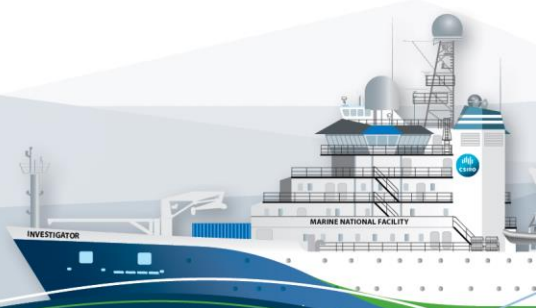
RV *Investigator*

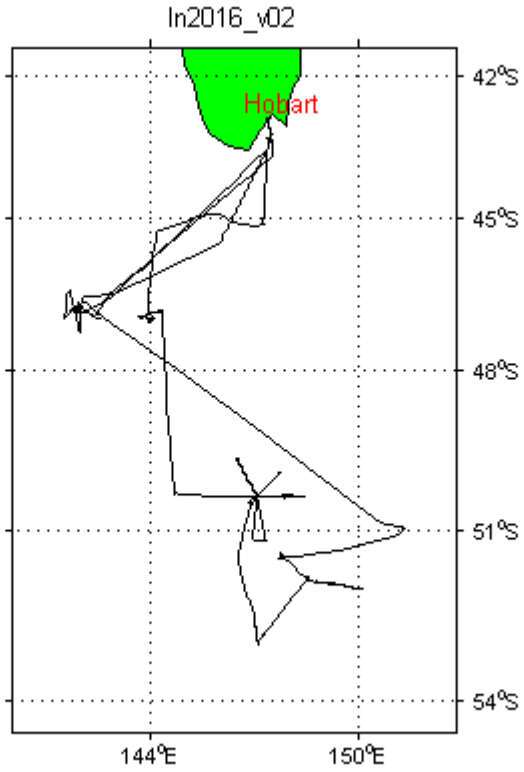
Underway Data Processing Summary Report

Voyage #:	IN2016_V02
Voyage title:	SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania CAPRICORN: Clouds, Aerosols, Precipitation, Radiation, and Atmospheric Composition over the Southern Ocean Eddy – Link eddy physics and biogeochemistry in the Antarctic Circumpolar Current south of Tasmania
Depart:	Hobart, Monday 14th March, 2016, 10:00 (local time)
Return:	Hobart, Saturday 16th April 2016, 09:30 (local time)
Data dates:	13 March, 2016, 23:08 – 15 April 2016 22:46
Chief Scientists:	Professor Tom Trull, CSIRO/ ACE CRC and Eric Schulz, BOM, – SOTS Dr Alain Protat – CAPRICORN Dr Peter Strutton, UTas, - Eddy
Data processed by:	Bernadette Heaney, CSIRO Oceans and Atmosphere, Hobart, Tasmania (completed November 2017)



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, 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.

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.

See Electronics report for this voyage for instruments used and their serial numbers.

Navigation, meteorological, thermosalinograph and IMOS data are preliminary quality controlled by combining all data from “Techsas” 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 06-April-2017 by running the Java application UWYMerger with data time range of 13 March, 2016, 23:08 – 15 April 2016 22:46 (UTC time): UWYMerger reads 5 second data from netcdf files which have been written by “TECHSAS” during acquisition.

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, gyro, Doppler log and ISAR SST radiometer and Aanderaa optode oxygen sensor and depth data. The depth data is derived in order of availability from the Kongsberg EM122 multibeam, Kongsberg EM710 multibeam or Simrad EK60 sounders.

For further description of instruments and Underway netCDF variables please refer to Appendix 1 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, atmospheric pressure and rain) 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 for previous voyages and a direct correlation with changing of 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 from this sensor are influenced by the prevailing wind and this effect (Bernoulli effect) becomes noticeable during notable wind direction changes. To overcome this phenomena, a Y section was introduced in the configuration of the intake to the sensor to ensure that the effect of the wind direction on the port and starboard is equalised in relation to this sensor. This has improved the data quality noticeably and therefore the data has been QCed as good.

