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Atlas of Albedo and Absorbed Solar Radiation Derived From Nimbus 6 Earth Radiation Budget Data Set—July 1975 to May 1978

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Introduction

Absorbed solar radiation (ASR) and outgoing longwave radiation (OLR) provide respectively the heat source and the heat sink which drive the motions of the atmosphere and oceans, thereby governing our weather and determining our climate. The importance of understanding the radiation budget of the Earth is discussed by Hartmann et al. (1986). In order to provide the needed measurements, Earth radiation budget (ERB) instruments were flown on the Nimbus 6 and 7 spacecraft (Smith et al. 1977; Jacobowitz et al. 1979; 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 estimated. The Nimbus 6 and 7 WFOV radiometers began providing measurements in July 1975 and November 1978, respectively. Other data sets, such as those of Winston et al. (1979a, 1979b), are now available for OLR (based on narrow-band measurements), but the ERB data set is one of the few which are extant for shortwave radiation. Major advantages of the ERB measurements are that they are broadband measurements and provide global coverage for a period of more than 10 years with a single type of instrumentation. Also, the measurements are stable and have low noise.

This paper is an atlas of monthly mean global maps of albedo and ASR for July 1975 to May 1978 based on measurements from the shortwave WFOV radiometer of the ERB instrument aboard the Nimbus 6 spacecraft. This atlas, which contains nearly 3 years of data, and the atlas of albedo and ASR based on the Nimbus 7 ERB shortwave measurements (Smith, Rutan, and Bess, 1990) comprise a 10-year set of albedo and ASR data for use by researchers. Profiles of zonal mean albedos are also tabulated. The time period contains the 1976–77 El Niño event.

The basic problem of analyzing WFOV radiometer measurements can be described with reference to figure 1. The WFOV radiometer measurement is the integral of radiances from all points at the top of the atmosphere, from nadir to the limb. For the Nimbus 6, this area of integration was a spherical cap with a radius equal to the arc for a geocentric angle of 31° about the subsatellite point. Computation of the albedo distribution from WFOV measurements is an inversion process requiring solution of the measurement integral equation. Data for this atlas were generated with the retrieval method of Smith and Rutan (1990).

A study of the climate of Earth by definition requires long-term data sets of important climatic parameters. Bess and Smith (1987a, 1987b) have analyzed OLR measurements using 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. They also included tabulations of the spherical harmonic coefficients, which may be used to compute these OLR distributions. The present atlas of albedo and ASR, the Nimbus 7 ERB results of Smith, Rutan, and Bess (1990), and the earlier OLR atlases define for a decade the two radiation streams whose balance governs the Earth's climate.

In addition, the Earth Radiation Budget Experiment (ERBE) has instruments on the Earth Radiation Budget Satellite (ERBS), which is in a precessing orbit with a 57° inclination, and on the NOAA 9 and NOAA 10 Sun-synchronous operational meteorological satellites. These spacecraft have made measurements since November 1984, January 1985, and November 1986, respectively. With those data, researchers will have at least 15 years of radiation budget information with which to study the short-term climate of the Earth.

The authors are grateful to H. Jacobowitz of NOAA for providing the Nimbus 6 data tapes which made this research possible.

Measurements

The Nimbus 6 spacecraft was in a Sun-synchronous orbit with an inclination of 99°, an altitude of 1100 km, and an Equator crossing time near noon for the portion of the orbit during which the spacecraft was in sunlight. From this altitude, the portion of the Earth within the field of view of the WFOV radiometer was a spherical cap with a radius equal to the arc of a 31° geocentric angle. The resolution of information retrievable from the shortwave WFOV measurements is only approximately 10° (Smith and Rutan 1990). Thus, the North and South Poles were within the resolution distance of the instrument during each orbit, so that the measurements in effect provided global coverage.

When the ERB instrument was on, WFOV measurements were taken at 4-sec intervals. Four consecutive measurements were averaged to produce one value every 16 sec. The data consist of these 16-sec averages together with the time, latitude, and longitude for each of the measurements.

Because of spacecraft power constraints, the nominal duty cycle of the ERB radiometer was 2 days on and 2 days off. This sampling is adequate for computing monthly average radiation maps (Bess and Smith 1987a, 1987b). However, there were times when the sampling was reduced from this level. There were 20 000 usable shortwave WFOV measurements taken during July 1975, the first month of Nimbus 6 ERB operation. During the next year, there were 14 000 to 29 000 usable shortwave measurements for each month. During the second year, there were 12 000 to 25 000 shortwave measurements each month, and in the third year there were 6000 to 14 000 usable measurements each month, except for August 1977, when there were only 3500 measurements. Because the sampling was reduced, the grid system for analysis of the Nimbus 6 data was changed to 10° increments in longitude, but the orbit angle and latitude increments were maintained at 5°. With this grid, at least 6000 shortwave measurements per month are required to produce usable albedo maps. With less than 6000 measurements, the resulting albedo map for August 1977 declined in quality.

Editing checks, calibration, and degradation corrections for the 3-year exposure of the shortwave WFOV radiometer to the space environment are discussed by Bess, Green, and Smith (1981) and Bess and Smith (1987a, 1987b). Shortwave measurements were not used when the solar zenith angle at the subsatellite point was greater than 90°, as measurements made under those conditions could be affected by sunlight on the Earth-facing side of the spacecraft and near the sensor. Although small, the errors from this effect negated the little information gained on albedo in this region of the orbit.

Method of Analysis

Monthly maps of albedo were computed from the shortwave WFOV radiometer measurements with the retrieval method developed by Smith and Rutan (1989). Additional discussion of the application of the method to 7 years of Nimbus 7 ERB measurements is given by Smith, Rutan, and Bess (1990).

Monthly average maps of the measurements are first compiled in terms of geocentric orbit angle of the spacecraft from the Equator[1] (this angle determines latitude, given the orbital inclination) and longitude of the subsatellite point. Grid intervals of 5° of orbit angle and 10° of longitude were used for this step. The albedo map which corresponds to this measurement map is then computed as the solution for the integral equation for the measurement. This solution for the albedo field is expressed as

$$A(\theta, \Phi) = \sum_{n=-N}^{N} \exp(\mathrm{in}\Phi) f_n(\theta)$$

where θ and Φ are the colatitude and longitude of a point. The Fourier terms for reduced albedo $f_n(\theta)$ are also computed as a series, with coefficients to be determined from the measurements (Smith and Rutan 1990; Smith, Rutan, and Bess, 1990). The summation limit N must be chosen carefully.

Because the measurement integral is a smoothing operator, it limits the resolution obtainable for the albedo field. Also, the albedo information which can be retrieved is limited by the low solar incidence near the terminator, which was at high latitudes for the Nimbus 6 orbit. Finally, the sampling restricts the resolution available. These three effects manifest themselves as errors which rapidly increase with increasing order of the terms in the solutions for $f_n(\theta)$ as the limit of resolution is approached. The series is terminated when the error due to including a term exceeds that due to deleting it (Smith and Rutan 1990).

The number of terms which could be used for each $f_n(\theta)$, which describe the albedo distributions, is listed in table I for each month in the data period. For wave number 0 (i.e., the zonal average), 28 to 34 terms were retrievable, and this number provided a latitudinal resolution of slightly better than 10° of latitude. One may expect 6° of resolution from so many terms, but many terms were required because of the loss of observability at high latitudes. The nominal longitudinal resolution with a wave number of 11 is approximately 30°. The number of terms was somewhat lower for the Nimbus 6 than for the Nimbus 7, listed by Smith, Rutan, and Bess (1990). This difference occurred because the Nimbus 6 was at a greater altitude (1100 km) than the Nimbus 7 (955 km.). Thus, less resolution was available from the Nimbus 6 measurements. In addition, the number of measurements available from the Nimbus 6 was considerably smaller than that from the Nimbus 7. As a consequence, the average monthly measurement map contains increased noise because of day-to-day variability of the albedo with weather patterns. This effect in turn reduced the number of terms of the series which could be retrieved. The number of terms for August 1977 was slightly less than that for most of the other months because of the reduced number of measurements for that month. This reduction in the number of terms corresponded to a reduction of resolution. The terms which comprised $f_n(\theta)$, or equivalently the albedo field, in regions of low solar incidence could not be evaluated from the measurements and are said to have been unobservable. These terms were computed from the zonal average albedo profiles compiled by Ellis and Vonder Haar (1976). The seasonal variation of observability because of solar declination changes has been treated

[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.

by Smith and Rutan (1989). Figure 2 shows the variation of observable regions during the year. Near the winter pole there is a region of polar night, within which the Sun does not shine at any time during the day. The albedo is not physically defined in this region. For Nimbus 6 there was an unobservable region near the terminator, within which the WFOV measurements provided little information. This unobservable region was approximately 20° of latitude for each hemisphere. Adjacent to this region was a transition region approximately 10° wide for most of the year, within which the measurements provided useful information but did not accurately define the albedo.

The albedo cannot be reliably retrieved at high latitudes from WFOV measurements because of the low solar incidence. However, the ASR error is the product of albedo error and solar incidence. As the latitude increases, the albedo error increases and the solar incidence decreases, so that at worst the error in ASR in the region of unobservability is 10 W/m^2. The ASR together with the outgoing longwave radiation are the quantities of primary interest in studies of Earth radiation budget. The albedo was used to compute the ASR, under the assumption that albedo is independent of solar zenith angle at each point. Thus, for low latitudes, the albedos were essentially noon values.

Results

This atlas contains monthly mean maps of albedo and of ASR for July 1975 to May 1978. These maps were computed from Nimbus 6 shortwave WFOV measurements. The albedo maps show contours with intervals of 5 percent. Dotted lines indicate albedos of less than 30 percent. The limitations of albedo results which have been retrieved from WFOV measurements are discussed in the previous section: the resolution is limited to 10°of latitude and 30°of longitude, and at high latitudes the results are based on a priori data. The ASR maps show contours with intervals of 25 W/m^2, with contours of 250 W/m^2 or greater given as dotted lines.

Zonal means of albedos are also presented in table II for each month. Averages of zonal mean albedos were computed for each month of the year over the 35-month data period and are plotted in figure 3. Figure 4 shows analogous averages for zonal mean ASR.

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 Nimbus 7 WFOV measurements as analyzed by Bess and Smith (1987a, 1987b).

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References

Bess, T. Dale; Green, Richard N.; and Smith, G. Louis 1981: Deconvolution of Wide Field-of-View Radiometer Measurements of Earth-Emitted Radiation. Part II: Analysis of First Year of Nimbus 6 ERB Data. *J. Atmos. Sci.*, vol. 38, no. 3, Mar., pp. 474–488.

Bess, T. Dale; and Smith, G. Louis 1987a: *Atlas of Wide-Field-of-View Outgoing Longwave Radiation Derived From Nimbus 6 Earth Radiation Budget Data Set—July 1975 to June 1978.* NASA RP-1185.

Bess, T. Dale; and Smith, G. Louis 1987b: *Atlas of Wide-Field-of-View Outgoing Longwave Radiation Derived From Nimbus 7 Earth Radiation Budget Data Set—November 1978 to October 1985.* NASA RP-1186.

Ellis, James S.; and Vonder Haar, Thomas H. 1976: Zonal Average Earth Radiation Budget Measurements From Satellites for Climate Studies. Atmospheric Science Paper 240 (NGR 06-002-102), Colorado State Univ., Jan. (Available as NASA CR-149319.)

Hartmann, D. L.; Ramanathan, V.; Berroir, A.; and Hunt, G. E. 1986: Earth Radiation Budget Data and Climate Research. *Reviews Geophys.*, vol. 24, no. 2, May, pp. 439–468.

Jacobowitz, H.; Smith, W. L..; Howell, H. B.; Nagle, F. W.; and Hickey, J. R. 1979: The First 18 Months of Planetary Radiation Budget Experiments From the Nimbus 6 ERB Experiment. *J. Atmos. Sci.*, vol. 36, no. 3, Mar., pp. 501–507.

Jacobowitz, Herbert; Soule, Harold V.; Kyle, H. Lee; House, Frederick B.; and NIMBUS 7 ERB Experiment Team 1984: The Earth Radiation Budget (ERB) Experiment: An Overview. *J. Geophys. Res.*, vol. 89, no. D4, June 30, pp. 5021–5038.

Smith, G. Louis; and Green, Richard N. 1981: Deconvolution of Wide Field-of-View Radiometer Measurements of Earth-Emitted Radiation. Part I: Theory. *J. Atmos. Sci.*, vol. 38, no. 3, Mar., pp. 461–473.

Smith, G. Louis; and Rutan, David 1989: Observability of Albedo by Shortwave Wide Field-of-View Radiometers in Various Orbits. *RSRM '87—Advances in Remote Sensing Retrieval Methods,* Adarsh Deepak, Henry E. Fleming, and John S. Theon, eds., A. Deepak Publ., pp. 475–484.

Smith, G. L.; and Rutan, D. 1990: Deconvolution of Wide-Field-of-View Measurements of Reflected Solar Radiation. *J. Appl. Meteorol.*, vol. 29, Jan.

Smith, G. Louis; Rutan, David; and Bess, T. Dale 1990: *Atlas of Albedo and Absorbed Solar Radiation Derived From Nimbus 7 Wide Field-of-View Earth Radiation Budget Data Set—November 1978 to October 1985.* NASA RP-1231.

Smith, W. L..; Hickey, J.; Howell, H. B.; Jacobowitz, H.; Hilleary, D. T.; and Drummond, A. J. 1977: Nimbus-6 Earth Radiation Budget Experiment, *Appl. Opt.*, vol. 16, no. 2, Feb., pp. 306–318.

Winston, Jay S.; Gruber, Arnold; Gray, Thomas I., Jr.; Varnadore, Marylin S.; Earnest, Charles L.; and Mannello, Luke P. 1979a: *Earth-Atmosphere Radiation Budget Analyses Derived From NOAA Satellite Data—June 1974–February 1978, Volume 1.* U.S. Dep. of Commerce, Aug.

Winston, Jay S.; Gruber, Arnold; Gray, Thomas I., Jr.; Varnadore, Marylin S.; Earnest, Charles L.; and Mannello, Luke P. 1979b: *Earth-Atmosphere Radiation Budget Analyses Derived From NOAA Satellite Data—June 1974–February 1978, Volume 2.* U.S. Dep. of Commerce, Aug.

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
July 1975	30	28	28	4	4	2	2	2	2	2	2	2
Aug. 1975	32	30	16	6	6	2	2	2	2	2	2	2
Sept. 1975	30	26	20	6	6	2	2	2	2	2	2	2
Oct. 1975	34	28	20	6	4	2	2	2	2	2	2	2
Nov. 1975	30	28	28	8	4	2	2	2	2	2	2	2
Dec. 1975	34	26	24	8	6	4	2	2	2	2	2	2
Jan. 1976	30	28	22	10	6	4	2	2	2	2	2	2
Feb. 1976	32	24	20	4	4	2	2	2	2	2	2	2
Mar. 1976	34	28	26	8	8	4	2	2	2	2	2	2
Apr. 1976	32	26	26	6	6	4	2	2	2	2	2	2
May 1976	34	30	22	4	4	2	2	2	2	2	2	2
June 1976	30	26	26	6	4	4	2	2	2	2	2	2

Table I. Continued

Month	Number of singular vectors for wave number of —											
	0	1	2	3	4	5	6	7	8	9	10	11
July 1976	34	24	24	4	4	4	2	2	2	2	2	2
Aug. 1976	32	28	24	6	4	4	2	2	2	2	2	2
Sept. 1976	32	28	20	6	2	2	2	2	2	2	2	2
Oct. 1976	30	26	24	6	6	4	2	2	2	2	2	2
Nov. 1976	34	28	24	4	4	4	2	2	2	2	2	2
Dec. 1976	32	30	28	8	6	4	2	2	2	2	2	2
Jan. 1977	34	28	28	4	4	4	2	2	2	2	2	2
Feb. 1977	30	28	22	4	4	2	2	2	2	2	2	2
Mar. 1977	32	26	26	8	4	4	2	2	2	2	2	2
Apr. 1977	30	28	28	6	6	4	2	2	2	2	2	2
May 1977	34	24	24	6	4	4	2	2	2	2	2	2
June 1977	30	28	22	4	4	2	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
July 1977	28	26	26	4	4	4	2	2	2	2	2	2
Aug. 1977	28	26	24	2	2	2	2	2	2	2	0	0
Sept. 1977	30	26	26	6	4	2	2	2	2	2	2	2
Oct. 1977	30	30	24	4	4	2	2	2	2	2	2	2
Nov. 1977	30	24	20	6	4	4	2	2	2	2	2	2
Dec. 1977	30	28	28	8	6	4	2	2	2	2	2	2
Jan. 1978	30	30	26	10	8	4	2	2	2	2	2	2
Feb. 1978	34	28	28	6	4	2	2	2	2	2	2	2
Mar. 1978	32	28	20	4	4	2	2	2	2	2	2	2
Apr. 1978	30	22	16	6	4	2	2	2	2	2	0	0
May 1978	28	22	20	4	4	2	2	2	2	2	2	2

Table II. Zonal Albedo Means for 1975 to 1978

(a) July 1975 to June 1976

LATITUDE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
85-90 N	.584	.587	.564	----	----	----	----	----	.525	.655	.659	.631
80-85 N	.593	.605	.563	----	----	----	----	----	.613	.641	.656	.619
75-80 N	.582	.587	.559	.585	----	----	----	----	.625	.641	.651	.606
70-75 N	.467	.475	.529	.564	----	----	----	.578	.701	.605	.571	.503
65-70 N	.349	.357	.453	.600	.610	----	.540	.526	.705	.532	.471	.389
60-65 N	.327	.339	.370	.587	.548	.600	.541	.528	.599	.451	.411	.351
55-60 N	.346	.376	.333	.495	.536	.563	.540	.504	.469	.387	.368	.351
50-55 N	.324	.358	.334	.387	.501	.559	.515	.456	.418	.356	.335	.330
45-50 N	.292	.293	.318	.338	.438	.485	.448	.402	.411	.336	.311	.309
40-45 N	.276	.257	.272	.324	.362	.381	.368	.363	.364	.309	.282	.289
35-40 N	.243	.242	.241	.284	.310	.323	.313	.341	.304	.286	.260	.256
30-35 N	.211	.217	.241	.241	.285	.318	.292	.316	.287	.274	.255	.231
25-30 N	.216	.213	.230	.232	.264	.295	.282	.269	.270	.248	.239	.222
20-25 N	.225	.229	.202	.224	.235	.238	.253	.218	.216	.207	.204	.210
15-20 N	.220	.229	.207	.206	.213	.207	.216	.190	.173	.181	.189	.197
10-15 N	.229	.225	.231	.226	.211	.212	.192	.182	.174	.178	.208	.212
5-10 N	.237	.236	.228	.241	.217	.215	.191	.184	.189	.194	.223	.234
0-5 N	.216	.229	.203	.207	.214	.214	.200	.201	.204	.215	.215	.217
0-5 S	.190	.188	.195	.182	.205	.212	.208	.221	.215	.210	.186	.187
5-10 S	.191	.168	.194	.188	.201	.208	.215	.217	.201	.180	.161	.185
10-15 S	.195	.185	.185	.187	.200	.214	.211	.196	.179	.168	.172	.186
15-20 S	.189	.194	.189	.187	.200	.217	.201	.195	.182	.186	.195	.185
20-25 S	.204	.191	.212	.210	.203	.195	.191	.200	.191	.200	.205	.202
25-30 S	.238	.215	.219	.222	.206	.189	.188	.194	.199	.209	.220	.229
30-35 S	.266	.263	.227	.225	.213	.212	.194	.206	.227	.242	.257	.250
35-40 S	.287	.284	.271	.253	.243	.230	.215	.241	.261	.288	.289	.275
40-45 S	.326	.285	.317	.284	.288	.256	.256	.274	.282	.312	.306	.323
45-50 S	.388	.320	.327	.303	.320	.307	.300	.306	.307	.327	.352	.396
50-55 S	.450	.404	.348	.342	.343	.339	.337	.343	.337	.377	.433	.472
55-60 S	.487	.484	.447	.415	.385	.356	.370	.371	.353	.456	.513	.520
60-65 S	.497	.516	.602	.500	.459	.419	.412	.405	.377	.527	.573	.522
65-70 S	.501	.514	.708	.578	.556	.525	.495	.492	.443	.571	.613	----
70-75 S	----	.504	.715	.645	.648	.622	.616	.632	.533	.598	----	----
75-80 S	----	----	.675	.688	.697	.676	.700	.728	.603	.619	----	----
80-85 S	----	----	.642	.696	.675	.669	.689	.722	.639	----	----	----
85-90 S	----	----	.633	.686	.617	.622	.628	.662	.661	----	----	----

Table II. Continued

(b) July 1976 to June 1977

LATITUDE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
85-90 N	.602	.572	.562	----	----	----	----	----	.521	.659	.665	.633
80-85 N	.637	.558	.550	----	----	----	----	----	.591	.658	.673	.624
75-80 N	.609	.530	.533	.575	----	----	----	----	.554	.660	.659	.599
70-75 N	.448	.442	.501	.522	----	----	----	.578	.581	.613	.553	.474
65-70 N	.322	.344	.442	.530	.616	----	.544	.527	.585	.523	.444	.351
60-65 N	.322	.311	.373	.520	.567	.595	.574	.530	.544	.445	.390	.326
55-60 N	.342	.331	.327	.470	.558	.555	.605	.503	.466	.396	.348	.340
50-55 N	.326	.325	.317	.397	.502	.556	.584	.451	.397	.360	.311	.322
45-50 N	.305	.282	.317	.336	.410	.496	.488	.393	.363	.322	.303	.302
40-45 N	.279	.257	.285	.306	.338	.392	.387	.350	.342	.293	.290	.288
35-40 N	.236	.248	.234	.292	.317	.314	.350	.317	.304	.280	.262	.260
30-35 N	.214	.217	.221	.262	.299	.297	.344	.284	.262	.266	.248	.236
25-30 N	.217	.196	.230	.223	.263	.289	.296	.250	.238	.234	.236	.224
20-25 N	.212	.208	.214	.205	.235	.245	.233	.216	.214	.204	.200	.208
15-20 N	.207	.216	.193	.206	.226	.206	.203	.189	.178	.186	.178	.193
10-15 N	.220	.209	.209	.204	.218	.212	.184	.173	.164	.172	.196	.209
5-10 N	.236	.218	.228	.210	.221	.220	.177	.182	.189	.181	.209	.227
0-5 N	.226	.228	.208	.217	.229	.214	.204	.210	.214	.215	.205	.206
0-5 S	.188	.203	.182	.206	.211	.214	.230	.225	.217	.221	.194	.182
5-10 S	.168	.181	.185	.190	.200	.213	.220	.212	.212	.198	.176	.192
10-15 S	.177	.197	.186	.190	.204	.199	.203	.196	.202	.191	.173	.192
15-20 S	.179	.203	.183	.193	.191	.188	.196	.195	.186	.198	.192	.181
20-25 S	.184	.186	.210	.195	.181	.185	.181	.194	.183	.194	.208	.198
25-30 S	.236	.210	.231	.209	.199	.178	.190	.195	.198	.197	.225	.233
30-35 S	.291	.280	.225	.236	.217	.196	.216	.212	.218	.237	.257	.255
35-40 S	.281	.303	.247	.263	.239	.241	.231	.234	.245	.291	.291	.274
40-45 S	.264	.279	.306	.289	.284	.278	.265	.255	.296	.319	.310	.319
45-50 S	.334	.318	.338	.323	.322	.310	.310	.294	.341	.331	.342	.393
50-55 S	.455	.451	.339	.360	.333	.338	.324	.341	.346	.362	.406	.471
55-60 S	.526	.576	.403	.401	.368	.353	.336	.364	.356	.422	.483	.521
60-65 S	.523	.607	.561	.476	.451	.399	.399	.390	.434	.485	.554	.523
65-70 S	.506	.565	.701	.587	.548	.509	.496	.480	.557	.540	.608	----
70-75 S	----	.516	.733	.687	.637	.624	.582	.626	.646	.584	----	----
75-80 S	----	----	.691	.728	.695	.667	.629	.726	.671	.618	----	----
80-85 S	----	----	.647	.716	.683	.646	.632	.719	.664	----	----	----
85-90 S	----	----	.634	.691	.623	.611	.612	.661	.664	----	----	----

Table II. Concluded

(c) July 1977 to May 1978

LATITUDE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
85-90 N	.569	.562	.564	----	----	----	----	----	.521	.664	.654	----
80-85 N	.546	.530	.564	----	----	----	----	----	.592	.676	.647	----
75-80 N	.532	.504	.564	.575	----	----	----	----	.556	.688	.651	----
70-75 N	.447	.444	.536	.522	----	----	----	.593	.583	.631	.577	----
65-70 N	.350	.366	.464	.530	.611	----	.541	.576	.581	.512	.458	----
60-65 N	.326	.320	.382	.519	.551	.590	.546	.600	.527	.412	.375	----
55-60 N	.352	.324	.342	.467	.539	.539	.554	.556	.447	.371	.346	----
50-55 N	.341	.334	.337	.390	.499	.541	.540	.458	.388	.363	.335	----
45-50 N	.286	.297	.316	.328	.426	.502	.480	.387	.362	.340	.308	----
40-45 N	.251	.241	.264	.298	.343	.422	.399	.379	.334	.295	.282	----
35-40 N	.245	.217	.227	.282	.299	.338	.329	.359	.291	.262	.269	----
30-35 N	.234	.223	.225	.252	.288	.289	.290	.293	.266	.248	.245	----
25-30 N	.213	.221	.219	.217	.271	.267	.266	.231	.259	.227	.216	----
20-25 N	.201	.201	.200	.209	.236	.238	.232	.203	.226	.193	.199	----
15-20 N	.207	.205	.205	.215	.208	.197	.199	.176	.172	.167	.196	----
10-15 N	.216	.229	.225	.214	.204	.183	.183	.161	.154	.162	.197	----
5-10 N	.220	.224	.219	.218	.203	.203	.189	.184	.178	.187	.204	----
0-5 N	.212	.197	.200	.223	.193	.221	.201	.208	.195	.217	.209	----
0-5 S	.196	.192	.198	.208	.196	.221	.210	.209	.197	.210	.194	----
5-10 S	.184	.203	.198	.189	.206	.220	.215	.215	.204	.183	.177	----
10-15 S	.180	.195	.184	.187	.204	.213	.207	.216	.198	.180	.177	----
15-20 S	.185	.183	.183	.190	.200	.196	.195	.197	.179	.191	.183	----
20-25 S	.200	.205	.204	.188	.209	.191	.192	.191	.182	.190	.191	----
25-30 S	.220	.243	.212	.200	.214	.199	.200	.207	.207	.197	.208	----
30-35 S	.246	.258	.219	.228	.212	.203	.211	.214	.220	.235	.239	----
35-40 S	.275	.255	.258	.254	.236	.220	.234	.235	.236	.280	.279	----
40-45 S	.308	.271	.303	.278	.282	.268	.273	.287	.288	.301	.317	----
45-50 S	.351	.336	.311	.316	.319	.320	.305	.320	.341	.318	.350	----
50-55 S	.404	.436	.319	.358	.343	.340	.322	.324	.349	.367	.393	----
55-60 S	.454	.511	.395	.403	.386	.361	.345	.347	.352	.441	.453	----
60-65 S	.482	.532	.530	.482	.461	.423	.394	.401	.418	.507	.530	----
65-70 S	.499	.520	.638	.604	.555	.518	.479	.480	.530	.555	.600	----
70-75 S	----	.505	.667	.712	.646	.608	.581	.583	.620	.590	----	----
75-80 S	----	----	.652	.751	.696	.657	.648	.666	.654	.619	----	----
80-85 S	----	----	.636	.729	.675	.652	.648	.682	.657	----	----	----
85-90 S	----	----	.633	.693	.618	.616	.616	.652	.663	----	----	----

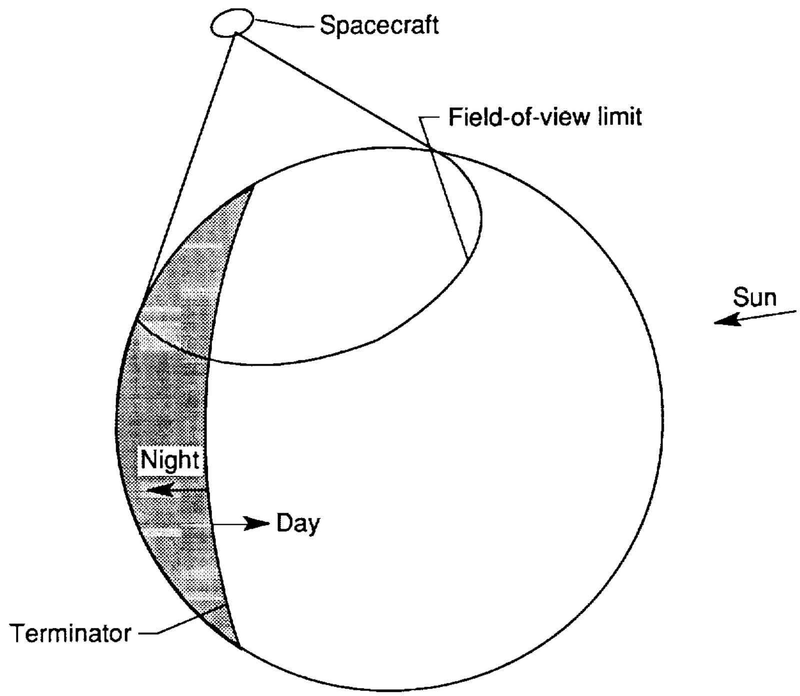


Figure 1. Wide-field-of-view coverage geometry.

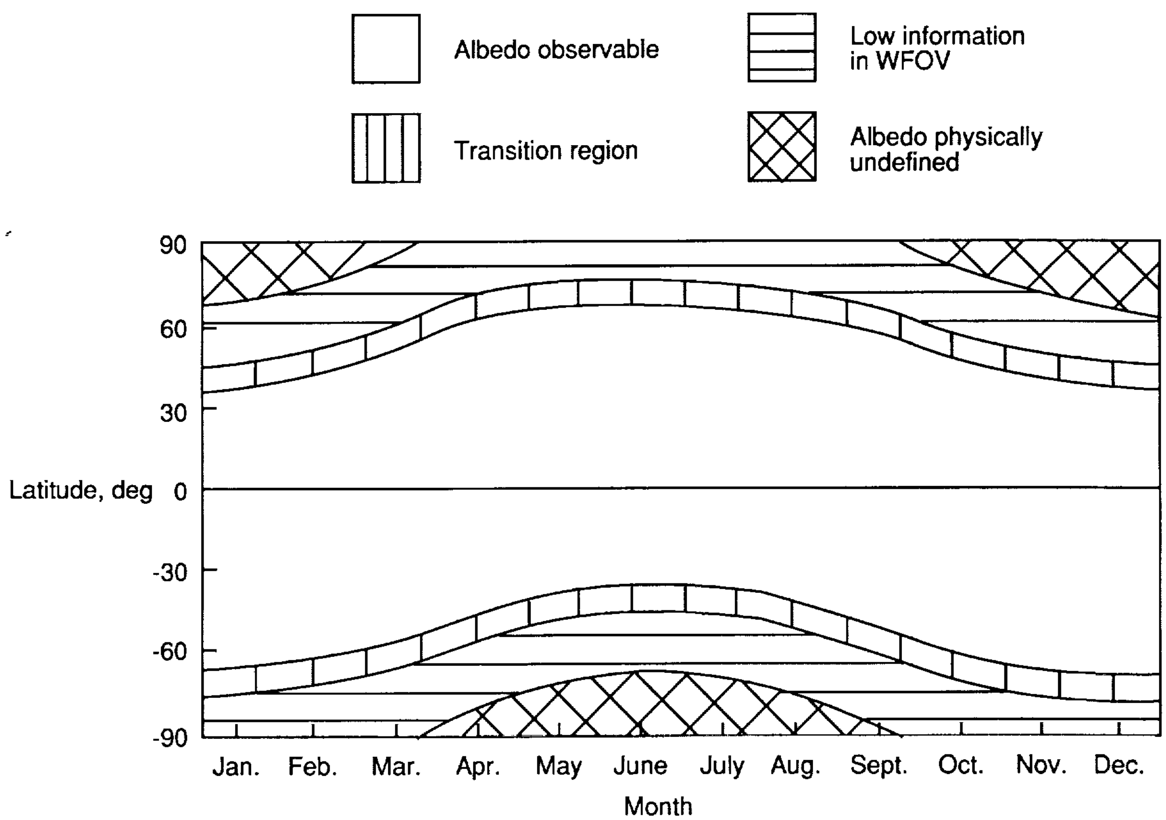
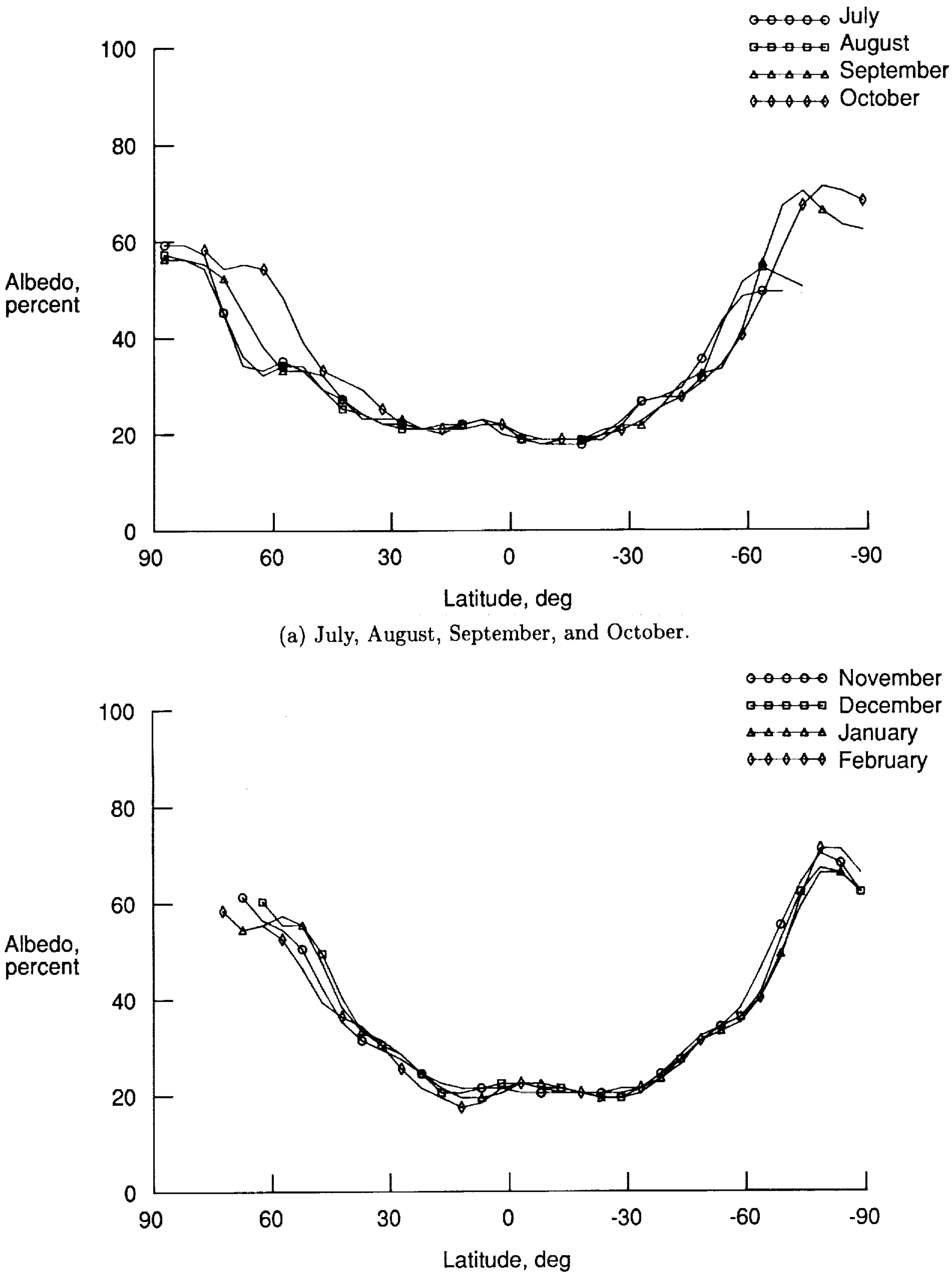


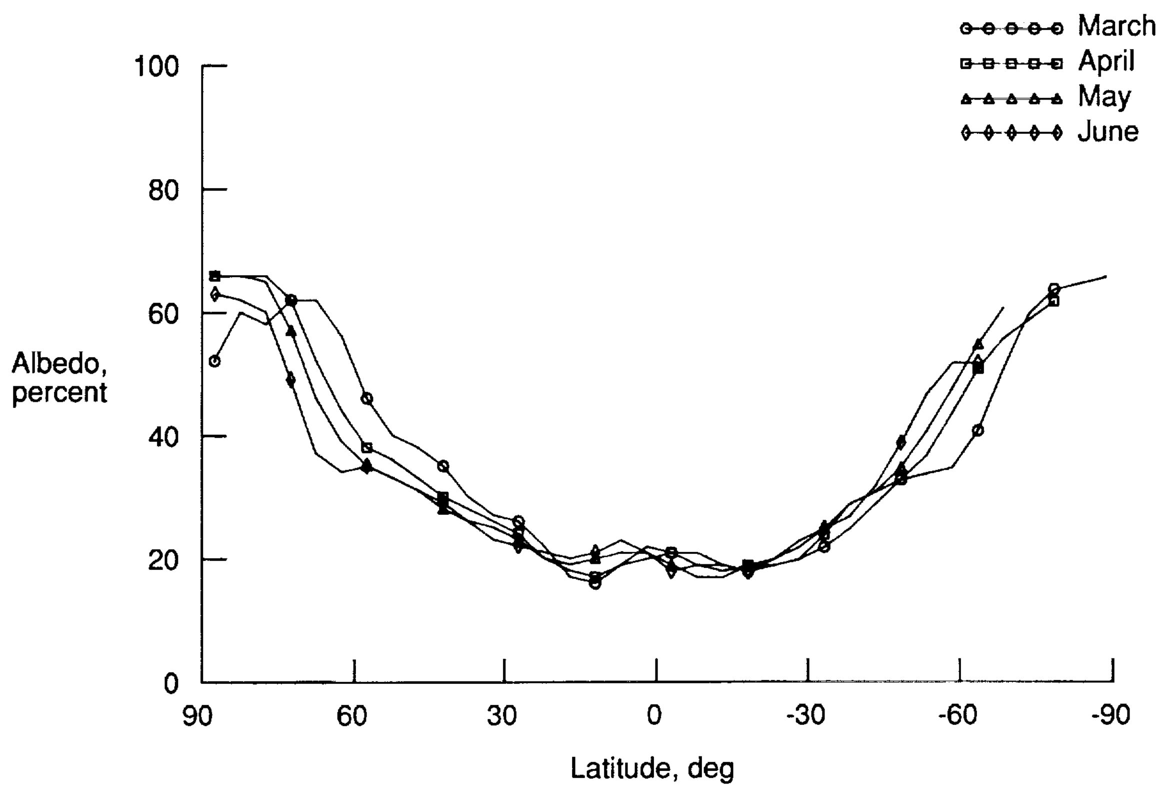
Figure 2. Variation of observable regions with time of year for Nimbus 6 orbit.



