Pacific Northwest
NATIONAL LABORATORY

Resource Assessment of OTEC, Tidal Stream and Ocean Current in Puerto Rico

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Pacific Northwest National Laboratory

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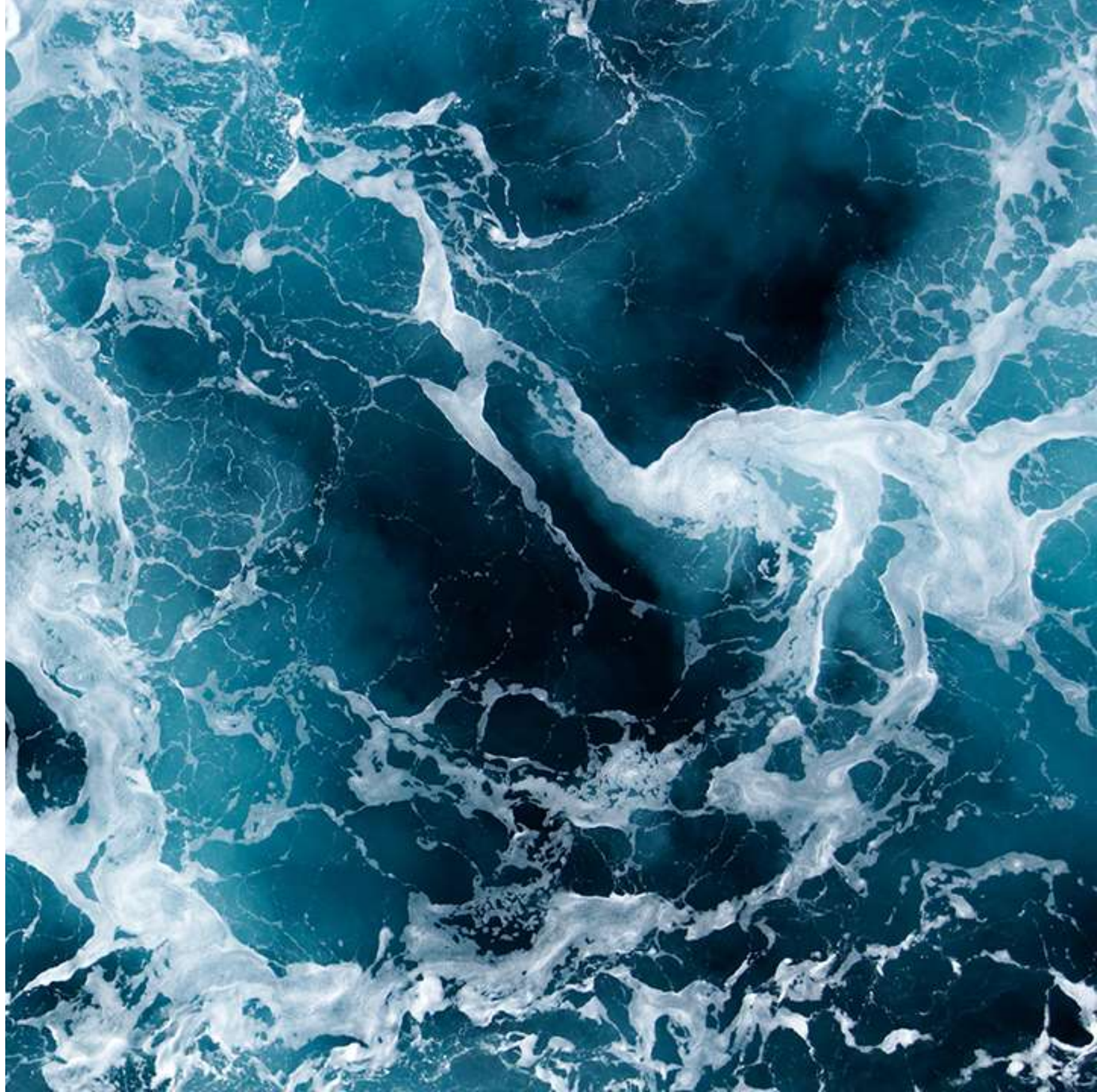
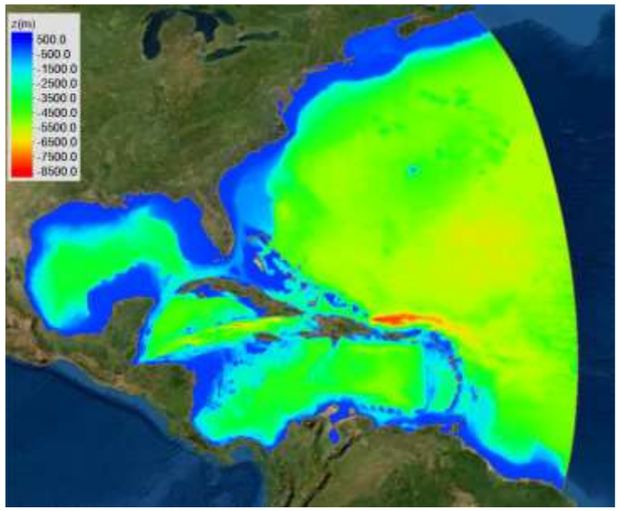


Background

- Puerto Rico is uniquely positioned for exploiting marine energy to meet their 100% renewable energy goal by 2050 and enhance their coastal resilience
- US DOE, Water Power Technologies Office (WPTO) funded the study of marine energy resource characterization and assessment
  - Wave
  - Tidal stream
  - Ocean Current
  - Ocean thermal energy conversion (OTEC)

Modeling Approach

- Leveraging existing and public model outputs
- Tidal Stream
  - ADvanced CIRCulation (ADCIRC)
  - High resolution – 30 to 100 m along Puerto Rico coastlines
  - One month simulation
- Ocean Current
  - American Seas (AmSeas) regional Navy Coastal Ocean Model (NCOM)
  - Resolution 1/30º
  - 8 years simulation (2014-2021)
- OTEC
  - HYbrid Coordinate Ocean Model (HYCOM)
  - Resolution 1/12º
  - 14 years simulation (2008 – 2021)

