TOVS OVER POLAR REGIONS

Hans-Joachim Lutz[1] and William L. Smith[2]

[1]Institut fuer Geophysik und Meteorologie
Universitaet zu Koeln (FRG)

[2]Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin
Madison, Wisconsin 63706 USA

1. INTRODUCTION

Because of the lack of radiosonde-stations (Fig. 1), there is a great need for satellite-derived temperature and moisture profiles in polar regions.

Up to now, statistical regression procedures have been used for retrieving operational temperature and moisture profiles from polar orbiting TIROS operational vertical sounding systems (TOVS). The results have been less than satisfactory because of a variety of complications including the high variable terrain altitude of the Antarctic plateau. About 80% of the Antarctic continent is higher than 2000 meters. It is difficult to detect cloud contamination because of the altitude of the plateau and the cold temperatures. There are also problems in detecting temperature inversions, which are often found in polar regions.

In this paper, improvements are made in using the simultaneous TOVS retrieval algorithm (Huang and Smith, 1986) in polar regions. Results from the modified procedure are compared with radiosonde profiles for several orbits over southern polar regions (December 1 and 21, 1987; February 4, 1988), and for one orbit over northern polar regions (February 4, 1987). The retrieved temperature profiles show a good agreement with radiosonde profiles, especially in the troposphere.

2. CLIMATE OF THE ANTARCTIC CONTINENT

The Antarctic continent is a cold desert. For example, the plateau station VOSTOK has an annual mean temperature of -60°C with a precipitation of 30mm per year. The coastal area is much warmer (-10°C to -20°C) and has also more precipitation.

Some other features of the Antarctic climate are the coreless winter and pointed summer. Coreless winter means that the temperature is nearly constant during the winter from the end of March to the end of September, especially on the plateau. Very often, katabatic winds transport cold air down to the coast. In the winter, the temperature profiles show strong inversions. At the end of winter, the continent is surrounded by an ice-area of about 18.8 million square kilometers. The short summer reaches its highest temperature in the beginning of January. On the plateau, the summer starts in mid-December and ends in mid-January. After reaching the peak, the temperature drops until the winter starts again at the end of March (Fig. 2). In summer, small inversions are found on the plateau. The sea-ice surrounds only parts of the continent, especially on the Weddell Sea. The surface air pressure shows a circumpolar pattern. A trough surrounds the continent between 60°S and 73°S. Over the plateau, a stationary high pressure area is found. The climate of the Antarctica is described in more detail by Schwerdtfeger (1984).

The features of the polar climate provides an indication of what to expect from satellite measurements. In particular, the high terrain of the plateau and the temperature inversions cause problems. Because of the dry atmosphere over polar regions, it is expected that channel 8 (11.1 micron, atmospheric window) and channel 10 (8.3 micron, water vapor of the lower troposphere) will show approximately the same brightness temperature.

3. CALIBRATION AND DATA VALIDATION

At the beginning, an attempt was made to validate the ITPP-3 in polar regions. The package was used without any changes, except for the acknowledgment of high altitude terrain. A radiosonde profile from this area was used as a first guess. The retrieved temperature profile was compared with the original radiosonde. The results can be seen in Figs. 3 and 4.

Afterwards several radiosonde profiles from polar stations were used to calculate brightness temperatures using the radiative transfer equation. These calculated brightness temperatures were compared with measured brightness temperatures to test the calibration algorithm and validation of the transmission functions. As shown in Table 1, there are significant differences in several channels. For the window channels 18 and 19 (4.0 and 3.7 micron) reflected sunlight causes these large differences. Because of the high altitude of the Antarctic plateau (at cloud level 1) and the ice and snow coverage, the 4.5 micron channels 13 to 17 are also contaminated with reflected sunlight. This causes an inconsistency of the 4.5 micron channels compared with the 15 micron channels. Therefore, the 4.5 micron channels are inappropriate for retrieving temperature profiles in polar regions during daylight.

For channels 1 and 2 (15 micron, upper atmosphere), it is difficult to compare measured and calculated brightness temperatures. Very often, the radiosondes reach only the 20 hPa level. Therefore, it is necessary to use temperature values from a polar standard atmosphere to interpolate the missing levels. Nevertheless, it seems that a gamma adjustment of the transmission function (Tau=Tau**Gamma) is useful because the measured brightness temperatures are always higher than the calculated values. This means that the peaks of the weighting function in channels 1 and 2 are at a higher (warmer) level.

Comparisons between retrieved profiles and radiosonde profiles show that a change of the transmittances using a gamma adjustment is required for channels 6 and 7 (15 micron, lower troposphere).

Another large discrepancy is observed between channel 10 (8.3 micron, water vapor in the lower troposphere) and channel 8 (11.1 micron, atmospheric window). Because of the dry atmosphere in polar regions, it is expected that channel 10 will have nearly the same temperature as channel 8. But as soon as the surface temperatures are below 250 Kelvin, the brightness temperature of channel 10 is higher than in channel 8. This fault is caused by using the space view in the calibration procedure. The TOVS calibration procedure shows that, by using space view and warm blackbody temperatures, the calculated cold blackbody temperatures for all channels are too warm compared with the actual blackbody temperature. For channel 10, this temperature is much too warm (Table 2). After changing the calibration procedure (i.e., using the cold and warm blackbodies), the brightness temperature in channel 10 is not only consistent with the brightness temperature in channel 8, but also the comparison with the calculated brightness temperature from the radiosonde profiles shows an agreement within 1 Kelvin (Table 3).

4. RETRIEVAL RESULTS

The results from the modified procedure are compared with radiosonde profiles for several orbits of NOAA-10. Three orbits over the southern polar regions (December 1 and 21, 1987; and February 4, 1988), and one orbit over the northern polar regions (February 4, 1988) are chosen. The time of the satellite overpass is near the launch time of radiosondes (00z and 12z).

After the improvements described above were made, a radiosonde profile again was used as a first guess. As it is shown in Figs. 5 and 6, the retrieved profile and the radiosonde profile are in agreement as should be expected. Only the moisture profile shows some significant differences.

