U.S. DEPARTMENT OF COMMERCE
U.S. Environmental Science Services Administration
" Weather Bureau

ESSA Technical Memorandum WBTM NMC 44

NORTHERN HEMISPHERE CLOUD COVER FOR SELECTED LATE FALL SEASONS USING TIROS NEPHANALYSES

Philip F. Clapp

NATIONAL METEOROLOGICAL CENTER

Suitland, Maryland
December 1968

National Oceanic and Atmospheric Administration

U.S. Joint Numerical Weather Prediction Unit

ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been a co-operative project between the NOAA Central Library, National Center for Environmental Prediction and the U.S. Air Force. This project includes the imaging of the full text of each document. To view the original documents, please contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x124 or www.reference@nodc.noaa.gov.

LASON
Imaging Contractor
12200 Kiln Court
Beltsville, MD 20704-1387
April 13, 2004

~~UDC 551.576:551.507.362.2(215-17)~~

551.5	Meteorology
.576	Clouds
551.5	Meteorology
.507.362.2	Satellites
(215-17)	Northern Hemisphere

148 151

ABSTRACT

Northern Hemisphere fields of mean cloudiness were constructed using TIROS nephanalyses for the late-fall seasons (Oct. to Dec.) of 3 years, 1962-64. These may be useful in studies of cloud climatology and year-to-year variations of the earth-atmosphere heat budget; and for designing and testing cloud-modeling procedures in numerical experiments.

Shortcomings were revealed in the present subjective nephanalysis documentation which hopefully will soon be corrected by the promising work now going on in digitizing the video pictures.

1. Introduction

In a previous study (Clapp, 1964) maps of average cloudiness for most of the Earth's surface were worked up for each season of one year, March 1962 through February 1963, using daily TIROS nephanalyses. The latter contain subjective estimates of cloud amount and structure made by meteorologists from the video pictures. That study has now been supplemented by the construction of new mean cloudiness charts, over the Northern Hemisphere only and for the late-fall season (Oct. to Dec.), of each of the 3 years 1962, 1963, and 1964, using the 1962 data together with additional information from the subsequent two years.

The immediate objectives of the present study are the same as before; to provide mean cloudiness values over large areas of the Earth for use in heat budget studies (Adem, 1965a, 1967) and for testing a thermodynamic numerical model for monthly forecasting (Adem, 1965b).

The results are summarized here in the belief that they will be of general interest in studies of cloud climatology and in relating cloudiness to the general circulation. Some aspects of the differences between satellite and surface cloud observations are also discussed.

The reason for using the nephanalyses as the basic source of TIROS cloud data is also the same as in the previous study: Although these are not suitable for rapid data processing, they are even now the only source of global data from the weather satellites containing quantitized cloud information. Considerable progress has been made in machine processing of the vidicon data (Bristor, Calicott and Bradford, 1966; Bristor, 1967, 1968; Taylor and Winston, 1968), so that now digitized daily and mean satellite pictures on a global scale are routinely available in polar and mercator projections. However, attempts to develop automatic methods for separating the cloud amount and structure from the background of the Earth's surface have not yet been operationally successful.

Similar studies of cloud cover using TIROS and ESSA nephanalyses, but for individual months and for the tropics and sub-tropics only, have been prepared by James C. Sadler of the University of Hawaii (to be published).

2. Procedure

The choice of the three late-fall seasons (rather than other times of the year or using the more conventional definition of seasons) was based entirely on the requirement for sufficient data over the hemisphere from which to construct meaningful analyses. Data coverage by the earlier TIROS series was very erratic due to their spin-oriented configuration, and gaps in both the video pictures and in radiation data were especially bothersome just prior to the advent of the "cartwheel" configuration TIROS and ESSA weather satellites (beginning January 1965). In spite of the care used in selecting the three seasons, data coverage was still unsatisfactory.

The original daily nephanalyses were kindly loaned by the Documentation Section of the National Environmental Satellite Center, U.S. Environmental Science Services Administration (ESSA). Reproductions of most of the ones used in this report, as well as the definition of the cloud symbols plotted on them are contained in several catalogues (ESSA-U.S. Weather Bureau, 1964 to 1966). The cloud-cover symbols, as well as their interpretation in terms of percentage of sky cover, are shown in Table 1.

The definition of the range in cloud cover corresponding to each of the symbols was unfortunately omitted in the catalogues prior to 1964. In the previous study (Clapp, 1964) it was assumed that the symbols clear (C), scattered (S), Broken (B) and overcast (⊕) correspond to the standard World Meteorological Organization definition of these terms.[1] This resulted in considerable overlapping in the ranges assigned to these 4 symbols and in their 3 combinations, and in a highly non-linear cloud-cover scale, as shown in Table 1 of the previous report. Later conversation with Col. James Jones, former head of the TIROS nephanalysis program, indicated that in practice little or no overlap was permitted. Therefore, non-overlapping ranges in cloudiness were chosen for use in the present project (third row of Table 1A), resulting in a more evenly distributed scale (last row).

In 1964, a change was made from a 7-class to a 5-class cloud-cover scale, as shown in Table 1B. The definition of the ranges in cloudiness for the 5 symbols clear, open (O), mostly open (MOP), mostly closed (MCO) and closed (C) is contained in the catalogues, and shown in row 3, with the central value (used as the cloud-cover scale) in row 4.

****

1 The cloud-cover ranges corresponding to the 4 main symbols are so defined in WMO Publication No. 9, Vol. B., Chapter III.

Mean cloudiness over the Northern Hemisphere for each of the 3 seasons was computed for each 5-degree latitude-longitude intersection covered by 1 or more "observations" in the form of individual nephanalyses. The computation was made simply by weighting the average cloud amount (last row of Tables 1A and B) by the number of observations in each class, and then summing and averaging for all classes. This represents a slight improvement over the procedure used in the previous study.

The partially subjective nature of the interpretation of the nephanalysis codes and the computation of mean cloudiness is illustrated by the differences in these procedures used in this study and in that of Godshall (1968).

As in the previous study, the mean seasonal cloudiness was plotted on a Northern Hemisphere base map and analysed by hand, at first by following exactly each plotted cloud amount. This resulted in a great deal of "noise" in the analysis, most of which is probably caused by large random errors due to the small number and poor distribution in time of the observations. Therefore, a final analysis was made by applying a heavy smoothing in drawing the individual isolines of cloud amount. This heavy smoothing no doubt eliminated some interesting detail which may have been quite real, but on the whole it probably increased the accuracy and spacial representativeness of the final values.

The final smoothed analyses are shown in Figs. 1 to 3. Before discussing them and other results it is essential to digress in order to take up some questions about their reliability; but it must be mentioned in passing that the chart for 1964 (Fig. 3) has been adjusted by adding 7% to the smoothed analysis.

