RESEARCH SUMMARY
CRUISE FR 9/95

MARITIME CONTINENTAL THUNDERSTORMS EXPERIMENT (MCTEX)
Air-Sea Interactions

Sail Darwin 1000 Tuesday 21 November 1995
Arrive Darwin 1000 Wednesday 6 December 1995

Principal Investigators

Dr Brian Sanderson
Bureau of Meteorology Research Centre,

Dr Frank Bradley
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Prof Ian Young
Dept. Civil and Maritime Engineering
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Itinerary

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Principal Investigators

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1 MCTEX Overview

The Maritime Continental Thunderstorm Experiment (MCTEX) was held 13 November to 10 December 1995 over Bathurst and Melville Islands, located approximately 50 km off the coast of Australia's Northern Territory. Deep convective systems developed over these islands on every day of the experimental period with the exception of 9 December when monsoonal conditions prevailed. On four occasions convective systems passed directly over the Franklin. In two instances the convective systems also passed directly over the directional waverider mooring. MCTEX provided a focused, detailed examination of the convective systems, from their origins to their final decay as they propagate off the islands.

The MCTEX measurement network consisted of: 15 automatic weather stations, a D-scale raingauge network, surface energy budget station, electrification observations, rawinsondes, AIR Tethersonde, 3 beam doppler profiler with RASS, doppler profilers, balloon microphysical observations, aircraft-based measurements, BMRC Doppler/polarised radar, CSIRO Lidar, cloud radar, and ship-based measurements from Franklin. Darwin has a S-Band satellite receiver so that NOAA AVHRR and TOVS data are available by direct readout.

2 Cruise Scientific Objectives

1. Measure air-sea fluxes of heat, water and momentum. These measurements are made in the context of land/sea breezes associated with daytime convection over Tiwi Islands and night-time convection over Beagle Gulf. These shipboard measurements are complemented by landbased flux measurements on the Tiwi Islands and airborne measurements during MCTEX Intensive Operation Periods (IOP's). Combined these data sets provide constraints for modelling and analysing major convective activity over the Tiwi Islands.
2. Compare ship-board flux/radiation measurements with those made from FIAMS Cessna.
3. Measure velocity, temperature, salinity and transmissivity structure of the water column and the water column response to the fluxes measured above.
4. Measure fine-scale temperature/salinity structure associated with the cool-skin and diurnal surface warming in the top two metres of the water column, to test parameterizations of the phenomena developed during TOGA COARE.
5. Measure sea waves using a directional waverider buoy. Our objective is to complement waverider data with radar, ship and aerosonde wind observations to determine generation and dissipation of sea waves.
6. Measure the decay of convective systems as they propagate from over land to over the ocean.

3 Summary Log of Cruise Activities

Measurement Systems The following measurement systems were operated through the cruise: bulk fluxes, turbulent fluxes, waverider, ships-ADCP/CEM-ADCP, ships meteorology, ships thermosalinograph, SeaSoar, and Silverfish.

Station and Mooring Locations Figure 1 shows station positions, mooring locations and the composite cruise track. A directional waverider buoy was initially moored at M1. Stations B1-B8 are within the Beagle Gulf and were mostly sampled during the first week of the cruise. Similarly the entrance of the Beagle Gulf (stations E1-E5) was surveyed at the beginning of the cruise. After one week of working in the Beagle Gulf it became clear that convective systems were mostly moving westwards off the Tiwi Islands and not impacting the Beagle Gulf. Our measurement program was, therefore, redirected to the area delimited by the stations W1-W5. The waverider was relocated to M2.

20/11/95 (Monday) Loaded and installed scientific equipment whilst at the dock. This included installation of a RDI 1200 ADCP and bulk flux equipment. The RDI 1200 ADCP was provided by the Centre for Environmental Mechanics in order to profile the currents in these shallow waters with a smaller bin size.

21/11/95 (Tuesday) Deployed the directional waverider at M1. CTD observations were obtained at B1-B3. Technical difficulties with the CTD eliminated any advantage of making further CTD measurements. A depth survey was made over the path between stations B1-B8 and E1-E5 preliminary to SeaSoar measurements in these shallow waters.

22/11/95 (Wednesday) SeaSoar tows in the box defined by B1-B8 identified several technical problems with SeaSoar, most of which were soon rectified. The SeaSoar wake avoidance airfoil was adjusted into a satisfactory configuration.

23/11/95 (Thursday) SeaSoar tows were made in the box defined by B1-B8. SeaSoar flipped upside down due to a technical problem related to its wake avoidance airfoil. To alleviate this problem we subsequently did all ship turns to starboard whilst towing SeaSoar. SeaSoar subsequently reported water in its electric drive and was taken onboard for a major overhaul.

24/11/95 (Friday) Operating around B1-B8 with the focus on B1-B3 during the day.

25/11/95 (Saturday) This was an Intensive Operations Period (IOP) to measure fluxes prior to full development of atmospheric convection over the Tiwi Islands. At 0930 local time a flux intercomparison was undertaken with the FIAMS Cessna. At 1500 local time a convective system propagated off the Tiwi Islands and propagated over shallow water to the north of B1-B3.

26/11/95 (Sunday) This was an IOP to study sea breezes and convective initiation. Ships flux measurements focused, therefore, on B1-B3.

27/11/95 (Monday) Due to uncertainties regarding the software for the CEM-ADCP we replaced it with the ships ADCP with 4 m vertical bin spacing. Again, the flux survey focused on B1-B3.

28/11/95 (Tuesday) Because of the lack of convective systems in the Beagle Gulf we explored the area E1-W3 to the west of Bathurst Island. SeaSoar was not deployed because this area had not been depth surveyed previously. In the afternoon we were positioned favourably and an electrical storm passed directly over the ship. A post-storm survey was undertaken.

29/11/95 (Wednesday) Focused on the area W1-W3 and again encountered a storm. Ships ADCP malfunctioned from time to time and required restarting. In the evening we surveyed W4-W5 as a prerequisite for determining any east-west fluxes. (Note the tidal current is mostly aligned north-south, convenient for our measurement strategy which necessarily required north-south ship tracks in order to collocate with storms).

30/11/95 (Thursday) This day was an IOP to measure post-storm fluxes. We relocated the waverider to M2 west of Bathurst Island. There was a flux intercomparison run with the FIAMS Cessna. There was no storm propagating off the island, but there was some drizzle from marine convective systems. Outflow from the Island convection propagated as roll cloud over the Beagle Gulf in the late afternoon. A night survey of the Beagle Gulf was undertaken and we encountered a large storm of continental origin that was propagating northwestwards.

1/12/95 (Friday) Surveyed E1-W1-W3.

2/12/95 (Saturday) Surveyed to the west of Bathurst Island. A final flux intercomparison was made with the FIAMS Cessna in the morning, after which SeaSoar was deployed. That afternoon we encountered a storm coincident with the wave-rider mooring. SeaSoar was down briefly due to the storms electrical activity.

3/12/95 (Sunday) Surveyed E1-W1-W3 before, during and after the passage of a storm that passed over the waverider mooring.

4/12/95 (Monday) Surveyed E1-W1-W3 but the storms only propagated a short distance offshore before fizzling out. One storm died only about 1.7 miles away from the waverider mooring.

5/12/95 (Tuesday) Recovered the waverider at slack tide (1100 local). Surveyed E1-W1-W3 but were poorly positioned when the storm propagated offshore (misplaced the ship by 2 miles). Continued dismantling equipment. Systems operating: bulk fluxes, ships-ADCP, ships meteorology, ships thermosalinograph.

4 Scientific Program

The measurement systems deployed for this cruise provided information about physical processes that might be divided into three categories: (1) Surface gravity wave generation, (2) Response of the water column to air-sea fluxes, (3) Air-sea fluxes (micrometeorology). A report by Dr Frank Bradley is appended and discusses the micrometeorology measurement program in detail. An electronics report written by David Edwards is also appended.

The measurement strategy was adaptive and relied heavily upon forecasts and analyses from the MCTEX meteorological observations over the Tiwi Islands. In particular, communications with Darwin Central and the Bathurst Radar site were invaluable. Communications were via the MCTEX radio channel, satellite cell phone, and INMARSAT. Given that convective systems develop on time scales of 30 minutes to 1 hour, communications had to be timely and sufficiently clear and comprehensive to convey complex radar information into a form for directing ships position and also for coordinating ship and aircraft operations. No single method of communication was consistently adequate for our task and there were several occasions when turning the ship 15 minutes earlier would have significantly improved our data.

Nevertheless, the ships communications were as good as could be hoped for given the state of the art and the ships communications contributed greatly to the overall success of MCTEX.

