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NATIONAL ENVIRONMENTAL SATELLITE CENTER NESC 43

Atlas of World Maps of Long-Wave Radiation and Albedo

For Seasons and Months Based on Measurements From Tiros IV and Tiros VII

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For Seasons and Months Based on Measurements From Tiros IV and Tiros VII

JAY S. WINSTON and V. RAY TAYLOR

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National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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ATLAS OF WORLD MAPS OF LONG-WAVE RADIATION AND ALBEDO FOR SEASONS AND MONTHS BASED ON MEASUREMENTS FROM TIROS IV AND TIROS VII

Jay S. Winston and V. Ray Taylor
National Environmental Satellite Center

ABSTRACT

Monthly and seasonal global charts of long-wave radiation and albedo are presented for the periods February - June 1962 (TIROS IV) and July 1963 - May 1964 (TIROS VII). Monthly average 700-mb. height and geostrophic wind charts for the Northern Hemisphere are shown for comparison with radiation data. Also given are difference maps for corresponding months of different years. Derivation of the data and the format in which the data are presented are discussed.

I. INTRODUCTION

Daily composite maps of outgoing long-wave radiation and albedo have been prepared in the Office of Research of the National Environmental Satellite Center for all days when usable measurements were made by the scanning (medium resolution) radiometers aboard TIROS IV and TIROS VII[1]. These charts have been used to derive various time averages of the radiation data for periods ranging from 5 days to seasons. In this atlas monthly and seasonal world charts of long-wave radiation and albedo (when available) covering the periods February - June 1962 (TIROS IV) and July 1963 - May 1964 (TIROS VII) are presented. Also shown are the monthly mean 700-mb. height and geostrophic wind speed fields for the Northern Hemisphere. These allow for ready comparison of the radiation patterns with the tropospheric flow over the Northern Hemisphere. Also, for those months when radiation data were available for two different years, charts are presented showing differences in the patterns of both long-wave radiation and 700-mb. height.

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1 At the time of this writing TIROS VII daily composites have been prepared continuously through May 1964. Some additional periods have been processed but poorer data coverage and less reliable data in the second year of operation of TIROS VII have forced us to give low priority to the further preparation of daily composites of TIROS VII data.

Some of the charts shown here have already been published [11] or are scheduled for publication [12], but a substantial number have not previously been prepared for publication. The purpose in presenting this collection of charts is to make available in a convenient and compact form all the monthly and seasonal global charts of the radiation data which we have prepared to date.

Discussion of the features of these charts is not given here since detailed discussions of many of the charts may be found in the published articles [11, 12]. However, for the convenience of those using this atlas, the derivation and reliability of the data are discussed and the analysis format of the charts is explained.

II. DERIVATION OF DATA

Details of the scanning radiometers on TIROS IV and TIROS VII, their pre- and post-launch characteristics, and the data-processing procedures are given in the radiation data catalogs and users' manuals [5-9]. The data were processed and mapped by electronic computer from copies of the Final Meteorological Radiation Tapes which contain digitized data from all five channels. Only data from the "single, open mode" of operation were used in this study, because of location uncertainties with the other two modes of operation [5, 6].

Values of outgoing long-wave radiation were derived from intensity values of channel 2 (8-12 μ). These were converted to total outgoing long-wave radiative flux using the relationships derived by Wark et al. [10]. Individual values from this channel were corrected for limb-darkening using average corrections derived empirically by Lienesch and Wark [2] from samples of TIROS IV and VII data.

Planetary albedo was obtained from intensity values of channel 3 (0.2 - 6.0 μ) of TIROS IV and of channel 5 (.55 - .75 μ) of TIROS VII. The use of the more spectrally restricted channel 5 measurement for TIROS VII was necessary because channel 3 did not behave reliably on this satellite [6]. Each individual intensity value, which has a particular solar zenith angle and a certain satellite viewing angle, is divided by the intensity of radiation that would reach that particular spot viewed from outside the atmosphere, assuming a solar constant of 2.00 ly. min.$^{-1}$. In this treatment of the data it is assumed that the reflecting and scattering properties of the atmosphere and the earth's surface are isotropic. Thus each value of reflectivity at a given spot is assumed to be representative of reflectivity in all directions and hence represents a value of albedo. Admittedly this is a very simple assumption. However, a study of angular dependence in these TIROS measurements for cloud cases [4] indicates that relatively small changes in albedo (a few percentage units) would generally result from applying an angular adjustment to the data for cloud cases. Such differences are much smaller than the differences between the average uncorrected albedo data and what are thought to be reasonable values for albedo. Thus even though the isotropic assumption could cause some errors in absolute magnitude, it is unlikely that the patterns of the albedo charts could be noticeably altered by applying an angular

adjustment to the data. In order to avoid lower intensities of reflected solar radiation, which would lead to more chance of error, no data with solar zenith angles greater than 60° were used. However, this restricts the data sample, mainly at higher latitudes.

The accuracy of the absolute values of the radiation data are questionable because of calibration and degradation problems. Certain correction factors have been presented by Staff Members, NASA [5-9]. These have been based largely on studies of "quasi-global" average values and are approximate at best. More detailed examination of daily average TIROS IV radiation values by Rao et al. [3] generally verified the degradation corrections for long-wave radiation presented in [5], but adjustments for the albedo values were found to be quite different. Although the corrections for albedo derived in [3] could not be firmly established as being markedly superior to those in [5], they did appear more reasonable when specific cases were examined. Thus the corrections given by Rao et al. were applied to all the TIROS IV data (both long-wave and albedo) appearing in this study. The degradation corrections presented for TIROS VII long-wave radiation data by Staff Members, NASA [6-9] are somewhat in doubt, particularly in view of some of the results achieved when the corrections were applied. For example, zonal averages for March-May 1964 using these corrections [1] appear to be too high at all latitudes when compared with the corrected TIROS IV values for the period March-May 1962 [12]. The TIROS VII albedo corrections of [1], which are based on the requirement for radiative equilibrium over the earth, are also in doubt since the albedo coverage was considerably less than what can really be considered "quasi-global." Furthermore, it is essentially a moot question whether radiative equilibrium is actually attained in a given season or even over a whole year. Evidently further study of the degradation correction question for TIROS VII radiation data is in order, but lacking such a study at this time, no corrections have been applied to the TIROS VII radiation data shown in the maps presented here, except in the case of the charts showing differences of long-wave radiation from one year to another.

The daily composite maps, from which the monthly and seasonal charts are compiled, consist of averages of all TIROS observations in 5 degree latitude-longitude boxes for all orbital passes acquired in a given daily sequence (i.e., over a period of up to 13 hours). At middle and higher latitudes (poleward of about latitude 30°) these average values usually consist of data from two or more consecutive orbits (about 1 1/2 hours apart); in lower latitudes they are usually from one pass. The number of orbital passes of radiation data acquired each day generally varied between 3 and 8, but even with maximum acquisition there were several major gaps in the data coverage. All daily composite values derived from a sufficient data sample (20 or more observations within a 5 degree box each day) were used in further temporal and spatial averaging of the data.

Since the local time at which a given location is observed changes from day to day, there can be some bias toward observations taken at certain local times depending upon the period of averaging. The full orbital-solar cycle was approximately 67 days for TIROS IV and about 75 days for TIROS VII. If the data are averaged over periods of 1 or more multiples of this cycle there is the opportunity to obtain a reasonable sampling of the radiation over all hours of the day at each location. For the TIROS VII data the approximately 90-day period of each season is fairly close to 75 days so that relatively little bias toward one part of the day is likely. (This is particularly true for the period used to represent the average for June-August 1963 which is very nearly 75 days.) With TIROS IV the 92-day period of March-May 1962 is closer to 1 1/2 cycles so that some bias exists toward either nighttime or daytime values for certain areas. For an average over a monthly period, which is somewhat less than half of the orbital-solar cycle, the data originate from periods emcompassing somewhat less than half of the day. These times of the day differ mainly with latitude, depending upon the portion of the orbit from which observations of each locality are made. Thus in a given month the data over a given area may have been acquired during daytime only, during nighttime only, or during both day and night. Of course, when both albedo and long-wave radiation charts are shown for a given month it is easy to determine by inspection which parts of the long-wave radiation data shown are based on predominantly daytime or nighttime measurements.

Presuming that diurnal variations in surface temperature and cloudiness are small over oceans, diurnal biases in the data are most important over land areas, particularly those with large diurnal variations in surface temperature and cloudiness. Since the influence of the daytime maxima in cloudiness and surface temperature tend to oppose each other insofar as long-wave radiation is concerned, the effect would be most pronounced in dry, cloudless areas where diurnal temperature variations are extreme. Thus such areas as the Sahara Desert, the Middle East, Australia, parts of southern Africa, and the southwestern United States and northwestern Mexico must be considered as subject to strong diurnal bias in many of the time-averaged long-wave radiation data shown here. It is possible that with careful consideration of the diurnal variation of temperature and cloudiness (amount, type, height of tops) determined from representative surface observations in many of the land areas, one could devise ways of adjusting the radiation values in these regions to be more representative of the entire 24 hours of the day. However, synoptic variations over the day are also involved, so the problem is quite complicated and can never be completely solved so long as the satellite measures the radiation at only one time of a given day.

Monthly mean 700-mb. height values were obtained from the Extended Forecast Division which prepares them from twice-daily objective analyses of the National Meteorological Center. Geostrophic wind speeds were calculated from the monthly mean 700-mb. height values.

III. EXPLANATION OF CHARTS

On the charts of outgoing long-wave radiation and albedo, isopleths cover all regions where there were representative values of the given quantity on at least one-tenth of the days in each period. Over the analyzed areas the number of days with data varied considerably. Regions of lesser data

coverage are indicated by the dashed isopleths which are used where data were available for less than one-third of the days. Isopleths of long-wave radiation are drawn at intervals of 2×10^{-2} ly. min.$^{-1}$. Areas with values less than 32×10^{-2} ly. min.$^{-1}$ are stippled and those with values greater than 36×10^{-2} ly. min.$^{-1}$ are hatched. H and L refer to maxima and minima of radiation, respectively. Isopleths of albedo are drawn at intervals of 5 percent. Areas with values less than 15 percent are hatched and those with more than 25 percent are stippled. H and L refer to maxima and minima of albedo, respectively. No albedo charts are presented for the months of July 1963, February and May 1964, and for the season March-May 1964, because of very sparse data during these periods.

In the charts showing monthly mean 700-mb. height and geostrophic wind, the height contours are drawn at intervals of 200 geopotential feet (solid), with some intermediate 100-ft. contours (dashed). H and L refer to centers of maximum and minimum height, respectively. Isotachs of geostrophic wind speed at 700 mb. (dotted lines) are drawn at intervals of 4 m. sec.$^{-1}$. F and S refer to maxima and minima of wind speed, respectively, except that S is not shown where H and L appear. Well-defined axes of maximum wind speed are indicated by heavy lines where speeds exceed 8 m. sec.$^{-1}$.

In the charts showing differences in outgoing long-wave radiation between the same months in two different years (February-May 1962 and February-May 1964) the differences were adjusted upward[2] to force the average difference over the area to be nearly zero. Isopleths of differences are drawn at intervals of 2×10^{-2} ly. min.$^{-1}$. Areas with negative differences are stippled. Isopleths are dashed in regions with data on less than one-third of the days in either month and no analysis is shown where data were available on less than one-tenth of the days in either month. Only centers with absolute values equal to or greater than 0.02 ly. min.$^{-1}$ are labeled.

ACKNOWLEDGMENTS

The assistance of Messrs. P. K. Rao and E. G. Astling in the analysis of monthly mean radiation and circulation maps is very much appreciated. We are also grateful to Messrs. R. Koffler and C. L. Earnest for excellent programing support in compiling and mapping the radiation and other data; to Messrs. J. M. Foard, J. J. Hildebrand, C. L. Jones, and G. J. Welch for extensive general assistance in the preparation of both radiation and other data; and to Mr. L. D. Hatton for this very painstaking work in drafting the figures.

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[2] By 0.01 ly. min.$^{-1}$ for February and by 0.02 ly. min.$^{-1}$ for March, April, and May.

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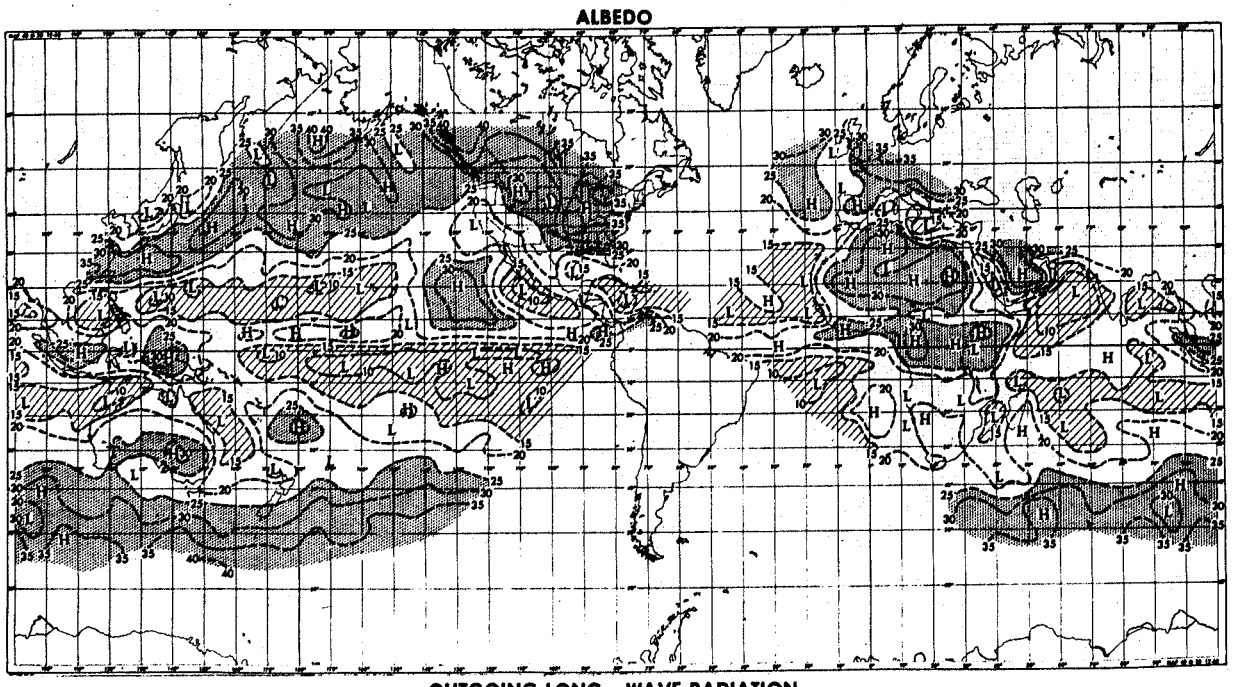
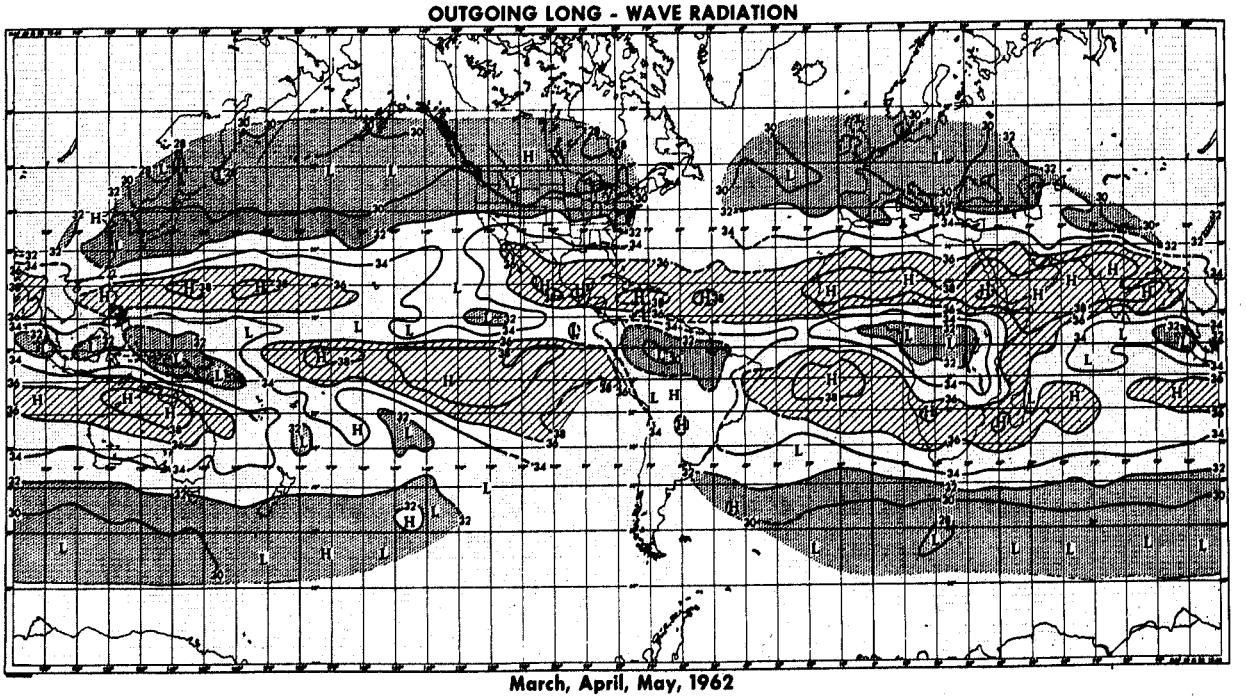
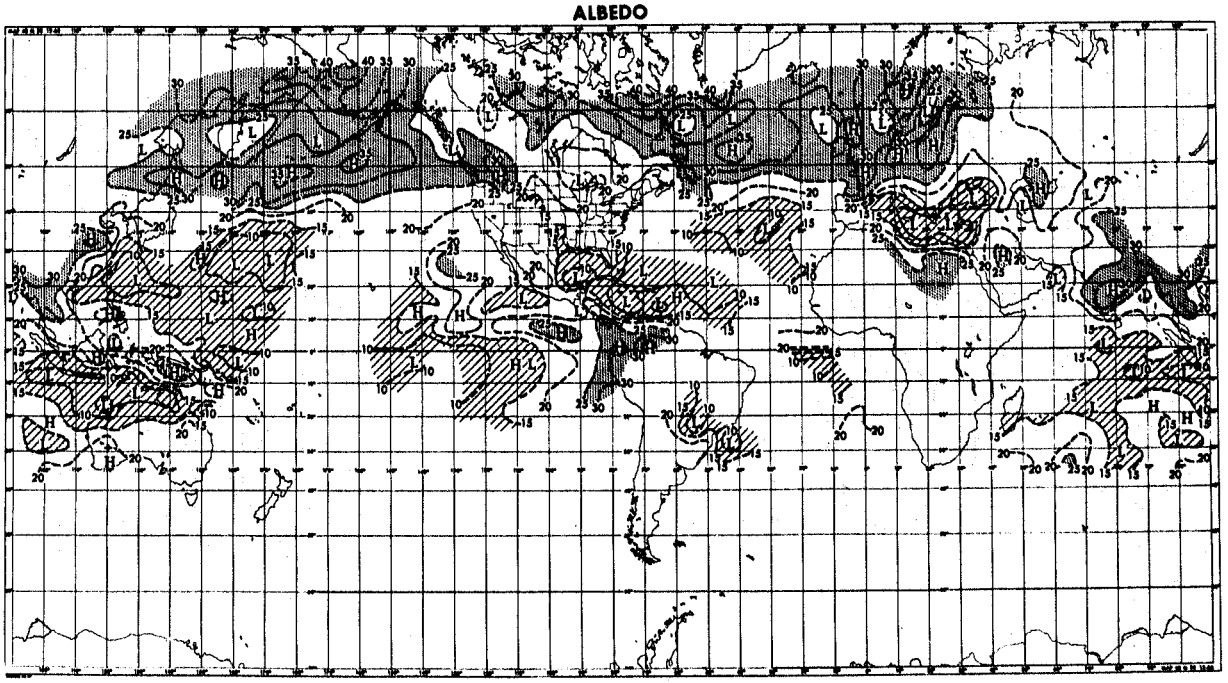




