REPORTING FORM 2024

The Atlantic Meridional Transect (AMT)

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1. Ongoing activities, in line with the IMBeR Grand and Innovation Challenges

(Among other uses, information will be used to update the IMBeR Annual Report to SCOR)

1.a. Grand Challenge I

Understanding and quantifying the state and variability of marine ecosystems - with focus on Research Objectives 1 to 3:

***Research Objective 1**. Evaluate and predict the cumulative effect of multiple stressors*
***Research Objective 2**. Integration of climate change and climate variability*
***Research Objective 3**. Impacts on society – preparation for a changed future*

AMT is a UK National Capability program which is delivered by the Plymouth Marine Laboratory and funded by the Natural Environment Research Council. Since 1995 the Atlantic Meridional Transect (AMT) has undertaken measurements of oceanographic and atmospheric variables during 30 research cruises on a passage between the UK and destinations in the South Atlantic. This program of observations and novel research activities has collected samples for microbial molecular characterisation since 2009, spans more than 100° of latitude, samples to ocean depths of up to 1000 m and crosses a range of ecosystems from sub-polar to tropical, from eutrophic shelf seas and upwelling systems, to oligotrophic mid-ocean gyres. AMT has enabled the acquisition of repeat measurements of several Essential Ocean Variables and other ecosystem parameters and rate processes at a resolution of ~160 km (over ~13000 km). In delivering these activities AMT has facilitated long-term calibration and validation of satellite ocean colour sensors; deployment of ARGO and Bio-ARGO floats; and has maintained a long-term mooring in the South Atlantic Gyre (2009 to 2023). AMT data is archived and managed by the British Oceanographic Data Centre (BODC), whilst key data are also directed to other focus specific databases.

AMT has enabled extensive investigation of biodiversity and biogeochemical processes and provided the first Atlantic Ocean basin scale measurements of: *Prochlorococcus and Synechococcus abundance (Zubkov et al., 2000); plankton net community production (Serret et al., 2001), respiration (Robinson et al., 2002), nitrification (Clark et al. 2007), mixotrophy (Hartman et al., 2012) and distribution of calcifying coccolithophores (Balch et al 2019). By engagement with other global scale programmes AMT contributes to understanding of global metagenome diversity (Larkin et al 2021).*

AMT research has contributed to the quantitative understanding of key interactions and feedbacks between the ocean and the atmosphere *which have included the role of ammonium in climate control (Jickells et al., 2003); enabled global prediction and model-validation of climate-relevant dimethylsulphide (Bell et al., 2006); provided first ocean basin budget of the global marine sources of atmospheric N2O and CH4 respectively (Forster et al., 2009) and enabled estimates of pCO2 in seawater from net community production measurements (Ford et al 2021).*

AMT observations are a key component of the monitoring and detection of long-term changes in the ocean, *driven by both natural variability and anthropogenic change. Kitidis et al. (2017) quantify changes in surface ocean CO2 and the carbonate system revealing a basin wide ocean acidification. AMT inputs to the global carbon project and annual carbon budget assessment (https://www.globalcarbonproject.org/). Long-term deployments of ocean moorings have revealed the contribution of atmospheric dust to deep ocean carbon sequestration (Pabortsava et al 2017). Whilst the integration of AMT data with satellites observations and biogeochemical modelling has characterised spatial and temporal variability of dominant oceanic provinces (Smyth et al 2017).*

Engagement with other organisations *including NASA and ESA has been key to the origin and continuation of AMT. Early efforts provided first validation and calibration of SeaWiFS generation satellites (e.g. Aiken & Hooker 1997), recent highlights have included ESA supported projects (www.amt4oceansatflux.org) which continue this work for the current Sentinel Satellites (Tilstone et al 2021), enabling greater characterisation of ocean processes (Lange et al 2020) and ocean-atmosphere exchange of climatically important gases (Holding et al 2019).*

Cited references can be found at: Publications (amt-uk.org)

1.b. Grand Challenge II

Improving scenarios, predictions and projections of future ocean-human systems at multiple scales - with focus on Research Objectives 4 to 6:

