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Storm Sections from Mobile-Ship, Upper-Air Observations

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INTRODUCTION

Recently Winn-Nielsen (1982) discussed the major aspects of the influence of the oceans on the atmosphere with emphasis on the processes of the climate system. He concluded that:

"- an enhanced observational system over the world oceans is needed to satisfy the requirements for reliable analyses and predictions;
- the observational system may, in the future, be obtained through a combination of ships of opportunity, a network of floating buoys, and satellite measurements."

Although not referred to by Winn-Nielsen because of its recent development, a mobile-ship, upper air sounding program may well be a part of that future enhanced observational system. The joint Canadian Atmospheric Environment Service - U.S. National Weather Service - National Center for Atmospheric Research program, entitled the Automated Shipboard Aerological Program (ASAP), is aimed at developing a mobile system, using modern communications, data processing and automated electronics and other capabilities, to obtain upper air meteorological data over the oceans, from ships of opportunity, in a cost effective way. The feasibility studies started in April, 1982 used the MV Friendship, an automobile carrier on the Japan - West Coast North America run, as a trial platform. The system has been described in detail (by Phillips, 1983) and its success to date has justified continuation of the development. The objective of this paper is to demonstrate the quality and usefulness of the data by examining the data on two crossings.

ASAP SYSTEM

The ASAP system consists of a wind-tracking module, an automatic balloon launcher and communications facilities, all in a sea-going container. The wind module makes use of the existing Omega navigation signals to compute successive sonde postions and hence the wind. The sondes, which also measure pressure, temperature, and humidity, are of light-weight design so that a smaller balloon, using less helium and requiring less enclosed space for inflation, can be utilized. The meteorological information is relayed through GOES-W to a land receiving station and hence into the Global Telecommunication System (GTS). It has been now demonstrated that the system can be operated by a single ship's officer without extensive training and further automation is planned.

The number of ascents per voyage is 15-20 and the success rate is over 80%. The quality of the data, as assessed by the meteorologists of the Pacific Weather Centre, Vancouver has been good (Horita, 1982). This opinion is based on a subjective assessment based on their experience in examining North Pacific upper air observations and some intercomparisons with nearby land stations (e.g. Kodiak in the Aleutian Islands). Further, the ASAP ascents are now routinely included in the data assimilation program of the Canadian Meteorological Centre's numerical analysis and prediction system. The ASAP ascents have not been rejected as anomalous.

STORM SECTIONS

The data used are from ascents during the west-bound trip from Portland, Oregon to Chiba, Japan between 21-29 December, 1982 and the return leg from Yokkaichi, Japan to Vancouver, British Columbia between 8-17 January, 1983. On the west-bound leg the MV Friendship travelled generally between 50-55°N and passed through the Aleutian chain while on the eastward leg the track was over the eastern Pacific between 45-50°N. On both voyages ascents were made at 00 and 12 GMT and between 170°W and the North American coast, all were successful. Further west the failure rate was higher due mainly to communications problems. This paper will only deal with the eastern part of the voyages. The locations of the ascents are shown on Figures 1 and 3.

WEST-BOUND CROSSING

On the west-bound crossing the weather pattern was dominated by a low over the eastern Pacific with a trough to a quasi-stationary low over the Aleutians and the Bering Sea. The weather map for 00 GMT 22 December (Figure 1) is typical and the slow northward progression of the low is indicated. The central pressure was lowest at the time of the map. It should be noted that 00 GMT is late afternoon over the Northeast Pacific while 12 GMT is in the middle of the night. Because of ship operating schedules the number of ship weather reports at 00 GMT is much greater than at 12 GMT, and hence, the positioning and central pressures of the low are better determined at 00 GMT.

Normally with a single radiosonde station the data cross section through a storm is determined entirely by storm track. However, in this case the station, the MV Friendship, is also moving. Because the structure of the low-pressure system was relatively constant, it is possible to identify the ship positions relative to the system. The low pressure system was assumed defined by the centre of the low and the orientation of the trough line to the Bering Sea. The apparent ship positions in the coordinate axes fixed to the low pressure system are shown in Figure 1. It can be seen that the ascents at 00 GMT 21 December (the 00/21 ascent), 12/21, 00/22, 12/22, and 00/23 make a cross section through the low centre. The data from these stations is shown in Figure 2, with spacing proportional to the distance from the low centre.

