RV *Investigator*

Underway Data Processing Summary Report

Voyage #:	**IN2021_V01**
Voyage title:	**Quantifying krill abundance for krill monitoring and management off the Australian Antarctic Territory**
Depart:	Hobart TAS, 13:00 Friday 29th January 2021
Return:	Hobart TAS, 08:00 Wednesday 24th March 2021
Data dates:	28-Jan-2021 22:33:50 to: 23-Mar-2021 21:56:45 UTC
Chief Scientist:	So Kawaguchi (Australian Antarctic Division)
Data processed by:	Vito Dirita (CSIRO)
Publication Date:	11 August 2021

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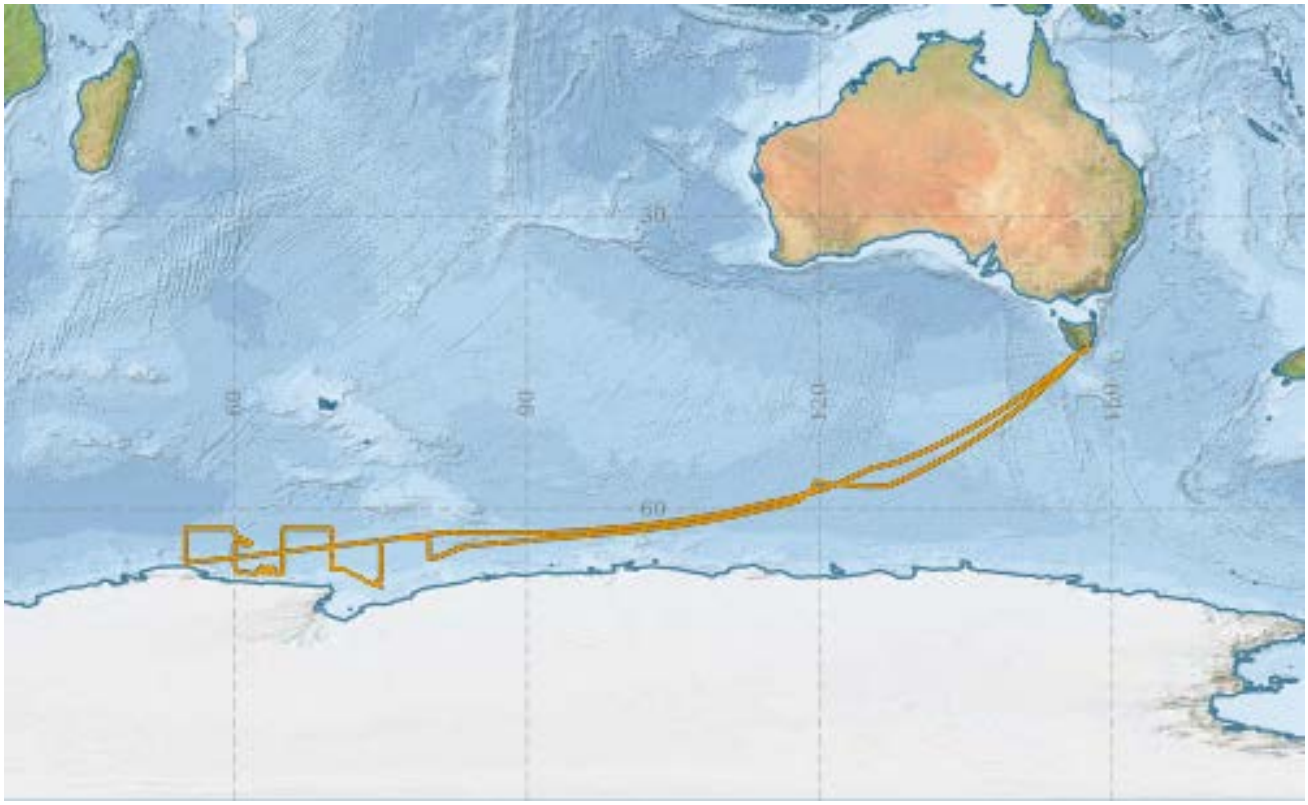
1.2 Summary

Commercial krill fishing in the Indian Ocean sector recommenced in 2016/17 after a 25-year hiatus and current catch limits for the region are based on surveys conducted 14 years ago. There has been no regular ecosystem monitoring to assess how the system has changed over this time.

