RESEARCH SUMMARY

CRUISE FR 1/93

Sailed	Townsville	2200	Thu	7 January 1993
Arrived	Rabaul	1400	Thu	21 January 1993
Sailed	Rabaul	1300	Fri	22 January 1993
Arrived	Townsville	1200	Tue	9 February 1993

HEAT FLUXES AND THE RESPONSE OF THE UPPER OCEAN DURING THE TOGA COUPLED OCEAN ATMOSPHERE RESPONSE EXPERIMENT

Principal Investigators

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February 1993

R.V. Franklin
National Facility
Oceanographic Research Vessel

Research Summary
Cruise FR01/93

Itinerary

Sailed	Townsville	2200	Wed 7 January 1993
Arrived	Rabaul	1400	Thurs 21 January 1993
Sailed	Rabaul	1300	Fri 22 January 1993
Arrived	Townsville	1200	Tues 09 February 1993

Principal Investigators

Dr T. J. McDougall, CSIRO Division of Oceanography
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Associate Investigators
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Cruise Objectives

(i) To measure all components of the heat budget of the surface mixed layer in the equatorial western Pacific, to an accuracy (measured over several days) of order 10 W m^{-2}, and to use the resulting estimates of heat fluxes in testing algorithms for the different heat flux terms.

(ii) To observe the response of the upper ocean to the surface injection of freshwater due to precipitation and to the arrival of westerly wind bursts, by three-dimensionally mapping the temperature and salinity in a volume moving with the mean motion of the upper water, and to compare these observations to the results of a one-dimensional model of the water column driven by the observed heat and fresh-water fluxes.

(iii) To measure the turbulent fluxes of heat and salt in the upper 200 m of the water column following a near-surface drogued buoy.

(iv) To obtain accurate measurements of ocean skin temperature, for comparison with satellite-based SST algorithms.

(v) To obtain detailed measurements of temperature gradients on either side of the air-sea interface for studies of diurnal heating and mixing dynamics.

(vi) To inter calibrate our flux measurements with those of neighbouring research vessels and aircraft.

Personnel

Ship's Crew

Master	Paddy Lorraine
Mate	Dick Dougal
2nd Mate	Bryce Bathe
Chief Engineer	John Scott
2nd Engineer	Peter Harding
Elec. Engineer	Don Roberts
Bosun	Norm Marsh
AB	Blue Hughes
AB	Kristain Hallen
AB	Paul Sanhueza
Greaser	Phil French
Chief Steward	Steve Corridon
Chief Cook	Gary Hall
2nd Cook	Bob Clayton

Scientific Party

Trevor McDougall	CSIRO	Oceanography	Chief Scientist
Jan Peterson	CSIRO	Oceanography	
Stuart Swan	CSIRO	Oceanography	
Frank Bradley	CSIRO	Environmental Mechanics	
Peter Coppin	CSIRO	Environmental Mechanics	
Gary Miller	CSIRO	Environmental Mechanics	
John Bryan	CSIRO	Environmental Mechanics	
Lindsay Pender	CSIRO	ORV	
Ian Helmond	CSIRO	ORV	
Phil Adams	CSIRO	ORV	
Mark Rayner	CSIRO	ORV	
Yuzhu You	Flinders Uni		

Cruise Narrative

The first day at sea was very wet and this hampered work on the back deck but work proceeded in the ops room and in the electronics laboratory where the microfish was checked and partially assembled. The foremast instruments for bulk parameters were also installed. During the next night the disc of the Bunyip SparcStation died and work continued through the day (Saturday 9th January) to isolate the source of the problem. On Sunday Lindsay installed the disc from Peter Coppin's PC into the SparcStation. As this seemed to work, Peter Coppin in turn cannibalised the disc out of Stuart Swan's computer. This had the effect of delaying a full test tow of the Bunyip system which we had planned to occur before arriving in the IFA. Meanwhile the Environmental Mechanics team continued to install their instruments on the foredeck as the weather and the seas began to improve on Sunday 10th January. These instruments had been taken in after cruise FR09/92 for the Christmas break in Townsville as a protective measure against the oxide dust which was everywhere at the Townsville berth. The equipment consisted of two sets of eddy-correlation flux sensors, a mast and boom; net, short and longwave radiation sensors, and an array of high-quality meteorological instruments for calculation of the bulk fluxes. The later, intended to measure continuously throughout the cruise, were operational by the afternoon of 10 January; turbulence sensors were operational by 12 January.

In the early hours of Tuesday morning 12 January we began our first SeaSoar survey, involving six East-West legs of 25nm spaced 5nm apart in the Northern dimension. On the basis of this survey we selected a site to deploy the drifter. Figure 1 shows the temperature and salinity at a depth of 25 m during this survey. The place where we deployed the buoy is marked with a cross. This position has allowed for the movement of water between when it was sampled on the survey and when we actually deployed the buoy. A CTD station (#3) was taken at this site, the drifter deployed and SeaSoar put in the water by 0830 local time on Wednesday 13 Jan, in preparation for the overflight of the NCAR Electra. Then we did triangular tow patterns with SeaSoar following the drifting buoy for the next day. Triangular tracks with one side downwind, assures that the wind is over the boom two thirds of the time for flux measurement.

The following morning (Thursday 14th), after retrieving SeaSoar and doing a CTD, we were overflown by both the Electra and the Flinders University Cessna. This second set of triangular tow patterns were all done with one leg directed northward, thus ensuring that we were sampling the same water, drifting at the velocity of the buoy. The S-θ curves on these triangles suggested that SeaSoar was indeed surfacing outside of the ship's wake on the starboard side. During this period we tested the silverfish which had been modified since the last cruise by the addition of a larger tail-fin. In the relatively smooth sea it was barely under control at 8 knots. At 7 knots it towed well, but was therefore incompatible with the operational speed of SeaSoar. The new technique was to have the winch line completely slack, and to adjust the depth range with the towline. On Thursday night we had up to 20 knots of wind and also 41mm of rain. The temperature profiles showed that there had been significant vertical mixing, forming a well-defined mixed layer. There are also very sharp fronts of salinity in the top 10m. Just as SeaSoar was being recovered from this deployment, the meteorological boom collapsed and we spent several hours getting it back on board. The recovery operation proved to be quite complicated and it was very ably directed by Ian Helmond. Most of the sensors were back in operation on a shortened boom one and a half days later, thanks to the efforts of the ship's crew.

The foremast instruments were unaffected by this collapse and continued operating except for about 3 hours when power to the foremast was turned off. Bulk measurements continued regardless. For the rest of the cruise we had a 6.5 m boom instead of 10 m, but without the vertical section, i.e. with no more measurements of vertical θ and q gradients. In the event, this was an advantage during the post-Rabaul leg of the cruise when weather and sea conditions would have forced us to retract the boom (with its vertical section) to only a reach of 3 m.

The next deployment (deployment number 5) was begun in the early hours of Sunday morning. This was the fourth such set of triangular patterns translating with the drifting buoy. The wind blew sufficiently to cause a surface mixed layer and the S-θ curve had little spread on it as we steamed around our triangular race track. The sea surface temperature increased during the day and the characteristic slope of the near-surface S-θ diagram re-appeared with the temperature and salinity increasing over the top 6m. The ratio of their increases is probably set by the ratio of the evaporation rate to the sum of sensible plus latent heat. It was now that we had a sufficiently long time series that the graph of heat content versus time began to look similar to that based on the atmospheric fluxes based on bulk formulae. At the end of this deployment Ian noticed that the tow cable had frayed at the entrance to the SeaSoar, having broken two strands of the outside armour. This must be a fatigue problem due to vibration, and emphasises the need to keep flexible fairing on this section of cable.

Having re-terminated the cable, we re-deployed SeaSoar for the last day of data before turning for Rabaul. The S-θ curve on this series of triangles was different to that on the previous triangles. In the depths below 20m it was warmer. This was the first day that we did not see an afternoon effect. However there were patches of quite low salinity, and these patches were not very deep (<6m). This would indicate that there had not been much input of energy from the sun and atmosphere this day:- it had been cloudy all day. The flashing light on the buoy stopped working and it became hard to find. Consequently we did smaller triangles, 5 nm on a side rather than 9 nm, so that we could keep the buoy within radar range. The surface mixed layer was the deepest we had seen it on this cruise. It was 20 m at the beginning of the deployment and was 40 m deep at the end.

The cruise track for the first drift (drift #1) is shown in Figure 2. The overall drift was to the south west at an average speed of about 0.2 knots.

During the first half of the cruise we had the SeaSoar in the water for so much of the time that we had little opportunity to debug the microfish, this requiring both vehicles for the communications to be properly tested. On the transit to Rabaul on 20th January we deployed the complete Bunyip system for about an hour. The communications were not perfect but this deployment gave us some data to work with. The next day, just before arriving in Rabaul another of the discs on Lindsay Pender's computer crashed. Fortunately it responded to reformatting. Atmospheric flux measurement continued during the transit across the COARE IFA towards Rabaul.

During the passage into Rabaul Harbour, the Flinders Cessna met us and performed low level flights comparing radiative SST measurements. It was then noticed for the first time that the SST radiometer, having appeared to work perfectly throughout this leg of the cruise, had been loose on its mount and had been viewing a target close to the horizon. Analysing its data against the ship's thermosalinograph indicates that the SST radiometer data will be unusable for the first half of the cruise.

The port call at Rabaul provided some well-earned rest and recreation:- some managed 13 holes of golf some saw the Japanese remains from the war on a bus tour, while others saw the inside of every pub and shop in Rabaul.

The first work following the port call was to conduct a second medium-scale survey with SeaSoar, measuring approximately 25 nm by 25 nm. The appropriate temperature for the bottom limit of a heat content integration would be 29.2°C or even 29.3°C rather than 28.9°C as we had used previously. There was a well-developed mixed layer on this deployment and in the daytime part of the survey there was the characteristic slope on the S-θ diagram due to the ratio of heating and evaporation at the sea surface. In Rabaul we had collected a new instrument for measuring the total air-sea heat flux. It was developed by a team at the University of Wisconsin that includes Francis Bretherton and Verner Suomi, the founder and previous director of the Space Science and Engineering Centre. It employs the same principle as the heat flux plate, well known in land-based micrometeorology, and if successful could be deployed in lager numbers, reporting the spatial distribution of heat flux via Argos.

Unfortunately, during deployment the ship lost control of the bow thruster and as a result the instrument suffered a severe blow as the ship drifted over it. After the buoy was deployed we began a series of triangles, the first of which was done without SeaSoar while running repairs were effected on it.

At the buoy deployment location we collected a sample of COARE IFA water for Dr Hallett, a cloud physicist flying on the NASA DC8, for purposes at present unclear.

On Sunday evening SeaSoar was deployed for three triangular trips. The electrical termination in the SeaSoar had been replaced and consequently there were almost no communications problems on this deployment. There was a 30 m deep mixed layer and the water mass characteristics were quite homogeneous around these triangles, confirming our choice of location for the drifting buoy. We brought the system in so that we could deploy Bunyip (ie the complete system) and we did a triangle with nothing in the water while we prepared the Bunyip microfish. We saw the Chinese vessel, RV Xiangyanghong 5, one of the rain radar ships in TOGA COARE.

We deployed Bunyip for the second time at 1537 local time on Monday 25 January. We did two and a half triangles on this deployment, each having westward downwind legs because of the persistent easterly wind. We commenced from due east of our buoy, on an extended "downwind leg". The low-frequency accelerations were all much higher than on previous cruises (by an order of magnitude or more) which must be due to the new hammerhead arrangement. The base levels of the variance of both the scalar variables, microconductivity and the FP07 thermistor, vary slowly with time which is probably linked to the phase of the sawtooth profile. When the microfish was noticed to be doing a large rolling motion it was recovered and the SeaSoar alone was deployed. This rolling had been caused by some of the sheet metal fairing of the hammerhead that had been bent backwards on the starboard side.

The following triangles with SeaSoar, commencing at 0430 local time on Tuesday 26th January also had westward downwind legs. In the early hours of the morning the mixed layer depth varied from 20 m to 30 m around the triangle and there was only about 0.05°C variation in the mixed layer temperature around the triangular path. We did 3 triangles and then recovered SeaSoar so that we could deploy the complete Bunyip system. After this deployment Ian noticed that the rubber bellows on the SeaSoar hydraulic unit was about to fail so this was replaced, delaying the next deployment somewhat.

Paying more attention to the Chechet radiometers (now correctly mounted) since Rabaul, it became clear that neither was giving sensible readings. Gary Miller worked intensively on both, and by the evening of 26 January, had the important SST unit operative. This remained in service for the remainder of the cruise. He subsequently made the sky radiometer work also, although whether its readings can be properly calibrated *post-facto* has yet to be determined.

On Wednesday 27 at 0122 local time we deployed the full Bunyip system and did butterfly patterns around the drifting buoy. The SeaSoar stabiliser was returned to the upright position for this deployment. Ian used cable ties to restrain the sheet metal of the hammerhead. The tail brushes were roped so as to stop any sharp knocking vibrations. On the CTD at the buoy before this deployment there was very little afternoon effect and the bottom of the mixed fluid was at 30 m. The roll was very good in level flight but was excessive in the sawtooth motion at a rise and fall rate of 1 m/s. At 1102 LT on 27 Jan power was lost to the disc and Exabyte unit on the SparcStation and this brought everything down for about 10 minutes. This was fixed at 1125 LT when file 78 was begun. Lindsay had to exchange the Exabyte unit with one from the VAX. A problem with the root area of the new Seagate disc arose at about 1245 LT and we ceased archiving until the system was up and running at 1320 LT, beginning file 79. The SeaSoar was towing out to the port side quite a lot and is clearing the wake on the port side. Ian and Lindsay say this depends on the shear of the current and is found to be persistent on any given leg. Each time the system required restarting it took a few times to get it going. At 1923 LT we stopped file 80 and began to bring in the SeaSoar and then connect up the microfish that was still in the water. We began file 81 with the microfish only in the water and we towed it at a variety of speeds.