3. Reliability of the mean cloudiness

It was hoped at the outset that limits of accuracy could be placed on the mean cloudiness values by comparing them with conventional observations made at surface weather stations. However, this turned out to be impractical because of systematic bias in the observations or processing of both surface and satellite data, and because of the poor distribution of satellite observations through time: i.e., most observations tended to be concentrated in one of the 3 fall months.

In spite of these limitations, some idea of the usefulness of the results was brought out in carrying out various tests of the processed TIROS data. These tests are summarized below.

Fig. 5 shows zonally averaged mean cloudiness (i.e., averages over all longitudes for each latitude circle) for each of the 3 late-fall seasons. It can be seen that the data for 1962 and 1963 are quite consistent with one another. As might be expected from experience with other weather parameters, an excess of one year over the other in a certain latitude band is compensated by a reversal of sign in another band. The 1964 data seem clearly inconsistent with those of the other two years, as shown also by the mean hemispheric differences listed in Table 2A. Evidently this indicates a systematic error in the computations associated with either the 7- or the 5-class codes.

The weight of evidence points to the 1964 data as containing the largest errors, as shown by the following comparisons with surface observations:

In Figs. 6 and 7 the TIROS latitudinal cloud "profiles" for 1963 and 1964 are repeated so as to compare them with corresponding profiles obtained from daily Northern Hemisphere cloud analyses kindly furnished by the Air Force Environmental Techniques Application Center (ETAC). The daily Air Force cloud charts were prepared north of about 15°N. using surface observations from land stations and ships at sea. In regions of scarce data some weight was given to previously determined climatological averages. No Air Force data were available for Fall 1962.

Fig. 6 shows that the Air Force and TIROS data are quite compatible for Fall 1963, although a hemispheric average of the former is slightly smaller than that of the latter (Table 2B). However, in 1964 (Fig. 7) the TIROS data appear to be systematically lower than the Air Force data. The hemispheric-averaged difference (Table 2B) has the same sign but is somewhat smaller than the differences among the TIROS data (Table 2A).

Another attempt to isolate errors in the TIROS seasonal mean cloudiness was made by plotting it against corresponding average daytime cloudiness (sunrise to sunset) for almost 200 first-order Weather Bureau stations over the conterminous U.S., (U.S. Dept. of Commerce, 1962 to 1964). A smooth curve of "best fit" was then drawn through the plotted points. This curve bisects the two curvilinear regression lines (Ezekiel, 1930, ch. 6), and was used here because it better represents the true relationship between any two variables than does either of the two regression lines. The curves of best fit for the 3 seasons are reproduced in Fig. 8, and the average differences between surface and TIROS cloudiness for all U.S. stations are shown in the first 3 rows of Table 2C. Again these suggest a large systematic error in the 1964 data, although in this case the average difference (line 3 of Table 2C) is somewhat larger than the corresponding values in Table 2A and B.

A similar but even larger systematic difference between surface and TIROS cloudiness over the U.S. was detected by Barnes (1966) (Table 2C, line 4). Although his data were drawn from all months of the years 1962 to 1965, all but 3 of 19 months were from 1964 and 1965, when the 5-class TIROS cloud code was in effect.

The impossibility of trying to establish a quantitative estimate of the TIROS errors is suggested by the inconsistencies between processed surface mean cloudiness values, as well as in their comparison with TIROS data. Such inconsistencies are revealed in the way the systematic differences depend on cloudiness. Thus it will be noted from the curves in Fig. 8 that for the years 1963 and 1964 the difference, surface minus TIROS cloudiness, increases in a positive sense with increasing cloudiness; but just the opposite trend is obtained on comparing latitudinal averages of Air Force surface and TIROS data for 1964 (Fig. 7).

This opposite trend in the differences is also found in all seasons of 1962 over the U.S. (Clapp, 1964, Fig. 6; and curve for 1962 in Fig. 8, this paper). This reversal in the trends between 1962 and 1963-64 is very unlikely to result from a basic change in observing practice at the first-order Weather Bureau stations, but rather to changes in the interpretation or processing of the TIROS video pictures.

Because of the difficulties enumerated above, it was decided to abandon any attempt to "correct" the TIROS processed data, and instead to make it more internally consistent simply by adding 7% to the 1964 values. This adjustment has been included in Figs. 3, 4, and 10.

4. Brief summary of results

The average cloudiness for all three seasons (Fig. 4) may be considered as a new estimate of cloudiness climatology for late Fall over the Northern Hemisphere. Comparison with previously published climatic cloud charts (e.g., Landsberg, 1945), reveals significant differences which may merely reflect secular changes in climate or the limitations of the short record used in the present study. On the other hand, some of the larger changes over the oceans undoubtedly are real, due to the scarcity of conventional historical data over vast areas of the sea.

The availability of mean cloud maps from the same season of 3 different years makes it possible to look into the feasibility of detecting changes or anomalies in cloud patterns from year-to-year; an important factor in testing numerical models or in studying changes in the heat budget of the atmosphere. Figs. 9 and 10 show the changes in the TIROS cloud patterns from 1962 to 1963 and from 1963 to 1964. The strong tendency for a reversal in sign of the more prominent change centers from 1962-63 to 1963-64 should be noted. This tendency for large departures to return to normal over long periods of time is well known for other meteorological parameters (e.g., compare Figs. 14 and 15), but may appear somewhat surprising in the cloud cover, which on a day-to-day time scale has a much more temporary or transient character than pressure or temperature. This result illustrates the mutual interdependence between cloudiness and the large-scale circulation centers.

Fig. 11 shows the change in cloud cover from 1963 to 1964 obtained from the Air Force cloud charts; and Figs. 12 and 13 the changes for both pairs of years from the Weather Bureau stations in the conterminous United States. These reveal a general agreement in pattern with the TIROS cloud changes (Figs. 9 and 10) but there are many important local differences, and the magnitude of the cloudiness changes based on the Air Force data seems generally smaller than the others.

In Figs. 14 and 15 are presented the corresponding changes in seasonal mean surface pressure over the Northern Hemisphere. These may give the reader some idea of possible relationships between cloud and circulation-pattern changes.

Finally, late-fall charts of planetary albedo for 1963 (Fig. 16) and of outgoing long-wave radiation for 1963 and 1964 (Figs. 17 and 18) are presented here for the sake of completeness, since these were prepared with the cloud charts as part of the same heat-budget study. These were based on TIROS 7 data kindly furnished by the Meteorological Satellite Laboratory of the National Environmental Satellite Center, ESSA.

The map of planetary albedo is based on very scanty information from the channel 5 radiometer, which like the vidicon cameras can operate only in sunlit regions; while the maps of outgoing long-wave radiation are based on more abundant information from the channel 2 radiometer, which can operate both day and night. A discussion of some of the problems and limitations involved in processing this type of data is contained in a report by Winston (1967).

5. Conclusions

Studies of the type summarized here serve not only the immediate purpose of developing a cloud climatology useful in heat-budget research, but also focus attention on the limitations of the present satellite cloud documentation and the need to develop more uniform procedures designed for rapid data processing.