The primary objective of the voyage was to ensure an orderly development of the krill fishery, allowing a precautionary update to the Krill catch limits in Australian Antarctic waters. To achieve this, by assessing the data and samples collected in determining the biomass estimates.

1.3 Voyage Track



1.4 Underway Data

Navigation data is acquired using the Seapath 330 plus position and reference unit, which is also differentially corrected by data from the FUGRO marine cstar 3610 receiver.

The Meteorological data consists of two port/starboard relative humidity and temperature sensors, vane type wind sensor, licor light sensor and barometric air pressure.

Data from the Integrated Marine Observing System sensors (IMOS) are also included. The sensors are port and starboard radiometers and pyranometers, ultrasonic wind speed and direction.

Refer to the Electronics report for this voyage for instruments used and their serial numbers.

Navigation, meteorological, IMOS and TSG data are preliminary quality controlled by combining all data from hourly recorded files to 5 second values in a netCDF formatted file. The combined data is referred to as: “underway data”.

A combined file was made on 25th March 2021 by running the Java application UWYMerger (V1.8.1) with data time range of: 28-Jan-2021 22:33:50 to 23-Mar-2021 21:56:45, Techsas1 was used as the data source.

Further, it should be noted that the merged data file contains additional underway instrument sensor data that are not quality controlled or processed and is provided for completeness only. This includes data from the air sampling instruments (i.e. two Ozone sensors, Absorption Photometer, Picarro and sampling inlet bearing), pCO2, Drop keel position, depth and gyro.

For further description of instruments, their mounted locations and Underway netCDF variables please refer to the Appendix at the end of this report.

1.5 Completeness and Data Quality

Navigation data (latitude and longitude, speed over ground, ship heading and course over ground); meteorological data (port and starboard for each of air temperature, relative humidity, relative and true wind speed and direction, PAR light, rain and atmospheric pressure) and IMOS data (port and starboard radiometers and pyranometers, ultrasonic relative wind direction and speed), Thermosalinograph (salinity and water temperature) data were evaluated and quality controlled. It should be noted that the underway netCDF file contains the raw unQC'd data. Therefore even though the QC'd variable may have been NaN'ed or otherwise adjusted or filtered, the raw data variable is always available in the netCDF underway file. This is useful if the end user wishes to apply a different QCing or filtering methodology.

1.6 Processing Comments

Atmospheric Pressure: No issues found with the barometric sensor with only a few points marked suspect. The foremast digital barometer was used.

Air Temperature: A number of minor discrepancies between the port and starboard air temperature sensors were noted, otherwise both sensors gave very close readings. These discrepancies usually occur during periods of rapid temperature change. This phenomenon has probably come about due to the rapid warming of the ship's metal structure and air due to the ship becoming stationary or cooling of the air temperature due to the ship speeding off from stationary or due to the evaporation of rain water around the sensor housing. Furthermore, they also seem to relate to when the ship is stationary with little wind or during/following periods of rainfall or as the result of a change in the ship speed that could be the result of hot exhaust gases being blown over the sensors depending on the wind direction. Approximately 2 hours of data (15/03/2021 18:35 to 20:24PM UTC) is missing from the port air sensor.

Latitude/Longitude: No issues found with the latitude and longitude data.

Humidity: Both sensors gave close readings. Approximately 2 hours of data (15/03/2021 18:35 to 20:24PM UTC) is missing from the port humidity sensor and some sections have been flagged as suspect.

Rain: Rain gauge heaters were turned on early in the voyage (7th February) due to presence of ice and snow (sensor freezing) resulting in notable differences between the port and starboard rain sensors. Heater status is not recorded by Techsas and as such further analysis of the causes of these differences is not possible.

Wind Speed: The port wind speed sensor stopped spinning several times throughout the voyage possibly due to ice buildup. On the 13th of March at approximately 20:45 UTC, the propeller became detached resulting in missing or zero wind speed and direction data for the remainder of the voyage (approximately 15%), as a consequence large portions of port wind speed and direction have been flagged as bad and NaN'ed.
Salt water ingress into the connector of the starboard wind speed sensor was detected on the 5th January (appx 15:00) resulting in excessive spikes and noise, additional filtering both manual and automated was applied.
In addition, it has been observed that due to the location of the port wind sensor relative to the ship's superstructure, the instrument could experience some interference when the wind direction is approximately from the starboard stern side which would result in greater fluctuations in both speed and direction measurements.
Likewise, the starboard wind speed and direction sensor could experience similar interference when the wind direction is approximately from the portside stern. An automated filter was used which flags second-difference spikes greater than 14 knots (suspect) and second-difference spikes greater than 18 knots flagged as bad (NaN'ed), the filter was applied to only a few selected regions.

