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National Oceanography Centre

Internal Document No. 04

Metadata for the WAGES instrumentation deployed on the *James Clark Ross* between May 2010 and September 2011

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2011

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DOCUMENT DATA SHEET

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PUBLICATION DATE 2011

TITLE

Metadata for the WAGES instrumentation deployed on the *James Clark Ross* between May 2010 and September 2011.

REFERENCE

Southampton, UK: National Oceanography Centre, Southampton, 54pp.
(National Oceanography Centre Internal Document, No. 04)
(Unpublished manuscript)

ABSTRACT

The RRS James Clark Ross makes meteorological measurements around Antarctica during the austral summer, in the Arctic during the boreal summer and in the Atlantic during passages between the two poles. In May 2010, as part of the WAGES project the ships existing systems were complemented by the AutoFlux system (Yelland et al., 2009) to measure the transfers of momentum, heat and CO2 between the atmosphere and the ocean. Similarly, a commercial directional wave radar "WAVEX" made by the Norwegian firm MIROS was installed.

This report describes the metadata for the WAGES instrumentation deployed on the RRS *James Clark Ross* between May 2010 and September 2011. Sensor serial numbers, dates of sensor changes andproblems with sensors are contained in the associated tables.

KEYWORDS

ISSUING ORGANISATION

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Metadata for the WAGES instrumentation deployed on the RRS *James Clark Ross* between May 2010 and September 2011

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1. Introduction

WAGES aims to improve our understanding of the air-sea fluxes of CO_2, sea-spray aerosol, sensible heat, latent heat and momentum. To achieve this it is necessary to obtain direct measurements of the fluxes themselves, along with the various physical parameters which drive the fluxes such as: the mean air-sea differences in CO_2 concentration (for the CO_2 flux), temperature (sensible heat flux) and humidity (latent heat flux); wind speed (all fluxes); sea state and whitecap fraction (CO_2 and aerosol fluxes in particular). To obtain a sufficiently large data set the fluxes and underlying parameters will be measured continuously using instrumentation deployed on the *RRS James Clark Ross* from May 2010 to at least September 2012.

The ship's existing systems were complemented by the AutoFlux system (Yelland et al., 2009) to measure the transfers of momentum, heat and CO_2 between the atmosphere and the ocean. A commercial directional wave radar "WAVEX" made by the Norwegian firm MIROS was installed in September 2010. After installation of the WAGES systems, two NOCS staff took part in an initial shake-down cruise. Details of the setup and operation of all the systems and sensors can be found in the cruise report (Yelland and Pascal, 2011). In 2006, the Plymouth Marine Laboratory installed a CASEX underway system to obtain CO_2 concentrations in the surface water and atmosphere.

The *James Clark Ross* spends the majority of time undertaking science around Antarctica. The ship heads north during the Antarctic winter and undertakes scientific cruises into the Arctic. Every year the ship spends August in refit. In September cargo bound for Antarctica is loaded onto the ship in Immingham. NOCS staff visited the ship during these periods.

Data are stored on the NOCS UNIX system. With the exception of the fast sampling raw data, all raw data were periodically archived to "RODIN" the NOCS data catalogue. Mean meteorological and wave data were routinely sent to BODC.

This report details the metadata associated with the measurements made during the first year of the WAGES project. The sensors used and dates sensors were changed are documented in Section 2. Section 3 describes orientation and alignments of the main flux sensors.

2. Instrumentation

In this section, each of the sensors is described in turn along with their tables of metadata. Table F gathers all the data streams together so that the performance of the system as a whole can be seen. In this table, port calls are highlighted in red and problems with sensors are highlighted in grey. Days of similar situations are grouped together, e.g. if the psychrometer water bottle was frozen for 3 days and no other problems had occurred then these days are grouped together.

The sensor sampling frequencies are summarised in Table D. Yearly time series plots of various parameters are given in Appendix F. Note that the data used here have only had basic QC applied, if any.

2.1 Fast response instrumentation

A Gill R3A Ultrasonic anemometer (Table A.1) and two open path Licor 7500 Gas Analysers (Tables A.2 and A.3) were located on the foremast (Figure 1, 2 and 3).

Licor1 was mounted forward of the foremast platform and Licor2 was mounted to starboard of the platform. The Licors were routinely shrouded, with the crew moving the shroud from one sensor to the other (see Table E).

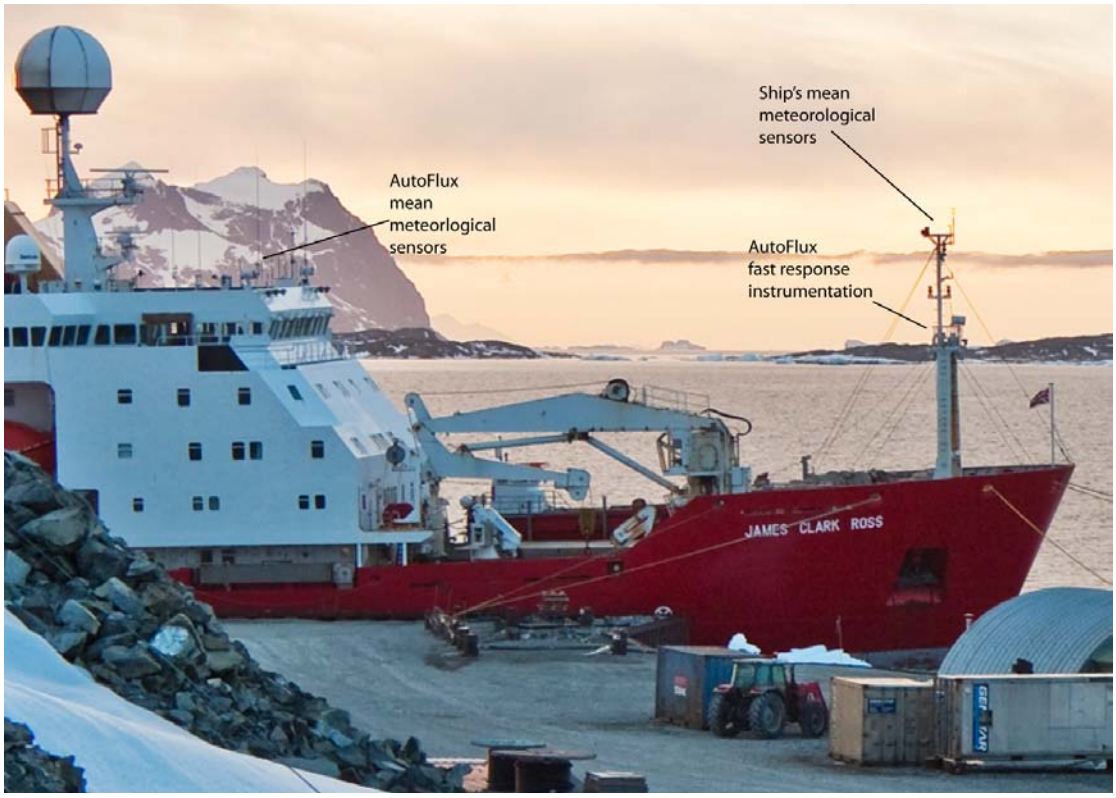


Figure 1. The locations of the instrumentation on the RRS *James Clark Ross*. The AutoFlux radiation, psychrometer (wet and dry bulb air temperature) and the Vaisala (air temperature and humidity) sensors are located on the bridge top. The ship's radiation, wind speed and Rotronic (air temperature and humidity) are located on the foremast extension.

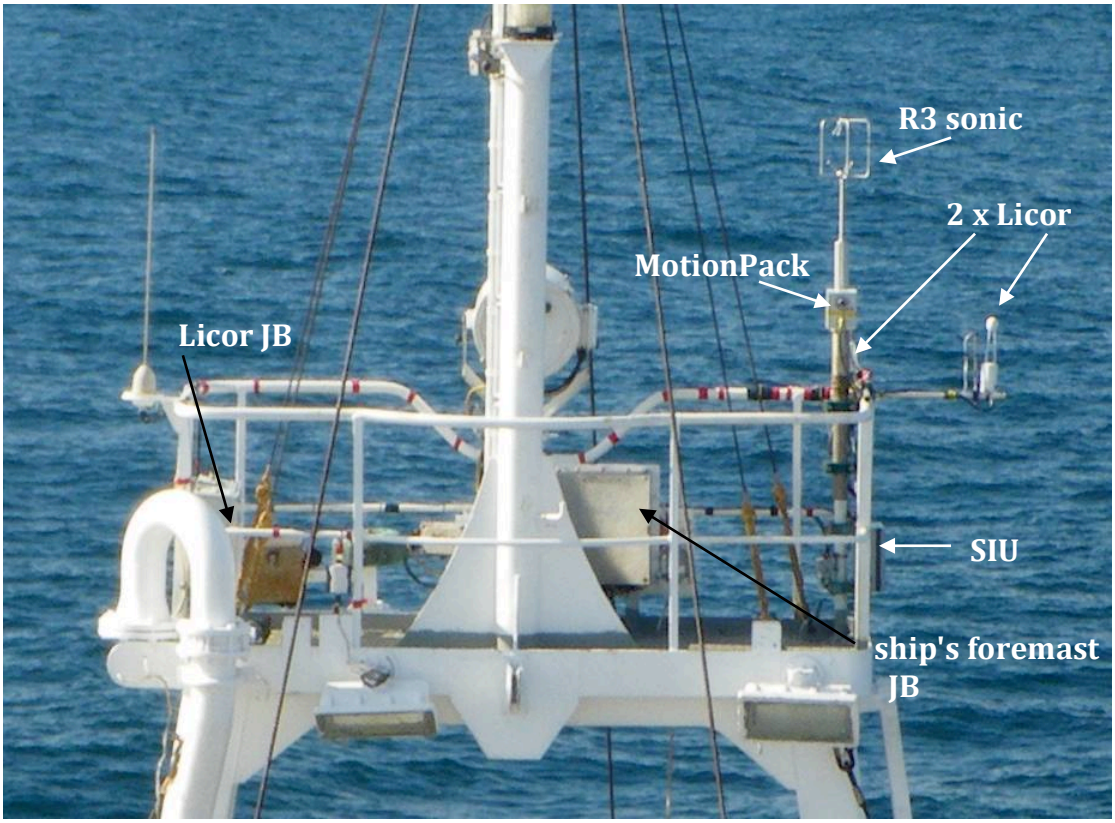


Figure 2. Photo of the fast-response sensors on the foremast platform, taken from the wheelhouse top on the passage from Frederikshavn to Portsmouth, 29th August 2010. The location of the sensor electronics ("Licor JB") and the ship's foremast junction box are also shown.

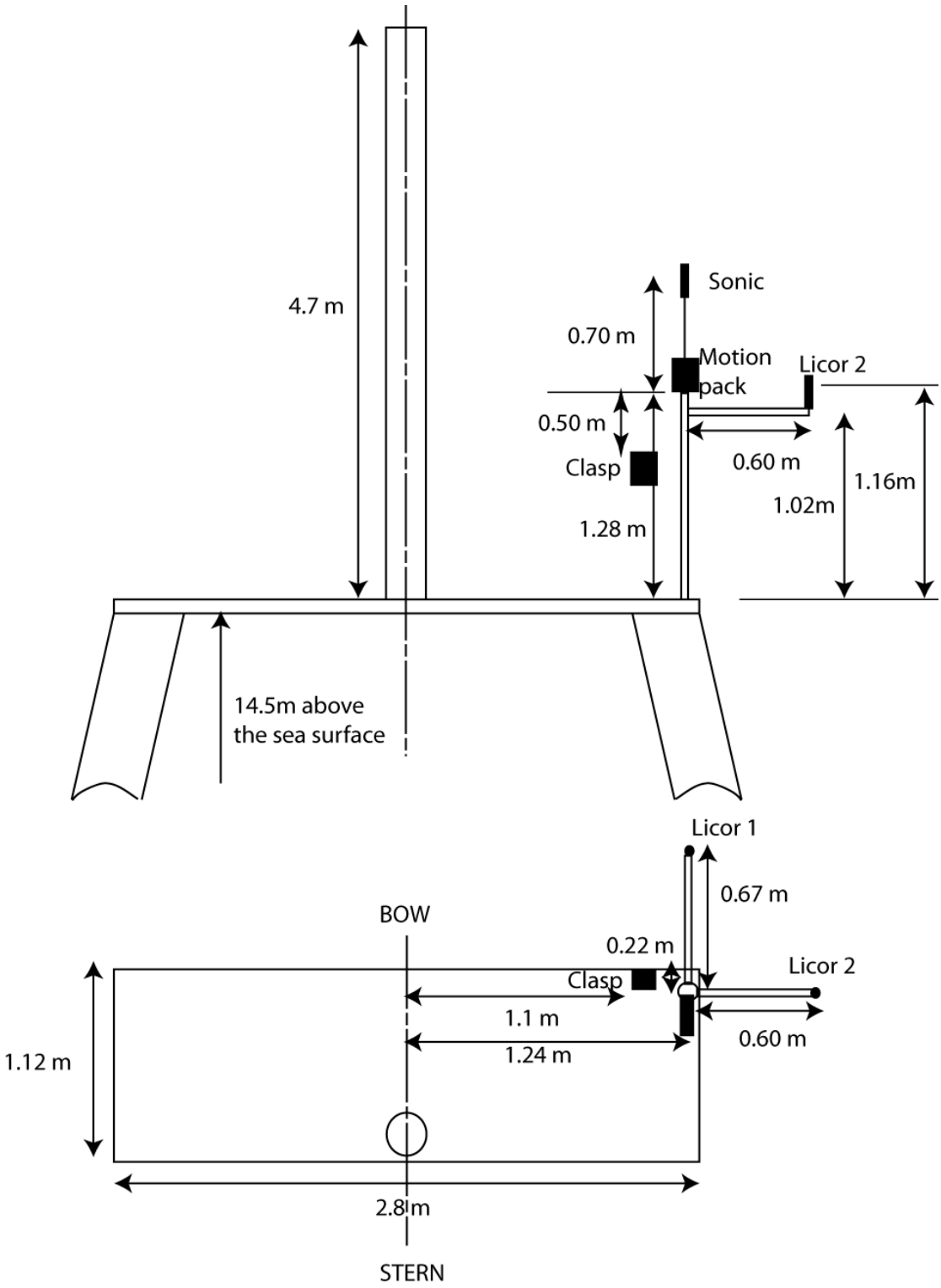


Figure 3. Layout of the foremast instrumentation. The top panel shows the view from the bridge looking forwards. The platform is 14.5 m above the sea surface (for a ship's draught of 5.6 m).

A SYSTRON DONNER MotionPak used 3 accelerometers and 3 rate gyros to record ship motion and was located close to the anemometer. All systems logged data at 20Hz. Details of the sensor changes can be found in Table A.1. Motionpak calibrations are given in Appendix A and B. Licor calibrations and sonic calibrations are contained in Appendix C and D respectively.

On the 28th September 2010 the sea-spray aerosol flux sensor "CLASP" was installed, in collaboration with Ian Brooks of Leeds University, UK. The sensor was mounted so that the intake was

0.95 m below, and 0.15m m to port of, the base of the R3 anemometer (Figure 2). Details are given in Table A.4.

