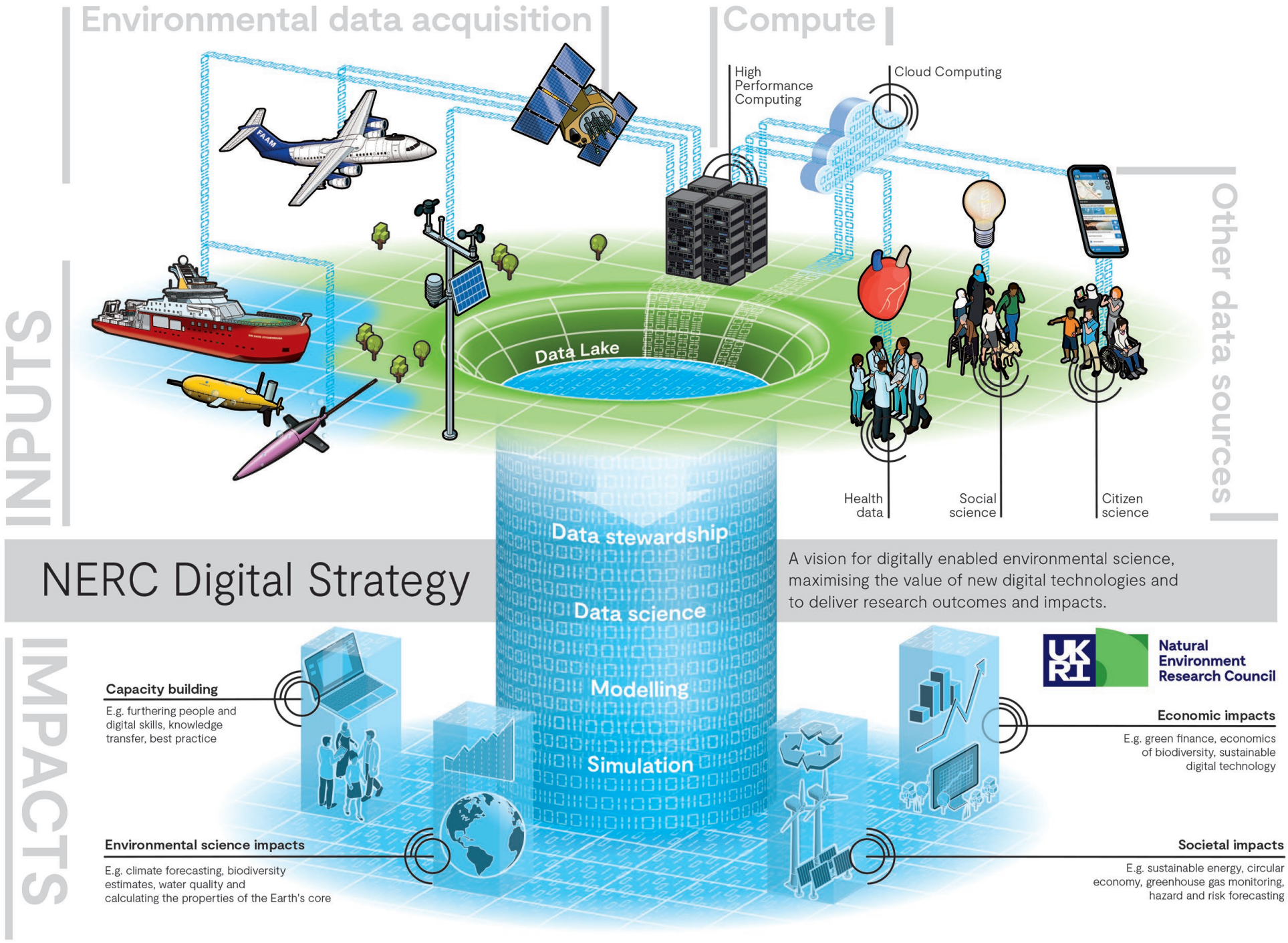
Natural Environment Research Council

Digitally Enabled Environmental Science

NERC Digital Strategy 2021-2030



Our Strategy

This Digital Strategy, the first of its kind for NERC, sets out a vision for digitally enabled environmental science for the next decade. We are entering a new era in which digital technology is central to our mission; we seek to maximise the benefits to environmental science of new digital technologies and the growth in data and compute power.

Our vision is to create a culture which places data and digital technologies at the heart of current and future UK environmental science. Digital technologies have the potential to transform environmental science and to address the breadth of NERC's science priorities, through efficiencies, new approaches, and even new scientific paradigms. We aim to ensure that all areas of environmental science are well positioned to capitalise upon the transformative potential of data and digital technologies, building upon substantial existing world-leading UK expertise. A digital-centric approach will be critical to building and maintaining the UK's strength in environmental science and transforming our understanding of the natural world.

