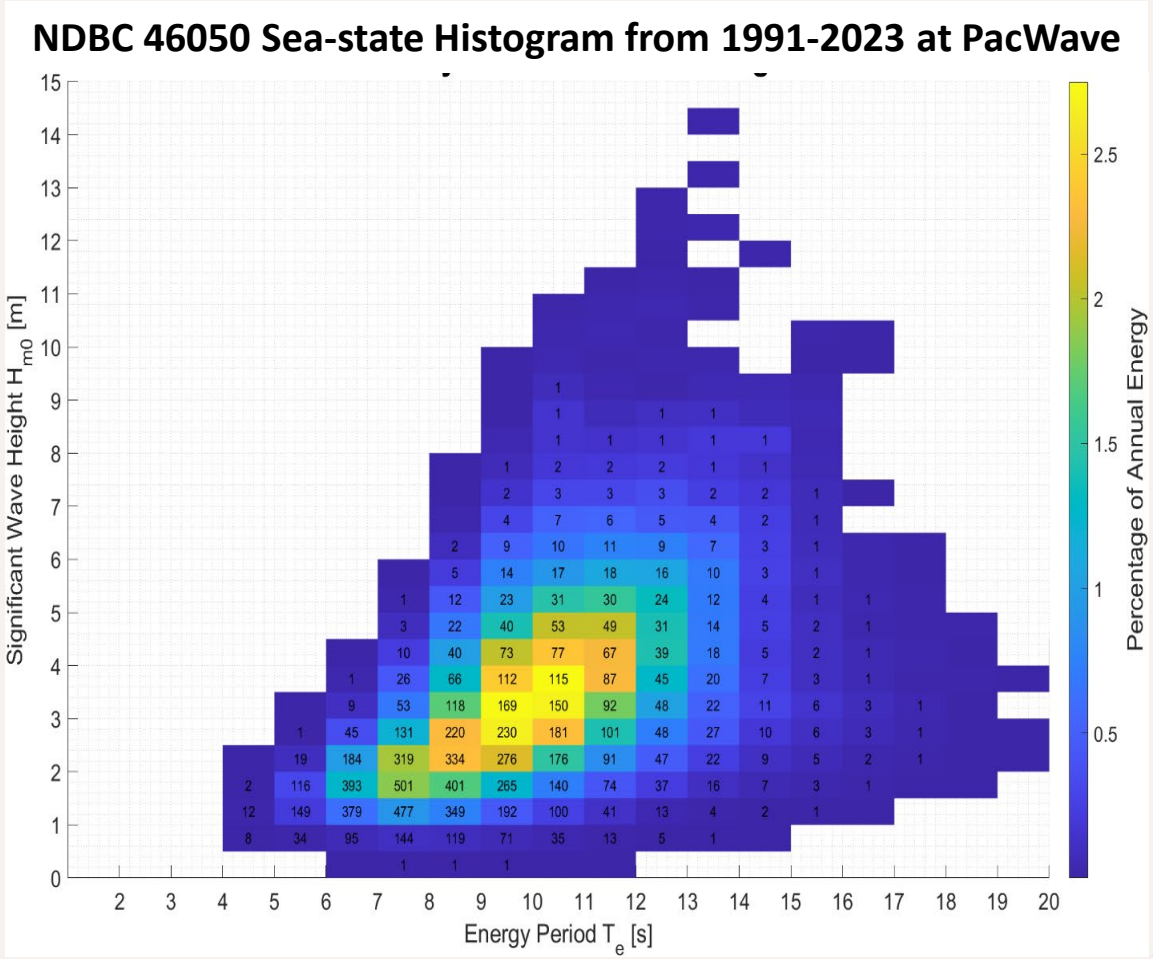
- Parameters
  - Wave height
  - Wave period
  - Wave direction
  - Others

TIME (PDT)	WDIR	WSPD kts	GST kts	WVHT ft	DPD sec	APD sec	MWD
2024-08-02 09:20 am	W	3.9	5.8	3.6	8	6.1	NW
2024-08-02 08:50 am	WSW	3.9	5.8	3.6	8	6.2	NW
2024-08-02 08:20 am	SW	3.9	3.9	3.6	8	6.2	NW

Models ≠ Measurements

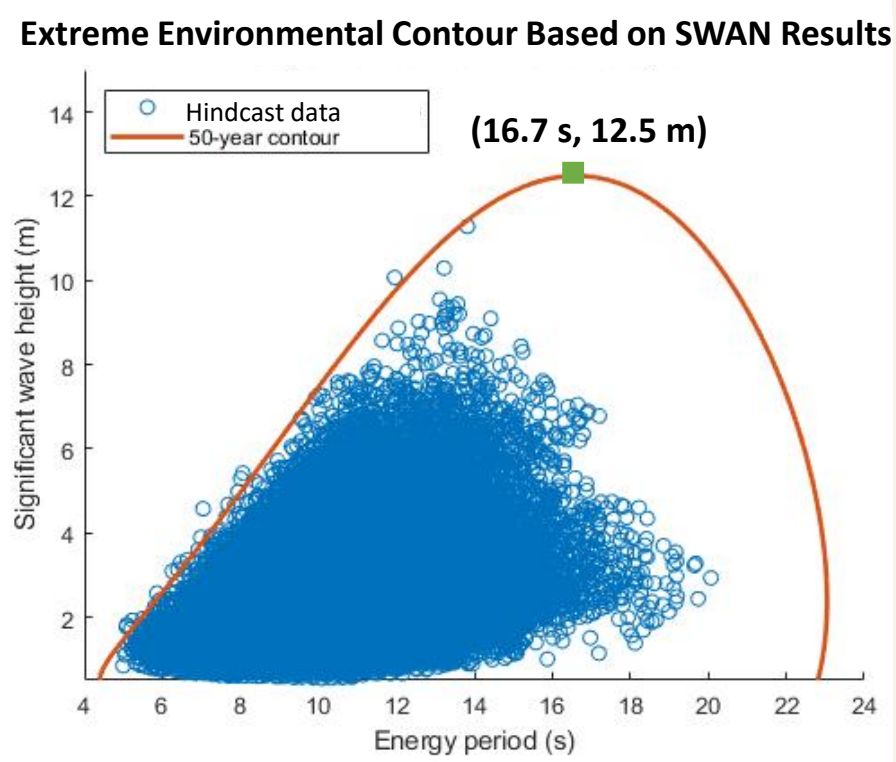


Dunkle, Gabrielle, Bryson Robertson, Gabriel García-Medina, and Zhaoqing Yang. "PacWave wave resource assessment." (2020).



