NERC Environmental Data Service

From observation to insight: developing standardised and trusted environmental data services

Final project report for AMPLIFY-EDS

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Executive Summary

The AMPLIFY-EDS project, funded under UKRI's Digital Research Infrastructure (DRI) programme, aimed to advance the Environmental Data Service (EDS) towards a federated, user-centred model by developing standardised, trusted workflows for real-time sensor data. Running from March 2024 to October 2025, the project delivered a proof-of-concept sensor commons, integrating live cross-domain temperature data streams through open standards and co-designed services.

Combining findings from technical experiment, user research, and learnings from the project team led to over 60 actionable recommendations that can be embedded into future iterations of the EDS roadmap.

The recommendations covered key themes spanning; governance, technical infrastructure, user needs, and stakeholder engagement. These aim to deliver a more integrated, automated, and AI-ready EDS ecosystem, reducing duplication, improving maintainability, and enabling real-time decision-making for complex environmental challenges. This foundational work will provide future benefits extending beyond science communities to policymakers, industry, and society, supporting informed responses to climate and environmental risks.

Contents

Context

The report provides a high-level summary of what we did, how it could be built upon in the future (including recommendations) and signposts to further details in a number of supporting technical reports.

We believe this report will be useful to anyone interested in how the Environmental Data Service (EDS) is transitioning to a single, federated service – following a Commons approach. It will also be of use to providers of data services who wish to integrate live cross-domain sensor data through a standardised framework.

Introduction

About the 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, and solar and space physics. The EDS is made up of a network of distributed data centres, each with domain-specific expertise.

Our main goal is to ensure that environmental data are made available, accessible and re-usable for the long-term in order to fully realise their value. We are funded by the Natural Environment Research Council (NERC), part of UK Research and Innovation. The EDS is a fundamental part of NERC's digital strategy and works with the Digital Solutions Hub, and other partners, to break down disciplinary barriers and facilitate data sharing beyond academic use.

The EDS recommissioning five-year plan set out a vision to transition to a single, federated EDS: a one-stop shop with the capability to meet varied and emerging environmental data requirements. This model aims to transform the EDS from more domain-specific applications to more flexible, cross-cutting services; removing the digital boundaries that currently require users to engage with multiple EDS data centres. This critical transition underpins NERC and UKRI strategic objectives to enhance data services (NERC Digital Strategy) and develop state-of-the-art national digital research infrastructure (UKRI Digital Research Infrastructure Programme). As the demand for integrated data, analytics and Artificial Intelligence (AI) continues to grow, the EDS must continue to adapt, integrate and evolve its services to match user needs.

What is a Commons and why should the EDS implement one?

A Commons is defined as "a common place supporting asset discovery, access, interoperability and asset re-use (aligned with the FAIR Principles), tailored for a community and managed by that community for the common good". It extends beyond a traditional data repository to include a range of digital assets such as datasets, models, workflows, and tools which are underpinned by shared standards and governance. A Commons approach is well suited to realising the EDS 5-year vision. It supports integration of cross-domain data and digital assets in a way that reduces fragmentation and increases interoperability. Through a narrow-middle design[1], a Commons standardises reusable core services, such as persistent identifiers, metadata, and application programming interfaces (APIs), thereby reducing technical maintenance overhead. At the same time, this approach supports innovation and scalability by preserving flexibility at the edges, allowing diverse tools, workflows, and user communities to evolve without compromising interoperability. The value of multi-domain Commons is increasingly being demonstrated through successful national[2] and international[3,4] implementations.

[1] https://medium.com/@rgrossman1/a-proposed-end-to-end-principle-for-data-commons-5872f2fa8a47
[2] https://civicdatacooperative.com/project/digital-commons/
[3] https://ardc.edu.au/
[4] https://doi.org/10.1093/jamiaopen/ooad092

For the EDS, implementing a Commons is critical because:

- It enhances FAIRness (Findable, Accessible, Interoperable, Reusable) of environmental data and assets, supporting open science and data-intensive research.
- It provides a unified, federated architecture that bridges diverse domains and data centres, reducing duplication and enabling cross-disciplinary collaboration.
- It supports innovation and scalability through a "narrow middle" design[5] - standardising core services like persistent identifiers, metadata, authentication, and Application Programming Interfaces (APIs) - reducing technical maintenance while allowing flexibility at the edges.
- It enables integration of data with methods and models, improving reproducibility and accelerating scientific discovery.
- Strong governance and community engagement ensure sustainability, adaptability, and trustworthiness of the infrastructure.

In short, following a Commons approach will deliver a step change in EDS capabilities; fostering interoperability, reducing technical debt, and creating a foundation for future developments such as digital twins and federated research infrastructures.

About the project

The AMPLIFY-EDS project was funded by the UKRI DRI Phase II call. It ran from March 2024 to Oct 2025.

This work builds upon previous work undertaken via the ENHANCE-EDS and BOOST-EDS projects. The central recommendation from previous project work is that the EDS should evolve towards a Commons architecture, building on the strong legacy of the existing data centres and the steps already taken around alignment and integration.

The AMPLIFY-EDS project aimed to carry out an intensive, collaborative deep dive into a specific topic from the EDS Roadmap – in this case on sensor data – whilst also working within the framework imposed by the overall Roadmap and Commons ambitions.

The main goals of the project were:

- To improve accessibility of sensor data by a wide range of users, from deep data science analytical and AI specialists to non-specialists

[5] https://medium.com/@rgrossman1/a-proposed-end-to-end-principle-for-data-commons-5872f2fa8a47

- To enable sensor data to be used to tackle multi-disciplinary environmental challenges
- To provide a proof-of-concept service combining air temperature data from multiple data sources (e.g. ship, aircraft, ground-based stations) in near-real time

The project prototyped a major advance in EDS capability, by integrating live cross-domain sensor data through a trusted, standardised Commons framework, supported by state-of-the-art digital tools and deep user engagement to seamlessly connect researchers, policymakers and innovators to NERC data with ease.

Motivation

In the 21st century, the environmental sciences have prioritised sensor technologies because they provide unambiguous, quantitative evidence for how natural processes are changing through time, driven by climate change. They are now feasible because low cost, low power sensors have been developed that can be emplaced widely across the landscape and which can communicate with base stations through ubiquitous mobile phone or broadband coverage in a minimally invasive way. Furthermore, the application of sensors in the most remote and harshest locations of the Earth are now possible as the accessibility of satellite communications grow. NERC have identified 'Next-Generation Environmental Sensing Systems' as a priority in its Digital Strategy.

Even before AMPLIFY-EDS all EDS data centres have prioritised handling such monitoring data. These solutions have evolved independently of each other between environmental science disciplines through differences in technology and funding sources.

AMPLIFY-EDS proposed to respond, driven by the EDS roadmap, to the clear goal of aligning on a technical solution for improving the integration of EDS sensor data, utilising a Commons architectural approach, the 'narrow middle'. There was a desire to make sure the way these data products and services were made available to end users was co-designed with real end user involvement. The user research, undertaken by this project, guided project delivery but not it's fundamental imperative. User research, from before AMPLIFY-EDS was used to inform both the technical work and the user research.

Easily accessible and standardised sensor data will deliver significant benefits across society, research communities, and the EDS. For society, improved data access enables informed decision-making to mitigate environmental challenges and support Government missions. For data users such as researchers and developers, it enhances the ability to address complex multi-domain issues like flooding or coastal erosion through integrated analysis, real-time sharing, and consistent terminology improving overall user experience.

