Ideas 2017

Ideas submitted as potential strategic programme areas

Title	**Summary**
Flow in a complex earth: addressing the impacts of sedimentary variability	Human activity is primarily focused in a relatively shallow zone of the geological subsurface (5 km or above). The need to understand and forecast fluid movement through intact sedimentary rocks in this zone is a growing socio-economic requirement, as new requirements for the subsurface are found. Rocks/sediments are highly complex in nature. This complexity is manifest at a range of scales, resulting in heterogeneity in physical parameters that impact flow. Unlike in meteorology, data is poorly sampled and the impact of heterogeneity on physical properties of the subsurface is poorly constrained, limiting accurate forecasting. To improve our handling of heterogeneity, we propose to: (i) characterise physical properties of and quantify the degree of heterogeneity in key UK geologies selected on the basis of relevance to current human activity/scarcity of data. (ii) develop generic methodologies for the translation of petrological and geophysical data to rock physical parameters for large-scale models, whilst reflecting heterogeneity. (iii) develop new approaches to modeling of heterogeneity in complex flow models (e.g., coupled Thermo-Hydro-Mechanical, multi-phase systems, contaminant transport). (iv) conduct targeted projects on topics most likely to benefit from improved capabilities. To truly impact this issue will require a major multi-disciplinary programme of work by UK institutions spanning a range of subsurface topics developing strong linkages across individual collaborations.
Transforming fractures – exploration of the deep-ocean highways	Segments of the Earth's mid-ocean ridge (MOR) system are offset by laterally moving transform faults. Over time, once lateral motion ceases, and for 1000s of kilometres from MOR to continental margin, fracture zones (FZs) trace the scars left in the lithosphere that mark their past locations. Besides these ubiquitous features recording the historic opening of the Earth's oceans and the readjustment of plate motions over thousands of millennia; they act as migration pathways for benthic fauna, channel deep ocean water movements, circulate fluid to deep within the Earth, couple stress and heat between juxtaposed plates, and host economically and technologically important mineral assemblages. FZs can also mark surface boundaries between deep Earth mantle domains. As such they lie at the heart of many of the Earth's processes that they impact on: resilience to earthquake hazard; economic development for a technology-driven society; heat transfer between the inner Earth, ocean and atmosphere that drives the climate; and sequestration of CO_2 that mitigates climate change. Although found throughout the ocean basins, FZs have rarely been studied in preference to the MORs that lie between them where new oceanic lithosphere is made. Consequently, our understanding of the role they play in the evolution of the Earth and its marine environment is quite limited. This strategic programme aims to affect a magnitude change in our understanding by creating an integrated multi- and cross-disciplinary research effort targeted at specific type examples. It will encompass passive monitoring of seismicity and ground motion to understand tectonic deformation, seabed and water column sampling for mineral, fluid, faunal and geochemical interactions, and sub-seabed remote imaging to couple surface observations to deep Earth processes. It will make best use of existing NERC's ships, autonomous platforms and robotic systems, whilst enhancing those to enable next-generation highest resolution imaging and sampling in the deepest-ocean environment.
An interdisciplinary research agenda for medical geology and health	Relationships between the natural environment and human health (Medical Geology, (MG)) are complex to establish and understand, but have a major impact on every person, every day of our lives as we interact with our surroundings. The adverse health effects of air and water pollution are internationally acknowledged, however

	this is not the case for soil this is despite the EU reporting (2013) that over 3 million European sites contain anthropogenically derived potentially contaminated soil (not including soils containing naturally occurring toxicants). Both essential elements and toxicants can be directly mobilised by natural physicochemical processes and man's activities, resulting in direct and indirect exposure can impact (beneficially and detrimentally) on human health. As the dynamic earth, geochemical, environmental, socio-economic, land regeneration and climatic landscapes respond to human needs, wants and activities. There is, therefore, a growing need to understand the complex relationships between geospatial environmental hazards (and their sources) and human health (including mental health and wellbeing). This SPA will build a cross-disciplinary framework and body of knowledge, to better understand the impacts of geochemical hazards (particularly soil) on human health. It will provide a robust scientific evidence-base that contributes to achieving Sustainable Development Goal 3 (SDG3) – Good Health and Well-being and the target of substantially reducing (by 2030) the number of deaths and illnesses from soil contamination. It will support the development of fit for purpose 21st century regulations and guidelines, and formulate adaptive solutions to enhance prevention, preparedness and response to the changing environment.