Junhui Lou, Bryson Robertson
“PacWave marine resource assessment update” Citation TBD

Models ≠ Measurements



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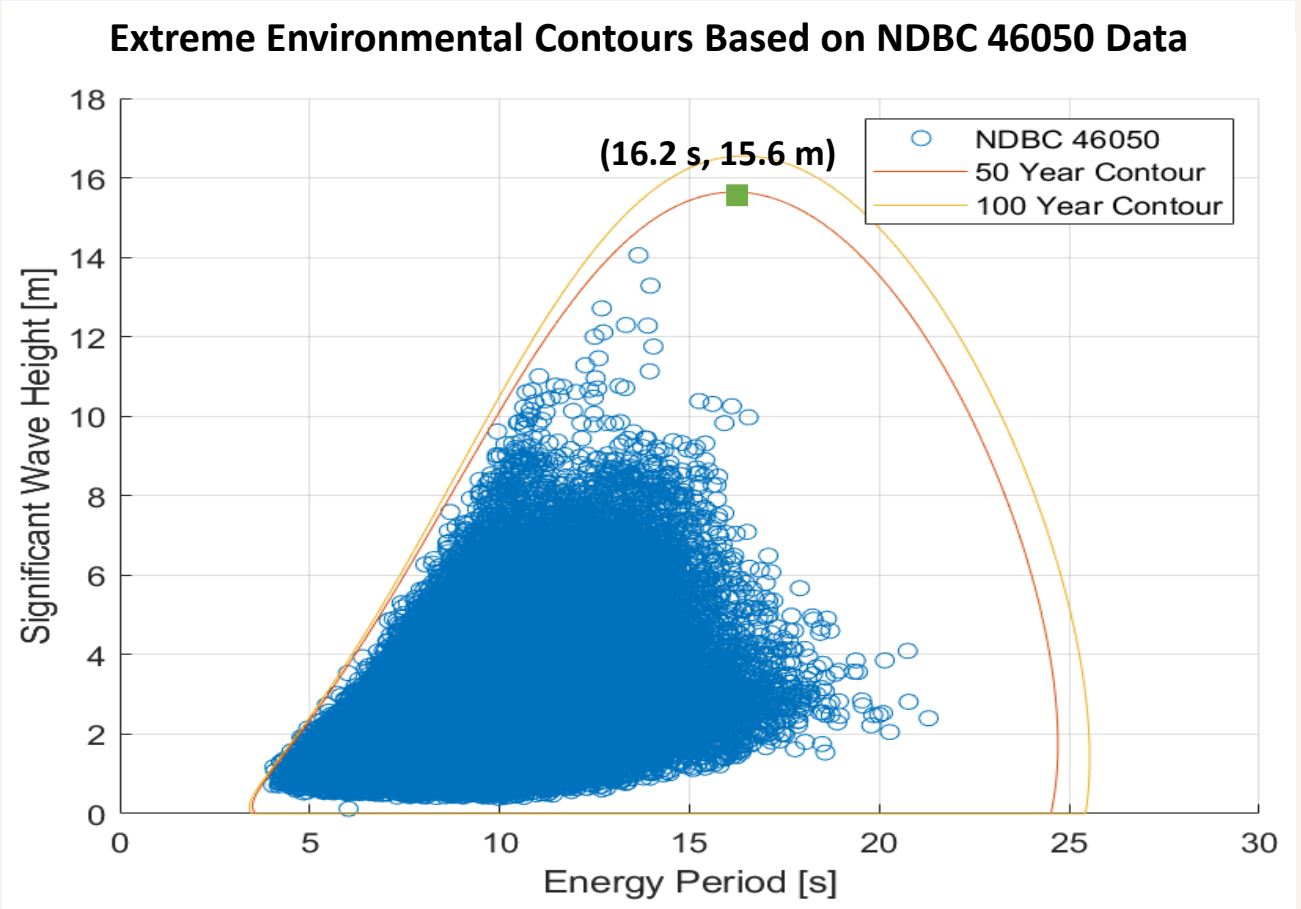

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International Electrotechnical Commission (IEC) – TC 114

Waves:

- Omnidirectional wave power
- Significant wave height
- Energy and peak period
- Wave direction
- Water Depth
- Spectral width

- Directionally resolved wave power
- Direction of…
- Directionality coefficient

Environmental Conditions:

- *Wind speed and direction (U_{10})*
- *Tidal and non-tidal current data*
- Water level fluctuations