4.1 Surface Gravity Wave Generation

The MCTEX program offered a unique physical environment in which to study the generation of surface gravity waves. Conditions are generally calm in these protected waters. However, the passage of convective storms off the Tiwi Islands provided impulsive wind forcing over a discrete area that could be well determined from the radar and other observational systems operating during MCTEX. Availability of funding limited us to only one directional waverider mooring. The original research plan had called for additional nondirectional waveriders, but these were deemed scientifically expendible because the finite forcing domain enables determination wave paths from the area of genesis to the waverider. The original concept was to orient the array of nondirectional waveriders along the expected wave path and thereby have wave amplitudes measured at several points for confirmatory purposes. However, having wave observations at a single point is sufficient to test wave growth models — in the present context.

The initial waverider mooring site was 11° 59.5′ S, 130° 26.5′ E in the Beagle Gulf. The doppler radar on Bathurst Island could best provide near-surface wind fields at this site. The site had the other advantages of being very sheltered from far-field conditions and it was expected that storms would occasionally propagate off the Tiwi Islands over this location. As it turned out the storms tracked generally westwards off the Tiwi Islands and passed too far to the north of the mooring. It was not possible to move the mooring northwards because the water was too shallow for safe vessel operations. On 28/11/1995 we explored the area to the west of Bathurst Island and found conditions there much more favourable. We were not able to move the waverider mooring immediately because of logistical constraints related to timing of tides (the mooring could only be recovered in daylight at slack water) and the requirement that we not miss opportunities of making flux measurements during the afternoon when storms pass offshore.

At 0600 (local time) on 30/11/1995 we recovered the waverider and redeployed it at 1100 to the west of Bathurst Island at 11° 30.4′ S, 130° 1.46′ E. The new mooring location is obscured from radar coverage of near-surface winds. However, it has the advantage that the dominant wind component is favourably aligned with the radar during storms. We expect that the combination of ship-borne near-surface wind measurements, radar coverage of winds down to about 500 m and mesoscale storm modelling being undertaken for MCTEX will provide adequate wind fields to test wave generation mechanisms at this location.

Waverider data (x,y,z displacements) were received on the ship via radio telemetry. Given the calm conditions, we found that the ship was within range (about 35 km) for good reception at most times, except for those instances when the vessel was operating to the west of Bathurst Island while the waverider was moored in Beagle Gulf. The waverider records wave spectra onboard, so even on those occasions when the ship was out of range we have essential data recorded, abeit not in real time. Each day the received waverider data were decoded and a preliminary analysis done using Matlab software written during the cruise. The provision of Matlab on one of the ships workstations greatly facilitated our work.

On two occasions (2-3/12/95) storms swept off Bathurst Island and passed directly over the waverider. The passage of the storms is accompanied by an abrupt development of strong easterly winds. Prior to passage of the storm the winds were very light and typically from the northwest. In both of the above storm events the ship was nearby so most waverider data was received, although nearby lightning strikes caused some data dropouts. The proximity of the ship also ensured a good ground-truthing for the wind field. Time series plots of the 2/12/95 waverider data are shown in Figure 2. The time units are arbitrary on these plots which show; status (where there are data drop outs), heave (vertical displacement), displacement in the north direction, and displacement in the west direction. The 2/12/95 storm occurred at about time= 4×10^4 and there is a clear increase in wave amplitude and substantial modification of wave direction. Note, these waves came from the shore (about 8-10 nautical miles to the East) and are totally distinct from any waves existing prior to the storm. There was some data dropout due to lightning in the storm of 2/12/95, but much less in the storm of 3/12/95. Figure 3 shows spectra for various intervals on 2/12/95. The passage of the storm corresponds to the development of significant high-frequency wind-wave activity that is not present either before or after the event.

In addition to the above there were other occasions when storms influenced the wave regime near the waverider, albeit much less directly. These event consisted of night time storms propagating off the mainland on 23/11/95 and 1/12/95 and near misses by daytime storms propagating off the Tiwi Islands on 25/11/95 and 4/12/95. The waverider response to these storms was much less dramatic, however, the measurements will be of some value for testing Bureau of Meteorology wave models.

4.2 Water Column Response

Water column measurements were made to determine the temperature and salinity response to surface heating/cooling and rainfall/evaporation. The primary measurement systems for this purpose were as follows: (1) The SeaSoar fitted to measure conductivity, temperature, light, and transmissivity through the top 2/3 of the water column. (2) The ships thermosalinograph, Sea Snake, and Silver Fish which measured near surface water temperature and salinity. (3) An ADCP to measure currents for purposes of estimating horizontal fluxes.

Our measurements in the Beagle Gulf indicated that the water column was vertically well mixed except for a diurnal cycle of stratifying the top few metres of the water column under calm conditions. There was, however, a diurnal cycle of heating and cooling as well as horizontal variability. Thus the ships thermosalinograph and Silver Fish were adequate for inferring much about the temperature and salinity structure in the Beagle Gulf, especially at night. This was fortunate, since the SeaSoar was having 'teething' problems early in the cruise.

Upon moving west of Bathurst Island (Stations E1, W1-W5) we found that the water column was not always vertically well mixed overnight, although XBT measurements indicated the bottom mixed layer usually extended to the lower limit of the SeaSoar depth cycle. Consequently we made extensive use of SeaSoar in the waters to the west of Bathurst Island. The persistence of stratification throughout the night is clear from a diurnal cycle of SeaSoar measurements plotted in Figure 4. The greater amount of rainfall in this area might contribute to maintenance of vertical thermal structure throughout the diurnal cycle. The above interpretation is preliminary subject to further analyses in which horizontal advection is treated with more rigour.

The experiment was greatly aided by the efforts of Lindsay Pender who wrote code so that SeaSoar data could be written in Matlab readable form. Having got the data into Matlab readable form it was trivial for me to produce time series, and various 2-D, 3-D and movie representations of the SeaSoar data fields immediately following each SeaSoar tow.

To deconvolve horizontal advection from our temporal information we require current information. Currents were measured using an onboard ADCP. Initially we used a high frequency ADCP kindly provided by Dr Ian Webster from the Centre for Environmental Mechanics. I was never confident that we were operating this instrument correctly, so I replaced it with the ships ADCP on the 27/11/95. The ships ADCP performed adequately with a 4 m bin resolution except it would stop from time to time and need to be restarted. This problem appeared to be software related.

There are strong (> 1 knot) tidal currents in what turned out to be our primary area of interest (i.e. west of Bathurst Island). The tidal currents run approximately north-south and as such are conveniently aligned with the transects along which SeaSoar was towed and fluxes were measured. Nontidal components of the current are expected to be weak because stratification and wind forcing were relatively slight. I expect that fitting a numerical model of the tides to our current observations will enable referencing of water masses relative to where they were when storm events occurred (at least for 1/2 a tidal cycle). Except near the bottom, the tidal currents had relatively little vertical shear — which also simplifies interpretation of vertical fluxes through the water column.

5 Acknowledgements

This was a delightful cruise, at least from my personal point of view. The Franklin is a well run and well equipped research vessel. I sincerely thank all those who so competently crew this ship — particularly the Master, Neil Cheshire, and Officers who went out of their way to be helpful. I would like to thank all members of the scientific party for the skills and good humour they brought to bear as required throughout this experiment. Special mention must be made of Lindsay Pender, Ian Hellmond, and Dave Edwards for their expert work with SeaSoar and the other equipment and software provided by the National Facility. I look forward to sailing with all of you again some day.

Scientific Party

Dr. Brian Sanderson, Bureau of Meteorology, BMRC, Chief Scientist
Dr. Frank Bradley, CSIRO CEM
Dr. Gary Miller, CSIRO CEM
Ms. Marion Tait, The Flinders University of South Australia
Mr. Michael Whimpey, Bureau of Meteorology, BMRC
Mr. Dave Edwards, CSIRO ORV, Cruise Manager
Mr. Lindsay Pender, CSIRO ORV
Mr. Ian Hellmond, CSIRO ORV
Mr. Bob Griffths, CSIRO Marmion

Station	Latitude	Longitude	Chart-Depth
B1	12	130 16.5	30 m
B2	12	130 25.9	30 m
B3	12	130 34.8	22 m
B4	12 9	130 34.8	22 m
B5	12 17.8	130 34.8	20 m
B6	12 17.8	130 25.9	33 m
B7	12 17.8	130 16.5	25 m
B8	12 9	130 16.5	36 m

E1	11	49.2	130		30 m
E2	11	59.4	130	3.8	55 m
E3	12	9.8	130	7.7	40 m
E4	12	20.5	130	11.5	28 m
E5	12	31	130	15.2	16 m
W1	11	35.5	129	58.9	25 m
W2	11	28.8	130	3	31 m
W3	11	20	130	3	22 m
W4	11	20	129	55	
W5	11	50	129	53	
W6	11	17	130	3	
W2.5	11	24.5	130	3	
W0.5	11	41	129	59	

Waverider Mooring location in Beagle Gulf

WRM	11	59.5	130	26.5	33 m

Waverider Mooring location west of Bathurst Island (Rocky Point)