While we took time to absorb the latest data from Bunyip we deployed SeaSoar again and did more butterflies around the buoy. The CTD before this deployment showed a mixed layer 30 m deep. The night-time SeaSoar profiles show a healthy mixed layer and the S-θ curve is quite compact. We did not do a CTD at the end of this deployment as we went looking for the Bretherton buoy and this took quite a time (4.5 hours from 1124 LT).

The rough deployment of the floating flux meter had obviously not affected its Argos transmission capability. Wisconsin had been receiving position and data since deployment and visually, despite damage, the disc was floating in the surface as designed. However at 0800 it was observed to be separated further from the CSIRO buoy and on the next pass at 1110 it had disappeared altogether. In the meantime the wind had increased to 15 knots and our search failed to find it. The tether was still attached to our buoy:- the attachment Wisconsin had made to their drifter had chaffed through the polypropylene line. Francis Bretherton regards this deployment as a valuable stage in development of the sensor, the only loss scientifically being the inability to inspect the system for endurance.

By now our buoy had drifted so far from the central IFA that we were not being overflown by the aircraft and we decided to retrieve the buoy and redeploy it east of the IMET mooring. Figure 3 shows the cruise track during the second drift of the cruise.

We began a SeaSoar survey very early Friday morning 29th January and deployed the buoy at first light the following morning. The wind got up to 30–35 knots during the SeaSoar survey and there was considerable rainfall. The mixed layer was significantly fresher in this region than it had been west of the IMET mooring; 34.05 psu as opposed to about 34.10 psu. The first leg of this survey was to the east, but then the sea became too rough to head back towards the west, so thereafter we did north-south legs. The first three north-south legs showed significant horizontal salinity structure in the mixed layer. The fourth leg had an amazing S–θ curve for the upper 100 m of the water column that bowed upwards like a boomerang. There was a large air-sea temperature difference with the ocean being 2°C warmer than the atmosphere.

After deploying the buoy at 1° 34.2'S 156° 21.4'E we began a series of butterfly patterns. The purpose of the butterfly patterns was to get the two-dimensional gradient of heat content at the buoy. While the survey showed much structure in the salinity of the mixed layer, we managed to put the buoy into a relatively homogeneous parcel of water. There was some stratification in the top 35 m that was mainly caused by a surface freshening but also a little surface cooling so that there was a weak maximum of potential temperature in the upper 35 m. These butterflies were small ones, so arranged that we did a complete circuit in about 3.5 hours and the two upwind legs cross almost at right angles at the buoy. The air temperature was as much as 2°C cooler than the oceanic mixed layer temperature at the beginning of this deployment. In fact the difference in potential temperature between the atmosphere and the ocean had been as much as 4°C for long periods during storm events. This should be an excellent data set for testing mixed layer models such as the Price, Weller & Pinkel (1986) model because we have the wind and buoyancy forcing and we are watching the restratification process which is the hardest part of the mixed layer cycle to model correctly. During the night we had to abandon the butterfly pattern and instead do triangles because the buoy drifted through the watch circle of PCM # 17. The buoy passed within 1.5 nm of it while Franklin kept at least 2 nm away from the mooring. By 1420 LT the temperature at 30 m around the butterfly track varied from 29.10°C to 29.20°C and the salinity there varied from 34.07 to 34.13 psu. At the same time there was a stable thermal stratification in the top 16 m of about 0.06°C on each vertical profile. On the CTD at the end of this deployment there was no increase of temperature in the top 10 m but the increasing salinity with depth was obvious from below 20 m while the water column was isothermal to 45 m.

For two or three days during this period, meteorological measurements were jeopardised by the presence of a large seabird which used the mast sonic anemometer as a vantage point for fishing and for roosting. Dislodged, it settled out of reach on the boom hygrometer, but was eventually discouraged by Peter Coppin with a long pole.

Ian Helmond had made an improved fairing for the hammerhead at the front of the microfish so we deployed Bunyip again. The vibrational accelerations and the data from the shear probes seemed little different than with the earlier rudimentary fairing. The system developed communication problems after being in the water for six hours and we brought it in and immediately deployed SeaSoar alone. During this deployment the buoy continued to drift eastwards away from the central IMET mooring. At the end of the deployment we did a CTD and then used the SeaSoar on deck to investigate the communication problem that occurred with the microfish on its previous deployment. At the end of this deployment the CTD showed that the salinity was constant to 40 m while the temperature was constant to 58 m:- shades of barrier layer formation. After working on the microfish communications on deck, SeaSoar was put back in the water while we readied the microfish for another deployment.

The air temperature was now up above 30.0°C (according to Delp) and there was now a stable temperature stratification in the top 20m with a remnant mixed layer below 25 m down to about 46 m. The wind was also quite significant, being about 17 knots, so this should be an excellent data set to test the restratification performance of various mixed-layer models. Water was advected into the region that had a lower temperature of the remnant mixed layer so that there was a temperature maximum between 50 m and 100 m, while the upper 30 m exhibited a stable temperature difference of about 0.12°C. Towards the end of the deployment (#18) the temperature structure showed that the water column was isothermal to 58 m but was isohaline to a shallower depth.

A short Bunyip deployment was carried out to test the effect of drag reduction and to test the HotFilm probe. The number of drag elements was reduced from 12 to 4 so that the total drag of the vehicle was halved. Nothing seemed to have improved on the system and so we brought it in for the more reliable SeaSoar system. This deployment was stopped so that we could recover the buoy and head towards the IMET mooring for the flux intercomparison work. The CTD at the end of the deployment showed that there was no afternoon effect (it being early morning) and the mixed layer was isothermal down to 70 m and isohaline down to 58 m. The cruise track during the third drift of this cruise is shown in Figure 4 where the butterfly patterns can be seen.

As with a similar activity during the pre-Christmas cruise (FR09/92), the flux intercomparison had been arranged by Mike Gregg, Frank Bradley and Kensuke Takeuchi in Tokyo during May 1992. Accurate air-sea flux measurement is the cornerstone of COARE objectives, but it is an extremely difficult measurement to make from shipboard. Only a small number of scientists believe that they have adequate technique to overcome the various problems of ship motion, air-flow distortion, instrumental accuracy etc. to measure fluxes directly, and nearly all (including the Franklin team) are involved in TOGA COARE. Intercomparison was therefore regarded as a vital component of the COARE programme, such intercomparison to include the IMET buoy. This work involved several three-hour legs at 3 knots into the wind with either one or two other vessels, the R/V Natsushima for all the time, and for half of the time, the R/V Moana Wave. The ships were separated by 0.5 nm in the cross-wind direction. Flux measuring aircraft were also intended to participate but only the Flinders Cessna appeared. We believe that the bad weather had disrupted the aircraft schedules. As during FR09/92, weather and wind conditions were absolutely ideal for the work. This intercomparison work lasted 24 hours and we finished at 1730 local time on Thursday 4th February, and then headed for Townsville.

During the intercomparison runs we took advantage of the low 3 knots ship speed to deploy the silverfish for the second time. An extension was fitted to the boom to carry the towline sheave, and tested initially with the goldfish (this was the previous incarnation of the silverfish). At this speed the towing behaviour of both gold and silverfish was immaculate, profiling down to 3 m was possible with the slack winch line technique, and a series of profiles through the surface were performed as originally intended under control of the winch. At 3 knots this will be a very valuable near-surface T/S profiler. Data from its first deployment indicated a gradient of 2°C in the top 1 m, with clean profiles and 2 m depth resolution. In the second deployment, it was isothermal to the surface due to the recent history of string winds and low radiation.

En route to Townsville most of us were busy with the packing of gear and preparing cruise data for analysis and reports. Soon after leaving the IFA it became obvious that the low that had been in the northern Coral Sea for some time was strengthening and was soon named a tropical cyclone, and then a severe tropical cyclone. On going through Jomard Entrance we headed for Grafton passage, the entrance to Cairns through the Great Barrier Reef. Severe Tropical Cyclone 'Oliver' was just south of our cruise track and was almost stationary for a few days. By the time we were traversing the Coral Sea, 'Oliver' had begun to move south-east, parallel to the coast. About 24 hours before our scheduled ETA in Townsville, 'Oliver' turned towards the coast and it was uncertain whether the port of Townsville may be closed by the time we arrived. As it turned out, 'Oliver' turned south again, maintaining a safe distance from the coastline and allowing us to arrive safely in port only five hours behind schedule. By 6PM on the 9th February we had completed the task of unloading all our gear from the Franklin and into the waiting containers.

Summary of work completed

SeaSoar proved remarkably reliable on this cruise, mainly due to Ian Helmond's work with the hydraulic unit on the previous cruise. SeaSoar or Bunyip was being towed and data was being collected for 85% of the available time in the IFA. The remaining time was spent in deployment, recovery, in doing CTDs , and a very small time doing repairs. The same cannot be said for the microfish of Bunyip. Communication between the ship and the two underwater bodies was often not reliable, and the preliminary view of the microstructure data is not encouraging. We are not confident that the present arrangement of shear probes will overcome the considerable limitations imposed by vehicle vibrations. Nevertheless, the cruise as a whole was very successful. We anticipate meeting all of the cruise objectives except the third which was concerned with the turbulent fluxes in the water column.

Here we show some selected results from the cruise. During the first drift of the buoy we did not experience strong winds and the water column showed a remnant mixed layer from about 35 m to 55 m (see Figure 5) separated from the diurnal effects by a transition region at about 30m. The data in Figure 5 are from the closest "cast" of the SeaSoar to the buoy, so that there is one cast for each of our triangular cruise tracks. A crude measure of the heat content of the water column is presented in Figure 6. This involves simply integrating the temperature down to a fixed depth of 20 m. The dashed line in the figure shows this heat content all the way around our series of triangles that constituted the cruise track while the diamonds on Figure 6 indicate when we passed the buoy. The full line is the estimate of the heat content that comes from temporally integrating the air-sea heat flux and subtracting the radiation that is lost to water deeper than 20 m. The air-sea heat flux is estimated from the bulk measurements and the LKB parameterization. We are encouraged by the agreement thus far, and look forward to implementing improved definitions of heat content and in allowing for the effects of lateral advection of water with respect to the drifting buoy.

On the atmospheric side, the need for very accurate flux measurement (10 Watts m^{-2}) to achieve the aims of TOGA-COARE has dominated our experimental technique. It has led to duplication of instruments and intercalibration of meteorological and radiation sensors, and of whole systems (inter-ship and aircraft). We are confident that the required accuracy will have been achieved when all the data has been analysed and scrutinised. Most of the bugs were removed from the system during the first COARE Franklin cruise (FR09/92). During FR01/93 important computer programs for signal monitoring and recording have been developed by John Bryan.

"First-pass" analysis of data was performed daily. The example in Figure 7 compares meteorological data from ship and buoy during the first drift. Overall agreement is excellent, indicating that the ship operated always within the scale of significant weather events. The difference in absolute values reflects the fact that the buoy measurements were 1.8 m above the sea surface while the ship sensors were at a height of 13 m.

The difference in rainfall pattern, Fig. 8, is partly due to the spatial variability characteristic of this highly convective region, but also indicates the difference in performance of the ship's optical rain-gauge and the buoy's funnel type.

The meteorological data from the ship's foremast shown in Figure 7 was run daily through the bulk model of Liu, Katsaros and Businger (1979) to obtain sensible and latent heat fluxes. With these fluxes, and our measured net radiation, we obtained daily estimates of the air-sea heat exchanges. This, with the estimated loss from the ocean mixed layer of short-wave radiation downward, enabled us to calculate the heat which should accumulate in the surface mixed layer of the ocean, represented by the solid, diurnally varying line in Figure 6.

These are "first-pass" results and several factors may change them, but probably only slightly. The following three features will be addressed in subsequent data processing. (i) We have validated the LKB model on previous cruises to the equatorial western Pacific; it represents low wind speed conditions well, but we have reservations about its performance at the high winds prevailing during the latter part of this cruise Calibration of LKB for these conditions must await processing of the "direct" fluxes from the turbulence instruments. (ii) During fairly clear days, the net flux is dominated by the radiation input. It is crucial that our net radiometers be calibrated immediately following the cruise. (iii) The meteorological observations must be "filtered" for periods when the wind was astern or the ship turning. With the short cruise legs that were typical of FR01/93, time lost for flux measurement may amount to 50% of the total.

Flux measurements for Drifts 2 and 3 are given in Figures 9 and 10. Conditions during the 3 drifts were quite different from one another, and form an excellent set of data representing various atmospheric forcing. Drift 2 was a series of days with fairly clear skies and high radiation. Because of periods of fairly strong winds increasing the evaporation rate, long-term air-sea exchange was small. In contrast, Drift 3 was a period of strong eastward winds and overcast skies — the diurnal cycle of heating was insignificant, and the ocean lost heat dramatically. Sustained latent heat flux over 200 Watts m^{-2} is an infrequent occurrence in this region.

Rainfall measurements were made with the NOAA optical rain-gauge mounted on the forecast to minimise obstruction and wind effects by the ship. A total of 202 mm fell throughout the cruise compared with 330 mm during FR09/92. The structure of one of the more significant storms is given in Figure 11. The maximum rain rate of 80 mm/hr is not high for this region of the Pacific ocean. Interestingly, the most dramatic storm was registered while we were in port at Rabaul – the total fall was 45 mm (not included in the 202 mm above) in about two hours with a maximum rate in excess of 200 mm/hr.