Since this project was intended primarily for obtaining mean cloud patterns over broad areas of the Earth, no attempt has been made here to investigate in detail the many complex factors leading to systematic or random errors in either the satellite or surface observations themselves or in their processing. Such investigations must be the subject of specialized research (e.g., Young, 1967). However, some of these factors had to be discussed in order to properly interpret the cloud charts.

One of the more important things which was revealed is the inconsistency within the subjective method, which no doubt is associated with the choice of a cloud code and its subjective interpretation. It was shown that this results in a large and systematic departure from surface-observed cloudiness which depends critically on cloud amount, and changes sharply from year to year.

Automation of this process may avoid these inconsistencies, but is not likely to do away with systematic differences between surface and satellite cloud data. Indeed, it seems clear that any attempt to force such agreement would be misguided, because there are probably real differences in the apparent cloud structure as seen from the Earth or from space. In fact, it is probable that the cloudiness as seen from space is more closely related to the radiation budget of the earth-atmosphere system.

Finally, it must not be assumed that the separation of cloud structure and amount from other radiation-related factors is an unimportant problem, because numerical models designed for extended and long-range weather forecasting must be capable of predicting the clouds in order to properly generate the heat budget. Therefore, accurate and timely maps of observed cloud structure and amount on a global scale will become increasingly essential both as input data to the models and for checking the cloud-modeling assumptions. Snow and ice cover will be a welcome "by-product" of such background separation. This, too, is an important element in the heat balance.

Acknowledgments

Special thanks are due Jay S. Winston and Thomas I. Gray of the Meteorological Satellite Laboratory, ESSA, for their help in obtaining and processing the TIROS nephanalysis and radiation data; and to Lt. Col. John Jones, U. S. Air Force, for a like service with regard to the Air Force cloud data.

REFERENCES

Adem, J., 1965a: Preliminary model for computing mid-tropospheric and surface temperatures from satellite data. J. Geophys. Res., 70, 2763-2767.

Adem, J., 1965b: Experiments aiming at monthly and seasonal numerical weather prediction. Mon. Wea. Rev., 93, 495-503.

Adem, J., 1967: On the relations between outgoing long-wave radiation, albedo and cloudiness. Mon. Wea. Rev., 95, 257-260.

Barnes, J. C., 1966: Note on the use of satellite observations to determine average cloudiness over a region. J. Geophys. Res., 71, 6137-6140.

Bristor, C. L., W.M. Callicott and R.F. Bradford, 1966: Operational processing of satellite cloud pictures by computer. Mon. Wea. Rev., 94, 515-527.

Bristor, C. L., 1967: Satellite data collection. Proc. IBM Scientific Computing Symposium on Environmental Sciences, Nov. 14-16, 1966, Yorktown Heights, N. Y., 5-17.

Bristor, C.L., 1968: Computer processing of satellite cloud pictures. Tech. Memo. NESCTM-3, U.S. Dept. of Commerce, Environmental Science Services Admin., 11 pp.

Clapp, P.F., 1964: Global cloud cover for seasons using TIROS nephanalyses. Mon. Wea. Rev., 92, 495-507.

ESSA - U.S. Weather Bureau, 1964-66: Catalogue of Meteorological Satellite Data, Television Cloud Photography, TIROS 5 to 8. Key to Meteorological Records Documentation No. 5.35 to 5.38, U.S. Government Printing Office, Washington, D. C.

Ezekiel, M., 1930: Methods of Correlation Analysis, London, John Wiley and Sons, Inc., 427 pp.

Godshall, F.A., 1968: Intertropical convergence zone and mean cloud amount in the tropical Pacific Ocean. Mon. Wea. Rev., 96 172-175.

Landsberg, 1945: Climatology. Sec. XII, Handbook of Meteorology, New York, McGraw-Hill Book Co., Inc., 928-997.

Taylor, V.R. and J.S. Winston, 1968: Monthly and seasonal mean global charts of brightness from ESSA 3 and 5 digitized pictures, Feb. 1967-Feb. 1968. ESSA Tech. Rpt. NESC-46, U.S. Dept. of Commerce, Environmental Science Services Admin., 8 pp. + 17 chts.

U.S. Dept. of Commerce, Weather Bureau, 1962-64: Climatological Data, National Summary. 13, 14, 15.

Winston, J.S., 1967: Planetary scale characteristics of monthly-mean long-wave radiation and albedo and some year-to-year variations. Mon. Wea. Rev., 95, 235-256.

Young, M.J., 1967: Variability in estimating total cloud cover from satellite pictures. J. Appl. Meteor., 6, 573-579.

Table 1.--Codes for Computing Mean Cloudiness from TIROS Nephanalyses.

A. 1962 and 1963

Symbols	C	CvS	S	SvB	B	Bv⊕	⊕
Code	1	2	3	4	5	6	7
Range (%)	0-12½	12½-25	25-50	50-62½	62½-75	75-87½	87½-100
Average (%)	6	22	38	54	69	82	94

B. 1964

Symbol	Clear*	O	MOP	MCO	C
Code	1	2	3	4	5
Range (%)	0	0-20	20-50	50-80	80-100
Average (%)	0	10	35	65	90

*Very few cases.

Table 2.--Differences in Average Cloudiness (Percent) for Late Fall, Oct. to Dec. (unless otherwise indicated).

A. Differences in TIROS cloudiness over Northern Hemisphere, Equator to 55°N.

1.	1963 minus 1964	+7.7
2.	1962 minus 1964	+7.2

B. Surface-observed* minus TIROS cloudiness over Northern Hemisphere, 15° to 55°N.

1.	1963	-1.4
2.	1964	+5.5

*From Air Force cloud charts.

C. Surface-observed* minus TIROS cloudiness over the U. S.

1.	1962	+1.5
2.	1963	+2.9
3.	1964	+10.6
4.	1962-1965 (all months)	+14.6

*1962, 1963 and 1964 computed in this study; 1962-1965 after Barnes (1966).

