DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE **RAPPORT 2021/49**

Davis Strait Site Survey and Paleo-studies

DaSSaP Cruise Report 13th to 18th August 2021

Tove Nielsen, Marit-Solveig Seidenkrantz, Katrine Juul Andresen,
Tine Lander Rasmussen, Ole Bennike, Eik Ehlert Britsch, Adrián López Quirós,
Tuomas Junna & Emilie Rosendal Bennedsen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

GEUS

Davis Strait Site Survey and Paleo-studies

DaSSaP Cruise Report 13th to 18th August 2021

DCH co-funded cruise with HDMS Lauge Koch

Tove Nielsen, Marit-Solveig Seidenkrantz, Katrine Juul Andresen,
Tine Lander Rasmussen, Ole Bennike, Eik Ehlert Britsch, Adrián López Quirós,
Tuomas Junna & Emilie Rosendal Bennedsen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

G E U S

1. INTRODUCTION 3

1.1 Acknowledgements 3

2. CRUISE OBJECTIVES 5

3. GENERAL SURVEY INFORMATION 7

3.1 List of DaSSaP participants 7

4. METHODS AND EQUIPMENT 8

4.1 Navigation and sample position 9

4.2 Subbotttom Profiler 9

4.3 Multibeam Bathymetry 10

4.4 Gravity Cores 10

4.5 Rumohr Cores 10

4.6 Water properties 11

5. SURVEY JOURNAL 12

5.1 Daily activity report 13

6. RESULTS 15

6.1 Acoustic data 15

6.2 Sediment samples 16

6.3 Water properties 17

7. APPENDICES 18

1. Introduction

The DaSSaP cruise with HDMS *Lauge Koch* took place August 13th to 18th 2021 and focused on retrieval of information on the southern Davis Strait area off West Greenland.

DaSSaP stands for '**Da**vis **S**trait **S**ite Survey **a**nd **P**aleo-studies'. The purpose of the cruise was to acquire high-resolution acoustic data and make sediment sampling in support of the International Ocean Discovery Project proposal no. 962 (IODP-962) drilling in Davis Strait. A second objective was to carry out paleoenvironmental and paleoceanographic studies of this important area, which forms an important gateway for transport of water from the Arctic Ocean to the North Atlantic region.

The DaSSaP cruise also contributed to the Danish ECOTIP Horizon 2020 project "*Arctic biodiversity change and its consequences*" (grant no. 869383), the Danish Geocenter project "*Eem for the future*" (2021-22), the Danish VILLUM young investigator project "*Past and Future Dynamics of the Greenland Ice Sheet: what is the Ocean hiding?"* (2015-2021), the Norwegian Research Council project CAGE (WP6) "*Methane, Ocean Acidification and CO_2*" (grant no. 223259), and the Danish DDF projects G-Ice (grant no. 7014-00113B) and Green-Shelf (grant no. 0135-00165B). Finally, the participating geology student at KU Emilie Rosendal Bennedsen will use DaSSaP data for her Master project, supervised by Camilla S. Andresen (GEUS).

1.1 Acknowledgements

The cruise was supported by a grant to the DaSSaP project by the Danish Centre for Marine Research (DCH, project no. 2021-05). This grant covered travel, daily allowance and accommodation expenses, round trip Denmark-Greenland freight of equipment and samples, use of DCH owned equipment and engineer salary.

The coring equipment was supplied by the Geological Survey of Denmark and Greenland (GEUS) and the Sparker system was supplied by Aarhus University (AU).
Workhours for T. Nielsen was supported by GEUS. Additional costs for consumables and travel were covered by the DFF project G-Ice. T.L. Rasmussen was supported by the Norwegian Research Council.

The success of the cruise strongly depended on the onshore technical help from John Boserup (GEUS), Per Trinhammer (AU) and Eik E. Britsch (DTU-Aqua), and especially by the operational skills of Captain Trygve R. Avlund and the crew of HDMS *Lauge Koch* and their help with handling the equipment and sediment sampling on board.

We thank all for their valuable efforts in making the DaSSaP cruise a success.

The DaSSaP team

Figure 1 The DaSSaP research team surrounded by their equipment and work containers on HDMS *Lauge Koch* aft deck. The team was composed of scientists, students and technician from the Geological Survey of Denmark and Greenland (GEUS), Aarhus University (AU), Tromsø University (UiT), Copenhagen University (KU) and DTU-Aqua.

Thanks To:

Dansk Center for Havforskning

GEUS

AARHUS UNIVERSITY

UNIVERSITETET I TROMSØ

2. Cruise objectives

A main uncertainty in assessing global sea-level rise during a warming climate is understanding the behaviour of modern ice sheets. To address this, the IODP-962 project will assess the history of the south Greenland Ice Sheet (GrIS) back in time and its interaction with ocean circulation, climate, greenhouse gases and sea-level by drilling into sediment drifts and glacial deposits of presumed Neogene age.

For this, the southern Davis Strait provides a unique setting due to a recently discovered interfingering between interglacial drift deposits and glacial debris flow deposits. By its proximity to GrIS, and because it provides a bathymetric hurdle for water exchange between the North Atlantic and Arctic oceans, Davis Strait is well suited for paleoenvironmental and paleoceanographic studies.

The current selection of IODP-962 drilling sites is based on low-resolution (7-10 m) seismic data. Yet, for safety and environmental issues, high-resolution seismic data is warranted prior to drilling. As conventional IODP drilling will not sample the uppermost sub-seabed section, shallow sediment coring is needed to close this gab.

Thus, the primary objectives of the DaSSaP cruise were:

1) to provide site survey data for the IODP-962 drilling sites, in particular the three primary sites (Fig. 2), by acquire highly-resolution acoustic and bathymetric data

2) to sample seabed and near-seabed sediments by taking HAPS, Rumohr and gravity cores at the vicinity of the IODP primary sites (Fig. 2)

3) preform CTD (Conductivity-Temperature-Depth measurement) casts for calibration of the bathymetry data and obtaining information on the modern setting for comparison with past changes in environment and ocean currents.

