Training satellites to monitor the ocean

Utilising the Atlantic Meridional Transect

Advancing humanity's knowledge and capability

Since 1978, satellite sensors have provided unprecedented data on ocean health, composition, and dynamics, drastically enhancing our understanding of marine environments. However, the accuracy of this data depends on calibrating and validating the sensors by training them against field measurements and developing algorithms to convert the data into usable information.

Oceanographic ships are essential for collecting these in-situ measurements in a diverse range of conditions. The Atlantic Meridional Transect (AMT) is a UK government National Capability programme, led by Plymouth Marine Laboratory (PML), is a prime example of such a platform, ensuring that satellite data accurately represents ocean conditions.

AMT has been instrumental in providing high-quality reference measurements, revolutionising the way we monitor ocean colour from space.

AMT is a long-running ocean observation programme that undertakes biological, chemical, and physical oceanographic research between the UK and destinations in the South Atlantic, sampling in open ocean oligotrophic, eutrophic and coastal waters covering sub-polar to tropical ecosystems.

This comprehensive sampling approach enables AMT to capture the variability and complexity of the Atlantic Ocean at multiple scales. For instance, AMT has produced a unique time series on the structure and biogeochemical properties of planktonic ecosystems, essential for validating models of the global carbon cycle. This has contributed to understanding of the ocean's role in the global climate system and international climate policy.

AMT's multidisciplinary approach, consistent methodology, and long-term commitment have established it as indispensable for advancing ocean knowledge and informing marine policy decisions.

Safeguarding the future of ocean observations requires financial and political support to continue to advance our understanding of the ocean's role in the Earth system

Securing the future of long-term ocean observations

The continued success of AMT relies on sustained funding to maintain its critical role in advancing our understanding of the Atlantic ecosystem and its influence on the global climate. Long-term environmental data collected by AMT is crucial for comprehensive climate and ocean monitoring[1], as well as for various commercial and societal applications, such as fish stock assessments and ocean forecasting systems.

Hydrographic research cruises are costly, but their contributions are invaluable. Investing in AMT ensures the continued advancement of our ocean observing capabilities. Sustaining this effort is crucial for enhancing current and future assessments and predictions of ocean dynamics and climate change.

As we face the growing challenges posed by climate change, it is more important than ever to prioritise programmes like AMT. By investing in AMT, we are investing in a better future for our planet, one in which we can make informed decisions based on reliable, long-term data and advanced satellite technology.
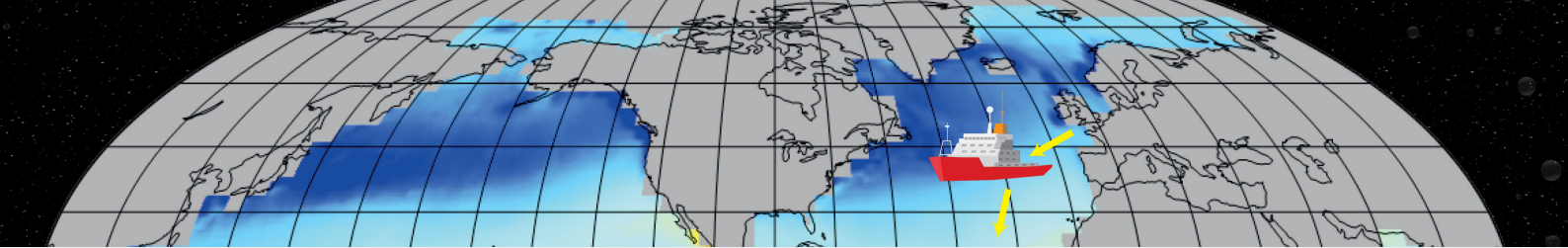
The impact of AMT on satellite validation

Satellite observations have revolutionised our understanding of the ocean by providing frequent, global coverage at a fraction of the cost of traditional in-situ monitoring. These observations offer unprecedented insights into ocean health, composition, and dynamics, enabling scientists to monitor vast areas of the ocean that would otherwise be inaccessible.

AMT has significantly improved the quality and reliability of satellite observations, ultimately enhancing our ability to monitor and protect the ocean. Today, the data provided by satellites contributes to a wide range of management, policy and governance applications. High quality data collected on AMT and used to validate satellite observations has resulted in a wide range of impacts, examples of which are given below.

Essential Ocean Variables

The data collected during AMT cruises have been used to create long-term time series of Essential Climate Variables (ECVs) and Essential Ocean Variables (EOVs)[2]. These sets of key parameters represent the essential components of the Earth's climate system and are critical for understanding both natural and climate change-induced environmental and biodiversity change and variability. AMT's consistent methodology and high-quality measurements[3] have been instrumental in establishing reliable time series of ECVs and EOVs, which serve as a foundation for monitoring the ocean's response to climate change.

Indicators for environmental protection monitoring

AMT data, combined with the expertise of PML scientists, have facilitated the development of environmental indices, notably the primary production indicator[4], which offers insights into marine ecosystem dynamics.

Primary production is a more robust water quality indicator than previous measures, as it reflects environmental pressures (e.g., contaminants, nutrient enrichment, pollution) not necessarily detected through chlorophyll-a changes. It serves as an early warning for direct pressure on marine food webs and indicates carbon flow from the base of the food chain to higher trophic levels, aiding in understanding the role of large fishes and marine mammals in ocean carbon sequestration and the biological carbon pump.

These indices inform environmental management bodies, enabling them to implement targeted monitoring measures and evidence-based policies to address oceanic changes proactively.

