Last updated: January 2021

Natural Environment Research Council

Guidance for developing and submitting ideas for strategic research highlight topics

NERC is inviting ideas to help us achieve the long-term ambitions outlined in our Delivery Plan: productive environment, healthy environment, resilient environment, digital environment and global environment. The ideas will be used to inform the development of new strategic research investments through the highlight topics (HTs) mechanism.

Ideas submitted by the community through this process will primarily be used to develop highlight topics, but ideas may also be used to develop investments through other funding routes.

What is an 'idea'?

By an 'idea' NERC means a statement of a possible course of research, presented for example as a sharply focussed question, gap, challenge or opportunity, that the proposer(s) consider would contribute to the delivery of the long-term ambitions outlined in our Delivery Plan (productive environment, healthy environment, resilient environment, digital environment and global environment). An idea should not be framed as a proposal on how to deliver specific science advances, but should instead set out where science advances are needed. This invitation is to submit ideas for strategic research, the aim of which is outlined below:

NERC scientists study the whole planet, from the edge of the atmosphere to the centre of the Earth, and excel at revealing the environmental challenges confronting the world. Tackling these complex problems requires us to go further, bringing together deep understanding of environmental science with a whole-systems approach.

NERC's ambition is to lead a broad and diverse research community to bring about the environmental solutions - clean air and water, limited climate warming, a circular economy, and diverse ecosystems - needed in the UK and worldwide, to foster a productive, healthy and resilient environment.

Strategic research should deliver new understanding that will, over time, help us to achieve the long-term ambitions of our Delivery Plan, which are the focus of our activities: productive environment, healthy environment, resilient environment, digital environment and global environment.

NERC is seeking ideas for highlight topics. Ideas for highlight topics should be sharply focused defined topic areas that can be delivered by independent projects up to the value of £4 million over a maximum of four years. Highlight topics should not require NERC to partner with other funding agencies in order to deliver the project.

An idea is not the same as a discovery science large grant outline. Large grant outlines state a problem and series of clearly defined science questions and then outline how a particular team will

address these. Strategic research ideas outline an area of research that needs concerted effort to make progress, and provides evidence that such progress is possible, but does not outline how specifically the progress can be made. For example, an idea can be persuasive if it can point to broad areas of innovation in analytical, modelling or measurement technologies that offer possible new insights into a hitherto intractable problem; a large grant outline would describe specific methodological routes to progress (including who would do the work).

Submitting an idea

Ideas can be developed by an individual or group within the research community. Ideas from those who use environmental science, such as business and policymakers, are also encouraged. It should be noted that there is no NERC funding available to support the development of ideas, but NERC staff are available to discuss your ideas and provide advice, especially on sections where you feel you might find it difficult to provide the level of specificity we have requested. In addition, NERC staff can:

- Identify related current investments or critical masses of expertise in particular science areas through research programmes or projects, and facilitate users to connect with relevant expertise to seek input into ideas.
- Direct users to relevant events convened by other organisations, such as learned societies, which often hold discussion meetings on topics of relevance to NERC's remit/strategy and will in some cases proactively organise the community to identify research priorities.

If you have any queries on the process or would like advice on a potential idea please contact us at idea@nerc.ukri.org in the first instance, and we will put you in touch with a NERC colleague who can help.

There is no limit on the number of ideas that each individual can submit, but each idea is evaluated on its own merits; there is no benefit in the prioritisation process of submitting multiple very similar ideas.

Example ideas

Two examples of ideas that had a useful level of specificity are included at **Annex A**. There is no perfect exemplar but these example ideas set out where scientific advances are needed to resolve issues, but importantly are not framed as proposals on how to deliver the scientific advances.

- Drivers and climate implications of recent rapid loss of Antarctic sea ice
- Urban climate feedbacks between street, neighbourhood, and city scale processes

On-Line Form

Ideas should be submitted on the on-line form, and include the following information:

- **Title**
- **Statement of the idea:** a short summary of the idea, around 200 words, suitable to be published on the NERC website

- **Research question(s):** a description of the scientific advance needed, its timeliness and novelty. The advances should be well-defined and specific and include relevant citations. They should be appropriate in scale for a highlight topic.

