RESEARCH SUMMARY

FRANKLIN

Research Cruise FR 9/94

AIR-SEA INTERACTION STUDIES IN THE EQUATORIAL INDIAN OCEAN

Itinerary

Sailed Colombo	1630 hrs	16 September 1994
Arrived Fremantle	1000 hrs	9 October, 1994.

Principal Investigators

Dr J S Godfrey	CSIRO Division of Oceanography
Dr E F Bradley	CSIRO Centre for Environmental Mechanics
Prof M Tomczak	Flinders University

Aims

The principal aims of the cruise were:

i to achieve an accurate heat budget closure following a drifting buoy for several days;
ii to recover a surface mooring at (0,84E).

In the Research Plan it had been intended that we should deploy a mooring at (0,90E); however, it turned out that we could not support this mooring, due to other commitments and some gear losses. In addition to these aims, we also planned :

iii to the test measurements of the near-surface skin effect, comparing SeaSoar against the bow-mounted Silverfish system developed by Dr. Bradley;

iv to test a surface "skimmer", for measuring the temperature of the top few centimetres of water;

v to investigate the performance of an Optical Rain Gauge (ORG) which had been specifically designed for use at sea;

vi obtain an accurate transect of surface heat fluxes on the return to Fremantle;

vii test the new electric drive unit in the SeaSoar.

viii At (27S,110E) - on our direct route home - deploy 950 drift cards commemorating the loss of HMAS *Sydney* near this spot in November, 1941.

Items iv-viii were not mentioned in the original cruise plan, but were considered small enough to add without concerning the Steering Committee. Items iv and v arose as matters of urgency, following uncertainties in the measurement of SST and rainfall reported by all observers during the TOGA-COARE workshop held in Toulouse in August 1994. Item viii was initiated by Dr. John Bye.

Cruise Narrative

The cruise track is shown in Figure 1a. The cruise was unusual for *Franklin*, in that we departed from a foreign port - Colombo. This turned out to create a few difficulties, the main one being that gaining access to the port took us easily half a day. It was eventually sorted out by a Port Agent, at no apparent cost apart from an exorbitant bus-hire charge of $50 (US) for a few hundred meters.

A reception was held at the ship on the morning before departure, for Sri Lankan Government officials. The Sri Lankan Minister of Shipping and Transport and the Minister for Science both attended, along with several scientists from the National Aquatic Resources Agency (NARA). Some good contacts were made, which could be useful for (e.g.) further work of the Indian Ocean Panel.

Helmond's new boom assembled quickly and proved very easy to handle. No serious problems were encountered with other gear. The foremast meteorological equipment was mounted while in port, as was the net radiometer at the end of the boom. The short- and long-wave radiometers had been already mounted on the mainmast by Phil Adams and were operating. The Optical Rain Gauge was mounted in its COARE position on the foremast, this time with a conventional funnel-type raingauge alongside it. Thus, when we left port we were already logging high quality meteorological data for bulk determination of the fluxes, a situation which continued throughout the cruise until just outside Fremantle.

Departure was delayed till 1630 local time, 16 September largely due to the fact that divers were hired to remove encrusted coral from the propellers. The time was used to replace winch sliprings, a job involving mercury that is better done in calm conditions.

A few hours after leaving Colombo, the ADCP showed a broad east/south-eastward current south of Sri Lanka, of about 2 knots. This is in accord with climatologies of surface currents. The ADCP showed that the current is confined to the top 200 m.

Mooring Recovery:

We arrived at the mooring location at 1340, local time. Unfortunately, no buoy was to be seen.

A visual and radar search was conducted of the 4 km^2 area within which the mooring had regularly reported its position - until May, when it stopped reporting, apparently due to a failure of its batteries (as had occurred about a year earlier). This search failed to show anything. Visibility was not very good, and sea clutter on radar was thought by the ship's officers to reduce the effective radar range to of order 1 sea mile. Janek Hansen, the boatswain, noted that seabirds are usually the best indicator of a surface mooring: no concentrations of birds were seen. We returned to the nominal buoy location and sent the "enable" code on the acoustic sounding unit: no reply was heard. This did not surprise us, since the moorings on the voyage to Sri Lanka were all recovered, despite the fact that they also failed to respond to the initial acoustic signal. However, after a short period of this we sent the "release" code several times. After waiting for well over an hour - considerably more than the 45 minutes expected - we still had not heard any consistent response from the mooring. We had drifted during this time; we returned to the mooring site, and sent the release code again. Visual searching continued until light started to fail. We then decided to continue to our experimental area. It is puzzling that no response was heard from the acoustic release - unless it coincidentally also had weak batteries.

The main experiment:

Various problems were encountered in assembling the SeaSoar in its new, lightweight configuration. Specifically, a (new) underwater connector failed upon putting the SeaSoar in the water, and on another occasion the electrical connection to the CTD on the SeaSoar failed. Partly to allow for such problems, and to bring the experiment to climatogically calmer conditions, the experiment site was chosen at (2S,90E) instead of at (2S, 87E) as originally planned. Nevertheless, the deployment of the buoy was delayed by a few hours after arrival at the experimental site. Once these SeaSoar problems were dealt with, it was found harder than anticipated to operate the SeaSoar successfully within the 1.7 tonne limit on cable tension. Nevertheless, all these problems had been satisfactorily addressed by the middle of the 9-day buoy deployment. A more detailed report on the SeaSoar is being prepared by Helmond and Pender. Figure 1b shows the cruise track during the experiment. The square with its diagonals was the survey before buoy deployment; subsequently we undertook triangles in the usual way.