Air Temperature: A number of minor discrepancies between the port and starboard air temperature sensors were noted (max differences of about 8.0 degrees), otherwise both sensors gave very close reading with the mean absolute difference of about 0.06 degrees. These discrepancies occurred usually during periods of rapid temperature change. This phenomenon has probably come about due to the rapid warming of the ships 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 values required one correction, 31-Mar-2016 13:32:55-01-Apr-2016 01:27:35. Starboard required 3; 31-Mar-2016 19:22:30- 01-Apr-2016 08:04:10; 04-Apr-2016 10:52:45 - 05-Apr-2016 09:05:45 and 15-Apr-2016 07:34:45- 15-Apr-2016 11:39:35.

Values were set to NaN and flagged 'bad','none','softwareError'.

Values over 100 and less than 103 have been adjusted back to 100% and QC flags set to 'good', 'adjusted','range'.

There was a maximum difference of 35.7% between the two sensors, with a mean absolute value of 1.21%. The recorded values are within instrument tolerance.

Wind Speed and Directions: Because the shipHeading was recorrected (see below) the portTrueWindSpeed, portTrueWindDir, stbdTrueWindSpeed and stbdTrueWindDir were recomputed using gyroHeading and flags set to 'good','adjusted','none,' till 26-Mar-2016 02:17. It was noted that although there was no raw seapath data in the nmea files, when that instrument was off, there was shipHeading values in the netcdf – Techsas reverts to sourcing data from the secondary navigation instrument. During the down time the true wind corrections were incorrect (they have been corrected now).

Maximum Wind Gust : As the maxWindGust is computed from the portTrueWindSpeed, which may have been derived from incorrect or no ship heading data (see below), the QC flags up till 26-Mar-2016 02:18 have been set to 'suspect','none','softwareError'. There were no changes made to the values.

CourseOG: The courseOG values when the ship is stationary, e.g. tied up at wharf, are not true values as the ship is not travelling a course. There was no data collected when the ship was at the wharf so all data was left flagged as 'good','none','No error'.

Ship Heading: shipHeading read from seapath files until 25 Mar 2016 23:08 was flagged 1 or 2 in the raw NMEA files because of bad quality data. The instrument was reset and after 26 March 2016 02:17 the data was flagged as "0" (good data).

When the flag is 2 there is no heading data in the file, but Techsas was reading the data as zero, as seen in the netcdf files produced. So when uwyMerger read data from the netcdf files, the resulting 5 second values were compromised and resulted in spikey, incorrect shipHeading data.

For this voyage, the shipHeading data was re- read from the raw seapath files. 5 second values were computed and written back into shipHeading. shipHeadingQC values up till 25-Mar-2016 23:05 were set to 'good','filtered','softwareError' .

PAR: It was noted that values recorded by the Port and starboard PAR sensor had a mean absolute difference of about 24.53 (uE/m²/s) respectively.

Pyranometers: The values recorded by the port and starboard Pyranometers had a mean absolute difference of 9.98 W/m^2. The starboard pyranometer data spiked and then flatlined, 23-Mar-2016 07:13 – 23-Mar-2016 20:43, this data was set to NaN and qc'd as bad.

Radiometers: The starboard radiometer data 23-Mar-2016 07:30:55 - 24-Mar-2016 02:57:55 was set to NaN and flags set to 'bad','none','softwareError'.The port and starboard radiometers had a mean absolute difference of 2.57 W/m^2

Ultrasonic Wind Direction: The ultrasonicRelWindDir has been incorrectly computed by Techsas. Comparing portRelWindDir, stbdRelWindDir and ultrasonicRelWindDir shows a linear averaging instead of a directional averaging had been used for the ultrasonicRelWindDir.