Examples of the silver-fish measurements during the two deployments are given in Figs 12 and 13. These profiles are each the average of successive 5 minutes-worth of "plunging" (perhaps 30–50 plunges) binned according to 40 mm depth intervals. The depth was measured with a pressure sensor, and clearly the measurement noise of the system is remarkably good. Stratification of 2°C over the top 50–80 cm of the profile is the main feature of the early deployment. After several days of high winds, even the strong radiation during the second deployment period had not produced even a small temperature gradient at the surface.

Other achievements worthy of note during this cruise and FR09/92; (1) The collation, while we were in the IFA, of a continuous record of half-hourly 180° cloud photographs, using the Macquarie University camera. A second camera was sent to the *Wecoma*, so between us the record should be complete for the TOGA-COARE intensive observation period. (2) We have been operating a fast response H_2O/CO_2 sensor, provided by the Oak Ridge group, for the measurement of water vapour flux. We also recorded the CO_2 signals, and expect to be able to determine CO_2 fluxes for selected periods. Mark Rayner performed regular calibration of the ship's pH system so that with water pCO_2 values, we can contribute to the contentious CO_2 exchange rate issue.

Attachments

Figures 1–13

Table of SeaSoar & Bunyip deployments #1 – #20 (8 pages).

Electronics Report

Computing Report

Hydrochemistry Report

Acknowledgments

The entire FRANKLIN crew is thanked for their excellent support and cooperation throughout the cruise. Special mention must also be made of several CSIRO staff who worked far beyond the call of duty. Were it not for the long hours put in by Phil Adams, Lindsay Pender and Ian Helmond, often well beyond the 12 hours per day for which they will receive compensation under the new award, this cruise would have contained gaping, unproductive holes.

GLOSSARY

ADCP - acoustic Doppler current profiler. Four acoustic beams are projected downward from transducers in the ship's hull. The reflections from biological scatterers and ocean structures are arranged according to depth. The frequencies of the reflected signals give a measure of the current profile down to several hundred metres . Substantial errors are introduced by gyro inaccuracies and the misalignment of the ADCP transducer package in the ship's hull. Recently the Division of Oceanography has acquired an ADCP for operation on a mooring.

CTD - a profiling instrument for measuring conductivity, temperature, and pressure (depth) and estimating oxygen content. Salinity can be inferred from the conductivity and temperature measurements. A rosette of 12 water sampling bottles is attached to the CTD; the bottles close sequentially on commands from a shipboard console, thereby providing samples both for CTD sensor calibration and nutrient analysis.

GPS - Global Positioning System. A network of satellites and a shipboard receiver capable of fixing the ship's position to several metres. This information is invaluable for determining absolute current profiles from the ADCP and, of course, for any precision navigation.

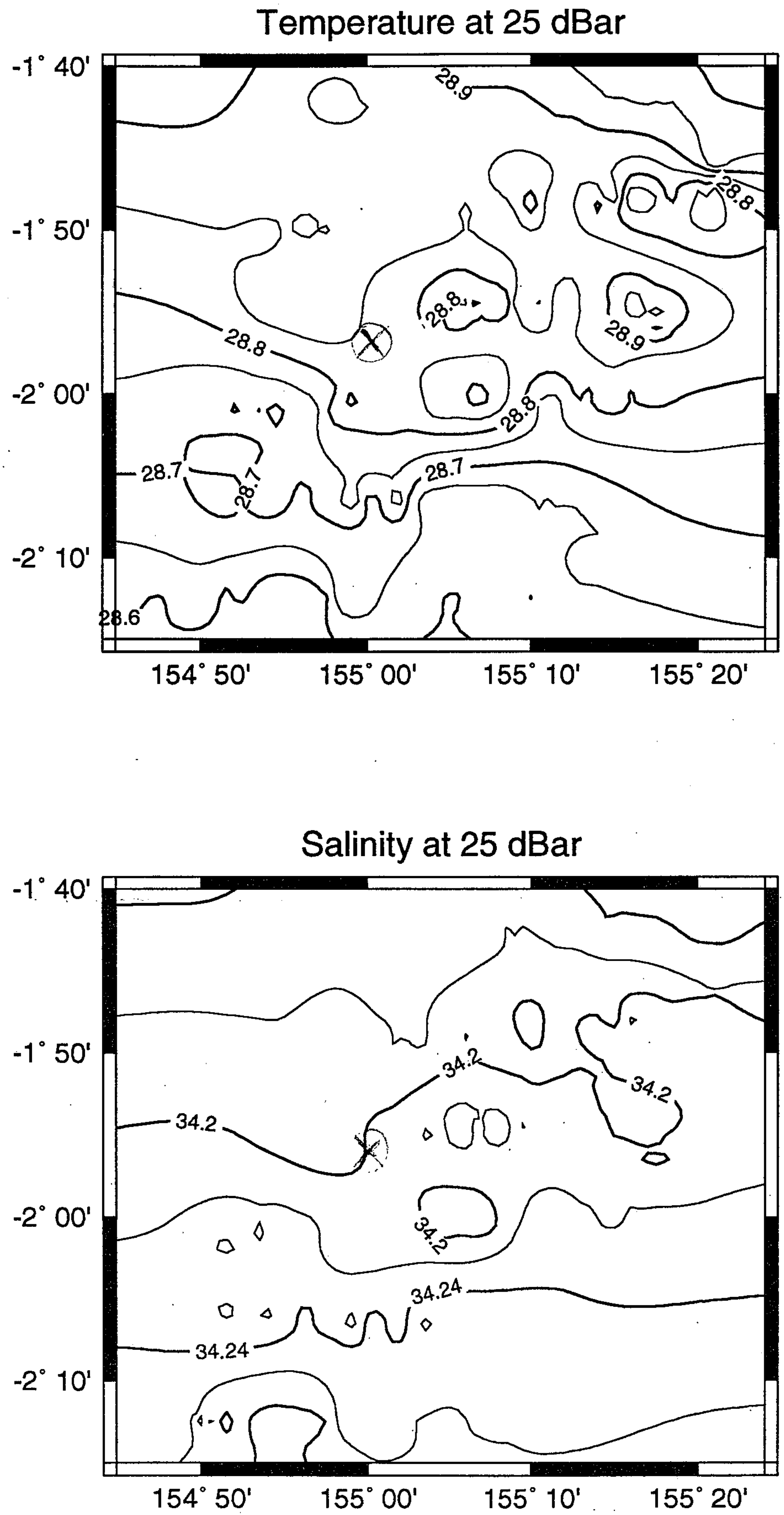
XBT — Expendable bathythermograph: a probe that is dropped from a ship and relays temperature information up a hair-thin, twin-core cable.

Bunyip and Seasoar — *Bunyip* is a streamlined 3m long towed body with sensors for temperature, conductivity, pressure, and microstructure. This vehicle is also called the microfish. It is passive and is towed 100m behind the active *Seasoar* which has wings that are controlled by the operator of the shipboard computer. The wings enable it to follow an undulating path with vertical excursions of as much as 200m. It completes one up and down cycle over a depth D each 4D that the ship advances.*Seasoar* is towed with up to 5 km of faired and unfaired cable behind *Franklin.* The wings of *Seasoar* are driven hydraulically by a motor powered by a propeller. *Seasoar* can be used without *Bunyip* for and, in that mode it carried its own CTD.

Silverfish and Goldfish These are two similar fish developed by Dr Frank Bradley for the purpose of obtaining vertical profiles of temperature and salinity in the top 3 m of the water column. There operate from the boom on *Franklin's* bow.

TOGA COARE TOGA stands for the Tropical Oceans Global Atmosphere experiment and COARE is the Coupled Ocean-Atmosphere Experiment of TOGA.

θ	the potential temperature, the same symbol being used for sea water and air.
S	the salinity of a water parcel
q	the specific humidity of air
SST	Sea Surface Temperature
PCM	Profiling Current Meter
IMET	Integrated METeorological buoy
IFA	the Intensive Flux Array TOGA-COARE
HotFilm Probe	a device for measuring fluid velocities with a heated probe



Temperature at 25 dBar
-1° 40'
-1° 50'
-2° 00'
-2° 10'
154° 50'
155° 00'
155° 10'
155° 20'
28.9
28.8
28.8
28.9
28.8
28.8
28.7
28.7
28.7
28.6
Salinity at 25 dBar
-1° 40'
-1° 50'
-2° 00'
-2° 10'
154° 50'
155° 00'
155° 10'
155° 20'
34.2
34.2
34.2
34.2
34.24
34.24

FIGURE 1

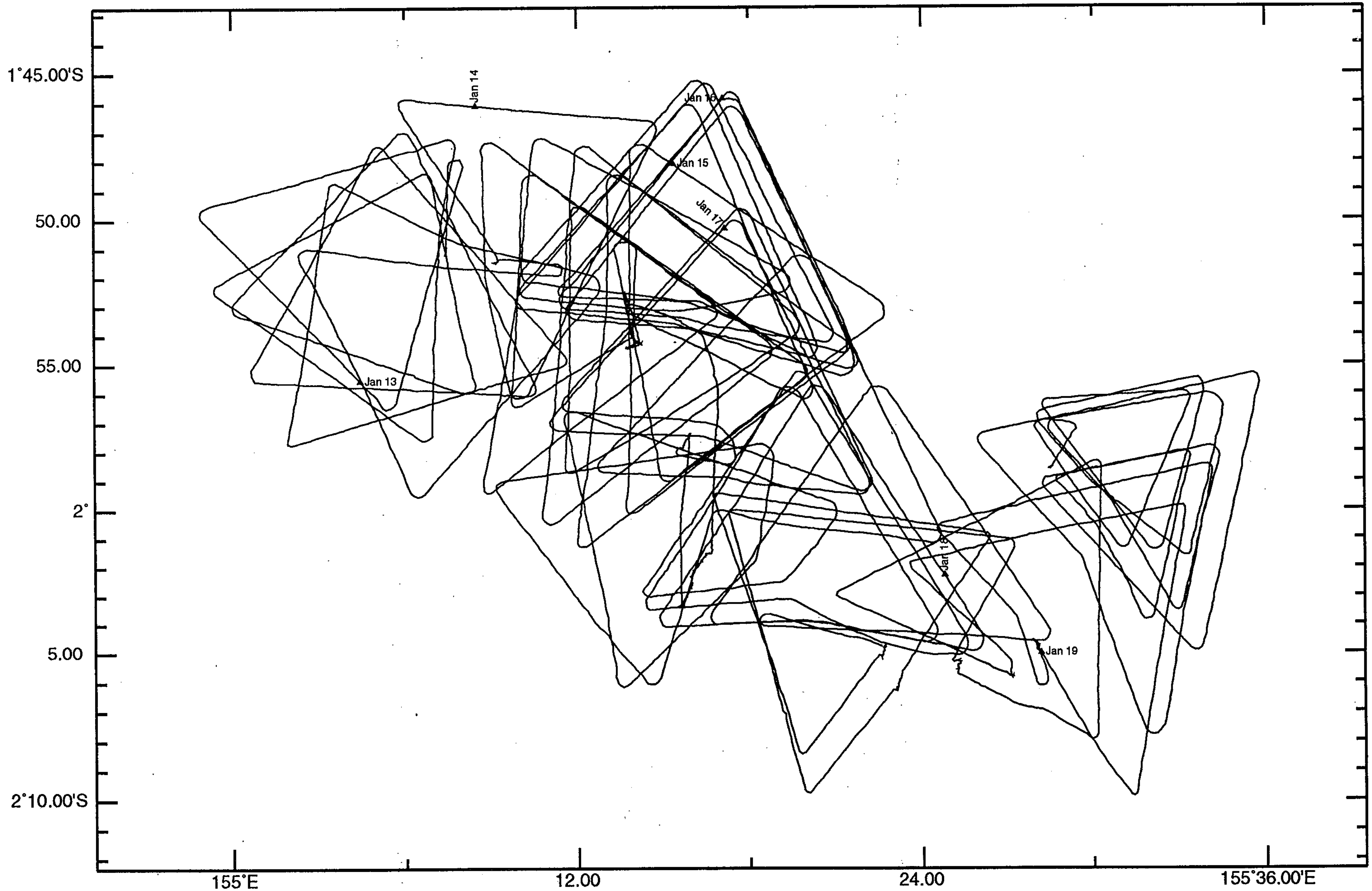
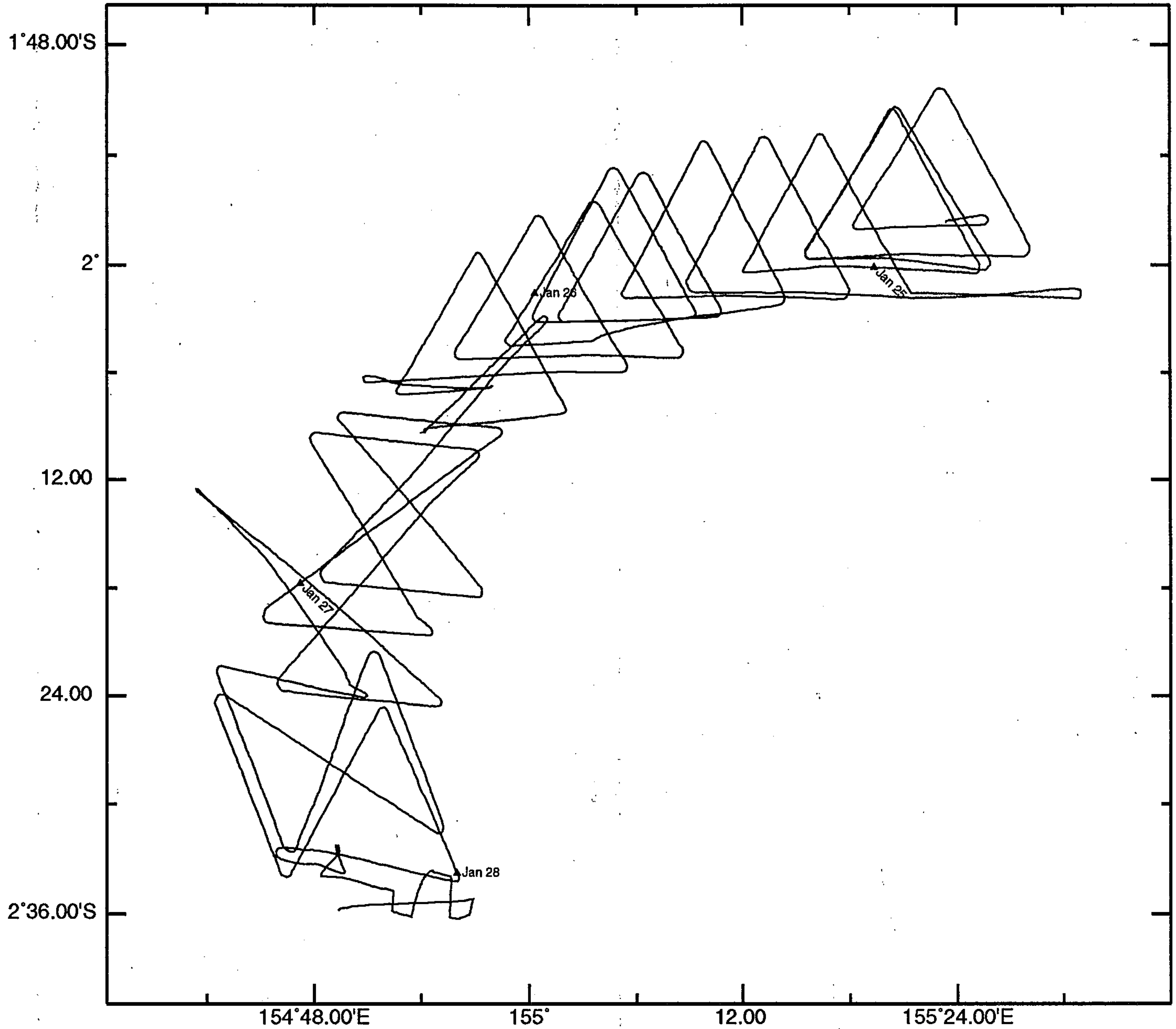

