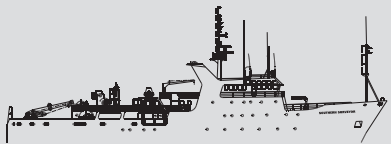

MARINE
NATIONAL FACILITY

2006 program

RV *Southern Surveyor*

CSIRO

voyage summary SS01/2006

SS01/2006

Characterising the monsoonal atmosphere and ocean near Darwin – a contribution to the Tropical Warm Pool International Cloud Experiment (TWP-ICE).

Itinerary

Departed Darwin 1000hrs, Friday 20 January 2006.
Arrived Darwin 0700hrs, Tuesday 14 February 2006

Principal Investigators

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- Peter Minnett (PI M-AERI) – University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL USA **Phone:** +1 305 3614104 **Email:** pminnett@rsmas.miami.edu

Scientific Objectives

In this voyage the RV Southern Surveyor will be deployed as part of a large experimental campaign carried out in the Darwin are – the Tropical Warm Pool International Cloud Experiment (TWP-ICE, for details see the web site http://www.bom.gov.au/bmrc/wefor/research/twpice.htm). In the context of this experiment the ship will fulfil four major roles, which are linked to the overall experiment objectives of TWP-ICE. Dr Christian Jakob will be the coordinating Chief PI of the deployment, while Dr Matthias Tomczak will be the Chief Scientist aboard the vessel. The other PI's are directly linked to the tasks below.

1) To serve as a base for a second cloud and radiation observatory similar to the land-based ARCS site through the deployment of the Pacific Northwest National Laboratory (PNNL) Atmospheric Remote Sensing Laboratory (PARSL) and the Marine Atmospheric Emitted Radiation Interferometer (M-AERI) on the vessel away from direct land boundary effects (PI: Mather, Minnett)

2) To extend the radiosonde observation network over the open ocean and thereby provide a critical link in closing the network around Darwin (PI: Bradley, Reynolds)

3) To provide observations of surface meteorology, air-sea fluxes and precipitation (PI: Bradley, Reynolds)

4) To provide measurements of the ocean state to support both ocean and coupled modelling (PI: Tomczak)

Voyage Objectives

The following is a notional voyage plan to achieve all the above objectives. As is often the case, it may need to be modified to suit the conditions we encounter on the day. For example, we are operating in a region and at a time when the dynamics of both ocean and atmosphere are expected to be quite complicated. The most severe problem from the flux measurement point of view would be lack of steady wind direction due to storm activity. So the plan should be understood as an indication of observational principles.

The ship will be deployed for 24 days at a location about 100 km west of Darwin (12°17'S, 129°53'E). This location will form the centre of the operations area and the central Flinders mooring will be deployed here. The ship will operate within a square box of side about 25km around the central mooring, always beneath cover of the Darwin weather radar. There will be a short instrument and SeaSoar trial period within the box, during which two other moorings will be deployed at its perimeter at 12°20'S, 129°58'E and 12o14'S, 129°48'E (see attached map). All these moorings are in shallow water, so deploying and retrieving them will take very little time.

There will then begin a voyage routine, which will continue throughout the IOP. To minimize the effects of flow distortion and ship motion on the wind measurements, the best strategy to obtain continuous time series of air-sea fluxes is to steam slowly upwind without ship maneuvers for as long as possible. At 2 knots the ship will travel from the central mooring to the edge of the box in 3 hours on its "flux leg". It will then deploy the SeaSoar in tow-yo mode and return to the mooring at 8kts on an "ocean structure leg" taking from 45min to 1hour. The ship will then turn and proceed again upwind which may, of course, have shifted direction. Note that in light winds flux measurements would be valid on the return leg – data would only be lost while the ship was turning. In a shifting wind situation, the flux leg may need higher speed to keep the relative wind within a reasonable sector over the bow, and the ship would cross the entire box in both directions. The actual routine and timing will need to be determined after some experience, particularly of the SeaSoar handling.

Throughout the voyage continuous measurements will be taken with the PARSL observatory, and radiosondes will be launched at three-hourly intervals. These will be closely scheduled, and it would be impractical, and unnecessary to try and synchronize the ship leg routines with launches. If a balloon is likely to coincide with either end of a leg, the turn will be delayed until the launch is completed. There will inevitably be other contingencies, which affect the voyage timing, such as occasional CTD casts for comparison with the SeaSoar and ship's thermosalinograph.