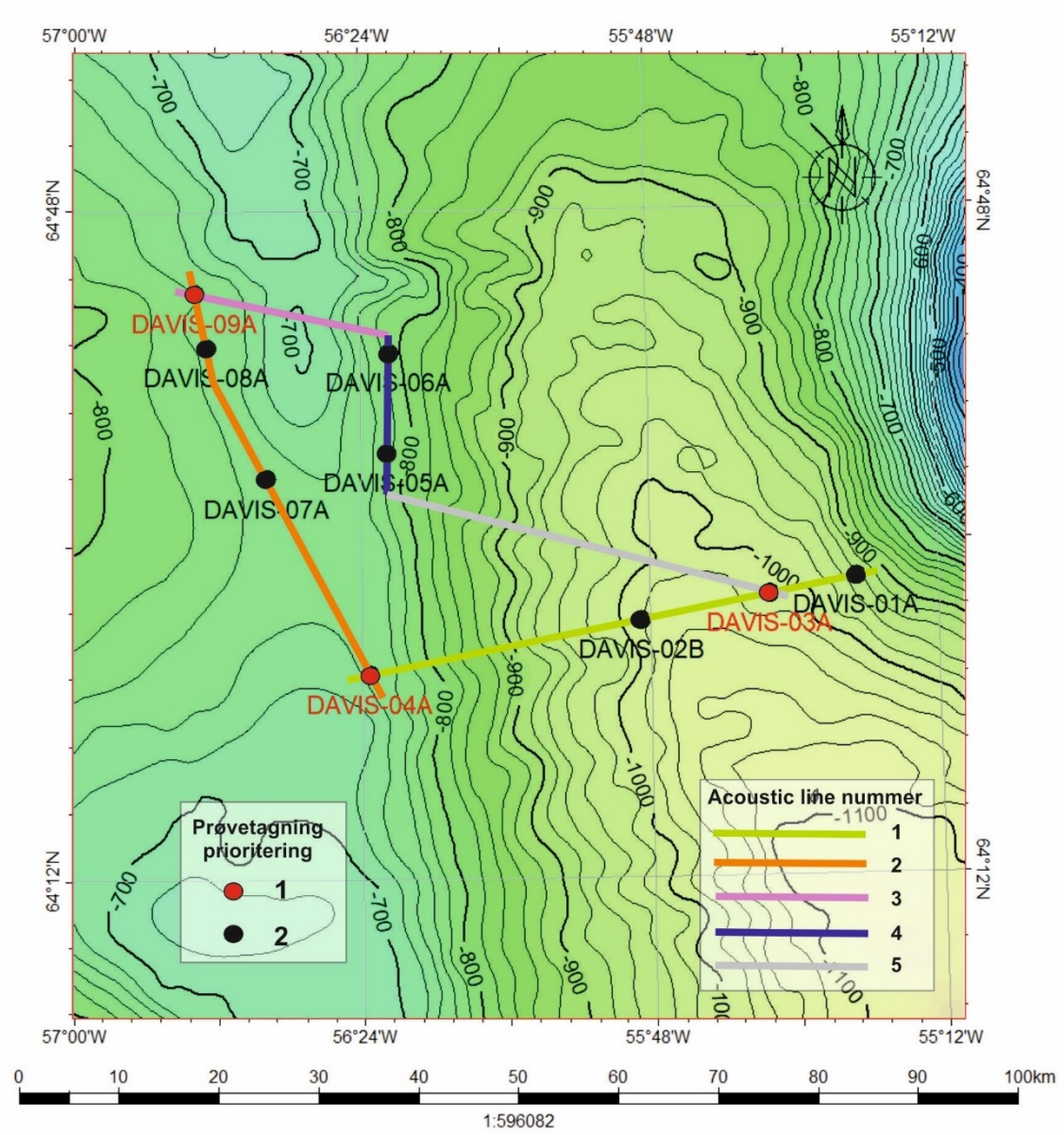

Figure 2. DaSSaP study area on the southern Davis Strait, showing the positions of IODP drilling site DAVIS-01 to -09. The scheduled acoustic runline paths 1 to 5 were planned to pass through all nine IODP drilling sites and with double pass of the three primary drilling sites (red dots). The sediment sampling stations were planned to take place at the three IODP primary drilling sites.

3. General survey information

Mobilization of cruise equipment and containers took place on 11th and 12th of August 2021 in Nuuk harbour (West Greenland).

The 5-days long DaSSaP cruise started when the vessel departed from Nuuk 13th of August at 8:00 hrs local time (UTC-3). Due to stormy weather, the first 30 hours of the cruise-time was spent in the inner Godthåbsfjorden ('Rødfiske dybet'), sheltering from the strong wind and waves in the open sea off west Greenland. The time was used to finalize the mobilization, testing the equipment and training scientists and ship crews in deck routines. On the 14th of August at c. 14:00 hrs the transit to the survey area on Davis Strait finally started. After nearly 10 hours of transit the survey began the 14th of August around 23:30 hrs and ended by midnight the 17th of August, where the transit back to Nuuk started. The ship returned to the harbour the 18th of August around 10:00 hrs, and at 13:00 hrs the DaSSaP scientists disembarked the ship.

The bad weather that postponed the transit to the survey area also created waves and swells that hampered deployment of the Sparker system and prevented sediment sampling during the first 24 hours after arrival at the survey area. During the following days, the wind and waves calmed down.

A few technical problems arose during the cruise. Due to mechanical issues on the launching system, acquisition of CTD data was prevented during the cruise. To provide the necessary water column data, vertical Rapid Casts were made instead.
Unfortunately, it turned out that the water depth at the DaSSaP survey area was too big for the single-channel Sparker system, and thus data acquisition with this system failed despite repeated attempts with different setups and long-distance help via e-mails from expert Per Trinhammer (AU). However, the onboard subbottom profiler and multibeam systems worked well.

During the 5 days of surveying a total of 39 combined Multibeam Bathymetry and Subbottom Profiler lines (incl. 3 site survey grids), 8 Gravity cores, 3 Rumohr cores and 4 Rapid Casts were acquired. Bearing in mind the weather and sea conditions that hampered data acquisition during parts of the cruise, this is considered a success.

3.1 List of DaSSaP participants

Tove Nielsen (lead, senior researcher, GEUS) – Acoustics
Marit-Solveig Seidenkrantz (co-lead, professor, Aarhus University) – Sediment sampling
Tine Lander Rasmussen (professor, Tromsø University) – Sediment sampling
Katrine Juul Andresen (ass. professor, Aarhus University) – Acoustics
Eik Ehlert Britsch (engineer, DTU-Aqua) – DTH equipment & Rapid Cast
Ole Bennike (senior researcher, GEUS) – Sediment sampling
Adrián López Quirós (postdoc, Aarhus University) – Sediment sampling / Acoustics
Tuomas Junna (PhD-student, Aarhus University) – Sediment sampling / Acoustics
Emilie Rosendal Bennedsen (master-student, Copenhagen University) – Sediment sampling

4. Methods and Equipment

Acoustic data were gathered by simultaneous acquisition of Multibeam Bathymetry (MB) soundings and Subbottom Profiler (SbP) data. The MB data provided seafloor morphology and gave information of the general seabed conditions and sedimentary processes. The SbP data imaged the shallowest sub-seabed setting and resolved the layers to a very high resolution. A plan of supplementing the MB and SbP data with acquisition of high-resolution Sparker data was abandoned as it turned out that the water depth within the survey area was too big for the Sparker System.

Sediment sampling was made by Gravity coring (GC) and Rumohr coring (RC) in order to make ground-truthing for the interpretation of the acoustic data and provide stratigraphy and age models for the youngest deposits and paleo-oceanographic information of the shallower sub-seabed sections at the three primary IODP drilling sites. A HAPS was deployed at the first (testing) station in order to test, if this equipment could be used to retrieve undisturbed surface samples, but bottom currents were too strong and it was decided not to use the HAPS again during the cruise, as time was too limited to risk unsuccessful deployments. As more than one sampling type (i.e., one or more GC, RC and RP) were often placed in close proximity, the various samplings were grouped under a common Station number. The coupling between Station (ST) number and the various cores are listed in Appendix 3.

CTD measurements of modern water mass parameter was abandoned because the CTD arm on the A-frame got stucked, preventing the use of the CTD equipment. Sampling of the necessary water column data was therefore done by making vertical Rapid Casts (RP) while keeping the ship still and turning off the propellers.

During the cruise, the following equipment were in use:

- Hull-mounted Multibeam echosounder (MB) (Reson SeaBat7160)
- Hull-mounted Sub-bottom Profiler (SbP) (Innomar ses-2000 – Deep)
- Ship-mounted Rapid Cast (RP) SVP hydrography system
- Ship-mounted Seabird SBE 21 SeaCat thermosalinograph (Ferry Box)
- A-frame and steel wire winch (A-frame system)
- 6 m Gravity corer (GC)
- Rumohr corer (RC)

The configuration of the containers, A-frame and winches on the aft deck is shown in Figure 3. During the DaSSaP cruise, the laboratory container was used as control room for the acoustic acquisition, enabled by linking-up the MB and SbP computers via remote desktop connections. This arrangement was setup to enable the surveyor to control both MB and SbP during the simultaneous acquisition. Communication between the laboratory container and the bridge took place by walkie-talkies.

