OAA Technical Memorandum NWS NMC 65

EVALUATION OF TIROS-N DATA, JANUARY-JUNE 1979

Washington, D.C.
June 1980

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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Washington, D.C.
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EVALUATION OF TIROS-N DATA, JANUARY-JUNE 1979

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ABSTRACT. A brief history is given of the use of TIROS-N data in NMC's analysis operations during the first half of 1979, together with comments on the quality of these data, in particular the deficiencies encountered. Finally, the impact of TIROS-N data on the Southern Hemisphere component of NMC's analysis and prognoses is described.

1. INTRODUCTION

Early in 1979, TIROS-N data were afflicted with numerous problems which inhibited their inclusion in the data base for the National Meteorological Center (NMC) Optimum Interpolation (OI) global analysis system. This necessitated the continued use of VTPR data from the NOAA-5 satellite to provide remote sensing temperature soundings over the data-sparse reaches of the Southern Hemisphere during most of the first special observing period of the Global Weather Experiment (formerly "FGGE").

During the period in which VTPR (Vertical Temperature Profile Radiometer) data provided the major portion of the Southern Hemisphere component of the OI system's data base, TIROS-N data were being evaluated offline from NMC's operations. Problems were uncovered and action was initiated to provide solutions. By about the end of February, solutions had been found to most of the major deficiencies of the TIROS-N data and although some less serious problems were still evident, these data were considered to be equal, or superior to, the VTPR soundings, which by then were beset with numerous deficiencies.

VTPR retrievals were discontinued at the end of February, but due to some minor programming difficulties at NMC, TIROS-N data were not introduced to the OI system's operational data base until March 5, and then in a somewhat limited configuration. The interval between the cessation of VTPR retrievals and the use of TIROS-N data by the OI system provided a situation which clearly illustrated the value of remote sensing atmospheric temperature data in the Southern Hemisphere. The 5-day period in which no remote sensing temperature data were available saw the standard of NMC's Southern Hemisphere analysis plunge to levels well below those that could be considered adequate. Analyses during this period often lacked temporal and spatial coherence, and at times were meteorologically unrealistic.

The initial use of TIROS-N data in NMC's analysis operations was limited to a restricted configuration in the Southern Hemisphere. The limits imposed upon the use of the data were:

- Latitudinal extent - 10° S to South Pole
- Vertical extent - surface to 100 mb
- Over oceanic regions only
- Only path A ("clear hole") and path B (N*) retrievals (see Smith et al. (1979) for definitions of retrieval paths.)

These limits, and those imposed later, were based on the results of continuing evaluations carried out at NMC.

The introduction of TIROS-N data to the OI data base brought about a rapid improvement in the quality of the Southern Hemisphere analyses, eliminating most of the inconsistencies and inaccuracies that had developed during the preceding several days.

On March 14, path C (microwave plus top four HIRS channels) retrievals were added to the Southern Hemisphere data base. On April 30 the restriction on the use of data above 100 mb was removed, and TIROS-N data were used for the first time in the Northern Hemisphere. The introduction of path C retrievals in the Southern Hemisphere appeared to have an impact on the analyses at levels 250 mb and below, the only analyses examined in this exercise.

2. METHODS USED TO ASSESS THE ACCURACY AND IMPACT OF TIROS-N DATA

The method used to assess the accuracy of TIROS-N data utilized a suite of programs encoded by John Horodeck of NMC's Systems Evaluation Branch. These programs provided statistical parameters on the differences between TIROS-N retrievals and conventional radiosonde observations located within specified time and space windows. Additional information was obtained from a variation of this approach developed by Phillips and Campana--in which the location differences and asynopticity of the data were accounted for by the use of an analysis procedure which interpolated one type of observation to the time and space location of the other. Both methods are described by Phillips et al. (1979).

The colocation approach proved to be more than adequate in the Northern Hemisphere where large numbers of pairings were obtained. In the Southern Hemisphere, however, particularly at middle and high latitudes, the frequency of colocations was less than desirable.

Assessment of the impact of TIROS-N data on NMC's analysis and prediction of the Southern Hemisphere's atmospheric circulations was severely restricted by time and resource constraints. Very few parallel "with" and "without" mode analysis/prognosis cycles were attempted during the exercise, although Phillips and Desmarais (1979) propose to conduct a series of these experiments during the northern winter of 1979-80. Impact evaluations were, by default, limited mainly to subjective methods based upon judgments on the quality of the analyses and prognoses produced. Even these subjective evaluations were clouded by other than data-related factors which occurred from time to time during the exercise.

The main methods used in evaluating the impact of TIROS data, within these limitations, were:

- examination of statistics of the fit of other forms of data by the OI system in the 'with' and 'without' modes
- subjective evaluation of the analyses produced in the 'with' and 'without' modes
- verification of about 3 months of 24- and 48-hour predictions for the Australian region, produced by two versions of a global spectral prediction model.

3. DATA ACCURACY AND IMPACT

Major deficiencies of the data are discussed below. Most of these apply to short periods, with only a few spanning the entire six months.