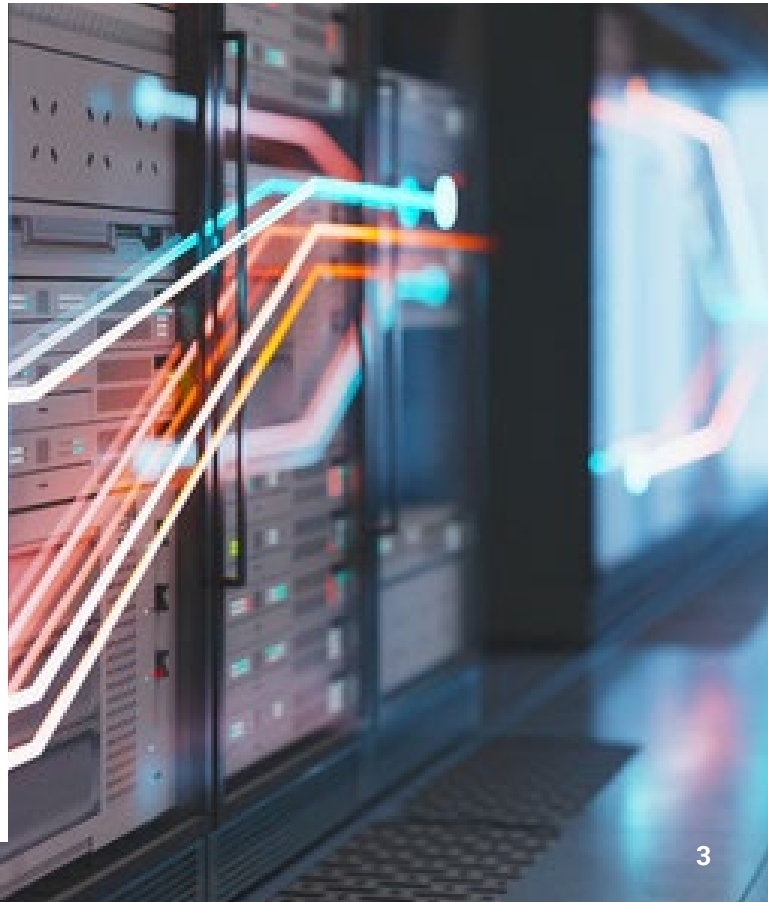
Environmental science seeks to address some of the most complex challenges in the modern world. They include: the consequences of the changing climate, population growth, urbanisation on a global scale, the patterns of change affecting land and its capacity to support diverse ecosystems, the ability of the ocean to buffer change, and the relationship between the ice shelves, the oceans and the atmosphere.

Addressing and understanding such complexities will require a new generation of digital technologies and capabilities to capture, integrate, access, analyse, understand, model, and simulate data from multiple sources, over a variety of scales, resolutions and frequencies.

Environmental science is currently producing unprecedented volumes of data. New technologies for sensing, measurement and modelling will see the available environmental data continue to grow in size and complexity. This rapid expansion in data production coincides with the emergence of significant step changes in compute power and data storage, as well as substantial growth in powerful new approaches to make sense of and use data, from data science to artificial intelligence (AI) and digital twins. There is a huge timely opportunity to bring together the potential of new datasets and novel tools to generate new scientific insights and applications. Realising this opportunity for whole systems thinking about data and digital technologies is the core goal of our digital strategy.

Realising our vision will require us to be ambitious, adventurous and highly collaborative. We will play a leadership role in driving forward a new generation of digitally enabled environmental science, exploring and creating new opportunities in partnership with environmental scientists and key stakeholders.

We will actively support a highly interdisciplinary and collaborative effort across and beyond the environmental science community, investing in our people, their digital skills, next-generation digital infrastructures, and leading-edge digital technologies. Together we will maximise the use of digital technologies, infrastructures, and data to maintain and build the UK's strength in environmental science for the 21st century.