Unfortunately, the conditions we encountered were not very "climatological". Winds were more typical of the Trades than the COARE region: steady ESE winds of about 15 knots prevailed. Diurnal warming was evident in CTD's, but the dramatic near-surface manifestations found in COARE did not occur. Consequently little work was possible towards objective (iii) above. The buoy suffered a minor mishap on deployment: the array of near-surface temperature sensors attached to the buoy did not enter the water correctly, and in trying to correct this the anemometer was damaged. The drifter was recovered briefly 2 days later and both defects were fixed.

Due to the strong winds, the ship spent 1/3 of its time with relative winds from aft, so that bulk flux estimates were made by alternating between the ship's mainmast anemometer and the calibrated foremast station. Luckily, the winds were steady enough that this will not present a major problem; and it has a benefit, in that it provides an extensive data set for calibrating the mainmast instruments (which badly needs doing.) The net radiometer operated well throughout the drift, at the end of the boom which was fully extended.

Following decisions made at the international COARE Data Workshop, Toulouse, August 1994, to specify SST as the true surface value, and the proposal of an algorithm to extrapolate it from the bulk measurement, we intended some effort to investigate near-surface temperature structure and test the algorithm (aims iii and v). We were equipped with three experimental schemes for doing this (a collaboration with Chris Fairall of the NOAA Environmental Technology Lab. in Boulder, CO). These were;

1. an improved version of the "Silverfish" T-S profiler, towed ahead of the ship from the boom. This was all prepared and operated well on deck, but the sea was so rough that deployment would have it risked losing it. This was not justified given that the conditions we need to achieve our objectives, light winds and a strongly stratified surface layer, were never experienced on this cruise;

2. a very simple device, the "Seasnake", consisting of a very high precision thermistor in the end of 5 m of garden hose which we towed from the side boom on the foredeck. At speeds up to 4 kts, even in the rough sea, this followed the contours of the waves remarkably well just below the surface, and was mostly clear of the ship's bow wave. At the Seasoar tow speed of 7 kts, especially pitching into the swell, the ship's wash was too severe and the Seasnake had to be brought in. This can be done easily and quickly by one person an account of the light and simple rigging. It could be towed further out from a much lighter side boom mounted 2 m further forward. This should be considered if the opportunity arises again to pursue the physics of ocean surface warming and cooling. Although the surface water was well mixed, the Seasnake indicated quite reasonable differences of a few tenths of a degree from the thermosalinograph temperatures;

3. a high-tech but relatively inexpensive IR radiometer (belonging to Chris Fairall) directed at the sea surface to measure radiative temperature. This device has not the resolution of the Barton/Cechet radiometer, but neither has it the complexity nor cost. We had plans to overcome the accuracy problem by using two such instruments switched alternately to view the sea surface and a container of continuously pumped sea water whose temperature is monitored accurately. In effect, we have a continually calibrated system. Again, because of the rough conditions with water washing over the foredeck much of the time, this exercise was not possible, but data from one of the IR radiometers was obtained on several days when conditions were not too severe, which will enable us to evaluate these sensors for use at sea.

Heat flux time series during transit:

One of the legacies of our participation in TOGA-COARE is a good understanding of the problems involved in the measurement of heat and momentum fluxes from aboard ship, the techniques needed to overcome measurement errors and the availability of a well-tested bulk flux algorithm. This experience now enables us to obtain bulk flux estimates with some confidence and a fair degree of accuracy. With the specialised and well-calibrated meteorological instruments installed for the main heat budget closure experiment, we have a good opportunity to observe the change in sensible and latent heat exchange over the long transect from Colombo to Fremantle. In one respect, the steady trade wind conditions which we have experienced throughout the cruise will prove an asset to the analysis of this data set; light wind, non-steady conditions would present complications in our interpretation. As can be seen from figure 2, in the "drift" area latent heat flux was fairly constant at around 120 W/m^2; as we travelled further south, stronger wind and drier air increased this to as much as 300 W/m^2 during some periods. All the necessary instruments operated well throughout the transect and we are confident that these observations will provide a valuable "calibration" of the accepted climatology of the region. Steaming for the most part into wind along this transect has also enabled us to obtain good performance evaluation of the ship's meteorological instruments. Briefly, however, both temperature and humidity sensors overestimate by a constant offset; by about 1C and 10% RH respectively. The wind sensors measure speed and direction fairly accurately as well as can be estimated by a comparison with the foremast instruments, which are themselves subject to angle of attack dependent flow distortion over the ship.

Test of the SeaSoar electric drive unit:

A short deployment of SeaSoar was carried out on 2 Oct, after two days of work on reconfiguring the instrument for the electric drive. The results are described in a separate report by Pender and Helmond.

Computing report:

No major difficulties were encountered with the data collection system itself, and there was no significant data loss due to computer down time. The SeaSoar data collection system worked without fault, however, the usual means of obtaining the data from the *Franklin* data collection system via shared memory system could not be implemented. This was overcome by connecting to the *Franklin* system through a serial port.

Deployment of drift cards:

Some correspondence with Hobart occurred over this item, since there was some concern on the Master's part over whether we would be in breach of the MARPOL Convention, according to which plastics may not be dumped at sea. However, it was eventually agreed that these engraved drift cards did not constitute marine pollution, and the cards were dropped as planned. Photographs of this event may be used for press purposes.

Preliminary Data Analysis:
The long (ten-day) period of Transit Duty gave us an excellent opportunity to analyse our quite complex set of results, using software developed for COARE over the last two years. Despite the problems referred to above, we believe we have an excellent data set for testing the accurate closure of the heat budget under Trade-like conditions - something that has not been done before.