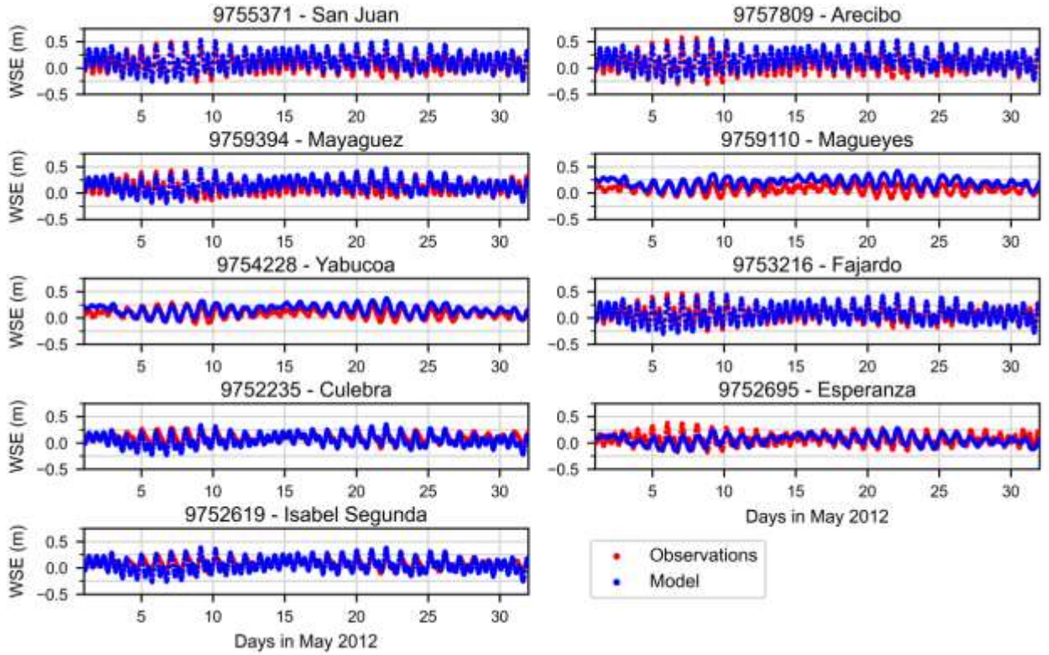


MODEL PROPERTIES FOR AMSEAS AND HYCOM

	AmSeas	HYCOM GOFS 3.0	HYCOM GOFS 3.1
Record length	2014 –2021	2008 –2018	2014 –2021
Horizontal resolution	1/30°	1/12°	1/12°
Number of vertical levels	40	33	40

Tidal Stream Resource Assessment

- Large model domain with high resolution in Puerto Rico
- Model validation with NOAA tide gauge data



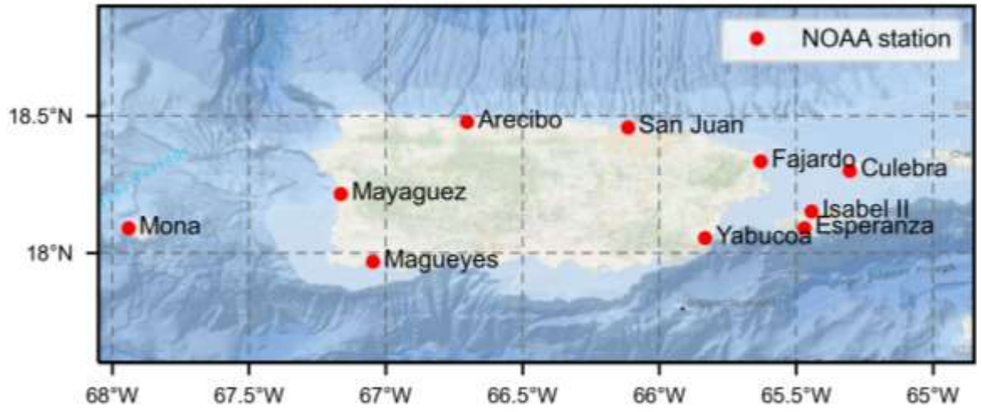


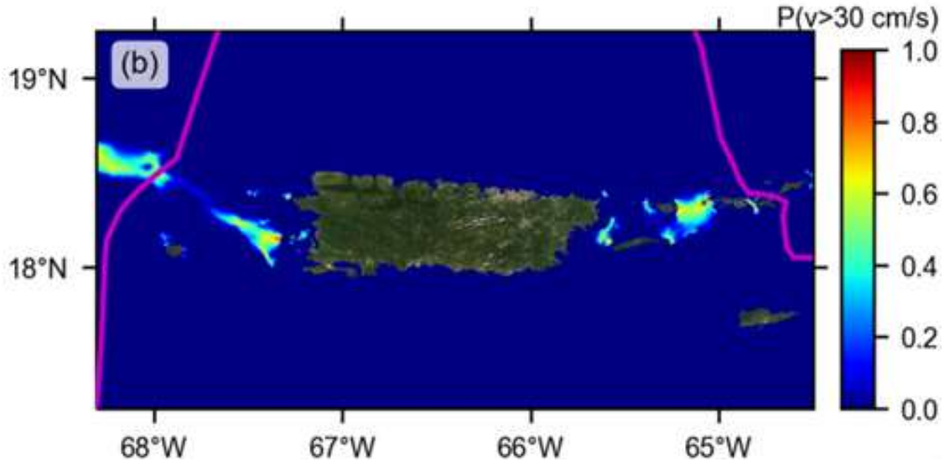
TABLE II
ERROR STATISTICS AT NOAA WATER LEVEL STATIONS

Station ID	Quantity	RMSE (m)	Bias (m)	R
9855371	San Juan	0.040	0.000	0.97
9757809	Arecibo	0.039	0.001	0.97
9759394	Mayaguez	0.034	0.001	0.96
9759110	Magueyes	0.032	0.000	0.91
9754228	Yabucoa	0.028	0.001	0.94
9753216	Fajardo	0.026	0.000	0.98
9759938	Mona	0.029	-0.001	0.93
9752235	Culebra	0.023	0.000	0.98
9752695	Esperanza	0.031	0.001	0.92
9752619	Isabel Segunda	0.024	0.001	0.98

