RESEARCH & INNOVATION SCOTLAND

Case Study

Global Climate Challenges for a Blue Green Economy: scientific evidence; its relevance; societal solutions.

Led by: SAGES

In collaboration with: MASTS, Scottish Government, SEFARI, RSE, RSGS, Climate-KIC, Blue Carbon Forum, NERC Arctic Office, Geoverbund, climateXchange

Practical solutions to challenges posed by global anthropogenic climate change are non-global: in national and regional regulatory frameworks, in devolved implementation of policy, in behavioural acceptance and desire for change, and in process-level understanding underpinning systems science research. Scotland is at the forefront of Climate Planning, with world-leading aspirations to shape a new way of living in the face of high-paced environmental change: land use for food and carbon stabilization, fresh water for energy and life, marine environment for energy and food. Aspirational plans need practical working solutions, which need underpinning evidence.

This symposium focussed on three challenge areas:

- Gathering Evidence: mosaic of underpinning research advancing earth system forecasting
- Assessing Relevance: issue-dependent evidence base needed for policy and regulation
- Designing Solutions: design and implementation of targeted solutions to achieve Climate Planning aspirations.

The symposium was opened by Roseanna Cunningham MSP, Cabinet Secretary for Environment, Climate Change and Land Reform

Significant Outcomes: Significant networking event taking a solutions-based approach to Global Climate Challenges. Bringing together policy makers, regulators, government scientists and university academics to consider practical steps required to meet climate-based aspirations of Scotland's Programme for Government.

The event pathed the way for the SAGES / Scottish Government Policy Internship Programme.

Next steps: On-going policy internship programme with Scottish Government. Increased pan-agency communications in the geosciences for pre-COP26 awareness raising events. A series of events, initially on-hold due to COP26 postponement, will now run right through from October 2020 to November 2021 – watch this space.

Book of Abstracts

27th - 28th November 2019

SAGES'19 Global Climate Challenges for a Blue Green Economy: Scientific evidence; Its relevance; Societal solutions.

John McIntyre Conference Centre, Pollock Halls Campus

SAGES Scottish Alliance for Geoscience, Environment and Society

Welcome

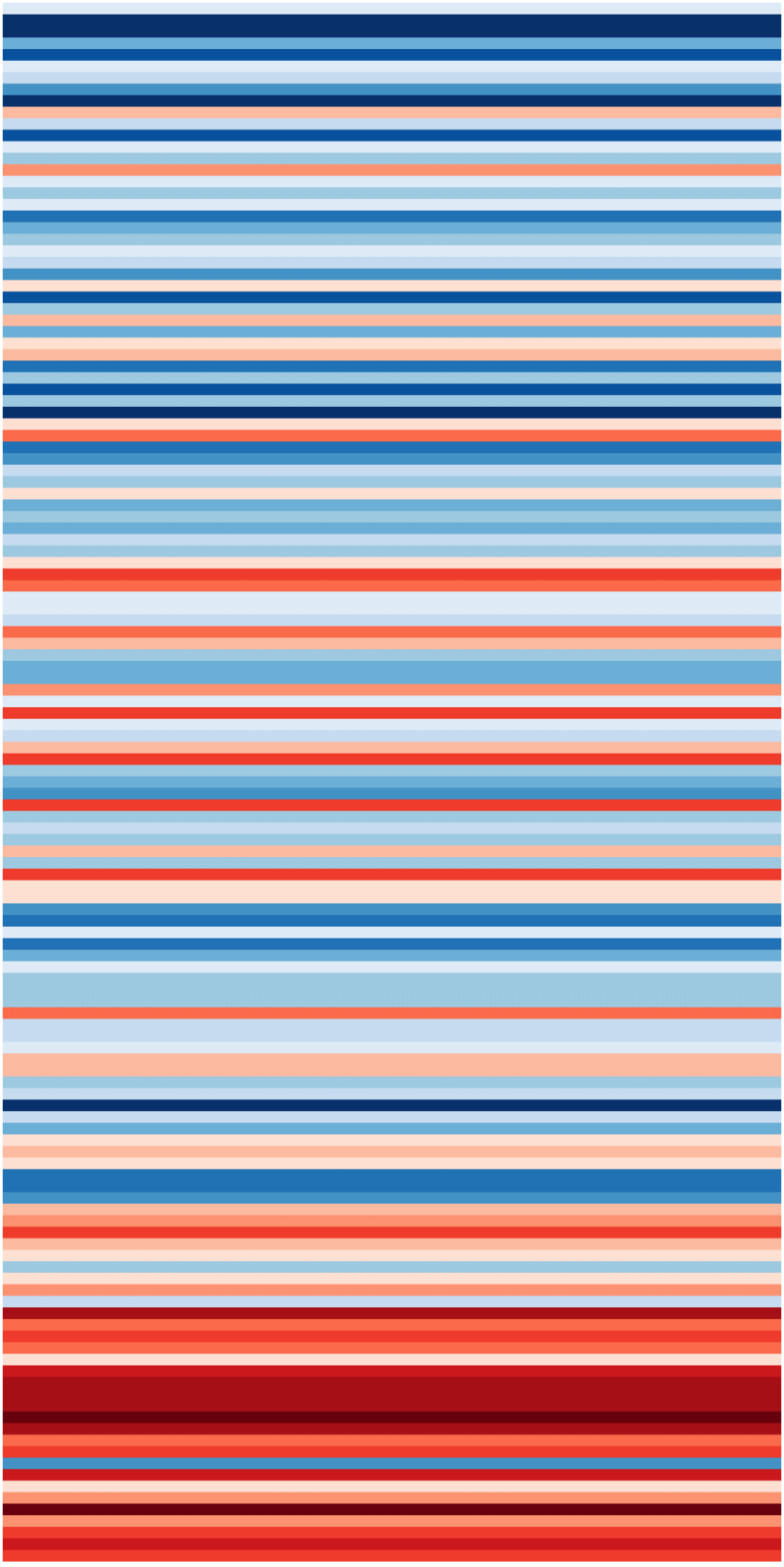
About 18 months ago we decided to organise a conference rather different from the standard 'academic' event, for what we thought could be the final SAGES conference (for an update on this, please read on ...).

We received a tremendously positive response to the idea behind this event; evidenced by the wide range of sponsors, partners and supporters (listed in this booklet). What you have before you these two days is a result of that positive response. Your enthusiastic interaction with the fine offerings from our keynotes, invited plenary speakers, and oral and poster presenters will cement the success of these two days. Please use your time here to express your views, to listen others, and to challenge ideas.

In April this year the Scottish Government was the first government to declare a climate emergency. Since then many others have followed suit, including the UK government. There is pride to be drawn from living in a country that has not only made this declaration, but also does not see economic growth for its own sake as a necessary measure of human progress. That is not to say Scotland has all the solutions, or the means or will to implement them. These are the things we are here to discuss. There is much to be welcomed in the Scottish Government's Programme for Scotland 2019-20 'Protecting Scotland's Future'. Reflecting this we have an opening address from the Cabinet Secretary for Environment, Climate Change and Land Reform, and a keynote address from Chief Scientific Adviser for Environment, Natural Resources and Agriculture.

'Challenge' is a word that is often used alongside the term 'climate emergency' – indeed we use both in describing this conference. This brings us back to thoughts on SAGES' future. SAGES is one of 11 research pools collaboratively co-funded by Scottish Government (via the Scottish Funding Council), Scottish universities, and Scottish research institutes. That we are able to offer this event as free-to-register is testament to the broad support of research networking in Scotland. In October this year an independent review of the pooling initiative recommended that research pools now undergo a transition into challenge-led research and innovation networks, with significant new funding. We see this conference as part of that transition, with our financial backing now secured to 2021. Beyond that date, we look forward to an enlightened future of significant new investment in the myriad of scientific 'challenges' surrounding the climate emergency.

Mark Inall
SAGES Director, Chair of SAGES Research and Innovation Organising Committee



Climate Warming Stripes for Scotland from 1884-2018

Source: showyourstripes.info

SAGES Scottish Alliance for Geoscience, Environment and Society

Conference Programme

DAY 1 - Wednesday 27th November 2019		
Timings	**Activity**	**Location**
08:00-09:00	**Arrival and Coffee**	Centro
09:00-09:15	**Welcome** Mark Inall, Director Des Thompson, Chair of Advisory Board	Pentland Suite
09:15-09:30	**Opening Address** Roseanna Cunningham MSP Cabinet Secretary for Environment, Climate Change and Land Reform,	Pentland Suite
09:30-10:00	**Keynote 1** Professor Andrew Millar Chief Scientific Advisor, Scottish Government	Pentland Suite
10:00-10:30	**Keynote 2** Dr Emily Shuckburgh, OBE (by video link) Cambridge Centre for Climate Change Mitigation Research	Pentland Suite
10:30-11:00	**Keynote 3** Gabi Hegerl Professor of Climate System Science, The University of Edinburgh	Pentland Suite
11:00-11:30	**Refreshment Break** Posters plus tea/coffee	Various
11:30-12:30	**Posters**	Concourse
12:30-13:30	**Lunch and Networking**	Centro
13:30-15:30	**Parallel Sessions #1 Evidence**	Various
15:30-16:00	**Break**	Centro

16:00-16:30	**Keynote 4** Professor Bob Furness Chair of SNH Scientific Advisory Committee Climate change and conserving Scottish seabirds	Pentland
16:30-18:00	**Posters and wine** Break-out space available	Concourse
18:00-19:00	**Move to Our Dynamic Earth**	Our Dynamic Earth
19:00-00:00	**Conference Dinner** Plus speaker	Our Dynamic Earth

DAY 2 - Thursday 28th November 2019		
Timings	**Activity**	**Location**
08:30-09:00	**Arrival & coffee**	Centro
09:00-09:30	**Keynote 5** Dr. Andy Kerr Climate - KIC	Pentland
09:30-09:45	**Posters:** Short break	Concourse
09:45-10:45	**Parallel Sessions #2 Relevance**	Various
10:45-11:15	**Refreshment Break**	Centro
11:15-12:15	**Posters then Lunch:** Breakout space available	Concourse
12:15-14:30	**Parallel #3 Solutions**	Various
16:30-17:00	**Awards presentation and closing comments**	Pentland
18:00-00:00	**Conference closes**	Close

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Oral Presentations

Assimilation of soil moisture data over Europe with TSMP-PDAF for the period 2001-2015

Oral

Dr. Bibi Sarwat Naz [1], ***Dr. Stefan Kollet*** [1], ***Dr. Harrie-Jan Hendricks Franssen*** [1], ***Dr. Carsten Montzka*** [1], ***Dr. Wolfgang Kurtz*** [2]

1. *Jülich Research Center, Institute of Bio- and Geosciences Agrosphere (IBG-3),* ***2.*** *Leibniz Supercomputing Centre, Environmental Computing Group*

Soil moisture is a key state variable which controls the exchange of water, energy and carbon fluxes between the land surface and atmosphere. As a result, it plays an important role in many regional-scale applications, including meteorology, hydrology, flood forecasting, drought monitoring, agriculture and climate change impact studies. However, soil moisture is a difficult variable to obtain because there are no high-resolution soil moisture observations available at the continental scale, and observations from measurements or remote sensing products are sparse and temporally and spatially discontinuous. Soil moisture reanalysis products are therefore needed which can provide downscaled estimates of the surface soil moisture with complete spatiotemporal coverage by combining remote sensing soil moisture observations with a land surface model using data assimilation techniques. Here we present a 16 years (2000–2015) high-resolution (3 km) soil moisture reanalysis dataset of the surface soil layer from the land surface data assimilation system TSMP-PDAF consisting of the Terrestrial System Modeling Platform and the Parallel Data Assimilation Framework. Satellite-derived soil moisture data are assimilated into the land surface model using an ensemble Kalman filter data assimilation scheme, producing a 3 km daily soil moisture reanalysis dataset over Europe. Simulated soil moisture from TSMP-PDAF was evaluated against 112 independent in-situ soil moisture observations over Europe. The results show TSMP-PDAF estimated surface soil moisture can well capture the temporal variation of observed soil moisture with the correlation coefficients mostly being above 0.5 for 80% of the stations. Moreover, our results show that this dataset is comparable to other global soil moisture products in capturing inter-annual, intra-seasonal patterns, and extreme events under different climatic conditions. The dataset presented here constitutes an important source of information for research in agriculture, flood and drought forecast, land cover changes, water quality and modeling of the global carbon and water cycles.

Can forest planting help us manipulate catchment sub-surface runoff pathways and contribute to natural flood management (NFM) strategies?

Oral

Mr. Leo Peskett [1], ***Prof. Alan MacDonald*** [2], ***Prof. Kate Heal*** [1], ***Prof. Jeffrey McDonnell*** [3], ***Dr. Andrew Black*** [4]

1. *University of Edinburgh,* ***2.*** *British Geological Survey,* ***3.*** *University of Saskatchewan, Canada,* ***4.*** *University of Dundee*

Efforts are increasing in Scotland, the wider UK and globally to harness the potential of forests to alter catchment water runoff and storage dynamics as a 'natural flood management' (NFM) strategy, particularly given a projected rise in the frequency and severity of floods with climate change [1]. But despite decades of research on forest hydrology, knowledge of how forests control catchment runoff is still limited, especially in relation to important, though less investigated subsurface runoff processes.

We examined how forest cover interacts with soils and geology to influence runoff pathways at different spatial and temporal scales, focusing on the 60 km^2 Eddleston Water NFM pilot site in the Scottish Borders. At the catchment scale, isotopic and geochemical tracers were used to investigate whether forest cover is a significant control on water storage and release over seasonal and storm event timescales. At the hillslope scale, dense subsurface monitoring (soil moisture, groundwater and time-lapse electrical resistivity tomography) compared improved grassland to an across-slope forest strip, similar to those promoted in NFM schemes to control runoff, to reveal water storage potential in soil underneath the forest and the downslope extent of any impacts on subsurface hydrological dynamics.

The results revealed complex interactions between land cover and runoff processes at different scales. Superficial geology and soil type were found to be more dominant controls on catchment storage over seasonal timescales, with land cover playing a secondary role. However, at the storm event timescale, and between catchments with similar superficial geology and soils, forest cover appears to attenuate runoff compared to improved grassland, reducing the fraction of event water runoff during high flow events in the study period. The hillslope scale work showed significant differences in subsurface moisture dynamics between the grassland and the forest strip over seasonal timescales, with deeper and seasonally extended drying of the forest soils (pictured), a lower water table, and less responsiveness to storms. Downslope of the forest, subsurface moisture dynamics were not altered, suggesting minimal impact of the forest on downslope water storage and flow paths.

The overall conclusion is that while forest cover appears to increase catchment and hillslope storage potential and alter runoff pathways to attenuate flow, impacts are sensitive to soil type, geology, and the location of forest. This has implications for planning NFM interventions based on forest planting.

[1] Dadson, S., et al. *Proc. R. Soc. Math. Phys. Eng. Sci.*473.

Keywords: flooding; forests; groundwater

Competitive Adsorption of Pharmaceuticals onto new Functionalised Materials Derived from Waste

Oral

Ms. Lisa Shearer [1], ***Dr. Sabolc Pap*** [1], ***Dr. Yuan Li*** [2], ***Dr. Mark Taggart*** [3], ***Prof. Stuart Gibb*** [1]

1. *Environmental Research Institute, North Highland College, University of the Highlands and Islands,* ***2.*** *Environmental Research Institute /North Highland College,* ***3.*** *Environmental Research Institute, University of the Highlands and Islands*

Efficient low-cost water treatment methods are required for the removal of contaminants from wastewater. Conventional forms of wastewater treatment (such as activated sludge and flocculation) are often ineffective for many pharmaceuticals and personal care products (PPCPs) (Archer *et al.*, 2017). Advanced tertiary treatments (i.e., ozonation, ultrafiltration or activated carbon removal) although effective, are normally prohibitively expensive (Crini *et al.*, 2019; Tan *et al.*, 2017). Here, we consider the use of low-cost adsorbents made from Scottish waste materials i.e., spent grain from distilleries and breweries, and crab carapace and mussel shell from the shellfish industry. These were used for the removal of 6 prioritised compounds. These were 5 pharmaceuticals of concern; metformin (an anti-diabetic), propranolol (a beta-blocker), clarithromycin (an antibiotic), sertraline (an antidepressant), naproxen (an anti-inflammatory) - and triclosan, an antimicrobial used in personal care products. Materials were functionalised using several methods such as magnetisation, acid and alkali treatment and encapsulation (into beads). Removal efficiency using raw materials was compared with functionalised forms of the same material. Experimental conditions used were: adsorbent dose - 4 g/L; initial contaminant concentration - 10 mg/L of each compound (in a mixture); room temperature stirring at 150 rpm; pH 7. Samples were taken at 1h, 6h and 24h during adsorption experiments and were analysed using an Agilent 1100 HPLC coupled to a Micromass Quattro Ultima Platinum mass spectrometer (equipped with an electrospray ionisation source). Results indicated that the modification of raw materials can improve removal efficiency for several compounds (see Figure). Magnetically modified brewer's spent grain (BSG) was more efficient for the removal of metformin, propranolol and naproxen. Improved efficiency at specific time points was also noted; for example, naproxen had 0% removal at 24 hours when using raw adsorbent material, but 90% removal at 24 hours when using the magnetic BSG. However, other modification methods (such as citric acid modification) gave a significant reduction in removal efficiency for several compounds, but an increase for metformin and naproxen. Future work will compare removal efficiency for all the modified materials (i.e., using encapsulation, magnetisation, citric acid, alkali and amine functionalisation) with these target compounds. The two most promising methods will then be studied in more detail. This will include optimisation experiments to consider the factors - time, solution pH, adsorbent dosage and rotation speed. So far, results indicate that functionalised low-cost waste material could be effective in the removal of pharmaceuticals from water.

Emergent Issues and New Research Directions in Integrated Water Cycle Management

Oral

Dr. Irena Connon [1]***, Dr. Daniel Gilmour*** [2]

1. *University of Dundee,* ***2.*** *Abertay University*

This paper will examine emergent issues in water cycle management in Scotland and beyond. The issues discussed represent integrated ideas that resulted from a collaborative research workshop held in 2019. This involved researchers from the natural and social sciences from seven Scottish universities and which aimed to identify key emergent issues and research directions in the area of water cycle management.
The key emergent issue identified was managing the changing urban/rural interface in Scotland's catchment management. In addition, ways of managing this changing catchment context need to be responsive to issues posed by climate change, with solutions focused on both adaptation and mitigation of emergent flood risk. Particular challenges for managing the water cycle at the emerging rural/urban nexus include:

- Discord in definition of boundaries which create difficulties in the application of policy and practice;
- Concern about whether the existing policy and legislative framework has kept pace with societal change;
- Changing dynamics of the urban/rural buffer zone; and how the increasing fluidity of the urban/rural boundary be incorporated into the water management practices; and
- Questions about the transfer of goods and services.

However, the changing urban/rural interface and the emergent challenges also present existing opportunities for collaborative research into the development of nature-based solutions for flood mitigation and their embedding in policy and practice, as part of the development of sustainable flood management in Scotland and ways of addressing the Sustainable Development Goals.
The paper will conclude with an overview of suggestions about how these ideas can be mobilised via integrative transdisciplinary research projects and joint funding applications over the course of the next year.
Keywords: Urban-Rural Interface, Catchment Management, Sustainable Development

Groundwater connectivity of a sheared gneiss aquifer system in the Cauvery river basin (peninsular India): Implications for water resources

Oral

Ms. Sarah Collins [1]

1. *British Geological Survey*

Connectivity of groundwater flow within crystalline-rock aquifers controls the sustainability of abstraction and baseflow to rivers, yet is often poorly constrained at a catchment scale. Here groundwater connectivity in a sheared gneiss aquifer is investigated by studying the intensively abstracted Berambadi catchment (84 km^2) in the Cauvery River Basin, southern India, with geological characterisation, aquifer properties testing, hydrograph analysis, hydrochemical tracers and a numerical groundwater flow model. Geological observations indicate that 40–70% of the gneiss is sheared, with an east–west trending steeply dipping foliation resulting in more frequent and deeper vertical fractures. Specific capacity tests (172) conducted at high and low groundwater level show an exponential decrease in hydraulic conductivity with depth; and borehole dilution tests confirm flowing fractures at depth (deepest 94 m). Significant lateral connectivity across the catchment is demonstrated by over 100 groundwater hydrographs, which exhibit remarkable uniformity from 2010 to 2018. Hydrochemical tracers (residence time tracers, Cl and stable isotopes) demonstrate little lateral groundwater flow despite the connectivity and instead infer mainly vertical flow. Testing the data with a numerical groundwater model confirms limited lateral groundwater flow in the catchment with the current level of abstraction. Simulations with reduced and no abstraction show increased groundwater lateral flow to topographic depressions generating baseflow.

The study indicates a well-connected system, both laterally and vertically, that has evolved with high abstraction from a laterally to a vertically dominated flow system. Likely as a result of shearing, a higher degree of lateral connectivity remains at low water levels than in many other basement aquifers. Because of their low storage and logarithmic reduction in hydraulic conductivity with depth, crystalline-rock aquifers in environments such as this, with high abstraction and seasonal recharge, constitute a highly variable water resource, meaning farmers must adapt to varying water availability. Importantly, this study indicates that abstraction is preventing baseflow to the river, which, if also occurring in other similar catchments, will have implications downstream in the Cauvery River Basin.

Groundwater use to reduce poverty and increase resilience in rural Africa

Oral

Prof. Alan MacDonald [1]

1. *British Geological Survey*

For many parts of the world, the development of groundwater increases water security and can lead to more sustainable livelihoods and a reduction in poverty. This is particularly the case for rural Africa where water insecurity is endemic. Drawing on a 4 year multi-scale interdisciplinary study of rural water supply in Ethiopia, Uganda and Malawi we investigate the functionality of rural water supply boreholes equipped with handpumps. Through detailed forensic hydrogeological, engineering, and water quality field work in conjunction with focus group discussions, participatory mapping and diary keeping we explore how the functionality of water supplies impacts on communities, particularly through drought and some of the multifaceted reasons driving poor functionality.

Two years of monitoring in the highlands of Ethiopia through the severe droughts of 2015/16 has demonstrated that boreholes equipped with handpumps provided a resilient water supply even through the worst parts of the drought [1]. Communities without access to deep groundwater and relied on shallow hand dug wells or small springs became increasingly water insecure as the drought progressed. This resulted in water use for individuals reducing to below 5 litres per day and water collection times rising to more than 12 hours for some communities. These water insecure communities had to reduce the number of meals eaten each day and often missed going to the farm or school.

A Survey of 600 hundred water points demonstrated that the dry season water quality of handpumps was generally good even without treatment, but many of the handpumps were not functioning to their design capacity or reliability. The reasons for this are complex and cannot be easily explained by poor management [3]. The main reasons for failure are the lack of affordable maintenance options regardless of the type or strength of governance arrangements. Longitudinal studies reveal intense and regular high demand on individual waterpoints as a result of festivals, funerals and failure of nearby sources. These extra demands create extra pressure and often results in conflict.

For many parts of Africa, sufficient groundwater can be found to sustain a handpump, if appropriate techniques are used to site and construct boreholes. Capacity for good siting and construction is often lacking however, and sub-standard equipment can be used which exacerbates problems. With the current emphasis on achieve the Sustainable Development Goals with universal access to clean water at households it is important not to forget the many that still lack even basic services and to ensure that the poorest are not left behind. The careful development of groundwater will in most cases offer the most affordable and reliable solution.

[1] MacDonald, A.M., Bell, R.A., Kebede, S. et al. *Environmental Research Letters*, 2019, 14, 095003.

[2] MacDonald, A.M., Bonsor, H.C., Ó Dochartaigh, B.É.. et al. *Environmental Research Letters*, 2012, 7, 024009.

[3] Whaley, L., MacAllister, D.J., Bonsor, H., et al. *Environmental Research Letters*, 2019, 14 085013.

How Clean Is Green? Using Biodiversity and Energy Justice to Resolve Conflicts between Sustainable Development Goals

Oral

Dr. Isabel Jones [1]

1. *University of Stirling*

United Nations Sustainable Development Goals (SDGs) promote global economic and social prosperity while simultaneously seeking to protect the environment. All UN member states are signatories to achieving SDGs under the 2030 Agenda for Sustainable Development. However, our global energy dilemma highlights and exemplifies trade-offs between SDGs. The increasing human population and growing energy demand challenges whether we can have secure, affordable and equitable energy without adversely affecting people and the environment [1]. Trade-offs and conflicts between SDGs and stakeholders prevent realisation of the 2030 sustainable development targets.

