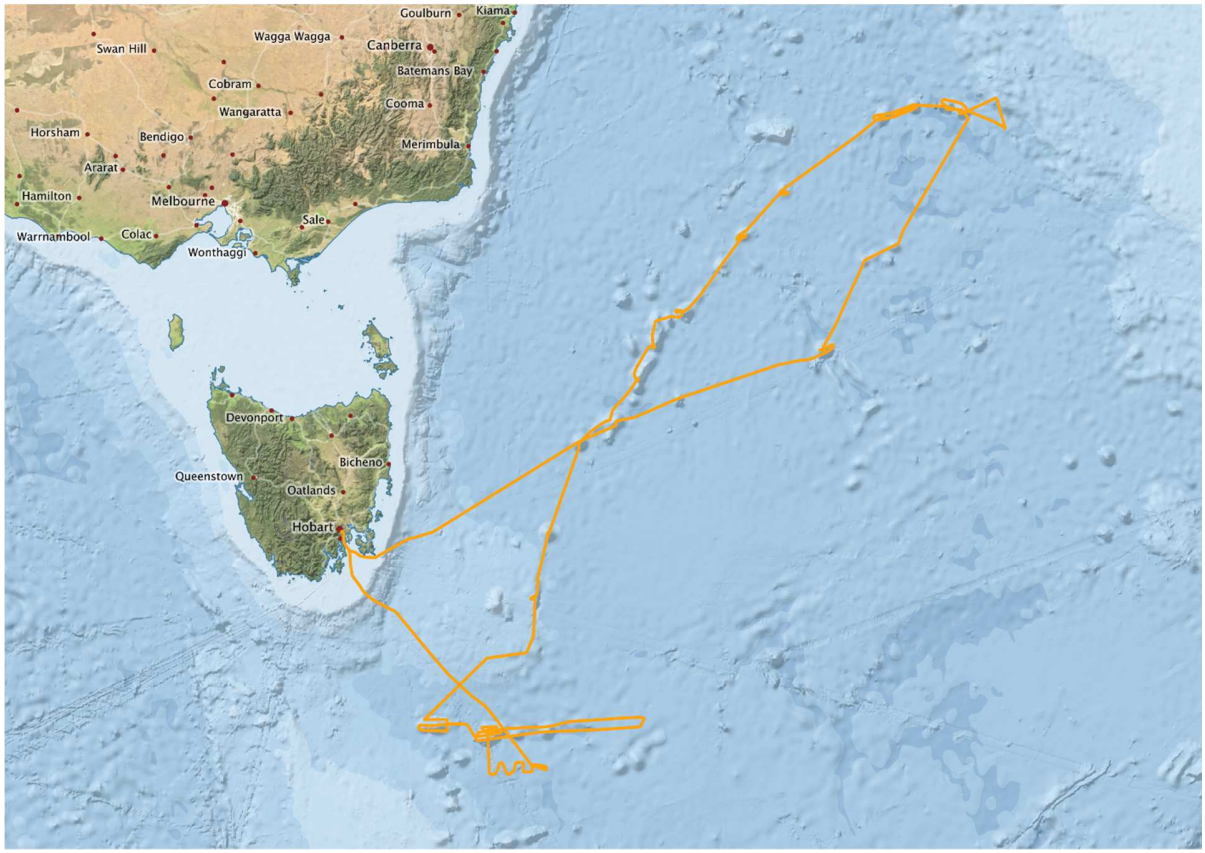
RV *Investigator*

Underway Data Processing Summary Report

Voyage #:	**in2018_v08**
Voyage title:	The Balleny mantle plume: key role in Tasmania-Antarctic breakup
Depart:	Hobart, 0900 Thursday, 27 December 2018 AEST
Return:	Hobart, 0900 Thursday, 10 January 2019 AEST
Data dates:	26-Dec-2018 22:06:35 to 09-Jan-2019 22:22:25
Chief Scientist:	Dr Joanne Whittaker
Data processed by:	Anoosh Sarraf, CSIRO Oceans and Atmosphere, Hobart, Tasmania.

1.1 Table of Contents

1.2 Voyage Track



1.3 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, siphoning rain gauge, licor light sensor and a barometer.

Thermosalinograph data is acquired with a Seabird SBE21 TSG and remote temperature by SBE38. Data from a flow meter is also recorded.