Wind Direction: An automated filter was implemented to remove data spikes and was applied to both the port and starboard (true and relative) wind direction. The filter was applied only in a few selected regions which appeared to be very noisy or spiky. The majority of the spikes appeared to have been correctly flagged and removed. However with automated filtering it is possible that a very small percentage of data points may have been misidentified. The filter removes data points when spikes are detected to be more than 75 degrees from the moving average. Please refer to the notes above relating to the malfunctioning port wind speed sensor.

CourseOG: Position and velocity (speedOG) are measured by differential GNSS using phase-smoothed pseudo-range and Doppler observations. When using high precision differential corrections a world wide accuracy of 10 -20 cm is possible.

Course Over Ground (COG) describes the direction of motion with respect to the ground that a vessel has moved relative to geographic north pole. Accordingly, should a vessel be stationary, it is not travelling a course (e.g., at the wharf).

Under conditions where a vessel is experiencing leeway (wind, current), a vessel's heading and COG may differ. This difference will typically be largest for vessels moving at slow speeds. When the ship speed is less than 0.5 knots (25.7 cm/s) course over ground values are seen to fluctuate and are highly variable. Course and speed overground were recomputed from 5 second latitude and longitude values (truncated to 7 decimal places, .000001 degree = 11.112 cm).

The resulting course overground values were compared to the original GPS derived values and agreed well, (i.e. a slight smoothing was achieved when the ship was underway and when the ship was almost stationary the result was similarly variable). The course overground data for this voyage has not been filtered and has been flagged as good.

shipHeading: No issues found with the shipHeading.

speedOG: No major issues found with the speedOG, however a few points have been flagged as suspect (or bad) and are primarily the result of the ship's roll/pitch motion or the ship surfing up and down swells resulting in rapid acceleration and deceleration measurements by the GNSS systems.

PAR: No major issues were found with the port and starboard PAR sensors, however some sections were marked as suspect for both the port and starboard PAR.

Pyranometer: No major issues were found with the port and starboard pyranometer sensors, however a few data points were marked as suspect for both the port and starboard pyranometer

Radiometer: The starboard radiometer was found on occasions to be noisy, subsequently some portions have been flagged as suspect.

Ultrasonic Wind Speed: The Gill Ultrasonic Anemometer froze up a few times during the voyage and stopped reporting data, subsequently approximately 4% of the wind speed and direction are missing.

Ultrasonic Wind Direction: The relative wind direction values for the ultrasonic wind sensor showed unusual characteristics. This was investigated and it appears that when the wind, more or less, is on the stern of the ship the ultrasonic wind direction values exhibit wild variations (i.e. large spikes) which are not manifested by the two vane type wind sensors to the same extent. It is our belief that this characteristic is most likely caused by the interaction of the ships superstructure/foremast/ship motion and the wind in relation to the ultrasonic wind sensor. Spikes greater than 80 degrees from the moving average were NaN'ed. Please refer to the ultrasonic wind speed notes above.

Water Temperature: Erroneous or suspect data has been NaN'ed and its flag set to {'bad', 'none', 'operatorFlagged'}.

Salinity: No issues found with the salinity data. Spikes greater than 0.01PSU have been removed. TSG S/N 2567 was used for the entire voyage.

TSG Calibration: During the course of the voyage, bottle salinity samples were collected from the underway seawater supply at regular (every few days) intervals, and the precise time of the sample was recorded. A total of 30 samples were collected and analyzed. These values were compared with the underway salinity measured by the TSG at the same precise date and time which was used to calculate a scaling coefficient for the TSG using Multiple Linear Regression. This resulted in a scale coefficient of 0.99987310. The residual had a standard deviation (S.D) of 0.00049303 PSU better than the required 0.01PSU. This was then applied to the salinity data and its QC flag set to {'good', 'manually adjusted', 'no error', salinityQC values of 48}. Salinity bottle calibration data can be found in the following file: *in2021_v01_TSGCal_BottleResults.csv.*