Large hydropower schemes (dam height >15 m) bring conflicts between SDGs and stakeholders into sharp focus. More than 9700 large hydropower dams have been constructed worldwide providing energy (SDG 7) and boosting industrial infrastructure development (SDG 9). However, such dams have displaced an estimated 40-80 million people, and, through reservoir creation and river flow disruption we have lost environments that are important for biodiversity and climate change mitigation. Thus, hydropower development puts significant pressure on SDGs that focus on local livelihoods and food security (SDGs 1, 2), justice and accountability (SDG 16), water, ecosystems and global biodiversity (SDGs 6, 14 and 15).

I will present research on the long-term ecological impacts of the Balbina Dam (Brazil)[2], alongside perspectives on the challenges surrounding large dam development when attempting to achieve "No Net Loss" of biodiversity in the tropics [3]. Finally, I will discuss future research plans relating to using hydropower development as a model system to explore conflicts and trade-offs between SDGs and stakeholders, bridging the historically separate socio-political and environmental sciences to resolve the multifaceted challenges presented by the global energy dilemma and the consequential increase in large dam construction.

[1] Gibson, L., Wilman, E.N., Laurance, W.F. *TREE*, 2017, 32, 922-935

[2] Jones, I.L., Peres, C.A., Benchimol, M., Bunnefeld, L., Dent, D.H. *J. Appl. Ecol.*, 2019, 56, 779-791

[3] Jones, I.L., Bull, J.W. *Sust. Dev.*, 2019

Keywords: hydropower, sustainable development, social-ecological conflict

How living with a disability affects responses to groundwater contamination in former brownfield sites in Australia: Lessons for policy and practice

Oral

Dr. Irena Connon [1]

1. *University of Dundee*

Recent research focusing upon human responses to land and groundwater legacy contamination in residential areas in Australia examined the prevalence and impact of worry and concern about exposure to contaminants within the chronic hazard context. However, although this research identified the significance of demographic and psychosocial determinants of worry, the question of how living with a disability affects resident worry about contamination remained unanswered. This presents an important concern as failure to understand how people with disabilities respond to groundwater contamination can be argued to be representative of inequality in inclusion in academic research and in the groundwater management and remediation policies that draw upon research evidence to improve communications and engagement with residents.

This paper addresses this shortcoming by presenting the findings of a cornerstone study that examined the relation between worry about environmental contamination and disability. The findings are based on a study of 486 adults living in 13 urban residential areas in Australia affected by a range of contaminants, including heavy metals, chlorinated solvents, putrescible waste, and hydrocarbons. Ordinal logistic regression analysis found respondents with a disability were significantly more likely to worry about contamination than those without. People living with a disability had significantly higher amounts of worry about the contamination than those living without. In addition, a ground-up, thematic-based analysis of open-ended survey questions revealed that a greater number of people living with a disability raised concerns about the impact of contamination for both human and environmental health compared to other respondents. A greater number of people living with a disability reported changing their daily habits because of concern about the contamination.

Worry about perceived risks associated with environmental contamination may be reduced through tailoring information to the concerns of specific population groups, including people living with disabilities. The findings about residents' perceptions of personal control over exposure to the contamination present important considerations for understanding the implications of worry for people living with and without a disability. This is because low perceived ability to limit contact with the contamination could potentially impede the possible adoption of adaptive action in response to higher levels of worry and increase the risks of despondency associated with living in areas affected by contamination. This has important implications for the policy and practice of environmental remediation, as it may be that having greater access to knowledge about how to limit exposure may help to promote adaptive action and a higher perceived ability to control exposure.

The study also presents important implications for the policy and practice of environmental remediation and groundwater management more broadly. Failure to engage with the experiences and concerns of people with disabilities could be argued to risk disseminating information that inadequately meets their needs. In addition, failure to engage people with disabilities in the development of water management strategies could also risk perpetuating existing inequalities of representation in policy and practice. Currently, many regulatory documents fail to reflect specific awareness of how disability may feature in shaping resident responses to risk. New understandings about the relation between disability and worry and indications of issues of worry should prove helpful for improving existing policy documents, which decision-makers draw upon when developing plans for responding to environmental contamination. This is particularly important given that studies in the sustainable remediation context found that recommendations for improving remediation practices are less likely to be fully endorsed by internal and external stakeholders until they have been embedded in regulatory institutional

documents. Therefore, ensuring that the needs of people with disabilities are successfully incorporated into developments in remediation practices requires the prioritization of policy and regulatory document reform.

Keywords: Groundwater Contamination, Policy and Practice, Water Hazard Management

Indicators to Promote Consideration of Sustainability Factors in Water Energy Food Nexus Innovations

Oral

Dr. Daniel Gilmour [1], ***Dr. Paula Forbes*** [1], ***Prof. Ruth Falconer*** [1], ***Mr. Nikolay Panayotov*** [1]

1. *Abertay University*

We have provided a support to decision-making with a WEF nexus approach by creating a set of sustainability indicators, which were derived from stakeholder consultations and workshops to include more than just financial aspects when assessing the viability of such innovations. Stakeholders were involved throughout the course of the project [1] (Hoolohan et al., 2018); interviews and focus groups were carried out with AD experts, both in industry and academia, entrepreneurs producing insects and relevant food redistribution companies were also consulted. By taking this bottom-up approach and placing stakeholders at the heart of the project, we aimed to produce a tool to support sustainable decision making. We chose to align our SIs with the current UN Sustainable Development Goals in a visualisation tool to help confer the benefits of the innovations, using three different future scenarios to explore possible sustainability transformations.

The Sustainability indicators and visualisation tools described in this paper were developed as part of the Stepping Up project http://steppingupnexus.org.uk. The full paper will describe in more detail how the Catalogue of SIs was developed and how we went on to use them in an interactive visualisation tool to explore both the different innovations and also 3 possible future scenarios.

Integrated governance for better nexus management: insights from studying implementation of water policies

Oral

Dr. Kerry Waylen [1], ***Dr. Kirsty Blackstock*** [1], ***Ms. Alba Juarez-Bourke*** [1], ***Dr. Keith Marshall*** [1]

1. *The James Hutton Institute*

This presentation reflects on the conference topic of 'Water' and offers a response to the third key challenge 'how do we deal with the sometimes conflicting demands of water users, including for example, the water/food/energy nexus?'. Integrating the delivery of different policy goals, in order to deliver multiple benefits is essential if we are to better manage the water-energy-food nexus in the face of climate change. As such, nexus management is as much about integrated governance as it is about integrating understanding of biophysical domains. However, exactly how we should achieve this is unclear.

To address this challenge, we have studied the links in the implementation of two key policies that shape water governance: the Water Framework Directive, which sets ambitious targets for water quality across Europe; and the Floods Directive, which mandates a process for appraising and planning to reduce flood risks [1]. Our insights have relevance to the integration of other policies – e.g. on energy and climate, which are needed to sustainably manage the nexus, as similar challenges are likely be encountered when trying to connect these planning processes.

Our research builds on academic work on topics such as institutional interplay and policy coherence. We began with a document analysis of plans made under both policies, and in particular cross-references between them, for the Czech Republic, Flanders, the Rhine, Spain Sweden and the UK. We then discussed experiences and expectations of integration with those concerned with creating and implementing the plans Flanders, Sweden and the four devolved regions of the UK (England, Wales, Scotland and Northern Ireland).

The document analysis suggested that shared consultation processes and Strategic Environmental Assessments were the main venues for integrating the two policies. In general, the plans indicated that linkages between flooding and water quality policies were at a relatively superficial and early stage: however, the interviews on integration revealed much more activity 'behind the scenes' to coordinate the implementation of the policies. A common theme was the importance of partnership working and coordination of departments and working groups, often linked with initiatives to improve data sharing. As a result, many of our practical recommendations to encourage integration were about reinforcing partnership working; (i) Explicitly reflect on understandings of integration, (ii) Work between and across levels, (iii) Formally value and enable coordination and collaboration, (iv) Explicitly document processes and progress in integration, and (v) Share new experiences. This shows that practical steps can be taken now to help better connect and integrate different policy goals.

However, we have also found many unresolved questions, such as how to fully reflect and reward integration via the culture and metrics of organizations that are accountable for the delivery of specific policies and goals. There is also an important question mark over which scale(s) are most appropriate to promote and achieve integration of different goals. Many individuals involved with creating the formal plans expected that catchment scale partnerships would be an appropriate unit for appraising and deciding how to balance and deliver multiple goals. Whether or not this is the case is a question that motivates our ongoing research [2].

Better connections across different policy domains may also offers conceptual insights to help reframe and reassess the goals themselves. For example, over the last decades, professionals working on flood risk management have come to recognize that we cannot protect societies from all flood-related risks solely through hard engineering infrastructure: so the sector also now encompasses other approaches to reducing flows, and works with society in order to mitigate the effects of floods through preparedness and responses. This suggests that we should not take for granted user 'demands' when considering any aspect of the water-energy-food nexus. Thus,

developing more integrated governance may also stimulate learning that reframes our goals for governance.

[1] Waylen, K.A., Blackstock, K.L., Tindale, S.J., Juarez Bourke, A. (2019) Governing integration: insights from integrating implementation of European water policies., *Water*, 11, Article No. 598.

[2] For more information about this work please visit https://www.hutton.ac.uk/research/projects/water-integration

Lessons from the 2018 drought: A tracer-based assessment of hydrological and water quality impacts

Oral

Ms. Jessica Fennell [1], ***Dr. Josie Geris*** [1], ***Dr. Mark Wilkinson*** [2], ***Dr. Ronald Daalmans*** [3], ***Prof. Chris Soulsby*** [1]

1. *University of Aberdeen,* ***2.*** *The James Hutton Institute,* ***3.*** *Chivas Brothers Ltd.*

Hydroclimatic extremes are predicted to occur more frequently [1] and linked to this, risk of elevated stream temperatures, particularly during low flows. These predicted trends pose water availability threats to the natural functioning of ecosystems and downstream water use. In humid northern environments, Nature Based Solutions (NBS) such as ponds, wetlands or tree planting are being increasingly explored for environmental risk mitigation (predominantly for flood risk or diffuse pollution management) [2]. However, relatively little research has been conducted on the potential for NBS for managing low flows and water temperature.

This research aims to explore how NBS could potentially affect hydrological processes relating to water availability and temperature. For an upland catchment (0.9km^2) in Scotland which supplies the Glenlivet Distillery with process and cooling water, we (i) characterise the 2018 drought, assessing the potential influence on water volumes, quality and temperature, and (ii) explore where, when and which types of NBS might be most appropriate. We combine historical rainfall, temperature and flow data with a dense hydrometric monitoring network. Monitoring also includes stable water isotopes and water quality parameters as tracers to understand surface and sub-surface hydrological functioning.

Results highlight the importance of groundwater contribution to the main stream for maintaining streamflow through the drought period. In addition, groundwater contribution may have buffered the effects of fluctuations in air temperatures - stream temperatures remained below 14ºC, despite air temperatures reaching 25ºC. This demonstrates the importance of recharge for maintaining groundwater resources. Certain NBS are designed to address these requirements by capturing water during storm events and increasing infiltration to deeper storage zones, so to test and therefore understand the full potential of these approaches is essential. Spatial variation in water source areas and temperatures indicates differences in the origins and ages of the water. This relates to differences in geology, soils and land use and suggests the efficacy of NBS will be spatially variable. This highlights the importance of obtaining an understanding of the catchment hydrological processes as an evidence base to guide site and measure selection for NBS. Future work will investigate NBS installation both on the field and within a modelling structure, combined with pressures on the catchment such as climate change. Eventually, this project will contribute to increase efficacy of NBS for mitigating the impacts of drought thereby potentially providing future resilience to ecosystems and industry.

[1] Stocker, T. F. et al. *'Technical Summary', Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2013, 33–115.

[2] Environment Agency *'Working with Natural Processes – Evidence Directory'*, 2017, 311

Keywords: low flows, water temperature, nature-based solutions

Modelling phosphorus pollution risk in Scottish rivers - a decision support tool

Oral

Dr. Miriam Glendell [1]

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Water pollution remains an important reason for the failure of 17% of Scottish waterbodies to reach Good Ecological Status under the Water Framework Directive[1]. UK Climate Projections 2018 indicate that Scotland's climate will become warmer, with drier summers, wetter winters and increased occurrence of extreme events, including droughts and intense rainfall. Understanding the likely impact of this profound environmental change on Scotland's water quality is critical to facilitate planning for effective, resilient actions to prevent future water quality deterioration and to climate-proof current mitigation efforts. However, understanding the potential impacts of such changes is extremely challenging and can not be done in isolation. The associated climate induced land use change will also have a significant impact on water quality, with the potential for both large-scale social and economic consequences. For example, the projected increase in rainfall driven erosion as rainfall intensity increases could lead to increased transfer of pollutants and sediment, while periods of dry weather may lead to increased concentrations of nutrients and contaminants. However, studies addressing these complex issues at a scale useful for Scottish decision makers are scarce [2], and the likely impacts and future sustainability of current mitigation efforts, in the Scottish context, are poorly understood.

Among multiple pressures affecting water quality, phosphorus (P) pollution remains a major cause of surface water quality failures. However, abating P pollution in agricultural catchments requires informed decisions about the likely effectiveness of land management mitigation measures and their spatial targeting, both under current conditions and future scenarios. In this work, we introduce a user-friendly decision support tool, based on Bayesian Belief Networks (BBNs) that allows the integration of uncertain information on the potential effects of water quality mitigation measures, including data, other model outputs and expert opinion, in one model. The PhosphoRisk decision support tool allows system-level thinking, revealing possible causal relationships between controlling factors to facilitate the understanding of the effects of land use on P pollution risk in Scottish catchments. The tool facilitates the co-construction of the modelling outcomes by the academic and the stakeholder communities. The modelled scenarios will help to inform targeting of water quality mitigation measures in high risk areas, while the quantified model uncertainties will inform further research and data collection. The tool will provide a user-friendly interface with clear visual outputs that can be easily updated as new data and understanding become available.

[1] Scottish Environment Protection Agency 2014 The river basin management plan for the Scotland river basin district: 2015-2027

[2] Dunn et al. 2015 A pragmatic methodology for horizon scanning of water quality linked to future climate and land use scenarios. Land Use Policy 44, 131-144.

Keywords: phosphorus, water quality, mitigation measures

Modelling the global response of lake phytoplankton communities to climate change

Oral

Dr. Ian Jones [1]

1. *University of Stirling*

Water quality is an important global issue. A particular concern is the growth of phytoplankton blooms, and especially toxic cyanobacterial blooms, resulting from nutrient enrichment. The relatively limited in situ data from around the world makes it difficult to assess the extent to which the climate overlying a lake, and therefore the lake location, influences the likelihood of algal blooms. Similarly, it is unclear to what degree future changes in climate will affect the likelihood of increases in algae. Nevertheless, as overlying climate affects not only lake temperature, but also the thermal stratification in a lake, and consequently the light experienced by algae in the mixed layer, it is expected that both location and climate change will influence phytoplankton dynamics. One way to explore this issue is to use a global numerical modelling approach, using a combination of lake physics and lake phytoplankton models, driven by present day meteorological data from around the world and meteorological outputs from future climate models. We will show results from such a worldwide modelling exercise simulating phytoplankton growth for an idealised model lake, both under present day and future climate conditions, underpinned by using present day satellite observations to validate the present day model outputs. The results show the extent to which geographical location can influence the growth of phytoplankton and which parts of the world will be most at risk of future increases in cyanobacterial blooms as a result of a warming climate. Understanding the variation in impacts of climatic change on phytoplankton communities around the globe is a necessary step to determining cost-effective remediation strategies for preserving water quality.

Phosphorous recovery from wastewater in dynamic columns using chitosan-calcite adsorbent

Oral

Dr. Sabolc Pap [1], ***Mrs. Barbara Bremner*** [1], ***Ms. Lisa Shearer*** [1], ***Mr. Huiyi Zhang*** [1], ***Prof. Stuart Gibb*** [1], ***Dr. Mark Taggart*** [2]

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Phosphorus (P) recovery from wastewater will become increasingly vital in the future as terrestrial rock phosphate deposits are expended [1]. Effective management of P as a critical resource will require new techniques to recover P from wastewater, ideally in a form that can be used in agriculture as fertiliser [2].

In this study, fixed-bed column conditions were tested using a KOH deacetylated calcite-chitosan based adsorbent (CCM) for P removal from aqueous solutions and wastewater effluent. Column studies were conducted at room temperature using glass columns (20 cm length, 2 cm internal diameter). P working solutions were continuously fed in an up-flow mode into the column by peristaltic pump. The influent contained different P concentrations (5, 10, and 20 mg/L) and this was passed through the column at varying bed heights (3, 6 and 10 cm) using three flow rates (3.5, 7.0, and 10.5 mL/min). Samples were collected at regular time intervals (using a fraction collector) in order to obtain the required breakthrough curves.

The fixed bed study confirmed that both breakthrough time (tb) and exhaustion time (te) increased with increasing bed depth, and with decreasing influent P concentration and flow rate. The optimal conditions were attained at a flow rate of 7 mL/min, initial P concentration of 5 mg/L and bed depth of 6 cm. From the tested models, the Clark model adequately described the adsorption of P in a dynamic P-CCM system. The above Figure shows a breakthrough curve comparison between real wastewater effluent and a synthetic solution using similar conditions (flow rate = 7 mL/min; bed depth = 6 cm). The initial concentration of P was 7.8 mg/L in the effluent compared with 5 mg/L in the synthetic solution. As expected, adsorption capacity decreased in the presence of wastewater effluent. Column tests indicated that the real effluent shortened the CCM breakthrough time by 49%. Besides a matrix effect, the higher initial P concentration in the wastewater also caused this notable decrease. According to these results, biofouling is not a very pronounced phenomenon with this CCM adsorbent. CCM showed selective affinity towards P, which is based on specific adsorption mechanisms between active sites and P anions. Additionally, ammonium and COD were reduced by the CCM (in the wastewater effluent), which suggests that the CCM has the potential to be used for ammonium and dissolved organic compound removal. Given a similarity between lab-scale experiments and either pilot or full-scale systems, the effluent breakthrough data were used to calculate parameters for a large-scale column based process. The design parameters required for column diameter, area, and bed volume were 35 cm, 961.6 cm2, and 37 cm3, respectively.

Scale-up and cost parameters are given - and the excellent performance of this adsorbent (versus other materials previously studied for P removal and recovery) with real secondary effluent indicates that this material could have significant potential within larger-scale applications.

Reducing at source water pollution by emerging contaminants resulting from consumer products: supporting responsible production and consumption practices

Oral

Ms. Lucille Groult [1]

1. *University of Dundee*

Emerging contaminants from Personal Care Products (PCPs) and household agents are now increasingly found as trace pollutants in water bodies, contributing to the pollution from so-called Contaminants of Emerging Concern (CECs). The fate and impact for the environment and human health is still barely understood. Yet, there is a scientific consensus that such increasing pollution might constitute an unprecedented risk to an unpredictable extend. Indeed, the growing evidence demonstrate a variety of adverse effects, such as persistence, transgenerational and combination effects [1].

With the media coverage of some emerging pollutants on the rise, such as nanoparticles, microplastics or endocrine disruptors, such concern over long term impacts is now raising public awareness and requires a societal response, beyond case-by-case regulation and costly pollution treatment approaches, unsuitable for diffuse pollution. Therefore, reducing the use of CECs at source seems to be a more appropriate alternative with the aim to improve availability and visibility of cleaner products and impact significantly consumer habits.

The challenges raised by CECs fulfil the conditions to trigger precautionary actions, being characterised by a high level of scientific uncertainty on mechanisms, impacts and scale, and threatening to significantly disturb complex natural processes as a result of human activity. Examples of such uncertainties identified are: unusual dose-effect relationships, uncontrollable combination of chemicals, long term effects (due to persistence, bioaccumulation and/or transgenerational effects), unknown pathways, transport and fate in the environment, mechanisms of action (e.g. endocrine disruption).

Evidence of such hazards are building up, however, action is required before the phenomena reach such a scale that irreversible harm can be caused, . Existing precautionary solutions have been identified to support substitution by design (e.g. green chemistry and green engineering principles applied to design and manufacturing of products [4]), alternative or responsible use (such as sustainable consumption, eco-labelling [5]). Their opportunity and barriers for implementation will be explored in the future via a social investigation.

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[3] European Environment Agency. *Late lessons from early warnings: the precautionary principle 1896–2000*, 2001, Environmental Issue Report 22, 210p.

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[5] Reisch, L. A., Thøgersen, J. (ed.) *Handbook of Research on Sustainable Consumption*, 2015, 480p.

Keywords: Emerging Contaminants, Sustainable Production, Sustainable Consumption.

Small water supplies: little evidence, large risks, multiple stakeholders, one database

Oral

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Small supplies are defined as supplies serving less than 5000 people and very small supplies refer to supplies serving less than 50 people [1]. The term small may be relevant to [2]: (i) reliance on decentralized, small-scale systems for treatment/purification and water distribution; (ii) limited capacity for protection or pollution control from source to tap; (iii) low availability of resources required to address operational cost, maintenance, treatment, source protection, risk assessment and monitoring; and (iv) less stringent regulations than those applied for public water supplies, e.g. the European Drinking Water Directive (DWD, Directive 98/83/EC) requires a less frequent monitoring in small supplies (i.e. one to four times a year) and places no obligation for the monitoring of very small water supplies.

Small rural supplies are vulnerable to catchment-based sources of microbiological and chemical pollution such as livestock, sewage and industrial discharges, and agricultural runoff. Vulnerability to pollution depends on precipitation, soil leaching potential, bedrock geology, and the type of small supply sources (springs, wells, boreholes or surface waters) and is different for each parameter [3, 4]. Changes in precipitation induced by anthropogenic climate change pose major risks to both the quality and the quantity of water available for small supplies: floods can impair surface water quality and cause widespread damage to infrastructure and treatment systems whereas decreasing rainfall combined with increased temperatures can increase algal blooms and lead to increased concentrations of chemical parameters in the sources of small supplies [3]. Addressing these challenges requires new paradigms in small supply monitoring, such as: risk-based monitoring (e.g. higher sampling frequency in supplies served by unimproved sources such as surface waters) [4, 5]; continuous assessment of the effectiveness of pollution control measures from catchment to tap [5]; and place-based monitoring, i.e. accounting for spatial and temporal patterns in the levels of microbiological and chemical parameters [4]. In Scotland, small supplies in rural and remote areas managed by their owners or users are known as Private Water Supplies (PWS) and serve approximately 4% of the resident population but this number may exceed 20% of the population locally. Monitoring is carried out in accordance with the standards set for each parameter in The Private Water Supply (Scotland) Regulations 2006, which transpose the DWD's requirements in the PWS context and place a duty on local authorities to monitor each PWS serving more than 50 people or providing water as part of a commercial or public activity, at least once a year. The question arises: Is the evidence collected with this monitoring sufficient to address the challenges posed by catchment-based pollution and climate change?

To answer this question, we developed a practical weight-of-evidence method to identify where the risk of water quality non-compliances in PWS is greatest in relation to catchment influences. The first step was to compile data from all possible lines of evidence on historical water quality data and catchment influences on water quality in a GIS-linked database to enable proper validation and access by all interested parties and subsequent analyses of the data. The second step was to statistically assess non- compliances in regulatory water quality data available for each PWS in the context of the water quality, land use, and any other information available at the associated waterbody (surface and groundwater). The third step was to identify a risk area specific for each drinking water parameter. The method applies to parameters monitored at the tap under the DWD and at a waterbody scale under the Water Framework Directive (WFD, Directive 2000/60/EC). Trials on five parameters (aluminium, nitrate, arsenic, cadmium and chromium) showed (i) insufficient PWS monitoring by local authorities; (ii) limited access to WFD parameter concentration data; (iii) lack of spatially explicit evidence on

risks from rural diffuse pollution; (iv) insufficient monitoring data in relation to extreme weather events (i.e. flood and low flows) under both DWD and WFD; and (v) difficulty in communicating the risk-based monitoring paradigm specific for each parameter to the regulatory community. However, the approach enabled a better understanding of evidence gaps and suggested opportunities for collaborative planning around a shared evidence-base.

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Water quality in peatland environments: the effects of land use change and climate

Oral

Dr. Nadeem Shah [1], ***Dr. Thomas Nisbet*** [1]

1. *Forest Research*

In this paper we describe the effects of land use change (peatland restoration by forest clearance) and climate extremes (storms and drought) on water quality.

