

Institution: Ulster University
Unit of Assessment: 14
<p>1. Unit context and structure, research and impact strategy</p> <p>Context and structure</p> <p>The School of Geography and Environmental Sciences at Ulster University (UU) undertakes research of the highest international quality. Our submission in previous research assessments demonstrates this and shows clear commitment and progression to delivering the sustainable growth of high-quality international research. In REF2014, we recorded a 37% improvement from RAE2008 in 4*/3* world-leading or internationally excellent research and we have carried this momentum into this REF cycle. Our research in REF2021 is strategically aligned with the University's Research and Impact Strategy (2017-2022) (See REF5a). Throughout REF2021, we have championed the delivery of innovative and impactful research in support of UU's priority interdisciplinary research themes - Sustainability, Social Renewal and Healthy Communities - which are closely aligned with the United Nations Sustainable Development Goals. Our research strategy flowed from the delivery of these strategic priorities and provided a clear focus for addressing issues of global relevance through multi- and inter-disciplinary research in geography and environmental sciences. Our research successes throughout REF2021 ensure that we have a sustainable, vibrant research environment that supports our researchers to make important contributions to the vitality of the University, our disciplinary base and to wider society.</p> <p>The School has a thriving research environment consisting of 21 academic staff, 4 technicians, 4 administrative support staff, 29 registered postgraduate researchers (PGRs) and during REF2021 we recruited 22 externally funded postdoctoral research associates (PDRAs). 100% of our academic staff and one of our PDRAs have Significant Research Responsibilities (SRR) giving a total submission 19.6 FTEs in REF2021. This is an increase of 6.5% FTEs since REF2014 and is a positive indicator of our sustainability. We provide a collaborative, integrated working environment to retain and sustain the vitality of the Unit, and to deliver our strategic goals for research and research-led teaching on our undergraduate and postgraduate degrees (Fig. 1). In 2020, we were ranked 12th out of 66 for geography and environmental studies across the UK in the Guardian university league tables, a performance that reflects our commitment to sustaining our culture of research-led teaching excellence across the School.</p> <p>The Unit is managed by the Research Director (RD) (Dunlop) and the Head of School (HoS) (Benetti) who provide strategic leadership in a collaborative working environment. Our research is focused in two research clusters, one for environmental processes, management and sustainability, and the other researching heritage, conflict and society, that operate within the Centre for Environmental Spatial Data Analytics (CESDA) (Fig. 1). Each cluster is led by an expert in their field (Jordan and McDowell), and the CESDA Director (Moore), supports the strategic development and leadership of interdisciplinary research. CESDA is a new research centre, established with institutional support, that provided new posts and research facilities to support the delivery of our REF2021 strategy (See sections 2 & 3). CESDA provides shared geo-spatial expertise and resources to develop and support interdisciplinary research across the School, University and international research community.</p>

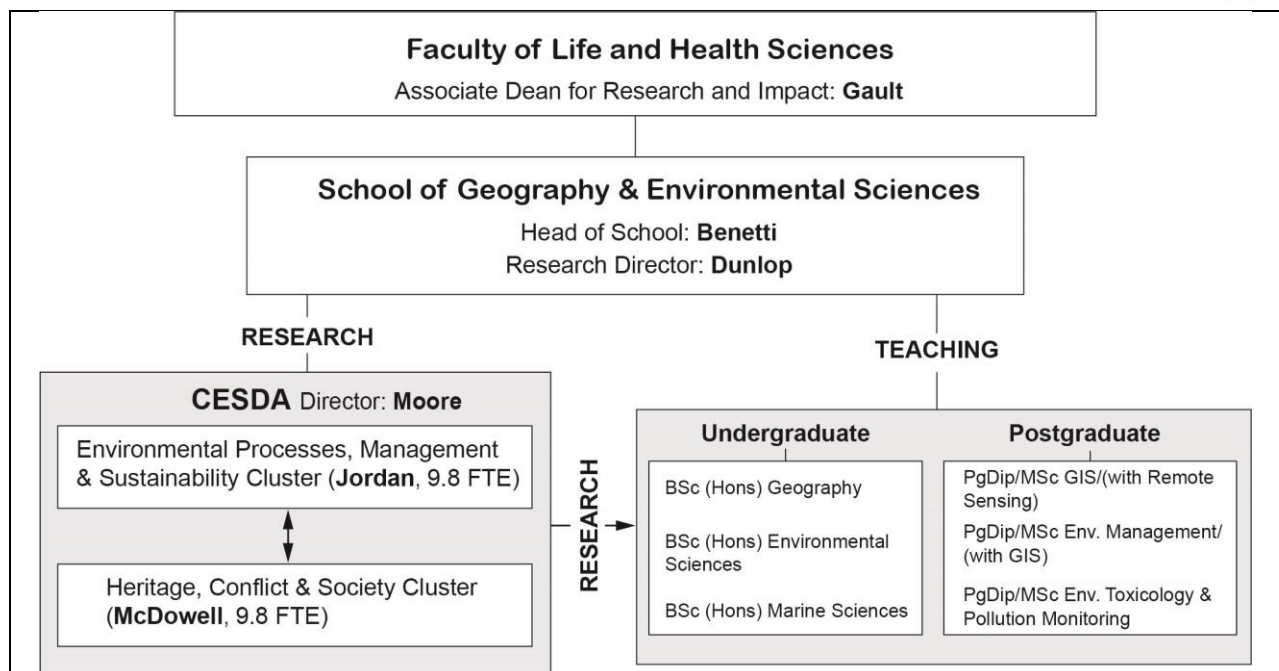


Figure 1. School/research unit structure

All staff are affiliated with a cluster, are encouraged to take part in the activities of the other and are members of CESDA. The RD, cluster leads and CESDA Director have bi-monthly research meetings to review and develop the research strategy. Our research structures provide clear focus for our mission and allow flexibility for staff to conduct research within their specialisms and across the clusters in interdisciplinary teams. We have created an inclusive research space that respects individual geographical disciplines, while creating strategic interdisciplinary collaborations to support the delivery of UU's strategic research themes, underpinned by a clearly articulated School strategy for research and impact that provides supportive opportunities for researchers to realise their potential and for their work to effect change within and beyond the academy.

The success of our approach and vitality of our research environment is evident in the 421 papers, 102 chapters and 9 books published during REF2021. **94% of our submitted outputs to REF2021 are in the top 10%** of Scimago Journal Rankings, 71% involve international co-authors and 58% are among the world's most cited publications (Scopus). Our citation rankings are one indicator of the vitality of our research, another is the financial support we obtained to fund it. Through the combination of the scope of our subject, the potential for practical application, and the Unit's commitment to sustainability and vitality, we developed impactful projects and strategically targeted a wide variety of funders from the UK, EU, all-Ireland and trans-continental sources that supported our activities in six continents, thirty-one countries, three oceans and on Mars. Evidence of the success of our strategy includes substantial funding over this REF period with £6.5M being awarded from **five of the nine UKRI Research Councils** (NERC, AHRC, BBSRC, ESRC, STFC), GCRF, EU research programmes and other competitive national and international funding agencies.