A. Problems Arising from Blending of Coefficients

Regression coefficients required to obtain atmospheric temperature data from the radiances measured by the satellite were derived for each of five zones, viz

North Pole to 60° N	- Zone 1
60° N to 30° N	- Zone 2
30° N to 30° S	- Zone 3
30° S to 60° S	- Zone 4
60° S to South Pole	- Zone 5

To avoid discontinuities in the retrieval temperatures at zone boundaries, the regression coefficients were blended across the boundaries. Thus, a retrieval at 55° S was based on the weighted average of zone 4 and zone 5 coefficients. The weighting factors used were based on the microwave channel 4 (at 57.95 GHz) reading and its location on a predetermined latitudinal profile of this value (see Phillips et al. for details).

The use of microwave channel 4 measurements to determine the weighting factors proved to be satisfactory through the southern summer. However, when the assumed profile, which in the summer reflected a low-stratospheric temperature distribution ranging from cold at the Equator to warm at the pole, was invalidated by rapid cooling of the Antarctic stratosphere, this procedure led to serious errors in high latitude retrievals. There were numerous instances during late April and early May in which near-Antarctic retrievals were based on weighted means of coefficients for zones 3 and 4 rather than those for zones 4 and 5. Accordingly, retrievals at high latitudes of the Southern Hemisphere during this period displayed marked warm biases.

B. Biases

During late March and early April, TIROS-N retrievals began to display significant departures from colocated radiosonde observations at middle and high latitudes of the Southern Hemisphere. Figure 1 shows the root-mean-square (rms) differences between retrieval temperatures and radiosonde soundings for the period March 26 to April 8. The figure shows rms differences in excess of 3° C in much of the troposphere between 45° and 65° S. Even more significant were the mean differences between the data types. Figure 2 shows that the retrievals had marked positive bias at near Antarctic latitudes and cold biases at middle latitudes.

By late April and early May the biases appeared to increase, particularly at high latitudes. Numerous instances of differences of nearly 10° C were noted between TIROS-N retrievals and neighboring radiosonde observations. Figure 3 provides an example of such an occurrence.

The effect of these warm biases at high latitudes together with the cold biases at middle latitudes was to provide, even in zonally and temporally averaged fields, north-south temperature gradient profiles that were significantly different from normal. Figure 4 shows profiles of north-south temperature gradients of zonally averaged TIROS mean layer temperatures for the period May 2 to 6 (solid lines). These profiles departed markedly from normal for the period. The most significant departures were the unrealistically tight gradient near 65° S and the lack of a maximum at middle latitudes.

The occurrences of these biases were at least partially attributable to the method used in blending regression coefficients. In mid-May, when NESS changed the method of deriving coefficients for middle to high latitude retrievals in the Southern Hemisphere, a marked improvement resulted in the quality of near-Antarctic retrievals. The dashed lines on figure 4 which represent the zonally averaged layer mean temperature gradients for the period May 15 to 17 (after the change was affected) illustrate the improvements. The unrealistic gradient near 65° S has been reduced considerably while the midlatitude gradients have increased in the latter case, probably reflecting activity of the southern polar front.

C. Terrain Problem

TIROS-N retrievals over land, particularly over high terrain, had been suspect throughout the period of assessment. The most inaccurate and

Table 1.--Globally Averaged RMS Differences (° C) Between TIROS-N Retrievals and Co-located (3 hour x 3°) Radiosonde Observations, 7 May - 17 June 1979

	Layer	1000/850	850/700	700/500	500/400	400/300	300/200	200/100
Retrieval Path	A	3.05	2.40	2.00	2.25	2.25	2.10	2.00
	B	3.45	2.85	2.25	2.40	2.40	2.65	2.20
	C	3.75	3.15	2.70	3.05	2.80	2.65	2.15

inconsistent retrievals were found over the Antarctic plateau, where errors of nearly 20° C at midtropospheric levels were not uncommon. However, instances of poor over-land retrievals were evident in other regions, among which were the mountainous areas of South America, parts of Australia, and the plateau of Southern Africa.

The quality of TIROS-N retrievals over high terrain has remained unreliable; consequently, NMC continues to use TIROS-N data over oceanic regions only. According to Noar (1979), the Australian National Meteorological Analysis Center has found that retrievals over Australia are not always compatible with radiosonde observations and other data.

D. Path C Retrievals

During the period early in March when only path A and path B retrievals were used in the Southern Hemisphere portions of NMC's OI analyses, it was often noted that the path C retrievals (which are available but were not used) were indicating warmer thermal ridges and colder thermal troughs than shown by the analyses. Upon the introduction of path C data to the OI systems data base on March 15, the analyses began to display more amplitude, particularly at midtropospheric levels at middle and high latitudes of the Southern Hemisphere. The implication is that path C retrievals were somewhat at variance with those of paths A and B.

Path C retrievals did in fact display larger rms differences from colocated radiosonde observations than did either path A or path B retrievals. Table 1, which displays globally averaged rms differences between radiosonde temperatures and paths A, B, and C retrievals, shows the larger 'error' levels of the path C data. Of more interest, however, is a comparison of the mean differences between radiosonde data and each of the retrieval types. Figure 5 displays latitude-altitude variations of the parameter D, where $D = (R-A)-(R-C)$ in which $(R-A)$ is the mean difference between radiosonde and colocated path A retrieval temperatures and (R-C) is the same, but for path C retrievals. The value D may, therefore, be equated to the mean difference, for a particular layer and latitude belt, between (hypothetically) colocated path C and path A retrievals. The figure has some interesting aspects, e.g.,

- path C retrievals were cooler throughout the equatorial troposphere. (Plots of (R-A) and (R-C) separately (not shown) indicated that negative values of D resulted from large (R-C) values.)