- **Delivery Plan priority themes:** a description of the impact the research will have, including relevant citations. Include specifically how the idea and expected outcomes of research will contribute to the delivery of the long-term ambitions outlined in our Delivery Plan (productive environment, healthy environment, resilient environment, digital environment and global environment.

- **Capacity:** whether the UK community has the capacity and infrastructure needed to do the research, including, if applicable, how the research builds on and complements existing activities and utilises NERC infrastructure. Required new capital investments and evidence for training needs should be specified in this section.

- **How the idea originated and has been developed:** including a note of the organisation(s) involved, and how the idea was generated, e.g. through workshops. This section should not include any individually identifiable information.

- **Identify why this idea is a highlight topic:** identifying why a highlight topic (sharply-focused defined topic areas) investment is most appropriate for the idea.

The ideas should be submitted via the on-line form. The form also includes identification questions and classification questions for analysis of the ideas by NERC. Ideas can be submitted to NERC at any time, although there will be regular cut-off dates for ideas to be considered by NERC in a particular round. The cut-off dates will be published on the NERC website.

National capability and the ideas process

NERC's national capability (NC) funding supports science that is vital for UK environmental science in the long term, but whose scale and complexity means it cannot be delivered in an openly competitive way. For example, capability may only exist in one place such as in NERC's research centres or large research infrastructure (e.g. ships, aircraft and polar bases). Programmes funded through NC can provide the foundation for other NERC-funded activities and NERC welcomes the submission of ideas which build upon and maximise the value of science and infrastructure funded through NC.

What happens to ideas?

Once an idea is submitted to NERC, the proposer relinquishes ownership of that idea and it becomes owned by NERC. There is no further input from the community. The ideas will be reviewed by Science Committee and a decision made on the next potential highlight topics areas. The decision makers will not know the identity of those submitting ideas, but will have information on whether the idea was developed by an individual or a group. Prioritisation will be based on the following criteria:

Criteria	**How assessed**
• Potential for scientific excellence • Timeliness and urgency of research question • Extent to which topic is already being or has recently been funded	Research question (s) section
• How the idea and expected outcomes of research will contribute to the delivery of the long-term ambitions outlined in our Delivery Plan (productive environment, healthy environment, resilient environment, digital environment and global environment). Potential for economic and/or societal impact	Delivery Plan priority themes section
• Readiness of UK research community and infrastructure	Capacity section

Process for highlight topics

We intend that highlight topics will be developed from single ideas or very few closely-related ideas; for example, two ideas may be matched up where a research user has strongly outlined a problem, which is related to an idea from a research provider specifying the science advances and UK capacity. The ideas will be reviewed and a decision made on those highlight topics to be included in the next call.

It is anticipated that each HT announcement of opportunity will be released approximately six to seven months after the HT idea cut-off.

Feedback and longevity of ideas

NERC will announce regular cut-off dates and will prioritise highlight topics from each round. After each round NERC will provide feedback to the community; we anticipate this feedback will be high level.

For ideas submitted as potential highlight topics the feedback will inform the submitter whether (a) their idea contributed to a highlight topic (b) whether it was felt to have potential but needed further development, or (c) whether it was not considered to be appropriate for strategic research investment at this time. Individual feedback will be given on the ideas in category (b) on how the ideas could be improved for future cut-offs.

Ideas have a lifetime of a single round to ensure they remain timely and resubmission is required if you would like your idea to be considered again. NERC encourages submitters to use their feedback and the ideas guidance to decide whether to resubmit ideas for future rounds.

ANNEX A: Example ideas

This annex contains two examples of ideas that had a useful level of specificity.