Of the aircraft flying during TWP-ICE, some will be measuring the state variables in the boundary layer, and surface fluxes. By observing spatial variability along the flight path, these complement the ship measurements and place them in

the context of the whole experimental area. Experience with TOGA-COARE tells us that confidence in the datasets is greatly enhanced by providing for careful intercomparisons between the measurements of ships and aircraft (flying as close as practical to the surface). Such comparison flights are scheduled in the experiment plan. Detailed flight plans for these comparison flights are currently being developed and will be made available as soon as planning for them has been completed.

Voyage Track

The area of operation is shown in Figure 1. The actual track consisted of a multitude of flux measurement transects of three hour length and performed at 2 – 2.5 knots against the prevailing wind direction. Most transects started from the centre of the area; occasional transects started from the perimeter, leading towards the centre. Seasoar transects were performed between the end of one flux measurement transect and the next.

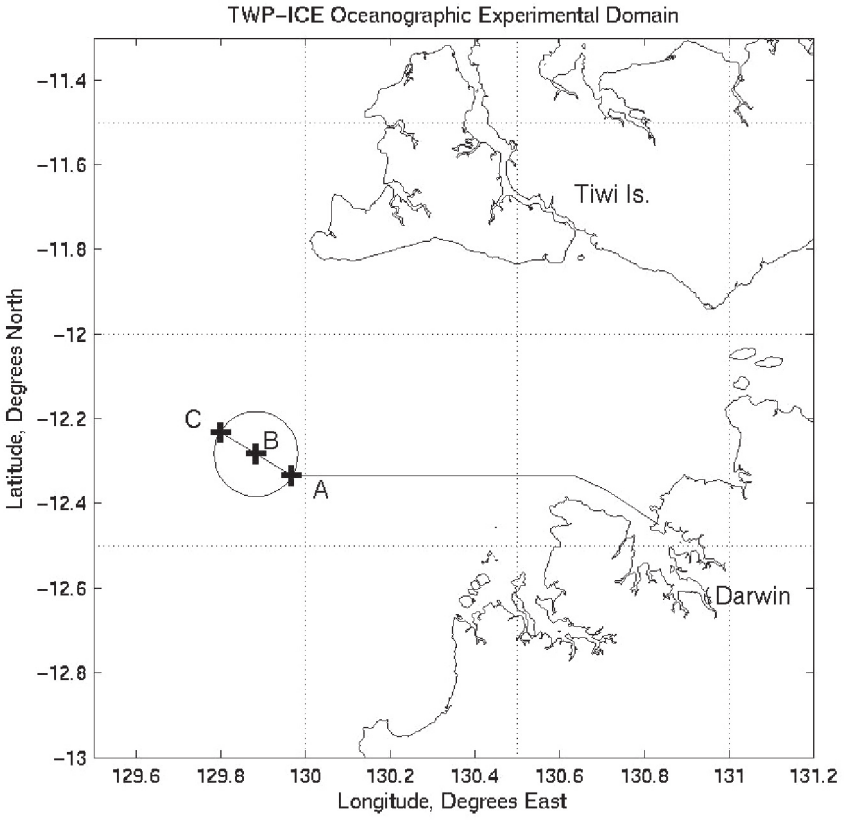

Figure 1: Voyage track and operation area. Positions marked A, B and C indicate instrument moorings.

Results

The atmospheric conditions encountered during the experiment were very unusual and required some adjustments to the programme. The middle atmosphere was extremely dry, which suppressed the expected high convection and associated rainfall, so that cirrus clouds were more prominent than cumulus. The presence of a tropical depression on the Northwest Shelf created rough conditions and unusual westerly airflow during the first part of the voyage.

Both the Atmospheric Remote Sensing Laboratory (PARSL) and the Marine Atmospheric Emitted Radiation Interferometer (M-AERI) performed well and returned excellent data for the given conditions. The radiosonde launches suffered from high wind conditions during the early part of the voyage but produced persistently good data thereafter until a few days before the return to port, when battery problems caused several sonde failures.

Although the data set produced by the oceanographic program is of high quality it will not be suitable to answer the original research aim, propagation of rainfall signals through the water column. It appears likely that it can serve as a good data base for a study of the effect of river run-off on the regional freshwater budget.

Voyage Narrative

Because voyage SS01/2006 was part of a coordinated international experiment, a daily report was sent via email to the TWP-ICE coordination centre in Darwin. The following narrative is an edited version of the daily reports. All times quoted are Northern Territory local times.

