Antarctic 150 mb Pressure Maps from TWERLE and Radiosondes (November 1975–March 1976)[1]

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ABSTRACT

Daily 150 mb maps south of 45°S were prepared for the period 16 November 1975–16 March 1976, using the extensive coverage of the TWERLE balloons in that area, in addition to the sparse radiosonde network. A sample of one daily map for each month, and five monthly average maps are given to demonstrate the technique and the potential information in the TWERLE data.

1. Introduction

A total of 411 TWERLE balloons (TWERLE Team, 1977) were launched in the Southern Hemisphere during the second half of 1975. These superpressure balloons float at a nominal density level of 0.252 kg m^{-3}, which over Antarctica corresponds to ~12.5 km. Each balloon carries three sensors: radar altimeter, ambient pressure and temperature. As long as the balloon's solar panel is sufficiently illuminated, the balloon transmits the information of the three sensors, once a minute. The transmissions are received by the Nimbus 6 satellite, whenever the satellite is within sight of the balloon. When the satellite subtrack passes within a few degrees from the balloon (overhead pass), the satellite is within sight of the balloon for about 20 min, out of which 15 transmissions, 1 min apart, were recorded. Non-overhead passes (slanted pass) can be seen for a shorter period. Four-minute passes were the shortest used. The balloon radio frequency is received by the satellite shifted by the Doppler effect. The change in the Doppler shift along the pass is used to calculate the balloon's position. Two consecutive passes yield the wind. This was done at NASA using an algorithm which processed the two-pass data simultaneously, and not by differing the positions and dividing by the time interval between the passes. The differing scheme was used when the NASA algorithm was not utilized, e.g., to calculate wind from two non-consecutive passes. Due to the near-polar orbit of Nimbus 6, the number of passes per day increases from 2 to 3 for a balloon near the equator, to 13 or 14, i.e., all the passes, near the pole. Consecutive passes are ~105 min apart.

During November 1975–March 1976, in addition to the continuous coverage by the satellite of near-polar balloons, two more factors contributed to the large amount of TWERLE data near Antarctica. These are the 24 h per day illumination of the solar panels and the high concentration of balloons in the area. From mid-November 1975 to mid-March 1976, there were 3–7 times as many TWERLE balloons south of 45°S as there were radiosonde reports. This

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increased density of 150 mb data enables more accurate 150 mb maps, than maps based on radiosondes only.

2. Data analysis

Each TWERLE balloon was analyzed to yield readiosonde-like information, namely, wind velocity and direction and the altitude of the 150 mb level in geopotential meters (gpm), as close as possible to 1200 GMT. Since the balloons float near, but not exactly at 150 mb, the hydrostatic equation was used to obtain the altitude of the 150 mb, as given by

$$Z(150) = (P + P_{\rm corr} - 150)(0.2T + 53.7) + (15\cos^2\phi - 75) + h. \quad (1)$$

Here $Z(150)$ is the altitude of the 150 mb-surface (gpm), P the pressure sensor reading (mb), $P_{\rm corr}$ a known calibrating correction of each pressure sensor (mb), T the temperature sensor reading (°C), h the altimeter reading (m), and ϕ the latitude. The first term on the right hand side is the hydrostatic correction (using a linear approximation). The second term is the conversion from the altitude in meters to the altitude in geopotential meters.

P, T and h used in (1) were the average of the up to 15 readings of the selected pass, after removing readings which were oustide 1.25σ. Typical rms values of the remaining data were 0.2 mb, 0.2°C and 12 m, respectively. Typically, 1–3 out of 15 readings were taken out before the final average was calculated. It should be pointed out that part of the rms values indicated above were not random sensor noise but true balloon motion (e.g., neutral buoyancy oscillations). There is strong correlation between P and h. Thus, the rms in $Z(150)$ is considerably less than 15 gpm, which is obtained when no correlation is assumed.

Typically, the balloons near Antarctica floated 0.5 km below 150 mb. The ambient pressure spread from 152 to 172 mb due mainly to the spread in latitude and in the time of year. Therefore, it was permissible to use the temperature at the balloon level as the average temperature of the layer to 150 mb. It also justified assigning the wind at the balloon level to the 150 mb level.