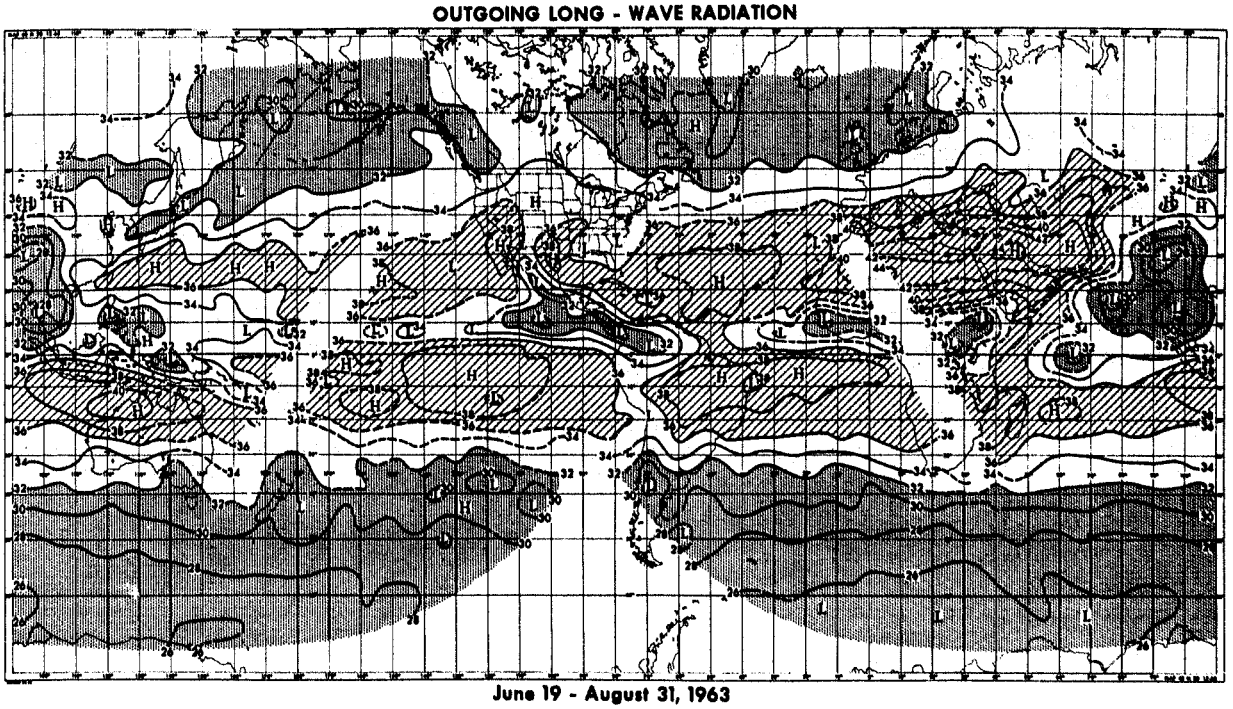
March, April, May, 1962

Figure 1

ALBEDO



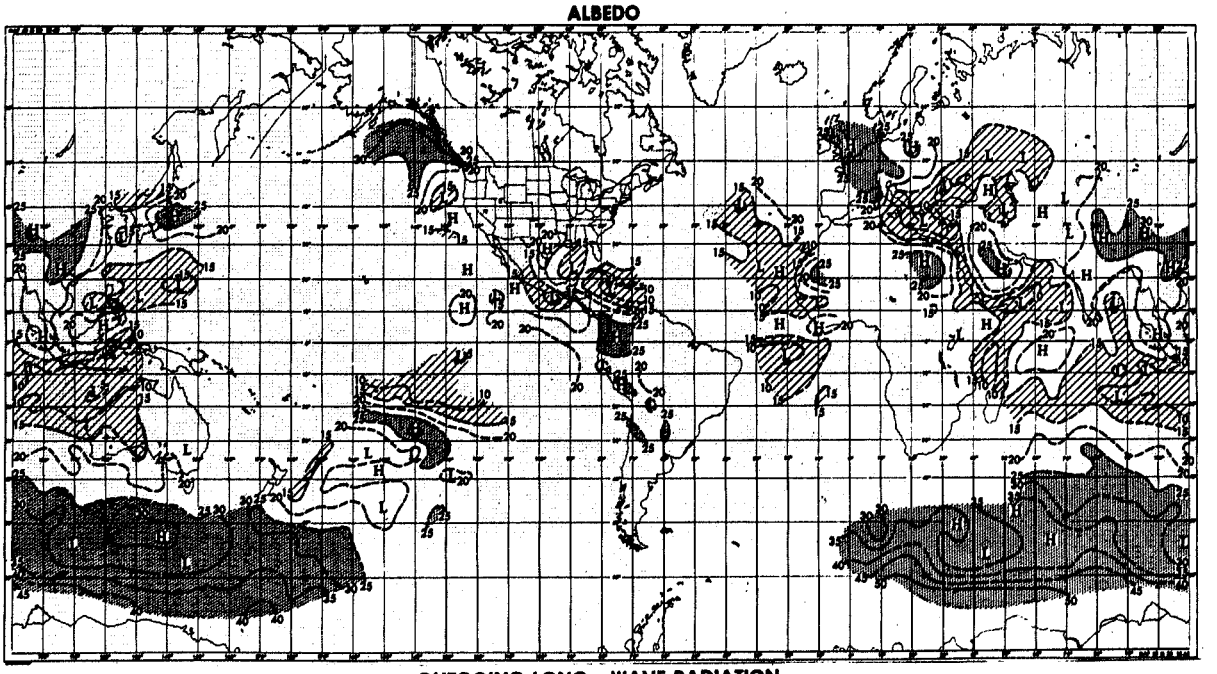
OUTGOING LONG - WAVE RADIATION



June 19 - August 31, 1963

Figure 2

ALBEDO



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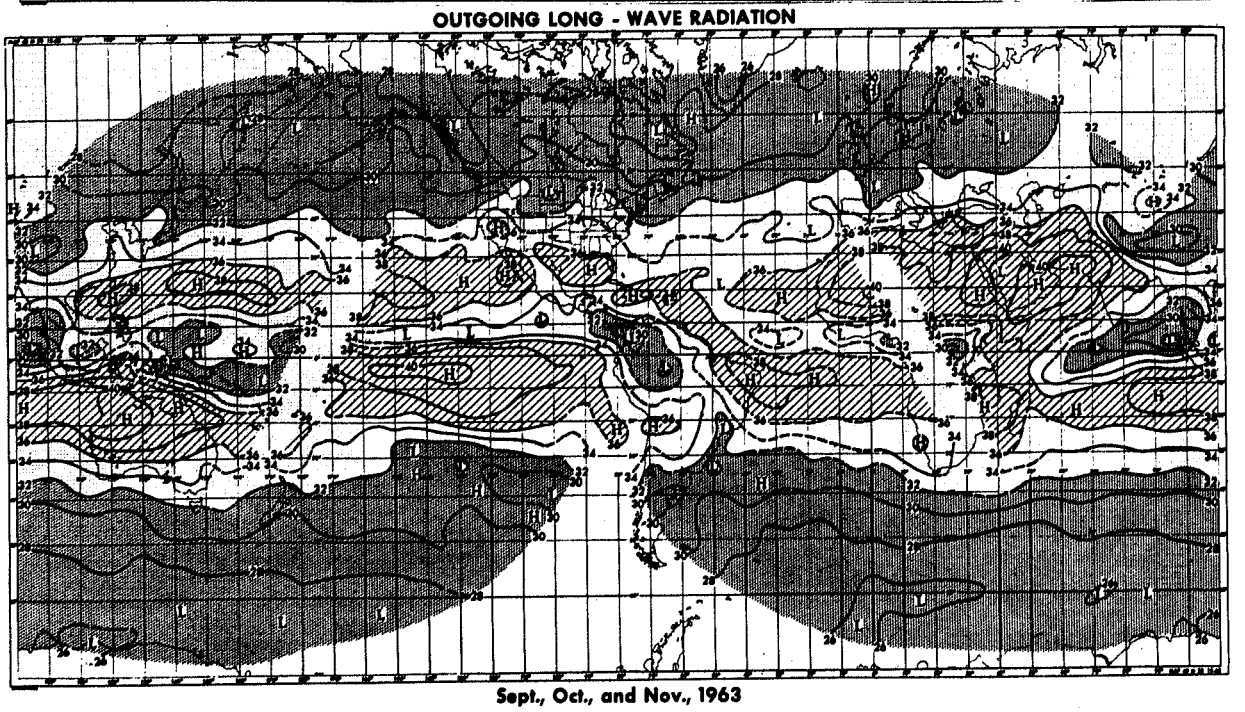
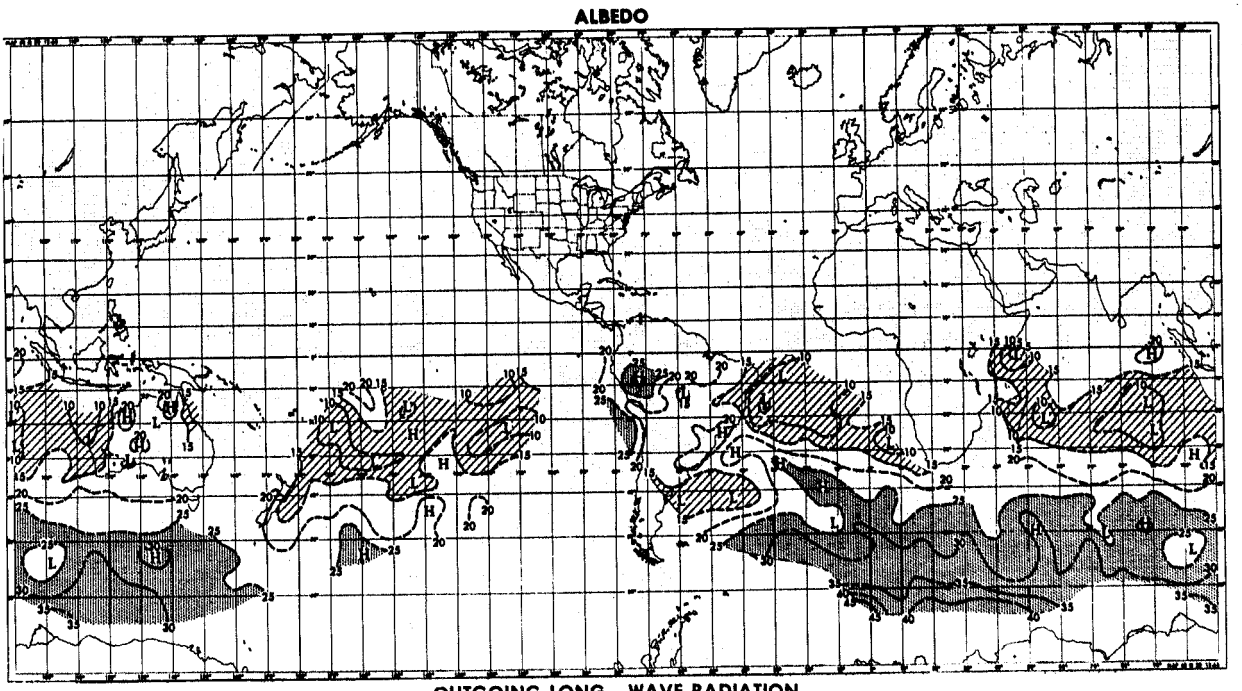
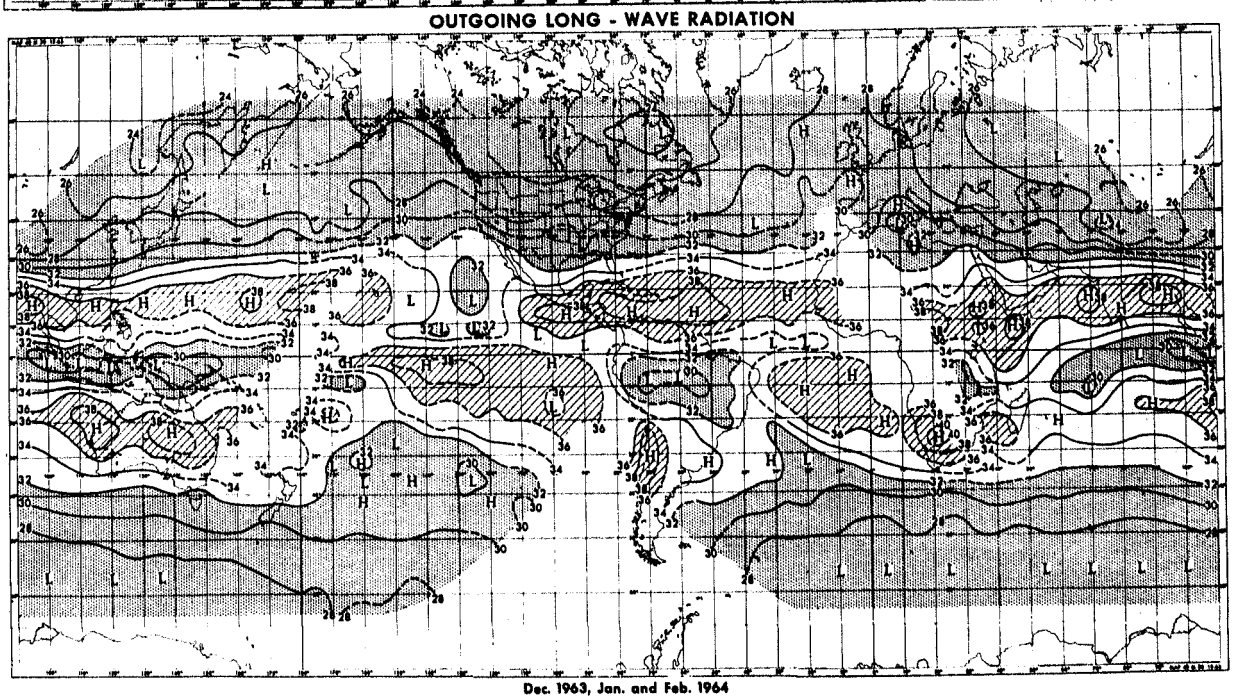