For the EDS, these advancements strengthen its capability to provide simplified, co-designed services, integrate data across disciplines, and reduce duplication of effort. They also support automation, minimise technical debt, and improve maintainability of data services, ensuring a more sustainable and efficient infrastructure for the future.

Sensor networks are playing an increasingly important role in environmental research, offering new ways to measure and understand the environment. However, these innovations also introduce diverse workflows, tools, and use cases, adding complexity to an already evolving data landscape. In this context, there is a growing need for more standardised approaches that support broader data reuse, greater interoperability, and deeper insight across both scientific and policy domains.

AMPLIFY-EDS responds to this need by aligning efforts across the EDS, building on existing systems while advancing best practices and common standards for real-time environmental sensor data.

What do users want from cross-domain environmental data?

The user research approach used in this project leveraged existing research from NERC Data Centres (12 publications) and was enhanced with new interviews with potential users outside of known NERC networks (23 candidates identified, 9 triaged and contacted, 6 interviewed). User types ranged from data providers (e.g., those deploying sensors) to downstream data analysts and ultimately decision makers, that derive actionable insights from monitoring data. The intention was to map community needs using personas and user journeys and explore their needs and preferences through a co-design approach involving the development and testing of prototypes.

Three core questions defined the scope of the investigation:

- Does the community need multi-domain data provided through a ‘thin middle’ standards framework?
- What are the user preferences for data access?
- What future user research will be needed?

Requirements for multi-domain data

The sources strongly validate the need for multi-domain environmental data through real world examples of scientific and commercial challenges that required environmental data to be integrated with that from another domain, sometimes outside of environmental science (Parton, Graham A. "2007 BADC User Survey Analysis." (2008); DSH-User-Research-Report_2024-1.pdf).

Researchers currently face frustrations due to data being scattered in multiple places and needing to standardise temporal and spatial scales. Consequently, users frequently request solutions that provide interoperability between datasets and potentially pre-aggregated data in thematic packages.

User preferences for data access interfaces

This query sought to understand what user experiences the EDS Data Commons Portal should prioritise to meet the needs of our end users and minimise their frustrations.

During interviews we used prototypes of visually engaging, plain English mock-ups, to explore preferences for a range of features, see Figure 1 below.

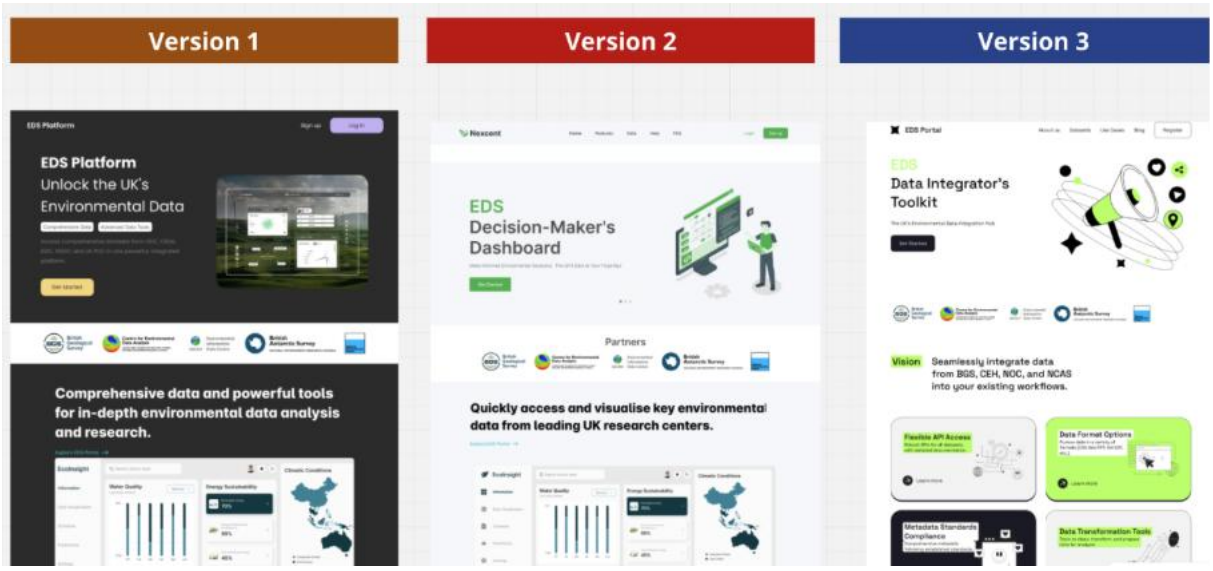

Figure 1: Front-end of EDS Data Commons Portal, a toolkit for collaborative user experience and business analysis.

User feedback highlighted that technical users strongly prefer access via API endpoints and standard technical formats like NET CDF, shapefiles, and geopackage. There was also a lot of support for the provision of simple formats like .CSV so long as they were well described with clear understandable column names.

Interviewees highlighted how little time they had to explore new data sources, formats and domains beyond their own areas of expertise, this lack of time appears to influence many of the requirements that follow.

Users are keen to find and use data that is "analysis ready" and supported by good metadata. There was a lot of interest in interfaces that allow the ready exploration of data in visual formats and with the ability to download only relevant parts (subsets) of large datasets. Poor metadata and inconsistent terminology remain significant barriers to verifying a dataset's suitability quickly.

In addition to good metadata (to aide data discovery and provide a good technical understanding of the dataset) both the desk study and interviews highlighted the need for easy to use 'onboarding materials', such as relatable case studies that allowed a user to understand the value and limitations of the data from one domain when applied in another domain.

Training, both in-person and online, was suggested as an effective way to reduce barriers to access, although this was countered by comments that some users were too busy to learn new formats or attend training, especially when they are not yet sure of the value of the dataset concerned. Two of the interviewees suggested that they would discover new data sources through articles on LinkedIn or through conferences, often through a referral by a trusted contact.

Future user research needs

Three key user groups emerged from this research as potential consumers of EDS services, they were quite technical in nature, willing to search for, explore and potentially exploit new sources of environmental data:

- **Dedicated Technology and Software Professionals**. Responsible for technical creation and integration of digital solutions, making API access critical for their daily work. Includes software developers focussed on the digital solution rather than insights from the data.

- **Specialised Data Analysts and Integration Experts**. Data professionals that require programmatic access (APIs) to combine, manage, and analyse large or diverse environmental datasets. Includes GIS Specialists and a growing cohort of researcher software engineers (RSEs) focussed on discovering insights from the data.
- **Industry and Infrastructure Professionals** that require automated integration with environmental data to assess risks and operational performance of a system. Includes staff within utility companies and regulators.

Through this project we gained a reasonable understanding of these user groups and that they would benefit from better onboarding materials, but the work of designing and testing those materials requires more time to undertake a co-creation process.

During the interviews, there was a significant interest in the potential for AI services, especially LLM interfaces, to reduce the barriers to access, provide plain English advice and simple visualisations /analysis of the data sources. These hypothetical LLM powered interfaces were not described as replacements for existing data processing and analytical steps but to quickly assess the meaning and value of new-to-me datasets.

During the desk study, we found that the first-hand anonymised quotes from real end users were much more re-usable than the interpreted analysis of past reports, so we recommend that future research should put in place the necessary consent process to ensure re-use through the publication of raw, anonymised, user research.