Research and Impact Strategy

Our REF2021 strategy focused on our core strengths to deliver world-class research in support of UU's Research and Impact Strategy, which at Faculty level, is overseen by the Associate Dean for Research and Impact (ADRI) (Fig. 1). The RD led the strategy in consultation with the ADRI, all School staff at multi-annual research away-days and further refined by the School's Research Committee. Our aim is to undertake internationally excellent research that:

- (1) Understands geological, earth surface and environmental processes in a changing world.
- (2) Deepens our knowledge about societal conflict, mobility, poverty, health and heritage.

- (3) Seeks to use this research to influence policy making and quality of life through public engagement.

Our objectives during this REF period were:

- Publish outputs that make important advances in the field
- Attract substantial competitive research funding
- Embed impact into our research culture
- Attract and retain high-quality research staff
- Produce high-quality PGRs
- Have mechanisms in place for staff development, diversity and equality to support research performance

We emphasise research integrity and rigour, which is supported by UU's Code of Practice for Professional Integrity in the Conduct of Research (See REF5a). All staff and PGRs are trained in UU's ethics policy with 100% completion of UU's research integrity course. All projects are screened by the School and University ethics committees before final approval. We recognise and value that our research should be openly accessible to all. Researchers are encouraged to publish in open access outlets and all staff use either the Gold or Green Open Access options and deposit research outputs in UU's open access portal, PURE. A dedicated administrator ensures that outputs comply with open access regulations and our research is publicly and freely accessible to the academic community and general public.

Achievements since REF2014

Environmental Processes, Management and Sustainability Cluster (Leader, **Jordan**, 9.8 FTE). Research in this cluster is aligned with UU's Sustainability theme, which we lead on behalf of UU. We focus on understanding the interlinked physical, biological and chemical processes operating in the Earth's crust and surface to enable a better understanding of the sustainability of environmental systems and their management. Key research themes are freshwater security, catchment dynamics, glaciation, palaeo-climate, sea-level change, coastal processes, earthquakes, planetary geomorphology and marine ecology.

Our catchment science and freshwater research enhances the sustainable management of water resources, enabling our researchers to achieve impact with important benefits for nature and society. Our large EU Interreg consortium projects include, €13.7M CatchmentCARE: Community Actions for Resilient Ecosystems (**Jordan, Arnscheidt, Douglas, McKenzie**, 2018-21, £804k), €5.3M, Source to Tap (**Jordan**, 2017-22, £295k) and €9.4M Collaborative Action for the Natura Network (CANN) (**Arnscheidt**, 2017-21, £300k). Catchment science achievements include: understanding how global climate circulation affects regional diffuse nutrient patterns across NW Europe (**Jordan**); new knowledge of macronutrient and sediment dynamics, links and feedbacks in river catchments using combinations of experimental, long-term and high-resolution data (**Hunter, Jordan**); and the development of a fine-scale GIS-based method that identifies pollution hotspots on agricultural land, which we operationalised into a public sector tool to improve water quality and presented as a REF2021 Impact Case Study (ICS) (**Jordan, Dunlop**). Freshwater biochemistry research discovered that filter feeding zooplankton encourages the growth and proliferation of multi-resistant bacteria in aquatic environments (**Arnscheidt**); antimicrobials and artificial estrogens from emerging pharmaceutical contaminants suppress microbial metabolism in urban rivers (**Hunter**); and that contaminant metal cycling in freshwater aquatic systems can be used to increase our understanding and modelling of metal partitioning behaviour in lakes (**Douglas**). Freshwater biogeography research provided a new explanation of the origin, range expansion and speciation of the groundwater crustacean *Niphargus* across Europe (**Arnscheidt**).

We are at the forefront of delivering cutting-edge science on how aeolian processes operate on Mars (**Avouac, Jackson, Cooper**). Our innovative research is being applied in a £375k UK Space Agency project, where our aeolian modelling of the Oxia Planum landing site, will be used by the European Space Agency to inform the landing plans and sampling locations for the ExoMars rover mission in 2022 (**Jackson**, STFC, 2019–22, £70k)

We use a range of techniques including remote sensing, geophysical survey, cosmogenic isotopes, radiocarbon dating, geomorphological and sedimentological analysis, and numerical modelling to refine our understanding of glacial systems and ice sheet–climate–ocean interactions. We played a leading role in international research consortiums such as the €4.4M EU Marie-Curie Action: Initial Training Network, Glaciated North Atlantic Margins (GLANAM) consortium (**Dunlop, Benetti**, 2013–17, £232k) and the £3.3M, BRITICE–CHRONO NERC consortium (**Benetti**, 2011–18, £34k) researching palaeo-ice sheet history and the role marine-based ice sheets played in the evolution of the Atlantic margin. Published highlights include developing a new understanding of the drivers of instability in marine-based ice sheets and creating new regional deglacial models, that have refined the pattern and timing of deglaciation in the western sector the British Irish Ice Sheet (**Dunlop, Benetti, Clark**). Our research generated important insights on how glaciers and ice sheets regulate and respond to global climate and drive sea level change (**Clark, McNabb, Cooper**); is informing policy challenges of sea-level rise and human migration (**Clark, Cooper**); and our novel remote-sensing approaches for measuring glacier velocities have produced new insights on the impacts of glaciation on mountainous landscapes during the past few million years (**Avouac**).

We collaborated with NGO Concern Worldwide in our NERC-PURE project, Aftershock Forecasting Tool for Emergency Response, (**Dunlop**, 2015-16, £154k) to co-develop approaches that give, near real-time probabilistic forecasts of the intensity and spatial distribution of aftershocks. Concern Worldwide operationalised these tools during its response to the devastating 2015 Nepal earthquake to provide safe humanitarian aid. We developed this further in collaboration with University of Edinburgh on the £160k NERC-GCRF project, Research for Emergency Aftershock Response (REAR) (**Dunlop, McDowell**, 2016-17, £6k). REAR deployed an interdisciplinary team of experts in social science, history, education, geography, earth science and computing to explore citizen science approaches to building community resilience to aftershocks. Our investigation of the Nepal earthquake provided a new understanding of seismic processes and shed new light on the source of destructive seismic waves during seismic ruptures (**Avouac**). We used a novel method to detect and image slow slip events (SSEs) along the subduction interface beneath the Cascadia megathrust, USA. These follow similar laws to regular earthquakes, opening the possibility that SSEs might be used to develop and test dynamic models of the seismic cycle with application to regular earthquakes (**Avouac**).