In order to accentuate the differences through the low pressure centre, the heights of pressure surfaces and their temperatures have been considered as relative to the model atmosphere for December at 40°N as tabulated by Houghton (1977). Thermodynamically (Figure 2a) the low appears as larger negative height anomalies (at any given pressure) that slope westward with altitude. The 300 mb low is 2 degrees west of the surface low. Warm temperture anomalies appear on the east side close to the low centre at the surfae and further east aloft due to southerly winds. The moistest areas are also on the east side. The colder air aloft is displaced westward. The wind field, show in Figure 2b, is consistent with the isobaric analyses. The strongest winds are the easterlies just northeast of the low centre. The observations of wind speed and direction are mutually consistent, both horizontally and vertically.

EAST-BOUND CROSSING

The storm structure on the east-bound leg was more complicated. On the 14-15 of January the ship passed a deepening low pressure centre that was moving north northeasterly and was at 56.5°N 150°W at 00 GMT 16 January 1983 (Figure 3). On 16-17 of January a different low centre with associated trough, moving northeasterly, passed over the ship. Thus during the 4 days two low pressure system sections were made as indicated by the relative ship tracks on Figure 3.

The temperatures on Figure 4a show the warm air on the east side and cold air further south on the west side. The temperature difference across the low exceeds 8°C at 800 mb and is nearly 3°C at 500 mb. The winds show the offset of the low centre tilting westward, with a wind speed minimum at 600 mb on the 00/15 sounding.

The section of three profiles in a north-south line through the east side of the low pressure system, including the trough of warm air aloft (TROWAL), is shown in Figure 5 (a and b). There is evidence of warm air aloft on the northern profile with relatively cold air below. The pressure surfaces show little variation between the northern two stations but rise in the south. The wind direction is remarkable for its uniformity (Figure 5b). The wind speeds increase closer to the low with a maximum of 37.2 m/s from the south at 500 mb.

SUMMARY

As indicated earlier, these case studies were examined for two reasons: to allow for some assessment of the data quality and to explore the structure of northeast Pacific storms. The assessment of data quality must be in terms of its consistency both internally and with our understanding of the reasonable structure of storms. In regard to both of these aspects the data from the ASAP upper air ascents appear to be of good quality. Information on the structure of storms was limited by the events that were observed. Through the course of the coming years of ASAP operation it is to be expected that a wider variety of weather types will be experienced. Of particular interest would be the possibility of the ship and weather element travelling together. Then repeated soundings would give an approximately Lagrangian measurement of the evolution of the weather element.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the efforts of the whole ASAP team who have made this program a success.