It is also worth noting that while this investigation helps us to understand the potential users of the EDS services, their preferences with regards to formats and supporting guidance, it did not explore which data was of most value to users. Interviewees asked what data would be available (which domains, temporal and spatial extents) and we imply from this that the EDS offer should clearly describe which high value datasets are available and/or which challenges our data relate to. It would be useful to delve into which data held by EDS partners should be prioritised and whether any combination of these might relate to strategic research topics or the UK Government missions. The current ‘HIGH5 for AI’ project is starting to explore such relationships and we would hope to build on this work in future funded projects.

Further reading

As part of this work, we published two new articles on the EDS co-creation toolkit to describe the methodology and to act as a case study. The intention being to publish these resources in an open, community space that encourages re-use by project managers, software developers and stakeholder focussed individuals that are more likely to read online guidance than a technical report hosted on a traditional document archive:

- When to Use Co-Creation - how and when to engage real end users to maximise the impact, especially when time or funding constrains such engagement.
- Finding the Unknown Users - how we used the customer sprint methodology to understand who needs integrated environmental data access and what features would serve them best.

What we did: turning ideas into implementation

The AMPLIFY-EDS team explored actionable technologies capable of delivering a Commons framework for sensor data.

Figure 2 shows an overview diagram of the dependencies between the different work packages in the project. In this report, we have not referenced all specific work packages as many of the work areas overlap. We believe the narrative is more impactful when told from the perspectives of all the work combined. For an overview of status of the project deliverables from the proposal, see *'Appendix: table of deliverables and recommendations'.*

It should also be made clear that most work was done in parallel due to time constraints – in an ideal world, the technical Commons work would not have started until the user research was complete.

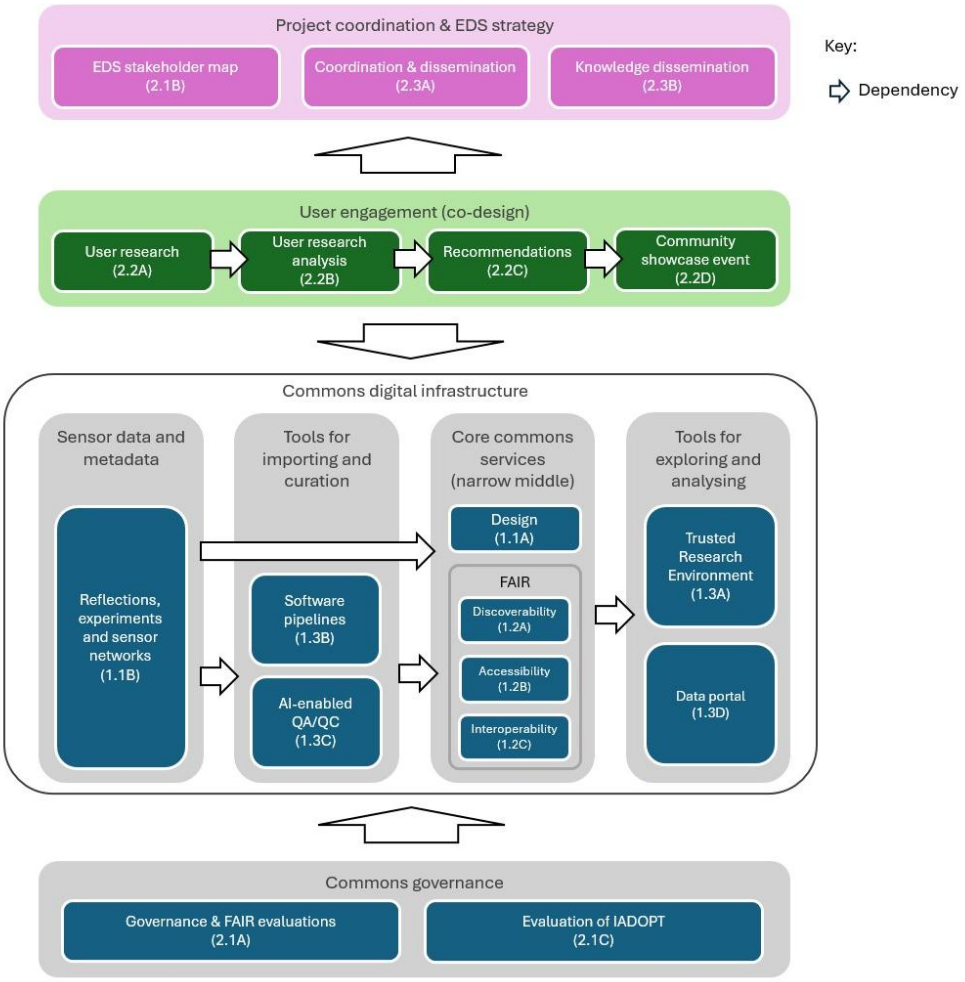

Figure 2: a dependency chart to summarise all work undertaken by the AMPLIFY project (with reference to the original work package numbers for deliverables)

Commons digital infrastructure

As shown in Figure 2, the Commons digital infrastructure consists of:

- Sensor data and metadata
- Tools for importing and curation
- Core Commons services (the 'narrow middle')
- Tools for exploring and analysing

These components are described below.

Sensor data and metadata

Digital research infrastructure for sensor data: pilot implementation

Our approach

One of the main goals of AMPLIFY-EDS is to develop a sensor Commons for the NERC Environmental Data Service (EDS). As part of this, UKCEH contributed to supporting reflections and activities (formally, sub-task 1.1B) designed to support the architectural work underpinning the sensor Commons. Specifically, we focussed on the core underlying sensor infrastructure underpinning the Floods and Droughts Research Infrastructure (FDRI). FDRI provides a strong case study to both inform the design of the sensor Commons at the heart of AMPLIFY-EDS, and provide feedback on specific design choices around technologies and semantic constructs. Our approach involved experimental design of the systems, multiple workshops, and a period of reflection leading to a set of findings and recommendations.

Summary

Built on cloud technologies and cloud-native principles, our FDRI infrastructure ensures portability, scalability and network independence, enabling us to meet emerging requirements and use cases such as real time or near real time data streaming across diverse data types including time series, images and more.

Key features include:

- **End-to-end pipeline** that ingests raw sensor data, processes it in real-time, and presents it through dashboards and APIs.
- **Network-agnostic architecture** supports multiple monitoring networks (COSMOS, NRFA).
- **Metadata driven** configuration and processing rules, enabling quick sensor onboarding without code changes.
- **Cloud-native infrastructure** deployed on Amazon Web Services (AWS).

We then organised three workshops to develop our findings:

- Workshop 1: FDRI / AMPLIFY-EDS meeting on sensor data models (webinar: 24/1/25)
- Workshop 2: Deep dive into technical architectures (webinar: 15/5/25)
- Workshop 3: Discussion with NEON (Discussion: 27/08/25)

Technical outcomes

The outcome of this work was largely positive demonstrating how our cloud-based approach can achieve our overarching goal of supporting the end-to-end pipeline. From data acquisition from sensors through quality assurance to potential ingestion, integrating the work on a data processing pipeline with the collation of associated meta-data (further supporting the ingestion process). We also saw a strong consensus emerging across the consortium of standards and interfaces that can support our broader aims. Next steps will involve demonstrating the generality of the approach.

Further details of the development work, workshops, findings and recommendations can be found in Booth at al, 2025 and Townsend, 2025.

