Fluids in New Zealand 2022

The University of Auckland (Virtual)

27–28 January 2022

Contents

About the Conference

The 10th Fluids in New Zealand (FiNZ) workshop will be held at The University of Auckland from 27th to 28th January 2022. While we were hoping to have an in-person workshop, we have opted for a virtual workshop due to uncertainties over COVID-19 restrictions and policies.

The workshop aims to bring together New Zealand researchers interested in fluid mechanics to discuss their recent work in a friendly and collaborative setting. A broad range of topics, including experimental, numerical and theoretical work, from academics and postgraduate students, is encouraged.

Organising Committee

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Acknowledgements

The organising committee gratefully acknowledges the financial support of the Department of Mechanical Engineering at The University of Auckland, for funding the student awards. These were awarded to the top two student presentations, as voted by academic staff.

Code of Conduct

As a New Zealand conference welcoming members from diverse backgrounds, organisations, and lived experiences, we are committed to the open exchange of ideas, freedom of thought and expression, and respectful debate. These require a community and an environment that recognises the inherent worth of every person and group, that fosters inclusion, dignity, understanding, and mutual respect, and embraces diversity.

Fluids in New Zealand (FiNZ) is dedicated to providing a harassment-free experience for everyone engaging with FiNZ 2022, regardless of gender, sexual orientation, disability, physical appearance, race, ethnicity, political affiliation, nationality, language, or religion – and not limited to these aspects. We are dedicated to cooperation, civility, and respect, and do not tolerate harassment in any form. Sexual or discriminatory language or imagery is not appropriate and will not be tolerated at this conference. Participants violating these rules may be sanctioned or expelled at the discretion of the organisers.

Harassment and hostile behaviour are not welcome at FiNZ. This includes speech or behaviour (including in public presentations and on-line discourse) that intimidates, creates discomfort, or interferes with a person's participation or opportunity for participation in the community or event. FiNZ 2022 aims to be an environment where harassment in any form does not take place, including but not limited to harassment based on race, gender, religion, age, colour, national origin, ancestry, disability, socioeconomic status, sexual orientation, or gender identity.

Harassment includes but is not limited to: inappropriate verbal comments as outlined above; sexual images in public spaces; deliberate intimidation, stalking, or following; harassing photography or recording; sustained disruption of talks or other events; inappropriate physical contact; unwelcome sexual attention; and advocating for or encouraging any of the above behaviour.

Participants asked to stop any harassing behaviour are expected to comply immediately.

Implementation

It is the responsibility of the FiNZ community as a whole to promote an inclusive and positive environment for our scholarly activities. If you are being harassed, notice that someone else is being harassed (active bystander principle), or have any other concerns, please contact a member of the FiNZ 2022 Organising Committee. Your support will help keep our community and our events a safe, welcoming, and friendly space for all fellow participants!

Protocol for conflict resolution

Report

1. If you are being harassed, notice that someone else is being harassed (active bystander principle), or have any other concerns, please immediately contact a member of the FiNZ 2022 Organising Committee.

Escalate

2. Find a member of the FiNZ 2022 Organising Committee. They will assist you. These parties will help participants contact hotel/venue security or local law enforcement, provide escorts, or otherwise assist those experiencing harassment and will help them to feel safe for the duration of the event.

3. If you have been harassed via email or social media, you may send emails or screenshots to michael.macdonald@auckland.ac.nz.

Resolve

4. The FiNZ 2022 Organising Committee will require anyone engaging in harassing behaviour to cease immediately or face expulsion or other sanctions.

5. Those sanctions can include reporting to the individual's organisation, and supporting the victim in making informal or formal complaints via that organisation's processes.

6. If an incident results in corrective action, then FiNZ will support those harmed by the incident, both publicly (where appropriate) and privately.

7. If any individual encounters problems or issues attempting to help a victim of harassment while following our anti-harassment policy and protocol, they are encouraged to engage with the FiNZ community and FiNZ 2022 Organising Committee for clarifications and/or to seek revisions. We are very open to revising any part of our policy or protocol if needed to ensure a safe and welcoming community in which harassment is not tolerated

This code of conduct was adapted from that of Te Pūnaha Matatini.

Programme

Day 1: Thursday 27 January 2022

08:50 Welcome

Session 1 Chair: John Cater

09:00 **Invited Speaker:** Sarah Wakes – *Adventures (not) on the beach: Wind flow over coastal dune systems*

09:45 Raghu Ande – *Numerical investigation of a five-beam array oscillating in a viscous fluid*

10:00 Ben Wilks – *Broadband energy absorption by graded arrays of vertical barriers*

10:15 Debolina Sarkar – *Microfluidics used to evaluate oomycete pathogenicity*

10:30 Break

Session 2 Chair: Stefanie Gutschmidt

11:00 Leighton Watson – *Infrasound radiation and fluid dynamics from impulsive volcanic eruptions: 2D aeroacoustic simulations*

11:15 Pasha Clothier and Michael MacDonald – *Kowhaiwhai and fluid dynamics*

11:30 Elizabeth McGeorge – *Beneath the surface: recovery of ice thickness from observations.*

11:45 Mark Battley – *Simulation of fluid-structure interaction for wave impacts on coastlines and coastal structures*

12:00 Miguel Moyers-Gonzalez – *Nonisothermal thin-film flow of a viscoplastic material over topography*

12:15 Lunch

Session 3 Chair: Richard Clarke

13:30 **Invited Speaker:** Alys Clark – *Fluid dynamics of the uterine blood vessels and their changes in pregnancy*

14:15 Daniel Clarke – *Characterisation of unsteady flow behaviour in a 3D-printed Schwarz Diamond monolith using MRI*

14:30 Brendan Harding – *Inertial migration of spherical particles suspended in flow through curved microfluidic ducts*

14:45 Joshua Looker – *Asymmetric Assembly of Lennard-Jones Janus Trimers*

15:00 Break

(Thursday programme continued)

Session 4 Chair: Michael MacDonald

15:30	Jonny Williams – *Simulating tropical cyclones impacting New Zealand*
15:45	Caleb Barr – *Shear stress induced low-density lipoprotein aggregation: The effect of shear stress on atherosclerosis*
Lightning presentations:	
16:00	Chris Hughes – *Condensation-frosting investigation on coating-free topographic wetting gradients for heat transfer surface applications*
16:05	Vinod Suresh – *Elastohydrodynamic lubrication in an annulus*
16:10	Rina Watt – *Exploring Ocean Wave Renewable Energy Potential Around New Zealand*
16:15	Sevgi Onal – *Mechanical cell compression and recovery in a flexible microdevice*
16:20	Sid Becker – *Exact solution analysis of the temperature profile in a micro-cantilever in order to induce flapping*
16:25	Alice Harang – *BG-Flood, an open-source GPU powered software for modelling floods in New-Zealand*
16:30	David Muchiri – *Extracting rheological details of lava flows from free surface measurements*
16:35	Q&A (all lightning presenters)
16:45	Virtual social event (BYO drink)

Day 2: Friday 28 January 2022

Session 5 Chair: Miguel Moyers-Gonzalez

09:00	**Invited Speaker:** Emilia Nowak – *Fundamental challenges in the processing industry*
09:45	James Hewett – *Isothermal thin-film flow of a viscoplastic material around an occlusion*
10:00	Geoff Willmott – *Drop Impacts in the Dynamic Microfluidics Laboratory: An Update*
10:15	Break

(Friday programme continued)

Session 6 Chair: Geoff Willmott

10:45	Duc Nguyen – *Using CFD to examine the effects of backdune morphology on the flow dynamics behind excavated foredune notches*
11:00	Theresa Bischof – *LES of Atmospheric Buoyancy Vortices for Power Generation*
11:15	Nicholas Kay – *Contributions of the upper and lower surfaces to Lift produced by Low Reynolds Number Aerofoils in Onset Turbulence*
11:30	**Open discussion:** Diversity and equity in fluid mechanics in New Zealand
12:00	Lunch

Session 7 Chair: Priyanka Dhopade

13:15	Kirill Misiiuk – *Development of Coating-Free Super Water-Repellent Micropatterned Aluminium for Spontaneous Droplet Motion*
13:30	Shuen Law – *Improving integral model for desalination discharges using data from large eddy simulation*
13:45	Paul Docherty – *A novel method for Navier-Stokes Identification and Correction of Erroneous Particle Image Velocimetry Data*
14:00	Selin Duruk – *3D Nonlinear Dynamics of a Thin Liquid Film on a Spinning Ellipsoid*
14:15	Break

Session 8 Chair: Ayoub Abdollahi

14:45	Ali Sefidan – *Numerical modelling of whole milk spray drying process*
15:00	Pouria Aghajannezhad – *The effect of geometrical and topological changes on the fluid flow through large-scale Discrete Fracture Networks*
15:15	Dimitrios Mitsotakis – *Equations for nonlinear and dispersive water waves over variable bottom topography*
15:30	Oscar Punch – *Numerical modelling of linear and oblique collisions of liquid-coated particles validated with experimental results*
15:45	Presentation of Student Awards and Closing
15:55	**Annual meeting:** Review of FiNZ2022; FiNZ2023; IUTAM Association[1]

[1]See end of booklet for further details on this item

Adventures (not) on the beach: Wind flow over coastal dune systems

Sarah Wakes[1]
[1]*Department of Mathematics and Statistics, University of Otago, New Zealand*

Kiwis love the beach but most of us probably don't spend much time thinking about what a valuable job the dune system at the back of the beach does. Coastal dune systems play an important role in protecting communities, property and land from the effects of climate change such as more frequent and severe storm surges and inundation events. However these dune systems are increasingly being put under pressure from factors such as our desire to live near the sea, existing geoengineering structures, resourcing constraints, topographic considerations as well as community pressure and expectations. These demands are often conflicting and coupled with the complexity of wind-sand interaction and dune dynamics it can be very difficult to formulate proactive longterm coastal management plans. Understanding better how wind flows and sand is transported over coastal dunes is essential to the development of better ongoing management of these systems. Methods such as field measurements and Computational Fluid Dynamics are used to investigate the flow structures that occur around coastal dune systems and will be discussed with a focus on the interaction of wind flow with dune morphology and vegetation cover. The challenge of building useful conceptual models for wind flows over coastal dune systems will also be explored in this talk.

Numerical investigation of a five-beam array oscillating in a viscous fluid

Raghu Ande, Stefanie Gutschmidt and Mathieu Sellier
Department of Mechanical Engineering, University of Canterbury, New Zealand

A two-dimensional computational fluid dynamics (CFD) investigation is carried out to understand the flow physics and array dynamics of identical beams oscillating in a viscous fluid. This investigation is carried out for a five-beam array oscillating in an unbounded fluid and close to the surface, at a small to large amplitude ratios, for selected Reynolds numbers. Our work examines the velocity configuration of beams active in phase for varying gaps between beams and their height from the surface. The hydrodynamic loading associated with the array of beams is represented by a complex hydrodynamic function, where the imaginary value represents the damping due to viscous drag, and its real value represents the added mass.

This two-dimensional CFD model can predict the array dynamics for all amplitude ratios ranging from small to large. Results suggest that the convection-driven nonlinearities become dominant with an increase in the amplitude ratio, which results in nonlinear viscous damping. Array of beams oscillating close to the surface experience higher viscous damping due to the presence of the rigid surface. Furthermore, the influence of neighbour and non-neighbour beams over each other can be observed with the multiple viscous layer interactions of a large array due to the fluid-coupling phenomenon.