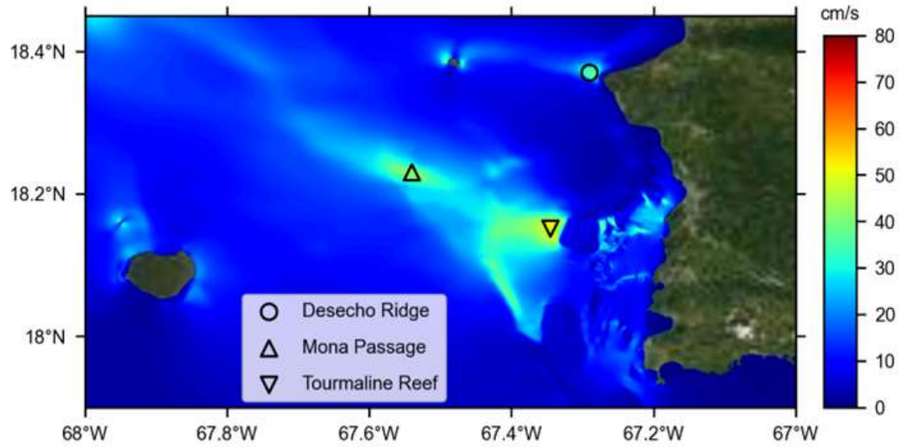
All measured time-series retrieved include N = 745 data points.

Tidal Stream Resource Assessment

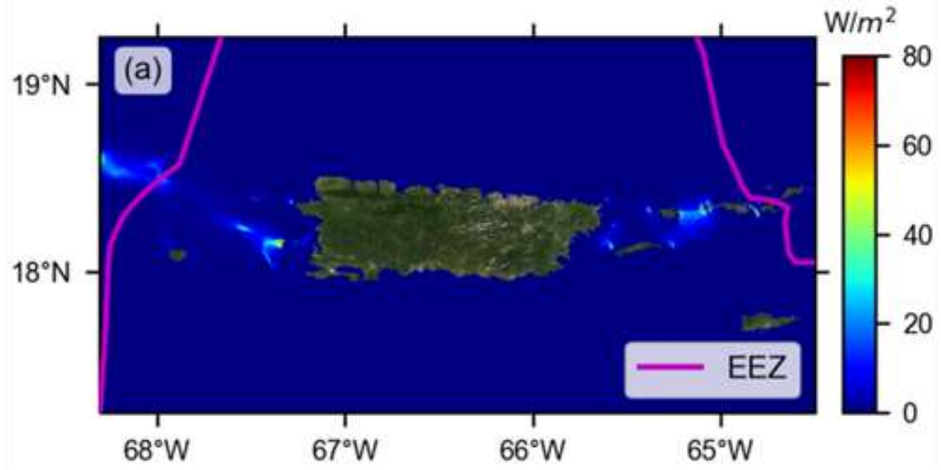
Probability of exceeding speeds of 30 cm/s