Research Objective 4*. Development of integrated data systems and approaches for predictions and projections*
Research Objective 5*. Development of predictive models and projections for use at regional scales*
Research Objective 6*. Development of alternative scenarios to bridge the gap between physical climate sciences and humanities*

Since 2012, there have been >239,000 downloads of AMT data by users in 34 countries. Rapid public availability of AMT data has enabled sophisticated model and machine learning outputs*: the use of neural networks has linked AMT and remote sensing observations to project accurate fields of pCO2 across the sparsely sampled South Atlantic (Ford et al 2022); AMT observations have validated the use of optical data in the improvement of biogeochemical models to further mechanistic understanding of phytoplankton diversity (Dutkiewicz et al 2015, 2021). Data assimilation methods are utilised to improve ecosystem simulations (Ciavatta et al 2018) and deep learning methods deployed to improve the resolution and accuracy of chlorophyll concentrations from high frequency optical measurements (Graban et al 2020).*

Cited references can be found at: Publications (amt-uk.org)

1.c. Grand Challenge III

Improving and achieving sustainable ocean governance - with focus on Research Objectives 7 to 9:

***Research Objective 7**. Develop knowledge on best practices for multilevel governance approaches to ocean climate adaptation and mitigation*
***Research Objective 8**. Develop understanding on key ingredients for transformation towards more sustainable, equitable and inclusive governance approaches to fisheries and aquaculture*
***Research Objective 9**. Support implementation of post-2020 biodiversity targets for marine spatial planning and marine protected areas*

Influence on Policy, Practice, Patients and the Public

Processing and validating satellite-derived ocean colour products to monitor for water quality to inform industry and deliver policy directives. PML has been instrumental in the validation and application of satellite data and the computation of comprehensive uncertainty budgets on in situ measurements, referenced by inter-comparisons to firmly establish them as Fiducial Reference Measurements (FRM's) for satellite validation. During the AMT4CO2Flux contract, PML were instrumental in developing a Chl-a algorithm that significantly improved the performance of the standard ESA-EUMETSAT Chl-a algorithm in open-ocean waters. In addition, installation of state-of-the-art eddy covariance CO_2 flux systems on two different ships (RRS James Clark Ross and RRS Discovery), accompanied by detailed measurements of the surface ocean on two Atlantic Meridional Transect (AMT) field campaigns (AMT28 & 29) and one Arctic Ocean campaign (DY151) provided near-fiducial data sets for gas flux and ocean acidification studies. These data verified the accepted uncertainties in global estimates of the air-sea flux of CO_2 and provided ocean acidification parameters calculated from a suite of satellite products over a range of Atlantic and Arctic locations.

1.d. Innovation Challenge 3

To advance understanding of ecological feedbacks in the Earth System

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1.e. Innovation Challenge 4

To advance and improve the use of social science data for ocean management, decision making and policy development

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1.f. Innovation Challenge 5

Interventions to change the course of climate impacts

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1.g. Innovation Challenge 6

Sustainable management of Blue Carbon ecosystems

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2. Selected highlights

2.a. Selected scientific highlights since last report (1-5)

Last report was submitted to SSC meeting, April 2023

- Research Topic published in Frontiers in Marine Science - *https://www.frontiersin.org/research-topics/24988/the-atlantic-meridional-transect-programme-1995-2023/magazine*
- Levered funding - *European Space Agency contract Atlantic Meridional Transect for CO_2 Flux (AMT4CO_2Flux; 4000136286/21/NL/FF/ab).*
  The impact of this work is to demonstrate the use of satellite data to estimate CO2 flux from the Atlantic Ocean and the status of ocean acidification in the Atlantic. This enhances our understanding of the role of the Atlantic Ocean in climate change feedback and highlights the area as an essential ecosystem service in regulating climate change. The contract also validates the latest Sentinel-3 (OLCI and SSTR) and Sentinel-1 (sea surface roughness) products using fiducial reference measurements.
- *Received endorsement for AMT by UN Ocean Decade Programme - Ocean Biomolecular Observing Network (OBON)*
- *Funding for continuation of AMT (2024 – 2029) approved under UK NERC ATLANTIS programme (https://noc.ac.uk/projects/atlantic-climate-environment-strategic-science)*
- *AMT 30 Cruise Report - DOI: 10.17031/d2vs-eg36*

2.b. Publications since last report

Please add all publications since last report to the table below (see notes for details on "Class" and "Activity" fields).

