Antarctic Research Vessel (ARV)

Operations Study: Design Reference Mission Candidates

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1. Purpose

Science funded by NSF will ultimately determine the missions upon which the Antarctic Research Vessel (ARV) embarks. Towards establishing a design reference mission (DRM) to facilitate the preliminary design process, the following science mission profile outlines a conceptual science expedition for the ARV. This expedition is based on historic Antarctic research expeditions and potential future missions. It anticipates the expanded ARV performance and support capabilities beyond the incumbent vessels and includes activities reflecting the ARV program's three primary key performance parameters (KPP):

- Polar Class PC3 vessel with the capability to independently break ice equal to or greater than 4.5 ft thickness at a vessel speed of equal to or greater than 3 knots.
- Mission endurance without replenishment equal to or greater than 90 days underway.
- Provisions for messing, berthing, sanitation, and scientific workspaces for required crew and equal to or greater than 55 science and technical personnel.

The mission activities shown assume fair weather. Adverse weather or ice conditions will preclude some scientific operations. While mission critical operations will still be available, they may take longer or require more resources to complete. When traveling to areas where a high percentage of ice coverage or multi-year ice is expected, the total duration of the mission may need to be reduced due to increased icebreaking activity demands on vessel endurance.

1.1. Acronyms

ADCP	Acoustic Doppler Current Profiler
ARV	Antarctic Research Vessel
ASC	Antarctic Support Contractor
ASV	Autonomous Surface Vehicle
ATV	All-Terrain Vehicle
AUV	Autonomous Underwater Vehicle
CFCs	Chlorofluorocarbons
CO2	Carbon Dioxide
CTD	Conductivity, Temperature, Depth
DIC	Dissolved Inorganic Carbon
DP	Dynamic Positioning
DRM	Design Reference Mission
DRMC	Design Reference Mission Candidate
JRI	James Ross Island
KPP	Key Performance Parameter
LADCP	Lowered Acoustic Doppler Current Profiler
LARS	Launch and Recovery System
LYT	Lyttelton, New Zealand
NAP	Northern Antarctic Peninsula
NSF	National Science Foundation
OPP	Office of Polar Programs
PC3	Polar Class 3
PCO2	Partial Pressure of Carbon Dioxide
PUQ	Punta Arenas, Chile

ROV	Remotely Operated Vehicle
SF6	Sulfur Hexafluoride
SOCCOM	Southern Ocean Carbon and Climate Observations and Modeling Project
SS	Sea State
TM	Trace Metal
TMC	Trace Metal Clean
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
US	United States
USBL	Ultra-Short Baseline
UVP	Underwater Vision Profiler
VMP	Vertical Microstructure Profiler
VTOL	Vertical Take-Off and Landing

2. DRM Candidate Assumptions

2.1. Basic Assumptions

The following is a list of basic assumptions taken when developing the DRM candidate mission activities and timeline:

- All listed mission activities are based on fair weather conditions towards determining vessel endurance.
- Each science activity listed in the detailed mission profiles assumes 12-hour shift time blocks (AM shift is 12:00AM to 12:00PM, PM shift is 12:00PM to 12:00AM)
- Open water transit assumes vessel speed of 10 knots in World Meteorological Organization Sea State code SS4 or less.
- The ability to conduct all vertical and towed science applications with limited impact to operations in SS4 or less (assuming constant towline tensions of up to 10,000 lbs of tension at 6 knots and 25,000 lbs at 4 knots).
- The amount of time to conduct science operations and to transit between study sites will vary according to weather and ice conditions.
- Mission is based on sailing with a full science complement of 55 personnel. ARV technical staff makeup will vary based on planned mission operations, but are included in the 55-person science complement.
- Deployment and recovery of gliders and moorings occurs as a regular activity. When possible, additional opportunistic deployments may occur beyond the described DRM profile.

2.2. Impacts of Seasonality

In the event of operations interrupted by heavy ice coverage in winter or in particular sites, the Chief Scientist, working in coordination with the captain of the vessel, may adjust operations by reducing the number of stations, prioritizing stations based on accessibility, or altering station locations. During the winter, heavy ice conditions may require more icebreaking between stations and reduce the overall number of days at sea or increase the number of transit days in comparison to science days.

The likelihood of heavy weather delays, which may affect daily science activities or reduce total mission durations accordingly, is higher in the winter season. Heavy weather may require slower vessel transit speeds (3-5 knots) and/or additional engine power to transit between stations.

2.3. Mission Activity Breakdown

Mission activities are categorized into “average” vessel operational modes as listed in Table 1 for the purposes of verifying ARV fuel storage capacity and achieving endurance performance requirements.

Table 1: ARV "Average" Operation Modes

No.	Mode Name	Description	Average Speed	Average Sea State	Average External Temp
1A	Open water transit	Generally, mission departure and return to homeport transits and longer transits between sites. Ship is in transit with an optimum speed of 10 knots in Sea State 4 or less. There is no use of any deployment equipment. This is equivalent to a cruise condition.	10 knots	4	24.1 ◦F
1B	Acoustically quiet transit	Quiet, survey mode for underwater surveillance and other sonar studies with an average speed of 6 knots in Sea State 4 or less.	6 knots	4	24.1 ◦F
2	Icebreaking	Deck and deployment equipment are not in use. An average of 40% of maximum propulsion power is assumed.	3 knots	0	24.1 ◦F
3	On Station	Typical science activities include CTD, mammal survey, field science, diving, AUV deployments, light coring. Ship is adrift on a track-line course.	0 knots	0	24.1 ◦F
4	On Station, DP	Typical science activities include ROV deployment, geotechnical drilling, any heave compensation needs, piston long coring. Ship is holding position within a tight margin using dynamic positioning system.	0 knots	0	24.1 ◦F
5	Deployment	Ship is in transit at 6 knots in Sea State 4 while towing scientific equipment up to 10,000 lbs. Mission operations include: net towing, trawling, dredging, mooring operations. This condition is equivalent to launch/recovery condition.	6 knots	4	24.1 ◦F
6	In-Port	Ship is docked in port. Activities include loading/unloading cargo and personnel. Most cranes are expected to be used as well as supporting equipment for science activities and workshops.	0 knots	0	24.1 ◦F
7	Ice Transit	Assumes limited floating ice debris with relatively clear transit paths where no ice breaking occurs. Average transit is 6 knots in calm water.	6 knots	0	24.1 ◦F

3. Design Reference Mission: Thwaites/Pine Island Bay

As a basis for the ARV DRM, a 90-day mission, based on previous 62-day cruises to the Amundsen Sea Embayment centered on the study of the Pine Island and Thwaites glaciers was derived to provide a measure for the associated KPP requirement achievement. This study area includes perhaps the most vulnerable glaciers to significant ice loss as a result of climate change and identified as a priority study area for ARV to support. The ARV Design Reference Mission is extended to 90 days by the inclusion of more advanced mission activities representing the ARV design's greater capabilities.

Season: Austral Spring/Summer: (December – March).

3.1. Summary of Expedition

This cruise is an interdisciplinary, international ship- and land-based program to study the potential instability of the Western Antarctic Ice Sheet Thwaites Glacier in Amundsen Sea. The glacier is unstable, and its disintegration is widely considered a bellwether for significant global sea level rise. The factors that drive this instability, and promote the possible breakup of Thwaites, are critical to understanding how fast sea level may rise, and the extent to which we can predict it, develop resilient communities, and save lives.

The cruise portion has three US/UK teams, comprised of 55 participants, working 24-hour operations divided into 12 hour rotations:

1. TEAM 1 – Evaluating the effects of atmospheric and oceanic processes on the changing regional ice shelves
2. TEAM 2 – Evaluating the climate-sensitive nature of glacial meltwater-driven micronutrient contributions driving regional productivity and CO2 uptake
3. TEAM 3 – Benthic coring to evaluate historical drivers of regional instability related to the potential collapse of Thwaites Glacier

Importantly, future work would be enhanced by the more robust ARV icebreaking capabilities that would allow the vessel to reliably penetrate into critically important multi-year ice areas. Ice Radar surveys and UAV Ice Reconnaissance missions will be utilized to improve efficiency and gain access between polynyas in challenging pack ice conditions.

The cruise requires interfacing and support of large third party AUV systems and associated Launch and Recovery Systems (LARS), Hangers and Support vans. A diverse suite of autonomous systems will be utilized to collect broad scientific data including UAVs (UAV Deck support), Gliders (Science Survey boat support), Autonomous Boats (Small Boat/AUV Hanger) and Wave Gliders outside the pack ice. This cruise will also support deployment of multi-season oceanographic mooring arrays. AUV Systems (Hugin 40' LARS, AutoSub 20' Hi-cube Hanger, 20' Support Van for each system) may be used to download mooring data in situations where overhead ice prevents release and recovery.

