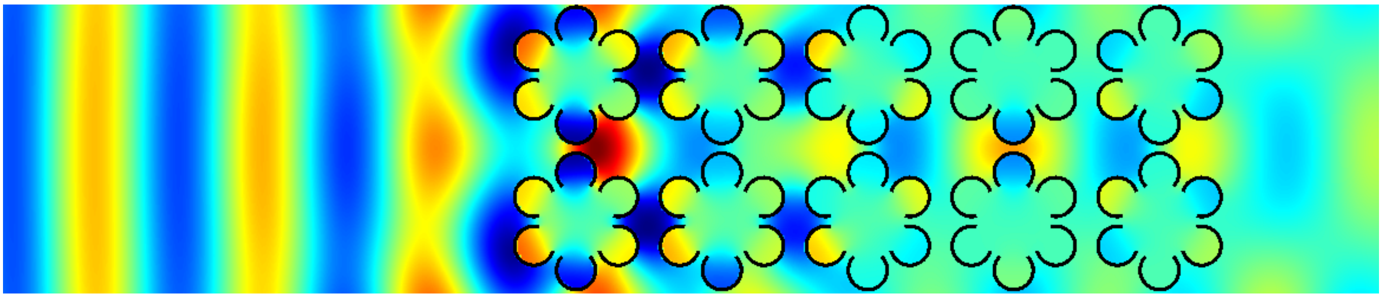


KOZWaves 2024

the 6th Australasian conference on wave science

31 January - 2 February, Dunedin, NZ

Conference booklet

Welcome to KOZWaves 2024

Thank you for travelling from all corners of the world to Dunedin, one of the greatest small cities in the world, and participating in the 6th KOZWaves meeting ... 10 years after the first one! The KOZWaves community has grown significantly in the past decade, with new people getting involved and new areas of wave science being explored at every meeting. KOZWaves 2024 is no exception. More than half the conference participants will attend their first KOZWaves in 2024, and the breadth of topics covered will likely make it the most multidisciplinary KOZWaves to date.

We hope that you enjoy the conference, and that it provides plenty of opportunities for you to connect with our wave science community, cross-pollinate ideas through artificial discipline boundaries and of course, have fun!

Local Organising Committee

Fabien Montiel, Joerg Hennig, Sam Lowrey, Ben Wilks.

KOZWaves Steering Committee

Ken Golden, Nicole Kessissoglou, Andrew Melatos, Natasha Movchan, Ann Roberts, Vladislav Sorokin, Colin Whittaker, Hugh Wolgamot

KOZWaves Executive Committee

Lule Bennetts, Ross McPhedran, Mike Meylan

Sponsors

Thanks to our sponsors for supporting KOZWaves 2024:

- Office of Naval Research Global (ONRG)
- ARC Centre for Transformative Meta-Optical Systems (TMOS)
- Dodd-Walls Centre for Photonic and Quantum Technologies
- Otago Energy Research Centre (OERC)
- New Zealand Mathematical Society (NZMS)
- University of Otago

Code of conduct

KOZWaves is dedicated to providing a safe, inclusive, and respectful environment for all participants of its conference series, regardless of gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, age, religion, nationality, or other personal characteristics. At KOZWaves 2024, the 6th Australasian conference on wave science, we expect all attendees, speakers, sponsors, and organisers to adhere to the code of conduct, the full version of which can be found on the conference website, at all conference-related events and activities.

Contact Information

If you experience or witness a code of conduct violation or have any concerns, please contact the conference chair Fabien Montiel at fabien.montiel@otago.ac.nz or other members of the local organising committee (Sam Lowrey, Joerg Hennig and Ben Wilks). All reports will be treated with confidentiality.

Other important contacts

- Dunedin police: dial 105 (or 111 for emergencies)
- Dunedin Urgent Doctors & Accident Centre: 03 479 2900
- 'Safe to talk' national sexual harm helpline: 0800 044 334
- Dunedin taxis: 03 477 7777

Acknowledgment

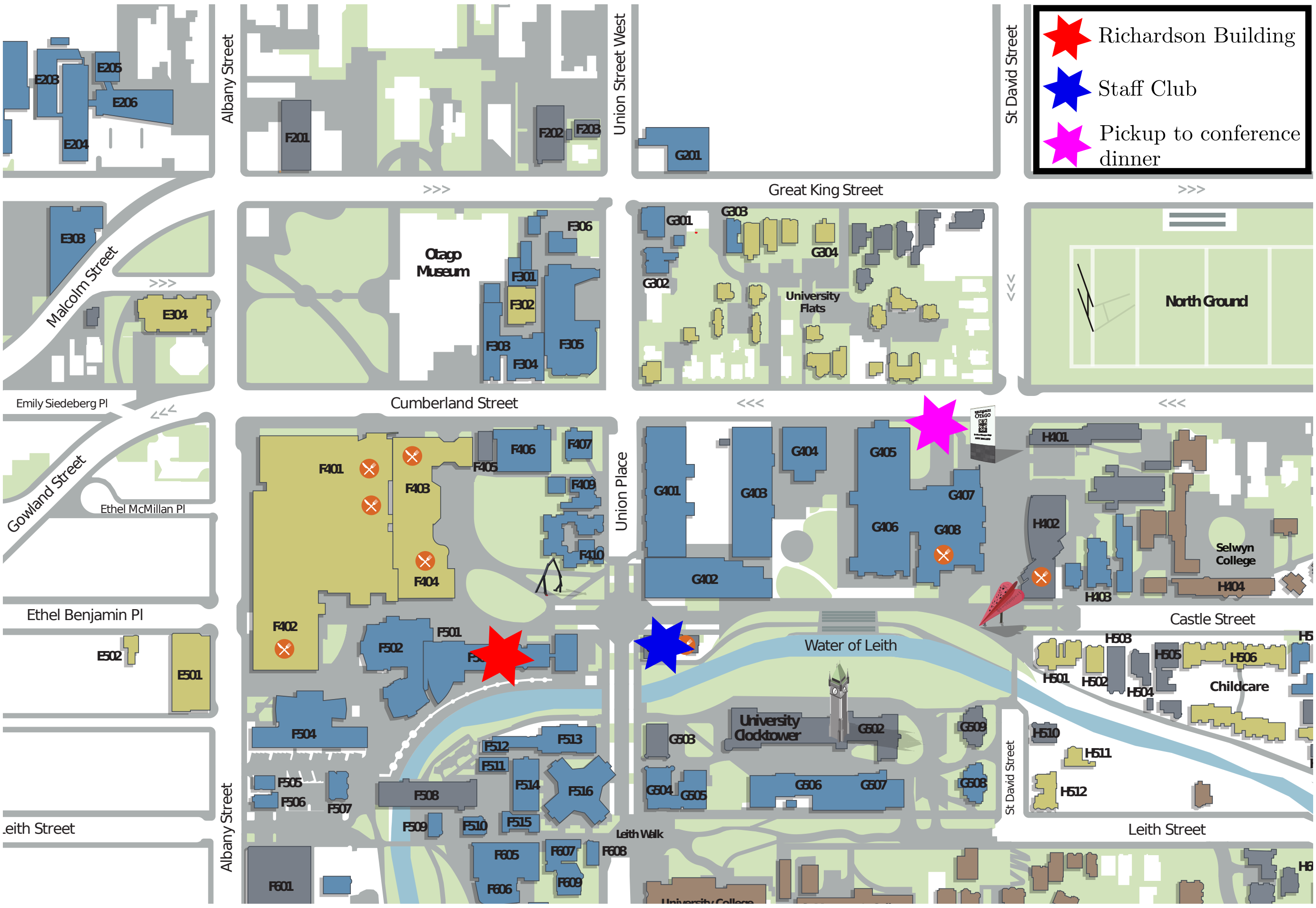
By attending KOZWaves 2024, you agree to abide by this code of conduct. The conference organisers reserve the right to update or modify this code as needed and to take appropriate action in response to violations. We appreciate your cooperation in creating a welcoming and respectful conference environment.