In the field of climate change response, we identified the effects of extreme storm seasons on the coasts of NW Europe (**Jackson**) and are applying this knowledge in pre-and post-storm research in the Caribbean (**Jackson**, Cefas 2019–20, £15.5k). We also discovered an integrated global signature of climate change manifest in decadal stabilisation of coastal dunes worldwide (**Jackson**). In a changing climate, our research shows that the effects of species loss on coastal sediment carbon capture and storage are mediated by ocean warming (**Hunter**). We are leaders in investigating geological constraints on coastal response to sea-level rise and the key role of the shoreface in this regard was the subject of our EU Marie Skłodowska-Curie Global Fellowship, NEARshore geological CONTROL (NEARCONTROL) (**Cooper**, 2016–19, £154k). In understanding coastal responses to sea-level rise, we applied our knowledge of decadal to centennial-scale coastal change with seismic-stratigraphic approaches to continental shelf sediments. This allows us to identify palaeo-shorelines and relate their development and preservation to sea level changes in near and far-field sites (**Cooper**). Coastal zone management and marine ecosystem sustainability are central components of the €6.4M EU Interreg Marine Protected Area Management and Monitoring (MarPAMM) consortium (**Jackson, Cooper, McGonigle**, 2018–22, £587k). MarPAMM is developing tools for monitoring and managing protected coastal environments, marine species and ecosystems in Ireland, NI and Scotland. MarPAMM will impact on national policy decisions in the UK and Ireland by providing Article 17

Submissions for the EC Habitats Directive and OSPAR under Natura 2000 through our collaborations with National Parks and Wildlife Service, Ireland, the NI Department of Agriculture Environment Rural Affairs (DAERA) and Marine Scotland Science.

Heritage, Conflict & Society Cluster (Leader, **McDowell**, 9.8 FTE). Research in this cluster is aligned with UU's strategic research themes, Social Renewal and Healthy Communities, and champions the delivery of innovative research on peace and conflict, economic disparity, health, mobility and cultural heritage and the interdisciplinary boundaries that span these.

A central facet of our research is understanding the core causes of violent conflict and developing cultural approaches to peacebuilding. We applied our extensive experience of researching the NI conflict to investigate the use of heritage spaces in the conflict cycle through several projects that examined memory and commemoration (**McDowell**, AHRC 2014 £21k; 2015 £78k; NI Strategic Investment Board, 2017, £15k; NI Executive Office (NIEO), 2018, £15k). This research pioneered a new understanding of how heritage sites and practices can help to underpin peacebuilding processes amongst interface communities in NI and in marginalised communities abroad (**McDowell**, Flanders Department of Foreign Affairs, 2017, £19k). **McDowell** was also an Expert Advisor to a specialist group of peacemakers for the Bogota Peacebuilding Forum during Colombia's peace talks (COFAMA, 2017–18, £61k). The NIEO strategy - *Together: Building a United Community* (TBUC) - committed government to removing all "peace walls" in NI by 2023 as a central facet for underpinning peace. In support of its lead role in the TBUC commitment, the Department of Justice commissioned research into the impacts these physical barriers have on NI society (**Cook** 2016–19, £29k), which was published as a series of policy briefs. We investigated the complexities of globalisation and conflict by examining migration at various scales from historic contexts (**Breen, Forsythe**) to the European refugee crisis (**McDowell**), children's experiences of mobility in divided societies (**Cook**), and by examining the ramifications of 'selling' migration to international students (**Beech**).

We developed strategic interdisciplinary partnerships with UU's Schools of Biomedical Sciences, Computing and Psychology to investigate how socio-economic deprivation affects aging and mental health. **Moore** developed novel GIS methodologies for three interdisciplinary projects that investigated: links between nutrition and healthy aging (BBSRC–JPI, 2017–19, £183k); how supervised machine learning techniques can identify key predictors of cognitive dysfunction in older people (National Health & Social Care Trust (HSC) 2019–21, £99k); and the geodemographic neighbourhood factors associated with mental health (HSC R&D Public Health Agency, 2019–2021, £205k). His publications provide new evidence on the importance of socio-spatial neighbourhood area effects on mental health and is a novel approach for enhancing medical and clinical datasets with socio-economic data to evaluate their robustness in respect of baseline populations.

Our fuel poverty research directly changed the policies and funding strategies of the NI government, who used our innovative GIS methodology to identify fuel-poor households across NI to provide £64M worth of energy efficiency measures (**McKenzie**, Dept. of Communities NI, 2017–21; £28k; 2018–21, £15k). This approach has brought significant economic benefits, including positive health and wellbeing gains equivalent to £93M and is presented as one of our ICS (**McKenzie**). We are extending our expertise to the wider UK in the £1.25M FAIR consortium (Fuel and transport poverty in the UK's energy transition) (**McKenzie**, 2020–22, £38k) that has 15 academic and 8 industrial partners working in collaboration with University of Oxford's Centre for Research into Energy Demand Solutions (CREDS). FAIR is investigating ways of delivering equitable energy transitions for the UK, as it moves towards a zero-carbon energy system to meet its obligations under the Paris Agreement and UK Climate Change Act.

Internationally, **Bhatti** developed geospatial techniques in the fields of urban and population geography and published new methods for assessing and analysing the determinants of urbanisation in Asia. This has significantly contributed to our understanding of spatial inequalities in terms of quality of life, infrastructure development, socioeconomic conditions and planning. His

published research is at the forefront of understanding how to mitigate against the negative impacts of urban heat islands in tropical cities.

Our heritage research focuses on understanding natural and anthropogenic processes that drive change in cultural landscapes to develop better mitigation strategies for conservation. In response, we created innovative remote sensing and geoscientific methods for quantifying this change. We developed novel methods for detecting submerged shipwrecks in ocean colour satellite data (**Quinn**) and new approaches for very high-resolution imaging of rapidly deteriorating metal-hulled historic shipwrecks (**Westley, Quinn, McGonigle** Irish National Development Plan Ship-Time Awards, 2015-16, €119k). We developed the first successful computational fluid dynamic simulations in underwater archaeology, to quantify the roles of linked hydro and sediment-dynamics in the formation and preservation of historic shipwrecks (**Quinn**). Our innovative satellite remote sensing approaches have also been applied to documenting endangered maritime heritage sites across conflict zones as part of the £2M 'Arcadia Fund' consortium, Maritime Endangered Archaeology in the Middle East and North Africa (MarEA) (**Breen, Westley, Quinn, Forsythe**, 2019–23, £784k). As part of the £2.6M AHRC GCRF 'Rising from the Depths' network, we are investigating the positive role that heritage can play in societal development in East Africa (**Breen**, 2017–21, £46k). This network funds innovation projects to fill knowledge gaps that currently limit the way marine cultural heritage (MCH) contributes to sustainable social, cultural and economic growth. In 2019, the 'Rising from the Depths' network awarded £129k for three GCRF projects led by **Forsythe** and **McGonigle** to: 1) assess long term sea-level change and societal response in Mozambique; 2) investigate how MCH can improve the socio-economic conditions for coastal communities in Kenya; and 3) explore the extent of traditional heritage knowledge among island fishing communities in Kenya and Tanzania, and how this knowledge has supported sustainable utilisation of marine and coastal resources.