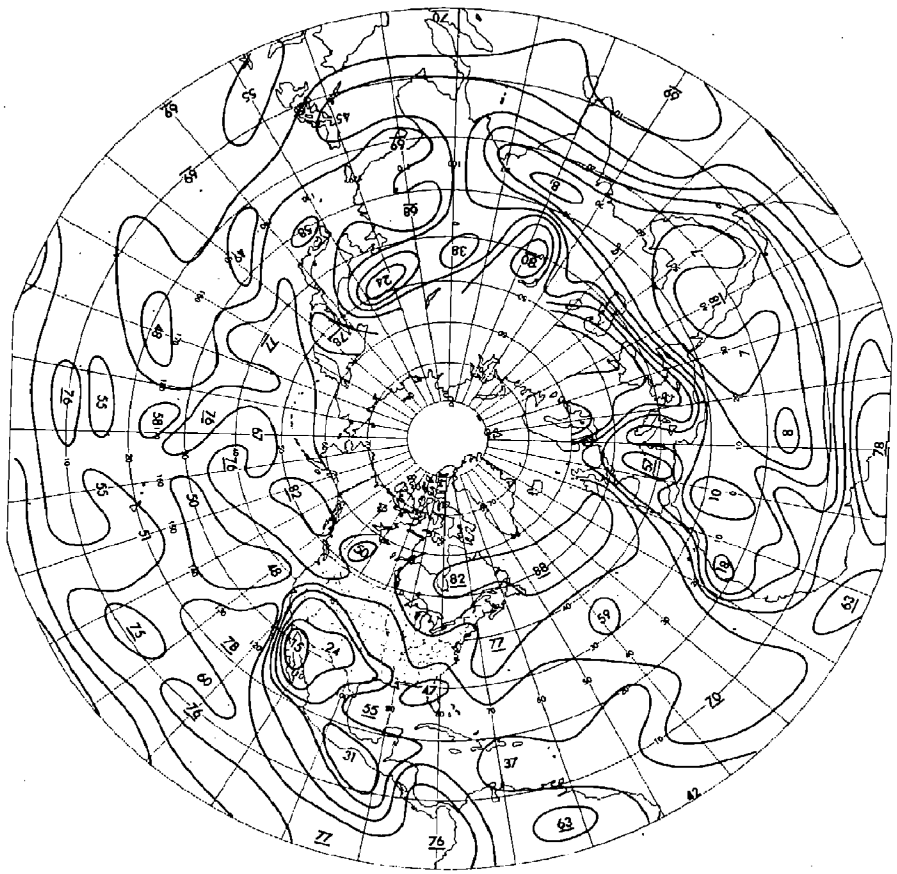


Fig. 1. Average daytime cloudiness from TIROS nephanalyses for late-fall (October to December) 1962. Isolines drawn for every 10 percent sky cover, with centers labelled in percent (maxima underlined).

Fig. 2. Same as Fig. 1, but for 1963.

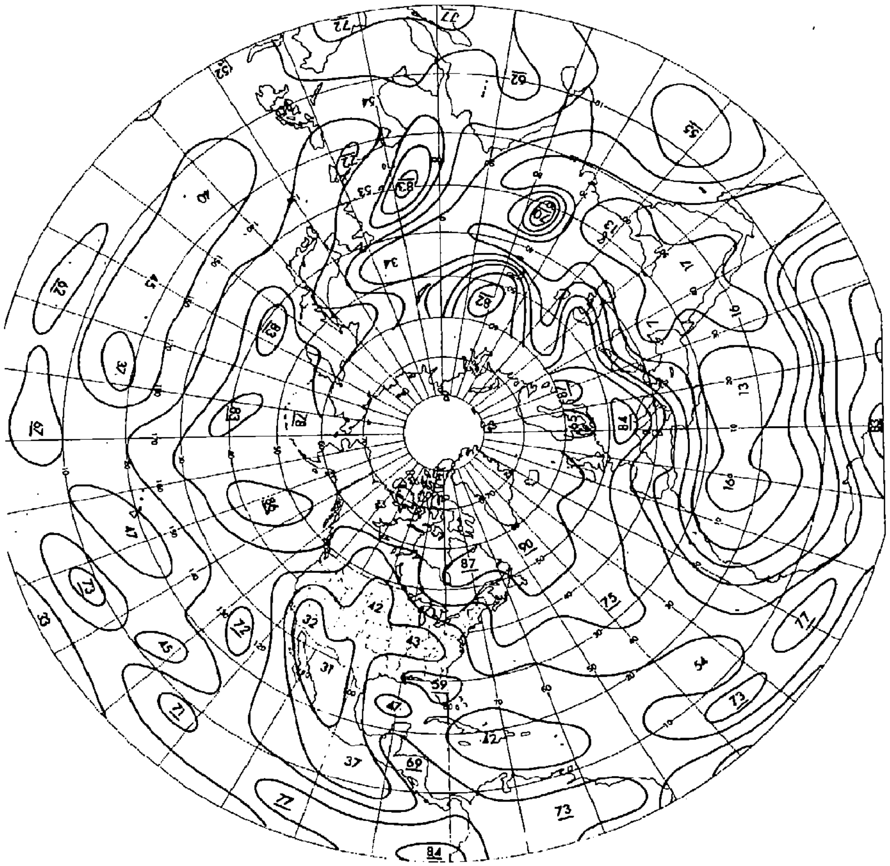


Fig. 3. Same as Fig. 1, but for 1964.

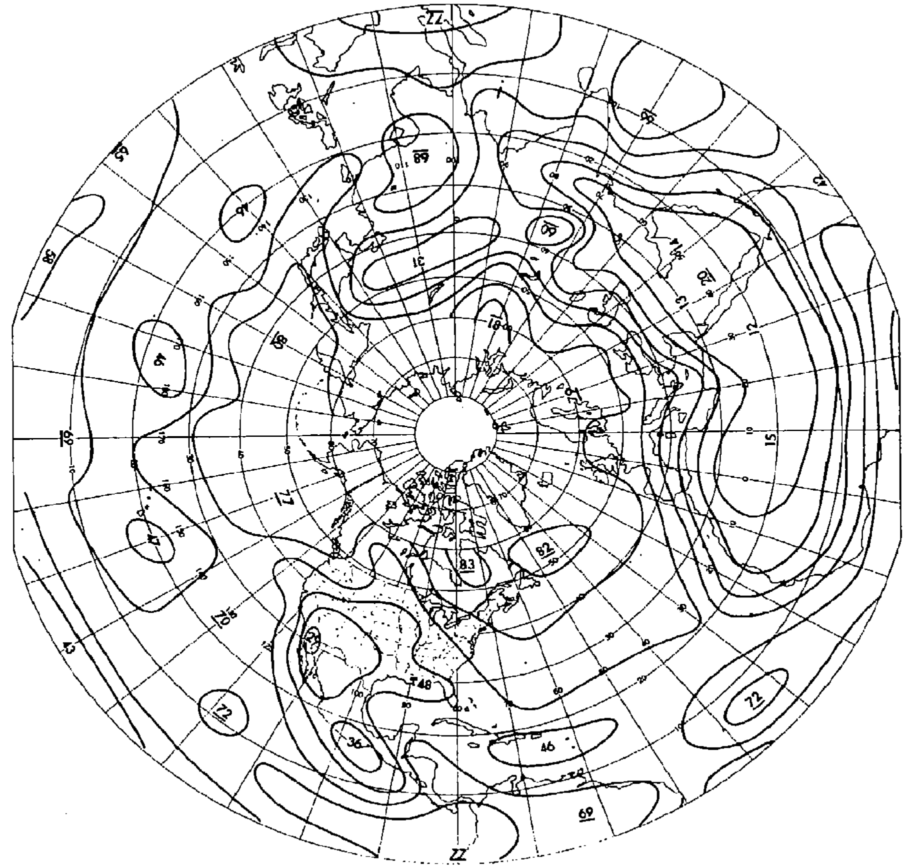


Fig. 4. Same as Fig. 1, but average for 3 years 1962-1964.