TSG Lag: Examination and comparison of the TSG water temperature profile against the sea surface water temperature showed a lag of approximately about 2.00 minutes between the two data sets and a mean thermal increase of +0.260C^{o} from the intake keel to the TSG. This lag is due to the time taken for the water to travel from the water intake on the port drop keel (where sea surface water temperature is measured) to the TSG located in the underway sea water lab on the ship (where the TSG sensor temperature and the conductivity is measured). When the precise location for the TSG salinity measurement is critical, this lag would need to be taken into account in order to determine the exact geolocation of the sampled value. For example, assuming a ship cruising speed of 10 knots and a lag of 2.00 minutes, the salinity measurements could be for a location about 617 meters away from the current ship location. Please note that the TSG and SBE38 SST intakes are located on the port drop keel, the intake depths are described in the Appendix Table 3.

Depth: Finally, the Depth data is no longer processed as part of the underway data set. The non QC'd data is available in the underway data. The QC'd depth data could be obtained from processed GSM dataset (centre beam) for this voyage.

Other Data Sets:

It should be noted that the underway netCDF file contains the raw unQC'ed data. Therefore even though the QC'd variable may have been NaN'ed or otherwise adjusted or filtered, the raw data variable is always available in the netCDF underway file. This is useful if the end user wishes to apply a different QCing or filtering methodology.

Comparing Port and Starboard Sensors:

The following table compares the mean-absolute-difference and max-absolute-differences between port and starboard sensor outputs prior to and after QCing has been applied. Please note that the **After QC**: column only accounts for values which are flagged as good.

Sensor:	Before QC		After QC:		
	mean(abs(diff))	max(abs(diff)	mean(abs(diff))	max(abs(diff)	Units:
Air Temp	0.06	1.1	0.06	1.1	*Degree Celsius*
Humidity	0.56	16.7	0.56	11.5	*%RH*
relWindSpeed	3.23	191.35	2.53	28.98	*knot*
trueWindSpeed	2.83	167.56	2.54	28.98	*knot*
relWindDir	10.56	179.98	9.9	178.71	*Degree*
trueWindDir	15.54	179.98	10.03	150.71	*Degree*
PAR	25.4	1366	23.51	1366	$uE/m^2/s$
Pyranometer	7.93	750.3	7.68	717.8	W/m^2
Radiometer	3.49	31.5	3.44	25.8	W/m^2
Rain	0.06	2.89	0.05	2.89	*mm*

Commonly Used QC Flags:

The datasets include quality control (QC) flags which are described in more detail in the references provided, normally however only a small subset is used, below are the most commonly used qc flags. Please note that on some systems and file formats, eg. netCDF, it is not possible to store unsigned byte values. In this case, flags greater than 127 are stored as negative numbers. To convert them to unsigned integers, simply add 256.

QC Flags Description					
Signed	**Unsigned**	**Description**	**Data State**	**Operation Type**	**Error Type**
-123	133	Bad (data is NaN'ed)	Bad	None	Error Flagged by processor
0	0	Good	Good	None	No error, data is good
-187	69	Suspect (data unchanged)	Suspect	None	Error flagged by processor
-135	121	Operator adjusted	Suspect	Manually adjusted	Data out of range
-115	141	Data missing	Bad	None	No data, missing for unknown reason
-53	203	not QC'd	No QC	None	Preliminary processing (calibration) only
-199	57	Operator adjusted	Good	Manually Adjusted	Data out of range
-208	48	Re-calibrated	Good	Manually Adjusted	None

1.7 Final Underway Data:

The navigation, meteorological and thermosalinograph data will be entered into the O&A divisional data warehouse. All data timestamps are in UTC.