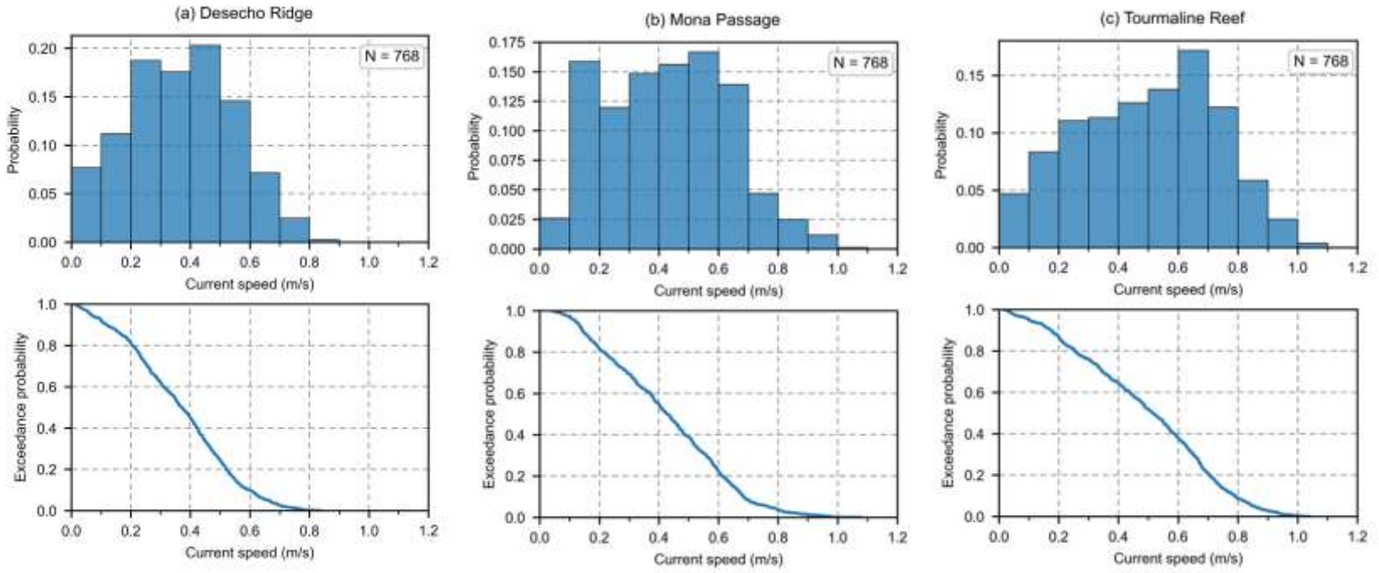


Tidal hotspots in Western Puerto Rico



Average tidal current power density





Ocean Current Resource Assessment

- Sea surface current data from AmSeas

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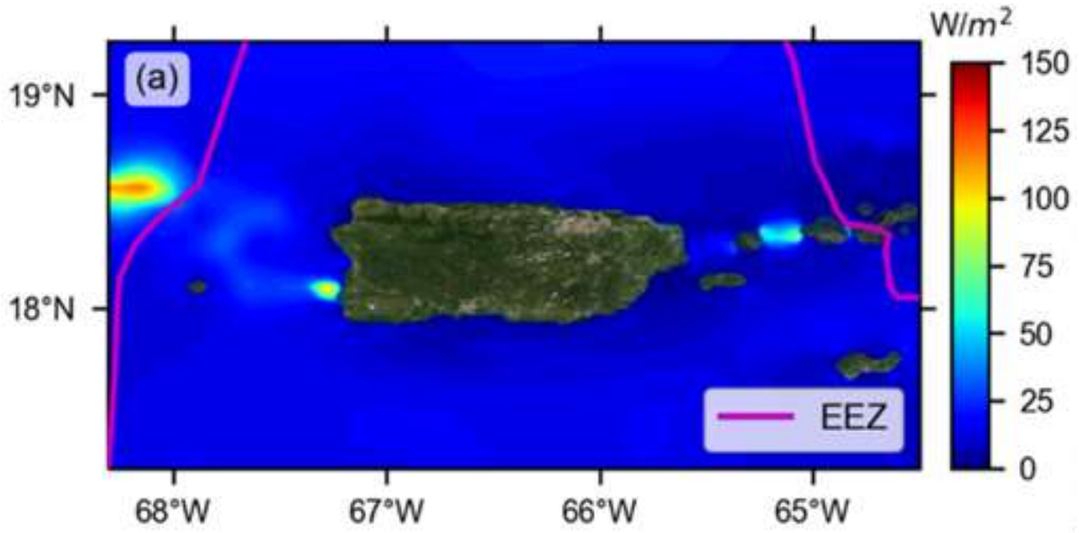
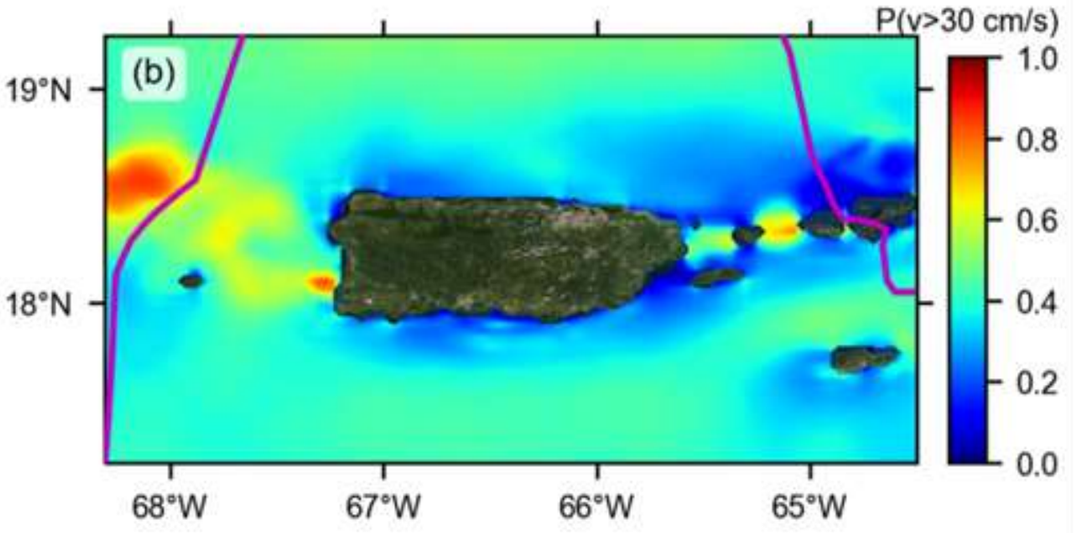
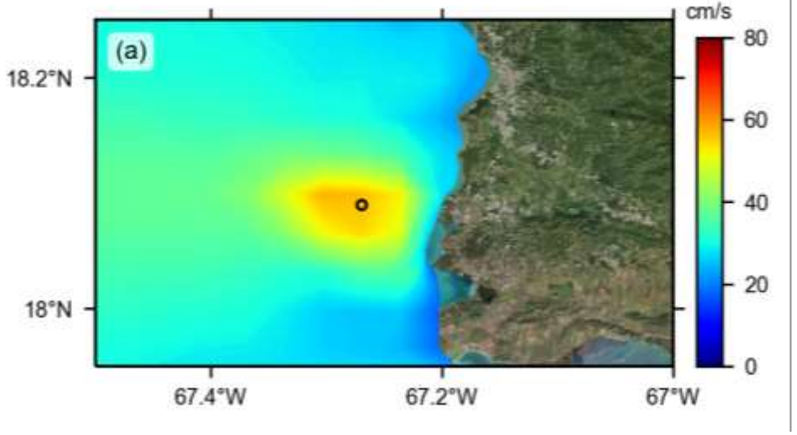


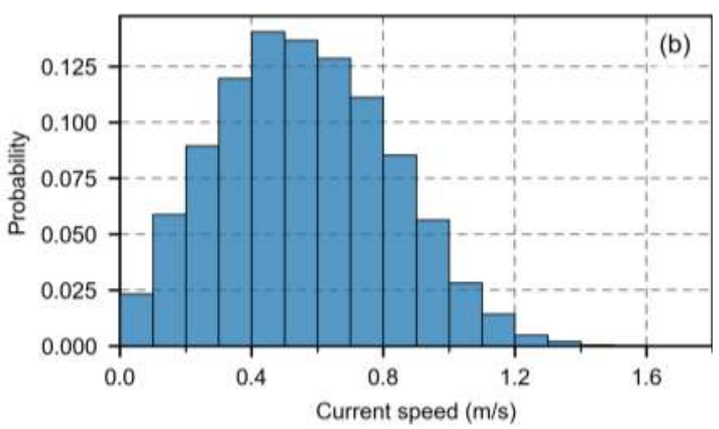
Probability of exceeding speeds of 30 cm/s