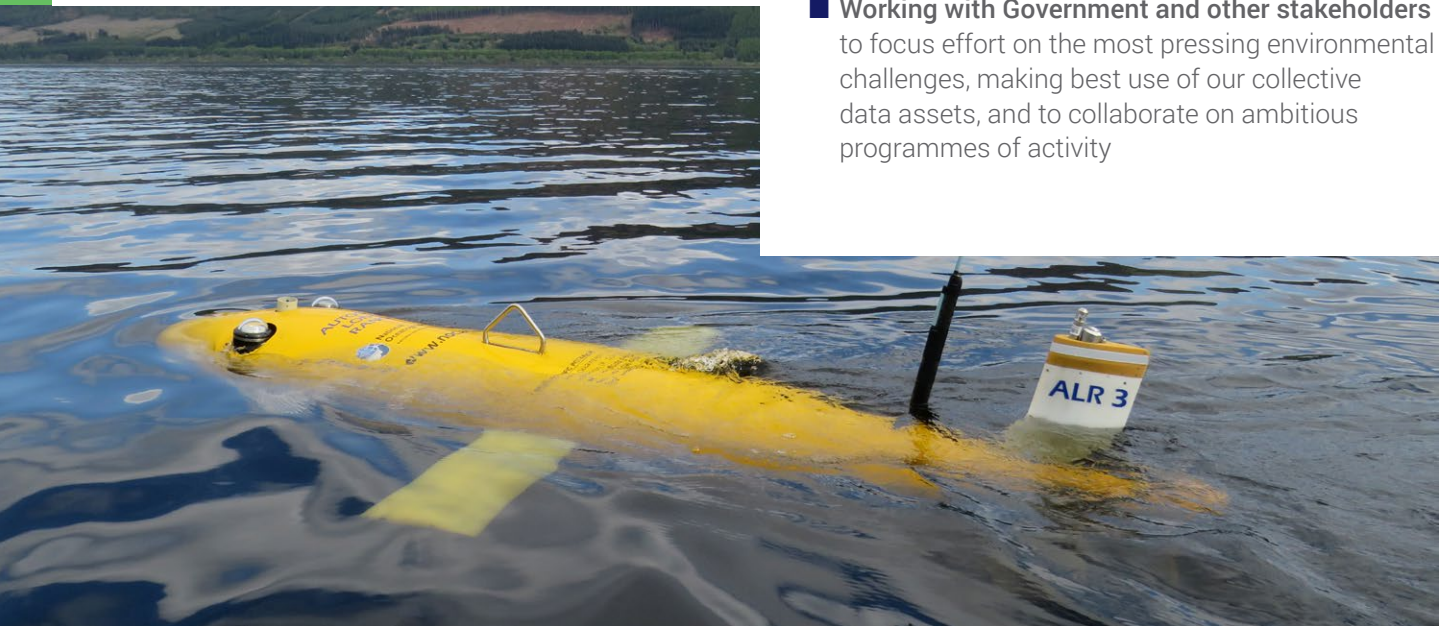


Working Together Towards a Digital Future

To realise our ambition of using digital technologies to transform our understanding and management of the natural world, we will build upon UK strengths and existing services. These include strengths in computationally intensive environmental science research, and existing NERC, UKRI and broader UK digital infrastructures including JASMIN[1] and the Environmental Data Service[2]. We will drive the development, adoption and use of new data tools, digital technologies and systems when addressing environmental science challenges. We will seek to transform interoperability across data sources, through action to enhance the entire data pipeline, from acquisition and generation, through enabling effective data access and supporting data skills, to supporting and promoting advanced integration across disciplines and applications.

We will build on our strategic partnerships including:

- **Working across UKRI** to support collaborative interdisciplinary research activities and to play a key role in UKRI's support for Digital Research Infrastructure
- **Promoting collaboration across the UK environmental science community** to support digitally enabled environmental science across the NERC portfolio
- **Supporting NERC Centres**[3] to maximise the use of data and digital technologies in delivering their missions, and to deliver effective data services for the wider research community
- **Working on a global stage**, seeking to support both world leading activities and collaborations with key researchers and stakeholders internationally
- **Working with Government and other stakeholders** to focus effort on the most pressing environmental challenges, making best use of our collective data assets, and to collaborate on ambitious programmes of activity



Delivery of our goals will be supported by enhanced governance of our digital research and infrastructure investments, ensuring we have the insight to invest for the benefit of the NERC community, and the oversight and advice we need. To understand and evaluate the impacts of our support for UK environmental science, we will seek to develop approaches to evaluate the change we facilitate, and to report periodically to the community on our progress.

NERC has a critical leadership role to play when considering how we advance the use of data and digital technologies to enable the transition to a net-zero target, and within the context of UKRI's sustainability goals[4]. There is the potential to deploy digital technologies, such as autonomous sensing or sampling systems, to directly impact the carbon emissions across environmental research domains. We will lead activities to understand how UKRI's Digital Research Infrastructure can transition to a net-zero target, seek to reduce the environmental impact of our digital activities, and deploy digital technologies to reduce carbon emissions.

To address the aspirations set out in this document we will develop a roadmap of actions in consultation with our community and key stakeholders. This will enable us to develop the key investments, partnerships, and culture change activities needed to deliver our strategic goals.

