UNITED KINGDOM RESEARCH AND INNOVATION

Iceland

Science & Port Call

Application for Consent to conduct
Marine Scientific Research

Date: 18 November 2021

1. General Information

1.1 Cruise name and/or number: SME 18/941 SEACHANGE
DY150

1.2 Sponsoring Institution(s):	
Name:	European Research Council
Address:	
Name of Director:	

1.3 Principal Investigator in charge of the Project :	
Name:	James Scourse
Country:	UK
Affiliation:	University of Exeter
Address:	College of Life and Environmental Sciences, University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9EZ, UK.
Telephone:	07858 512645
Fax:	
Email:	j.scourse@exeter.ac.uk
Website (for CV and photo):	https://geography.exeter.ac.uk/staff/index.php?web_id=James_Scourse

1.4 Entity(ies)/Participant(s) from Coastal State involved in the planning of the project:	
Name:	Esther Ruth Gudmundsdottir
Affiliation:	University of Iceland
Address:	Faculty of Earth Sciences, Askja Room 233, Strulugata 7, 101 Reykjavik, Iceland
Telephone:	+354 525 4255
Fax:	
Email:	estherrg@hi.is
Website (for CV and photo):	https://uni.hi.is/estherrg/home/

2. Description of Project

2.1 Nature and objectives of the project:
A significant amount of research has been undertaken on marine historical ecology in which instrumental and historical archives are used to reconstruct, for instance, fishing intensity and the impacts of fishing on the marine ecosystem. However, these data only extend back exceptionally a few hundred years and, in the case of historical archives, they cannot reconstruct the preanthropogenic baseline since they are, by definition, related to anthropogenic activity. These studies document post-impact states and are therefore unable to contrast pre- with post-impact states. The need for longer-term, natural, archives has now been fulfilled through the demonstration that some hard-shelled marine organisms, notably bivalve molluscs, are exceptionally long-lived (including the longest-lived animal known to science, Arctica islandica) and contain annual growth increments akin to tree-rings. These growth structures can be cross-matched to generate annually-resolved archives of marine history potentially extending back thousands of years. Unlike sediment-based reconstructions of the marine environment, these sclerochronological archives contain no age-dependent error (meaning that increments dating to a specific year can be identified and analysed) and they are internally replicated since many individual shells are used to construct the chronologies. Theacquisition of growth increment series from these archives, and their contained geochemistry (stable oxygen and carbon isotopes) have been used to generate ultra-high-resolution records of marine climate, notably the first annually-resolved record of marine climate for the last millennium from the global ocean. SEACHANGE will exploit the

technical breakthrough represented by sclerochronological crossdating and apply novel techniques to generate biological/ecological histories of the ocean resolved to individual years. Such a prospect has not been possible until now. The advent of compound-specific carbon and nitrogen stable isotopic analysis from shell carbonate and shell-bound organic content respectively enables assessments of marine productivity and trophic structure. The recent demonstration that shell carbonate contains environmental DNA (eDNA) relating to the marine environment at the time of calcification unlocks the potential of shell increments to encode information on changes in biodiversity through time. The interpretation of these proxies can be calibrated via instrumental and historical ecological data using split calibration-verification statistics over the instrumental/historical time period (last few decades), and sclerochronological eDNA biodiversity assessments can be complemented and independently verified through sedimentary eDNA analyses and the analysis of the fossil content of sediment cores over the Holocene timescale. The co-generation of oxygen isotopic data – which provides information on changes in the physical environment (density, salinity, temperature) – will enable non-climatic anthropogenic forcings to be separated from anthropogenic biological impacts.The longevity and preservation of annually resolved shell material in many different marine settings (latitude/depth) provides the opportunity to investigate at annual resolution the impact of anthropogenic disturbance on marine ecosystems from the subpolar regions to the tropics. We will run ecosystem models to predict and simulate the impacts of biodiversity change and species loss on ecosystem functioning and compare model simulations with observations.

In the North Sea and on the north Icelandic shelf, we have the following objectives:

1. To evaluate change in marine biodiversity/ecosystem functioning across the transition to agriculture by examining shell middens and marine sediment sequences from Denmark, and sclerochronological series from the Fladen Ground

2. To evaluate changes in marine biodiversity/ecosystem functioning across (a) the medieval intensification of marine resource exploitation and terrestrial land-use around AD 1000, and (b) the industrial transition at ~ AD 1800, by examining middens in Orkney, sclerochronological series from the Fladen Ground, marine sediment cores from the Fladen Ground and Skagerrak, and marine historical ecological records for the North Sea.

3. Objective: to evaluate changes in marine biodiversity/ecosystem functioning around north and east Iceland resulting from the first settlement of Iceland in AD 874, the intensification in fisheries after the thirteenth century, and then the advent of industrial scale fishing over the last 100 years.

2.2 If designated as part of a larger scale project, then provide the name of the project and the Organisation responsible for coordinating the project:

European Research Council (ERC) Synergy Project SEACHANGE (ERC856488). Corresponding Principal Investigator: James Scourse (University of Exeter)

2.3 Relevant previous or future research projects:

March 2006: £248,744 from the EU (UWB component of 39 partner EU Framework 6 Integrated Project, SUSTDEV-2004-3.1.4.1, 017008-2) for 'European climate of the last millennium' to work on an *Arctica* sclerochronology for the last 1000 years from the North Icelandic shelf (with C.A. Richardson, SOS UWB). *Bjarni Saemundsson* BO5 research cruise north Icelandic Shelf (Scourse Co-I).

July 2010: £338,678 from NERC for 'Ultra-high-resolution proxy record of Last Millennium North Atlantic temperature anomalies' (NE/H023356/1 with C.A. Richardson, SOS BU and I.R. Hall, Cardiff).

August 2012: £182,495 from NERC for 'BRITICE-CHRONO: Constraining rates and styles of marine-influenced ice sheet decay' (NE/J007579/1, led by C. Clark, Sheffield). *James Cook* research cruise western British Isles JC106 (2014; Scourse Co-I)

August 2013: £2,692,540 from EU Framework 7 for Marie Curie Initial Training Network (FP7-PEOPLE-2013-ITN 604802) (£579,375 to Bangor University): 'Annually-resolved archives of marine climate change – development of molluscan sclerochronology for marine environmental monitoring and climatology' (Scourse PI, with partners in Germany, Croatia, Norway, Aberdeen, France and The Netherlands). *Prince Madog* research cruise to Hebrides (2014: Scourse Chief Scientist)

July 2015: £53,193 from NERC for 'Climate of the LAst Millennium (CLAM): An integrated data-model approach to reconstruct and interpret annual variability in North Atlantic Circulation' (NE/N002733/1 with I.R. Hall, D. Reynolds, Cardiff, and P. Halloran, Exeter).