Earth System Plastics	Earth System Plastics addresses the burgeoning quantity of plastics on our planet – now >8 billion tons, and projected to be 40 billion by 2050: it is a major feature of the changed, Anthropocene, state of our planet. The pathways, transformations and ultimate fate of these plastics, over medium- and long-term time scales, have received scant attention. Plastics leakage to the oceans is around 10 million tons/year, but this is dwarfed by the amount of plastics at/near the Earth surface (~3 billion tons) and 'locked away' in landfills (~5 billion tons). Much risks release into the sedimentary cycle as sea level rises over coming decades/centuries and coastal landscapes are eroded, greatly amplifying plastics flux into the oceans and along their coastlines, with enormous environmental, social and economic costs. These processes will affect all waste and coastal infrastructure, but plastics are a key component given their durability, ease of transport, concentration in the marine realm and harmful biological interactions. There are immense gaps in our knowledge: we know virtually nothing about the longevity and physico-chemical degradation of plastics in the environment, and how plastics will be incorporated into the short/medium term into sedimentary successions and in the long term into the geological record, or of how this complex, protracted process will interact with the biosphere. In short, we need to find out where will all this plastic will end up, as what, and how it will change - and affect its surroundings - in the process.
The role of the Southern Ocean as a global sink for plastic debris	Around 75% of all the litter in our oceans is plastic, and an estimated 5 million tonnes of plastic waste enter the seas annually. Once in the ocean, plastic debris undergoes continuous fragmentation through weathering processes, generating micro- (<5mm) as well as nanoscale plastics (<1µm). Due to their small size, micro- and nanoplastics have the potential to cause a wide range of biological challenges to marine organisms across a number of different trophic levels. Ingestion of these particles can also result in their transfer along food chains, potentially decreasing transfer efficiencies and threatening the energetic viability of consumers, particularly those at higher trophic levels. Global estimates of plastic entering in the ocean exceed current in situ measurements by three orders of magnitude. This highlights that some of the major sinks for plastics entering the ocean have yet to be identified. The Southern Ocean (SO) has yet to be adequately considered as a sink for plastic debris although recent surveys have found surprisingly high levels of plastics in surface waters. The potential impacts of this debris on the sensitive Antarctic marine ecosystem could be profound, interfering not only with food web processes but also the globally important role of this region as a carbon sink. We propose a major effort to quantify and parameterise levels of plastic pollution in the SO, including the identification of the major processes that drive the plastic load in this region and its penetration into food webs and biogeochemical cycles.

A fully integrated approach to understanding Arctic teleconnections	The Arctic is warming faster than any other region on the globe – a phenomenon known as Polar Amplification. Changes in this region are known to have a two-way coupling with regions further afield, and are therefore important for predictability on a range of timescales. Traditionally, studies have considered only one element of the coupled Arctic system at a time, e.g. sea ice or land ice, permafrost or terrestrial snow, ocean or atmosphere, dynamics or biogeochemistry. Yet, there remains considerable distance between our understanding of each element versus our understanding of the teleconnections between them. For instance, research hints that climate warming is driving coincident recession of Northern Hemisphere sea ice, land ice and snow cover; but processes intersecting these systems: freshwater fluxes, oceanic circulation patterns, the polar energy budget and storm tracks, readily feed back on and amplify each other. Many unanswered questions concern how these elements interact. An integrated earth-system approach is required to understand how these diverse elements of the Arctic co-vary and augment or compensate for each other. The ultimate goal is to improve the predictability of mid-to-high latitude climate processes which is important for both operational and research applications.