General Information

Travelling from the airport

To get to the city from the airport, we recommend that you take a shared-ride Super Shuttle (no booking required), available just outside the terminal. Taxis are also available. Note that there are no airport buses in Dunedin.

University campus map



Conference venue

The conference will be held in the Moot Court lecture theatre, which is located on the **10th floor of the Richardson Building**. The red star on the map indicates the location of the Richardson Building.

Icebreaker

The icebreaker BBQ will be held from 6pm to 9pm on Tuesday 30th January at the University Staff Club. The blue star on the campus map indicates the location of the Staff Club.

Conference dinner

The conference dinner will be on Thursday 1st February at the historical Larnach Castle, which is located $\sim$ 30 minutes from the city. A bus will pick us up at 6.30pm that day at the intersection of Cumberland Street and St David Street (in front of the big university monument), and take us to the venue. The magenta star on the campus map indicates the location of the bus pickup.

Registration

A registration desk will be available at the university Staff Club during the icebreaker BBQ and outside the lecture theatre on Wednesday 31st January from 8.15am.

Morning/afternoon teas and lunches

Morning/afternoon teas and lunches will be provided in seminar room 5, located just across the hall from the conference venue.

Internet access

If Eduroam is supported by your home institution, you will be able to connect to the `Eduroam` wireless network. If you don't have access to Eduroam, please ask someone at the registration desk for alternative options.

Publishing opportunity

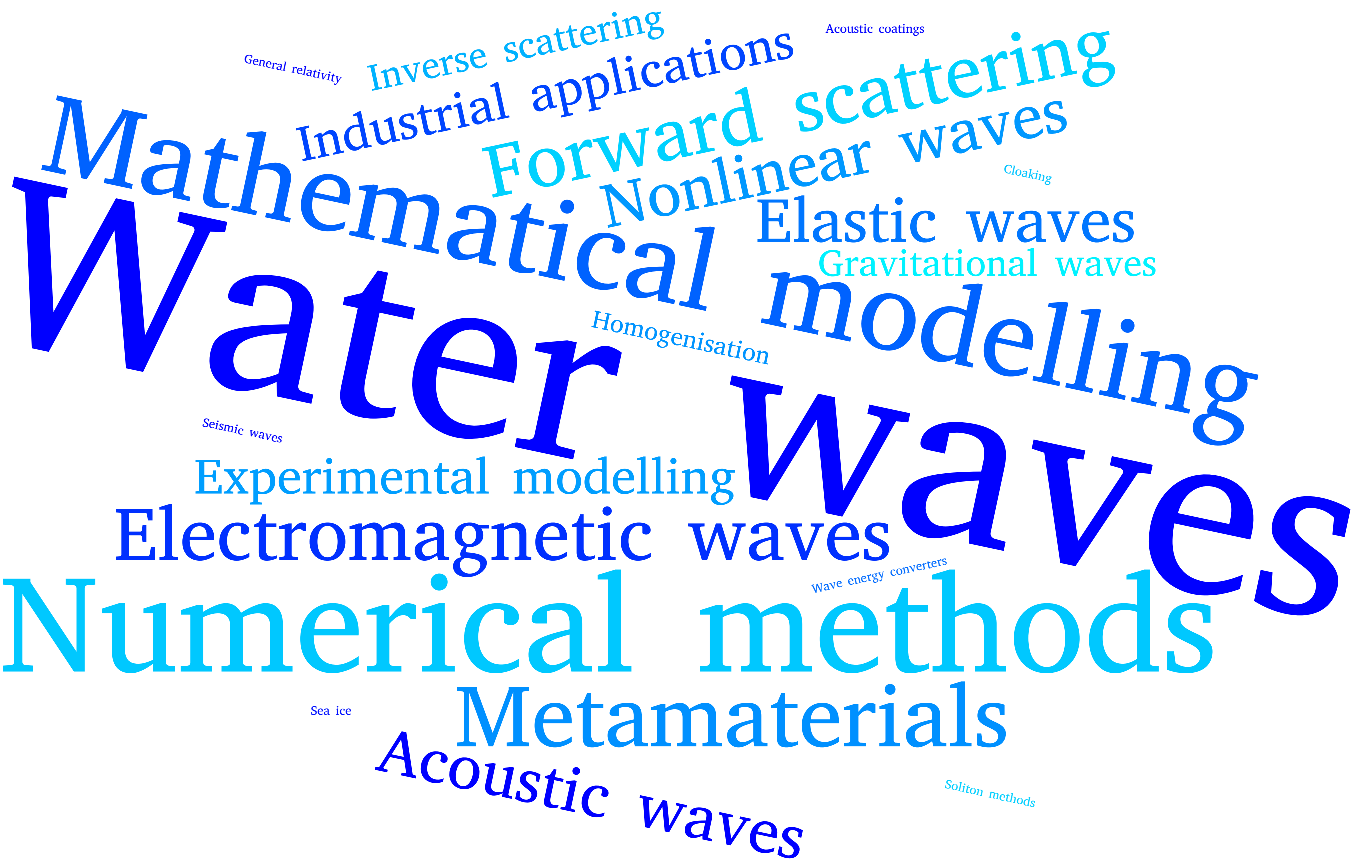
It is our great pleasure to announce that a Special Issue in the journal *Wave Motion* on *Cross-Disciplinary Advances in Wave Motion* will be associated with KOZWaves 2024. **Manuscripts submission will open in March 2024** and is available to all the conference participants and their collaborators.

The Special Issue will be co-edited by Fabien Montiel (Otago), Marie Graff (Auckland), Vladislav Sorokin (Auckland) and Jordan Pitt (Sydney).

This initiative builds on the success of the journal's past Special Issues *Recent Advances on Wave Motion in Fluids and Solids* and *Theoretical and Numerical Advances in Wave Science* associated with KOZWaves 2015 and KOZWaves 2018, respectively.

If you have any question about this opportunity, don't hesitate to get in touch with anyone in the guest editor team.

Conference programme



Wednesday, 31st January

08:45-09:00 Welcome

09:00-10:40 Session 1: Acoustic wave scattering and metamaterials (chair: Fabien Montiel)

09:00 **Invited Speaker**: David Abrahams (University of Cambridge, UK)
Analytical approaches to the design of acoustic metamaterials and metasurfaces

09:50 Afnan Aldosri (University of Newcastle, OZ)
Solving wave scattering problem in waveguides

10:15 Alex McIntosh (University of New South Wales, OZ)
Sound scattering by monopolar and dipolar type resonators in a soft coating

10:40-11:10 Morning tea

11:10-12:50 Session 2: Water wave/structure interactions (chair: Thomas Adcock)

11:10 Hugh Wolgamot (University of Western Australia, OZ)
Generalised phase manipulation for water wave-structure interaction

11:35 Alex Skvortsov (Defence Science and Technology Group, OZ)
Surface water waves generated by a moving piercing cylinder

12:00 Aidan Archer (University Of Western Australia, OZ)
Reductions in jacket drag loads and enhancements in tidal turbine power: a new actuator disc model for water wave and current loads in a channel

12:25 Mathieu Sellier (University of Canterbury, NZ)
Identification of rheological parameters for shallow water flows of viscoplastic fluids using elevation hydrographs

12:50-13:50 Lunch

13:50-15:30 Session 3: Earth and space science (chair: Chris Stevens)

13:50 **Invited Speaker**: Jen Andrews (GNS Science, NZ)
Earthquake early warning and rapid characterisation: a few years spent chasing seconds

14:40 Romain Meyrand (University of Otago, NZ)
Stochastic echoes in collisionless plasmas

15:05 Jonathan Squire (University of Otago, NZ)
Switchbacks: nonlinear magnetic waves in the solar wind

