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Atlas of Albedo and Absorbed Solar Radiation Derived From Nimbus 7 Earth Radiation Budget Data Set—November 1978 to October 1985

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Introduction

The weather and climate of the Earth are driven by solar radiation which is absorbed by the Earth and its atmosphere and subsequently emitted as outgoing longwave radiation (OLR). Because of the importance of understanding the flows of radiation into and out of the Earth and its atmosphere, Earth radiation budget (ERB) instruments were flown on the Nimbus 6 and 7 spacecraft (Smith et al. 1977; Jacobowitz et al. 1984). These instruments included wide-field-of-view (WFOV) radiometers to provide measurements from which the reflected solar radiation and OLR can be computed. The Nimbus 6 and 7 WFOV radiometers began providing data in July 1975 and November 1978, respectively. As of the present paper, the Nimbus 7 ERB WFOV radiometers continue to operate and produce data. Major advantages of the ERB data are that they are broadband measurements, they cover a period of more than 10 years, and they are of good quality.

This paper is an atlas of monthly mean global maps of albedo and absorbed solar radiation (ASR) for November 1978 to October 1985 derived from measurements from the shortwave WFOV radiometer aboard the Nimbus 7 spacecraft. The deconvolution method which is used to produce the maps and tables is briefly discussed here so that the user may understand their generation and their limitations. A full description of the albedo retrieval method is given by Smith and Rutan (1990).

Bess and Smith (1987a, 1987b) have used the resolution enhancement technique of Smith and Green (1981) and Bess, Green, and Smith (1981) to produce atlases of monthly mean global maps of OLR based on 3 years of Nimbus 6 and 7 years of Nimbus 7 data. Those atlases also include tabulations of the spherical harmonic coefficients which quantify these OLR distributions for use by researchers. The atlas herein of albedo and ASR together with the OLR atlases define the two radiation streams whose balance governs the Earth's climate. A study of the climate of Earth by definition requires a long-term data set. This paper includes 7 years of albedo and ASR maps and provides a resource for researchers studying the radiation budget of the Earth. A companion paper (Smith, Rutan, and Bess 1990) provides similar data, based on Nimbus 6 data, for July 1975 to May 1978.

Data Set

The Nimbus 7 spacecraft was launched into a Sun-synchronous orbit with an inclination of 99°, an altitude of 955 km, and a daytime Equator crossing time near noon. From this altitude, the field of view of the WFOV radiometer is an area with a radius equal to the arc for a geocentric angle of 30°. As shown herein, the resolution of information retrievable from the WFOV measurements is approximately 10°. Thus, the North and South Poles are within the resolution distance of the instrument during each orbit, and the measurements, in effect, provide global coverage.

The shortwave radiometer consists of a thermopile detector, which measures the radiant flux impinging on it, covered by a high-grade quartz dome which filters out radiation with wavelengths longer than 5 μm (Smith et al. 1977; Jacobowitz et al. 1984). The digitized measurements are processed and calibrations are applied to produce data in terms of physical units, and these data are then recorded on the Solar and Earth Flux Data Tapes (SEFDT) by the Nimbus 7 Data Processing Team. These tapes include the time, latitude, and longitude for each of the measurements and are available from the National Space Science and Data Center, NASA Goddard Space Flight Center, Greenbelt, Maryland.

Measurements are nominally recorded every 16 seconds, but operational problems usually reduce the number of data points actually available. Because of spacecraft power limitations, the ERB instrument was operated in a duty cycle of 3 days on and 1 day off from launch until September 1983, after which it operated full time for extended periods. For the portion of the orbit during which the spacecraft was over the sunlit portion of Earth, there were 20 000 usable shortwave WFOV measurements in November 1978, when the Nimbus 7 ERB instrument began operation. For the next year, there were 33 000 to 43 000 usable shortwave measurements for each month. During succeeding years there were 38 000 to 50 000 shortwave measurements each month until the last year included herein (1985), when there were 56 000 to 66 000 usable measurements each month. With 20 000 or more shortwave measurements in a month, the sampling of the Earth was adequate to produce good albedo maps.

Method of Analysis

Although the WFOV radiometers are operationally simple, the analysis of the data is somewhat complex. The measured quantity is the shortwave radiant flux which impinges on the radiometer. This flux is an integral over the entire field of view of the radiometer. (See fig. 1.) The problem of analysis of WFOV measurements is thus to solve this integral equation for the albedo field. The spatial resolution which is retrievable from the WFOV data is quite large. The technique for solution of the measurement equation is treated by Smith and Rutan (1990) and is based on Smith (1981). This section gives a summary of the method and the limitations which are imposed by the low-resolution measurement.

The measurement equation for reflected solar radiation may be written as

$$m(\Theta_S, \Phi_S, \Theta_H, \Phi_H) = \frac{1}{\pi} H \int_{\mathrm{FOV}} R(\Theta_T, \Phi_T, \theta, \phi - \phi_H, \xi) \cos^* \xi \, G(\alpha) A(\Theta_T, \Phi_T) \, d\Omega \qquad (1)$$

where m is the measurement in W/m^2 at the sensor. (A list of symbols appears after the references.) The geometry of the measurement is shown in figure 2. The colatitude and longitude of the subsatellite point are Θ_S and Φ_S. The colatitude and longitude of the subsolar point are Θ_H and Φ_H, and the solar irradiance at the Earth's position is H. The mean value of H (i.e., the solar constant) is taken to be 1368 W/m^2, and variation of H due to the eccentricity of the Earth's orbit is taken into account. The function $\cos^* \xi$ is defined by

$$\cos^* \xi \begin{cases} = \cos \xi & (0^\circ \leq \xi < 90^\circ) \\ = 0 & (\xi \geq 90^\circ) \end{cases}$$

The sensor directional response is $G(\alpha)$, where α is nadir angle of the scene from the spacecraft location. For the WFOV radiometer, which responds as a flat plate, $G(\alpha) = \cos \alpha$. The albedo A at a point at the top of the atmosphere is a function of colatitude Θ_T and longitude Φ_T of the Earth scene, and is assumed to be constant with local time and solar zenith angle. The top of the atmosphere is taken to be at an altitude of 30 km. The bidirectional reflection function R expresses the anisotropy of the reflected radiation as a function of scene location (Θ_T and Φ_T), viewing geometry (described by θ and $\phi - \phi_H$), and solar zenith angle (ξ).

The measurement equation (1) is an integral equation which can be solved for the albedo in the form

$$A(\Theta_T, \Phi_T) = \sum_{n=-N}^{N} \exp(\mathrm{i}n\Phi_T) f_n(\Theta_T) \qquad (2)$$

The $f_n(\Theta_T)$ terms are solutions of the discrete form of equation (1), which is Fourier resolved in longitude and expressed as

$$\mathbf{B}_n \mathbf{f}_n = \mathbf{g}_n \qquad (3)$$

where the components of $\mathbf{g}_n$ are values of an η grid of the complex Fourier transform $g_n(\eta)$ in longitude of the measurement map. Because the $\mathbf{B}_n$ matrices are singular, the $\mathbf{f}_n$ terms are computed by the method of singular value decomposition (e.g., Twomey, 1977), whereby they are written as

$$\mathbf{f}_n = \sum_{j=1}^{M} \lambda_{nj}^{-1} (\mathbf{v}_{nj}^T \mathbf{g}_n) \mathbf{u}_{nj} + \sum_{j=M+1}^{J} \sigma_{nj} \mathbf{u}_{nj} \qquad (4)$$

where M is the number of resolvable terms and J is the number of points in the Θ_T grid. The λ_{nj} and $\mathbf{u}_{nj}$ terms are singular values and singular vectors of the $\mathbf{B}_n$ matrices, and as such are discrete approximations to the eigenvalues and eigenfunctions of the measurement integral equation. The $\mathbf{v}_{jn}$ terms comprise a set of vectors which is reciprocal to the $\mathbf{u}_{jn}$ set. The σ_{nj} values are the singular-vector coefficients which are unobservable, that is, not resolvable.

The σ_{nj} values cannot be determined from the solution of equation (3) for two reasons. First, terms which include σ_{nj} are those with high wave numbers; this results in a limitation of resolution in the final results. Second, there are unobservable parts of the solution because of low solar illumination near the terminator, which for Nimbus 7 is at high latitudes. The method of singular value decomposition thus has the advantage of defining which parts of the albedo field can be determined from the measurements (the first summation of equation (4)) and which parts cannot be determined from the measurements, that is, they are unobservable (the second summation of equation (4)). For the present work, the unobservable parts were computed from the compilation by Ellis and Vonder Haar (1976).

Example Application

The major aspects of the albedo retrieval technique are demonstrated in this section for the month of September. September provides a near-equinox case, for which all points of the Earth are sunlit during some days of the month. Thus, the domain of the albedo solution is 90° N. to 90° S. (90° to −90°) for September. A solar declination of 2.9° was used for September. Because the solar declination is small and the spacecraft crosses the Equator near noon, the illumination conditions are very nearly symmetric in terms of the orbit angle η from the Equator crossing.

The first step of the retrieval is to compute the singular values λ_{nj} and singular vectors $\mathbf{u}_{nj}$ of the measurement matrices $\mathbf{B}_n$. Figure 3 shows that for September the singular values λ_{nj} decrease exponentially with increasing latitudinal wave number j. This rapid decrease of λ_{nj} with j is of considerable importance in equation (4). For large j, any error in

$\mathbf{g}_n$ is magnified by the large value of λ_{nj}^{-1}, so that exponentially increasing errors dominate the high-order terms. This problem puts a practical restriction on the number of terms in the first summation of equation (4), thereby limiting the resolution obtainable from the WFOV measurements.

The singular vectors $\mathbf{u}_{nj}$ form a complete set for each n, so that any albedo distribution can be expressed in terms of $\mathbf{u}_{nj}$. Some singular vectors $\mathbf{u}_{nj}$ are shown in figures 4(a) to 4(d) for the zonal case ($n = 0$). Because of the near symmetry of solar illumination for this case, the odd singular vectors are very nearly symmetric, and the even singular vectors are very nearly skew symmetric. They vanish at the poles for all but the highest order vectors. The highest order singular vectors have zero or near-zero eigenvalues, so that the terms which describe the albedo at the poles cannot be retrieved from WFOV data and are, therefore, included in the second summation of equation (4). Physically, the low solar illumination over the small areas at the poles produces only a negligible effect on WFOV measurements regardless of albedo; thus, the measurements contain very little information on albedo for the poles.

The shortwave WFOV measurement results are now considered. The monthly mean map of shortwave WFOV measurements is formed in terms of longitude of the subsatellite point and orbit angle η with a 5° by 5° resolution grid system.[1] Figure 5 shows the shortwave WFOV measurement map for September 1981. The map is next decomposed into a Fourier series for each η grid value, the result being the set of complex $\mathbf{g}_n$ vectors. Figures 6(a) and 6(b) show the results for $n = 0$ to 5. For September, the $g_0(\eta)$ distribution is fairly symmetric, corresponding to the nearly symmetric illumination for the Nimbus 7 orbit and the somewhat symmetrical zonal distribution of albedo with latitude.

The measurements appear in the albedo in the terms $\mathbf{v}_{nj}^T\mathbf{g}_n$. Figure 7 shows the magnitudes of these terms for $n = 0$ (zonal case) as a function of their order j (i.e., the latitudinal wave number). This inner product is the projection of $\mathbf{g}_n$ onto $\mathbf{v}_{nj}$ as a basis set. These terms form two sequences. One sequence (the upper set of points) consists of odd-order terms, which decrease exponentially with increasing order j. The sequence decreases because the integration over the field of view of incoming radiances by the WFOV radiometer smooths out features of the albedo field. The other sequence (the lower set of points) consists of even-order terms, which are much smaller than those of the first sequence. The near symmetry of the zonal average measurements causes the smallness of the even-order terms.

The effect of the λ_{nj}^{-1} multiplier is to undo the smoothing effect of the WFOV measurement. The terms $\lambda_{nj}^{-1}(\mathbf{v}_{nj}^T\mathbf{g}_n)$ are the projections of the retrieved albedo onto the $\mathbf{u}_{nj}$ basis. Figure 8 shows the magnitudes of these terms for $n = 0$ for September 1981 as a function of order j. As a consequence of the division by λ_{nj}, these terms do not show rapid convergence. Smith and Rutan (1990) discuss the number of terms which should be used in the first summation in equation (4). The number of terms which is used for each longitudinal wave number is listed in table I for each month in this atlas.

Figure 9 shows the $f_0(\Theta_T)$ profile (i.e., the zonal average albedo) as computed from the measurements in the first summation for varying number of terms M for September 1981. The retrieved albedo converges except at high latitudes, where there is difficulty because of illumination and sizes of zones as discussed earlier. These results are not acceptable at the high latitudes, where the albedo is quite high because of snow and ice cover and also increased Rayleigh scattering in the atmosphere at large solar zenith angles. The high-latitude part of the solution comes from the second summation, which is computed from a priori data taken from Ellis and Vonder Haar (1976). Figure 10 shows the latitudinal profile of the contribution of the second summation to albedo for varying M. The case $M = 0$ corresponds to the a priori albedo profile. For increasing M, terms are deleted from the second summation, and the effect is to leave the unobservable albedo distribution at high latitudes. The total estimate of albedo uses both summations and is shown in figure 11 for $M = 18$. The a priori information is only included in the zonal average term ($n = 0$).

If the albedo is the same as the a priori albedo for the unobservable regions, then no error is incurred by this procedure. The error is the deviation of the albedo from the a priori albedo in these regions. Nevertheless, the unobservable component provides a useful measure of the potential for error.

The dependence of observability on latitudes is summarized in figure 12, which shows a northern winter case for the Nimbus 7 spacecraft. From 40° N. to 70° S. (region IV) the albedo can be retrieved with no significant contribution from the unobservable part of the albedo distribution. In this region the albedo is defined by the WFOV measurements. In latitudes 67° N. to 50° N. (region II) and 80° S. to

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[1] The orbit angle is used rather than latitude of the subsatellite point because for the fixed orbit inclination of 99° the latitude is defined uniquely, but at high latitudes there may be measurements for both ascending and descending parts of the orbit, so that the latitude does not uniquely define the viewing conditions.

90° S. (region VI) the WFOV measurements provide very little information. In latitudes 50° N. to 40° N. (region III) and 70° S. to 80° S. (region V) the WFOV measurements provide significant information, but the part of the distribution which is unobservable in the WFOV measurements is also significant. These are transition regions between regions IV and II and regions IV and VI. The albedo is physically undefined for latitudes poleward of 67° N. (region I) because this region is in darkness for the example shown.

These boundaries are a function of the orbit characteristics of the spacecraft. In particular, the boundaries of the observable regions are a function of the solar declination angle and, thus, of the time of year. Figure 13 shows the variation of the observable regions during the year. The Nimbus 7 has an unobservable region which is approximately 20° in latitude in each hemisphere plus a transition region of approximately 10° for most of the year.

Although the albedo is unobservable in the high latitudes, the more important parameter is the absorbed solar energy ASR, for which the albedo is only an intermediate parameter. At the high latitudes the solar irradiance is small, so the effect of albedo errors is reduced. Figure 14 shows zonal profiles of the incident solar radiation, the ASR, and the component of ASR due to the unobservable component of albedo. The ASR contribution due to the unobservable component of albedo is quite small. Thus, for the purpose of computing ASR from WFOV measurements, observability does not create a problem for large-scale features. Small-scale features cannot be retrieved, that is, the resolution of the ASR is limited.

Results

The method described in the previous sections has been used to compute monthly mean maps of albedo and ASR for November 1978 to October 1985 from Nimbus 7 ERB WFOV shortwave measurements. The zonal means of albedo are also listed for each month in table II. The zonal means for each month of the year have been averaged for the 7-year data period to produce climatological zonal means for each month. These are shown in figure 15. Likewise, the zonal means of ASR are shown in figure 16.

The albedo maps show contours of albedo expressed in percent with intervals of 5 percent. Contours of albedos less than 30 percent are shown as dotted lines. The ASR maps show contours with intervals of 25 W/m^2, with contours of 250 W/m^2 or greater shown as dotted lines.

These geographical distributions of albedo and ASR are presented as a resource for researchers in studies of the radiation budget of the Earth. This atlas of shortwave data complements the atlases of outgoing longwave radiation based on Nimbus 6 and 7 WFOV measurements as analyzed by Bess and Smith (1987a, 1987b).

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Symbols

A	albedo
$\mathbf{B}_n$	matrix for measurement integral over nth Fourier term in longitude
$f_n(\Theta_T)$	latitudinal function for nth Fourier term for reduced albedo
$G(\alpha)$	angular response of sensor
$g_n(\eta)$	orbit angle function for nth Fourier term for measurements
H	solar irradiance, W/m^2
j	index for singular values and singular vectors in singular value decomposition solution of discretized measurement equation
m	measurement, W/m^2
N	number of Fourier terms in longitude
R	bidirectional reflectance function
$\mathbf{u}_{nj}$	singular vector of $\mathbf{B}_n$
$\mathbf{v}_{nj}$	singular vector of $\mathbf{B}_n$
α	nadir angle at spacecraft, deg
η	geocentric angle from Equator crossing to spacecraft
Θ	colatitude
θ	zenith angle of radiation
λ_{nj}	jth singular value of nth Fourier term
ξ	solar zenith angle, deg
σ_{nj}	singular-vector coefficients for unobservable components of albedo
Φ	longitude
ϕ	azimuth angle of radiation, deg
Ω	solid angle, rad

Subscripts:

H	subsolar point
S	subsatellite point
T	target, or Earth, scene

Table I. Number of Singular Vectors Used for Each Longitudinal Wave Number

Month	Number of singular vectors for wave number of—											
	0	1	2	3	4	5	6	7	8	9	10	11
Nov. 1978	30	16	10	4	4	4	2	2	2	2	2	2
Dec. 1978	36	28	26	12	2	2	2	2	2	2	2	2
Jan. 1979	36	30	26	6	2	2	2	2	2	2	2	2
Feb. 1979	26	16	12	4	2	2	2	2	2	2	2	2
Mar. 1979	38	30	16	6	4	2	2	2	2	2	2	2
Apr. 1979	28	26	18	4	4	2	2	2	2	2	2	2
May 1979	32	30	26	4	4	2	2	2	2	2	2	2
June 1979	32	26	24	10	6	2	2	2	2	2	2	2
July 1979	36	22	14	4	4	2	2	2	2	2	2	2
Aug. 1979	34	18	16	6	4	2	2	2	2	2	2	2
Sept. 1979	38	24	22	12	4	4	2	2	2	2	2	2
Oct. 1979	36	30	16	6	4	2	2	2	2	2	2	2
Nov. 1979	32	26	20	6	2	2	2	2	2	2	2	2
Dec. 1979	34	26	20	10	4	2	2	2	2	2	2	2
Jan. 1980	30	30	26	6	4	2	2	2	2	2	2	2
Feb. 1980	34	28	24	6	2	2	2	2	2	2	2	2
Mar. 1980	38	30	22	6	4	2	2	2	2	2	2	2
Apr. 1980	32	28	28	6	6	4	2	2	2	2	2	2
May 1980	30	24	22	6	2	2	2	2	2	2	2	2
June 1980	34	22	16	4	2	2	2	2	2	2	2	2
July 1980	34	28	20	4	2	2	2	2	2	2	2	2
Aug. 1980	34	22	20	8	6	2	2	2	2	2	2	2
Sept. 1980	30	24	22	6	2	2	2	2	2	2	2	2
Oct. 1980	36	28	18	6	2	2	2	2	2	2	2	2
Nov. 1980	30	28	20	4	2	2	2	2	2	2	2	2
Dec. 1980	34	28	20	8	4	2	2	2	2	2	2	2
Jan. 1981	30	24	12	6	2	2	2	2	2	2	2	2
Feb. 1981	30	26	22	8	6	2	2	2	2	2	2	2
Mar. 1981	36	18	12	4	2	2	2	2	2	2	2	2
Apr. 1981	34	30	28	8	6	4	2	2	2	2	2	2
May 1981	34	22	20	4	4	2	2	2	2	2	2	2
June 1981	32	28	24	4	2	2	2	2	2	2	2	2
July 1981	34	22	20	4	4	2	2	2	2	2	2	2
Aug. 1981	34	30	26	6	4	2	2	2	2	2	2	2
Sept. 1981	36	24	22	6	4	4	2	2	2	2	2	2
Oct. 1981	34	24	18	4	4	2	2	2	2	2	2	2
Nov. 1981	34	18	12	6	4	2	2	2	2	2	2	2
Dec. 1981	36	26	22	6	4	2	2	2	2	2	2	2
Jan. 1982	30	28	12	4	2	2	2	2	2	2	2	2
Feb. 1982	30	22	20	4	2	2	2	2	2	2	2	2
Mar. 1982	32	28	16	4	2	2	2	2	2	2	2	2
Apr. 1982	30	28	24	6	6	4	2	2	2	2	2	2
May 1982	34	26	18	2	2	2	2	2	2	2	2	2
June 1982	32	24	20	6	4	2	2	2	2	2	2	2
July 1982	32	22	20	6	4	2	2	2	2	2	2	2
Aug. 1982	36	26	12	4	4	2	2	2	2	2	2	2
Sept. 1982	32	24	18	8	6	4	2	2	2	2	2	2

Table I. Concluded

Month	Number of singular vectors for wave number of—											
	0	1	2	3	4	5	6	7	8	9	10	11
Oct. 1982	30	28	22	4	4	4	2	2	2	2	2	2
Nov. 1982	30	28	22	6	4	4	2	2	2	2	2	2
Dec. 1982	34	30	28	6	4	2	2	2	2	2	2	2
Jan. 1983	34	32	18	8	6	4	2	2	2	2	2	2
Feb. 1983	30	18	16	6	2	2	2	2	2	2	2	2
Mar. 1983	36	30	28	6	4	2	2	2	2	2	2	2
Apr. 1983	36	28	26	6	4	2	2	2	2	2	2	2
May 1983	32	26	16	6	4	2	2	2	2	2	2	2
June 1983	30	26	18	4	4	2	2	2	2	2	2	2
July 1983	30	24	14	4	2	2	2	2	2	2	2	2
Aug. 1983	34	26	22	6	4	2	2	2	2	2	2	2
Sept. 1983	32	24	22	4	4	4	2	2	2	2	2	2
Oct. 1983	30	26	20	4	4	2	2	2	2	2	2	2
Nov. 1983	32	24	12	6	6	4	2	2	2	2	2	2
Dec. 1983	34	28	26	4	4	4	2	2	2	2	2	2
Jan. 1984	32	18	12	4	4	2	2	2	2	2	2	2
Feb. 1984	36	28	22	6	6	4	2	2	2	2	2	2
Mar. 1984	32	26	12	4	4	2	2	2	2	2	2	2
Apr. 1984	28	26	18	6	4	2	2	2	2	2	2	2
May 1984	32	26	24	6	4	2	2	2	2	2	2	2
June 1984	30	30	22	4	4	2	2	2	2	2	2	2
July 1984	30	26	26	8	6	4	2	2	2	2	2	2
Aug. 1984	30	22	18	6	4	2	2	2	2	2	2	2
Sept. 1984	32	24	22	6	4	4	2	2	2	2	2	2
Oct. 1984	30	28	20	4	2	2	2	2	2	2	2	2
Nov. 1984	30	26	12	6	2	2	2	2	2	2	2	2
Dec. 1984	34	28	26	6	2	2	2	2	2	2	2	2
Jan. 1985	30	28	16	6	4	2	2	2	2	2	2	2
Feb. 1985	30	26	20	4	4	2	2	2	2	2	2	2
Mar. 1985	36	28	18	6	4	2	2	2	2	2	2	2
Apr. 1985	28	28	22	8	4	2	2	2	2	2	2	2
May 1985	32	24	22	6	6	4	2	2	2	2	2	2
June 1985	32	24	16	4	4	2	2	2	2	2	2	2
July 1985	30	22	18	6	4	2	2	2	2	2	2	2
Aug. 1985	34	24	20	4	2	2	2	2	2	2	2	2
Sept. 1985	32	26	20	4	4	2	2	2	2	2	2	2
Oct. 1985	30	28	22	4	4	2	2	2	2	2	2	2

Table II. Zonal Albedo Means for 1978 to 1985

(a) November 1978 to October 1979

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.516	.642	.647	.627	.572	.573	.566	----
80-85 N	----	----	----	----	.596	.637	.647	.613	.550	.577	.593	----
75-80 N	----	----	----	----	.586	.648	.661	.613	.520	.550	.611	.576
70-75 N	----	----	----	.566	.625	.630	.606	.535	.442	.458	.563	.535
65-70 N	.625	----	.531	.514	.597	.573	.508	.426	.364	.381	.451	.549
60-65 N	.521	.537	.529	.519	.513	.495	.423	.369	.352	.371	.379	.524
55-60 N	.487	.478	.525	.507	.453	.419	.363	.356	.357	.366	.378	.448
50-55 N	.441	.574	.503	.478	.436	.378	.327	.337	.336	.330	.356	.374
45-50 N	.394	.532	.453	.441	.403	.363	.313	.312	.312	.300	.296	.349
40-45 N	.364	.386	.404	.399	.350	.337	.303	.289	.285	.272	.267	.335
35-40 N	.347	.368	.370	.357	.320	.297	.282	.261	.255	.227	.253	.288
30-35 N	.323	.342	.334	.322	.298	.268	.260	.237	.236	.207	.228	.240
25-30 N	.279	.263	.288	.282	.261	.243	.244	.225	.227	.220	.222	.222
20-25 N	.237	.246	.244	.229	.225	.208	.219	.214	.210	.214	.219	.207
15-20 N	.221	.214	.212	.187	.189	.179	.193	.210	.216	.213	.204	.196
10-15 N	.227	.212	.188	.179	.170	.183	.199	.231	.243	.236	.216	.217
5-10 N	.233	.230	.188	.193	.194	.209	.224	.258	.248	.234	.229	.236
0-5 N	.231	.214	.207	.206	.216	.222	.225	.245	.229	.210	.212	.223
0-5 S	.221	.246	.217	.217	.213	.210	.202	.207	.204	.202	.201	.205
5-10 S	.214	.231	.218	.222	.210	.193	.192	.191	.190	.192	.199	.199
10-15 S	.210	.208	.221	.208	.199	.185	.194	.188	.196	.179	.193	.192
15-20 S	.207	.205	.217	.191	.195	.187	.196	.193	.202	.192	.202	.195
20-25 S	.204	.192	.204	.198	.206	.204	.212	.215	.205	.212	.210	.209
25-30 S	.202	.216	.196	.218	.210	.231	.244	.242	.239	.220	.218	.219
30-35 S	.218	.231	.201	.222	.231	.258	.273	.266	.278	.264	.250	.239
35-40 S	.257	.232	.226	.233	.273	.282	.301	.298	.291	.311	.277	.274
40-45 S	.301	.282	.272	.289	.300	.310	.341	.350	.322	.311	.299	.302
45-50 S	.334	.313	.317	.353	.343	.352	.390	.418	.407	.330	.347	.329
50-55 S	.371	.370	.351	.372	.401	.406	.438	.485	.497	.426	.386	.374
55-60 S	.424	.372	.384	.372	.414	.458	.488	.524	.532	.534	.425	.440
60-65 S	.502	.445	.428	.424	.440	.499	.545	.523	.517	.568	.536	.530
65-70 S	.615	.561	.512	.549	.576	.536	.598	----	.501	.542	.679	.641
70-75 S	.743	.660	.641	.683	.734	.573	----	----	----	.506	.739	.731
75-80 S	.812	.740	.737	.743	.771	.605	----	----	----	----	.705	.757
80-85 S	.759	.677	.721	.712	.715	----	----	----	----	----	.652	.730
85-90 S	.640	.599	.628	.647	.661	----	----	----	----	----	.633	.690

Table II. Continued

(b) November 1979 to October 1980

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.527	.653	.654	.624	.577	.584	.565	----
80-85 N	----	----	----	----	.607	.645	.648	.628	.572	.620	.567	----
75-80 N	----	----	----	----	.596	.650	.660	.620	.536	.588	.570	.580
70-75 N	----	----	----	.578	.634	.623	.609	.520	.448	.451	.549	.548
65-70 N	.626	----	.536	.527	.603	.561	.513	.410	.375	.344	.481	.570
60-65 N	.538	.530	.533	.528	.514	.482	.430	.359	.358	.354	.398	.548
55-60 N	.523	.460	.528	.499	.453	.408	.375	.344	.351	.376	.352	.460
50-55 N	.490	.547	.505	.450	.443	.366	.345	.347	.343	.342	.349	.369
45-50 N	.433	.505	.456	.410	.419	.345	.330	.338	.323	.306	.335	.340
40-45 N	.367	.367	.405	.388	.367	.321	.313	.296	.276	.283	.282	.335
35-40 N	.322	.356	.369	.358	.335	.294	.283	.254	.244	.241	.237	.293
30-35 N	.297	.339	.336	.316	.308	.270	.250	.235	.237	.226	.237	.248
25-30 N	.270	.273	.289	.274	.261	.244	.228	.219	.226	.238	.236	.239
20-25 N	.237	.254	.233	.233	.220	.209	.208	.212	.215	.215	.210	.226
15-20 N	.216	.205	.195	.191	.188	.181	.190	.218	.223	.203	.212	.204
10-15 N	.220	.199	.181	.169	.172	.178	.196	.229	.236	.235	.235	.222
5-10 N	.231	.224	.186	.182	.193	.203	.223	.246	.248	.238	.224	.240
0-5 N	.230	.202	.202	.203	.215	.223	.229	.239	.235	.214	.197	.216
0-5 S	.214	.232	.220	.214	.213	.212	.203	.204	.197	.209	.197	.198
5-10 S	.204	.225	.231	.221	.209	.189	.185	.192	.184	.198	.194	.201
10-15 S	.201	.209	.225	.217	.198	.186	.187	.198	.199	.181	.178	.193
15-20 S	.200	.215	.208	.201	.191	.195	.191	.188	.195	.198	.191	.188
20-25 S	.202	.202	.192	.193	.199	.202	.203	.204	.198	.215	.219	.206
25-30 S	.212	.206	.189	.198	.204	.216	.233	.250	.250	.208	.214	.216
30-35 S	.227	.212	.202	.213	.222	.252	.269	.279	.288	.248	.223	.228
35-40 S	.248	.224	.232	.242	.263	.292	.302	.295	.292	.304	.283	.262
40-45 S	.277	.279	.277	.285	.299	.323	.338	.356	.337	.307	.328	.289
45-50 S	.311	.305	.321	.327	.342	.354	.376	.456	.446	.337	.328	.317
50-55 S	.345	.362	.357	.365	.389	.398	.422	.533	.540	.465	.359	.377
55-60 S	.391	.367	.384	.397	.400	.451	.478	.554	.557	.597	.479	.449
60-65 S	.478	.438	.422	.431	.429	.499	.544	.527	.524	.624	.631	.527
65-70 S	.595	.545	.505	.509	.555	.542	.605	----	.499	.570	.715	.636
70-75 S	.685	.640	.631	.646	.700	.582	----	----	----	.510	.708	.753
75-80 S	.709	.730	.721	.753	.745	.616	----	----	----	----	.665	.803
80-85 S	.668	.678	.707	.746	.710	----	----	----	----	----	.640	.765
85-90 S	.610	.598	.629	.669	.673	----	----	----	----	----	.634	.700

Table II. Continued

(c) November 1980 to October 1981

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.521	.661	.655	.618	.581	.584	.565	----
80-85 N	----	----	----	----	.600	.700	.679	.599	.583	.616	.585	----
75-80 N	----	----	----	----	.590	.717	.681	.594	.542	.584	.609	.578
70-75 N	----	----	----	.575	.644	.648	.590	.508	.440	.451	.597	.542
65-70 N	.625	----	.533	.530	.644	.544	.482	.397	.365	.347	.511	.560
60-65 N	.542	.543	.537	.541	.560	.478	.413	.348	.356	.349	.404	.538
55-60 N	.536	.498	.541	.524	.451	.433	.360	.347	.344	.361	.360	.455
50-55 N	.508	.603	.523	.474	.400	.377	.334	.335	.326	.322	.361	.365
45-50 N	.446	.546	.464	.411	.396	.335	.335	.317	.314	.292	.332	.330
40-45 N	.367	.365	.393	.362	.363	.324	.317	.304	.281	.277	.274	.323
35-40 N	.308	.333	.343	.336	.311	.303	.284	.280	.248	.241	.251	.289
30-35 N	.286	.333	.321	.315	.290	.269	.259	.245	.232	.224	.249	.249
25-30 N	.268	.287	.299	.277	.268	.247	.235	.222	.227	.238	.226	.240
20-25 N	.232	.264	.250	.229	.217	.220	.206	.210	.226	.227	.211	.228
15-20 N	.205	.212	.203	.196	.183	.183	.191	.208	.232	.227	.217	.204
10-15 N	.210	.210	.189	.182	.178	.184	.199	.228	.235	.251	.218	.215
5-10 N	.224	.227	.199	.184	.182	.213	.224	.242	.238	.236	.227	.231
0-5 N	.214	.199	.207	.202	.205	.219	.235	.218	.228	.198	.232	.212
0-5 S	.207	.230	.213	.222	.221	.211	.203	.190	.201	.189	.205	.195
5-10 S	.216	.220	.226	.222	.206	.200	.173	.190	.192	.181	.193	.201
10-15 S	.214	.207	.230	.212	.196	.182	.183	.185	.203	.171	.206	.196
15-20 S	.200	.222	.217	.209	.200	.187	.194	.183	.192	.192	.194	.196
20-25 S	.199	.204	.204	.197	.191	.210	.199	.215	.192	.210	.190	.216
25-30 S	.205	.205	.198	.190	.199	.212	.234	.253	.240	.208	.226	.221
30-35 S	.215	.219	.205	.217	.236	.231	.280	.274	.276	.260	.242	.225
35-40 S	.245	.234	.233	.248	.257	.292	.301	.306	.284	.319	.249	.261
40-45 S	.286	.289	.274	.270	.288	.337	.327	.375	.333	.313	.306	.294
45-50 S	.312	.311	.311	.316	.360	.348	.394	.457	.443	.332	.360	.321
50-55 S	.340	.353	.342	.373	.395	.389	.478	.518	.536	.459	.364	.377
55-60 S	.402	.346	.374	.399	.383	.483	.538	.542	.554	.595	.420	.452
60-65 S	.490	.423	.410	.421	.445	.568	.575	.524	.523	.627	.584	.531
65-70 S	.583	.533	.487	.515	.604	.604	.602	----	.498	.573	.737	.641
70-75 S	.670	.631	.622	.673	.734	.608	----	----	----	.513	.764	.765
75-80 S	.717	.735	.732	.777	.748	.613	----	----	----	----	.705	.819
80-85 S	.689	.693	.724	.755	.701	----	----	----	----	----	.650	.778
85-90 S	.616	.606	.632	.666	.666	----	----	----	----	----	.633	.703

Table II. Continued

(d) November 1981 to October 1982

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.519	.653	.658	.622	.576	.585	.561	----
80-85 N	----	----	----	----	.589	.667	.686	.622	.577	.621	.568	----
75-80 N	----	----	----	----	.556	.684	.693	.628	.552	.594	.583	.571
70-75 N	----	----	----	.574	.591	.646	.608	.537	.454	.460	.577	.525
65-70 N	.635	----	.535	.530	.604	.562	.508	.412	.347	.351	.521	.543
60-65 N	.568	.543	.541	.541	.566	.480	.443	.357	.330	.357	.427	.544
55-60 N	.572	.502	.553	.525	.482	.422	.384	.357	.357	.377	.355	.499
50-55 N	.532	.603	.545	.476	.404	.383	.343	.342	.344	.339	.338	.415
45-50 N	.438	.539	.493	.416	.376	.341	.331	.318	.308	.300	.337	.343
40-45 N	.348	.364	.416	.374	.370	.308	.309	.303	.284	.281	.300	.314
35-40 N	.318	.342	.351	.357	.337	.300	.280	.278	.262	.240	.249	.307
30-35 N	.314	.334	.318	.338	.294	.292	.263	.249	.233	.217	.238	.280
25-30 N	.276	.269	.295	.294	.271	.259	.243	.240	.227	.235	.247	.236
20-25 N	.225	.252	.251	.237	.241	.223	.216	.229	.223	.224	.227	.217
15-20 N	.215	.224	.207	.198	.191	.195	.204	.211	.216	.217	.216	.215
10-15 N	.226	.220	.191	.182	.172	.178	.210	.226	.242	.247	.238	.209
5-10 N	.225	.228	.201	.182	.198	.193	.227	.251	.261	.249	.240	.218
0-5 N	.219	.207	.212	.199	.215	.221	.237	.230	.228	.218	.210	.233
0-5 S	.211	.233	.216	.220	.213	.213	.207	.199	.191	.206	.199	.218
5-10 S	.198	.220	.223	.221	.214	.186	.178	.203	.193	.198	.205	.192
10-15 S	.199	.213	.221	.213	.199	.189	.188	.203	.196	.188	.188	.191
15-20 S	.202	.216	.210	.212	.181	.204	.200	.195	.192	.210	.183	.195
20-25 S	.202	.197	.202	.197	.203	.202	.200	.222	.218	.225	.210	.190
25-30 S	.218	.216	.198	.188	.235	.214	.226	.259	.252	.209	.219	.204
30-35 S	.239	.226	.205	.214	.235	.255	.267	.277	.261	.244	.223	.237
35-40 S	.252	.231	.234	.246	.248	.291	.290	.307	.281	.305	.270	.263
40-45 S	.279	.287	.283	.271	.315	.305	.323	.381	.352	.304	.324	.289
45-50 S	.318	.309	.323	.317	.368	.341	.398	.470	.446	.323	.332	.339
50-55 S	.345	.359	.350	.372	.360	.420	.487	.531	.508	.449	.349	.388
55-60 S	.392	.362	.377	.393	.375	.505	.546	.548	.523	.591	.450	.429
60-65 S	.485	.422	.417	.411	.487	.557	.581	.524	.507	.628	.601	.513
65-70 S	.590	.533	.502	.509	.634	.579	.606	----	.497	.576	.698	.654
70-75 S	.675	.651	.635	.677	.713	.594	----	----	----	.513	.700	.775
75-80 S	.717	.741	.737	.789	.709	.613	----	----	----	----	.661	.805
80-85 S	.688	.673	.723	.765	.677	----	----	----	----	----	.634	.755
85-90 S	.618	.593	.631	.667	.663	----	----	----	----	----	.628	.692

Table II. Continued

(e) November 1982 to October 1983

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.519	.655	.647	.626	.576	.579	.563	----
80-85 N	----	----	----	----	.598	.679	.664	.630	.576	.609	.562	----
75-80 N	----	----	----	----	.586	.690	.679	.625	.547	.578	.564	.581
70-75 N	----	----	----	.579	.639	.632	.607	.517	.454	.455	.549	.558
65-70 N	.625	----	.537	.539	.642	.539	.502	.395	.361	.356	.498	.613
60-65 N	.541	.544	.555	.558	.566	.476	.433	.349	.346	.357	.424	.653
55-60 N	.534	.495	.576	.547	.463	.433	.392	.346	.354	.362	.369	.613
50-55 N	.509	.596	.560	.495	.409	.379	.354	.342	.333	.318	.350	.486
45-50 N	.454	.541	.479	.423	.395	.333	.326	.335	.309	.287	.338	.345
40-45 N	.381	.369	.386	.370	.362	.321	.308	.313	.288	.272	.296	.283
35-40 N	.324	.342	.340	.349	.323	.314	.285	.277	.257	.232	.245	.303
30-35 N	.299	.338	.330	.332	.310	.286	.256	.255	.227	.214	.235	.301
25-30 N	.280	.283	.298	.290	.282	.254	.236	.244	.221	.232	.238	.239
20-25 N	.246	.257	.246	.233	.224	.218	.212	.216	.212	.220	.211	.206
15-20 N	.212	.209	.216	.193	.184	.172	.181	.193	.206	.215	.197	.245
10-15 N	.208	.210	.191	.172	.165	.155	.176	.205	.235	.244	.229	.265
5-10 N	.221	.232	.180	.166	.159	.180	.204	.230	.252	.242	.245	.235
0-5 N	.220	.215	.210	.194	.193	.205	.225	.231	.229	.213	.216	.220
0-5 S	.211	.249	.246	.235	.235	.223	.216	.215	.209	.203	.197	.225
5-10 S	.209	.227	.238	.238	.233	.225	.201	.198	.204	.190	.197	.201
10-15 S	.202	.197	.215	.210	.215	.199	.188	.178	.190	.172	.181	.173
15-20 S	.194	.205	.206	.200	.206	.188	.183	.184	.188	.187	.175	.181
20-25 S	.205	.192	.195	.200	.195	.209	.203	.220	.226	.205	.203	.202
25-30 S	.220	.200	.195	.196	.204	.221	.238	.250	.256	.205	.214	.205
30-35 S	.224	.216	.208	.216	.235	.237	.259	.267	.263	.252	.218	.216
35-40 S	,240	.225	.224	.246	.255	.291	.280	.300	.290	.310	.269	.250
40-45 S	.280	.275	.263	.274	.291	.335	.327	.359	.363	.306	.332	.270
45-50 S	.317	.305	.313	.315	.359	.344	.389	.429	.446	.325	.344	.282
50-55 S	.346	.360	.337	.361	.387	.377	.445	.489	.498	.441	.356	.329
55-60 S	.397	.358	.361	.384	.378	.465	.495	.522	.511	.571	.454	.413
60-65 S	.485	.432	.415	.410	.445	.554	.545	.516	.500	.605	.609	.484
65-70 S	.589	.545	.501	.508	.605	.596	.593	----	.494	.560	.710	.513
70-75 S	.679	.637	.618	.666	.731	.607	----	----	----	.507	.712	.526
75-80 S	.720	.728	.717	.770	.743	.613	----	----	----	----	.670	.562
80-85 S	.685	.682	.716	.750	.697	----	----	----	----	----	.639	.616
85-90 S	.615	.604	.632	.665	.664	----	----	----	----	----	.632	.666

Table II. Continued

(f) November 1983 to October 1984

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.521	.656	.662	.635	.583	.564	.564	----
80-85 N	----	----	----	----	.593	.653	.681	.632	.579	.532	.563	----
75-80 N	----	----	----	----	.565	.664	.692	.619	.546	.502	.565	.574
70-75 N	----	----	----	.589	.607	.642	.608	.508	.449	.432	.551	.518
65-70 N	.634	----	.540	.565	.622	.576	.485	.392	.358	.350	.499	.522
60-65 N	.557	.539	.544	.588	.578	.483	.405	.361	.352	.311	.425	.512
55-60 N	.555	.481	.551	.555	.486	.395	.370	.367	.369	.310	.368	.467
50-55 N	.525	.577	.533	.472	.407	.353	.348	.352	.346	.301	.346	.398
45-50 N	.452	.528	.470	.406	.387	.346	.327	.330	.312	.265	.332	.340
40-45 N	.368	.367	.392	.389	.381	.334	.311	.305	.281	.232	.288	.308
35-40 N	.318	.345	.337	.361	.336	.307	.288	.270	.249	.211	.236	.290
30-35 N	.302	.337	.316	.303	.282	.283	.256	.247	.229	.193	.230	.261
25-30 N	.272	.280	.299	.263	.258	.255	.235	.241	.237	.194	.246	.227
20-25 N	.226	.256	.252	.242	.231	.215	.215	.230	.234	.208	.227	.218
15-20 N	.206	.207	.211	.206	.181	.181	.189	.220	.218	.212	.205	.226
10-15 N	.222	.210	.202	.178	.159	.175	.187	.232	.228	.207	.217	.228
5-10 N	.230	.233	.209	.193	.180	.192	.213	.240	.237	.203	.225	.229
0-5 N	.213	.198	.205	.208	.199	.210	.223	.219	.219	.191	.204	.219
0-5 S	.203	.219	.198	.206	.210	.216	.205	.194	.203	.171	.194	.196
5-10 S	.204	.214	.209	.213	.224	.214	.192	.188	.202	.161	.197	.184
10-15 S	.203	.204	.214	.212	.213	.202	.191	.183	.195	.164	.181	.198
15-20 S	.202	.212	.202	.195	.186	.190	.190	.189	.199	.171	.175	.204
20-25 S	.208	.198	.191	.199	.193	.197	.210	.217	.234	.179	.201	.198
25-30 S	.217	.212	.195	.207	.221	.225	.247	.247	.263	.202	.219	.209
30-35 S	.234	.224	.207	.214	.231	.255	.272	.271	.272	.238	.234	.237
35-40 S	.255	.226	.229	.246	.253	.281	.291	.305	.302	.258	.284	.260
40-45 S	.277	.274	.271	.288	.314	.315	.336	.359	.372	.268	.331	.287
45-50 S	.310	.303	.320	.320	.362	.370	.398	.423	.451	.309	.333	.337
50-55 S	.351	.356	.358	.362	.362	.436	.458	.486	.501	.392	.348	.387
55-60 S	.398	.354	.383	.407	.383	.491	.508	.525	.515	.468	.451	.435
60-65 S	.475	.431	.420	.437	.481	.526	.560	.523	.507	.504	.605	.525
65-70 S	.592	.547	.507	.503	.606	.556	.607	----	.502	.508	.704	.662
70-75 S	.694	.643	.636	.649	.678	.587	----	----	----	.503	.707	.774
75-80 S	.725	.731	.725	.772	.685	.618	----	----	----	----	.667	.798
80-85 S	.682	.679	.710	.767	.668	----	----	----	----	----	.639	.753
85-90 S	.616	.601	.632	.674	.664	----	----	----	----	----	.633	.697

Table II. Concluded

(g) November 1984 to October 1985

LATITUDE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
85-90 N	----	----	----	----	.522	.655	.662	.628	.577	.588	.564	----
80-85 N	----	----	----	----	.601	.651	.680	.610	.561	.612	.565	----
75-80 N	----	----	----	----	.591	.662	.694	.596	.529	.583	.569	.575
70-75 N	----	----	----	.579	.644	.642	.621	.497	.446	.466	.554	.522
65-70 N	.630	----	.540	.533	.642	.584	.511	.384	.364	.371	.498	.532
60-65 N	.542	.539	.543	.545	.559	.504	.435	.350	.349	.366	.417	.528
55-60 N	.529	.484	.549	.532	.458	.426	.388	.365	.357	.369	.357	.483
50-55 N	.498	.583	.535	.492	.418	.382	.346	.355	.342	.333	.340	.407
45-50 N	.442	.537	.484	.438	.416	.357	.318	.325	.318	.304	.334	.339
40-45 N	.374	.379	.418	.391	.376	.324	.307	.299	.287	.279	.298	.307
35-40 N	.319	.357	.365	.356	.319	.291	.286	.274	.247	.230	.250	.298
30-35 N	.288	.344	.331	.325	.297	.276	.257	.250	.222	.212	.238	.277
25-30 N	.262	.282	.301	.282	.275	.259	.233	.235	.230	.232	.238	.238
20-25 N	.230	.260	.255	.235	.227	.225	.209	.221	.225	.224	.212	.215
15-20 N	.211	.215	.211	.202	.198	.195	.192	.214	.210	.219	.202	.217
10-15 N	.219	.215	.191	.187	.188	.189	.203	.231	.228	.242	.231	.219
5-10 N	.230	.231	.198	.186	.182	.199	.226	.245	.241	.239	.241	.221
0-5 N	.217	.203	.209	.199	.197	.203	.222	.220	.215	.214	.214	.218
0-5 S	.199	.232	.212	.216	.215	.202	.200	.187	.193	.208	.197	.203
5-10 S	.200	.223	.218	.220	.207	.205	.195	.185	.195	.197	.199	.192
10-15 S	.204	.206	.220	.214	.199	.201	.197	.191	.192	.184	.185	.200
15-20 S	.199	.218	.207	.208	.200	.191	.192	.198	.194	.201	.186	.208
20-25 S	.206	.206	.190	.193	.192	.198	.207	.224	.223	.217	.215	.210
25-30 S	.217	.211	.188	.193	.205	.225	.242	.251	.251	.215	.227	.221
30-35 S	.223	.222	.205	.224	.239	.253	.271	.270	.267	.259	.231	.245
35-40 S	.241	.235	.236	.254	.258	.275	.297	.303	.299	.310	.275	.264
40-45 S	.280	.289	.279	.278	.291	.304	.347	.366	.369	.303	.323	.284
45-50 S	.316	.312	.323	.322	.358	.358	.408	.443	.446	.327	.332	.322
50-55 S	.347	.358	.356	.375	.388	.424	.462	.507	.496	.454	.357	.371
55-60 S	.402	.355	.379	.398	.380	.482	.509	.538	.512	.590	.467	.434
60-65 S	.492	.434	.413	.422	.443	.522	.559	.528	.506	.623	.621	.540
65-70 S	.597	.549	.497	.516	.596	.554	.607	----	.502	.574	.715	.675
70-75 S	.687	.640	.629	.669	.718	.587	----	----	----	.518	.712	.775
75-80 S	.727	.727	.726	.769	.734	.618	----	----	----	----	.669	.792
80-85 S	.692	.677	.714	.750	.695	----	----	----	----	----	.639	.748
85-90 S	.621	.601	.634	.668	.666	----	----	----	----	----	.633	.696

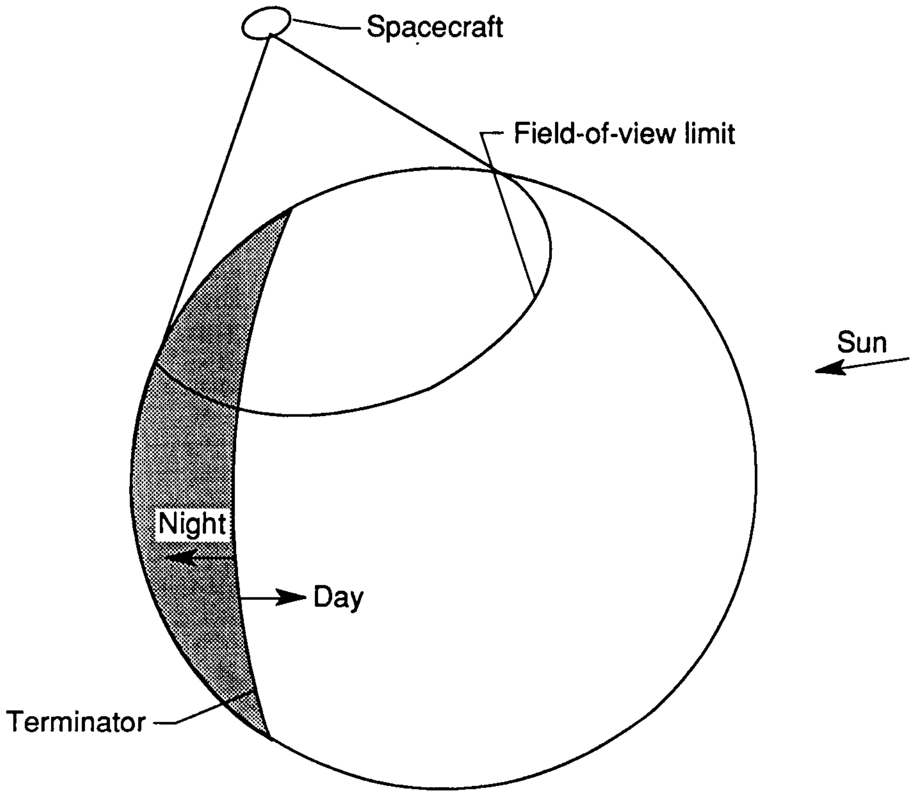


Figure 1. Wide-field-of-view coverage geometry.

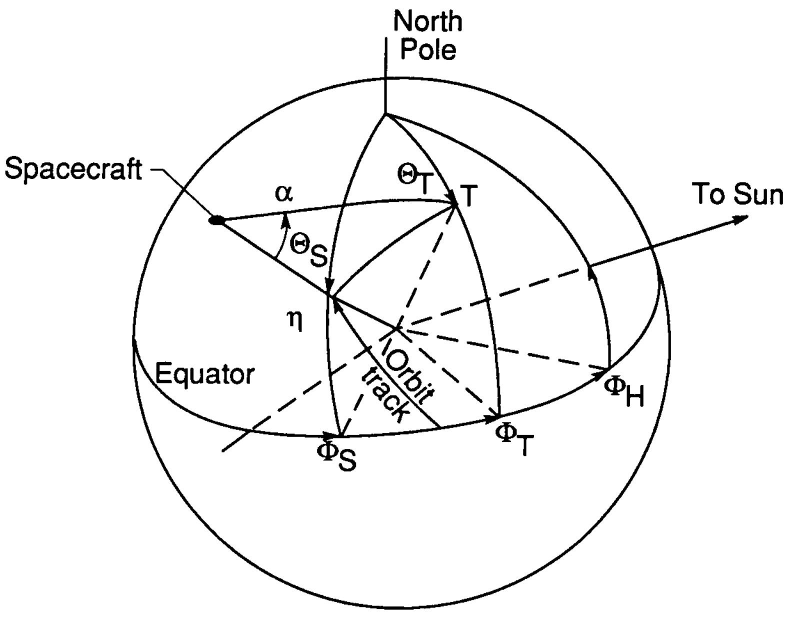


Figure 2. Geometry of Earth, satellite, Sun, and scene.

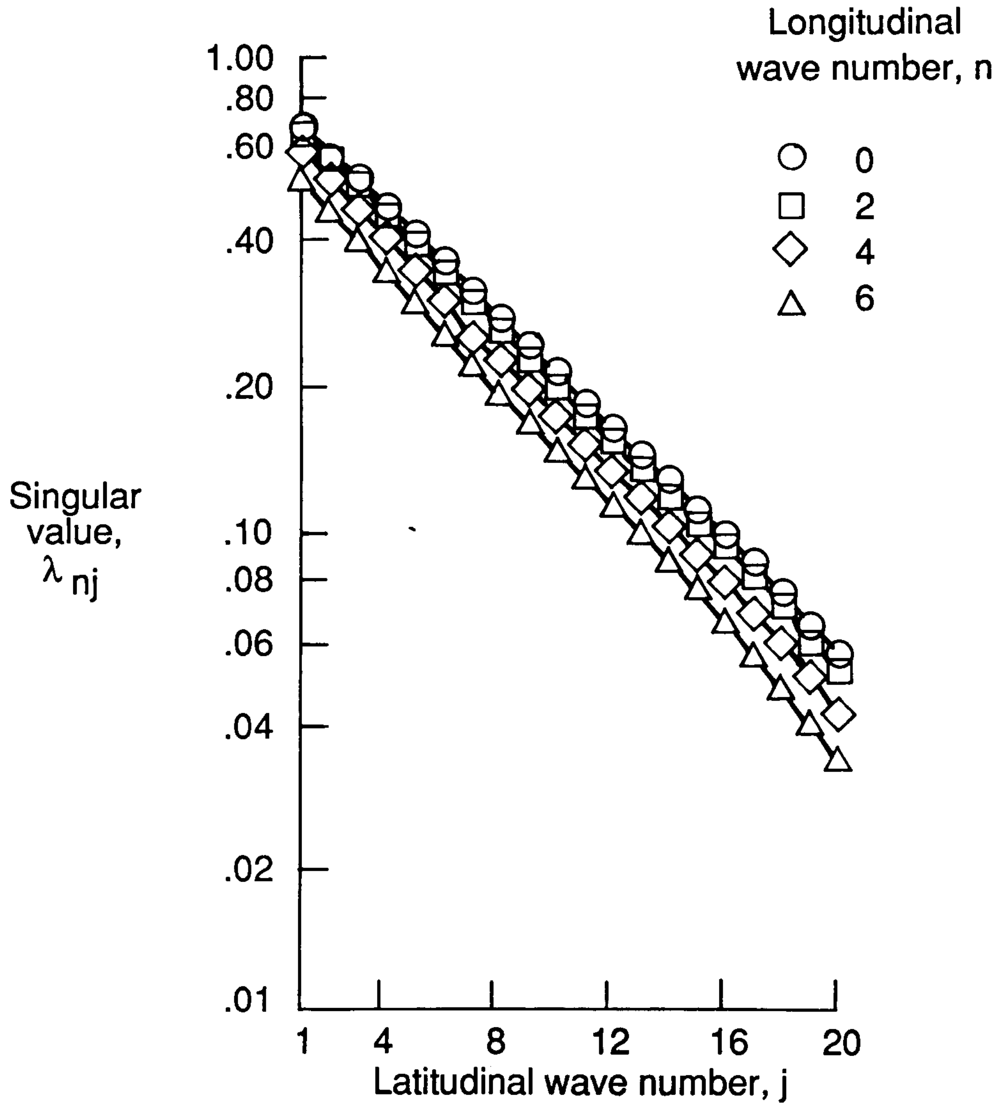
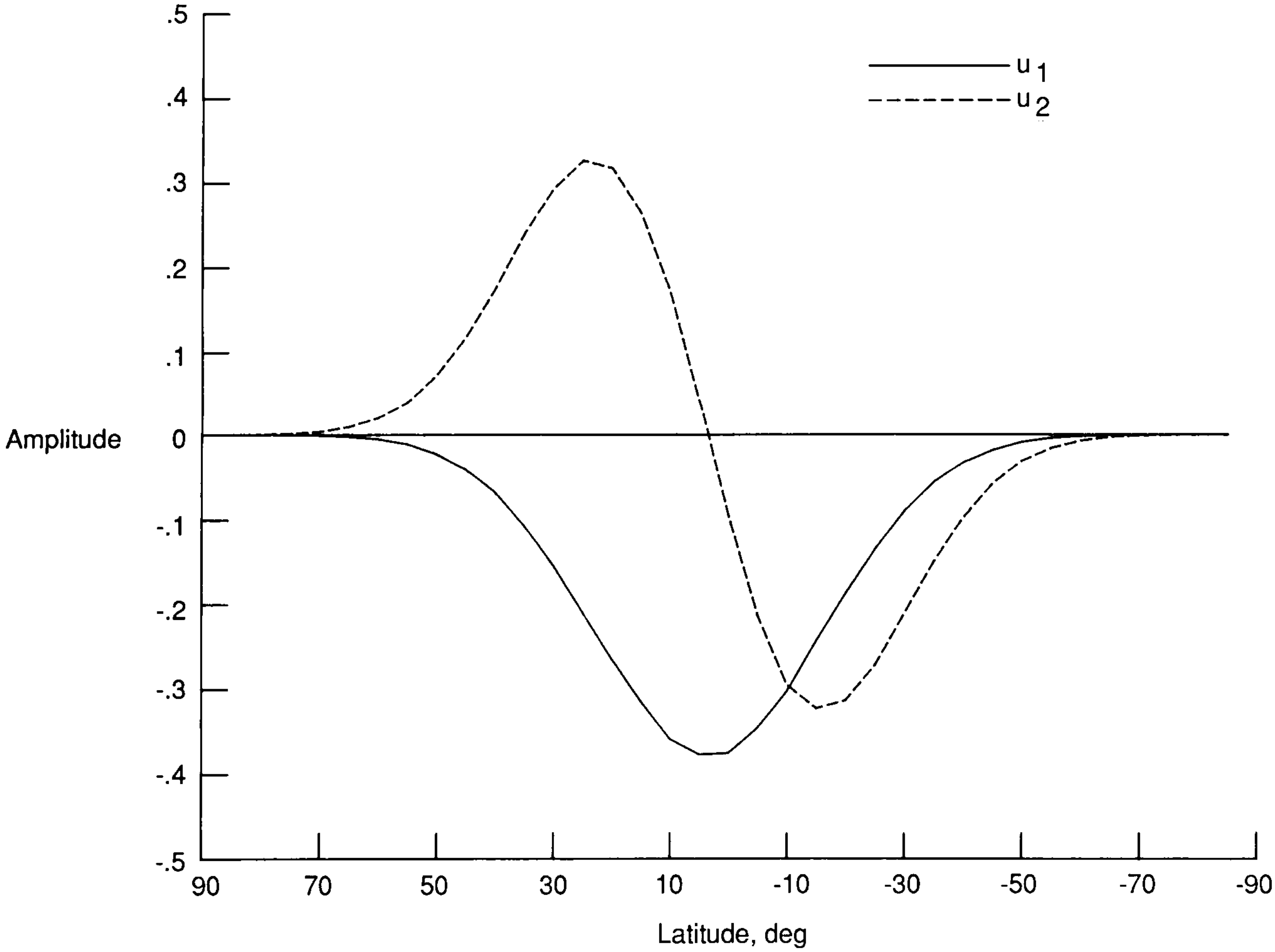
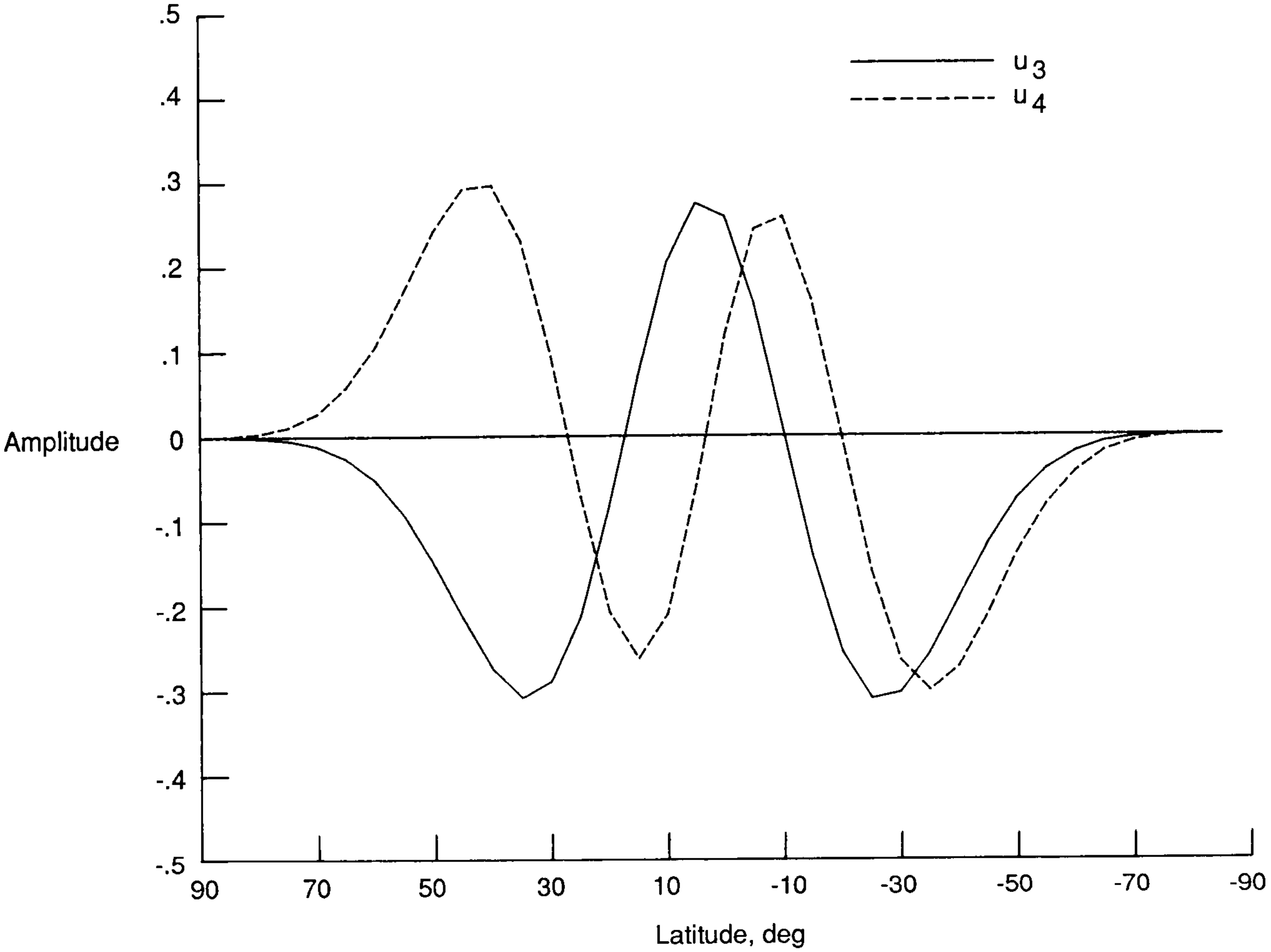


Figure 3. Singular values λ_{nj} of measurement matrices for Nimbus 7 for September.



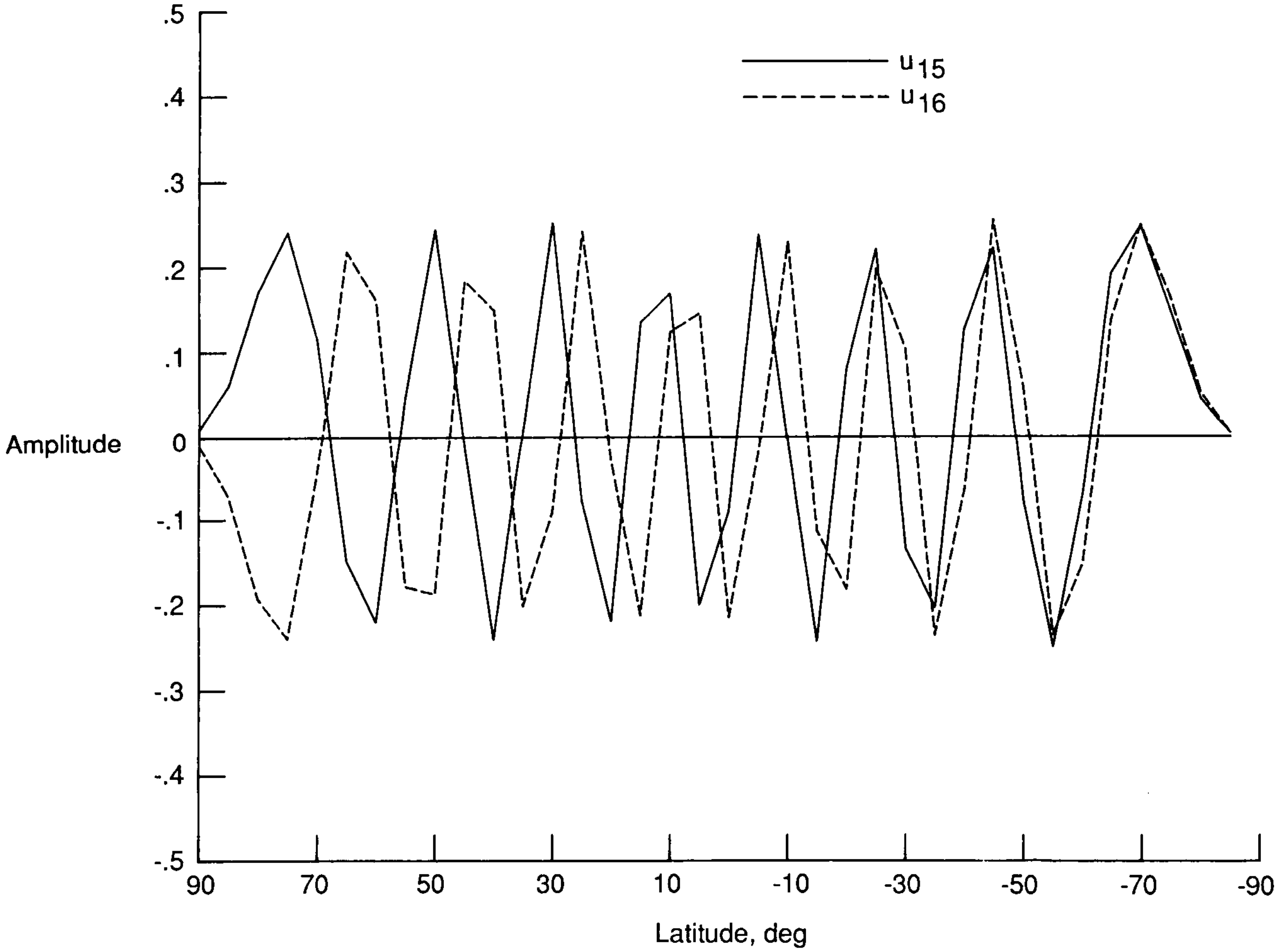
(a) u_1 and u_2.

Figure 4. Singular vectors u_{0j} of measurement matrices for Nimbus 7 for September.



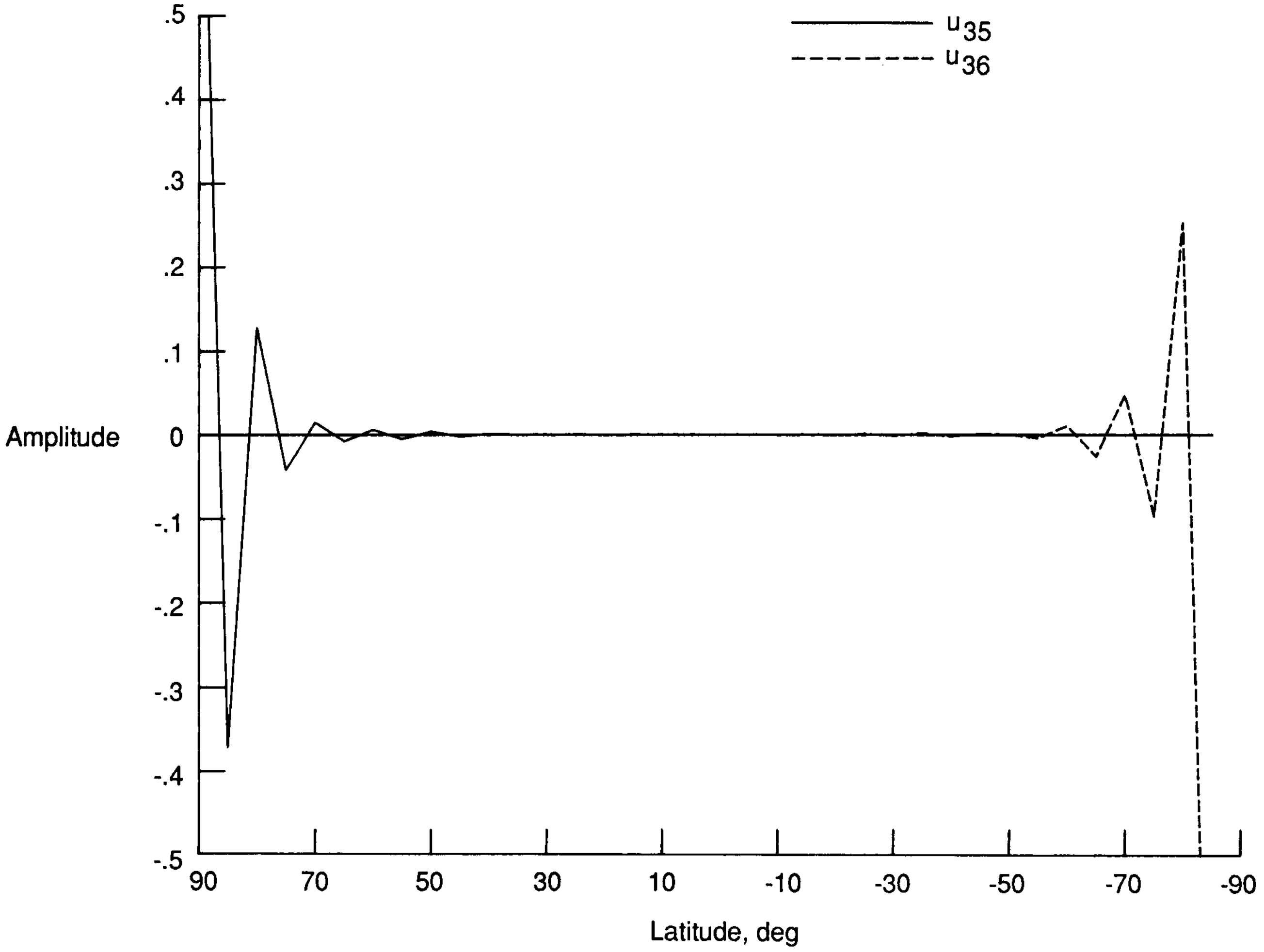
(b) u_3 and u_4.

Figure 4. Continued.



(c) u_{15} and u_{16}.

Figure 4. Continued.



(d) u_{35} and u_{36}.

Figure 4. Concluded.

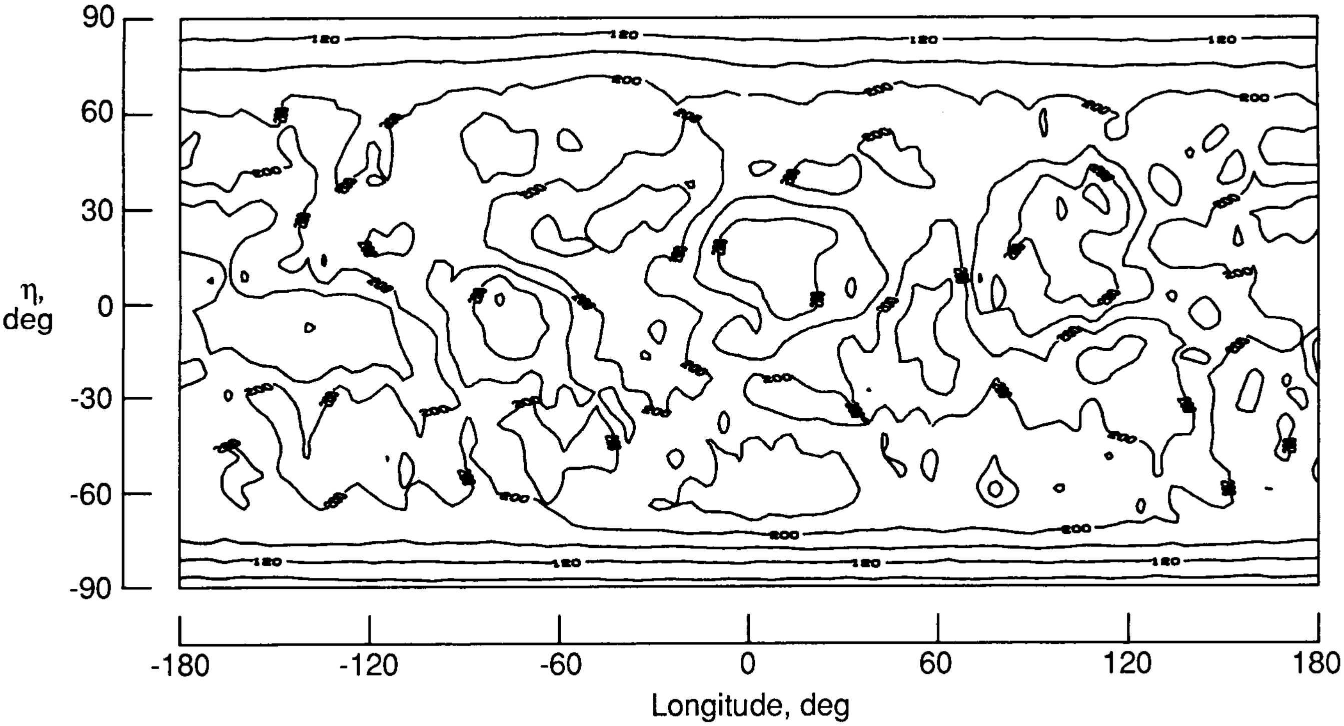
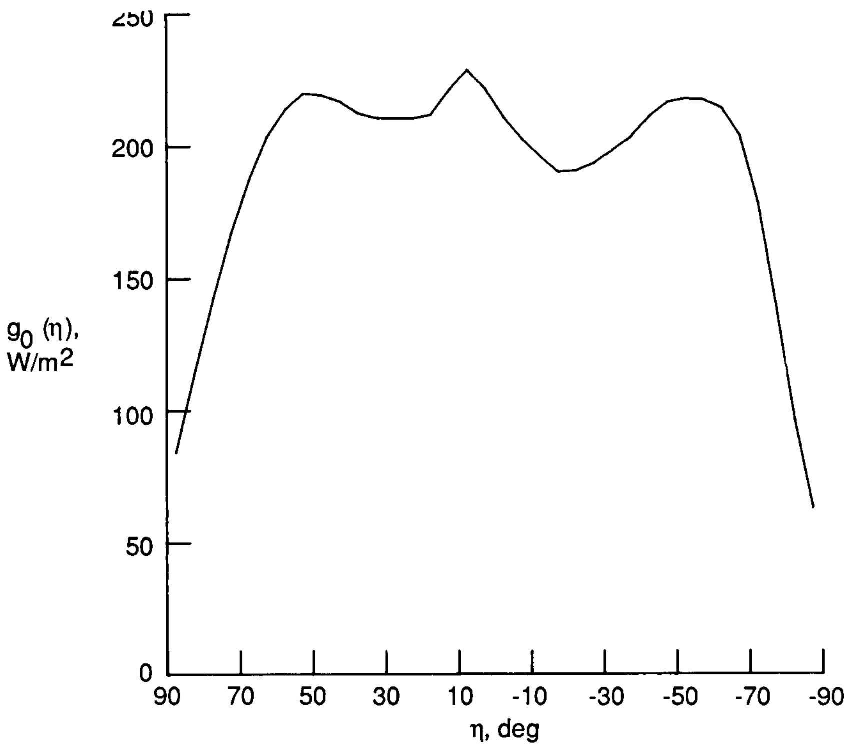
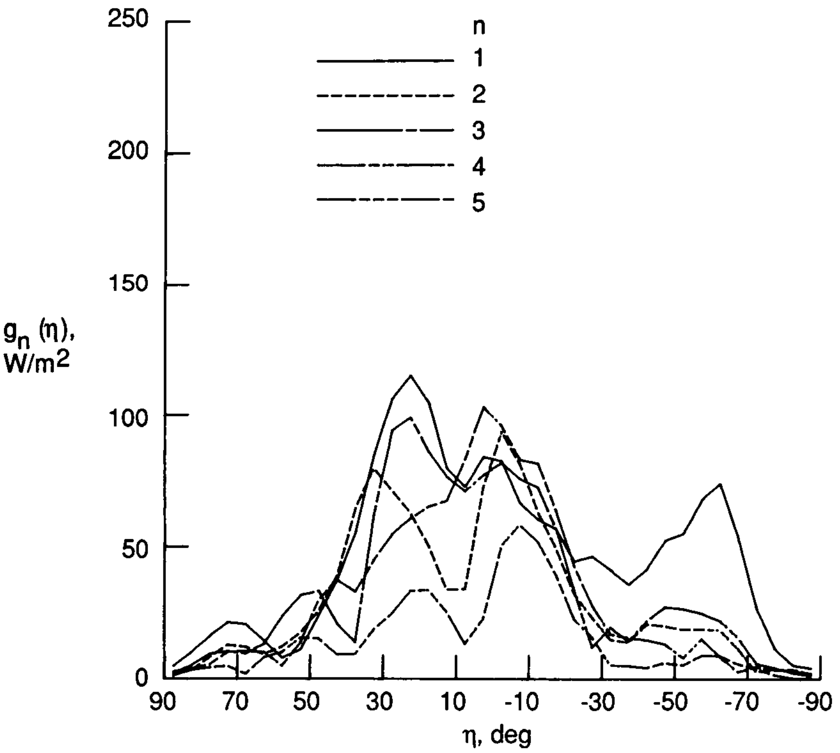


Figure 5. Shortwave WFOV measurement map for Nimbus 7 for September 1981.



(a) $n = 0$ (zonal profile).

Figure 6. Profiles of measurement map Fourier components $g_n(\eta)$ for September 1981.



(b) $n = 1$ to 5.

Figure 6. Concluded.

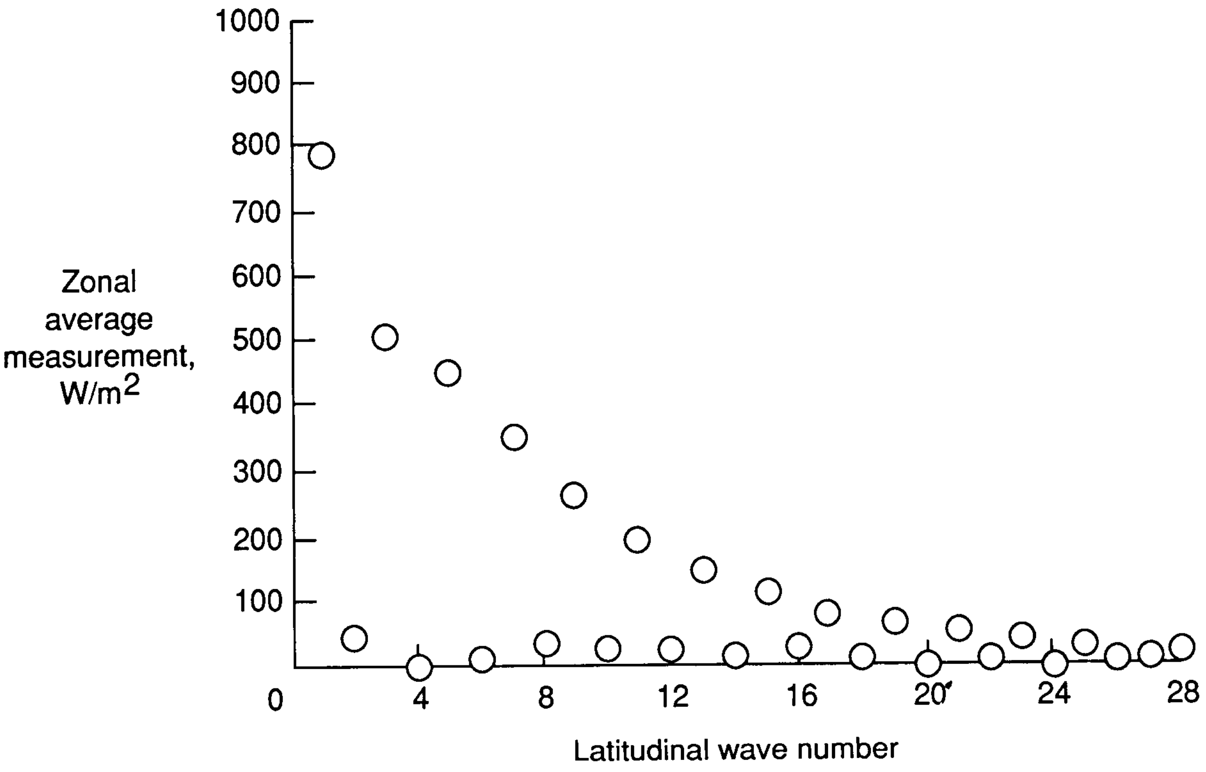


Figure 7. Magnitudes of zonal average measurements $g_0(\eta)$ with $\mathbf{v}_{nj}$ as basis for September 1981.

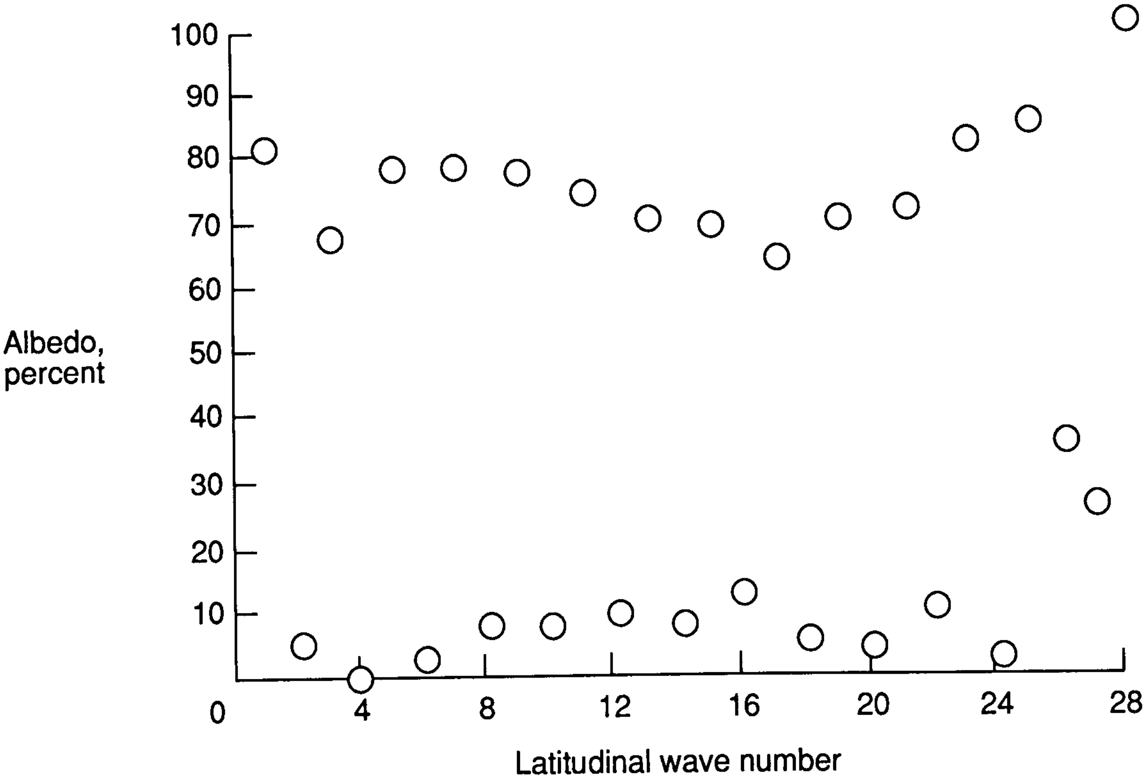


Figure 8. Magnitudes of zonal average albedo $f_0(\theta_T)$ with $\mathbf{u}_{nj}$ as basis for September 1981.

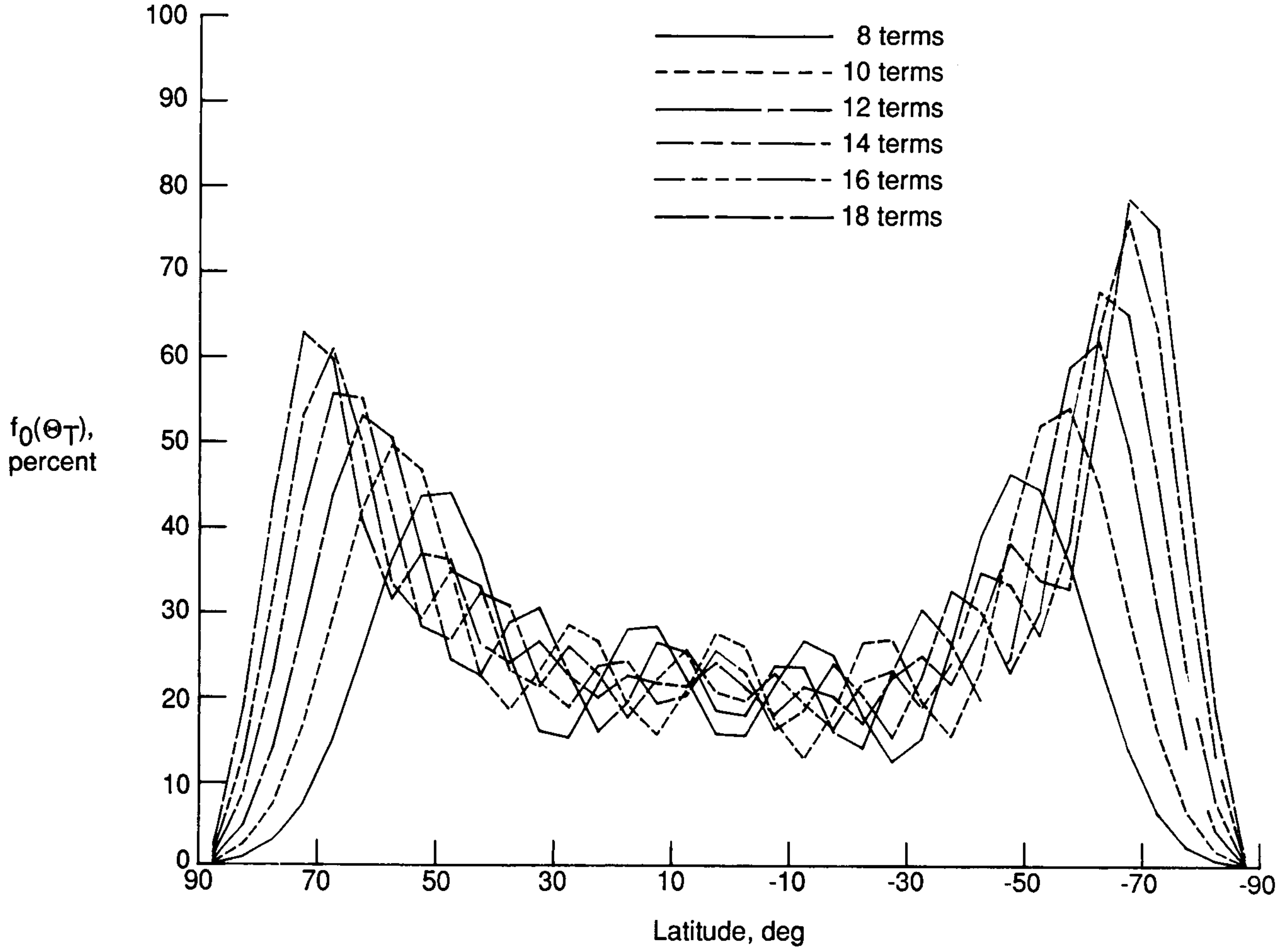


Figure 9. Zonal average albedo profile $f_0(\theta_T)$ for September 1981 built from combination of observable terms.

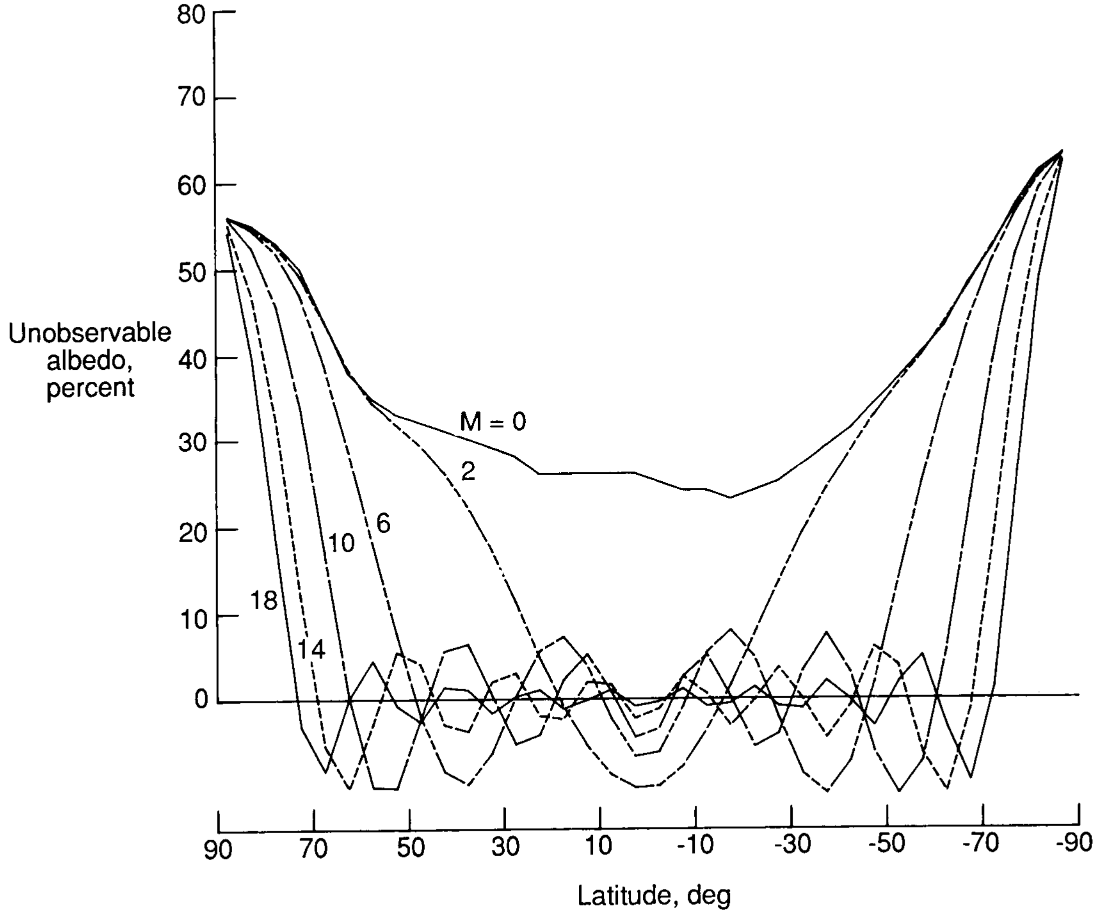


Figure 10. Latitudinal profile of unobservable part of zonal average albedo profile $f_0(\theta_T)$ (second summation in eq. (4)) based on a priori data for September 1981.

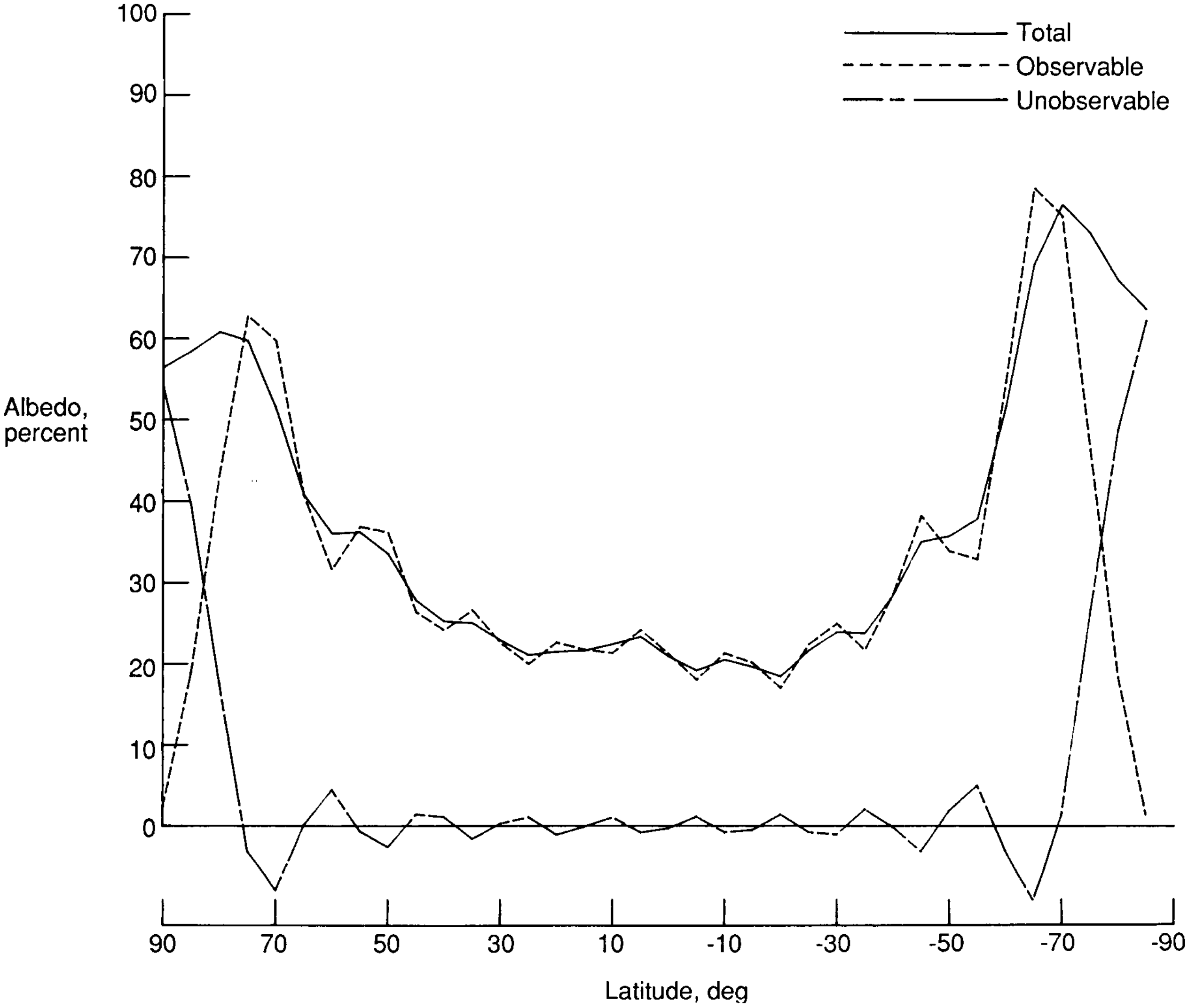


Figure 11. Total estimate of zonal albedo profile formed from 18 terms. Also shown are observable part and unobservable part of solution based on a priori information for September 1981.