A preliminary calibration of all CTD and SeaSoar data was performed, using the salinity samples analysed by Latham. (The SeaSoar was calibrated by inserting the sensors in a seawater bath after recovery: this was made possible by use of new Seabird sensors on the SeaSoar). Butt assembled a blended data set of temperature-salinity data near the buoy from the CTD and the SeaSoar.

Figure 3 shows our first attempt at a closure. The full line gives the time integral of the net heat flux into the water. This will change somewhat with further work on calibrating the meteorological data. The dots are heat content, after allowing for vertically uniform stretching and shrinking above each isopycnal. This was necessary, due to strong internal tides. The chosen isopycnals lie at depths of 40-70 m, near the base of the mixed layer; unlike COARE, the mixed layer depth was quite well-defined (Figure 4), and was deep enough so that radiative penetration to the base of the mixed layer is only a few watts/m^2.

The SeaSoar lightmeter data was compared for the first time with pyranometer data on the mainmast. The ratio of SeaSoar light to the pyranometer reading is shown in Figure 5, along with the Soloviev attenuation profile. This fits the data considerably better than the Simpson-Paulson profile we had previously used.

However, the present indications are that horizontal advection will be quite large. The currents measured at the 29.5 m current meter on the drifter (Figure 6) were quite steady, at about (0.10m/s:0.05 m/s) to the (north,east) respectively; and from the ADCP vertical shears were small (Figure 7). The horizontal temperature gradients were also very constant vertically, and rather consistent in time. The time and depth average of these is (0.29E-05C/m, 0.08 E-05C/m). The scalar product of these two mean vectors, integrated over the top 30 m, suggests an average advective warming of the water over the top 30 m of about 30 watts/m^2 - a substantial contribution. Further analysis of the budget will continue; however, we are already at a similar stage in analysing these data as we are after nearly two years of work on the COARE data set. We have also refined our methods considerably due to the fact that we had 10 days of transit time to analyse our data.

Optical Rain Gauge Evaluation.
The problem perceived at the Toulouse COARE Data Workshop by scientists analysing the rainfall data from several sources, was that the ORG's overestimate by up to a factor of 2. The ORG provided to *Franklin* for COARE was one of the few to operate throughout the

experiment without failure, and we had assumed that its performance was reliable. However, a careful comparison of our data from the ORG, the ship's siphon raingauge and the one on the drifting buoy revealed that we appeared to experience the same problem; calibrated on land the ORG agreed with other types of raingauge - on the ship it overestimated up to a factor of 2. On the present cruise we have been fortunate to experience several rainstorms of various intensities, duration and wind direction relative to the ship. The problem seems to be associated with whether or not the rain is falling vertically or being wind driven relative to the ship. It raises the question of exactly what we need to measure to obtain an appropriate rainfall estimate. We are confident that our measurements will throw some light on both the instrumental and philosophical problems. Dr Bradley proposes to further examine the former in the Soils Division raintower in Canberra.

Three non-CSIRO personnel were among the scientific staff on this cruise (Shulz, Tanner and von Bibra). Their presence was much appreciated;they participated in the routine tasks during the main experiment, and contributed to the analysis of the data. eg. the lightmeter data of Figure 5, and the buoy track and ship track of Figure 1 were developed by the students. Godfrey asked for and received some much-needed tuition in relatively recent computing methods which he would not have found time for in Hobart.

Acknowledgements

We would like to acknowledge the able and willing help provided by the Master, Ian Sneddon, and the crew of *Franklin* , in what turned out to be a quite demanding cruise.

Scientific Personnel:

J.S. Godfrey	CSIRO - DO	Chief Scientist
E.F. Bradley	Centre for Environmental Mechanics	
J.A. Butt	CSIRO -DO	
D.W. Edwards	CSIRO - ORV	
I. Helmond	CSIRO - ORV	
V. Latham	CSIRO - ORV	
L. Pender	CSIRO - ORV	
E. Shulz	Flinders University	
E. Tanner	Australian OceanographicData Centre	
M. von Bibra	Melbourne University	