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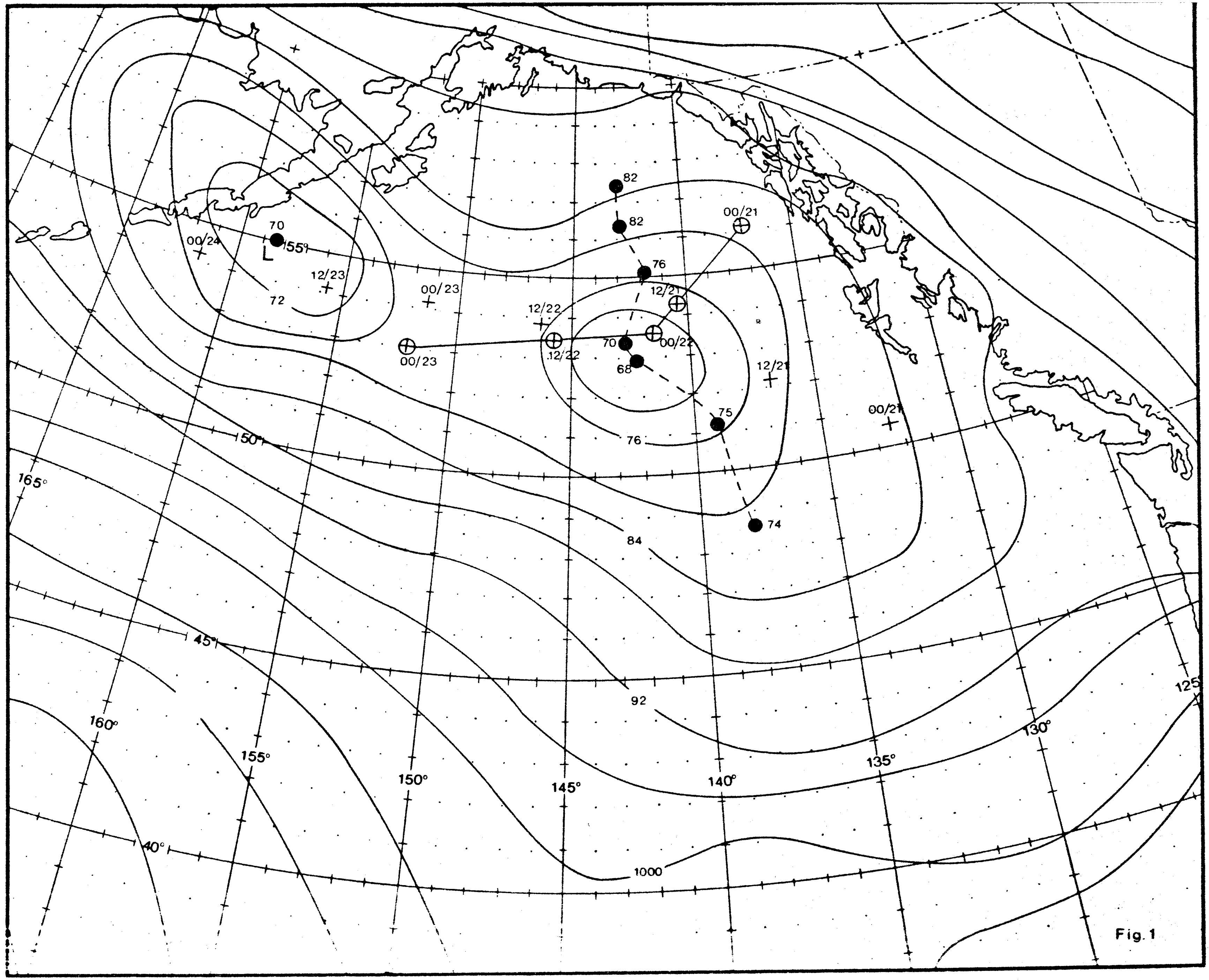

Figure 1. Weather map at 00 GMT, 22 December, 1982. Solid dots show locations of low centre at 12 hour intervals with numbers indicating the pressure. Pluses are ship locations and circled pluses are ships locations relative to low centre and weather pattern.