With a regression first guess, the errors in the retrieved profile are much larger (Fig. 7). Using a special climatology profile in southern polar regions (south of 60°S) as a first guess, the results become more acceptable (Fig. 8). This is also shown for coastal stations (Figs. 9 and 10). Only in the high atmosphere are larger differences between retrieved profiles and radiosondes found.

For retrieving temperature and moisture profiles over all chosen orbits, the climatology profiles were used as a first guess. In northern polar regions, good agreement between retrieved profiles and radiosondes is also found (Figs. 11 and 12).

After retrieving temperature and moisture profiles, the 500 hPa and 200 hPa heights were calculated. The radiosonde stations were located in the orbit (Fig. 13) and the retrieved and measured heights were compared. As can be seen, there are still problems with the navigation near the pole. Figures 14 and 15 show the results for 500 hPa and 200 hPa, respectively. The heights calculated from satellite measurements are within 100 meters of the radiosonde measurement.

5. SUMMARY

The physical simultaneous retrieval approach has been modified to operate in polar regions. Because of discrepancies in observed radiances arising from the space view, the calibration procedure was altered to use only cold and warm blackbody views. The calculated transmittances have been tuned using gamma adjustments. Because of the reflected sunlight problem, channels 13 to 17 (4.5 micron) and channels 18 and 19 (4.0 and 3.7 micron) are not used in the retrieval algorithm. A special climatological profile is used as a first guess in southern polar regions (south of 60°S).

The results from the modified procedure are compared with radiosonde profiles for several orbits over southern polar regions (December 1 and 21, 1987; February 4, 1988) and one orbit over northern polar regions (February 4, 1988). The retrieved temperature profiles are within 2 Kelvin of the radiosonde measurements over most of the troposphere and they are less accurate in the higher atmosphere.

6. REFERENCES

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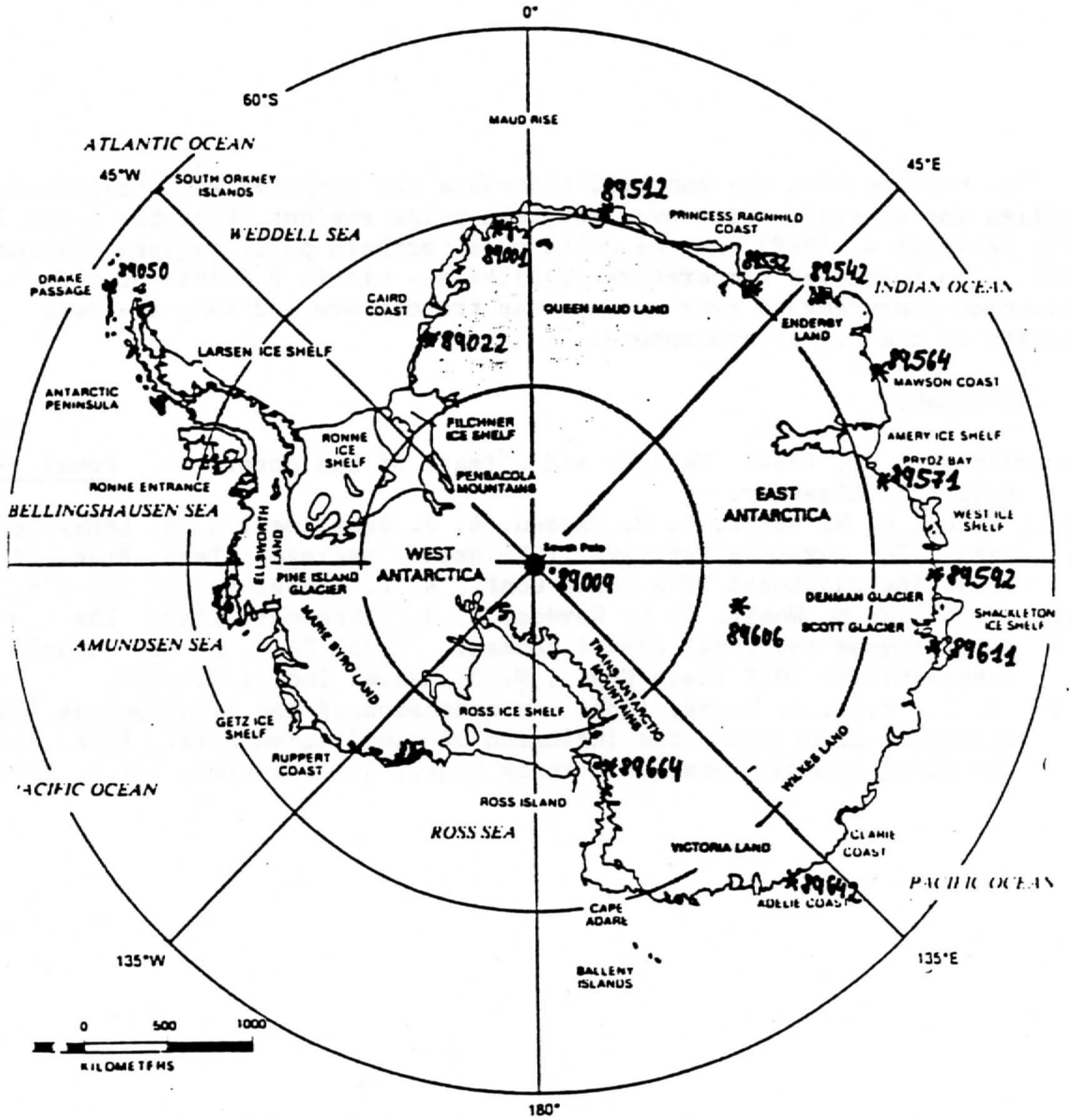

Fig. 1. The antarctic continent with the location of the radiosonde stations.

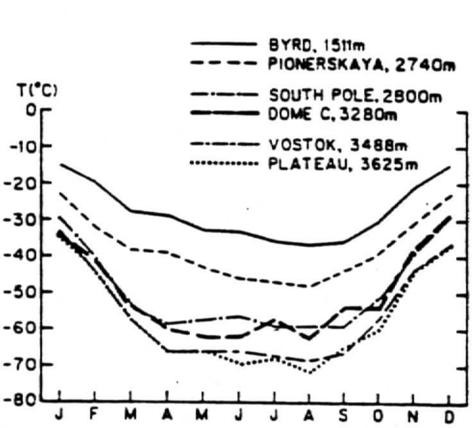

Fig. 2. Annual course of surface temperature at several antarctic stations.

