University of Dundee

39th Scottish Fluid Mechanics Meeting

Painting by Grace Elder, Fine Art Student, University of Dundee
Inspired by experiments in a rotating tank

Book of Abstracts

27th May 2026

Contents

About

SFMM 2026

Welcome to the 39th Scottish Fluid Mechanics Meeting.

The Scottish Fluid Mechanics Meeting offers an informal setting to discuss ongoing fluid mechanics research from across Scotland and beyond. It is particularly aimed towards offering PhD students and early career researchers an opportunity to introduce themselves and their work, alongside contributions from more senior researchers.

Organisers

Lead Organiser

Dr Tom Eaves

Committee Members

Dr Alan Cuthbertson
Dr Anirban Guha

On-the-day Assistants

Mr Yi Yuan
Dr Jorge Sandoval

Sponsors

The Meeting is kindly sponsored by Dantec Dynamics Ltd and LaVision Ltd, whose kind contribution allowed us to keep registration fees low and accessible to a wider range of attendees.

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Programme

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09:55–10:10	**Wall modes and pattern formation in molten salt magnetoconvection** Asif Nawaz, Andrei Teimurazov, Matthew McCormack, Olga Shishkina & Moritz Linkmann *School of Mathematics and Maxwell Institute for Mathematical Sciences, University of Edinburgh and Max Planck Institute for Dynamics and Self-Organization, Göttingen*
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10:25–10:40	**Data-driven modelling of diffusion coefficients in porous media** Quinn Stein, Humphrey Yiu & Ali Ozel *School of Engineering and Physical Sciences, Heriot-Watt University*

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11:15–11:30	**Deepfake turbulence yields short solutions to the Navier-Stokes equations** Jeremy P. Parker *Mathematics, University of Dundee*
11:30–11:45	**Branches of dynamo action in spherical shells of different aspect ratio** Francesca Coke & Rob Teed *School of Mathematics and Statistics, University of Glasgow*
11:45–12:00	**Chaotic orbits of multiple immersed ellipsoids** Andrew Boyd, Mark Sawyer, David Scott, Rama Govindarajan & Prashant Valluri *School of Engineering, University of Edinburgh*
12:00–12:15	**Collective effects in the phase change of falling raindrops** Lucile Bisquert, Debarshi Debnath, David Scott, Rama Govindarajan & Prashant Valluri

	School of Engineering and Edinburgh Parallel Computing Centre, University of Edinburgh and International Centre for Theoretical Science, Tata Institute of Fundamental Research, Bengaluru
12:15–12:30	**Fluidization hydrodynamics in gas-solid vortex units: a CFD study** Shuxian Jiang & Victor Francia *Institute of Mechanical, Process and Energy Engineering, Heriot-Watt University*
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15:35–15:50	**The fluid mechanics of grounding zone wedges** Tanisha Kumari, Matthew Durey, Peter Stewart & Katarzyna Kowal

School of Mathematics and Statistics, University of Glasgow

15:50–16:05 **A representative wave for cross-shore sediment transport**
O. E. Neshamar, B. E. Larsen & A. Petridis
Technical University of Denmark

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Anirban Guha
Civil Engineering, University of Dundee

16:20–16:35 **Resonant triad interactions of gravity waves in variable-depth containers**
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School of Mathematics & Statistics, University of Glasgow

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Hamish C. F. C. Hay, David Rees Jones, Eric Hester & Daphné Lemasquerier
School of Mathematics and Statistics, University of St Andrews and Department of Mathematical Sciences, University of Bath

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Posters

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   The Scottish Association for Marine Science, SAMS
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   School of Mathematics and Statistcs, University of Glasgow
3. **Taylor dispersion for flow down channels with porous membranes**
   Raymond Callaghan, Katarzyna Kowal & Matthew Durey
   School of Science and Engineering, University of Glasgow
4. **Exploring Jupiter's zonal jets using a wave-mean flow interaction and laboratory analogue approach**
   Madeleine A. Heideman
   School of Mathematics & Statistics, University of St Andrews
5. **Heterogeneity-induced oscillations in active nematics**
   Alexander J. H. Houston, Geoff McKay, Michael Grinfeld & Nigel J. Mottram1
   School of Mathematics and Statistics, University of Glasgow and Department of Mathematics and Statistics, University of Strathclyde
6. **Turbulent polymer stretching**
   Demosthenes Kivotides
   School of Engineering, University of Strathclyde
7. **Wide-field tracking of floating plastic particles over continuous streamwise ridges in an open-channel flume**
   Denisa Krstienova, Mark Stewart, Yunqiang Zhu & Vladimir Nikora
   School of Engineering, University of Aberdeen
8. **Effect of aneurysm neck width on the haemodynamics of dual intracranial aneurysms**
   Sheila Legus-Christman & Asimina Kazakidi
   Department of Biomedical Engineering, University of Strathclyde
9. **Size-based separation of soft particles in suspension in inertial microfluidics**
   Jeanne Michalon, Qi Zhou, Timm Krüger & Benjamin Owen1
   School of Engineering and College of Medicine & Veterinary Medicine, University of Edinburgh
10. **Reaction infiltration instability in a compacting porous medium: channel and wave modes**
    Min Huang, John F. Rudge & David W. Rees Jones
    Department of Earth Sciences, University of Cambridge and School of Mathematics and Statistics, University of St Andrews
11. **Bistability and force balance in rotating spherical shell dynamo simulations**
    Ayesha Sarwar, Robert Teed & Radostin Simitev
    School of Mathematics and Statistics, University of Glasgow
12. **Rotating convection in a spherical shell with combined vertical and horizontal thermal forcing**
    Yu Sun, Ankit Barik & Daphné Lemasquerier
    School of Mathematics and Statistics, University of St Andrews and Department of Earth and Planetary Sciences, Johns Hopkins University and School of Physics Science and Engineering, Tongji University

13. **The role of magnetic diffusion on the onset of magnetoconvection in a spherical shell**
    Francis Swan, Robert Teed & Radostin Simitev
    School of Mathematics and Statistics, University of Glasgow
14. **Thermo-electrohydrodynamic convection in spherical Taylor-Couette flow**
    P. S. B. Szabo, Y. Gaillard & C. Egbers
    Department of Aerodynamics and Fluid Mechanics, Brandenburg University of Technology Cottbus-Senftenberg
15. **Evaporation of a rivulet on an inclined planar substrate**
    Fryderyk Tomczyk, Stephen K. Wilson & Alexander W. Wray
    Department of Mathematics and Statistics, University of Strathclyde and Department of Mathematical Sciences, University of Bath

Information about Talks and Posters

Talks

- Talks will be 12 minutes in length, with an additional 3 minutes for questions and change-over.

- Presenters should use their own laptop if possible.

Posters

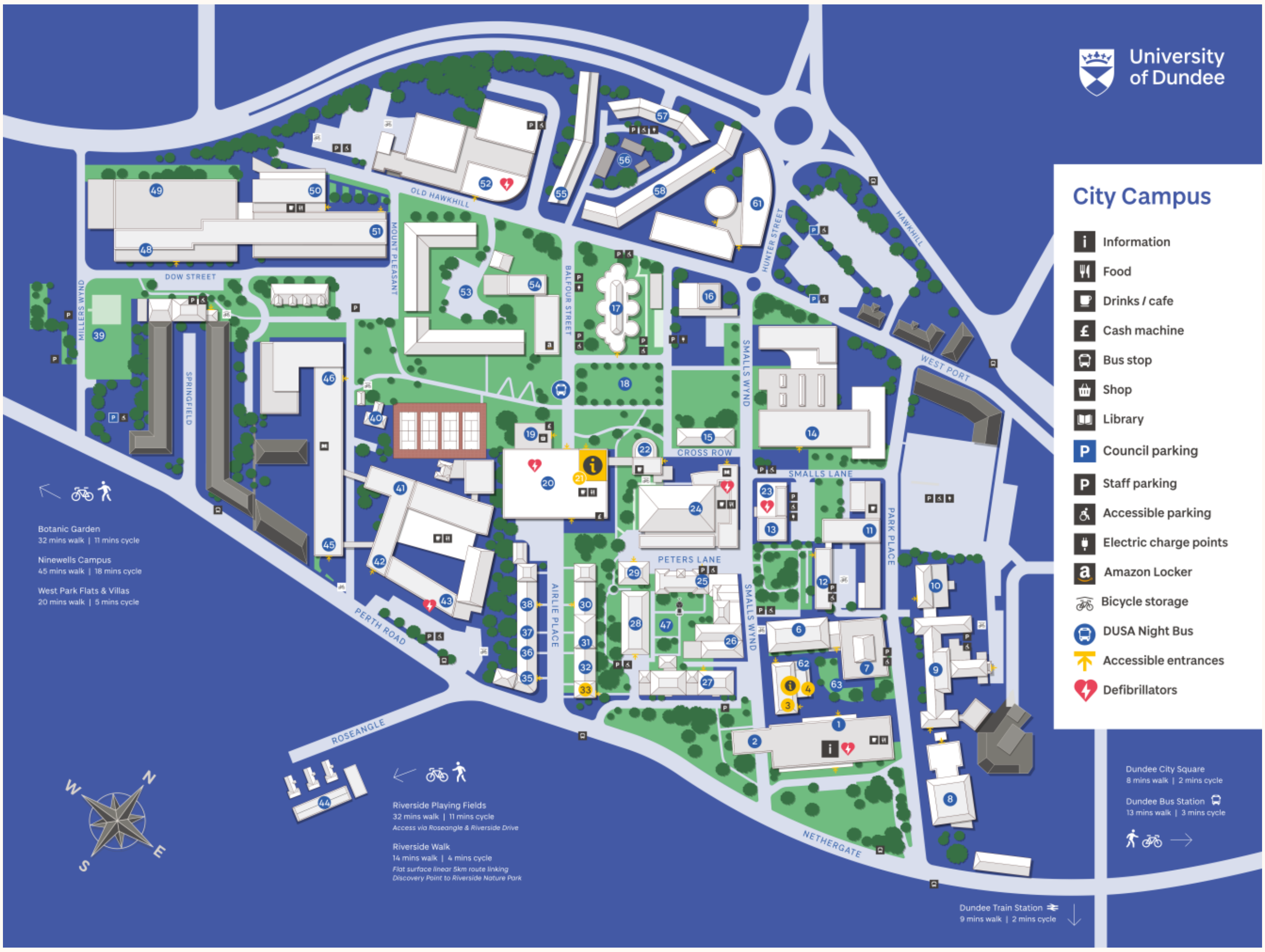
- Posters must be A0 size and portrait orientation.

