Effect of parametric wave spectra on mean annual power

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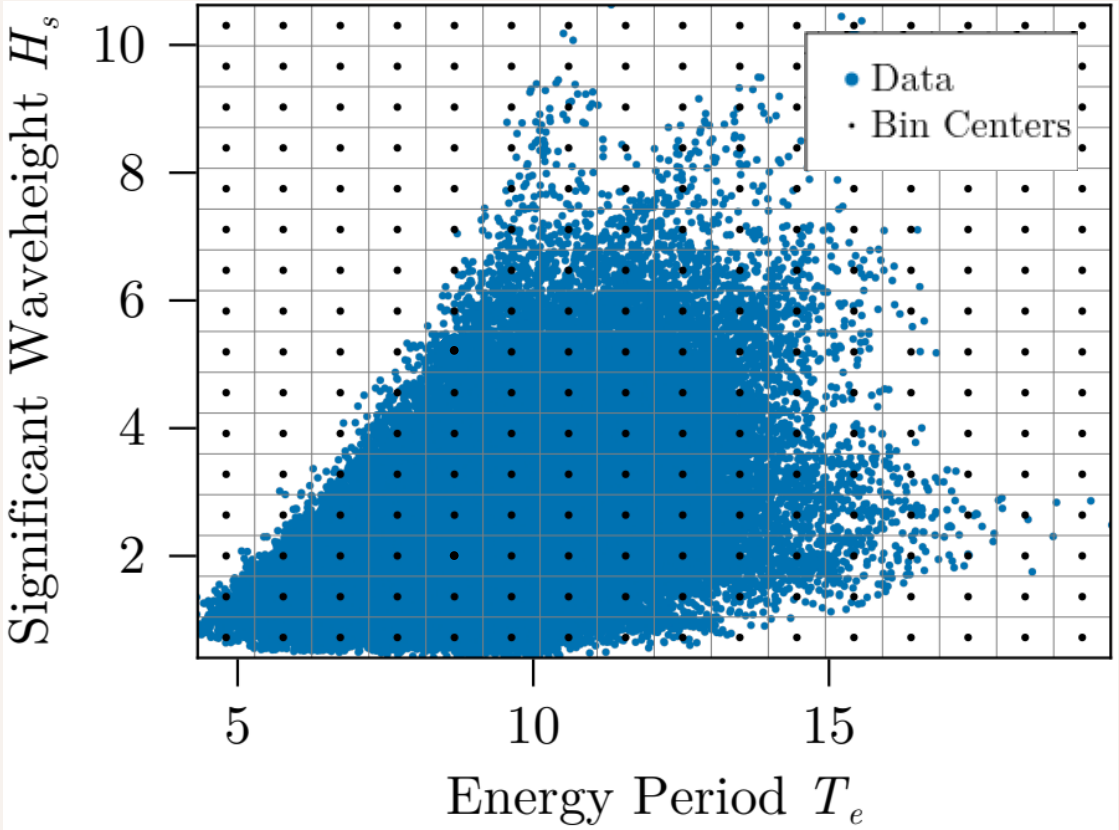
SAND2024-10236C

Annual Energy Estimate

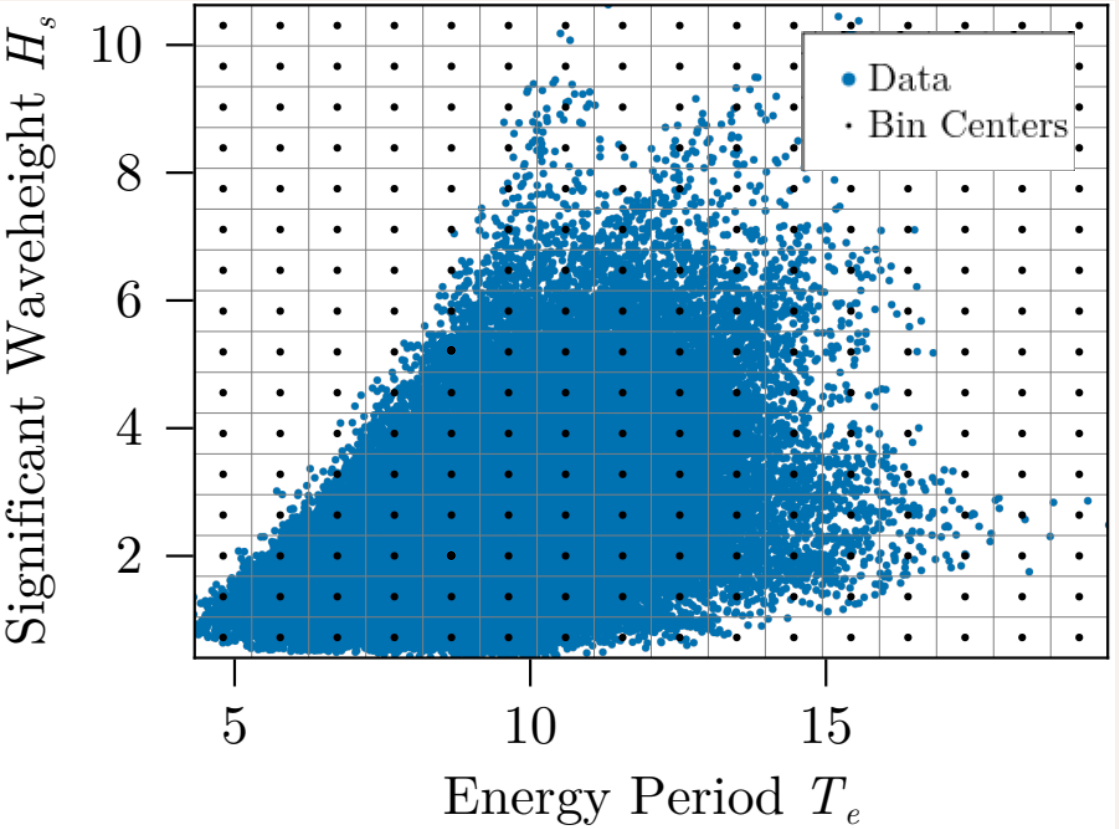
- Method of bins
- IEC Standards[1]
  - Min 10 years, Max 1s & 0.5m bins
  - H_s and T_e required
  - Other parameters optional