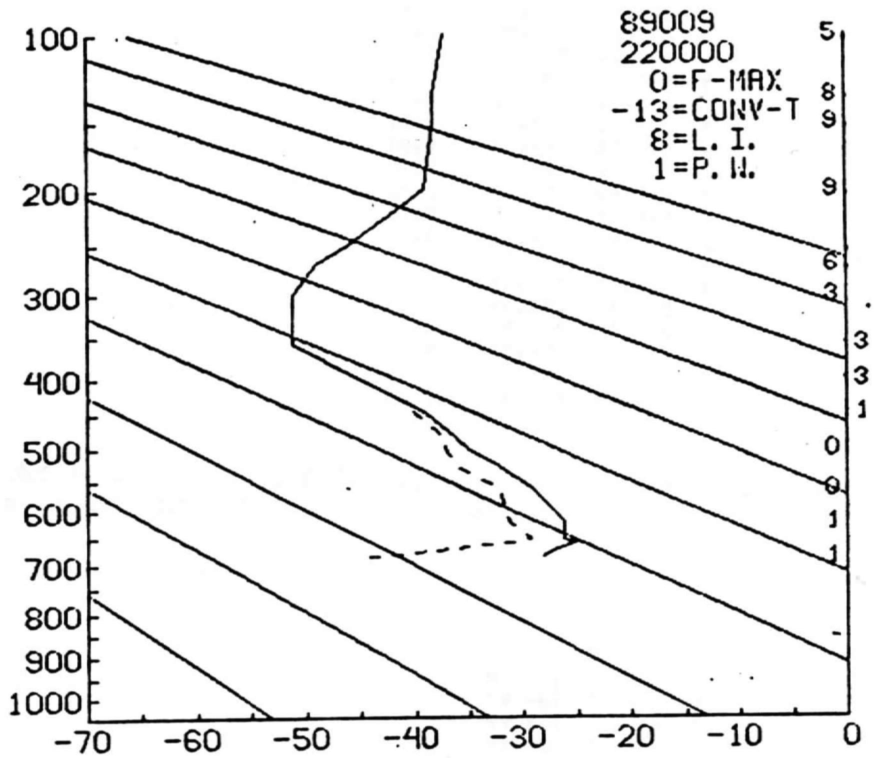

Fig. 3. Radiosonde profile from December 22, 1987 (time: 00z). Station: 89009 (Southpole).

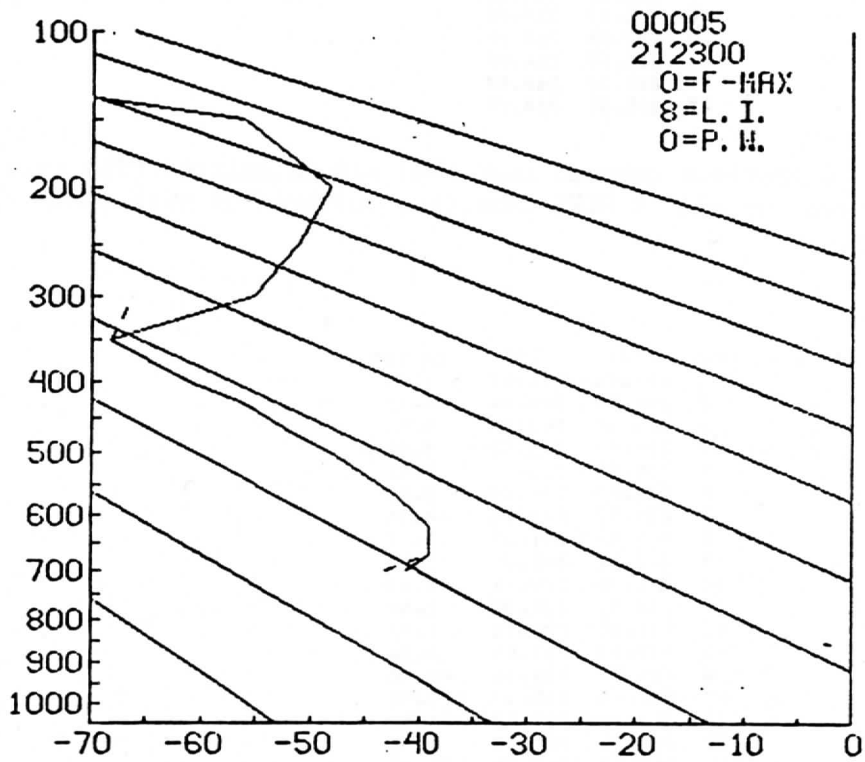

Fig. 4. Retrieved profile, orbit from December 21, 1987 (time: 23z). First guess: RAOB profile.

CH.	TSAT	TBB	TN-TBB
1	257.61	248.77	8.84
2	245.17	242.73	2.44
3	242.07	240.99	1.08
4	236.74	236.00	0.74
5	237.53	236.77	0.76
6	237.32	237.12	0.20
7	239.31	239.72	-0.41
8	242.04	242.03	0.01
9	243.94	242.04	1.90
10	243.69	241.19	2.50
11	238.38	238.14	0.24
12	231.60	232.73	-1.13
13	241.08	238.03	3.05
14	236.59	235.78	0.91
15	237.72	235.55	2.17
16	243.34	237.82	5.52
17	261.12	254.35	6.77
18	260.83	241.42	19.41
19	274.81	241.86	32.95

Table 1. Comparison between measured (TSAT) and calculated (TBB) (from radiosonde data) brightness temperatures for all 19 HIRS channels.

CH	TG	TM
1	265.15	264.99
2	265.05	264.99
3	265.16	264.99
4	265.21	264.99
5	265.24	264.99
6	265.27	264.99
7	265.28	264.99
8	265.28	264.99
9	265.39	264.99
10	265.94	264.99
11	265.19	264.99
12	265.14	264.99
13	265.27	264.99
14	265.22	264.99
15	265.19	264.99
16	265.24	264.99
17	265.25	264.99
18	265.26	264.99
19	265.30	264.99

Table 2. Comparison between real (TM) and calculated (TG) cold blackbody temperatures for all 19 HIRS channels; calibration with space view and warm blackbody.