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

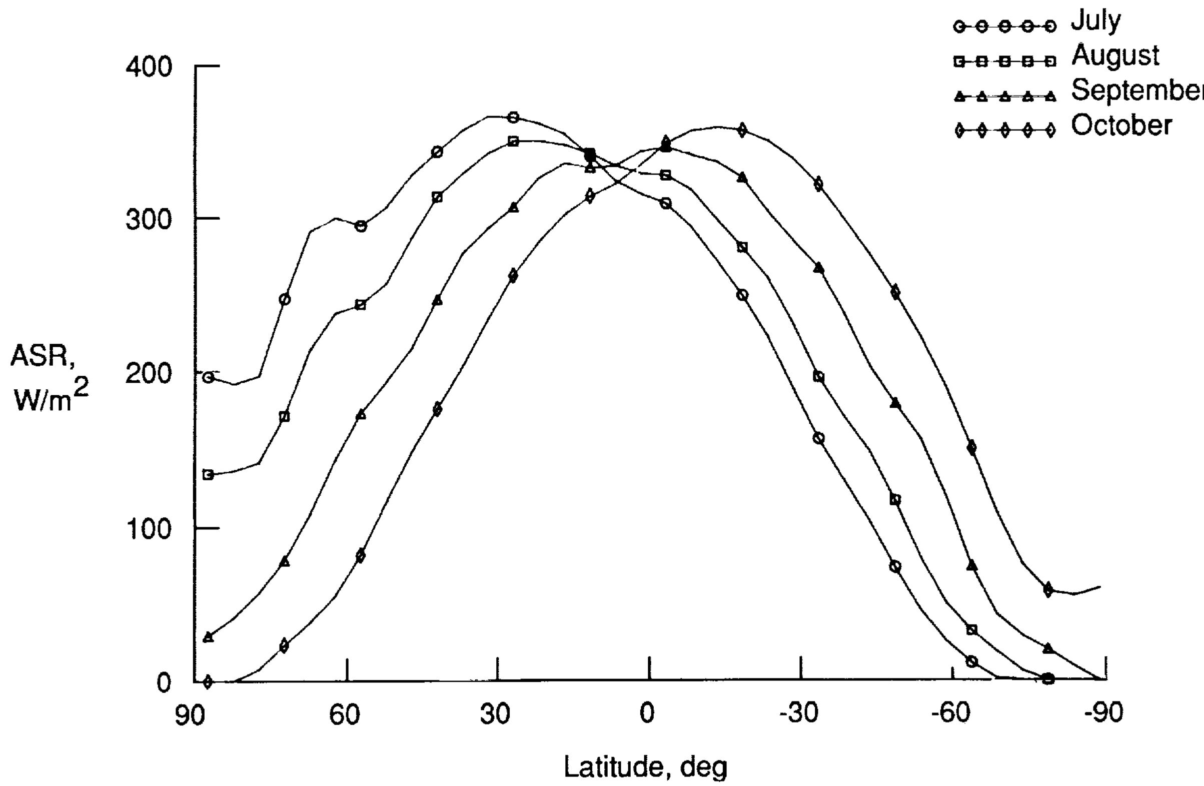
(b) November, December, January, and February.

Figure 3. Three-year averages (1975 to 1978) of zonal mean albedos.

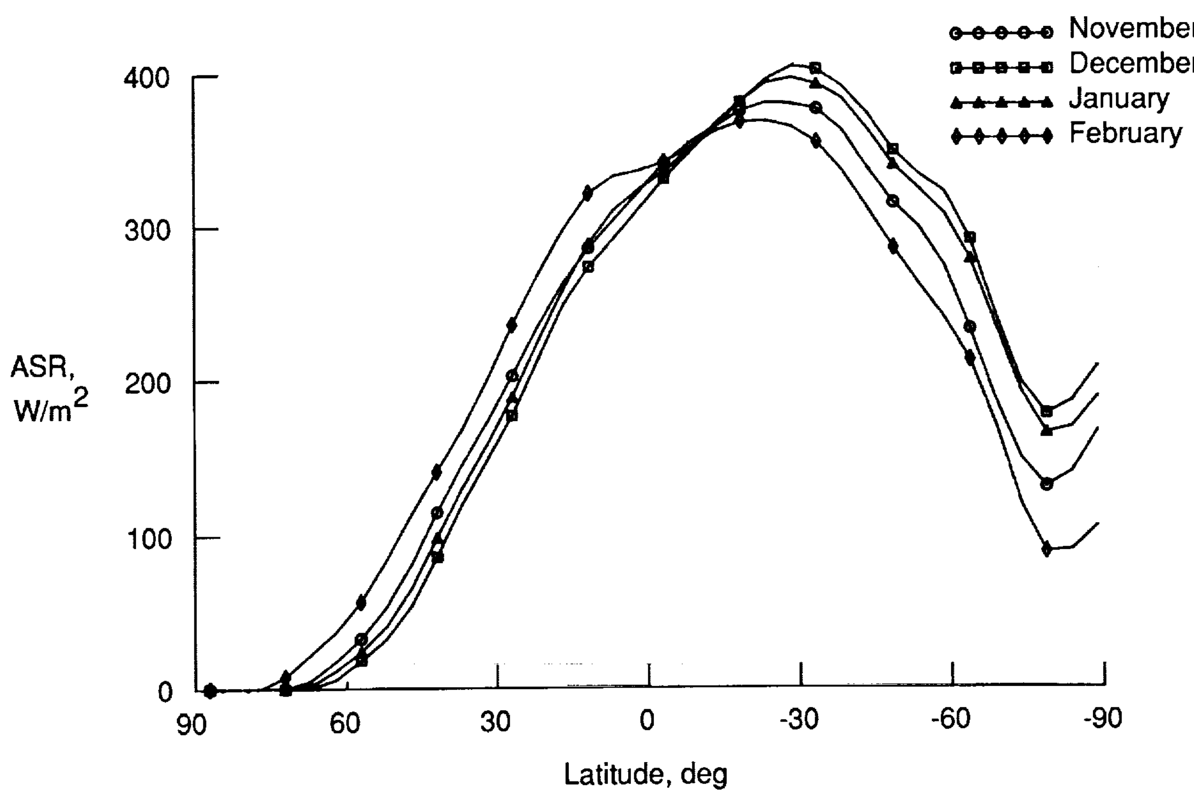


(c) March, April, May, and June.

Figure 3. Concluded.

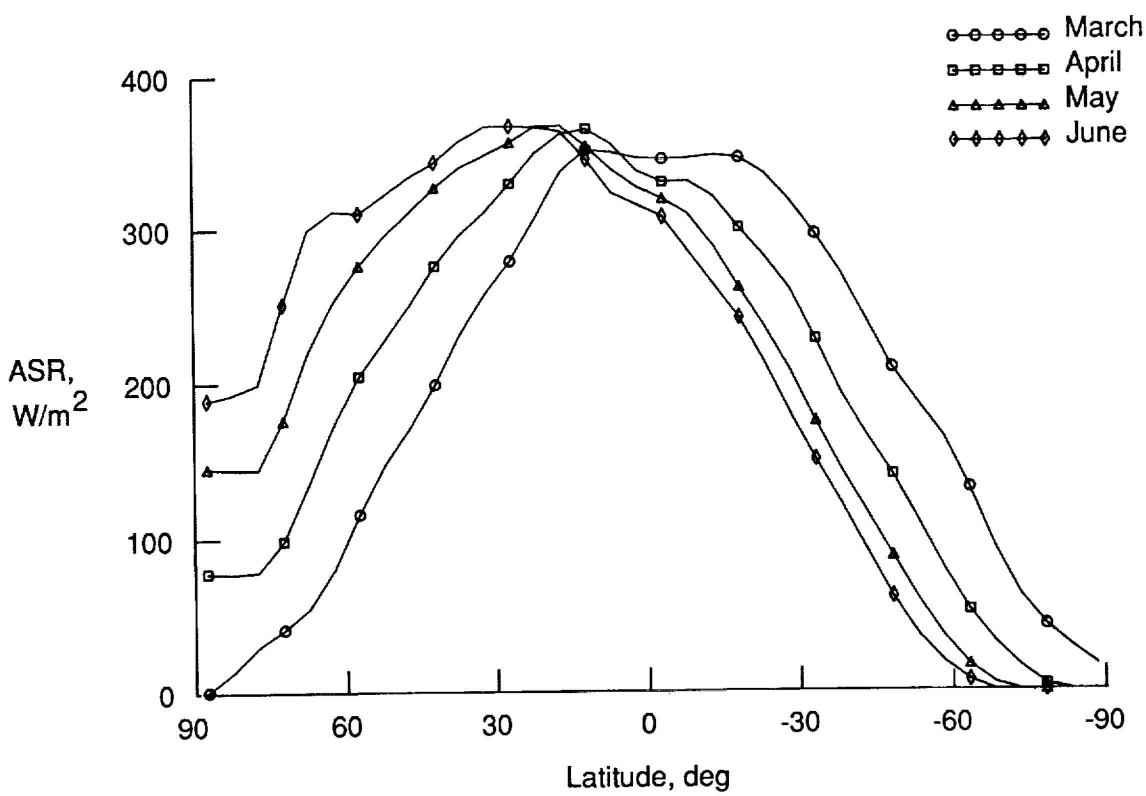


(a) July, August, September, and October.



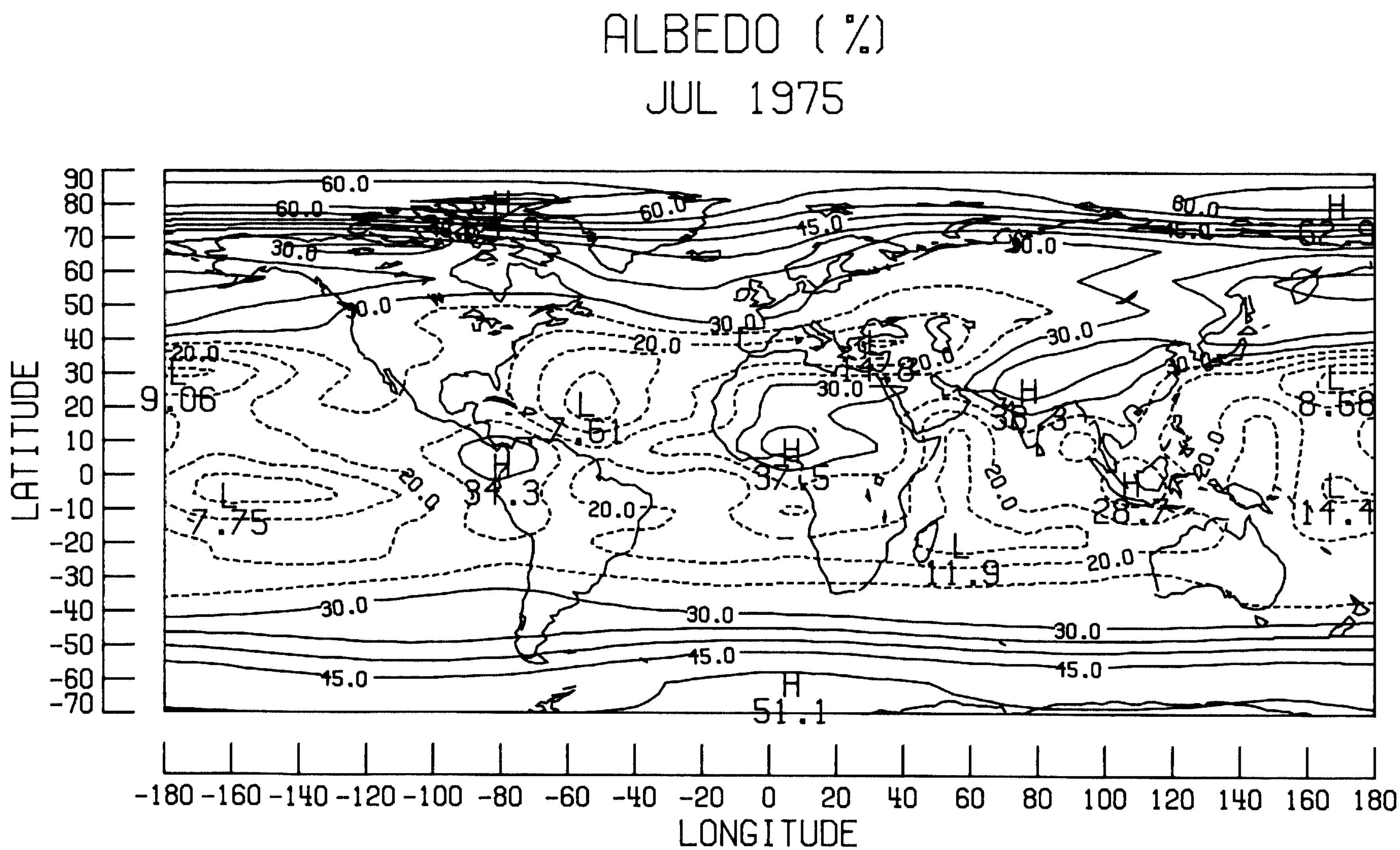
(b) November, December, January, and February.

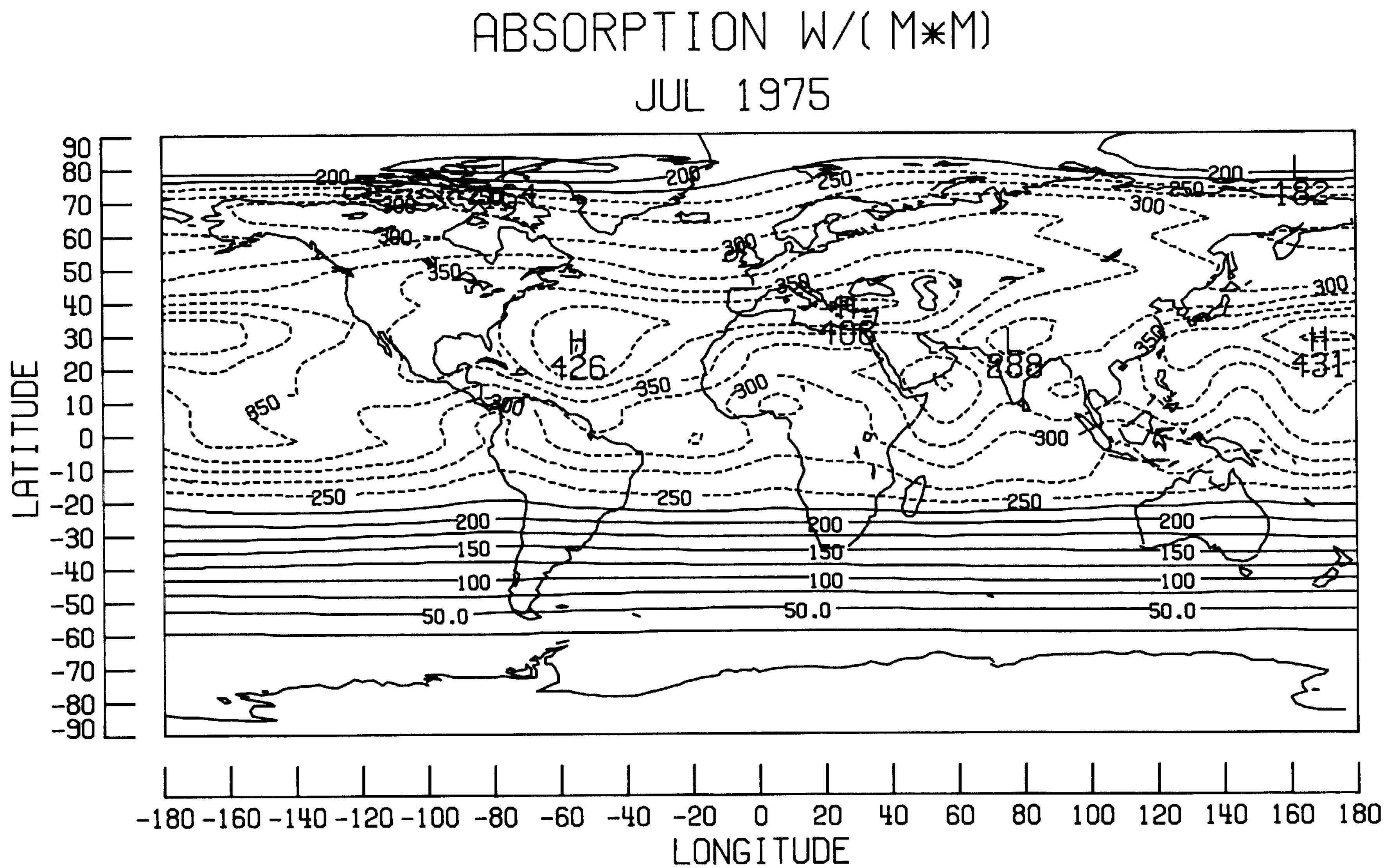
Figure 4. Three-year averages (1975 to 1978) of zonal mean absorbed solar radiation.

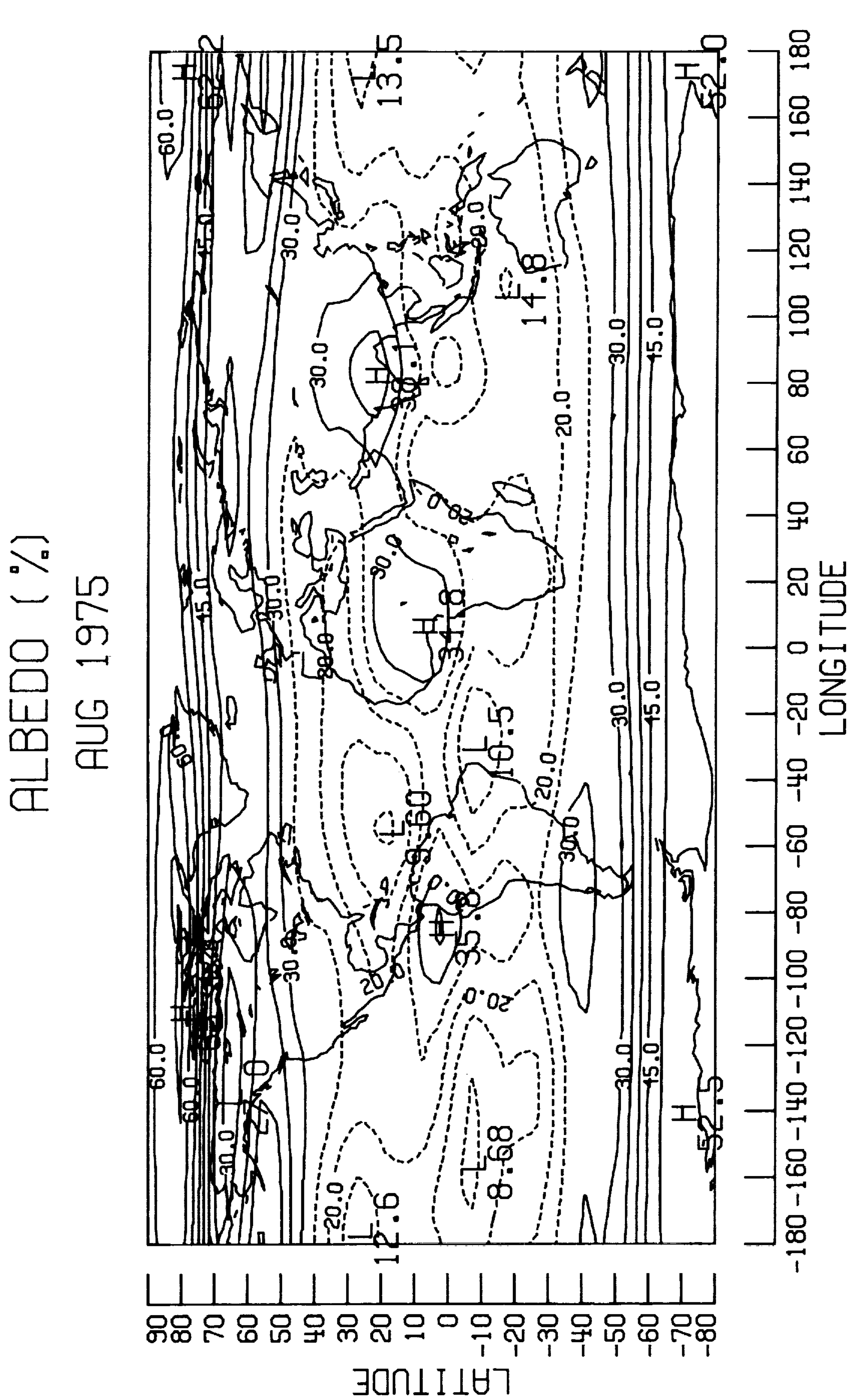


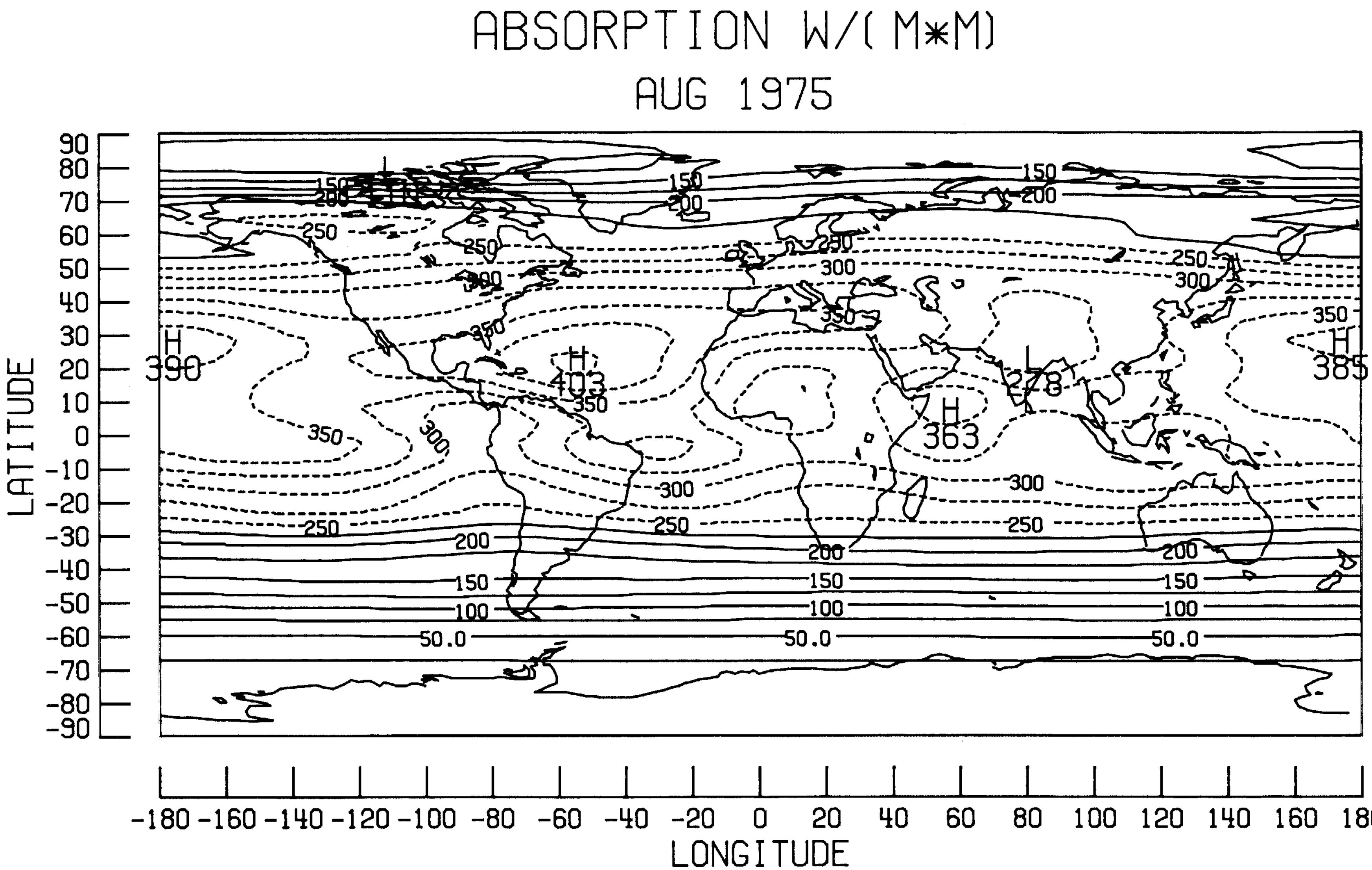
(c) March, April, May, and June.

Figure 4. Concluded.

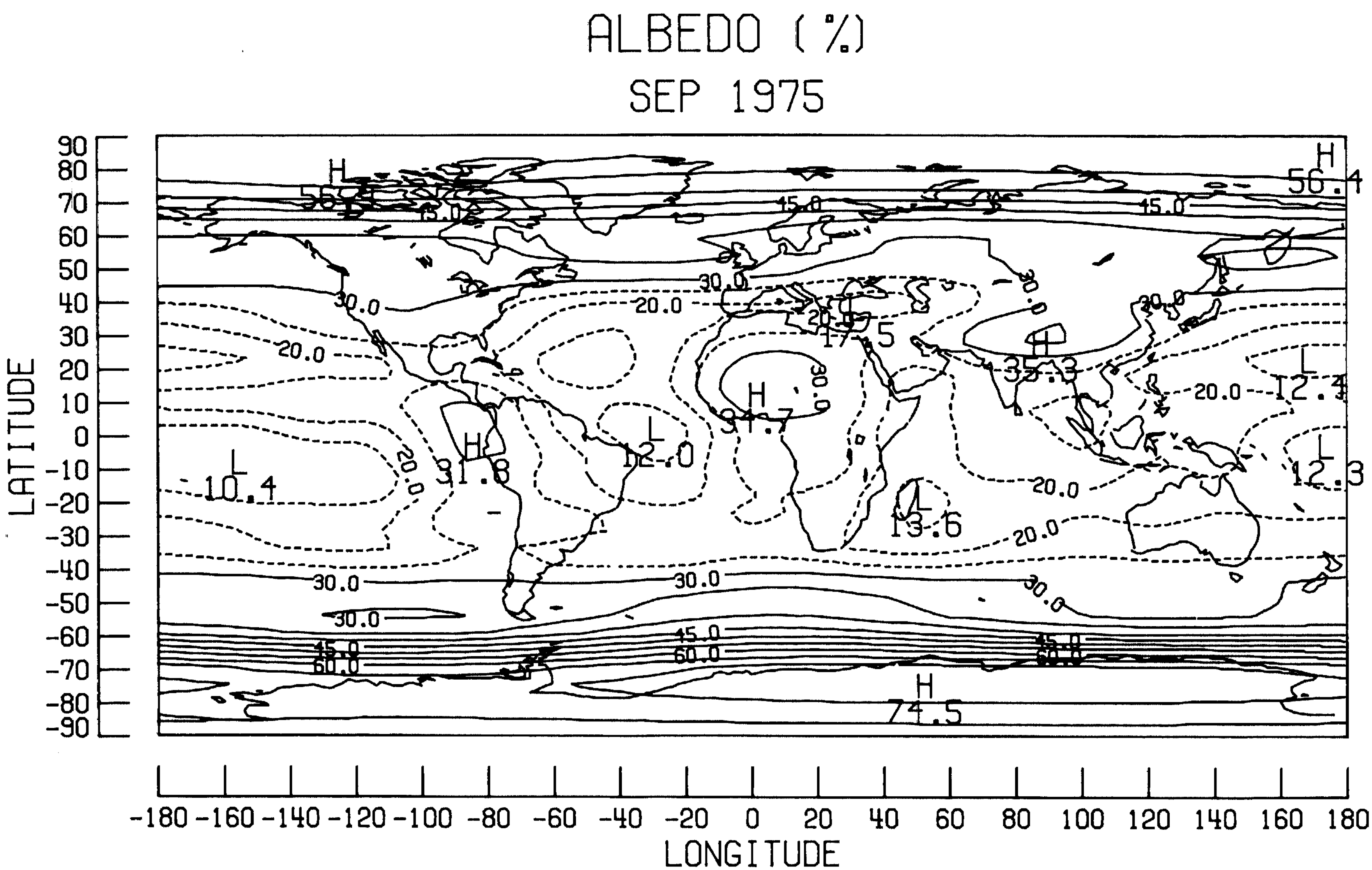

ALBEDO (%)
JUL 1975
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
LONGITUDE
60.0
30.0
45.0
20.0
L
H
9.06
7.75
7.61
34.3
37.5
11.9
28.7
8.68
14.4
51.1

