Grantham Institute - Climate Change and the Environment PhD student call

The Department of Civil and Environmental Engineering (CEE) is advertising 8 projects for the competitive Grantham Institute ‘Climate Change and Environment’ PhD call.

The call offers 4 studentships to start in October 2025 (or earlier depending on candidate availability) across 6 departments at Imperial. The CEE Department can nominate 2 candidates for funding, with the final review and selection process managed by the Grantham Institute Leadership team.

How to apply:

Candidates are asked to review the 8 CEE projects open for application:

1. **Monitoring and evaluation of nature-based solutions for water security.**
2. **Exploring stratified turbulent mixing by shear instabilities in coastal waters.**
3. **Closing the gap in upper ocean mixing using surface waves.**
4. **Transport of large plastics in turbulent suspensions.**
5. **Quantifying the relationship between air flow, vegetation, soil water content and slope stability**
6. **Machine Learning Prediction of Urban Canopy Flows**
7. **The interaction of volcanic intrusions with the ambient wind**
8. **Environmental and health risks related to the recycling of waste wind turbine blades**

Candidates should submit the following documents to the lead academic supervisor of the project with whom they are interested in working:

- Cover Letter detailing your motivation, research interests, and relevant experience.
- Curriculum Vitae (CV) including academic achievements and publications (if any).
- Copies of transcripts (undergraduate and graduate).
- Contact information for two academic references.

The deadline for applications is **5pm (UK time) 10 January 2025**. Application via the Imperial College Registry is not necessary at this stage.

Funding details:

Studentships will provide funding for 3.5 years and include:

- London weighted UKRI stipend (£21,237 per annum for 24/25)
- Home fees at UKRI indicative fee level (£4,786 per annum for 24/25)
- £5,000 research expenses associated with the project (for consumables, conference attendance and travel associated with the research)

The studentships are eligible for Home and Overseas students. For overseas students, the difference between home and overseas fees would need to be organised and sourced externally (Faculty of Engineering 2024_2025).

1. Monitoring and evaluation of nature-based solutions for water security

- Lead supervisor: Professor Wouter Buytaert w.buytaert@imperial.ac.uk
- Co-supervisor: Alejandro Dussaillant, UKCEH

The world is not on track to achieve the United Nation's Sustainable Development Goals. The indicators of progress towards Goal 6, to ensure access to water and sanitation for all, are especially dire. Novel solutions need to be developed to give more people access to safe drinking water, and to protect them from floods and droughts.

Nature-based solutions (NBS) leverage natural processes such as soil water storage, infiltration, and recharge, to enhance river basin processes and water availability. Since the publication of the UN World Water Development Report, they are very high on the national and international policy agenda. NBS are very promising policy tools because of the multiple benefits they can provide, and because they can be very flexible under conditions of future climate change and its uncertainties.

However, the potential performance of NBS is highly context specific and therefore needs to be carefully evaluated and integrated in existing and new management practices. The scientific evidence base to support this process is still very thin, which entails a risk that NBS fail to deliver their expected benefits or produce unintended negative impacts.

This project will design and develop novel approaches and technologies to monitor and evaluate NBS interventions at the river basin scale. To do so, it will leverage the brand-new Floods and Droughts Research Infrastructure. This once-in-a-lifetime UK Government Investment (£38 million) will produce one of the world's largest integrated data collection and monitoring infrastructures for floods and droughts. It will give the student access to state-of-the-art monitoring equipment, digital infrastructure, and monitoring sites. This unique opportunity will enable the characterisation and evaluation of various nature-based solutions, such as wetland construction, leaky dams, and buffer strips, at an unprecedented level of detail and resolution.

2. Exploring stratified turbulent mixing by shear instabilities in coastal waters

- Lead supervisor: Dr Adrien Lefauve lefauve.adrien@gmail.com
  Dr Lefauve is joining Imperial as a Lecturer in 2025.

Water will likely become the gold of the 21st century due to its central role to life, health, and economic growth and its increasing scarcity. Estuaries are particularly interesting as they represent critical transition and exchange zones between freshwater and marine environments and often host great cities, including London. Sea-level rise, industrialisation and pollution put estuaries and their essential services under pressure. Understanding the transport and mixing of buoyant freshwater and denser saltwater layers is critical to engineering efforts to mitigate climate change.