2.2 WAGES Mean meteorological sensors

Wet and dry bulb air temperatures were measured using a NOCS aspirated psychrometer, mounted above the bridge (Figure 4). The wet bulb water reservoir occasionally ran dry or froze and was refilled when necessary by the crew (Table B.1). Relative humidity was calculated from the psychrometer and pressure data in near real time. In addition to the psychrometer, a Vaisala HMP45A or HMP155 sensor was also used to measure air temperature and relative humidity (Table B.2): the Vaisala sensor was mounted close to the psychrometer. The psychrometer and Vaisala sensors were located at heights of 18.7 m and 18.5 m above the sea surface respectively (for a ship's draught of 5.6 m).

Figure 4 Photo of the mean meteorological sensors on the bridge top. Photo taken in Immingham, UK on the 3rd October 2011.

Two radiation sensors were located above the bridge at a height of 20.5 m above the sea surface. An Eppley Precision Infrared (PIR) Pyrgyometer (Table B.3) was used to measure the downwelling long wave radiation (3.5 to 50 μm). Short wave radiation was measured using a Kipp and Zonen CM11 (310-2800nm) sensor (table B.4).

Sea surface temperature (SST) was measured using a PRT 100 sensor at the water inlet (depth about 6 m). A seabird SBE45 MicroTSG thermosalinograph was used to calculate underway salinity in real time. All the mean meteorological data stream were logged every 10 seconds. Instrument sampling rates are found in Table E.

2.3 BAS sensors

Atmospheric pressure was measured by two Vaisala PTB201B1A2B sensors (serial numbers: V145002 and V145003) located in the UIC at a height of 8 m above sea level (for a ship's draught of 5.6 m). No height correction to sea level was applied to the measurements. No other metadata data are available.

A "bird table" platform mounted on top of the foremast extension carries a WindMaster sonic anemometer, two Rontronic air temperature and humidity sensors (Table B.9), and two each of

shortwave radiation (Kipp and Zonen SP Lite) and photosyntheticly active radiation (Kipp and Zonen ParLite) sensors. The ship's anemometer was at a height of 20.8 m above the water and the air temp sensors are at a height of 20.4 m.

Salinity was calculated using an underway SBE45 Micro thermosalinograph (TSG) system (Table B.5) which was located in the prep lab. Sampling rates for the BAS systems are included in Table D.

2.4 Navigation Systems

The navigation data was acquired from the ship's systems at 1 Hz. Position, speed and course relative to the earth and ship's heading was acquired using a Kongsberg Seapath 200 system. The heading from the ship's gyro and the ship's speed relative to the water (EM log) was logged in the 'NAVN' data stream, but was not included in the AutoFlux data.

2.5 Digital camera system

A Mobotix M24 digital camera was located on the port side of the ship's bridge (Figure 5) to measure the whitecap fraction of the breaking waves. The camera faced forwards and was set at various sampling frequencies (Table B.6).

Figure 5. The bridge camera system located on the port side of the bridge.

2.6 Wave systems

During September 2010 a WAVEX directional wave radar was installed as part of the WAGES project (Figure 6). The X-band scanner was installed on the port side of the ships's mast at a height of 22 m above the sea surface (based on a ship's draught of 5.6m). The antenna was temporarily removed during the Portsmouth refit (23rd June 2011) for structural alterations to the platform, but was replaced with the bow mark facing the stern (i.e. 180 degrees out). This was corrected on during the September 2011 port call in Immingham.

The WAVEX software was set up to sample for a 2 minute period out of every 5 minutes. Spectra and mean parameters were recorded every 5 minutes and raw data were recorded twice per hour. The WAVEX software allows up to eight mean parameters to be output over a serial link, which were recorded by the AutoFlux acquisition system. These are detailed in Table B.7 and any problems are noted in Table B.8.

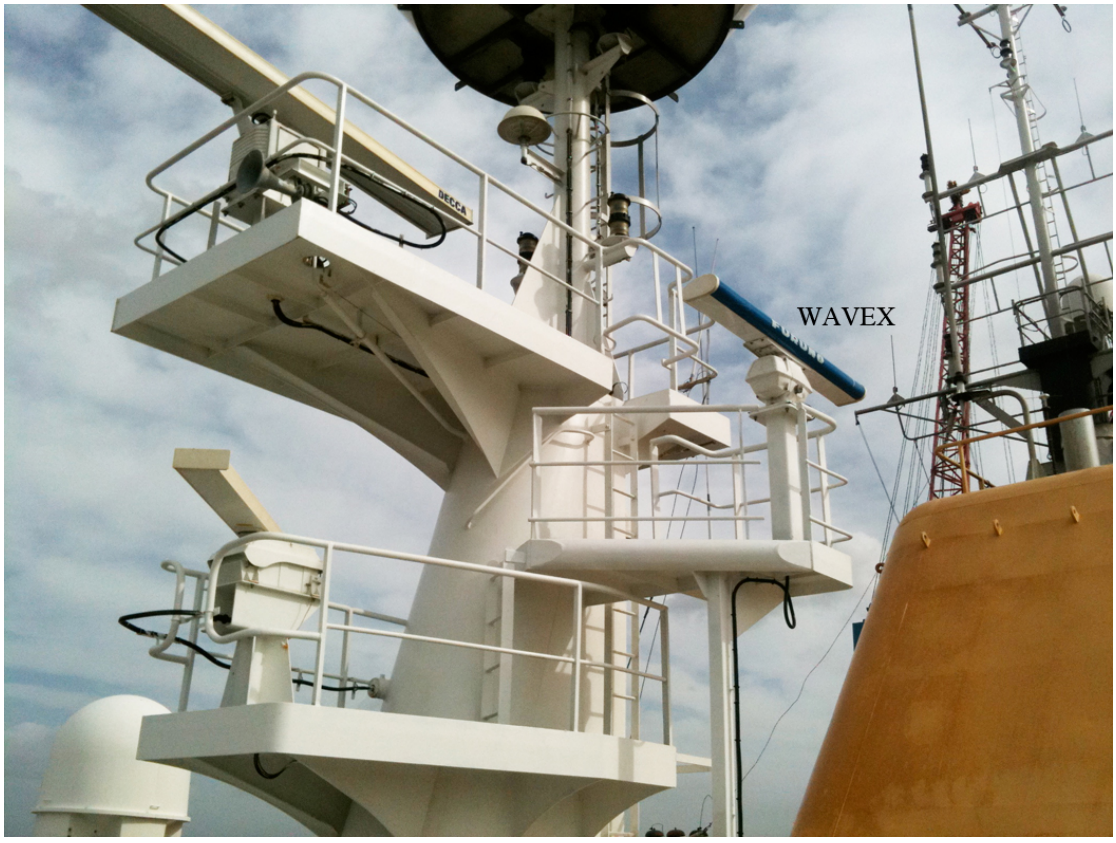


Figure 6 The WAVEX wave radar antenna located above the bridge top. Photo taken in Immingham, UK on the 3rd October 2011.

2.7 PML CO_2 system (CASIX)

The PML underway pCO_2 system on board uses a non-dispersive infrared (NDIR) detector to measure the atmospheric pCO_2 and seawater pCO_2, using a vented dual-chamber spray-head equilibrator for the latter. The system was calibrated using three standard gases (nominally 250 ppm CO_2 in air; 450 ppm CO_2 in air and high-purity N_2 = zero ppm CO_2) which were run in turn every 6 equilibrator cycles and one atmospheric cycle, i.e. one standard is run, then 6 equilibrator cycles, one atmospheric cycle then the next standard. Total repeat time for this sequence is 30 mins. Absolute calibrations for these gases were determined against NOAA certified standards prior to deployment.

3. Alignments of the R3 sonic and the MotionPak relative to each other and to the ship.

The AutoFlux automated processing assumes that the R3 is aligned perfectly with the ship. Any offset will affect the true wind speed calculation since the measured wind velocity will be offset from

the ship velocity. For a ship speed of less than 2 m/s, a 5° yaw offset (rotation in the horizontal plane) would cause a bias of less than 0.01 m/s. When the ship is on passage to/from port, a ship speed of 6 m/s and a 5° offset would result in a bias of less than 0.025 m/s.

Small offsets do need to be taken into account during the calculation of the turbulent air-sea fluxes using the eddy correlation (EC) method. The anemometer data need to be aligned as closely as possible with the MotionPak (MP) data, by rotating the frames of reference to allow for any physical misalignments between the two sensors. Once the anemometer data have been corrected for ship motion, the corrected data then need to be rotated in to the ship frame or reference to allow for any significant yaw offset before correcting the data again for mean ship speed. As before, this latter correction for ship speed has only a very marginal impact on the resulting wind speeds. Here we look first at the yaw offset. Then we will briefly discuss the alignments in the fore-aft and port/starboard directions.

3.1 Yaw Offsets

The R3 sonic and MotionPak (MP) were changed on a number of occasions (Table A.1) for calibration. When these sensors are replaced it is a requirement that their alignments be as close as possible to the instruments that were removed. It is difficult to align sensors on a ship since there are no straight structures, which can be used as a reference. The most difficult aspect to quantify is the yaw offset, i.e. rotation about the vertical axis.

To reduce the error in the yaw offset, the R3 and the MP they were joined together as one unit using a mounting plate. This allowed the two to be aligned closely in the horizontal plane, and the yaw offset could be quantified using the method of Brooks (2008). The various combinations of R3 and MP sensors were examined: these are summarised in Table F. The MP was located in a fixed position on the horizontal mounting plate, and the sonic attached to the plate using slotted screw holes. The yaw offsets were determined for the sonic rotated as far as the slots allowed in either direction, with an anticlockwise rotation (as viewed from above) corresponding to the anemometer being rotated hard to port when on the ship. This allowed the offset between the R3 and MP to be known.

When the pair where installed on the ship, the sonic was again rotated hard to port and the pair were aligned so that the R3 strut was oriented fore/aft. The R3 and MP were aligned by eye, usually by someone standing on the bridge top at the same distance from the centre line as the instruments. The MP is mounted in a rectangular box whose straight sides are used to align the sensor visually. The head of the sonic anemometer has three struts, one directly "aft" of the sensor volume and two more located at 60° either side of the aft strut. The aft strut was used to align the sonic fore/aft.

3.4 Fore/aft and port/starboard alignments.

Tables C show the tilts of the various foremast sensors as measured using a hand-held electronic inclinometer during port calls. The inclinometer has an accuracy of about 0.1 deg, but an offset of 0.1 can be caused if the feet of the inclinometer are not correctly placed. Much larger errors are introduced by changes in the trim of the ship: since the measurements were taken in port the trim of the ship could change while the measurements were being made as stores and fuel etc were loaded.

The R3 and MP were joined on the same flat metal base plate. In addition, the method of obtaining the fore/aft and port/stbd tilts was improved by measuring the tilts of the ship sonic before all the other sensors were measured, and again afterwards. Comparison of the two measurements of the ship sonic showed if the trim of the ship had changed significantly.

4. Summary

This report describes the metadata for the WAGES instrumentation deployed on the RRS *James Clark Ross* between May 2010 and September 2011. Sensor serial numbers, dates of sensor changes and problems with sensors are contained in the associated tables.

Acknowledgemnts

WAGES is funded by NERC standard grants (NE/G003696/1 and NE/G00353X/1) and by Oceans 2025 and is a follow on project from various NERC UK-SOLAS projects (NE/F007442/1, NE/C001826/1, NE/C001869/1, NE/C001834/1, NE/G000115/1, NE/G000123/1).

References

Yelland, M. J., Pascal, R. W., Taylor, P. K. and Moat, B. I., 2009: AutoFlux: an autonomous system for the direct measurement of the air-sea fluxes of CO2, heat and momentum. *Journal of Operational Oceanography*, **2**(1), 15-23.

Yelland and Pascal, 2011: RRS James Clark Ross Cruises 254A, Southampton, UK, National Oceanography Centre Southampton, *pp. (National Oceanography Centre Southampton Cruise Report No.*).

TABLES A Fast response sensors: Instrument serial numbers and sensor changes

A.1 Sonic anemometer and MotionPak

year	sensor	location	Old serial number	New serial number	jday	month	day	Motion Pack	comment
2010	sonic	foremast	-	227	142	May	22	682	Mobilisation: Vigo Spain
2010	sonic	foremast	227	391	236	August	24	791	Mobilisation: Frederikshaven
2011	sonic	foremast	391	removed	144	May	24	791	Sensors removed in Portland before refit in Portsmouth. SIU swapped (see SIU pulldown)
2011	sonic	foremast		227	173	June	22	682	Refit in Portsmouth
2011	sonic	foremast	227	391	263	September	20	682	Immingham

A.2 Licor 1 (Forward of the foremast)

year	sensor	location	Old serial number	New serial number	jday	month	day	Sensor calibration	comment
2010	licor1	forward	-	1114	142	May	22	Appendix C	Mobilisation: Vigo Spain
2010	licor1	forward	1114	1114	236	August	24		Mobilisation: Frederikshaven
2011	licor1	forward	1114	removed	144	May	24		Sensors removed in Portland before refit in Portsmouth
2011	licor1	forward	-	0614	171	June	20	Appendix C	During refit in Portsmouth
2011	licor1	forward	0614	1113	264	September	21	Appendix C	Immingham

A.3 Licor 2 (starboard of the foremast)

year	sensor	location	Old serial number	New serial number	jday	month	day	Sensor calibration	comment
2010	licor2	starboard	-	1113	142	May	22	Appendix C	Mobilisation: Vigo Spain
2010	licor2	starboard	1113	1113	236	August	24		Mobiisation: Frederikshaven
2011	licor2	starboard	1113	removed	144	May	24		sensors removed in Portland before refit in Portsmouth
2011	licor2	starboard	-	0825	171	June	20	Appendix C	During refit in Portsmouth

2011	licor2	starboard	0825	1114	264	September	21	Appendix C	Immingham

A.4 CLASP

year	sensor	location	Old serial number	New serial number	jday	month	day	Sensor calibration	comment
2010	clasp	foremast	installed	H	270	September	27		
2010	clasp	foremast	H	I	346	December	12		
2011	clasp	foremast	I	K	077	March	18		
2011	clasp	foremast	K	removed	144	May	24		sensors removed in Portland before refit in Portsmouth
2011	clasp	foremast	-	G	171	June	20		During refit in Portsmouth
2011	clasp	foremast	G	L	264	September	21		Immingham

TABLES B Mean met systems: Instrument serial numbers and sensor changes

B.1 Psychrometer

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	psychrometer	bridge top	-	1028	236	August	24	DRY: -1.225153e+1, 3.910999e-2, 5.411647E-7, 4.485326E-10, 0 WET: -1.037088e+1 ,3.914122E-2, 1.250447e-6, 2.783538e-10, 0	Mobilisation: Frederikshavn
2011	psychrometer	bridge top	1028	removed	144	May	24	-	Sensors removed in Portland before refit in Portsmouth
2011	psychrometer	bridge top	-	1028	174	June	23	DRY: -1.266876e+1, 4.072815e-2, -1.396824E-6, 1.182991E-9, 0 WET: -1.097948e+1 ,4.159742E-2, -1.909793e-6, 1.552030e-9, 0	Refit in Portsmouth

B.2 Vaisala air temperature and Humidity

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	vaisala	bridge top	-	4440006	236	August	24	AIR:-40,0.1,0,0,0 RH:0,0.1,0,0,0	Mobilisation: Frederikshavn
2011	vaisala	bridge top	4440006	removed	144	May	24	-	Sensors removed in Portland before refit in Portsmouth
2011	vaisala	bridge top	-	F4340001	174	June	23	AIR:-40,0.1,0,0,0 RH:0,0.1,0,0,0	New style sensor (HMP155). Refit in Portsmouth
2011	vaisala	bridge top	F4340001	BROWN	264	September	21	AIR:-40,0.1,0,0,0 RH:0,0.1,0,0,0	Immingham

B.3 Long wave sensors

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	LW	bridge top	-	31171	236	August	24	E1:0,1,0,0,0 Td1:0,1,0,0,0 Ts1:0,1,0,0,0	Mobilisation: Frederikshavn
2011	LW	bridge top	31171	removed	144	May	24		sensors removed in Portland before refit in Portsmouth
2011	LW	bridge top	-	31171	173	June	22	E1:0,1,0,0,0 Td1:0,1,0,0,0 Ts1:0,1,0,0,0	refit in Portsmouth

B.4 Short wave sensors

year	sensor	location	Old Serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	TIR	bridge top		902837	236	August	24	0,0.22173,0,0,0	Mobilisation: Frederikshavn
2011	TIR	bridge top	902837	removed	144	May	24		sensors removed in Portland before refit in Portsmouth
2011	TIR	bridge top	-	902837	173	June	22	0,0.22173,0,0,0	refit in Portsmouth

B.5 MicroTSG

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	TSG	cross alley		SN072	144	May	24		AutoFLux installed
2010	TSG	cross alley	SN072	SN0016	168	june	17		TSG reading 1 PSU high.TSG replaced

B.6 Bridge Camera systems

year	sensor	location	jday	month	day	comment
2010	camera	bridge	158	June	7	camera installed.sampling every 5 minutes
2010	camera	bridge	349	December	15	1 minute sampling
2011	camera	bridge	264	September	21	sampling changed from every minute to every 15 seconds.