1°45.00'S
50.00
55.00
2°
5.00
2°10.00'S
155°E
12.00
24.00
155°36.00'E
Jan 13
Jan 14
Jan 15
Jan 17
Jan 19

FIGURE 2



1°48.00'S
2°
12.00
24.00
2°36.00'S
154°48.00'E
155°
12.00
155°24.00'E
Jan 25
Jan 26
Jan 27
Jan 28

FIGURE 3

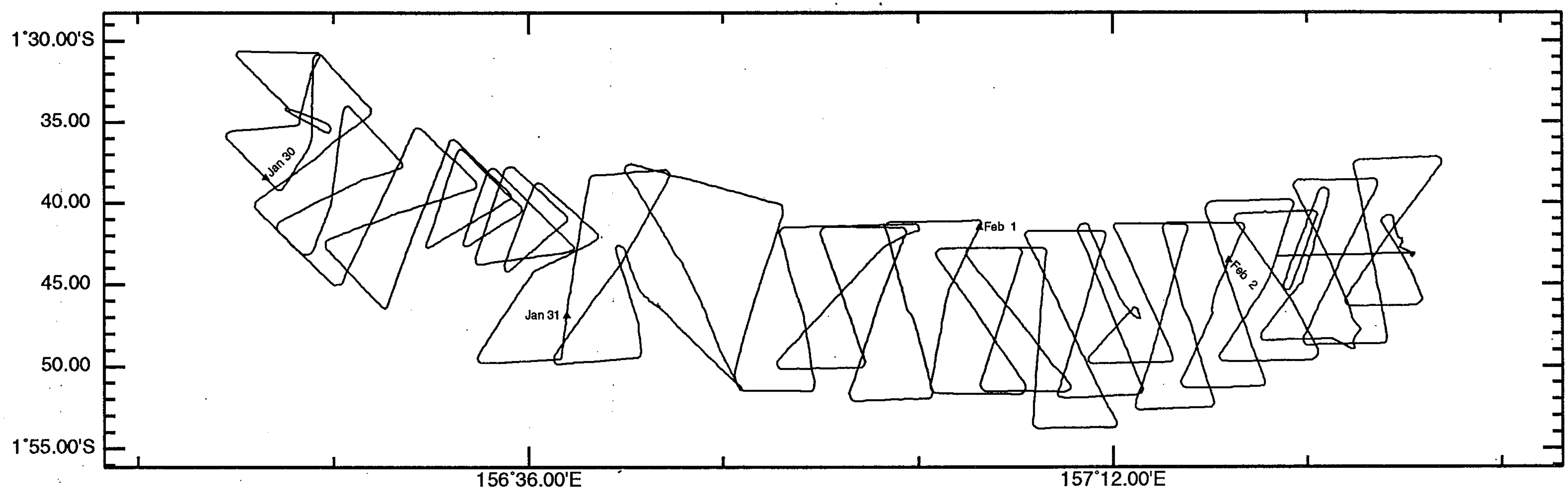

1°30.00'S
35.00
40.00
45.00
50.00
1°55.00'S
156°36.00'E
157°12.00'E
Jan 30
Jan 31
Feb 1
Feb 2

FIGURE 4

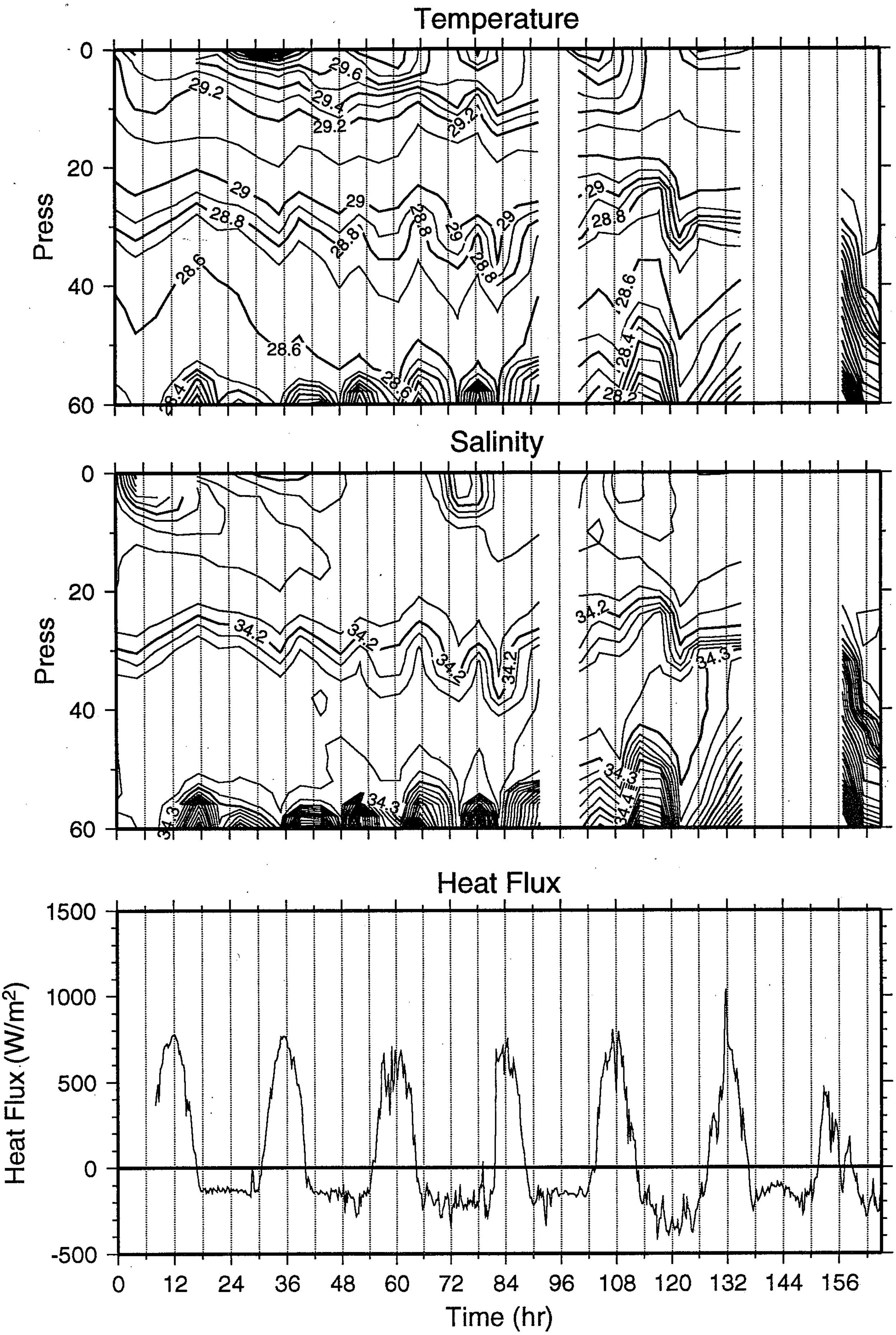

Temperature
Press
0
20
40
60
29.6
29.2
29.4
29.2
29.2
29
29
28.8
28.8
28.8
29
29
28.8
29
28.8
28.6
28.6
28.6
28.4
28.6
28.4
28.2
Salinity
Press
0
20
40
60
34.2
34.2
34.2
34.2
34.2
34.3
34.3
34.3
34.3
34.4
Heat Flux
Heat Flux (W/m²)
1500
1000
500
0
-500
0 12 24 36 48 60 72 84 96 108 120 132 144 156
Time (hr)

FIGURE 5

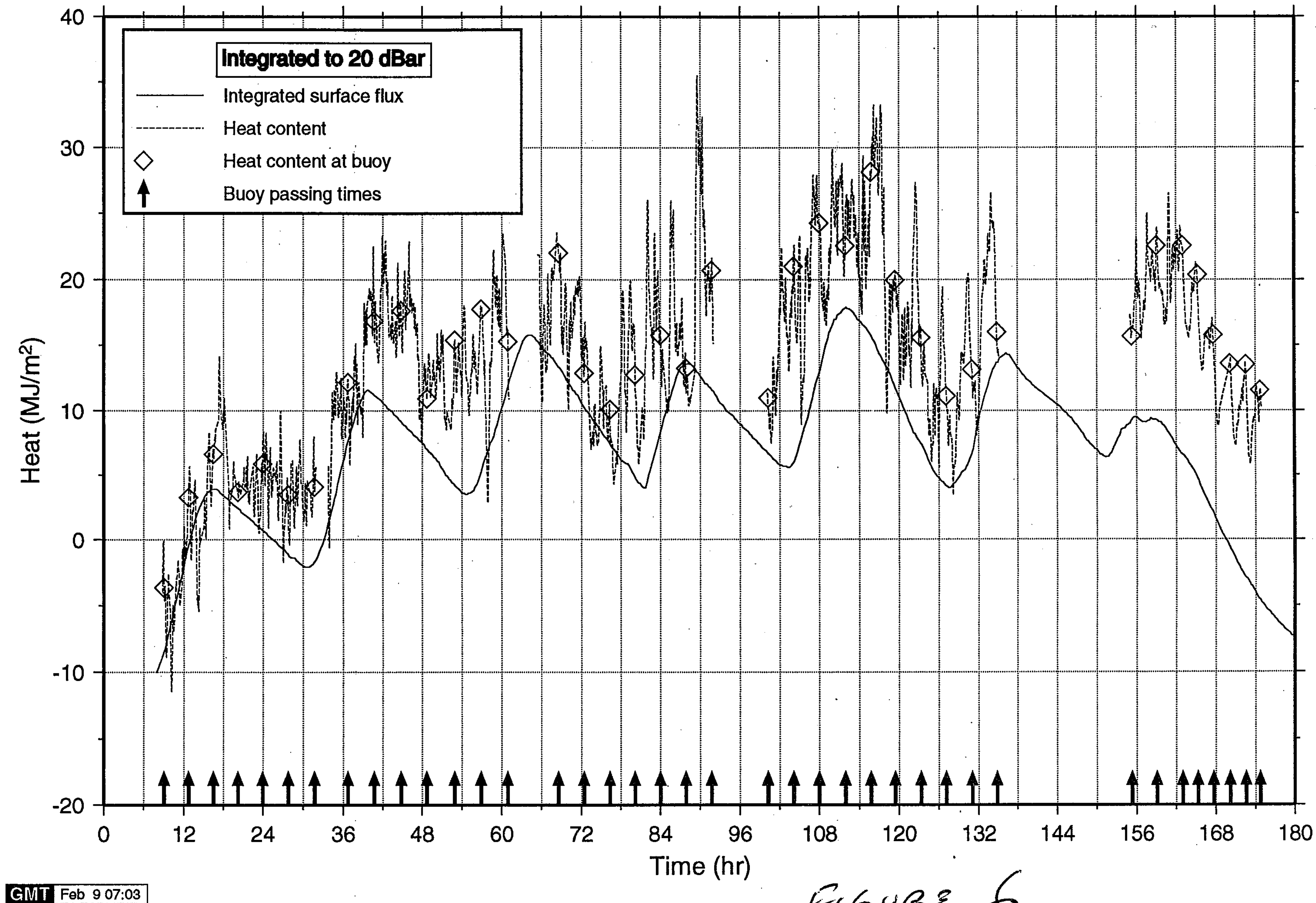

Integrated to 20 dBar
Integrated surface flux
Heat content
Heat content at buoy
Buoy passing times
Heat (MJ/m²)
Time (hr)
40
30
20
10
0
-10
-20
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
180
GMT Feb 9 07:03