Additionally, the cruise requires the full suite of physical, chemical and biological related vessel sampling gear, including:

- Multi-beam and Sub-bottom sonars, Hi-PAP USBL
- Multi-spectral radiometers and full suite of Meteorological and Atmospheric sensors, PCO2 (Science mast, Bow mast)

- Corers and Bottom samplers (Mega Core, Box Corer and Kasten Corers, Smith MacIntyre Grab, staged on the working deck
- Piston Long Corer (15m-40m)
- Plankton sampling (Tucker trawl, Bongo/Ring nets)
- Standard and Trace Metal clean CTD rosettes (up to 36 bottles)
- Towed Benthic Camera, live video and high resolution stills (fiber cable)
- Acoustic Tow Body for AutoSub Comms (Starboard side mechanical wire)
- Acoustic locating beacon deployments
- Autonomous surface vehicles, (AutoNaut-5, Wave Glider)
- Sea Gliders
- UAV Systems, both Science and Operations (x1 FRV-90 VTOL, x2 Vector UAVs, x2 Quadcopter UAVs, additional science party UAVs)
- Vertical Microstructure Profiler (VMP), on bolt pattern, stern over-boarded
- Trace Metal Clean (TMC) Lab Vans x2 separated somewhat from coring and other activities
- Moorings/Floatation storage van
- Multiple Science and Cold storage vans
- Shipboard aquaria and incubators, flow through seawater system
- Deck Incubators, flow through seawater system, location not shaded by the ship's structure
- Fully outfitted Aquarium Room, Wet and Dry labs to facilitate sample analysis and allow for the ship to be a sampling platform for both atmospheric and oceanic parameters. Managed sediment/drains
- Dry labs outfitted with chemical storage cabinets and fume hoods.
- 10m Science Survey Work boat for Glider deployment/recovery (pax rated LARS)
- 6m Rigid hulled open boats (island and sea ice access for bio tagging efforts with seals)
- Large A-frames and Deep Sea winches for deployment and recovery.
- Mooring Winch, on bolt pattern supporting mooring operations aft working deck
- TMC Winch, on bolt pattern supporting TMC operations, over-boarding Starboard handling system
- Stacked Ballast (mild steel) secured on bolt pattern for Moorings
- Silent ship operational capabilities for multi-beam and bio acoustic survey (EK-80)
- Capacity for –80ºC freezer space

3.2. Operational Area

Amundsen Sea Embayment, Pine Island Bay, West Antarctica.

3.3. Operational Environment and Temperature

For the DRM, average daily temperature data from the *Nathaniel B. Palmer* between January and March from 2019 to 2022, representing the study site (Thwaites) and some of the Amundsen Sea, was analyzed to determine an average temperature for the 90-day duration Thwaites mission. The lowest average temperature evaluated, -4.4 °C (24.1 °F), with a standard deviation of 2.8 °C (5 °F), is applied as the mission average outdoor air temperature for all DRM activities.

3.4. Vessel Movement

Total Distance Traveled: Approx 8,500 Nautical Miles
Start Port: Punta Arenas, Chile
End Port: Punta Arenas, Chile

Table 2: DRM Thwaites/Pine Island Bay – Vessel Movement Summary

Location	Fair Weather Duration (days)		
	Southern Ocean	Amundsen Embayment	Amundsen Sea
1A - Open water transit	10	-	-
1B - Acoustically quiet transit	-	17.5	-
2 - Icebreaking	2	9	-
3 - On station	-	32	-
4 - On station, DP	-	11.5	-
5 - Deployment	-	4	-
6 - In-Port	1	-	-
7 - Ice Transit	-	3	1
Totals (91-day total mission duration*)	**13**	**77**	**1**
*** DRM includes 0.5 days of In-Port activity prior to and following the 90-day science mission duration to account for fuel burn associated with certain mobilization and de-mobilization activities.**			

Table 3: DRM Thwaites/Pine Island Bay – Vessel Movement Daily Activities

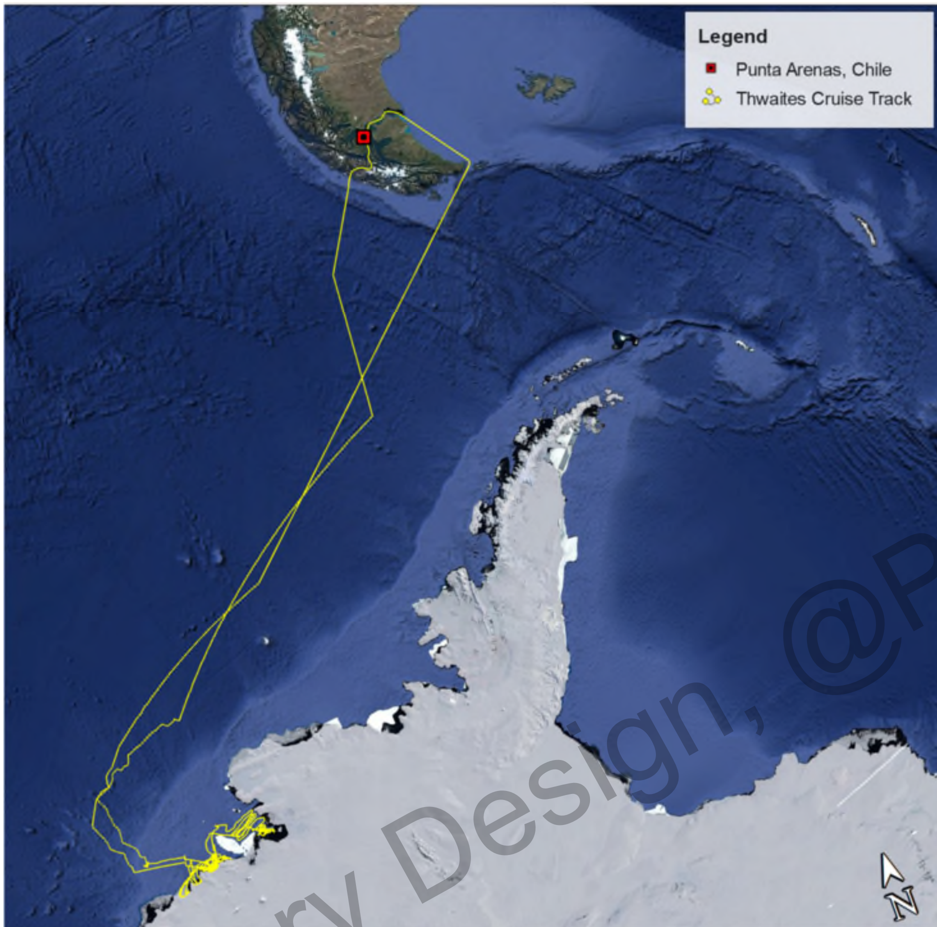
Activity Start		Activity End		Activity Hours	Location	Operation	Cruise days	Activity Type	Approx. Mileage
Date	Shift	Date	Shift						
13-Dec	PM	13-Dec	PM	12	Punta Arenas, Chile (PUQ)	Depart	N/A	6 - In-Port	0
14-Dec	AM	18-Dec	PM	120	PUQ to Amundsen Embayment	Transit open ocean	**1 - 5**	1A - Open water transit	1,320
19-Dec	AM	20-Dec	PM	48		Icebreaking into science area	**6 - 7**	2 - Icebreaking	144
21-Dec	AM	22-Dec	PM	48	Amundsen Embayment	CTD work	8 - 9	3 - On station	0
23-Dec	AM	23-Dec	PM	24		Trace metal tow-fish	9 - 10	1B - Acoustically quiet transit	144
24-Dec	AM	24-Dec	AM	12		Sea glider deployment	11	3 - On station	0
24-Dec	PM	27-Dec	AM	72		Transit - first and second year ice	11 - 14	2 - Icebreaking	216
27-Dec	PM	28-Dec	PM	36		CTD work	14 - 15	3 - On station	0
30-Dec	AM	30-Dec	AM	12		Sea glider deployments	16	3 - On station	0
30-Dec	PM	30-Dec	PM	12		Transit - first and second year ice	16	2 - Icebreaking	36
31-Dec	AM	31-Dec	AM	12		Mega-core/CTD	17	4 - On station, DP	0

Activity Start		Activity End		Activity	Location	Operation	Cruise	Activity Type	Approx.
Date	Shift	Date	Shift	Hours			days		Mileage
31-Dec	PM	31-Dec	PM	12		VMP transect	17	1B - Acoustically quiet transit	72
1-Jan	AM	1-Jan	AM	12		Transit light ice	18	7 - Ice transit	72
1-Jan	PM	1-Jan	PM	12		Sea glider and AUV deployment	18	3 - On station	0
2-Jan	AM	2-Jan	AM	12		CTD work	19	3 - On station	0
2-Jan	PM	2-Jan	PM	12		Transit to open water	19	7 - Ice transit	72
3-Jan	AM	3-Jan	AM	12		Small boat ops- seal tagging	20	3 - On station	0
3-Jan	PM	3-Jan	PM	12		CTD work	20	4 - On station, DP	0
4-Jan	AM	4-Jan	AM	12		Sea glider deployments	21	3 - On station	0
4-Jan	PM	4-Jan	PM	12		Transit to open water	21	7 - Ice transit	72
5-Jan	AM	5-Jan	AM	12		Mega-core/CTD	22	4 - On station, DP	0
5-Jan	PM	5-Jan	PM	12		VMP transect	22	1B - Acoustically quiet transit	72
6-Jan	AM	6-Jan	AM	12		Sea glider and AUV recovery	23	3 - On station	0
6-Jan	PM	6-Jan	PM	12		Multi-beam/ sub-bottom survey	23	1B - Acoustically quiet transit	72
7-Jan	AM	7-Jan	AM	12		Transit to open water	24	7 - Ice transit	72
7-Jan	PM	7-Jan	PM	12		CTD cast	24	3 - On station	0
8-Jan	AM	8-Jan	AM	12		Sea glider deployments	25	3 - On station	0
8-Jan	PM	8-Jan	PM	12		Kasten/mega/jumbo coring	25	4 - On station, DP	0
9-Jan	AM	9-Jan	AM	12		Towed Benthic camera survey	26	5 - Deployment	0
9-Jan	PM	9-Jan	PM	12		Multi-Beam/Sub bottom survey	26	1B - Acoustically quiet transit	72
10-Jan	AM	10-Jan	AM	12		Large AUV deployment	27	3 - On station	0
10-Jan	PM	11-Jan	PM	36		CTD work	27 - 28	3 - On station	0
12-Jan	AM	12-Jan	AM	12		AUV recovery	29	3 - On station	0
12-Jan	PM	12-Jan	PM	12		Autonomous surface boat deployment	29	3 - On station	0
13-Jan	AM	13-Jan	AM	12		Kasten/Mega/Box coring	30	4 - On station, DP	0
13-Jan	PM	18-Jan	AM	72		CTD and TM CTD work	30 - 33	3 - On station	0
18-Jan	PM	18-Jan	PM	12		Trace metal tow-fish	33	1B - Acoustically quiet transit	72
19-Jan	AM	19-Jan	AM	12		Multi-beam/ Sub-bottom survey	34	1B - Acoustically quiet transit	72
19-Jan	PM	19-Jan	PM	12		Autonomous surface boat recovery	34	3 - On station	0
20-Jan	AM	20-Jan	AM	12		Large AUV recovery	35	3 - On station	0
20-Jan	PM	20-Jan	PM	12		Multi-beam/Sub-bottom survey	35	1B - Acoustically quiet transit	72
21-Jan	AM	21-Jan	PM	24		Transit - first and second year ice	36	2 - Icebreaking	72
22-Jan	AM	25-Jan	PM	96		Multi-beam/ sub-bottom/ VMP survey	37 - 40	1B - Acoustically quiet transit	576
26-Jan	AM	28-Jan	AM	60		CTD line	41 - 43	3 - On station	0
28-Jan	PM	29-Jan	PM	36		Kasten/Mega/Box coring	43 - 44	4 - On station, DP	0
30-Jan	AM	30-Jan	AM	12		Sea glider deployments	45	3 - On station	0
30-Jan	PM	30-Jan	PM	12		Small boat ops- seal tagging	45	3 - On station	0

