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RRS *JAMES CLARK ROSS* CRUISE 52
11 SEP - 17 OCT 2000

AutoFlux trials cruise,
UK to Falklands Passage

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2000

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ABSTRACT

This report describes the work undertaken on the AutoFlux system by SOC staff on the RRS *James Clark Ross* during the UK to Falklands passage between 11 September and 17 October 2000. This work coincided with the Atlantic Meridional Transect (AMT) 11 cruise (JR52) which ended on 11 October 2000, and is described elsewhere (Woodward, 2000). The SOC presence on the ship was sponsored by John King (BAS) as part of his Q3 (Antarctic Climate Processes) science program.

The aim of the cruise was to test and develop the AutoFlux air-sea interaction system and its associated prototype instrumentation. The system is intended to provide real-time air-sea fluxes of momentum, sensible heat, latent heat and CO2, in addition to the usual mean meteorological parameters. The fluxes are calculated via the 'inertial dissipation' method (Yelland *et al.,* 1998), using data from various fast-response instruments. Most of the instruments used in the system have been well proved during SOC research cruises over the last 10 years or more, but the dedicated sonic temperature sensor and the infra-red H2O/CO2 sensor are prototype instruments developed by colleagues involved in the AutoFlux project (MAST project MAS3-CT97-0108). Likewise, the logging and processing system is itself based on software systems which have been developed at SOC/IOS since the 1980s, but many aspects of the system are new and were tested and developed further during the cruise. By the fourth week of the cruise the system was automatically producing hourly direct measurements of the air-sea fluxes and was sending summary messages of the data back to SOC via the ORBCOMM satellite communications system in near real time.

KEYWORDS
AIR SEA INTERACTION, AIR WATER EXCHANGES, AUTOFLUX, CRUISE 52 2000, *JAMES CLARK ROSS,* METEOROLOGICAL MEASUREMENT, SURFACE FLUXES

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Swath Bathymetry group		From:	Role:
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BARKER	Andy	BAS	IT Support
AFANASYEV	Vsevolod	BAS	ET Support

Supernumerary		From:
BONNER	Don	Falkland Islands

Key

BAS:	British Antarctic Survey
OCU:	Oxford/Cardiff University
PML:	Plymouth Marine Laboratory
SOC:	Southampton Oceanography Centre
SOI:	Spanish Oceanographic Institute
UIN:	University of Newcastle
UIO:	University of Oviedo
UIV:	University of Vigo

Ship's personnel

Name:		Rank / Rating:
BURGAN	Jerry	Master
CHAPMAN	Graham	Chief Officer
McCARTHY	Justin	Second Officer
MACLEOD	Neil	Third Officer
MEE	Steve	Radio Officer
ANDERSON	Duncan	Chief Engineer
SMITH	Colin	Second Engineer
MACASKILL	Robert	Third Engineer
ARMOUR	Gerry	Fourth Engineer
TREVETT	Doug	Deck Engineer
ROWE	Anthony	Electrician
GIBSON	Hamish	Catering Officer
BRADBURY	Pippa	Doctor
BROOKES	Russell	Deck Cadet
BURNETT	Dean	Engineer Cadet
LANG	Colin	Bosun
PECK	David	Bosun's Mate
BOWEN	Martin	Seaman
CHAPPELL	Kelvin	Seaman
DALE	George	Seaman
DICKSON	Keith	Seaman
TRUSSLER	Luke	Seaman
ALLEN	Erwin	Motorman
PARSLEY	Richard	Motorman
MCMANAMY	Danny	Chief Cook
MACASKILL	Tracey	Second Cook
JONES	Lee	Second Steward
HADGRAFT	Simon	Steward
RAWORTH	Graham	Steward
WEIRS	Michael	Steward

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Acknowledgements

Thanks are due to the officers and crew of the RRS *James Clark Ross*, particularly the navigation officers for their diligence over the cloud observations, to John King (BAS) for sponsoring our presence on the ship, and to the AMT science team for making the SOC gatecrashers welcome on their cruise. We are also grateful to our AutoFlux colleagues who made the sonic temperature and the H2O/CO2 sensors available to us, as well as to Dave Hosom and Co. from Woods Hole Oceanographic Institute for the loan of their sea surface temperature system.

1. Introduction

The Southampton Oceanography Centre's JRD Meteorology Team took part in the U.K. to Falklands passage on the RRS *James Clark Ross* in order to trial the "AutoFlux" air-sea interaction system and its associated prototype instrumentation. The SOC presence on the cruise was sponsored by John King (BAS) as part of his Q3 science program. This work coincided with the Atlantic Meridional Transect (AMT) 11 cruise (JR52) which ended on 11 October 2000, and is described elsewhere (Woodward, 2000).

The AutoFlux system is intended to provide real-time air-sea fluxes of momentum, sensible heat, latent heat and CO2, in addition to the usual mean meteorological parameters (AutoFlux Group, 1996). The fluxes are calculated via the "inertial dissipation" method (Yelland *et al.*, 1998), using data from various fast-response instruments. Most of the instruments used in the system have been well proved during SOC research cruises over the last 10 years or more, but the dedicated sonic temperature sensor (Gill Instruments Ltd.) and the infra-red H2O/CO2 sensor (Mierij Co. and the Royal Netherlands Meteorological Institute "KNMI") are prototype instruments developed by colleagues involved in the AutoFlux project (MAST project MAS3-CT97-0108). In addition to these fast response prototype instruments, the cruise also provided an opportunity to test the Woods Hole Oceanographic Institute (WHOI) sea surface temperature system. The AutoFlux logging and processing system is itself based on software systems which have been developed at SOC/IOS since the 1980s, but many aspects of the system are new and were tested and developed further during the cruise.

The AutoFlux system was set up while the ship was still in Grimsby and logged data continuously from the time of departure (0400 GMT on 12 September, day 256). The ship called in to Portsmouth for about 12 hours (from 0700 to 1900 on day 257) and in to Montevideo for just over 2 days (from 1200 day 285 to 1900 day 287). The system was shut down on 16 October at 1500 GMT, about 20 hours before docking in Stanley. Figure 1 shows the ship track from Portsmouth to the point at which the system was shut down. A wide range of conditions were experienced; 1 minute averages of U_{10N} varied from calm to 20 m/s with a mean of 7 m/s, sea surface temperatures varied from 5° to 30°, air temperatures from 5° to 30°, and the air-sea temperature difference ranged from –4° to 4°.

This report discusses the AutoFlux instrumentation (Section 2) and the AutoFlux logging system (Section 3). Data from the ship's navigation and scientific instrumentation were also obtained (Section 4). Hourly visual cloud observations (Section 5) were also taken throughout the cruise as part of a separate SOC Meteorology Team study into the parameterisation of downwelling longwave radiation from Voluntary Observing Ship cloud observations. Section 6 describes the performance and reliability of the AutoFlux system and associated instrumentation. Section 7 discusses the initial comparisons made between the AutoFlux and ship data streams, and includes a "first look" at the longwave parameterisation (Section 7.2). Finally, Section 8 summarises the major AutoFlux system developments achieved during the cruise. All times in this report are given as GMT.

More information on air-sea fluxes and the AutoFlux project in particular can be found under;

http://www.soc.soton.ac.uk/JRD/MET/AUTOFLUX

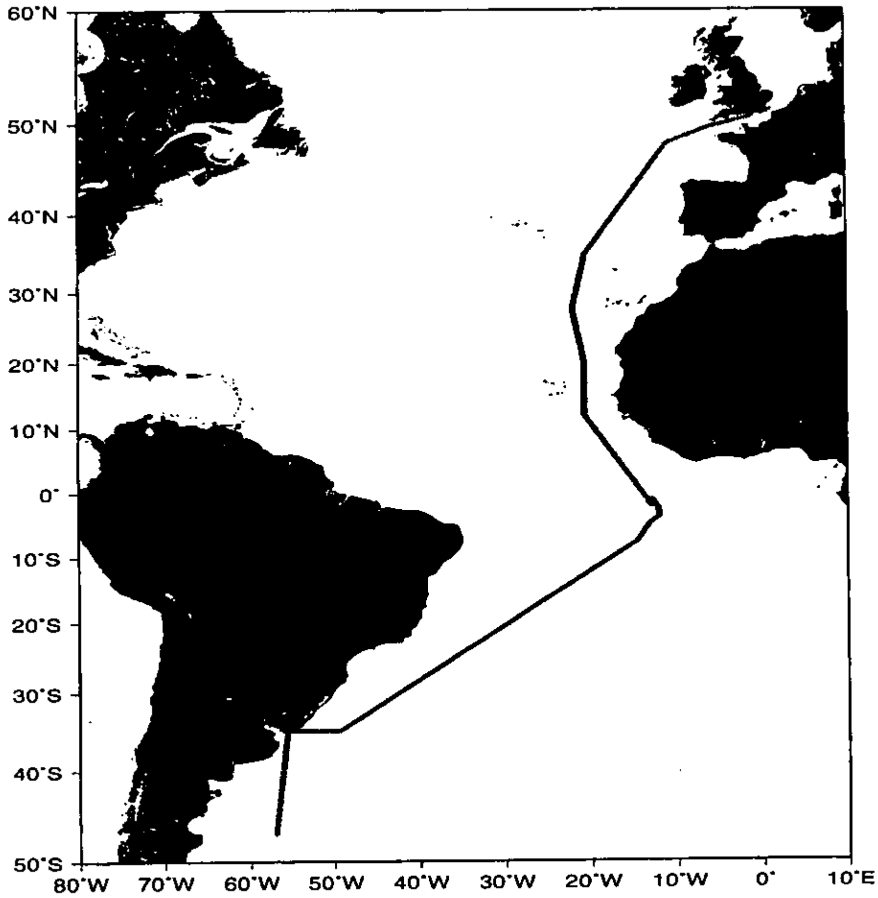

Figure 1. The ship track.