1 JASMIN
2 NERC Environmental Data Service
3 NERC research centres – UKRI
4 UKRI-050920-SustainabilityStrategy.pdf

A Digital Ecosystem Approach

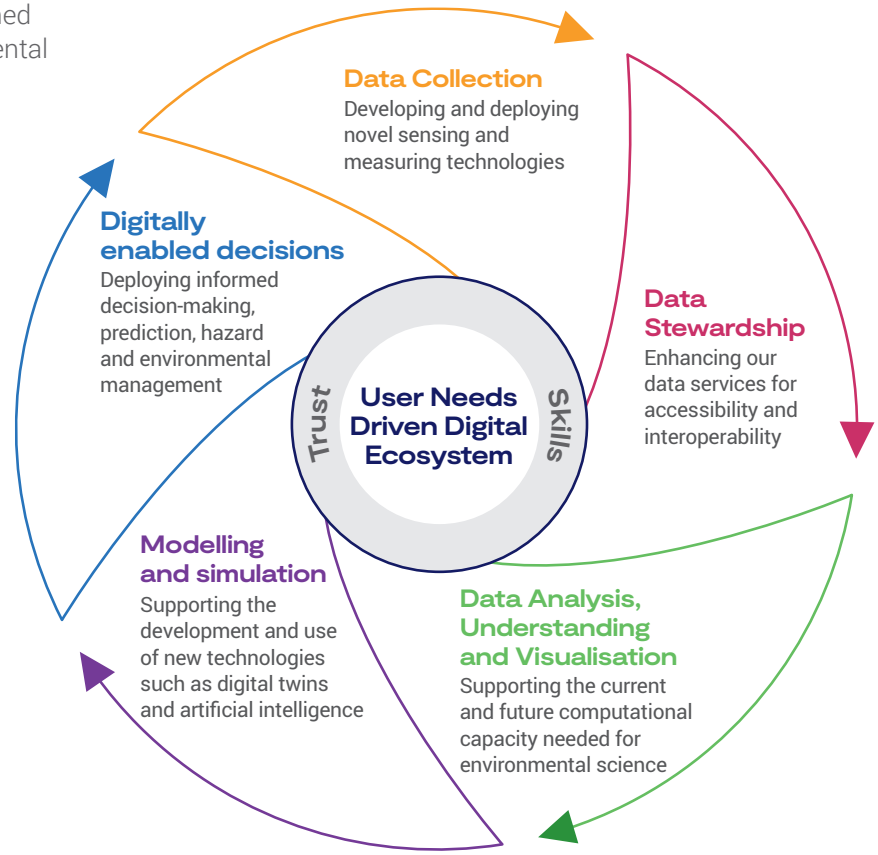
Over the next decade, the pace of digital transformation of environmental science will accelerate. Maximising the value and use of our data for understanding and decision-making will require us to think in highly connected ways about data collection, digital infrastructure, and the effective use of data science tools. It will require us to change our ways of thinking about data flows, to design in the use of digital tools at the start of our environmental research, and to have effective feedback and connectivity between measurements, analyses, models and decisions. It will require us to be ambitious about exploring the transformative potential of digital technologies for environmental science across all domains. Critically it will require us to maintain and build trust and confidence in data and digital technologies across the environmental research community.

Realising our vision for digitally enabled environmental science requires **a Digital Ecosystem** approach with integration across the cycle from data collection to its effective use. There are multiple definitions of a 'digital ecosystem' in the public and private sectors but they are all based on the principle of connectivity across a network of actors to achieve value and outcomes for all. In this environmental science context, taking a 'digital ecosystem approach' will focus on maximising the value and use of data to advance our understanding of the environment, by connecting across the complex environmental pipeline and stakeholder landscape.

Our digital ecosystem approach is at its heart collaborative and multi-disciplinary. It will require connectivity, common understanding and collaboration between domain experts and technical specialists, with co-designed and co-owned approaches to addressing key environmental science challenges. It will require the development of technical, professional and domain-specific skills across the environmental research community.

In taking a Digital Ecosystem approach we will:

- Place data science, digital tools and digital infrastructures at the heart of NERC's research and collaboration activities
- Embed a core focus on trust and confidence in data and digital tools for environmental science, enabling their effective adoption and use
- Support user-driven, systems-based approaches to data and digital technologies, enabling their effective use in environmental science
- Enable collaboration and learning across domains and disciplines, and the development of new digital skills, to support the development of new tools and techniques based on the latest technologies such as AI and digital twinning



Our Strategic Themes

To realise our vision we have developed seven strategic themes spanning the landscape of NERC's commitment to world-class environmental science through digital research, skills, and infrastructure.

Next-Generation Environmental Sensing Systems

Computational Resources for Environmental Science

Enhancing our Data services

Pioneering Computational Science

Data Science Tools and Techniques

Developing People and Skills

Facilitating Confidence and Trust in Digital Research

1. Next-Generation Environmental Sensing Systems

Sources of environmental data are continuously expanding and offering new opportunities for understanding the natural world. Data from emerging technologies – such as ubiquitous sensing and connectivity, Internet of Things (IoT) networks, edge computing, quantum technologies, and robotic and autonomous systems –are already starting to transform environmental science. New opportunities are then being realised from their integration with other information sources such as remote sensing, computational modelling, and digitised information from analogue collections. Furthermore, the potential to bring the computational resource to the data through approaches such as edge computing offers the potential to develop and use sensors and sensing systems in fundamentally new ways. These new sources of data and information have huge potential to drive new science and environmental understanding.

Our ambition is to ensure that environmental datasets are easily available and can be used with a range of digital and data science tools to inform, address and transform key challenges and questions in environmental science and policy. We will support systems-based development of new environmental sensing technologies, supporting integrated approaches to data acquisition and ensuring that data are optimised and accessible for use to address critical environmental challenges.