There is no perfect exemplar but these ideas set out where scientific advances are needed to resolve issues, but importantly are not framed as proposals on how to deliver the scientific advances:

- Drivers and climate implications of recent rapid loss of Antarctic sea ice
- Urban climate feedbacks between street, neighbourhood, and city scale processes

Example 1: Drivers and climate implications of recent rapid loss of Antarctic sea ice

Text of the idea that was submitted to NERC

Title: Drivers and climate implications of recent rapid loss of Antarctic sea ice
Statement of the idea: In contrast to the Arctic, annual mean sea ice extent (SIE) across the Antarctic/Southern Ocean increased between 1979–2014 at a rate of 1.8 % per decade. In spring 2016, this picture changed dramatically; Antarctic SIE decreased at a rate 46% faster than the mean and 18% faster than in any previous spring. The precipitous year-on-year decline was such that 2017-2019 all set records for minimum Antarctic SIE across the 40 year-long dataset. The nature of Antarctic sea ice decline differs markedly from that of the Arctic - the rate has been faster, and the change of state during 2016 is unique to the Antarctic. The sector that contributed most (34% of the 2016 decrease) to the total decline was the Weddell Sea. Indeed, over the last 5 years the extent of summer sea ice in the Weddell Sea has decreased by 50%, coincident with large changes in the ocean environment. The 2016 change of state and the rapid SIE decline appear linked to a combination of record storms and the reappearance of a major polynya, but insufficient data mean that details are lacking. Sea ice is a recognised key climate indicator. Antarctic sea ice is a critical part of the global system with key roles in reflecting solar energy, driving global ocean meridional overturning circulation, and absorbing anthropogenic heat and CO2. Yet changes in sea ice extent are not reliably captured in models, highlighting major inadequacies either in system-level understanding or the way that processes are represented in models. This Highlight Topic will deliver i) an extensive observational programme to capture unprecedented information on the relative role of oceanic vs atmospheric processes in driving recent Antarctic SIE decline; ii) process-level descriptions of key parameters coupled with new data products against which to test improvements in sea ice models. The goal is to deliver step-change in our understanding of the Antarctic sea ice system, and tools to assess impacts on the wider climate system.
Research Question(s): The scientific advance needed is quantitative process-level understanding of the drivers controlling current Antarctic sea ice extent and their effective incorporation into models. The timeliness is two-fold: i) the major and rapid change in Antarctic sea ice behaviour since 2016, which is unprecedented in the 40-year record; ii) recent improvements in model resolution which enable the incorporation of smaller- scale processes into the model grid than previously possible. The UK community has access to novel operational platforms, technology and numerical tools, including digital environment platforms, and environmental modelling including the application of AI. Together, these assets will provide the required tools to answer the following questions: 1) What atmospheric and oceanic processes caused the rapid change in Antarctic sea ice observed (in particular in the Weddell Sea sector) in 2016? 2) Can these processes be represented reliably in models to reproduce observed changes in Antarctic sea ice extent? 3) What has been the short-term effect, of the sudden decrease in Antarctic sea ice, on global oceanic circulation patterns? 4) Is this a "new normal" and what are the implications for exchange and redistribution of heat and CO2 over decadal timescales?
Challenges *(being replaced in 2021 with Delivery plan priority themes)***:** This Highlight Topic will ultimately deliver a numerical modelling system that can simulate observed changes in Antarctic sea ice based on detailed process-level understanding of the atmospheric and oceanic drivers. This advance will enable assessments of future Antarctic sea ice and the concomitant climate impacts. Such information is critical for

