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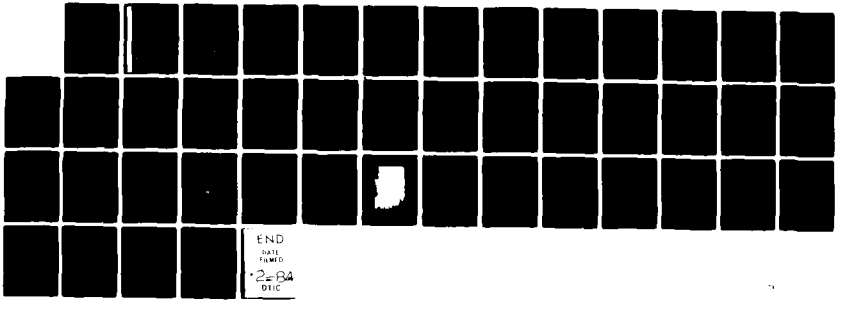

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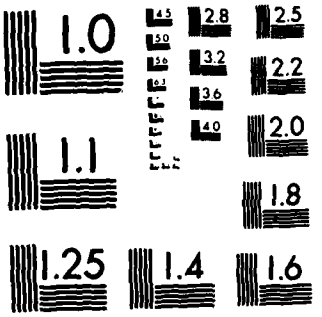

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RANRL TECHNICAL MEMORANDUM (EXTERNAL) No. 4/83

COMPARISONS OF N.A.S. NOWRA OCEANOGRAPHIC ANALYSES WITH INDEPENDENTLY OBTAINED SHIP AND SATELLITE DATA

BY

P. J. MULHEARN

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COMPARISONS OF N.A.S. NOWRA OCEANOGRAPHIC ANALYSES WITH INDEPENDENTLY OBTAINED SHIP AND SATELLITE DATA

P. J. MULLEARN

ABSTRACT

Comparisons are made between weekly oceanographic analyses prepared by the Naval Air Station, Nowra, and independently obtained data from ship cruises and high resolution infra-red satellite imagery. Analyses prepared by Nowra were for sea-surface temperature, temperature at a depth of 250 m, and surface mixed-layer depth. Good agreement was found for the location of warm-core rings, through Nowra's use of satellite-tracked buoys. However the position of the Tasman Front was poorly determined in their analyses, because of the lack of adequate data. Methods of improving analyses and future prospects are discussed.

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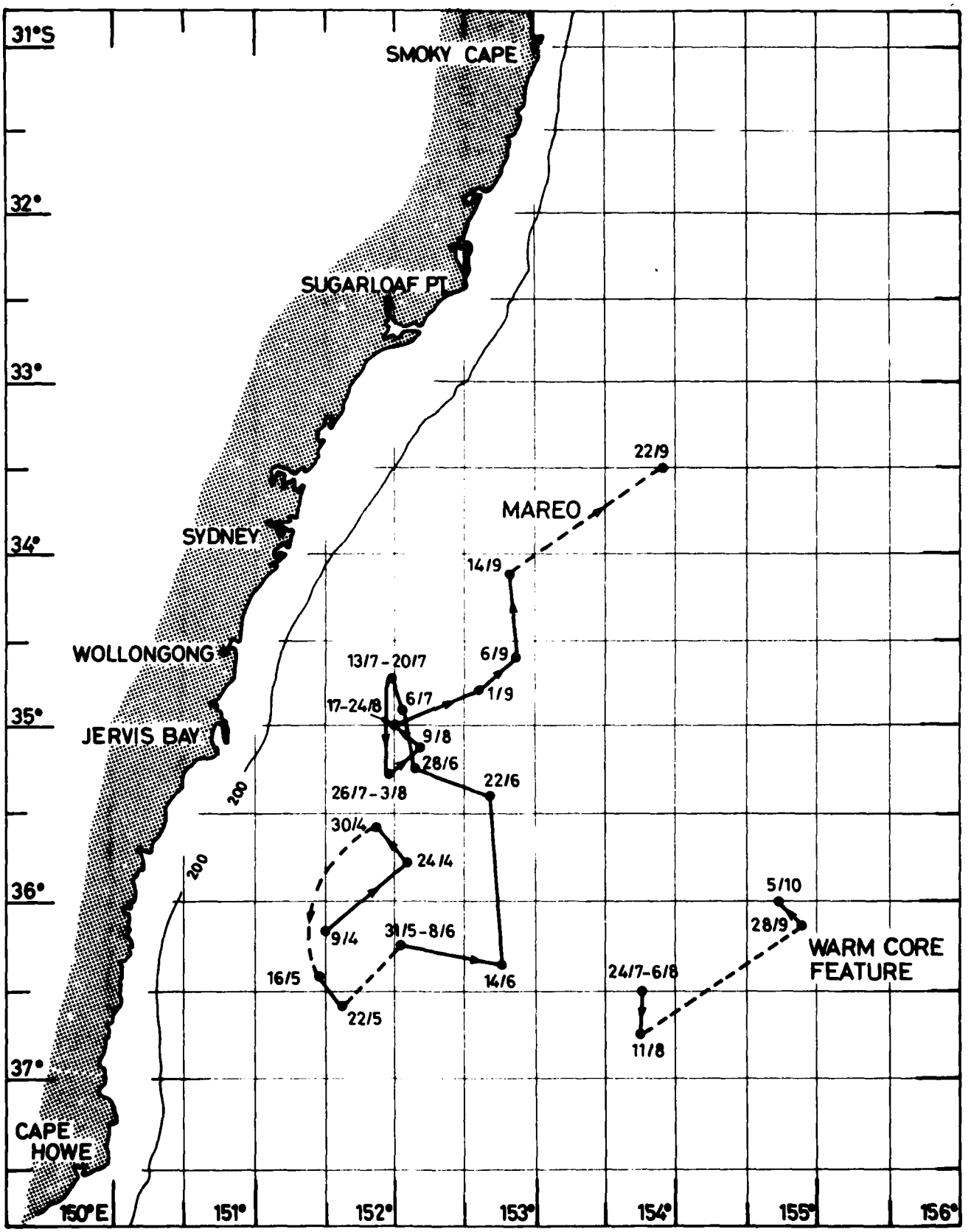

Fig. 1. Track of warm-core ring "Mareo" from 9 April to 22 Sept. and warm core feature to south-east from 24 July to 5 Oct. 1981

1. INTRODUCTION

For several years the meteorological/oceanographic officers at the R.A.N. Air Station, Nowra (N.A.S., Nowra) have been producing weekly real-time oceanographic analyses for the western Tasman Sea - in particular for the area between 31° and 37.5°S, and from the coast out to 156°E. Weekly charts are produced of sea-surface temperature (S.S.T.), temperature at a depth of 250 m (T_{250}), surface mixed-layer depth (M.L.D.), and paths of the C.S.I.R.O.'s satellite-tracked buoys.

Throughout 1981 four expendable bathythermograph (XBT) surveys were carried out by HMAS Kimbla in order to assess the accuracy of the N.A.S. Nowra analyses. These XBT data were not sent to Nowra until after the latter had produced their analyses. RANRL personnel were on board for the first cruise but the ship's crew alone carried out the other three. Four aerial surveys using air expendable bathythermographs (AXBT) were also carried out. These cruises, and N.A.S. Nowra data base are discussed in section 3.

Another source of data against which N.A.S. Nowra's analyses could be compared from June to December was the high-resolution infra-red (i.r.) imagery from the United States' N.O.A.A. satellites. These images generally arrived at RANRL four to six weeks after a satellite's acquisition of an image and on average there was one per week. However cloud cover obscured ocean features on many occasions.

In section 2 the main oceanographic features of 1981 are summarised. Section 3 discusses the cruise dates and data available to Nowra for concurrent analyses. In section 4 comparisons are made between cruise results, coincident high resolution i.r. imagery and N.A.S. Nowra's analyses, while in section 5 Nowra analyses are compared briefly with

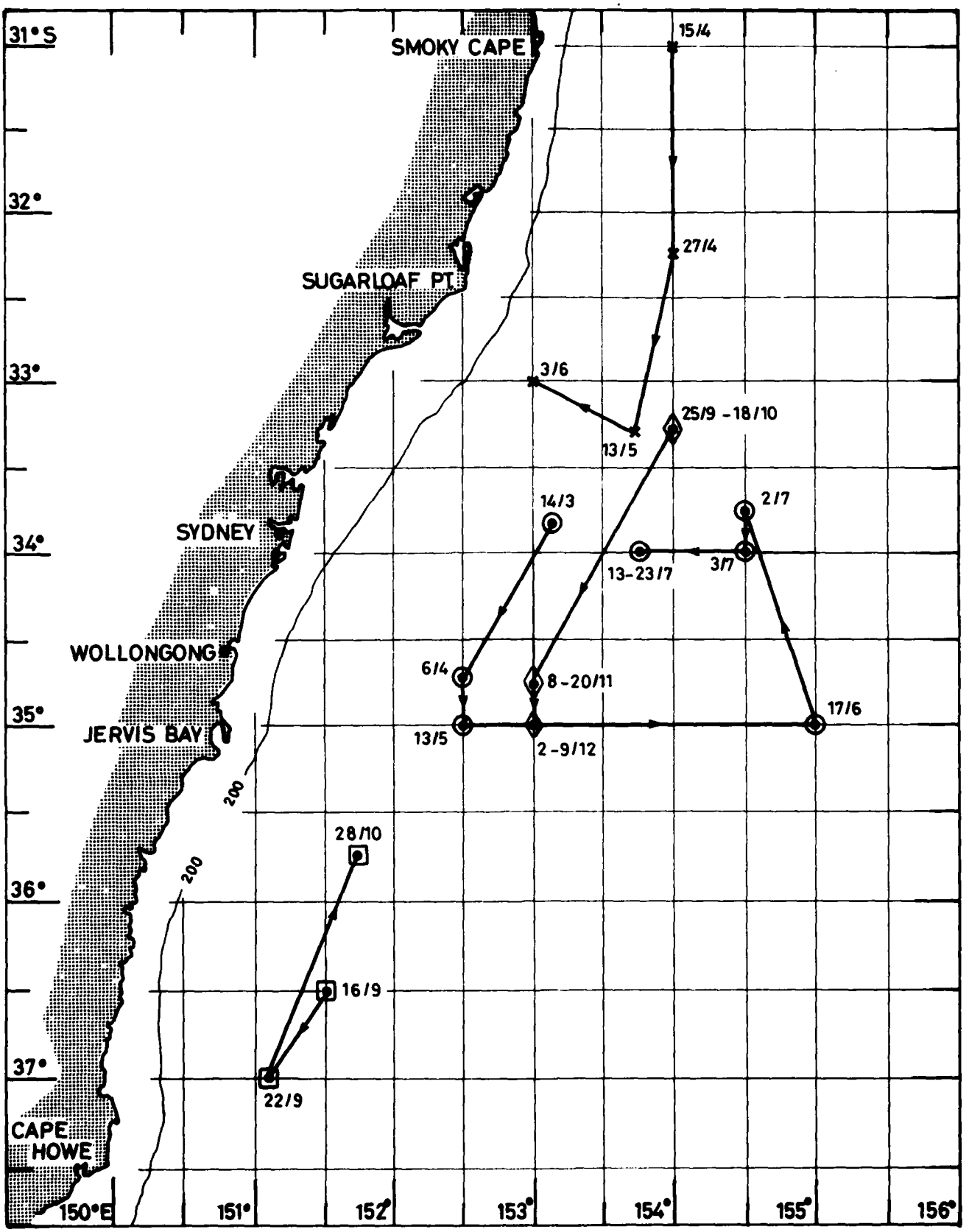

Fig. 2. Tracks of warm-core rings Nigel, ×, and Olga, ◈, and of two cold-core features, ◉, ⊡

satellite images obtained at times for which independent cruise data were not available.

Finally in section 6 these comparisons are discussed with regard to currently achievable accuracies and future desirable improvements in the ocean-analysis scheme.

2. MAIN OCEANOGRAPHIC FEATURES OF 1981

At the start of 1981 two warm-core rings "Leo" and "Maria" were present off the N.S.W. coast between 35° and 37°S and these coalesced in about late January. The combined ring, called "Mareo", migrated northwards with its centre describing anticlockwise loops (Cresswell, 1982). In July a section appeared to break off and a weak, warm-core feature was observed through to October near 36½°S, 154½°E (fig. 1).

In April an anticyclonic feature, very elongated parallel to the coast, became apparent off the northern N.S.W. coast centred east of Smoky Cape. In early May this had separated from the East Australian Current (EAC) to form warm-core ring "Nigel". It was observed to move south till early June and it is assumed that it merged once more with the E.A.C. after that date, as it was no longer detected.

In November a new warm-core ring - "Olga" - was found off Newcastle, with remnants of "Leo's" isothermal layer entrained around its edges. "Olga" moved towards the south-west until December.

In March a strong cold-core ring was found east of Sydney and its centre followed an anti-clockwise path through to at least late July. A smaller cold-core feature was observed off-shore between Jervis Bay and Eden in September and October. The tracks of these four features are shown in Fig. 2.

3. KIMBLA CRUISES AND N.A.S. NOWRA'S DATA BASE

In 1981 H.M.A.S. Kimbla performed four XBT surveys off the N.S.W. coast for comparison with the N.A.S. Nowra analyses. Cruise dates were:

RANRL 5/81 11-15 March

RANRL 13/81 14-19 September

RANRL 15/81 28-30 October and 7-10 November

RANRL 14/81 16-20 November.

Data regularly available to N.A.S. Nowra were infra-red images from the Japanese Geostationary Meteorological Satellite (GMS) (Mulhearn, 1982a), fleet XBT's, and positions of satellite tracked buoys, (Cresswell and others, 1978). Airborne surveys deploying AXBT's were also available for 13 March, 13 May, 9 July and 22 September (Mulhearn, 1982b). From about the middle of the year until mid October the time delay in receiving GMS data was too great for it to be useful. Although data from coinciding AXBT flights was not available for any of the analyses done concurrently with the ship cruises, due to several days delay in transmission of results, the two coincident flights together with the two carried out at times between ship cruises did provide a useful history for the evolution of oceanographic features. N.A.S. Nowra analysis periods for which ship data was available were 9-16 March, 4-21 September, 2-9 November and 16-23 November. For the analysis of 9-16 March there were GMS imagery, many XBT's between the coast and 152°E from 33.5° to 36.5°S, and excellent buoy tracks within the warm-core ring south-east of Jervis Bay. There were also two research cruises to the north-east of Sydney in February.

For the analysis of 14-21 September there were many XBT's over the analysis area and good buoy tracks within the warm-core ring.

For the analysis of 2-9 November there were few XBT's or buoy data, either in that week or in the previous month, but some GMS images were available. For that of 16-23 November there were a number of XBT's between Sydney and Jervis Bay out to 152°E, good buoy tracks, and some GMS imagery.

Throughout 1981 the satellite-tracked buoys provided excellent data on the position of the centres of warm-core rings on a continuous basis.

For purposes of comparing sea-truth data to the analyses made by N.A.S. Nowra from data routinely available to them, Kimbla cruise data was not sent to Nowra until after their weekly analysis for the period had been independently made from their regularly available data sources. (Nowra could then update their analyses with the cruise data.) In data sparse regions N.A.S. Nowra used previous analyses in arriving at their current one.

4. COMPARISON BETWEEN KIMBLA CRUISE DATA, INFRA-RED IMAGERY, AND N.A.S. NOWRA ANALYSES

Comparisons for the four analysis periods 9-16 March, 4-21 September, 2-9 November and 16-23 November are discussed in turn.