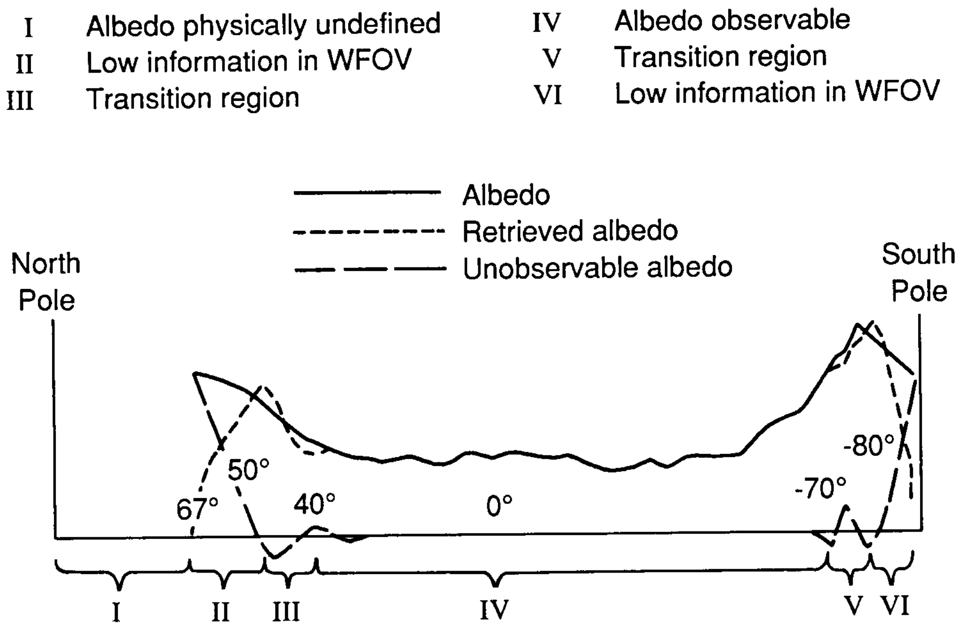


Figure 12. Dependence of observability on latitude for typical northern winter case for Nimbus 7 orbit.

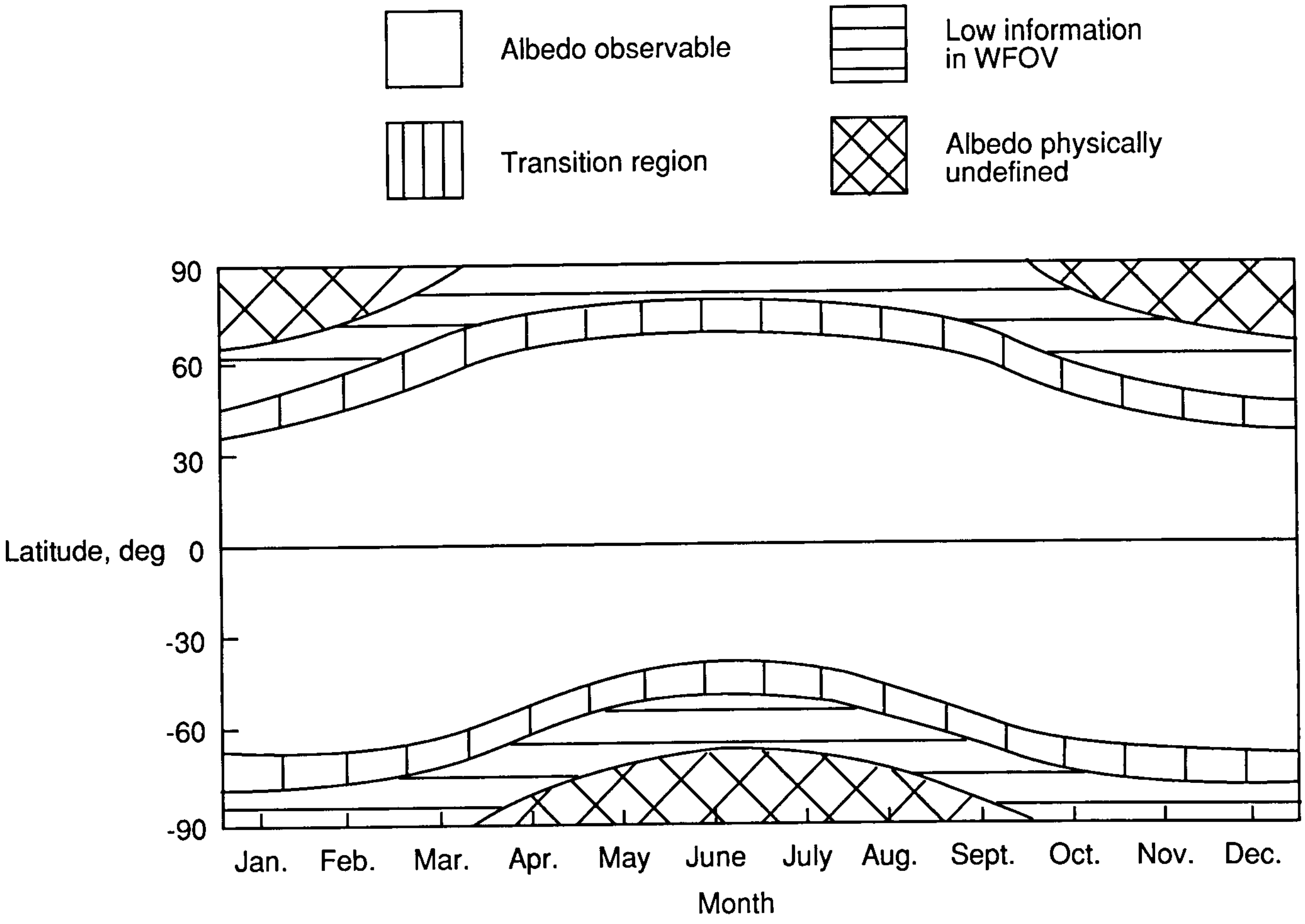


Figure 13. Variation of observable regions with time of year for Nimbus 7 orbit.

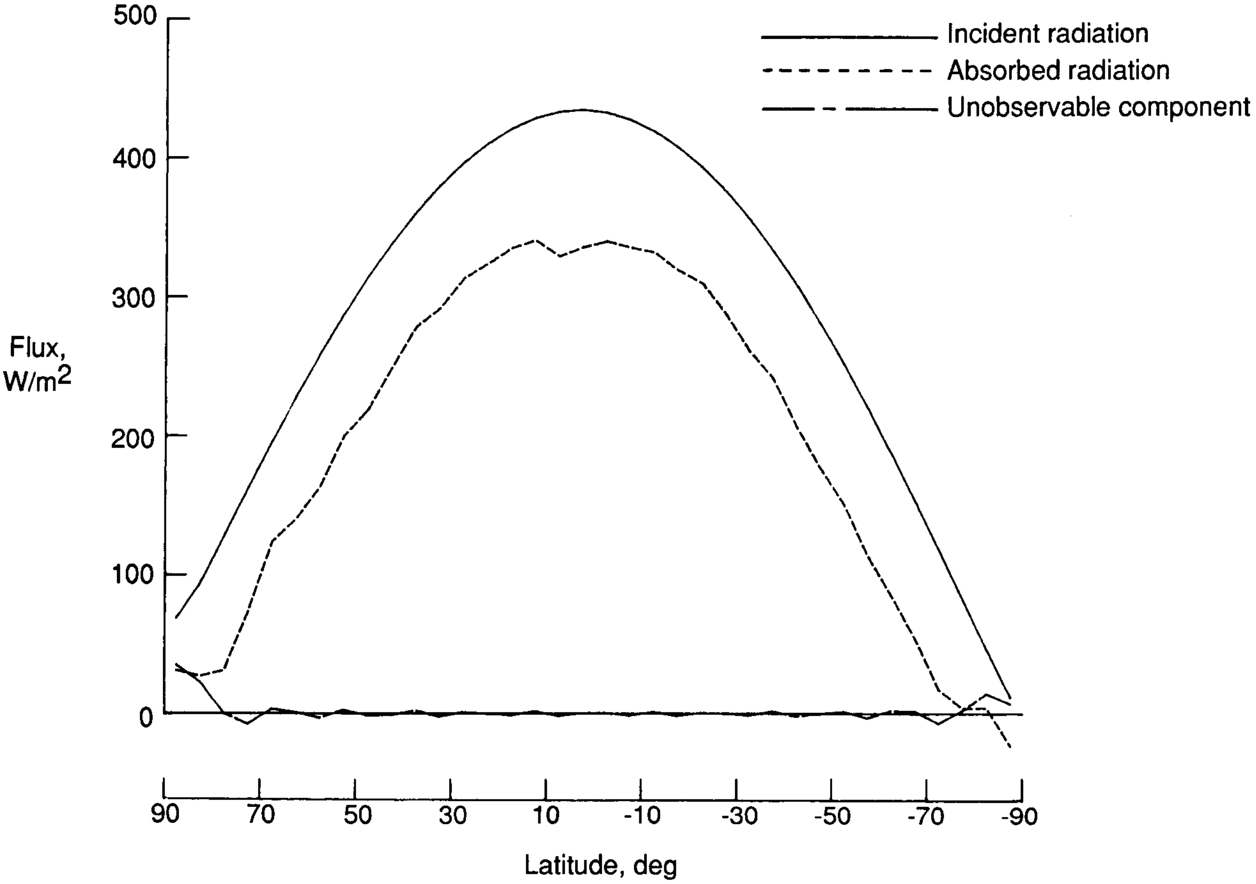
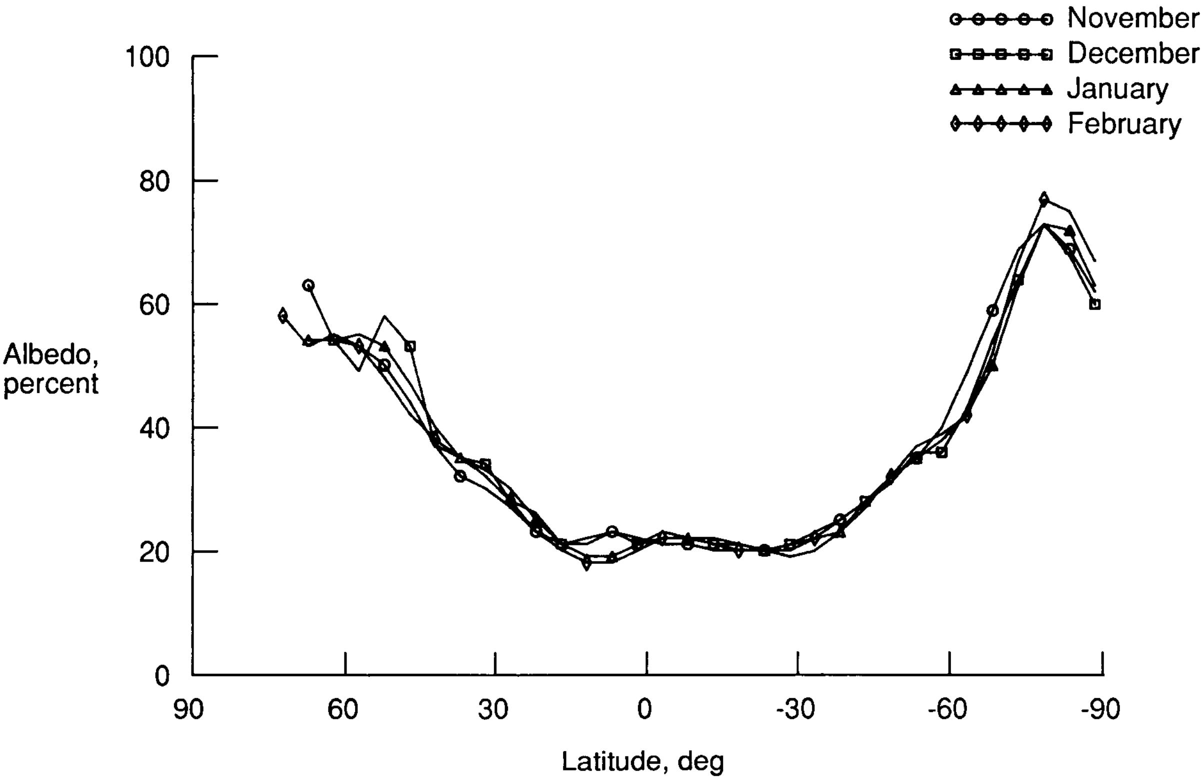
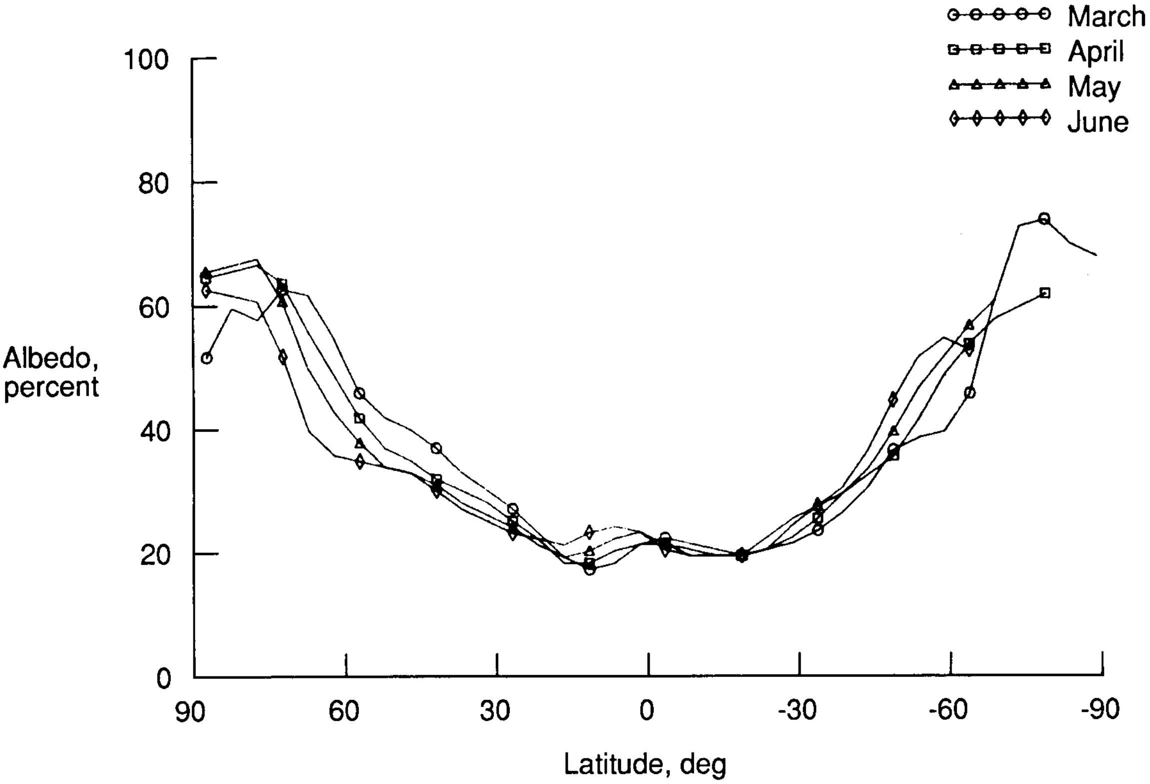


Figure 14. Zonal average profiles of incident and absorbed solar flux for September 1981.

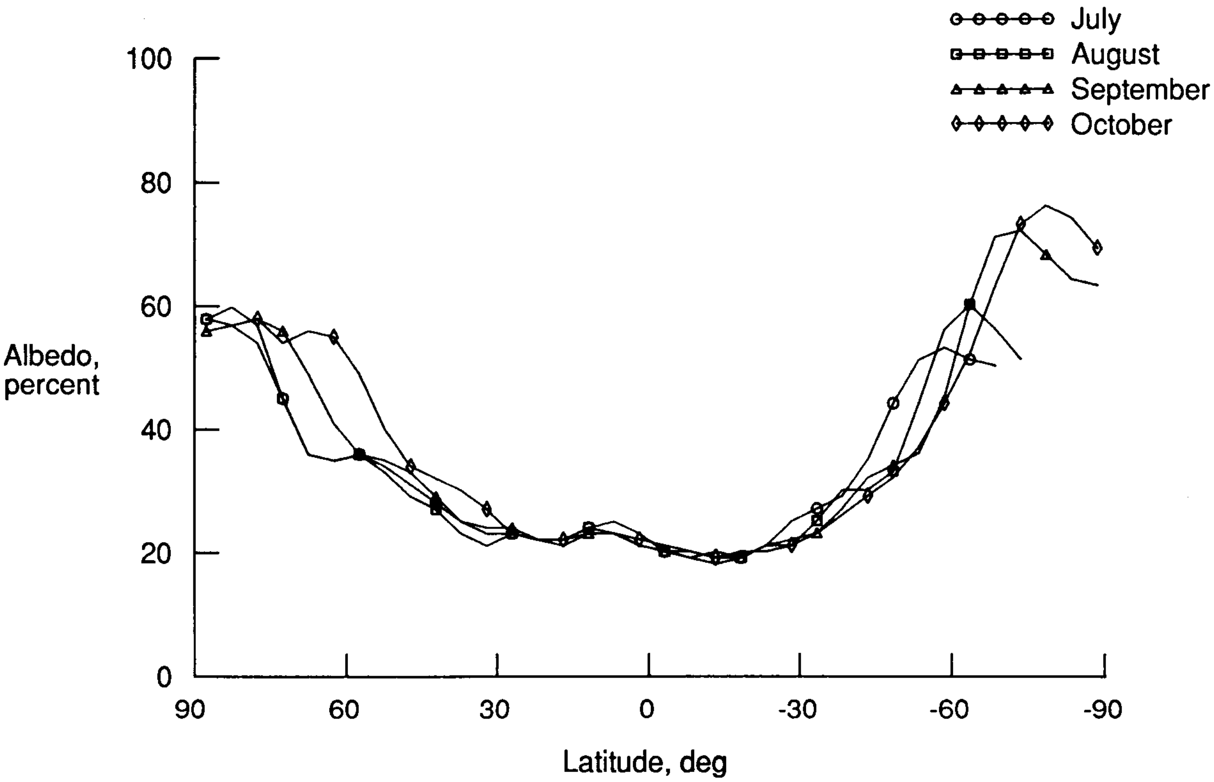


(a) November, December, January, and February.



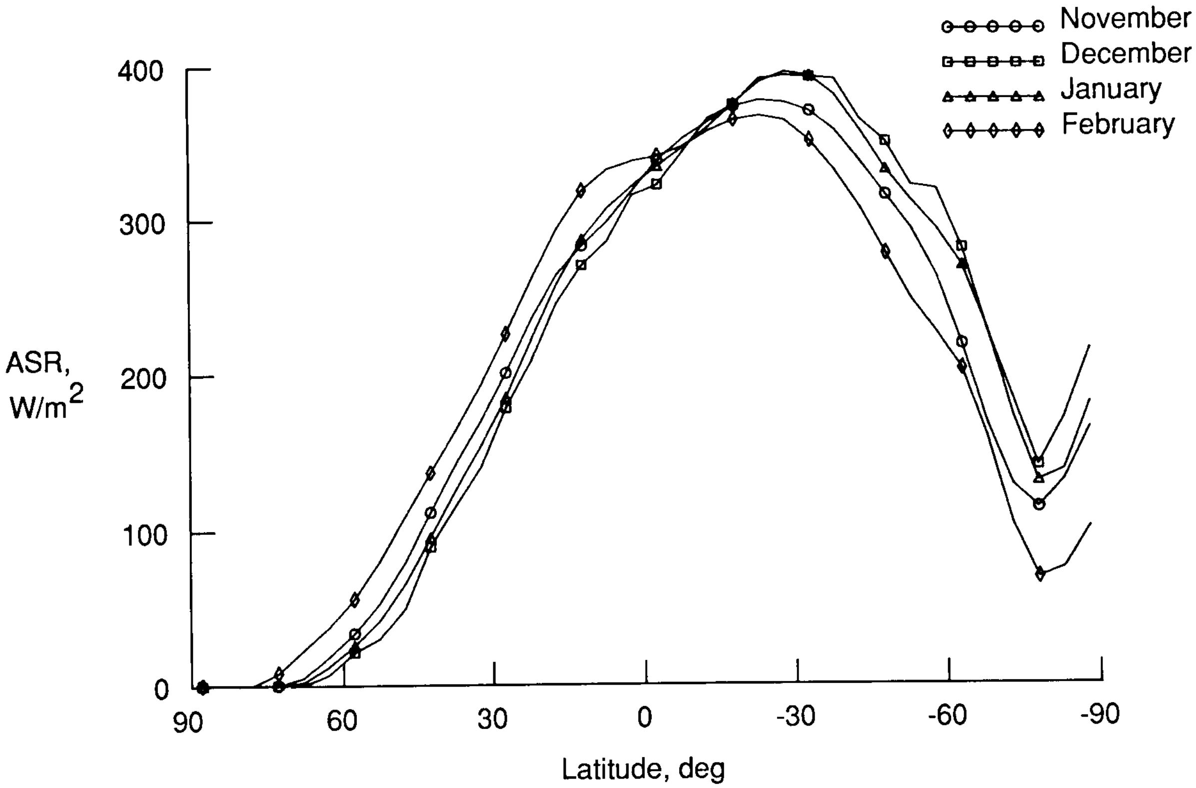
(b) March, April, May, and June.

Figure 15. Seven-year zonal mean albedos.

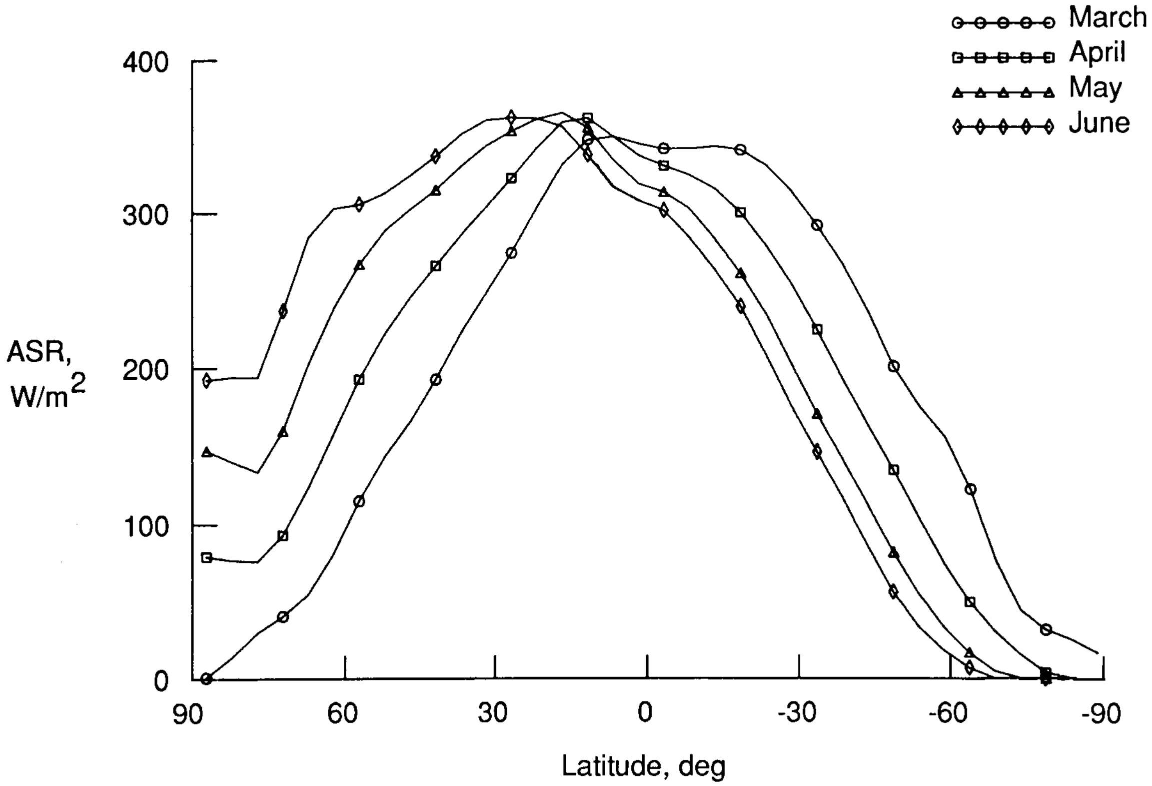


(c) July, August, September, and October.

Figure 15. Concluded.

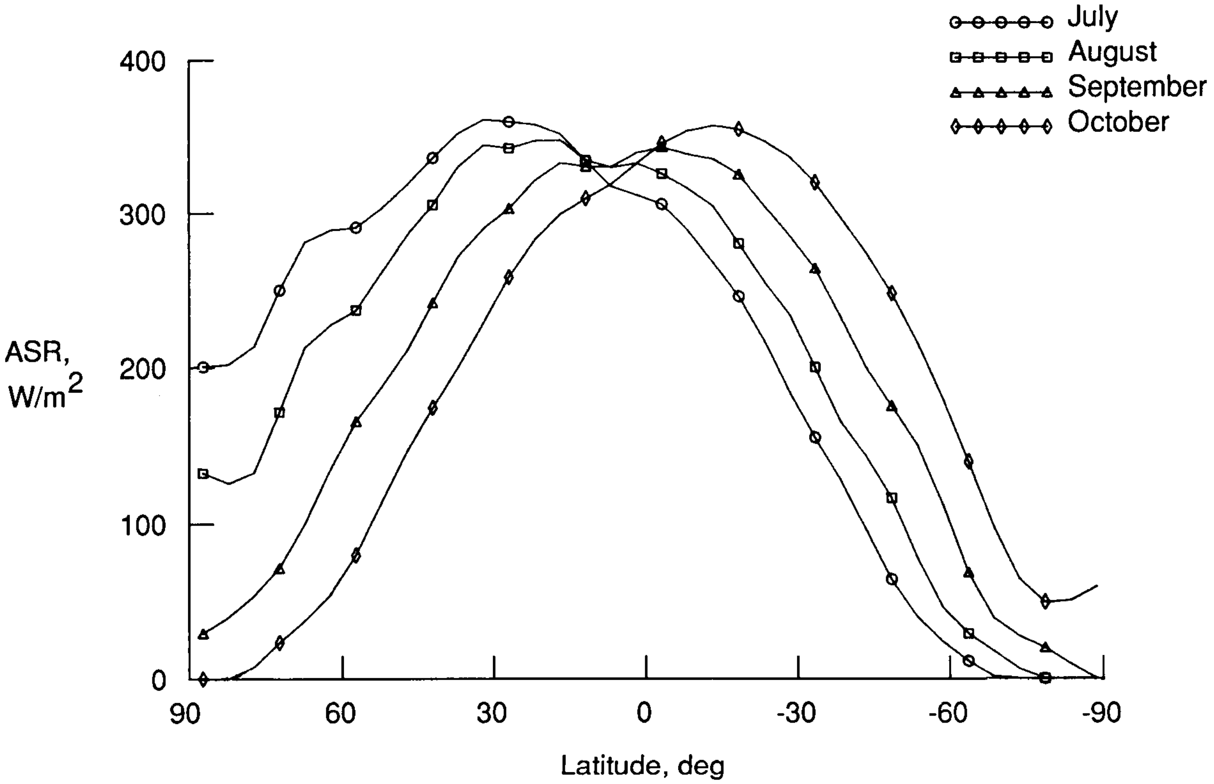


(a) November, December, January, and February.



(b) March, April, May, and June.

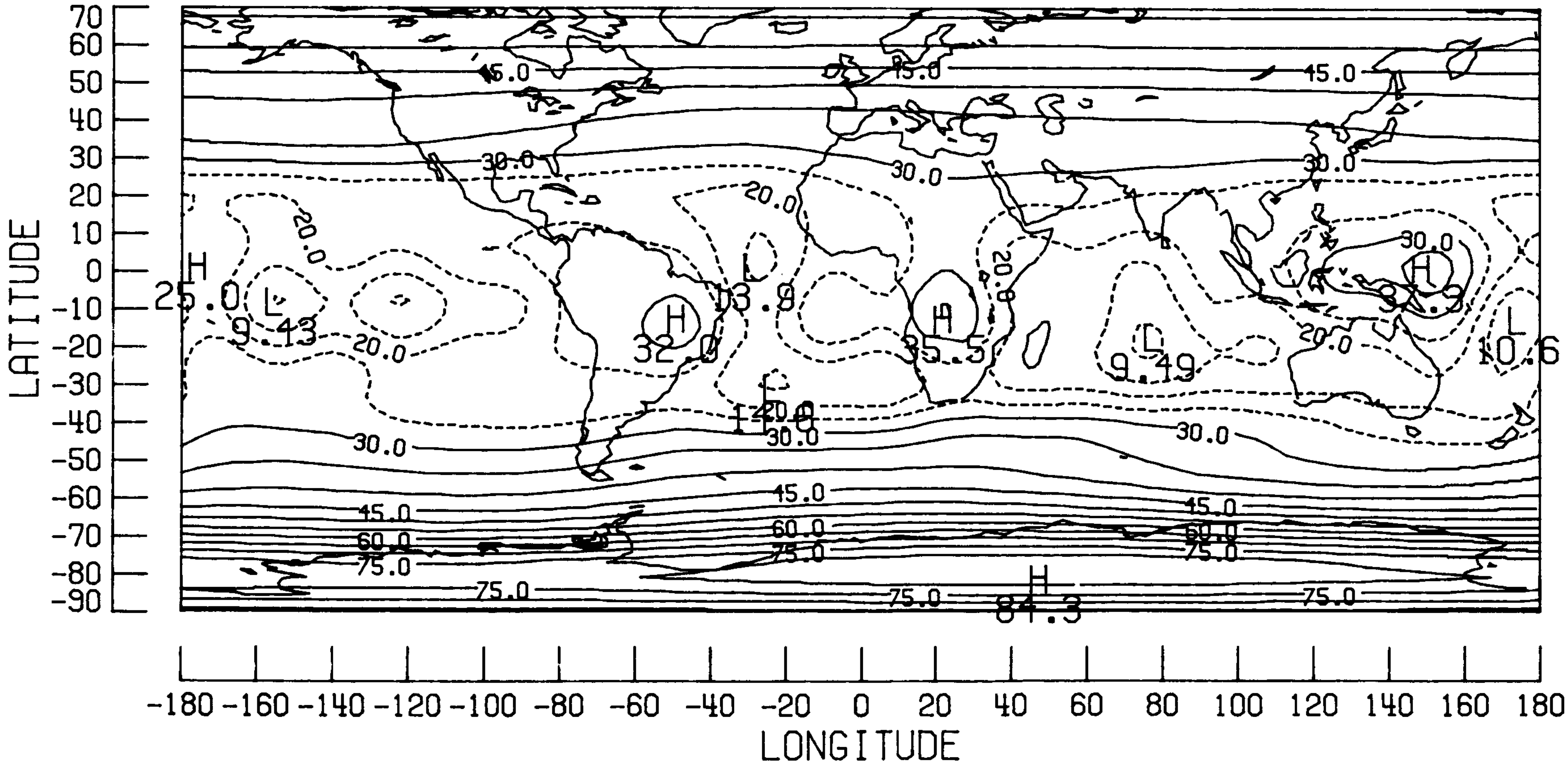
Figure 16. Seven-year zonal mean absorbed solar radiation.



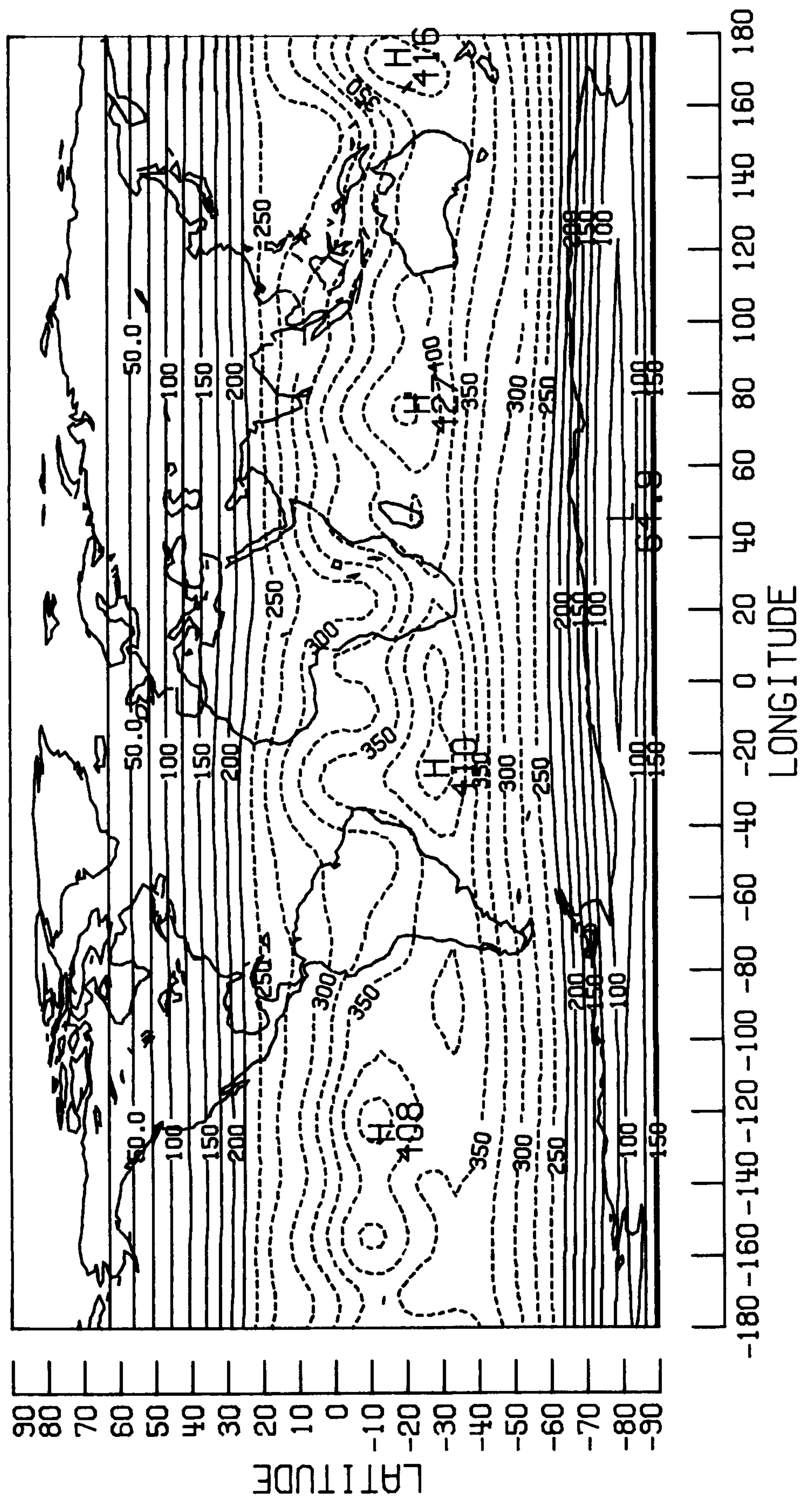
(c) July, August, September, and October.

Figure 16. Concluded.

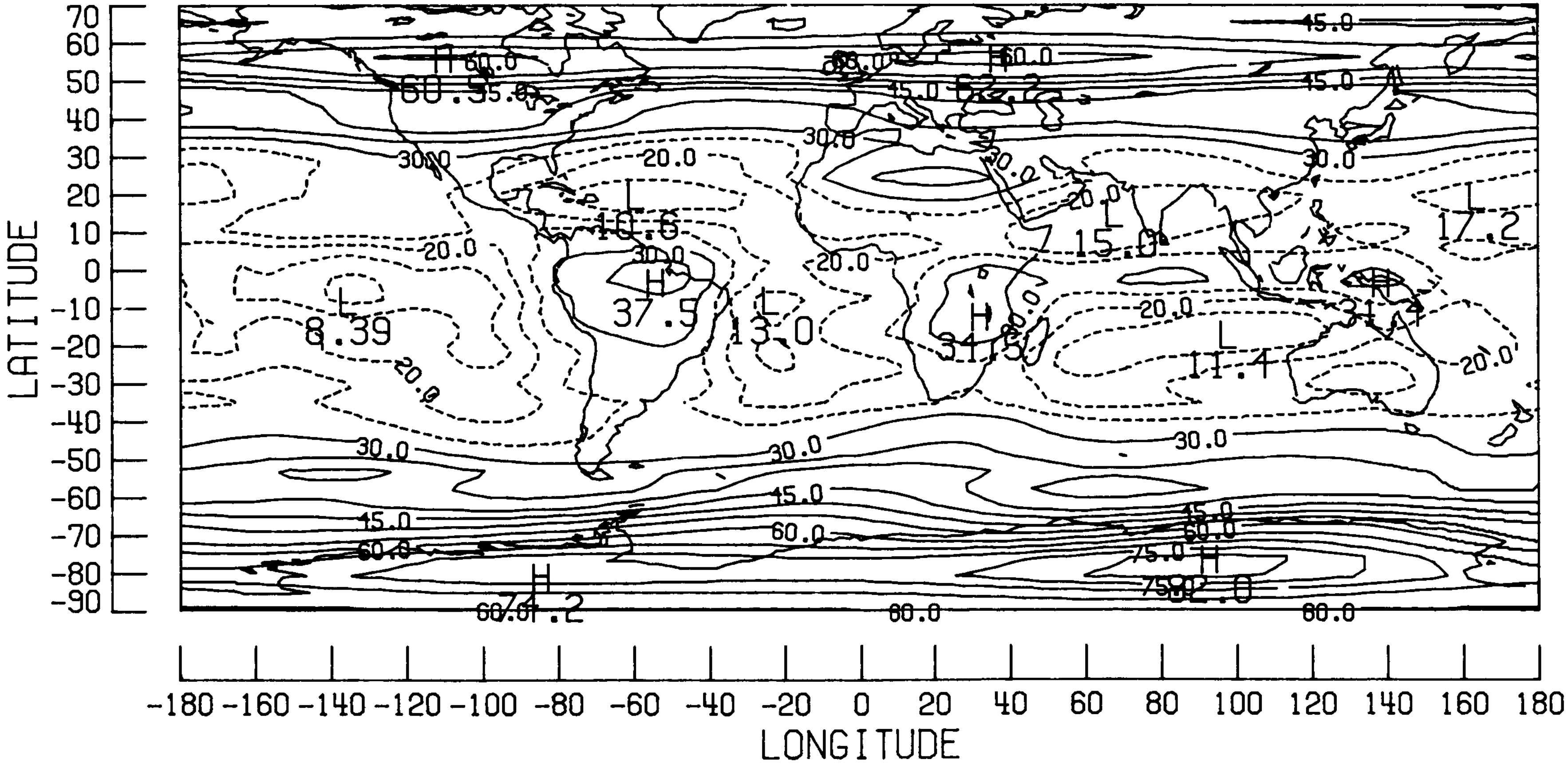
ALBEDO (%)
NOV 1978



ABSORPTION W/(M*M)
NOV 1978

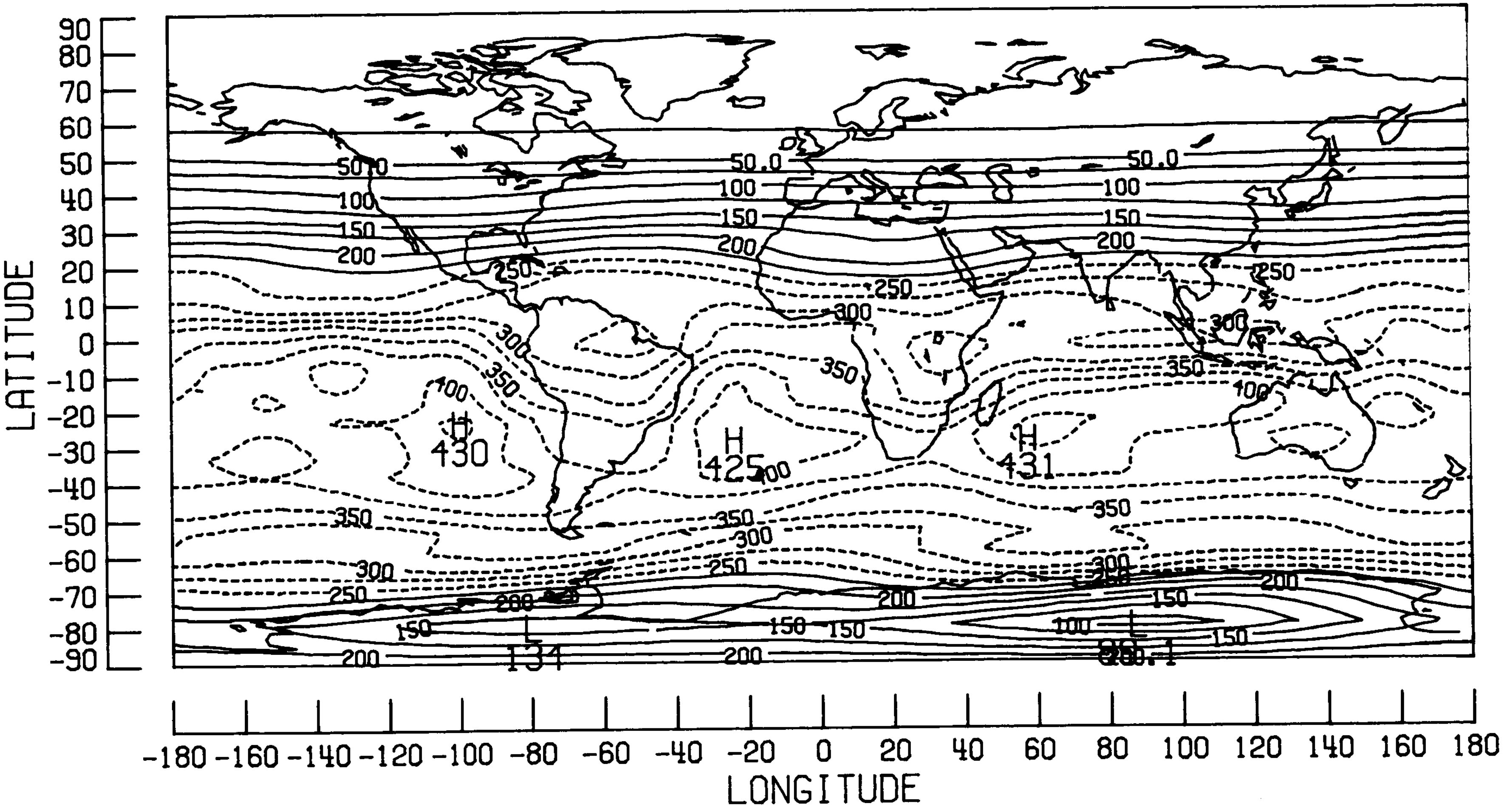


ALBEDO (%)
DEC 1978



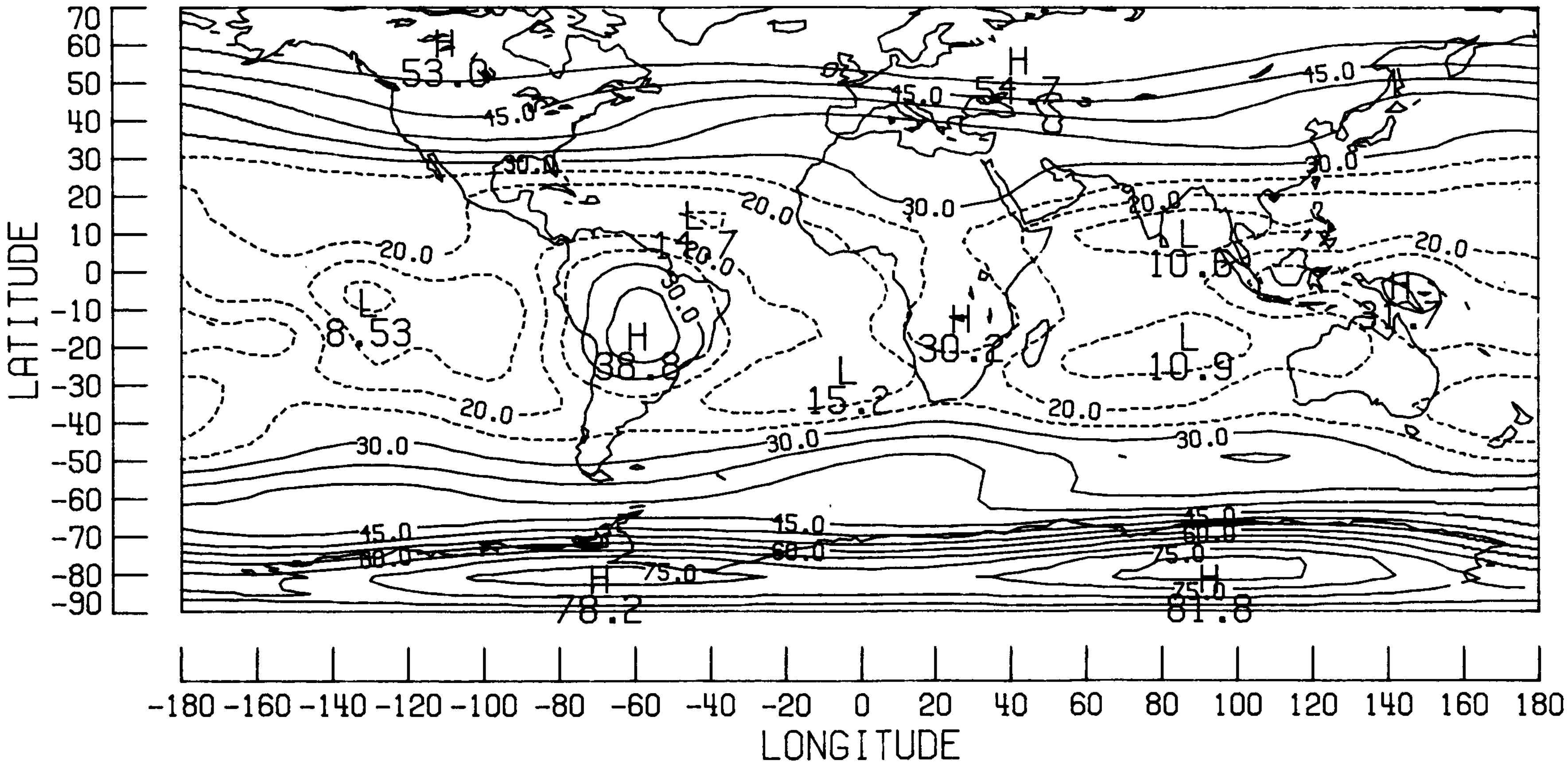
ABSORPTION W/(M*M)

DEC 1978



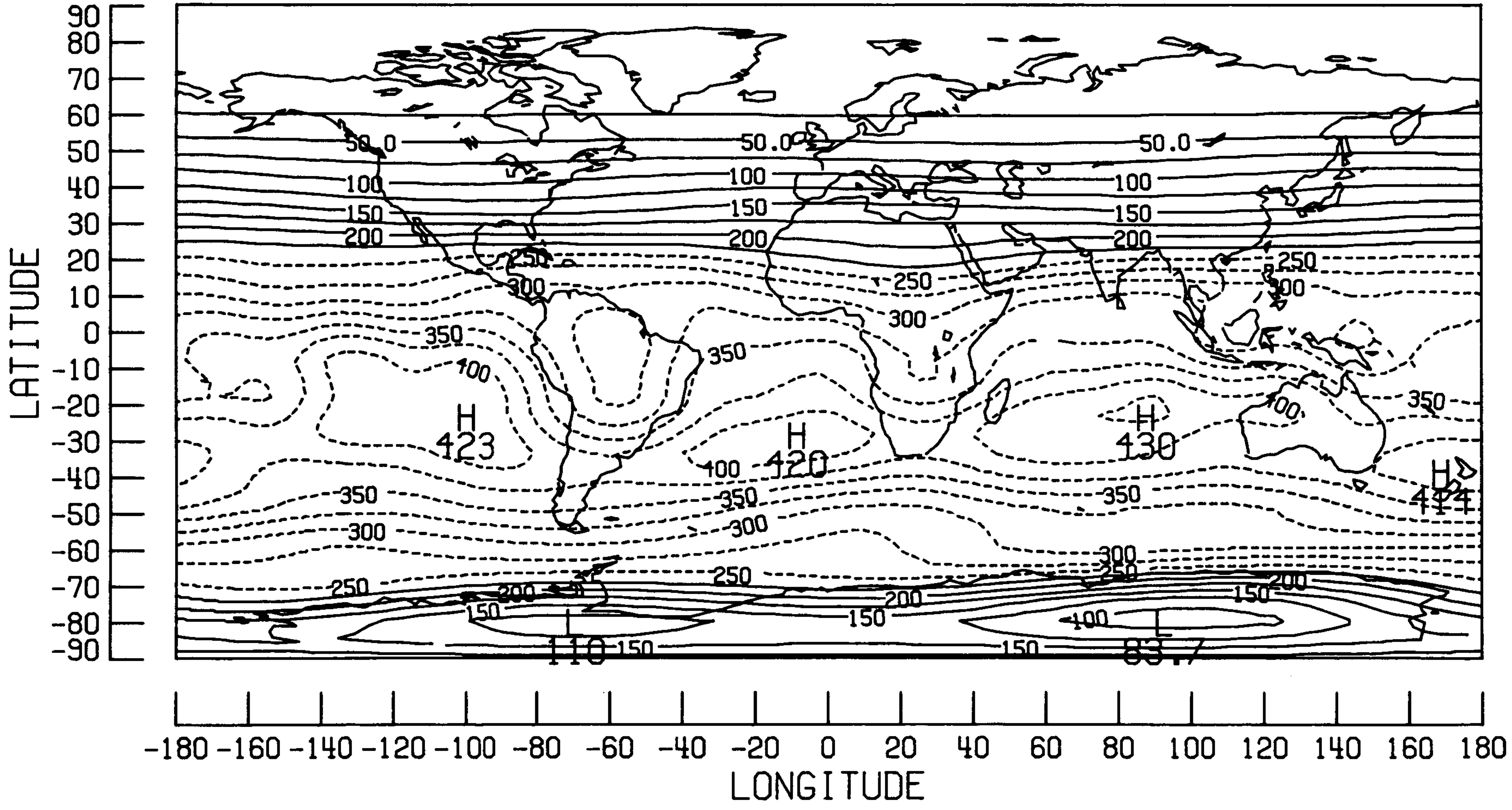
ALBEDO (%)

JAN 1979

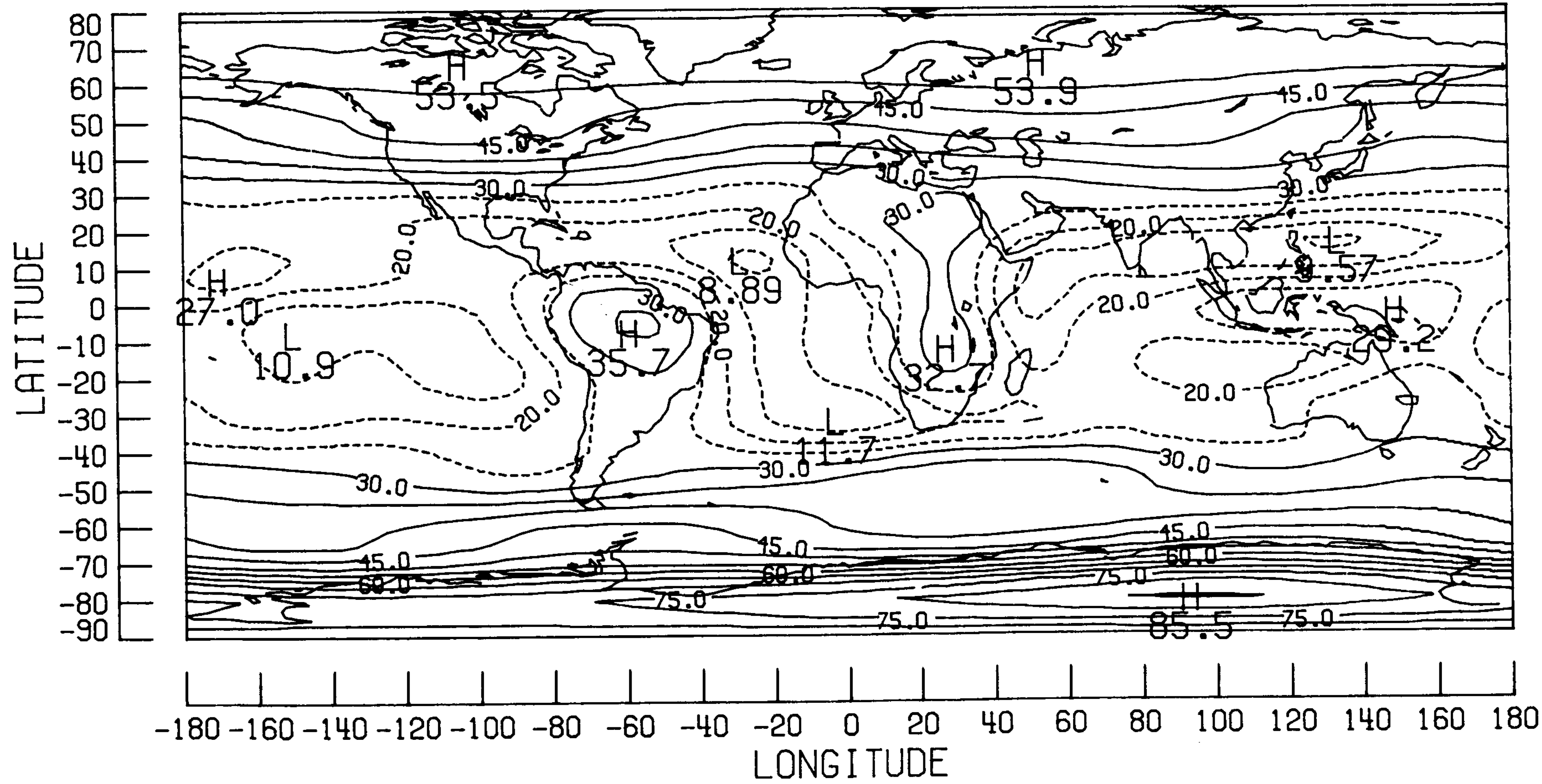


ABSORPTION W/(M*M)

JAN 1979

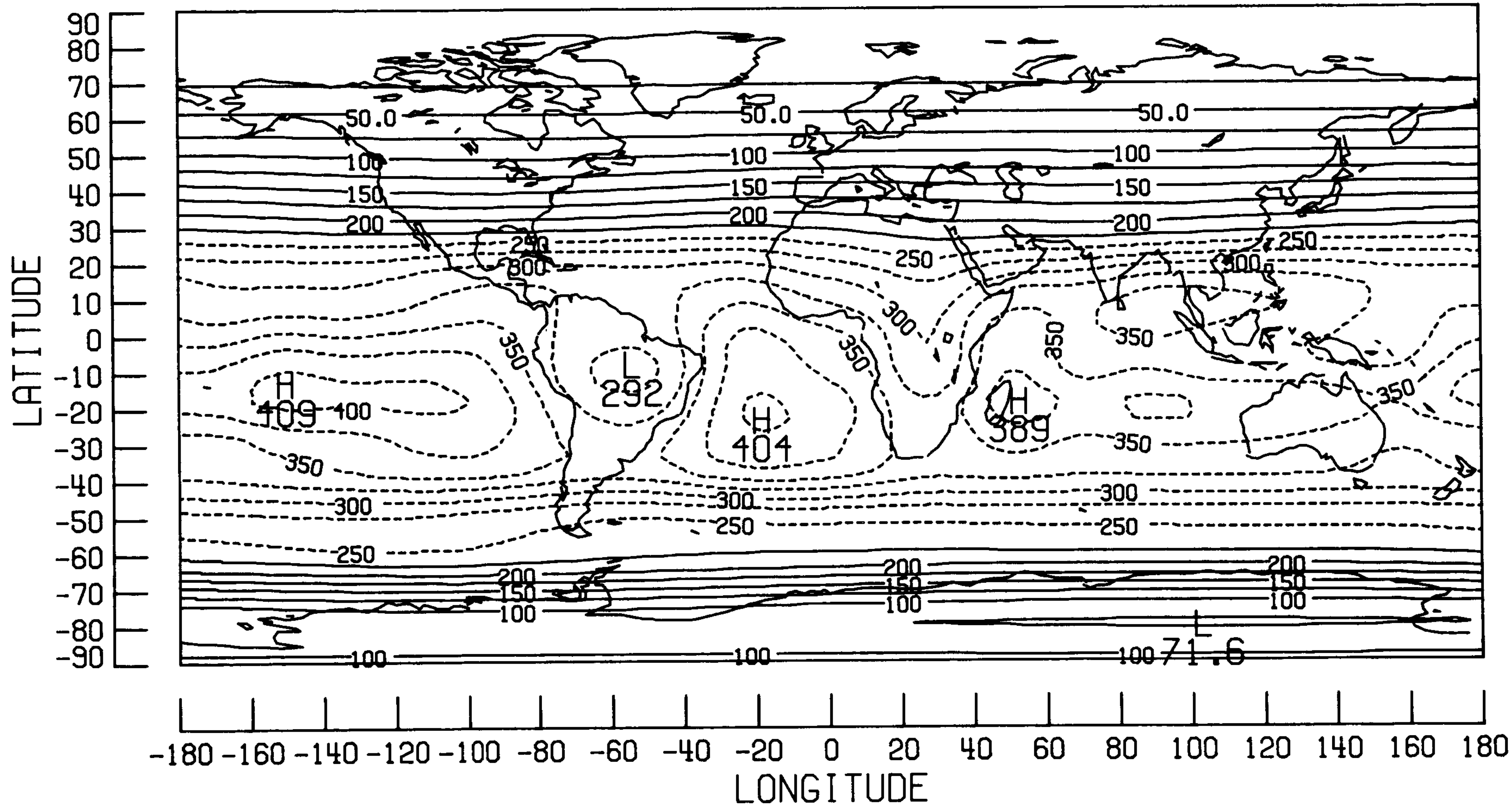


ALBEDO (%)
FEB 1979



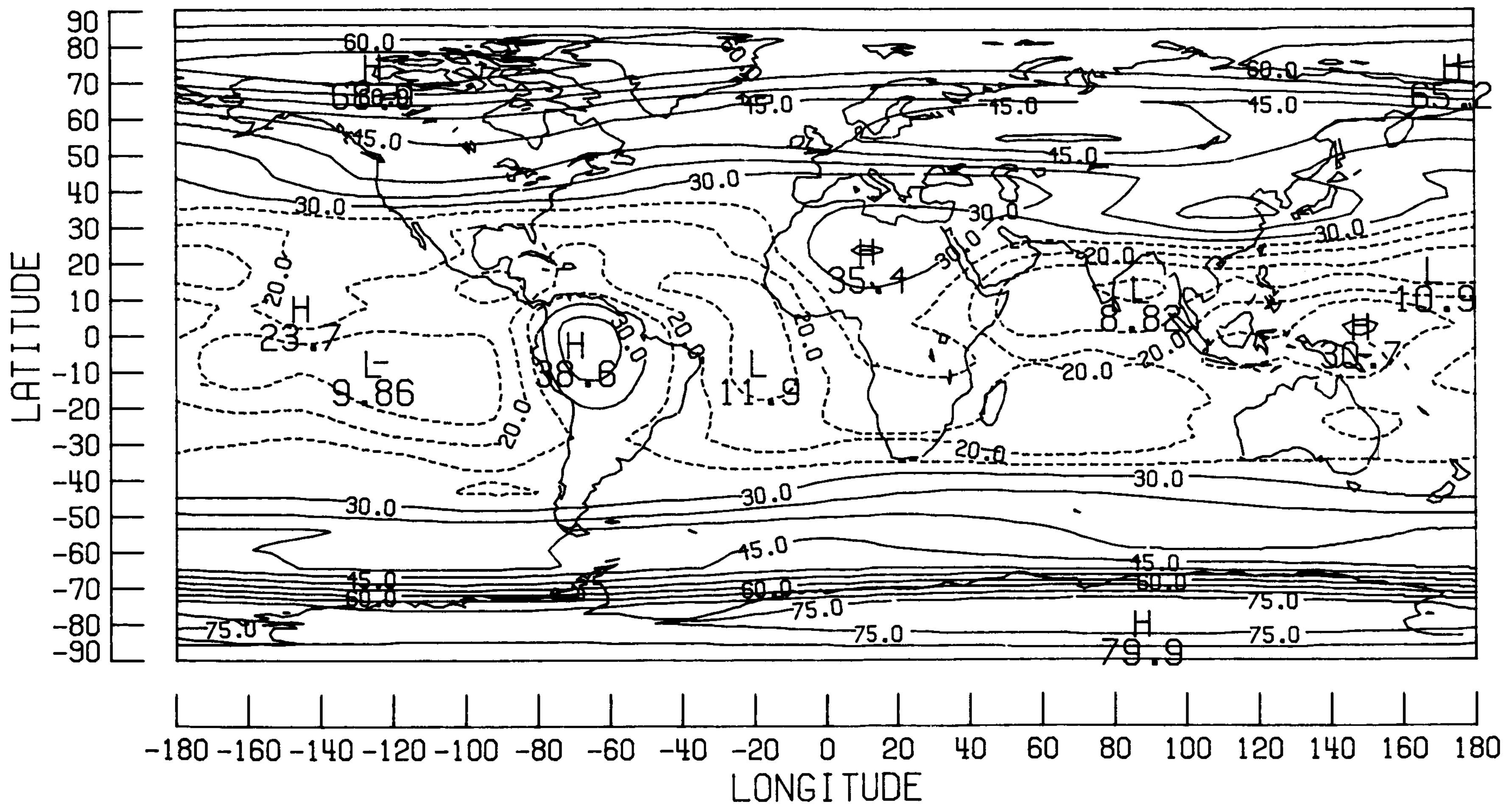
ABSORPTION W/(M*M)

FEB 1979



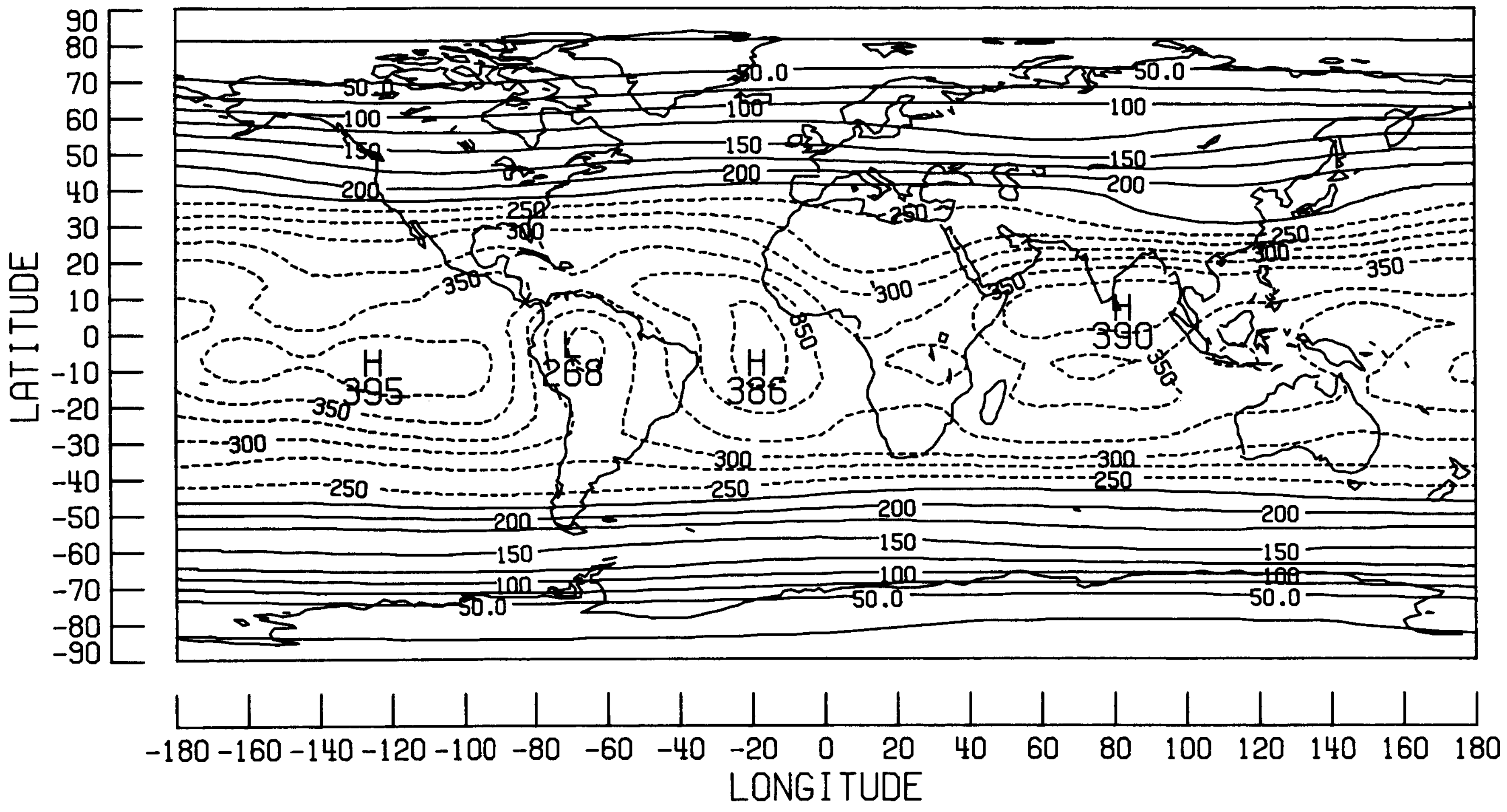
ALBEDO (%)

MAR 1979

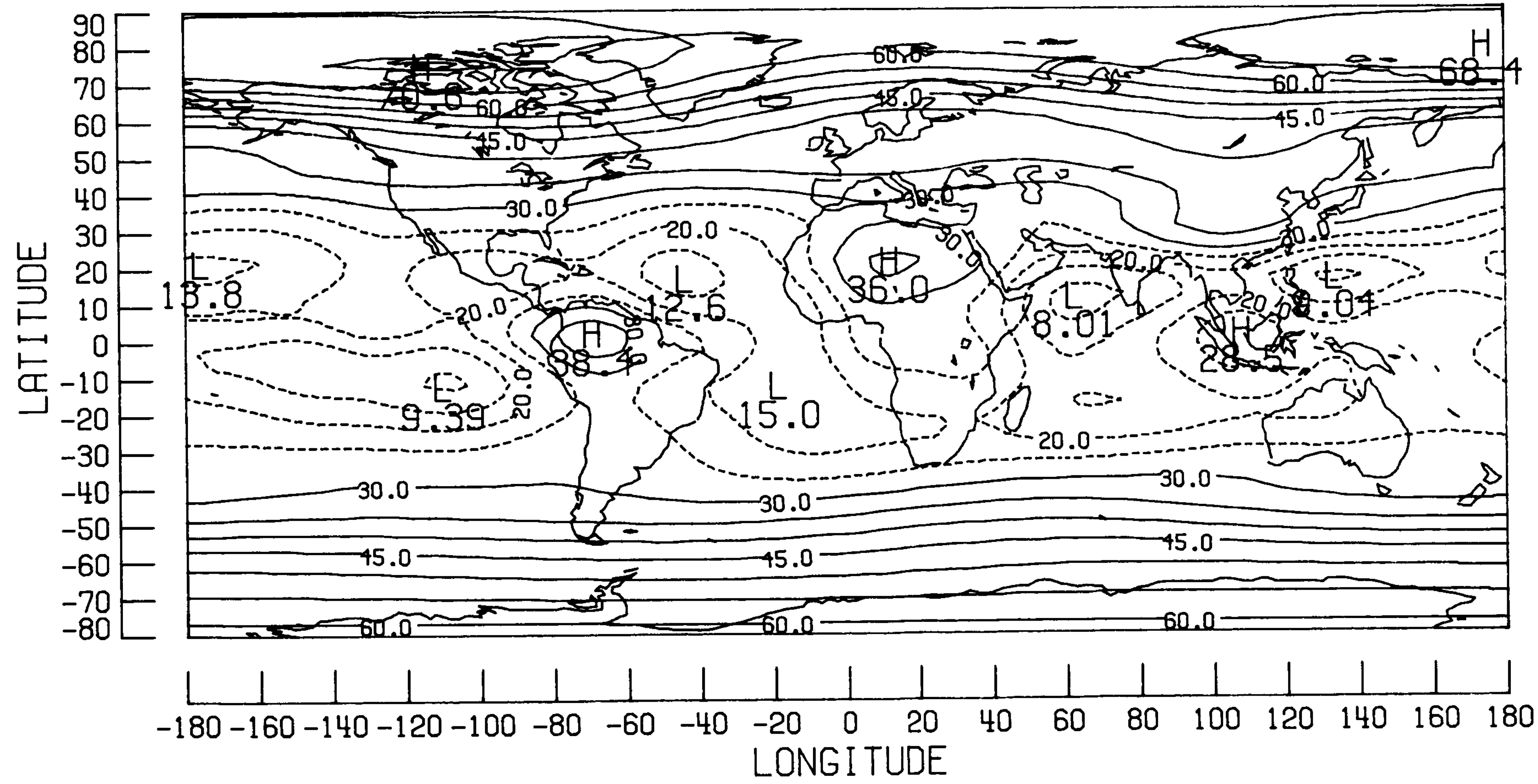


ABSORPTION W/(M*M)

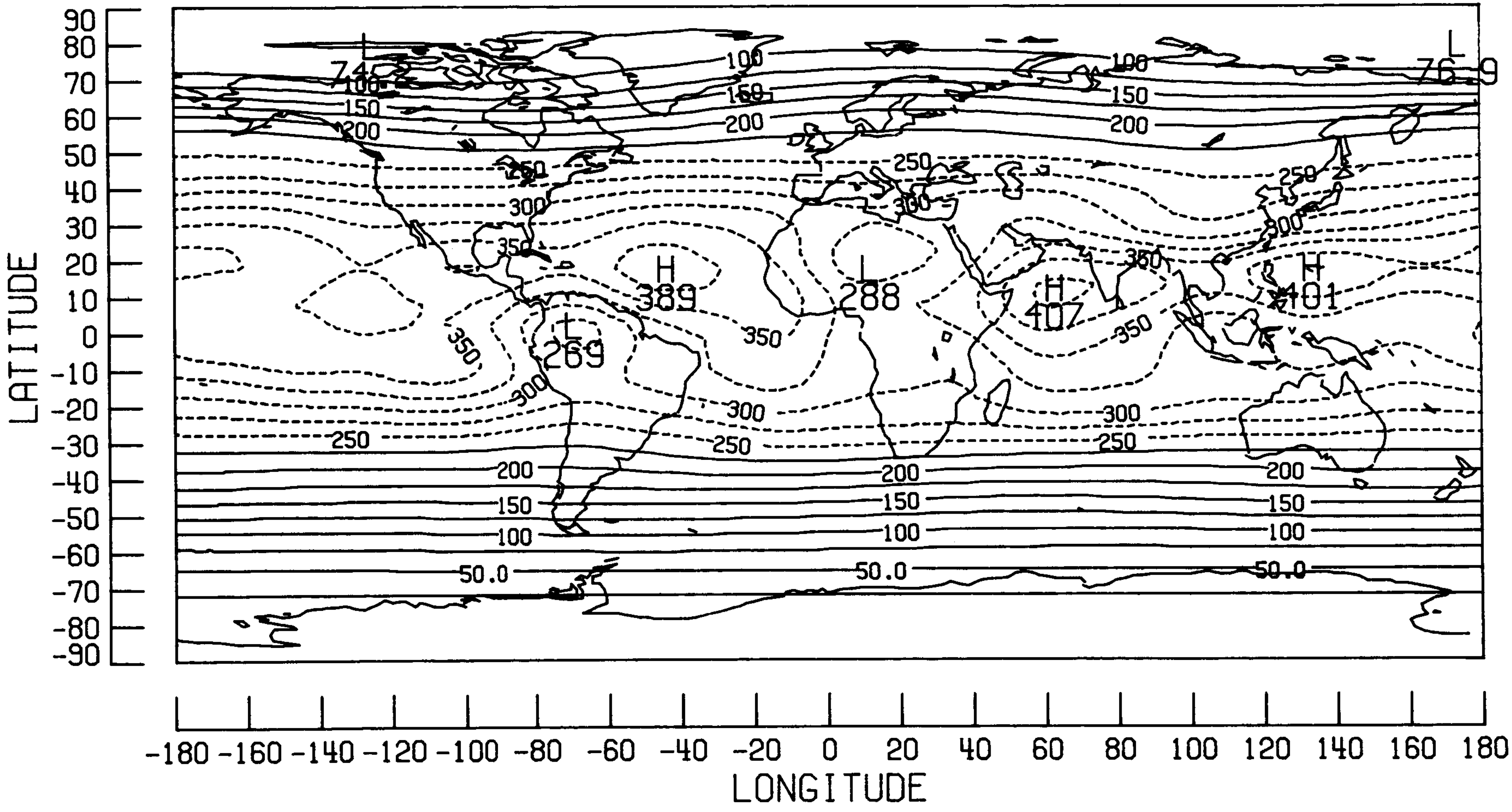
MAR 1979



ALBEDO (%)
APR 1979

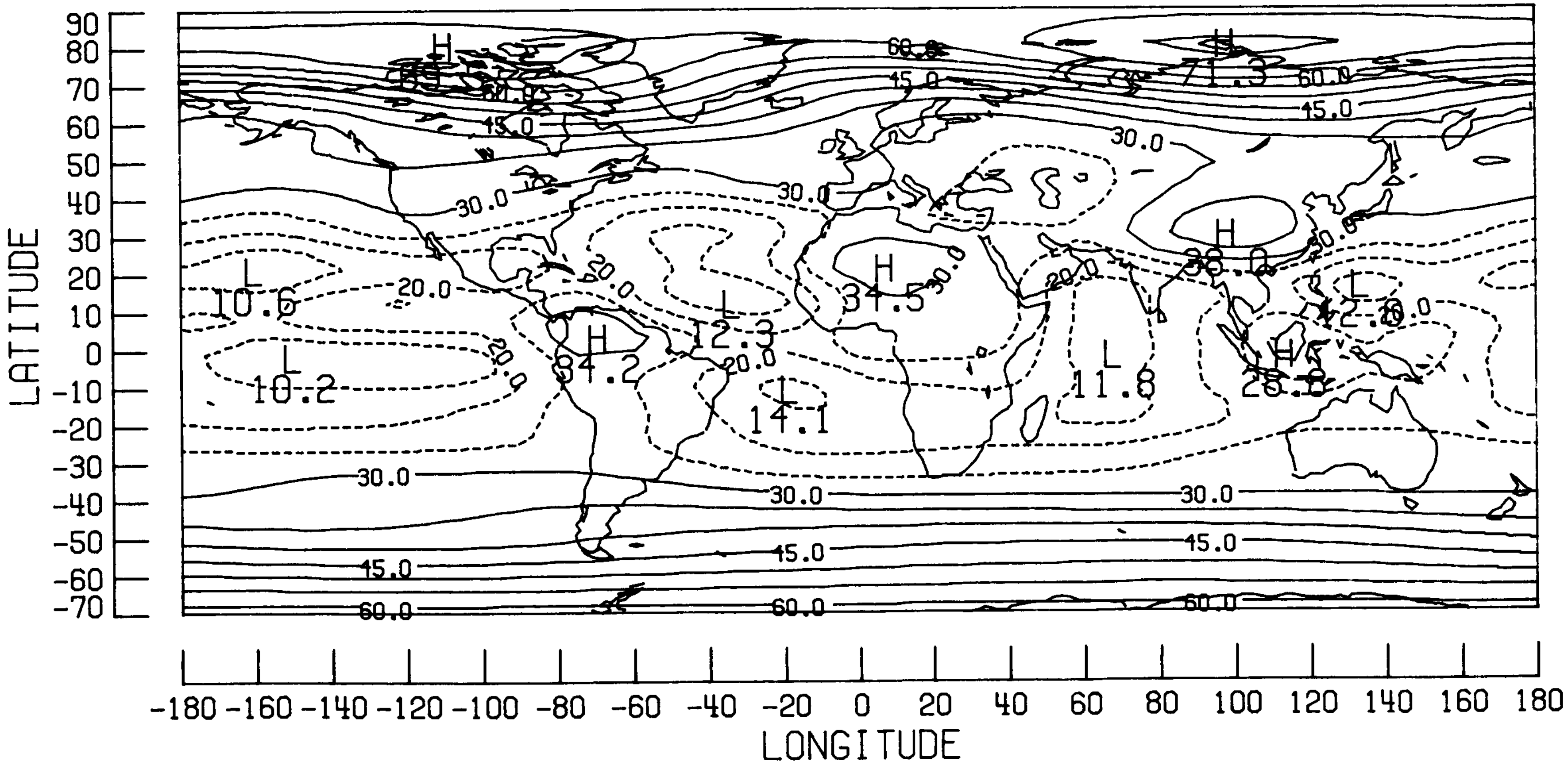


ABSORPTION W/(M*M)
APR 1979



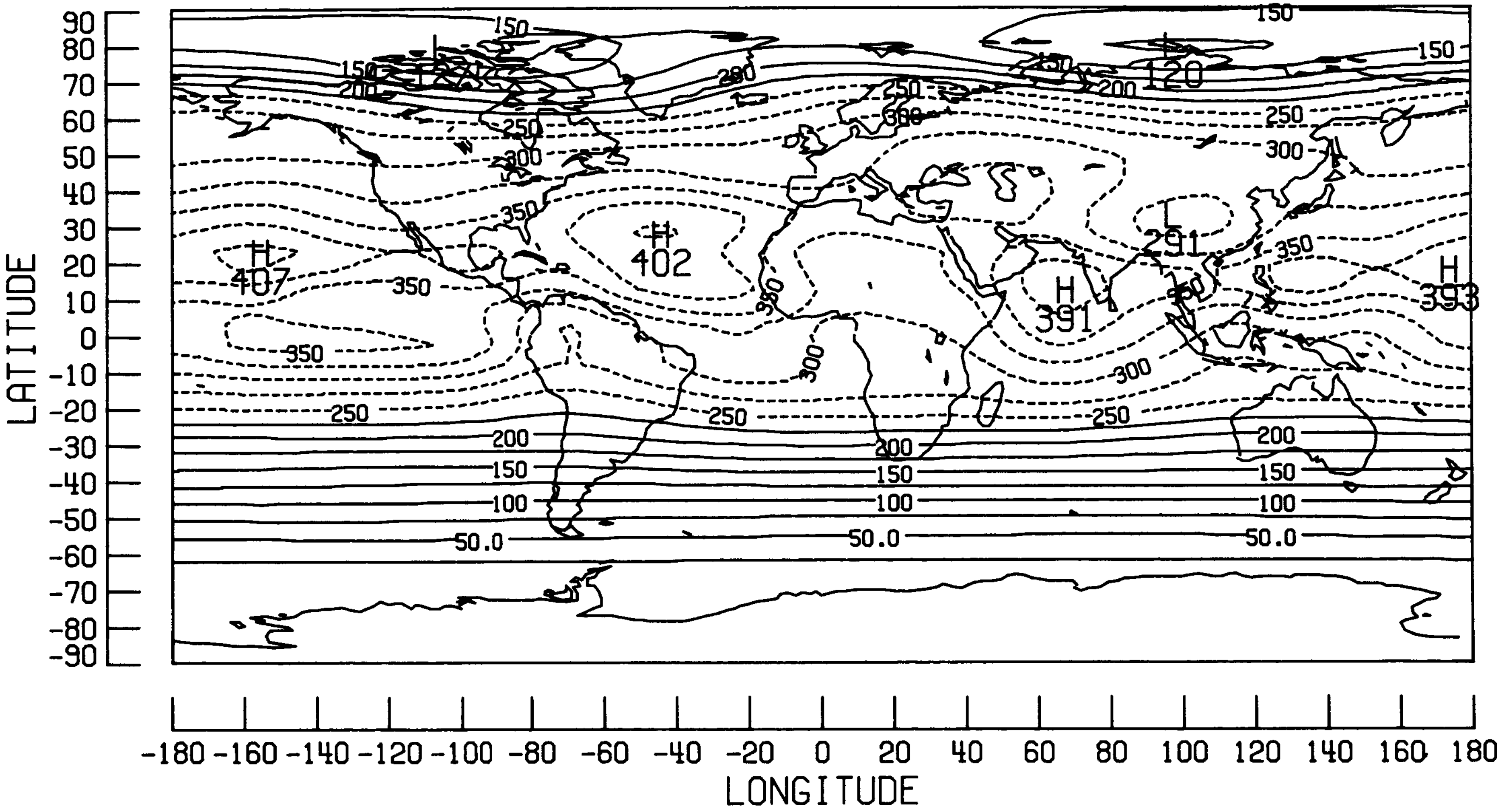
ALBEDO (%)

MAY 1979

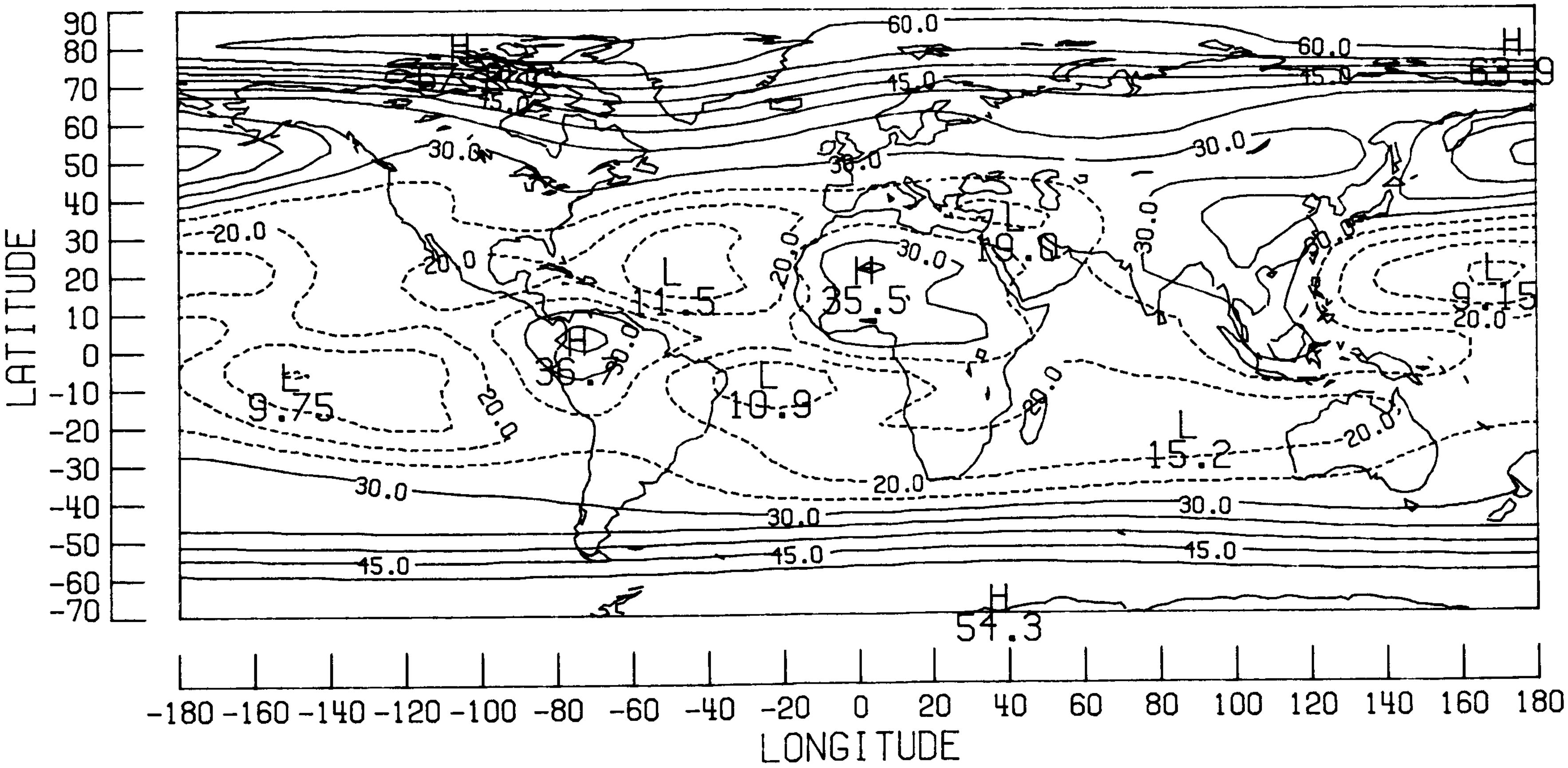


ABSORPTION W/(M*M)

MAY 1979

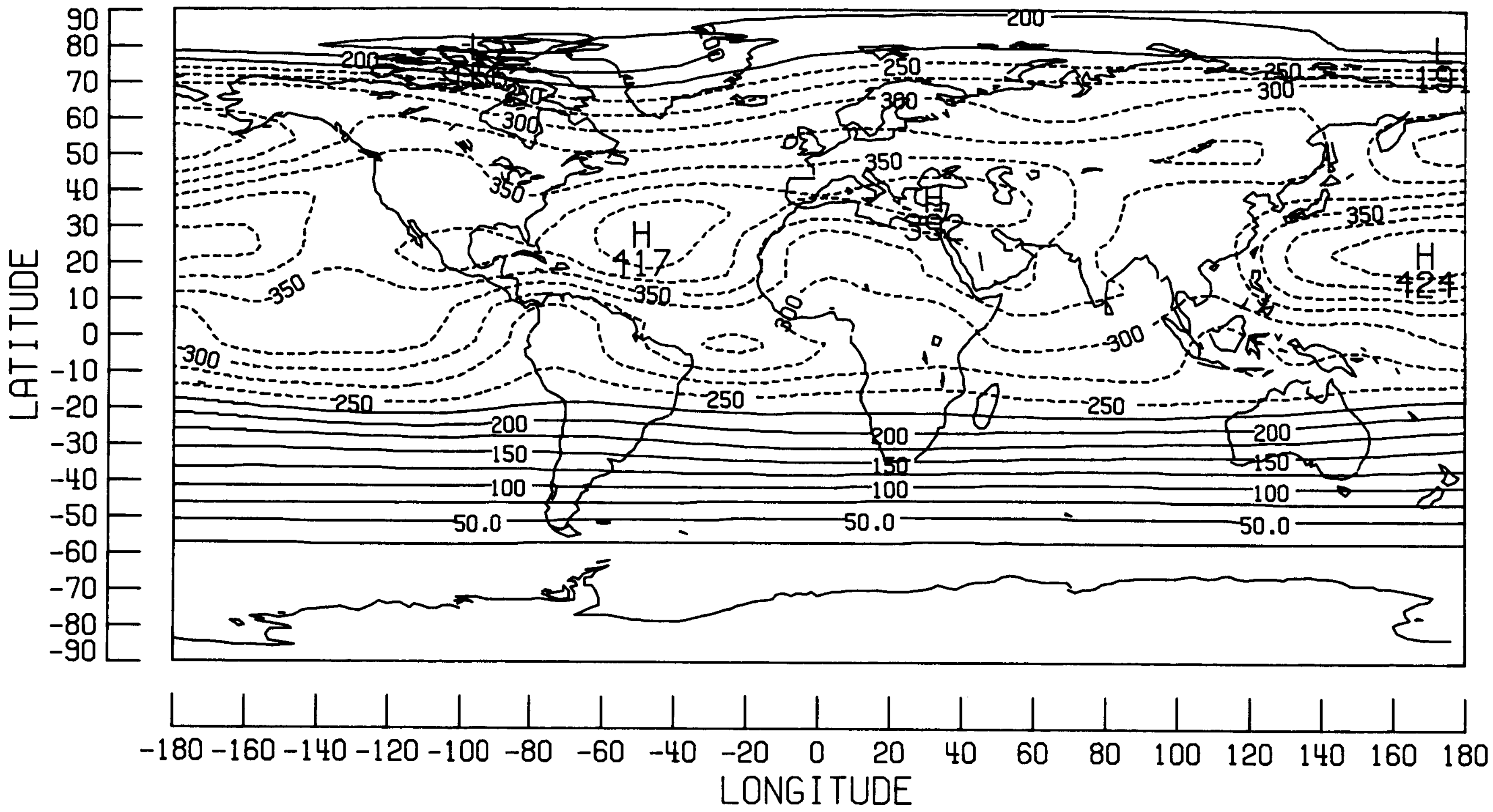


ALBEDO (%)
JUN 1979

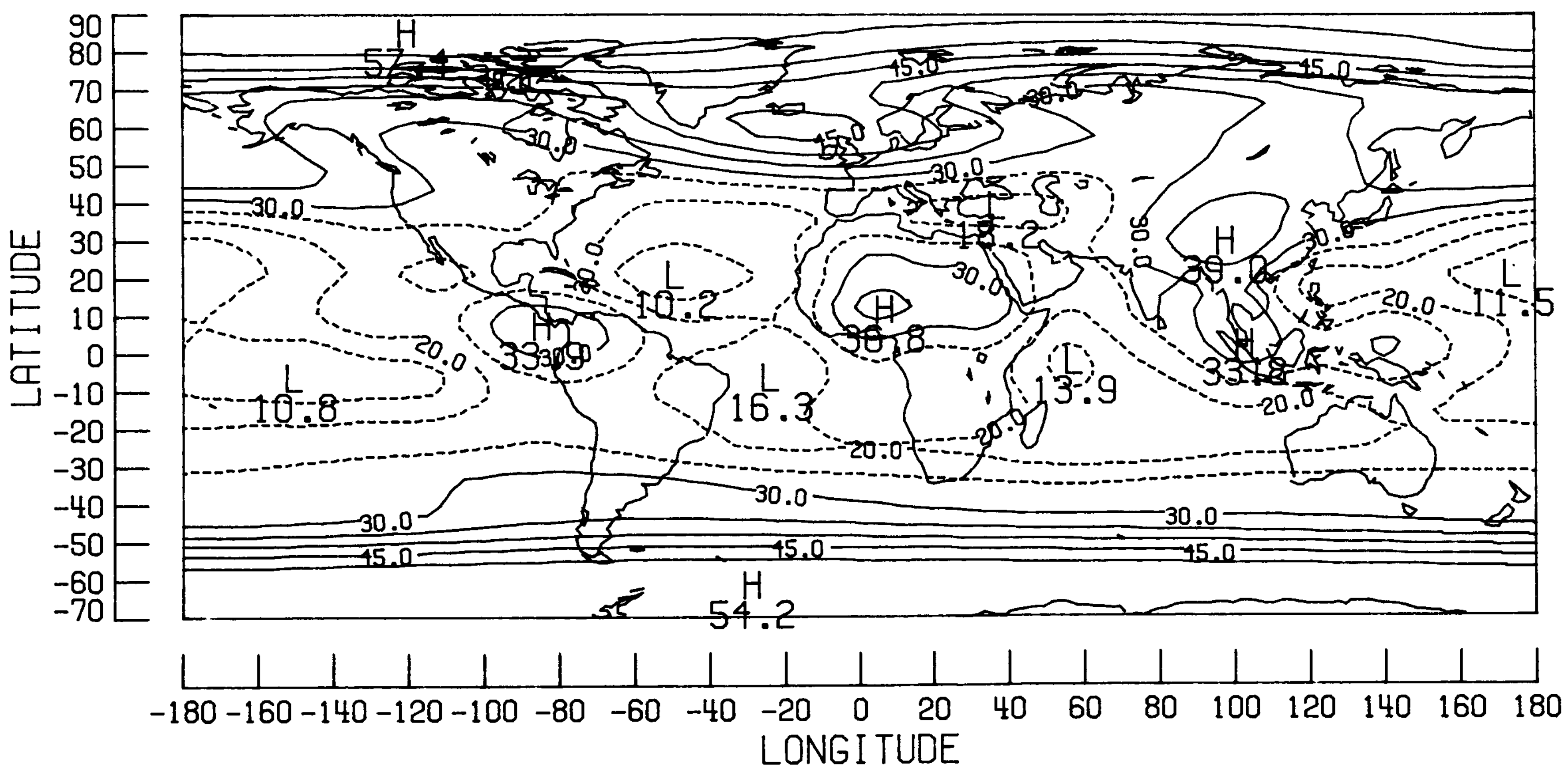


ABSORPTION W/(M*M)