future IPCC assessments and international policy (including for UK Risk Register and World Economic Forum Global Risk Reports). Antarctic data are critical for comparison to Arctic processes, advanced through the recent international Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. Our Idea is aligned to NERC's priority area of "Resilient Environment". The timescale and rate of major changes in polar sea ice are currently highly uncertain. Given the central role that they play in Earth's climate system, this makes it extremely challenging to anticipate future climate scenarios with high confidence. To deliver this Idea will require developments across a range of technologies. Development of novel sensors for long-term deployment within the sea ice zone will require miniaturisation and astute power-management; there is scope for innovation in robotics; innovative data analysis techniques including machine learning will enable maximum exploitation of diverse datasets. This Idea is thus aligned to another of NERC's priority areas, that of "Digital Environment". Changes in climate are anticipated across the globe as a result of polar sea ice loss. The research questions posed within this Idea feed into wider assessments of environmental risk and environmental sustainability, and are thus aligned with NERC's priority area "Productive Environment".
Capacity: The UK has an outstanding record in sea ice research and operations in the polar regions. Our capacity extends to: - the needed logistics and infrastructure to carry out world class observational studies in the sea ice zone, including the new UK polar research vessel, RRS Sir David Attenborough, instrumented aircraft, autonomous vehicles and buoys, expertise in tagging seals to probe areas below the ice, world-class research station adjacent to the Weddell Sea sea ice zone; - hosting world- leading research communities in polar meteorology and oceanography, sea ice, and environmental modelling, which are required to address the cross-disciplinary research proposed here; - participating in satellite observing programmes (UK, European and international) focused on sea ice and other aspects of the polar environment; - internationally-recognised modelling expertise, including theoretical studies of sea ice and the development of the sea ice component in global, coupled climate models; - world-leading machine learning research groups within Universities and at the Alan Turing Institute who are now collaborating with the UK sea ice science community; - co-ordinating international high-profile programmes, such as the European Union's largest sea ice based programme ICE-ARC, a 12 million euros and 23 Partner institutes across Europe, including Russia.
How the idea originated and has been developed: Given the visibility of the challenge a number of international workshops over recent years have highlighted the need for further research into Antarctic sea ice variability and change. These include the Royal Society meeting on sea ice in 2014, the major National Academies of Sciences, Engineering, and Medicine workshop in 2016 (proceedings published by the US National Academy of Sciences available at www.nap.edu/24696), and the SCAR AntClim21 workshop in 2019. Many UK and international scientists highlighted the need to understand recent Antarctic sea ice changes in the 'call for action' in Nature in 2017 (available online at go.nature.com/2tjeebi). This specific submission has been built from these foundations of workshops and discussions by a group of scientists with expertise in sea ice physics, meteorology, oceanography, data science, and numerical modelling, from the British Antarctic Survey and the Alan Turing Institute.
Identify why this idea is a HT: There is a clear focus to this Highlight Topic Idea – to identify and quantify key drivers of change in Antarctic sea ice since 2016, and successfully incorporate them into numerical models. Outcomes could be delivered by a number of independent projects, ideally extending across boundaries of traditional skills-sets. The scale and duration of funding would enable advances beyond those available through standard funding routes. In particular, four year Highlight Topic projects would: • enable novel approaches to autonomous observations that could be deployed and sustained over a requisite number of years; • support projects that embrace advances in numerical techniques, including AI, in conjunction with new environmental data; • enable development in capability of numerical models that would allow incorporation of new system-level knowledge, and support new assessments of changing sea ice impact.

Example 2: Urban climate feedbacks between street, neighbourhood, and city scale processes