Activity Start		Activity End		Activity	Location	Operation	Cruise	Activity Type	Approx.
Date	Shift	Date	Shift	Hours			days		Mileage
31-Jan	AM	31-Jan	AM	12		Mid-water net tows	46	5 - Deployment	0
31-Jan	PM	31-Jan	PM	12		Multi-beam/Sub bottom survey	46	1B - Acoustically quiet transit	72
1-Feb	AM	1-Feb	AM	12		Large AUV deployment	47	3 - On station	0
1-Feb	PM	2-Feb	PM	36		Piston long corer	47 - 48	4 - On station, DP	0
3-Feb	AM	3-Feb	AM	12		Autonomous surface boat deployment	48	3 - On station	0
3-Feb	PM	3-Feb	PM	12		Trace metal tow-fish	49	1B - Acoustically quiet transit	72
4-Feb	AM	5-Feb	AM	36		Piston Long Corer	50 - 51	4 - On station, DP	0
5-Feb	PM	5-Feb	PM	12		Autonomous surface boat recovery	51	3 - On station	0
6-Feb	AM	6-Feb	AM	12		Large AUV recovery	52	3 - On station	0
6-Feb	PM	7-Feb	AM	24		CTD	52 - 53	3 - On station	0
7-Feb	PM	7-Feb	PM	12		Large AUV deployment	53	3 - On station	0
8-Feb	AM	8-Feb	AM	12		Mooring recovery	54	5 - Deployment	0
8-Feb	PM	8-Feb	PM	12		VMP transect	54	1B - Acoustically quiet transit	72
9-Feb	AM	10-Feb	AM	36		ROV deployment x2	55 - 56	4 - On station, DP	0
10-Feb	PM	10-Feb	PM	12		Small boat ops- seal tagging	56	3 - On station	0
11-Feb	AM	11-Feb	AM	12		Midwater net tows	57	5 - Deployment	0
11-Feb	PM	12-Feb	PM	36		CTD and TM CTD work	57 - 58	3 - On station	0
13-Feb	AM	13-Feb	AM	12		Trace metal tow-fish	59	1B - Acoustically quiet transit	72
13-Feb	PM	13-Feb	PM	12		Autonomous surface boat recovery	59	3 - On station	0
14-Feb	AM	14-Feb	AM	12		Large AUV recovery	60	3 - On station	0
14-Feb	PM	14-Feb	PM	12		Kasten/Mega/Box coring	60	4 - On station, DP	0
15-Feb	AM	15-Feb	AM	12		Multi-beam/Sub bottom survey	61	1B - Acoustically quiet transit	72
15-Feb	PM	15-Feb	PM	12		Small boat ops- seal tagging	61	3 - On station	0
16-Feb	AM	16-Feb	AM	12		Midwater net trawl/bioacoustics	62	5 - Deployment	0
16-Feb	PM	18-Feb	AM	48		CTD and TM CTD work	62 - 64	3 - On station	0
18-Feb	PM	18-Feb	PM	12		Trace metal tow-fish	64	1B - Acoustically quiet transit	72
19-Feb	AM	21-Feb	AM	36		Multi-beam/ sub-bottom survey	65 - 66	1B - Acoustically quiet transit	216
21-Feb	PM	21-Feb	PM	12		VMP transect	66	1B - Acoustically quiet transit	72
22-Feb	AM	22-Feb	AM	12		Small boat ops- seal tagging	67	3 - On station	0
22-Feb	PM	22-Feb	PM	12		Piston Long corer	67	4 - On Station, DP	0
23-Feb	AM	23-Feb	AM	12		Large AUV deployment	68	3 - On station	0
23-Feb	PM	23-Feb	PM	12		Mooring recovery	68	5 - Deployment	0
24-Feb	AM	24-Feb	AM	12		Large AUV recovery	69	3 - On station	0
24-Feb	PM	24-Feb	PM	12		Piston Long Corer	69	4 - On Station, DP	0
25-Feb	AM	28-Feb	PM	96		Multi-beam/ sub-bottom survey	70 - 73	1B - Acoustically quiet transit	576

Activity Start		Activity End		Activity Hours	Location	Operation	Cruise days	Activity Type	Approx. Mileage
Date	Shift	Date	Shift						
1-Mar	AM	1-Mar	PM	24		Midwater net tows	74	5 – Deployment	0
2-Mar	AM	3-Mar	AM	36		Piston long corer	75 - 76	4 – On station, DP	0
3-Mar	PM	3-Mar	PM	12		CTD line	76	3 – On station	0
4-Mar	AM	5-Mar	PM	48		Transit - first and second year ice	77 - 78	2 - Icebreaking	144
6-Mar	AM	6-Mar	AM	12		Small boat ops- seal tagging	79	3 - On station	0
6-Mar	PM	6-Mar	PM	12		Transit - first and second year ice	79	2 - Icebreaking	36
7-Mar	AM	8-Mar	PM	48		Small boat ops- seal tagging	80 - 81	3 - On station	0
9-Mar	AM	10-Mar	PM	48		Transit - first and second year ice	82 - 83	2 - Icebreaking	144
11-Mar	AM	11-Mar	PM	24		Transit to open water	84	7 – Ice Transit	144
12-Mar	AM	12-Mar	PM	24	Amundsen Sea	Transit to open water	85	7 - Ice transit	144
13-Mar	AM	17-Mar	PM	120	Amundsen Sea to PUQ	Transit open ocean	86 - 90	1A - Open water transit	1,320
18-Mar	AM	18-Mar	AM	12	Punta Arenas, Chile (PUQ)	Arrive Punta Arenas, Chile	**N/A**	6 – In-Port	0

Figure 1: 90-day Thwaites Glacier Cruise Track



Appendix A: Alternate Design Reference Mission Candidates

During the development of the ARV DRM, additional mission candidates were evaluated. The Thwaites\Pine Island Bay mission was ultimately selected as it represented the most diverse in terms of science activities and ARV operating modes for a 90-day mission. The following summarizes two additional mission scopes considered for the ARV design.

1. DRM Candidate (DRMC) 2: Larsen C

This Design Reference Mission Candidate is a 90 day cruise to the Larsen C ice shelf to allow for studies focusing on the rapidly changing dynamics on the eastern side of the Antarctic Peninsula.

Austral Spring and Summer: (January – March).

1.1. Summary of Expedition

This cruise would focus in areas previously covered by ice shelves that are now exposed to light and atmospheric gas exchange. Changes in ice cover and sea-ice dynamics are altering ecosystem function. This region is also important for deep water formation, which affects global ocean circulation patterns. This would be a glaciology/geology/biology/physical oceanography collaborative effort. Operations in the area will also allow the support of separate project field camps in the James Ross/Seymore Island area over the duration of the cruise.

- 6-7 science teams, with a full science complement of 55 persons.
- 24 hour operations divided into 12 hour rotations.

With the disintegration of the Larsen Ice shelf large amounts of glacial ice have been added to the multi-year sea ice in the Weddell Sea. Already challenging ice conditions, plus the increased inclusion of glacier ice require robust ship icebreaking capabilities to allow the vessel to more reliably access and operate in critically important multi-year ice areas. Ice Radar surveys and unmanned aerial vehicle (UAV) Ice Reconnaissance missions will also be utilized to improve efficiency and maintain operations in challenging ice conditions with shifting leads and pressure.

This cruise requires the interfacing and support of third party ROV and sea-bed Geo Technical Drilling systems. The Geo Technical drill and Piston Long Core will be used to recover samples from targets previously identified in seismic surveys of the area. These systems have significant power and containerized support equipment requirements.