JUN 1979

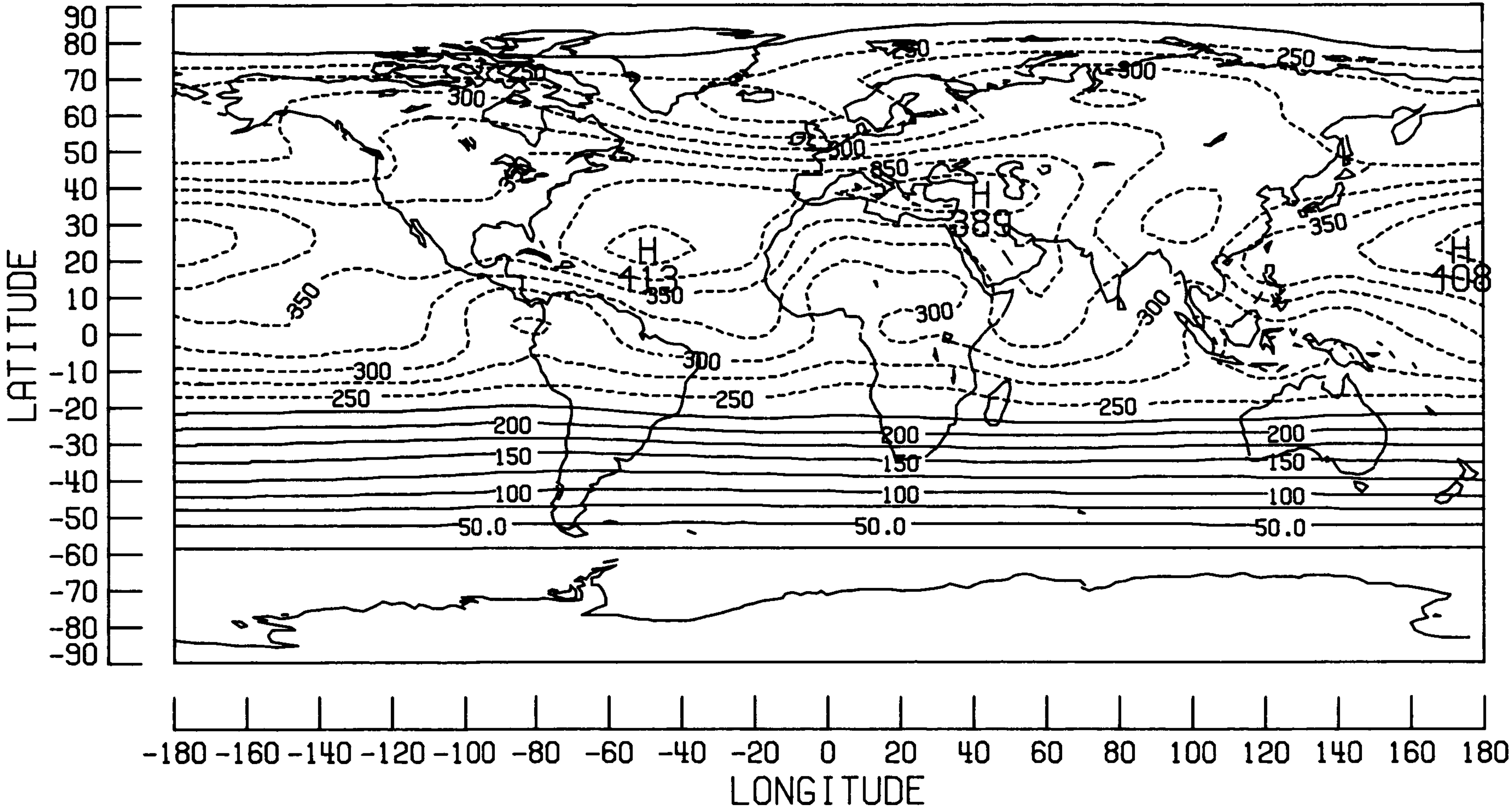


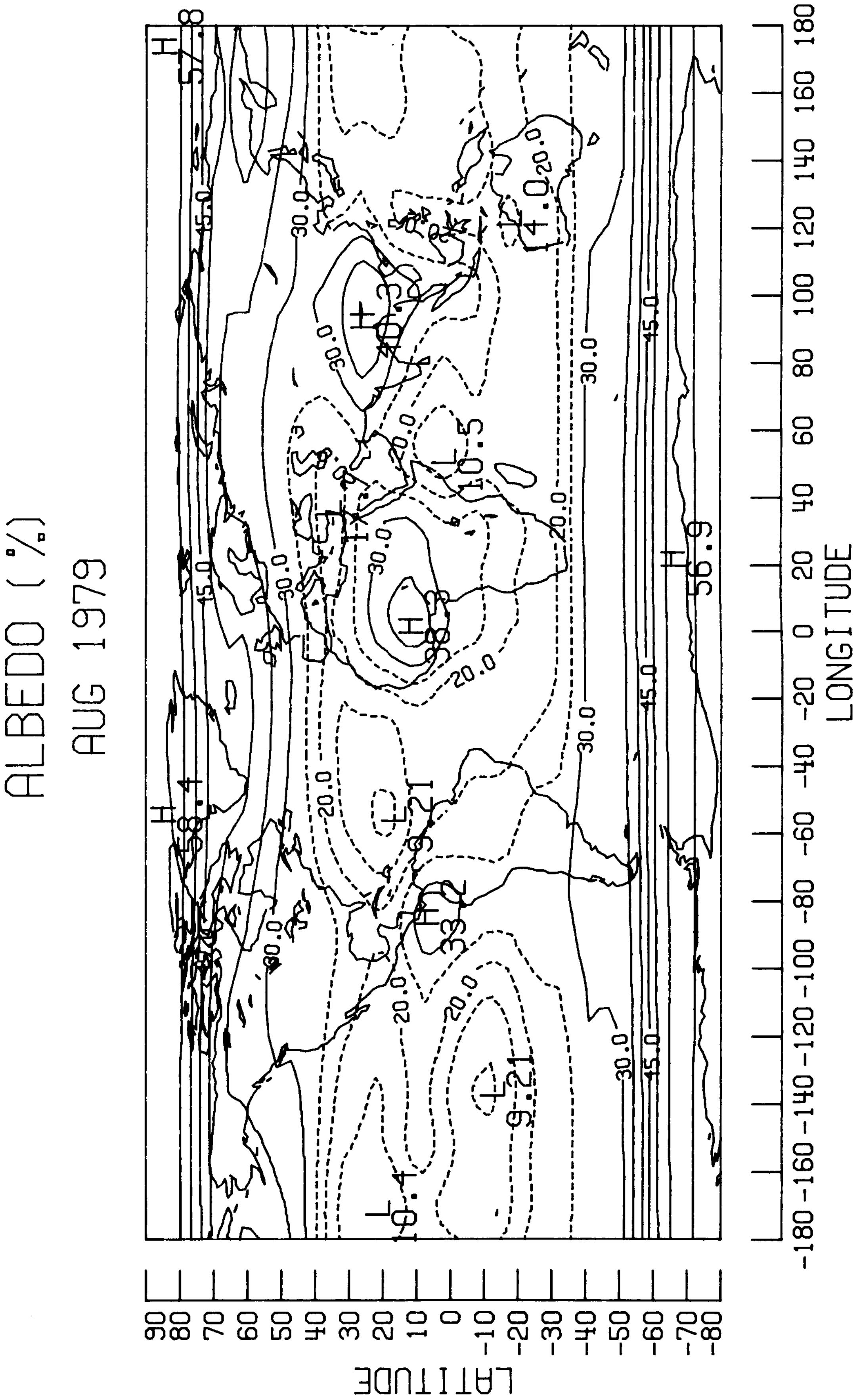
ALBEDO (%)
JUL 1979

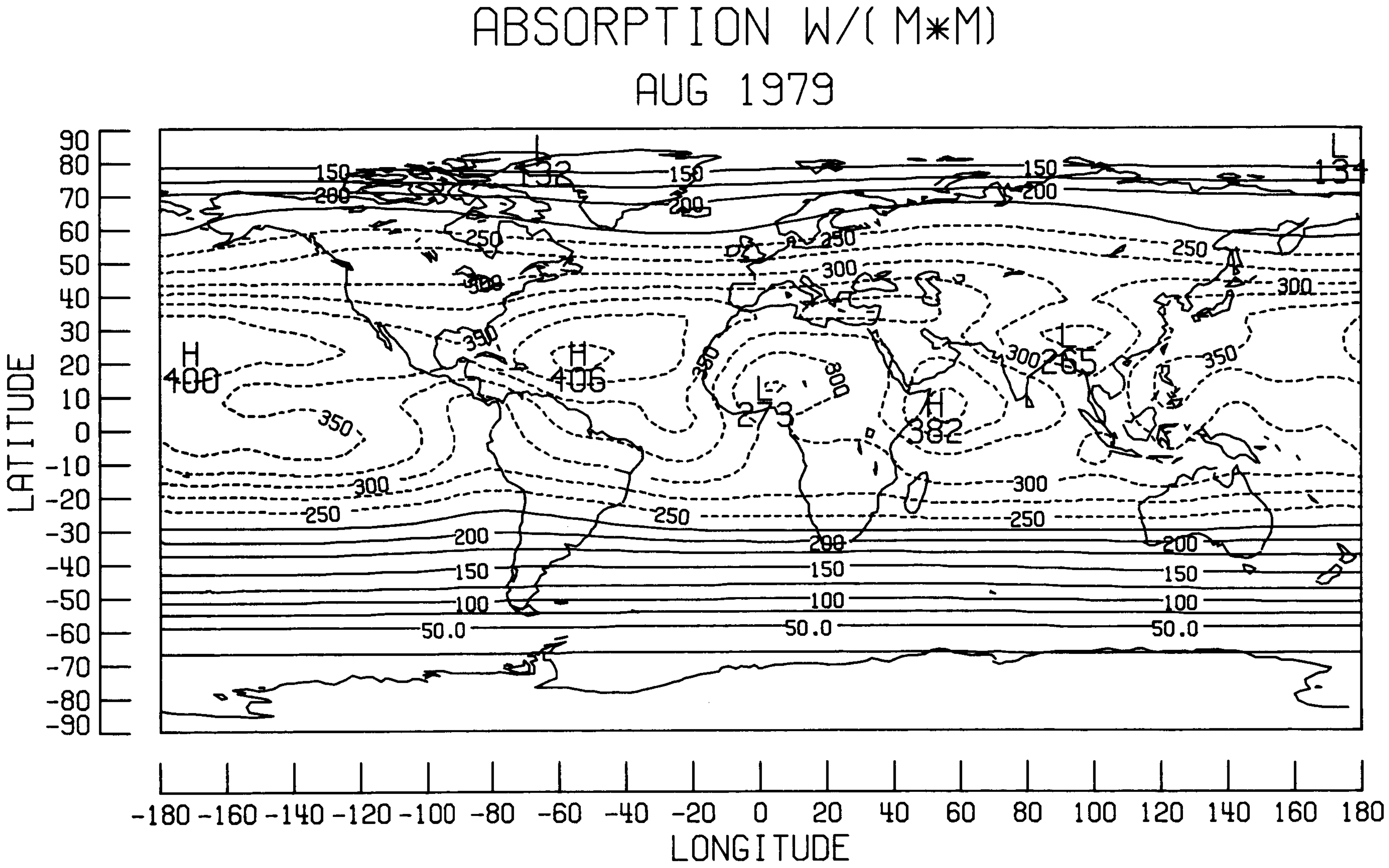


ABSORPTION W/(M*M)

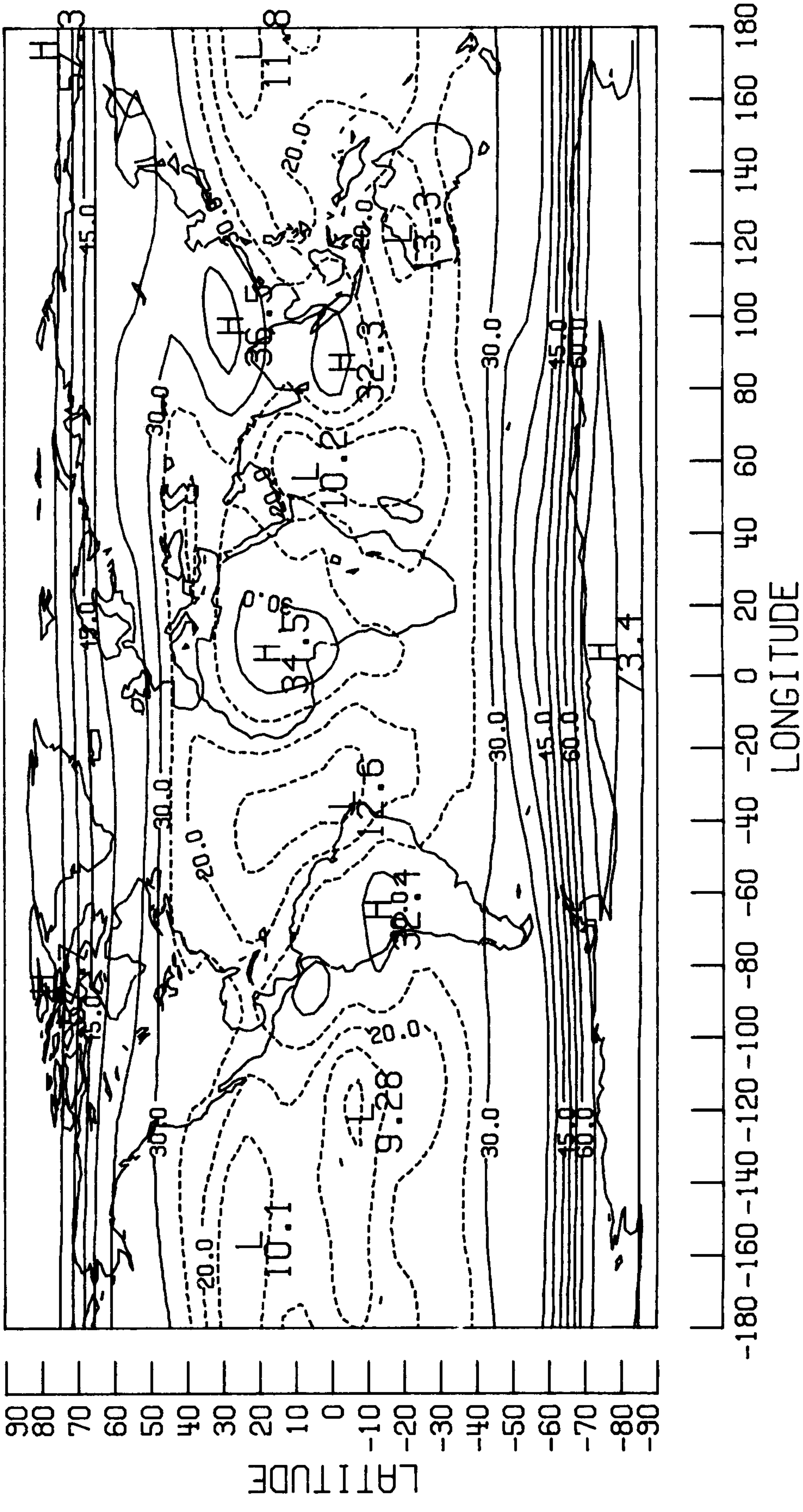
JUL 1979




ALBEDO (%)
AUG 1979
LONGITUDE
LATITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80
H 57.8
H 58.4
H 40.3
H 38.3
H 33.2
H 56.9
L 14.0
L 10.5
L 9.21
L 9.21
L 10.4
45.0
30.0
20.0

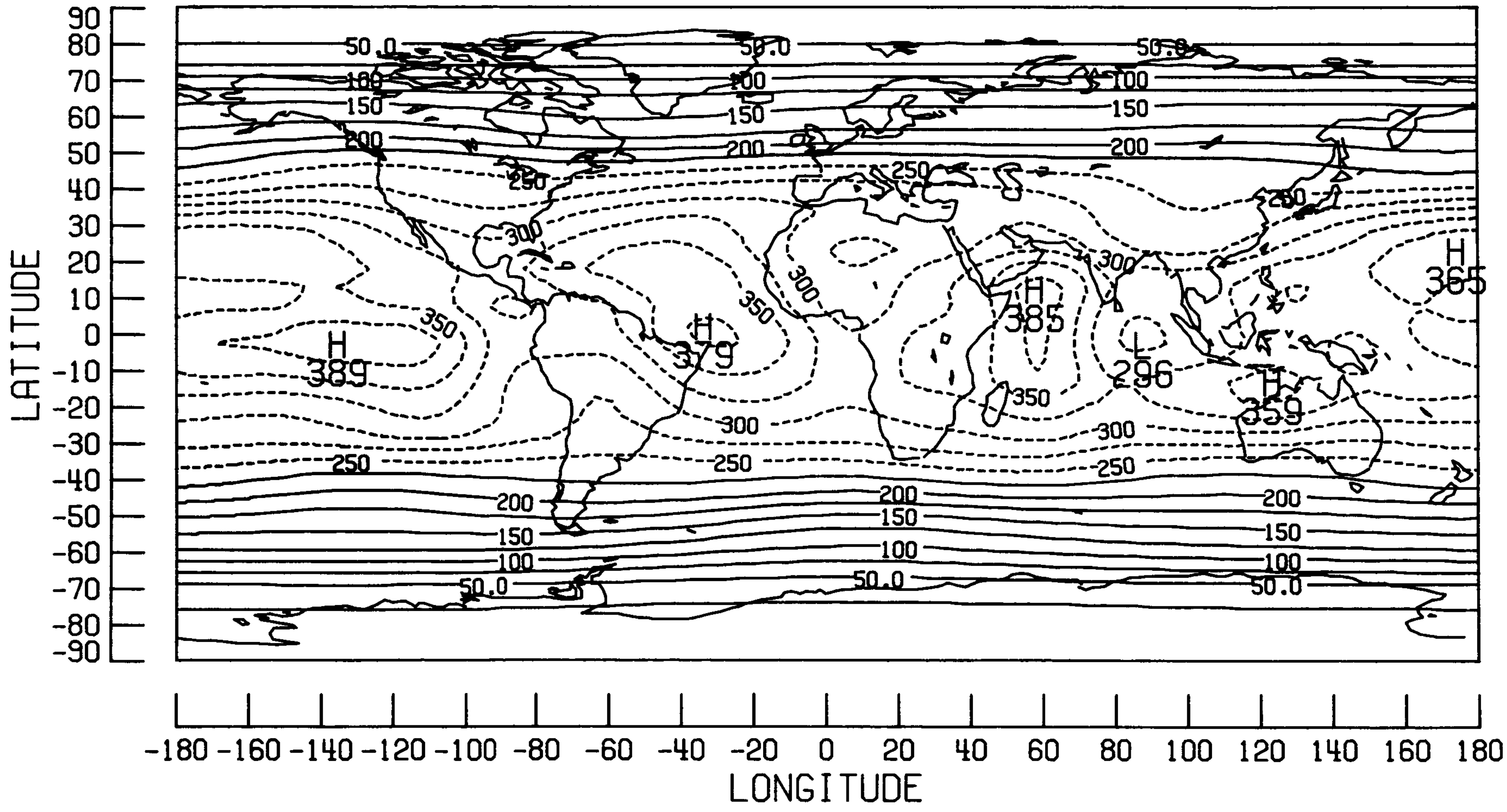

ABSORPTION W/(M*M)
AUG 1979
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
L
132
L
134
H
400
H
406
L
273
H
382
L
265
150
200
250
300
350
50.0
100

ALBEDO (%)
SEP 1979



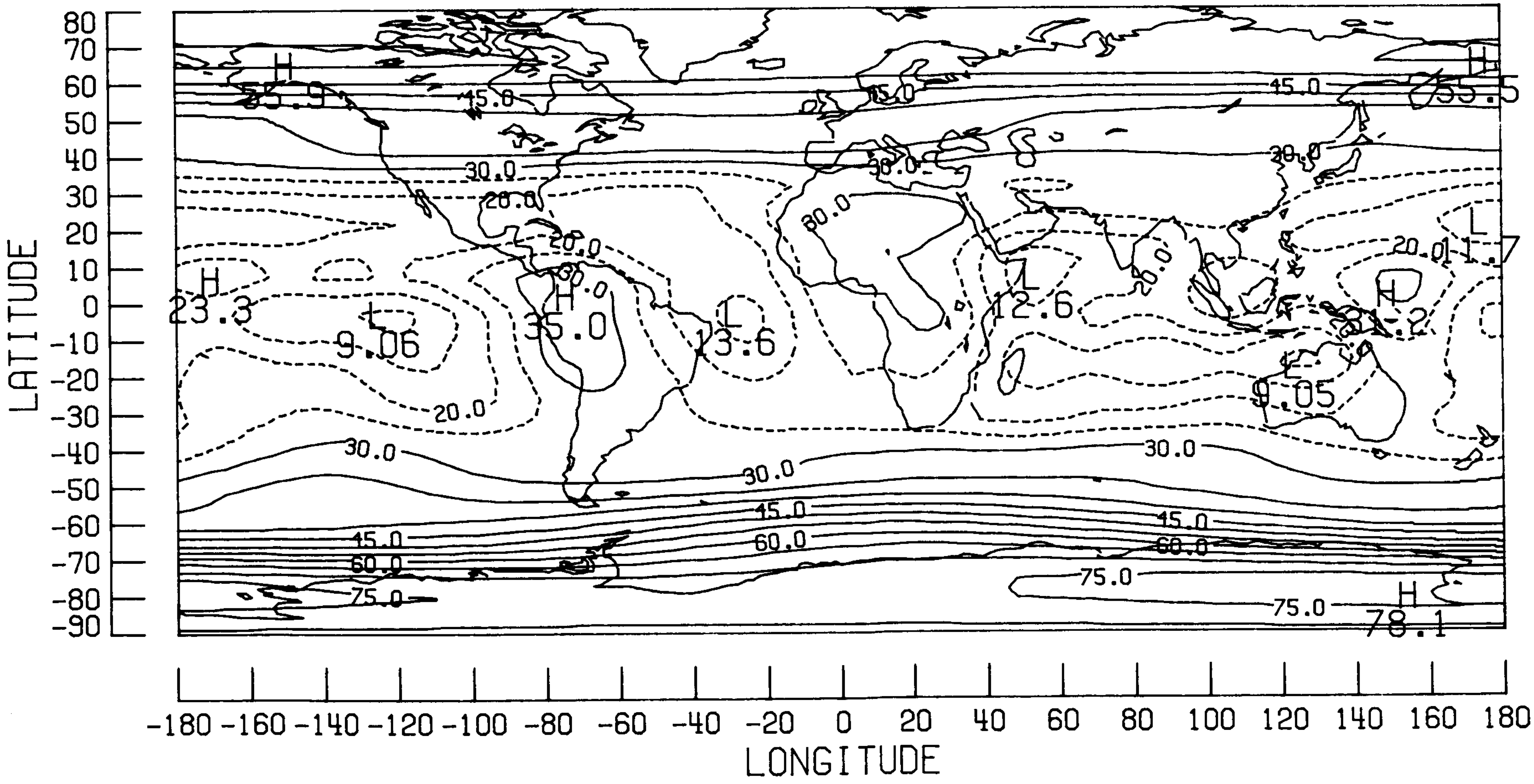
ABSORPTION W/(M*M)

SEP 1979



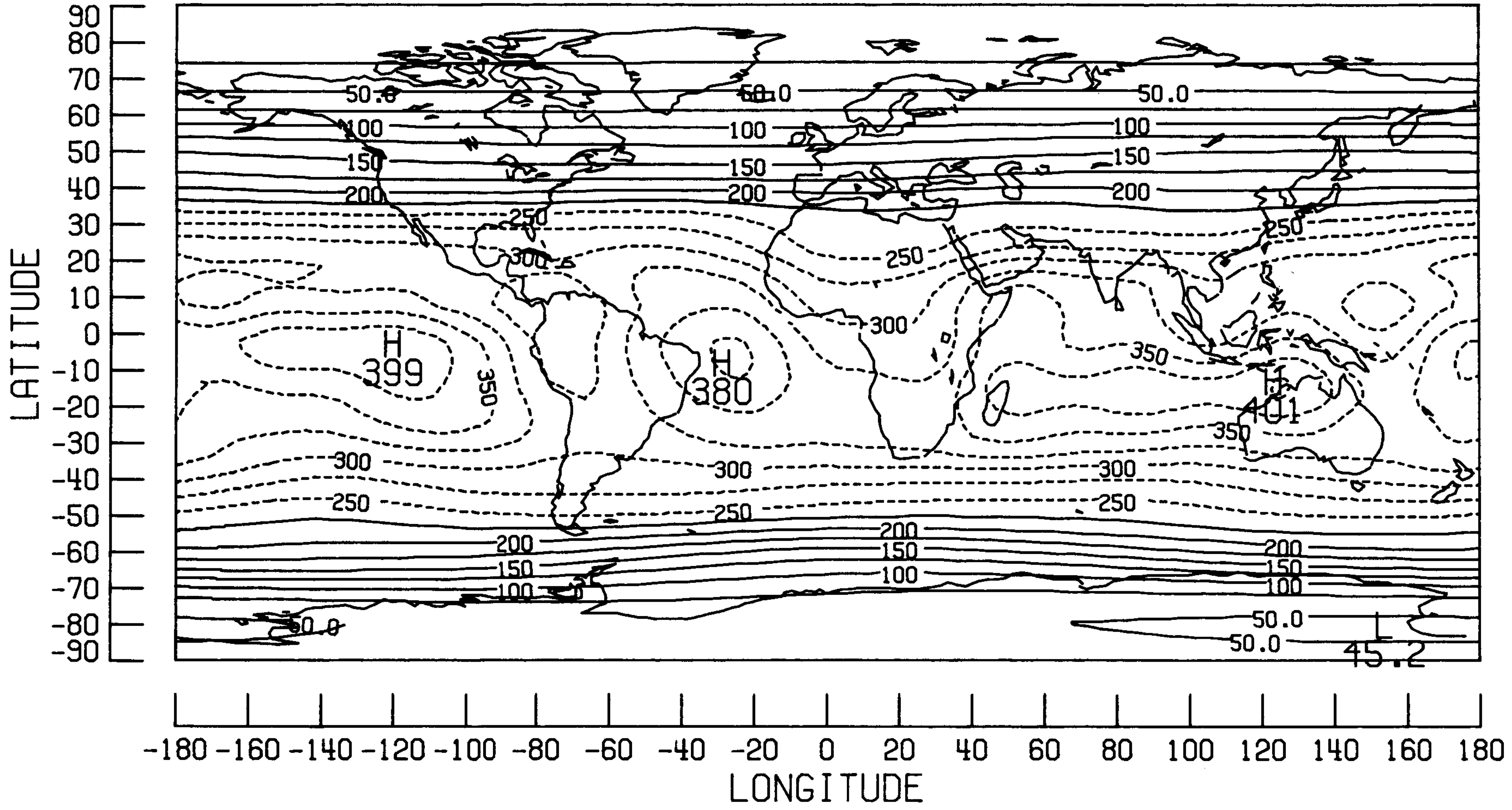
ALBEDO (%)

OCT 1979

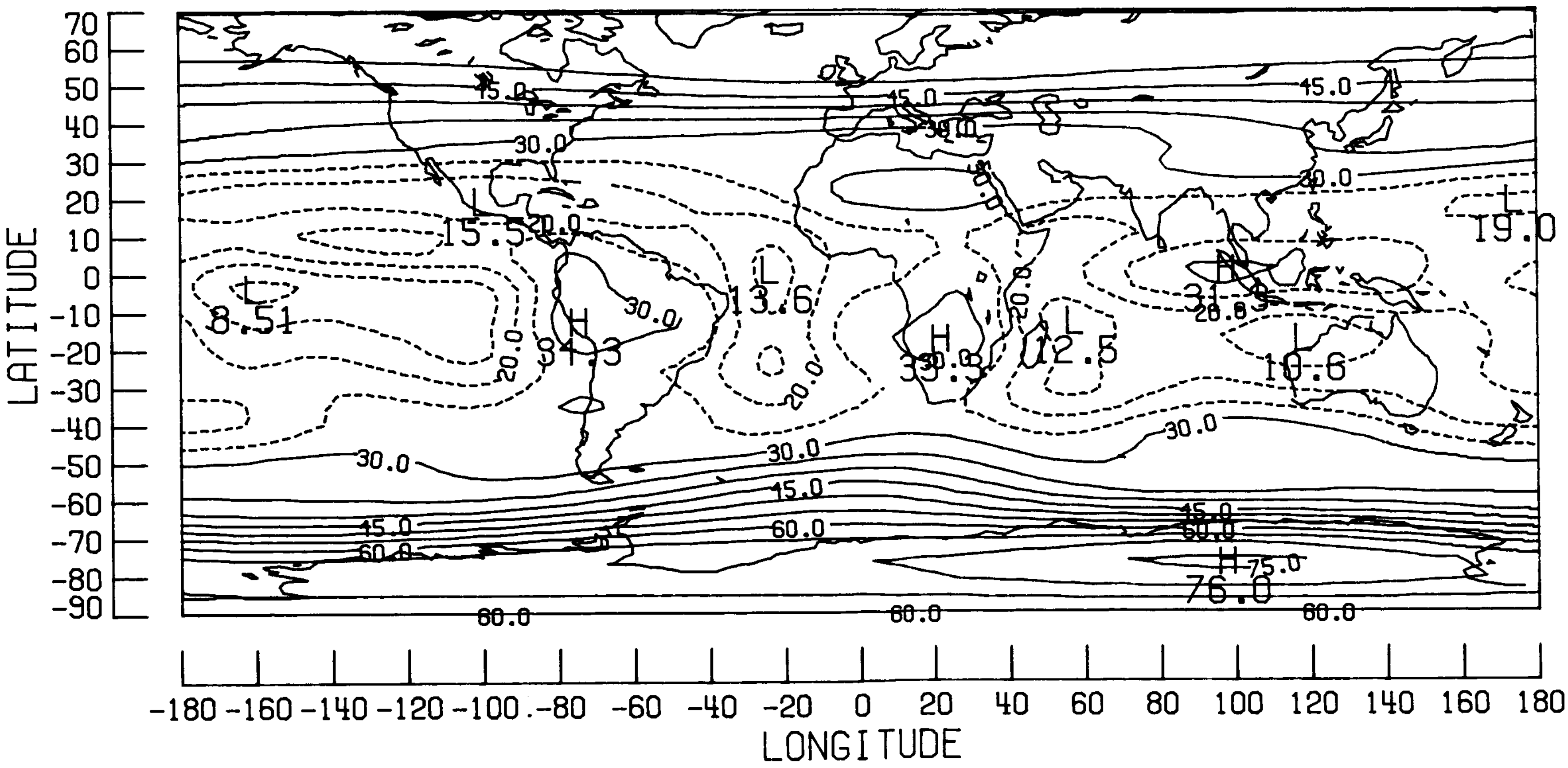


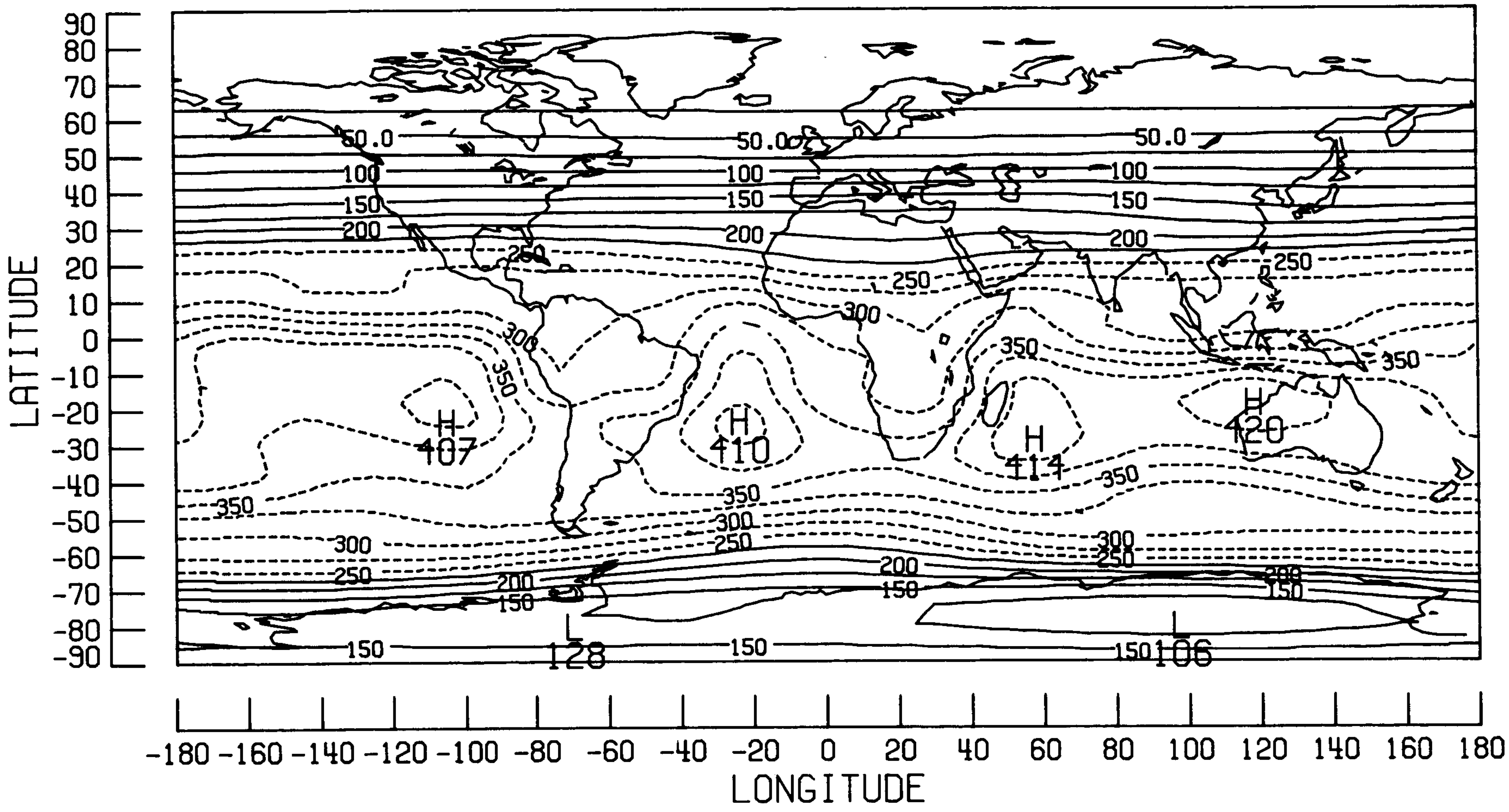
ABSORPTION W/(M*M)

OCT 1979



ALBEDO (%)
NOV 1979

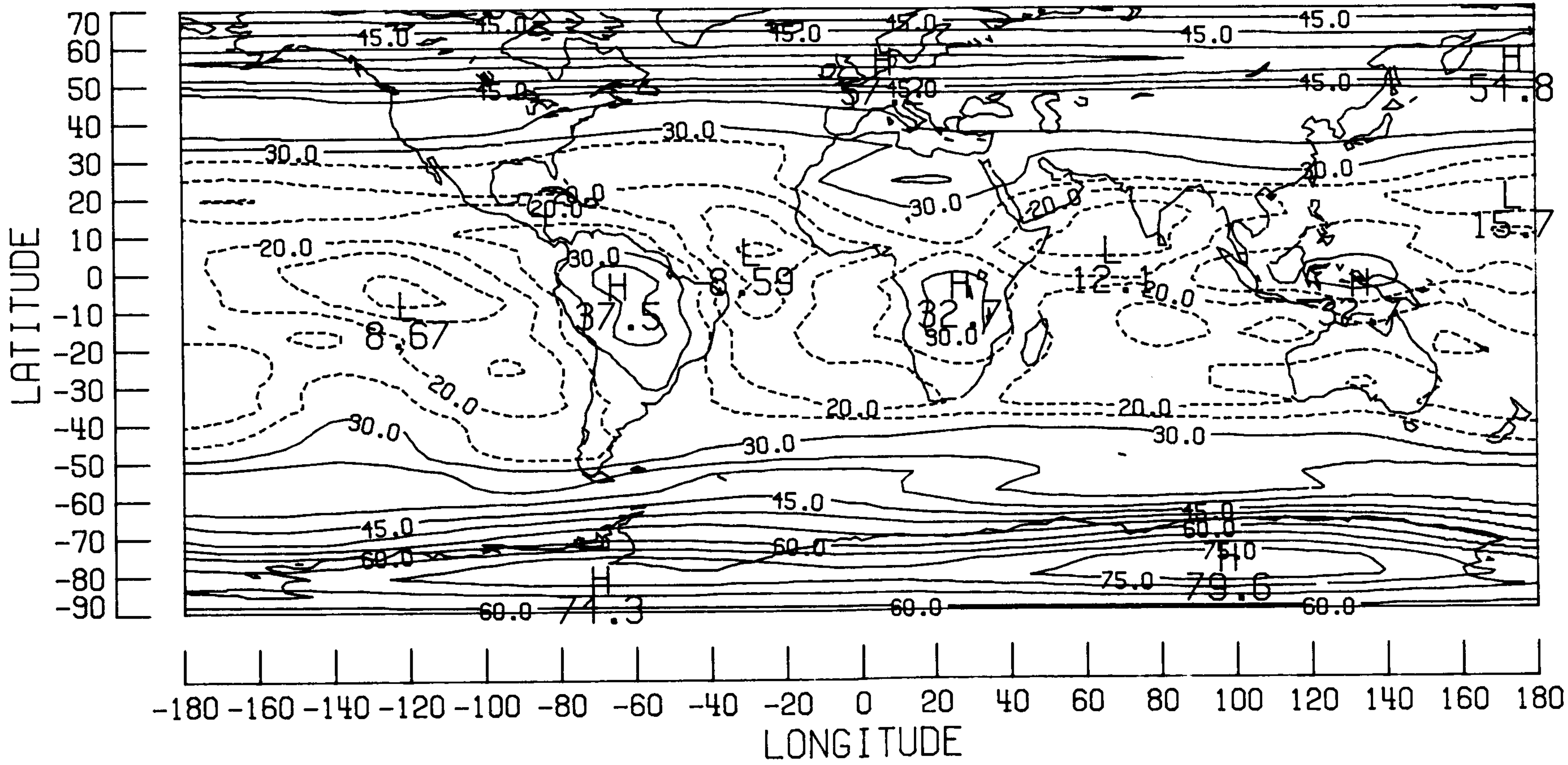




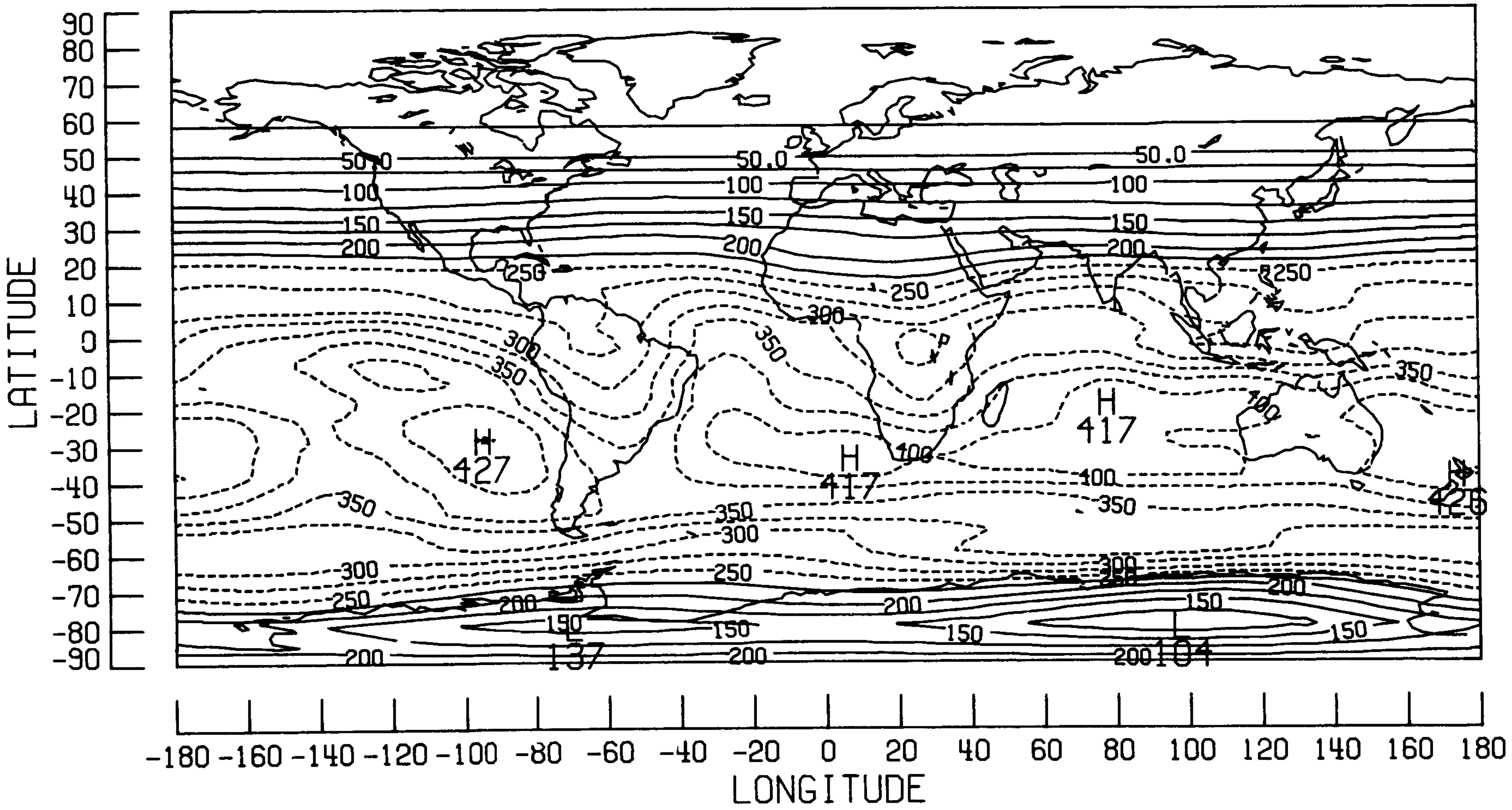
ABSORPTION W/(M*M)

NOV 1979

ALBEDO (%)
DEC 1979

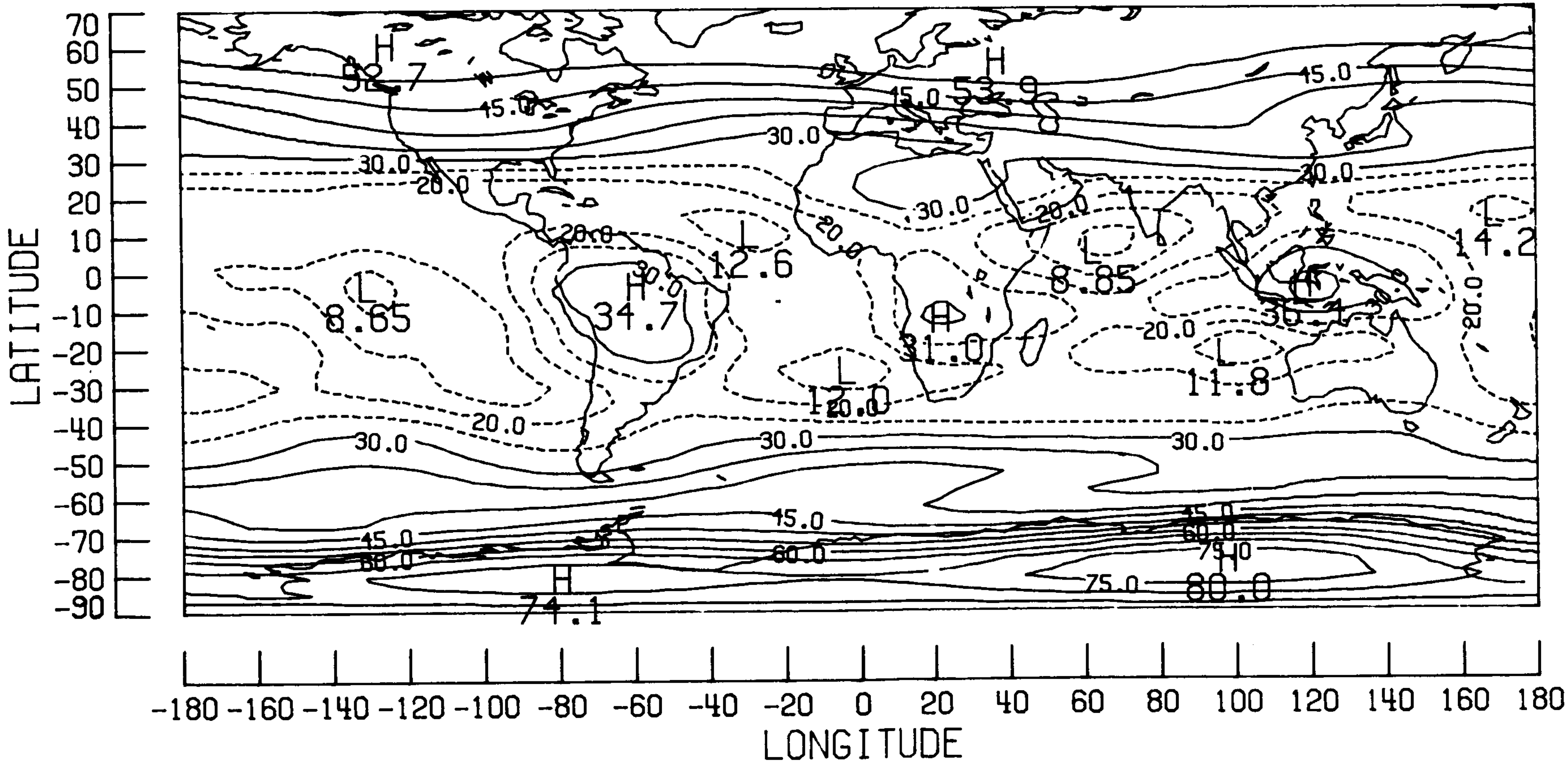


ABSORPTION W/(M*M)
DEC 1979



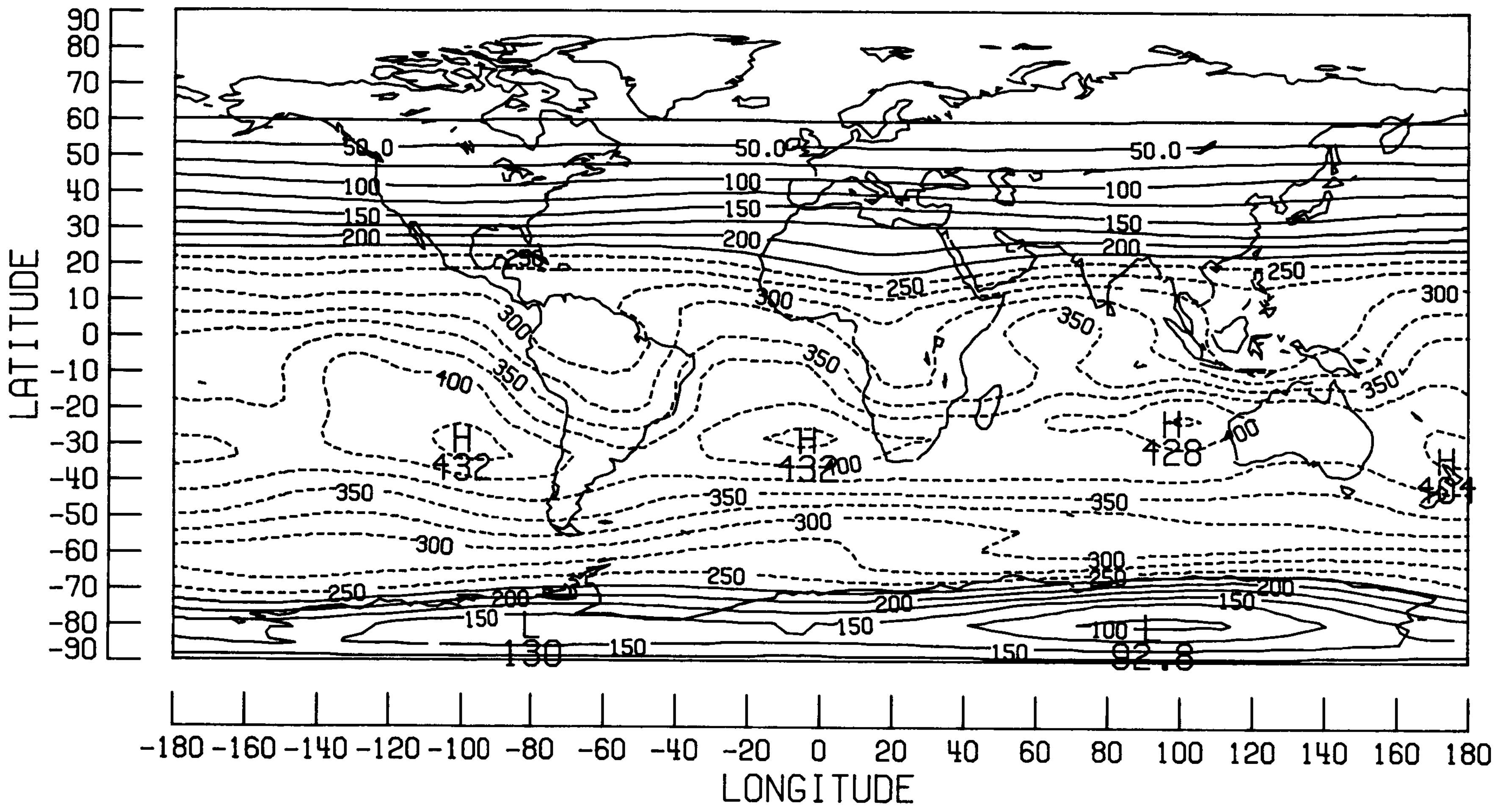
ALBEDO (%)

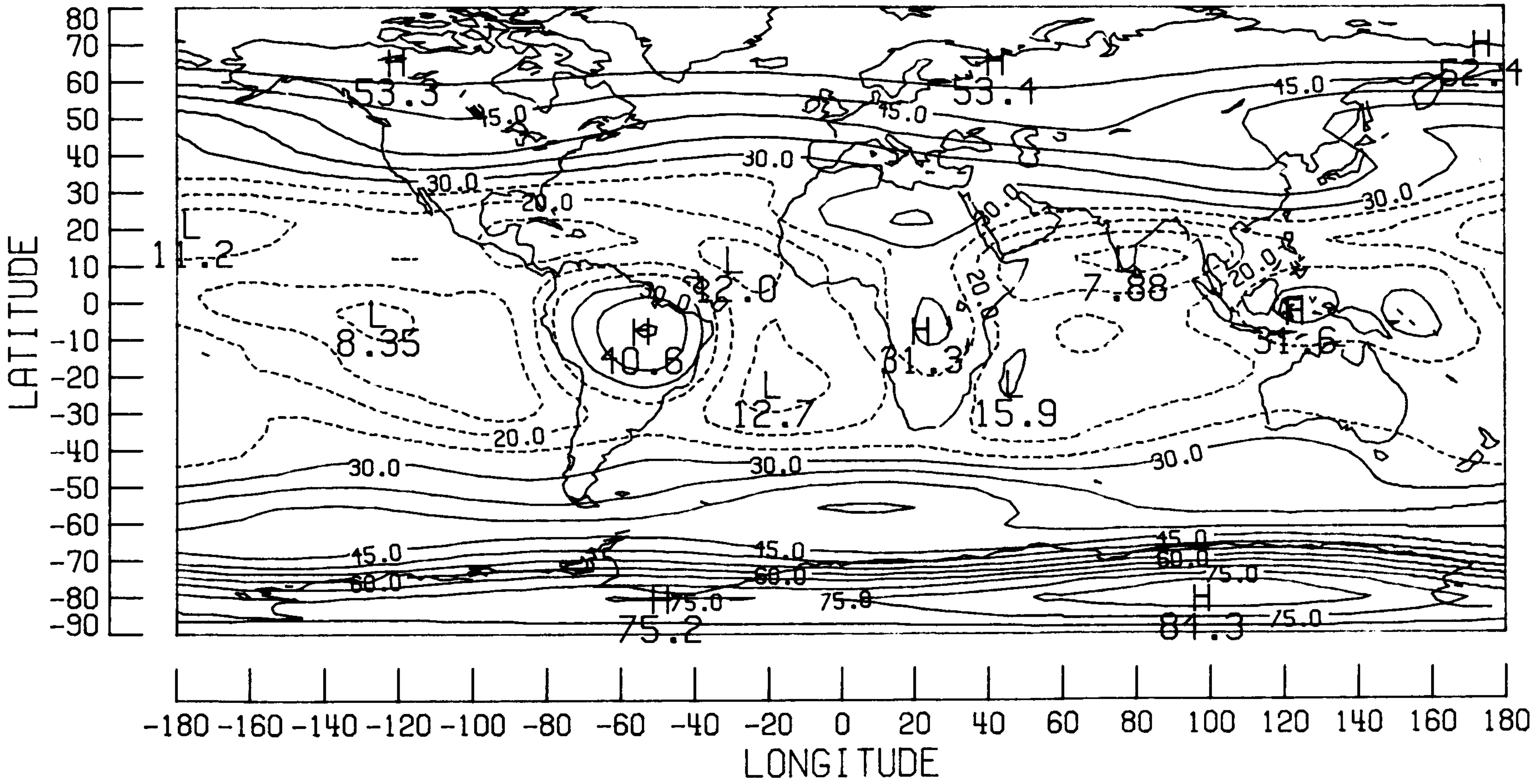
JAN 1980



ABSORPTION W/(M*M)

JAN 1980

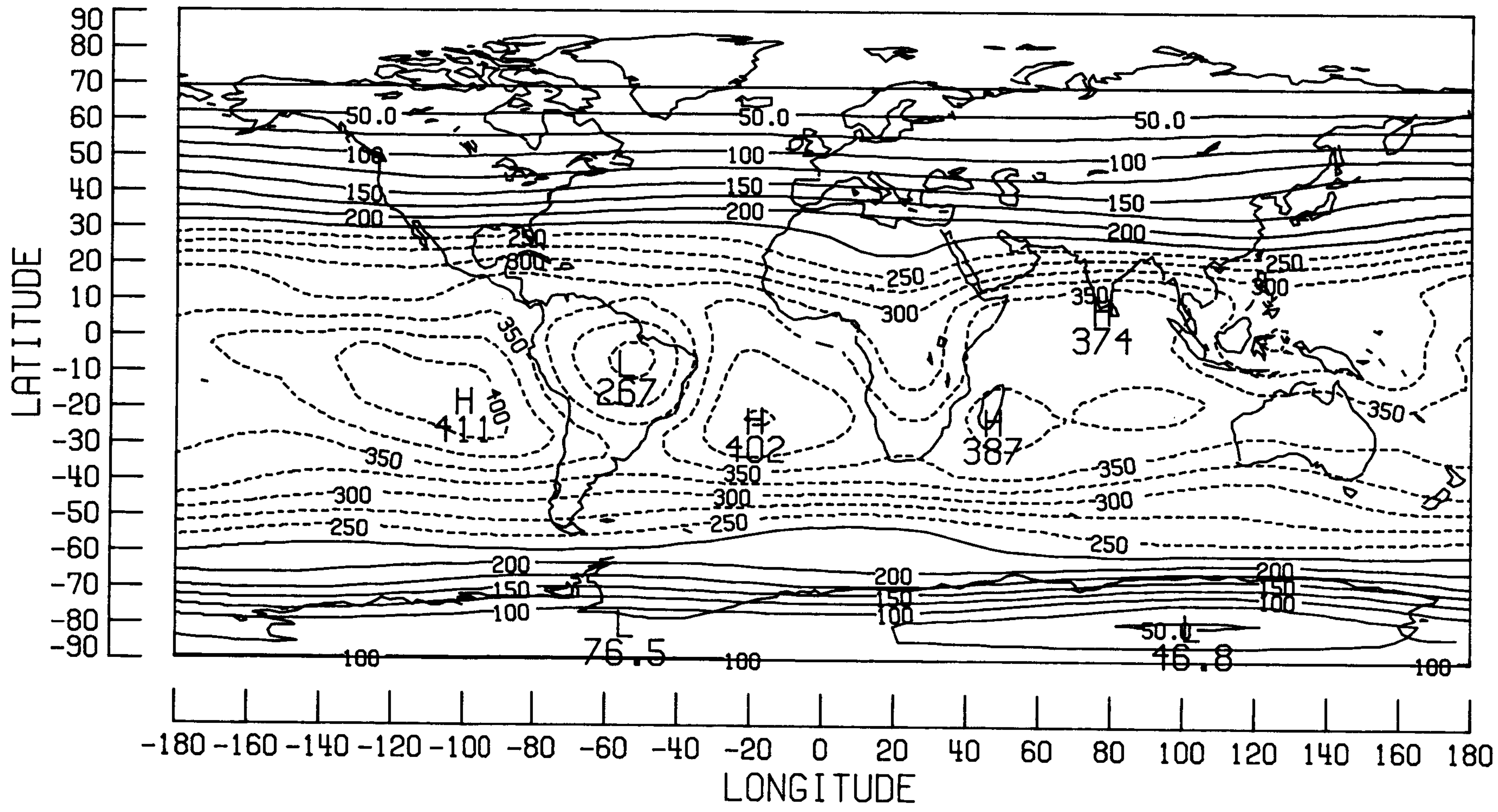


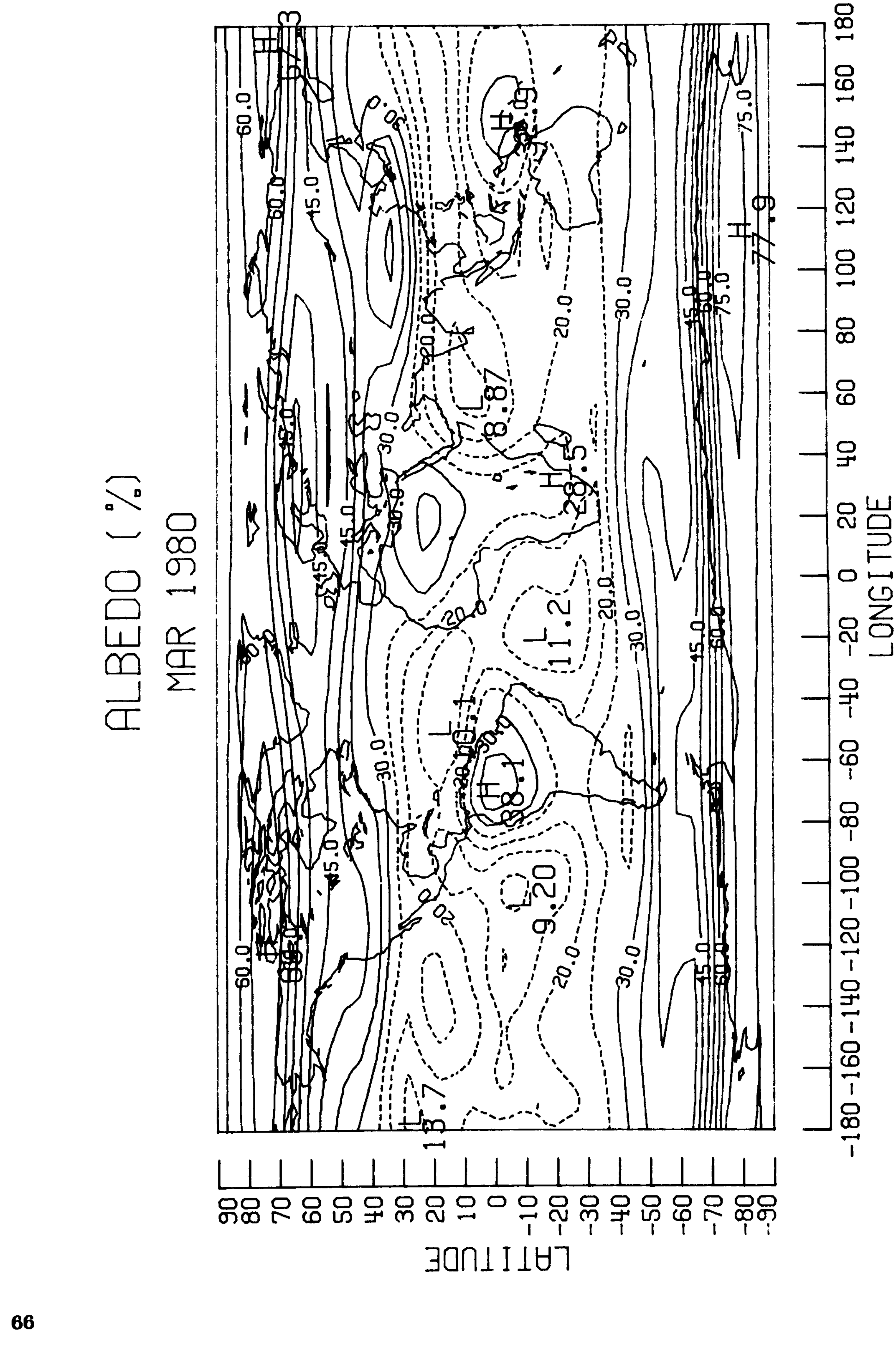


ALBEDO (%)
FEB 1980

ABSORPTION W/(M*M)

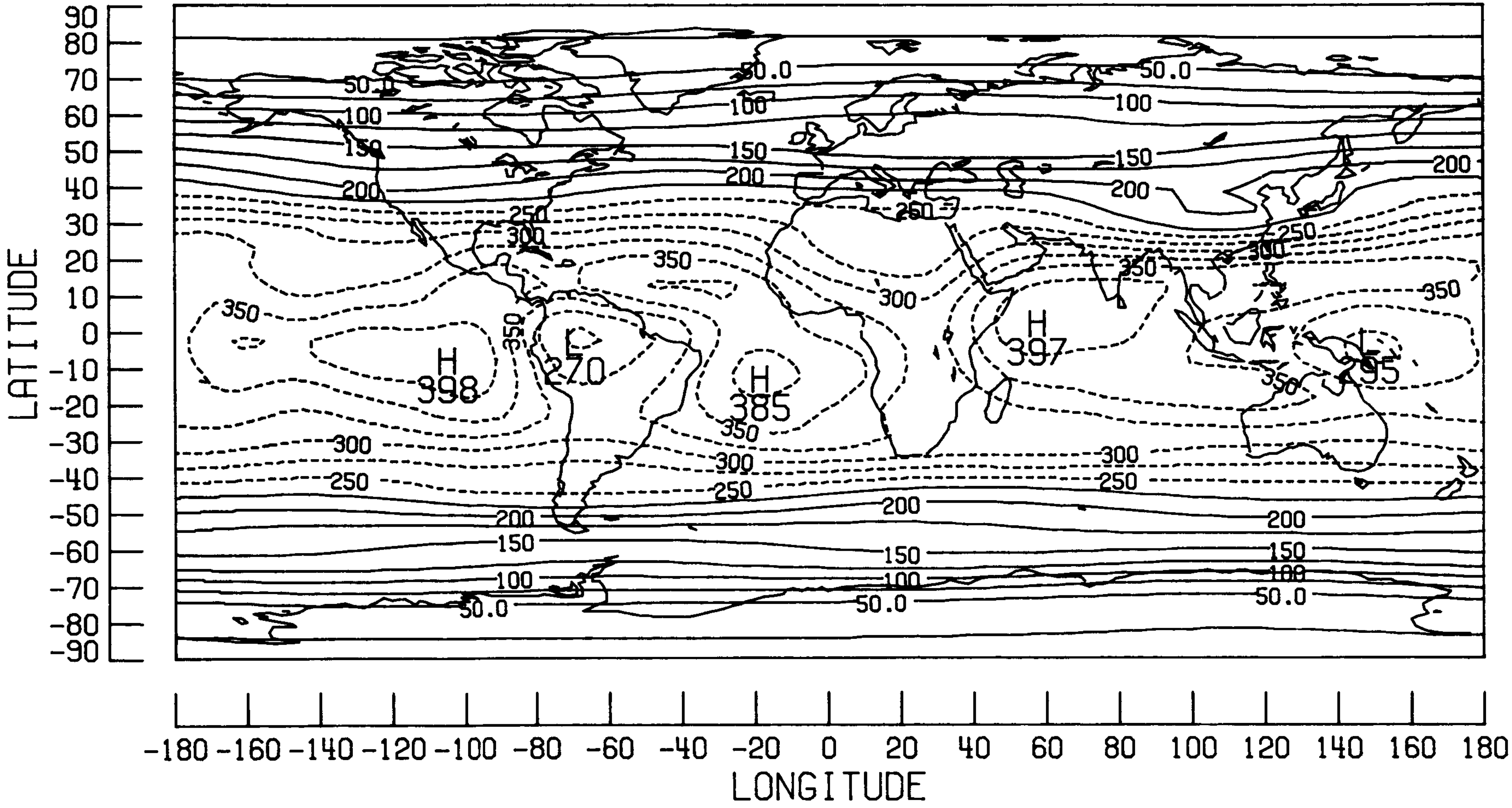
FEB 1980





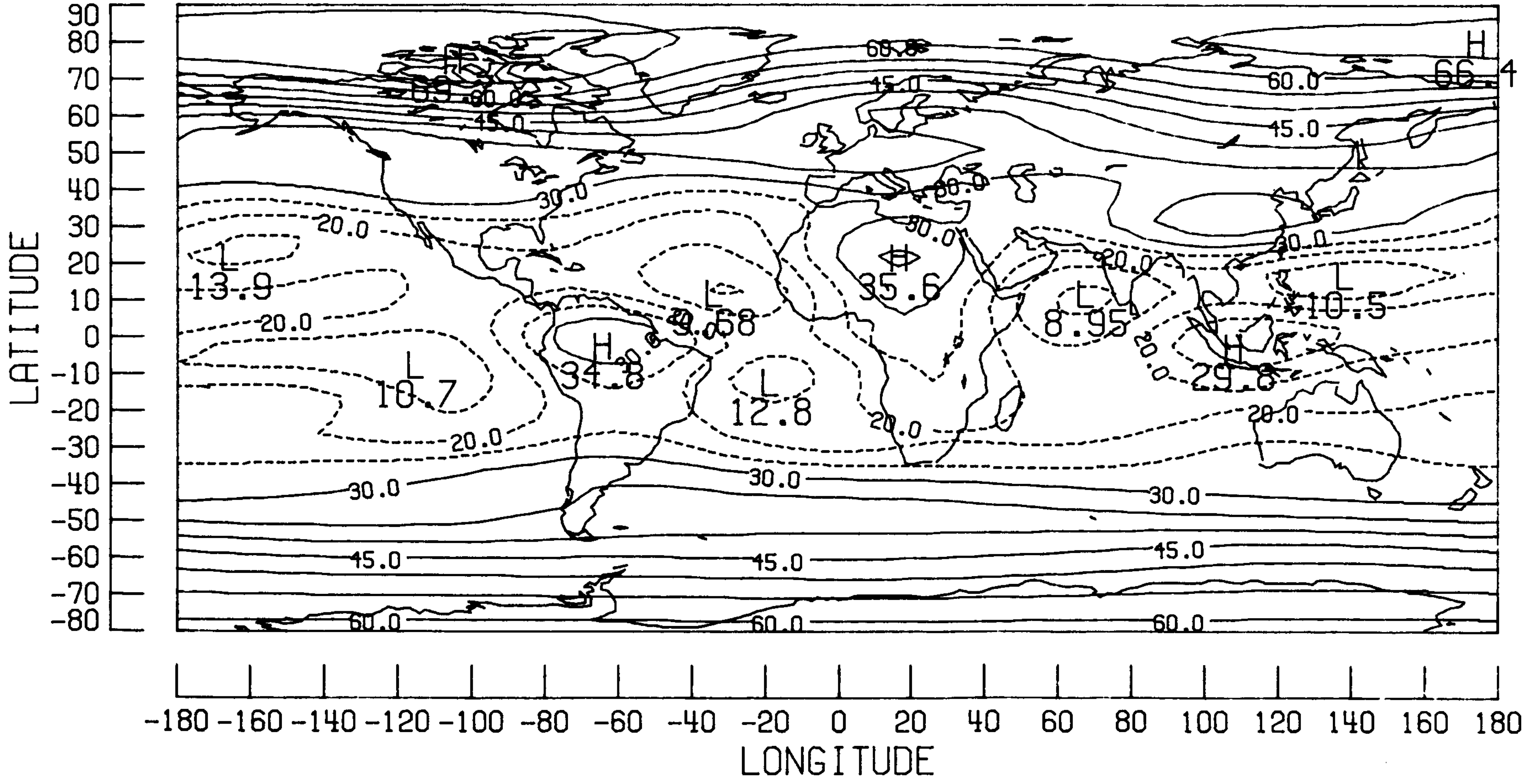
ALBEDO (%)

MAR 1980



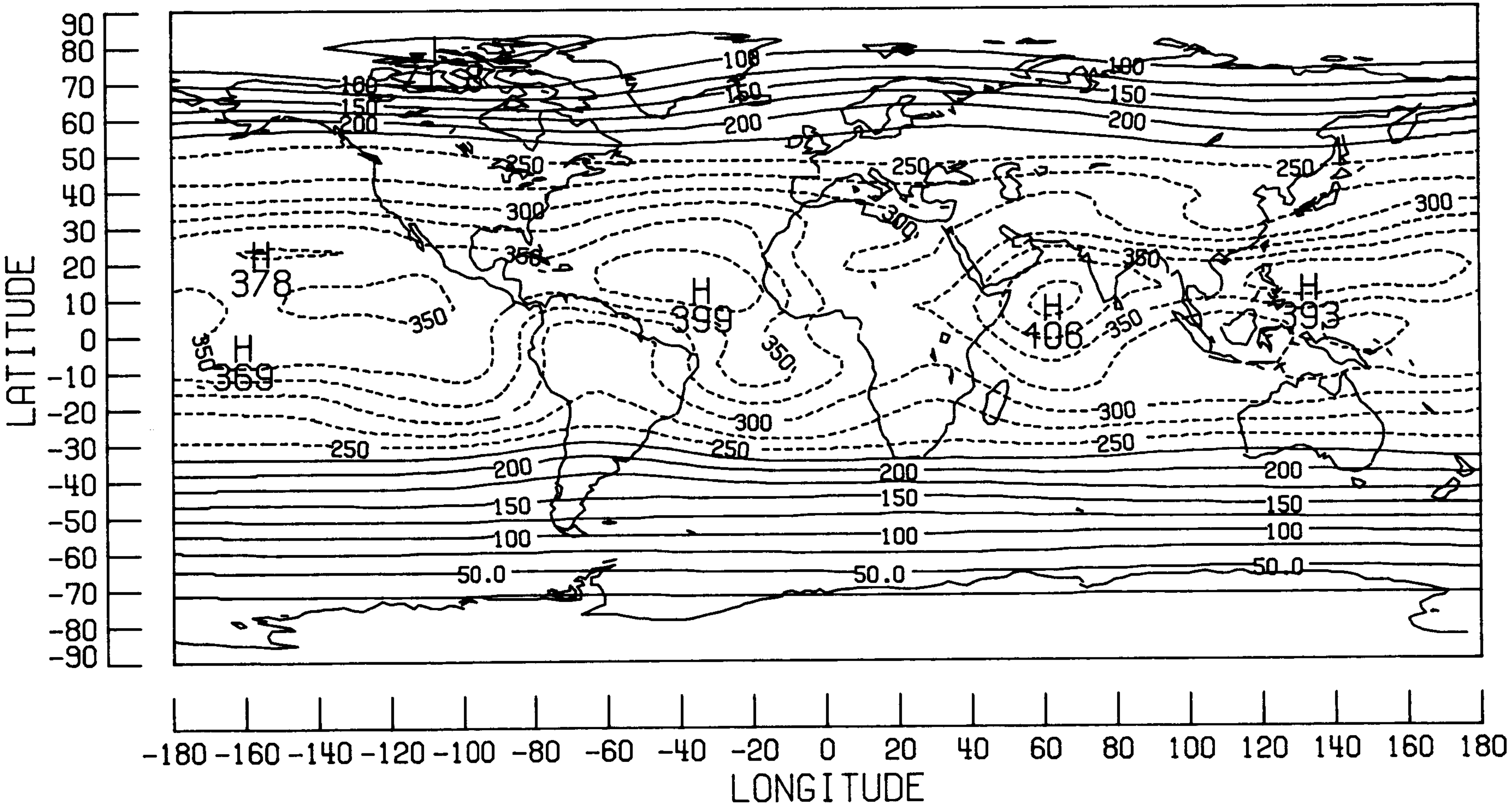
ABSORPTION W/(M*M)
MAR 1980

ALBEDO (%)
APR 1980

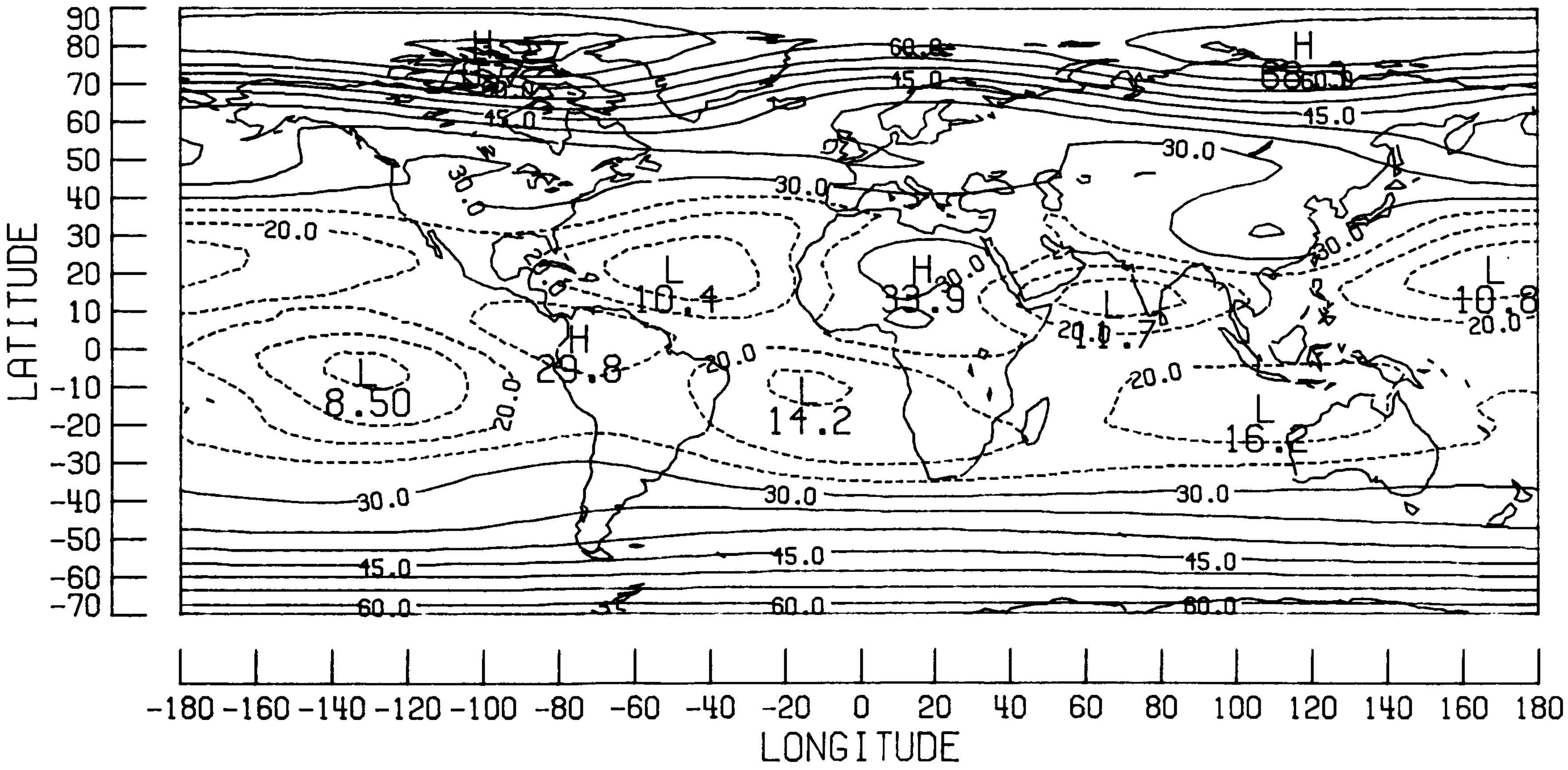


ABSORPTION W/(M*M)

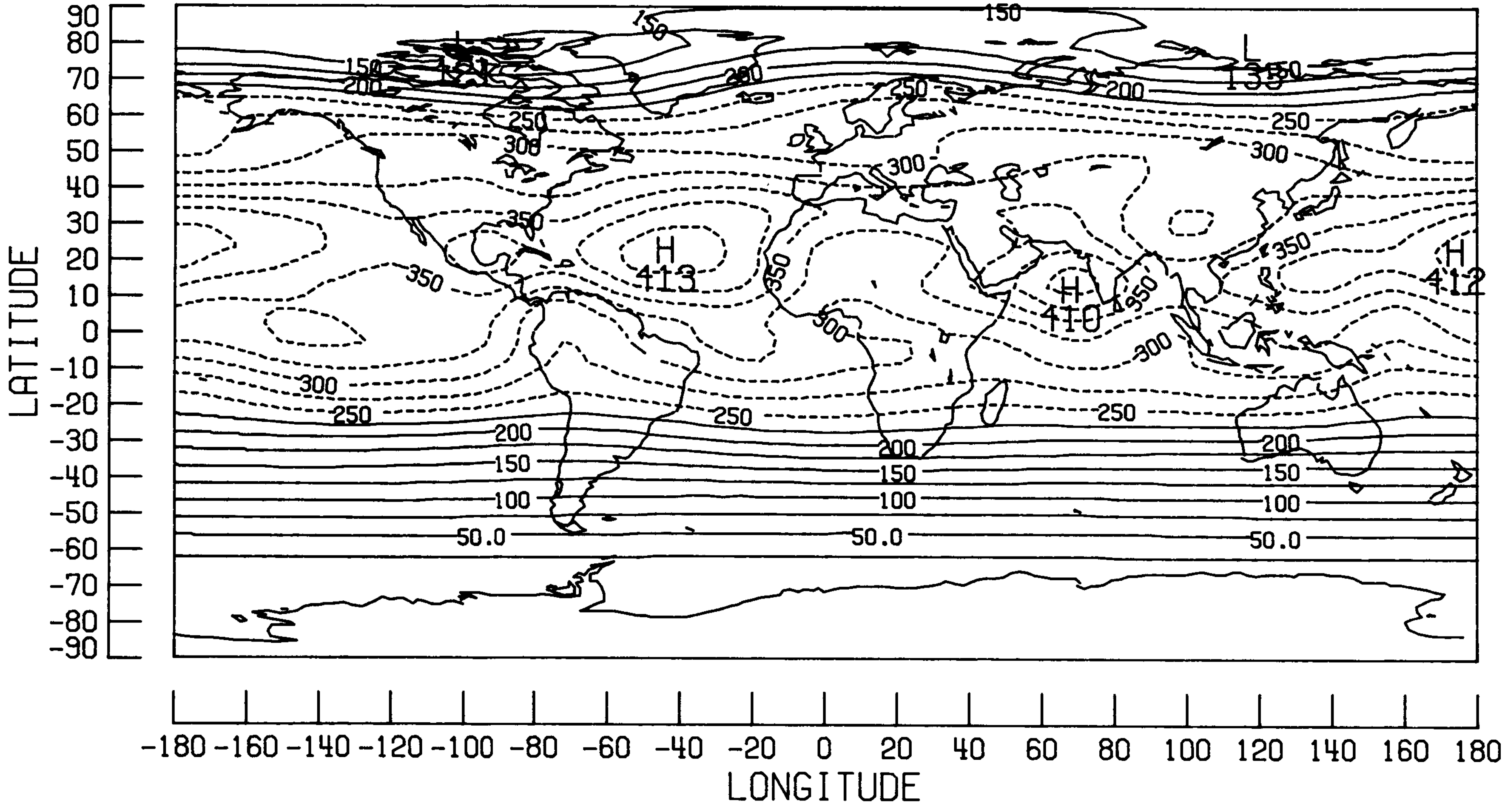
APR 1980

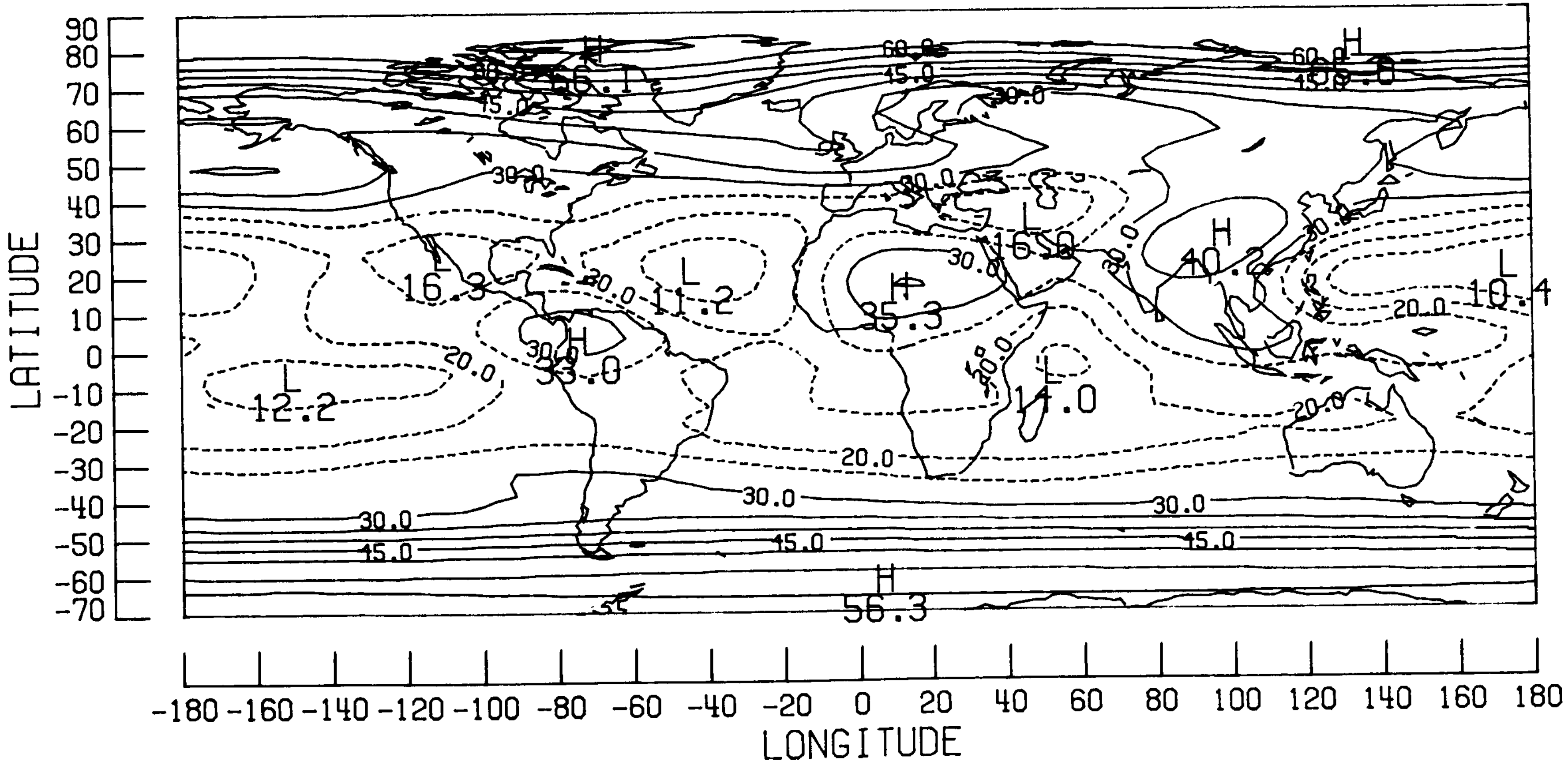


ALBEDO (%)
MAY 1980



ABSORPTION W/(M*M)
MAY 1980

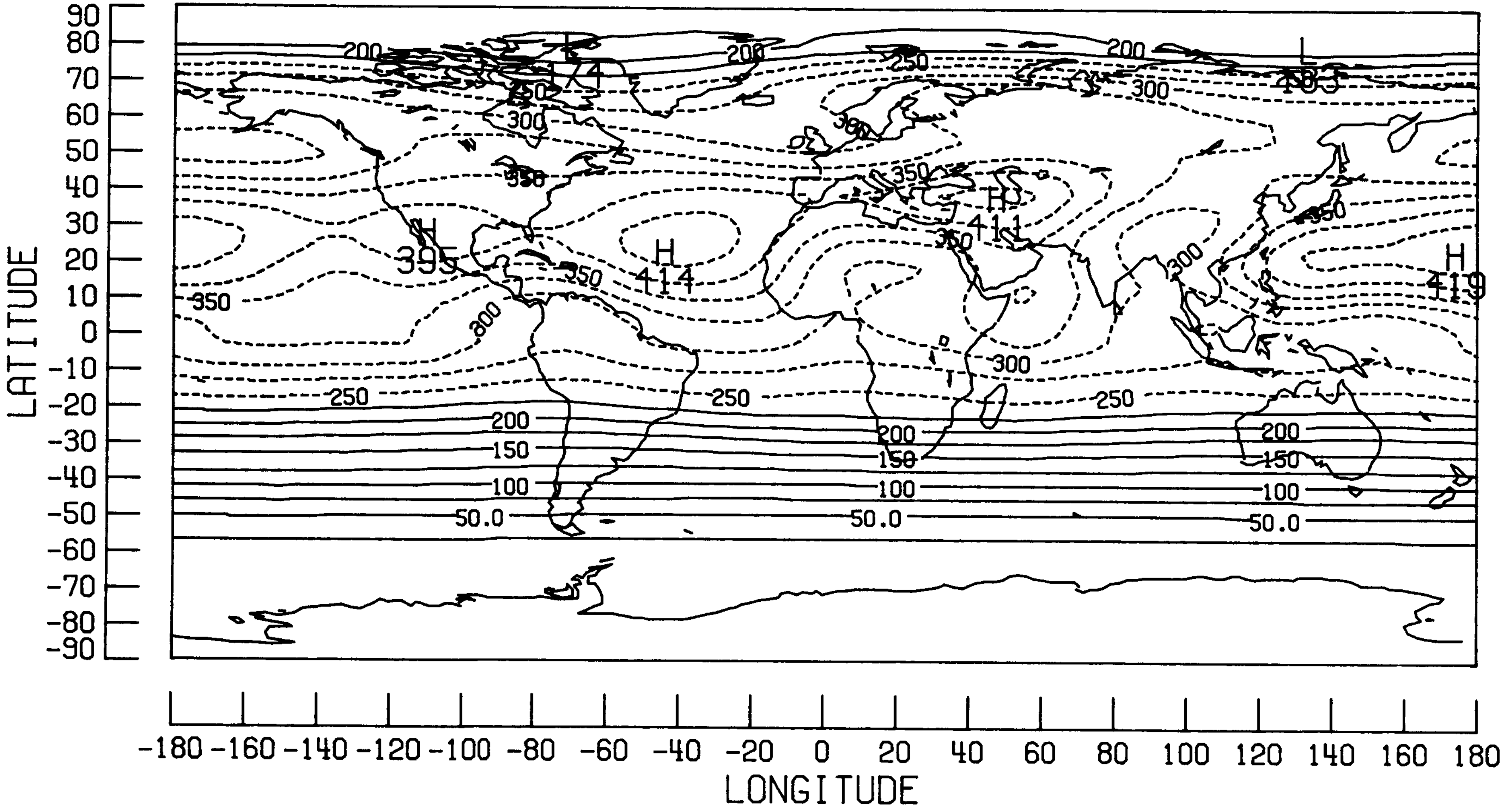


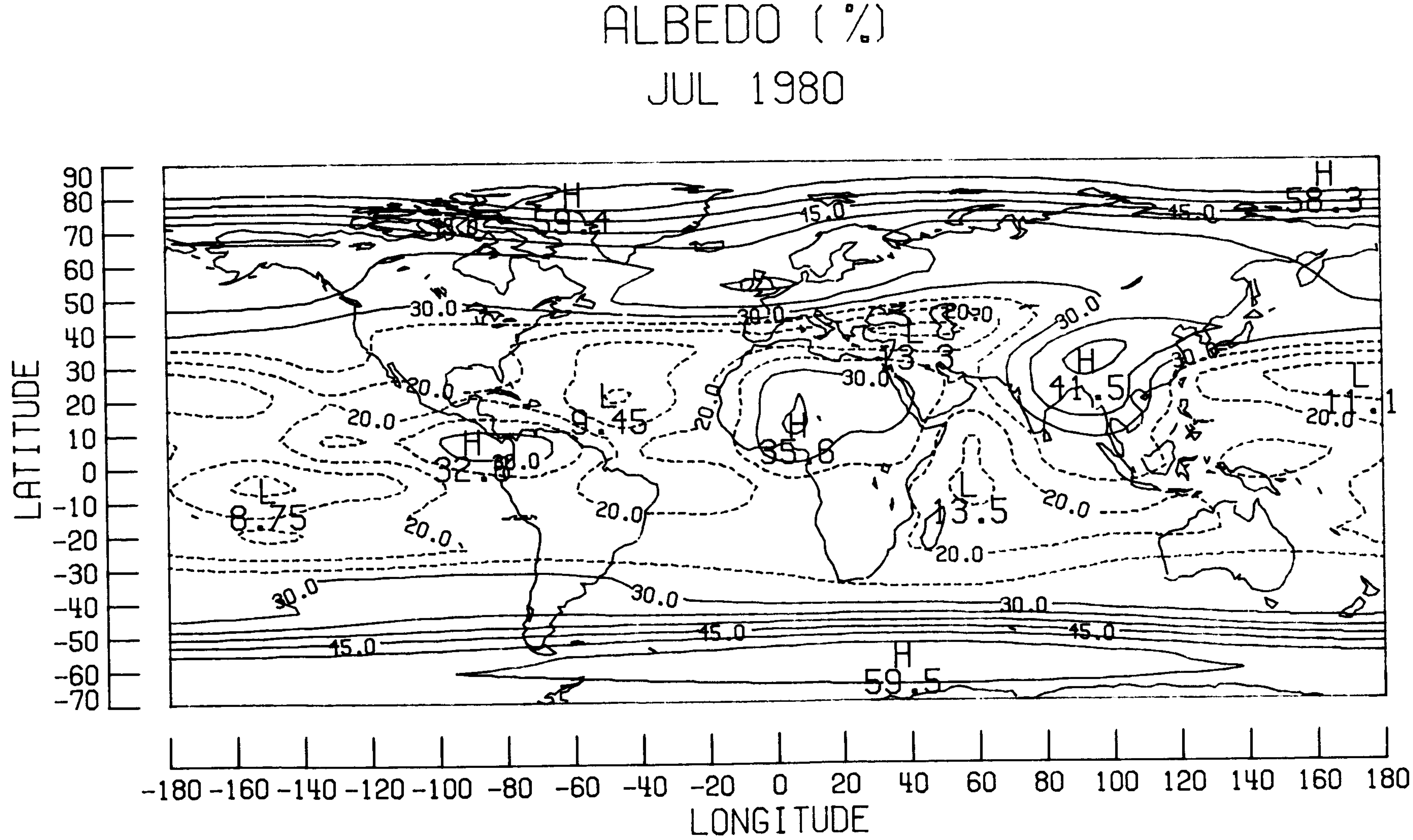


ALBEDO (%)
JUN 1980

ABSORPTION W/(M*M)

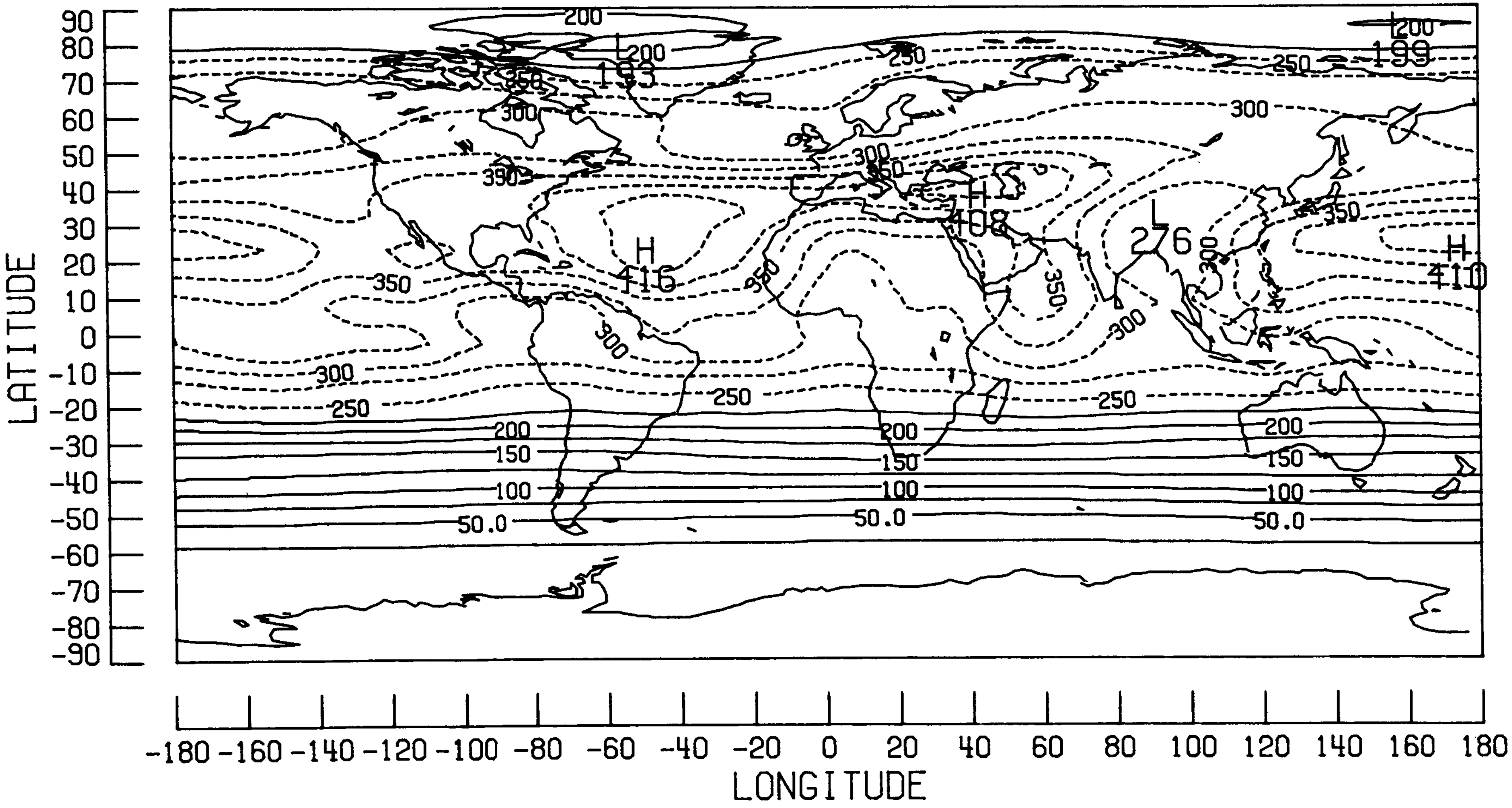
JUN 1980



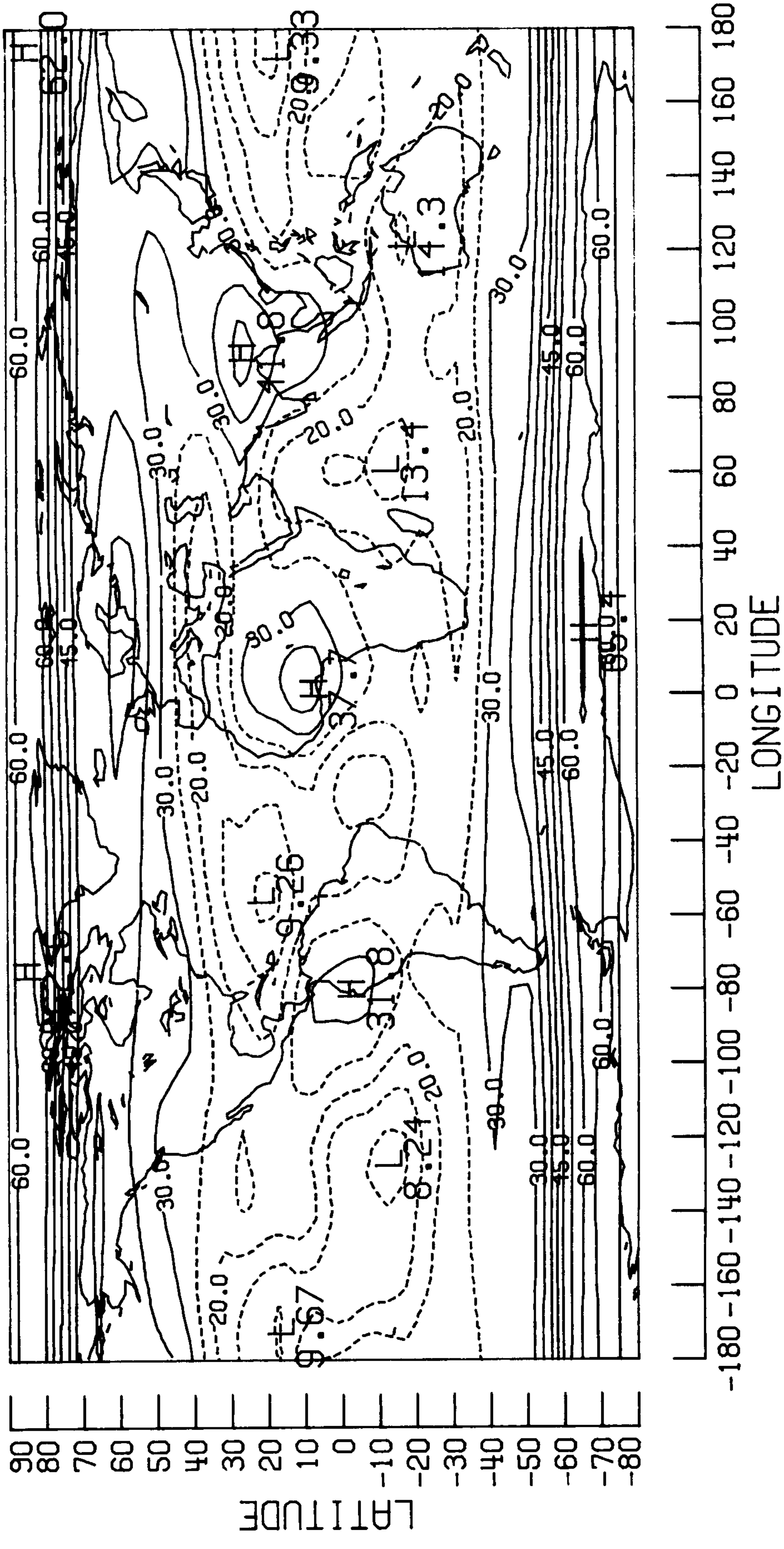

ALBEDO (%)
JUL 1980
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
H
59.4
H
58.3
H
41.5
H
35.8
H
32.8
H
59.5
L
13.3
L
11.1
L
9.45
L
8.75
L
13.5
15.0
45.0
30.0
20.0