Friday 20/01 The ship departed from Stokes Hill Warf under light drizzle after very heavy rainfall in the half hour before. The rain later abated, but the day remained overcast.

All three moorings were deployed as planned, each followed by a CTD station. All mooring deployments were completed by about 23.00h. The ship then returned to the central buoy and commenced the regular pattern of the voyage: 3 hours at 2 knots into the wind to measure heat flux components, followed by a return to the central buoy at 8 knots dedicated to oceanography.

Saturday 21/01 The day remained mostly overcast. After long drizzle periods it turned dry before noon.

The first radiosonde launch, panned for 08:45h, did not eventuate since the password for the laptop could not be determined until after the launch window. Regular launches commenced at 11:45h.

The pattern of three hour 2 knot runs and 8 knot returns to the centre buoy, with CTD stations at the end points of the runs, was followed through the night.

The CTDs reveal a surprising degree of spatial variability in the salinity field. One station did not have any vertical structure, other stations showed a fresh layer of 5 - 10 m thickness on top (fresher by 0.3 - 0.4 psu compared with the layer below), yet others showed thin sheets of alternating fresher and more saline water in the top 10 m.

Sunday 22/01 The weather is still mostly overcast with occasional light rain.

The Seasoar was in the water for the first time late this afternoon but had a few problems. CTD stations at the end of every transect continue instead.

Monday 23/01 The ship experienced several hours of extremely heavy rain around midnight, from a system that on the radar looked like being only a few miles across but that hovered over the ship for quite a while. There is a lot of freshwater in the sea, much more than can be explained from local rain alone, so there must have been some significant falls over land as well to increase land run-off. The Seasoar is operational and producing good transects.

Tuesday 24/01 The weather is deteriorating. Towards the end of the day the ship was under nearly perpetual monsoonal downpour. Towards the night the wind had built up to 25 knots gusting to over 30 knots.

Our central mooring – the only one that carries a radar reflector and a light at several meters above the sea surface – was sighted and appears to cope well with the seas.

Wednesday 25/01 This has been our first day when the sun was strong enough to cast a shadow occasionally. But the wind is still blowing at 28 knots gusting to 33 knots, which tests the seaworthiness of crew and equipment.

When the ship gets hit by a particularly nasty wave a heavy shudder runs through the ship, followed by a sequence of resonant vibrations. This is life at sea, but it appears that not all equipment is built to tolerate it. Connor's radar gave up after one particularly strong bang on the hull, and Connor is now searching through its innards to find the loose connection.

Thursday 26/01 The sun was out for quite some time today, turning the sea into beautiful bottle green capped with plenty of white. The wind hasn't changed (28 knots gusting to 32) but the scenery is so much nicer now and very enjoyable.

Connor secured all electronics cards that had rattled loose in his radar, and the instrument should now be ready for use at sea.

The radiosonde launches, which suffered from a large failure rate as a result of the weather, have much improved since we decided to let the ship go off course for the launches. This produces only a five minute departure from the ideal track during the flux runs and doubles the success rate of the balloon launches.

Friday 27/01 The weather continues to cause minor problems for the ship programme. There has also been little rain lately, and the strong stratification seen during the first couple of days has entirely disappeared, thanks to vigorous wave and tidal mixing. We therefore decided not to expose the Seasoar to the rough seas until more rain and less wave action may make the situation more interesting again.

Saturday 28/01 The weather is the same as yesterday, winds 25 - 30 knots with choppy seas on a significant swell. It is expected to remain the same at least for another three days. We left the area at 7:00 hours towards to return one of the scientific crew, who had suffered from severe sea sickness and lost significant weight, to Darwin and used the occasion to take delivery of a spare pressure sensor for the Seasoar.

We decided to take the opportunity to obtain a long Seasoar run from the estuarine conditions near Darwin out to the area of the experiment. It could have been a good idea under different circumstances, but shallow water, heavy seas and low ship speed combined to strike us where we did not expect it. The Seasoar had to be kept on only 20 - 25 m of wire, and with the ship heaving and pitching 3 - 4 m the Seasoar was jerked around, flew occasionally under slack wire, eventually overturned and lost its roll control steering mechanism, putting the instrument out of action until emergency repairs can be made.

We returned to the experimental area about midnight. The return run was a test for all equipment, which appears to be now rattle-proof. All systems work reasonably well, with the occasional electronics problems. The Lidar is finally operational as well.