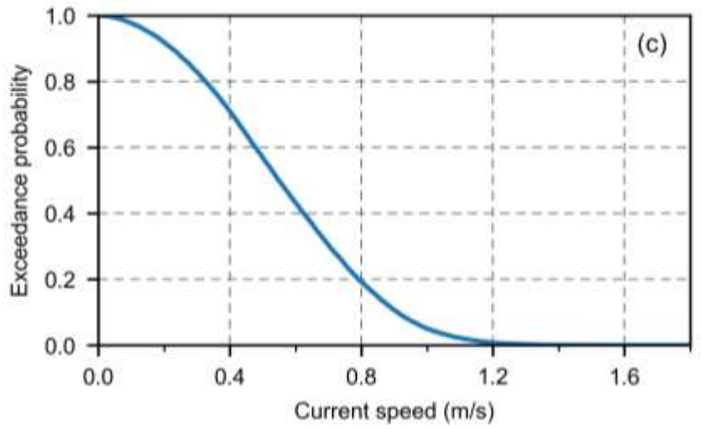


Ocean Current Resource Assessment – Hotspots

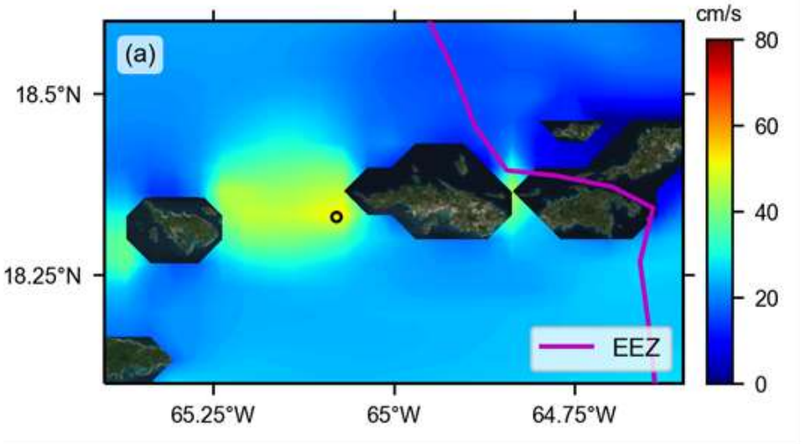
Southern Tourmaline Reef

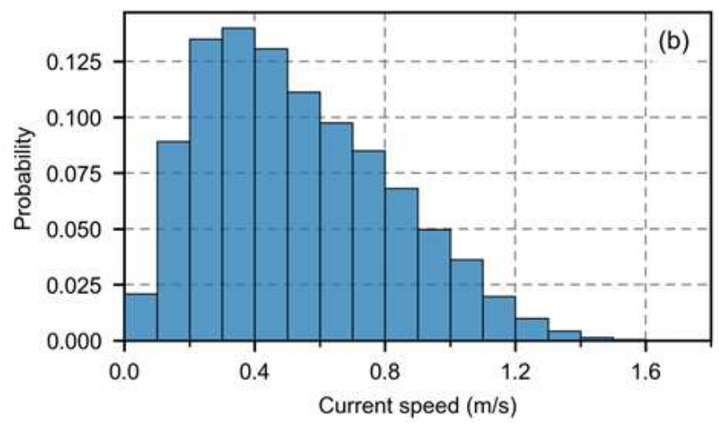


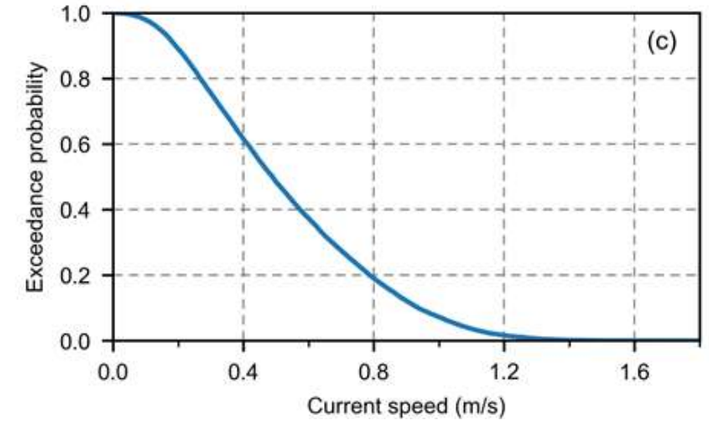




Charlotte Amalie and Culebra

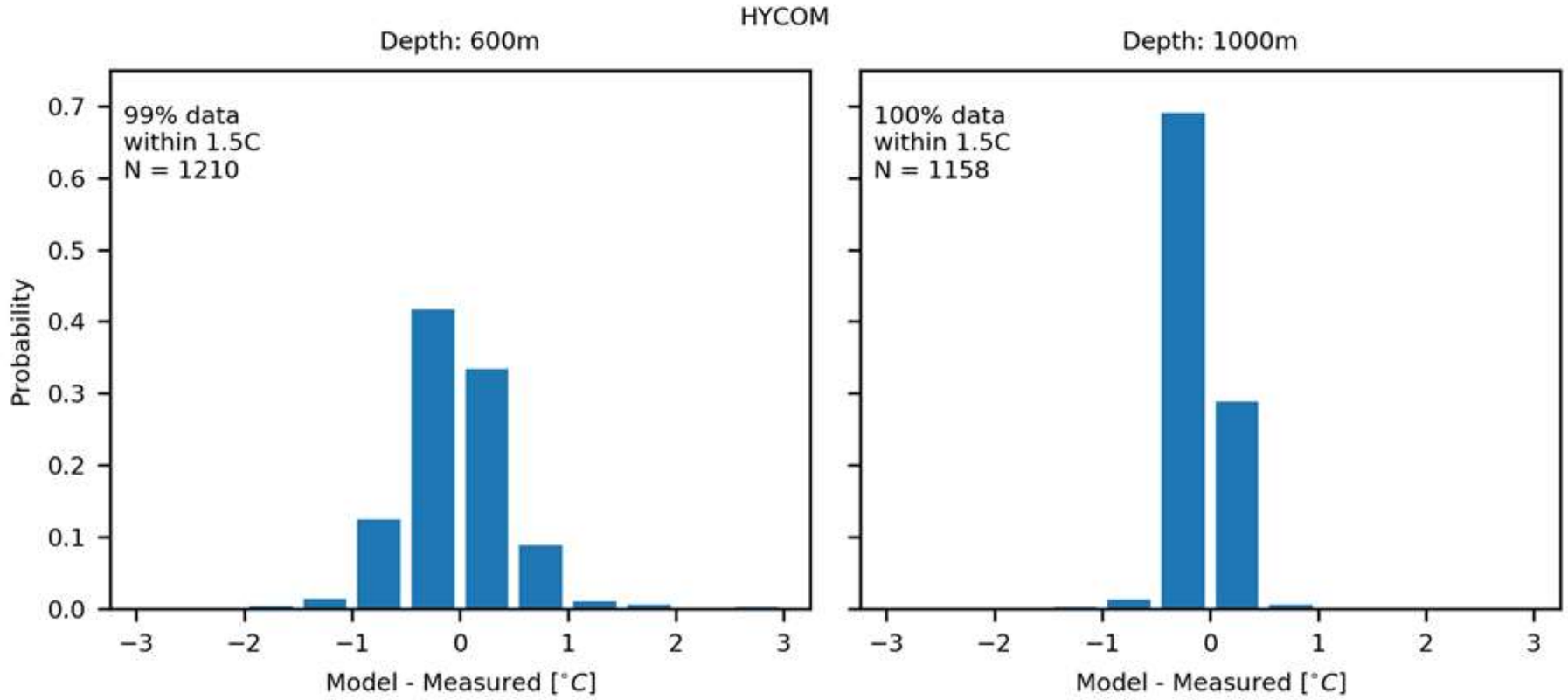






OTEC Resource Assessment – Model Data

- 3D temperature data from HYCOM
- Model validation – average difference in temperature between HYCOM and Argo floats at (left) 600 m and (right) 1,000 m water depth