Achieving impact

To achieve impact, we used our strategic partnerships in industry, local government, NGOs, charities and community organisations to build collaborative projects with clear societal benefits. UU supported our researchers through the Impact Development Series, a dedicated support programme designed to help researchers understand and enhance research impact, track and evidence it and generate new pathways to impact. Dedicated Faculty Impact Officers (FIO) were also appointed to support staff and we provided bespoke, Unit-level initiatives to help staff create impactful research:

- CESDA provided interdisciplinary expertise and resources to stimulate the development of innovative geospatial solutions for real world problems and supported ICS leads to develop novel GIS tools that were central components of our ICSs.
- The RD provided seed corn funding to support and encourage staff to develop impactful research projects.
- In addition to participating in the Impact Development Series, we ran impact workshops for our staff and PGRs, delivered by Fast Track Impact, that focused on strategies to develop and embed impact into research.
- The FIO and RD held regular meetings with ICS leads to review progress and provided targeted financial support and practical assistance to support the development of high-quality ICSs.

Our approach was central to identifying two projects that delivered significant impacts in the areas of water quality management (**Jordan, Dunlop**) and fuel poverty remediation (**McKenzie**) that we presented as two ICS's for REF2021. Our approach has embedded a strong, sustainable impact agenda within the Unit and our leadership on interdisciplinary consortiums designed to deliver tangible impacts, such as MarPAMM (2018–22), FAIR (2020–22), AHRC GCRF Rising from the Depths (2017–21) MarEA (2019–23) CatchmentCARE: (2018-21) and our UK Space Agency work

on Mars (2019–22), provide clear evidence of the vitality of our impact agenda and will allow us to deliver meaningful impacts over the next REF cycle.

Future strategic aims and goals for research and impact

Our future strategy will capitalise on our significant achievements in REF2021 to develop further world-leading research which aims to bring about meaningful impacts for science and society:

- We are partners in the All-Ireland Climate and Biodiversity Research Network (AICBRN) that was established in 2019. This major initiative brings together leading science and social science research centres across the whole island of Ireland to tackle the climate and biodiversity emergency where a trans-national, multidisciplinary approach is essential. The AICBRN's ambitious 10-year €100M plan includes the recruitment of world-leading professorial chairs, the creation of an all-island centre for research training, postdoctoral fellowships, and infrastructure grants to maximize research impact. The AICBRN will connect with national funding agencies, government and industry bodies to develop the large-scale multidisciplinary initiatives necessary to underpin policy, industrial strategies, and opportunities to benefit society.
- We will use our international networks to build the large multidisciplinary teams that are necessary to address major societal challenges and support our goals of generating impactful research and maintaining sustainable income. We will develop innovative research projects that are suitable for targeting UKRI and other major funding bodies. In addition to having access to Horizon Europe (2021-27), our unique place within the UK gives us access to other EU funding streams including EU PEACE IV, INTERREG VA (until 2023) and PEACE PLUS (€650M, 2021–27). With our strong track record of achieving success in these programs, we are ideally positioned to lead innovative projects that will secure sustainable funding. In addition, with our Irish partners, we will apply for other cross-border funding to the Science Foundation Ireland, and the Irish Environmental Protection Agency and Department of Agriculture, Food and the Marine.

2. People

Staffing strategy and staff development

UU has signed up to the Concordat to Support the Career Development of Researchers and the Unit has embraced the University's initiatives designed to effectively implement all aspects of the Institutional Contract Research Staff (CRS) policy. We adhere to the University's policy to provide equality of opportunity to all. Diversity and inclusivity are valued, actively promoted and embedded in all research processes and policies as outlined in UU's REF2021 Code of Practice, which places people at its centre and ensures barrier free processes to maximise inclusivity and participation in REF. We used it as our roadmap for identifying SRR staff and selecting outputs for REF2021. UU is highly committed to the principles that underpin the Athena SWAN Charter and the School's commitment to these policies was recognised by achieving a **Bronze Athena SWAN Award in 2017**. Our team comprises a dynamic blend of senior staff, providing research leadership, and high-calibre mid to early career researchers working in a highly collaborative environment that is central to our vitality, and our age profile ensures our staffing levels remain sustainable (Figures 2 & 3).