B.7 WAVEX serial output parameters

WAVEX	comment
Hm0	Hs = Hm0 = significant wave height
Tm01	Tm02=(m0/m2)**0.5=zero-upcrossing. Tm01 = Te =period of peak energy
Tp1	Tp1 = Primary wave peak period
Dp1-t	Dp1-t = primary wave peak direction
m4 (4dec. p.)	$SPRI_t$ = total energy directional spread
m1 (4dec. p.)	Tp2 = secondary wave peak period
m2 (4dec. p.)	Dp2-t = secondary wave peak direction
Dpt-t	Dpt-t = total energy peak direction

B.8 WAVEX system

year	sensor	location	jday	month	day	comment
2010	wavex	main mast	257	September	14	
2011	wavex	main mast	174	June	23	Antenna removed and platform altered. NOTE: Antenna was put back with the bow mark facing the stern.
2011	wavex	main mast	263	September	20	Antenna orientation corrected

B.9 BAS Air temperature and Humidity sensors

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2010	Rotronic1	Bird table	43124014 model: MP103A	-	144	May	24		Sensor failed. No air temp or humidity.
2011	Rotronic1	Bird table	43124014 model: MP103A	0119462370 model: HC2-S3	202	July	21		

year	sensor	location	Old serial number	New serial number	jday	month	day	New sensor calibration	comment
2011	Rotronic2	Bird table	43124014 model: MP103A	0119462370 model: HC2-S3	202	July	21		

Table C Instrument tilts by instrument

LICOR1 forward

numbers/names in brackets indicate more than one measurement made during a port call.

year	JDAY	day	month	fore/aft (degrees)	port/starboard (degrees)	measurement point
2010	146	26	May	leaning aft 2.0	leaning to port 2.0	instrument
2010	243	31	August	leaning aft 2.0	leaning to port 6.0	instrument
2011	171	20	June	leaning forwards 5.8	leaning to port 17.4	instrument
2011	263	20	September	leaning aft 1.9	leaning to port 17.8	instrument
2011	264	21	September	leaning forwards 3.8	leaning to port 17.2	instrument

LICOR2 starboard

numbers/names in brackets indicate more than one measurement made during a port call.

year	JDAY	day	month	fore/aft (degrees)	port/starboard (degrees)	measurement point
2010	146	26	May	leaning 0.0	leaning 0.0	instrument
2010	243	31	August	leaning aft 4.0	leaning to stbd 3.0	instrument
2011	171	20	June	leaning forwards 4.6	leaning to stbd 3.0	instrument
2011	263	20	September	leaning aft 5.6	leaning to stbd 2.1	instrument
2011	264	21	September	leaning forward 6.8	leaning to stbd 4.3	instrument

R3 sonic

numbers/names in brackets indicate more than one measurement made during a port call.

year	JDAY	day	month	fore/aft (degrees)	port/starboard (degrees)	yaw (degrees)	measurement point	F/A R3-motion pack	P/S R3-motion pack
2010	145	25	May	leaning aft 1.0	leaning to stbd 1.0		instrument	0.0	0.0
2010	146	26	May	leaning forward 0.3	leaning to stbd 0.2		instrument	0.3	0.2
2010	158	07	June	leaning forward 0.4	leaning to stbd 0.1		instrument	0.3	0.1
2010	160	09	June	leaning aft 0.8	leaning to stbd 1.1		junction box		
2010	160	09	June	leaning aft 0.2	leaning to stbd 2.4		instrument	-0.2	0.1
2010	160	09	June	leaning aft 0.8	leaning to stbd 1.1		junction box		
2010	243(1)	31	August	leaning aft 0.4	leaning to port 0.4		junction box		
2010	243(1)	31	August	leaning aft 0.7	leaning to port 0.4		instrument	0.0	0.2
2010	243(1)	31	August	leaning aft 0.4	leaning to port 0.4		junction box		
2010	243(2)	31	August	leaning aft 0.3	leaning to stbd 0.3		junction box		
2010	243(2)	31	August	leaning aft 0.2	leaning to stbd 0.2		instrument	0.0	-0.1
2010	243(2)	31	August	leaning aft 0.3	leaning to stbd 0.3		junction box		
2011	171	20	June	leaning aft 0.4	leaning to stbd 2.1		pole		
2011	171	20	June	leaning aft 0.1	leaning to port 1.8		instrument	-0.5	0.0
2011	171	20	June	leaning aft 0.4	leaning to stbd 1.4		pole		
2011	263	20	September	leaning aft 0.6	leaning to port 0.3		pole		
2011	263	20	September	leaning aft 0.6	leaning to port 0.3		instrument	-0.3	-1.4
2011	263	20	September	leaning aft 0.5	leaning to port 0.3		pole		
2011	264	21	September	leaning aft 0.4	leaning to port 1.6		pole		
2011	264	21	September	leaning aft 0.6	leaning to port 1.4		instrument	-0.3	0
2011	264	21	September	leaning aft 0.6	leaning to port 1.5		pole		

Motion pack

numbers/names in brackets indicate more than one measurement made during a port call.

year	JDAY	day	month	fore/aft (degrees)	port/starboard (degrees)	yaw (degrees)	measurement point
2010	145	25	May	leaning aft 1.0	leaning to stbd 1.0		instrument
2010	146	26	May	leaning 0.0	leaning 0.0		instrument
2010	158	07	June	leaning forwards 0.1	leaning 0.0		instrument
2010	160	09	June	leaning aft 0.4	leaning to stbd 2.3		instrument
2011	171	20	June	leaning aft 0.6	leaning to port 1.8		instrument
2011	243(1)	31	August	leaning aft 0.7	leaning to port 0.2		instrument
2011	243(2)	31	August	leaning aft 0.2	leaning to stbd 0.3		instrument
2011	263	20	September	leaning aft 0.9	leaning to port 1.7		instrument
2011	264	21	September	leaning aft 0.9	leaning to port 1.4		instrument

Table D Sensor sampling frequencies

system	time period	comment
Thermosalinograph TSG	5 seconds	
CASEX CO_2 system	Contact PML	
Navigation	1 second	
AUTOFLUX mean met	10 seconds	SW, LW, air temp, humidity
BAS ship's wind speed	2 second	Gill WindMaster sonic
BAS ship's mean meteorology	10 seconds	
R3A sonic	20 Hz	
Licors	20 Hz	
WAVEX	2 minutes out of every 5 minutes	

Table E Sensor problems (red = port call, yellow = manned cruise, grey = sensor problem, n/i=not installed)

2010

year	jday	psychrometer	Vaisala	Licor 1 forward	Licor2 starboard	Clasp	Wavex	Sonic	Ship;s RH/T	navigation	CO2	TSG	camers	Other sensors
2010 Vigo	145 to 147	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	148 to 152	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	153	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no data					
2010	154	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	155	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no data					
2010	156	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010 arrive Immingham	157 to 164	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no data			tsg turned off		
2010	165 to 169	n/i	n/i	unshrouded	shrouded	n/i	n/i							
2010 Longyearbyen	170	n/i	n/i	unshrouded	shrouded	n/i	n/i					tsg off		
2010	171	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	172	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg off. in ice		
2010	173 to 181	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	182	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg off		
2010 arrive Longyearbyen	183	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg off		
2010 depart Longyearbyen	184	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	185	n/i	n/i	unshrouded	unshrouded	n/i	n/i							

	to 188													
year	**jday**	**psychrometer**	**Vaisala**	**Licor 1 forward**	**Licor2 starboard**	**Clasp**	**Wavex**	**Sonic**	**Ship;s RH/T**	**navigation**	**CO2**	**TSG**	**camers**	**Other sensors**
2010	189	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg off. in ice		
2010	190	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg off. in ice		
2010	191 to 198	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010	199	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no data	no data		no data		
2010	200	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no data	no data		no data		
2010	201	n/i	n/i	unshrouded	unshrouded	n/i	n/i							
2010 arrive Longyearbyen	202 to 203	n/i	n/i	unshrouded	unshrouded	n/i	n/i					tsg turned off		
2010	204 to 208	n/i	n/i	shrouded	unshrouded	n/i	n/i							
2010	209	n/i	n/i	shrouded	unshrouded	n/i	n/i					tsg off		
2010 arrive Peterhead	210	n/i	n/i	unshrouded	unshrouded	n/i	n/i		no ship1 air/RH			tsg off		
2010 depart Peterhead	211	n/i	n/i	no data	no data	n/i	n/i	no data	no ship1 air/RH			tsg off	No images	
2010	212	n/i	n/i	no data	no data	n/i	n/i	no data	no ship1 air/RH			tsg off	No images	
2010 arrive Frederikshavn	213 to 240	n/i	n/i	no data	no data	n/i	n/i	no data	no ship1 air/RH			tsg off	No images	
2010	241 to 242			unshrouded	unshrouded	n/i			no ship1 air/RH				No images	
2010 arrive Portsmouth	243 to 244			shrouded	shrouded	n/i			no ship1 air/RH			tsg off	No images	
2010	245 to 246			shrouded	shrouded	n/i			no ship1 air/RH					

year	jday	psychrometer	Vaisala	Licor 1 forward	Licor2 starboard	Clasp	Wavex	Sonic	Ship;s RH/T	navigation	CO2	TSG	camers	Other sensors
2010 Immingham	247 to 270			shrouded	shrouded	n/i			no ship1 air/RH			tsg off		
2010 depart Immingham	271			shrouded	shrouded	mixed			no ship1 air/RH					
2010	272			shrouded	shrouded	mixed			no ship1 air/RH					
2010 arrive Falmouth	273 to 274			shrouded	shrouded				no ship1 air/RH			water off		
2010 depart Falmouth	275			unshrouded	unshrouded				no ship1 air/RH					
2010	276 to 293			unshrouded	unshrouded				no ship1 air/RH					
2010	294			unshrouded	unshrouded	mixed			no ship1 air/RH					
2010	295			unshrouded	unshrouded	no data		no data	no ship1 air/RH					
2010	296			no data	no data	no data		no data	no ship1 air/RH					
2010 arrive FI	297 to 299			no data	no data	no data		no data	no ship1 air/RH			water off		
2010 depart FI	300			no data	no data	no data		no data	no ship1 air/RH					
2010	301			unshrouded	unshrouded	no data		no data	no ship1 air/RH					
2010 arrive SG	302 to 304			unshrouded	unshrouded	no data		no data	no ship1 air/RH			water off		
2010 depart SG	305			unshrouded	unshrouded	no data			no ship1 air/RH					
2010	306 to 307			unshrouded	unshrouded	no data			no ship1 air/RH					
2010	308			shrouded	shrouded	no data			no ship1			water off		

arrive FI	to 310								air/RH					
year	**jday**	**psychrometer**	**Vaisala**	**Licor 1 forward**	**Licor2 starboard**	**Clasp**	**Wavex**	**Sonic**	**Ship;s RH/T**	**navigation**	**CO2**	**TSG**	**camers**	**Other sensors**
2010 depart FI	311			shrouded	shrouded				no ship1 air/RH					
2010	312			shrouded	shrouded				no ship1 air/RH					
2010	313	frozen		shrouded	shrouded	mixed			no ship1 air/RH			water off.in ice		
2010	314	frozen		unshrouded	unshrouded				no ship1 air/RH			water off.in ice		
2010	315 to 319			unshrouded	unshrouded				no ship1 air/RH			water off.in ice		
2010	320			shrouded	shrouded				no ship1 air/RH			water off.in ice		
2010	321	frozen		shrouded	shrouded				no ship1 air/RH					
2010	322	frozen		shrouded	shrouded				no ship1 air/RH					
2010	323	frozen		shrouded	shrouded	mixed			no ship1 air/RH			water off.in ice		
2010	324	frozen		shrouded	shrouded				no ship1 air/RH			water off.in ice		
2010	325	frozen		unshrouded	unshrouded	mixed			no ship1 air/RH			water off.in ice		
2010	326 to 329	frozen		unshrouded	unshrouded				no ship1 air/RH			water off.in ice		
2010	330	frozen		unshrouded	unshrouded	mixed			no ship1 air/RH			water off.in ice		
2010	331	frozen		unshrouded	unshrouded				no ship1 air/RH			water off.in ice		
2010	332	frozen		unshrouded	unshrouded				no ship1 air/RH					
2010	333	frozen		unshrouded	unshrouded	mixed			no ship1 air/RH			water off.in ice		
2010	334	frozen		unshrouded	unshrouded				no ship1			water off.in ice		

									air/RH					
year	**jday**	**psychrometer**	**Vaisala**	**Licor 1 forward**	**Licor2 starboard**	**Clasp**	**Wavex**	**Sonic**	**Ship;s RH/T**	**navigation**	**CO2**	**TSG**	**camers**	**Other sensors**
2010	335	frozen		unshrouded	unshrouded				no ship1 air/RH			water off.in ice		
2010 arrive Rothera	336	frozen		unshrouded	unshrouded	mixed			no ship1 air/RH			water off.in ice		
2010 Rothera	337			unshrouded	unshrouded	bad			no ship1 air/RH			water off.in ice		
2010 Rothera	338	frozen		unshrouded	unshrouded		bad		no ship1 air/RH			water off.in ice		
2010 Depart Rothera	339	frozen		unshrouded	unshrouded			no data	no ship1 air/RH			water off.in ice		
2010	340	frozen		unshrouded	unshrouded	bad			no ship1 air/RH			water off.in ice		
2010	341	frozen		unshrouded	unshrouded	bad			no ship1 air/RH			water off.in ice		
2010	342	frozen		unshrouded	unshrouded	bad			no ship1 air/RH					
2010	343	frozen		unshrouded	unshrouded	bad			no ship1 air/RH					
2010 arrive FI	344 to 347			unshrouded	unshrouded	bad			no ship1 air/RH			water off		
2010 depart FI	348			unshrouded	unshrouded				no ship1 air/RH					
2010 manned cruise	349			unshrouded	unshrouded				no ship1 air/RH					
2010 manned cruise	350			unshrouded	unshrouded				no ship1 air/RH			water off		
2010 arrive FI	351 to 354			unshrouded	unshrouded				no ship1 air/RH			water off		
2010 depart FI	355			unshrouded	unshrouded				missing data	missing data				
2010	356 to 358			unshrouded	unshrouded				no ship1 air/RH					
2010	359			unshrouded	unshrouded	mixed			no ship1					

									air/RH					
year	**jday**	**psychrometer**	**Vaisala**	**Licor 1 forward**	**Licor2 starboard**	**Clasp**	**Wavex**	**Sonic**	**Ship;s RH/T**	**navigation**	**CO2**	**TSG**	**camers**	**Other sensors**
2010	360 to 362			unshrouded	unshrouded	bad			no ship1 air/RH					
2010	363	frozen		unshrouded	unshrouded	bad			no ship1 air/RH					
2010	364	frozen		unshrouded	unshrouded	bad			no ship1 air/RH	missing data				
2010	365			unshrouded	unshrouded	bad			missing data	missing data				