Ultrasonic wind speed and direction were extracted from the $WIMMV nmea strings in .METEO files. The ultrasonic wind speed values appear to be low and ultrasonic wind direction values erratic when the relative wind direction is around 100° to 120° which could be due to the placement of the instrument on the lower yardarm to the port side. There are also gaps in the ultrasonic data at that wind direction.

Initial despiking of the ultrasonic wind speed and ultrasonic wind direction data was done by using a weighted average over a 20 second span.

5 second values were interpolated (using matlab interp1 and nearest method) and inserted into the underway netcdf file.

The ultrasonicTrueWindDir and ultrasonicTrueWindSpeed were recomputed.

The ultrasonicRelWindSpeedQC, ultrasonicRelWindDirQC, ultrasonicTrueWindDirQC and ultrasonicTrueWindDirQC values were set to 'good','none','No error' where there was data.

Where there was no data in the WIMMV nmea string, the data value is NaN and the QC flag set to 'bad','none','noData'.

ultrasonicRelWindDir and ultrasonicTrueWindDir were inspected for deviations from port and starboard vane data and unrealistic data was set to 'NaN' and flagged as 'bad', 'none', 'flagged by processor'.

Thermosalinograph (TSG): Salinity and tsgSensorTemp data were cleaned while locating obvious spikes or times when the tsgWaterFlow was off.

A filter utilising the second difference (with a magnitude of 0.2) was applied to the salinity data in order to NaN and remove data spikes and set its QC flag to ('bad','none','operatorFlagged').

Although 3 TSG vs CTD calibration runs were done onboard only run 2 seemed usable.

The scale and offset value of 0.99927879342841752 & 0.000652114645542563, with respect to the manufacturer's calibration, was obtained from a CTD file, in2016_v02007Ctd.nc and checked against the CTD processing report. The CTD/TSG calibration files and the CTD file were checked to ensure the same sensors were used (primary temperature 4722 and primary conductivity 3868).

This data was then used to derive the TSG salinity calibration against the calibrated CTD data.

Using CTD/TSG calibration run in2016_v02002Ctd.nc with the TSG conductivity lag of zero, and a TSG lag of 23, a TSG conductivity scaling factor of 0.999678056652043 was calculated against the primary CTD conductivity cell. This was then applied to the TSG conductivity data to derive calibrated TSG salinity. The TSG salinity QC flag was set to {'good' ,'manually adjusted','no error'}.

More salinity spikes were removed after calibration, by again running a second difference filter of 0.2 and then picking residual bad points manually, for elimination.

During the reviewing process, the CTD/TSG calibration run in2016_v02003CTD.nc was found to contain recoverable data which was used to obtain a more accurate calibration.

This calibration run was incorporated into the calibration process and a new averaged conductivity scale factor of 0.999913301674685 with respect to the latest TSG salinity data was derived and applied.

This double step process has in effective applied an average scaling factor of 0.9995979205835 with respect to the original salinity values.

(Note: the scaling factor is calculated and actually applied to the conductivity from which Salinity is derived)

Water Temperature: Examination and comparison of the TSG water temperature profile against the sea surface water temperature showed a lag of approximately about 2 minutes and 6 secs between the two data sets and thermal increase of 0.19 C from the intake to the TSG. This lag is due to the time it takes 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 CTD area 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 geo location of the sampled value.

For example, assuming a ship cruising speed of 10 knots and a lag of 2 minutes and 6 seconds, the salinity measurements could be for a location about 648 meters away from the current ship location.

Depth: The Depth data is no longer processed as part of the underway data set. The non QCed data is available in the underway data. The QCed 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 UNQCed data. Therefore even though the QCed variable may have been NaNed or otherwise adjusted, 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 methodology.

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.

The following files have been created.