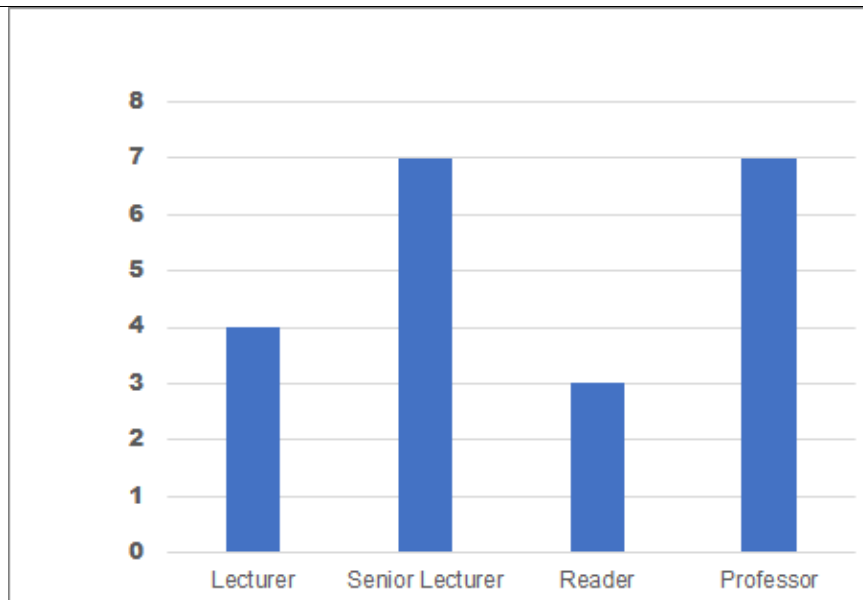


Figure 2. Staff Grades

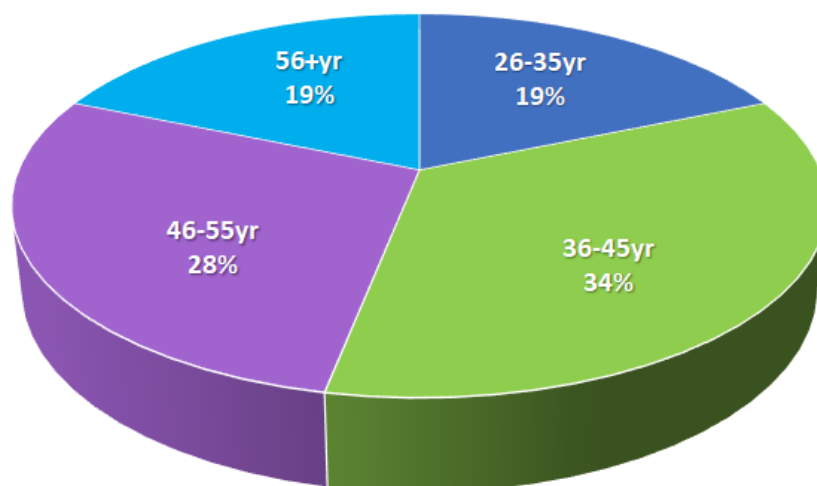


Figure 3. Age profiles

Our staffing strategy is central to the sustainability of the Unit and strategic succession planning ensures that there is continuity in our key research areas and vitality in new appointments. In support of our REF2021 strategy, UU funded new posts that strengthened the interdisciplinary expertise of CESDA and our research clusters. Since REF2014 we have appointed two internationally leading adjunct professors (**Avouac, Clark**) and a new lecturer (**McNabb**) to develop new capabilities in remote sensing big data analysis and bring additional strategic leadership in the fields of palaeo-climate, earthquake science and planetary geomorphology. We made new appointments in human geography to increase CESDA's capabilities to deliver GIS and spatial data analytical approaches in human geography (**Bhatti**) and to develop new themes in cultural geography (**Beech**). In addition, **Hunter** was appointed to deliver teaching and research in marine and freshwater ecosystems to cover a member of staff who is developing research into paleo-landscapes on a three-year career break at the Flanders Marine Institute, Belgium. We also appointed 6 Visiting Professors to build new or strengthen existing international collaborations (Table 1).

Table 1

Martin Roy , UQAM, Canada	Alistair McIlgorm , Wollongong, Australia	Antonio Klein , Santa Catarina, Brazil
Joe Kelley , Maine, USA	Andrew Green , Kwazulu-Natal, South Africa	David Gregory , National Museum of Denmark

The RD and HoS use an academic workload model to allocate teaching, research and administrative duties in a transparent and equitable manner. This helps maximise the potential for staff to return high-quality research, whilst also delivering innovative teaching. In 2015 we restructured curricula to ensure staff have a minimum allocation of 40% research time across the academic year and where possible, concentrated teaching commitments into one semester to facilitate periods of dedicated research time. Staff are appraised annually to review research performance and receive guidance for their research plans. Additional research development opportunities are provided by UU's RIGOUR (grants support), SOARING (outputs support), Impact Development Series (impact support) and Research Mentoring programme (See REF5a), which 68% of our staff have participated in during this REF. All staff, whether full-time or part-time, have access to the School research budget and can take part in our School research leave scheme, which provides leave for one semester for each completed period of nine semesters' service, to concentrate on a research plan approved by the RD and HoS. Staff can also apply to UU's Sabbatical Leave scheme and external programs to facilitate longer spells of research leave. **Arnscheidt** was successful in the UU sabbatical scheme and in 2020 won a Fulbright Commission award to support a secondment in the USA.

Staff can reduce their FTE contracts consistent with individual personal circumstances and can take career breaks (as three staff have done this cycle) without disadvantage. Staff returning from carers' leave are provided with financial support from the School research budget and UU's Returning Carers' Scheme (REF5a) and teaching loads are carefully managed. To support the leadership potential of female staff, we encourage participation in the Aurora Programme. Two completed Aurora during this REF and progressed to leadership roles, **Beech** on the University Senate and **McDowell** as the lead for one of our research clusters. We also appointed a female HoS in 2019 (**Benetti**). We strengthened our research seminar series to ensure a gender balance among speakers and hold an annual International Women's Day seminar delivered by a prominent female geographer or environmental scientist.

We prioritise the support of ECRs (**Beech, Bhatti, McNabb**), who are assigned a personal mentor and submit a one-to-two-year research development plan. New appointments are allocated generous start-up funds to generate preliminary data for strategically identified research grant application(s) and networking. Start-up packages include the allocation of a PGR, co-supervised with a senior academic. Formal mentoring policies incorporate the preparation and review of first research grants, and papers are reviewed by expert panels with feedback at every stage.

Rewarding staff is central to our staffing strategy and the RD and HoS work closely with staff to maximise their prospects of progression and reward within UUs promotional structures. We run workshops lead by UU's People and Culture department and senior academics also provide mentorship. In this assessment period, seven staff were successful, including one promotion to professor (**Dunlop**) and six to senior lecturer (**Arnscheidt, Benetti, Forsythe, McDowell, McGonigle, McKenzie**).

Training and supervision of PGRs

A distinctive development at UU in this REF period has been the establishment of a single cross-University Doctoral College which oversees PGR degree provision, doctoral training and researcher development (REF5a). We have a dynamic PGR community with a dedicated space in our Doctoral Research Hub, an investment during this REF cycle to integrate our PGRs into a central facility at the heart of the School. PhD scholarships from the Department for the Economy (DfE) and UU Vice-Chancellor's Research Scholarships (VCRS), are allocated by the Doctoral College as part of the UU annual PhD competition and on average we are awarded four each year. These awards provide full fees and subsistence to cover laboratory work, field research and conference attendance, and are equivalent to UKRI studentships. We increased our PhD allocation with successes in the annual UU interdisciplinary PhD award competition (three this cycle – **Arnscheidt, Dunlop, Jordan**) and prestigious externally funded PhD scholarships (11 this cycle) from various sources including the EU Marie Curie ITN project GLANAM (one), the EU Interreg project CANN (one), Commonwealth Scholarship Commission in the UK (one), Irish Agriculture and Food Development Authority, Walsh Fellowships (four), Irish Department of Agriculture, Food and the Marine (one) and DAERA (three). The number and diversity of awards ensures that we have high quality candidates and **excellent completion rates of 32.29 FTE, which is an increase of 15% from REF2014 (28 FTE)**. The internationalisation of our PGR community is supported by these funders, along with the University's VCRS competition, with 39% of our completions this period being non-UK PGRs.

All PGR students have a support committee with primary and secondary supervisors. For interdisciplinary projects, joint cross-school and external supervisory arrangements are common. We actively support interdisciplinary PhDs and are currently co-supervising innovative research projects with UU's Schools of Computing, Biomedical Sciences, Psychology and Art and Design. All academic staff currently engage in PhD supervision and regular contact includes formal monthly meetings and annual progress monitoring, documented through UU's online PhD manager system, as well as formal meetings with the RD and Postgraduate Tutor. The Doctoral College provides a Researcher Development Programme (RDP) and is an integral part of the doctoral programme. Our staff contribute training and seminars as part of the institution-wide programme. The RDP is informed and guided by the Vitae Researcher Development Framework (VRDF). School staff also deliver in-house specialised training specific to the requirements of our PGRs and they all undertake a Training Needs Analysis (TNA) at the beginning of their studies, which is reviewed annually in consultation with their supervisors. The TNA is structured around the VRDF and is used to develop a personal development plan which is mapped on to the RDP offer.