Next-generation sensor data acquisition onboard the NERC research vessels

Our approach

As part of AMPLIFY-EDS activity 1.1B, this experiment focussed on the data acquisition stage of the proposed EDS sensor Commons. The British Antarctic Survey (BAS) and National Oceanography Centre (NOC) collaborated to design and trial a prototype system based on Kubernetes orchestration and Apache Kafka messaging. This approach emphasized containerization, independent functional components, and message-driven workflows to improve resilience, scalability, and flexibility. The prototype was deployed on the RRS *Sir David Attenborough*, running in parallel with the existing system (RVDAS) before becoming the primary logging platform in October 2025. Care was taken to ensure continuity for end users while enabling a more robust technical foundation.

Summary

The project successfully demonstrated that a Kafka-based, Kubernetes-orchestrated system could replace the legacy RVDAS platform. The new Data Acquisition and Metadata Platform (DAMP) addressed key limitations of RVDAS, including difficulties in adding sensors, lack of resilience, and duplicated functions. By leveraging open-source components and CI/CD pipelines, DAMP reduced reliance on bespoke code and streamlined deployment. User engagement through workshops, cruise feedback, and webinars ensured that development remained aligned with practical needs. Lessons learned highlighted the importance of IT integration, the challenges of Kubernetes networking, and the role of “software patchworking” in assembling open-source tools into a coherent system.

Technical outcomes

DAMP introduced several technical advances:

- **Containerized architecture**: Each sensor reader, parser, and writer runs independently, improving resilience and scalability.
- **Kafka message broker**: Provides reliable, fault-tolerant communication between components, enabling ship-to-shore replication with minimal delay.
- **Automated deployment**: GitLab CI/CD pipelines and Helm charts simplified installation and configuration across different vessels and environments.
- **Enhanced flexibility**: New sensors can be added or modified without disrupting existing data flows, and stream processing capabilities can be integrated in future.
- **Resilience improvements**: Kubernetes self-healing and Kafka clustering ensure high availability, reducing downtime risks.

Together, these outcomes establish a foundation for future enhancements such as multi-node Kubernetes clusters, integration of Apache NiFi for translation, and real-time stream processing with Apache Flink or Spark.

A full report describing the DAMP experiment can be found here.

This provides the background and history of data acquisition onboard NERC vessels, the previous acquisition system (RVDAS) and its limitations, the architecture of the new system (DAMP) and lessons learned in its development, and a list of next steps after the AMPLIFY-EDS project concludes.

Tools for importing and curation

A key activity focused on developing an understanding of orchestration workflow software to provide a robust foundation for reliably importing and transforming data within a data Commons (Task 1.3B). Orchestration workflows coordinate and automate multiple interdependent processing steps, such as validation, transformation, quality-control, and metadata generation, ensuring they execute in the correct order, at scale, and with clear error handling. This capability is especially critical when dealing with high-volume, heterogeneous, or streaming data sources that require pre-processing or transformation, where manual or ad hoc approaches quickly become brittle and unmanageable.

The FDRI pilot implementation leveraged Argo Workflows running on a Kubernetes cluster hosted on AWS to prepare sensor data from the UKCEH COSMOS soil moisture network, with pipeline steps including pre-processing, quality control, and data infilling. UKCEH has also experimented with AI-enhanced pipelines for image data, specifically the classification of plankton images using the Python-based Luigi workflow engine, providing experience with an alternative orchestration technology. By using orchestration software, a data Commons can achieve reproducibility, transparency, and clear data provenance within its pipelines, making datasets easier to trust, reuse, and audit. In addition, these tools support automation and scalability across cloud and containerised environments, reducing operational overhead and enabling the data Commons to evolve as new data sources, standards, and user needs emerge.

Core Commons services (the 'narrow middle')

SensorThingsAPI for the EDS: a standardised service for real time Internet of Things (IoT)

Our approach

To achieve our goals (Tasks 1.1A, 1.2), we built on an established standard within the sensor data domain (the OGC (Open Geospatial Consortium) SensorThings API). This positions us to integrate with a wider ecosystem of tools and platforms already using or moving toward this approach.

A key component of this work is the creation of a SensorThings data profile tailored to environmental science, which includes:

- More standardised vocabularies
- Improved metadata conventions
- Enhanced discoverability and usability of data streams

This profile supports richer, more consistent data integration across EDS services and partner platforms.

Summary

AMPLIFY-EDS proposed to respond, driven by the EDS roadmap, to the clear goal of aligning on a technical solution for improving the integration of EDS monitoring data, utilising a common architectural approach, the 'thin middle'. There was a desire to make sure the way these data products and services were made available to end users was co-designed with real end user involvement. The user research, undertaken by this project, guided project delivery but not it's fundamental imperative. User research, from before AMPLIFY-EDS was used to inform both the technical work and the user research.

This work aimed to demonstrate practical interoperability and semantic enhancement in real-time sensor data sharing across multiple environmental data streams.

We established a standardised, open, and scalable infrastructure for real time environmental sensor data exchange within the EDS ecosystem.

This was achieved by deploying the semantically enhanced OGC SensorThings API, combined with a centralised Rabbit MQ broker and a set of agreements that comprise the thin middle of our sensor Commons.

Our approach integrates both technical and semantic interoperability, ensuring that sensor observations are not only machine-accessible but also contextually meaningful and discoverable across different domains.

Technical outcomes

- Standardise real-time sensor data publication using the OGC SensorThings API.
- Enable interoperability between different sensor vendors and platforms.
- Demonstrate interoperability and usability through interactive tools like Leaflet web maps and Jupyter Notebooks.
- Develop and publish community profiles of SensorThings for the Environmental Data Service (EDS).
- Semantically enhance the SensorThings data model using NVS vocabularies and community-agreed standards.
- Contribute Building Blocks to the OGC newly established OGC Building Blocks that semantically uplift sensorThingsAPI.
- A draft vocabulary work across EDS to create a cross domain “Processing steps” vocabulary that notifies the end user of the type of data they are receiving.
- Investigate an alternative technical implementation for sensorThingsAPI other than FROST server in order to use data stored in a public cloud architecture (Amazon Web Services).

Collectively, these enable standardised provision of streamed environmental sensor data outputs in AI-ready formats. This will enable easier ingestion of dynamic monitoring data by analytical tools, including models, visualisation tools, and AI algorithms.

Further technical details about this work can be found here:
https://nora.nerc.ac.uk/id/eprint/541040

Improving the discoverability of research methods & workflows

There is a growing need for environmental research outputs (such as datasets, workflows, and software) to be discoverable and reusable by both humans and machines. We have developed the Digital Objects Ontology (DOO) and suggested some standardisation of metadata practices. By doing so, we improve transparency, traceability, and interoperability, ensuring that research outputs comply with FAIR principles and deliver long-term value to the scientific community.

A full report on this work is available on NORA. The Digital Objects Ontology is available at https://nerc-ceh.github.io/digital-objects-ontology

Tools for exploring and analysing

Data visualisation and analysis

Tools were developed to demonstrate the broader impact of the Commons architecture in providing a single, coherent view of data that removes the complexity of interacting with multiple underlying disparate sensor networks (Task 1.3D). They highlight how a Commons approach enables seamless discovery, access, and integration of cross-domain data, allowing users to focus on insight and analysis rather than data plumbing and infrastructure.

Two demonstration applications were developed to illustrate this impact for different audiences. For non-technical users, a Leaflet-based web application using map-based visualisation shows how data from the EDS Commons can be easily visualised but also combined with other BGS (British Geological Survey) environmental data networks, reinforcing the value of a unified access layer. For more technical users, JupyterLab-based digital notebooks provide reusable boilerplates for exploring and analysing Commons data locally. This demonstrates how common vocabularies, semantics and standardised interfaces enable consistent data extraction and interactive analysis, while abstracting away the heterogeneity of the underlying sensor systems. Together, these tools illustrate how a data Commons can lower barriers to reuse, support interdisciplinary research, and accelerate the translation of data into knowledge.

