SEANA/M-Phase Cruise Report

RRS Discovery (DY151)

(16th May – 27th June 2022)

Principal Scientist: Professor Zongbo Shi

The University of Birmingham

Table of Contents

Acknowledgement.. 4

1 Overview 5

2. Science Reports 10

2.1 New particle formation observations 11

2.2 Volatile Organic Compounds (VOCs) measurement 14

2.3 Measurements of airborne particles and GHGs 16

2.4 Observations of aerosol composition and source apportionment 19

2.5 Characterization of the scattering properties of marine particles and black carbon 24

2.6 Offline measurements of PM chemical composition 26

2.7 Individual particle observations 322

2.8 Ice-nucleating particle analysis 366

2.9 Measuring Ozone, NO_x, NO_y, CO and SO_2 49

2.10 Measurements of trave-level Sulfur Dioxide using a highly sensitive laser-induced fluorescence system 533

2.11 Measurements of optical properties and collection of samples for the extraction of Algal Pigments by High Performance Liquid Chromatography (HPLC), Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC) 577

2.12 Aerosol particles, and Cloud Condensation and Ice Nuclei 622

2.13 NMFSS Ship Systems Computing and Underway Instruments 69

Acknowledgement

The science party would like to extend their gratitude to Captain Antione Gatti and his officers, Chief Engineer Jim Bills and all the crew who supported our activities throughout with dedication and extreme professionalism. We appreciate the flexibility of the crew in accommodating the numerous requests.

Our thanks are also extended to the team from NMF (Jon Short, Jack Arnott and Nick Harker) who provided superb technical support and ensured the delivery of all scientific activities.

I would like to thank all scientists onboard for their contribution to the science and logistics. I have learned a lot from every one of you.

I would like to thank Valerija Forbes, Colin Leggett, Yuqin Dai, Mao Du and Xiaomi Teng personally for their support in dealing with seasickness.

Zongbo Shi

15 Oct 2022

1 Overview

RRS Discovery departed Reykjavik Iceland on the 20th May 2022, sailing across the Atlantic Ocean to Labrador Sea and Davis Strait before returning to Southampton on 26 June (see ship track below). Onboard were teams from the Universities of Birmingham, Exeter, York, and Zhejiang, British Antarctic Survey, and Plymouth Marine Laboratory. Operations onboard included the measurement of atmospheric parameters, including:

- size distributions of particles from 1 nm to 20 µm;
- gaseous pollutants such as volatile organic compounds, nitrogen oxides, HONO, HCHO, carbon monoxide, and sulphur dioxide;
- molecular clusters and highly oxygenated organic compounds that contribute to the formation of new particles;
- chemical composition of aerosol particles including both organic molecular tracers and inorganic species, black carbon;
- particle number and mass concentrations; and
- optical observations of atmospheric particles and radiation.

Furthermore, surface ocean chlorophyll a concentrations and routinely measured parameters onboard such as salinity were also recorded.

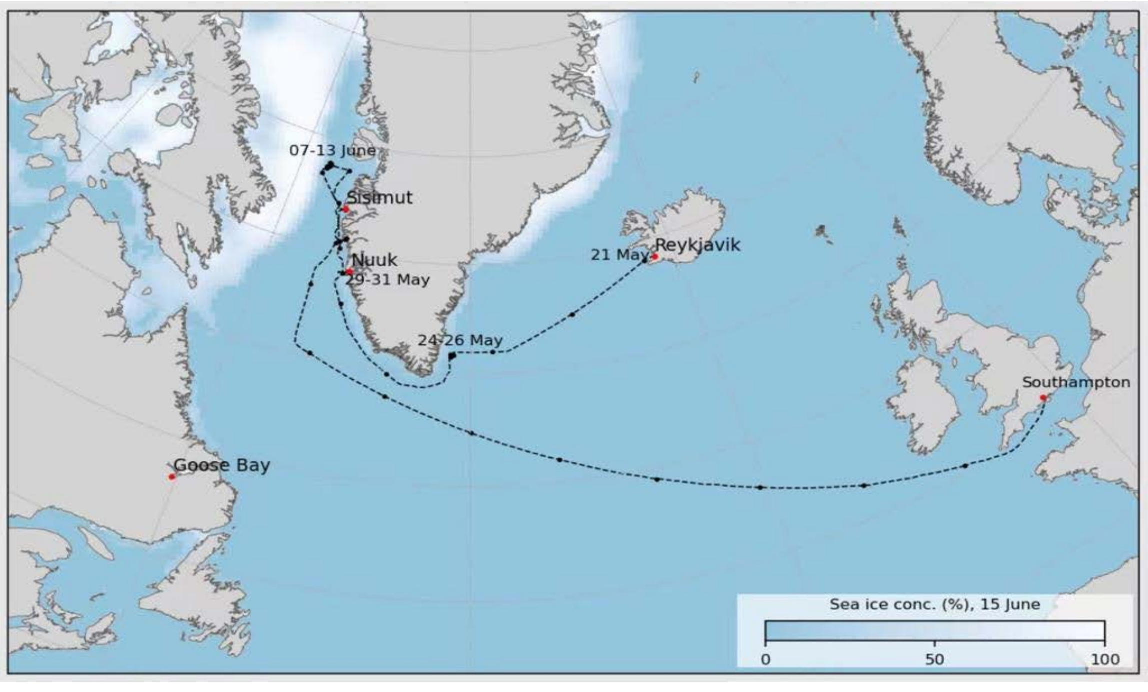


Figure 1. DY151 ship track

The main objectives of DY151 are:

- To understand the sources and processes of aerosol particles, cloud condensation nuclei and ice nuclei
- 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.

During the cruise, we collected the essential data to address these objectives. With these new data we will further improve process parameterisations in a global aerosol model and evaluate the new model against the SEANA/M-Phase observations.

DY151 has delivered significant additional science than originally planned in SEANA proposal thanks to significantly enhanced science capacity, including from M-Phase and new project partners. Overall, the total number of instruments has nearly tripled from the original proposal and the number of additional scientific partners also increased by more than three times. This enabled us to better understand the sources of aerosol particles, cloud condensation and ice nuclei, the formation and growth of new particles, and gas-phase chemistry.

The photos of scientists and the cruise travel log are listed below.

Note: please contact the principal scientist Prof Zongbo Shi (email address: z.shi@bham.ac.uk), if you have any questions about this report.

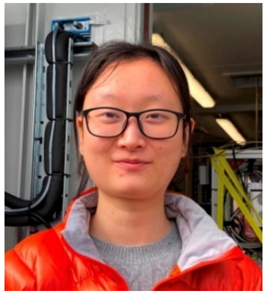
Scientists

Gavin Tilstone

Jo Browse

Zongbo Shi

Amelie **Kirchgaessner**



Xiaomi Teng

Joanna Dyson

Yuqing Dai

Yangmei Zhang

Roberto Sommariva

Loren Temple

Mark Tarn

Mao Du

Congbo Song

Sarah Barr

Agung Kramawijaya

Anna Callaghan

Katie Bastin

Katie Thompson

Vipul Lal Chandani

Table 1. Cruise log for DY151

Date	Time (Ship time)	Events	Location	Weather
16 May 2022	15:56	All scientists board RRS Discovery, and all people have negative PCR tests.	Iceland Reykjavik	Calm
17 May 2022	-	Scientists access the container and set up instruments.	Iceland Reykjavik	Calm
18 May 2022	-	The departure of cruise is delayed to enable more time to prepare for instruments.	Iceland Reykjavik	Calm
19 May 2022	-	Delayed again and planned to sail on 20th May.	Iceland Reykjavik	Calm
20 May 2022	20:15	The Cruise left Reykjavik at 20:15 pm.	Iceland Reykjavik	Calm
21 May 2022	-	First Quiz. The social distance policy is loosed due to all negative PCR test results.	-	
22 May 2022	14:00	Cov-19 day. Four crews test positive and the distance rule keeps.	-	
23 May 2022	-	Arrived at the southeast coast of Greenland and stayed in order to avoid the storm. NPF event observed (high biogenic emissions suspected)	Greenland southeast	Calm
24 May 2022	-	Fogbow occurs at 8:20 am and disappears at 8:40 am when the sun rises.	Greenland southeast	Fog
25 May 2022	-		Greenland southeast	Calm
26 May 2022	23:59	The cruise leaves the coastal at 0:00 am (midnight) and sails to Nuuk, the capital of Greenland with around 17,000 population.	Greenland southeast	Calm
27 May 2022	8:40	Sea salts became crystals in the morning (after waves reached high deck). RRS Discovery near Paamiut (southwest side of Greenland) at around 12:00 am.	-	
28 May 2022	-	Scheduled ship incineration from 9:30 am to 11:30 am (could affect observations).	-	
29 May 2022	-	Near Nuuk station.	Nuuk	
30 May 2022	9:00	Stationed at Nuuk at 9:00 am, heavily fog occurred, and disappeared at 11:00 am	Nuuk	Fog
31 May 2022	8:00	Left Nuuk at 8:00 am towards Kangerlussuaq valley on the north; sea waves were strong during the night	-	Strong wind
1 June 2022	8:00	Arrived at Maniitsoq fjord at around 8:00 am; witnessed whales blowing at around 11:00 am	Maniitsoq fjord	Calm
2 June 2022	-	Stayed in the valley one more day due to NPF event.	Maniitsoq fjord	Calm

3 June 2022	20:00	RRS Discovery left the Maniitsoq fjord at 7:00 am and arrived at Sisimiut (the second largest city with 5,500 population in Greenland) at 20:00 pm, staying here for 24 hours.	Sisimiut	Calm
4 June 2022	20:00	Rescue boat test at 8:30 am; rescue boat returned due to fault; smoke emission from the ship's laundry output port during 20:30 pm to 23:55 pm. The cruise left Sisimiut at 20:00 pm. The Sun never sets at 67.16N 54.53W.	Sisimiut	Windy
5 June 2022	11:05	Arrived at the station nearby the west costal of Greenland at 11:05 am, ship incineration from 9:00 to 11:00 am and waste gases emitted from a port near the container (may cause pollution signals).	-	-
6 June 2022	10:30	Left the station at 10:30 am to melting sea ice region.	-	-
8 June 2022	-	Rescue boat events started from 10:00 am to 17:00 pm. RRS Discovery moved 10 nautical miles to the northwest at 21:00 pm to test the potential impact of rescue boat itself.	-	-
9 June 2022	-	Fog events around 13:00 pm - 15:00 pm.		Fog
10 June 2022	19:10	Snow for a while.	-	-
12 June 2022	23:59	Left melting sea ice (Davis Strait) at the midnight to the south.	-	-
13 June 2022	20:40	Arrived at the fjord station (close to Maniitsoq) at 20:40 pm	-	-
14 June 2022	19:00	RRS Discovery went far away from coastal around 12 nautical miles at 19:00 pm and then come back to the fjord (around 3 nautical miles) at 21:00 pm.	-	-
16 June 2022	9:00	The cruise sails back to Southampton at 9:00 am	-	-
17 June 2022	-		Open Sea	Strong wind
18 June 2022	-		Open Sea	Strong wind
19 June 2022	-		Open Sea	Strong wind
20 June 2022	9:30	Ship incineration from 9:30 am to 11:30 am.	-	-
21 June 2022	-	Fog events all day.	-	Fog
26 June 2022	11:00	The Cruise arrives Southampton at 11am		

2. Science Reports

2.1 New particle formation observations

Mao Du, Congbo Song

School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Objectives

- To characterize new particle formation events.
- To understand the formation mechanisms of new particles and their growth in this region.
- To estimate the contribution of new particle formation to cloud condensation nuclei.

Methods

The size distribution of particles was observed by a few instruments: Particle Sizer Magnifier (PSM, size range from 1 to 3nm, using scanning mode with the time period for each scan of 4 mins), Neutral Cluster and Air Ion Spectrometer (NAIS, size range from 2-40nm, time resolution: 1.5 mins), Nano scanning mobility particle sizer (NanoSMPS, size range from 1.95 to 63.8nm) and LongSMPS (size range from 14.8 to 700nm). Those measurements will be used to calculate the formation and growth rates of new particles and condensation sink of all particles. The time resolution of NanoSMPS and LongSMPS is 5 mins. The concentration of sulfuric acid, iodide acid and the highly oxidised molecules were determined by an atmospheric pressure interface time-of-flight (Api-ToF) with time resolution of 0.25s. Cloud condensation nuclei (CCN) counter was used to determine the concentration of CCN at different supersaturations. Additionally, gas-phase measurements (such as VOCs concentration from PTR-ToF, O_3, CO and NOx mixing ratios), meteorological data (e.g., wind direction, wind speed and air mass back trajectory) and surface ocean data (such as the chlorophyll *a* concentration) will support the interpretation of new particle formation mechanisms.

Data were collected continuously throughout the cruise except during maintenance and power failure.

Preliminary results

Figures 1-3 show the raw number size distribution of particles measured by the PSM, Nano-SMPS, Long-SMPS and NAIS from 7th June to 8th June 2022, illustrating a new particle formation event. New particles started to form at about midday and then continued to grow until midnight, after when the particle median diameter remain relatively constant. The long- and nano-SMPSs cover different size ranges to enable us to obtain a larger range of sizes of particles, helping to understand the growth of new particles.

We are currently working to merge the long- and non-SMPS data to obtain a combined size distribution, which can then be used to better calculate the formation and growth rates. We are also extracting data from the API-ToF and PTR-ToF-MS. The CCN data will be analysed to estimate the critical diameter of particles and the fraction of such particles which are able to contribute the CCN. The air mass back trajectory data will be obtained via the HYPSPLIT mode, which will be used to understand the air mass origin. All data will be integrated to understand the formation and growth of new particles and estimate their contribution to CCN.

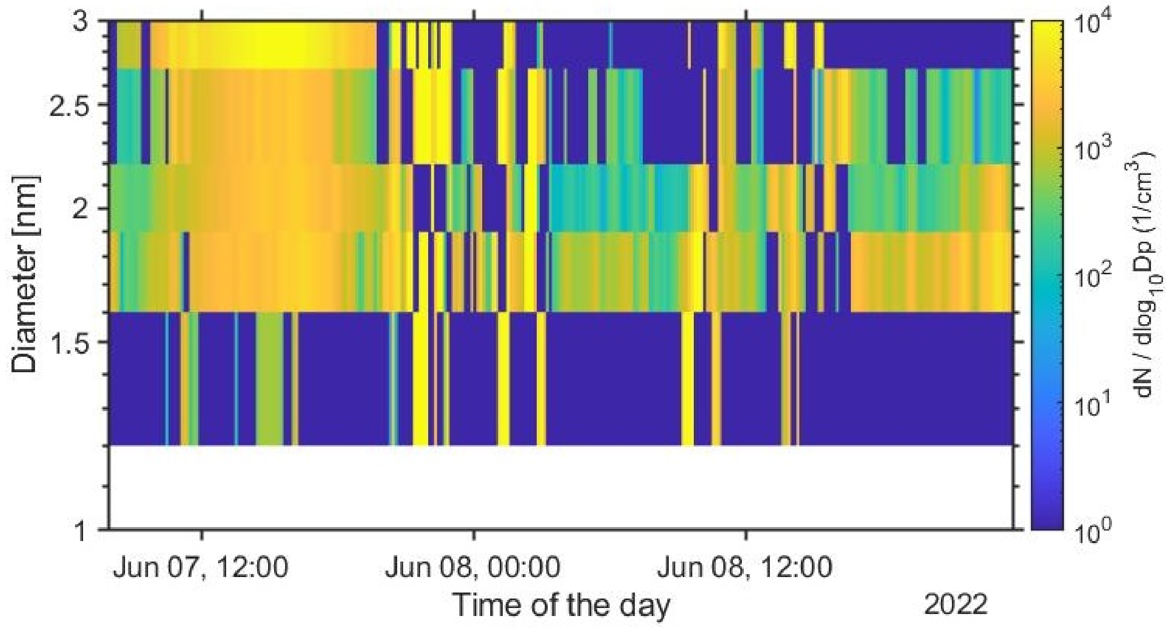


Figure 1. Time-series of the size distribution for PSM (for diameter from 1-3nm) from 7th June to 8th June.

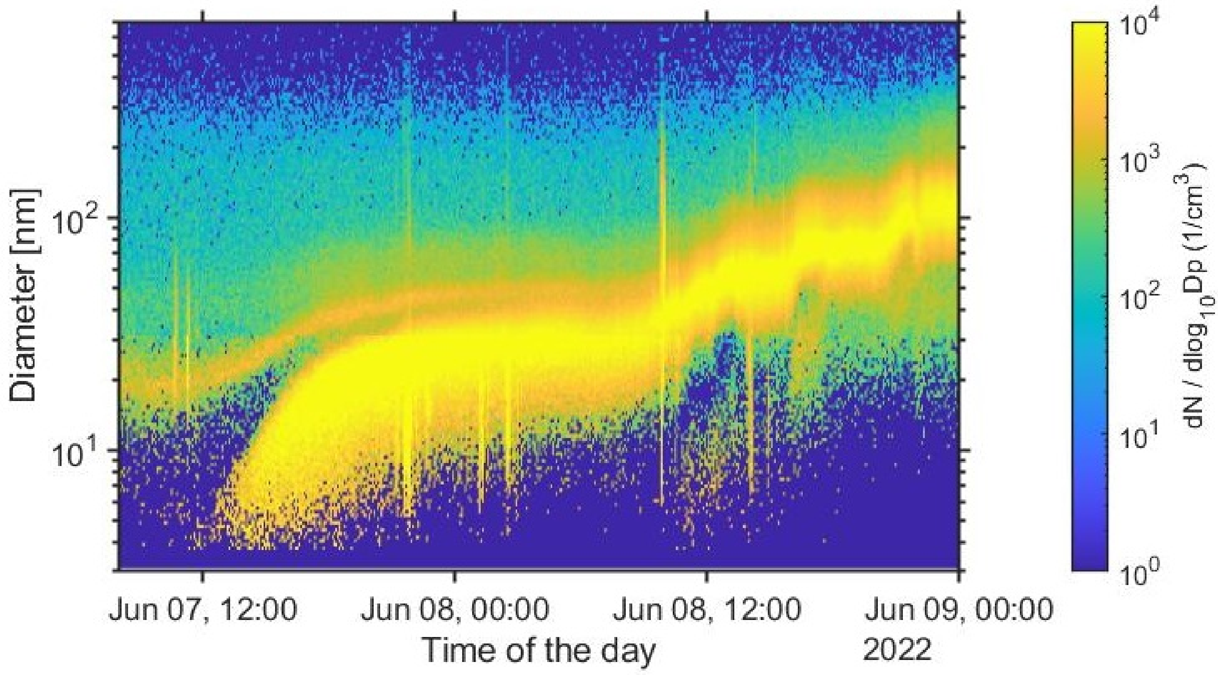


Figure 2. Time-series of the size distribution for NanoSMPS(for diameter from 3-40nm) and LongSMPS (for diameter from 40-700nm) from 7th June to 8th June.

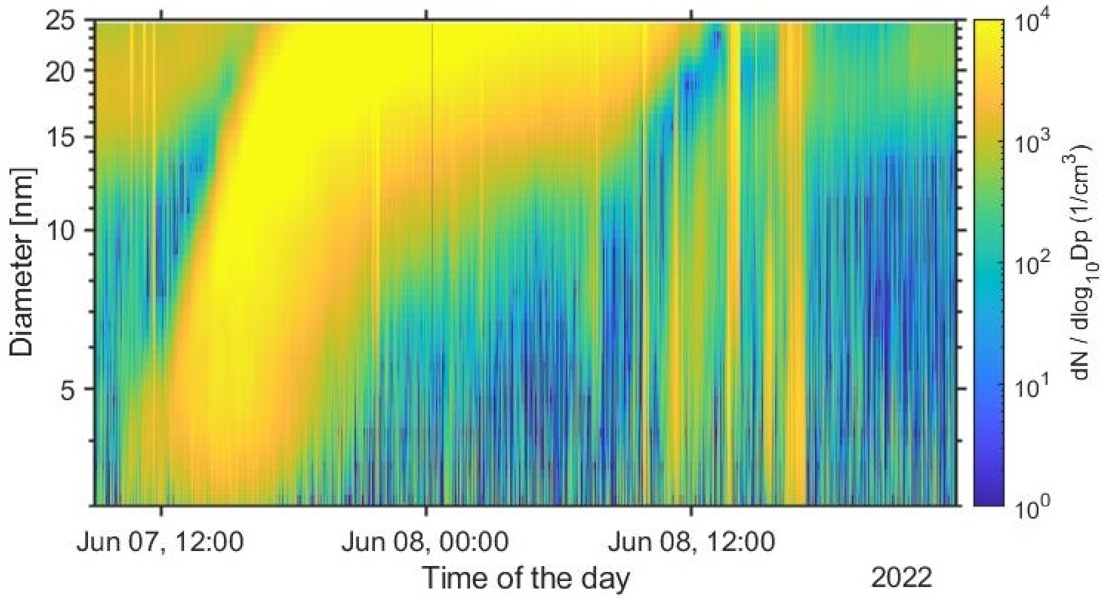


Figure 3. Time-series of the size distribution for NAIS negative particle mode from 7th June to 8th June.

