ASC RESEARCH VESSEL REPLACEMENT PROGRAM

CLIMATE STUDY

PREPARED FOR

LEIDOS, ASC
CENTENNIAL, CO

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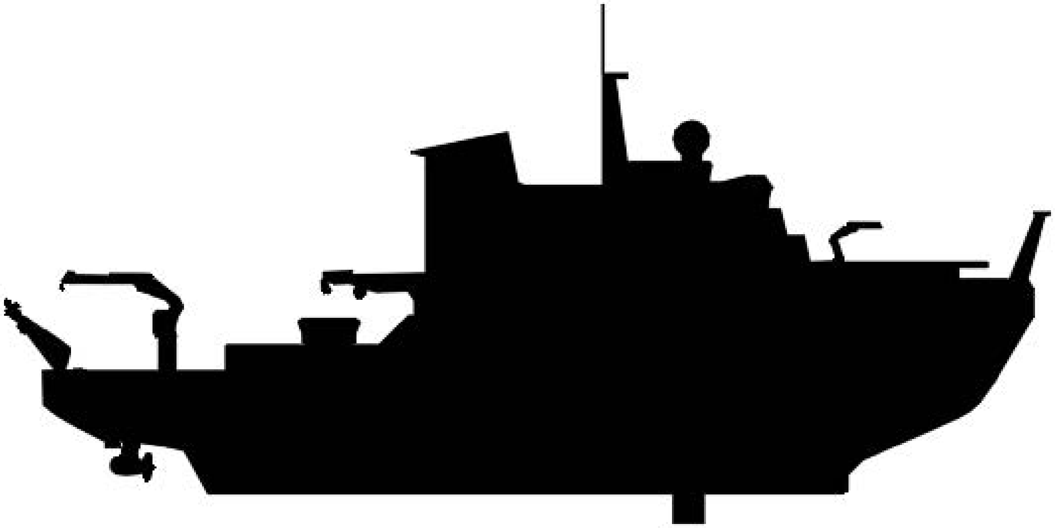

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Revision History

Section	Rev	Description	Date	Approved
All	-	Revised in response to client comments on preliminary reports.	6/8/2021	TSL

References

1. *Seakeeping Study*, Glosten, Document No. 19136-000-05, Rev. -, 4 May 2021.
2. *Deck De-Icing Systems Study*, Glosten, Document No. 19136-000-09, Rev. -, 29 April 2021.
3. *[NBP Specifications] Attachment B – Technical Requirements,* Raytheon Polar Services Company, Rev. 3, 15 November 2002.
4. *ERA5 hourly data on single levels from 1979 to present*, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), https://doi.org/10.24381/cds.adbb2d47, accessed 12 November 2020.
5. *Report of the Ad Hoc Subcommittee on the U.S. Antarctic Research Vessel Procurement*, National Science Foundation (NSF) Office of Polar Programs Advisory Committee, 14 August 2019.
6. *Ice Environment Study,* Glosten, Document No. 19136-000-06, Rev. -, 29 April 2021.
7. *Requirements concerning POLAR CLASS*, International Association of Classification Societies, Rev. 2, 2016.
8. *Sea Ice Nomenclature,* World Meteorological Organization (WMO) No. 259, March 2014.
9. *International Code for Ships Operating in Polar Waters (Polar Code),* International Maritime Organization (IMO), Marine Environment Protection Committee, MEPC 68/21Add.1, Annex 10.
10. *Ocean Class AGOR System Specification*, Naval Sea Systems Command, Version 1.11, 9 December 2010.
11. *Ice Class Selection Study for Palmer Replacement*, American Bureau of Shipping (ABS), Report No. HTEC-2020-4557330-1, 6 January 2020.
12. *Rules for Building and Classing Marine Vessels*, ABS, 2020.
13. *Guide for Vessels Operating in Low Temperature Environments*, ABS, February 2016.

Executive Summary

The ARV Performance Specifications are based in part on the natural environment in which the vessel will operate throughout its service life. Climatological factors that will influence the vessel design were reviewed (Table 1) and recommendations were made for how each should be incorporated into the Performance Specifications. Extreme values are provided for most climatological factor such that the vessel designer will be able to select materials and equipment allowing the ARV to operate safely and effectively in all design conditions.