ABSORPTION W/(M*M)

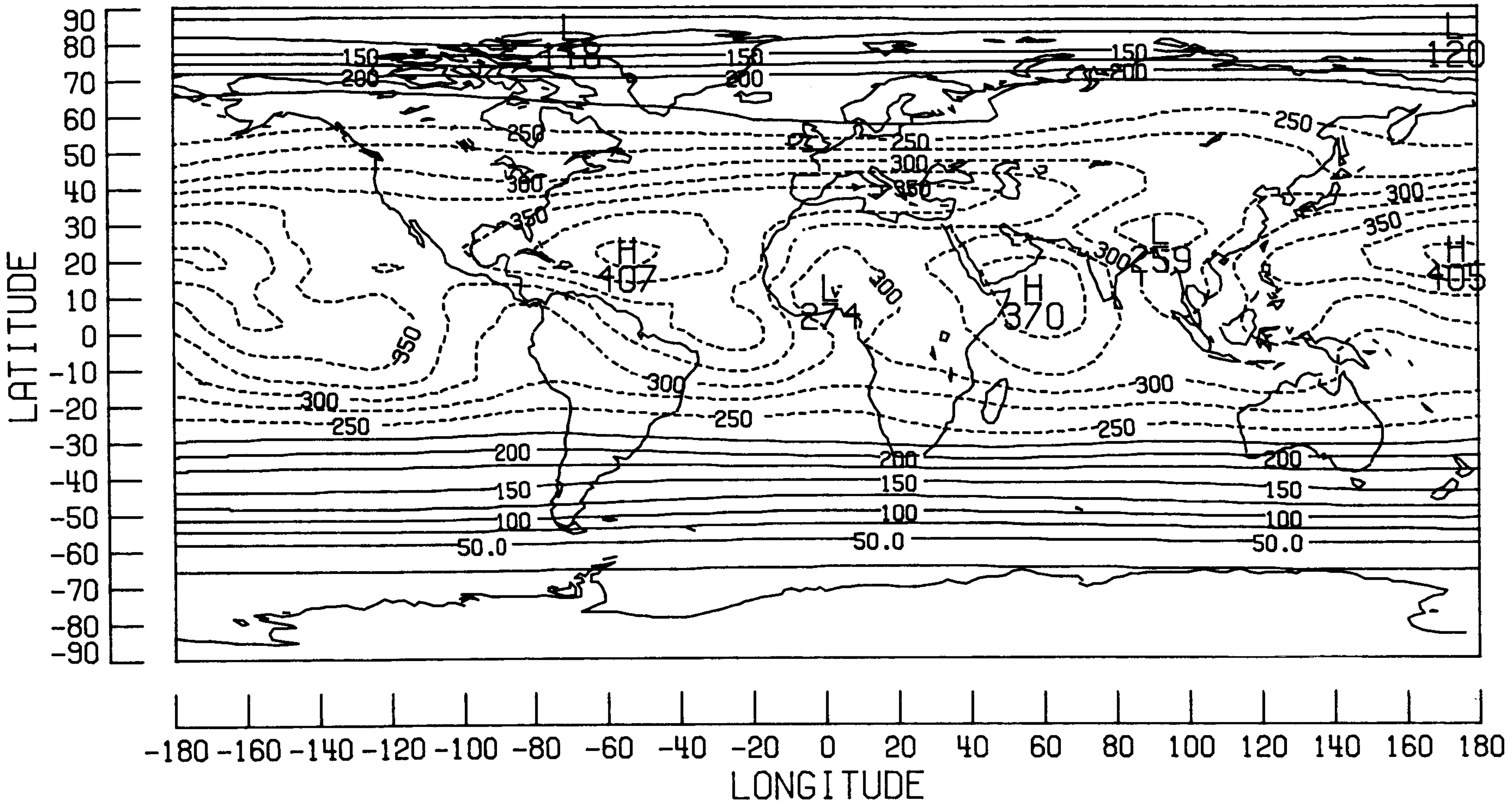
JUL 1980



ALBEDO (%)
AUG 1980

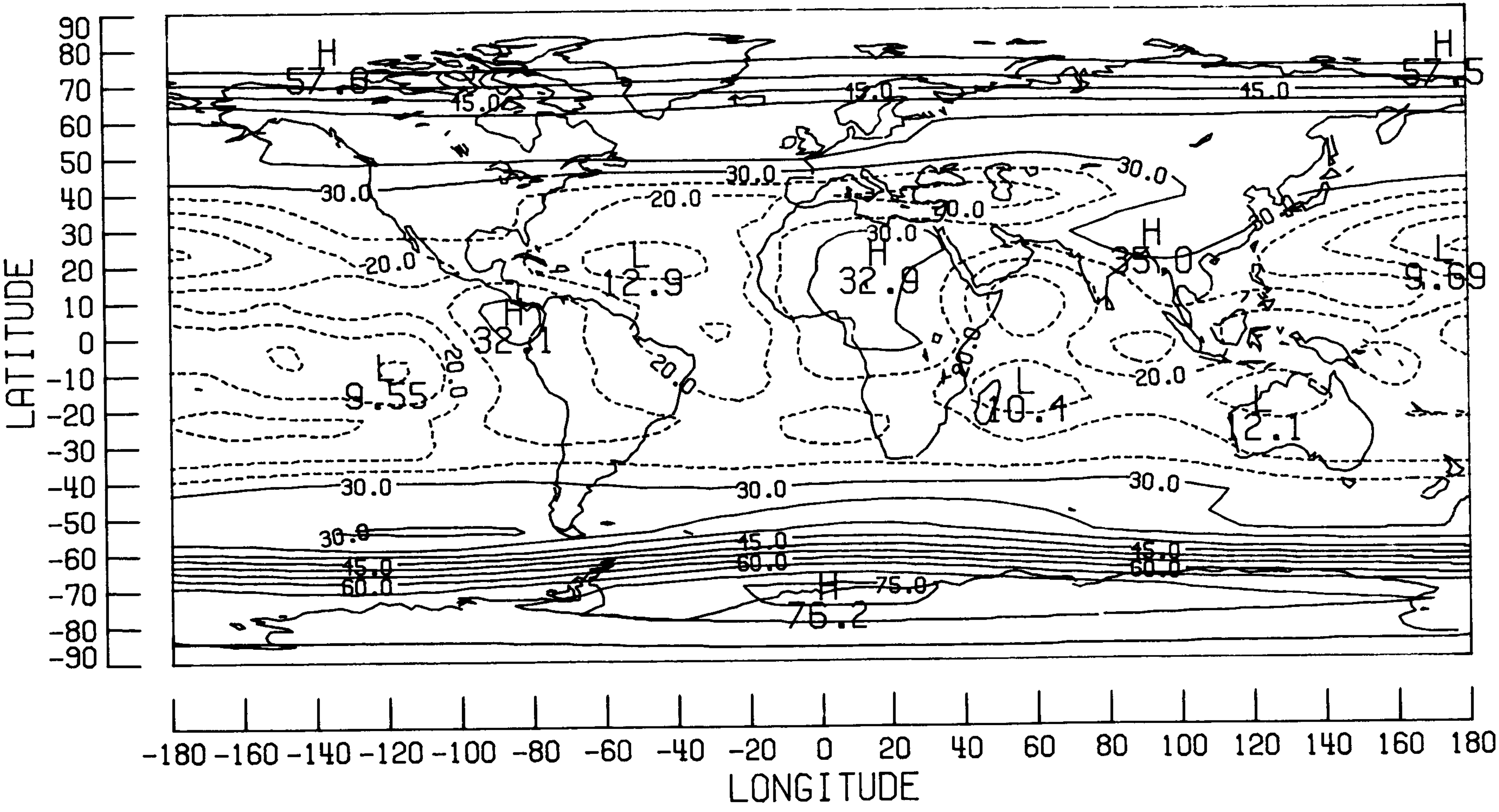


ABSORPTION W/(M*M)
AUG 1980



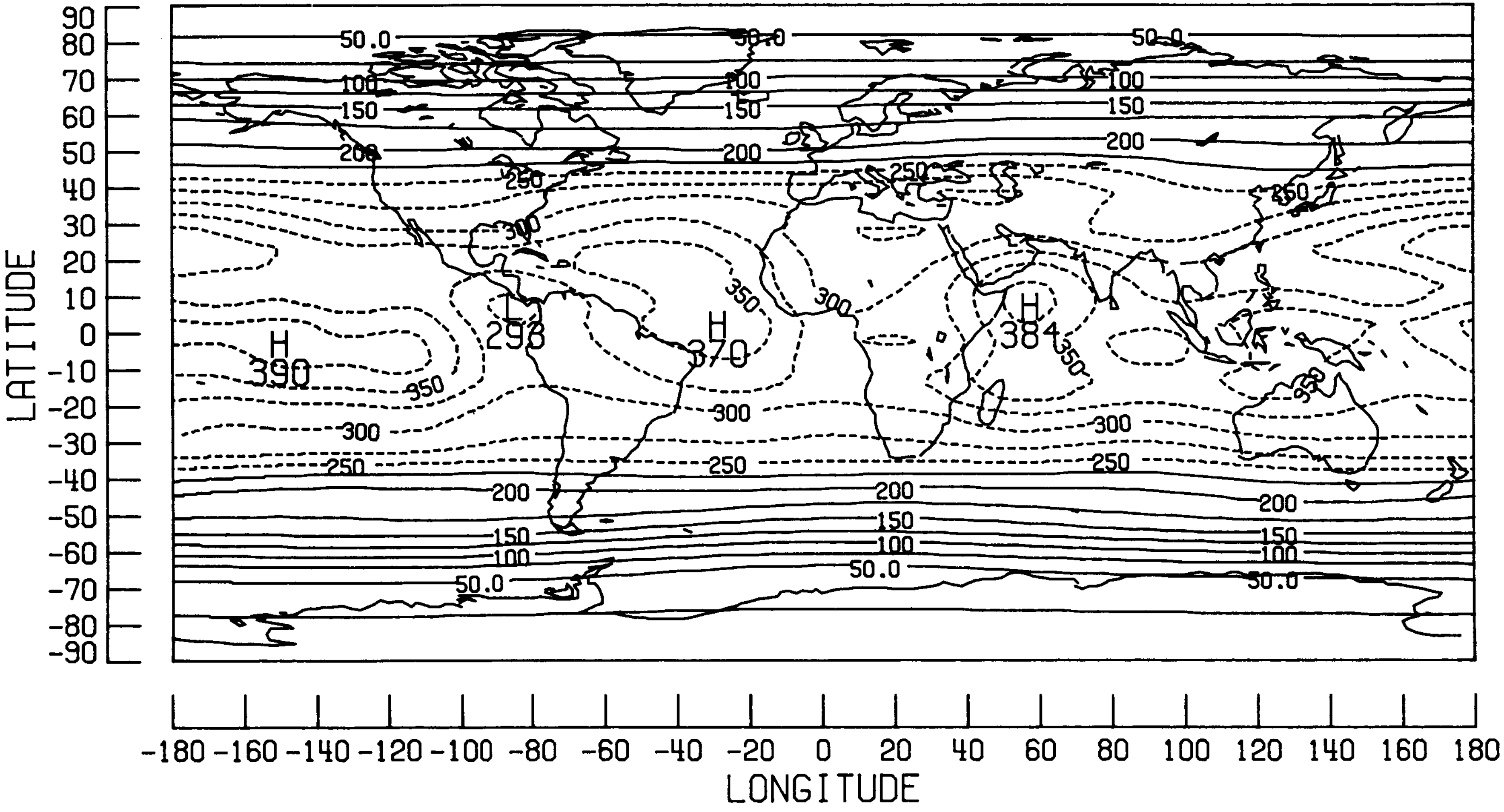
ALBEDO (%)

SEP 1980

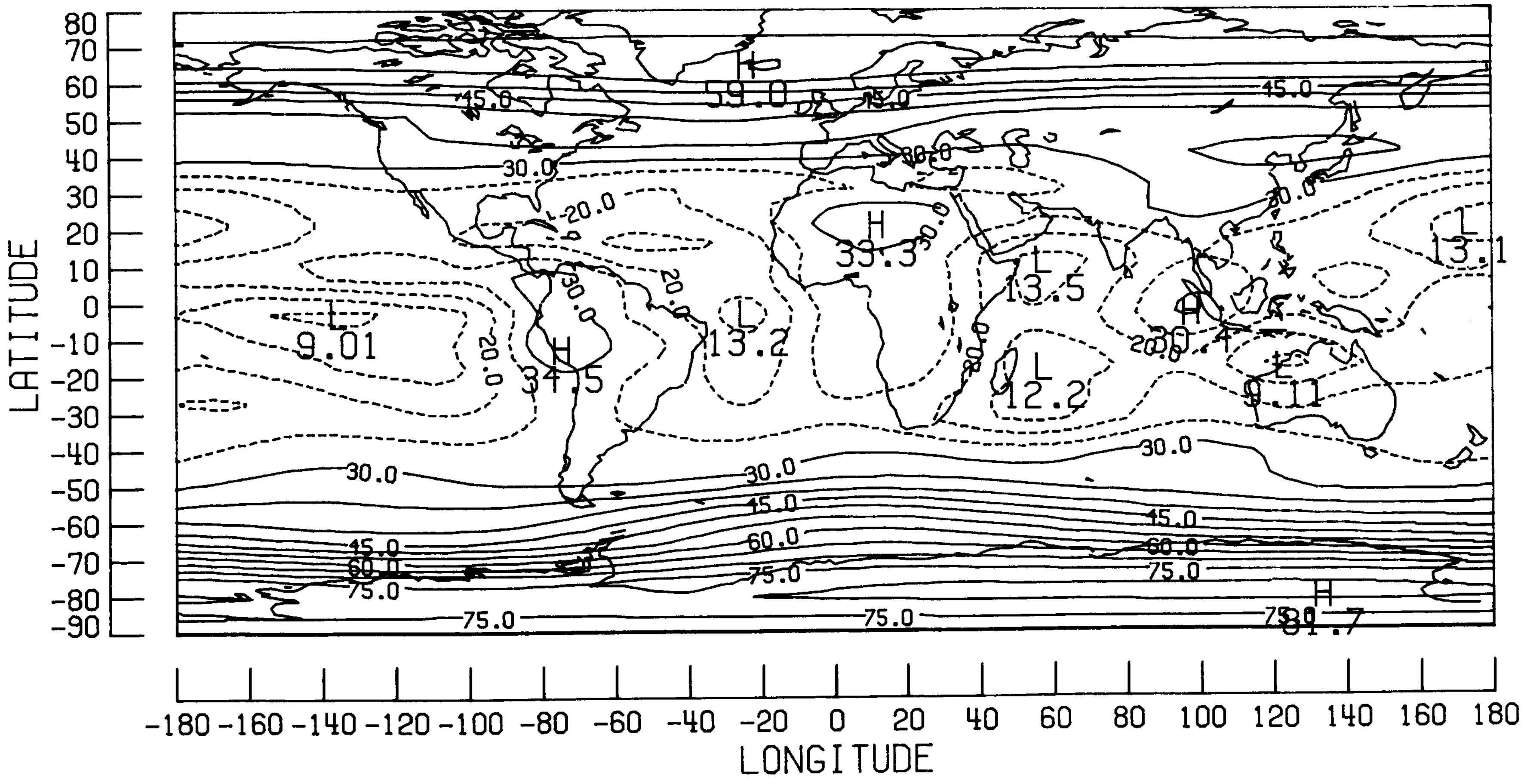


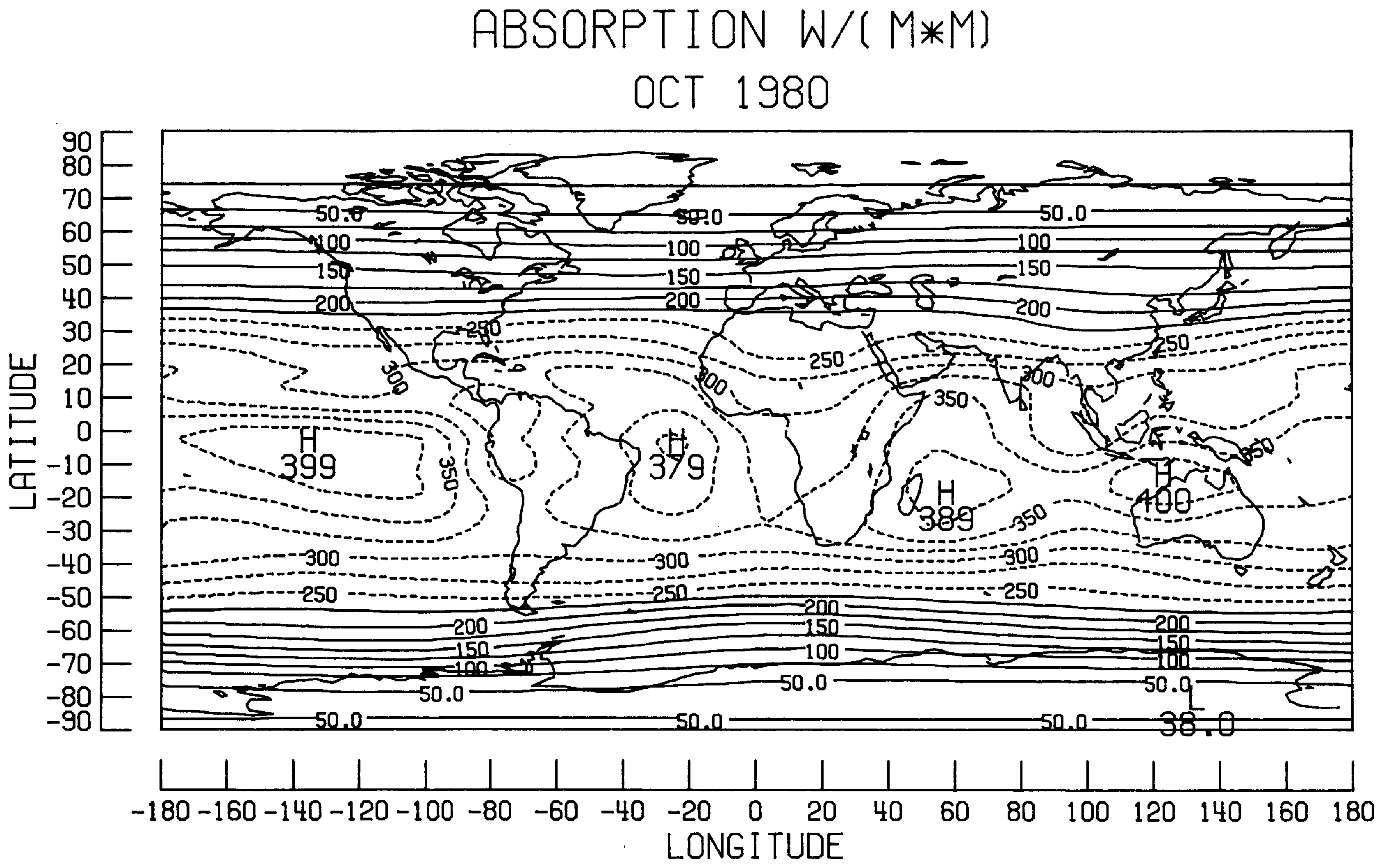
ABSORPTION W/(M*M)

SEP 1980



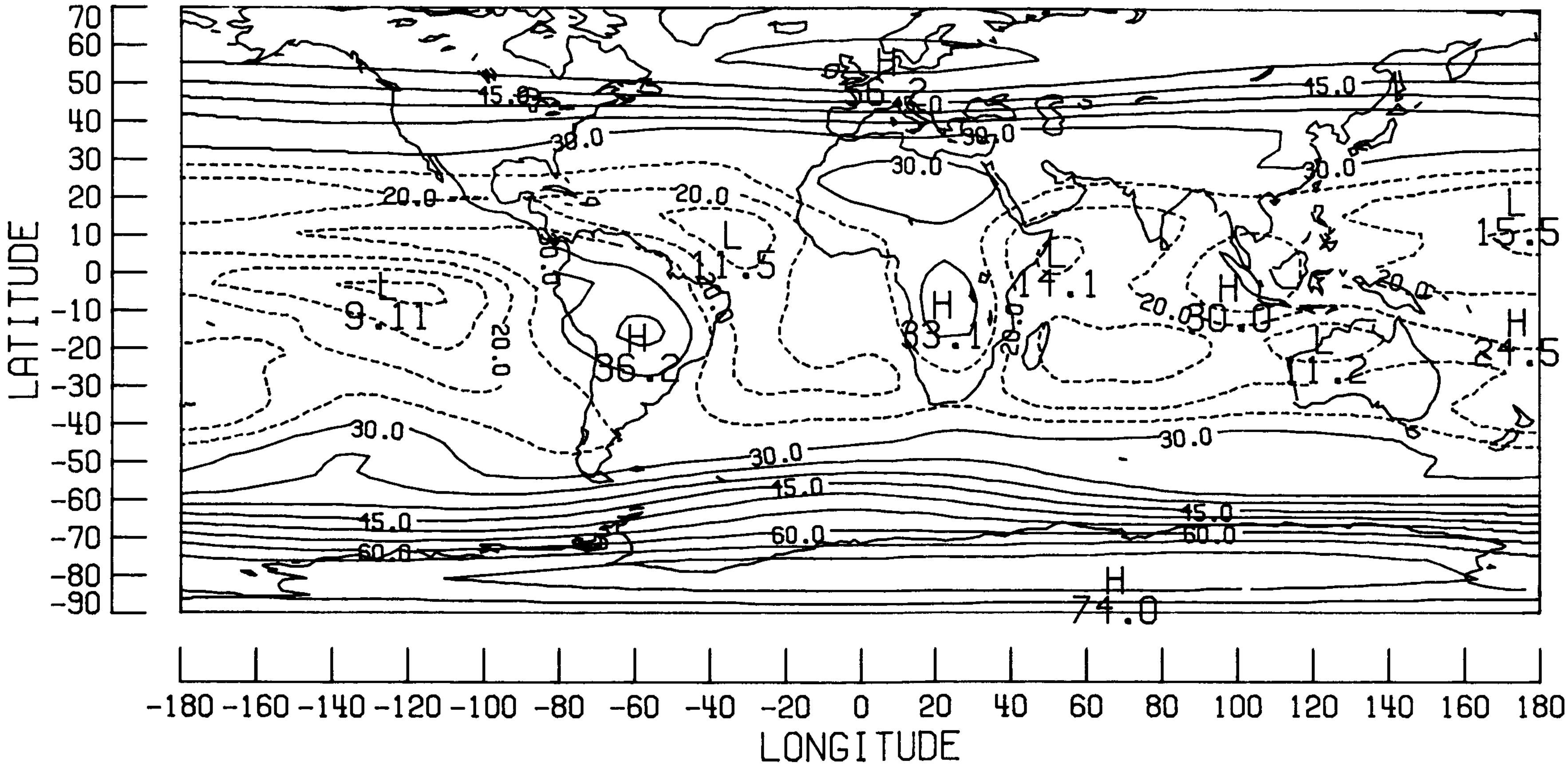
ALBEDO (%)
OCT 1980



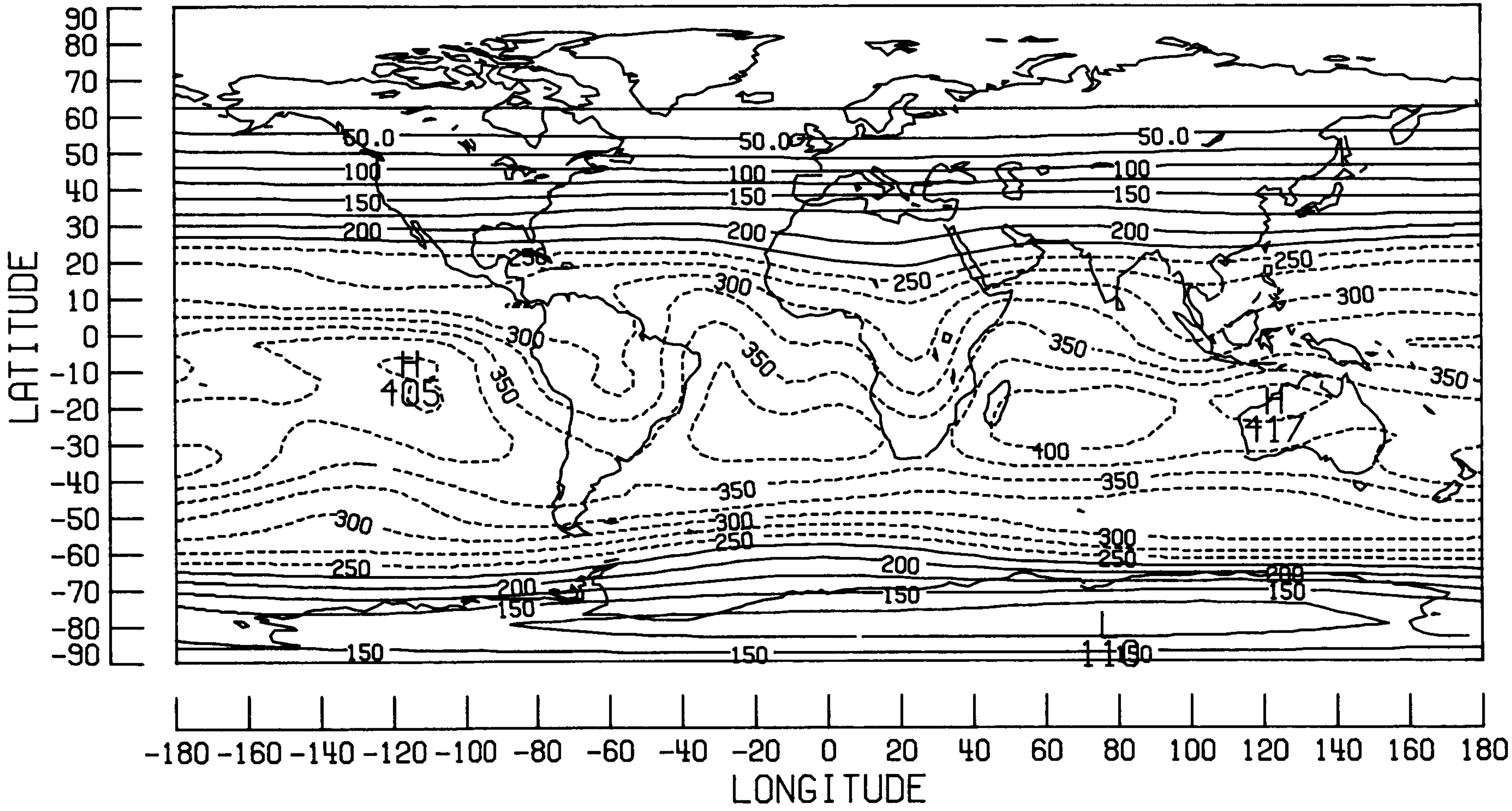
ABSORPTION W/(M*M)
OCT 1980
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
50.0
100
150
200
250
300
350
H
399
H
379
H
389
H
400
L
38.0

ALBEDO (%)

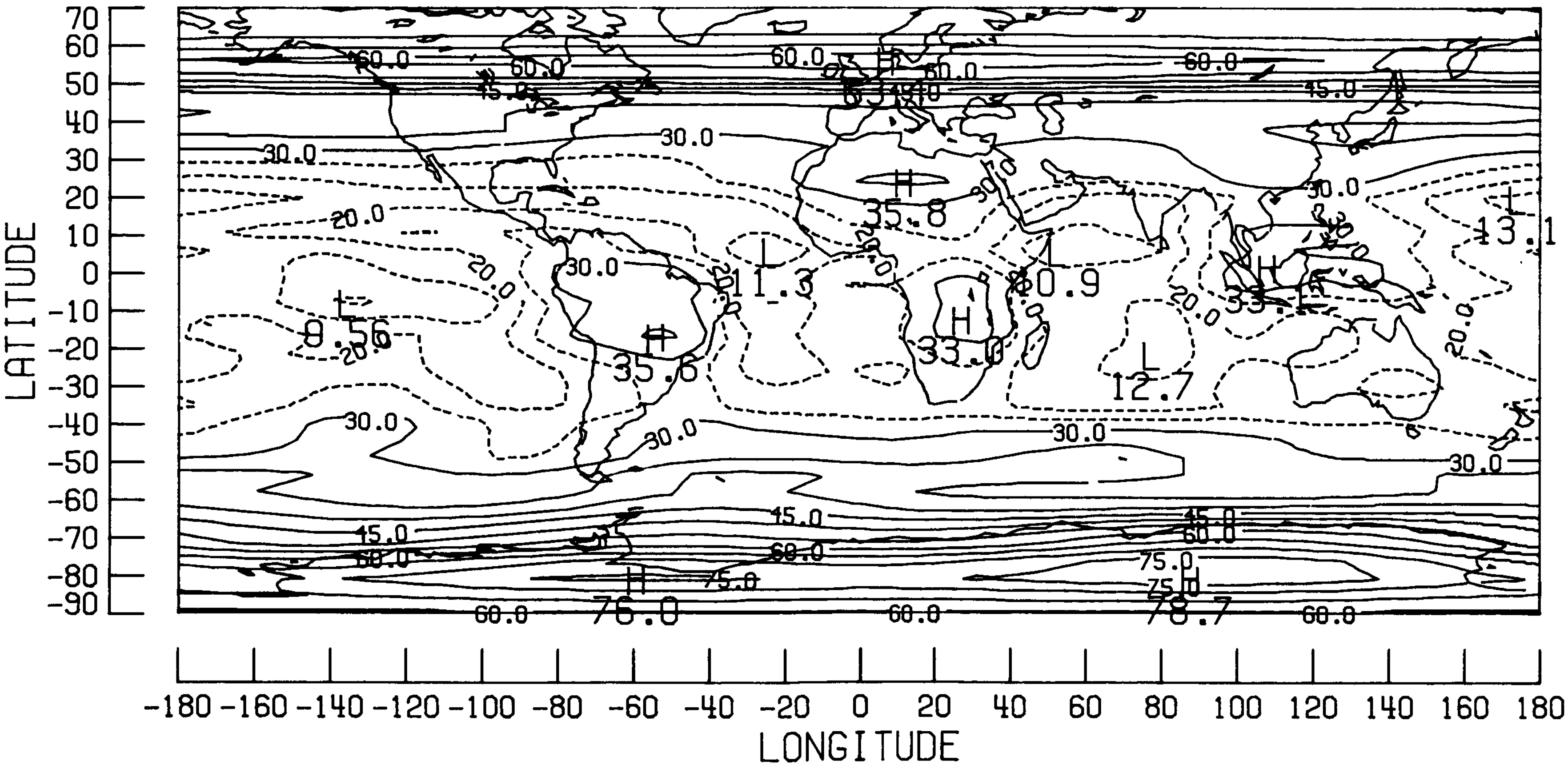
NOV 1980

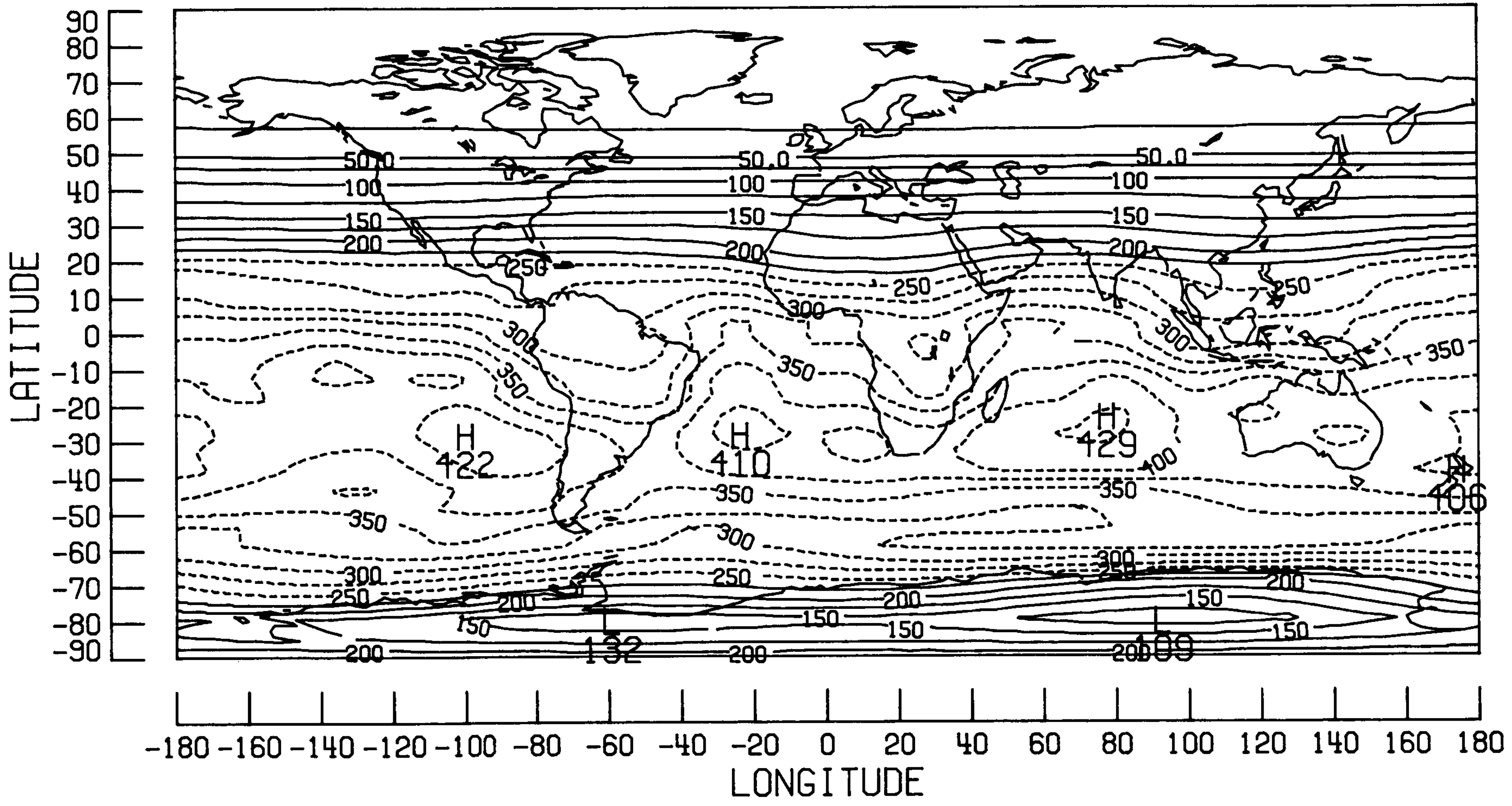


ABSORPTION W/(M*M)
NOV 1980



ALBEDO (%)
DEC 1980

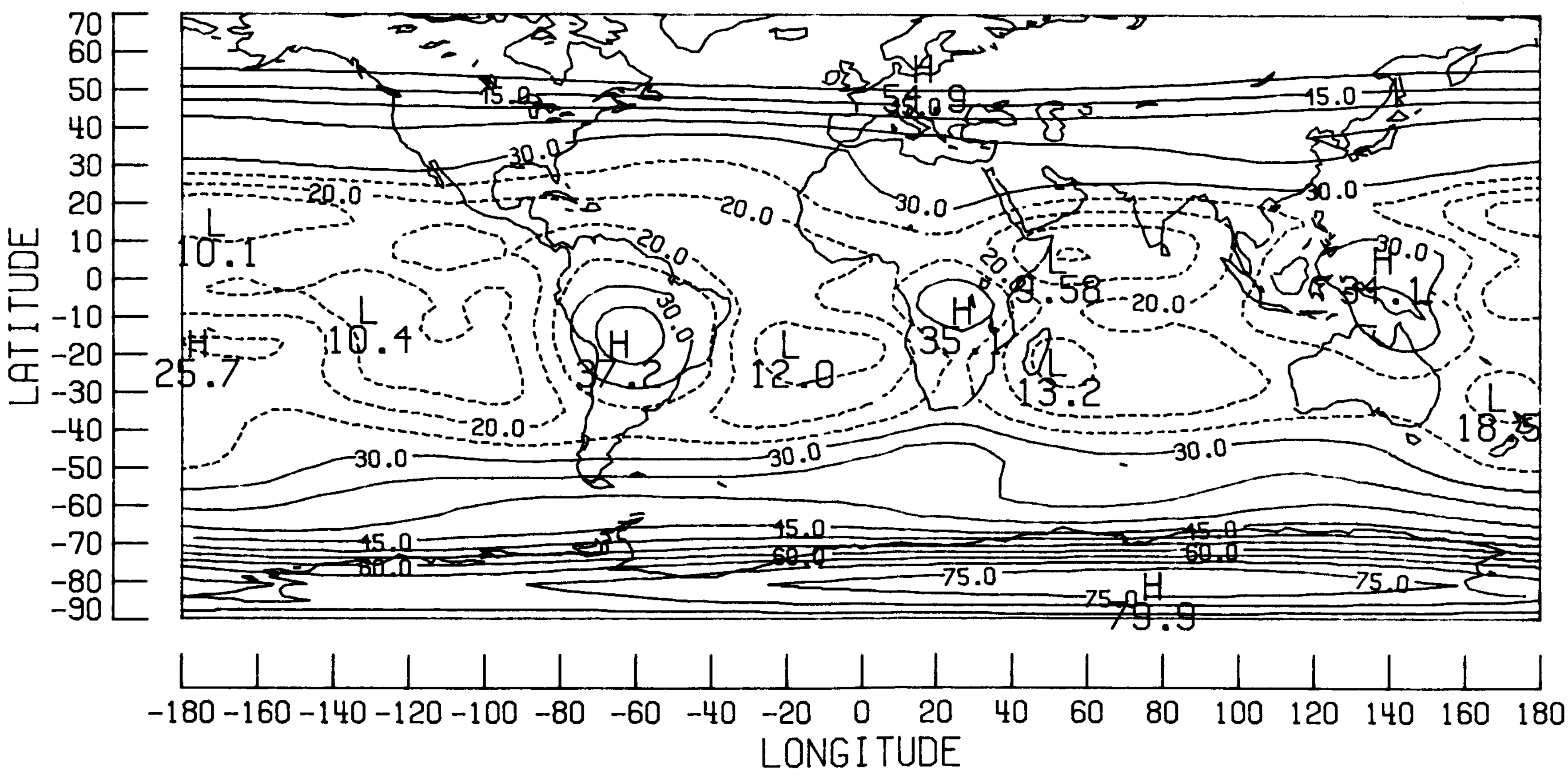




ABSORPTION W/(M*M)

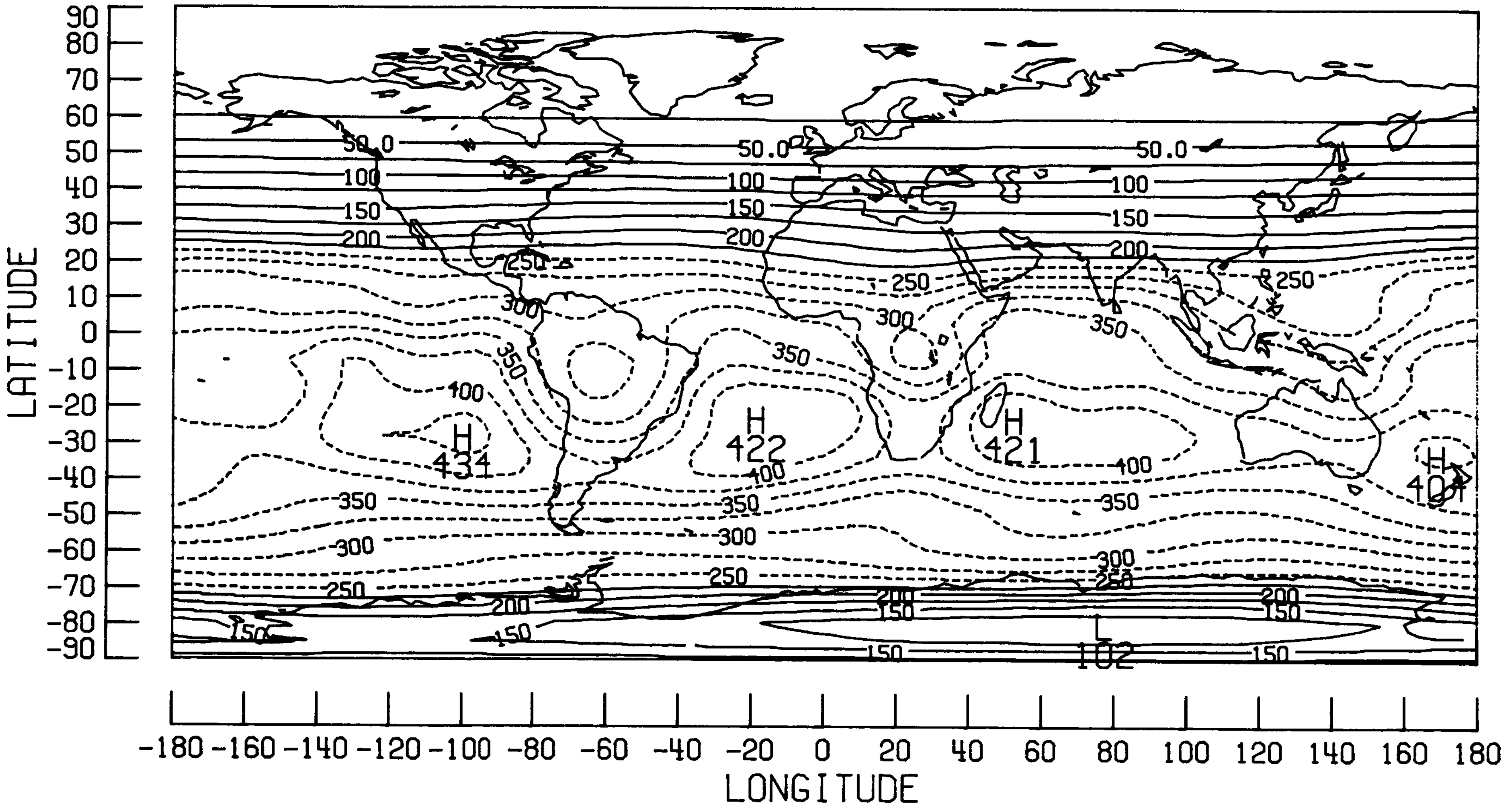
DEC 1980

ALBEDO (%)
JAN 1981

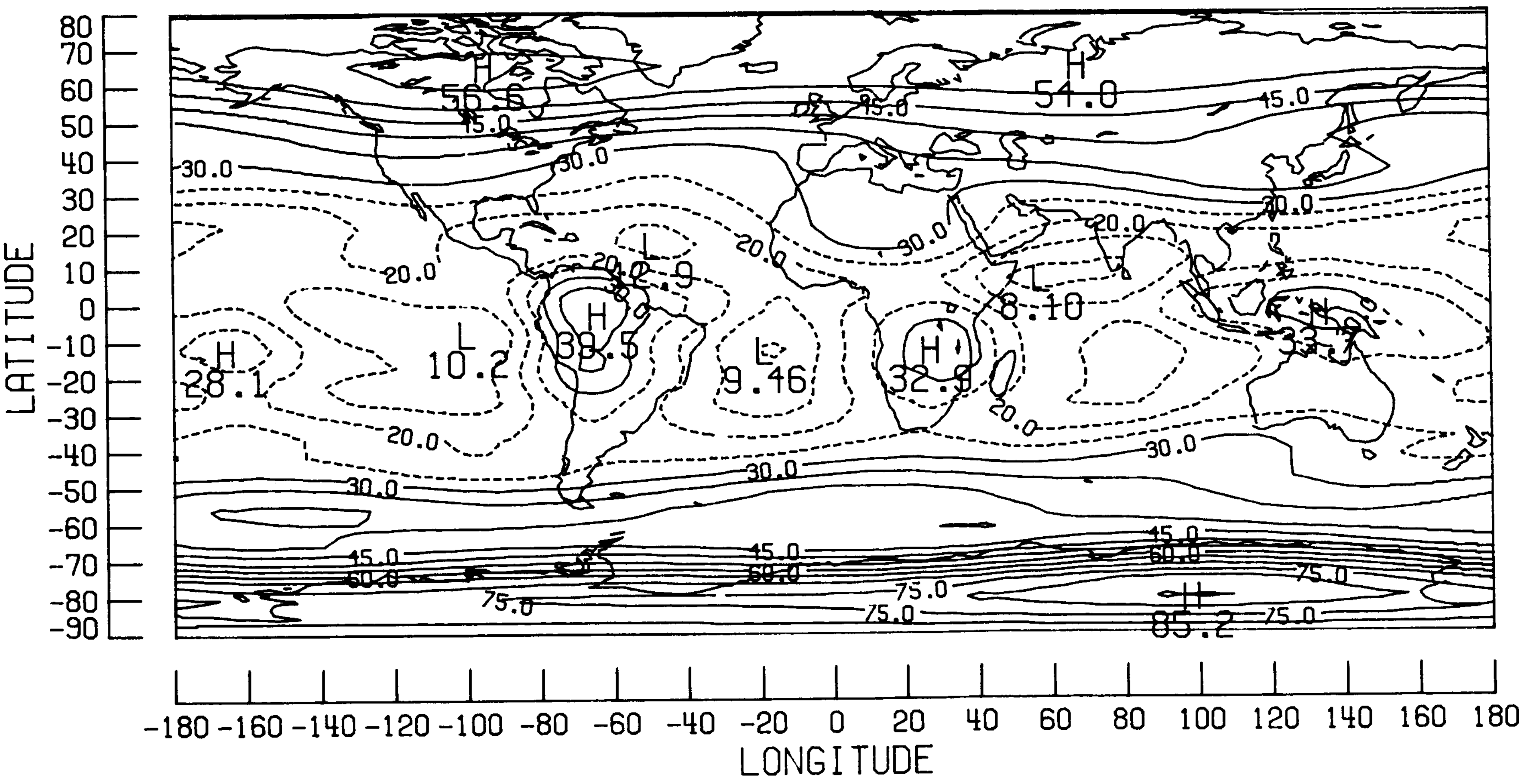


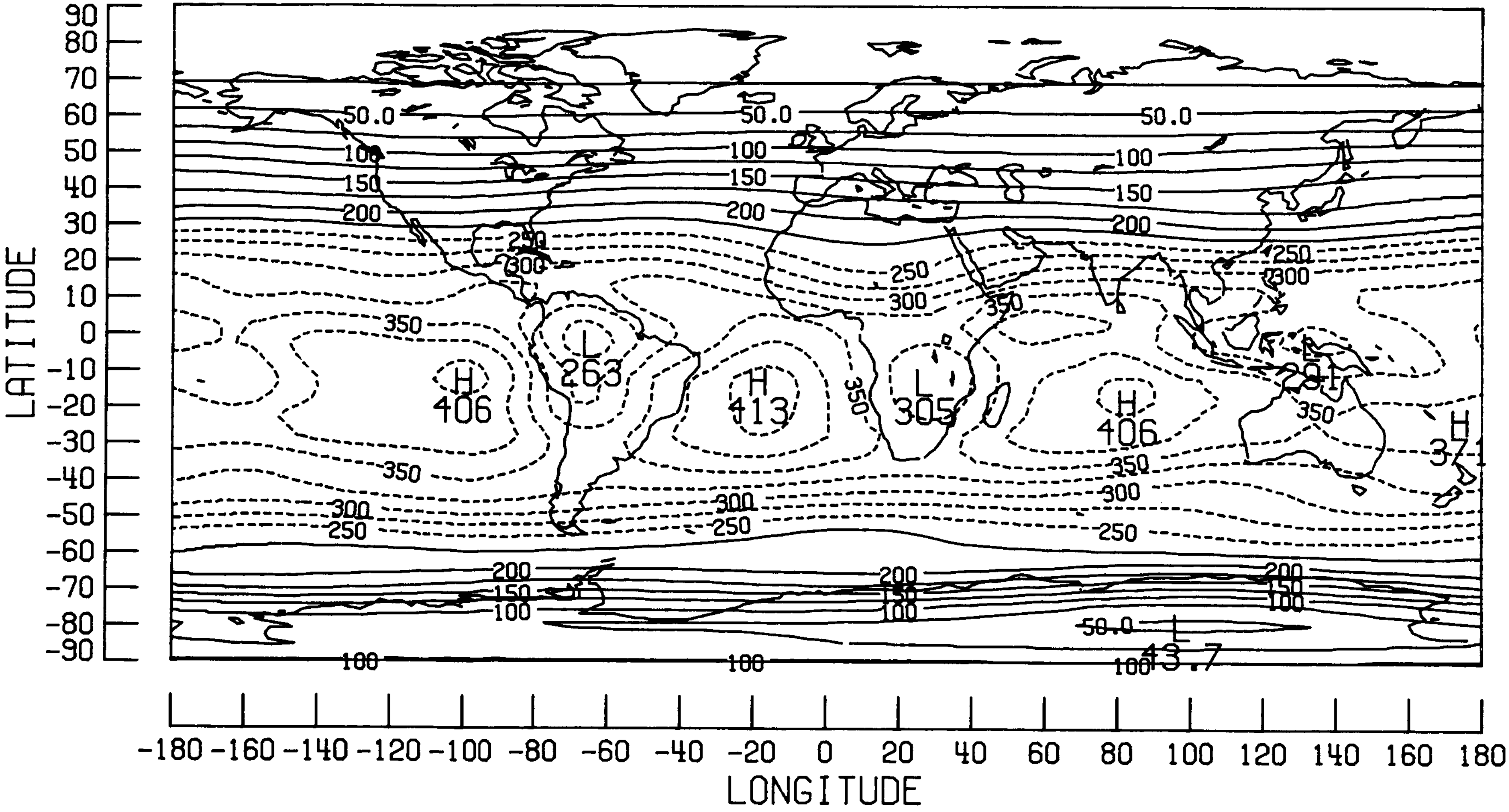
ABSORPTION W/(M*M)

JAN 1981

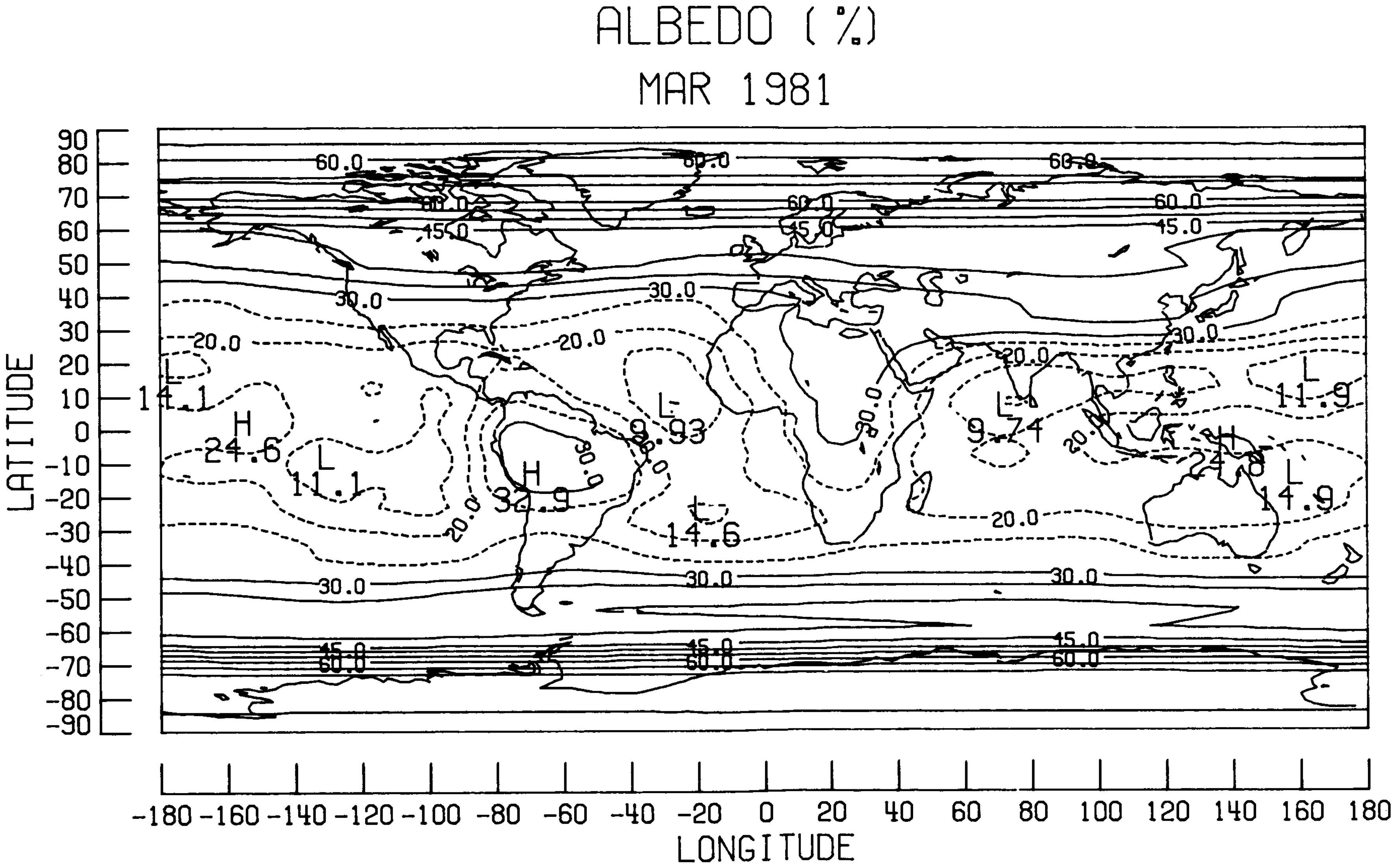


ALBEDO (%)
FEB 1981



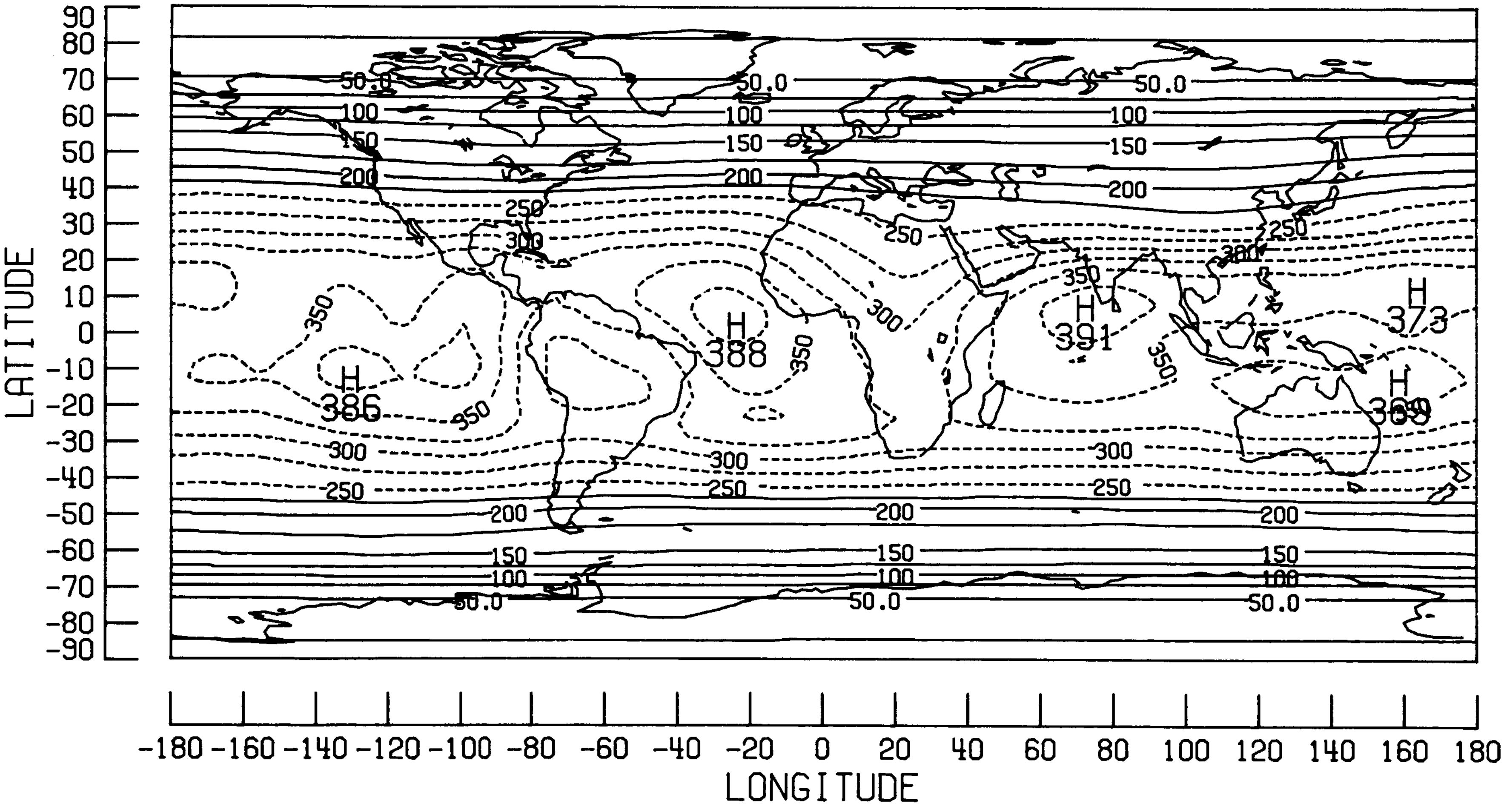


ABSORPTION W/(M*M)
FEB 1981

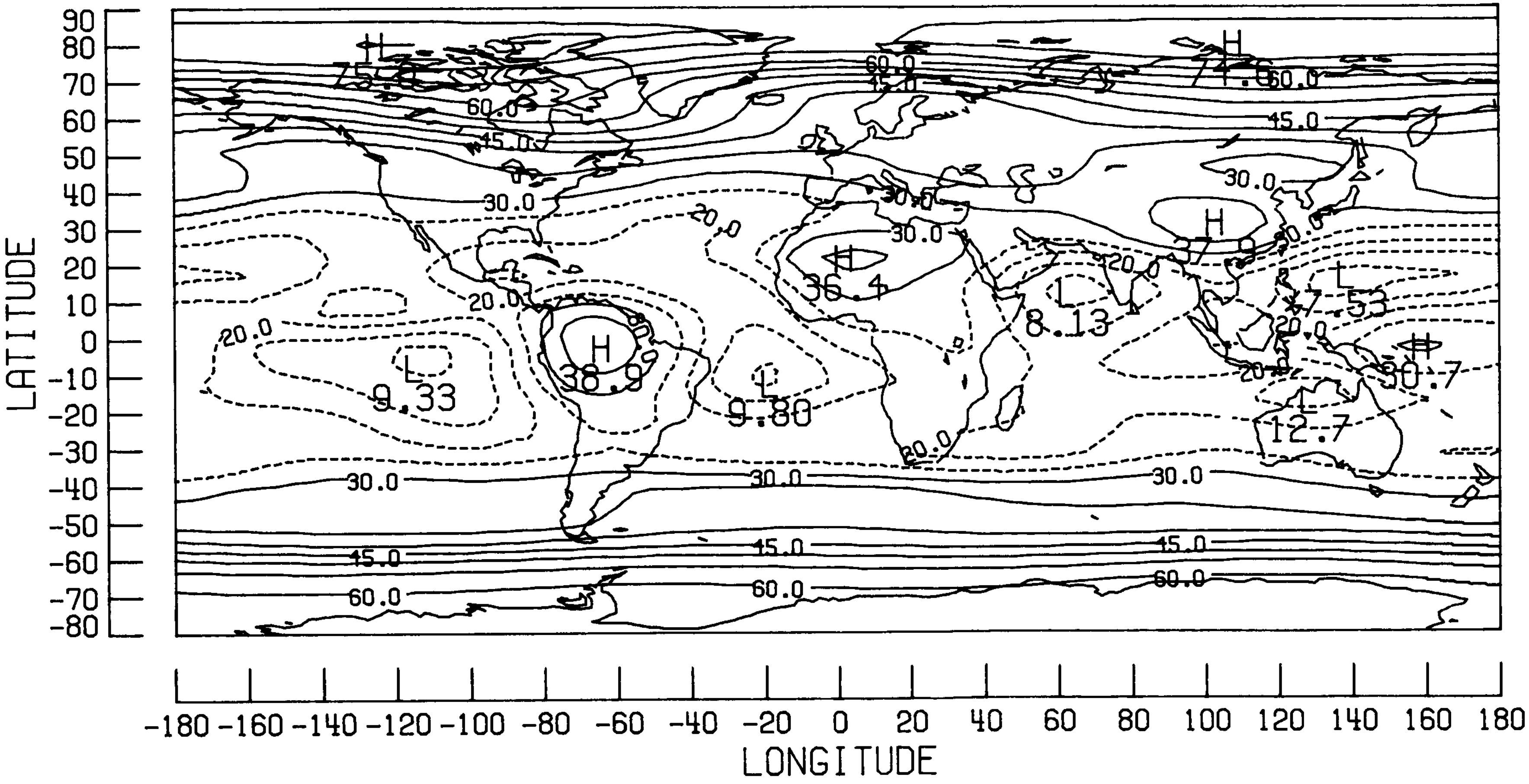

ALBEDO (%)
MAR 1981
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
60.0
45.0
30.0
20.0
L
14.1
H
24.6
L
11.1
H
32.9
L
9.93
L
14.6
L
9.74
H
24.8
L
11.9
L
14.9

ABSORPTION W/(M*M)

MAR 1981

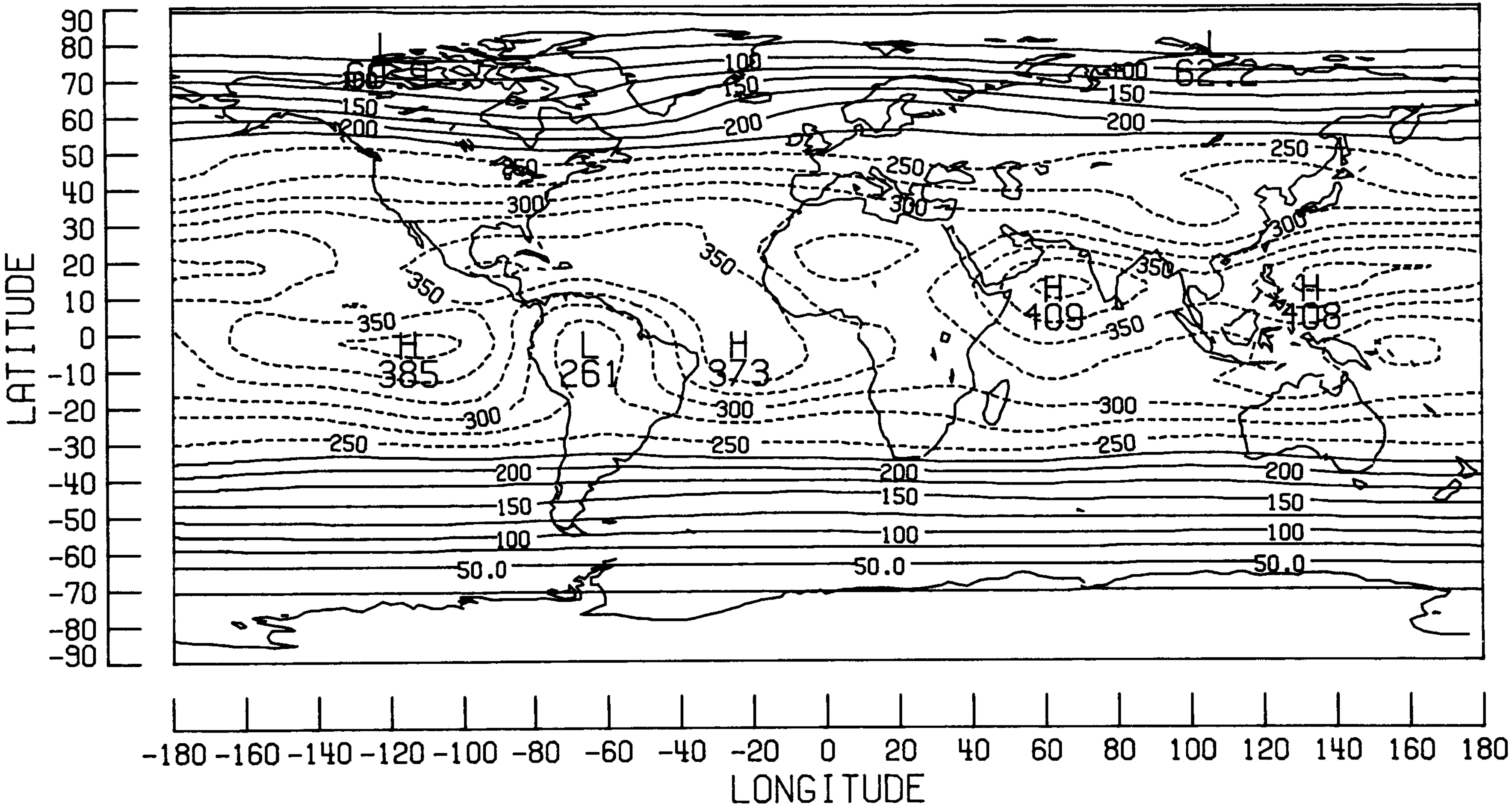


ALBEDO (%)
APR 1981

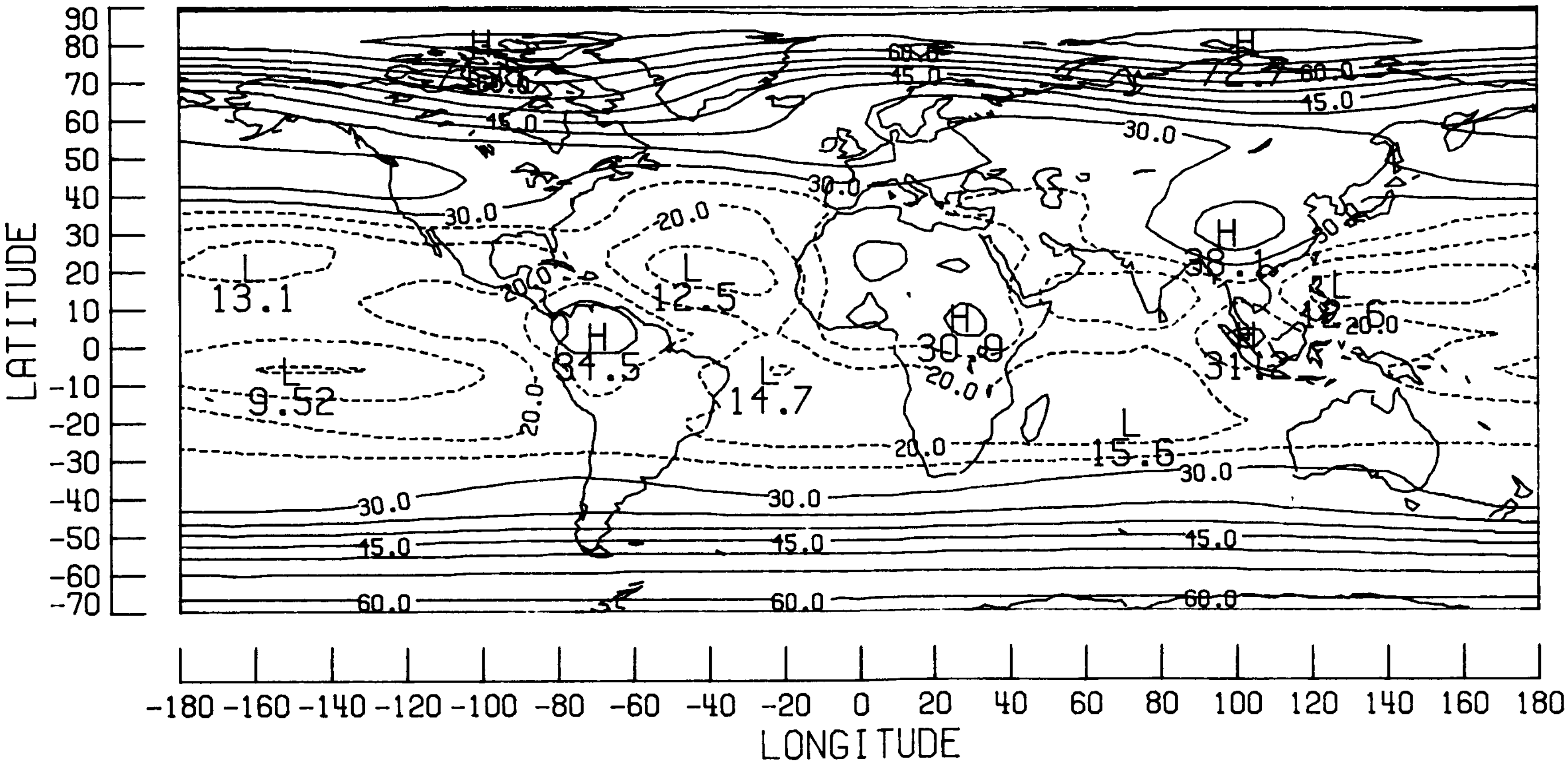


ABSORPTION W/(M*M)

APR 1981

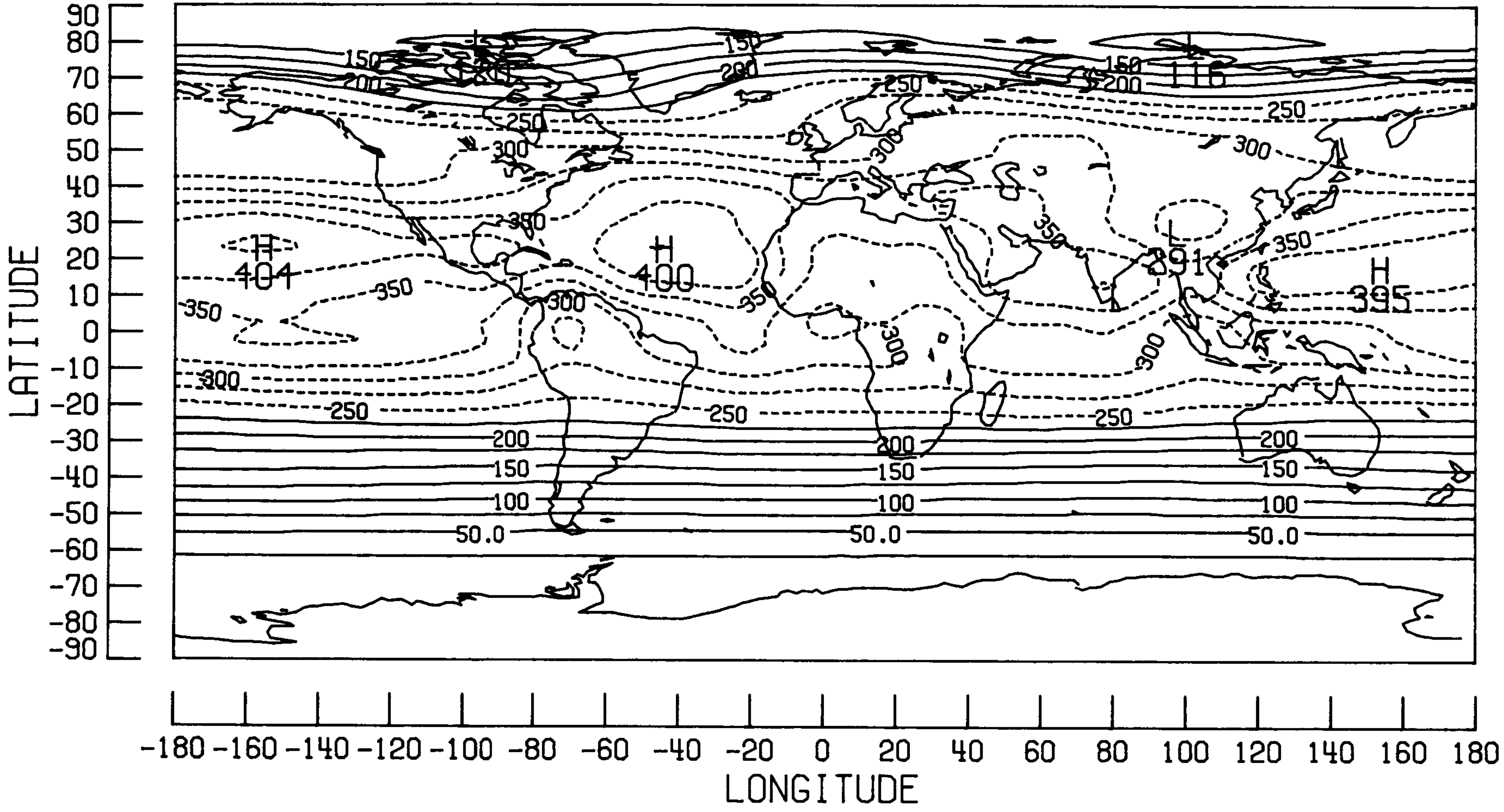


ALBEDO (%)
MAY 1981

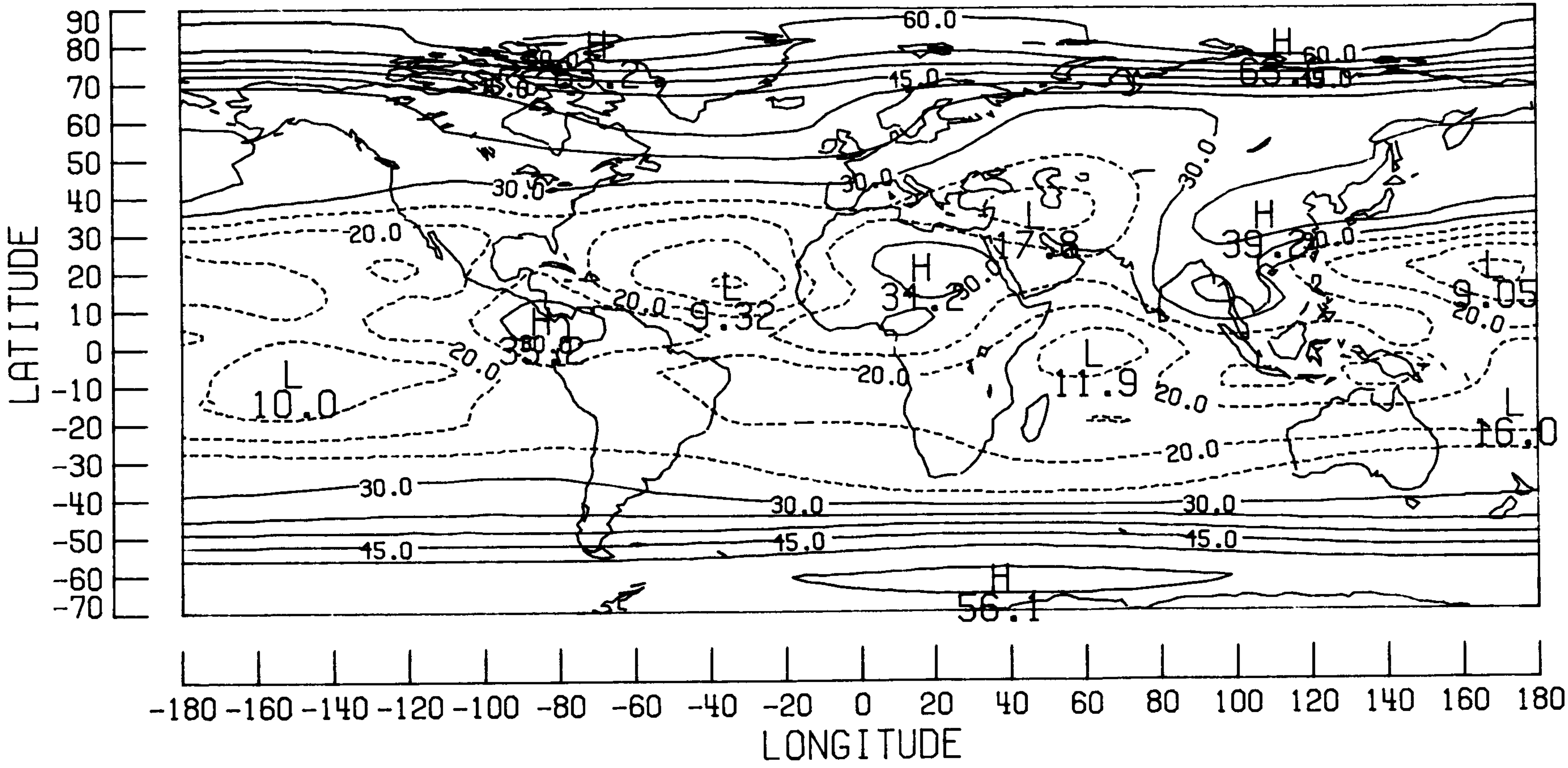


ABSORPTION W/(M*M)

MAY 1981

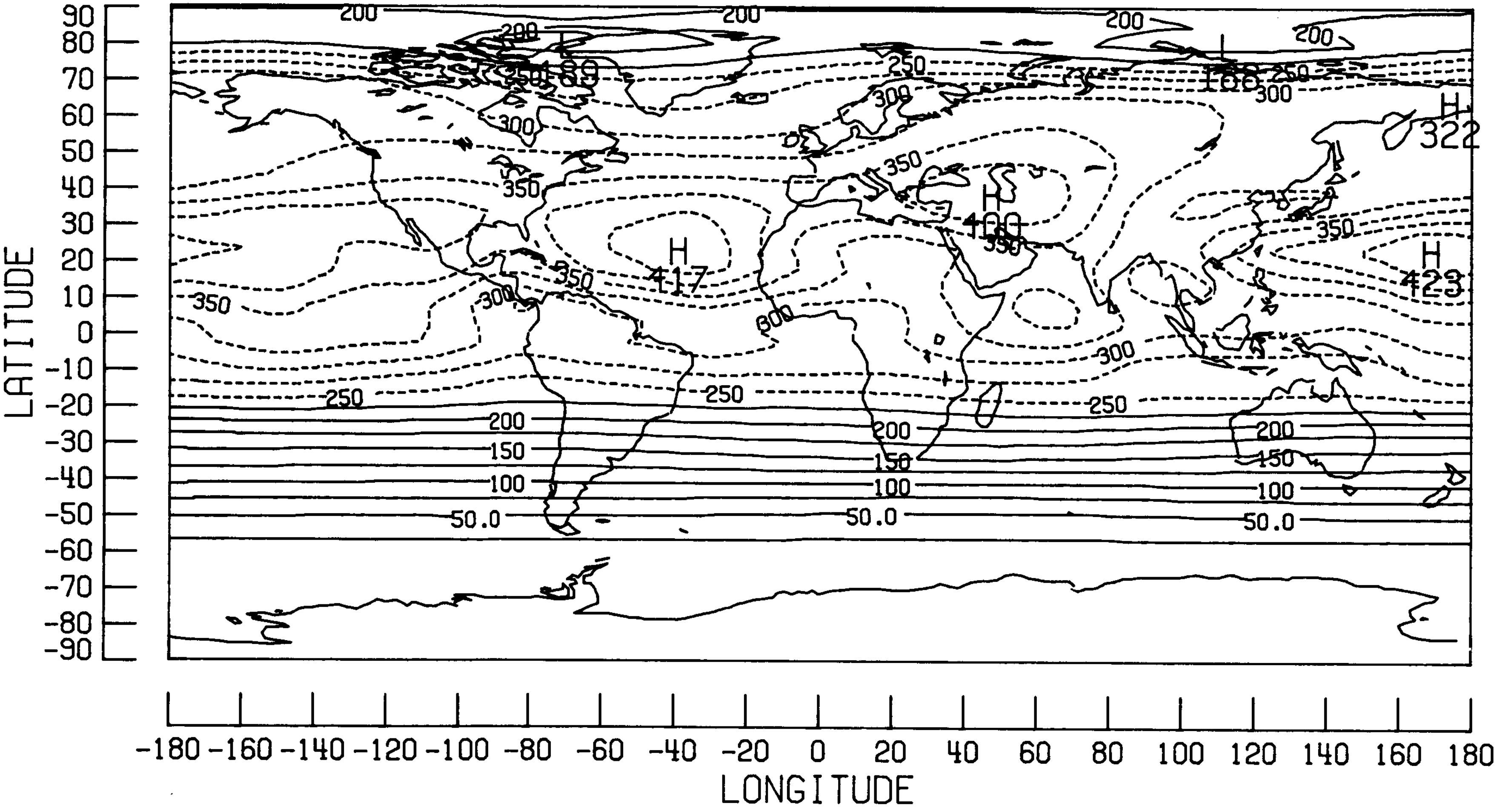


ALBEDO (%)
JUN 1981



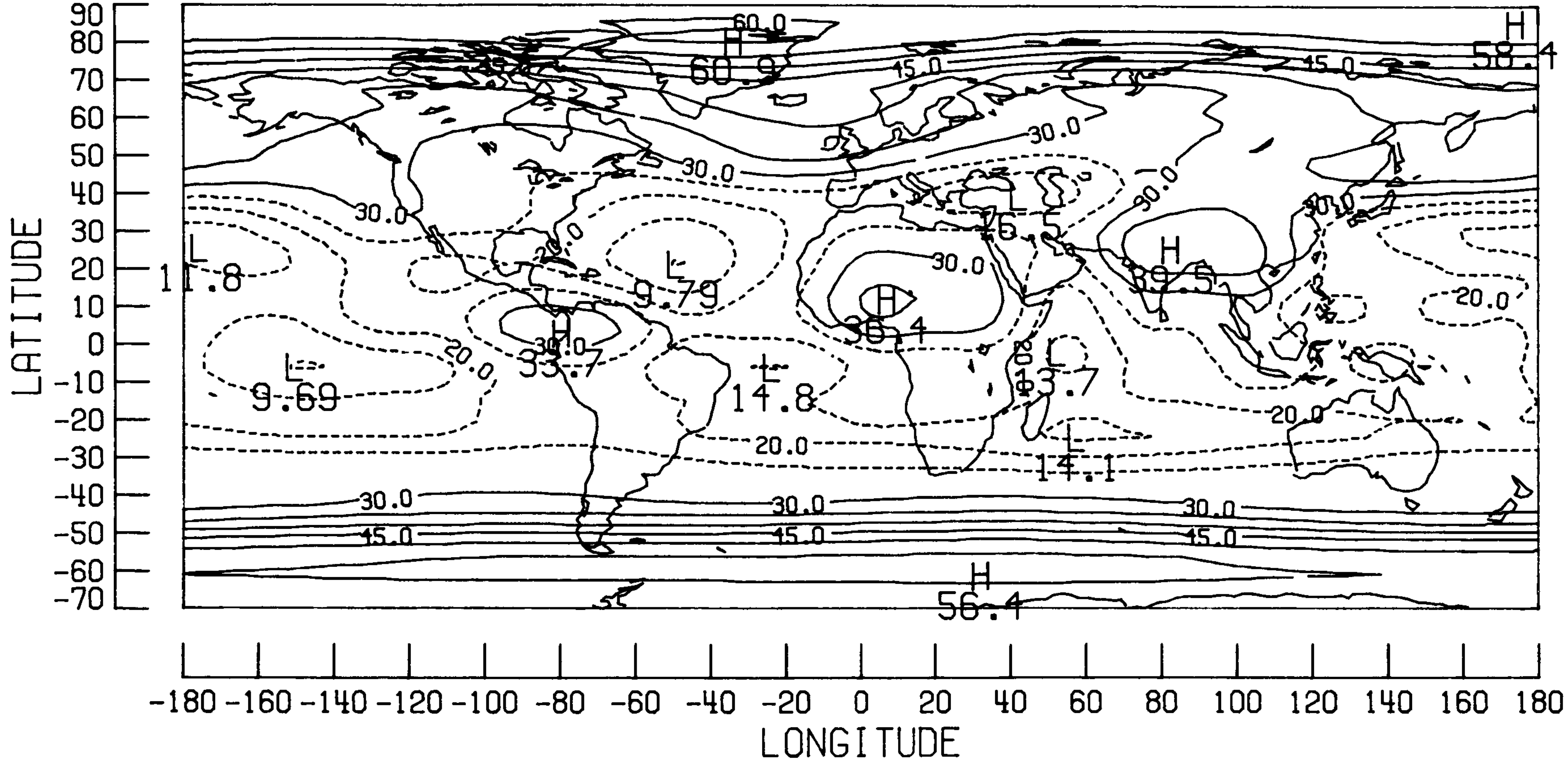
ABSORPTION W/(M*M)

JUN 1981



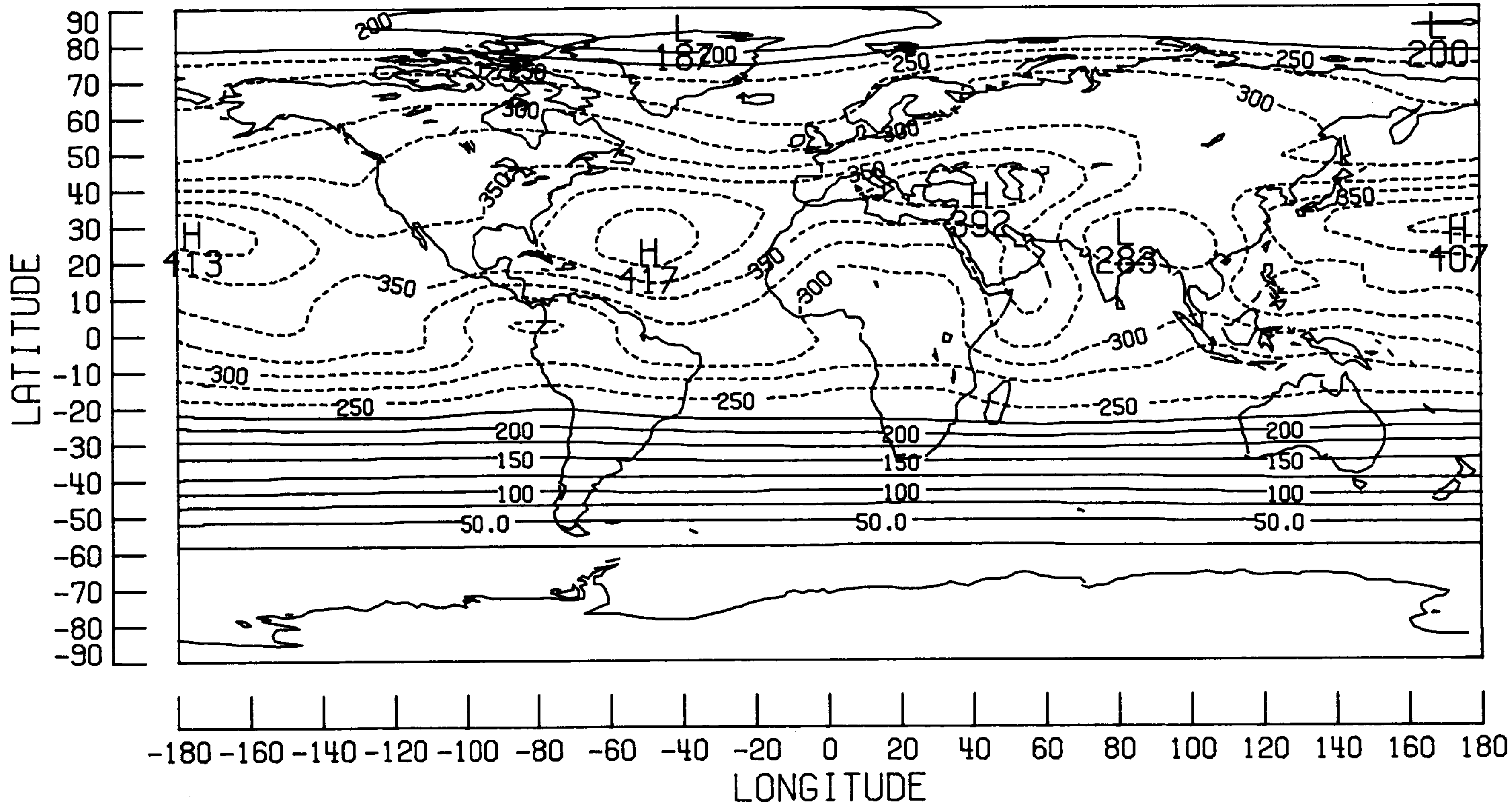
C-2

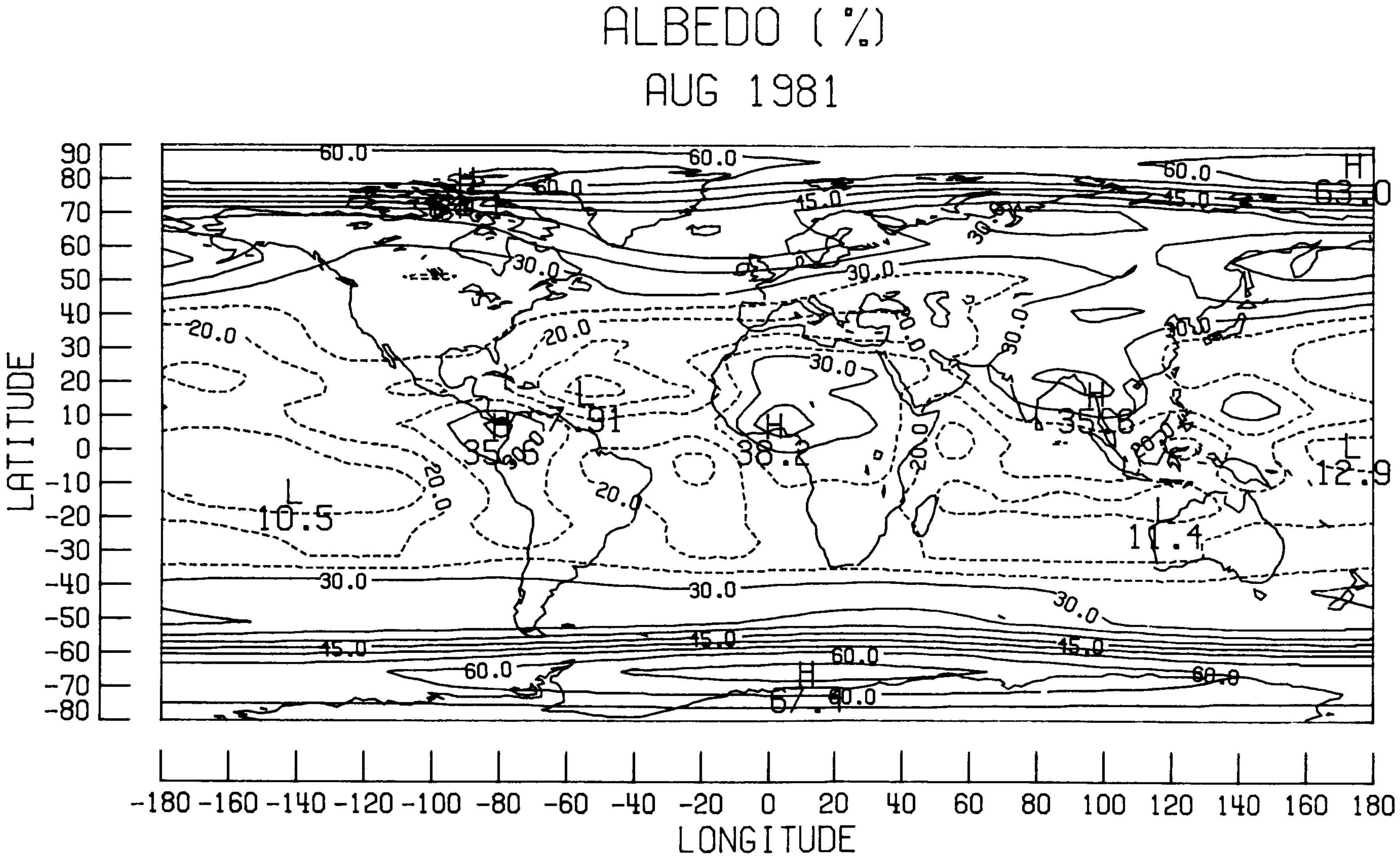
ALBEDO (%)
JUL 1981



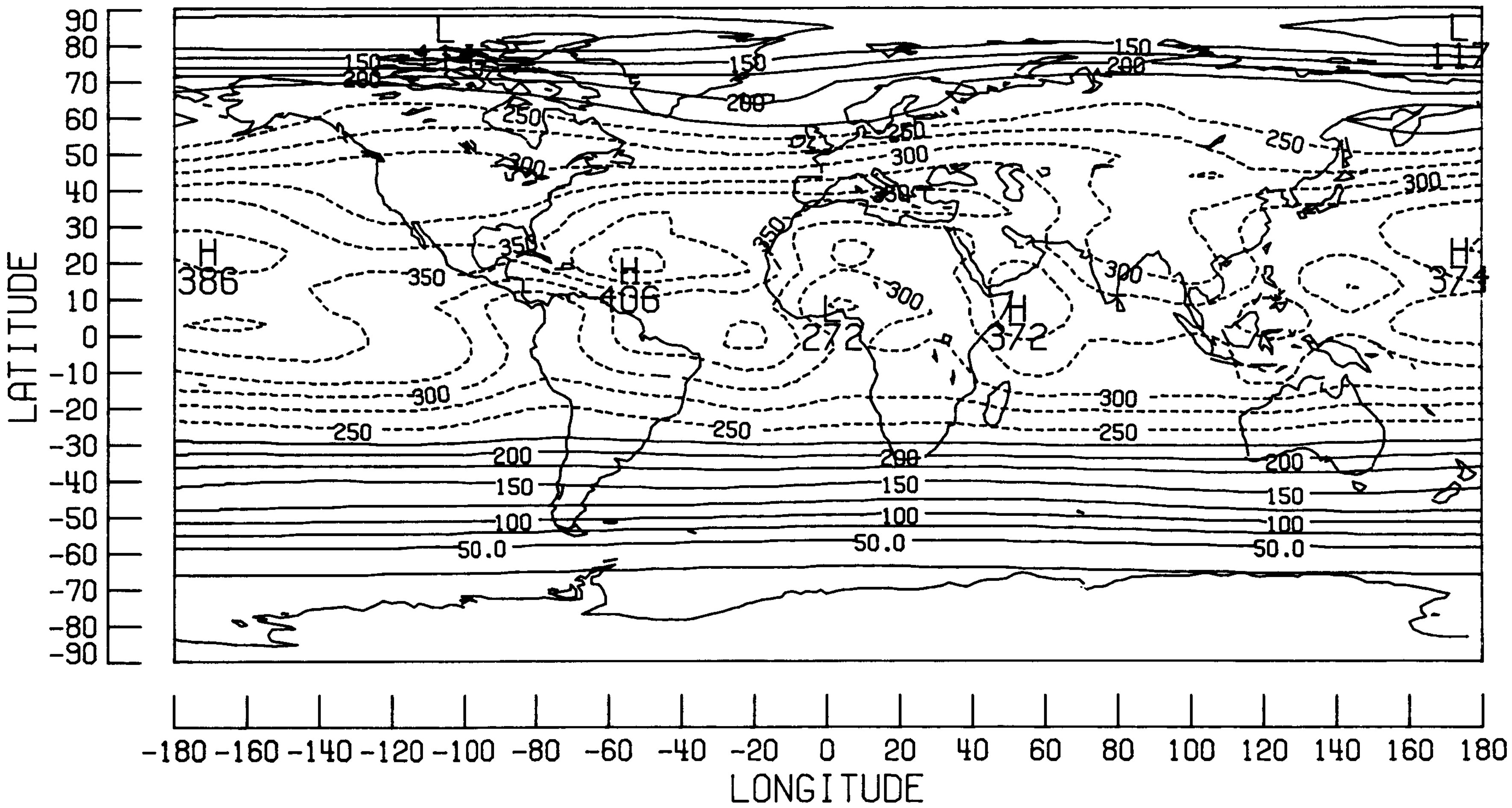
ABSORPTION W/(M*M)