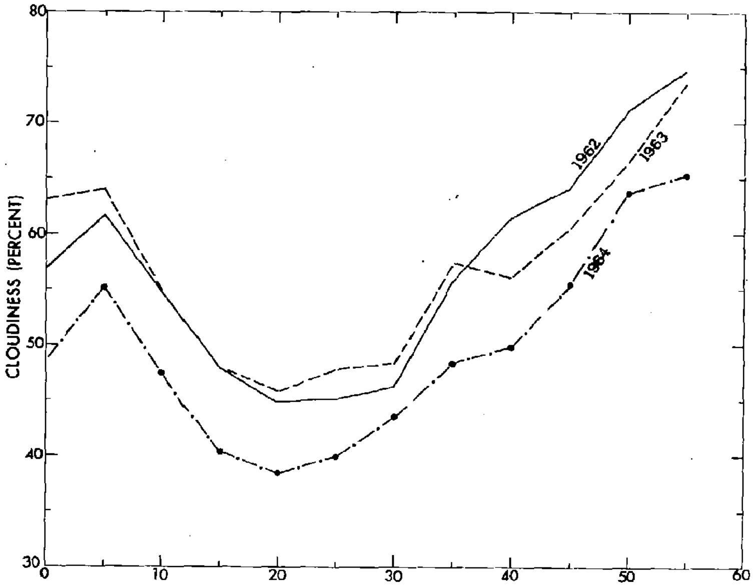


Fig. 5. Zonally-averaged cloudiness vs. latitude from TIROS nephanalyses for 3 late-fall seasons (Oct. to Dec.). Solid Curve, 1962; dashed, 1963; dash-dot, 1964.

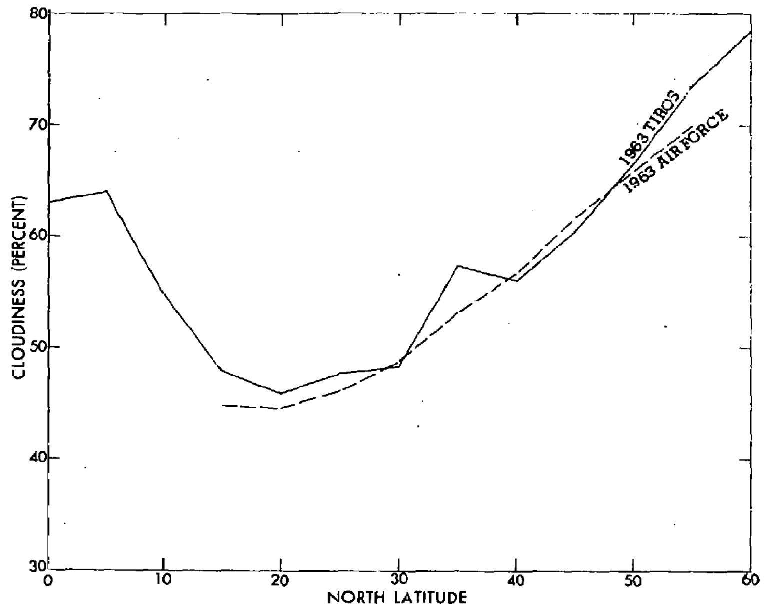


Fig. 6. Zonally-averaged cloudiness vs. latitude for late-fall 1963. Solid curve, from TIROS nephanalyses; dashed, from surface observations compiled by Air Force (ETAC).

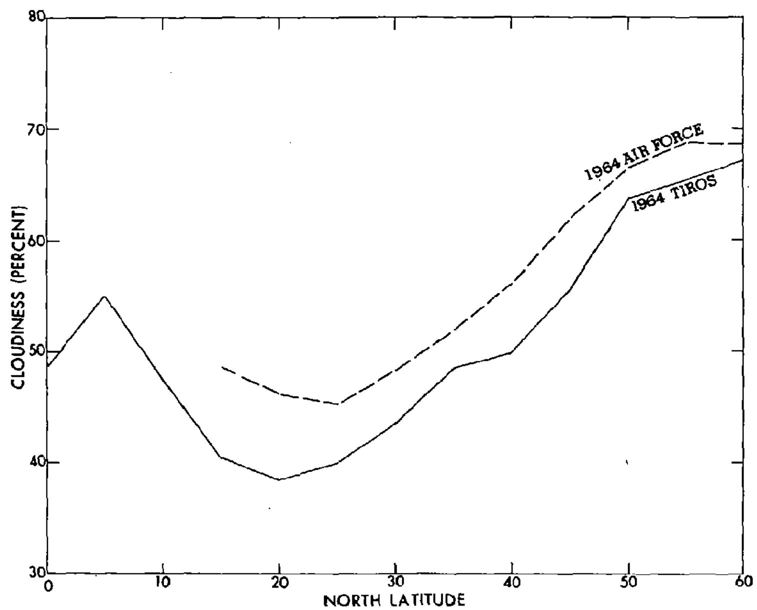


Fig. 7. Same as Fig. 6, but for 1964.

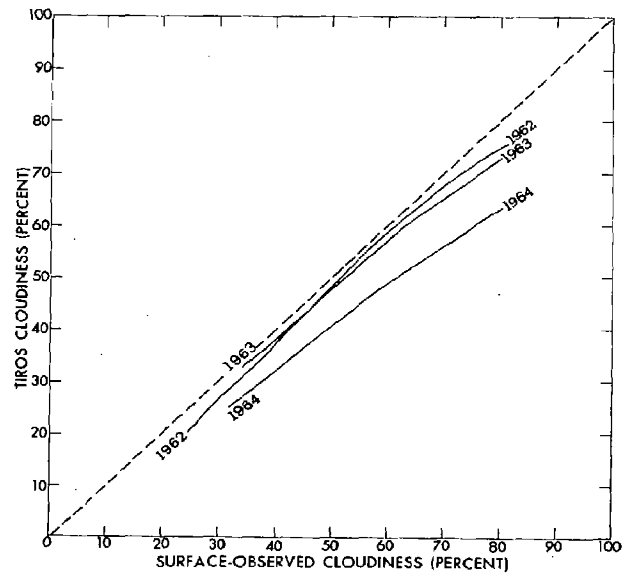


Fig. 8. Curves of best fit (solid) relating mean cloudiness from surface observations at about 200 stations over the U.S. with that interpolated from TIROS cloud charts, late-fall (October to December) of the years 1962, 1963 and 1964. Dashed line represents perfect agreement.