PGRs are fully integrated into academic life, participating in and organising departmental seminars, workshops and social events through their PGR Society. They can develop teaching skills by completing a UU Advance HE-accredited postgraduate teaching award (with conferment of Associate Fellowship of Advance HE) and undertake paid teaching in laboratory and field classes on our degrees. All PGRs are encouraged to present research at key meetings and publish in peer-reviewed journals. We have a strong record of accomplishment of PGR engagement at the annual Doctoral College festival of research, a celebration of PhD research excellence across the institution (see REF5a). Two PGRs came first and runner up in the best oral presentation category in 2018 and 2019, and both won the university-level Three Minute Thesis (3MT®) competition. **Both also represented the University at the UK national 3MT®, where one reached the semi-finals in 2018 and one reached the UK finals, finishing UK runner up and winner of the 2019 People's Choice Award.** Exemplar international conference awards include: Outstanding Student Presentation Award, Cryosphere, American Geophysical Union (AGU) Fall Meeting, 2016; best early career oral presentation at the Society for Applied Microbiology (SfAM) Conference, 2018; and the Guy Lortie award for the outstanding poster, Canadian Quaternary Association biennial meeting, 2015. All PGRs enhance their grant writing and research income track records by applying for grants with their supervisors. In this assessment, PGRs received over 40 awards from funding bodies and learned societies such as

the British Society for Geomorphology, Quaternary Research Association, SfAM, Royal Irish Academy, NERC bursaries, NERC Cosmogenic Isotope Analysis Facility, and two Fulbright Commission scholarships.

In the 2019 Advance HE **Postgraduate Research Experience Survey (PRES)** we achieved an **overall satisfaction score of 83.6%, exceeding the national average score** of 82.4% across all subject areas and 79% in the Geography and Archaeology category. These results reflect the vitality of our high-quality PGR environment and will provide a benchmark as we strive for continuous improvement over the next REF period.

3. Income, infrastructure and facilities

Income

Our total income in REF2021 is £6.5M with a recorded spend of over £5.6M. A key indicator of our success is the increased investment from prestigious funders. £4.98M (89%) of our spend comes from UKRI, Royal Society, British Academy and EU sources. This is an **11% increase in spend from the same sources in REF2014** (£4.49M). Our successes include 14 UKRI awards (five NERC, six AHRC, one BBSRC, one ESRC, one STFC), 9 EU awards and funding from major charities (British Academy/Leverhulme, National Trust, Arcadia). Our UKRI GCRF awards reflect our commitment to solving important societal challenges. We secured 3 in-kind NERC isotope facility awards (£29k, 2015-19, **Dunlop** and **Benetti**) and over **€850k of competitive in-kind funding** from the following national/international ship-time programmes:

- Six - Irish National Development Plan Ship-Time Awards (**Benetti, Dunlop, McGonigle, Quinn, Westley**, 2015-20, €784k,)
- Three - EUMarineRobots Awards (**Arnscheidt, McGonigle, Quinn**, 2020, €63k)
- One - EUROFLEETS2 Award for the PANTHER project (€104.5k) (**Benetti**, 2016–17, £6.7k)

These supported interdisciplinary research at sea where we investigated paleoglaciation, paleoclimate, World War shipwrecks, seabed habitats, geology and geohazards in the Mediterranean, Celtic and Irish Seas and the Irish and Canadian Atlantic.

Infrastructure and facilities

Our research infrastructure supports the delivery of innovative, internationally competitive research that is central to our vitality. Our facilities are continuously renewed by external grants and through targeted institutional funding to support our research strategy. In 2019, UU prioritised £176k of DfE Higher Education Research Capital (HERC) funds and an additional £157k of institutional funding to purchase a bespoke state-of-the-art inshore vessel to strategically support CESDA's ambitions to conduct multidisciplinary science at sea. The new vessel has hydraulic gantry for launch and recovery of equipment, a RESON SeaBat 7125 multibeam echosounder and inspection class ROVs for high-resolution seabed mapping and hydrographic surveying in UK and Irish waters.

In addition, we operate a suite of field equipment for high-resolution investigations of urban, terrestrial, freshwater and marine environments. Survey platforms include three differential GPS-enabled quad bikes, two mobile differential GPS units, a fleet of eight vehicles (including three 4x4s) and two freshwater RVs. We have professional survey-grade quadcopter and fixed-wing drones mounted with various environmental sensors for high resolution, rapid remote-sensing surveys. We operate a high-definition terrestrial scanner and the only high-resolution underwater laser scanner in Ireland, funded by a £162k Irish Marine Institute Specialist Marine Research Equipment and Small Infrastructure grant. A £240k NERC-funded aeolian equipment suite includes 18 load cell sediment traps, 16 audio impact sensors and 24 ultrasonic anemometers. Our dedicated £300k coastal, marine and freshwater acoustic remote-sensing suite includes a

multi-frequency ground penetrating radar, echosounders, chirp and boomer seismic profilers and sidescan sonar.

The School has purpose-built analytical chemistry, sediment analysis, benthic ecology, plant ecology and marine geophysics laboratories supported by four School technicians and 4 Faculty IT staff. Our water chemistry facilities include inductively coupled plasma mass spectrometer (ICP-MS), ultraviolet-visible photometry, fluorescence spectrometry, dissolved organic carbon (DOC) analysis and ion chromatography. We have provision for microbiological analysis, and climate cabinets and chambers are available for temperature-controlled experiments. An instrumentation suite for high-resolution freshwater monitoring includes phosphorous and nitrate analysers, a total organic carbon/inorganic carbon analyser and multi-parameter water quality sondes. We also operate a Joint Research Equipment Initiative NERC-funded remote access sampler and sediment trap for high resolution water sampling in freshwater environments. Our microscope suite has research grade dissection microscopes with computer-aided image analysis and an inverted microscope for phytoplankton analysis. Sediment analysis facilities include refrigerated storage containing over 350m of deep and shallow water marine sediment cores for paleoenvironmental research, 100m of lake sediment cores and approximately two thousand preserved water samples from lakes across the globe. The sediment laboratory is used for core splitting/sampling and contains preparation equipment (ovens, shaking tables, infrared lamps, core splitter), a Malvern Mastersizer and a settling column. Our marine geophysics laboratory is equipped with hardware and software to process, analyse and integrate high-resolution bathymetry, backscatter, seismic and radar data.