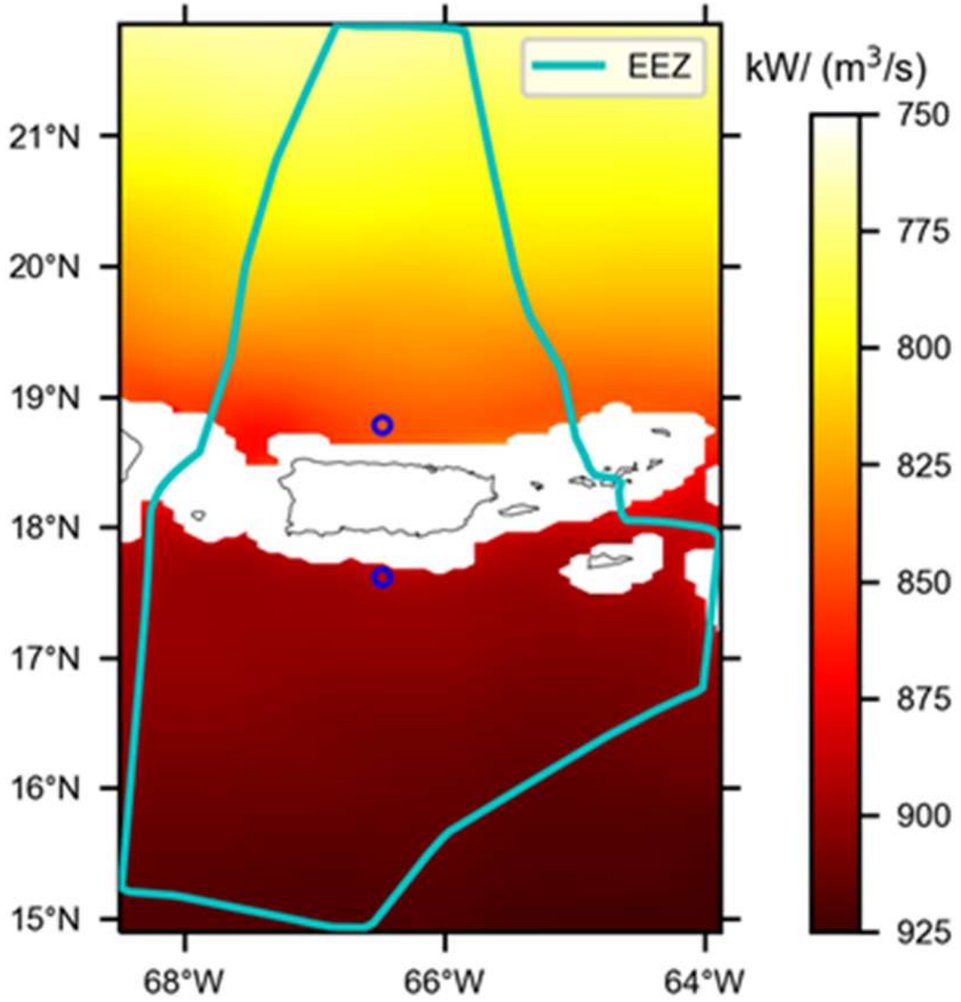


OTEC Resource Assessment

- Criteria: minimal thermal gradient of 20°C between the warm sea surface and cold-water intake depth
- OTEC Power Density:

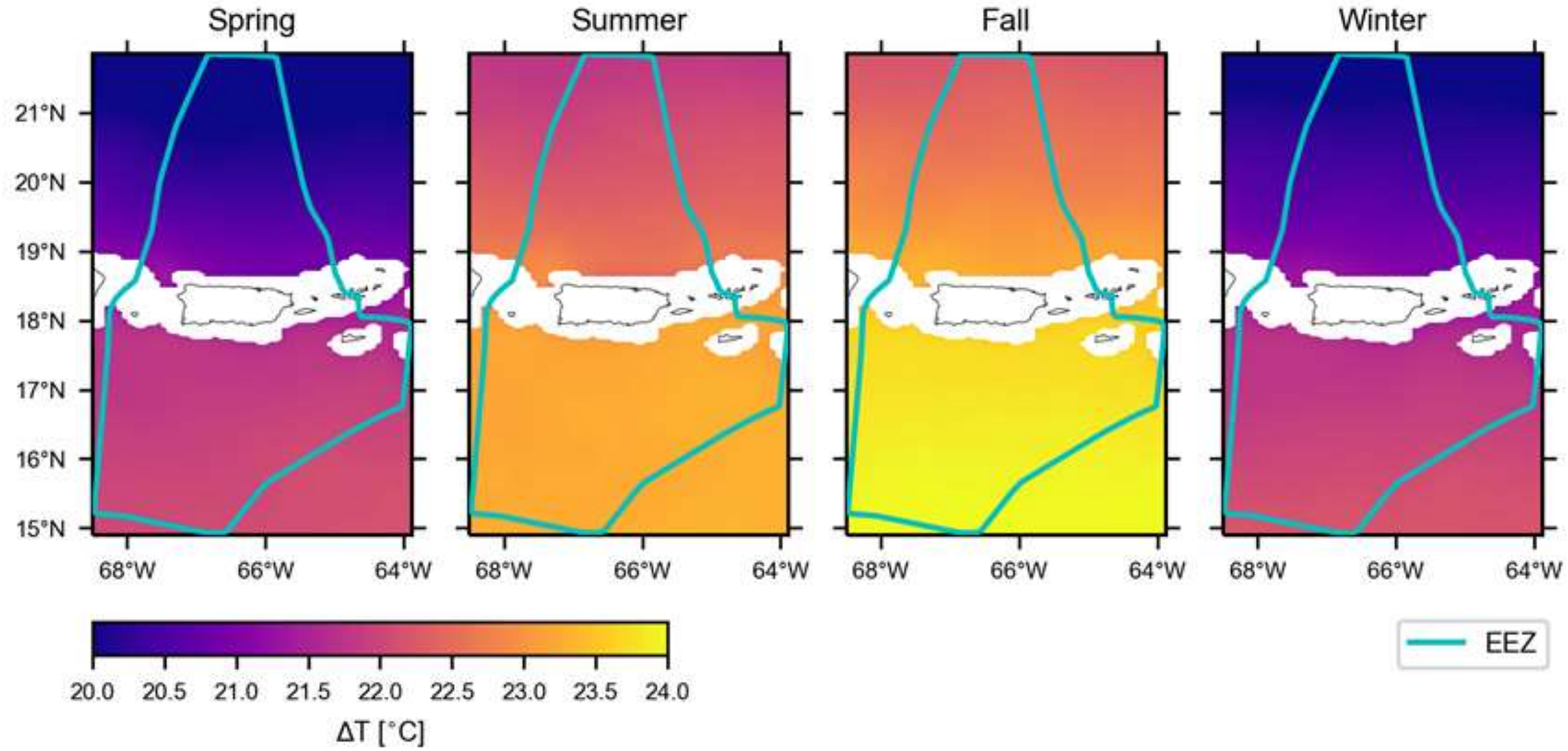
$$\frac{P}{Q} = \frac{\rho_w C_p E_{TG} (\Delta T)^2 (1-PL)}{8(273+SST)}$$