2.2 Volatile Organic Compounds (VOCs) measurement

Roberto Sommariva, Vipul Lal Chandani

School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Objectives

- To measure the concentrations and vertical flux of volatile organic compounds in the study region.
- To identify the sources and processes contributing to VOCs.
- To support the investigation on the sources of secondary particulate pollution and on the mechanisms of new particle formation.

Method

We used an online proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS) to measure highly time resolved concentrations of trace VOCs (10 Hz). The instrument was calibrated using a standard calibration gas mixture every week during the campaign. The instrument was running almost continuously from 24th May to 22nd June 2022.

Once the data were collected, we will use eddy covariance method to estimate the vertical flux of selected VOCs.

Preliminary results

The following figure shows the time series of selected VOC species benzene, toluene, di-methyl sulfide (DMS) and methyl sulfonic acid (MSA) for the sampling days. DMS, originated from the ocean, and MSA, formed in the atmosphere from DMS, showed a different time series. Toluene and benzene also had a different trend, suggesting they are from different sources.

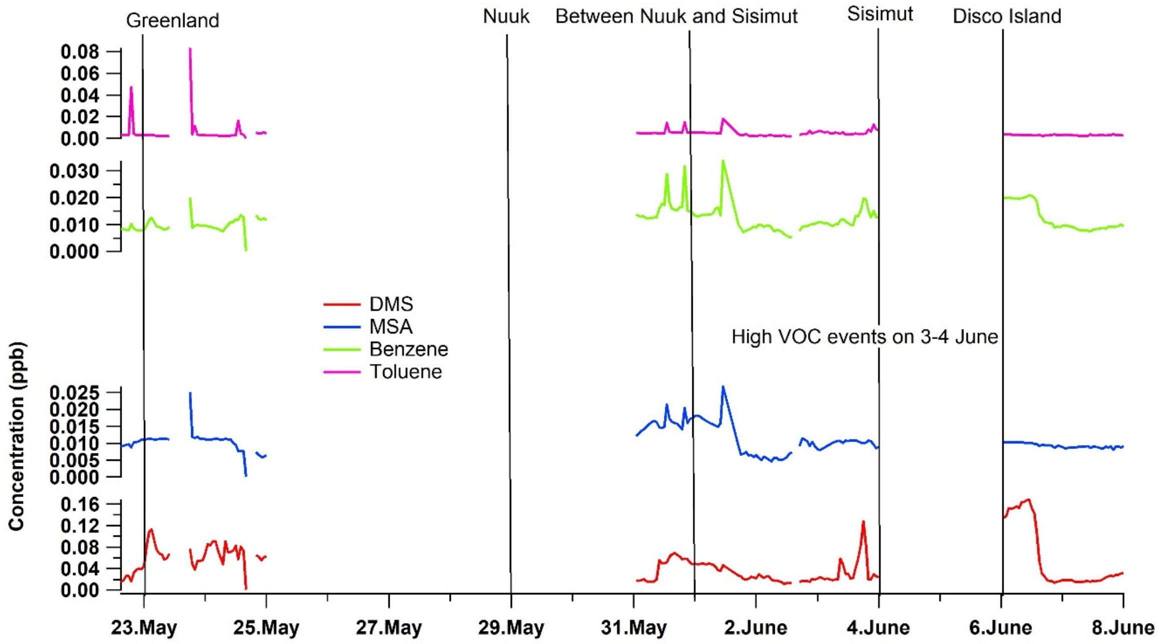


Figure 4. Time-series of selected VOCs for selected periods. Data extraction is ongoing.

2.3 Measurements of particle concentration and GHGs

Yuqing Dai

School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Objectives

- To determine the concentration of airborne particles and major / trace elements in the study region;
- To determine the concentration of greenhouse gases - N_2O and CH_4.

Methods

Particle concentration observations

Continuous measurements of PM_1, $PM_{2.5}$, PM_4, PM_{10}, total particles (TSP), and the particle number concentration were made using Palas Fidas 200 from 07/04/2022 to 23/06/2022 with a time resolution of 1 min during the cruise. The inlet was mounted on Birmingham container on the front deck of RRS Discovery with a water protected cabinet and a drying tube that raises the temperature of the intake to 40 degrees to minimize measuring errors.

Greenhouse gases (GHG) sampling

Greenhouse gases (GHG) including nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2), and ammonia (NH_3) and water vapour (H_2O) were measured continuously using Picarro G2508 that employed precise cavity ring-down spectroscopy (CRDS) technology. The sampling period was from 18/05/2022 to 23/06/2022. The temporal resolution is 1 second. The instrument was installed in Leeds container, with the inlet mounted on the top of the container.

Concentration of elements in $PM_{2.5}$ and PM_{10}

A range of elements within $PM_{2.5}$ and PM_{10} were measured using two Xact 625i monitoring system based on EPA method IO 3.3: Determination of Metals in Ambient PM using XRF. Xact monitors were installed within Birmingham container with individual inlets. The sampling period was from 17/05/2022 to 23/06/2022, and the temporal resolution is 4 hours. Available elements include Si, Fe, Al, S, K, Ti, Ca, V, Ni, etc.

Meteorological data

Two wind sensors were mounted on the monkey island of the ship to collect wind information for the wind controller. These sensors provided wind direction and speed on the horizontal axis. The sampling period was from 21/05/2022 to 23/06/2022. It is worth noting that the recorded wind direction is related to the bow of RRS Discovery and not the true wind direction.

SVOC sampling

Semi-volatile Organic Compound (SVOC) sampling was conducted using SVOC sampler during the DY151 cruise. The instrument was stored in an independent cabinet that was fixed on the top of Birmingham Container, and the sampler has seven channels that change automatically every 24 hours (with weekly maintenance), with an air flow rate of 1.5 L/min. Each channel provided two samples daily – a Teflon filter that collected particles and an absorbent tube that collected gases.

Preliminary results

Figure 1 shows that PM_{10} ranges from <1 µg m^{-3} to over 40 µg m^{-3}. Sea salt concentration, estimated from Cl measured by Xact correlated well with PM_{10}.

Table 1 shows the information for each SVOC samples collected.

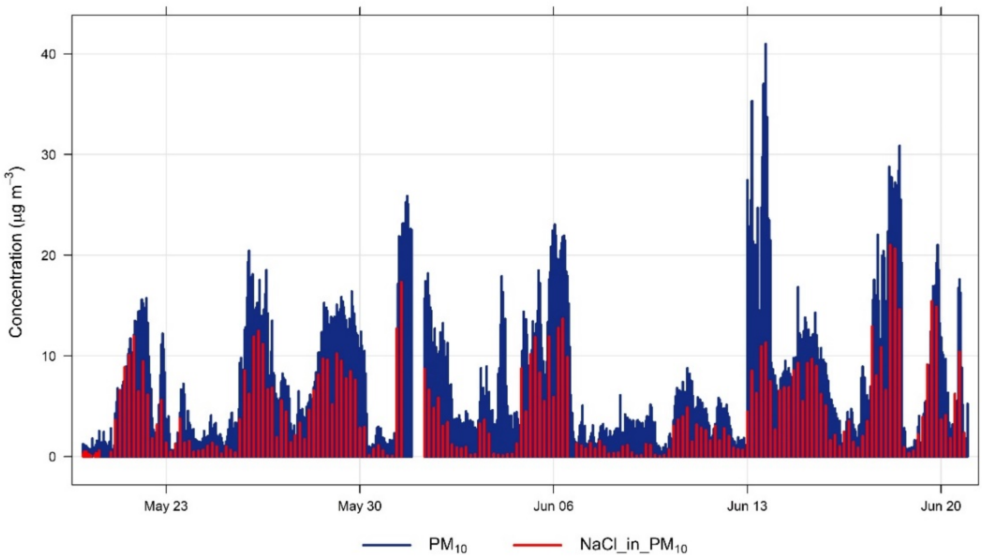


Figure 5. Time-series of concentration for PM_{10} from Fidas and NaCl estimated from X-act.

Table 1. Record of SVOC sampler sampling

Channel	**Filter NO.**	**Adsorption Tube NO.**	**Start Date**	**End Date**
C6	13	315312	20220624 12:30	20220625 12:30
C5	14	297677	20220622 12:30	20220623 12:30
C4	15	286918	20220620 12:30	20220621 12:30
C3	16	286917	20220618 12:30	20220619 12:30
C2	17	315320	20220616 12:30	20220617 12:30
C1	18	315304	20220614 12:30	20220615 12:30
C6	19	366511	20220612 15:40	20220613 15:40
C5	20	297675	20220611 15:40	20220612 15:40
C4	21	366528	20220610 15:40	20220611 15:40
C3	22	366517	20220609 15:40	20220610 15:40
C2	23	366523	20220608 15:40	20220609 15:40
C1	24	297672	20220607 15:40	20220608 15:40
C6	25	315322	20220606 11:08	20220607 11:08
C5	26	286930	20220605 11:08	20220606 11:08
C4	27	315325	20220604 11:08	20220605 11:08
C3	28	315314	20220603 11:08	20220604 11:08
C2	29	366537	20220602 11:08	20220603 11:08
C1	30	315302	20220601 11:08	20220602 11:08
C1	32	286926	20220524 10:55	20220525 10:55
C5	35	286929	20220528 10:55	20220529 10:55
C3	36	366532	20220526 10:55	20220527 10:55
C4	37	286921	20220527 10:55	20220528 10:55
C2	39	315321	20220525 10:55	20220526 10:55
C6	40	315303	20220529 10:55	20220530 10:55

2.4 Observations of aerosol composition and source apportionment

Yangmei Zhang[1], Vipul Lal Chandali[2]

[1]Chinese Academy of Meteorological Sciences, Beijing, China,

[2]School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Objectives

- To determine the mass concentrations of major chemical species in $PM_{2.5}$ including organics, sulfate, nitrate, ammonium, chloride, sodium and Methane Sulfonic Acid (MSA).
- To understand the sources and processes controlling temporal variation of $PM_{2.5}$ and its components.

Methods

An aerodyne high-resolution time of flight Aerosol Mass Spectrometer (HR-TOF-AMS) and an online quadrupole-aerosol chemical speciation monitor (Q-ACSM) were employed to measure the chemical species mass concentrations for $PM_{2.5}$. The time resolution of the measurement is 1 minute and 30mins for the HR-TOF-AMS and Q-ACSM, respectively.

Aerosols was introduced into the instrument through a sampling inlet that restricts the flow with a 120μm (or similar diameter) critical orifice and then through the lens which focuses the aerosols into a tight beam of approximately one millimetre using 6 apertures while removing most of the atmospheric gas. The chopper was placed in closed position so that no particles pass through and open position not blocking the beam so that all the particles pass through. A high-resolution time of flight mass spectrometer was used to measure both the background of the chamber (beam closed) and the total signal (beam open). The difference of these two signals gives the particulate signal at each mass with the exception of some of the predominant air species (N_2, O_2, Argon, and CO_2). The MS mode is especially useful to determine the overall composition of total aerosol mass and noting the individual chemical species with the largest concentration.

For the Q-ACSM measurement, the particles were sampled using a $PM_{2.5}$ cyclone inlet and dried using a Nafion dryer before entering the instrument. Standard calibrations of ionization efficiency were performed at the beginning and the end of campaign.

For the HR-TOF-MS, we originally planned to carry out both general atmospheric aerosol mode and flux mode measurement at the same time; unfortunately, there is problem with the AMS chopper, and the alternation mode measurement also showed unusual behaviour, so we gave up the flux mode measurement and only kept the atmospheric aerosol measurement.

During the cruise, on-line measurement started from 23 to 26 May using the long inlet tube for the flux measurement (when the instrument mal-functioned). From 27 May to 27 June, the inlet was shortened to the roof of container. Data were missing during the flow rate calibration, ionization efficiency calibration and relative ionization efficiency of interested species, methane sulfonic acid calibration as well as some occasional crash from the software and power supply.

$PM_{2.5}$ chemical composition data was measured by the Q-ACSM every 30 min for the following days: 22nd May to 3rd June & 14th June to 22nd June. From 4th June to 13th June, the instrument had a technical problem, and no data were collected.

Provisional results

Major chemical species

The temporal variation in mass concentration of organics, sulfate, nitrate, ammonium and chloride were measured during the cruise campaign (an example is shown in Figure 1). The results indicate the sulfate mass concentrations varied from 0.01-1.5 µg/m^3, organics varied in larger range from 0.1 to 12 µg/m^3. Nitrate, ammonium and chloride concentrations were lower than those of organics and sulfate. During 8th-10th June 13th -14th June and 16th-19th June, organics reached around 10 µg/m^3. The sources of these species will be investigated, including the possibility of ship stack emission contamination.

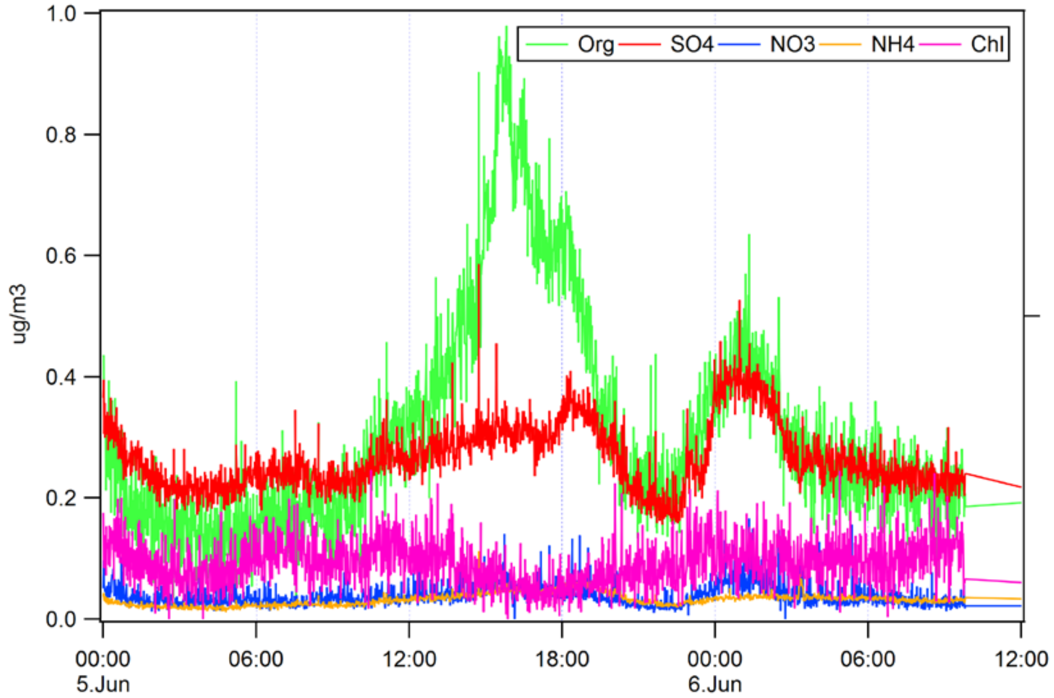


Figure 6. An example for time series of chemical species in June during the cruise from HR-TOF-MS.

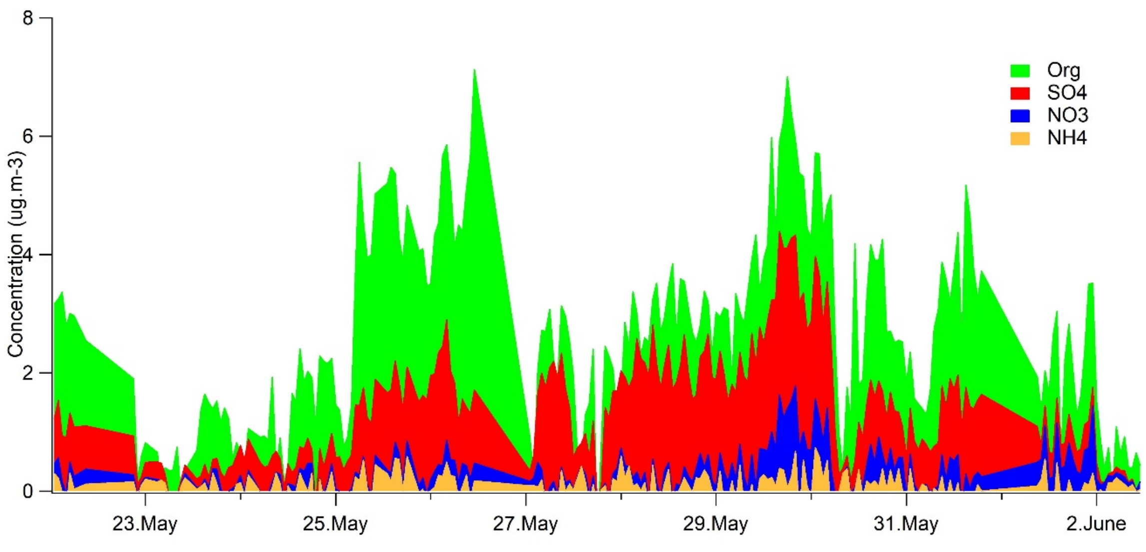


Figure 7. Time-series of concentrations for speciated $PM_{2.5}$ from Q-ACSM.

Sea salt and MSA from HR-TOF-MS

Sea salt and methane sulfonic acid (MSA) are two important marine aerosol species. Sea salt aerosol produce from breaking waves influence marine boundary layer heterogeneous chemistry, atmospheric optics and cloud physics. It was reported that in the marine regions with little continental impact, sea salt aerosol can contribute ~5-90% of the marine cloud condensation nuclei.

Dimethylsulfide (DMS) emission contribute greatly to the global biogenic sulfur budget, and its oxidation products can contribute to aerosol mass, specifically as sulfuric acid and methane sulfonic acid (MSA). Furthermore, sulfuric acid is a known nucleation compound, and MSA may be able to participant in nucleation when bases are available. During this cruise, the mass level of sea salt and MSA aerosol was quantified based on higher specific ions from the AMS mass spectrum as well as laboratory experiment and in-situ calibrations.

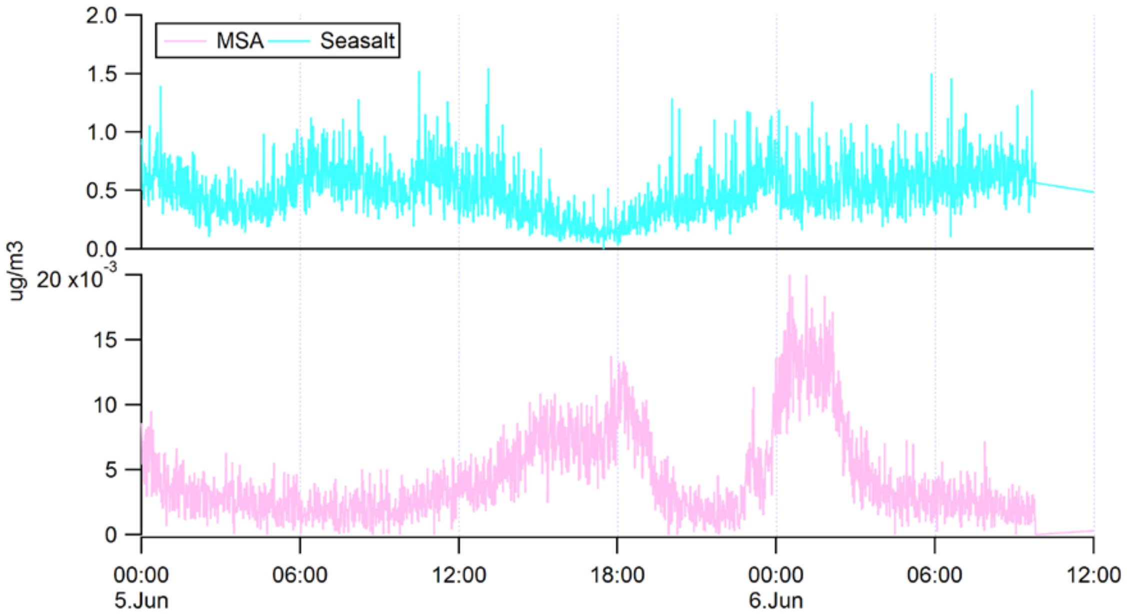


Figure 8. An example for mass concentrations of sea salt and MSA in June. It should be noted that sea salt data require further validation.