- at middle and high latitudes path C retrievals were generally warmer at lower levels and cooler at mid- to upper tropospheric levels.

Note that from the latter half of June to the end of July path C retrievals at near-equatorial latitudes of the Northern Hemisphere were displaying markedly cold biases at the lowest levels; (see fig. 6). Errors of up to 8° C were not uncommon in path C retrievals, particularly in areas of dense convective cloud. The large cold biases were attributed to contamination of the soundings by heavy precipitation.

E. Overall Assessment of Data Accuracy

Notwithstanding the numerous problems that have been encountered and those that remain, TIROS-N data have been of significant value in defining the atmospheric circulation of the Southern Hemisphere. Some of the problems have limited the use and utility of the data, e.g., the poor retrievals over land, particularly over high terrain, have caused NMC to limit the use of TIROS-N data to oceanic regions. Continuing biases and high error levels of path C retrievals limit the value of these data by forcing up the error levels ascribed to them by the OI system. These limitations have prevented realization of the promise that TIROS-N would provide good data over land and in cloudy areas. Nevertheless, the TIROS-N data have helped define broad scale circulation patterns, isotherm concentrations associated with frontal zones and jet streams, and secondary disturbances. Overall, TIROS-N has been of great value in providing objective analyses of atmospheric circulation patterns of the Southern Hemisphere which, without the benefit of remote sensing data, would have been only qualitative.

4. IMPACT OF TIROS-N DATA

Time and resource constraints severely limited the ability to undertake 'with' and 'without' model analysis (prognosis cycling experiments) an ideal means of assessing the impact of a particular data form. In the few 'with' and 'without' mode experiments that were run, some significant differences were noted; however, lack of ground truth in the areas of interest in the Southern Hemisphere forced the evaluations of the analyses to be based on little more than compatibility with interpretation of satellite cloud imagery. These evaluations seemed to indicate that the 'with' model analyses were superior.

Fortunately, minor programming problems at NMC early in March prevented the use of TIROS-N data in the center's OI analysis, immediately following the cessation of VTPR retrievals on February 28. The 5 days that ensued before TIROS-N data were used saw the standards of NMC's Southern Hemisphere analyses plunge to levels far below those that could be considered satisfactory -- proof by default that remote sensing temperature soundings are needed for reasonable analysis of the Southern Hemisphere atmospheric circulation.

However, the fit of conventional data by the OI analyses prior to February 28 was not significantly different from that after March 5. Hence, while TIROS-N data appeared to have a marked impact on the situation where no satellite sounding data were used, they did not have a similar impact on the period when VTPR data were available. For example, figure 7, which displays plots of weekly average rms differences between a selection of conventional observation parameters and the analyses, indicates that the use of TIROS-N data did not impact significantly on the fit of conventional data by the OI analyses. If anything, the fit of these data was slightly worse following the use of TIROS-N data than it was while VTPR data were being used. The lack of positive impact, as measured by the fit of conventional data, does not necessarily reflect a lack of improvement of the TIROS-N data over the VTPR retrievals. In fact, Phillips et al. indicate that TIROS-N data, particularly paths A and B retrievals, were more accurate than VTPR soundings.

In an attempt to assess the impact of TIROS-N data on the performance of prediction models run at NMC, about 3 months of 24- and 48-hour predictions produced by a 6-layer, 20-mode and a 7-layer, 24-mode spectral coordinate primitive equation model were verified. The verifications were limited to examination of S1 skill scores and rms errors and to subjective evaluations by senior meteorologists in the Special Projects Branch of NESS. The validity of the verifications was severely clouded by a number of factors not related to data which occurred irregularly throughout the exercise. As a result the only conclusion that could be drawn was that the forecasts were useful and reasonably accurate at both 24 and 48 hours, indicating that TIROS-N data did not have any obviously detrimental effects on the quality of the predictions.

5. OVERALL ASSESSMENT OF IMPACT OF TIROS-N DATA

Although it can be shown that the use of TIROS-N data in the Southern Hemisphere component of NMC's global analysis/prognosis system had a significant impact when compared to period in which no remote sensing temperature data were used, it could not be shown that these data had any more positive impact than the VTPR data. It may be argued that this result was caused partly by the restricted configuration in which TIROS-N data were used and partly by the failure of the new system to provide consistently accurate data in cloudy regions. These two factors, which effectively negated two of the major expected improvements of the TIROS-N system over the VTPR system, would have inhibited any dramatic impact.

6. CONCLUSION

The TIROS-N data coverage has more than compensated for the cessation of VTPR retrievals. The higher horizontal and vertical resolution afforded by TIROS-N has helped define a smaller scale of system than was possible with VTPR retrievals. Additionally, Phillips et al. have shown that TIROS-N data, particularly paths A and B retrievals, are more accurate than VTPR. In spite of these improvements, TIROS-N has not fully lived up to expectations because it has failed to provide consistently accurate data in cloudy areas and over land, particularly over high terrain. However, as Phillips et al. point out, means of improving TIROS-N data accuracy are under study, and if solutions can be found to overcome some of the problems referred to, the impact of the data may be more positive.

ACKNOWLEDGMENTS

The author expresses his thanks to John Horodeck for providing the TIROS-N radiosonde co-location statistics, to Gene Brown for drafting the figures, and to Dawn Starosta and Tina East for typing the paper.