CH.	TSAT	TBB	TN-TBB
1	256.96	253.17	3.73
2	244.82	244.94	-0.12
3	241.61	240.98	0.63
4	235.99	235.97	0.02
5	236.75	236.64	0.11
6	236.59	236.59	0.00
7	238.62	238.96	-0.34
8	241.34	241.33	0.01
9	242.91	241.34	1.57
10	241.24	240.55	0.69
11	237.81	236.32	1.49
12	231.10	229.71	1.39
13	239.97	237.63	2.34
14	235.24	235.54	-0.30
15	236.40	235.49	0.90
16	242.36	237.82	4.54
17	260.75	254.35	6.41
18	260.49	240.76	19.73
19	274.71	241.18	33.53

Table 3. Comparison between measured (TSAT) and calculated (TBB) (from radiosonde data) brightness temperatures for all 19 HIRS channels after the improvements were made.

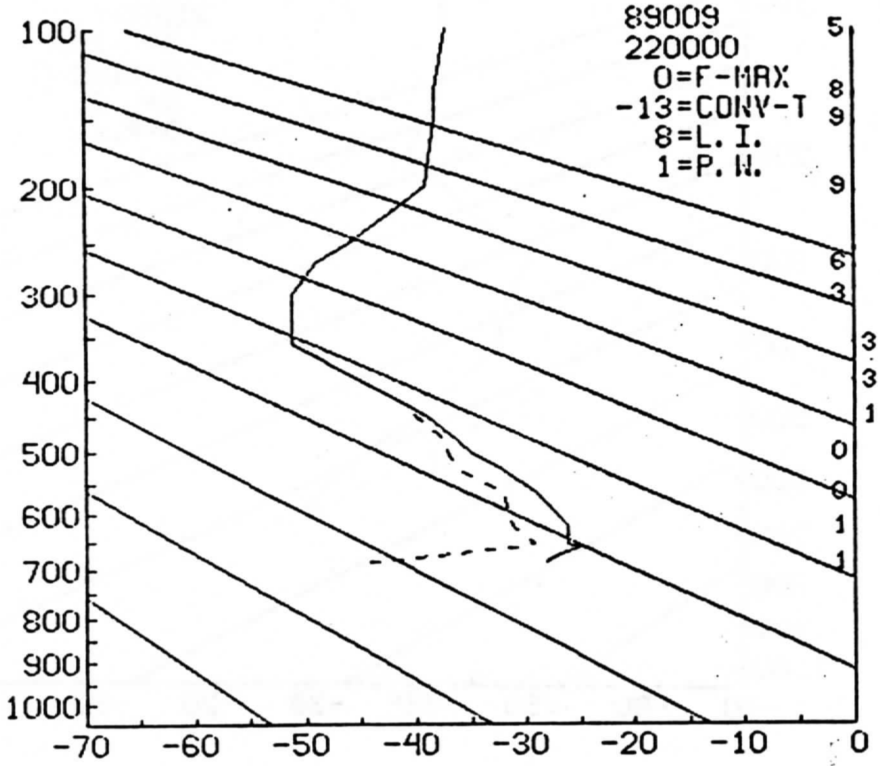

Fig. 5. Radiosonde profile from December 22, 1987 (time: 00z). Station: 89009 (Southpole).

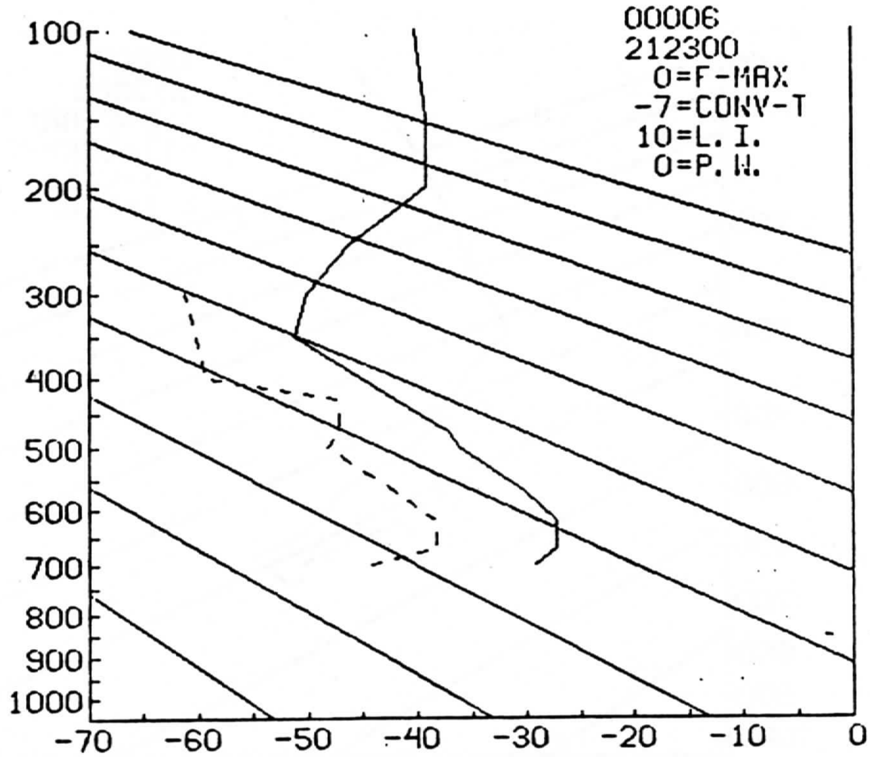

Fig. 6. Retrieved profile after changes were made. Orbit from December 22, 1987 (time: 23z). First guess: RAOB profile.