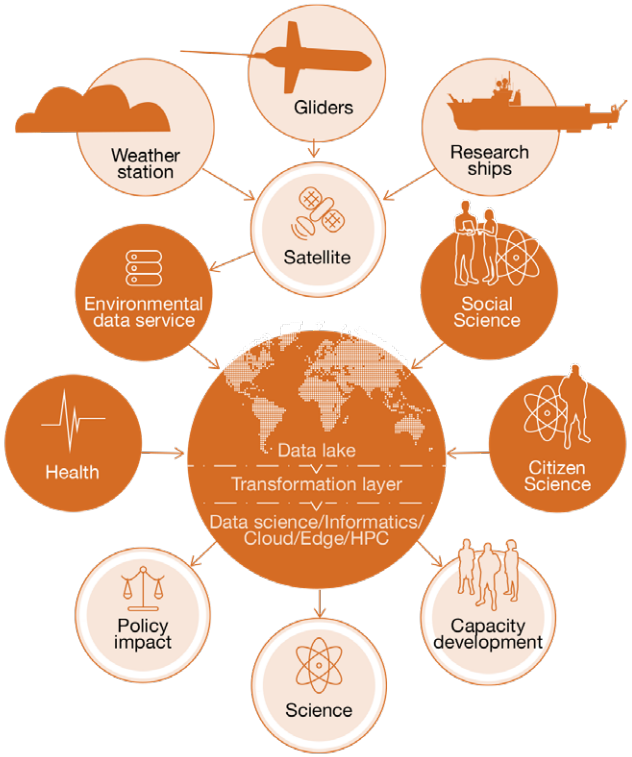
We will seek to:

- Support the development of next-generation environmental sensing and measurement systems designed for user needs, with effective connectivity and feedback between data capture and use
- Support the development of an ecosystem of digital infrastructure, embracing sensor networks, data capture and transmission, Big Data technology, modelling and visualisation
- Facilitate the development and deployment of contemporary data capture tools and technologies to address environmental science questions

NOC Autonomous Vehicles

Autonomous vehicles are the future of marine science. The ability to explore the oceans and collect data via unmanned, untethered robotic vehicles has greatly increased the scope of the information and understanding we can have about our oceans. New and innovative autonomous vehicles being developed at the National Oceanographic Centre (NOC) are pushing the limits on how we can explore our oceans, with capabilities allowing us to reach new depths, travel under ice, take readings in remote areas and collect data during high sea states.

The Net Zero Ocean Capability (NZOC) scoping project sets out a vision to inform planning for future low-carbon oceanographic research through the development of a data ecosystem integrating the use of next-generation ship technologies, marine autonomous systems and environmental sensors. The project envisages the use of emerging platform technologies, underpinned by appropriate digital research infrastructure and is closely linked to the NERC Digital Strategy, with an ambition to link the observing network to data portals that can be accessed by multiple users.



2. Enhancing our Data Services

NERC, our centres, our Environmental Data Service and our research community, hold valuable and exciting data assets, enabling targeted and longitudinal understanding of the natural world and its phenomena. As available environmental data volumes and complexities continue to grow, and environmental science addresses ever more challenging problems, our digital and data services will play an ever-increasing role in delivering research outcomes and impacts; we must therefore ensure that our services evolve to remain effective across both the existing and broadening user-community.

Our ambition is to continually enhance our existing services and to deliver new data and digital services which exploit and enable pioneering technology, enable multi-disciplinarity and support the whole NERC community and our stakeholders to make the best use of our data for new discoveries.

We will seek to:

- Ensure that NERC data capabilities and services can be effectively accessed and used, and that they are secure, accessible, interoperable and user friendly
- Support the development and use of leading-edge data services and capabilities for future environmental science
- Enable researchers and stakeholders from across and beyond the environmental science community to access and get value from NERC data resources

The NERC Environmental Data Service

The Environmental Data Service (EDS) provides a focal point for scientific data and information spanning all environmental science domains: atmosphere and climate, earth observation, polar and cryosphere, marine, terrestrial and freshwater, geoscience, solar and space physics. The data are available, accessible and reusable to multi-sector and multi-disciplinary users; ensuring that the data are trustworthy for users is a foundational principle of the service. The data holdings therefore provide a key resource that underpins our current and future understanding of the environment, informing business decisions, new research and government policy focused on addressing key environmental challenges and societal issues such as climate change and the conservation of endangered species.

The Digital Solutions Programme

There is huge potential for data generated from UK environmental science to support policy and decision-making across a broad range of sectors and applications including health, transport, insurance, housing, urban and regional planning. The £7m Digital Solutions Programme, led by the University of Manchester and initiated in 2021, will drive a step change in the use of our environmental data assets for economic, societal and environmental benefits across the UK. The programme will be user-driven, working with users and partners across local and national government and agencies, and the private and third sectors. It will seek to integrate NERC environmental datasets with a diverse range of social, economic, health, and other environmental datasets to support previously unrealisable policy and decision-making.