FIGURE 6

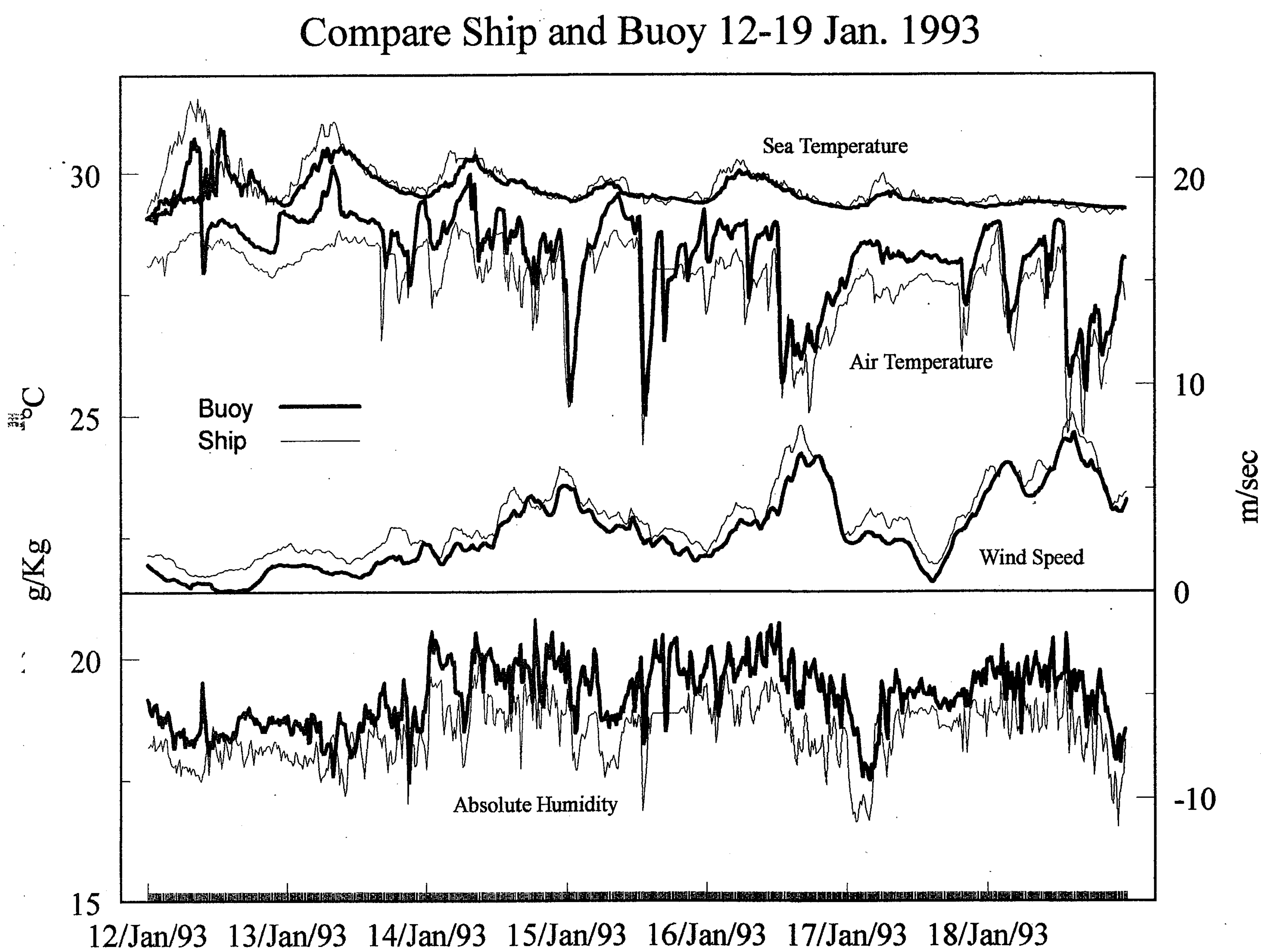
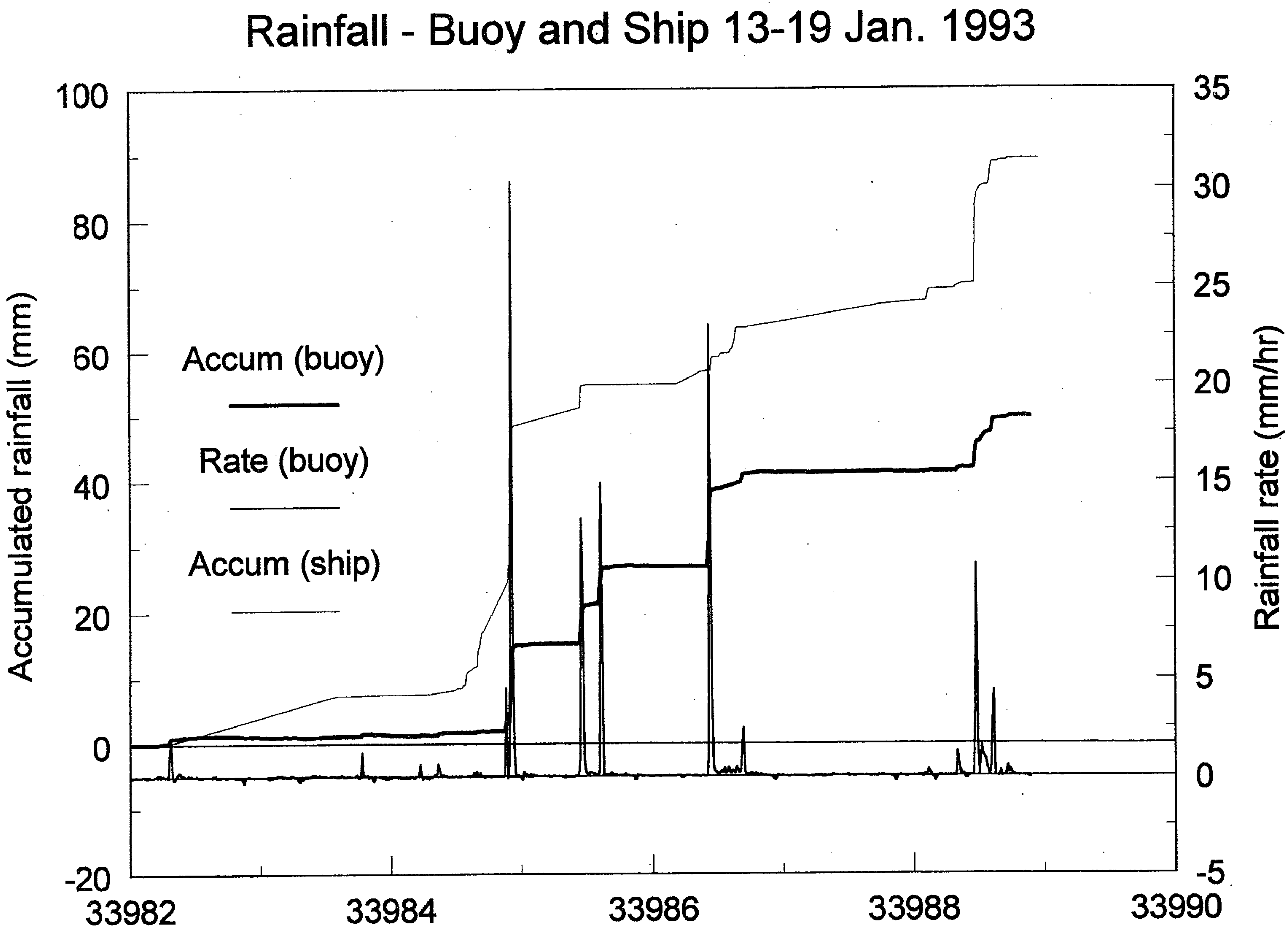

Compare Ship and Buoy 12-19 Jan. 1993
Sea Temperature
Air Temperature
Wind Speed
Absolute Humidity
Buoy
Ship
°C
g/Kg
m/sec
30
25
20
15
20
10
0
-10
12/Jan/93
13/Jan/93
14/Jan/93
15/Jan/93
16/Jan/93
17/Jan/93
18/Jan/93

FIGURE 7



Rainfall - Buoy and Ship 13-19 Jan. 1993
100
80
60
40
20
0
-20
Accumulated rainfall (mm)
35
30
25
20
15
10
5
0
-5
Rainfall rate (mm/hr)
Accum (buoy)
Rate (buoy)
Accum (ship)
33982
33984
33986
33988
33990
Day number

FIGURE 8

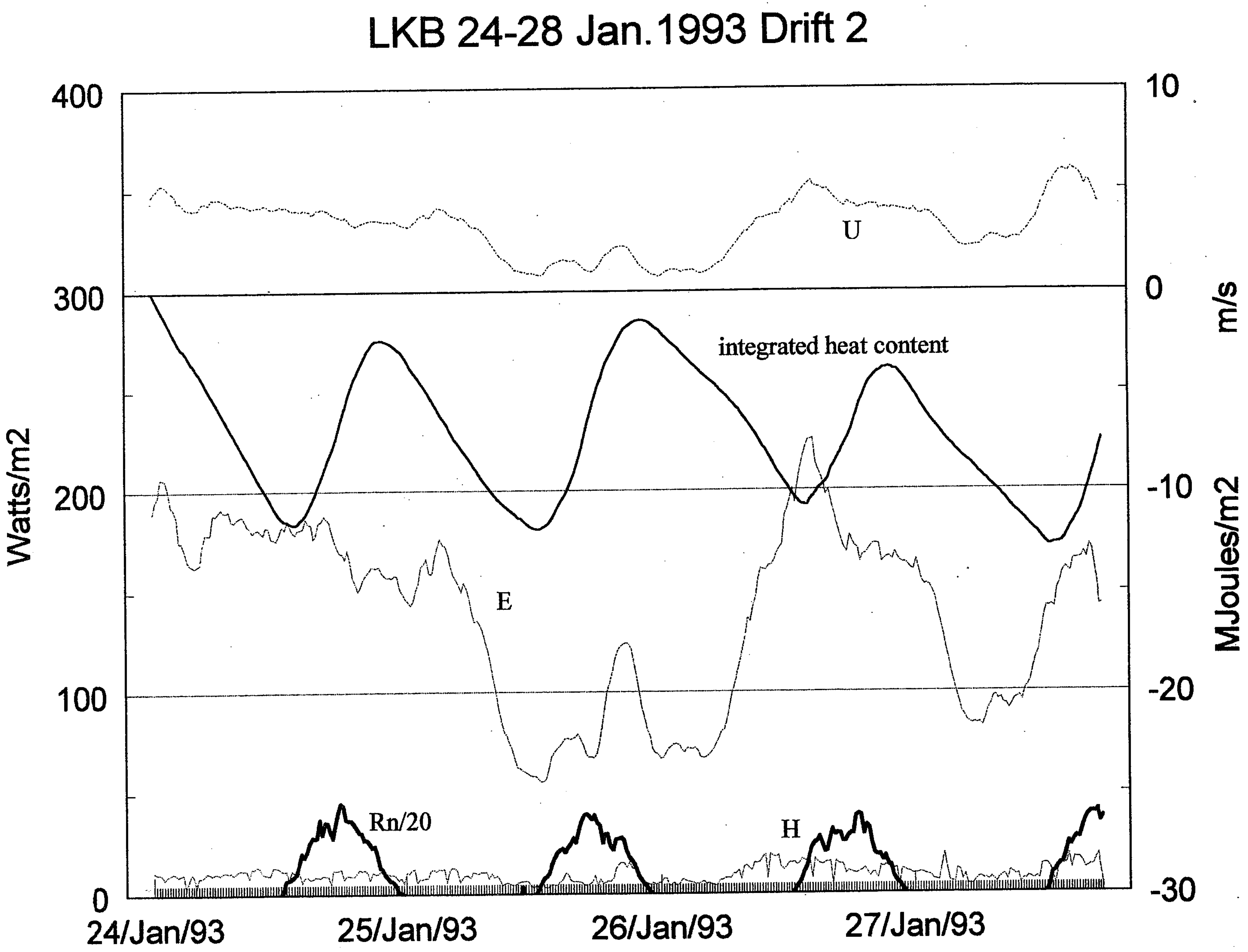

LKB 24-28 Jan. 1993 Drift 2
400
300
200
100
0
Watts/m2
10
0
-10
-20
-30
m/s
MJoules/m2
U
integrated heat content
E
Rn/20
H
24/Jan/93
25/Jan/93
26/Jan/93
27/Jan/93