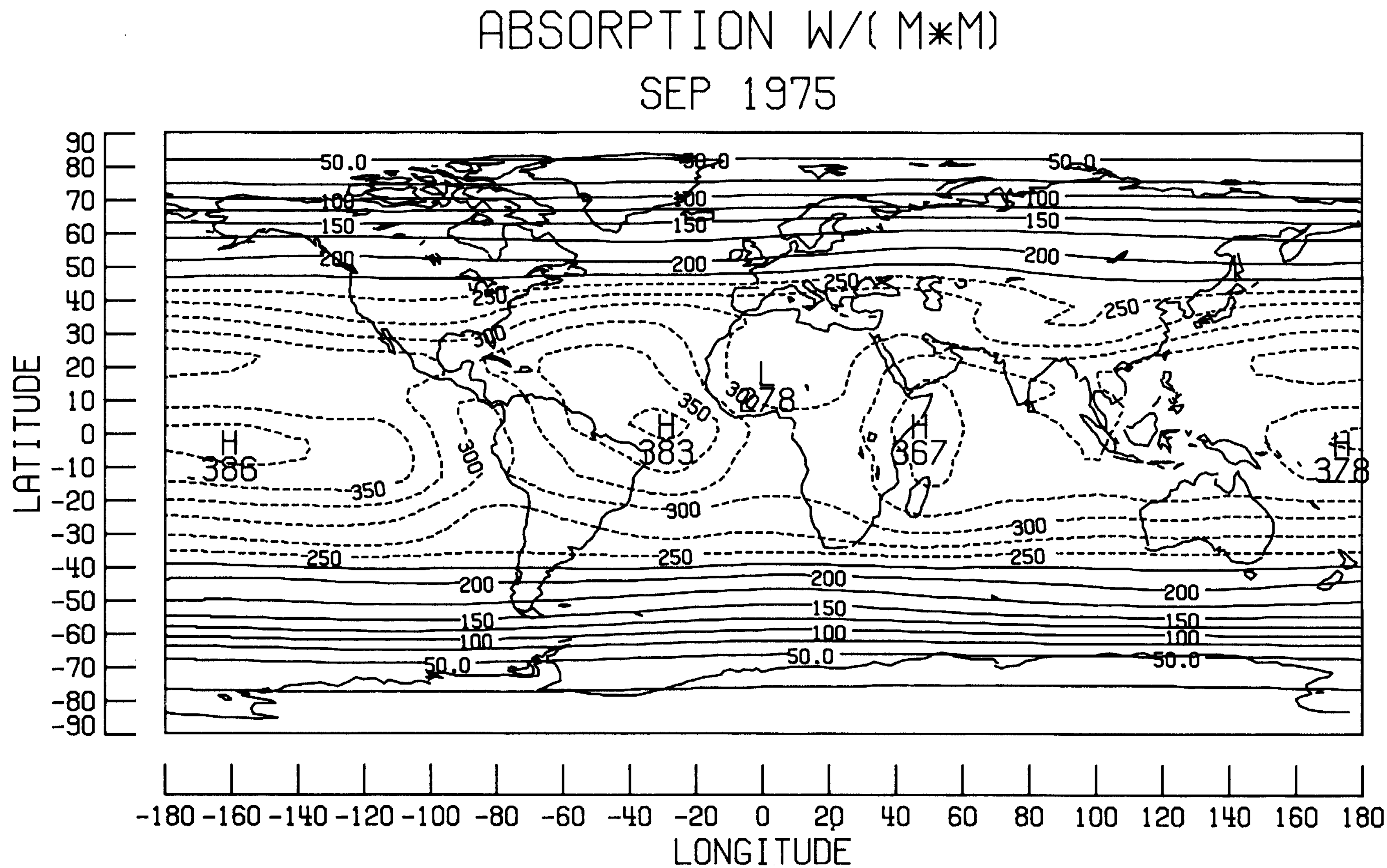

ABSORPTION W/(M*M)
JUL 1975
LATITUDE
LONGITUDE
H 426
H 406
H 431
L 288
L 182
350
300
250
200
150
100
50.0

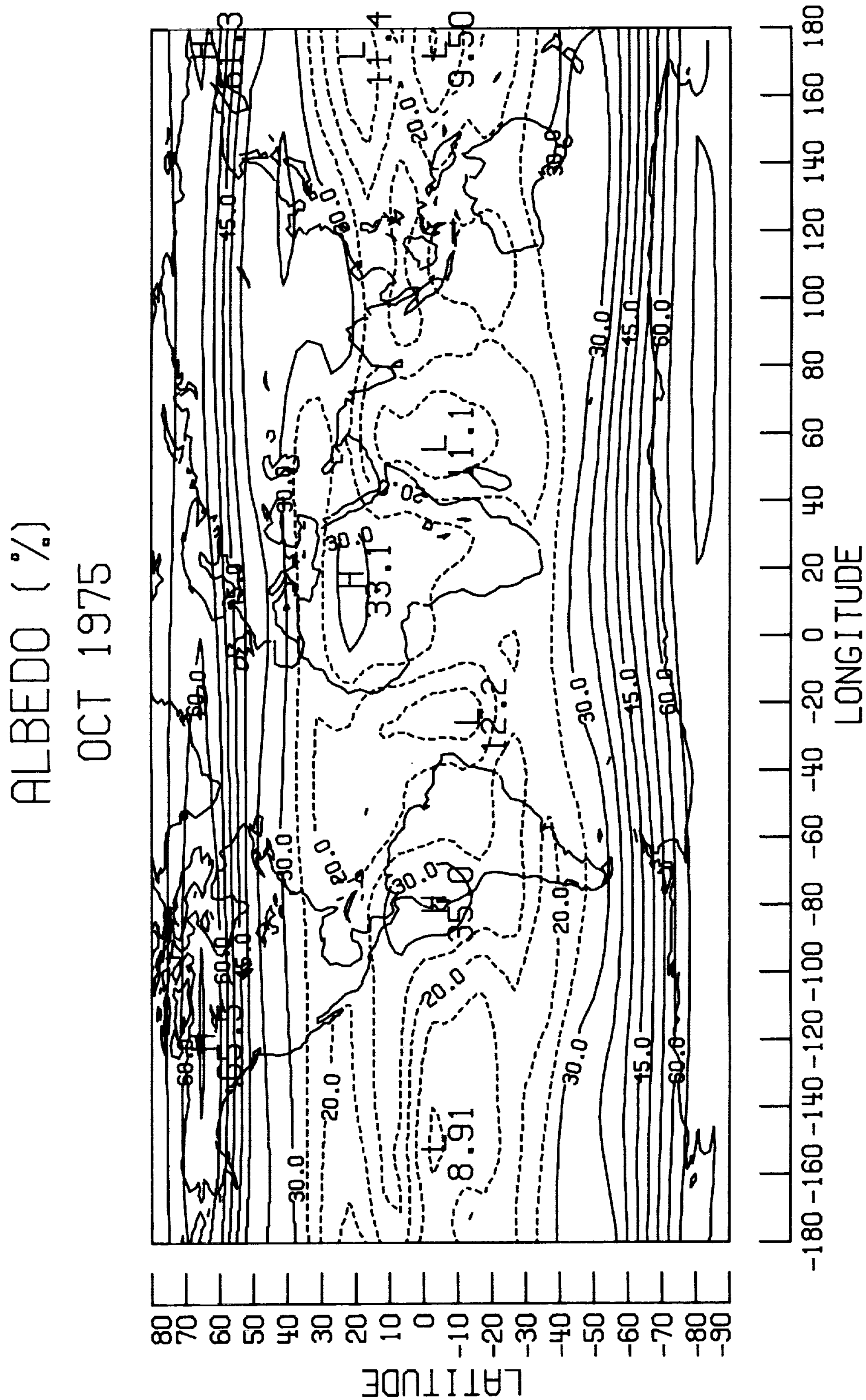

ALBEDO (%)
AUG 1975
LONGITUDE
LATITUDE



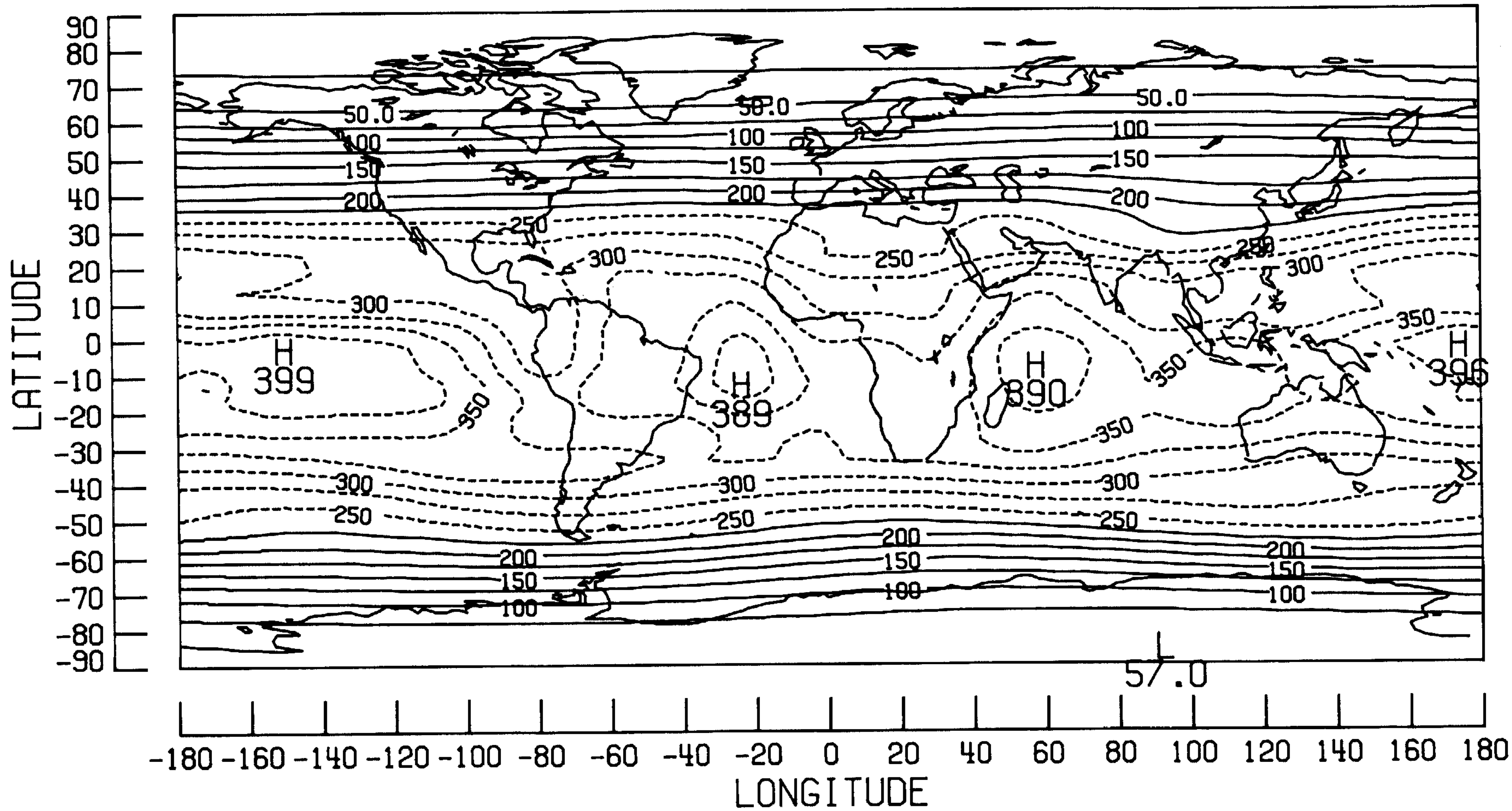
ABSORPTION W/(M*M)
AUG 1975
LATITUDE
LONGITUDE
H 390
H 403
H 363
L 278
H 385
350
300
250
200
150
100
50.0


ALBEDO (%)
SEP 1975
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
H
56.4
15.0
30.0
20.0
L
10.4
31.8
12.0
34.7
17.5
35.3
12.4
12.3
13.6
45.0
60.0
74.5

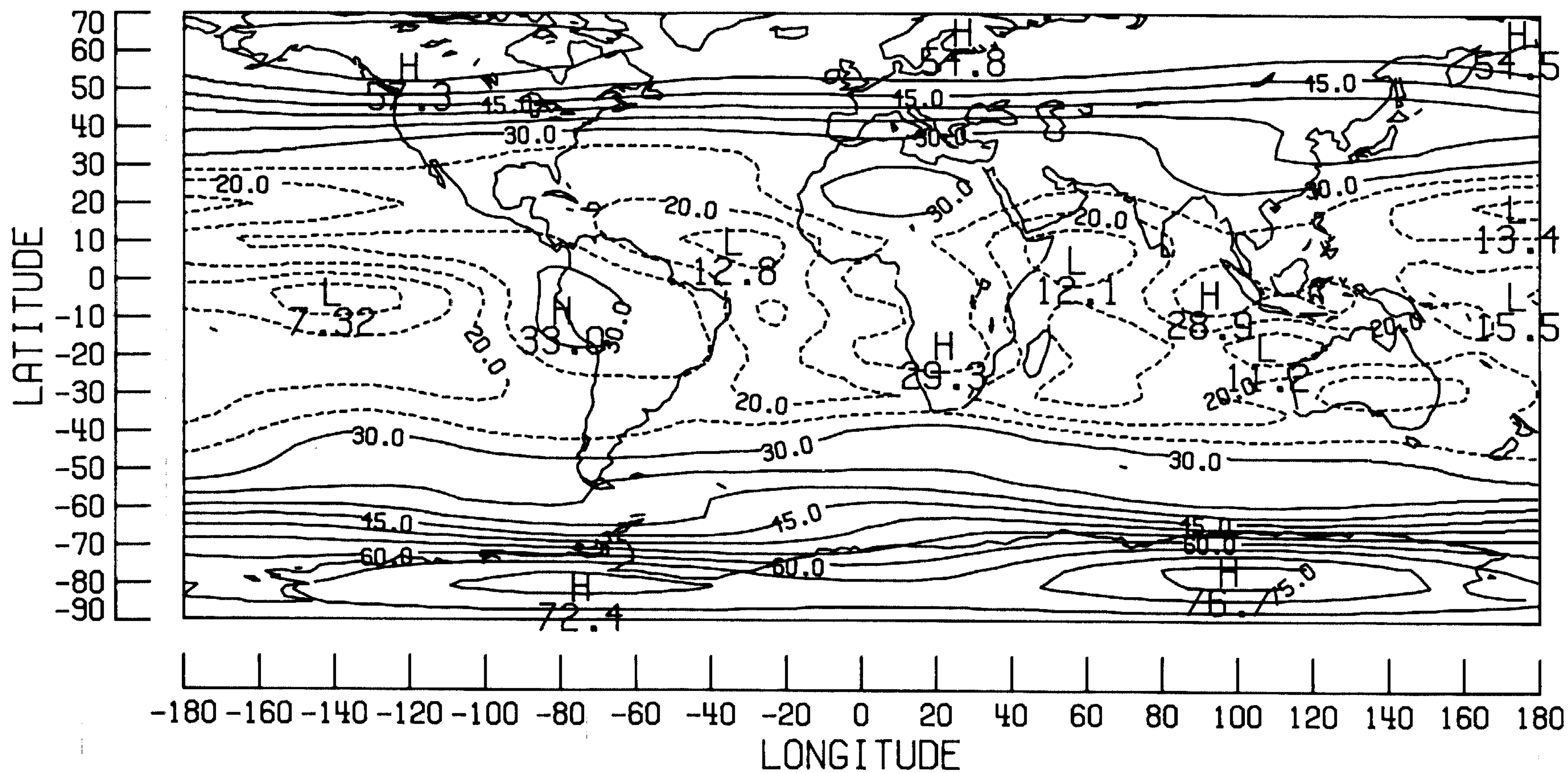

ABSORPTION W/(M*M)
SEP 1975
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
50.0
100
150
200
250
300
350
H
386
383
367
378
L
278


ALBEDO (%)
OCT 1975
LONGITUDE
LATITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
H
33.1
H
35.0
L
8.91
L
11.1
L
11.4
L
9.50
L
12.2

ABSORPTION W/(M*M)
OCT 1975

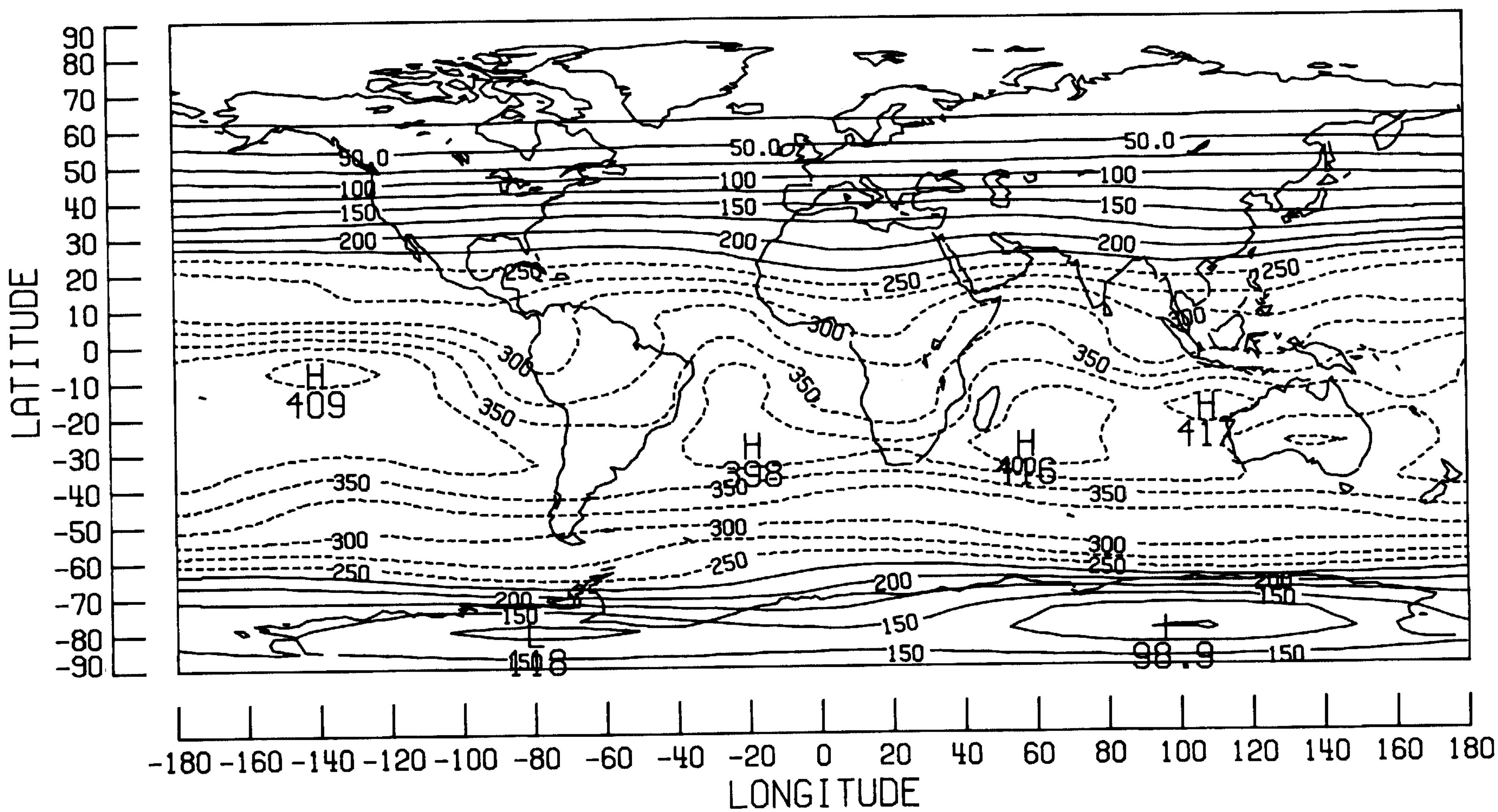


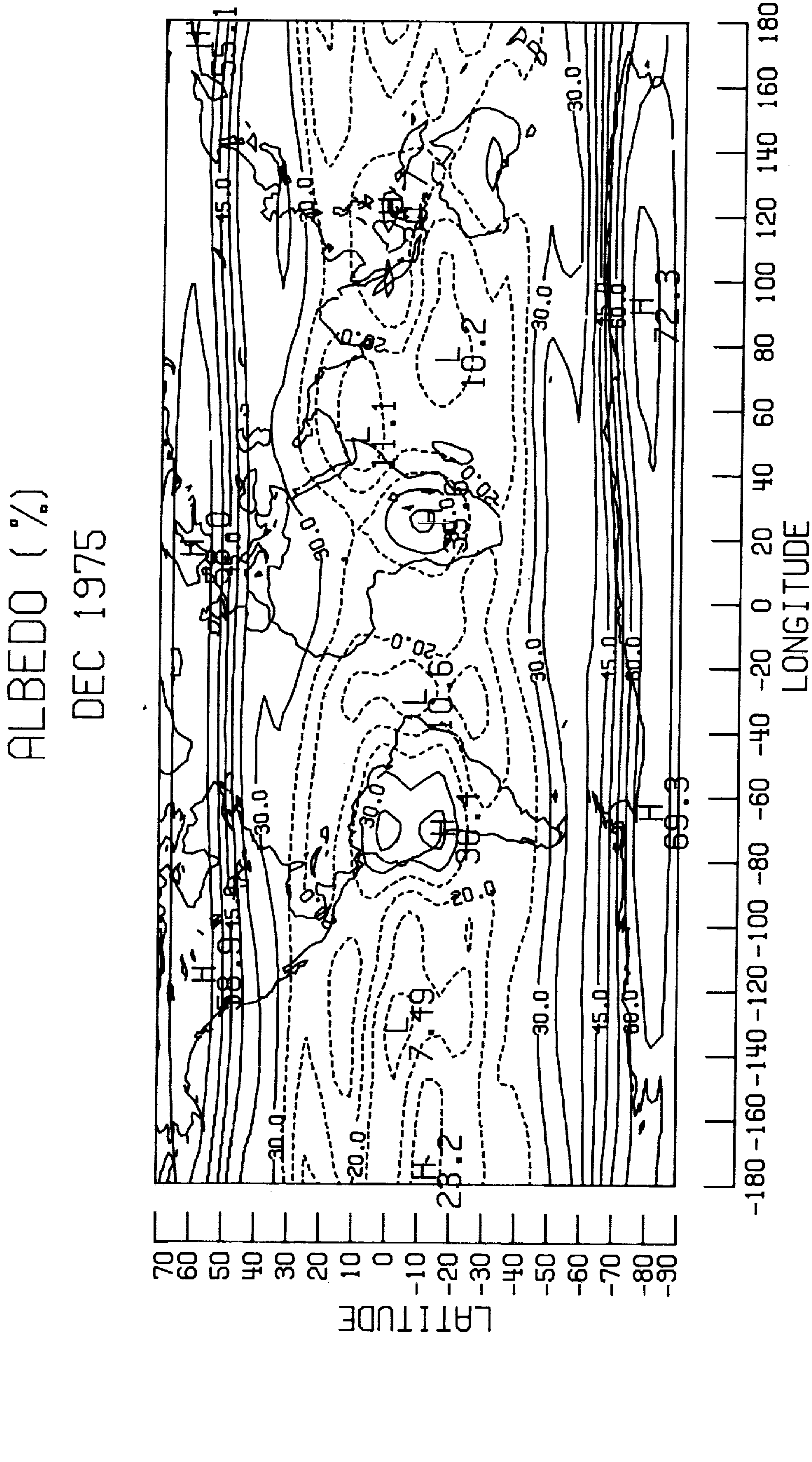
ALBEDO (%)
NOV 1975

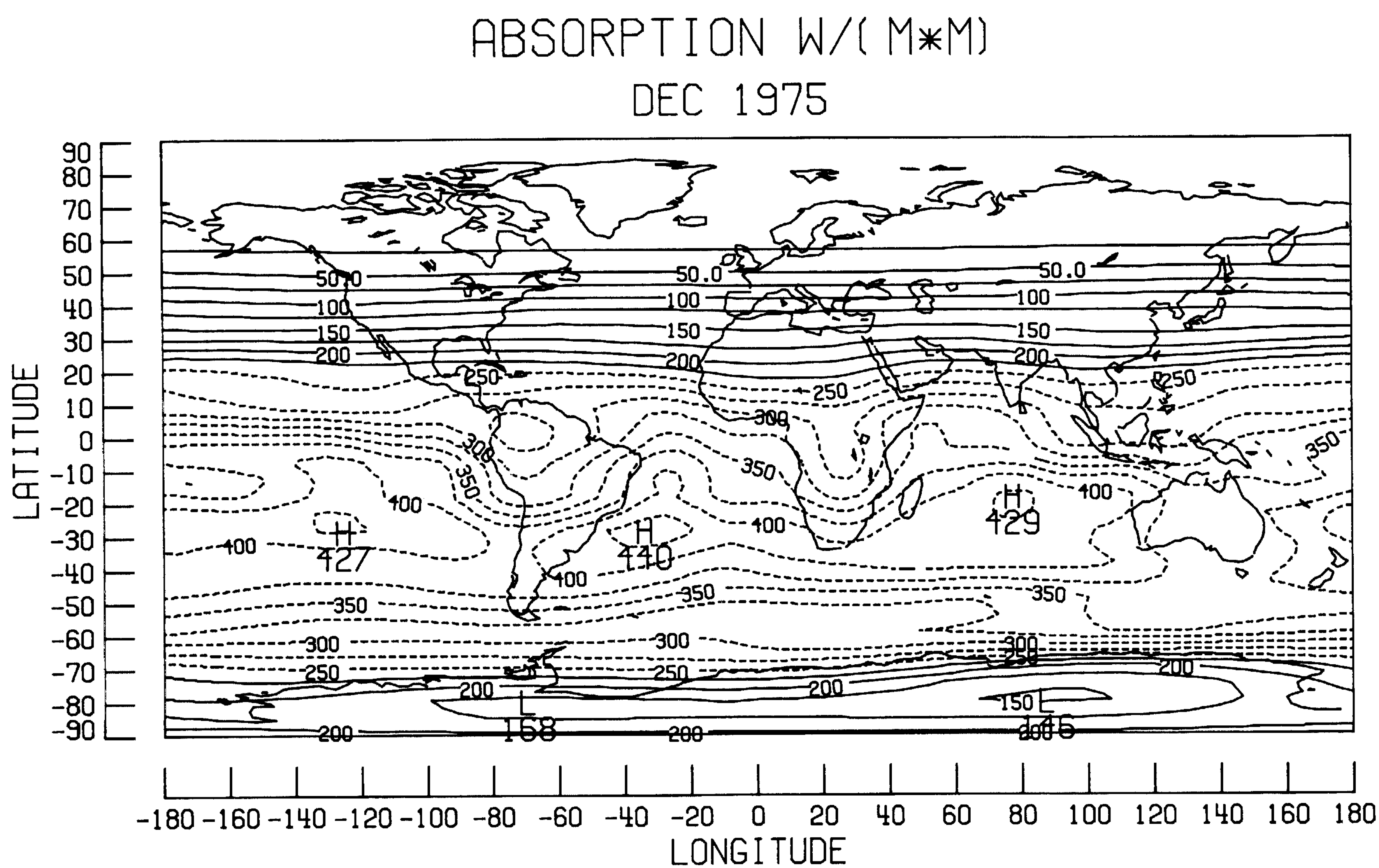


ABSORPTION W/(M*M)

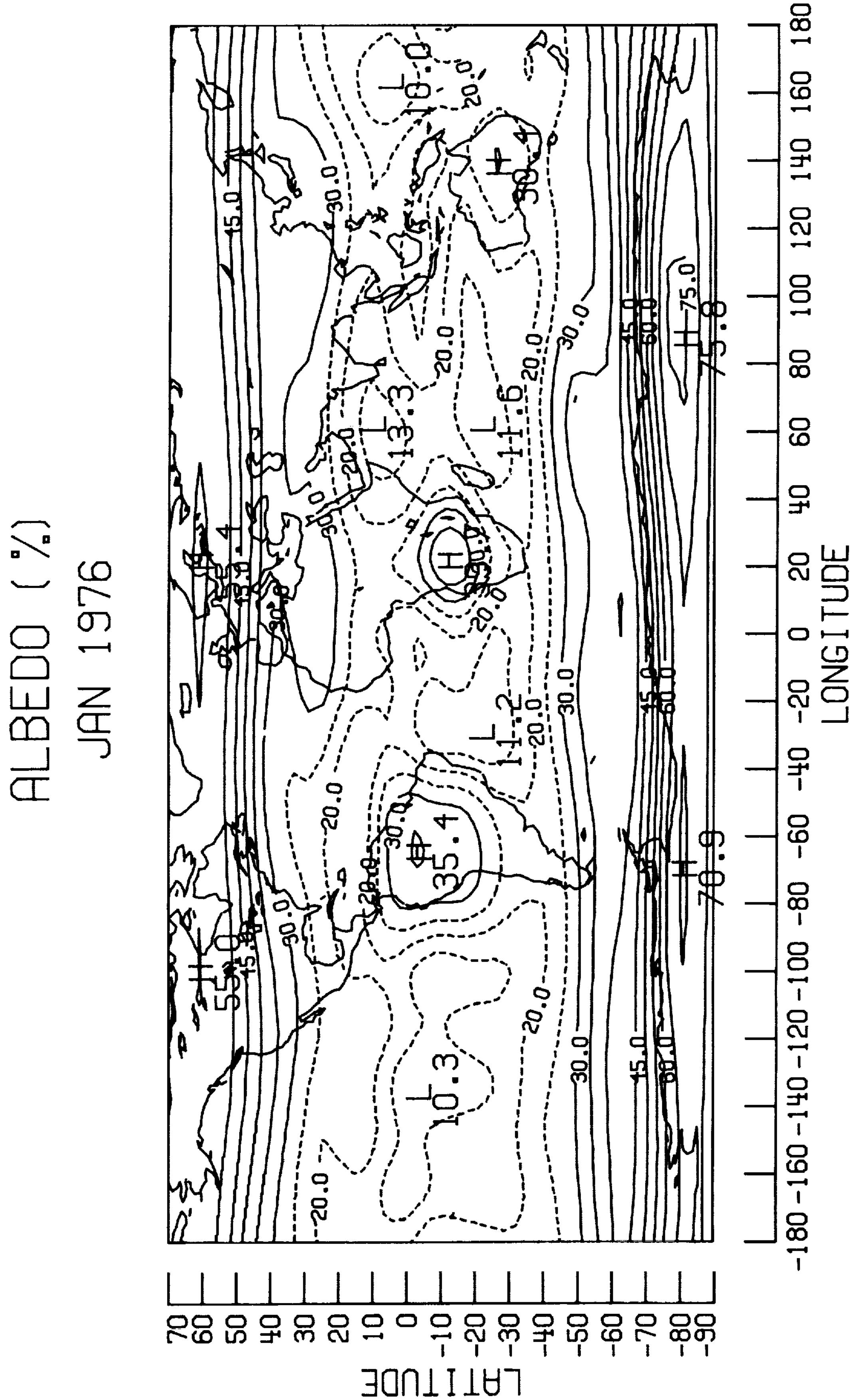
NOV 1975

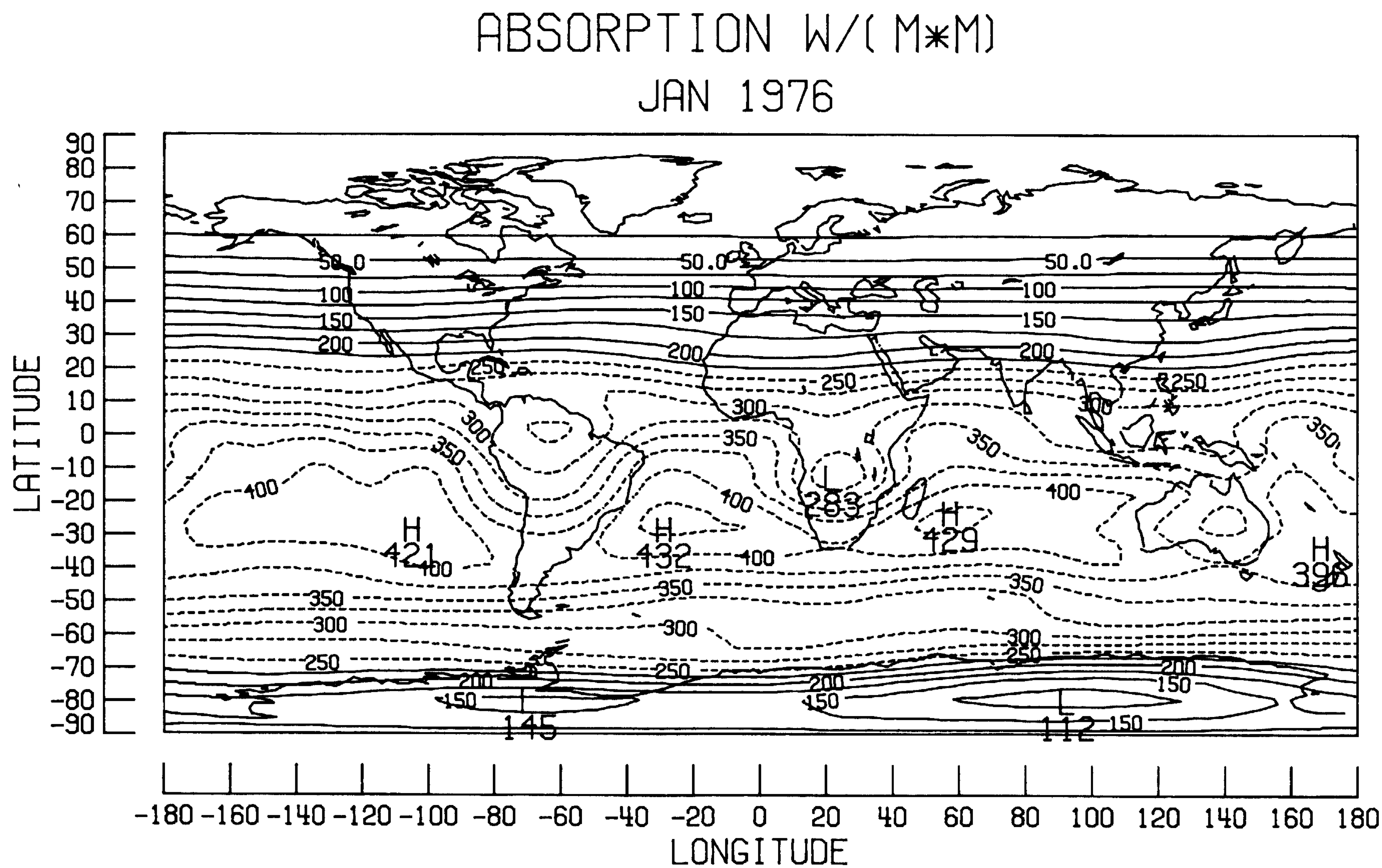


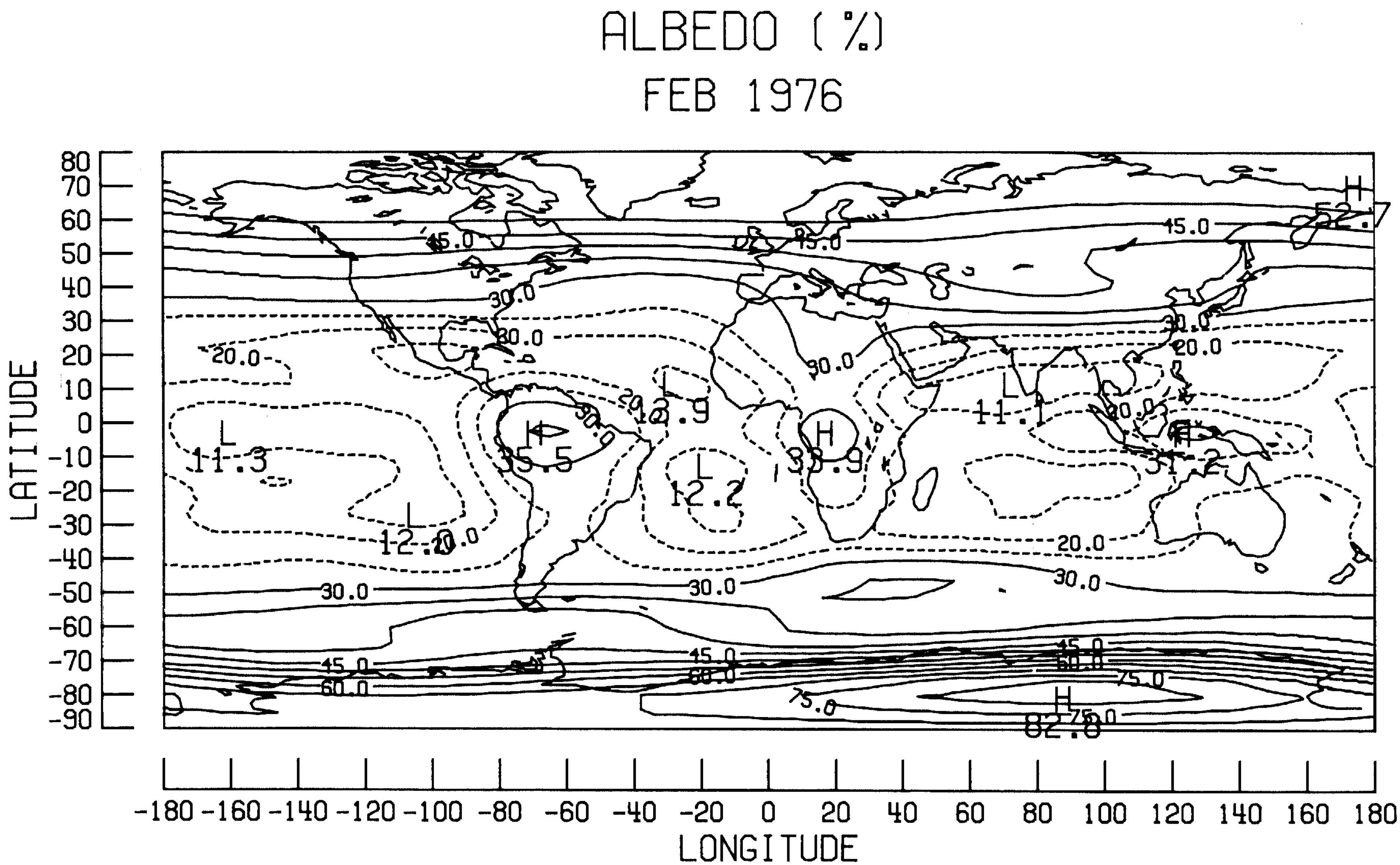

ALBEDO (%)
DEC 1975
LONGITUDE
LATITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90



ABSORPTION W/(M*M)
DEC 1975
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
427
H
440
H
429
L
158
L
146