JUL 1981

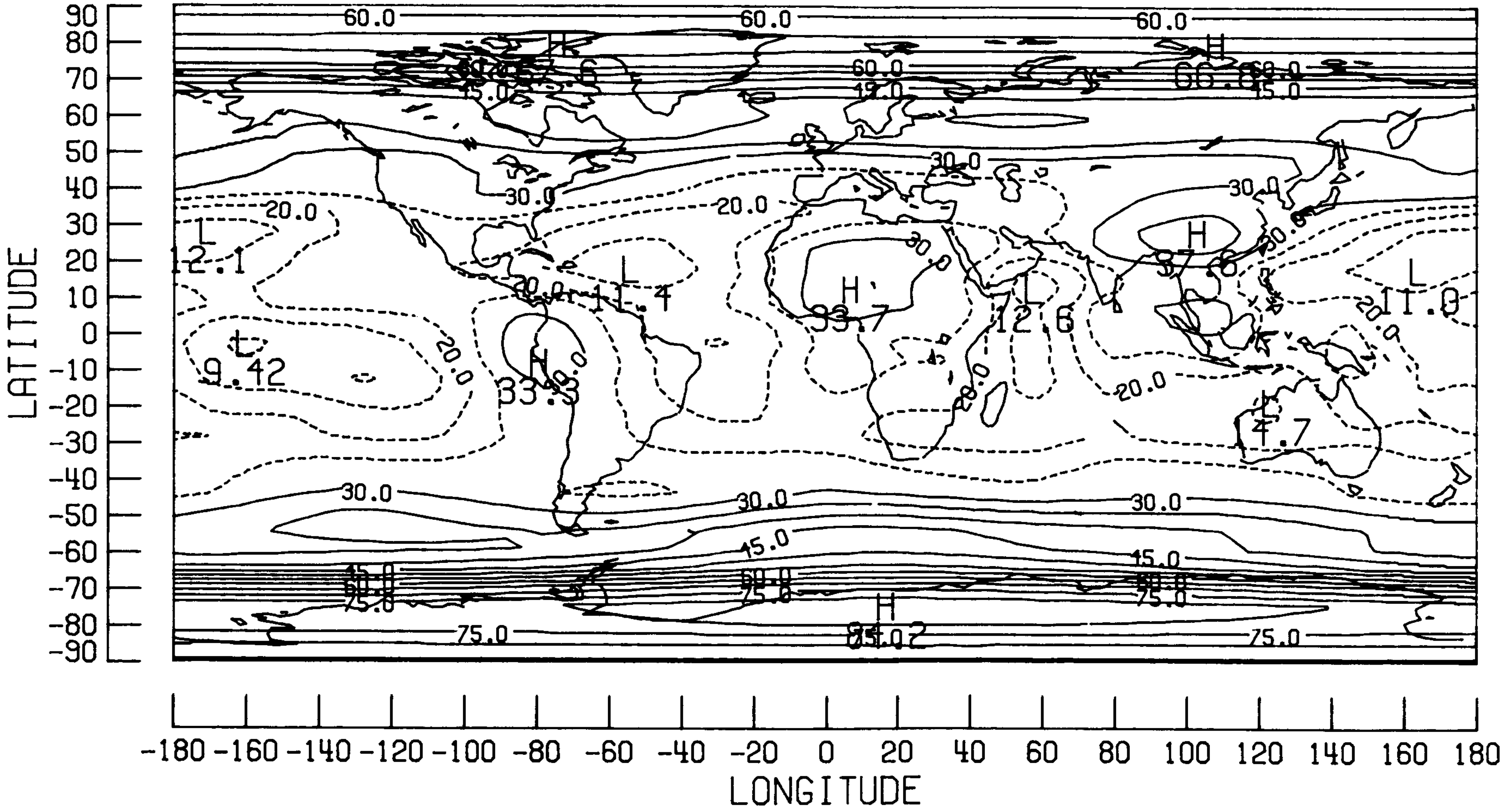



ALBEDO (%)
AUG 1981
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
60.0
45.0
30.0
20.0
H
63.0
L
12.9
H
35.6
L
7.91
H
38.2
L
11.4
L
10.5
H
67.4

ABSORPTION W/(M*M)
AUG 1981

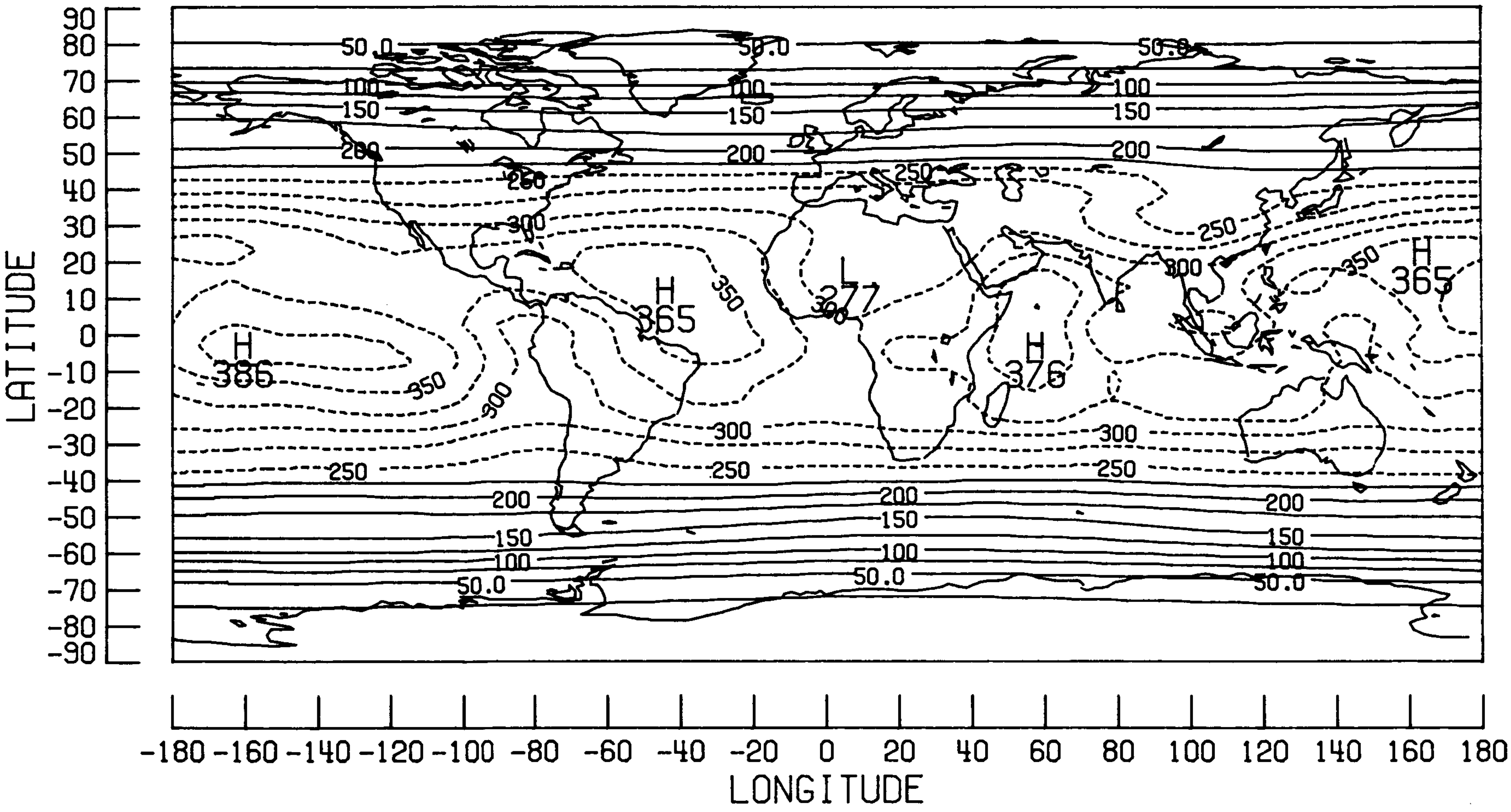


ALBEDO (%)
SEP 1981

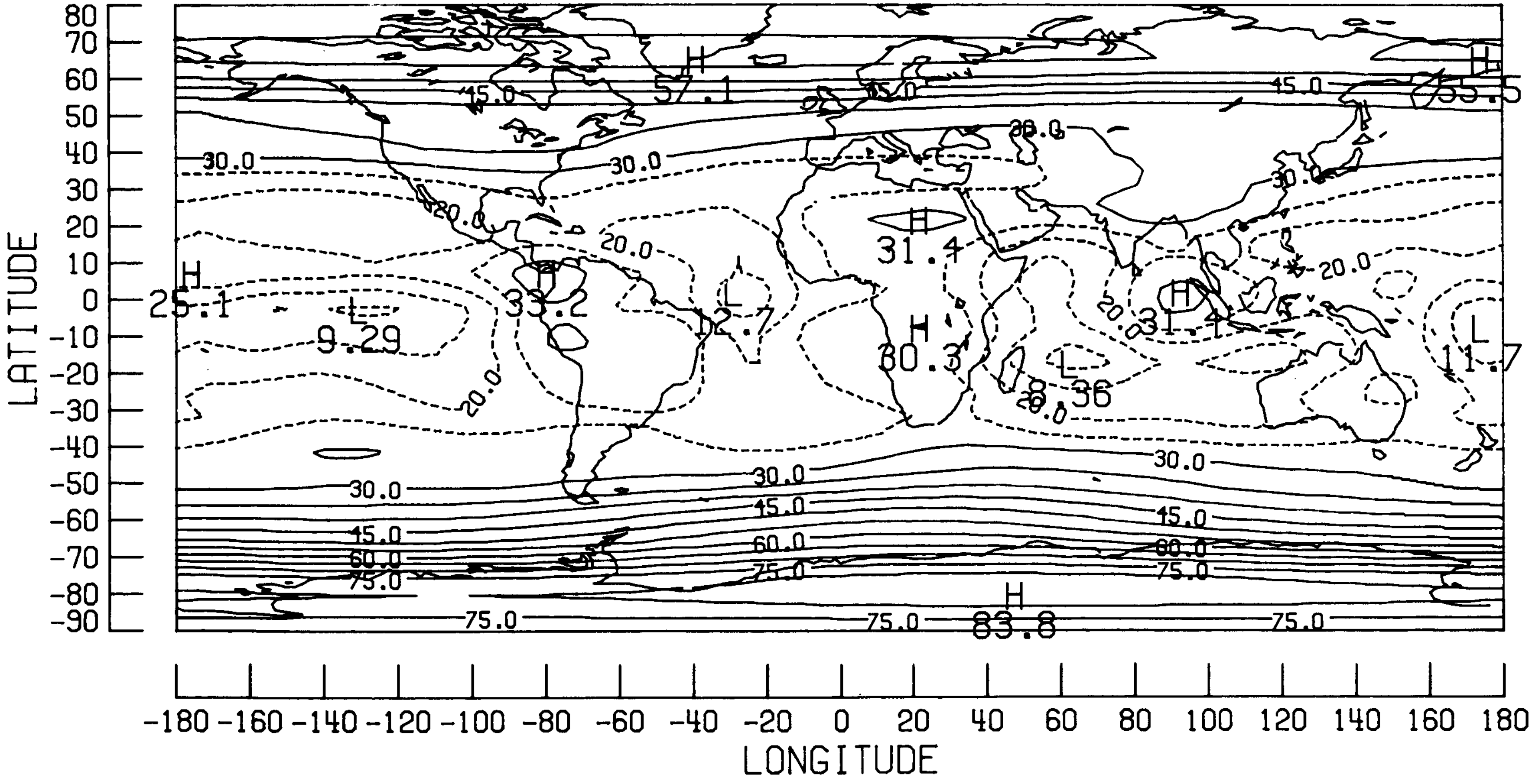


ABSORPTION W/(M*M)

SEP 1981

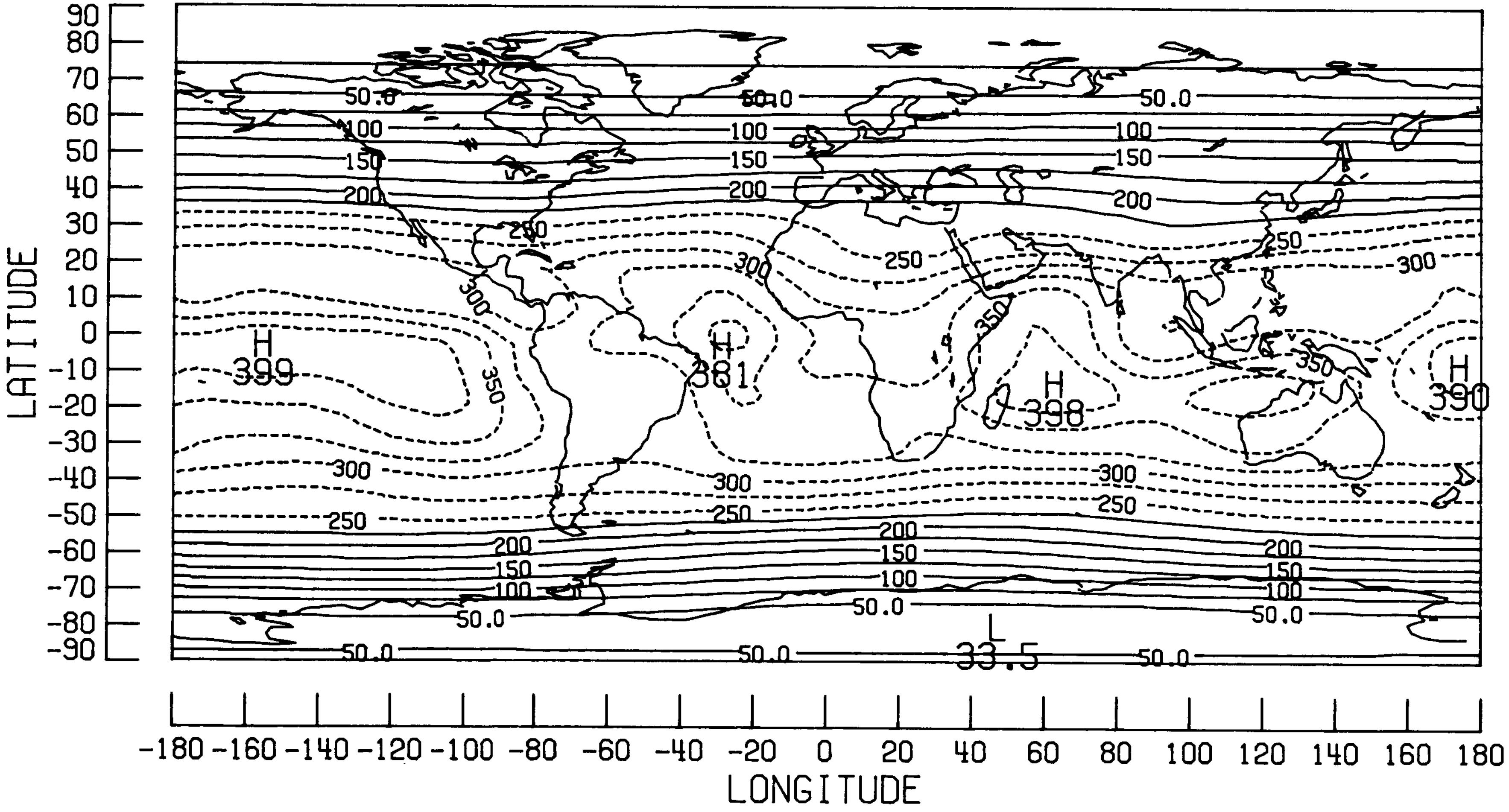


ALBEDO (%)
OCT 1981

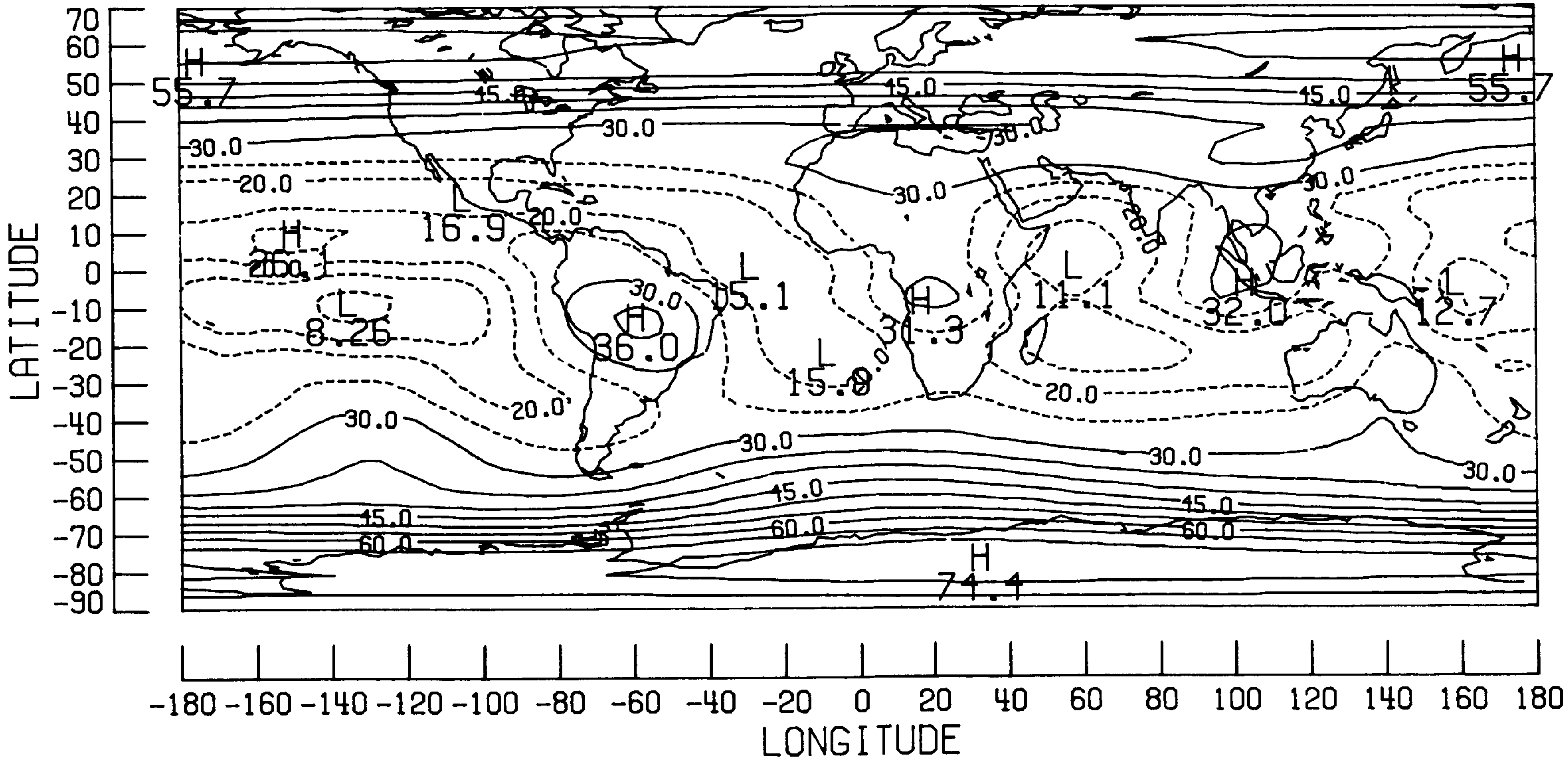


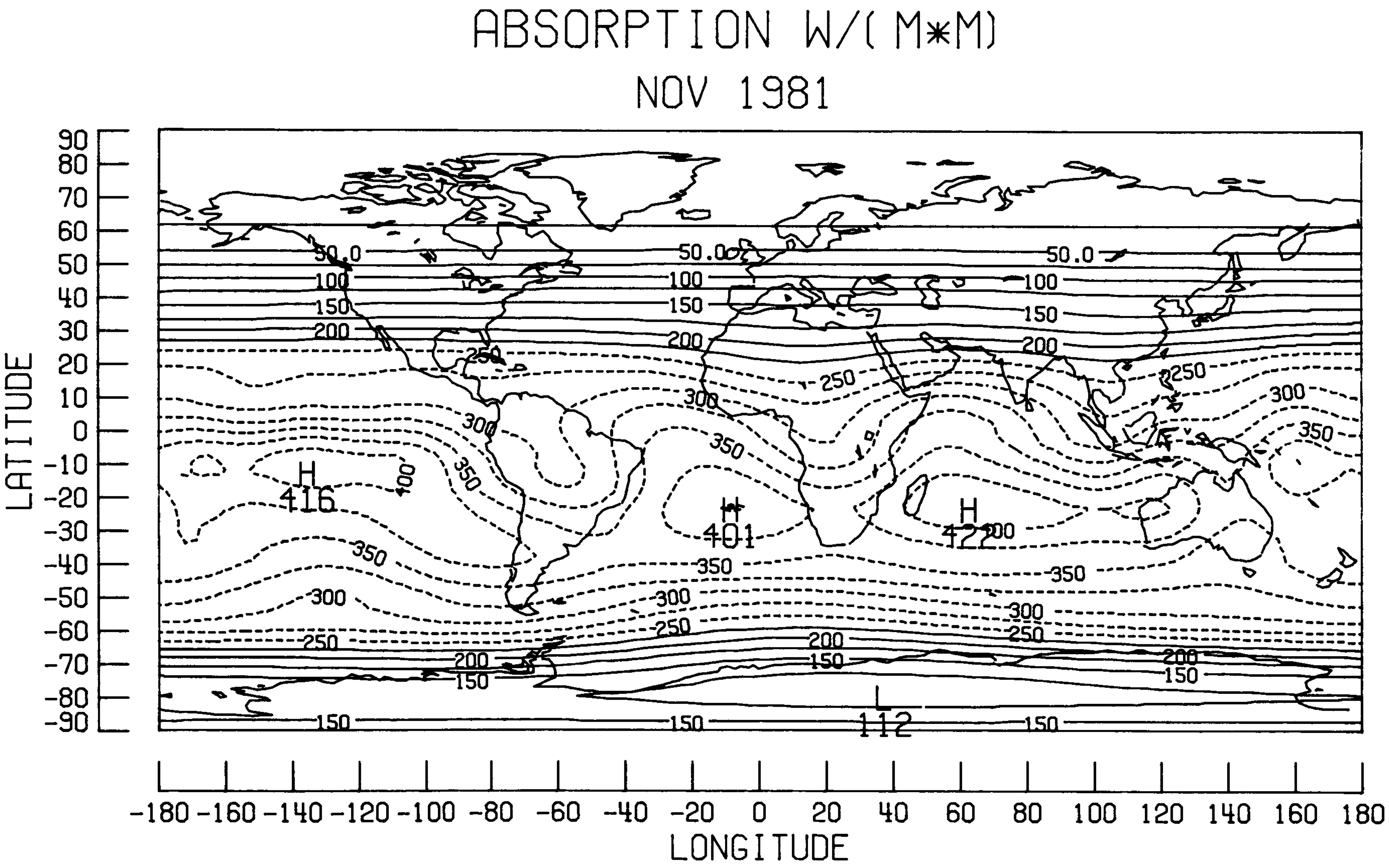
ABSORPTION W/(M*M)

OCT 1981

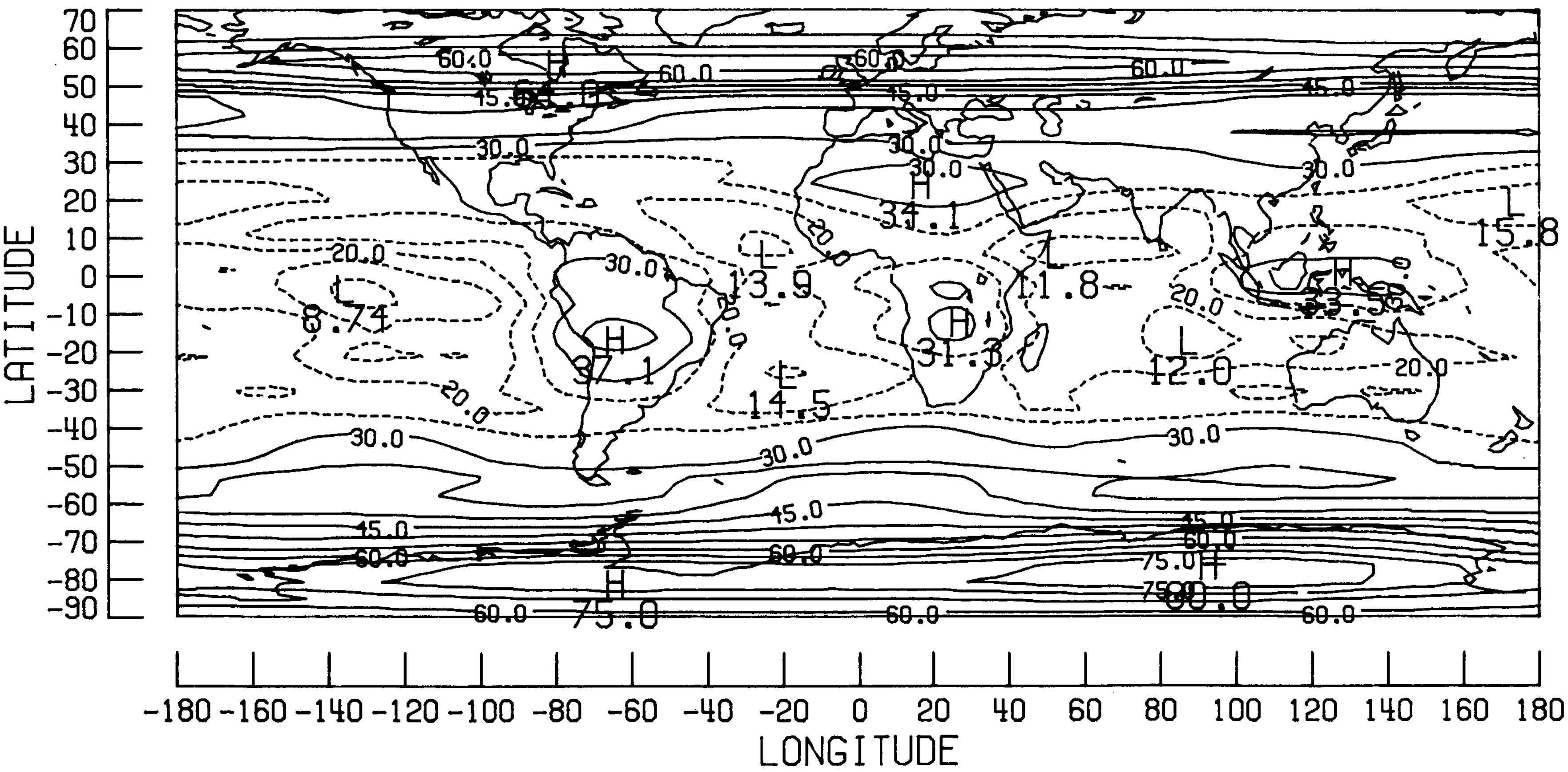


ALBEDO (%)
NOV 1981



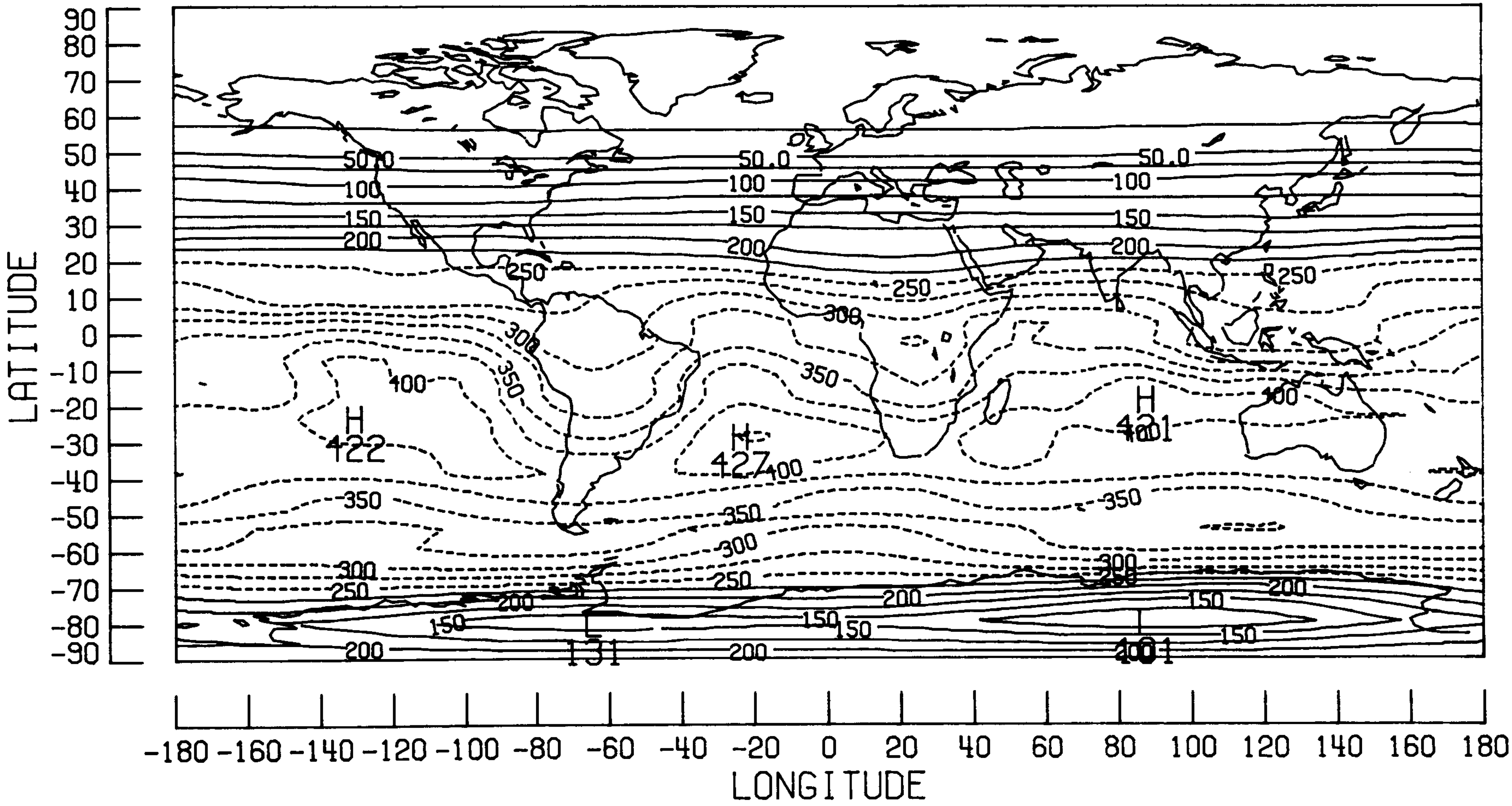

ABSORPTION W/(M*M)
NOV 1981
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
50.0
100
150
200
250
300
350
400
H
416
H
401
H
422
L
112

ALBEDO (%)
DEC 1981



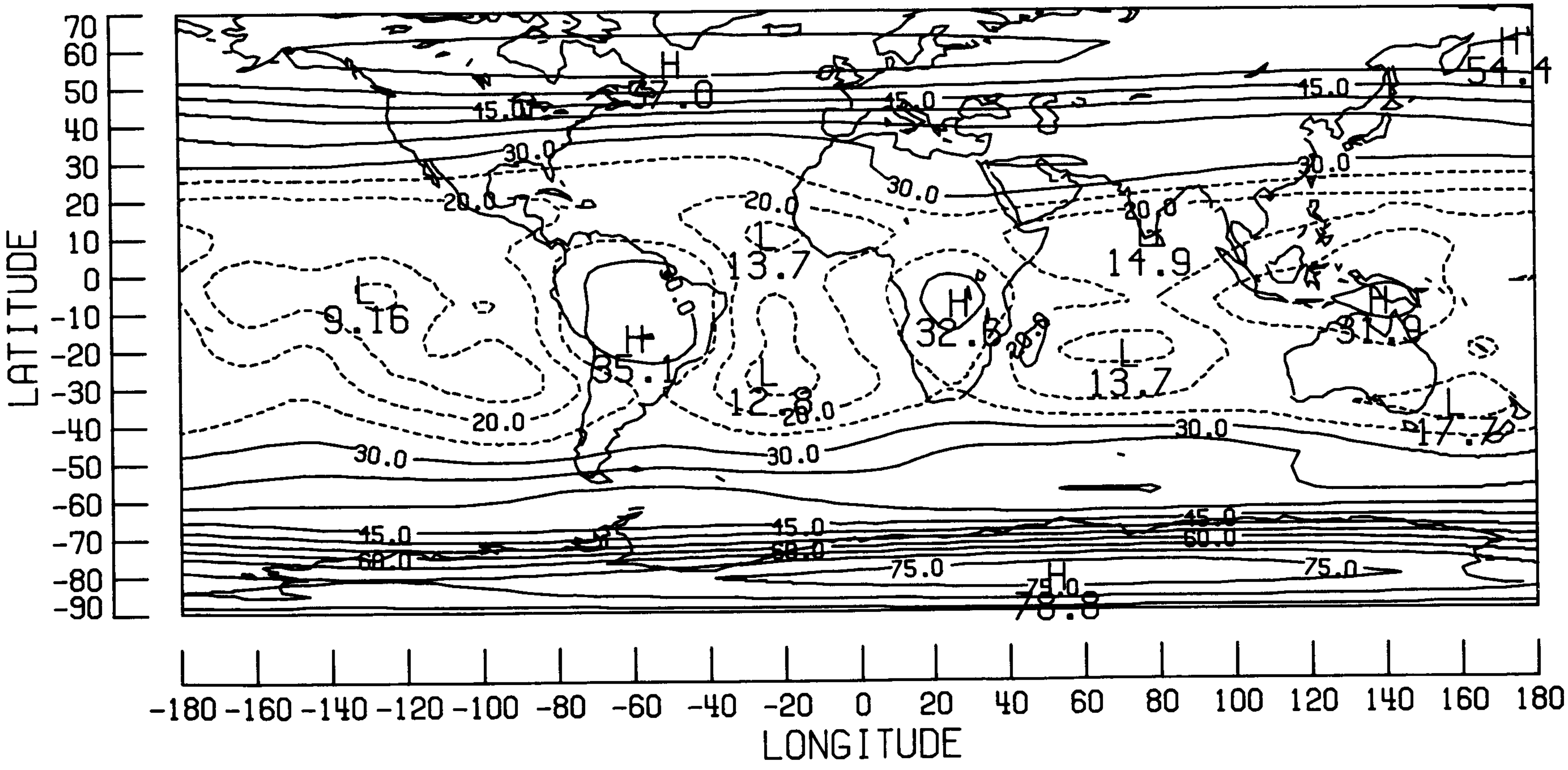
ABSORPTION W/(M*M)

DEC 1981



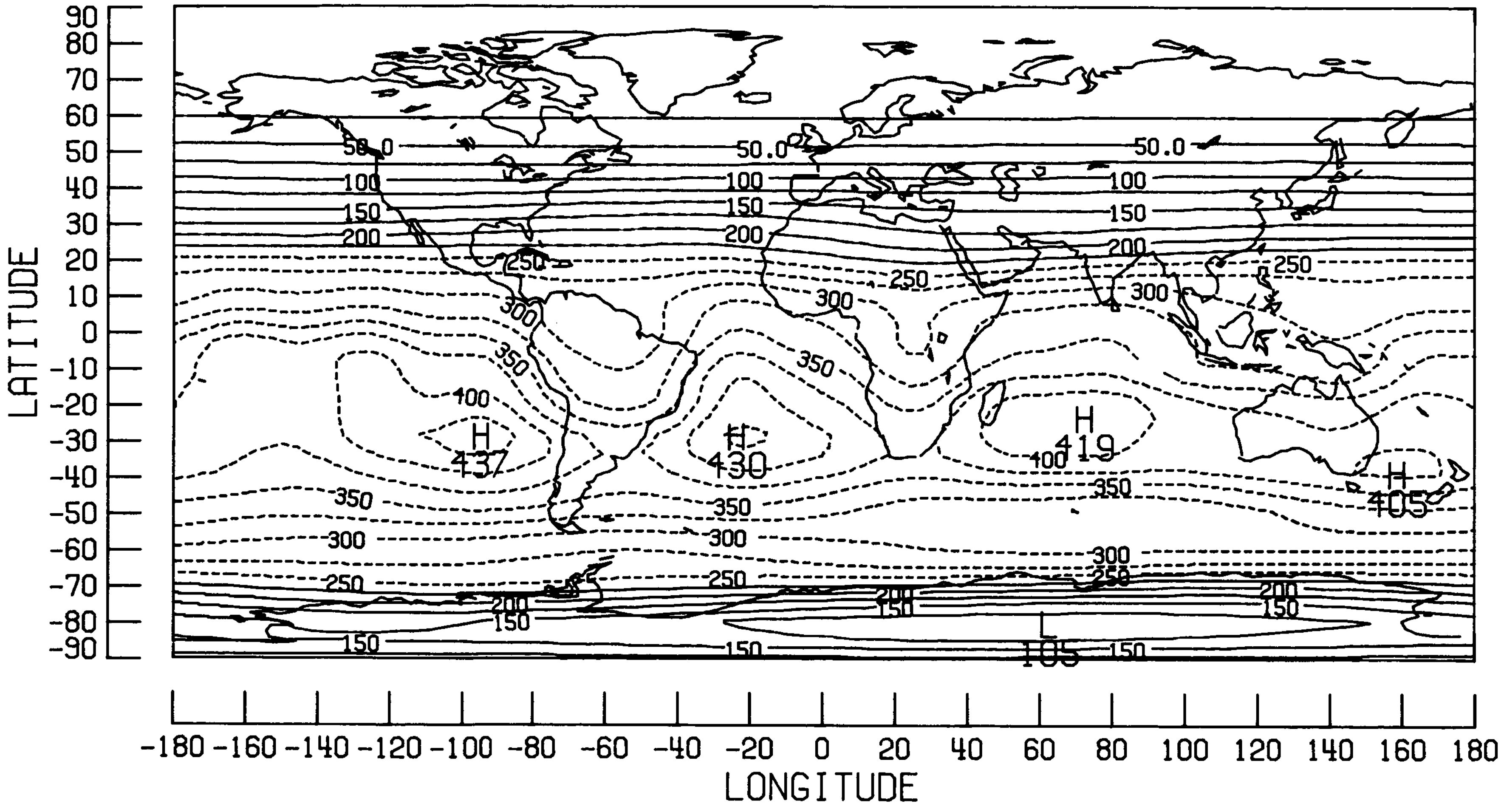
ALBEDO (%)

JAN 1982

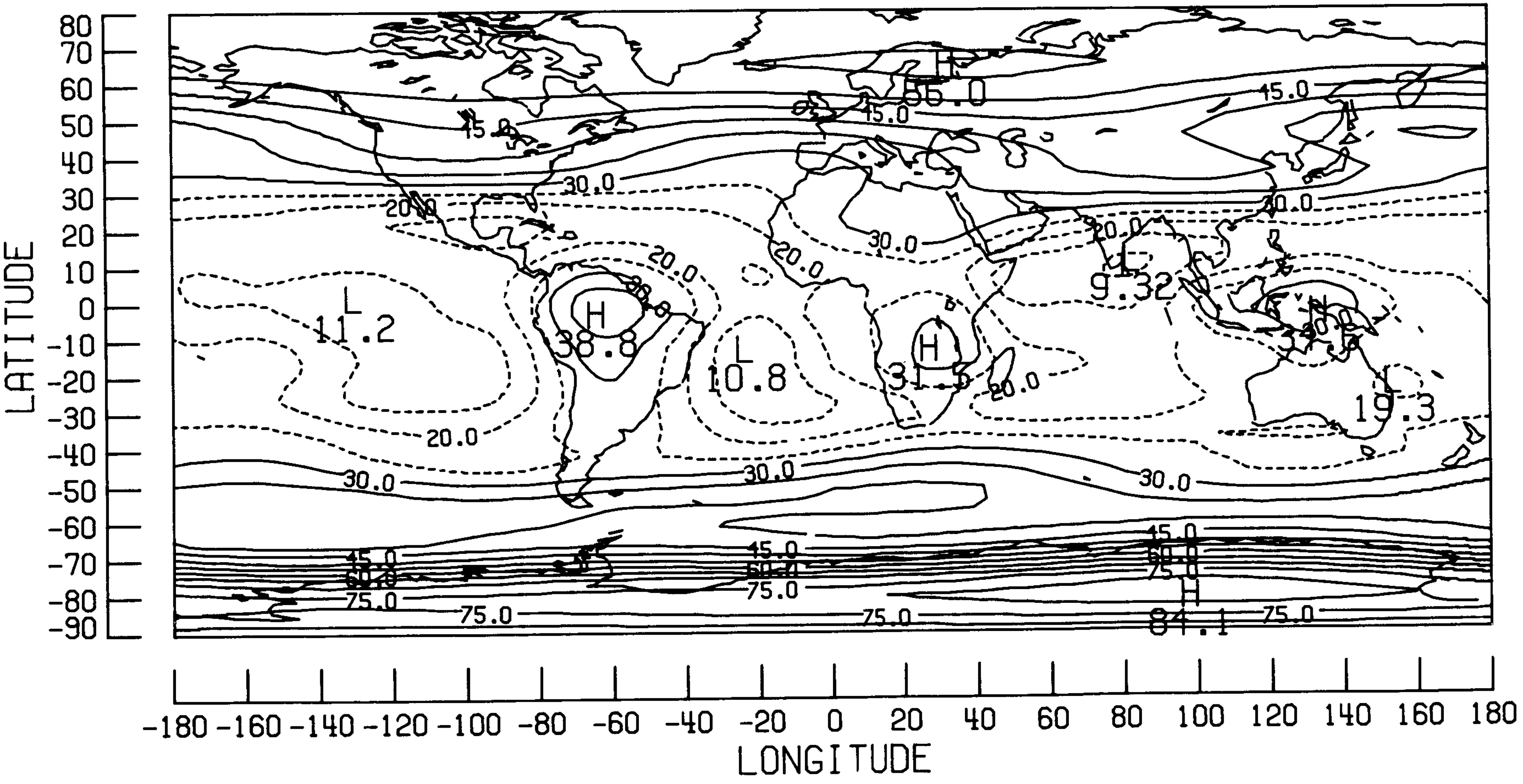


ABSORPTION W/(M*M)

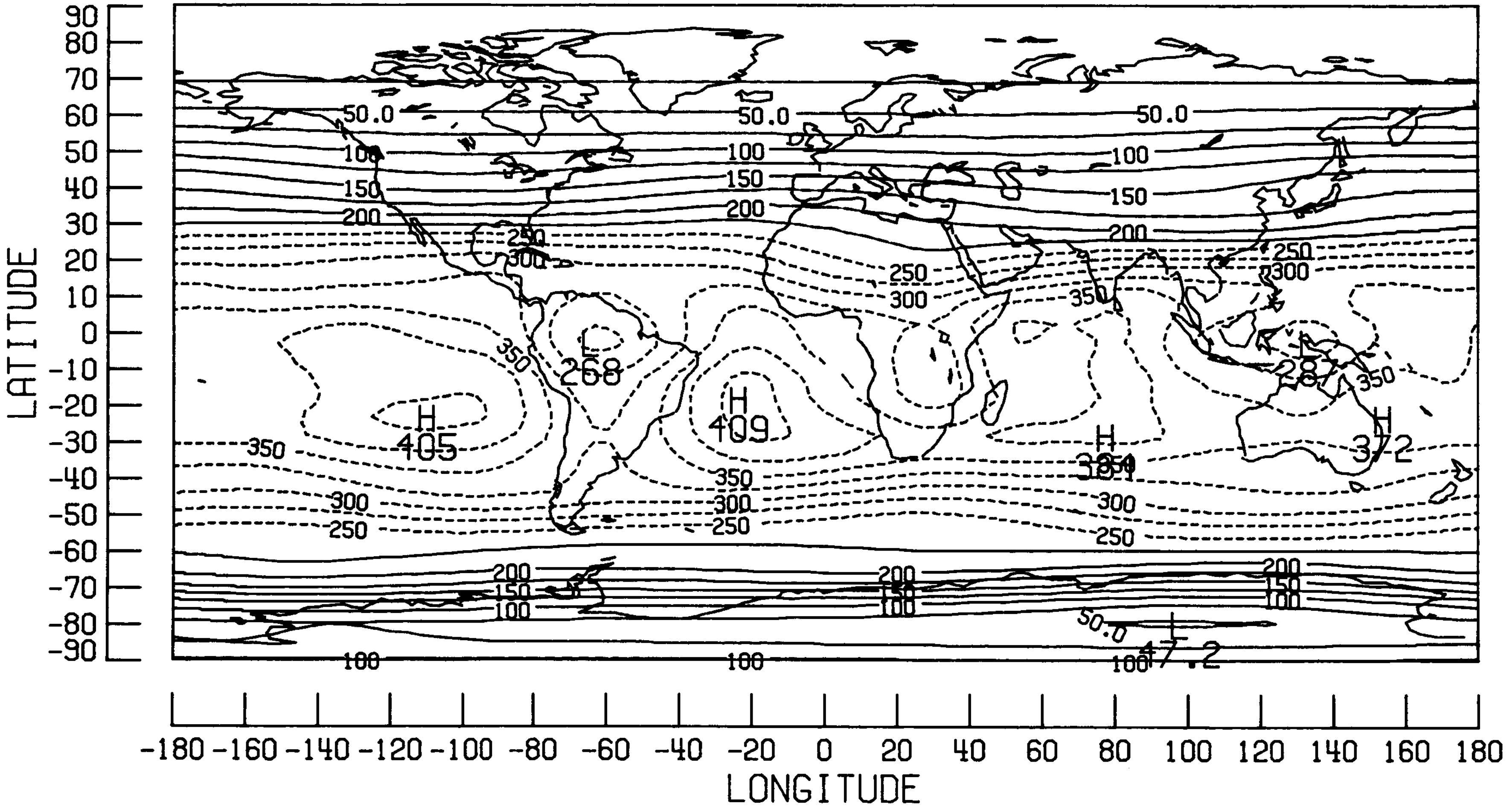
JAN 1982



ALBEDO (%)
FEB 1982

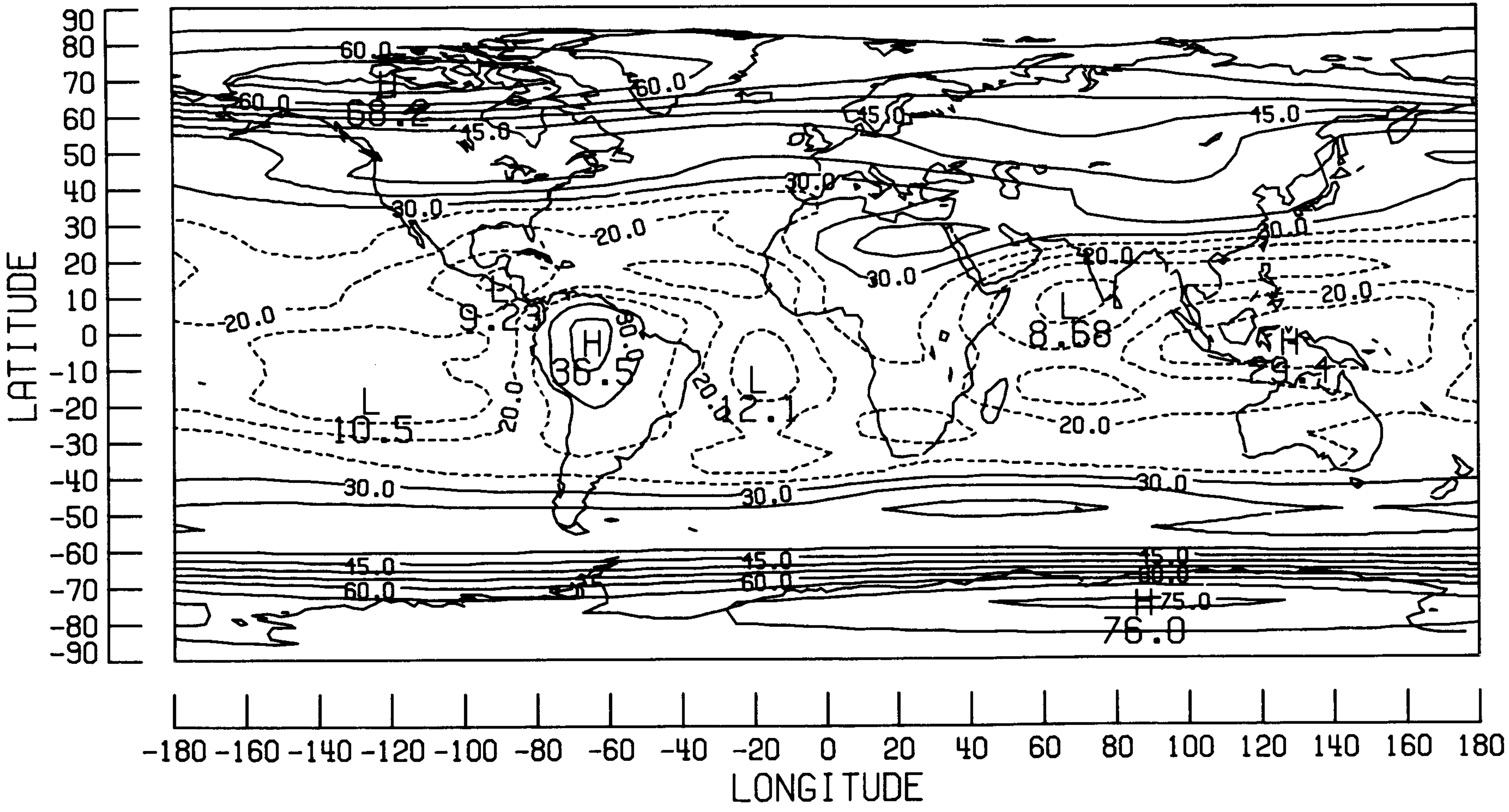


ABSORPTION W/(M*M)
FEB 1982



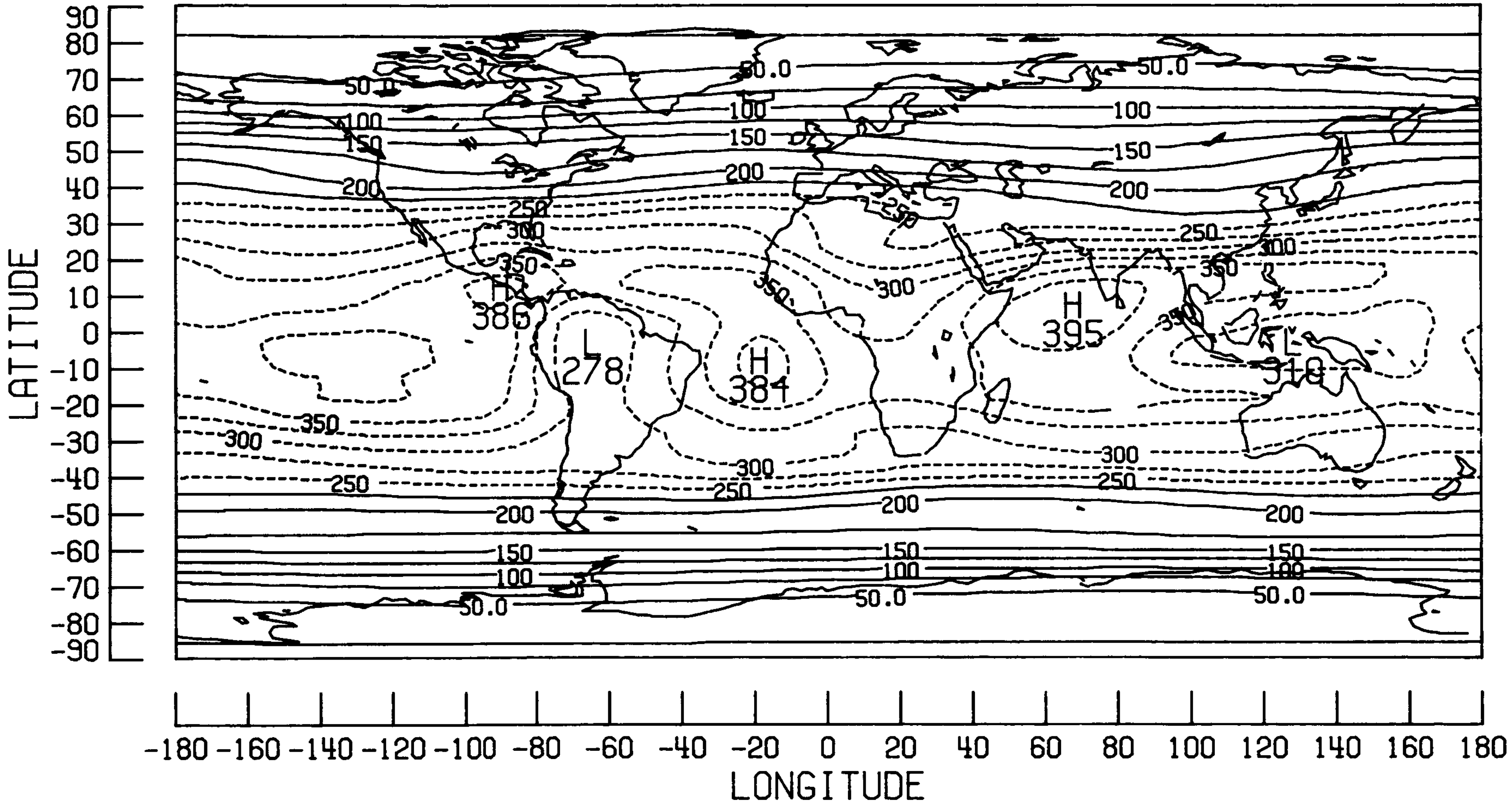
ALBEDO (%)

MAR 1982

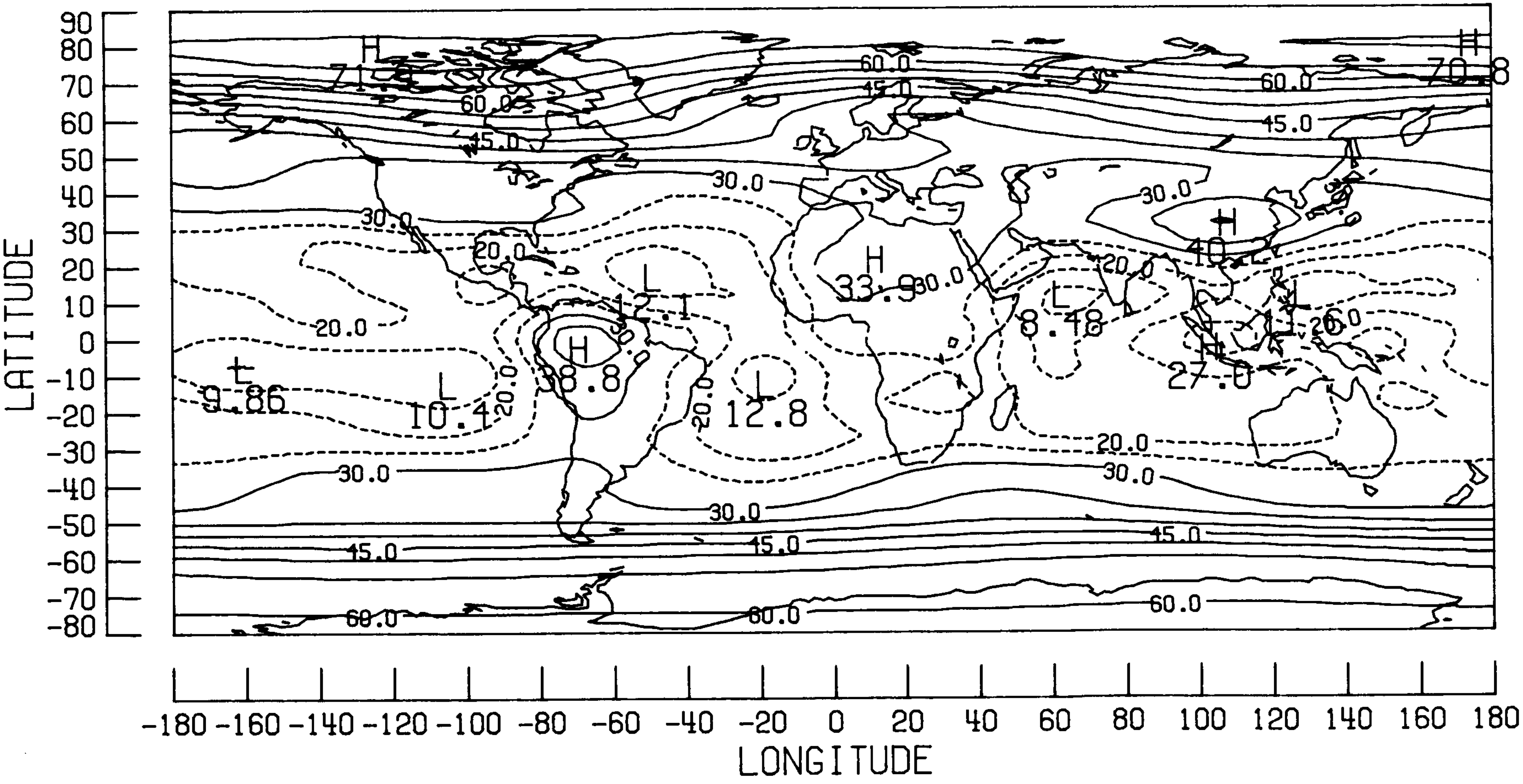


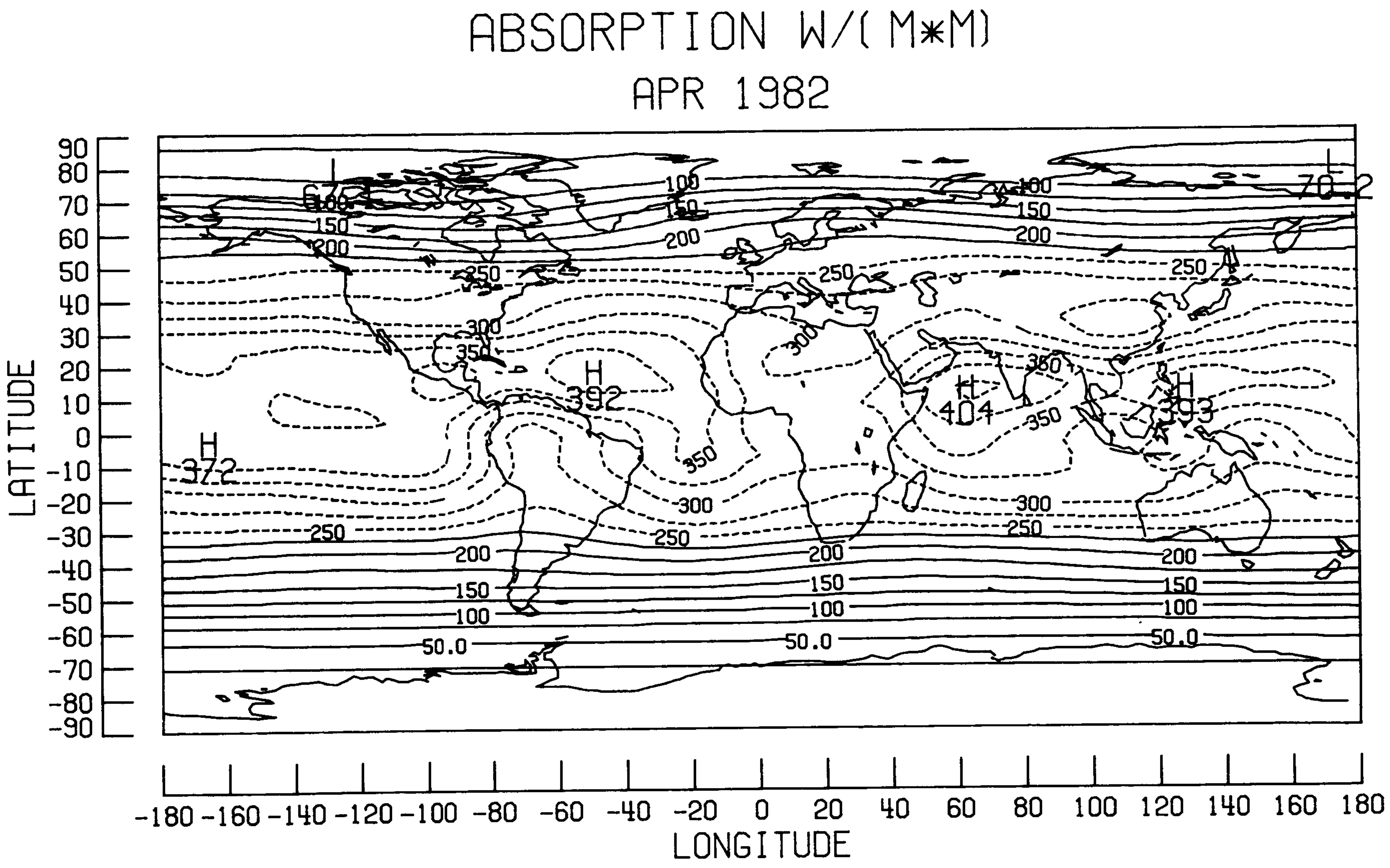
ABSORPTION W/(M*M)

MAR 1982



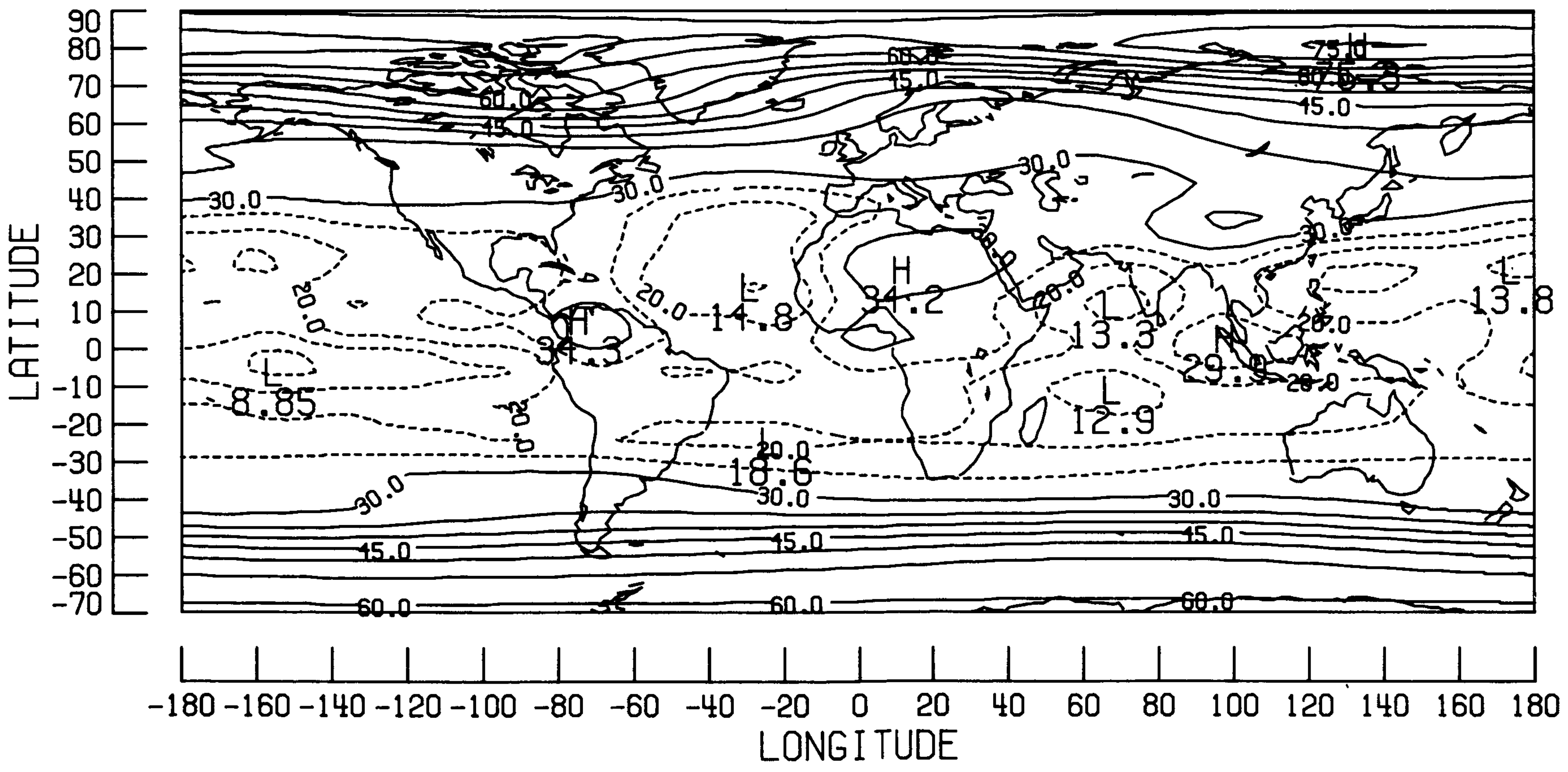
ALBEDO (%)
APR 1982

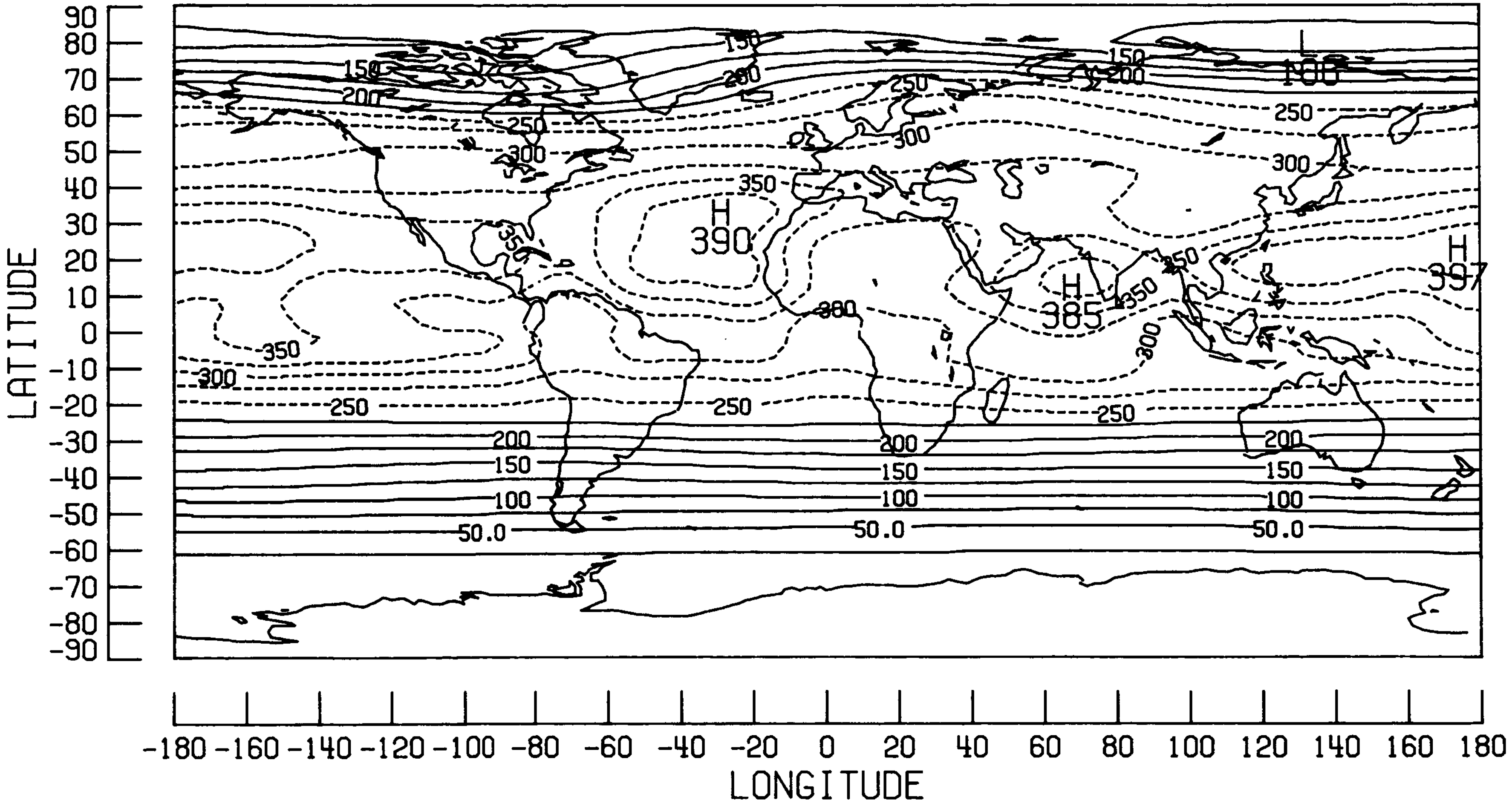


ABSORPTION W/(M*M)
APR 1982
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
L
L
70.2
H
372
H
392
H
404
H
393
100
150
200
250
300
350
50.0

ALBEDO (%)

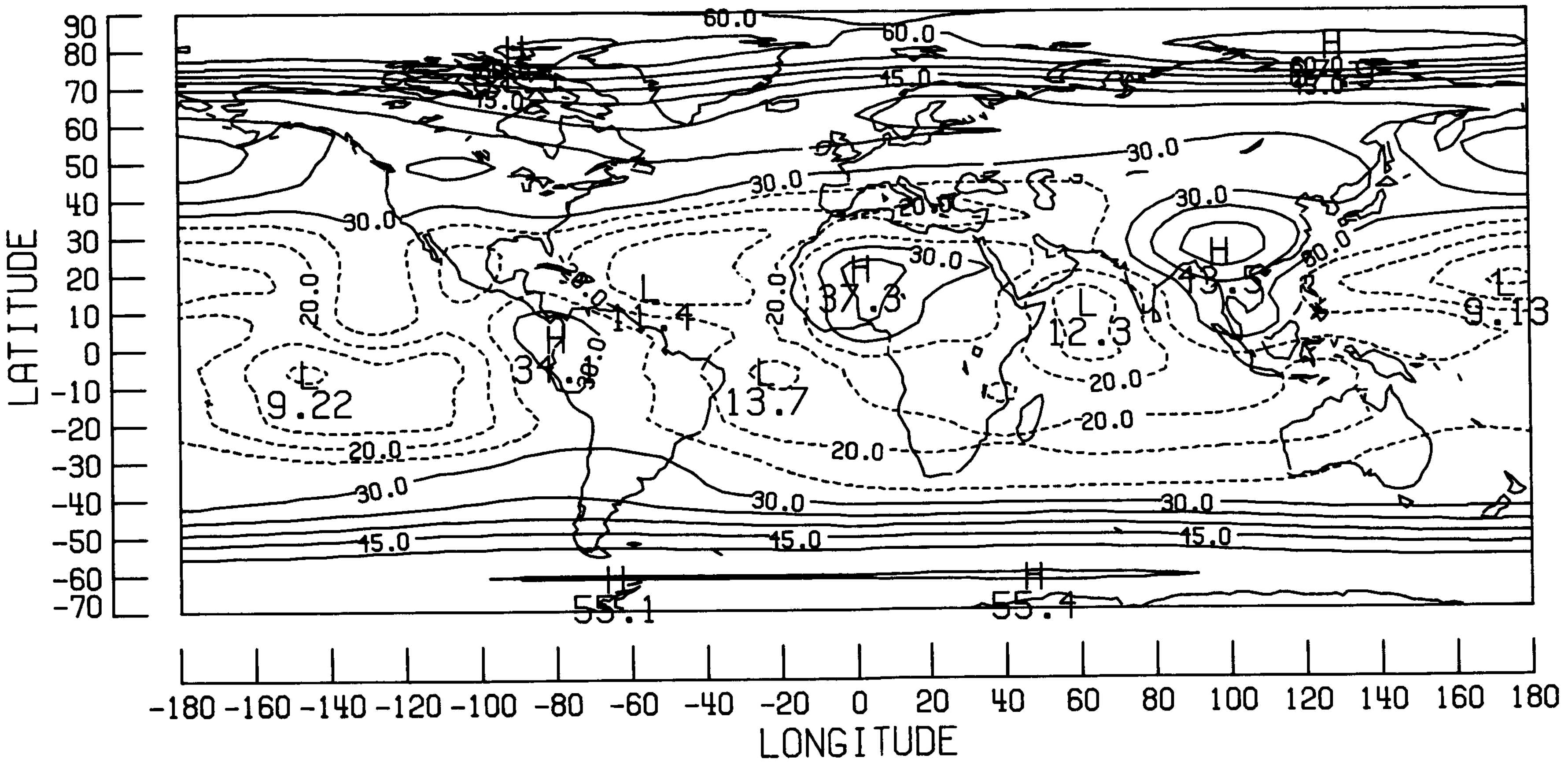
MAY 1982



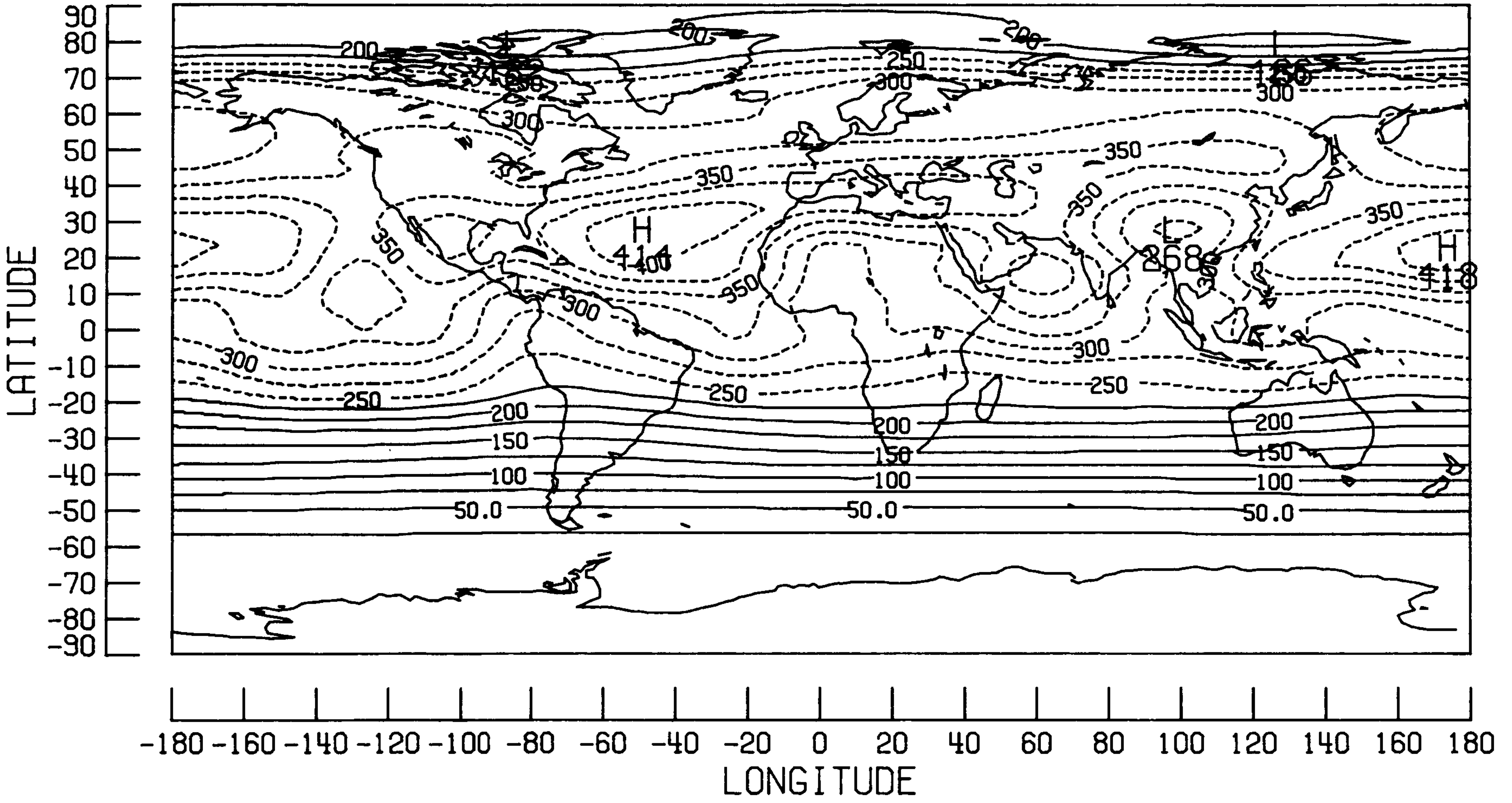


ABSORPTION W/(M*M)

MAY 1982



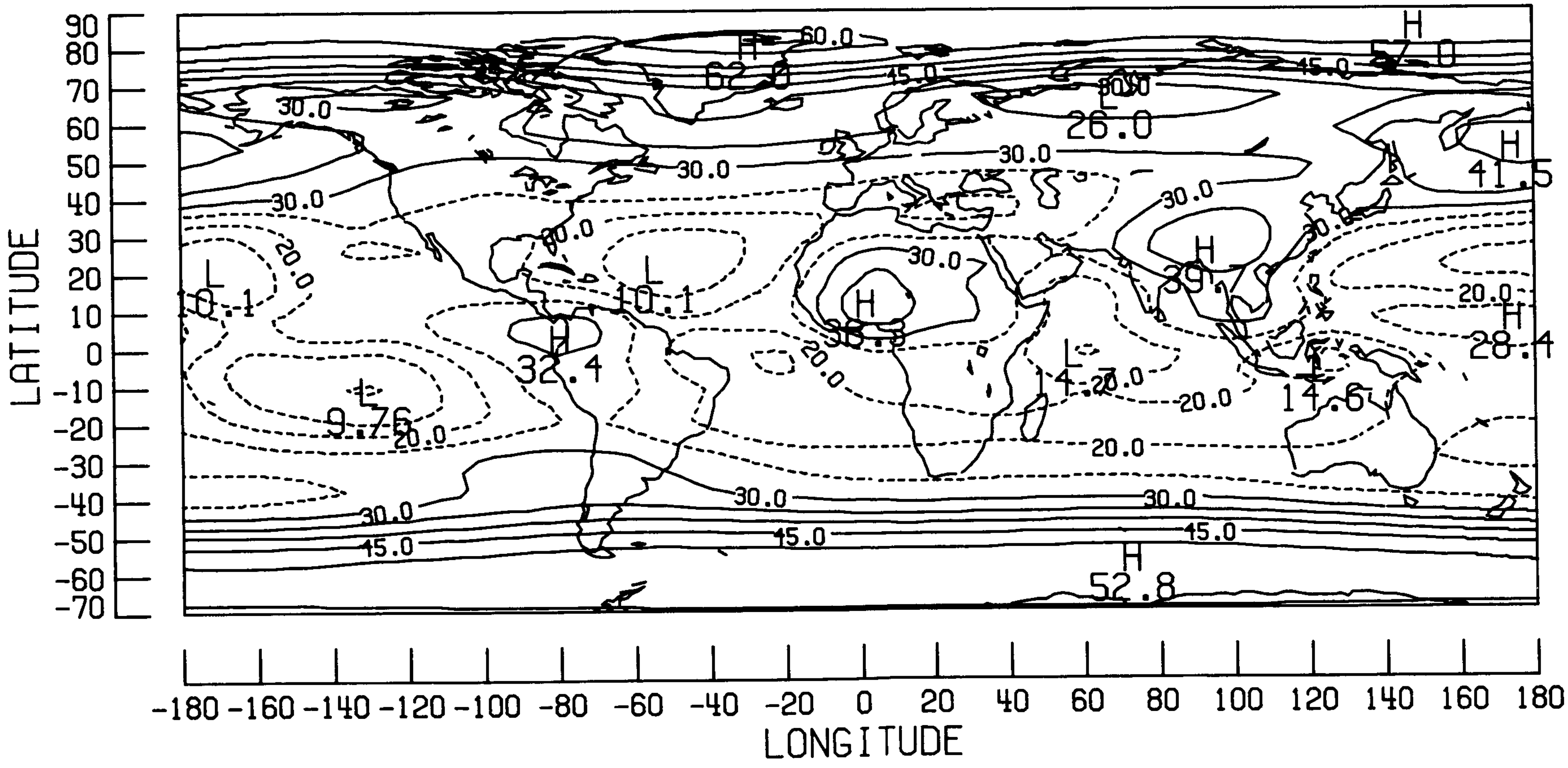
ALBEDO (%)
JUN 1982



ABSORPTION W/(M*M)
JUN 1982

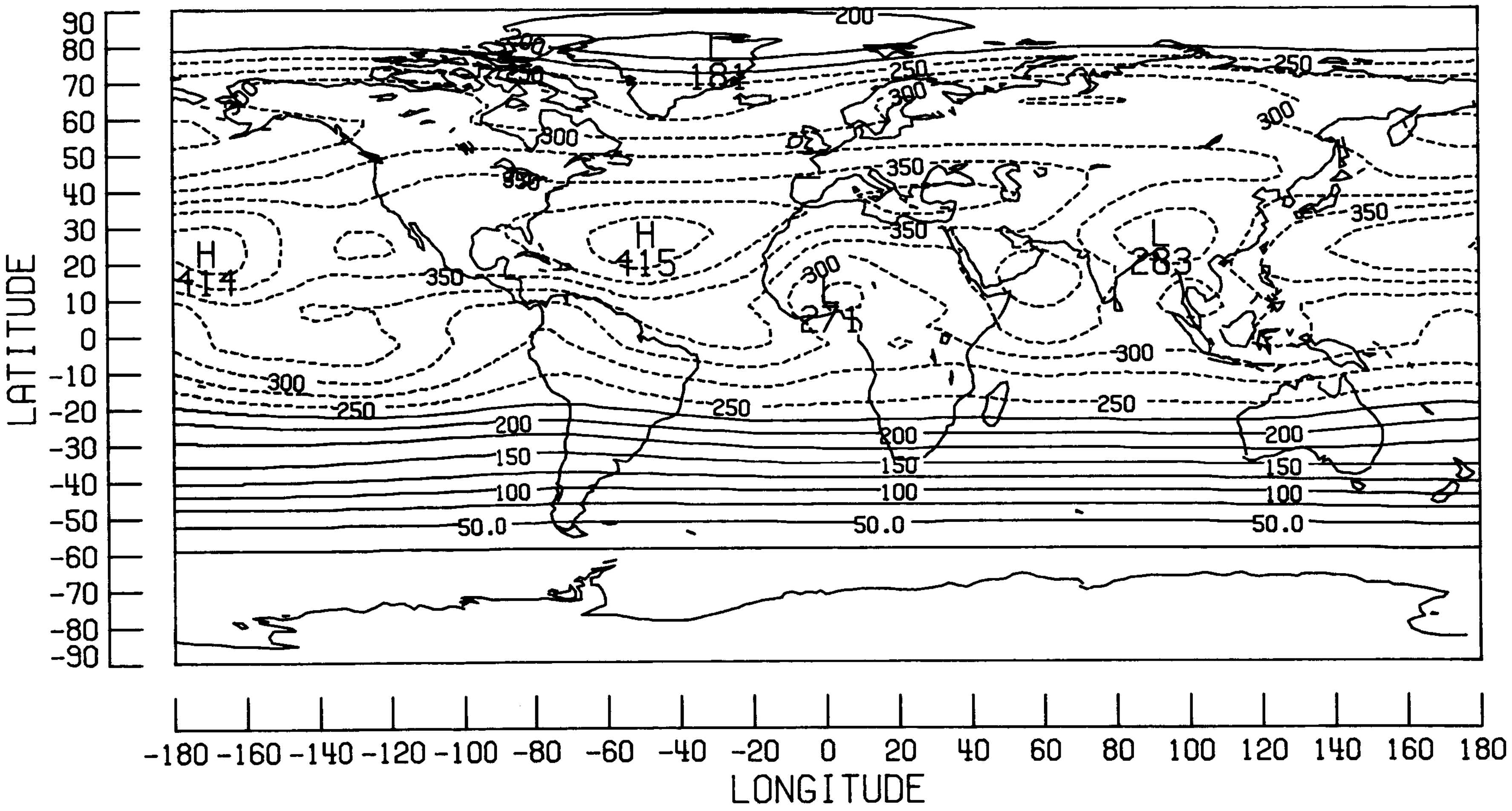
ALBEDO (%)

JUL 1982



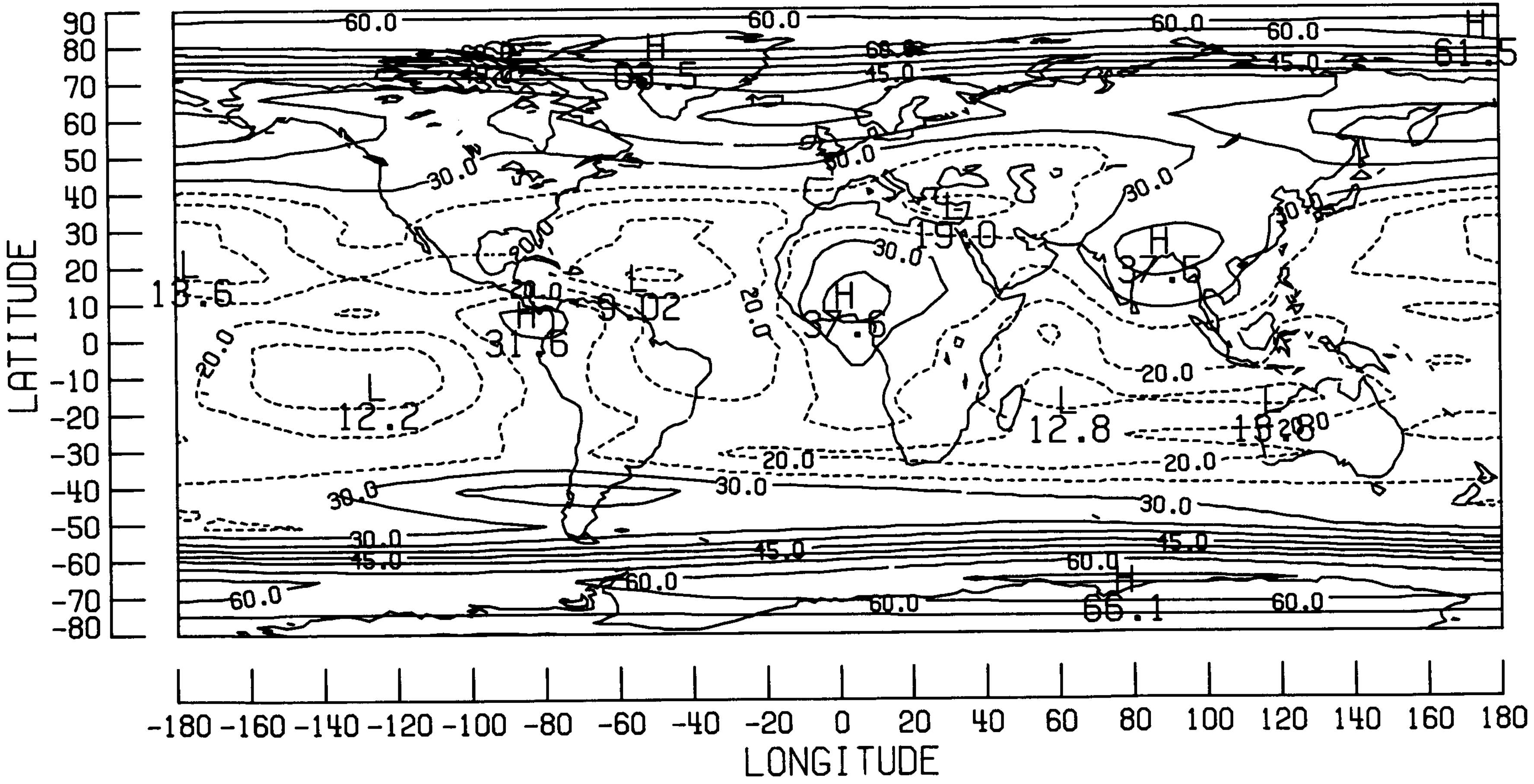
ABSORPTION W/(M*M)

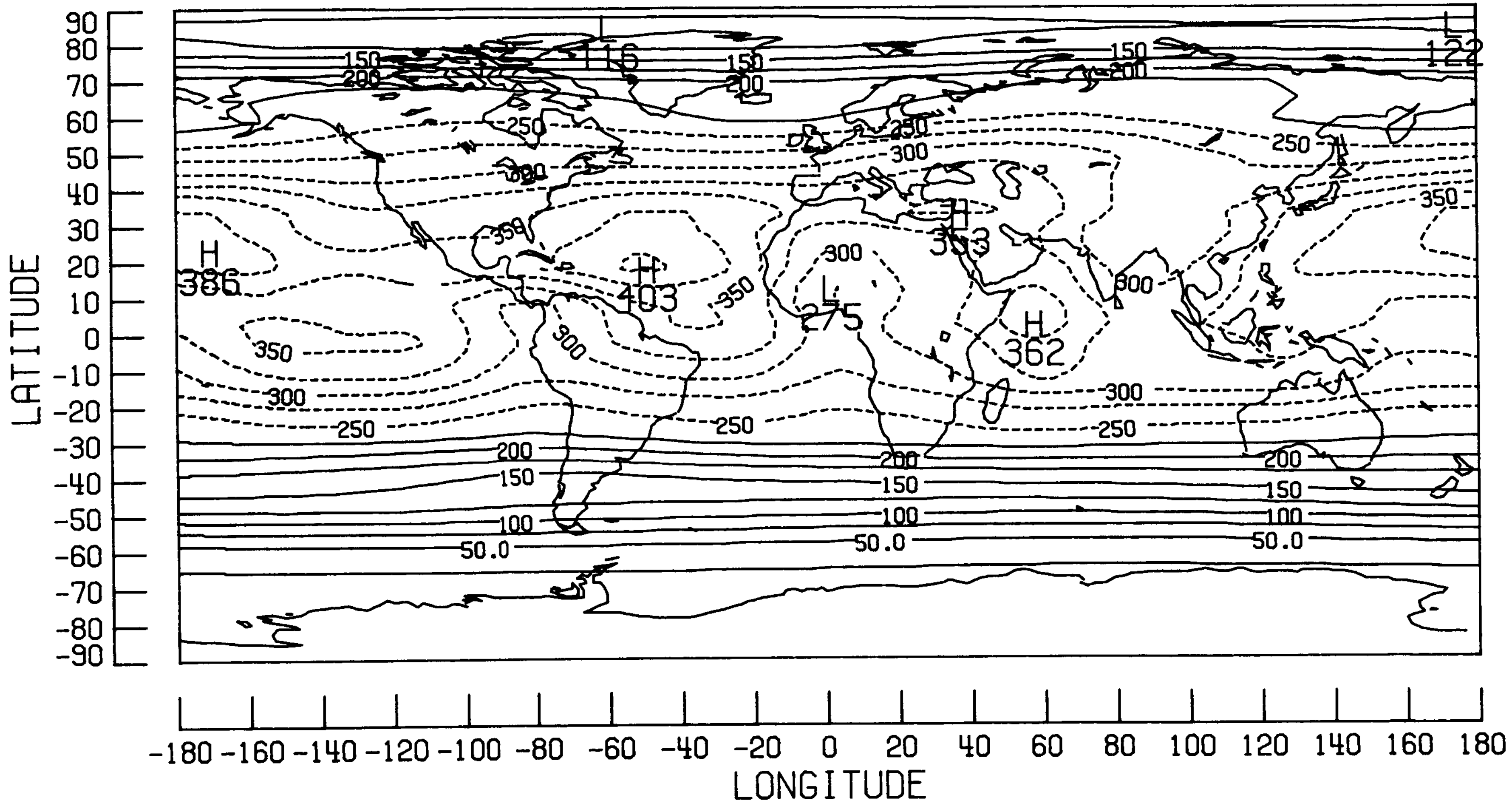
JUL 1982



ALBEDO (%)

AUG 1982



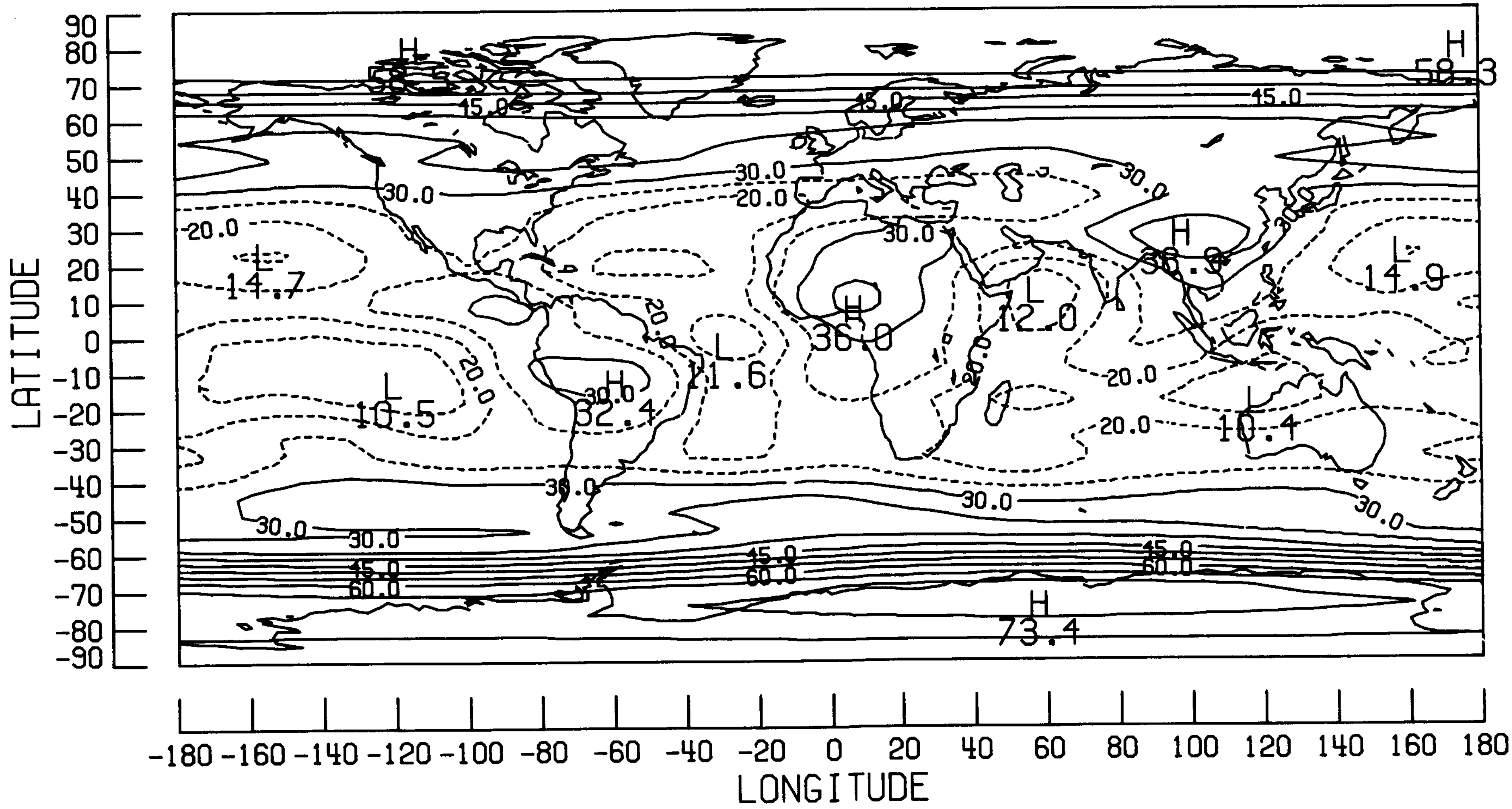


ABSORPTION W/(M*M)