FIGURE 9

LKB 29 Jan.- 2 Feb. 1993 - Drift 3

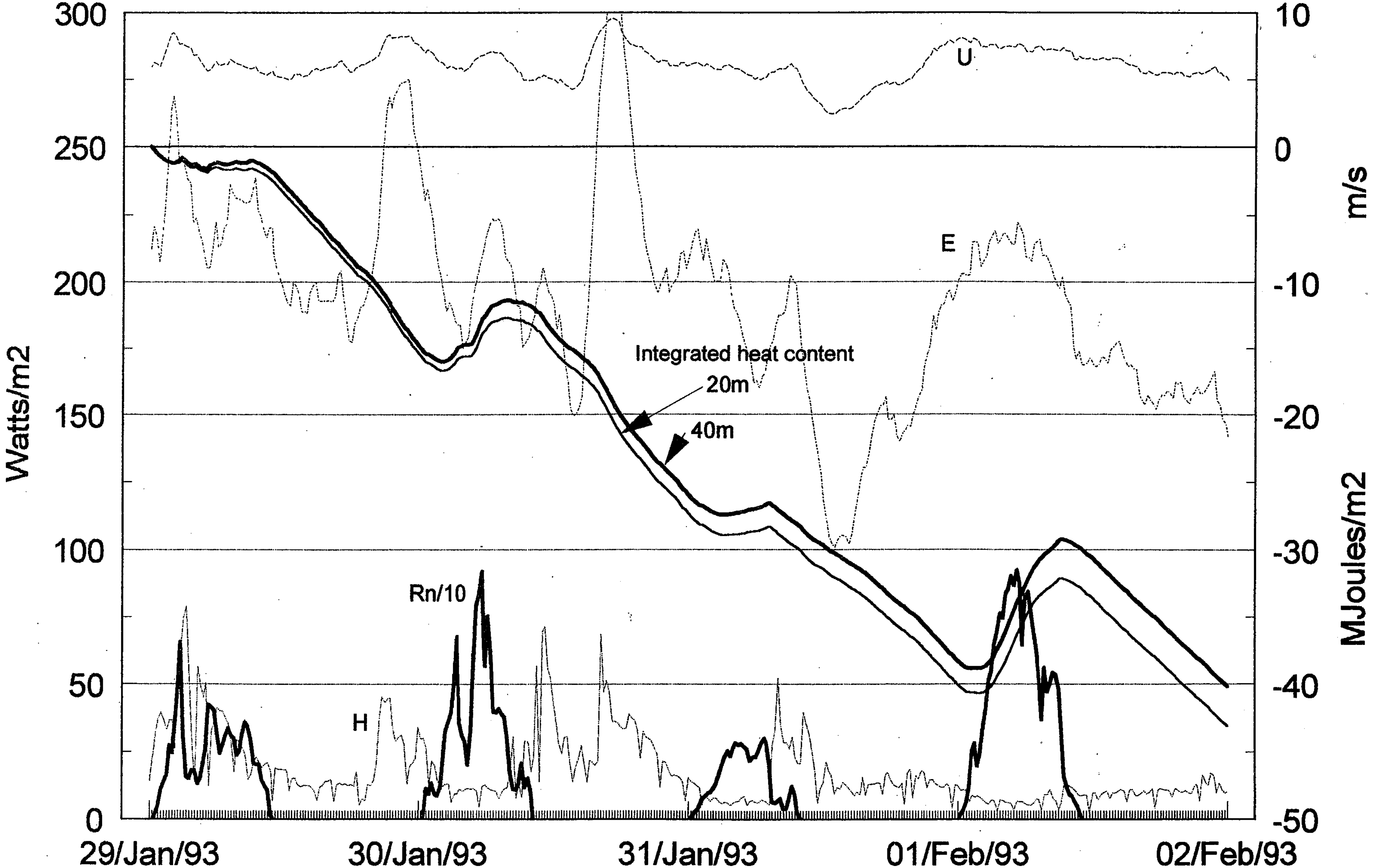


FIGURE 10

Franklin - Optical Rain Gauge

Rain event 31-Jan-93 UTC

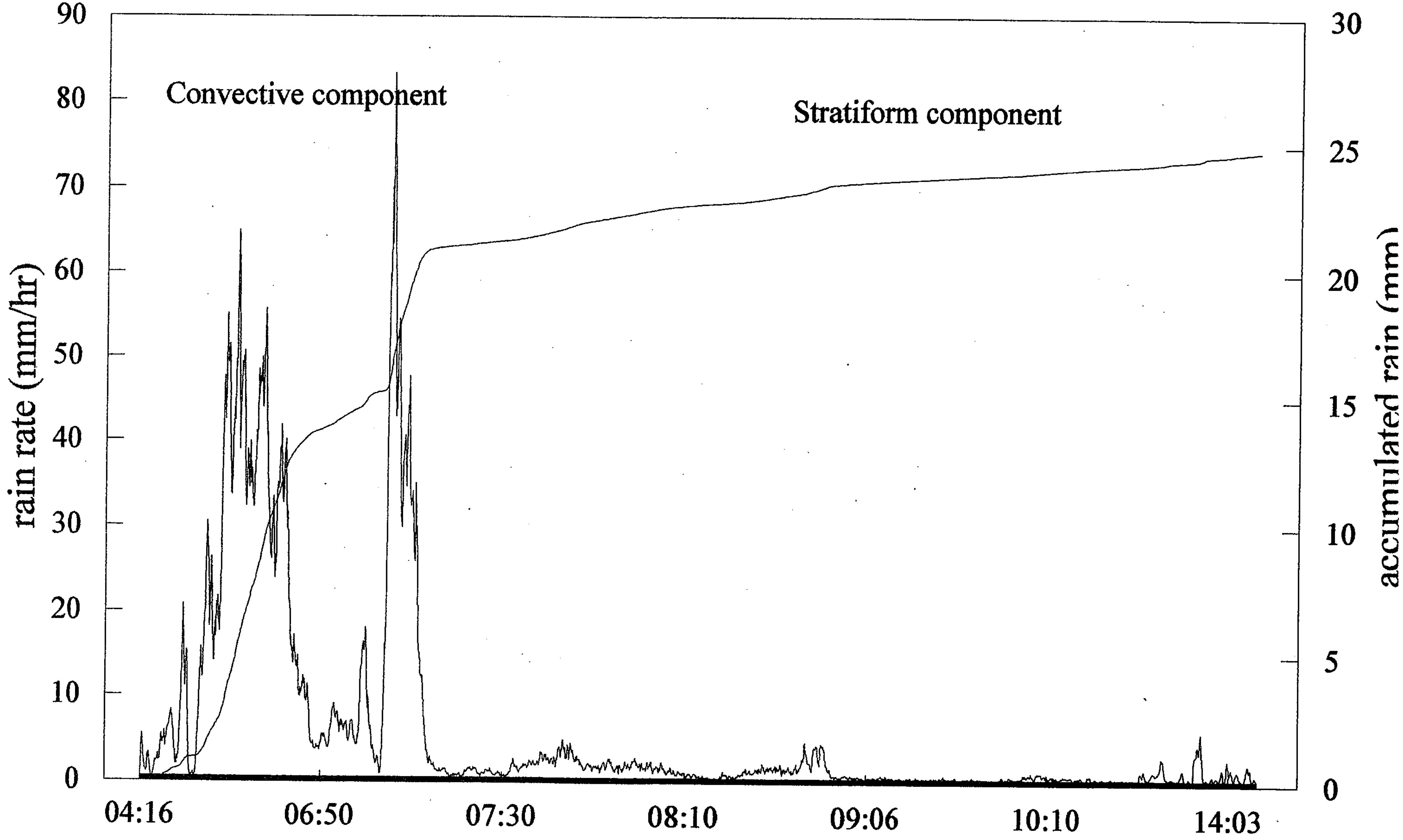


FIGURE 1)