Sunday 29/01 The weather report promises more winds of 25 - 30 knots and seas of 3 m on 2 m swell at least until Wednesday, not the best conditions for our experiment. Connor was thrown off guard while working on the Lidar and kicked some of the optics out of alignment, so he is now back to adjusting it and hopes to have it going again tomorrow. The instrumentation on the mast has been exposed to some wave spray, and Mike and Jeremiah had to take the humidity sensor down to check it out.

The oceanography program is dormant at the moment, while plywood and a steel plate have been found to build a new roll steering mechanism for the Seasoar.

Monday 30/01 There is progress at some sections of the science front. Connor's radar works well with increased sensitivity and produced some good images. Our radiosonde performance record is holding up well.

For a few days now we could not only see the marker buy of the centre mooring but not the much larger surface buoy. Today we received an email that it had been found at Gunn Point northeast of Darwin. We notified the Bureau of Meteorology in Darwin, who will organize its retrieval.

Tuesday 31/01 The humidity sensor is back on the mast again, in the hope that the problem with spray does not reoccur. Given the state of the sea, which has not changed and is not going to change for another two days at least, we can only hope for the best.

Wednesday 01/02 The wind has "calmed" to 20 - 25 knots, and towards the end of the day was falling below 20 knots and gusting to only 23 knots. The seas are visibly better, with not half as many whitecaps around as before. We hope to get back to some interesting oceanography by Friday.

Connor says that he saw got his first cloud images in his lidar and is looking forward to better atmospheric conditions.

Thursday 02/02 We passed the mid-point of the experiment, and the conditions are finally getting quite acceptable. The wind is down to 15 - 20 knots, the whitecaps are gone, and the sea is getting better by the hour.

A review of the rainfall situation shows that we had about 400 mm of rain during 22 - 24 January and less than 50 mm since then, which is 9 days now. The stratification produced by the freshwater is long gone, but we do see a daily temperature cycle. So we decided to monitor temperature rather than salinity for the time being and do

regular CTDs until massive rain can produce a salinity signal again, calling for the use of Seasoar. It is becoming clear that the synoptic situation is not at all similar to the one for which TWP-ICE was planned, and the focus of the experiment is being redefined.

Friday 03/02 Another perfect sunset in an unusually clear atmosphere. Connor's lidar indicated no cirrus and clear sky for a while, so Mike got his photometer out and took some fine readings as the sun stood very high. About 85% of the solar constant reached the ship!

Eric processed the flux components. The result shows that the ocean has been cooling, quite an unusual situation for January-February in the Timor Sea but not unrealistic for the very high wind conditions and cloud-covered skies of our first ten days. The oceanic water column, which is well defined through the shallow water depth of about 45 metres and well mixed to within 0.005 degree Celsius, cooled by 0.7 degrees during these days.

We are now monitoring the expected warming under strong solar radiation from a sky that shows only scattered low cloud and a few patches of high cloud. The daily range of the sea is about 0.15 - 0.2 degrees. The "thermocline" is well defined as a 0.15 degree jump across a few metres that propagates down and disappears at night.

Saturday 04/02 Mike's photometer gave an even higher reading than yesterday, and judging from the starry night the atmosphere is indeed very transparent to various wavelengths.

We pulled the remains of the central mooring up today, as the surface buoy and its instrumentation had already been recovered the buoy from Gunn Point. This is a bonus in some sense, since the instruments kept recording while the buoy drifted (rather than lying useless on the sea floor), and we will have a nice transect of temperature and salinity between the experimental area and Gunn Point.

The ocean is clearly warming now. We continue our flux runs, monitor the daily heating and cooling cycle with CTDs and wait for rain.

Sunday 05/02 Another day with few clouds and low winds.

We had another look at the CTD data from the previous days. They show a distinct difference in both temperature and salinity between the centre of the area and the western perimeter, even when the water column is vertically completely mixed. This horizontal gradient appears to be surprisingly persistent and spurns us to return to Seasoar tows as soon as the repairs to its roll control gear are completed.

Monday 06/02 Winds today were around the 5 - 8 knot mark. We have to cover the Seasor when it is parked on the deck because the heat will shut down the electronics otherwise.

Two CTD casts at the central location showed very different temperature/salinity conditions from the other casts, apparently from water swept towards the centre by the tide. So we decided to shift the experiment to the eastern part of the area, performing flux runs from the perimeter towards the centre and using the Seasoar to monitor the sea on the return run. Seasoar is back in the water, with plywood stabilizers and soft steel rudder.Its first transects do indeed show much more structure in the east than in the west, with water bodies of different temperatures separated by fronts.