2. Instrumentation

The SOC Meteorology Team instrumented the JCR with a variety of meteorological sensors, plus a GPS navigation system. The mean meteorological sensors (Table 1) measured air temperature and humidity, air pressure, sea surface temperature, incoming shortwave (300-3000 nm) radiation and incoming longwave (4-50 micron) radiation. The surface fluxes of momentum, heat, moisture and CO2 were obtained using the fast-response instruments in Table 2. The HS sonic anemometer provided mean wind speed and direction data in addition to the momentum flux estimates. The AutoFlux system also incorporates navigation instruments (Table 3) in order to obtain ship's position and to correct the meteorological data for ship speed and heading.

The positions of the instruments are indicated in Figure 2. Most of the instruments were mounted on the ship's foremast in order to obtain the best exposure. The psychrometers and the fast response sensors were all located on the foremast platform and the radiation sensors were mounted on the "bird table" at the top of the foremast extension. The heights relative to the ship's waterline of the instruments on the foremast platform were; HS sonic anemometer, 15.75 m; psychrometers. 15.40 m; sonic temperature sensor, 15.75 m (both positions); IFM H2O/CO2 sensor 15.55 m (first position) and 15.30 m (second position). The sonic temperature and the IFM sensors were both moved on day 277 at around 1200 GMT.

The sea surface temperature (sst) "soap" (thermistor) was trailed over the port side of the ship (not the starboard as illustrated). The Woods Hole hull contact sst sensor was located in the void space next to the transducer space on the starboard side of the ship, about 3.5 m below the water line.

Sensor	Channel, variable name	Address	serial no.	Calibration $Y = C0 + C1*X + C2*X^2 + C3*X^3$	Sensor position	Parameter (accuracy)
Psychrometer	1 pds2	$ARD	IO2002 DRY	C0 -10.10419 C1 3.687167e-2 C2 4.437374 e-6 C3 -1.244586-10	Foremast platform. To stbd of HS sonic.	wet- and dry-bulb air temperatures, and humidity (0.05°)
Psychrometer	2 pws2	$ERD	IO2002 WET	C0 -10.15374 C1 3.847717-2 C2 2.047162-6 C3 -1.487345-10		
Psychrometer	3 pdp1	$VRD	IO2003 DRY	C0 -10.27104 C1 3.757243 e-2 C2 3.514678-6 C3 -8.593494-10	Foremast platform. To port of HS sonic.	wet- and dry-bulb air temperatures, and humidity (0.05°)
Psychrometer	4 pwp1	$WRD	IO2003 WET	C0 -10.11169 C1 3.79443e-2 C2 3.070856 -6 C3 -6.940979-10		
SST "soap" to day 269 10:50	5 soap sst	$XRD	PD0002/52	C0 70.01189 C1 -0.1188988 C2 1.404794e-4 C3 -1.003271e-7	Over port side of foredeck	sea surface temperature (0.1°)
SST "soap" from day 269 10:50	5 soap sst	$XRD	PD0005/53	C0 71.34180732 C1 -0.127521707 C2 1.57588211e-4 C3 -1.172824837e-7	Over port side of foredeck	sea surface temperature (0.1°)
Eppley LW Dome	6, Td1	$HRD	31170	C1 1	foremast top forwards position	incoming LW radiation
Body	7, Ts1	$QRD	31170	C1 1		
Thermopile	8, E1	$2RD	31170	C1 1		
Eppley LW Dome	9, Td2	$BRD	27225	C1 1	foremast top aft position	incoming LW radiation
Body	10, Ts2	$6RD	27225	C1 1		
Thermopile	11, E2	$CRD	27225	C1 1		
Kipp & Zonen SW	12 SWm	$1RD	27225	C1 1	foremast top, port side	incoming SW radiation
Vaisala Pressure	13 press	n/a	ptb220	1	UIC	air pressure
WHOI hull sst	sstMEAN	n/a		n/a	void space	sea surface temp.

Table 1. The mean meteorological sensors. Left to right, the columns show; sensor type, channel number and variable name, rhopoint address, serial number of instrument, calibration applied, position on ship, and the parameter measured.

Sensor	Program	Location	Data Rate	Sections	derived flux
Gill Horizontally Symmetrical Research Ultrasonic Anemometer	gillhs	Port side of foremast platform	20 Hz	64	momentum and heat
Gill dedicated sonic temperature sensor	stemphs	Port (to day 277 12:00) then stbd side of platform	20 Hz	64	heat
IFM IR H20/CO2 sensor	ifmhs	Port side of foremast platform	10 Hz	32	H2O and CO2

Table 2. The fast response sensors.

Instrument	Acquisition program	Position	Sampling rate	Parameters
CSI LGBX - PRO GPS receiver	gps6	aerial on aft rail of wheelhouse deck	1 or 0.5 Hz	GPS time, lat, lon, sog, cog and QC information
KVH fluxgate compass	gps6	UIC lab	1 Hz	ship's heading (magnetic)

Table 3. The navigation instruments.

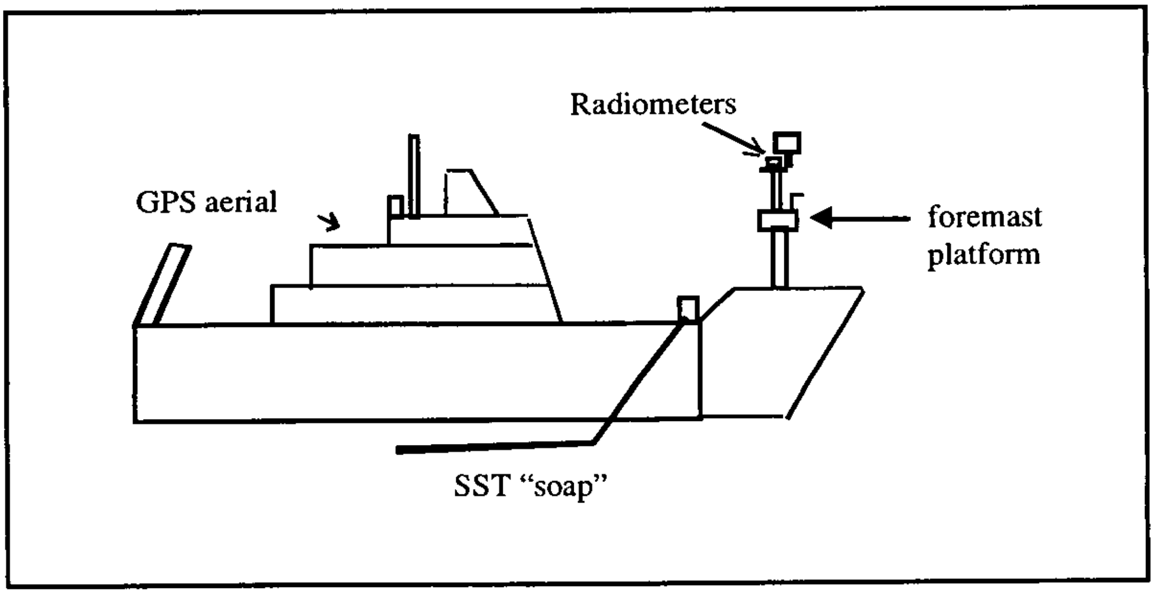

Figure 2a. Schematic of the instrument locations.

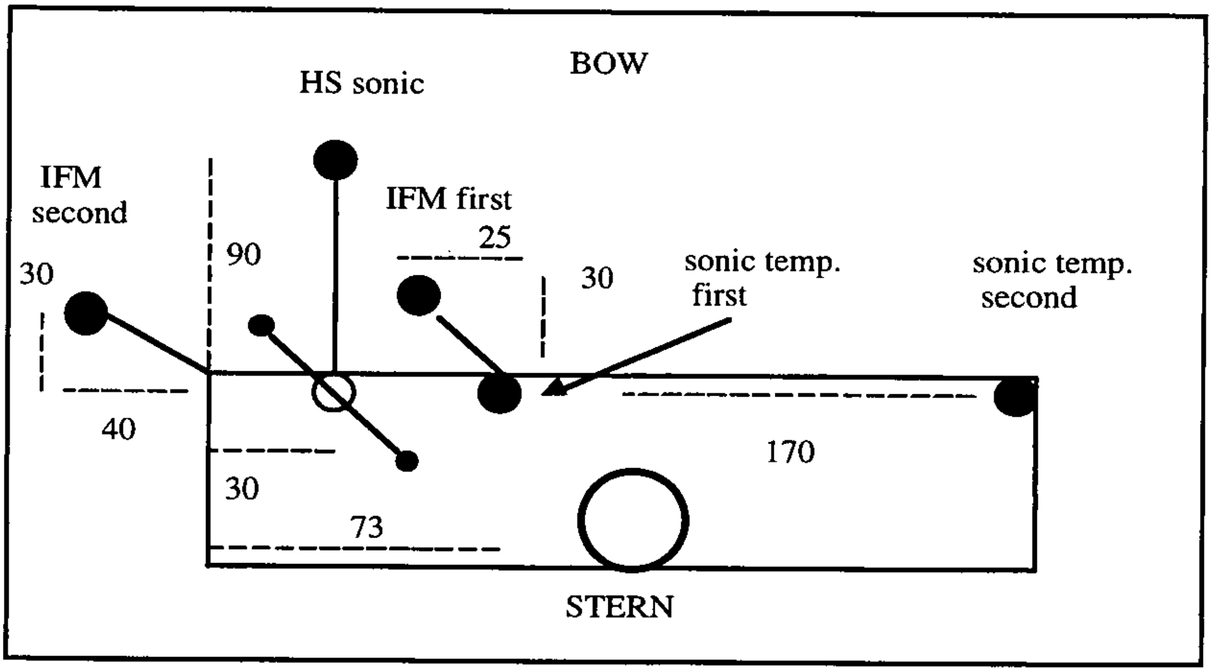

Figure 2b. Schematic plan view of the foremast platform, showing the positions of the fast response sensors (large black circles) in their initial ("first") and final ("second") positions. The two psychrometers are also shown (small black circles). Distances (dashed lines) are given in cm.