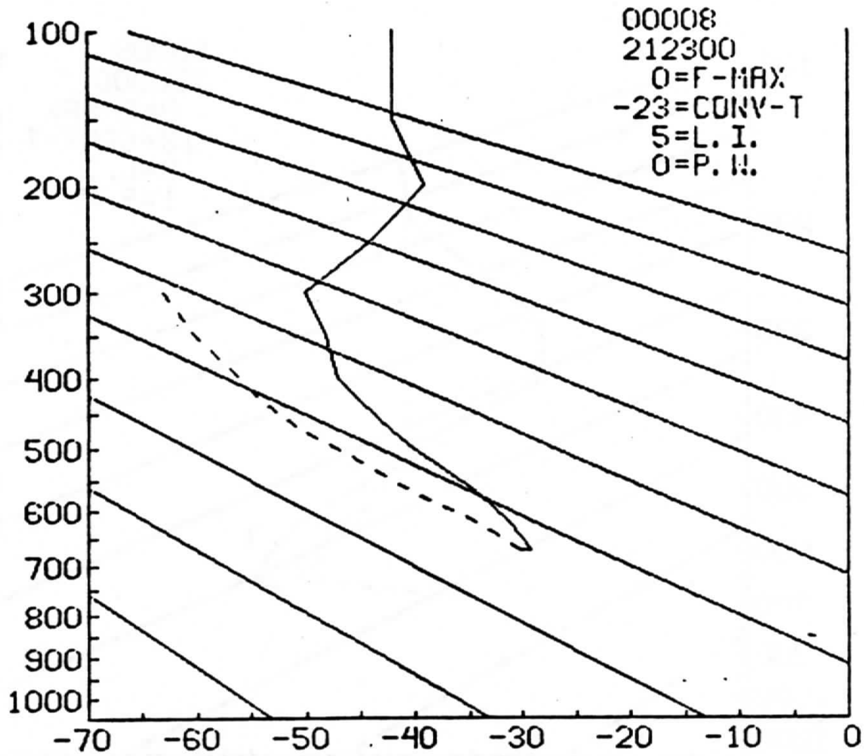

Fig. 7. Retrieved profile like in Fig. 6, but with a regression first guess.

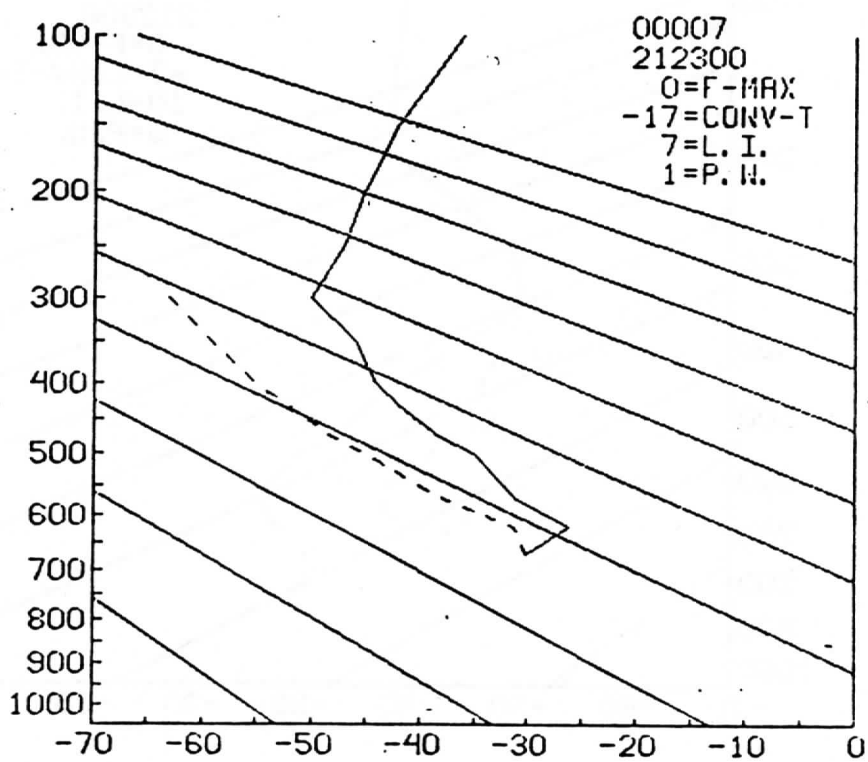

Fig. 8. Retrieved profile like in Fig. 6, but with a climatological profile as a first guess.

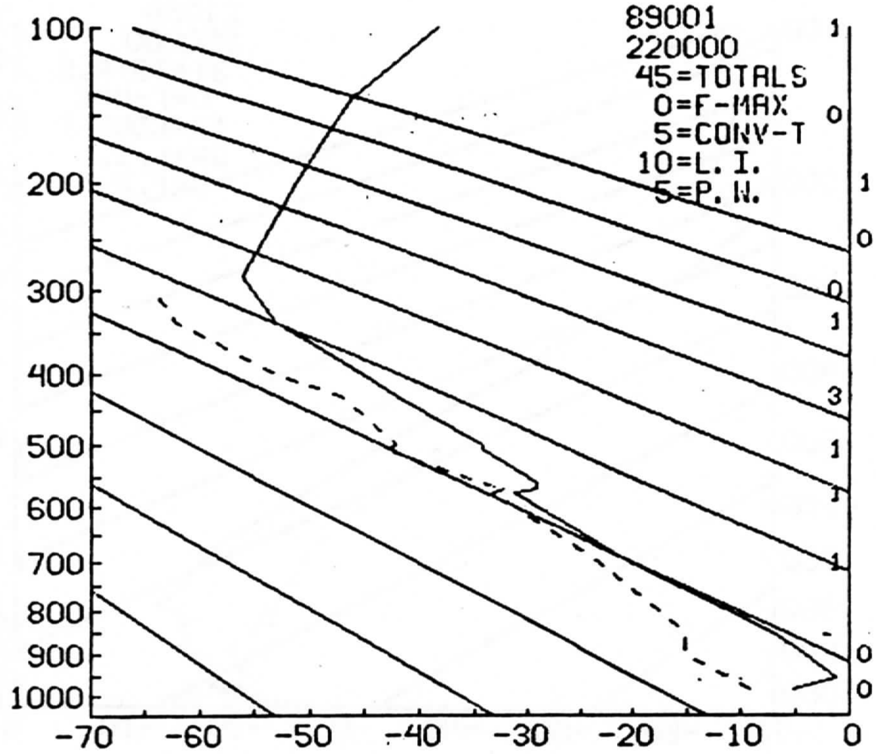

Fig. 9. Radiosonde profile from December 22, 1987 (time: 00z). Station: 89001 (SANAE).