2011

year	**jday**	**psychrometer**	**Vaisala**	**Licor 1 forward**	**Licor2 starboard**	**Clasp**	**Wavex**	**Sonic**	**Ship;s RH/T**	**navigation**	**CO2**	**TSG**	**camers**	**Other sensors**
2011 depart Stromness	001			unshrouded	unshrouded	bad	no data		no ship1 air/RH			water off		
	002		bad data	unshrouded	unshrouded	bad	no data		no ship1 air/RH					
2011	003 to 006	dried out	bad data	unshrouded	unshrouded	bad			no ship1 air/RH					
2011	007		bad data	unshrouded	unshrouded				no ship1 air/RH					
2011	008		bad data	unshrouded	unshrouded		off		no ship1 air/RH			water off (pump tripped)		
2011	009		bad data	unshrouded	unshrouded	mixed	off		no ship1 air/RH					
2011	010		bad data	unshrouded	unshrouded		off		no ship1 air/RH					
2011	011		bad data	unshrouded	unshrouded	mixed	off		no ship1 air/RH					
2011	012		bad data	unshrouded	unshrouded		off		no ship1 air/RH					
2011	013		bad data	unshrouded	unshrouded	mixed			no ship1					

									air/RH					
2011	014		bad data	unshrouded	unshrouded				no ship1 air/RH			tsg off		
2011 KEP	015		bad data	unshrouded	unshrouded				no ship1 air/RH			water off		
2011	016		bad data	unshrouded	unshrouded				no ship1 air/RH					
2011	017		bad data	unshrouded	unshrouded				no ship1 air/RH			water off (pump tripped)	No images	
2011	018		bad data	unshrouded	unshrouded				no ship1 air/RH			water off	No images	
2011 FI	019 to 027		bad data	unshrouded	unshrouded	mixed	no data		no ship1 air/RH			water off	No images	
2011 depart FI	028		bad data	unshrouded	unshrouded				no ship1 air/RH				No images	
2011	029		bad data	unshrouded	unshrouded				no ship1 air/RH				No images	
2011	030		bad data	unshrouded	unshrouded		mixed		no ship1 air/RH				No images	
2011	031		bad data	unshrouded	unshrouded	bad			no ship1 air/RH				No images	
2011	032		bad data	unshrouded	unshrouded	bad	no data		no ship1 air/RH				No images	
2011	033 to 036		bad data	unshrouded	unshrouded	bad			no ship1 air/RH				No images	
2011	037	frozen	bad data	unshrouded	unshrouded	bad			no ship1 air/RH				No images	
2011	038	frozen	bad data	unshrouded	unshrouded	bad			no ship1 air/RH				No images	
2011	039	frozen	bad data	unshrouded	unshrouded	bad			no ship1 air/RH			tsg off.ice	No images	
2011	040	frozen	bad data	unshrouded	unshrouded	mixed			no ship1 air/RH			tsg off. ice	No images	
2011	041	frozen	bad data	unshrouded	unshrouded				no ship1 air/RH				No images	
2011	042	frozen	bad data	unshrouded	unshrouded		no data		no ship1			tsg off.ice	No images	

	to 045								air/RH					
2011	046	frozen	bad data	unshrouded	unshrouded		no data	frozen	no ship1 air/RH			tsg off.ice	No images	
2011	047	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice	No images	
2011	048	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice	No images	
2011	049	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH				No images	
2011	050	frozen	bad data	unshrouded	unshrouded		no data	SIU resistor blown. sync fault	no ship1 air/RH				No images	
2011	051	frozen	bad data	unshrouded	unshrouded		no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice	No images	
2011	052 to 056	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice	No images	
2011	057	frozen	bad data	unshrouded	unshrouded		no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice	No images	
2011	058	frozen	no data	no data	no data	no data	no data	no data	no ship1 air/RH			tsg off.ice		no SW
2011	059	frozen	bad data	unshrouded	unshrouded		no data	SIU resistor blown. sync fault	no ship1 air/RH			tsg off.ice		
2011	060	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH					
2011	061	frozen	bad data	unshrouded	unshrouded	mixed	no data	SIU resistor blown. sync fault	no ship1 air/RH					
2011	062 to 066	frozen	bad data	unshrouded	unshrouded	mixed		SIU resistor blown. sync fault	no ship1 air/RH					
2011	067 to 068	frozen	bad data	unshrouded	unshrouded			SIU resistor blown. sync fault	no ship1 air/RH			tsg off.in ice		

2011	069	frozen	bad data	unshrouded	unshrouded	mixed		SIU resistor blown. sync fault	no ship1 air/RH					
2011	070 to 071		bad data	unshrouded	unshrouded	mixed		SIU resistor blown. sync fault	no ship1 air/RH					
2011	072		bad data	unshrouded	unshrouded			SIU resistor blown. sync fault	no ship1 air/RH					
2011	073		bad data	unshrouded	unshrouded	mixed		SIU resistor blown. sync fault	no ship1 air/RH					
2011 FI	074 to 077		bad data	unshrouded	unshrouded	mixed		SIU resistor blown. sync fault	no ship1 air/RH			tsg off		
2011 depart FI	078		bad data	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH					
2011 manned	079 to 083		no humidity	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH					
2011 manned	084		no humidity	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 or ship2 air/RH					
2011 manned	085 to 087	frozen	bad data	unshrouded	unshrouded			SIU resistor blown	no ship1 or ship2 air/RH					
2011 manned	088	frozen	no data	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 or ship2 air/RH					
2011 manned	089	frozen	no data	unshrouded	unshrouded			SIU resistor blown	no ship1 or ship2 air/RH					
2011 manned	090	frozen	no data	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 or ship2 air/RH			tsg off.tripped		
2011 manned	091	frozen	bad data	unshrouded	unshrouded			SIU resistor blown	no ship1 or ship2 air/RH					
2011 manned	092 to 094		bad data	unshrouded	unshrouded	mixed		SIU resistor blown	no ship1 or ship2 air/RH			tsg off		
2011 manned	095		bad data	unshrouded	unshrouded			SIU resistor blown	no ship1 or ship2 air/RH			tsg off		
2011 arrive Punta	096 to 098		bad data	unshrouded	unshrouded		off	SIU resistor blown	no ship1 air/RH			tsg off		

2011 depart Punta	099		bad data	shrouded	unshrouded	mixed	off	SIU resistor blown	no ship1 air/RH			tsg off		
2011	100 to 103	frozen	bad data	shrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH					
2011	104 to 105		bad data	shrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH					
2011	106 to 107		bad data	shrouded	unshrouded	bad		SIU resistor blown	no ship1 air/RH					
2011	108	frozen	bad data	shrouded	unshrouded	bad		SIU resistor blown	no ship1 air/RH					
2011	109	frozen	bad data	shrouded	unshrouded	bad		SIU resistor blown	no ship1 air/RH					
2011	110 to 112		no data	shrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH					
2011	113		no data	shrouded	unshrouded	mixed		SIU resistor blown	no ship1 air/RH			tsg tripped		
2011	114 to 115		no data	shrouded	unshrouded	mixed	off	SIU resistor blown	no ship1 air/RH					
2011 FI	116 to 119	dried out	no data	unshrouded	shrouded	bad	off	SIU resistor blown	no ship1 air/RH			tsg off		
2011 depart FI	120	no data	no data	unshrouded	shrouded	no data		SIU resistor blown	no ship1 air/RH					no LW
2011	121	no data	no data	unshrouded	shrouded	no data		SIU resistor blown	no ship1 air/RH					no LW
2011	122		no data	unshrouded	shrouded			SIU resistor blown	no ship1 air/RH					no LW
2011	123	dried out	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH					no LW
2011	124	dried out	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH					no LW
2011	125		no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH					no LW
2011	126		no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH					no LW

2011	127		no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	128 to 130		no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	131		no data	unshrouded	shrouded	mixed	no data	SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	132	dried out	no data	unshrouded	shrouded	mixed	no data	SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	133 to 134		no data	unshrouded	shrouded	bad		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	135	dried out	no data	unshrouded	shrouded	bad		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	136	dried out	no data	unshrouded	shrouded		mixed	SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	137	dried out	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	138		no data	unshrouded	shrouded	bad		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	139	suspect humidity	no data	unshrouded	shrouded	mixed	no data	SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	140	suspect humidity	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	141	suspect humidity	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	142	suspect humidity	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011	143	suspect humidity	no data	unshrouded	shrouded	mixed		SIU resistor blown	no ship1 air/RH			flow meter failed		no LW
2011 Portland,UK	144 to 150	removed	removed	unshrouded	shrouded		off	SIU resistor blown	no ship1 air/RH			tsg off		system OFF
2011 depart Portland,UK	151	removed	removed	unshrouded	shrouded		off		no ship1 air/RH			tsg off		system OFF
2011 Portsmouth	152 to 178	removed	removed	unshrouded	shrouded		off		no ship1 air/RH			tsg off		system OFF
2011	179			shrouded	shrouded		Antenna		no ship1					

depart Portsmouth							backwards		air/RH					
2011	180			shrouded	shrouded		Antenna backwards		no ship1 air/RH					
2011	181			shrouded	shrouded		Antenna backwards		no ship1 air/RH					
2011	182			shrouded	shrouded		Antenna backwards		no ship1 air/RH					
2011	183			shrouded	shrouded		Antenna backwards		no ship1 air/RH					
2011	184			shrouded	shrouded		Antenna backwards		no ship1 air/RH			tsg off		
2011 arrive Glasgow	185 to 206			shrouded	shrouded		Antenna backwards		no ship1 air/RH			tsg off		
2011 Glasgow	206	dried out	no temp	shrouded	shrouded		Antenna backwards					tsg off		
2011 depart Glasgow	207	dried out	no temp	shrouded	shrouded		Antenna backwards							
2011	208 to 212		no temp	shrouded	shrouded		Antenna backwards							
2011 Ny Alesund	213		no temp	unshrouded	unshrouded		Antenna backwards					tsg off		
2011 Longyearbyen	214		no temp	unshrouded	unshrouded		Antenna backwards					tsg off		
2011	215 to 231		no temp	unshrouded	unshrouded		Antenna backwards							
2011 Longyearbyen	232		no temp	unshrouded	unshrouded		Antenna backwards							
2011	233		no temp	unshrouded	unshrouded		Antenna backwards							
2011	234		no temp	unshrouded	unshrouded		Antenna backwards							no SW or LW
2011	235		no temp	unshrouded	unshrouded		Antenna backwards							
2011	236		no temp	unshrouded	unshrouded		Antenna backwards							

2011 Longyearbyen	237 to 238		no temp	unshrouded	unshrouded		Antenna backwards					tsg off		
2011 depart Longyearbyen	239		no temp	unshrouded	unshrouded		Antenna backwards							
2011	240 to 243		no temp	unshrouded	unshrouded		Antenna backwards							
2011	244 to 247	dried out	no temp	unshrouded	unshrouded		Antenna backwards							
2011 arrive Longyearbyen	248	dried out	no temp	unshrouded	unshrouded		Antenna backwards							
2011 depart Longyearbyen	249	dried out	no temp	unshrouded	unshrouded		Antenna backwards							
2011	250	dried out	no temp	unshrouded	unshrouded		Antenna backwards							
2011	251 to 256		no temp	unshrouded	unshrouded		Antenna backwards							
2011 Immingham	257 to 266			unshrouded	unshrouded		Antenna backwards					tsg off		
2011 depart Immingham	267			unshrouded	unshrouded							tsg off		

Table F. Anemometer and motion instrument offsets determined in the lab.

MotionPak and Sonic mounted together on a metal plate with the Sonic aligned approximately forward facing, and the MotionPak box in line behind it with the box wiring emerging from the rear. The Sonic is twisted hard to anticlockwise against its mounting bolts when viewed from above.

The offsets given are the rotational offsets of the Sonic with respect to the MotionPak frame of reference. A positive fore-aft offset means the Sonic is leaning forwards. A positive port-starboard offset means the Sonic is leaning to starboard when viewed from behind. A positive yaw angle corresponds to a rotation of the Sonic clockwise when viewed from above. Uncertainties shown are the standard deviation of the measurements made.