Sept., Oct., and Nov., 1963

Figure 3

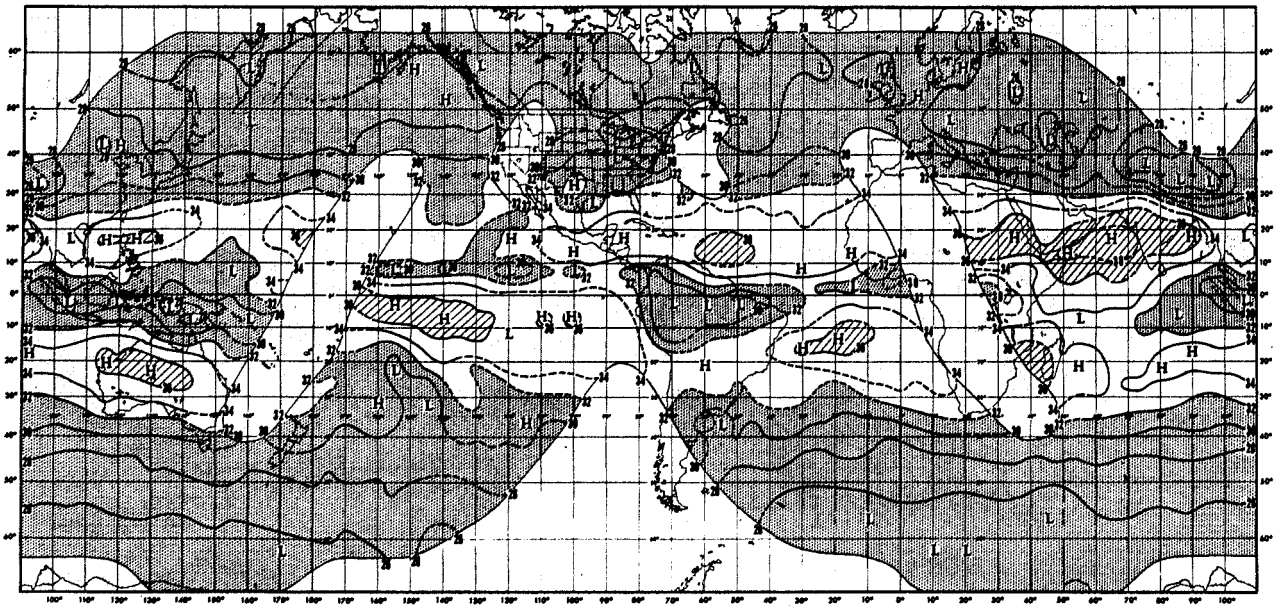




Dec. 1963, Jan. and Feb. 1964

Figure 4

OUTGOING LONG-WAVE RADIATION



MARCH, APRIL, MAY 1964

Figure 5

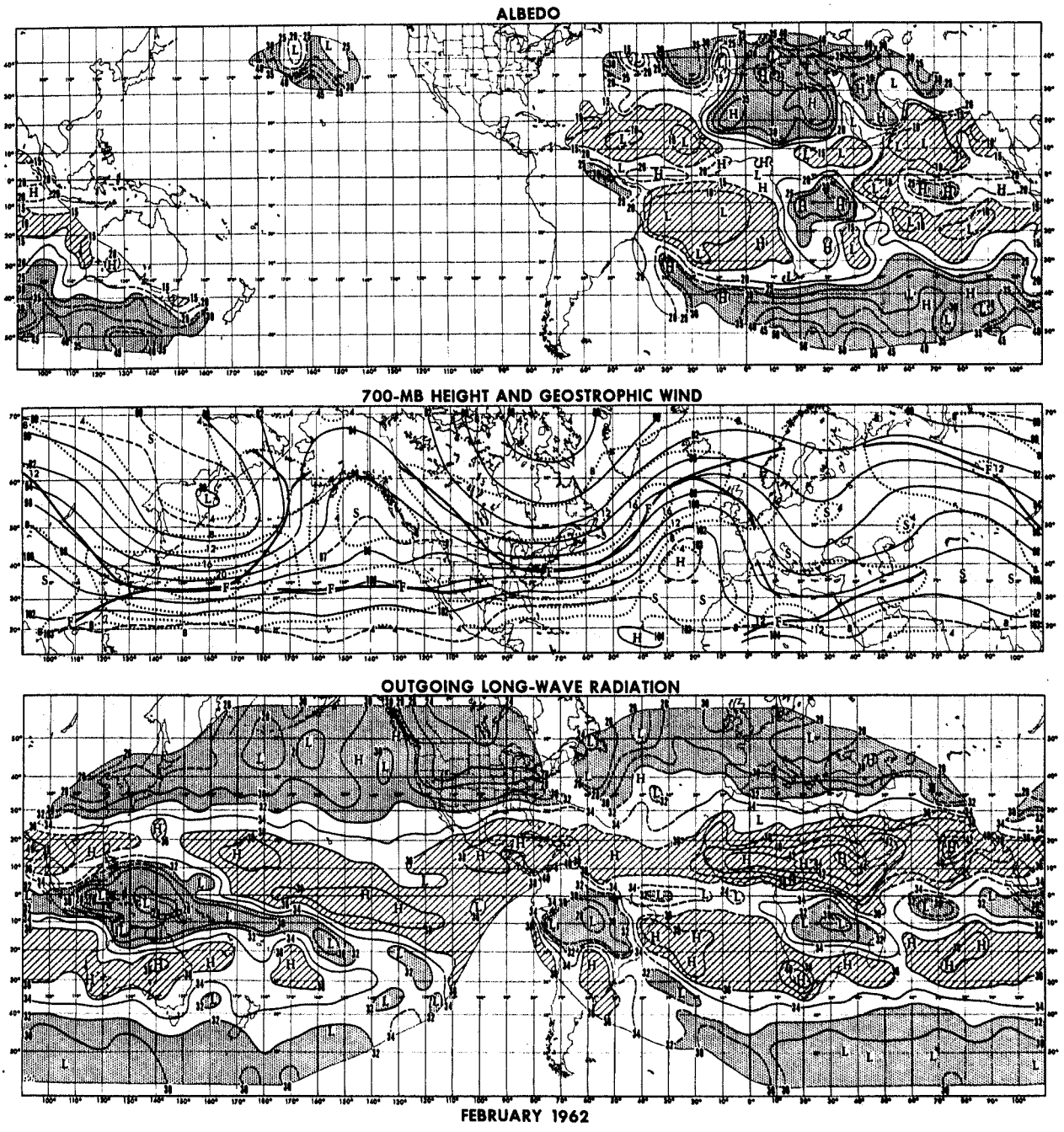

ALBEDO
700-MB HEIGHT AND GEOSTROPHIC WIND
OUTGOING LONG-WAVE RADIATION
FEBRUARY 1962

Figure 6

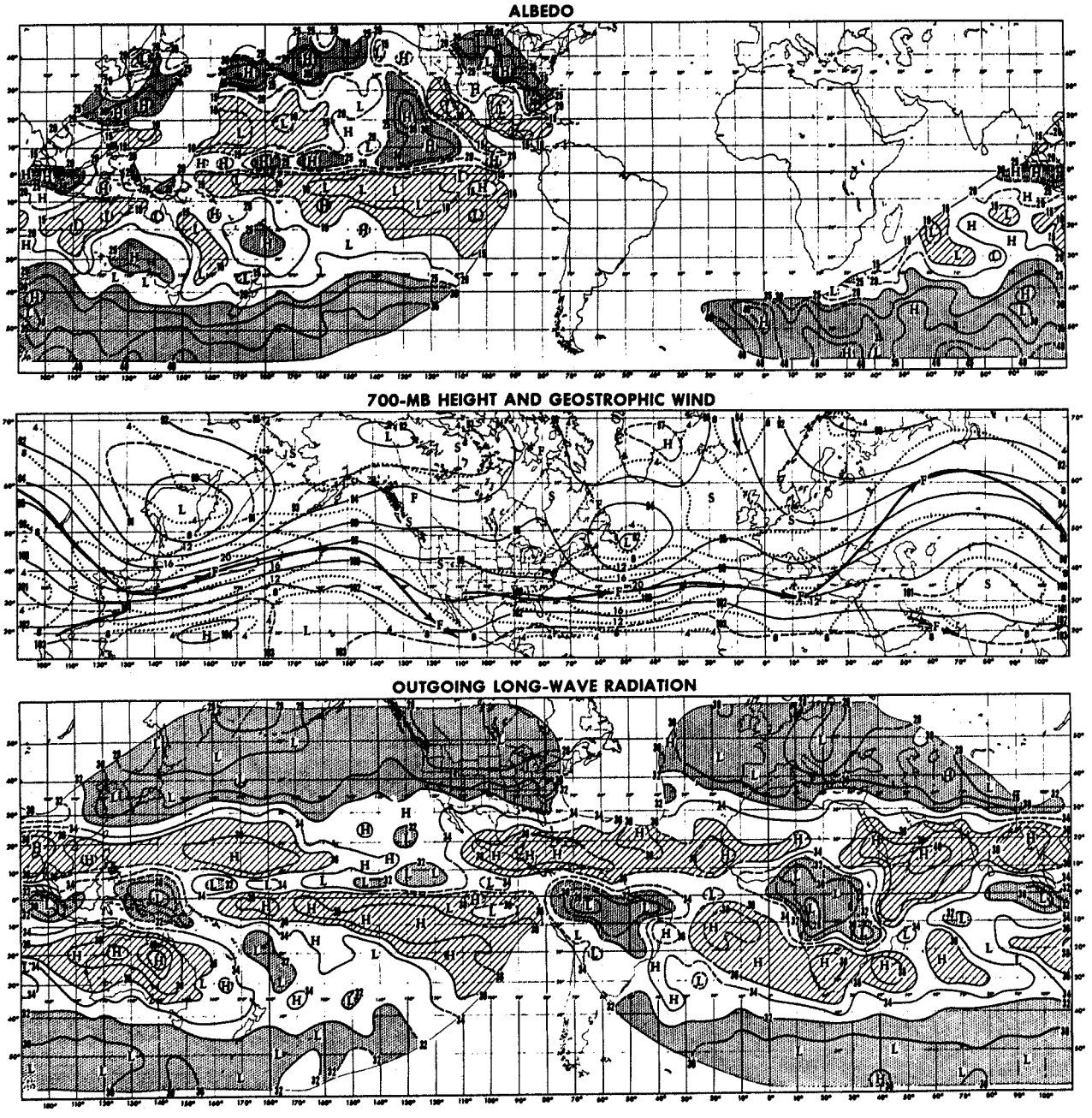

ALBEDO
700-MB HEIGHT AND GEOSTROPHIC WIND
OUTGOING LONG-WAVE RADIATION
MARCH 1962

Figure 7

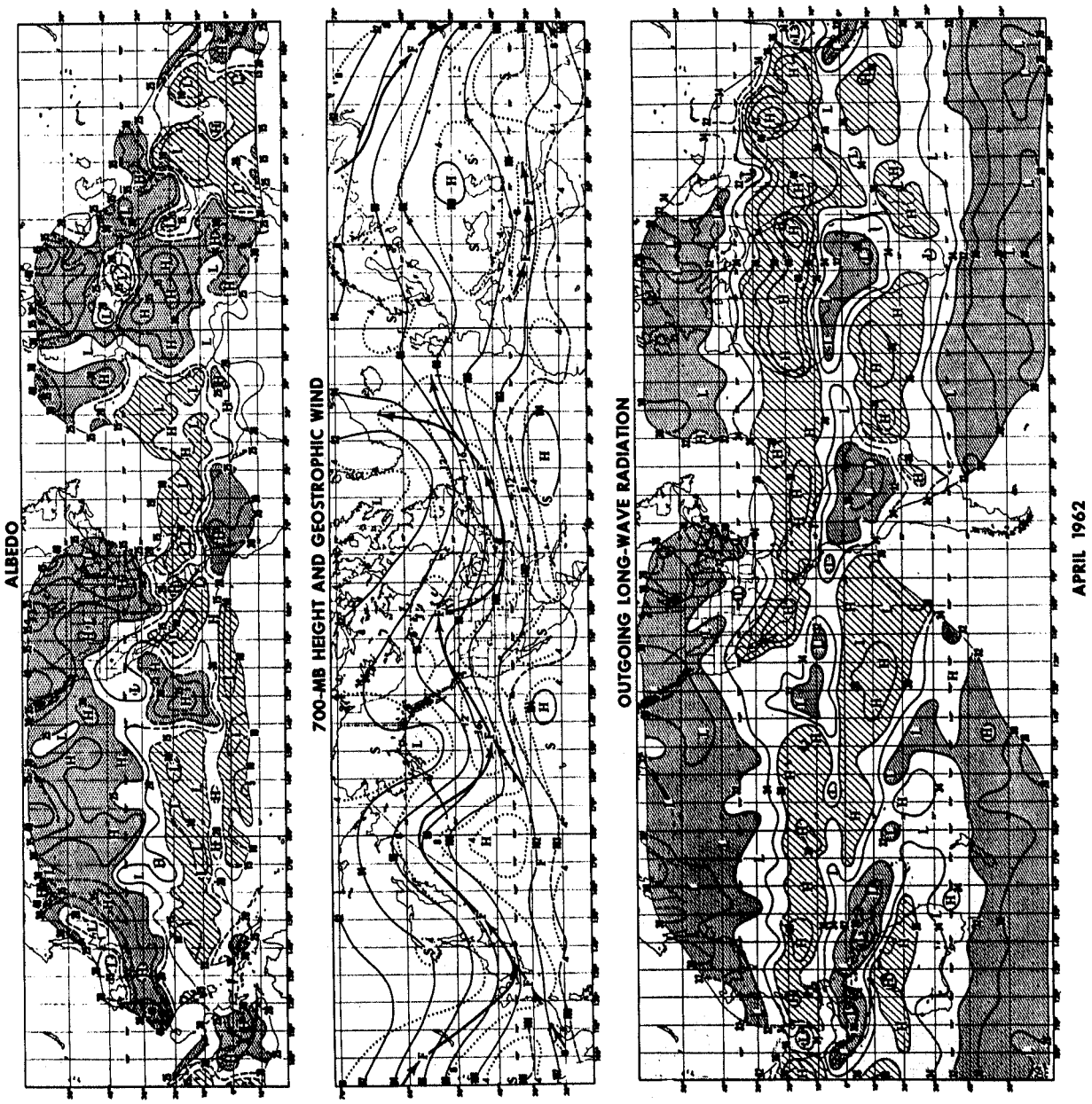
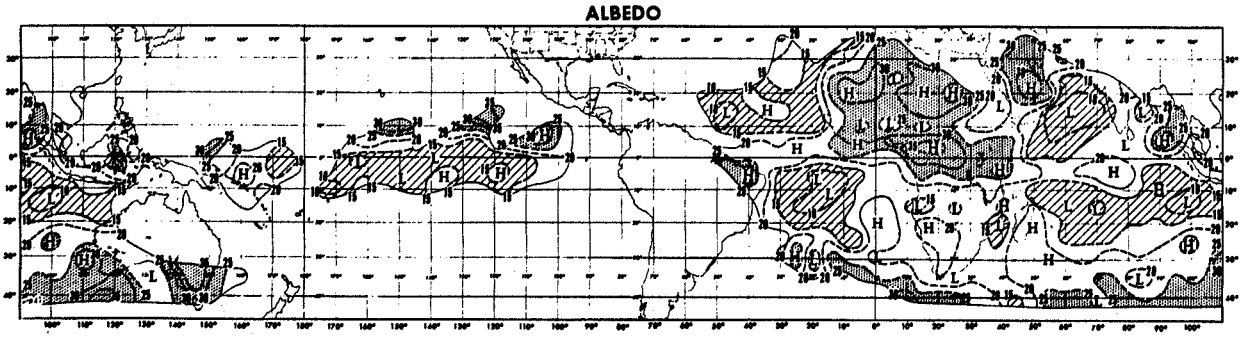
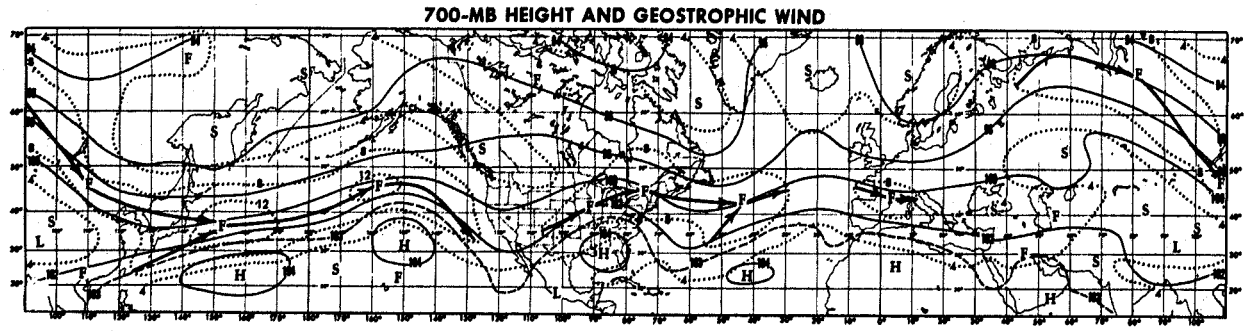
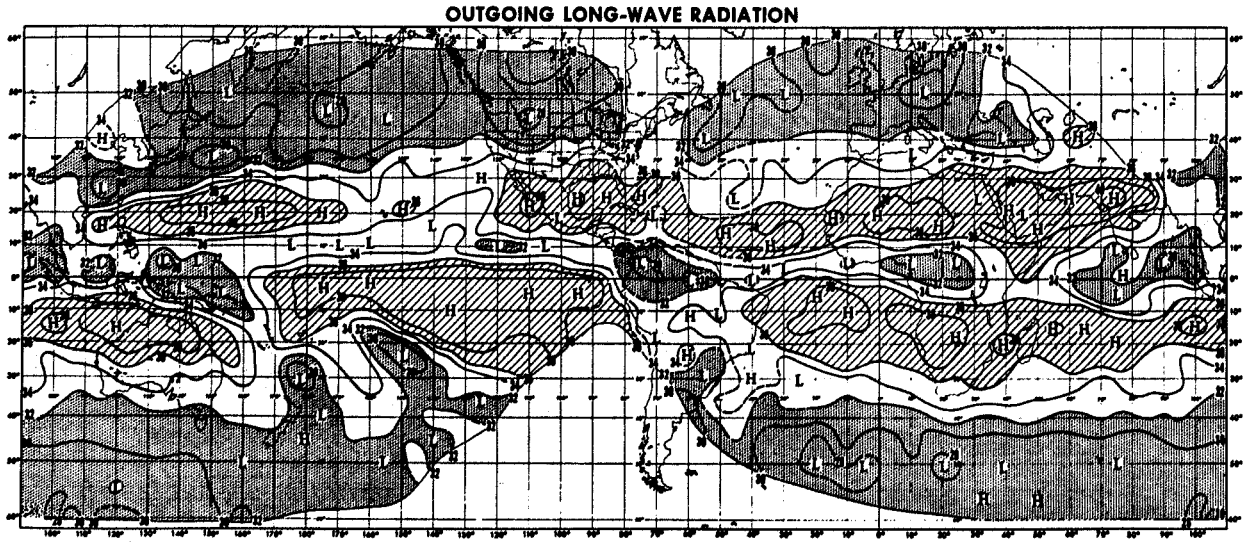