3. The AutoFlux logging system.

3.1 System management

All the SOC instruments were logged via the AutoFlux system (Pascal *et al.,* 2000). The exception to this was the WHOI hull sensor which was only received at SOC on the day of departure to the ship. The hull sensor was initially logged via a PC, but a UNIX management program was written and the sensor was integrated into the AutoFlux system on day 272. The AutoFlux system was based on one Unix workstation, named "southerly" (SO). A second identical workstation ("southeasterly", SE) was used for system development. Both workstations were networked but were set up in stand-alone mode and not integrated into the ship's system. Each workstation was cross-mounted with the other, allowing easy transfer of data and software between them and the sharing of devices installed on either station. Backups of both were performed weekly to CD (via the CD writer on SO) and exabyte (via the drive on SE). Table A1.1 (Appendix 1) lists the various modifications to the logging system that took place during the cruise.

The AutoFlux data acquisition system on SO ran multiple real time data acquisition and system programs, and this workstation was equipped with 8 extra serial ports for the multiple serial communications required. Both workstations had a variety of extra features, such as an auto-boot function and other system software designed to make the data acquisition as robust and reliable as possible. These applications were;

Powerchute:- Both systems were attached to uninterruptible power supplies (UPSs) which were managed by UPS powerchute software. This monitors UPS loads, utility supply etc. and includes a background process which provides orderly shutdown of the host computer in the event of an extended AC power failure.

Program Monitor:- Runs the data acquisition programs and continues to monitor that they are currently active. If an acquisition program crashes it is automatically re-started and an indicator is set. As additional data analysis programs were written and implemented these were also managed by the Program Monitor.

Time Sync:- This program acquires time from the GPS receiver and adjusts the workstation time if the error is greater than 1 second. Jumps greater than 10 seconds are flagged and control is passed to the user before any adjustments are made.

3.2 Data acquisition

Data were acquired continuously throughout the cruise using various logging programs on SO. These were;

"Gmet2" – This acquires the mean meteorological variables and was set up to sample the 13 channels of data listed in Table 1. Each sensor is attached to a Rhopoint module which converts the sensor output into digital data, and communicates it to the logging system via an RS485 network. The sensors were interrogated once every 10 seconds.

"Gillhs", "stemphs" and **"ifmhs"** – These programs logged and processed data from the HS sonic anemometer, the sonic temperature sensor and the IFM fast-response H2O/CO2 sensor respectively. The programs are very similar. To take the HS sonic as an example, 64 sections of data were obtained every hour, each section consisting of 1024 data samples which are output from the anemometer at a rate of 20 Hz. At the end of the 64 sections the data are processed to produce spectra and quality control parameters. The different data rates of the three instruments and the number of sections obtained every hour are listed in Table 2.

"GPS6" - This managed the GPS differential navigation system and the fluxgate compass. Data were logged continuously at a rate of 1 Hz. This data rate was unnecessarily high and was reduced to 0.5 Hz on day 276.

"acm" - This was the UNIX management program written for the WHOI hull sensor. This sensor communicates data via two modems, one placed near the sensor and the other placed in the Gravimeter Room. The two modems communicate acoustically via the ship's frame. From the Gravimeter Room the data were transmitted via the ship's scientific wiring. To conserve battery life, the modems were sent to sleep for 10 minutes at a time and then interrogated for sea surface temperature data from the hull sensor, which returned three values on each interrogation.

3.3 Data processing and fluxes

The following UNIX scripts were written during the cruise in order to process the data streams and produce the surface fluxes. These scripts utilise a suite of "pexec" FORTRAN programs. The scripts were managed by the CVI program "scp" which ran them hourly (except for "scrp.daily" which is run once a day).

"scrp.amet" – reads the calibrated mean meteorological data into a PEXEC file, applies basic quality control criteria and selects which psychrometer data to use. Also calculates the longwave radiation from the 3 channels output by the Epply sensors.

"scrp.anav" – reads the GPS and gyro information into a PEXEC file and converts heading and direction variables into north and east components prior to averaging.

"**scrp.HULL**" – reads the WHOI data into a PEXEC file and applies basic quality control criteria.

"**scrp.HS**" – reads the "*.mws" summary files from the HS sonic anemometer into a PEXEC file.

"**scrp.IFM**" - reads the "*.mws" summary files from the IFM sensor into a PEXEC file.

"**scrp.STEMP**" - reads the "*.mws" summary files from the sonic temperature sensor into a PEXEC file.

"**scrp.flux**" – merges the 6 separate data streams above into one file (averaging the mean meteorological and navigation data, and interpolating the WHOI sst data). If any data streams are absent they are replaced by dummy data files. Further quality control is applied and then true wind speed, true wind direction and surface fluxes are calculated.

"**scrp.plot**" – writes out an ASCII file of processed data, fluxes and quality control parameters for use in the AutoFlux display and the ORBCOMM message.

"**scrp.daily**" – appends the hourly files from each data stream and the hourly flux files into separate daily files which are moved to an archive directory. The previous day's hourly files are then removed once the daily files have been created successfully.

4. Ship data streams

Some of the ship's data streams were logged for comparison with the AutoFlux data. These data streams were;

adcp	(acoustic doppler current profiler - to correct wind speed relative to surface currents)
anemom	(ship's anemometer on the "bird table")
dop_log	(doppler log - to correct wind speed relative to surface currents)
em_log	(electromagnetic log - to correct wind speed relative to surface currents)
gps_nmea	(navigation stream - to check AutoFlux navigation system)
gyro	(gyro compass - to check AutoFlux compass system)
oceanlog	(thermosalinograph data plus air pressure and other mean met data)
CTD	(temperature channels obtained in order to calibrate the other sst sensors)

Initial examination of the ship's data streams showed that;

1) The adcp did not produce sensible data while the ship was underway, and the data did not improve sufficiently to be useful while on station.

2) The doppler log worked intermittently to start with and was then turned off.

3) The em log has yet to be examined, but, as it only measures one component of ship velocity relative to the water and there is a lack of comparison data due to the failure of the adcp and doppler log, it's usefulness will be very limited.

4) The ship's anemometer worked (Section 7.3)

5) The ship's navigation data streams had no problems beyond initial time jumps when the ship's clock was being set. The Level C time stamp occasionally produced time jumps around midnight due to rounding errors when converting between seconds and decimal jday. A comparison with the AutoFlux navigation data is given in Section 7.3.

6) The oceanlogger data were primarily logged for the sea surface temperature from the thermosalinograph (TSG) which will be discussed in Section 7.1 However, it was noticed that neither the PAR sensor nor the humidity sensor were working. Both of these instruments need attention, as does the junction box on the foremast platform.

5. Visual cloud observations

Two independent sets of visual cloud observations were made every hour by a) the ship staff on the bridge, and b) by the SOC staff (supplemented by early morning obs by Don Bonner, Pippa Bradbury and Steve Mee). These were used as part of a separate project aimed at parameterising the downwelling longwave radiation in terms of cloud cover and possibly type. Initial results are shown in Section 7.2.

6. Instrument problems and system downtime.

Data logging was begun on day 256.0 while still in Grimsby, and continued during the port call in Portsmouth (day 257 from 07:00 to 20:00). The system was stopped for data backups. These took place during days;
262 (12:00 - 14:20)
269 (13:00 - 14:00)
275 (18:00 - 21:00)
285 (13:00) - Montevideo. System off while in port. Restarted on 287 (19:00)
290 (15:00) - system off
Other system interruptions are listed in Table A1.2 in Appendix 1. The system performed reliably throughout, with interruptions to the logging caused only by system modifications or backups.

The battery in the **WHOI hull sensor** went flat on day 275 at around 06:00. This was a new battery at the start of the cruise and should have lasted for 6 months. Access to the sensor in the void space was obtained while on the CTD station on day 272 at 11:00 and the dead battery was replaced with the spare. The system was back on line at 12:20. The batteries in the remote modem (in the void space) gave out around 03:00 on day 284. These were replaced on day 285 when the ship arrived in Montevideo. Apart from these problems with the batteries, the system functioned very well throughout the cruise. The success rate for a returned sst measurement when the sensor was interrogated was over 95 %. Table A1.3 in Appendix 1 lists problems and developments for both the WHOI hull sensor and the SOC "soap".