Silver Fish - 5 min profiles

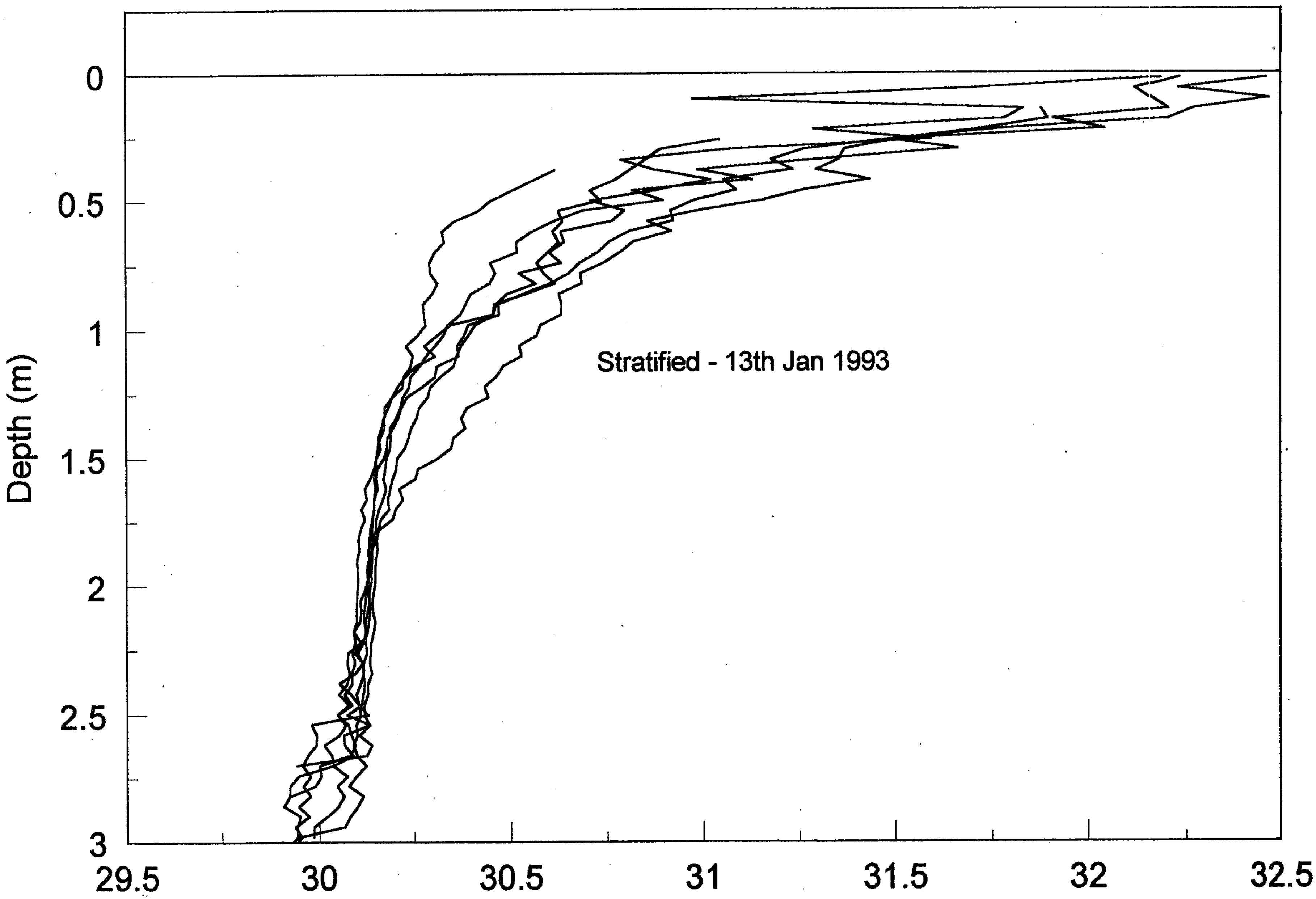


FIGURE 12

Silver Fish - 5 min profiles

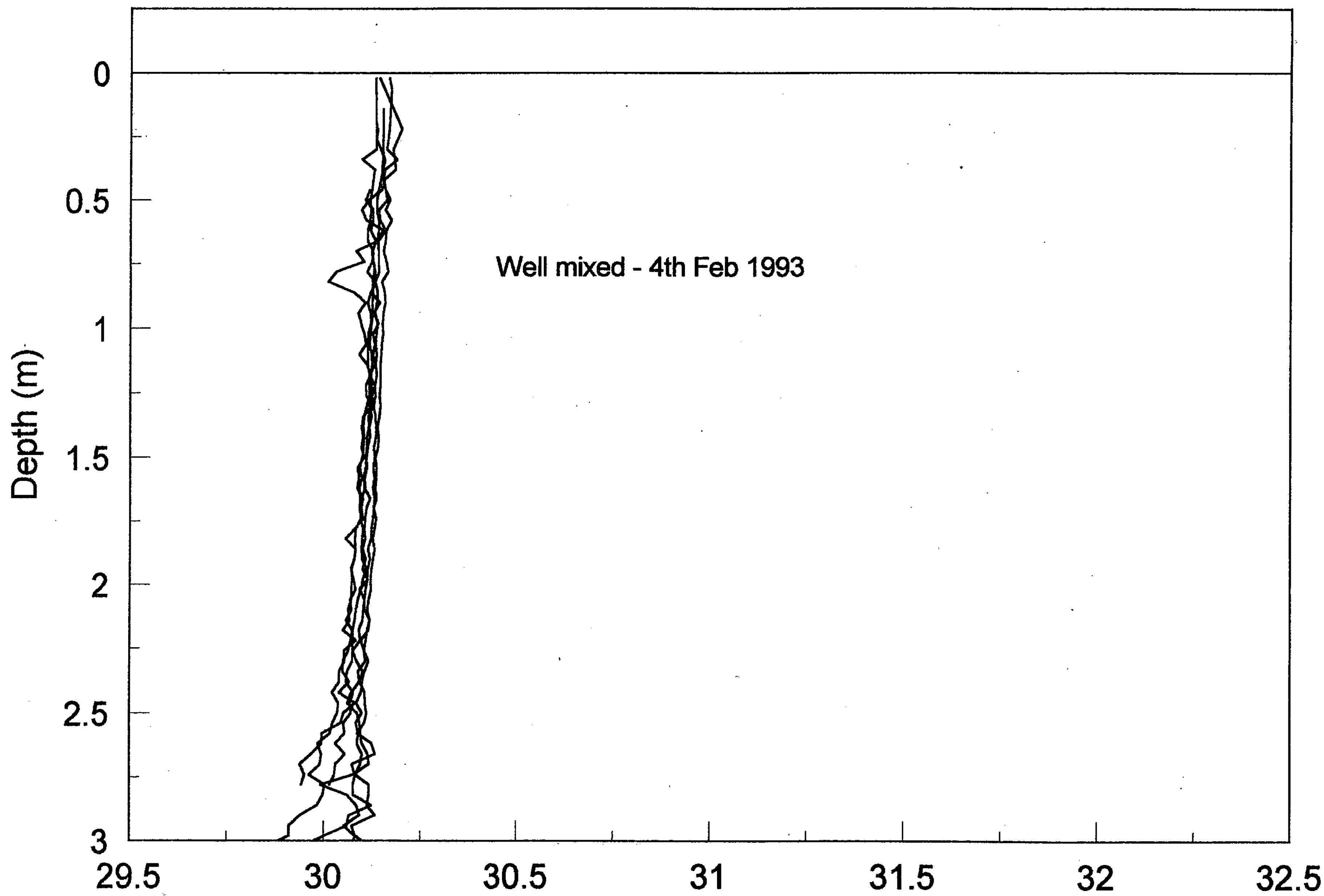


FIGURE 13

Table of SeaSoar & Bunyip Deployments, Fr01/93, page 1

#	Time In	Position In	Time Out	Position Out	Sensors	Comments
1	*Mon 11 Jan 1930 UTC* — Tues 12 Jan 0525 LT	2° 12.4′S 154° 47.1′E	*Tues 12 Jan 1750 UTC* — Wed 13 Jan 0350 LT	1° 42.2′S 154° 55.5′E	SeaSoar only, with 4π	First Survey. Begin towing towards the East (090) as part of 6 legs, each 25nm long, each one being 5nm north of the last one, and staggered to account for the mean advection of the mixed layer fluid. The velocity at a depth of 24 m at the beginning was about 0.8 kn towards 075. We did a set distance through the water, so that the eastward and westward tows are of unequal length over the ground. The CTD (stn #1) showed a sub-surface isothermal and isohaline layer from 25 to 55 m depth: a remnant mixed layer. The first leg showed no structure in the S-θ diagram in or just below the mixed layer. There was a front in the structure from 90m to 170m. On the second leg we steamed on ship headings rather than due West etc. On the 4th leg the effect of the wind was obvious (also on the 2nd and 3rd legs) so we changed to a system of waypoints. The first leg and the 1st northward jog consisted of files 1-3. Thereafter there was one file per leg, and these files include the subsequent northward jogs. Files 1–8 incl.
2	*Tue 12 Jan 2239 UTC* — Wed 13 Jan 0839 LT	1° 48.0′S 155° 07.6′E	*Wed 12 Jan 2202 UTC* — Thurs 14 Jan 0802 LT	1° 51.8′S 155° 09.1′E	SeaSoar only, with 4π	Start of the triangles following the buoy. Doing triangles rather than pairs of triangles . Buoy in water at 2140 UTC. SeaSoar in water at 2215 UTC. At 2245 UTC we were on course 192. Pass buoy for the 1st time at a distance of 2 cables = 364m. We always pass the buoy on the Port side because the SeaSoar is meant to tow off to the Starboard side. Always turning to starboard so as to keep SeaSoar on the inside of the triangles. First fly-past of the NCAR Electra N308D at 0910 AM and a second overpass a few minutes later. A new file is made for each triangle, beginning at the leg after the one that includes the buoy. Overflown at 1046 LT and this was the last one. At 1102 LT turn to heading 071, the second side of the triangle. At 1216 LT change course to 189 towards the buoy. Alongside the buoy at 1246 LT. It had drifted at 0.8 knots at 190 during this interval. Began file 10 at 1331 LT at the beginning of the next Δ. Near the end of this leg we reduced speed to 7 knots to see how the Bradley skimmer would go at this speed:- at the same time we took in 100m of faired cable. This 7 knot speed necessitated a new file, File 10. This 7 knot speed was maintained through the turn and down the first bit of the second leg. Then the speed was slowly increased to 7.5 knots. .... Last time we past the buoy was at 0743. The buoy drifted quite slowly over this whole drift (of about a day):- it was less than 0.1 knot at 100°. The aircraft (Electra and Cessna) are due to overfly us from 0900 onwards for a couple of hours. Files 9–16 incl.
3	*Wed 13 Jan 2325 UTC* — Thurs 14 Jan 0925 LT	1° 47.0′S 155° 06.3′E	*Fri 15 Jan 0325 UTC* — Fri 15 Jan 1325 LT	1° 52.0′S 155° 13.3′E	SeaSoar only, with 4π	Start of more triangles following the buoy. The Electra and Cessna overflew us several times, both before we had it in the water and after (especially the Cessna). Overflight at 1019 LT, among many previous flight-pasts. In this way we have covered the same ground-track relative to the buoy. The S-θ curves of the top part of the water column seem to confirm that the SeaSoar is surfacing sufficiently to the starboard of the ship's wake. Files 18 onwards are over the same track. These triangles were all done with northward legs from the buoy. On the last triangle we went too far north by 15 minutes (this was File 23). Of course the line that includes the buoy always overlaps in translated space. Files 17–23 incl.

Key
DSP = Dual Shear Probe. µCond = Microconductivity Probe. FP07 = Fast Response Thermistor. 4π = 4π quantum sensor.
LT = Local Time which is Townsville time, which is one hour behind Hobart Summer Time.

Table of SeaSoar & Bunyip Deployments, Fr01/93 (Continued), page 2

#	Time In	Position In	Time Out	Position Out	Sensors	Comments
4	*Fri 15 Jan 0700 UTC* —— Fri 15 Jan 1700 LT	1° 55.0′S 155° 12.3′E	*Sat 16 Jan 1000 UTC* —— Sat 16 Jan 2000 LT	1° 53.3′S 155° 13.9′E	SeaSoar only, with 4π	Start of more triangles following the buoy. These triangles are also along a fixed direction so that we have repetition of the water. We had up to 20 knots of wind overnight on this deployment and also 41 mm of rain. The temperature profiles showed that there had been significant vertical mixing. There are also very sharp fronts of salinity in the top 10m. These triangles had the bottom leg east-west. Just as SeaSoar was being recovered from this deployment, the Bradley boom collapsed and we spent several hours getting it back on board. Files 24–30 incl.
5	*Sat 16 Jan 1757 UTC* —— Sun 17 Jan 0357 LT	1° 58.2′S 155° 17.5′E	*Sun 17 Jan 0517 UTC* —— Mon 18 Jan 1517 LT	2° 04.0′S 155° 18.4′E	SeaSoar only, with 4π	Start of more triangles following the buoy. This deployment happened after having got the Bradley boom on board and having taken a CTD. The ship was not quite going fast enough for some of the time on the first triangle so that some of the sawteeth do not reach the surface. On the first 3 triangles there is the fresh salinity at a temperature of about 29.3, the salinity varying from 34.14 to 34.17. The depth at this temperature is about 12m. At a depth of 4-6 m the temperature is about 29.65 and the salinity range is even bigger, from 34.12-34.185. The first three triangles were done in the same directions but then we had to change directions because the wind strength and direction was not appropriate for Frank. There was a good-looking surface mixed layer at night time on this deployment. Then the temperature increased during the day, and the characteristic slope of the S-θ diagram of the very near-surface water (top 6m), probably due to the ratio of the evaporation rate to the sum of sensible plus latent heat. At the end of this deployment we had intended to deploy the whole system, but two problems occurred. First the microfish would not talk to us when it was connected on the back deck, and second, the tow cable had frayed at the entrance to the SeaSoar, breaking two strands of the outside armour. This must be a fatigue problem due to vibration, and emphasises the need to keep flexible fairing on this section of cable. Files 31–40 incl.
6	*Mon 18 Jan 0050 UTC* —— Tues 19 Jan 1050 LT	2° 05.5′S 155° 28.3′E	*Tues 19 Jan 2058 UTC* —— Wed 20 Jan 0658 LT	1° 57.1′S 155° 28.1′E	SeaSoar only, with 4π	Start of more triangles following the buoy. Having re-terminated the cable into SeaSoar, we re-deployed it here to get the last day of data following the buoy before turning for Rabaul. The first 7 minutes were in an upwind direction and then we turned around to go past the buoy on a regular downwind direction of 315°. The buoy was hard to find on this first downwind leg. The S-θ curve on this series of triangles was different to that on the previous triangles. In the >20m range it was warmer. This is the first day that we have not seen an afternoon effect. There are patches of quite low salinity though, and these patches are not very deep (<6m). This would indicate that there has not been much input of energy from the sun and atmosphere today. It has been cloudy all day (I am writing this at 1630 LT). Ian says that at about 1800 LT, SeaSoar was not clearing the wake. From about 1900 LT we are going to do reduced-size triangles in order to keep closer to the drifting buoy because its flashing light has stopped flashing. The legs will be 60% of their previous length. Several times during the night the system had to be aborted and restarted. Once Lindsay changed the CPU board in the Sun 3/160. The surface mixed layer was the deepest we had seen it on this cruise. At the end of this deployment we took out the drifting buoy and then did a CTD (CTD #14), and this showed that the mixed layer was 40m deep. It had been only 20m deep on the previous CTD done at the beginning of this deployment. Files 41–48 incl.

Key
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Table of SeaSoar & Bunyip Deployments, Fr01/93 (Continued), page 3

#	Time In	Position In	Time Out	Position Out	Sensors	Comments
7	*Wed 20 Jan 1027 UTC* —— Wed 20 Jan 2027 LT	3° 34.6´S 153° 51.0´E	*Wed 20 Jan 1115 UTC* —— Wed 20 Jan 2115 LT	3° 39.0´S 153° 47.7´E	SeaSoar with 4π, 2 DSP, DOμCond, μCond	This is a test deployment of Bunyip coming towards Rabaul. We noticed as we were deploying it that the port DSP was broken (it was obviously bent). We think the port DSP is DSP#2. The SeaSoar seems to be travelling nose up at a ship speed of 6 knots. We had 10 minutes at 6 knots. There was an offset between the two Seabird conductivities of close to 1mS. The reason for this was subsequently found to be due to the conductivity cables being plugged in around the wrong way. The first crash was at 2058 LT. The one accelerometer channel that we could see was going up and down with the 0–100m flight path, as was the two parts of the live DSP. The micro data all lost their variance at about 2110 LT although a few minutes later the accelerometer channel regained its variance but the other microstructure data did not (DSP and μConds). Files 41–48 incl.
	Rabaul	**Rabaul**	**Rabaul**	**Rabaul**	**Rabaul**	**Rabaul Port Call**
8	*Sat 23 Jan 0548 UTC* —— Sat 23 Jan 1548 LT	2° 15.8´S 154° 12.7´E	*Sun 24 Jan 0313 UTC* —— Sun 24 Jan 1313 LT	1° 53.7´S 155° 07.4´E	SeaSoar with 4π	Second Survey. This is the Survey at the start of the second half of the cruise. Still having communications problems with the microfish and still have no idea why the micro stuff died on the last Bunyip deployment, so we are deploying SeaSoar alone for this survey. On the CTD before this deployment there was a very high oxygen concentration from 20m to 40m. This was not there on the way up with the CTD. The NEC-III went dead at the beginning of this deployment and we had to use the one from the bridge. Having the ship steer directions due East, North, West, North etc. The wind is coming from the East at 9 knots, and the current must be coming from the North because that is the direction of our drift on the map (at least for the first one and a half legs). The appropriate temperature to integrate down now would be 29.2°C or even 29.3°C not 28.9°C. There is that characteristic slope on the S-θ diagram due to the ratio of heating and evaporation. On the basis of this survey we decided on a position to deploy the drifting buoy. There are a lot of communications problems on this SeaSoar deployment. The problems are concentrated near the surface for some strange reason. After this deployment Ian found that the resistance of the connector varied under movement. He then re-terminated the cable electrically. There were almost no communications problems on the next deployment. Also we found a lot of water in the connector from the mainfish to the microfish that had had a dummy in it. It must have sealed on the end O-ring of the dummy and so kept the salt water out of contact with the 300 Volts. Also we burnt out a varistor and the fuse in the mainfish at the end of this deployment simply by powering it up straightaway after turning the power supply off. The ship did one regular triangle for Bradley et al. without SeaSoar in the water. Files 49–56 incl.
9	*Sun 24 Jan 1200 UTC* —— Sun 24 Jan 2200 LT	1° 57.6´S 155° 25.7´E	*Mon 25 Jan 0042 UTC* —— Mon 25 Jan 1042 LT	2° 00.3´S 155° 13.2´E	SeaSoar with 4π	Doing triangular patterns near the drifting buoy. The triangles all have westward downwind legs because of the persistent easterly wind. There was a 30 m deep mixed layer and the water mass characteristics were quite homogeneous around the triangles, confirming our choice of location for the drifting buoy. Did 3 triangles on this deployment. Brought the system in so that we can deploy Bunyip (ie the complete system). Did a triangle with nothing in the water while we button up the microfish. Files 57–61 incl.

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Table of SeaSoar & Bunyip Deployments, Fr01/93 (Continued), page 4

#	Time In	Position In	Time Out	Position Out	Sensors	Comments
10	*Mon 25 Jan 0537 UTC* — Mon 25 Jan 1537 LT	2° 01.7´S 155° 24.6´E	*Mon 25 Jan 1720 UTC* — Tues 26 Jan 0320 LT	1° 56.5´S 155° 07.5´E	SeaSoar with 4π, 2 DSP, FP07, µCond	Second Bunyip microfish deployment. Saw a Chinese vessel with lots of radars at the deployment site, it was the RV Xiangyanghong 5. All the triangles have westward downwind legs because of the persistent easterly wind. We did two and a half triangles on this deployment. Commencing from due east of our buoy, on an extended "downwind leg". On this leg we did some towing at constant depth and at different speeds. The accelerations are all much higher (an order of magnitude or more) which must be due to the new hammerhead arrangement. The base levels of the variance of both the scalar variables, microconductivity and the FP07 temperature vary slowly with time which is probably linked to the phase of the sawtooth profile. On the second main leg of the first triangle it had trouble reaching the surface (presumably because of the extra drag of the mainfish) and we increased speed to 8.7 knots. At the end of the next leg we reduced speed to 8 knots and brought in two turns of the cable. When the microfish was noticed to be doing a huge rolling motion, it was recovered. This had been caused by two of the sheet metal fairings of the hammerhead that had been bent backwards on the starboard side. There were almost no communication problems on this deployment. This is probably due to the provision of an extra short ground wire that avoids the main loom of wires, so avoiding a mysterious 0.2 Volt drop between the grounds up at the comms end of the microfish in the region of the comparator. Did not do a CTD between this deployment and the next. Files 62–69 incl.
11	*Mon 25 Jan 1830 UTC* — Tues 26 Jan 0430 LT	2° 02.4´S 155° 10.8´E	*Tues 26 Jan 0745 UTC* — Tues 26 Jan 1745 LT	2° 06.6´S 154° 51.0´E	SeaSoar with 4π	Doing triangles with SeaSoar alone. The triangles have westward downwind legs because of the persistent easterly wind. From deployment at 0430 LT until 0900 LT the mixed layer depth varied from 20 m to 30 m and there was only about 0.05°C variation in the mixed layer temperature around the triangular path. Did 3 triangles and brought SeaSoar in so that we can deploy the complete Bunyip system. Did a CTD at the buoy after this deployment and before the next. After this deployment Ian noticed that the bellows on the SeaSoar hydraulic unit was about to fail so this was replaced, delaying the next deployment somewhat. Files 70–73 incl.