Digital Solutions Hub Trusted Research Environment

The DSH team have built a GIS-Enabled Trusted Research Environment (TRE) using the eLab Digital Workbench deployed in AWS with support from JISC (Task 1.3A). A TRE is a secure, governed digital workspace that allows researchers to access, link, and analyse sensitive or restricted data without that data ever leaving a controlled environment.

Within the eLab Esri Enterprise GIS components have been installed to enable geospatial data analysis to be undertaken on sensitive data in a secure environment. This includes a range of use cases including:

- developing specific data products to support the linkage of Christie Cancer Research Centre data and NERC datasets to improve the understanding of the impact of environmental factors on inequalities in cancer incidence, treatment, and outcomes.
- linking the DSH UPRN (Unique Property Reference Numbers) data products to the UK National Atmospheric Emissions Inventory.
- linking indoor air quality at kitchen, living room and bedroom scales across Greater Manchester.
- data feeds from real time sensor networks where the exact location of the censors would benefit from being held within a TRE to reduced risk of location disclosure.

For NERC a TRE is not a replacement for open data services, but a complementary capability which would allow the EDS to also support:

- controlled-access datasets e.g. restricted observations, embargoed project data.
- sensitive linkages e.g. environmental data joined to health, population or infrastructure data.

Across UKRI, there is a clear move toward TREs, sometimes referred to as Secure Data Environments, as more research heads towards cross-council data integration. By adopting or federating TRE capability this allows NERC to align with UKRI infrastructure strategy with potential to become a natural home for environment and society research pipelines and helps the NERC EDS to evolve and position itself beyond solely a data download service.

Trusted Research Environment: architecture and implementation, a case study

A theoretical examination of the use of a Trusted Research Environment (TRE) for integrating static and dynamic environmental data sets was explored by BGS. The project proposal predicated that an environmental TRE would be implemented by the University of Manchester hosted Digital Solution infrastructure. For technical reasons beyond the scope of this report, this has not been implemented within the timescale of the AMPLIFY-EDS project.

Therefore, the conceptual thinking for how a TRE might be implemented for a use case of provision of confidential water resource data was explored. This requirement crosscuts data supplied by BGS, from the National Geoscience Data Centre (NGDC) and integrates it in combination with data supplied from a hypothetical and confidential water industry data source, and also a conceptual data source provided by an environmental regulator (such as the Environmental Agency for England or Scottish Environmental Protection Agency).

The objective was to provide an understanding of how a hypothetical model incorporating both geospatial and sensor driven modelling data sources could be implemented within a specimen TRE to demonstrate how this could be developed from both an architecture and modelling standpoint.

Full details can be found here: https://nora.nerc.ac.uk/id/eprint/540180

How have we told people about this work?

Commons governance

Governance and FAIR evaluations

In March 2025, a Data Governance workshop was held with key members from across the EDS attending. This workshop focused on distilling a suitable definition for data governance within the EDS (what is governed), what form this would take (how we enact the governance), what roles are required to make it succeed (who makes the decisions).

A summary report, containing governance recommendations can be found here: https://zenodo.org/records/19923522

This work has had limited progress made (due to various reasons - resourcing/staff availability, lack of clear governance processes for the EDS to report to). General governance recommendations from the project will be reported and discussed at the EDS Data Operations Group in early 2026.

Evaluation of IADOPT

One piece of work that looked at one explicit data governance element was an evaluation into the I-ADOPT framework and its benefits in enhancing discoverability of data held in multiple repositories.

The **I-ADOPT Framework Ontology** is a lightweight ontology primarily designed to facilitate interoperability between existing variable description models (including ontologies, taxonomy, and structured controlled vocabularies). To provide semantically interoperable observable properties in the EDS sensor lifecycle, we chose to use the cf standard_names vocabulary to annotate our properties in the STA implementation. We focused on air temperature and modelled this term using the I-ADOPT framework as seen here.

This will future-proof EDS data annotated with semantic artefacts structured using the I-ADOPT framework, making the data more findable and easier to integrate with datasets from other disciplines, particularly at a time when cross-domain research is critically important in addressing climate change and its impacts.

Further work is planned on governance, and indeed this area features heavily in our recommendations (as discussed below). We will build on what has been done in AMPLIFY-EDS and in the previous ENHANCE-EDS project, extending the work beyond data governance and making this central to the management of NERC EDS more generally.

Project coordination and EDS strategy

Stakeholder mapping

Improved stakeholder mapping and dissemination planning for the EDS as a whole (and specifically for this project) were also undertaken. This work was designed in a flexible and scalable way - allowing for future projects to adapt and improve the stakeholder analysis for their purposes.

Figure 3 below shows the specific stakeholder mapping for the AMPLIFY-EDS project – alongside proposed dissemination actions for each type of stakeholder group. The full stakeholder map is an internal EDS document and is not suitable for sharing in this report.

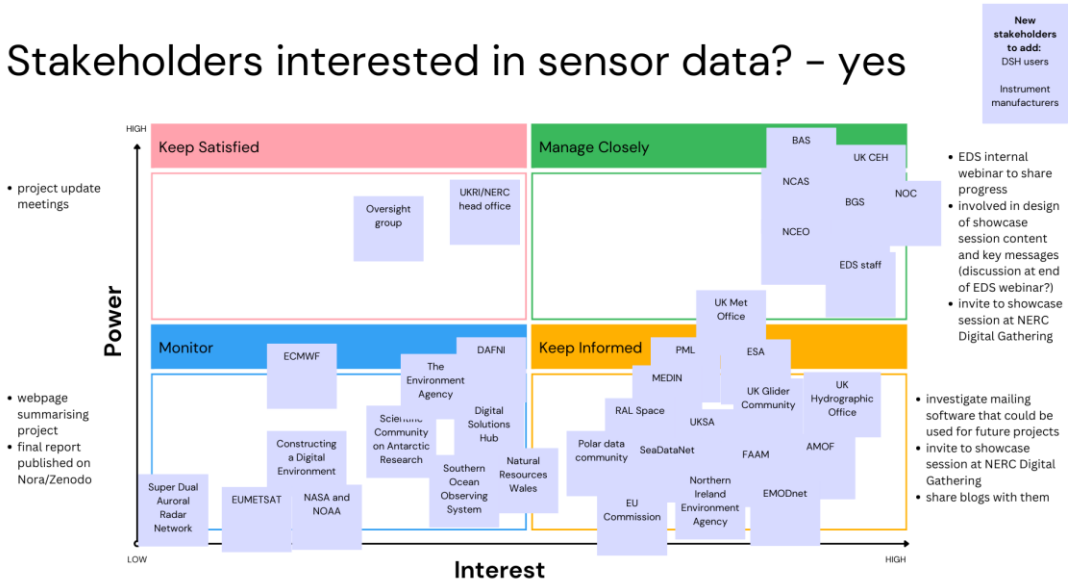

Figure 3: Analysis of requirements of stakeholders interested in EDS sensor data

Dissemination

Website

As the project contained complex technical work, that often felt disjointed to a non-technical observer, we undertook interviews with the core project team. This helped us to explore their thoughts about the project work and to gain a clearer understanding of how the technical work pieced together into a clearer narrative. A set of interview questions were discussed via an online video call, a transcript from the call was recorded and then summarised by AI (CoPilot). This was then used to create a new project overview webpage on the EDS website: https://eds.ukri.org/projects/amplify

In person conference

We showcased the work of the EDS (including this project) at the NERC Digital Gathering, held at Cranfield University from 7–9 October 2025. The event brought together over 170 attendees from across the environmental science community to explore digital innovation and data-driven solutions.