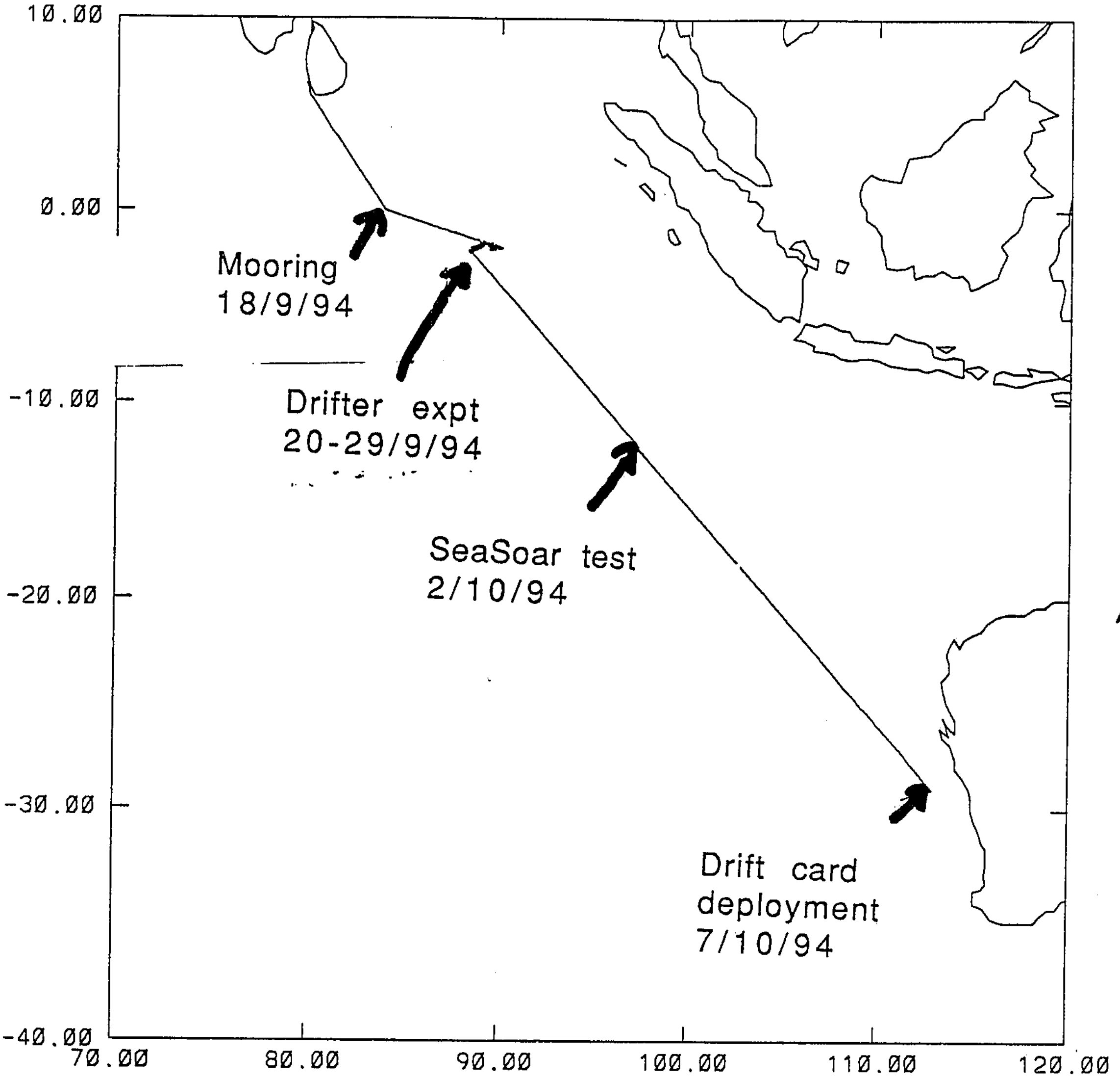

Figure 1a

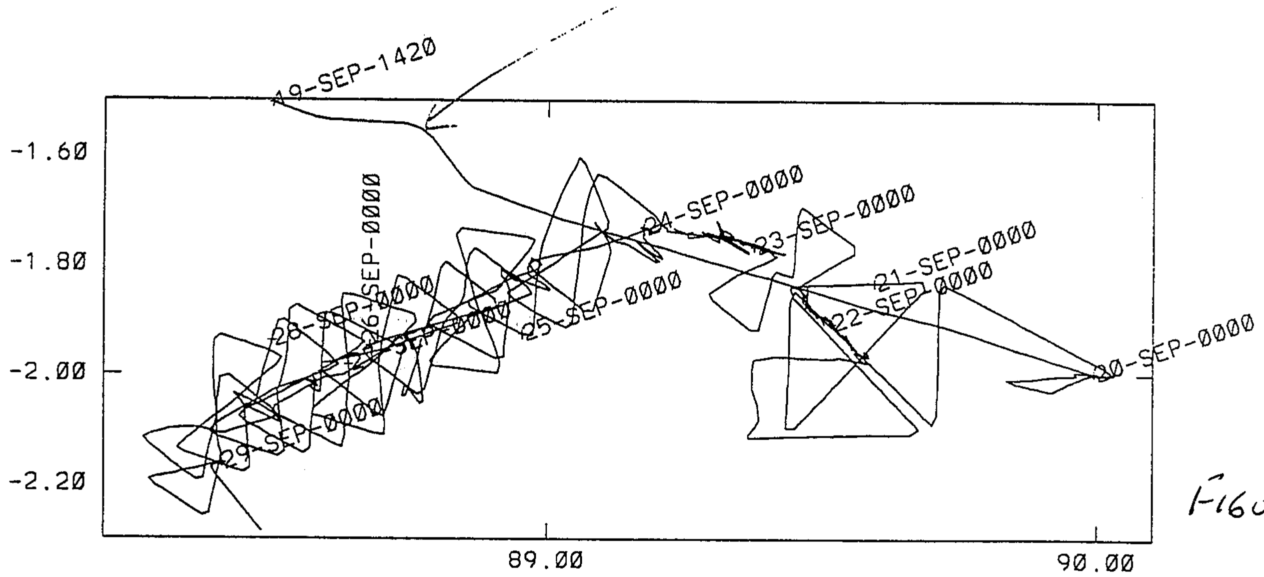

FIGURE 1

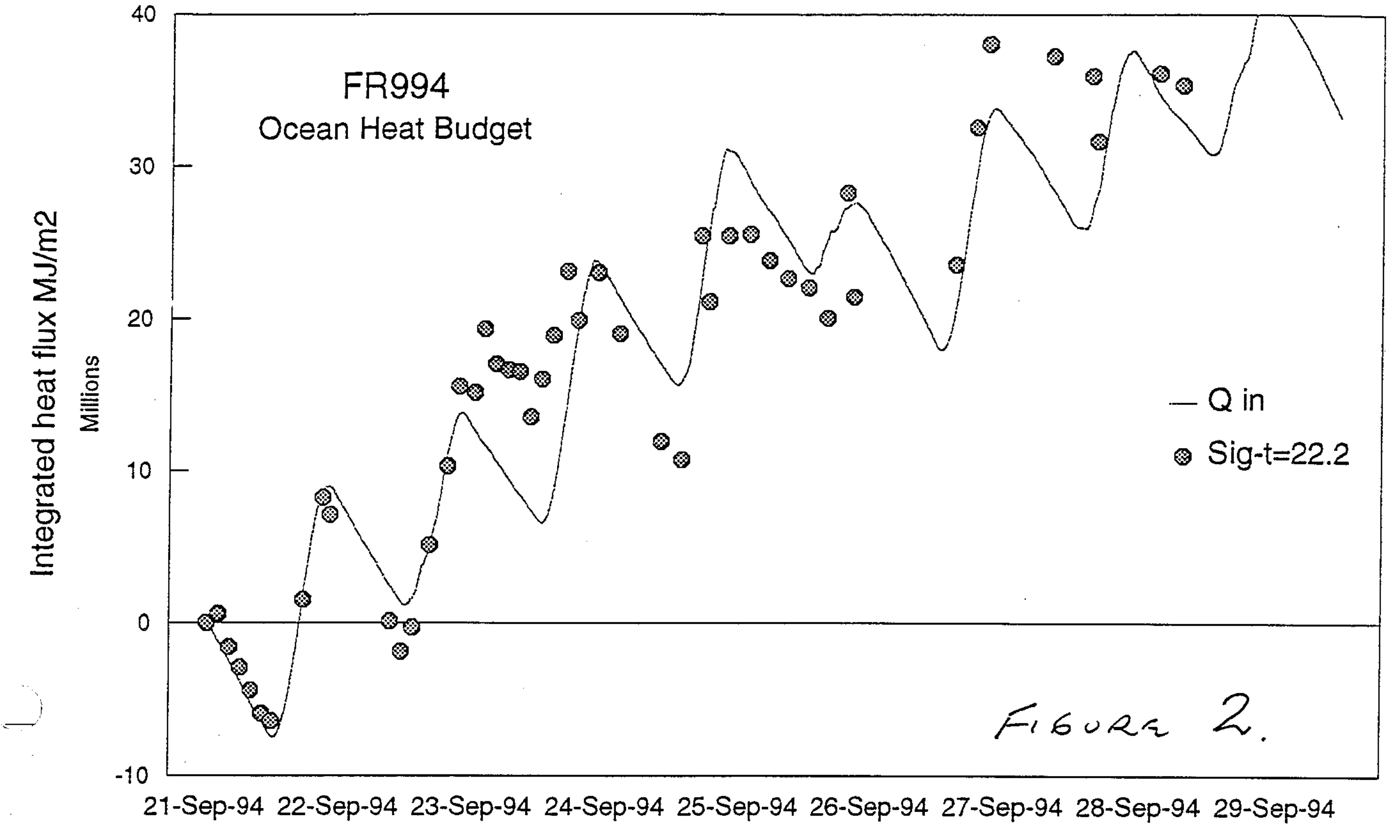
FR994
Ocean Heat Budget
Integrated heat flux MJ/m2
Millions
40
30
20
10
0
-10
— Q in
● Sig-t=22.2
21-Sep-94
22-Sep-94
23-Sep-94
24-Sep-94
25-Sep-94
26-Sep-94