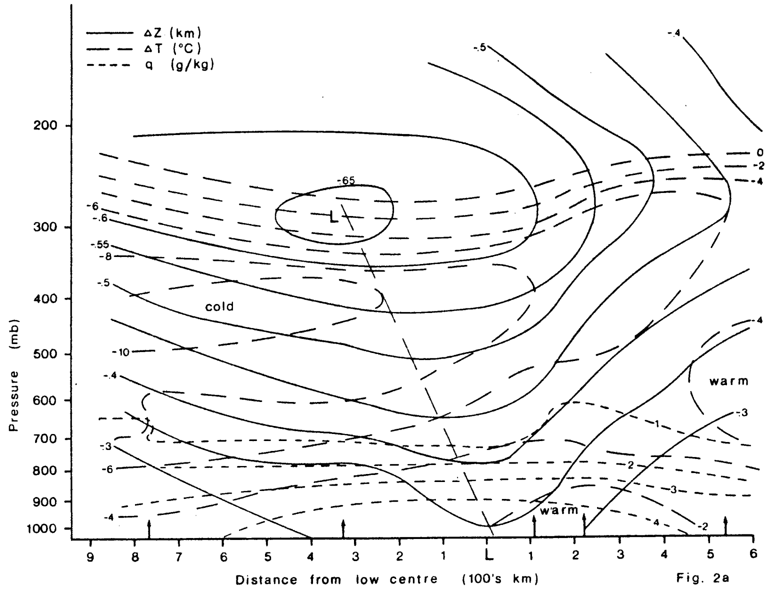

Figure 2a. Thermodynamic cross section through low centre of 22 December, 1982. The height and temperature values are relative to a model atmosphere (Houghton, 1977). The vertical arrows are locations of ascents used in the analysis. The sloping dashed line is along the maximum negative height anomalies.

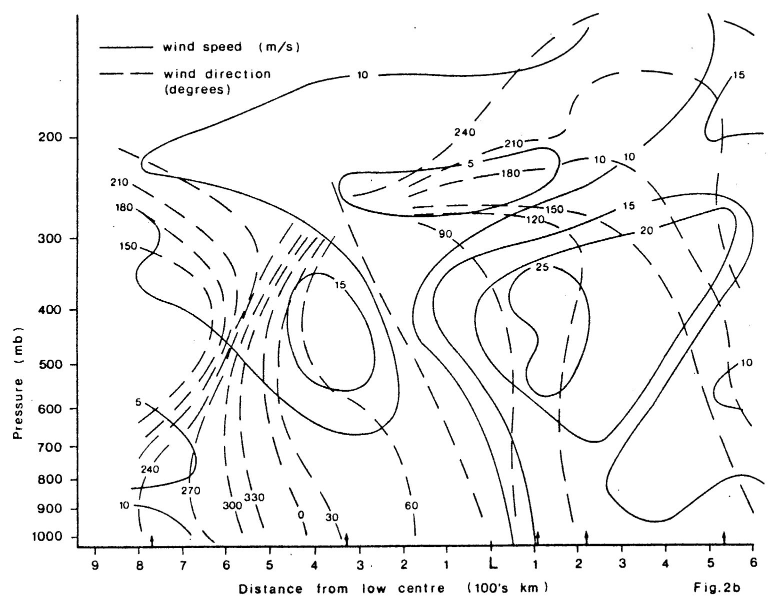

Figure 2b. Wind cross section through low centre of 22 December, 1982. The vertical arrows are locations of ascents used in the analysis. The sloping dashed line from L is along the maximum negative height anomalies.