15:30-16:00 Afternoon tea

16:00-17:40 Session 4: Wave/ice interactions (chair: Sophie Thery)

16:00 Alberto Alberello (University of East Anglia, UK)
Wave directionality in sea ice

16:25 Martin Forbes (University of Otago, NZ)
Evaluating sea ice models in WAVEWATCH III®

16:50 Rafa Santana (NIWA, NZ)
Modelling Antarctic sea ice variability using a brittle rheology

17:15 Luke Bennetts (University of Adelaide, OZ)
A thin plate approximation for ocean wave interactions with an ice shelf

17:40 End of day 1

Thursday, 1st February

08:55-09:00 Housekeeping

09:00-10:40 Session 5: Wave energy (chair: Ben Wilks)

09:00 **Invited Speaker**: Nataliia Sergiienko (University of Adelaide, OZ)
Using wave energy converters to protect coasts and offshore structures

09:50 Amy-Rose Westcott (University of Adelaide, OZ)
Broadband energy capture by an array of heaving buoys

10:15 Vladislav Sorokin (University of Auckland, NZ)
A point absorber Wave Energy Converter for supplying energy to aquafarms

10:40-11:10 Morning tea

11:10-12:50 Session 6: Metamaterials (chair: Kei Matsushima)

11:10 Sophie Thery (University of Canterbury, NZ)
Cloaking in water waves by thin floating plates

11:35 Ali Adham (University of Auckland, NZ)
Broadband attenuation regions in finite structures with graded resonators

12:00 Frances Fulton (University of Auckland, NZ)
Nonlinear Periodically Attached Absorbers for Vibration Transmission Mitigation in Linear Structures

12:25 Ann Roberts (University of Melbourne, OZ)
Beyond traditional optics: metasurfaces in image processing

12:50-13:50 Lunch

13:50-15:30 Session 7: Physical Oceanography (chair: Hugh Wolgamot)

13:50 **Invited Speaker**: Ton van den Bremer (TU Delft, Netherland)
The role of surface gravity waves in transporting floating marine pollution

14:40 Thomas Adcock (University of Oxford, UK)
Predicting tidal waves: a recasting of Munk & Cartwright's response method facilitated by machine learning

15:05 Christo Rautenbach (NIWA, NZ)
Wave set-up in constricted estuaries

15:30-16:00 Afternoon tea

16:00-17:15 Session 8: Gravitational waves and general relativity (chair: Jonathan Squire)

16:00 Jörg Frauendiener (University of Otago, NZ)
Gravitational waves: a conceptual introduction

16:25 Chris Stevens (University of Canterbury, NZ)
Gravitational waves: a numerical exploration of the global scattering problem

16:50 Joerg Hennig (University of Otago, NZ)
Soliton methods and the black hole balance problem

17:15 End of day 2

18:30-22:30 Conference dinner at Larnach Castle

Friday, 2nd February

08:55-09:00 Housekeeping

09:00-10:40 Session 9: Numerical methods in wave propagation (chair: Marie Graff)

09:00 **Invited Speaker**: Marcus Grote (University of Basel, Switzerland)
Explicit local time-stepping methods for wave propagation

09:50 Ben Wilks (University of Otago, NZ)
Canonical time-domain scattering in one dimension using the generalised eigenfunction expansion method

10:15 Stuart Hawkins (Macquarie University, OZ)
A numerically stable T-matrix algorithm

10:40-11:10 Morning tea

11:10-12:50 Session 10: Forward/inverse scattering (chair: Stuart Hawkins)

11:10 Marie Graff (University of Auckland, NZ)
Recent advances on the Adaptive Eigenspace Inversion method

11:35 Matthew Fernandes (Macquarie University, OZ)
An efficient surrogate model for acoustic multiple scattering

12:00 Kei Matsushima (University of Tokyo, Japan)
On Rayleigh-Bloch waves swapping between physical and unphysical Riemann sheets

12:25 Malte Peter (Universität Augsburg, Germany)
Identification of microstructural information from macroscopic boundary measurements in linear elasticity

12:50-13:50 Lunch

13:50-15:30 Session 11: Photonics and metamaterials (chair: Ann Roberts)

13:50 **Invited Speaker**: Teri Odom (Northwestern University, USA)
Moiré Nanophotonics

14:40 Tristan Lawrie (University Of Nottingham, UK)
A Quantum Graph Approach to Metamaterial Design

15:05 John Lekner (Victoria University of Wellington, NZ)
Theory of electromagnetic pulses

15:30-16:00 Afternoon tea

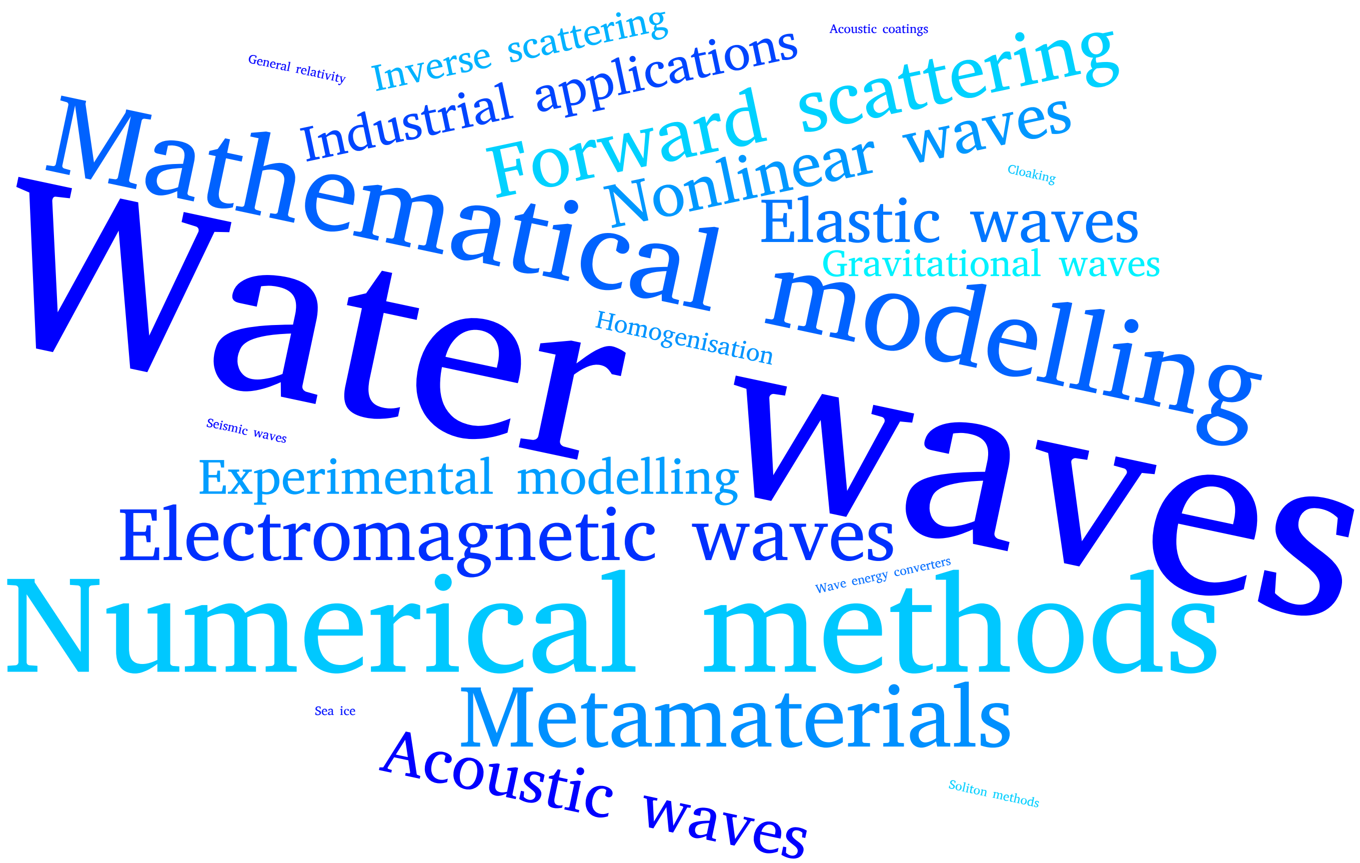
16:00-16:50 Session 12: Low-frequency ocean waves (chair: Rafa Santana)

16:00 Rehab Aljabri (University of Newcastle, OZ)
Time-Dependent vibrations of an ice shelf

16:25 Mike Meylan (University of Newcastle, OZ)
Simulation of three-dimensional tsunami waves including static compression.