	11	30.4	130	1.46	25 m

Weigh Point

WP14	11	55	130	1.5	27 m

Brian Sanderson

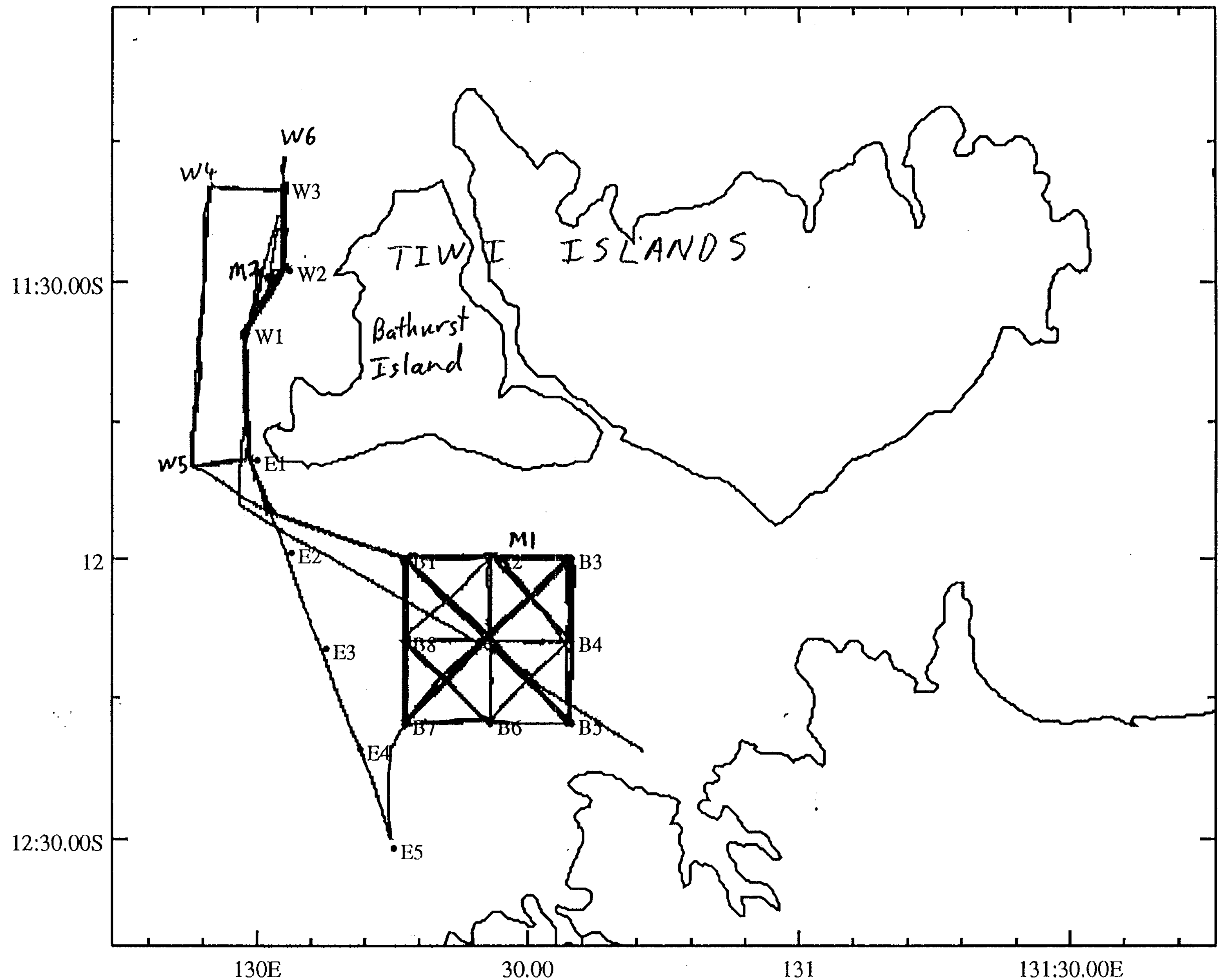
TIWI ISLANDS
Bathurst Island
W1
W2
W3
W4
W5
W6
M2
M1
E1
E2
E3
E4
E5
B1
B2
B3
B4
B5
B6
B7
B8
11:30.00S
12
12:30.00S
130E
30.00
131
131:30.00E