Tuesday 07/02 Winds were again light (< 10 knots). The sky was overcast for much of the time, with occasional sunny breaks, and there was an early very light shower but no promising atmospheric convection. We continue to concentrate on the eastern part of the experimental area.

Wednesday 08/02 Very light winds again, sometimes around the 5 knot mark. The sea temperature of the upper five metres is well above 30°C during the afternoon. The vertical structure shows multiple layers, reflecting the heating and mixing conditions under decreasing light winds.

Given the light and variable winds it is sometimes difficult to predict the wind direction for the next three hours, which was the basis for our decision to perform the flux runs from the east inward towards the centre of the area. Last night we ended up running along the area perimeter instead. We therefore reverted to a pattern where all flux runs start at the centre.

Thursday 09/02 Very light winds but a bit more cloud cover than yesterday. The surface layer of the sea is well above 30°C down to 5 metres and more, in places even at night. The horizontal inhomogeneity is quite striking. We processed some of the Seasoar data in detail and found that there are also still significant freshened patches of water floating around.

Friday 10/02 Few clouds, winds often less than 5 knots and on occasions dying altogether. We can see convective systems over the land and lightning at night, but here the sun is burning and the deck scorching hot.

We had visited the north west mooring on occasions and for a number of days could not see its marker buoy, so we decided that it may be wise not to wait to the last day to recover what is left of it. This morning the ship successfully dragged for it and recovered the floatation buoy and instrument; only the small marker buoy is missing. We uploaded the data; at first glance the instrument appears to have worked well.

Saturday 11/02 Very light winds again but a noticeable swell from the south east, which tells us that the land crews must have witnessed some good storms. Nothing of that sort at the ship; occasional periods of shade but not enough to keep the instrumentation cool when it is parked on the deck

The records from the north west mooring look good. The degree of structure in the Seasoar tows is surprising; regions with saline water above fresher water alternate with regions where the fresher water is on top of the more saline water. It all has to do with the unusual temperature history (cooling for a week, followed by strong heating for a week). The different temperatures affect the density enough to determine where the freshwater is slotted in.

Sunday 12/02 Winds were light as usual but cloud cover was more persistent for lengthy periods.

Preliminary processing of the mooring data shows pronounced salinity variations at spring tides, caused presumably by the strong spring tide currents that make the mooring lean over periodically.

The last Seasoar transect – a tow through the entire experimental area – was completed around 6.30 pm. The ship now only does flux runs and returns between the runs to the centre.

Monday 13/02 The south east mooring was retrieved at low tide shortly after noon. The scientific crew began dismounting the equipment and packing for speedy unloading next morning.

Summary

Despite the unexpected environmental conditions that required a partial re-orientation of the voyage objectives the research voyage can be regarded very successful. It produced data of very high quality which will become an important component of the TWP-ICE data set. Taken in combination with the land-based TWP_ICE data it will offer a rare opportunity to study air/sea interaction and tropical ocean conditions. It will be of immense value for any effort to model the tropical seas north of Australia.

Personnel

Scientific Participants

Matthias Tomczak	Flinders University	Chief Scientist
Simon Borlace	Flinders University	Oceanographer
Eric Schulz	Bureau of meteorology	Meteorologist
Mike Reynolds	Brookhaven National Lab.	Meteorologist
Jeremiah Reynolds	BNL	Flux support
Connor Flynn	Pacific Northwest Lab.	PARSL cloud radars
Chuck Pavlovski	DoE	PARSL and soundings
Peter Minnett	University of Miami	M-AERI
Alex Williams	BoM	Senior sonde operator
Wing Ng*	University of NSW	Student sonde operator
Melissa Coman	ANU	Student sonde operator
Ron Plaschke	CSIRO National Facility	Voyage Manager
Mark Underwood	CSIRO National Facility	Electronics
Lindsay Pender	CSIRO National Facility	Computing, Seasoar

* 20 – 28 January only.

Marine Crew

Leslie Morrow	Master
Madelaine Habib	First Mate
Drew Meincke	Second Mate
Robert Ferries	Trainee Mate
John Morton	Chief Engineer
David Jonker	First Engineer
Christopher Heap	Second Engineer
Malcolm McDougall	Boatswain
Graham McDougall	Integrated Rating
Anthony van Roy	Integrated Rating
Mark Ridley	Integrated Rating
Phillip French	Integrated Rating
Charmayne Aylett	Chief Steward
Andrew Goss	Chief Cook
Jason Phillips	Second Cook

Matthias Tomczak
Chief Scientist