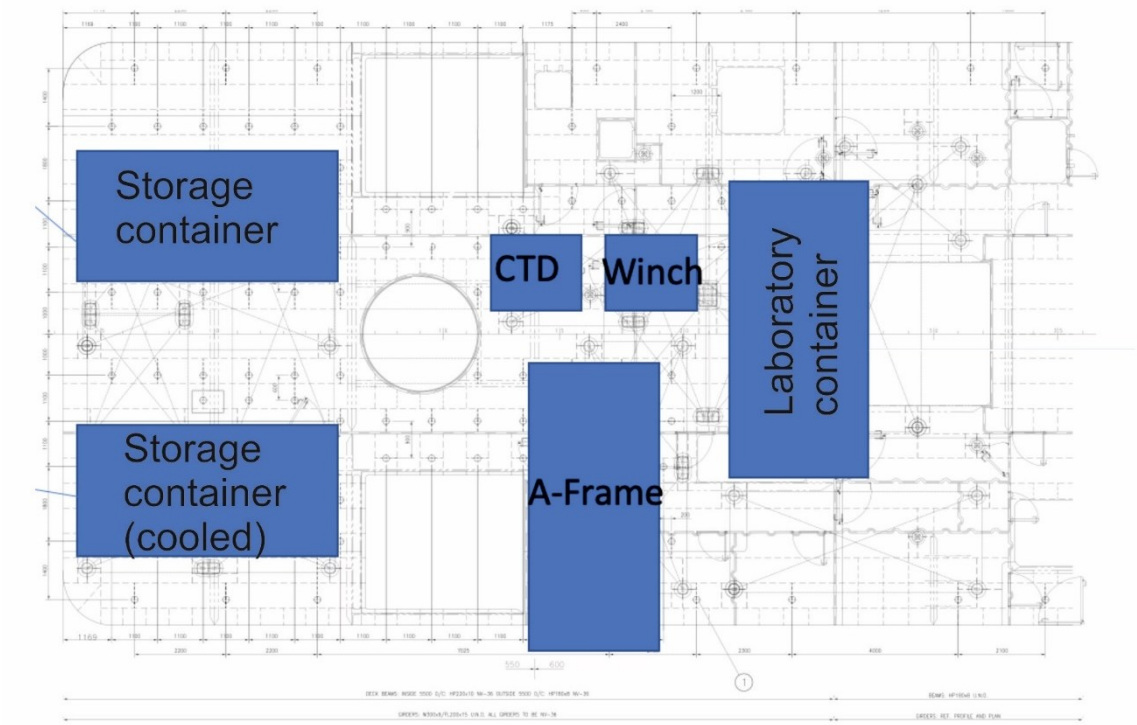

Figure 3. Configuration of containers, A-frame and winches at the aft deck. During the DaSSaP cruise, the laboratory container was used as acoustic control room and the sediment cores and samples were stored in the non-cooled container. The CTD was not in use during the DaSSaP cruise.

4.1 Navigation and sample position

The positioning was supplied by the ships DGPS navigational system that came from a POSMV module. The position of the sediment sampling sites was determined by readings on the bridge at the time the equipment was at the bottom. The start and end position for the Rapid Casts were likewise read on the bridge. During acoustic acquisition, the ships navigation was fed into the recording software for the MB and SbP, i.e., Seabat 7125 UI and SESWIN, respectively, together with the NaviPac, NaviScan and Helmsmann Display software.

4.2 Subbotttom Profiler

For mapping of the shallow sub-seabed, the Innomar SES-2000 Deep Sub-Bottom Profiler was used. The instrument is hull-mounted on the ship and is connected to a motion sensor for recording the heave, pitch and roll variations. The SES-2000 Deep instrument is a Narrow-Beam Parametric subbottom profiler system of the pinger type, with a fixed high-frequency (HF) component of 35 kHz and a low-frequency (LF) range of 2-7 kHz.
The coupling of the instrument to the ship's navigation and clock, as well as the general surveying settings for the SbP during the DaSSaP cruise can be found in Appendix 1.

Both HF and LF data was acquired and stored. The naming of the runlines followed the numbering of the planned main lines (see Fig. 2), e.g., DaSSaP_01 for planned runline 1, followed by +/- 1000, 2000 etc for the parallel staggered lines on either side of the main line, e.g., DaSSaP_01_+1000.
The stored Innomar data files were named '*cruise year date time_data type_frequency type*', e.g., 'DaSSap20210814002106_RAW_HF'. The coupling between runlines and SbP data-files are listed in Appendix 2. Data was stored in both RAW, SES and SEGY format.

4.3 Multibeam Bathymetry

For areal mapping of the seabed bathymetry, the hull-mounted multibeam echosounder system Reson SeaBat 7160 was used. This system has a primary frequency of 44 kHz and a variable swath coverage depending on the water depth. See Appendix 1 for more information of the surveying settings for the MB during the cruise.
The stored Multibeam Bathymetry data files were named '*Ship_year date time_line number*', e.g., 'LAKO_2115Aug012725_1N002'. The coupling between runlines and MB datafiles are listed in Appendix 2. For naming of runlines, see section 4.2 above.

4.4 Gravity Cores

For coring, a 6-m long gravity corer (GC) with an inner plastic corer liner diameter of 12 cm was used. The corer weights 750 kilo when empty and ca. 1000 kilo if filled with sediments. The system was launched and retrieved at the starboard side of the ship, using the A-frame system. When on deck, the core catcher was sampled first. Hereafter the gravity core liner was cut into 1 m sections that was capped, sealed, and marked before stored cold for later onshore investigations.
Naming and numbering of GC cores and core-sections, as well as rapid casts, follow the concept '*ship year -cruise name -station number -cast number sampling type'* (HAPS, R = Rumohr; G= Gravity, Rapid =Rapid cast), e.g., LK21-DaSSaP-ST2-11G. Gravity cores were cut into ca. 1-m section on board, with "section 1" being the first section pulled out of the corer, i.e. the deepest section. Each section was capped, labelled, and taped for transport.
The coupling between sampling Station (ST) number and the various GC cores are listed in Appendix 3.

4.5 Rumohr Cores

A Rumohr corer (RC) system was used for undisturbed sampling of the seabed sediments. The weight of the corer is 80 kg. The plastic core liner was 75 mm in diameter and the length varied between 1m and 2m. The system was deployed from the ships starboard side using the A-frame system.
When on deck, the core was kept in a vertical position before the water was extracted from the liner using a thin hose and syringes. Subsequently the top sediment was covered by a disk of flower foam, the plastic liner was cut to length and the core was capped and taped at both ends. None of the Rumohr cores has to be cut into sections. Naming and numbering of

Rumohr cores follow the concept described in section 4.4 (with “R” designating “Rumohr core”). See Appendix 3 for coupling between sampling station numbers and the various RC cores.

4.6 Water properties

Throughout the cruise temperature and salinity were measured continuously in the surface layer (5 m below sea surface) by the ship-mounted Seabird SBE 21 SeaCat thermosalinograph system (or ‘Ferry Box’), and data simultaneous stored with position and time in the instrument memory.
Vertical profiles of water properties (depth, sound velocity, temperature) were acquired at selected positions using the ship-mounted Rapid Cast SVP hydrography system. During this procedure, the measurement probe was lowered down through the water coloumn from the ship stern at the lower aft deck, while keeping the ship still and turn off the propellers. Naming and numbering of the casts following the concept described in section 4.4 (with “Rapid” designating “Rapid Cast”). See Appendix 3 for the coupling between station numbers and the various Rapid Casts.