Figure 1

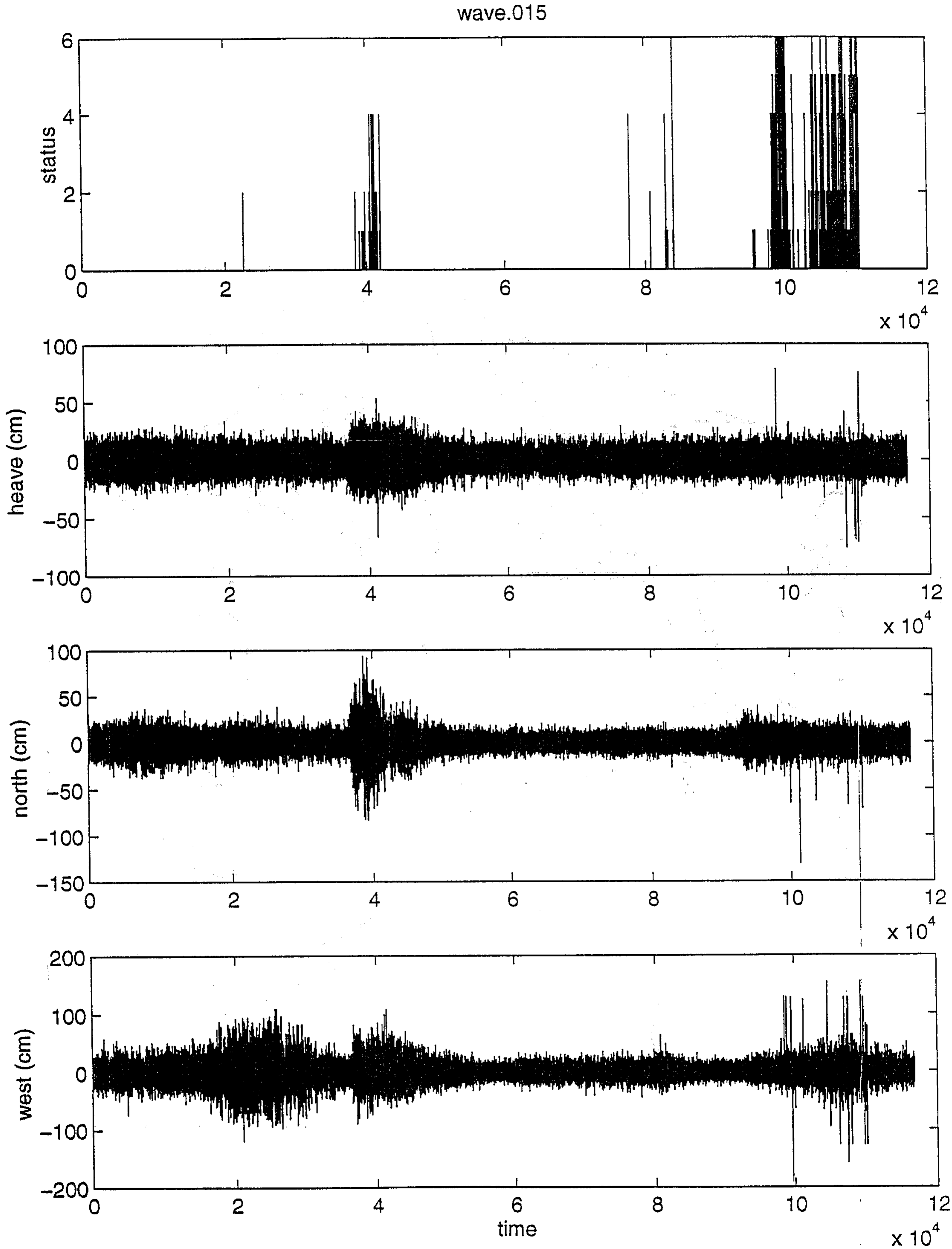

Figure 2

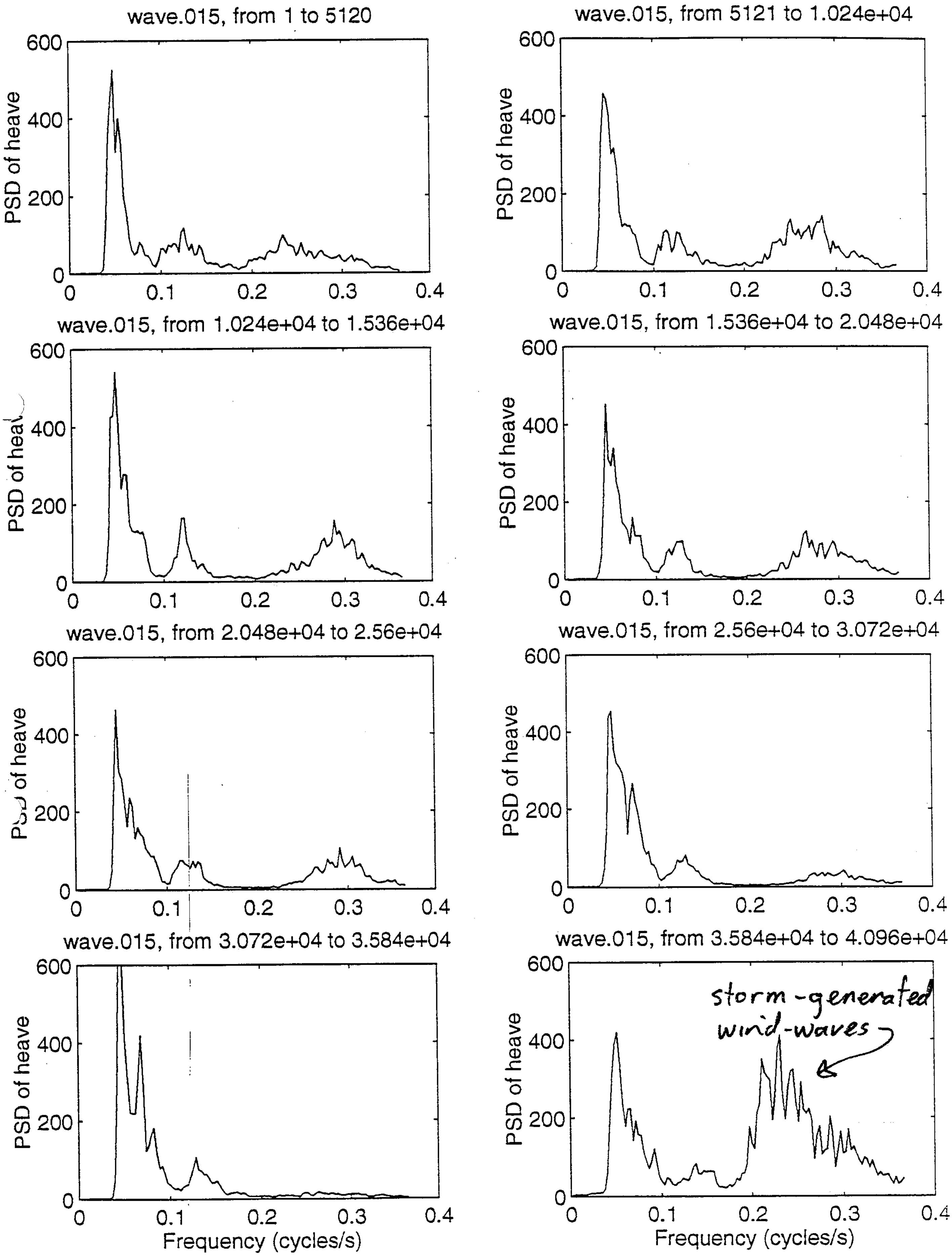
wave.015, from 1 to 5120
wave.015, from 5121 to 1.024e+04
wave.015, from 1.024e+04 to 1.536e+04
wave.015, from 1.536e+04 to 2.048e+04
wave.015, from 2.048e+04 to 2.56e+04
wave.015, from 2.56e+04 to 3.072e+04
wave.015, from 3.072e+04 to 3.584e+04
wave.015, from 3.584e+04 to 4.096e+04
PSD of heave
Frequency (cycles/s)
0
200
400
600
0.1
0.2
0.3
0.4
storm-generated wind-waves

Figure 3a

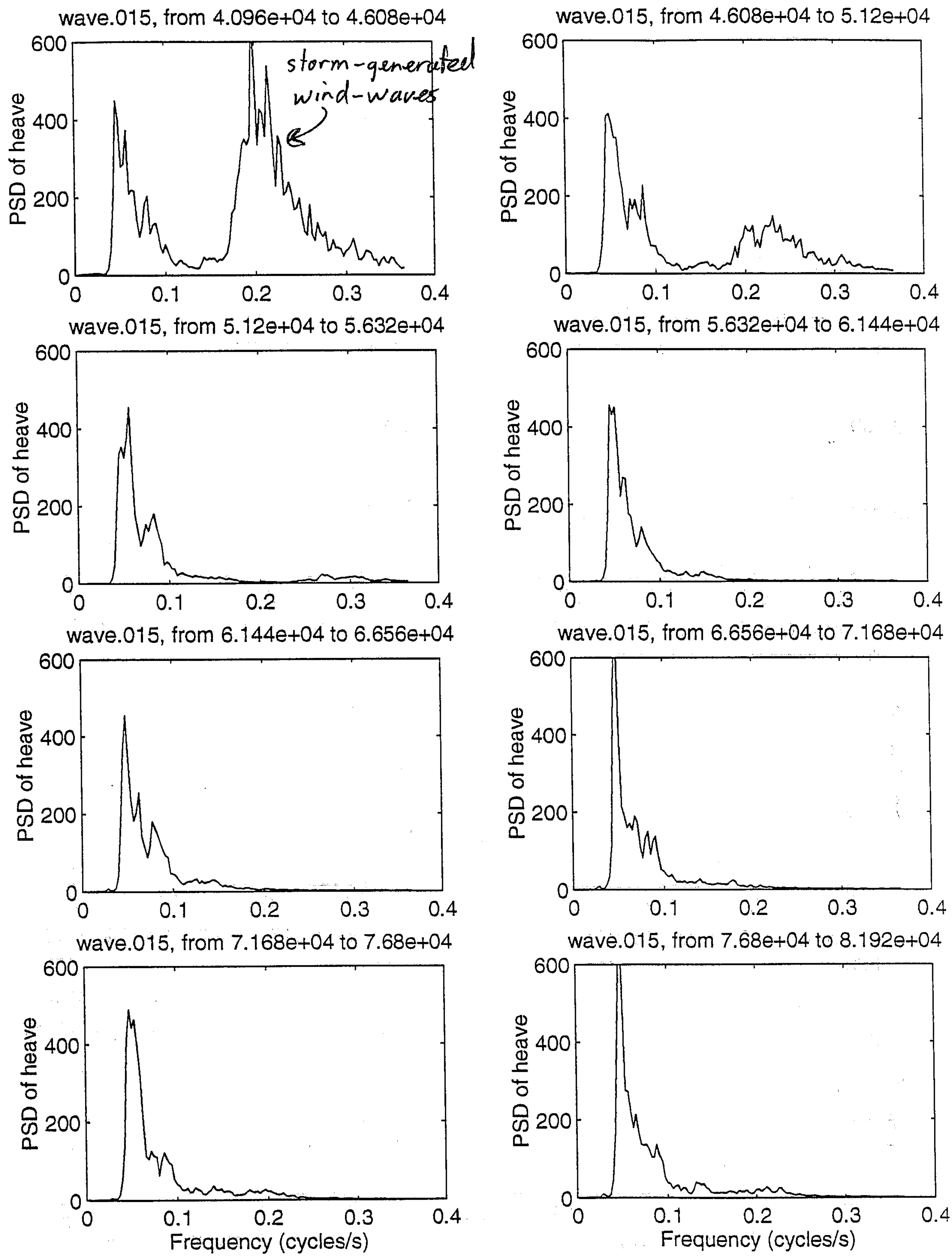
wave.015, from 4.096e+04 to 4.608e+04
storm-generated wind-waves
wave.015, from 4.608e+04 to 5.12e+04
wave.015, from 5.12e+04 to 5.632e+04
wave.015, from 5.632e+04 to 6.144e+04
wave.015, from 6.144e+04 to 6.656e+04
wave.015, from 6.656e+04 to 7.168e+04
wave.015, from 7.168e+04 to 7.68e+04
wave.015, from 7.68e+04 to 8.192e+04
PSD of heave
0
200
400
600
0.1
0.2
0.3
0.4
Frequency (cycles/s)