Based on the calibration results, the mass concentrations of sea salt and MSA during 26th may and 20th June were first investigated. The mass levels of sea salt varied from 0.05 to 2 µg/m^3, while MSA concentration varied from 0.003 to 0.10 µg/m^3. The sea salt level is similar with some previous studies. The MSA concentration is slightly lower than that of Mace Head station in Autumn.

References

Phinney, L., Richard Leaitch, W., Lohmann, U., Boudries, H., Worsnop, D. R., Jayne, J.T., Toom-Sauntry, D., Wadleigh, M., Sharma, S., Shantz, N., Leaitch, W. R., Lohmann, U., Boudries, H., Worsnop, D. R., Jayne, J. T., Toom-Sauntry, D., Wadleigh, M., Sharma, S., Shantz, N., Richard Leaitch, W., Lohmann, U., Boudries, H., Worsnop, D. R., Jayne, J. T., Toom-Sauntry, D., Wadleigh, M., Sharma, S., Shantz, N., Leaitch, W. R., Lohmann, U., Boudries, H., Worsnop, D. R., Jayne, J. T., Toom-Sauntry, D., Wadleigh, M., Sharma, S. and Shantz, N., 2006. Characterization of the aerosol over the sub-arctic north east Pacific Ocean. Deep Sea Res. II-Topical Study Oceanogr., 53, 2410–2433, doi:10.1016/j.dsr2.2006.05.044|ISSN 0967-0645.

Huang, D. D., Li, Y. J., Lee, B.P and Chan, C. K., 2015. Analysis of Organic Sulfur Compounds in Atmospheric Aerosols at the HKUST Supersite in Hong Kong Using HRToF-AMS. Environ. Sci. Tech. 49, 3672-3679.

Huang, S., Poulain, L., van Pinxteren, D., van Pinxteren, M., Wu, Z., Herrmann, H. and Wiedensohler, A., 2017. Latitudinal and Seasonal Distribution of Particulate MSA over the Atlantic using a Validated Quantification Method with HR-ToF-AMS. Environ. Sci. Technol., 51, 418–426.

Willis, M. D., Burkart, J., Thomas, J. L., Köllner, F., Schneider, J., Bozem, H., Hoor, P. M., Aliabadi, A. A., Schulz, H., Herber, A. B., Leaitch, W. R. and Abbatt, J. P. D., 2016. Growth of nucleation mode particles in the summertime Arctic: a case study. Atmos. Chem. Phys., 16, 7663–7679.

Zorn, S. R., Drewnick, F., Schott, M., Hoffmann, T. and Borrmann, S., 2008 Characterization of the South Atlantic marine boundary layer aerosol using an aerodyne aerosol mass spectrometer. Atmos. Chem. Phys., 8, 4711–4728, doi:10.5194/acp-8-4711-2008.

2.5 Characterization of the scattering properties of marine particles and black carbon

Xiaomi Teng[1], Mao Du[2], Darrel Baumgardner[3]

[1]Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou 310027, China

[2]School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

[3] Droplet Measurement Technologies, USA.

Objectives

- To determine of BC mass concentrations, size distributions, and mixing state.
- To determine the scattering property of marine aerosol particles.

Methods

A series of online measurements were deployed to measure the concentration of aerosol particles. The aerodynamic diameter and light-scattering intensity of aerosols were measured by the aerodynamic particle sizer (APS). The mass concentration and size of black carbon were determined by the single-particle soot photometer extended range (SP2XR) and Aethalometer Model AE33 (AE33). The Aurora 3000 Multi Wavelength Integrating Nephelometer (with backscatter) was used to monitor the scattering and back-scattering property of particles under 2.5 micrometre. The scattering coefficient can be obtained from three wavelengths. These measurements were combined with backscatter measurements that only sample 90° - 170°, therefore allowing a more in-depth analysis of particle scattering.

The instruments were deployed continuously to measure the aerosol particles from 23rd May 2022 to 23rd June except during power cuts.

Preliminary results

Time series of scattering of particles from nephelometer is displayed in Figure 9. The mass concentration of black carbon from the AE33 is shown in Figure 10. We are working on the data from the APS and SP2XR to further characterize black carbon properties.

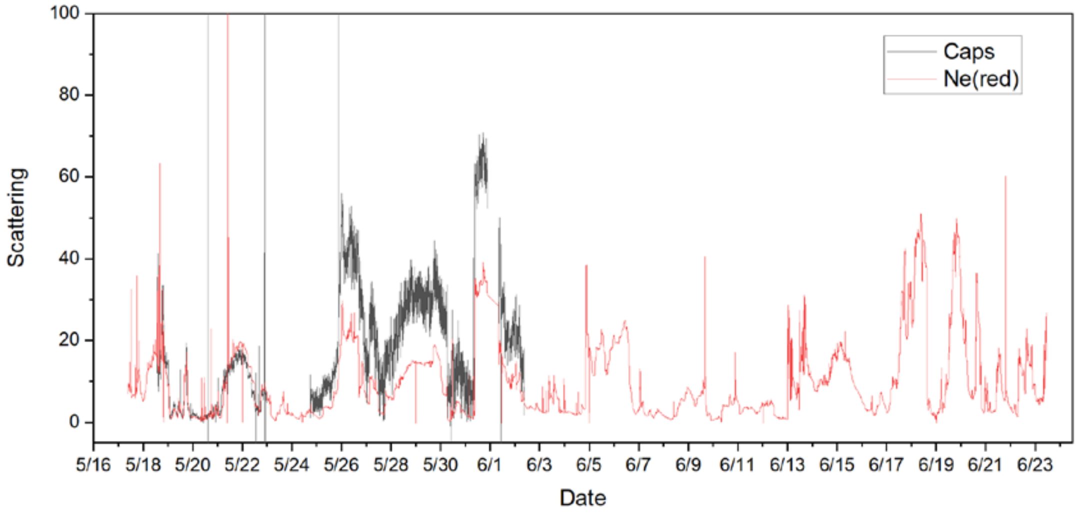


Figure 9 Time series of scattering properties of particles by using a nephelometer.

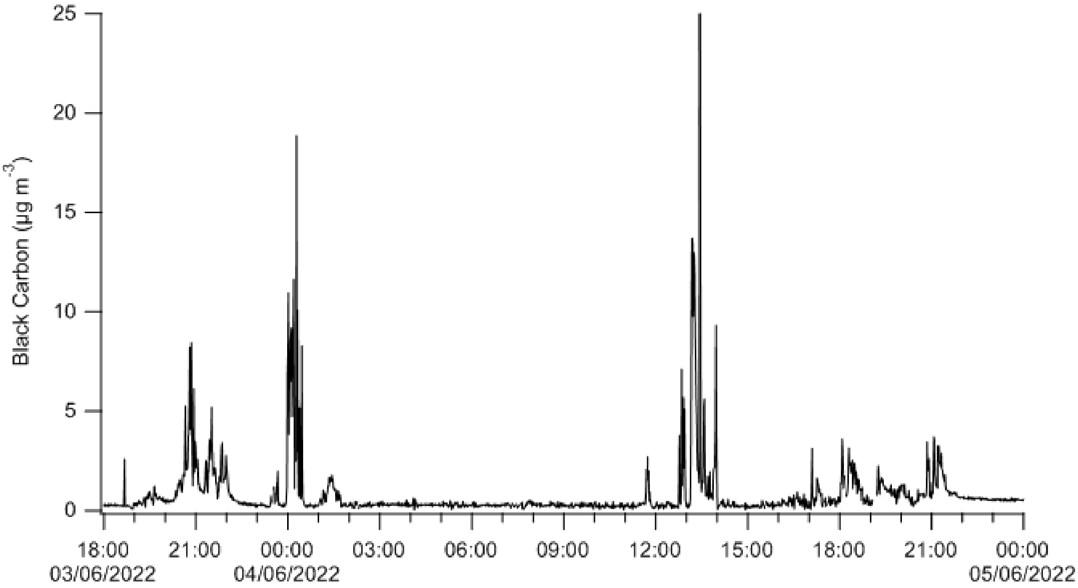


Figure 10. The mass concentration of black carbon during a selected period using an AE33.

2.6 Offline measurements of PM chemical composition

Agung Ghani Kramawijaya

School of Geography Earth and Environment Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Objectives

- To determine the chemical composition of airborne particles.
- To quantify the sources of airborne particles.

Sampling and methodology

The samplers were installed in the Monkey Island of the DISCOVERRY. The aerosols were collected on Teflon membrane, quartz, and polycarbonate filters using Medium Volume Sampler (Partisol, TSI), High Volume Sampler (TISCH, MCV, Digitel), and Low Volume Samplers (Minivol). Teflon membrane filters are weighted via a high accuracy scale at University of Birmingham before boarding the cruise. The quartz filters are baked at the temperature of 550 ºC for overnight, helping to remove the potential organic contaminants on the filters. The quartz filters are soaked in acid solution for overnight and washed by using Mili-Q water and baked at the temperature of 550 ºC for overnight in order to reduce background concentration of the filter. The samples were stored in a freezer (-20ºC).

The samples will be analyzed using a series of offline analytical techniques such as Gas chromatography Gas chromatography–mass spectrometry (GC-GCMS), Inductively Coupled Plasma Mass Spectrometry (ICPMS), X-ray fluorescence (XRF) etc., correspondingly. The collection information (starting time, end time, position) of each sample is shown from Table 2 - Table 9.

Table 2. Records for the Low Volume Sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
MP-1	22/05/22 10:35:00 ~ 25/05/22 11:13:00	61.6405 ~ 60.8566	-34.04969 ~ -41.61894
MP-2	25/05/22 13:17:00 ~	60.831 ~	-41.64296 ~

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
	26/05/22 09:51:00	59.5402	-42.58224
MP-3	26/05/22 09:57:22 ~ 28/05/22 09:32:35	59.5346 ~ 63.8343	-42.61096 ~ -52.58549
MP-4	28/05/22 10:32:24 ~ 31/05/22 09:30:00	63.935 ~ 64.0579	-52.44511 ~ -52.15263
MP-5	31/05/22 10:29:48 ~ 2/6/2022 9:30:04	64.1068 ~ 65.6479	-52.35067 ~ -52.80055
MP-6	2/6/2022 10:27:09 ~ 4/6/2022 21:01:09	65.6479 ~ 66.91	-52.80043 ~ -53.86908
MP-7	5/6/2022 7:14:48 ~ 7/6/2022 9:34:21	68.1787 ~ 68.8456	-54.99131 ~ -56.71179
MP-8	7/6/2022 10:31:18 ~ 9/6/2022 9:28:31	68.8333 ~ 68.7213	-56.62212 ~ -56.73178
MT-9	9/6/2022 10:08:58 ~ 11/6/2022 9:26:03	68.7212 ~ 68.6395	-56.73193 ~ -56.9867
MT-10	11/6/2022 10:09:25 ~ 13/6/2022 9:27:17	68.6395 ~ 67.1302	-56.98671 ~ -54.57024
MT-11	13/6/2022 10:28:42 ~ 16/6/2022 08:25:11	66.983 ~ 65.3172	-54.37722 ~ -53.70968
MT-12	16/6/2022 10:20:52 ~ 18/6/2022 18:14:36	65.1112 ~ 59.2023	-53.86262 ~ -48.66171

Table 3. Records for the Partisol Sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
PB-1	26/05/22 10:45:00 ~ 28/05/22 09:29:50	59.49578 ~ 63.8297	-42.8362 ~ -52.5922
PB-2	28/05/22 10:30:00 ~ 31/05/22 09:31:25	63.93103 ~ 64.05626	-52.4512 ~ -52.1588
PB-3	31/05/22 10:45:00 ~ 2/6/2022 10:45:00	64.13336 ~ 65.64788	-52.3598 ~ -52.8004
PB-4	2/6/2022 10:45:00 ~ 4/6/2022 21:01:00	65.64788 ~ 66.91003	-52.8004 ~ -53.8682
PB-5	5/6/2022 7:17:02 ~ 7/6/2022 6:17:04	68.18442 ~ 68.85371	-54.9861 ~ -56.7494
PB-5	7/6/2022 7:17:02 ~ 9/6/2022 6:14:00	68.85255 ~ 68.72128	-56.7482 ~ -56.7315

Table 4. records for the TSI sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
TSI-1	22/05/22 10:00:00 ~ 26/05/22 09:52:09	61.68107 ~ 59.53923	-33.8671 ~ -42.5872
TSI-2	26/05/22 10:41:16 ~ 31/05/22 09:32:05	59.49883 ~ 64.0556	-42.8191 ~ -52.1616
TSI-3	31/05/22 10:30:00 ~ 7/6/2022 9:36:04	64.10708 ~ 68.84542	-52.3508 ~ -56.7092
TSI-4	7/6/2022 10:32:31 ~ 14/6/2022 9:29:27	68.83314 ~ 65.44043	-56.6203 ~ -53.4166
TSI-5	14/6/2022 10: 20:05 ~ 21/06/2022 11:58:27	65.44278 ~ 55.23397	-53.3937 ~ -30.2523

Table 5. Records for the TISCH sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
TISCH-1	25/05/22 10:38:00 ~ 26/05/22 9:52:08	60.85851 ~ 59.539248	-41.6041 ~ -42.5872
TISCH-2	26/05/22 10:31:02 ~ 28/05/22 09:33:12	59.506857 ~ 63.835319	-42.772 ~ -52.584
TISCH-3	31/05/22 10:37:10 ~ 2/6/2022 9:30:02	64.119025 ~ 65.647896	-52.3554 ~ -52.8006
TISCH-4	2/6/2022 10:27:08 ~ 4/6/2022 21:00:00	65.647883 ~ 66.909909	-52.8004 ~ -53.8622
TISCH-5	5/6/2022 7:10:16 ~ 7/6/2022 9:35:14	68.167527~ 68.845552	-55.0046 ~ -56.7105
TISCH-6	7/6/2022 10:34:49 ~ 9/6/2022 9:31:02	68.832652 ~ 68.721276	-56.6166 ~ -56.7318
TISCH-7	9/6/2022 10:10:30 ~ 11/6/2022 9:28:36	68.721212 ~ 68.639471	-56.7319 ~ -56.9867
TISCH-8	11/6/2022 10:10:54 ~ 13/6/2022 9:29:16	68.639467 ~ 67.126018	-56.9867 ~ -54.5605
TISCH-9	13/6/2022 10:28:05 ~ 16/6/2022 08:25:54	66.984631 ~ 65.317186	-54.3784 ~ -53.7096
TISCH-10	16/6/2022 09:19:07 ~ 20/6/2022 09:44:21	65.269186 ~ 56.825948	-53.7588 ~ -37.364
TISCH-11	20/6/2022 18:02:24 ~ 22/6/2022 18:02:28	56.344839 ~ 53.334222	-35.1455 ~ -22.0168

Table 6. Records for the MCV A sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
MA-1	22/05/22 10:00:00 ~ 26/05/22 09:53:30	61.68107 ~ 59.53797	-33.86706 ~ -42.59315
MA-2	26/05/22 10:03:57 ~ 28/05/22 09:32:50	59.52905 ~ 63.83471	-42.64264 ~ -52.58485
MA-3	28/05/22 10:32:10 ~ 31/05/22 09:31:50	63.93465 ~ 64.05587	-52.44571 ~ -52.16061
MA-4	31/05/22 10:31:04 ~ 2/6/2022 9:30:50	64.10874 ~ 65.6479	-52.35161 ~ -52.80055
MA-5	2/6/2022 10:32:00 ~ 4/6/2022 21:00:20	65.64789 ~ 66.90993	-52.80039 ~ -53.86423
MA-6	5/6/2022 7:11:55 ~ 7/6/2022 9:36:17	68.17159 ~ 68.84538	-54.99965 ~ -56.70885
MA-7	7/6/2022 10:33:41 ~ 9/6/2022 9:30:43	68.83293 ~ 68.72128	-56.61849 ~ -56.73183
MA-8	9/6/2022 10:15:35 ~ 11/6/2022 9:27:25	68.72121 ~ 68.63948	-56.73189 ~ -56.98671
MA-9	11/6/2022 10:08:41 ~ 13/6/2022 09:31:00	68.63947 ~ 67.12244	-56.98672 ~ -54.552
MA-10	13/6/2022 10:45:45 ~ 16/6/2022 08:26:50	66.93761 ~ 65.31715	-54.34369 ~ -53.70949
MA-11	16/6/2022 09:15:57 ~ 20/6/2022 09:48:25	65.27729 ~ 56.82212	-53.75127 ~ -37.3467

Table 7. Records for the MCV B sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
MB-1	22/05/22 10:00:00 ~ 26/05/22 09:53:00	61.68107 ~ 59.53842	-33.8671 ~ -42.5909
MB-2	26/05/22 10:03:43 ~ 28/05/22 09:32:35	59.52924 ~ 63.8343	-42.6415 ~ -52.5855
MB-3	28/05/22 10:31:50 ~ 31/05/22 09:33:50	63.93411 ~ 64.05456	-52.4466 ~ -52.1686
MB-4	31/05/22 10:31:21 ~ 2/6/2022 9:30:33	64.1092 ~ 65.64789	-52.3518 ~ -52.8006
MB-5	2/6/2022 10:30:02 ~ 4/6/2022 21:00:30	65.64789 ~ 66.90995	-52.8004 ~ -53.8652
MB-6	5/6/2022 7:12:26 ~	68.17286 ~	-54.9981 ~

	7/6/2022 9:37:24	68.84517	-56.707
MB-7	7/6/2022 10:32:05 ~ 9/6/2022 9:30:37	68.8332 ~ 68.72128	-56.6209 ~ -56.7318
MB-8	9/6/2022 10:14:40 ~ 11/6/2022 9:27:49	68.72121 ~ 68.63948	-56.7319 ~ -56.9867
MB9	11/6/2022 10:12:17 ~ 13/6/2022 09:31:10	68.63947 ~ 67.12209	-56.9867 ~ -54.5512
MB-10	13/6/2022 10:45:56 ~ 16/6/2022 08:27:32	66.93712 ~ 65.31712	-54.3434 ~ -53.7094
MB-11	16/6/2022 09:14:28 ~ 20/6/2022 09:48:25	65.28108 ~ 56.82212	-53.7476 ~ -37.3467

Table 8. Records for the Digitel A sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
DA-1	22/05/22 10:00:00 ~ 24/05/22 09:50:00	61.68107 ~ 60.88159	-33.8671 ~ -41.6316
DA-2	24/05/22 10:00:00 ~ 26/05/22 09:50:00	60.88157 ~ 59.54095	-41.6313 ~ -42.5777
DA-3	26/05/22 10:00:00 ~ 28/05/22 09:31:15	59.5325 ~ 63.83214	-42.6237 ~ -52.5887
DA-4	28/05/22 10:30:00 ~ 31/05/22 09:33:35	63.93103 ~ 64.05446	-52.4512 ~ -52.1676
DA-5	31/05/22 10:30:00 ~ 2/6/2022 9:30:00	64.10708 ~ 65.6479	-52.3508 ~ -52.8005
DA-6	2/6/2022 10:30:00 ~ 4/6/2022 21:00:50	65.64789 ~ 66.91	-52.8004 ~ -53.8672
DA-7	5/6/2022 7:12:56 ~ 7/6/2022 6:12:56	68.1741 ~ 68.8541	-54.9966 ~ -56.7498
DA-8	7/6/2022 7:12:56 ~ 9/6/2022 9:29:47	68.85255 ~ 68.72128	-56.7482 ~ -56.7318
DA-9	9/6/2022 10:15:15 ~ 11/6/2022 9:26:59	68.72121 ~ 68.63948	-56.7319 ~ -56.9867
DA-10	11/6/2022 10:11:30 ~ 13/6/2022 11:09:53	68.63947 ~ 66.90589	-56.9867 ~ -54.466
DA-11	13/6/2022 11:17:57 ~ 15/06/22 15:18:28	66.89723 ~ 65.31698	-54.5188 ~ -53.7569
DA-12	15/06/22 16:18:28 ~ 16/06/22 09:35:30	65.31645 ~ 65.22912	-53.7599 ~ -53.7987
DA-13	16/06/22 09:37:00 ~ 19/06/22 08:20:57	65.22533 ~ 58.2706	-53.7999 ~ -44.1373
DA-14	20/06/22 17:58:57 ~ 22/06/22 17:48:57	56.34829 ~ 53.34817	-35.1623 ~ -22.0753

Table 9. Records for the Digitel B sampler

Sample ID	Start Date Time ~ Stop Date Time (dd/mm/yy hh:mm:ss)	Start Latitude ~ Stop Latitude (Degree)	Start Longitude ~ Stop Latitude (Degree)
DB-1	22/05/22 10:00:00 ~ 24/05/22 09:50:00	61.68107 ~ 60.88159	-33.8671 ~ -41.6316
DB-2	24/05/22 10:00:00 ~ 26/05/22 09:50:00	60.88157 ~ 59.54095	-41.6313 ~ -42.5777
DB-3	26/05/22 10:00:00 ~ 31/05/22 09:31:45	59.5325 ~ 64.05595	-42.6237 ~ -52.1603
DB-4	31/05/22 10:30:00 ~ 2/6/2022 9:30:00	64.10708 ~ 65.6479	-52.3508 ~ -52.8005
DB-5	2/6/2022 10:30:00 ~ 4/6/2022 21:00:40	65.64789 ~ 66.90998	-52.8004 ~ -53.8662
DB-6	5/6/2022 7:12:56 ~ 7/6/2022 6:12:56	68.1741 ~ 68.8541	-54.9966 ~ -56.7498
DB-7	7/6/2022 7:12:56 ~ 9/6/2022 9:29:11	68.85255 ~ 68.72128	-56.7482 ~ -56.7318
DB-8	9/6/2022 10:08:00 ~ 11/6/2022 9:26:45	68.72122 ~ 68.63948	-56.7319 ~ -56.9867
DB-9	11/6/2022 10:10:30 ~ 13/6/2022 11:10:24	68.63947 ~ 66.90531	-56.9867 ~ -54.4693
DB-10	13/6/2022 11:17:27 ~ 15/06/22 15:17:38	66.89779 ~ 65.31698	-54.5155 ~ -53.7568
DB-11	15/06/22 16:17:38 ~ 16/06/22 09:35:51	65.31642 ~ 65.22826	-53.7602 ~ -53.7994
DB-12	16/06/22 09:37:00 ~ 19/06/22 09:46:33	65.22533 ~ 58.17853	-53.7999 ~ -43.7012
DB-13	20/06/22 18:01:42 ~ 22/06/22 18:02:00	56.34565 ~ 53.33469	-35.1488 ~ -22.0188

2.7 Individual particle observations

Xiaomi Teng, Weijun Li

Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou 310027, China

Objectives

- To determine the microscopic properties including size, chemical composition and mixing state of individual aerosol particles in the study region.
- To determine the types and concentration of microplastics particles.