16:50-17:00 Conference wrap-up

Abstracts


Acoustic coatings
General relativity
Inverse scattering
Industrial applications
Forward scattering
Mathematical modelling
Nonlinear waves
Cloaking
Elastic waves
Gravitational waves
Water waves
Homogenisation
Seismic waves
Experimental modelling
Electromagnetic waves
Wave energy converters
Numerical methods
Sea ice
Metamaterials
Acoustic waves
Soliton methods

Invited Speakers

David Abrahams (University of Cambridge, UK)

Analytical approaches to the design of acoustic metamaterials and metasurfaces

In this talk I will outline a framework for describing the effective propagation or scattering response of two-dimensional composite bodies or surfaces composed of subharmonic resonator inclusions. We shall focus on acoustic waves, and employ as a Helmholtz resonator element, a rigid cylinder with a narrow notch (or neck) connecting to an interior cavity.

Multipole methods have been used to good effect to obtain the effective behaviour of cylindrical inclusions in the many areas of photonics and phononics. We examine this design element, the resonant cylinder, to create metamaterials and metasurfaces, via the combined methods of matched asymptotic expansions and multipoles.

I shall commence the talk by summarising the low-frequency propagation characteristics of a single cylinder, then a two-dimensional array of circular cylindrical resonators, and then extend to the reflection and transmission properties of a surface containing such elements. I shall conclude by offering brief results and indicating the benefits of this approach to practical metamaterial design.

MJA Smith and ID Abrahams, Tailored acoustic metamaterials I and II, Proceedings Royal Society A478, 20220124 and 20220125, June 2022.
MJA Smith, PA Cotterill, D Nigro, WJ Parnell and ID Abrahams, Asymptotics of the meta-atom, Philosophical Transactions Royal Society 380, 20210383, October 2022.

Jen Andrews (GNS Science, NZ)

Earthquake early warning and rapid characterisation: a few years spent chasing seconds

Earthquake early warning (EEW) and rapid characterisation systems aim to provide reliable, actionable information in the seconds to hours after significant events. They are designed to provide critical data in the earliest time windows, in order to mitigate impact, and aid response and recovery. Development and implementation of these systems has accelerated globally over recent years, partly driven by rapid technological advances, and while the intention behind each system is similar, the scientific and technical approaches can be very different. This presentation will be a personal perspective on some of the science, practice and pragmatic aspects of EEW, based on my experiences within the development team for the ShakeAlert earthquake early warning system for the US West Coast, and the Rapid Characterisation of Earthquake and Tsunami program in New Zealand. Working on algorithm development to characterise earthquake parameters and ground motions involves balancing science with technology, and accuracy with speed. Such a highly applied field also involves the broader context of society's expectations for such systems, as well as learning from real-time performance and preparing for potential worst-case scenarios.

Marcus Grote (University of Basel, Switzerland)

Explicit local time-stepping methods for wave propagation

Adaptivity and mesh refinement are certainly key for the efficient numerical simulation of wave phenomena in complex geometry. Locally refined meshes, however, severely constrain the time-step of any explicit time-marching scheme due to the CFL stability condition governed by the smallest elements in the mesh. When mesh refinement is restricted to a small subregion, the use of implicit methods, or a tiny time-step in the entire computational domain, are very high a price to pay. Explicit local time-stepping schemes (LTS) overcome that bottleneck due to a few small elements by using smaller time-steps precisely where the smallest elements in the mesh are located. When combined with a finite element discretization in space with an essentially diagonal mass matrix, the resulting time-marching schemes remain fully explicit and thus inherently parallel.

Teri Odom (Northwestern University, USA)

Moiré Nanophotonics

The superposition of two or more periodic structures can result in moiré patterns and phenomena in a wide range of materials. This talk will describe how moiré lattices made from plasmonic nanoparticles enable new ways to manipulate light in the near-field and far-field. We will discuss how electromagnetic waves at optical frequencies can be trapped in-plane by periodic plasmonic lattices, resulting in reduced scattering and increased local confinement. Also, we will explain how ultralong-range interactions between stacked nanoparticle lattices can exhibit unexpected moiré phenomena because of the uniqueness of photonic systems. Our approach to control light waves offers a promising approach for applications in biosensors, reconfigurable nano-laser systems, exciton-polariton devices, and quantum optical circuits.

Nataliia Sergiienko (University of Adelaide, OZ)

Using wave energy converters to protect coasts and offshore structures

The idea of converting the energy of ocean waves appeared in the 18th century. Since then, thousands of different concepts and prototypes have been developed, and a couple dozen have been tested in the ocean. Historically, wave energy converters (WECs) have been developed for utility-scale power generation, while most recently, other markets have emerged for the use of WECs. The main wave power conversion principle states that “to absorb waves means to generate waves”. Therefore, WECs are seen as effective devices that can destructively interfere with an incident wave to protect offshore structures and prevent coastal erosion. This presentation will cover the results from numerical and experimental studies demonstrating the benefits of WECs for offshore applications.

Ton van den Bremer (TU Delft, Netherlands)

The role of surface gravity waves in transporting floating marine pollution

Floating plastic marine litter has rapidly become one of the most acute environmental problems, particularly affecting marine ecosystems. The total oceanic plastic budget is poorly understood. To understand this budget, an improved understanding of the physical processes governing transport and dispersion is required. Floating marine litter is transported by several mechanisms, including surface waves. In studies of marine litter transport, the wave-induced drift is set to be equal to the Stokes drift, corresponding to the Lagrangian-mean wave-induced drift of an infinitesimally small tracer. I will discuss the origins of Stokes drift and reveal why and when waves can transport floating marine pollution in a different direction and at a different speed compared to the Stokes drift.

Contributed Talks

Thomas Adcock (University Of Oxford, UK)

Predicting tidal waves: a recasting of Munk & Cartwright's response method facilitated by machine learning

Tidal water levels and currents result from the propagation of long water waves around the earth. These are primarily driven by astronomical forcing but the magnitude of the tide is strongly dependent on local resonances. Harmonic analysis is the standard technique used to predict tides given a timeseries of field data. However, this approach has shortcomings and approximations which led to Munk & Cartwright developing the "response method" in the 1960s. However, this approach did not gain traction for a variety of reasons. We have revisited this approach, using machine learning to overcome the input selection and non-linear fitting problems which have prevented the adoption of a response approach. This allows us to make predictions using an order of magnitude less data than with harmonic analysis—this has applications for analysis of satellite data, interpreting short measurements of currents, etc. Our approach is an example of using machine learning to enable more of the physics to be included in the problem than with a traditional approach—we hope our approach may have application to other wave problems.