27-Sep-94
28-Sep-94
29-Sep-94

FIGURA 2.

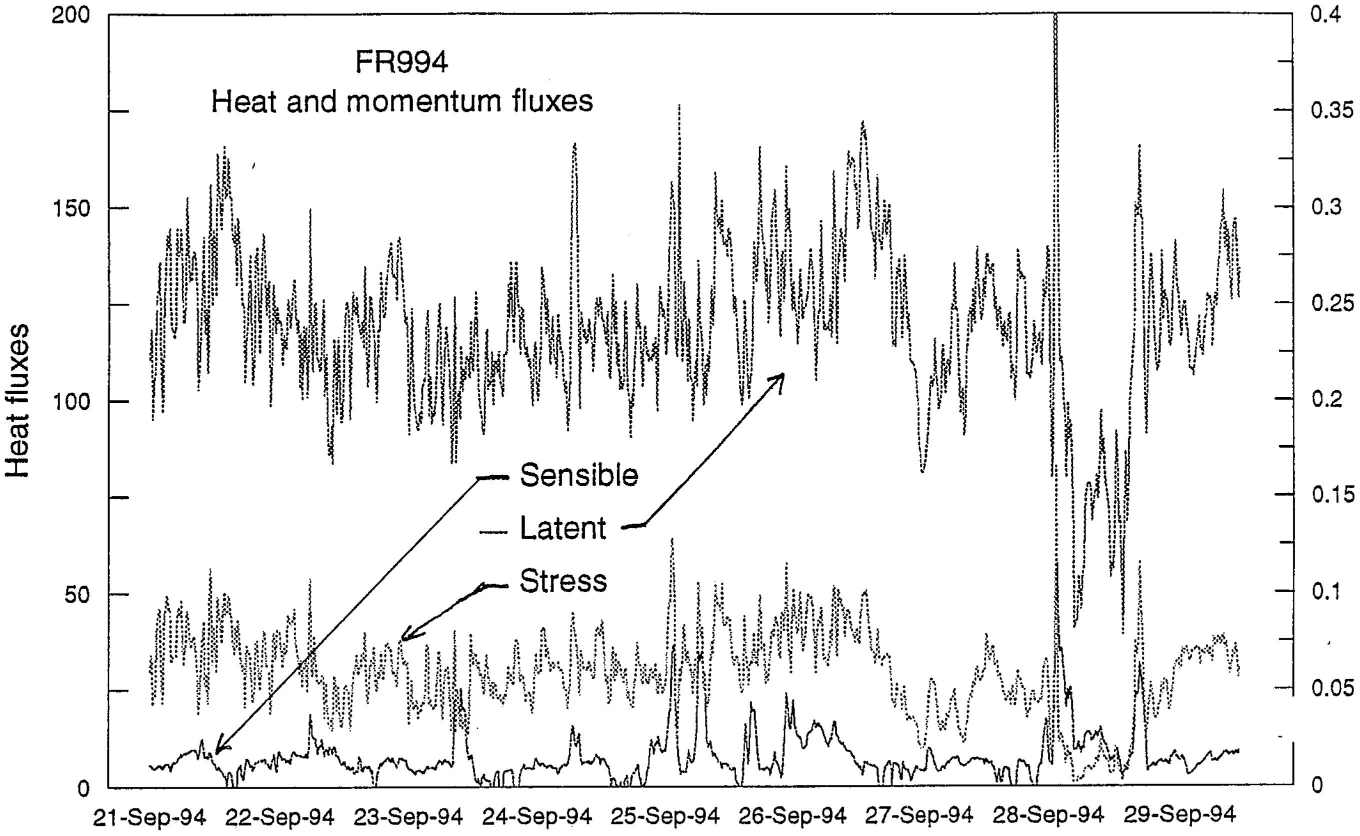
FR994
Heat and momentum fluxes
Heat fluxes
200
150
100
50
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Sensible
Latent
Stress
21-Sep-94
22-Sep-94
23-Sep-94
24-Sep-94
25-Sep-94
26-Sep-94
27-Sep-94
28-Sep-94
29-Sep-94