	Final Underway (csv) QC'd Data:					
	Parameter Name:	parameterQC:	% Good	% Suspect	% Bad	% Missing
1	latitude	latitudeQC	100	0	0	0
2	longitude	longitudeQC	100	0	0	0
3	speedOG	speedOGQC	100	0	0	0
4	courseOG	courseOGQC	100	0	0	0
5	shipHeading	shipHeadingQC	100	0	0	0
6	portAirTemp	portAirTempQC	99.86	0	0	0.14
7	stbdAirTemp	stbdAirTempQC	100	0	0	0
8	portHumidity	portHumidityQC	99.84	0.02	0	0.14
9	stbdHumidity:	stbdHumidityQC	100	0	0	0
10	atmPressure:	atmPressureQC	100	0	0	0
11	portRelWindDir	portRelWindDirQC	75.74	9.37	0.06	14.83
12	stbdRelWindDir	stbdRelWindDirQC	99.89	0.04	0.07	0
13	portTrueWindDir	portTrueWindDirQC	77.27	2.33	5.57	14.83
14	stbdTrueWindDir	stbdTrueWindDirQC	99.98	0.01	0.01	0
15	portRelWindSpeed	portRelWindSpeedQC	78.21	0.48	6.46	14.84
16	stbdRelWindSpeed	stbdRelWindSpeedQC	98.5	1.2	0.3	0
17	portTrueWindSpeed	portTrueWindSpeedQC	78.47	0.22	6.47	14.84
18	stbdTrueWindSpeed	stbdTrueWindSpeedQC	98.58	1.18	0.24	0
19	maxWindGust	maxWindGustQC	78.69	0.01	21.3	0.01
20	portRain	portRainQC	100	0	0	0
21	stbdRain	stbdRainQC	98.65	1.35	0	0
22	portPAR	portPARQC	99.87	0.13	0	0
23	stbdPAR	stbdPARQC	99.72	0.28	0	0
24	portPyranometer	portPyranometerQC	99.99	0.01	0	0
25	stbdPyranometer	stbdPyranometerQC	99.93	0.07	0	0
26	portRadiometer	portRadiometerQC	100	0	0	0
27	stbdRadiometer	stbdRadiometerQC	98.41	1.59	0	0
28	ultrasonicRelWindSpeed	ultrasonicRelWindSpeedQC	96.01	0.05	0.1	3.85
29	ultrasonicTrueWindSpeed	ultrasonicTrueWindSpeedQC	96	0.05	0.1	3.85
30	ultrasonicRelWindDir	ultrasonicRelWindDirQC	95.9	0.09	0.16	3.85
31	ultrasonicTrueWindDir	ultrasonicTrueWindDirQC	96.12	0.01	0.02	3.85
32	salinity	salinityQC	99.28	0	0.27	0.45
33	waterTemp	waterTempQC	99.5	0.01	0	0.49

1.8 Final Dataset Files

The final datasets for publication and distribution:

Final Dataset Files	
IN2021_V01uwy5sec.csv	5 second resolution csv format dataset of of QC'd parameters
IN2021_V01uwy10sec.csv	10 second resolution csv format (interpolated) dataset of QC'd parameters
IN2021_V01uwy1min.csv	1 minute resolution csv format (interpolated) dataset of QC'd parameters
IN2021_V01uwy5min.csv	5 minute resolution csv format (interpolated) dataset of QC'd parameters
IN2021_V01uwy.nc	5 second resolution netcdf format full dataset including unQC'd data

1.9 References

Subversion repository version of DPG Matlab generic tools 3974

Pender, L., 2000. Data Quality Control flags.
http://www.marine.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf

Atmospheric sensors:

\\fstas1-hba.nexus.csiro.au\CMAR-SHARE4\Groups\Marine Technology and Equipment\Marine Instrumentation\Data\Investigator\Systems Documentation\Met Station\Documentation\Met Instrument Location Survey\Radialshots_Weathersensors_Rev4.pdf

1.10 APPENDIX:

TABLE-1: Underway Sensors

The table below contains the description of Ship sensors and Underway netCDF variables.