We continue to invest heavily in innovative computer facilities, which are essential for numerical modelling and geospatial analysis within CESDA. We have our own high-performance computing (HPC) cluster with 388 cores, which supports significant model-based analyses of earth surface, and planetary modelling of airflow and oceanographic processes and patterns. UU and QUB share a £2.1M EPSRC Kelvin-2 project for a HPC with 8000 CPU cores and 32 GPU nodes with a high performance 2 Petabyte of scratch storage, interconnected via a high-speed network that our staff can access to address some of society's biggest challenges using big data spatial analytics. We license specialist software for geospatial analysis, including the ESRI ArcGIS, ERDAS Imagine, IVS Fledermaus, CARIS HIPS & SIPS and HIS Kingdom Suite

We are members of the National Oceanography Centre, Association of Marine Science National Capability Beneficiaries with representation on the NERC Marine Facilities Advisory Board (**McGonigle**). We also actively engage with Ireland's National Marine Equipment Pool through the Irish Marine Institute, to share access to marine research facilities and expertise. Collaborative research on antimicrobial resistance and the fate of chemicals in freshwater systems with colleagues at UU's Centre for Molecular Biosciences provides access to world class laboratory facilities, including an X series ICP-MS, next-generation DNA sequencing, scanning electron microscopy and fluorescence microscopy facilities. Our collaboration with CalTech (**Avouac**), provides access to CalTech's supercomputing facility and the Bruce Murray Laboratory for Planetary Visualisation. Our collaboration with Oregon State University (**Clark**) provide access to state-of-the-art stable isotope, elemental analysis and HPLC facilities, electron microprobe, ice core and Quaternary geochemistry, plasma spectrometry and Argon geochronology laboratories.

4. Collaboration and contribution to the research base, economy and society

We have a vibrant global research outlook, collaborating with researchers at 140 institutions in 31 countries, as well as with representatives and stakeholders in government organisations and industry. Our collaborations provide valuable opportunities for competitive grant submissions, interdisciplinary publications, for expertise exchange, and for PhD researchers to visit other labs and learn new techniques.

Network grants were a strong feature of REF2021, that we used to contribute to the research base, economy and society through our impactful research projects. Our catchment science and

freshwater research, applied to sustainable water resources management for the benefit of nature and society, exemplifies this approach. As part of the €13.7M EU Interreg CatchmentCARE consortium **Jordan**, **Arnscheidt**, **Douglas** and **McKenzie** are developing novel chemical remediation techniques to manage nutrient enrichment problems in cross-border river basins in Ireland, that will contribute to EU obligations to deliver improved water quality. The primary focus of the €5.3M EU Interreg Source-to-Tap project is to improve water quality in two cross-border catchments that provide drinking water to six Irish border counties (**Jordan**). The €9.4M EU Interreg CANN biodiversity project will produce conservation action plans to improve the condition of protected bog and wetland habitats across Scotland and Ireland (**Arnscheidt**). The €6.4M EU Interreg MarPAMM consortium is developing innovative approaches and tools for monitoring and managing protected coastal and marine ecosystems in Ireland, NI and Western Scotland and the research will inform national environmental management policies (**Jackson**, **Cooper** and **McGonigle**).

Other major consortium projects that had economic and societal benefits include the outcomes of applied research that was conducted with industrial partners in the €4.4m GLANAM consortium (**Dunlop**, **Benetti**). GLANAM had six university teams and four industrial partners that included Norway's leading oil and gas production company Statoil and three smaller mineral exploration companies. Our industrial partners benefited from fundamental research to improve their understanding of how former ice sheets affected hydrocarbon reservoirs in the North Atlantic, Barents Sea and North Sea region. We also collaborated with them to improve their understanding of the potential of gas hydrates as an energy source and how their instability can influence submarine hazards and contribute to climate change. **Dunlop** was also part of a £2.3M NERC 10 partner consortium project: "Will climate change alter the landslide-tsunami risk to the UK?" (2012–16), which assessed the potential threat of this hazard to the UK.

Our response to major international societal challenges is evidenced by the award of several GCRF grants. We are empowering East African communities through research in the £2.6M AHRC Rising-from-the-depths GCRF network, that is exploring how maritime heritage can be utilised by local communities for socio-economic development (**Breen**, **Forsythe** and **McGonigle**). Our interdisciplinary NERC-GCRF project REAR explored how public engagement, citizen science and mobile technology can increase earthquake resilience in the most vulnerable communities (**Dunlop** and **McDowell**). The £2M Arcadia Foundation MarEA project (**Breen**, **Forsythe**, **Westley** and **Quinn**) is comprehensively documenting the key threats to maritime heritage across the Middle East and North Africa that will inform mitigation strategies to ensure the sustainable preservation of important heritage locations.

The Administrative Data Research Centre (ADRC) (2018–21) is a £905k ESRC collaborative interdisciplinary research partnership between UU, QUB and the NI Statistics and Research Agency where **Moore** is applying geo-spatial analysis to understand complex health issues. This includes examining hospital use, treatment and outcomes of people with mental illness and life limiting conditions, the effects of variations in health care provision and social care services for people living with dementia, and how population density and poverty adversely affect health.

McDowell's research projects fostered important collaborations with the NI Government, public bodies and community groups to develop peace building initiatives that have empowered divided communities to use heritage sites as peace and conflict resolution spaces. In 2015-16 she was an Expert Advisor to Historic Royal Palaces on how to open the 100-acre NI Hillsborough Castle estate for public use.

As a civic university, we encourage staff engagement with the public through TV and radio contributions (BBC, RTE), our School Twitter account and community events such as the NI Science Festival and school workshops. We support active participation in the wider academy and below we highlight our contributions to the research base, which are marks of recognition of the School being a centre of research excellence and an exemplary collaborative partner.

Exemplar Editorial Boards: **Clark:** Editor, Journal of Climate (2012–15); Associate Editor (2017–present); Associate Editor, Atmosphere-Ocean (2012–17). **Avouac:** Editor in Chief, Earth and Planetary Sciences Letters; Co-Editor in Chief, Tectonophysics (2014–18); **Jordan:** Associate Editor, Environmental Science and Policy (2012–16) Guest Editor, AMBIO (2019–20). **Dunlop:** Associate Editor, Journal of Maps (2018–present). **Benetti:** Guest Editor, Geosciences Special Issue - Interacting Alongslope and Downslope Sedimentary Processes (2019); Geological Society of London's Special Issue - Subaqueous Mass Movements and their Consequences (2020). **McDowell:** Guest Editor, Irish Political Studies (2016). **Breen:** Associate Editor, Journal of North Atlantic Studies (2014–present); Consulting Editor, International Journal of Historical Archaeology (2014–present). **Forsythe:** Guest Editor, IKUWA Special Edition Journal of Maritime Archaeology (2019). **Jackson:** Associate Editor, Journal of Coastal Research (2008–16); Invited Reviewer, Second Order Drafts (SOD) Working Group (WG) I contributions to the IPCC Sixth Assessment Report (AR6). **Cooper:** Advisory Board, Italian Journal of Engineering Geology and Environment; Guest Editor for GeoMarine Letters, Vol 38, Special Issue (2018); Journal of Coastal Research Special Issue 70 (2014); Invited Reviewer, SOD, WG II, contributions to the IPCC AR6.