Peatland deforestation is occurring in the tropical and temperate zones with implications for ecology, water quality and global warming. In Scotland, climate change concerns and the Scottish Government's Climate Change Plan are driving a number of climate change adaptation measures, including large-scale clearance of non-native coniferous trees from peatland sites; the aims include habitat restoration and protection of soil carbon stocks but there are concerns about the impact of such a rapid change in forest cover on water quality, particularly in terms of dissolved organic carbon (DOC) transport, sediment delivery and nutrient losses. Eutrophication has been reported in local waters supporting sensitive species such as the freshwater pearl mussel following deforestation on peat; the mussel is threatened throughout its Holarctic range and slipping to extinction, placing even greater importance on the need to protect remaining viable populations. In this presentation we present the results from almost ten years of monitoring at Flanders Moss in central Scotland, a 400 ha lowland raised bog that was extensively planted with non-native conifers in the 1960s and 1970s and subject to progressive clearance in the 2010s as the first stage of a peatland restoration programme. Our results show that forest clearance for peatland restoration can significantly affect water quality and that climatic effects play a significant role. We consider the implications of our findings for peatland restoration policy and practice.

We also present data from a long-term study (24 years) where we are investigating the effects of peatland afforestation and forest growth on water quality. A cyclone hit the site in December 2011 and was followed by another violent storm in 2012. The impact of the storms on water quality was remarkable causing changes in water quality not seen in the previous 17 years of monitoring.

Poster Presentations

Aerial detection of plastic pollution in the marine environment with a novel, hyperspectral infrared camera

Poster

Ms. Jennifer Cocking [1], ***Dr. Philip Anderson*** [1], ***Dr. Bhavani Narayanaswamy*** [1], ***Dr. Claire Waluda*** [2], ***Dr. Hugh Mortimer*** [3]

1. *Scottish Association for Marine Science,* ***2.*** *British Antarctic Survey,* ***3.*** *Rutherford Appleton Laboratory*

As the inventors of plastic and the designers of its ubiquitous applications, we – collectively – are impeccably positioned to minimize the consequences of our widespread and persistent pollution of the world's waterways. Our research team is developing a novel, infrared imaging system to detect plastic items in the marine environment, from the air. With this system, we aim to address several remaining challenges consistently highlighted by the plastic pollution research community. An objective tool for detecting and mapping debris reports inherently standardized units of environmental contamination, eliminates bias associated with observation sampling, and removes the need for time-consuming and nuanced preparation, transport, and processing of physical samples. The hyperspectral, infrared camera is sensitive to many more wavelengths of light than a conventional red-green-blue camera, and these infrared wavelengths overlap with those commonly used to distinguish and sort different types of plastic in a commercial recycling plant. In a compact package, this imaging technology can be deployed by unmanned aerial vehicle (UAV), allowing access to remote locations while reducing the cost of survey operations. The Poles are often described as "pristine" precisely due to their distance from large human populations. They may be regarded as valuable indicators or case studies, revealing implications for the rest of the planet. Litter observations and data collected in the Arctic region of Svalbard in 2018 and 2019 will be presented. These results will further inform the technology's development and deployment in Scotland.

An Assessment of the Performance of the PLUS+ Tool to Evaluate WFD Compliance in Scottish Standing Waters

Poster

Dr. Rachel Helliwell [1]

1. *The James Hutton Institute*

Phosphorus is one of the major causes of waterbodies in Scotland being at less than Good Ecological Status (GES) according to the Water Framework Directive (WFD). There are more than 8,000 standing waters in Scotland but only about 330 are routinely monitored to assess compliance with the WFD. To fill this gap, we calculate total phosphorus (TP) in standing waters with the export coefficient tool PLUS+ (Phosphorus Land Use and Slope). Modelled TP values were compared to WFD target concentrations for high, good, moderate, poor and bad status. The PLUS+ tool was applied to 323 monitored catchments and 7,471 unmonitored catchments. The tool was assessed against TP concentrations observed in 2014 and found to perform well in the rural catchments. 51% of standing waters had the same modelled and observed WFD class (i.e. High, Good, Moderate, Poor, Bad), a further 40% of standing waters had a modelled WFD class within one class of observed water quality. The tool performed less well in catchments with larger inputs of TP from urban sources (e.g. sewage). The greatest deviations between measured and modelled classes were explained by the shortage of data from waste water treatment works, fish farms, migratory bird populations, levels of uncertainty in TP measurements and the processes associated with in-loch P cycling. The limitations of the tool were assessed at six case study sites and recommendations for improving model performance are proposed.

Assessing risk from climate change for increasing dissolved organic carbon concentrations in raw water from Scottish drinking water catchments

Poster

Mrs. Carolin Vorstius [1], ***Prof. John Rowan*** [1], ***Dr. Iain Brown*** [1]

1. *University of Dundee*

Increasing trends in dissolved organic carbon (DOC) raise concerns over rising costs for its removal from drinking water, as well as the capability of existing water treatment assets to effectively cope with increasing concentrations. Limited information on changing DOC concentrations and its linkages to climate and land use changes adds complexity for water utilities when planning investment and adaptation strategies. This research investigates the relationships between rainfall, temperature and total organic carbon (TOC) in raw water sources throughout Scotland, and links them to catchment attributes, in order to better understand impacts of projected changes in climate and to estimate effects of land use and the potential benefits of catchment intervention and management. The results lead to a base map of risk that supports the identification of catchments most susceptible to climate and land use changes in terms of increasing DOC concentrations.

Environmental Health challenges in In-formal WEEE recycling: opportunities from local engagement, Port Harcourt, Nigeria.

Poster

Mr. Ogechukwu Okwu [1], ***Dr. Evi Viza*** [1], ***Prof. Andrew Hursthouse*** [1]

1. *university of the West of Scotland*

ABSTRACT

The practice of informal waste recycling is a generic issue across developing countries, due to rapid population growth, and alongside the generation of waste at an unprecedented rate. For example, global annual waste arising from Waste Electrical Electronic Equipment (WEEE) has increased from 33.8 to 49.8 million tons between the year 2010 through 2018. Despite incineration, landfill, and other waste management techniques like, reuse, reduce and recycle (3Rs), dumping of WEEE into water bodies still dominates waste disposal options in developing countries. This act is detrimental to the aquatic eco-system and affects coastline activities against the Blue-Green economy initiative that solely base on sustainable development of the aquatic environment. Many studies have highlighted the increased risk to human health and the environment from poor hygiene and enhanced exposure to potentially harmful substances during Informal WEEE recycling. However, the practice of informal recycling provides an income opportunity for informal WEEE workers and identify with being a net benefit to waste management practices. It also creates a positive contribution to socio-economic development due to weak infrastructure as crude processes are employed to recover valuable materials and precious metals in WEEE generated. Port-Harcourt, one of the fastest-growing city in Nigeria, is facing a high population increase due to influx of migrants from its local communities and neighbouring states, for improved economic status in the oil-rich state of the nation. This urban movement has increased Informal recyclers that dominates the illegal processing of WEEE, which affects the aquatic habitat and challenge to the Blue-Green initiative of the United Nations. This paper will explore the challenges of maintaining a Blue-Green sustainable economy that meets the present needs of the people without jeopardizing the ability of the future generation to meet their needs. Also, improve occupational health and safety of the WEEE stakeholders by engaging Lean techniques which will help reduce risk in informal recycling and opportunity for integration of both sectors for a safe operation.

Keywords

Informal WEEE recycling; hazardous material; health and safety

Evaluation of marine plastic modification methods for enhanced adsorption of inorganic and organic pollutants

Poster

Mr. Huiyi Zhang [1]

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There is growing global awareness of the presence and negative impacts of waste plastic in the marine environment. Many studies have implied that plastics can additionally act as a vector for transport of contaminants [1] [2]. However, the ability of waste plastics to adsorb pollutants suggests a possible application as adsorbents within water and wastewater treatment processes. The adsoprtion of heavy metals (Pb, Cr and Co) and hydrophobic organic contaminants [pentachlorobenzene (PeCB), 2,2',4,4'tetrabromodiphenyl ether (BDE 47), and tetrabromobisphenol (TBBPA)] by plastic rope material was examined. Both new rope and rope recovered from the marine environment were tested. The marine derived samples [polypropylene (PP) ropes] were collected from Scottish beaches around the north and east coasts. Surface modification was carried out by using strong and weak acids (citric and nitric acid) and polyethylenimine as reagents. The results indicated that the marine eroded PP ropes have the capacity to adsorb pollutants from solution. Modification generally improved the adsorption efficiency of organic compounds, and the polyethylenimine treated green plastic gives the best results (removed 49% for PeCB, 88% for BDE 47 and 90% for TBBPA). In the case of heavy metals, untreated rope lakcs significant adsorption affinity and treatment with nitric acid resulted in a product with a lower adsorption capacity, probably as a result of blocking the pores and changing the physical structure of the material. Citric acid treatment slightly improved the adsorption efficiency (removed 18% for Cr, 16% for Co, and 55% for Pb with green colour plastics), while polyethylenimine treatment enhanced the removal efficiency (removed 25% for Cr, 26% for Co and 69% for Pb with green colour plastic). This work suggests that plastic ropes recovered from the marine environment could be a useful resource for the development of materials for removing heavy metals and hydrophobic organic contaminants in wastewater. Further studies will focus on developing products using alternative modification techniques, the identification of adsorption mechanisms and combining traditional filtration material (e.g. activated carbon) with the marine plastic based materials to extend the breakthrough and exhaustion times.

How to determine the absolute surface temperature of a stream using an UAV

Poster

Ms. Eva Loerke [1], ***Dr. Pauline Miller*** [2], ***Dr. Josie Geris*** [1], ***Dr. Ina Pohle*** [2]

1. *University of Aberdeen,* ***2.*** *The James Hutton Institute*

Thermal refuges in streams are becoming increasingly important in consequence of climate change. Typically, stream temperature is monitored by using in-situ sensors. But to address this small-scale spatial variability, higher resolution is needed. A low-cost approach to achieve high spatial resolution are unmanned aerial vehicles (UAV). In combination with lightweight thermal infrared (TIR) sensors they have increasingly being utilized for analysing variations in temperature of water bodies, including rivers and lakes. Though they enable the possibility to measure radiant surface temperature at high spatial resolution (Fig. 1), calibration is essential to obtain geometrically and radiometrically corrected absolute temperature measurements.

This poster adresses the current state of geometric calibration and radiometric correction for UAV-based lightweight TIR sensors. Additionally, it presents a low-cost approach for validating the temperature accuracy of TIR sensors using a thermal (longwave) infrared sensor (Optris® PI-450). The PI-450 is a Focal Plane Array (FPA) based on uncooled microbolometers [1] which has been widely used for a variety of research, including estimations of temperature differences on a lake surface [2] and analysing evapotranspiration of temperate grassland [3]. For this project the PI-450 is mounted on a hexacopter UAV (Matrice 600, DJI) together with an RGB and a multispectral camera. This setup is used in combination with in-situ sensors to evaluate the impact of nature-based solutions on stream surface temperature.

Hydrological and land use controls on microbial water contamination in the southwest China karst region

Poster

Ms. Sarah Buckerfield [1]

1. *University of Stirling*

Faecally contaminated water is the leading cause of waterborne disease, resulting in an estimated 1.8 million deaths world-wide annually. Understanding the spatial and temporal controls on microbial contaminant delivery to catchment drainage systems in the range of land-use and geo-hydrological settings relevant to human water consumption hence requires urgent research attention. This project investigated hydrological and land-use controls on faecal contamination of catchment water resources in the southwest China karst region, characterised by the highest national poverty rates, and covering 20% of China's land area. Karst aquifers have distinctive hydrology and supply 25% of the world's population with drinking water, making them a critical geological setting for understanding and managing microbial water pollution. Using *E. coli,*a well-established faecal-indicator organism as a measure of microbial contamination levels, we performed: (i) long-term monitoring of *E. coli* through seasonal and agricultural cycles across the range of land-use types relevant to this region, and (ii) high-resolution temporal sampling of *E. coli* over rainfall events of varying magnitude at increasing catchment scales. Land-use was found to be the dominant control on *E. coli* contamination levels regardless of spatial position in the karst hydrological system, but rainfall events caused an increase in *E. coli*concentration of 1-3 orders of magnitude in both urban and agricultural settings, and were the key drivers of *E. coli* export from agricultural catchments, particularly when coinciding with manure applications to land. Findings from this research indicate that in order to reduce human exposure to faecally-contaminated water, improvement in treatment infrastructure is required for urban areas, consumption of catchment water resources should be avoided for 3-4 days following rainfall, and that improvements in organic fertiliser management may reduce microbial contaminant export from agricultural catchments.

Sensitivity and uncertainty of petrophysical models for predicting storage heterogeneity from electrical resistivity tomography in poorly productive hard-rock aquifers

Poster

Mr. Jesus Alberto Mezquita Gonzalez [1]

1. *University of Aberdeen*

Weathered/fractured hardrock aquifers are complex, heterogeneous groundwater systems with overall low storage capacity. This work develops a methodology using near surface geophysical techniques Electrical Resistivity Tomography (ERT), Magnetic Resonance Sounding (MRS) and borehole logging to estimate hardrock aquifers' storage properties applying Archie (AR) and Waxman & Smits (WS) petrophysical models, and further assess their sensitivity and uncertainty. The data consists in both surface and borehole hydrogeophysical measurements in a micaschist aquifer in Ireland. In this case study, WS appears as most suitable approach because it allows to account for the significant clay content present in the subsurface as a result bedrock weathering. This property is not accounted for in AR, which therefore largely overestimates the pore space model values [1]. An important finding in this study is the high sensitivity of both models to the cementation factor. WS models are in addition highly sensitive to the clay properties, namely the cation exchange capacity. Consequently, uncertainty analyses determined the higher uncertainty in the deep, high resistivity, massive bedrock zone, with WS being the most affected. A comparison of MRS water content and ERT porosity shows that WS model results fit much better MRS water content measurements while AR model overestimate values. Availability and accuracy of spatial data on the cementation factor and clay properties are key to achieve realistic storage models with high confidence

The Effect of Hospital Wastewater on Pharmaceutical Loads and Water Quality in an Urban Wastewater System

Poster

Ms. Lydia Niemi [1]

1. *Environmental Research Institute, UHI*

Pharmaceuticals are extensively used and introduced into our wastewater where inadequate removal leads to release into surface waters [1]. Hospitals have been identified as a key point-source for pharmaceuticals entering municipal sewers and waterways [2], and rural hospitals are of concern as subsequent treatment may be carried out with smaller, less advanced wastewater treatment plants (WWTP). The possibility of separately treating hospital wastewater is a current topic of discussion for water quality regulators and environmental protection bodies in the UK, but more research into hospital discharge and conventional wastewater treatment techniques is needed. This temporally intensive 'water cycle' study focused on Caithness General Hospital in Wick, Scotland. The main objective was to determine hospital impact on pharmaceuticals entering the local wastewater system, and, to consider the WWTP removal efficiency for the combined hospital and municipal pharmaceutical load. Samples were collected daily for one month to assess water quality and pharmaceuticals in: (i) the untreated potable water supply; (ii) the treated hospital tap water; (iii) the combined hospital wastewater discharge; (iv) the combined municipal WWTP influent; and (v) the final WWTP treated effluent. Target compounds included paracetamol, diclofenac and ibuprofen (analgesics/anti-inflammatories), clarithromycin and trimethoprim (antibiotics), carbamazepine and fluoxetine (psychiatric drugs) and 17α-ethynylestradiol (synthetic hormone). Several of these compounds are of eco-toxicological concern, and are included on water monitoring watch lists in the UK and EU (e.g. *the Water Framework Directive*) [3]. Pharmaceutical concentrations in the hospital discharge and WWTP influent and effluent were in the mid-high ng/L range, with the analgesics/anti-inflammatories and antibiotics quantified in the highest concentrations. WWTP removal efficiency was calculated from the influent and effluent concentrations, and indicated that the conventional treatment techniques employed in Wick are ineffective for pharmaceuticals. Statistical analysis identified significant correlations between water quality parameters, but less between pharmaceutical compounds in the wastewater. Results suggested that the hospital is an important source of select pharmaceuticals entering Wick municipal wastewater, and associated water quality parameters are impacted. These results may inform future decision making on hospital wastewater management. This is the first study to the author's knowledge which investigated water quality and pharmaceutical content in relation to the full-water cycle around a hospital in the UK.

Water and climate feedbacks of common European land use types under warm and dry conditions 2018

Poster

Dr. Alexander Graf [1]

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The year 2018 was characterized by less precipitation, higher potential evapotranspiration, and a larger sum of growing degree days than usual over large regions of Europe. This provides an opportunity to study the feedbacks to expect more frequently under a changing future climate from a landscape originally equilibrated to cooler and wetter conditions. We here focus on feedbacks related to ecosystem services such as atmospheric heating or cooling, CO_2 uptake, and freshwater production. The network of eddy-covariance stations promoted by initiatives like ICOS (www.icos-re.eu) and TERENO (www.tereno.net) is now dense enough to compare these feedbacks between 2018 and previous years. The network spans different locations in Europe that are affected by varying drought intensities and have different land uses such as forest, grassland, crop and wetland. Analysis of these data shows that the sensible heat flux (heating of the atmosphere by the surface) was consistently and considerably larger than usual across the drought-affected sites. Net ecosystem productivity (CO_2 uptake) was considerably reduced on average, but not consistently across all drought-affected sites, and latent heat flux (evapotranspiration) was reduced only slightly on average, with a large variability of both positive and negative changes depending on site. Typical factors enhancing the preservation or even increase of evapotranspiration and productivity, included a usually cool and wet climate, a large reservoir of stored soil or surface water, and perennial vegetation. In contrast, water-limited sites or sites characterized by early harvest of crops in 2018 and a bare soil afterwards, tended to show strong reductions in evapotranspiration and productivity. Despite the opposing changes in absolute evapotranspiration, the fraction of precipitation used for evapotranspiration increased clearly across drought-affected sites. Based on these findings and evidence from cropped sites with and without the application of catch crops after harvest, we discuss the potential of land management to modulate ecosystem service responses to increased temperatures and drought and the resulting trade-offs: Maintaining an active plant canopy and thus evapotranspiration mitigates atmospheric warming both locally through smaller sensible heat fluxes and globally through preservation of CO_2 uptake. However, this comes at the cost of reduced groundwater recharge and surface water discharge.

Carbon

Oral Presentations

Carbon metabolism and blue carbon sequestration potential of seagrass beds across Scotland

Oral

Dr. Irene Olive [1]

1. *University of Glasgow*

Seagrass meadows are recognized as key CO_2 sinks holding a very high ecological and economic value as blue carbon storage sites associated to their productivity [1], [2]. Seagrasses can contribute to counterbalancing greenhouse-gas emissions by increasing carbon stores while providing key ecosystem services to coastal communities [1], [3]. In Scotland, seagrass meadows are considered a key contributor to blue carbon in coastal areas [4].

Seagrass beds occur along the Scottish coast, from the Northern Islands to South Ayrshire, covering a large latitudinal range of environmental conditions. However, at present, a latitudinal evaluation of the carbon sequestration capacity of Scottish seagrass meadows is lacking. This study determined the carbon metabolic status of seagrass communities (*Zostera marina)* in Scotland to estimate their role in carbon sequestration and thus potential contribution to the blue carbon repository of Scotland.

The carbon metabolic status of *Z. marina* individuals was measured following a Scottish latitudinal gradient during Summer 2019 (Orkney (59°00'20.4"N, 3°06'40.9"W), Loch Sween (55°58'58.6"N, 5°39'34.5"W), and Ayr (55°24'13.9"N, 4°45'55.6"W). The carbon metabolic balance was estimated by determining net photosynthesis and respiration of seagrass individuals using in situ incubation chambers. A positive metabolic balance was recorded in all meadows studied indicating a good physiological and metabolic status of *Z. marina*. Different metabolic strategies were detected in *Z. marina* beds across the Scottish latitudinal gradient potentially affecting their role in carbon sequestration and blue carbon storage capacity. The role of environmental forcing and implications on blue carbon sink capacity are also discussed.

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Keywords: blue carbon, Scotland, seagrass

Coastal Blue Carbon Resources: Responding to the Global Climate Emergency

Oral

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1. *University of St Andrews*

Occupying only 0.2% of the ocean surface area, coastal vegetated habitats (including saltmarshes) contribute 50% of global carbon (C) burial in marine sediments. Intertidal saltmarsh habitats bury C at a greater rate and store more C per unit area than their subtidal and terrestrial counterparts. Saltmarshes therefore provide a globally significant climate regulation service by sequestering CO2 through burial and long-term storage of C. Future sea-level rise has the potential to stimulate enhanced C sequestration in saltmarshes, but some important unanswered questions include: What are the key environmental processes that control C accretion in saltmarshes? How do rates of C accretion in saltmarshes vary under different rates of sea-level rise? To what extent will existing saltmarsh C stocks be affected by predicted sea-level rise? We present preliminary data to demonstrate field and laboratory-based approaches that are providing first-order constraints on UK saltmarsh C stocks and highlight the significance of regional gradients in Relative Sea Level history as important long-term drivers of C accretion.

Exploring the Role of Terrestrial Carbon in the Coastal Marine Environment

Oral

Dr. Craig Smeaton [1]

1. *University of St-Andrews*

Fjords are recognized as globally significant hotspots for the burial and long-term storage of marine and terrestrially derived organic carbon (OC). By trapping and locking away OC over geological timescales, fjord sediments provide a potentially important yet largely overlooked climate regulation service. The proximity of fjords to the terrestrial environment in combination with their geomorphology and hydrography results in the fjordic sediments being subsidized with organic carbon (OC) from the terrestrial environment. This terrestrial OC (OC_{terr}) transferred to the marine environment has traditionally be considered lost to the atmosphere in the form of CO_2 in most carbon (C) accounting schemes yet globally it is estimated that 55% of OC trapped in fjord sediments is derived from terrestrial sources [1]. Within the Scottish fjords I has been estimated that 42% and 64% of the C stored in Loch Sunart and Teacuis (Fig.1) respectively originates from terrestrial sources [2]. So is this terrestrial OC truly lost?

Here, we estimate the quantity of OC_{terr} held within Scotland's fjords with the aim of better understanding the recent and long-term role of the terrestrial environment in the evolution of the nationally significant sedimentary OC stores. By understanding this subsidy of OC from the terrestrial to the marine environment we can take the first steps in quantifying the terrestrial OC stored in the coastal marine environment and potentially revise the quantity of terrestrial OC considered lost in current C accounting approaches.

Highlighting the potential of basalt quarry and demolished concrete fines for low-carbon applications: a regional characterisation study.

Oral

Ms. Carla C. Casas [1], ***Dr. Ehsan Jorat*** [1], ***Prof. Joseph Akunna*** [1]

1. *Abertay University*

In the UK, production of aggregates from igneous rocks arrived at 43.7 million tonnes in 2014 (Idoine et al., 2016). Estimated efficiency ratios for aggregate production ranges between 3-40% (Mitchell et al., 2008) producing <4 mm aggregate known as quarry fines. With no current market for the quarry fines, stockpiles remain in quarries, representing 99% of the mining and quarrying sector 'residues'. This by-product remains in an unweathered state and contains large proportion of fine particles, therefore represents a large reactive surface area. Potential uses of Ca-rich basaltic fines comprise atmospheric CO_2 sequestration, soil stabilisation or remineralisation of agricultural soils. We present dissolution experiments on quarry fines materials obtained from five quarries across east Scotland, one quarry from north-east England and, additionally, crushed concrete from a demolished site in Dundee (Scotland) to provide a comparison between rapid element release in solution at low liquid to solid ratio. Selection of quarries was based on bedrock geological description provided by the BGS, where rocks of basaltic composition were targeted. Samples were characterised by their grain size distribution and weathered elements in the cation-enriched solution were determined by ICP-OES. Results show i) an overall preferential release of Na; ii) Ca was the most abundant dissolved element in concrete and three of the six quarry materials and; iii) Mg and Fe (also capable of inorganic CO_2 sequestration) presence in solution were highest in two other quarries. In conclusion, demolished concrete and five out of the six studied quarries qualified for high CO_2 sequestration potential, among other applications.