Methods

The sampler was installed in the monkey island of the cruise. Single stage impactor samplers were used to collect individual particles on different types of transmission electricity microscopic (TEM) matrices, such as copper, silicon, and lacey carbon film. An ARA Sampler with a TSP impactor was used to sample micro-plastics on quartz or polycarbonate filters.

TEM will be used to determine the size, morphology, composition and mixing state of individual particles, which will help to determine their sources and the aging processes. The collection records for each sample are shown in Table 10 - Table 12.

Table 10. Sampling records – Silicon plates

No.	DATE	UTC Time	No.	DATE	UTC Time
1-1	20220525	0:30-1:30	14-1	20220608	8:30-9:30
1-2	20220525	0:30-1:30	14-2	20220608	8:30-9:30
2-1	20220526	10:00-11:00	15-1	20220608	18:30-19:30
2-2	20220526	10:00-11:00	15-2	20220608	18:30-19:30
3-1	20220526	14:00-15:00	16	20220609	15:00-16:30
3-2	20220526	14:00-15:00	17-1	20220610	18:30-19:50
4-1	20220527	20:00-21:00	17-2	20220610	18:30-19:50
4-2	20220527	20:00-21:00	18-1	20220611	19:40-21:19
5-1	20220529	14:00-15:00	18-2	20220611	19:40-21:19
5-2	20220529	14:00-15:00	19-1	20220612	14:00-15:39
6-1	20220530	10:30-11:30	19-2	20220612	14:00-15:39
6-2	20220530	10:30-11:30	20-1	20220613	14:09-15:48
7-1	20220530	14:00-15:00	20-2	20220613	14:09-15:48
7-2	20220530	14:00-15:00	21-1	20220614	12:45-14:24

8-1	20220601	9:30-10:30		21-2	20220614	12:45-14:24
8-2	20220601	9:30-10:30		22-2	20220615	19:05-20:50
9-1	20220602	10:25-11:35		22-2	20220615	19:05-20:50
9-2	20220602	10:25-11:35		23-1	20220616	13:00-14:39
10-1	20220603	10:25-11:35		23-2	20220616	13:00-14:39
10-2	20220603	10:25-11:35		24-1	20220620	15:50-17:29
11-1	20220604	14:30-16:09		24-2	20220620	15:50-17:29
11-2	20220604	14:30-16:09		25-1	20220621	15:00-16:20
12-1	20220605	13:30-14:00		25-2	20220621	15:00-16:20
12-2	20220605	13:30-14:00		26-1	20220622	15:00-16:20
13-1	20220606	0:00-1:30		26-2	20220622	15:00-16:20
13-2	20220606	0:00-1:30				

Table 11. Sampling records - copper plates

No.	DATE	TIME (UTC)		No.	DATE	TIME (UTC)
BOX1						
A1	20220520	afternoon		K2	20220602	10:25-11:35
A2	20220520	afternoon		K3	20220602	10:25-11:35
A3	20220520	20:30-21:30		K4	20220602	14:00-15:00
A4	20220520	20:30-21:30		K5	20220602	14:00-15:00
A5	20220521	9:00-10:00		L1	20220602	16:30-17:40
B1	20220521	9:00-10:00		L2	20220602	16:30-17:40
B2	20220522	9:00-10:00		L3	20220603	0:00-1:10
B3	20220522	9:00-10:00		L4	20220603	0:00-1:10
B4	20220522	14:30-15:30		L5	20220603	11:20-12:30
B5	20220522	14:30-15:30		L6	20220603	11:20-12:30
B6	20220523	0:30-1:30		M1	20220603	14:30-15:50
C1	20220523	0:30-1:30		M2	20220603	14:30-15:50
C2	20220523	16:00-17:00		M3	20220603	18:30-19:40
C3	20220523	16:00-17:00		M4	20220603	18:30-19:40
C4	20220524	0:30-1:30		M5	20220604	0:00-1:20
C5	20220524	0:30-1:30		N1	20220604	0:00-1:20
D1	20220524	9:00-10:00		N2	20220604	10:30-11:40
D2	20220524	9:00-10:00		N3	20220604	10:30-11:40
D3	20220525	10:00-11:00		N4	20220604	11:30-12:50
D4	20220525	10:00-11:00		N5	20220604	11:30-12:50
D5	20220525	14:00-15:00		N6	20220604	14:30-15:50
D6	20220525	14:00-15:00		O1	20220604	14:30-15:50
E1	20220526	0:30-1:30		O2	20220604	18:30-19:50
E2	20220526	0:30-1:30		O3	20220604	18:30-19:50
E3	20220526	10:00-11:00		O4	20220605	0:30-1:50
E4	20220526	10:00-11:00		O5	20220605	0:30-1:50
E5	20220526	19:00-20:00		P1	20220605	13:30-14:50
F1	20220526	19:00-20:00		P2	20220605	13:30-14:50

F2	20220527	9:00-10:00		P3	20220605	19:00-20:20
F3	20220527	9:00-10:00		P4	20220605	19:00-20:20
F4	20220527	12:30-13:30		P5	20220606	0:00-1:20
F5	20220527	12:30-13:30		P6	20220606	0:00-1:20
F6	20220528	0:30-1:30		Q1	20220606	17:30-18:50
G1	20220528	0:30-1:30		Q2	20220606	17:30-18:50
G2	20220528	12:30-13:30		Q3	20220607	0:30-1:50
G3	20220528	12:30-13:30		Q4	20220607	0:30-1:50
G4	20220529	14:00-15:00		Q5	20220607	10:00-11:20
G5	20220529	14:00-15:00		R1	20220607	10:00-11:20
H1	20220530	10:30-11:30		R2	20220607	14:30-15:50
H2	20220530	10:30-11:30		R3	20220607	14:30-15:50
H3	20220530	14:00-15:00		R4	20220607	18:30-19:50
H4	20220530	14:00-15:00		R5	20220607	18:30-19:50
H5	20220530	14:18-15:30		R6	20220608	0:00-1:20
H6	20220530	14:18-15:30		S1	20220608	0:00-1:20
I1	20220531	14:00-15:10		S2	20220608	8:30-9:50
I2	20220531	14:00-15:10		S3	20220608	8:30-9:50
I3	20220530	0:30-1:30		S4	20220608	13:10-14:30
I4	20220530	0:30-1:30		S5	20220608	13:10-14:30
I5	20220531	10:00-11:00		T1	20220608	14:30-15:05
J1	20220531	10:00-11:00		T2	20220608	14:30-15:05
J2	20220601	9:30-10:40		T3	20220608	18:30-19:50
J3	20220601	9:30-10:40		T4	20220608	18:30-19:50
J4	20220601	14:00-15:40		T5	20220609	0:00-1:20
J5	20220601	14:00-15:40		T6	20220609	0:00-1:20
J6	20220601	19:00-20:10				
K1	20220601	19:00-20:10				
BOX2						
A1	20220609	10:30-11:50		I1	20220614	10:30-11:50
A2	20220609	10:30-11:50		I2	20220614	10:30-11:50
A3	20220609	13:30-14:50		I3	20220614	14:51-16:11
A4	20220609	13:30-14:50		I4	20220614	14:51-16:11
A5	20220609	15:00-16:20		I5	20220614	18:30-19:50
B1	20220609	19:30-20:50		J1	20220614	18:30-19:50
B2	20220609	19:30-20:50		J2	20220614	22:05-23:25
B3	20220609	21:30-22:50		J3	20220614	22:05-23:25
B4	20220610	0:00-1:20		J4	20220615	1:00-2:20
B5	20220610	0:00-1:20		J5	20220615	1:00-2:20
C1	20220610	10:20-11:40		K1	20220615	3:00-4:20
C2	20220610	10:20-11:40		K2	20220615	3:00-4:20
C3	20220610	13:30-14:50		K3	20220615	9:40-11:00
C4	20220610	13:30-14:50		K4	20220615	9:40-11:00
C5	20220610	18:30-19:50		K5	20220615	13:00-14:20
D1	20220610	18:30-19:50		L1	20220615	13:00-14:20
D2	20220611	0:30-1:50		L2	20220615	15:00-16:20
D3	20220611	0:30-1:50		L3	20220615	15:00-16:20

D4	20220611	15:25-16:45		L4	20220615	19:05-20:25
D5	20220611	15:25-16:45		L5	20220615	19:05-20:25
E1	20220611	19:40-21:00		M1	20220615	22:20-23:40
E2	20220611	19:40-21:00		M2	20220615	22:20-23:40
E3	20220612	0:30-1:50		M3	20220616	3:20-4:59
E4	20220612	0:30-1:50		M4	20220616	3:20-4:59
E5	20220612	12:17-13:37		M5	20220616	9:00-10:20
F1	20220612	12:17-13:37		N1	20220616	9:00-10:20
F2	20220612	14:00-15:20		N2	20220616	12:47-14:26
F3	20220612	14:00-15:20		N3	20220616	12:47-14:26
F4	20220613	12:30-1:50		N4	20220619	10:10-11:30
F5	20220613	12:30-1:50		N5	20220619	10:10-11:30
G1	20220613	1:30-2:50		O1	20220620	15:50-17:10
G2	20220613	1:30-2:50		O2	20220620	15:50-17:10
G3	20220613	11:13-12:33		O3	20220620	19:50-21:29
G4	20220613	11:13-12:33		O4	20220620	19:50-21:29
G5	20220613	14:09-15:29		O5	20220621	15:00-16:20
H1	20220613	14:09-15:29		P1	20220621	15:00-16:20
H2	20220613	18:25-19:45		P2	20220622	11:00-12:20
H3	20220613	18:25-19:45		P3	20220622	11:00-12:20
H4	20220614	1:30-2:50		P4	20220622	15:00-16:20
H5	20220614	1:30-2:50		P5	20220622	15:00-16:20

Table 12 Sampling record for filters for microplastic analysis

No.	DATE	Filter Type	FLOW RATE (L/min)	COMMENT
ZSX-16	0520-0521	quartz	16.7	Reykjavik
ZSX-1	0521-0523	quartz	16.7	East Greenland
ZSX-2	0523-0529	quartz	16.7	East-west Greenland
ZSX-3	0529-0607	quartz	16.7	Nuuk\Kangalussaqua\Sisimiut
ZSX-19	0607-0609	quartz	16.7	Open sea
ZSX-20	0609-0612	quartz	16.7	Open sea
ZSX-21	0612-0616	quartz	16.7	Open sea
ZSX-22	616	quartz	16.7	WET
dm-21-52	0616-0617	quartz	16.7	WET
dm-21-53	0619-0623	quartz	16.7	Open sea
ZSX-17	0530-0531	quartz	20	NUUK
ZSX-18	0531-0607	polycarbonate	5	Kangerlussaqua, Sisimiut, Sea ice
dm-21-55	0607-0609	polycarbonate	5	Open sea
dm-21-52	0609-0612	polycarbonate	5	Sea ice
dm-21-61	0613-0614	polycarbonate	5	Open sea; ship emission
dm-21-62	0614-0616	polycarbonate	5	Open sea
ZSX-23	0616-0617	polycarbonate	5	Return open sea; wet
ZSX-25	0620-0623	polycarbonate	5	Return open sea

2.8 Ice-nucleating particle analysis

Mark Tarn, Sarah Barr, Kathleen Thompson, Katherine Bastin

School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, England.

Objectives

- To determine the concentration of ice-nucleating particle (INP) in the ambient air and seawater in the Labrador Sea region, which typically features mixed-phase cloud systems that would be susceptible to the presence of INPs.
- To evaluate sources of the ice-nucleating particle (INP) sources.

Methods

Online measurements

Online measurements were taken from the University of Leeds "IcePod" shipping container-based mobile laboratory situated (O'Sullivan et al., 2018) on the port side of the foredeck of the *RRS Discovery*. A heated total suspended particle (TSP) inlet head (Digitel) and sampling tube that protruded 1 m from the IcePod roof was used to draw aerosol into the IcePod at a flow rate of 33.33 litres per minute (LPM), whereupon a flow splitter (O'Sullivan et al., 2018) was used to direct the aerosol into four instruments: a portable ice nucleation experiment (PINE) chamber (PINE-04, Bilfinger Noell GmbH) at 2 LPM, an aerodynamic particle sizer (APS) spectrometer (Model 3321, TSI) at 5 LPM, a scanning mobility particle sizer (SMPS) spectrometer (Model 3936, TSI) at 3.5 LPM, and a wide issue bioaerosol sensor (WIBS, University of Manchester) at 1.6 LPM, with the remaining 21.23 LPM being drawn through the sampling system via a vacuum pump with a mass flow controller (MFC). The PINE, APS and WIBS were operational from 19th May to 26th June 2022, while the SMPS experienced issues with inlet flows at the start of the cruise and so was operational from 24th May to 26th June 2022. All instruments had their data backed up every 1-2 days as new files.

The PINE chamber (Möhler et al. 2021) measured INP concentrations by drawing ambient air into a chamber and performing an adiabatic expansion to form a cloud, whereupon the number of ice crystals present were detected via an optical particle counter (OPC) to determine the INP concentration. This allowed an ambient INP concentration to be measured approximately every 6 minutes at a nominal temperature of −28 °C. Sampling using the PINE chamber had to be temporarily suspended each day or so for a few hours to allow its inlet to de-ice, and on several occasions the OPC lost communication with the laptop (which may be related to icing of the inlet) to the extent that from several hours to 1-2 days of data were occasionally lost whilst trying to resolve the issue (notably on 21st-22nd May, 27th May, 28th-29th May, 1st June, 6th June, 7th-9th June).

The APS continuously measured total aerosol particle concentrations for particles in the size range of 0.5 to 20 µm with a 20 second time resolution, apart from a 9 hour gap in the data on the morning 30th May when the APS stopped taking measurements after midnight.

The SMPS measured total aerosol particle concentrations near-continuously for particles in the size range of 15 to 661 nm with a 135 second time resolution. However, some of the data may need to be filtered as there were occasional errors, e.g. when the differential mobility analyser (DMA) read as being disconnected when it was not (1st June, 13th-14th June, 17th-18th June), and when the neutraliser was not turned on following a restart of the instrument (24th-29th May, 3rd-5th June, 18th-19th June, 19th-20th June). The flow rates in the SMPS were calibrated at the start of the cruise.

The WIBS measured the concentrations of fluorescent particles that may be biological (e.g., bacteria, spores), although a lack of on-board expertise in the analysis of the WIBS data meant that it would have to be processed by the University of Manchester after the completion of the cruise.

Instances where the online measurements may have been sampling the *RRS Discovery*'s own emissions will be determined at a later date in coordination with the other science parties in order to account for any resultant discrepancies in the data.

Offline INP measurements

Three filter-based aerosol samplers were located on the monkey island of the *RRS Discovery* in order to collect ambient aerosol particles for subsequent INP analysis in the General Purpose Lab. The samplers were connected to the University of Birmingham's Pollution Control System (PCS), which turned the samplers off when either the wind speed dropped below 2 m s^{-1} and/or the wind direction was ~180° relative to the ship in order to ensure that the emissions from the ship's chimney were not being sampled.

The samplers comprised a Digitel DPA14 automated filter changing sampler with a heated TSP inlet head sampling at 33.33 LPM, and two MesaLabs BGI PQ100 samplers with PM_{10} (particulate matter ≤10 μm) inlet heads sampling at 16.67 LPM. Polycarbonate filters (47 mm diameter, 0.4 μm pore size) were used with each of the samplers to collect aerosols. Filters were typically collected on a daily basis (up to 24 hours) using the Digitel DPA14, while filters were typically collected for 1-2 days when using the PQ100 samplers due to their lower flow rates, although in both cases the actual amount of air sampled could be much lower than initially expected depending on when the PCS was on/off (all sampled volumes were later calculated based on the PCS data). An unreliable flow rate with one of the PQ100 samplers resulted in that sampler being used to collect filters to be stored for post-cruise analysis by scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) (Sanchez-Marroquin et al., 2019) in order to characterise the types of particles collected. The remaining PQ100 sampler was thereafter typically used to sample $PM_{2.5}$ (particulate matter ≤2.5 μm) using an insertable size cut-off component.

Filters for INP analysis were collected from the samplers and taken to the General Purpose Lab where they were placed into a centrifuge tube with 4 mL of purified water, then vortexed for 10 min to wash the aerosol particles off the filter and into an aqueous suspension (O'Sullivan et al., 2018). This suspension then underwent a droplet freezing assay using the Microlitre Nucleation by Immersed Particle Instrument (μL-NIPI) technique (Whale et al., 2015), using one of three cold stage instruments set up in the lab. The results of these assays provided INP spectra that provide INP concentrations over a range of droplet freezing temperatures, typically from 0 to −26 °C, thus providing complementary data to the PINE chamber that was measuring continuously at −28 °C. Samples were either analysed the day they were collected or the following day. Samples that showed a high level of ice-nucleating activity were further assessed by repeated testing and by performing a heat test (Daily et al., 2022): an aliquot of suspension was placed in boiling water for 30 min and then retested on the μL-NIPI, whereupon a loss of ice-nucleating activity could be a potential indication that the INPs in the sample were proteinaceous (i.e. biological) in origin. All samples were stored in the freezer following their analysis for future testing if required.

The µL-NIPI instruments were tested every morning by performing a droplet freezing assay on purified water “blanks” to ensure that they were performing appropriately and that no contamination was being introduced by the water (the same water used to prepare the aqueous suspensions from the filters) or from the lab air. “Handling blanks” were also performed with each sampler at occasional intervals by setting a filter up in the sampler and then removing it without drawing any air through it. Subsequent droplet freezing analysis of these handling blanks thus demonstrated whether any contamination was introduced by the preparation and handling of the filters.

An optical particle counter (OPC) (OPC-N3, AlphaSense) was located next to the filter samplers on the monkey island during the cruise to monitor aerosol concentrations at that location. For most of the cruise, the OPC was connected to the PCS and so switched off alongside the samplers whenever the PCS activated. From 9th to 15th June the OPC was disconnected from the PCS and allowed to run near-continuously, but developed a fault shortly after the 15th June and no new data was obtained thereafter.

On 2nd June (Ikkamuit fjord) and 4th June (Sisimuit bay), an impinger (Coriolis µAir, Bertin Instruments) was used to sample aerosol particles directly into water at a high flow rate of 300 LPM for 1.5-2 hours. These water samples were then analysed using the µL-NIPI technique to generate INP spectra.

A further droplet freezing assay instrument was set up in the General Purpose Lab, the Lab-on-a-Chip Nucleation by Immersed Particle Instrument (LOC-NIPI) (Tarn et al., 2020), which can extend the INP spectra down to homogeneous freezing (around −35 °C), but this instrument encountered problems with droplet productions whenever the ship rolled to starboard due to the high-density oil used in it. The instrument was thus deemed unusable on the ship without a gyroscopic gimble stabilisation system to keep it level, hence no data was collected on this cruise using the LOC-NIPI.