5. Survey journal

Surveying took place 24 hours per day and acoustic acquisition, sediment sampling and Rapid Casts were preformed both day and night. During the cruise the science party took shifts, ensuring experienced personnel to be on duty at all shifts. The shifts between acoustic acquisition and sediment sampling operations had to be organized on a daily basis due to weather conditions and to ensure that the only DaSSaP technician on board could get the necessary rest.

All DaSSaP people participated in the mobilization operation that also involved containers and equipment for the subsequent ICAROS cruise. Due to shortage of a second technician in the DaSSaP team, and despite good help from the ship crew, the mobilization ended up stretching over 2½ days. Some of the time spent was however, made up at the end of the DaSSaP cruise as de-mobilizing of equipment and containers in turn was carried out by the following ICAROS cruise team.

Weather and sea conditions were changing over the 5 days the cruise lasted, starting with strong winds that created high seas and swells, followed by some days of suitable surveying conditions (albeit with still fairly large swells), and ending with increasingly more wind and waves on the return trip to Nuuk. An overview of the weather and sea conditions is shown in Table 1.

Lists of acquired Multibeam Bathymetry (MB) and Subbottom Profiler (SbP) lines are shown in Appendix 2. Information on sediment sampling stations and equipment type, i.e., HAPS, Rumohr core (RC) and Gravity core (GC), is shown in Appendix 3, which also list the pre-formed Rapid Casts (RP) profiles.

Table 1 – Weather and sea conditions during the DaSSaP cruise

Date	Wind	Sea	Tempera-tur	Comments
13-08-2021	NE to SW, 5-9 m/s	Calm	12-18^{0}C	In Godthåbsfjorden due to bad weather in Davis Strait
14-08-2021	SW to SE, 6-10 m/s	Calm to moderate	8-16^{0}C	Left the fjord at lunch time, headed for survey area
15-08-2021	S, 3-9m/s	Moderate	7-8^{0}C	High swells in survey area
16-08-2021	SW-SE 5-6 m/s	Low to moderate	6-7^{0}C	Swells and waves calmed down
17-08-2021	SE-E, 3-8 m/s	Low	5-7^{0}C	Wind increased during the night
18-08-2021	SE 8 m/s	Moderate	5^{0}C	In Nuuk at lunch time

5.1 Daily activity report

All following indications of time refer to local Western Greenland Standard (UTC-3) time. References to line names and sampling station numbers in the daily activity report below can be found in Appendix 2 and 3.

11/8-2021: Mobilization of equipment and containers for the DaSSaP and ICAROS cruises in Nuuk harbour.

12/8-2021: Continued mobilization of DaSSaP and ICAROS equipment. DaSSaP team embarking the ship in Nuuk harbour at 10:30 hrs. Due to storm warning, equipment and containers on deck was lashed in the evening, in order to prepare the ship for a possible SAR (Search and Rescue) event.

13/8-2021: Departure from Nuuk at 8:00 hrs, heading for the inner Godthåbsfjord (Nuup Kangerlua) to shelter from the storm in Davis Strait. Mobilization continued during transit. At 9:00 hrs, presentation to the ship crew on the purpose of the DaSSaP cruise. Arrived 'Rødfiske Dybet' at 11:30 hrs and lay still in calm sea. Mobilization finalized at 16:00 hrs and wet testing of equipment and training of students and ship crew in handling the coring equipment started. Sampling test with HAPS and RC at Station 1A failed. Moved to deeper water in the fjord system ('Ummanaq Sullua') and successfully sampled RC, GC and made RP at Station 1B. At 20:30 hrs successful test of MB, SbP and logging of navigation data. At 21:30 hrs returned to 'Rødfiske dybet' for the night.

14/8-2021: Still in 'Rødfiske dybet'. At 8:00 hrs to 12:00 hrs, worked to optimize the configurations of the Sparker catamaran and streamer system at the starboard side of the ship, and tested the draft through the water without firing the catamaran. At 12:30 hrs returned to Station 1B and successfully tested the RP system while laying still with the propellers turned off. At 14:00 hrs left Godthåbsfjord and headed for the eastern end of planned acoustic runline 1 (Fig. 2). At 23:30 hrs start of runline 1 with MB and SbP (no Sparker due to wind and wave).

15/8-2021: Continued acquisition of MB and SbP along planned acoustic runlines (Fig. 1). Sea conditions still not suitable for Sparker acquisition. At 15:00 hrs, grid of planned acoustic lines finalized. Made site survey grid with MB and SbP at the DAVIS-03 site. At 16:30 hrs transit to DAVIS-04 to make site survey here, acquiring MB and SbP parallel staggered to runline 1. At 20:00 hrs, finalized the DAVIS-04 site survey grid. Tested sea conditions for possible GC and Sparker – still too high waves and swells. Made RP (Station 2) at DAVIS-04 site and started transit toward DAVIS-09 site, acquiring MB and SbP parallel staggered to runline 2. At 22:00 hrs arrived DAVIS-09 site and started site survey. Site survey grid completed at 23:30.

16/8-2021: Started sediment sampling at the DAVIS-09 site around midnight. Made RP (Station 3). Attempt to take RC (Station 3) failed as the equipment was caught be the strong surface current. At 1:20 hrs, GC (Station 3) on deck. At 2:00 hrs, prepared for Sparker surveying. No return signal despite several attempts to change acquisition layout and

parameters. At 9:00 hrs, the Sparker surveying was abandoned. Returned to DAVIS-04 site to resume sediment sampling, acquiring MB and SbP parallel staggered to runline 2 during transit. At 11:00 hrs to 15:00 hrs, retrieved 2 GC (Station 2). Transit to DAVIS-03 site, acquiring MB and SbP parallel staggered to runline 1. Arrived the site at 19:00 hrs and started sampling. Took 2 GC, 2 RC and one RP (all Station 4). At 23:45 hrs, headed eastward to reach shallower water depth for a new Sparker test, acquiring MB and SbP parallel staggered to runline 1.

17/8-2021: Started Sparker test around midnight at 750 m water depth. Retrieved the Sparker gear at 0:30 hrs as it did not work properly at the water depths within the survey area. Returned to the area around DAVIS-04 and started additional MB and SbP surveying east of this site at 01:00 hrs to map iceberg plough marks. Stopped for sampling at 12:45 hrs, retrieved one GC between ploughmarks (Station 5) and one GC within a ploughmark (Station 6). Further coring was deemed unsafe due to increasing wind and waves, so the MB and SbP surveying in the area was resumed. At 21:45 hrs, transit back to Nuuk started by heading westwards, acquiring MB and SbP parallel staggered to runline 1.

18/8-2021: Continued acquisition of MB and SbP until DAVIS-03 site was reached. At 00:30 hrs, surveying stopped and transit back to Nuuk continued full speed. Arrived Nuuk harbour at 10:00 hrs. Packed Sparker equipment and DaSSaP cores, cleaned deck and container, and copied MB, SbP, navigation and RP data to external harddisks. At 13:00 hrs, DaSSaP scientists disembarked the ship.

6. Results

General survey results and preliminary observations are summarized below.

Overall, the quality of the acquired Subbottom Profiler and Multibeam Bathymetry data was fair to good and useable for the project purpose, and the planned runline grid was completed. The quality and length of the sediment cores was satisfactory when taking the coarse and hard sediment with many pebbles into account. Moreover, considering the few days of reasonable working weather, we are pleased that we managed to core all three primary IODP drilling sites. In addition, we managed to sample a few additional core sites added based on interesting features (plowmarks) identified through some additional Subbottom Profiler and Multibeam investigations.