How does land management influence fire resilience and carbon fate in blanket bogs? The FIRE BLANKET Project

Oral

Dr. Roxane Andersen [1], ***Ms. Paula Fernandez-Garcia*** [1], ***Dr. Paul Gaffney*** [2], ***Dr. Peter Gilbert*** [1], ***Dr. Mark Hancock*** [3], ***Dr. David Large*** [4], ***Dr. Christopher Marshall*** [4], ***Dr. Dan Mayor*** [5], ***Dr. Jason McIlveny*** [1], ***Mr. Don Monteith*** [6], ***Dr. Amy Pickard*** [6], ***Prof. Richard Sanders*** [5], ***Dr. Benjamin Williamson*** [1]

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The soil carbon (C) pool is a significant but disproportionately distributed reservoir in the global C cycle, with northern peatlands holding 30% in only 3% of the Earth's land surface [1]. Maintaining and enhancing their C storage is recognised as an important policy objective towards meeting Greenhouse Gas (GHG) targets [2]. Management interventions can influence both the storage capacity and the vulnerability of the stock to climate-change induced increases in drought frequency and severity, and incidence of wildfires [3]. Destabilisation of the C store can also have negative effects on peatland-derived drinking water supplies and freshwater habitats. Quantification of these interactions is vital in informing best management practice. However, it is also challenging because of the ephemeral nature of some threats and the usual paucity of high quality ground-based observations within an area of interest capable of providing the necessary pre-impact and control data.
Following a dry and warm spell in spring 2019, a wildfire burnt approximately 60 km^2 of blanket bog in May 2019 within the Flow Country peatlands of North Scotland (Figure 1). Unlike other wildfires in the UK, it covered a large area that includes peatlands under a range of management regimes: drained, drained and afforested, under restoration (through forestry removal and drain blocking) and near-natural. As well as the breadth of management types, the fire covered an area of the Flow Country that is actively used for scientific research, where a wide range of prior data are available. This presented an unprecedented and urgent opportunity to quantify the interacting effects of fire, drought and human interventions on peatland C storage and water quality. Here we present our new NERC funded FIRE BLANKET project, which as three main objectives:

- To estimate the immediate C losses and the fire resilience of blanket bogs under different management regimes, including afforestation
- To understand legacies of fire on the fate of the vast C store held in the peat and on the water quality by determining how the interplay between management and burning severity alters the post-fire fate of dissolved organic matter, water quality and aquatic C exports from land to sea.
- To develop future-proof management strategies for drained and afforested blanket bogs

By introducing the range of methods deployed to complement existing datasets and early findings, we hope to stimulate conversation and highlight opportunities for future work and new collaborations.

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HOW WATER POTENTIAL SHIFTS DRIVE THE PHYSICAL PROTECTION OF CARBOON IN SOIL

Oral

Ms. RONG QU [1], ***Prof. Paul Hallett*** [1]

1. *Institute of Biological & Environmental Sciences, University of Aberdeen*

Compared to studies focusing on carbon chemistry or biological processes, much less research has explored physical mechanisms that protect carbon in soil, with most past studies imposing drastic wet/dry cycles or not controlling water potential effectively during incubation. We argue that the extent of the water potential shift, or maximum drying of the soil, is a major determinant in the physical stabilization of carbon in soil. This has major implications to the concept of priming, as deep roots will dry soils more, so any priming effect may be offset by greater physical protection. Topsoil and subsoil of a sandy loam soil were amended with a decomposable organic residue (green barley powder), incubated for 5 days before being dried under very controlled conditions to either -5kPa, -20kPa and -50kPa water potential. Some samples were rewetted to -5kPa, to investigate whether hysteresis of hydrological and mechanical properties increased with added organic residue. Novel small-scale testing methods measured the mechanical properties Hardness and Elasticity, and the hydrological properties of water sorptivity, ethanol sorpotivity, water repellency and water retention. We found that for soils not amended with organic residue that the water potential had a large impact on hydrological and mechanical behavior. However, returning soils to -5 kPa from more negative water potentials showed no hysteresis. Organic residue amendment caused water repellency increased in topsoil while remained unchanged in subsoil, no hysteresis was found. These findings suggest that previous research that controlled water potential poorly did not induce an unexpected artefact and that moderate changes to water potential have little influence on the physical stabilization of newly added organic residues to soil.

Inputs of leaf and root litter from an advancing arctic treeline species accelerate tundra soil decomposition

Oral

Dr. Jens Subke [1], ***Dr. Tom Parker*** [1], ***Dr. Christian Knoblauch*** [2], ***Ms. Ilona Kater*** [3], ***Prof. Philip Wookey*** [1]

1. *University of Stirling,* ***2.*** *University of Hamburg,* ***3.*** *University of Durham*

Increasing temperatures in the Arctic are causing the advance of deciduous tree and shrub species onto the tundra. Tree growth will increase ecosystem litter production, leading to an expectation of carbon (C) accumulation in the soil. However, treeline forests often store less soil C than adjacent tundra [1]. We added ^{13}C-labelled leaf and root litter as well as ^{13}C-labelled litter derived leachate (dissolved carbon) from the treeline-forming *Betula pubescens* to forest and tundra soil in northern Sweden in order to test whether they increased the decomposition of extant soil C. Addition of all forms of input (leaf litter, root litter and leachate C) increased the loss of C from tundra soils in the form of respired CO_2 and dissolved organic C. We demonstrate a clear positive priming effect, whereby fresh C input from trees stimulates microbial activity and soil C decomposition. Our result challenges expectations that treeline expansion will result in net C sequestration in the Arctic.

Interactions between ice shelves, sea ice and primary production in the Southern Ocean

Oral

Mr. Andrew Twelves [1], ***Dr. Daniel Goldberg*** [1], ***Dr. Sian Henley*** [1], ***Dr. Dan Jones*** [2], ***Dr. Matthew Mazloff*** [3], ***Prof. Raja Ganeshram*** [1]

1. *University of Edinburgh,* ***2.*** *British Antarctic Survey,* ***3.*** *Scripps Institution of Oceanography*

Interactions between ice shelves, sea ice and primary production in the Southern Ocean

A.Twelves[a], D. Goldberg[a], S.Henley[a], D.Jones[b], M.Mazloff[c], R Ganeshram[a]

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Primary production in the waters around Antarctica plays a large role in the sequestering of atmospheric CO2, an important process to consider in future climate projections. Mesoscale iron enrichment experiments have shown that phytoplankton blooms in much of the Southern Ocean are iron-limited [1], whilst remote sensing has shown a pattern of large blooms occurring close to fast melting ice-shelves [2]. This has led to the suggestion that meltwater plumes are carrying glacial iron into coastal polynyas (regions persistently free of sea-ice) and thus fuelling high net primary productivity (NPP). However the mechanism underlying this transport of iron is still poorly understood, as sources from glacial meltwater compete with the melt-driven upwelling of iron from Circumpolar Deep Water (CDW) [3]. Furthermore both ice shelves and sea ice are sensitive to global carbon cycles via oceanic and atmospheric warming. Together these complex feedbacks between climate, cryosphere and NPP will dictate the future viability of the Southern Ocean as a carbon sink. In this work the Biology Light Iron Nutrients Gases model (BLING) [4] is used within the MIT general circulation model (MITgcm) to study the response of phytoplankton blooms to iron from different sources, as well as to changes in ocean optics due to high chlorophyll concentrations. It is shown that glacial iron is able to stimulate a higher peak in NPP without necessarily leading to an increase in annual productivity, and that self-shading plays a large role in limiting phytoplankton growth rates. Furthermore, sensitivity studies conducted by changing boundary conditions demonstrate that changes both in CDW properties and in surface irradiance can lead to large changes in productivity.

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Keywords: Antarctica, phytoplankton, feedbacks,

Modeling Dynamics in Solids: From Origin of Life to Modern Challenges

Oral

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- What interactions are key for retaining carbon in soils?
- Why some solvents are better at creating "high-surface" materials?
- How pollutants can be captured and retained by layered minerals?
- What was the pivotal reaction turning geochemistry into biochemistry on the early Earth?

These seemingly unrelated questions share a common feature – they rely on specific physiochemical interactions between small molecules and soil-forming minerals.
Molecular modelling is a powerful tool allowing us to rationalise existing data and produce testable hypotheses. Within this talk, on examples from my recent work [1-6], I will demonstrate how the development and application of computational techniques enables providing key information about large-scale processes occurring on our planet. I anticipate this talk will introduce molecular modeling on minerals to wider public and enable fruitful interdisciplinary conversations.

Quantifying Marine Sedimentary Carbon Resources: a new spatial analysis approach using seafloor acoustic data, imagery, and ground-truthing data in Scotland

Oral

Mrs. Corallie Hunt [1]

1. *University of St Andrews*

The coastal environment plays a key role in the global carbon (C) cycle acting as a C sink and thus providing an important climate regulation service. Marine sediments are the repository of sinking particulate organic matter effectively burying organic carbon (OC) over geological timescales. Fjords are shown to be global hotspots for C-burial [1] due to their geomorphology and proximity to land, trapping large inputs of sedimentary material before it can be transported offshore. A full sedimentary C-stock estimate of Loch Creran, a Scottish fjord, showed a significant long-term store of C from combined marine and terrestrial sources [2]. However, the spatial distribution of this C store was not considered. We have used a recent multibeam echosounder (MBES) survey, taken at Loch Creran on the west coast of Scotland, to develop a new methodology for predicting the distribution of OC in surface sediments (upper 10 cm). The acoustic backscatter data show a heterogeneous seabed implying a variable depositional environment and therefore C storage potential. Leveraging known relationships of backscatter as a predictor of sediment type [3] and sediment type as a predictor of OC storage [4], we show that acoustic backscatter could be used as a proxy for OC storage. Using an integrated approach, we combined MBES survey, video imagery and ground-truthing data to improve the spatial mapping and quantification of OC contained within Loch Creran's surficial sedimentary store. We have produced a high-resolution spatial map of sedimentary OC across the survey area and have used this to calculate a well-constrained 10 cm surface stock of OC. This initial work shows that high resolution MBES surveys have the potential application in identification of OC hotspots enabling consideration of this vulnerable sedimentary resource in seabed management, planning and climate mitigation strategies.

Rapid mineralization of natural CO2; a hope for climate mitigation?

Oral

Dr. Domokos Gyore [1], ***Dr. Csilla Király*** [2], ***Ms. Dóra Cseresznyés*** [3], ***Dr. Zsuzsanna Szabó-Krausz*** [4], ***Dr. Ágnes Szamosfalvi*** [5], ***Dr. György Czuppon*** [6], ***Dr. György Falus*** [5], ***Dr. Csaba Szabó*** [3], ***Prof. Finlay Stuart*** [1]

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Carbon capture and storage has the potential to remove 10^9 t CO_2/yr and thus stabilise atmospheric CO_2 concentrations until global energy production stops relying on fossil fuel burning [1]. Underground reservoirs provide safe and secure means of storing CO_2 on 10's kyr time scale, the mineralization of injected CO_2 as carbonate results in its permanent removal. Precipitation of injected CO_2 is governed by the availability of carbonate-forming cations (Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Na^{+}), consequently, basalts and saline sedimentary formations are suitable hosts for this purpose. While mineralization of injected CO_2 is thought to require 10s kyr [1], recent studies have shown that the mineralization of 10^2 t CO_2 in basalts occurs over a few years [2]. It is therefore timely that large CO_2 volume fields are studied in order to better understand how CO_2 is mineralised to allow industrial scale CO_2 storage.

The Mihályi-Répcelak field (NW Hungary) contains 22 Mt CO_2 derived from late Miocene magmatism. Commercial extraction of 10^5 t CO_2/yr in the last decade makes it the largest industrialised onshore natural CO_2 field where CO_2 is retained in a saline formation. Extensive carbonate, primarily dawsonite [$NaAl(CO_3)(OH)_2$] mineralisation in the CO_2 reservoir implies ideal conditions for mineralization of the magmatic CO_2 exist [3,4]. Thermodynamic geochemical modelling implies that carbonate precipitation is linked to the recent decrease in reservoir pressure making the Mihályi-Répcelak field an exceptional opportunity to study CO_2 mineralization. The isotopic composition of CO_2 and He of commercially-extracted gases in 2010 [5] and 2017 shows a significant loss of CO_2 from the gas phase in 7 years. Typically, $CO_2/^3He$ ratios and $\delta^{13}C_{CO2}$ decrease with time. Change of this magnitude cannot be due to changes in reservoir parameters or CO_2 dissolution in normal pH groundwaters. They are the first indication that gas geochemistry can be used to identify the loss of free CO_2 to solid carbonate phase over human timescales. This is supported by changes in groundwater chemistry and changes in the CO_2 production. Clearly large amounts of CO_2 are being mineralised more rapidly than previously thought simply by reduction of reservoir CO_2 pressure.

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Keywords: Carbon Capture and Storage, mineral storage, gas isotope geochemsitry

Scotland's blue carbon: understanding the loss of carbon from decaying seaweed

Oral

Mr. Alasdair O'Dell [1], ***Prof. Michael Burrows*** [1], ***Dr. Pippa Moore*** [2], ***Dr. Ian Davies*** [3], ***Dr. Daniel Smale*** [4], ***Prof. John Baxter*** [5]

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The term 'blue carbon' refers to the carbon sequestered by organisms in oceanic and inter-tidal habitats, mainly by photosynthetic autotrophs [1]. There is growing interest in the potential for blue carbon to offset anthropogenic CO2 release. A significant contribution from seaweed to long-term carbon storage has been suggested [2], but the processes which govern sequestration of seaweed carbon are multi-faceted and key areas remain unexplored. Detrital production can be high from seaweed beds, with some studies showing up to 82% of net primary productivity (NPP, on average 45%) is lost as detritus in exposed areas [3]. Scotland's seaweed may produce up to 1.73 MtCyr-1, mostly from kelp forests on open coasts and lining deep fjord systems where organic carbon rapidly accumulates in sediments [4],[5]. This detritus is also transported away from the shore before making its way below the deeper 'carbon sequestration horizon'; the depth at which dissolved or particulate carbon from seaweed is considered sequestered. After loss from living plants, carbon in seaweed detritus in the ocean is (i) transformed into smaller particles, (ii) ingested by grazers or detritivores, (iii) produces dissolved inorganic carbon from respiration during decay (re-mineralization) and (iv) loses dissolved organic carbon through exudation and cell lysis [6]. By incubating detached fragments of the dominant seaweed species in West Scotland, this study aims to measure rates of decomposition and the loss of dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) from seaweed in seawater. Preliminary results show the mass of solid material decreases during incubation and DOC release is greater than DIC (see below).

The overall aim of this study is to better understand these processes of carbon loss between detachment of plants and eventual burial in sediments, and thereby clarify this component of the blue carbon cycle.

Spatiotemporal dynamics of methane and carbon dioxide in an urban river

Oral

Mr. Chao Gu [1]

1. *University of Glasgow*

Rivers are a significant conduit for carbon (C) transport and transformation. Most rivers are a source of carbon to the atmosphere as either methane (CH_4) or carbon dioxide (CO_2) with greenhouse gas emissions from fluvial systems accounting for a significant proportion of annual global emissions. It is crucial to identify the sources and controls of fluvial CH_4 and CO_2 emissions as climate induced hydrological change continues.

The River Kelvin flows through several different land use types (e.g., hills, grassland, pasture, forest, urban centres), draining an area of roughly 352 km^2. Variable land use types make the Kelvin River catchment an ideal natural laboratory to understand land use controls on fluvial carbon transport. Weekly sampling is being undertaken at Kelvingrove Park in the catchment's urban centre, where close (1.2 km) to the River Clyde Estuary, discharging a terrestrial C load into the marine environment. So far we understand that 1) the mean concentration of dissolved CH_4 ($[CH_4]$) at the temporal study site was 209 ± 78 nM while the mean $\delta^{13}CH_4$ was -50.4 ± 4.9 ‰, the mean dissolved CO_2 ($[CO_2^*]$) was 49 ± 15 µM while the mean $\delta^{13}CO_2$ was -18.2 ± 3.71 ‰, and the mean dissolved inorganic carbon (DIC) was 1.49 ± 0.60 mM while the mean δ^{13}C-DIC was -16.1 ± 2.22 ‰, respectively; 2) fluvial CH_4 and CO_2^* are oversaturated with respect to atmospheric equilibrium and the River Kelvin plays a role of C source of efflux to the atmosphere; 3) the positive correlation between CH_4 and CO_2^* reveals that fluvial CH_4 and CO_2^* may share similar sources or drivers across the temporal gradients, for example, CH_4 and CO_2^* from groundwater-derived and organic carbon degradation; 4) area-scale source or serval source exist in the flowing path of the River Kelvin and keep high gas concentrations in upstream, landfills appear to be the major one, and thus, the C emissions from landfills have been underestimated. The thorough knowledge of not only C emissions from surface rivers but also the potential impacts of land use types, for example, landfills, to the atmosphere through rivers is needed for the C emission control policy development.

Stable isotope study of a natural CO2 occurrence in the Pannonian Basin

Oral

Ms. Dóra Cseresznyés [1], ***Dr. Csilla Király*** [2], ***Dr. György Czuppon*** [3], ***Dr. Attila Demény*** [3], ***Dr. Csaba Szabó*** [1], ***Dr. György Falus*** [4]

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CO_2 capture from industrial activities and its storage in a geological formation is becoming more and more important in recent years because the concentration of CO_2 is continuously increasing in the atmosphere in relation with anthropogenic emissions. In order to ensure the long-term safety of the geological storage of CO_2, it is necessary to know the geological environment, and possible physical and chemical reactions within the reservoir resulting due to the CO_2 flooding.

Prior to CO_2 flooding the water is in equilibrium with the reservoir. During and following the CO_2 flooding into the geological reservoir, some of the CO_2 is dissolved to the water phase causing its pH to decrease. Therefore, some minerals (e.g. carbonates, alumosilicates) will dissolve and some will reprecipitate (carbonates, clay minerals). Among the new minerals, the most important is the dawsonite as it is sensitive to the large CO_2 inflow. Moreover, in the reservoir carbonate minerals, which formed before the CO_2 flooding can be also found. Therefore, these carbonates need to be distinguished from the carbonate minerals formed by the CO_2 flooding. The study of natural CO_2 reservoirs can help to understand and predict the processes, which likely take place in a geological CO_2 reservoir on geological time scale and characterize the minerals formed due to the CO_2 flooding. This was the reason to chose the best-known natural CO_2 occurrence in the Pannonian Basin located in the Mihályi-Répcelak area (the Little Hungarian Plain, Western Hungary). The studied reservoir rock is a sandstone that consists of detrital (quartz, feldspar, mica, dolomite, calcite, metamorphic and clayey rock fragments) and diagenetic minerals, mostly carbonates e.g. calcite, ankerite in two generations, siderite and dawsonite.

In order to distinguish the different carbonate generations and to determine their origins and the conditions under which they were formed, stable isotope (C, O) analyses have been conducted on siderite and dawsonite separates. In case of dawsonite, the hydrogen isotopic composition of structural OH^- was also determined. Using the obtained isotopic values and appropriate fractionation factors the $\delta^{13}C$ values of CO_2 in equilibrium with dawsonite, siderite as well as the $\delta^{18}O$ values of water in equilibrium also with these carbonates were calculated. The $\delta^{13}C$ values of CO_2 in equilibrium with siderite indicate that the dawsonite and siderite formed during different diagenetic processes. The CO_2, which was present during the formation of dawsonite, had magmatic origin, whereas the porewater likely had meteoric origin and the oxygen isotopic composition was probably modified during the water-rock interaction.

Keywords: CCS, stable isotope, dawsonite

The Carbon Balance of Permafrost Ecosystems

Oral

Dr. Lorna Street [1], ***Dr. Tom Parker*** [2], ***Dr. Jens Subke*** [2], ***Prof. Philip Wookey*** [2]

1. *The University of Edinburgh,* ***2.*** *University of Stirling*

Permafrost soils store large amounts of carbon – about 1300 billion tonnes – roughly two to three times the total carbon stored in trees worldwide. Thawing and warming of permafrost soils will likely stimulate decomposition of this stored carbon, resulting is CO_2 and methane release. Carbon loss from permafrost soils therefore represents an additional anthropogenic source of greenhouse gases to the atmosphere.

Unfortunately there is still a huge amount of uncertainty over how serious carbon losses from permafrost ecosystems might be. As soils warm, plant growth in northern latitudes is also expected to increase, and this could potentially offset some of the carbon losses from soil. Recent large-scale modelling studies suggest net carbon losses by 2100 of between 10 billion and 100 billion tonnes[1]. Estimated emissions budgets for achieving a 1.5°C warming target generally fall around 100 - 200 billion tonnes[2], so potential carbon feedbacks from permafrost ecosystems will be important in determining whether or not the 1.5°C target is met.

In this talk I will review our current understanding of the likely climate feedbacks arising from carbon loss from permafrost ecosystems, and discuss the key uncertainties. I will present results from experimental studies in the Arctic which suggest that current model estimates are missing an important process, meaning that carbon losses from permafrost ecosystems may be greater than currently expected. I will also attempt to address the question: what more is needed to accurately predict carbon cycling in permafrost systems?

The influence of seagrass on sedimentary characteristics and the role this could play in carbon sequestration in Scottish seagrass meadows

Oral

Ms. Dani Whitlock [1], ***Prof. Mark Huxham*** [1], ***Dr. Gillian Mackinnon*** [2], ***Prof. John Baxter*** [3]

1. *Edinburgh Napier University,* ***2.*** *Scottish Universities Environmental Research Centre,* ***3.*** *Honorary Professor, School of Biology, University of St Andrews*

Seagrass meadows are ecologically and economically important habitats that have most recently been recognised as globally significant carbon sinks, but much remains unknown about how the habitat traps carbon and how seagrass meadows can be managed to preserve and enhance this ability (Burrows et al., 2017; Nellemann et al., 2009). A carbon stocks assessment of Scottish seagrass sediments has established: a) that most Scottish seagrass meadows, in common with seagrass elsewhere, show significantly enhanced sediment carbon storage compared with areas where seagrass is absent and b) there are large differences between sites that are not explained simply by the presence or absence of seagrass (Potouroglou et al., in prep).

With the majority of carbon stored within the sediment below seagrass rather than the biomass itself it is important to understand the role of sedimentary characteristics, including grain size and sediment stability of seagrass beds, could play in promoting the storage of carbon.

This talk focuses on the sedimentary characteristics of seagrass meadows versus adjacent bare mudflats, including grain size and sediment stability and explores the influence of these sedimentary characteristics on carbon sequestration in seagrass meadows.

Tree planting on deep organic soils leads to significantly increased soil respiration and net loss of ecosystem carbon in Scottish heather moorlands

Oral

Ms. Nina Friggens [1], ***Prof. Alison Hester*** [2], ***Dr. Ruth Mitchell*** [2], ***Dr. Tom Parker*** [1], ***Dr. Jens Subke*** [1], ***Prof. Philip Wookey*** [1]

1. *University of Stirling,* ***2.*** *The James Hutton Institute*

Increased tree planting is proposed by the Scottish government[1] to combat climate change through carbon (C) sequestration in tree biomass. However, this change in vegetation, whilst increasing aboveground C sequestration, will also modify belowground microbial communities, thereby changing decomposition mechanisms, with potential cascading effects on soil C storage and turnover. In Scottish heather moorlands, which are rich soil C stores[2], this change in microbial communities may lead to altered decomposition and loss of stored soil C to the atmosphere as CO_2. Using plots of native deciduous (*Betula pubescens*) and coniferous (*Pinus sylvestris*) trees experimentally planted onto Scottish moorland (*Calluna vulgaris*) twelve and 39 years previously, we found increased soil respiration and significant loss of soil C below planted trees, not compensated for by increased tree biomass. This evidence indicates that, despite the many other recognised benefits of tree planting, whole ecosystem C, both above and below ground, must be taken into account when deciding where to plant trees in order for this climate mitigation strategy to contribute positively towards Scotland's target of net zero CO_2 by 2050.

Poster Presentations

Aquatic carbon export in the year immediately following restoration of a drained afforested blanket bog

Poster

Dr. Paul Gaffney [1], ***Dr. Roxane Andersen*** [1], ***Dr. Mark Taggart*** [1], ***Dr. Mark Hancock*** [2]

1. *Environmental Research Institute, University of the Highlands and Islands,* ***2.*** *RSPB*

The riverine transport of aquatic carbon from land to ocean is a major pathway within the global carbon cycle. Peatland catchments are a particularly important contributor to this due to their significance as terrestrial carbon stores. This study determined concentrations and export of aquatic carbon from a drained afforested blanket bog catchment undergoing drain blocking and conifer removal (termed forest-to-bog restoration), and from an open bog catchment and an afforested catchment (predominantly planted with conifers). Using a before-after-control-impact (BACI) design, we found no significant increases in concentrations or export of aquatic carbon (DOC, POC or DIC) in the first year following forest-to-bog restoration. However, increased DOC concentrations were observed in the first summer (2015) post-restoration, and seasonally increased DOC export was noted during storm events in the autumn of the same year. The lack of significant effects of forest-to-bog restoration on aquatic carbon export (across the whole restoration period) may be a consequence of the small proportion of the catchment (12%) undergoing management. Further restoration planned in future may lead to cumulative effects on aquatic carbon that should be monitored. In terms of management, the harvesting/removal of stems and brash from the site may help to mitigate effects on aquatic carbon, by removing a potential DOC and POC source.