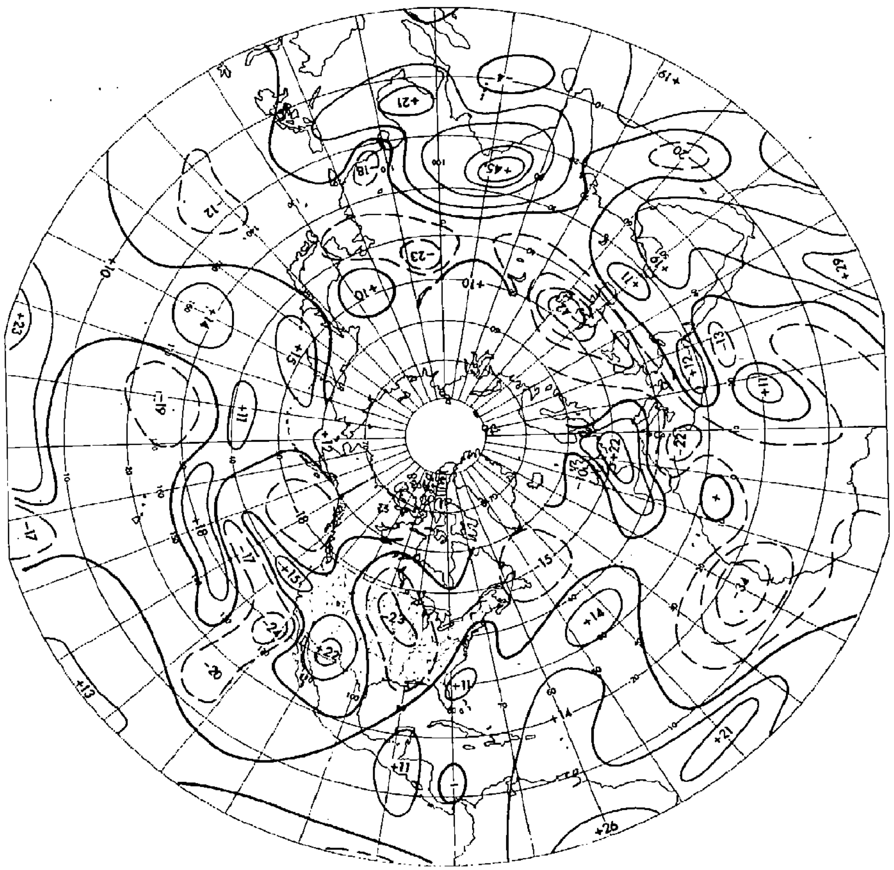


Fig. 9. Change in late-fall cloudiness, 1963 minus 1962; from TIROS cloud patterns shown in Figs. 1 and 2. Isolines drawn for each 10-percent change, with zero line heavier; positive change solid and negative, dashed. Centers labelled in percent.

Fig. 10. Same as Fig. 9, but for 1964 minus 1963 and from Figs. 2 and 3.

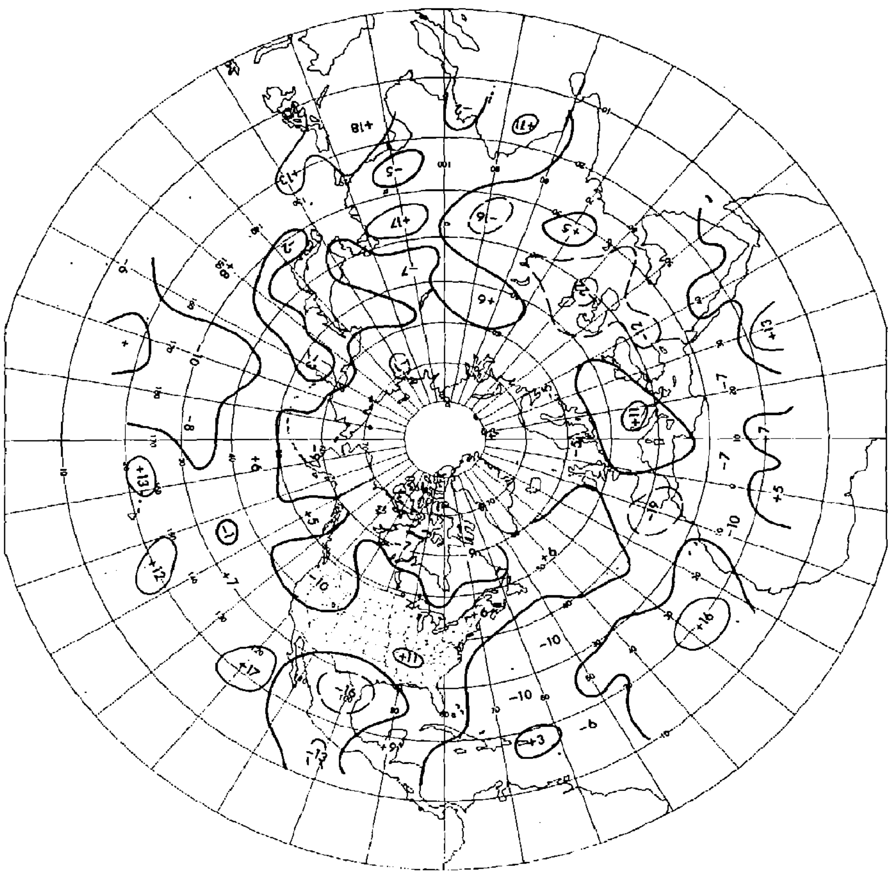


Fig. 11. Change in late-fall cloudiness, 1964 minus 1963; from cloud maps based on surface observations compiled by Air Force (ETAC). See Fig. 9 for units.