October 2016: £354,396 from NERC for 'Impacts of deglaciation on marine benthic ecosystems in Antarctica' (NE/P003087/1 with S. Jenkins, C.A. Richardson, and M. Meredith, D. Barnes, BAS and A.J. Brante, Universidad Católica de la Santísima, Concepción, Chile). *James Clark Ross* cruises Antarctic Peninsula 17001, 18003, 19002 (2017-2020; Scourse PSO 19002).

March 2017: £56,700 from the Icelandic Research Council for 'Long-term otolith and bivalve growth chronologies in relation to cod stock dynamics and climate in the NE Atlantic' (with P.G. Butler; PI Steve Campana, University of Iceland).

2.4 Previous publications relating to the project:

AUSTIN, W.E.N. & **SCOURSE, J.D.** 1997. Evolution of seasonal stratification in the Celtic Sea during the Holocene. *Journal of the Geological Society* **154**, 249-256.

SCOURSE, J.D., AUSTIN, W.E.N., LONG, B.T., ASSINDER, D.J. & HUWS, D. 2002. Holocene evolution of seasonal stratification in the Celtic Sea: refined age model, mixing depths and foraminiferal stratigraphy. *Marine Geology* **191**, 119-145.

MARRET, F. & **SCOURSE, J.D.** 2002. Control of modern dinoflagellate cyst distribution in the Irish and Celtic seas by seasonal stratification dynamics. *Marine Micropalaeontology* **47**, 101-116.

SCOTT, G.A., **SCOURSE, J.D.** & AUSTIN, W.E.N. 2003. The distribution of benthic foraminifera in the Celtic Sea: the significance of seasonal stratification. *Journal of Foraminiferal Research* **33,** 32-61.

MARRET, F., EIRÍKSSON, J., KNUDSEN, K.L., TURON, J.-L. & **SCOURSE, J.D.** 2004. Distribution of dinoflagellate cyst assemblages in surface sediments from the northern and western shelf of Iceland. *Review of Palaeobotany and Palynology* **128**, 35-53.

MARRET, F., **SCOURSE, J.D.** & AUSTIN, W.E.N. 2004. Holocene shelf sea seasonal stratification dynamics: a dinoflagellate cyst record from the Celtic Sea. *The Holocene* **14**, 689-696.

SCOURSE, J.D., KENNEDY, H., SCOTT, G.A. & AUSTIN, W.E.N. 2004. Stable isotopic analyses of modern benthic foraminifera from seasonally stratified shelf seas; disequilibria and the "seasonal effect". *The Holocene* **14**, 758-769.

AUSTIN, W.E.N., CAGE, A.G. & **SCOURSE, J.D.** 2006. Mid-latitude shelf seas: A NW European perspective on the seasonal dynamics of temperature, salinity and oxygen isotopes. *The Holocene* **16**, 936-947.

SCOURSE, J.D., RICHARDSON, C.A., FORSYTHE, G., HARRIS, I., HEINEMEIER, J., FRASER, N., BRIFFA, K. & JONES, P. 2006. First cross-matched floating chronology from the marine fossil record: data from growth lines of the long-lived bivalve mollusc *Arctica islandica*. *The Holocene* **16**, 967-974.

WANAMAKER, A.D.Jr, HEINEMEIER, J., **SCOURSE, J.D.**, RICHARDSON, C.A., BUTLER, P.G. & EIRÍKSSON, J. 2008. Very long-lived molluscs confirm 17th century AD tephra-based radiocarbon reservoir ages for north Icelandic shelf waters. *Radiocarbon* **50**, 399-412.

BUTLER, P.G., **SCOURSE, J.D.**, RICHARDSON, C.A., WANAMAKER, A.D., BRYANT, C.L. & BENNELL, J.D. 2009. Continuous radiocarbon marine reservoir calibration and the Suess effect in the Irish Sea: results from the first multi-centennial shell-based marine master chronology. *Earth and Planetary Science Letters* **279**, 230-241. doi:10.1016/j.epsl.2008.12.043

BUTLER, P.G., RICHARDSON, C.A., **SCOURSE, J.D.**, WITBAARD, R., SCHÖNE, B.R., FRASER, N.M., WANAMAKER, A.D.,Jr., HARRIS, I. & ROBERTSON, I. 2009. Accurate increment identification and the spatial extent of the common signal in five *Arctica islandica* chronologies from the Fladen Ground, northern North Sea. *Paleoceanography* **24** PA2210, doi:10.1029/2008PA001715

BUTLER, P.G., RICHARDSON, C.A., **SCOURSE, J.D.**, WANAMAKER, A.D., SHAMMON, T.M. & BENNELL, J.D. 2010. Marine climate in the Irish Sea: analysis of a 489-year marine master chronology derived from growth increments in the shell of the clam *Arctica islandica*. *Quaternary Science Reviews*