Offline size-resolved INP measurements

To try to determine what size ranges any INPs in the region might be in, a cascade impactor (Sioutas, SKC) with a portable pump (Leland Legacy, SKC) was mounted on the foremast for periods of 2-3 days, sampling at 9 LPM in order to capture size-segregated aerosol particles onto a series of polycarbonate filters (25 mm diameter, 0.05 µm pore size) (Porter et al., 2020). The filters were washed with 3 mL water in a sample tube to form a suspension, similar to the other offline filter analysis methods, for droplet freezing analysis via the µL-NIPI to generate INP spectra for the particle size ranges: 0.25-0.5 µm, 0.5-1.0 µm, 1.0-2.5 µm, 2.5-10 µm. All samples were stored in a freezer following their analysis for any future testing should it be required.

An OPC (OPC-N3, AlphaSense) was located next to the cascade impactor on the foremast in order to monitor the aerosol concentrations during each sampling period.

Offline seawater measurements

INP concentrations in the seawater were measured by collecting twice daily (typically around 9:30 and 14:30) samples from the underway seawater supply of the *RRS Discovery*, at a water depth of 5.5 m. Samples were filtered through a 0.22 µm syringe filter and then a droplet freezing analysis performed via the µL-NIPI technique. Highly ice nucleation active samples were also heat tested as described for the offline filter analysis, and some samples were analysed both filtered and unfiltered. A further 8 samples of surface seawater were collected in the bay of Sisimuit (4th June) from the rescue boat while the rescue boat was being tested. A further 16 samples were collected from the rescue boat during another boat testing day white at the sea ice edge (8th June): 8 samples on a transect north-to-south down the sea ice edge, and then 8 samples west-to-east from the sea ice edge. All samples were stored in a freezer following their analysis for any future testing should it be required.

Provisional Results

Online measurements

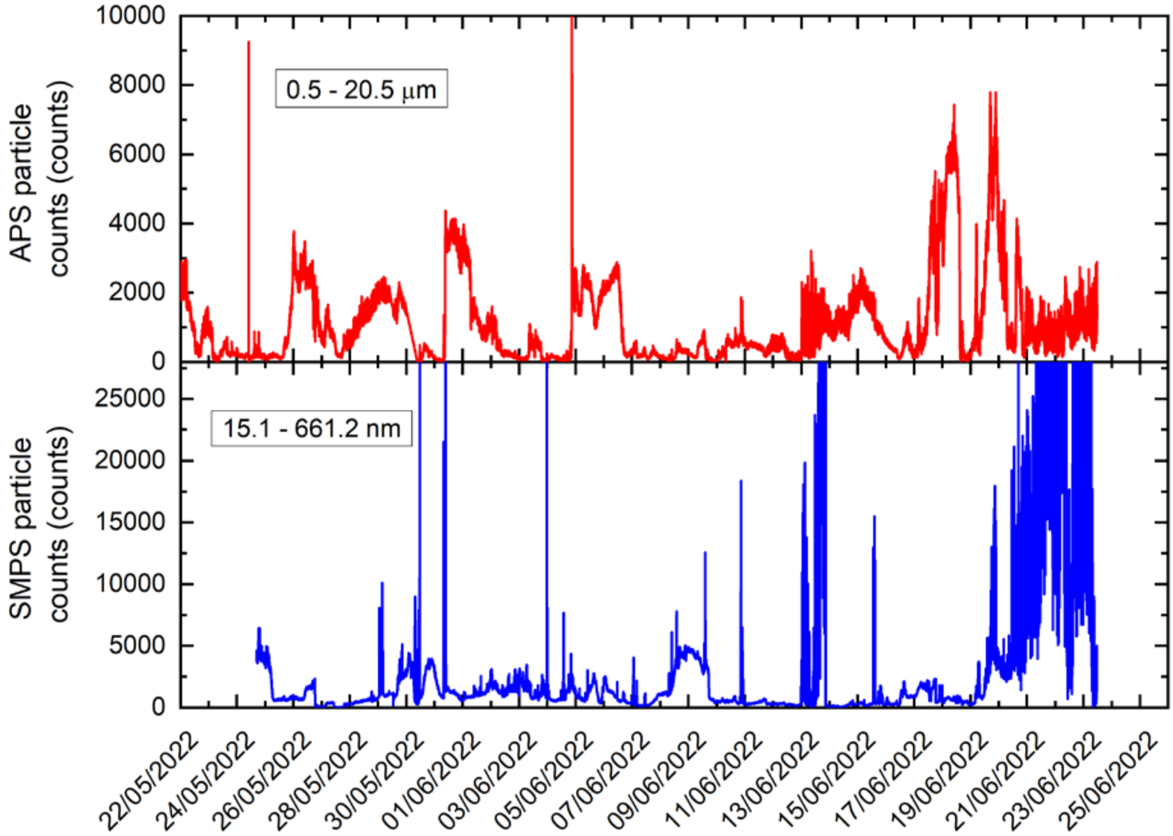


Figure 11. Measurements of aerosol particles throughout the DY151 cruise, with the APS (top) measuring particles in the 0.5-20.5 µm size range and the SMPS (bottom) measuring in the 15.1-661.2 nm size range. Some of the SMPS data will need to be filtered due to the occurrence of errors for some sections of the cruise.

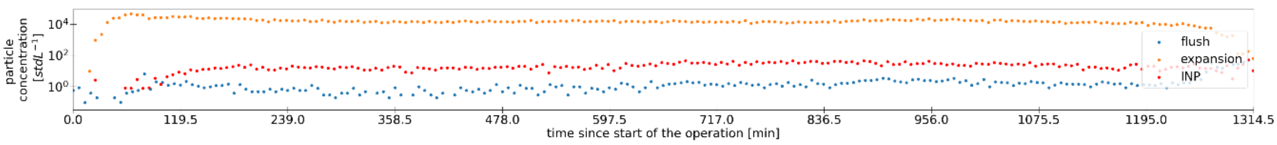


Figure 12. Example of ice-nucleating particle (INP) concentrations measured in the ambient air using the Portable Ice Nucleation Experiment (PINE) chamber (16th June 2022). INP concentrations were measured isothermally at −28 °C.

Offline INP measurements

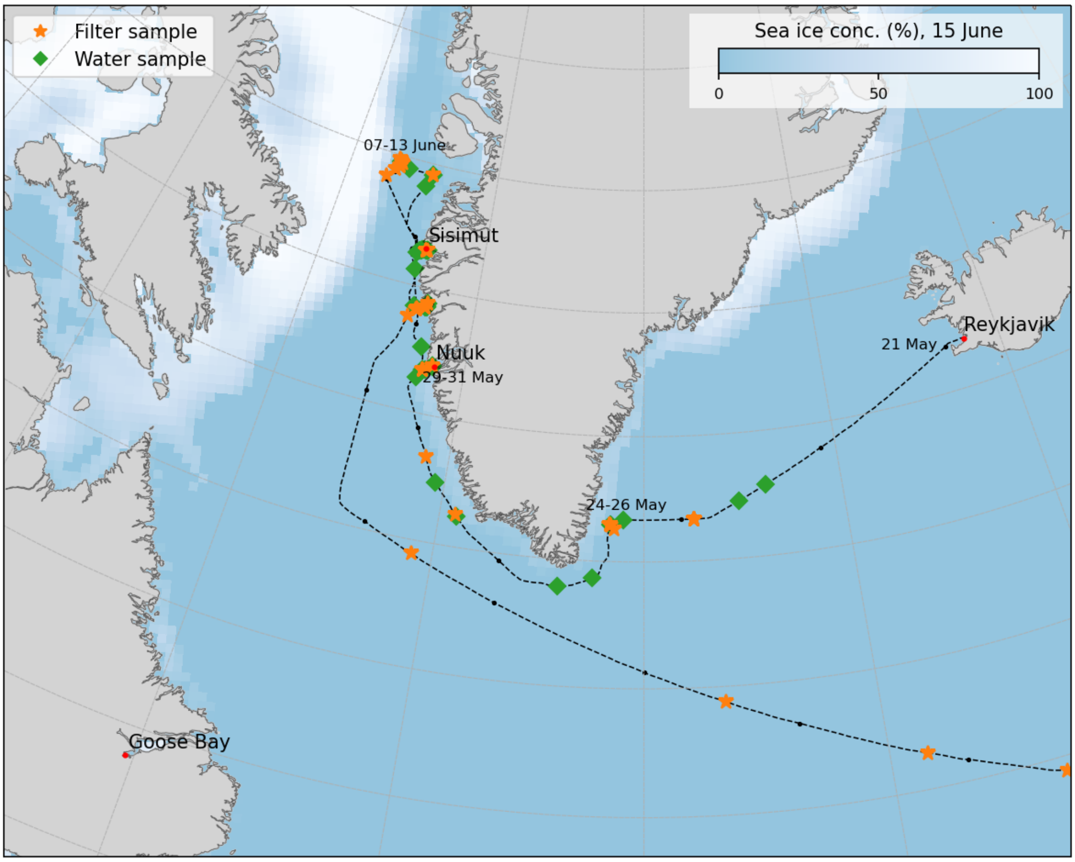


Figure 13. Location of start of each filter sample (orange) and seawater sample (green), along with the ship track and sea ice concentration (as of 15th June). Details of samples shown are in Table 13-15.

Table 13. Start time, end time and location of all filters collected from samplers located on the monkey island of RRS Discovery. Final sampling time and resulting sampling volume will be corrected to account for times when instruments were paused due to the PCS.

D	Start time	End time	Sampler	Inlet	Start LAT	Start LON	End LAT	End LON
1	22/05/2022 15:52	23/05/2022 15:52	MesaB	PM10	61.271332	-35.640769	60.883606	-41.627401
2	22/05/2022 15:52	23/05/2022 15:52	Digitel	TSP	61.271332	-35.640769	60.883606	-41.627401
3	23/05/2022 17:59	24/05/2022 12:34	Digitel	TSP	60.88188	-41.631735	60.88653	-41.654677
4	24/05/2022 13:16	25/05/2022 10:34	MesaB	PM10	60.891323	-41.652616	60.8587	-41.602583
5	24/05/2022 18:07	25/05/2022 10:34	Digitel	TSP	60.784462	-41.420751	60.8587	-41.602583
6	25/05/2022 11:10	25/05/2022 20:04	Digitel	TSP	60.856731	-41.617718	60.836543	-41.653995

7	27/05/2022 18:53	28/05/2022 09:24	MesaB	PM10	61.993981	-51.163544	63.821602	-52.603679
8	27/05/2022 09:45	28/05/2022 09:28	Digitel	TSP	60.800705	-49.298684	63.830049	-52.591736
9	28/05/2022 13:49	29/05/2022 09:45	Digitel	TSP	64.050486	-52.291163	64.050447	-52.291273
10	28/05/2022 13:46	29/05/2022 19:06	MesaB	PM10	64.050494	-52.291187	64.043408	-52.321322
11	29/05/2022 19:06	30/05/2022 11:55	Digitel	TSP	64.043408	-52.321322	64.177183	-51.79746
12	29/05/2022 19:52	31/05/2022 09:18	MesaB	PM10	64.04339	-52.32121	64.070077	-52.10798
13	01/06/2022 07:30	02/06/2022 08:30	Digitel	TSP	65.540559	-52.930716	65.634739	-52.806174
14	01/06/2022 07:35	02/06/2022 09:49	MesaB	PM10	65.544576	-52.912453	65.64789	-52.800547
15	02/06/2022 12:59	03/06/2022 06:00	Digitel	TSP	65.647963	-52.800094	65.647956	-52.800855
16	02/06/2022 10:42	03/06/2022 09:49	MesaB	PM2.5	65.647885	-52.800392	65.57037	-53.806593
17	03/06/2022 19:07	04/06/2022 20:07	Digitel	TSP	66.904001	-53.650617	66.898616	-53.569168
18	03/06/2022 19:11	04/06/2022 20:28	MesaB	PM2.5	66.902432	-53.616665	66.905428	-53.685372
19	04/06/2022 20:10	04/06/2022 20:32	Digitel	TSP	66.898652	-53.57794	66.905428	-53.685372
20	05/06/2022 11:39	06/06/2022 10:49	MesaB	PM2.5	68.740303	-54.37097	68.738346	-54.436386
21	05/06/2022 16:48	06/06/2022 10:49	Digitel	TSP	68.740366	-54.370789	68.738346	-54.436386
22	07/06/2022 11:14	08/06/2022 11:14	Digitel	TSP	68.831015	-56.616099	68.895476	-56.857087
23	08/06/2022 11:14	09/06/2022 11:14	Digitel	TSP	68.895476	-56.857087	68.721115	-56.732083
24	08/06/2022 18:54	11/06/2022 09:25	MesaB	PM2.5	68.88458	-56.799081	68.639475	-56.986706
25	09/06/2022 20:08	10/06/2022 20:08	Digitel	TSP	68.720809	-56.731518	68.74246	-56.292721
26	11/06/2022 13:32	12/06/2022 13:32	Digitel	TSP	68.639471	-56.986715	68.425823	-57.441156
27	11/06/2022 13:35	12/06/2022 22:14	MesaB	PM2.5	68.639465	-56.986699	68.36447	-57.410336
28	12/06/2022 13:32	13/06/2022 11:44	Digitel	TSP	68.425823	-57.441156	66.853403	-54.648338
29	13/06/2022 20:43	15/06/2022 19:14	MesaB	PM2.5	65.445191	-53.401843	65.322584	-53.723479
30	13/06/2022 20:47	14/06/2022 05:47	Digitel	TSP	65.445191	-53.401843	65.440414	-53.426052
31	14/06/2022 05:48	15/06/2022 16:56	Digitel	TSP	65.440237	-53.427176	65.317581	-53.753135
32	16/06/2022 09:18	17/06/2022 09:18	Digitel	TSP	65.266803	-53.760566	61.660037	-54.99411

33	18/06/2022 10:20	19/06/2022 10:20	Digitel	TSP	59.679941	-51.017118	58.142081	-43.526214
34	21/06/2022 18:27	23/06/2022 10:22	MesaB	PM10	54.843062	-28.492543	52.338729	-17.870088
35	22/06/2022 13:00	23/06/2022 12:00	Digitel	TSP	53.658983	-23.320991	52.231095	-17.428956
36	23/06/2022 10:43	23/06/2022 11:13	MesaB	PM10	52.310933	-17.761413	52.278447	-17.628222

Size-resolved INP spectra

Table 14. Start time, end time and location of filters collected using the SKC multistage cascade impactors located on the foremast of *RRS Discovery*. Note: Each sample run consists of 4 separate filters sampled concurrently (further details outline in methods section above)

ID	Start TIME	End TIME	Sampler	Start lat	Start lon	End lat	End lon
1	21/05/2022 17:35	22/05/2022 12:52	Impactor	62.86518	-28.6574	61.48136	-34.7347
2	21/05/2022 17:35	22/05/2022 12:52	Impactor	62.86518	-28.6574	61.48136	-34.7347
3	22/05/2022 16:30	N/A	Impactor	61.22582	-35.8375	N/A	N/A
4	24/05/2022 13:37	25/05/2022 20:20	Impactor	60.88805	-41.6665	60.83799	-41.6554
5	28/05/2022 12:57	29/05/2022 08:57	Impactor	64.05048	-52.2912	64.05047	-52.2909
6	30/05/2022 11:28	31/05/2022 07:28	Impactor	64.17737	-51.7969	64.1772	-51.7975
7	01/06/2022 07:43	03/06/2022 08:55	Impactor	65.5507	-52.8792	65.5019	-53.4825
8	03/06/2022 18:49	04/06/2022 20:36	Impactor	66.90861	-53.7563	66.90712	-53.7142
9	07/06/2022 11:18	09/06/2022 10:48	Impactor	68.8322	-56.6259	68.72115	-56.7319
10	09/06/2022 10:55	12/06/2022 12:44	Impactor	68.72116	-56.732	68.43167	-57.4086
11	14/06/2022 11:06	15/06/2022 19:21	Impactor	65.44447	-53.3792	65.32268	-53.7229

Offline seawater measurements

Table 15. Time and location of all seawater samples collected from the underway seawater supply of the RRS Discovery

ID	time	LAT	LON	Fluorescence (volt)	Salinity (PSU)	Temp (^{o}C)	Comments
1	22/05/2022 09:46	61.700055	-33.802324	0.425700009	34.84690094	6.451200008	North Atlantic
2	22/05/2022 14:22	61.373611	-35.20778	0.162699997	34.84889984	5.788099766	North Atlantic
3	23/05/2022 09:03	61.000777	-41.001008	0.137600005	34.8932991	5.512800217	North Atlantic
4	23/05/2022 14:41	60.878983	-41.627513	0.265199989	33.86289978	2.446700096	East of Greenland
5	25/05/2022 10:04	60.860802	-41.586525	NaN	33.9510994	2.476999998	East of Greenland
6	26/05/2022 09:08	59.60227	-42.425802	NaN	34.17449951	3.699700117	Greenland Peninsula
7	26/05/2022 14:43	59.346446	-44.007754	0.376899987	33.6629982	1.849699974	Greenland Peninsula
8	27/05/2022 09:05	60.724612	-49.14232	1.15260005	32.86050034	-0.0117	S-W Greenland
9	27/05/2022 14:48	61.448089	-50.462884	0.424800009	32.98320007	0.399800003	S-W Greenland
10	28/05/2022 09:32	63.834302	-52.585485	0.373800009	33.54079819	1.063300014	S-W Greenland
11	28/05/2022 14:35	64.050447	-52.291163	0.1778	33.44530106	1.149799943	Off-Nuuk
12	29/05/2022 11:20	64.050472	-52.29122	0.177900001	33.44449997	1.199599981	Off-Nuuk
13	29/05/2022 15:49	64.044762	-52.315496	0.189700007	33.4612999	1.246500015	Off-Nuuk
14	30/05/2022 09:10	64.156048	-51.808217	0.400200009	33.22969818	1.617900014	Fjord
15	30/05/2022 12:08	64.177186	-51.797463	0.263200015	33.23350143	1.572600007	Nuuk Fjord
16	30/05/2022 14:35	64.177184	-51.797468	0.338	33.02510071	2.547199965	Nuuk Fjord
17	30/05/2022 19:00	64.177202	-51.797064	0.48969999	33.13140106	2.225500107	Nuuk Fjord
18	31/05/2022 07:39	64.177194	-51.7975	NaN	33.07369995	2.125699997	Nuuk Fjord
19	31/05/2022 09:27	64.06119	-52.141127	NaN	33.42779922	1.438500047	Nuuk Fjord
20	31/05/2022 15:42	64.584504	-52.619187	0.256500006	33.42969894	1.902400017	West of Greenland
21	01/06/2022 07:27	65.538045	-52.94195	0.228	33.29729843	2.648000002	Ikkamiut Fjord
22	01/06/2022 09:01	65.557709	-52.84172	0.132799998	33.35580063	2.128299952	Ikkamiut Fjord
23	01/06/2022 14:42	65.584568	-52.838605	0.1175	33.34280014	2.998300076	Ikkamiut Fjord
24	01/06/2022 18:37	65.584581	-52.838604	0.128600001	33.14189911	2.825500011	Ikkamiut Fjord
25	02/06/2022 09:22	65.647893	-52.800546	0.190899998	33.26229858	3.162400007	Tunu

26	02/06/2022 12:07	65.647897	-52.800391	0.108000003	33.02159882	4.004300117	Tunu
27	02/06/2022 14:24	65.64809	-52.799978	0.161699995	33.34759903	2.778800011	Tunu
28	03/06/2022 09:10	65.527375	-53.563713	0.284299999	33.50260162	1.782799959	West of Greenland
29	03/06/2022 15:00	66.408745	-54.042305	0.224900007	33.75910187	1.958299994	West of Greenland
30	03/06/2022 17:30	66.804099	-54.215462	0.2368	33.4518013	0.864400029	Sisimuit Transect
31	03/06/2022 18:00	66.85378	-54.062737	0.248899996	33.56159973	1.449300051	Sisimuit Transect
32	03/06/2022 18:16	66.877896	-53.969378	NaN	33.61940002	1.647300005	Sisimuit Transect
33	03/06/2022 18:30	66.898391	-53.890247	0.290499985	33.60630035	2.239900112	Sisimuit Transect
34	03/06/2022 18:45	66.908769	-53.791965	0.203199998	33.55270004	2.804699898	Sisimuit Transect
35	03/06/2022 19:00	66.905532	-53.686033	0.118100002	33.33670044	3.248800039	Sisimuit Transect
36	03/06/2022 19:15	66.90136	-53.586445	0.140200004	33.49509811	2.724999905	Sisimuit Transect
37	03/06/2022 19:30	66.900439	-53.564822	NaN	33.54299927	2.115400076	Sisimuit Transect
38	04/06/2022 11:04	66.898576	-53.569987	0.294	33.42440033	2.671900034	Sisimuit Fjord
39	04/06/2022 12:57	66.898575	-53.569975	0.251800001	33.39099884	2.614000082	Sisimuit Fjord
40	04/06/2022 16:58	66.898437	-53.568995	0.307500005	33.47850037	2.294399977	Sisimuit Fjord
41	04/06/2022 18:51	66.898417	-53.569019	0.1131	33.15370178	5.921000004	Sisimuit Fjord
46	05/06/2022 09:00	68.433867	-54.698597	NaN	33.19010162	0.937099993	East of Greenland
47	05/06/2022 14:38	68.740442	-54.370669	0.093099996	33.33720016	2.454099894	East of Greenland
42	06/06/2022 09:00	68.74034	-54.370845	0.093099996	33.33890152	2.015599966	East of Greenland
44	06/06/2022 09:12	68.740341	-54.370839	0.093199998	33.3390007	1.995100021	East of Greenland
43	06/06/2022 14:38	68.739743	-56.020837	NaN	33.30149841	-0.187999994	East of Greenland
45	06/06/2022 14:46	68.739703	-56.076722	0.2588	33.2961998	-0.221200004	East of Greenland
48	07/06/2022 09:17	68.847685	-56.733581	0.386500001	33.1167984	-0.497000009	At the sea ice
49	07/06/2022 16:17	68.802288	-56.727139	NaN	33.14569855	-0.0125	At the Sea Ice
50	08/06/2022 14:39	68.887423	-56.737163	0.341899991	33.04410172	-0.425300002	At the Sea Ice
51	09/06/2022 09:34	68.721274	-56.731897	0.149100006	32.97000122	0.511200011	At the Sea Ice