At the event we:

- Delivered a **talk**: *Highlights from the NERC Environmental Data Service*
- Hosted a **workshop**: *Shaping the Future of AI-Ready, User-Driven Environmental Data*

- Ran an **exhibition stand** with interactive feedback activities
- Supported the **hackathon** with JASMIN/CEDA (Centre for Environmental Data Analysis) resources

View the full detailed event report, including lessons learnt and recommended next steps here: https://zenodo.org/records/17869635

Future dissemination

A webinar will be planned for early 2026 to reuse the content shared at the in-person event. This will allow additional people to understand about the recent work undertaken by the EDS.

The recommendations and learnings from this project will feed into future iterations of the EDS roadmap.

How can this work benefit the wider EDS?

Predominantly the initial benefits from this project have been felt by experts working across our organisations. For example; data managers (who ensure data are Findable, Accessible, Interoperable and Reuseable) and software engineers (who build tools to share/access/analyse data). The project has enabled enhanced foundational infrastructure and relationships to form with impacts such as:

- Shared support for our services, including integrated and efficient workflows
- The project leveraged existing solutions across centres to avoid reinventing the wheel (e.g. sharing knowledge about semantics, vocabularies and standards)
- Using common and standardised terminology to minimise misunderstandings between researchers across different disciplines
- Improved system resilience and extensibility
- Shared learning, knowledge, solutions and collaboration across our network of experts
- This project facilitated connections which led to new cross domain projects (e.g. API4AI)

Recommendations

The AMPLIFY-EDS project identified over 60 actionable recommendations aimed at strengthening governance, improving technical infrastructure, and enhancing user engagement across the EDS. A recommendations table, including suggested owners for exploring the recommendations in future work, can be found in the appendix.

A major theme is governance, with calls to establish a formal data Commons governance framework for the NERC EDS, to includes roles and responsibilities, governance structures, decisions around standards, interfaces and architectural approaches, managing the roadmap, collating and reacting to user feedback, and managing risk. The issue of governance is particularly pertinent given the potential innovations identified in AMPLIFY-EDS and the need for common approaches; without this, there is a risk of fragmented approaches across the community. We can build on the recently established NERC EDS Management Board, the work on data governance within AMPLIFY-EDS and the previous work on governance and Commons-based approaches from the previous ENHANCE-EDS project.

Implementing user feedback, create dedicated groups (such as a Technical Design Authority), and embed recommendations into the EDS roadmap. Engagement with broader UKRI initiatives, such as DAREUK (Data and Analytics Research Environments UK) for Trusted Research Environments, is also advised.

On technical and data innovation, recommendations emphasise advancing SensorThings API adoption, standardising sensor streams, and integrating globally resolvable identifiers and controlled vocabularies. There is a strong push towards automation in data ingestion, real-time processing, and cloud-native architectures, alongside exploring AI-driven tools like chatbots and securing funding for AI-readiness. Open-sourcing key components (e.g. DAMP) and improving interoperability through frameworks (like CDIF) are highlighted as strategic priorities.

For user needs and stakeholder engagement, the project advocates creating a user research guide (which would expand upon content in the existing co-creation toolkit), promoting co-creation practices, and ensuring fair representation at events. Outreach beyond environmental sectors and tailored workshop strategies are recommended to broaden impact. Lessons learnt stress the importance of clear project planning, formalised project management roles, and maintaining an EDS-wide knowledge base to inform future proposals.

Collectively, these recommendations aim to deliver a more integrated, user-centred, and technically robust EDS ecosystem, positioning it to support cross-domain research and emerging digital infrastructure needs.

Key themes and insights

Key areas identified:

- Governance – how can we effectively work together across our federated teams/services? How do we prevent further disaggregation of services given the different governance and priorities of EDS host institutions?
- User needs – how can these be efficiently embedded into future work?
- Data and informatics – how can we ensure project findings are embedded and shared across our operational services and day-to-day workflows?
- Stakeholder engagement – how can we ensure we're telling the right people about our recent work?
- Project coordination, resourcing & future funding – how can we ensure we are sharing project management good practice for future work?

A summary of the key insights for each theme can be found below.

Governance

- Governance and management remain central to EDS roadmap objectives and successful collaborative projects.
- General governance recommendations from the project will be reported and discussed at the EDS Data Operations Group in early 2026.
- Need for clear mechanisms to action feedback and recommendations (e.g. via roadmap implementation plan).
- Suggestions to improve representation and coordination across EDS teams for events.
- Co-creation toolkit emphasises governance as a shared responsibility - early involvement of stakeholders improves adoption.
- SensorThings work introduced community profiles and standard agreements for interoperability across the EDS
- Move from project-by-project engagement to a holistic co-design process for user needs
- Formalise engagement with DAREUK for Trusted Research Environments (TREs)
- Adopting a narrow/thin middle architecture across EDS should be a priority

User needs

- People don't know how to do user research – we could provide guidance
- External interest in contributing to the co-creation toolkit
- Involving users at early design stages for better outcomes (e.g. through hackathons and community workshops)
- Value of iterative feedback loops
- Strong need/interest in onboarding materials, documentation, and training
- Future user research should prioritise publishing anonymised user quotes for reuse

Data & informatics

- Improved cross-data centre relationships and collaborations focussed on tackling specific complex data challenges
- AI-readiness and analysis ready data (supported by good metadata) are priorities
    - Challenges: lack of clear documentation for workflows, resource requirements for AI.
    - Suggested solutions: flowcharts, helpdesk chatbots, reproducible workflows.
- Users need simple, consistent APIs and machine-readable metadata.
- SensorThings API implementation delivered:
    - Standardised real-time sensor data exchange using OGC SensorThings API
    - Semantic enrichment with NVS vocabularies and I-ADOPT framework
    - Interoperability demos via Leaflet web maps and Jupyter Notebooks
- The technical experiments have greatly helped the push towards automated ingestion of sensor data and metadata across the EDS
- Address areas for further work e.g. QC flagging, AI use cases, and data provider tools

Stakeholder engagement

- An updated stakeholder map and dissemination plan were created in a flexible/scalable way for future reuse
- New processes for how to gather information and disseminate the project work were explored and are being reused already in future projects

- Difficulty reaching beyond existing communities - need to connect with wider sectors like law, insurance, health.
- Variety of methods used at the Digital Gathering event were effective for engagement
- SensorThings demos provided accessible interfaces (React frontend, Leaflet maps) for non-specialists
- Co-creation approaches improve trust and uptake with stakeholders
- To further gain value on this work, we should target future outreach to non-environmental sectors for sensor data

Project coordination, resourcing & future funding

- Project management was reasonably unstructured with limited leadership through the first six months of the project particularly. This resulted in the project having a slow start and a lack of cohesion across the project team. Once a new PI was put in place in December 2024 the project experienced better leadership and project management was implemented.
- Standard project management practices were put in place (including regular team catch ups, creation of risk registers, action logs, deliverable tracking and regular project retrospectives).
- In future projects, the implementation of templated and structured ways of managing a project from the outset is essential. It would help avoid slow and unguided projects as well as promote standard practices across the EDS.
- A lessons learnt log was created to collate and capture key insights from the project. Many of these lessons highlight the need for improved project management. Recommendations from these lessons have been shared with appropriate EDS management to be actioned.
- Reporting time must be included in future project timelines. It takes a long time to coordinate across many different streams of work to ensure a clear narrative is provided
- Projects focussing on a single shared problem promotes collaboration and connectivity across teams
- An EDS-wide lessons learnt log should be created and actively explored when planning future projects to ensure the same mistakes are not made again
- Project proposal writing should be improved by using a standard template with clear deliverables/outputs and provides clarity on resourcing and roles from the outset.