***Publication** with DOI*	***Class 1, 2, 3***	***Activity****
Brewin, R.J.W., and G. Dall'Olmo. 2024. Ocean-colour anomalies quantified by the human eye. Journal of Plankton Research. doi:10.1093/plankt/fbae027	*3*	
Rees, A.P., T.J. Smyth, and V. Brotas. 2024. Editorial: The Atlantic Meridional Transect Programme (1995-2023). Frontiers in Marine Science 11 1358174. doi:10.3389/fmars.2024.1358174	*3*	
Sha, B., J.H. Johansson, M. Salter, S. Blichner, and I. Cousins. 2024. Constraining global transport of perfluoroalkyl acids on sea spray aerosol using field measurements. Science 10 (14), 1026. doi:10.1126/sciadv.adl1026	*3*	
Sheward, R.M., A.J. Poulton, J.R. Young, J. de Vries, F.M. Monteiro, and J.O. Herrie. 2024. Cellular morphological trait	*3*	

dataset for extant coccolithophores from the Atlantic Ocean. Scientific Data 11 720. doi:10.1038/s41597-024-03544-1		
Torcello-Requena, A., A. Murphy, I.D.E.A. Lidbury, F.D. Pitt, R. Stark, A.D. Millard, R.J. Puxty, Y. Chen, and D.J. Scanlan. 2024. A distinct, high-affinity, alkaline phosphatase facilitates occupation of P-depleted environments by marine picocyanobacteria. Proceedings of the National Academy of Sciences 121 (20), e2312892121. doi:10.1073/pnas.2312892121	*3*	
Allen, R., K.E. Bird, J.C. Murrell, and M. Cunliffe. 2023. Latitudinal variation in the potential activity of Atlantic Ocean bacterioplankton revealed through 16S rRNA and 16S rRNA gene metabarcoding. Frontiers in Marine Science 10 1241333. doi:10.3389/fmars.2023.1241333	*3*	
Barlow, R., T. Lamont, J. Viljoen, R. Airs, R.J.W. Brewin, G. Tilstone, J.A. Aiken, E.M.S. Woodward, and C. Harris. 2023. Latitudinal variability and adaptation of phytoplankton in the Atlantic Ocean Journal of Marine Systems 239 103844. doi:10.1016/j.jmarsys.2022.103844	*3*	
Bian, V., M. Cai, and C.L. Follett. 2023. Understanding opposing predictions of Prochlorococcus in a changing climate. Nature Communications 14 1445. doi:10.1038/s41467-023-36928-9 *Brewin, R.J.W., J. Pitarch, G. Dall'Olmo, H. van der Woerd, L. J., X. Sun, and G.H. Tilstone. 2023. Evaluating historic and modern optical techniques for monitoring phytoplankton biomass in the Atlantic Ocean. Frontiers in Marine Science 10 1111416. doi:10.3389/fmars.2023.1111416*	*3*	
Brewin, R.J.W., S. Sathyendranath, G. Kulk, M.-H. Rio, J.A. Concha, T.G. Bell, A. Bracher, C. Fichot, T.L. Frolicher, M. Galí, et al. 2023. Ocean carbon from space: Current status and priorities for the next decade. Earth-Science Reviews 240 104386. doi:10.1016/j.earscirev.2023.104386	*3*	
Brotas, V., A. Ferreira, V. Veloso, A. Tracana, C.V. Guerreiro, G.A. Tarran, E.M.S. Woodward, L. Ribeiro, J. Netting, D. Clewley, et al. 2023. Assessing phytoplankton community composition in the Atlantic Ocean from in situ and satellite observations. Frontiers in Marine Science 10 1229692. doi:10.3389/fmars.2023.1229692	*3*	
Brown, I.J., V. Kitidis, and A.P. Rees. 2023. Simultaneous high-precision, high-frequency measurements of methane and nitrous oxide in seawater by cavity ring-down spectroscopy. Frontiers in Marine Science 10 119772. doi:10.3389/fmars.2023.1197727	*3*	