ALBEDO
700-MB HEIGHT AND GEOSTROPHIC WIND
OUTGOING LONG-WAVE RADIATION
APRIL 1962

Figure 8



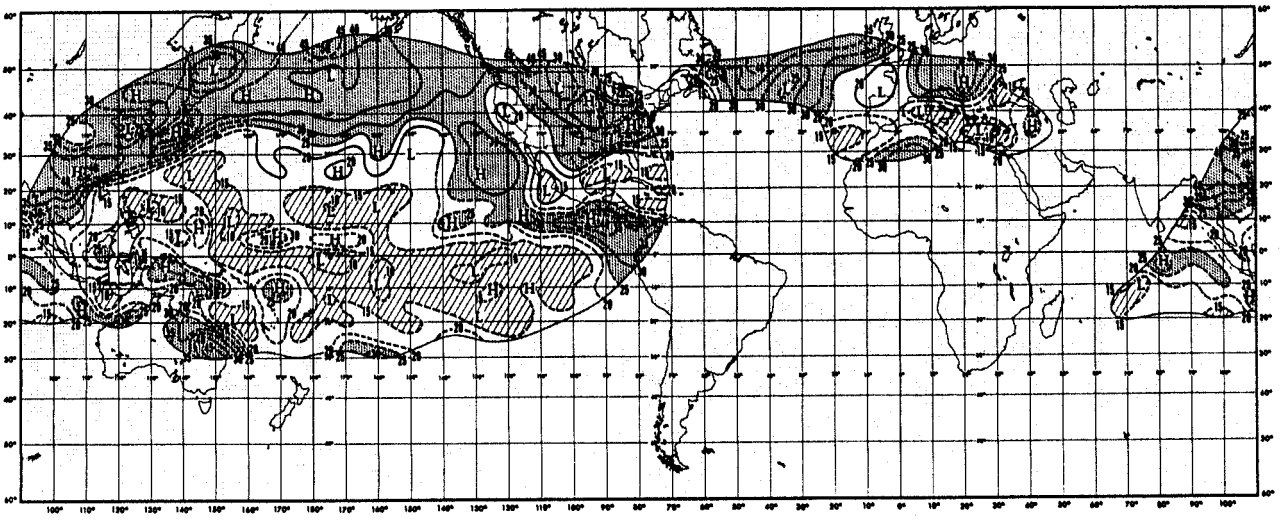




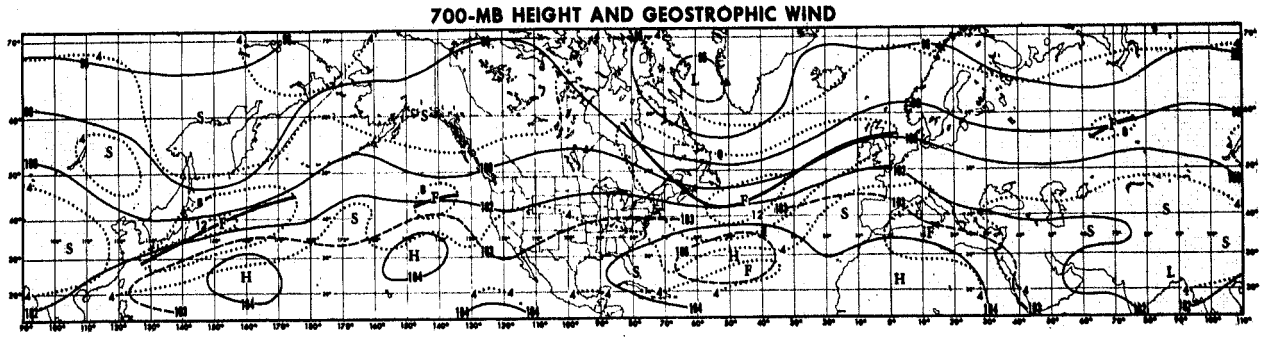
MAY 1962

Figure 9

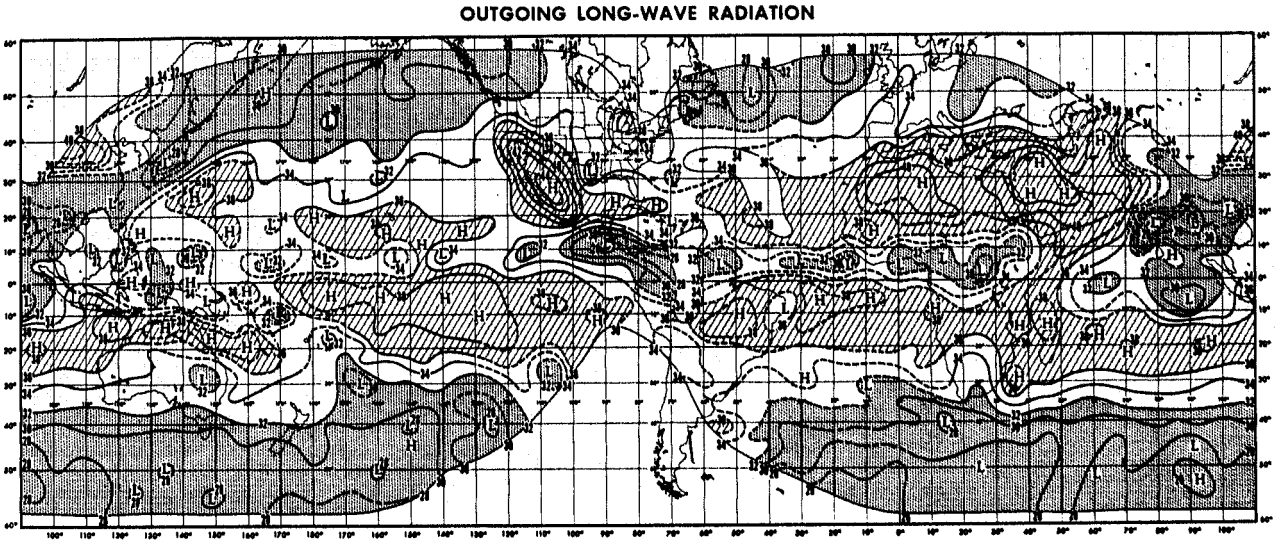
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



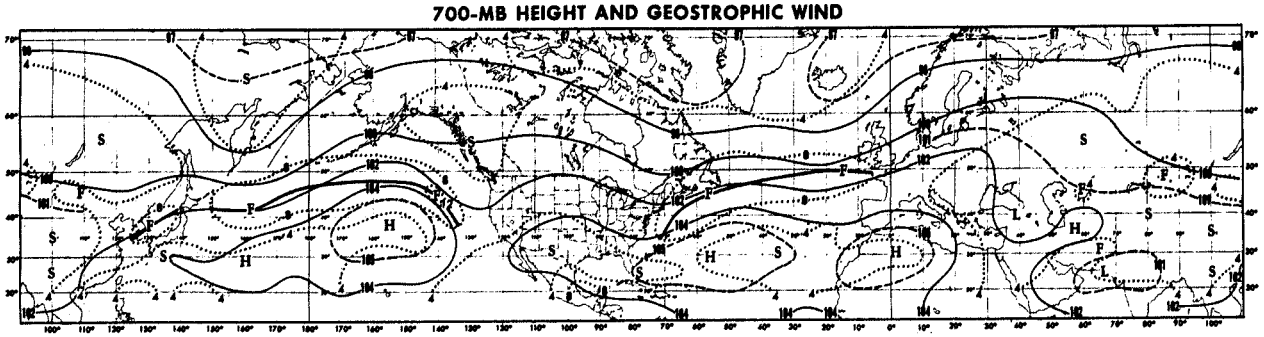
OUTGOING LONG-WAVE RADIATION



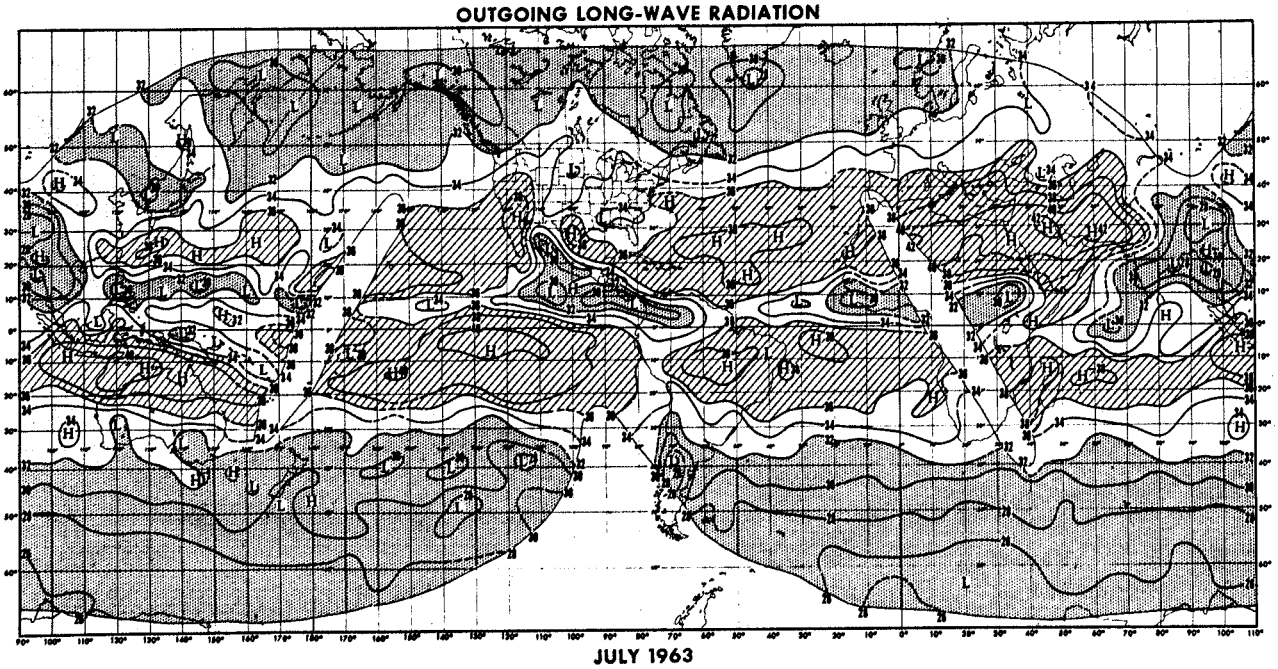
JUNE 1962

Figure 10

700-MB HEIGHT AND GEOSTROPHIC WIND



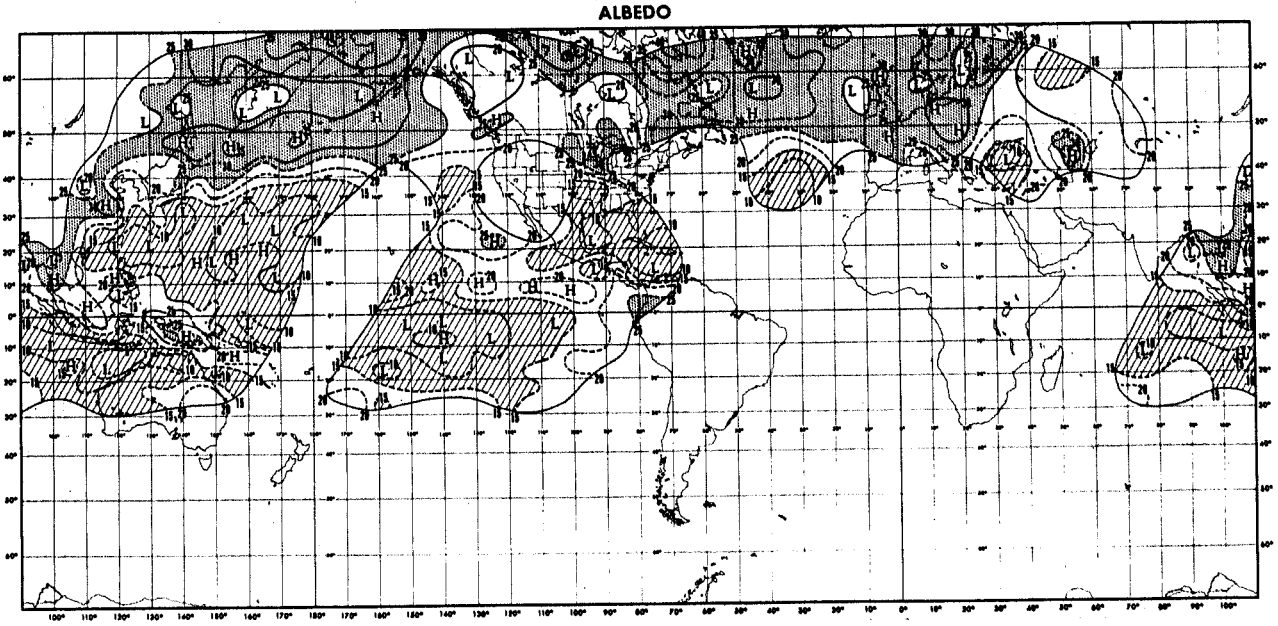
OUTGOING LONG-WAVE RADIATION



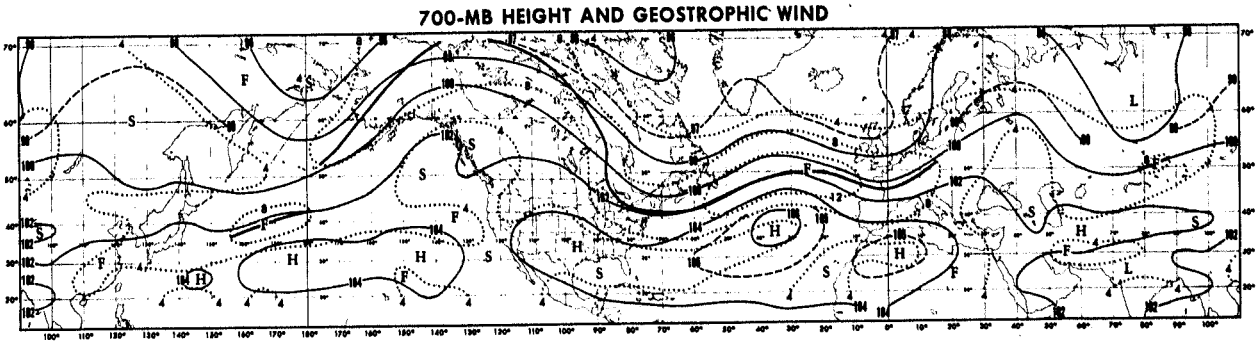
JULY 1963

Figure 11

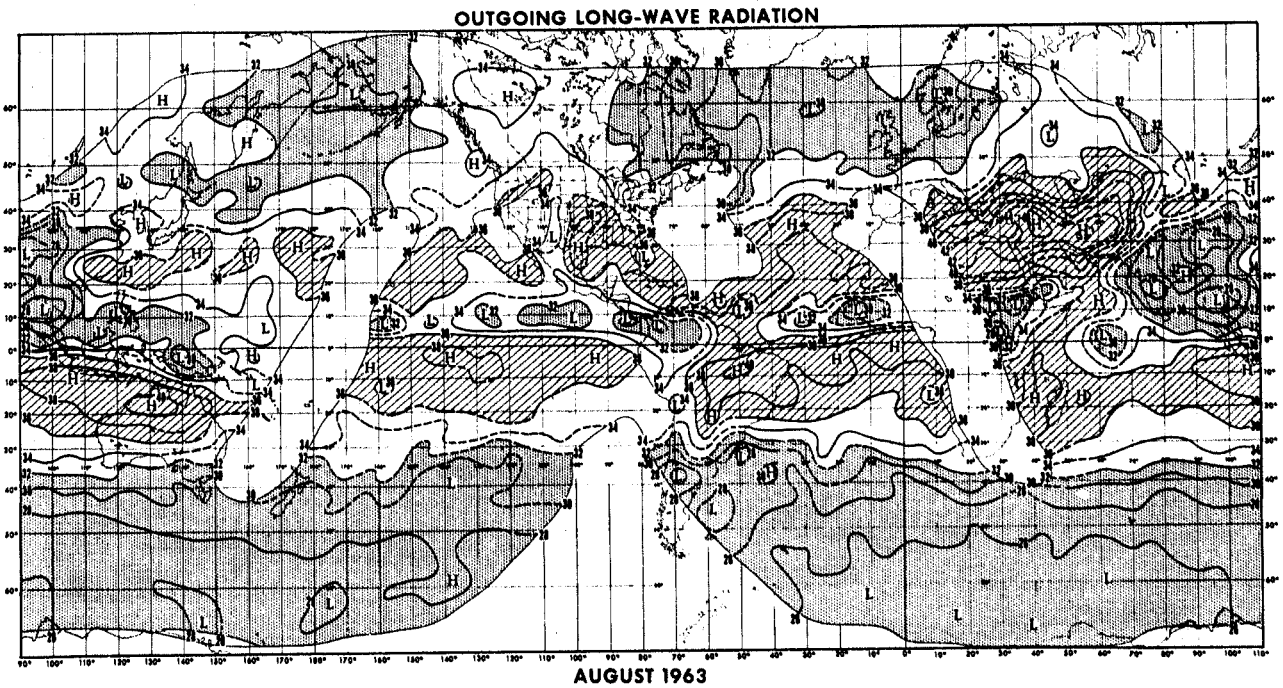
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