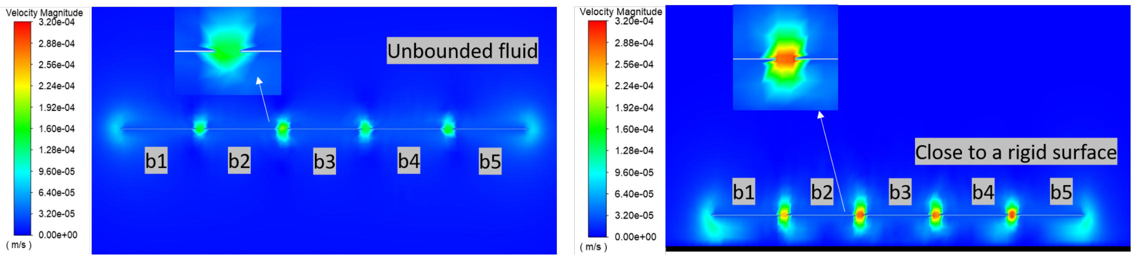

Figure 1: Velocity-profile of a five-beam array oscillating in a fluid environment

Broadband energy absorption by graded arrays of vertical barriers

Ben Wilks[1], Fabien Montiel[1] and Sarah Wakes[1,2]
[1] *Department of Mathematics and Statistics, The University of Otago, New Zealand*

The rainbow reflection effect describes the broadband spatial separation of wave spectral components caused by a spatially graded array of resonators. Although mainly studied in optics and acoustics, this phenomenon has recently been demonstrated both theoretically and experimentally for water waves travelling through an array of vertical cylinders. This talk will focus on the scattering of linear water waves by an array of vertical, surface-piercing barriers in which both the submergence and spacing between the barriers are spatially graded. The rainbow reflection effect arises naturally in such arrays, as wave energy temporarily becomes amplified at different locations depending on frequency. This begs the question of whether the localised energy can be harvested effectively, which could lead to applications in wave-energy conversion. Thus, we extend the wave/barriers scattering problem by positioning heave-restricted, rectangular floating bodies equipped with a linear damping mechanism within the array. Using constrained optimisation, passive rainbow absorbing structures are designed that achieve near-perfect absorption over (i) a discrete set of frequencies, and (ii) over an octave.

Microfluidics used to evaluate oomycete pathogenicity

Debolina Sarkar1, 2, Ashley Garrill1, 2 and Volker Nock2, 3

[1]*School of Biological Sciences, University of Canterbury, Christchurch 8041, New Zealand*
[2]*Biomolecular Interaction Centre, Department of Electrical and Computer Engineering, University of Canterbury, Christchurch 8041, New Zealand*

[3]*The MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington 6140, New Zealand*

The oomycete *Phytophthora* can cause serious threats to native flora and agriculture and food biosecurity [1, 2]. These organisms can infect their host plants via motile zoospores. These can travel between sites of infection via water in the soil in response to electric fields [3]. The movement of the pathogens in response to electric fields are one way in which they are thought to be able to locate their hosts.

This paper reports the fabrication and application of a microfluidic Lab-on-a-Chip (LOC) platform to study the electrotactic movements of pathogenic microorganisms (Fig: 1). The movement of the pathogens in response to electric fields are one way in which they are thought to be able to locate their hosts. This tool offers a unique opportunity to study electrotactic movements that may be responsible for the ability of the pathogens to locate and invade host tissue.

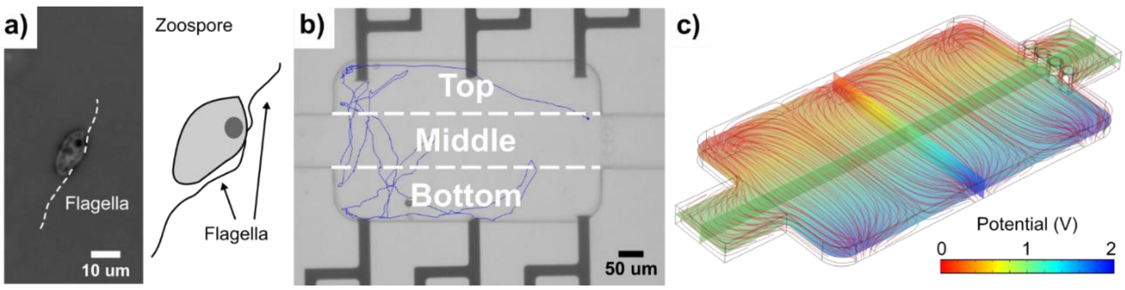

Figure 1: (a) Optical micrograph of an individual *P. nicotianae* zoospore on the chip and schematic highlighting two flagella which provide motility. (b) An example of zoospore tracking with the blue line representing where the zoospore had swum. Also indicated are the observation chamber top, middle and bottom zones that were used for residence time analysis (c) Finite element simulation (Comsol Multiphysics V5.5) of the electric potential and current density (streamlines) in the chamber when the top electrodes were grounded, and 2 V DC applied to the bottom electrodes.

References:
[1] S. Kamoun, et al., *Molecular plant pathology*, **2010**, 16, 413-434.
[2] Y. Sun, A. Tayagui, S. Sale, D. Sarkar, V. Nock, and A. Garrill, *Micromachines*, **2021**, 12, 639.
[3] P. van West, et al., *Mol. Plant-Microbe Interact.*, **2002**, 15, 790-798

Infrasound radiation and fluid dynamics from impulsive volcanic eruptions: 2D aeroacoustic simulations

Leighton M. Watson[1], Eric M. Dunham[2,3], Danyal Mohaddes[4], Jeff Labahn[5], Thomas Jaravel[5], Matthias Ihme[4]
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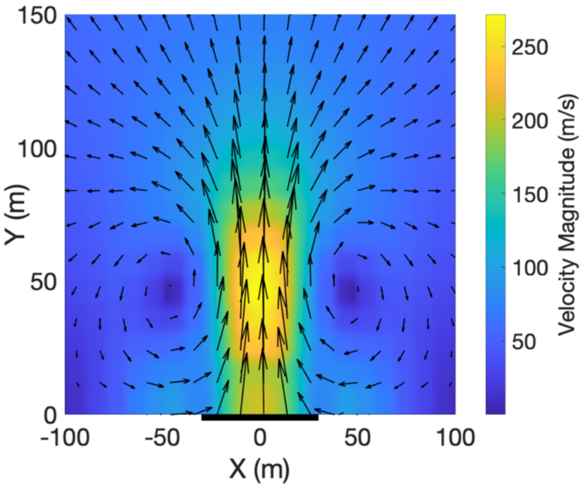
Volcanic eruptions are violent phenomena that exhibit complex fluid dynamics. Eruption of material from a volcanic vent can displace atmospheric air and produce low frequency sound waves (< 20 Hz) termed infrasound. Infrasound observations are increasingly used to constrain properties of volcanic eruptions, such as volume and mass eruption rates. In order to better interpret infrasound observations, however, there is a need to better understand the relationship between the fluid dynamics of the eruption and sound generation.

In this work we perform two-dimensional computational aeroacoustic simulations where we solve the compressible Navier-Stokes equations for pure-air with a large eddy simulation approximation. We simulate idealized impulsive volcanic eruptions where the exit velocity is specified, and the eruption is pressure-balanced with the atmosphere. Our nonlinear simulation results are compared with the commonly-used analytical linear acoustics model of a compact monopole source radiating acoustic waves isotopically in a half space. The monopole source model matches the simulations for low exit velocities (up to 100 m/s or M≈0.3 where M is the Mach number); however, the two solutions diverge as the exit velocity increases with the simulations developing lower peak amplitude, more rapid onset, and anisotropic radiation with stronger infrasound signals recorded above the vent than on Earth's surface.



Our simulations show that interpreting ground-based infrasound observations with the monopole source model can result in an underestimation of the erupted volume for eruptions with sonic or supersonic exit velocities. We examine nonlinear effects and show that nonlinear effects during propagation are relatively minor for the parameters considered. Instead, the dominant nonlinear effect is advection by the complex flow structure that develops above the vent. This work demonstrates the need to consider anisotropic radiation patterns and near-vent fluid dynamics when interpreting infrasound observations, particularly for eruptions with sonic or supersonic exit velocities.

Kowhaiwhai and fluid dynamics

Pasha Ian Clothier[1], Dr Michael MacDonald[2]
[1]*Kaiako Art and Design, The Learning Connexion, Wellington Aotearoa New Zealand*
[2]*Department of Mechanical Engineering, The University of Auckland, New Zealand*

It is well known that fluid dynamics occupied a central role in Chaos Theory, from Robert Shaw studying a dripping tap, to engineer E Atlee Jackson exploring nonlinear dynamics in storm water drainage. Less well known is that in Te Taiao Māori as given by Dr Te Huirangi Eruera Waikerepuru, wai in the sense of flow occupied a central place, from the waters of birth, to 'ko wai au' (whose your name?), to Universal elements, through to what is called by scientists the hydrological cycle, the concept of which in Te Ao Māori includes the breath. Easily the most well-known artist to explore fluid dynamics is Leonardo da Vinci, who researched the interrupted flow of the river Arno, turbulence in the human heart, and conceptualised restrictions on the flow of water while trying to understand layering in water flows.

This presentation brings these elements together through the lens of fluid dynamics - the study of self-similarity and von Karman vortex streets - in the context of kowhaiwhai. It is not well known that kowhaiwhai originated as hoe – canoe paddle – decoration. From examples traded with Cook in 1769, a Polynesian awareness of self-similarity in flow is apparent and several kowhaiwhai resemble von Karman vortex streets. In addition, self-similarity is key to recursion across scales, an important contribution to knowledge of natural systems in Western Science.

Pasha Ian Clothier is an artist who has been discussing these issues with Dr Michael MacDonald, the latter creating a flow animation using fluid dynamics software. The figure given below shows the hoe as illustrated on Cook's first voyage to Aotearoa, with a von Karman vortex street from 20th century French experiments on the right. The animation by Dr MacDonald will be shown during the presentation, along with examples of kowhaiwhai suitable to the discussion.

Beneath the surface: recovery of ice thickness from observations.

Elizabeth K. McGeorge[1], Miguel Moyers-Gonzalez[1], Mathieu Sellier[2] and Phillip Wilson [1]

[1]*School of Mathematics and Statistics, University of Canterbury, New Zealand* [2]*Department of Mechanical Engineering, University of Canterbury, New Zealand*

This talk will explore the inverse problem of recovering simultaneously the ice thickness and basal slip of an ice flow governed by the shallow ice approximation. The inversion is presented as an optimal control problem constrained by a linear elliptic partial differential equation with an unknown diffusion coefficient. First, a proof of concept using the one-dimensional case is presented. Here, the optimisation is approached using an augmented Lagrangian algorithm. Then, some preliminary results of extending the theory to the two-dimensional problem are shown. In the extension, the optimisation step is tackled using the open source adjoint based package; dolfin-adjoint.

Simulation of fluid-structure interaction for wave impacts on coastlines and coastal structures

M. Battley[1], C. Pearson[1], D. Yang[1], A. Shim[2], M. MacDonald[2], P. Higuera[3], and C. Whittaker[3]
[1]*Department of Engineering Science, The University of Auckland, New Zealand*
[2]*Department of Mechanical Engineering, The University of Auckland, New Zealand*
[2]*Department of Civil and Environmental Engineering, The University of Auckland, New Zealand*

Our coastlines are already experiencing the effects of a changing climate, and the cost to maintain traditional coastal protection infrastructure is untenable in many locations. The coastal environment is highly dynamic, and the physics of the wave action and interaction with the coastline and its infrastructure are very challenging to model, significantly limiting our ability to develop novel coastal management systems. To develop more effective mitigation approaches for coastal wave impacts we need to understand the time-history of transient hydrodynamic loads and the effect of the wave characteristics on coastal structures. This requires the ability to simulate the wave action as it reaches the coastline and the fluid-structure interaction when waves impact on rigid and flexible structures, above and below static water level.

This presentation will describe recent work on developing numerical methods for simulating such wave impacts using both Coupled-Eulerian-Lagrangian Finite Element Analysis (CEL-FEA) and volume of fluid Computational Fluid Dynamics coupled with Finite Element Analysis (CFD-FEA) based methods. Results will be presented for benchmark cases of solitary wave propagation along a flume and up sloping beaches, and wave impacts on rigid and flexible sea-wall structures. Outputs include water surface elevations, wave run-up, impact pressures and deformations of the impacted wall.