The science missions also require diverse small boat capabilities to support and enhance the efforts of all groups. Field camp put ins and take outs will be supported by the 10m Landing Craft work boat and a pair of 6m rigid hulled open boats. Whale tagging, biopsy, survey and glider recovery will be supported by 6m rigid hulled open boats and the 10m Science Survey work boat. The Science Survey work boat will also conduct close scale EK-80 surveys and may provide bathymetric surveys of field camp landing areas and other near shore areas of interest. 10m Landing Craft work boat can also support pot fishing in addition to the ship’s trawling efforts for benthic survey.

Science autonomous systems will include UAV operations for observations, photogrammetric surveys and sampling for multiple disciplines. The Sea Ice reconnaissance UAV can also be used to conduct daily over flight of the field camps for safety checks. An autonomous surface vehicle (ASV) Wave Glider will be deployed after crossing the Drake and recovered at the end in South Georgia vicinity. Slocum Gliders will provide both short and long time series surveys, including bio-acoustics.

This cruise would require a full complement of scientific equipment, including:

- Multi-beam and Sub-bottom sonars, Hi-PAP USBL, hull mounted ADCP
- Multi-spectral radiometers and full suite of Meteorological and Atmospheric sensors, PCO2 (Science mast, Bow mast)
- Light Sediment Coring samplers (Mega Core, Box Core, Kasten Core,)
- Geotechnical sea-floor drilling rig (Mebo, BGS), 30’ Aft Aframe, x7 20’ ISO support vans, bolt pattern
- ROV operations (JASON II/Media), LARS/Crane Starboard deployed, x4 20 ISO support vans, bolt pattern
- Standard and Trace Metal Clean (TMC) CTD rosettes (up to 36 bottles) with full complement of physical, chemical and biological sensors
- Autonomous surface vehicles (Wave Glider)
- Slocum Gliders
- UAV Systems, both Science and Operations
- Large plankton nets (MOCNESS, IKMT)
- Benthic Trawls (Blake Trawl, Otter Trawl, Epibenthic sled) and Benthic Camera still/video (YoYo camera)
- TMC Lab Van, x2 Rads Lab Vans
- Moorings/Floatation storage van
- x3 Science van (Core splitter, Core logger, CT Scan, etc.)
- x3 Cold storage vans (drill and piston core storage)
- Shipboard aquaria and incubators, flow through seawater system
- Deck Incubators, flow through seawater system, location not shaded by the ship’s structure
- Fully outfitted Aquarium Room, Wet and Dry labs to facilitate sample analysis and allow for the ship to be a sampling and experimental platform for atmospheric, biological and oceanic parameters. Managed sediment/drains
- 10m Science Survey Work boat (focused acoustic surveys, marine mammal support, near shore bathy surveys, pot fishing)
- 10m Landing Craft Work boat (Field camp put in/take out, shore access, pot fishing)
- ATV and trailer for island-based field camp support

- x2 6m Rigid hulled open boats (tagging, biopsy, shore/ice access, glider recovery)
- Large A frames and Deep Sea winches for deployment and recovery.
- Mooring Winch, on bolt pattern supporting mooring operations aft working deck
- TMC Winch, on bolt pattern supporting TMC operations, over-boarding Starboard handling system
- Stacked RR Wheel ballast secured on bolt pattern for Moorings
- Silent ship operational capabilities for multi-beam and bio acoustic survey (EK-80)
- Shipboard Cold rooms for subsampling and experiments
- -80^{o}C freezers for sample storage
- Van with Liquid Nitrogen Generator
- Water wall with on-line sensors connected to SeaWater Intake to take along-track measurements of pCO2, physical and biological variables

1.2. Operational Area

Eastern Antarctic Peninsula, Weddell Sea and South Atlantic Ocean.

The Larsen C ice shelf is most directly accessed from the western Weddell Sea. Departures from the USAP gateway port of Punta Arenas, Chile require 7-10 days. Terminating at the South Africa gateway port would add an additional 2-3 weeks of transit time, reducing science days. For this example cruise, Larsen area work was combined with science along the Scotia Arc which would require 90 days.

Primary sampling areas are:

- James Ross Island
- Former sites of Larsen A and B Ice Shelves, (Scar Inlet)
- Edge of the present Larsen C Ice Shelf
- Scotia Arc
- South Georgia Island/Cumberland Bay

1.3. Vessel Movement

Total Distance Traveled: 5,800 Nautical Miles

Start Port: Punta Arenas, Chile

End Port: Punta Arenas, Chile

Table 4: DRMC2 Larsen C – Vessel Movement Summary

Location	Fair Weather Duration (days)			
	Southern Ocean	James Ross Island/Larsen B Site	Larsen C Site	Scotia Arc
Open water transit	9.5	2	-	-
Acoustically quiet transit	-	2.5	4.5	3
Icebreaking	1	8	11	-
On station	-	6	5.5	3.5
On station, DP	-	3	13.5	-
Deployment	-	3	6.5	3
In-Port	1	-	-	-
Ice Transit	-	3	0.5	-
Totals (90-day total mission duration)	**11.5**	**27.5**	**41.5**	**9.5**

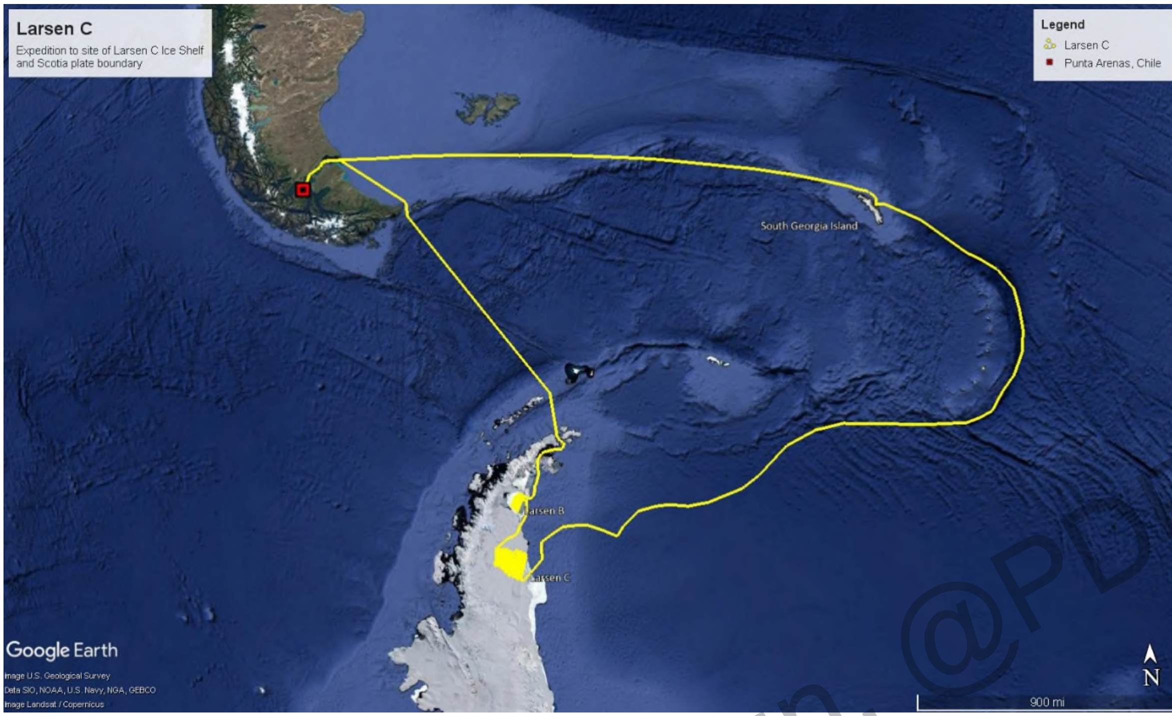
Table 5: DRMC2 Larsen C vicinity – Vessel Movement Daily Activities

Activity Start		Activity End		Activity Hours	Location	Operation	Cruise days	Activity Type
Date	Shift	Date	Loca tion					
5-Jan	AM	5-Jan	AM	12	Punta Arenas, Chile (PUQ)	Depart	1	In-Port
5-Jan	PM	9-Jan	PM	108	PUQ- Trinity Peninsula	Transit open ocean, Wave Glider deploy in open water (Approx 900 nm)	1 - 4	Open water transit
10-Jan	AM	11-Jan	AM	36	Prince Gustav Channel	Transit - first and second year ice (Approx 170 nm)	5 - 7	Icebreaking
11-Jan	PM	13-Jan	PM	60	James Ross Island (JRI)	On station for paleontology field camp put-in, Small Boat ops	7 - 9	On station
14-Jan	AM	17-Jan	AM	84	South of JRI to Scar Inlet	Transit second and multi-year ice	10 - 13	Icebreaking
17-Jan	PM	19-Jan	PM	60	Former Larsen A and B sites	Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	13 - 15	Acoustically quiet transit
20-Jan	AM	21-Jan	PM	48		Light Coring, Benthic Trawls	16 - 17	Deployment
22-Jan	AM	24-Jan	PM	72		ROV Ops	18 - 20	On Station, DP
25-Jan	AM	27-Jan	AM	60		CTD-LADCP/TMC	21 - 23	On station
27-Jan	PM	27-Jan	PM	12		Jumbo Piston Coring	23	Deployment
28-Jan	AM	28-Jan	AM	12		Transit and CTD work	24	Open water transit
28-Jan	PM	28-Jan	PM	12		Mooring deployment	24	Deployment
29-Jan	AM	30-Jan	AM	36		Transit and CTD work	25 - 26	Open water transit
30-Jan	PM	2-Feb	AM	72	Scar Inlet to JRI	Transit to open water	26 - 29	Ice transit
2-Feb	PM	3-Feb	AM	24	JRI	On station for paleontology field camp take out, Small Boat ops	29 - 30	On station