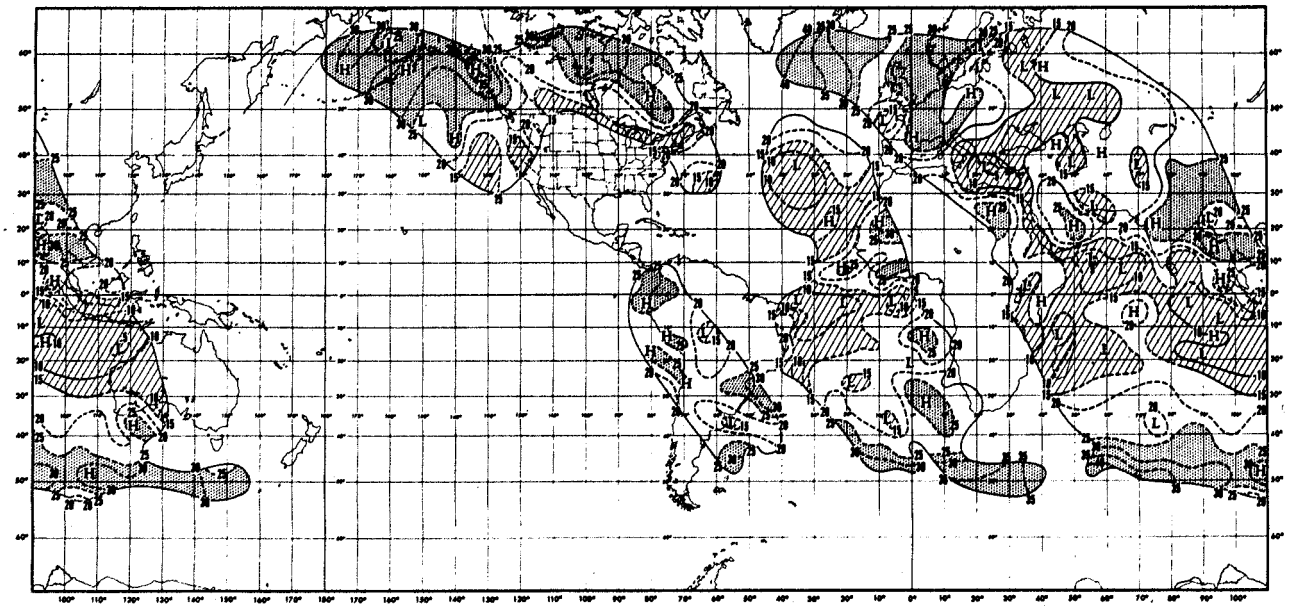
OUTGOING LONG-WAVE RADIATION



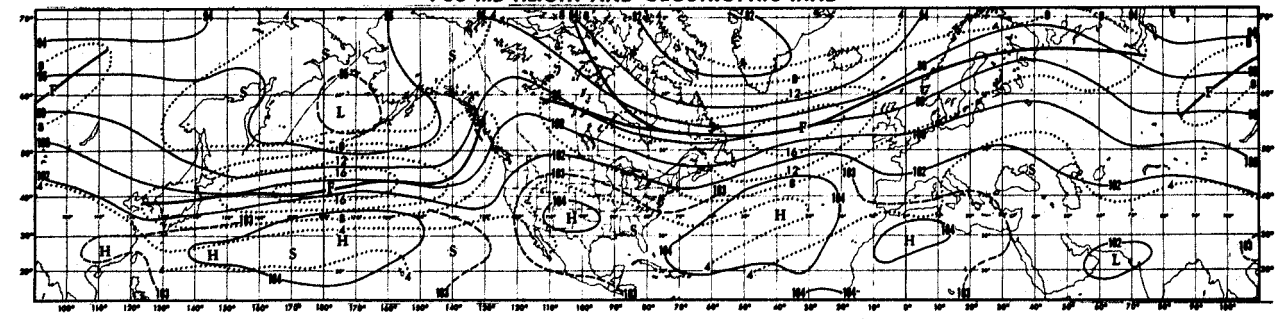
AUGUST 1963

Figure 12

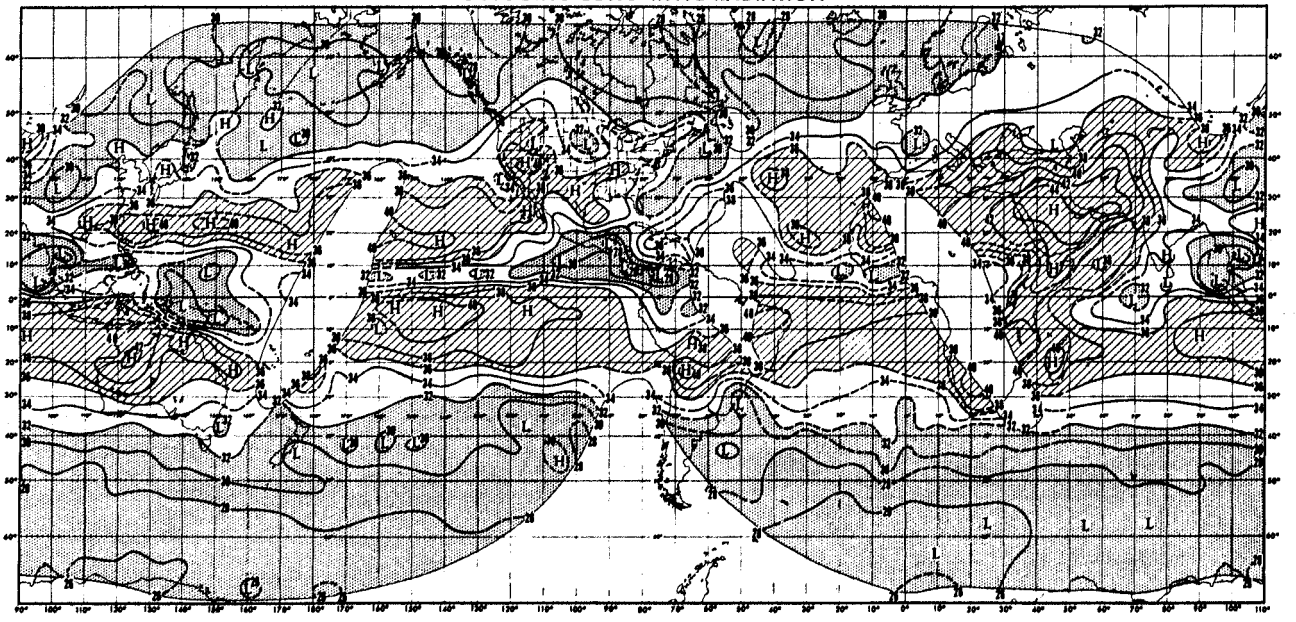
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



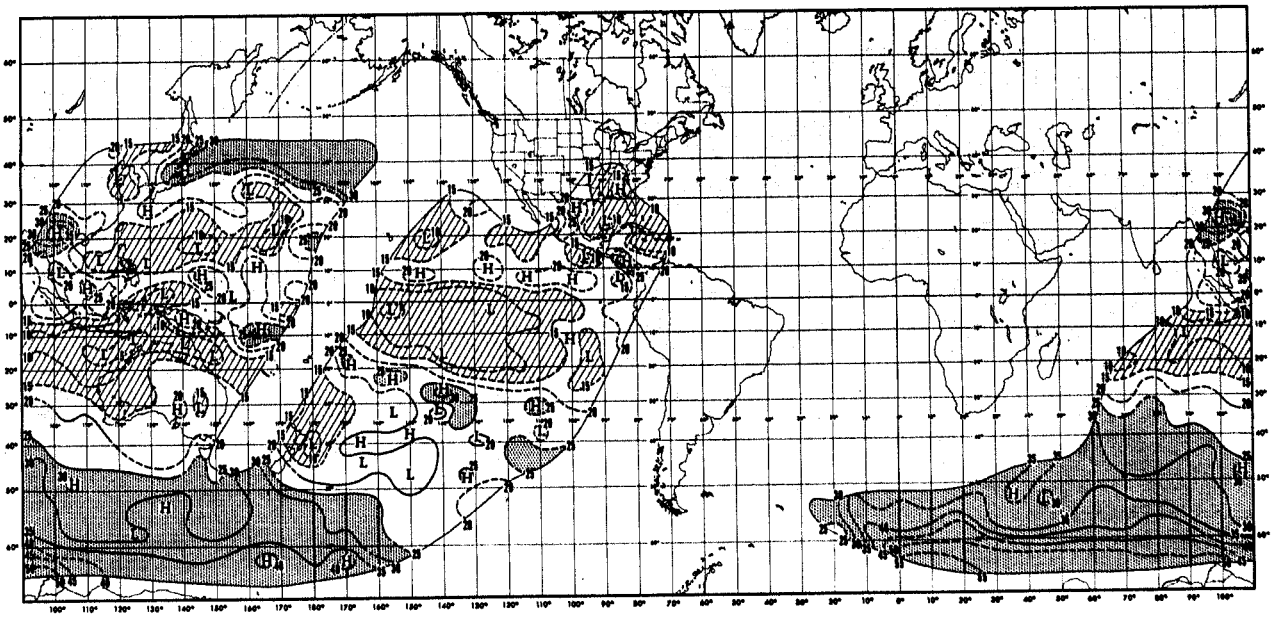
OUTGOING LONG-WAVE RADIATION



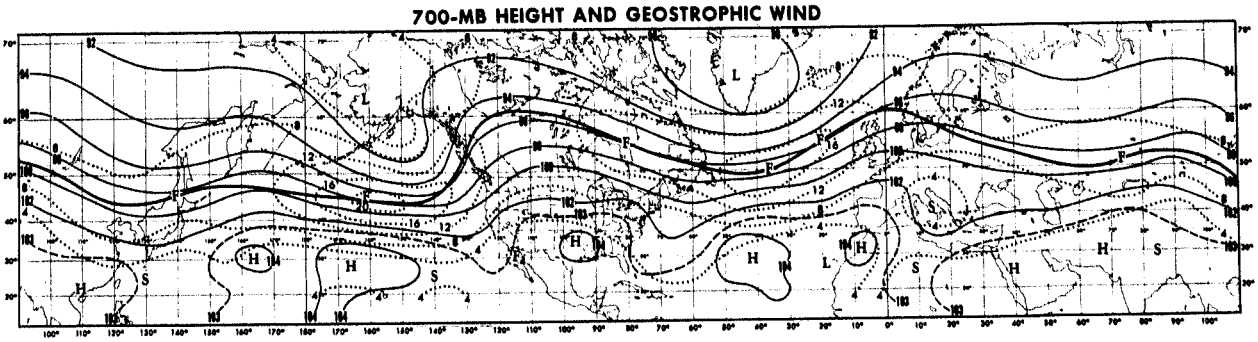
SEPTEMBER 1963

Figure 13

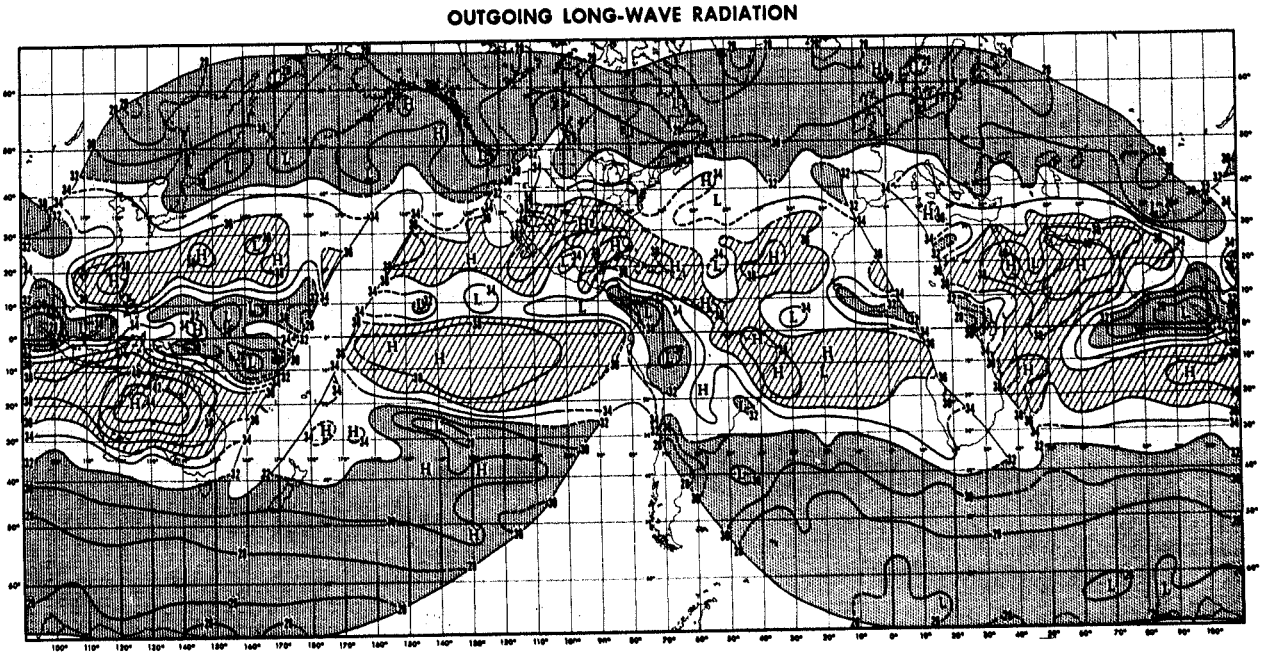
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



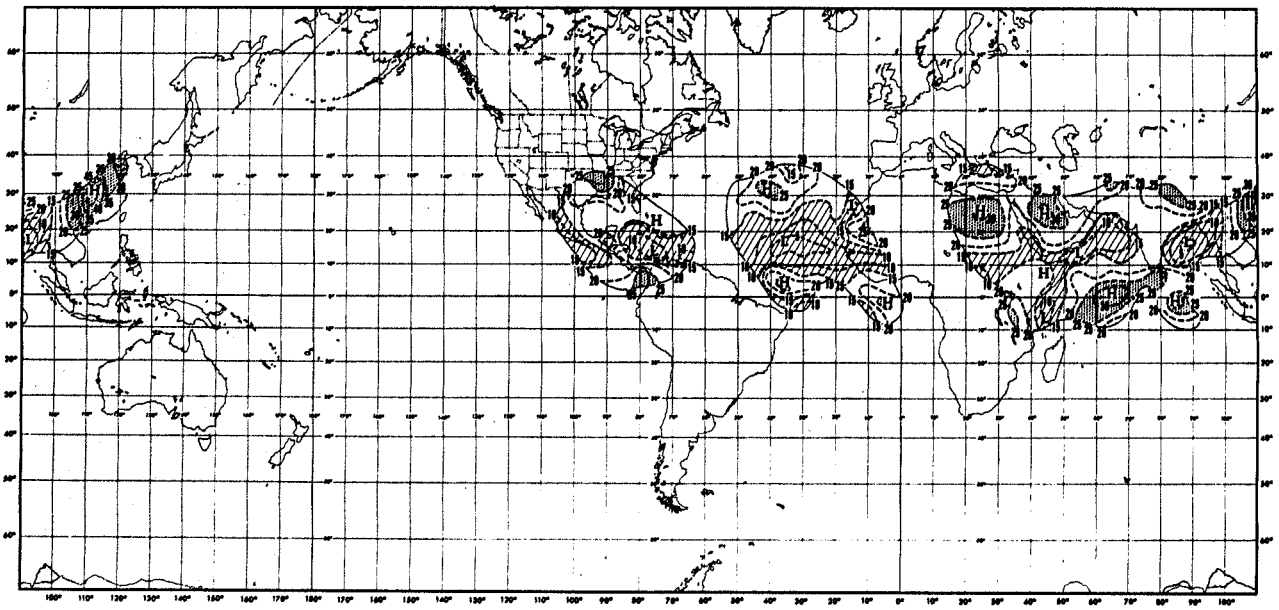
OUTGOING LONG-WAVE RADIATION



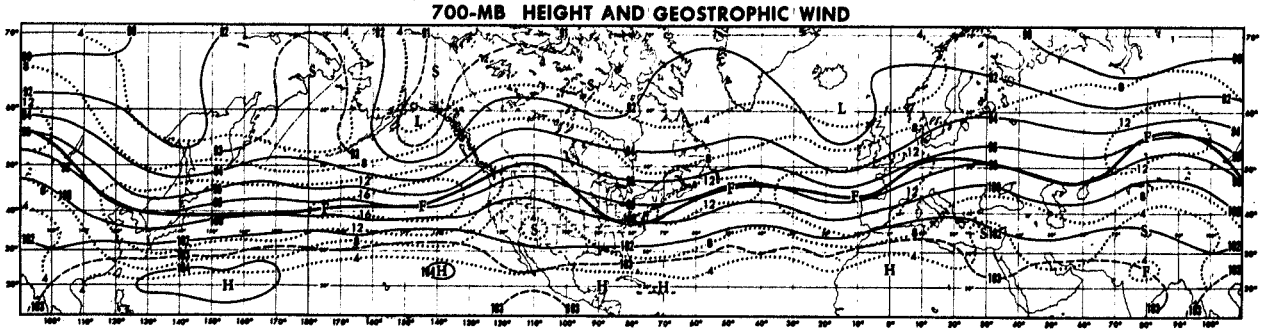
OCTOBER 1963

Figure 14

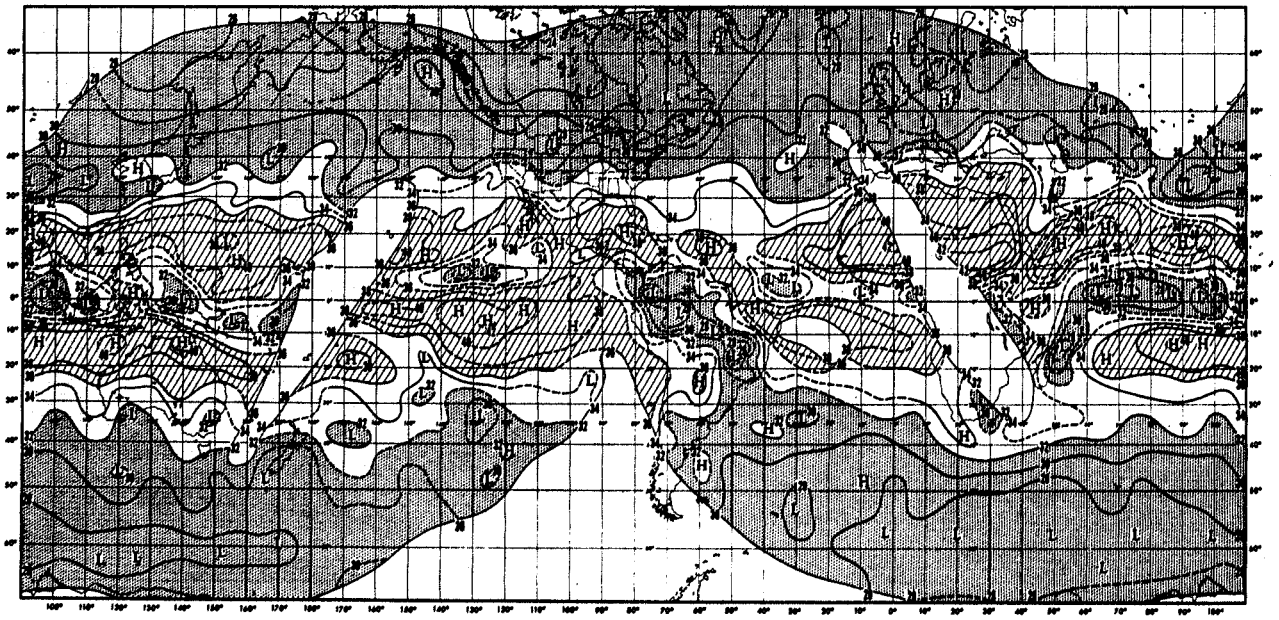
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