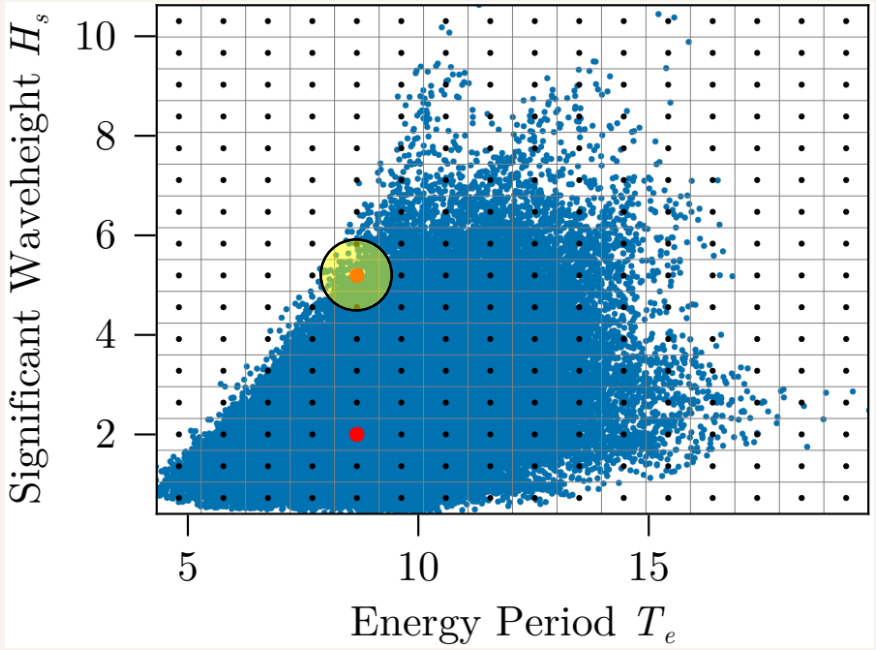
[1] IEC TS 62600-100, "Marine energy-wave, tidal and other water current converters-part 100: Electricity producing wave energy converters - power performance assessment." International Electrotechnical Commission, Tech. Rep., 2012.

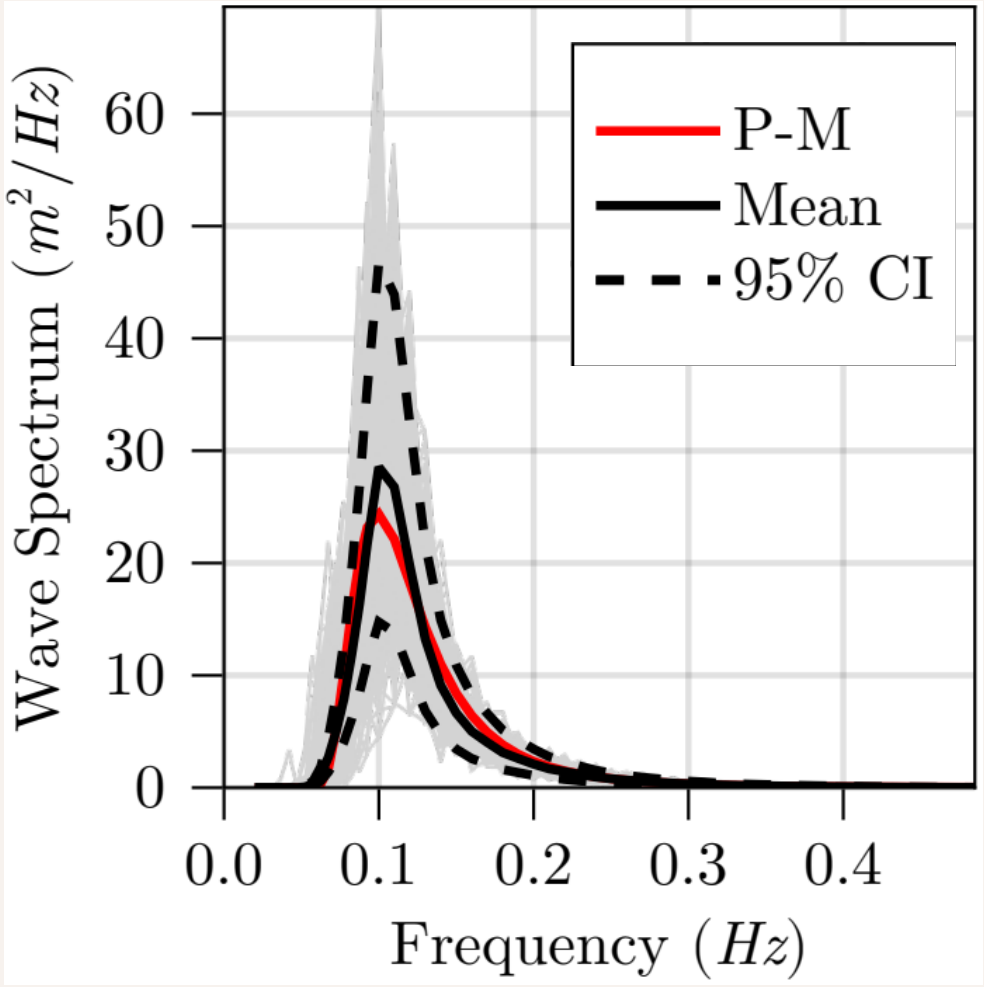
Current Assumptions

- All observed spectra within a bin are just different realizations of the same underlying stationary & ergodic Gaussian process
- Difference between them is due to sampling error (finite record)
  - χ^2 Sampling Error