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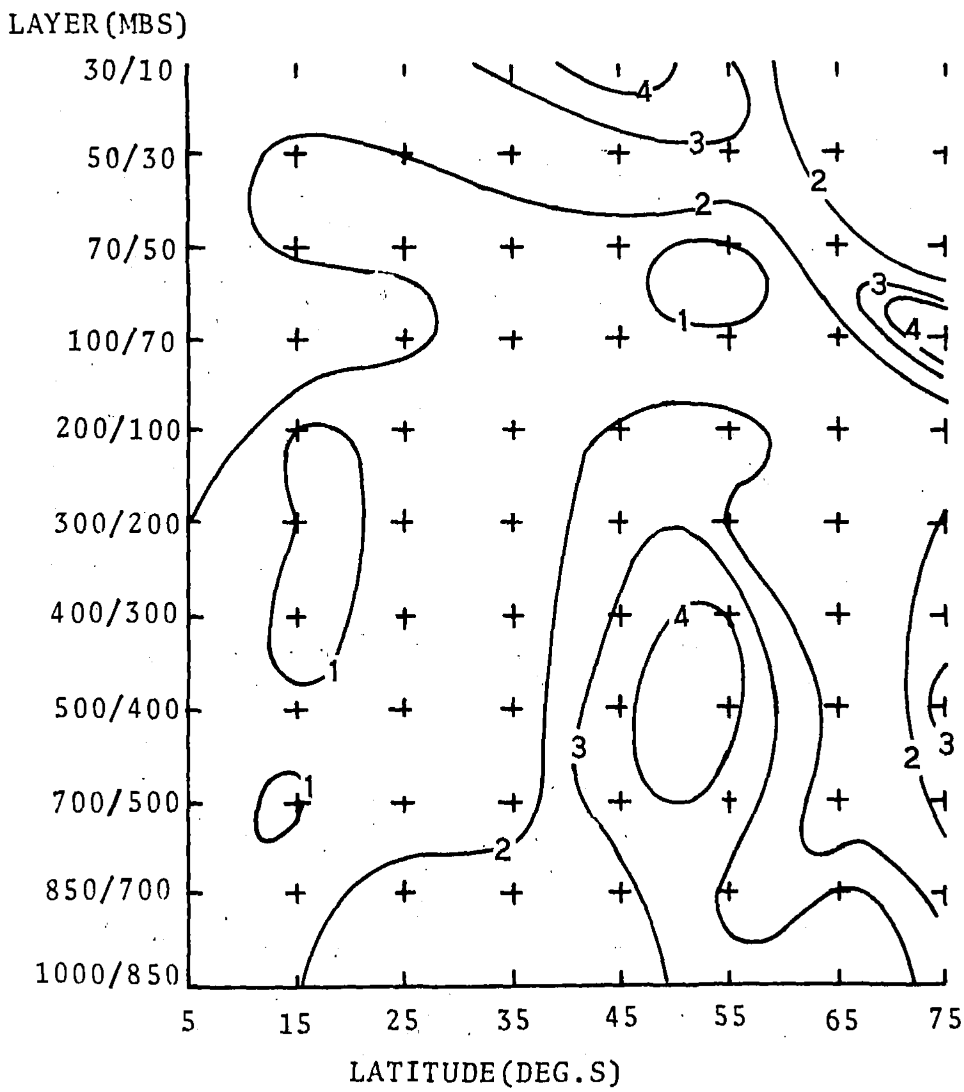

Figure 1.--RMS differences between retrieval temperatures and radiosonde soundings in the Southern Hemisphere for the period March 26 to April 8, 1979.