3-Feb	PM	5-Feb	PM	60	South of JRI to Larsen C site	Transit second and multi-year ice	30 - 32	Icebreaking
6-Feb	AM	6-Feb	AM	12	Edge of Larsen C site		33	Icebreaking
6-Feb	PM	6-Feb	PM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	33	Acoustically quiet transit
7-Feb	AM	7-Feb	AM	12		AUV deployment, Gliders	34	On station
7-Feb	PM	10-Feb	AM	72		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	34 - 37	Acoustically quiet transit
10-Feb	PM	10-Feb	PM	12		Jumbo Piston Coring	37	Deployment
11-Feb	AM	11-Feb	AM	12		CTD-LADCP/TMC	38	On Station
11-Feb	PM	11-Feb	PM	12		Light Coring	38	Deployment
12-Feb	AM	12-Feb	AM	12		Transit - first and second year ice	39	Icebreaking
12-Feb	PM	12-Feb	PM	12		ROV Ops	39	On station, DP
13-Feb	AM	13-Feb	AM	12		Jumbo Piston Coring	40	Deployment
13-Feb	PM	13-Feb	PM	12		Benthic Trawls and YoYo Camera	40	Deployment
14-Feb	AM	14-Feb	AM	12		Mooring deployment	41	Deployment
14-Feb	PM	14-Feb	PM	12		Mid-water Plankton (MOCNESS)	41	Deployment
15-Feb	AM	15-Feb	AM	12		ROV Ops	42	On Station, DP
15-Feb	PM	15-Feb	PM	12		ROV Ops	42	On Station, DP
16-Feb	AM	16-Feb	AM	12		AUV recovery, Gliders	43	On Station
16-Feb	PM	16-Feb	PM	12		Transit - first and second year ice	43	Icebreaking
17-Feb	AM	17-Feb	AM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	44	Acoustically quiet transit
17-Feb	PM	17-Feb	PM	12		AUV deployment	44	On station
18-Feb	AM	18-Feb	AM	12		CTD-LADCP/TMC	45	On Station
18-Feb	PM	18-Feb	PM	12		Light Coring	45	Deployment
19-Feb	AM	19-Feb	AM	12		Benthic Trawls	46	Deployment
19-Feb	PM	19-Feb	PM	12		ROV Ops	46	On station, DP
20-Feb	AM	20-Feb	PM	24		Geotechnical drilling	47	On station, DP
21-Feb	AM	21-Feb	PM	24		CTD-LADCP/TMC	48	On station
22-Feb	AM	24-Feb	AM	60		Geotechnical drilling	49 - 51	On station, DP
24-Feb	PM	24-Feb	PM	12		Transit - first and second year ice	51	Icebreaking
25-Feb	AM	25-Feb	AM	12		GPS Site install, Small Boat Ops	52	On station
25-Feb	PM	27-Feb	PM	60		Geotechnical drilling	52 - 54	On station, DP
28-Feb	AM	28-Feb	AM	12		Transit - first and second year ice	55	Icebreaking
28-Feb	PM	28-Feb	PM	12		AUV recovery	55	On station
1-Mar	AM	1-Mar	AM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	56	Acoustically quiet transit
1-Mar	PM	2-Mar	PM	36		Geotechnical drilling	56 - 57	On station, DP
3-Mar	AM	3-Mar	AM	12		Mooring deployment	58	Deployment
3-Mar	PM	3-Mar	PM	12		CTD-LADCP/TMC	58	On Station
4-Mar	AM	4-Mar	AM	12		Light Coring	59	Deployment
4-Mar	PM	4-Mar	PM	12		CTD-LADCP/TMC	60	On Station
5-Mar	AM	6-Mar	PM	48		Geotechnical drilling	60 - 61	On station, DP
7-Mar	AM	7-Mar	PM	24		Benthic Trawls	62	Deployment

8-Mar	AM	8-Mar	AM	12		Transit to station	63	Ice transit
8-Mar	PM	10-Mar	AM	48		Geotechnical drilling	63 - 65	On station, DP
10-Mar	PM	10-Mar	PM	12		Piston Long Coring	65	Deployment
11-Mar	AM	13-Mar	AM	60	Exit Larsen C	Transit - first and second year ice	66 - 68	Icebreaking
13-Mar	PM	19-Mar	PM	156	Larsen C to southern Scotia Arc	Transit second and multi-year ice	68 - 74	Icebreaking
20-Mar	AM	20-Mar	AM	12	Scotia Arc	Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	75	Acoustically quiet transit
20-Mar	PM	20-Mar	PM	12		CTD-LADCP	75	On station
21-Mar	AM	21-Mar	AM	12		Benthic Trawls	76	Deployment
21-Mar	PM	21-Mar	PM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	76	Acoustically quiet transit
22-Mar	AM	22-Mar	AM	12		CTD-LADCP	77	On station
22-Mar	PM	22-Mar	PM	12		Benthic Trawls	77	Deployment
23-Mar	AM	23-Mar	AM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	78	Acoustically quiet transit
23-Mar	PM	23-Mar	PM	12		CTD-LADCP	78	On station
24-Mar	AM	24-Mar	AM	12		Benthic Trawls	79	Deployment
24-Mar	PM	24-Mar	PM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	79	Acoustically quiet transit
25-Mar	AM	25-Mar	AM	12		CTD-LADCP	80	On station
25-Mar	PM	25-Mar	PM	12		Benthic Trawls	80	Deployment
26-Mar	AM	26-Mar	AM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	81	Acoustically quiet transit
26-Mar	PM	26-Mar	PM	12		CTD-LADCP	81	On station
27-Mar	AM	27-Mar	AM	12		Benthic Trawls	82	Deployment
27-Mar	PM	27-Mar	PM	12		Bio-Acoustic (EK) survey with midwater plankton nets (MOCNESS)	82	Acoustically quiet transit
28-Mar	AM	28-Mar	PM	24		Stop at South Georgia- Field camp resupply, Landing Craft work boat	83	On station
29-Mar	AM	29-Mar	AM	12		Mooring recovery	84	Deployment
29-Mar	PM	4-Apr	AM	**144**	South Georgia **Larson C** - PUQ	Transit (Approx 1,260 nm)	84 - 90	Open water transit
4-Apr	PM	4-Apr	PM	12	Punta Arenas, Chile (PUQ)	Arrival	90	In-Port

Figure 2: Example Larsen C cruise track



2. DRM Candidate (DRMC) 3: Wilkes / George V Coast

Another potential Design Reference Mission Candidate, this 90 day cruise to the George V Coast would allow for sampling, coring, sea floor mapping, onshore deployments for sampling, and ocean and land-based geophysics adjacent to the Wilkes subglacial basin.

Austral Spring: (December – March).

2.1. Summary of Expedition

The concept is a joint land-based geophysics, geology and ice coring in conjunction with offshore geophysics and coring to quantify the past and potential future contribution of glaciers along the Wilkes Land coast to sea level rise.

The East Antarctic presents challenges with both remoteness and it's difficult ice conditions with harder than typical ice in embayments and other areas of interest. This requires robust ship icebreaking capabilities to allow the vessel to more reliably access and operate in this known challenging area of great scientific interest. Ice Radar surveys and UAV Ice Reconnaissance missions will also be utilized to improve efficiency and maintain operations in challenging ice conditions and to help locate areas of access.

Science autonomous systems will include UAVs, Gliders, Under Ice Vehicle and Autonomous Boat (deployed at the beginning of the cruise and recovered at the end). This cruise will conduct a seismic reflection survey to further resolve favorable coring sites. The cruise will also deploy a series of complex instrumented base time series moorings (Totten M-series) requiring TOGS mooring for orientation (proximity to south magnetic pole).

Natural collaborations exist with Australian, French, New Zealand, and the Chinese Antarctic Programs. All of these NAPs have been significantly challenged working in this area aboard less capable Ice Breakers.

The cruise would also perform US Antarctic Treaty-based inspections at stations along the route.

An extended cruise, such as this, would utilize the ARV as a floating lab, opening up possibilities for running experiments in real time, which are currently mostly limited to station work.

- 6-7 science groups (total of 55 persons) working 24 hours a day.