MotionPak sn	Sonic sn	Fore-aft tilt offset (°)	Port-star' tilt offset (°)	Yaw offset (°)	Date of experiment
682	227	0.20 ± 0.07	0.20 ± 0.03	-8.21 ± 0.14	Sep' 2010
682	38	0.06 ± 0.02	0.20 ± 0.03	-7.48 ± 0.24	June 2011
682	391	0.21 ± 0.05	0.49 ± 0.03	-8.01 ± 0.13	June 2011
791	227				Pending
791	38	0.25 ± 0.06	-0.61 ± 0.02	-7.68 ± 0.24	July 2011
791	391	0.42 ± 0.02	-0.43 ± 0.01	-7.93 ± 0.22	July 2011

Appendix A Motion pack 0791

MotionPak Factory Details: 10/7/2006

Accels	X axis	Yaxis	Z axis	Spec
Scale factor	1.276	1.279	1.309	1.300 ±10%
0g bias	0.86	-4.34	0.80	±12
RSS align	0.81	0.85	0.27	<1.00
Pen Align (°)	0.09	-0.80	-0.20	
Hin Align (°)	0.81	0.28	-0.18	

Rates	X axis	Yaxis	Z axis	Spec
S/F (mV/°/S)	49.898	49.995	50.112	50.000 ±1%
Bias	0.04	-0.18	0.03	±1.8
RSS align	0.36	0.55	0.14	<1.00
Align1 (°)	-0.32	0.54	0.02	
Align2 (°)	0.14	0.05	0.13	

Appendix B Motion pack 0682

MotionPak Factory Details: 8/8/2003

Accels	X axis	Yaxis	Z axis	Spec
Scale factor	1.270	1.296	1.299	1.300 ±10%
0g bias	3.66	4.05	3.35	±12
RSS align	0.03	0.03	0.03	<1.00
Pen Align (°)	0.01	0.01	-0.03	
Hin Align (°)	-0.03	0.03	0.01	

Rates	X axis	Yaxis	Z axis	Spec
S/F (mV/°/S)	49.823	50.190	50.113	50.000 ±1%
Bias	0.00	0.11	-0.14	±1.8
RSS align	0.52	0.12	0.22	<1.00
Align1 (°)	-0.50	0.05	-0.19	
Align2 (°)	0.12	0.11	0.11	

Appendix C Licor calibrations

75H-0614

	75H-0614		
	23-Jun-03	28-Jul-05	11-Jun-08
CO2			
A	1.46722E+02	1.48959E+02	1.617720E+02
B	9.17028E+03	6.81639E+03	-3.318770E+04
C	4.28852E+07	4.58741E+07	8.473450E+07
D	-1.32324E+10	-1.40085E+10	-2.883290E+10
E	1.79769E+12	1.87077E+12	3.806110E+12
XS	1.50000E-03	1.20000E-03	1.800000E-03
Z	6.00000E-04	4.00000E-04	4.000000E-04
H2O			
A	4.66765E+03	4.65536E+03	4.896680E+03
B	4.15604E+06	4.26315E+06	3.984990E+06
C	-1.39683E+08	-2.20559E+08	-1.314120E+08
XS	-5.00000E-04	-1.00000E-03	-8.000000E-04
Z	1.67000E-02	1.27000E-02	9.300000E-03
Pressure			
A0			1.058800E+01
A1			2.603600E+01
Zero/Span			
CO2 zero	9.24600E-01	9.25100E-01	9.251000E-01
CO2 span	1.00160E+00	1.00110E+00	9.982000E-01
H2O zero	7.19500E-01	7.27600E-01	7.323000E-01
H2O Span	9.91300E-01	9.95000E-01	9.978000E-01

CO2 abs/kPa	mmol/m3/kPa	mmol/m3/kPa	Diff	%
8.38E-04	0.150373	0.149376	**0.000996**	**0.67**
H2O				
6.27E-04	4.540513	4.604442	**-0.063929**	**-1.39**

	75H-0825		
	25-Jan-05	5-Jun-08	15-Jun-09
CO2			
A	1.30869E+02	1.46146E+02	1.397630E+02
B	1.44519E+04	-2.16892E+04	-3.741580E+03
C	2.60842E+07	5.88330E+07	4.463380E+07
D	-6.73129E+09	-1.79119E+10	-1.343830E+10
E	8.43984E+11	2.16918E+12	1.688310E+12
XS	1.60000E-03	1.30000E-03	3.000000E-03
Z	2.80000E-03	2.60000E-03	2.900000E-03
H2O			
A	4.50452E+03	4.51498E+03	4.669280E+03
B	3.32272E+06	3.74952E+06	3.704450E+06
C	9.89638E+07	-1.29123E+08	-7.034610E+07
XS	-4.00000E-04	-1.10000E-03	-4.000000E-04
Z	2.40000E-02	1.42000E-02	1.730000E-02
Pressure			
A0		1.04790E+01	1.060600E+01
A1		2.60360E+01	2.603600E+01
Zero/Span			
CO2 zero	9.83700E-01	9.83600E-01	9.819000E-01
CO2 span	1.00000E+00	1.00000E+00	9.983000E-01
H2O zero	7.27300E-01	7.47900E-01	7.456000E-01
H2O Span	9.87500E-01	9.91800E-01	9.934000E-01

CO2 abs/kPa	mmol/m3/kPa	mmol/m3/kPa	Diff	%
8.38E-04	0.133836	0.134741	**-0.000905**	**-0.67**
H2O				
6.27E-04	4.273110	4.366626	**-0.093516**	**-2.14**

	75H-1113	
	31-Jul-06	6-Apr-09
CO2		
A	1.48438E+02	1.50466E+02
B	-5.26643E+03	-6.67083E+03
C	5.30750E+07	5.67693E+07
D	-1.66528E+10	-1.84491E+10
E	2.14891E+12	2.45252E+12
XS	1.70000E-03	2.40000E-03
Z	-2.00000E-04	0.00000E+00
H2O		
A	5.07357E+03	5.26040E+03
B	3.80152E+06	3.66483E+06
C	-1.15045E+08	-6.51934E+07
XS	-1.80000E-03	-1.20000E-03
Z	2.11000E-02	1.70000E-02
Pressure		
A0	1.05560E+01	1.04310E+01
A1	2.60360E+01	2.60360E+01
Zero/Span		
CO2 zero	9.08000E-01	9.07900E-01
CO2 span	1.00000E+00	1.00470E+00
H2O zero	9.16000E-01	9.28500E-01
H2O Span	9.96000E-01	1.00410E+00

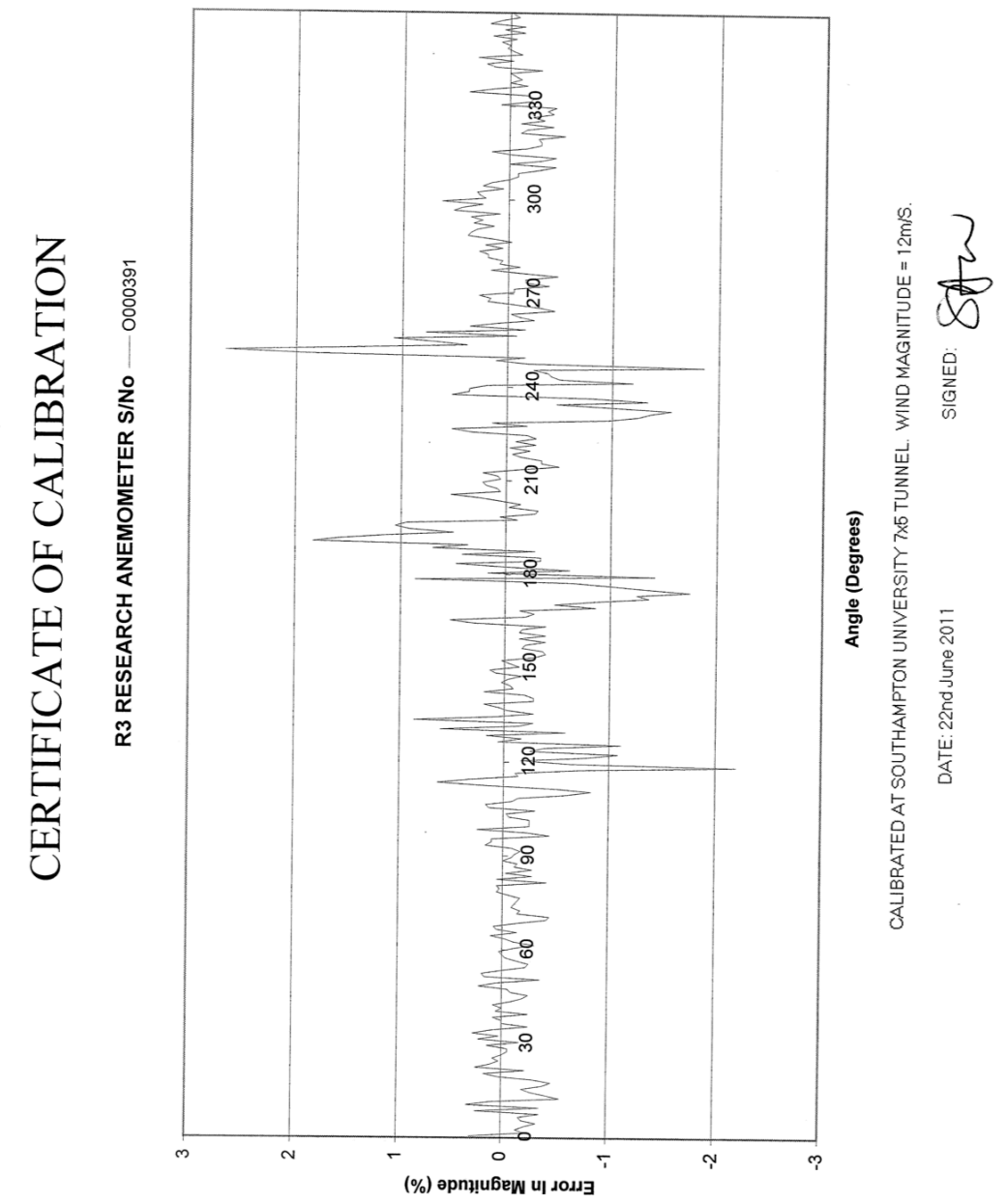
CO2 abs/kPa	mmol/m3/kPa	mmol/m3/kPa	Diff	%
8.38E-04	0.144505	0.146630	**-0.002125**	**-1.45**
H2O				
6.27E-04	4.647258	4.722952	**-0.075694**	**-1.60**

	75H-1114	
	31-Jul-06	9-Jun-09
CO2		
A	1.55021E+02	1.57928E+02
B	-5.35142E+03	-1.08867E+04
C	5.93488E+07	6.71827E+07
D	-1.93517E+10	-2.29411E+10
E	2.58283E+12	3.14962E+12
XS	1.90000E-03	4.00000E-03
Z	-1.50000E-03	-9.00000E-04
H2O		
A	5.07675E+03	5.29671E+03
B	4.00700E+06	3.68981E+06
C	-1.68006E+08	-3.93517E+07
XS	-1.80000E-03	-1.20000E-03
Z	2.13000E-02	1.73000E-02
Pressure		
A0	1.05560E+01	1.06070E+01
A1	2.60360E+01	2.60360E+01
Zero/Span		
CO2 zero	8.82200E-01	8.80600E-01
CO2 span	1.00100E+00	1.00000E+00
H2O zero	9.40600E-01	9.51400E-01
H2O Span	9.95300E-01	1.00130E+00

CO2 abs/kPa	mmol/m3/kPa	mmol/m3/kPa	Diff	%
8.38E-04	0.152495	0.154117	**-0.001622**	**-1.05**
H2O				
6.27E-04	4.716978	4.761909	**-0.044931**	**-0.94**

APPENDIX D Sonic anemometer calibrations

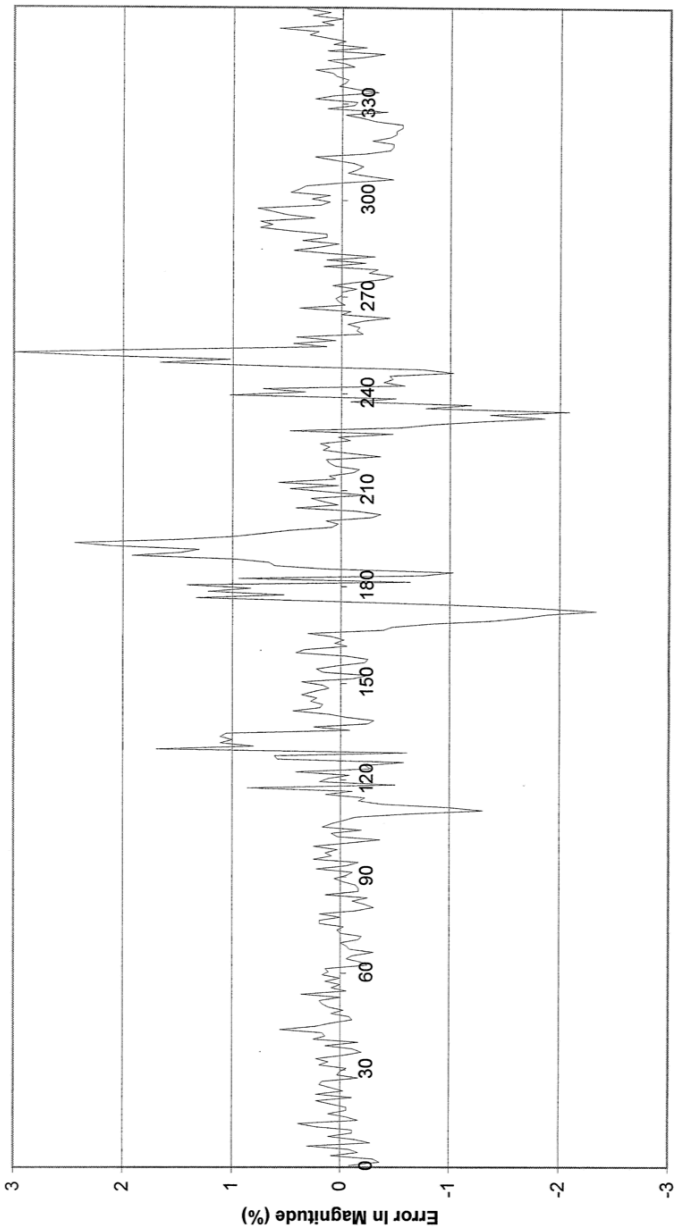
Sonic 0391



Sonic 0227

CERTIFICATE OF CALIBRATION

R3 RESEARCH ANEMOMETER S/No —— O000227



CALIBRATED AT SOUTHAMPTON UNIVERSITY 7x5 TUNNEL. WIND MAGNITUDE = 12m/S.