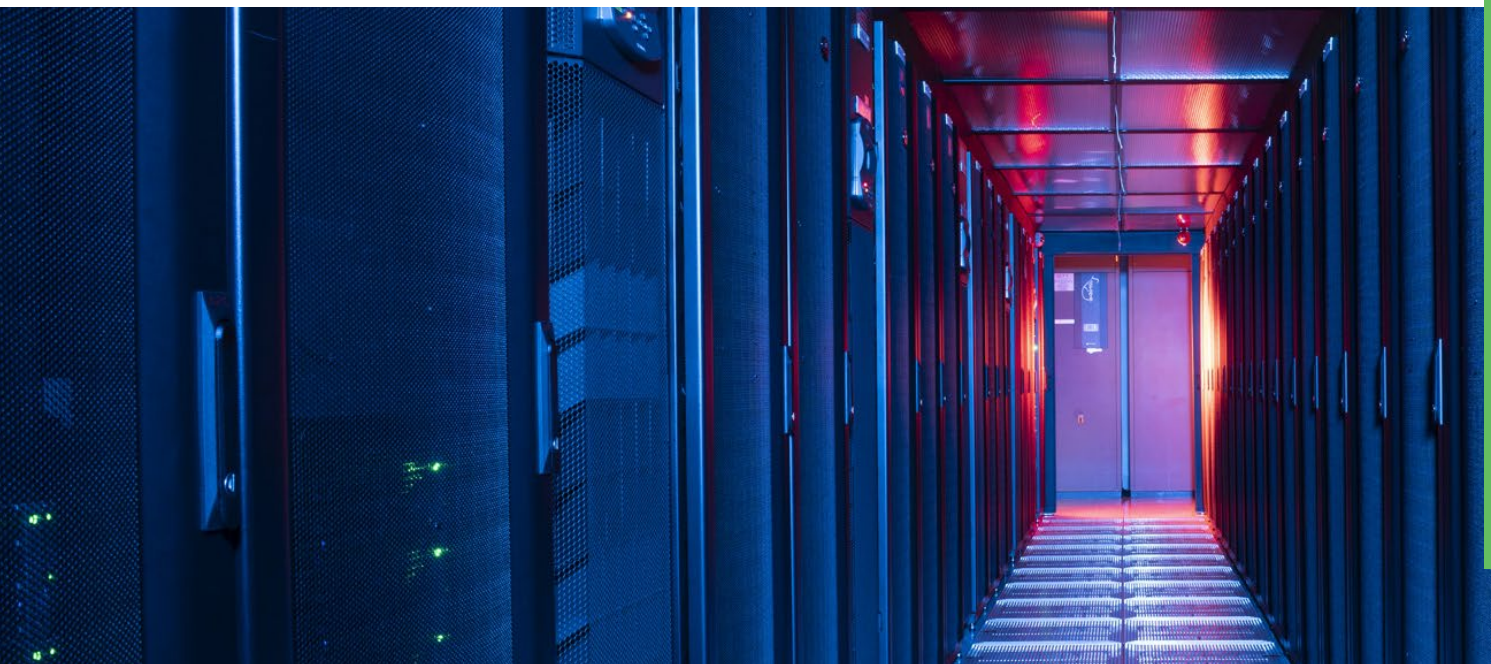
3. Computational Resources for Environmental Science

Contemporary modelling and simulation approaches, underpinned by increasing computing power, are already transforming environmental science. Opportunities such as AI and near-real-time computing have the potential to further advance our science. The scale and complexity of the challenges places ever-growing demands on computational capacity. We must seek to ensure that computational capacity does not limit scientific advance, whilst promoting awareness and mitigation of the environmental impacts of computational research.

Our ambition is for the NERC community to have access to compute resources optimised for their needs, and for access to meet the requirements for the advancement of environmental science.

We will seek to:

- Build and maintain a forward-looking view of the likely computational capacity needs for environmental science over the next decade, and support the necessary capability development
- Ensure that High Performance Computing (HPC) provision remains fit for purpose for the NERC community, and maintains the UK's global competitiveness, working in partnership with the JASMIN team, UKRI colleagues, and key partners such as the Met Office
- Ensure that hardware and software infrastructure can keep pace with the growing need for near-real-time computing capabilities for environmental science



JASMIN

JASMIN is a globally unique data analysis facility, that provides storage and compute to enable data-intensive environmental science. The facility currently supports over 2,000 researchers, exploring topics ranging from climate change and oceanography, to air pollution and earthquake deformation.

Environmental data are becoming increasingly large in volume. Analysing climate models or satellite data at a global scale requires very data-intensive workflows, for which JASMIN provides the required flexibility, being centred more around storage and data analysis than a 'traditional' supercomputer. By pooling data and resources JASMIN delivers economies of scale in cost and energy usage; it enables large-scale analysis, and it facilitates collaboration between multi-disciplinary projects.

JASMIN's unique mix of services support a variety of types of research which would otherwise not have been possible. For example, the Primavera project used JASMIN to better predict climate change and help mitigate risks. This enabled over 100 scientists across Europe to collaboratively analyse over 2 Petabytes of climate simulations in record time.

JASMIN is hosted and managed by the Science & Technology Facilities Council on behalf of the Natural Environment Research Council.

4. Pioneering Computational Science

The increasing use of data and digital technologies such as AI will not only impact on our need for compute capacity, it will also push the boundaries of current computational capabilities. For example, environmental digital twins will require new approaches to real-time assimilation of data into computational models, with the concurrent use of AI or data science approaches, pushing the limits of computational capabilities. To build and maintain the UK's leading edge in digitally enabled environmental science we will need to work in partnership, across UKRI, nationally and internationally, to provide world-leading computational capabilities for the UK environmental science community.

Our ambition is to push the boundaries of what is possible for environmental simulation and modelling. This will require us to work in partnership with computational scientists and the wider high-performance computing community to support next-generation computational capabilities for the environmental science community.