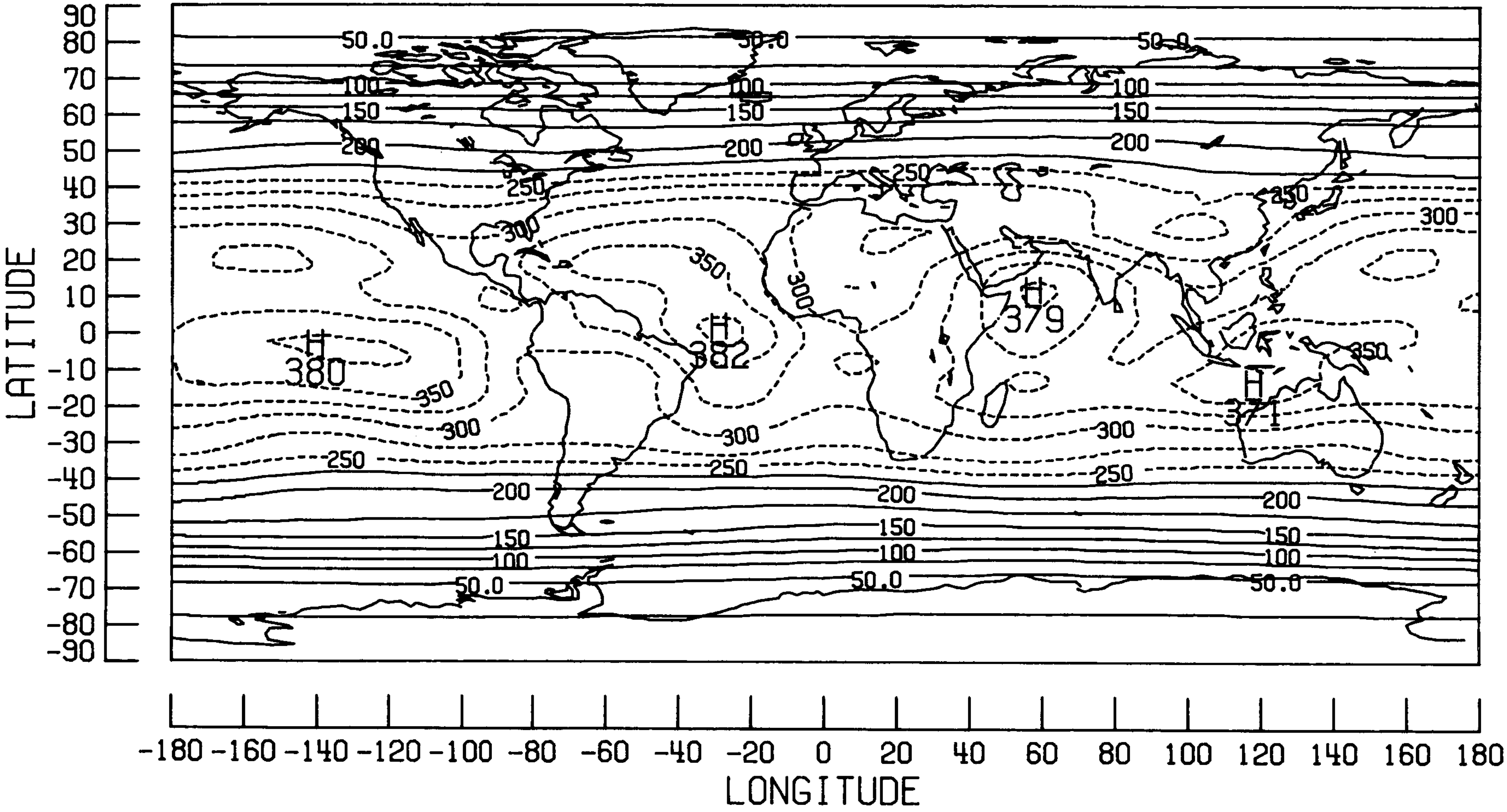
AUG 1982

ALBEDO (%)

SEP 1982

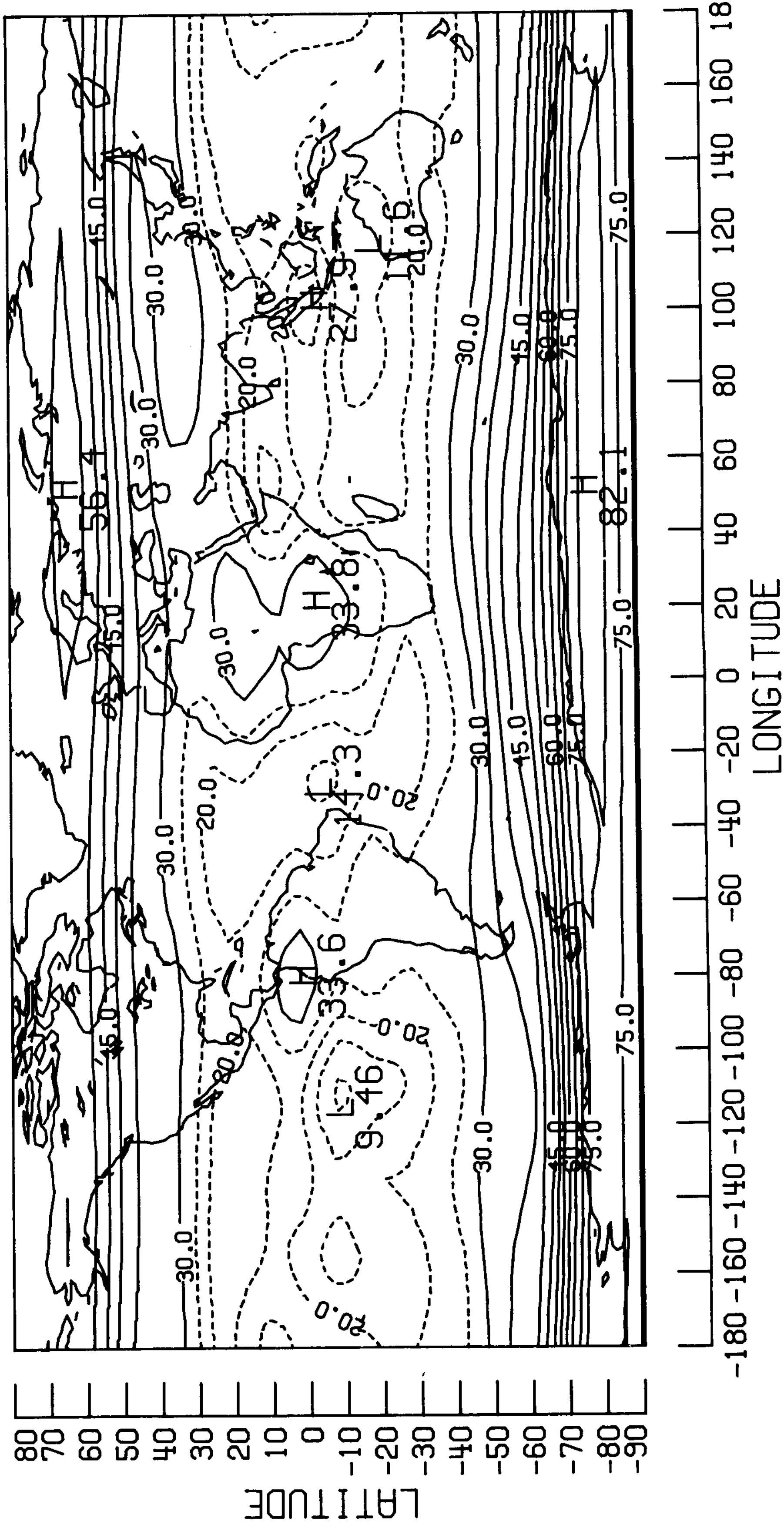


ABSORPTION W/(M*M)
SEP 1982



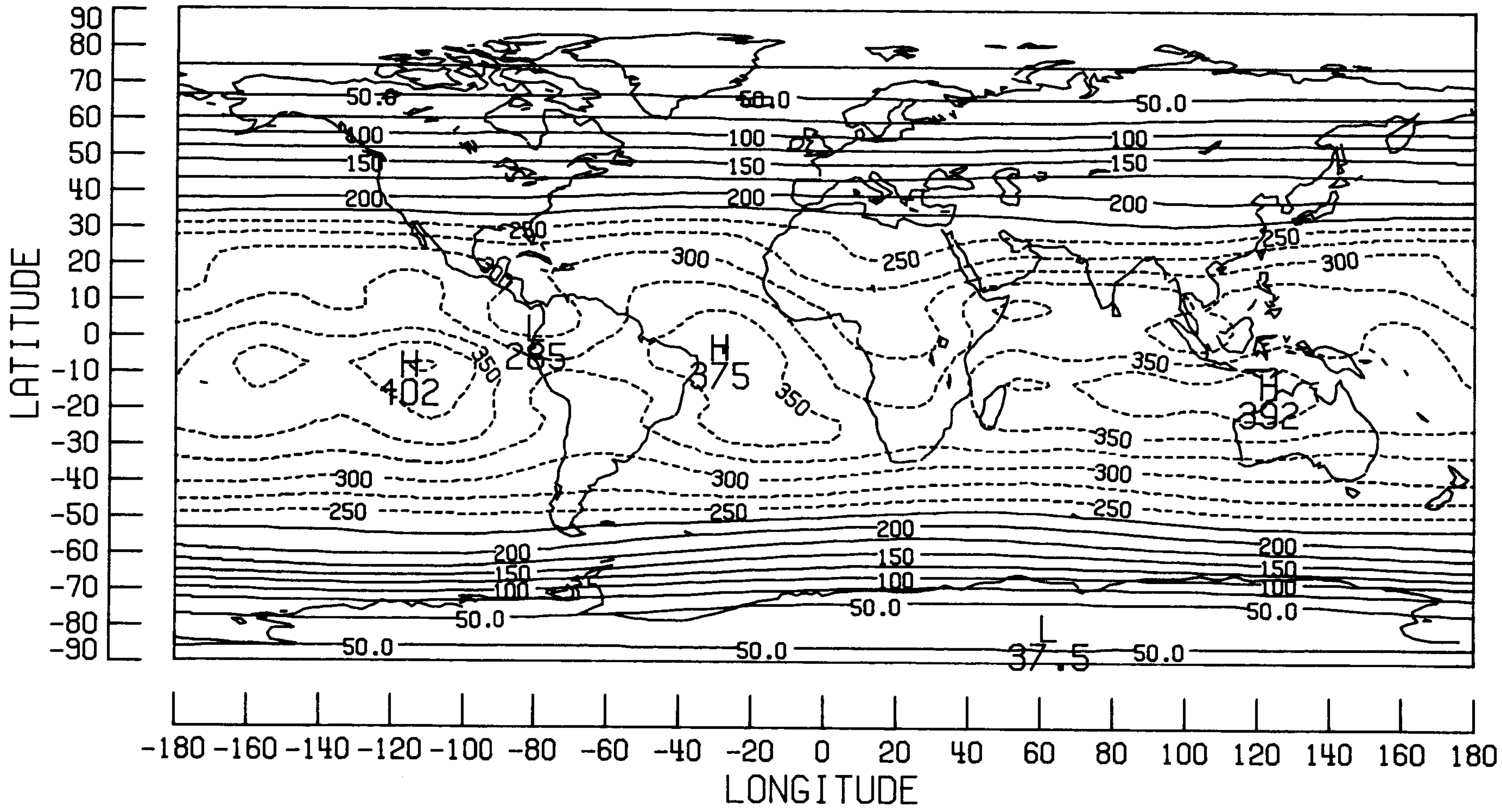
ALBEDO (%)

OCT 1982



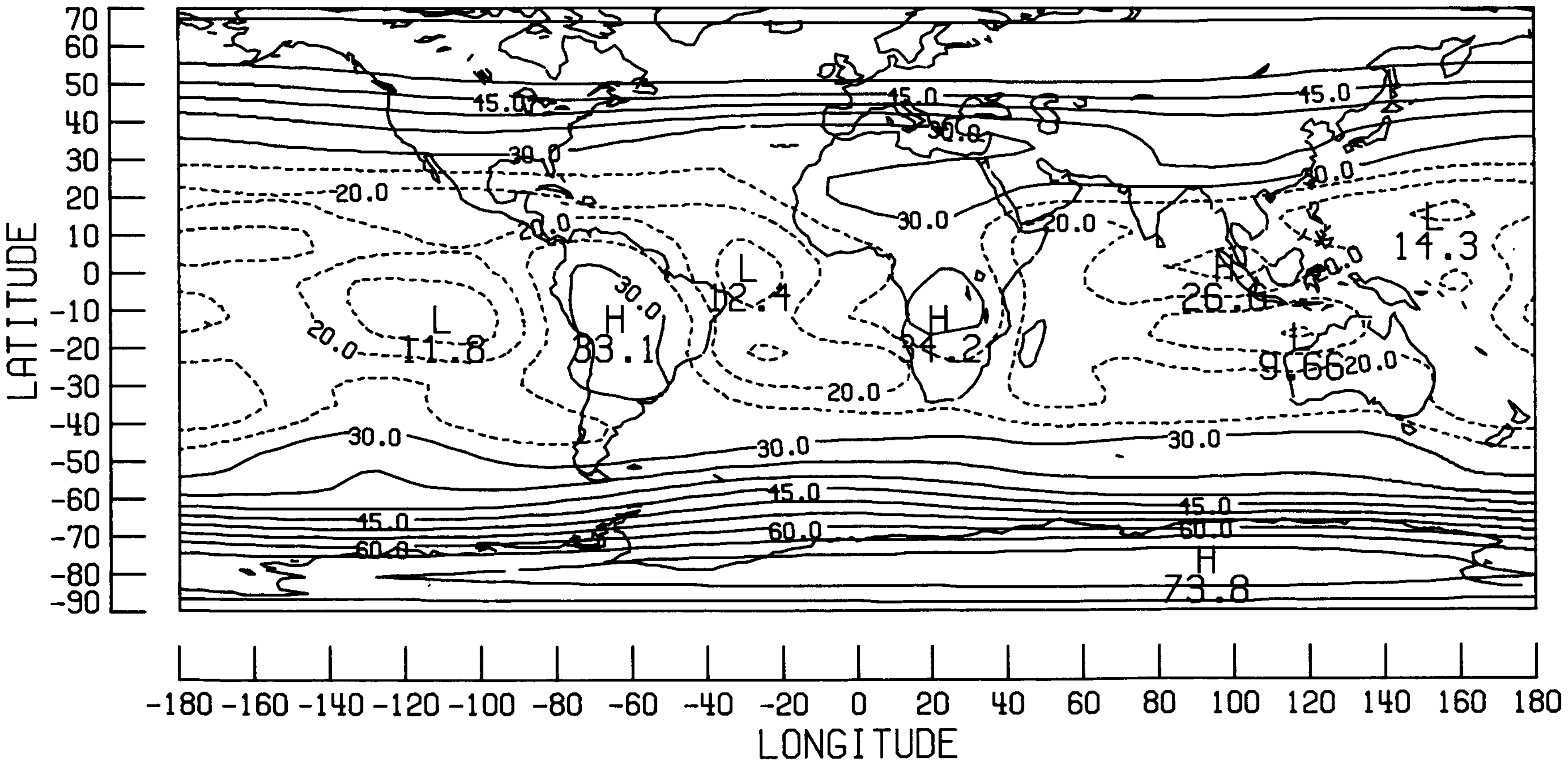
ABSORPTION W/(M*M)

OCT 1982



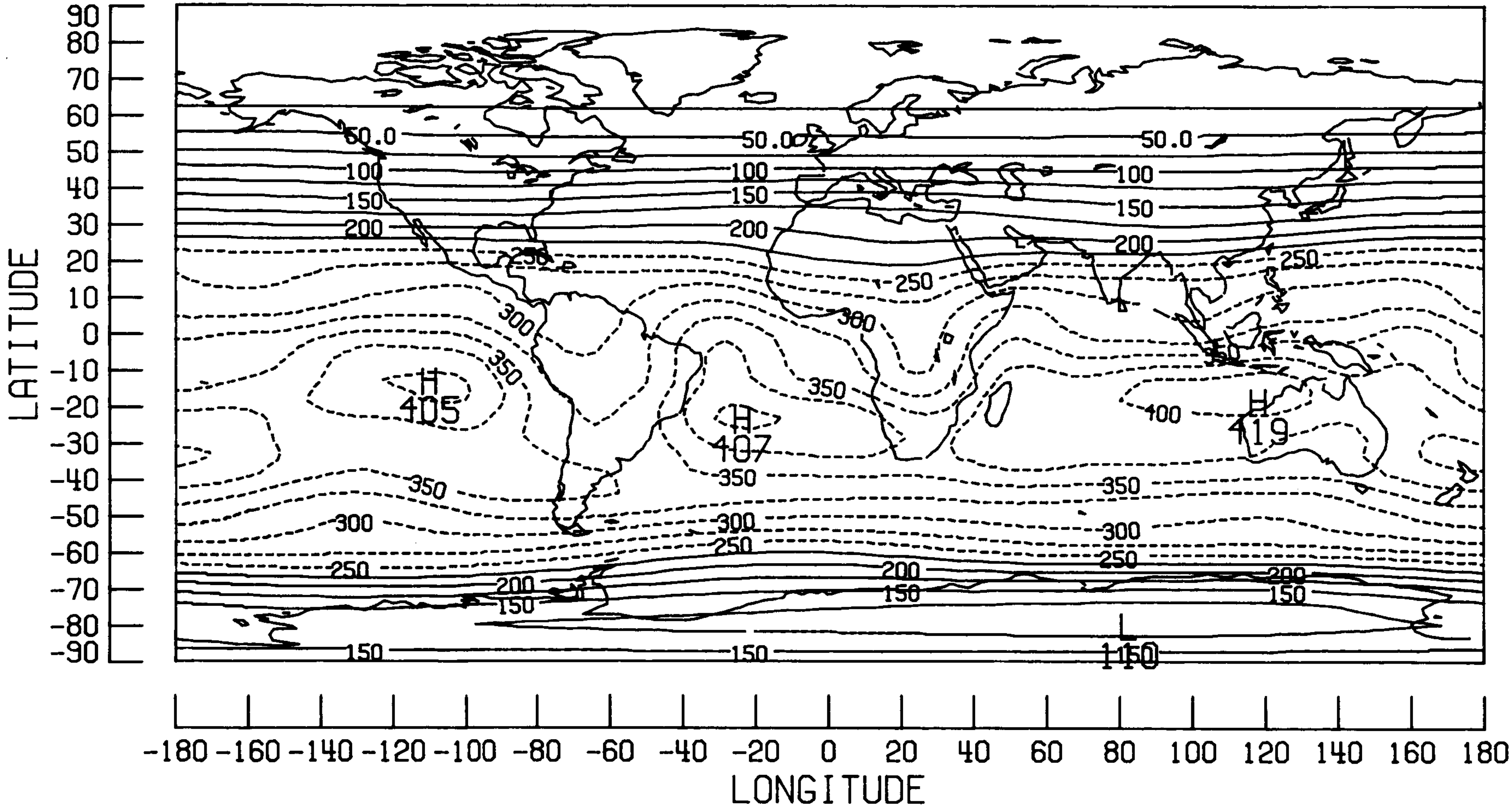
ALBEDO (%)

NOV 1982

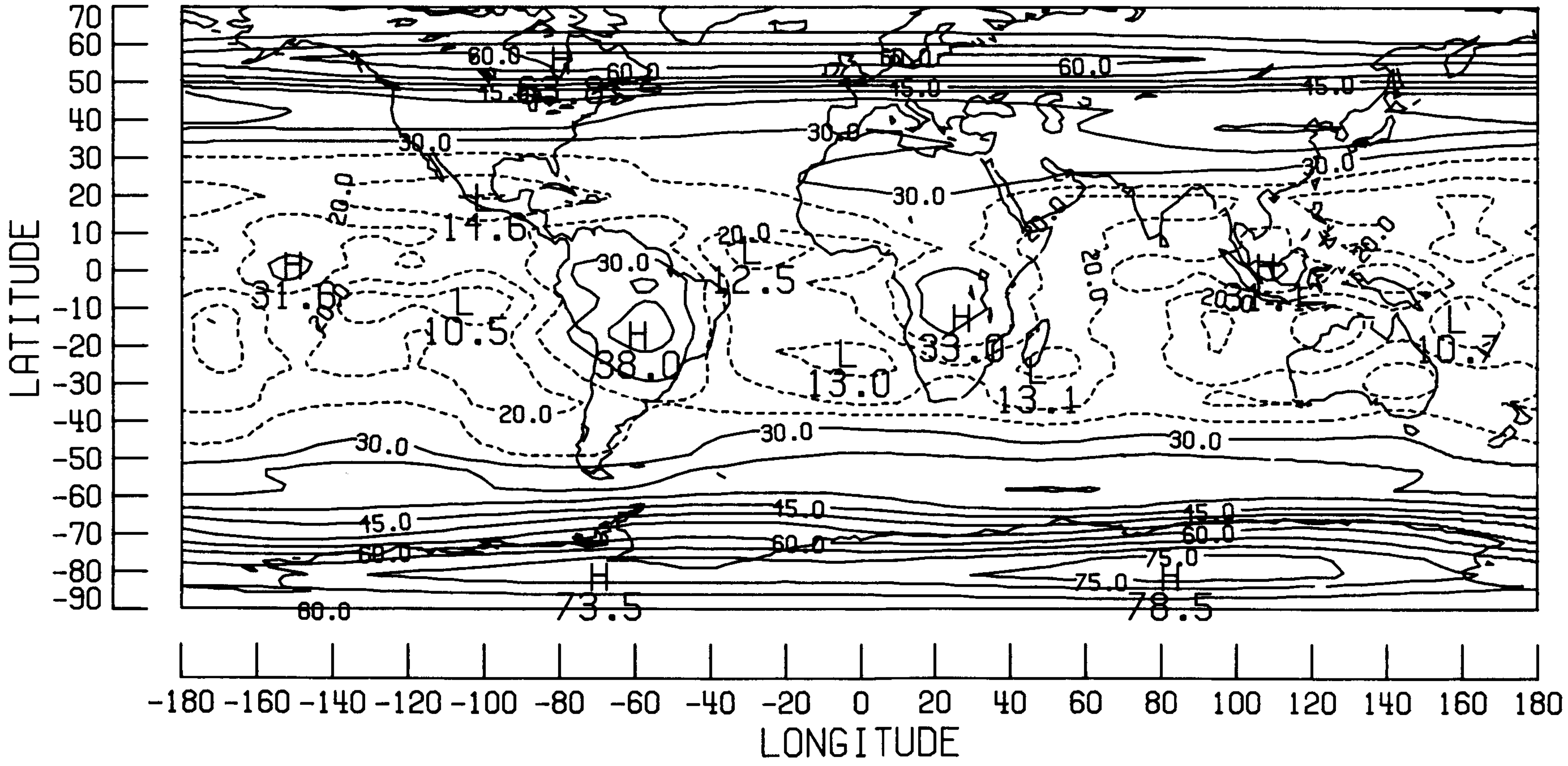


ABSORPTION W/(M*M)

NOV 1982

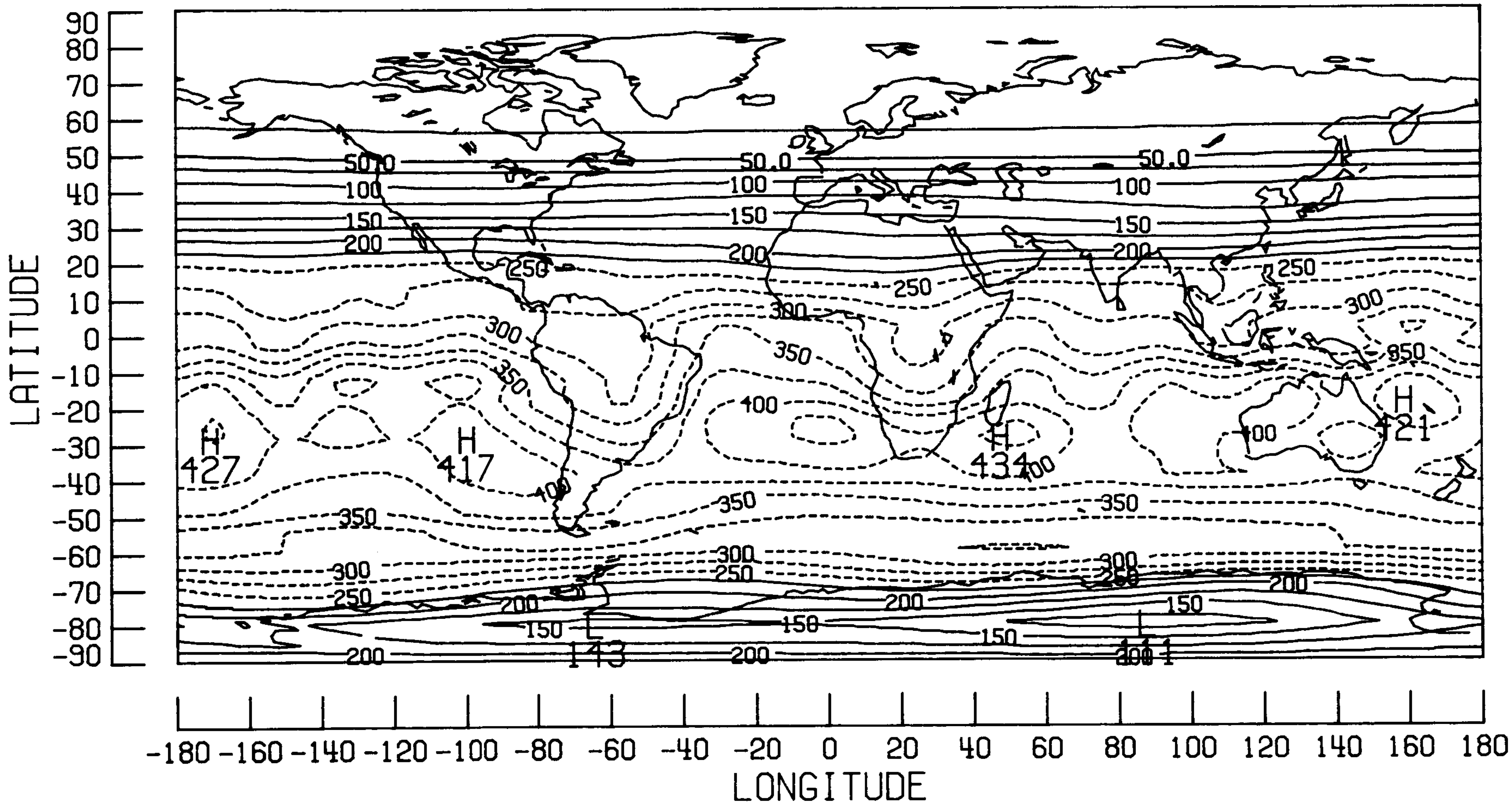


ALBEDO (%)
DEC 1982

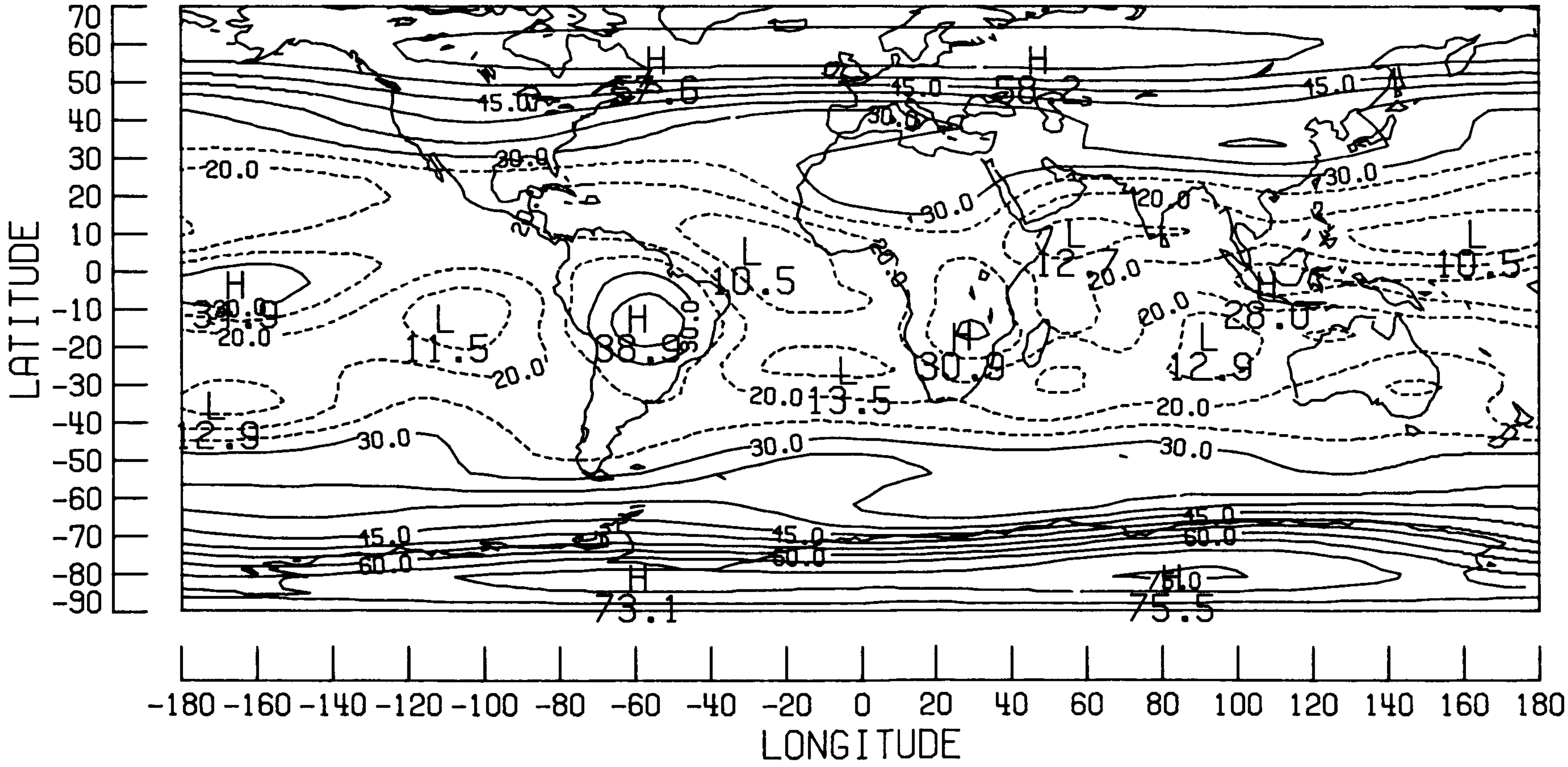


ABSORPTION W/(M*M)

DEC 1982

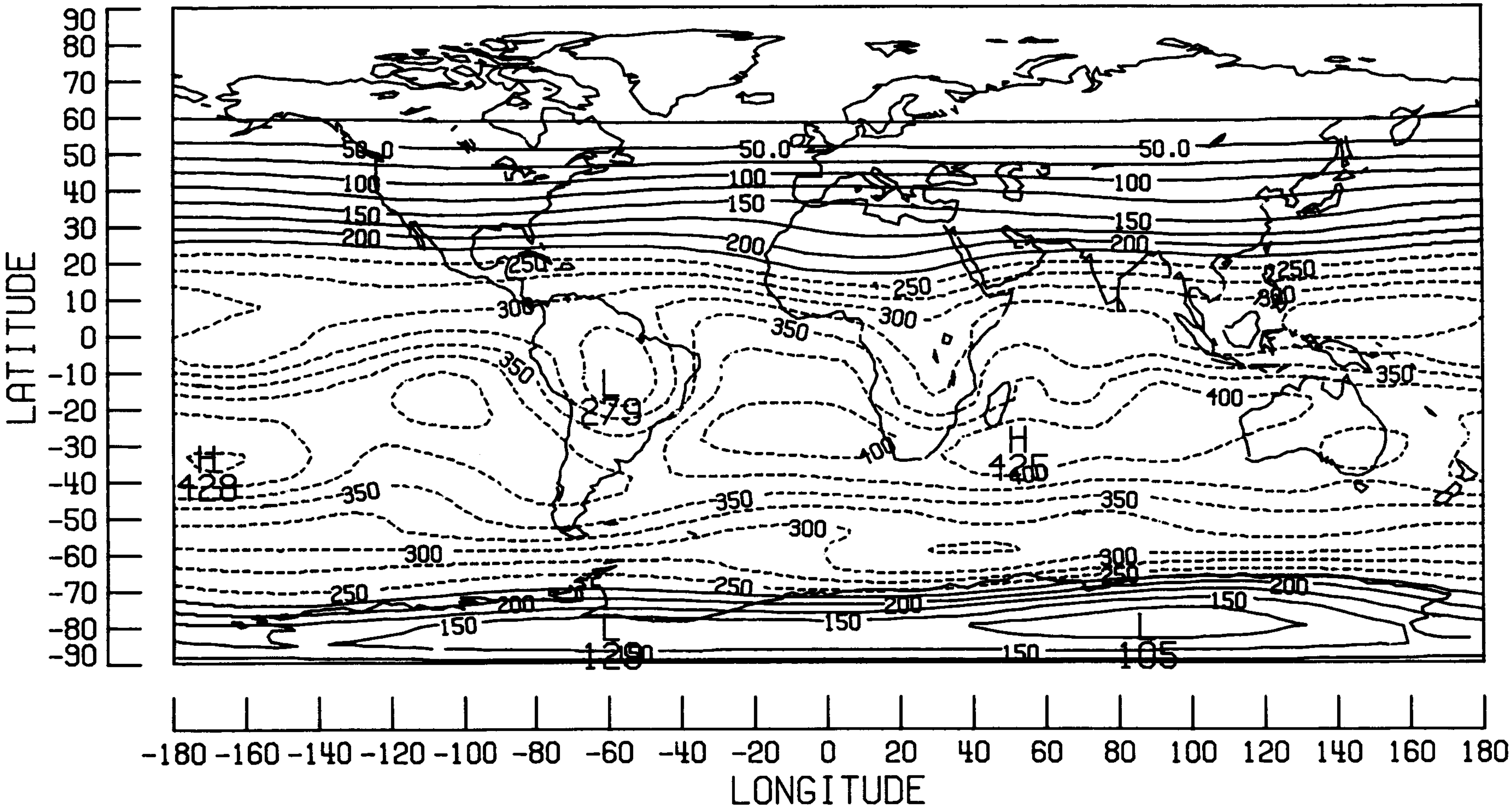


ALBEDO (%)
JAN 1983



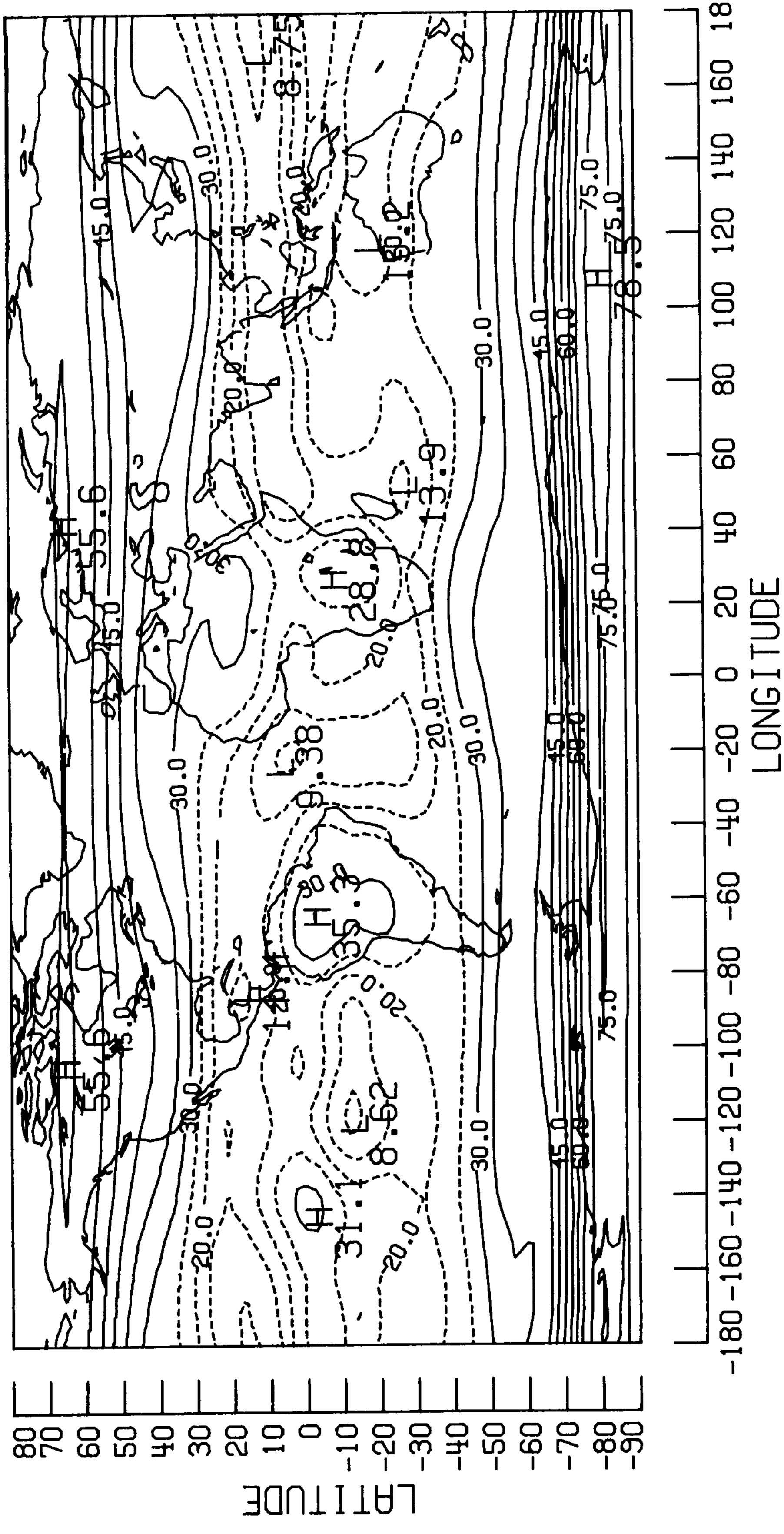
ABSORPTION W/(M*M)

JAN 1983



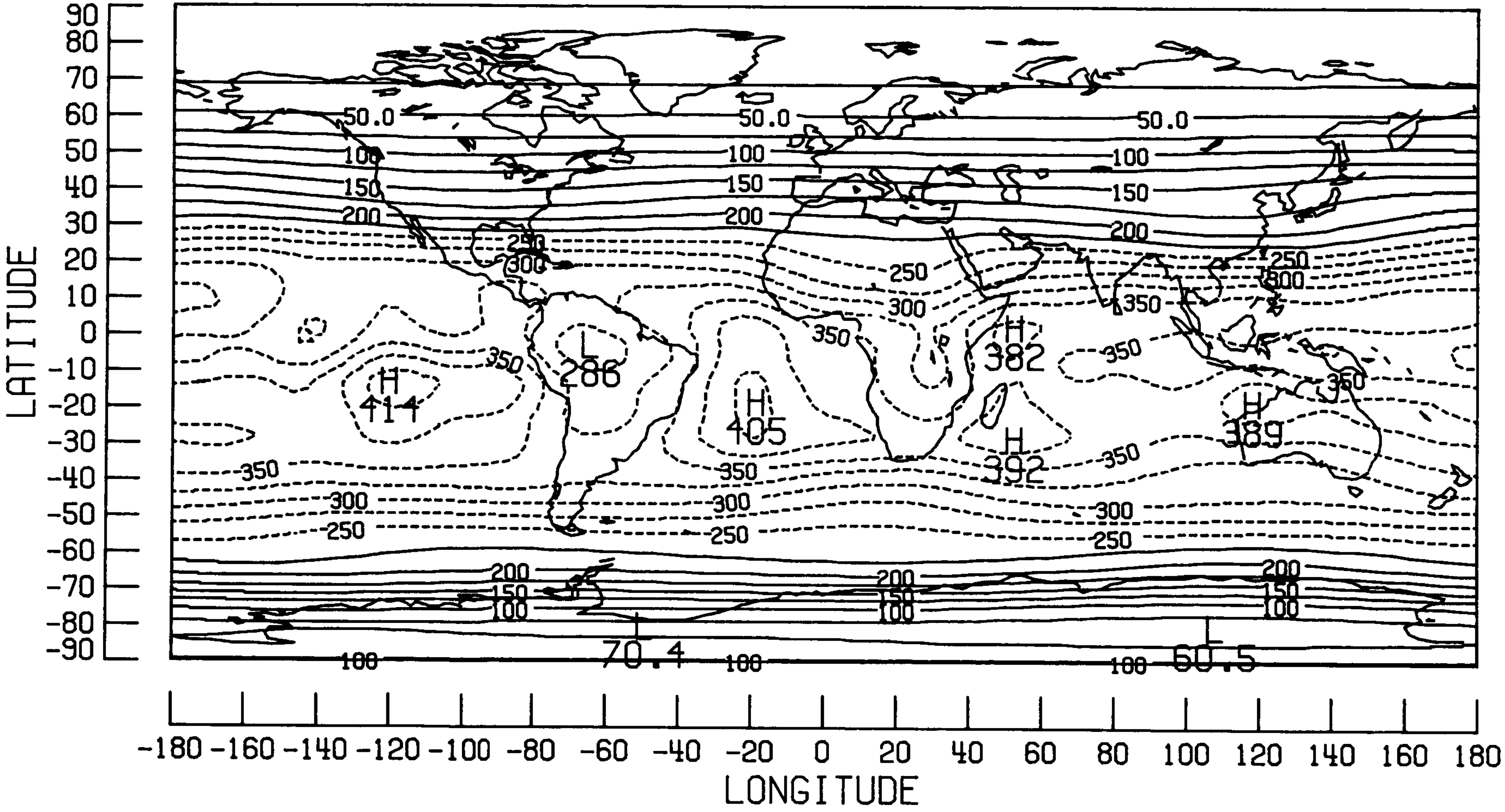
ALBEDO (%)

FEB 1983



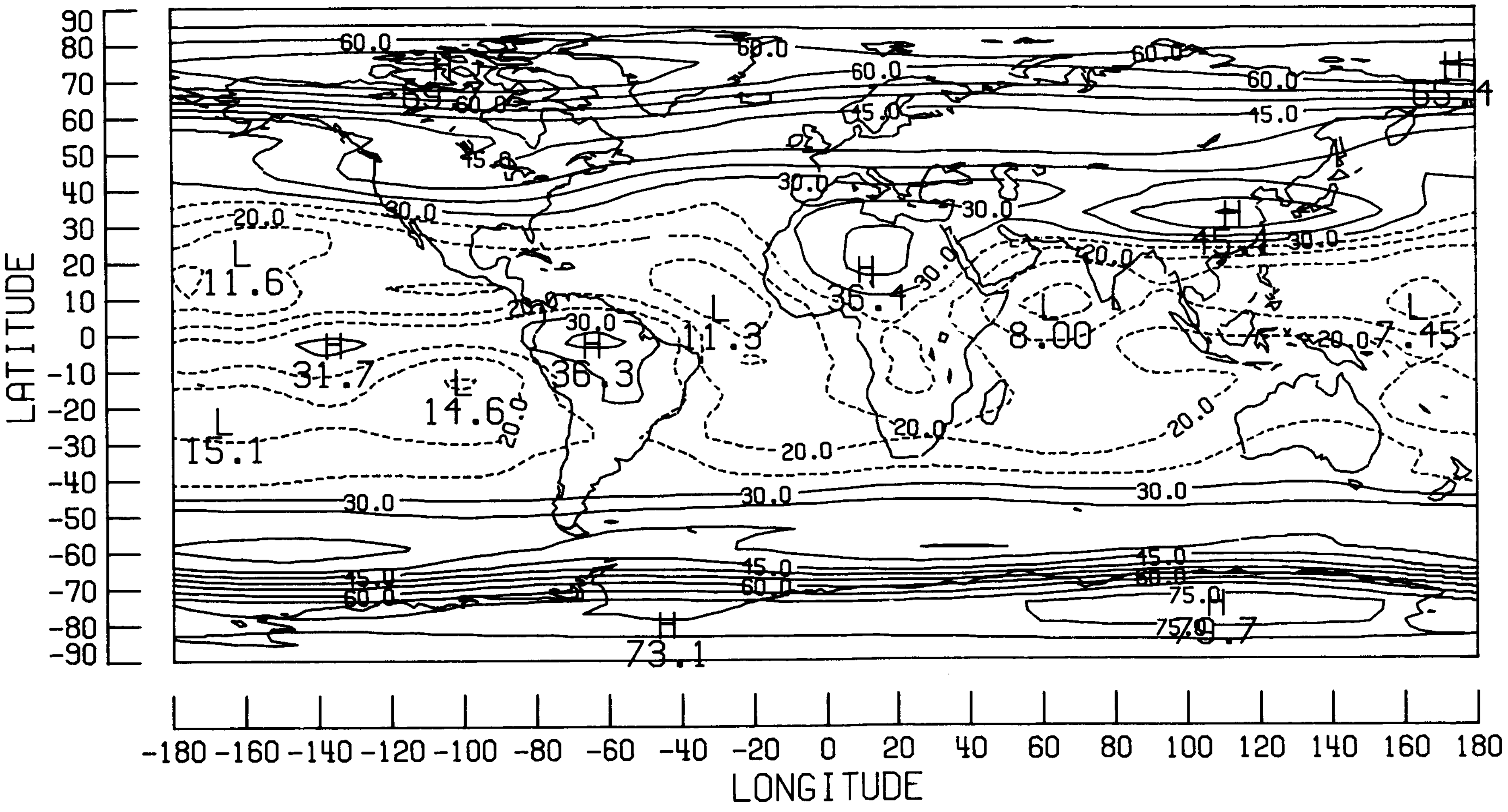
ABSORPTION W/(M*M)

FEB 1983



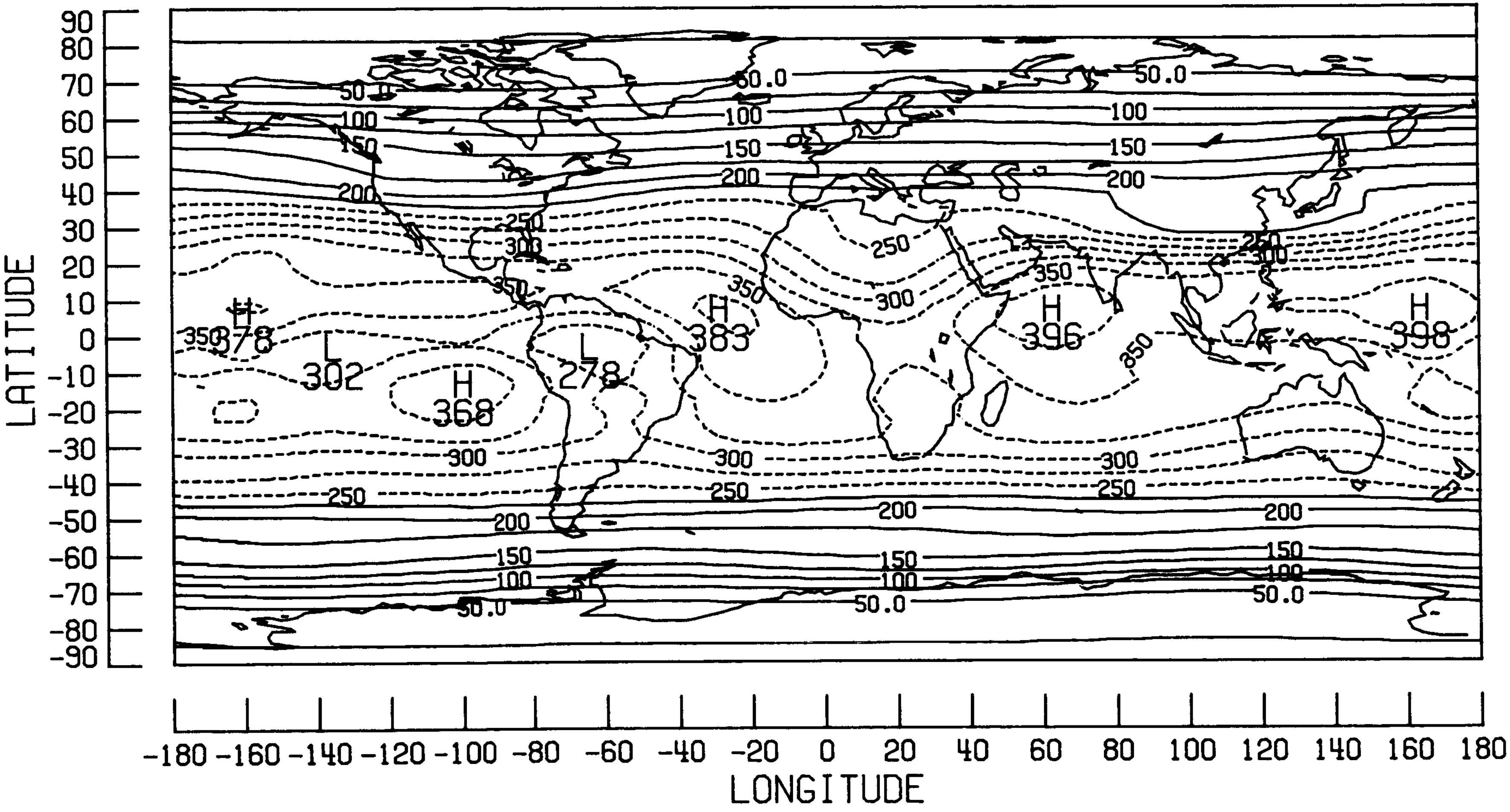
ALBEDO (%)

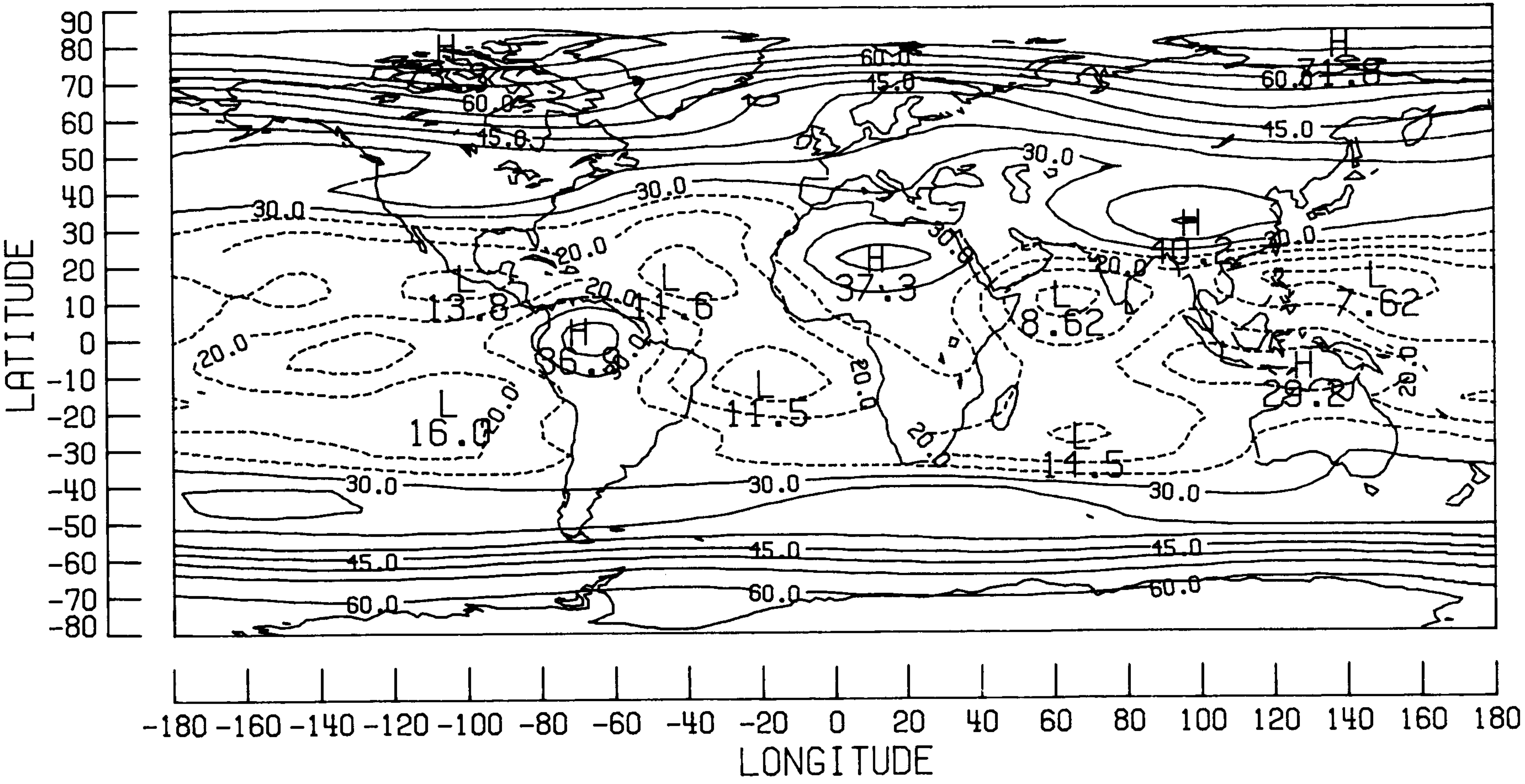
MAR 1983



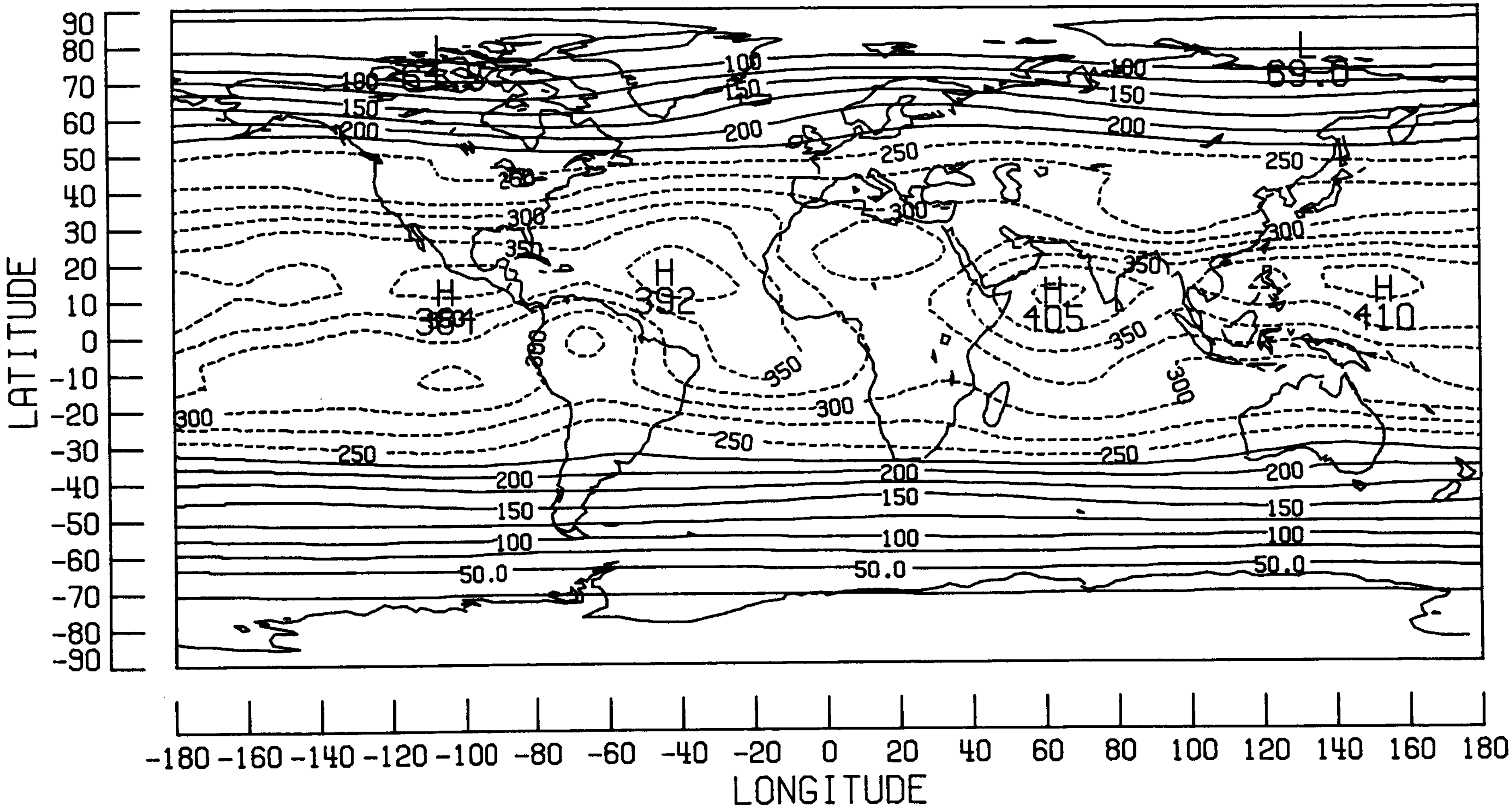
ABSORPTION W/(M*M)

MAR 1983





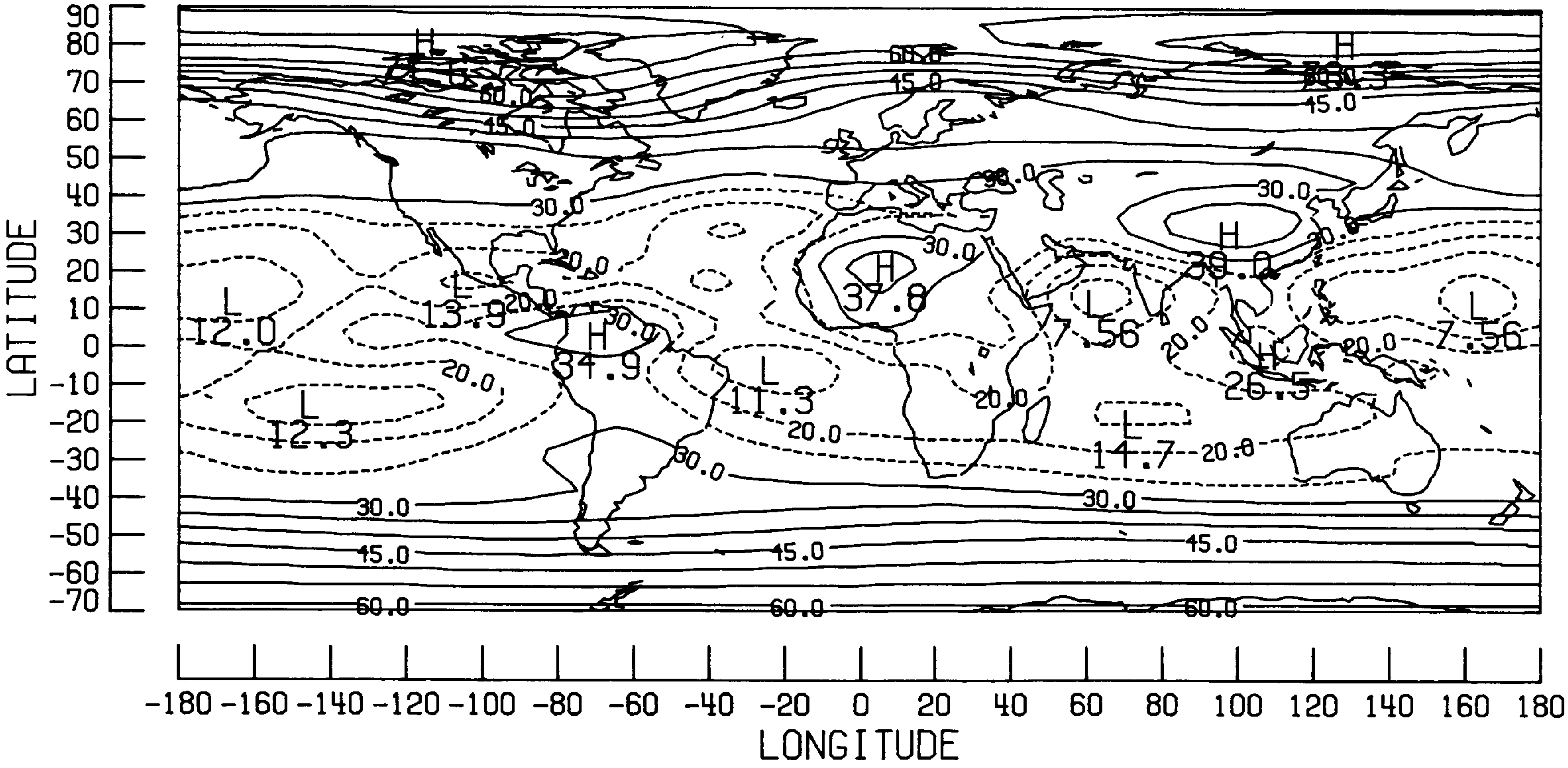
ALBEDO (%)
APR 1983



ABSORPTION W/(M*M)

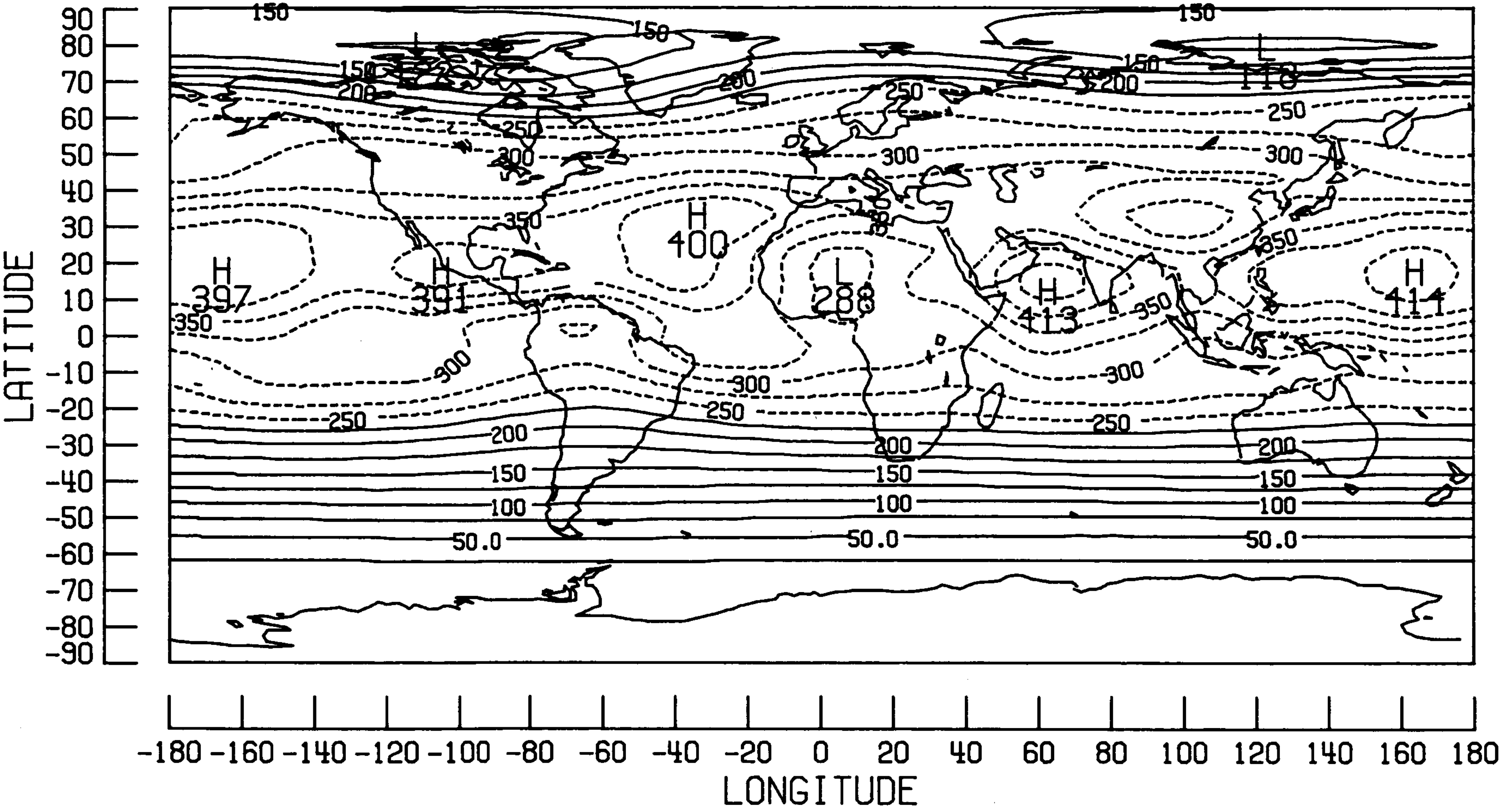
APR 1983

ALBEDO (%)
MAY 1983

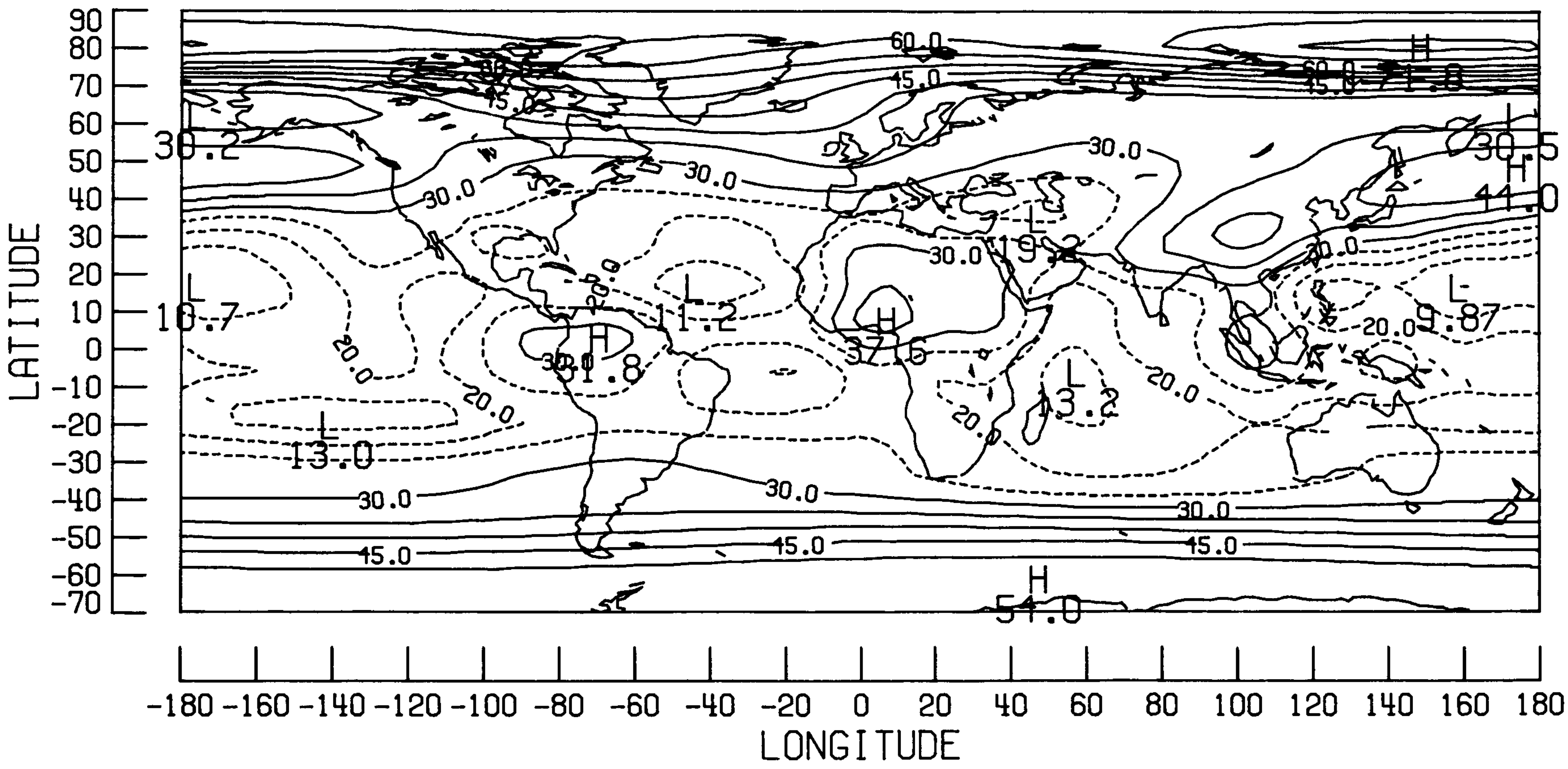


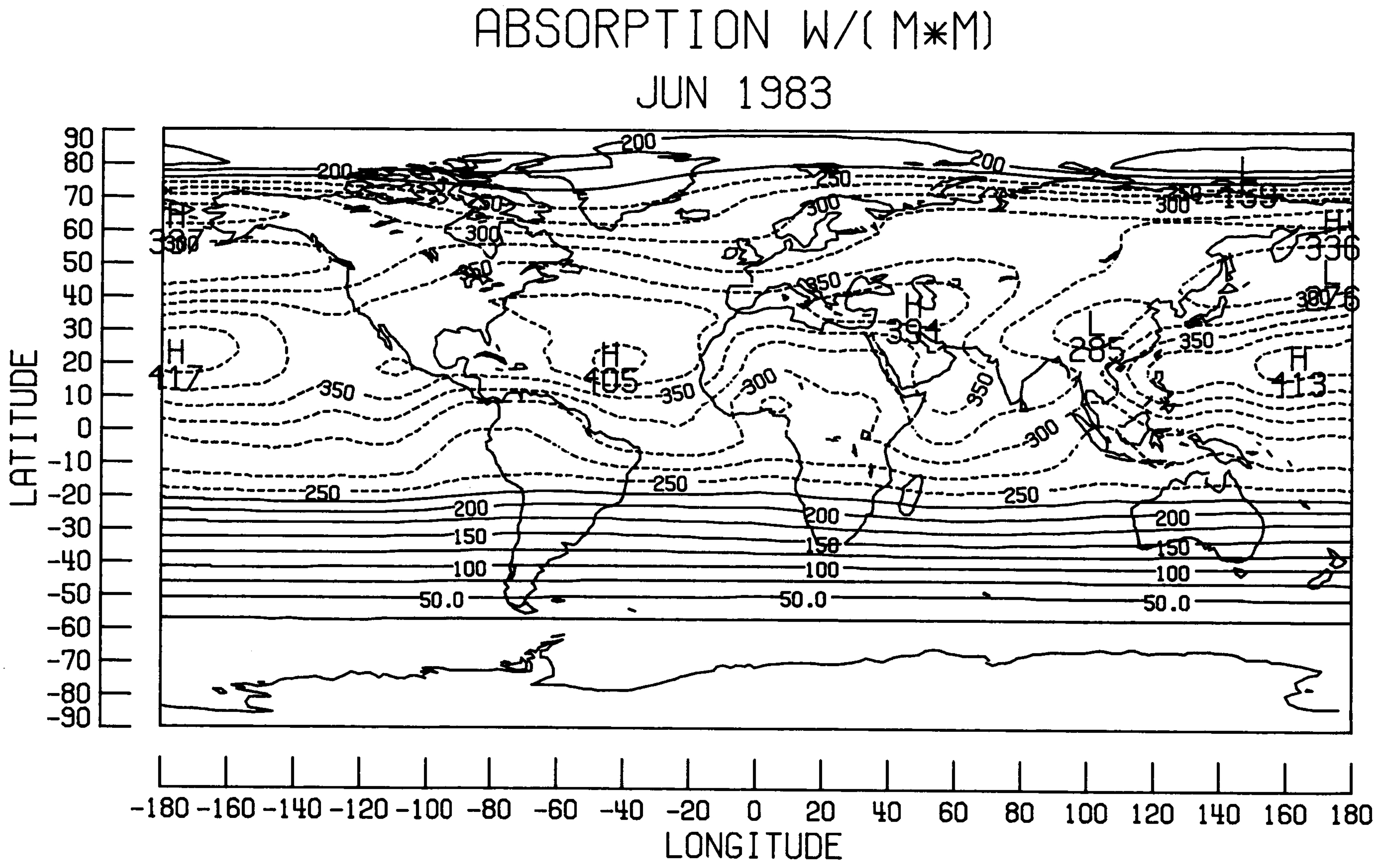
ABSORPTION W/(M*M)

MAY 1983

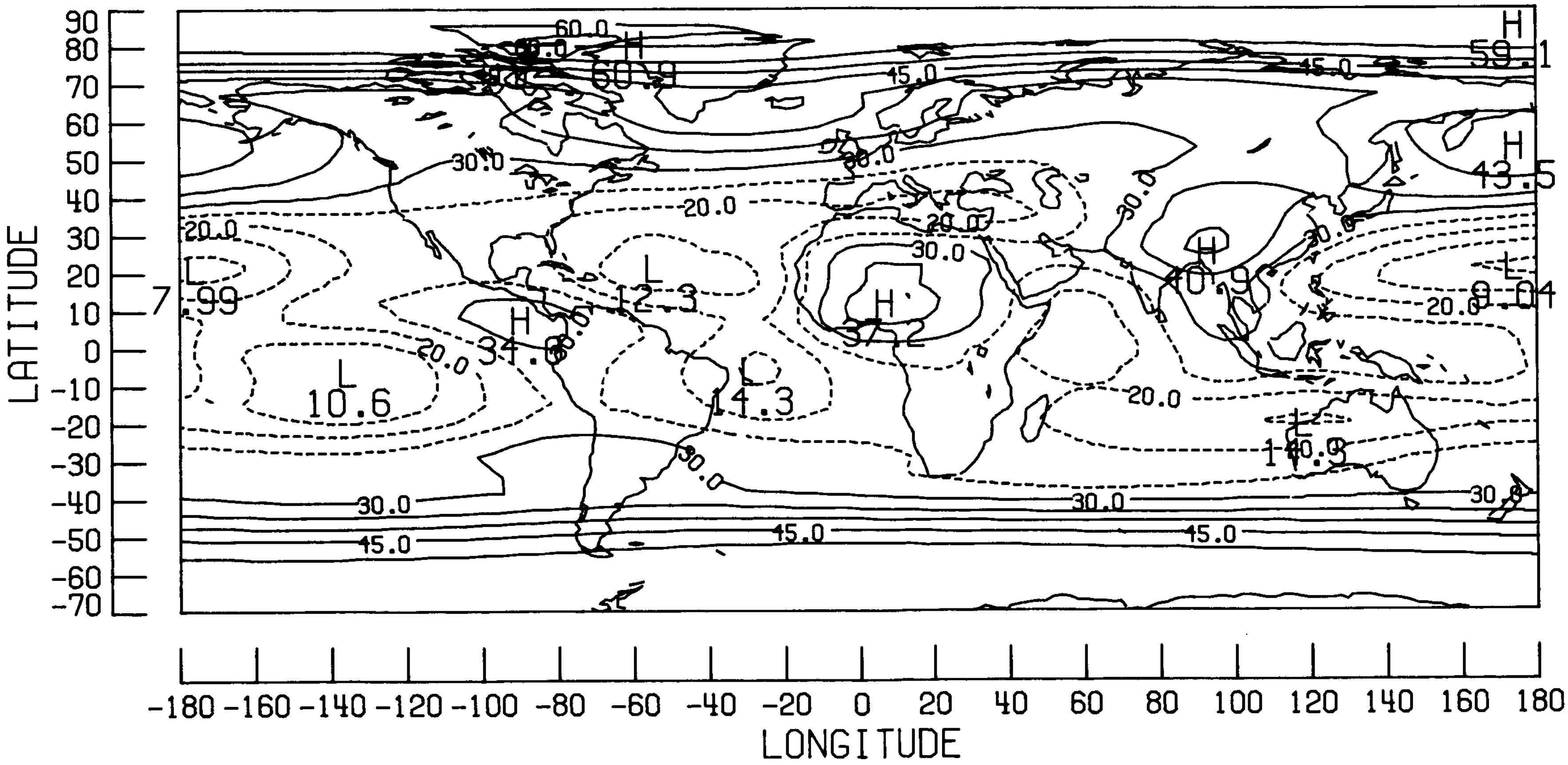


ALBEDO (%)
JUN 1983



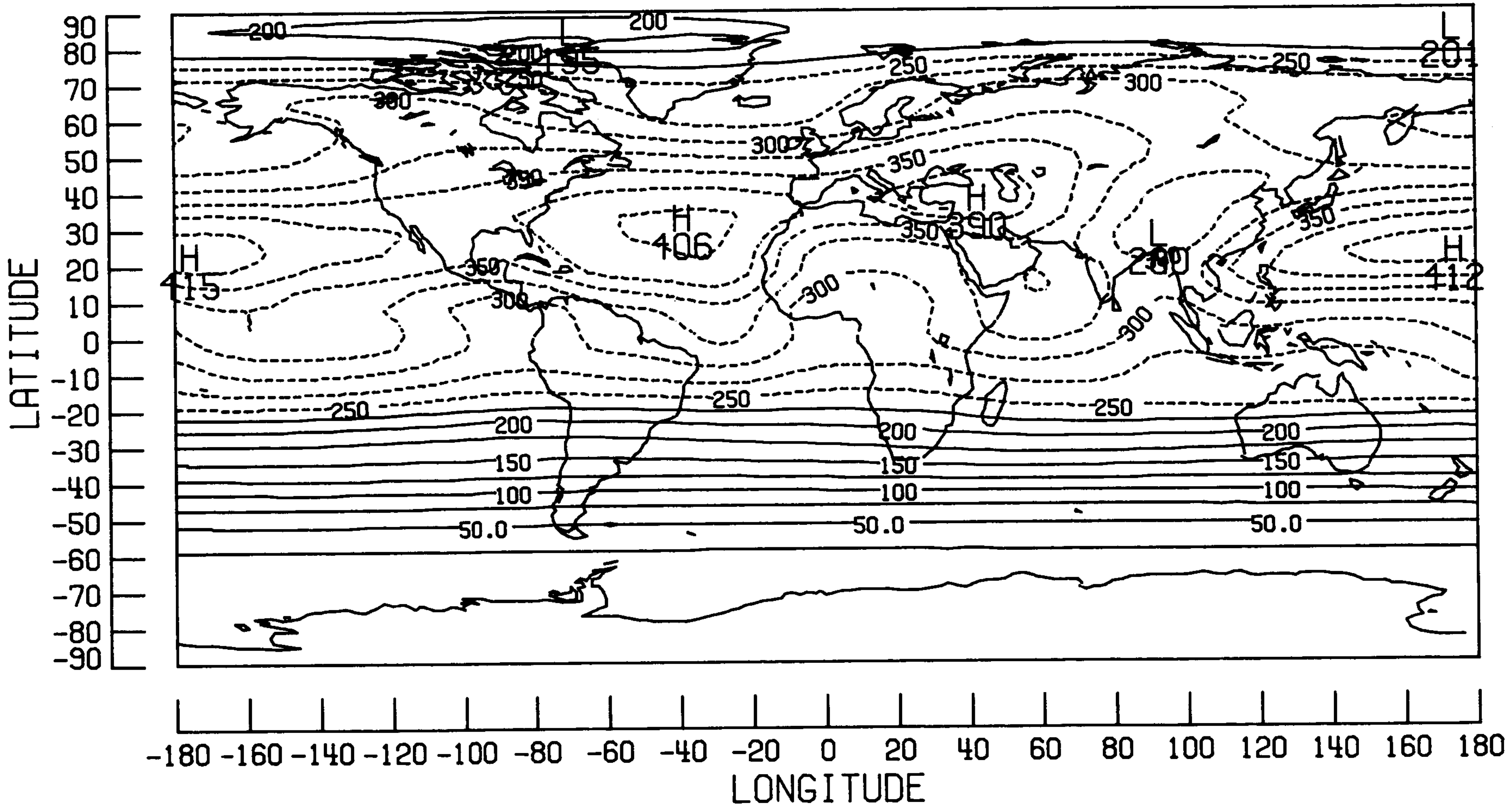

ABSORPTION W/(M*M)
JUN 1983
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
H
417
H
405
H
394
L
285
H
413
H
336
H
337
50.0
100
150
200
250
300
350

ALBEDO (%)
JUL 1983



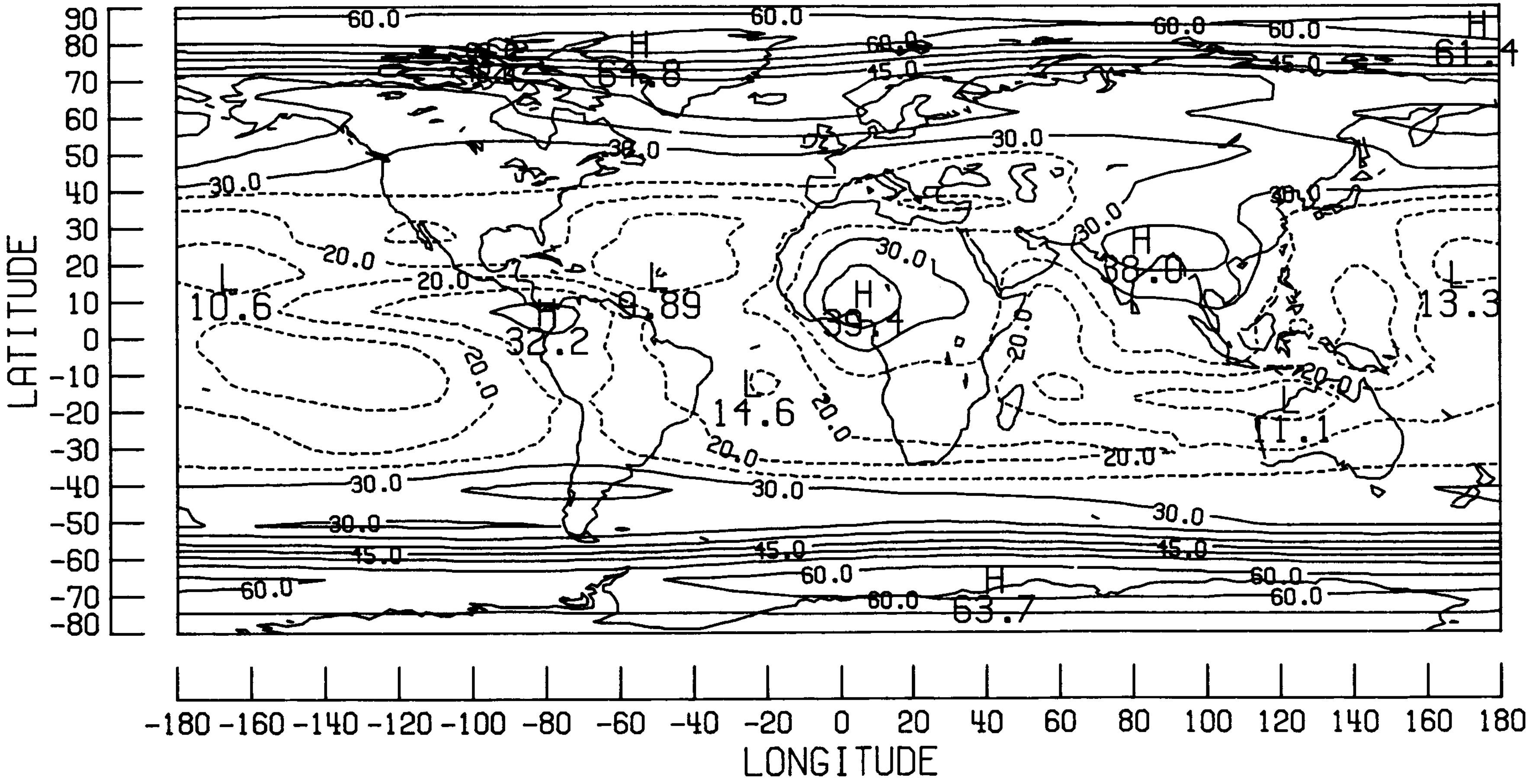
ABSORPTION W/(M*M)

JUL 1983



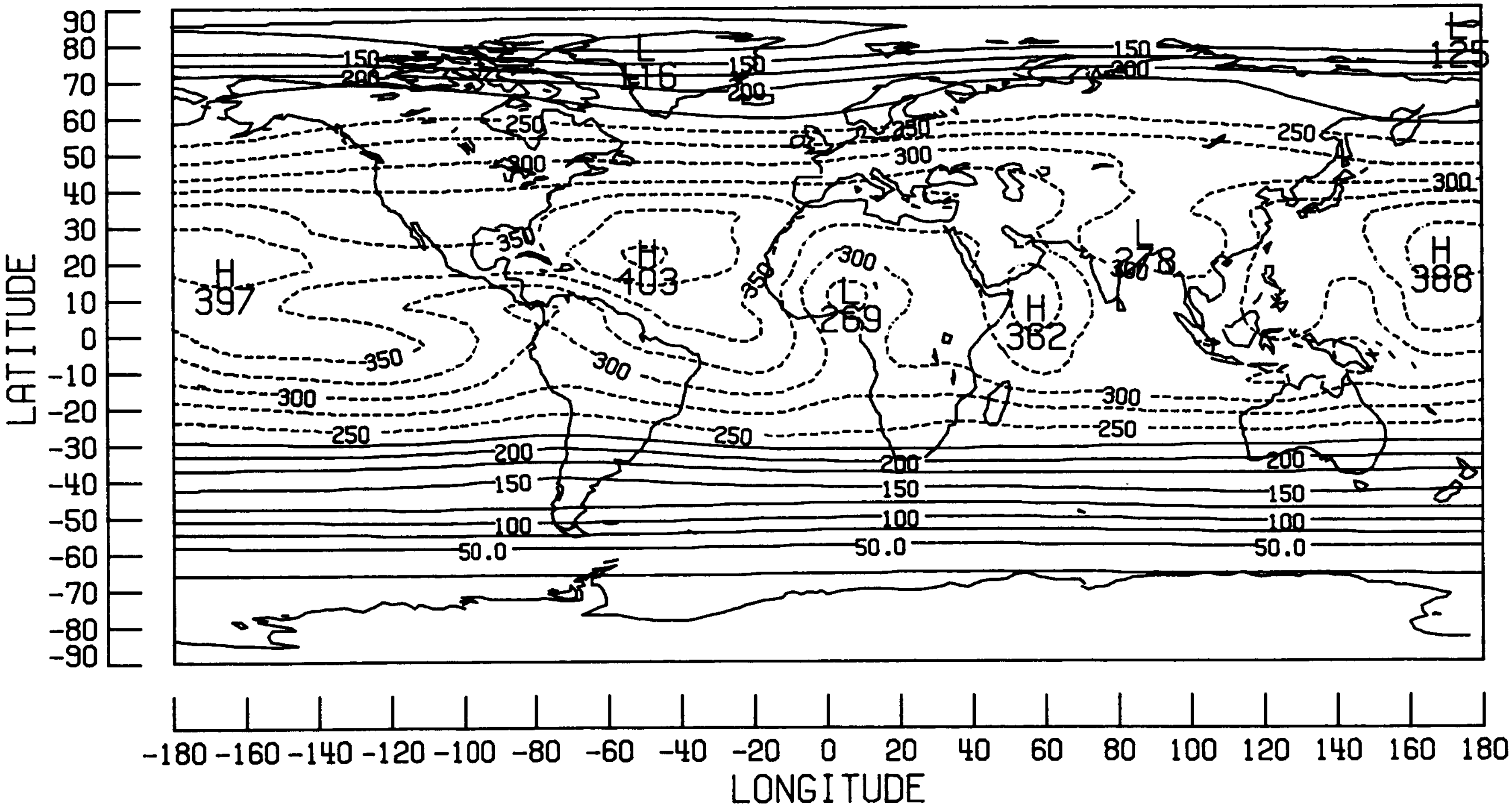
ALBEDO (%)

AUG 1983



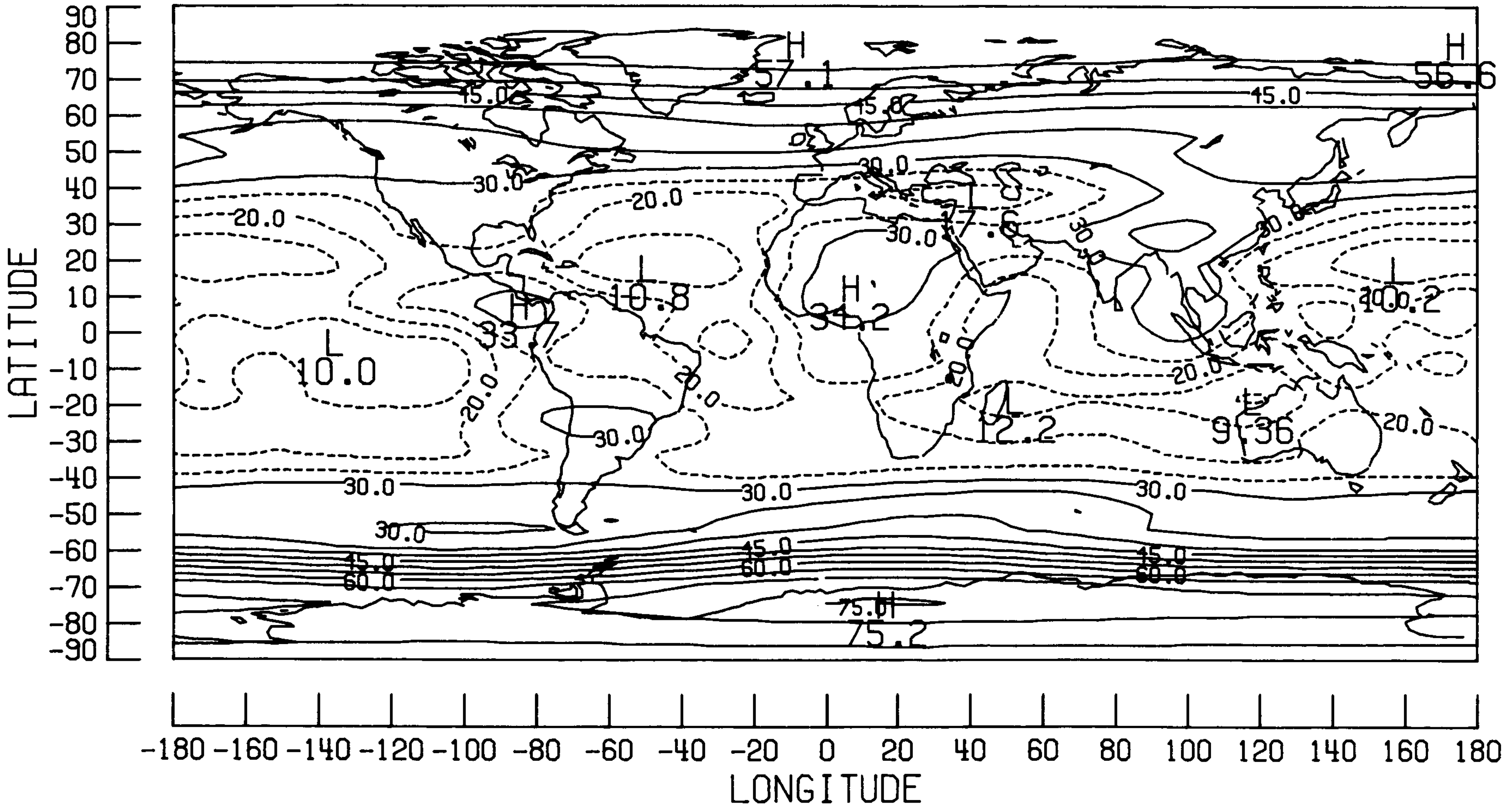
ABSORPTION W/(M*M)

AUG 1983



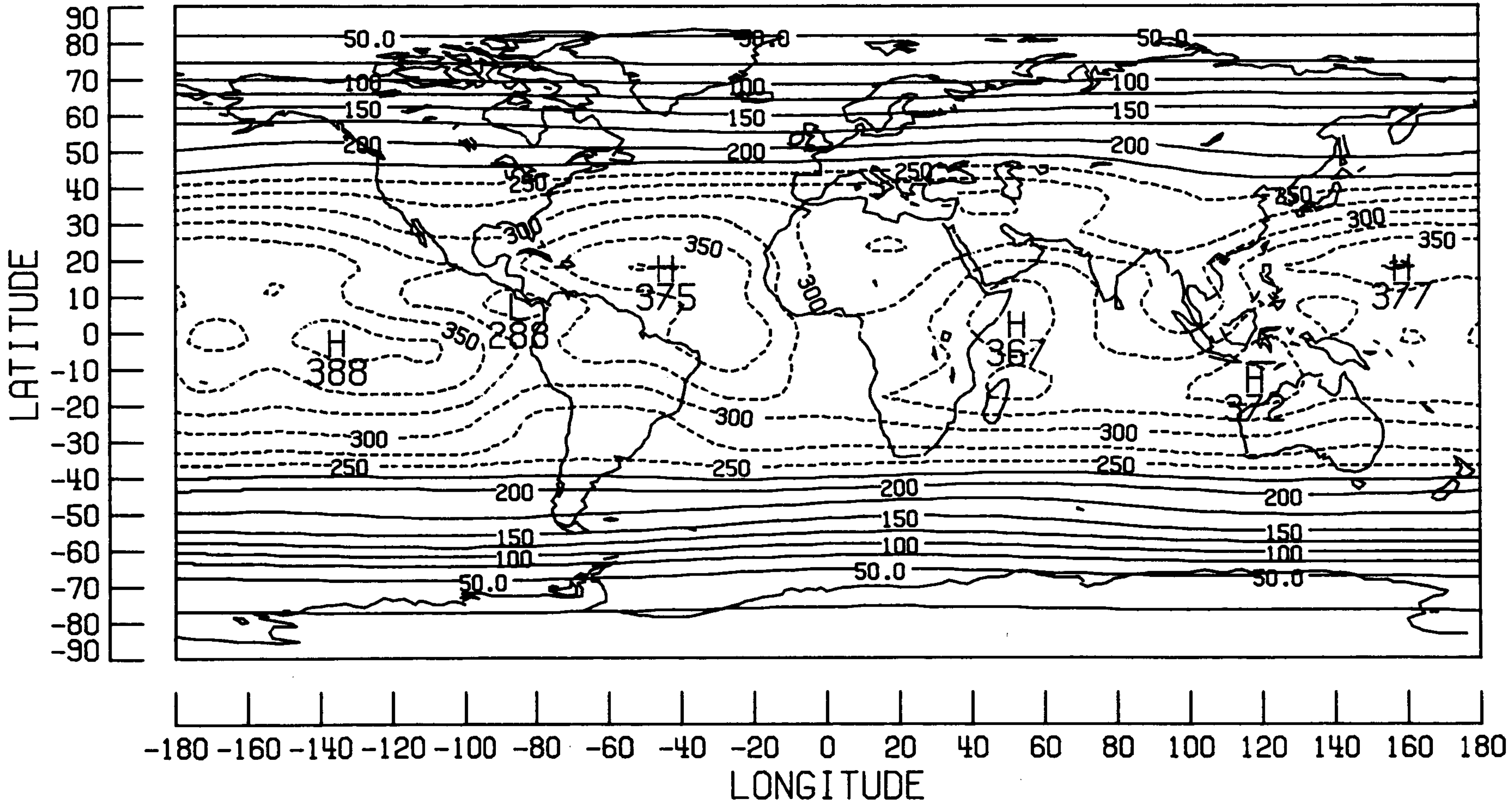
ALBEDO (%)