This project will tackle one of the most fundamental questions in environmental fluid mechanics: how does turbulence mix density-stratified (i.e. layered) fluids? The scientific challenge is rooted in the extremely vast spectrum of length scales over which energy is distributed and exchanged, preventing direct computations. This project will focus on the lifecycle, turbulent energy cascade, and mixing of large-scale shear instabilities, which are the primary structures responsible for mixing in estuaries. Recent field observations in a salt-stratified estuary prove that mixing does not generally occur by overturning in the ‘cores’ of the primary 'billows', as previously thought. Instead, we will investigate the game-changing hypothesis that mixing occurs along their ‘braids’ by secondary shear instabilities, leading to much smaller and faster overturns with different mixing properties.

You will perform mathematical analysis of state-of-the-art observational data, including multibeam echograms (acoustic backscatter) which provide a high-resolution picture of underwater turbulent mixing. You will use these analyses to formulate fluid mechanical models that bridge the challenging spectrum of scales. The goal will be to develop new hypotheses and design a new fieldwork campaign to gather complementary data. There will be the opportunity to perform fieldwork in the USA in collaboration with the world-leading Woods Hole Oceanographic Institution. The ideal outcome is to distil the new physics of mixing into practical reduced-order models called parameterisations. This will in turn improve the coastal numerical models that are used to address the sustainability challenges of this century.

This PhD will help you develop valuable skills, including the modelling of physical systems (turbulence, parameterisations of coastal models), data science (advanced image analysis, handling large environmental datasets) and fieldwork in a multi-disciplinarity context (coastal oceanography and fluid mechanics).

3. Closing the gap in upper ocean mixing using surface waves.

- Lead supervisor: Dr Costanza Rodda c.rodda@imperial.ac.uk
- Co supervisors: Dr Ioannis Karmpadakis

Mixing in the upper ocean is critical for regulating heat, nutrients, and gas exchanges, directly influencing marine ecosystems, weather patterns, and global climate. This project aims to study the mixing mechanisms caused by the combination of wind stress and surface waves, combining laboratory experiments and advanced analytical methods, including stochastic modelling and machine learning.

The interaction between wind stress and surface waves is a fundamental process in the upper ocean. Wind stress generates shear currents and turbulent mixing, while surface waves, particularly those influenced by the wind, contribute additional energy and momentum to the system. Together, these processes modulate the turbulence intensity in the upper mixed layer and impact the exchange of heat, mass, and momentum across the thermocline. However, their combined effects on thermocline erosion, entrainment, and mixing remain insufficiently understood due to the complexity of their interaction.

By determining how energy from wind-induced currents and wave-induced motions contributes to turbulent kinetic energy and mixing at the thermocline, this research seeks to improve predictive models for ocean mixing, with implications for climate studies and environmental engineering applications.

Research Objectives:

- Conduct laboratory experiments to simulate wind-wave interactions and capture their influence on thermocline mixing.
- Investigate the coupling of physical mixing processes with environmental variables, improving understanding of upper ocean dynamics.
- A novel combination of stochastic modelling and machine learning approaches to analyse and predict complex ocean mixing processes.

We are seeking highly motivated candidates with a strong background in civil and environmental engineering, mechanical engineering, physical oceanography, or related disciplines. Candidates should have: a master's degree (or equivalent) with an Upper Second-Class Honours Degree in engineering, physics, or applied mathematics; experience or coursework in fluid mechanics, numerical modelling, or experimental methods; programming skills (e.g., MATLAB, Python, or similar tools); an interest in interdisciplinary research bridging experimental and analytical approaches.

4. Quantifying the relationship between air flow, vegetation, soil water content and slope stability

- Lead supervisor: Dr Katerina Tsiampousi aikaterini.tsiampousi05@imperial.ac.uk
- Co-supervisor: Professor Maarten van Reeuwijk

The amount of water within the soil pores of sloping ground and the pressure that it experiences have long been connected to the stability of the slope. Therefore, the net effect of rainfall and evapotranspiration is related to slope stability. For example, we all recognise from experience that landslides often occur after intense rainfall, whereas slopes appear more stable during dry periods when the soil dries out through evapotranspiration.

Vegetation helps stabilise slopes through the direct action of the root system acting as anchors, but also through enhancing evapotranspiration and reducing the amount of water in the ground. Despite its undisputable benefits, vegetation also poses threats for civil infrastructure. For example, leaves on train tracks, canopy that obscures road signs or roots that damage road surfaces pose dangers that are addressed by managing the side vegetation.

While managing side vegetation, mistakes are often made such as clearing vegetation that is crucial for slope stability and landslides occur as a result. It is important that a “correct” balance between evapotranspiration and rainfall is achieved, but engineers do not currently know how to achieve it.