Underway Data Instrument and Identifier	Sensor Description	Position	netCDF variable	QC	Variable Description	Variable units
Navigation Instruments:						
Seapath 330+ with Seatex MRU 5+ and FUGRO Seastar 3610 DGNSS receiver	DGPS system providing position, attitude, velocity, acceleration and timing information.	Monkey Island & Bridge equipment room				
			Longitude	yes	Longitude	Degree East
			Latitude	yes	Latitude	Degree North
			speedOG	yes	Ship speed over ground	Knot
			courseOG	yes	Ship course over ground	Degree
			shipHeading	yes	Heading of the ship	Degree
			alt	no	Altitude re: mean sea level (geoid)	Metres
Northrup Grumman Sperry 4914-CA Navigat X MK1	Gyrocompass	Bridge				
			gyroHeading	No	Gyro Heading	Degree
Kongsberg Maritime Skipper DL850	3 Axis doppler log - measuring vessel speed through water	Gondola	(no data)			
			longitudinalWaterSpeed	No	Longitudinal water speed	knot
			transverseWaterSpeed	No	Transversal water speed	knot
			longitudinalGroundSpeed	No	Longitudinal ground speed	knot
			transverseGroundSpeed	No	Transversal ground speed	knot
			lockOnWater	No	Lock on water flag	n/a
			lockonGround	No	Lock on ground flag	n/a
Sea Water Instruments:						
Sea-Bird-SBE 21 TSG	Thermosalinograph (TSG)	CTD Space				
			salinity	Yes	Measures sea surface salinity	Practical Salinity Units (PSU)
			tsgSensorTemp	No	Water temperature measurement in the TSG canister	Degree Celsius (degC)
Burkert 8045	Flow meter	CTD space				
			tsgFlow	No	Flow rate of sea water through the TSG	l/min
Burkert 8045	Flow meter	Underway Seawater Lab				
			labMainFlow	No	Underway lab main seawater flow rate	l/min
Kobold MIK-C	Flow meter	Underway Seawater Lab				
			labBranchFlow	No	Underway lab branch seawater flow rate	l/min
Sea-Bird - SBE 38	Remote Temperature Probe	Port Drop Keel				

			waterTemp	Yes	Sea surface water temperature measurement	Degree Celsius (degC)
Wet Labs Wetstar Fluorometer	Fluorometer	Underway Seawater Lab				
			fluorescence	No	Measures active phytoplankton biomass and chlorophyll concentrations	Percentage of the full scale voltage
CSIRO Hobart pCO2	Underway pCO_2 system measuring surface water CO_2 mole fraction	Underway Seawater Lab				
			equTemp	No	Equilibrator water temperature	Degree Celsius (degC)
			XCO2	No	XCO2	ppm
			waterVapour	No	Water vapour	mmol/mole
			licorPressure	No	Licor pressure	hPa
			equPressure	No	Equilibrator pressure	hPa
			waterFlow	No	Water flow	l/min
			licorFlow	No	Licor flow	ml/min
			ventFlow	No	Vent Flow	ml/min
			condTemp	No	Condenser Temperature	Degree Celsius (degC)
			pumpSpeed	No	CO2 Pump Speed	l/min
Aanderaa Oxygen Optode 3835	**Oxygen Sensor**	**Underway Seawater Lab**				
			do		oxygen	uM
			doSaturation		Air saturation	Percentage (%)
			optodeWaterTemp		Optode water temperature	Degrees Celsius (degC)
CSIRO Drop keel sensor	Measuring drop keel draft	Port & starboard				
			portKeelExtension		Port drop keel extension	meters
			starboardKeelExtension		Starboard drop keel extension	meters
Met Instruments:						
Rotronic T&RH HC2A-S3	Temperature and Humidity Sensor	Foremast (Starboard)				
			stbdAirTemp	Yes	Starboard air temperature measurement	Degree Celsius (degC)
			stbdHumidity	Yes	Starboard humidity measurement	Percentage (%)
			stbdDewPoint	Yes	Starboard Dew Point	Degree Celsius (degC)
Rotronic T&RH HC2A-S3	Temperature and Humidity Sensor	Foremast (Port)				
			portAirTemp	Yes	Port air temperature measurement	Degree Celsius (degC)
			portHumidity	Yes	Port humidity measurement	Percentage (%)
			portDewPoint	Yes	Port Dew Point	Degree Celsius (degC)
Vaisala Ship's Barometer PTB330	Atmospheric pressure	Bridge Wing	atmPressureBridge	Yes	Atmospheric pressure measurement	Millibar (mbar)
Vaisala Ship's Barometer PTB330	Atmospheric pressure	Foremast	atmPressure	Yes	Atmospheric pressure measurement	Millibar (mbar)