Current Assumptions not entirely True





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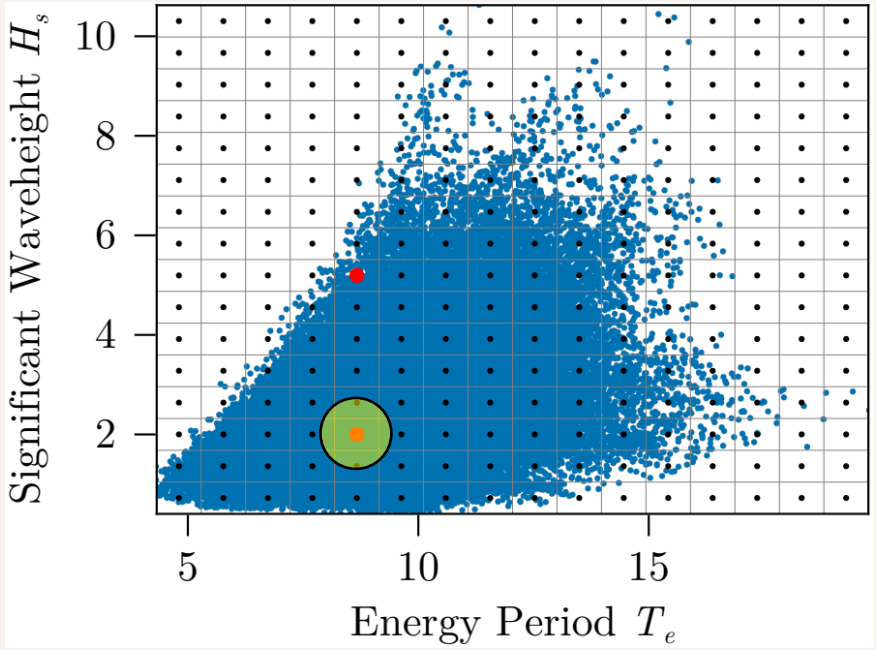