This cruise would require a full complement of scientific equipment, including:

- Multibeam and Sub-bottom sonars, Hi-PAP USBL
- Multi-spectral radiometers and full suite of Meteorological and Atmospheric sensors, PCO2 (Science mast, Bow mast)
- Light Sediment Coring samplers (Mega Core, Box Core, Kasten Core,)
- Dredges (Rock Dredge, Basket Dredge)
- Piston Long Corer 40-50m, (traction winch, synthetics)

- Seismic Survey, (GI source array, x2 multi-channel streamers), x1 Seismic workshop van, x2 Gun winches, x2 Streamer winches, Seismic compressors (primary and back up), bolt pattern
- Hi-Volume Standard CTD rosette (up to 36 bottles)
- Trace Metal Clean (TMC) CTD rosettes (up to 36 bottles)
- Towed Benthic Camera, Live video with Hi-res stills (fiber cable)
- McClane Pumps
- UAV Systems, both Science (photogrammetrics and ice surfaces) and Operations (Ice Reccy)
- Gliders (Slocum, Improved Sea Gliders)
- Autonomous Boat (Sail Drone)
- TMC Lab Van, Rads Lab Van
- Moorings/Floatation storage van
- Moorings ballast and Instrumented Base assemblies on working deck
- x3 Science van (Core splitter, Core logger, CT Scan etc.)
- x2 Cold storage vans (piston core storage)
- Silent ship operational capabilities for multibeam and sub bottom surveys
- Shipboard aquaria and incubators, flow through seawater system
- Deck Incubators, flow through seawater system, location not shaded by the ship's structure
- Fully outfitted Aquarium Room, Wet and Dry labs to facilitate sample analysis and allow for the ship to be a sampling platform for both atmospheric and oceanic parameters. Managed sediment/drains.
- Shipboard Cold rooms for subsampling and experiments and –80^{o}C freezers for sample storage and vans with Liquid Nitrogen Generator.
- Wet labs outfitted with chemical storage cabinets and fume hoods.
- Large A frames and Deep Sea winches for deployment and recovery.
- Mooring Winch, on bolt pattern supporting mooring operations aft working deck
- TMC Winch, on bolt pattern supporting TMC operations, over-boarding Starboard handling system
- 10m Science Survey Work boat (Station inspections, Glider deploy/recovery, near shore bathy surveys)
- 6m Rigid hulled open boats (sea ice access)
- 10m Landing Craft Work boat (foreign station resupply efforts)

2.2. Operational Area

Regions off Wilkes and George V Land, East Antarctica and Dumont d'Urville Sea

George V Coast can be accessed from McMurdo, Jang Bogo or Dumont d'Urville Stations. Timing is critical to allow access due to sea ice.

Primary sampling areas are:

- Mertz- Ninnis trough
- Wilkes subglacial basin
- Dumont d'Urville Sea
- Continental margin off the Totten Glacier and Holmes Glacier (Wilkes Land)

2.3. Vessel Movement

Total Distance Traveled: 9,800 Nautical Miles

Start Port: Lyttelton, NZ

End Port: Lyttelton, NZ

Table 6: DRMC3 Wilkes / George V Coast – Vessel Movement Summary

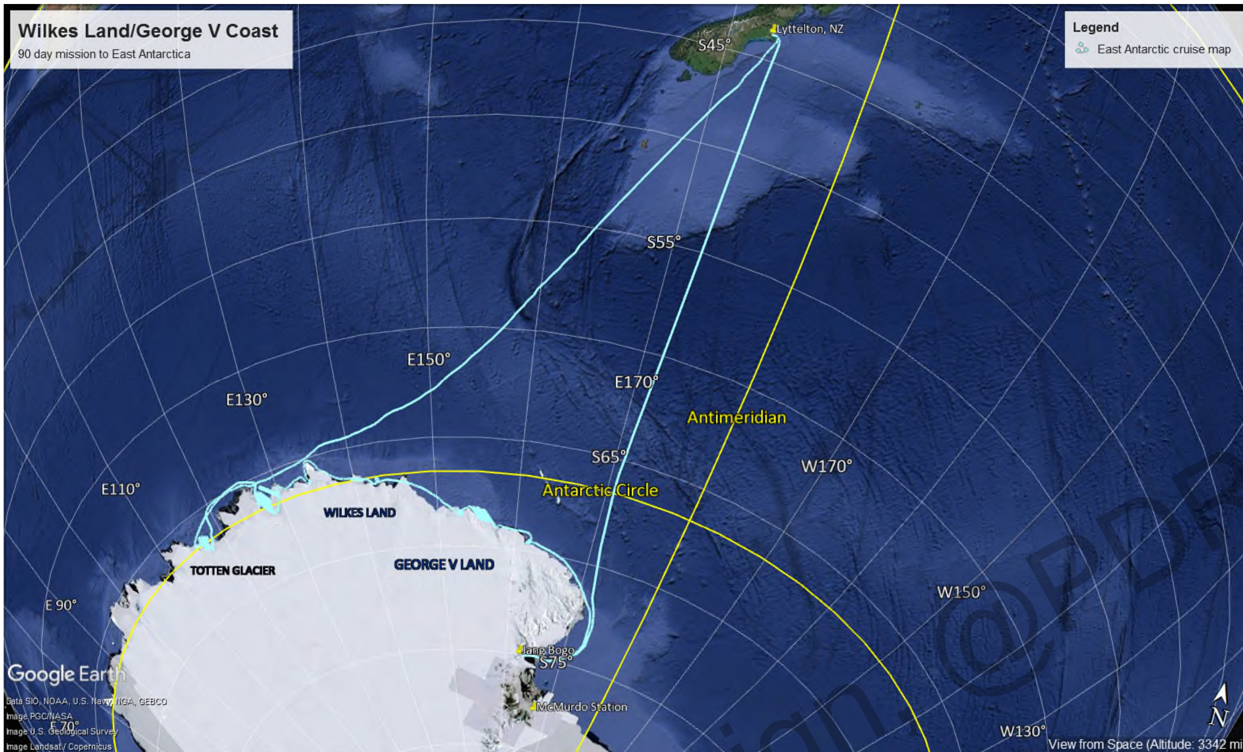
Location	Fair Weather Duration (days)			
	Southern Ocean	Casey to Totten	Totten to Holmes	Holmes to Jang Bogo
Open water transit	16	1	1.5	3
Acoustically quiet transit	-	6.5	14.5	5
Icebreaking	-	2	-	1.5
On station	-	2	7	1.5
On station, DP	-	1.5	8	-
Deployment	-	2	7.5	1
In-Port	1.0	-	-	-
Ice Transit	-	3	1.5	3.5
Totals (90-day total mission duration)	**16.5**	**18**	**40**	**15.5**

Table 7: DRMC3 Wilkes / George V Coast – Vessel Movement Daily Activities

Activity Start		Activity End		Activity Hours	Location	Operation	Cruise days	Activity Type
Date	Shift	Date	Location					
22-Dec	AM	22-Dec	AM	12	Lyttelton, NZ	Depart	1	In-Port
22-Dec	PM	30-Dec	PM	204	LYT- ice edge (Approx. 2,000 nm)	Transit open ocean - drifter buoys, Sail Drone deploy en route	1 - 9	Open Water Transit
31-Dec	AM	1-Jan	PM	48	Ice edge to Casey Station	Transit - first and second year ice	10 - 11	Icebreaking
2-Jan	AM	2-Jan	PM	24	Casey Station	Treaty inspection	12	On station
3-Jan	AM	3-Jan	AM	12	Casey area to Totten Glacier	Transit open ocean	13	Open Water Transit
3-Jan	PM	5-Jan	PM	60		Multi-beam/ sub-bottom/ magnetometer survey	13 - 15	Acoustically quiet transit
6-Jan	AM	6-Jan	AM	12		Rock Dredge/Basket Dredge	16	Deployment
6-Jan	PM	7-Jan	PM	36		Multi-beam/ sub-bottom/ magnetometer survey	16 - 17	Acoustically quiet transit
8-Jan	AM	8-Jan	PM	24		Light Coring	17 - 18	Deployment
9-Jan	AM	10-Jan	AM	36		Multi-beam/ sub-bottom/ magnetometer survey	19 - 20	Acoustically quiet transit
10-Jan	PM	10-Jan	PM	12		CTD/TMC/McClane pumps	20	On station
11-Jan	AM	11-Jan	PM	24		Multi-beam/ sub-bottom/ magnetometer survey	21	Acoustically quiet transit
12-Jan	AM	12-Jan	PM	24		Piston Long Coring	22	On Station, DP
13-Jan	AM	15-Jan	PM	72		CTD line + Transit light ice	23 - 25	Ice transit
16-Jan	AM	16-Jan	AM	12		Transit open ocean	26	Open Water Transit
16-Jan	PM	16-Jan	PM	12		CTD/TMC/McClane pumps	26	On station
17-Jan	AM	17-Jan	AM	12		Light Coring	27	Deployment
17-Jan	PM	17-Jan	PM	12		Piston Long Coring	27	On station, DP
18-Jan	AM	20-Jan	AM	60	Totten to Holmes Glacier	Transit light ice	28 - 29	Ice Transit
20-Jan	PM	20-Jan	PM	12		Light Coring	29	Deployment
21-Jan	AM	21-Jan	AM	12		Rock Dredge/Basket Dredge	30	Deployment
21-Jan	PM	1-Feb	AM	264		Seismic survey	30 - 42	Acoustically quiet transit
1-Feb	PM	1-Feb	PM	12		Light Coring	42	Deployment
2-Feb	AM	2-Feb	PM	24		Light Coring	43	Deployment
3-Feb	AM	3-Feb	AM	12		Transit open water	44	Open Water Transit
3-Feb	PM	3-Feb	PM	12		Light Coring	44	Deployment
4-Feb	AM	4-Feb	PM	24		Piston Long Coring	45	On station, DP
5-Feb	AM	5-Feb	AM	12		Transit open water	46	Open Water Transit
5-Feb	PM	5-Feb	PM	12		Light Coring	46	Deployment
6-Feb	AM	7-Feb	AM	36		Piston Long Coring	47 - 48	On station, DP
7-Feb	PM	11-Feb	PM	108		CTD- LADCP/TMC line- Holmes Glacier face	48 - 52	On station
12-Feb	AM	12-Feb	AM	12		Towed Benthic camera transect	53	Deployment
12-Feb	PM	12-Feb	PM	12		Piston Long Coring	53	On station, DP
13-Feb	AM	13-Feb	AM	12		Light Coring	54	Deployment
13-Feb	PM	13-Feb	PM	12		Transit open water	54	Open Water Transit
14-Feb	AM	14-Feb	AM	12		Towed Benthic camera transect	55	Deployment
14-Feb	PM	14-Feb	PM	12		Light Coring	55	Deployment
15-Feb	AM	16-Feb	AM	36		Light Coring	56 - 57	Deployment