ALBEDO (%)
JAN 1976
LONGITUDE
LATITUDE


ABSORPTION W/(M*M)
JAN 1976
LATITUDE
LONGITUDE
H
421
H
432
L
283
H
429
H
396
145
L
112


ALBEDO (%)
FEB 1976
LATITUDE
LONGITUDE
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
45.0
30.0
20.0
60.0
75.0
L
H
11.3
12.2
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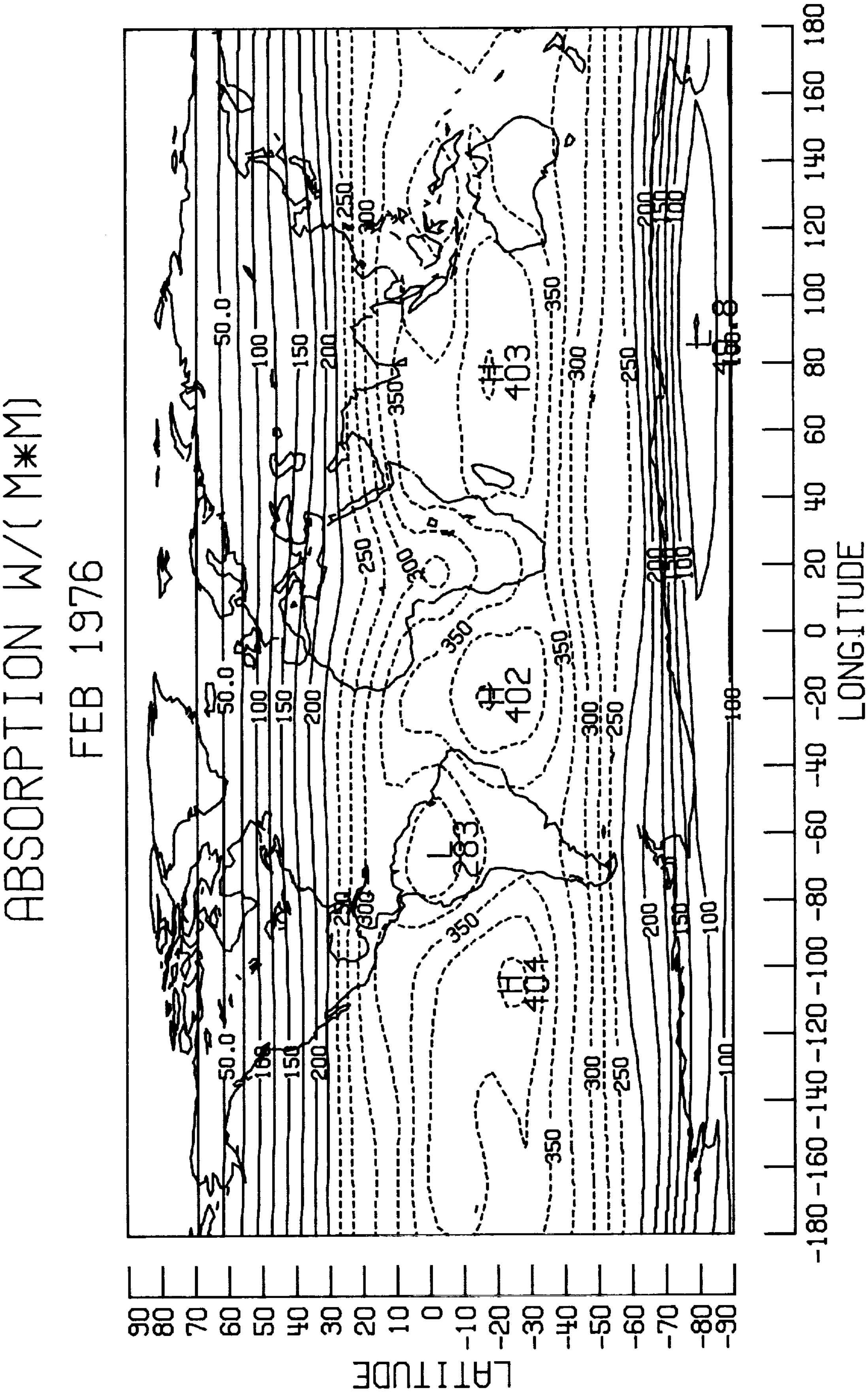
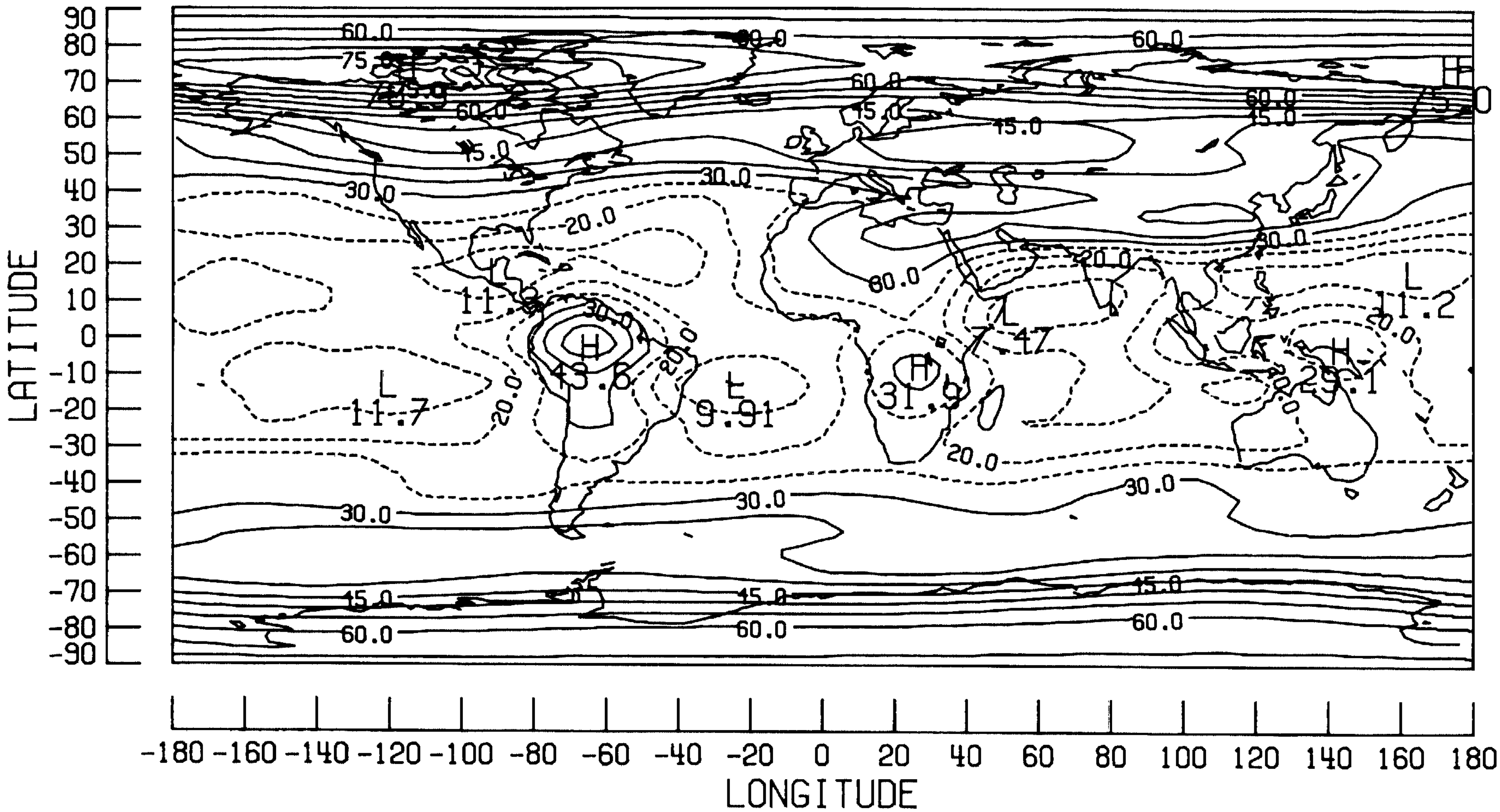
11.1
31.2
82.8

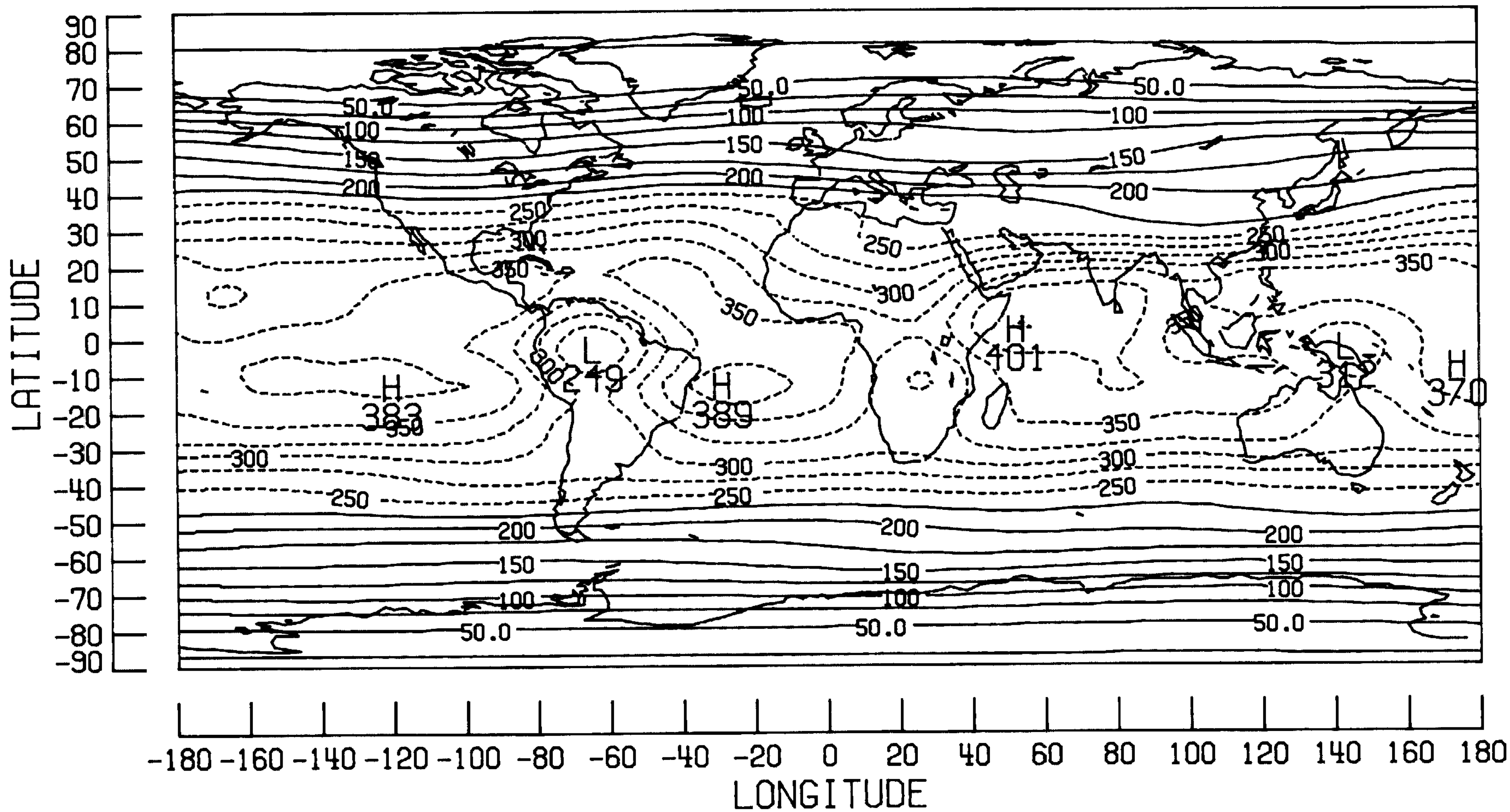

ABSORPTION W/(M*M)
FEB 1976
LONGITUDE
LATITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
H 404
H 402
H 403
L 283

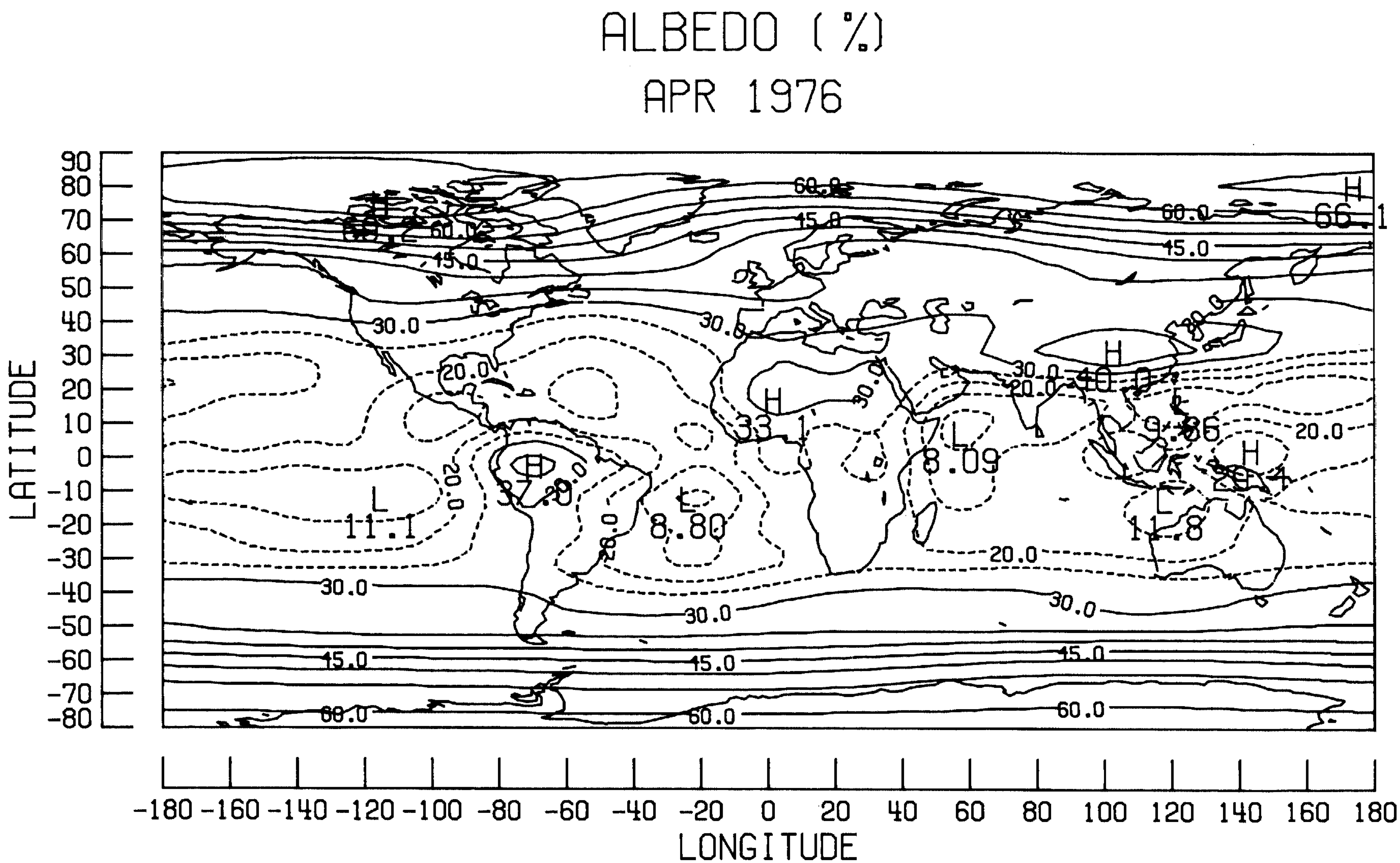
ALBEDO (%)
MAR 1976

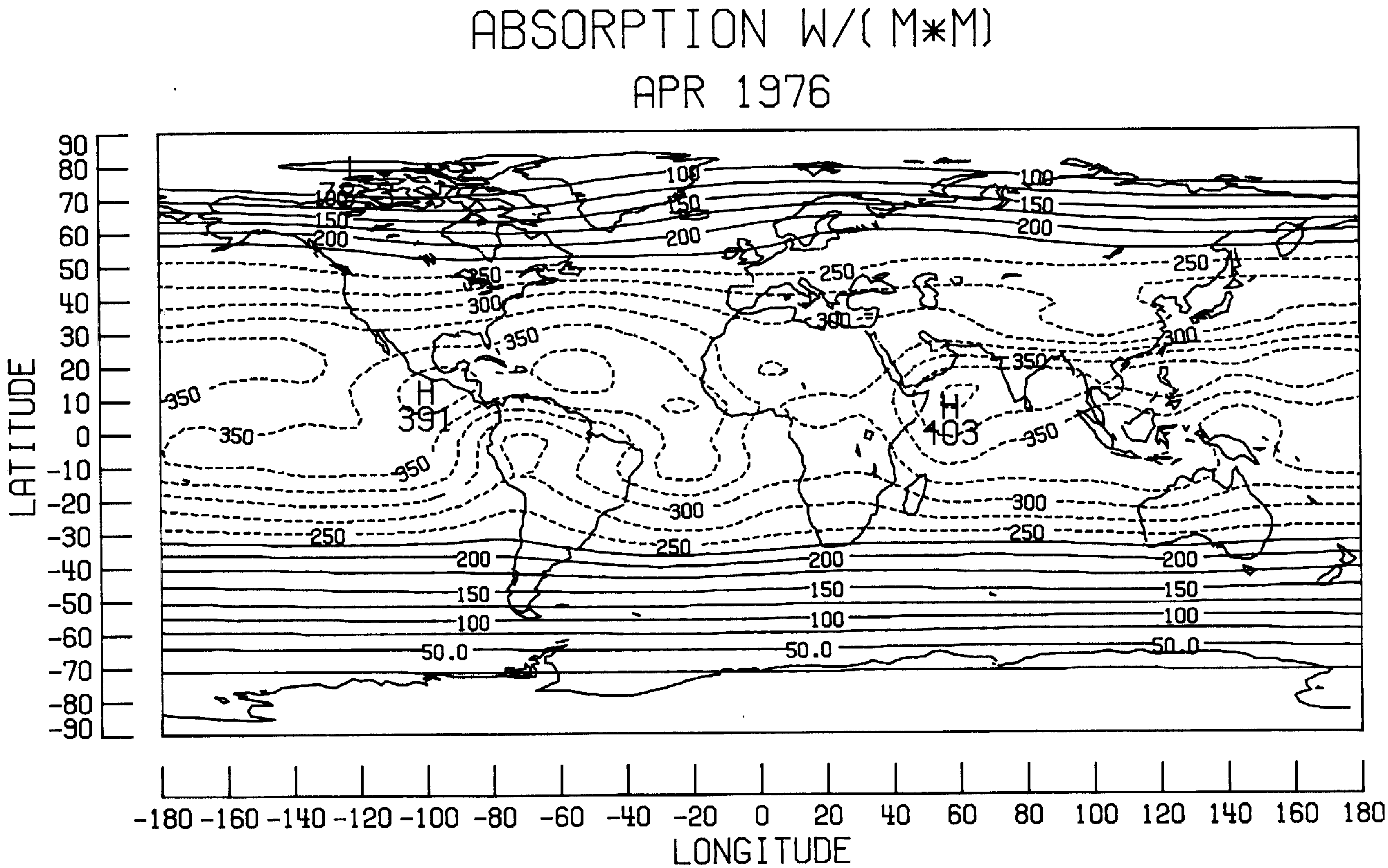


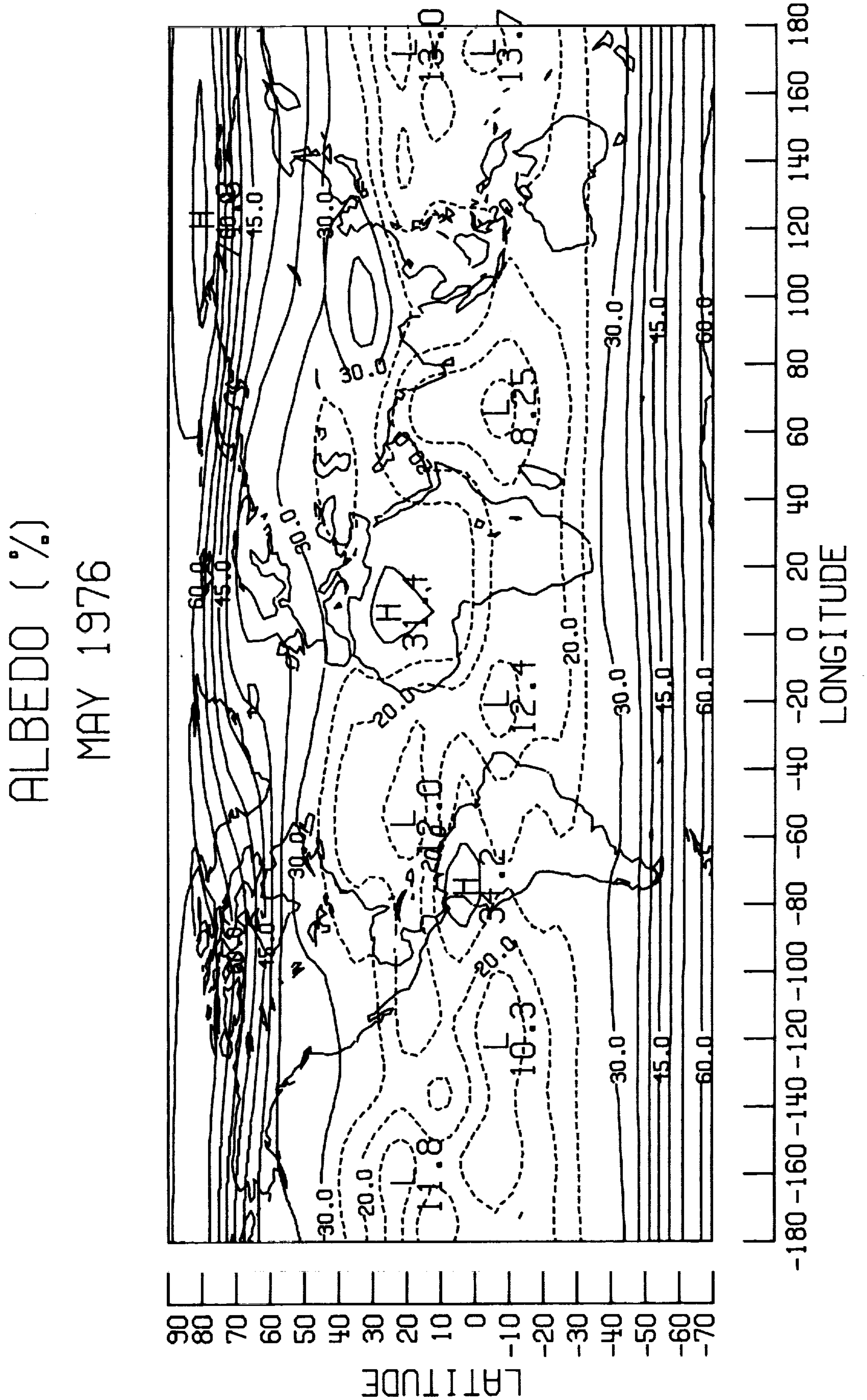
ABSORPTION W/(M*M)

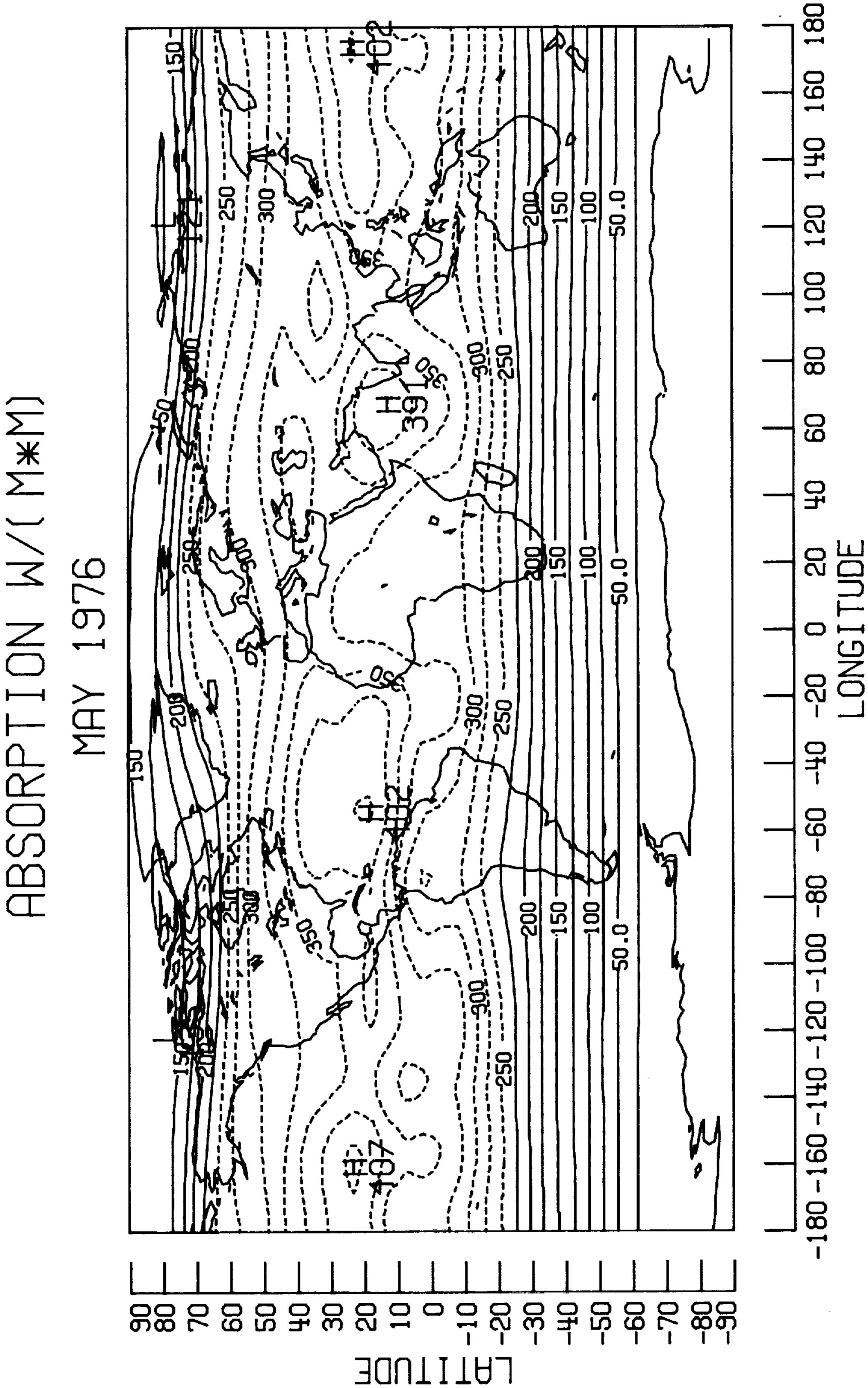
MAR 1976

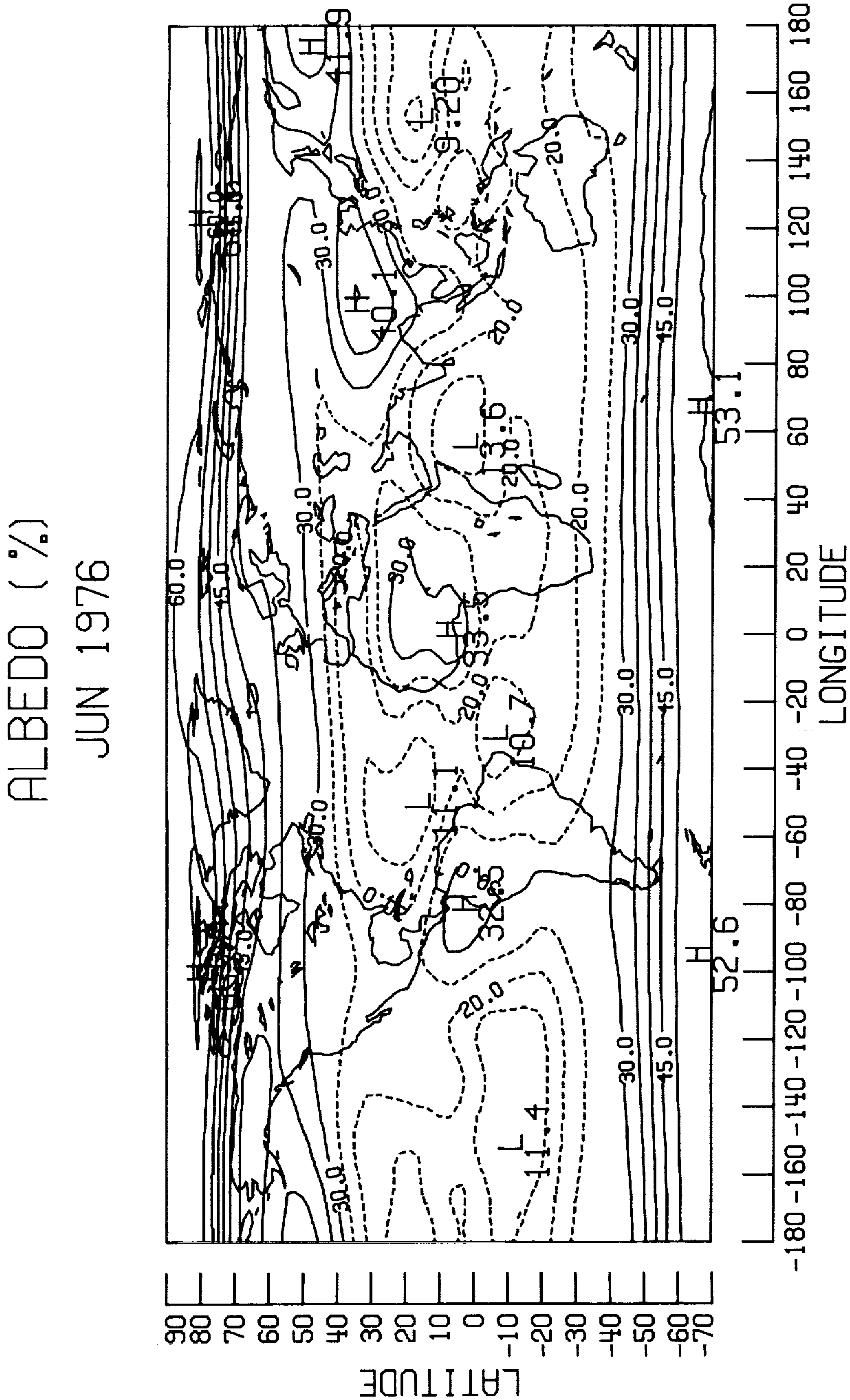


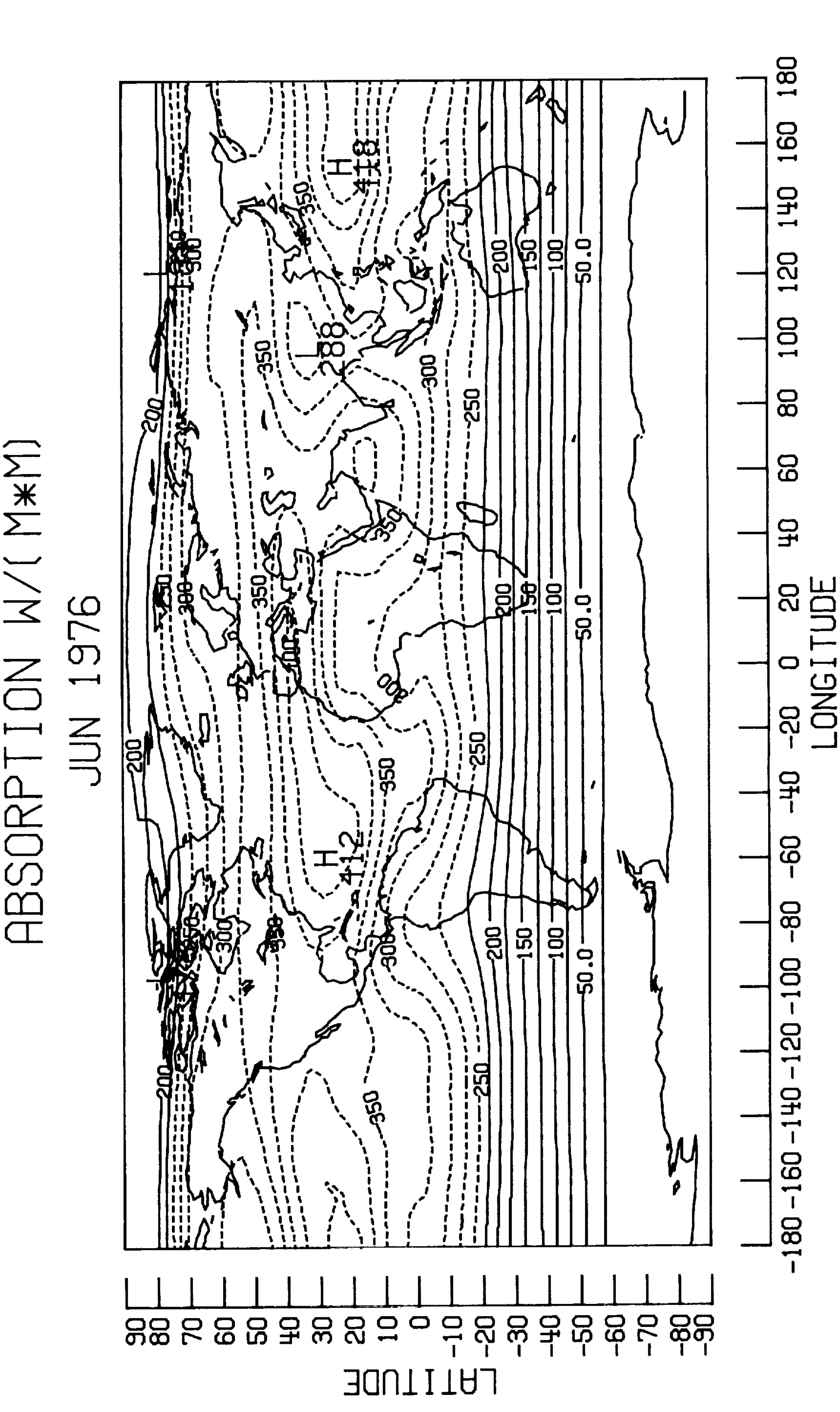

ALBEDO (%)
APR 1976
LATITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
LONGITUDE

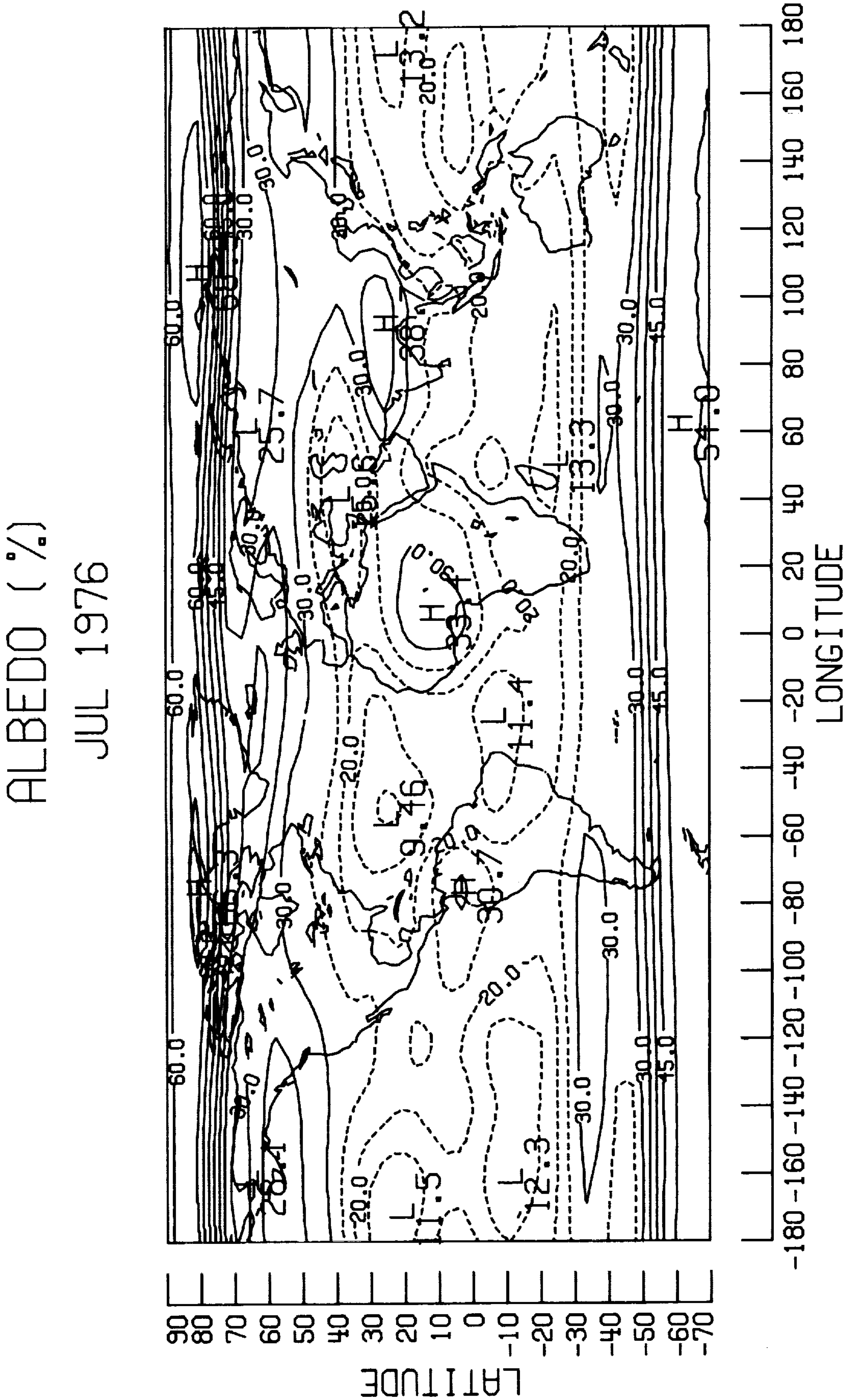

ABSORPTION W/(M*M)
APR 1976
LATITUDE
LONGITUDE
H
391
H
403
350
300
250
200
150
100
50.0


ALBEDO (%)
MAY 1976
LONGITUDE
LATITUDE

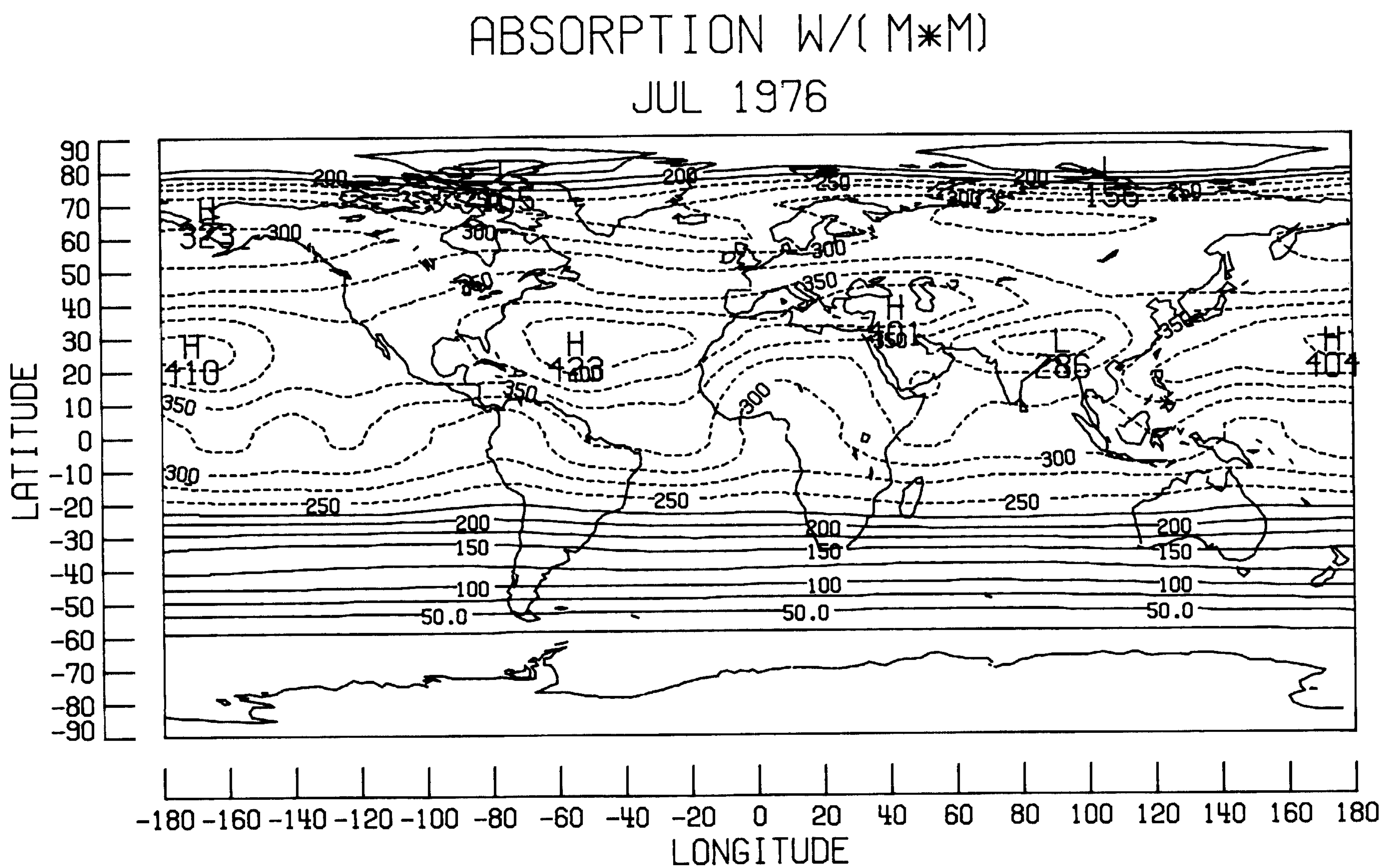

ABSORPTION W/(M*M)
MAY 1976
LONGITUDE
LATITUDE


ALBEDO (%)
JUN 1976
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


ABSORPTION W/(M*M)
JUN 1976
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 -90
H 412
H 418
L 288
350
300
250
200
150
100
50.0