There were several criteria for checking the sensor's readings, the position and the wind. If all were met for the pass closest to 1200 GMT, then this pass was chosen. If not, the next closest pass was checked, etc. Thus, most data are within 105 min of 1200 GMT. In balloons over land or in balloons which had a broken altimeter or pressure sensor, only wind data were used. In balloons with a broken temperature sensor, a fixed −50°C temperature was used in Eq. (1). The worst case error due to a broken tem-

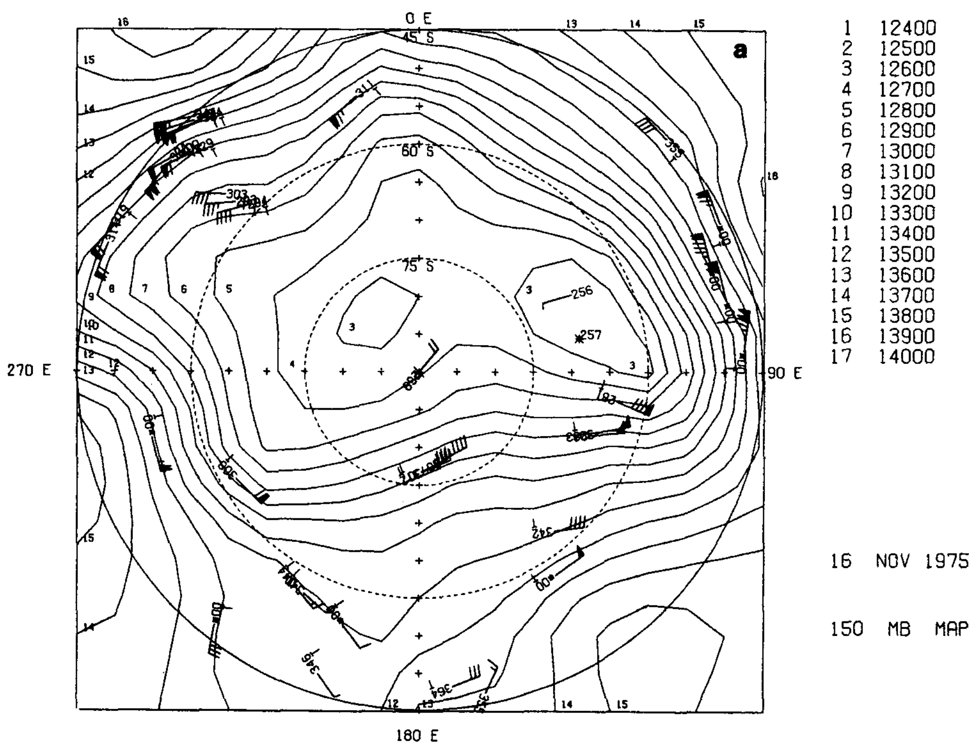

FIG. 1. Daily 150 mb maps (1200 GMT) for (a) 16 November, 1975, (b) 16 December 1975, (c) 16 January 1976, (d) 16 February 1976 and (e) 16 March 1976.

perature sensor would be 45 m. About 10% of the balloons had a broken temperature sensor.

1200 GMT data were not available for balloons in a narrow section on both sides of 180°E longitude, north of 70°S. In the rare cases when the only available data were more than 6 h off 1200 GMT, then balloons east of 180°E were allowed data only before GMT noon and balloons west of 180°E were allowed