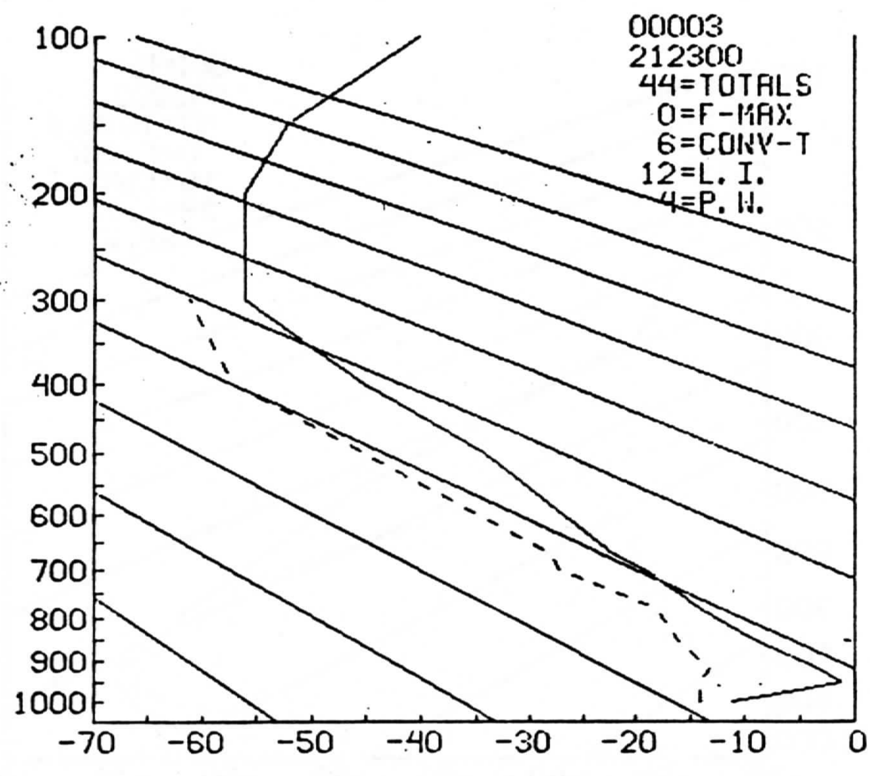

Fig. 10. Retreived profile, orbit from December 22, 1987 (time: 23z). First guess: climatological profile.

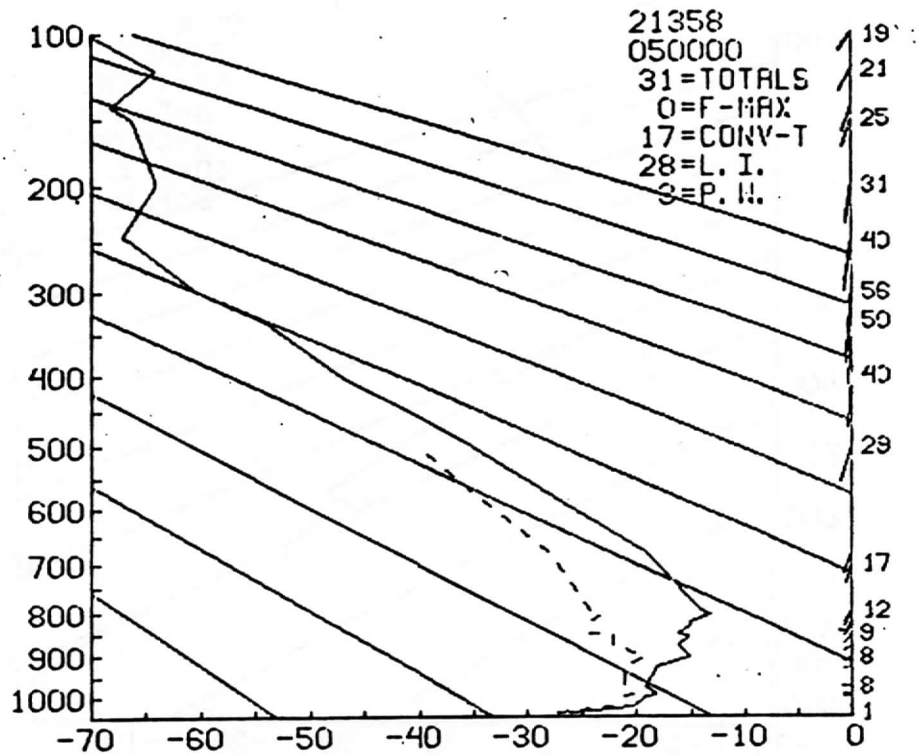

Fig. 11. Radiosonde profile from February 5, 1988 (time: 00z). Station: 21358 (northern Siberia).

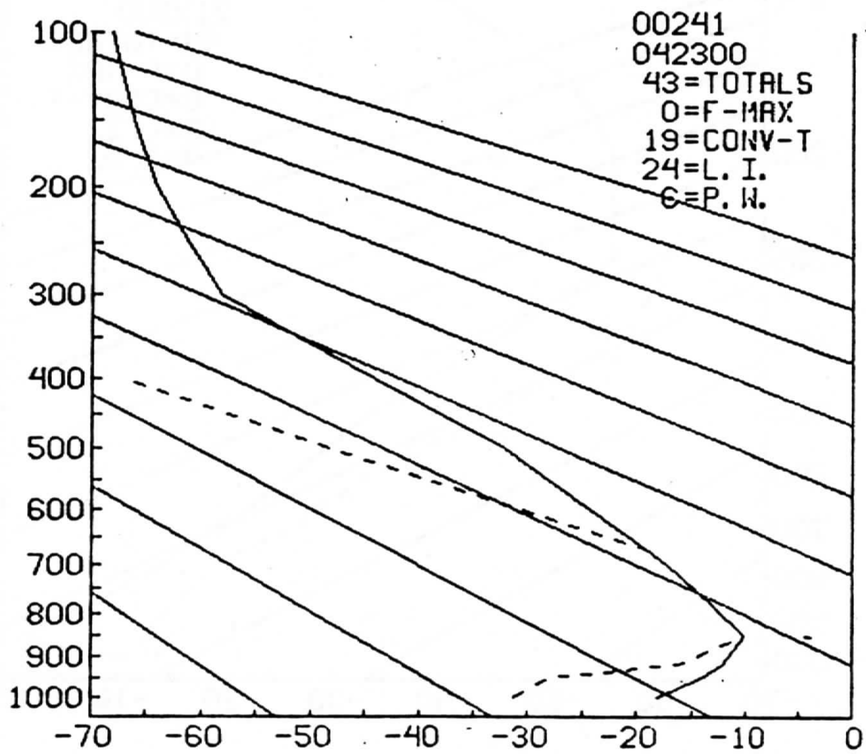

Fig. 12. Retrieved profile, orbit from February 4, 1988 (time: 23z). First guess: climatological profile.