RM Young Wind Sensor Type 05107	Vane type wind sensor	Foremast (Port)				
			portRelWindSpeed	Yes	Wind speed relative to the ship	knot
			portRelWindDir	Yes	Wind direction relative to the ship	Degree
			portTrueWindSpeed	Yes	True wind speed, corrected for ship speed	knot
			portTrueWindDir	Yes	True wind direction, corrected for ship heading	Degree
			maxWindGust	Yes	True maximum wind gust corrected for ship speed	knot
RM Young Wind Sensor Type 05108	Vane type wind sensor	Foremast (Starboard)				
			stbdRelWindSpeed	Yes	Wind speed relative to the ship	knot
			stbdRelWindDir	Yes	Wind direction relative to the ship	Degree
			stbdTrueWindSpeed	Yes	True wind speed, corrected for ship speed	knot
			stbdTrueWindDir	Yes	True wind direction, corrected for ship heading	Degree
Gill WindObserver II	Ultrasonic Wind Sensor	Foremast (Port)				
			ultrasonicRelWindSpeed	Yes	Wind speed relative to the ship	knot
			ultrasonicRelWindDir	Yes	Wind direction relative to the ship	Degree
			ultrasonicTrueWindSpeed	Yes	True wind speed, corrected for ship speed and direction	knot
			ultrasonicTrueWindDir	Yes	True wind direction, corrected for ship speed and heading	Degree
RM Young Rain Gauge type 50202	Syphoning Rain Sensor	Foremast				
			portRain	Yes	Accumulated hourly rain	mm
			stbdRain	Yes	Accumulated hourly rain	mm
Eppley PIR	Precision Infrared Radiometer	Monkey Island (Starboard)				
			stbdRadiometer	Yes	Measure radiation in the band 4-100 micron, longwave radiation	W/m^2
Eppley PIR	Precision Infrared Radiometer	Monkey Island (Port)				
			portRadiometer	Yes	Measure radiation in the band 4-100 micron, longwave radiation	W/m^2
Eppley PSP	Precision Spectral Pyranometer	Monkey Island (Starboard)				
			stbdPyranometer	Yes	Measure radiation in the band 0.2 - 4 micron, shortwave radiation	W/m^2
Eppley PSP	Precision Infrared Radiometer	Monkey Island (Port)				
			portPyranometer	Yes	Measure radiation in the band 0.2 - 4 micron, shortwave radiation.	W/m^2

LI-COR LI-190 Quantum Sensor	Photosynthetically Active Radiation	Monkey Island (Starboard)				
			stbdPAR	Yes	measures radiation in the photosynthetically active region of 0.4-0.7 micron	uE/m^2/s
LI-COR LI-190 Quantum Sensor	Photosynthetically Active Radiation	Monkey Island (Port)				
			portPAR	Yes	measures radiation in the photosynthetically active region of 0.4-0.7 micron	uE/m^2/s
Uni-Southampton ISAR SST	Radiation sea surface temperature	Bridge Wing (Port)				
			isarWaterTemp	No	ISAR Water Temperature	Degree Celsius (degC)
Air Sampling Systems:						
CSIRO air sampling inlet	Air inlet controller	foremast				
			inletBearing	No	Air sampling inlet bearing	degree
			trackingBearing	No	Tracking target bearing	degree
Thermo Scientific MAAP Model 5102	Multi-angle Absorption Photometer (MAAP)	Aerosol Lab (air sampling inlet)				
			blackCarbonConc	No	Concentration of black carbon	ug/m^3
			airFlow	No	Air flow rate	Litre per Hour (L/h)
Thermo Scientific Model 49i Ozone Analyzer	Ozone Monitor					
			o3Ozone1	No	Ozone measurement	ppb
			ozone1Meterflags	No	Instrument specific quality flag	n/a
Thermo Scientific Model 49i Ozone Analyzer	Ozone Monitor					
			o3Ozone2	No	Ozone measurement	ppb
			ozone2Meterflags	No	Instrument specific quality flag	n/a
Picarro Model G2301 CRDS Analyzer	Greenhouse Gas Spectrometer CO2, CH4, H2O Near IR Laser					
			co2Dry	No	CO2 dry concentration	ppm
			ch4Dry	No	CH4 dry concentration	ppm
			H2O	No	Water concentration percentage	Dimensionless
Depth:						
Kongsberg EM122 multibeam sounder		Gondola	depth	No	Water depth,	meters
Kongsberg EM710 multibeam sounder		Gondola	depth	No	Water depth,	meters
EK60, 18KHz sounder		Port Drop Keel	Depth, (if not provided by EM122 or EM710)	No	Water depth	meters

TABLE-2: Location of Meteorological Instruments:

Date:	26/03/2019
Surveyors:	Stuart Edwards
	Matt Boyd
	CSIRO GSM Team
Instrument:	Leica TCRP 1205+ Total Station AND extrapolation from drawings
Sensors surveyed with respect to existing vessel coordinate system:	
	X-axis is positive toward starboard and perpendicular to Y -axis
	Y-axis is positive forward and parallel to vessel centreline keel
	Z-axis is positive upwards
CRP is MRU5+ located in transceiver room on 1st platform deck	
MRU5+ is 2.066m to Starboard of the V/L centreline & 53.439m fwd from transom. (Obtained from Parker Maritime)	
ΔH of Load Line measured from 02 level with Plumbob and tape, 9m from 02 Deck. Height of 02 deck calculated to be 8.707m above CRP on 1st Plat deck. Load Line height datum below vessel CRP	

ID	Description	X	Y	Z	Comment	Final Height Above Summer Load Line
LL	Summer Load Line	7.222	-10.695	-0.293	Waterline reference	0.000
WS1	Foremast Propeller Anemometer Stbd	-0.513	35.811	24.487	Measured to base of sensor	24.780
WS2	Foremast Propeller Anemometer Port	-3.361	35.867	24.228	Measured to base of sensor	24.521
WS3	Foremast Gill Ultrasonic Anemometer	-3.344	35.986	21.812	Measured to base of sensor	22.105
WS4	Precipitation Sensor Siphoning Port (formerly called "Central")	-2.621	35.999	21.260	Measured to base of sensor	21.553
WS10	Monkey Island Radiometer Plate Stbd	-0.164	-0.430	24.980	Measured to centre bottom face of disc	25.273
WS11	Monkey Island Radiometer Plate Port	-3.753	-0.389	24.927	Measured to centre bottom face of disc	25.220
WS12	Bridge Digital Barometer	-1.559	-4.243	20.265	Measured to centre of unit	20.558
WS13	SST Radiometer (Port Bridge Wing)	-11.77	-3.3	19.3	Measured to centre of bottle (Taped Measurement)	19.593
	Foremast T&RH Sensor (Port)	-2.636	35.1	24.451	Relative measurements and estimates from drawings	24.744
	Foremast T&RH Sensor (Starboard)	-1.253	35.101	24.451	Relative measurements and estimates from drawings	24.744
	Precipitation Sensor Siphoning (Starboard)	-1.241	35.101	21.260	Relative measurements and estimates from drawings	21.553
	Foremast Digital Barometer	-3.316	32.596	9.61	Relative measurements and estimates from drawings	9.903

TABLE-3: Drop Keel Data

	Reference Point	Vertical Offset in metres (positive up)			
Drop Keel Position		**Flush with Hull**	**Flush with gondola**	**Intermediate**	**Fully extracted**
Drop Keel Extension	**Base of Hull**	**0.00**	**-1.194**	**-2.00**	**-4.00**
Base of Hull	Ship's Central reference Point (CRP)	-6.54			
Base of Drop Keel	CRP	-6.54	-7.73	-8.54	-10.54
SBE38 SST Intake	Base of Drop Keel	0.30			
SBE38 SST Intake	CRP	-6.24	-7.43	-8.24	-10.24
Summer Load Line (SLL	CRP	-0.29			
SBE38 SST Intake	**SLL (ie Depth below waterline)**	**-5.95**	**-7.14**	**-7.95**	**-9.95**
TSG Intake	Base of Drop Keel	0.54			
TSG Intake	CRP	-6.00	-7.19	-8.00	-10.00
TSG Intake	**SLL (ie Depth below waterline)**	**-5.71**	**-6.90**	**-7.71**	**-9.71**

The above information was compiled from the following CSIRO internal documents:

[1] \\fstas1-hba.nexus.csiro.au\CMAR-SHARE4\Groups\Marine Technology and Equipment\GSM\RV Investigator\Calibration Data and Reports\Dimensional Control Report\13000615B_RV Investigator.pdf

[2] \\fstas1-hba.nexus.csiro.au\CMAR-SHARE4\Groups\Marine Technology and Equipment\Marine Instrumentation\Data\Investigator\Systems Documentation\Met Station\Documentation\Met Instrument Location Survey\Radialshots_Weathersensors_Rev4.xlsx

[3] \\fstas1-hba.nexus.csiro.au\CMAR-SHARE4\Groups\Marine Technology and Equipment\Marine Instrumentation\Data\Investigator\Systems Documentation\Drop Keels\RV Investigator Drop Keel Arrangements.docx