Table 1   Climatological factors reviewed

Climatological Factor	Impacts on Design
Waves	Seakeeping Dynamic Positioning
Ice	Icebreaking Structure/Materials Machinery Stability Seakeeping/Maneuverability
Water Temperature	Structure/Materials Machinery Ice Accretion
Air Temperature	Machinery Ice Accretion Accommodations
Wind	Stability Dynamic Positioning
Current	Dynamic Positioning Maintaining Trackline
Snow	Operations Machinery Stability Icebreaking

Waves

A design wave environment was developed for inclusion in the Performance Specifications. Historical wave height data at a location representative of typical ARV open ocean operations was used to estimate a distribution of wave heights the ARV will likely encounter throughout its design life, as summarized in Table 2. This same data set was used to evaluate seakeeping in the *Seakeeping Study* (Reference 1) to develop appropriate seakeeping criteria and estimate anti-roll tank sizing for the ARV.

Table 2 ARV design wave environment

Sea State	Significant Wave Height (ft)	Open Ocean, 2049		
		Avg. Modal Period (sec)	Percent of Time	Percent of Time Exceeded
≤ 4	0 - 8.2	8.5 (SS4)	18.1%	81.9%
5	8.2 - 13.1	9.4	51.0%	30.9%
6	13.1 - 19.7	10.4	27.1%	3.7%
7	19.7 - 29.5	11.2	3.6%	0.1%
8	29.5 - 45.9	12.2	0.1%	0.0%

Ice

Assuming a required IACS Polar Class (PC) level of PC3 is required, icebreaking capability in commensurate ice thicknesses is recommended. Ice accretion calculations for stability are recommended, and the *Deck De-Icing Systems Study* (Reference 2) is referenced for recommended ice accretion mitigation systems.

Water Temperature

Low and high design water temperatures are recommended based on prescribed requirements for vessels with similar worldwide and cold weather operating profiles. A low water temperature of 28°F and a high water temperature of 90°F are recommended.

Air Temperature

A Mean Daily Low Temperature (MDLT) of -35°C and Polar Service Temperature (PST) of --45°C were calculated and recommended for inclusion in appropriate sections of the Performance Specifications. Recommendations for updates to the design high air temperature are also made.

Wind

Design wind speeds for survival (100 knots) and dynamic positioning (35 knots) are recommended.

Current

A design current of 2 knots is recommended for specifications related to maneuvering, dynamic positioning, and maintaining trackline.

Snow

The *Deck De-Icing Systems Study* (Reference 2) is referenced for mitigating risks to operations and safety due to snow accumulation on the vessel.

A design snow cover of 12 inches is recommended for icebreaking design conditions, assuming the vessel Polar Class is required to be level PC3.

Section 1 Introduction

The ARV Performance Specifications are based in part on the natural environment in which the vessel will operate throughout its service life. The natural environment is composed of a set of environmental factors, some of which are implicitly contained within design codes required by the Performance Specifications, and others of which must be stated explicitly. The purpose of this study is to review the climatological factors that will influence the vessel design and recommend how they should be incorporated into the Performance Specifications.

Section 2 Wave Environment

The wave environment in which ARV operates will directly impact its ability to meet core mission requirements. Waves cause vessel motions that impact its safety, comfort, and ability to perform science missions. Waves in the open ocean also create significant resistance to open water transit, so can be a propulsion power design driver. While it is likely that icebreaking will be the design driver for ARV, open water transit must be considered, particularly for fuel consumption.

The design wave environment influences the seakeeping requirements of the vessel. Overly conservative seakeeping requirements (requiring unjustifiably high levels of operability in high sea states) would unnecessarily add to the size and cost of the vessel, whereas anti-conservative seakeeping requirements (requiring unjustifiably low levels of operability in high sea states) would hinder its ability to carry out its intended mission. Definition of the wave environment will allow for proper tuning of the seakeeping requirements to a satisfactory level of conservatism. A seakeeping study (Reference 1) was performed using the wave results developed in this study.

This analysis evaluates wave heights at a location that is representative of the wave environments in which the vessel will be required to operate for most of its service life. It is assumed that the ARV will be registered in the United States but will likely be homeported in Chile and will regularly transit the equator. It will spend significant operations in ice-laden seas around the Antarctic continent. It will operate all around Antarctica, with resupply transits most often between Antarctica and South America, but also on occasion to other locations such as New Zealand and Australia. It will occasionally operate in regions all over the world.

It is assumed that waves will be negligible while the ARV is quayside and while operating in ice. Therefore, the location of 60° South, 60° West was chosen to be representative of the vessel's general open ocean exposure profile (Figure 1). This is approximately the same location used in the charter specification for the requisition of R/V *Nathaniel B. Palmer* (Reference 3).