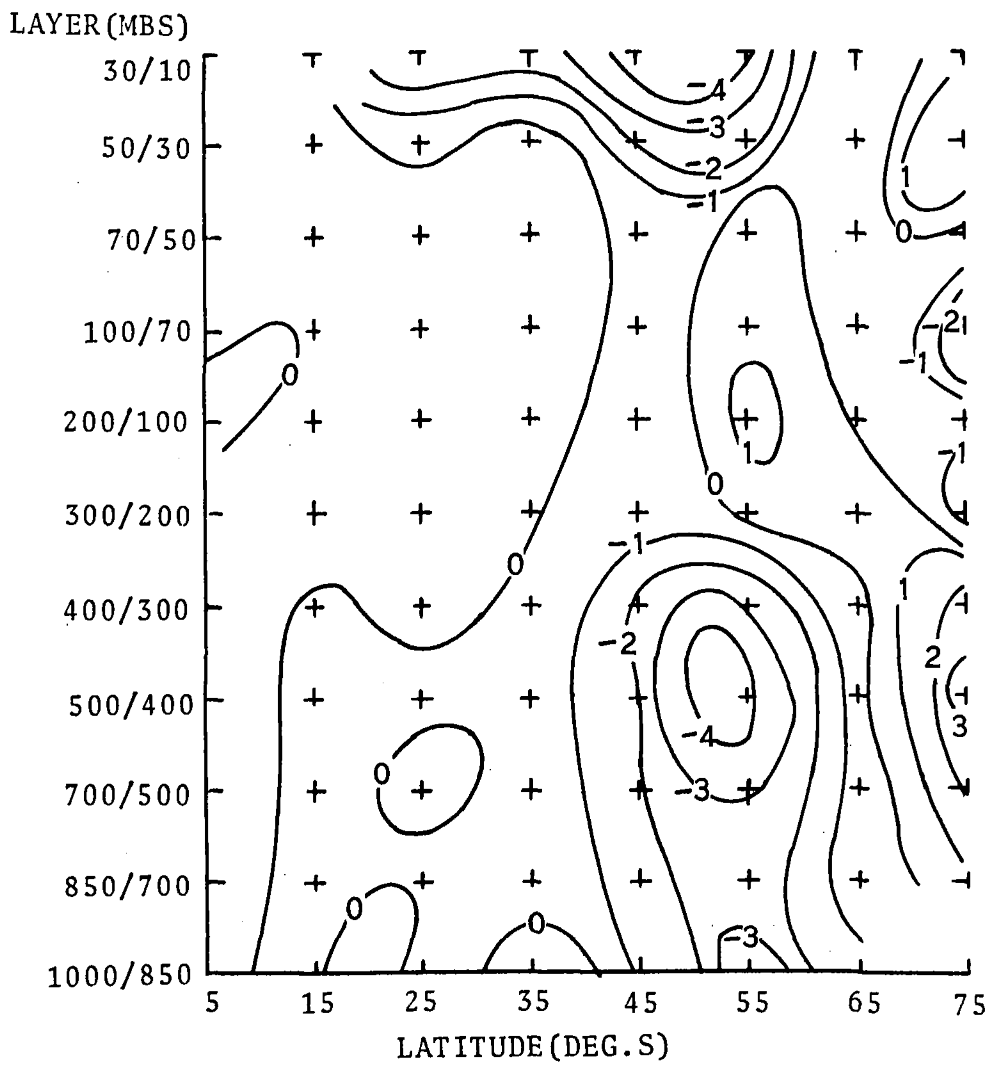

Figure 2.--Biases of retrieval temperatures in the Southern Hemisphere for the period March 26 to April 8, 1979.

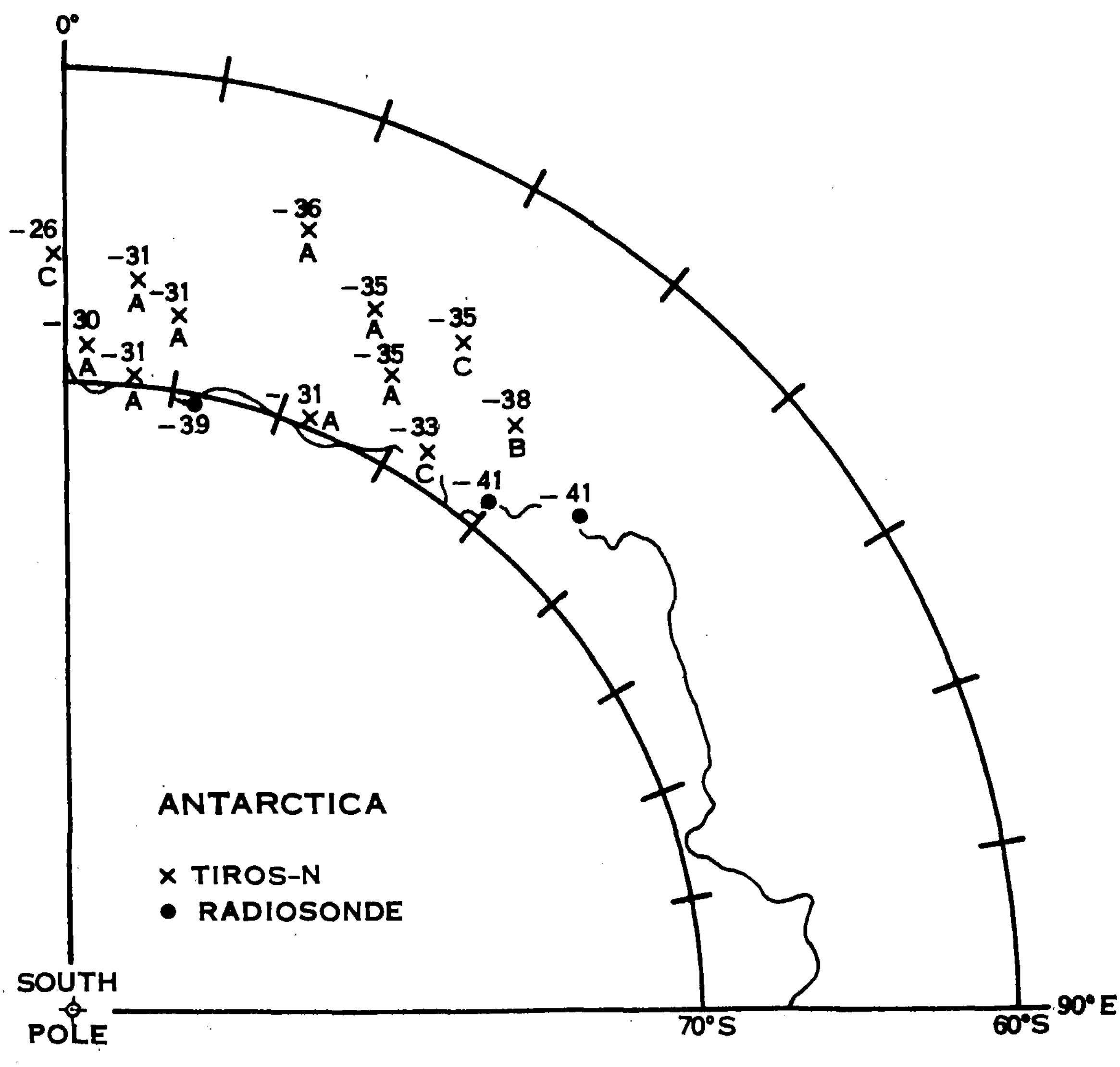

Figure 3.--Sample of inconsistent temperature observations by TIROS-N and radiosondes at high latitudes.