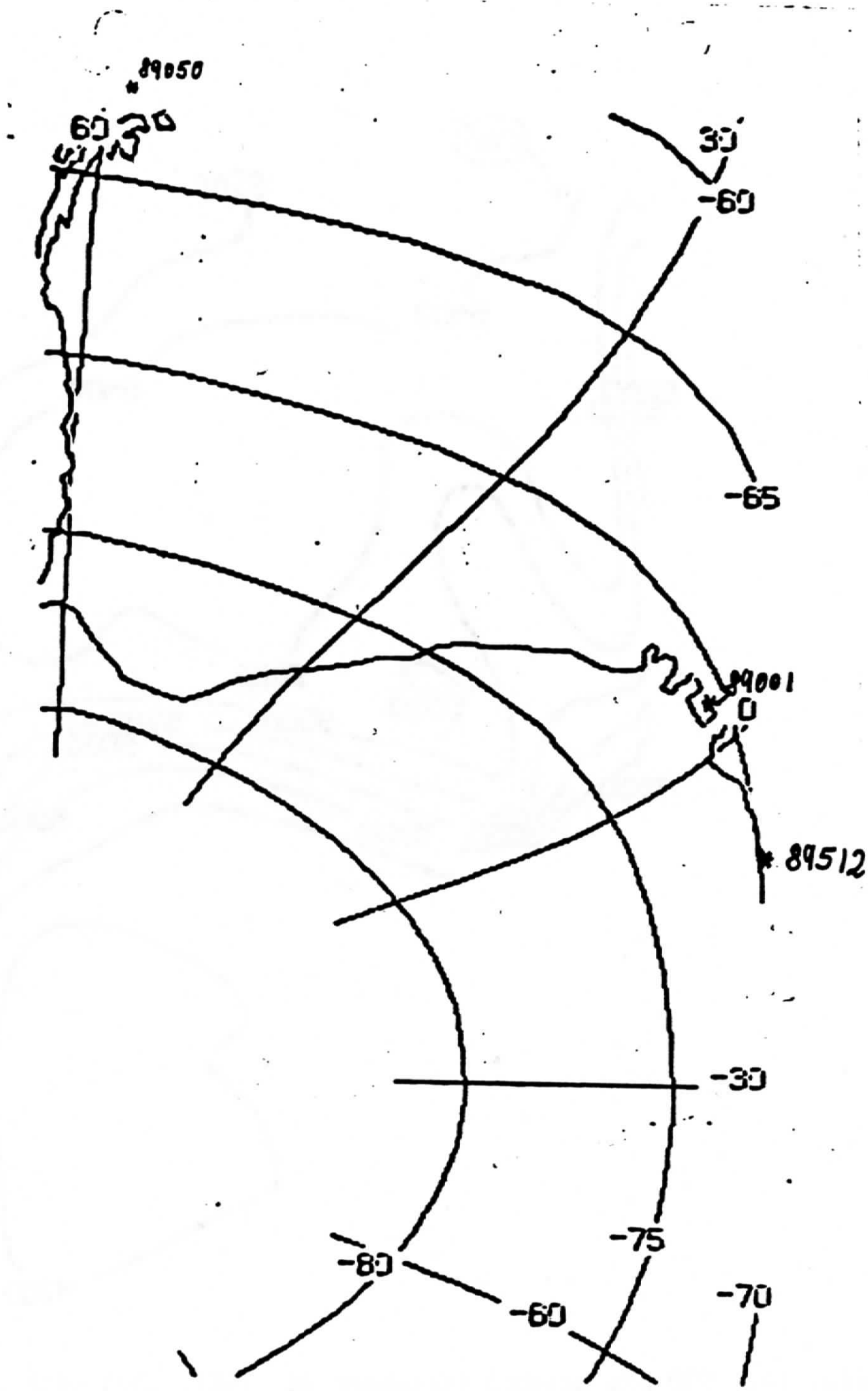

Fig. 13. Location of the orbit from December 21, 1987 (time: 23z) over the Antarctic region and the location of Station 89001 SANAE, Station 89050 Bellinghausen, Station 89512 Novolazar.