Text of the idea that was submitted to NERC

Title: Urban climate feedbacks between street, neighbourhood, and city scale processes
Statement of the idea: Most of the world's population is experiencing urban climate change, e.g. urban heat islands, in addition to global climate change. Only recently have representations of cities been included in weather forecasts. The UKCP18 climate projections (2.2km resolution) show urban phenomena in new detail. However, to provide Integrated Urban Services to maintain city operations and inform future development, next generation models need to resolve neighbourhoods (0.1-1 km). This order of magnitude change raises questions as to which processes need to be parameterised or resolved. While city scales (~10 km) are captured by mesoscale models, street- scale (<0.1 km) currently requires computational fluid dynamic (CFD) models. The neighbourhood scale lies in a "grey zone" - buildings are not resolved but their effects need to be represented - and is a research priority. This HT will facilitate sustainable, resilient and healthy city development through improved modelling and observational capability that crosses neighbourhood-influenced scales. For instance, tall buildings may increase winds locally (improving pollutant dispersion) but reduce them elsewhere in the neighbourhood. Increasing building height can also increase city-scale friction and reduce winds. Urban greening cools air by enhancing evaporation but may reduce pollutant dispersion due to weakening boundary layer convection. Trade-offs and feedbacks between street, neighbourhood and city scale processes are critical to understand. The way we use our cities also affects urban climate. 4.5M UK homes already overheat in summer (CCC, 2019). If air conditioning becomes more common, resulting "anthropogenic" heat release from outlets will worsen urban heatwaves. Changes in city life impact temperatures and emissions, such as the drop in traffic flows and energy demand due to Covid-19 lockdown in spring 2020. Including anthropogenic effects in models is crucial to assessing low-energy adaptation measures.
Research Question(s): Recent developments in modelling and observational techniques can start to address urban climate feedbacks across scales. With increased computing power, the gap between numerical weather prediction (NWP) and CFD models is closing. Good progress has been made at each scale but the challenges are coupling and physics representation. New techniques are needed to tackle this: e.g. integrate building- vegetation-atmosphere exchange with anthropogenic heat release; incorporate impacts of realistic urban morphology; couple NWP and CFD models; and exploit CFD simulations to optimise NWP parametrization or observation networks. Observations across scales are needed to understand urban climate processes and to evaluate numerical models. As standard meteorological networks avoid urban areas, there is minimal data in cities. Many of the new data sources are only at street level but there is a need to understand the vertical structure of the atmosphere. Questions about representativity, accuracy, and how to integrate point observations with volume-averaged model output across a highly heterogeneous landscape need addressing. Projects would include elements of new theoretical frameworks, modelling techniques and synthesis of observational data to address research questions such as: 1) Green infrastructure is beneficial in terms of health and biodiversity – how can it be planned without adversely affecting city climate and pollution dispersion? 2) How does anthropogenic heat and water vapour release affect neighbourhood temperature and humidity? How can these fluxes be represented in very high resolution (e.g. 0.1 km) mesoscale models? 3) How do changes in building form affect predictions of wind and pollution dispersion at neighbourhood and city scales? Hence, what level of representation (eg urban canopy, street network, 3D morphology) is required for different models? 4) How can observations and modelling be combined to improve predictions of urban weather and climate?
Challenges *(being replaced in 2021 with Delivery plan priority themes)***:** This Highlight Topic addresses two NERC challenges: Resilience to environmental hazards: Urban hazards such as floods, heat-waves, pollution episodes and wind storms are a risk to infrastructure and people, some of whom are highly vulnerable. Vulnerable populations may be housed in city locations determined largely by socio- economic factors: the proposed work can support city authorities in identifying whether they are also living in "adverse microclimates" and thus target interventions (e.g. passive cooling measures, greening). The proposed area of work supports efforts to avoid poor urban design that worsens resilience to airborne hazards such as pollution, toxic gas release or airborne infections. This HT would contribute modelling tools to quantify ventilation across scales for more complex urban form than is represented in current operational air quality models. The resultant enhanced modelling and observational capability paves the way for better nowcasting

at smaller spatial scales; emergency response for toxic/hazardous emissions; and response to flash floods and windstorms, highlighted as urban risks within DEFRA's Climate Change Risk Assessment. Managing environmental change: Urban areas are dynamic, with constant change in infrastructure, land-use and population. Current climate projections, such as UKCP18, include a representation of cities but lack urban development projections that expand and change cities on a similar timescale as that of large-scale climate drivers. This HT would investigate anthropogenic urban climate change drivers at street and neighbourhood scales and provide a basis for future parameterizations in coarser resolution climate models. This HT could also benefit the UK construction and civil engineering sectors, e.g. designing effective blue/green infrastructure in cities to combat flooding and overheating, and wind engineering considerations for new tall buildings.