The results demonstrate that CEL-FEA can model the fluid motion, wave generation, propagation, shoaling and impact of water waves with a high degree of accuracy. It was found that the CEL-FEA method was less accurate at modelling impact pressures and forces on rigid structures than CFD, but further work is required to understand the influence of contact stiffness and mesh refinement on these results. The CEL-FEA method does however provide extensive capabilities to simulate complex structural deformations and damage evolution. The two-way coupled CFD-FEA simulation approach was also able to accurately predict the wave propagation and beach/wall impacts and predicted significant reductions in impact pressures for flexible sea-walls compared to rigid structures. This preliminary work is being continued as part of a recently funded MBIE Smart Ideas Research project.

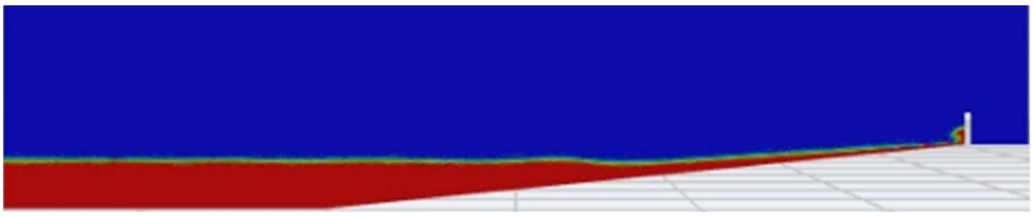
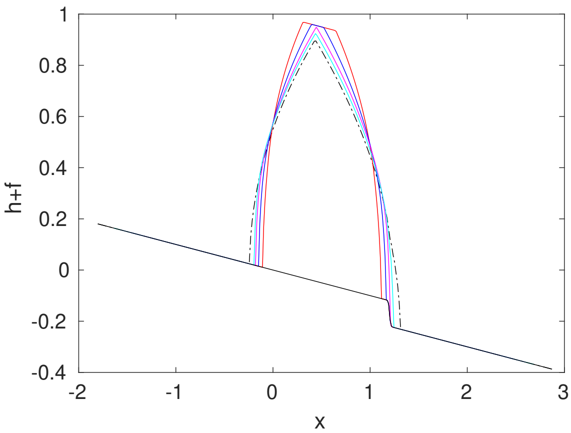


Figure 1. Wave impact on sea-wall (CFD-FEA)

Nonisothermal thin-film flow of a viscoplastic material over topography

Miguel Moyers-Gonzalez[1], James Hewett[2], Dale Cusack[3], Ben Kennedy[3] and Mathieu Sellier[2]
[1]*School of Mathematics and Statistics, University of Canterbury, New Zealand*
[2]*Department of Mechanical Engineering, University of Canterbury, New Zealand*
[3]*School of Earth and Environment, University of Canterbury, New Zealand*

We consider the flow of a viscoplastic fluid on a horizontal or an inclined surface with a flat, step-up and step-down topography. A particular application of interest is the spread of a fixed mass – a block – of material under its own weight. The rheology of the fluid is described by the Bingham model which includes the effect of yield stress, i.e. a threshold stress which must be exceeded before flow can occur. Both the plastic viscosity and the yield stress are modelled with temperature-dependent parameters. The flow is described by the lubrication approximation, and the heat transfer by a depth-averaged energy conservation equation. Results show that for large values of the yield stress, only the outer fraction of the fluid spreads outward, the inner fraction remaining unyielded. We also present an analysis which predicts the threshold value of the yield stress for which partial slump occurs.



Fluid dynamics of the uterine blood vessels and their changes in pregnancy

Alys R Clark[1], Hanna Allerkamp[1,2], Stephanie Leighton[1] and Joanna L. James[2]
[1]*Auckland Bioengineering Institute, The University of Auckland, New Zealand*
[2]*Department of Obstetrics and Gynaecology, Faculty of Medical and Health Sciences, The University of Auckland, New Zealand*

Before we are born we are sustained within the uterus with oxygen and nutrients via a close connection between two circulations (maternal and fetal) at the placenta. The placenta is a fetal organ, but is bathed in maternal blood that is delivered to its surface by the blood vessels of the uterus. These blood vessels carry a remarkable 15-fold increase in blood flow from the onset of pregnancy to the end of gestation. To do this there is a remodelling of the blood vessels in the uterus, which in part is actively driven by cell migration from the placenta itself, but also occurs due to changes in the mechanical environment of the blood vessel and/or the hormonal environment of the uterus.

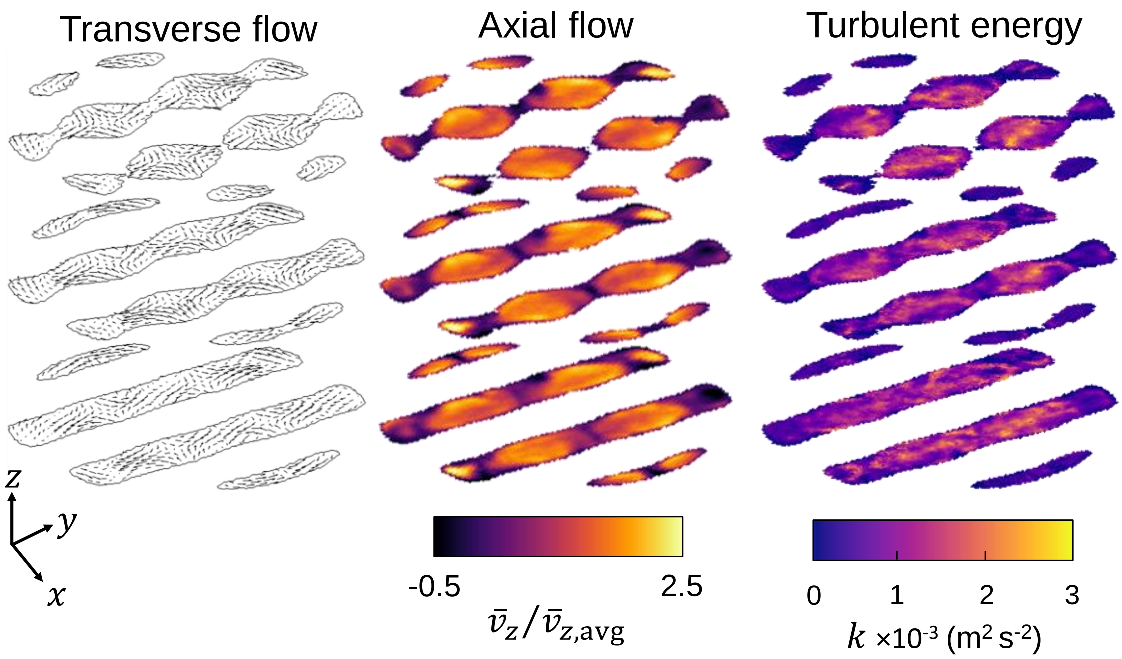
Correlative links have been made between the structure of the blood vessels of the uterus and problems with pregnancy, including fetal growth restriction, where a fetus does not grow as is expected. The adaption of the blood vessels of the uterus provides the critical nutrient supply to drive healthy growth and development, however, the primary mechanistic drivers of inadequate growth are not well-known. In part because the vasculature of the uterus and fetus is inaccessible to direct measurement. Mechanistic insights could be the key to improving the rate of detection of fetal growth restriction, which is currently estimated missed in up to half of cases.

Here we present a series of computational models of uterine blood vessel function and flow dynamics which cover key scales of interest in assessing the evolution of uterine function over pregnancy. We discuss the strengths and weaknesses of model and data availability to understand the system, and the implications of inadequate remodelling of the vasculature. Finally, we discuss how models of fluid mechanical behaviour of the system could be used going forward to better understand which arteries matter for the delivery of nutrients to the fetus, and whether dysfunction in these arteries could be identified in routine clinical practice.

Characterisation of unsteady flow behaviour in a 3D-printed Schwarz Diamond monolith using MRI

Daniel Clarke[1], Conan Fee[2,3], Petrik Galvosas[1], and Daniel Holland[4]
[1]*MacDiarmid Institute for Advanced Materials and Nanotechnology, School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2]*Biomolecular Interaction Centre, University of Canterbury, Christchurch, New Zealand*
[3]*School of Product Design, University of Canterbury, Christchurch, New Zealand*
[4]*Department of Chemical and Process Engineering, University of Canterbury, Christchurch, New Zealand*

Process industries perform heat/mass transfer, chemical reaction and separation operations using devices that typically comprise pipes, plates and particles. 3D-printing has enabled the fabrication of new channel morphologies to produce flow structures that enhance process performance. One such category of novel channel structures are the triply periodic minimal surfaces (TPMS), which includes the Schwarz Diamond surface. These surfaces have excellent potential for use with low Reynolds number operations such as chromatography because the uniform channel structure distributes flow evenly across the system. In addition, TPMS-structured channels may promote the generation of vortices and turbulence for use in high Reynolds number applications (Re > 100) such as heat exchangers. Understanding the characteristics of this flow regime is important for optimising process performance. Furthermore, numerical simulations of flow under these conditions require validation to confirm that turbulence is modelled accurately. For these reasons we employ magnetic resonance imaging (MRI) to measure flow through a 3D-printed Schwarz Diamond TPMS column for Reynolds numbers up to ~300 (shown in the figure). MRI can non-invasively measure the spatially resolved mean and variance of the velocity distribution in three dimensions. Using these data, the transition to turbulent unsteady flow is examined. There is also scope for additional analysis such as identifying regions where strong shear and high turbulence intensity are correlated, and characterisation of the boundary layer.



Inertial migration of spherical particles suspended in flow through curved microfluidic ducts

Brendan Harding[1]
[1] *School of Mathematics and Statistics, Victoria University of Wellington, New Zealand*

Finite size particles suspended in flow through micro-scale ducts are known to migrate across streamlines and, in some cases, focus towards stable equilibria whose location depends on a variety of factors. This occurs due to the inertial lift force which arises from the modified inertia of the fluid in a neighbourhood of the particle. This phenomena has a variety of practical applications involving the separation and isolation of cells. Ducts are often curved to allow sufficient duct length within a small device/chip, but this results in a secondary fluid motion which further complicates migration dynamics. I will present some of the modelling and analysis of migration dynamics for spherical particle migration in curved ducts having a rectangular cross-section. One important discovery is that at low flow rates the focusing behaviour is approximately characterised by the dimensionless parameter $\kappa = \ell^4/(4a^3R)$, with ℓ being the duct height, a the particle radius, and R the duct bend radius. I will briefly touch on current directions of our research.

Asymmetric Assembly of Lennard-Jones Janus Trimers

Joshua Looker,[1] Sina Safaei,[1,2] Qaisar Latif,[1,2] Shaun C. Hendy[1,2,3] and Geoff R. Willmott[1,2,4]
[1]*Department of Physics, The University of Auckland, New Zealand*
[2]*The MacDiarmid Institute for Advanced Materials and Nanotechnology, New Zealand*
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[4]*School of Chemical Sciences, The University of Auckland, New Zealand*

The study of Janus particles in solution is a fast-developing field that may allow for the development of new functional materials due to their asymmetric and self-assembling nature [1]. There is widespread interest in identifying design rules for the self-assembly of these Janus particles to better understand their potential use in future materials [1-2]. We have recently shown that Lennard-Jones Janus dimers are affected by orientational entropy, and are therefore most likely to come into contact at polar angles close to 45° [3]. Trimers are also a key kinetic step in many self-assemblies [4]. Understanding the likelihood that different orientations of the nanoparticles are reached during self-assembly is essential for identifying design rules. In this study, the relative probabilities and configurational degeneracies of self-assembly at different angular orientations and for different trimer geometries has been studied using molecular dynamics simulations and numerical calculations. Preliminary results will be discussed and compared with experimental observations of Janus particles interacting in microfluidic flows.