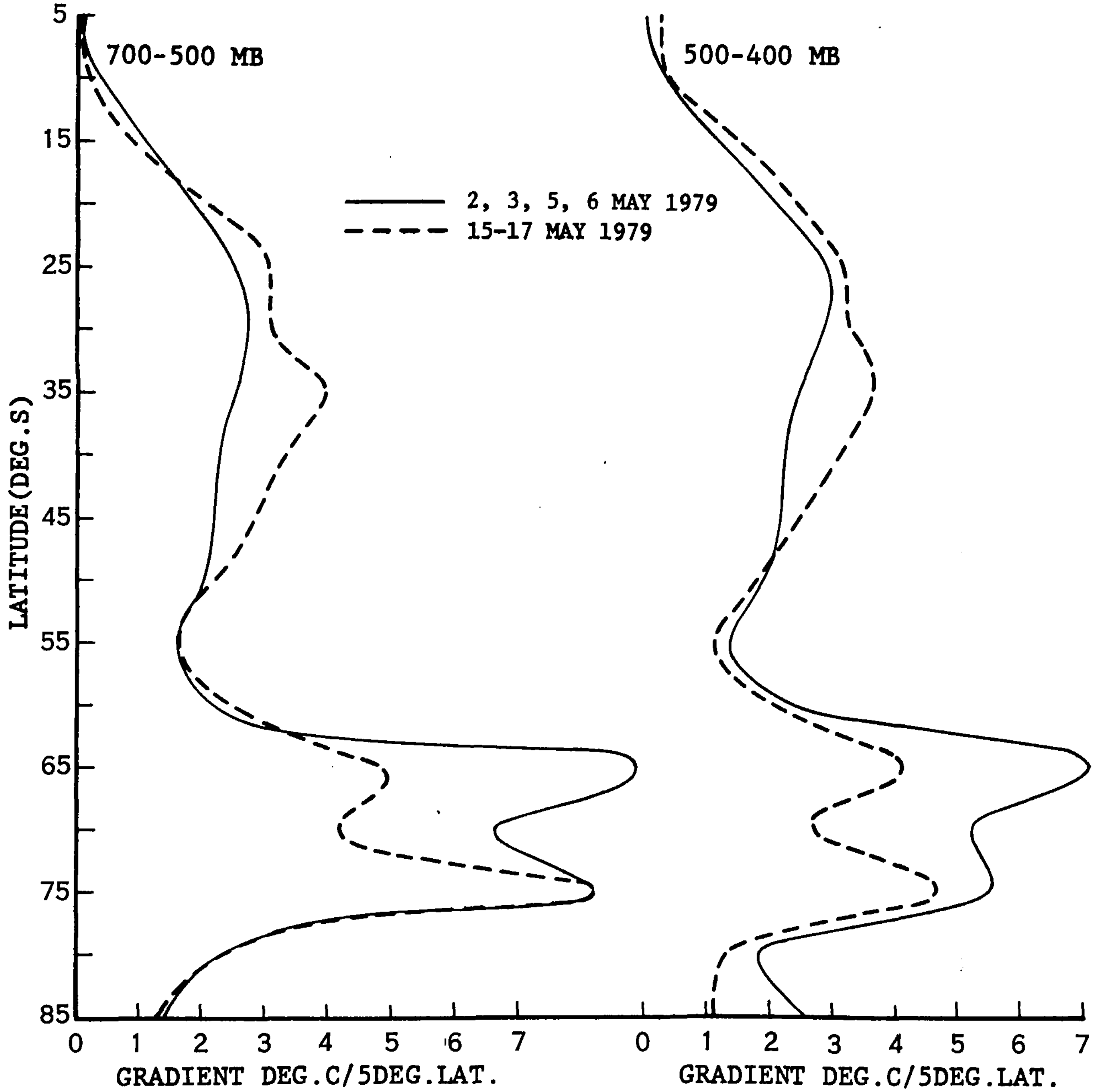

Figure 4.--Profiles of north-south temperatures gradients of zonally averaged TIROS mean layer temperatures.