The SST **"soap"** data suggested a near-surface cooling which reached a maximum around 15:00 on successive afternoons during the early part of the cruise. This was shown to be a spurious signal (Section 7.1) caused possibly by heating of the electronics unit on deck. The soap was replaced by a different sensor and electronics unit on 269 at 10:50. During the night of day 271/272 the electronics unit was ripped from its support, presumably by seas taken on over the bow, and the connector to the soap itself became detached. The soap was brought in board by Luke Trussler during the night. The connector was repaired and the same soap re-deployed on day 272 at 13:40.

The starboard **psychrometer wet bulb** dried out periodically, and had to be manually wetted to make the wick work. This did not cause analysis problems because the processing automatically compares the two wet bulb values and uses the lowest available.

The **IFM H2O/CO2** sensor hung periodically (Table A1.4 in Appendix 1). System checks were implemented which reduced the frequency of this problem, but further modifications need to be made. The mirror and lenses were cleaned every day by jets of distilled water which could be activated from the UIC. The effectiveness of this has yet to be judged.

The **HS sonic anemometer** data acquisition would lose sync periodically, but this would only affect one 1024 sample section at a time, with sync usually being re-established on the next section. Modifications were made to the serial port configuration file to increase the default buffer size from 64 bytes to 1024, but this failed to cure the problem.

7. Initial results.

7.1 Sea surface temperature measurements.

There were four sst sensors in use; the CTD (various depths, accuracy of 0.001°), TSG (intake at 7 m, accuracy 0.01°), soap (surface, accuracy 0.1°) and WHOI sensor (depth of 3.5 m, accuracy unknown). From day 259 to 266, the soap was raised to the surface during the second CTD cast of the day (around 11:00 GMT), but for the first cast at around 05:00 the soap was not raised and would sink to a depth of 4 to 7 m. The CTD data from the first 10 casts were each averaged into ten 1m depth bins, from zero to 10 m. The files included data from both the up- and the down-casts. The depth bins spanned a time period of around 30 seconds, and this interval was used to average the 10 second values from the soap.

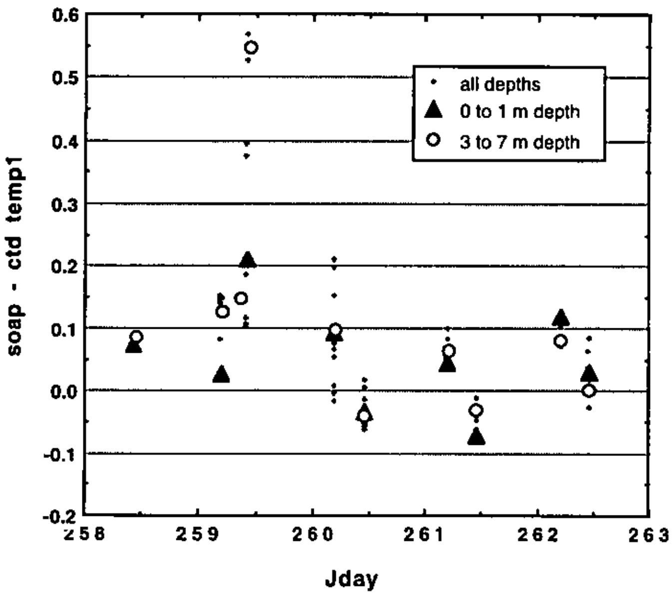

Figure 3. Soap - CTD temp1 sst differences for the first nine CTD casts.

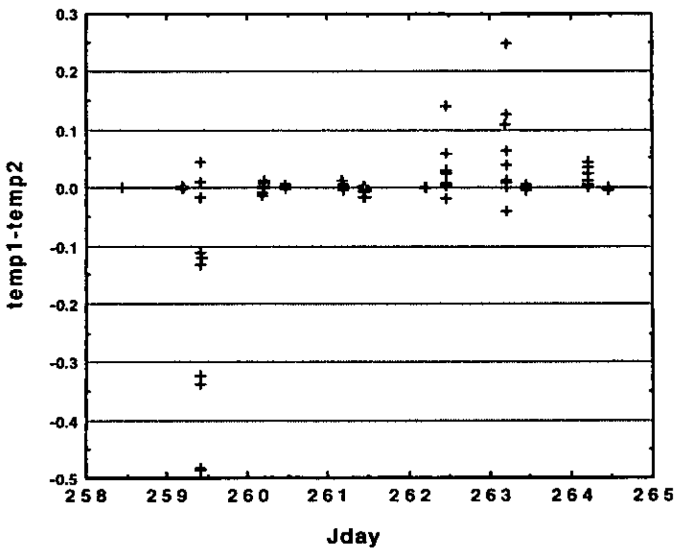

Figure 4. Difference in the CTD sensor temperatures against Jday.

Figure 3 shows the difference between the soap and CTD (temp1 channel) temperatures from the various depths. The data is scattered by about 0.1°, but there is not enough data to show any significant offset. The large difference which occurred during day 259 was thought to be due to a problem with the CTD rather than the soap data. Figure 4 shows the difference between the sst data from the two temperature sensors on the CTD.

The two sensors usually agree to within 0.003° but there are periods when the difference reaches 0.5°. A -0.5° offset in the CTD temp sensor 1 would be consistent with the disparities seen in Figures 3 and 4. This offset is confirmed by the comparison between the ship's thermosalinograph (TSG) temperatures and that from the CTD temp1 sensor (Figure 5). However, the scatter which occurs in Figure 4 during days 262 and 263 does not occur in either the soap or TSG comparisons, which suggests that on these occasions the CTD temp2 sensor may be at fault. This is confirmed in Figure 6 which shows the difference between the TSG and the CTD temp2 sensor. Finally, replaying the CTD casts showed that on cast 3 (day 259) the temp1 channel on the upcast lagged behind the temp2 channel. It was concluded that on this occasion the pumped flow to the temp1 sensor may have become blocked. No further examination of the CTD casts were made during the cruise, but it is recommended that both channels should be examined for every cast to check for recurrences of the problem.

A direct comparison between the TSG and the soap is shown in Figure 7. It can be seen that the difference between the two varied with time of day. As the day progressed, the soap sst became increasingly colder compared to the TSG, reaching a maximum offset of -0.2° at around 15:00 GMT. This is the opposite trend which would occur if the water temperature at 7 m stays relatively constant, and the surface waters are heated up during the day. Also shown is a comparison of the soap sst with the WHOI sst for one day; the same trend is seen which confirms that it is due to the soap data rather than the TSG. The cool surface "skin effect" is only seen in the first few microns, and can not be the cause of the cooling seen by the soap at a depth of a few cm or more. It was thought that there may have been a problem due to heating of the soap electronics unit on deck. This will not be confirmed until post-cruise calibrations have been performed. However, the AMT PSO kindly agreed to perform an extra CTD dip during the afternoon of day 268 at about 15:00 which confirmed that the surface cooling effect was indeed spurious; repeated shallow surface profiles with the CTD proved that there was no surface cooled layer.

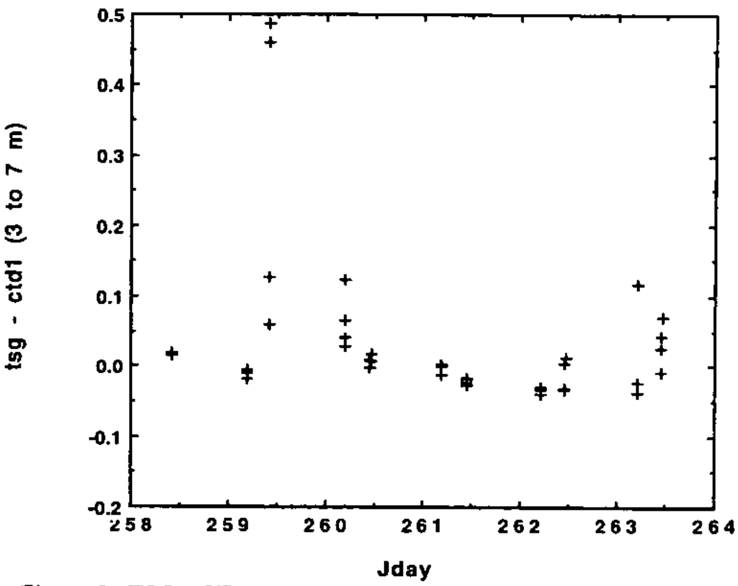

Figure 5. TSG - CTD temp1 sst differences between 3 and 7 m.

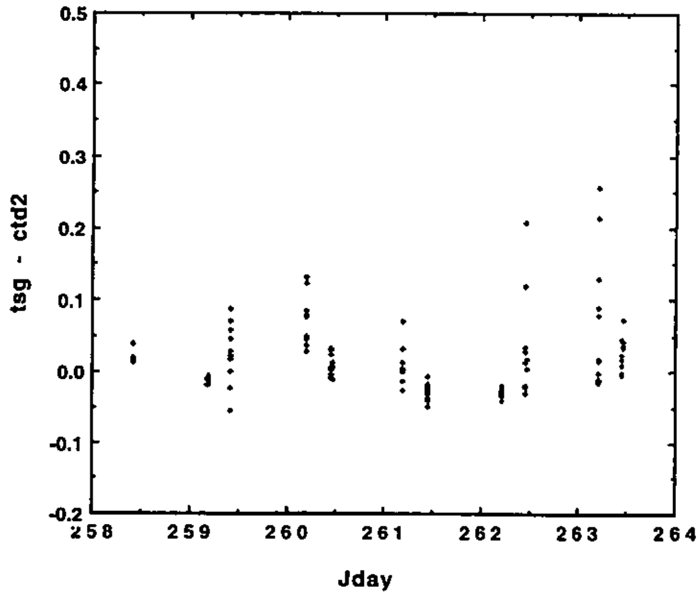

Figure 6. TSG - CTD temp2 sst differences against time.