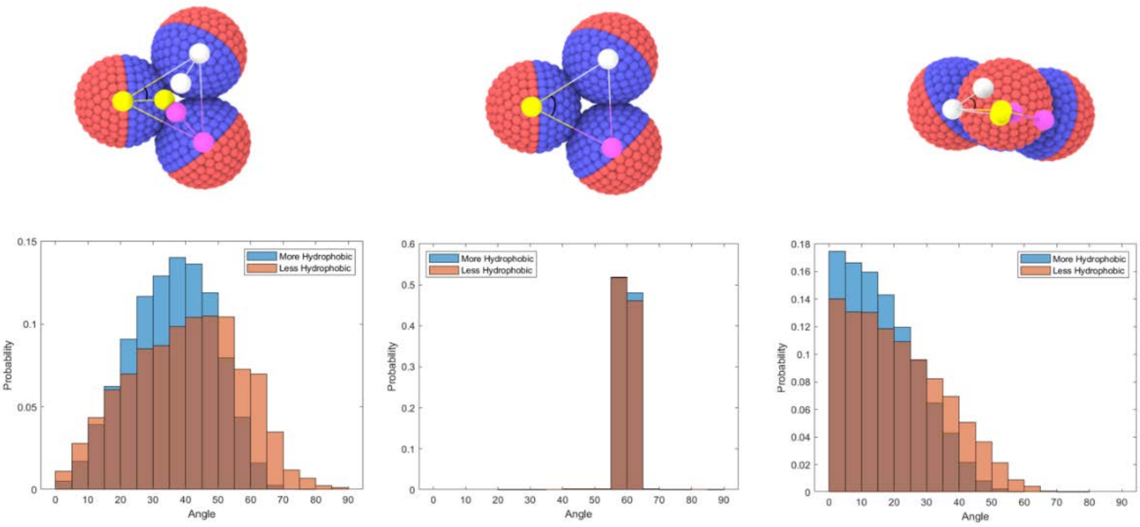

Figure 1: Orientations of Janus particle trimers, with diagrams showing measured angles (above) and corresponding probability distribution calculations (below). From left to right, centre-centre-pole angles, centre-centre angles, and centre-pole bisecting plane angle.

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Simulating tropical cyclones impacting New Zealand

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Tropical cyclones consist of strong winds around a moving central area of anomalously low pressure originating near the equator. In this work we characterise these systems using an open-source Python code applied to observed and simulated sea-level pressure datasets. Our results show that the models studied capture the shape of the distribution of tropical storm pressures well. However, the models tend to underestimate the number of the most damaging - i.e. lowest pressure - systems. We examine the effect of different surface boundary conditions on model-observation agreement in simulations of the recent past and present preliminary results on how we may expect the systems to change under various future climate change scenarios.

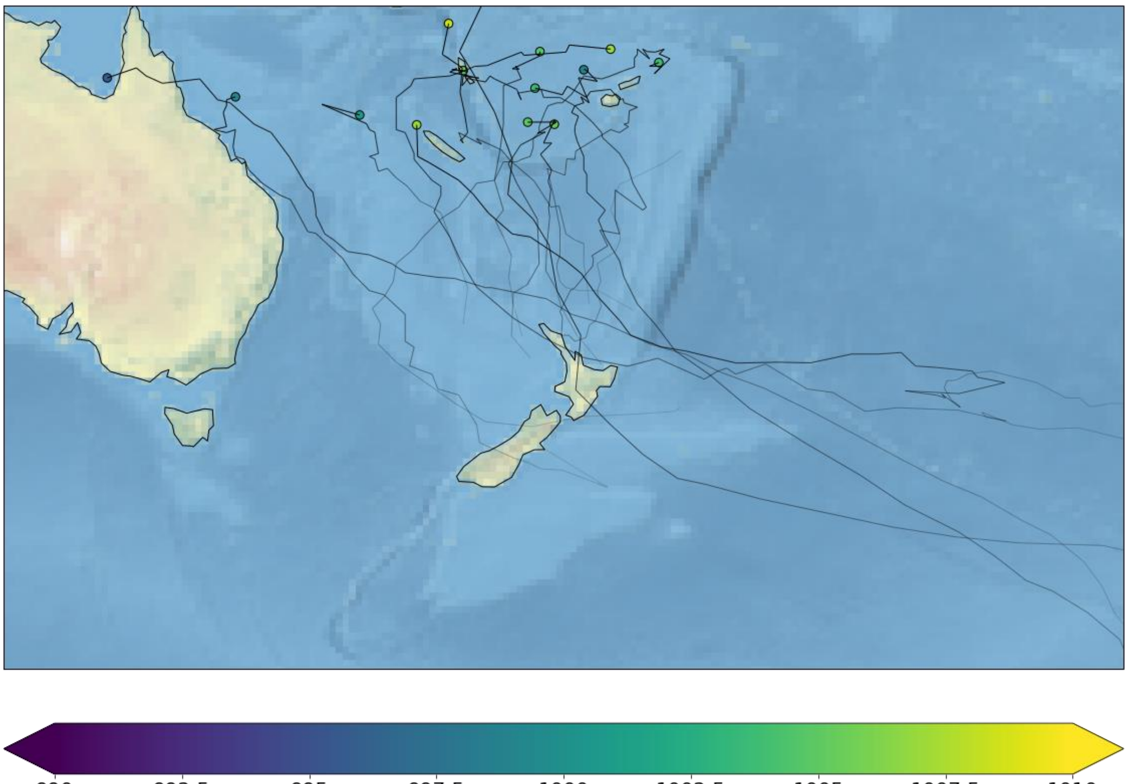

Figure 1: Tropical cyclones simulated by the New Zealand Earth System Model 1989-2008. Only those which 'hit' - or come very close to - New Zealand are shown. Their starting points are indicated by their starting sea-level pressure.

Shear stress induced low-density lipoprotein aggregation: The effect of shear stress on atherosclerosis

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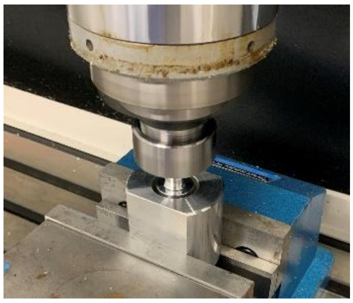

In 2019, cardiovascular diseases (CVDs) represented 32% of all global deaths. Atheroslcerosis was the leading cause of CVD. An important mechanism in the formation of atherosclerotic plaques is the aggreation of low-density lipoproteins (LDL). While aggregated LDL (agLDL) formation is well researched, current research mainly focuses on agLDL formation through enzyme action. Our research focuses on the effect of shear stress on agLDL formation.

We designed an apparatus that imposed constant shear rate on an LDL solution. Using a milling machine for accurate speed control, we tested the LDL solution at different shear rates and found the shear stress required for agLDL formation. We discovered that the shear stresses required for aggregation are within the range of shear stresses experienced in the human vasculature.

While further research will be required to elucidate the applicability of these results *in-vivo,* this research provides a first indication of the shear stresses required for agLDL aggregation. It could thus provide important thresholds for designing haemodyamic implants. Furthermore, it the research may also help explain other issues, such as restenosis proximal to implanted stents.

Condensation-frosting investigation on coating-free topographic wetting gradients for heat transfer surface applications

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Condensation-frosting is a common phenomenon across various heating, ventilation, and air conditioning (HVAC) systems. Surface coverage of condensation or frost can present a heat transfer resistance between the surface and the surrounding air, often an integral component of system's operation. The reduced energy expenditure resulting from a decreased need to defrost and/or remove condensation from heat transfer surfaces reduces the operational cost of the system. As such, the development of heat transfer surfaces with anti-frosting qualities has become an area of interest.
In the present work, aluminium surfaces with coating-free topographical wetting gradient micropatterns, are investigated for the microdroplet growth mechanism, frost wavefront propagation and heat transfer coefficient, and are compared against control (flat) surfaces. Previous work on gradient surfaces has found that in-plane forces acting on droplets with diameters below the capillary length result in spontaneous droplet motion. It is thought that this will enhance surface water management by removing condensed droplets at smaller radii and hinder the propagation of a frost wavefront across the surface. The surfaces can therefore be important for heat exchanger applications.
We will present the current results from our experimental investigations into condensation on polished control aluminium, including the image processing methodology that allows the generation of growth curves which track average droplet radius as a function of time, and the construction of a wind tunnel to test for condensation-frosting conditions.

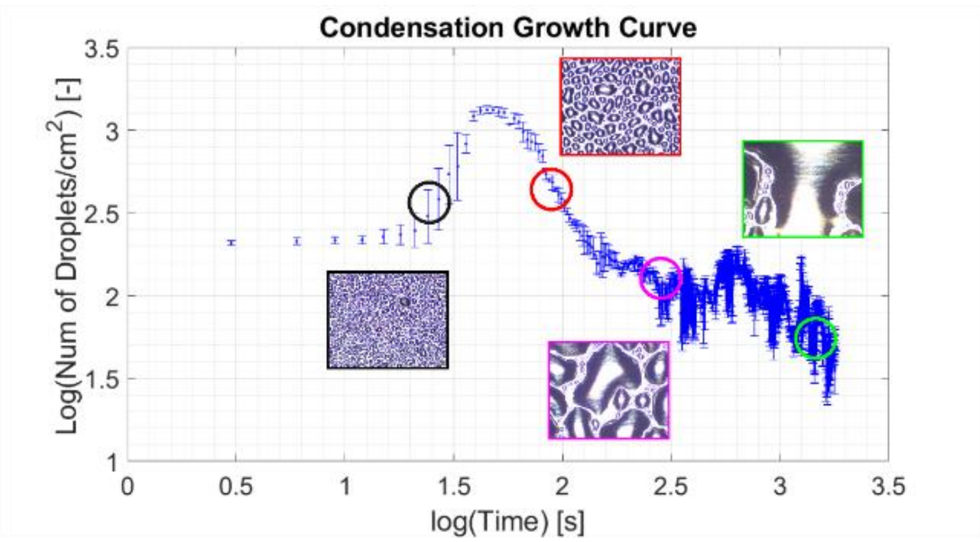

Figure 1. Log-log plot of the number of condensate droplets (averaged over 3 tests) on a surface vs. time. Top-down images of surface condensation at four points as the surface is cooled below dew point are highlighted.

Elastohydrodynamic lubrication in an annulus

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Lubrication theory provides an approximation of the Navier-Stokes equations for low Reynolds flows in narrow or slowly varying geometries. Classical lubrication theory considers the solid boundaries to be rigid. Elastohydrodynamic lubrication (EHL) considers the elastic deflection of the boundaries in response to variations in the fluid pressure. It is thus a coupled fluid-structure interaction problem. There is an extensive body of literature on EHL (e.g. reviewed in Refs. [1] and [2]) motivated by lubrication in machine elements such as gears and bearings. Here I present an EHL problem motivated by biomechanics. The glymphatic system refers to a pathway of cerebrospinal fluid (CSF) transport in the brain in the narrow paravascular annulus surrounding cerebral arteries [3]. The motive force for flow in the annulus is the pulsation of the arterial wall driven by pulsatile blood flow. The outer boundary of the annulus also deflects in response to variations in the annular fluid pressure. Using EHL theory I derive equations for the fluid velocity, pressure and boundary locations of a glymphatic annulus and discuss numerical difficulties in the solution of the equations.