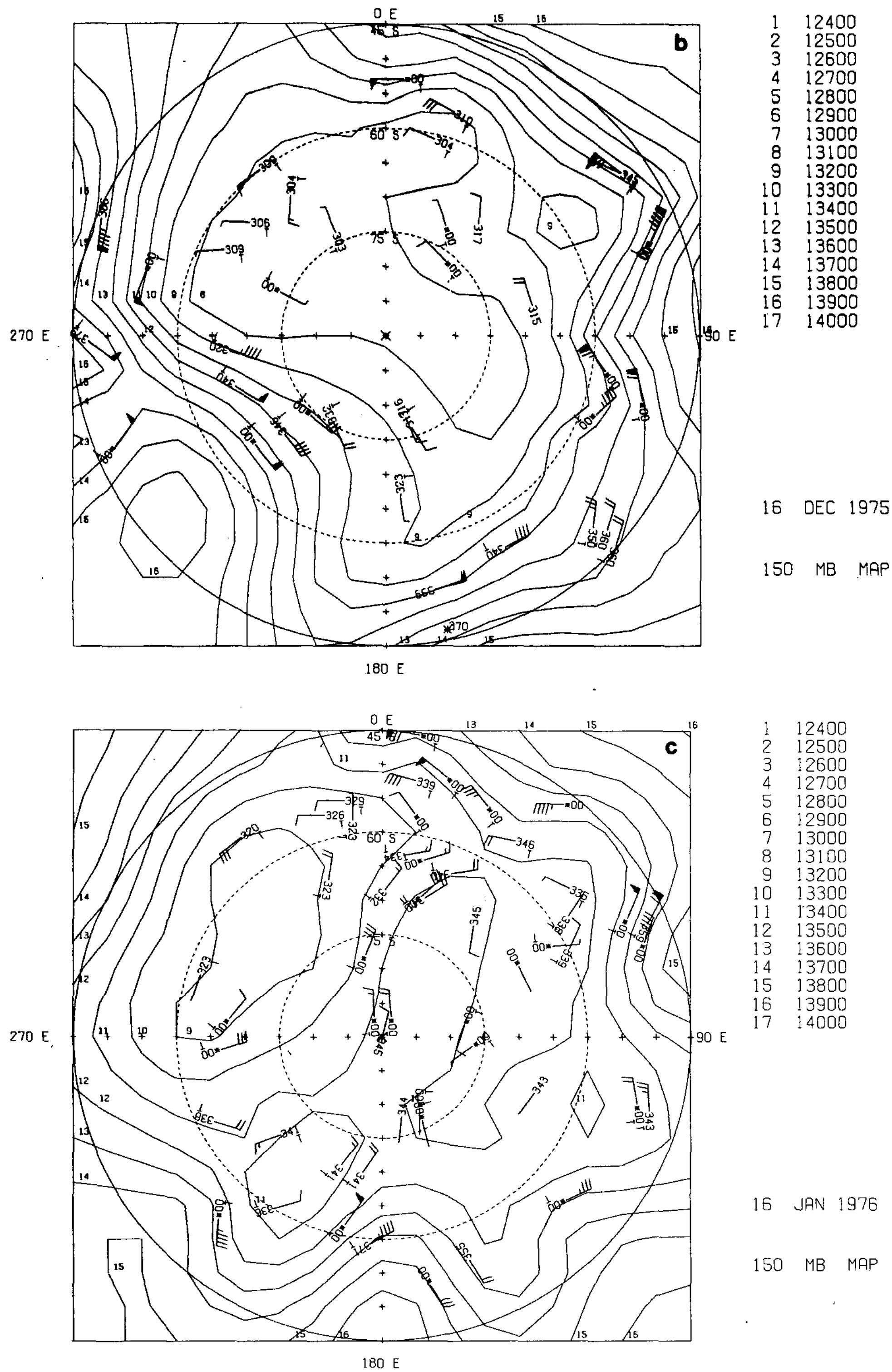

FIG. 1. (*Continued*)

data only after 1200 GMT. This was done to prevent two points, close in space, from being assigned data separated in time, unless the points are on opposite sides of the 180° meridian.

Once the TWERLE balloons had the data format of the radiosonde data at 150 mb, they were added to the 1200 GMT radiosonde stations. Only balloons and radiosonde stations south of 45°S were used in