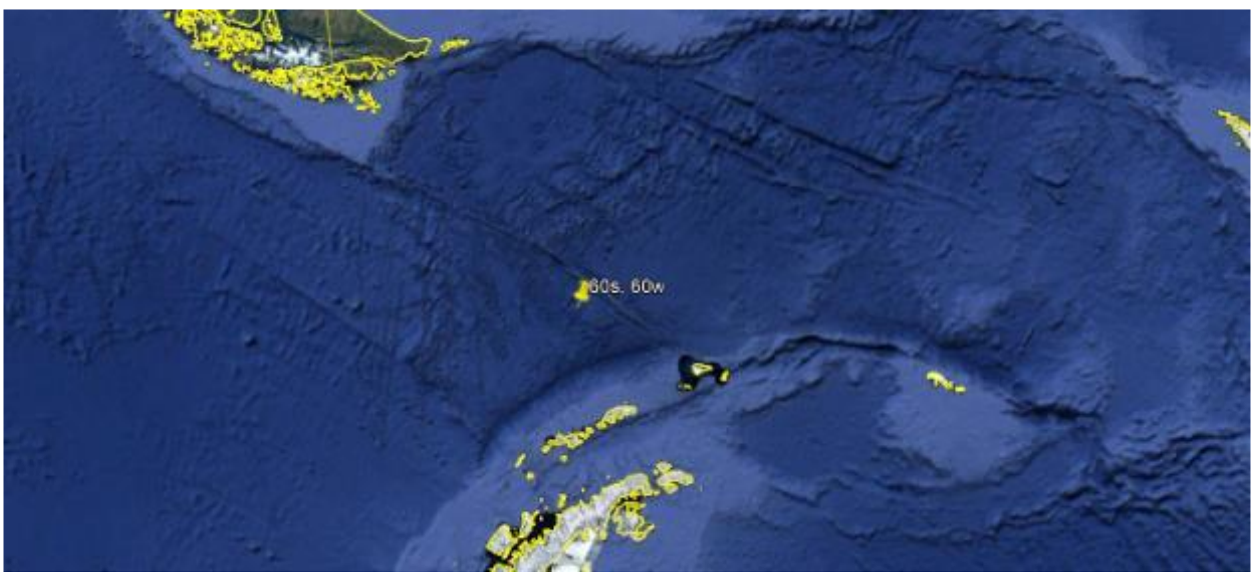

Figure 1 Representative location for sea state analysis (60° South, 60° West) [Source: Google Earth]

2.1 Open Ocean Sea State Distribution

Historical wave data was analyzed and extrapolated to establish the distribution of expected wave heights. Historical wave data was obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 reanalysis dataset (Reference 4). This dataset provides average significant wave heights between selected nodes on a global grid. Significant wave height corresponds to the average ⅓rd of highest waves, and correlates well to the wave height estimates of experienced observers at sea.

The smallest possible area was selected based on the resolution of the ERA5 grid (30 nm x 15 nm) to minimize smoothing of peak wave heights due to averaging. Hourly-averaged significant wave heights were collected for the past ten years (November 2010 through October 2020), as summarized in Figure 2. This wave data was binned by significant wave height according to the Douglas Sea State Scale.

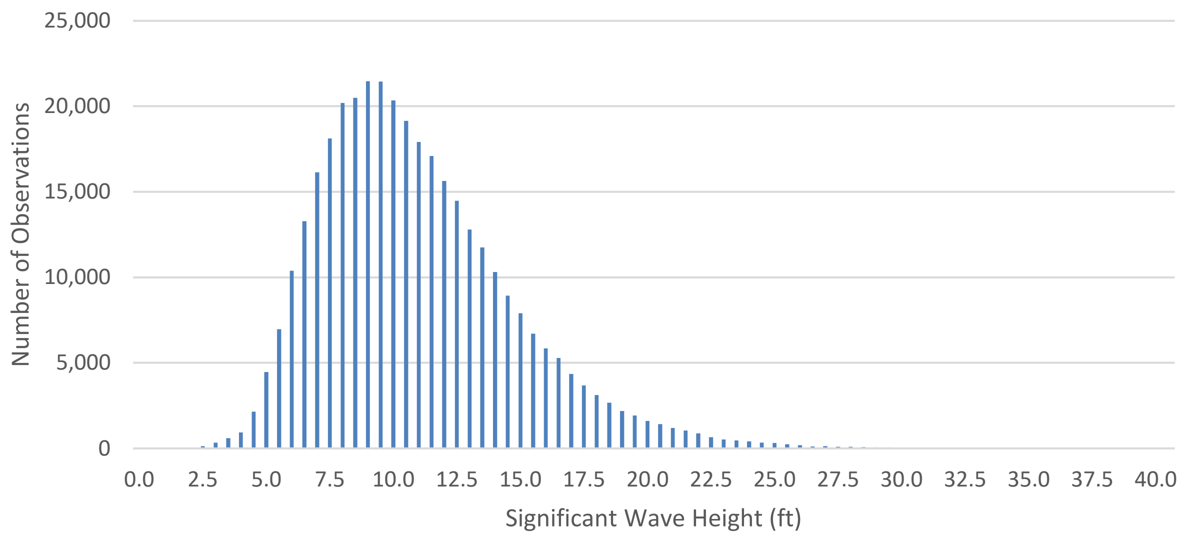

Figure 2 Wave height distribution at 60° South, 60° West, November 2010 through October 2020