FIGURE 3.

22. 2097

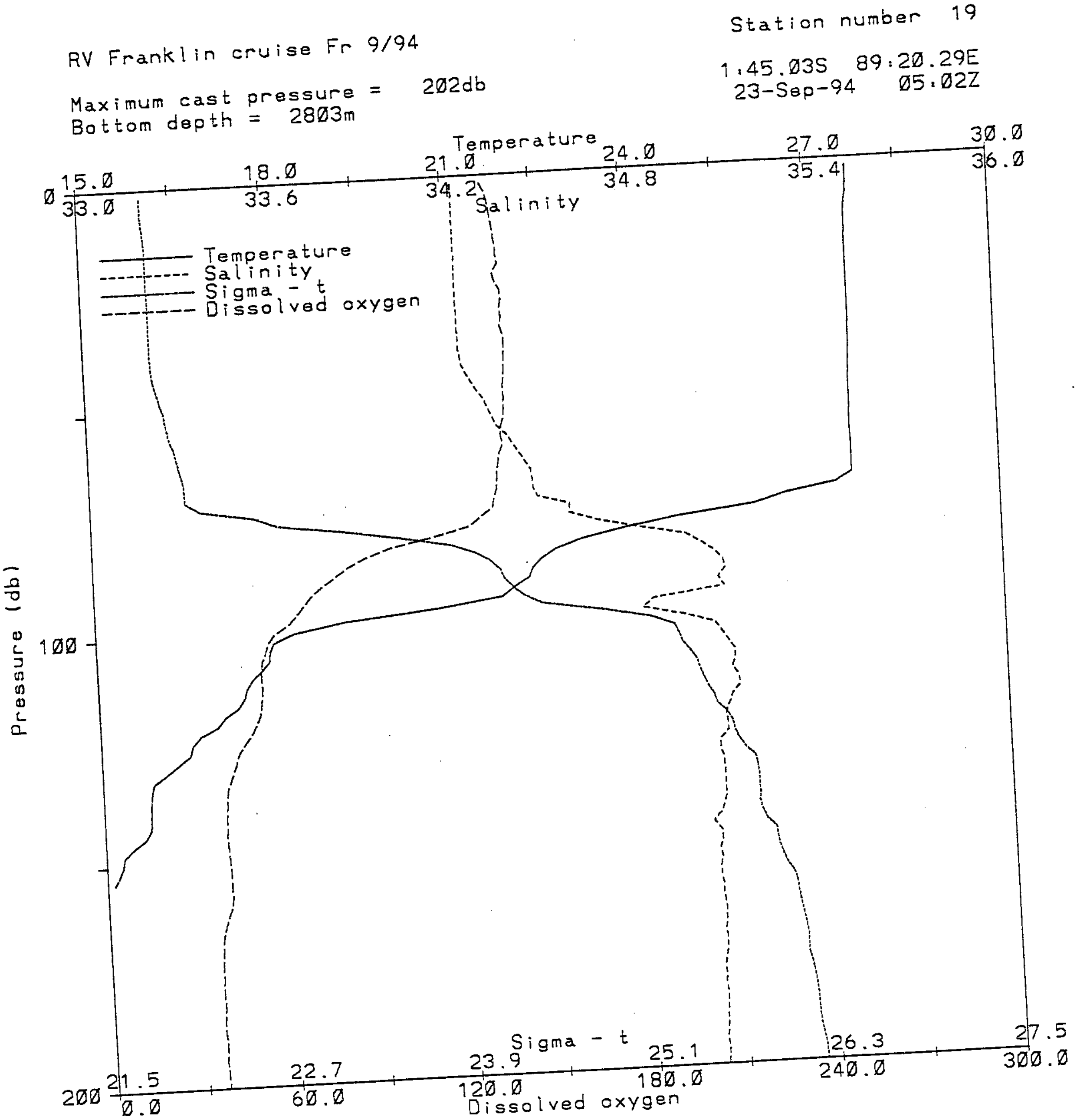

FIGURE 4.