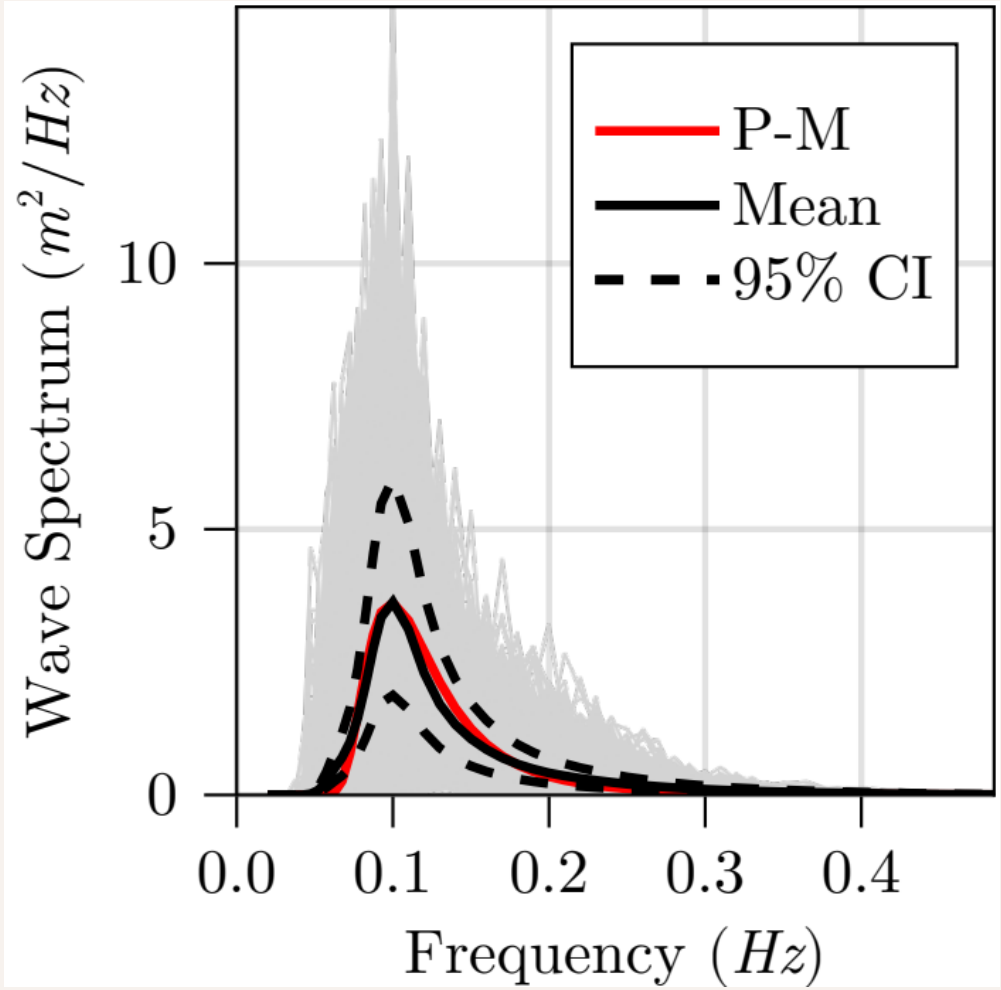

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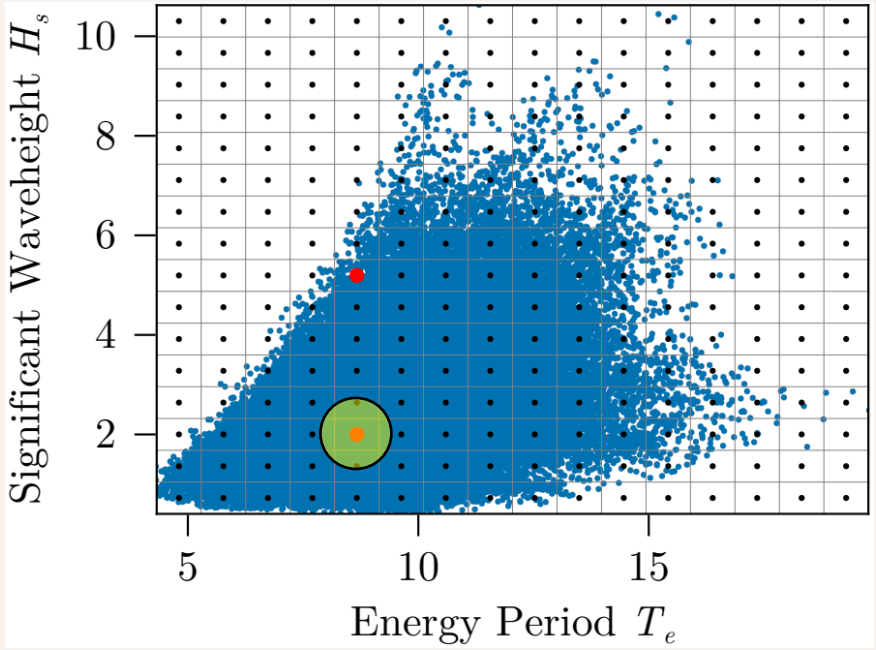
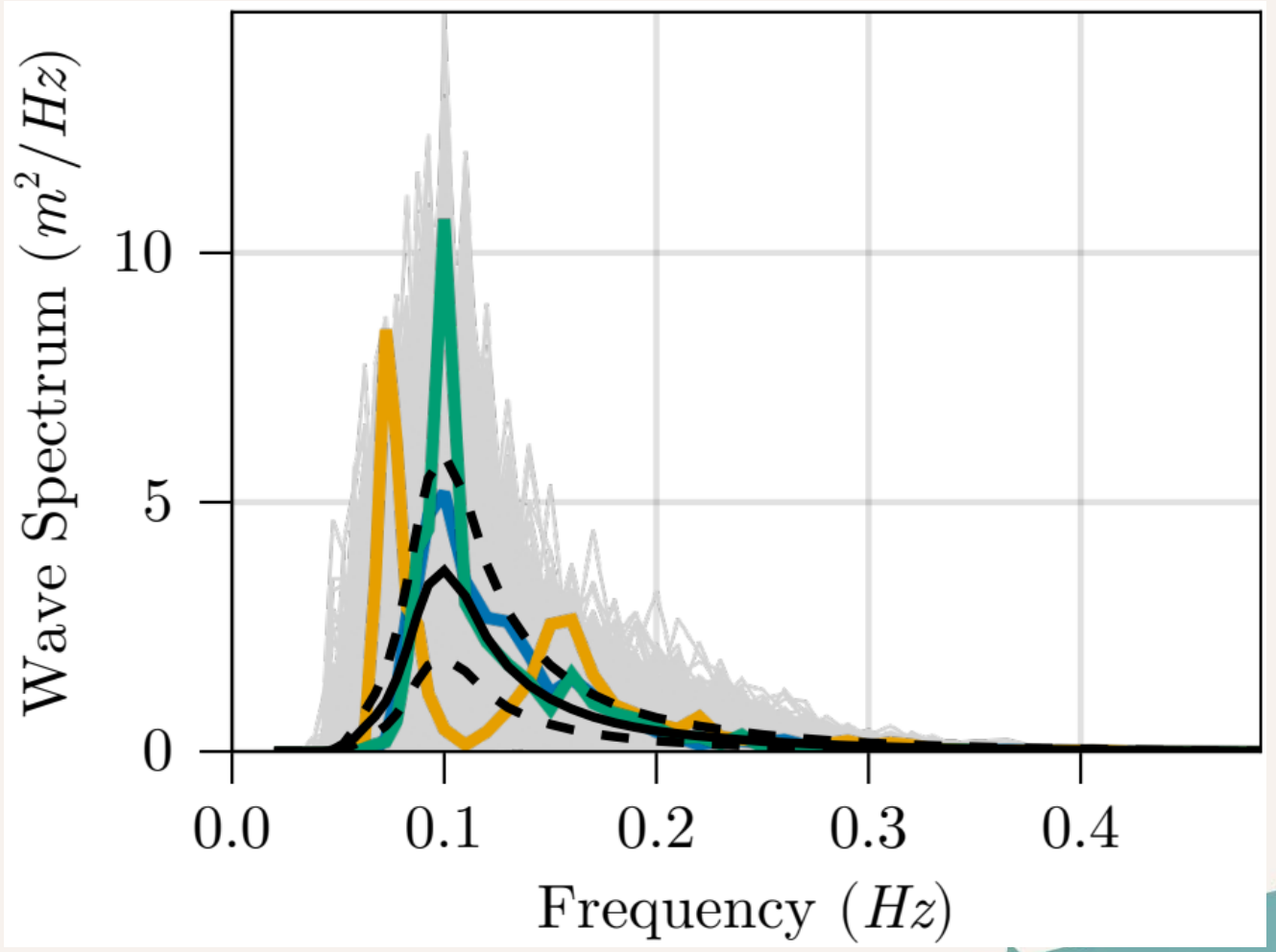


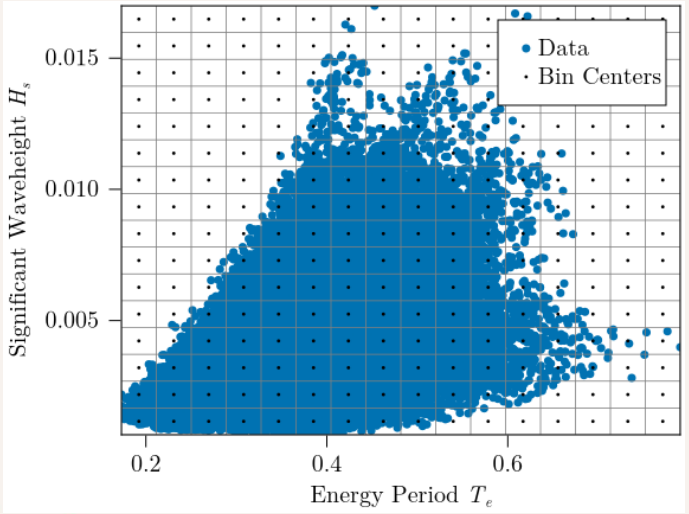


Motivation

- How does this affect Mean Annual Power (MAP)?
- Can we get more accurate MAP with more parameters?