Ali Ihsan Adham (University of Auckland, NZ)

Broadband attenuation regions in finite structures with graded resonators

The presence of bandgaps, stemming from Bragg scattering in periodic elastic structures, is a well-established phenomenon, causing wave propagation suppression due to interference between incident and reflected waves on structural discontinuities. However, such bandgaps are a result of structural periodicity. In aperiodic and asymmetrical structures, this effect doesn't occur, but attenuation regions still emerge due to wave reflection from boundaries and structural discontinuities through impedance mismatches. In this work, we introduce a framework for predicting and expanding attenuation regions in an axially vibrating rod by strategically tuning and placing graded resonators, i.e., resonators whose properties vary independently. To expand the attenuation regions, it is found the tuning frequency of a resonator should be equal to one of the zero-transmission frequencies of a bare rod while the position of the resonator on the rod is set to be at a node of the displacement at the tuning frequency. We demonstrate that periodicity and uniformity are not prerequisites for destructive wave interference, graded resonators can offer broader and deeper attenuation regions, and the advantage of independent resonator placement and tuning. A strategy to create broadband attenuation regions is demonstrated for various boundary conditions with multiple graded resonators.

Alberto Alberello (University of East Anglia, UK)

Wave directionality in sea ice

Ocean waves and sea ice properties are intimately linked in the marginal ice zone (MIZ), nevertheless a definitive modelling paradigm for the wave attenuation in the MIZ is missing. The evolution of wave directional properties in the MIZ is a proxy for the attenuation mechanism but paucity of measurements and disagreement between them contributed to current uncertainty. In this talk we show that viscous sea ice attenuation, tipycal in the MIZ, tilts the mean wave direction orthogonal to the sea ice edge and the narrows directionality, in qualitative agreement with recent observations from the Arctic. Tilting away from the normal direction can occur in complex, bimodal, sea states. The analysis highlights the need for high quality directional measurements in the field to reduce uncertainty in the definition of the attenuation rate.

Afnan Aldosri (University of Newcastle, OZ)

Solving Wave Scattering Problem in Waveguides

In this talk, the mode matching method is used to solve wave propagation in ducts connected to rectangular regions. Various solutions of increasing complexity are calculated, exploiting symmetry as appropriate. The final problem we consider the scattering by two ducts at right angles connected through a rectangular region. The solution has applications in understanding the scattering of acoustic waves in waveguides and water waves in channels. Time domain simulations will be presented.

Rehab Aljabri (University of Newcastle, OZ)

Time-dependent vibrations of an ice shelf

I will explain a method to calculate the vibrations of an ice shelf floating on shallow water under different boundary conditions. In addition, we will examine two conditions at the seaward edge of the ice shelf, no-flux and no pressure. Furthermore, the method extends to find the mode shapes of the ice shelf-water system. These mode shapes describe the system's behaviour and explain what happened in the ice shelf/cavity system. The solutions for the two cases will be simulated in the time domain for the vertical displacement and the potential velocity for different initial conditions. These solutions are obtained through a numerical method that reduces all the calculations to matrix multiplication.

Aidan Archer (University of Western Australia, OZ)

Reductions in jacket drag loads and enhancements in tidal turbine power: a new actuator disc model for water wave and current loads in a channel

Recent experimental measurements of the flow interactions between an offshore jacket structure composed of slender members and combined waves and current showed dramatic flow blockage effects, where the mean flow effectively stopped in the wake of the jacket. These flow interactions with porous structures like jackets and turbines are commonly modelled with actuator disc theory which represent the structures as porous obstacles. An existing actuator disc model in unbounded mean and oscillatory flow predicts the same flow blockage effect that was recently experimentally measured, but the model is limited in modelling cases with high drag loading. To address this, a new actuator disc model is presented to explore the interaction of combined waves and currents with a porous structure. It is shown that by bounding the flow with a finite channel, these previous modelling limitations can be overcome. Further, application of the model to turbines indicates that the time-averaged power removed from the flow is increased with the addition of wave-driven oscillatory flow, which may have implications for the energy extraction from emerging floating tidal energy systems placed in environments with waves and currents.

Luke Bennetts (University of Adelaide, OZ)

A thin plate approximation for ocean wave interactions with an ice shelf

A variational principle is proposed to derive the governing equations for the problem of ocean wave interactions with a floating ice shelf, where the ice shelf is modelled by the full linear equations of elasticity and has an Archimedean draught. The variational principle is used to form a thin-plate approximation for the ice shelf, which includes water–ice coupling at the shelf front and extensional waves in the shelf, in contrast to the benchmark thin-plate approximation for ocean wave interactions with an ice shelf. The thin-plate approximation is combined with a single-mode approximation in the water, where the vertical motion is constrained to the eigenfunction that supports propagating waves. The new terms in the approximation are shown to have a major impact on predictions of ice shelf strains for wave periods in the swell regime.

Matthew Fernandes (Macquarie University, OZ)

An Efficient surrogate model for acoustic multiple scattering

Recent experimental measurements of the flow interactions between an offshore jacket structure composed of slender members and combined waves and current showed dramatic flow blockage effects, where the mean flow effectively stopped in the wake of the jacket. These flow interactions with porous structures like jackets and turbines are commonly modelled with actuator disc theory which represent the structures as porous obstacles. An existing actuator disc model in unbounded mean and oscillatory flow predicts the same flow blockage effect that was recently experimentally measured, but the model is limited in modelling cases with high drag loading. To address this, a new actuator disc model is presented to explore the interaction of combined waves and currents with a porous structure. It is shown that by bounding the flow with a finite channel, these previous modelling limitations can be overcome. Further, application of the model to turbines indicates that the time-averaged power removed from the flow is increased with the addition of wave-driven oscillatory flow, which may have implications for the energy extraction from emerging floating tidal energy systems placed in environments with waves and currents.

Martin Forbes (University Of Otago, NZ)

Evaluating sea ice models in WAVEWATCH III®

The extent of sea ice is a crucial component of the global climate system, and the marginal ice zone (MIZ) describes its outer edge, where the sea ice breaks up into floes as a result of wave interactions. The MIZ is typically tens to hundreds of km wide and its retreat or expansion is correlated with significant wave height. Wave-induced break-up of the sea ice is therefore assumed to be an important driver in the outward delineation of Antarctic sea ice extent. This has led to a flurry of recent studies on understanding ocean-wave sea ice interaction, followed by a suite of sea ice dependent attenuation models in ocean wave forecast models.

In this work, we conduct the first comprehensive evaluation of the sea ice models implemented in the widely used ocean wave forecast model, WAVEWATCH III® (WWIII). Using default parameter values for each sea ice model, ocean waves are hindcast in the Ross Sea over a period that coincides with buoy in ice deployments during the PIPERS campaign. The buoy data are then used to evaluate the performance of the different sea ice implementations in WWIII.

Jörg Frauendiener (University Of Otago, NZ)

Gravitational waves: a conceptual introduction

Gravitational waves were predicted by Albert Einstein in 1917 based on his approximate solution of the field equations describing his theory of gravitation. They have been a controversial issue in the early stages of the development of the theory but, ultimately, in the early 1960s it was theoretically established that they existed. It took another 50 years until they were experimentally detected. This talk will give an overview of the fundamental principles and conceptual issues that are relevant for understanding this phenomenon.

Frances Fulton (University Of Auckland, NZ)

Nonlinear periodically attached absorbers for vibration transmission mitigation in linear structures

Previously, it has been shown that nonlinear vibration absorbers can feature certain benefits for vibration suppression as compared to their linear counterparts. While an active area of research, there is still a lack of comprehensive theoretical understanding of the dynamics of continuous systems, such as rods, beams and plates, when one or more nonlinear vibration absorber is attached. The focus of the present research is to analyse the vibration transmission behaviour of a rod with periodically attached Duffing type nonlinear absorbers. An analytical and numerical investigation into the vibration transmission and absorber displacement for one absorber attached to a rod has been completed. First order and second order harmonic solutions are compared and stability of solutions is assessed. Preliminary research into a rod with 2 absorbers attached will also be presented. The next steps are to build an analytical model to predict the vibration transmission for a rod with multiple nonlinear absorbers attached and complete an experimental study to validate analytical and numerical results.