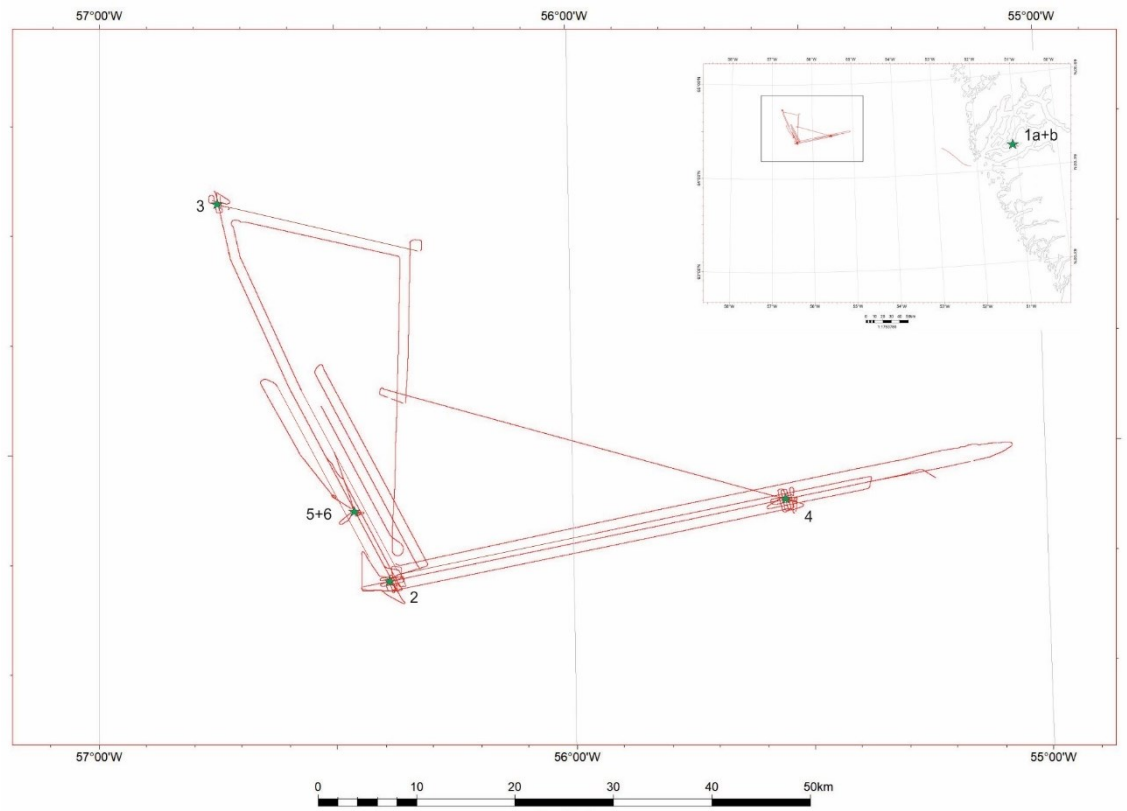

Figure 4 Overview of acoustic lines (red) collected during the DaSSaP cruise. Multibeam Bathymetry and Subbottom Profiler data were acquired simultaneous along each line. Green stars and labels indicate position and number of the sediment sampling stations. Note the small site surveys covering the three primary IODP drilling sites DAVIS-03, 04 and 09, which are covered by sampling Stations 4, 2 and 3, respectively (see Fig. 2).

6.1 Acoustic data

The acoustic survey in the Davis Strait started in the eastern end of the study area by simultaneous acquisition of MB and SbP data along the planned runlines, connecting and crossing all nine proposed IODP drilling sites (see Figs. 2 and 3), followed by small dense survey grids over all the three primary IODP sites, i.e. DAVIS-03, -04 and 09 (Fig. 3).

The observation of several large iceberg ploughmarks in the vicinity of primary IODP drilling site DAVIS-04 (Fig. 2) required extra focus, and thus additional acoustic acquisition was made in that area (Figs. 4 and 5).

After then cruise, the SbP data were loaded into the seismic interpretation programs 'Petrel' and 'KingdomSuite' at GEUS and AAU, respectively, for further processing and analysis. Processing and interpretation of the MB data will likewise be performed both at GEUS and at AAU in near future.

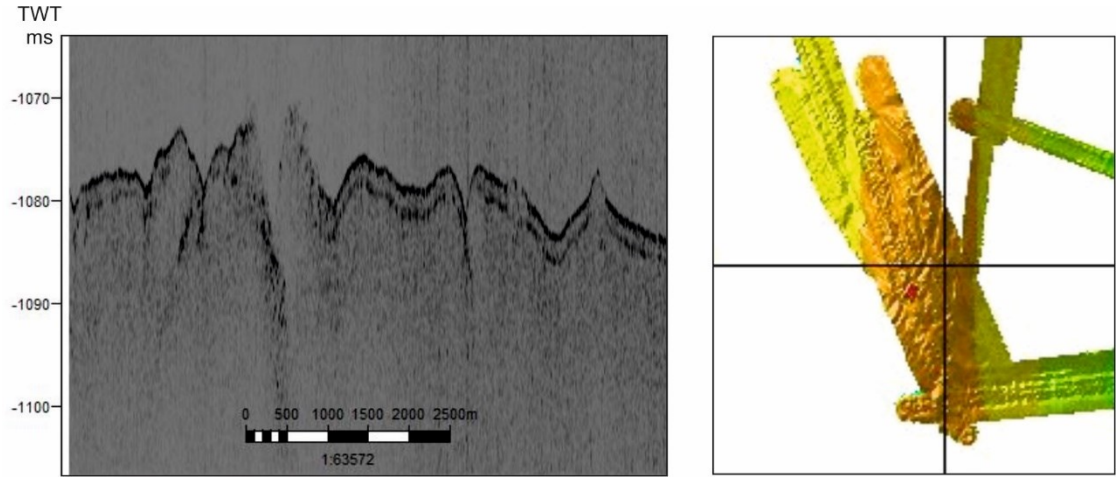

Figure 5 Subbottom Profile (left; Petrel version) and Multibeam Bathymetry mosaic (right; onboard version) showing the iceberg ploughed area of sediment sample Stations 5 and 6 (see Fig. 4). The red dot on the mosaic show position of Station 6 within a deep ploughmark.

6.2 Sediment samples

A preliminary investigation of the content of the gravity cores was made during the cruise by inspection of the sediments in the core catcher and at either ends of the core sections.

Generally, the Gravity cores taken at the DAVIS-04 and -09 drilling sites on top of the contourite ridge were relatively coarse grained and thus penetration was therefore low (between 47, 52, and 116 cm) here. At the deeper-water stations, sediments were on average finer-grained, albeit still with pebble and stones. However, here the finer-grained sediments allowed retrieval of 116-538 cm long gravity cores at the deeper sites in Davis Strait. At our test site in Godthåbsfjorden, the very soft sediments resulted in overshooting of the core and loss of top sediments; 578 cm sediment was recovered.

After the cruise, all DaSSaP Gravity cores from Davis Strait have been opened, checked, and photographed in the laboratory at Aarhus University – see figure 6. Preliminary investigations indicate that most of the sediments are from the last glacial period. The Gravity core from the Godthåbsfjord test site has not yet been opened. However, here the very soft sediments suggests that the core represents Holocene deposits.

Figure 6 Opening of DASSAP gravity cores in the laboratory at Aarhus University. The cores show a wide variety of lithologies. Some sections had a greenish color upon opening (Photo C. Pearce, AAU).