Assessing the Influences of Demersal Trawling on Sedimentary Marine Carbon Stores

Poster

Ms. Kirsty Black [1], ***Prof. William Austin*** [1]

1. *University of St Andrews*

Shelf and coastal seas hold vast quantities of sedimentary carbon which contribute to atmospheric carbon dioxide removal and long-term storage. However, the stability and resilience of this key component of global natural capital remains poorly quantified, particularly under anthropogenic stressors. Demersal trawling activity is the most significant cause of anthropogenic disturbance to the seabed, leading to massive sediment resuspension events and wide scale impact to benthic communities. The impacts of trawling on benthic ecosystems and biodiversity are well reported and understood within the literature (e.g. [1, 2]); however, a knowledge gap remains regarding the post-trawl fate of sedimentary carbon. We hypothesise that the large-scale resuspension events caused by trawling may contribute towards an enhancement in localised carbon cycling, and thus a reduction in the net carbon storage within these sediments. We also hypothesise that these resuspension events may lead to sediment sorting due to differences in the settling velocities of sediment grain sizes. Using a closed tank system, a series of controlled incubation experiments mimicking the effects of benthic fishing were conducted over a 21-day period. The aim of this experiment was to better understand the biogeochemical processes which occur in marine sediments during massive resuspension events, with a particular emphasis on the fate of resuspended organic carbon matter and its potential vulnerability.

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Burn Hillfort Burn, Dun Deardail Inferno

Poster

Ms. Amanda-Jane Dolan [1], ***Dr. Clare Wilson*** [1], ***Dr. Christian Schroeder*** [1]

1. *University of Stirling*

Arthur C. Clarke called vitrified hillforts "One of the greatest mysteries of humankind" and today much about them remains a mystery [1].

Vitrified hillforts are timberlaced, stone-built structures, with ramparts over four meters thick by three metres in height. These ramparts consisted of two outer walls, comprised of boulders, encasing a rubble core with timber interlacing, which were subject to a fire of such a temperature that the walls have welded together. The interior space of Dun Deardail measures 46 x 27 metres at the widest points and would have been Inhabited with numerous wooden structure thatched huts. These hillforts have been mainly built in the Iron Age, with most dated to between 2500 – 2000 years ago with many showing reuse throughout history. There is a general population of these hillforts thinly spread over much of continental Europe, however, they are mainly concentrated in mainland Scotland and so are often referred to as a peculiarly Scottish phenomenon [2].

This melting and fusing of rock needed temperatures in excess of 1000□C and even though Iron Age people had great knowledge and skill with fire and smelting, this rock melting on a huge scale would not have been an easy task using Iron Age technology. There have been several attempts to recreate this vitrification phenomenon in the field in modern times, however none have been particularly successful.

Vitrified hillforts are a hugely contentious issue in Scottish archaeology, and it has been debated whether the rocks were melted as a constructional process or whether the vitrification was a by-product of a destructive process either accidentally or deliberately by hillfort occupiers or by an opposing army. This research seeks to determine the provenance of the materials used in the construction process and the temperature and conditions under which the rocks in the hillforts melted.

Laboratory analysis has concluded that the temperature of the melt at the vitrified hillforts examined was in the region of 1100-1200°C and, using data from p-XRF, SEM-EDS and experimental furnace melting, evidence will be presented about the temperature and conditions of vitrification and the constraints that rampart geology has on the vitrification process.

There are still many questions regarding the geological processes of vitrification. This poster seeks to discuss the comparison of Scottish vitrified hillfort sites and attempt to answer some of the hot questions Scottish vitrified hillforts.

Fertiliser optimisation for the growth of oil palm (Elaeis guineensis) seedlings in the main nursery

Poster

Mr. Longwin Sii [1]***, Dr. Yit Arn Teh*** [2]***, Dr. Lip Khoon Kho*** [3]

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As one of the world's largest palm oil producer, Malaysia exported approximately 24.27 million metric tons (MMT) of palm oil products in 2011. The rise of the palm oil industry has driven a rapid increase in the use of fertilisers to hasten the growth of oil palms (Elaeis guineensis). High levels of nitrogen (N) fertilisation are normally carried out to improve crop yield, but almost 28 – 50% of N is often lost via gas flux (including volatilisation) after application. Addition of composts as a soil amendment has the potential to reduce the cost of chemical fertiliser addition. This nursery study was conducted to investigate the growth of oil palms seedlings in a nursery with different fertiliser combinations. Six different combinations of fertilisers were added to the main nursery oil palm seedlings every month: compost A (cma), compost B (cmb), NPK compound fertiliser (cp45), urea, compost A and cp45 mixture (cma.cp45), and compost B and cp45 mixture (cmb.cp45). Seedlings treated with cmb.cp45 had an increased RGR at 0.020 ± 0.007 g d-1 up until the second harvesting round and subsequently a slowed but still higher RGR rate than other treatments at 0.010 ± 0.002 g d-1. The total biomass of seedlings treated with cmb.cp45 was 1.3 ± 0.3 kg, which was up to 4.5 times higher than the other treatments, with 83.6% biomass accumulated aboveground, while 16.4% of plant biomass was accumulated belowground. The LAI of the seedlings with cmb.cp45 applied was 5.00 ± 1.52 m^2 m^{-2}, though the SLA was not statistically different from other treatments. R:S ratio of the seedlings treated with cmb.cp45 was the lowest at 0.2 ± 0.1. Overall, the performance of the treatments ranked in descending order was: cmb.cp45 > cma.cp45 > cp45 > urea > cma = cmb. We recommend that inorganic fertilisers should be used in conjunction with organic fertilisers to better improve the growth of crops.

How to get your research into the Scottish Parliament

Poster

Dr. Damon Davies [1]

1. *The Scottish Parliament*

On 25 September 2019, the Scottish Parliament passed the Climate Change (Emissions Reduction Targets) (Scotland) Bill, endorsing some of the most stringent statutory greenhouse gas emissions reduction targets in the world, aiming for net-zero by 2045.

The Bill also sets new interim targets for greenhouse gas emissions reductions of 75% by 2030 and 90% by 2040.

The Scottish Government has undertaken to definitively end the nation's contribution to climate change within a generation by making a just transition to a low carbon economy, and the Scottish Parliament has a key role to play in ensuring that this happens.

The primary role of the Scottish Parliament is to scrutinise the Scottish Government. Parliament staff need access to relevant and timely evidence as well as an awareness of key policy issues and will draw upon many sources, including academic expertise.

Over the coming decades, expert knowledge in Geoscience and the environment, and society's interaction with the Earth's natural systems will be crucial to holding the Scottish Government to account on its climate change targets. It will also be key to providing practical solutions to transitioning to a low carbon economy.

The Scottish Parliament Information Centre, or SPICe as it's commonly referred to, is the Parliament's internal research hub and provides an impartial information and research service to MSPs, MSP staff, and other Parliament staff including Committee Clerks. SPICe is staffed by information and subject specialists who need to be aware of key policy issues in their subject areas. SPICe provides a range of engagement opportunities for academics to engage with SPICe colleagues and the wider Parliament.

This poster presentation provides some tips from SPICe on how to get your research into the Scottish Parliament.

Investigating the fate of organic material in Scottish coralline algae beds

Poster

Ms. Kelly James [1], ***Ms. Francesca Necci*** [1], ***Prof. John Baxter*** [2], ***Dr. Ian Davies*** [3], ***Dr. Heidi Burdett*** [4], ***Dr. Nick Kamenos*** [1]

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Blue carbon (carbon stored in marine ecosystems) has been recognised internationally as part of the solution for slowing down atmospheric carbon dioxide increases [1]. Blue carbon plays an important role in the natural carbon cycle, with the per-unit contribution of coastal habitats to long-term carbon storage significantly higher than terrestrial forests [1].

Coralline algal (CA) beds are globally distributed, ecosystem engineers [2,3]. As CA beds can store large quantities of blue carbon over millennia, they are effective blue carbon stores [3,4]. Organic carbon, which is stored in the sediments of CA beds, can either come from the bed itself (e.g. in species that live within the bed), or from outside the bed (e.g. seagrass and kelp fronds from coastal systems) [4]. The amount of organic carbon stored within a CA bed is determined by several factors including how easily broken down the material is. Currently, there is little information regarding the degradation of organic material in CA beds. Understanding this would give a better understanding of the current and future role of CA beds in the global carbon cycle.

This study investigated the breakdown of labile (easy to break down) and refractory (hard to break down) carbon compounds in CA beds. Two sets of experiments were run – the first using green tea (labile) and rooibos tea (refractory) as a standardised carbon source [5], and the second using kelp (labile) and seagrass (refractory) as natural sources of carbon known to be found within CA beds. For each experiment, organic material was added to CA beds in porous bags and left for 3 days. Over this time, the total oxygen uptake was measured as a proxy for the breakdown of carbon compounds [6].

The timing of maximum breakdown varied with the type of organic material added to the CA beds. Both green tea and kelp were broken down rapidly within the first 24-36 hours before returning to background levels. Seagrass was also broken down, though not as rapidly as green tea and kelp. Rooibos tea was not broken down during the experiment, likely due to its refractory nature [5]. By the end of the experiment, green tea, kelp and seagrass decreased in mass by 15-37%, with a large proportion of carbon remaining once bacterial activity had returned to background levels.

The results suggest that CA beds are effective carbon sinks and have an important role in the natural carbon cycle. Although the initial increase in labile carbon breakdown was rapid, a large proportion of material was not broken down and could, therefore, be buried in the CA beds via sedimentation. Furthermore, the results suggest that two common carbon sources in CA beds, kelp and seagrass, are more labile than refractory by nature. Further work is needed to establish the environmental variables driving the breakdown of organic material in CA beds. This would allow accurate predictions to be made of the role of CA beds in carbon drawdown in a changing climate.

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MICP and Geotechnical Engineering: Modelling Approach

Poster

Mr. Harry Eggo [1], ***Dr. Cornelia Doerich-Stavridis*** [1], ***Prof. Carl Schaschke*** [2], ***Dr. Ehsan Jorat*** [1]

1. *Abertay University,* ***2.*** *university of the West of Scotland*

Microbial Induced Calcite Precipitation (MICP) is a ground improvement technique that utilises naturally occurring chemical reactions to change soil properties [1]. A modelling approach has been developed to quantify the extent of improvement MICP processes have on soils, with the aim of creating a numerical model to investigate the effectiveness of real world applications, specifically combatting internal erosion in earth dams.

Reservoirs provide water for essential activities such as irrigation, human consumption, and production of hydroelectricity. A long-standing problem is vulnerability to seepage-induced internal erosion, with internal erosion-induced collapse the third most important mode for earth dam failure in the UK [2]. Investigations into MICP, to combat erosion control, in sand-clay soils have shown potential to reduce susceptibility to erosion [3].

Using input parameters such as soil type and concentration of chemicals, MICP treatment is initially related to a change in permeability of soil. A new methodology has then been used to estimate how changes in permeability relate to changes in geomechanical parameters (used in Hardening Soil Model); aided by experimental data obtained through geomechanical testing which drive data fitting techniques.

By computing predictions of settlement using new modelling techniques and comparing them against empirically recorded settlement values, it was determined how accurately the model performed. A comparison showed good agreement at critical points in the prediction of deformation of samples under loading. Precise predictions for geomechanical parameters are usually within 20% accuracy. Further, prediction of final settlement values on treated samples that have undergone loading falls between 10% - 15%.

The model, in conjunction with finite element tools used in engineering software Abaqus, has then been applied to investigate the impact of applying MICP to an existing embankment located in Castel San Vincenzo, Central Italy [4]. Preliminary results indicate that the application of MICP results in performance improvement and reduced deformation when subjected to standard operating parameters, such as the normal loading induced by water.

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Keywords: MICP, Dams, Geomechanical

Reliance on Fossil Fuels in the Scottish Public Sector

Poster

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The consumption of fossil fuels from energy creation is the most significant contributor to human induced climate change, [1] however fossil fuels remain the most dominant of energy sources, whilst the use of renewable energy is growing at a slow rate, [2]. International action in tackling climate change has led to increased pressures to measure, record and report carbon footprints. The public sector has a key role to play in reducing emissions and increasing uptake of renewable energy technologies.

The study aims to investigate and present findings from an exploratory study on the reliance on fossil fuels in Scotland 's public sector with focus on Universities and Local Government Authorities. A multi-method qualitative study approach is employed, using information gathered from a literature review, case study, and thematic analysis of semi-structured interviews with sector professionals.

The case study developed a carbon footprint baseline for a School at the University of the West of Scotland. Electricity was the greatest contributor of overall emissions followed by travel, and over 45% of all emissions resulted from fossil fuel sources through road travel, air travel and gas use in buildings. These findings are in line with findings of similar studies [3], [4]. The thematic analysis of semi-structured interview responses resulted in five key themes namely: 'evidence of ongoing reliance on fossil fuels', 'efforts to reduce fossil fuel use', 'actions required to reduce reliance on fossil fuels', 'barriers to moving away from fossil fuels' and 'carbon reporting'. The use of fossil fuel energy sources in buildings for space heating, cooling, and electricity, and its persistent reliance for transportation, evidence reliance on fossil fuels, [5], [6]. Government and organisational initiatives, and the uptake of renewable and low carbon energy justify efforts to reduce fossil fuel use however, a zero-carbon energy revolution, reduced energy consumption and carbon offsets, and financial instruments and governance are further required. Lack of funding and support, practicalities and cost implications, and lack of an alternative energy source to replace fossil fuels are sub themes highlighting the main barriers to moving away from fossil fuels. Difficulties in estimating accurate carbon emissions associated with procurement, reducing emissions associated with staff mileage and influencing staff travel behaviours are also highlighted, in line with studies highlighting difficulties in estimating Scope 3 emissions, for example, [7].

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Keywords: carbon footprint, fossil fuels, public sector

The Mobilisation of Pyrogenic Carbon via Savanna Riverine Ecosystems: Preliminary Indications of a Dynamic System.

Poster

Dr. Adrian Bass [1], ***Dr. Philippa Ascough*** [2]

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Quantifying and characterizing the global stocks of carbon is critical to establish comprehensive baselines upon which to base future measurements and projections. Pyrogenic carbon (formed through incomplete combustion of organic material) is an underexplored carbon cycle component yet represents one of the most important potential long-term carbon stores. Savanna ecosystems are pyrogenic carbon hotspots, exposed to regular cycles of burning and thus understanding the formation and subsequent processing / relocation of pyrogenic carbon here is of importance.

Fluvial relocation of pyrogenic carbon is a critical unknown, with debate over whether its export is coupled or decoupled from other non-pyrogenic components. Further, how this export potentially changes depending on source vegetation (grass vs. tree) is to be elucidated. This study details results from a preliminary survey of dissolved and particulate pyrogenic carbon export in a mixed vegetation savanna catchment in South Africa. Preliminary data indicates a complex system where dissolved pyrogenic carbon export is decoupled from other DOC export under different flow conditions and indicates a potentially higher propensity for grass-derived pyrogenic carbon to be exported during higher flow events. This has implications for long-term carbon storage in savanna catchments in systems that are globally shifting to more tree-dominated.

The Public Perception and Value of Scottish Saltmarshes and their Potential for Climate Change Mitigation

Poster

Ms. Simone Riegel [1]

1. *University of St Andrews*

Saltmarshes are unique coastal habitats, located in sheltered coastal areas including estuaries, the heads of sea-lochs, and behind barrier islands. It is known that they provide many ecosystem services, such as flood defence and biodiversity support and there is a growing understanding of their potential for carbon sequestration and storage. Flooding by diurnal tides causes low oxygen conditions in the associated soil, which aids long-term carbon sequestration and storage within this Blue Carbon habitat. Carbon from external sources such as terrestrial run-off is also trapped by saltmarsh vegetation. Due to these conditions, saltmarshes are area by area more effective carbon stores than terrestrial forests (MacLeod et al. 2011). These recent scientific advances on the role of saltmarshes for carbon storage are not yet significantly reflected in the Scottish climate change mitigation policy. This interdisciplinary project aims to address an opportunity to include Blue Carbon in climate change policy by investigating the amount and potential for carbon storage in Scottish saltmarshes and determining the Scottish population's management preferences for these coastal habitats. The results from this research will inform policy recommendations for future saltmarsh management.

To get a better understanding of the carbon stored in Scottish saltmarshes, we have collected soil cores from the Loch of Stenness and Waulkmill Bay saltmarshes on Mainland, Orkney and the Nith and Wigtown saltmarshes in Dumfries and Galloway. This data will be supplemented with data from future sites and with secondary data. In order to draw policy recommendations that align with the general public preferences, we investigate the perceptions and values associated with saltmarshes. Petrolia et al. (2014), for example, have found that the coastal wetlands are valued most for supporting fisheries and for the storm protection and wildlife habitat they provide. To address the question of the perception and value associated with the carbon storage ecosystem service provided by Scottish saltmarshes, we ran a series of focus groups and interviews on Mainland, Orkney in spring and in Dumfries in summer 2019, respectively. We find that saltmarshes are perceived and valued as providers of flood defence, recreation, and biodiversity services, while the carbon storage service remains mostly unknown to participants. However, one participant indicated they had learnt about the carbon storage service through a popular BBC television programme, which demonstrates a rising visibility of this service.

The next steps of this projects are to implement a larger scale questionnaire with a representative sample of the population to investigate whether our preliminary results are generalisable. We will investigate preferred policy strategies and the role of carbon storage in these preferences in a choice experiment, which will enable us to draw conclusions about whether rising awareness on the role of saltmarshes in storing carbon has the potential to increase public support towards saltmarsh protection policies.

The focus of this poster is on the data from the Orkney saltmarshes as well as on the focus groups and interviews and how they inform the following stages of the research.

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Keywords: Blue Carbon, Ecosystem Services Valuation, Policy

Planetary Wellbeing

Oral Presentations

Climate change and mental health: new emotional geographies

Oral

Prof. Hester Parr [1], ***Dr. Ian Shaw*** [1]

1. *University of Glasgow*

What kinds of feelings emerge individually and collectively as climate change transforms our lives? What are the psychic, social and political implications of those feelings? What kinds of ideas, theories and practices need to be in place to respond to these new kind of emotional geographies? In this paper, we set out a philosophically informed argument for engaging in questions of *climate change, emotions and mental health* using interdisciplinary literatures. We draw critical attention to new popular ideas about 'eco-anxiety' and 'ecological grief' but in order to locate such categories in particular places and societies. We discuss a local example from Glasgow – the International Green Academy – to examine how models of educational practice can transform ecological anxieties into spaces of hope.

Delivering evidence to inform policy and practice: people and planet responses to the wellbeing of people working within nature

Oral

Prof. Lorna Dawson [1]***, Dr. Charles Bestwick*** [1]

1. *SEFARI Gateway*

Delivering evidence to inform policy and practice: people and planet responses to the wellbeing of people working within nature

Prof. L Dawson and Dr C Bestwick

SEFARI Gateway

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We are intrinsically linked to our Planet. There would be no people without a planet. However, if people no longer survive, the planet will still likely exist. People rely on the very earth they stand on for provision of their good food, clean water, fresh air, a platform for housing and transport, energy supply and many aspects of our diverse culture.

Examples from SEFARI and across the Scottish Government Strategic Portfolio, will be presented, illustrating how and where the current global climate and biodiversity emergency issues are being addressed, through a better understanding of the interplay between the wellbeing of people and our planet. Evidence will be provided showing clear links between the wellbeing of people, nature and climate - from the physical, natural sciences and from social and economic studies. Greenspace, peatland restoration and ecosystem services provision in the uplands will be featured.

With a climate emergency now recognised, we must act quickly and adapt policy and practice. With a rapidly reducing biodiversity it is a critical time to provide the evidence required for the best action to be taken. Co-operation across knowledge networks, collaboration and partnership working, forging common ground and understanding, is vital, and examples will be discussed of how SEFARI (through SEFARI's knowledge and impact centre, SEFARI Gateway), is forging new partnerships to ensure Scottish Government funded research expertise is best placed and responsive to deliver multiple benefits. We will illustrate how strategic research can help us to act effectively and efficiently in developing the most appropriate policies and innovative practices to achieve our long-term goals for the benefit of both current and future generations. Effective strategies such as implementation of resilient management in woodlands and tools for conservation of endangered species will be discussed.

Through a better understanding of the links between nature and wellbeing we will be able to make a step change to systems, narratives, mind-sets and behaviours. Examples from the context of farming, food, environment and the countryside will be presented – from changing local community opinions through direct community participation, catchment management solutions to deal with erosion and biodiversity loss, through to climate solutions in agriculture and in the provision of sustainable food choices.

Keywords: biodiversity, climate, evidence, greenspace, participation, people, policy, practice, research, sustainable food uplands, wellbeing, woodlands

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Ecosystem Services Bundles in Urban Areas: Planning our Green Spaces for Multiple Benefits

Oral

Ms. Nada Saidi [1], ***Prof. Chris Spray*** [1], ***Mr. Andrew Allan*** [1], ***Dr. Rebecca Wade*** [2]

1. *University of Dundee,* ***2.*** *Abertay University*

The contribution of green spaces to urban sustainability and well-being, through the ecosystem services (ES) they provide, is increasingly recognised by researchers and practitioners alike [1]. However, the lack of an integrated assessment methodology showing the interlinkages between the multiple urban ES, may lead to missed opportunities to act on synergies between ES or to avoid trade-offs. The concept of bundles of ES, i.e. ES consistently associated together, has been useful in uncovering and visualising such interactions – but very few bundle approaches have been designed for urban areas and none include an assessment of the extent to which findings could actually be taken up by planners and managers [2].

With this presentation, I intend to share some results from the implementation of a bundle approach in the City of Edinburgh. Nine ES, including three directly contributing to the mitigation of and adaptation to climate change (namely carbon storage, temperature regulation and run-off retention) were selected and their provision mapped at data zone scale. The application of statistical clustering techniques identified five bundle types corresponding to five clusters of data zones exhibiting different levels of synergies (see figure).

The potential value of this approach for decision-making will be illustrated by presenting the key drivers for the formation of bundles as identified using regression analyses, and by showing preliminary insights from consideration of deprivation data. An outline of current research efforts to investigate how such an assessment could be integrated into urban decision-making will also be included in the presentation.

[1] Mcphearson, T., Andersson, E., Elmqvist, T. & Frantzeskaki, N. (2015). Resilience of and through urban ecosystem services. Ecosystem Services, 12, 152-156

[2] Saidi, N., & Spray, C. (2018). Ecosystem services bundles: challenges and opportunities for implementation and further research. Environmental Research Letters, 13(11), 113001

Keywords: ecosystem services, synergies, decision-making

Green Health Partnerships in Scotland, delivering health benefits for people and nature

Oral

Dr. Rebecca Wade [1], ***Dr. Viola Marx*** [2]

1. *Abertay University,* ***2.*** *NHS Tayside*

The environment we live and work in has a fundamental impact on our health and wellbeing. Natural environments within our landscapes, including those that are managed, farmed and urban are important components of 'healthy places' with a role in promoting, maintaining and restoring good health, and preventing poor health. Greater use of the outdoors can contribute to improving public health, tackling health inequalities and improving wellbeing.

In Scotland we recognise that the natural environment and associated green infrastructure is an important and undervalued asset for improving societal wellbeing and public health. Improvements in public health can be gained by increasing physical activity through green exercise - outdoor recreation, volunteering, play and learning, gardening and active travel. Wellbeing benefits can be gained through enhanced contact with good quality natural and green/blue spaces even without physical activity.

Green Health Partnerships in Scotland have been established for over a year. They are supported by multiple national and local organisations and take a cross-sector approach to joining-up nature and health. This talk will provide an overview of the first full year of operation of Our Natural Health Service in Scotland, which has been delivered via four local green health partnerships. The partnerships are based in Dundee, Lanarkshire, North Ayrshire and Highland region. They are developing green health services which support people to engage with the natural environment and be more active more often outdoors. Each partnership has taken a unique approach to delivery. This heterogeneous approach has developed within the local partnerships and is necessarily specific to the geographical and community conditions in their areas. The partnerships have required and achieved collaboration and collective action. Supported nationally by Scottish Government, Scottish Natural Heritage and The NHS in Scotland, there are many others involved at local level who are critical to the successful delivery of green health agendas.

We will provide an overview of the 'Our Natural Health Service' programme within Scotland, but will provide a more detailed focus on the mechanisms for delivery within the Dundee Green Health Partnership. In exploring the progress of the initiative we will highlight challenges and opportunities that have arisen, including the roll-out of Green health prescriptions in Dundee GP surgeries, and how the increased focus on green space for health may impact green space provision and maintenance.

Improving wellbeing through Urban Nature: a vision for the future?