One key component that affects evapotranspiration but is often neglected during vegetation management is air turbulence. When removing and replacing vegetation the air flow around it changes, changing the amount of water it removes from the ground.

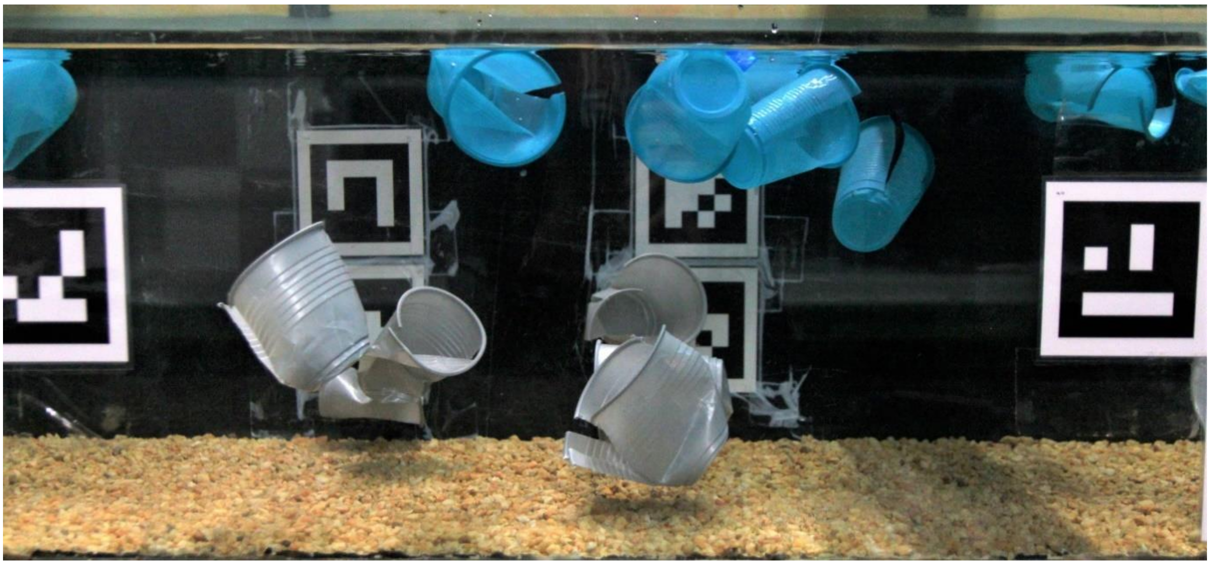
The aim of this PhD project is to model air flow around vegetation in slopes of different geometries and quantify numerically its effect on evapotranspiration and pore water pressure.

5. Transport of large plastics in turbulent suspensions

- Lead supervisor: Dr Daniel Valero d.valero@imperial.ac.uk
- Co supervisors: Dr John Craske, Professor Eric Climent.

This project will construct new physics-based models for the transport of plastics in turbulent environments. It will combine fluid mechanics experiments of inertial particles in heterogeneous turbulent flows with stochastic numerical modelling. The main aim of this project is to enable plastic transport models that reflect the fate-defining complexities of plastic-fluid interactions.

Plastics disperse throughout the environment, yet knowledge of the specific transport processes involved is extremely limited. However, recent evidence suggests that large plastics exhibit transport mechanisms unlike any other pollutants. The aim of this project is to understand the physics behind these new mechanisms so that they can be accurately represented in simplified models. The behaviour of irregularly and randomly shaped particles will be examined by conducting detailed fluid mechanics experiments able to disclose the 3D response of a plastic particle to a turbulent flow. Depending on the applicants' skills and preferences, there will be opportunity to incorporate high-fidelity simulation of these flows, to complement beyond experimental limitations. The simplified models developed for this project will enable accurate prediction of the pollution resulting from the transport of plastic and, therefore, inform regulations, mitigation and remedial measures.