DATE: 22nd June 2011 SIGNED:

APPENDIX E – Time series plots

Air temperatures

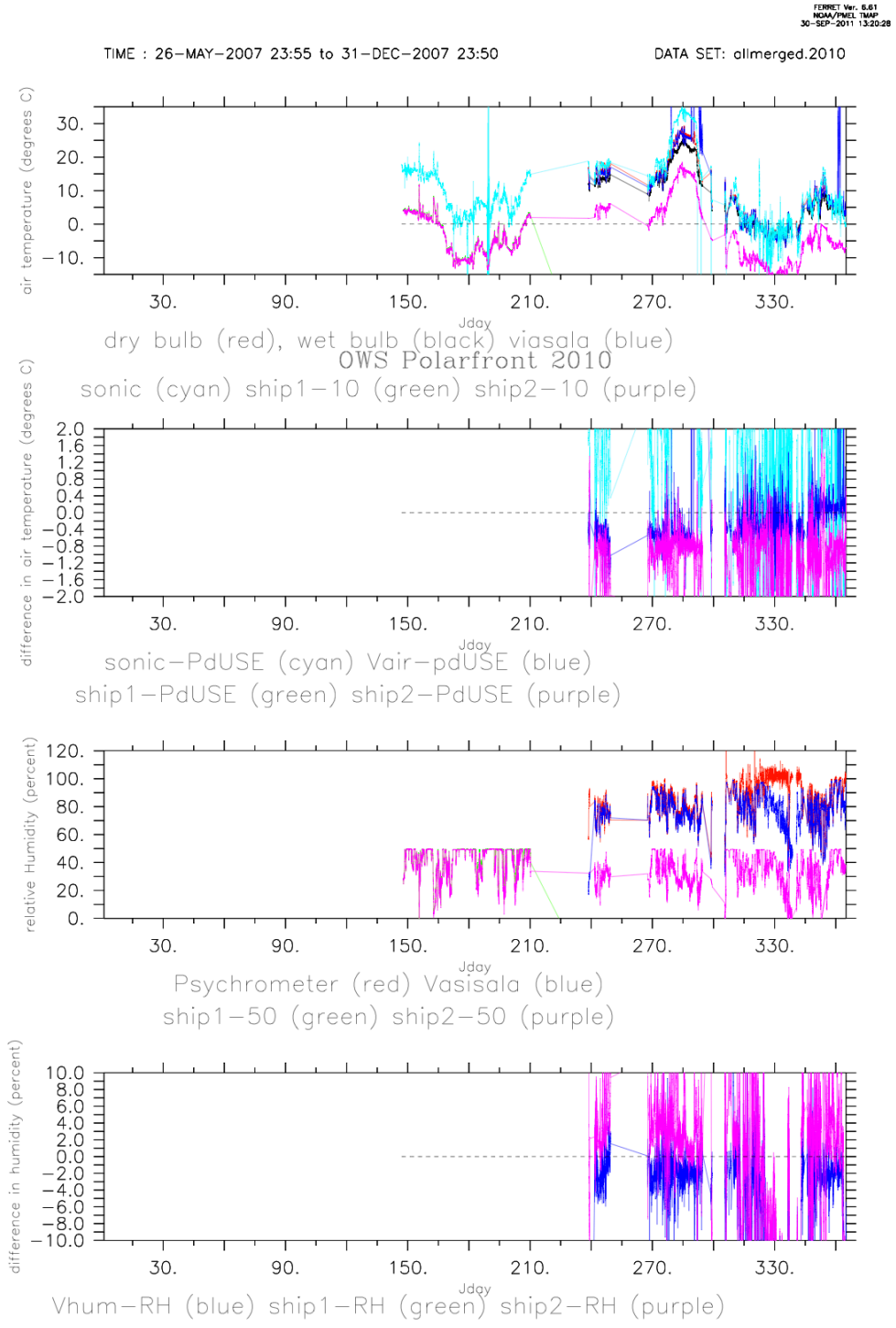
The figures show yearly time series of 10 minute spot values. Only basic quality control criteria have been applied to these data. Each page contains four plots showing different variables over each year.

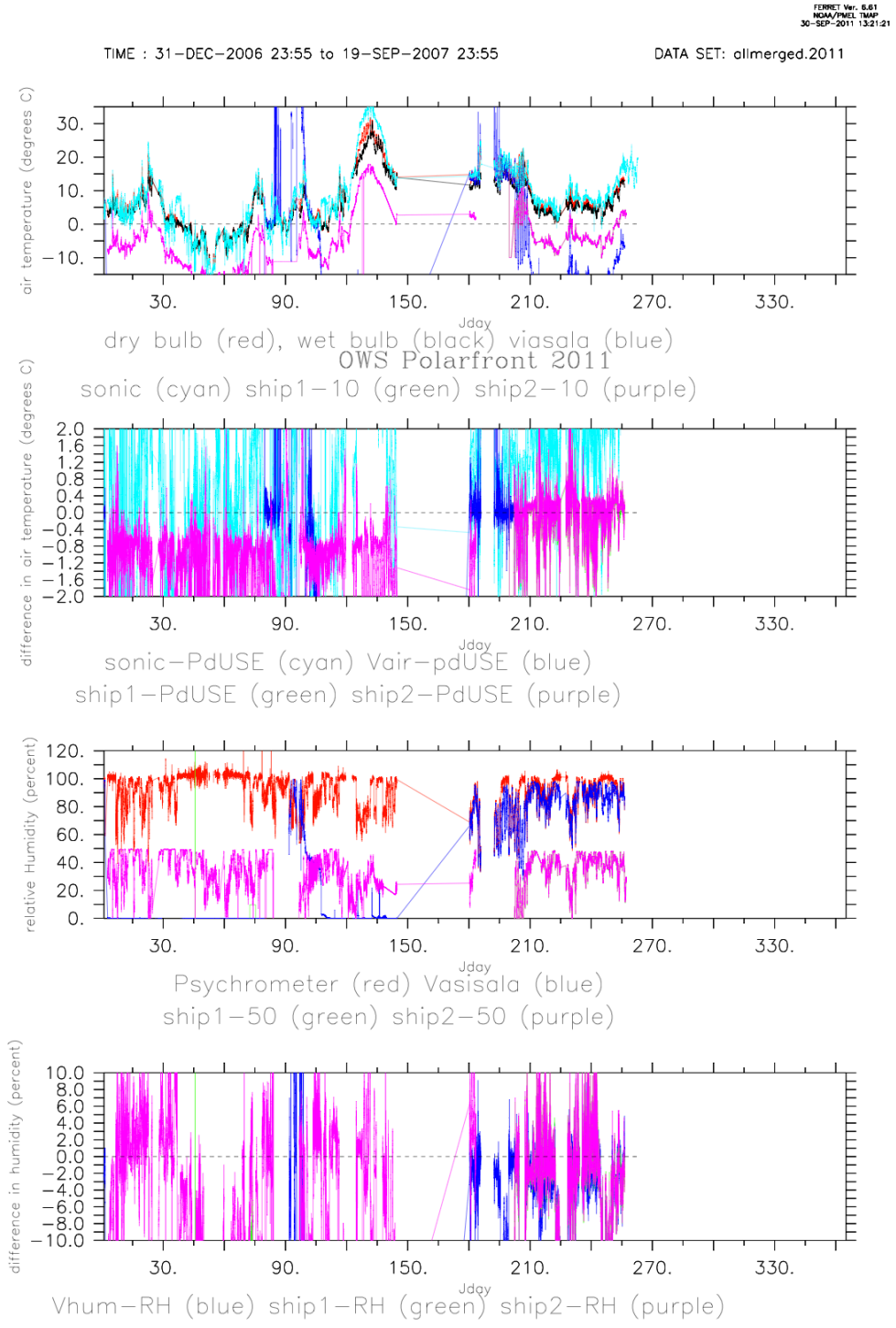
Top panel - the wet and dry air temperature from the psychrometer, the Vaisala sensor, the R3 sonic, and the ships two Rotronic air temperature sensors (ship1 and ship2). Note: the Rotronic sensors are offset by -10 in the plot.

Upper middle panel – the difference in air temperature between the psychrometer dry bulb, and the Vaisala, Sonic and Rotronic (ship1 and ship2).

Lower middle panel – relative humidity from the Vaisala, Rotronic, and calculated using the Psychrometer. Note: the Rotronic sensors are offset by -50 in the plot.

Bottom panel – difference in humidity between the psychrometer, and the Vaisala and Rotronic.

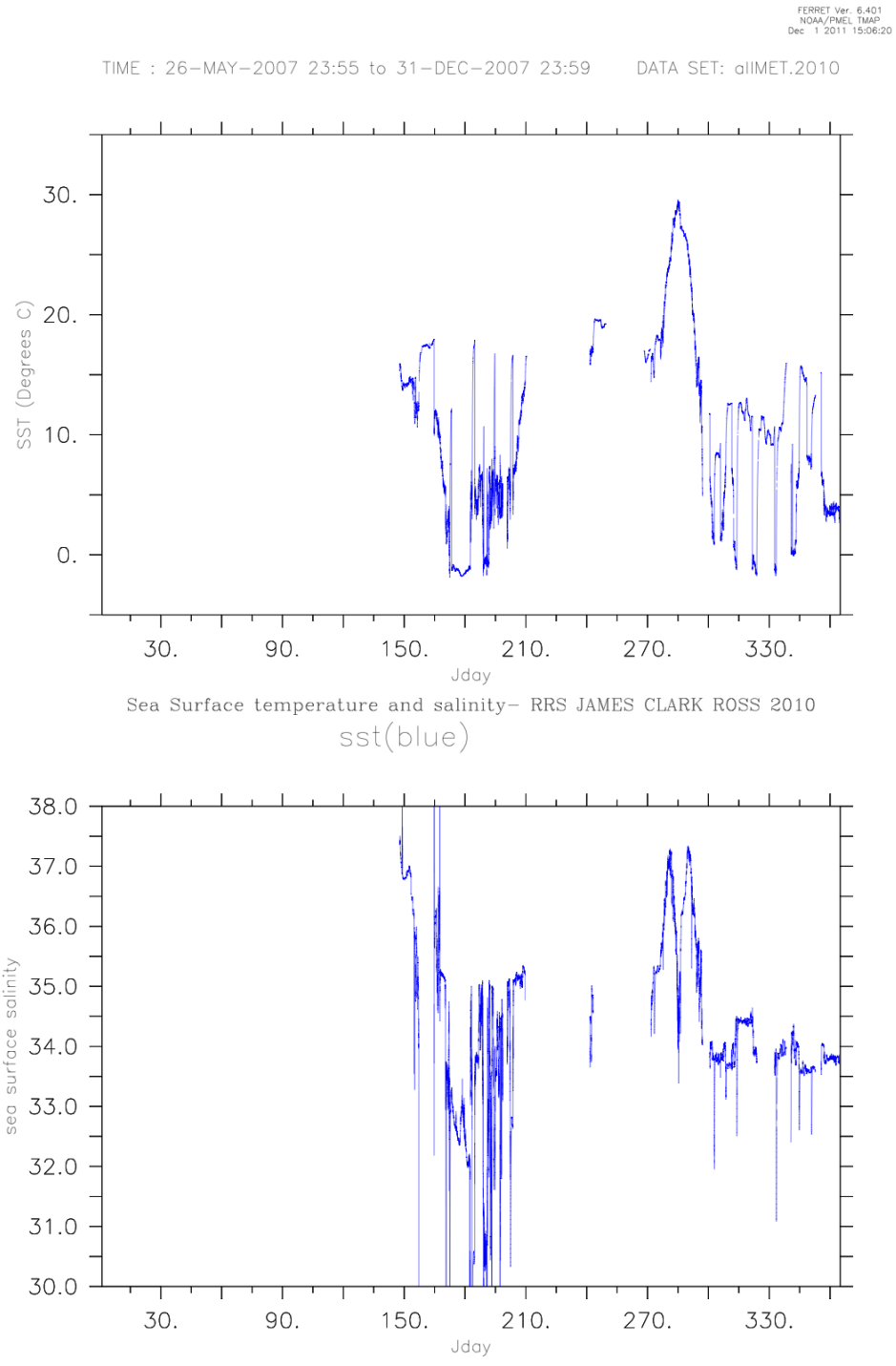

FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 13:20:28
TIME : 26-MAY-2007 23:55 to 31-DEC-2007 23:50
DATA SET: allmerged.2010
air temperature (degrees C)
30.
20.
10.
0.
-10.
30.
90.
150.
210.
270.
330.
Jday
dry bulb (red), wet bulb (black) viasala (blue)
OWS Polarfront 2010
sonic (cyan) ship1-10 (green) ship2-10 (purple)
difference in air temperature (degrees C)
2.0
1.6
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
-1.6
-2.0
30.
90.
150.
210.
270.
330.
Jday
sonic-PdUSE (cyan) Vair-pdUSE (blue)
ship1-PdUSE (green) ship2-PdUSE (purple)
relative Humidity (percent)
120.
100.
80.
60.
40.
20.
0.
30.
90.
150.
210.
270.
330.
Jday
Psychrometer (red) Vasisala (blue)
ship1-50 (green) ship2-50 (purple)
difference in humidity (percent)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
30.
90.
150.
210.
270.
330.
Jday
Vhum-RH (blue) ship1-RH (green) ship2-RH (purple)

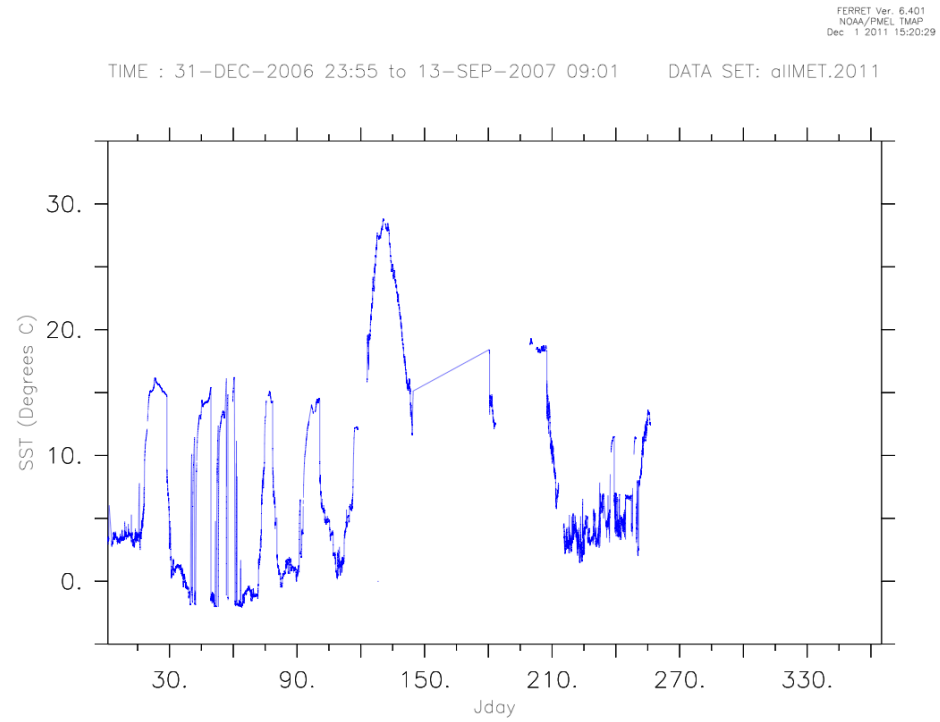

FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 13:21:21
TIME : 31-DEC-2006 23:55 to 19-SEP-2007 23:55
DATA SET: allmerged.2011
air temperature (degrees C)
30.
20.
10.
0.
-10.
30.
90.
150.
210.
270.
330.
Jday
dry bulb (red), wet bulb (black) viasala (blue)
OWS Polarfront 2011
sonic (cyan) ship1-10 (green) ship2-10 (purple)
difference in air temperature (degrees C)
2.0
1.6
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
-1.6
-2.0
30.
90.
150.
210.
270.
330.
Jday
sonic-PdUSE (cyan) Vair-pdUSE (blue)
ship1-PdUSE (green) ship2-PdUSE (purple)
relative Humidity (percent)
120.
100.
80.
60.
40.
20.
0.
30.
90.
150.
210.
270.
330.
Jday
Psychrometer (red) Vasisala (blue)
ship1-50 (green) ship2-50 (purple)
difference in humidity (percent)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
30.
90.
150.
210.
270.
330.
Jday
Vhum-RH (blue) ship1-RH (green) ship2-RH (purple)

Sea surface temperature and uncorrected salinity

The figures show yearly time series of 10 minute spot values. Only basic quality control criteria have been applied to these data. Each page contains three plots showing different variables over each year.
Top panel - the sea surface intake temperature.