- A template Collaboration Agreement should be created for all EDS collaborative projects with standardised Terms and Conditions that can be used for future EDS projects, regardless of the coordinating institute to minimise confusion and complexity and simplify approach to sharing outcomes.
- EDS project reporting should be given exemption from institutional publication processes to simplify report signoff and ensure that all EDS reports are archived long-term and available via NORA.

Impact beyond the EDS science communities

Anyone wishing to access environmental data from across multiple different domains will benefit from the foundational work undertaken by this project. It will also benefit discipline focussed research by simplifying access and lowering barriers for entry.

We anticipate it being particularly useful for:

- **Researchers/scientists/data analysts/modellers** - who integrate sensor data across multiple domains
    - Improving reliability of data analysis: reduction in disciplinary silos and bridging gaps between domains to ensure domain knowledge is transparent and traceable
    - More accessible, easier to use data for non-specialists
- **AI systems** – to automate and build tools to support data ingest/quality check/access/analysis
    - More accessible, AI-ready data: by tackling inconsistent formats, standards, and metadata across datasets
- **Sensor deployers/instrument operators/remote operators** – who are responsible for ensuring the data is high quality
    - A lowering of barriers for data providers: by giving them a plug and play system that can evolve for new and broader communities
- **Managers of Digital Research Infrastructure** – who can learn and build upon the project outputs for their research domains
    - International alignment: our work has expanded upon global standards and open-source tools that others can benefit from
    - Act as expert consultants: digital research infrastructures in different domains will have similar challenges and can adapt project outputs for their use cases

- **Decision makers/policymakers (e.g. government, local councils)** - who use environmental data from multiple domains to make decisions that impact wider society
    - More informed decision making: supporting stakeholders with robust data to make informed infrastructure and environmental choices
    - Preventative value: avoiding disasters (e.g. floods) through improved modelling and planning
    - Future real-time decision-making and improved policy decisions

Ultimately, **citizens – the individuals who are affected by environmental change in their local area** – will benefit due to the foundational data infrastructure enabling informed robust decisions to be made in response to our changing climate.

Example external impacts

Open Geospatial Consortium

In March 2025, the Open Geospatial Consortium (OGC) engaged with members of the project team at BODC (British Oceanographic Data Centre) to explore the SensorThings API (STA), the I-ADOPT framework, and the feasibility of delivering STA in JSON-LD rather than plain JSON. Through these discussions, Rob Atkinson (OGC) introduced the concept of OGC Building Blocks, including early exemplars that mapped STA JSON to widely adopted ontologies such as SOSA and SSN. BODC worked closely with OGC in the co-creation of these Building Blocks, providing practical input and iterative feedback on both the technical approach and the development process.

The most significant outcome of this collaboration has been the implementation of staLD, which leverages `the Building Blocks and a context-per-element approach to enable semantically enriched, interoperable STA representations aligned with established standards. Building on this success, BODC and OGC are now in active discussions on how to scale and formalise this work further, in response to growing interest from a wide range of organisations seeking to adopt and operationalise this approach.

LandSeaLot, Plymouth Marine Laboratory (PML):
BODC participates in LandSeaLot that focuses on the observation of the land-sea interface and especially closing the observation gaps in this work domain. LandSeaLot aims to support researchers with additional cost-efficient sensors, where they will be deployed, tested, and data assessed for integration into the LandSeaLot Integration Labs (LILs) research products. We are in discussions with LandSeaLot and PML of adopting the sensorThingsAPI and the STALD implementation for their sensor data streaming.

Interfaces for AI
While the SensorThings API provides a robust machine-readable interface, its AI readiness depends on the explicit representation of semantics. The staLD implementation addresses this by delivering STA as JSON-LD with element-level contexts and mappings to widely adopted ontologies (e.g. SOSA/SSN and I-ADOPT), enabling semantic clarity, cross-domain integration, and AI-driven analysis at scale.

How could this work be built upon?

In an era defined by data-driven research and decision-making, the ability to deliver timely, actionable environmental insight is critical. The AMPLIFY-EDS project, alongside the complementary BOOST-EDS project, has demonstrated a step change in EDS capability through the prototyping of cross-data-centre integrated services and tools. The next transformative opportunity is to reimagine how EDS connects these services with data users, leaning on an understanding of the latest practices adopted by data-based SMEs to maximise the value of their data.

An EDS-supported data marketplace is a compelling vision: a dynamic, trusted hub that transforms integrated EDS services into user-oriented data products, making them both discoverable, accessible, and reusable across domains and sectors in ways that traditional data catalogues do not support. Through rich search and filtering, data preview, and transparent access mechanisms, such a marketplace would allow NERC users to discover relevant data products and services and products based on their specific needs, facilitating the development of actionable insight from NERC data - a key NERC Digital Strategy. Underpinned by strong governance, a suite of Commons services and tools, continuous user research, and targeted training/support, this approach would unlock the full potential of NERC data assets, acting as a catalyst for analytics, AI, accelerating innovation, and strengthening the evidence base for policy and decision-making.

The user research conducted in this project compliments and feeds into the ambitions of the new EDS project – UNITED (User Needs Informed Technologies for Environmental Data). Funded by the National Federated Compute Services NetworkPlus initiative, the project seeks to design a framework for federated computing roadmaps from the perspective of user needs – using our experience in the EDS as a case study. The EDS roadmap was originally designed by senior members of the EDS based on an implied understanding of users and was always intended to act as a 'living document'. The EDS roadmap is due a refresh and the UNITED project could provide a vehicle to conduct this update considering real end user needs as well as a landscape review of roadmaps for other federated research infrastructure e.g. BioFAIR.

As a data service, a crucial future challenge of more integrated, automated and domain independent services will be supporting rapid advancements in Artificial Intelligence (AI) in support of NERC's ambitions. This is not only directly through the application of Large Language Models across our services to enable users to discover, use and generate data with ease, but also indirectly through the provisioning AI-ready data. Supporting trustworthy AI (e.g. from bias) and its application with respect to aspects like machine learning types (e.g. labelled and non-labelled data sources), access to large data volumes, facilitating tokenisation and decoding, and devising strategies for the long-term preservation and publication of provenance and reusable training datasets will be essential to any future roadmap approaches. Our SensorThingsAPI graph-based Commons approach has already taken major steps towards providing structured labelled context to cross-domain data sources and grounding AI in real-world facts and reasoning.

Successful funding opportunities are already being explored by the EDS, including exploring AI-ready Application Programming Interfaces (APIs) to improve accessibility for models (past project - API4AI, current project - High5 for AI) as well as support for foundation models (current project - FRAME-FM). These projects are offering transformative potential to change how NERC addresses complex environmental challenges. Finally, an indirect outcome of the AMPLIFY-EDS project work is that representatives from the AI teams from four of our host institutes (BAS, BGS, NOC and UKCEH) have met to discuss opportunities to collaborate on AI related issues, beyond the project. The outcome is a suggestion for creation of an AI Special Interest Group within the governance of the EDS as a mechanism to ensure that AI is fully explored in the EDS roadmap.