Oral

Prof. Anna Jorgensen [1]

1. *University of Sheffield*

Improving well-being throughout the nature (IWUN) was a three year interdisciplinary research project investigating the relationship between health and well-being and natural environments in the city of Sheffield, and exploring how to harness the benefits of nature more effectively in local services. We identified many opportunities for boosting population health and well-being, and especially mental-health, e.g. through the planning design and management of urban parks and green spaces and urban areas more generally. However we also encountered a number of challenges sitting at the complex interfaces between austerity politics and complex and siloed forms of governance and service provision. This talk will explore opportunities for implementing the IWUN findings in spite of these challenges. It will look at areas of structural and infrastructural change, challenge and possibility, including transport and travel, housing, health and social care, integrative place-based approaches, climate change and extinction rebellion. The aim of the talk is to identify the opportunities that exist to provide healthier environments benefiting people and planet and provide impetus and inspiration to grasp those opportunities.

One Health Breakthrough Partnership- reducing environmental harm from pharmaceuticals in the Scottish Highlands using a multifaceted upstream approach

Oral

Ms. Sharon Pfleger [1]

1. *NHS Highland*

Context Plastic in our oceans has come under the spotlight in the Blue Planet programmes and is now on everyone's radar across the world. However the pollution of our environment by pharmaceuticals (medicines) is invisible. Medicines enter the waste water system by human excretion, inappropriate disposal and production processes. The prescription of a medicine is the commonest intervention in healthcare and use is increasing every year. Inevitably environmental harm will also increase. Waste water treatment plants (WWTP) are not currently designed to remove all medicines from the water. Even the most efficient treatment solutions leave 10% in the water. More than 600 pharmaceuticals and metabolites have been found in the environment worldwide in water, soil and sludge and now in drinking water, fish, livestock and vegetables and increasing antimicrobial resistance.... and may have deleterious effects on human health too. Aim To ensure that we minimise the volume and impact of environmentally hazardous medicines entering the water with a multi-faceted approach. Methods • A unique collaboration with key public partners - One Health Breakthrough Partnership- to drive forward practical changes across all sectors. • Working towards the Alliance for Water Stewardship (AWS) standard for good water stewardship (due Summer 2019) in Caithness Hospital. • Considering prescribing choices to minimise

Poster Presentations

A baseline study to understand water quality and the waste water treatment cycle in Caithness General Hospital.

Poster

Ms. Sharon Pfleger [1]

1. *NHS Highland*

Author 1 NHS- prepared the abstract submission and is a founding partner and the health service lead for the One Health Breakthrough Partnership (OHBP) seeking to reduce env harm initially by tackling pharmaceutical pollution, but also Antimicrobial resistance and vet medicines. No conflicts of interest. Authors 2,3,4 (ERI)- carried out the water sampling and prepared a report on findings as part of a tripartite project between NHS (Pfleger), HIE (Duncan) and ERI and founding Gibb is a founding partner of OHBP. No conflicts of interest. Author 5 (Duncan) - founding partner of OHBP. Work of OHBP part funded by HIE. No conflicts of interest.

HOT: Hadal zones of our Overseas Territories

Poster

Ms. Heather Stewart [1], ***Dr. Alan Jamieson*** [2]

1. *British Geological Survey,* ***2.*** *Newcastle University*

HOT: Hadal zones of our Overseas Territories is a multi-disciplinary program that will deliver a step-change in our understanding of the fundamental ecological and geological processes in the South Sandwich Trench (SST). The SST reaches water depths of 8266 m ±13m at a location known as Meteor Deep, named after the German research vessel who first sounded it in 1926, and uniquely is the only sub-zero hadal environment on Earth. This Darwin Plus (Round 7) funded project will improve understanding of marine biodiversity and geodiversity to fill an identified knowledge gap supporting the existing Marine Protected Area and obligations under the Convention of Biological Diversity.

The South Georgia and the South Sandwich Islands Marine Protected Area (MPA) is one of the largest MPAs on Earth covering >1 million km^2 and includes the SST. Predicting trench habitats and their fauna cannot be extrapolated from shallower systems as they exhibit stark ecotones and abrupt changes in geology, making MPA management at depths >6000m at best difficult. The MPA is designed to ensure the protection and conservation of the region's rich and diverse marine life, whilst allowing sustainable and carefully regulated fisheries.

Key outcomes of the 5-year review of the MPA (November 2017) included: a need to enhance bathymetric knowledge around the region; recognition there is a lack of data on the abyssal and hadal ecosystems; that more information is needed on assemblages versus biodiversity, ecosystem processes and function; and general information on how to record long-term change to factors such as climate change.

This project will make use of high-resolution bathymetric maps of the South Sandwich Trench acquired using the latest generation full-ocean-depth EM124 by the Five Deeps Expedition (www.fivedeeps.com). These data form a primary dataset for geological and geomorphological analysis and provide the context for research into the biological communities of these deeps. With the newly collected invertebrate samples from the SST, this project will utilise specimens of scavenging amphipods including: new species from the genus *Hirondellea, and Bathycallisoma schellenbergi.* These species are model species for understanding the historical and present connectivity of the hadal zone and its effects on speciation. The remoteness and uniqueness of the low temperatures and high pressures of the South Sandwich Trench makes these recent findings highly important in resolving ultra-deep sea speciation on a large geographical scale.

Looking beyond biomass: How do species view their environment?

Poster

Mr. Euan McRae [1], ***Dr. Neil Banas*** [1], ***Prof. Geraint Tarling*** [2], ***Prof. Eugene Murphy*** [2], ***Dr. Douglas Speirs*** [1]

1. *University of Strathclyde,* ***2.*** *British Antarctic Survey*

In the future oceanic primary production is projected to change and impact the biomass and structure of marine ecosystems, [1]. Earth system models allow us to gain an insight into where and how such changes will be seen. However, biomass alone does not tell the full story: the impacts of changing primary production on keystone and flagship species - such as krill, seals and whales – depend as much on the quality and availability of their food as the biomass.

Population models which describe how species interact with their environments help to fill this gap. One such model for zooplankton, coltrane [2], resolves individual life history strategies, population dynamics and community composition. Zooplankton play a key role in marine food webs, in some cases forming a direct link between primary production and species at the highest trophic level. By describing how temperature and prey influence key life history traits throughout an individual's life, coltrane provides an insight into how zooplankton view their environment and, in turn, how they are likely to respond to future changes.

Coltrane has been applied in multiple testbeds throughout the Arctic, sub-Arctic and Antarctic to resolve copepod communities. Results from the Antarctic suggest that the timing of prey availability is equally as important – if not more – to the success of copepod populations as the magnitude of their prey. In future work, the coltrane model will be adapted to resolve a wider range of zooplankton species, particularly Antarctic krill.

Securing reactive nitrogen for high value food and feed production in integrated bioremediation and energy generation systems

Poster

Dr. Georgina Robinson [1]

1. *Scottish Association for Marine Science*

Nitrogen has been identified as one of the drivers of global food insecurity and climate change, therefore proper nitrogen management will be critical to feed a growing global population subject to short-term environmental shocks and long-term environmental change. Current inefficiencies of nitrogen use occur at multiple levels within the aquaculture and agriculture production chain leading to net nitrogen loading in the global nitrogen cycle and constituting a major threat to the sustainability of the planet in terms of reactive nitrogen pollution. The current paradigm to deal with the accumulation of reactive nitrogen, is to close the loop in the nitrogen cycle, by converting reactive nitrogen back to its inert form as N_2gas, leading to the emission of nitrous oxides that contribute to global warming. This research in this UKRI Future Leaders Fellowship will challenge the current paradigm to close the loop in the nitrogen cycle, by offering a more economically and environmentally sustainable alternative to closing the nitrogen cycle loop.

The fellowship will address global challenges in agriculture and food security (AFS) research by developing integrated waste treatment, protein production and energy generation systems to treat nitrogen rich waste from land-based intensive agriculture and aquaculture systems. These ecologically-driven systems are designed to harness the synergistic and concerted actions of microbial communities and deposit feeding invertebrates, to re-use and up-cycle N-rich waste into high value protein for human food (sea cucumbers) and alternative protein sources (polychaetes and earthworms) for agro-industry and provide a sustainable source of bioenergy by operating as soil/sediment microbial fuel cells (SMFC). The systems will be scalable, transferable and adaptable to a range of different environments and industries. During the course of the fellowship, the systems will be developed in tropical (Mauritius) and temperate (UK) environments, in marine (aquaculture) and terrestrial (agriculture) environments. These low-tech systems offer a simple, low cost option to diversify production in the agro-industry sector, increase revenue, and reduce environmental impacts and greenhouse gas emissions in the UK and lower income tropical countries. Furthermore, the large-scale dissemination and adoption of this technology has the potential to correct imbalances in the global nitrogen cycle and secure food and feed production systems for generations to come.

The Fragile Cryosphere

Oral Presentations

AntArchitecture: An international project to use Antarctic englacial layering to interrogate stability of the Antarctic Ice Sheets

Oral

Prof. Robert Bingham [1], ***Mr. Julien Bodart*** [1]

1. *University of Edinburgh*

"AntArchitecture" is a new Action Group of the Scientific Committee for Antarctic Research that aims for the first time to determine the stability of the Antarctic ice sheets over past glacial cycles directly from the internal architecture of the ice. Internal architecture describes the 3D internal structure of the ice imaged by multiple radar-sounding surveys undertaken across Antarctica over the last five decades.

Determining the stability of different parts of Antarctica is crucial because there is mounting evidence that collapses of polar ice sheets fed rapid global sea level rise up to 9 m higher than today during the last interglacial period, ~127-116 ka. In this context, the volume and current behaviour of ice in Antarctica give cause for concern: both the West Antarctic and East Antarctic ice sheets (hereafter WAIS and EAIS respectively) contain sufficient ice to raise global sea levels by 58 m. Since the onset of satellite observations in the 1990s, both have lost mass. Present losses from the WAIS contribute an estimated 10% of observed global sea-level rise, are occurring at ever-increasing rates, and appear to support the longstanding hypothesis that the WAIS is "unstable"; in other words capable of diminishing rapidly with concomitant impacts on global sea levels. There is also a growing awareness that parts of the EAIS may also be as unstable as parts of the WAIS. There is, therefore, a pressing societal imperative to assess the (in)stability of both the WAIS and EAIS, thereby to gauge how rapidly future changes to both of these ice sheets will contribute to future global sea-level rise.

An expanded outline of AntArchitecture and its timeline of activities can be accessed here: https://www.scar.org/science/antarchitecture/about/

This presentation provides a status report of activities and achievement of AntArchitecture to July 2019.

Arctic Education – Past Successes and Future Possibilities

Oral

Prof. Finlo Cottier [1]

1. *Scottish Association for Marine Science*

With a new policy relationship developing between Scotland and its Arctic neighbours, there is need and a mandate to develop opportunities in Arctic education. Mobility of students and staff in the pursuit of enhanced learning about the Arctic acts to bind us more closely with Arctic nations, as the network and experiences of the alumni grow. A workforce that has experienced life in the high north, with contacts and connections in the north, is well placed to support Scotland's future relationship with the Arctic. This talk will highlight some examples of where Scotland is providing unique opportunities for Arctic education with the public, undergraduates and postgraduates. It will describe opportunities through the University of the Arctic and give case studies exploring the benefits of Arctic educational experiences.

Cold Ice in a Warm Bath? Warm proglacial lakes and rapid retreat of a lake terminating Arctic glacier

Oral

Mr. Adrian Dye [1], ***Dr. David Rippin*** [1], ***Dr. Rob Bryant*** [2]

1. *University of York,* ***2.*** *Univesity of Sheffield*

Glaciers in contact with proglacial lakes show accelerated mass loss rates through mechanical and thermal processes, particularly through thermal undercutting of the ice front. As glaciers retreat from their Little Ice Age maxima (~100 years ago) and respond to increasing air temperatures (Arctic Scandinavia: cf. July 2018) they often develop proglacial lakes, which can be an important store of freshwater. However, the prevalence, status and role of proglacial lakes in Arctic glacial systems have received relatively little attention. As a consequence, despite significant increases in air temperatures, a common assumption persists that proglacial lakes remain at 1^{o}C.

We present the first recorded proglacial lake temperatures and time lapse imagery (2017 and 2019) from the front of an actively calving Arctic glacier, which rapidly lost 10,523m^2 of ice (0.67% of area in Randolph Glacier Inventory, 2008) between 2014 and 2018. We present temperature observations directly from the ice front in July 2017 derived from the innovative use of thermal infrared imagery, supplemented by several detailed thermistor temperature surveys (using an ASV). We present a 10-day temperature record directly from the calving front from July 2019, with temperatures up to 5^{o}C and frequent calving events throughout the melt season. Furthermore, day time maximum proglacial lake surface temperatures of 8^{o}C were recorded during the fieldwork in 2017 and surface skin temperatures of 8^{o}C have also been observed in ASTER satellite 2014 thermal image analysis at this lake.

We also present a very strong relationship between thermistor data of lake surface temperatures and surface skin temperatures from ASTER satellite data (R^2 = 0.9365). Thus, demonstrating that ASTER satellite data can be used to retrieve lake temperatures in remote areas. At the regional scale, analysis of AST08 data demonstrate that 11 out of the 12 largest proglacial lakes in Arctic Sweden had daytime surface skin temperatures of >4^{o}C (maximum 14^{o}C) in August 2014 and all 12 proglacial lakes were >4^{o}C in July 2018.

Previous melt models for lacustrine terminating glaciers have been compromised by a lack of data from the hazardous water to ice contact point and assume a uniform temperature of 1^{o}C. We provide a solution to this limitation of previous melt models, with a series of temperature datasets that are vital in calculating future lacustrine glacier retreat rates with predicted climate change. The temperatures reported by this study are substantially warmer than expected from an Arctic proglacial lake, which also raises questions as to how this will affect ecology in river catchments downstream. Combined with rapid thermal undercutting and associated calving, this study provides the first direct evidence of proglacial lake temperatures directly impacting on the rapid retreat of an Arctic glacier.

Inter-decadal climate variability induces dichotomous ice response along Pacific-facing West Antarctica

Oral

Dr. Frazer Christie [1]

1. *Scott Polar Research Institute*

West Antarctica has experienced dramatic ice losses contributing to global sea-level rise in recent decades, particularly from Pine Island and Thwaites Glaciers. Here, we derive the first comprehensive inter-decadal record of glacier retreat around West Antarctica's Pacific-facing margin and compare this dataset to contemporaneous estimates of ice flow, thinning and the state of the Southern Ocean and its atmosphere. Between 2003 and 2015 net glacier retreat and acceleration were extensive along the Bellingshausen Sea coastline, but slowed into the Amundsen Sea. We attribute this to an east-west-graduated weakening of offshore westerly winds, which reduced warm water inflow to the Amundsen Sea ice margin. The along-coast gradient in westerlies is most enhanced in austral wintertime, strongly implicating remote atmospheric forcing from the central tropical Pacific, rather than depletion of stratospheric ozone, as the primary driver of West Antarctic ice losses over the observational period.

This research was supported by a SAGES Postdoctoral & Early Career Research Exchange (PECRE) enabled visit to the University of Washington, and the later award of a SAGES Small Grant.

Observing the Cryosphere with millimetre wave radar: The case study of Rhone Glacier

Oral

Mr. William Harcourt [1], ***Dr. Duncan Robertson*** [1], ***Dr. David Macfarlane*** [1], ***Prof. Brice Rea*** [2], ***Dr. Matteo Spagnolo*** [2]

1. *University of St Andrews,* ***2.*** *University of Aberdeen*

Improving our understanding of the processes governing mass loss from the cryosphere is inhibited by a lack of data at high spatial and temporal resolution. Satellite sensors can provide regional to global scale coverage of glacier processes but fail to resolve processes that occur rapidly, for example glacier calving. To observe these processes, the glaciology community must invest in new techniques that can monitor these processes adequately and fill this major research gap. Here, we will discuss the implementation of a new technique for observing glacier processes at high spatial and temporal resolution. Ground-based millimetre wave radar is a new surveying modality for imaging topography. Millimetre waves offer a compromise between angular resolution and atmospheric propagation, in which high resolution measurements can be achieved through most weather conditions. In this work, we have used the All-weather Volcano Topography Imaging Sensor (AVTIS) millimetre wave radar to map Rhône Glacier in the Swiss Alps. This is the first time millimetre wave radar has been used to image glaciers. Our aim was to characterise the backscattering properties of glacial ice at millimetre wavelengths for the first time and use this as a foundation for applying this system to other glacier locations. Unfortunately, there exists very little data on the scattering properties of natural terrain at millimetre wavelengths [2] and no data exists on the scattering of glacial ice at these wavelengths. While the dielectric properties of pure ice have been characterised across the electromagnetic spectrum [3], other factors such as surface roughness play an important role in the radar backscatter. This study represents the first investigation into the reflectivity of ice at millimeter wavelengths and the assessment of the utility of millimeter wave radar as a surveying tool. We will report on the future application of this instrument in glaciological studies and the unique perspective it can offer.

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[3] Warren, S.G. and Brandt, R.E. *J. Geophys. Res.,* 2008, 113, D14220.

Predicting mass loss from Greenland's marine-terminating outlet glaciers

Oral

Dr. Tom Cowton [1]

1. *University of St Andrews*

The Greenland Ice Sheet is the largest ice mass in the northern hemisphere, containing sufficient fresh water to raise sea levels by 7m if it were to melt completely. Approximately half the mass loss from the Greenland Ice Sheet during any year occurs through marine-terminating outlet glaciers, which lose ice directly to the ocean through the processes of iceberg calving and submarine melting. In recent decades, the rate of mass loss from Greenland's marine-terminating glaciers has proven to be highly variable, making it one of the largest sources of uncertainty in sea level rise predictions. This talk will report on some of the recent efforts to understand and model the processes controlling the rate of mass loss from these glaciers, and present our best estimates of the likely rate of mass loss over the 21st Century.

Repeat Subglacial Lake Drainage and Filling Beneath Thwaites Glacier, WestAntarctic Ice Sheet

Oral

Mr. George Malczyk [1]

1. *University of Edinburgh*

Active subglacial lakes have been identified throughout Antarctica, offering a window into subglacial environments and into controls on ice dynamics. Between June 2013 and January 2014 a system of connected subglacial lakes drained in unison under the Thwaites glacier in the West Antarctic ice sheet, the first time that such a system has been observed in the Amundsen Sea Sector. Estimates based on catchment scale melt production suggested that lake drainages of this type should occur every 20 to 80 years. We collected elevations from January 2011 to December 2019 over the Thwaites lake region using the CryoSat-2 swath interferometric mode, as well as ice velocity from the Sentinel-1 SAR mission since 2014. Using various elevation time series approaches, we obtain time dependent elevations over each lake. Results indicate that the upstream lakes undertake a second episode of drainage during mid-2017, only 3 years after the previous event, and that a new lake drained. Unlike the 2013-2014 episode, this new drainage episode contributed to filling one of the downstream lake with no evidence of further downstream activity. This new sub-glacial lake activity under Thwaites offer the possibility to explore lake connectivity, subglacial melt production and the interaction with ice dynamics

Risk of Large and Rapid Sea Level Rise from West Antarctica

Oral

Prof. Doug Benn [1], ***Dr. Anna Crawford*** [1], ***Dr. Joe Todd*** [1]

1. *University of St Andrews*

The IPCC *Special Report on the Ocean and Cryosphere in a Changing Climate*[1] highlights increasing risk of extreme sea level situations in the coming decades as a result of melting glaciers and ice sheets. Increased risk exists in all future climate scenarios, but is greatest for the highest greenhouse gas emission pathways. Uncertainty remains high, particularly because of the complexity of ice-dynamical processes where glaciers are impacted by warm ocean currents. This is the circumstance for much of West Antarctica. The West Antarctic Ice Sheet (WAIS) rests on a bed that lies well below sea level, and enhanced melt due to warming oceans causes WAIS outlet glaciers to be vulnerable to a process known as marine ice cliff instability (MICI). MICI initiates when ice cliffs reach such heights that their own weight creates forces that exceed the strength of ice, resulting in collapse of the terminus. This process could become self-sustaining and destabilise large sectors of WAIS. Recent work [2] has raised the possibility that MICI could greatly accelerate rates of ice loss in West Antarctica, with a mean sea-level contribution of 0.64–1.14 m *from Antarctica alone*by 2100 under the highest emission pathway. These results are not included in IPCC sea level projections due to deep uncertainty over the ability of ice sheet models to accurately represent MICI processes. However, the IPCC recognise the possibility that rates of sea level rise "could be considerably higher than the *likely*range projected by models that do not include these processes." [1, ch. 4 p. 39]

As part of the International Thwaites Glacier Collaboration, the DOMINOS project is developing the next generation of computer models to understand MICI processes and predict future rates of ice loss under alternative carbon futures. Our models explicitly represent fracturing and iceberg calving processes, and confirm that ice sheet margins will become unstable if fringing ice shelves are lost and expose high ice cliffs. With increasing ice cliff height, the interval between ice break-up events decreases and their size increases, providing the basis for predicting ice retreat rates in simpler models of the entire ice sheet.

Recent observations indicate that fringing ice shelves in West Antarctica are undergoing rapid disintegration (e.g. Thwaites and Pine Island Glaciers), and that a transition from ice shelf margins to marine ice cliffs may be imminent. There is an urgent need to recognise and understand the potentially large contribution of West Antarctica to 21st C sea level rise, and to build additional sea-level potential into mitigation and adaptation strategies.

[1] IPCC (2019) Special Report on the Ocean and Cryosphere in a Changing Climate.

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Keywords: ice sheet instability, Thwaites Glacier, Antarctica

Scotland and the Arctic

Oral

Dr. Tobias Bolch [1]

1. *University of St Andrews*

Historically, Scotland and the Arctic have been connected by social and cultural ties. More recently, mainly through trade and tourism, economic links have flourished. Some of this is underpinned by the expanding number of scientific and academic partnerships that have developed between Scotland and its Arctic neighbours. Scotland is also excelling in technological innovation to tackle climate change and in environmental protection. There is no doubt that Scotland has considerable expertise across many sectors and is well placed as a valuable partner in Arctic matters. The development of the Scottish Government's Arctic Policy Framework is demonstration of the significance placed on Scottish-Arctic issues in Scotland. This presentation provides an insight into the mapping exercise carried out for the purposes of the Scottish Government's Arctic Policy Framework, highlighting key Scottish Arctic relationships, pointing to Scottish strengths across sectors and exploring avenues for even closer cooperation

The challenges of predicting future sea level rise and its potential consequences for society

Oral

Prof. Jonathan Bamber [1]

1. *The University of Bristol*

Sea level rise is expected to be one of the most serious and damaging consequences of climate change. Despite its importance and potential societal impacts, it has, to date, proved challenging to predict future SLR and, in particular, characterize the plausible upper bounds and probabilities of different projections. This is because the largest uncertainty lies in what the ice sheets covering Antarctica and Greenland may do. Together they have the potential to raise global mean sea level by 65 m. The most recent assessment suggests that a SLR of 2 m would flood land occupied by 630 m people, roughly a tenth of the population of the planet.

What is the probability of a SLR of 2 m by 2100, or sooner? This question has proved difficult to answer because the ice sheets have the longest response time of any part of the climate system, while reliable observations span just a few decades. In addition, several potentially critical processes are poorly understand and/o contested in terms of their role in future trends. Planning for adaptation strategies, however, takes decades. The Thames Barrier, for example, took almost forty years to implement after the devastating floods of 1957.

Various approaches, including Monte Carlo ensemble emulator simulations, probabilistic or plausibility methods, and Semi Empirical Models have been used in attempts to address the gap in our predictive capability. To explore and quantify the uncertainties in ice sheet projections since the AR5, a Structured Expert Judgement (SEJ) exercise - involving 23 experts from North America and Europe - was undertaken in 2018. SEJ is particularly useful for problems that are not readily tractable by deterministic modelling but for which some understanding and limited observations exist. The approach has been used to assess the risk of volcanic eruptions, Earthquakes, spread of vector borne diseases and epidemics. It is particularly useful for investigating the uncertainties in the state of the art and for capturing expert understanding of processes that are poorly known or unobserved: the known unknowns and the unknown unknowns.

The results of the SEJ indicated that estimates, particularly for probabilities beyond the likely range used in the IPCC AR5 (the 17th-83rd percentile), have grown substantially since the AR5. The results indicated a 5% probability that global mean sea level could exceed 2 m by 2100, for a business-as-usual temperature scenario, with the ice sheets contributing 178 cm. Our findings are being used by national and local agencies in coastal and worst case scenario planning. Here, I consider what the results imply about our current understanding, and what the implications of an unlikely, but plausible, SLR of 2 m could be for humanity.

The Changing Arctic Ocean: Implications for marine biology and biogeochemistry

Oral

Dr. Kirsty Crocket [1]

1. *University of Edinburgh*

The Arctic is responding in unknown ways to profound changes in the physical environment as well as to multiple natural and anthropogenic events that place stress on Arctic ecosystems. The scale of the challenges facing the Arctic is immense and is further compounded by the rapid rate of change.