Our Study: Wave data

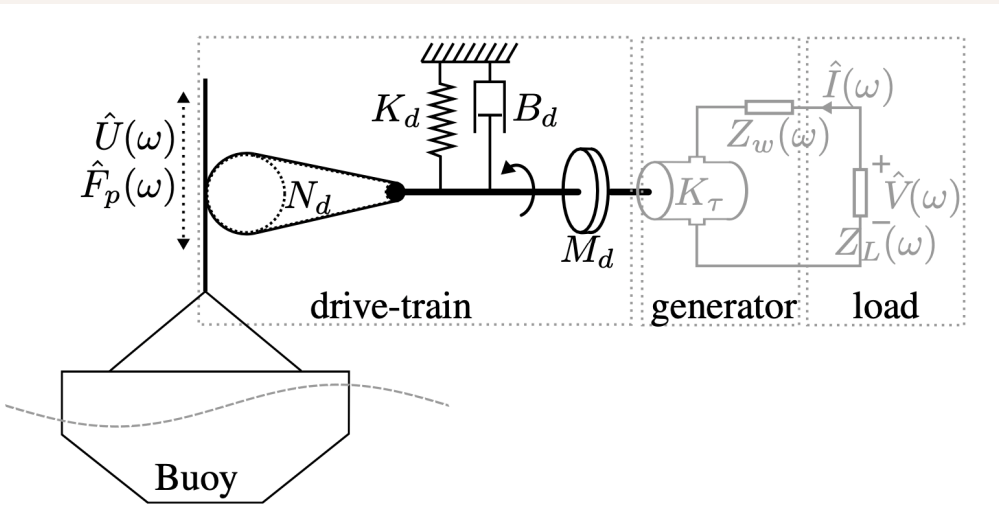
- Novel 4-Parameter Study for MAP
- NDBC Buoy 46050
  - PacWave



Year	No. Spectra	% Spectra	Avg. Power
2009	8524	97.3%	1337 W
2010	8402	95.9%	1721 W
2012	8493	96.7%	1506 W
2013	8510	97.1%	1076 W
2014	8704	99.4%	1313 W
2016	8687	98.99%	1515 W
2017	8693	99.2%	1334 W
2018	8686	99.2%	1246 W
2019	8643	98.7%	1172 W
2020	8615	98.1%	1355 W
2021	8586	98.0%	1528 W
	94543	**98.0%**	**1378 W**