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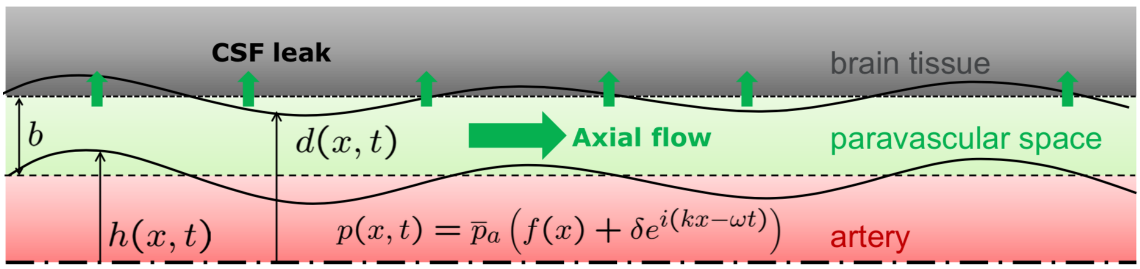

Exploring Ocean Wave Renewable Energy Potential Around New Zealand

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With the rise of global temperatures, the New Zealand government has announced its ambition towards net carbon zero 2050 (Climate Change Response (Zero Carbon) Amendment Act 2019). This will require a significant transition away from fossil fuels and increase the demand for renewables. A current source of interest is ocean wave energy where it was estimated in NIWA's EnergyScape™ 2009 report an average of 97 GW of wave power available around New Zealand (de Vos et al. 2009). In this presentation we build on NIWA's investigation and report on preliminary findings from a summer project for the potential to deploy ocean wave energy converters (WEC) in New Zealand as another type of renewable. Our focus is to explore the seasonal and spatial variability of wave energy in New Zealand and assess its ability to match with electricity demand and populated centres in comparison with other renewable resources. Ocean wave model outputs, provided by MetOcean Solutions are used to quantify wave energy available in New Zealand. It has been hypothesized that the best sources of wave energy may come from the South-West coast (see figure 1).

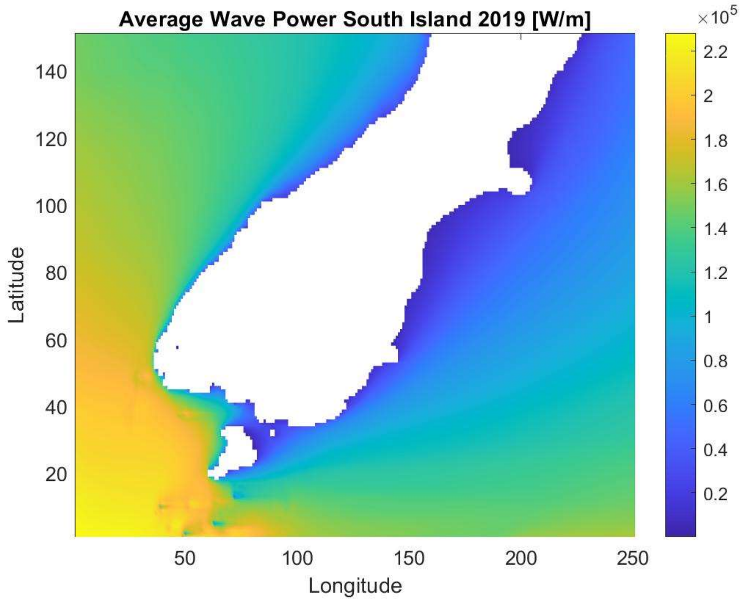

Figure 1: Heat Map of Average 2019 Wave Power created in MATLAB

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Mechanical cell compression and recovery in a flexible microdevice

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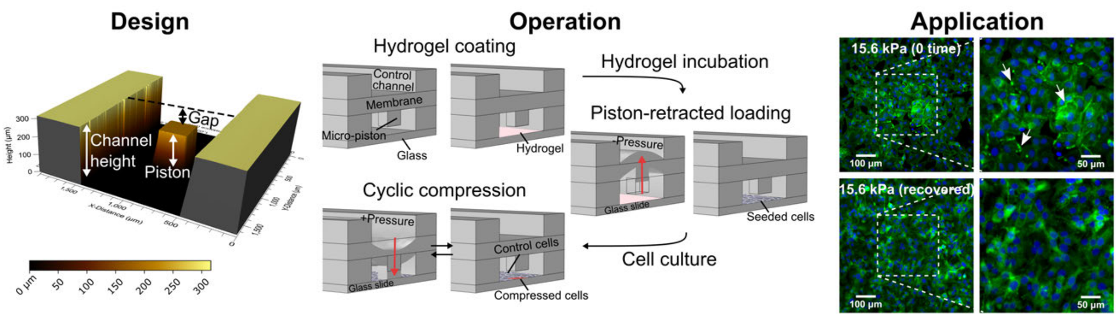
Mechanical forces shape physiological structure and function within cell and tissue microenvironments, during which cells strive to restore their shape or develop an adaptive mechanism to maintain cell integrity depending on strength and type of the mechanical loading. While some cells are shown to experience permanent plastic deformation after a repetitive mechanical tensile loading and unloading, the impact of such repetitive compression on plastic deformation of cells is yet to be discovered. As such, the ability to apply cyclic compression is crucial for any experimental setup aimed at the study of mechanical compression taking place in cell and tissue microenvironments. In our previous work we developed a flexible microdevice to apply dynamic and controlled compression on living cells in microfluidic settings. We used a computational model to calculate the maximum contact pressure of a PDMS actuator, called micro-piston, monolithically attached to a membrane inside the microdevice. We showed that simulations were in good agreement with optical profilometer measurements of vertical displacement of the micro-piston at given externally applied pressures. Here, we extended this agreement to a correlation between the computational model and cell compression applications within independent microdevices fabricated with different membrane thicknesses. The capability of our compression platform to apply sequential cyclic compression on living cells is demonstrated. Live imaging of the actin cytoskeleton dynamics of the compressed cells was performed for the applied varying pressures in ascending order during cell compression. Additionally, recovery of the compressed cells was investigated by capturing subcellular structures, such as actin cytoskeleton and nuclei profiles of the cells, at zero time and 24h-recovery after compression. This was performed for a range of mild pressures within the physiological range. The extent of recovery of the compressed cells can give insights into the plasticity of the cancer cells. As demonstrated in this work, the developed platform can control the strength and duration of cyclic compression, while enabling the observation of morphological and cytoskeletal and nuclear changes in cells, thus providing a powerful new tool for the study of mechanobiological processes in cancer and cell biology in general.



Exact solution analysis of the temperature profile in a micro-cantilever in order to induce flapping

Sid Becker
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The combination of heaters in micro-cantilevers has been implemented in a variety of practical and scientific applications, perhaps most notably in atomic force microscopy (AFM). The microcantilever is composed primarily of silicon (Si) and each heater is composed of a thin electrically conductive layer (often gold (Au) or aluminium (Al). Part of the conductive metal can be doped (for example with phosphorous) so that when this region of the metal layer is exposed to an electric field, some of the electrical power is dissipated as heat (hence this part of the layer acts as a micro heater). The disparate thermal expansion characteristics of the Si and the heater can result in a deflection along the length of the cantilever: Al has a thermal expansion coefficient about an order of magnitude higher than that of Si.
This presentation considers the exact solution to the transient periodic heat transfer within a micro-cantilever that has two integrated heaters. It is proposed that when two periodic electric fields are applied to the outer layers so that they are out of sync with one another, the resulting temperature profile at the Si-Al interface will be similarly periodic and out of sync. This would, in principle, result in a controlled flapping of the cantilever that would result in a flow patter in the surrounding fluid and should result in an enhanced heat transfer between the cantilever and the surrounding fluid medium. The micro-cantilever beam (Fig. 1a) is composed of the following 5 layers: a 0.7 µm thick outer layer composed of Al, a 0.5 µm thick adhesive layer of SiO_2, a 5 µm thick core layer of Si, a 0.7 mm layer of SiO_2, and a 0.5 µm thick outer layer of Al. The Green's function solution is used in an analysis of the 1-D transient problem of heat transfer through a composite medium in which the outer surfaces are exposed to periodic volumetric heating of 10^{14}W/m^3 which given the microscale of the cantilever corresponds to a power on the order of mW and this is applied at a frequency of 20 kHz. Because the cantilever is anticipated to flap, the flapping motion should increase the cooling of the outer cantilever surfaces by convection, in this study a heat transfer coefficient of 5×10^5W/m^{2}K is applied. Quasi-steady results are depicted in (Fig. 1b) of the outer surface temperatures indicating clearly the periodic fluctuation of the maximum temperature between the outer surfaces. Within the microcantilever the asynchronous periodic profile at two times one half a period apart is seen (Fig. 1c) suggesting that at this frequency the inner SI has a relatively stable profile while the outer Al layers experience the fluctuating temperatures which would still allow for the flapping resulting from the differences in thermal expansion of the different layers; in this case the thermal conductivity of the SiO2 layer is about an order of magnitude smaller than of the other layers and acts to promote the extreme temperature differences between the Al and the Si which would further benefit the difference in deflection and increase the flapping.

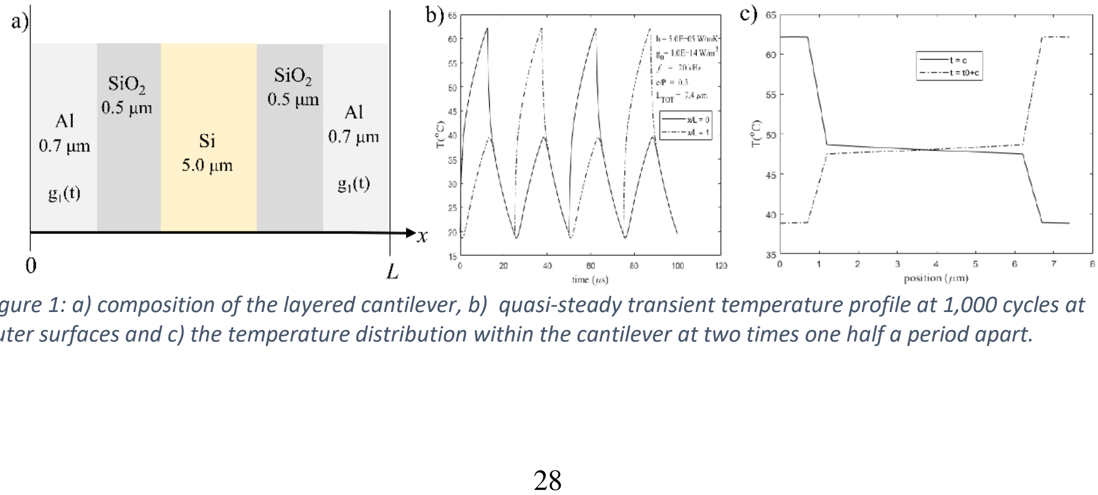

Figure 1: a) composition of the layered cantilever, b) quasi-steady transient temperature profile at 1,000 cycles at outer surfaces and c) the temperature distribution within the cantilever at two times one half a period apart.

BG-Flood, an open-source GPU powered software for modelling floods in New-Zealand

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Keywords: Modelling, Shallow Water, Flooding, GPU, Adaptative Mesh.

As confirmed in the last IPCC report (IPCC AR6, IPCC Working Group I Co-Chair Panmao Zhai), "climate change is already affecting every region on Earth, in multiple ways". Its consequences include the increase of sea level, the intensification of extreme weather events, including heavy rains, and the perturbation of the global circulation. In 2021, severe flood events affected New Zealand (Canterbury in May, Westport in July) and the world (Central Europe in July, India in November), highlighting the need for forecasting and accurate inundation hazard assessment. Part of the Endeavour project "Mā te haumaru ō nga puna wai: Increasing flood resilience across Aotearoa", the numerical shallow water model, BG-Flood, is developed to create inundation maps. It allows the modelling of a large range of forcings relevant for inundation such as storm surge, tide or tsunamis, rainfall and river discharge. To simultaneously handle large scale domains and smaller scale processes, an adaptative quad-tree mesh is used, run on Graphic Processing Units (GPU, on NVIDIA). The relatively simple adaptative quad-tree mesh generation allows the desired mesh to be create quasi-automatically, based on the initial domain or forcings (DEM, rain, slopes), area of interest (user defined) or physics properties (velocity after an initial coarse run). The code will be included in an automatic workflow, integrating recent LiDAR data, idealised future storms and a hydrodynamic model to reproduce rainfall in upper basins; to create inundation maps for the whole country and calculate the associated risks for the communities.

The code will be illustrated using the flooding of Westport area (West Coast, NZ) in July 2021. This model is open-source and available at: https://github.com/CyprienBosserelle/BG_Flood/.