A. Early March

Charts of sea-surface temperature (SST), 250 m temperature (T_{250}) and mixed-layer depth (MLD) from Nowra analyses of 9 to 16 March are shown in Figs. 3, 5 and 7, while corresponding charts from the Kimbla cruise of 11 to 15 March are presented in Figs. 4, 6 and 8 respectively.

It is hard to discern a pattern in the ship data for SST, but these are generally within ±2°C of the values in Nowra's analysis (see Fig. 9). Comparison of the T_{250} charts show that the position of the warm-core ring south-east of Jervis Bay was well determined although Nowra does not show closure of the isotherms to the south. The large perturbation of the ring's northern

edge shown in the Nowra analysis was probably a very transient phenomenon, but it did displace that edge by approximately 30 nautical miles (nm).

The cold-core feature seen in the cruise data, centred near 34°S, 153°E, is displaced approximately 60 nm to the south-west in the Nowra analysis and is much too weak in their analysis. The Tasman Front was not encountered on the cruise but must have been at least 50 nm further to the east than is shown on Fig. 5 by the locus of the 16°C isotherm in the north and north-east. Spot values of T_{250} are compared in Fig. 10.

Mixed-layer depths from the cruise data were difficult to contour due to shallow, warm surface layers over parts of the region but cruise values were generally within ±20 m of those from the Nowra analysis (Fig. 11).

The good location of the warm-core ring in the Nowra analysis was due to the use of satellite-tracked buoys and the poor location of other features to the north-east was due to lack of data.

B. September

Nowra analysis results for 14 to 21 September for S.S.T., T_{250} and MLD are shown in Figs. 12, 14 and 16 respectively, while corresponding results from a cruise of 14 to 19 September are shown in Figs. 13, 15 and 17 respectively. The scales at which the two sets of results are drawn is slightly different so that some care is needed in comparing them.

In the SST patterns the warm south-west edge of ring Mareo can be seen in both, offshore between Sydney and Jervis Bay, but the warm tongue extending south to Jervis Bay in the Nowra analysis is not seen in the Kimbla data. The reason for this discrepancy is unclear. However SST's from Kimbla are about 2°C warmer near 37°S, 152°E. Overall SST's agree within ±2°C, 80% of the time. See Fig. 18.

The T_{250} patterns indicate that at the time of Kimbla's pass the western edge of Mareo was about 20 nm further east than the Nowra analyses indicate. The western edge of the anticyclonic feature in the south-east also appears to have been about 30 nm further west than Nowra indicated.

However it is known that ring centres typically move at 1 to 6 km/day and have been observed to move at 17 km/day (9nm/day), Mulhearn (1983). In the south-west of the area the 11° and $12^{\circ}C$ contours appear to be about 70 nm too far north in the Nowra analyses.

There appears to be little agreement between the cruise data for MLD and the Nowra analysis values. Kimbla found many temperature profiles with zero or very small MLD's, probably due to surface heating. MLD's agreed within ±20 m on only 56% of occasions. MLD analyses were abandoned for the rest of the year because of the difficulty of allowing for transient thermoclines and "afternoon effects" due to surface heating.

Fig. 19 is a high-resolution i.r. image for the 16 September from the NOAA-7 satellite and a sketch of the main features is shown on a conventional projection on Fig. 20. The position of ring Mareo agrees with Nowra's analysis but the small swirl ESE of Jervis Bay and the apparently clockwise cold-core circulation centred near $36.5^{\circ}S$, $151.5^{\circ}E$ are entirely absent on Nowra's analysis. Some sign of the last feature can be seen in Kimbla's data. Nowra did not have access to satellite data at the time of these analyses so it is not surprising they were undetected.

C. October - November

Nowra analyses of SST and T_{250} for 2 to 9 November are presented on Figs. 21 and 23 respectively, while those from the Kimbla surveys of 28 - 29 October and 8 - 10 November are on Figs. 22 and 24 respectively.

The patterns of SST from the two data sets are dissimilar but they all agree within $\pm 2^{\circ}C$. The main discrepancy is south of $37^{\circ}S$ where Kimbla's values stay higher.

There are major discrepancies between the T_{250} results. Kimbla's data reveal a weak anticlockwise circulation centred near $37.25^{\circ}S$, $151.25^{\circ}E$ and a clockwise circulation centred near $36^{\circ}S$, $152^{\circ}E$. Neither of these is present on the Nowra analysis. The south-west edge of the warm-core ring in the Nowra analysis was in approximately the right position but the front here on the Nowra analysis was shown to be far too weak by the Kimbla data.

This N.A.S. analysis was so poor because of the sparsity of data reaching Nowra at this time, as previously described in Section 3.

D. November

SST and T_{250} analyses from N.A.S. Nowra for 16 - 23 November are shown in Figs. 25 and 27 respectively, with Kimbla's cruise data on Figs. 26 and 28 respectively. Main oceanographic features at this time were the East Australian Current (E.A.C.) running along $32^{\circ}S$ and ring "Olga" centred off Woollongong. The SST's show little contrast at this time except for a 3° to $4^{\circ}C$ jump across the E.A.C. at $32^{\circ}S$. The N.A.S. Nowra analysis has the front tending to the south-east rather than due east but the cruise data fit either interpretation. 87% of individual SST values agree within $\pm 1^{\circ}C$.

On the T_{250} maps the comparison for the E.A.C. is the same as for SST's. The Kimbla data would put Olga's centre slightly further to the south-west but agreement is quite close. The positions of the fronts around the ring agree within 20 nm.

5. COMPARISON OF NOWRA ANALYSES WITH HIGH RESOLUTION SATELLITE INFRA-RED IMAGERY FOR PERIODS HAVING NO CRUISE DATA

From June to December 1981 infra-red imagery was available from N.O.A.A., approximately four to six weeks after date of acquisition. In general, positions of the warm-core rings as observed by the satellite agreed well with positions from the N.A.S. Nowra analyses. However on many occasions the position of the Tasman Front was quite wrong in the latter analysis. This was caused by lack of data and substitution of past history as a "best guess" estimate of frontal position. In future it would be better if past history was only used for about a month.

The infra-red images at times revealed a quite complex, and at times confused, picture with various swirls and streamers not apparent on ship surveys. However the Tasman Front was generally quite clear, when not obscured by cloud.

6. DISCUSSION

In general the location of warm-core rings was well determined in N.A.S. Nowra analyses, due largely to the use of C.S.I.R.O.'s satellite tracked buoys. There were discrepancies of the order of 20 nm between analyses and cruise results in the location of fronts around rings, but this could well be due to short period fluctuations in frontal location.

At times cold-core features were overlooked in the Nowra analyses and the position of the Tasman Front was quite wrong. These discrepancies, especially the latter, would have been overcome with better availability of satellite data, such as is now provided from Macquarie University.

There were serious difficulties in plotting up mixed-layer depths,

especially after surface warming had commenced, and practical solutions to this problem require further investigation. A combination of theoretical modelling of the "afternoon" effect (e.g. Hill, 1980) and use of climatological studies (e.g. Mulhearn, 1983; Mulhearn and Hamilton, 1982) and of statistical correlations between SST, MLD and season may provide an answer (Hackett, 1983).

There are some indications that short term fluctuations of fronts can easily cause location errors of order 20 nm. Theoretical models of waves on fronts may help in this area.

Adequate quantities of data in real-time are clearly essential for reasonable analyses. The R.A.N. is trying to organise more regular AXBT surveys, and is acquiring its own satellite-tracked buoys. These in combination with regular G.M.S. infra-red imagery should go a long way towards providing sufficient information for significant improvements in real-time ocean analyses in the East Australian Area.

ACKNOWLEDGEMENTS

The assistance of the officers and men of HMAS Kimbla in data gathering and the keen cooperation of the met./oc. officers at N.A.S. Nowra and the willingness of Dr. George Cresswell of CSIRO to allow access to his buoy data are all gratefully acknowledged.

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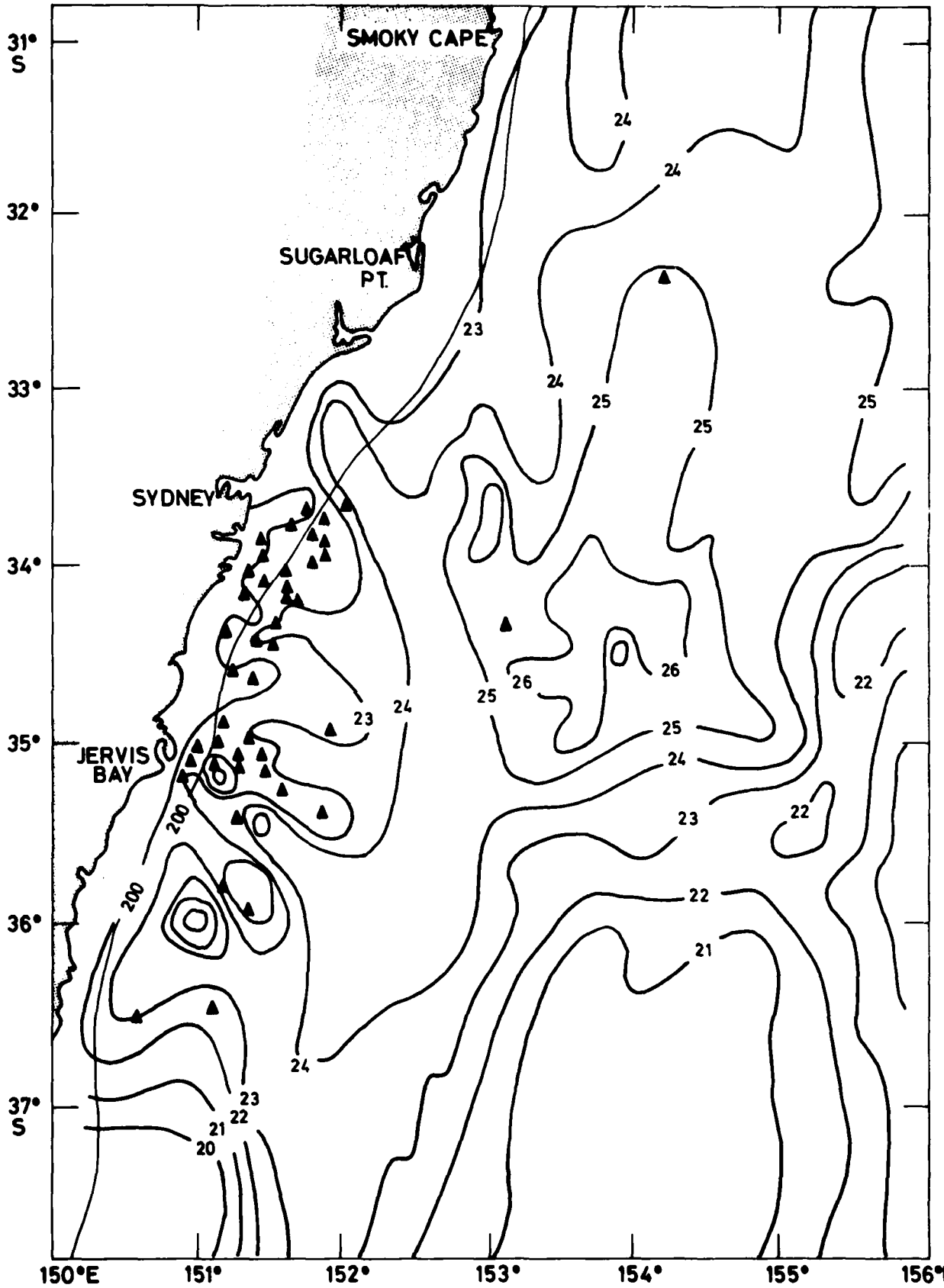

Fig.3. Nowra analysis SST 090001Z to 160001Z March 1981.(°C).
(▲'s are positions of XBT's in this analysis week.)

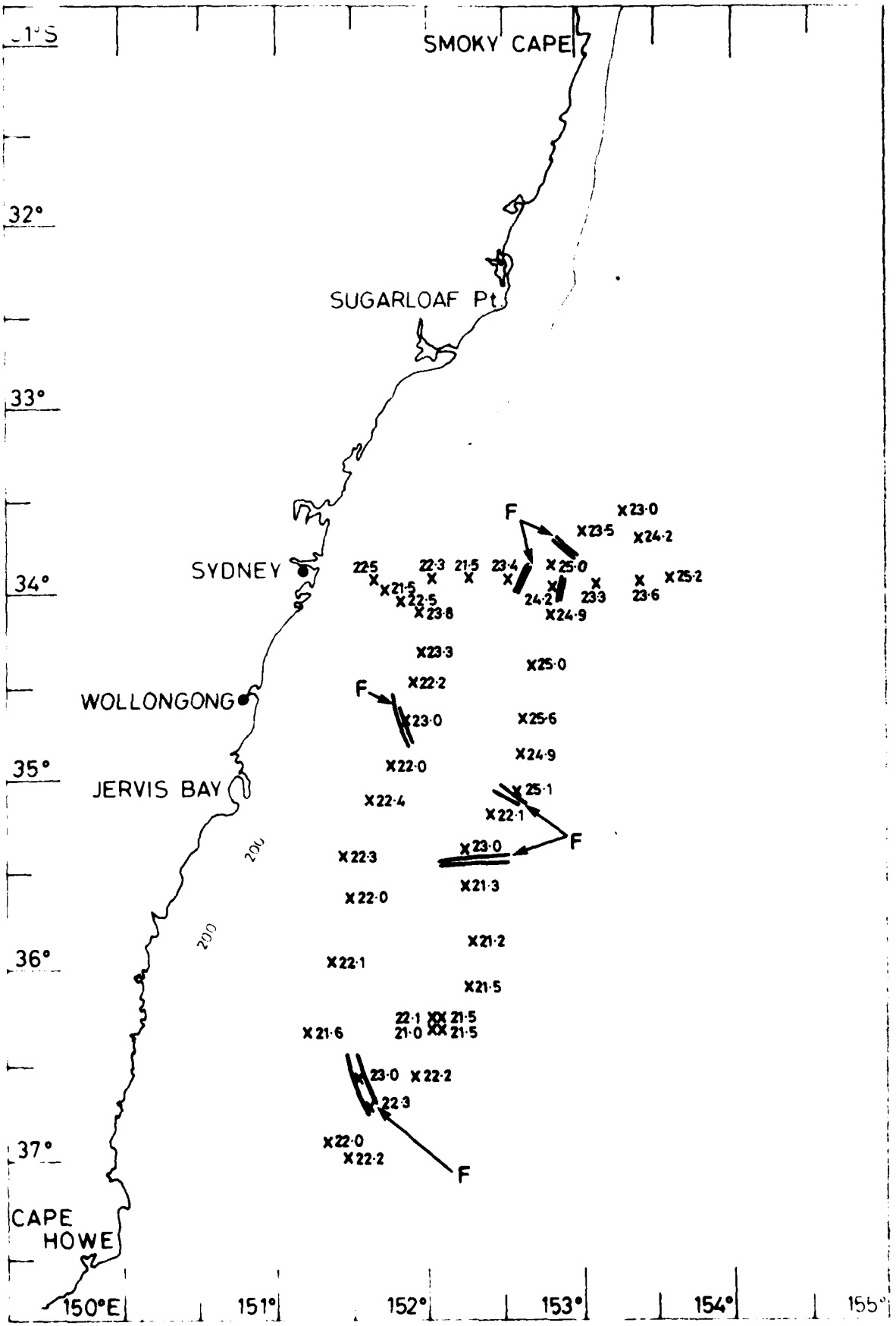

Fig.4. SST from Kimbla 11-15 March (°C)