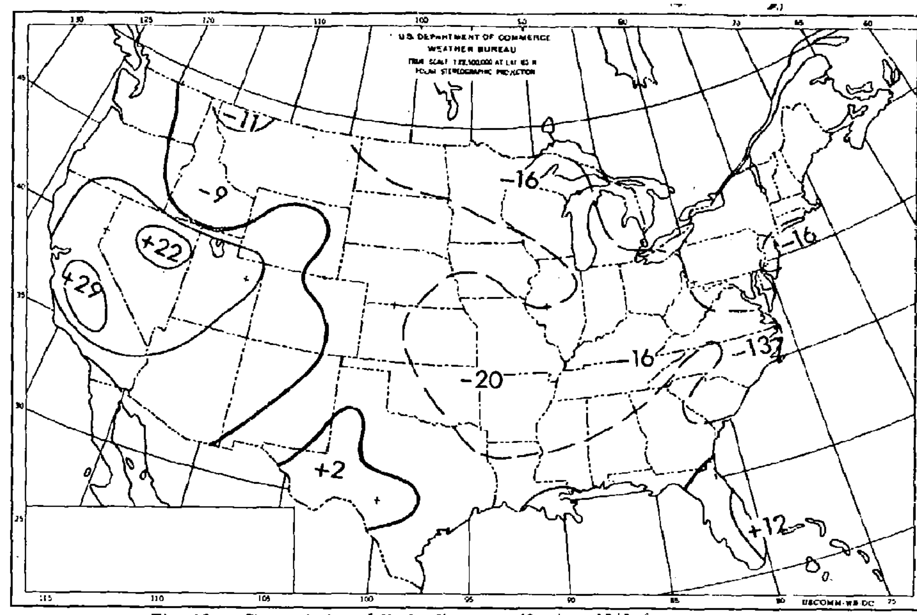
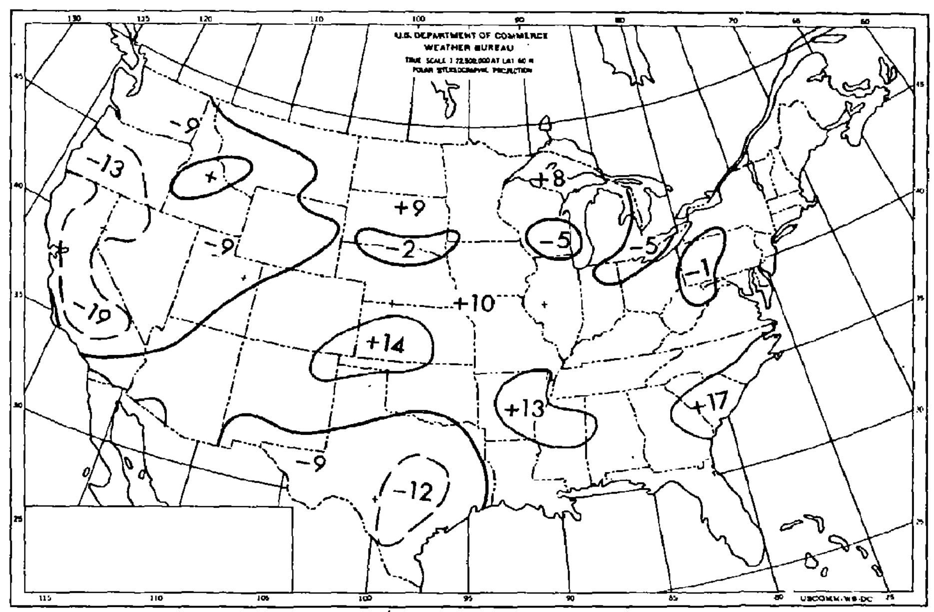


Fig. 12. Change in late-fall cloudiness, 1963 minus 1962; from average cloudiness at about 200 weather stations over the U.S. See Fig. 9 for units.



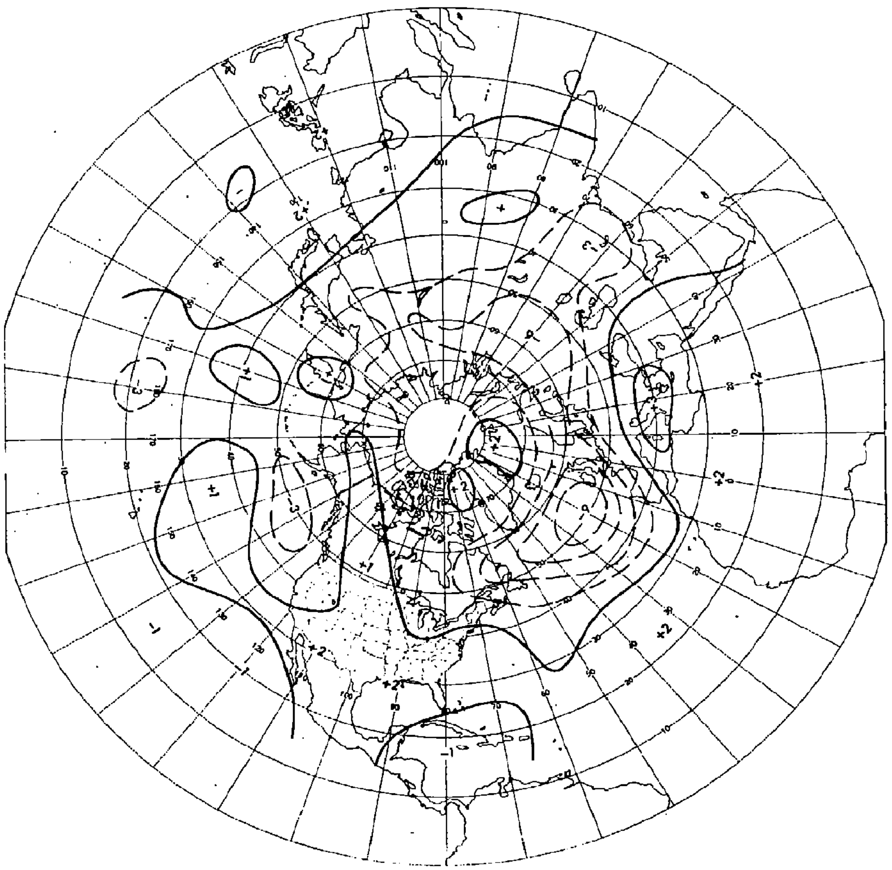


Fig. 14. Change in sea-level pressure, late Fall 1963 minus 1962. Isolines drawn for each 2 mb. change, with zero line heavier; positive change solid and negative, dashed. Centers labelled in mb.