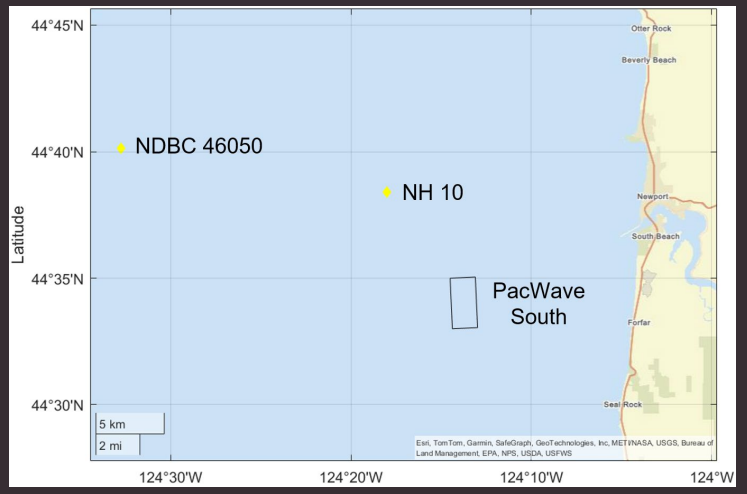
- Wave partitions

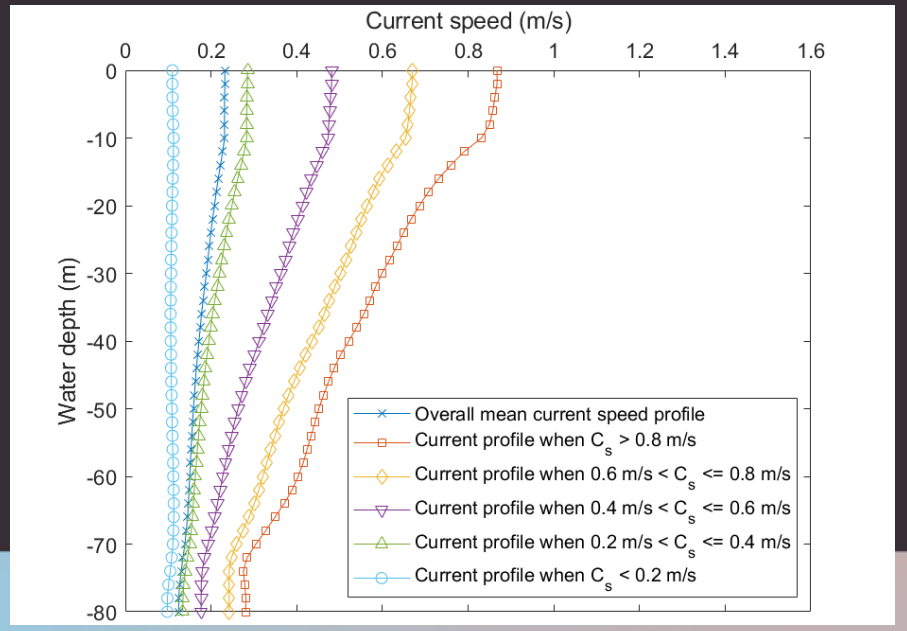
IEC TC-114: Marine energy -Wave, tidal and other water current converters

Concurrent Metocean Resource Assessment: PacWave

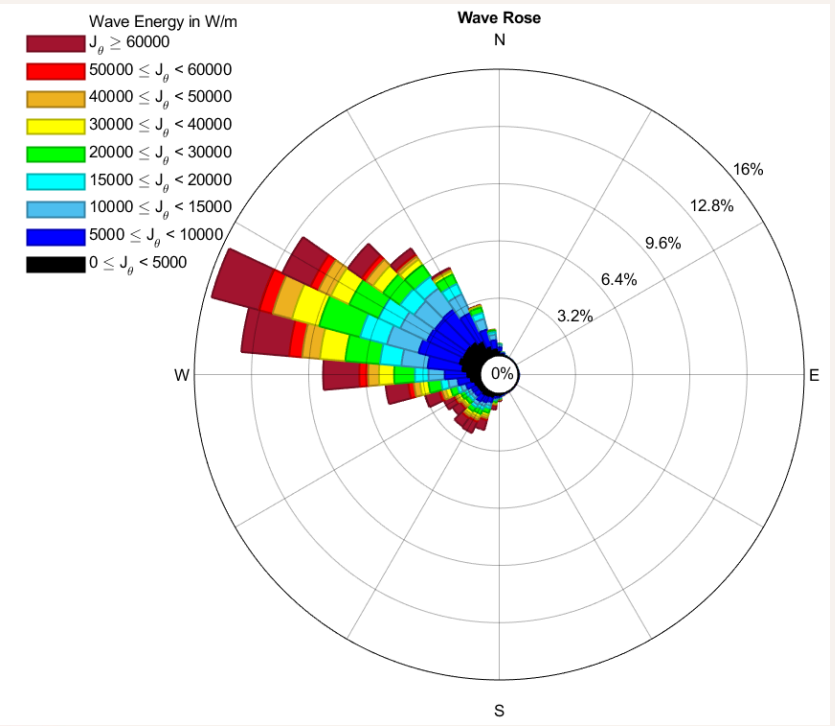
- NDBC Stonewall Banks Buoy
  - Station 46050 (1991-)
  - Additional parameters:
    - Wind speed
    - Wind direction

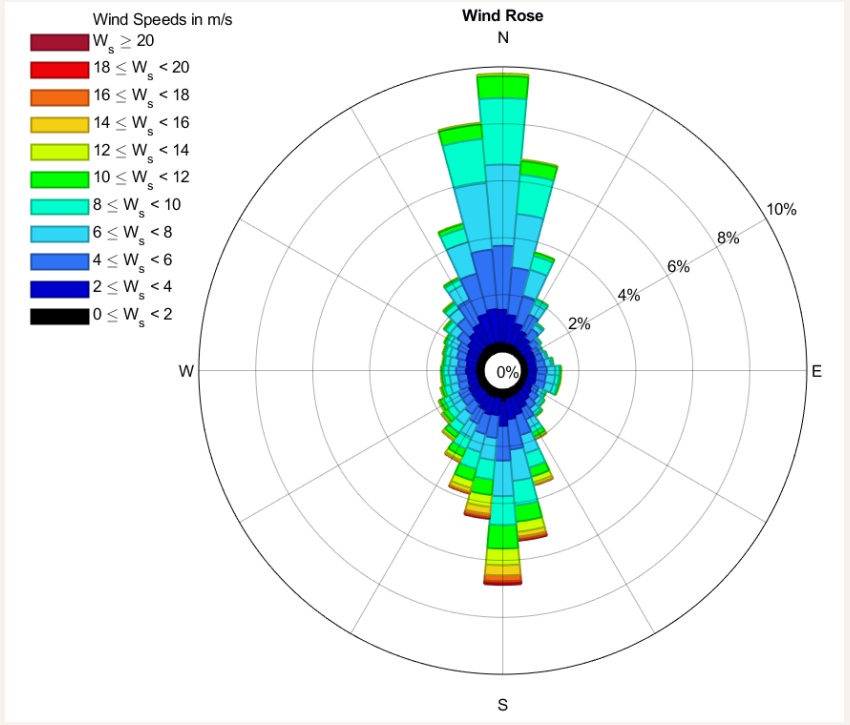
- NH-10 station
  - Parameters:
    - Current speed along water depth
    - Current direction along water depth
  - C. M. Risien, B. T. Cervantes, M. R. Fewings, J. A. Barth, and P. M. Kosro, “A stitch in time: Combining more than two decades of mooring data from the central Oregon shelf,” Data Brief, vol. 48, 2023