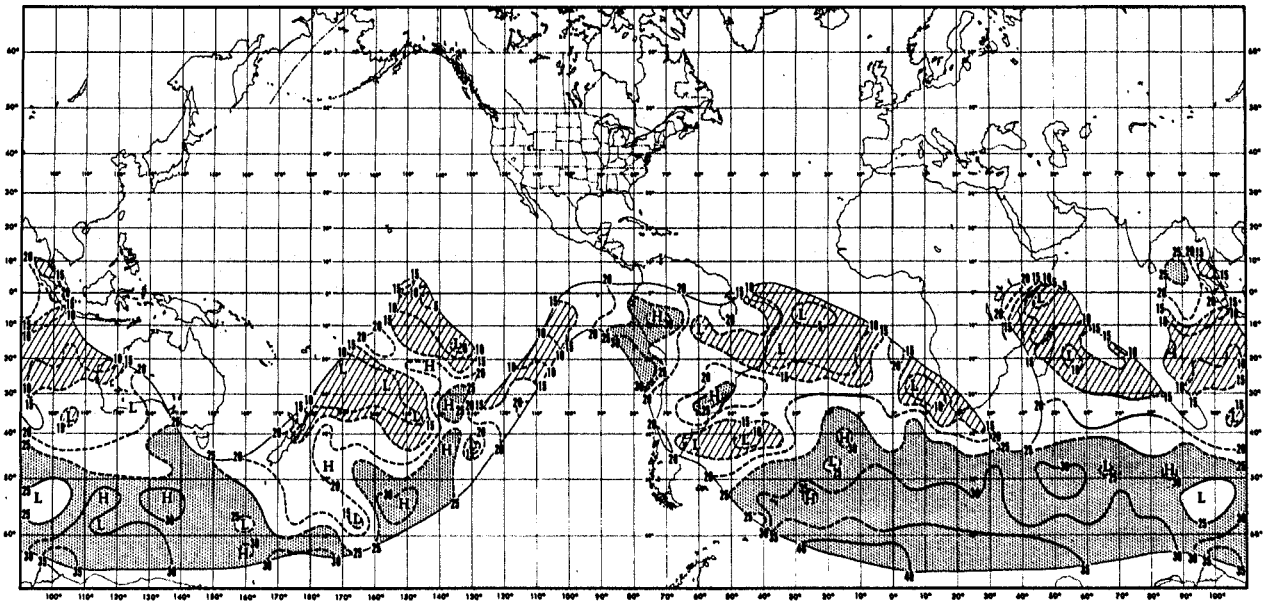
OUTGOING LONG-WAVE RADIATION



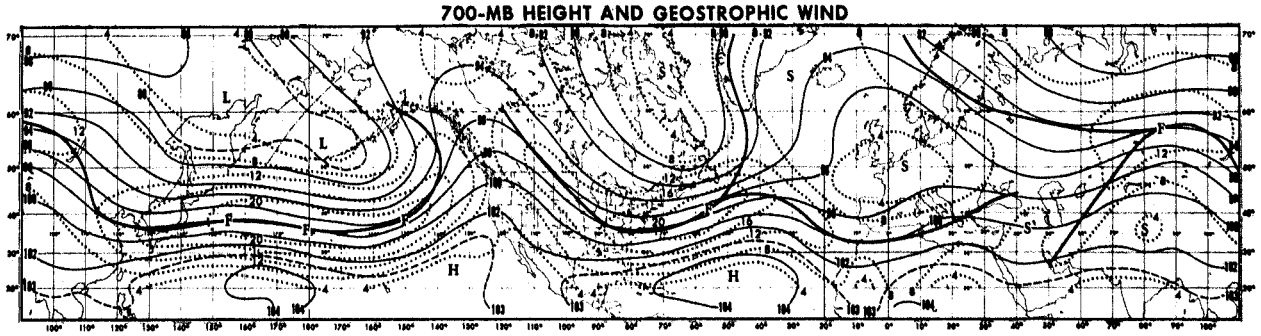
NOVEMBER 1963

Figure 15

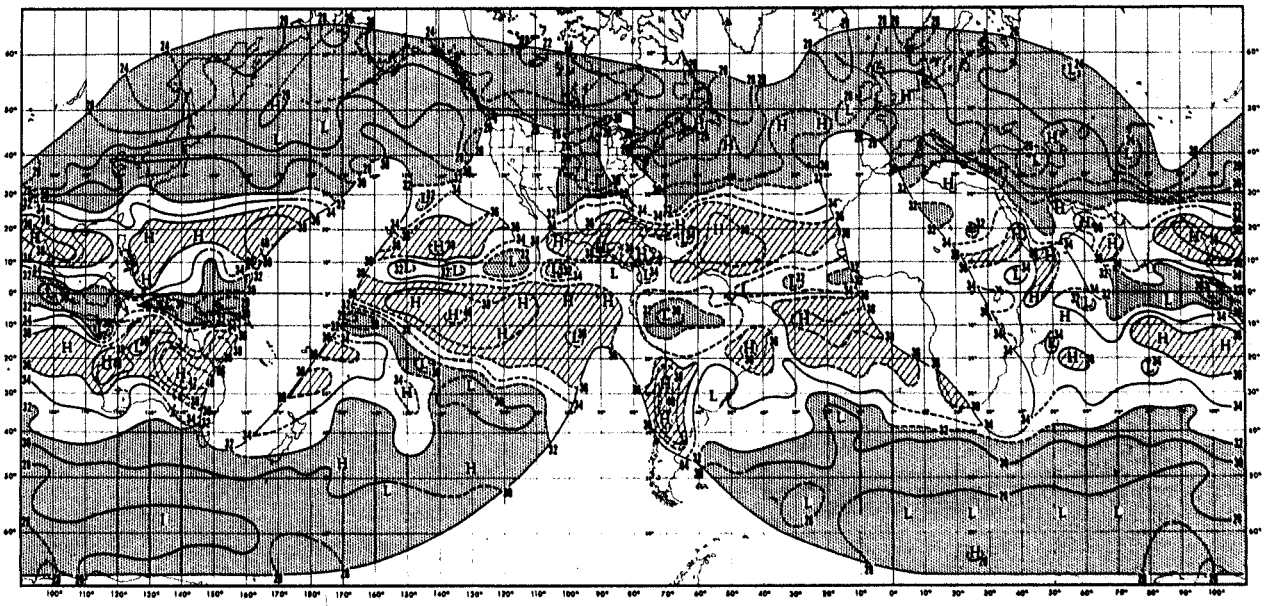
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



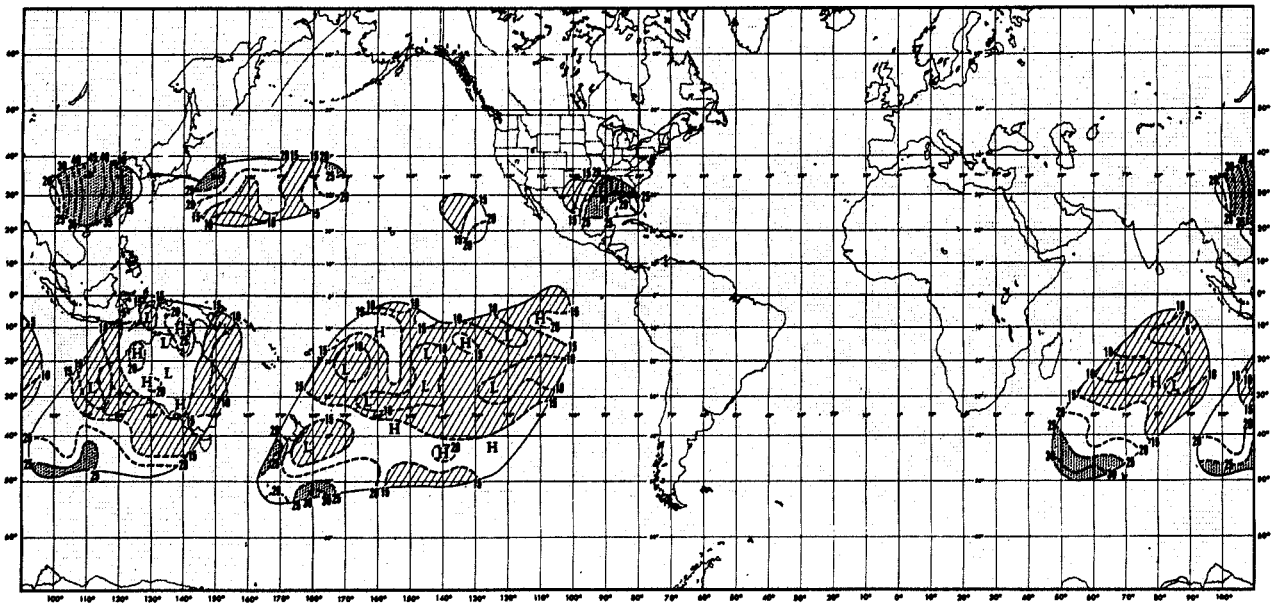
OUTGOING LONG-WAVE RADIATION



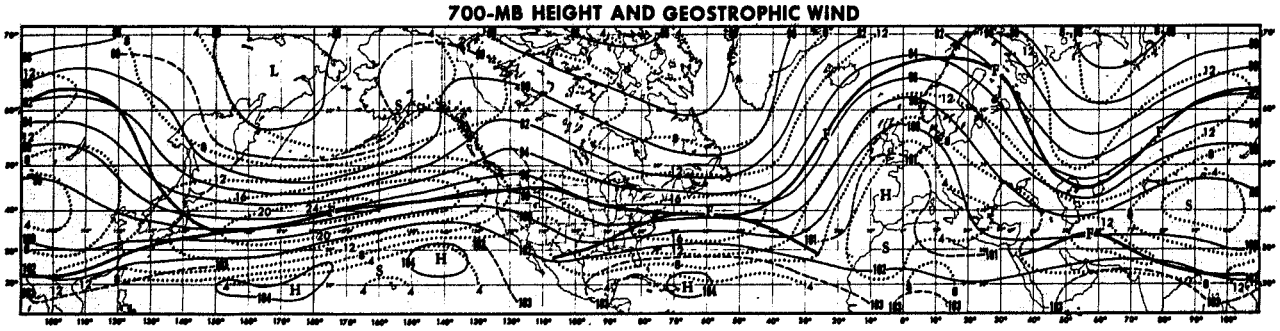
DECEMBER 1963

Figure 16

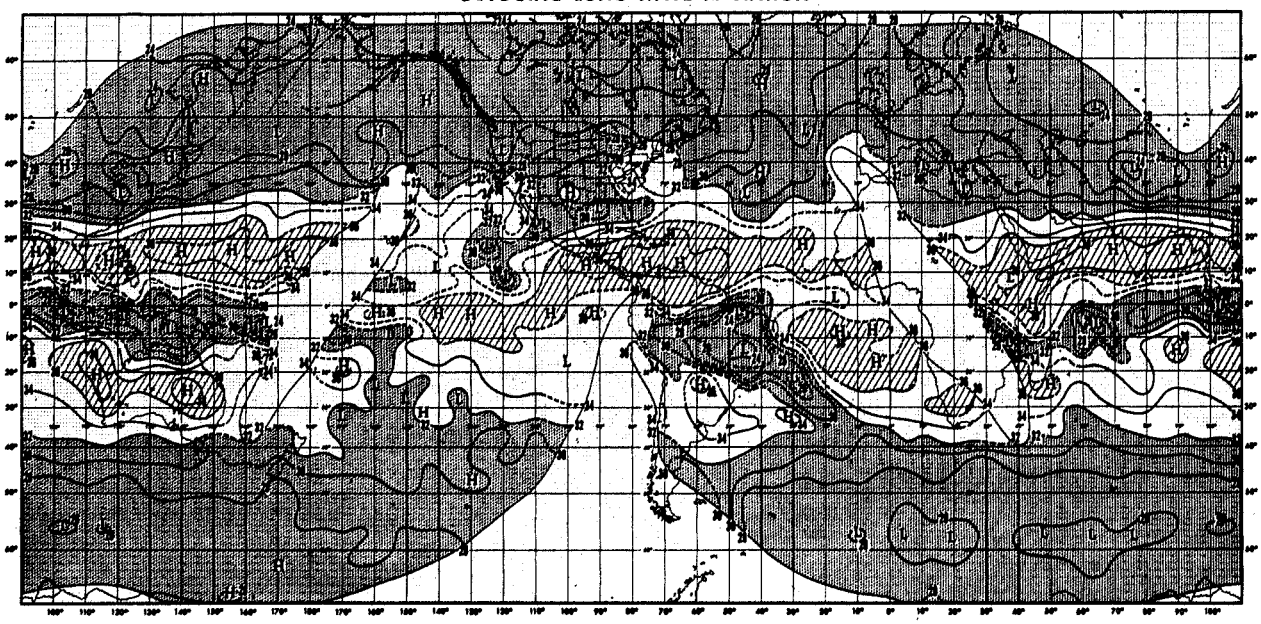
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