To address the uncertainties generated by climate change in the Arctic Ocean, the UK and Germany have jointly invested £20 million in the research programme ***"Changing Arctic Ocean: Implications for marine biology and biogeochemistry."*** The over-arching goal of this 5-year (2017-2022) flagship programme is to understand how change in the physical environment (ice and ocean) affects the large-scale ecosystem structure and biogeochemical functioning of the Arctic Ocean. The science outputs will address the potential major impacts and refine projections of change for future ecosystem services.

At the core of the programme are four large projects that started in February 2017, funded by the UK Research and Innovation Natural Environment Research Council (UKRI NERC). A further 12 projects joined the programme in July 2018, co-funded by UKRI NERC and the German Federal Ministry of Education and Research. This co-funding of research projects by the UK and Germany represents a first, and brings with it benefits for the programme's international collaboration, access to large-scale research infrastructure, and advantages of shared scientific expertise. The programme has more than 200 scientists, from 32 UK and German research institutions, working with Arctic research teams in 15 other countries to meet the programme's objectives.

The focus of the 16 projects spans many of the effects of climate change on the Arctic Ocean's ecosystem, driven principally by warming and the cascade of impacts from the retreat and thinning of sea ice: e.g. release of chemical pollutants and plastics from melting sea ice; exposure of the ocean's surface to the atmosphere and the release of climate-sensitive gases; alteration of the balance of nutrient concentrations due to ocean circulation changes and the "Atlantification" of the Arctic Ocean; release of soil nutrients and toxins to the Arctic Ocean from permafrost thaw; the impact of surface ocean changes on the seafloor, including carbon sequestration.

With an extensive array and variety of approaches employed to monitor change in the Arctic, the programme is generating substantial datasets that cover physical, chemical and biological parameters of change in the Arctic Ocean. These data contribute to testing and refining outputs in more than 20 different numerical models employed in the programme. These help to predict and quantify how the Arctic Ocean is and will respond to change. Future projections by numerical models are important because they contribute information about likely scenarios that help to refine the decision-making process. In this contribution, I outline the scope of the programme, the focus of the projects, the research questions they are addressing, and how science outputs from the projects support evidence-based policy making.

The Changing Mountain Cryosphere - Why should be care?!

Oral

Dr. Tobias Bolch [1]

1. *University of St Andrews*

The cryosphere (snow, glaciers and permafrost) characterises most mountain regions on Earth. About 250 million people live directly in these mountains and about 1.6 billion live in areas which receive water from the Earth's water towers. Roughly 25% of the Earth's surface is underlain by permafrost while glaciers and ice caps outside the Greenland and Antarctic ice sheets cover about 700,000 km^2
(which is more than three times the area of the UK). Climate change, however, significantly affects the cryosphere. Recent estimates show that the glaciers and ice caps are increasingly losing mass and contributed up to 1 mm per year to global sea-level rise in the recent past (Fig. 1) which is about 25-30% of the total [1, 2]. The remaining 70 – 75% are due to thermal expansion of the Ocean and ice loss from the Greenland and Antarctic ice sheets. Glacier mass changes vary greatly from region to region. Some regions have experienced rapid mass loss, while others have had even positive mass balances in the last decade (e.g. the Western Kunlun Shan) [3]. Even in these regions, however, glaciers will very likely significantly decline until the end of this century and in several mountain regions with smaller low-lying glaciers like in the European Alps almost 80% of the glacierised area is likely to disappear. Snow cover declined over the recent decades especially at lower elevations and the permafrost temperatures increased to record high levels concomitant with receding glaciers and rising temperatures [3]. Besides a significant contribution to past and future global sea-level rise and hence impacting people and infrastructure at the coasts globally, the observed and projected cryospheric changes will also directly and indirectly affect a large percentage of the population living in the mountains and their downstream areas. The timing and magnitude of the river runoff will change with higher flows in the spring due to earlier snow melt and lower flows in summer due to decreasing glacier melt water contribution in the long run. However, initially glacier melt water increases with increasing melt. Considering the water availability and water demand within the large glacierised catchments of the globe, the most vulnerable catchments are located in Asia in regions with low summer precipitation, high population density and high water demand for irrigation such as the Indus and Aral sea catchments. The transboundary nature of these and most of the other large watersheds complicates political solutions to possible water shortages. Further impacts of cryospheric changes are increasing hazards and risks due to destabilising of mountain slopes (especially due to permafrost thaw) and outbursts of glacial lakes which form behind damming moraines when glaciers recede. Especially the latter can also impact larger downstream areas and cause transboundary impacts as the subsequent debris flows and flash floods can reach distances of 100 km or more.

The role of sea ice loss in the Atlantification of the Barents Sea

Oral

Dr. Marie Porter [1], ***Prof. Finlo Cottier*** [1], ***Prof. Randi Ingvaldson*** [2]

1. *Scottish Association for Marine Science,* ***2.*** *Institute of Marine Research, Bergen*

The Barents Sea is a shallow sea (300-500 m), to the north of Norway. It has two contrasting regions, separated by the polar front. To the south is a thermally stratified, Atlantic Water dominated system, with nutrients generally distributed throughout the water column. North of the polar front is a salinity stratified Arctic/Atlantic water column, often overlain by sea ice in the winter. In this region nutrients become limited to subsurface waters after a period of intense utilisation during the spring bloom.

Over recent years it has become apparent that the Barents Sea is a warming hotspot in the Arctic and as such it is rapidly losing ice. The increasing ice melt is thought to increase stratification north of the polar front, increasing its resistance to mixing with deeper nutrient rich waters. We hypothesise that we have now passed a threshold in ice melt and that there is now insufficient ice for this effect to be seen.

Using autonomous instruments to collect data in the Barents Sea, from the polar night through to high summer we show that north of the polar front stratification is reducing and is becoming increasingly dependent on heat input rather than freshwater. This previously Arctic sector of the sea is now becoming more Atlantic and more prone to mixing. The northward progression of these Atlantic conditions is known as Atlantification and has impacts on the local biology from plankton and the benthos through to fish and apex predators.

Poster Presentations

An assessment of the influence of active volcanism on the glacier equilibrium line altitude in the Andes.

Poster

Mr. Jan Jaszewski [1]

1. *University of Aberdeen*

Volcanic activity beneath the ice poses a great socioeconomic hazard and its hydro-glaciological response may drastically influence the security and livelihood of mountain communities, enforcing the pronounce impacts on the ongoing climate change. Clearly volcanic activity might have a profound influence on glacier retreat, stability and viability and until recently the impact of active volcanoes on modern glaciers has been very poorly understood. Direct human access to ice-clad volcanoes is logistically difficult and hazardous, thus remote sensing techniques for undertaking monitoring programs are highly relevant. Understanding the relative sensitivity of the glacier equilibrium line altitude to subglacial volcanic forcing across different climatic regimes along South American Cordillera is investigated. Volcanic activity may have significant impact on glacier stability. It is hypothesized that the ELA of glaciers situated on volcanos (VG) will be higher than non-volcanic glaciers (NVG) in a region due to the higher geothermal heat flux. In this study 51 out of 69 glacio-volcanic centres in the Andes have been analysed along a latitudinal transect of the Andean Volcanic Arc (AVA). The methods used for this project combine various remote-sensing techniques applied in a GIS utilizing the recognized volcanic (Global Volcanism Programme), glacier outlines (Randolph Glacier Inventory 6.0), and heat-flow (American Association of Petroleum Geologists) datasets and eruption activity information in order to determine ΔELA variation between VGs (<1km from the vent) and NVGs (<10km from the vent). This regional study analysed 1001 glaciers (of size greater than 0.3) and calculated their ELA based on assumed BR ratios (1.75), allowing a regional comparison. The ELA has been calculated using RGI outlines and freely available DEMs, using an ELA-calculation-toolbox in ArcGIS. This study presents the regional variation of glacier ELA and volcanic-nonvolcanic ΔELA across Andean Mountain Range (4°N-41°S). The ELA on VGs shows a significant increase from the regional ELA exceeding 800m in north and centre of the region. Regional change of ΔELA is cross-plotted against eruption history geothermal heat flux, in order to determine the controls on ΔELA parameter. This study quantifies the influence of volcanic activity on the ELA of glaciers in the Andes.

Keywords: glaciovolcanism, ELA, Andes

Arctic Productivity in the Seasonal Ice Zone: A Scottish-led contribution to international Arctic marine research and policy.

Poster

Prof. Finlo Cottier [1], ***Dr. Sian Henley*** [2], ***Dr. Bhavani Narayanaswamy*** [3], ***Prof. Keith Davidson*** [3], ***Dr. Kim Last*** [3], ***Prof. Mark Inall*** [3], ***Dr. Callum Whyte*** [3], ***Dr. Marie Porter*** [3], ***Dr. Laura Hobbs*** [3], ***Dr. David McKee*** [4], ***Dr. Neil Banas*** [4], ***Dr. Katharina Lefering*** [4], ***Prof. Andrew Brierley*** [5], ***Dr. Lars Boehme*** [5], ***Dr. Heather Bouman*** [6], ***Dr. Phil Hwang*** [7]

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We are witnessing the emergence of a new ocean to the north of Scotland. Reduced sea ice cover in the Arctic means that the Arctic Ocean is becoming fresher, warmer and more illuminated than ever before. Rather than being perceived as a remote and isolated ocean, the Arctic Ocean plays a critical role for our climate, our weather, and the health of the marine ecosystem. One significant activity that is central to many marine research endeavours are the international partnerships within the Arctic marine research community. Here we highlight the work and contributions of the UKRI funded "Arctic PRIZE", a project within the NERC Changing Arctic Ocean Program that aims to understand how change in the physical environment (ice and ocean) will affect the large-scale ecosystem structure and biogeochemical functioning of the Arctic Ocean. We demonstrate the new understanding we have gained of the extreme seasonality in the Arctic and link between sea ice cover, ocean processes and marine ecosystem function; illustrating the importance and benefits of collaborative alliances with Arctic institutes. We also give examples of where the knowledge within "Arctic PRIZE" has contributed to policy development.

Examining the role of the subglacial topography on dynamic thinning at a large tidewater glacier in the Canadian Arctic

Poster

Mr. William Harcourt [1], ***Dr. Steven Palmer*** [2], ***Dr. Damien Mansell*** [2], ***Dr. Anne Le Brocq*** [2], ***Mr. Oliver Bartlett*** [2], ***Dr. Noel Gourmelen*** [3], ***Mr. Paul Tepes*** [3], ***Prof. Julian Dowdeswell*** [4], ***Dr. Donald Blankenship*** [5], ***Dr. Duncan Young*** [5]

1. *University of St Andrews,* ***2.*** *University of Exeter,* ***3.*** *University of Edinburgh,* ***4.*** *University of Cambridge,* ***5.*** *University of Texas*

This study examines the role of the subglacial topography on glacier dynamics at the Trinity-Wykeham Glacier system (TWG), Canadian Arctic [1]. The TWG is an outlet glacier of the Prince of Wales Ice Field (POW) and has a surface area of 3,046 km^2. Previous studies have shown that ice discharge from the TWG accounts for over half of the dynamic discharge from the Canadian Arctic [2] but the mechanisms controlling this loss are not well understood. Ice-penetrating radar surveys in the summer of 2014 are used to map the subglacial topography of the TWG and reveal that both Trinity Glacier and Wykeham Glacier lie on a bed that sits below sea level up to ~40 km and ~30 km inland, respectively. We used satellite feature-tracking methods to quantify annual velocity estimates between 2000 and 2016. The velocity of Trinity Glacier doubled from 500 m yr^{-1} to 1,000 m yr^{-1}, while the flow regime of Wykeham Glacier was complicated by the presence of a bedrock pinning point at its terminus, leading to the redirection of ice flow around this protrusion. Simultaneously, we measured rates of surface thinning (d*h*/d*t*) using ICESat (2003-2009) and CryoSat-2 (2010-2016) observations and find that rates of surface lowering increased from 4 m yr^{-1} (2003-2009) to 6 m yr^{-1} (2010-2016). The TWG also retreated 4.45 km between 2000 and 2016. Our results suggest that the subglacial topography exerts a strong influence on ice dynamics. The bed of Trinity Glacier is more streamlined than Wykeham Glacier, which may explain why the velocity of Trinity Glacier is larger than Wykeham Glacier. The bed of Wykeham Glacier is characterized by a set of bedrock ridges that obstruct ice flow, enhance basal friction and reduce the flux of ice to the terminus. Further, by using the principle of hydrostatic flotation we show that both Trinity Glacier and Wykeham Glacier are floating at their termini, which is likely to enhance the dynamic thinning we have observed. The presence of bedrock ridges aid surface crevassing and we observe the presence of drained lakes at these locations. Because estimates of seasonal ice flow suggest that the velocity of both glaciers speed up during spring and slow down during summer, we suggest that hydrological connections between the surface and the bed are an important part of ice dynamics in the region. Given that increasing summer air temperatures have been suggested to be the main control of mass balance across the Canadian Arctic ice caps [3], the strong hydrodynamical coupling at the TWG could be an important component of mass loss in the future.

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Glacier extent and climate in the Maritime Alps during the Younger Dryas

Poster

Dr. Matteo Spagnolo [1], ***Prof. Adriano Ribolini*** [2]

1. *University of Aberdeen,* ***2.*** *University of Pisa*

This study focuses on an Egesen-stadial moraine located at 1906-1920 m asl in the NE Maritime Alps, Europe. Three moraine boulders are dated, via cosmogenic isotope analyses, to 12,490 ± 1120, 12,260 ± 1220 and 13,840 ± 1240 yr, an age compatible with the Younger Dryas cooling event. The reconstructed glacier that deposited the moraine has an equilibrium line altitude of 2349 ± 5 m asl, calculated with an Accumulation Area Balance Ratio of 1.6. The result is very similar to the equilibrium line altitude of another reconstructed glacier that deposited a moraine also dated to Younger Dryas, in the SW Maritime Alps. The similarity suggests comparable climatic conditions across the region during the cooling event. The Younger Dryas palaeoprecipitation is 1549 ±26 mm/yr, calculated using the empirical law that links precipitation and temperature at a glacier equilibrium line altitude, with palaeotemperatures obtained from nearby palynological and chironomids studies. The palaeoprecipitation is similar to the present, thus indicating non-arid conditions during the Younger Dryas. This is probably due to the Maritime Alps peculiar position, at the crossroads between air masses from the Mediterranean and the North Atlantic, the latter displaced by the southward migration of the polar front. The equilibrium line altitude interval defined by the two reconstructed glaciers, is used to model the extent of another 66 potential Younger Dryas glaciers in the region. Each modelled glacier is reconstructed by iteratively changing the position of its front until the reconstructed glacier has an ELA that falls within the interval. The result, which is checked against geomorphological evidence, shows that glaciers covered 83.74 km^2 during the Younger Dryas, with a volume of 5.39 km^3. All valley heads were occupied by ice, except for the Maddalena/Larche Pass (1999 m asl), an ideal site for future archaeological, palaeoecological and palaeozoological studies.

Interferometric Radar Altimetry for polar monitoring

Poster

Dr. Noel Gourmelen [1]

1. *University of Edinburgh*

Reference and repeat-observations of ice sheet margin topography is critical to identify changes in ice thickness, provide estimates of mass gain or loss and thus quantify the contribution of the cryosphere to sea level change. Over the last 25 years, radar altimetry has been instrumental in monitoring ice sheets and their contribution to sea level change. The European Space Agency Altimetry mission CryoSat-2 is the first radar altimetry mission with a SAR/Interferometry radar altimeter payload. The aim of this new technology is to gain a better insight into the evolution of the cryosphere, in particular over the steep slopes typically found along ice sheet margins where the majority of the mass loss is taking place. CryoSat's revolutionary design features a Synthetic Interferometric Radar Altimeter (SIRAL), with two antennas for interferometry, the corresponding SAR Interferometer (SARIn) mode of operation increases spatial resolution while resolving the angular origin of off-nadir echoes occurring over sloping terrain. The SARIn mode is activated over ice sheet margins and the elevation for the Point Of Closest Approach (POCA), or level-2, is a standard product of the CryoSat-2 mission.

The Interferometric mode of CryoSat-2 provides the ability to resolve substantially more than just the elevation at the POCA. If the ground terrain slope is only a few degrees, the CryoSat-2 altimeter operates in a manner such that the interferometric phase of the altimeter echoes may be unwrapped to produce a wide swath of elevation measurements across the satellite ground track beyond the POCA. This technique provides the opportunity to increase spatial resolution and to recover elevation over regions where conventional radar altimetry fails.

Here we will discuss recent results provided by swath altimetry over all components of the Cryosphere including the Greenland and Antarctic Ice Sheets, ice shelves, ice caps and mountain glaciers. We will also discuss a series of thematic products derived from swath processing of CryoSat and available to the community. Finally, we will discuss remaining challenges in SARIn altimetry and the proposed developments as part of the Polar Ice Topography (PICE), a candidate mission for the Copernicus Sentinel expansion programme.

Modelling the impact of iceberg submarine melting on the properties and circulation of Kangerdluggsuaq Fjord and Sermilik Fjord, East Greenland

Poster

Mr. Benjamin Davison [1]

1. *University of St Andrews*

The melting of icebergs within Greenland's iceberg-choked glacial fjords provides a large and distributed source of liquid freshwater throughout the year. However, the impact of this freshwater flux on fjord properties and circulation remain unknown. Here, we use a general circulation model to simulate iceberg submarine melting within two large fjords in East Greenland. We find that iceberg submarine melting results in cooling of up to 5°C and freshening of up to 0.5 psu throughout the upper few hundred metres of both fjords, compared to experiments without icebergs. The resulting freshwater flux, which is of the order of hundreds of cumecs, invigorates fjord circulation and augments the circulation driven by glacial runoff. The net effect of these changes is a 5-30% reduction in up-fjord oceanic heat flux in both fjords, compared to experiments without icebergs. The impact of iceberg submarine melting on fjord water properties and circulation varies non-linearly with glacial runoff volume and approximately linearly with fractional iceberg cover. Our results highlight the significant impact that icebergs have on fjord water properties and circulation in Greenland's iceberg-choked glacial fjords, with implications for both glacier stability and regional ocean circulation.

Recovery of Englacial Stratigraphy across Pine Island Glacier: Proof of Concept for Analysing the Internal Architecture of West Antarctica

Poster

Mr. Julien Bodart [1]

1. *University of Edinburgh*

Concerns over the potential collapse and future contribution of the West Antarctic Ice Sheet (WAIS) to sea level rise have resulted in significant scientific interest over the last three decades. Central to this issue are dynamic changes to large glacier catchments draining the WAIS, such as the thinning and mass loss observed over Pine Island Glacier (PIG) in recent years. Whilst much work has focused on assessing current changes in the mass balance of PIG, few studies have utilised the geometry of radar-sounded internal layers to reconstruct past changes to the catchment. A key challenge when analysing Radio-Echo Sounding data is the identification and interpretation of the internal layers themselves, which are influenced by choices made in the processing flows or artefacts produced during the data-acquisition phase. Here, we use a novel approach to radar processing that utilises two data-acquisition modes from the 2004-2005 PASIN airborne survey to assess the internal stratigraphy of the PIG catchment. From this, we construct a tentative age-depth relationship based on the tracing of three consistent horizons at varying depths within the ice column. We tie in these horizons with further internal layers traced across PIG's main trunk and tributaries from GPR data acquired as part of the 2013-2014 iSTAR science programme. Lastly, we produce 3-dimensional elevation maps of layer stratigraphy to assess the englacial conditions of the glacier catchment. Our results act as a proof of concept that wider layer tracing is possible across a significant proportion of the WAIS.

Retreat of tidewater glaciers in the Scoresby Sund region, east Greenland, 1985-2018

Poster

Dr. Tom Cowton [1]

1. *Un*

Mass loss from the Greenland Ice Sheet (GrIS) has doubled in the last ~20 years with between one third and one half of the ice mass lost annually from the GrIS by the calving of icebergs and submarine melting at the termini of marine-terminating outlet glaciers around the fringes of the ice sheet. The recent rapid retreat of the tidewater glaciers around the fringes of the GrIS has been attributed to a combined ocean-climate forcing. However, the timing and pattern of these changes in terminus position has been of variable nature in differing regions around Greenland, as well as between individual glaciers within the same region and thus it has proven to be difficult to isolate the principal controls on the retreat of tidewater glaciers. This project sought to improve the prediction of tidewater glacier retreat by investigating the main controls on the terminus positions on a set of 18 tidewater glaciers in the Scoresby Sund region of east Greenland. A primary dataset of monthly terminus positions for 1985-2018 was generated and statistical analysis linked changes in air and ocean temperature over time with concurrent changes in terminus positions. Our findings highlight a step-change in terminus retreat in this region in early 2000s, which corresponded with a period of atmospheric warming. Whilst the response of these glaciers to this forcing appears to be modulated by individual glacier and fjord characteristics, we find no systematic link between the magnitude of glacier retreat and metrics of glacier size such as terminus width or catchment area.

Synergies between buried landscapes, past climates and future windfarms offshore.

Poster

Dr. Carol Cotterill [1], ***Prof. Emrys Phillips*** [1], ***Ms. Kirstin Johnson*** [1], ***Dr. Leo James*** [2]

1. *British Geological Survey,* ***2.*** *RPS Energy*

There is a growing synergy between offshore windfarm developments and our understanding of the last glacial / interglacial transition. To date, over £15bn has been invested into commercial offshore windfarm projects in the UK, with an anticipated £15-20bn in the pipeline for future developments. The increasing cost reduction in associated technologies means that there is the potential for a substantial increase in the number of offshore turbines (thousands) which will be deployed by 2030. In March 2019, BEIS announced that one third of the UK's power should come from renewable energy sources by 2030.

This drive to meet clean energy targets has led to a dramatic increase in high-resolution seismic dataset acquisition across the North Sea Basin, which in turn is driving a new wave of detailed mapping of buried land-systems and the climatic processes they represent. Using modern analogues we can begin to unravel the interaction between climate, sea-level response and landform development. The offshore development process therefore benefits both science and geoscience application, increasing scientific knowledge whilst reducing risk in foundation design.

However, what is very noticeable in the case studies I will present from Dogger Bank and Dudgeon windfarms is that an integrated overview is vital when approaching either landscape reconstruction or geotechnical engineering, drawing on geology, glacial processes, geotechnical properties of soils and geophysical interpretation. Using this holistic approach towards data analysis, and the synergies between developers needs and scientific curiosity, we are moving towards not only cleaner energy sources but also a level of understanding that can begin to support future predictions about climatic changes and the impact on our coastlines in the future.

The configuration of Northern Hemisphere ice sheets through the Quaternary

Poster

Ms. Christine Batchelor [1]

1. *Scott Polar Research Institute, University of Cambridge, Cambridge*

Knowledge of the extent, volume and timing of Quaternary ice sheets is fundamental to studies of sealevel change, global climate, landscape evolution, genetic diversity and anthropology. Although the last few decades have seen unprecedented growth in the size and diversity of empirical datasets used to reconstruct and date palaeo-ice sheet extent, together with major improvements in our ability to simulate their dynamics in numerical models, most of these reconstructions focus on ice-sheet deglaciation from the Last Glacial Maximum (LGM). Comparatively little is known about global changes in ice-sheet configuration in the deeper past. Here, we synthesise available empirical evidence and model outputs related to pre-LGM ice sheets to produce hypotheses of Northern Hemisphere ice-sheet configuration over 17 key time-slices that span the last ~3 million years. Our reconstructions are used to assess spatial differences in ice-sheet configuration within and between glacial periods, produce new first-order estimates of global sea level associated with each time-slice, and explore the implications for Northern Hemisphere landscape evolution.

The GeoSnow Project

Poster

Mr. Alex Priestley [1]

1. *University of Edinburgh*

Modelling snowmelt is important for water resource management, flood forecasting and avalanche risk prediction. The behaviour of liquid water in snow has a big influence on melting processes. This project applies geophysical measurement techniques in a novel fashion to seasonal snow in order to monitor the way liquid water behaves. Following laboratory tests using artificial snow, a monitoring system was installed at a French alpine site in autumn 2018. Along with monitoring, modelling is being carried out using a snow hydrology model. Model simulations are compared to the geophysical measurements of liquid water, and model parameters adjusted to reduce errors in the modelled snowmelt runoff. The end aim of this project is to be able to use geophysical monitoring of snow to improve forecasts of snowmelt runoff, and improve our understanding of the importance of liquid water in snow.