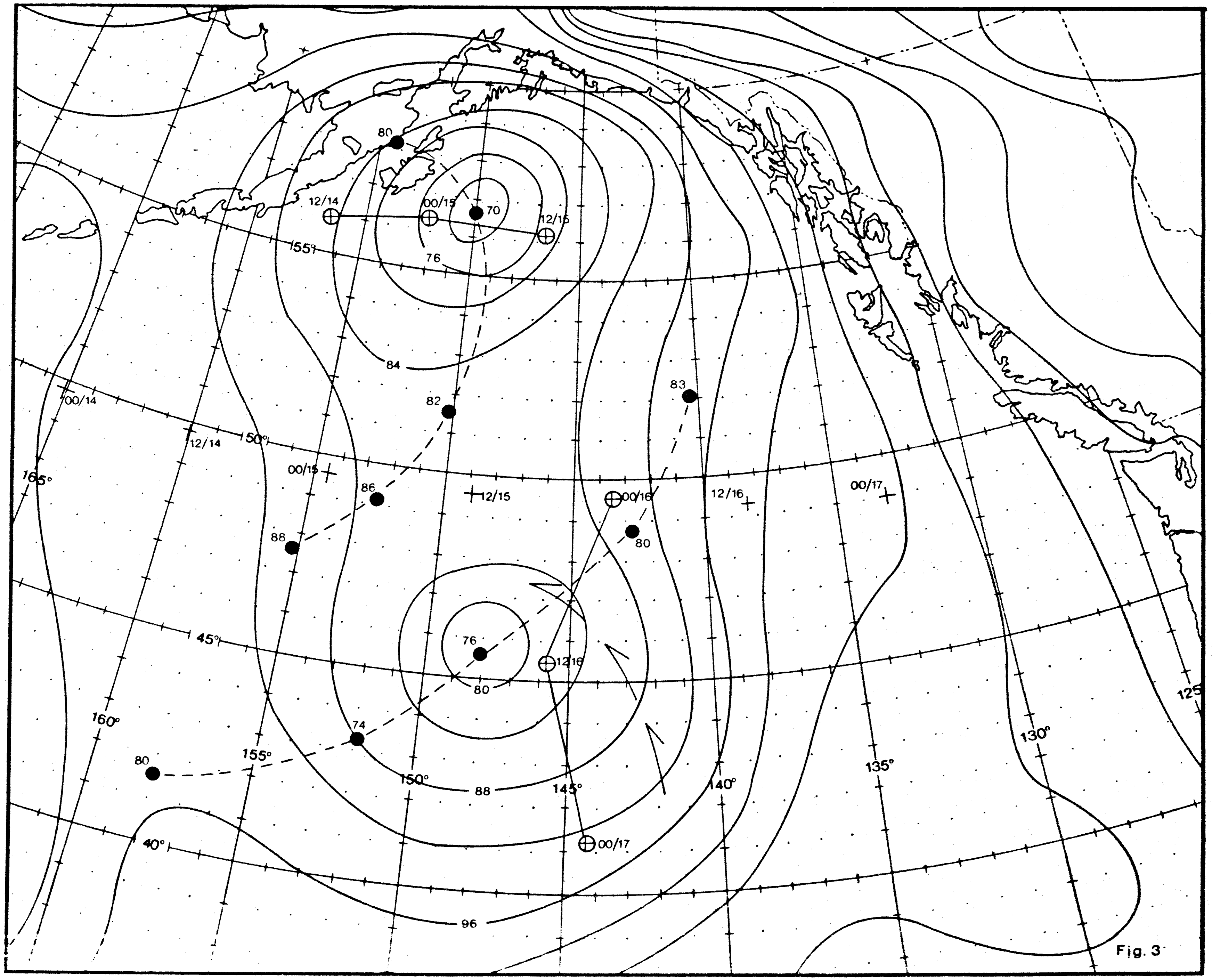

Figure 3. Weather map of 00 GMT, 16 January, 1983. The symbols indicate low centre positions (solid dots); ship positions (pluses) and relative ship positions (circled pluses).

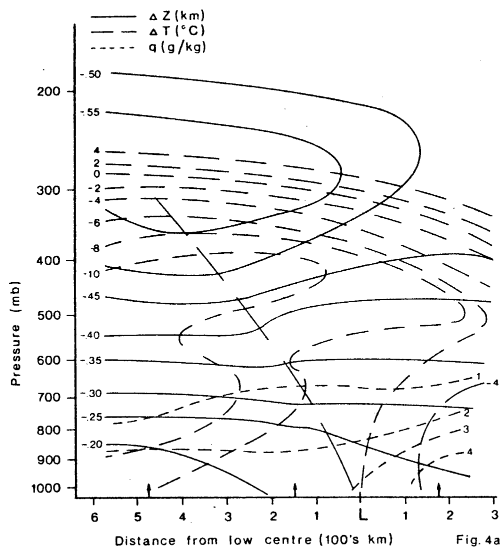

Figure 4a. Thermodynamic cross section through low centre (near 57 N) on 16 January, 1983 (see Figure 2a for details).