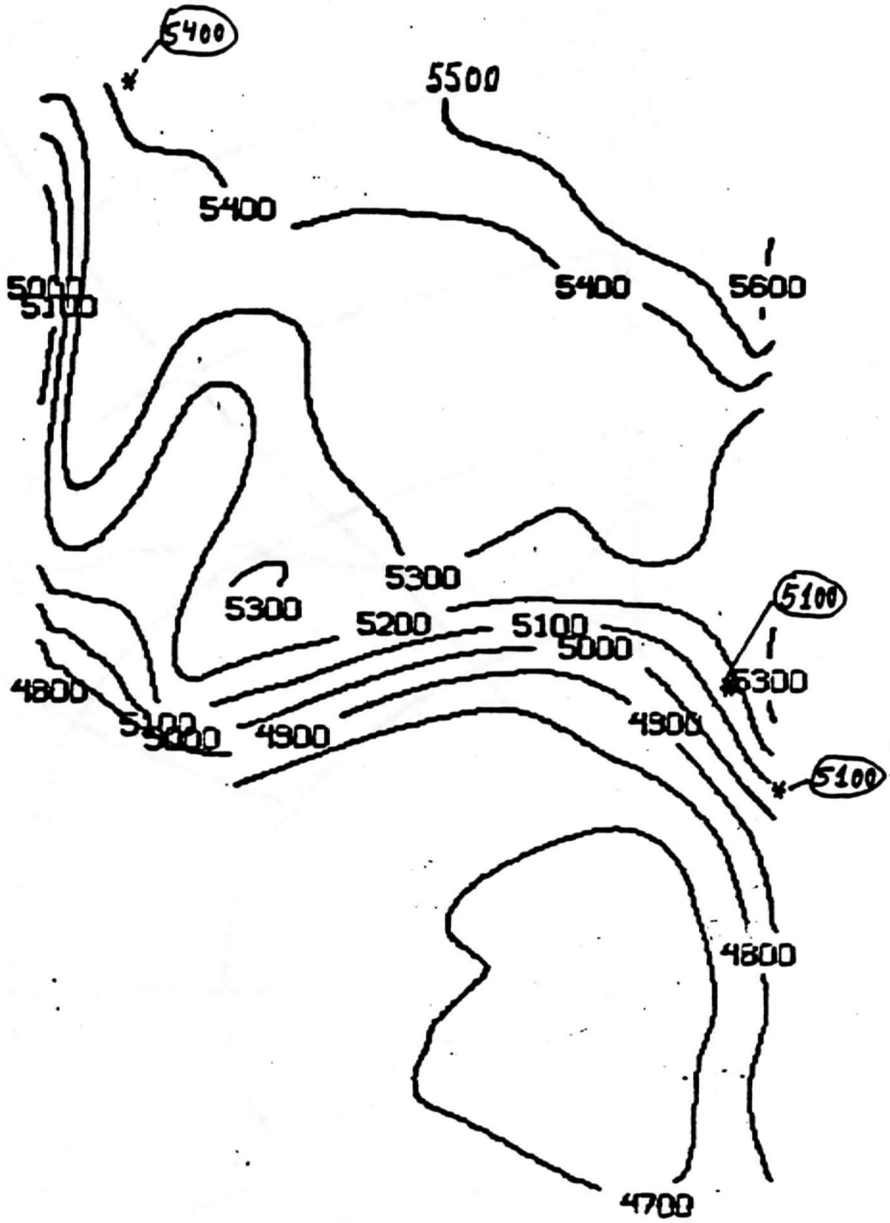

Fig. 14. 500 hPa heights (December 22, 1987, 23z) with the location and results of the three radiosonde stations (encircled) in that area.

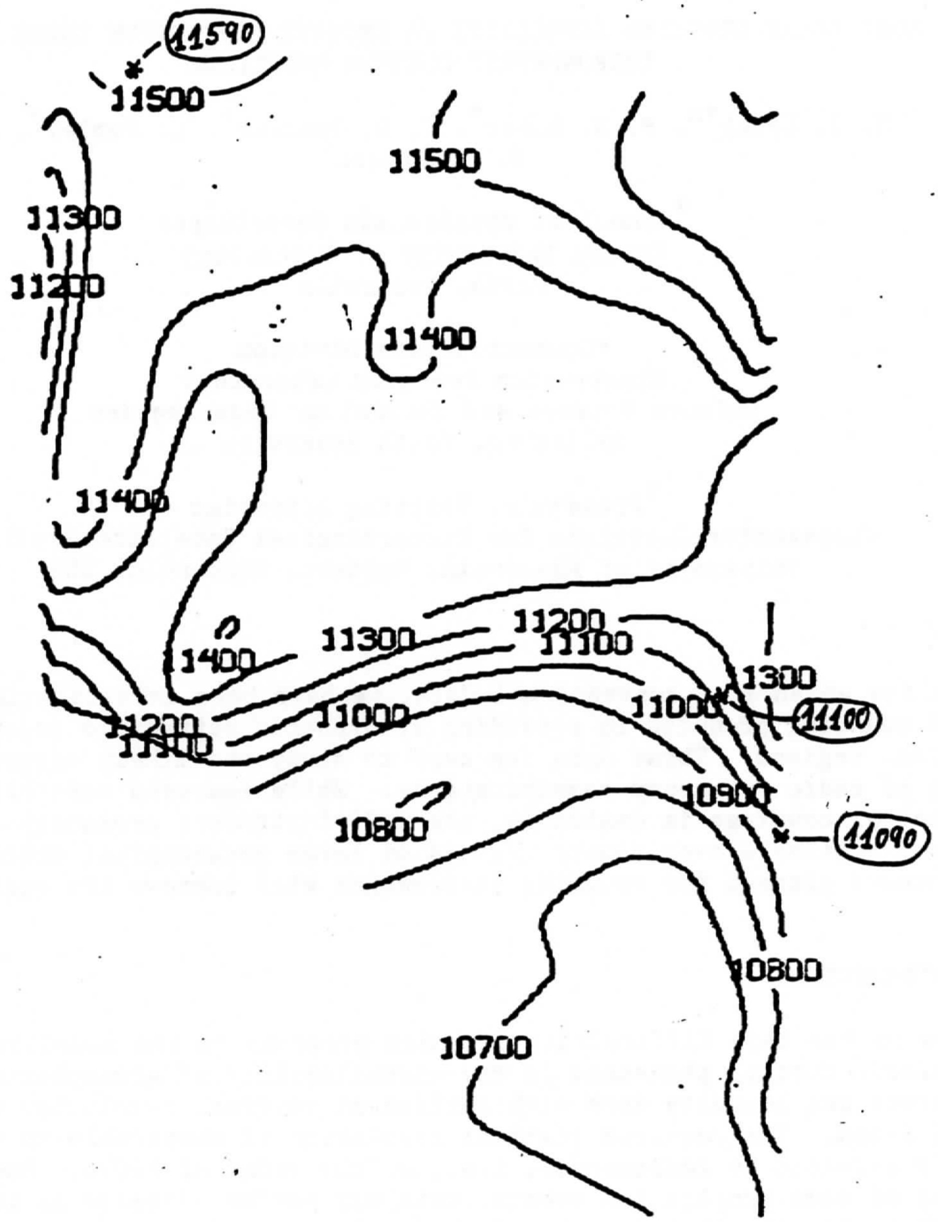

Fig. 15. 200 hPa heights (December 21, 1987, 23z) with the location and results of the three radiosonde stations (encircled) in that area.

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Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin
1225 West Dayton Street
Madison, Wisconsin 53706
(608) 262-0544

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