The Key Aspects of Air Pollution for Effective Mitigation – What, Where, and When?	Air quality represents one of the leading factors responsible for the loss of quality of life and is thought to contribute to at least 7 million deaths per annum world-wide. Many UK cities breach World Health Organization guidelines levels for particulate matter and gaseous pollutants, which likely has significant consequences for the health of the local population and for the environment. As a result the UK Government have recently published the Air Quality Plan identifying 37 zones across the UK where urgent action is required to improve air quality. Such action may include the introduction of clean air zones, or infrastructural measures. There is, however, much debate surrounding the efficacy of these restrictions. This is largely due to a lack of understanding regarding the sources of pollution, their relative contributions and how this varies in space and time according to a multitude of factors (e.g. local weather, seasonality, other human activities). Moreover, these factors vary between cities according to location, and the presence of specific emissions sources such as industry, airports and ports. What is needed is: • Better temporal and spatial resolution of measurements of a number of pollutants (e.g. particulate matter [PM], NOx, ozone, SO2 etc.). • Improved methods of the source apportionment using real-time chemical sensors and other analytical chemical methods. • Better understanding of the generation of point sources of pollution, their chemical characteristics and the causes and consequences of temporal variability. • More understanding of the consequences on human health and the environment of the most relevant pollutant types and sources. • Better modelling of improved and existing datasets of pollution sources including the interactions between climate, human activity and pollution. The programme we propose will consist of: 1.) The development of low cost/high quality sensor networks for real time pollution monitoring in UK cities. 2.) The use of novel source characteristics and source apportionment to better identify the sources of PM and gaseous pollution in UK cities. 3.) In-depth screening of relative toxicity of specific point source emissions. 4.) Innovative modelling approaches to predict pollution levels and spatio-temporal variability. 5.) New methods of public and stakeholder engagement including citizen science (e.g. https://www.wunderground.com/). A central aspect of the success of this effort will be the integration and cross-validation of these multidisciplinary datasets, techniques and models that would not be possible without a coordinated investment. Ultimately, the outcomes of this

	programme will enable more effective measures to mitigate air pollution and its associated health and environmental impacts through targeted and cost-effective legislation.
Seafloor Volcano Observatories: understanding processes and risk on the world's most dangerous underwater volcanoes	The more we survey the seafloor the more we are identifying potentially dangerous underwater volcanoes near population centres. Large eruptions at such volcanoes poses significant but unrecognized threats to coastal communities, marine/coastal infrastructure and the marine environment. Global estimates of risk from volcanic activity mostly ignore submarine volcanoes, yet the deadly eruption of Kolumbo, near Santorini, in 1650 triggered tsunamis and toxic emissions that swept across nearby islands, the Havre eruption in 2012 produced a pumice raft of >400 km2 that floated for weeks, restless volcanoes in the Tyrrhenian and Aegean threaten the inhabitants (and tourist populations) of the Italian and Greek Islands and submerged calderas (e.g. Campi Flegrei, Santorini, Krakatoa) also pose a significant threat. We have no direct observations of an explosive underwater eruption so the dynamics of seafloor eruptions, fundamentally different to those on land, remain poorly understood. Land-based observatories combine multiple data sources to monitor volcanoes and predict eruptions. We propose to identify and instrument dangerous seafloor volcanoes comparably and build on existing hydrophone, autonomous surface and submarine platform facilities to monitor volcanic activity and broadcast the data to land live for the first time. This approach will make it possible to assess and monitor risk and provide unique datasets to study the dynamics of eruptions.
Regional Consequences of Atlantic Climate Variability for the UK	NERC has invested £9M in the National Capability programme "North Atlantic Climate System Integrated Study (ACSIS)" over 2016-21, with a focus on basin-scale, interannual to multi-decadal variability of the Atlantic climate system, the consequences of which are wide-ranging and far-reaching. Here we propose a strategic programme to address the consequences of Atlantic climate variability for the UK, specific to three key areas: (i) the adjacent marine region, encompassing the shelf break, shelf seas and coasts; (ii) hydrological and terrestrial ecosystem responses, including changes in flood risk and biodiversity; (iii) the regional atmosphere, including effects on high impact weather and air quality. Informed by the observations and computer model simulations of ACSIS, such consequences can be attributed to changes in the larger-scale Atlantic climate system. This will add understanding and predictive capability to the scientific knowledge that currently informs national policy in relation to natural resources and hazards. Specific examples of consequences include, but are not limited to: • Changes in storm intensity that disturb fragile ecosystems such as ancient woodland • Changes in weather that impact the sustainability of key UK agricultural sectors • Changes in ocean currents and weather that influence productivity in UK shelf seas • Changes in runoff affecting "Regions Of Freshwater Influence" (ROFIs) around UK coasts • Changes in the provenance of dominant air masses that influence boundary layer atmospheric composition, including dust and ozone levels In each case, ACSIS climate simulations for the present day and the future can be used together to explore the extent to which these Atlantic influences are predictable, informing UK policymaking as we adapt to environmental change in a more variable climate system.