Choo, L.-Q. 2023. Genome-wide phylogeography reveals cryptic speciation in the circumglobal planktonic calcifier Limacina bulimoides. Molecular Ecology 32 (12), 3200-3219. doi:10.1111/mec.16931	*3*	
Ford, D.J., G.H. Tilstone, J.D. Shutler, V. Kitidis, K.L. Sheen, G. Dall'Olmo, and I.B.M. Orselli. 2023. Mesoscale eddies enhance the air-sea CO2 sink in the South Atlantic Ocean. Geophysical Research Letters 50 e2022GL102137. doi:10.1029/2022GL102137	*3*	
González-García, C., S. Agustí, J.A. Aiken, A. Bertrand, G. Bittencourt Farias, A. Bode, C. Carré, R. Gonçalves-Araujo, D.S. Harbour, M. Huete-Ortega, et al. 2023. Basin-scale variability in phytoplankton size-abundance spectra across the Atlantic Ocean Progress in Oceanography 217 103104. doi:10.1016/j.pocean.2023.103104	*3*	
Guerreiro, C.V., A. Ferreira, L. Cros, J.-B. Stuut, A.R. Baker, A. Tracana, C. Pinto, V. Veloso, A.P. Rees, M.A.P. Cachão, et al. 2023. Response of coccolithophore communities to oceanographic and atmospheric processes across the North- and Equatorial Atlantic Frontiers in Marine Science 10 1119488. doi:10.3389/fmars.2023.1119488	*3*	
Li, H., G.A. Tarran, G. Dall'Olmo, A.P. Rees, M. Denis, C. Wang, G. Grégori, Y. Dong, Y. Zhao, W. Zhang, et al. 2023. Organization of planktonic Tintinnina assemblages in the Atlantic Ocean. Frontiers in Marine Science 10 1082495. doi:10.3389/fmars.2023.1082495	*3*	
Lin, J., Z. Lee, G.H. Tilstone, X.W. Liu, J., M. Ondrusek, and S. Groom. 2023. Revised spectral optimization approach to remove surface-reflected radiance for the estimation of remote-sensing reflectance from the above-water method. Optics Express 31 22964-22981. doi:10.1364/OE.486981	*3*	
Malysheva, A.S., P.V. Lobanova, and G.H. Tilstone. 2023. Development of a maximum specific photosynthetic rate algorithm based on remote sensing data: a case study for the Atlantic Ocean. Oceanology 63 (Suppl 1), S202-S214. doi:10.1134/S000143702307010X	*3*	
Pardo, S., G.H. Tilstone, R.J.W. Brewin, G. Dall'Olmo, J. Lin, F. Nencioli, H. Evers-King, T.G.D. Casal, and C.J. Donlon. 2023. Radiometric assessment of OLCI, VIIRS, and MODIS using fiducial reference measurements along the Atlantic Meridional Transect. Remote Sensing Environment 299 113844. doi:10.1016/j.rse.2023.113844	*3*	