Figure 3b

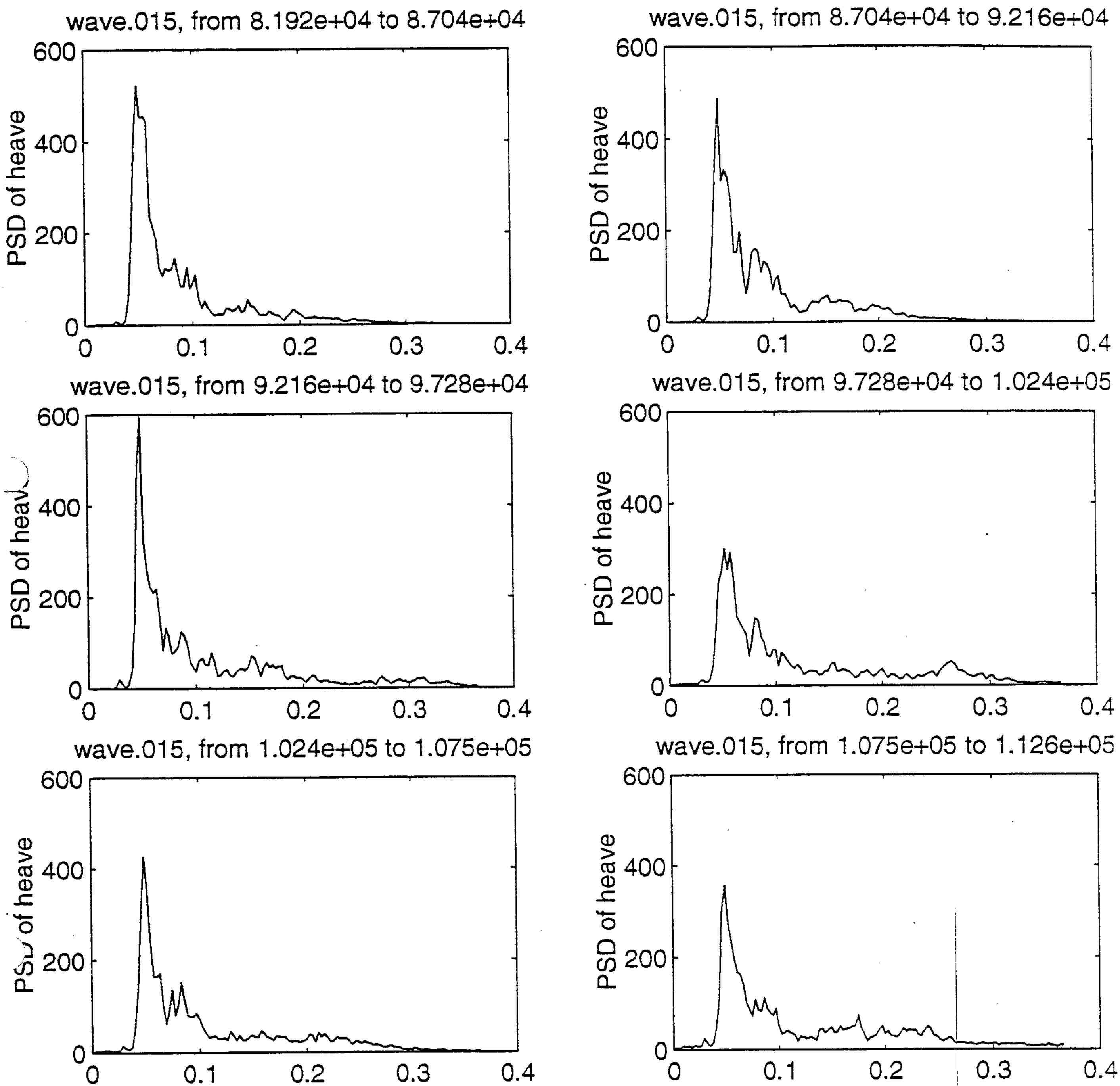
wave.015, from 8.192e+04 to 8.704e+04
wave.015, from 8.704e+04 to 9.216e+04
wave.015, from 9.216e+04 to 9.728e+04
wave.015, from 9.728e+04 to 1.024e+05
wave.015, from 1.024e+05 to 1.075e+05
wave.015, from 1.075e+05 to 1.126e+05
PSD of heave
0
200
400
600
0
0.1
0.2
0.3
0.4

Figure 3c

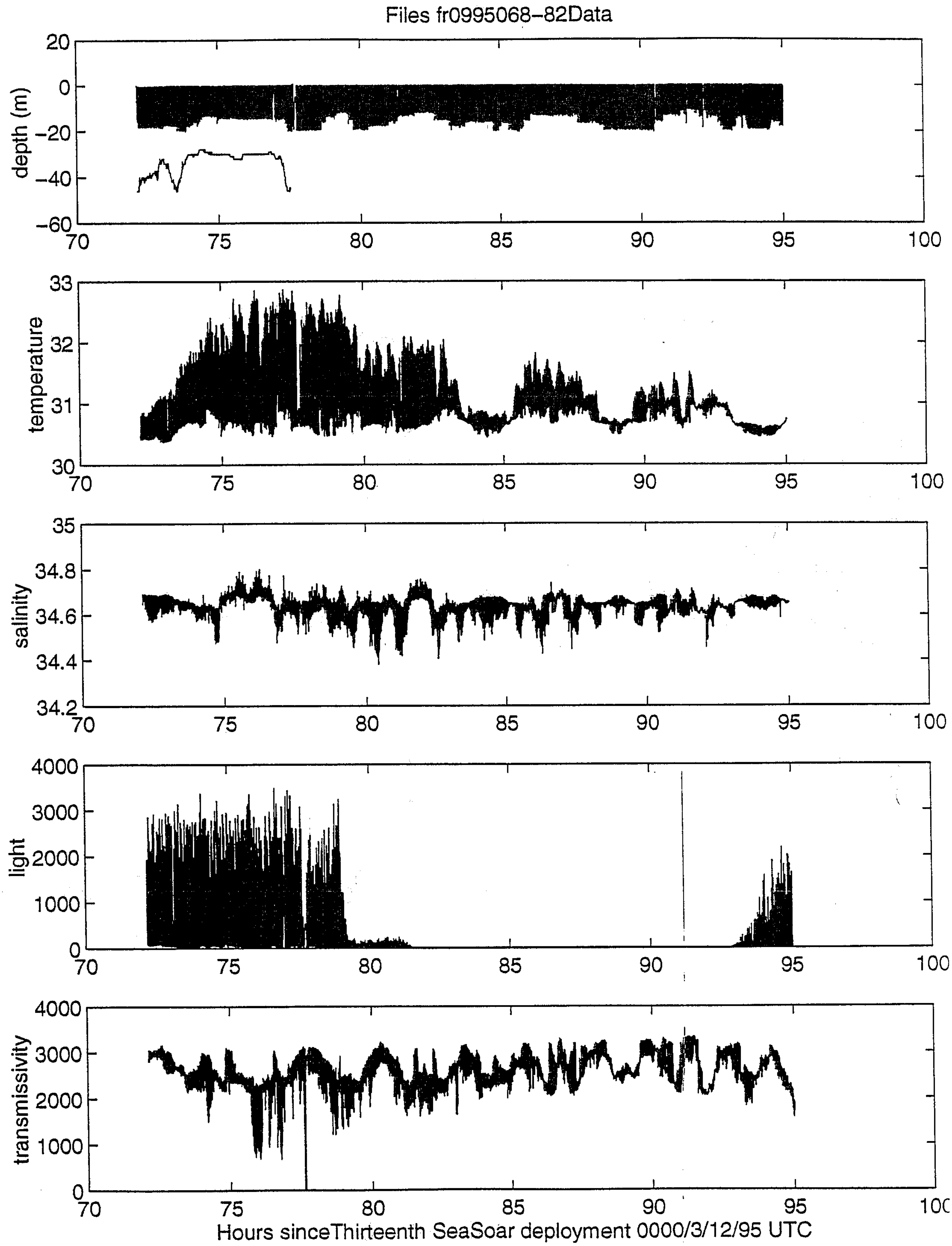
Files fr0995068–82Data
depth (m)
temperature
salinity
light
transmissivity
Hours sinceThirteenth SeaSoar deployment 0000/3/12/95 UTC

Figure 4

For Cruise Report FR9/95

Micrometeorology

1. Instrumentation

The Mk II bowsprit boom, designed by Ian Helmond, was installed while the ship was still in port. The tubular aluminium design is easy to assemble, and both elegant and functional. It had its first trial during cruise FR7/94, when it carried only a net radiometer, but could not be deployed for much of that cruise because of rough weather. It had a tendency to rotate, which has now been overcome by fitting a friction brake. At the same time, the rotation enables the crossarm to be levelled against the horizon, independent of the ship's angle of list. Before being used again, some damage to the brake needs repair, and the three stays need replacing. The galvanising on the wire rope used was obviously of poor quality and it has rusted.

In contrast to FR7/94, the boom has been fully extended throughout this cruise, carrying instruments to measure eddy fluxes. The Solent sonic anemometer, belonging to Ian Young at ADFA, has operated reliably throughout the cruise, despite being exposed to several torrential rainstorms. The only malfunction was when the lid blew off the box containing the power supply and interface unit which then filled with water. David Edwards dismantled, dried and cleaned the unit, and the sonic was running again within an hour. This sonic is expensive, but we recommend it highly for use at sea. The infra-red gas analyser (IRGA) is a combined H_2O/CO_2 instrument developed by the Oak Ridge Diffusion Lab. of NOAA, and first used by us for the COARE cruises. CEM have now obtained several for field use and we had two on board. The first one suffered from water ingress during a heavy rainstorm, and a coincidental electronic fault, but it has been repaired. The other has survived several storms without damage. We regard these as the best high-frequency humidiometers avilable, particularly for use at sea. The vessel's pitch, roll and yaw, needed to correct the sonic wind measurements, were obtained with a set of 6 accelerometers mounted in the ops. room.