Comparison of Light ratio from Fr09/94, 1 day, with Soloviev profile.

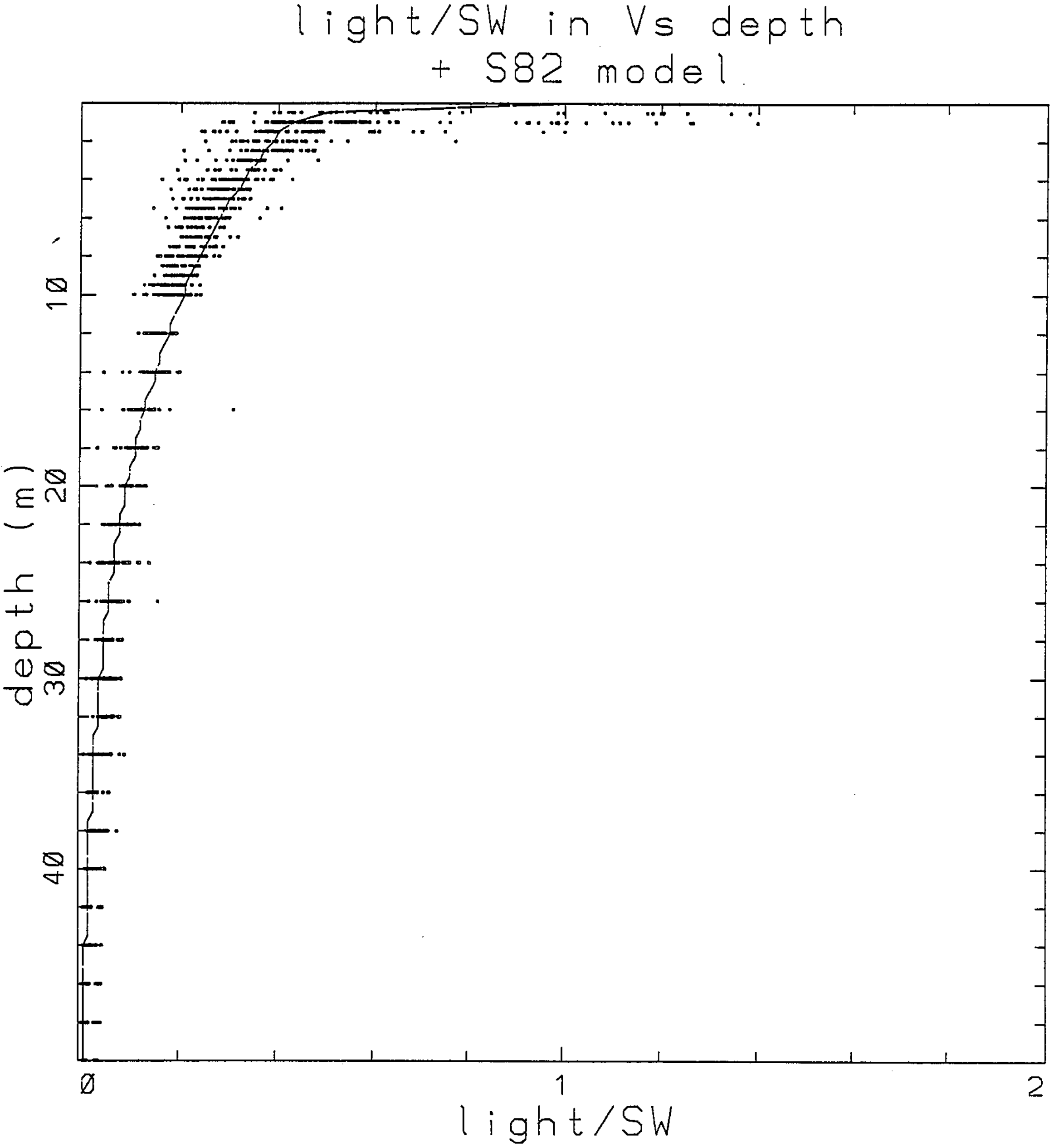

FIGURE 5.