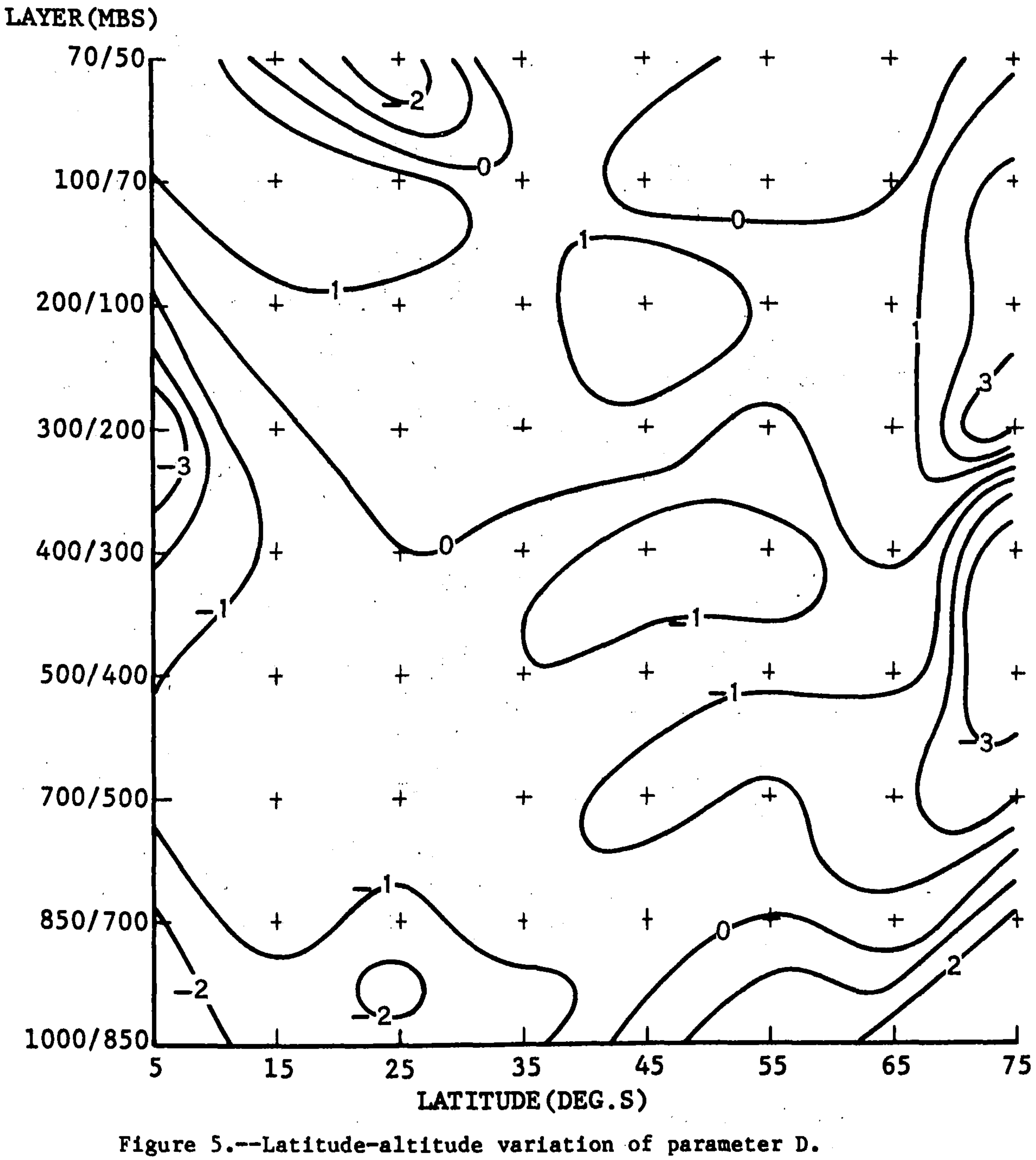

Figure 5.--Latitude-altitude variation of parameter D.