Exemplar Panel Memberships: **McDowell:** AHRC peer review college; reviewer for NERC and ESRC Brexit Fellowships, British Academy post-doctoral fellowships. **Jackson and Jordan:** members of the NERC peer review college. **Jordan:** served on two NERC panel C discovery science panels (2014, 2016) and on the India–UK water quality (Newton–Bhabha Fund) peer review panel in New Delhi (2016). **Benetti:** Vice-Chair (2013–present), EU-FP7 Marie-Curie IEF/IIF/IOF fellowship evaluation panels; H2020 Marie Skłodowska-Curie individual fellowship evaluations; Expert Evaluator, EU-FP7 R&D programme “New and renewable sources of energy, energy efficiency & innovation”. **Dunlop:** Expert Evaluator, National Science Foundation (NSF), USA (2017–19); Natural Sciences and Engineering Research Council of Canada (2017). **Cooper:** Expert Evaluator for the European Strategy Forum on Research Infrastructures (2020). Panel member, Geology and Physical Geography, the Danish Agency for Science and Higher Education Independent Research Fund (2020). Expert Peer Reviewer for the following: National Research Foundation, South Africa (2014–20); Singapore Ministry of Education (2019); Italian Ministry of Education (2013–19); Joint Nature Conservation Committee (2018); International Union for Conservation of Nature (2017); UK Institute of Civil Engineers (2017).

Exemplar National research committees: **Avouac:** President-elect of the Tectonophysics section, AGU (2020); Committee on Space Research (COSPAR) (2001–present). **Dunlop:** Geological Survey of NI Science Advisory Board (2019–present); Royal Irish Academy, Geographical Sciences Committee (2010–14). **Benetti:** Committee Member, Irish Quaternary Association (IQUA) (2016–present); member of UNESCO IGCP Project 585 E-Marshall (2015–20). **Cooper:** Climate NI Steering Group (2014–present); National Trust, Natural Environment Advisory Group, Coastal Specialist (2020–present); member of UNESCO IGCP Project 639 Sea-level change from minutes to Millennia (2016–2020). **Jackson:** NI Executive Coastal Forum steering group (2020–present). **McGonigle:** NERC Marine Facilities Advisory Board (2019–present); NOC Association of Marine Science National Capability Beneficiaries (2019–present). **McKenzie:** EU Energy Poverty Observatory (2014–present). **Breen:** Board of Directors of the Government of Ireland heritage research Discovery Programme (2016–19). **Jordan:** member of the DAERA Nutrients Action Programme Scientific Working Group (2020–present).

Exemplar External appointments: **Cooper:** Honorary Research Professor, University of KwaZulu-Natal (2018–21); CNPQ Special Visiting Professor at Universidade Federal do Rio Grande do Sul and Universidade Federal de Santa Catarina (2013–17). **Jackson:** Honorary Fellow University KwaZulu-Natal (2019–present). **Benetti:** Visiting Assistant Professor, University of Trinidad and Tobago (2016–17). **Quinn:** Adjunct Professor, Memorial University of Newfoundland (2009–17). **McGonigle:** Affiliate Faculty Researcher, Alaska Pacific University, USA (2017–present). **Avouac:** Technology Advisory Council of British Petroleum (2014–18).

Exemplar Keynotes and Invited lectures: **Dunlop:** Invited talks, AGU, USA (2016); UKRI and Met Office Climate Resilience Programme, Belfast (2019). **Jordan:** Invited keynotes - 28th Annual

Fertiliser and Lime Research Centre International Workshop, New Zealand (2015); International Workshop on temporal high-resolution water quality monitoring and analysis, Germany (2014). **Cooper:** keynotes at IGCP 639 “Sea-level change from minutes to millennia” Conference, Oman (2016); British Council Newton Fund, Researcher Links Workshop, Brazil (2019) and Durban (2018). **Jackson:** keynote, Portuguese Conference on Coastal and Estuarine Morphodynamics, Portugal (2015); Littoral Geomorphology Conference, Spain (2015). **Hunter:** Invited talk, India-UK Water Centre workshop on Safe and Sustainable Technologies and Strategies for Integrated Freshwater Resource Management, India (2019). **Forsythe:** invited lecture, University of Notre Dame, USA (2018). **Benetti:** Invited lecture, Science Uncovered – A celebration of science for European Researchers’ Night, Ulster Museum, Belfast (2017); IQUA Annual Symposium, Dublin (2015). **McKenzie:** Invited talk, Energy Justice and Energy Poverty Conference, Centre for the Study of Risk & Inequality QUB, Belfast (2019).

Exemplar Conference Organising Committees: **Dunlop, Benetti:** Local Organising Committee, 20th Congress of the International Union for Quaternary Research (INQUA) Dublin (2019); Glaciated North Atlantic Margins 4th Annual Workshop, UU (2016). **Benetti:** Committee for International Symposium on Subaqueous Mass Movements and Their Consequences, Dublin (2020); Organiser, IQUA Spring Meeting, UU (2016). **Jackson:** Scientific Committees for International Conference on Coastal Dynamics, Denmark (2018); International Conference on Aeolian Research, Bordeaux (2018). **Cooper:** Scientific Committees for International Coastal Symposium, Spain (2020); International Conference, Marine Navigation and Safety of Sea Transportation, Poland (2019); International Coastal Symposium, South Africa (2014); Coasts in Crisis: Sea Level Rise and Inundation and the Drivers for Adaptation, AGU, Ocean sciences Meeting, USA (2016); Session VI. Tools & Surveys, Littoral, France (2016). **Hunter:** Session Chair, Drinking Water Availability and Quality, India-UK Water Centre Workshop on Safe and Sustainable Technologies and Strategies for Integrated Freshwater Resource Management (2019). **Forsythe:** Chair of International Congress on the Anthropology of Salt (2015, 2018). **Jordan:** Scientific Committee, LuWQ2019, Denmark (2019).

Awards: **Clark:** Fellow, American Association for the Advancement of Science (2016); Fellowship, Radcliffe Institute for Advanced Study, Harvard University (2016). **Avouac:** Wolfson Merit Award of the Royal Society, UK (2014), Editors’ Citation for Excellence in Refereeing, Geophysical Research Letters (2015). **Arnscheidt:** Fulbright All-Disciplines Scholar Award (2020). UUs Senior Distinguished Research Award (**Jordan** 2018).