Getting to the Venue

Venue

SFMM 2026 will take place in the **Dalhousie Building** on the University of Dundee's City Campus. This building is **number 61** on the campus map below. The main entrance is located at the intersection of Old Hawkhill, Small's Wynd, and Hunter Street.

Coffee and lunch breaks will be in the Dalhousie Building foyer (ground floor entrance), and the seminar room is off this foyer.



Travel

The Dalhousie Building is a short walk from both the Dundee Train Station (15 minutes) and the Dundee Bus Station (20 minutes). Both Stagecoach and Xplore Dundee offer local bus services between the Train and Bus Stations and the City Campus.

Public, pay-and-display parking (managed by Dundee City Council) is available directly opposite the Dalhousie Building, with entry from Hunter Street (the larger section of the car park) or from Old Hawkhill (the smaller section). There are other car parks nearby, including at South Tay Street, and larger multi-story car parks including on West Marketgait (eastbound) and near the train station, on Greenmarket.

Abstracts
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Talks

(in order of presentation)

Particle migration in Poiseuille flow of a viscoplastic fluid

James Malcolm, Mónica S. N. Oliveira & Emad Chaparian
Department of Mechanical & Aerospace Engineering, University of Strathclyde

Particle migration is a fundamental physical phenomenon in microfluidics used for applications ranging from rigid particle manipulation to cell separation. Migration of particles is primarily due to the shear-induced force and the wall-interaction lift force, leading to an equilibrium position. Here, we study the motion of rigid particles in a viscoplastic fluid flow in a cylindrical conduit. This phenomenon has previously been studied in complex fluid environments exhibiting both viscoelastic and elasto-visco-plastic rheologies.[1] In this study, we shed light on the effect of viscoplastic rheology on particle migration, contributing to a more comprehensive understanding of how fluid rheology can be leveraged for targeted particle sorting. Robust computations employing a coupled CFD-DEM solver (i.e. LIGGGHTS & OpenFOAM) with "two-way coupling" are conducted to resolve particle-fluid interactions. The simulations consider a wide range of Bingham numbers and particle's initial positions. The formation of a core unyielded region in the centre of the conduit (where the fluid behaves as a "soft solid") can trap the particles within. However, particles which are partially in the core unyielded region can escape and migrate towards equilibrium position in the annular sheared region. This differs from the Newtonian equilibrium position due to the redistribution of the shear gradient compared to the Newtonian fluid flow counterpart. Hence, there is a critical radius below which the particles are unable to migrate.

[1] Chaparian, E., Ardekani, M. N., Brandt, L., and Tammisola, O., "Particle migration in channel flow of an elastoviscoplastic fluid," J. Non-Newtonian Fluid Mech., Vol. 284, 2020, pp. 104376.

Wall modes and pattern formation in molten salt magnetoconvection

Asif Nawaz*, Andrei Teimurazov†, Matthew McCormack*, Olga Shishkina†
& Moritz Linkmann*
*School of Mathematics and Maxwell Institute for Mathematical Sciences,
University of Edinburgh
†Max Planck Institute for Dynamics and Self-Organization, Göttingen

Magnetoconvection in electrically conducting fluids under strong imposed magnetic fields is central to heat extraction in fusion reactor cooling blankets. Most canonical results and many blanket-relevant studies focus on liquid metals, however, several proposed concepts use molten salts whose thermal diffusion is comparatively weak, with Prandtl numbers (Pr) in the range 10-30. While linear theory for wall-mode and bulk onset is Pr-independent for most relevant working fluids, little is known about nonlinear effects even in a Rayleigh-Bènard setup, such as near-onset pattern formation, wall-mode selection with increasing Rayleigh number (Ra), and the transition to turbulence. Recent results from numerical linear stability analysis in cylindrical domains show that multiple wall modes with different azimuthal wavenumbers are closely spaced at onset.[1] This near-degeneracy, which results in transitions between wall-mode states of different azimuthal structure as observed in the liquid metal case,[2] implies strong modal competition and potential multistability. Here, we present direct numerical simulations of magnetoconvection in cylindrical domains of aspect ratio 2 subject to a vertical magnetic field in the high-Pr molten-salt regime. We investigate (i) the nonlinear selection, potential coexistence, and transitions between competing wallmode branches, and (ii) the sequence of pattern changes across Ra from steady wall modes towards time dependence and eventually turbulence. In contrast to the liquid metal case, we observe high-wavenumber wall-mode patterns to emerge with increasing Ra, that remain dynamically relevant beyond bulk onset. Preliminary results suggest the co-existence of wall modes with different wavelengths close to onset.

[1] Tao, X., Zhu, X., Ni, M.-J., and Xie, Y.-C., "Onset and length scales of wall modes in confined magnetoconvection with a vertical magnetic field," Journal of Fluid Mechanics, Vol. 1026, 2026, pp. A41.
[2] Xu, Y., Horn, S., and Aurnou, J. M., "Transition from wall modes to multimodality in liquid gallium magnetoconvection," Physical Review Fluids, Vol. 8, No. 10, 2023, pp. 103503.

Computer modelling of metals in the continuous casting

Wei Dou, Thomas Jones & Ping Lin
School of School of Science and Engineering, University of Dundee

In the continuous casting of metals, liquid metal flows from a furnace into a mould, where cooling water reduces the mould wall temperature to initiate solidification. Through heat transfer, the liquid metal undergoes a phase transition from liquid to solid state, after which the solidified metal gradually cools to ambient conditions. This process may produce defects such as surface pulse marks and internal porosity. Our research aims to simulate the pure copper solidification process and investigate the influence of different casting motion.

To capture the effects of fluid motion on solidification, we use the phase-field approach which can be readily solved by publicly available PDE solvers. As is done by many in the field, we treat the solid phase as a highly viscous liquid. Building on previous work,[1,2] we developed a phase-field model for the solidification process of a liquid metal, which accommodates distinct physical properties for each phase while preserving thermodynamic consistency. The model employs an order parameter in phase-field equation that varies continuously between phases, providing an explicit representation of the solidification front.

In our simulation, the thermophysical properties of pure copper are assumed to be uniform within each phase. Temperature-dependent parameters may be incorporated as well. The governing equations are discretised and solved numerically using the finite element platform FEniCS. We validate the model by comparing its results with those available in literature.

[1] Guo, Z. and Lin, P., "A thermodynamically consistent phase-field model for twophase flows with thermocapillary effects," Journal of Fluid Mechanics, Vol. 766, 2015, pp. 226–271.
[2] Anderson, D. M., McFadden, G. B., and Wheeler, A. A., "A phase-field model of solidification with convection," Physica D: Nonlinear Phenomena, Vol. 135, No. 1, 2000, pp. 175–194.

Data-driven modelling of diffusion coefficients in porous media

Quinn Stein, Humphrey Yiu & Ali Ozel
School of Engineering and Physical Sciences, Heriot-Watt University

Accurate characterisation of diffusive transport in porous solid-liquid systems is essential for many engineering problems such as catalytic reactor design, drug delivery in biological tissues, environmental remediation. Diffusion coefficients in porous media differ significantly from those in bulk aqueous solution due to pore size, polymer-solute interactions and environmental conditions. Conventional parameter estimation requires extensive calibration experiments with a narrow descriptive scope for these systems. We present a data-driven computational framework using a physics-informed neural network (PINN)1 to directly extract diffusion coefficients from spatiotemporal concentration fields obtained via fluorescence imaging. The PINN incorporates the governing diffusion equation directly into the training alongside boundary conditions and interior observations via a multi-objective loss function. Minimising the loss recovers key transport parameters while simultaneously reconstructing the propagation of the concentration field. Framework validation utilises Rhodamine B as a model solute with spatiotemporal concentration fields extracted from time-series fluorescence video frames as PINN input. The network successfully generates low error in the constructed concentration fields (See Figure 1) and physically consistent diffusion coefficients. Future work will extend this to optimised catalytic particle-laden flow systems for both diffusion and reaction kinetics, enabling simultaneous multi-parameter estimation across varied structural and compositional configurations.

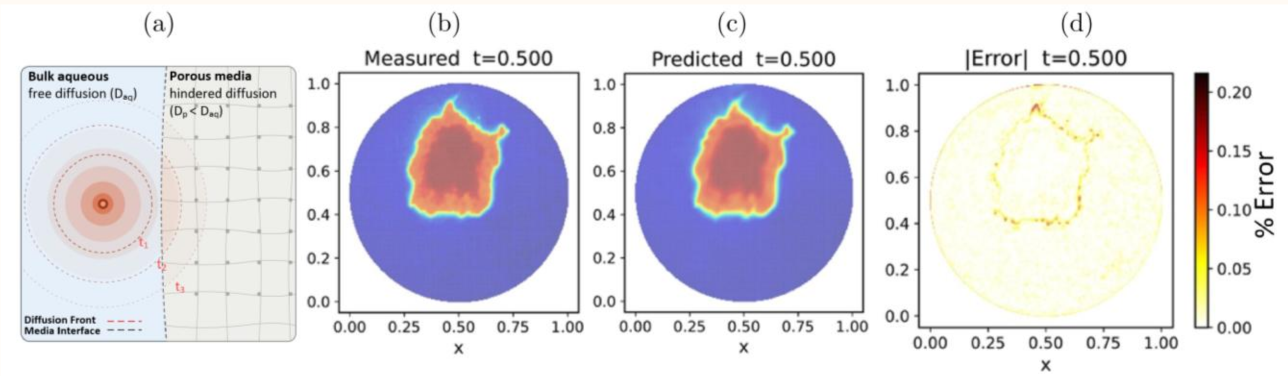

Figure 1: Rhodamine B diffusion through a porous medium. (a) Example diffusive process into porous media; Concentration colormaps: (b) Ground truth concentration field; (c) PINN concentration predictions; (d) Relative error between ground truth and predictions.

[1] Raissi, M., Perdikaris, P., and Karniadakis, G., “Physics-informed neural networks...,” J. Comput. Phys., Vol. 378, 2019, pp. 686–707.

The Helmholtz resonance of a submerged dock with a backplate

Christopher J.P. Wakefield[*] & Cathal P. Cummins[*,†]
[*] *School of Energy, Geoscience, Infrastructure and Society (EGIS0), Heriot-Watt University*
[†]*Department of Mathematics, Maxwell Institute for Mathematical Sciences, Heriot-Watt University*

In the field of wave-structure interaction (WSI), numerous examples exist where the response of the structure exhibits resonant and non-resonant behaviour. These include the Helmholtz or pumping resonances experienced by harbours and basins communicating with larger bodies of water via a mouth or channel.[1] Similarly, there are examples where a non-resonant structure can, with minimal modification, begin to exhibit resonant behaviour. This can be observed in the quasi-resonance demonstrated by a finite dock which has undergone a small rotation.[2]

This work unifies these behaviours through the analysis of the related problem of the interaction of monochromatic waves with a semi-enclosed, rectangular, surface-piercing cavity in two-dimensions using the eigenfunction matching method. An examination of the impact of a broad range of cavity geometries on parameters such as mouth-impedance and mouthcorrection is undertaken. This examination delineates the boundaries between a number of resonant and non-resonant cases from the WSI literature. The resulting delineation is represented on a regime map relating these parameters to the cavities' resonant behaviour.