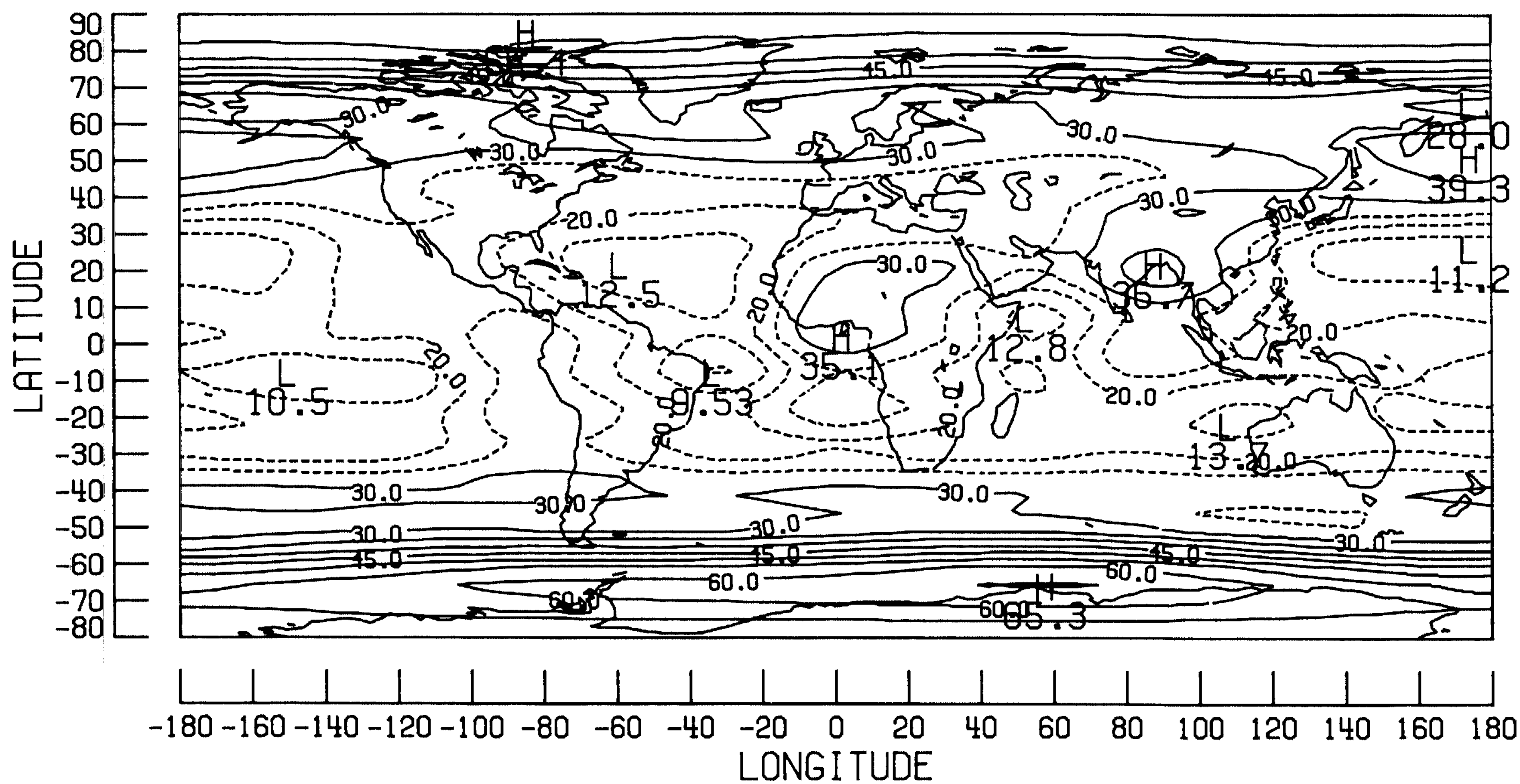


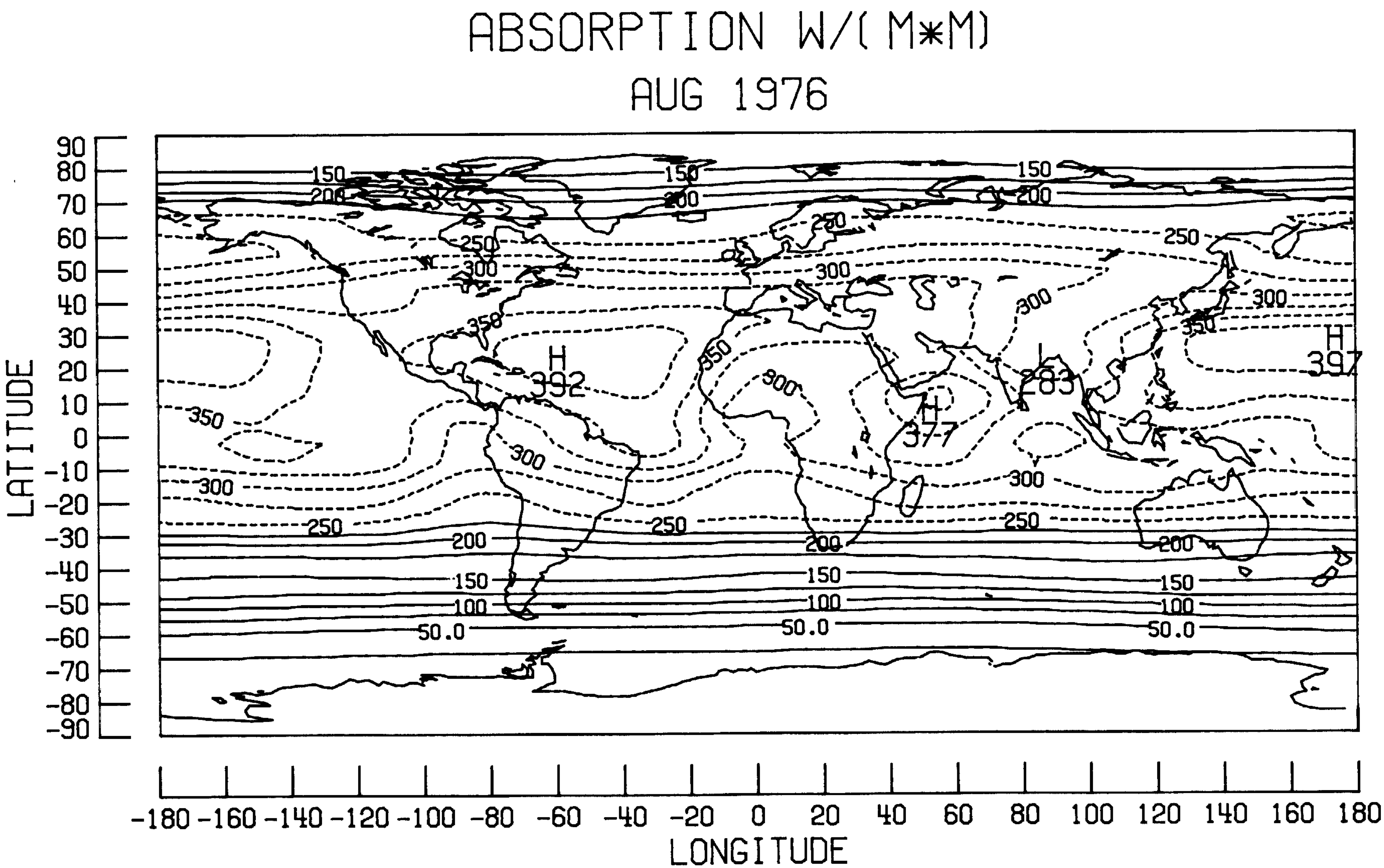
ALBEDO (%)
JUL 1976
LONGITUDE
LATITUDE

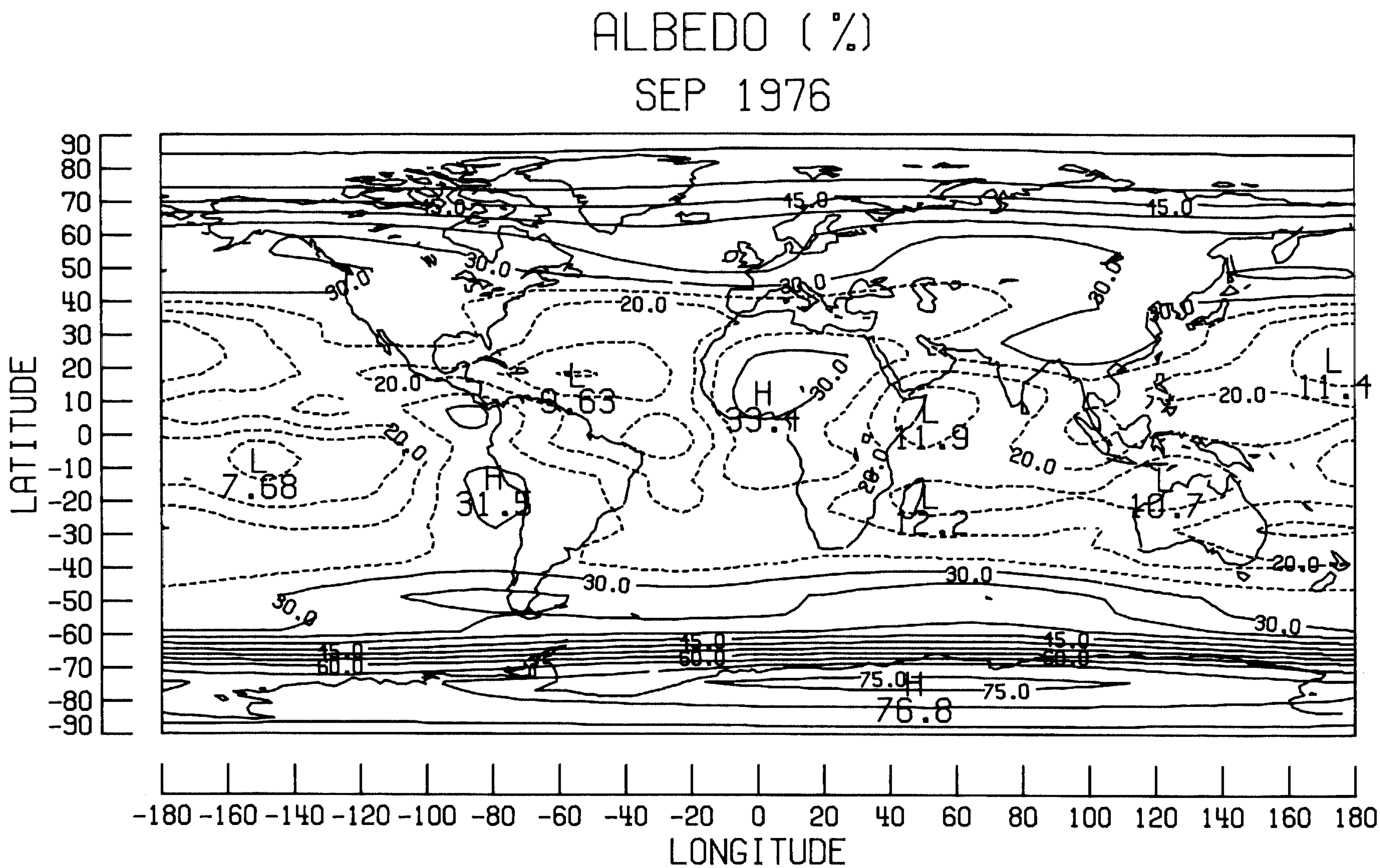


ABSORPTION W/(M*M)
JUL 1976
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
H
323
H
410
H
423
H
401
L
286
L
156
H
404
350
300
250
200
150
100
50.0

ALBEDO (%)
AUG 1976

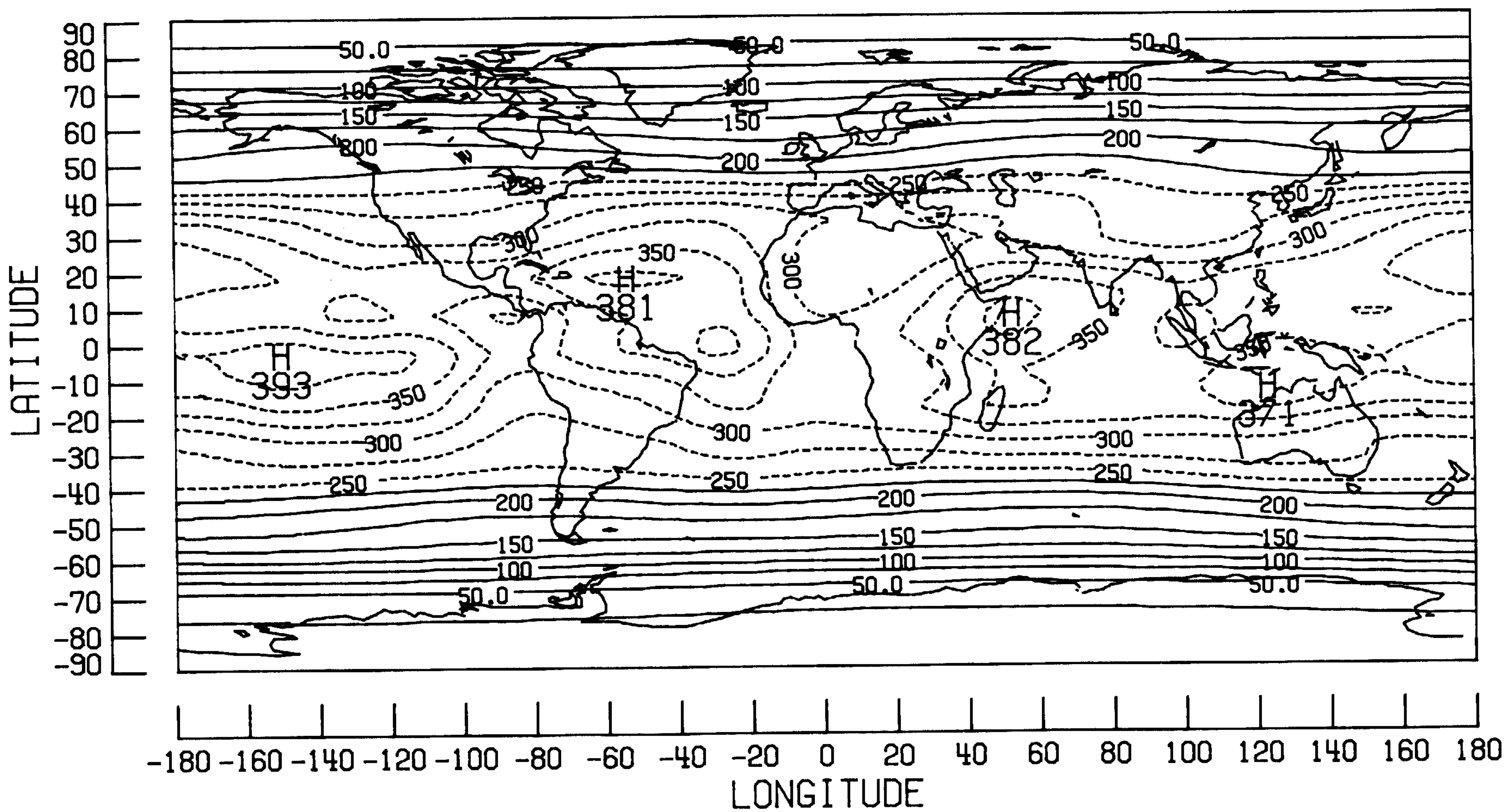


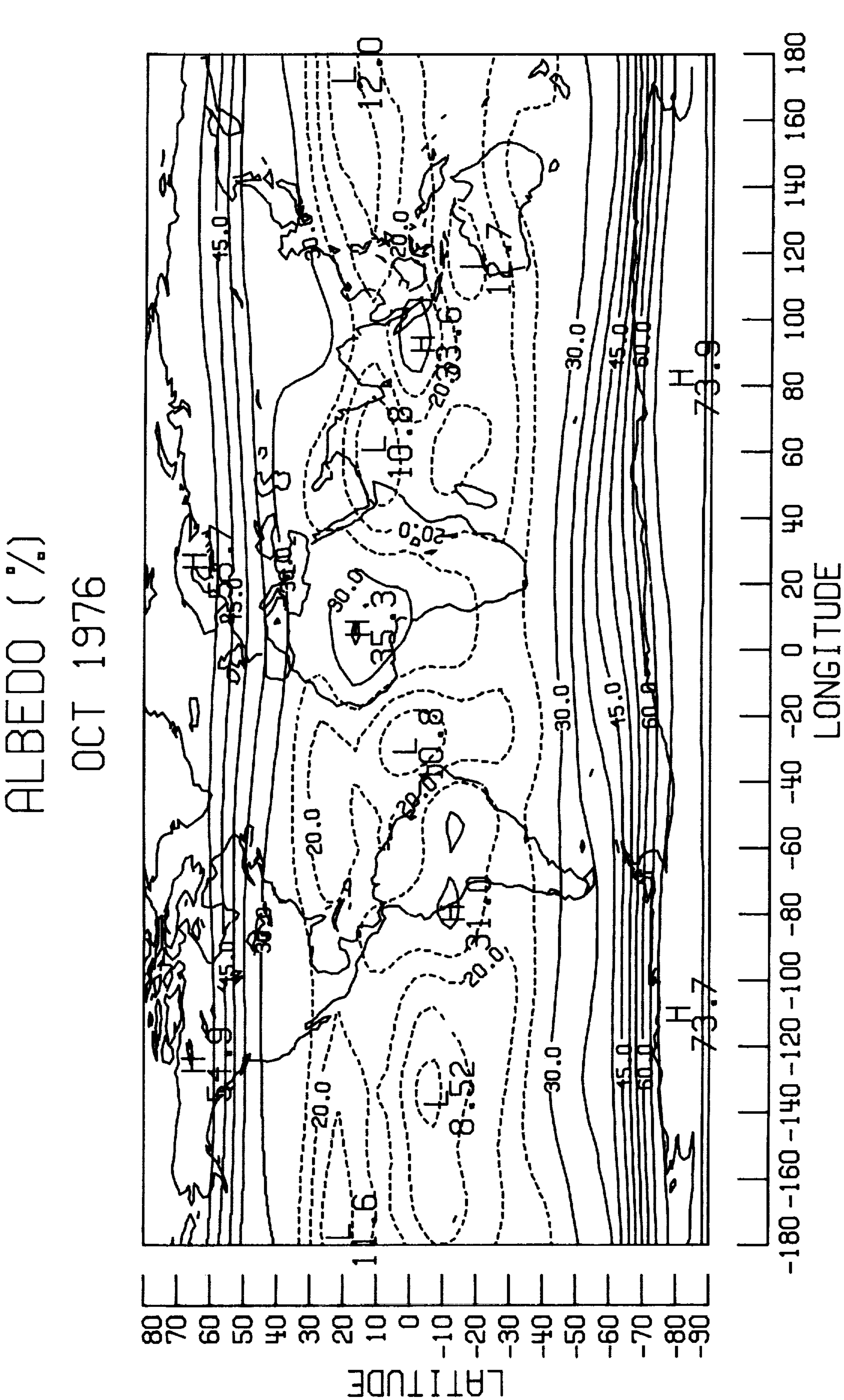

ABSORPTION W/(M*M)
AUG 1976
LATITUDE
LONGITUDE
H 392
H 377
H 397
L 283
150
200
250
300
350
100
50.0


ALBEDO (%)
SEP 1976
LATITUDE
LONGITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
15.0
30.0
20.0
45.0
60.0
75.0
H
L
7.68
31.9
9.63
33.4
11.9
12.2
10.7
11.4
76.8

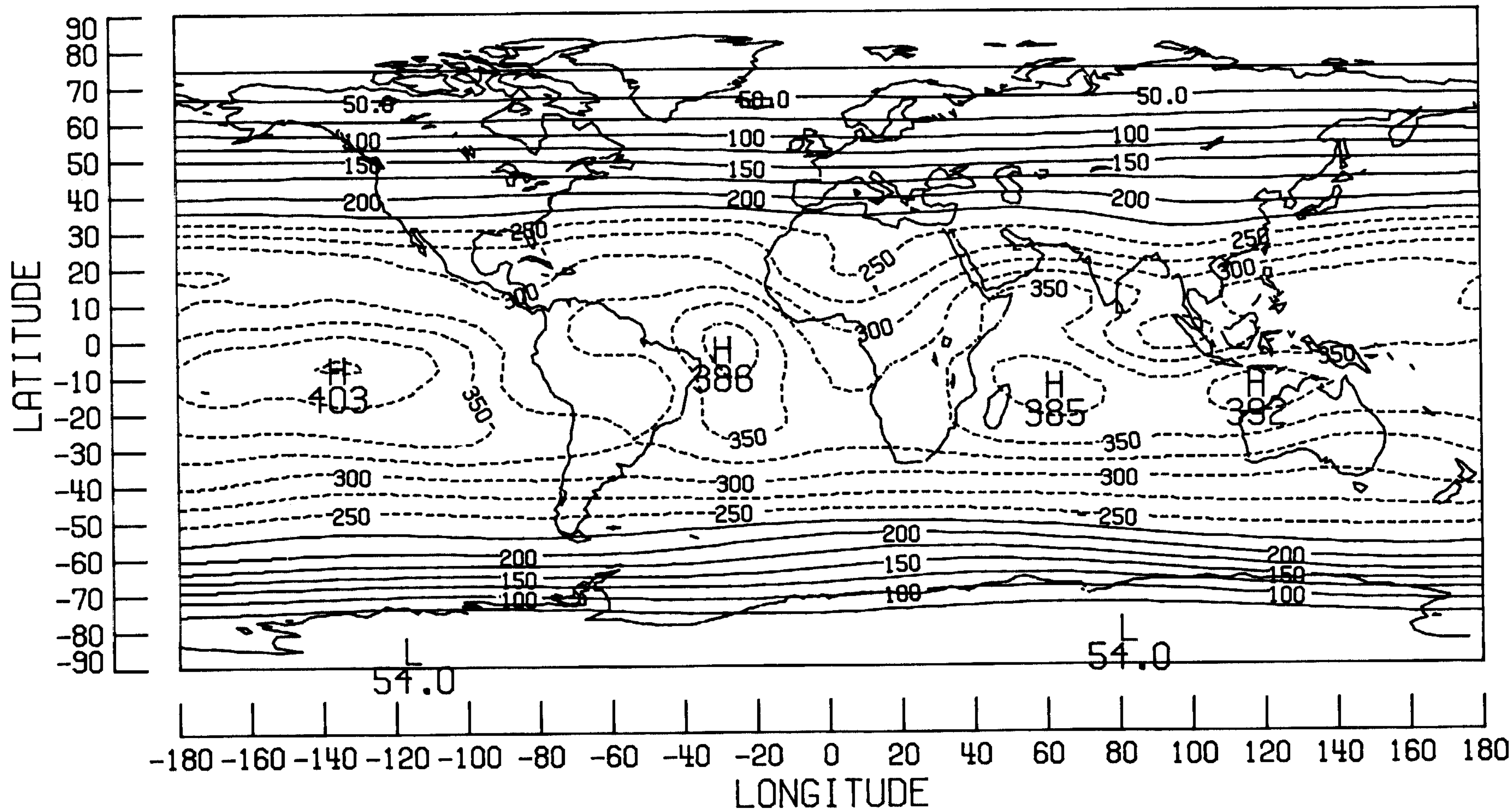
ABSORPTION W/(M*M)

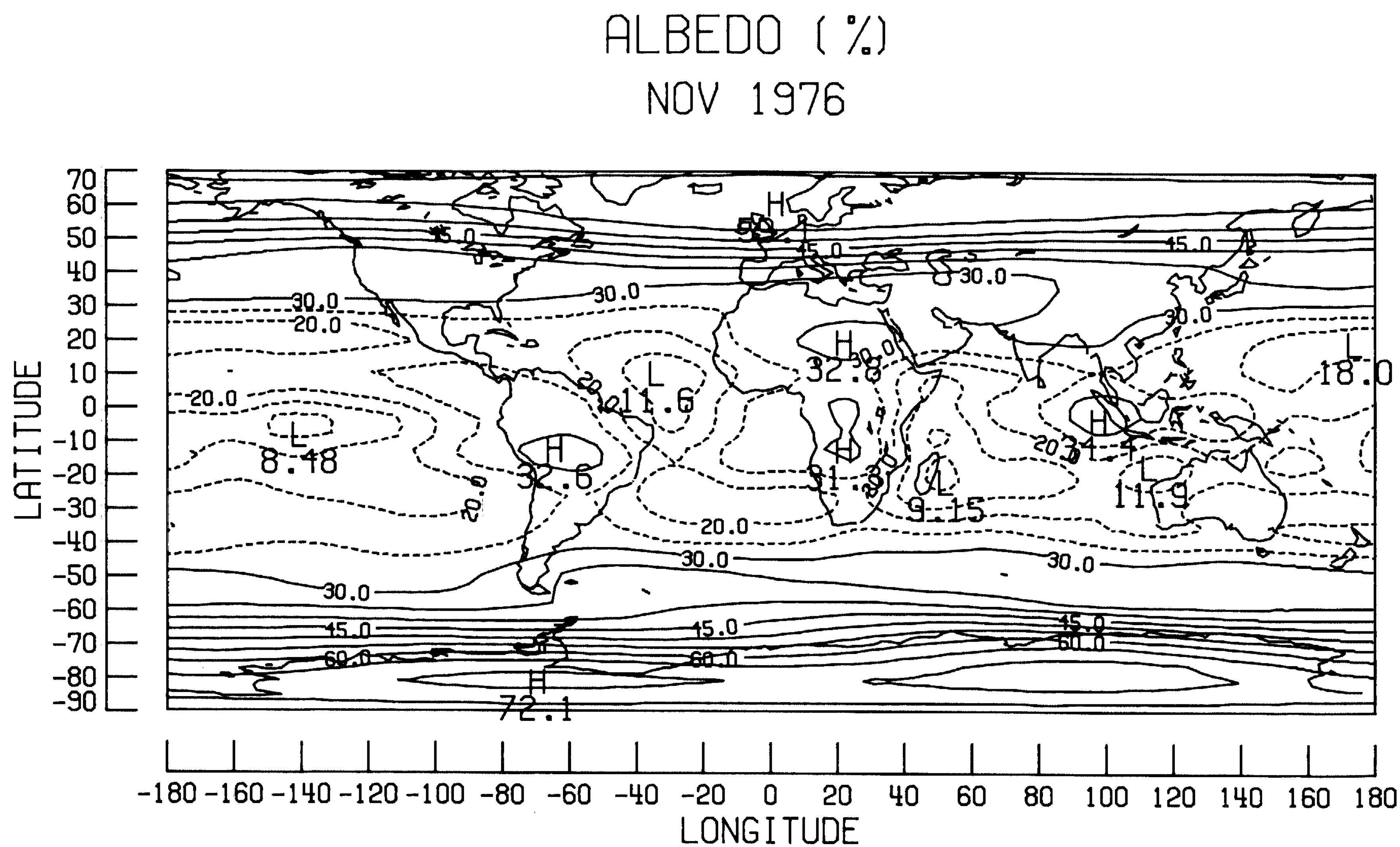
SEP 1976

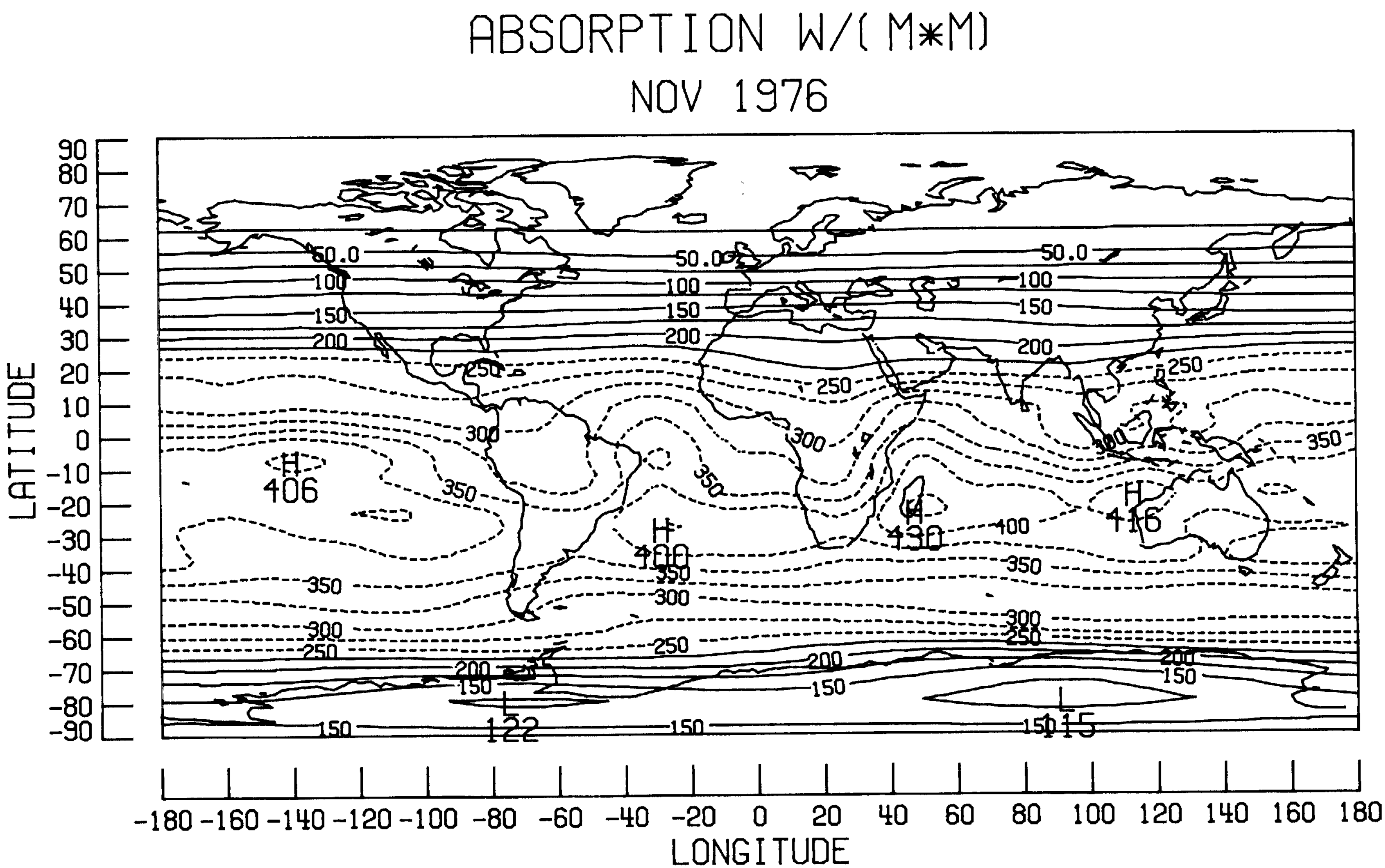



ALBEDO (%)
OCT 1976
LONGITUDE
LATITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
H
73.9
73.7
35.3
8.52
10.8
L
30.0
45.0
60.0
20.0

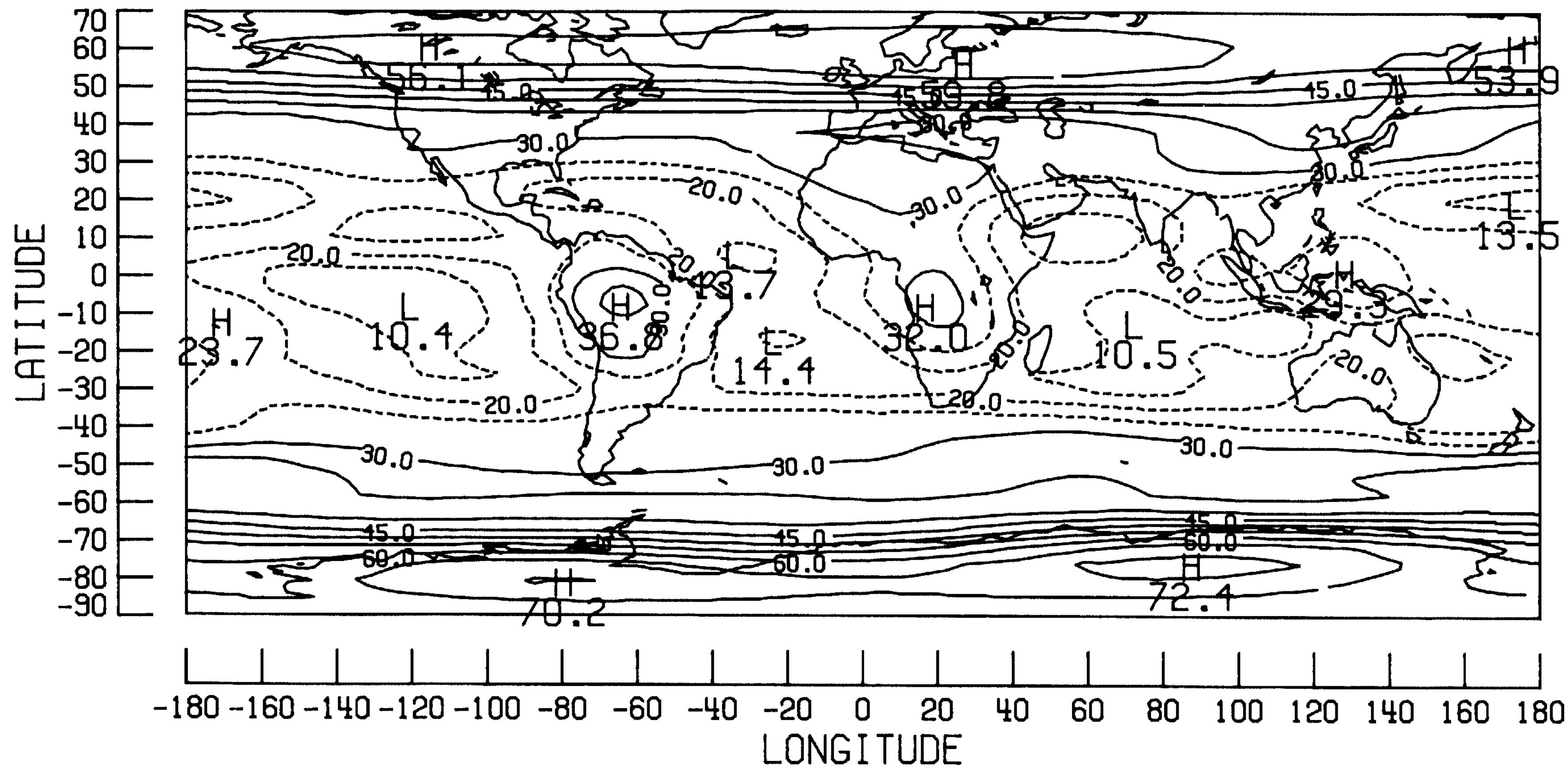
ABSORPTION W/(M*M)
OCT 1976




ALBEDO (%)
NOV 1976
LATITUDE
LONGITUDE
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
H
L
8.48
32.6
11.6
32.8
31.3
9.15
34.4
11.9
18.0
72.1
15.0
30.0
20.0
45.0
60.0