29, 1614-1632. doi:10.1016/j.quascirev.2009.07.010.
BUTLER, P.G., WANAMAKER, A.D. Jr., **SCOURSE, J.D.**, RICHARDSON, C.A. & REYNOLDS, D.R. 2011. Long-term stability of $\delta^{13}C$ with respect to biological age in the aragonite shell of mature specimens of the bivalve mollusk *Arctica islandica*. *Palaeogeography, Palaeoclimatology, Palaeoecology* **302**, 21-30. doi:10.1016/j.palaeo.2010.03.038.
WANAMAKER, A.D. Jr,, BUTLER, P.G., **SCOURSE, J.D.**, HEINEMEIER, J., EIRÍKSSON, J., KNUDSEN, K.L. & RICHARDSON, C.A. 2012. Surface changes in the North Atlantic meridional overturning circulation during the last millennium. *Nature Communications* **3**:899 doi: 10.1038/ncomms1901.
SCOURSE, J.D., WANAMAKER, A.D. Jr., WEIDMAN, C., HEINEMEIER, J., REIMER, P.J., BUTLER, P.G. & RICHARDSON, C.A. 2012. The marine radiocarbon bomb-pulse across the temperate North Atlantic: a compilation of $\Delta^{14}C$ time histories from *Arctica islandica* growth increments. *Radiocarbon* **54**, 165-186.
BUTLER, P.G., WANAMAKER, A.D. Jr,, **SCOURSE, J.D.**, RICHARDSON, C.A. & REYNOLDS, D.J. 2013. Variability of marine climate on the North Icelandic shelf in a 1,357-year proxy archive based on growth increments in the bivalve *Arctica islandica* . *Palaeogeography, Palaeoclimatology, Palaeoecology* **373**, 141-151.
CUNNINGHAM, L.K., AUSTIN, W.E.N., KNUDSEN, K.L., EIRÍKSSON, J., **SCOURSE, J.D.**, WANAMAKER, A.D., Jr, BUTLER, P., CAGE, A., RICHTER, T., HUSUM, K., HALD, M., ANDERSSON, C., ZORITA, E., LINDERHOLM, H., GUNNARSON, B.E., SICRE, M.A., SEJRUP, H.P., JIANG, H. & WILSON, R.J.S. 2013. Reconstructions of surface ocean conditions from the North East Atlantic and Nordic Seas during the last millennium. *The Holocene*. **23**, 921-935.
REYNOLDS, D.J., BUTLER, P.G., WILLIAMS, S.M., **SCOURSE, J.D.**, RICHARDSON, C.A., WANAMAKER, A.D. Jr., AUSTIN, W.E.N., CAGE, A. & SAYER, M. 2013. A multiproxy reconstruction of Hebridean (NW Scotland) spring sea surface temperatures between AD 1805 and 2010. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **386**, 275-285.
REYNOLDS, D.J., **SCOURSE, J.D.**, HALL, I.R., NEDERBRAGT, A., WANAMAKER, A.D., HALLORAN, P., BUTLER, P.G., RICHARDSON, C.A., HEINEMEIER, J., EIRÍKSSON, J. & KNUDSEN, K.L. 2016. Annually-resolved North Atlantic marine climate over the Last Millennium. *Nature Communications.* doi: 10.1038/ncomms13502
ROMÁN-GONZÁLEZ, A., **SCOURSE, J.D.**, RICHARDSON, C.A., PECK, L.S., BENTLEY, M.J. & BUTLER, P.G. 2016. A scleroclimatological proxy for Antarctic coastal waters based on the marine bivalve *Yoldia eightsi* (Jay, 1839) from South Orkney Islands. *The Holocene* 27, 271-281. doi: 10.1177/09596836616658525
REYNOLDS, D.J., RICHARDSON, C.A., **SCOURSE, J.D.**, BUTLER, P.G., HOLLYMAN, P., ROMÁN-GONZÁLEZ, A. & HALL, I.R. 2017. Reconstructing North Atlantic marine climate variability using an absolutely-dated sclerochronological network. *Palaeogeography, Palaeoclimatology, Palaeoecology* **465**, 333-346. doi: 10.1016/j.palaeo.2016.08.006
DER SARKISSIAN, C., PICHEREAU, V., DUPONT, C., ILSØE, P.C., PERRIGAULT, M., BUTLER, P.G., CHAUVAUD, L., EIRÍKSSON, J., **SCOURSE, J.D.**, PAILLARD, C. & ORLANDO, L. 2017. Ancient DNA analysis identifies mollusc shells as new metagenomics archives of the past. *Molecular Ecology Resources* 2017, 1-19. doi: 10.1111/1755-0998.12679
REYNOLDS, D.J., HALL, I.R., SLATER, S., **SCOURSE, J.D.,** HALLORAN, P. & SAYER, M.D.J. 2017. Reconstructing past seasonal to multi-centennial scale variability in the NE Atlantic Ocean using the long-lived marine bivalve mollusc *Glycymeris glycymeris*. *Paleoceanography*. doi/10.1002/2017PA003154
REYNOLDS, D.J., HALL, I.R., **SCOURSE, J.D.**, RICHARDSON, C.A., WANAMAKER, A.D. & BUTLER, P.G. 2017. Biological and climate controls on North Atlantic marine carbon dynamics over the last millennium: insights from an absolutely-dated shell based record from the North Icelandic Shelf. *Global Biogeochemical Cycles* doi.org/10.1002/2017GB005708
EIRÍKSSON, J., **SCOURSE, J.D.**, BUTLER, P.G., REYNOLDS, D.J. & SÍMONARSON, L.A. 2017. Langlífar kúskeljar, skeljatímatal og ástand sjávar við Norðurland í þúsund ár. *Náttúrufræðingurinn* **87**, 95–108.
REYNOLDS, D.J., HALL, I.R., SLATER, S., METTE, M., WANAMAKER, A.D., **SCOURSE, J.D.**, GARRY, F & HALLORAN, P. 2018. Isolating and reconstructing key components of North Atlantic Ocean variability from a sclerochronological spatial network. *Paleoceanography and Paleoclimatology* **33**, 1086-1098. https://doi.org/10.1029/2018PA003366
BLACK, B.A., ANDERSSON, C., BUTLER, P.G., CARROLL, M.L., DeLONG, K.L., REYNOLDS, D.J., SCHÖNE, B.R., **SCOURSE, J.D.**, VAN DER SLEEN, P., WANAMAKER, A.D. & WITBAARD, R. 2019. The revolution of crossdating in marine paleoecology and paleoclimatology. *Biology Letters* **15**: 20180665. http://dx.doi.org/10.1098/rsbl.2018.0665
ESTRELLA-MARTÍNEZ, J., SCHÖNE, B.R., THURSTAN, R.H., CAPUZZO, E., **SCOURSE, J.D.** & BUTLER, P.G. 2019. Reconstruction of Atlantic herring (*Clupea harengus*) recruitment in the North Sea for the past 455 years based on the $\delta^{13}C$ from annual shell increments of the ocean quahog (*Arctica islandica). Fish and Fisheries* **20**, 537-551. doi:10.1111/faf.12362