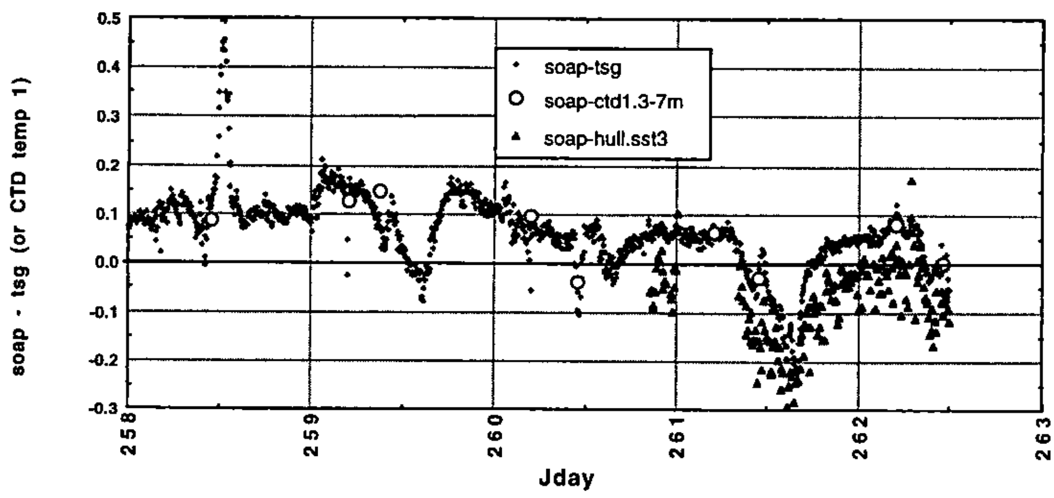

Figure 7. Soap - TSG ssts (crosses) and Soap - CTD1 (open circles) at a depth of 3 to 7 m and Soap -WHOI sst1(triangles) at a depth of 3.5 m.

The night-time offset of about +0.05° in the soap data may be real. Post-cruise comparisons of soap night-time surface data (obtained while the ship steams) with that during the 05:00 CTD stations during which the soap sinks to a few meters or more should confirm this.

Discounting periods where the CTD temperature sensors behaved erratically, the conclusion drawn from this initial examination are;

a) The two CTD sensors agree to within 0.003° (s.d. 0.010°).

b) The TSG data reads about 0.01° high (s.d. 0.03°)

c) The soap sst is scattered and depends on both depth and time of day.

Post-cruise analysis of the data will be done to examine the various sensors for time drifts and/or temperature-dependent offsets.

The fourth sst sensor was the prototype hull contact system, kindly loaned to SOC by Dave Hosom of the Woods Hole Oceanographic Institute. This will be the main sst sensor for future deployments of the AutoFlux system, especially on merchant ships which do not have a TSG and from which it would be impractical to deploy a "soap". The hull sensor is attached magnetically to the inside of the outer hull (about 3.5m below the water line) and communicates with the AutoFlux logging system via acoustic modems. The TSG data is used here as the standard of comparison for the WHOI sensor since 1) it was also at a depth of more than a meter or so, 2) it compared better with the CTD data than the soap did. Figure 8 shows a scatter plot of the three sst values obtained from the WHOI sensor every 10 minutes against the TSG sst data. It can be seen that the WHOI sensor overestimates the SST by about 0.1°. Again, post cruise comparisons of WHOI sensor data with the full set of CTD surface temperatures will be performed to examine the WHOI sensor for time- and/or temperature-dependent drifts.

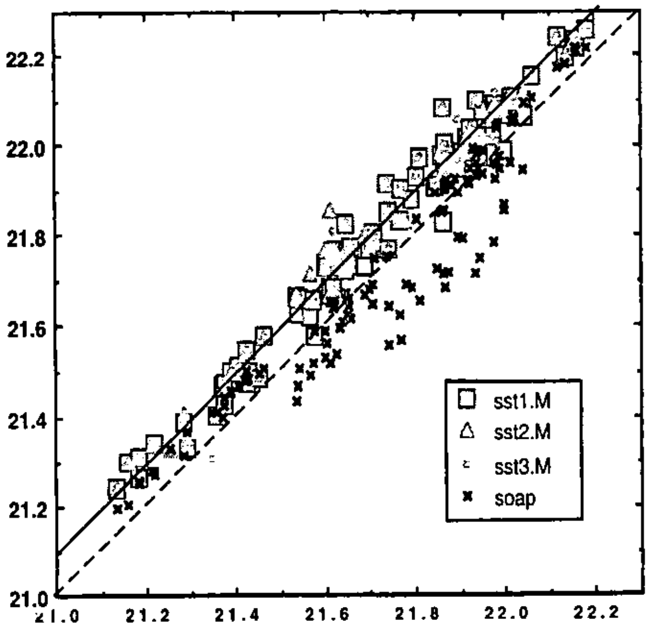

Figure 8. Comparison of the three sst temperatures from the WHOI sensor with the TSG data.

7.2 Longwave parameterisation from cloud obs.

The two independent sets of hourly cloud obs were compared. More than 50% of the coincident obs agreed exactly for total cloud fraction, and 80% agreed to within one okta. Obs which disagreed by more than one okta were discarded in this initial analysis. The total cloud fraction was used to derive a downwelling longwave radiation flux (Josey *et al.*, 1997) and this is compared in Figure 9 to the measured downwelling longwave radiation (Pascal and Josey, 2000) from one of the Eppley pyrgeometer sensors on the "bird table". The comparison is good across most of the longwave range encountered.

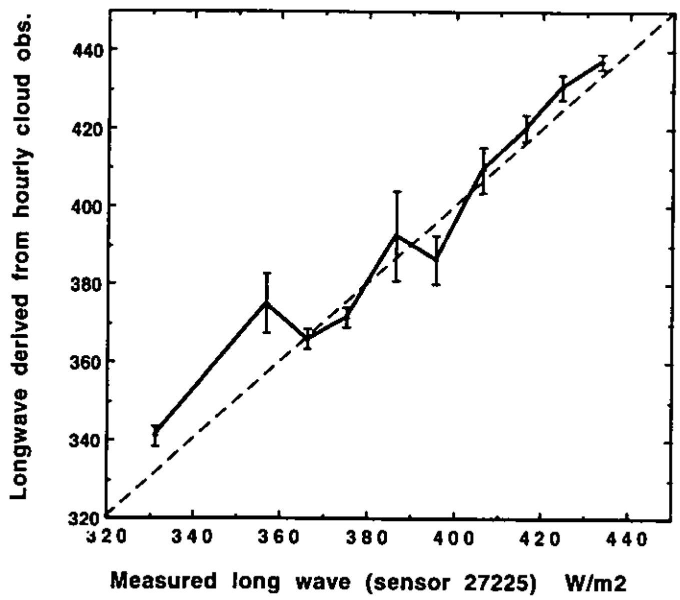

Figure 9. Comparison of longwave radiation derived from the hourly cloud observations against that measured by the Eppley instrument.

7.3 Mean met parameters

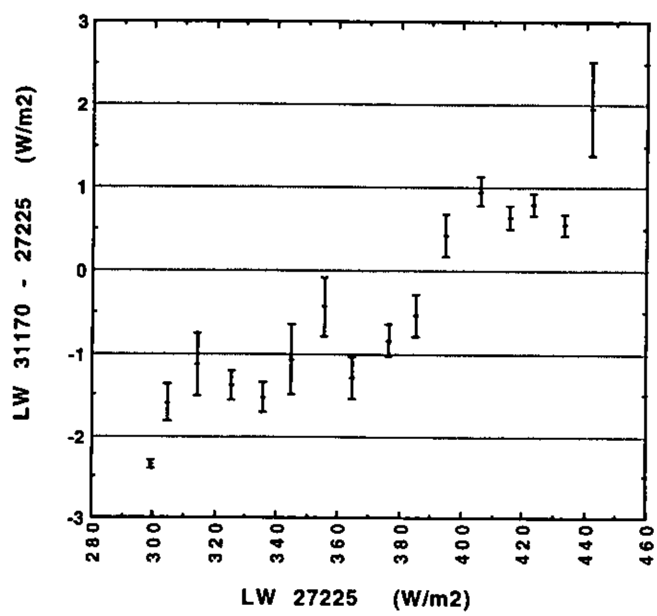

Figure 10. The difference in longwave radiation from the two pyrgeometers. The error bars indicate the standard deviation of the mean.

An initial comparisons of the two **pyrgeometers** suggested that the SOC calibration value of 4.42 for the sensitivity for sensor 27225 was too high. Using the manufacturer's value of 4.17 resulted in a better agreement between the two sensors. This is shown in Figure 10, where the mean difference between the two pyrgeometers is averaged against downwelling longwave radiation. There is still a longwave-dependent trend, but the over-all agreement to within 3 W/m^2 is excellent.

A comparison of **air pressures** from the ship's digital barometer with those from the AutoFlux barometer gave good agreement, with the ship barometer reading 0.04 mb higher on average (standard deviation 0.05 mb). Both instruments are situated in the UIC lab and neither have a correction applied for height above sea level (7 m).