52	09/06/2022 14:47	68.721025	-56.730801	0.091200002	33.00510025	1.340999961	At the Sea Ice
53	10/06/2022 09:35	68.693723	-56.648801	0.129899994	33.06129837	0.961199999	At the Sea Ice
54	10/06/2022 14:32	68.693759	-56.64866	0.093199998	33.00149918	1.082000017	At the Sea Ice
55	11/06/2022 11:13	68.639472	-56.986714	0.131200001	32.66650009	-0.0726	At the Sea Ice
56	11/06/2022 14:33	68.639467	-56.986715	NaN	32.67300034	0.400000006	At the Sea Ice
57	13/06/2022 10:41	66.948055	-54.351411	NaN	33.32099915	1.190099955	W of Greenland, Sbound
58	13/06/2022 14:31	66.461742	-54.127294	0.257999986	33.66360092	1.986199975	W of Greenland, Sbound
59	13/06/2022 16:31	66.129295	-53.9041	0.1743	33.48619843	2.308599949	West of Greenland
60	14/06/2022 12:37	65.447174	-53.359609	NaN	33.52080154	2.174400091	Off-Ammaqqoq
61	14/06/2022 14:30	65.449405	-53.342378	0.225799993	33.52730179	2.256500006	Off-Ammaqqoq
62	15/06/2022 10:41	65.446503	-53.356531	0.238299996	33.54930115	2.261899948	Off-Ammaqqoq
63	15/06/2022 14:29	65.319701	-53.741025	0.100400001	33.55400085	2.566200018	South Labrador
64	16/06/2022 08:54	65.316429	-53.708103	0.128600001	33.54790115	2.732800007	South Labrador
65	16/06/2022 14:45	64.648351	-54.155087	0.128199995	33.53319931	2.346400023	South Labrador
66	17/06/2022 14:48	60.877897	-55.001529	0.1382	33.78229904	4.710000038	South Labrador
67	18/06/2022 09:09	59.730468	-51.293469	NaN	34.12070084	3.839600086	Atlantic
68	19/06/2022 14:00	57.925629	-42.4732	0.245100006	34.81349945	5.386000156	Atlantic
69	20/06/2022 14:32	56.551809	-36.106408	0.131099999	34.79629898	8.152500153	Atlantic
70	21/06/2022 14:19	55.088883	-29.619315	NaN	34.87260056	10.99349976	Atlantic
71	22/06/2022 14:34	53.563911	-22.924484	0.187199995	35.3022995	13.28059959	Atlantic
72	23/06/2022 11:48	52.243836	-17.482272	0.0757	0.047800001	13.85369968	Atlantic

References

Daily, M. I., Tarn, M. D., Whale, T. F., Murray, B. J., 2022. An evaluation of the heat test for the ice-nucleating ability of minerals and biological material. Atmos. Meas. Tech., 15, 2635-2665.

Möhler, O., Adams, M., Lacher, L., Vogel, F., Nadolny, J., Ullrich, R., Boffo, C., Pfeuffer, T., Hobl, A., Weiß, M., Vepuri, H. S. K., Hiranuma, N., Murray, B. J., 2021. The Portable Ice Nucleation Experiment (PINE): a new online instrument for laboratory studies and automated long-term field observations of ice-nucleating particles. Atmos. Meas. Tech., 14, 1143-1166.

Porter, G. C. E., Sikora, S. N. F., Adams, M. P., Proske, U., Harrison, A. D., Tarn, M. D., Brooks, I. M., Murray, B. J. 2020. Resolving the size of ice-nucleating particles with a balloon deployable aerosol sampler: the SHARK. Atmos. Meas. Tech., 13, 2905-2921.

Sanchez-Marroquin, A., Hedges, D. H. P., Hiscock, M., Parker, S. T., Rosenberg, P. D., Trembath, J., Walshaw, R., Burke, I. T., McQuaid, J. B., Murray, B. J., 2019. Characterisation of the filter inlet system on the FAAM BAe-146 research aircraft and its use for size-resolved aerosol composition measurements. Atmos. Meas. Tech., 12, 5741-5763.

O'Sullivan, D., Adams, M. P., Tarn, M. D., Harrison, A. D., Vergara-Temprado, J., Porter, G. C. E., Holden, M. A., Sanchez-Marroquin, A., Carotenuto, F., Whale, T. F., McQuaid, J. B., Walshaw, R., Hedges, D. H. P., Burke, I. T, Cui, Z., Murray, B. J., 2018. Contributions of biogenic material to the atmospheric ice-nucleating particle population in North Western Europe. Sci. Rep., 8, 13821.

Tarn, M. D., Sikora, S. N. F., Porter, G. C. E., Wyld, B. V., Alayof, M., Reicher, N., Harrison, A. D., Rudich, Y., Shim, J.-U., Murray, B. J., 2020. On-chip analysis of atmospheric ice-nucleating particles in continuous flow. Lab Chip, 20, 2889-2910.

Whale, T. F., Murray, B. J., O'Sullivan, D., Wilson, T. W., Umo, N. S., Baustian, K. J., Atkinson, J. D., Workneh, D. A., Morris, G. J., 2015. A technique for quantifying heterogeneous ice nucleation in microlitre supercooled water droplets. Atmos. Meas. Tech., 8, 2437-2447.

Acknowledgements

We wish to thank the captain and the crew of the *RRS Discovery*, and the National Marine Facility (NMF) team for their support during the DY151 cruise. We also thank the rest of the science team for their help, discussions and cooperation throughout the campaign.

2.9 Ozone, NO_x, NO_y, CO and SO_2

Anna Callaghan

Wolfson Atmospheric Chemistry Observatory (WACL), University of York

Objectives

- To determine climate relevant gases (O_3, NO_x, NO_y, CO and SO_2) in order to better understand chemical processes over the Arctic and North Atlantic Oceans
- To collect a dataset of climate relevant gases to be used in climate models to improve our predictions of the effect an increase in emissions in this region will have

Method

The instruments and inlet setup are pictured below in figures 14 and 15. O_3 was measured using a Thermo 49iq ozone analyser. Two Teledyne T200UP instruments were used, one to measure NO_x and one, fitted with a Molybdenum NO_y converter at the inlet, to measure NO_y. The NO_x instrument was zeroed for 10 minutes every 23 hours and a 100 ppb gas cylinder of NO in N_2 was used roughly once a week during the cruise to check the sensitivity of both T200UP instruments. CO was detected using an AL5005 Aerolaser, which was calibrated and zeroed automatically every 23 hours. Lastly, a Teledyne T101 analyser was used to measure SO_2. This instrument was also zeroed automatically once a day, on the same cycle as the T200UP instruments. All the instruments were located inside the BAS container for the duration of the cruise, with the BAS container itself placed on the foredeck. The inlets for all the instruments were on the roof of the BAS container. As mentioned above, one of the T200UP instruments was connected to an NO_y converter, which was placed at the inlet on the roof of the BAS container.

The two T200UP instruments and the CO instruments used external pumps, with the T200UP pumps pulling roughly 1000 cc/min and the CO pump for collecting the sample pulling roughly 800 cc/min, whereas the CO pump for the CO_2 in Ar and N6 N_2 was pulling roughly 200 cc/min. The O_3 analyser and the SO_2 analyser used internal pumps.

Measurements were recorded almost continually from 23rd May to 22nd June for NO_x, NO_y and CO and until 23rd June for O_3 and SO_2. The time resolution on these measurements was 10 seconds.

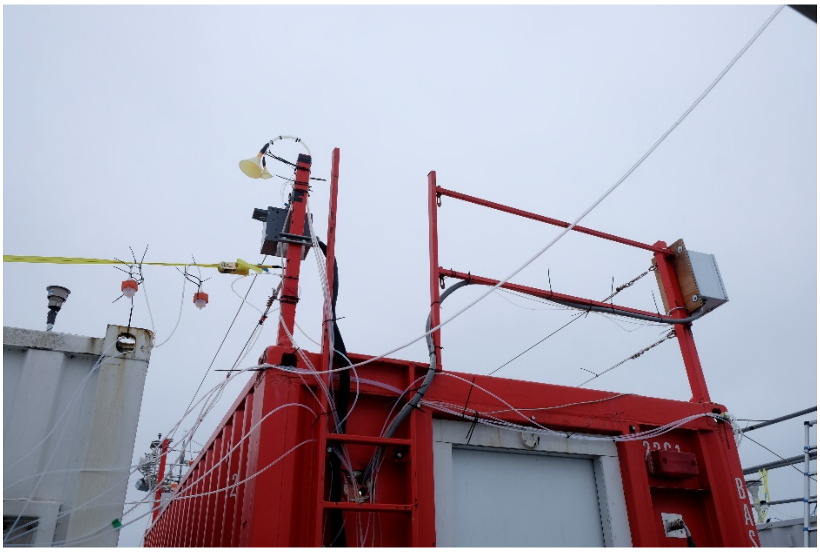


Figure 14. Photograph of the O_3, NO_x , SO_2 and CO inlets on the left (covered by the big and small funnel) and the NO_y converter box on the right of the roof of the BAS container.

Figure 15. The rack of instruments used during the cruise. The O_3 analyser is missing from this photograph as it was held in a different rack.

Provisional Results

Figure 16 shows the timeseries of different chemical species for the SEANA cruise. The calibrations have been applied to the CO data by Katie Read and zeroes have been applied to the NO (-0.036) and NO_2 (-0.135) data. This was done by filtering any unsuitable zero cycles (cycles taken when there were measurement or instrumental issues) and taking the average of each cycle. The large spike seen on 13th June is due to the ship stack being blown towards the inlet the whole day due to wind direction and the ship's heading, as well as fumes from a fire that occurred in the crew's laundry on 3rd June being vented.

Figure 17 above shows the timeseries from the SEANA cruise filtered to remove any instances when there was a possibility that the ship stack had been sampled rather than the background atmosphere. This was done by looking at the relative wind direction and removing data when this value was between 157.5 ° and 202.5 °, which removed all situations when there was a tailwind and therefore the ship stack was being blown towards the containers, which were on the foredeck. As well as the wind direction, the wind speed was also examined and situations when it was below 2 ms^{-1} were also filtered out, to remove all times when low wind speeds resulted in the possibility of sampling the ship stack.

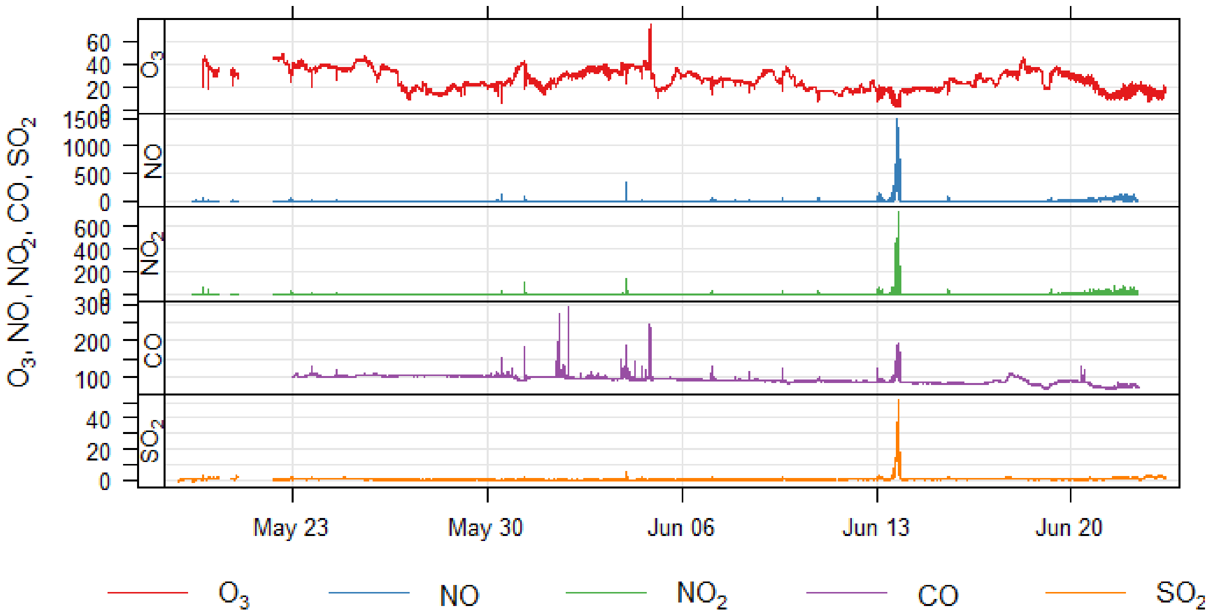


Figure 16. Timeseries of O_3, NO, NO_2, NO_y, CO and SO_2

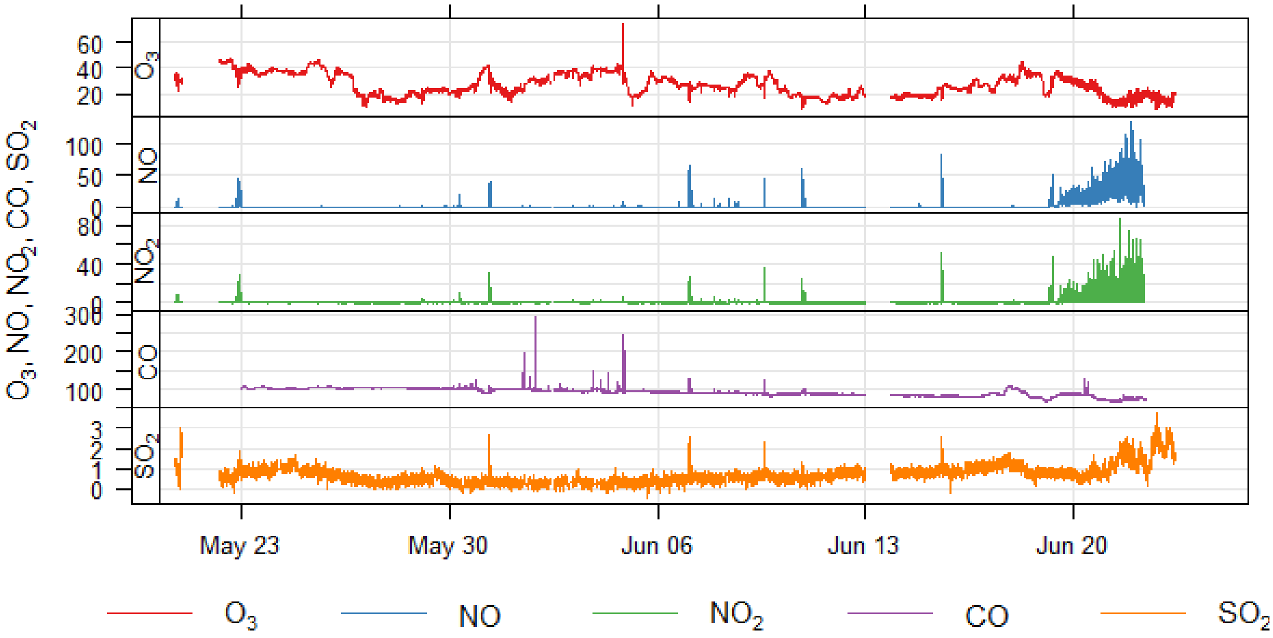


Figure 17. Timeseries shown in figure 16, filtered to remove any instances when wind speed or direction indicated that there was a risk of sampling the ship's stack.

2.10 Measurements of trave-level Sulfur Dioxide using a highly sensitive laser-induced fluorescence system

Loren Temple
Wolfson Atmospheric Chemistry Laboratories (WACL), University of York

Objectives

- To demonstrate the new University of York LIF-SO_2 instrument for low ppt level measurements of sulfur dioxide (SO_2)
- To quantify ambient SO_2 concentrations in the Arctic for comparison with models, and provide a baseline pre-shipping dataset.
- To provide a unique constraint on our understanding of new particle formation and growth in the marine arctic atmosphere.
- To investigate the sources of SO_2, in particular the relationship between SO_2 and dimethyl sulfide (DMS), looking at areas of both high and low phytoplankton levels.

Method

The University of York LIF-SO_2 instrument is a custom-built system for the highly sensitive detection of SO_2 via laser-induced fluorescence, and is based on the system originally demonstrated by Rollins et al. (2016). The basic operating principle is the excitation of SO_2 at 216.9 nm, generated from the fifth harmonic of a custom-built tuneable fibre-amplified semiconductor diode laser system at 1084.5 nm, and the subsequent detection of the resultant fluorescence photons. The laser wavelength is rapidly (~10 Hz) tuned on and off a strong SO_2 transition, with the difference between these signals being directly proportional to the SO_2 concentration within the sample cell. The laser wavelength is tracked using a reference cell containing a known SO_2 concentration. Both the measurement and reference cells are operated at low pressure (~500 mbar) in order to maximise the SO_2 fluorescence lifetime. Multi-point calibrations are performed across the expected concentration range approximately every 3 hours, although this frequency is varied as required, in order to ensure the instrument sensitivity is well characterised. During the SEANA deployment, the LIF-SO_2 instrument had a 3σ limit of detection of 16 pptv at a 10-minute averaging time.

As the York LIF-SO_2 only made its first ambient measurements in April 2022, the SEANA deployment was a crucial learning experience for the operation of the instrument in the field. The instrument (Fig.18 left) was located in the BAS container on the foredeck. The instrument inlet (Fig.18 right) was located on the roof of the container, and a critical orifice was used to drop the pressure in the ~10 m inlet line in order to minimise wall effects. Calibrations were performed both at the tip of the inlet and immediately before entering the instrument in order to quantify any inlet effects. As the LIF-SO_2 had previously not been operated for a prolonged period of time, or in such challenging conditions, there were many issues impacting data coverage. These were primarily due to a laser failure early in the cruise, and complications optimising the spare laser that was brought in case of this eventuality. Overall, the LIF-SO_2 obtained over 2 weeks of data during the cruise, which is viewed as a major success given the new nature of the instrument and the limited testing of such a complex custom-built system prior to the deployment.

Figure 18. Photographs of the LIF-SO_2 instrument in the rack (left) and the SO_2 inlet on the roof of the BAS container (right), covered by an orange funnel (marked with an arrow).

Provisional Results

Figure 19 shows a preliminary time series of the LIF-SO_2 data (red) compared with the SO_2 measurement made by the commercial Teledyne fluorescence instrument (see cruise report by Callaghan). The preliminary LIF-SO_2 data shown is yet to have final calibrations and an observed zero correction (of the order of approximately -40 pptv) applied. This preliminary data does, however, show the significant benefits of the LIF-SO_2 for measuring the low levels of SO_2 present in pristine environments over alternative technologies. The high limit of detection and drifting background of the Teledyne instrument means that the data outside of spikes when the ship stack was being sampled is unable to provide any more than a relatively high (100s of pptv) upper limit on the background SO_2 mixing ratios. In contrast, the low limit of detection of the LIF-SO_2 means that background SO_2 levels of 10s of pptv can be seen in the time averaged data, and structure within this background can also be observed. Once final calibrations and zeros have been applied, these data will provide a unique constraint on SO_2 levels in the remote arctic marine environment, and thus our representation of key processes such as new particle formation.