The NSF *Report of the Ad Hoc Subcommittee on the U.S. Antarctic Research Vessel Procurement* (OPP/AC RV report, Reference 5) described a trend of increasing wave heights in the Southern Ocean. This was based on a study conducted between 1985 and 2018 which found an increase of 0.66 cm/yr to 1.0 cm/yr in significant wave height. A linear regression performed on the ERA5 data collected for 60° South, 60° West between 1979 and 2020 showed an expected increase of 0.72 cm/yr for the same area, indicating good agreement with the reference.

The trend of increasing wave heights was incorporated into the sea state distribution by linearly extrapolating wave heights from the dates of the collected data through half the anticipated service life of the vessel. Assuming a 2029 commissioning year and a service life of 40 years, sea state probabilities were predicted through 2049.

Table 3 presents the results of the wave climate analysis, including sea states for the analyzed years and extrapolated to 2049, the half-service life of the vessel. This same data set was used to evaluate seakeeping in the *Seakeeping Study* (Reference 1) to develop appropriate seakeeping criteria and estimate anti-roll tank sizing for the ARV.

Table 3 Sea state distribution, representative location, 2010-2020 and expected 2049

Sea State	Significant Wave Height Range (ft)	2010-2020 Average Modal Period (sec)	2010-2020 Percent of Time	2010-2020 Percent of Time Exceeded	Extrapolated to 2049 Percent of Time	Extrapolated to 2049 Percent of Time Exceeded
≤ 2	0.0 - 1.6	5.8 (SS2)	0.0%	100.0%	0.0%	100.0%
3	1.6 - 4.1	6.9	0.9%	99.1%	0.5%	99.5%
4	4.1 - 8.2	8.5	25.2%	73.8%	17.7%	81.9%
5	8.2 - 13.1	9.4	49.1%	24.8%	51.0%	30.9%
6	13.1 - 19.7	10.4	22.0%	2.8%	27.1%	3.7%
7	19.7 - 29.5	11.2	2.7%	0.1%	3.6%	0.1%
8	29.5 - 45.9	12.2	0.1%	0.0%	0.1%	0.0%

Sea state distributions for winter (April 1st through October 31st) and summer (November 1st through March 31st) are presented in Table 4.

Table 4 Sea state distribution for summer and winter, expected 2049

Sea State	Significant Wave Height Range (ft)	Summer (November - March) Average Modal Period (sec)	Summer Percent of Time	Summer Percent of Time Exceeded	Winter (April - October) Average Modal Period (sec)	Winter Percent of Time	Winter Percent of Time Exceeded
≤ 2	0 - 1.6	5.8 (SS2)	0.0%	100.0%	5.8	0.0%	100.0%
3	1.6 - 4.1	6.9	0.1%	99.9%	6.7	0.8%	99.2%
4	4.1 - 8.2	8.5	21.5%	78.4%	8.4	14.9%	84.4%
5	8.2 - 13.1	9.4	55.0%	23.5%	9.4	48.2%	36.2%
6	13.1 - 19.7	10.4	21.6%	1.8%	10.4	31.1%	5.1%
7	19.7 - 29.5	11.2	1.8%	0.0%	11.2	4.9%	0.2%
8	29.5 - 45.9	12.2	0.0%	0.0%	12.2	0.2%	0.0%

Section 3 Ice

3.1 Ice Environment

The ice environment in which the ARV will be operating was analyzed in a stand-alone ice environment study (Reference 6). In that study, representative ice-prone locations where critical science will be conducted were evaluated to provide information needed to decide whether the vessel should be certified to an IACS Polar Class level of PC3 or PC4. The ice environment is prescribed by the polar class level.

The following are the IACS Polar Class Descriptions (Reference 7), based on WMO Sea Ice Nomenclature (Reference 8):

- PC3 – Year-round operation in second-year ice which may include multiyear ice inclusions.
- PC4 - Year-round operation in thick first-year ice which may include old ice inclusions

The WMO sea ice terms found in the above PC3 and PC4 definitions are shown in Table 5.