EU policy targets

Satellite-derived primary production indicators are now a well-recognised baseline for healthy seas and Good Environmental Status[5]. These indicators have supported implementation of the EU's Marine Strategy Framework Directive and Water Framework Directive. These policies require Member States to develop environmental targets and indicators. Ocean colour products, including primary production, are used to establish and report against these targets.

Ocean Reports

In 2023, OSPAR used satellite-derived primary production levels for the first time in their decadal Quality Status Report[6], marking a key transition from their long-established and more costly use of in-situ chlorophyll-a data. AMT's contributions to satellite validation, combined with the expertise of PML scientists in utilising satellite data, have been essential in enabling this shift towards more comprehensive and cost-effective ocean monitoring.

Climate Change Policy

AMT data have been used in Intergovernmental Panel on Climate Change (IPCC) assessments[11] and Ocean State reports[12], which inform policy decisions and national and international legislation. For example, the UK's net-zero emissions target is based on evidence from the latest IPCC reports, highlighting the far-reaching impact of the AMT campaign on climate change policy at the national level. By providing reliable, long-term data on ocean health and function, AMT has played a crucial role in informing evidence-based climate policies.
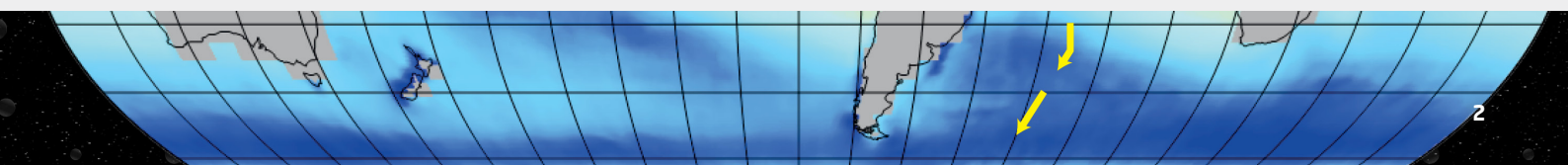
Capacity building

AMT has played a pivotal role in capacity building and capability development within the global oceanographic community. In collaboration with several national UK centres, including the UK Met Office, the AMT campaign has deployed over 100 Argo and Bio-Argo floats, collecting and providing physical and biogeochemical ocean data that is freely available to the global observational, satellite, and modelling communities.

The AMT programme has provided training opportunities for more than 100 PhD students and early-career researchers from developing nations, fostering international collaboration and knowledge exchange. By involving 310 sea-going scientists from 81 institutes across 31 countries, the AMT campaign has contributed to the development of a global network of skilled ocean scientists and facilitated the exchange of best practices, knowledge, and data sharing worldwide.

The high quality and free availability of AMT data have undoubtedly spurred the appetite of the data-hungry and data-deprived oceanographic community worldwide. Between 2012 and 2022, AMT data were downloaded more than 239,000 times by registered British Oceanographic Data Centre (BODC) users in 34 countries, including 168 unique UK ocean data users.

Serving as an ideal platform for national and international scientific collaboration, AMT provides a training arena for the next generation of oceanographers and an ideal facility for the validation of novel technology, further contributing to capacity building efforts in the oceanographic community.

PML's pioneering work connecting satellite data to in-water biology through AMT is unparalleled. The in-situ observations they provide are crucial for decoding complex optical signals seen from space. By collecting this essential validation data today, the Atlantic Meridional Transect is laying the foundation for monitoring and understanding our changing oceans in the years to come.

Craig Donlon
Head of Earth Observation System Architect Office, European Space Agency

The AMT field programme embodies the aspirations of the EuroGO-SHIP initiative, which aims to provide high-quality hydrographic data and the infrastructure necessary for systematic observation of European marine waters. This initiative is crucial for safeguarding current and future assessments and predictions of ocean dynamics and climate change.

Richard Sanders
EuroGO-SHIP

Scientific impact

The AMT programme has significantly improved the accuracy of global chlorophyll-a concentrations[7,8] and primary production estimates[9], particularly in the low-chlorophyll oligotrophic gyres. As a result, scientists now have a better understanding of the distribution and dynamics of phytoplankton, which form the base of the marine food web and play a crucial role in the global carbon cycle.

The commitment of AMT scientists to collecting high-quality Fiducial Reference Measurements has been instrumental in ensuring the accuracy and reliability of satellite-derived ocean colour data[10]. By employing consistent methodology and state-of-the-art instrumentation across diverse oceanic regions, AMT scientific and technical teams are compiling high-quality, long-term chlorophyll-a time series. These data serve as the foundation for a wide range of quality-controlled in-situ and satellite-derived ocean colour products. The AMT campaign has proven invaluable for validating satellite measurements and improving our understanding of the global ocean.

Collaborations with international space agencies, such as the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Space Agency (ESA), and the United States National Aeronautics and Space Administration (NASA), have been essential to the success of the AMT programme. These partnerships have facilitated the exchange of expertise, data, and technology, ultimately enhancing the scientific impact of the AMT campaign.

The scientific findings generated by the AMT programme have been disseminated through a substantial body of literature, with over 400 peer-reviewed publications covering a wide range of disciplines. These studies have advanced our understanding of the physical, chemical, and biological processes occurring in the Atlantic Ocean, providing new insights into the functioning of ocean ecosystems and their response to climate change and anthropogenic pressures.

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AMT has contributed to over 400 refereed publications for a full list of
publications see the AMT website, www.amt-uk.org.

AMT data is freely available to download from the British Oceanographic Data Centre website, www.bodc.ac.uk.

**Invest in the future of our oceans by supporting the AMT
programme through funding or collaboration.**

**To learn more about contributing to AMT or utilising our data in your
research or decision-making, please contact us at amt@pml.ac.uk.**

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