[1] Miles, J. W. and Lee, Y. K., "Helmholtz resonance of harbours," Journal of Fluid Mechanics, Vol. 67, No. 3, feb 1975, pp. 445–464.
[2] Parsons, N. F. and McIver, P., "Scattering of water waves by an inclined surface-piercing plate," The Quarterly Journal of Mechanics and Applied Mathematics, Vol. 52, No. 4, nov 1999, pp. 513–524.

Deepfake turbulence yields short solutions to the Navier-Stokes equations

Jeremy P Parker
Mathematics, University of Dundee

Periodic orbit theory (POT) underpins the tantalising idea that chaotic systems can be understood by considering only exactly periodic solutions, closed trajectories in state space. This has been successful for many simple systems including both ordinary and partial differential equations, but despite several attempts, this has yet to be realised for turbulence. POT relies on a hierarchy of period orbits, with longer ones constructed from the shortest, which makes finding the shortest orbits crucial for this method to work. Here we train a diffusion model, a type of generative artificial intelligence, to create timeseries which appear to be very short trajectories to the 2D Navier-Stokes equations with a sinusoidal forcing – the Kolmogorov flow. By converging these synthetic timeseries to true solutions, we find a large number of very short periodic orbits. The fact that we find so many, with no evidence of a hierarchy, implies that periodic orbit theory is not feasible for this system, and in turn is unlikely to work for 3D turbulence and other more complicated fluid dynamical problems.

References

[1] Parker, J. P., & Schneider, T. M. (2026). From synthetic turbulence to true solutions: A deep diffusion model for discovering periodic orbits in the Navier-Stokes equations. *arXiv preprint arXiv:2602.23181*.

Branches of dynamo action in spherical shells of different aspect ratio

Francesca Coke & Rob Teed
School of Mathematics and Statistics, University of Glasgow

Earth's inner core has been growing since its nucleation, and throughout this time the electrically conducting fluid outer core has sustained a convection driven dynamo providing Earth with a magnetic field. Numerical models with an inner/outer core aspect ratio appropriate for the present-day geodynamo have produced two distinct dipolar branches of solutions in parameter space: the viscously-dominated "weak-field" regime and the magnetically-dominated "strong-field" regime.[1] The strong-field regime, expected to be operating in Earth's core, can be classified by a measure of the Lorentz force compared to the Coriolis force, the "Elsasser number". Regions of bistability between the strong- and weak-field regime exist[2] across a range of parameter values in models appropriate for present-day Earth. It is easier to drive a dynamo with a larger aspect ratio,[3] however, the existence of dipole-dominated solutions becomes constrained by the geometry, and multipolar dynamos are preferred.[4] In this work, through numerical simulations, we investigate whether bistability between the strong- and weak-field regimes exists in models of Earth with a varying aspect ratio. Provided the magnetic diffusivity is low enough, dipolar dynamos can persist in large aspect ratio shells.

[1] Dormy, E., "Strong-field spherical dynamos," J. Fluid Mech., 2016.
[2] Teed, R. J. and Dormy, E., "Scaling of strong-field spherical dynamos," Geophys. Res. Lett., 2025.
[3] Heimpel, M., Aurnou, J., Al-Shamali, F., and Perez, N. G., "A numerical study of dynamo action as a function of spherical shell geometry," Earth Planet. Sci. Lett., 2005.
[4] Goudard, L. and Dormy, E., "Relations between the dynamo region geometry and the magnetic behavior of stars and planets," EPL, 2008.

Chaotic orbits of multiple immersed ellipsoids

Andrew Boyd, Mark Sawyer, David Scott, Rama Govindarajan & Prashant Valluri
School of Engineering, University of Edinburgh

Building on prior investigations of the complex dynamics of a single immersed ellipsoid1 this work examines the coupled translational and rotational dynamics of multiple immersed ellipsoids in both inviscid and viscous flow regimes. Previous studies have shown that even a single rigid body may exhibit chaotic motion under viscous conditions as a consequence of vortex shedding.[1] The present study extends this analysis to systems of multiple bodies, with particular emphasis on how hydrodynamic interactions influence the onset and modulation of chaotic dynamics as the number of solids increases.

For inviscid flow, Kirchhoff's equations are generalised to multi-body configurations, following the classical formulation of Lamb.[2] In contrast to the single-body case, analytical expressions for added mass and inertia are no longer available, and the governing potential flow is therefore solved numerically using boundary integral equations. Hydrodynamic forces and moments are obtained by interpolation over surface elements. The resulting fully coupled six-degree-of-freedom equations of motion are integrated numerically, with rotational dynamics represented using quaternions. The computational framework is implemented in Rust and parallelised with high efficiency.

The resulting dynamics are analysed using recurrence quantification analysis and cross-correlation techniques to characterise chaotic behaviour and inter-body coupling.[3] The inviscid predictions are systematically compared with fully resolved viscous simulations performed using the Xcompact3D solver.[4] The results provide new insight into the role of multi-body hydrodynamic interactions in shaping complex and chaotic solid–fluid dynamics.

[1] Essmann et.al., 2020. *Chaotic dynamics of an immersed ellipsoidal body in viscous flow*. Journal of Fluid Mechanics, **899**, A12.
[2] Lamb, H., 1932. *Hydrodynamics*. 6th ed. Cambridge: Cambridge University Press.
[3] Marwan, N., Romano, M.C., Thiel, M. and Kurths, J., 2007. Recurrence plots for the analysis of complex systems. *Physics Reports*, **438**(5–6), pp.237–329.
[4] Laizet, S. and Lamballais, E., 2009. High-order compact schemes for incompressible flows: A simple and efficient method with quasi-spectral accuracy. *Journal of Computational Physics*, **228**(16), pp.5989–6015.

Collective effects in the phase change of falling raindrops

Lucile Bisquert*, Debarshi Debnath*, David Scott†, Rama Govindarajan‡ & Prashant Valluri*
*Institute for Multiscale Thermofluids, School of Engineering, University of Edinburgh
†Edinburgh Parallel Computing Centre, University of Edinburgh
‡International Centre for Theoretical Science, Tata Institute of Fundamental Research, Bengaluru

Rainfall results from a succession of processes including droplet formation within clouds, gravitational descent through the atmosphere, and impact at the surface. As raindrops fall under gravity, they interact with the surrounding air, deform under aerodynamic forces, and exchange heat and mass with the environment through evaporation or condensation.

The phase change depends strongly on ambient conditions, and in particular on the local relative humidity. In slightly supersaturated environments, with relative humidity of order 105%, water vapour is available in excess and droplets may experience condensation while descending. Such conditions can be found locally inside moist convective clouds, for example within cumulus or cumulonimbus systems, such as those often observed during the monsoon season. In contrast, when droplets fall through subsaturated air with relative humidity around 95%, the surrounding environment favours evaporation, leading to a reduction of droplet volume during descent.

When many droplets fall together, they interact, so that the volume evolution of a droplet depends not only on the ambient conditions but also on the presence and spacing of neighbouring droplets. In the present work we explore how these interactions can modify the local humidity and convective flow experienced by each droplet, affecting the rate of evaporation or condensation. To investigate these collective effects, we perform three-dimensional simulations using a numerical framework based on a diffuse-interface approach. With our in-house finite volume solver (https://sourceforge.net/projects/tpls/),[1] we capture the dynamics of droplet deformation, evaporation or condensation, and interactions with the surrounding gas phase by coupling the Cahn–Hilliard equation with the conservation equations for mass, momentum, and energy, while phase change is treated using a diffusion-limited formulation.

[1] Sáenz, P. J., Sefiane, K., Kim, J., Matar, O. K., and Valluri, P. (2015). Evaporation of sessile drops: a three-dimensional approach. Journal of Fluid Mechanics, 772, 705-739.

Fluidization hydrodynamics in gas-solid vortex units: a CFD study

Shuxian Jiang & Victor Francia
Institute of Mechanical, Process and Energy Engineering, Heriot-Watt University

The interfacial velocity in traditional gas-solid fluidized beds is limited by the terminal velocity of particles under gravity. Fluidizing solids against a centrifugal force instead of gravity allows to operate at higher gas-solid slip velocities, generate transport rates orders of magnitude higher[1] and design more efficient, compact units.[2] Mechanically rotating designs can operate at centrifugal accelerations from tens to thousands of times gravity, but are difficult to scale due to the use of moving parts and motors. Gas-Solid Vortex Units (GSVUs) can generate the same swirling motion in a static unit using tangential gas inlets but suffer from less flexibility because the solids rotation and the inwards drag are both intrinsically coupled to the gas flow rate. The lack of an independent control of rotation and flowrate limits the ability to adapt to changing process conditions, such particle size, density, or solid loading, necessary in batch, sequential and cyclic operations.

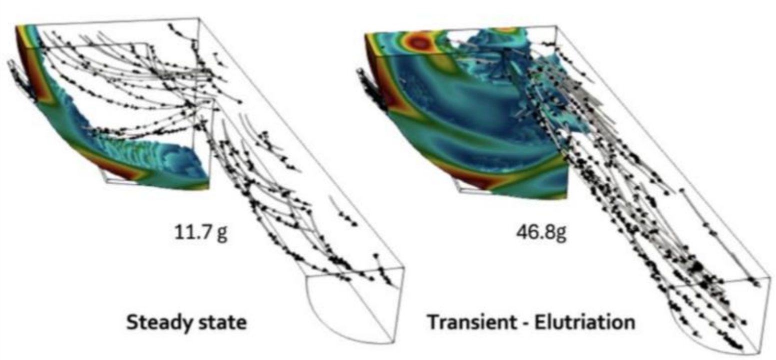

Fig 1. Rotational solid bed and gas flow streamlines in a GSVU. Solid phase shown as an isosurface ($\varepsilon_s \geq 0.05$). Simulation of a quarter section of a standard unit[3].