6. Machine Learning Prediction of Urban Canopy Flows

- Lead supervisor: Professor Maarten van Reeuwijk m.vanreeuwijk@imperial.ac.uk
- Co supervisors: Dr Lewis Blunn (Met Office), Dr Omduth Coceal (University of Reading)

Conventionally, in weather and climate models, the turbulent exchange of momentum and scalars between the urban surface and the atmosphere is parametrised using Monin-Obukhov Similarity Theory (MOST) (e.g., as is done currently by the Met Office urban surface-exchange scheme (Porson et al., 2010)). Turbulent exchange must be parametrised, since it is too computationally expensive to run simulations at urban canopy turbulence-permitting resolutions over large portions of the globe. However, parametrising turbulent exchange with MOST is limited, as there is currently no set of equations defining MOST parameters that performs well across different urban layouts (Sützl et al., 2021). Also, MOST does not represent the flow beneath the building tops, which means that it does not provide information on the turbulence statistics and spatial variability of variables within the urban canopy. The rise of machine learning (ML) has the potential to revolutionise the accuracy and spatial detail provided by urban canopy models, owing to ML's computational efficiency and ability to learn complex non-linear relationships.

In this PhD project, ML models will be developed to improve existing parametrisations (e.g., new MOST parameter equations), provide fast emulators of existing state-of-the-art (but computationally expensive) parametrisations, and directly emulate the 3D time-averaged flow and turbulence statistics within the urban canopy. ML models emulating the 3D flow have already been demonstrated to capture the main flow characteristics and give improved estimation of the drag coefficient for a single urban layout (Lu et al., 2023). If such models can be developed so that they generalise well to a wide range of urban layouts, then they could be used to provide unprecedentedly accurate representation of turbulent exchange in weather and climate models for different cities around the world. Also, weather and climate simulations could be downscaled, providing intra-street level flow information.

Training data will be high-fidelity urban canopy turbulence permitting (~1 m grid length) simulations. These include existing large-eddy simulation (LES) and direct numerical simulation (DNS) datasets of different urban canopy flows (e.g., Nazarian et al., 2024). Also, new datasets will be generated using the uDALES LES model (Suter et al., 2022).

Urban areas have modified surface roughness and heat fluxes compared to vegetated areas, which impacts the meteorology of cities. For example, cities tend to have elevated temperatures (i.e., the "urban heat island" effect) and increased likelihood of extreme precipitation. Accurate representation of urban turbulent exchange in weather and climate models is therefore crucial. Consequently, the Met Office are developing a next generation of high-resolution "urban-scale" weather models, that will have a new urban canopy model in place of the current one based on MOST.

This PhD project has the potential to inform development of the urban canopy model. The Intergovernmental Panel on Climate Change (IPCC) Assessment Report 7 (AR7) will have a special report on "Climate Change and Cities" in recognition that urban climates have been underrepresented in global climate science. Climate models are typically too coarse to resolve individual cities, but ML has the potential to downscale climate models so that details within the city can be mapped. For example, ML downscaling could be used to predict how flow will change in the city in response to climate change under different city planning scenarios, enabling decision makers to design cities that are cool and have clean air. The work will have synergies with the Met Office AI4Climate project.

References:

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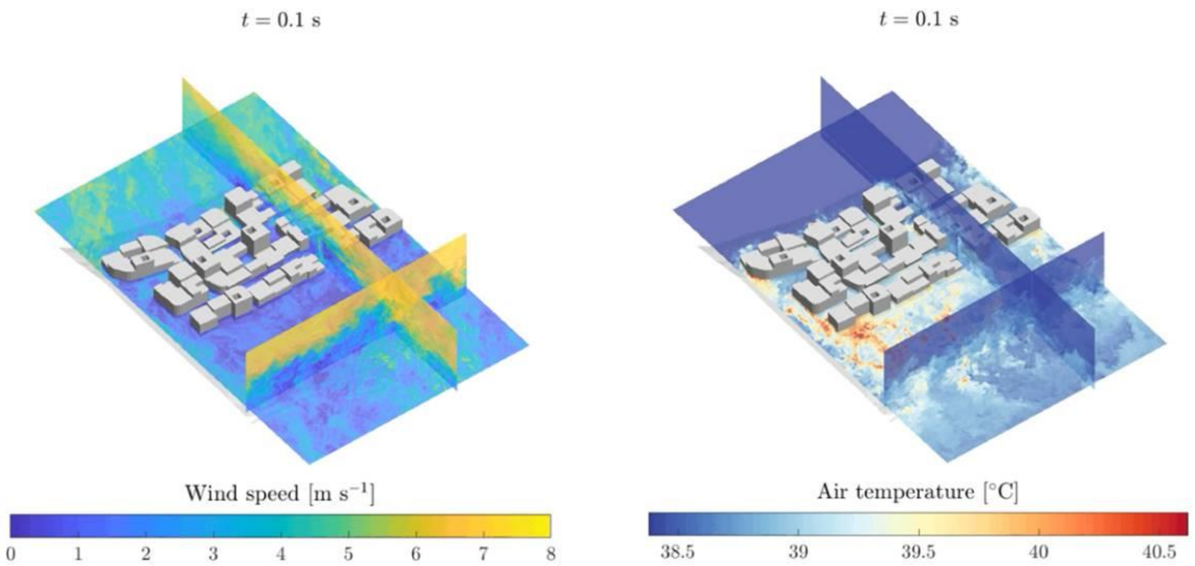