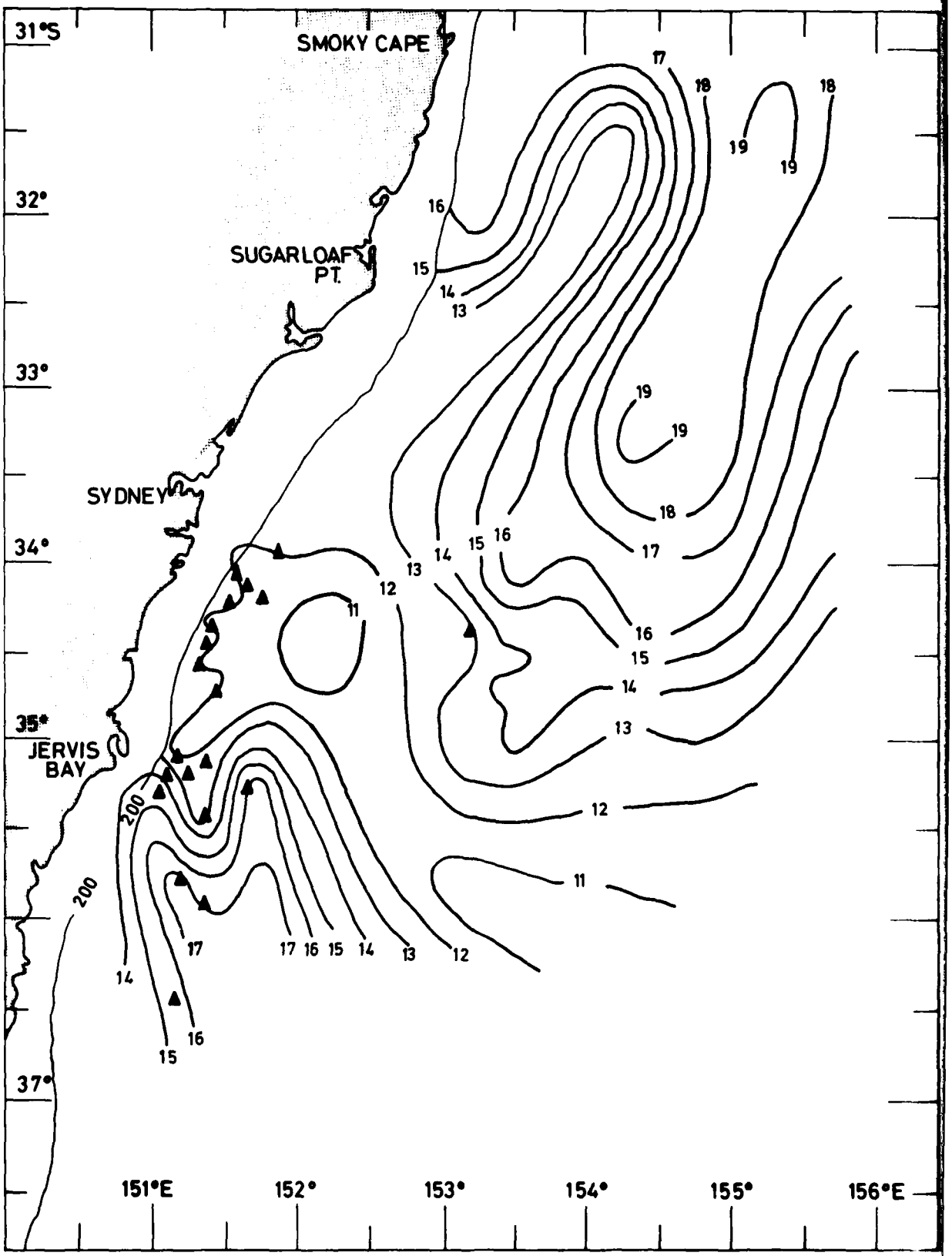

Fig.5. Nowra analysis 250m Temp. 090001Z to 160001Z Mar. 81. (°C)

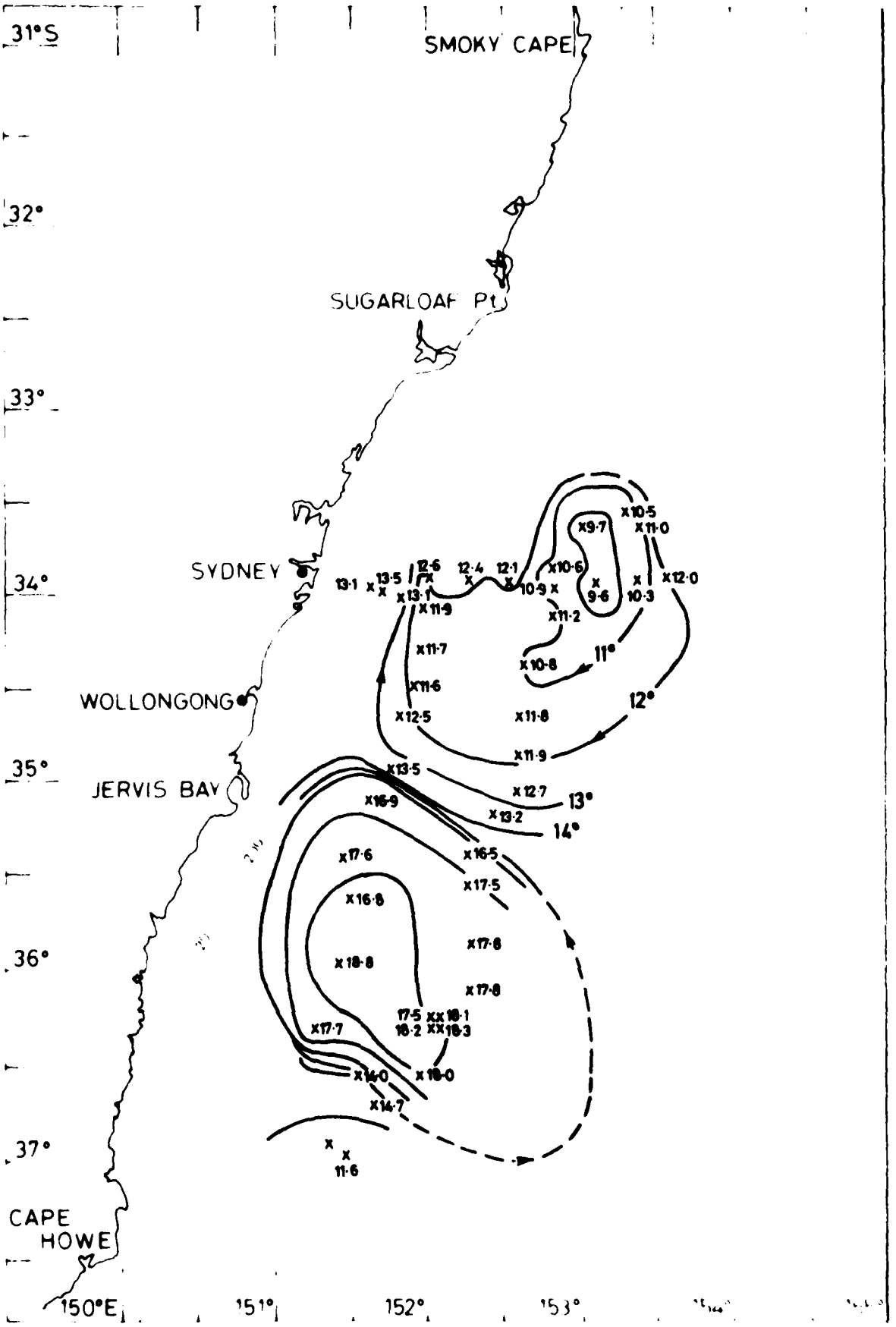

Fig. 6. T_{250} from Kimbla 11-15 March (°C)

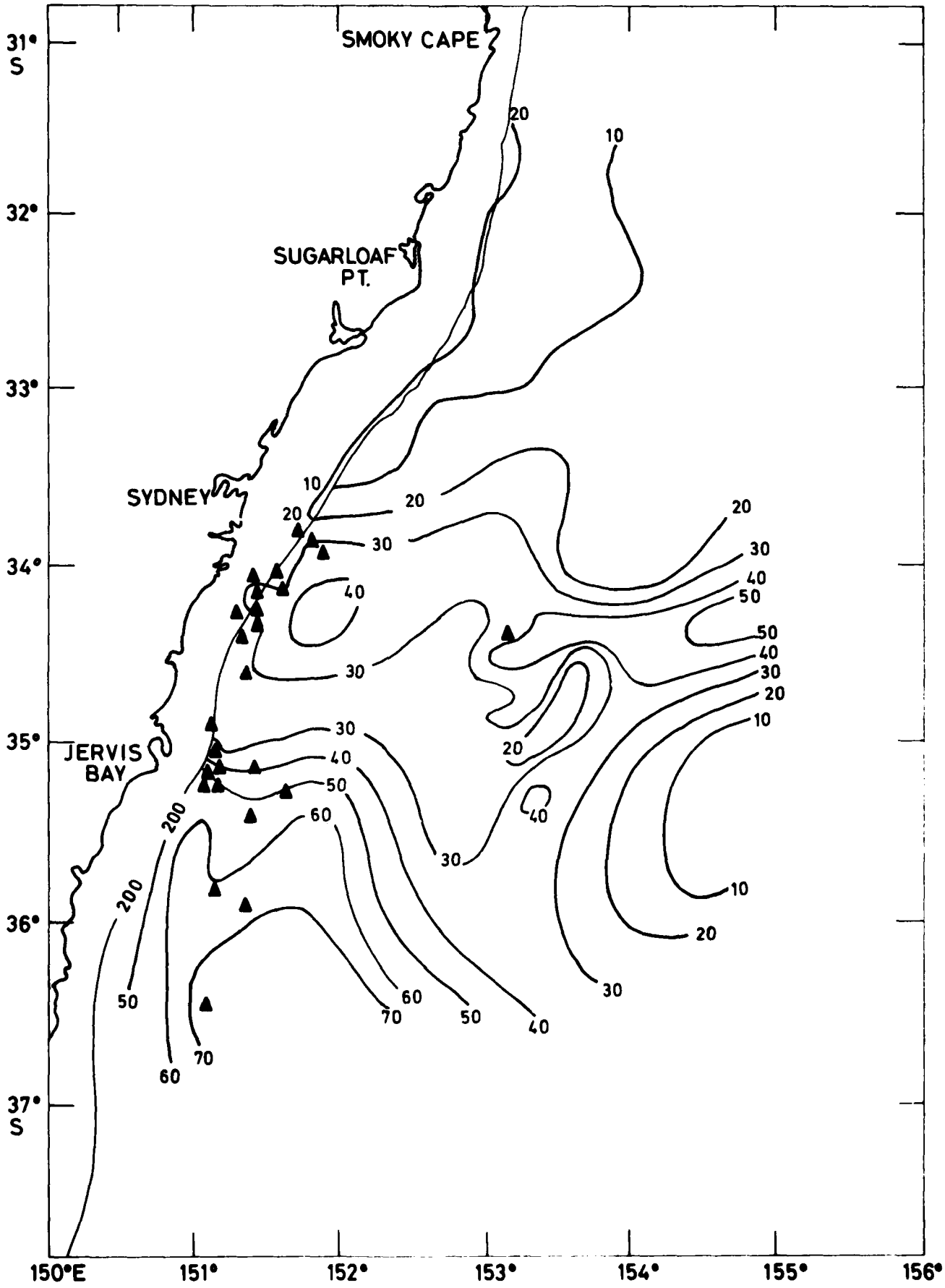

Fig.7. Nowra analysis Mixed-layer depth (metres) 090001Z to 160001Z March 1981.

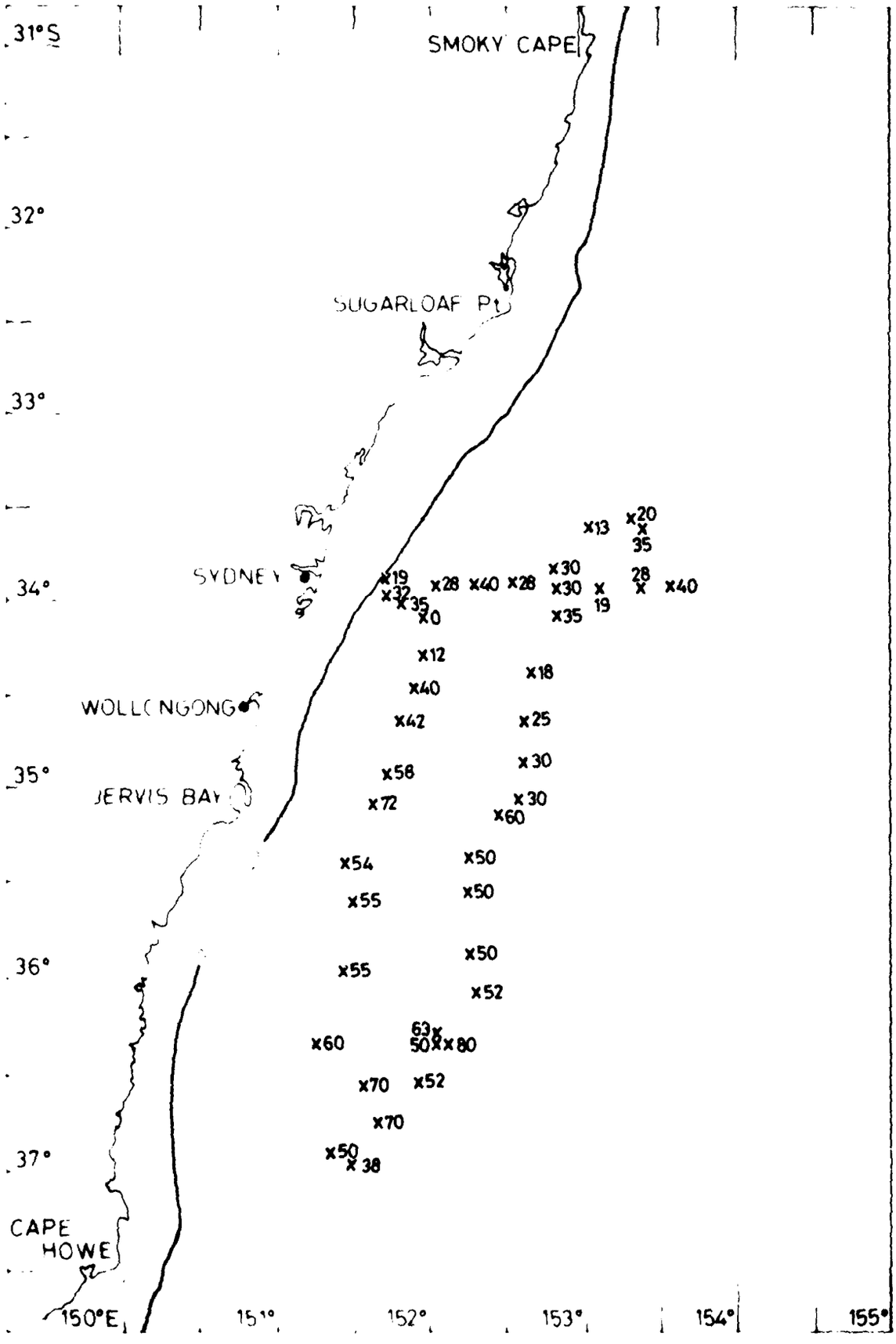

Fig. 8. Mixed layer depth (m) from Kimbla 11-15 Mar.