The depth data is derived in order of availability from the Kongsberg EM122 or EM710 multibeam or Simrad EK60 sounders.

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, thermosalinograph, IMOS and depth 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 4th Feb 2019 by running the Java application UWYMerger with data time range of 26-Dec-2018 22:06:35 to 09-Jan-2019 22:22:25 UTC.

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, ISAR SST, gyro and Doppler log.

Techsas1 was used as the data source. The ISAR SST was not available on this voyage.

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

1.4 Completeness and Data Quality

Navigation data (latitude and longitude, speed over ground, ship heading and course over ground); meteorological data (port and starboard air temperature, port and starboard humidity, port and starboard relative and true wind direction and speed, maximum wind gust, port and starboard PAR light, port and starboard 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.

1.5 Processing Comments

Atmospheric Pressure: In previous voyages, the atmospheric pressure values (*atmPressure*) showed unusual characteristics. Minor increases and decreases in pressure values were noted. These were investigated and a direct correlation with changing wind direction was noted. It is believed that due to the position of the intake of the atmospheric pressure sensor on the ship's superstructure, the values were influenced by the prevailing wind and this effect (Bernoulli effect) becomes noticeable during notable wind direction changes.

To overcome this phenomena, the original barometer (located on the bridge at a height of 20.558m above the summer load line) was replaced by an identical barometer located on the foremast at a lower height (9.903m above the summer load line). It appears that no significant improvement was achieved and pressure changes are still evident when wind direction changes occur. The data has been flagged as good but please be aware that this issue still persists. In addition, it should also be noted that in line with past practice, the pressure data is not corrected for instrument mounting height.

The AtmPressure was switch from the foremast barometer to the bridge barometer at 06-Jan-2019 04:07:50. The values between 06-Jan-2019 03:51:20--04:07:50 were NaNed whilst the sensors where being switched over. Since the change smoother data was observed.

Finally, given that the same sensor variable name of AtmPressure was used to record data from two sensors mounted at different heights, this height difference needs to be taken into account when using the data from the point of the switch on 06-Jan-2019 04:07:50 onwards .

Air Temperature: A number of minor discrepancies between the port and starboard air temperature sensors were noted (max difference of about 1.1 degrees Celsius), otherwise both sensors gave very close reading with the mean absolute difference of about 0.1 degrees. These discrepancies occurred usually 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.

Humidity: Port Humidity sensor values went off scale on a number of occasions during the voyage. These were NaNed and their QC flags set to {'bad', 'none', 'operatorFlagged'}. A small portion of the data exceeding 100% but remaining within instrument range has been adjusted back down to 100% and QCed as {'good','adjusted','range' } for both sensors. Following the data clean up, the max difference of about 11.43% between the port and starboard humidity sensors with the mean absolute difference of about 0.85% was obtained. This was a great improvement on the UNQCed data with max and mean difference of 16.3% and 2.57% respectively.

Rain: No issues found with the port and starboard siphoning rain gauges.

Wind Speed: The wind speed values from the starboard wind sensor deviated significantly from the other two (port and ultrasonic) sensors throughout the voyage. A mechanical fault was later discovered with the starboard wind speed sensor.

An automated wind speed filter was implemented to flag regions where the deviation from the other sensors was greater than 3.3 knots (set to suspect) and 3.5 knots (data NaNed) with a hysteresis thresholds bands of +/-5%. This was applied to both relative and true starboard wind speed.

Following the application of the filter, the mean difference between starboard and port relative wind speed was about 1.27 knots with a max absolute difference of 7.9 knots. This was a great improvement over the pre-filter values of 1.9 and 24.2 knots respectively.

Wind Direction: An automated filter was implemented to remove data spikes and was applied to both the port and starboard (relative) wind direction. The filter removed points where the magnitude of the second difference was greater than 48 degrees. The majority of the spikes appear to have been correctly flagged and removed. However with automated filtering it is always possible that a very small number of data points may have been misidentified.

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 worldwide 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.

PAR: It was noted that values recorded by the Port and starboard PAR (Photosynthetically Active Radiation) sensors had a mean absolute difference of about 15.46 (uE/m^2/s) respectively.

Pyranometer: No issues found with the Pyranometer sensor. The values recorded by the port and starboard Pyranometer had a mean absolute difference of 7.83 W/m^2 respectively.