Filename	Parameters	Resolution
IN2016_V02uwy10.csv	latitude, latitudeQC, longitude, longitudeQC, speedOG, speedOGQC, courseOG, courseOGQC, shipHeading, shipHeadingQC, portAirTemp, portAirTempQC, stbdAirTemp, stbdAirTempQC, portHumidity, portHumidityQC, 'stbdHumidity, stbdHumidityQC, atmPressure, atmPressureQC, rain, rainQC, portPAR, portPARQC, stbdPAR, stbdPARQC,portRelWindDir, portRelWindDirQC, portTrueWindDir, portTrueWindDirQC, portRelWindSpeed, portRelWindSpeedQC, portTrueWindSpeed, portTrueWindSpeedQC, stbdRelWindDir, stbdRelWindDirQC, stbdTrueWindDir, stbdTrueWindDirQC, stbdRelWindSpeed, stbdRelWindSpeedQC, stbdTrueWindSpeed, stbdTrueWindSpeedQC, maxWindGust, maxWindGustQC, stbdRadiometer, stbdRadiometerQC, portRadiometer, portRadiometerQC, stbdPyranometer, stbdPyranometerQC, portPyranometer, portPyranometerQC,ultrasoniRelWindSpeed, ultrasonicRelWindSpeedQC, ultrasonicRelWindDir, ultrasonicRelWindDirQC, ultrasonicTrueWindSpeed, ultrasonicTrueWindSpeedQC, ultrasonicTrueWindDir, ultrasonicTrueWindDirQC, salinity, salinityQC, waterTemp, waterTempQC,	10 seconds
IN2016_V02uwy5min.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

Appendix 1

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 (°C)
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 (°C)
Wet Labs Wetstar Fluorometer	Fluorometer	Underway Seawater Lab				
			fluorescence	No	Measures active phytoplankton biomass and chlorophyll concentrations	Dimensionless
CSIRO Hobart pCO2	Underway pCO_2 system measuring surface water CO_2 mole fraction	Underway Seawater Lab				
			equTemp	No	Equilibrator water temperature	Degree Celsius (°C)
			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 (°C)
			pumpSpeed	No	CO2 Pump Speed	l/min
Aanderaa Oxygen Optode 3835	**Oxygen Sensor**	**Underway Seawater Lab**				
			do	No	oxygen	uM/L
			doSaturation	No	Air saturation	Percentage (%)
			optodeWaterTemp	No	Optode water temperature	Degrees Celsius (°C)
CSIRO Drop keel sensor	Measuring drop keel draft	Port & starboard				
			portKeelExtension	No	Port drop keel extension	meters
			starboardKeelExtension	No	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 (°C)
			stbdHumidity	Yes	Starboard humidity measurement	Percentage (%)
Vaisala T&RH HMT333	Temperature and Humidity Sensor	Foremast (Port)				
			portAirTemp	Yes	Port air temperature measurement	Degree Celsius (°C)
			portHumidity	Yes	Port humidity measurement	Percentage (%)
Vaisala Ship's Barometer PTB330	Atmospheric pressure	Bridge Wing				

			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				
			rain	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/m²
Eppley PIR	Precision Infrared Radiometer	Monkey Island (Port)				
			portRadiometer	Yes	Measure radiation in the band 4-100 micron, longwave radiation	W/m²
Eppley PSP	Precision Spectral Pyranometer	Monkey Island (Starboard)				
			stbdPyranometer	Yes	Measure radiation in the band 0.2 - 4 micron, shortwave radiation	W/m²
Eppley PSP	Precision Infrared Radiometer	Monkey Island (Port)				
			portPyranometer	Yes	Measure radiation in the band 0.2 - 4 micron, shortwave radiation.	W/m²
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/m²/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/m²/s
Uni-Southampton ISAR SST	Radiation sea surface temperature	Bridge Wing (Port)				

			isarWaterTemp	No	ISAR Water Temperature	Degree Celsius (°C)
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/m³
			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
Water Depth Systems						

Kongsberg EM122 multibeam sounder		Gondola	depth	No	Water depth	metres
Kongsberg EM710 multibeam sounder		Gondola	depth (if not provided by EM122)	No	Water depth	metres
Simrad EK 60, 18 kHz sounder		Port drop keel	depth (if not provided by either of above)	No	Water depth	metres