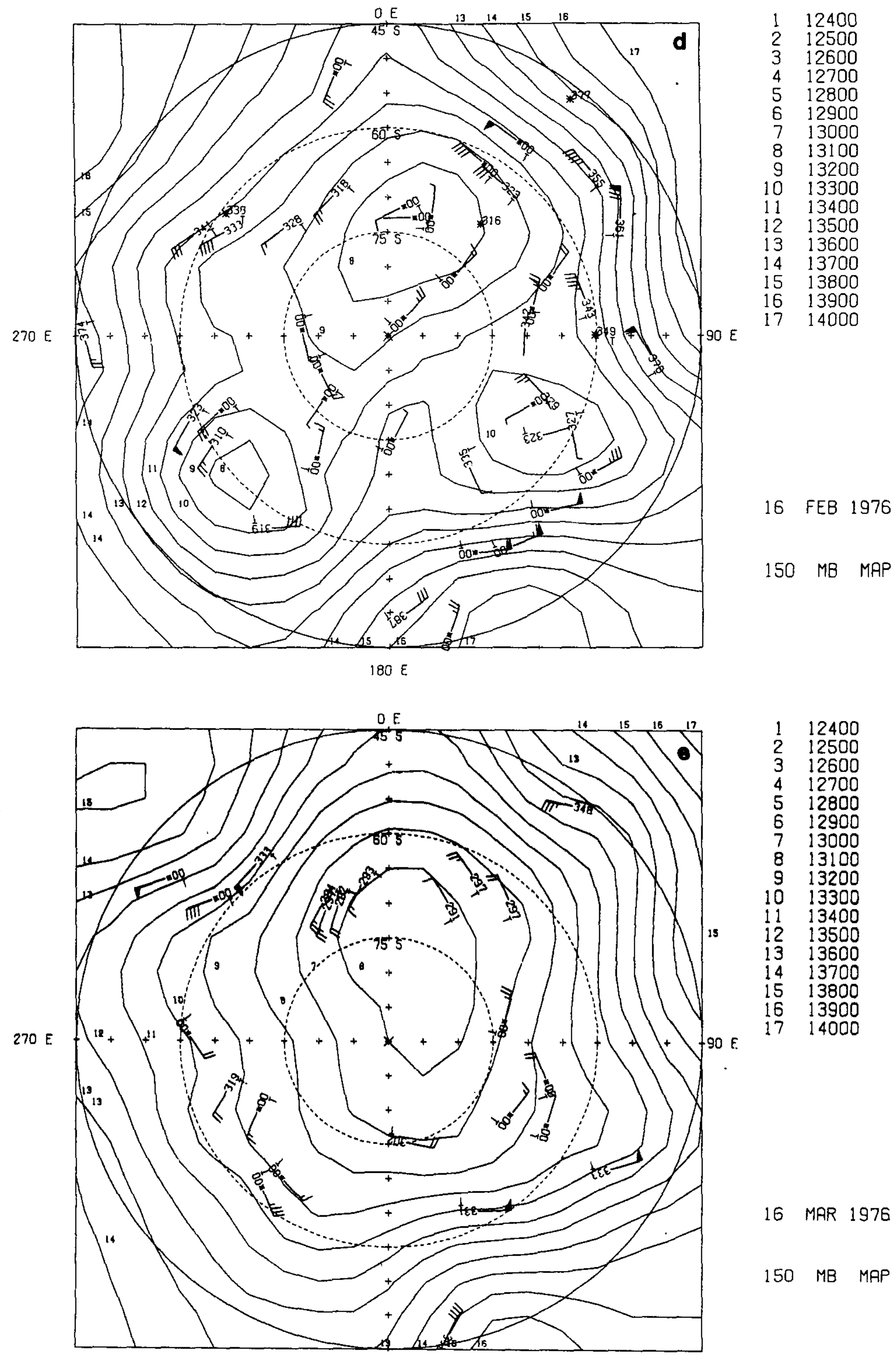

FIG. 1. (*Continued*)

the objective analysis. The objective analysis utilized the Cressman (1959) technique with only minor modifications. The 1200 GMT results of the previous day were used as the initial condition for an intermediate map of 0000 GMT, in which only 0000 GMT radiosonde reports were used. The 0000 GMT intermediate map was used in order not to lose overland radiosonde reports if they happen to appear only at 0000 GMT. On the other hand, to add 0000 GMT TWERLE data would double the amount