A comparison between the ship's **air temperature** sensor and the dry bulb temperature from the psychrometers shows that the ship's sensor under-estimates the temperature by 0.4 degrees on average (s.d. 0.1 degrees). During the 1999 ARCICE cruise to the Arctic, the ship's sensor underestimated by 0.8 degrees (s.d. 0.2) which suggests a temperature-dependent calibration error on the ship's sensor. The difference between the two psychrometer dry bulbs was 0.03 (s.d. 0.09).

Data from the ship's **anemometer** were compared to that from the HS sonic anemometer. It was thought that the HS anemometer was not oriented exactly for-aft, and that it was pointed to port by about 5 degrees. This was confirmed by a comparison of relative wind direction from the two instruments, which suggested a 7 degree offset on the HS sonic relative wind direction for winds directly onto the bow, i.e. the relative wind directions from the HS overestimate by 7 degrees. A comparison of relative wind speeds show that the ship's anemometer reads high by about 6% compared to the HS. The ship anemometer is mounted at a height of 20 m whereas the HS is at 16 m. This height difference would result in the ship anemometer reading high by 3 % (due to the logarithmic vertical profile of wind speed), i.e. it is thought that the ship anemometer has a calibration error of about 5% (the HS sonic was calibrated prior to the cruise).

7.4 Navigation systems

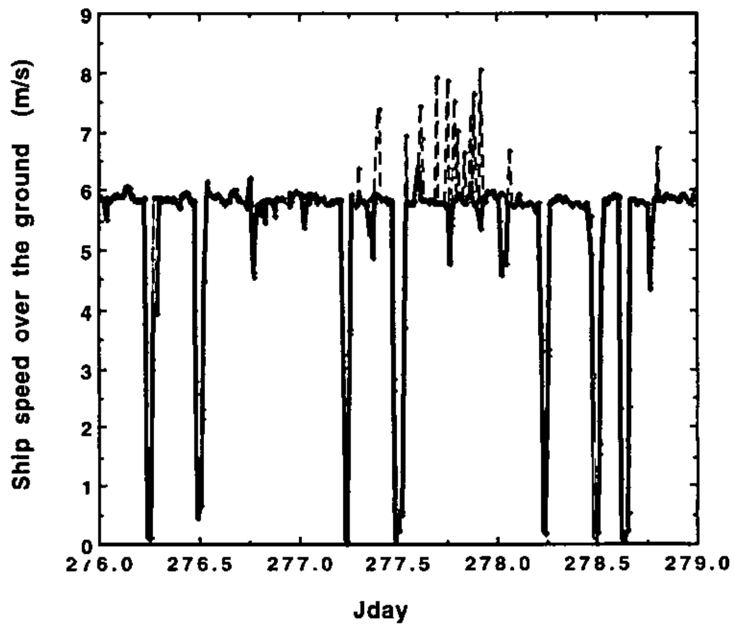

Figure 11. Ship speed over the ground from the ship's GPS (solid line) and the AutoFlux GPS (dashed line).

A comparison of the ship's heading from the gyro (true heading) data stream with that from the AutoFlux fluxgate compass (magnetic heading) showed reasonable agreement in the mean. Fifteen minute averaged data showed a scatter of 8 degrees (standard deviation). Ship speed over the ground from the nmea data stream and the AutoFlux GPS agreed very well on average (to within a few cm/s). However, there was one period when the two differed by up to 2 m/s. This is shown in Figure 11, which displays a time series of ship speed from the two systems from day 276 to day 279. It can be seen that the data from the AutoFlux navigation system is overestimating by up to 2 m/s during the latter part of day 277. This period coincided with the time that alterations were made to the sampling rate of the AutoFlux navigation system, but further investigation is needed to confirm the cause of the erroneous speeds.

8. Summary.

By the fourth week of JR52 the system was automatically producing hourly direct measurements of the air-sea fluxes and was sending summary messages of the data back to SOC via the ORBCOMM satellite communications system in near real time.

Major system developments achieved during the cruise included;

> The ORBCOMM communication system was fully integrated into the AutoFlux system and automatically sent hour summary data back to SOC. The ORBCOMM management program "orby" performed reliably.
>
> The WHOI sea surface temperature system was installed successfully and was also fully integrated into the AutoFlux system using the program "acm".
>
> The system time synchronisation program was merged into the GPS management program in order to free up a serial port which was required for the ORBCOMM system.
>
> A suite of nine UNIX scripts were written to process all the data streams, merge them together and calculate the surface fluxes. Execution of these scripts was managed by the program "scp", which ran the UNIX scripts every hour.

Other system developments are listed in Table A1.1 in Appendix 1.

A new full-screen display was produced to plot the calculated surface fluxes as well as the mean meteorological parameters in near-real time (using data which are 30 to 60 minutes old). This is illustrated in Figure 12. The performance of the prototype IFM H2O/CO2 sensor and the sonic temperature sensor will be examined thoroughly post-cruise, as will the quality of the fluxes produced by these instruments.

Time series of the mean meteorological conditions and the calculated surface fluxes are displayed in the Figures in Appendix 2.

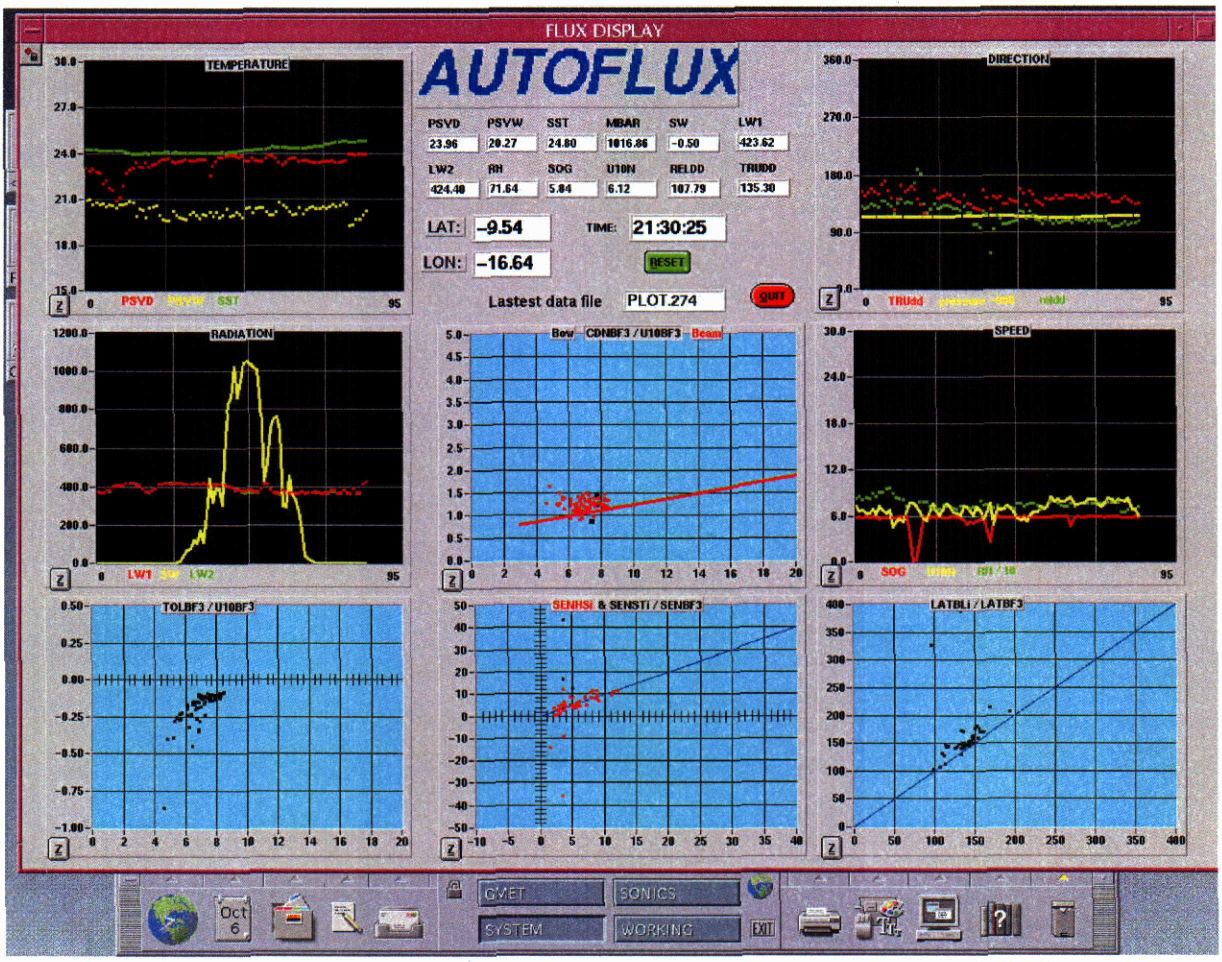

Figure 12. The real-time surface fluxes display, which is split into 9 panels. From left to right and top to bottom these are:-

1) A time-series (24 hours) of quality controlled wet and dry bulb air temperatures plus sea surface temperature from the WHOI system.

2) Digital data and the name of the data file used.

3) A time series of true and relative wind directions, plus air pressure (-900 mb).

4) A time series of downwelling longwave radiation from the two pyrgeometers and downwelling shortwave radiation from the Kip and Zonen sensor.

5) A C_{D10N} (the 10 m neutral drag coefficient) to U_{10N} (10 m neutral wind speed) scatter plot plus the Smith (1980) relationship as a reference line. Data obtained for relative wind directions within 30 degrees of the bow are shown as larger black points, and those outside this range as smaller red points.