Worldwide comparison of calculated glacier equilibrium line altitudes, from satellite-derived glacier topography, versus empirically measured ELAs

Poster

Ms. Rachel Oien [1], ***Prof. Brice Rea*** [1], ***Dr. Matteo Spagnolo*** [1], ***Dr. Iestyn D. Barr*** [2], ***Prof. Robert Bingham*** [3]

1. *University of Aberdeen,* ***2.*** *Manchester Metropolitan University,* ***3.*** *University of Edinburgh*

Glaciers are linked to climate, and an empirical relationship has been demonstrated linking their equilibrium line altitude (ELA) with temperature and precipitation. Due to this relationship, palaeoglaciers are readily used to infer palaeoclimate conditions. Glaciers are reconstructed through various numerical (recommended) or cartographic methods. The 3D topographic surface of reconstructed glaciers is then used to calculate their ELA. Here, we present the results examining the accuracy of the Area-Altitude Balance Ratio (AABR) and Accumulation-Area Ratio (AAR) methods, which are accepted as robust methods to estimate palaeoglacier ELAs. We used an ArcGIS toolbox, which is freely available, to extract the ELA of 64 extant glaciers worldwide based on their digital elevation model and a polygon of their surface area. They were calculated via the AABR and AAR using the global (1.75 and 0.58) and regional recommended ratio values. The results were compared with ELA extracted from empirical measurements available from the World Glacier Monitoring Service (WGMS) for the same 64 glaciers. The correlations between the ELAs obtained via the two methods (empirical vs. GIS), for the AABR and AAR, had an r^2= 0.95-97. The minimum difference between the empirically-measured and GIS-calculated ELAs is between 0 – 3 m (depending on the ratio method) and the median difference of 52 – 70 m. These results validate the AABR and AAR approach for estimating GIS ELAs for extant and palaeoglaciers. The error in ELA measurements translates to a palaeotemperature error of 0.34 -0.46 □, and 94 – 127 mm of annual precipitation. These error measurements can be considered as negligible, especially in the context of palaeoclimate reconstructions, thus further validating the tested approach.

Whole Earth Systems

Oral Presentations

Advancing Earth System Modelling capacity to contribute to solving Earth's grand challenges

Oral

Dr. Stefan Kollet [1]

1. *Jülich Research Center, Institute of Bio- and Geosciences Agrosphere (IBG-3)*

Societies are facing major challenges related e.g. climate change, availability of food, clean water and georesources. The Earth system science community develops and applies tools that provide decision-makers with the understanding and information required to address and manage these grand challenges. Because the Earth system is subject to natural and anthropogenic forcing as well as to substantial internal variability, understanding and predicting the complex Earth system under different forcing scenarios requires an advanced Earth system model capacity. The Advanced Earth System Modelling Capacity project (ESM, www.esm-project.net) funded by the German Helmholtz Association is an effort that started in April 2017 and involves eight research centres in Germany. ESM aims to provide innovative strategies to advance and apply current Earth system modelling infrastructures encompassing four major development strands that are enhancing the representation of individual Earth system model compartments; developing a flexible framework for the effective coupling of Earth system model components; advancing Earth system data assimilation capacity; and coordinating and performing state-of-the-art experiments (frontier simulations). In this presentation we will provide an overview of the ESM project highlighting key activities and outcomes, and contributions to the Earth system modelling community worldwide.

Climate forcing and response to greenhouse gases, aerosols and ozone

Oral

Mr. Alcide Zhao [1]

1. *The University of Edinburgh*

It is crucial to reduce uncertainties in our understanding of the climate impacts of short-lived climate forcers (SLCFs), in the context that their emissions/concentrations are anticipated to decrease significantly in the coming decades worldwide. Using the Community Earth System Model (CESM1), we performed time-slice experiments to investigate the effective radiative forcing (ERF) and climate responses to 1970-2010 changes in well-mixed greenhouse gases, anthropogenic aerosols, as well as tropospheric and stratospheric ozone. Once the present-day climate has fully responded to 1970-2010 changes in all forcings, both the global mean temperature and precipitation responses are twice as large as the transient ones, with wet regions getting wetter, and dry regions drier. The temperature response per unit ERF for short-lived species varies considerably across many factors including forcing agents, and the magnitudes and locations of emission changes. This suggests that the ERF should be used carefully to interpret the climate impacts of SLCFs. Changes in both the mean and the probability distribution of global mean daily precipitation are driven mainly by GHG increases. However, changes in the frequency distributions of regional mean daily precipitation are more strongly influenced by changes in aerosols, rather than greenhouse gases. This is particularly true over Asia and Europe where aerosol changes have significant impacts on the frequency of heavy-to-extreme precipitation. Our results may help guide more reliable near-future climate projections and allow us to manage climate risks more effectively.

Exploration of the shallow subsurface structures by the non-invasive radiomagnetotelluric method

Oral

Prof. Bülent Tezkan [1]

1. *University of Cologne*

Electromagnetic methods (EM) are frequently used for the characterization of shallow structures. These methods use the electrical conductivity as petrophysical parameter which is sensitive to porosity, water saturation and clay content. Radiomagnetotellurics (RMT) is a relative new EM-technique which is extensively used in connection with near surface exploration in the last years. The method uses existing radiotransmitters as source broadcasting in the frequency range between 10 kHz and 1 MHz. The frequency dependend apparent resistivity and phases can be obtained by measuring the components of the electric and magnetic field at the surface. The distribution of radiotransmitters in Europa is dense enough for using their plane waves to estimate RMT transfer functions. They are interpreted using the 2D/3D inversion algorithms developed for the magnetotelluric data. Especially, 2D inversion techniques are routinely used to derive the 2D conductivity distribution of the subsurface from the RMT data.

In addition to conventional radiomagnetotellurics, Controlled Source Radiomagnetotellurics (CSRMT) is developed for near surface applications. A rectangular signal with base frequencies between 0.1 kHz and 150 kHz are injected through a grounded electric dipole which is used as a transmitter. Electric and magnetic field components are observed at these frequencies and at their subharmonics, usually in the far field, so that apparent resistivities and phases can be obtained in the broad frequency range between 1 kHz and 1 Mhz. Inline or broadside configuration can be used. Similar to controlled source audiomagnetotellurics measurements tonsorial measurement are also possible by using two transmitters located perpendicular of each other.

After introduction to the physical background of CSRMT and RMT, case studies (waste site exploration, groundwater contamination) about RMT and CSRMT method will be presented

iAtlantic – an integrated assessment of Atlantic ecosystems in space and time

Oral

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Over the next century, the magnitude and rates of environmental change in the deep and open Atlantic Ocean are expected to be faster and more severe in some areas than others[1]. Regional understanding and monitoring capacity of how climate change impacts these ecosystems are currently disjointed at larger scales, making whole ocean management and governance less effective than it could be if climate-ocean interactions and ecosystem status could be assessed the same way across the Atlantic. Meanwhile, technological innovation and changing markets have modified how humans interact with their environment[2] leading to the expansion of fisheries into new and deeper waters further offshore[3], increasing exploration for deep-sea minerals, bioprospecting from deep-sea organisms, and hydrocarbon extraction in deep frontiers[4]. Ecosystem resilience to the pressures from climate change and human activities depends on ecosystem status (e.g., connectivity, distribution and diversity, temporal stability, functioning), but here too our understanding is disjointed across scientific disciplines and from a strong imbalance in knowledge of deep and open-ocean ecosystems in the North versus South.

The new iAtlantic project will advance the scaling and integration of observing frameworks to provide managers with the correct spatial tools to handle and optimise decision-making in an all-Atlantic context characterised by spatiotemporal variations in multiple stressors and ecosystem resilience. iAtlantic will implement disciplinary diversity to account for the inherent multidimensionality of physico-biogeochemical drivers of change and the multitude of possible ecosystem responses[5] so that a common understanding of Atlantic ecosystem stability and resilience can be developed[6].

To achieve this, iAtlantic will integrate ecosystem data with major circulation pathways connecting the North and South Atlantic. Ocean physics and ecosystem connectivity will enable high-resolution oceanographic hindcasts and forecasts of future circulation together with ground-truthing genomic data. Advances in eDNA genomics, machine learning and autonomous underwater robotics will be combined with existing data to provide a step-changes in predictive habitat mapping approaches to expand species and biodiversity observations from local to basin scales. Ecological timeseries, including innovative palaeoceanographic and genomic reconstructions, will provide an unprecedented view of the impacts of climate change on Atlantic ecosystems. Assessment of the impact of multiple stressors will identify key drivers of ecosystem change and tipping points. New data will come from 12 carefully selected regions in the deep sea and open ocean that are of international conservation significance and of interest to Blue Economy and Blue Growth sectors. Innovative and efficient data handling and data publishing approaches will establish a better integrated Atlantic Ocean observation data community. Finally, capacity and cooperation between science, industry and policymakers bordering the Atlantic will be boosted by joint multi-disciplinary research cruises, enhanced S Atlantic monitoring arrays, scientific training events, iAtlantic Fellowships and industry focused workshops.

The iAtlantic consortium includes 33 partners from Argentina, Brazil, Canada, the EU, the USA and South Africa.

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Linking simulated fire in an Earth System model to fire processes inferred from observations

Oral

Dr. Douglas Kelley [1]

1. *Land Surface Modeller, The Centre for Ecology & Hydrology*

The first version United Kingdom Earth System Model (UKESM1) is the result of a joint project between the Natural Environment Research Council (NERC) and the Met Office Hadley Centre. The model builds on the HadGEM3 GCM adding carbon and nitrogen cycles, interactive atmospheric chemistry and aerosols, and dynamic vegetation. One key process missing from UKESM1 is a representation of fire[1]. Fire is the most prominent natural terrestrial disturbance, it influences the local vegetation dynamics and has wider feedbacks to the climate system through the carbon cycle and aerosol emissions. Correct simulation of changes in fire and fire impacts is therefore vital when developing an Earth System Model. However, modelling the complex interplay of climate, vegetation and human drivers of fire on a global scale has proven to be difficult. When fire has been modelled simulated properties of fire regimes, such as burnt area and emissions, generally show very poor performance against observations. In addition, the uncertainty in modelled impacts of fire on local vegetation is also poorly constrained by observations [2]. When introducing a coupled fire component to the UKESM we are overcoming these issues by using a Bayesian inference technique to constrain fire parameters to remotely sensed and meteorological observations. We map the sensitivity of burnt area to observed controls imposed by fuel continuity, fuel moisture, natural and human ignitions, and land use suppression [3] (top figure). We then assess UKESMs ability to reproduce these controls and attribute any biases in fire model outputs to simulated climate biases, climate bias impact on vegetation and fuel production, and performance of dynamic vegetation in the land surface component. We also compare the impact of fire on tropical tree cover (bottom figure) relative to other climate and human controls and show that fire has a much smaller influence on tree cover in savanna ecosystem than predicted in land-surface models. These results have a number of implications for fire modelling. In many areas poor simulation of fire is shown to be due to the impact of climate biases on vegetation rather than vegetation dynamics themselves. Land use has a larger impact on both fire and tree cover than fire enabled global vegetation models currently simulate. Additionally, we find that whereas fire seems to have little impact on tree cover in areas which already experience regular burning, such as tropical savannas, it has the potential to impact tree cover under environmental change in more humid forests. This is particularly evident in areas of deforestation in Amazonia and Indonesia. The potential impact on tree cover in two of the largest forested areas of the world gives added impetus to understanding the impacts of fire regime trends on local ecosystem function and as well as their feedback to the wider Earth System.

Tracing toxic flood events in sedimentary archives - the potential of organic indicators

Oral

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1. *RWTH Aachen University*

Recurring and devastating coastal hazards such as storms, river floods and tsunamis are unpreventable and immanent in times of climate change and rising sea levels. However, science-based and sustainable mitigation measures can prevent immense destruction and protect lives in case of an event. Therefore, new methods need to be developed to gain more information on the mechanisms, deposits and environmental impact of the diverse toxic flood event types on individual coastlines. Here, not only recent events but also information from historical floods as deposited in sedimentary archives can be used to learn from the past.

We present insights from a new organic-geochemical approach to investigate such deposits (e.g [1,2]). A variety of natural and anthropogenic organic markers such as polycyclic aromatic hydrocarbons, pesticides and other anthropogenic markers have been used showing significant concentration increases and a broader variety of imported compounds in event deposits. The particular dimension of event related pollution, however, is depending on other factors, such as the grain size distribution, the permeability and the content of organic matter. Therefore, multi-proxy analyses including standard methods extended by new geochemical markers are necessary. Multi-proxy, high-resolution studies can be used to expand our current knowledge of maximum inundation distances, distribution patterns (by mapping) or pollution sources (by their high source specificity). The better the understanding of past events by the application of diverse methods, the better the hazard assessment and preparedness of an endangered coastal area.

Poster Presentations

A deep palaeoweathering system in the Southern Uplands, Scotland: Preliminary observations and implications for the origins of alluvial gold

Poster

Dr. Simon Cuthbert [1], ***Prof. Andrew Hursthouse*** [1], ***Dr. Sam Rice*** [1], ***Mr. Gabriele Broetto*** [1]

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An extensively developed deep weathering profile has been recognised in the Leadhills-Wanlockhead area of the Southern Uplands of Scotland. It is exposed in numerous actively eroding gullies cut by headwater streams of tributaries within the major catchments of this area and appears to occur exclusively at altitudes above 400m AMSL, suggesting that this palaeosol forms a carapace on the upland plateau over an area of > 100km^2, but has been incised by the main glacial troughs. It has developed on mafic-rich greywackes, black shales and cherts and porphyry dykes. It coincides with a region of abundant alluvial gold that has been worked in this area during historical times, historical but elusive bedrock lode gold veins and quartz veins with intensively pyritised mineralisation haloes. A well-preserved example shows, from base to top in a ~4m vertical profile, fresh to slightly weathered, fractured greywacke (saprock), grey-olive reduced saprolite, pale yellow-brown grading to bright orange-red oxidised saprolite locally grading up into a mottled orange-red regolithic breccia of saprolite clasts having yellow-brown cores and reddened rims. This has a sharp, erosive upper contact with a pale grey, matrix-supported breccia of mainly unweathered greywacke and shale with minor saprolite clasts (ablation till). No lateritic duricrust was preserved on top of the saprolite and red palaeosol. X-ray powder diffraction analysis indicates kaolinite, illite, chlorite and gibbsite in the clay fraction of the saprolite, suggesting intensive leaching. A preserved, extensive, deep-weathered paleo-surface in this area testifies to very limited glacial erosion consistent with a cold based ice mass and proximity to an ice divide[1]. The age of this deep-weathering system is currently unknown, but must at least predate the Last Glacial Maximum. Hence it may relate to a previous interstadial or, by analogy with similar saprolites in NE Scotland, may be pre-Quaternary[3]. The Leadhills-Wanlockhead area is thought to have been close to a major ice-divide during the Last Glacial Maximum[1]. A till-capped, deep-weathered soil profile in this area potentially contains a very useful inventory of pre-glacial, meteoric cosmogenic nuclides similar to other high-latitude, glaciated saprolites[5]. The gullies in which the saprolite is mainly exposed are the most active sites of contemporary erosion in the area and hence may be providing a major source of the active, gold-yielding alluvium. Alluvial gold grains collected from numerous locations in the Leadhills-Wanlockhead area show strong depletion in Ag on their outer rims that often show a finely porous texture, known to be a characteristic of saprolitic gold[4]. Pathfinder element concentrations in the palaeosol and modern stream sediment fines appear to have been depleted by pedogenic leaching, but selective extraction experiments indicate that some elements have been retained in oxy-hydroxide phases derived by pyrite oxidation in weathering. Hence the discovery of a deep-weathering carapace in this area has importance for understanding supergene processes in the development of potential gold resources. We speculate that late Cenozoic, episodes of high partial pressure of atmospheric CO_2may have led to enhanced weathering leading to saprolite and grus profiles at unusually high latitudes, and this may offer a novel exploration concept for saprolite placer gold.

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Keywords: Deep palaeoweathering, Southern Uplands of Scotland, alluvial gold

Atmospheric circulation over Europe during the Younger Dryas

Poster

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The Younger Dryas (YD) was a period of rapid climate change (cooling) which occurred between approximately 12.9 to 11.7 thousand years ago, at the end of the last glaciation. The YD is of specific interest as one, of the many, suggested causes could result present-day from increased meltwater runoff and iceberg discharge from the Greenland Ice Sheet. In comparison to the preceding interstadial an atmospheric circulation reorganisation occurred during the YD, as indicated by proxy-derived air temperatures, but its nature has only been observed in numerical models. Here we present the first empirical palaeoglacier-derived reconstruction of YD precipitation across Europe. It utilised 132 palaeoglaciers, rigorously assessed for chronology (recalculating ages where necessary) and reconstructed consistently using an equilibrium flowline approach. The palaeoglacier Equilibrium Line Altitudes (ELA) were calculated using the area altitude balance ratio. Europe-wide temperature reconstructions were determined from the published literature and used to determine the mean summer air temperature at the palaeoglacier ELA which were converted to precipitation at the ELA using an empirical relationship. The regional scale of this study (Morocco to Norway and Ireland to Turkey) provides evidence for a southward displacement of a dominant west-east zonal storm track. Positive precipitation anomalies (YD minus modern) are found along much of the western seaboard of Europe, south of 60°N, and in the Mediterranean. A negative precipitation anomaly is located over the Fennoscandian ice sheet (FIS) and the North European Plain (NEP), as far south as the Alps. This is consistent with a southern displacement of the zonal storm track, which is linked to a concomitant southward shift of the Polar Frontal Jet Stream (PFJS), generating cold air outbreaks and enhanced cyclogenesis, especially over the eastern Mediterranean. Following a circulation weather type approach, this pattern most closely resembles the modern Scandinavian (SCAND) circulation better explains the YD precipitation anomalies than a persistent negative phase NAO, which has been suggested for the Last Glacial Maximum.

Deposition of proglacial sediments along an active ice margin during the Last Glacial Maximum, Dogger Bank, southern central North Sea

Poster

Ms. Kirstin Johnson [1], ***Prof. Emrys Phillips*** [1], ***Dr. Carol Cotterill*** [1], ***Dr. Leo James*** [2]

1. *British Geological Survey,* ***2.*** *RPS Energy*

High-resolution seismic data from the Dogger Bank in the southern central North Sea has revealed that the Dogger Bank Formation records a complex history of ice-marginal to proglacial sedimentation and penecontemporaneous, large-scale, glacitectonic deformation during the Last Glacial Maximum. The study site presented here is located along the margin of the Weichselian aged British and Irish Ice Sheet and Fennoscandian Ice Sheet, within the Dogger Bank area.

The resulting glacigenic landsystem and sedimentary sequences reveal the presence of a number of sedimentological features including meltwater channels, outwash fans and plains, desiccation surfaces and lacustrine systems, as well as a plethora of glacitectonic arcuate thrust-block moraines.

Here we focus on the development of the meltwater channel systems, outwash flood sheets and fan systems which formed during the northward retreat of the ice sheet across Dogger Bank. The fans are up to 2.5km wide and comprise sediment packages (up to 50m thick) with inclined reflectors. They are interpreted as forming an ice marginal apron system occupying a low lying sedimentary basin formed between the larger, higher relief moraines located within the southern margin of the Dogger Bank. Large channels up to 1km wide and between 30m and 70m deep have been identified incised into a thick (up to 40m thick) sequence of outwash sediments. These sediments exhibit varying degrees of deformation, linked to a history of active retreat of the ice margin. The complex internal architecture of the channels indicate that they record several periods of sedimentation separated by prominent erosive surfaces. Desiccation surfaces are preserved within both the channels and laterally extensive outwash plains, indicating several periods of intense periglacial weathering (drying, alteration) occurred during deglaciation. This sedimentary assemblage therefore records a complex history of deposition, meltwater release and channel incision separated by phases of periglacial weathering and glacitectonic deformation during the deglaciation of the Dogger Bank towards the end of the Weichselian glaciation.

This work highlights the development of periglacial environments as deglaciation occurs, providing a 3D snapshot of analogues to current landscapes developing within existing glacial systems. **Acknowledgements:** The authors thank the Forewind consortium for providing the seismic data

Keywords: periglacial, landsystem, Quaternary

Geological seabed characterisation to underpin marine science and resource management

Poster

Mr. Dayton Dove [1], ***Mr. Gareth Carter*** [1], ***Mr. Rhys Cooper*** [1], ***Dr. Carol Cotterill*** [1], ***Dr. Jeremy Everest*** [1], ***Dr. Joana Gafeira*** [1], ***Prof. Emrys Phillips*** [1], ***Ms. Heather Stewart*** [1]

1. *British Geological Survey*

The British Geological Survey (BGS) are undertaking a renewed programme of offshore mapping to characterise the processes that created, and continue to govern/modify the seabed environment. With increasing societal and political motivation to conserve and manage marine ecosystems, and the need to extract more renewable energy from within the marine environment, there is a requirement for improved fundamental information (e.g. morphology, composition, stability/transience) on this important interface between the sub-surface geology and the overlying water-column.

New geological mapping will primarily rely on publically-available high-resolution bathymetry around the UK offshore, delivering detailed maps of seabed geomorphology, seabed substrate, and seabed geology (i.e. Quaternary and Bedrock units present at/near seabed). Demonstration geospatial products will soon be released from the Bristol Channel, and a large area around the Orkney Islands. Where required, regional and national-scale maps are also being developed with suitable continuous data (e.g. EMODnet bathymetry).

In terms of example applications, these map products will enable improved seafloor, sub-seafloor, and palaeo-environmental models required to develop effective design and emplacement strategies for offshore renewables infrastructure. The mapping will also underpin the improved assessment of organic carbon stocks/stability in coastal and shelf sediments, a potentially significant and currently unaccounted-for influence on national estimates of greenhouse gas emissions. Beyond specific applications, we hope these maps will provide an enabling resource for any scientists aiming to better understand the physical, chemical, and biological processes occurring at the seabed, as well as marine managers, commercial operators, and policy makers looking for detailed and standardised geoscientific information to inform decision making.

Quantifying morphological change in a tropical river system using Google Earth Engine and topographic analyses

Poster

Dr. Richard Boothroyd [1], ***Dr. Richard Williams*** [1], ***Prof. Trevor Hoey*** [2], ***Ms. Pamela Tolentino*** [3], ***Mr. John Edward Perez*** [3], ***Mr. Esmael Guardian*** [3], ***Dr. Brian Barrett*** [1], ***Dr. Carlos Primo David*** [3]

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Multi-temporal catchment-scale analyses of planform change offer opportunities to investigate the evolutionary trajectories of rivers. In recent years a variety of tools have been demonstrated that are capable of delineating and characterising river channels, but efforts to scale these analyses up to multi-temporal, catchment-scale applications are in their infancy. Google Earth Engine (GEE) offers a cloud-based computing platform, with an archive of open-access satellite imagery, where it is possible to readily implement such applications and achieve analyses that are of a sufficiently large spatial and temporal scale. This provides new data for river and flood hazard management and allows for the investigation of the fundamental controls on river morphodynamics. Here, we use GEE to quantify spatial-temporal morphological change for the Abulug River, a tropical river system located in northern Luzon (Philippines). The system is particularly dynamic, with fluctuating sediment supplies and anthropogenic activities including artificial alignment, confinement and gravel extraction. Using annual temporal composites of Sentinel-2 imagery at a 10 m spatial resolution over the last 4 years, the geomorphologically active riverscape is classified from spectral information (including surface water and exposed river sediment). Repeat application of the workflow at annual intervals reveal areas of enhanced mobility and a first-order quantification of annual areal change. Analysis of satellite imagery complements further topographic analyses using an IfSAR 10 m digital elevation model (DEM). The findings exemplify the dynamism of tropical river systems and offer new insights into their morphological behaviour.

Simulation Lab Terrestrial Systems of Geoverbund ABC/J

Poster

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We present recent activities of Simulation Laboratory Terrestrial Systems (SimLab TerrSys), followed by its role in the wider community called Geoverbund ABC/J which consists of geoscientists at University of Bonn, Aachen, Cologne and the Research Centre Jülich. In one attempt to connect geoscientific community with the HPC resources, SimLab TerrSys maintains and develops Terrestrial System Modeling Platform (TerrSysMP) - an in-house earth system model. We use TerrSysMP for our daily monitoring runs since several years now and have created a substantial output of variables in atmosphere, land surface and subsurface (see [1]).

TerrSysMP was developed to model the interaction between ground and surface flow processes with that of the lower atmosphere up to several kilometers in height. TerrSysMP is composed of an atmospheric model (Consortium for Small-Scale Modeling - COSMO), a land surface model (the NCAR Community Land Model - CLM3.5), and a subsurface flow model (ParFlow). These three models are coupled together using the OASIS3-MCT coupler which exchanges information between models during run-time, managing different temporal-spatial scales of the atmosphere, land and subsurface models.

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