We will seek to:

- Ensure that NERC plays an effective UKRI collaboration and leadership role as well as a national-level partnership role in the development of future compute technologies such as exascale
- Build new and grow existing partnerships to enable access to key compute capabilities for the NERC community
- Monitor and horizon scan the environmental science and UKRI portfolios to identify emerging computational demands and computational technologies

Constructing a Digital Environment

The £10.4m NERC-led UKRI investment 'Constructing a Digital Environment' has started developing the 'digitally enabled environment'. This involved creating an integrated network of sensors, methodologies, and tools for assessing, analysing, monitoring and forecasting the state of the natural environment at higher spatial resolutions and frequency than previously possible.

This investment has supported innovative research, applying digital technologies to address environmental challenges including carbon sequestration, flooding, greenhouse gas monitoring and threats to sea defences. Through the work of NERC's Digital Environment Champions and our Network of Experts, we have built a community of researchers and innovators connecting directly between environmental digital technologies and benefits for policy-makers, businesses and communities.

5. Data Science Tools and Techniques

The UK environmental science community are already huge developers and users of new data science tools and techniques. New approaches such as AI, digital twins and machine learning will bring new capabilities to environmental science and may even transform the way we do research. They can detect patterns, classify, and make probabilistic predictions; they can be used across scales, large collections of data, and environmental domains. They will enable us to make use of the ever-expanding volume and complexity of both the datasets available to us and the systems we wish to understand.

Our ambition is to realise the potential of technologies such as AI, machine learning and digital twinning to advance world-leading environmental science, by supporting the development of new approaches to interrogating datasets and using them to develop new scientific insight, understanding and methodologies.

We will seek to:

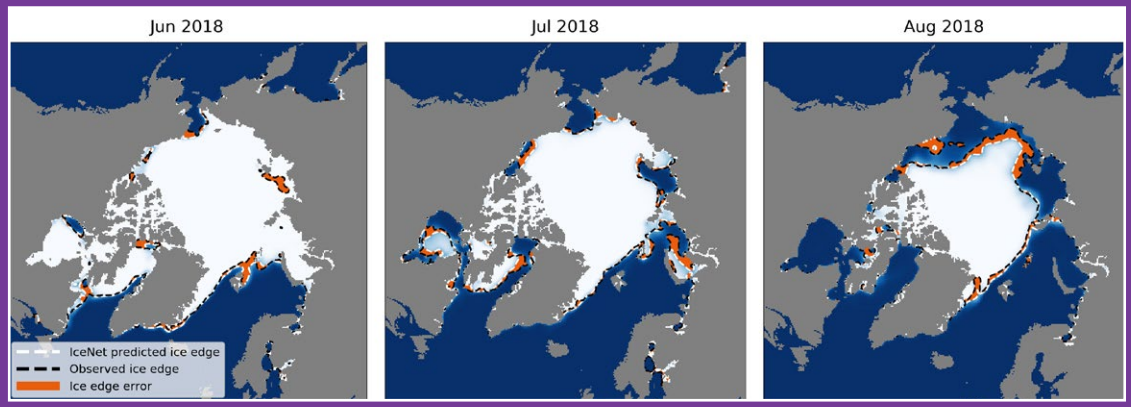
- Enable new transformative discoveries in environmental science, supported by leading edge data science tools and technologies
- Provide leadership to develop and foster new paradigms, such as digital twinning, for understanding and representing complexity in environmental science
- Support interdisciplinary collaborations directly connecting the development of innovative digital tools and their use in addressing environmental science challenges, as well as across other scientific domains and societal challenges

Artificial Intelligence (AI) to help predict Arctic sea ice loss

A new AI tool developed by the British Antarctic Survey and The Alan Turing Institute is set to enable scientists to more accurately forecast Arctic Sea ice conditions up to six months into the future. The improved predictions could underpin new early-warning systems that protect Arctic wildlife and coastal communities from the impacts of sea ice loss.

The AI system, IceNet, uses AI to 'learn' how sea ice changes from thousands of years of climate simulation data. It is almost 95% accurate in predicting whether sea ice will be present two months ahead; better than traditional approaches to forecasting. The system has the potential to fulfil an urgent gap in forecasting sea ice for Arctic sustainability efforts and runs thousands of times faster than traditional methods.

Maps showing IceNet's 1-month-ahead forecasts for Arctic sea ice over the 2018 melting season (June to August). Overlaid are the predicted and true ice edges, and the error between them.



PYRAMID: Integrating Data Sources for Flood Risk Prediction

Flooding can pose a huge risk to our homes and infrastructures, and dynamic real-time prediction of flood risk poses huge challenges due to the sheer scale of datasets and models which need to be brought together. The PYRAMID project, led by Newcastle University, has worked with key stakeholders from the Environment Agency to the local community to develop a near-real-time tool for flood-risk prediction. Their approach has integrated data from new and existing sources as diverse as hydrological measurements, sensors on bin lorries, and citizen science, and assimilated it into complex hydrological and hydrodynamic models in order to realise a real-time prediction tool.