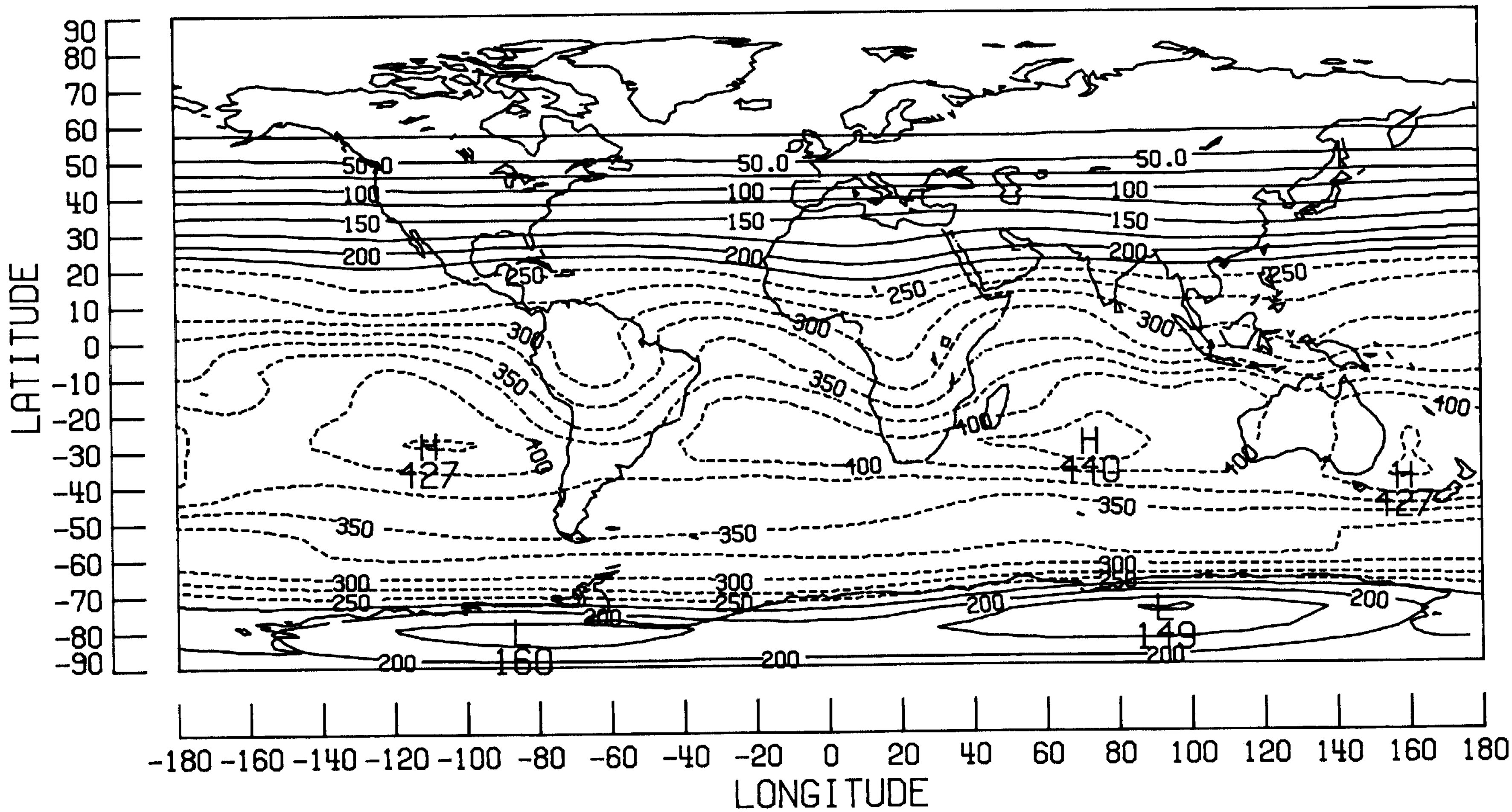

ABSORPTION W/(M*M)
NOV 1976
LATITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
LONGITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
50.0
100
150
200
250
300
350
400
H
406
H
400
H
430
H
416
L
122
L
115

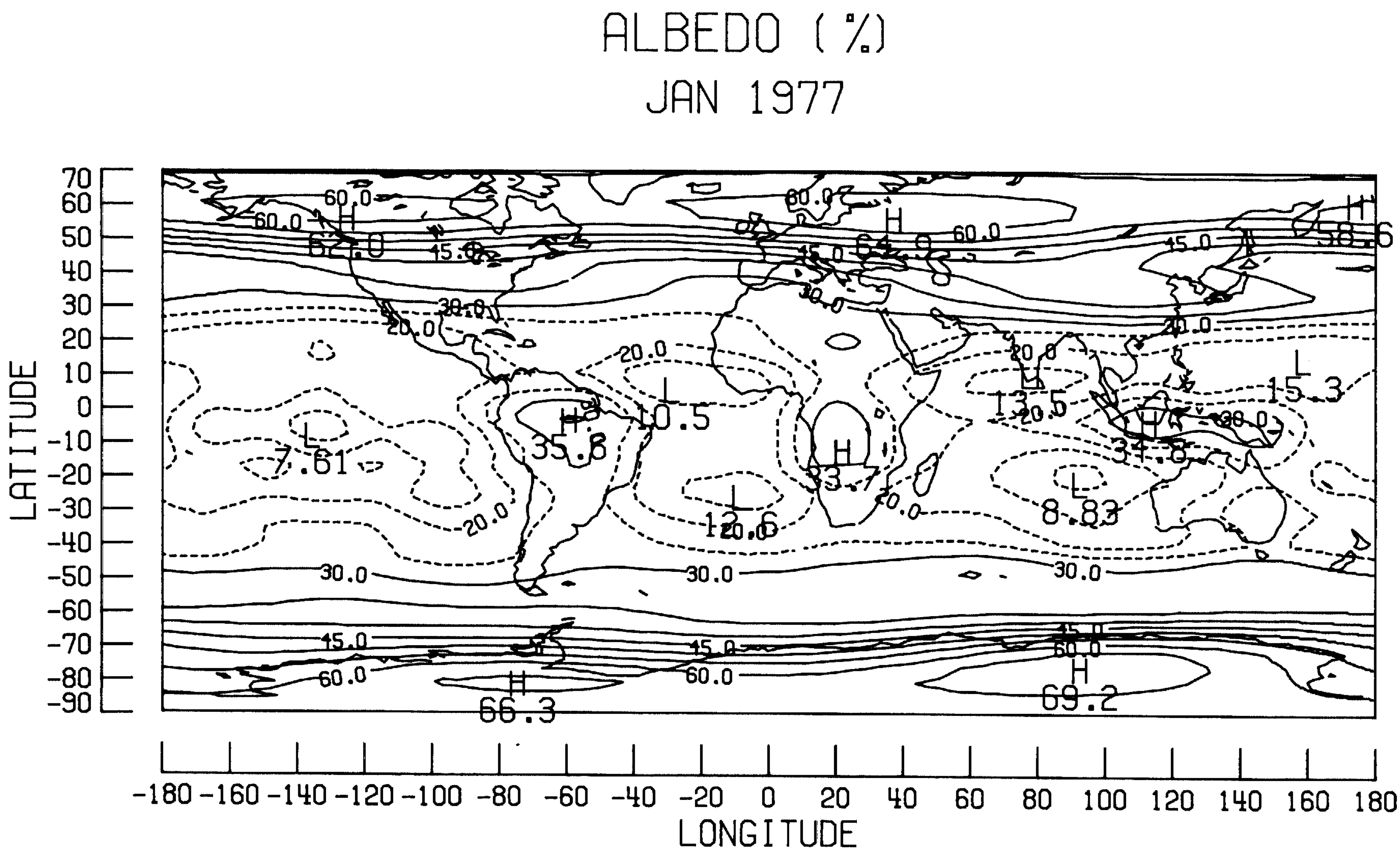
ALBEDO (%)
DEC 1976

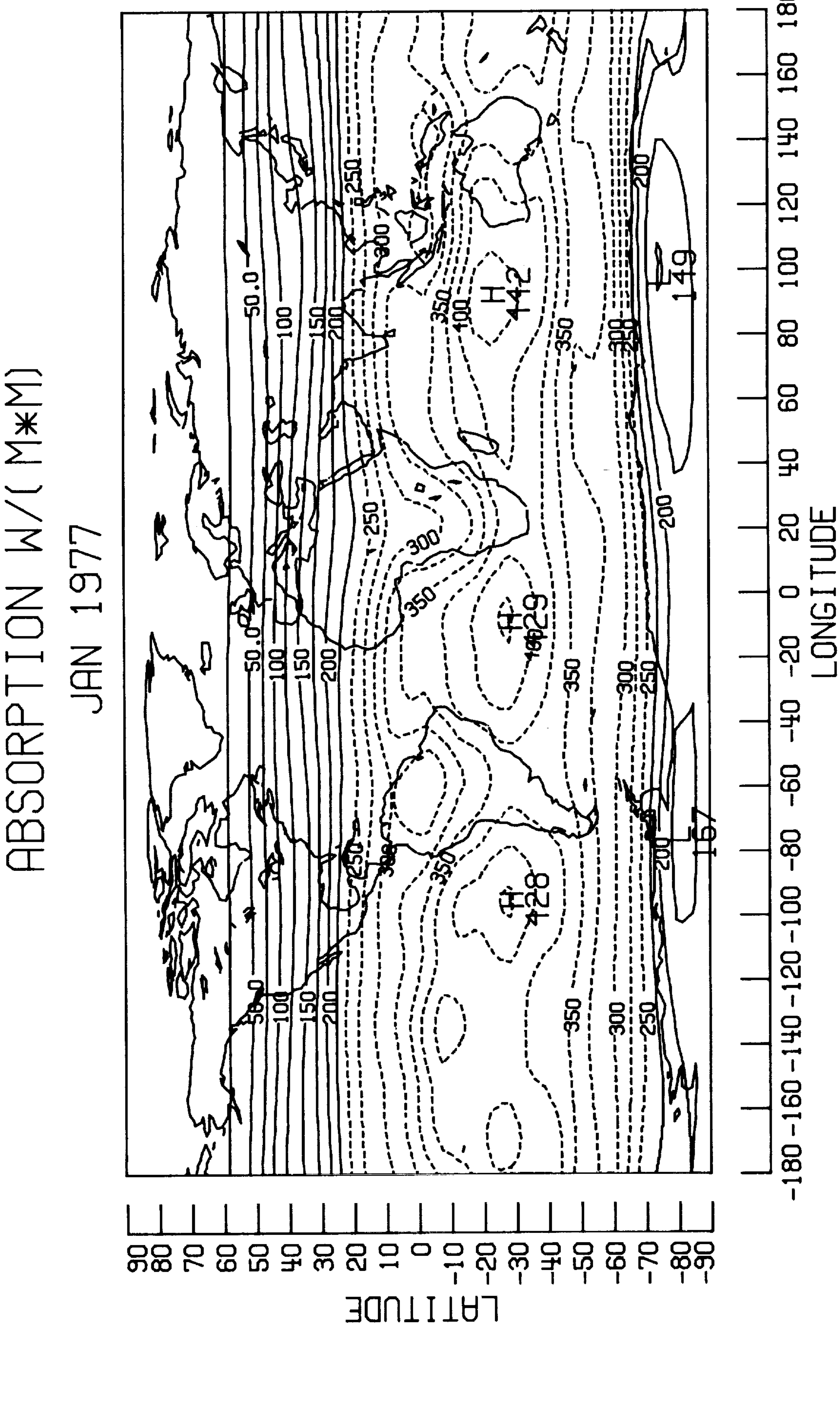


ABSORPTION W/(M*M)

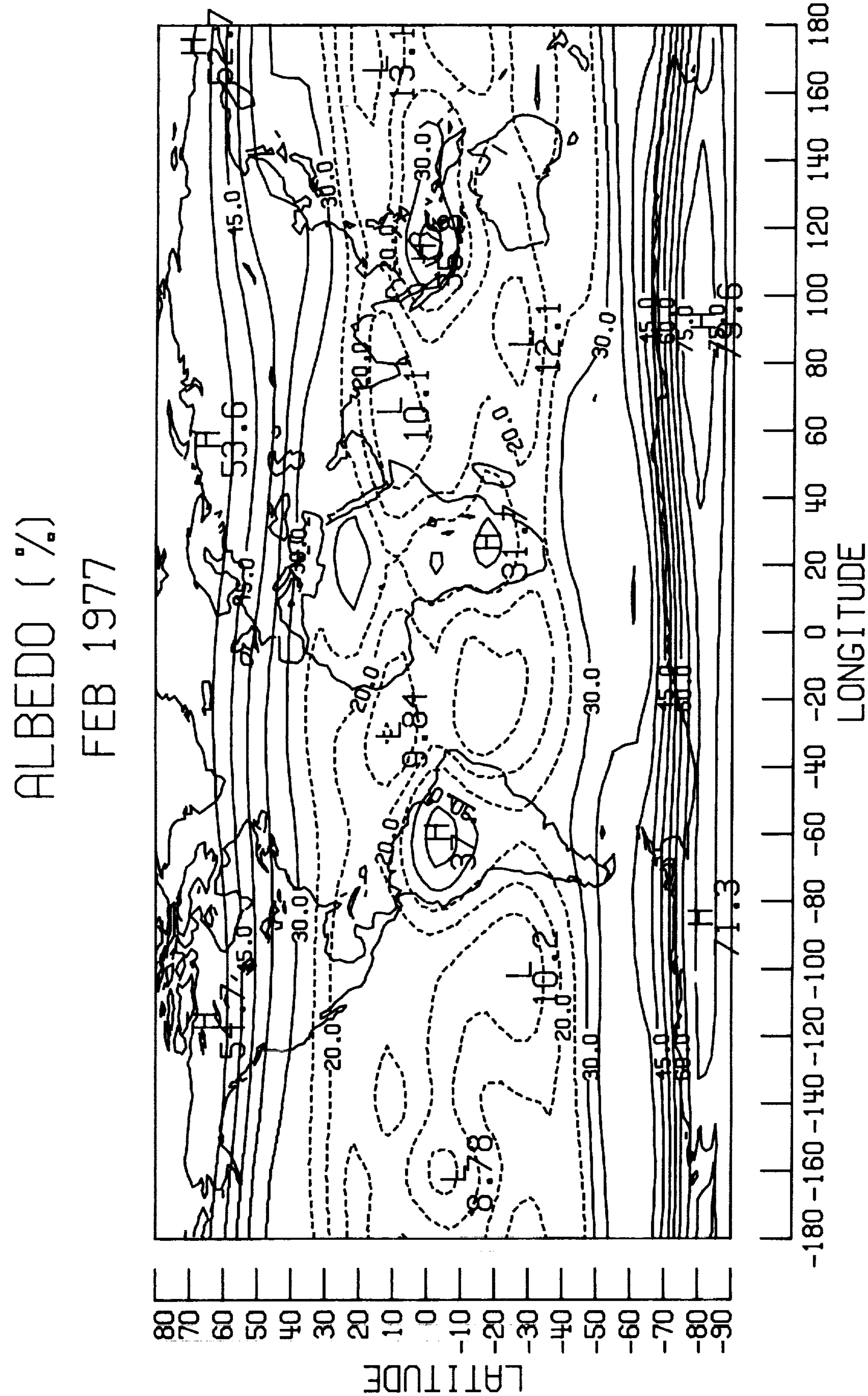
DEC 1976




ALBEDO (%)
JAN 1977
LATITUDE
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
62.0
H
64.9
H
58.6
L
7.61
H
35.6
L
10.5
L
12.6
H
33.7
L
13.5
L
8.83
H
34.8
L
15.3
H
66.3
H
69.2
60.0
45.0
30.0
20.0
15.0

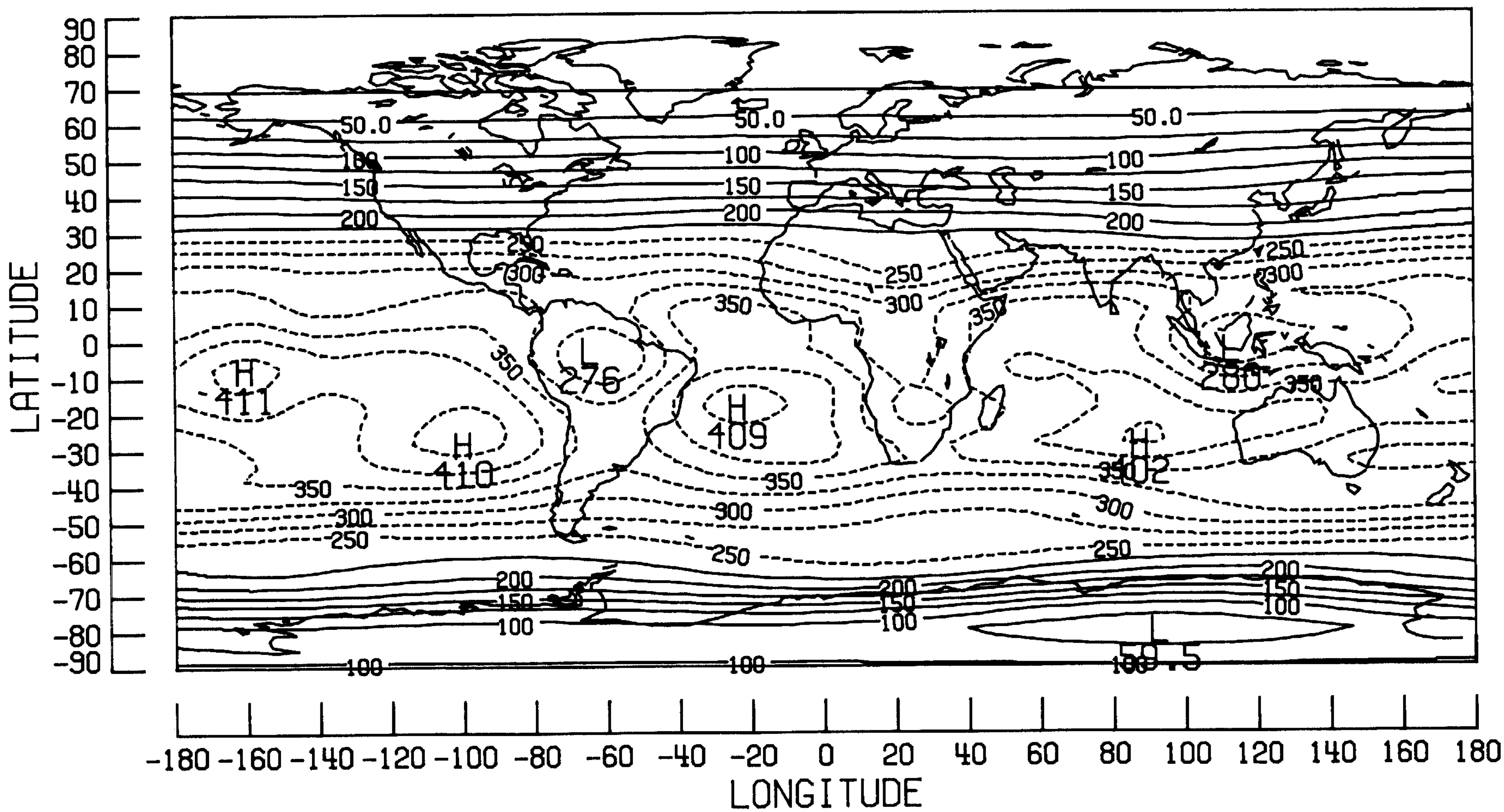


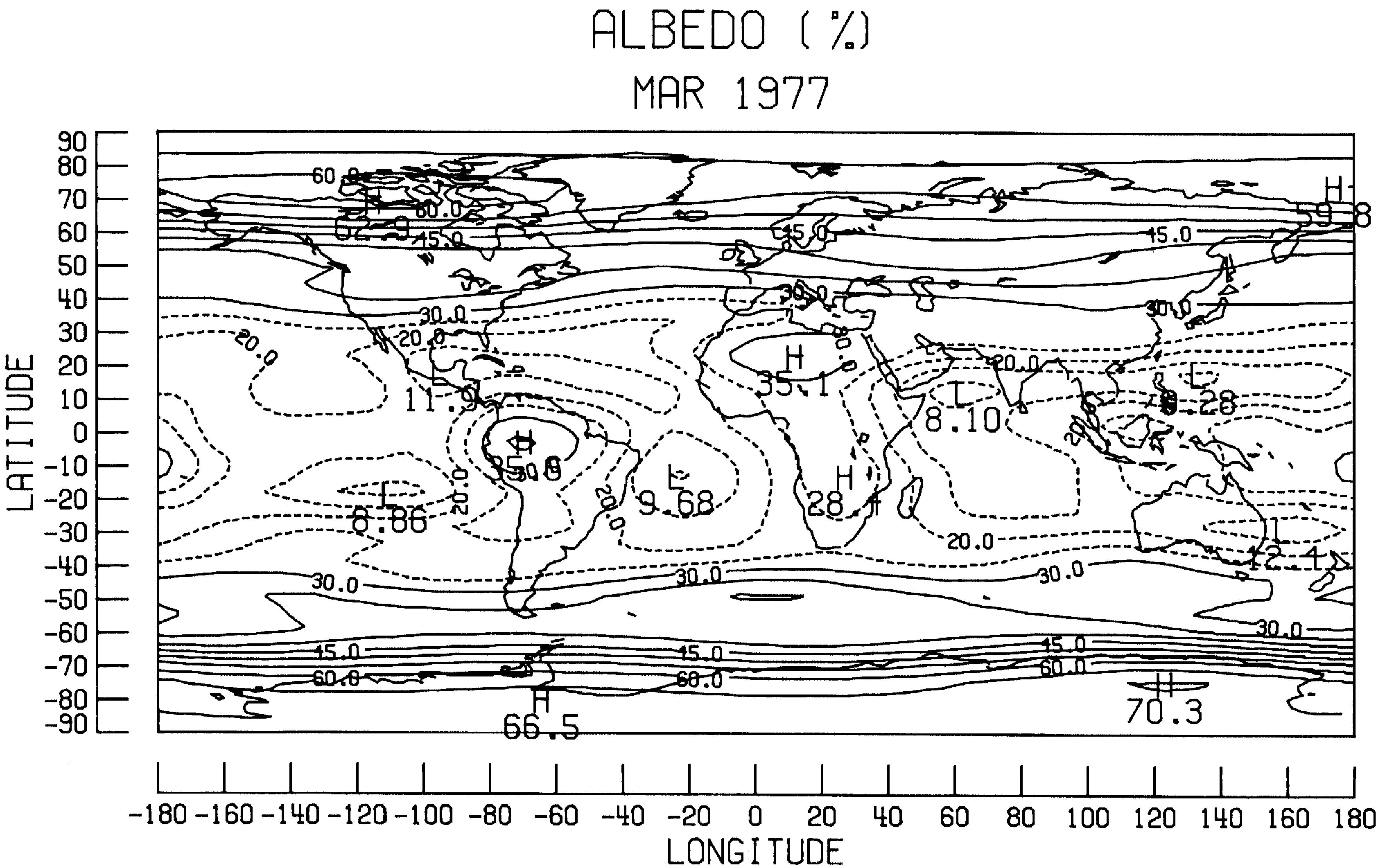
ABSORPTION W/(M*M)
JAN 1977
LATITUDE
LONGITUDE



ALBEDO (%)
FEB 1977
LONGITUDE
LATITUDE

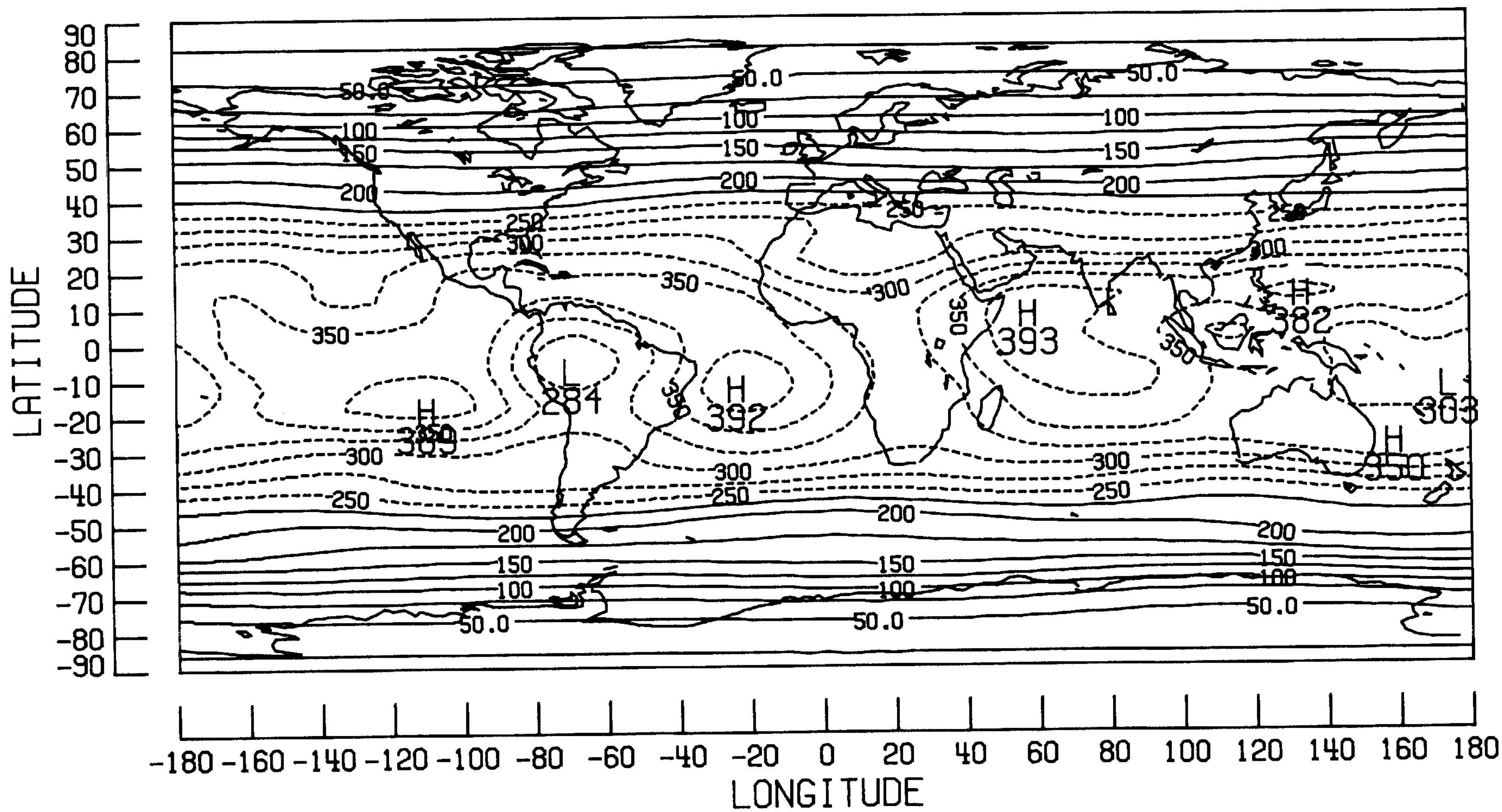
ABSORPTION W/(M*M)
FEB 1977



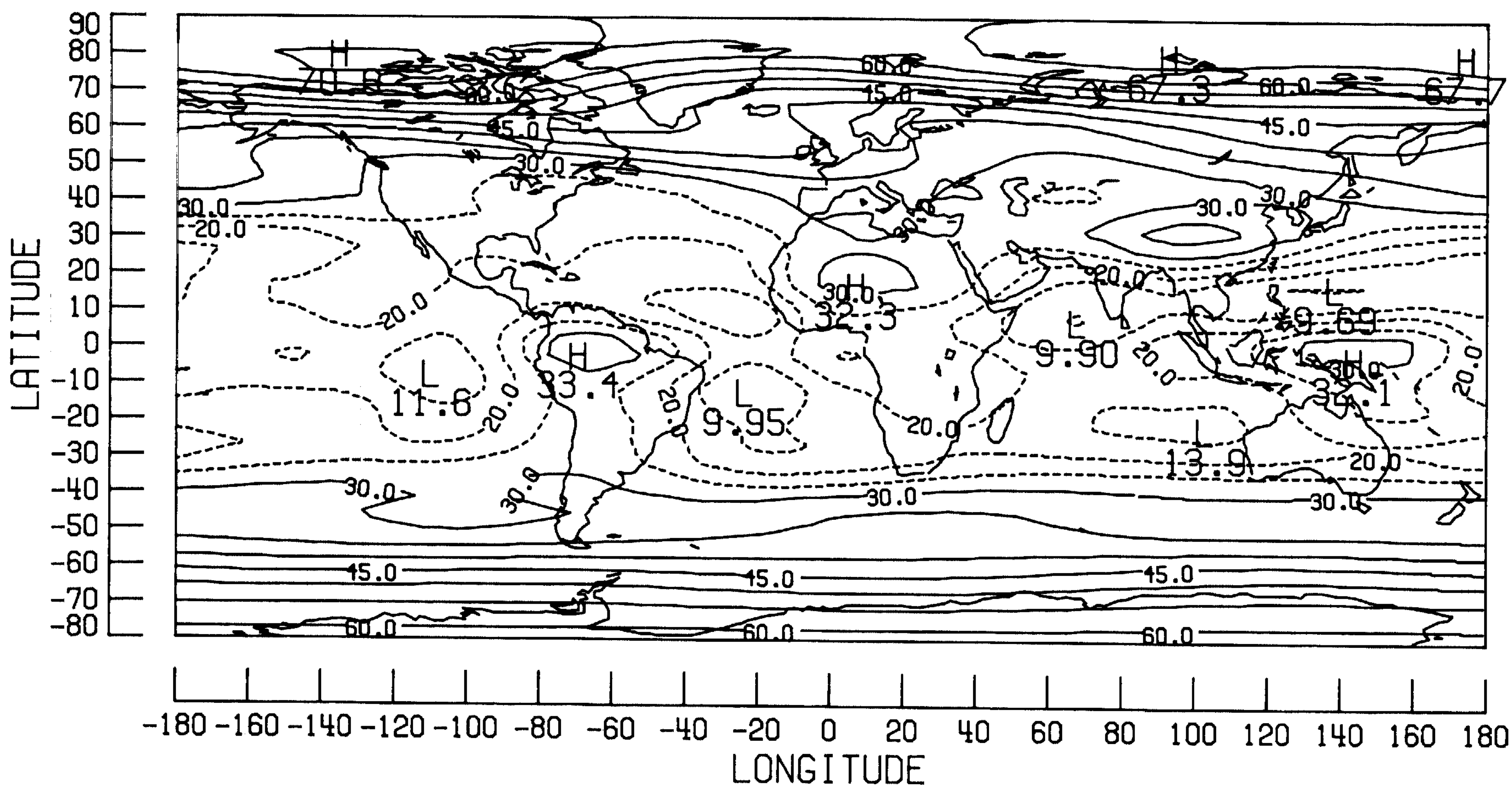

ALBEDO (%)
MAR 1977
LATITUDE
LONGITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
H 62.9
H 59.8
H 35.1
H 28.4
H 66.5
H 70.3
L 11.9
L 8.86
L 9.68
L 8.10
L 12.4
60.0
45.0
30.0
20.0

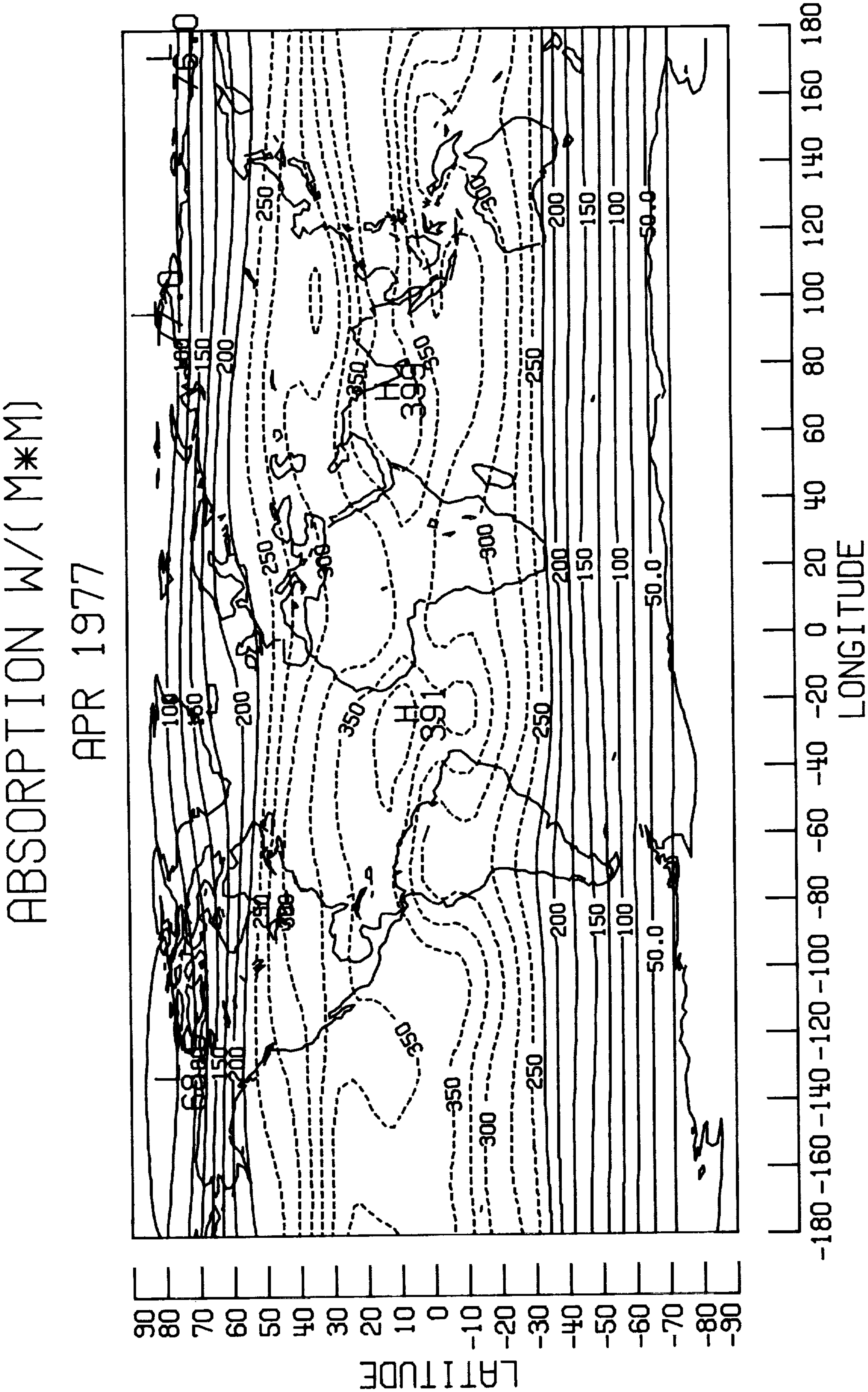
ABSORPTION W/(M*M)