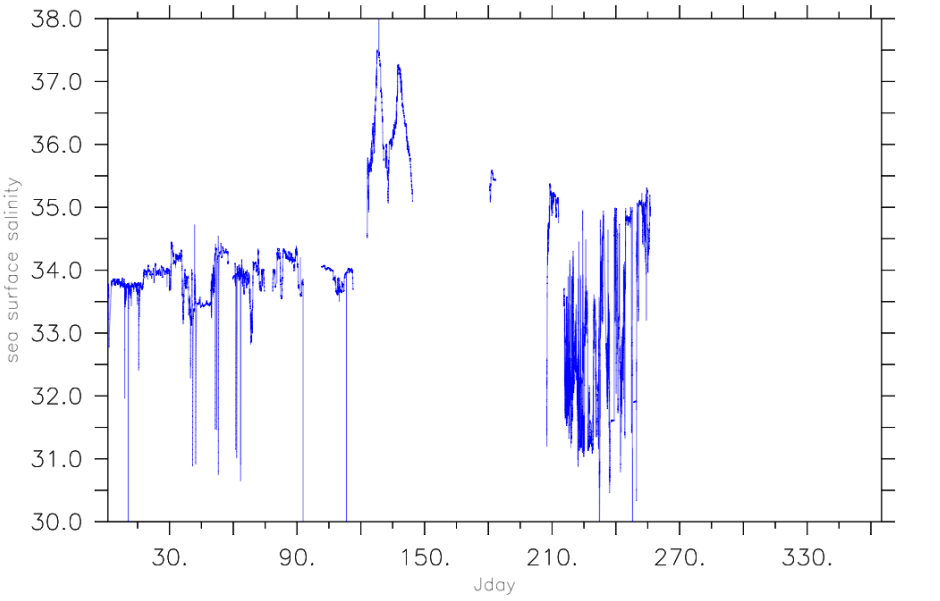
Bottom panel – the uncorrected sea surface salinity.


FERRET Ver. 6.401
NOAA/PMEL TMAP
Dec 1 2011 15:06:20
TIME : 26-MAY-2007 23:55 to 31-DEC-2007 23:59
DATA SET: allMET.2010
SST (Degrees C)
30.
20.
10.
0.
30.
90.
150.
210.
270.
330.
Jday
Sea Surface temperature and salinity- RRS JAMES CLARK ROSS 2010
sst(blue)
sea surface salinity
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
30.
90.
150.
210.
270.
330.
Jday



Sea Surface temperature and salinity- RRS JAMES CLARK ROSS 2011

sst(blue)

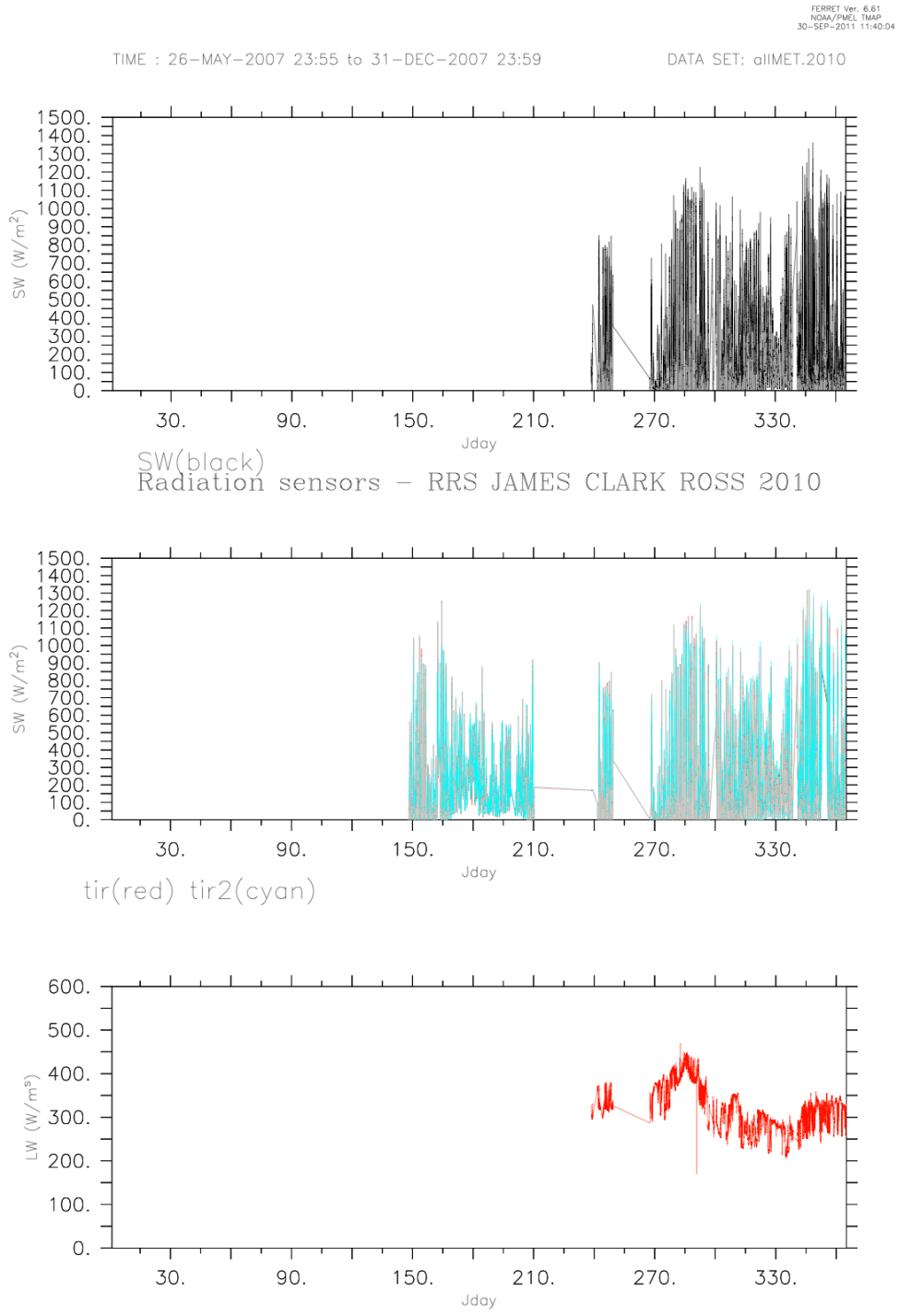


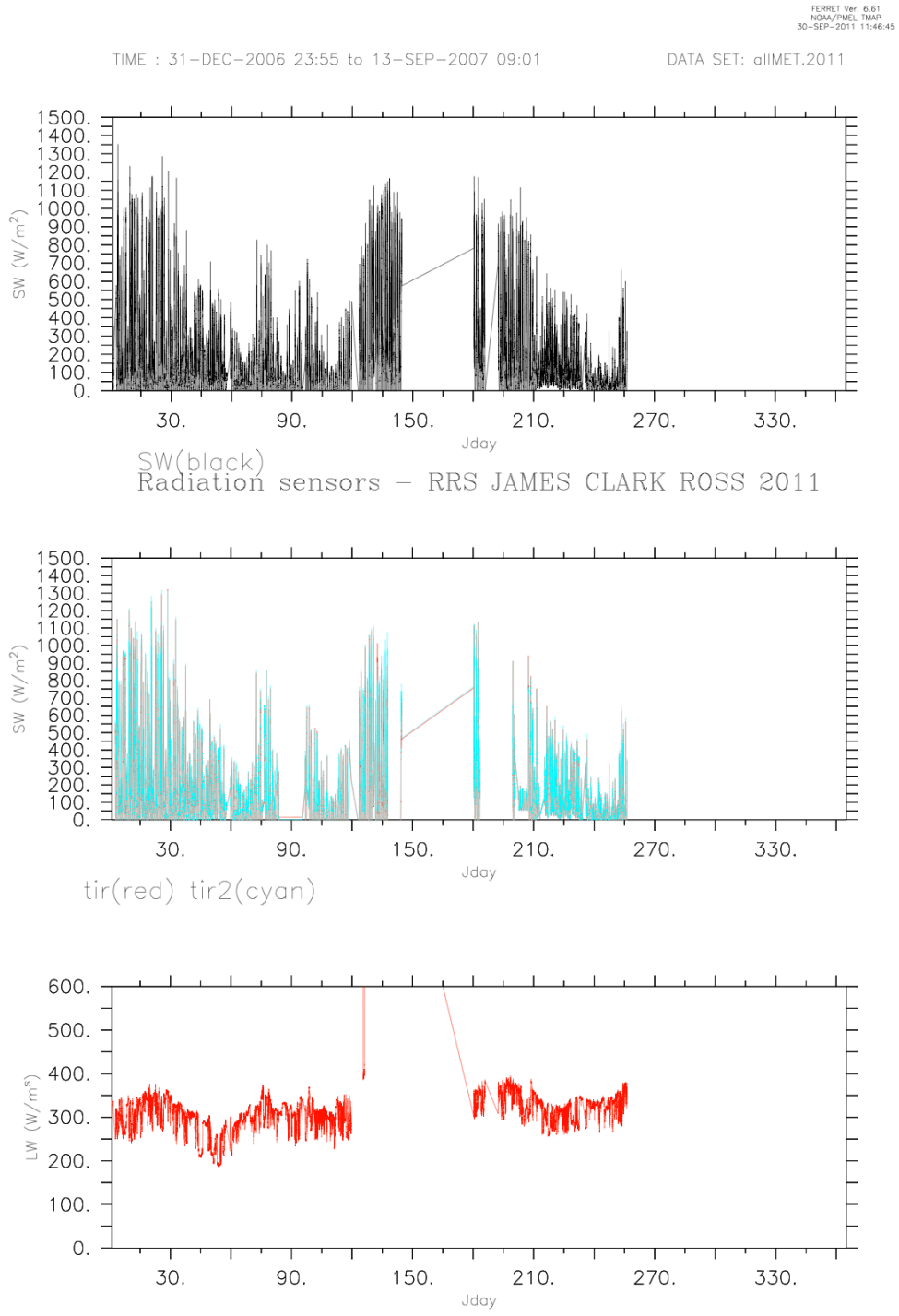
Radiation sensors

The figures show yearly time series of 10 minute spot values. Only basic quality control criteria have been applied to these data. Each page contains two plots showing different variables over each year.
Top panel - the short wave radiation (W/m^2) from the AutoFlux sensors.

Middle panel – the short wave radiation (W/m^2) from the ship's sensors.

Bottom panel – the long wave radiation (W/m^2).


FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 11:40:04
TIME : 26-MAY-2007 23:55 to 31-DEC-2007 23:59
DATA SET: allMET.2010
SW (W/m2)
1500.
1400.
1300.
1200.
1100.
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
30.
90.
150.
210.
270.
330.
Jday
SW(black)
Radiation sensors - RRS JAMES CLARK ROSS 2010
SW (W/m2)
1500.
1400.
1300.
1200.
1100.
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
30.
90.
150.
210.
270.
330.
Jday
tir(red) tir2(cyan)
LW (W/m2)
600.
500.
400.
300.
200.
100.
0.
30.
90.
150.
210.
270.
330.
Jday


FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 11:46:45
TIME : 31-DEC-2006 23:55 to 13-SEP-2007 09:01
DATA SET: allMET.2011
SW (W/m2)
Jday
SW(black)
Radiation sensors - RRS JAMES CLARK ROSS 2011
tir(red) tir2(cyan)
LW (W/m2)