The boom carried the net radiometer again, and the ship's pair of Eppley short- and long-wave incoming radiation sensors were mounted high on the main mast with modified voltage-to-current circuits.

The usual set of high-quality meteorological instruments was installed on the foremast for measurement of bulk fluxes. They consist of a cup anemometer and wind vane, a psychrometer and an optical raingauge (ORG). These instruments were augmented with a new design Vaisala temperature/humidity sensor installed in our standard ventilated radiation shield. The latter are much simpler to maintain than the psychrometer, and have recently been successfully used during the CEM OASIS experiment. The installation here was intended to investigate their usefulness as a replacement for the psychrometer on the ship. The two used during this cruise tracked the psychrometer well, but with offsets of order 1°C and 1 g/kg using the manufacturers calibration. Individually calibrated they could be useful. The ship's Rotronics read consistently 2°C and 1.5 g/kg higher than the psychrometer.

Our old ORG was installed as usual on an arm to starboard. A second new type ORG provided by NASA-Goddard was similarly mounted on the foremast, but aligned fore-and-aft as part of a continuing effort to evaluate the performance of these instruments for rainfall measurement at sea. This is associated with the NASA TRMM program. A Nylex funnel gauge was also mounted on the foremast, and the ship's RMYoung siphon gauge was already in place on the yard-arm.

Sea surface temperature was measured with the "Seasnake", a high-precision thermistor mounted in the end of a 10m length of garden hose trailed in the water from the foredeck side-boom fully extended. This is a very simple, but most successful scheme for measuring temperature in the top few centimetres (possibly 5cm) of the ocean. It can thus measure diurnal warming of the surface layer, relative to the measurement of the thermosalinograph at about 2.4m depth. It is most effective when this warming is at its most important and dramatic, when the wind is light and the sea slight as on this cruise, so that it is towed outside the ship's bow wake. A lighter, more easily operated side boom would be a great advantage for this sensor, which exerts very little force on its towing point.

The Mark II silverfish (hull design by Ian Helmond, electronics by Garry Miller) had its first deployment during this cruise. It is a stainless steel bomb-shaped body, towed with 5mm wire ahead of the ship from a sheave at the end of the boom. High-frequency temperature and conductivity sensors developed by Mike Head (Precision Measurement Engineering, San Diego) protrude from the nose, and depth is measured by a pressure sensor connected to an appropriately located port. Signals return to the foredeck via a comms cable. During the cruise, its internal batteries were abandoned in favour of a deck-mounted power supply and the cable accordingly replaced with one provided by Dave Edwards. Unlike the heavy Mark I wing design, this sensor is very easy to deploy and retrieve, and it tows stably up to at least 11 kts ship speed. It has been deployed almost continuously at 8 kts during the cruise, recording on battery-powered laptop computers after early problems when these were connected to their mains charger units. So far, only quality inspection of the raw data has been possible; the high frequency data stream leads to large files and software is needed to reduce it to tractable bites, and apply calibrations. Michael Whimpey has written a Fortran program to begin this process. Bob Griffith has provided analysis of calibration samples taken during the deployment. Sea conditions for this cruise have been slight with almost no swell; as in the past, we had relied on the ship pitching to profile from the surface down to at least 3 metres depth. We have therefore changed the depth of the instrument by hand from time to time. In smooth seas such as this, a small winch profiling unit will be necessary.

2. Data Recording and Analysis

The slow-sampled meteorological instruments are logged with three Series 500 Datatakers installed at the rear of the bridge. These have performed reliably, except for one which suffered damage during one of the electric storms. This blew the input multiplexers, which are in fact designed to serve as fuses and lightning protection; we carry many spares, and they were replaced.

The turbulence signals were logged at 20 Hz and processed on-line with a 3-computer network designed at CEM by Peter Coppin and John Bryan. The logger/server is a 386 with 4 serial ports and a 16-channel A/D board, having a 1 Gbyte hard disc. A second 386 interfaced to a DAT tape serves as a backup unit, and also having a 1 Gbyte disc can become the logger/server if the first computer goes down. The large Silverfish files are unloaded onto this machine using PDQ (courtesy Dave Edwards) and backed up onto DAT tape. The third unit is a 66MHz 486 (EFB's desk computer) with an HP 550C colour printer attached, which is used for data processing, accessing files from the server.

The 1-minute day-files of data from the ship's met., thermosalinograph, gps and log-gyro records were extracted each day from the ship's archive by Marion Tait, for input to the bulk flux and rainfall calculations.

3. Observations and Sample Results.

The aim of the micrometeorology effort on the MCTEX cruise was to provide detail of the air-sea exchange processes in the region of the Tiwi Islands and the Beagle Gulf. This involves measurement of the near-surface meteorological parameters, temperature, humidity, wind speed, rainfall and radiation and derivation of the fluxes of momentum and of sensible and latent heat. It is also important to obtain temperature and salinity gradients in the upper levels of the ocean, which affect near-surface stratification and mixing of surface water with that below. We planned to survey the experimental area under undisturbed conditions, and to document the response to thunderstorms which developed over the islands and moved out over the sea.

Along the way, we hoped also to obtain information relevant to a number of issues of special importance. Among these were evaluation of a new version of the optical raingauges which are now widely used to monitor rainfall over the oceans, testing of the new silverfish CTD and intercomparison of surface measurements with the Flinders Cessna. The following sample observations are presented as an indication of the type and quality of data obtained.

The initial operation area was in the Beagle Gulf, adhering strictly to the cruise schedule as described in the MCTEX Experiment Plan. The waverider buoy was deployed as planned and for several days we thoroughly surveyed the region to the south, criss-crossing the Gulf measuring fluxes continuously under fairly uniform conditions. Most days we observed massive cloud systems build up over the islands and over Darwin, but none of them moved out over the Gulf. On 28 Nov. we therefore relocated to survey the west coast of Bathurst island.since systems appeared to be moving predominantly in that direction. In the subsequent week we encountered 4 significant storms. Many others developed strongly over the nearby coastline but dissipated before reaching our track a mile or so offshore. Unless the event is particularly energetic, the ocean seems to destroy the storm and restrict its movement westward.

Briefly, the four rainstorms encountered were (approx times GMT):

Name	Date	Time	ORG Rainfall	1' rainrate	1' wind gust
Mstorm1	28 Nov.	0530-0700	40mm	130 mm/hr	10 m/s
Mstorm2	29 Nov.	0715-0800	14mm	90 mm/hr	17 m/s
Mstorm3	2 Dec.	0545-0645	50-60 mm	120 mm/hr	8 m/s
Mstorm4	3 Dec.	0715-0815	8 mm	80 mm/hr	10 m/s

Note however, that had our track been through a different part of the storm cell, or at a slightly different time, the above numbers could have been quite different. In all cases, we only had one chance to intersect the cell; by the time we turned to retrace our path, it had moved away to the west. Note also that each one of these maximum rainrates is as heavy as the best we observed occasionally during COARE.

Figure 1 shows the air and sea temperatures for 29 November. It illustrates the discrepancy between the ventilated psychrometer and the other two instruments. Temperature and humidity are sampled from time to time during the day with a hand-held Assman psychrometer, which seems to validate the foremast psychrometer. Air temperature drop during the storm was a massive 6°C and recovery very slow. On this day, the sea temperature at the surface did not diverge significantly from that measured by the ship's thermosalinograph at 2.4 metres depth.

Figure 2 is the corresponding air specific humidity measured by the three instruments and occasionally by the Assman. Same conclusion. Isn't it odd that the air is less humid during a torrential rainstorm than the rest of the time when it is clear?

In Figure 3 we illustrate the structure of Mstorm1 (28 November). This succession of individual rain bursts is typical of our small sample. In this case the two ORGs agree very well, but this is not true in the other three cases. Their exposure depends on the direction of the wind during the storm, and in all cases ORG #1 was unfavourably situated in the lee of the foremast as we travelled south down the coast. Both funnel gauges lost catch due to the wind effect as experienced during COARE and described in Bradley and Paulson (unpublished ms, 1995). Their correction scheme, not shown here, brings the siphon gauge into reasonable agreement with the ORGs.

The temperature record during this day is shown in Figure 4. Early in the morning there is a strong thermal gradient in the upper ocean. At 0100 GMT the log book records that the sea is absolutely flat, and the sky clear overhead but with cloud building up already over the islands. By solar noon the difference between the seasnake on the surface and the ship measurement below 2 metres was over 1.5°C. As soon as the storm hit, indicated by the sharp 6°C drop in temperature, this temperature difference was destroyed. It is perhaps surprising that the surface temperature did not cool below the temperature at depth in response to the cold rain; presumably the accompanying strong wind mixed the surface water down immediately. For the rest of the day, this temperature record indicates both large-scale and small-scale spatial variability, the latter exhibiting an intriguing regular pattern.