16-Feb	PM	18-Feb	AM	48		Piston Long Coring	57 - 59	On station, DP
18-Feb	PM	18-Feb	PM	12		Mooring deployment	59	Deployment
19-Feb	AM	19-Feb	AM	12		CTD- LADCP/TMC/McClane pumps	60	On station, DP
19-Feb	PM	19-Feb	PM	12		Light Coring	60	Deployment
20-Feb	AM	20-Feb	AM	12		Light Coring	61	Deployment
20-Feb	PM	22-Feb	PM	60		Multi-beam/ sub-bottom/ Magnetometer survey	61 - 63	Acoustically quiet transit
23-Feb	AM	25-Feb	AM	60		CTD- LADCP/TMC/McClane pumps	64 - 66	On station
25-Feb	PM	25-Feb	PM	12		Light Coring	66	Deployment
26-Feb	AM	26-Feb	AM	12		Towed Benthic camera transect	67	Deployment
26-Feb	PM	26-Feb	PM	12		Blake trawl/Mac Grab/Rock dredge	67	Deployment
27-Feb	AM	28-Feb	AM	36	Holmes Glacier to Dumont d'Urville	Transit - first and second year ice	68 - 69	Icebreaking
28-Feb	PM	28-Feb	PM	12	Arrive Dumont d'Urville	Treaty inspection	69	On station
1-Mar	AM	1-Mar	AM	12	d'Urville to Mertz Glacier	Transit open water	69.5	Open Water Transit
1-Mar	PM	3-Mar	PM	60		Multi-beam/ sub-bottom/ magnetometer survey	70 - 72	Acoustically quiet transit
4-Mar	AM	4-Mar	AM	12		Rock Dredge/Basket Dredge	73	Deployment
4-Mar	PM	5-Mar	PM	36		Multi-beam/ sub-bottom/ magnetometer survey	73 - 74	Acoustically quiet transit
6-Mar	AM	6-Mar	AM	12		Light Coring	75	Deployment
6-Mar	PM	6-Mar	PM	12		CTD-LADCP/TMC/McClane pumps	75	On station
7-Mar	AM	7-Mar	PM	24		Multi-beam/ sub-bottom/ magnetometer survey	76	Acoustically quiet transit
8-Mar	AM	11-Mar	AM	84		CTD line + Transit light ice	77 - 80	Ice Transit
11-Mar	PM	13-Mar	PM	60	Mertz-Ninnis Glacier to Jang Bogo	Transit open ocean	80 - 82	Open Water Transit
14-Mar	AM	14-Mar	AM	12	Arrive Jang Bogo	Treaty inspection	83	On station
14-Mar	PM	21-Mar	PM	180	Jang Bogo to Lyttleton (Approx 1,900 nm)	Transit open ocean	83 - 90	Open Water Transit

Figure 3: Eastern Antarctic Glacier cruise track

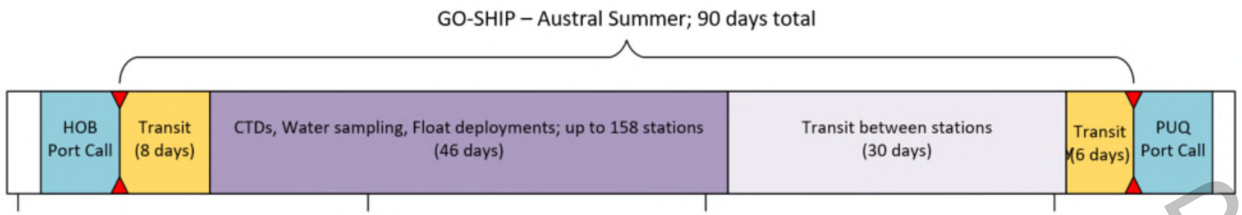


Appendix B: Additional mission profiles

The following information includes additional mission profiles researched during the development of the ARV DRM.

1. Science Mission 4: GO-SHIP

Figure 4: GO-SHIP block schedule assuming 90 days in austral summer



1.1. Summary of Expedition

The GO-SHIP science expedition repeats sampling of the Pacific Ocean S04P hydrographic line for the US Global Ocean Carbon and Repeat Hydrography Program. The survey of the line consists of vertical deployment operations – CTDs, LADCP, UVP, and water samples as well as underway multi-beam data collection. Sample stations are spaced approximately 30 nm from each other and target sites range from 200 m in depth to full depth profiles (usually within 10 m of the bottom). During transits and in between sample locations numerous types of floats are deployed including SOCCOM floats, Argo floats – FSU floats, CSCIRO floats, EM-APEX floats as well as drifters.

Water samples are measured for features such as salinity, dissolved oxygen, nutrients, dissolved inorganic carbon (DIC), pH, alkalinity, and CFCs/SF6. Some sampling water would be stored and shipped back to CONUS for shore based laboratory analysis.

1.2. Operational Area

Pacific and Ross Sea. Sampling area begins at Cape Adare (70.45°S, 168.48°W) to 73.48°W along the 67°S line to the Antarctic Peninsula. It includes spurs south from 67°S along the 150°W end of the P16S line and also along the 170°E, 170°W, and 103°W lines all the way to the continental shelf in order to complete the southern ends of the P14S, P15S, and P18S lines.

1.3. Vessel Movements

Total Distance Traveled: 9,265 Nautical Miles

Start Port: Hobart, Australia

End Port: Punta Arenas, Chile

Table 8: Summary of GO-SHIP locations and science operations

Location	Activity Type	Activity Detail	Summer Duration (days)	Winter Duration (days)
Southern Ocean	Open water transit	Transit to study area	8	13
Ross Sea/Southern Ocean/Amundsen Sea	On station	CTD - up to 158 stations	46	30
Ross Sea/Southern Ocean/Amundsen Sea	Open water transit/Ice Transit	Transit between stations	30	38
Palmer Peninsula Region	Open water transit	Transit from study area	6	9
Total			**90**	**90**

Figure 5: GO-SHIP cruise track with 2019 summer sea ice average (pink line) and extent (white shading)

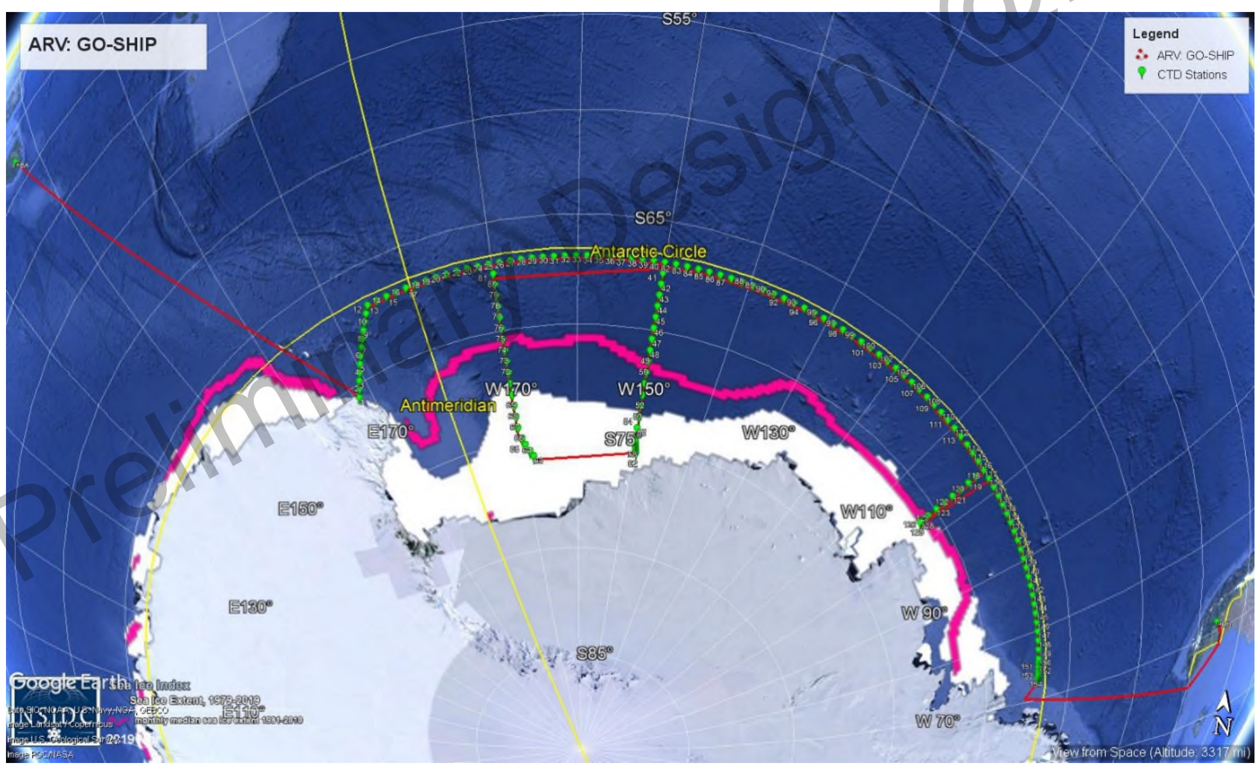
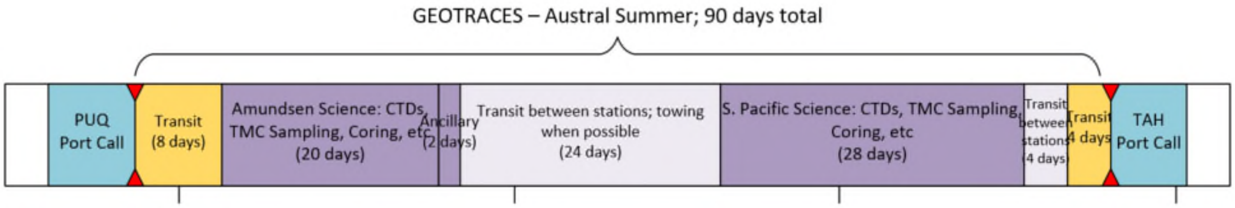