SEP 1983

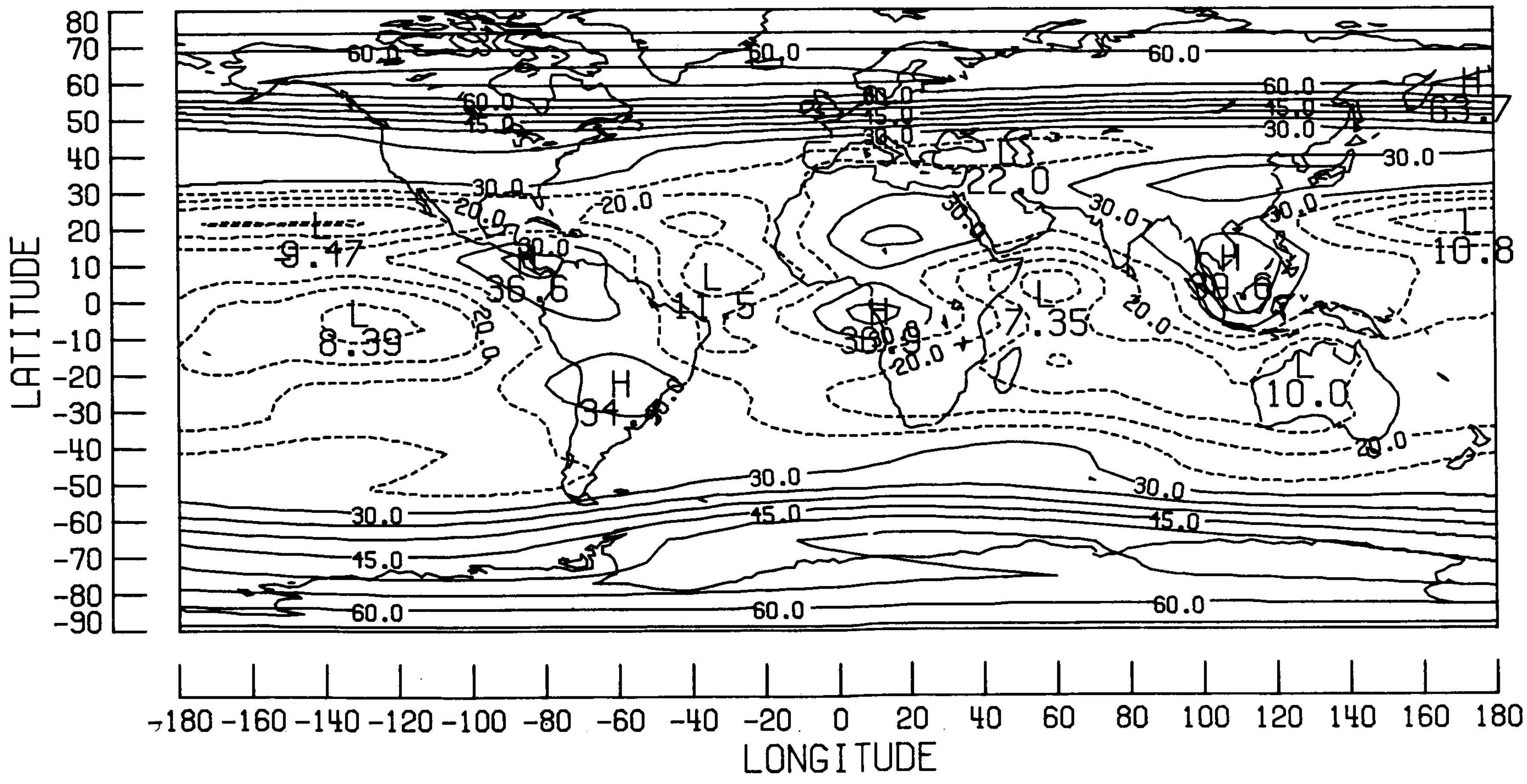


ABSORPTION W/(M*M)

SEP 1983

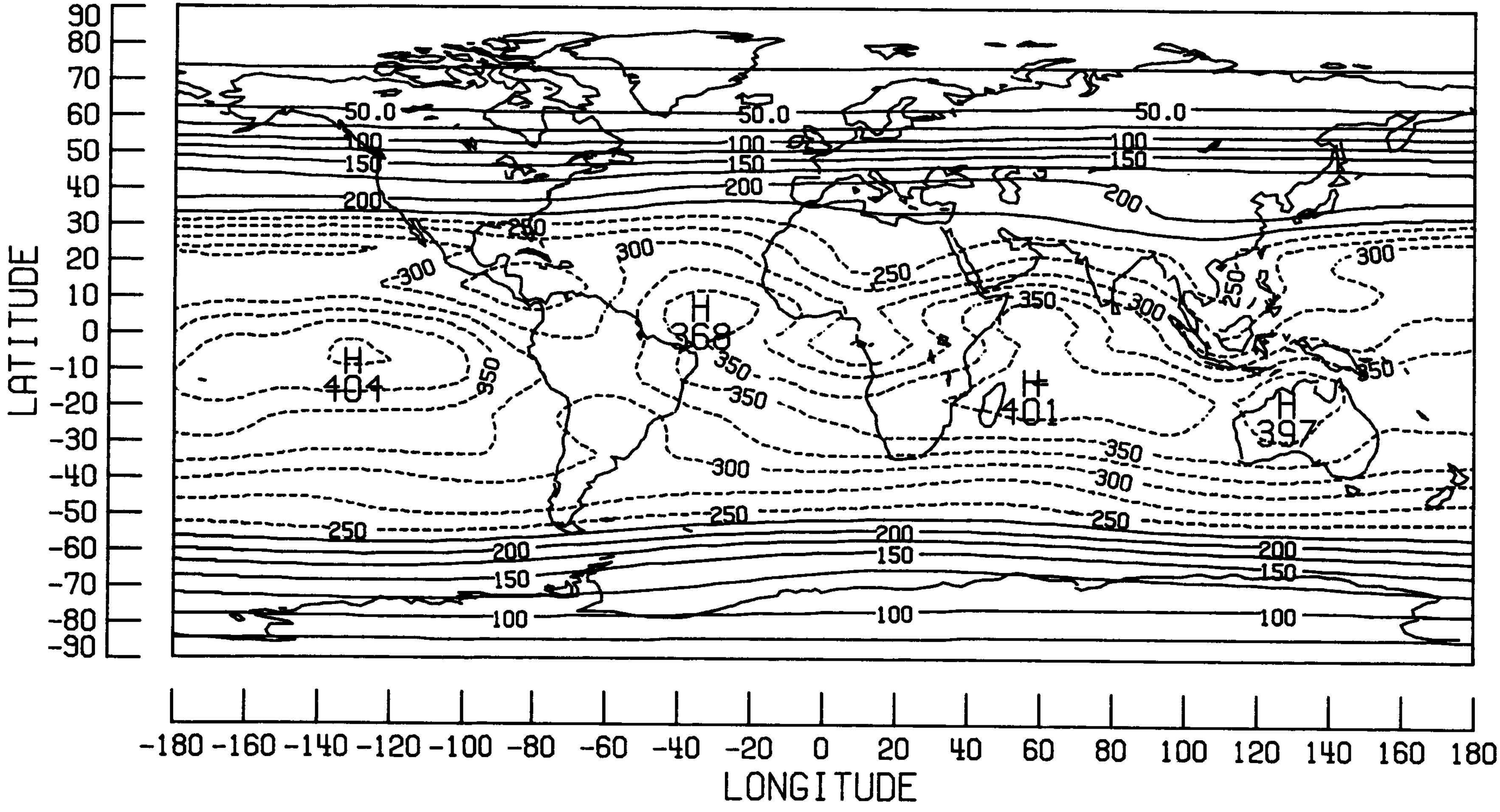


ALBEDO (%)
OCT 1983



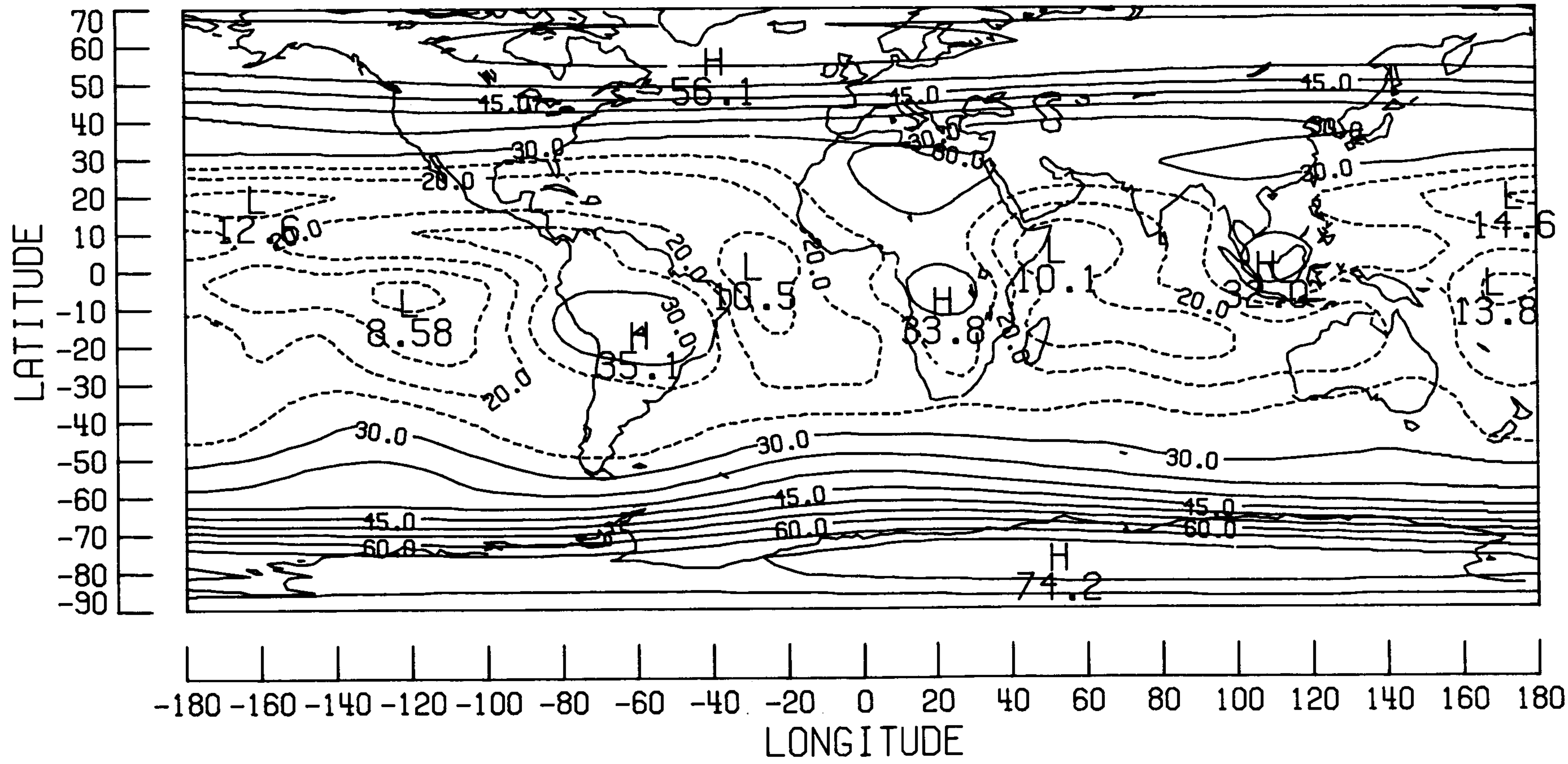
ABSORPTION W/(M*M)

OCT 1983



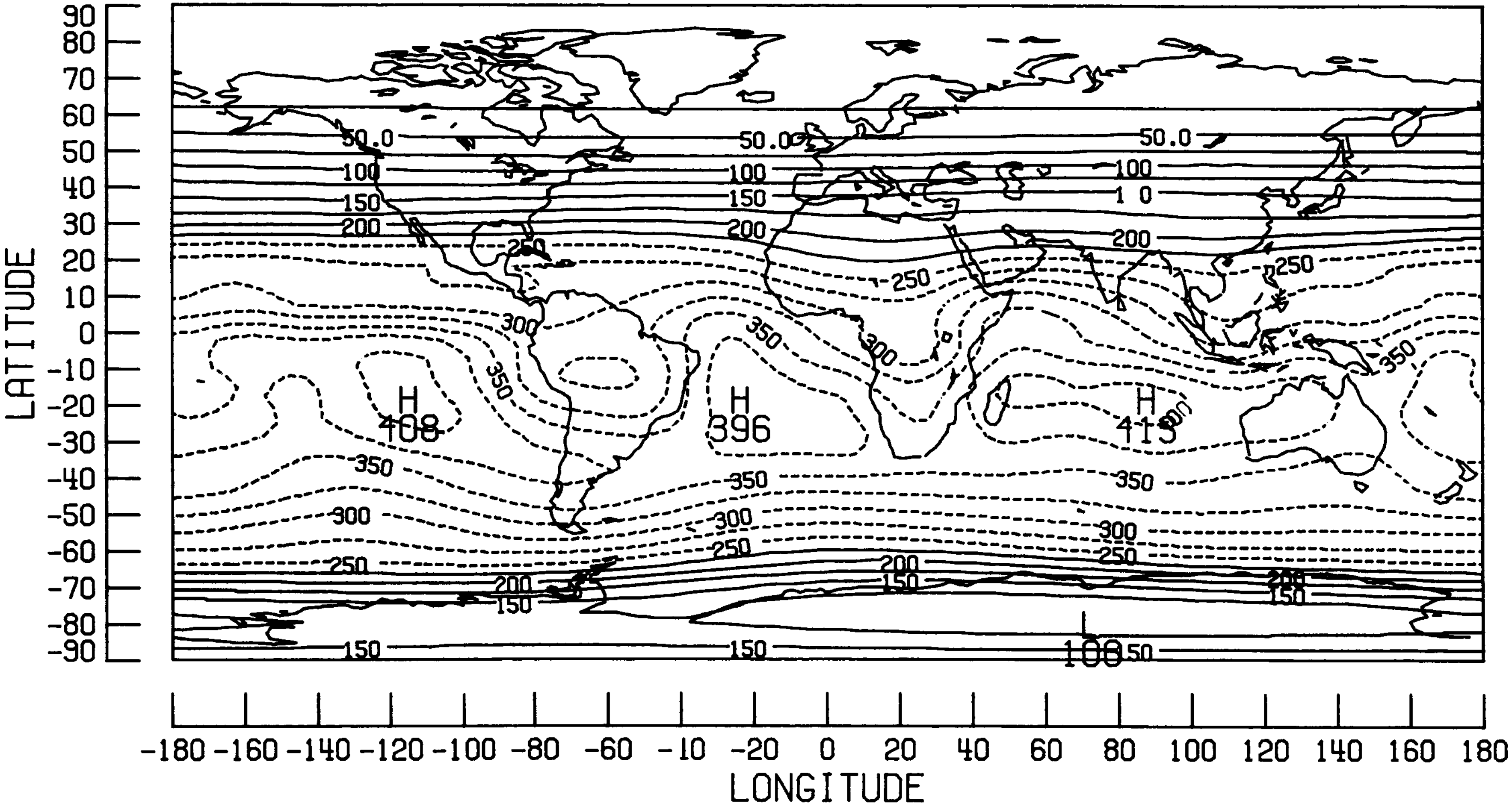
ALBEDO (%)

NOV 1983



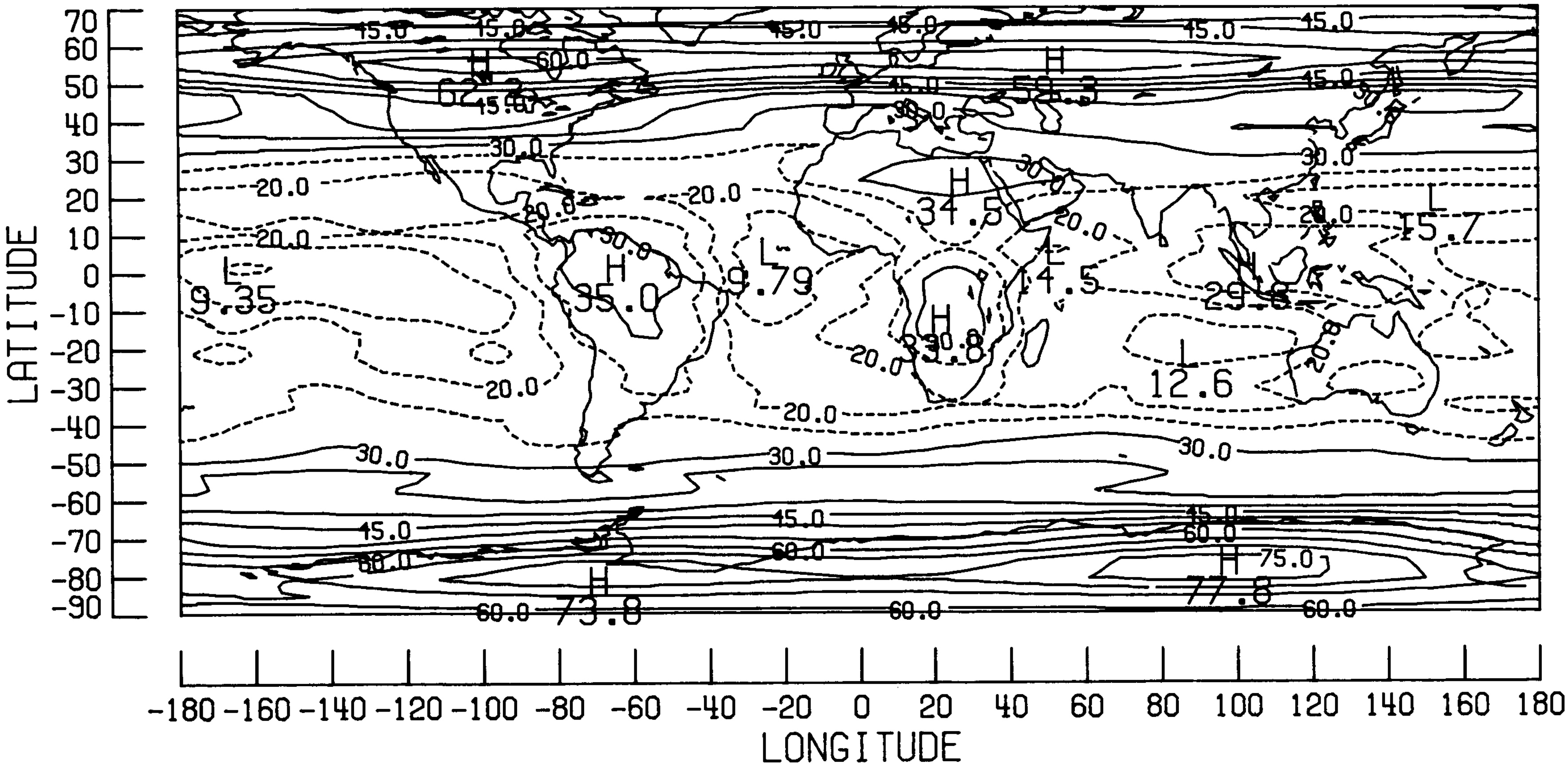
ABSORPTION W/(M*M)

NOV 1983



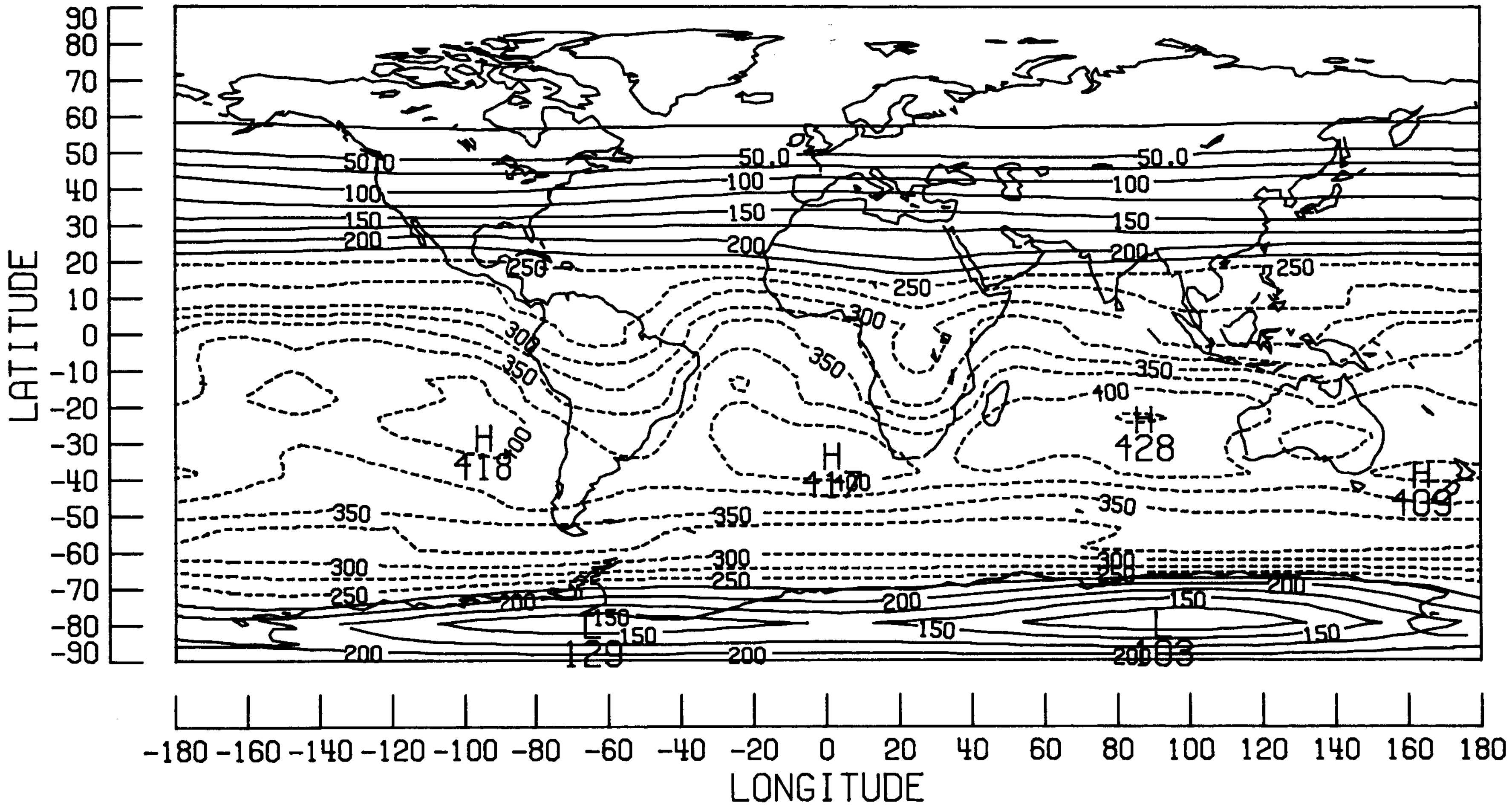
ALBEDO (%)

DEC 1983



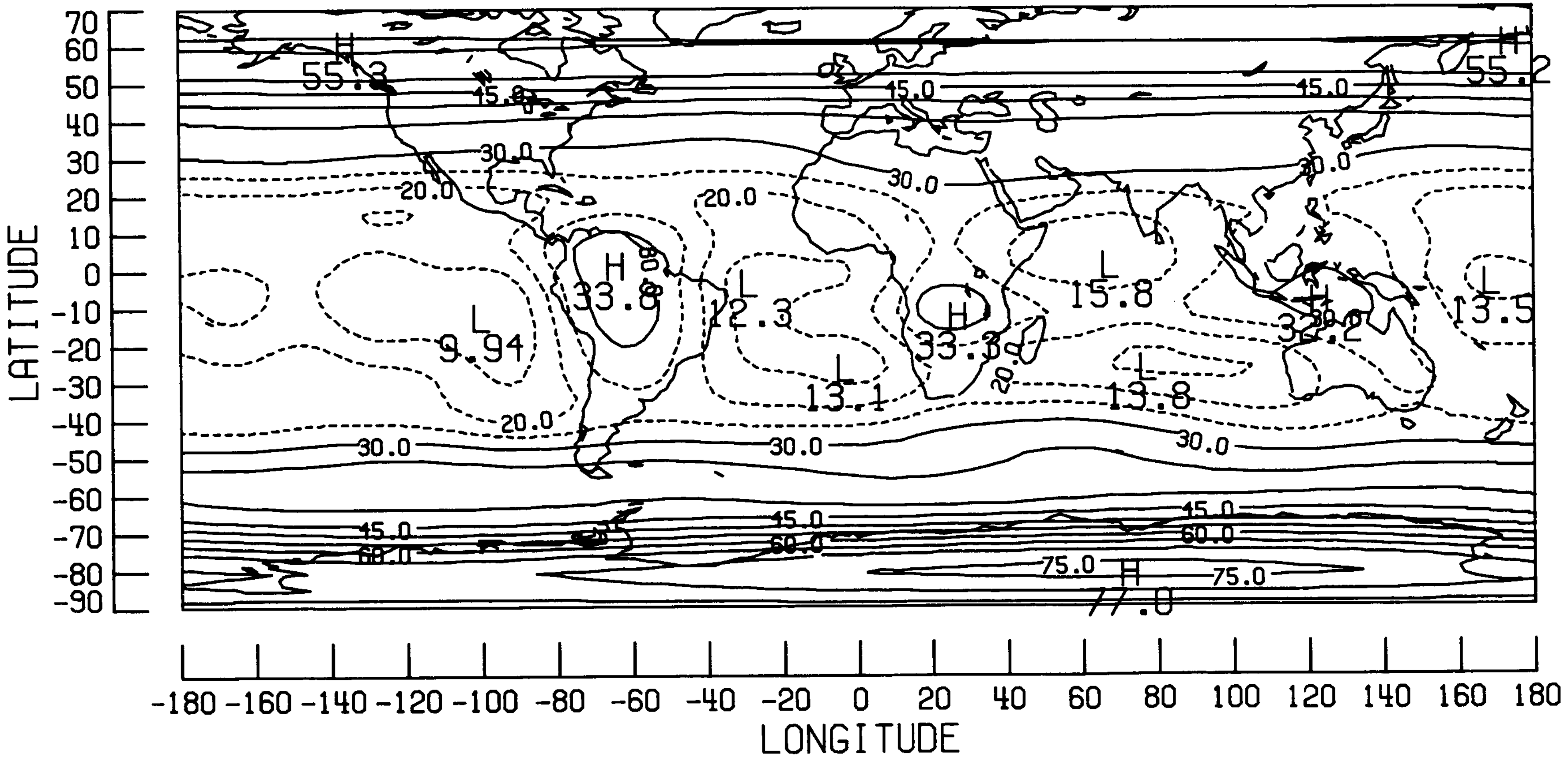
ABSORPTION W/(M*M)

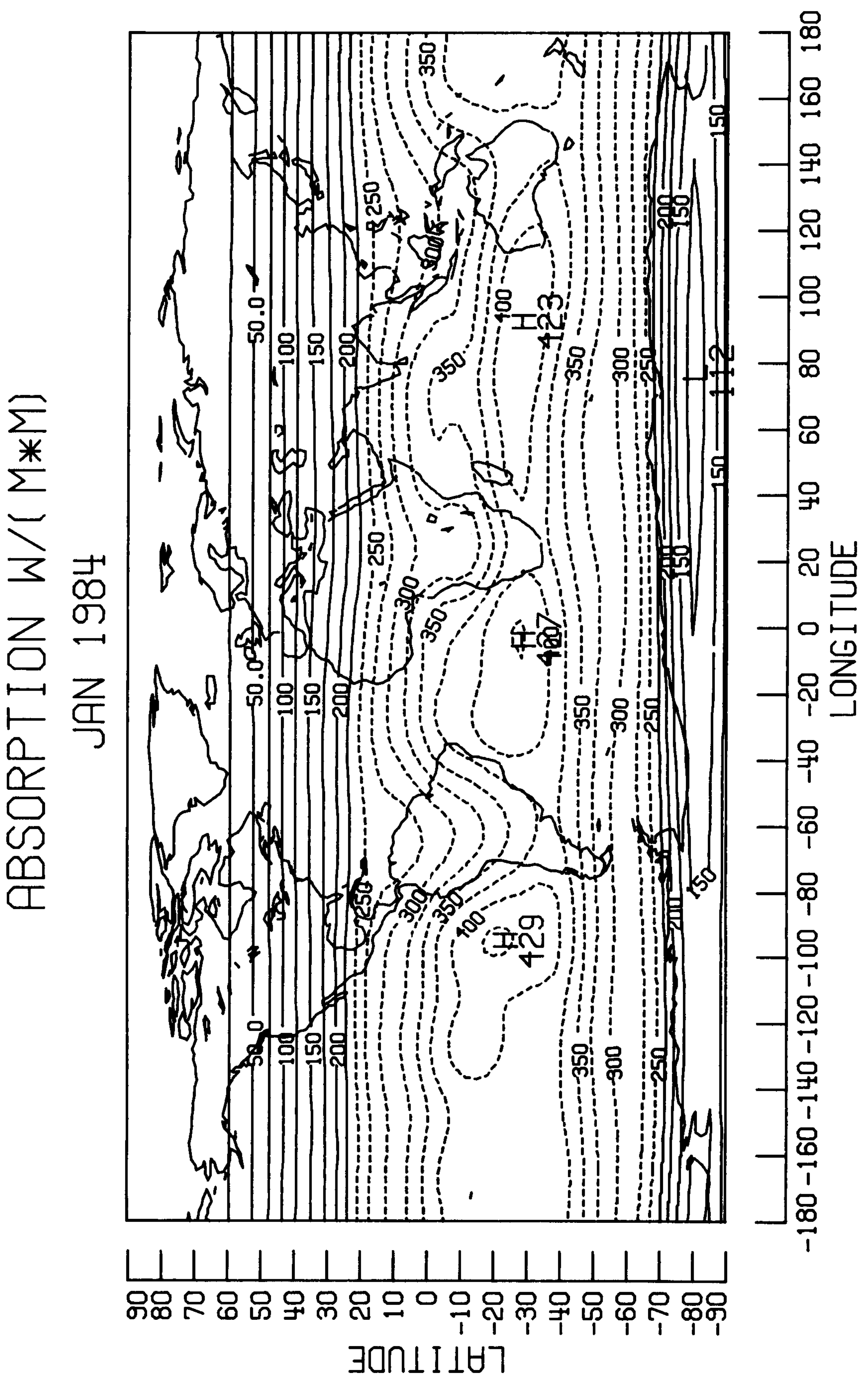
DEC 1983



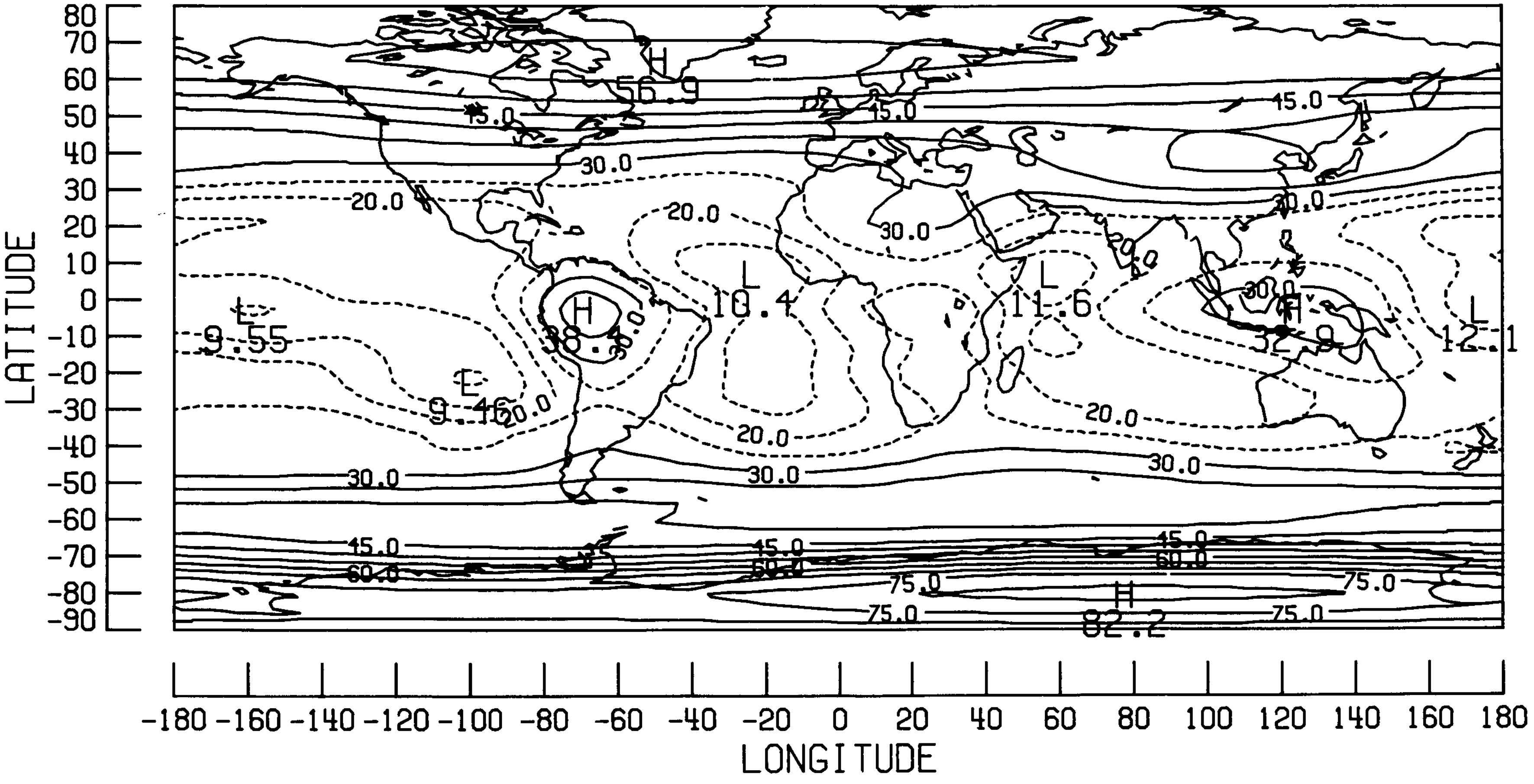
ALBEDO (%)

JAN 1984



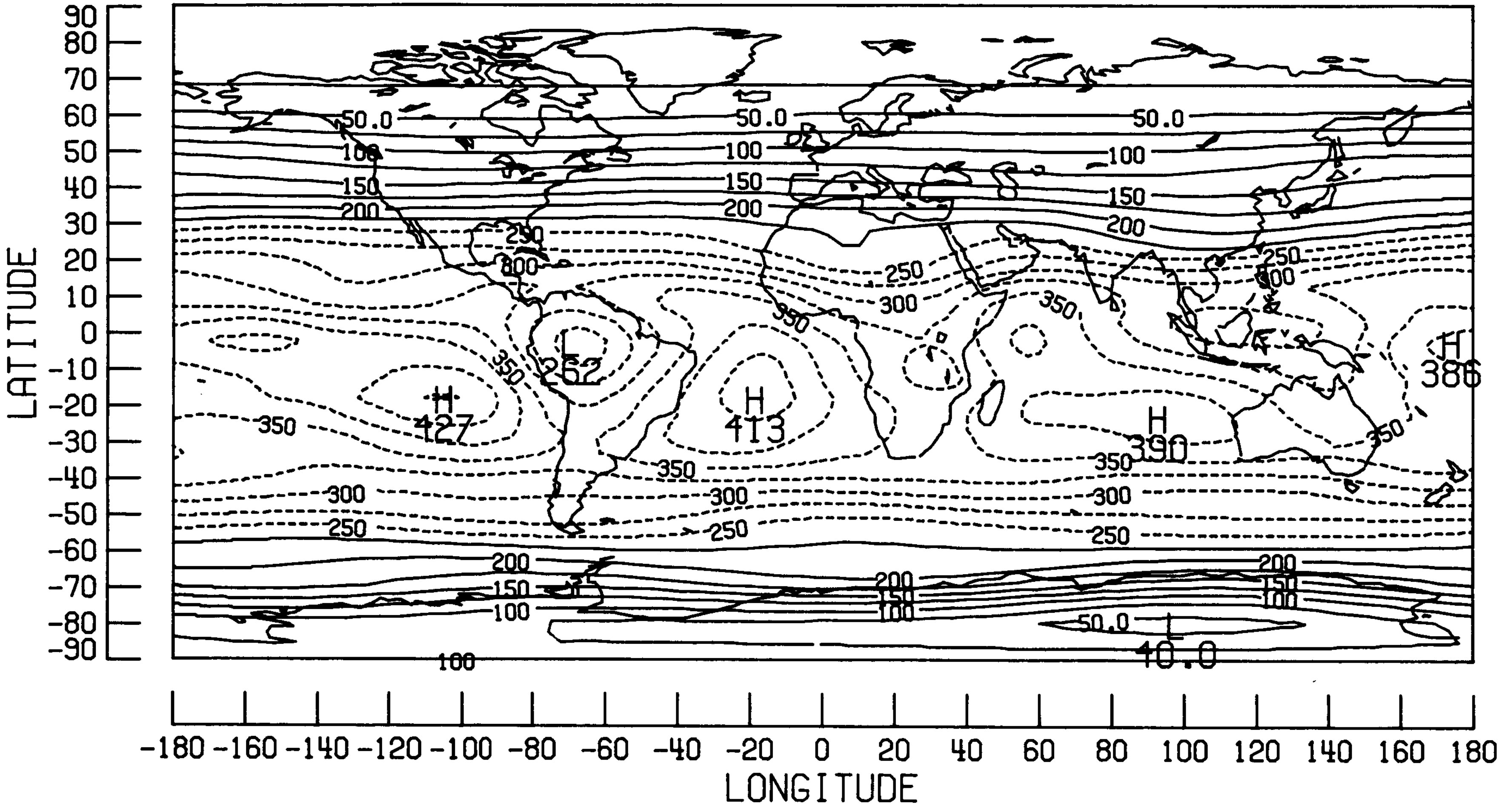

ABSORPTION W/(M*M)
JAN 1984
LATITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
LONGITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
50.0
100
150
200
250
300
350
400
H
429
407
423
L
112
150
200
250
300
350

ALBEDO (%)
FEB 1984

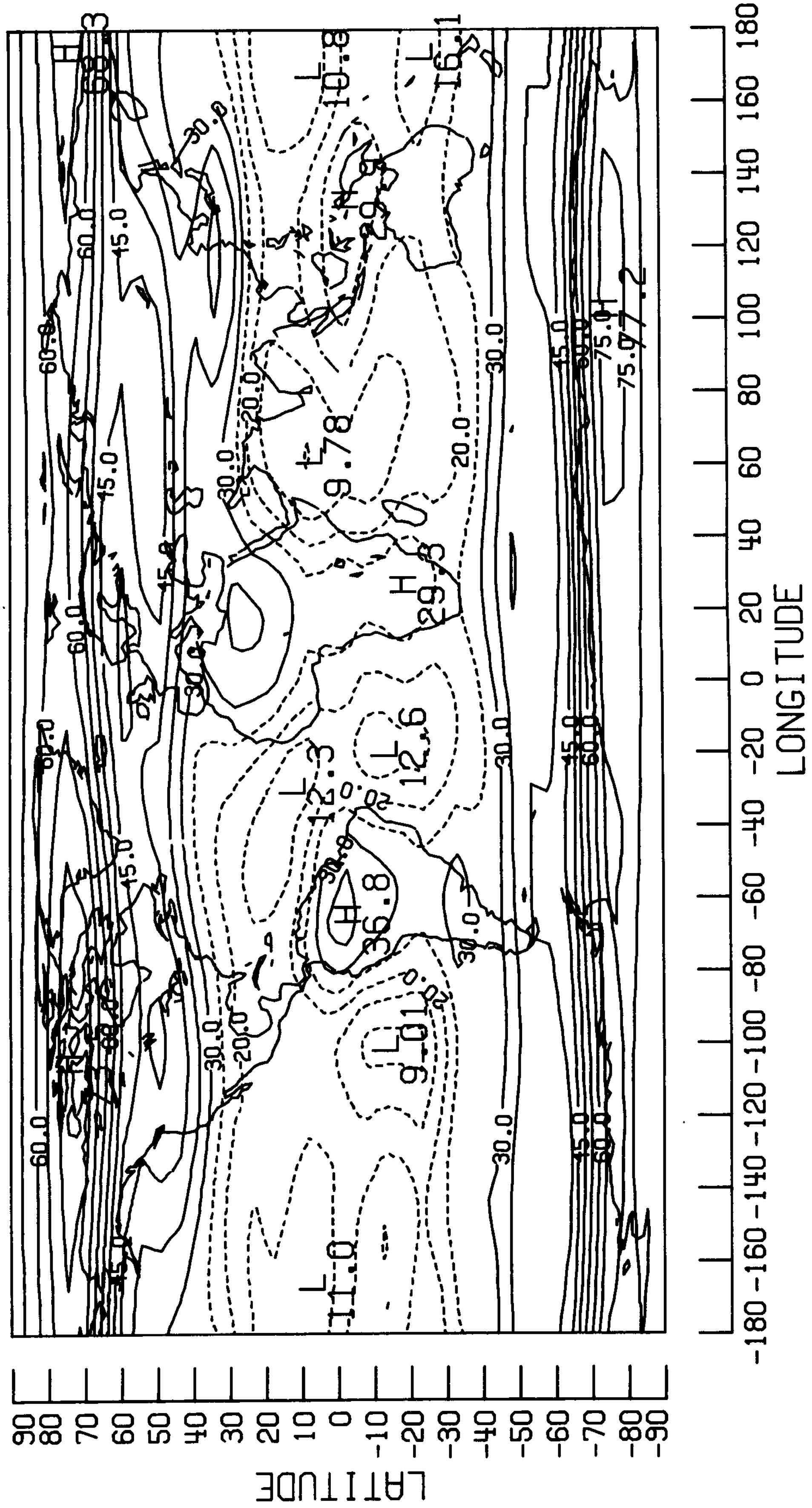


ABSORPTION W/(M*M)

FEB 1984

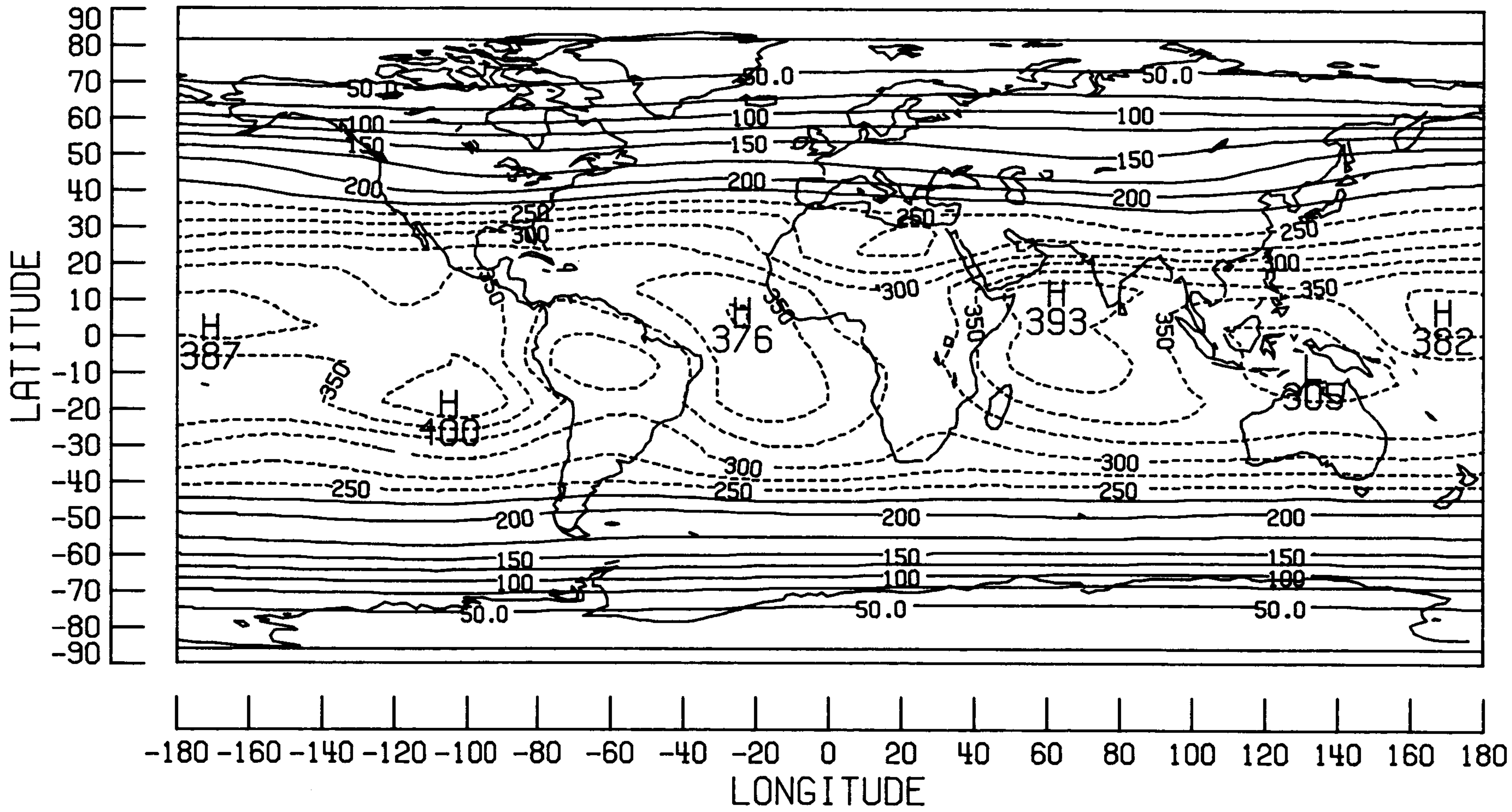


ALBEDO (%)
MAR 1984

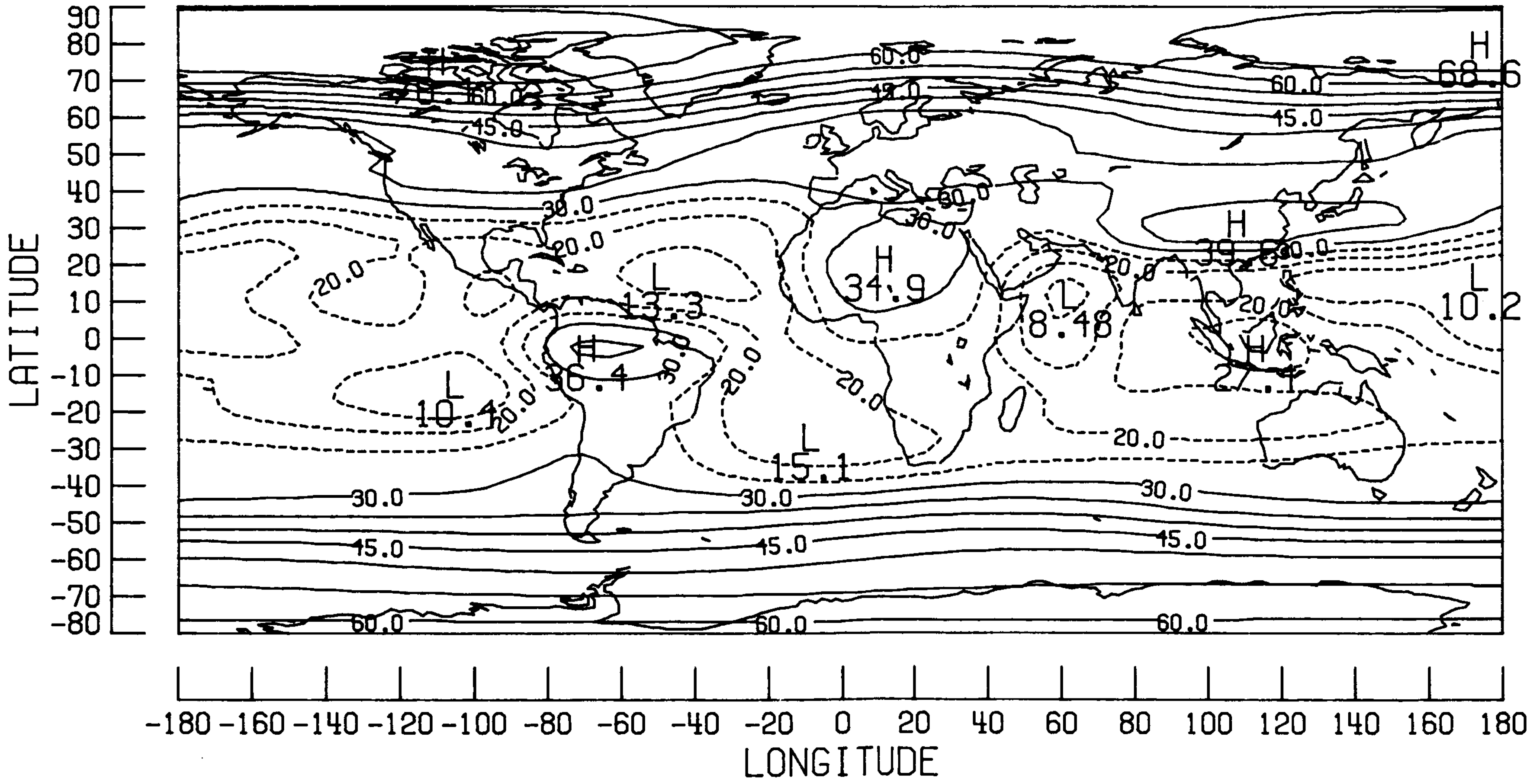


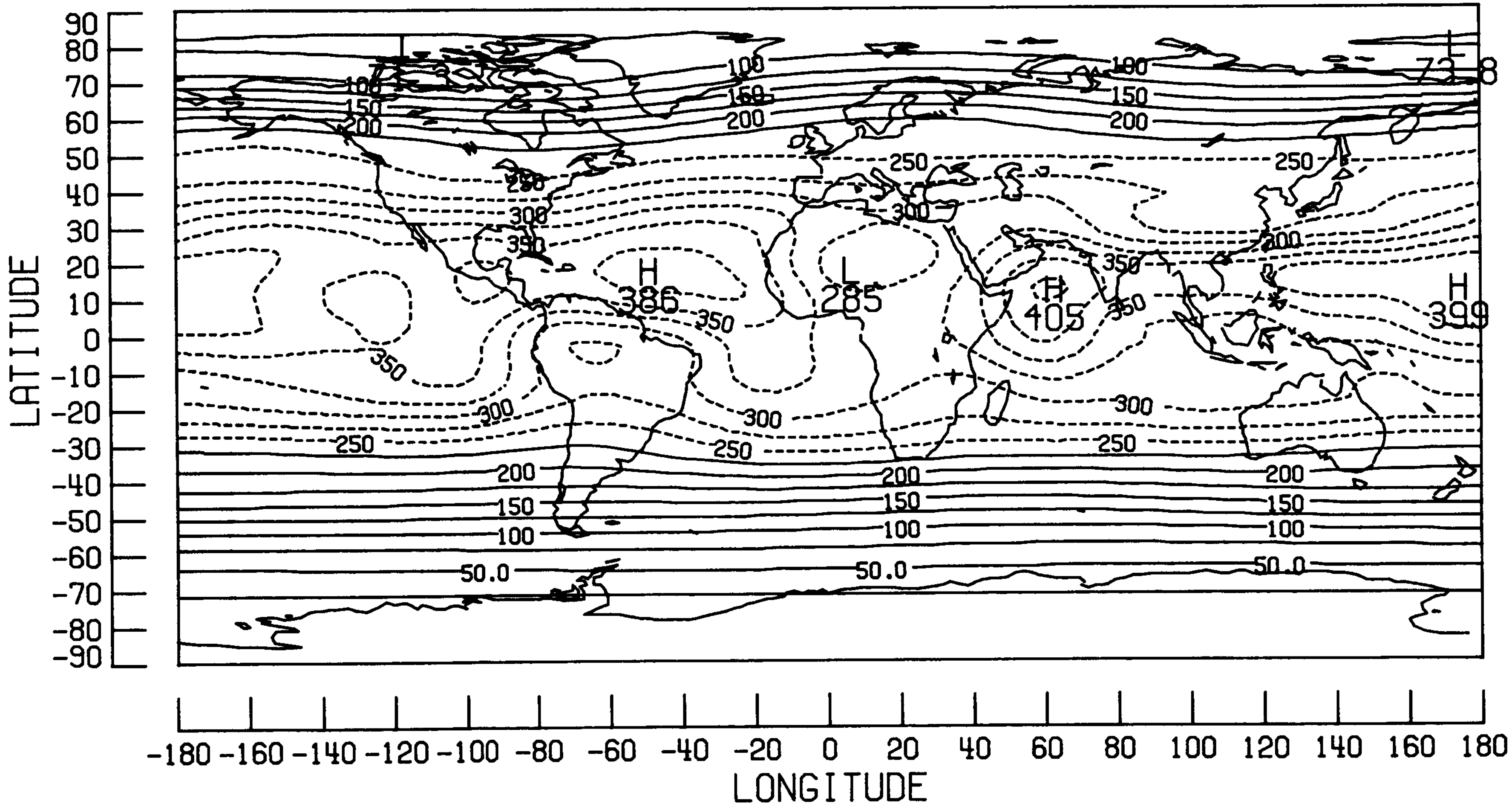
ABSORPTION W/(M*M)

MAR 1984



ALBEDO (%)
APR 1984

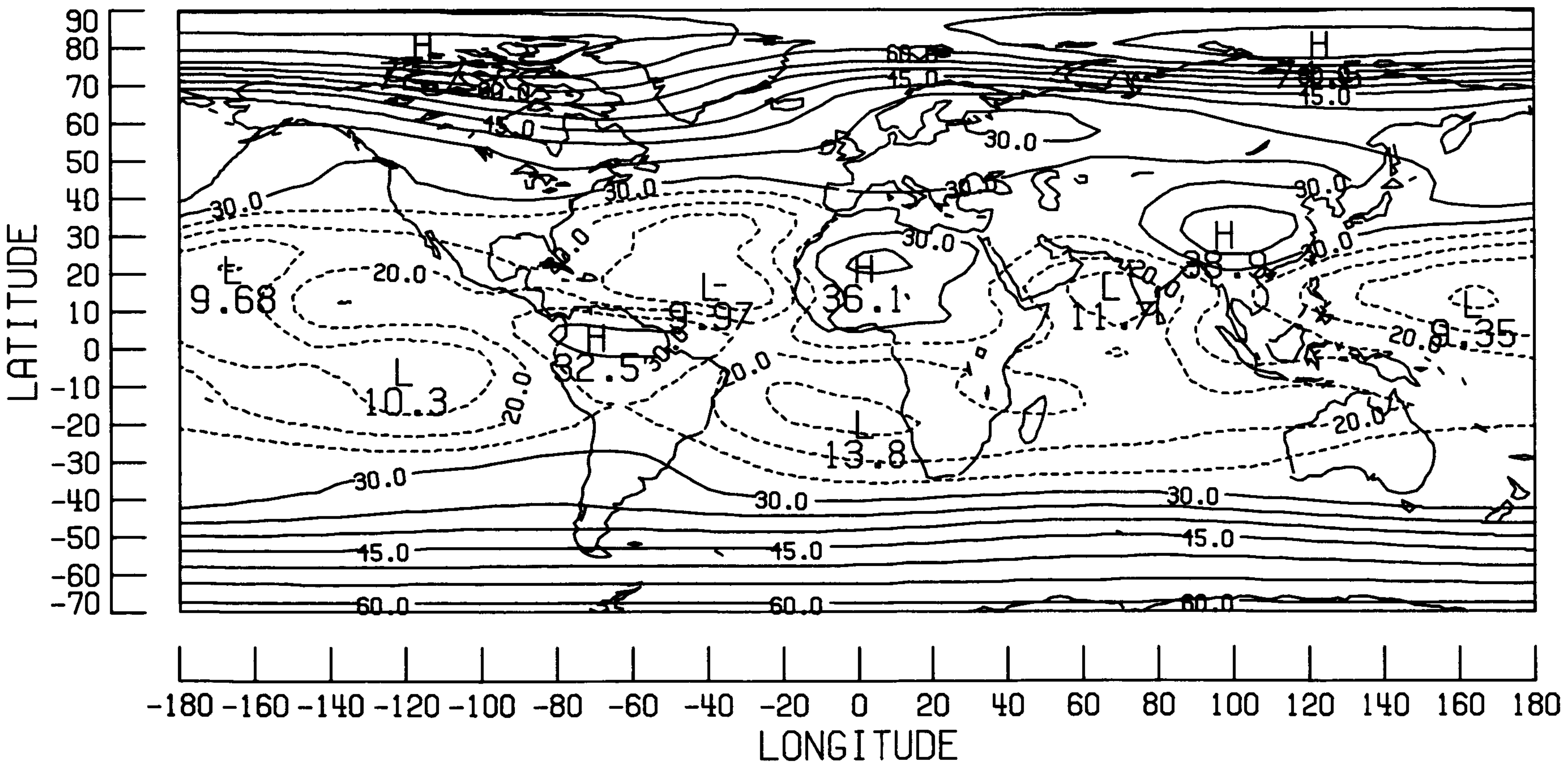




ABSORPTION W/(M*M)

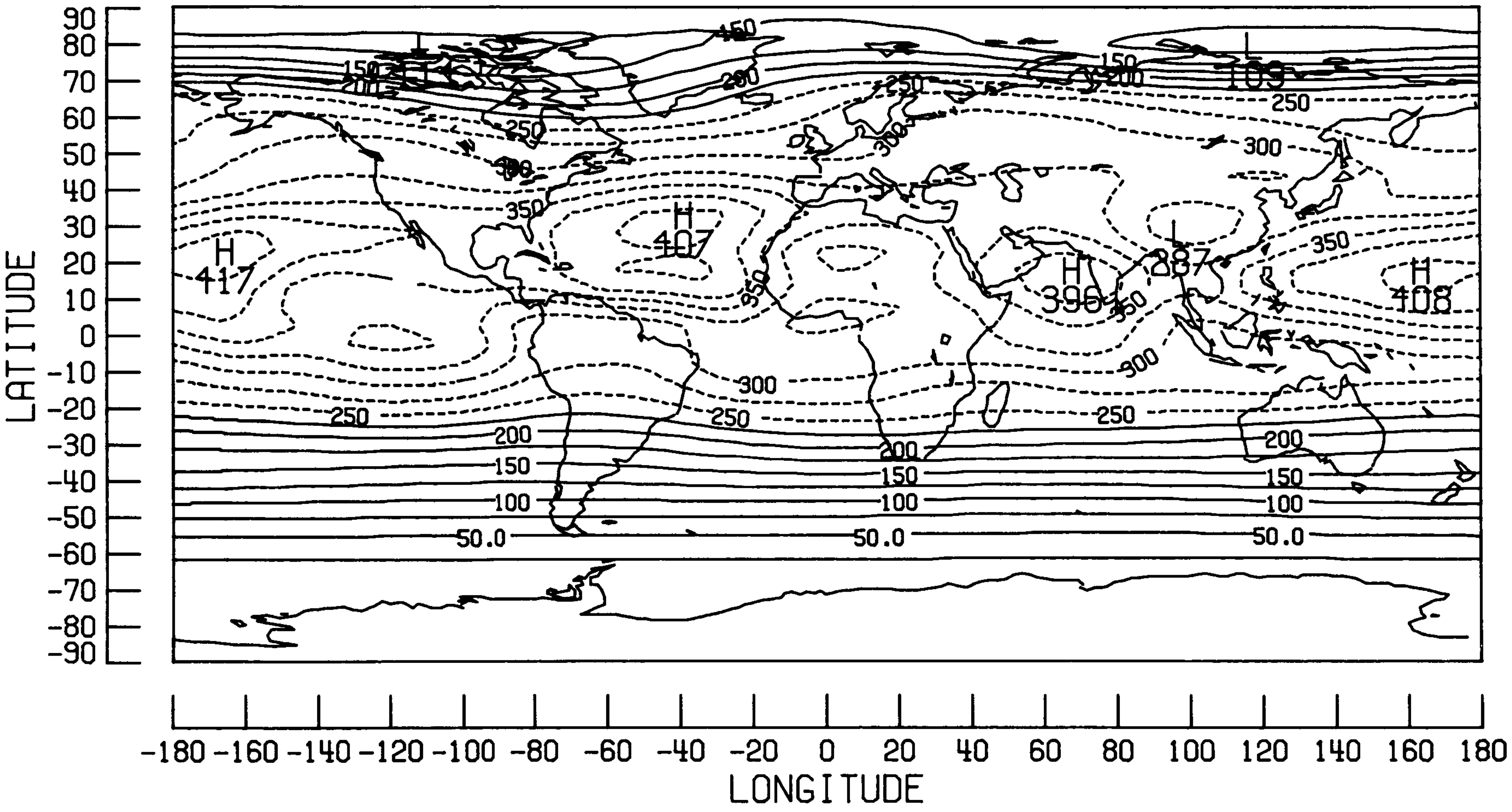
APR 1984

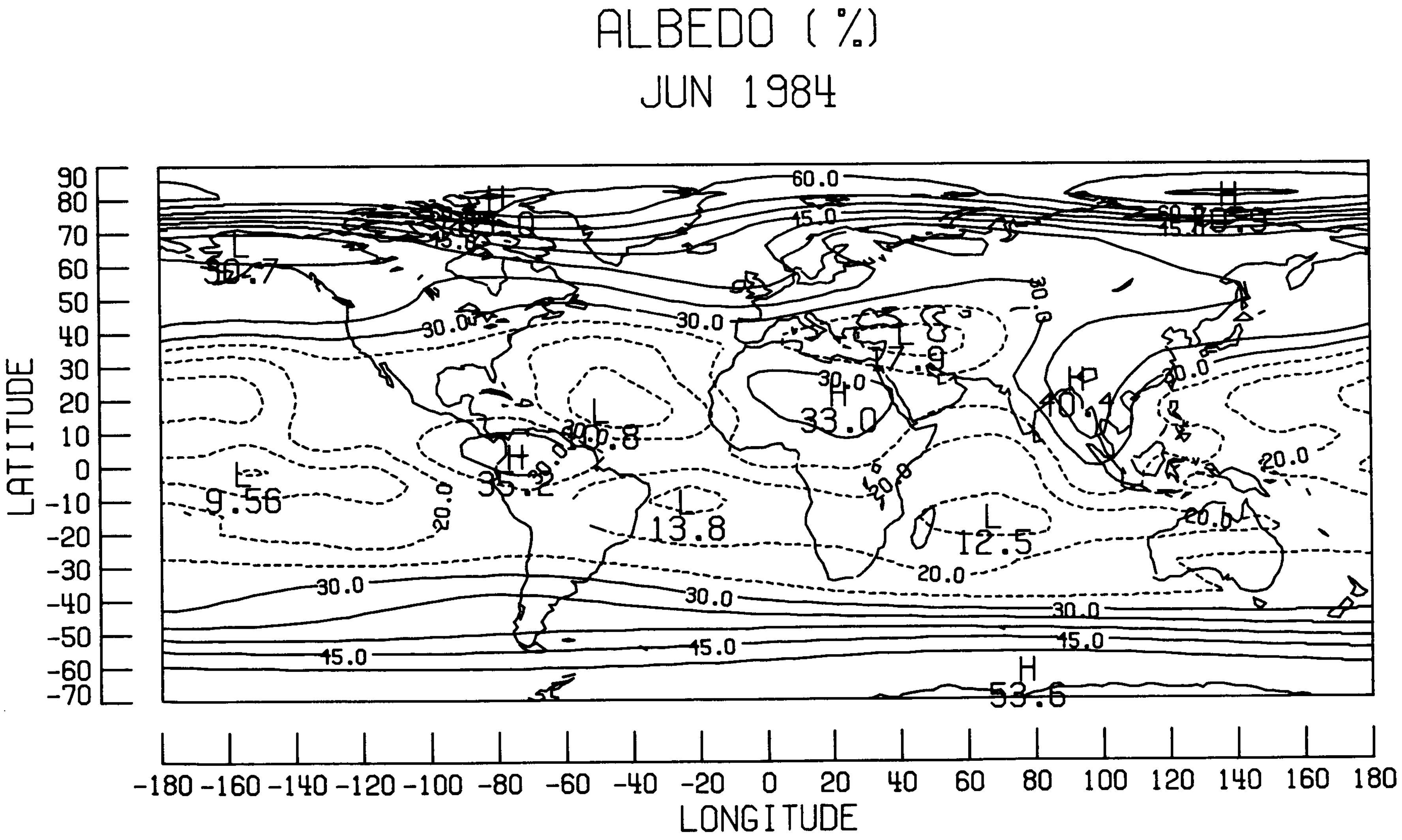
ALBEDO (%)
MAY 1984



ABSORPTION W/(M*M)

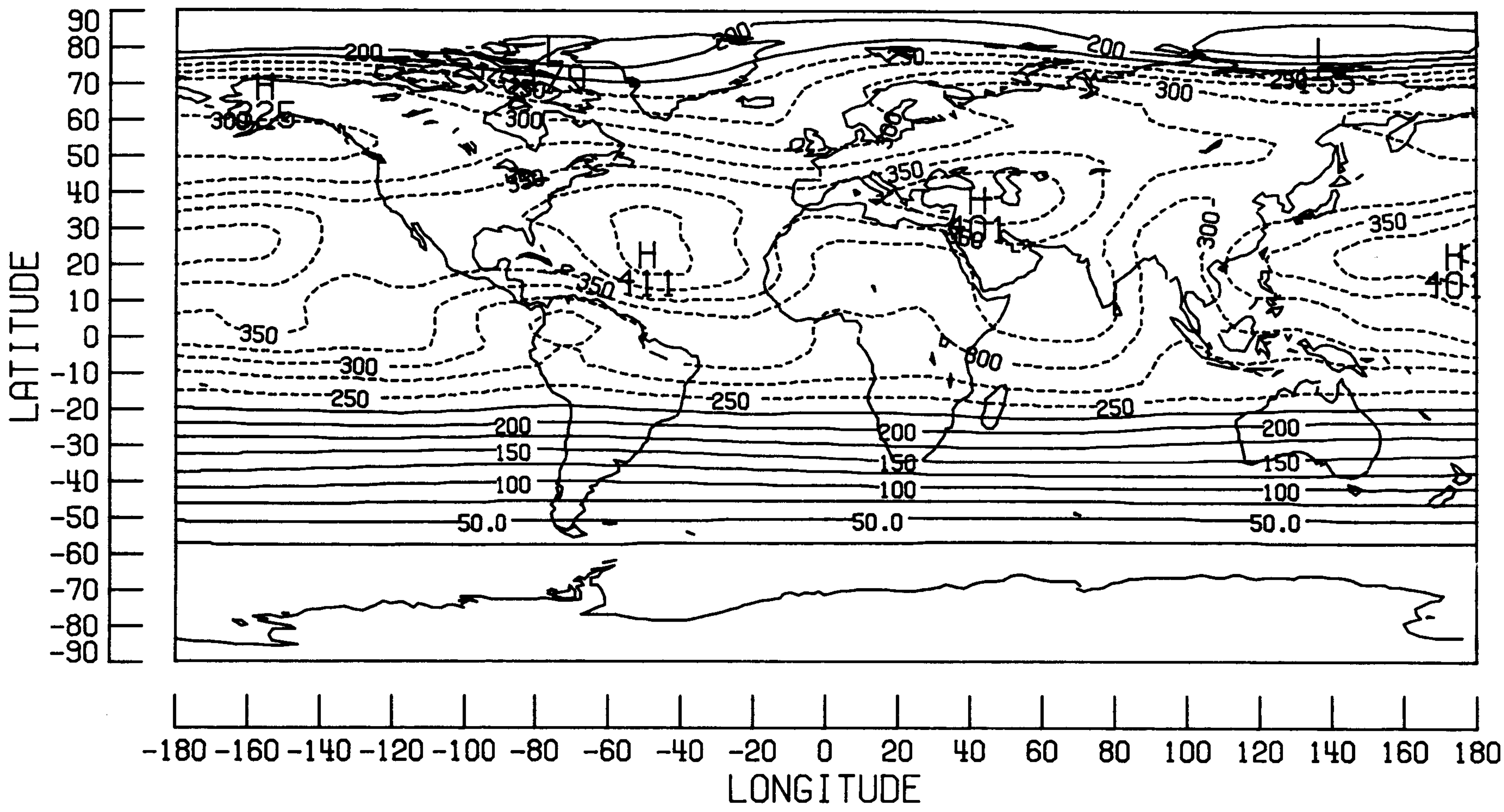
MAY 1984

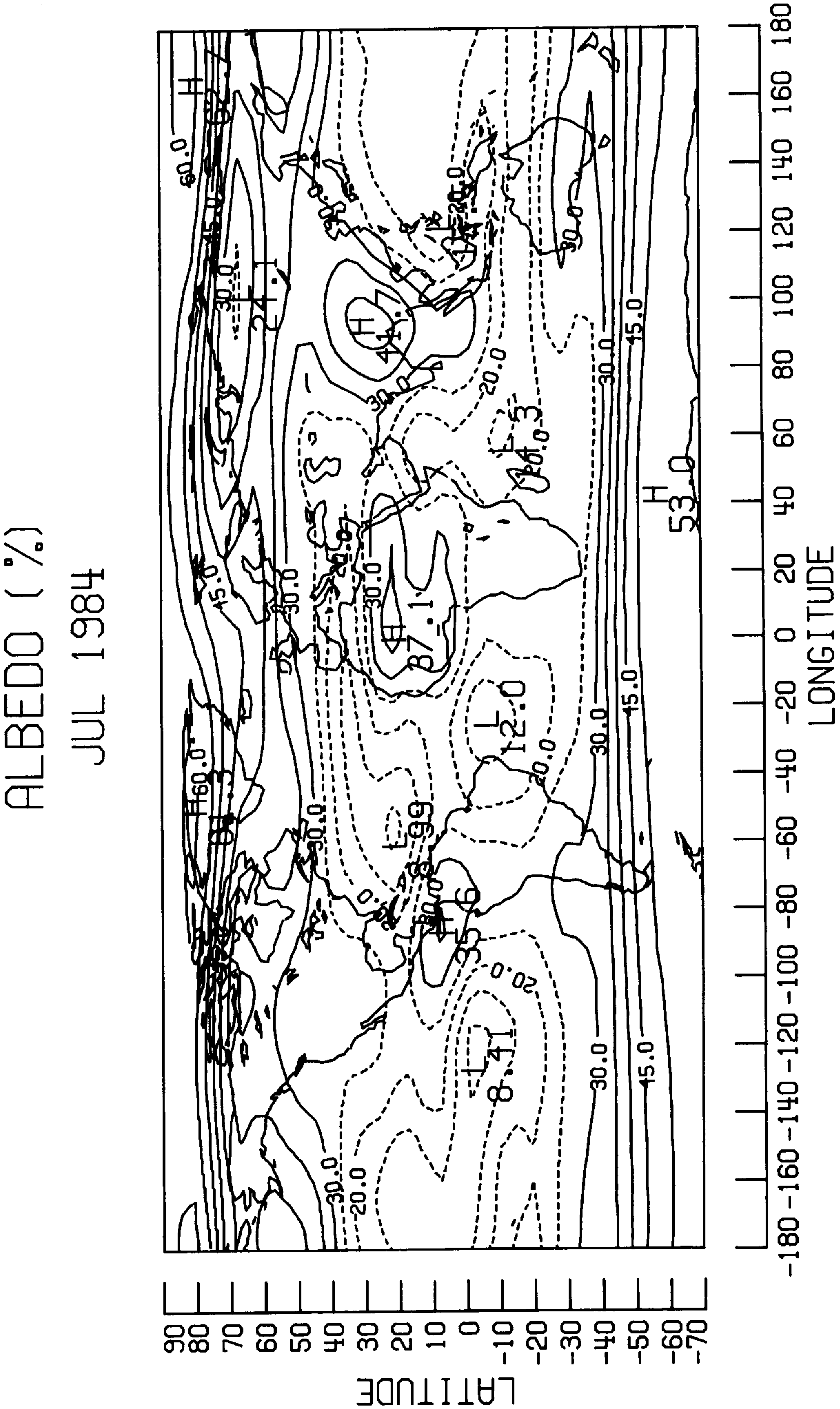



ALBEDO (%)
JUN 1984
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
60.0
45.0
30.0
20.0
L
50.7
L
9.56
H
35.2
L
40.8
L
13.8
H
33.0
L
17.9
L
12.5
H
40.4
H
53.6
H

ABSORPTION W/(M*M)

JUN 1984



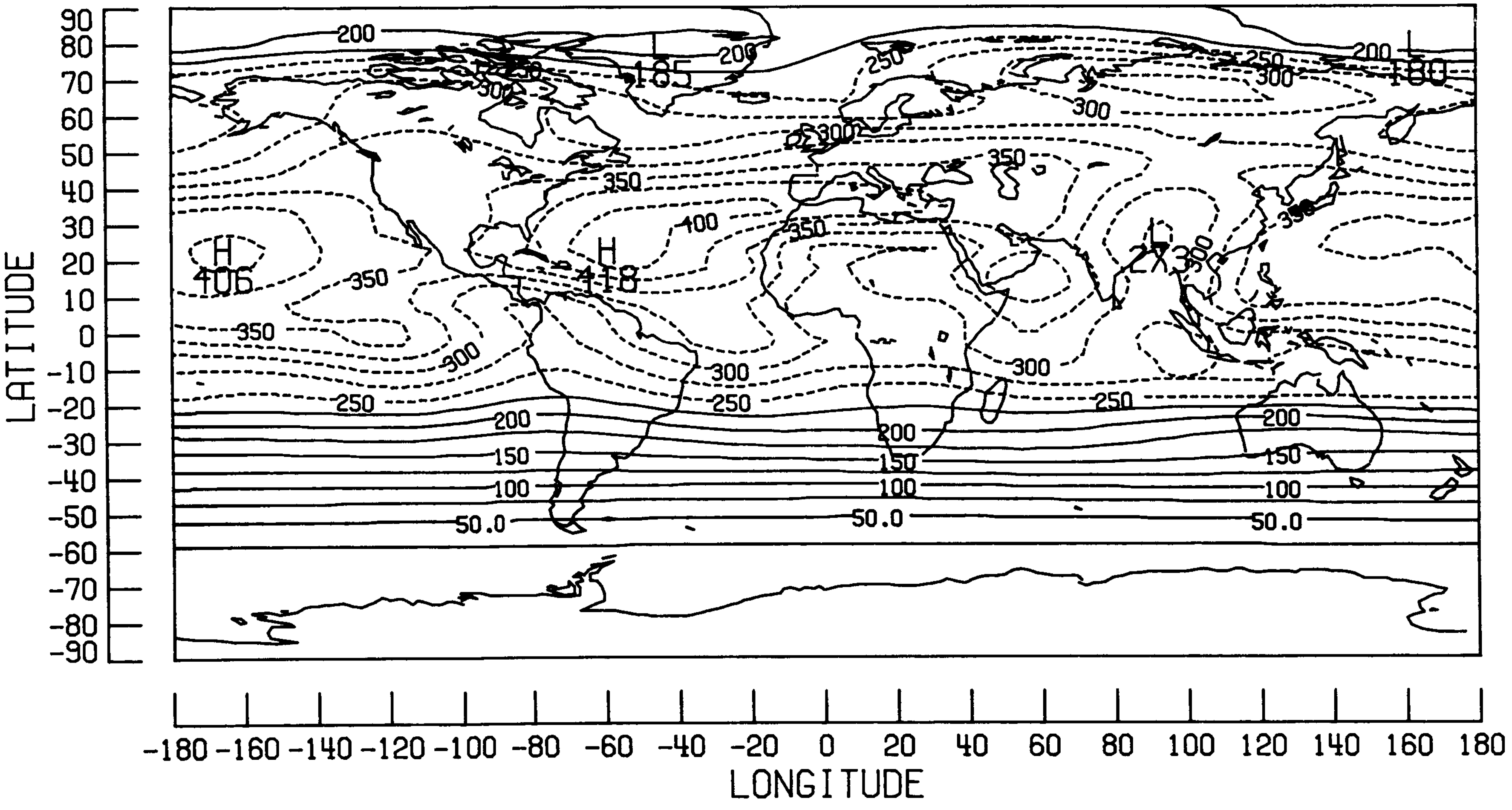


ALBEDO (%)

JUL 1984

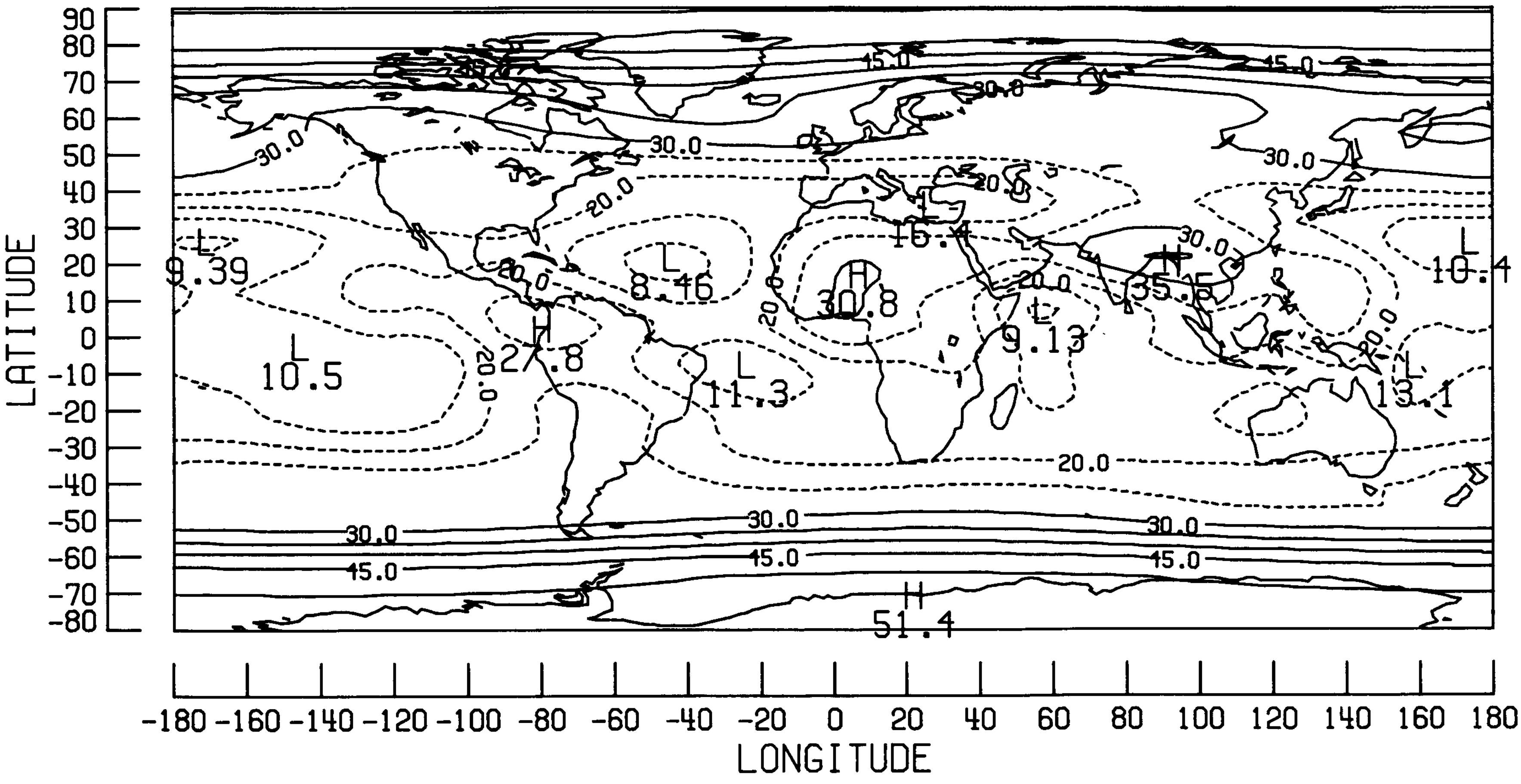
ABSORPTION W/(M*M)

JUL 1984

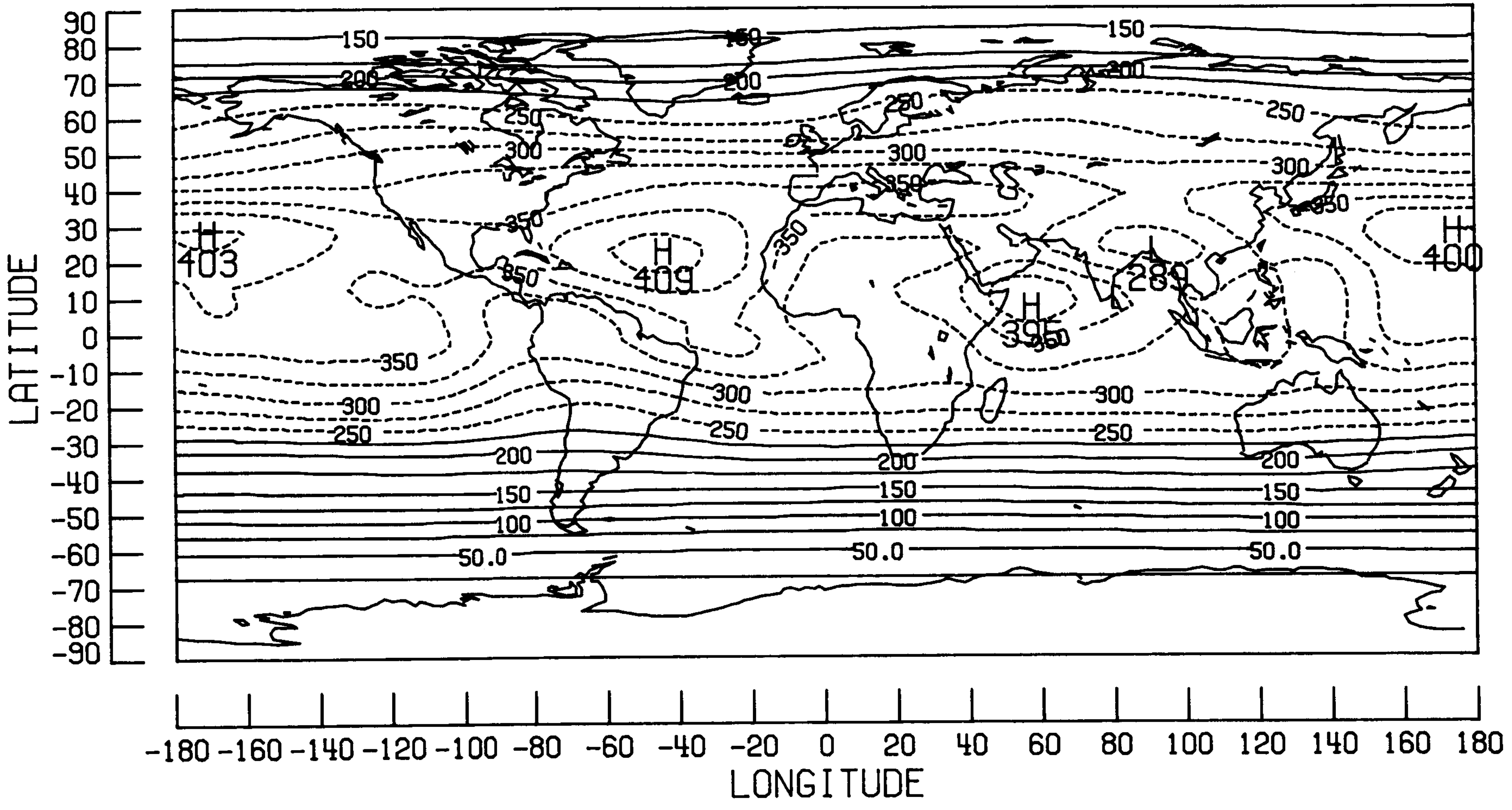


ALBEDO (%)

AUG 1984

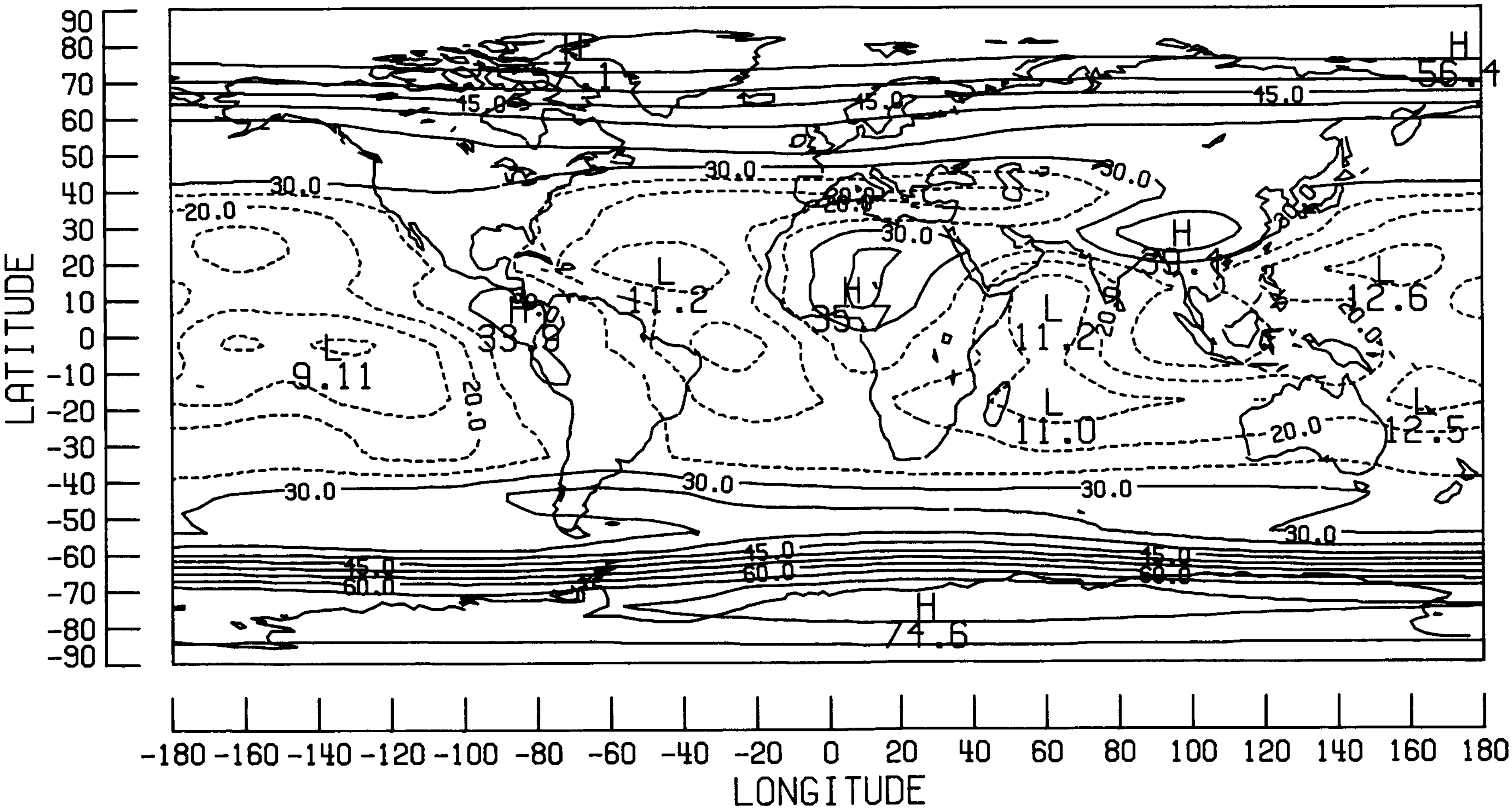


ABSORPTION W/(M*M)
AUG 1984



ALBEDO (%)

SEP 1984



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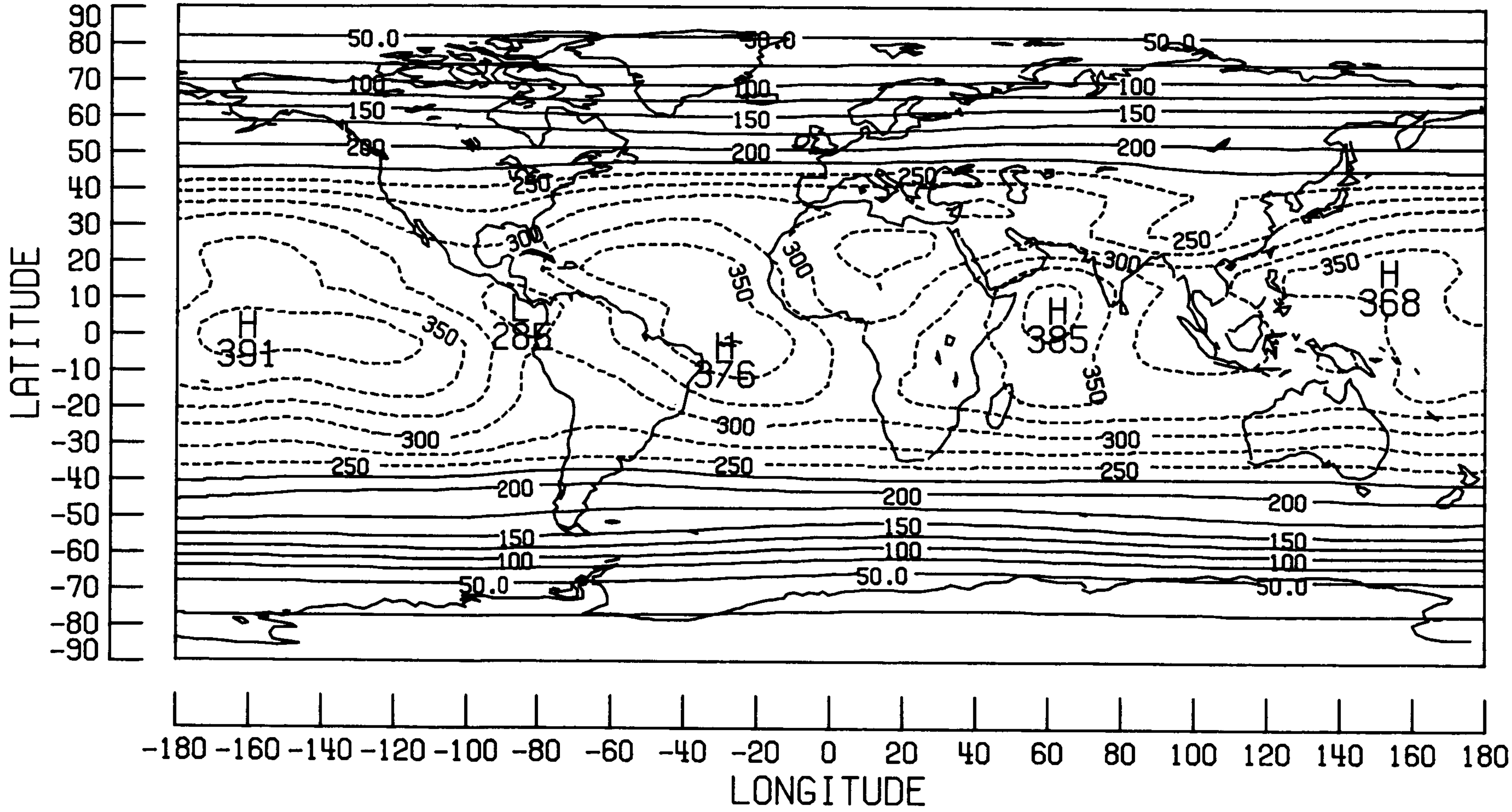
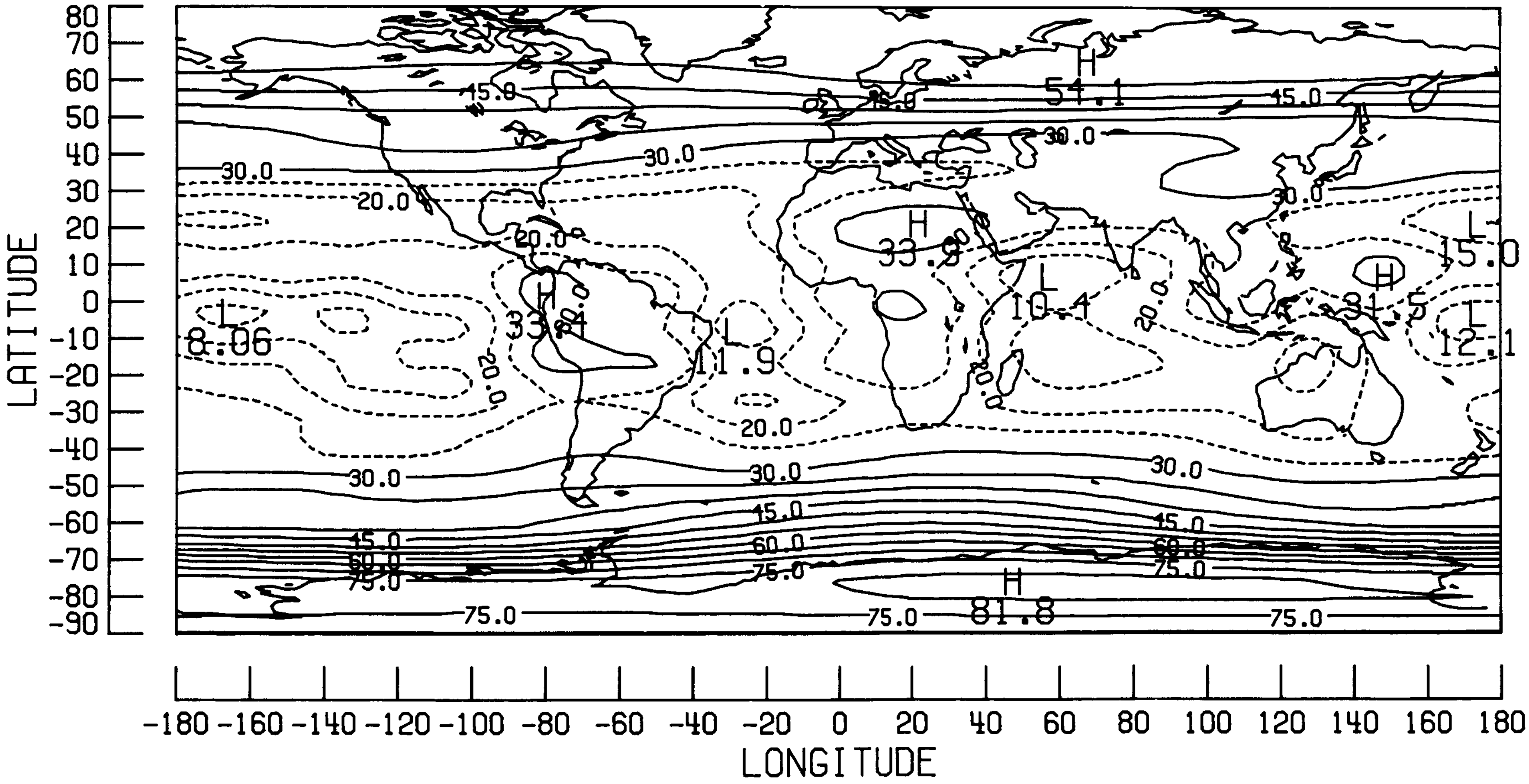