This contribution investigates the hydrodynamics of GSVUs to develop effective control strategies to control bed expansion and stability. The core challenge lies in understanding how the efficiency of the angular momentum transfer depends on design and process conditions, and how it leads to different flow regimes. To address this question, we employ an opensource computational platform (OpenFOAM) to investigate the response of a rotational bed to varying design parameters and process conditions. The framework utilizes transient RANS with a Reynolds Stress Model (RSM) for the gas phase, and a transient Euler-Euler (Two-Fluid Model) to describe the multiphase system (Fig 1). The platform is first validated against gas and gas-solid experiments.[3] A simulation campaign under different loading and inlet designs is then used to illustrate the stability and evolution of rotational fluidized beds. Quantifying the relation between different GSVU inlet design and the angular momentum transfer efficiency, this study identifies a suitable window for stable operation and sets the basis to explore new designs capable to manipulate rotational speed and flowrate independently.

[1] J. De Wilde, A. De Broqueville, "Rotating fluidized beds in a static geometry: experimental proof of concept." AIChE Journal, Vol. 53, No. 4, 2007, pp. 793-810.
[2] B. Wang et al., "Toward predictive multiscale models for HiGee devices." Current Opinion in Chemical Engineering, Vol. 51, 2026, pp: 101230.
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Dynamics of chemically propelled elastic filaments

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Chemically active particles are an artificial prototype for active matter. These microscale submerged objects self-propel by consuming a fuel in the surrounding fluid: surface chemical reactions alter the local solute concentration, and solute-surface interactions cause any resulting concentration gradients to drive slip flows close to the surface. We theoretically investigate how slender elastic filaments move under this propulsion mechanism1, by combining an asymptotically accurate slender body theory for calculating the slip flows2 with a computationally efficient method for simulating the elastohydrodynamics of filaments3. By considering canonical examples of surface chemical patterning, we explore the suite of dynamic behaviours of chemoelastohydrodynamic filaments in simulations across a wide range of material stiffnesses. As the filament becomes more deformable, the dynamic behaviour progresses from rigid motion, through buckling and out-of-plane transitions, towards chaos.

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Influence of surface tension effects on thermal-hydraulic transport in microchannels

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This study numerically investigates the interplay between forced convection and thermocapillary flow driven by surface tension gradients in a free-surface microchannel heat sink. Marangoni stresses, induced by thermal gradients, emerging as a result of heating from below, interact with the bulk fluid, thereby modifying flow structure and altering heat transfer performance. To explore a new category of liquids where surface Marangoni stresses change direction according to the temperature range (leading to the so-called reverse Marangoni effect), numerical results are presented for pure water and various binary and ternary mixtures known in the literature for their ability to support such phenomena (water-based solutions including ammonia, methanol, ethylene glycol, and propylene glycol). Temperatures ranging from 20°C to 100°C are considered accordingly together with two distinct values of the (imposed) Reynolds number (Re = 50 and 100). The results demonstrate that thermocapillary effects significantly augments heat transfer efficiency, particularly at higher thermal gradients. At Re = 100 and a temperature difference of 80°C (20°C to 100°C), the Nusselt number for pure water increases by 52.7% compared to the case neglecting surface tension effects. For ternary mixtures, the enhancement is even more pronounced, reaching a maximum increase of 56.1% at Re = 50. Notably, the Water-Ethylene Glycol mixture achieves a 45.5% improvement at Re = 100, while the Methanol-based mixture exhibits superior performance at lower inertia. Furthermore, the friction factors remain relatively constant across the configurations, indicating that significant thermal enhancement can be achieved without excessive pressure drop penalties[1]. These findings confirm that, although largely overlooked to date, surface tension gradients represent an effective mechanism for heat transfer augmentation in microchannels. Moreover, evidence is provided that the utilization of multicomponent fluids to tune Marangoni effects offers a promising strategy for the design and optimization of high-performance microscale thermal management systems.

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A model for walking droplets over submerged barriers

Zubaydah Alotaibi, Katarzyna N. Kowal & Matthew Durey
School of Mathematics and Statistics, University of Glasgow

The hydrodynamic pilot-wave system, renowned for its ability to imitate quantum phenomena on a macroscopic scale, consists of a droplet bouncing and self-propelling across the surface of a vertically vibrating liquid bath.[1] The majority of hydrodynamic quantum analogues exhibited by this system leverage variations in fluid depth to generate wave-mediated forces that deflect the droplet's path in a manner similar to that of quantum potentials. However, modelling walking droplets over submerged steps has proven challenging, as existing models are either too complex for theoretical analysis or too simple to capture canonical pilot-wave phenomena.

We fill this gap by developing a minimal stroboscopic trajectory equation that accounts for depth changes by varying in space the local amplitude and slope of the waves generated along the droplet's path. In one spatial dimension, the model reduces to a dynamical system of four variables. We analyse the droplet's motion over slopes, corrals, and barriers. For multiple droplets interacting between cavities, we explore numerically the onset of long-range synchronisation and intermittent chaos. Finally, we discuss potential extensions of the modelling framework.

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Effect of cell softness on the separation between circulating tumour cells from blood

Roslyn Hay, Timm Krüger & Benjamin Owen
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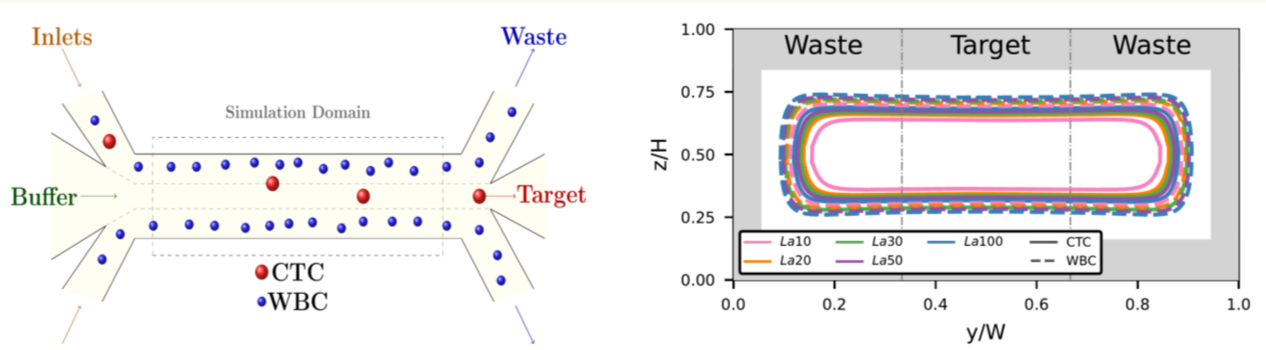
Early diagnosis of cancer significantly improves survival rates. Unfortunately, symptoms of cancer are more prevalent during the later stages of the disease, leading to a later diagnosis. Circulating tumour cells (CTCs), which detach from the primary tumour and enter the bloodstream, act as an early biomarker of cancer. Inertial microfluidic (IMF) devices have shown the potential to separate CTCs from white blood cells (WBCs).[1] For clinical translation, full separation of the CTCs is required; however, this remains a challenge due to an incomplete understanding of the underlying physics. IMF devices are designed mainly on the basis of differences in cell size; however, another influential factor that is known to affect migration rates in IMF devices is cell softness. We simulate the migration dynamics of CTCs and WBCs in a straight microchannel using a 3D lattice Boltzmann solver. We find different trends between suspensions when the softness of the CTC or the WBCs is varied, allowing a characterisation of cell interaction types and their effects on migration rates. We conclude that cell size and softness are coupled factors that influence interaction effects due to cross-sectional behaviour. These findings highlight the importance of accounting for cell softness in the design of inertial microfluidic devices.



(a) Schematic of IMF Device, highlighting the target stream, specific outlets and simulation domain

(b) Cross-sectional paths of CTCs and WBCs with varied cell softness

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Single-molecule DNA dynamics in heterogeneous microfluidic flows: from conformational response to length-based separation

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E. Chaparian[*] & Mónica S. N. Oliveira[*]
[*]*James Weir Fluids Laboratory, Department of Mechanical and Aerospace Engineering, University of Strathclyde*
[†]*PMMH, CNRS, ESPCI Paris PSL*

Understanding polymer dynamics at the microscale is key to advancing microfluidic technologies for biotechnology and soft matter systems. Here, we combine experiments and Brownian dynamics simulations to investigate the behaviour of single DNA molecules in microfluidic devices with periodic pillar arrays. These structured environments generate highly heterogeneous flow fields with tuneable kinematics, producing spatially varying strain that drives a diverse range of molecular conformations, trajectories, and deformation modes. We demonstrate that subtle changes in flow orientation and conditions lead to pronounced differences in single-molecule dynamics. Furthermore, we show that such microstructured flows can be harnessed for the selective separation of DNA molecules by length, arising from their distinct nonlinear responses to non-uniform flow fields. Our findings establish a framework for exploiting flow heterogeneity, enabling molecular manipulation and informing microfluidic separation strategies.

PLGA fibre formation by wet and microfluidic spinning in conventional and green solvents

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University of Coimbra

Polymeric fibres are used in biomedical applications, such as wound dressings and bioactive sutures, due to their high surface area and porosity, which support controlled release of therapeutic agents. In this work, we explore green solvents for the manufacture of biodegradable poly(lactic-co-glycolic acid) (PLGA) fibres, using wet and microfluidic spinning. These methods offer mild processing conditions but require careful control of polymer solutions properties and solvent–non-solvent exchange to achieve stable fibre formation.

PLGA solutions were prepared at varying concentrations using a conventional solvent, dimethyl sulfoxide (DMSO), and compared with greener alternatives, such as dimethyl carbonate (DMC), and the bio-based solvent dihydrolevoglucosenone (DLG). Steady shear and oscillatory tests were used for rheological characterisation of the polymeric solutions, as well as time stability studies to assess changes in their properties over time.

PLGA/DMSO solutions provide a robust processing window, enabling reproducible formation of continuous micrometric fibres by both wet spinning and microfluidic spinning. DLG-based systems, however, showed higher viscosity and more pronounced viscoelastic behaviour, particularly at higher concentrations. These properties were used to estimate flow conditions and define practical spinning windows for fibre production. The resulting fibres were characterised using tensile testing to compare their mechanical properties, and by FTIR to compare solvent-processed PLGA with the as-supplied polymer to assess possible processing/solvent related effects, and detect any undesired residual solvent, which would be critical for biomedical applications.