6) A time series of ship speed over the ground, U_{10N} and the relative humidity (% / 10).

7) The atmospheric stability parameter, z/L, vs U_{10N}.

8) Sensible heat flux from the HS sonic anemometer (red) and the sonic temperature sensor (black) against the bulk sensible heat flux.

9) Latent heat flux from the IFM H2O/CO2 sensor vs the bulk latent heat flux.

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Appendix 1.

Table A1.1. List of system modifications.

day	System modification
261	Reset comms timeout for reading data to 0.1 sec when comms restarting. This is set to 5 sec while acquiring the SST and should have been reset afterwards.
262	Sonic temp program now does error checks and adds error bits to ".log" file. HS sonic program now plots PSD (rather than log PSD) so that spikes are more visible. Also done for both sonic temp and IFM sensors.
266	Both the Gmet and Navigation programs have been modified to make hourly data files which are stored in a daily directory.
271	HS sonic, IFM and sonic temp programs create ".mws" files hourly (rather than daily). Scripts to run these programs modified accordingly.
272	Flux processing script implemented. Script program modified to run Hullcom script, order now: 05 min - Navigation, Met, Hullcom 10 min - IFM, STEMP, HS 15 min - flux 30 min - flux display and ORBCOMM message
273	Modification to stc.conf file to increase the serial buffer 'drain_size' from 64 bytes to 1024 in the hop that this would make the HS sonic less likely to lose sync. Hullcom program altered to produce hourly data files, and this system integrated on southerly.
274	First attempt to run longwave/cloud obs program name bulklw.F.
276	scprog altered so that it manages to do the 2300 file of the previous day (needed day-1 as well as hour -1) Changed GPS nav program to incorporate the system time synchronisation. Altered time sync function to take 2 consecutive 10 sec time errors before setting an alert. GPS modified for 2 s (rather than 1 s) sample rate from GPS (program starts with line com write "$PASHsNME,PER,2\n" to set GPS output to 2 seconds). Data acquisition line also modified so that if comms "time out" then try again once (this will work for both 1 & 2 sec sampling)
278	GPS navigation program crashed, variable size error. Increased variable size and restarted.
279	Activate scripts to write ASCII flux data out to a file for AutoFlux display
281	Updated script program to run "daily" script. Updated ORBCOMM to read Plot.jjjhh file and transmit data hourly.
282	Changed scrp.flux to use pintrp.F on WHOI ssts - were getting absent data at start of the hourly file due to 10 minute sampling interval - this was making U10n absent in the 15 minute averages and making the plots messy.... Daily script not working as trying to update today's file not yesterday's. Program modified (now jday –1), and also includes check for first day of year i.e. jday(1) -1 equals 365. This of course also has to include leap years when jday will equal 366. ORBCOMM not working as running before plot script. Now set to 35 past hour and all OK.
284	ORBCOMM program altered to get pressure in mb-900 and RH/10

Table A1.2. List of events for system shut-downs, psychrometers and other instruments.

day, time (GMT)	System and other instrument events
256 0400	Sailed from Grimsby
257 0700	Arrived in Portsmouth LW sensors not good – OK after switching 10 kOhms resistors on in box in lab.
257 1900	Sailed from Portsmouth.
259 1100	System time slow by more than 10 s (may have been due to copying across large amounts of data). System clock correction overshot - reset manually.
260 0800	GPS "DIFF" (differential) was OFF
262 1200	Southerly stopped for backup. Restarted at 1417.
263 1216	Increased psychrometer fan power. Thought lack of flow to the stbd psy. was causing stbd dry bulb temp to read high by up to 0.5°. Increase in power made no difference.
264 1100	Up foremast. Psychrometer bottles little used, port psy had used more than stbd..
265 2030	Psy fan power lower still - one may be duff.
266 1300	Removed stbd psy fan (not working). 1340 new fan installed.
267 1045	Changed mean met sampling to 5 channels (meant to change to 5 sec sampling rather than 10 but cocked it up). Back to normal at 11:20.
269 0850	Southerly halted for data back up - restarted 1005
269 1257	Southerly halted again for further backups - restarted at 1358.
269	Noticed that stbd psychrometer wet bulb had not been wicking since the previous evening.
270 1330	Went up foremast to get the stbd psychrometer wet bulb to wick.
274	Starboard wet bulb drying out again in the early hours...
275 1800	Southerly halted for backups. Restarted 2055
277 1130	Up foremast. Wetted stbd wet bulb, wick was hard against bar inside so pulled more through, hopefully now will stay wet.
277 1235	Left foremast after MOVING SONIC TEMP SENSOR to stbd fore corner.
285 1200	Docked in Montevideo System halted 1300 for backups etc.
287 1400	Up mast - wetted wet bulb wicks, filled bottles etc.
287 1455	AutoFlux system restarted
287 1900	Sailed from Montevideo
287 200	Wet bulb not wicking despite manual wetting earlier in the day
288	Data from LWs had edit limits set too low/high, so have had unnecessary absent data in processed files since day 285 - will need to reprocess.
289 1555	Went head to wind (just for us) until 1705.
289 2135	ORBCOMM failed -"message not received"
290 1500	Wind light and from astern. Foggy. Stopped logging. system off.

Table A1.3. List of events for the "soap" and WHOI ("Hullcom") sst sensors.

day, time (GMT)	"Soap" or WHOI Hullcom event	comment
257 2100	Soap deployed	
259 1000	Soap lifted to surface during CTD station	
259 1230	Stopped Hullcom for software mods. Restarted about 1430.	
260 1100	Soap to surface during CTD station.	
261 0800	Hullcom stopped for mods. Started 0900	
261 1100	Soap to surface	
262 1100	Soap to surface.	
263 1100	Soap to surface	
263 0830	Hullcom stopped for mods. Started 1100	
264 1100	Soap to surface	
265 1100	Soap to surface	
266 1400	No CTDs. Took bucket temps.	Test for 0.2 deg changes with depth (cooler at surface).
266 1450	Soap on deck to adjust weights Back in 1515 ish.	Soap towed more deeply under water.
267 1045	Soap on deck about 1045. Temperature profiles with soap from 1050 to 1110.	Test for 0.2 deg changes with depth (cooler at surface).
268	Left soap to hang deep during both CTD stations.	
268 1500	Soap and CTD surface temp profiles from 1450 to 1525	Test for 0.2 deg changes with depth (cooler at surface).
269 1050	Soap PD002 and electronics 52 were replaced by PD005 and elecs 53. Cal file changed.	Suspected problem with heating of electronics unit 52.
270	Soap left full depth during CTD stations	
273 1800	Hullcom modified for hourly data files. Restarted at 1838 Crashed then ran OK from 1920 onwards.	
275 0615	Hullcom not working.	Modems OK. Problem with sensor.
276 1115	RWP to void space to replace sensor batteries. Restarted logging at 1220.	Batteries were new and should have lasted 6 months.
278 1110	Hullcom time reset. Modified to accept different cycle times.	
281 2130	ORBCOMM mods caused Hullcom to perform badly for an hour or so until problem solved.	When first run ORBCOMM looked at Hullcom serial port.
282 0100	Soap not working from midnight.	
282 0800	Ship side brought soap inboard. Seas had ripped electronics off support and disconnected cable	
282 1340	Connector repaired and (same) soap out.	

Table A1.3 (continued). List of events for the "soap" and WHOI ("Hullcom") sst sensors.

day, time (GMT)	"Soap" or WHOI Hullcom event	comment
284 0250	Hullcom remote modem batteries dying.	
284 2205	Soap brought inboard ready for arrival in Montevideo.	
285 1600	Hullcom remote modem batteries replaced in Montevideo.	
287 1800	Hullcom set to 10 minutes	
287 1940	Soap deployed (sailed 1900)	
287 2020	Hullcom program altered: flushes serial port when first activates read data.	
288	Hullcom data had edit limits set too low/high since day 285.	- will need to reprocess data.

Table A1.4. List of events for the IFM H_2O/CO_2 sensor.

day, time (GMT)	IFM H2O/CO2 event	comment
259 1154	washed lenses and mirror.	
260 0906	washed lenses and mirror.	
260 1500 260 1600	IFM failed to start at 1500 and again at 1600.	Program didn't crash, but seemed to fail to complete processing in time for 1500 - don't know why it didn't start at 1600.
260 1615	Program restarted.	
261 0942	washed	
262 0907	washed	
263 0600	Program hung.	Had completed the processing of the data run started at 0500 but failed to restart the data stream for the next period at 0600.
263 0820	Program halted, data stream checked with xterm / tip then restarted.	
263 1038	washed	
263 1330 to 1345	washed MANUALLY	reservoir had lots of water, should squirt for longer
264 1100 ish	washed MANUALLY	
265 1237	washed for 20 sec	
266 1230-1300	washed MANUALLY	
266 1700	Hung at start of data acquisition at 1700,	Quit program, start data with xterm, started program 1750
267 1126	washed	
268 1045	washed	
269 0955	washed	
270 0941	washed	
270 1340	washed MANUALLY	
271 0800	Failed to start at 0800 -	Quit program, start data with xterm, started program 1750
271 1255	New version of program for hourly ".mws" files launched.	Mws files had previously been daily.
272 1951	washed	
273 1053	washed	
274 1156	washed	
275 1100	Hung at start of acquisition.	Quit prog, used tip to verify data stream ok, then restarted prog.
275 1200	Hung at 1200. (OK at 1300)	
275 1107	washed	
276 1259	washed	
277 1130	washed MANUALLY	
277 1235	SENSOR MOVED FURTHER TO PORT	See Figure 2b
278 1335	washed	