MAR 1977



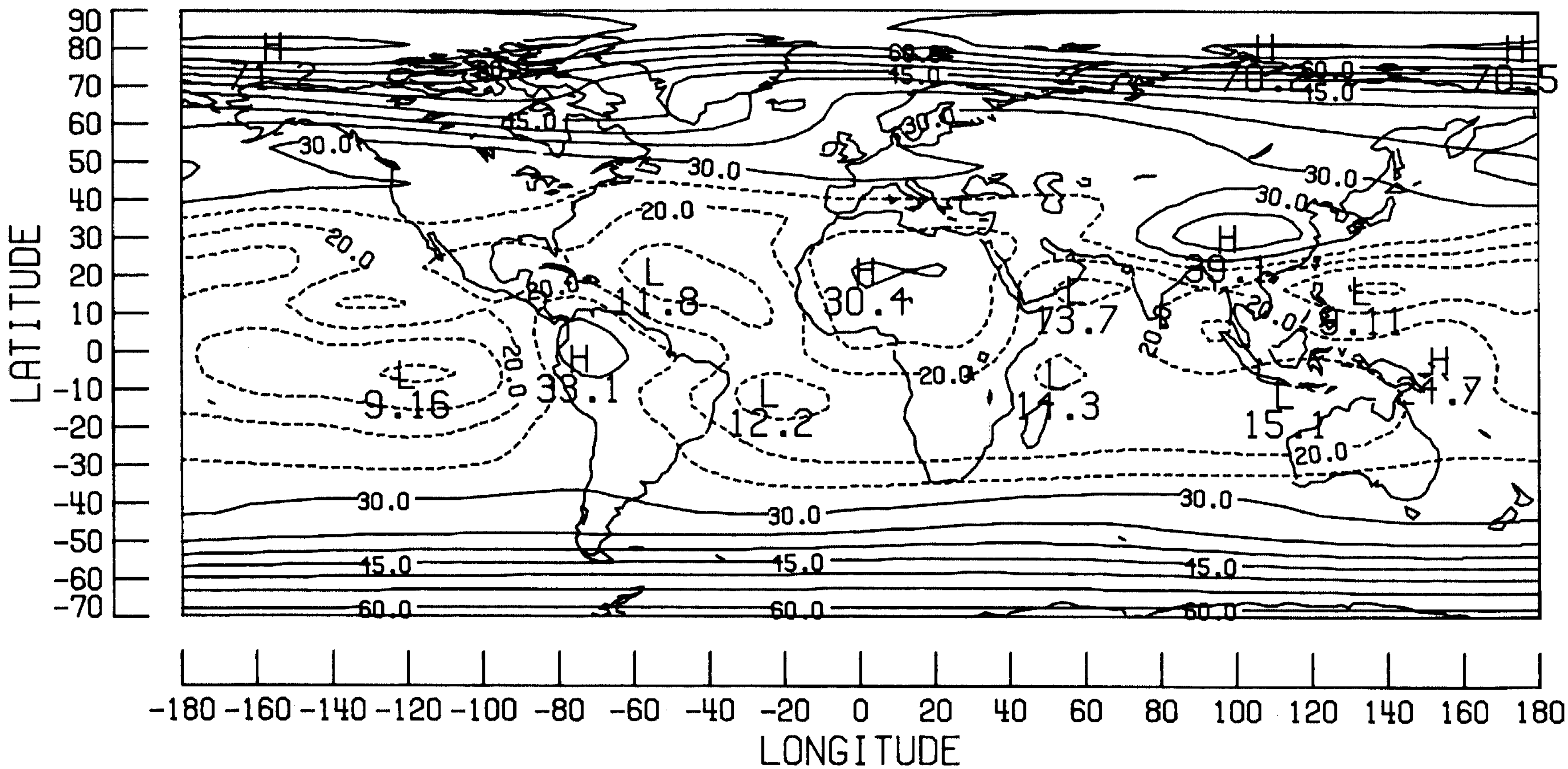
ALBEDO (%)
APR 1977





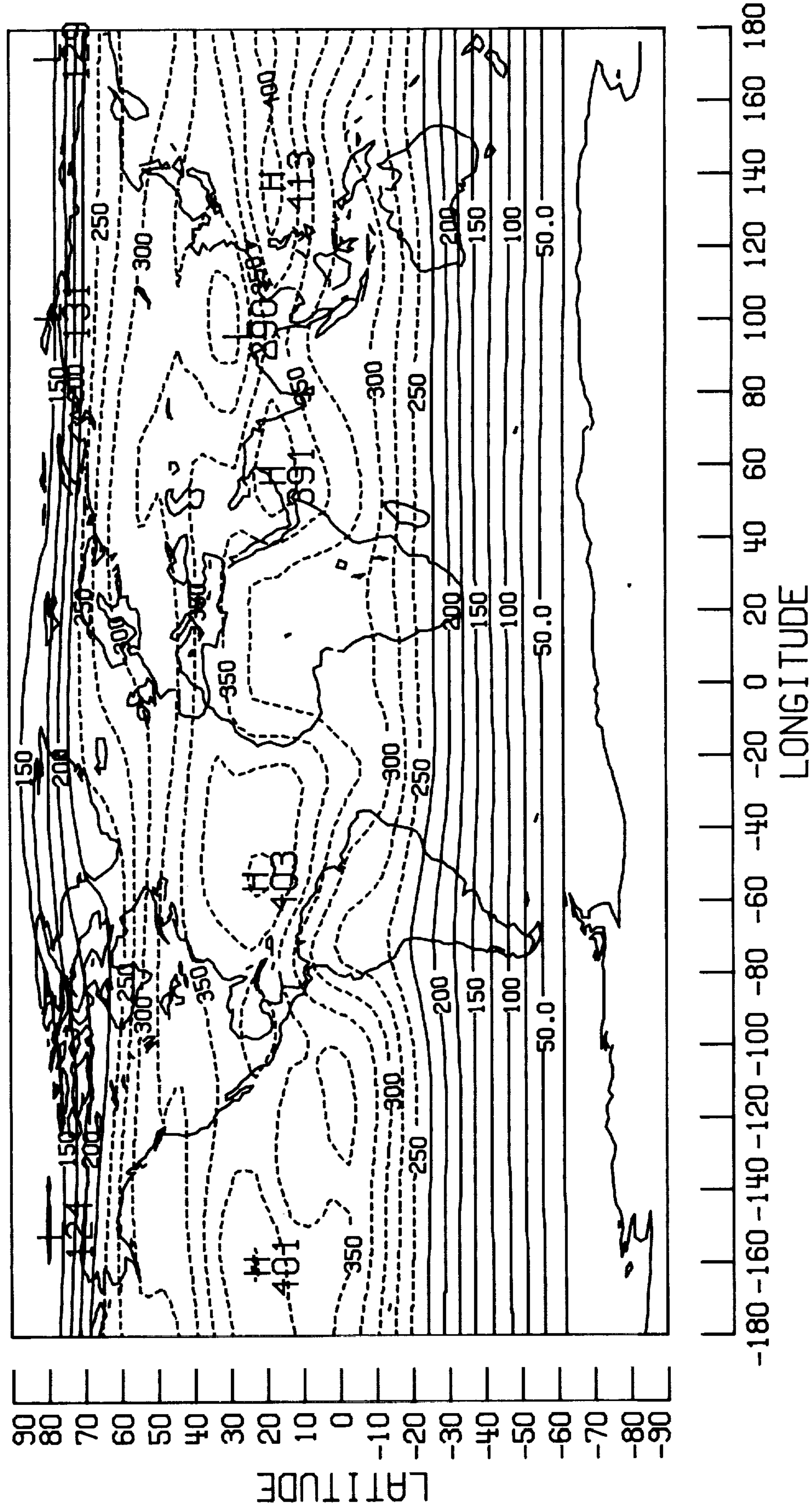
ABSORPTION W/(M*M)
APR 1977
LATITUDE
LONGITUDE

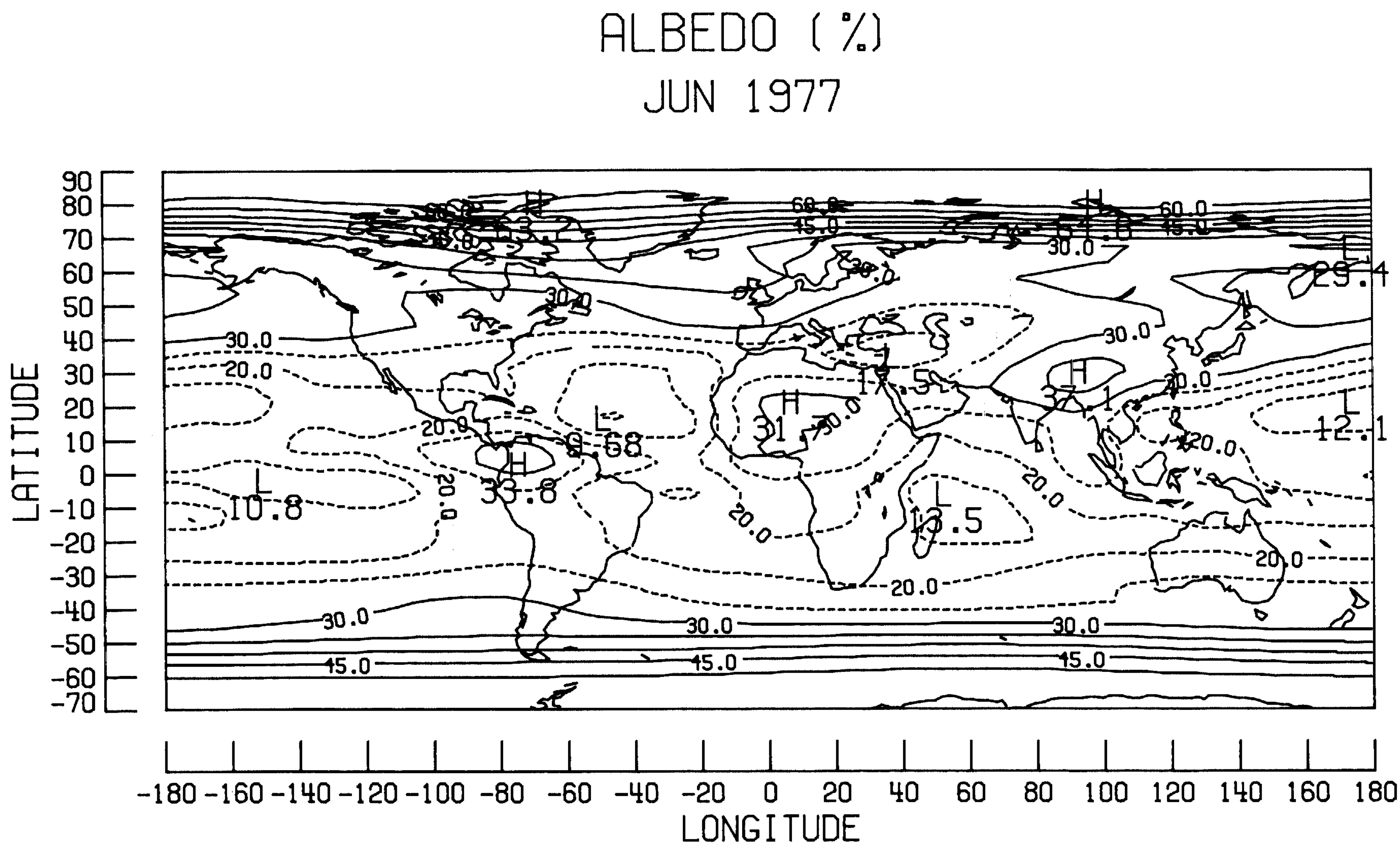
ALBEDO (%)
MAY 1977



ABSORPTION W/(M*M)

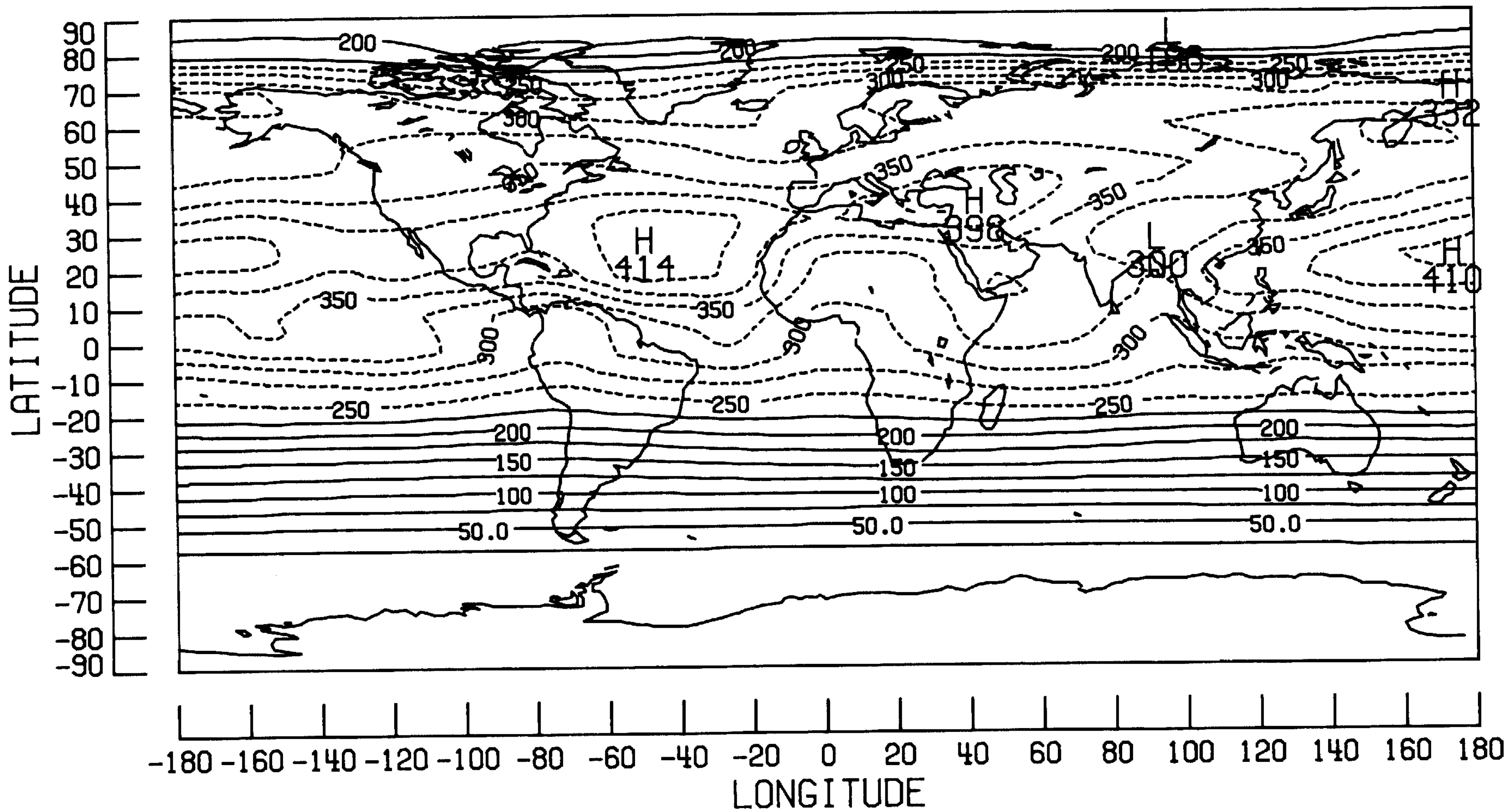
MAY 1977

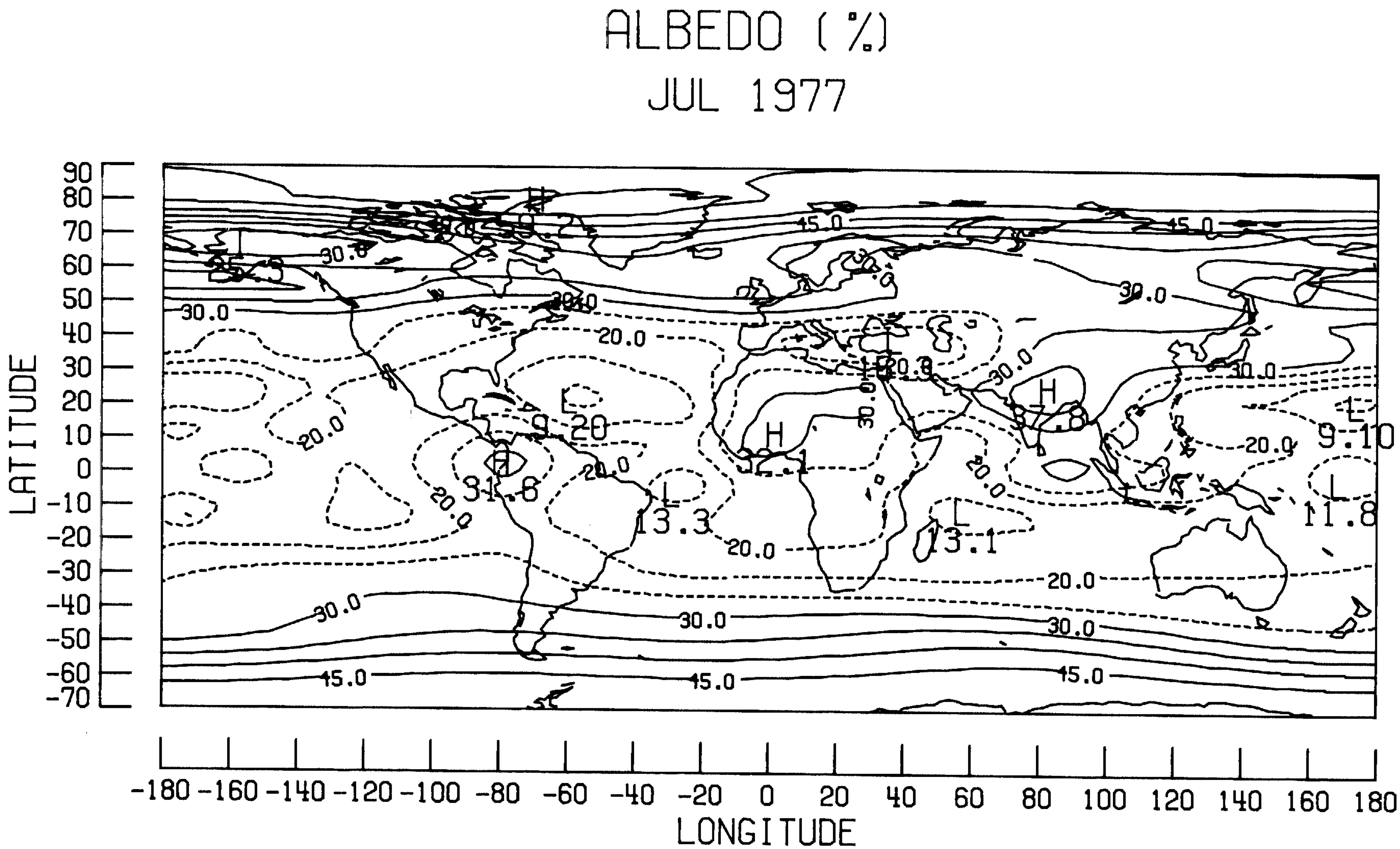



ALBEDO (%)
JUN 1977
LATITUDE
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
LONGITUDE
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
30.0
20.0
45.0
60.0
L
10.8
H
33.8
9.68
31
37.1
13.5
12.1
29.4

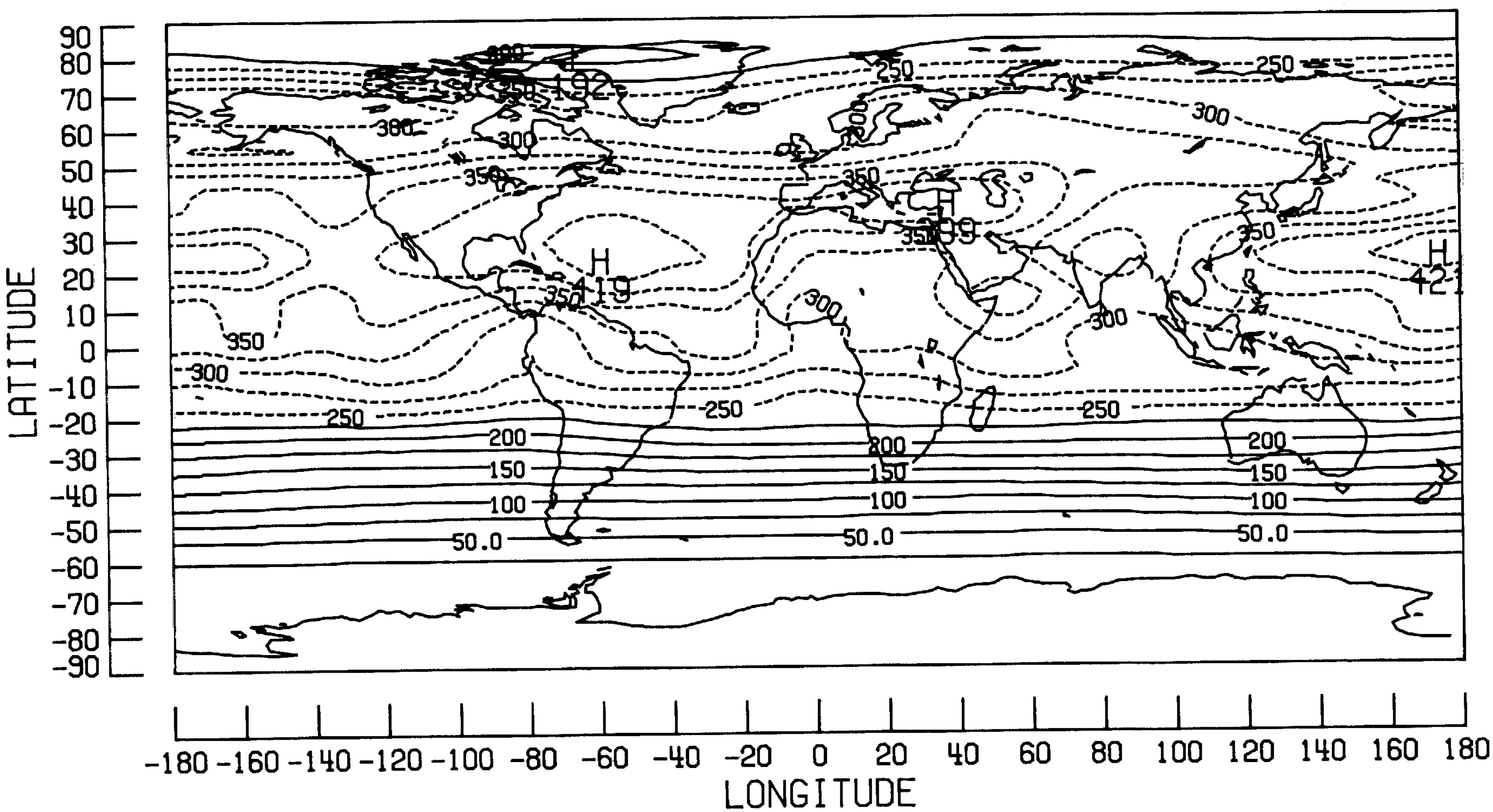
ABSORPTION W/(M*M)

JUN 1977



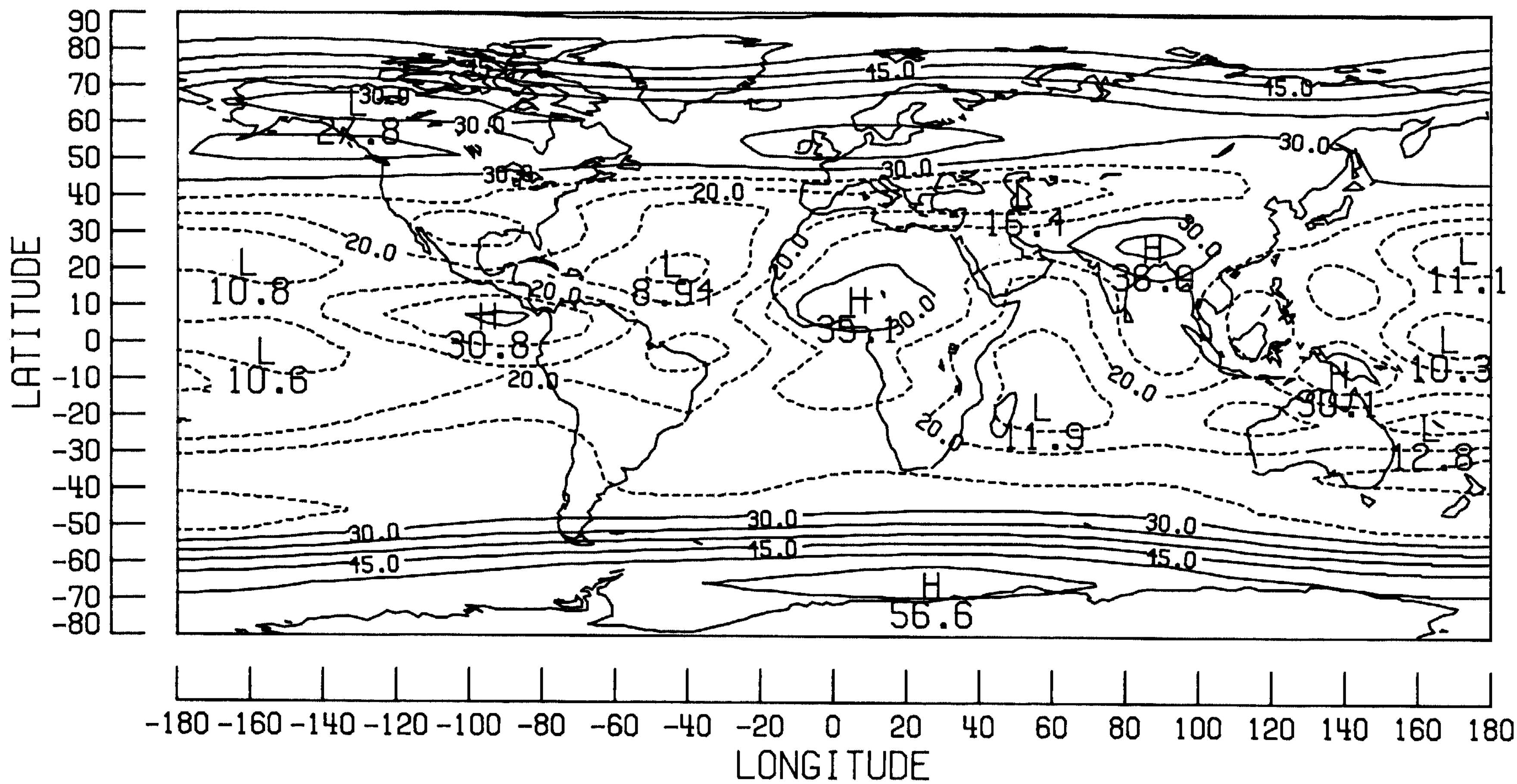

ALBEDO (%)
JUL 1977
LATITUDE
LONGITUDE
H
L
9.20
31.8
13.3
32.1
37.8
13.1
9.10
11.8
20.0
30.0
45.0

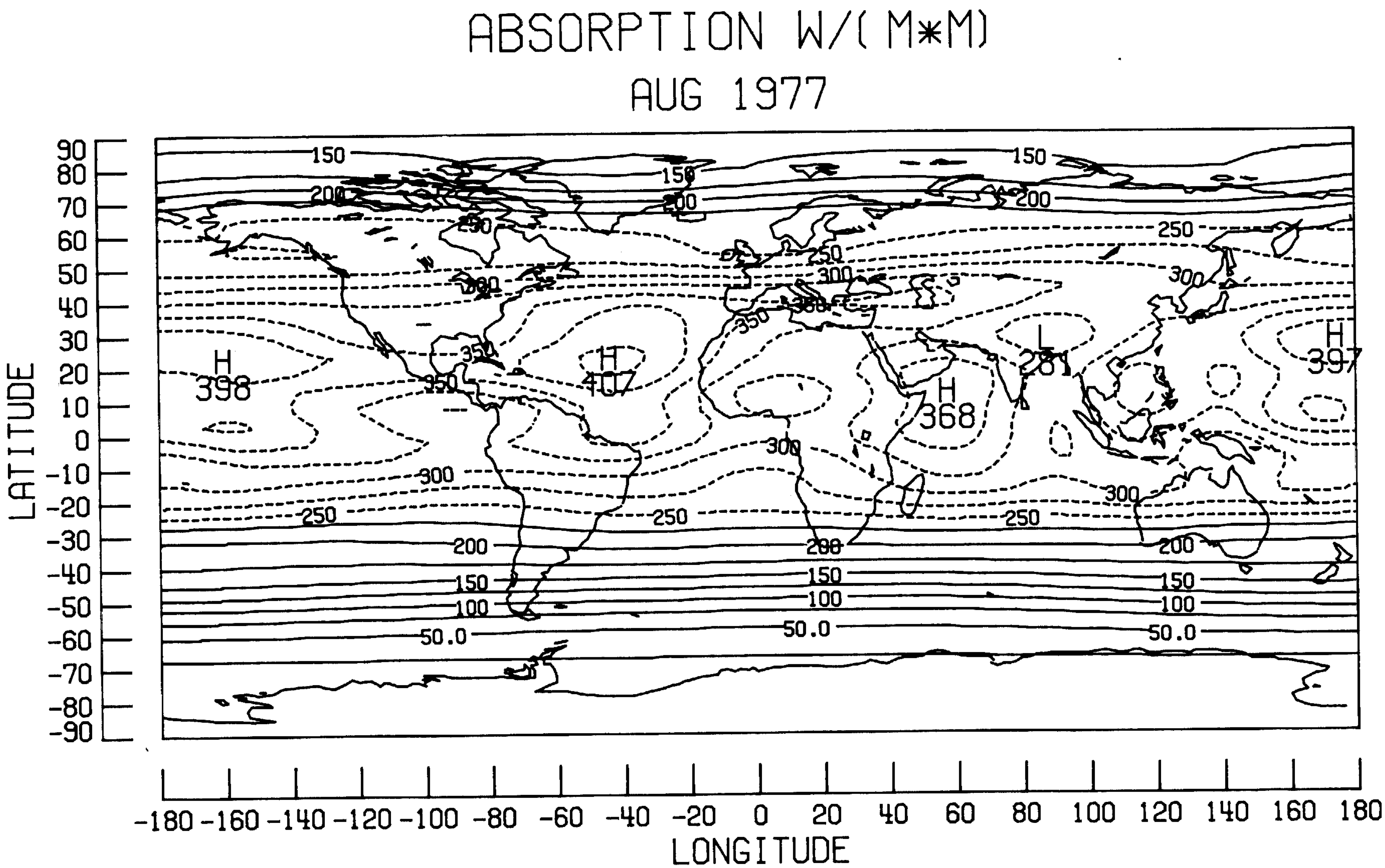
ABSORPTION W/(M*M)
JUL 1977

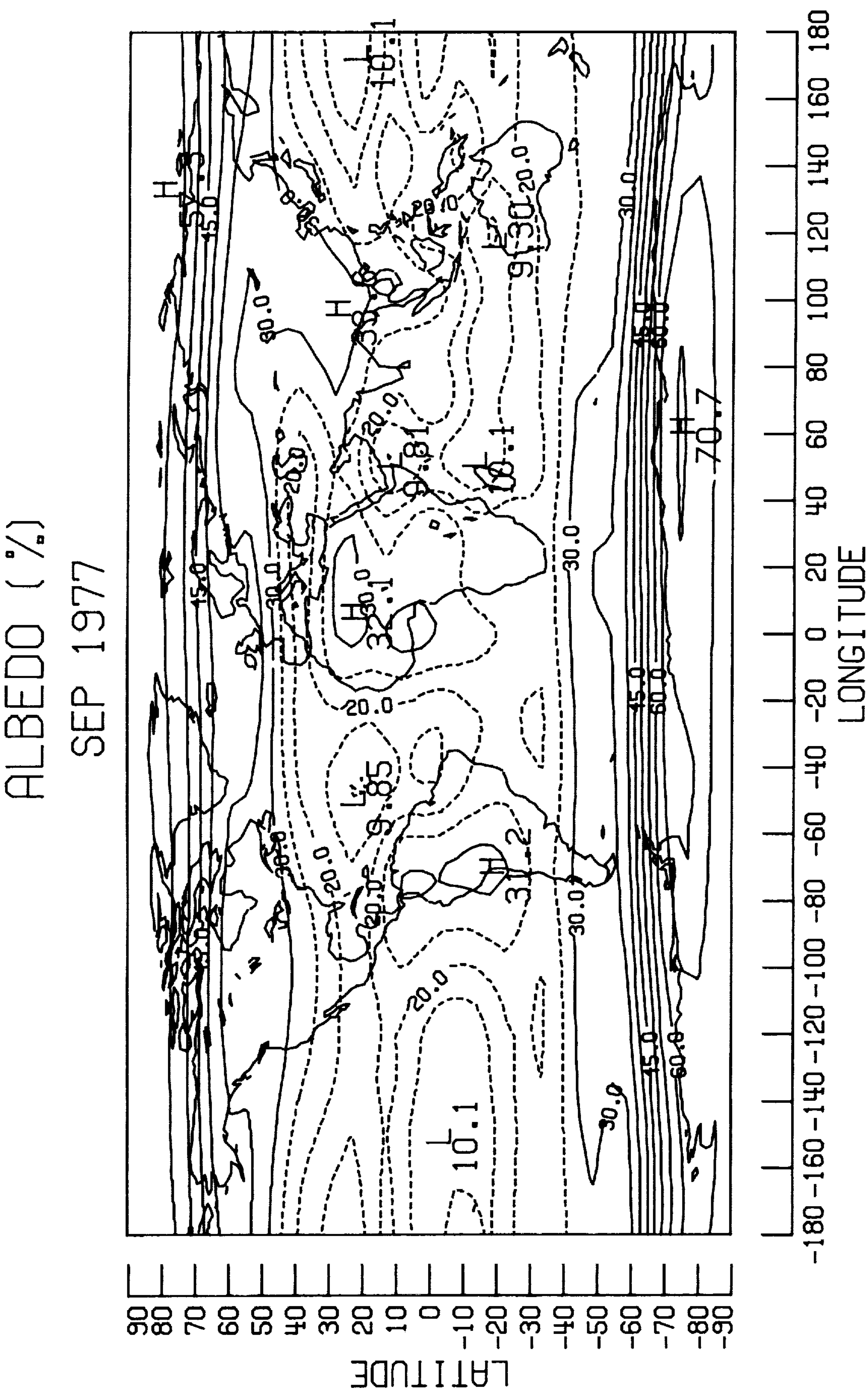


ALBEDO (%)