Extracting rheological details of lava flows from free surface measurements

David Muchiri[1]
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Lava flows pose a great danger to inhabitants living near active volcanoes. The recent eruptions on the island of La Palma in Spain remind us of the risks and threats of lava flows to inhabited areas. Understanding the rheology of lava flows is critical to predicting its flow path for risk assessments and management plans. Measuring lava rheology at field conditions is extremely difficult, but there is an increasing availability of aerial imaging of lava flows which provides a rich set of information at the surface containing a hidden signature of the rheology. The goal is to unravel this signature to be able to infer lava rheology from the available surface measurements. In this talk, I will briefly discuss the Shallow Water equations model derived to adequately simulate lava flows with a Herschel-Buckley rheology. I will then show the possibility to infer some rheological parameters from free surface data by variational data assimilation (VDA) inversion approach using an open-source DassFlow platform.

Fundamental challenges in the processing industry

Emilia Nowak
School of Food and Advanced Technology, College of Sciences, Massey University, Manawatu, NZ

Design of the industrial-scale processes needs the resolution of a number of fundamental open problems in multiphase systems. Capturing physics and chemistry across the relevant length- and time-scales: from nanometres to kilometres, and from nanoseconds to hours, respectively, enables accurate modeling of processes and desired products.

Individual small length-scale phenomena (coalescence, breakage, wetting) influence global flow field and operational conditions (e.g., pressure drop) as well as production control and multiphase structures. These are crucially important in FMCG, fine chemicals, catalysis, oil, and food sectors that are heavily relying on semi-empiricism that may result in unsafe operation and product failure.

In this talk, a range of open problems will be shown for the multiphase systems that remain challenging in industry and academia and essential investigations in the relevant time- and length-scales that will lead to novel manufacturing routes, equipment, and process design.

Isothermal thin-film flow of a viscoplastic material around an occlusion

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Viscoplastic fluids are found in both natural and industrial settings, and in this work we focus on modelling such fluids under gravity-driven flow down inclined planes, using the thin-film approximation. An occlusion within the computational domain is included to model the impact of obstructions on lava flows from volcanic eruptions. The rheology of viscoplastic materials consist of a yield stress which must be reached before deformation occurs, which can lead to plug-like flows. We compare the steady-state flow dynamics, including the wetted line on the occlusion, for both viscoplastic and Newtonian rheology models.

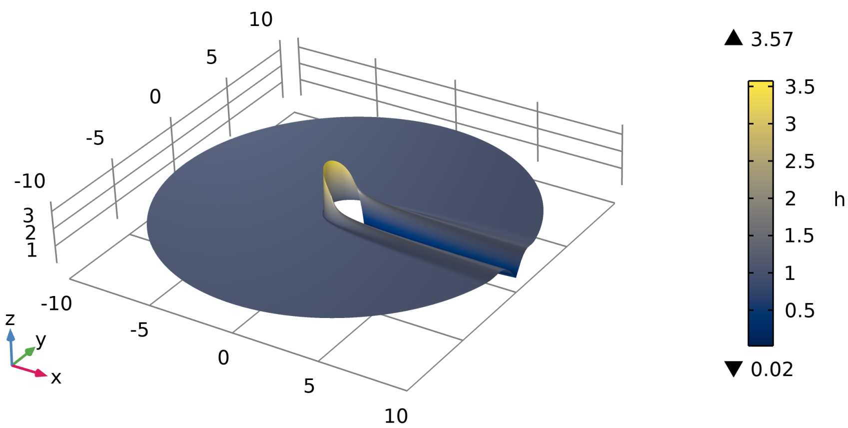

Figure: Non-dimensional thin-film thickness, h, of a flow down an inclined plane around a cylindrical occlusion. The relatively high gradient of the incline (oriented about the y-axis) has caused a dry region downstream of the cylinder, $x > 0$.

Drop Impacts in the Dynamic Microfluidics Laboratory: An Update

Geoff R. Willmott,[1,2] Ayoub Abdollahi,[1] Rishabh Gandhi[1] and Matheu Broom[1]
[1] *The MacDiarmid Institute for Advanced Materials and Nanotechnology, Department of Physics, The University of Auckland, New Zealand*
[2]*School of Chemical Sciences, The University of Auckland, New Zealand*

The Dynamic Microfluidics Lab at the University of Auckland has been primarily set up for high-resolution optical studies of liquid drop impact events. This presentation will cover our recent work in two areas.

Firstly, we will discuss impacts of dairy product droplets on to stainless steel, which has relevance for industrial food production. In particular, milk powder is produced by drying drops during spray drying. We have studied drop impacts for various rheologically-interesting solutions at room temprature [1] (Figure 1(a)), then moved on to study the dynamics of drops on fouled surfaces and at raised temperatures. In the latter case, the rheology of the droplet depends on temperature and drying time, and the drop will dry from the outside inwards so that the drop rheology is non-uniform.

Secondly, the results of a detailed analysis of the fully wet impact region created when water drops land on hydrophobic micropillar arrays [2] will be briefly presented. This work has been the first to systematically study the asymmetries of this impact region and the microbubbles found within it. Strinking patterns have been observed, both regular and more stochastic in nature (Figure (b)).

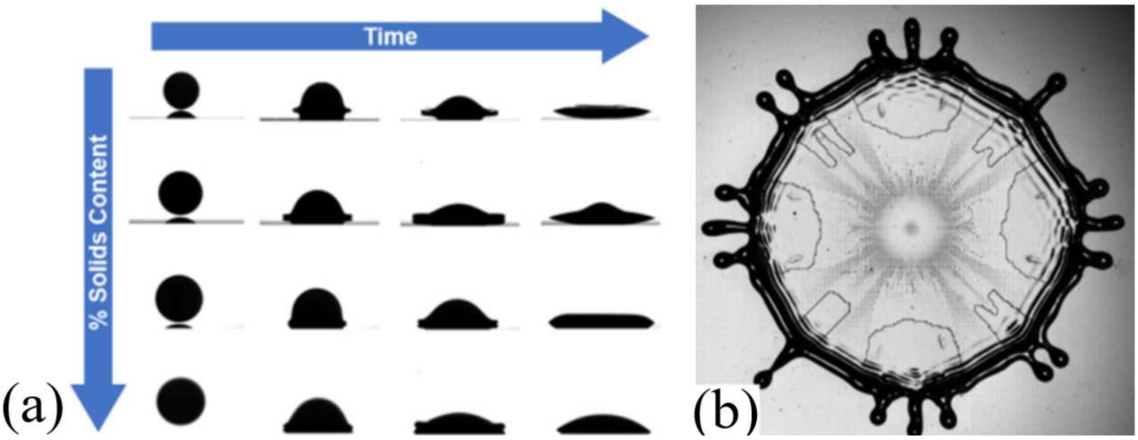

Figure: (a) Side-on images showing the evolution dairy product drop impacts, from [1]. (b) Drop impact on a square array of micropillars, from [2]. The impact region is indicated by thin dark lines within the thick black outer rim.

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USING CFD TO EXAMINE THE EFFECTS OF BACKDUNE MORPHOLOGY ON THE FLOW DYNAMICS BEHIND EXCAVATED FOREDUNE NOTCHES

Duc Nguyen[1], Sarah Wakes[2] and Mike Hilton[1]
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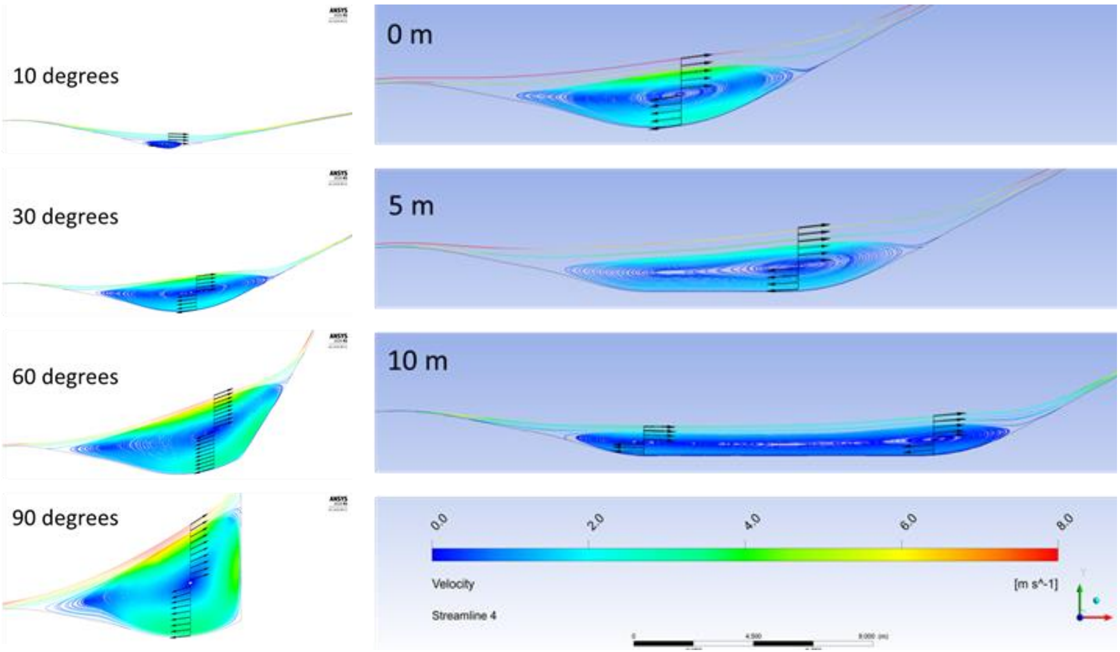
Coastal foredunes play an important role to protect low-lying communities from coastal hazards such as storm surges and marine flooding. Excavation of foredune notches aims to facilitate sand transport from the beach through the notches and deposition on the backdune. This foredune notching intervention aims to promote dune landward migration to reduce the dune erosion caused by increased storminess and sea level rise in the context of climate change.

This study uses the Computational Fluid Dynamics (CFD) to examine the effects of backdune morphology on the flow dynamics behind an excavated foredune notch at St Kilda beach, Dunedin, New Zealand. The effects of the slope of the stoss face of backdune infrastructure (a sea dyke, in this case, namely John Wilson Drive varying from 0^o to 90^o); and the distance between the foredune crest and John Wilson Drive (varying from 0 m to 50 m), on the flow are examined using approximately 100 two-dimensional simulations. The sensitivity of other set-up parameters including domain length, mesh size and inlet wind speeds are also examined.

The patterns of wind flow behind an excavated foredune notch are strongly influenced by the morphology of John Wilson Drive. The dimension of flow recirculation zone shifts to higher; and wind direction at the swale shifts to more upward when the slope increases. In contrast, the recirculation zone shifts to shorter and longer when the distance between John Wilson Drive and the foredune crest increases. The findings of this study aim to support coastal managers in planning coastal infrastructures to maximise the efficacy of foredune notching intervention.



LES of Atmospheric Buoyancy Vortices for Power Generation

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In the turbulent convective boundary layer of the atmosphere, vortices like dust devils and tornadoes can be observed at different scales and strengths. Only few research studies have focused on the availability of energy in vortices, for instance the Atmospheric Vortex Engine (AVE) by Michaud (Applied Energy 62, p. 241-251, 1999) or the Solar Vortex Engine (SVE) experiment by Al-Kayiem et al. (Renewable Energy 121, p. 389-399, 2018). As renewable energy is becoming increasingly important, vortex power is a promising new technology to reduce carbon emissions. A numerical model was developed using the Large Eddy Simulation (LES) method to study atmospheric vortices for power generation.

A central heat source, which produces the buoyancy force for the vertical vortex, is modelled as a heated cylindrical volume near the ground surface. Further away from the centre, a momentum source ring introduces the swirling flow and represents radial swirl vanes. A similar approach to the actuator disk model is applied for the vertical turbine in the centre to extract momentum from the buoyancy vortex.

The effect of turbine coefficients, like power and thrust coefficients, on the vortex is investigated. Placing a turbine at the centre extracts momentum and therefore reduces the vortex tangential velocity. The resulting torque combined with turbine speed gives an estimate of the available energy. The aim is to extract energy without significantly impacting the stability, structure and duration of the vortex.