Beyond Saffman-Taylor: viscous fingering of free-surface flows

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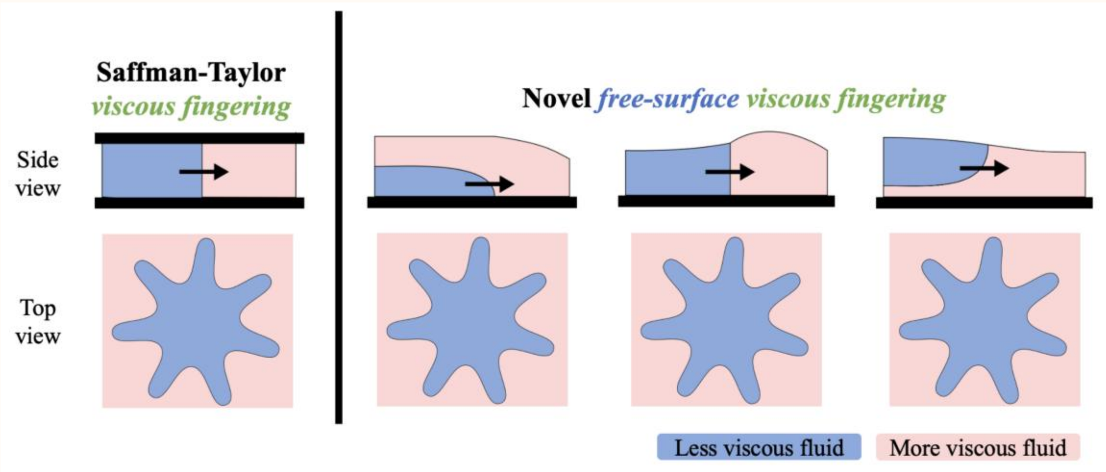
A fluid front propagating under gravity becomes susceptible to a previously unrecognized hydrodynamic instability when advancing into a fluid of higher viscosity. Despite fundamental differences in the type of flow, the novel instability curiously resembles a number of hallmark features typical of its closest predecessor: the well-known Saffman-Taylor instability. For both types of instability, a change in pressure gradient owing to a viscosity contrast provides the essential destabilizing mechanism. The two systems diverge, however, in their geometric and dynamical constraints: the Saffman-Taylor instability arises in confined configurations such as porous media or Hele-Shaw cells, whereas the present mechanism operates in unconfined free-surface flows. Here, we elucidate the physical origin of the novel instability and outline the classes of flows that are so far known to be susceptible to it. We further offer possible stabilising mechanisms and highlight a number of real-world implications across scales, from levee breakouts to nasal drug delivery.



The fluid mechanics of grounding zone wedges

Tanisha Kumari, Matthew Durey, Peter Stewart & Katarzyna Kowal
School of Mathematics and Statistics, University of Glasgow

We examine the deposition of a thin layer of viscous fluid beneath another as both fluids intrude towards an inviscid ocean, motivated by the formation of sedimentary grounding zone wedges beneath marine ice sheets. Over large time and length scales, such as those of the Antarctic ice sheet, both ice and the subglacial sediment, or till, over which it flows, exhibit fluid-like behaviour. We use this analogy to employ lubrication theory to model both ice and till as thin films of viscous fluid that spread over rigid bedrock and into an inviscid ocean. Upstream, the ice sheet is in contact with the bedrock. As it flows towards the ocean, the ice sheet detaches from the bedrock at the grounding line, beyond which it feeds into a freely floating ice shelf. We assume that vertical shear stress provides the dominant resistance to the flow of the ice and till and viscous extensional stress provides the dominant resistance to the flow of the shelf.[1] While the rheology of ice and till is non-Newtonian, much of the underlying physical principles can be understood using a Newtonian rheology,[2] which is where we begin whilst retaining the essential viscosplastic properties of till downstream of the grounding line. We demonstrate that a wedge necessarily forms at the grounding line and use a combination of asymptotic analysis and numerical simulations to characterise it across a range of key dimensionless parameter values.

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A representative wave for cross-shore sediment transport

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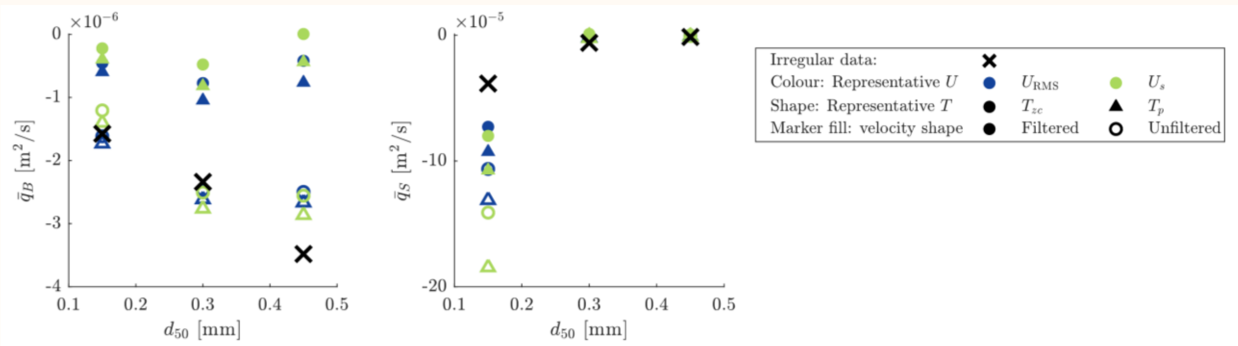
When modelling long-term coastal sediment transport, it is common to represent an irregular wave field in terms of a small number of representative average parameters, such as the characteristic wave height, wave period, skewness, and asymmetry. While such representative formulations have been shown to perform relatively well when modelling longshore-directed sediment movement, cross-shore directed transport is much more dependent on unsteady flow dynamics, resulting in significant uncertainty. This work presents a conceptual investigation of whether cross-shore sediment transport under irregular waves can be predicted based purely on a set of representative parameters, by way of idealised numerical simulations.

1-D RANS simulations have been performed for a wide range of "realistic" irregular cross-shore flows, and for each case, a number of different representative wave formulations were subsequently simulated. The figure shows results for a given flow case over three different sand beds, showing the net bedload (left) and suspended load (right) predicted using a number of different combinations of representative parameters, as indicated in the legend. The degree of agreement between irregular and representative cases depends strongly on the set of representative parameters used, and optimal parameters for the suspended load and bedload may often differ. The presentation will detail results from the full set of conditions tested, and potential strategies for more robust representation will be discussed.



Inferring pycnocline depth from sea surface data and satellite images of internal solitary waves

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Pycnocline – the critical density interface separating the ocean's upper mixed layer from deeper water masses – is the site of significant biological primary production and of the exchange of heat, carbon, and nutrients. Pycnocline depth is typically determined via in situ measurement programs. Remote sensing offers a lower-cost, wider-coverage alternative, in which pycnocline depth is inferred from the sea-surface signature of nonlinear internal solitary waves (ISWs). Such inference requires the formulation of inverse models derived from wave properties. ISW-based formulation reveals dependence on subsurface information, thereby defeating the purpose. Current inverse models, which provide a working alternative by replacing ISW's properties with linear interfacial waves, yield limited success. Therefore, despite significant progress in satellite oceanography, its applicability in advancing pycnocline depth reconstruction has remained underutilised for many decades. Here, we develop an ISW-based inverse model that eliminates the need for subsurface information. Using MODIS-TERRA images acquired under sunglint conditions off the Amazon shelf, we conduct the largest case study consisting of 168 mode-1 ISWs from 2005 to 2021, reconstruct the corresponding pycnocline depths, and compare with Reanalysis data. Our model not only offers theoretical simplicity but also shows a step-change improvement over the current linear-wave-based model, with mean reconstruction error reducing from 70% to 21%. This improved predictability results from the inclusion of additional sea-surface information – ISW's width estimate and surface currents. The outcomes of our study have important implications for operational oceanography and can inform marine and submarine navigation and downstream operations.

Resonant triad interactions of gravity waves in variable-depth containers

Jie Yang, Katarzyna Kowal & Matthew Durey
School of Mathematics & Statistics, University of Glasgow

Controlling the side-to-side sloshing of liquid in a container is crucial in many industrial processes, where motion can be driven by external forcing or internal resonance. The latter is known to generate three standing wave modes interaction and continuously exchange energy in cylindrical basins, but is absent in rectangular tanks, where the required spatiotemporal mode correlation cannot be satisfied. We demonstrate herein that resonant triads may be excited when the depth of a rectangular tank varies in space, and that the time scale of the energy exchange shortens as the bathymetry becomes more pronounced. We combine asymptotic analysis and numerical computation to identify the types of topography that induce the strongest triad interactions, paying particular attention to the limits of small- and large-amplitude depth variations.

I will present two qualitatively different cases for the onset of triads: one forms at finite depth involving initially three uncorrelated modes, and the other forms in the shallow-water limit involving three correlated wave modes. Two classes of triad are identified: weakly correlated triads forming for small variations in depth, and strongly correlated triads forming across deep basins connected by shallow ridges. Our study highlights a new mechanism for exciting internal resonances in variable-depth, sloshing-prone basins, such as cruise ship, swimming pools and harbours.

Horizontal convection in icy moon oceans with melting and freezing

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†Department of Mathematical Sciences, University of Bath

Thermal buoyancy is a primary driver of icy-satellite ocean dynamics, caused by mantle heating at the seafloor and cooling at the ice-ocean interface. A significant driver of mantle heating is dissipation by cyclic tidal deformation. When this buoyancy forcing is spatially uniform, laboratory and numerical experiments have shown that it can create overturning circulation, melting and freezing of the overlying ice, and alternating east-west jets of rapid circulation. Tidal dissipation, however, naturally varies in space, causing differential heating of the ocean bottom. These temperature variations will drive horizontal convection, a largescale overturning circulation with a zonal structure. Here, we investigate the mechanics of this horizontal convection, its interaction with Rayleigh-Bénard (vertical) convection, and dynamic feedback with ice-shell thickness, melting, and freezing.

We perform non-rotating simulations of convection in a 2D Cartesian geometry with a mobile ice-ocean interface using the pseudo-spectral code, Dedalus. A sinusoidal temperature profile is imposed on the bottom of the ocean as well as a vertical (average) temperature difference. The relative amplitude of horizontal to Rayleigh-Bénard convection is varied by changing the ratio of the vertical to horizontal temperature differences, as well as the aspect ratio of the domain. The phase change between pure water and ice is captured using the phase field method. We perform sensitivity tests to determine the optimum phase field parameters that best approximate stagnation-point flow solutions in the vicinity of the ice-ocean interface. These optimum parameters vary as a function of vertical Rayleigh number. We then investigate the competition between Rayleigh-Bénard and horizontal convection without phase change, before including melting and freezing to study the dynamic feedback of ice topology on this competition. Finally, we seek to place our simulations in the context of icy-satellite oceans by determining scaling relationships between the horizontal Rayleigh and Nusselt numbers.

Abstracts
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Posters

(alphabetical)

NORWESTCOMS: operational Scottish coastal modelling system

Dmitry Aleynik, Keith Davidson, Tim M. Szewczyk & Andrew Dale
The Scottish Association for Marine Science, SAMS

The novel NORWESTCOMS coupled atmosphere-ocean-wave modelling system addresses the demand for reliable operational forecasting of currents and sea state near the North and West coasts of Scotland. Our hydrodynamic modelling system is designed for regions with equally complex coastlines indented by numerous fjords, peninsulas and islands to provide early warning of approaching natural (plankton blooms, outburst of sea lice) and anthropogenic hazards (spreading substances, plastic particles), allowing sufficient time for deployment of efficient protective and mitigation measures at aquaculture sites and by coastal communities.