Our Study: WEC model

- WaveBot
  - Linear Wave-To-Wire Model
  - Optimal controller



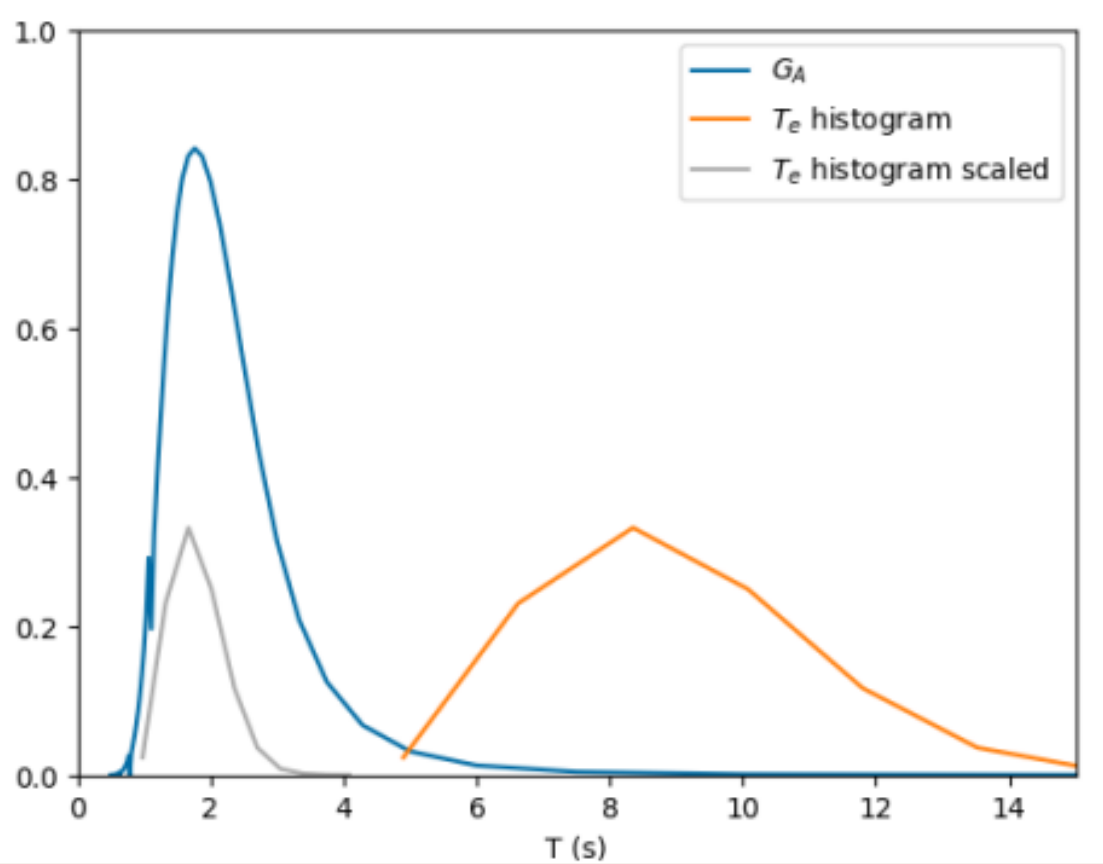
Wave Scaling

$$S(f) = S_o(f_o)\frac{H_s^2 T_e}{H_{s,o}^2 T_{e,o}}$$

$$\tilde{f} = f\frac{T_e}{T_{e,o}}$$

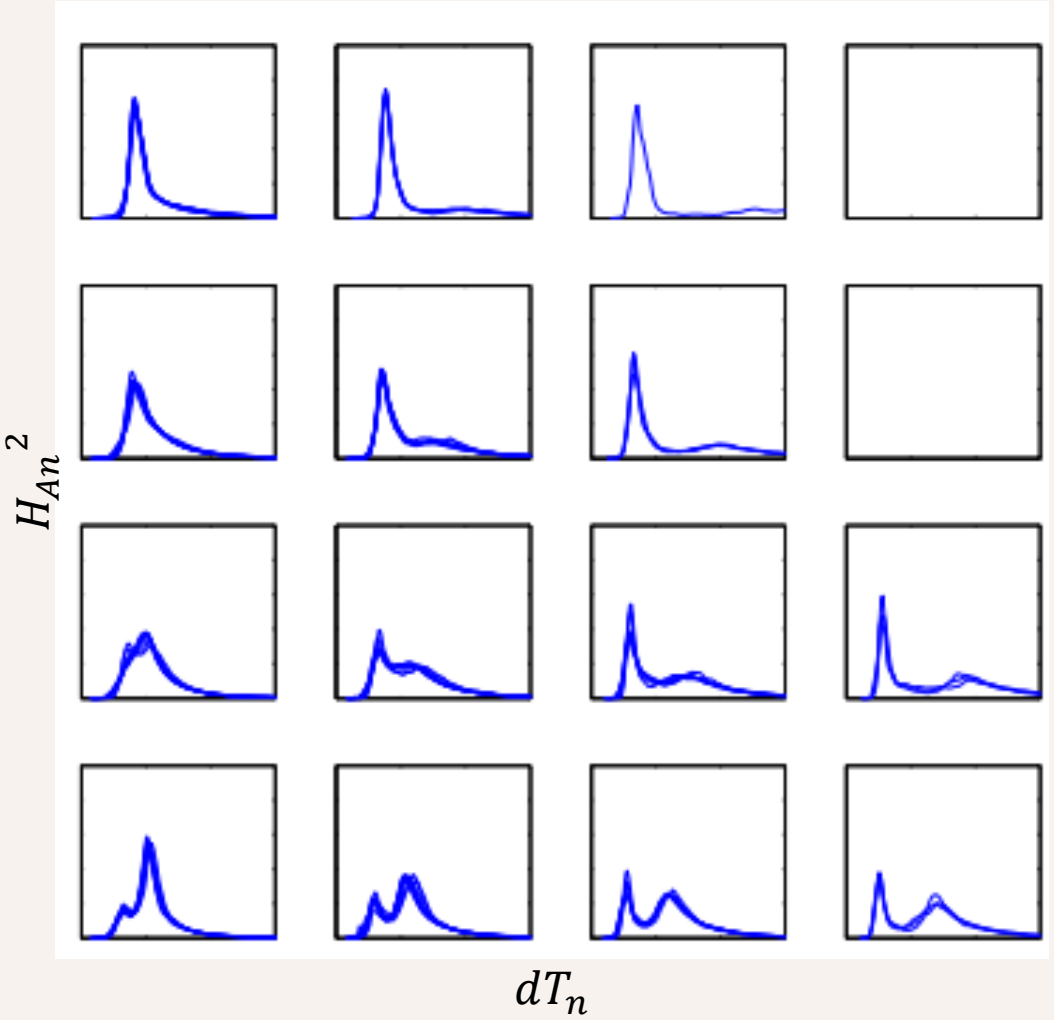
$$T_e = \alpha T_{e,o} \qquad \alpha = {}^1/_5$$

$$E = \frac{1}{625}E_o$$



PM & Mackay

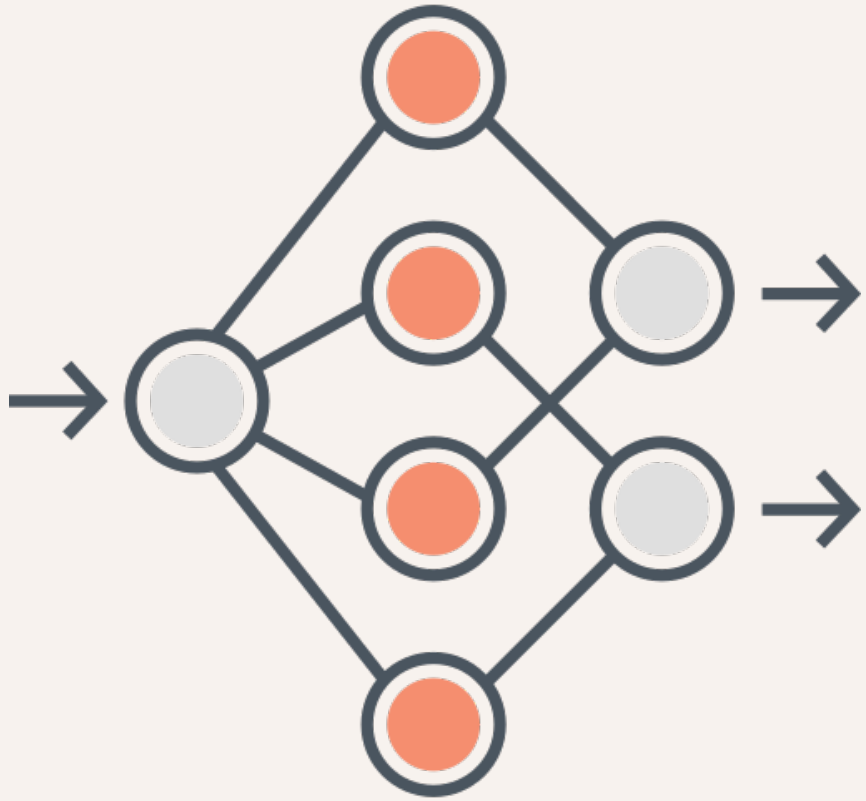
- Pierson Moskowitz as baseline
- Mackay[2] 4-parameter spectra
  - H_s and T_e
  - Two additional shape parameters: H_{An}^2 and dT_n
  - Formulates spectrum as a sum of 2 JONSWAP spectra
  - Relies on lookup tables and interpolations