Table 5 WMO Sea Ice Nomenclature (Reference 8)

First-year ice	Sea ice of not more than one winter's growth, developing from young ice; thickness 30 cm – 2 m. May be subdivided into thin first-year ice/white ice, medium first-year ice and thick first-year ice.
Multiyear Ice	Old ice up to 3 m or more thick which has survived at least two summers' melt. Hummocks even smoother than in second-year ice, and the ice is almost salt-free. Colour, where bare, is usually blue. Melt pattern consists of large interconnecting irregular puddles and a well-developed drainage system.
Old ice	Sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. Most topographic features are smoother than on first-year ice. May be subdivided into residual, second-year ice and multi-year ice.
Sea ice	Any form of ice found at sea which has originated from the freezing of sea water.
Second-year ice	Old ice which has survived only one summer's melt; typical thickness up to 2.5 m and sometimes more. Because it is thicker than first-year ice, it stands higher out of the water. In contrast to multi-year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.
Thick first-year ice	First-year ice over 120 cm thick.

The OPP/AC RV report (Reference 5) prescribes specific quantitative ice performance criteria based on the Polar Class assumptions for the vessel that PC4 is the threshold and PC3 is the objective:

- Threshold: PC4, Capable of independently breaking sea ice with a thickness > 3 feet.
- Objective: PC3, Capable of independently breaking sea ice with a thickness > 4.5 feet with 12 inches of snow at a continuous speed >3 knots.

At this stage, it is recommended that either PC3 or PC4 is required outright, to provide more direction to the bid designer (see *Ice Environment Study*, Reference 6, for more details).

Assuming PC3 is required, the following threshold and objective icebreaking requirements are recommended:

- Threshold: PC3, Capable of independently breaking sea ice with a thickness > 3 feet.
- Objective: PC3, Capable of independently breaking sea ice with a thickness > 4.5 feet with 12 inches of snow at a continuous speed >3 knots.

The other ice and snow capability requirements from the OPP/AC RV report should be used in the ARV Performance Specifications.

3.2 Ice Accretion

The ARV must be designed to adequately mitigate the risks of ice accretion: the buildup of ice on the vessel due to precipitation, spray, and freezing temperatures. The IMO Polar Code (Reference 9) provides ice accretion assumptions for stability calculations. It is recommended that these assumptions be prescribed in the ARV Specifications.

Additionally, it is recommended that asymmetric ice loading be evaluated. Often, significantly more ice can accumulate on one side of a vessel than the other. Asymmetric ice loading may result in less overall weight, but the asymmetry can be a greater risk to stability than symmetric ice loading.

The *Deck De-Icing Systems Study* (Reference 2) recommends design elements and technologies to be used to prevent and remove ice on the vessel.

Section 4 Water Temperature

The OPP/AC RV report (Reference 5) prescribes a design low water temperature of 28°F and a design high water temperature of 90°F. Similar requirements are found in other ocean-going vessel specifications including those for the UNOLS Ocean Class AGOR (Reference 10) and the charter specifications used in the procurement of R/V *Nathaniel B. Palmer* (Reference 3). These design water temperatures are sensible, since they represent the theoretical minimum for seawater, and the highest seawater temperatures from around the world. The ARV Specifications currently specify these temperatures, and it is recommended that they be maintained. However, the specifications currently also include an objective high temperature of 95°F. This should be eliminated to save the designer from unnecessary effort and the design from an unnecessarily onerous objective.

Section 5 Air Temperature

Air temperature has wide-ranging vessel design impacts, including equipment selection, build material selection, and crew performance. The designer will need to know extreme low and high design temperatures, which are provided in this section.

5.1 Low Air Temperature

The IMO Polar Code requires that a Polar Service Temperature (PST) be determined for vessels operating in low air temperature environments. The PST is derived from the minimum temperature in which the vessel is designed to be operated. The PST is to be used as the design temperature for all navigation and safety systems that could be needed in such environments. The PST should also be considered the default design low temperature for other design decisions where justification for higher temperature is not provided. With proper justification, higher design air temperatures may be acceptable for certain systems and components. It will be up to the designer to justify appropriate minimum temperatures for other such systems.

According to the IMO Polar Code, the PST is set to at least 10°C lower than the lowest Mean Daily Low Temperature (MDLT). In this study, we determined the MDLT for the ARV and then subtracted 10°C to compute the PST.

It was assumed that the ARV should be capable of year-round operation in the study areas defined in the *Ice Environment Study* (Reference 6). The lowest weekly MDLT in each study area was determined for the coldest weeks of the year using data provided by ABS (Reference 11). The data was collected from maps based on the NOAA Operational Model Archive and Distribution System (NOMADS), for the ten years spanning January 1, 2010 to December 31, 2019.