The system consists of two FVCOM domains (NORSCOMS and WESTCOMS[1,2,3]), extending between the shelf-break west of the Hebrides, Orkney, Shetland and the Scottish mainland. The horizontal resolution of the unstructured prismatic mesh is flexible: 2.5 km at the model's open boundaries (nested into NWS CMEMS) and enhanced to 30 m nearshore and around points of interest. The regional atmospheric model WRF is driven by GFS (d084001, NCEP) to provide adequate forcing (net, short & long-wave radiation fluxes across the air-sea interface, wind) to stir surface currents and wave simulations (SWAN-WeStCOMS). The highest resolution of WRF (d03 domain) is 2 km, which is comparable to characteristic length scales of the terrain and coastline. It can resolve wind intensification parallel to the shoreline, along glens, and sheltering behind hills and islands high enough to induce capping inversions of the atmospheric boundary layer, blocking lateral wind components and guiding the propagation of gravity waves excited along the inversion isolines. Improvement in the modelling of nearshore salinity achieved by integrating WRF precipitation over 229 & 455 river catchment areas, respectively, which also reflects large interannual variability in monthly rainfall (from 25% to 175% over the 30-year monthly mean). A novel spatially varying depth-dependent Heat Scaling Factor enables elimination of excessive heat loss in winter and heat accumulation in summer in the shallow parts of multiple shallow sea lochs, reducing the bias of model sea-water temperature against glider and mooring observations below 10C. Bias of sea-surface currents is under 2.85 ± 4.69 $cm \cdot s^{-1}$ compared to 485 SEPA's current meters, making it suitable for regional and fine-scale local environmental impact assessments.

WESTCOMS was initially developed on the national supercomputer ARCHER; now we run it with an HPC system at SAMS twice a week. Predictions are hosted on thredds.sams.ac.uk and www.habreports.org portals. This work was funded by a series of EU and UKRI NERC/BBSRC projects, currently supported by Aqua-Plankton APP18033 and E(tive)lice APP19201 grants, EC HORIZON-MISSIION Coast-Scapes project #101213138; the NORSCOMS was enabled via the Plankton-Predict grant from SAIC.[4]

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[3] Szewczyk T.M., Aleynik D. & Davidson K. 2025. Harmful Algae. 142, 13 p., 102781 https://doi.org/10.1016/j.hal.2024.102781)
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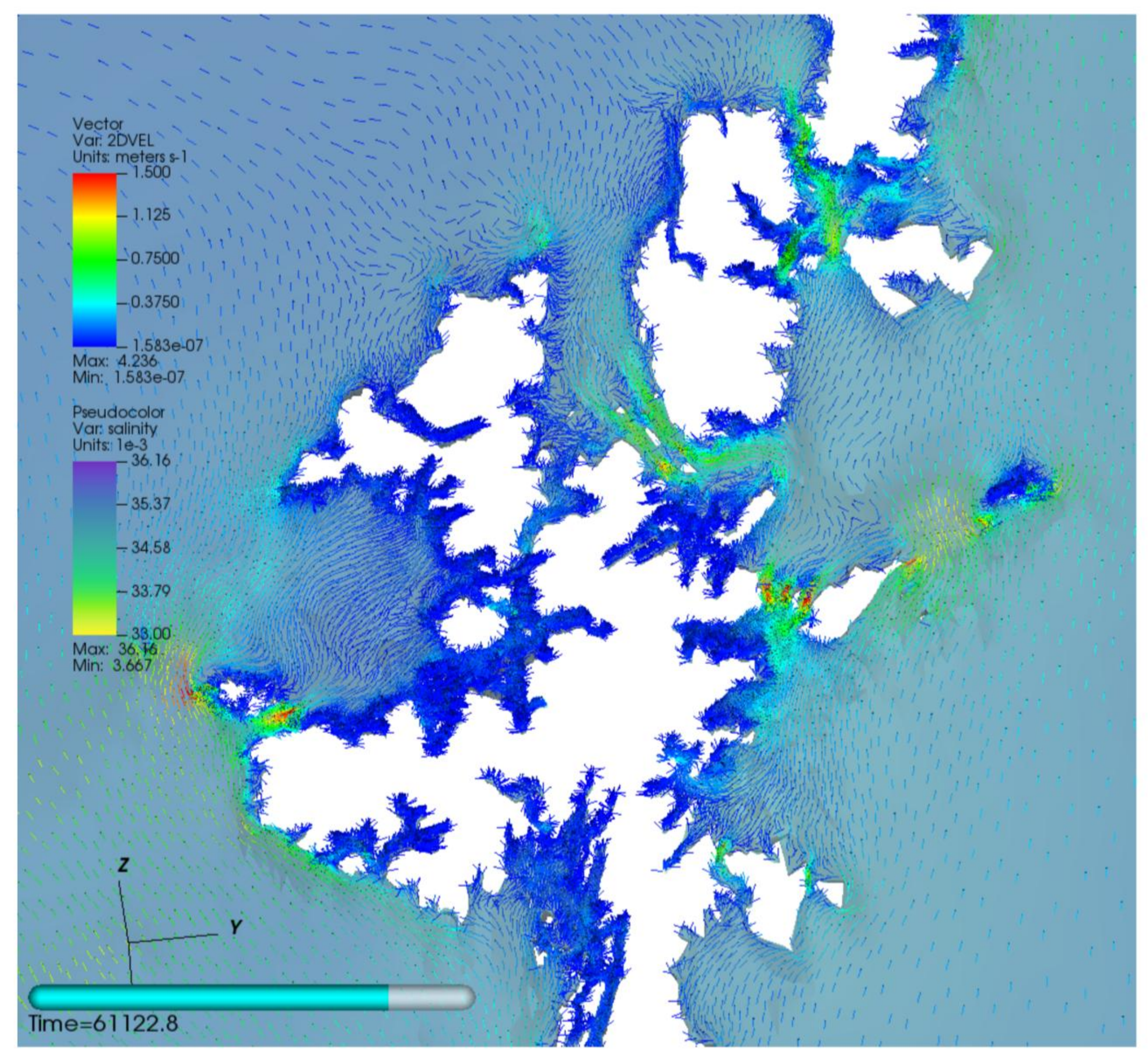

Figure 1. NORSCOMS sea surface currents near Shetlands, 19:00 23rd March 2026.

Pulsatile fluid flow through axisymmetric porous membranes

Hessah Almaaz, Matthew Durey & Katarzyna Kowal
School of Mathematics and Statistcs, University of Glasgow

In a range of physiological and industrial systems, particles are transported and filtered through permeable membranes. The net filtration depends on the form of the fluid delivery, including whether the flow is steady or pulsatile. In this study, we investigate the influence of fluid pulsation on particle transport through porous hollow fibres, which are typically long, thin, and well-described by an axisymmetric geometry. Although pulsatile flow has been suggested to enhance filtration efficiency, the mechanisms underlying this effect remain poorly understood.

To address this, we develop a fluid-mechanical model for unsteady viscous flow in an axisymmetric porous fibre, explicitly accounting for rapid temporal variations in the fluid flux between pulses. The membrane is modelled as a homogeneous porous medium, and the governing equations are formulated in cylindrical coordinates under the assumption of axisymmetry. From this framework, we derive an evolution equation for the fluid flux, which we analyse using a combination of numerical computation and asymptotic methods. Our theoretical framework is readily extendable to more complex geometries relevant to practical applications and gives insight into the extent to which fluid pulsation offers an efficient filtration mechanism.

Taylor dispersion for flow down channels with porous membranes

Raymond Callaghan, Katarzyna Kowal & Matthew Durey
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Membrane-based solute separation underpins technologies in chemical processing, oil and gas production, water desalination, and pharmaceutical processes. In many such cases, the molecules of interest are advected down a channel with a porous membrane interface. The shear flow down the channel induces additional diffusive effects known as Taylor dispersion, however, these are dependent on membrane porosity and membrane fluxes.[1] We investigate solute transport in coupled 2D contraflow channels separated by a resistive porous membrane and quantify how filtration efficiency varies with membrane porosity and fluxes. Importantly, we do not assume cross-sectional homogeneity of solute in the channel common to Taylor-Aris theory. Using separation of variables we obtain an eigenvalue problem for the decay rate of concentration in each channel. This yields analytic solutions for the eigenfunctions in each domain. Eigenvalues are determined by enforcing an Evans-type residual matching condition at the membrane interface, allowing construction of matched composite eigenfunctions. Our analysis highlights that inhomogeneity of cross-channel concentration fundamentally modifies the effective dispersion and decay rates in each channel. These results provide a quantitative framework for exploring beyond the limitations of the classical asymptotic theory for Taylor dispersion, with implications for future design and optimisation of membrane-based separation systems.

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Exploring Jupiter's zonal jets using a wave-mean flow interaction and laboratory analogue approach

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The solar system giant planets are predominantly fluid bodies making them huge laboratories in which many facets of planetary fluid dynamics can be explored. Jupiter, in particular, prominently exhibits east-west winds called zonal jets, driven by a nonlinear energy cascade from small scales to large scales, making the jets the dominant housing of kinetic energy at the cloud level. There are still many open questions as to the generation and stabilisation and three-dimensional structure of these jets that are being investigated through theory, observations, and simulations. In this project, the goal is to use laboratory experiments to investigate the emergence and equilibration of zonal jets from Rossby wave radiation, and the interaction of wave-driven jets with stratified layers.

This exploration involves the design and building of an experiment which represents an analogue of Jupiter's fluid structure. This is achieved through a 1-metre diameter by 1-meter high cylindrical tank partially filled with water, spun up to 80 revolutions per minute. The paraboloidal shape of the water free surface due to the centrifugal force creates a topographic β effect responsible for the propagation of Rossby waves. A local forcing mechanism (vertically oscillating disk) is embarked in the rotating frame to excite a Rossby wave which generates a mean flow. The flow will be tracked using Particle Image Velocimetry which utilises a laser to illuminate neutrally buoyant particles carried by the flow. This will allow us to investigate the energetic feedback mechanisms between Rossby waves and a mean flow and its dependence on parameters such as the rotation rate, beta effect, frequency and amplitude of the waves. We will compare our experimental results with quasi-linear theories of Rossby wave-mean flow interactions and extrapolate to Jupiter's atmospheric and interior conditions.