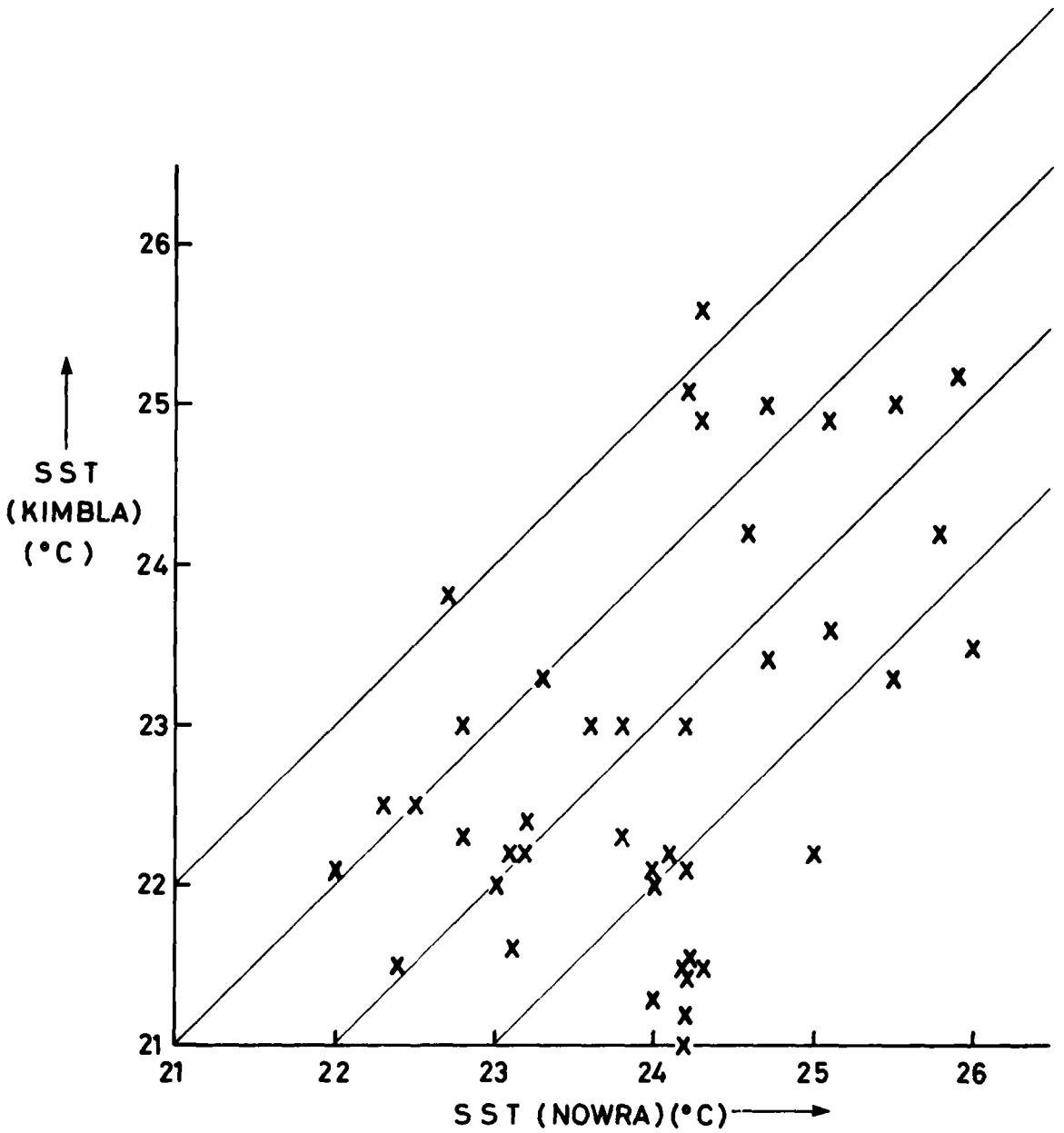

Fig. 9. SST from Kimbla vs those of Nowra's analysis March 1981.

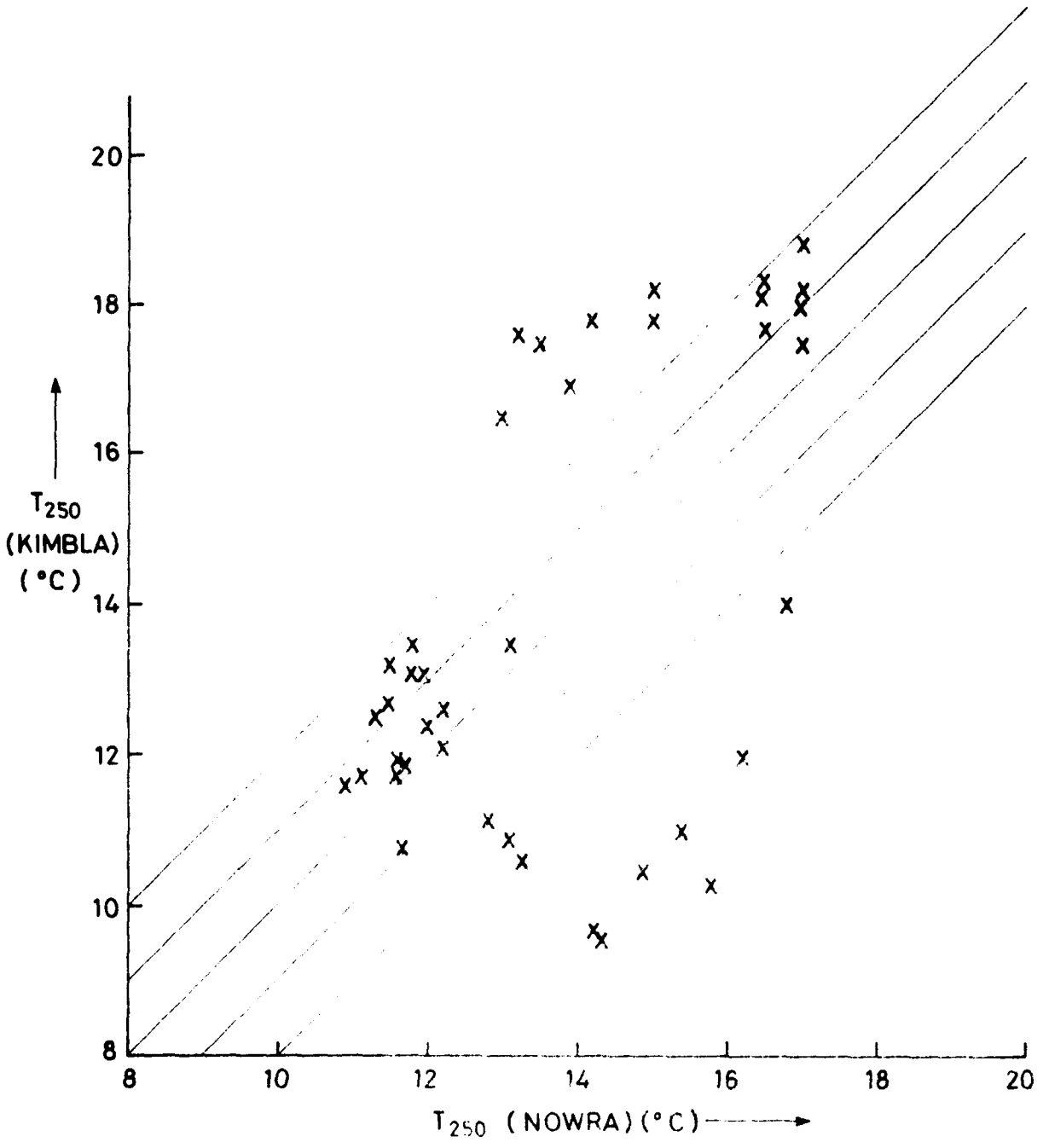

Fig. 10. T_{250}'s from Kimbla vs Nowra's March 1981.

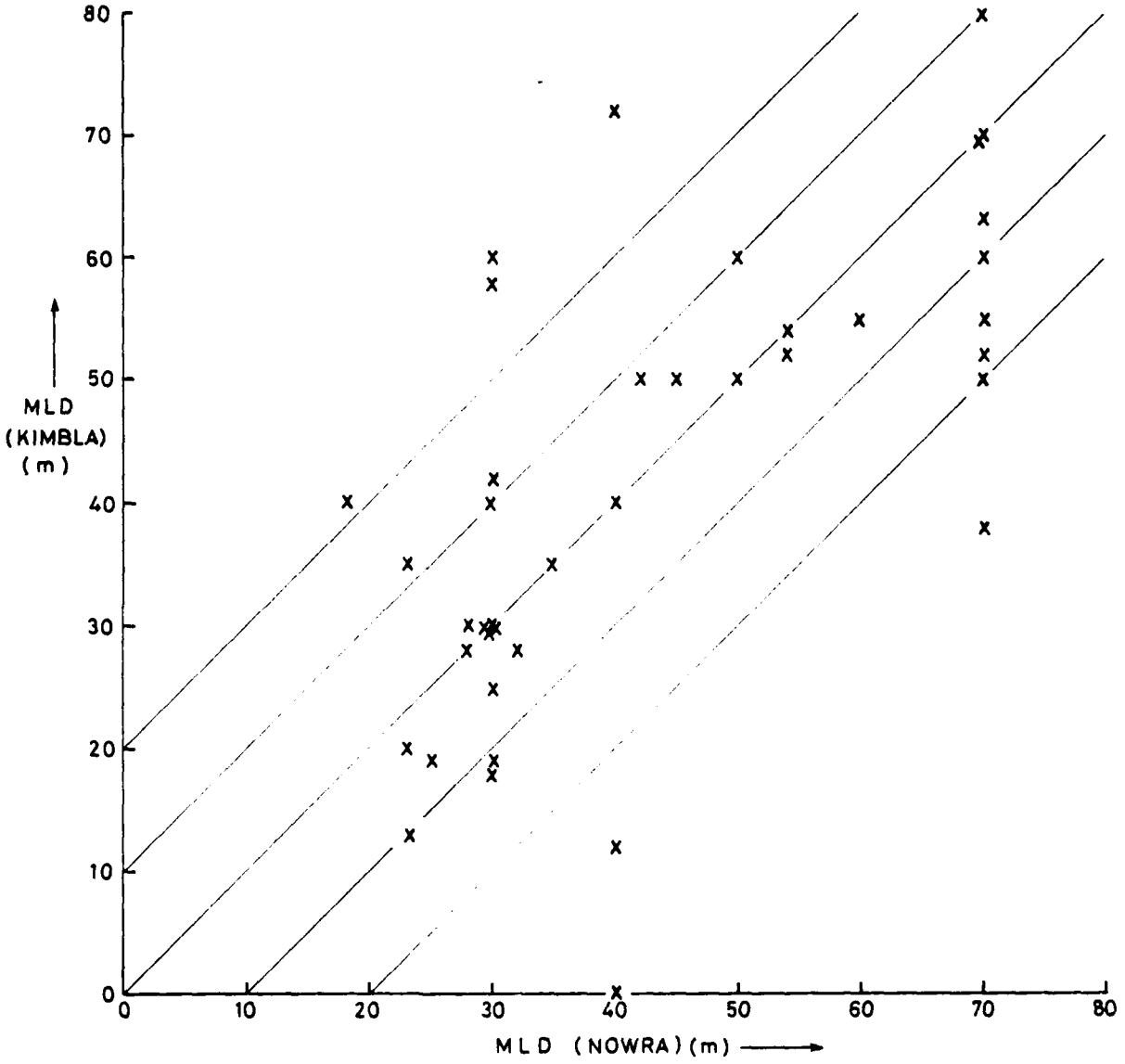

Fig. 11. Comparison of mixed layer depths from Kimbla and Nowra, March 1981.

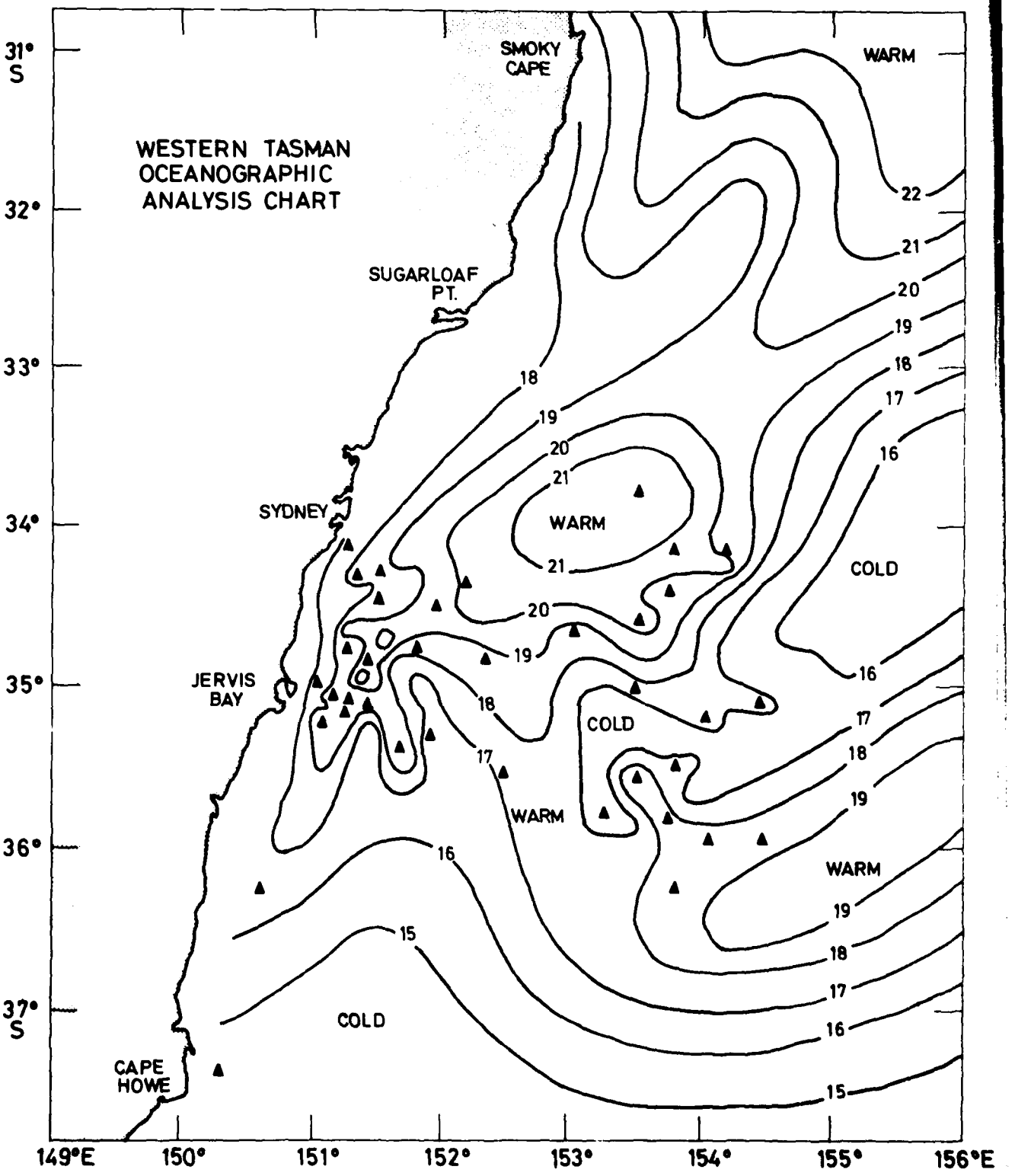

Fig.12. SST. 14-21 September 1981 from Nowra. (°C)
(▲'s are positions of XBT's in this analysis week.)