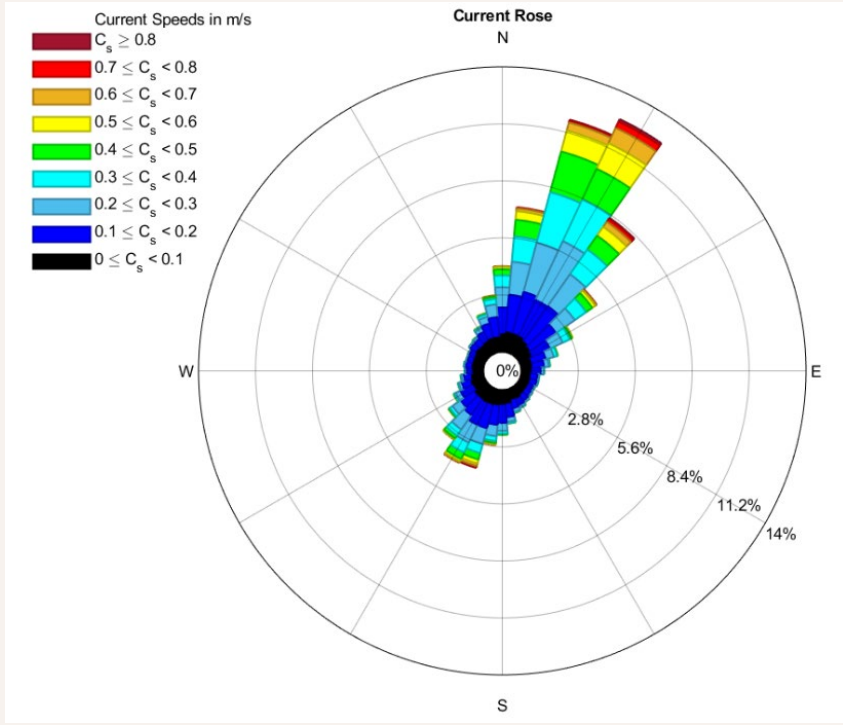




Individual Wave, Wind, and Current Conditions





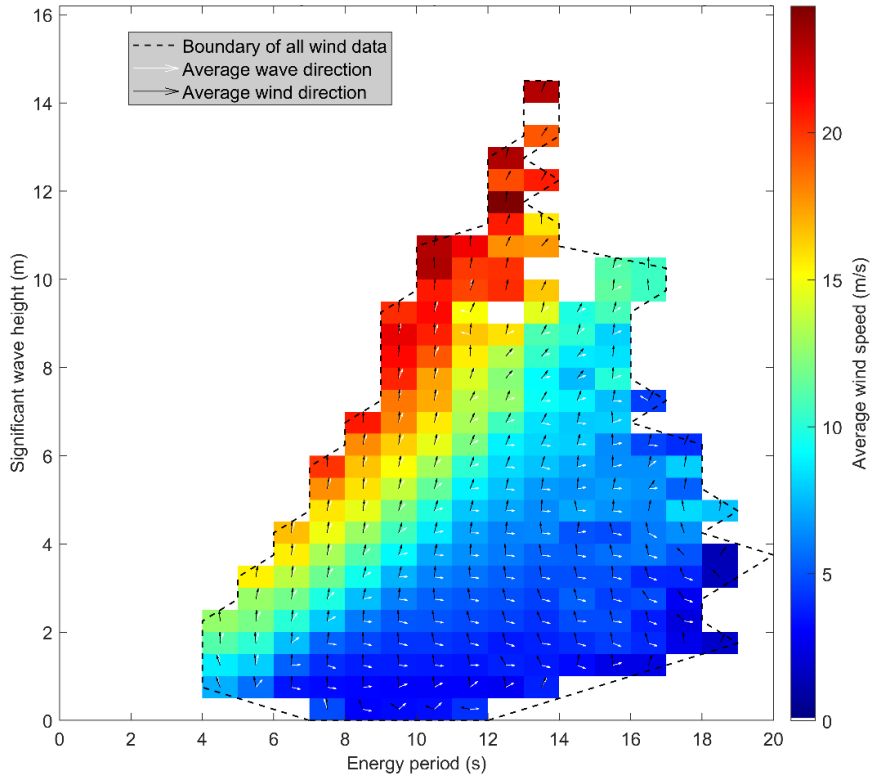


- Plotting wave, wind or current as isolated phenomena is important and necessary, but not enough when modeling any offshore structure, especially under extreme conditions
- The co-temporal distributions of winds, waves, and currents is important !

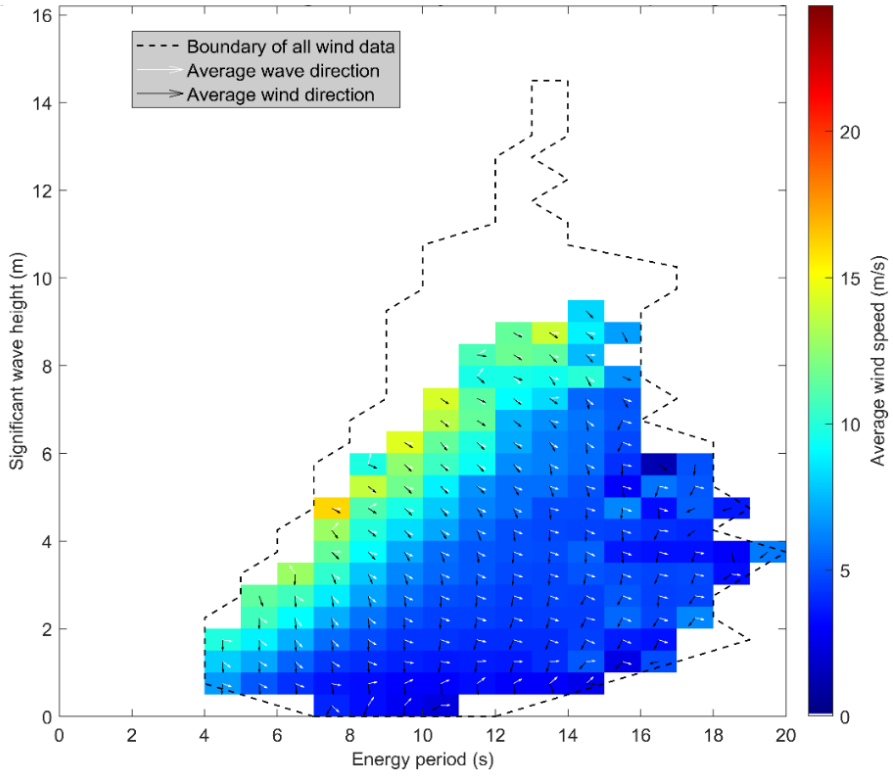
Co-Temporal Metocean Conditions (Wave + Wind)

- For winds coming from southerly directions, larger wind speeds generally occur with larger wave heights.
- For winds coming from northerly directions, lower wind speeds and associated wave conditions were noted.