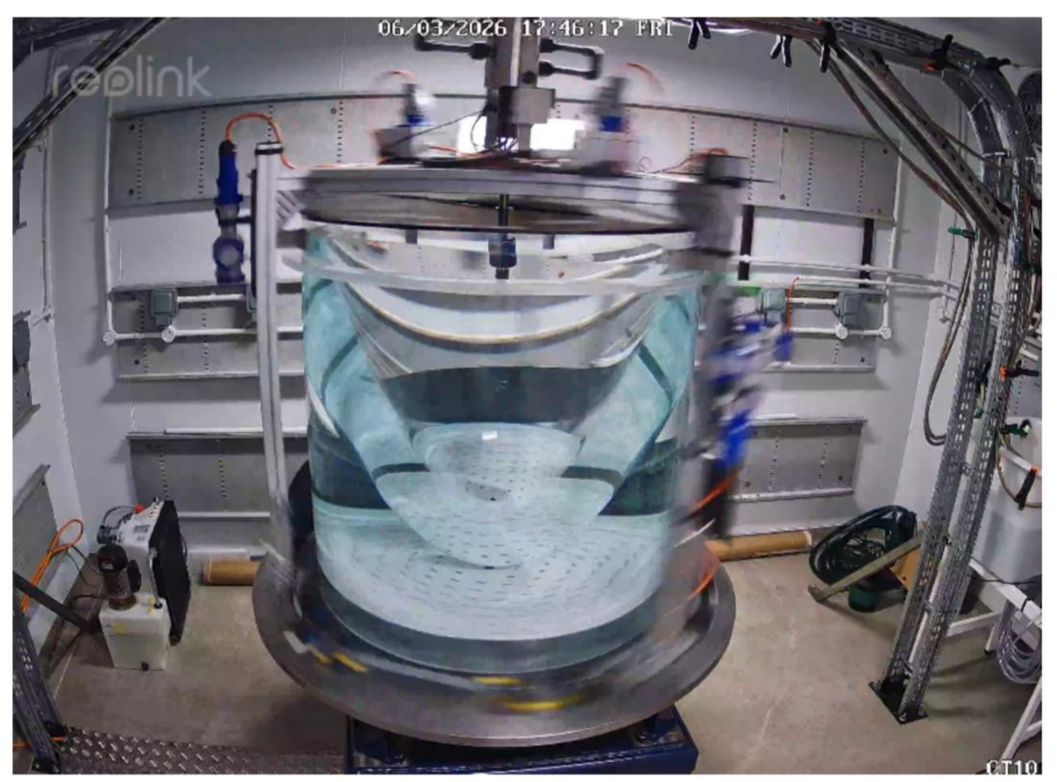

Figure 1: Snapshot of the spinning tank in the laboratory while spinning at 80 RPM.

Heterogeneity-induced oscillations in active nematics

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†Department of Mathematics and Statistics, University of Strathclyde

The framework of active nematics may be used to model many living systems, including cell layers and bacteria.[1] The study of active nematics has focused on uniform activity, but real biological systems are not homogeneous, rather they have population variance or are composed of different species. As well as arising naturally, it has been recently demonstrated that the structure of activity in a material can be controlled through modulating light intensity.[2] This provides motivation to understand the effects of activity patterning, both to gain insight into the in vivo behaviour of living systems and to enable desired dynamics to be engineered in active matter.

A central feature of active nematics is that, when confined, they exhibit a transition to a flowing state, provided their activity exceeds a critical value.3 In this context we show that activity variation allows control of the structure of the flowing state and, most strikingly, can lead to oscillatory dynamics. We show analytically that the behaviour of the confined active nematic can be mapped onto a dynamical system, the coefficients of which are determined by the activity variation, and confirm these results numerically. We find that an activity gradient can induce oscillations, and in this case determine how the properties of the system influence the frequency of the oscillations.

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Turbulent polymer stretching

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School of Engineering, University of Strathclyde

By solving a system of Navier-Stokes equation for a turbulent fluid and Langevin equation for the bead-spring dynamics of an ensemble of polymer chains, we compute flow-chain interactions in ultra-dilute solutions. Our polymer model includes nonlinear elasticity, excluded volume effects and hydrodynamic interactions.

The polymers stretch predominantly as material line elements, yet finite deviations arising from elasticity and excluded-volume forces occur with measurable probability. The chain end-to-end distance exhibits a power-law scaling regime. Polymers preferentially sample regions of axisymmetric biaxial extension, where they reach their largest extensions and stretch most rapidly.

The chains align strongly with the second strain-rate eigenvector and tend to anti-align with the third; consequently, the second eigenvalue contributes significantly to polymer compression, despite its magnitude typically being smaller than that of the third. Along polymer trajectories, vorticity tends to align with both the first and second eigenvectors, a behavior that differs from the corresponding Eulerian statistics and from Lagrangian vortex-stretching phenomenology.

All finite-time Lyapunov-exponent probability density functions exhibit departures from Gaussianity, and the intermediate finite-time Lyapunov exponent is positive in all realizations. The largest and intermediate exponents are positively correlated, whereas the intermediate and smallest exponents are anticorrelated.

Wide-field tracking of floating plastic particles over continuous streamwise ridges in an open-channel flume

Denisa Krstienova, Mark Stewart, Yunqiang Zhu & Vladimir Nikora
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Plastic transport in rivers is of growing environmental concern, as rivers act both as critical freshwater resources and as major pathways conveying plastics to the oceans.[1] Compared with bedload and suspended transport, floating plastic transport has received relatively limited attention to date, yet is likely to be strongly influenced by near-surface flow structures generated by bed topography. Earlier studies of streamwise-continuous symmetric ridges showed that such surfaces can generate organised secondary-current vortices,[2] while more recent work on symmetry-breaking ridge geometries has demonstrated that asymmetric triangular ridges can alter secondary-current topology and induce net spanwise flow.[3] Building on this developing understanding, the present study investigates how ridge geometry influences the surface transport of floating plastic particles using a newly developed modular multi-camera tracking system.

The system comprises four synchronised cameras (Lucid Vision Labs Triton2; 2448 × 2048 pixels; 30 fps at full frame) that can be arranged in multiple configurations depending on the measurement requirements. A custom software application, Luna, was developed to control image acquisition, calibration and post-processing. The system was first deployed in an 11 m long, 0.4 m wide open-channel flume in the Fluid Mechanics Research Laboratory at the University of Aberdeen.

Experiments were conducted for five bed configurations: a "Velcro only" baseline and four ridged cases employing either symmetric or asymmetric triangular ridges (peak height 4 mm, width 40 mm). The ridges were arranged either as 10 adjacent strips covering the full bed width or as 5 evenly spaced strips separated by 50 mm gaps. To assess the influence of particle geometry on transport, three floating particle types were considered: a disc (diameter 20 mm, thickness 0.5 mm), a rectangle (10 × 20 mm, thickness 0.35 mm) and a sphere (diameter 4.7 mm). The mean flow depth was fixed at 100 mm. Cameras were mounted approximately 1 m above the flume, normal to the water surface along the flume centreline, providing a stitched panoramic field of view of 5.3 m. For each bed configuration, 100 video recordings were obtained for each particle type.

The stitched panoramic images enabled extraction of particle centroids, from which trajectory lengths and streamwise and transverse velocities were determined. In addition, the rotation of the disc and rectangular particles was tracked to quantify their response to ridge-induced flow structures. The resulting dataset provides a basis for examining how bed symmetry, ridge shape and ridge spacing influence the near-surface transport of floating plastics in river-like flows.

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Effect of aneurysm neck width on the haemodynamics of dual intracranial aneurysms

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Intracranial aneurysms are abnormal dilations of cerebral arteries[1] that pose a significant risk of subarachnoid haemorrhage. Approximately 25% of patients exhibit multiple aneurysms, which is associated with increased risk of rupture.[2] While haemodynamic effects are known to influence aneurysms, the interaction between multiple ones in the same vascular tree remains unclear. This study investigated the impact of proximal aneurysm neck width on the haemodynamics of a distal dilation within the same vascular tree. A patient-specific, dual intracranial aneurysm model was investigated using Computational Fluid Dynamics (CFD) methods in Simcenter Star-ccm+, meshed with polyhedral and prismatic elements. Five additional geometries were generated by widening or narrowing the neck width of the proximal aneurysm using mesh morphing. Simulations were conducted using a pulsatile, non-Newtonian flow inlet, governed by the Navier-Stokes equations. Modifying the proximal neck width led to increased velocity streamlines in the proximal aneurysm, and shifted the formed vortex centre, but caused minimal variation in the flow patterns of the distal aneurysm. As the proximal neck width increased, the wall shear stress (WSS) of the proximal aneurysm increased, while the WSS of the distal aneurysm displayed minimal changes. The low shear area (LSA), percentage of the dome area with WSS <0.4 Pa, of the proximal aneurysm exponentially decreased from 88.07% at the smallest neck width to 21.99% at the largest neck width, whereas the LSA of the distal aneurysm remained low and relatively constant, around 0.2%, as the proximal neck width changed. These effects were likely due to the specific vascular architecture, since the proximal aneurysm was located to the left of the stagnation point of the first bifurcation,[3] while the distal aneurysm extended from the right artery. Consequently, most blood flow reached the distal aneurysm without passing through the proximal one. While the predicted rupture risk of the proximal aneurysm changed with the neck width, the risk for the distal aneurysm remained largely unaffected. These findings provide an insight into the haemodynamics of dual aneurysms, suggesting that the spatial arrangement and proximity to a bifurcation may determine whether morphological changes in one aneurysm will influence another. Understanding these haemodynamic dependencies can help predict rupture risk and clinical decision-making in patients with dual aneurysms.

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Size-based separation of soft particles in suspension in inertial microfluidics

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Circulating tumour cells are a known biomarker of cancer and can be detected in the bloodstream from Stage 1 onwards. Inertial microfluidic devices (IMF) leverage inertial forces to separate particles in suspensions based on their characteristics. Current IMF devices are restricted to using diluted blood samples to limit particle-particle interactions and enhance inertial focusing. Dilutions are resource-intensive for sample preparation and postprocessing. To develop a diagnostic device that handles whole blood, we need to develop an understanding of inertial behaviour in dense suspensions and the role of particle interplay. We used a 3D in-house immersed-boundary-lattice-Boltzmann-finite-element code to uncover the underlying physical mechanisms involved in fluid–particle and particle–particle interactions. We investigated the effect of overall particle concentration and particle size on the focusing performance of semi-dilute to dense heterogeneous suspensions (5–20%), comparing to homogeneous equivalents. We found that separation of particles based on size in heterogeneous suspensions is possible at concentrations up to 20%, and that separation is better in mixtures of particles with confinement ratios χ= 0.3 and χ= 0.2 than with χ= 0.3 and χ= 0.1 mixtures, see Fig 1. Such results pave the way for early-stage, label-free, and high-throughput cancer diagnostic devices.