Table A1.4 (continued). List of events for the IFM H2O/CO2 sensor.

day, time (GMT)	IFM H2O/CO2 event	comment
278 2100	Missed 2100 start time. Left it to see if it would catch the next hour - it did indeed.	due to measured humidity of ~300 g/m3? – may have had difficulty processing
280 1253	washed MANUALLY and braced sensor with string	
281 2207	washed	water reached the lenses or at least interrupted the path - head wind with relative speed of 18 m/s
282 1058	washed	
283 1806	washed	
284 0000 284 0300	0245 – saw that program had hung at 0000 trying to acquire data. Hung while "acquiring data" at 0300.	Quit program, ran xterm checked data stream ok then restarted.
284 1211	washed	
287 1400	washed MANUALLY prior to leaving Montevideo	IFM comms problem sorted when southerly re-booted.
287 1956	washed	
288 1159	washed	
288 1500	Noticed that H2O values OK on acquisition display, but become garbage when written to the "mws" data file. Problem caused by dimension of binary variable. Program modified and restarted at 1500.	Problem began on day 285 about 1130. Caused when the binary H2O data cast from double to short which has a maximum of 32768 which was exceeded by the reference value. Raw data OK and will be replayed post-cruise
288 1800	Noticed processed CO2 values low by about 50% compared to the real time display. The processed data had a different temp (20°) for the temp compensation value (display value 25°).	Will replay data with new software to use last hours air temp.
289 1521	washed?	no evidence on display that water was reaching path
289 1548	washed?	no evidence on display that water was reaching path

Appendix 2.

The following Figures show time series of 15 minute averages of the mean meteorological variables and the calculated surface fluxes. Fluxes were calculated using sst from the WHOI sensor and will be absent when this sensor was not working.

The first Figure shows data from the start of day 256 to the end of day 291;

Top panel - the wet (pw*) and dry (pd*) bulb temperatures from the two psychrometers plus sea surface temperatures as measured by the soap (sstsoa.M) and the virtual temperature from the dedicated sonic temperature sensor.

Middle panel - downwelling radiation from the shortwave sensor (SWm.M) and the two longwave sensors (LW*), plus air pressure (press.M) in mb.

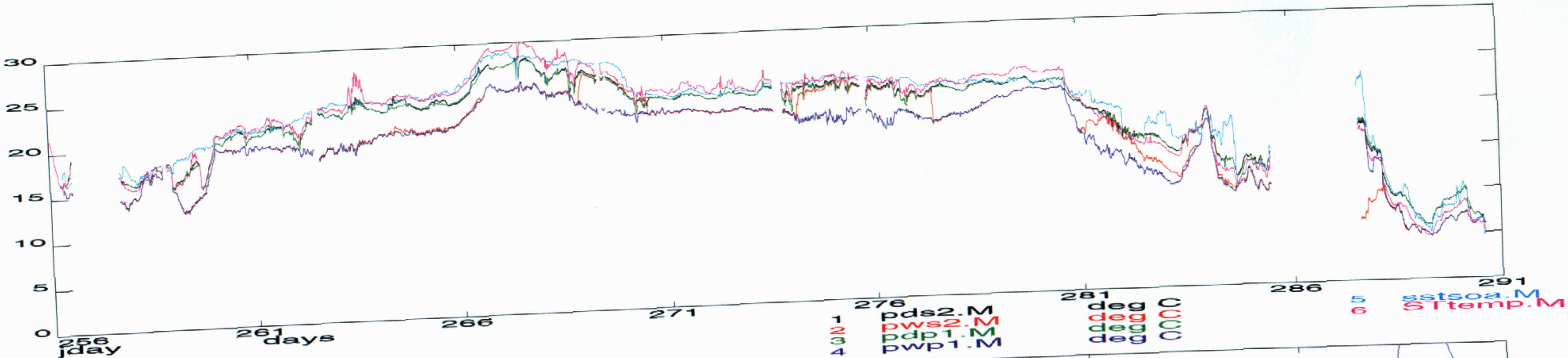
Bottom panel - sea surface temperature from the soap (sstsoa.M), the WHOI hull sensor (sstMEAN) and the TSG (sstem), plus the stability parameter z/L (scale –2 to 1 not shown).

The second Figure also shows data from day 256 to end of day 291;

Top panel - the 10 m neutral wind speed (U10BF3), the relative wind speed (spdENV) and the relative wind direction (reldd) where wind onto the bow is represented by 180 degrees.

Middle panel - Sensible heat fluxes from HS (SENHSi) and from bulk formulae (SENBF3) and likewise for the latent heat flux.

Bottom panel - Specific humidity from the psychrometer data (QA g/kg), mean H2O from the IFM sensor (H2O g/m3) and mean CO2 (CO2 g/m3) from the IFM.



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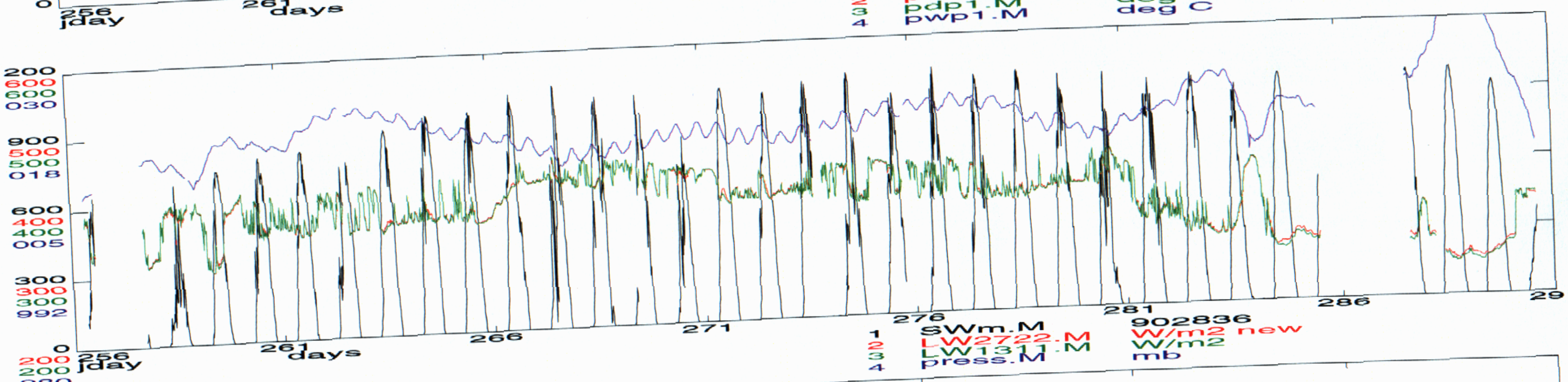

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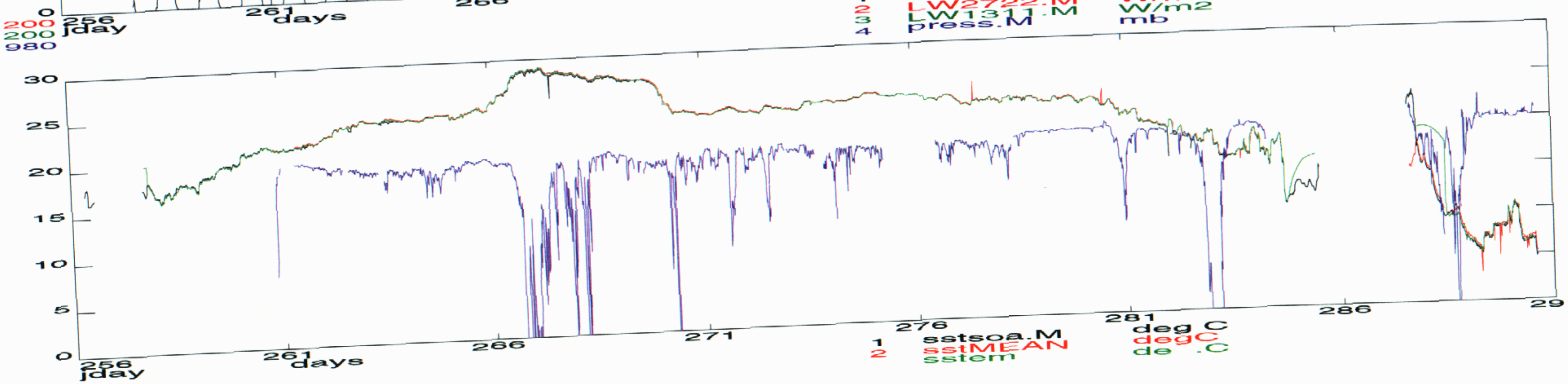
2 LW2722.M W/m2 new
3 LW1311.M W/m2
4 press.M mb



30
25
20
15
10
5
0
256
jday
261
days
266
271
276
281
286
291
1 sstsoa.M deg C
2 sstMEAN degC
sstem de .C


jday
days
256
261
266
271
276
281
286
291
1 U10BF3 m/s
2 spdENV m/s
3 reldd bow=180
1 SENHSi W/m**2
2 LATHSi W/m**2
3 SENBF3 W/m**2
4 LATBF3 W/m**2
1 QA g/kg
2 H2O gm^-3
m^-3