The Flinders Cessna aircraft flew over the Franklin on three occasions to record intercomparison data. It is regrettable that these events were so brief and so few; during COARE the scheduled periods of intercomparison between the ships and aircraft (including the Cessna) have proved to be the only avenue through which the COARE goal for accuracy of air-sea exchange could be realised. The three fly-pasts, comprising several passings in each case, were at 0005 on 25 Nov., 0715 on 30 Nov. and 0200 on 2 Dec. Figure 5 shows a very preliminary analysis of the Franklin flux measurements on 25 Nov. in the Beagle Gulf. The bulk estimates were calculated using the latest version of the COARE algorithm, as amended at the 3rd workshop of the COARE Flux Group in Honolulu, August 1995 (Bradley and Weller, 1995).

At the time of the ship-aircraft intercomparison on that day, the bulk and turbulent latent heat flux estimates agree well at about 90 Wm^{-2} but from then on, and indeed for the rest of the cruise, the bulk measurement is significantly lower than the eddy-correlation. Part of this discrepancy may be due to the fact that the turbulent fluxes are not yet corrected for ship motion. Sensible heat fluxes are small, as usual in the tropical ocean, but again a discrepancy is obvious. The net radiation time series is typical of the period when we were operating in this area, peaking around 900 Wm^{-2} . Similar radiation levels occurred most mornings along our west coast track, but afternoons were generally cloudy, even in the absence of local storms.

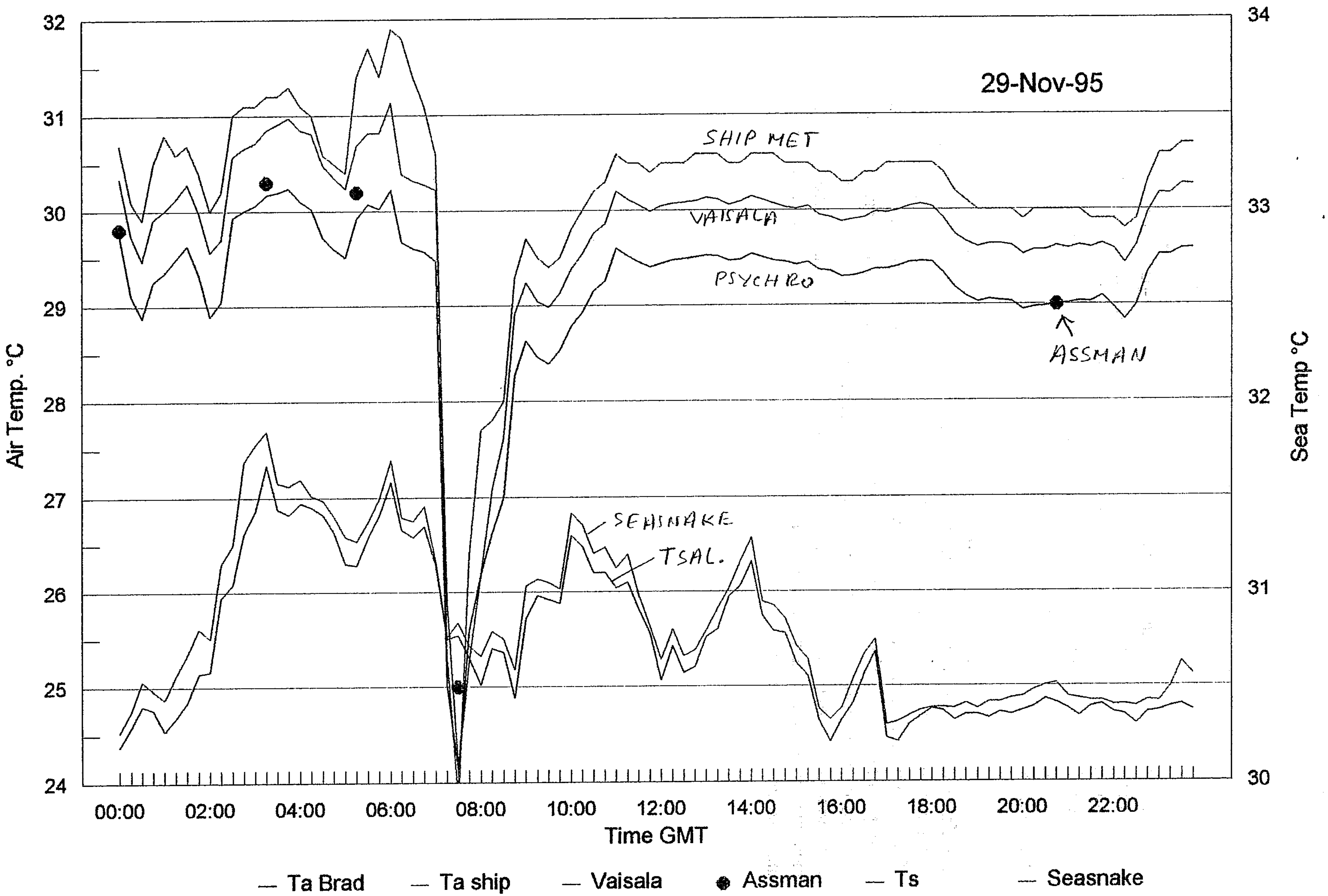
29-Nov-95
SHIP MET
VAISALA
PSYCHRO
ASSMAN
SEASNAKE
TSAL.
Air Temp. °C
Sea Temp °C
Time GMT
32
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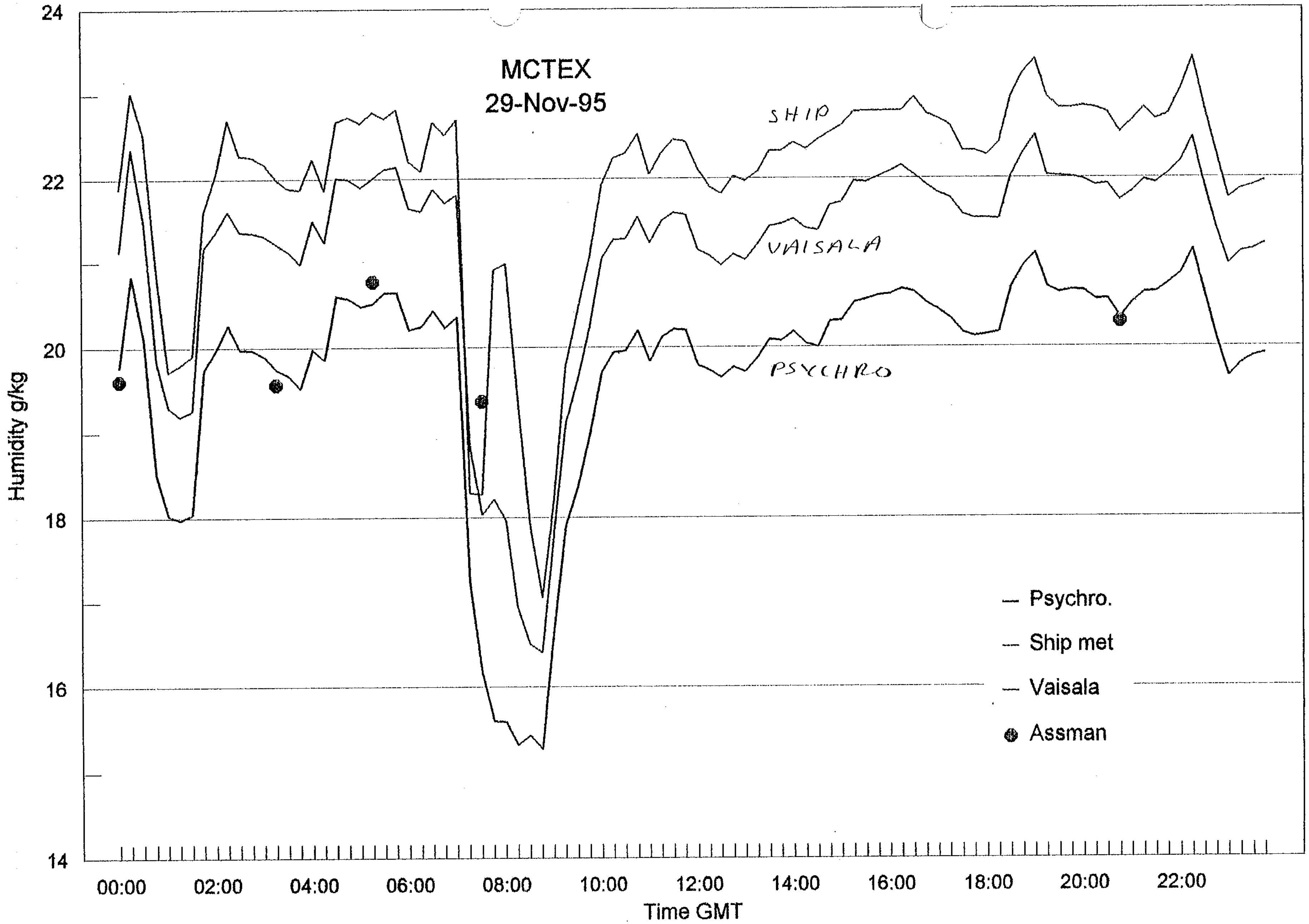
Fig 1