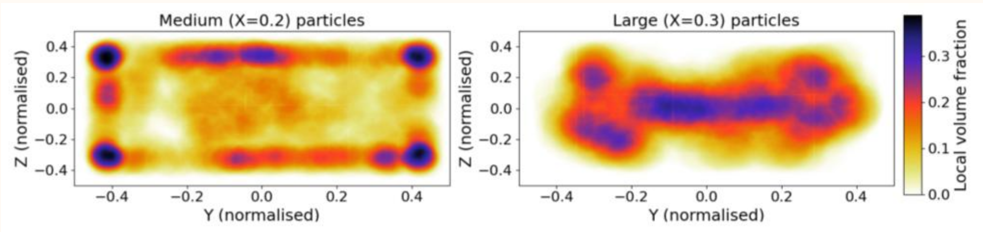

Figure 1: Time averaged cross-sectional particle distribution for heterogeneous suspension at 20%. Confinement ratio X is the particle diameter over height of the channel Z.

Reaction infiltration instability in a compacting porous medium: channel and wave modes

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Reactive flows through compacting porous media are susceptible to instabilities, leading to focused flow through high-porosity channels. This mechanism is believed to be geologically significant, responsible for the formation of high-porosity 'dunite channels' in the partially molten asthenospheric mantle. The instability relies on magma advection against a chemical solubility gradient and the porosity-dependent permeability of the porous host rock. It is affected by the bulk deformation (compaction) of the porous system. The system undergoes both channelling instabilities and exhibits growing compaction–dissolution waves.[1]

In previous work, we analysed the channelling mode of the instability using linear stability analysis. We analysed the asymptotic properties of the dispersion relationships to understand the physical controls on the instability.[2] Here, we extend the linear analysis to investigate the compaction-dissolution wave mode. We perform nonlinear numerical simulations and show that the linear theory successfully predicts the main features of the nonlinear simulations. We develop a regime diagram to show that, compared to high-porosity channels, compaction-dissolution waves are favoured in systems with lower reaction rates or greater susceptibility to compaction. This study is currently under review, and the associated software is available.[3]

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Bistability and force balance in rotating spherical shell dynamo simulations

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The geodynamo is the process responsible for the generation and maintenance of the Earth's magnetic field, driven by the motion of electrically conducting fluid in the outer core. Due to computational constraints, it is currently not possible to simulate dynamos at the actual parameters of the Earth. Therefore, besides improving resolution, studies often analyze these simulations from different perspectives to achieve Earth-like dynamos. One approach is to attain a dynamical force balance similar to that expected for outer-core dynamics. However, dynamo solutions are not strict functions of Earth's parameters and can exhibit bistable behavior.[1,2] In this work, we demonstrate that different force hierarchies exist between these coexisting branches. In particular, we assess the force balance hierarchies of these bistable, self-consistent dynamo solutions in rotating Boussinesq convection within a spherical shell, using stress-free boundary conditions. In incompressible flows, the gradient (irrotational) components of the forces do not influence the dynamics. Therefore, the curls of the forces, which represent their solenoidal contributions, are particularly important.[3] Hence, along each attractor, we analyze both the forces and the curls[3] of forces in the outer core.

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Rotating convection in a spherical shell with combined vertical and horizontal thermal forcing

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Rotating turbulent thermal convection is ubiquitous in geophysical and astrophysical settings, such as in the liquid outer core of the Earth and the subsurface oceans of icy moons. In addition to classical rotating convection in spherical shells, where the fluid layer is uniformly heated from below and cooled from above, lateral thermal heterogeneities can arise. This is the case at the solid mantle boundary of subsurface ocean on icy moons, due to tidal heating, as well as at the core-mantle boundary in the Earth's interior, due to processes in the mantle. These lateral thermal heterogeneities will induce horizontal convection and significantly influence the circulation of the ocean or liquid core. In this project, we aim to quantify this effect using direct numerical simulations.

We use the open-source spectral solver MagIC (URL: https:// magic-sph.github.io/) to model rotating turbulent convection in spherical shells. The convective flow is driven by a uniform top-to-bottom temperature difference, and we investigate how it evolves as the intensity of bottom thermal heterogeneity varies, keeping its pattern fixed (azimuthal order m=2). We show that increasing lateral thermal forcing significantly alters the structure of the flow and the resulting heat flux pattern at the top surface. These results could be used to provide observable predictions of topography features of the ice crusts of icy moons for upcoming missions for the Jovian system.

The role of magnetic diffusion on the onset of magnetoconvection in a spherical shell

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Earth's magnetic field is maintained by a self-exciting dynamo driven by convection in the liquid iron outer core. Numerical dynamo studies at high magnetic Prandtl number Pm (ratio of viscous to magnetic diffusivity) reveal two distinct dipolar regimes: weak-field dipolar (WD) and strong-field dipolar (SD),[1] the latter of which is the most relevant for modelling natural dynamos. A sufficiently strong magnetic field can relax the onset condition in rapidly rotating convection.[2] It has been proposed that this effect triggers the emergence of the strong-field dynamo regime. To analyse this, the structures of the most unstable linear modes ("onset modes") are considered, motivated by Sakuraba's detailed spherical study.[2] The emergence of distinct dynamo branches encourages a systematic study of how the variety of onset modes in magnetoconvection changes as Pm is varied. Although the onset of magnetoconvection in spherical geometry with an axial field has been studied previously, our work places emphasis on the understudied effect of varying Pm. All computations are performed using the Dedalus project framework.[3] We aim to demonstrate the relationship between onset mode structure and Pm, and consider implications for our understanding of the mechanism that underpins the emergence of the SD regime.

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Thermo-electrohydrodynamic convection in spherical Taylor-Couette flow

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Small-scale laboratory spherical shell experiments, such as the Geophysical Flow Simulator (GeoFlow) and Atmospheric Flow Simulator (AtmoFlow), are designed to investigate fundamental flow dynamics relevant to planetary interiors and atmospheres. These experimental platforms employ thermally forced spherical shells, with independent temperature control at the inner and outer boundaries, and allow for both solid-body and differential rotation. A synthetic gravity-like body force is generated by a central electric field. To suppress buoyancy-driven natural convection, the experiments are conducted under microgravity conditions, for example aboard the International Space Station (ISS). The applied synthetic central force arises from the dielectrophoretic effect and decays with radial distance.[1] The resulting thermo-electrohydrodynamic (TEHD) convection has been previously investigated in the GeoFlow, an ISS-based experiment operated from 2008 to 2017. Building on these studies, the present work introduces differential rotation in spherical shells with an aspect ratio of 0.7 to explore fundamental flow dynamics relevant to large celestial bodies.

Here we present performed numerical investigations of TEHD convection in rotating spherical shells.[2] The governing parameters include the electric Rayleigh number, the Taylor number, and the thermoelectric coupling parameter, with the electric body force determined by Gauss's law and the temperature-dependent permittivity. Simulations are carried out in a rotating reference frame attached to the outer shell, such that the relative rotation between the shells is quantified by the Rossby number.

The results demonstrate that the interplay between rotational momentum transport and electric buoyancy leads to distinct flow regimes, depending on the magnitude of the control parameters. Previous studies have shown that the dielectrophoretic force induces radially oriented plume-like structures,[1,3] whereas differential rotation drives largescale circulation between equatorial and polar regions.[4,5] The present study combines these two transport mechanisms and examines the resulting flow structures. Numerical simulations are performed using the open-source finite-volume ecosystem OpenFOAM.[6] The simulations reveal multiple convective regimes within the spherical gap, which are classified according to their flow patters and dynamical behaviour. Furthermore, the heat flux across the shell is analysed as a function of the forcing strength, providing estimates of thermal transport efficiency. Variations in heat transfer are correlated with kinetic energy, highlighting the coupling between convective flow structures and energy transport.[7] This study advances the understanding of coupled thermal and momentum transport in rotating spherical systems.

Acknowledgement

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Evaporation of a rivulet on an inclined planar substrate

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The effects of uniform evaporation on the shape and length of a rivulet on an inclined planar substrate are investigated. Specifically, a mathematical model for the steady gravity-driven flow of a thin rivulet1,2 on an inclined planar substrate undergoing uniform evaporation is derived and analysed for a rivulet with either a fixed semi-width or fixed contact angle. In Particular, we determine the variation of the rivulet length, footprint area, and volume with the problem parameters. In particular, it is found that pendant rivulets only exist when their initial semi-width is below a critical value, and that the maximum possible length of a rivulet with fixed semi-width is

$$\frac{\bar{\beta}^3 \sin(\alpha)}{3|\cos(\alpha)|^{3/2}}$$

where β and α are the contact angle of the rivulet at the inlet and inclination angle of the substrate.

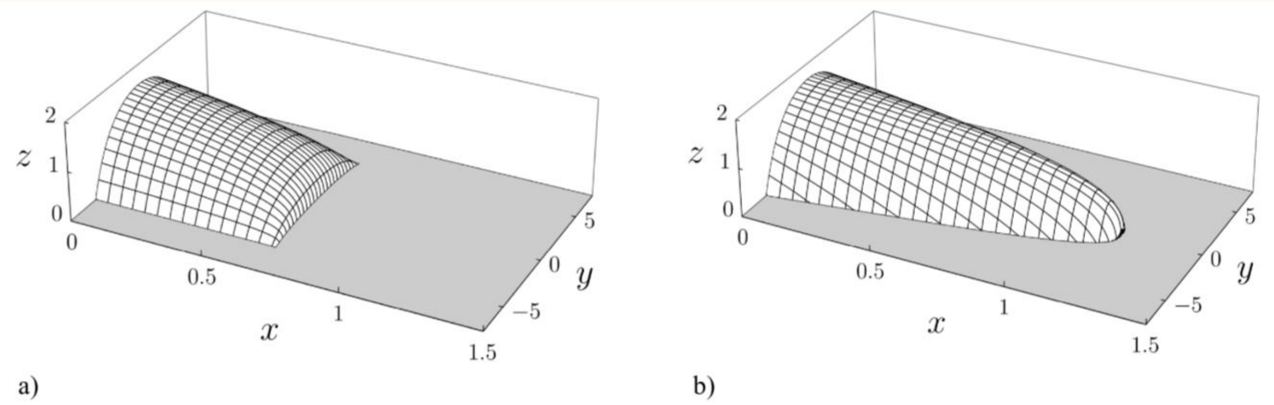

Figure 1. Examples of a uniformly evaporating sessile rivulet with (a) fixed semi-width and (b) fixed contact angle on an inclined planar substrate.

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