Mathematical method for spectral density estimation set to unlock ocean mysteries

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Researchers at The University of Western Australia's ARC Industrial Transformation Research Hub for Transforming Energy Infrastructure through Digital Engineering (TIDE) have made a significant mathematical breakthrough that could help transform ocean research and technology.

Research Fellow Dr. Lachlan Astfalck, from UWA's School of Physics, Mathematics and Computing, and his team developed a new method for

spectral density estimation, addressing long-standing biases and paving the way for more accurate oceanographic studies.

The study was published in the journal *Biometrika*, known for its emphasis on original methodological and theoretical contributions of direct or potential value in applications.

"Understanding the ocean is crucial for numerous fields, including offshore engineering, climate assessment and modeling, renewable technologies, defense and transport," Dr. Astfalck said.

"Our new method allows researchers and industry professionals to advance ocean technologies with greater confidence and accuracy."

Spectral density estimation is a mathematical technique used to measure the energy contribution of oscillatory signals, such as waves and currents, by identifying which frequencies carry the most energy.

"Traditionally, Welch's estimator has been the go-to method for this analysis due to its ease of use and widespread citation, however this method has an inherent risk of bias, which can distort the expected estimates based on the model's assumption, a problem often overlooked," Dr. Astfalck said.

The TIDE team developed the debiased Welch estimator, which uses non-parametric statistical learning to remove these biases.

"Our method improves the accuracy and reliability of spectral calculations without requiring specific assumptions about the data's shape or distribution, which is particularly useful when dealing with complex data that doesn't follow known analytical patterns, such as internal tides in oceanic shelf regions," Dr. Astfalck said.

The new method was recently applied in a TIDE research project by Senior Lecturer at UWA's Oceans Graduate School and TIDE collaborator, Dr. Matt Rayson, to look at complex non-linear ocean processes.

"The ocean is difficult to measure and understand and the work we are doing is all about uncovering some of those mysteries," Dr. Rayson said.

"The new method means we can better understand ocean processes, climate models, ocean currents and sediment transport, bringing us closer to developing the next generation of numerical ocean models."

More information: Lachlan C Astfalck et al, Debiasing Welch's Method for Spectral Density Estimation, *Biometrika* (2024). DOI: 10.1093/biomet/asae033

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