Phongphattarawat, S., H.A. Bouman, M.W. Lomas, S. Sathyendranath, G.A. Tarran, O. Ulloa, and M.V. Zubkov. 2023. Ecophysiological basis of spatiotemporal patterns in picophytoplankton pigments in the global ocean. Frontiers in Marine Science 10 1112177. doi:10.3389/fmars.2023.1112177	*3*	
Pinti, J., T. DeVries, T. Norin, C. Serra-Pompei, R. Proud, D.A. Siegel, T. Kiørboe, C.M. Petrik, K.H. Andersen, A.S. Brierley, et al. 2023. Model estimates of metazoans' contributions to the biological carbon pump. Biogeosciences 20 (5), 997-1009. doi:10.5194/bg-20-997-2023	*3*	
Quartly, G., J. Aiken, R.J.W. Brewin, and A. Yool. 2023. The link between surface and sub-surface chlorophyll-a in the centre of the Atlantic subtropical gyres: A comparison of observations and model. Frontiers in Marine Science 10 1197753. doi:10.3389/fmars.2023.1197753	*3*	
Reintjes, G., A. Heins, C. Wang, and R. Amann. 2023. Abundance and composition of particles and their attached microbiomes along an Atlantic Meridional Transect. Frontiers in Marine Science 10 1051510. doi:10.3389/fmars.2023.1051510	*3*	
Savvidou, E., B. Sha, M. Salter, I. Cousins, and J. Johansson. 2023. Horizontal and vertical distribution of perfluoroalkyl acids (PFAAs) in the water column of the Atlantic Ocean. Environmental Science and Technology Letters 10 (5), 418-424. doi:10.1021/acs.estlett.3c00119	*3*	
Serret, P., J. Lozano, C.B. Harris, P.K. Lange, G.A. Tarran, G.H. Tilstone, E.M.S. Woodward, and M.V. Zubkov. 2023. Respiration, phytoplankton size and the metabolic balance in the Atlantic gyres. Frontiers in Marine Science 10 1222895. doi:10.3389/fmars.2023.1222895	*3*	
Smyth, T.J., D. Moffat, G.A. Tarran, S. Sathyendranath, F. Ribalet, and J. Casey. 2023. Determining drivers of phytoplankton carbon to chlorophyll ratio at Atlantic Basin scale. Frontiers in Marine Science 10 1191216. doi:10.3389/fmars.2023.1191216	*3*	
Sun, X., R.J.W. Brewin, S. Sathyendranath, G. Dall'Olmo, R. Airs, R. Barlow, A. Bracher, V. Brotas, M. Kheireddine, T. Lamont, et al. 2023. Coupling ecological concepts with an ocean-colour model: Phytoplankton size structure. Remote Sensing of Environment 285 113415. doi:10.1016/j.rse.2022.113415	*3*	

**If appropriate, please list the IMBeR activity through / by / from / during which the publication arose*

*******Notes on publications********

Publications are logged in the IMBeR Zotero library which is publicly accessible online –

Publications since 2016 | Publications prior to 2016

Publications are categorised by "Class" and linked to "Activities":

Class 1 publications are specifically generated through/by/from/during ***IMBeR activities*** - for example, arising from IMBIZOs and IMBeR conferences such as the IMBeR open science meeting and the IMBeR West Pacific symposia and from the activities of the working groups, regional programmes and the SPIS scoping teams.

Class 2 publications are on topics relevant to the IMBeR Science Plan that benefitted from some interaction with IMBeR or ***IMBeR activities***, for example by IMBeR symposium attendees, past and present SSC members, working group, regional programme and endorsed project members, or national contacts.

Class 3 publications are on topics relevant to the IMBeR Science Plan but for which there is no direct link to or benefit from an IMBeR activity. These might include publications by SSC members, working group, regional programme or endorsed project members or members of the IMBeR international community that were written as part of the normal scientific activity of the authors and would have occurred irrespective of IMBeR's existence. You can report Class 3 publications, but they will no longer be logged in the IMBeR database.

[See "What is an IMBeR publication?" for further information]

Why list 'Class' and 'Activity'? This helps us to declare authentically which publications IMBeR has helped to generate, and it makes it easier for us to demonstrate the value of the Regional Programmes, the Working Groups, and IMBeR in general, and it helps us to justify support for IMBeR activities when we can list tangible outputs.

2.c. Events, Meetings, and Workshops

List all international and national events, meetings and workshops. Describe the level of participation: e.g. chairing session/workshop, organising meeting. Include Endorsed Projects committee meetings and workshops.

Format: Title of event. Date. Location. Description of participation. Any other pertinent details.

ASLO Aquatic Sciences Meeting, 4 - 9 June 2023, Palma de Mallorca, Spain. SS035 Physical and Biogeochemical Controls of Primary Production Dynamics in Aquatic Ecosystems. Oral presentation: Contrasting patterns in primary production in the Atlantic Ocean over the past two decades. Abstract Number: 5863.

Sentinel-3 Validation Team meeting 5 – 7 December 2023, EUMETSAT, Darmstadt, Germany. Ocean colour validation using fiducial reference measurements. (Oral presentation).