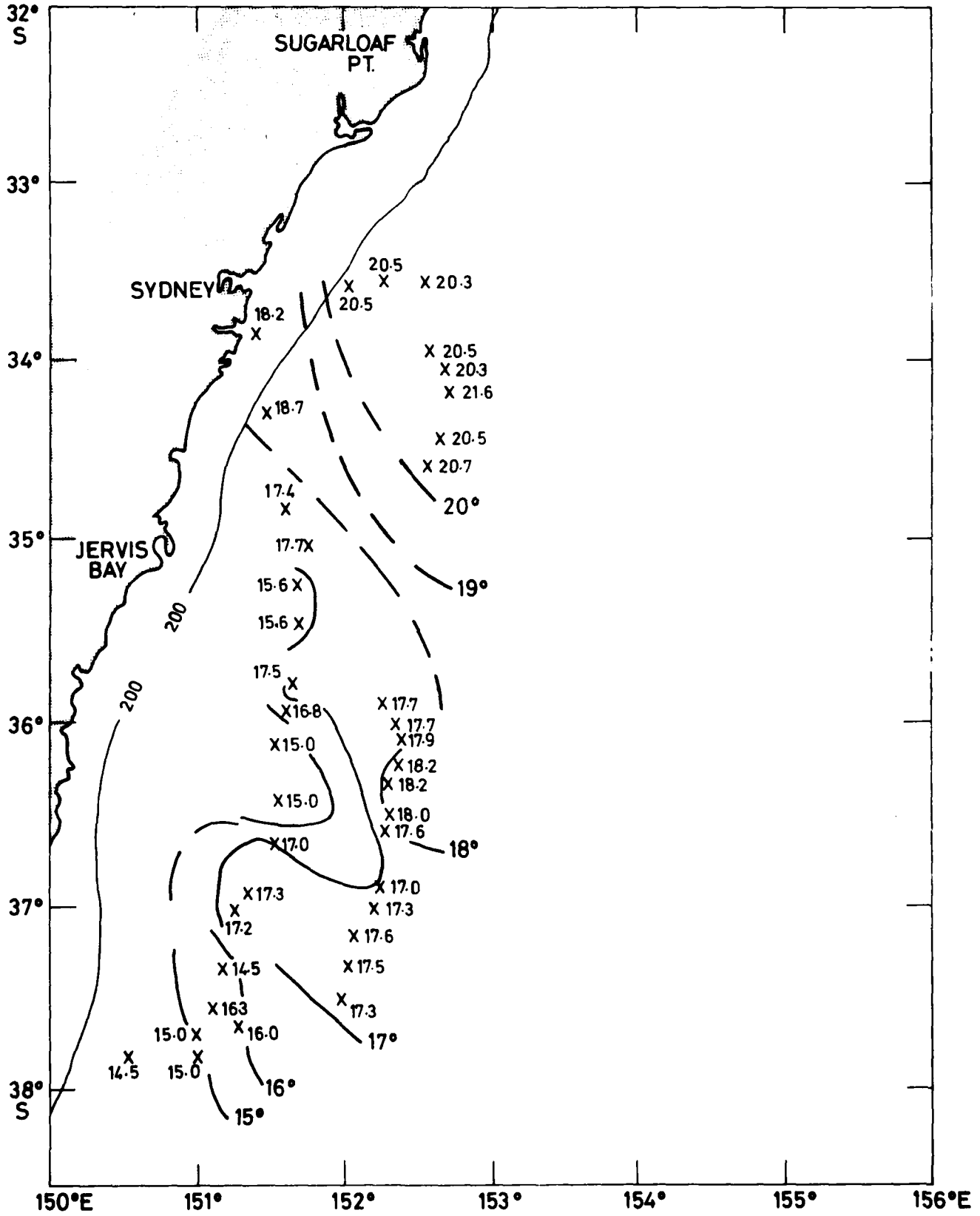

Fig. 13. SST. 14–19 September 1981 from Kimbla (°C)

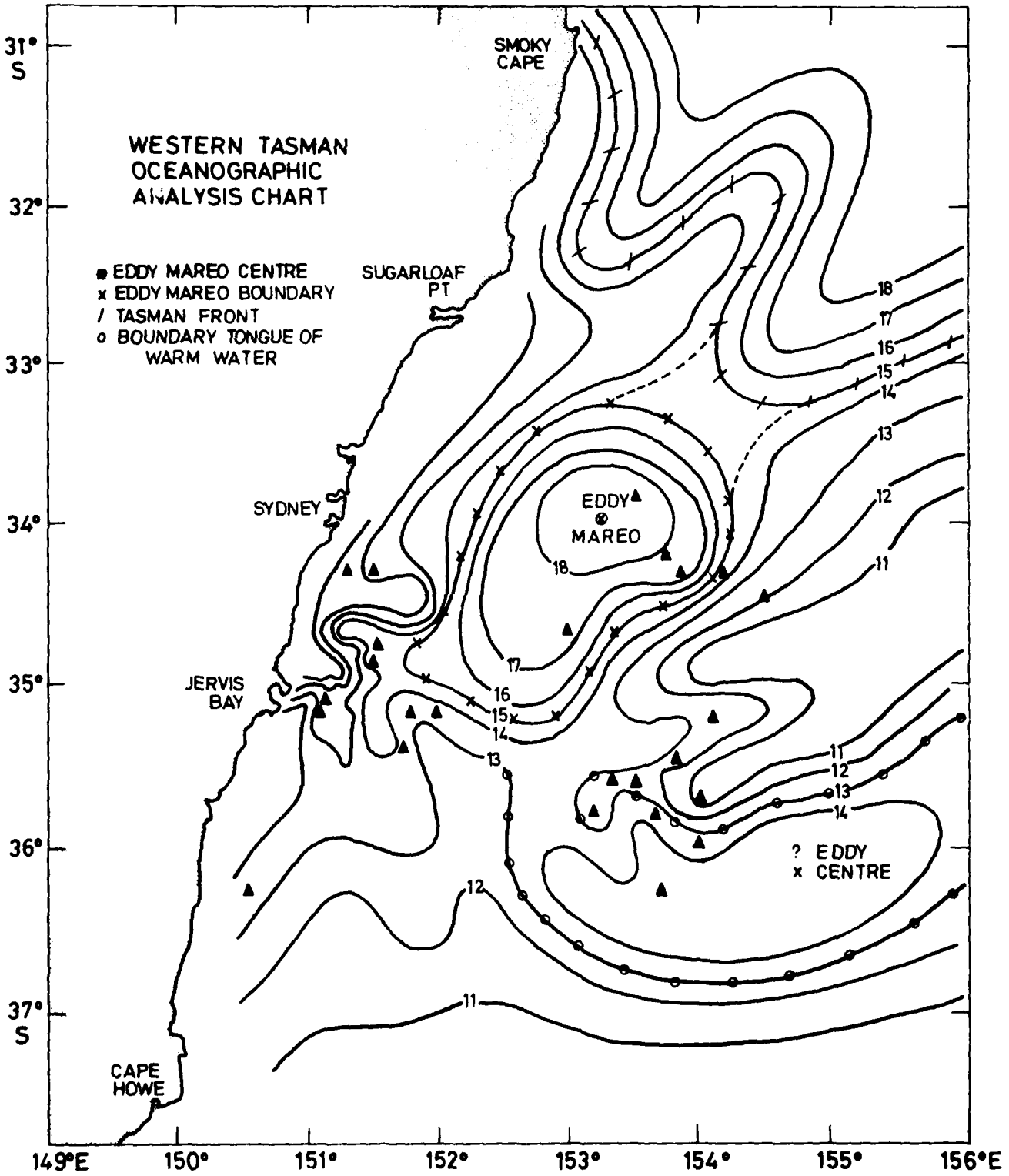

Fig. 14. 250m Temperatures 14-21 Sept. 1981 from Nowra (°C)

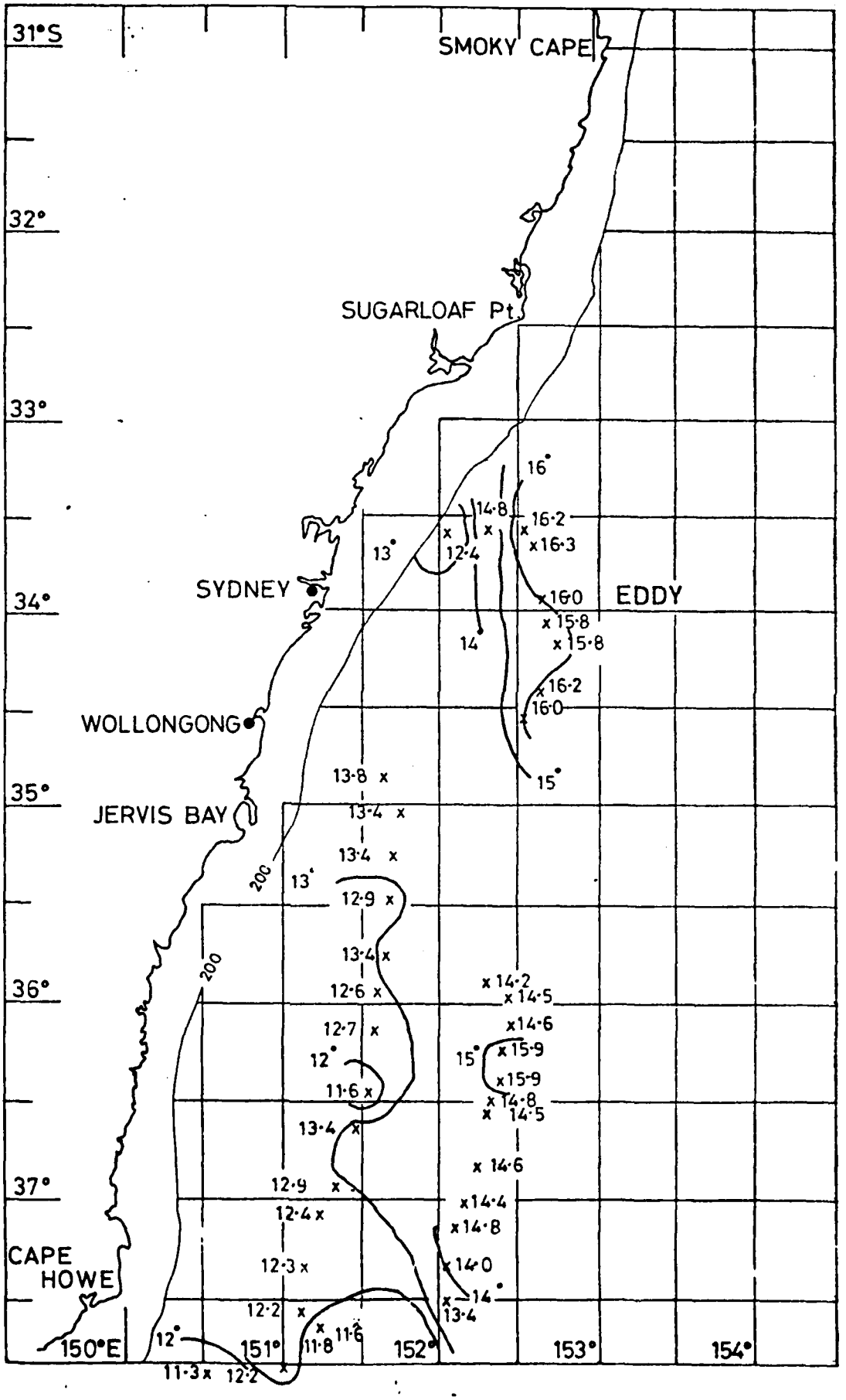

Fig.15. T 250 from Kimbla 14–19 Sept. 81 (°C)

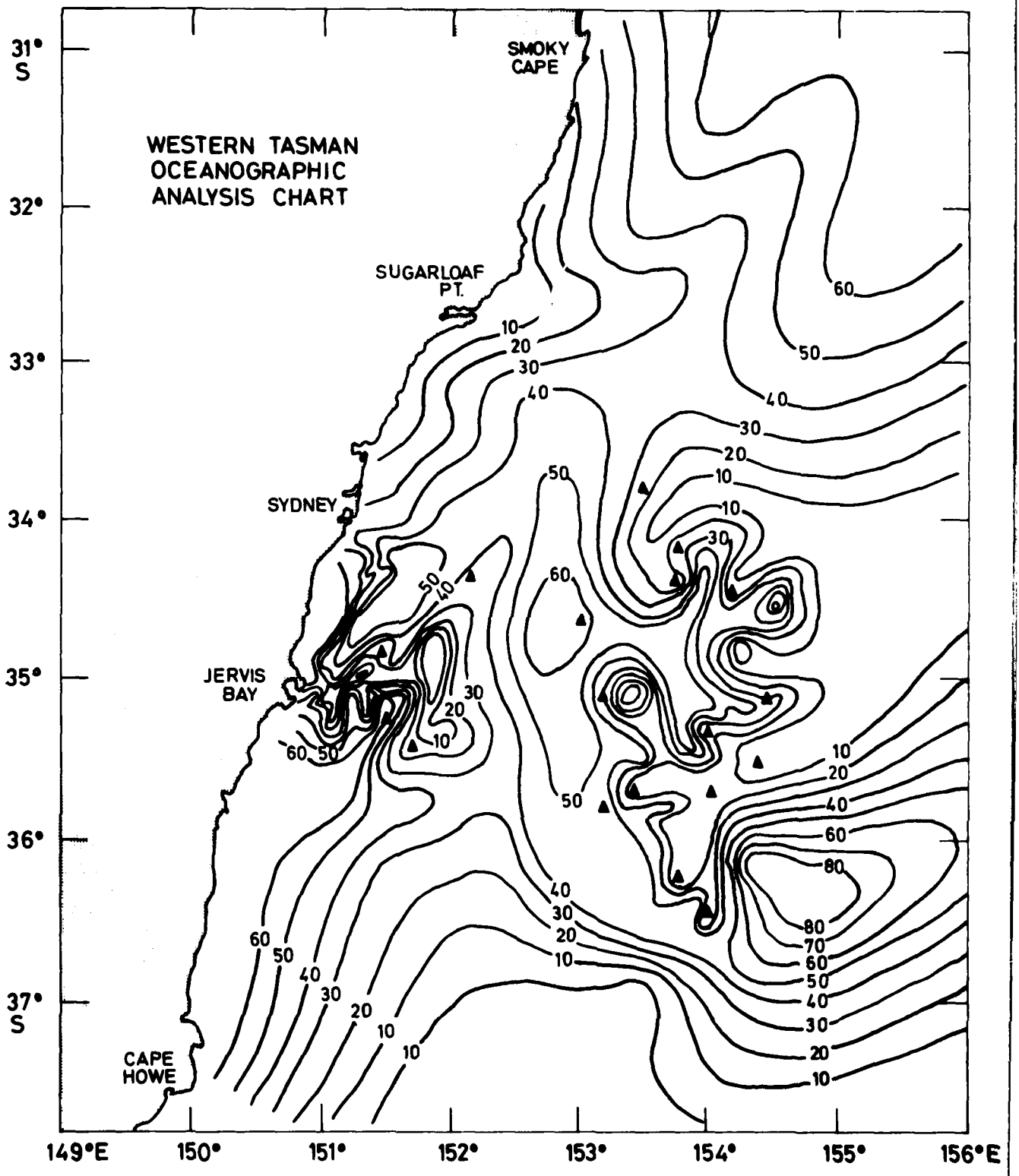

Fig. 16. Mixed-layer depth (metres) 14-21 September 1981 from Nowra.