Temperatures were reported in bands of 5°C. For conservatism, the MDLT for each point in time at each study area was interpreted as the bottom of the band of the minimum recorded temperature within the study area. For example, Figure 3 shows MDLT for mid-July. The Weddell Sea study area contains two MDLT bands: (yellow, -15°C to -20°C; and green, -20°C to -25°C). The Weddell Sea MDLT for this time period was transcribed as -25°C.

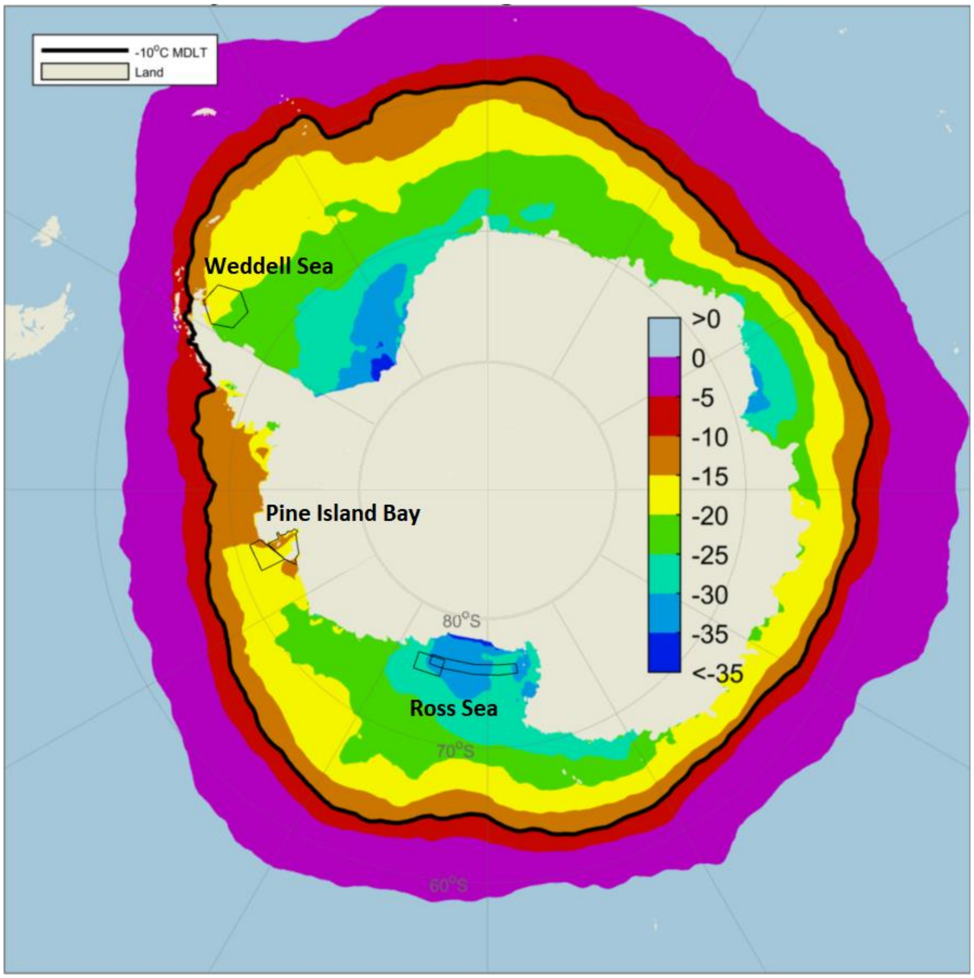

Figure 3 Mid-July MDLT data (Reference 11)

The minimum MDLT for each study area is shown in Table 6.

Table 6 Minimum annual MDLT values for each study area

Study Area	Minimum Annual MDLT (°C)
Weddell Sea	-30
Pine Island Bay – North	-30
Pine Island Bay – South	-30
Ross Sea – East	-35
Ross Sea – West	-35

The Ross Sea was found to have the lowest MDLT of the five study areas, with a minimum MDLT of -35°C. This results in a PST of -45°C. Figure 4 shows the MDLT for the Ross Sea western study area throughout the year.