Marie Graff (University Of Auckland, NZ)

Recent advances on the adaptive eigenspace inversion method

Parameter estimation is a fundamental task in engineering and science such as medical imaging and seismology. The aim of imaging is to infer characteristics of a medium from indirect measurements. Imaging problems are often cast as PDE constrained optimisation problems that are typically ill-posed in the sense of Hadamard. Therefore, regularisation is needed to define a well-posed problem and stabilise the solution. In this talk, we analyse and extend a novel regularisation technique called Adaptive Eigenspace Inversion (AEI). We will develop a probabilistic analogue of the method using the Bayesian formalism to bring uncertainty quantification to our reconstruction using AEI.

Stuart Hawkins (Macquarie University, OZ)

A numerically stable T-matrix algorithm

The T-matrix is an important tool for scattering simulations and is widely used in many applications. In its original form, the T-matrix was computed using the null field method or extended boundary condition method (EBCM). It is well known that the EBCM is numerically unstable for particles that deviate significantly from a sphere. However, the EBCM is not intrinsic to the T-matrix and in this talk we describe a completely different approach that is numerically stable for all scatterers. The key to our method is calculating the T-matrix in the far field instead of on the scatterer surface. We present new numerical results demonstrating the enhanced numerical stability of our method for light scattering by geometries with large aspect ratios and large size parameters.

Joerg Hennig (University Of Otago, NZ)

Soliton methods and the black hole balance problem

Soliton methods were initially introduced to study equations like the Korteweg-de Vries, which describes nonlinear water waves. Interestingly, the same methods can also be used to analyse equilibrium configurations in general relativity. An intriguing open problem is the question as to whether stationary equilibrium configurations can exist. Due to the nonlinear effect of the spin-spin repulsion of rotating objects, and perhaps by considering charged objects with an additional electromagnetic repulsion, it remains a possibility that such unusual configurations do exist. An important example of an n-body system is a (hypothetical) equilibrium configuration with n aligned black holes. By studying the linear matrix problem that is equivalent to the Einstein equations for axixymmetric and stationary (electro) vacuum spacetimes, we obtain the most general form of the boundary data on the symmetry axis in terms of a finite number of parameters. In the simplest case $n = 1$, this leads to a constructive uniqueness proof of the Kerr (-Newman) solution. For $n = 2$ and vacuum, one obtains non-existence of stationary two-black-hole configurations. For $n = 2$ with electrovacuum, and for larger n, it remains an open problem whether the well-defined finite solution families contain any physically reasonable solutions, i.e. spacetimes without naked singularities, magnetic

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Alex McIntosh (University of New South Wales, OZ)

Sound scattering by monopolar and dipolar type resonators in a soft coating

The acoustic performance of coatings with symmetric and asymmetric distributions of resonant inclusions is presented. The coatings are designed using gratings of cavities and hard particles embedded in a soft material with an acoustic impedance similar to water. The problem is translated to sound scattering by monopolar and dipolar resonators in a one-dimensional waveguide. Coupling mechanisms for different combinations of the monopolar and dipolar resonators are analysed, from which the sound absorption for coating designs are maximised in a broad frequency range.

Tristan Lawrie (University Of Nottingham, UK)

A quantum graph approach to metamaterial design

Since the turn of the century, metamaterials have gained a large amount of attention due to their potential for possessing highly nontrivial and exotic properties—such as cloaking or perfect lensing. There has been a great push to create reliable mathematical models that accurately describe the required material composition. Here, we consider a quantum graph approach to metamaterial design. An infinite square periodic quantum graph, constructed from vertices and edges, acts as a paradigm for a 2D metamaterial. Wave transport occurs along the edges with vertices acting as scatterers modelling sub-wavelength resonant elements. These resonant elements are constructed with the help of finite quantum graphs attached to each vertex of the lattice with customisable properties controlled by a unitary scattering matrix. The metamaterial properties are understood and engineered by manipulating the band diagram of the periodic structure. The engineered properties are then demonstrated in terms of the refection and transmission behaviour of Gaussian beam solutions at an interface between two different metamaterials. We demonstrate both positive and negative refraction and beam steering. As well as both complete reflection transmission at the material interface, via the introduction of resonant structures at the boundary.

John Lekner (Victoria University of Wellington, NZ)

Theory of electromagnetic pulses

I shall give some highlights from the 2ed (in preparation) of my book with Institute of Physics Publishing [1]. The book deals with short, and thus highly non-monochromatic, pulses satisfying the following criteria:

- They satisfy Maxwell's equations.
- They have finite energy, momentum, and angular momentum.
- They are causal, meaning that they do not contain backward-propagating elements.

The pulses satisfying all three criteria are formed from solutions of the wave equation of the form

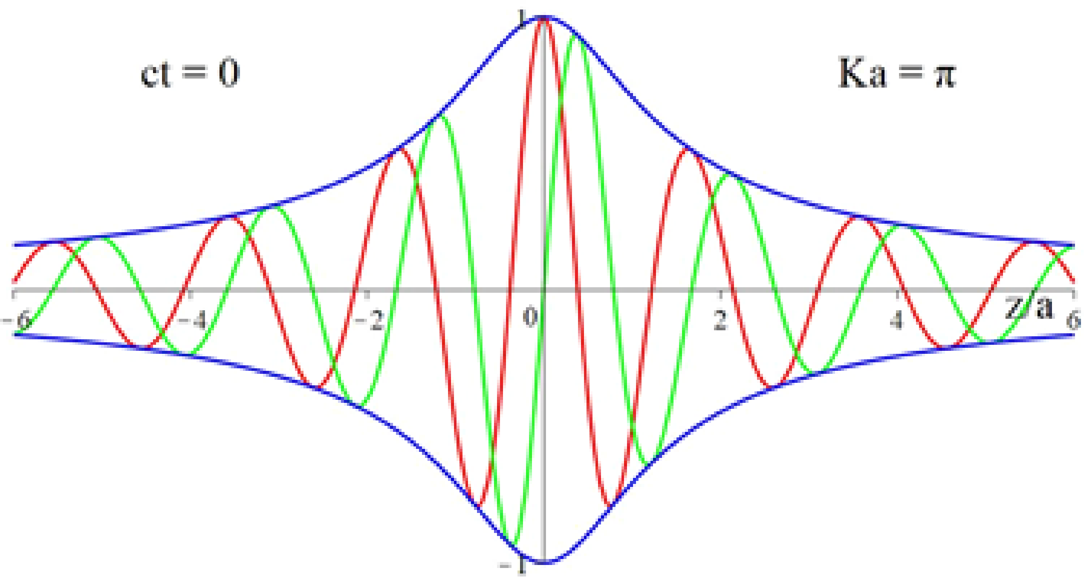
$$\psi_m(\rho,\phi,z,t) = e^{im\phi}\int_0^\infty dk e^{-ikct}\int_0^k dq w(k,q)\, e^{iqz} J_m(\kappa\rho), \qquad \kappa = \sqrt{k^2 - q^2} \tag{1}$$

These are wavenumber superpositions of $e^{iqz-ikct}J_m(\kappa\rho)$ (cylindrical coordinates). Examples are

$$\psi(\rho,z,t) = R^{-1}F(R - iz), \qquad R^2 = (a+ict)^2 + \rho^2, \qquad \text{any differentiable F} \tag{2}$$

$$G_K(\rho,z,t) = \frac{a^2 e^{iKz-KR}}{R(R-iz)}, \qquad w(k,q) = a^2 e^{(K-k)a} \qquad (k \geq K, q \geq K;\ \text{zero otherwise}) \tag{3}$$

The figure shows a particular case of G_K; envelope (blue), real and imaginary parts (red and green):



An advantage of the formulation (1) is that the pulse total energy, momentum and angular momentum are all expressible in terms of the wavenumber weight function $w(k,q)$. For TE and TM pulses,

$$\begin{bmatrix} U \\ cP_z \\ cJ_z \end{bmatrix} = \frac{\pi}{2}\int_0^\infty dk \int_0^k dq |w(k,q)|^2 \left(k^2 - q^2\right) \begin{bmatrix} k \\ q \\ m \end{bmatrix}$$

For the $m = 0$ pulse G_K these are $U = \frac{\pi}{16a}\left(4 + 5Ka + 2K^2a^2\right)$, $cP_z = \frac{\pi}{32a}\left(3 + 6Ka + 4K^2a^2\right)$.