[2] E. Mackay, “A unified model for unimodal and bimodal ocean wave spectra,” International Journal of Marine Energy, vol. 15, pp. 17–40, 2016, selected Papers from the European Wave and Tidal Energy Conference 2015, Nante, France. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2214166916300273

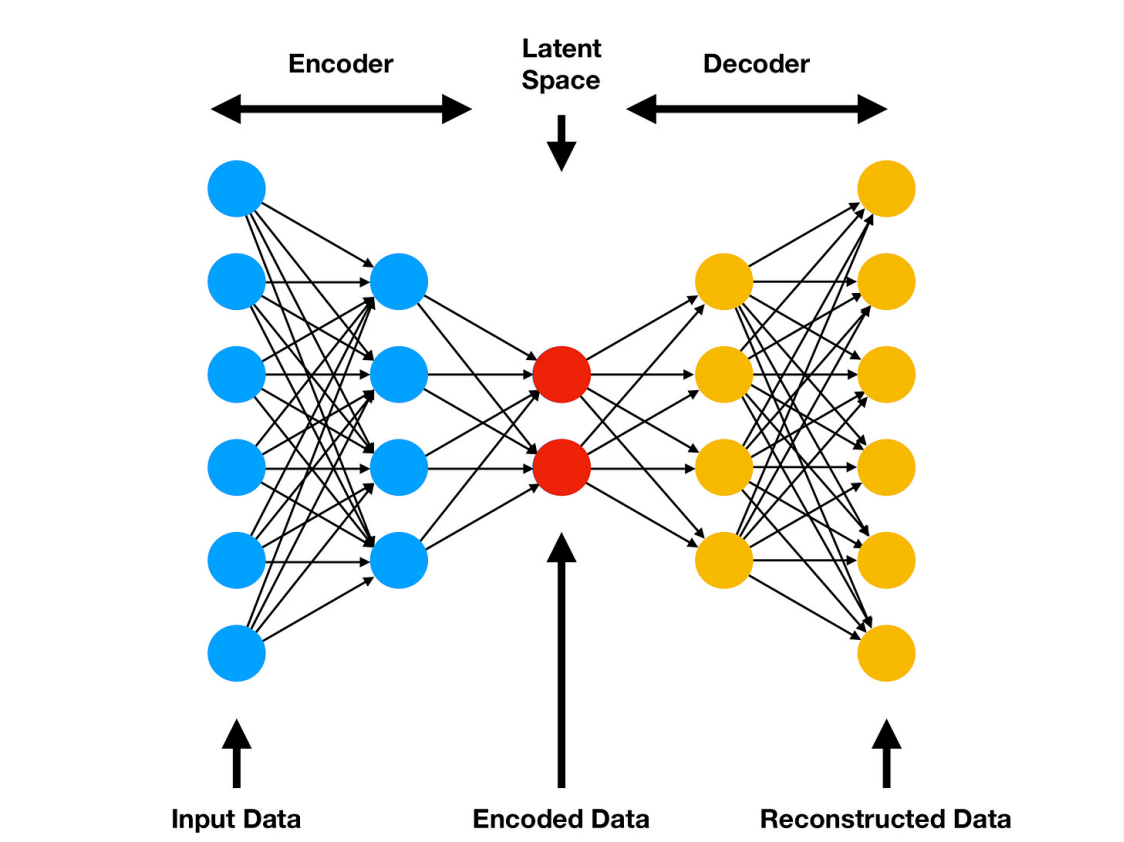
ML-Based 4-parameter spectra

- Machine learning
  - Site-specific spectra
- 2-shape Parameters
- Using Autoencoder