F. 5

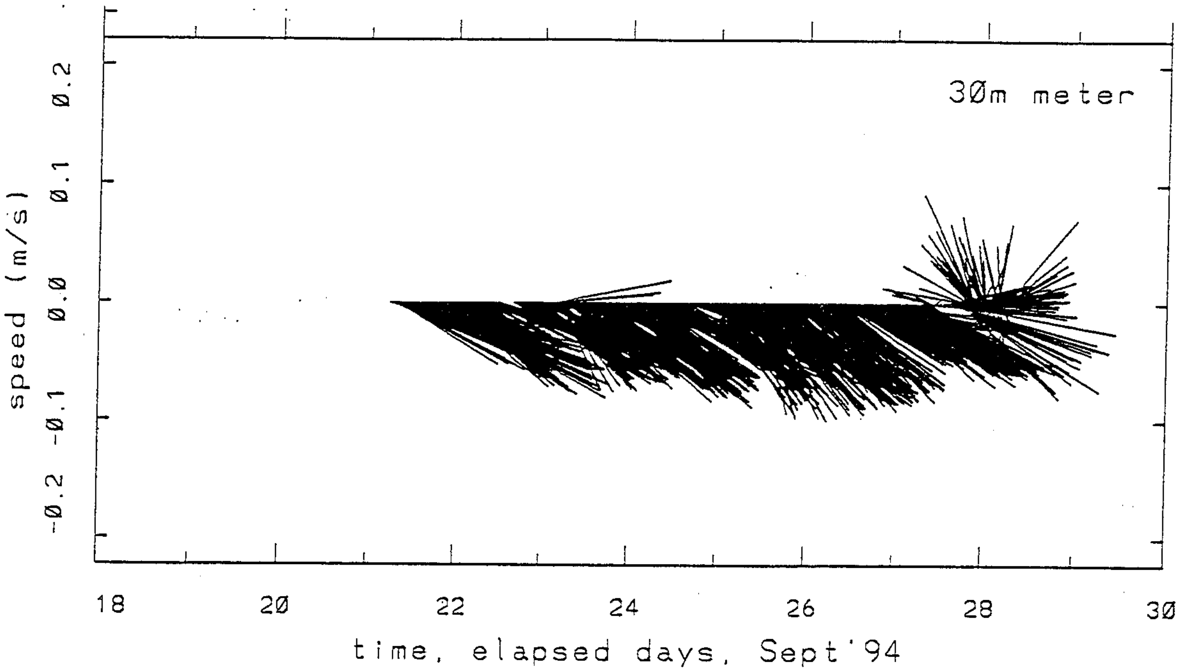
30m meter
speed (m/s)
0.2
0.1
0.0
-0.1
-0.2
18
20
22
24
26
28
30
time, elapsed days, Sept'94

FIGURE 6.

FR9/94 ADCP data
near the drifter

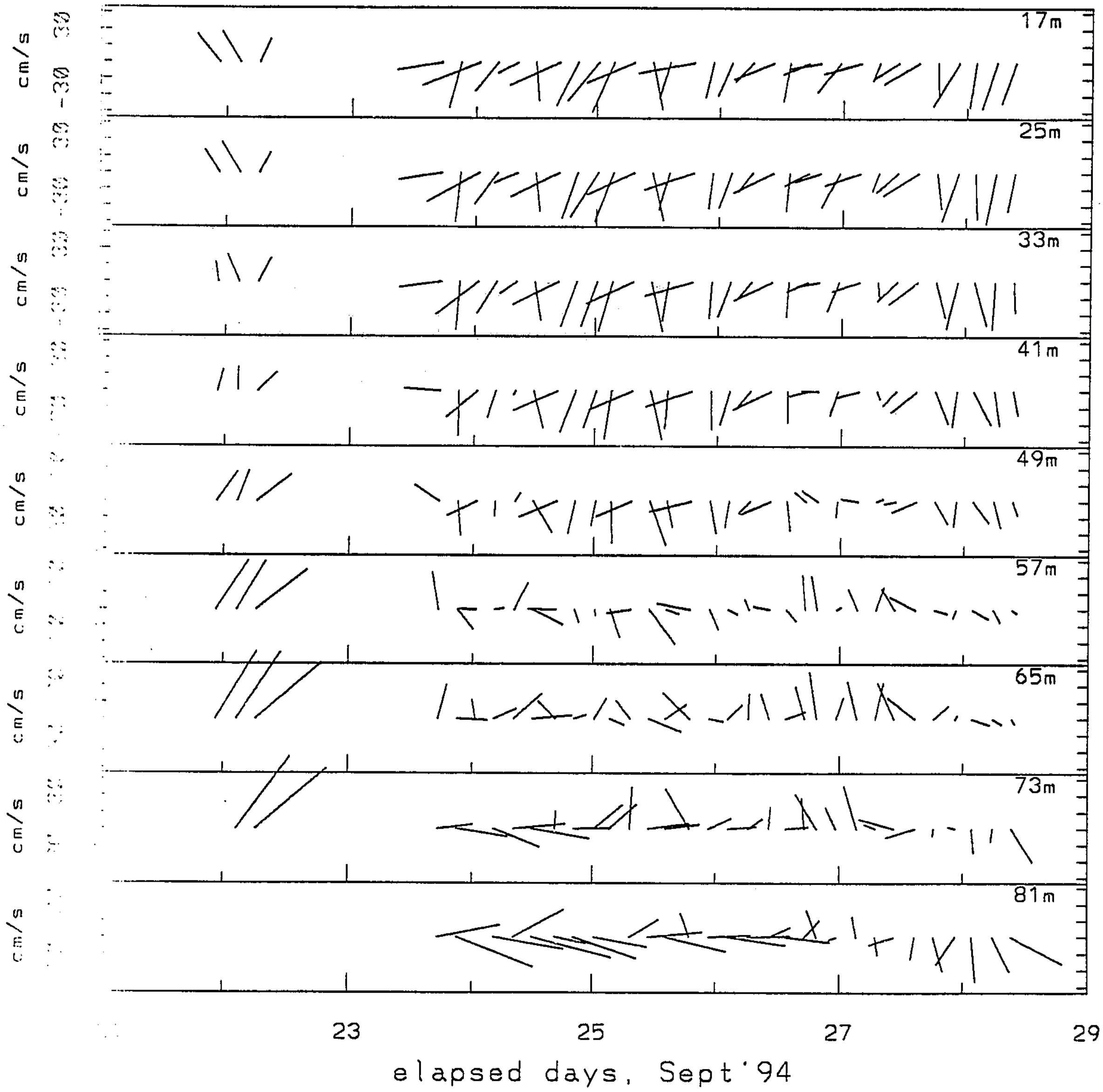

FIGURE 7.

Fig 7