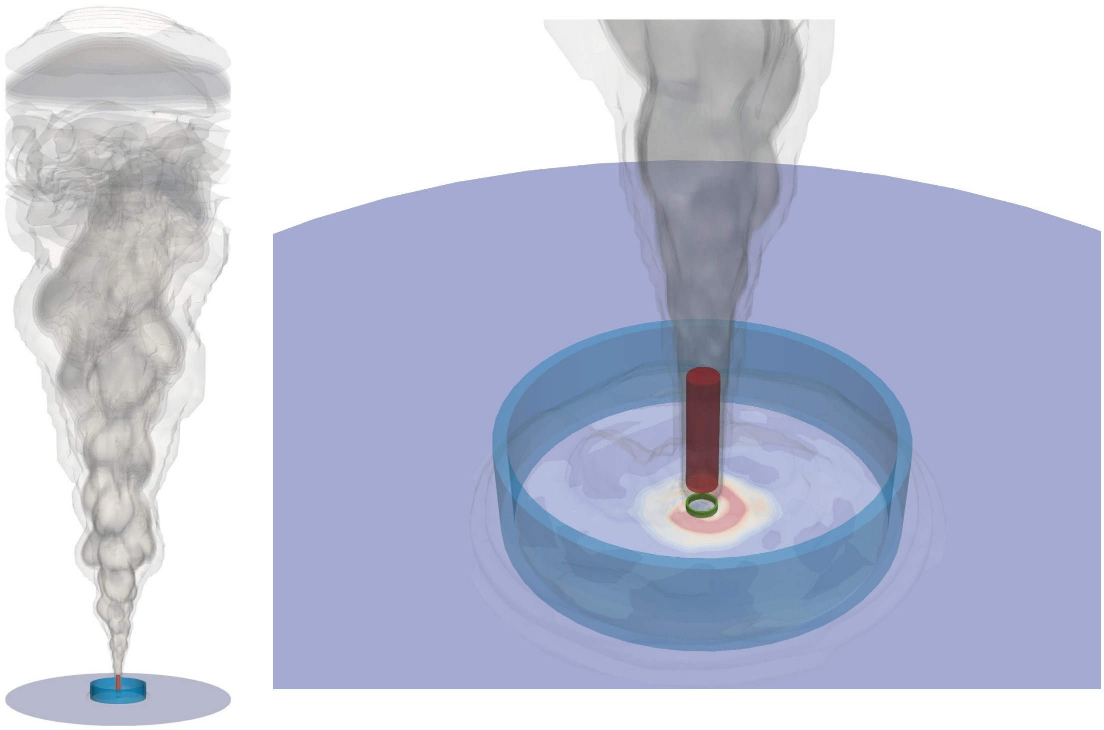

Figure 1: LES model of atmospheric buoyancy for power generation.

Contributions of the upper and lower surfaces to Lift produced by Low Reynolds Number Aerofoils in Onset Turbulence

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Low Reynolds number aerofoils are of interest in many applications, such as turbomachinery and wind turbines. One rapidly-developing application, however, is the small, fixed-wing Unmanned Aerial Vehicle (UAV). These operate at wing chord-based Reynolds numbers between 50,000 and 500,000, with 100,000 being typical [1-2]. Often flying at low altitude due to power and regulatory constraints, the highly-turbulent atmospheric boundary layer forms a significant hazard [3]. It has been seen that these conditions can induce leading-edge vortices on the suction surface, creating an irregular form of dynamic stall [4-5]. This has led to a focus on the behaviour of the suction surface and how it responds to turbulence. However, less attention has been paid to the pressure surface, and how this contributes to the net aerofoil loads.

A NACA0012 and NACA4412 were tested at a Reynolds number of 100,000 in the University of Auckland wind tunnel. To replicate UAV flight conditions, testing was undertaken at three onset turbulence intensities (1.3%, 5% and 15%), with the angle of attack (AoA) ranging from -6° to +20°. The local surface pressures were recorded mid-span on each surface from 75 pressure taps, and integrated to provide the lift coefficient for each surface as well as the net aerofoil load. For the local pressures and the lift contribution of each surface, the mean and standard deviation were of interest, capturing the net performance change and variability in the unsteady response.

It was seen that increasing the onset turbulence intensity increased the mean suction on both surfaces, and thus the lift contribution of the pressure surface became increasingly negative. This was due to the greater chordwise extent of the suction region on the pressure surface. The time-averaged maximum pressure was seen to move aft along the chord and decrease in magnitude. The more cambered NACA4412 saw a more positive contribution for both surfaces, having a positive pressure on the pressure surface at moderate AoA. As is expected, the increase in turbulence intensity increased the standard deviation of the lift coefficient. However, whereas the suction surface saw an increase in this parameter as the AoA is increased, the reverse occurred for the pressure surface.

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Development of Coating-Free Super Water-Repellent Micropatterned Aluminium for Spontaneous Droplet Motion

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Nature has evolved a number of impressive water management solutions. The most cited and well-known example is the super water repellent lotus leaf. Behind this "magic" property are random microscale bumps with superimposed nanoscale hairs forming a hierarchical structure. Some spiders create spindle-knot/joint couplings on their web, providing a surface tension gradient that can passively transport sub-millilitre droplets without external forces such as weight force. In the current industrial era humanity is relying on metals and their alloys for numerous applications. The main issue is that metals are hydrophilic, having strong adhesion during liquid-solid interaction. The most established way to eliminate it is to hide the metal surface under a lower surface energy coating.

Inspired by nature, we have engineered passive gradient surfaces, that imitate the lotus leaf's superhydrophobicity and liquid transport properties of some spider silk. Such a coating-free surface could be made on a metal via one-step industrial methods, such as, micromilling and laser ablation. Such a surface can promote dropwise condensation over film-wise, improving water droplet removal, and spontaneous motion of certain sized droplets.

We will present a theoretical explanation, the modelling procedure and a survey of micro/nanofabrication approaches to produce microstructures with fixed- and variable-pitch, and results which clearly demonstrate passive gradient-driven droplet motion on theoretically designed and micro/nanoengineered, all-metal, hierarchical superhydrophobic gradients.

These surfaces can potentially enhance heat exchangers by improving the air-side heat transfer coefficient, and/or promoting delay (or elimination) of ice-/frost-formation under extreme weather conditions, which may be beneficial for wind turbine blades.

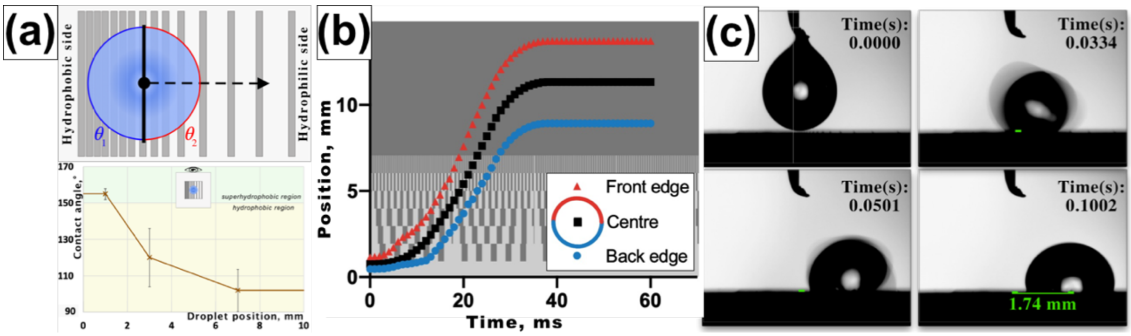

Fig. 1. (a) schematic of the linear wetting gradient (upper) and wetting properties of the gradient (lower); (b) results of numerical modelling of a 7 µL droplet on a stipe-based gradient; and (c) observation of spontaneous droplet motion on a coating-less aluminium surface with topographical linear gradient.

Improving integral model for desalination discharges using data from large eddy simulation

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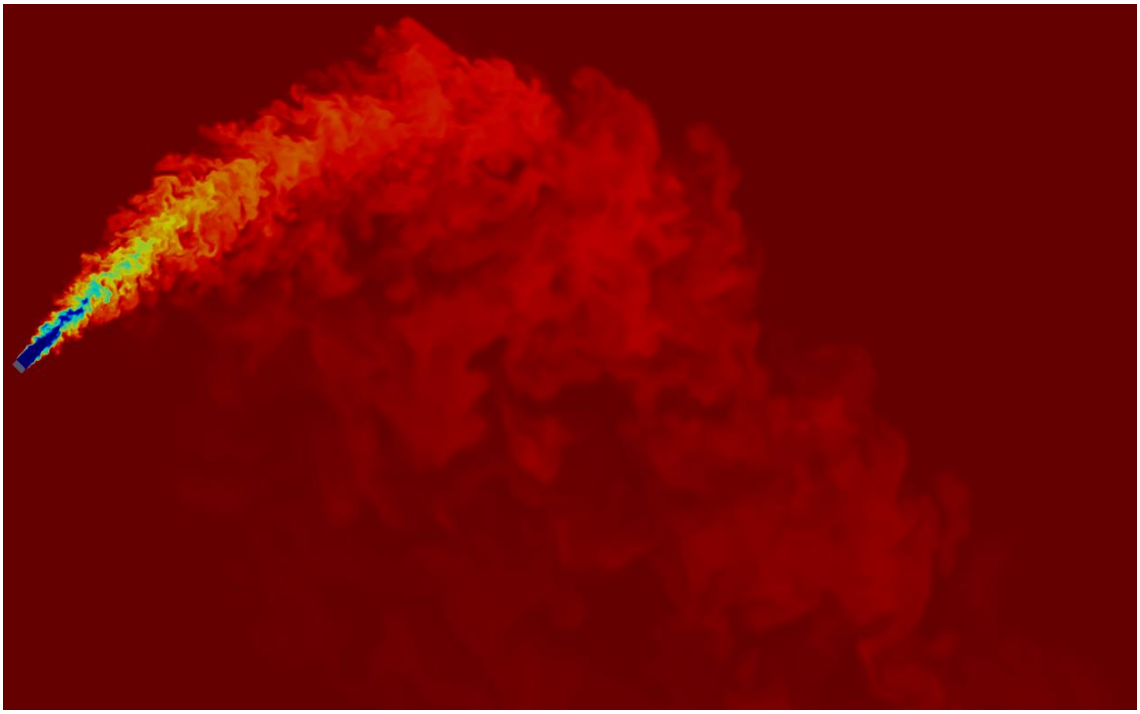
Elevated salinity and contaminant levels in the effluent discharged from large-scale desalination plants are potential threats to the coastal environment. Therefore, many previous researchers have developed integral (theoretical) models to predict the behaviour of the flows generated from desalination discharges, known as inclined negatively buoyant jets (INBJs). Integral models are commonly used in environmental impact assessments and are considerably less time-consuming than computational fluid dynamics (CFD) simulations. However, substantial discrepancies between integral model outputs and experimental data remains. These discrepancies are partly due to a lack of understandings of the physics, because it is difficult to obtain non-intrusive three-dimensional and high spatial-temporal resolution flow measurements. Computational fluid dynamics simulations potentially offer the opportunity to analyse these flows in more detail, because they provide the freedom to extract three-dimensional (3D) information in various forms.

An earlier phase of this study has developed and verified a 3D large eddy simulation (LES) of an INBJ that captures more details of the flow field compared with other published CFD studies. The downward detraining fluxes driven by buoyancy induced instabilities - a unique feature of these flows which is challenging to model as highlighted in previous studies - have also been captured. Quantifying and relating the detraining fluxes with bulk flow parameters may provide information for improving one of the most recently available integral models (Reduced Buoyancy Flux). However, identifying a practically significant edge between the main and the detrained flow is challenging in these free-shear flows. This presentation discusses the progress and remaining challenges for this aspect of the research programme.



A novel method for Navier-Stokes Identification and Correction of Erroneous Particle Image Velocimetry Data

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Spurious vectors can appear after processing of particle image velocimetry (PIV) data, typically as a result of light reflection, camera resolution and incorrect particle tracing. To replace the erroneous vectors, current correction methods use linear extrapolation or interpolation from neighbouring vectors. These methods, however, are not representative of known fluid flow behaviour. Using the Navier-Stokes equations, this study developed a technique for locating and replacing these spurious vectors.