Figure 6: GO-SHIP cruise track with 2019 winter sea ice average (pink line) and extent (white shading)

2. Science Mission 5: GEOTRACES

Figure 7: GEOTRACES



2.1. Summary of Expedition

The GEOTRACES science expedition will measure a broad suite of tracer elements, radioisotopes and stable isotopes due to the role they play in regulating primary production and as tracers for both past and present biological, biogeochemical, and physical processes. This 90-day expedition will provide the science party an opportunity to conduct a series of transects across the Amundsen Sea sector of the Antarctic continental margin and also the South Pacific sector (roughly along the 150W line) of the GP17 transect line. The science team plans to sample approximately 60 hydrographic sampling stations – 30 of the sample stations lie in the Antarctic sector of the GP17 area. Vertical sampling operations will be primarily CTDs and TMC CTDs to depths ranging from less than 1000m to 3000m. Surface water sampling using a small boat (Ancillary Operations) or TMC towfish system (Towed Operations) and sediment sampling with a multi-corer (Vertical Operations) may also be conducted at sample stations on the continental shelf. Timing at stations will vary between 5 to 30 hours.

2.2. Operational Area

Amundsen Sea region with focus on the Amundsen Sea polynya all the way up to the South Pacific roughly following the 150W line north toward Tahiti.

2.3. Vessel Movements

Total Distance Traveled:	8,785 Nautical Miles
Start Port:	Punta Arenas, Chile
End Port:	Pape’ete, Tahiti

Table 9: Summary of GEOTRACES locations and science operations

Location	Activity Type	Activity Detail	Summer (days)	Winter (days)
Drake Passage/ Southern Ocean	Open water transit	Punta Arenas to Amundsen Sea	8	13
Amundsen Sea	On station	30 Sample Stations- CTD, etc.	20	16
Amundsen Sea	Deployment	Towing when possible between stations	0	0
Amundsen Sea	On station	Surface water sampling- small boat or manned basket	2	2
Amundsen Sea	Open water transit/Ice Transit	Transit between stations	24	28
South Pacific	On station	30 Sample Stations- CTD, etc.	28	23
South Pacific	Deployment	Towing between stations	0	0
South Pacific	Open water transit	Transit between stations	4	4
South Pacific	Open water transit	South Pacific To Pape'ete	4	4
Total			**90**	**90**

Figure 8: Complete GEOTRACES GP17 cruise track with 2019 summer sea ice median extent (pink line) and March 2019 extent (white shading); No plots available for South Pacific CTD stations

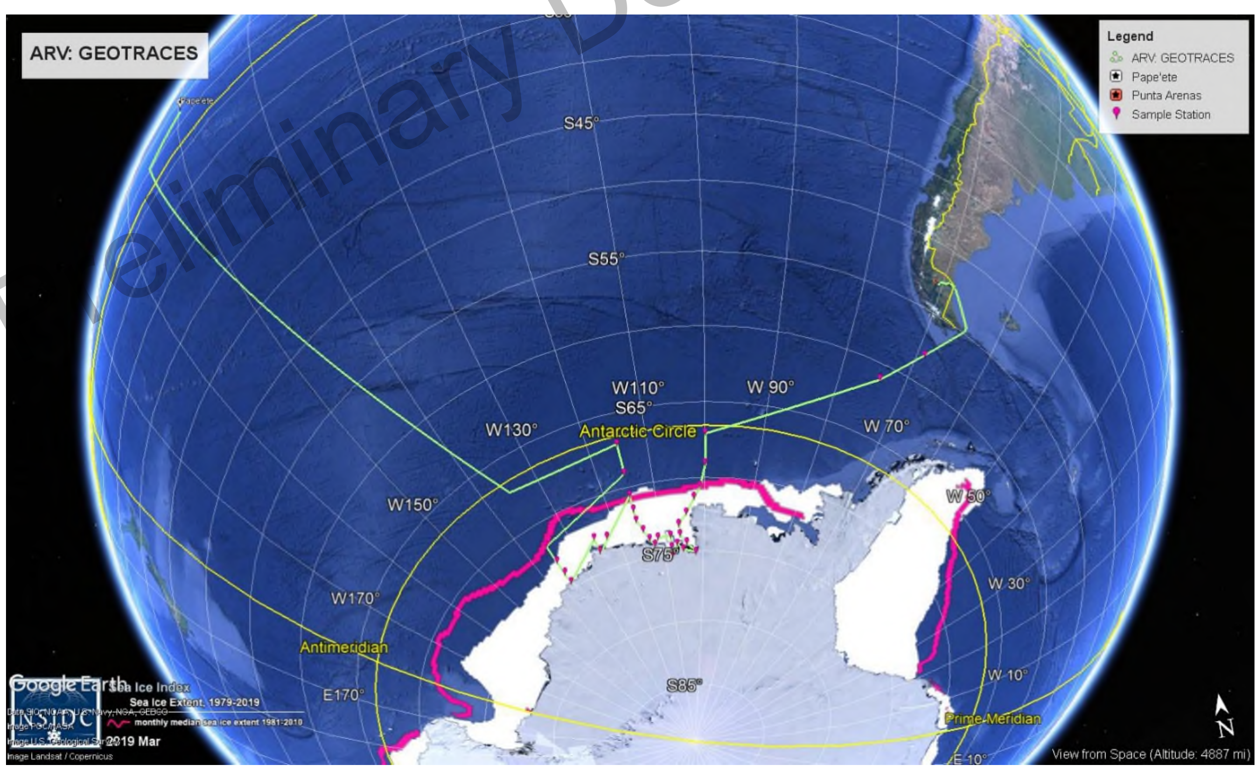


Figure 9: Antarctic section of GEOTRACES GP17 cruise track

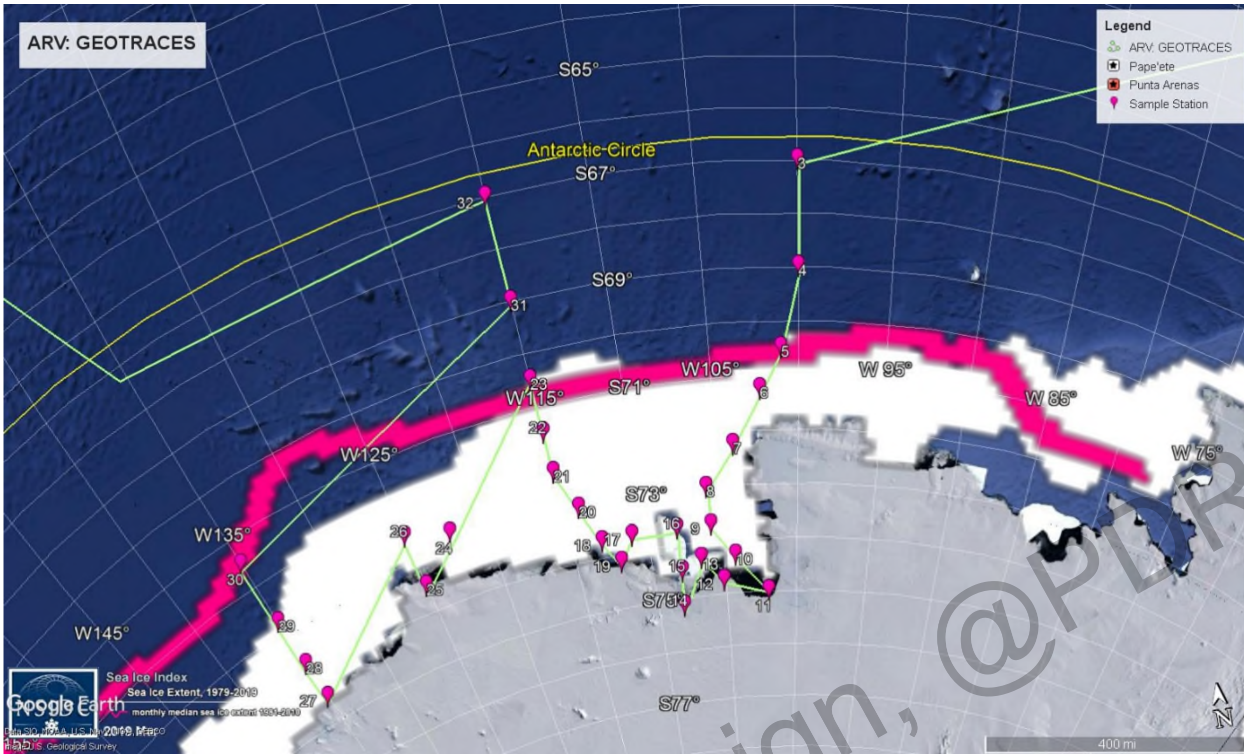


Figure 10: Complete GEOTRACES GP17 cruise track with 2019 winter sea ice median extent (pink line) and September 2019 extent (white shading); No plots available for South Pacific CTD stations