Average Speed and Direction of Wind Coming from Southerly Directions



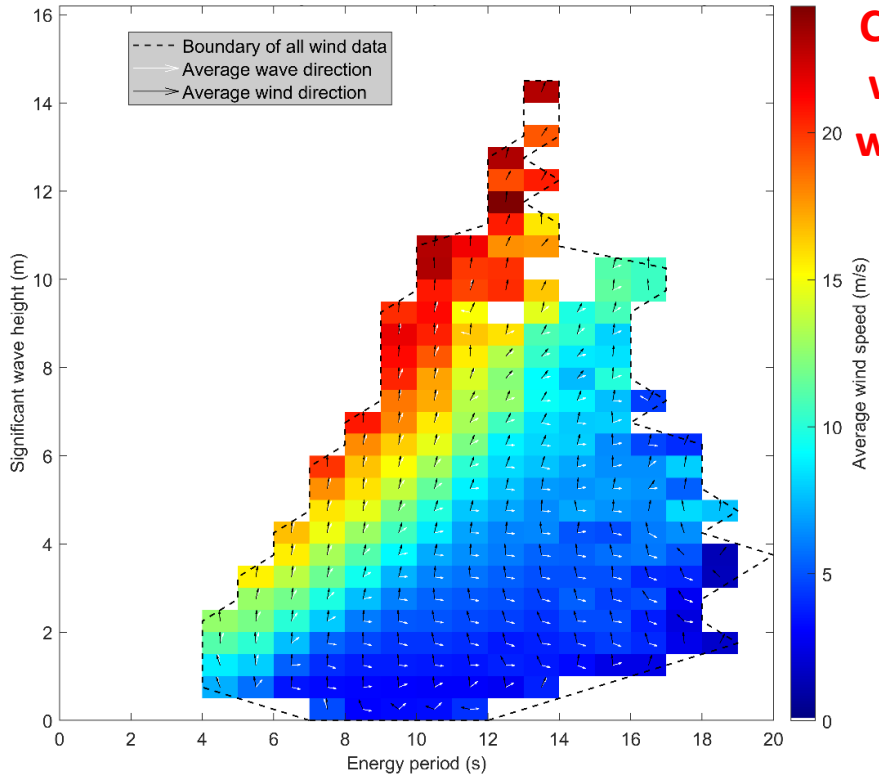
Average Speed and Direction of Wind Coming from Northerly Directions



Co-Temporal Metocean Conditions (Wave + Wind)

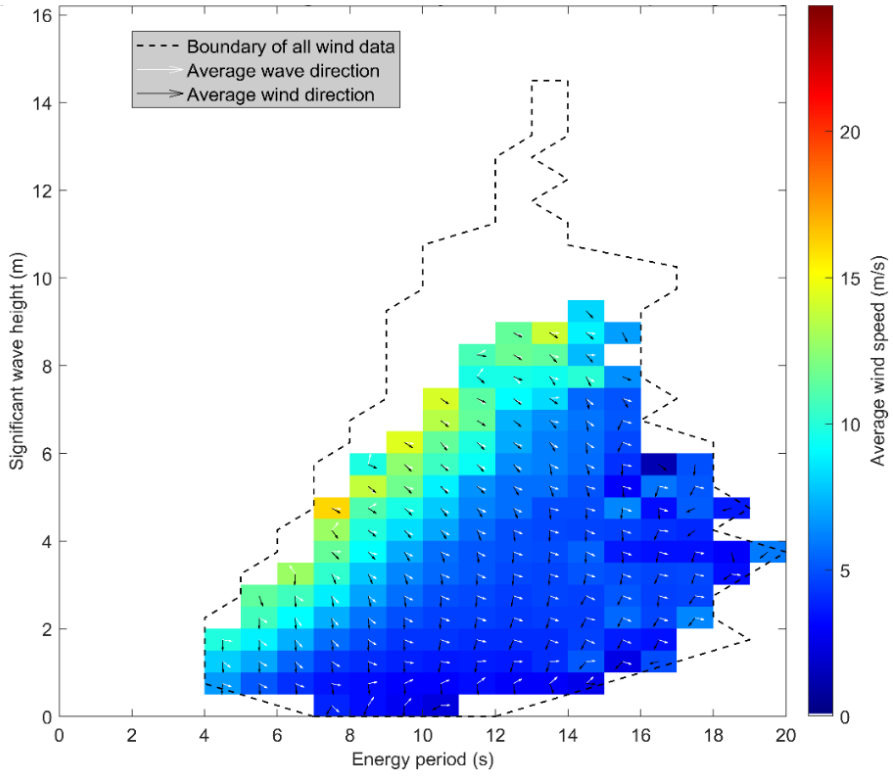
- Under operational conditions with moderate or small wind speeds and wave heights, the average wave directions were westerly.
- Under extreme conditions with high wind speeds and large wave heights, the average wave directions shift towards the north.

Average Speed and Direction of Wind Coming from Southerly Directions



Concurrent largest winds and largest waves towards the north

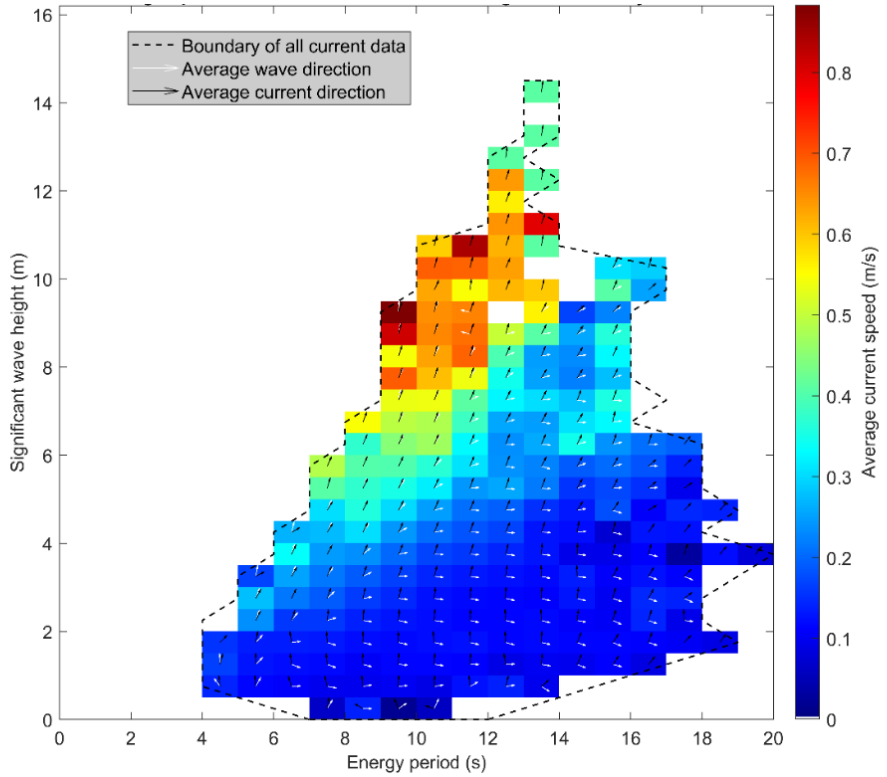
Average Speed and Direction of Wind Coming from Northerly Directions