The algorithm developed in this study first located the erroneous vectors using the momentum and continuity equations. Then, regions of flow that covered the spurious vectors were replaced using a proposed Navier-Stokes correction approach. To test the approach, some vectors in a CFD generated flow field were perturbed. Typical linear interpolation produced a 5.4% average error with the CFD field. In comparison, the proposed Navier-Stokes correction produced a 1.7% average error.

The Navier-Stokes correction approach proposed in this study automatically locates erroneous vectors, potentially reducing experimental time for PIV practitioners. In particular, it may mitigate the need for multiple images for statistical analysis or manual linear interpolation. Furthermore, it corrects the data based on known fluid dynamic behaviour, resulting in a more accurate representation of the flow field under investigation.

3D Nonlinear Dynamics of a Thin Liquid Film on a Spinning Ellipsoid

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The present work investigates the three-dimensional flow of a thin liquid film deposited on a tri-axial ellipsoid, rotating around its vertical axis at constant angular velocity. The lubrication approximation model expressing the evolution of the film thickness, originally developed for arbitrary substrates, has been adjusted to reflect the geometrical properties of the substrate and the forces acting on the system. This modified model, which incorporates the relative impact of the gravitational, centrifugal and capillary forces, is employed for the numerical investigation. The results validate and extend the conclusions of our former studies covering the axisymmetric case and bring about an advanced understanding by exploring non-axisymmetric effects. The parametric studies shed light on the significance of non-constant curvature on an axisymmetric substrate and how to manipulate the interface profiles by imposing rotation.

Numerical modelling of whole milk spray drying process

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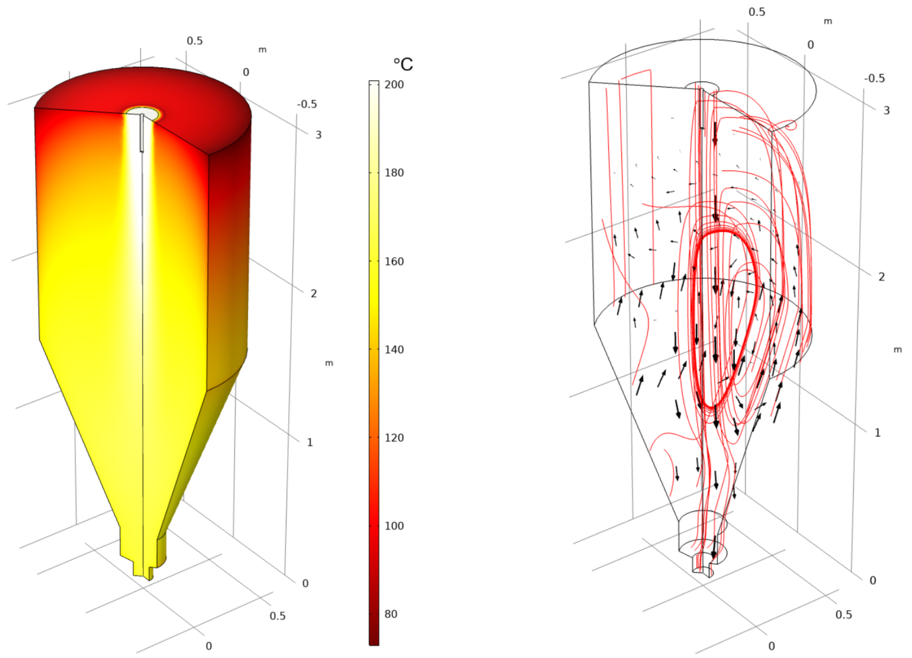
The spray drying process involves evaporating the solvent from a liquid droplet containing a solute, transforming it into a powder. This technique is routinely used in the dairy industry to produce milk powder to extend shelf life and make the product more dense for transportation purposes. In this study, the spray drying process of whole milk has been investigated with a numerical model. A four-stage comprehensive droplet evaporation model, validated against experiments, was developed and implemented in MATLAB. This drying model was then coupled in COMSOL Multiphysics with an Euler-Lagrange model of the transport of milk droplets within a drying chamber. According to the results, a larger injection angle led to a longer residence time due to recirculation, which resulted in droplets containing less moisture upon leaving the chamber. Increasing the injection velocity resulted in a higher moisture content in the final product due to the shorter residence time of droplets within the chamber. Additionally, in order to achieve a lower moisture content of the final milk powder, the airflow rate and temperature of the chamber should be increased, and the humidity should be decreased.



(a) (b)

Figure 1: Airflow pattern inside the spray dryer. a) Steady state temperature field, b) steady state streamlines along with logarithmic vectors showing the velocity magnitude and direction.

The effect of geometrical and topological changes on the fluid flow through large-scale Discrete Fracture Networks

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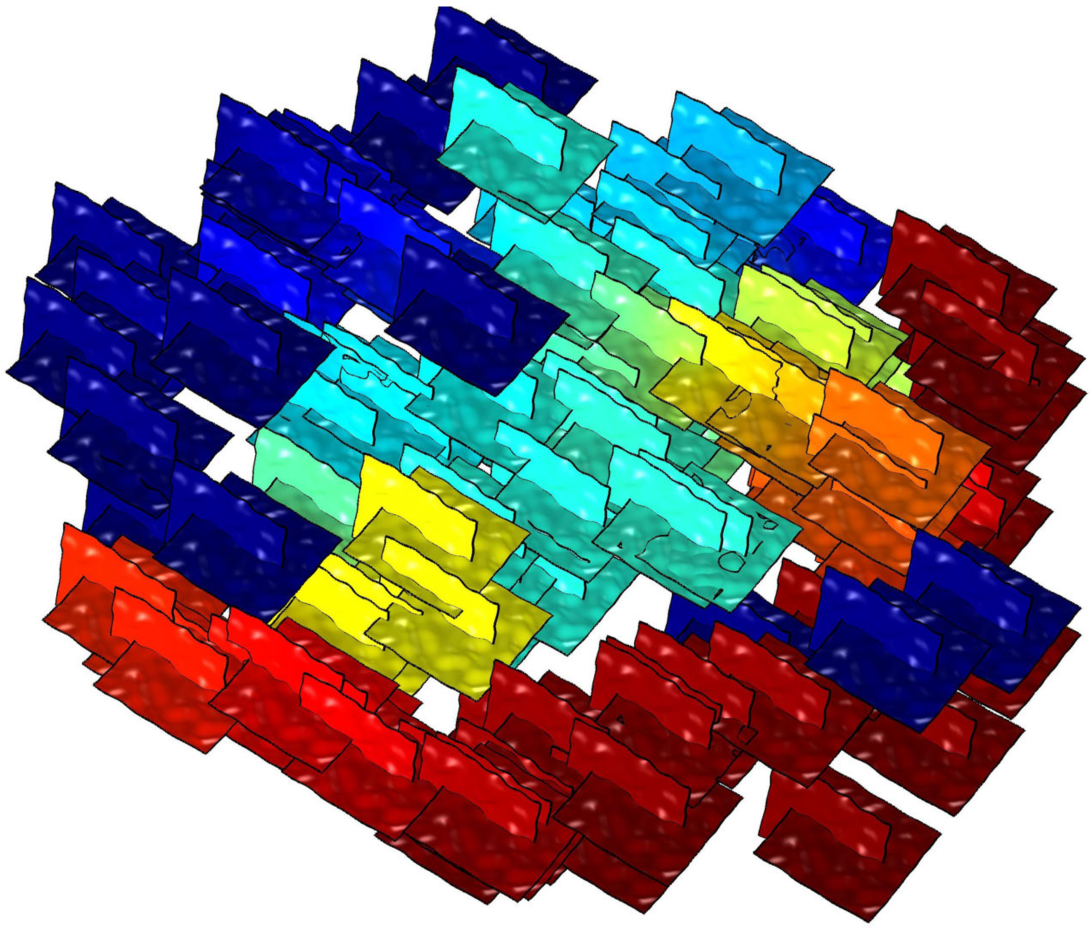
Using a novel computationally efficient approach, we investigate the effect of geometrical and topological variations on hydraulic resistance in large scale discrete fracture networks at low Reynolds numbers. The approach we used is based on patching Hele-Shaw cells, each representing individual fractures. Different realizations of two hundred fractures were generated randomly. The fluid flow was modelled with different arrangement of fractures. We evaluated the validity of simplified models by comparing them to solutions of the Navier-Stokes equations (NSE) for a network consisting of nine fractures. An excellent agreement was found between the HS approximation and the full NSE with an average deviation of 0.12%. According to our results, increasing surface roughness causes an increase in hydraulic resistance. Furthermore, the number of active fractures in the networks was found to be more influential on the flow resistance than the connection length of fractures. All simulations were performed for Reynolds numbers less than 10.



Equations for nonlinear and dispersive water waves over variable bottom topography

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A class of weakly nonlinear and weakly dispersive systems of partial differential equations of Boussinesq-type is presented. These mathematically justified equations describe the propagation of small amplitude, long water waves (such as tsunamis) in the ocean and approximate basic equations of fluid mechanics. Contrary to other Boussinesq systems, the new systems can be used in bounded domains with physically and mathematically justified boundary conditions.

Numerical modelling of linear and oblique collisions of liquid-coated particles validated with experimental results

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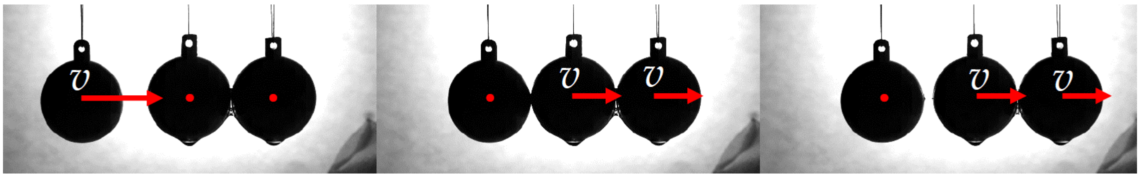
Many industrial applications and natural phenomena consist of mixtures of granular materials and liquids. The inclusion of the liquid forces creates vastly different contact dynamics. In this study, we consider particles coated in thin layers of viscous fluids such that the capillary number is high and viscous forces dominate. High-speed imaging and particle tracking velocimetry is used to experimentally investigate the particle collision dynamics of smooth spheres for both linear collisions and oblique collisions between 15° - 60°. The experiments are used to examine three theoretical models. The models are implemented via LIGGGHTS™ using the discrete-element method (DEM). A key problem of these models is how they treat the viscous force term; as the particles approach one another, the viscous force tends towards infinity. Most existing models impose a cap on the viscous force term; when this cap is reached, the particles continue to approach another but the viscous force remains constant. A more recent model assumes a hard-sphere collision occurs when this viscous force cap is reached. These fundamentally different approaches result in different collision outcomes. Good agreement between the viscous force cap models and experiments was achieved, however it required the inclusion of an empirically fitted, non-physical parameter. The hard-sphere model also requires the inclusion of a non-physical parameter, the glass transition pressure, however, this parameter has been consistent for different experimental conditions and previous studies. Thus, it appears that the hard-sphere model is much better able to describe the collisions of smooth particles coated in thin layers of viscous fluids.



Annual Meeting Agenda

1. Review of FiNZ2022.

2. FiNZ2023.

3. IUTAM Association.

   New Zealand is a member country of the International Union of Theoretical and Applied Mechanics (IUTAM), which is affiliated to the International Council for Science (ICSU) and organises a number of symposia each year as well as the four yearly ICTAM conference. The Royal Society of NZ, through whom NZ's membership is administered, have suggested that NZ's membership of IUTAM be formally hosted by an appropriate society, as is the case with many of the other international affiliations it oversees. As the current IUTAM representative for NZ, Richard Clarke from the University of Auckland, would like to discuss the idea of FINZ (as a formal society) being the IUTAM host.

4. Any other business.