[1] Theory of electromagnetic pulses, IoP Publishing, Bristol (2018)

[2] Family of oscillatory electromagnetic pulses Phys. Rev. A 108, 063502 (2023)

Kei Matsushima (University of Tokyo, Japan)

On Rayleigh-Bloch waves swapping between physical and unphysical Riemann sheets

In this talk, we discuss Rayleigh-Bloch waves along singly-periodic obstacles in two dimensions. To achieve this, we introduce a quasi-periodic Green's function and formulate a boundary integral equation equivalent to the periodic problem. Above the cutoff frequency, Rayleigh-Bloch wavenumbers become complex, necessitating a careful investigation of the Green function's multivaluedness. We present numerical evidence suggesting that the Rayleigh-Bloch wavenumbers lie on a complex manifold, comprising both physical and unphysical sheets. Notably, the latter has been overlooked in existing literature.

This is joint work with Luke Bennetts (University of Adelaide) and Malte Peter (University of Augsburg).

Mike Meylan (University Of Newcastle, OZ)

Simulation of three-dimensional tsunami waves including static compression

An analytical solution of three-dimensional surface wave profiles due to arbitrary ocean bottom motion in a compressible ocean is obtained. This solution includes the static ocean background compression which has previously been neglected. Time-domain simulations of the surface profile in three dimensions and the pressure distribution within the water column are calculated. We show that the influence of static compression is small and the main influence is to change the tsumani wave speed.

Romain Meyrand (University Of Otago, NZ)

Stochastic echoes in collisionless plasmas

In a collisionless, magnetized plasma, particles may stream freely along magnetic field lines, leading to "phase mixing" of their distribution function and consequently, to smoothing out of any "compressive" fluctuations (of density, pressure, etc.). This rapid mixing underlies Landau damping of these fluctuations in a quiescent plasma—one of the most fundamental physical phenomena that makes plasma different from a conventional fluid. Nevertheless, broad power-law spectra of compressive fluctuations are observed in turbulent astrophysical plasmas (most vividly, in the solar wind) under conditions conducive to strong Landau damping. By direct numerical simulations and theoretical arguments, I will show that this is due to strong suppression of phase mixing by "stochastic echoes," arising due to nonlinear advection of the particle distribution by turbulent motions. Other than resolving the long-standing puzzle of observed compressive fluctuations in the solar wind, this suggest a conceptual shift for understanding kinetic plasma turbulence generally: rather than being a system where Landau damping plays the role of dissipation, a collisionless plasma is effectively dissipationless, except at very small scales.

Malte Peter (Universität Augsburg, Germany)

Identification of microstructural information from macroscopic boundary measurements in linear elasticity

We consider the upscaled linear elasticity problem in the context of periodic homogenisation in the regime where the wavelength is much larger that the microstructure. Based on measurements of the deformation of the (macroscopic) boundary of a body for a given forcing, it is the aim to deduce information on the geometry of the microstructure. For a parametrised microstructure, we are able to prove that there exists at least one solution of the associated minimisation problem based on the L^2-difference of the measured deformation and the resulting deformation for a given parameter. To facilitate the use of gradient-based algorithms, we derive the Gâteaux derivatives using the Lagrangian method of Céa, and we present numerical experiments showcasing the functioning of the method.

This is joint work with T. Lochner (University of Augsburg).

Christo Rautenbach (NIWA, NZ)

Wave set-up in constricted estuaries

Coastal inundation is a well-studied topic. Surprisingly, the extent and dynamics of wave-set-up in estuaries with constricted entrances has not been thoroughly investigated. The current literature mainly deals with the open coast and river mouths and the results vary significantly. The offshore wave height and period, entrance depth and local beach slope are predominantly considered as the main variables influencing wave set-up. Within estuaries the distance from the mouth is also considered. New Zealand estuaries (called harbours locally) are varied and represent a large range of hydro-systems (Hume, 2016). Here, wave set-up in estuaries with a constricted entrance will be investigated and compared to wave set-up reported in literature, with values ranging between 2 and 14% of the offshore significant wave height (Mohd Zaki, 2021). Estuaries with a large intertidal area and constricted entrances have not been investigated in combination with waves before (de Ruiter, Mullarney et al., 2017; de Ruiter, Mullarney et al., 2019). Ohiwa estuary (harbour), situated on the North Island of New Zealand in the Bay of Plenty district, will be the focus area of the present study. This study is a scenario based, numerical investigation, aimed at understanding the quantity and extent of wave set-up in the estuary during extreme events. The validated numerical model (estuarine water levels and inundation extents) found wave set-up to be significant in these types of estuaries, adding approximately 10 and 25% to the water levels within the estuary during an extreme event's high and low tide respectively (as compared to a spring tidal range of 1.7 m). The estuary entrance geomorphic configuration was found to make little difference to the total water level observed in the estuary but did influence the storm-tidal asymmetry and low tide level (estuary drainage). The wave set-up dissipated in the estuary and mostly contributed to elevated water levels in proximity of the entrance and deep tidal channels. This was consistent with previous studies focusing on open, river mouth, estuaries. Understanding prolonged high-water levels in these types of systems has implications for coastal infrastructure, the local ecology and farming (pasture inundation tolerance durations).

Ann Roberts (University of Melbourne, OZ)

Beyond traditional optics: metasurfaces in image processing

With increasing concerns over energy consumption and processing speeds, there is an emerging interest in new all-optical approaches to manipulating images. Metasurfaces have been demonstrated to have significant potential for performing both image processing and optical analogue computing and provide a new avenue for extracting information from optical fields. They have been used in traditional 4f optical systems as novel spatial filters and can be designed to directly manipulate the spatial frequency content of an image. Although techniques such as edge enhancement have attracted widespread attention, visualisation of the phase of an optical field is another important application. This permits direct imaging of samples, such as unstained biological cells with weak absorption, without the requirement for staining. Traditionally phase imaging has been performed using methods including digital holographic and Differential Interference Contrast (DIC) microscopy that require relatively bulky, and sometimes expensive, components. Sophisticated computational strategies for extracting phase from intensity also exist, but these can be relatively slow. The use of metasurfaces provides an avenue to access this information directly, with reduced computational overhead, and using compact and potentially inexpensive devices. This presentation will discuss recent developments in nanophotonic approaches to all-optical image processing with a focus on phase imaging.

Rafa Santana (University of Otago, NZ)

Modelling Antarctic sea ice variability using a brittle rheology

Sea ice plays an important role in determining the exchange of heat, salt, and momentum between the atmospheres and oceans. The Next Generation Sea Ice Model (neXtSIM) is a Lagrangian model aimed to study the behaviour of sea ice in response to various environmental factors. neXtSIM was applied for the Southern Ocean using both a novel brittle rheology (BBM) and a typical Elastic-Viscous-Plastic (EVP) rheology. Both runs well-represented the seasonal cycle of sea ice extent but tended to overestimate it by about $2.5 \times 106\,\mathrm{km}^2$ (14%) in winter due to a colder ocean forcing. The BBM had larger drift correlation (0.73) in comparison to the EVP run (0.54). This happened because, in the BBM run, sea ice fractures more easily and is more effectively transported by the wind and currents. In contrast, sea ice tends to deform as a viscous fluid in the EVP run. Fractured ice in the BBM run also leads to thicker ice due to increased ridging and ice growth which tends to generate a larger Pan-Antarctic sea ice volume. Preliminary results of a wave-sea-ice coupled model show the penetration of swell hundreds of kilometres into the pack revealing the importance of waves for climate projections.