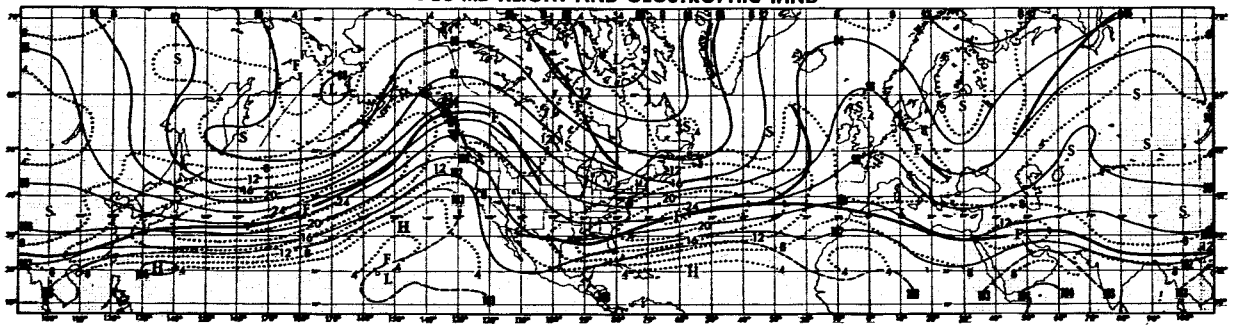
OUTGOING LONG-WAVE RADIATION



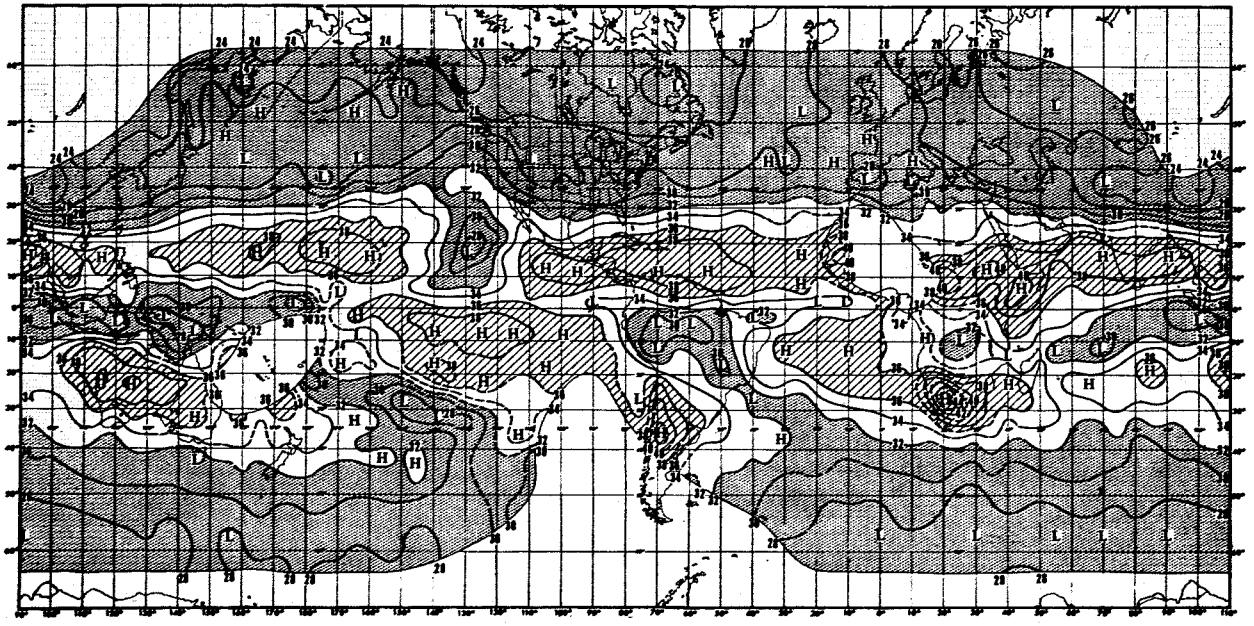
JANUARY 1964

Figure 17

700-MB HEIGHT AND GEOSTROPHIC WIND



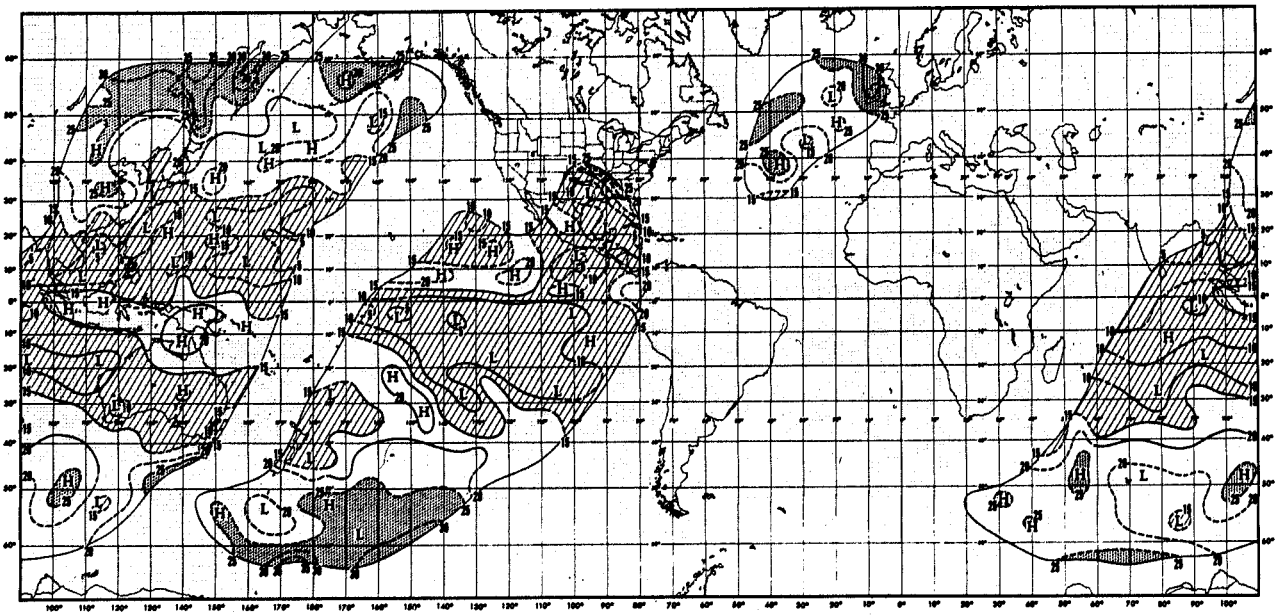
OUTGOING LONG-WAVE RADIATION



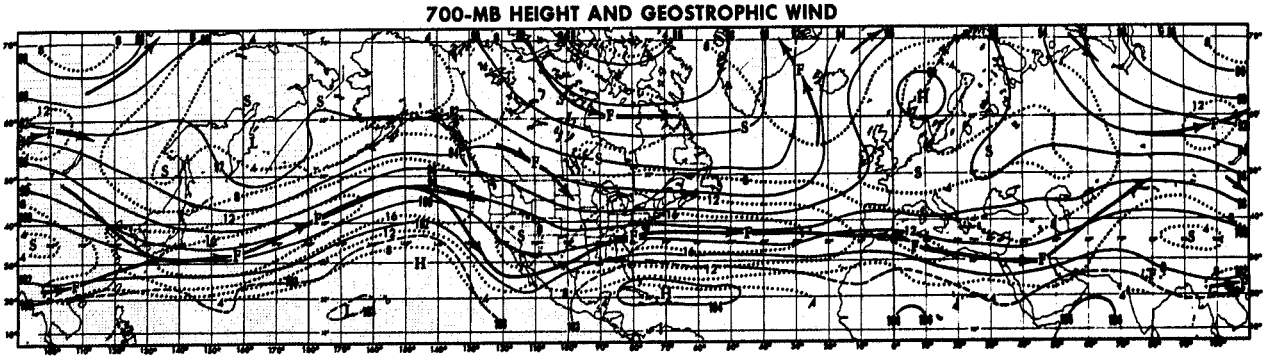
FEBRUARY 1964

Figure 18

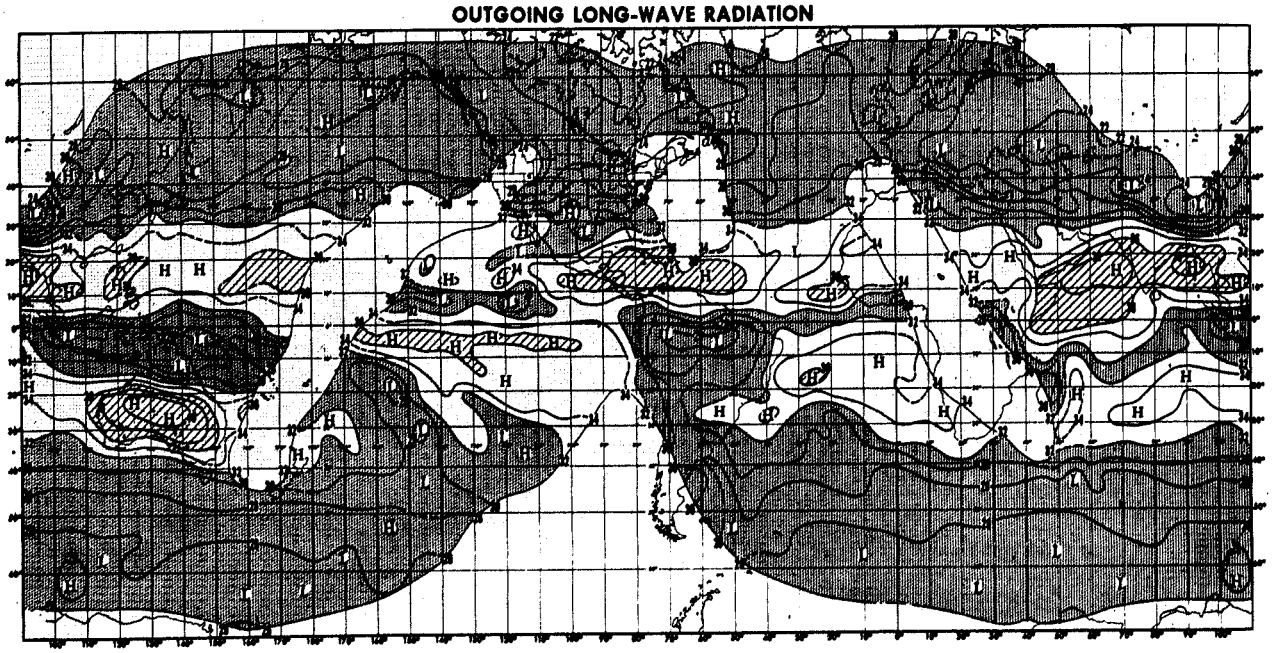
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