  - P = the thermal power,
  - Q = the deep seawater flowrate,
  - ρ_w = the average density of water,
  - C_p = the specific heat of water,
  - E_{TG} = the turbo generator efficiency,
  - PL = the losses due to pumping, and
  - ΔT = the temperature differential between sea surface and cold-water intake

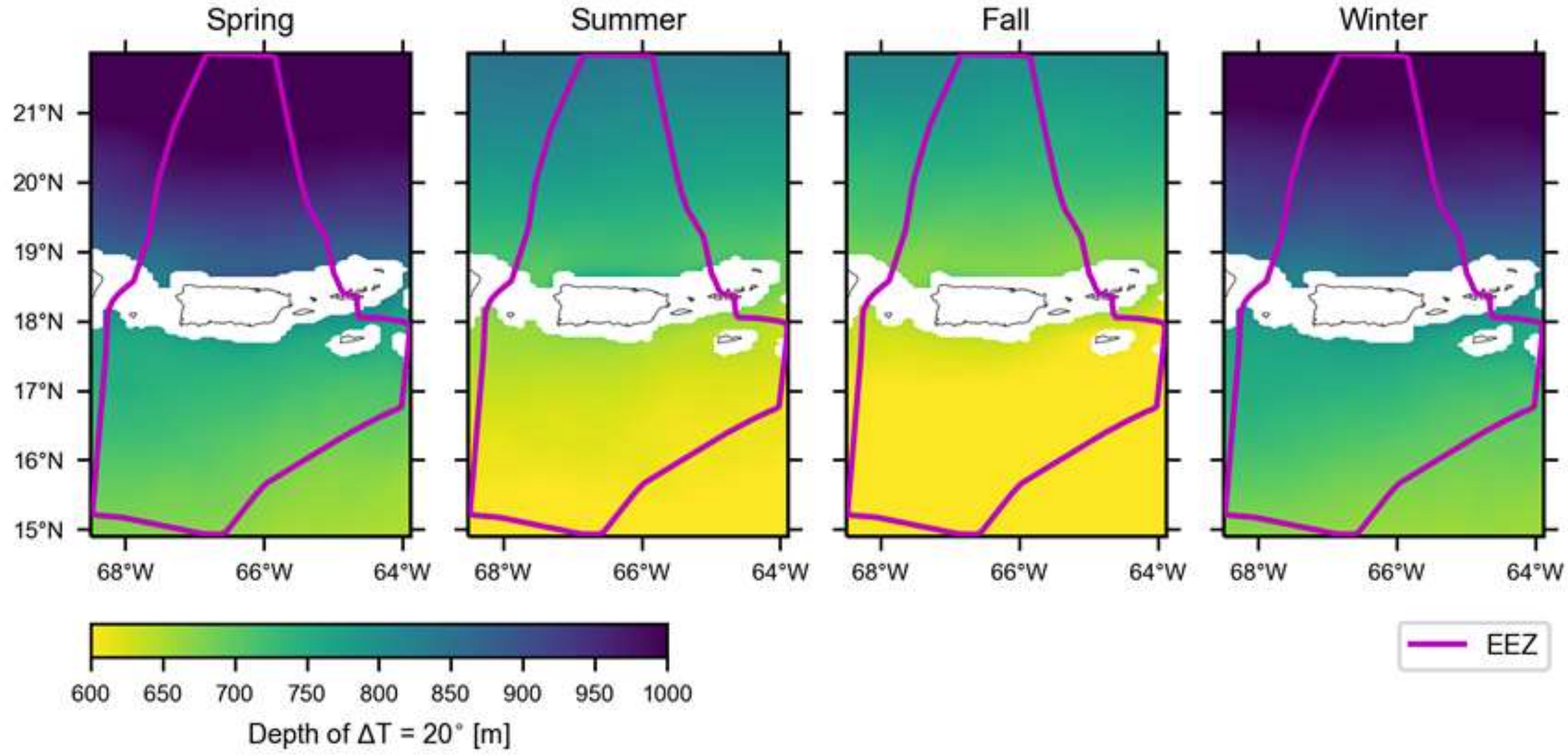


OTEC power density at 1000m depth based on average values of SST and ΔT

OTEC Resource Assessment – ΔT at 1000m Depth

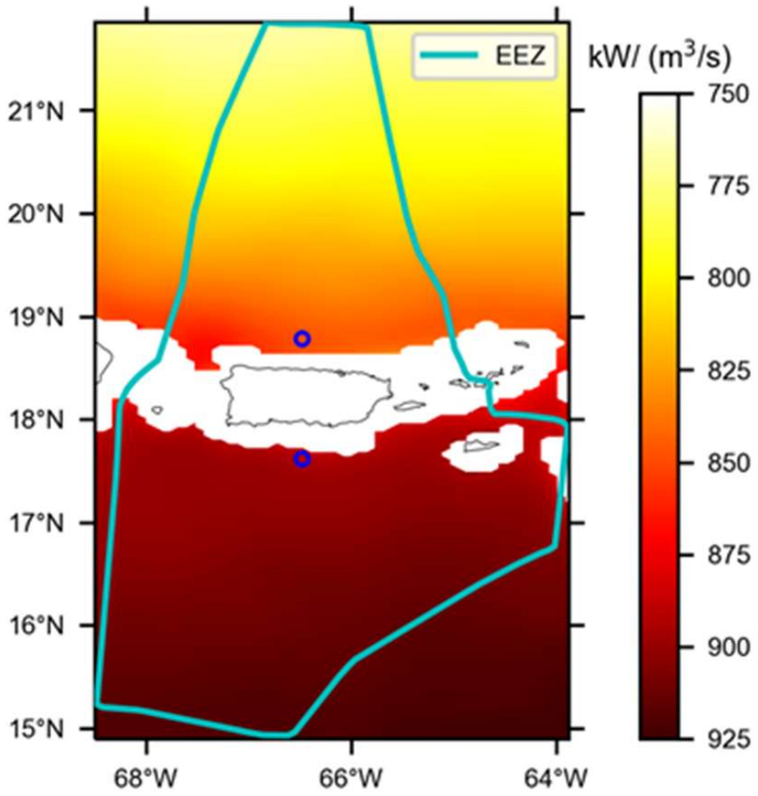


OTEC Resource Assessment – OTEC Operation Depth with ΔT = 20 °C



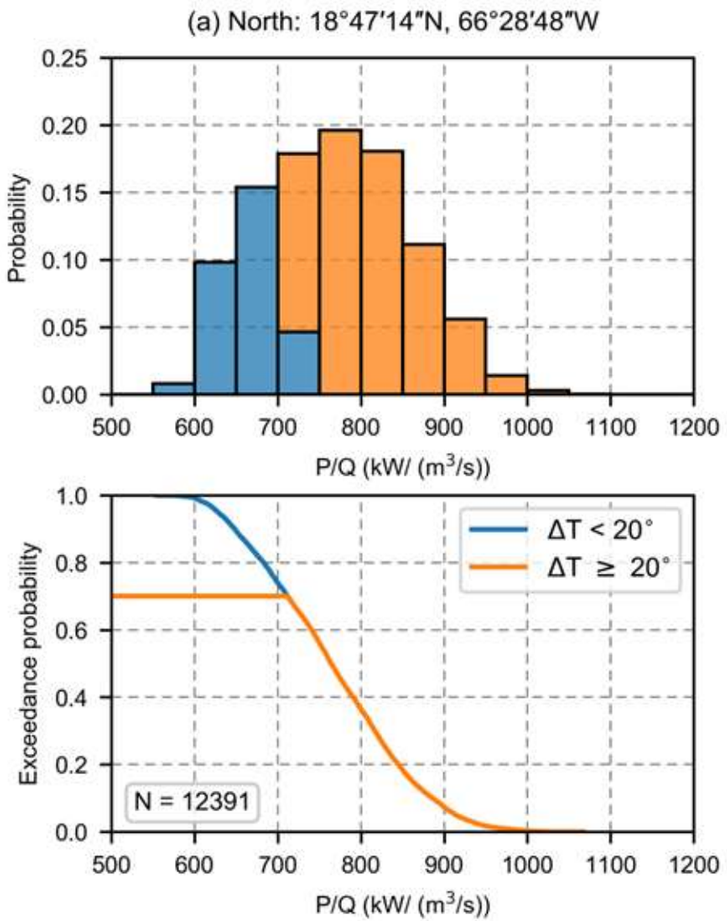
OTEC Resource Assessment