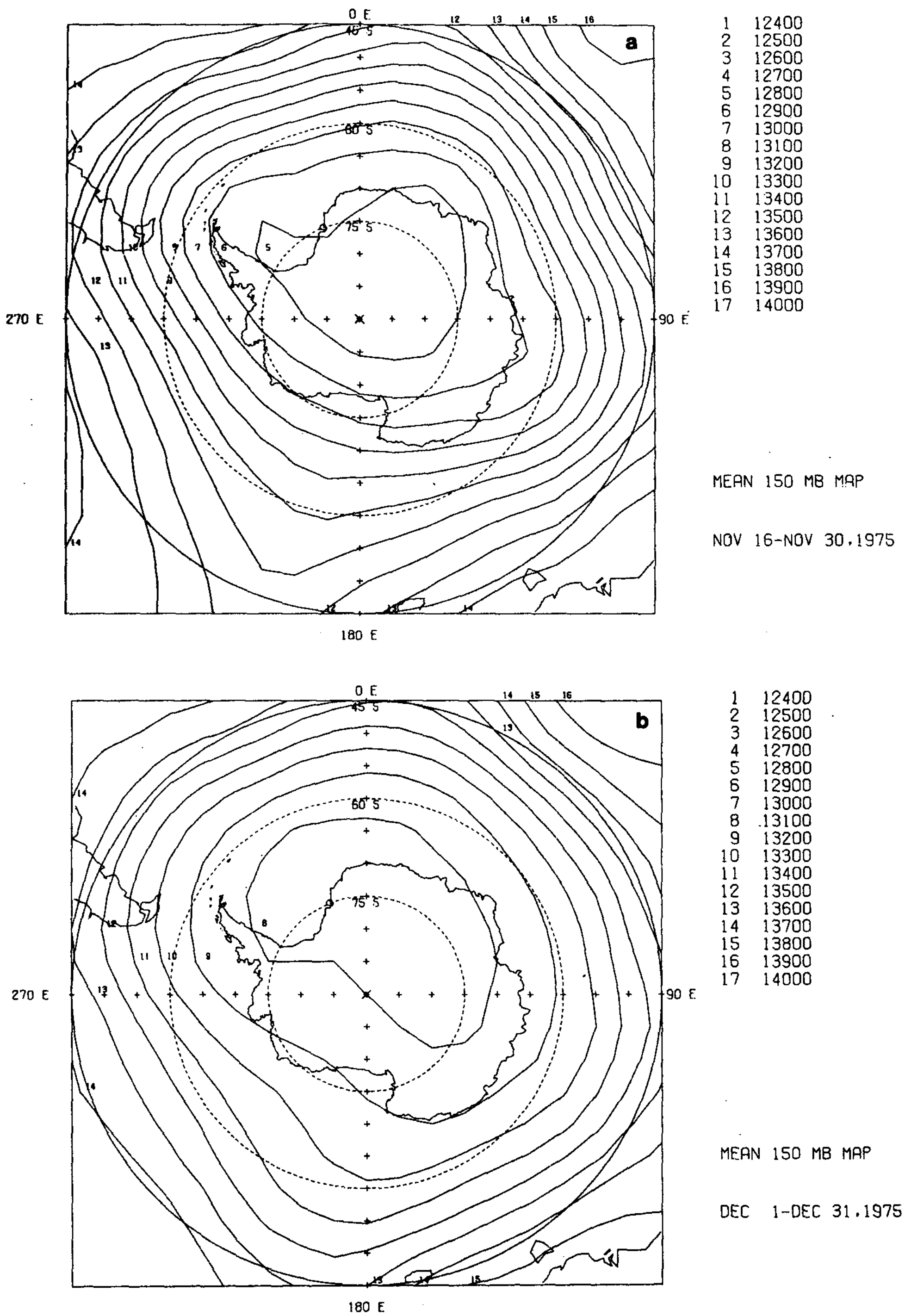

FIG. 2. Average 150 mb maps (1200 GMT) for (a) 16–30 November 1975, (b) 1–31 December 1975, (c) 1–31 January 1976, (d) 1–29 February 1976 and (e) 1–16 March 1976.

of work. The radiosondes-only 0000 GMT intermediate map is a reasonable compromise.