Capacity: Over a decade of projects funded by NERC, EPSRC and the EU (ClearfLo, ACTUAL, REFRESH, BRIDGE, DAPPLE, LUCID, REPARTEE, Hi-Temp, UrbanFluxes, DIPLOS,

MAGIC, urbisphere) have resulted in collective UK experience in urban measurement and modelling that is world-leading. In London the NERC ClearfLo project (2010- 2014) established equipment and measurement platforms (e.g. augmented air quality supersite at Marylebone Road, BT Tower monitoring at 160/190 m) that could be exploited under this HT. Work done under this HT (which is more focused on urban climate physics) would complement the SPF Clean Air: Analysis and Solutions Programme Wave 1 activities, e.g. co-operation in deployment of meteorological instrumentation alongside pollution measurements funded under the NERC-funded OSCA and APEx projects. With other projects also focusing on London as a test site, it could become an attractive "Urban Laboratory" in the UK that could stimulate international partnerships and model comparisons. Non-research community observation networks exist in London and other UK cities but require evaluation (e.g. see LCCP "Observing London" report). The HT also complements the work of the new research networks that will arise from Wave 2 funding focused on air quality challenges across the indoor/outdoor continuum. This HT would contribute detailed investigations of how urban form and materials affect the immediate environment of buildings in terms of pollution dispersion. The Met Office modelling and research/operational observation capability would be fully engaged in the HT, as it is beneficial to their strategy of developing Next Generation Models to be run at high spatial resolution over urban areas. Facilities such as the NCAS-AMF EnFlo wind tunnel laboratory at the University of Surrey and the ARCHER HPC service would also be used.

How the idea originated and has been developed: In Nov 2016 a Met Office (MO)/NERC Joint Weather and Climate Research Programme workshop (organized by Univ. of Reading and MO) brought together 50 key UK and international scientists to formulate the key requirements for an urban meteorological research strategy [1]. The Urban Working Group (informal research network between the MO and Universities of Reading, Surrey, Southampton and Birmingham) has contributed to ongoing development of the strategy and latest research updates. The EPSRC-funded UK Fluids Network has also facilitated discussions: in particular the Urban Fluid Mechanics Special Interest Group has held biannual workshops to scope strategic research ideas in the area of this HT. Network members include stakeholders from the construction sector. The idea has also been informed by London Climate Change Partnership (including GLA, Thames Water, Transport for London) discussions. [1] Barlow JF, Best MJ, Bohnenstengel SI et al. (2017) Developing a research strategy to better understand, observe and simulate urban atmospheric processes at kilometre to sub-kilometre scales. Bulletin of the American Meteorological Society, 98(10), ES261-ES264, doi:10.1175/BAMS-D-17- 0106.1

Identify why this idea is a HT: This idea is a HT because urban areas need to be healthy environments that are resilient to future climate change. However, there is a lack of integrated observational and modelling capability to inform how urban environmental change can be optimized. Focus is needed to deal with the heterogeneity of city landscapes and the large, local impact of human activity on the atmosphere. Focusing on interactions across scales in the urban atmosphere is an opportunity to bring together researchers across disciplines and communities, aside from being a pressing need to develop "fit for purpose" parameterizations and observation networks to support city management and weather forecasting of the future.

Independent projects funded under this topic could span different ranges of scales, i.e. street to neighbourhood, or neighbourhood to city, to improve understanding of urban climate feedbacks. Whilst the suggested research questions are linked by underlying heat and water vapour transport and flow processes, each project could focus on a particular aspect depending on the disciplines of the applicants and the specific environmental problem motivating the work, e.g. impact of transport and energy sector change at urban scales, optimizing ventilation potential of urban areas for fresh air. The HT would motivate ambitious research that builds on existing achievements and national capability. Urban observational datasets

and equipment exist that projects could exploit. Fine-scale modelling could deliver new understanding of what an urban observation network should look like to capture adequately horizontal and vertical variability, informing future data assimilation needs. New exascale computational resources will allow urban complexity to be captured.