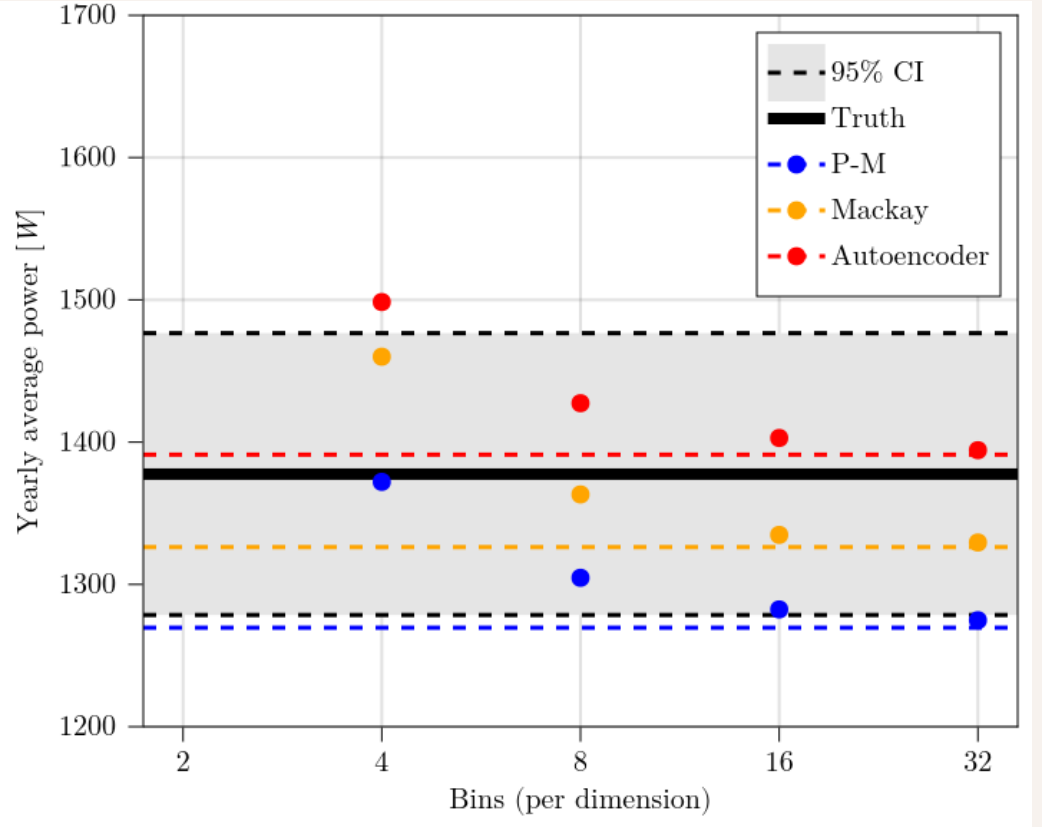
Autoencoders

- Neural Network for Encoding
  - No labeled Data
  - Lower Dimensional Representation
- Physics Informed Neural Network
  - Hard Constraint - H_s =1 and T_e =1
  - Less Iterations
  - Less Data needed



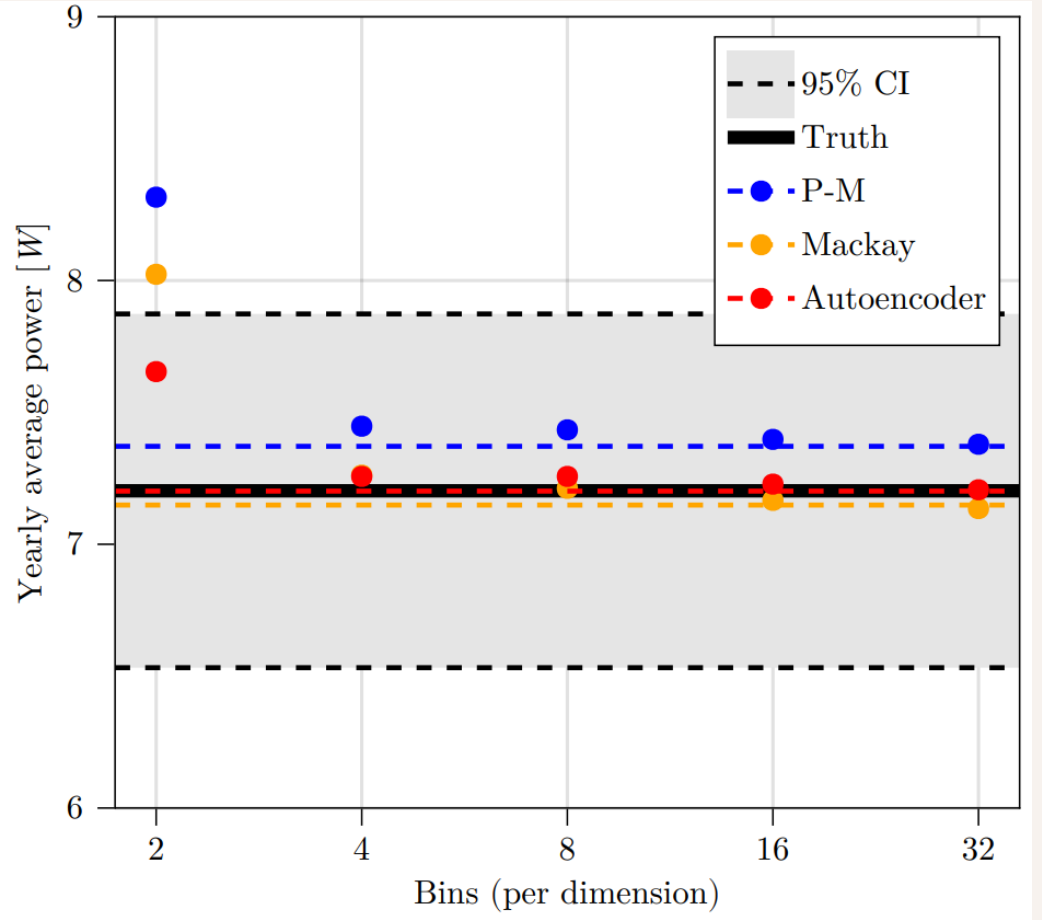
Results – Mean Annual Power

Method	Power	% Error
Ground Truth	1377 W	
Pierson-Moskowitz	1269 W	7.84 %
Mackay	1326 W	3.73 %
Autoencoder	1391 W	0.99 %



Results – Scaled waves

Method	Power	% Error
Ground Truth	7.2027 W	
Pierson-Moskowitz	7.3714 W	2.34 %
Mackay	7.1487 W	0.75 %
Autoencoder	7.2015 W	0.01 %



Discussion

- 2-Parameters are insufficient while 4-parameters are sufficient for accurate MAP
- Simple study: linear model
- Neither Mackay or the autoencoder are closed form
- Autoencoder Tradeoffs
  - Pros: site-specific, accurate
  - Cons: black box, latent variables carry unknown meaning

Questions?

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This research was supported by the U.S. Department of Energy's Water Power Technologies Office. Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government

Appendix

- Loss: RMSE
- 20 Epochs
- Layers Parameters:
  - Encoder 200, 32, 16, 2,
  - Decoder 16, 32, 200