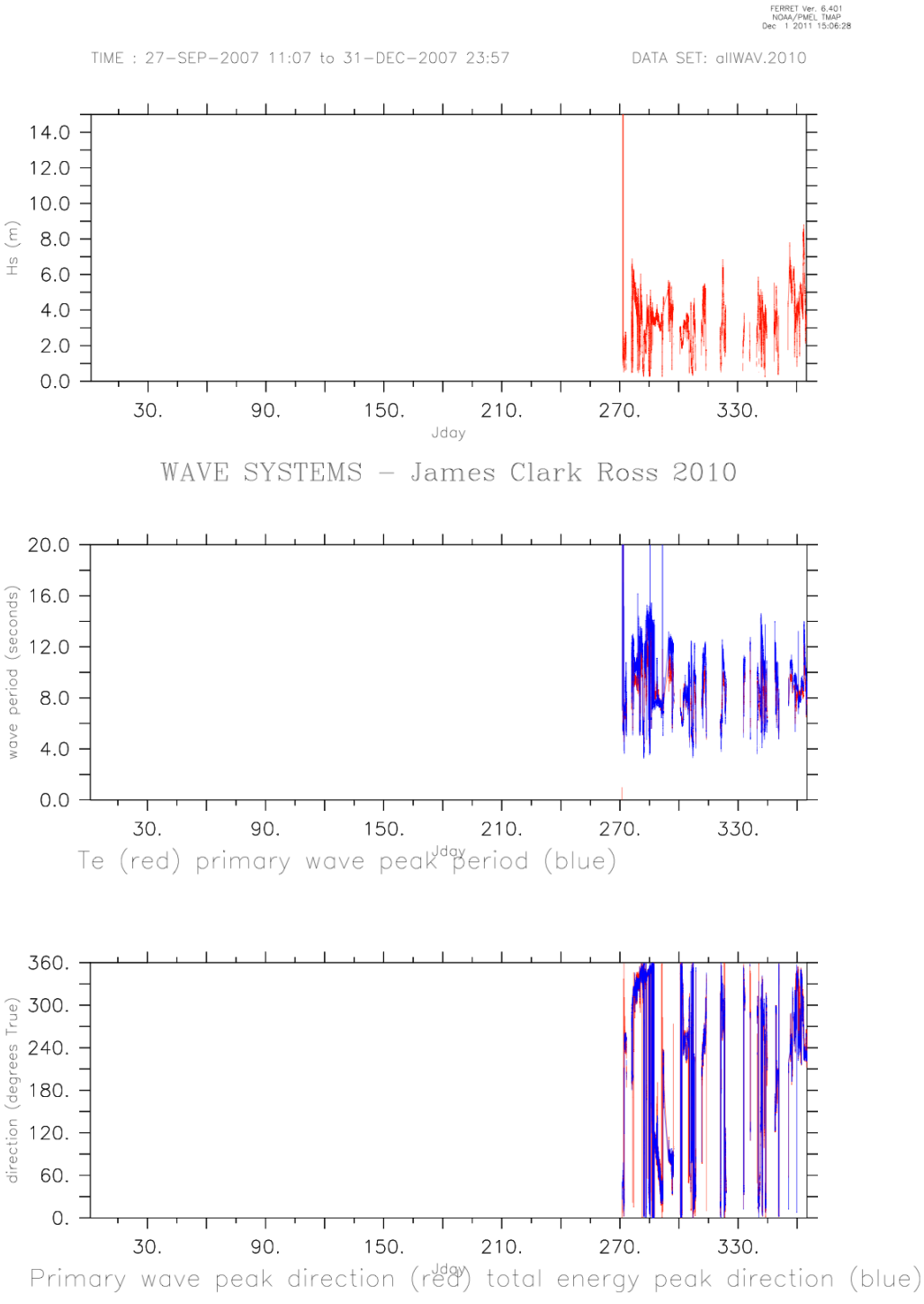
Wave systems

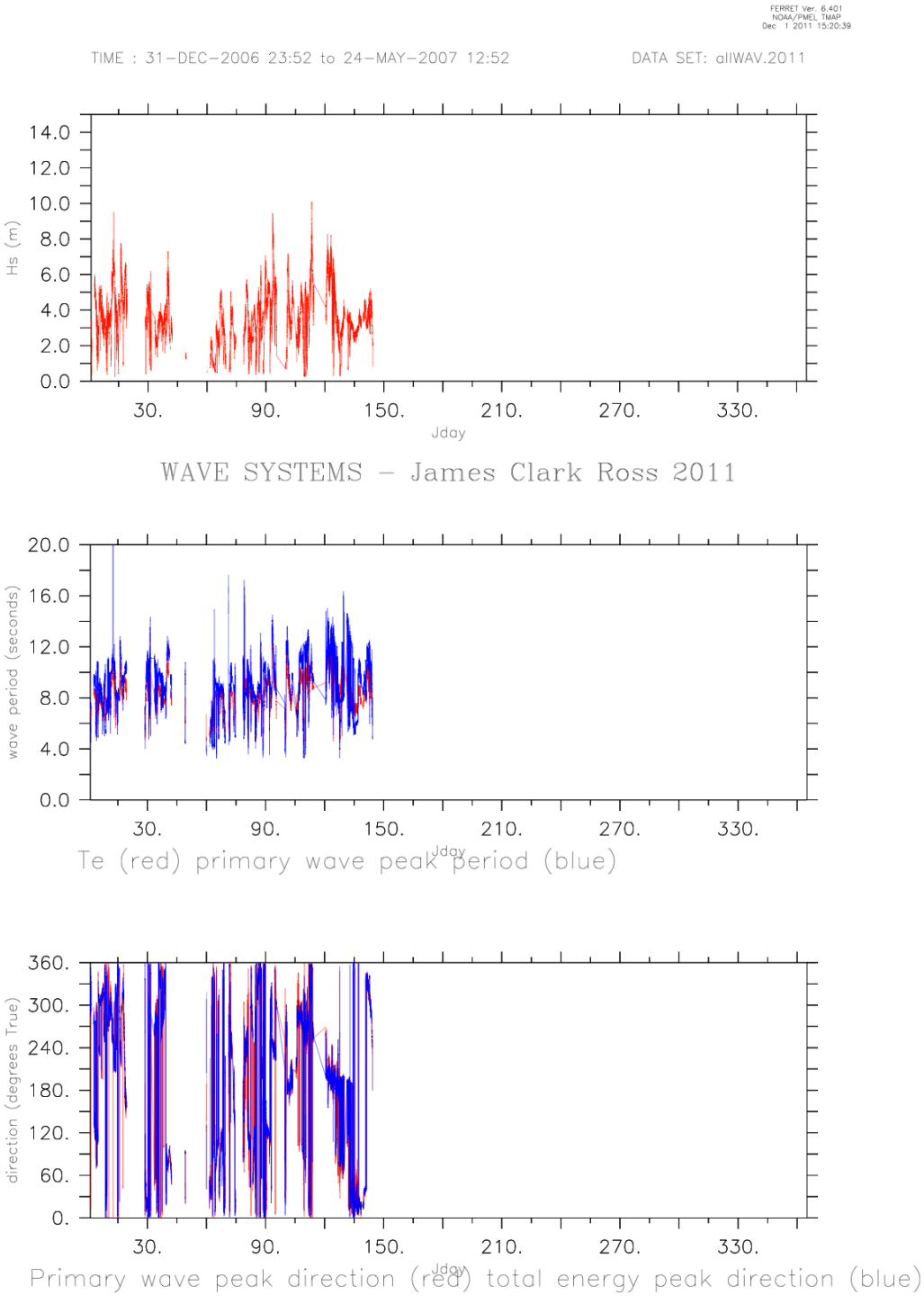
The figures show a yearly time series of 10 minute spot values. Only basic quality control criteria have been applied to these data. Each page contains four plots showing different variables over each year.

Top panel - the significant wave height (Hs) measured by the WAVEX wave radar.

Middle panel – the energy period (T_E) and the primary wave peak period.

Bottom panel – the wave directions.


FERRET Ver. 6.401
NOAA/PMEL TMAP
Dec 1 2011 15:06:28
TIME : 27-SEP-2007 11:07 to 31-DEC-2007 23:57
DATA SET: allWAV.2010
Hs (m)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
30.
90.
150.
210.
270.
330.
Jday
WAVE SYSTEMS - James Clark Ross 2010
wave period (seconds)
20.0
16.0
12.0
8.0
4.0
0.0
30.
90.
150.
210.
270.
330.
Jday
Te (red) primary wave peak period (blue)
direction (degrees True)
360.
300.
240.
180.
120.
60.
0.
30.
90.
150.
210.
270.
330.
Jday
Primary wave peak direction (red) total energy peak direction (blue)


FERRET Ver. 6.401
NOAA/PMEL TMAP
Dec 1 2011 15:20:39
TIME : 31-DEC-2006 23:52 to 24-MAY-2007 12:52
DATA SET: allWAV.2011
Hs (m)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
30.
90.
150.
210.
270.
330.
Jday
WAVE SYSTEMS - James Clark Ross 2011
wave period (seconds)
20.0
16.0
12.0
8.0
4.0
0.0
Jday
Te (red) primary wave peak period (blue)
direction (degrees True)
360.
300.
240.
180.
120.
60.
0.
Jday
Primary wave peak direction (red) total energy peak direction (blue)

Wind speed and direction

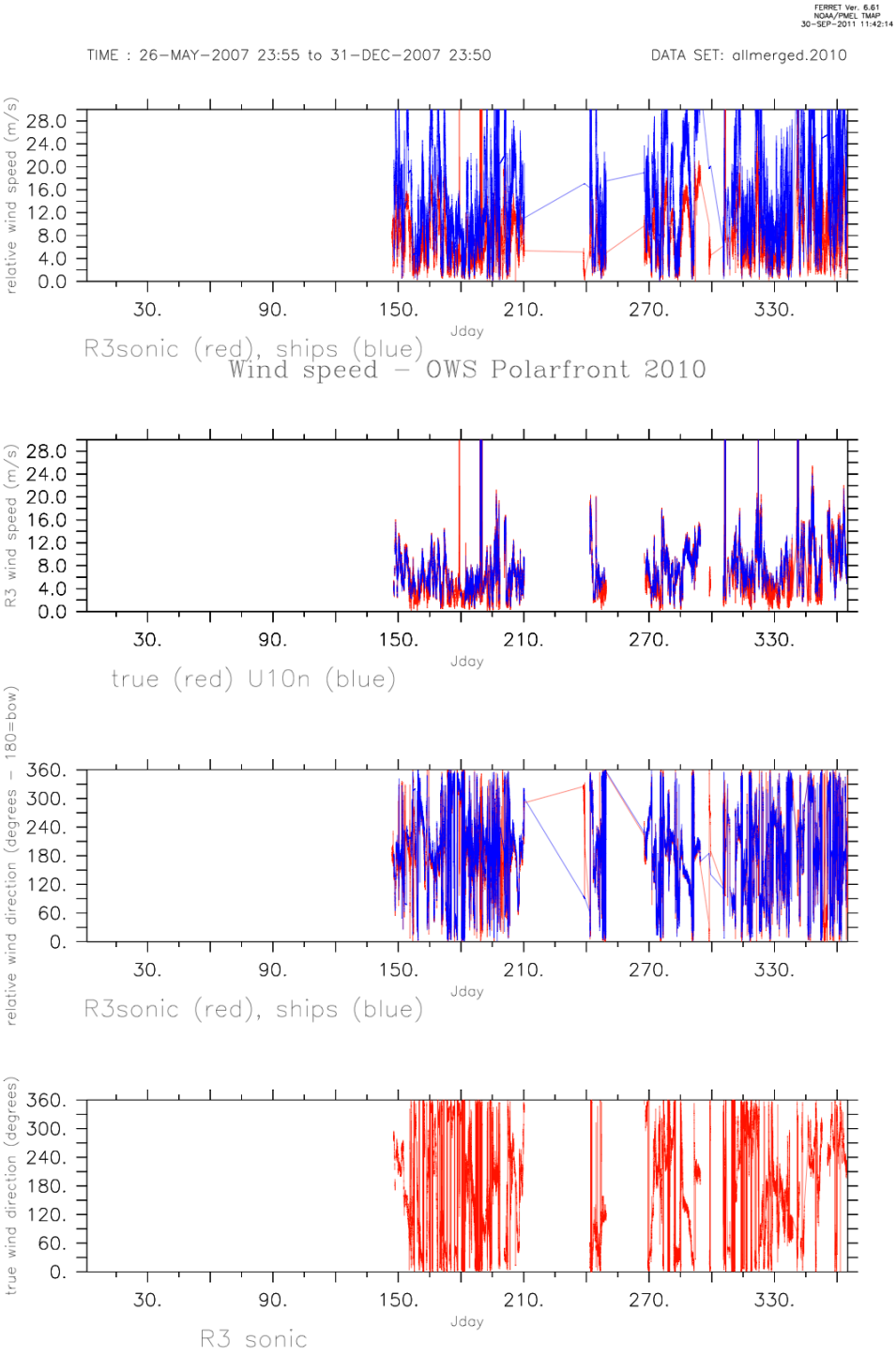
The figures show a yearly time series of 10 minute spot values. Only basic quality control criteria have been applied to these data. Each page contains four plots showing different variables over each year.

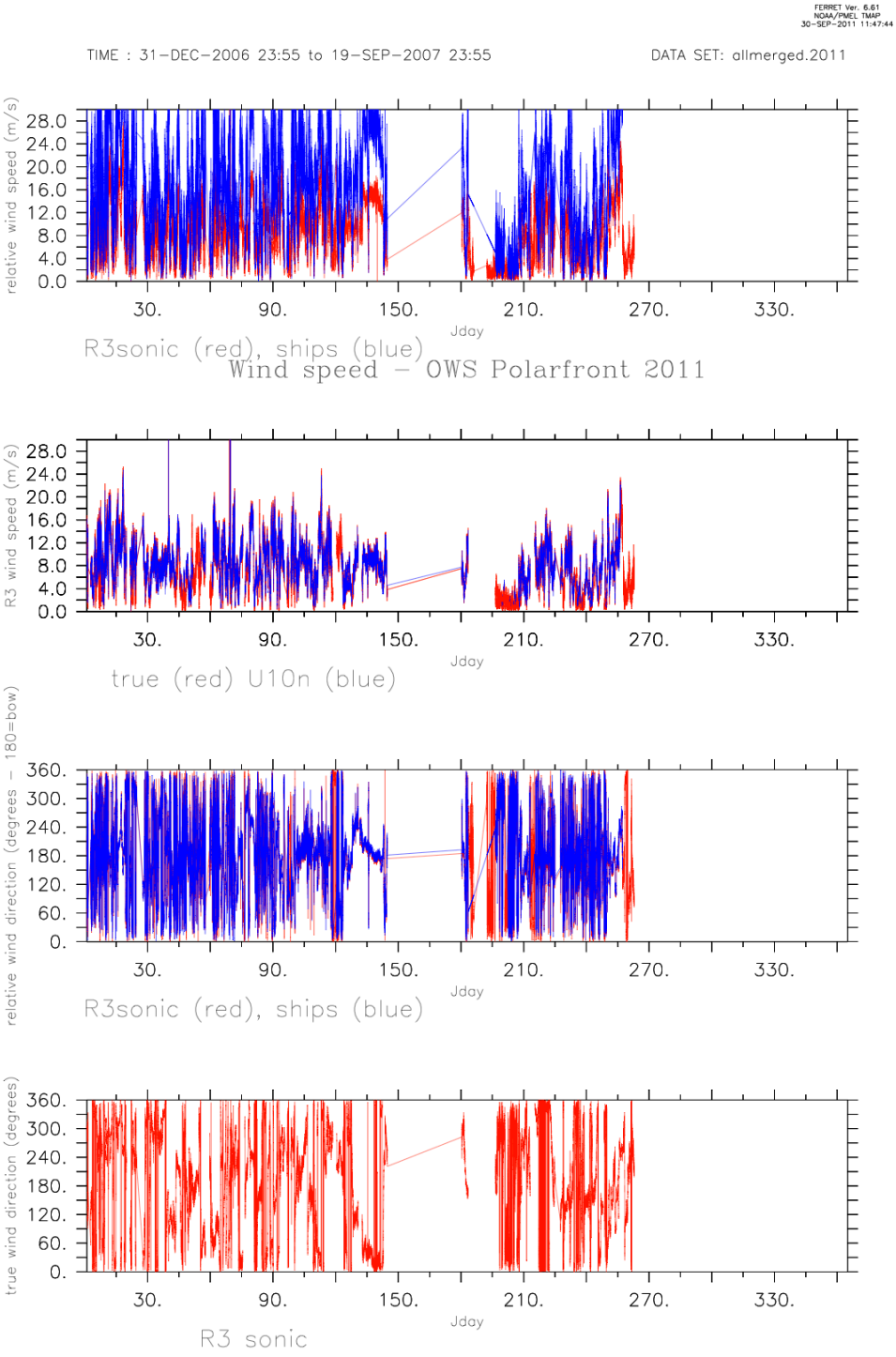
Top panel - the relative wind speed measured by the AutoFlux R3 sonic and the ship's WindMaster anemometer.

Upper middle panel – the true wind speed measured from the R3 anemometer and the R3 anemometer wind speed speed corrected to a height of 10 m and neutral atmospheric stability.

Lower middle panel –wind direction relative to the ship measured using the AutoFlux R3 sonic and the ship's WindMaster anemometer. Note: the relative wind direction for flows directly over the bow is 180 degrees.

Bottom panel – the true wind direction from the R3 sonic. Note: direction is from, e.g. 180 degrees is from the South.


FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 11:42:14
TIME : 26-MAY-2007 23:55 to 31-DEC-2007 23:50
DATA SET: allmerged.2010
relative wind speed (m/s)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
30.
90.
150.
210.
270.
330.
Jday
R3sonic (red), ships (blue)
Wind speed - OWS Polarfront 2010
R3 wind speed (m/s)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
30.
90.
150.
210.
270.
330.
Jday
true (red) U10n (blue)
relative wind direction (degrees - 180=bow)
360.
300.
240.
180.
120.
60.
0.
30.
90.
150.
210.
270.
330.
Jday
R3sonic (red), ships (blue)
true wind direction (degrees)
360.
300.
240.
180.
120.
60.
0.
30.
90.
150.
210.
270.
330.
Jday
R3 sonic


FERRET Ver. 6.61
NOAA/PMEL TMAP
30-SEP-2011 11:47:44
TIME : 31-DEC-2006 23:55 to 19-SEP-2007 23:55
DATA SET: allmerged.2011
relative wind speed (m/s)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
30.
90.
150.
210.
270.
330.
Jday
R3sonic (red), ships (blue)
Wind speed - OWS Polarfront 2011
R3 wind speed (m/s)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
30.
90.
150.
210.
270.
330.
Jday
true (red) U10n (blue)
relative wind direction (degrees - 180=bow)
360.
300.
240.
180.
120.
60.
0.
30.
90.
150.
210.
270.
330.
Jday
R3sonic (red), ships (blue)
true wind direction (degrees)
360.
300.
240.
180.
120.
60.
0.
30.
90.
150.
210.
270.
330.
Jday
R3 sonic