Open GHG

Monitoring trends in greenhouses gases is critical to national and global understanding of the effects of climate change and the policies implemented to mitigate against climate change. The amount of data from sensors that measure greenhouses gases has grown dramatically over recent years, as has the complexity of the atmospheric, meteorological and emissions models needed to interpret these measurements.

The OpenGHG project, led by the University of Bristol in partnership with the UK Centre for Ecology and Hydrology and the Centre for Environmental Data Analysis, has built a cloud-based hub which enables researchers to bring together the breadth of data and models required to analyse emissions trends, for the benefit of users and policy-makers across the UK.

6. Developing People and Skills

Our vision for digitally enabled environmental science will be realised by an environmental science community with effective digital skills. Skilled people, both technical professionals and domain experts, are integral to the measurement, access, interpretation and use of data and the deployment of new digital technologies. Support for individuals and teams to advance their skills and to collaborate across or move between traditional discipline areas will provide a platform for successful delivery of environmental science with digital technology at its heart.

Our ambition is to enable the UK environmental science community to develop the digital skills they need to maximise the opportunity of new digital technologies, and to support the skilled researchers, software engineers, data scientists and other research technical professionals who are critical to implementing this strategy.

We will seek to:

- Support the development of career pathways for research technical professionals, in partnership with colleagues across UKRI, with our centres and the broader research landscape
- Play a leading role in attracting and supporting a diverse and inclusive pipeline of digitally aware environmental scientists
- Work in partnership with the data and computational science communities to support environmental scientists in developing digital skills, enabling them to explore and use new data science and digital technologies

UKRI AI Centre for Doctoral Training (CDT) in Environmental Intelligence: Data Science and AI for Sustainable Futures

The Environmental Intelligence CDT, based at the University of Exeter, is one of 16 AI CDTs supported by UKRI to develop novel artificial intelligence methodologies and use AI technologies to tackle key challenges. The centre is pioneering new research and training in using data science and AI to understand the complex interactions between the environment, climate, natural ecosystems, human, social and economic systems, and health. The centre delivers training in three core areas of Environmental Intelligence: Data Science & AI; Environmental Challenges; and Data in Society, equipping students with the skills they require to conduct inter-disciplinary research using AI to discover new insights and to develop solutions to a wide range of challenges associated with our changing environment. There is a strong emphasis on translating cutting-edge research to real-world applications, and its students benefit from the opportunity to develop their research during placements with partners from business, industry and government. Over a period of seven years, the centre will train over 50 doctoral students in this exciting interdisciplinary area, enabling them to become researchers, innovators, and policy-makers at the increasingly important interface between environmental and digital sciences.

7. Facilitating Confidence and Trust in Digital Research

For data and digital technologies to be used effectively by the environmental science community they must be trustworthy and reliable, traceable, accessible and usable. NERC will take a leadership role, working across UKRI, to facilitate adoption of new digital technologies by demonstrating their trustworthiness. A foundation for facilitating confidence and trust will be ensuring that our data meet the expectations of FAIR (findable, accessible, interoperable, re-usable) and TRUST (transparency, responsibility, user focus, sustainability, technology).

Our ambition is to facilitate confidence and trust in digital research, and to ensure that NERC's data assets can be used and re-used with confidence by colleagues from across and beyond the environmental science community, by other disciplines and across sectors.

We will seek to:

- Ensure NERC's data policy and governance frameworks remain fit for purpose, accounting for the challenges of ethics, transparency, robustness, and FAIR[5] and TRUST[6] principles
- Support the development and use of best-practice approaches for environmental science domains in modelling, software development, and the use of data science approaches
- Play a leadership role in creating an open science and open data culture for environmental science

[5] https://doi.org/10.1038/sdata.2016.18

[6] https://doi.org/10.1038/s41597-020-0486-7

Many colleagues were closely involved in developing this strategy on behalf of NERC and the UK Environmental Science community. Thanks are particularly due to:

Andrea Sharpe, Natural Environment Research Council (NERC)
Anna Angus-Smyth, Natural Environment Research Council (NERC)
Beth Wingate, The University of Exeter
Bryan Lawrence, National Centre for Atmospheric Science (NCAS)
David Topping, The University of Manchester
Garry Baker, British Geological Survey (BGS)
Helen Peat, British Antarctic Survey (BAS)
Iain Williams, Natural Environment Research Council (NERC)
John Brodholt, University College London (UCL)
John Siddorn, National Oceanography Centre (NOC)
John Watkins, UK Centre for Ecology & Hydrology (UKCEH)
Kevin Ashley, The University of Edinburgh
Kate Royse, British Geological Survey (BGS)
Martin Juckes, Centre for Environmental Data Analysis (CEDA) & National Centre for Atmospheric Science (NCAS)
Richard Kingston, The University of Manchester
Robin McCandliss, National Oceanography Centre (NOC)
Ron Corstanje, Cranfield University
Sam Pepler, Science & Technology Facilities Council (STFC)
Simon Gardner, Natural Environment Research Council (NERC)
Stephen Hallett, Cranfield University
Stephen Mobbs, National Centre for Atmospheric Science (NCAS)
Victoria Bennett, Centre for Environmental Data Analysis (CEDA) & National Centre for Earth Observation (NCEO)

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