Integrating and understanding processes underpinning the biogeochemistry of the nitrogen cycle (N-CASCADE)	The conversion of atmospheric nitrogen (N2) to biologically reactive forms (Nr) is essential to support plant growth and food production. However, the increased use of N fertilisers, low fertilizer use efficiency and fossil fuel combustion have doubled the global fixation of N2, contributing to global warming, threatening biodiversity and damaging human health as Nr cascades through the atmosphere, soils and waters, before returning to atmospheric N2 (Steffen et al. 2015). Key pathways of the N-cycle are highly uncertain and impede our ability to mitigate the above mentioned societal challenges. To rectify this, meticulously integrated N budget studies are required that trace N from the first step, the biological fixation of N2

	(BNF) to Nr, to the final step, denitrification to N2, in natural and managed ecosystems. Newly emerging technological advances (molecular, stable isotopic tracer, natural abundance techniques, imaging and laser technologies) combined with large-scale 15N tracer experiments and process models, will allow a step-change in measurement capability, going beyond previous N research, providing fundamental new insights into the dynamics of the terrestrial and freshwater N-cycle. This SPA will deliver the underpinning science required to support strategies to double N use efficiency and halve reactive N pollution. Improved understanding of the N-CASCADE will be especially timely by providing the data needed to support policy engagement within the newly established International Nitrogen Management System (INMS).
Realising the potential of low enthalpy geothermal energy	Geothermal energy provides a source of heat that is ideal for space heating, which currently accounts for about 25% of the UK's carbon emissions. Long established in Southampton, the use of geothermal energy for district heating schemes has yet to become widespread, partly because the commercial risk is too great. The key obstacle to progress requires research to inform potential producers of energy and so reduce business risk, and to inform the public sector as regulators and planners, building confidence in the decisions that need to be made. Low enthalpy geothermal systems exploit the temperature difference between subsurface waters and the surface, extracting energy for space heating. In reverse, heat can be stored underground. The simplest approach is to extract groundwater, take the heat that is needed, and then either return the water through a system of circulation, or discharge to surface water systems. In detail, the production of heat in this way depends on a sound scientific understanding of groundwater as a resource, the mechanical behavior of the host rocks, the influence of geochemistry and geomicrobiology on the efficiency of the process (scaling/biofouling), and the heat budget of the system. The effects of the surface engineering on surrounding systems also need to be understood, e.g. the direct effects of scaling and biofouling within the plant, but also wider implications of waste heat, or of treated produced water on local surface waters or sewage systems. The exploitation of geothermal energy depends on the combination of this scientific knowledge with other disciplines, so that all aspects can be described, modelled and understood, and made accessible to stakeholders involved in supplying the recipient communities.
Blue Carbon	Global warming is largely forced by the accumulation of carbon dioxide in the atmosphere. There are major gaps in our understanding of the carbon cycle and our ability to either calculate or influence the growth of atmospheric carbon dioxide due to a lack of knowledge of reservoirs, fluxes and processes in the coastal zone. Those gaps will be closed - with respect to UK waters in particular and mid-latitude marginal seas in general - by an integrated programme of measurement (in situ and remote) and modelling. The main reservoirs of carbon should be identified in the water column of the shelf seas, in pelagic and benthic systems and in organic and carbonate-rich sediments around the UK coastline; our "blue carbon" stores. The processes maintaining these reservoirs, or leading to secular changes, should be identified and modelled. Key and sentinel benthic habitats in UK waters should be identified. The contemporary value and projections of the role of Blue Carbon in the global carbon budget will be established, thereby improving predictions of the accumulation of atmospheric carbon dioxide and global warming. A management strategy will be devised for safeguarding the storage of blue carbon against external pressures (global warming, ocean acidification and industrial development) and enhancing storage where practical.