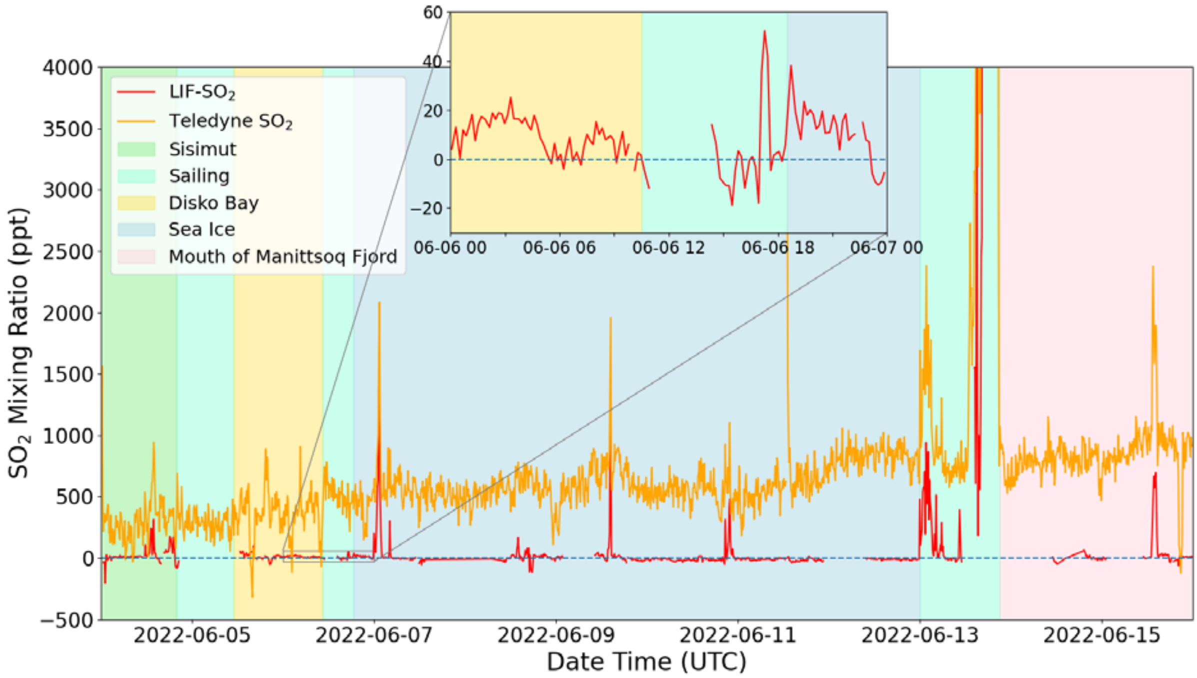


Figure 19. Preliminary time series of the SO_2 mixing ratios measured by the LIF-SO_2 instrument (red) compared to the Teledyne SO_2 instrument (orange). Both datasets are averaged to 10 minutes and any calibrations have been filtered out. However, both datasets are yet to be filtered for any instances when the ship's stack is being measured and the instrument's zeros are also yet to be applied.

References

Rollins, A. W., Thornberry, T. D., Ciciora, S. J., McLaughlin, R. J., Watts, L. A., Hanisco, T. F., Baumann, E., Giorgetta, F. R., Bui, T. V., Fahey, D. W., and Gao, R.-S., 2016. A laser-induced fluorescence instrument for aircraft measurements of sulfur dioxide in the upper troposphere and lower stratosphere, Atmos. Meas. Tech., 9, 4601–4613, https://doi.org/10.5194/amt-9-4601-2016

2.11 Measurements of optical properties and collection of samples for the extraction of Algal Pigments by High Performance Liquid Chromatography (HPLC), Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC).

Gavin Tilstone Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK.

Objectives

- To determine surface optical properties along the DY151 cruise track in support of European Space Agency satellite calibration / validation activities.
- To assess the phytoplankton pigment composition along the DY151 cruise track.
- To provide an extensive Chl-*a* dataset for the calibration of the ACS optics instrument.
- To collect samples for the determination of TA and DIC in seawater for the development of ocean acidification algorithms from satellite data.

Methods

Optical Properties

Particulate optical backscattering coefficient (470, 532, 700 nm), beam-attenuation and absorption coefficients (400–750 nm) were determined quasi-continuously from the ship's underway water following methods detailed in Dall'Olmo et al. (2009).

Above-water radiometric measurements were taken quasi-continuously using a Satlantic HyperSAS system following the methods outlined in Tilstone et al. (2020). The HyperSAS optical remote-sensing system provided hyperspectral measurements of spectral water-leaving radiance and downwelling spectral irradiance, from which the above-water remote-sensing reflectance can be computed. The 136-channel HyperOCR radiance and irradiance sensors were mounted onboard the ship to simultaneously to view the sea surface and sky.

High Performance Liquid Chromatography.

Seawater samples were collected from the ship’s underway system. Seawater was sampled into 9.5 L polypropylene carboys. Using forceps, GF/F filters were placed on the filter rig with the smoother side facing down. Filter papers were fully covered over sintered glass circles such that there were no gaps and water could only pass-through GF/F filters. Seawater samples were mixed to avoid issues with sedimentation. 1-2 L samples (depending on phytoplankton biomass, e.g., 1 L in productive waters and 2 L in less productive waters) were measured using the measuring cylinders, and then decanted into rinsed polypropylene bottles with siphon tubes and inverted into a 6 port vacuum filtration rig. Samples were filtered using a low-medium vacuum setting on the vacuum pump. When the last of the water passed through the filter paper, the vacuum pump was stopped, and the GF/F filter was stored in a 2 mL cryovial. Two to five samples were filtered daily from seawater taken from the ships underway system. Frozen samples were transported back to Plymouth Marine Laboratory in a liquid nitrogen dry shipper for analysis after the cruise. Table 1 details the HPLC samples taken during the cruise.

Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC).

Dissolved CO_2 reacts with water to form carbonic acid (H_2CO_3). H_2CO_3 dissociates to bicarbonate (HCO_3-) and carbonate (CO_3^2-) with the concomitant release of H+, causing a reduction in pH (Dickson et al. 2007). Total alkalinity (TA) of seawater describes the sum of the concentrations of anions and defines the capacity of seawater to neutralise acid. Dissolved Inorganic Carbon is defined as the sum of all carbonate system species in seawater DIC= H_2CO_3+HCO_3-, CO_3^2-. Seawater samples from the ships underway system were collected along the DY151 cruise track. The samples were collected in 250 mL borosilicate glass bottles with glass stoppers greased with Apiezon-M grease. The samples were preserved with 50 µL of saturated HgCl2 for latter analysis at PML (Plymouth Marine Laboratory). Table 16 summarise the locations that the samples were collected.

Table 16. HPLC, DIC and TA samples collected.

Sample ID	Year	Month	Day	Latitude	Longitude	Data ID
DY151_UW001	2022	May	21	62.95	-28.35	HPLC, TA, DIC
DY151_UW002	2022	May	21	62.79	-28.95	HPLC, TA, DIC
DY151_UW003	2022	May	22	61.40	-35.09	HPLC, TA, DIC
DY151_UW004	2022	May	22	61.16	-36.14	HPLC, TA, DIC
DY151_UW005	2022	May	23	61.01	-36.77	HPLC, TA, DIC
DY151_UW006	2022	May	23	60.95	-41.42	HPLC, TA, DIC
DY151_UW007	2022	May	23	60.88	-41.63	HPLC, TA, DIC
DY151_UW008	2022	May	23	60.88	-41.63	HPLC, TA, DIC
DY151_UW009	2022	May	24	60.88	-41.63	HPLC

DY151_UW010	2022	May	24	60.88	-41.63	HPLC
DY151_UW011	2022	May	24	60.88	-41.68	HPLC
DY151_UW012	2022	May	24	60.77	-41.43	HPLC
DY151_UW013	2022	May	25	60.88	-41.48	HPLC
DY151_UW014	2022	May	25	60.86	-41.58	HPLC
DY151_UW015	2022	May	25	60.83	-41.64	HPLC
DY151_UW016	2022	May	25	60.82	-41.64	HPLC, TA, DIC
DY151_UW017	2022	May	25	60.83	-41.65	HPLC
DY151_UW018	2022	May	26	59.60	-42.36	HPLC, TA, DIC
DY151_UW019	2022	May	26	59.42	-43.23	HPLC
DY151_UW020	2022	May	26	59.34	-43.20	HPLC, TA, DIC
DY151_UW021	2022	May	26	59.41	-45.48	HPLC
DY151_UW022	2022	May	27	60.39	-48.51	HPLC
DY151_UW023	2022	May	27	60.74	-49.17	HPLC, TA, DIC
DY151_UW024	2022	May	27	61.12	-49.83	HPLC
DY151_UW025	2022	May	27	61.61	-50.76	HPLC, TA, DIC
DY151_UW026	2022	May	27	61.87	-51.05	HPLC
DY151_UW027	2022	May	28	63.46	-52.77	HPLC
DY151_UW028	2022	May	28	63.84	-52.57	HPLC, TA, DIC
DY151_UW029	2022	May	28	64.05	-52.29	HPLC
DY151_UW030	2022	May	28	64.05	-52.29	HPLC, TA, DIC
DY151_UW031	2022	May	28	64.05	-52.29	HPLC
DY151_UW032	2022	May	28	64.05	-52.29	HPLC
DY151_UW033	2022	May	29	64.05	-52.29	HPLC
DY151_UW034	2022	May	29	64.05	-52.29	HPLC, TA, DIC
DY151_UW035	2022	May	29	64.05	-52.24	HPLC
DY151_UW036	2022	May	29	64.04	-52.32	HPLC, TA, DIC
DY151_UW037	2022	May	29	64.04	-52.32	HPLC
DY151_UW038	2022	May	30	64.06	-52.42	HPLC
DY151_UW039	2022	May	30	64.18	-51.80	HPLC, TA, DIC
DY151_UW040	2022	May	30	64.18	-51.80	HPLC
DY151_UW041	2022	May	30	64.18	-51.80	HPLC, TA, DIC
DY151_UW042	2022	May	31	64.18	-51.80	HPLC, TA, DIC
DY151_UW043	2022	May	31	64.13	-52.36	HPLC
DY151_UW044	2022	May	31	64.42	-52.48	HPLC
DY151_UW045	2022	May	31	64.69	-52.82	HPLC, TA, DIC
DY151_UW046	2022	June	1	65.39	-53.30	HPLC, TA, DIC
DY151_UW047	2022	June	1	65.58	-52.85	HPLC
DY151_UW048	2022	June	1	65.58	-52.84	HPLC, TA, DIC
DY151_UW049	2022	June	2	65.58	-52.84	HPLC
DY151_UW050	2022	June	2	65.60	-52.80	HPLC, TA, DIC
DY151_UW051	2022	June	2	65.65	-52.80	HPLC, TA, DIC
DY151_UW052	2022	June	3	65.53	-53.61	HPLC, TA, DIC
DY151_UW053	2022	June	3	66.08	-53.92	HPLC
DY151_UW054	2022	June	3	66.91	-53.78	HPLC, TA, DIC
DY151_UW055	2022	June	4	66.90	-53.56	HPLC, TA, DIC
DY151_UW056	2022	June	4	66.90	-53.57	HPLC, TA, DIC
DY151_UW057	2022	June	5	68.03	-54.53	HPLC, TA, DIC
DY151_UW058	2022	June	5	68.59	-55.17	HPLC
DY151_UW059	2022	June	5	68.74	-54.37	HPLC, TA, DIC
DY151_UW060	2022	June	6	68.74	-54.37	HPLC
DY151_UW061	2022	June	6	68.74	-55.13	HPLC, TA, DIC

DY151_UW062	2022	June	6	68.74	-56.26	HPLC
DY151_UW063	2022	June	6	68.86	-56.75	HPLC, TA, DIC
DY151_UW064	2022	June	7	68.85	-56.75	HPLC, TA, DIC
DY151_UW065	2022	June	7	68.80	-56.73	HPLC, TA, DIC
DY151_UW066	2022	June	8	68.80	-56.73	HPLC, TA, DIC
DY151_UW067	2022	June	8	68.89	-56.73	HPLC, TA, DIC
DY151_UW068	2022	June	9	68.72	-56.73	HPLC, TA, DIC
DY151_UW069	2022	June	9	68.72	-56.73	HPLC, TA, DIC
DY151_UW070	2022	June	10	68.71	-56.67	HPLC, TA, DIC
DY151_UW071	2022	June	10	68.69	-56.65	HPLC, TA, DIC
DY151_UW072	2022	June	11	68.64	-56.99	HPLC, TA, DIC
DY151_UW073	2022	June	11	68.64	-56.99	HPLC, TA, DIC
DY151_UW074	2022	June	12	68.52	-57.22	HPLC, TA, DIC
DY151_UW075	2022	June	12	68.41	-57.53	HPLC, TA, DIC
DY151_UW076	2022	June	13	66.90	-54.51	HPLC, TA, DIC
DY151_UW077	2022	June	13	66.90	-54.51	HPLC, TA, DIC
DY151_UW078	2022	June	14	65.44	-53.44	HPLC, TA, DIC
DY151_UW079	2022	June	14	65.45	-53.36	HPLC
DY151_UW080	2022	June	14	65.45	-53.34	HPLC, TA, DIC
DY151_UW081	2022	June	15	65.45	-53.35	HPLC, TA, DIC
DY151_UW082	2022	June	15	65.45	-53.36	HPLC
DY151_UW083	2022	June	15	65.32	-53.76	HPLC, TA, DIC
DY151_UW084	2022	June	16	65.32	-53.72	HPLC
DY151_UW085	2022	June	16	65.01	-53.93	HPLC, TA, DIC
DY151_UW086	2022	June	16	64.60	-54.22	HPLC, TA, DIC
DY151_UW087	2022	June	17	62.28	-55.00	HPLC, TA, DIC
DY151_UW088	2022	June	17	61.51	-55.00	HPLC
DY151_UW089	2022	June	17	60.95	-55.01	HPLC, TA, DIC
DY151_UW090	2022	June	17	60.46	-54.78	HPLC
DY151_UW091	2022	June	18	59.83	-51.75	HPLC, TA, DIC
DY151_UW092	2022	June	18	59.65	-50.87	HPLC
DY151_UW093	2022	June	18	59.35	-49.41	HPLC, TA, DIC
DY151_UW094	2022	June	19	58.47	-45.09	HPLC, TA, DIC
DY151_UW095	2022	June	19	58.21	-43.85	HPLC
DY151_UW096	2022	June	19	57.98	-42.74	HPLC
DY151_UW097	2022	June	19	57.74	-41.60	HPLC, TA, DIC
DY151_UW098	2022	June	20	57.01	-38.22	HPLC, TA, DIC
DY151_UW099	2022	June	20	56.75	-37.01	HPLC
DY151_UW100	2022	June	20	56.57	-36.18	HPLC, TA, DIC
DY151_UW101	2022	June	20	56.33	-35.08	HPLC
DY151_UW102	2022	June	21	55.59	-31.76	HPLC, TA, DIC
DY151_UW103	2022	June	21	55.33	-30.62	HPLC
DY151_UW104	2022	June	21	55.07	-29.56	HPLC, TA, DIC
DY151_UW105	2022	June	21	54.84	-28.49	HPLC
DY151_UW106	2022	June	22	54.84	-28.49	HPLC, TA, DIC
DY151_UW107	2022	June	22	53.87	-24.31	HPLC
DY151_UW108	2022	June	22	53.64	-23.20	HPLC
DY151_UW109	2022	June	22	53.35	-22.10	HPLC, TA, DIC
DY151_UW110	2022	June	22	53.16	-21.25	HPLC, TA, DIC
DY151_UW111	2022	June	23	52.48	-18.45	HPLC, TA, DIC
DY151_UW112	2022	June	23	52.45	-17.96	HPLC, TA, DIC
DY151_UW113	2022	June	23	52.22	-17.39	HPLC, TA, DIC

References

Dall'Olmo et al., 2009. Significant contribution of large particles to optical backscattering in the open ocean. Biogeosciences, 6, 947–967.

Dickson, A. G., C. L. Sabine, and J. R. Christion, 2007. Guide to best practices for ocean CO2 measurements. PICES Special Publication 3, p. 191. PICES Special Publication 3.

Tilstone, G., Dall'Olmo, G., Hieronymi, M., Ruddick, K., Beck, M., Ligi, M., Costa, M., D'Alimonte, D., Vellucci, V., Vansteenwegen, D., Bracher, A., Wiegmann, S., Kuusk, J., Vabson, V., Ansko, I., Vendt, R., Donlon, C., Casal, T., 2020. Field Intercomparison of Radiometer Measurements for Ocean Colour Validation. Remote Sens.,12, 1587.

Acknowledgements.

Underway samples were funded through the European Space Agency contract: Atlantic Meridional Transect for CO_2 Flux project (AMT4CO_2Flux; Contract No. ESA-CIP-PEO-FF-ar-LE-2021-00671).

2.12 Aerosol particles and Cloud Condensation and Ice Nuclei

Joanna Dyson, Amélie Kirchgaessner

British Antarctic Survey, Cambridge, UK

Objectives

- Improve understanding of new particle formation and growth in the Arctic and North Atlantic and provide a baseline of aerosol concentration in this region
- Understand the contribution of sub-60 nm aerosols through size segregation to the formation of CCN in the artic regions.
- Add to the very limited measurements of particle number and mass concentration in the Arctic and the North Atlantic.
- Add to the very limited available information about IN abundance and characteristics in the Arctic and the North Atlantic.
- Determine what, if any, effect washing of filters prior to exposure has on the quality of the measurements.

Method

In order to measure the number, surface area, mass and volume size distributions of aerosols in the sub-60 nm size range throughout the cruise, a Scanning Mobility Particle Sizer (Electrostatic Classifier TSI Model 2080 and Differential Mobility Analyser TSI Model 3081) was coupled to a Condensation Particle Counter (TSI Model 3776) to measure the aerosol size distribution from 2-64 nm. The SMPS-CPC system was housed with the BAS Lab container stationed on the foredeck of the RRS Discovery. The SMPS-CPC instrument used a roof inlet in the container with a PM_{10} inlet head (Digital) with a pump attached to pull 16.7 litres per minute through the inlet system. From this air flow, the SMPS pulled 1.5 litres per minute on high flow mode in order to measure down to 2 nm particle size. Butanol was used to grow the particles in the CPC to a measurable size, from which a total particle concentration was recorded at a time resolution of 5 minutes. Measurements were taken continuously between 23/05 and 20/06/2022.

By the SMPS to a Cloud Condensation Nuclei Counter (DMT, CCN-100), the activation ratio of cloud condensation nuclei from aerosol particles in monodisperse size segregated bins can be measured.

The Grimm 11-D aerosol spectrometer was installed in the lab container close to roof gland plate with the PM_{10} inlet. The air was led through a dryer cartridge before entering the instrument. Measurements were taken quasi-continuously from May 22th to June 22nd 2022 (the instrument was switched off during known potential pollution events, e.g. venting the ship's galley). Temporal resolution of the measurement was 6 seconds. The instrument sorts particles into 23 equidistant bins in the range between 0.25 to 10µm. Output files provide number concentration and mass concentration of the detected particles.

We also installed reusable Savillex PFA cassettes on top of container (Figure 20). Air flow was provided by a pump with the nominal flow rate of 25l/min which was housed inside the lab container. A line of Teflon tubing was fed through a gland plate onto the roof of the container where the line was tee-d to pull air through the two filter cassettes. Flow rates at the pump and at the cassettes was regularly monitored.

Figure 20: Photo of the filter cassettes on the roof of the lab container.

Whatman 47mm polycarbonate hydrophilic filters with a 0.2 µm pore size were exposed for approximately 48 hours to take into account the low expected number of IN and the reduced flow rate in the split suction line.

One cassette was always used to sample with a pre-washed filter, the other with an untreated filter. Filter washing was done prior to the cruise in the clean room at BAS. The washing procedure consisted of three repetitions of ten minutes sonification in MilliQ water, changing the water after each cycle. Filter changes were carried out under a laminar flow hood, and cassettes were rinsed with MilliQ each time the filters were changed. Additionally, two filters were exposed to the ship's stack, one for 5 minutes, and the other for 30 minutes (Figure 21).