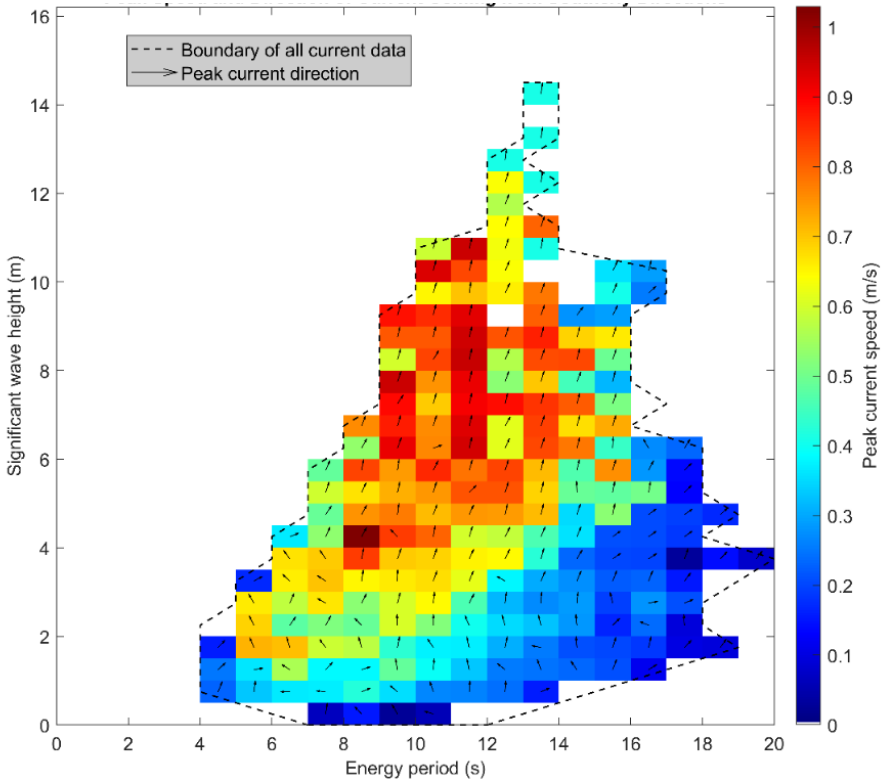
Co-Temporal Metocean Conditions (Wave + Current)

- For the currents coming from southerly directions, larger average current speeds generally occurred with larger wave heights; largest peak current speeds generally occurred at moderate to large wave heights.

Average Speed of Current Coming from Southerly Directions



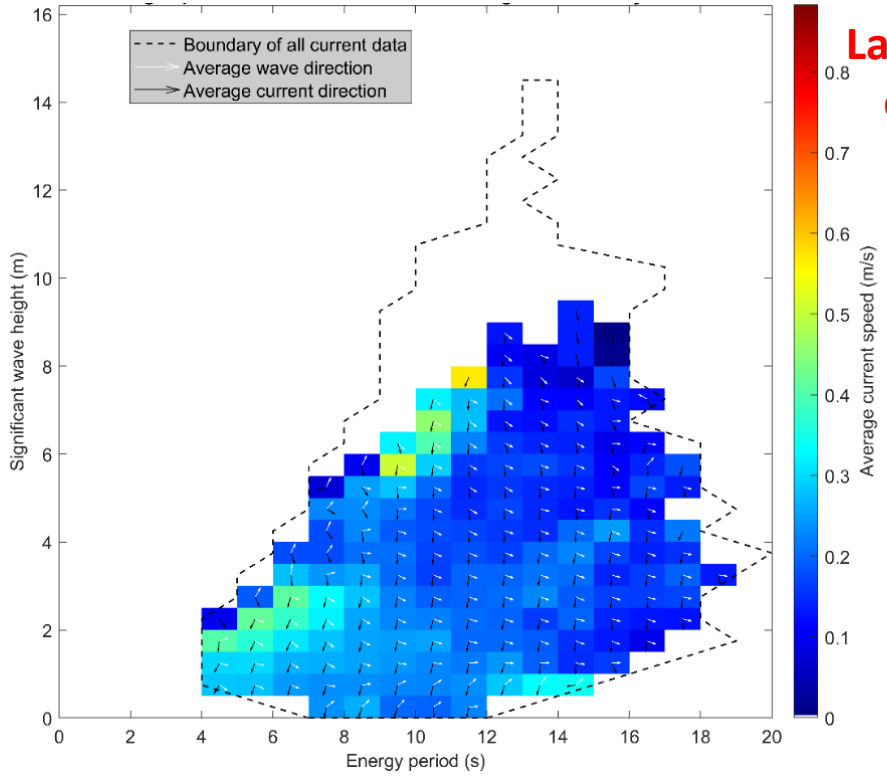
Peak Speed of Current Coming from Southerly Directions



Co-Temporal Metocean Conditions (Wave + Current)

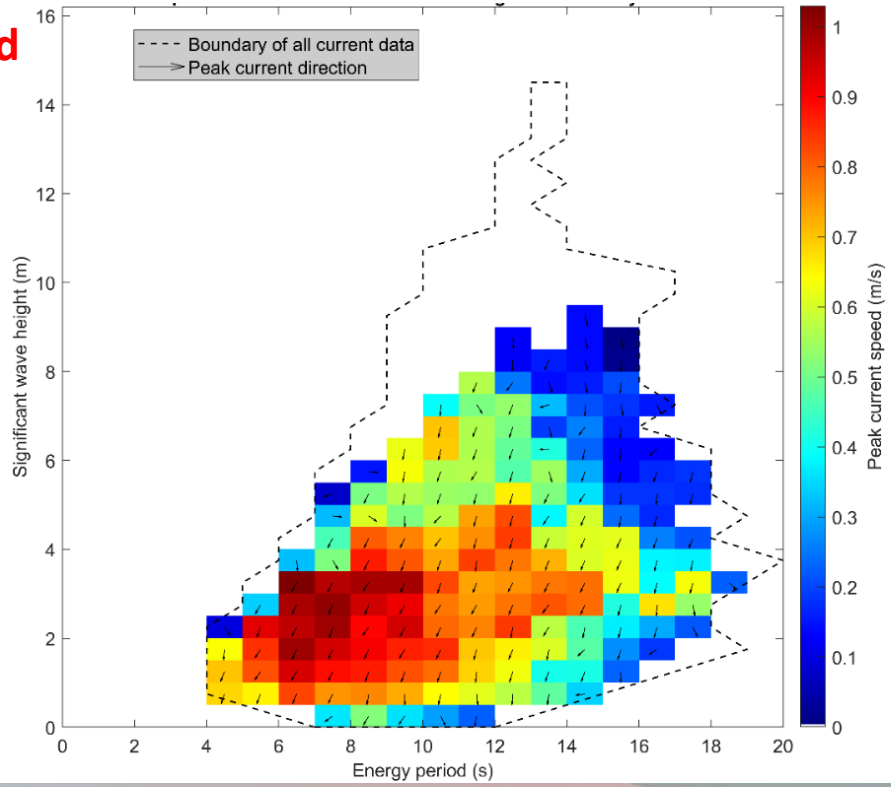
- For the currents coming from northerly directions, moderate average current speeds generally occurred at sea states with both moderate and small wave heights; largest peak current speeds generally occurred at moderate to small wave heights.