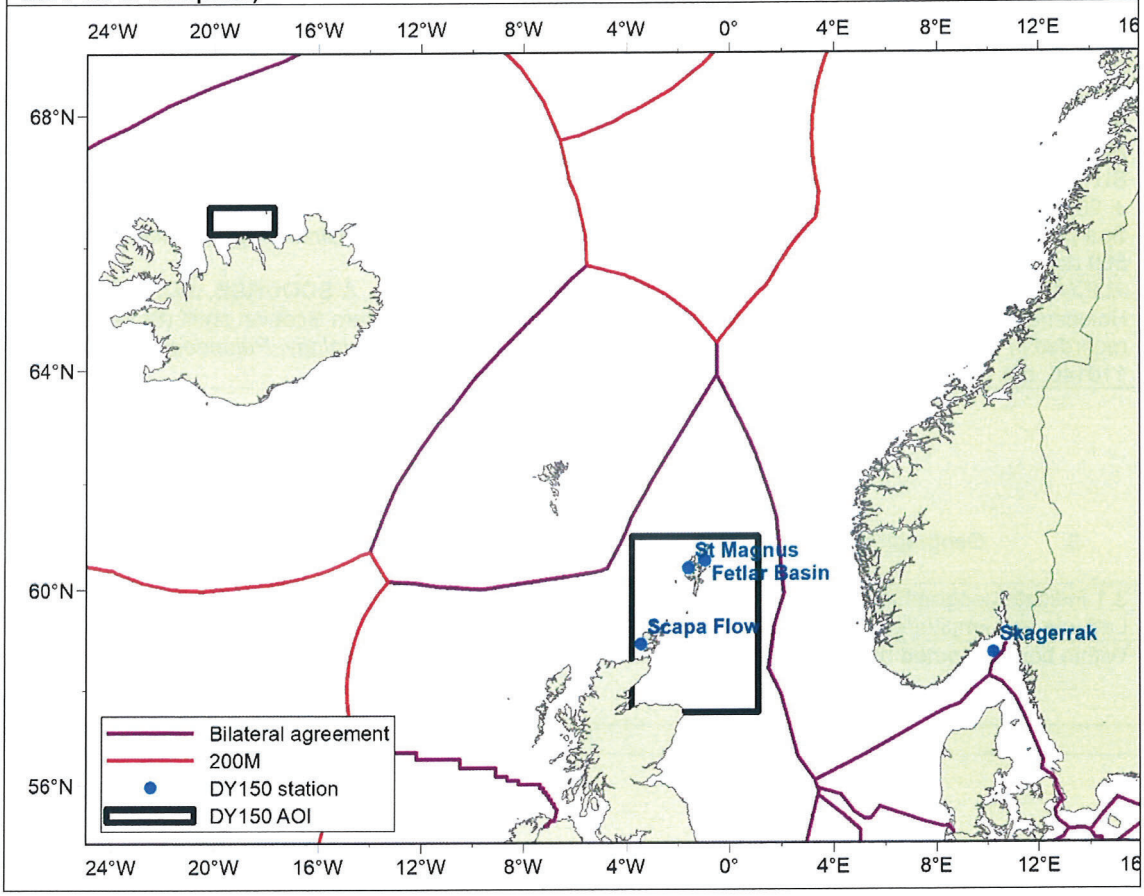
ESTRELLA-MARTÍNEZ, J., ASCOUGH, P., SCHÖNE, B.R., **SCOURSE, J.D.**, & BUTLER, P.G. 2019. 8.2 ka event North Sea hydrography determined by bivalve shell stable isotope geochemistry. *Scientific Reports* **9**:6753. doi.org/10.1038/s41598-019-43219-1
HALLORAN, P., HALL, I.R., MENARY, M., REYNOLDS, D.J., **SCOURSE, J.D.**, SCREEN, J., BOZZO, A., DUNSTONE, N., PHIPPS, S., SCHURER, A.P., SUEYOSHI, T. & ZHOU, T. 2020. Natural drivers of multidecadal Arctic sea-ice variability over the last millennium. *Scientific Reports* 10:688. doi.org/10.1038/s41598-020-57472-2
BARNES, D.K.A., SANDS, C.J., COOK, A., HOWARD, F., ROMÁN-GONZÁLEZ, A., MUÑOZ RAMIREZ, C., RETALLICK, K., **SCOURSE, J.D.**, VAN LANDEGHEM, K.K.J. & ZWERSCHKE, N. 2020. Blue carbon gains from glacial retreat along Antarctic fjords: what should we expect? *Global Change Biology* **26**, 2750–2755 https://doi.org/10.1111/gcb.15055 [5
BUTLER, P.G., FRASER, N.M., **SCOURSE, J.D.**, RICHARDSON, C.A., BRYANT, C. & HEINEMEIER, J. 2020. Is there a reliable taphonomic clock in the temperate North Atlantic? An example from a North Sea population of the mollusc *Arctica islandica*. *Palaeogeography, Palaeoclimatology, Palaeoecology* **560** doi.org/10.1016/j.palaeo.2020.109975
ALEXANDROFF, S.J., BUTLER, P.G., HOLLYMAN, P., SCHÖNE, B.R., & **SCOURSE, J.D.** 2021. Late Holocene annually resolved seasonal temperature variability of the western Scottish shelf (St Kilda) recorded in *Glycymeris glycymeris* shells. *Palaeogeography, Palaeoclimatology, Palaeoecology* **562**, 110146. doi: https://doi.org/10.1016/j.palaeo.2020.110146

3. Geographical Areas

3.1 Indicate geographical areas in which the project is to be conducted (with reference in Latitude and longitude, including coordinates of cruise/track/way points)
Within box delineated by 66.624N -20.164W, 66.624N -17.67W, 66.211N -20.164W, 66.211N -17.67W

UNITED KINGDOM RESEARCH AND INNOVATION
Iceland
Science & Port Call

3.2 Attach chart(s) at an appropriate scale (1 page, high-resolution) showing the geographical Areas of the intended work and, as far as practicable, the location and depth of sampling Stations, the tracks of survey lines, and the locations of installations and equipment. **(NB: make Sure 3.1 is complete)**



4. Methods and means to be used

4.1 Particulars of vessel:	
Name:	RRS Discovery
Type/Class:	Lloyds Register Lloyd's +100A1 Oceanographic Research Vessel, IWS, Ice Class 1D +LMC, UMS, DP(AM), Green Passport, Shipwright (SERS)
Nationality (Flag State):	British
Identification Number (IMO/Lloyds No.):	9588029
Owner:	United Kingdom Research & Innovation
Operator:	National Marine Facilities
Overall length (meters):	99.70 Metres
Maximum draft:	6.60 Metres
Displacement/Gross Tonnage:	Net Tonnage: 1785 Gross Tonnage: 5952
Propulsion:	Diesel Electric
Cruising & maximum speed:	12 Knots & 15 Knots Max Speed
Call sign:	2FGX5
INMARSAT number and method and capability of communication (including emergency frequencies):	773238856 – Voice 783255483 – Fax 423593533 – Sat C
Name of Master:	TBA
Number of Crew:	24
Number of Scientists on board:	28

4.2 Particulars of Aircraft:	
Name:	N/A

UNITED KINGDOM RESEARCH AND INNOVATION
Iceland
Science & Port Call

Make/Model:	
Nationality (flag State):	
Website for diagram & Specifications:	
Owner:	
Operator:	
Overall Length (meters):	
Propulsion:	
Cruising & Maximum speed:	
Registration No.:	
Call Sign:	
Method and capability of communication (including emergency frequencies):	
Name of Pilot:	
Number of crew:	
Number of scientists on board:	
Details of sensor packages:	
Other relevant information:	

4.3 Particulars of Autonomous Underwater Vehicle (AUV):	
Name:	N/A
Manufacturer and make/model:	
Nationality (Flag State):	
Website for diagram & Specifications:	
Owner:	
Operator:	
Overall length (meters):	
Displacement/Gross tonnage:	
Cruising & Maximum speed:	
Range/Endurance:	
Method and capability of communication (including emergency frequencies):	
Details of sensor packages:	
Other relevant information:	