Global Earth System Projections and Services	Quantitative projections of future climate and environmental change should be a major part of the evidence base for the development of government and industrial strategy. To be useful in policy and decision-making, projections must account for the range of possible outcomes caused by uncertainties in models and the observations used to develop and evaluate them. We propose a strategic programme to develop a UK capability for delivering 'Earth Systems' projections, on time scales of decades to centuries, including quantified uncertainties. The

	programme will go far beyond the current world-leading UK capacity in physical climate projections (e.g. temperature and rainfall) and will support the transition from 'Climate Services' to 'Earth Systems Services' in support of global decision-making in both the public and private sectors. Earth Systems projections will encompass a wide range of variables such as changes in air quality and aerosols, land-surface features such as vegetation cover, the oceans and their ecosystems, and the cycles of carbon and other greenhouse gases The programme draws on a wide range of UK expertise on Earth System processes combined with the new capability offered by the UK Earth System model (UKESM) and expertise in developing and applying statistical methods to quantify uncertainty in future projections. UKESM is co-owned by NERC and the Met Office and simulates coupled processes and feedbacks between the physical, chemical and biological components that determine Earth System change. The programme will address fundamental challenges in quantifying and reducing uncertainty in Earth System projections. These include the identification of key processes and sources of uncertainty associated with physical, chemical and biogeochemical systems; optimum design of experiments to quantify the impact of processes and parameters on feedbacks that may enhance or damp the forced response, exploitation of new and existing observations to provide constraints on projections, consideration of the impact of model biases, the importance of unresolved or simplified processes and the application of statistical techniques to produce projections with quantified and traceable uncertainties.
Indian Ocean Systems on the Brink	The Indian ocean is key for global nutrient and energy cycles, biodiversity levels and food supply; 1) It takes up heat from the atmosphere and exports it to the rest of the ocean, thus compensating for Atlantic and Southern Ocean heat loss and regulating surface temperatures. 2) It connects the Pacific and Atlantic Oceans via the Indonesian Throughflow and Agulhas leakage and thus partially regulates northwards Atlantic heat transport and hence European climate 3) It contains one of three major oxygen minimum zones, is home to two thirds of the global continental margin that is connected to oxygen deficient waters, with these factors causing it to contain 20% of the oceanic loss of fixed nitrogen 4) It is a significant biodiversity reservoir with potentially large underexploited mesopelagic fisheries and important coral populations. It is also changing rapidly; nutrient inputs have increased by an order of magnitude in the last 50 years, surface pH and interior oxygen levels have reduced significantly and it is rapidly warming. The effects of these 'multiple stressors' are complex, non linear and hard to predict due to a paucity of data and understanding. We propose a major programme to address these issues using autonomous technologies, ships, models and remote sensing techniques.
Improving agricultural efficiency through tackling food waste in primary production	Indicative analysis suggests that at least 1Mt of food is wasted in UK primary production, worth hundreds of millions (£), yet there is no reliable evidence at a national or regional scale to direct action to tackle this. Authors of existing estimates, e.g. the UN's FAO, the EU, and national researchers, acknowledge the limitations of work so far. Addressing this evidence gap can improve the efficient use of important resources such as water, soil and nutrients, and reduce greenhouse gas emissions. It will also reduce costs for the food and farming sectors, and benefit citizens by reducing pressure on food prices. Delivering a step change in the sustainable production and consumption of food and drink is critically important. Just meeting global demand for food might increase global temperatures by 2°C by 2050. The UK currently wastes around 10Mt of food per year, worth £17 billion. Experience has shown that no one project is capable of tackling this complicated research challenge. Instead a strategic programme of research and collaboration is proposed, bringing together UK academia and industry in this rapidly emerging

	research area. It is expected that research outputs will be used to develop tools to monitor trends in primary production food waste. This will deliver continued value to UK businesses and policy makers, and enable the UK to provide international leadership by making this available to other countries, particularly those supplying the UK's food and drink.