Average Speed of Current Coming from Northerly Directions



Largest currents could occur at small and moderate wave heights

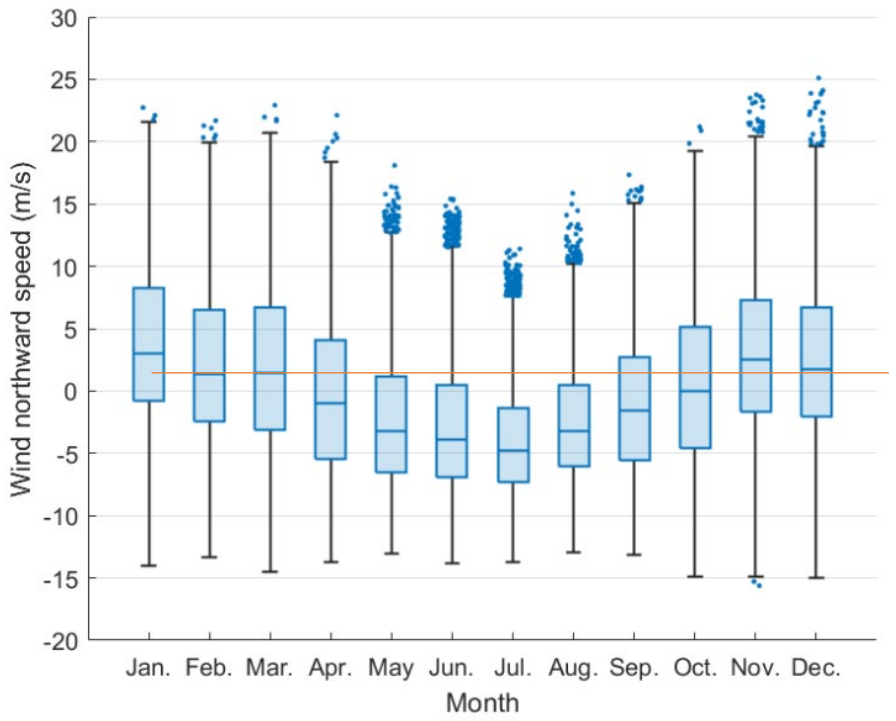
Peak Speed of Current Coming from Northerly Directions



Co-Temporal Metocean Conditions (Wind + Current)

- The dominant surface current direction is influenced by (1) both the large-scale California Current, which moves southward throughout the year along the western coast of North America, and (2) the local wind-induced current, which moves either southward or northward depending on the month of the year.

Box Plot of Monthly Wind Conditions at PacWave



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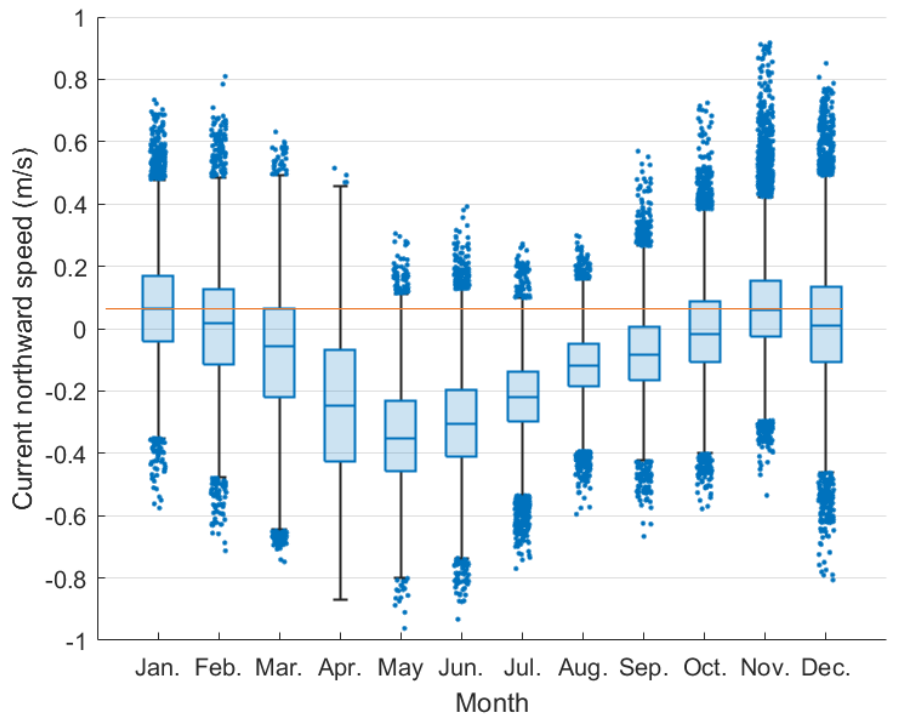
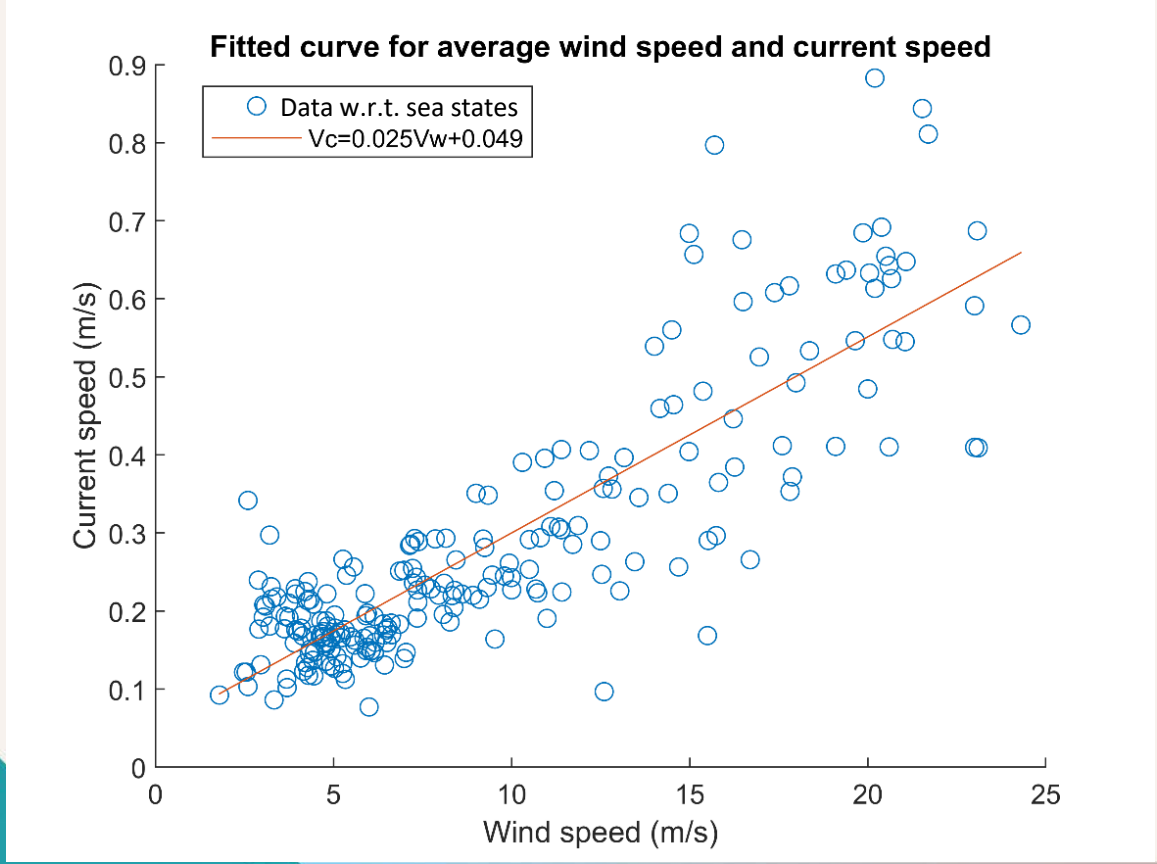