4.4 Particulars of Unmanned Surface Vehicles (USV):	
Name:	N/A
Manufacturer and make/model:	
Nationality (Flag State):	
Website for diagram & Specifications:	
Owner:	
Operator:	
Overall length (meters):	
Displacement/Gross tonnage:	
Cruising & Maximum speed:	
Range/Endurance:	
Method and capability of communication (including emergency frequencies):	
Details of sensor packages:	
Other relevant information:	

4.5 Particulars of Unmanned Air Vehicles (UAV) :	
Name:	N/A
Make/Model:	
Nationality (flag State):	
Website for diagram & Specifications:	

UNITED KINGDOM RESEARCH AND INNOVATION
Iceland
Science & Port Call

Owner:	
Operator:	
Overall Length (meters):	
Propulsion:	
Cruising & Maximum speed:	
Registration No.:	
Call Sign:	
Method and capability of communication (including emergency frequencies):	
Name of Pilot:	
Number of crew:	
Number of scientists on board:	
Details of sensor packages:	
Other relevant information:	

4.6 other craft in the project, including its use:
N/A

4.7 Particulars of methods and scientific instruments:		
Types of samples and Measurements:	Methods to be used:	Instruments to be used:
Geophysics	Multibeam swath bathymetry	EM710
Seabed sediment sampling	Piston coring Multicoring	Standard piston corer Megacorer
Water properties and water sampling	CTD	NMF 24-way CTD frame; Seabird 911 CTD; altimeter.
Benthic biological sampling	Trawling Arctica dredge	Agassiz trawl Bespoke Arctica dredge

4.8 Indicate nature and quantity of substances to be released into the marine environment:
Nil

4.9 Indicate whether drilling will be carried out. If yes, please specify:
Coring, not drilling (both piston and multicoring)

4.9.1 Indicate whether explosives will be used. If yes, please specify type and trade name, Chemical content, depth of trade class and stowage, size, depth of detonation, frequency of Detonation, and position in latitude and longitude:
No

5. Installations and Equipment

Details of installations and equipment (including dates of laying, servicing, method and Anticipated timeframe for recover, as far as possible exact locations and depth, and Measurements):
None

6. Dates

6.1 Expected dates of first entry into and final departure from the research area by the research vessel and/or other platforms:
First entry: 5 May 2022, Final departure: 12 May 2022
6.2 Indicate if multiple entries are expected:
No

UNITED KINGDOM RESEARCH AND INNOVATION
Iceland
Science & Port Call

7. Port Calls

7.1 Dates and Names of intended ports of call:
Reykjavik, Iceland 14-19 May 2022 (end of cruise)

7.2 Any special logistical requirements at ports of call:
NO

7.3 Name/Address/Telephone of shipping agent (if available):
Nesskip H.F Nesskip House Austurstrond 1 172 Selt Jarnarnes, Reykjavik PC101 Tel: 00 354 5639900 Email: operations@nesskip.is

8. Participation of the representative of the Coastal State

8.1 Modalities of the participation of the representative of the Coastal State in the research Project:
N/A

8.2 Proposed dates and ports for embarkation/disembarkation:
Southampton, UK: 16th April 2022 (start of cruise) Reykjavik, Iceland: 14th May 2022 (end of cruise)

9. Access to Data, Samples and Research Results

9.1 Expected dates of submission to Coastal State of preliminary report, which should include The expected dates of submission of the data and research results:
TBC

9.2 Anticipated dates of submission to the Coastal State of the final report **(This must be within 1 year of completion of the cruise)**
TBC

9.3 Proposed means for access by Coastal State to data (including formal) and samples as per BODC Weblink: **https://www.bodc.ac.uk/resources/inventories/cruiseinventory/search/**
TBC

9.4 Proposed means to provide Coastal State with assessment of data, samples and Research results:
TBC

9.5 Proposed means to provide assistance in assessment or interpretation of data, samples And research results:
TBC

9.6 Proposed means of making results internationally available (to obtain cruise reports these Can be obtained via the BODC weblink see below:
TBC

10. Other permits Submitted

UNITED KINGDOM RESEARCH AND INNOVATION

Iceland

Science & Port Call

10.1 Indicate other types of Coastal State permits anticipated for this research (received or Pending):
N/A

11. List of Supporting Documentation

11.1 List of attachments, such as additional forms required by the Coastal State, etc.:
N/A

Signature:

Contact information of the focal point:
Name:
Country:
Affiliation:
Address:
Telephone:
Email:

UPLOAD YOUR FINAL CRUISE REPORT: https://www.bodc.ac.uk/resources/inventories/cruise_inventory/search/

SEND YOUR FINAL CRUISE REPORT: msrapplications@fco.gov.uk

UNITED KINGDOM RESEARCH AND INNOVATION

Iceland

Science & Port Call

Application for Consent to conduct
Marine Scientific Research

Date: 18 November 2021

1. General Information

1.1 Cruise name and/or number:
DY151

1.2 Sponsoring Institution(s):	
Name:	University of Birmingham
Address:	School of Geography Earth and Environmental Sciences Edgbaston Birmingham B15 2TT
Name of Director:	Jon Oldfield (Head of School)

1.3 Principal Investigator in charge of the Project :	
Name:	Zongbo Shi
Country:	UK
Affiliation:	The University of Birmingham
Address:	School of Geography Earth and Environmental Sciences Edgbaston Birmingham B15 2TT
Telephone:	00447548132896
Fax:	
Email:	z.shi@bham.ac.uk
Website (for CV and photo):	https://www.birmingham.ac.uk/staff/profiles/gees/shi-zongbo.aspx

1.4 Entity(ies)/Participant(s) from Coastal State involved in the planning of the project:	
Name:	N/A
Affiliation:	
Address:	
Telephone:	
Fax:	
Email:	
Website (for CV and photo):	

2. Description of Project

2.1 Nature and objectives of the project:
The overall aim is to reduce the uncertainties in modelling the response of aerosol, cloud condensation nuclei (CCN), and ice nuclei (IN) to changes in anthropogenic emissions and natural environments, so that we can better predict future climate in the Arctic. The cruise is atmospheric focused. The main objectives include: - To understand the sources and processes of aerosol particles, cloud condensation nuclei and ice nuclei (coarse particles are key) - To elucidate the formation and growth mechanism of new particles - To update a global aerosol model based on mechanistic understanding on particle source and processes from the observations. - To evaluate the new model against pan-Arctic observations - To predict the potential impact of future shipping emissions along the Northwest Passage (likely to be completely open in the summer by 2050) and changing climate on aerosol, CCN, IN and clouds

2.2 If designated as part of a larger scale project, then provide the name of the project and the Organisation responsible for coordinating the project:
N/A

2.3 Relevant previous or future research projects:
N/A
2.4 Previous publications relating to the project:

Arnold S, Law K, Brock C, Thomas J, Starkweather S, von Salzen K, Stohl A, Sharma S, Lund M, Flanner M, Petaja T, Tanimoto H, Gamble J, Dibb JE, Melamed M, Johnson N, Fidel M, Tynkkynen VP, Baklanvo A, Eckhardt S, Monks SA, Browse J, Bozem H (2016). Arctic air pollution: Challenges and opportunities for the next decade. *Elementa: Science of the Anthropocene*, *4*, 000104-000104.