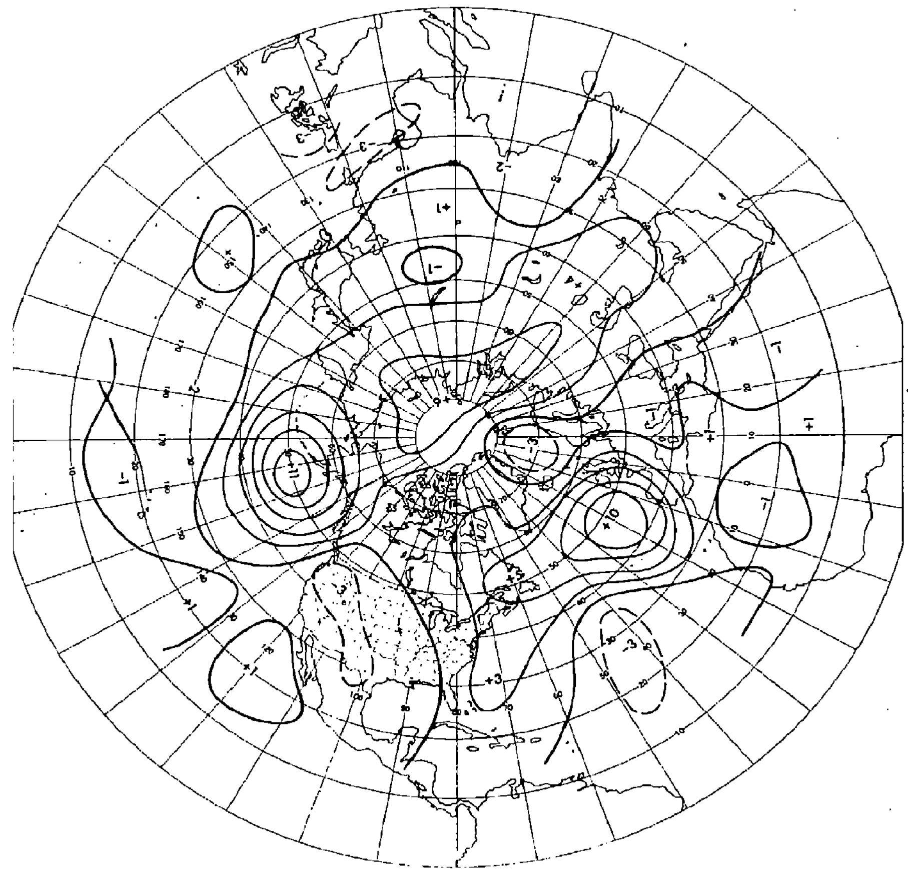


Fig. 15. Same as Fig. 14, but for 1964 minus 1963.

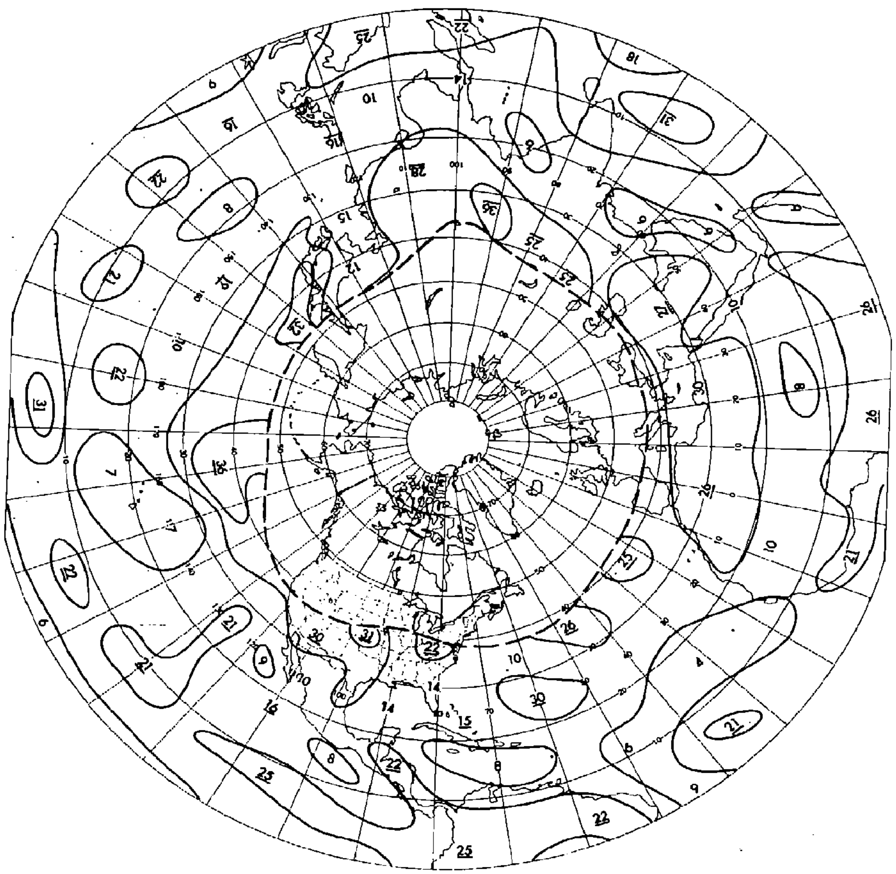


Fig. 16. Planetary albedo, late Fall 1963, from TIROS 7 channel 5 radiometer data. Centers labelled in percent (maxima underlined) with isolines for each 10 percent. No observations north of dashed line.

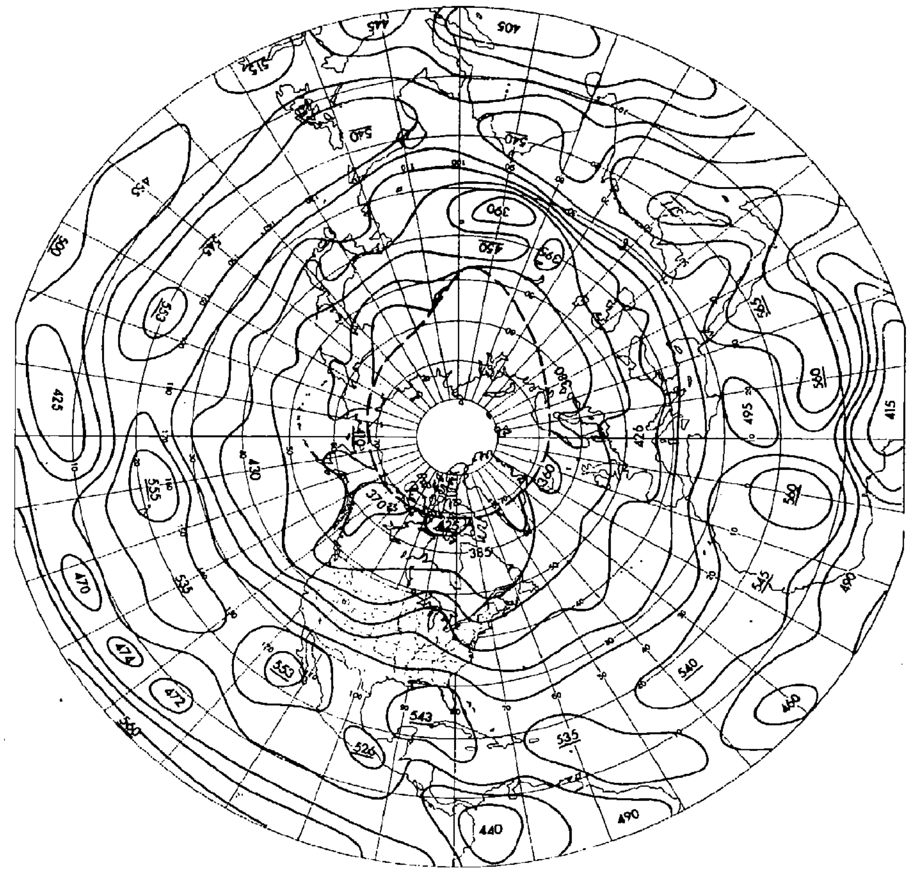


Fig. 17. Outgoing long-wave radiation, late Fall 1963, from TIROS 7 channel 2 radiometer data. Centers labelled in cal. cm. $^{-2}$ day $^{-1}$ (maxima underlined) with isolines each 25 units. No observations north of dashed line.

Fig. 18. Same as Fig. 17, but for 1964.