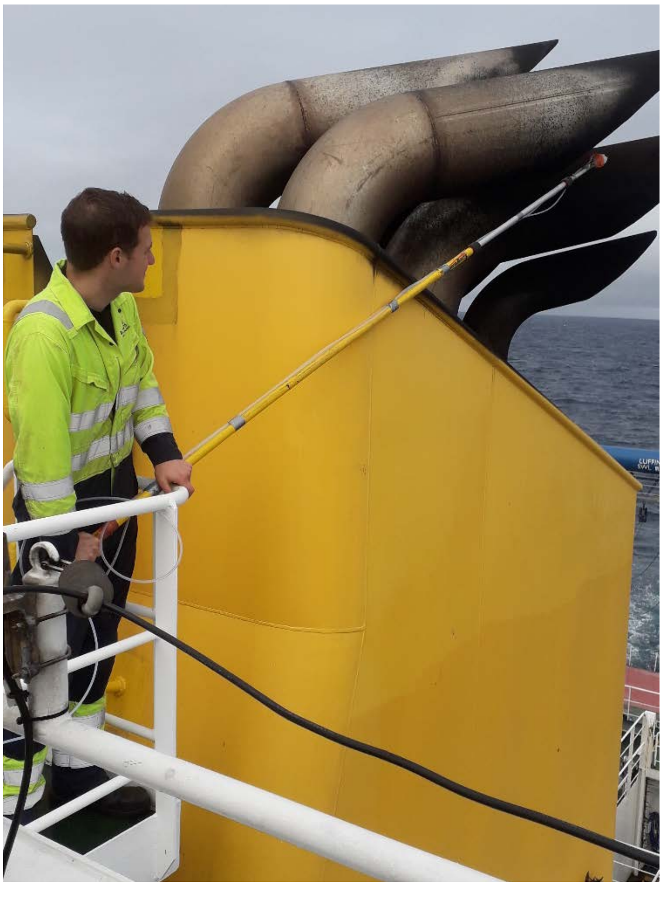


Figure 21: Photo of IN sampling from the ship's stack.

Provisional Results

Due to difficulties with both the instrument and the method, no size-segregated CCN measurements were made during the DY151 cruise.

The below data is the raw time series and will require filtering for electrical artefacts, sections where testing occurred, ship smokestack etc. The below panel of Figure 22 shows the same data as the first but is zoomed in to show the daily variation in the total aerosol number concentration across the DY151 cruise.

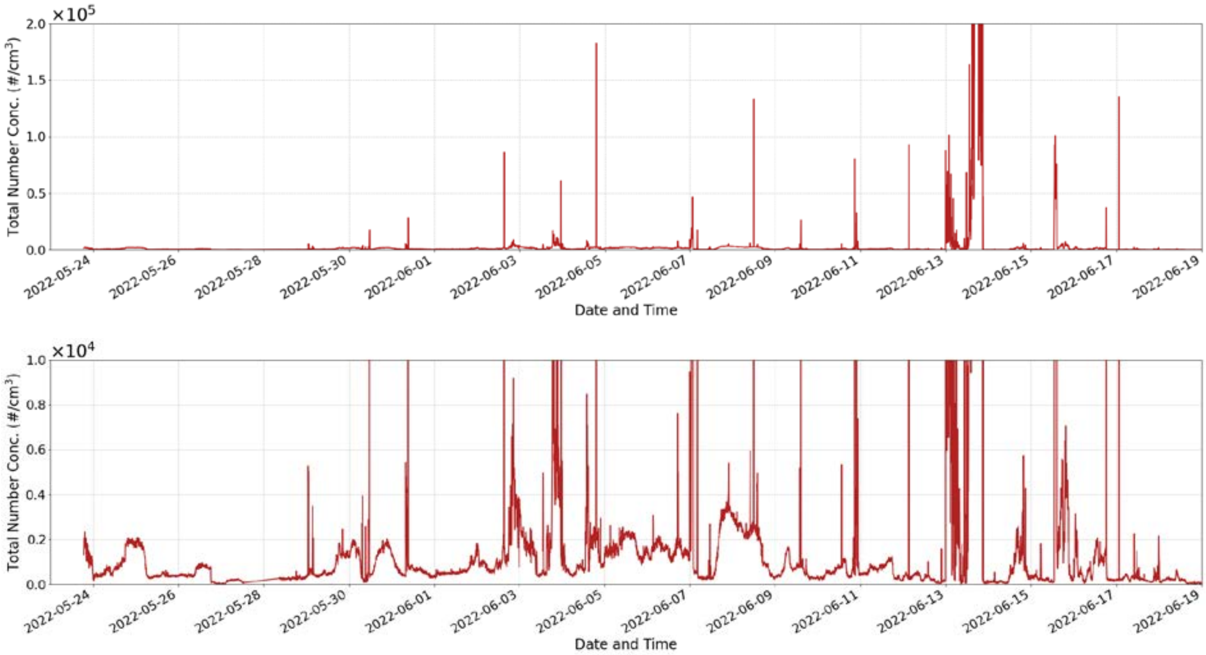


Figure 22. the total number concentration of particles.

Figure 23 and 24 shows number concentration and mass concentration of total particles based on raw data. There is a lot of variation throughout the cruise. Especially the periods of rapid change need more detailed analysis. A first look at bin segregated data also shows that the relative contribution of different sized particles varies hugely, often on time scales of several hours.

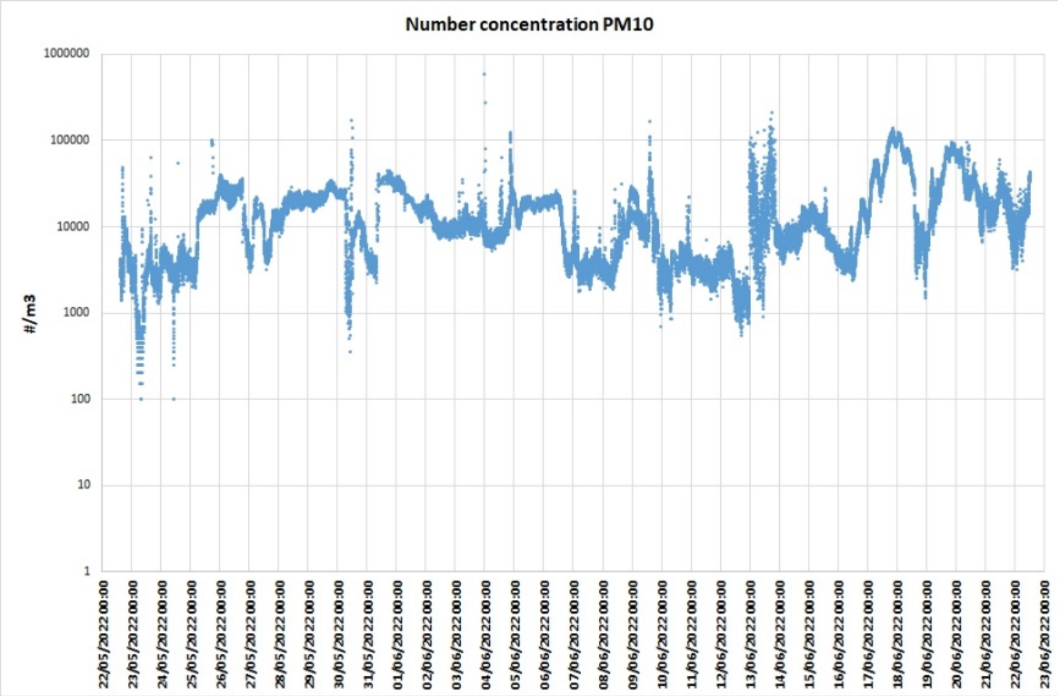


Figure 23: Number concentration per cubic metre of particles with a diameter between 0.25 and 10µm (to). Mass concentration per cubic meter of particles with diameters between 0.25 and 10µm (bottom).

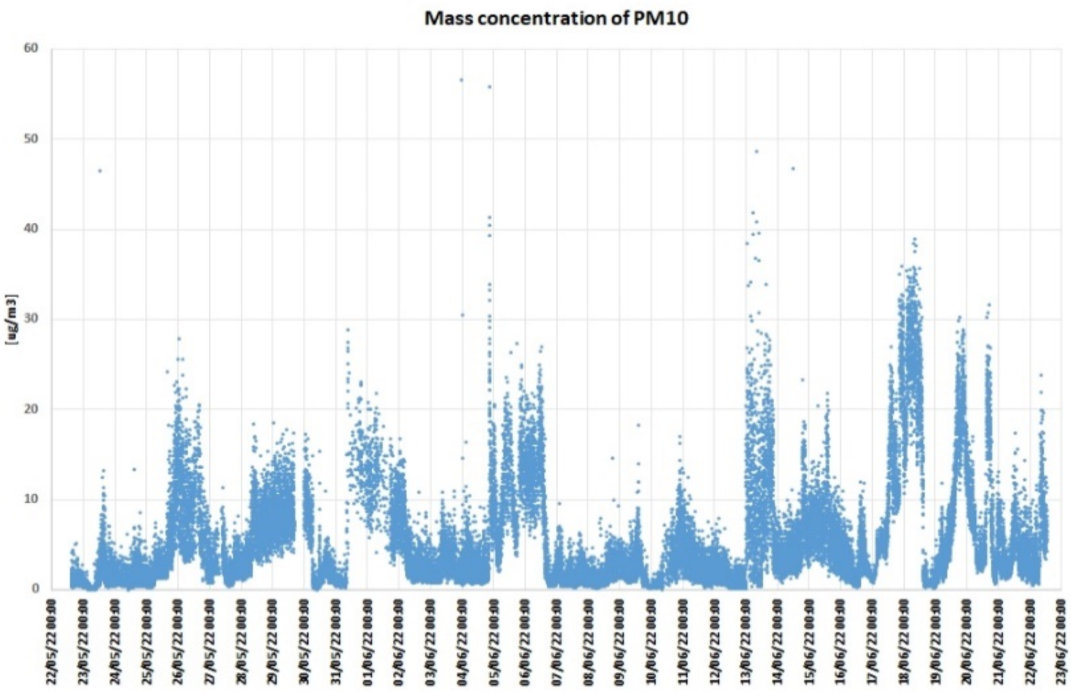


Figure 24: Mass concentration per cubic meter of particles with diameters between 0.25 and 10µm.

For the analysis the filters are immersed and shaken in 10ml MilliQ to create a suspension. An array of 1µl droplets of this suspension is cooled on a cold stage to monitor the freezing temperature. An AI algorithm has been trained to detect droplets freezing in high resolution photos of the array (Figure 25).

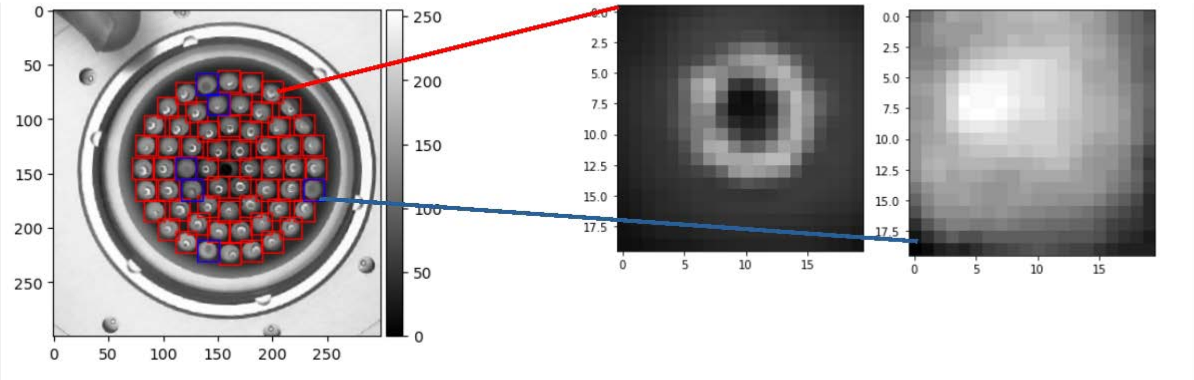


Figure 25: Example of a droplet array in the cold stage (left). Close up of a frozen droplet (centre), and of a frozen droplet (right).

2.13 NMFSS Ship Systems Computing and Underway Instruments

Nick Harker

National Oceanography Center, Southampton

Overview

Ship Scientific Systems (SSS) is responsible for operating and managing the Ship's scientific information technology infrastructure, data acquisition, compilation and delivery, and the suite of ship-fitted instruments and sensors in support of the Marine Facilities Programme (MFP).

All times in this report are in UTC.

Scientific computer systems

Underway data acquisition

The data acquisition systems used on this cruise are detailed in the table below. The data and data description documents are filed per system in the *Data* and *Documentation* directories respectively within Ship Systems folder on the cruise data disk.

Table 17 Data acquisition systems used on this cruise.

Data acquisition system	Usage	Data products	Directory system name
Ifremer TechSAS	Continuous	NetCDF ASCII pseudo-NMEA	/TechSAS/
NMF RVDAS	Continuous	ASCII Raw NMEA	/RVDAS/
Kongsberg SIS (EM122)	Discrete	Kongsberg .all	/Acoustics/EM-122/
Kongsberg SIS (EM710)	Discrete	Kongsberg .all	/Acoustics/EM-710/
Kongsberg SBP	Unused	None	/Acoustics/SBP-120/
Kongsberg EA640	Continuous	None, redirected to Techsas/RVDAS RAM	/Acoustics/EA-640/
Kongsberg EK80	Unused		/Acoustics/EK-60/
UHDAS (ADCPs)	Continuous	ASCII raw, RBIN, GBIN, CODAS files	/Acoustics/ADCP/
VMDAS (ADCPs)	Unused		/Acoustics/ADCP/
Sonardyne Ranger2	Unused		/Acoustics/USBL/

Data description documents per system:

/Ship_Systems/Documentation/[System]/Data_Description

Data directories per system:

/Ship_Systems/Data/[System]/

Significant acquisition events and gaps

Cruise departed Reykjavik, Iceland on the evening of the 20/05/2022 with ship meteorology sensors recording. Acoustics were turned on at 20:55.

Underway water instrumentation was started 21/05/2022 at 14:20

Underway water sensor acquisition was halted on 14/06/2022 between 9:30-11:20 for cleaning of the SBE45, fluorometer & transmissometer.

Sensors on the drop keels (Ea640, ADCPs, SBE38) were shut off on 15/06/2022 between 08:30-13:14 due to drop keel tests being performed.

Underway water instrumentation was shut off on 23/06/2022 at 11:25 in anticipation of entering Irish waters and remained off for the duration of the trip.

Acoustics were shut off on 23/06/2022 at 16:00 due to entering Irish waters and were not turned back on again after this point.

GPS and meteorology data was logged for the full duration of the cruise (Reykjarvik dock to Southampton dock).

Multibeam data was recorded discontinuously, running during passage in international and dipcleared waters (Iceland & Greenland) dependant on weather and work sites.

Instrumentation

Table 18. Position, attitude and time

System	Navigation (Position, attitude, time)
Statement of Capability	/Ship_Systems/Documentation/GPS_and_Attitude
Data product(s)	NetCDF: /Ship_Systems/Data/TechSAS/NetCDF/ Pseudo-NMEA: /Ship_Systems/Data/TechSAS/NMEA/

	Raw NMEA: /Ship_Systems/Data/RVDAS/NMEA/		
Data description	/Ship_Systems/Documentation/TechSAS /Ship_Systems/Documentation/RVDAS		
Other documentation	/Ship_Systems/Documentation/GPS_and_Attitude		
Component	Purpose	Outputs	Headline Specifications
Applanix PosMV	Primary GPS and attitude.	Serial NMEA to acquisition systems, multibeam and ADCP.	Positional accuracy within 2 m.
Kongsberg Seapath 330	Secondary GPS and attitude.	Serial and UDP NMEA to acquisition systems and multibeam	Positional accuracy within 1 m.
Oceaneering CNav 3050	Correction service for primary and secondary GPS and dynamic positioning.	To primary and secondary GPS	Positional accuracy within 0.15 m.
Fugro Seastar / MarineStar	Correction service for primary and secondary GPS and dynamic positioning.	To primary and secondary GPS	Positional accuracy within 0.15 m.
Meinberg NTP Clock	Provide network time	NTP protocol over the local network.	

Ocean and atmosphere monitoring systems

Table 19. SURFMET

System	SURFMET (Surface water and atmospheric monitoring)	
Statement of Capability	/Ship_Systems/Documentation/Surfmet	
Data product(s)	NetCDF: /Ship_Systems/Data/TechSAS/NetCDF/ Pseudo-NMEA: /Ship_Systems/Data/TechSAS/NMEA/ Raw NMEA: /Ship_Systems/Data/RVDAS/NMEA/ Underway records & Autosal: /Ship_Systems/Data/Autosal	
Data description	/Ship_Systems/Documentation/TechSAS /Ship_Systems/Documentation/RVDAS	
Underway events and other documentation	/Ship_Systems/Documentation/Surfmet	
Calibration info	See Ship Fitted Sensor sheet for calibration info for each sensor.	
Component	Purpose	Outputs
Inlet temperature probe (SBE38)	Measure temperature of water at hull inlet	UDP NMEA to SBE45
Drop keel temperature probe (SBE38)	Measure temperature of water in drop keel space	UDP NMEA to Surfmet VM

Thermosalinograph (SBE45)	Measure temp, sal and conductivity at sampling board	Serial to Interface Box
Interface Box (SBE 90402)	Signals management	Serial to Moxa
Transmissometer (CST)	Measure of transmittance	Voltage output to Surfmet VM
Fluorometer (WS3S)	Measure of fluorescence	Voltage output to Surfmet VM
Air temperature and humidity probe (HMP155)	Temperature and humidity at met platform	Analogue to NUDAM
Ambient light sensors (PAR, TIR)	Ambient light at met platform	Analogue to NUDAM
Barometer (PTB210)	Atmospheric pressure at met platform	Analogue to NUDAM
Anemometer (Windsonic)	Wind speed and direction at met platform	Serial to Moxa

The NMF Surfmet system was run throughout the cruise, except times for cleaning, entering and leaving port, and whilst alongside. Please see the separate information sheet for details of the sensors used and whether their recorded data have calibrations applied or not.

Hydroacoustic systems

Table 20. The summary of hydroacoustic systems

System	Acoustics		
Statement of Capability	/Ship_Systems/Documentation/Acoustics		
Data product(s)	Raw: /Ship_Systems/Data/Acoustics NetCDF (EA640, EM122cb): /Ship_Systems/Data/TechSAS NMEA (EA640, EM122cb): /Ship_Systems/Data/RVDAS Sound Velocity Profiles used: /Ship_Systems/Data/Acoustics/Sound_Velocity		
Data description	/Ship_Systems/Documentation/Acoustics		
Other documentation	/Ship_Systems/Documentation/Acoustics		
Component	Purpose	Outputs	Operation
10/12 kHz Single beam (Kongsberg EA-640)	Primary depth sounder	NMEA over serial,	Discrete Free running
12 kHz Multibeam (Kongsberg EM-122)	Full-ocean-depth multibeam swath.	Binary swath, centre-beam NMEA, *.all files, optional water column data	Discrete Free running

70 kHz Multibeam (Kongsberg EM-710)	Coastal/shallow multibeam swath.	Binary swath, centre-beam NMEA, *.all files.	Discrete Free running
Sub-bottom Profiler (Kongsberg SBP-120)	Multi-frequency echogram to provide along-track sub-bottom imagery.	BMP, raw files, optional water column data.	Unused
Drop keel sound velocity sensor	Provide sound velocity at transducer depth	Value over serial to Kongsberg SIS.	Continuous
Sound velocity profilers (Valeport Midas, Lockheed XBT)	Direct measurement of sound velocity in water column.	ASCII pressure vs sound velocity files. Manually loaded into Kongsberg SIS or Sonardyne Ranger2.	Discrete Single profile
75 kHz ADCP (Teledyne OS75)	Along-track ocean current profiler	(via UHDAS)	Continuous Free running
150 kHz ADCP (Teledyne OS150)	Along-track ocean current profiler	(via UHDAS)	Continuous Free running
USBL (Sonardyne Ranger2)	Underwater positioning system to track deployed packages or vehicles.	NMEA over serial	Unused

Marine Mammal Protection

/Ship_Systems/Documentation/Acoustics/MMOs

Table 21. the summary of marine mammal protection

System	Actions taken to protect mammals, in compliance with NERC and JNCC protocols
12 kHz Multibeam (Kongsberg EM-122)	60-minute bridge observation. Marine mammal protection ramped start initiated at 45 minutes into observation if no mammals sighted. Clock restarted if mammals sighted.
Sub-bottom Profiler (Kongsberg SBP-120)	System not used.

MMO surveys were performed before use and restart of EM122 if it had been off for more than 10 minutes.

ADCPs

Path of ADCP data on the cruise datastore: /Ship_Systems/Data/Acoustics/ADCP

Table 22. The summary of ADCPs

Attribute	Value
Acquisition software	UHDAS
Frequencies used	75 kHz, 150 kHz
Running mode	Free-running (untriggered)
Configuration details	os150: Narrow band 40 bins, length 8m, 4m blanking, os75: narrow band, 60bins, length 16m, 8m blanking. Performance from beam 1 is currently degraded so running a 3 beam solution. Bottom tracking was used leaving port in Iceland to allow calibration data to be collected.

Other Systems

Cable Logging and Monitoring

Winch activity (none this cruise) is monitored and logged using the CLAM system.