Co-Temporal Metocean Conditions (Wind + Current)

- Relationship between wind speed and current speed across both operational and hash wave conditions at PacWave.

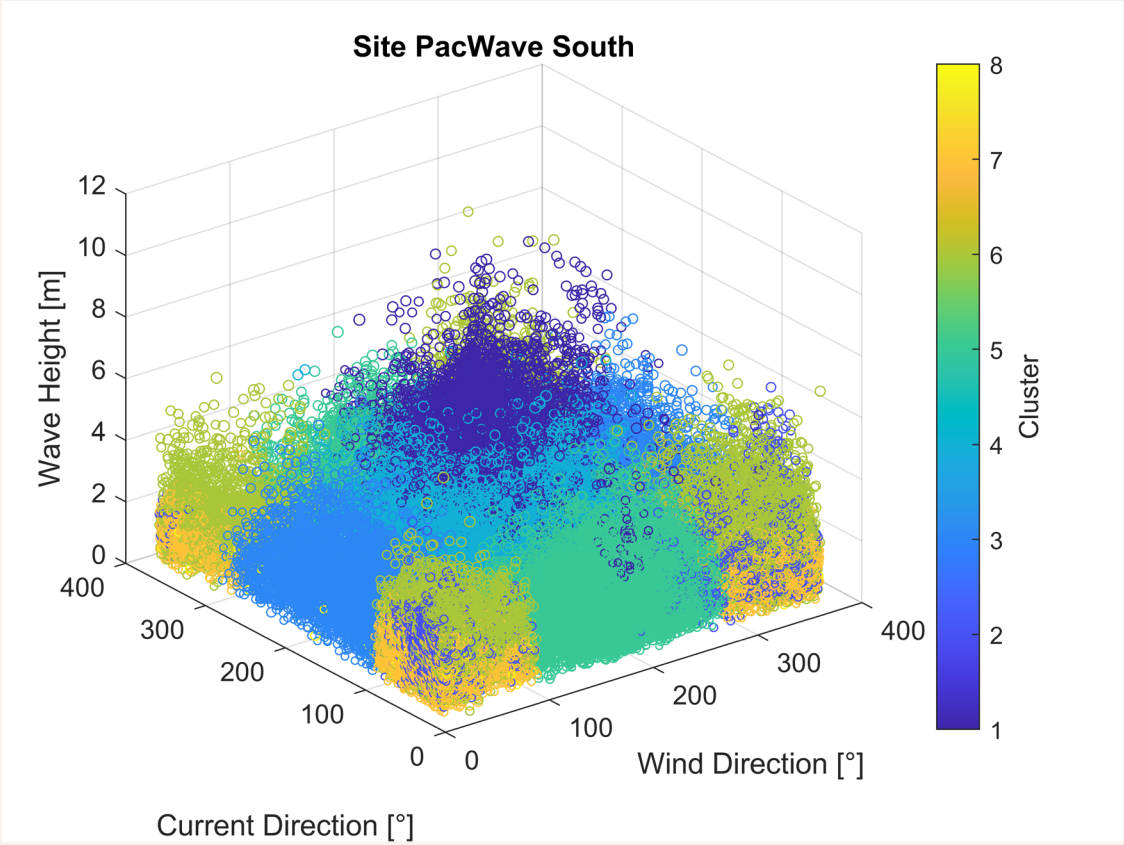
$$V_c = 0.025\,V_w + 0.049$$



Down selecting metocean conditions at PacWave

- K-means clustering analysis

Case #	Wave height Hs (m)	Energy period Te (s)	Wave direction (°) *	Wind speed (m/s)	Wind direction (°) *	Current speed (m/s)	Current direction (°) *
1	4.03	9.48	238	11.34	196	0.25	221
2	1.95	7.80	309	7.07	351	0.52	29
3	2.24	9.40	289	4.79	3	0.12	171
4	2.36	9.67	272	5.44	174	0.13	186
5	1.90	9.07	276	4.77	182	0.20	15
6	2.65	10.76	285	4.99	356	0.18	13
7	1.60	7.39	307	5.56	359	0.21	27
8	1.60	6.37	23	8.62	9	0.38	26



*The directions are defined as the direction from which wave, wind, and current originate. The units are degrees from true north, increasing clockwise.

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