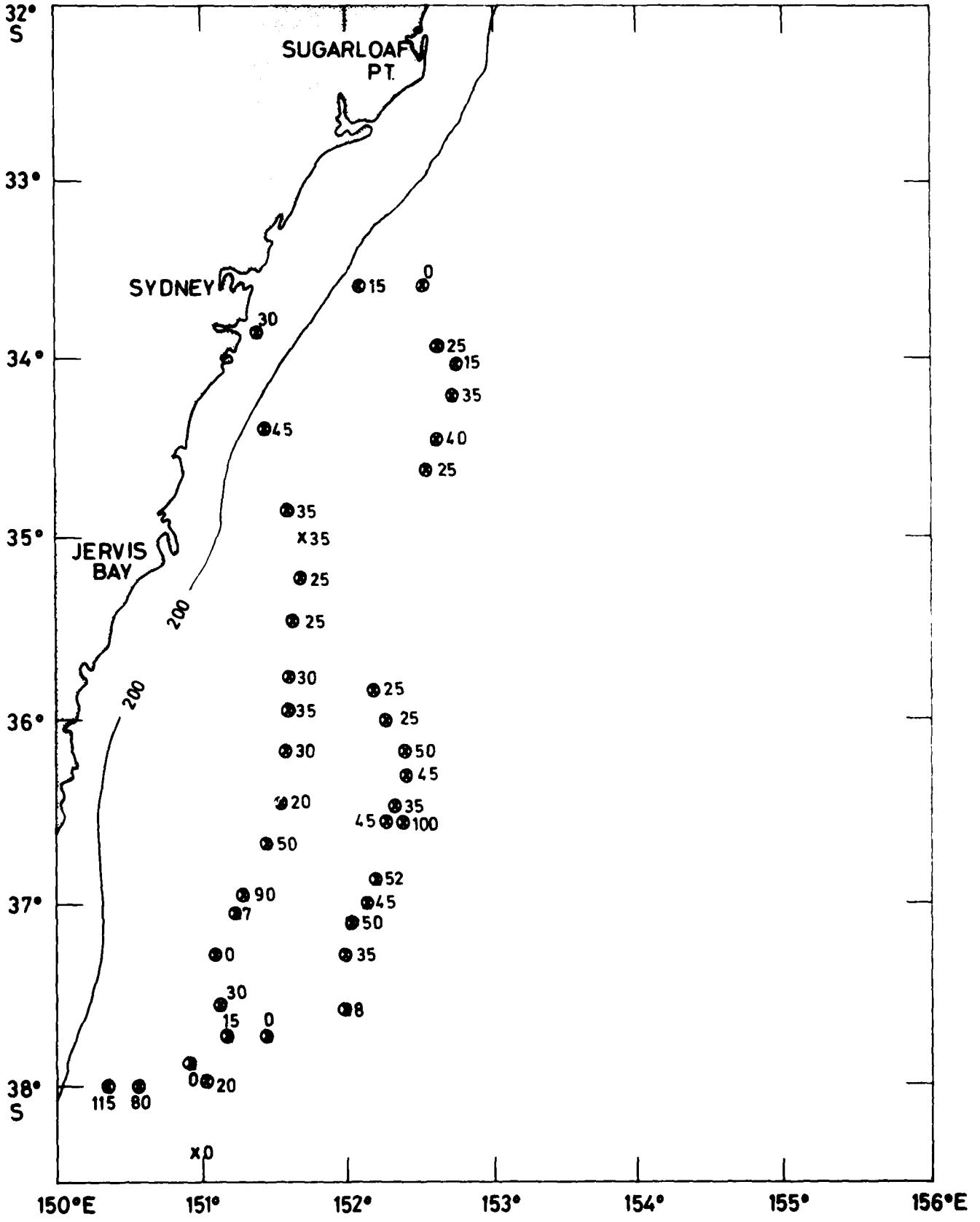

Fig. 17. Mixed-layer depth (metres) 14-18 September 1981 from Kimbla.

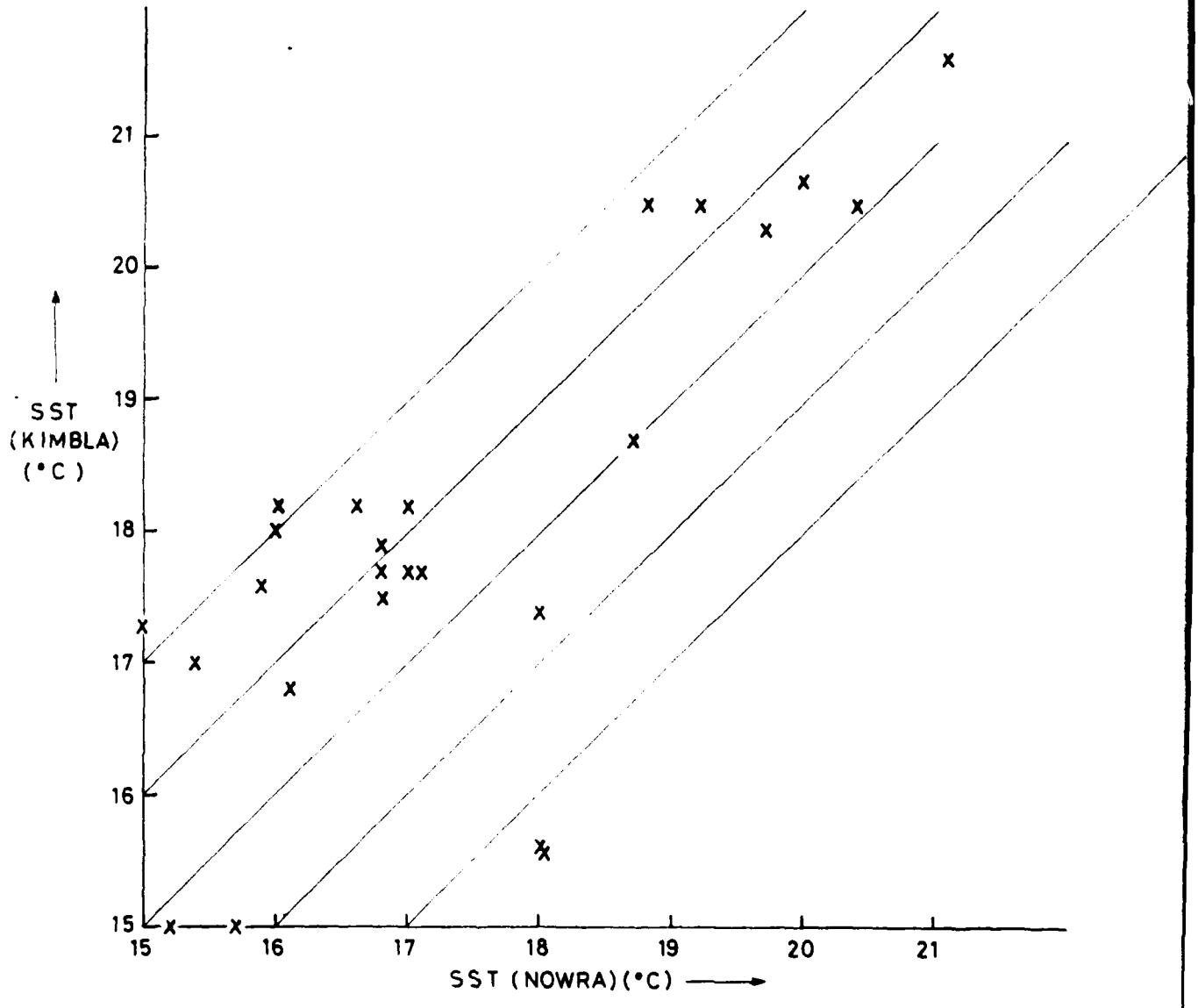

Fig. 18. Comparison of SST from Kimbla and Nowra September 1981.

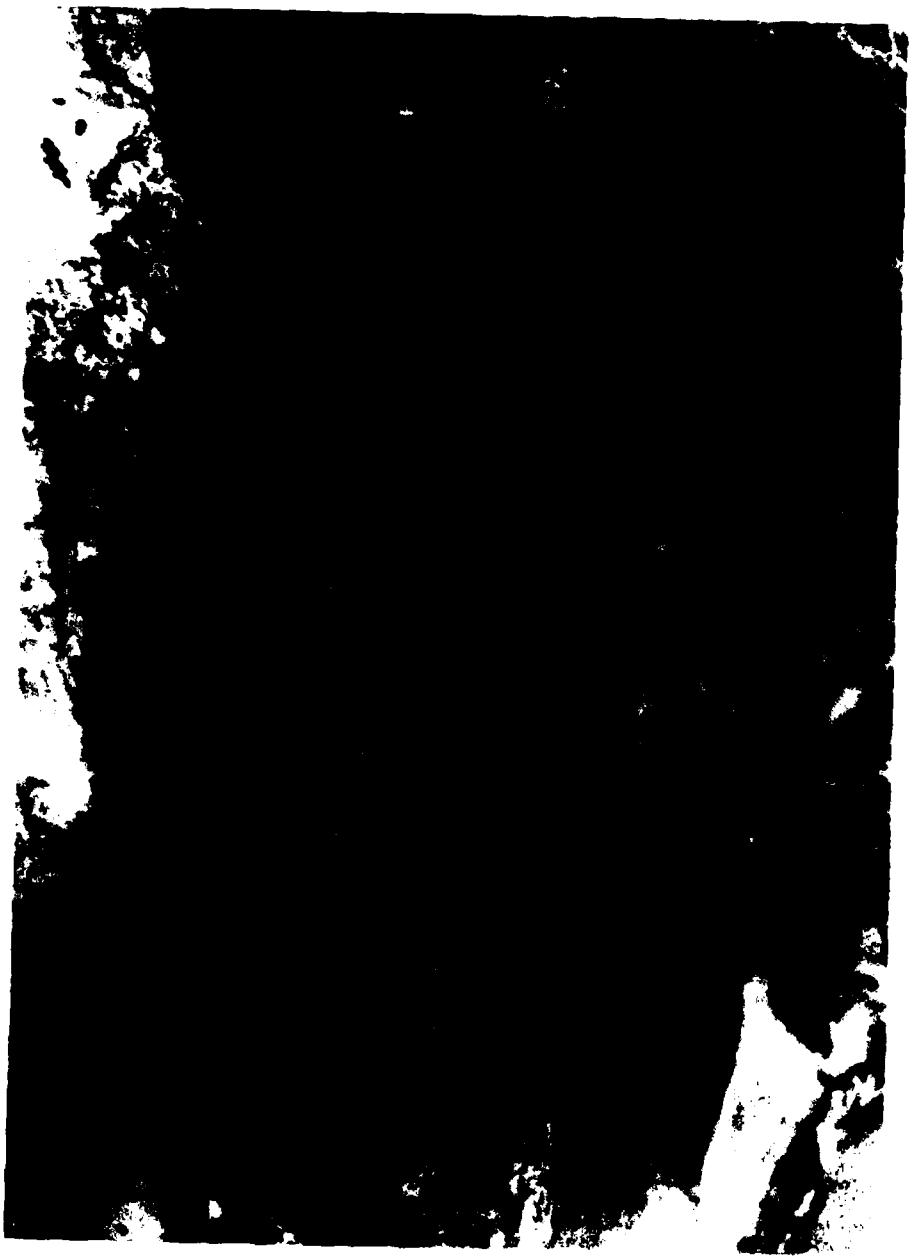

Fig. 19 Infra-red image of 16 September 1981 from the N.O.A.A. - 7 satellite.

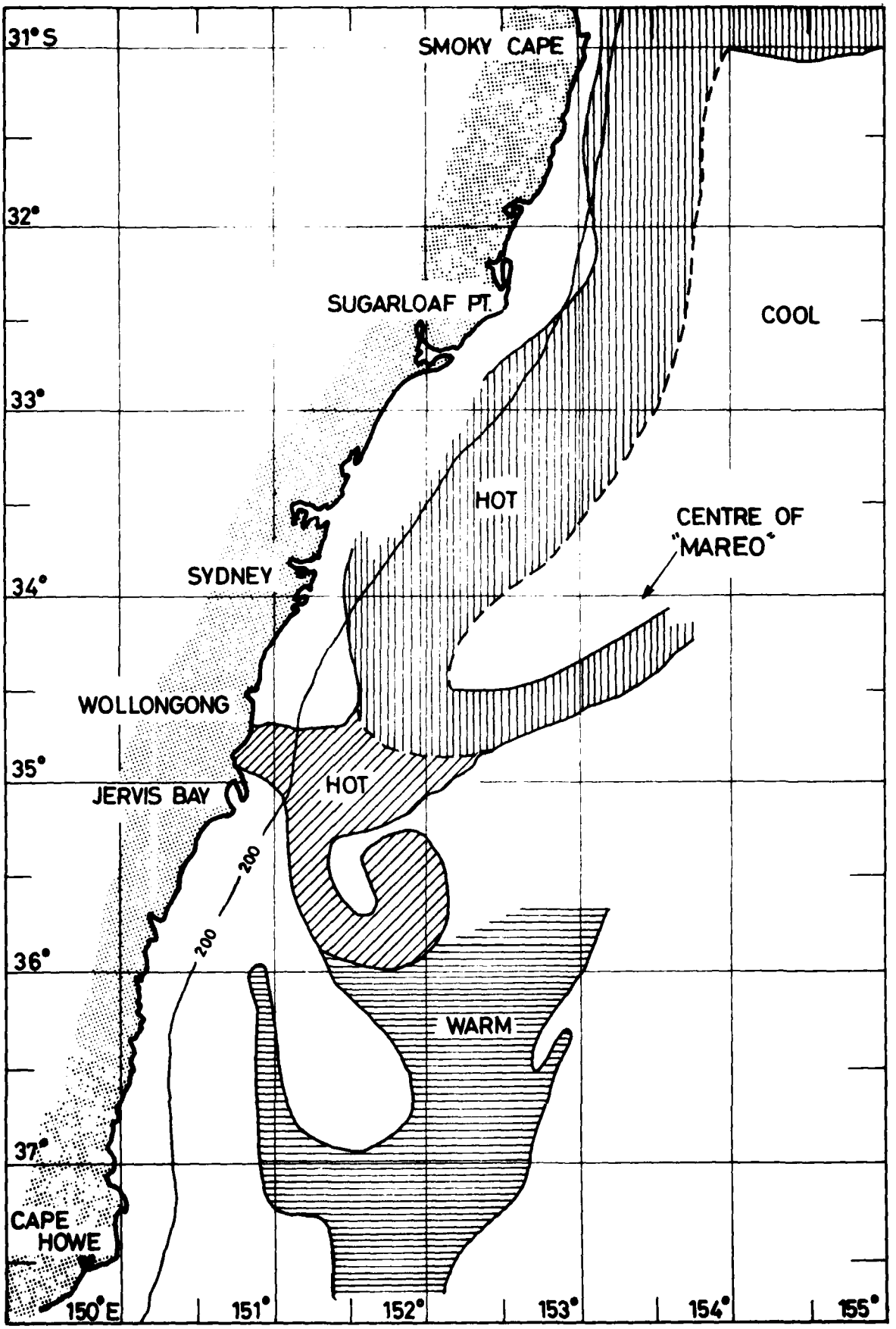

Fig. 20. Main features of i.r. image of 16 September 1981.