Mathieu Sellier (University of Canterbury, NZ)

Identification of rheological parameters for shallow water flows of viscoplastic fluids using elevation hydrographs

In this study, the rheological parameters, in particular yield stress and consistency index, for viscoplastic fluids are inferred from the elevation hydrographs derived from experiments. The direct model consisting of the shallow water equations with a Herschel–Bulkley rheology, is used to simulate a fluid flowing down an inclined plane, and past a cylindrical occlusion. Numerical simulations are validated with experimental and related results from the literature. The aim is to infer the unknown rheological parameters using hydrograph measurements in the wetting line region between the fluid and the occlusion. The rheological identification problem is formulated to minimize an objective functional that measures the discrepancy between the elevation hydrographs from the model output and experimental data. The inverse solver is tested on both synthetic and laboratory data. The set of rheological parameters inferred is compared with the values measured on a rheometer for the fluid used in the experiments. Inference of the unknown flow quantities from the wetting free-surface data has direct applications not only in industrial settings, to predict the wetting dynamics, but also in geophysical ones for risk assessments and management plans.

Alex Skvortsov (Defence Science and Technology Group, OZ)

Surface water waves generated by a moving piercing cylinder

Understanding of interface gravity waves generated by vertical surface piercing cylinders is important for many engineering applications (wind turbines, oil and gas platforms, port structures etc). Despite a simple mathematical setting the problem imposes significant challenges for analytical treatment (free surface, viscosity, splashes, two-phase flow, etc), and advanced capability for numerical treatment. We present a simplified model of the phenomenon in which the cylinder is modeled by a moving localised distribution of pressure on the free surface (Gaussian axisymmetric hut). The values of some parameters of this distribution are determined from energy consideration and the value of one parameter is deduced from fitting the experimental data. The model can be treated semi-analytically (with light calculations in Matlab). The review of the experimental program is also presented.

Vladislav Sorokin (University of Auckland, NZ)

A point absorber Wave Energy Converter for supplying energy to aquafarms

The talk concerns the development and testing of a single degree of freedom Wave Energy Converter (WEC) that can harvest energy from heave and surge motion of waves in nearshore conditions. The device specifically targets supplying energy to aquafarms, usually located nearshore in relatively sheltered bays and harbours, and has been designed to be attached to existing aquafarming structures. The device consists of a buoy that can slide up and down with the waves along a linear rail, with this linear motion converted into rotations of a generator using magnetic coupling.

Effects of mounting orientations of the device, i.e. the angle of the linear rail with respect to the vertical, on the power output were studied for a range of wave frequencies and amplitudes. Based on this modelling, a scale prototype was manufactured and tested in the University of Auckland wave flume, using regular shallow and intermediate waves. It is shown both experimentally and theoretically that increasing the mounting orientation angle increased the device's power output across all wave frequencies. The maximum time-average power achieved for a 6.4 kg moving buoy was 12.6 W with a wave height of 0.32 m and frequency of 0.5 Hz.

Jonathan Squire (University of Otago, NZ)

Switchbacks: nonlinear magnetic waves in the solar wind

NASA's Parker Solar Probe spacecraft, which is currently exploring regions closer than ever before to our Sun, has observed copious "switchbacks" – sudden, sharp reversals of the magnetic field that propagate outwards through the solar wind. Switchbacks are most likely large-amplitude magnetic waves (so-called "Alfvén waves") that result from the balance between magnetic tension and the inertia of the plasma. Unlike sound waves or water waves, Alfvén waves can propagate undamped and without breaking at arbitrary amplitude, including once the perturbation becomes larger than the background magnetic field, explaining the full field reversals observed in switchbacks. Moreover, such large-amplitude nonlinear waves behave almost identically to their linear cousins, propagating in inhomogeneous environments just as predicted by linear WKB theory. I will give an overview of switchback observations and theory, discussing how they propagate and grow in the solar corona, and their possible role in dissipating to heat the corona and accelerate the solar wind.

Chris Stevens (University of Canterbury, NZ)

Gravitational waves: a numerical exploration of the global scattering problem

Although gravitational waves were postulated within Einstein's theory of relativity way back in 1917, their corresponding scattering problem is still completely open. One major difficulty is incorporating past and future infinity, where the in and out-states are respectively defined. Furthermore, fundamental hindrances within the conformal field equations — the Einstein equations regularly extended to include the points at infinity — make global propagation from the past to future difficult. This talk continues from Jörg Frauendiener's and discusses a novel mathematical and numerical framework for attacking the global gravitational wave scattering problem.

Sophie Thery (Augsburg Universität, Germany)

Cloaking in water waves by thin floating plates

We apply the cloaking principle mostly used in electromagnetics in the context of water waves. The cloak consists of circular thin floating plates surrounding a region not affected by external waves. This effect is made possible by first finding a single cloaking plate made of non-homogeneous and anisotropic material, which is subsequently approximated by multiple isotropic homogeneous plates using homogenization techniques.

Amy-Rose Westcott (University of Adelaide, OZ)

Broadband energy capture by an array of heaving buoys

Broadband energy capture is sought by grading the resonant properties of an array of heaving buoy-type wave energy converters (WECs) in 2D, thereby extending the work by Wilks et al. (2022) to a WEC-array. Linear potential-flow theory is applied and WEC interactions are modelled using multiple-wave scattering theory in the frequency domain. The resonant properties of WECs are tuned via a linear spring-damper power take-off mechanism.

Bloch-Floquet theory is applied to determine the grading of WEC-resonances (controlled via the PTO spring terms) which prevents transmission on the targeted power capture interval. Near-perfect absorption at individual frequencies is then obtained by manipulating the complex-frequency zeros of the reflection coefficient through the extraction of incident energy (using the PTO damping terms).

The resulting graded array captures near-perfect absorption ($> 98\%$ of incident energy) from a targeted band of wavelengths spanning twice the array's length. Additionally, the grading of the (a) WEC-array can be optimised to achieve near-perfect, broadband absorption. Lastly, forcing by a transient wave packet is considered to demonstrate the temporal behaviour of the array.

Ben Wilks (University of Otago, NZ)

Canonical time-domain scattering in one dimension using the generalised eigenfunction expansion method

Wave scattering on a infinite stretched string, which we model using the classical wave equation, is an useful prototype of acoustic wave and water wave scattering on unbounded domains. In this talk, we discuss the solution to this problem using the generalised eigenfunction expansion method, which seeks to diagonalise the time-evolution operator. Its eigenfunctions are single-frequency solutions—precisely those that arise from solving the corresponding frequency domain problem with a sinusoidal incident wave.

The generalised eigenfunction expansion of the solution arises from the spectral theorem, which requires that the underlying time-evolution operator is self adjoint. However, this operator fails to be self adjoint when energy is not conserved. We will explore a work-around to this problem in the case of a simple point absorber. The work-around involves embedding the lossy system in a larger system in which energy is conserved.

Hugh Wolgamot (University of Western Australia, OZ)

Generalised phase manipulation for water wave-structure interaction

Phase combinations have recently gained popularity in wave basin and numerical tests as a method to extract higher-order components of the forces, surface elevations or other responses of interest. By taking advantage of the Stokes' harmonic structure, these techniques use control of the wavemaker to enable clean separation of nonlinear terms. In cases where there are multiple controlled inputs (i.e. an actuated structure(s) in waves), many more combinations become possible, suggesting the prospect of separating nonlinear terms on the basis of their 'driving' signals. This is particularly important for renewable energy devices like wave energy converters and floating offshore wind turbines, where responses driven by motions can be controlled to some extent using active control on the structure. This talk will explore this area and illustrate with examples.