Four Rumohr cores were successfully retrieved, although all were very short only 22-25 cm long. None of the Rumohr cores have yet been opened in the laboratory.

6.3 Water properties

The Ferry Box data were logged through the entire cruise for scientific purpose, and the result are shown in figure 7.

The data from the Rapid Castes will be used to analyse the various water column properties at the sample stations, and to calculate the water column sound velocity to be used for calibration of the acquired Multibeam bathymetry data.

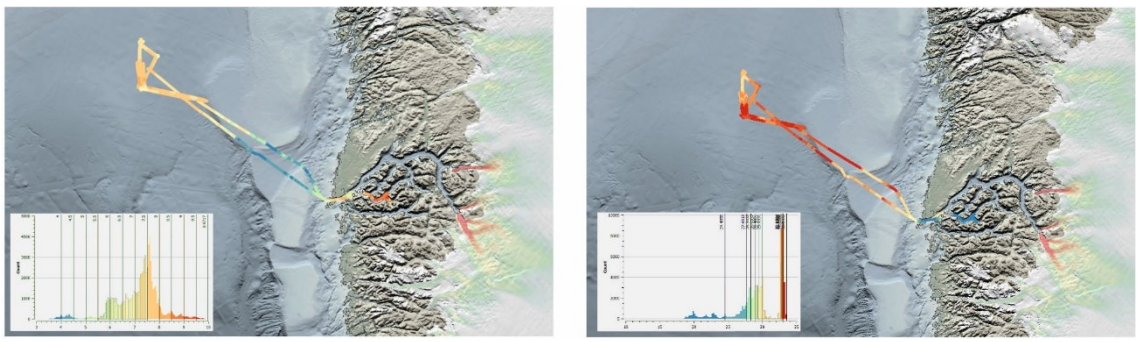

Figure 7 Ferry Box data measured 5 m below sea-surface along the DaSSaP cruise track. Left – Salinity (psu) ; Right – Temperature (C)

7. Appendices

Appendix 1 – DaSSaP 2021 Instrument settings

Appendix 2 – DaSSaP 2021 Acoustic line log

Appendix 3 – DaSSaP 2021 Sampling and cast list

APPENDIX 1

DASSAP 2021 Acoustic instrument settings

Instrument type	Innomar SES-2000 Deep, Narrow-Beam Parametric Sub-bottom Profiler
SIS string Longitude	1
SIS string Latitude	2
SIS string UTMX	5
SIS string UTMY	6
SIS string 3	Fix Mark
SIS string 4	Fix KP
SIS string 7	Longitude
SIS string 8	Latitude
Standard UTM Conversion	Meridian 21 (57 Deg W), WGS84 ; UTM 21
Transducer depth	set for 545 cm
LF Frekvens	2-7 kHz
HF Frekvens	35 kHz
Sound velocity	1500 m/s
Time stamp on .ses files	from computer - danish summertime

INNOMAR SETTINGS IN STUDY AREA (ca. 700-1100 m water depth)

Range		**Threshold**	
Auto Range Start	OFF	LF Mode	LOG
Use LF-waterdepth	OFF	LF Min level	5
Ping Rate	Maximum, ranges from 1-11 pps ca	LF SRange	10
Length	50 m	HF Mode	LOG
General		HF Min Level	1
Ship	LAKO	HF SRange	10
Travel	DaSSap 2021	**Gain**	
Area	Davies Strait	LF Gain	60 dB
Depth		HF Gain	46 dB
LF detection sesibility	30%	LF Auto Gain control	OFF
HF detection sensibility	30%	HF Auto Gain Control	OFF
Detection offset	10%-20%	Deep Water Amplifier	OFF
Bottom Averaging	5	**Transmit**	
Process		LF frequency	4 kHz
Stacking	2	LF Pulses	2
Smoothing	3	High Energy Mode	OFF
soft TVG	0.5	Multi Frequency Mode	OFF
LF Depth for TVG	OFF	Dual Range Mode	OFF
Normalize Gain	OFF	Beam Steering Mode	OFF
Reduce Noise	ON	Deep Sea Pulse Mode	ON
Median Filter	ON	Burst Mode	OFF
Swell Filter	OFF	Chirp Mode	OFF

MB SETTINGS IN STUDY AREA (ca. 700-1100 m water depth)

Instrument type	Reson Seabat 7160
Primary high frequncy	44kHz
Range	varies, typically 1300 m
Power	full power (223 dB)
Beam Mode	Best coverage (512ED) (equi-distant)
Ping rate	Max
Actual ping rate	ca. 1.1 pps
Beam width	1.5 degree (minimum)
Pulse length	8.8 ms (nearly maximum) very good result for deep water using this
Pulse Type	CW (constant frequency at 41.5 kHz), not used FM (Frequency modulated)
HOrizontal steering	0 degrees
Coverage angle	80 degrees (cut down from 150 degree because of noise from Innomar
Absolute depth gates	600 and 900 m ca. to cut off most noise
Online sound velocity probe	varies typically around 1470-1480 m/s
Absorption	0.0 dB/km
Spreading	3.0 dB
Tracker	OFF (data not good if used)

APPENDIX 2

DaSSap 2021 Subbottom Profiler (SbP)and Multibeam Bathymetry (MB)

Date	Time (UTC-3)	Runline	SMG	CMG	Latitude	Longitude	SbP file	SbP recording settings	Water depth SbP	MB file	MB settings	Water depth MB	Comments
dd-mm-yyyy	hh:mm	name	knot	deg	DEC.MIN	DEC.MIN	name	Range (length), LF Freq, LF Pulse, Ping Rate, Gain	m	name	Gain (db), Ping Rate (pps), Pulse type, Coverage Angle; Pulse Length	m	
DaSSap RUNLINES THROUGH ALL IODP SITES													
14-08-2021	23:30	DaSSap_01	8	302	64°28.1200	-55°13.8912	DaSSap_20210815_032835	length 100 m, 4 kHz, 1 pulse, 0.97 pps, Reduce Noise + Median filter ON	860	LAKO_2115Aug012725_1N002		841	moving into runline at first
	23:54							HE mode afprøves	930				on runline, SOL, experient with speed and pulse mode
15-08-2021	0:14		6	258				High Energy Mode and Deep Sea Pulse Mode, ping rate 3.4pps	980				Cause noisy MB; still experimenting with settings
	0:28									NA	NA	NA	MB turned off due to low data qality
	00:41		5.8	259			_043514	4 kHz, LF puls 1, Gain LF 60 dB HF 55 dB, length 50 m, HE + Deep Sea Mode, pingrate 4.36, stacking 3, smoothing 5, LF Min Level 5	1010	NA	NA	NA	
	01:35									_1N003	60 db; 1.3 pps; CW; 70 degree coverage angle; pulse lenght 8.8 ms		
	02:00												passing DAVIS-02
	02:50							Range 100 m					lost the seabed reflection; refound at 02:54
	02:56							Range 50 m					
	04:34												Passing DAVIS-04, screenshot DAVIS-04 and 04-2
	04:51	DaSSap_02			64°22.5962	-56°26.0008	_084607			_1N007			EOL, Turn from line 1 to line 2
	05:14		6 kt										SOL, On line 2, hdg 330 degrees. SOG 6 kt
	05:27												Passing DAVIS-04 on line 2 hdg 332, screenshot DAVIS-04-3
	05:45		8 kt										Speed up to 8 kt
	06:45												Passed DAVIS-07A
	08:00												Passed DAVIS-08A, location skipped on map, exact time of DAVIS-08A +/- 3 min
	08:26	DaSSaP_03	8	102	64°44.4756	-56°45.9525	_122315	ange 50 m, LF 4 kHz, LF Puls 1		N012			Turn from line 2 to 3, SOL
	10:10		7	103					815				EOL runline 03
	10:12						_140756	same		N014	same		turning towards runline 04
15-08-2021	10:20	DaSSap_04	6.7	170	64°41.4896'	-56°20.2813	_141740	same	805	N014	same	780	SOL
	10:25		8										speed increased to 8 kmots