Appendix: supporting materials

Blair, G.; Samreen, F.; Brown, M.; Trembath, P; Fry, M; Ginger, D.; Cooper, H; Rawsthorne, H; Shaw, N. (2025) Reflections from our experimentation in supporting sensor data in the Floods and Droughts Research Infrastructure (FDRI) programme. Retrieved from https://nora.nerc.ac.uk/id/eprint/540894

Booth, J., Bell, P., Kingdon, A., Heaven, R., Card, C., Sauze, C., Tso, M. 2025 . *NERC Environmental Data Services: API 4 AI project kickoff workshop report.* Retrieved from https://nora.nerc.ac.uk/id/eprint/539107/

Card, C.; Heaven, R.; Kingdon, A.; Bell, P.; Baldwin, A.; Carter, J.; Coney, J.; Cooper, J.; Gonzalez Alvarez, I.; Hollaway, M.; McCormack, M.; Poulter, D.; Stephens, A.; Trembath, P. (2025). *Publishing Environmental Data APIs for use in AI workflows: recommendations and demonstrators of a standard approach within the NERC Environmental Data Service.* NERC. Retrieved from https://nora.nerc.ac.uk/id/eprint/539708/

Kingdon, A.; Kadochnikova, A.; Joseph, T. (2025). *Trusted Research Environment: architecture and implementation, a case study.* Retrieved from https://nora.nerc.ac.uk/id/eprint/540180

Kokkinaki, A., Kingdon, A., Walsh, C., Moncoiffe, G., Darroch, L. 2025 *SensorThingsAPI for the EDS: a standardised service for real time Internet of Things (IoT)*. Liverpool, NOC, 16pp. (Unpublished). Retrieved from: https://nora.nerc.ac.uk/id/eprint/541040/

Peplar, S., 2026. Governance Recommendations from the NERC Environmental Data Service (EDS) Amplify Project: https://zenodo.org/records/19923522

Rawsthorne, H.; Long, R.; Trembath, P. (2025). *Improving the discoverability of research methods and workflows: a deliverable report for the AMPLIFY-EDS project.* Retrieved from https://nora.nerc.ac.uk/id/eprint/540729

Tate, A.J.; Crosier, M.C.; Lopez, C.J.; Dawson, B.; Phillips, D.P.; Bridger, M.; Ward, J. (2025) *Next-generation sensor data acquisition onboard NERC deep water research vessels: a deliverable report for the AMPLIFY-EDS project.* Retrieved from https://nora.nerc.ac.uk/id/eprint/540864/

Townsend, P. (2025). *Sharing highlights from the Environmental Data Service at the NERC Digital Gathering 2025.* Retrieved from https://doi.org/10.5281/zenodo.17869635

A new project overview webpage on the EDS website: https://eds.ukri.org/projects/amplify

Appendix: table of deliverables and recommendations

A summary of all deliverables and recommendations from the project can be found in the spreadsheet published here:

Townsend, P., Anderson, E., Blair, G. S., Darroch, L., Kingdon, A., Kokkinaki, A., Kingston, R., Pepler, S., Tate, A., Trembath, P., & Watson, C. (2026). *AMPLIFY-EDS project: spreadsheet of recommendations and deliverables*. Retrieved from https://doi.org/10.5281/zenodo.18256058

Appendix: full URLs for embedded links

Environmental Data Service (EDS) webpage: https://eds.ukri.org/about-us

Natural Environment Research Council (NERC) webpage: https://www.ukri.org/councils/nerc/

UK Research and Innovation (UKRI) webpage: https://www.ukri.org/

NERC Digital Strategy: https://www.ukri.org/publications/natural-environment-research-council-nerc-digital-strategy-2021-2030/

Digital Solutions Hub: https://www.digital-solutions.uk/

UKRI Digital Research Infrastructure Programme: https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/digital-research-infrastructure-programme/

ENHANCE project page: https://eds.ukri.org/projects/enhance

BOOST project page: https://eds.ukri.org/projects/boost

UNITED project page: https://eds.ukri.org/projects/united

FRAME-FM project page: https://eds.ukri.org/projects/frame-fm

AMPLIFY project page: https://eds.ukri.org/projects/amplify

High5forAI project page: https://eds.ukri.org/projects/high5-ai

API4AI project page: https://eds.ukri.org/projects/api4ai

Digital Solutions 'Second User Research Report': https://www.digital-solutions.uk/wp-content/uploads/2024/05/DSH-User-Research-Report_2024-1.pdf

NERC-EDS 'When to Use Co-Creation': https://nerc-eds.github.io/co-creation-toolkit/toolkit/when-to-use-co-creation/

NERC-EDS 'Finding the Unknown Users': https://nerc-eds.github.io/co-creation-toolkit/case-studies/integrated-environmental-data-platform/

NERC Open Research Archive (NORA) for publication 'Publishing Environmental Data APIs for use in AI workflows: recommendations and demonstrators of a standard approach within the NERC Environmental Data Service': https://nora.nerc.ac.uk/id/eprint/539708/

Zenodo publication of 'Sharing highlights from the Environmental Data Service at the NERC Digital Gathering 2025': https://zenodo.org/records/17869635

NERC Open Research Archive (NORA) for publication 'Next-generation sensor data acquisition onboard NERC deep water research vessels: a deliverable report for the AMPLIFY-EDS project': https://nora.nerc.ac.uk/id/eprint/540864/

NERC Open Research Archive (NORA) for publication 'Improving the discoverability of research methods and workflows: a deliverable report for the AMPLIFY-EDS project': https://nora.nerc.ac.uk/id/eprint/540729

NERC-CEH Digital Objects Ontology: https://nerc-ceh.github.io/digital-objects-ontology

NERC Digital Solutions Programme webpage: https://www.digital-solutions.uk/

eLab Digital Workbench: https://assets.bmh.manchester.ac.uk/diids/elab/homepage/index.html

The Christie NHS Foundation Trust: https://www.christie.nhs.uk/research-and-innovation

NERC Open Research Archive (NORA) for publication 'Trusted Research Environment: architecture and implementation, a case study': https://nora.nerc.ac.uk/id/eprint/540180/

I-ADOPT Framework Ontology: https://i-adopt.github.io/ontology/index.html

NERC-EDS NERC Vocabulary Server (NVS) page for ‘air_temperature’: https://vocab.nerc.ac.uk/collection/P07/current/CFSN0023/

NERC Digital Gathering 2025 event webpage: https://sites.google.com/ncas.ac.uk/digitalgathering2025/home

NERC Open Research Archive (NORA) for publication ‘Contributions to the development of the next-generation NERC Environmental Data Service: Building Interoperability - a NERC Data Commons RoadMap’: https://nora.nerc.ac.uk/id/eprint/538375/

NERC-EDS ‘Co-Creation Toolkit’: https://nerc-eds.github.io/co-creation-toolkit/

National Federated Compute Services NetworkPlus initiative: https://nfcs-networkplus.ac.uk/

Federated STA Data - Leaflet Map Example: https://britishgeologicalsurvey.github.io/sensor-things-api-demo/web-maps/federated.html

Jupyter-Lab digital notebooks: https://github.com/NERC-EDS/sensorCommons/tree/notebooks/Notebooks