OTEC Power Density

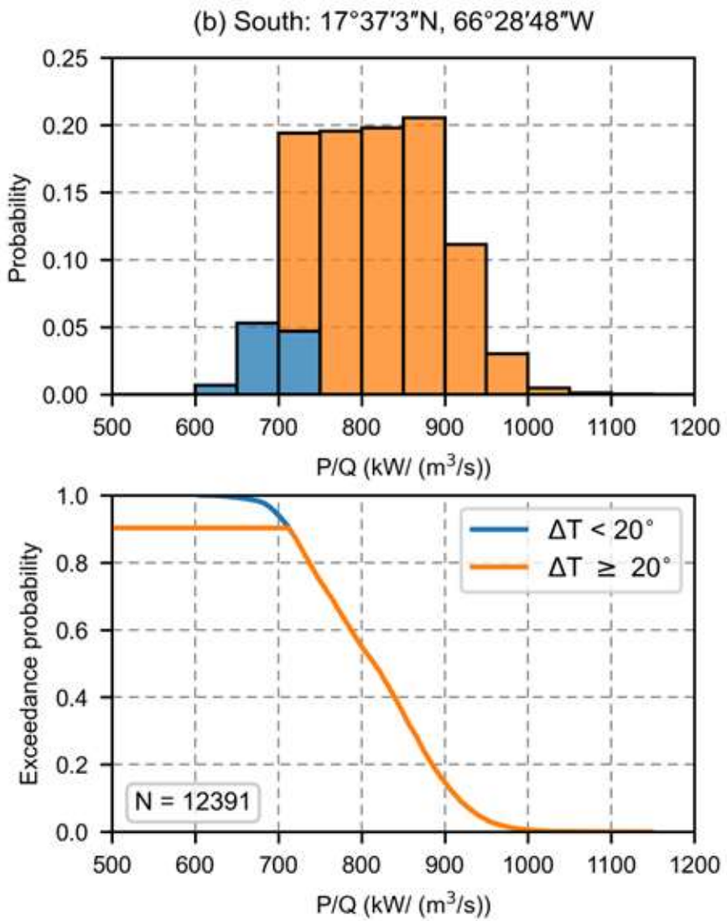


OTEC power density at 1000m depth based on average values of SST and ΔT

North Shore



South Shore



Conclusions

- Tidal stream and ocean current hot spots are identified near the western coast of the main island

- OTEC is the most promising marine energy source for electricity generation, especially in the southern coastal water of Puerto Rico

Acknowledgement: This project was funded by the US Department of Energy, Water Power Technologies Office

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Thank you

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