	11:23		8	182					782	N015		755	EOL runline 04
	11:27						_152454	HE mode turned oof, Deep Sea Puls mode remainng, test with Deep water amplifyier. not better so removed again, also experimenting a bit with gain settings					turning towards runeline 05, experimenting with settings during turn
15-08-2021	11:42	DaSSap_05	7.2	112	64°33.5150'	-56°23.3981	_153955	Range 50 m, LF 60 dB, HF 46 dB, LF 4 kHz, LF Puls 1, Deep Sea Pulse MOde ON, 10.42pps	760	N016	same	750	SOL
	12:02							LF pulses changed to 2	815				
	14:34												passing through DAVIS-03
	14:41		8.8	105			_181210		1017	N019		984	EOL
	14:42						_183834			N020			turning to site survey DAVIS-03
							DaSSap SURVEY LINES THROUGH CORING POSITIONS COMPLETED						
								SITE SURVEY DAVIS-03					
	14:52	DAVIS_03_site_survey_2_mother line	8.0	344			_184841			N020			SOL, site survey
	14:57												EOL, turning towards next line
	15:01	DAVIS_03_site_survey_2_+600	7.1	166	64°27.4856'	-55°33.9431	_185800		1017	N021		999	SOL
	15:08		8.2	166									EOL, turning towards next line
	15:11	DAVIS_03_site_survey_2_-300	7.9	343	64°26.9172'	-55°32.5132	_190803		1025	N022		1003	SOL
	15:20												EOL, turnings towards next line
	15:25	DAVIS_03_site_survey_2_+300	8.2	166			_191949		1015	N023		991	SOL
	15:30												EOL, turnings towards next line
	15:35	DAVIS_03_site_survey_2_-600	8.1	346	64°26.8271'	-55°32.0551	_193109		1020	N024		1003	SOL
	15:42												EOL, turnings towards next line
	15:48	DAVIS_03_site_survey_1_mother line	7.3	258	64°27.4077'	-55°32.4746	_194454		1014	N025		992	SOL
	15:57												EOL, turning towards next line
		DAVIS_03_site_survey_1_+600			64°26.9185'	-55°34.4558	_195734		1023	N026		996	SOL
	16:09												EOL, turning towards next line
	16:12	DAVIS_03_site_survey_1_+300	7.7	259	64°27.2577'	-55°32.2550	_200846		1013	N027		992	SOL
	16:22												EOL, starting transit to core position DAVIS-04
							DAVIS-03 SITE SURVEY COMPLETE, TRANSIT TO DAVIS-04A SITE						
	16:23	DaSSap_runline 01	10.8	258			_201935		1023	N028		995	transit to DAVIS-04, high speed, recording SbP + MB
	16:59												seafloor lost due to unattending surveyor
								DAVIS-04 SITE SURVEY					
	18:17	DAVIS_04_site_survey_1_+300			64°23.1610'	-56°21.8602	_221417		818	N030			SOL
	18:24												EOL, turning towards new line
	18:27	DAVIS_04_site_survey_1_+600	9	77	64°23.8210'	-56°23.6404	_222435		806	N031		721	SOL
	18:35												EOL, turning towards new line

	18:39	DAVIS_04_site_survey_1_mother line			64°23.3014'	-56°22.135	_223631		820	N032		728	SOL
	18:48												EOL, turning towards new line
	18:52	DAVIS_04_site_survey_2_+600			64°23.0531'	-56°23.4373	_224853		810			721	SOL
	18:57												EOL, turning towards new line
	19:00	DAVIS_04_site_survey_2_mother line	7.6	334	64°22.8988'	-56°22.4569	_225728		816	N034		729	SOL
	19:06												EOL, turning towards new line
	19:07	DAVIS_04_site_survey_2_+300	7.9	156			_230414		811	N035			SOL
	19:13												EOL, site survey at DAVIS-04 complete
							DAVIS-04A SITE SURVEY COMPLETE						
	19:25		0-1				_230414			N/A			test om vi kan ligge stille til gravity coring + lodret Rapit Cast (sound Velocity,Temp, Depth). For meget dønninger - fortsætter med MB+Innomar
	19:52		11-12		64°23.9663'	-56°24.0656	_230414		805	N037		740	transit to DAVIS-09, high speed but still recrding SBP + MB. Sediment accumulation on ploughmar flanks c. 20:18 (64°26.6485';
	22:00		8		64°44.3436'	-56 44.9514	_015741		840	N040			transit + DAVIS-09_site_survey_1
	22:10	DAVIS_09_site_survey_1_mother line			64°43.7516'	-56 43.7722			841				SOL DAVIS-09_site_survey_1
	22:17	DAVIS_09_site_survey_1_+600	8		64°43.9429'	-56 45.6746	_021457		845	16Aug003904_3 N000		750	SOL DAVIS-09_site_survey_1_600
	22:28	DAVIS_09_site_survey_1_+300	8		64°43.4209'	-56 43.8636	_022638		840				SOL DAVIS-09_site_survey_1_300
	22:39	DAVIS_09_site_survey_2_mother line	8		64°43.7803'	-56 45.7006	_023531		846	N002		750	SOL DAVIS-09_site_survey_2
	22:50	DAVIS_09_site_survey_2_+600	8		64°43.3854'	-56 45.0472	_024739		845	N003			SOL DAVIS-09_site_survey_2_600
	23:01		8		64°44.1936'	-56 44.6124			830	N004			EOL DAVIS-09_site_survey
							DAVIS-09A SITE SURVEY COMPLETE - SPARKER TEST						
16-08-2021	02:00												sparker deployed in water, but no visible seafloor. Testing differet things with deployment and cheaspeake software
							SPARKER TEST ENDED -TRANSIT AND CORING DAVIS-04						
	08:55	DaSSap_extra_1	4		64°29.7142'	-56 30.9202	_20000			N011		810	still no Sparker signal; run MB and SpB paralle to southern part of line DaSSaP line 2 (c. 200 m eastwards)= DaSSaP_ekstra_1
	10:51												At site DAVIS-04, sparker retrieved
	12:30												coring at DAVIS-04
							TRANSIT AND CORING DAVIS-03						
16-08-2021	14:42	DaSSap_Extra_2	8	7.9			_184203	same	840	N016	same	753	
	18:00	DaSSap_Extra_3	6-8		64°26.7119'	-56 35.4079	_215704			N020			
	19.00	on site			64°27.2259'	-56 33.0279	_023028						coring at DAVIS-03; recording SpB; make Rapis Cast
								NEW SPARKER TEST					