Radiometer: No issues found with the Radiometer sensor. The mean absolute difference of 4.61 W/m^2 between the port and starboard Radiometer.

Ultrasonic Wind Speed: The ultrasonic wind speed generally reads slightly lower than either the port/starboard vane type wind sensors, this is likely to be due to the lower height mounting on the foremast compared to the other two sensors.

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 extend. 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. The automated wind direction filter was applied to a few selected regions which appeared to be very noisy or spiky for both true and relative ultrasonic wind direction.

Water Temperature: A few short periods of erroneous flat lined data has been NaNed and its flag set to {'bad', 'none', 'operatorFlagged'}. This may have been caused due to SBE38 control deck unit problem.

Salinity: No significant issues were found with the salinity data. Spikes greater than 0.1PSU have been removed with additional manual QCing. TSG S/N 3439 was used for the entire voyage.

TSG Calibration: There were no salinity sample bottles collected during this voyage. Therefore averaging the salinity scaling coefficient from the two adjacent in2018_v06 and in2019_v01 voyages, the calibration scaling factor of 1.00062472 was calculated. This was then applied to the salinity data and its QC flag set to {‘good’, ‘manually adjusted’, ‘no error’}.

TSG Lag: Examination and comparison of the TSG water temperature profile against the sea surface water temperature showed a lag of approximately about 2.9 minutes between the two data sets and a mean thermal increase of about 0.16C^o from the intake 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 2.3 minutes, the salinity measurements could be for a location about 720 meters away from the current ship location.

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.

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 NaNed 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.

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.

Signed	Unsigned	Description	Data State	Operation Type	Error Type
0	0	Good	Good	None	No error, data is good
-53	203	not QC'd	No QC	None	Preliminary processing (calibration) only
48	48	Good	Good	Manually adjusted	No error
-123	133	Bad (data is NaNed)	Bad	None	Error Flagged by processor
-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
-199	57	Operator adjusted	good	Manually Adjusted	Data out of range

1.6 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.

Filename	Parameters	Resolution
in2018_v08uwy10sec.csv	latitude, latitudeQC, longitude, longitudeQC, speedOG, speedOGQC, courseOG, courseOGQC, shipHeading, shipHeadingQC, portAirTemp, portAirTempQC, stbdAirTemp, stbdAirTempQC, portHumidity, portHumidityQC, stbdHumidity, stbdHumidityQC, atmPressure, atmPressureQC, portRain, portRainQC, stbdRain, stbdRainQC, portPAR, portPARQC, stbdPAR, stbdPARQC, portRelWindDir, portRelWindDirQC, portTrueWindDir, portTrueWindDirQC, portRelWindSpeed, portRelWindSpeedQC, portTrueWindSpeed, portTrueWindSpeedQC, stbdRelWindDir, stbdRelWindDirQC, stbdTrueWindDir, stbdTrueWindDirQC, stbdRelWindSpeed, stbdRelWindSpeedQC, stbdTrueWindSpeed,	10 seconds

	stbdTrueWindSpeedQC, maxWindGust, maxWindGustQC, stbdRadiometer, stbdRadiometerQC, portRadiometer, portRadiometerQC, stbdPyranometer, stbdPyranometerQC, portPyranometer, portPyranometerQC,ultrasonicRelWindSpeed, ultrasonicRelWindSpeedQC, ultrasonicRelWindDir, ultrasonicRelWindDirQC, ultrasonicTrueWindSpeed, ultrasonicTrueWindSpeedQC, ultrasonicTrueWindDir, ultrasonicTrueWindDirQC, salinity, salinityQC , waterTemp, waterTempQC	
in2018_v08uwy5min.csv	Ditto 10 second data	5 minutes

1.7 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

1.8 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				
			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/L
			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:						
Vaisala T&RH HMT333	Temperature and Humidity Sensor	Foremast (Starboard)				
			stbdAirTemp	Yes	Starboard air temperature measurement	Degree Celsius (degC)
			stbdHumidity	Yes	Starboard humidity measurement	Percentage (%)
Vaisala T&RH HMT333	Temperature and Humidity Sensor	Foremast (Port)				
			portAirTemp	Yes	Port air temperature measurement	Degree Celsius (degC)
			portHumidity	Yes	Port humidity measurement	Percentage (%)
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