3. International collaboration and links

Participants and associated collaborators on AMT30 (2023) cruise:

Joaquin Chaves	*NASA, USA*
Harrison Smith	*NASA, USA*
Kirsten Fentzke	*Uni Michigan State, USA*
Scott Freeman	*NASA, USA*
Dalton Hardisty	*Uni Michigan State, USA*
Federico Ienna	*Uni Lisbon, Portugal*
Yessica Contreras Pacheco	*CICESE, Mexico*
Mayibongwe Buthelezi	*Uni Pretoria, South Africa*
Andreia Tracana	*Uni Lisbon, Portugal*
Vanda Brotas	*Uni Lisbon, Portugal*
Thulani Makhalanyane	*Uni Pretoria, South Africa*

4. Input to management, policy and SOCIETY* over the last year

Add anything that is not covered under "1.c. Grand Challenge III"

**As previous reporting forms requested 'input to management and policy' only, please add any 'input to society' not captured in previous reports*

Add text…

5. Education, outreach and Capacity Development

Add text…

6. Changes to data management

Please note this will be placed on the endorsed project webpage

Name and e-mail of the person in charge of data management:

Roseanna Wright, roswri@bodc.ac.uk

Name of the data centre where your project data are stored:

British Oceanographic Data Centre (BODC)

Direct web link where the project data are available:

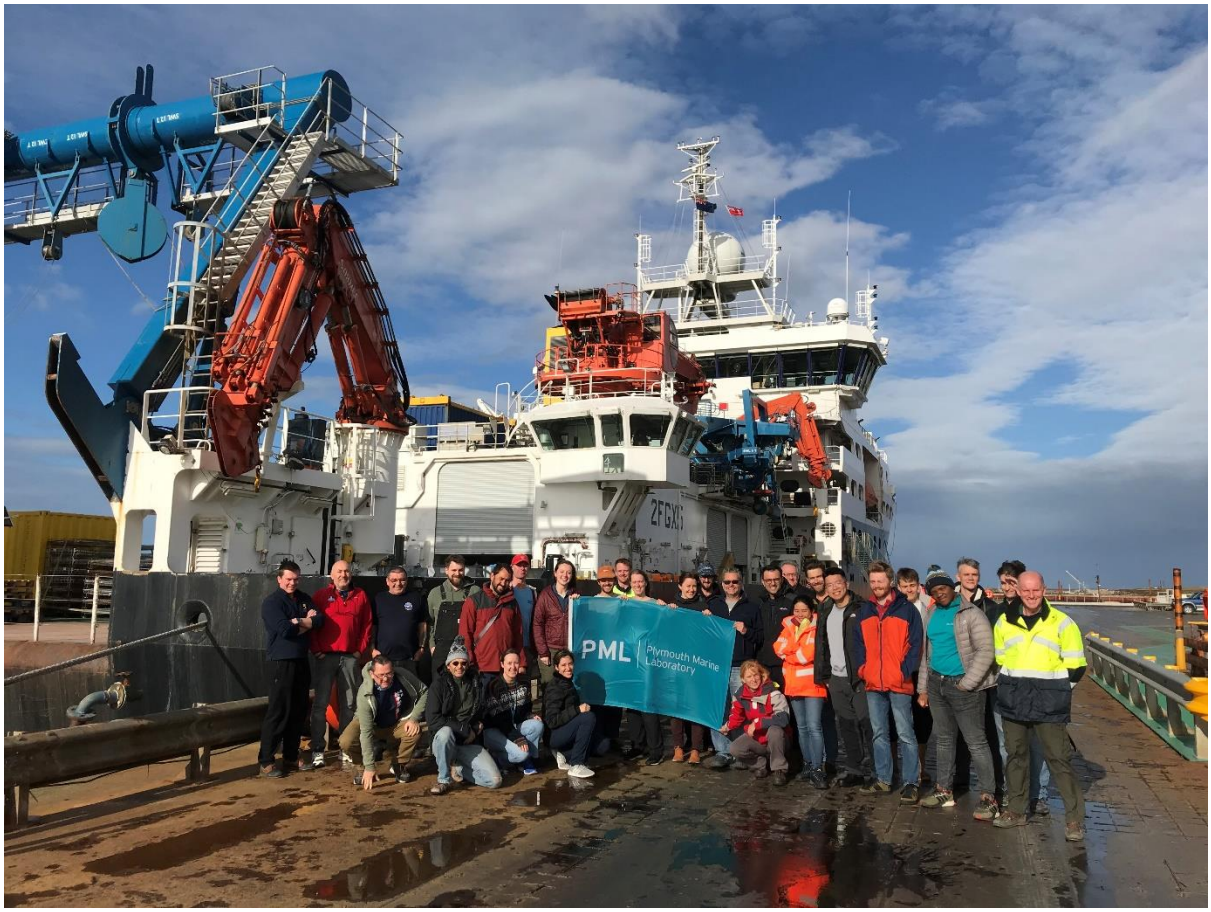
Cruise inventory - search results (bodc.ac.uk)