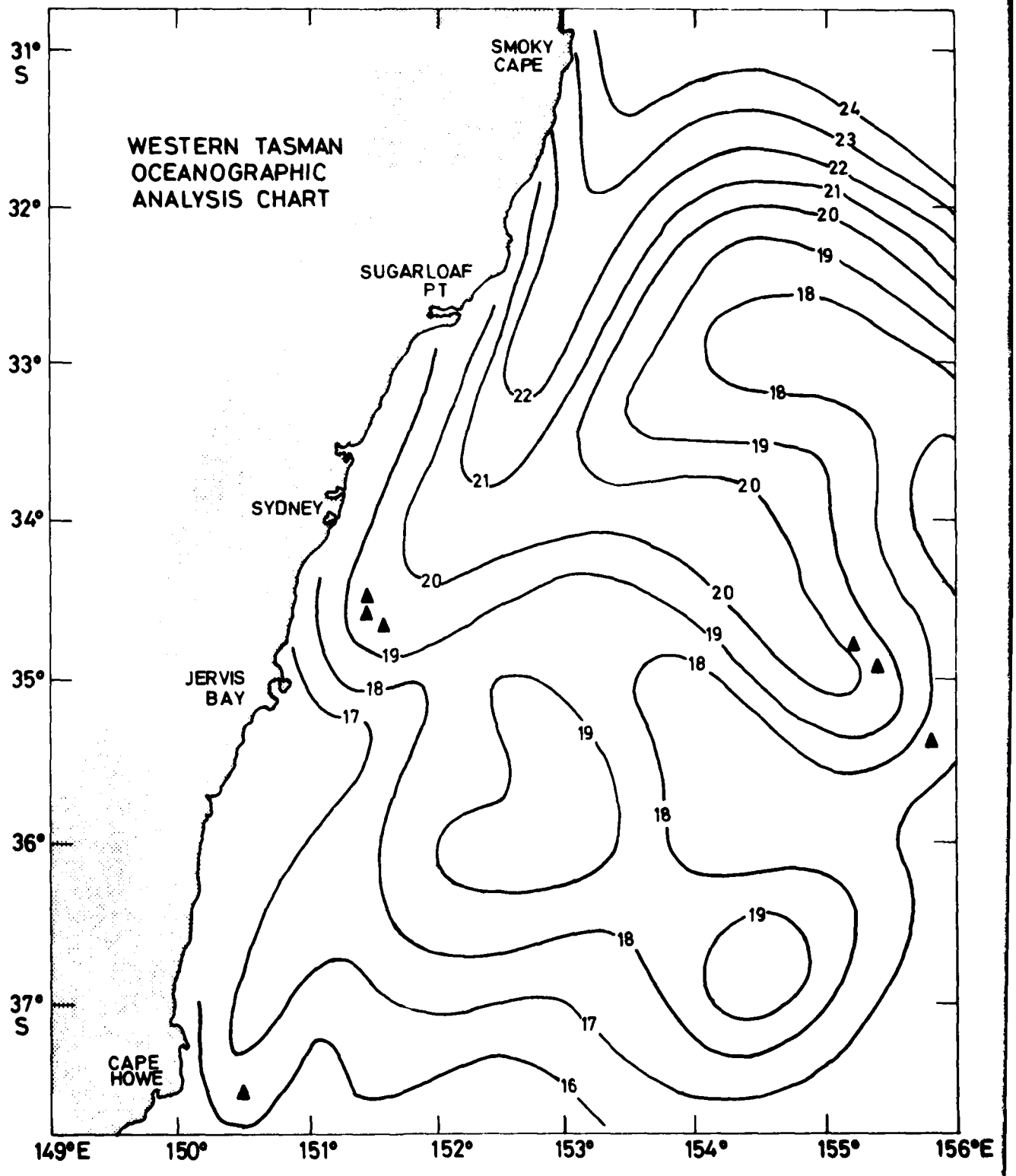

Fig. 21. SST 2-9 Nov. 1981 from Nowra (°C).

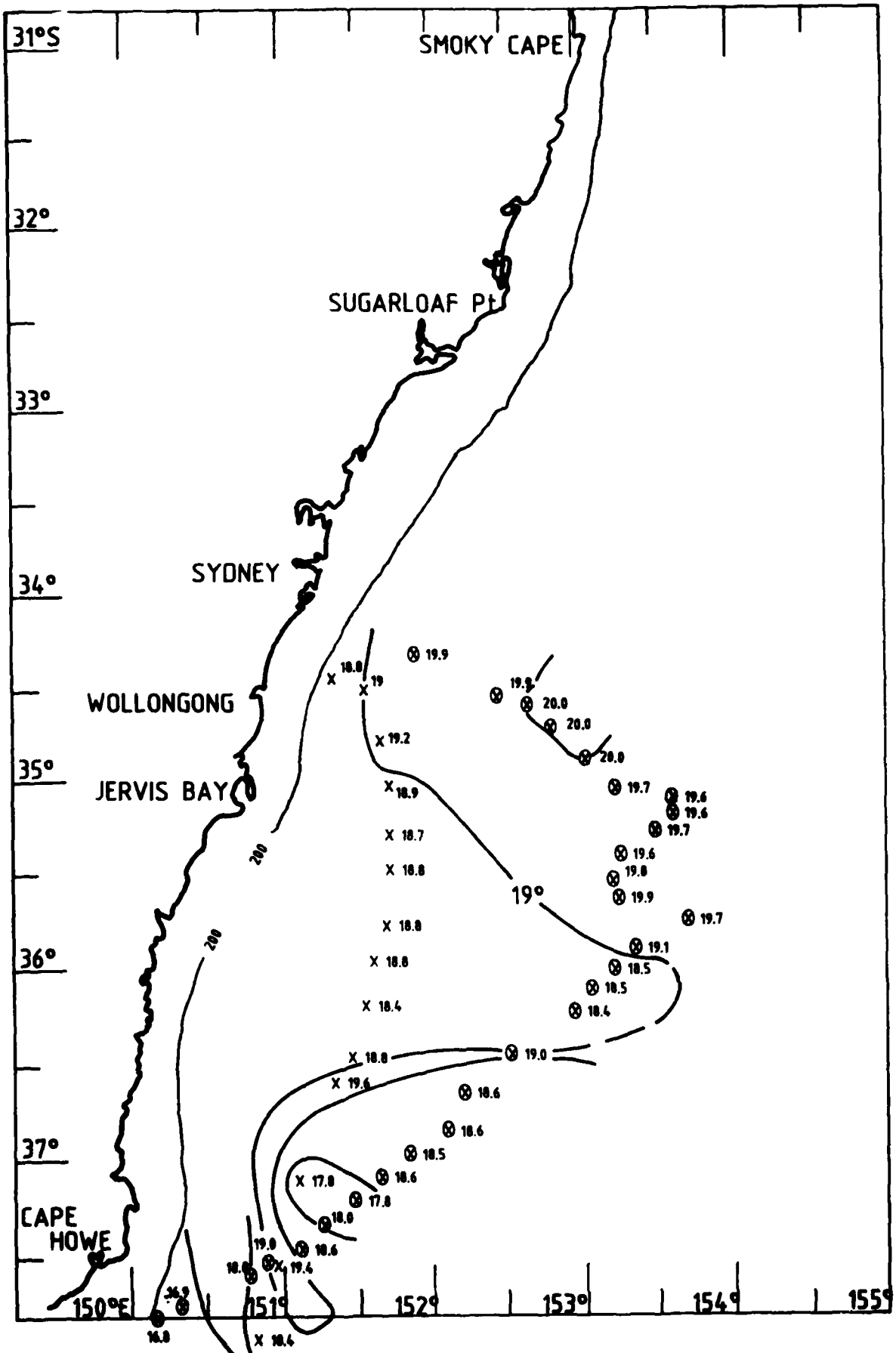

Fig. 22. SST from Kimbla x 28-29 Oct. 81
⊗ 8-10 Nov. 81.

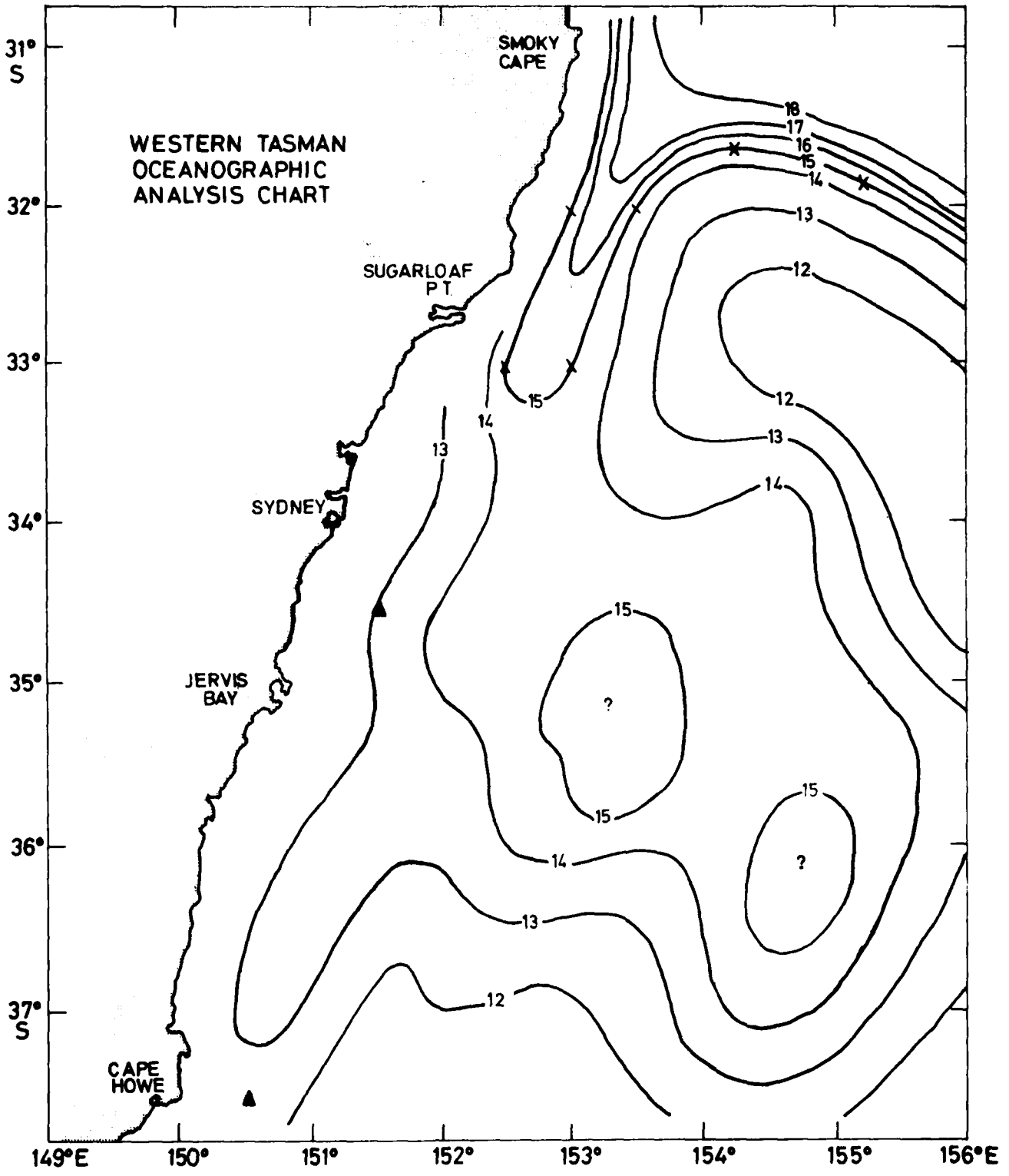

Fig. 23. 250m Temperatures 2-9 Nov. 1981 from Nowra (°C)

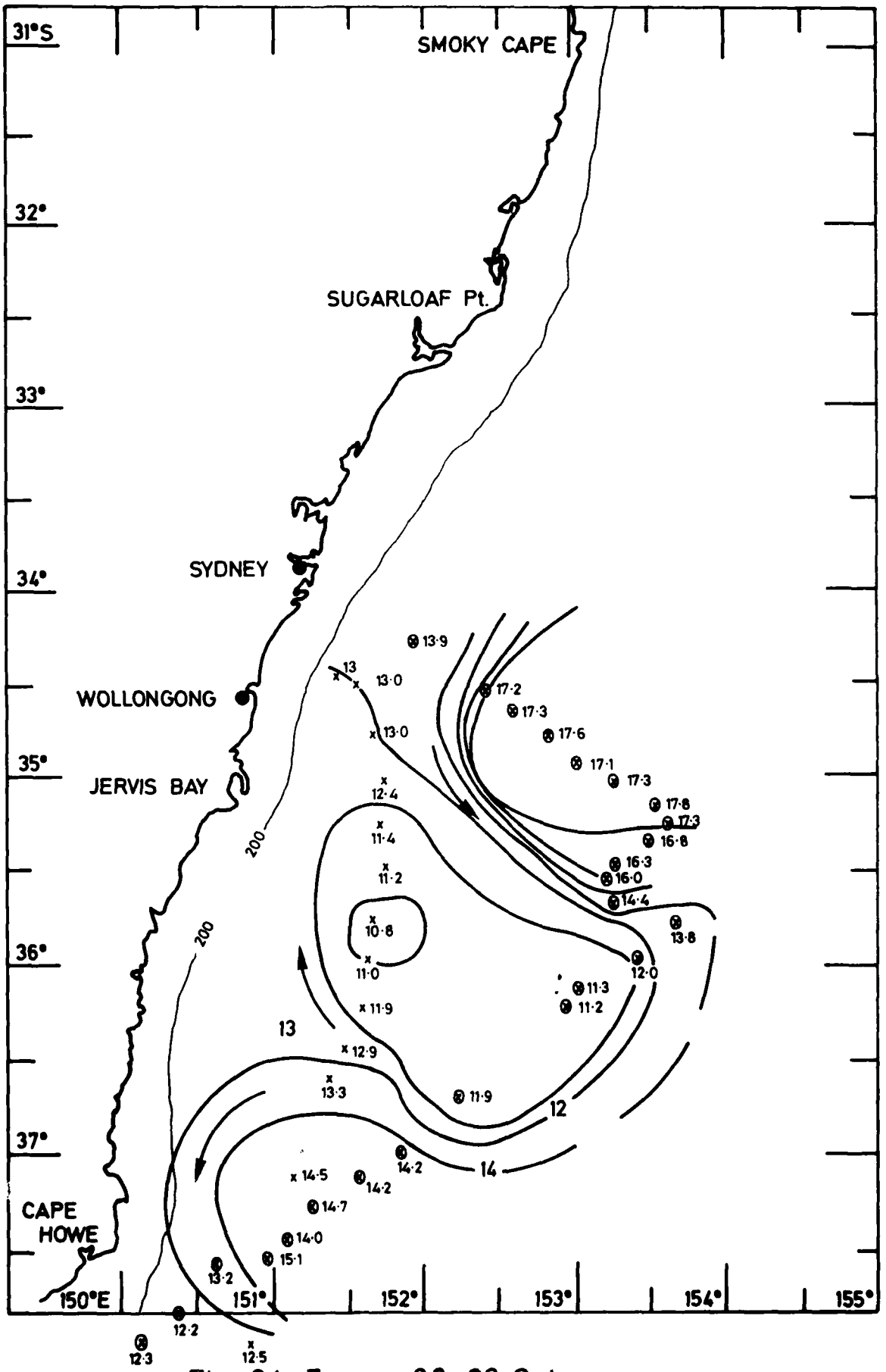

Fig. 24. T_{250} × 28-29 Oct.
● 8-10 Nov.