Mapping the Chemosphere	Statement of the idea: Fewer than 5% of the 150,000 synthetic chemicals currently used in consumer and industrial products have been safety tested due to the slow pace and high cost of current testing models. Ecosystems are increasingly saturated with these compounds, but their effects remain largely unknown. For regulation to be effective, chemical safety testing to be truly prospective, and for environmental health efforts to be prioritised and managed, all sectors must have access to sufficient data backed by affordable, accurate, and rapid methods of testing, monitoring, and analysis. With the UK now poised to develop its own regulatory framework for chemical safety management, it is timely that we undertake a significant initiative to generate the next-generation translational toxicological knowledge required to concurrently protect the health of people and of the ecosystems that we rely upon.To address this knowledge gap, and the challenge of transforming environmental health protection, we propose a program of research that brings together multidisciplinary UK experts around a unifying goal of 'Mapping the Chemosphere'. The programme we propose would consist of: 1) Research to develop applications and deploy existing non-targeted strategies to generate and visualize high-resolution chemical maps of ecosystems, as well as rural and urban environments. This research would ultimately provide comprehensive and quantitative information about chemical mixtures found in actual environments, without a need to interrogate individual (a priori known) compounds. 2) Research that uses emerging technologies to chart the 'exposome' and bridge the artificial divide between ecotoxicology and human toxicology. This research stands to reveal the prevalence of chemicals as mixtures interacting with biological processes, including the occurrence of non-chemical stressors.3) Research to predict the harmful effects of chemical exposures on most animals, including human, based on empirical knowledge of biology, biochemistry, genetics and/or functional genomics shared among a minimal set of 3-R compliant model species. This research would enhance foundational understanding of mechanisms of toxicity in light of Adverse Outcome Pathways (AOPs) as the near-future regulatory paradigm.4) Computational tools and approaches that are tailored to data integration and model selection challenges in ecotoxicology. This research would ideally discover pattern that reveal or predict threats across different spatiotemporal scales and help develop strategies for improving human and ecosystem resilience to chemical exposures.5) Most importantly, strong coordination among the research themes, including cases studies with relevant public and private sector stakeholders.
Resolving the Antarctic sea ice paradox	Statement of the idea: If there is a single phenomenon that climate sceptics seize upon to denigrate the science underlying climate change it is the recent (and seemingly paradoxical) increase in the sea ice extent in the Antarctic. Why at a time of record high concentrations of greenhouse gases and rapid decrease in Arctic sea ice, has the extent of Antarctic sea ice increased at a statistically significant rate over recent decades? Furthermore, why do virtually all the coupled climate models that form the basis of the Intergovernmental Panel on Climate Change (IPCC) initiative have Antarctic sea ice decreasing in their simulations of recent global climate, whilst satellite records reveal the exact opposite? Are key processes or feedbacks not adequately represented, or are even missing, in our models? Or is the Antarctic atmosphere/ocean/sea ice system in a particularly anomalous state at present? These questions demand an evidence-based explanation. In an extraordinary move, 22 scientists from four countries penned a commentary piece in Nature (19 July 2017) to highlight the need to seriously address this paradox. In fact, this commentary piece revealed that the puzzle had just become more complex. While

	Antarctic sea ice extent reached consecutive record maxima in 2012, 2013 and 2014, in 2017 it dropped significantly, to the lowest level ever observed in the satellite record. Our understanding of the drivers behind Antarctic sea ice variability is clearly incomplete. The recent extreme swings in Antarctic sea ice extent and our complete failure to model them underline the need for progress in understanding correctly the inter-linked processes that drive Antarctic sea ice variability on short to medium time scales. Progress can only be achieved through a cross-disciplinary research programme that seamlessly marries together expertise from many natural science disciplines including sea ice physics, biology, oceanography, and meteorology. Theoretical and modelling studies are required to help interpret observational programmes. To put observations and model predictions in context with past history, paleoclimate studies must complement this approach. We therefore propose the first cross-disciplinary research programme whose key focus is improving the representation of Antarctic sea ice in climate models. This would consist of: (1) A focused observational programme that will provide near-continuous data-streams, over an annual cycle, on poorly-constrained variables and processes. These observations will make use of the UK's long-term investment in logistics: ice-strengthened ships, and aircraft, as well as our advances in technology: autonomous buoys, drones, mammal-mounted instruments, aerial and sub-ice autonomous vehicles. We will take advantage of satellite-mounted sensors, to ensure that observations are placed in a regional context. (2) A major modelling programme, in which the parameters observed in (1) are used to challenge models and thus help us to identify the underlying reasons why Antarctic sea ice is so poorly represented in coupled climate models. Efforts will then focus on improving models through better representation/parameterisation of key processes. Sea ice properties are very sensitive to model errors in ocean conditions and atmospheric circulation, so this effort must cross the traditional boundaries of environmental modelling. (3) Reconstructions of past Antarctic sea ice extent, using ice core and ocean sediment proxy data that would allow the recent observed changes to be set within the context of long-term natural climate variability. (4) Using the knowledge gained from (1)-(3), development of improved projections for Antarctic sea ice through the 21st century and assessment of the regional and global impacts of these changes.