7. The interaction of volcanic intrusions with the ambient wind

- Lead supervisor: Professor Maarten van Reeuwijk m.vanreeuwijk@imperial.ac.uk
- Co supervisors: Dr Ben Devenish, Dr Gabriel Rooney (Met Office)

The eruption of Eyjafjallajökull in 2010 demonstrated the widespread disruption that the spread of volcanic ash in the atmosphere can cause and hence the need for reliable predictions of its dispersion. Many outstanding issues remain, including accurate source characterisation and better understanding the processes which spread volcanic ash downwind of an eruption.

For powerful eruptions, the buoyancy of the ash cloud itself can be a major factor as it spreads downwind. The ash cloud or intrusion may travel faster than the ambient wind, move upwind and spread more widely than would be expected under the action of turbulent dispersion alone. While some theoretical progress has been made in studying the interaction between intrusions and the ambient wind (Baines 2013, Rooney and Devenish 2014) it has been limited to a uniform wind. Numerical simulations now offer the possibility of making reliable simulations of buoyant plumes and intrusions. Direct numerical simulation (DNS) is capable of resolving all scales of turbulence but at a limited Reynolds number; large-eddy simulation (LES) can achieve higher Reynolds numbers at the expense of resolving the smallest scales. These techniques provide complementary ways of simulating buoyant plumes and intrusions. This project will consider buoyant spreading in LES and DNS using more realistic wind profiles to assess the importance of shear, including wind turning with height. In addition the project will also quantify the mixing of the intrusion with the environment and how this is affected by the presence of ash particles. The aim here is to extend the phenomenological model of Rooney and Devenish (2014) to more realistic conditions.

The incorporation of buoyant spreading within NAME presents some conceptual difficulties due to the nature of the model. NAME is a Lagrangian stochastic model that follows independently moving particles through the atmosphere. Buoyancy effects such as intrusions depend on the buoyancy of a cloud of particles as a whole. One approach to overcoming this difficulty is to assign each particle a velocity determined from a phenomenological model such as that presented by Rooney and Devenish (2014). Simulations show that this can be effective in modelling the buoyant spread from large eruptions such as that of Mt Pinatubo in 1991 (Webster et al. 2020). Yet difficulties with this approach remain such as how the model interfaces with the ambient flow. Results from the LES and DNS studies will be used to refine and improve the modelling of intrusions within NAME.

References:

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8. Environmental and health risks related to the recycling of waste wind turbine blades

- Lead supervisor: Dr Chao Wu c.wu@imperial.ac.uk
- Co supervisors: Professor Terry Tetley, Dr Geoff Fowler

The rapid expansion of wind energy in the UK is key to achieving Net Zero targets, with wind turbines playing a pivotal role in reducing carbon emissions. However, the growing amount of waste from decommissioned wind turbine blades—made from tough, non-recyclable fiber-reinforced polymers (FRPs)—poses significant environmental challenges. The disposal of these blades in landfills results in the release of harmful microplastics and fibers that pollute soils and waterways, while mechanical recycling processes generate hazardous airborne particles, raising serious health concerns.

This project investigates the environmental and health risks associated with the recycling of waste wind turbine blades, focusing on two primary issues: the environmental release of microplastics and fibers during disposal, and the potential toxicity of inhaled dust from the recycling process.

Research Objectives:

- **Environmental Impact**: To understand the degradation of FRP materials in landfills, simulating the leaching of microplastics and fibers into soils. The project will assess how these pollutants spread over time and under different environmental conditions, contributing to soil and water contamination.
- **Health Impact**: To explore the toxicity of airborne particles from wind turbine blade recycling. Using in vitro lung cell models, this objective will assess the respiratory risks associated with inhaling dust from shredded turbine blades, a growing concern for workers and communities near recycling facilities.
- **Mitigation Strategies**: Based on the findings from the environmental and health assessments, the project will propose strategies to reduce pollution and health risks. These will include designing ventilation systems and recommending personal protective equipment (PPE) for workers, thus promoting safer recycling practices.

This research aligns with NERC's remits of '*Pollution*' and '*Environment and health*'.