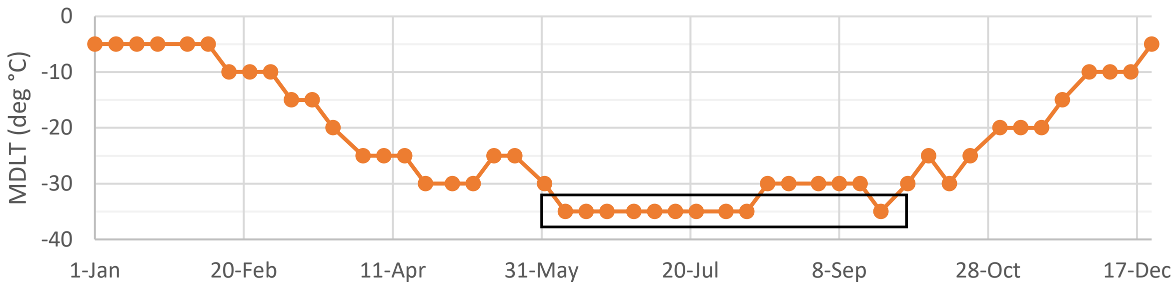

Figure 4 Mean daily low temperature, Ross Sea western study area

After identifying the -45°C PST, the ABS Harsh Environment Technology Center was contacted to discuss the validity and implications of this temperature. ABS confirmed that the method used to calculate MDLT in this study is sensible and valid, and that -45°C falls within the typical range of temperatures for icebreaking vessels in polar climates. Similar vessels commonly have PSTs around -50°C.

In terms of design implications, ABS advised that below approximately -20°C, equipment selection generally becomes more limited. Limiting the ARV to environments with temperatures above -20°C could be considered, but this would be hugely detrimental to the mission capability of the ARV. It was assumed this is not the preference of the owner.

IMO only requires equipment be rated to the PST that is needed to ensure proper navigation and crew safety. For example, deck cranes, unless used to deploy lifesaving or evacuation equipment, do not need to be rated to operate at -45°C. Equipment should also be rated according to its most likely use scenario. For example, it is unlikely that a lifeboat will be put into the water at -45°C, therefore it may be possible for it to be rated at a higher temperature than PST. The lifeboat may however be placed on the ice as temporary shelter at that temperature; therefore, its heating system should be capable of operation at PST.

Another important aspect of design impacted by PST is the grades of steel to be used. According to ABS Marine Vessel Rules § 3-1-2/3.7 (Reference 12), the design temperature t_D for steel is the MDLT, but no more than 13°C above PST (whichever is less) must be used. Therefore, based on our recommended MDLT of -35°C and PST of -45°C, the design temperature for steel is -35°C.

Very cold climates also experience low humidity. Dryness causes crew discomfort and increases the buildup and discharge of static electricity, which can damage equipment and be a fire and explosion risk. The ABS *Guide for Vessels Operating in Low Temperatures Environments* (Reference 13, Appendix 4.8) requires humidity to be added to the makeup air to achieve between 40% and 70% relative humidity. The Performance Specifications currently require the capability to dehumidify in humid environments; they should be updated to also include adding humidity in dry environments.

5.2 High Air Temperature

The OPP/AC RV report (Reference 5) prescribes a design dry bulb high air temperature of 100°F, since the vessel shall be capable of worldwide year-round operation, including in tropical climates. It is recommended that humidity be taken into account as well by specifying a wet bulb temperature. A design wet bulb temperature of 82°F is recommended. This matches the Ocean Class AGOR requirement (Reference 10). It is recommended that the ARV Performance Specifications be updated to include these dry and wet bulb design high temperatures.

Section 6 Wind

The OPP/AC RV report (Reference 5) states that the vessel shall be capable of enduring a maximum sustained wind speed of 100 kt. This same requirement is found in the specifications used to procure the charter R/V *Nathaniel B. Palmer* (NBP specifications, Reference 3). The NBP specifications go on to require that this wind speed be used in intact stability calculations, as well as a slightly reduced wind speed (80 knots) be used in intact stability calculations that include icing. It is recommended that these same requirements be used in the ARV Performance Specifications.

A design wind speed should also be specified for dynamic positioning. The OPP/AC RV report OCMSR, and Ocean Class AGOR specifications all require a 35-knot beam wind for stationkeeping calculations. The ARV Performance Specifications already state this requirement, and it should be maintained.

Section 7 Current

The ARV will be required to hold station as well as maintain a constant trackline over the seabed for acoustic surveying and towing in locations subject to significant ocean current. It is recommended that the ARV Performance Specifications require the vessel to have these capabilities in current equivalent to other oceangoing research vessels. A design side-current of 2 knots is specified in the OPP/AC RV report and is typical for oceangoing research vessels, including the NBP and Ocean Class AGOR. It is recommended that a design current of 2 knots be required by the ARV Performance Specifications.