	22:45		11		64°26.4407'	-56 31.9538	_024430			17Aug004417_1 N000			full speed eastwards along DaSSaP_runline_01 to reach shallower water depth for Sparker test
	23:45		2		64°29.0113'	-56 09.3391	_034406			_1N001			new Sparker test
17-08-21	00:08		2										start of test at c. 750 wd
	00:32		2-		64°29.5202'	-56 05.2601	_042817			_1N001			Not succesfull - test stopped. Transit to DaSSaP_runline_01-1000
							SBP + MB ADDITIONAL SURVEYING						
	00:58	DaSSap_01_+1000	8.3	266			_045346		635	N003		628	SOL,
	05:09		7.7	257			_084236		760	N007		743	EOL, turning towards next line
	05:14	DaSSap_02_+1000	7.6	329			_090919		747	N008		732	SOL
	05:37												passing ploughmarks
	06:42												pockmark ?
	07:46		7.4	321			_102944		768			750	EOL, turning towards next line
	7:49	DaSSap_03_+1000	7.3	46			_102944		765			750	SOL
	09:00		7.6	104	64°40.8281'	-56 21.8885	_120000		790			775	EOL,
	09:01	DaSSaP_04_+1000	7.6	104	64°40.8281'	-56 21.8885	_120000		790			775	SOL
	9:55				64°29.5202'	-56 05.2601'	143838			N014			Reached EOL but continue the line, heading for DAVIS-04 station
	11:19	DaSSap_02_+2000	8	305	64°25.2146'	-56°22.1679'	151628		747	_2N015		732	SOL (MB mapping of ploughmarks near DAVIS 04)
	12:23		7.8	332	64°32.7488'	-56°31.9030'			756				EOL
	12:42		11	160	64°30.0924'	-56°30.1368'	163947		741				SOL, transit to coring site in plougmark field north of DAVIS-04. Core name =site Plough-1 (64dg26.864'; -56dg27.577)
	13:17		2										drifting towards Plough-1, coring complete
	14:20												EOL - did not hit the position
	14:21		2		64°26.2642'	-56°29.0197'	181805			N/A			SOL - new attemt to get a core at the original site Plough-1 (name=Plough-2)
	15:20												coring complete - apparently at the target position
	15:33	NA	11.9	301			_181805		740	N019		728	steady course while securing the core
	15:39	NA					_193655		750	N019		731	core secure - transit to DAVIS-07
							SBP+MB ADDITIONAL SURVYEING CONTINUED						
17-08-2021	16:25	DaSSaP_02_-1000	8	148	64°33.5600'	-56°37.1096'	_202707	same	778	N020	same	768	SOL
	18:03		9.2		64°22.7517'	-56°24.0051'	_214657		750	N022		734	EOL, turning towards next line
	18:18	DaSSaP_02_+3000	8	331	64°23.8686'	-56°19.7016'	_221543	same	771	N022	same	754	SOL
	19:45				64°34.4426'	-56°32.5390'	_233632						EOL, turning towards next line
	19:50	DaSSaP_02_+4000	8	159	64°34.8912'	-56°31.6109'	_234716		747	N025	same	732	SOL
	21:21		8.4	150	64°24.0561'	-56°18.5693'	20210818_012030		782	N026		759	EOL, turning towards next line
18-08-2021	21:44	DaSSaP_01_-1000	8.2	78	64°22.5364'	-56°22.9798'	_014137	same	739	N027	same	723	SOL
	00:30		7.9	78	64°26.6673'	-56°32.8174'	041405		1026	230DATA\N002		1009	EOL, EOS, line stopped when DAVIS-03 was reached
							END OF SURVEY - TRANSIT BACK TO NUUK (NO RECORDING DURING TRANSIT)						

APPENDIX 3

DaSSaP 2021

Sampling and cast list

Deployment no.	Station no.	IODP sites	Name	Type	Time Start deployment (UTC-3/UTC)	Latitude Start (N)	Longitude Start (W)	Water depth Start (m)	Latitude bottom	Longitude bottom	Water depth Bottom (m)	Time Stop (UTC3/UTC)	Weather, Wind Speed	Result	Core length (cm)	Comments
1	1A		LK21-DaSSaP-ST1A-01HAPS	HAPS	-	-	-	-	64 13,3675N	051 05,7306W	270	15:58/18:58	2 m/s	Failed		
2	1A		LK21-DaSSaP-ST1A-02HAPS	HAPS	-	-	-	-	64 16,3847N	051 05,6934W	269	16:11/19:11	2 m/s	Failed		
3	1A		LK21-DaSSaP-ST01A-03R	Rumohr lot	-	-	-	-	64 16,4941N	051 05,5178W	247	17:43/20:43	Fair weather	Failed		
4	1B		LK21-DaSSaP-ST1B-04R	Rumohr lot					64 15,1351N	051 06,4468W	430	18:14/21:14	Fair weather	Success	22	
5	1B		LK21-DaSSaP-ST1B-05G	Gravity corer					64 14,7707N	051 06,8795W	456	19:02/22:02	Fair weather	Success	578	Core overshot, lost min 40-50cm of top
6	1B		LK21-DaSSaP-ST1B-06A-Rapid	Rapid Cast	11:48/14:48	64 14,7174	51 06,9055	467	64 14,6970N	051 06,9363W	471	11:55/14:55	Fair weather	Success		
7	1B		LK21-DaSSaP-ST1B-06B-Rapid	Rapid Cast	12:15/15:15	64 14,6120	51 07,1040	467	64 14,5878N	051 07,1586W	469	12:21/15:21	Fair weather	Success		
8	2	Davis-04A	LK21-DaSSaP-ST2-07-Rapid	Rapid Cast	15. august				64 22,7449N	056 21,8228W	744 (715)	16:39/19:39	heavy waves, coring deemed unsafe	Success		
9	3	Davis-09A	LK21-DaSSaP-ST3-08-Rapid	Rapid Cast	15/16. august				64 44,2601N	056 44,8866W	767	22:43/01:43	fairly heavy waves	Success		
10	3	Davis-09A	LK21-DaSSaP-ST3-09G	Gravity corer	15/16. august				64 43,6917N	056 44,8541W	770	23:54/02:54	fairly heavy waves	Success	52	
	3	Davis-09A	LK21-DaSSaP-ST3-10R	Rumohr lot	15/16. august				?	?	?		fairly heavy waves	Failed		
11	2	Davis-04A	LK21-DaSSaP-ST2-11G	Gravity corer	16. august				64 23,1619N	056 22,8683W	765	11:48/14:48	no wind and waves less than 2 m	Success	47	
12	2	Davis-04A	LK21-DaSSaP-ST2-12G	Gravity corer	16. august				64 23,0426N	056 23,1625W	770	12:43/15:03	no wind and waves less than 2 m	Success	116	
13	4	Davis-03A	LK21-DaSSaP-ST4-13G	Gravity corer	16. august				64 27,1771N	055 32,6601W	1050	16:18/19:18	no wind and waves less than 2 m	Success	538	
14	4	Davis-03A	LK21-DaSSaP-ST4-17-Rapid	Rapid Cast	16. august				64 27,1253N	055 32,1432W	1010	16:59/19:59	no wind and waves less than 2 m	Success		
15	4	Davis-03A	LK21-DaSSaP-ST4-14G	Gravity corer	16. august				64 27,0858N	055 31,7164	1050	17:51/20:51	no wind and waves less than 2 m	Success	414	
16	4	Davis-03A	LK21-DaSSaP-ST4-15R	Rumohr lot	16. august				64 26,9128N	055 31,6739W	1050	18:35/21:35	no wind and waves less than 2 m	Success	25	
17	4	Davis-03A	LK21-DaSSaP-ST4-16R	Rumohr lot	16. august				64 26,6517N	055 31,7381W	1000+	19:15/22:15	no wind and waves less than 2 m	Success	25	
18	5	plowmark area	LK21-DaSSaP-ST5-18G	Gravity corer	17. august				64 26,8914N	056 27,2930W	730	12:46/15:46	wind, quite heavy waves	Success	165	Between plowmarks
19	6	plowmark area	LK21-DaSSaP-ST4-19G	Gravity corer	17. august				64 26,8917N	056 27,5475W	770	14:12/17:12	wind, quite heavy waves. Coring	Success	167	In big plowmark
														Total	2149	