The intermediate map served as the initial condition for the 1200 GMT map, where both TWERLE and 1200 GMT radiosondes were used for the objective analysis and are also plotted on the contour map. The grid points are a net of squares parallel to the 270–90°E line (and to the 0–180°E line). Each square side is 5° latitude long.

In addition to the careful computer check of the TWERLE data, the first run of each map is manually checked. This run includes plotting all the balloon's

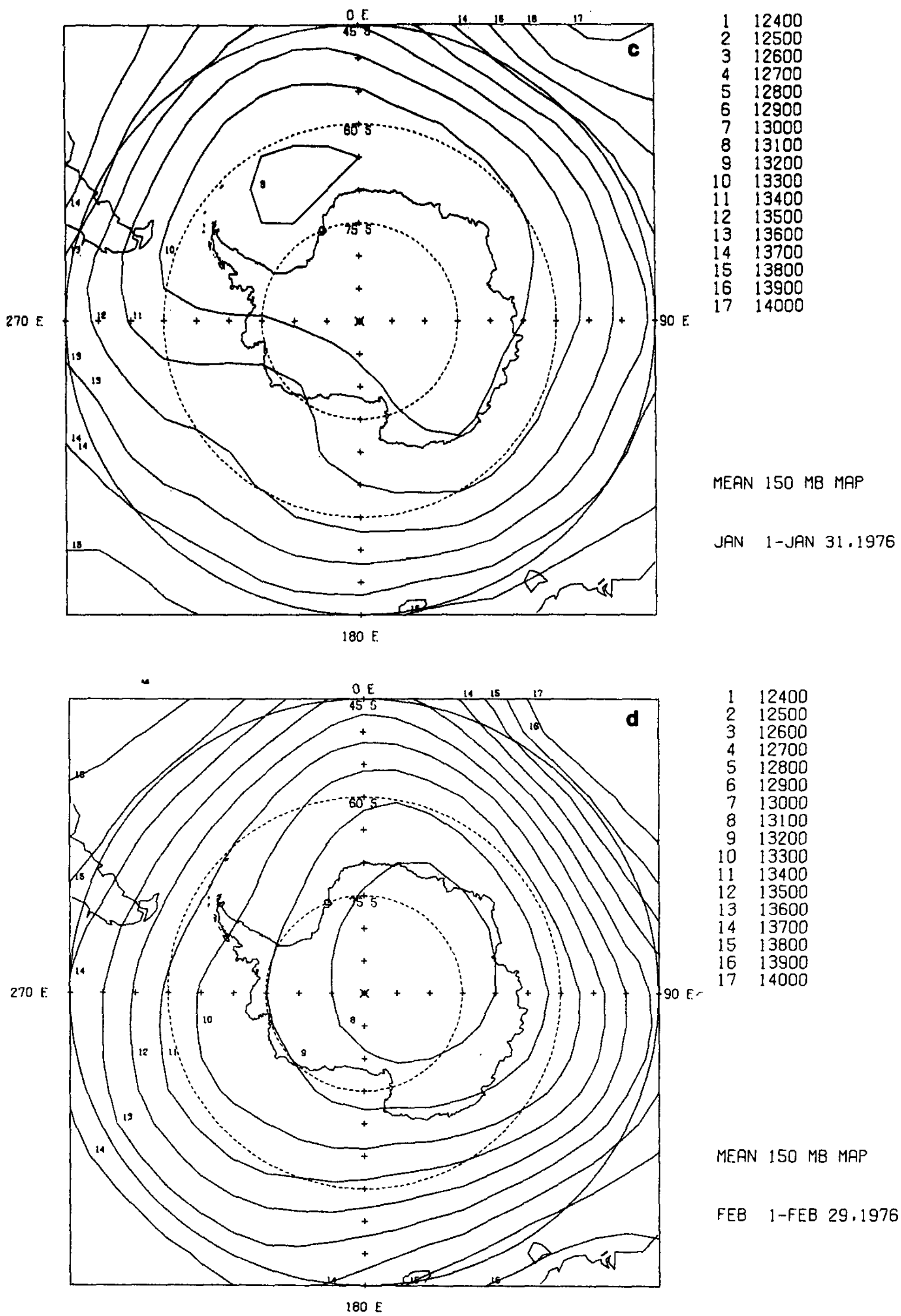

FIG. 2. (*Continued*)