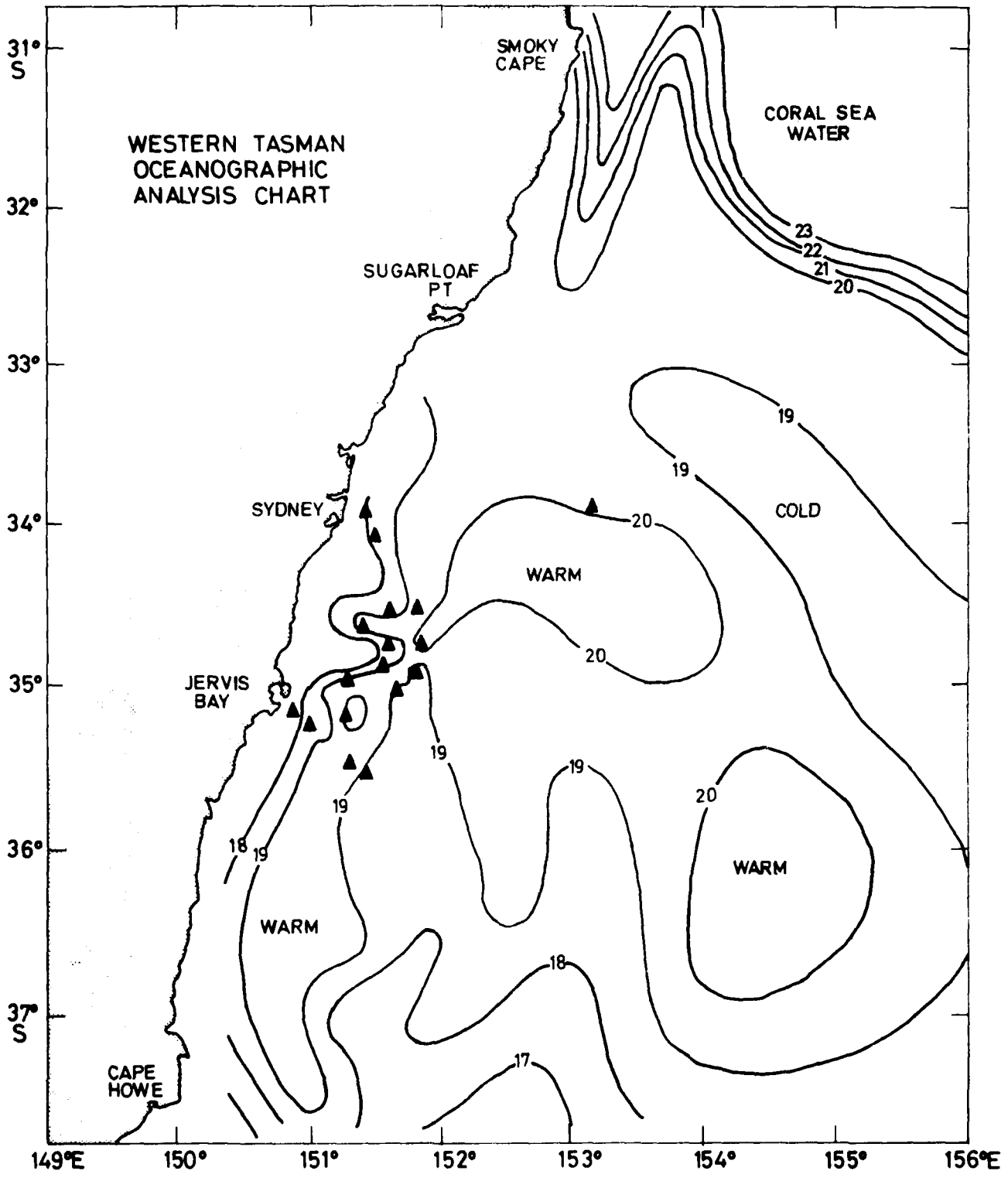

Fig. 25. SST 16-23 Nov. 1981 from Nowra (°C).

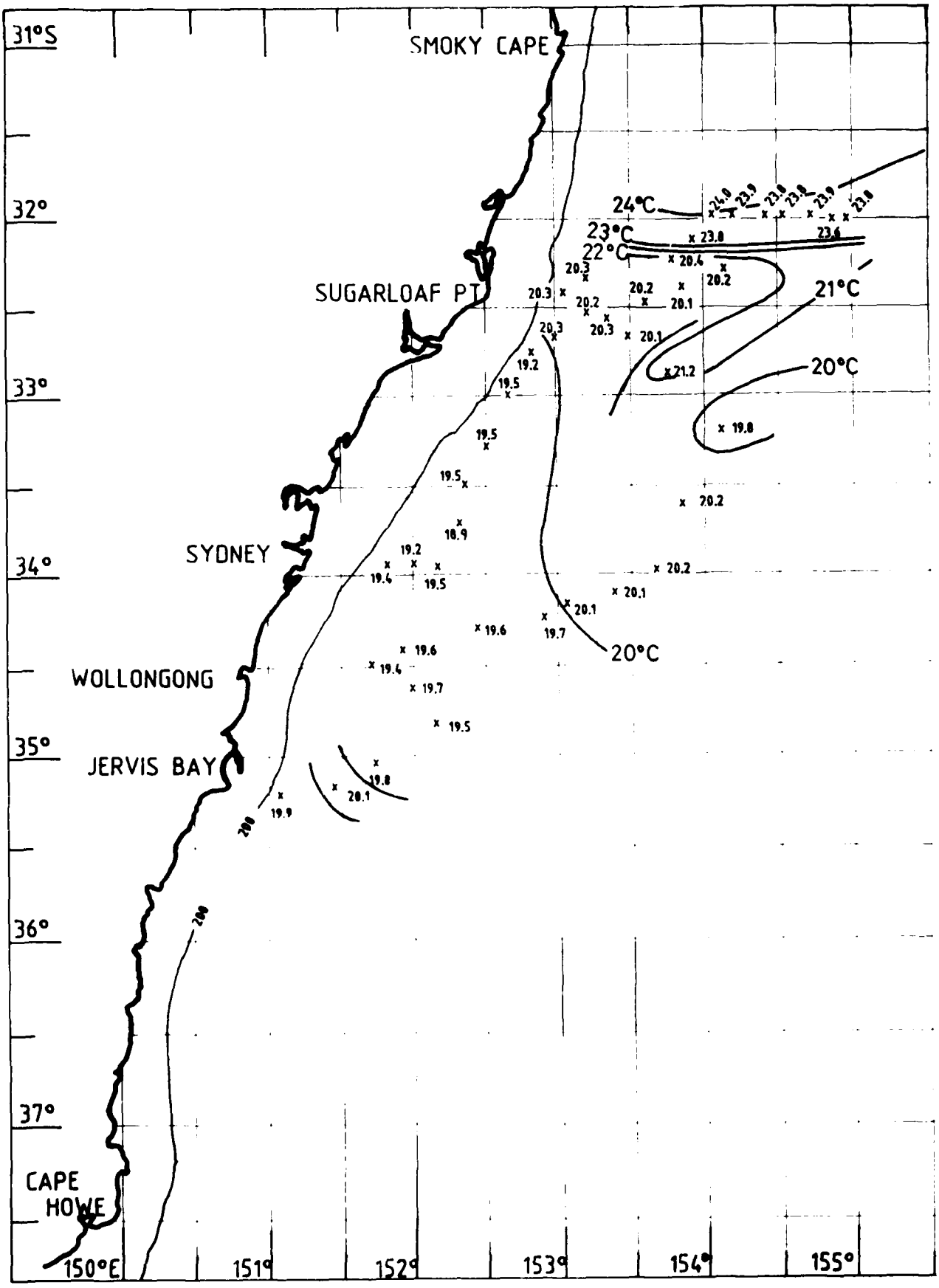

Fig. 26. SST(°C) from Kimbla 16-20 Nov. 81.

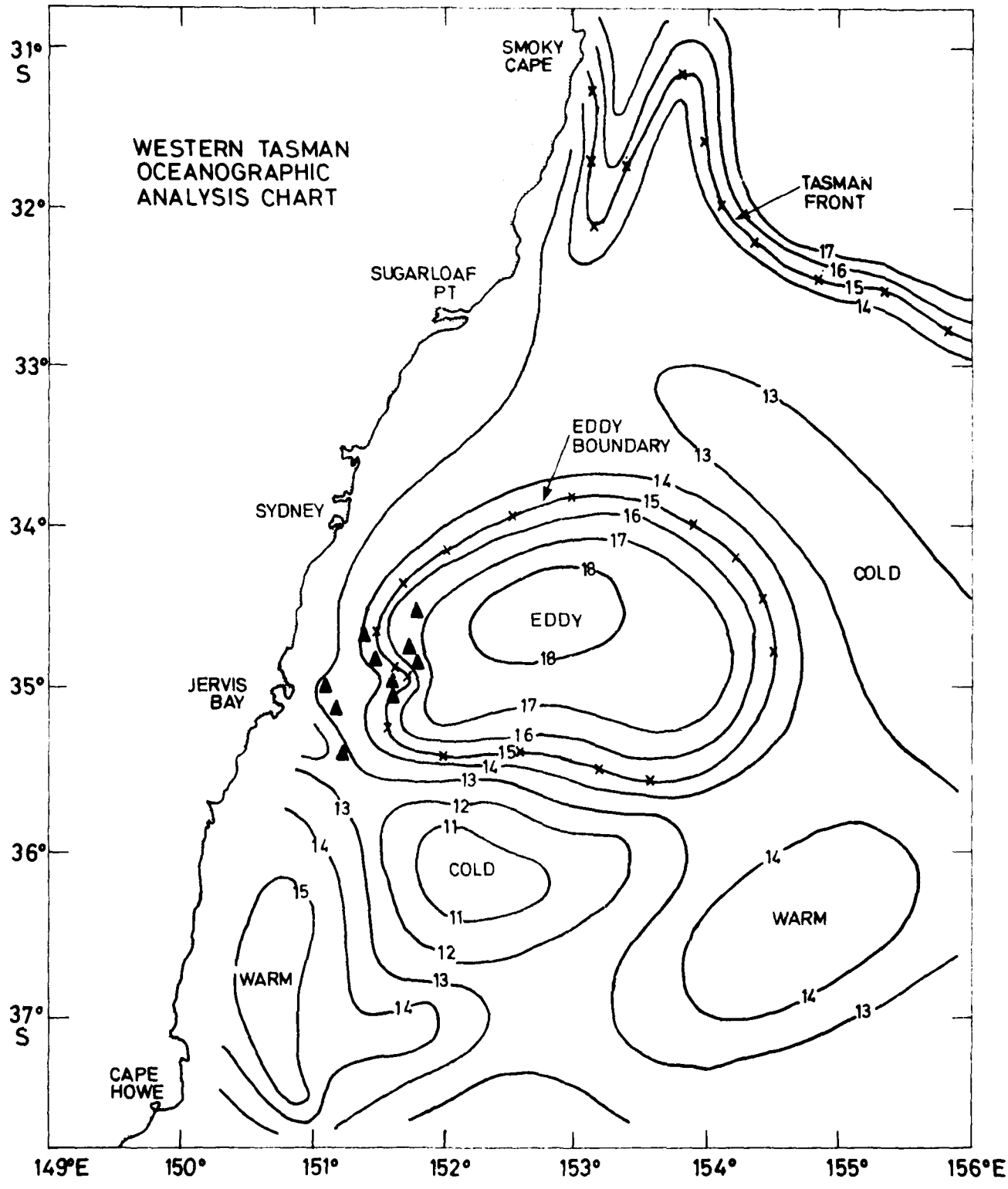

Fig. 27. 250m Isotherm 16-23 Nov. 1981 from Nowra (°C).

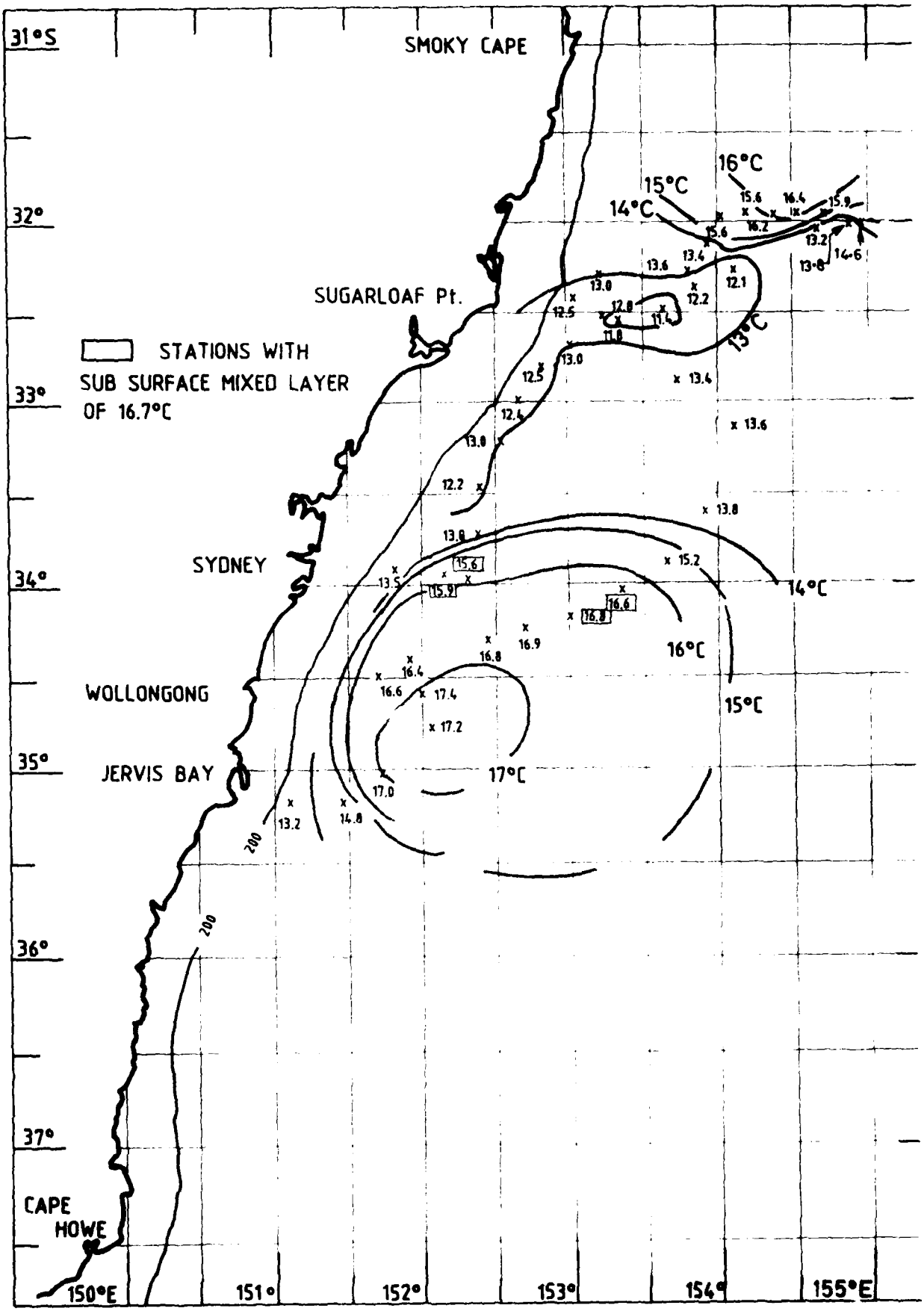

Fig. 28. T_{250} (°C) from Kimbla 16-20 Nov. 81.

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16. Abstract

Comparisons are made between weekly oceanographic analyses prepared by the Naval Air Station, Nowra, and independently obtained data from ship cruises and high resolution infrared satellite imagery. Analyses prepared by Nowra were for sea-surface temperature, temperature at a depth of 250 m, and surface mixed-layer depth. Good agreement was found for the location of warm-core rings, through Nowra's use of satellite-tracked buoys. However the position of the Tasman Front was poorly determined in their analyses, because of the lack of adequate data. Methods of improving analyses and future prospects are discussed.

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