ALBEDO (%)

OCT 1984



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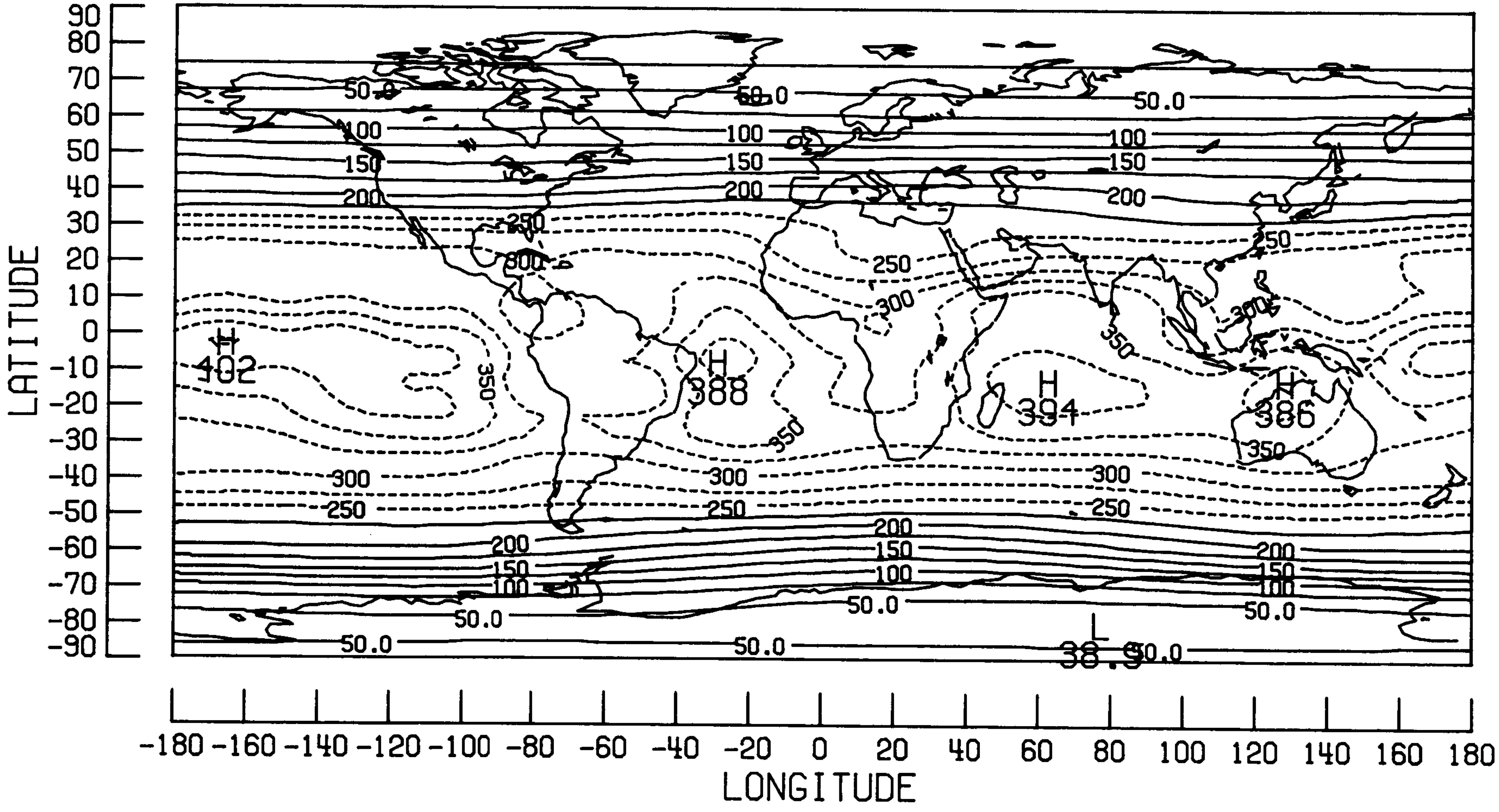

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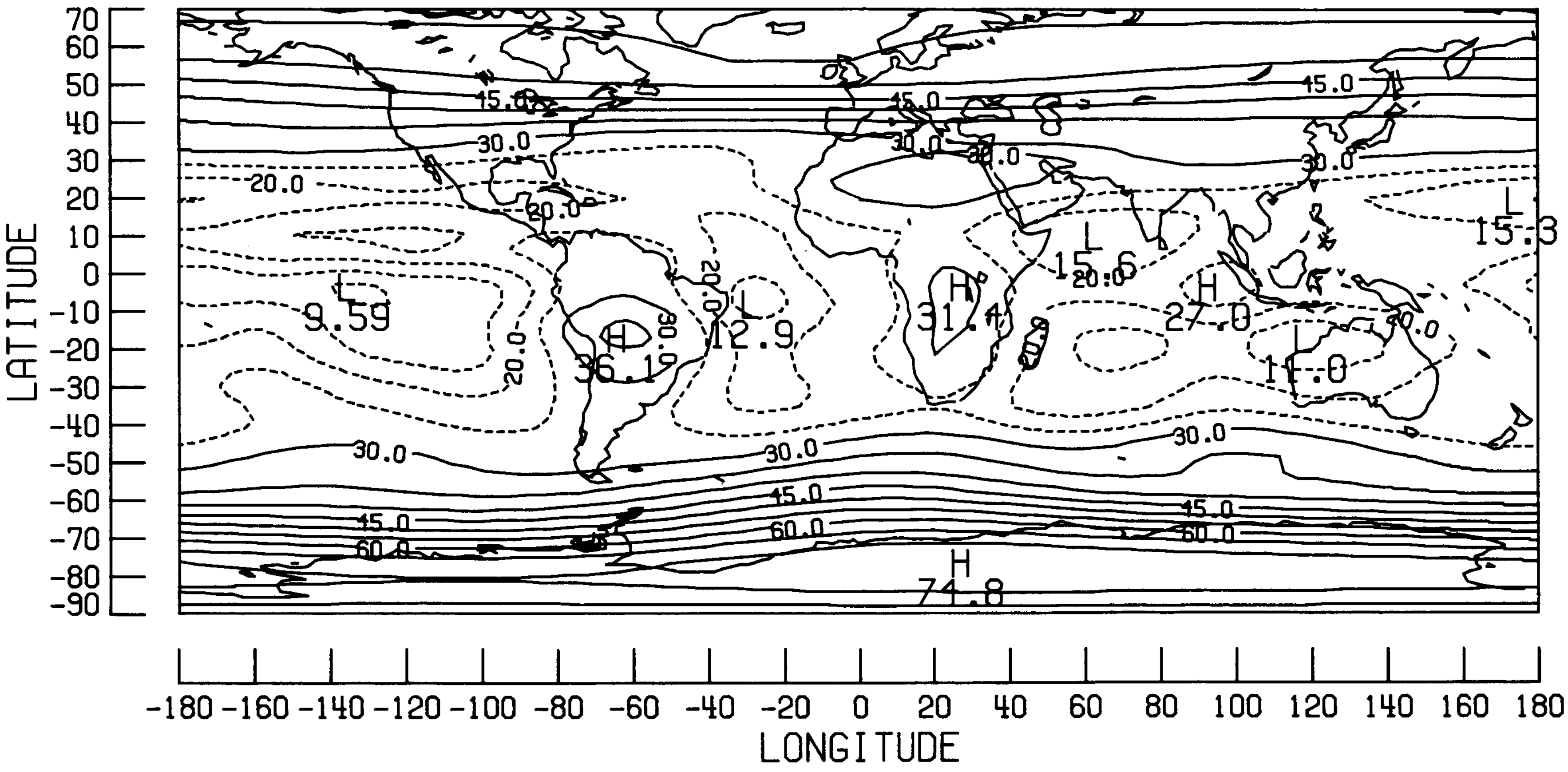
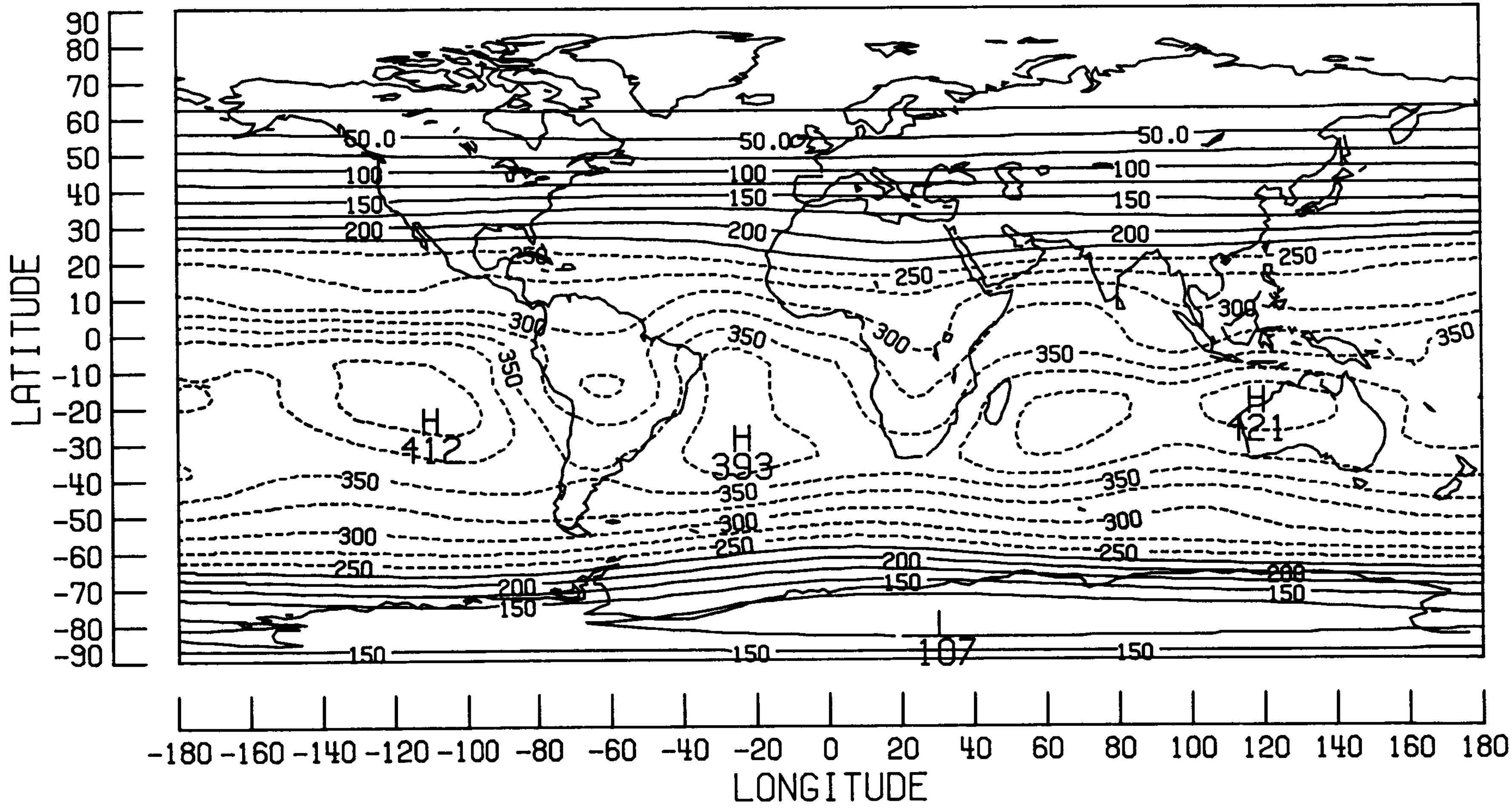
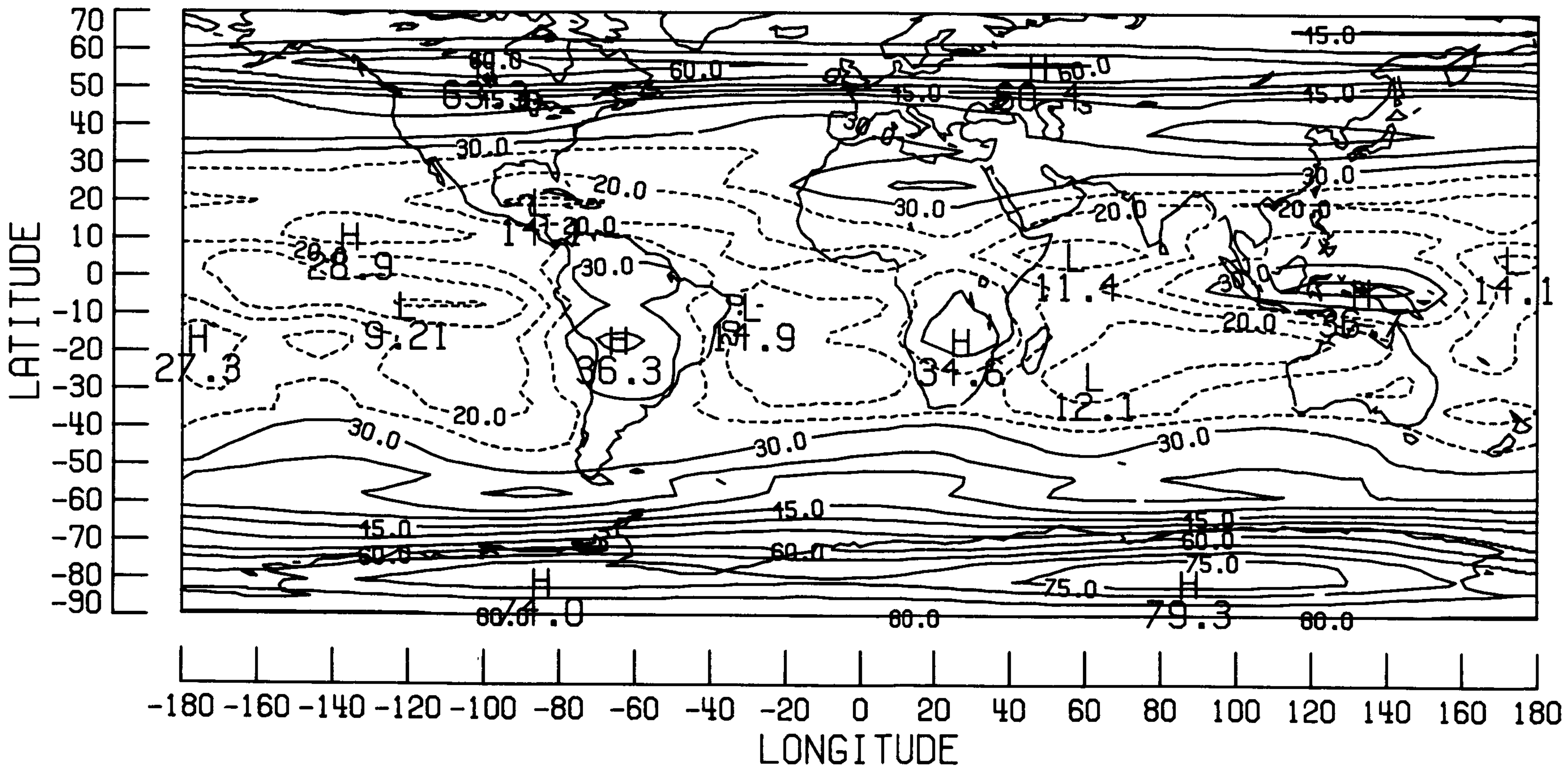
NOV 1984





ABSORPTION W/(M*M)
NOV 1984

ALBEDO (%)
DEC 1984



ABSORPTION W/(M*M)

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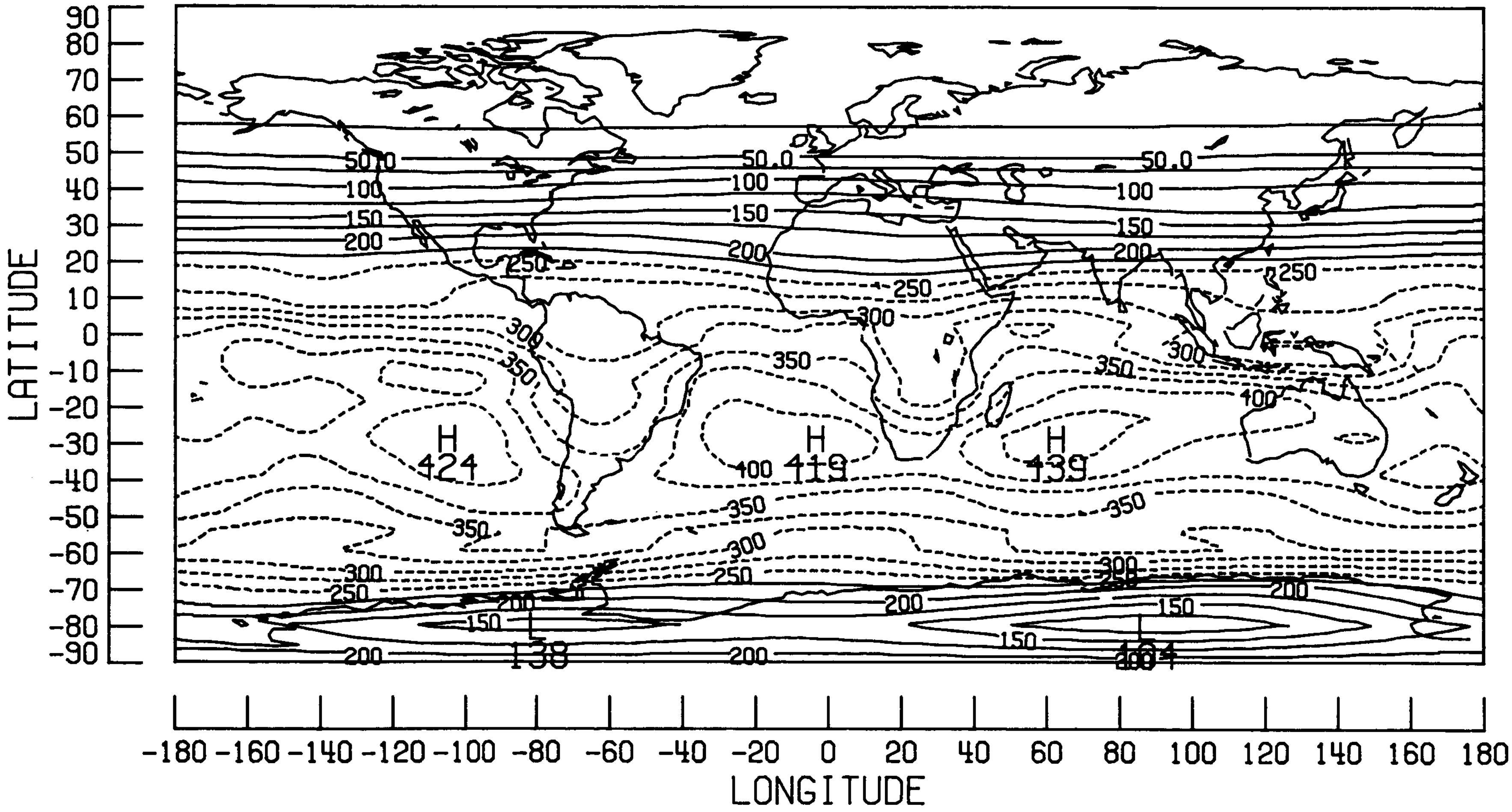
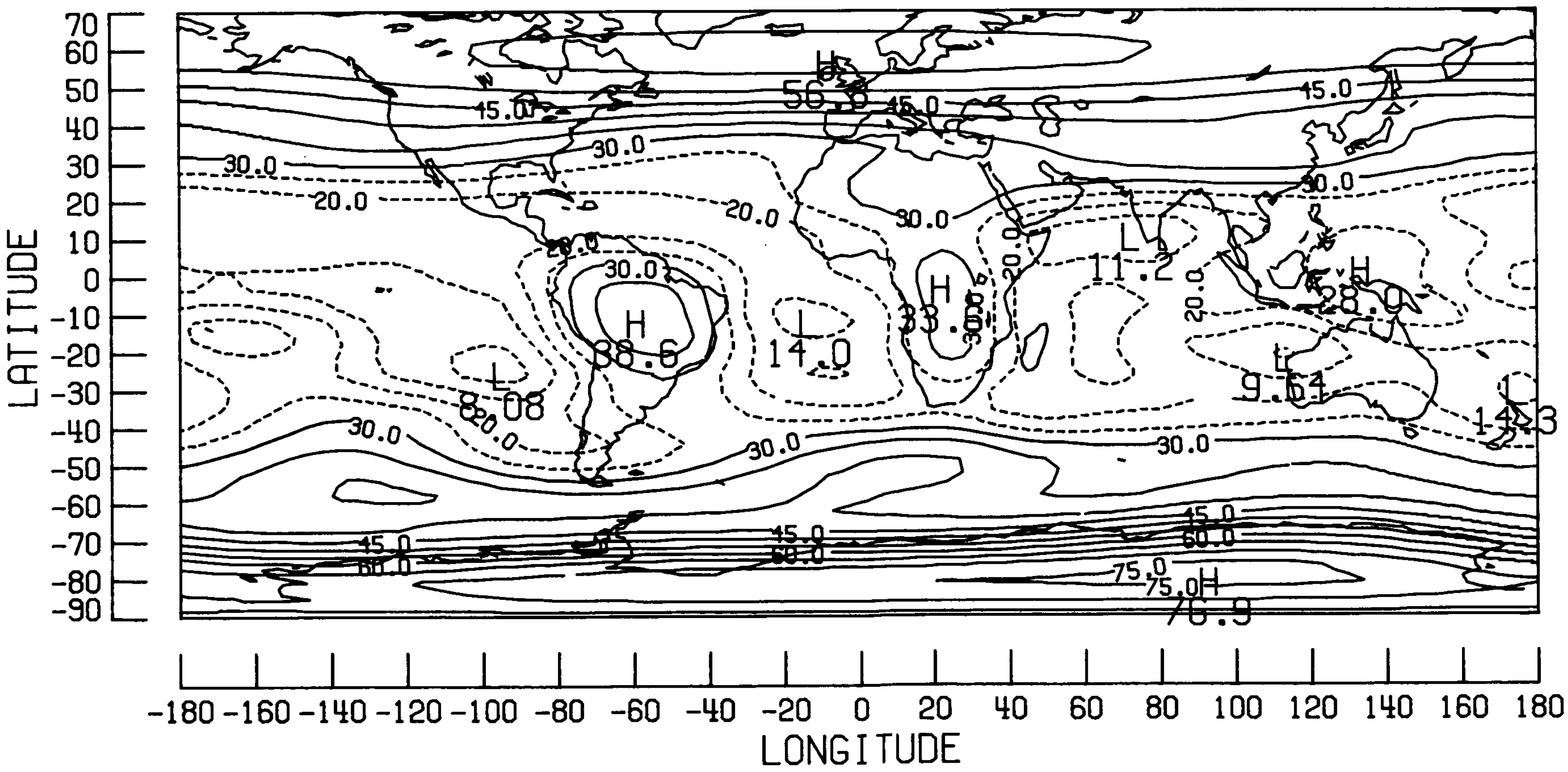


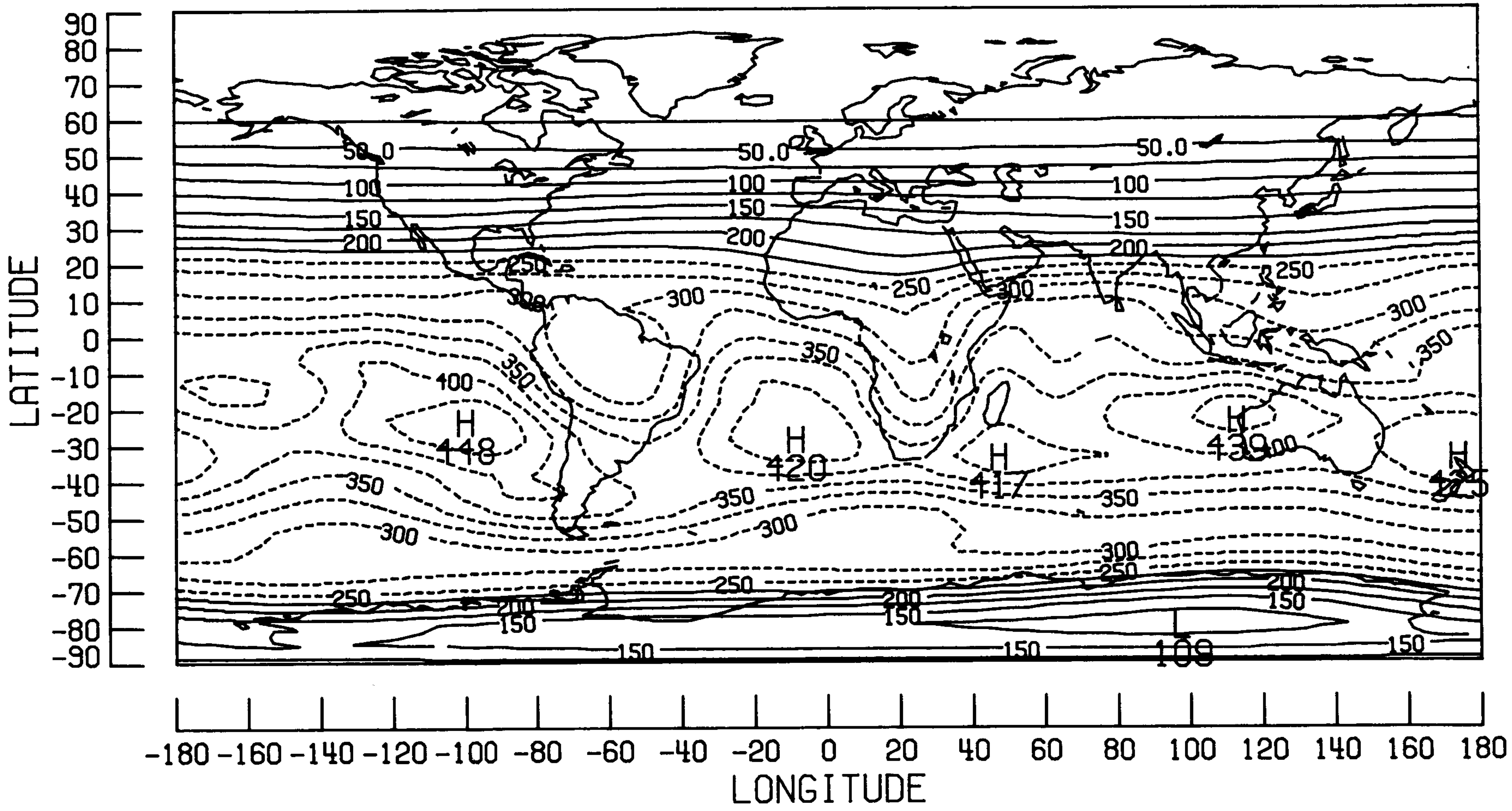


ALBEDO (%)

JAN 1985

ABSORPTION W/(M*M)

JAN 1985



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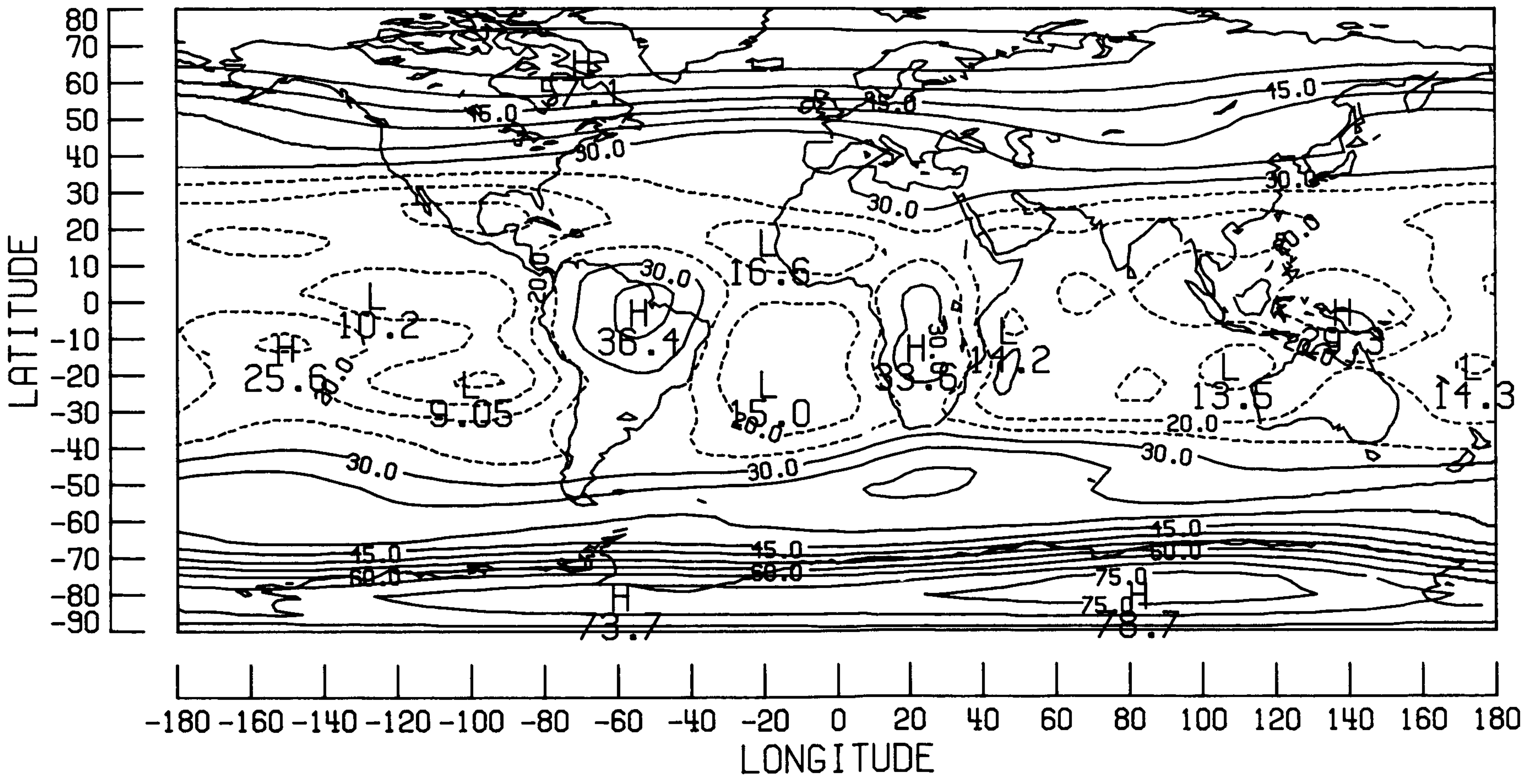

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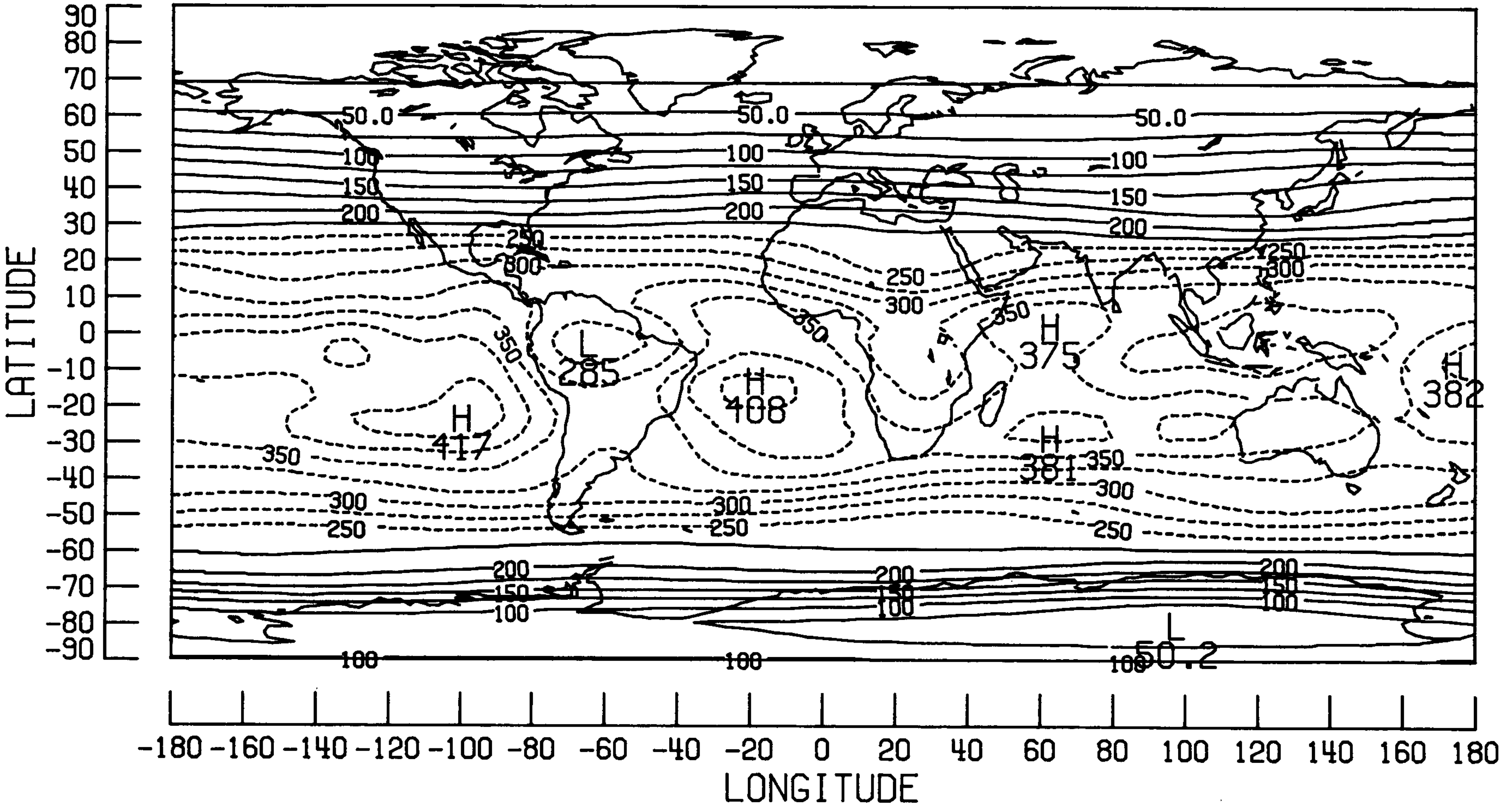

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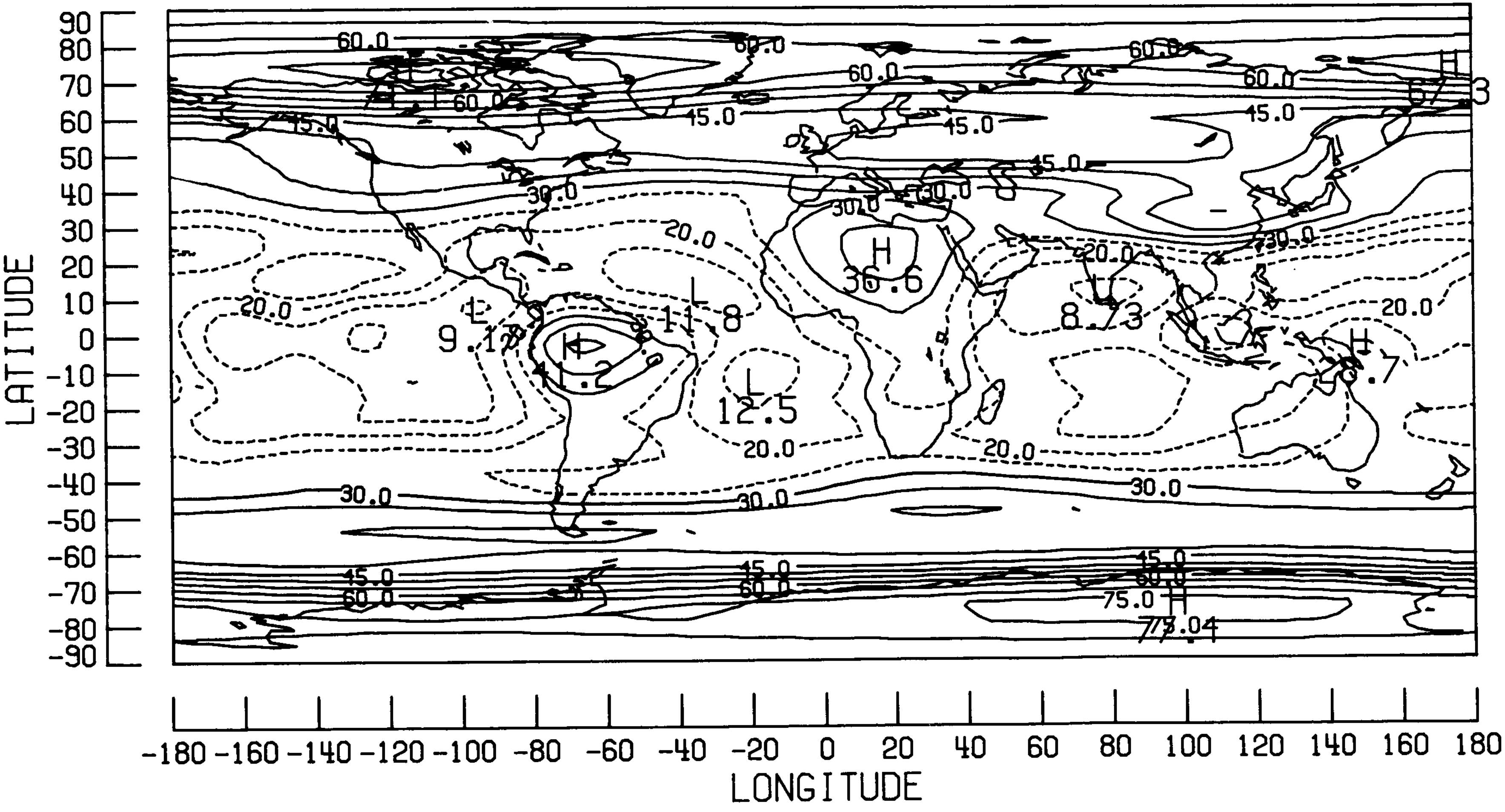
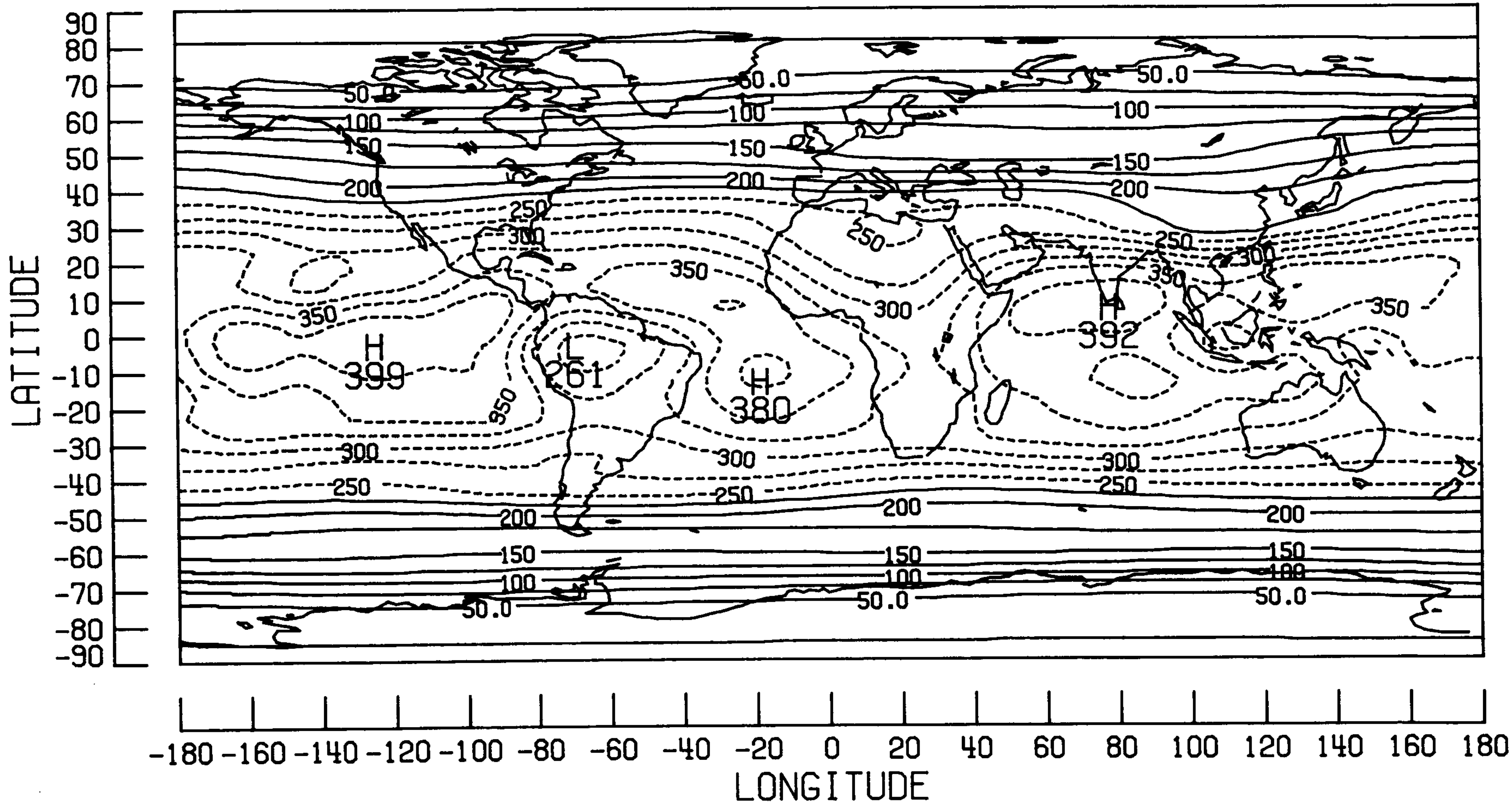


ABSORPTION W/(M*M)

MAR 1985



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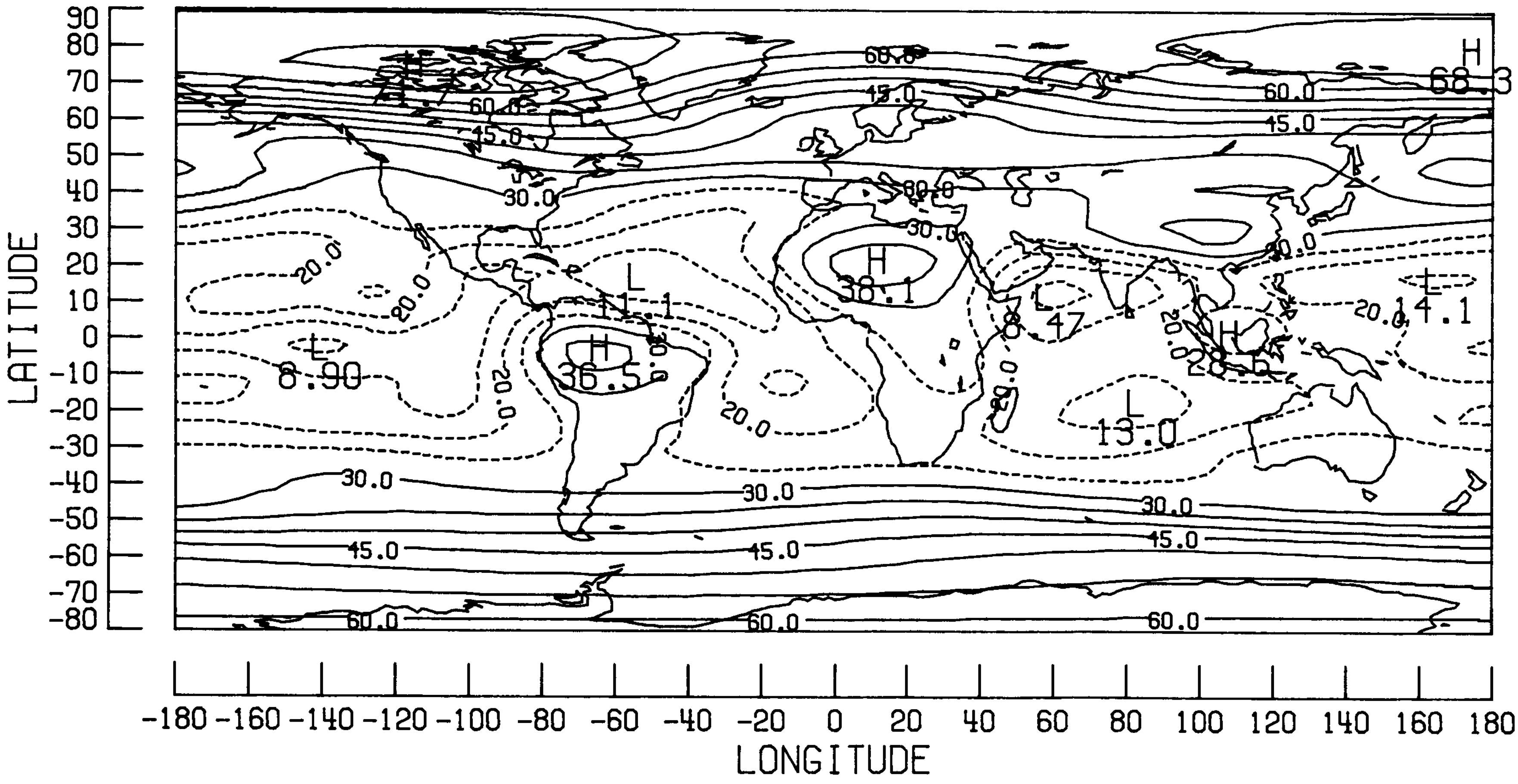
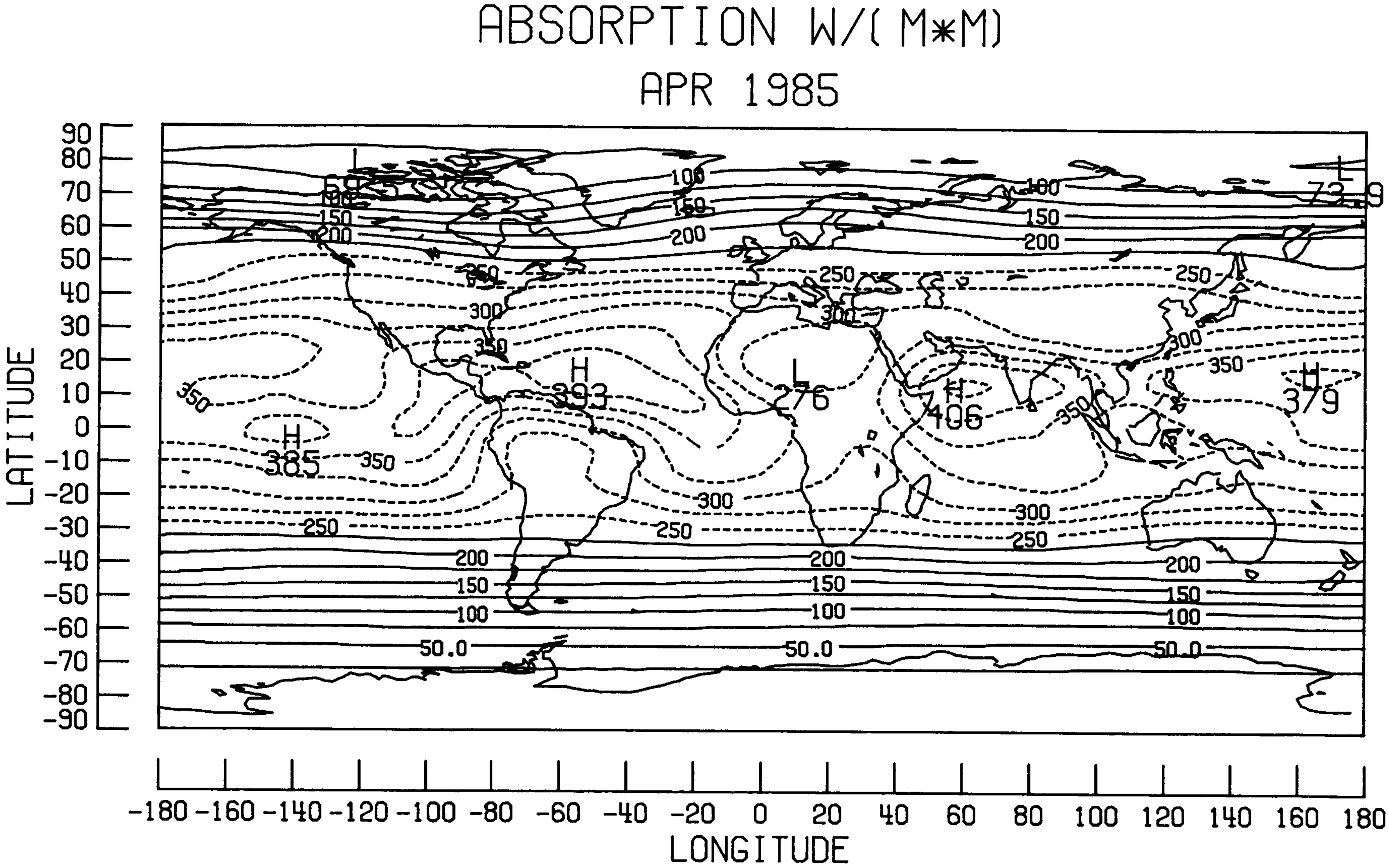
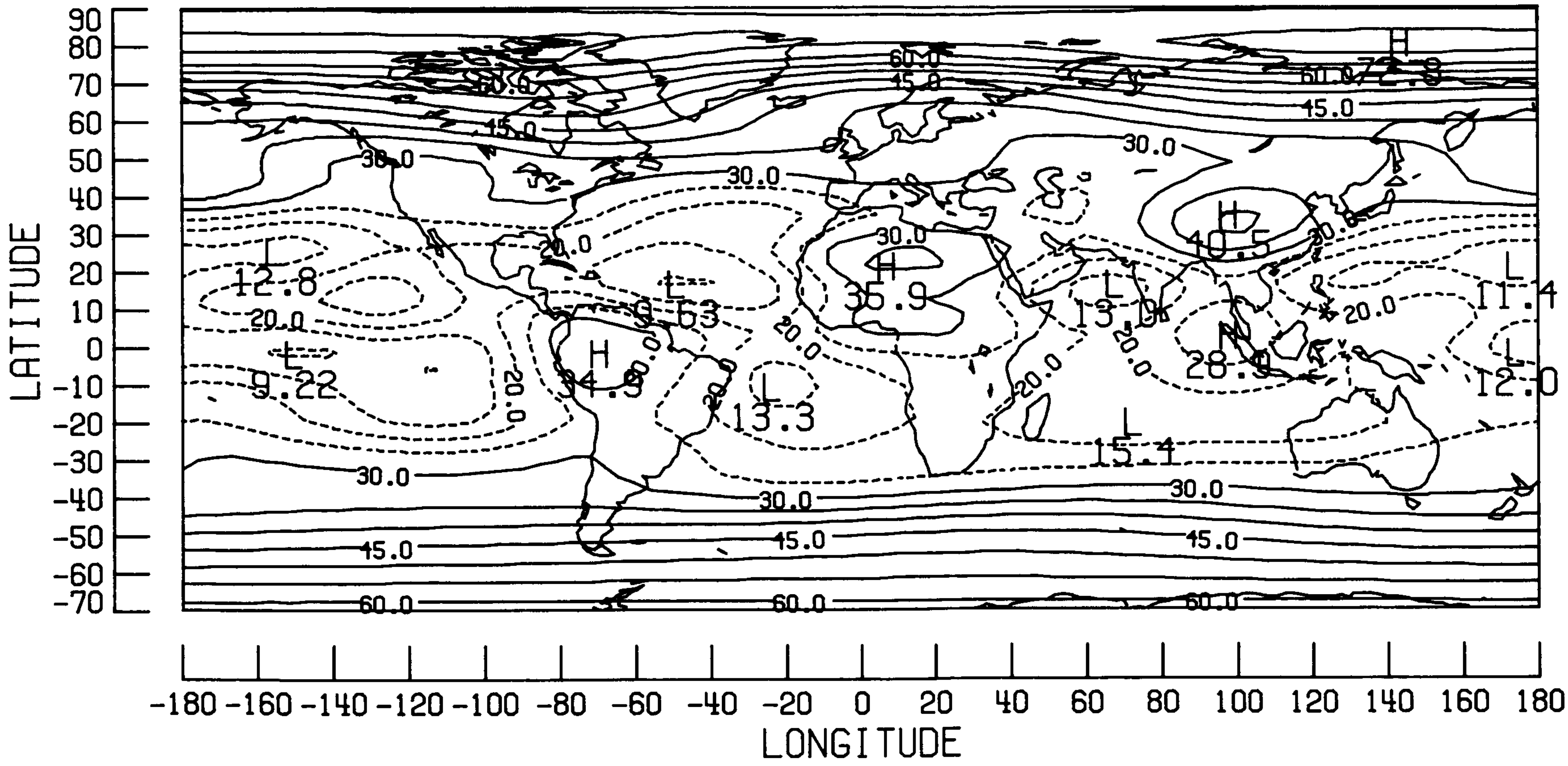




ABSORPTION W/(M*M)

APR 1985

ALBEDO (%)
MAY 1985



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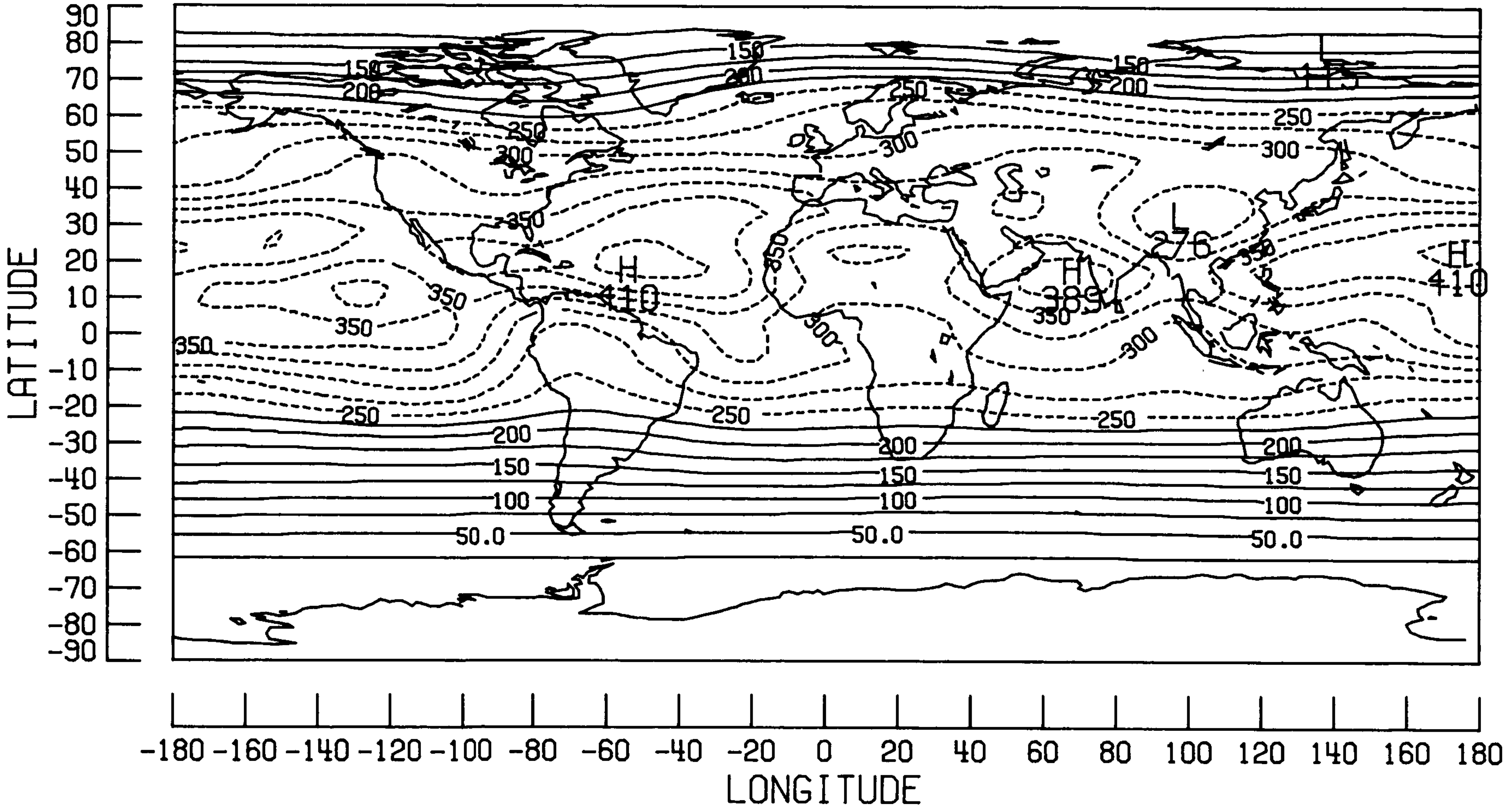
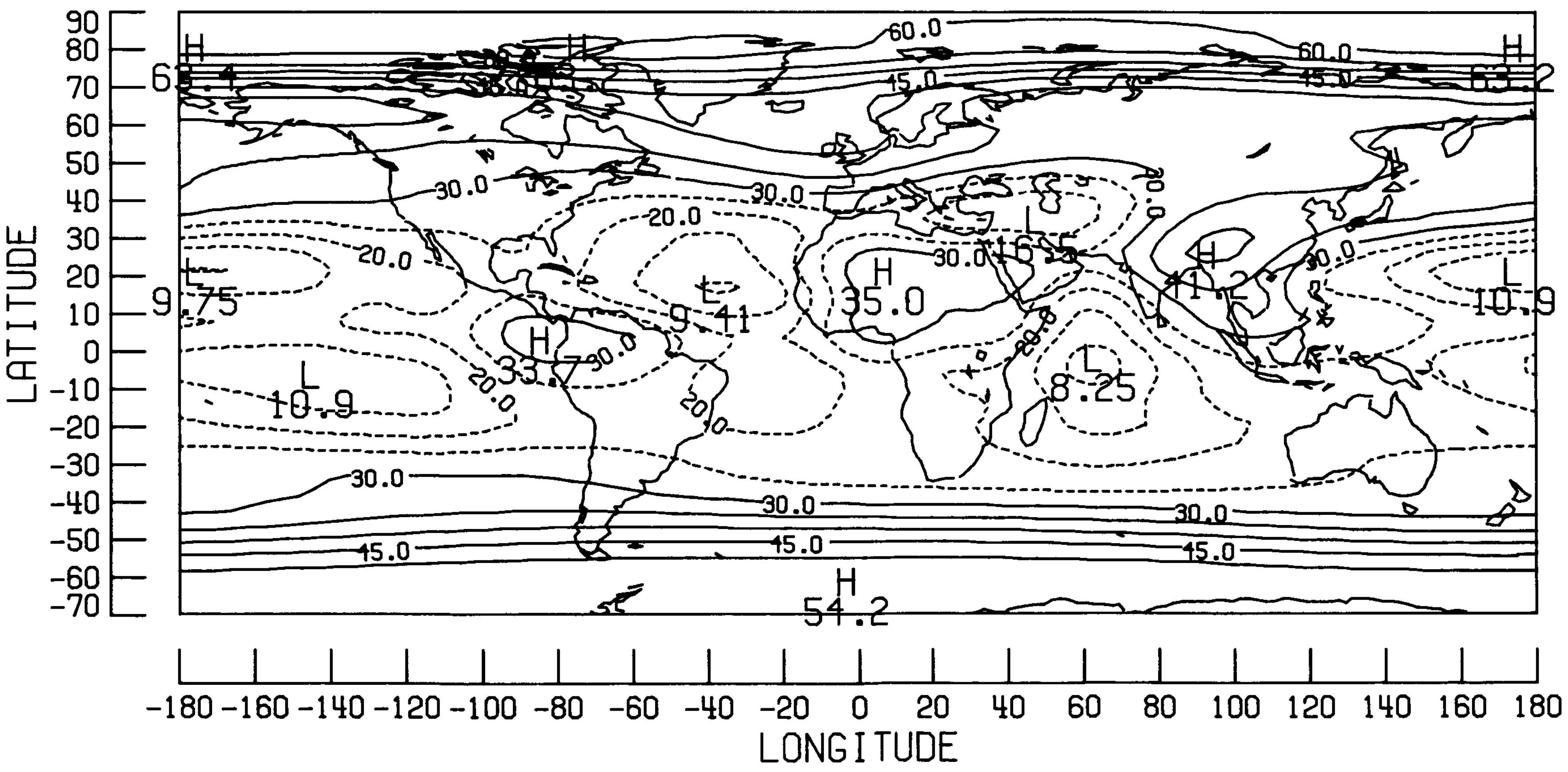
MAY 1985



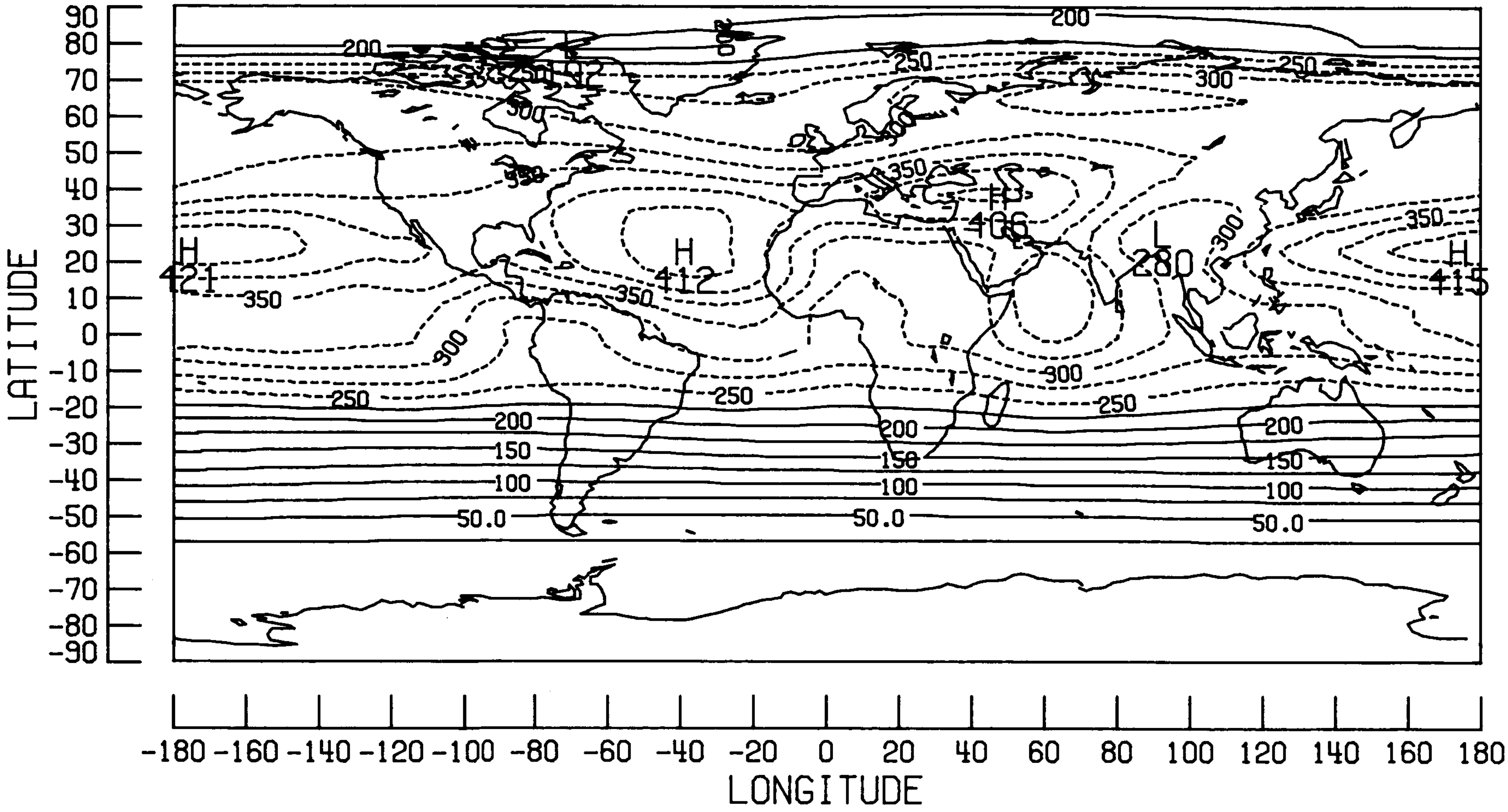


ALBEDO (%)

JUN 1985

ABSORPTION W/(M*M)

JUN 1985



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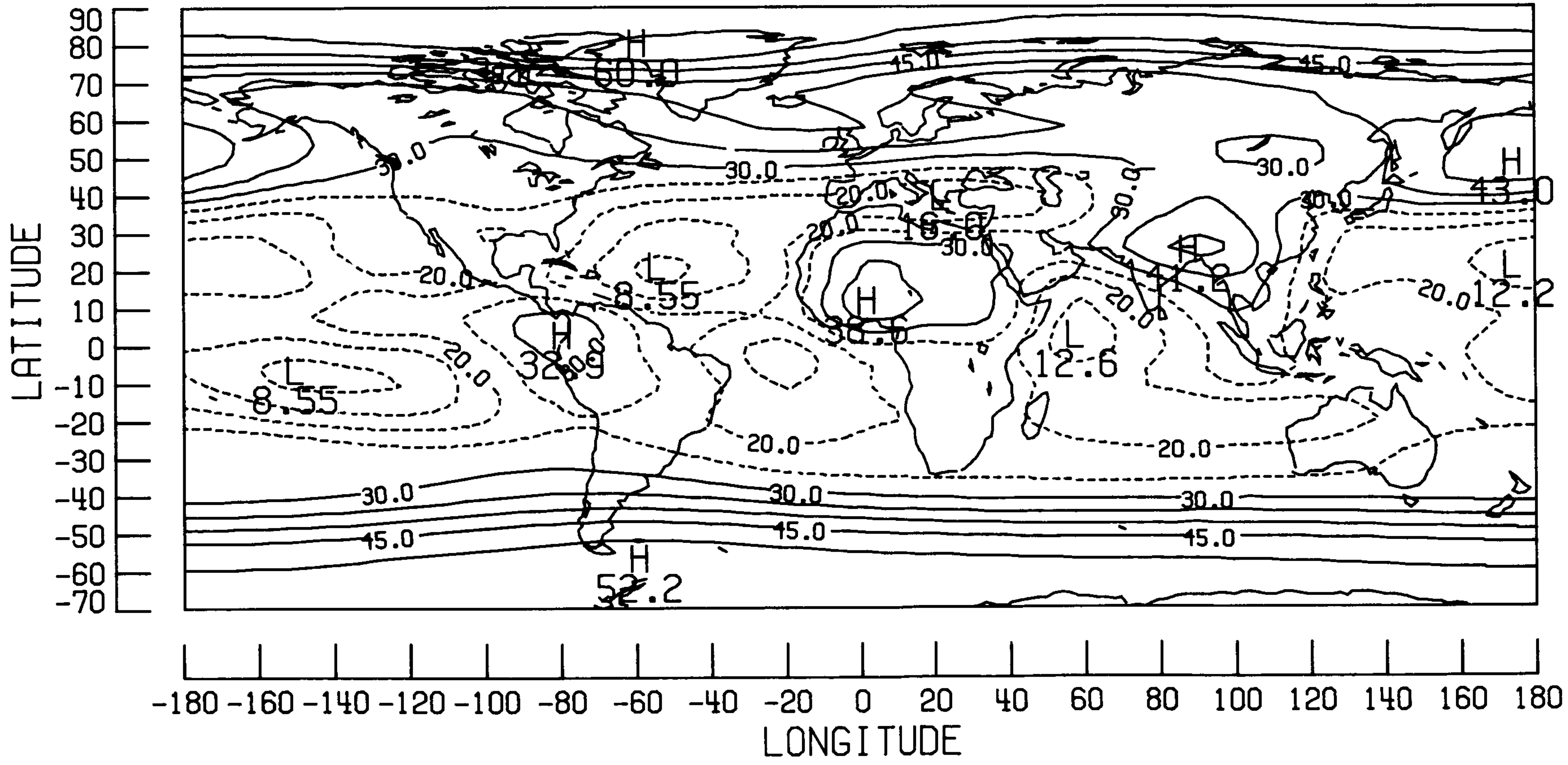
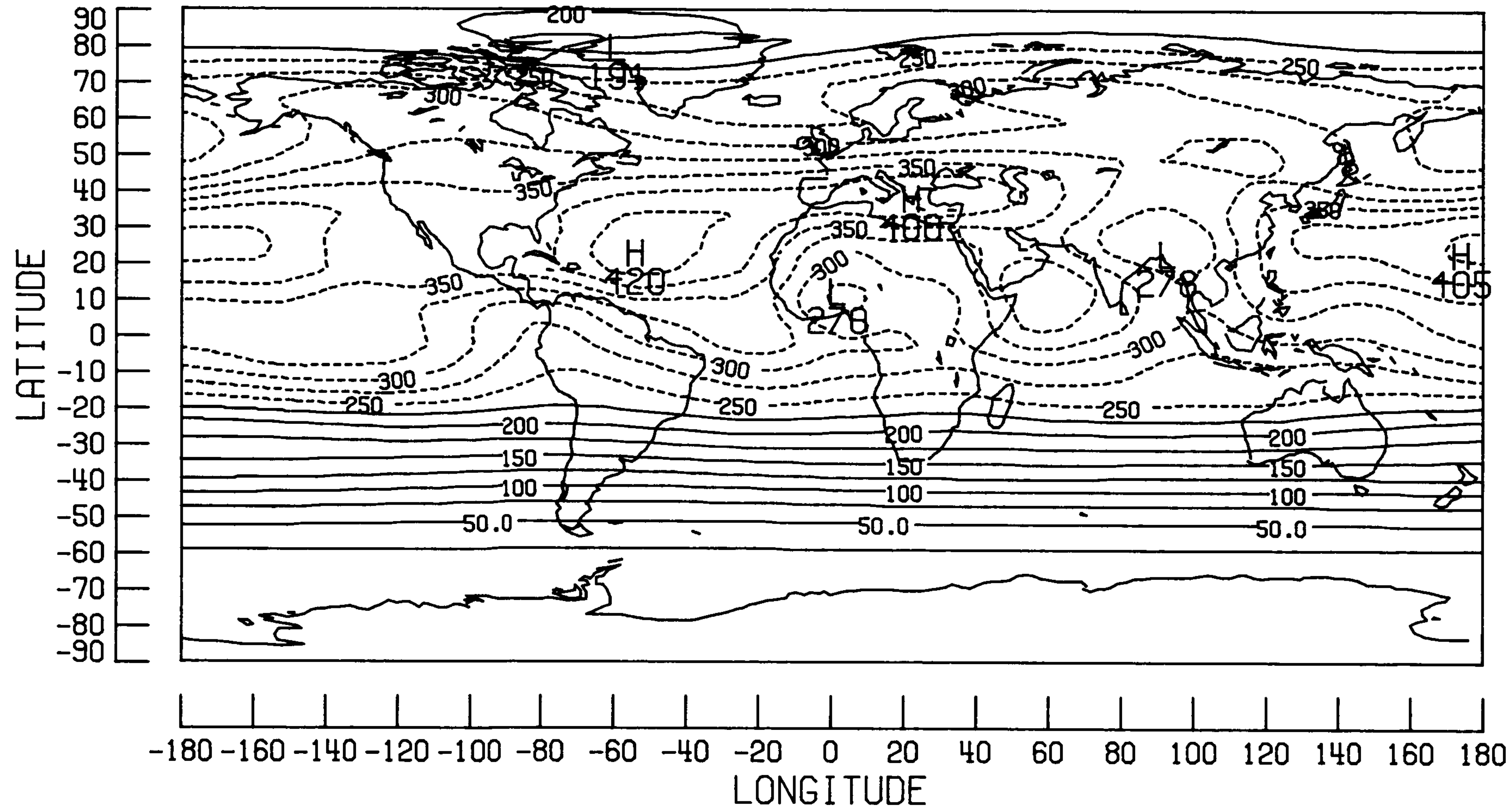


C-3

ABSORPTION W/(M*M)

JUL 1985



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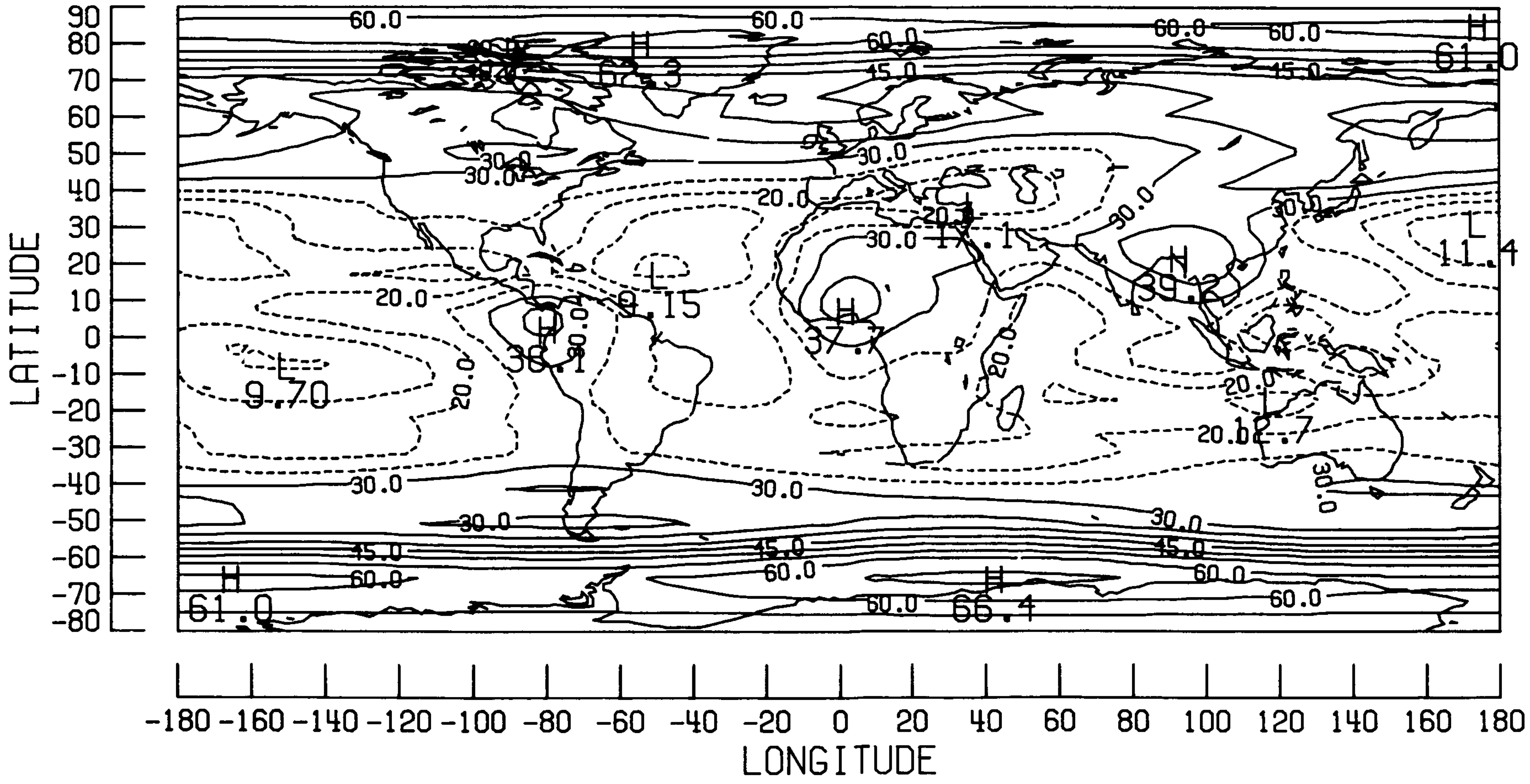

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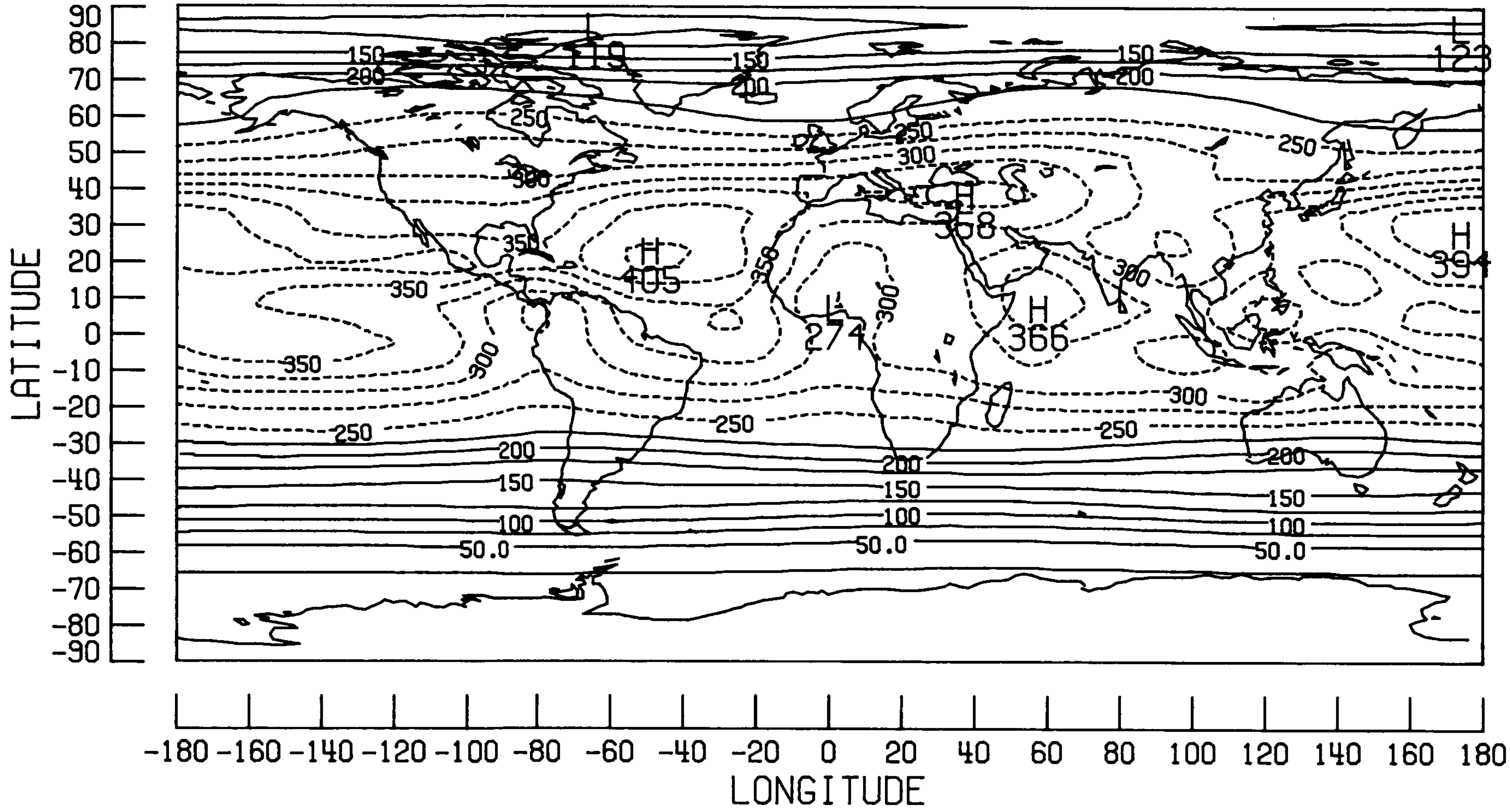

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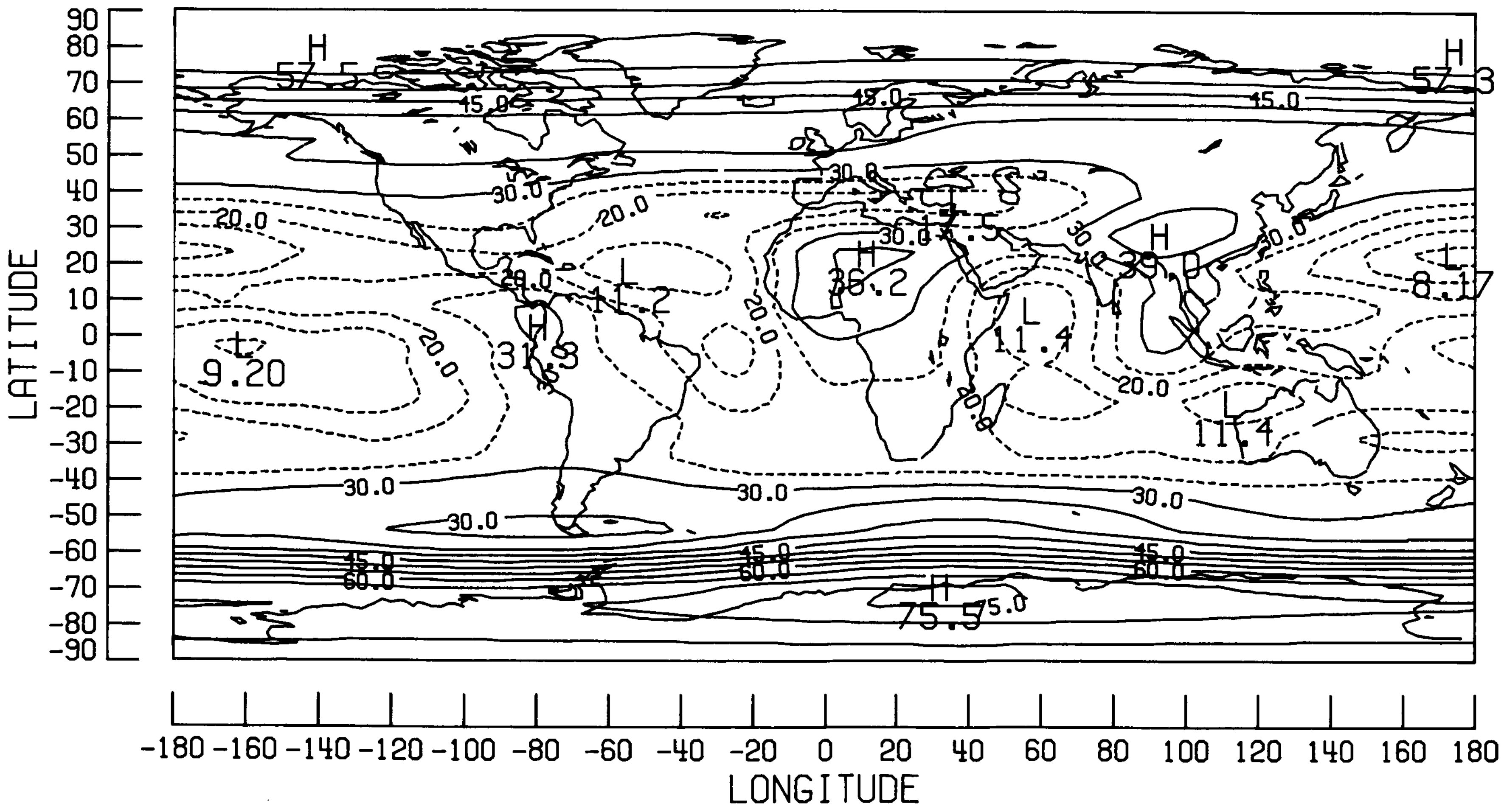

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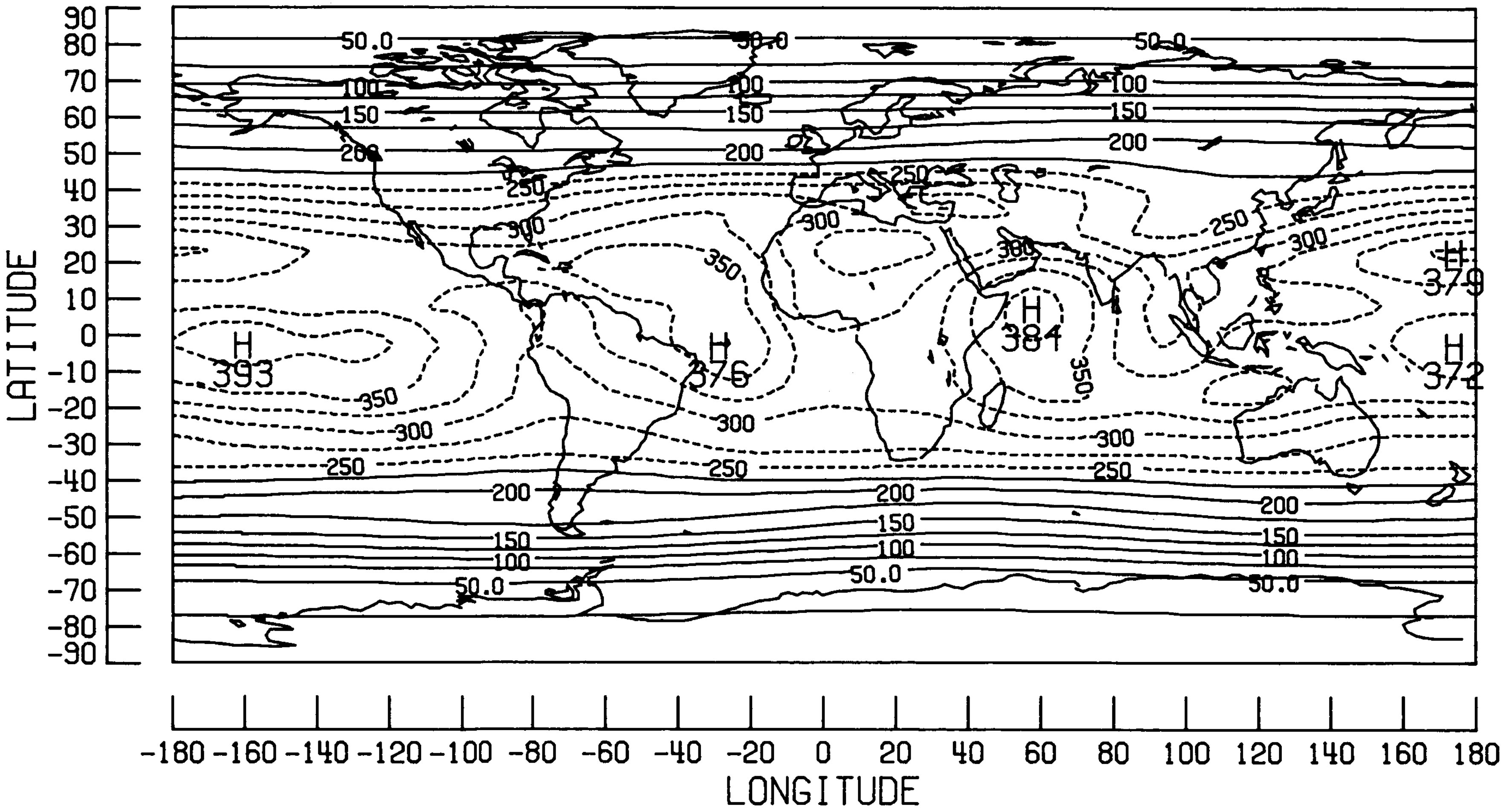
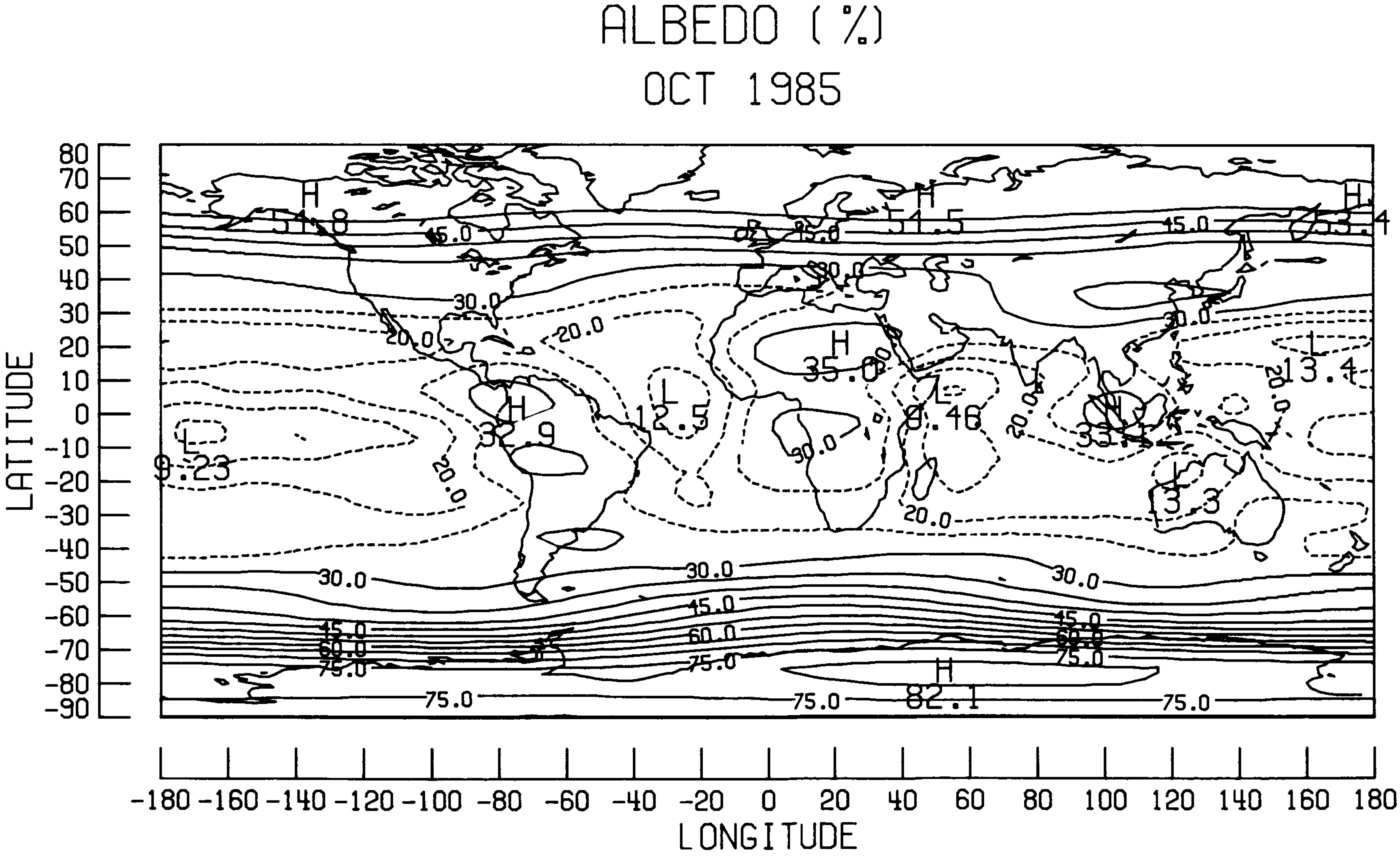
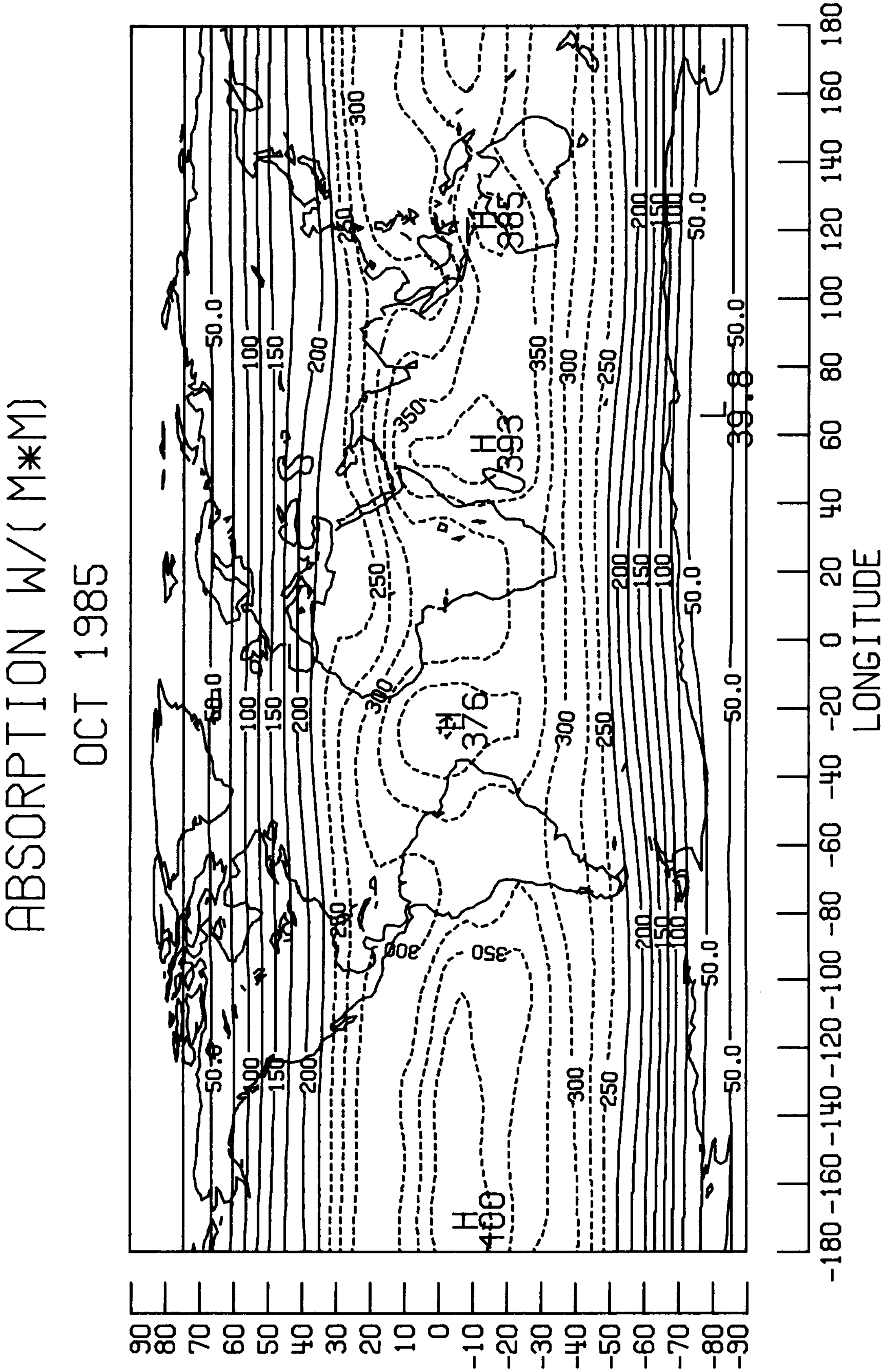




ALBEDO (%)

OCT 1985



ABSORPTION W/(M*M)

OCT 1985

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Atlas of Nimbus 6 data for July 1975 to May 1978 is presented in NASA RP-1230, 1990.

16. Abstract

An atlas of monthly mean global contour maps of albedo and absorbed solar radiation is presented. This atlas contains 7 years of continuous data from November 1978 to October 1985. The data were retrieved from measurements made by the second Earth radiation budget (ERB) wide-field-of-view instrument, which flew on the Nimbus 7 spacecraft in 1978. The deconvolution method used to produce these data is briefly discussed so that the user may understand their generation and limitations. These geographical distributions of albedo and absorbed solar radiation are provided as a resource for researchers studying the radiation budget of the Earth. This atlas complements the atlases of outgoing longwave radiation by Bess and Smith in NASA RP-1185 and RP-1186, also based on the Nimbus 6 and 7 ERB data.

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