Baldo, C., Formenti, P., Nowak, S., Chevaillier, S., Cazaunau, M., Pangui, E., Di Biagio, C., Doussin, J.-F., Ignatyev, K., Dagsson-Waldhauserova, P., Arnalds, O., MacKenzie, A. R., and Shi, Z., 2020. Distinct chemical and mineralogical composition of Icelandic dust compared to northern African and Asian dust, Atmospheric Chemistry and Physics, 20, 13521–13539

Browse J, Carslaw KS, Mann GW, Birch CE, Arnold SR, Leck C (2014). The complex response of Arctic aerosol to sea-ice retreat. *Atmospheric Chemistry and Physics*, *14*(14), 7543-7557.

Browse J, Carslaw KS, Schmidt A, Corbett JJ (2013). Impact of future Arctic shipping on high latitude black carbon deposition. *Geophysical Research Letters*, *40*(16), 4459-4463.

Dall´Osto et al., 2017. Arctic sea ice melt leads to atmospheric new particle formation. Scientific Reports 7, Article number: 3318, doi:10.1038/s41598-017-03328-1

Reddington CL, Carslaw KS, Stier P, Schutgens N, Coe H, Liu D, Allan J, Browse J, Pringle KJ, Lee LA, et al (2017). The global aerosol synthesis and science project (GASSP): Measurements and modeling to reduce uncertainty. *Bulletin of the American Meteorological Society*, *98*(9), 1857-1877.

Song, C., Dall'Osto, M., Lupi, A., Mazzola, M., Traversi, R., Becagli, S., Gilardoni, S., Vratolis, S., Yttri, K. E., Beddows, D. C. S., Schmale, J., Brean, J., Kramawijaya, A. G., Harrison, R. M., and Shi, Z., 2021. Differentiation of coarse-mode anthropogenic, marine and dust particles in the High Arctic islands of Svalbard. *Atmospheric Chemistry and Physics*, 21, 11317–11335.

Wilson TW, Ladino LA, Alpert PA, Breckels MN, Brooks IM, Browse J, Burrows SM, Carslaw KS, Huffman JA, Judd C, et al (2015). A marine biogenic source of atmospheric ice-nucleating particles. *Nature*, *525*(7568), 234-238.

Yu, H., Li, W., Zhang, Y., Tunved, P., Dall'Osto, M., Shen, X., Sun, J., Zhang, X., Shi, Z., 2019. Organic coating on sulfate and soot particles in summer Arctic atmosphere. *Atmospheric Chemistry and Physics,* 19, 10433–10446, https://doi.org/10.5194/acp-19-10433-2019.

Zhang, C., Shi, Z., Zhao, J., Zhang, Y., Yu, Y., Mu, Y., Yao, X., Feng, L., Zhang, F., Chen, Y., Liu, X., Shi, J., Gao, H., 2021. Impact of air emissions from shipping on marine phytoplankton growth. *Science of the Total Environment*, 769, 145488.

3. Geographical Areas

3.1 Indicate geographical areas in which the project is to be conducted (with reference in Latitude and longitude, including coordinates of cruise/track/way points)
Area 1: ocean area (note excluding land) with the following coordinates 67.00000, - 73.0000; 67.00000, -22.0000 50.00000, - 73.0000; 50.00000, -22.0000 Area 2: ocean area (note excluding land) with the following coordinates 75.00000, -85.00000; 75.00000, -50.00000; 67.00000, - 64.0000; 67.00000, -50.00000

3.2 Attach chart(s) at an appropriate scale (1 page, high-resolution) showing the geographical Areas of the intended work and, as far as practicable, the location and depth of sampling Stations, the tracks of survey lines, and the locations of installations and equipment. **(NB: make**

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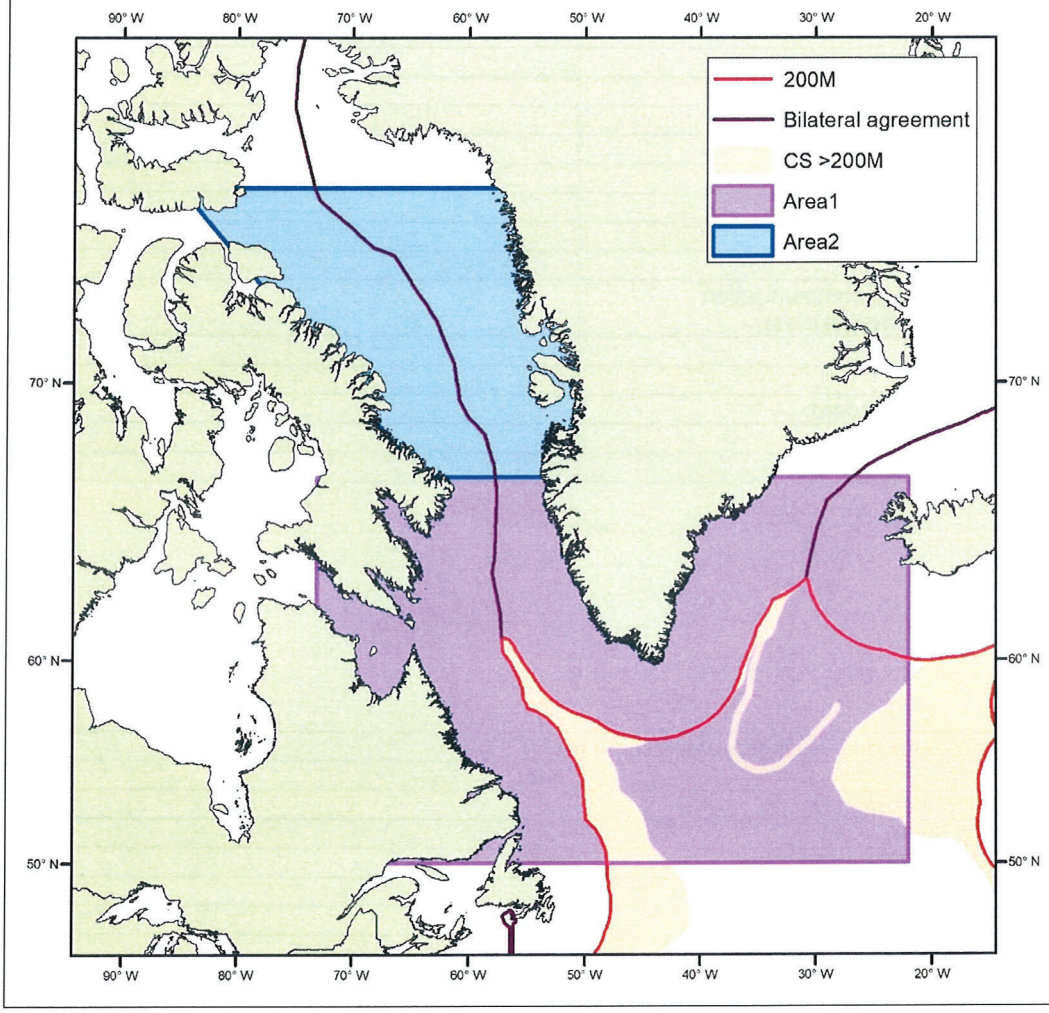
Sure 3.1 is complete)