The cryosphere and sea level in a warmer world	The IPCC predicts a global sea level rise of 52-98 cm by the year 2100. This is based on the 'high greenhouse emissions' scenario that national governments have, as yet, shown no ability to deviate from. We are therefore locked into a future where our coastal communities, infrastructure and economic stability will be progressively, and sometimes catastrophically, impacted by sea level rise and extreme events. Many scientists consider these IPCC future sea level estimates conservative. This is largely due to a dependence on 'process models' that produce steady state changes with beguilingly smooth sea level curves for the different greenhouse gas emissions scenarios. This gives policymakers the impression that if we adopt one or another of the emissions targets then sea level will react in a controllable and predictable way. It won't. Without exception, data on past sea levels, greenhouse gasses and global ice volume show a system that is not in steady state. Sea level, in particular has shown rapid jumps through the last glacial interglacial cycle resulting from fast and non-linear changes in the ice sheets. One model shows that these could add at least another meter of sea level rise by 2100. Although a significant challenge for models, better understanding (and predicting), the risk of these non-linear events is the scientific challenge of our generation. To address this we propose a major, multi- and cross-disciplinary programme of observations, focusing on the last interglacial period (130-115 thousand years ago). This period is critical for understanding sea level and climate change because it offers the only accessible analogue period of bipolar warmth reaching magnitudes

	comparable to those simulated during this century by IPCC high greenhouse gas emissions scenarios. Critically, it also includes analogues of non-linear behavior of the ice sheets and periods where sea levels were 6-9 m higher than today. Deploying NERC ships, polar logistics, models and expertise across institutes, HEI's and partnerships abroad, the programme we propose would consist of: 1. Deploying NERC ships to core interglacial marine sediments now identified at the polar continental margins and using (i) iceberg rafted debris provenance to reconstruct the timing, extent and locations of polar ice-sheet loss, and (ii) palaeo-seawater temperature proxies to evaluate the role of ocean forcing in driving ice sheet collapse, and to identify threshold levels. 2. Intensifying the search for last interglacial ice (especially in the deep, marine-based sectors of the West Antarctic Ice Sheet, and parts of Greenland), thereby geographically defining the parts of the cryosphere that contributed to sea level rise during the last interglacial. Tracking known interglacial ice layers in blue ice at interior mountains, and in ice cores at coastal ice domes, into the interior of the ice sheet using radar. Verifying the 3 dimensional extent of interglacial ice from isotopic analyses of deep ice layers collected with rapid access drills. 3. Seeking new higher resolution vertical and horizontal ice core records to characterize regional climate, ice sheet, sea ice extent, and environmental change during the last interglacial in Antarctica; coring in regions sensitive to potential collapse of the West Antarctic Ice Sheet is especially critical (and not covered by the NERC/NSF Thwaites programme). 4. Identifying the sources of known sea level jumps during the onset of last interglacial warming and modelling the processes in the earth system that caused them.
Plastic pollution in the marine environment	The accumulation and potential impacts of plastic pollution is now considered a major environmental issue. Most plastics degrade very slowly so almost all plastic ever made (~eight billion tonnes) is still present in our environment in some form. Recent estimates suggest ~ 5.25 trillion pieces of plastic are in the oceans, and by 2050 the total weight of plastic may exceed the weight of fish. Plastic is the most abundant type of ocean debris (>80%) and 90% of this is found in remote open oceans, mostly as particles < 5mm in size. This presents a huge threat to marine organisms from physical ingestion and absorbed organic pollutants in and on the plastics, and introduction of non-indigenous pests. The impact will affect the whole marine food chain, and be a major hazard for indigenous wildlife and food security. While there is currently intense interest from government, commerce, NGOs and media on plastic pollution, the core scientific understanding of the short and long-term impact of plastics on the marine environment is lacking. NERC could spearhead a major new research effort involving quantification of the major plastic sources, transport pathways to ocean sinks, and physical, chemical and biological consequences. The remote sensing, ship, aircraft and drone infrastructure is ideal for supporting such a coordinated UK effort, especially in remote regions. Along with partnerships with other research councils, government departments and industry, NERC science has the potential to provide solutions to this looming environmental hazard.