Section 8 Snow

Snow is a risk to operations and safety on deck. These risks are mitigated through effective use of deck de-icing systems. The *Deck De-Icing Systems Study* (Reference 2) covers these systems and recommended applications on the ARV in detail.

Snow can also have a significant impact on icebreaking performance due to the drag it causes. The Antarctic tends to have thicker snow cover than the Arctic, which should be reflected in ARV requirements when compared to Arctic icebreakers.

The OPP/AC RV report (Reference 5) states an objective of PC3, with icebreaking through at least 4.5 feet of ice covered by 12 inches of snow. Assuming PC3 is adopted as a threshold, it is recommended that icebreaking through commensurate ice with 12 inches of snow is also adopted as a threshold.

Section 9 Specification Changes

9.1 Recommended Changes

<table>
<tr><th>Specifications Section</th><th>Specifications Update</th></tr>
<tr><td colspan="2">Wave Environment</td></tr>
<tr><td>044.4.1
Sea States</td><td>Add percent of time each sea state is exceeded to Sea State definition table.</td></tr>
<tr><td colspan="2">Ice Environment</td></tr>
<tr><td>044.4
Operating Environment</td><td>Require the vessel to be capable of surviving an extreme icing event, as required by the IMO International Code For Ships Operating In Polar Waters (Reference 9) and including the following:

The following icing allowance shall be made in the stability calculations:
30 kg/m^2 on exposed weather decks and gangways;
7.5 kg/m^2 for the projected area of each side of the ship above the water plane; and
The projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.
In addition to the above, require the designer to consider asymmetric icing.</td></tr>
<tr><td>070.7
Icebreaking Performance</td><td>Require either PC3 or PC4 outright (threshold only, no objective).

Assuming PC3, update specifications with the following:
Threshold: PC3, Capable of independently breaking sea ice with a thickness > 3 feet.
Objective: PC3, Capable of independently breaking sea ice with a thickness > 4.5 feet with 12 inches of snow at a continuous speed >3 knots.
Align remaining specifications with following requirements from OPP/AC RV report:
Ice flexural strength = 500 kPa.
Average speed in thin (0.5 m or less) ice = 5 to 6 knots.
Level ice astern = 1.4 m (4.5 ft), same as ahead.
Maneuvering characteristics (turning radius, turning out of an existing channel, starturn, etc.):
Maximum turning diameter of 3×LWL to 4×LWL in 1.4 m (4.5 ft) level ice ahead.
Maximum turning diameter of 2×LWL to 3×LWL in 0.7 m (2.3 ft) level ice.
Ability to break out of its own channel in 1.4 m (4.5 ft) level ice.</td></tr>
</table>

Specifications Section	Specifications Update
079.1 Stability	Require stability calculations to include the ice accretion assumptions from Section 044.4, or justifiable alternative ice accretion calculations.
Water Temperature	
044.4.2 Exterior Environmental Temperatures	Change Maximum water temperature objective from 95°F to 90°F.
Air Temperature	
044.4.2 Exterior Environmental Temperatures	Changed exterior design temperatures as follows (thresholds only, no objectives): • Maximum temperature (dry bulb) to 100°F. • Maximum temperature (wet bulb): 82°F. • Minimum temperature (dry bulb) to -45°C (-49°F).
044.4.2 Exterior Environmental Temperatures	Specify PST as -45°C (-49°F).
044.4.3 Interior Climate Control	Add minimum relative humidity in heating season as 40% (all spaces).
070.8 Classification & Regulatory Requirements	Modify CCO-POLAR objectives and threshold to CCO-POLAR(-35°C, -45°C).
Wind Environment	
044.4 Operating Environment	Require the vessel to be capable of enduring a maximum sustained wind speed of 100 kt.
079.1 Stability	Require stability calculations to include the ship sustaining a 100 kt beam wind heeling moment and an 80 kt beam wind heeling moment with the icing described in Section 044.4 (to be added per recommendation above).
Current Environment	
070.5.1 Maneuvering	Specify design current of 2.0 knots.
070.5.1.2 Acoustic Survey Trackline	Specify design current of 2.0 knots in all specified sea conditions.
070.5.1.3 Towing Trackline	Specify design current of 2.0 knots

Specifications Section	Specifications Update
070.5.1.4 Slow Speed Trackline for Small Samplers and Towed Devices	Specify design current of 2.0 knots.
Snow Environment	
Deck De-Icing	See *Deck De-Icing Systems* report (Reference 2).
070.7 Icebreaking Performance	See recommended Ice Environment updates, above.

9.2 Required Owner Decisions

There are no required owner decisions other than approving or disapproving of the above recommended specification changes.