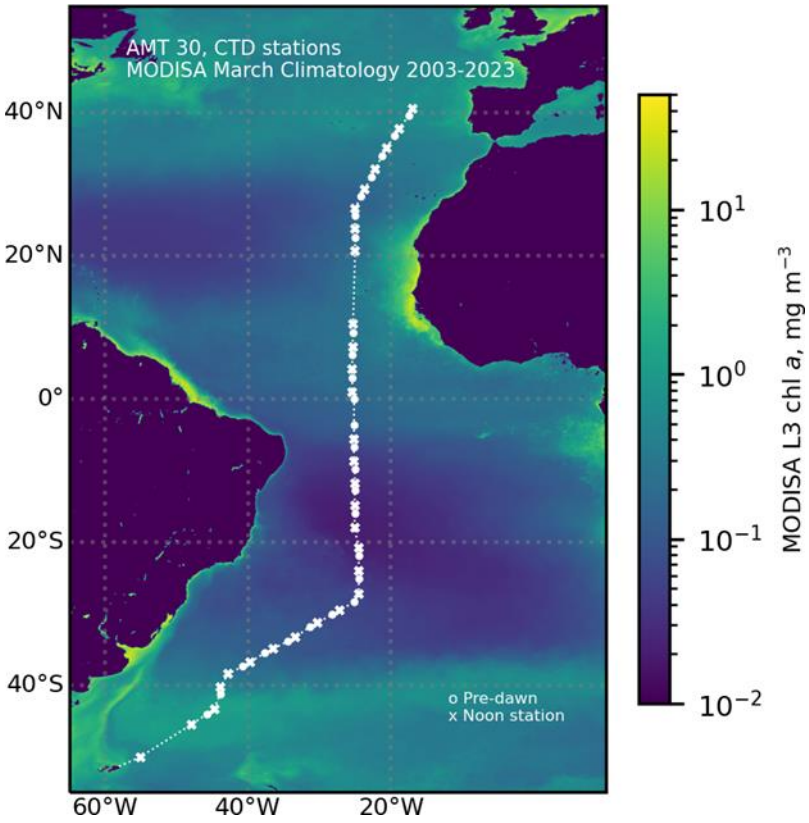
7. Changes to Organisational Structure and/or funding sources

8. Images / Figures

*****It is always good to have some recent photos / figures / infographics to create more exposure for the Regional Programmes, Working Groups, etc. These can range from those suitable for a very scientific audience, to those that would engage the general public. IMBeR would use these, on the website (e.g. http://www.imber.info/ and http://www.imber.info/en/news), in tweets (@imber_ipo), in presentations, etc. In addition, Future Earth (one of our sponsors) regularly asks us to provide high quality images for their glossy reports. These can highlight the activities of IMBeR and their other Global Research Projects (see pdfs of past Future Earth reports here https://futureearth.org/publications/annual-reports/)*

*So, please provide any images that you might think are useful. These can be pasted in this document or emailed as an attachment to imber@ecnu.edu.cn.*****





9. Anything not covered above

AMT website - [The Atlantic Meridional Transect (amt-uk.org)]

10. How to improve this form

Please give suggestions on how to improve this form and make it better next time.

Make it smaller!

11. Appendices

Add appropriate meeting / workshop reports and include URLs (this helps to track where online content is missing)

Add text…