4. Methods and means to be used

4.1 Particulars of vessel:	
Name:	RRS Discovery
Type/Class:	Lloyds Register Lloyd's +100A1 Oceanographic Research Vessel, IWS, Ice Class 1D +LMC, UMS, DP(AM), Green Passport, Shipwright (SERS)
Nationality (Flag State):	British
Identification Number (IMO/Lloyds No.):	9588029
Owner:	United Kingdom Research & Innovation
Operator:	National Marine Facilities
Overall length (meters):	99.70 Metres
Maximum draft:	6.60 Metres
Displacement/Gross Tonnage:	Net Tonnage: 1785 Gross Tonnage: 5952
Propulsion:	Diesel Electric
Cruising & maximum speed:	12 Knots & 15 Knots Max Speed
Call sign:	2FGX5
INMARSAT number and method and capability of communication (including emergency frequencies):	773238856 – Voice 783255483 – Fax 423593533 – Sat C
Name of Master:	TBA
Number of Crew:	24
Number of Scientists on board:	28

4.2 Particulars of Aircraft:

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Name:	N/A
Make/Model:	
Nationality (flag State):	
Website for diagram & Specifications:	
Owner:	
Operator:	
Overall Length (meters):	
Propulsion:	
Cruising & Maximum speed:	
Registration No.:	
Call Sign:	
Method and capability of communication (including emergency frequencies):	
Name of Pilot:	
Number of crew:	
Number of scientists on board:	
Details of sensor packages:	
Other relevant information:	

4.3 Particulars of Autonomous Underwater Vehicle (AUV):	
Name:	N/A
Manufacturer and make/model:	
Nationality (Flag State):	
Website for diagram & Specifications:	
Owner:	
Operator:	
Overall length (meters):	
Displacement/Gross tonnage:	
Cruising & Maximum speed:	
Range/Endurance:	
Method and capability of communication (including emergency frequencies):	
Details of sensor packages:	
Other relevant information:	

4.4 Particulars of Unmanned Surface Vehicles (USV):	
Name:	Matrice 300 RTK
Manufacturer and make/model:	DJJ
Nationality (Flag State):	UK
Website for diagram & Specifications:	https://store.dji.com/uk/product/matrice-300-rtk-and-dji-care?vid=103131
Owner:	University of Birmingham
Operator:	To be confirmed (a postdoc to be recruited)
Overall length (meters):	0.9 m
Displacement/Gross tonnage:	9 kg
Cruising & Maximum speed:	23 m/s
Range/Endurance:	
Method and capability of communication (including emergency frequencies):	
Details of sensor packages:	
Other relevant information:	

4.5 Particulars of Unmanned Air Vehicles (UAV) :	
Name:	Matrice 300 RTK
Make/Model:	DJJ

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Nationality (flag State):	UK
Website for diagram & Specifications:	https://store.dji.com/uk/product/matrice-300-rtk-and-dji-care?vid=103131
Owner:	University of Birmingham
Operator:	To be confirmed (a postdoc to be recruited)
Overall Length (meters):	0.9 m
Propulsion:	9 kg
Cruising & Maximum speed:	23 m/s
Registration No.:	Not yet purchased
Call Sign:	
Method and capability of communication (including emergency frequencies):	Operating Frequency 2.4000-2.4835 GHz 5.725-5.850 GHz EIRP 2.4000-2.4835 GHz: 29.5 dBm (FCC) 18.5dBm (CE) 18.5 dBm (SRRC); 18.5dBm (MIC) 5.725-5.850 GHz: 28.5 dBm (FCC); 12.5dBm (CE) 20.5 dBm (SRRC)
Name of Pilot:	To be confirmed
Number of crew:	To be confirmed
Number of scientists on board:	21 on the ship
Details of sensor packages:	Vision System Obstacle Sensing Range Forward/Backward/Left/Right: 0.7-40m Upward/Downward: 0.6-30m FOV Forward/Backward/Downward: 65° (H), 50° (V) Left/Right/Upward: 75°(H), 60°(V) Operating Environment Surfaces with clear patterns and adequate lighting (> 15 lux) FPV Camera Resolution 960p FOV 145° Frame rate 30 fps Infrared ToF Sensing System Obstacle Sensing Range 0.1-8m FOV 30° (±15°) Operating Environment Large, diffuse and reflective obstacles (reflectivity >10%)
Other relevant information:	

4.6 other craft in the project, including its use:
N/A

4.7 Particulars of methods and scientific instruments:		
Types of samples and Measurements:	Methods to be used:	Instruments to be used:
Particle size distribution 6-	Online observation	Scanning Mobility Particle Sizer