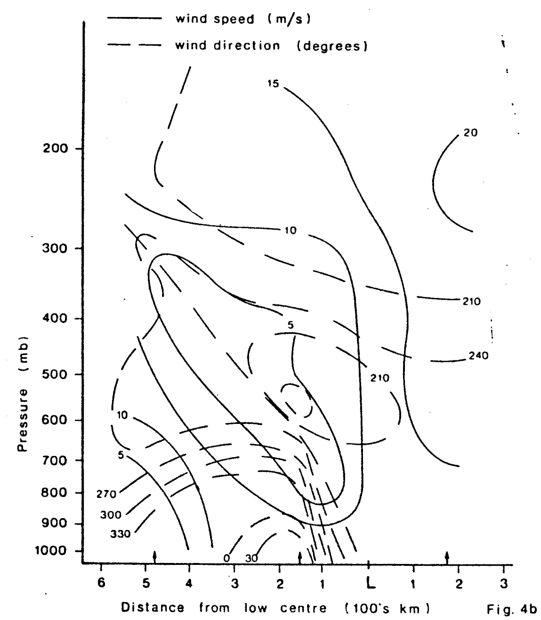

Figure 4b. Wind cross section through low centre (near 57 N) on 16 January 1983 (see Figure 2b for details).

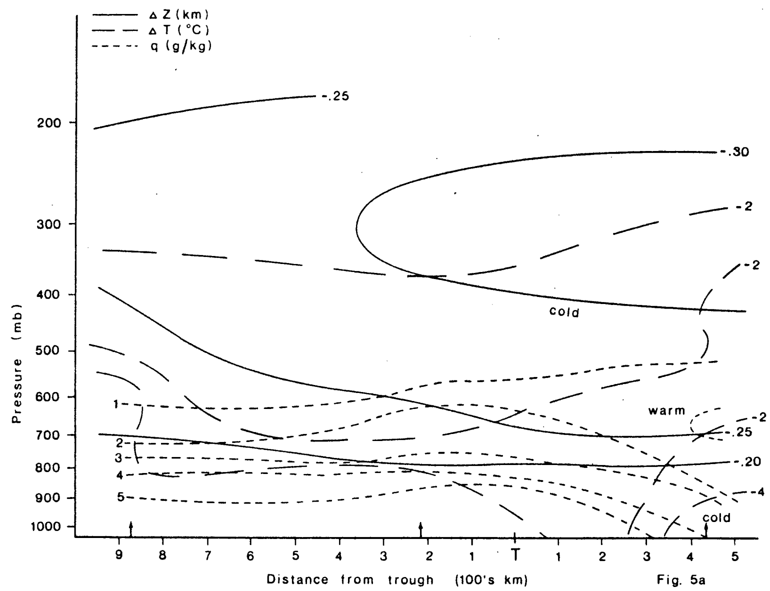

Figure 5a. Thermodynamic cross section through low (near 45 N) of 16 January, 1983. (See Figure 2a for details).

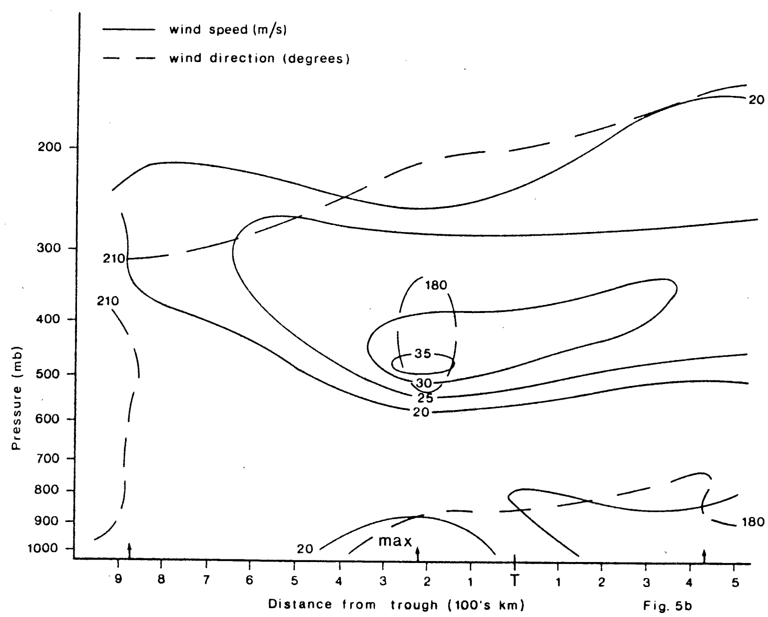

Figure 5b. Wind cross section through low (near 45 N) of 16 January, 1983. (See Figure 2b for details).