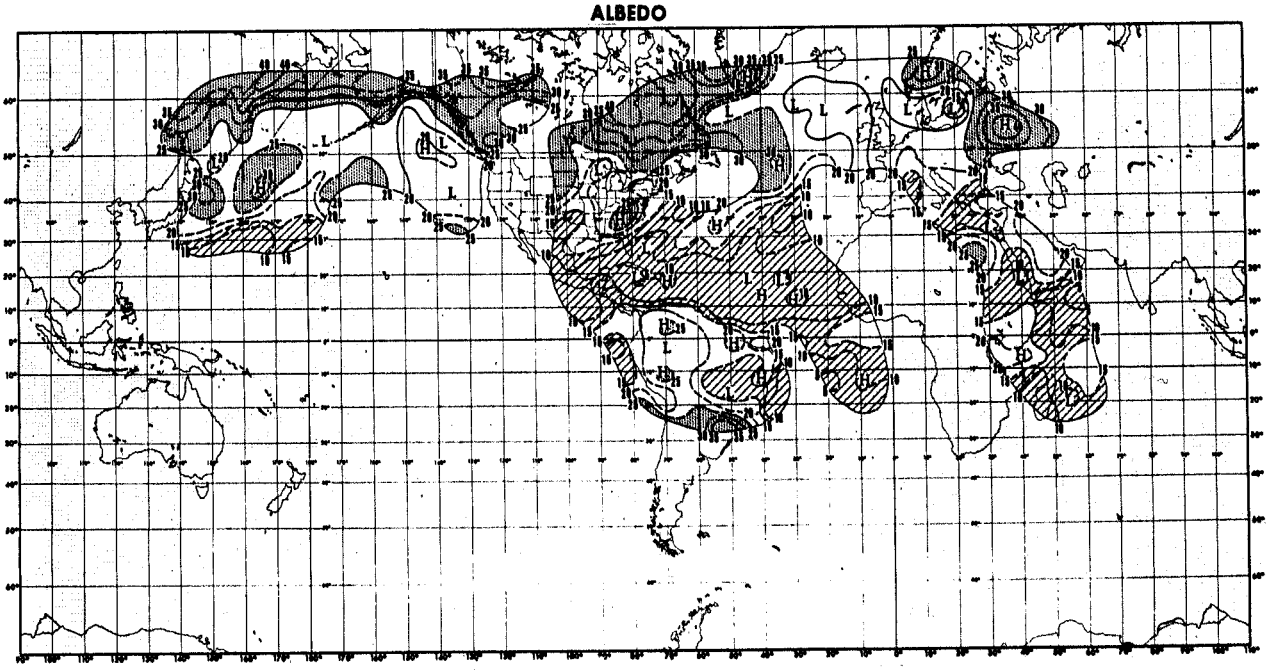
OUTGOING LONG-WAVE RADIATION



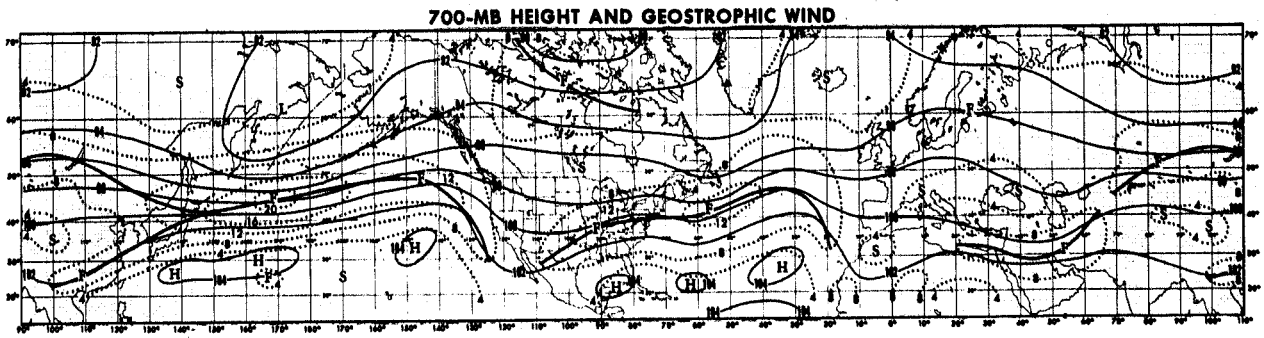
MARCH 1964

Figure 19

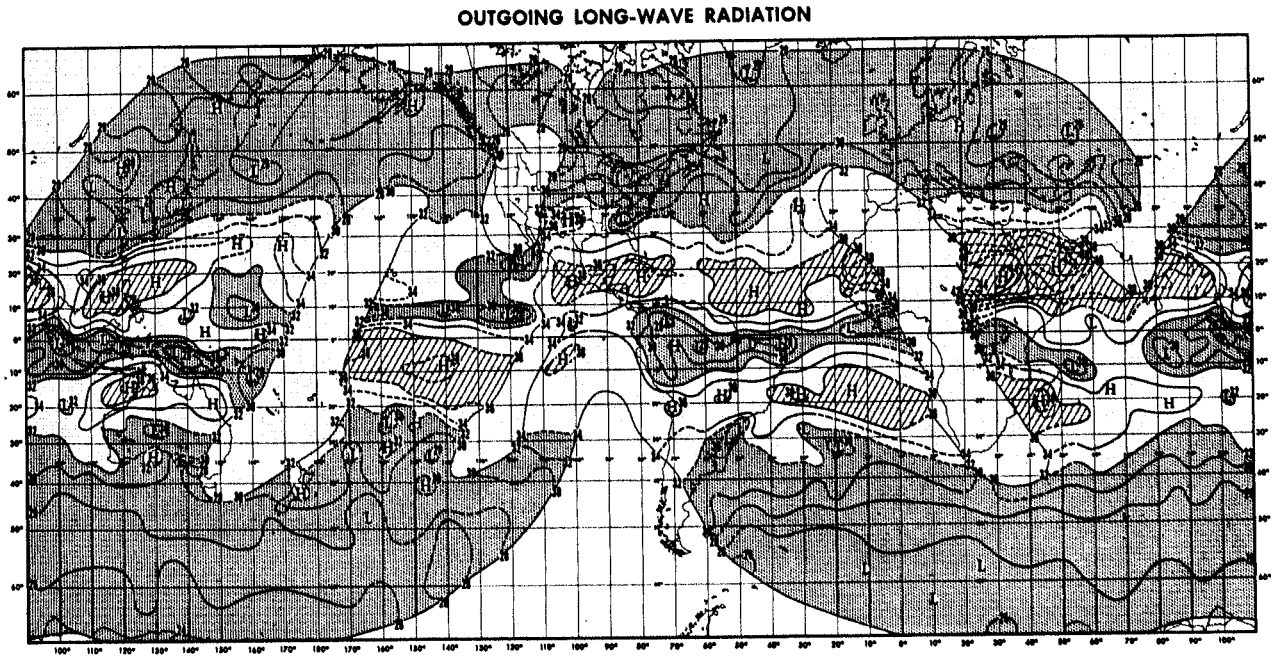
ALBEDO



700-MB HEIGHT AND GEOSTROPHIC WIND



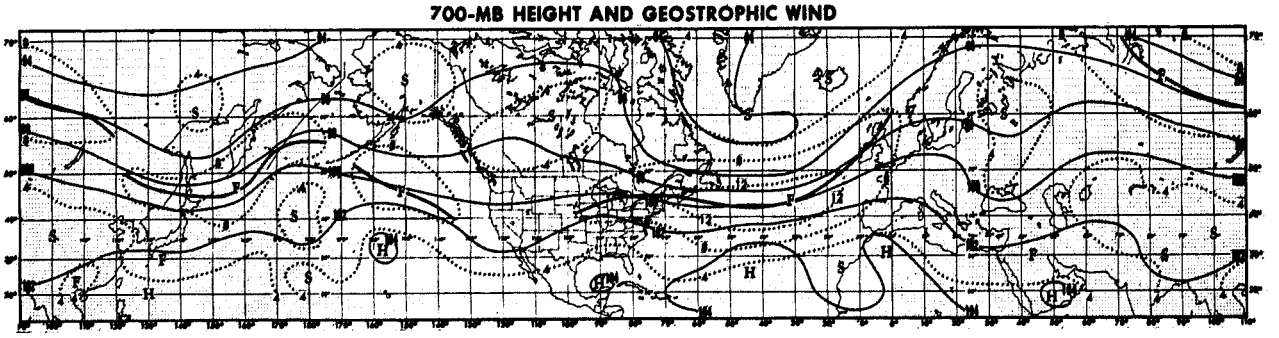
OUTGOING LONG-WAVE RADIATION



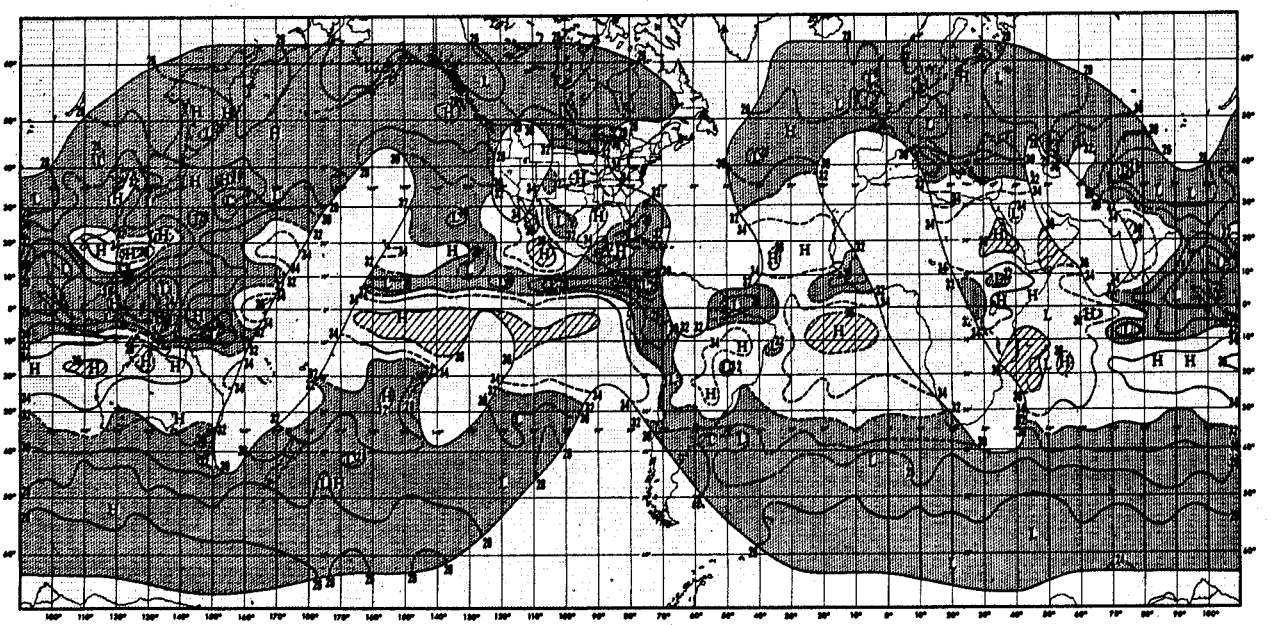
APRIL 1964

Figure 20

700-MB HEIGHT AND GEOSTROPHIC WIND



OUTGOING LONG-WAVE RADIATION

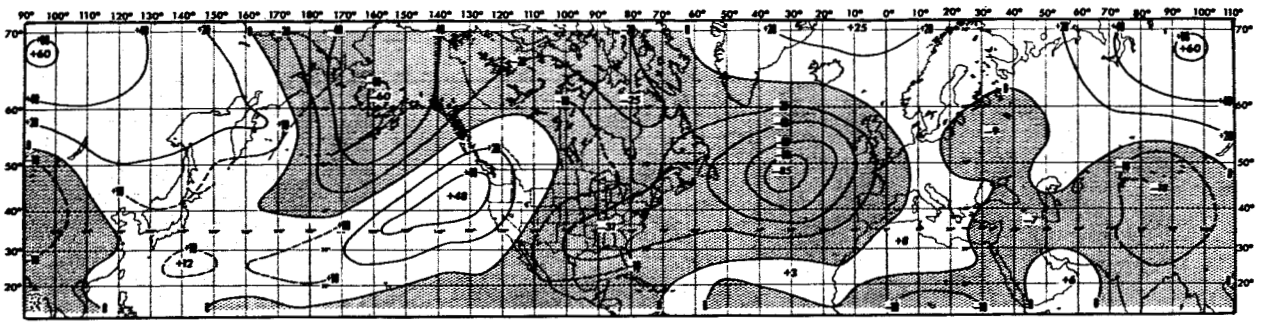


MAY 1964

Figure 21

DIFFERENCE IN 700-MB HEIGHT

FEBRUARY 1962 TO FEBRUARY 1964



DIFFERENCE IN OUTGOING LONG-WAVE RADIATION

FEBRUARY 1962 TO FEBRUARY 1964

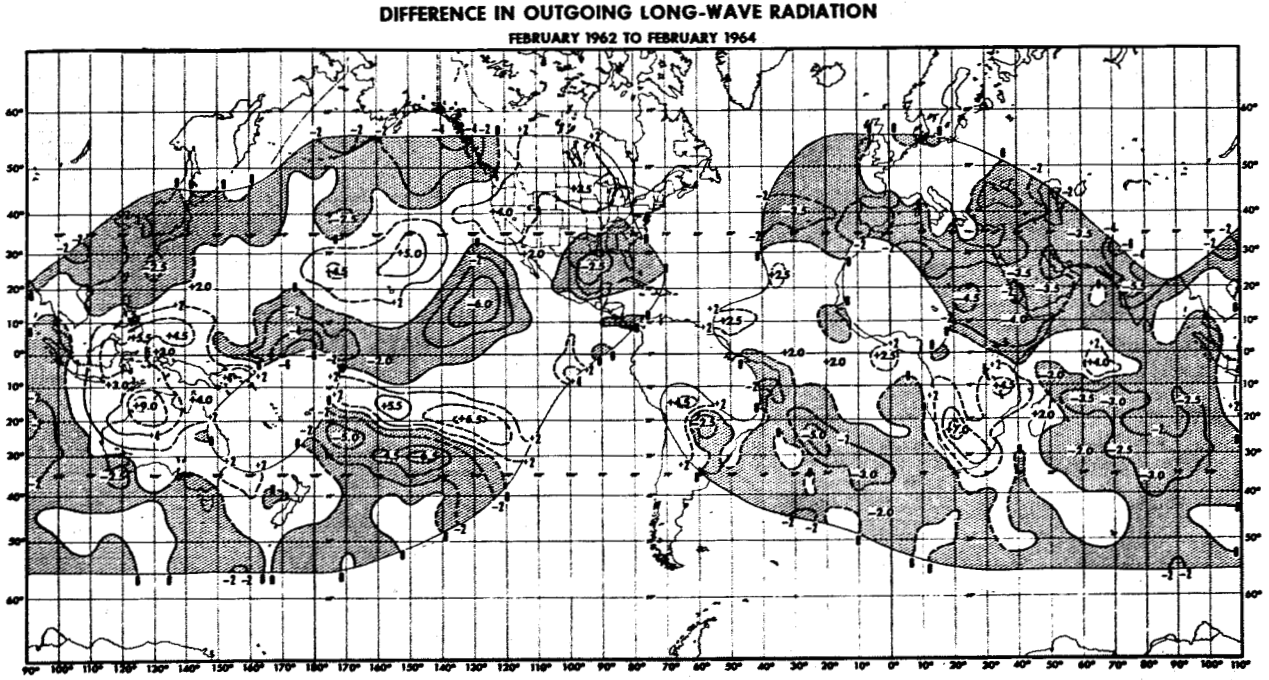
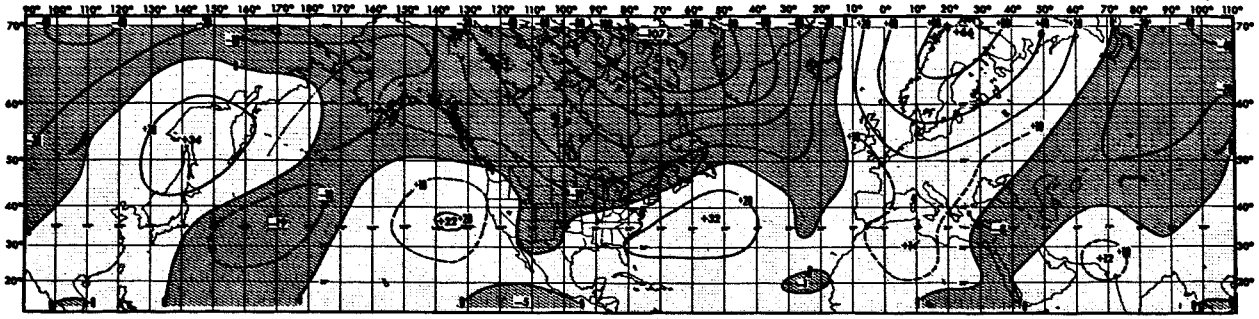


Figure 22

DIFFERENCE IN 700-MB HEIGHT

MARCH 1962 TO MARCH 1964



DIFFERENCE IN OUTGOING LONG-WAVE RADIATION

MARCH 1962 TO MARCH 1964

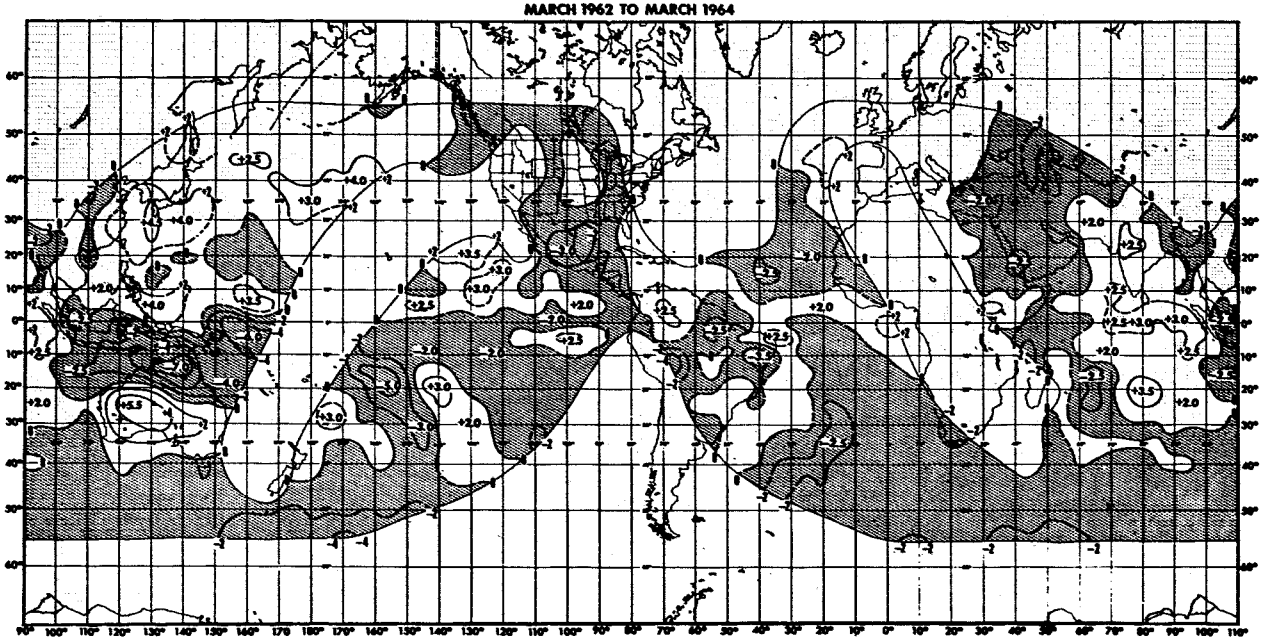
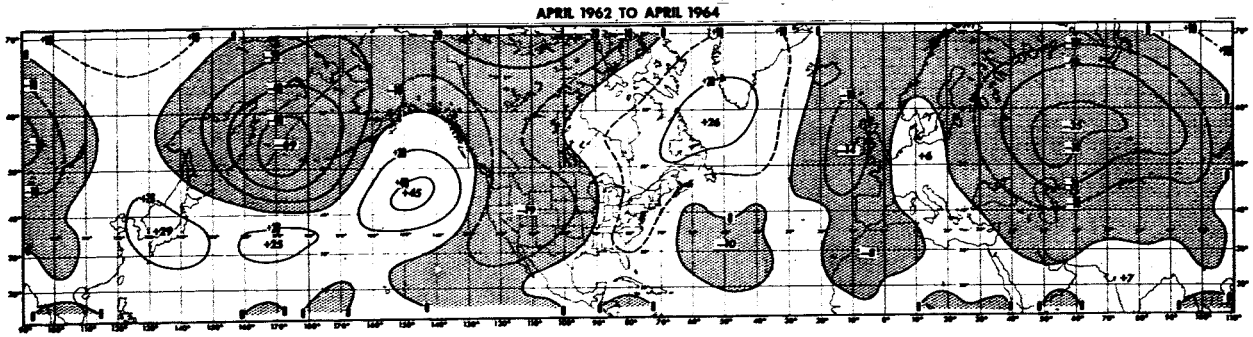


Figure 23

DIFFERENCE IN 700-MB HEIGHT
APRIL 1962 TO APRIL 1964



DIFFERENCE IN OUTGOING LONG-WAVE RADIATION
APRIL 1962 TO APRIL 1964

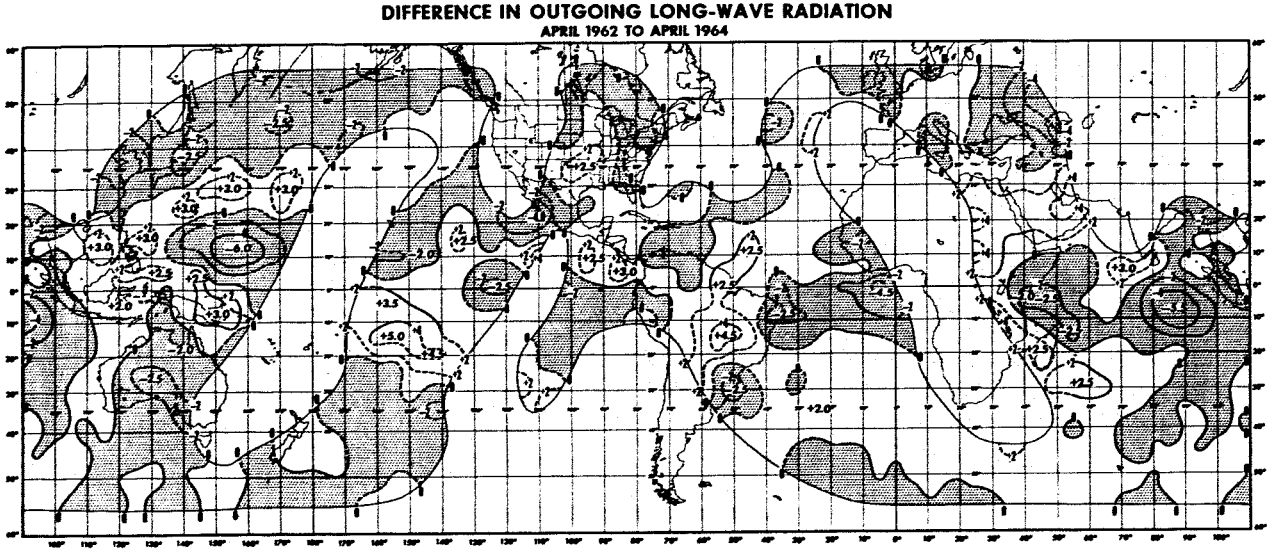
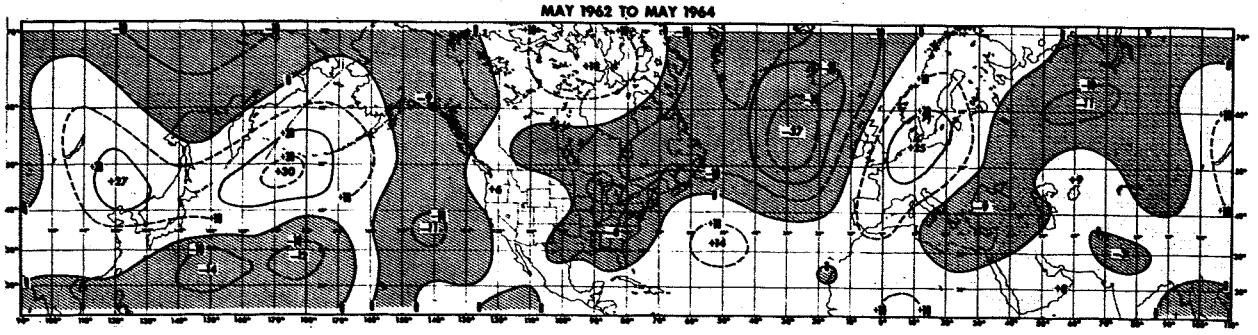


Figure 24

DIFFERENCE IN 700-MB HEIGHT
MAY 1962 TO MAY 1964



DIFFERENCE IN OUTGOING LONG-WAVE RADIATION
MAY 1962 TO MAY 1964

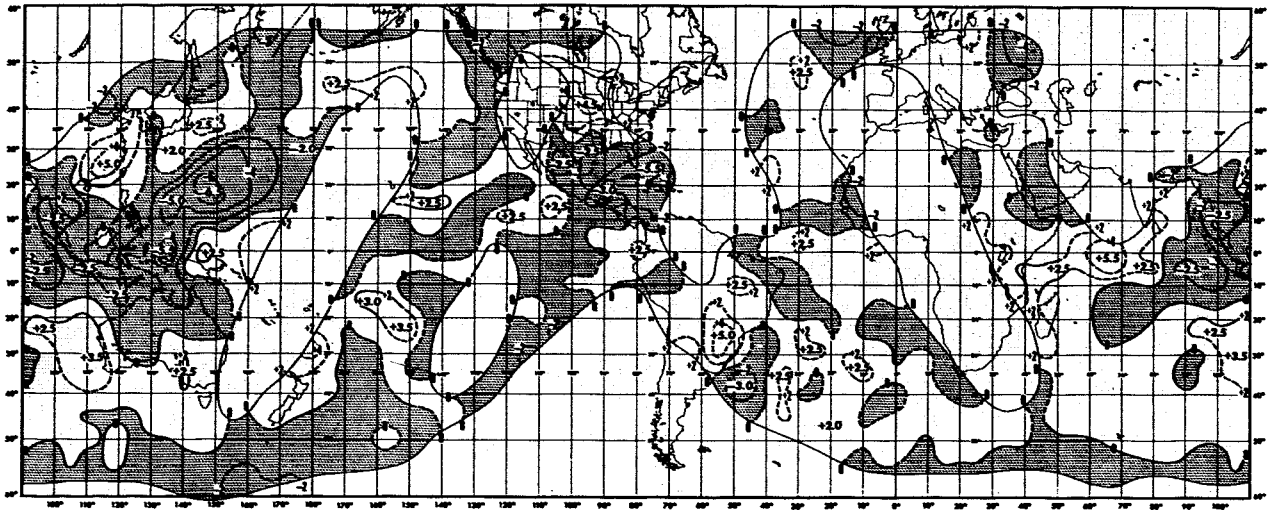


Figure 25