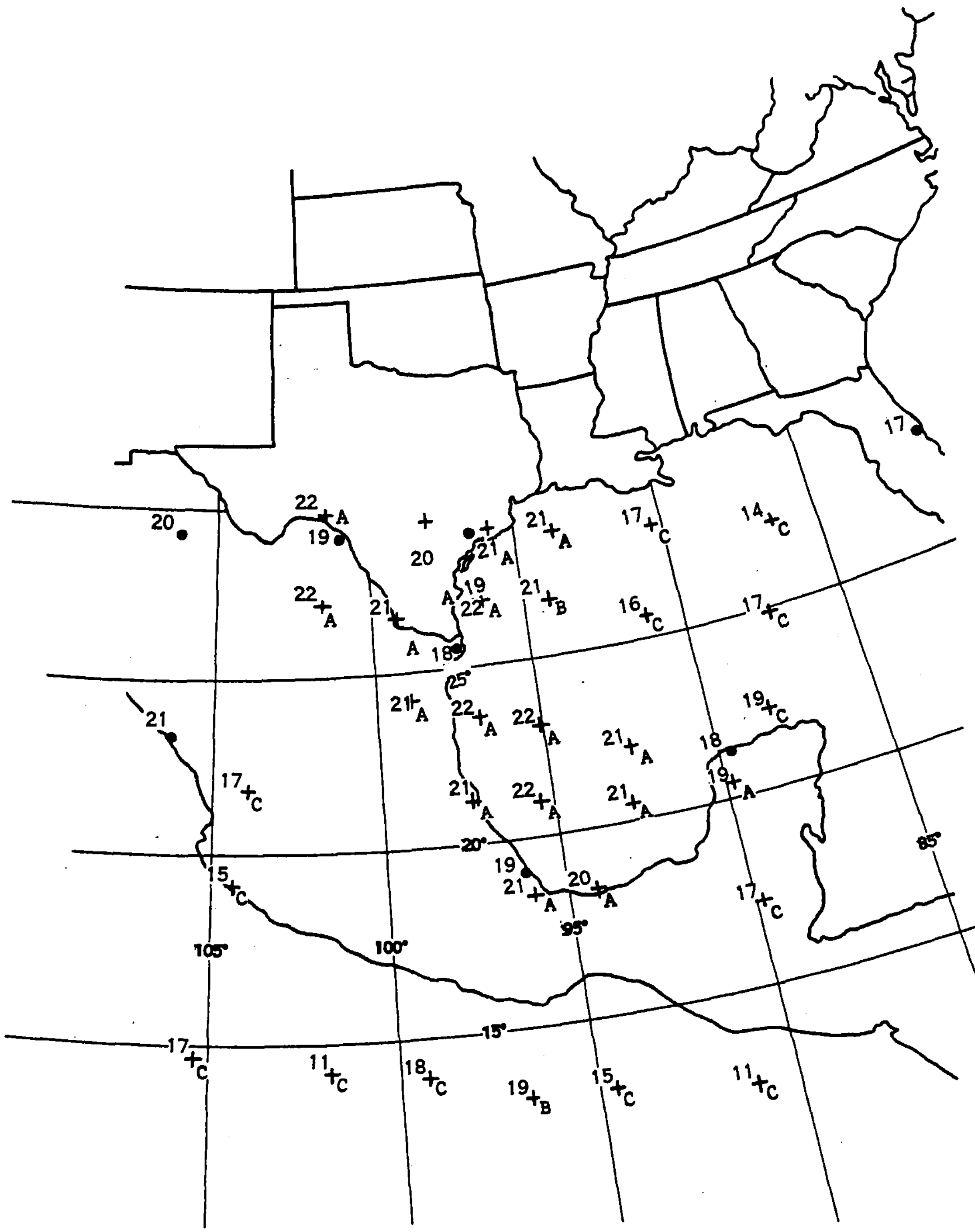

Figure 6.--Low-level bias of retrieval temperatures at near equatorial latitudes of the Northern Hemisphere.

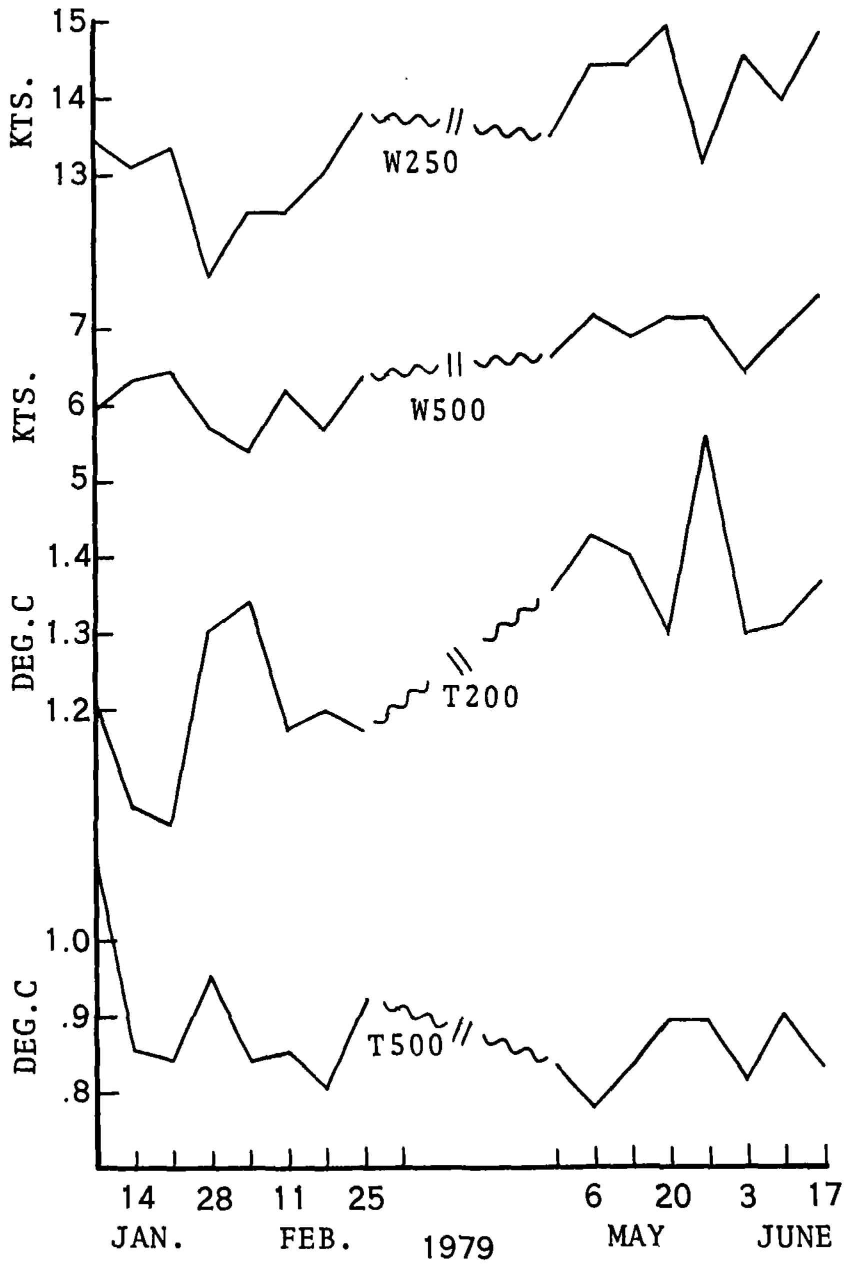

Figure 7.--Plots of weekly rms differences between a selection of conventional observation parameters and the analyses.

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