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500nm		
Total particle number conc. >2.5 nm	Online observation	Condensation Nuclei Counter
Particle size distribution 1 -5 nm	Online observation	Particle Size Magnifier
Number concentration of cloud condensation nuclei	Online observation	cloud condenation nuclei counter
Concentration of ions / clusters / Highly oxidised organic matter	Online observation	Api-ToF mass spectrometer
Particulate matter mass / Size distribution	Online observation	FIDAS
NH_3 concentration	Online observation	NH_3 analyser
Atmospheric NOx/CO/O_3 concentration	Online observation	Gas analysers
Black carbon concentration	Online observation	Aethalometer
Quartz filter 24-hr $PM_{2.5}$: primary and secondary organic tracer	Sample for offline observation	Digitel PM sampler
PTFE filer 24-hr $PM_{2.5}$ for offline analysis (weight + crustal elements)	Sample for offline observation	Partisol PM sampler
PTFE filter - particle mas size distribution: composition	Sample for offline observation	TSI Med vol impactor PM sampler
Whatman: Nutrients - Fe /P	Sample for offline observation	UEA high vol PM sampler (TBC)
Quartz: C isotope	Sample for offline observation	MSV high vol PM sampler
Quartz: S / N isotope	Sample for offline observation	MSV high vol PM sampler
Polycarbonate: SEM individual particle	Sample for offline observation	MiniVol Low Vol
Non-refractory aerosol composition	Online observation	Aerosol Chemical Speciation Monitor
VOC concentration / flux	Online observation	PTR-Qi-ToF mass spectrometer
VOC concentration in sea water	Online observation	PTR-ToF mass spectrometer
N2O and CH4 concentration	Online observation	Picarro G2508
Metal concentration in PM2.5	Online observation	Xact - X-ray online aerosol monitor
Metal concentration in PM10	Online observation	Xact - X-ray online aerosol monitor
Coarse particle Size distribution / sources	Online observation	Aerodynamic Particle Sizer
Single particle composition	Online observation	Single Particle Aerosol mass spectrometer
Size resolved non refractory - PM1	Online observation	HR-ToF-Aerosol mass spectrometer
Ice nuclei concentration	Online observation	Ice nuclei counter - SPIN
Total particle number conc. >2.5 nm	Online observation	Condensation Nuclei Counter
Size distribution 6-500nm	Online observation	Scanning Mobility Particle Sizer
Trace metals	Sample for offline observation	High Vol PM sampler
Isoprene and DMS concentration	Online observation	iDirac
Single particle composition	Sample for offline observation	Impactor PM sampler
Light scattering	Online observation	nephelometer
SO2 concentration	Online observation	SO2 analyser
Wind observation	Online observation	Anemometers
Ice nuclei numbers	Online observation	PINE chamber

Ice nuclei numbers	Sample for offline observation	Digitel low vol PM sampler
Particle size distribution 10-560 nm	Online observation	Scanning Mobility Particle Sizer
Particle size distribution >300 nm	Online observation	Aerodynamic Particle Sizer
Ice nuclei numbers	Sample for offline observation	Mesalab low vol samplers
Ice nuclei numbers	Sample for offline observation	Cascade impactors: Moudi + SHARK
Vertical distribution of aerosol and clouds	Online observation	Aerosol lidar
Vertical distribution of ozone	Online observation	O_3 lidar
Bioaerosol number concentration	Online observation	Wideband Integrated Bioaerosol Sensor
Black carbon concentration and size	Online observation	Single particle soot photometer
Aerosol extinction	Online observation	CAPS spectroscopy
Acidic and alkaline gases, and aerosol ionic composition	Online observation	Online ion chromatography
Acidic and alkaline gases	Offline denuder for absorption of gases	Offline ion chromatography
Organic molecular markers	Offline aerosol sampling	High volume PM sampler
Chlorophyll / nutrient concentration	Offline sampling and lab analysis	Chlorophyll luminoscope and nutrient analyser
Aariable fluorescence by maximum fluorescence	Offline sampling and lab analysis	Luminoscope
ClNO2, and halogenated VOCs	Online observation	ToF-CIMS

4.8 Indicate nature and quantity of substances to be released into the marine environment:
None

4.9 Indicate whether drilling will be carried out. If yes, please specify:
None

4.9.1 Indicate whether explosives will be used. If yes, please specify type and trade name, Chemical content, depth of trade class and stowage, size, depth of detonation, frequency of Detonation, and position in latitude and longitude:
None

5. Installations and Equipment

Details of installations and equipment (including dates of laying, servicing, method and Anticipated timeframe for recover, as far as possible exact locations and depth, and Measurements):
None

6. Dates

6.1 Expected dates of first entry into and final departure from the research area by the research vessel and/or other platforms:
First entry: 19 May 2022 Last exit: 28 May 2022

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6.2 Indicate if multiple entries are expected:
Yes

7. Port Calls

7.1 Dates and Names of intended ports of call:
Reykjavik, Iceland : 14 May – 19th May 2022 (Embarkation)

7.2 Any special logistical requirements at ports of call:
No

7.3 Name/Address/Telephone of shipping agent (if available):
Nesskip H.F Nesskip House Austurstrond 1 172 Selt Jarnarnes, Reykjavik PC101 Tel: 00 354 5639900 Email: operations@nesskip.is

8. Participation of the representative of the Coastal State

8.1 Modalities of the participation of the representative of the Coastal State in the research Project:
One berth for an observer from each coastal state is offered in accordance with UNCLOS Art 249 (1a).

8.2 Proposed dates and ports for embarkation/disembarkation:
Embarkation: Reykjavik, Iceland: 19th May 2022 (Start of Cruise) Disembarkation: Southampton, UK: 27 June 2022 (End of Cruise)

9. Access to Data, Samples and Research Results

9.1 Expected dates of submission to Coastal State of preliminary report, which should include The expected dates of submission of the data and research results:
One week after the completion of the cruise

9.2 Anticipated dates of submission to the Coastal State of the final report **(This must be within 1 year of completion of the cruise)**
6 months after the completion of the cruise

9.3 Proposed means for access by Coastal State to data (including formal) and samples as per BODC Weblink: **https://www.bodc.ac.uk/resources/inventories/cruiseinventory/search/**
Atmospheric and ocean observational data will be accessible via a dedicated depository in BADC: https:/www.badc.ac.uk and BODC separately. Atmospheric samples will be archived for potential access by Coastal State.

9.4 Proposed means to provide Coastal State with assessment of data, samples and Research results:
1. Scientific papers and reports 2. Web depositories: BADC (www.badc.ac.uk) and BODC (www.bodc.ac.uk) 3. Presentation at program and other meetings

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9.5 Proposed means to provide assistance in assessment or interpretation of data, samples And research results:
1. Scientific papers and reports 2. Web depositories: BADC (www.badc.ac.uk) and BODC (www.bodc.ac.uk) 3. Presentation at program and other meetings

9.6 Proposed means of making results internationally available (to obtain cruise reports these Can be obtained via the BODC weblink see below:
Cruise report will be made publically available via BODC weblink. **https://www.bodc.ac.uk/resources/inventories/cruiseinventory/search/** Scientific results will be published in international peer-reviewed journals and presented to international / national conferences / workshops.

10. Other permits Submitted

10.1 Indicate other types of Coastal State permits anticipated for this research (received or Pending):
None

11. List of Supporting Documentation

11.1 List of attachments, such as additional forms required by the Coastal State, etc.:
None

Signature: Shi Zongbo

Contact information of the focal point:
Name: Zongbo Shi
Country: UK
Affiliation: University of Birmingham
Address: School of Geography Earth and Environmental Sciences
Edgbaston
Birmingham
B15 2TT

Telephone: 00 44 1217548132896
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