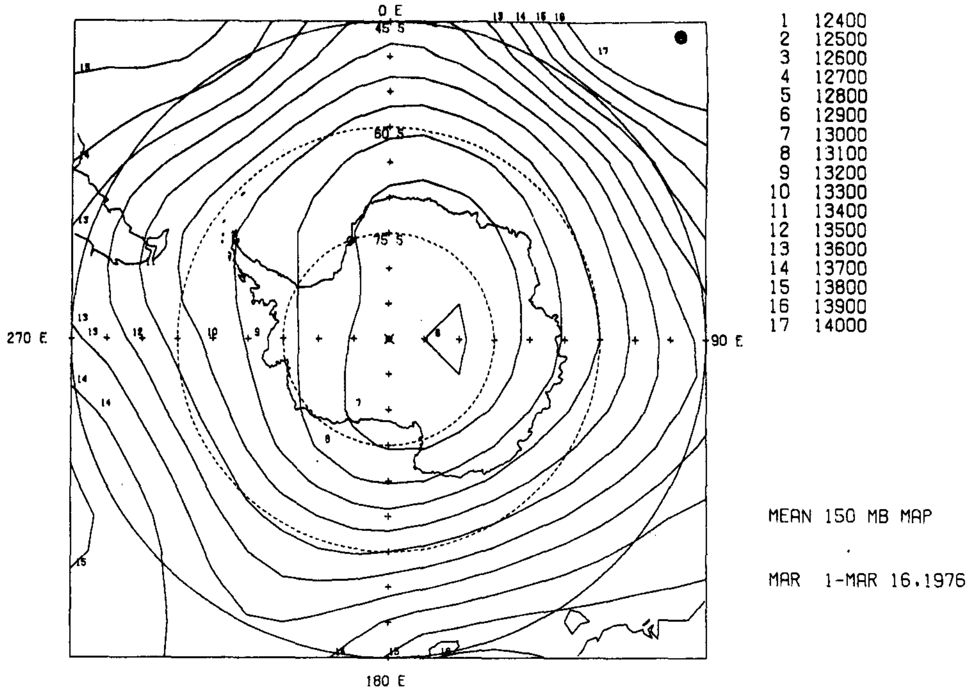

FIG. 2. (*Continued*)

positions for the entire day, which brings out immediately any erroneous position or wind.

3. Maps

Figs. 1a–1e are daily 150 mb maps of the 16th day of each month from November 1975 to March 1976. The contour lines are 100 m apart with a legend table on the right. TWERLE balloons are marked with a T below the last altitude digit; the mark *00 indicates no $Z(150)$ data available for that TWERLE balloon or radiosonde station. A missing wind vector indicates missing wind. Contour lines north of 45°S should not be relied on. All maps are 1200 GMT maps. The maps are given in equidistance azimuthal polar projection.

The five daily maps are samples of more than 120 daily maps prepared for the austral summer of 1975–76. All the daily maps from 16 November 1975 to 31 January 1976 appear in NCAR/TN-141 (Levanon *et al.*, 1979).

Figs. 2a–2e are the monthly average 150 mb maps for these five months (with the exception that the map for November includes only the second half of the month and the map for March, only the first half). The monthly maps were prepared by averaging the data at each grid point.

4. Conclusions

The 150 daily pressure maps presented here were compared with the 200 mb charts of the Bureau of Meteorology in Melbourne. The Melbourne analyses utilize a first guess which is derived by climatological extrapolation from the 500 mb analyses. Then the Cressman analysis procedure is used with all conventional wind and radiosonde reports. The TWERLE based maps were considerably more detailed and we believe that they are the most detailed high-altitude maps of Antarctica made so far. The maps demonstrate the potential of TWERLE-like balloons for operational meteorology.

The average monthly pressure maps given here will be supplemented by average temperature and wind maps (Kushnir, 1979) and a comparison with previous reports on Antarctic climatology.

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