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Table of SeaSoar & Bunyip Deployments, Fr01/93 (Continued), page 5

#	Time In	Position In	Time Out	Position Out	Sensors	Comments
12	*Tues 26 Jan* *1522 UTC* —— Wed 27 Jan 0122 LT	2° 03.5′S 155° 00.1′E	*Wed 27 Jan* *1023 UTC* —— Wed 27 Jan 2023 LT	2° 13.5′S 154° 42.5′E	SeaSoar with 4π, 2 DSP, FP07, μCond	Bunyiping in a butterfly pattern around the drifting buoy. Same sensors as the last microfish deployment. The microfish had not been opened in between. The SeaSoar stabiliser was returned to the upright position for this deployment. Ian used cable ties to keep the sheet metal under control. The tail brushes were roped so as to stop the sharp knocking vibrations. At the beginning we towed at 8 knots at 100 m. During a normal U-turn and level flight at 100 m, the microfish had a roll of -30°. After the turn it was down to a degree or two. In this level flight the pitch varied very little ±1°, and there is about 20 m difference between the two fish so that the buoyancy and drag were trimmed nicely. As we were first coming to the buoy we ran at 100 m at 8 knots until 0155 then went to 6 knots. From 0208 we towed at 4 knots, settling down to 150 m after 0215 LT. Ian arranged to have only 320 m out so that we reach the surface and at 0225 LT we began towing at 7.5 knots in "triangular (depth)" mode from 0 – 150 m. On the CTD at the buoy before this deployment there was very little afternoon effect left and the bottom of the mixed fluid was at 30 m. The microfish rolls a fair bit on the sawtooth pattern. This may imply a large yawing motion as well which just may mean that the shear probes can exceed their angle of attack to the flow. The roll was very good in level flight but is excessive in the sawtooth motion at a rise and fall rate of 1 m/s. At 1102 LT on 27 Jan power was lost to the disc and Exabyte unit on the SparcStation and this brought everything down for about 10 minutes. This was fixed at 1125 LT when file 78 was begun. Sometime around 1200 LT the shear probes went dead. Lindsay exchanged the Exabyte unit with one from downstairs. Had a problem with the root area of the Seagate disc at about 1245 LT and we ceased archiving until the system was up and running at 1320 LT, beginning file 79. The shear probes became jumbled at about 1340 LT (flag = 2). The vertical accelerations were by far the largest. This is much different to the previous situation where the *x* acceleration was the largest. It is towing out to the port side quite a lot and is clearing the wake on the port side. This is with the stabilizer in the vertical position. Ian and Lindsay say this depends on the shear of the current and is persistent on a given leg. The "flag = 2" problem persisted for the rest of the deployment. Each time the system required restarting it took a few times to get it going. At 1923 LT we stopped file 80 and began to bring in the SeaSoar and then connect up the microfish that was still in the water. (It seems that some of the previous files of deployment #x were not written to Exabyte). Begin file 81 with the microfish only in the water at a speed of 6 knots and with it sitting at 4.5 m. It was being towed from the big wheel at maximum height. Then 6.5 knots with a depth of 3.5 m. Red shear is very high while green shear is at its usual value. The *z* accelaeration is now very small!! Implicates the extra length of cable that is now not there or the SeaSoar? Then went to 7.5 knots at 2013 LT:- it died at the same time for two minutes. By 2019 LT we were going 3.7 knots it was at a depth of 11 m and the red shear was much smaller. By 2025 we were going 2.3 knots and the depth was 14 m. Then brought it in. Files 74–81 incl.

Key
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#	Time In	Position In	Time Out	Position Out	Sensors	Comments
13	*Wed 27 Jan 1300 UTC* —— Wed 27 Jan 2300 LT	2° 23.8´S 154° 49.4´E	*Thurs 28 Jan 0124 UTC* —— Thurs 28 Jan 1124 LT	2° 32.4´S 154° 46.6´E	SeaSoar with 4π	Doing butterflies around the buoy with SeaSoar alone. Passed the buoy just as we were turning on the system in the ops room. Disregard file 82. Started file 83 at 2305 LT. The CTD before this deployment showed a mixed layer 30 m deep. The nighttime SeaSoar profiles show a healthy mixed layer and the S-θ curve is pretty compact. Did not do a CTD at the end of this deployment as we went looking for the Bretherton buoy and this took quite a time (4.5 hours from 1124 LT). Since our buoy had drifted so far from the central IFA we decided to pick the buoy up and go east of the IMET mooring. Files 82–86 incl.
	Move Buoy	**Move Buoy**	**Move Buoy**	**Move Buoy**	**Move Buoy**	**Move Buoy**
14	*Thurs 28 Jan 1635 UTC* —— Fri 29 Jan 0235 LT	1° 41.4´S 156° 14.8´E	*Fri 29 Jan 1520 UTC* —— Sat 30 Jan 0120 LT	1° 48.6´S 156° 13.6´E	SeaSoar with 4π	Third Survey. Doing a SeaSoar Survey to the East of the IFA minefield. Towing to the east initially. The wind is as large as 30–35 knots. Did not do a CTD before this deployment because the bow thruster was not working. The mixed layer is much fresher here than it had been in the previous region west of the IMET mooring:– 34.05 as opposed to about 34.10. In the first 4 sawteeth on this deployment there was a large variation of the mixed-layer salinity, from 34.045 to 34.095. The change in SST was much smaller, less than 0.02°C. The first leg of this deployment was to the east, then the sea was too rough to head back towards the west, so we did north-south legs. The first three north south legs showed significant horizontal salinity structure in the mixed layer. The fourth leg had an amazing S–θ curve that bowed upwards like a boomerang. There was a large air-sea temerature difference (ocean 29.4 and the atmosphere 2° cooler) and strong winds. Files 87–92 incl.
15	*Fri 29 Jan 2034 UTC* —— Sat 30 Jan 0634 LT	1° 35.2´S 156° 22.8´E	*Sun 31 Jan 0446 UTC* —— Sun 31 Jan 1446 LT	1° 42.7´S 156° 41.8´E	SeaSoar with 4π	Deploy buoy and begin butterfly patterns with reduced size of each leg. There is a full hour on each of the diagonals and at the end of both downwind legs we turn 40 minutes after the previous turn. At the beginning of this deployment the SST was 29.18°C by the thermosalinograph and 29.28°C on the SeaSoar while SSS was 34.04 on the thermosalinograph and 34.07 on the SeaSoar. The air temperature was 28.2°C at the start. By 0930 LT the air temperature was as low as 24.9°C and the day was rainy and overcast. Despite very patchy water on the survey, we have found quite a homogeneous parcel for this deployment. The S-θ curve looks good, but there is a salinity stratification in the top 35 m. This should be an excellent data set for testing mixed layer models such as the PWP model because we have the wind and buoyancy forcing and we are watching the restratification process which is the hardest part of the mixed layer cycle to get right. During the night we had to abandon butterflies because the buoy drifted through the watch circle of PCM # 17. The buoy passed within 1.5 nm of it while Franklin kept at least 2 nm away from the mooring. At 1200 LT on 31 Jan the SSS was 34.12 and there was a tiny temperature stratification in the top 8 m while the mixed layer proper was 25 m deep and the wind was as much as 12 knots. There must be a Kamenkovitch/ Ozmidov scaling going on here? On this deployment there developed a few of those comms problems that have in the past been indicative of a connector or a termination problem. By 1420 LT the temperature at 30 m varied from 29.10°C to 29.2°C and the salinity there varied from 34.07 to 34.13 psu. At the same time there was a stable thermal stratification in the top 16 m of about 0.06°C on each vertical profile. On the CTD at the end of this deployment there was no incrlarse of temperature in the top 10 m but the increasing salinity with depth was obvious at 20 m in a mixed layer that was 45 m deep. Files 93–103 incl.

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#	Time In	Position In	Time Out	Position Out	Sensors	Comments
16	*Sun 31 Jan 0848 UTC* —— Sun 31 Jan 1848 LT	1° 44.9´S 156° 46.0´E	*Sun 31 Jan 1434 UTC* —— Mon 01 Feb 0034 LT	1° 41.6´S 156° 51.6´E	SeaSoar with 4π, 2 DSP, FP07, DOμCond	Bunyip deployment with extra sideways fairing that Ian had made out of two halves of an aluminiunm tube and two quarter spheres. We delayed the deployment for a while until a bad rain squall passed and then we realized that the CTD had not been connected in the mainfish. This led to a very lengthy deployment with the microfish being in the water for 2 hours and the mainfish sitting on the deck. Note the different sensor combination. Had a problem starting the system:- same problems as before. The solution is to just power it off and on enough times. There are 60 turns of the cable out instead of the 63 turns for the SeaSoar alone. First bombed out at 1855 LT. Then we towed at 8 knots at 50 m (mainfish depth with the microfish at 50 m) to get some data for comparison for the fairing. The acceleration variace seems the same as before and is dominated by the low frequency cable vibrations. The shear probe variance also seemed pretty similar on the NEC display. Then from 1903 LT we towed at 30 m (mainfish depth with the microfish at 50 m) at 8 knots. From 1906 LT we began the triangular flight path from the surface to 150 m. There is something wrong with the FP07 temperature because it has a high pedestal. The DOμCond looks a bit like turbulence. Had a water level detect (which was a false alarm) and then a communicatioons breakdown. A later look at the spectra showed that the y and z spectra are similar above 50 Hz and the x acceleration spectra are a factor of 10 more than x and y. NOTE THAT XAND Z WERE INTERCHANGED TO DATE IN THE WIRING INSIDE THE MICROFISH. Files 104–106 incl.
17	*Sun 31 Jan 1553 UTC* —— Mon 01 Feb 0153 LT	1° 41.4´S 156° 59.8´E	*Mon 01 Feb 1416 UTC* —— Tues 02 Feb 0016 LT	1° 41.7´S 157° 09.8´E	SeaSoar with 4π	SeaSoar only butterfly deployment. The buoy continues to drift eastwards away from the central IMET mooring. At the end of this deployment we did a CTD and then used the SeaSoar on deck to check out the communication problem that occurred with the microfish on its previous deployment. The mixed layer continues to be quite deep (45 m). At the end of this deployment the CTD showed that the salinity was constant to 40 m while the temperature was constant to 58 m:- shades of barrier layer formation. The SeaSoar was brought in so as to test out the microfish on deck. Files 107–114 incl.
18	*Mon 01 Feb 1917 UTC* —— Tues 02 Feb 0517 LT	1° 41.3´S 157° 13.4´E	*Tues 02 Feb 0500 UTC* —— Tues 02 Feb 1500 LT	1° 49.7´S 157° 18.6´E	SeaSoar with 4π	SeaSoar only butterfly deployment. SeaSoar was put back in while we button up the microfish. The air temperature is now up above 30.0°C (30.3°C at 1100 LT) and there is now stable temperature stratification in the top 20m and there is a remnant mixed layer below 25 m down to about 46 m. The wind is also not tiny, being about 17 knots, so this should be an excellent data set to test the restratification performance of various mixed-layer models. At 1210 LT we did come into a bit of a front that is about 1 nm from the buoy. Water was advected into the region that had a lower temperature of the remnant mixed layer so that there was a temperature maximum between 50 m and 100 m, while the upper 30 m exhibited a stable temperature difference of about 0.12°C. In file 116 the temperature structure shows that the mixed layer is about 58 m deep, while the isohaline layer is less deep. Files 115–116 incl.

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#	Time In	Position In	Time Out	Position Out	Sensors	Comments
19	*Tues 02 Feb 0557 UTC* — Tues 02 Feb 1557 LT	1° 49.6´S 157° 24.3´E	*Tues 02 Feb 0840 UTC* — Tues 02 Feb 1840 LT	1° 44.9´S 157° 22.6´E	SeaSoar with 4π, HotFilm, DSP, FP07, DOµCond	A short Bunyip deployment to test out the reduced drag elements and the HotFilm probe. The HotFilm probe was installed and the extra sideways fairing was again used. The number of drag elements was reduced from 12 to 4 so that the total drag is halved. The microfish was opened up for the first time for ages before this deployment. The x, y and z accelerations are now wired correctly. The DOµCond probe was re-platinised just before this deployment. Start with an 8 knot run towards the buoy on a course of 330°. Begin with a constant depth of 50 m. It was 1405 LT when we had straightened up on course 330°. The DOµCond and FP07 signals seem to be seeing some turbulence when it is high. From about 1800 LT the system became very unreliable, with only one down and one up cast before it clagged up. Files 117–120 incl.
20	*Tues 02 Feb 0930 UTC* — Tues 02 Feb 1930 LT	1° 40.5´S 157° 24.4´E	*Tues 02 Feb 2020 UTC* — Wed 03 Feb 0620 LT	1° 41.3´S 157° 28.6´E	SeaSoar with 4π	SeaSoar butterflies around the drifting buoy. The CTD at the end of the deployment showed that there was no afternoon effect (it being early morning) and the mixed layer was isothermal down to 70 m and isohaline down to 58 m. This deployment was stopped so that we could recover the buoy and head towards the IMET mooring for the flux intercomparison work. Files 121–123 incl.

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