Reducing Uncertainty in Climate Sensitivity due to Clouds	Statement of the idea: There is an unprecedented challenge facing the aerosols, clouds and climate community. Lack of understanding of physical processes in clouds and interactions with aerosols that control aerosol-induced radiative forcing and cloud feedbacks are unanimously agreed to be the largest causes of uncertainty in current estimates of climate sensitivity (e.g. IPCC report, 2014). Climate sensitivity is broadly defined as the equilibrium global mean surface temperature change following a doubling of the concentration of atmospheric CO_2. It depends on internal feedback processes, including cloud feedbacks that amplify or dampen the influence of radiative forcing on climate. Understanding and quantifying aerosol and cloud processes will therefore result in more accurate climate projections, which has enormous societal impacts. The scientific problem is how to reduce the uncertainties. The idea we are submitting as a potential SPA is to address this

	problem by bringing together scientists with expertise in aerosols, chemistry, land surfaces, clouds and climate, in an integrated programme, the result of which will produce demonstrable model improvements with consequent reduction in uncertainty. This will be achieved by: (1) Using existing in-situ and satellite observations; (2) Making new targeted field observations in optimum locations; (3) Performing laboratory experiments; (4) Using and improving process models to derive new parameterizations; and (5) Using and improving climate models. Cloud processes (by which we mean microphysics, dynamics and thermodynamics) have to be parameterized in climate models and some even in 1D process models; there is little hope of being able to explicitly resolve these processes in climate models in the near future. There have been advances in the understanding of climate feedback associated with changes in low-level liquid clouds. However, even in this regime, precipitation and small-scale dynamical feedbacks add complexity and significant uncertainty. Cloud feedbacks and aerosol forcing in other cloud regimes, such as tropical anvils involving mixed-phase cloud microphysics, remain uncertain mainly because of the lack of understanding of the aerosol and cloud processes and interactions, and their representation in climate models.
Implications of Climate Change for Environmental Impact Assessment	Contaminant behaviour in the environment is influenced by a number of environmental parameters (temperature, salinity, pH, hypoxia, eutrophication etc) and will affect bioavailability, and ultimately, effects. Likewise, adaptive stress to these changing conditions is likely to influence the susceptibility of organisms to contaminants of known and emerging significance, potentially compromising biomarker endpoint results used in environmental impact assessments. Relevant data are required for environmental risk assessment, to inform current predicted environmental concentrations (PECs) and predicted no effect concentration (PNEC) models in order to properly assess risks to the environment and human health, particularly under a changing climate, which .
Diagnostics for environmental pathogens	There is little knowledge of distribution or abundance of various pathogens (bacteria, viruses, protozoa) in the environment which are of relevance to aquaculture or agriculture. Rapid surveillance methods usable in the field would enable study of the ecology of these organisms before they become problematic. At the moment, industry reacts to the emergence of a problem rather than planning to avoid it. This is very costly and potentially catastrophic. Knowledge of these organisms would also improve our knowledge of the functioning of natural systems, as the role of pathogens in natural mortality in, for example, aquatic systems is poorly characterised.
Mixture toxicology: a re-evaluation of the principal paradigm of toxicology that "the dose makes the poison"	Appreciation of the presence of complex mixtures of toxicants in the environment has existed for many years but only recently have the technological advancements become available to effectively address the implications of mixture exposure in organisms. Many thousands of anthropogenic substances are released into the environment, and, of these substances, numerous chemicals are designed to biologically active (e.g., pharmaceutical chemicals). Chemical risk assessments are almost exclusively developed for individual substances and the ability of environmental protection agencies to deliver on their remit is severely limited by inability to assess the toxicology of mixtures. New insights have emerged regarding toxicology of mixtures that include appreciation for the timing and sequence of exposure to specific substances within mixtures and concepts of toxicokinetic recovery and toxicodynamic parameters that influence mechanism of toxicity. The discipline of environmental toxicology is poised to undergo rapid advancements in understanding risk and hazards of chemical mixtures, and investment in research to support these development is urgently needed.