MCTEX
29-Nov-95
SHIP
VAISALA
PSYCHRO
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Ship met
Vaisala
Assman
Humidity g/kg
24
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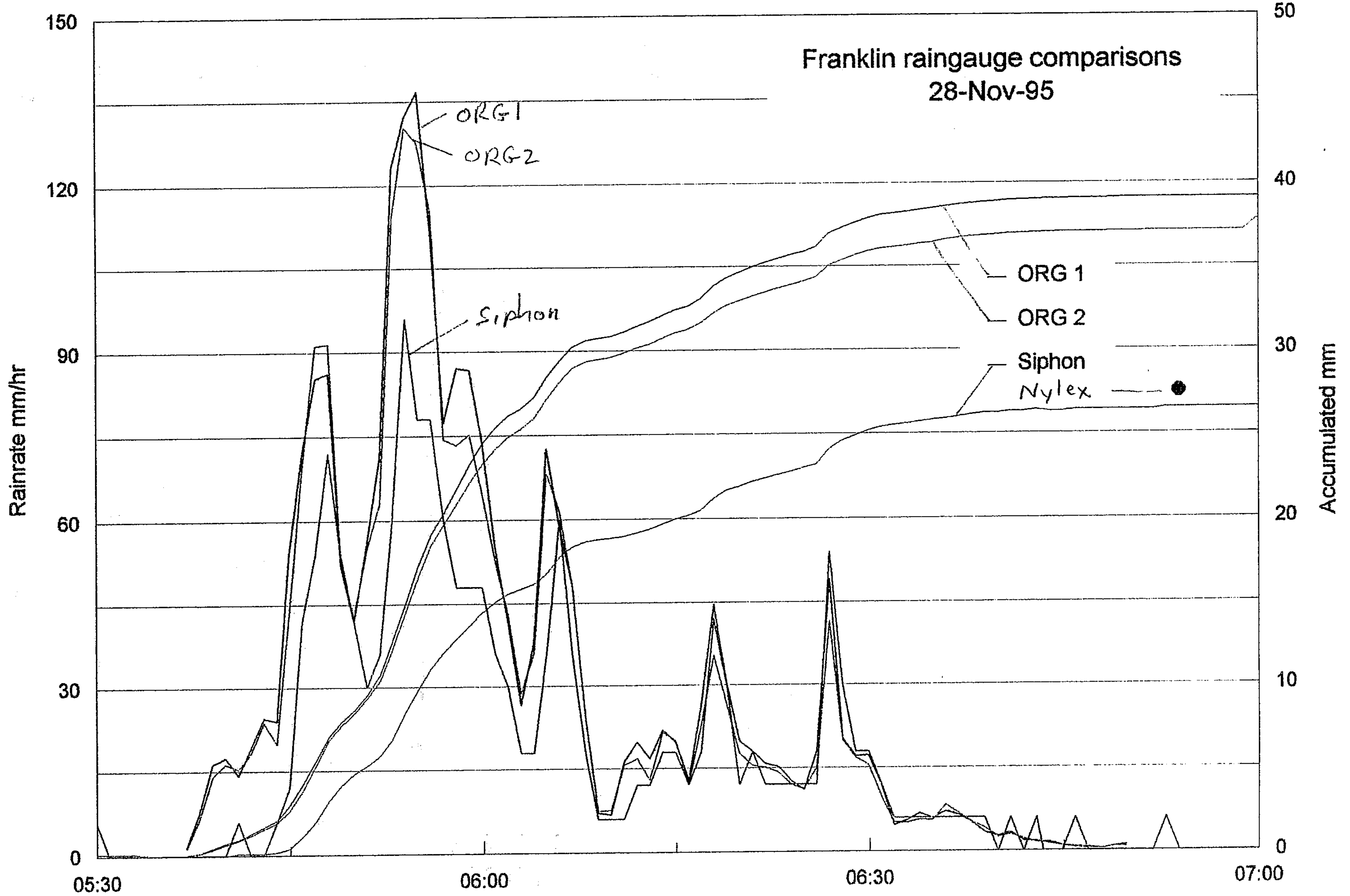
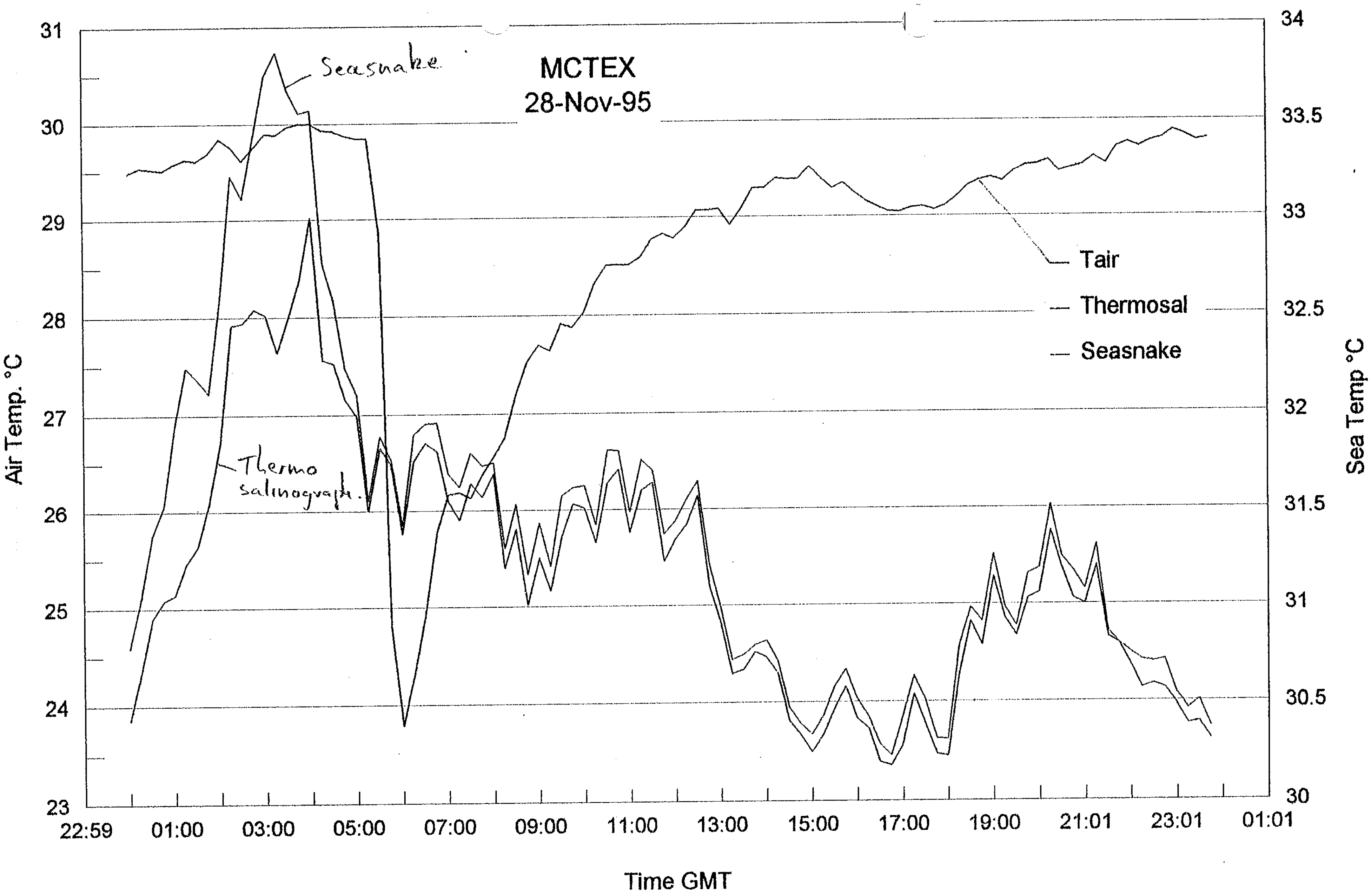
Time GMT


Franklin raingauge comparisons
28-Nov-95
Rainrate mm/hr
Accumulated mm
0
30
60
90
120
150
10
20
40
50
05:30
06:00
06:30
07:00
ORG 1
ORG 2
Siphon
Nylex
ORG1
ORG2
Siphon


MCTEX
28-Nov-95
Seasnake
Thermo salinograph.
Tair
Thermosal
Seasnake
Air Temp. °C
Sea Temp °C
Time GMT
31
30
29
28
27
26
25
24
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34
33.5
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32.5
32
31.5
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Fig 4