AUG 1977

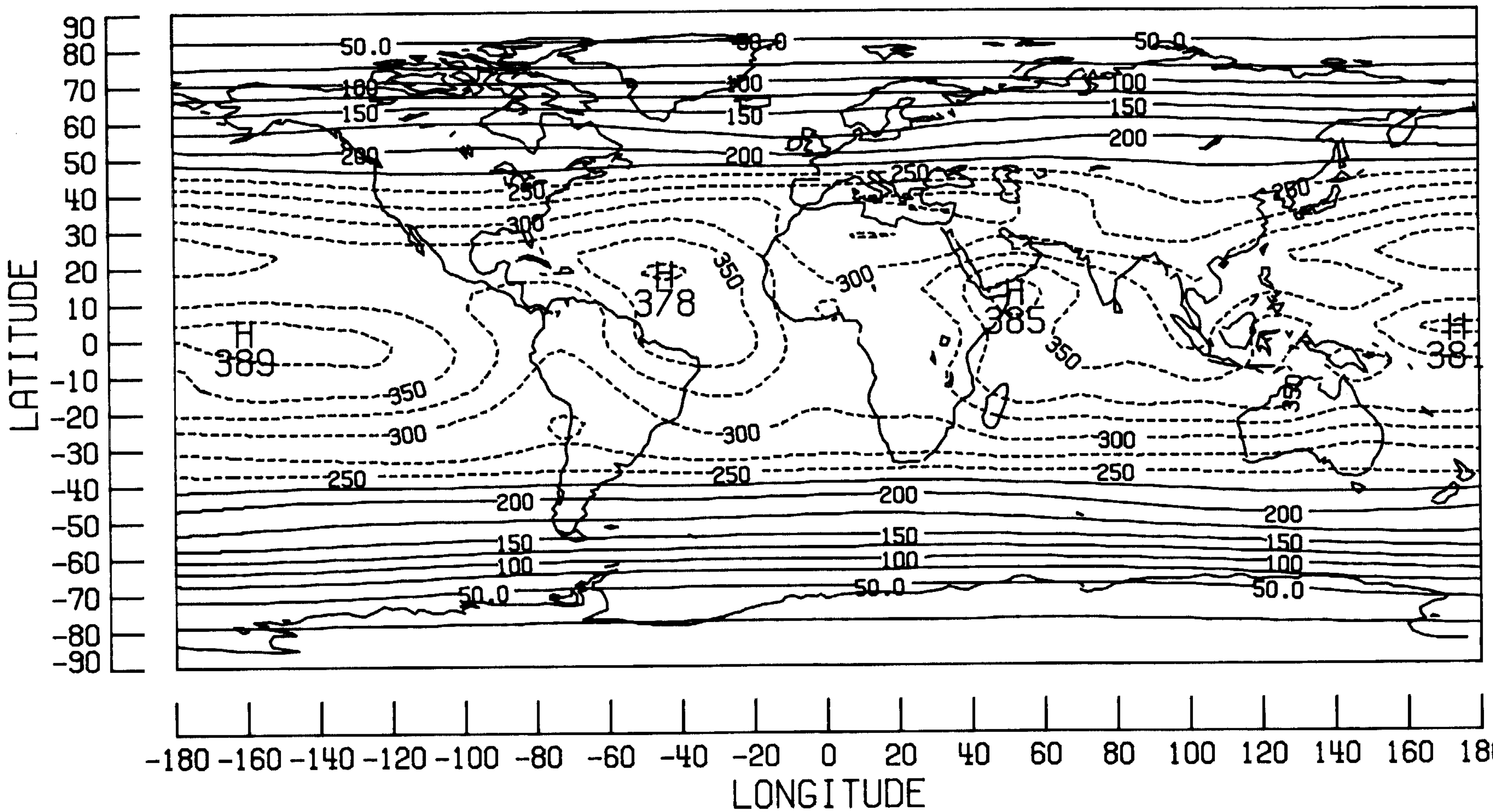


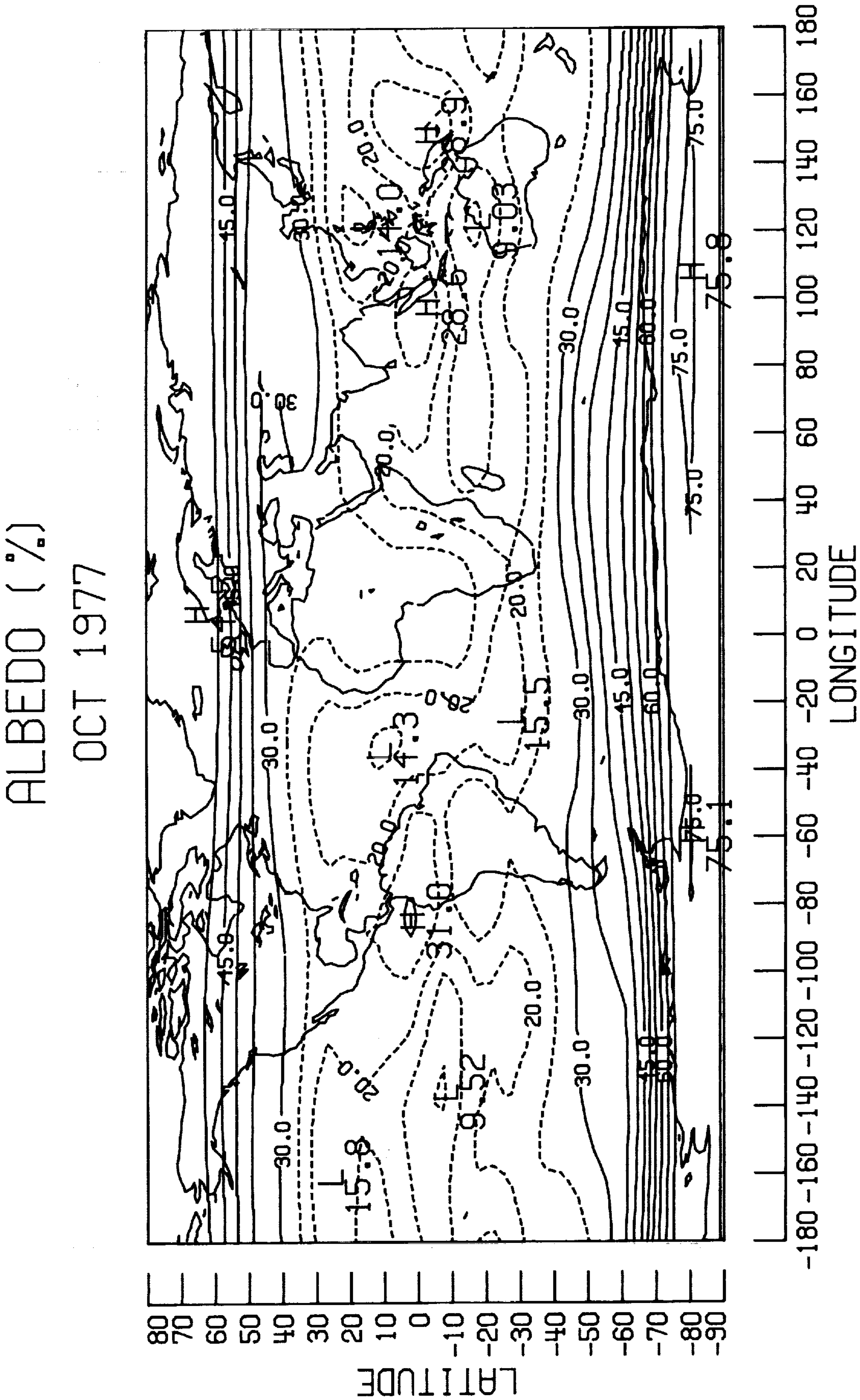

ABSORPTION W/(M*M)
AUG 1977
LATITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
LONGITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
150
200
250
300
350
H 398
H 407
H 368
L 281
H 397
100
50.0

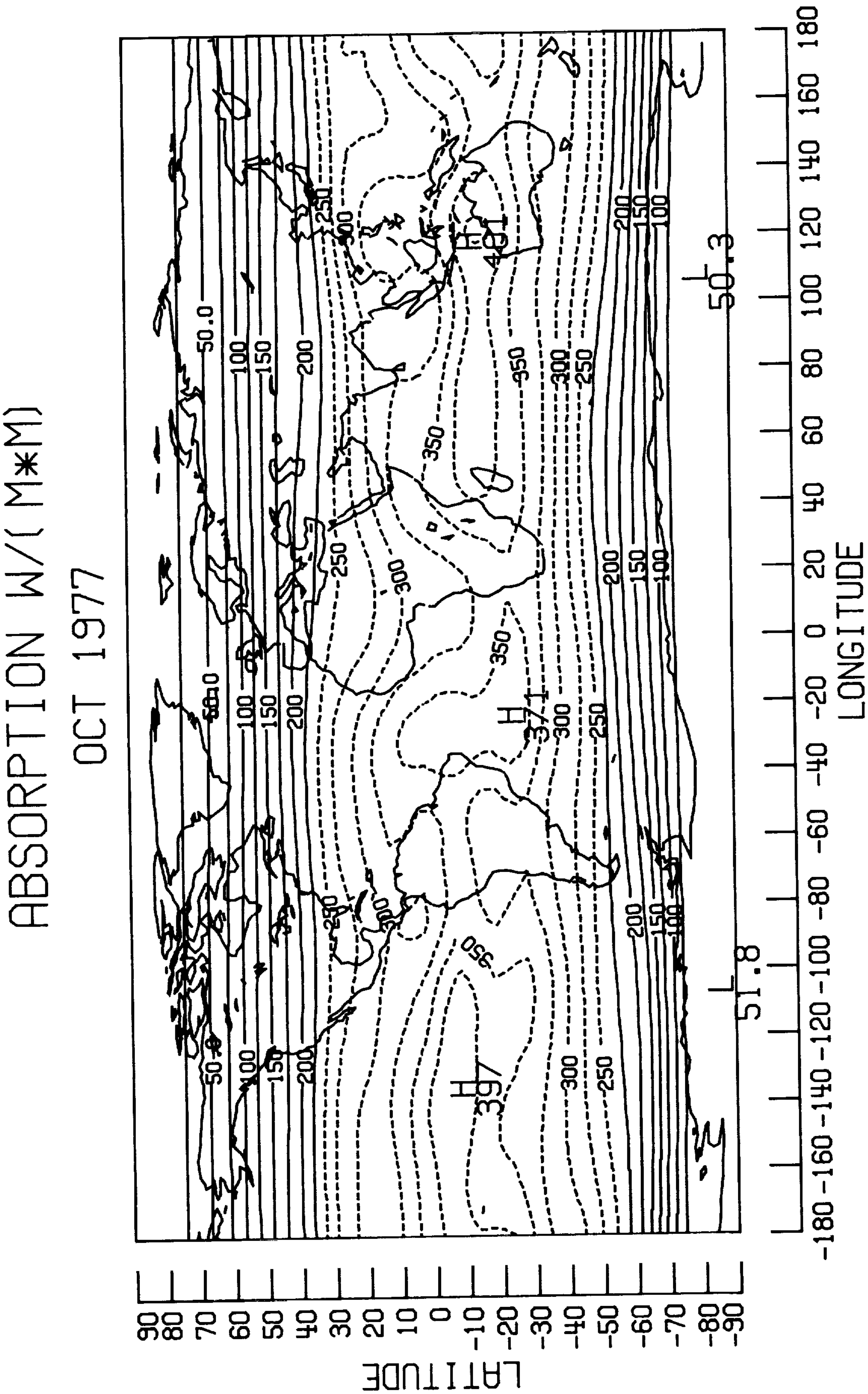

ALBEDO (%)
SEP 1977
LONGITUDE
LATITUDE

ABSORPTION W/(M*M)

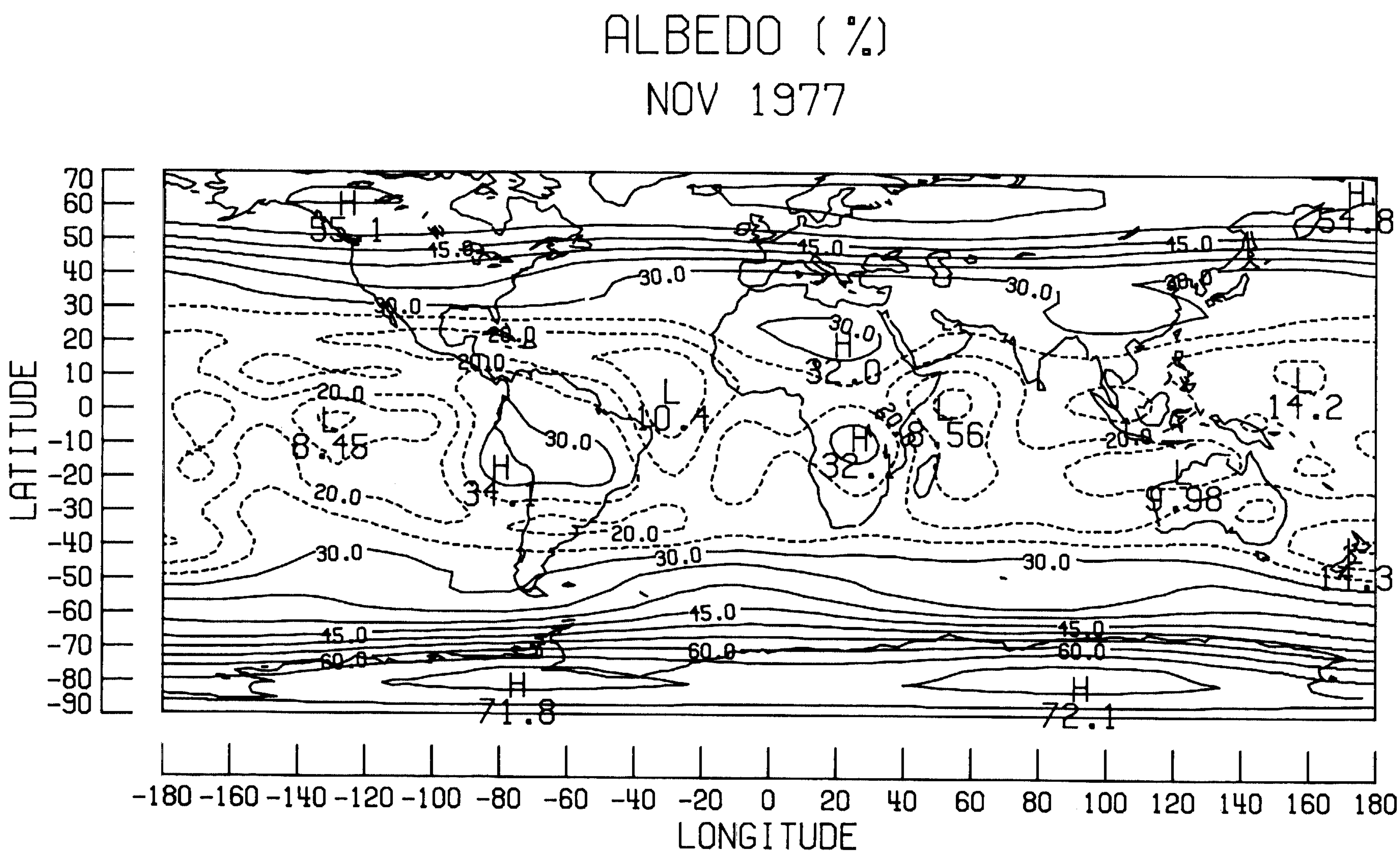
SEP 1977



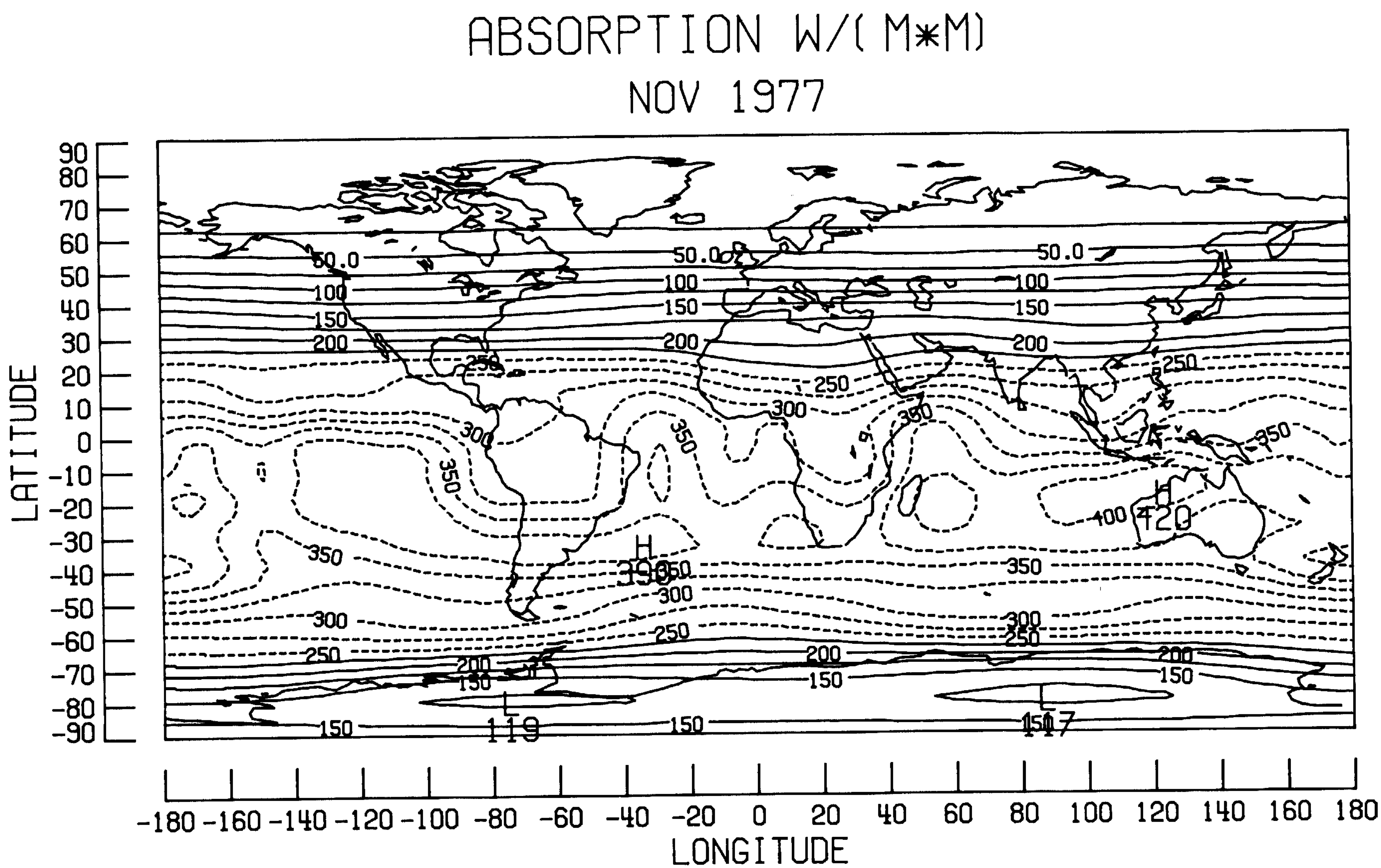

ALBEDO (%)
OCT 1977
LONGITUDE
LATITUDE

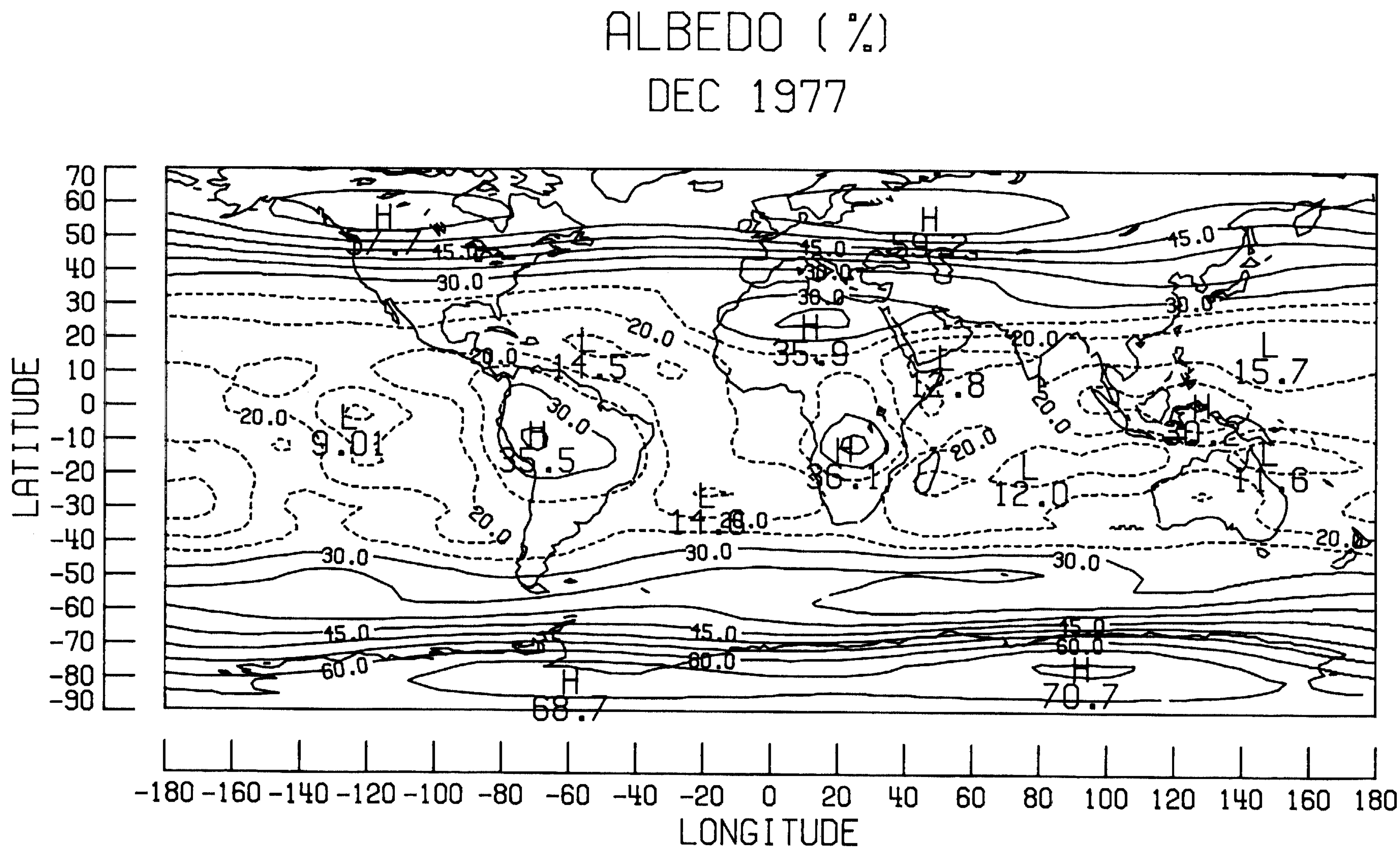


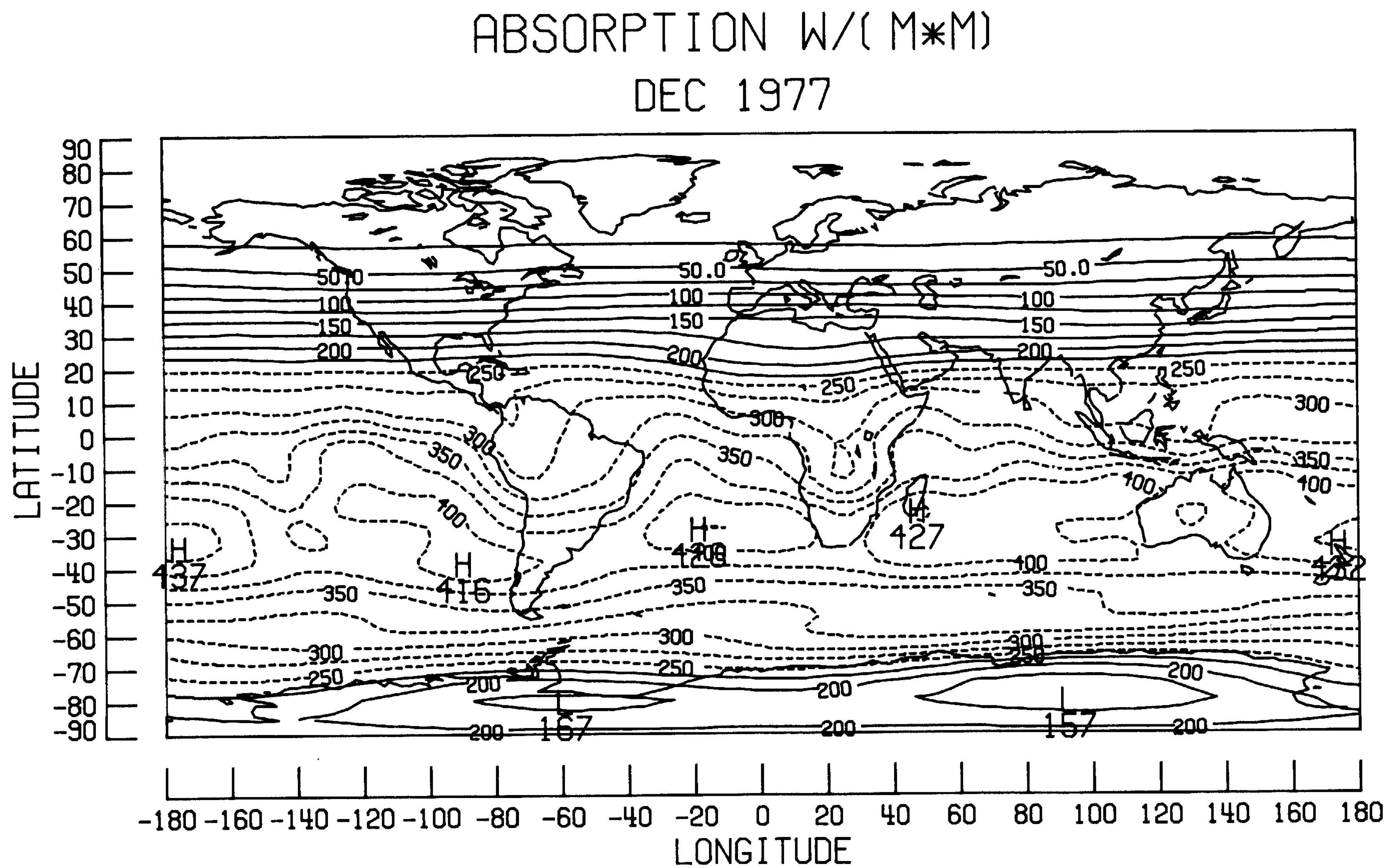
ABSORPTION W/(M*M)
OCT 1977
LONGITUDE
LATITUDE



ALBEDO (%)
NOV 1977
LATITUDE
LONGITUDE
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180

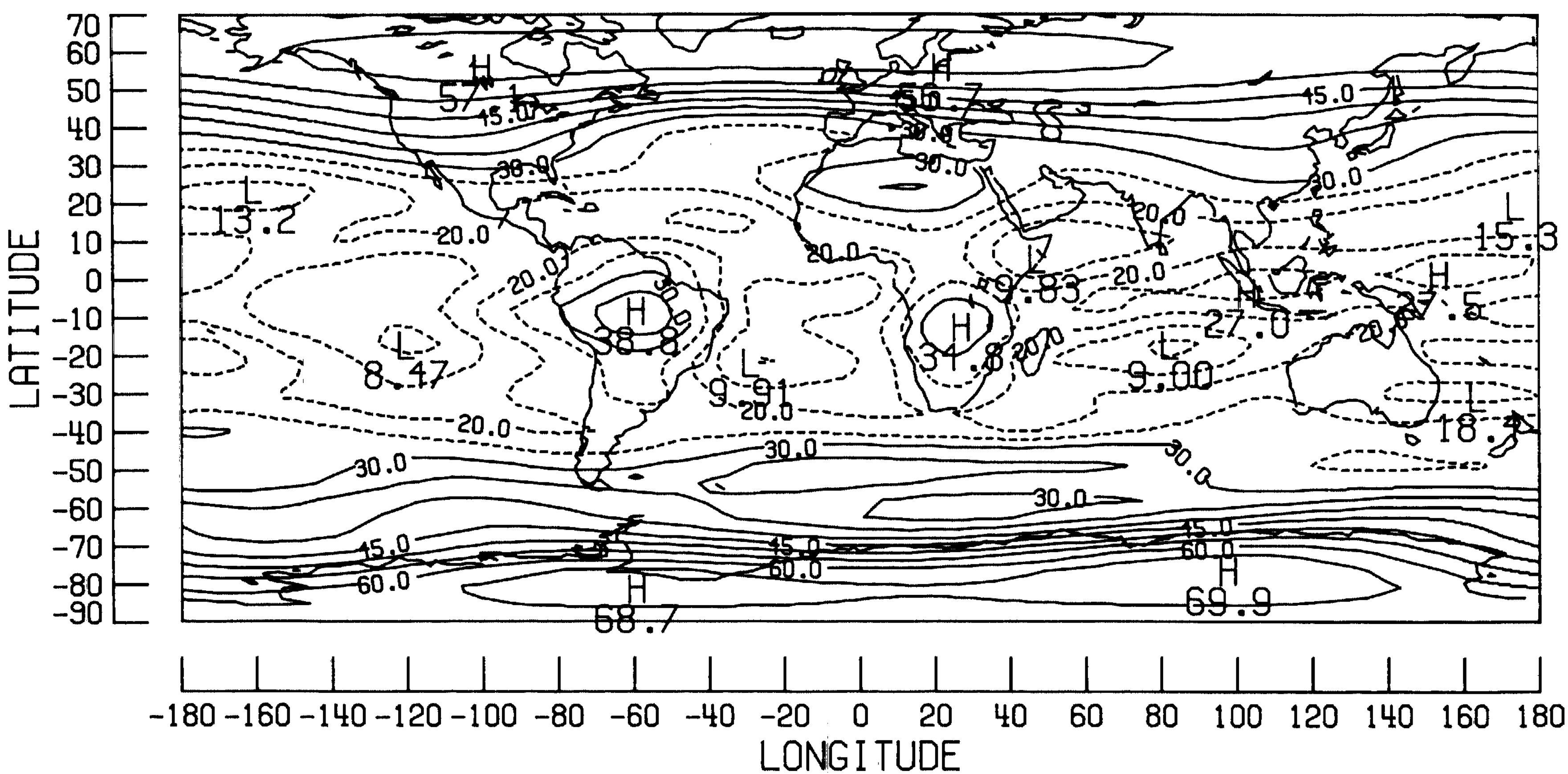

ABSORPTION W/(M*M)
NOV 1977
LATITUDE
LONGITUDE
H
390
H
420
L
119
L
117

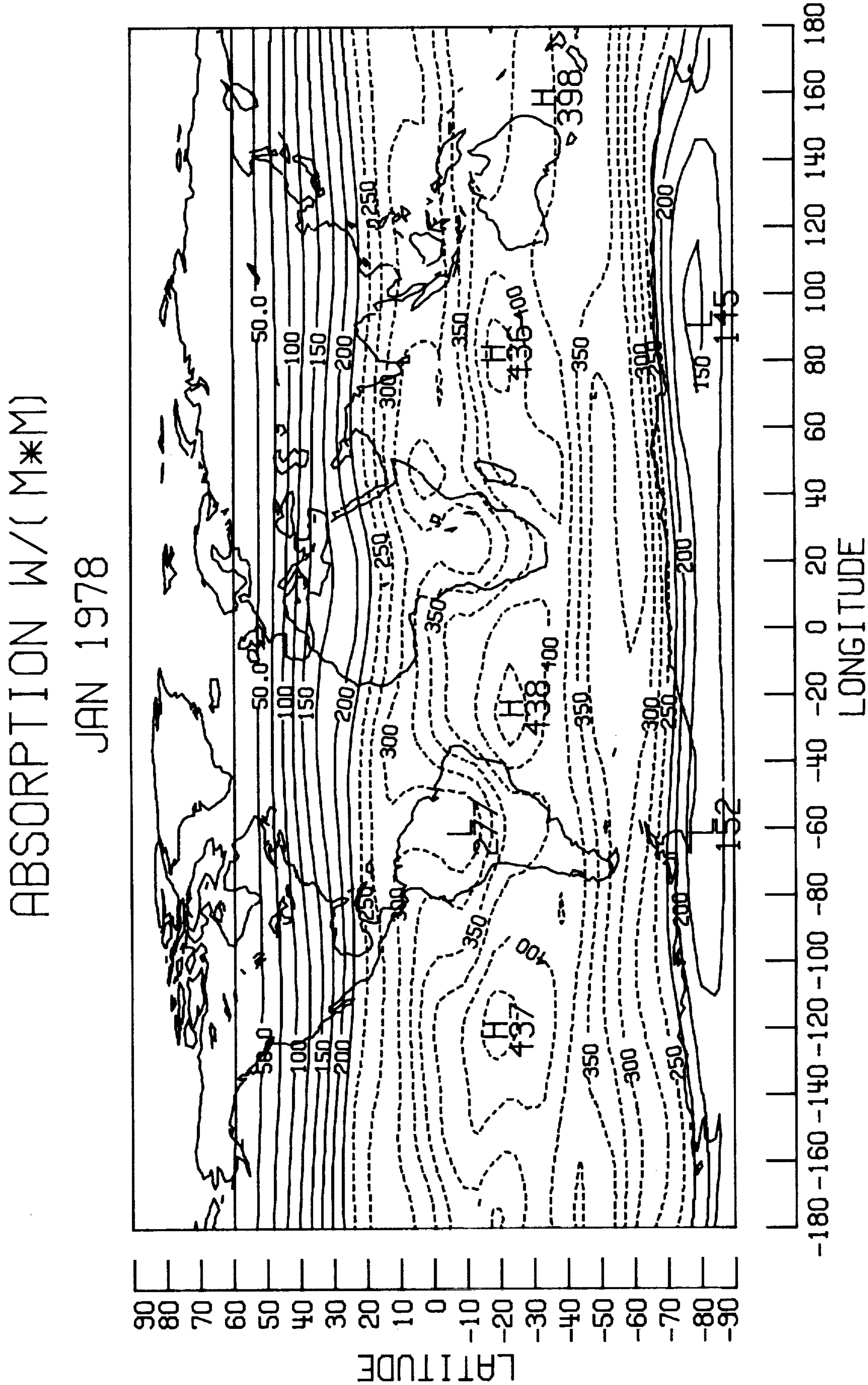

ALBEDO (%)
DEC 1977
LATITUDE
70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
LONGITUDE
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
15.0
30.0
20.0
60.0
H
L
14.5
9.01
35.5
35.9
36.1
12.0
15.7
68.7
70.7


ABSORPTION W/(M*M)
DEC 1977
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
437
H
416
H
427
L
167
L
157

ALBEDO (%)

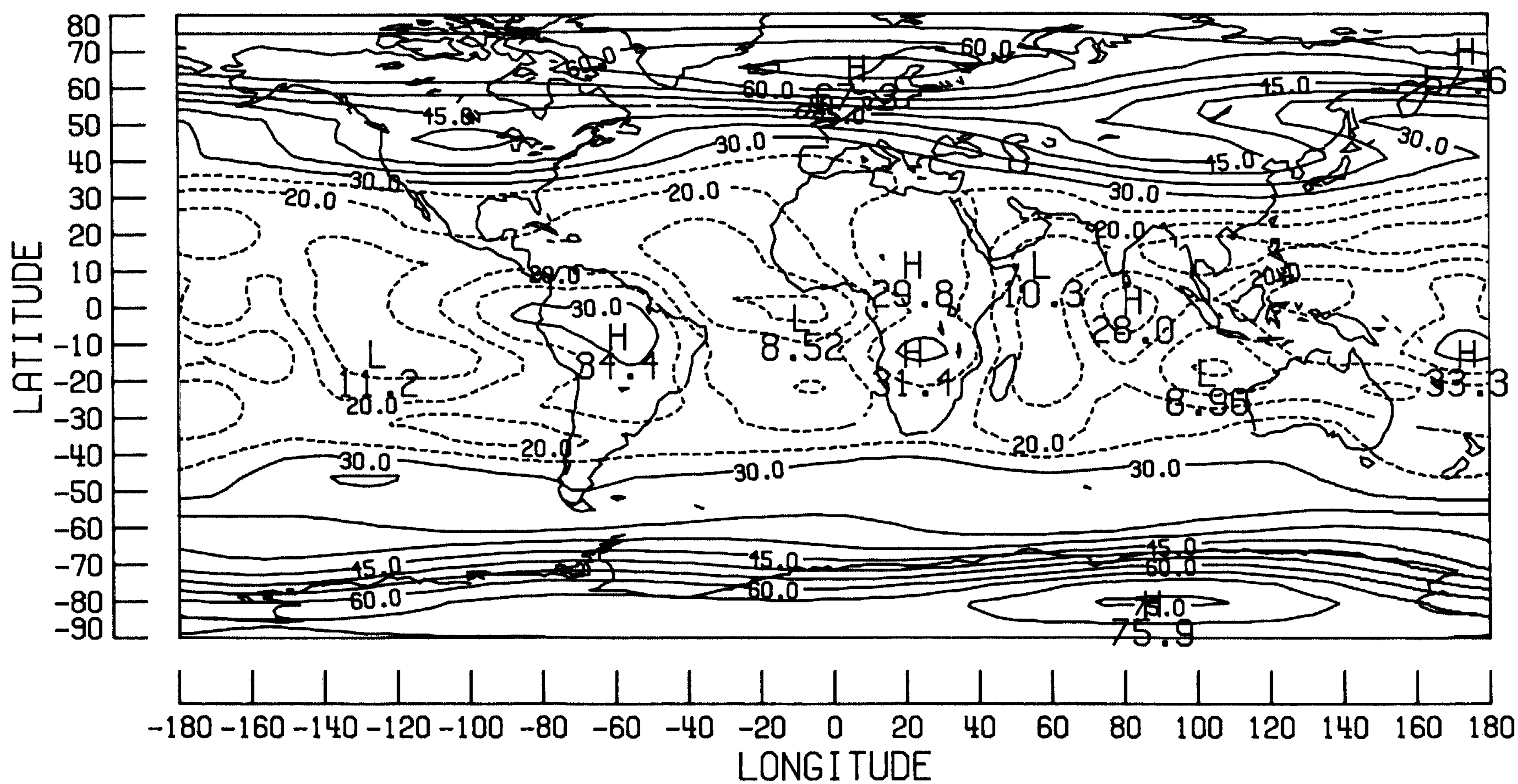
JAN 1978



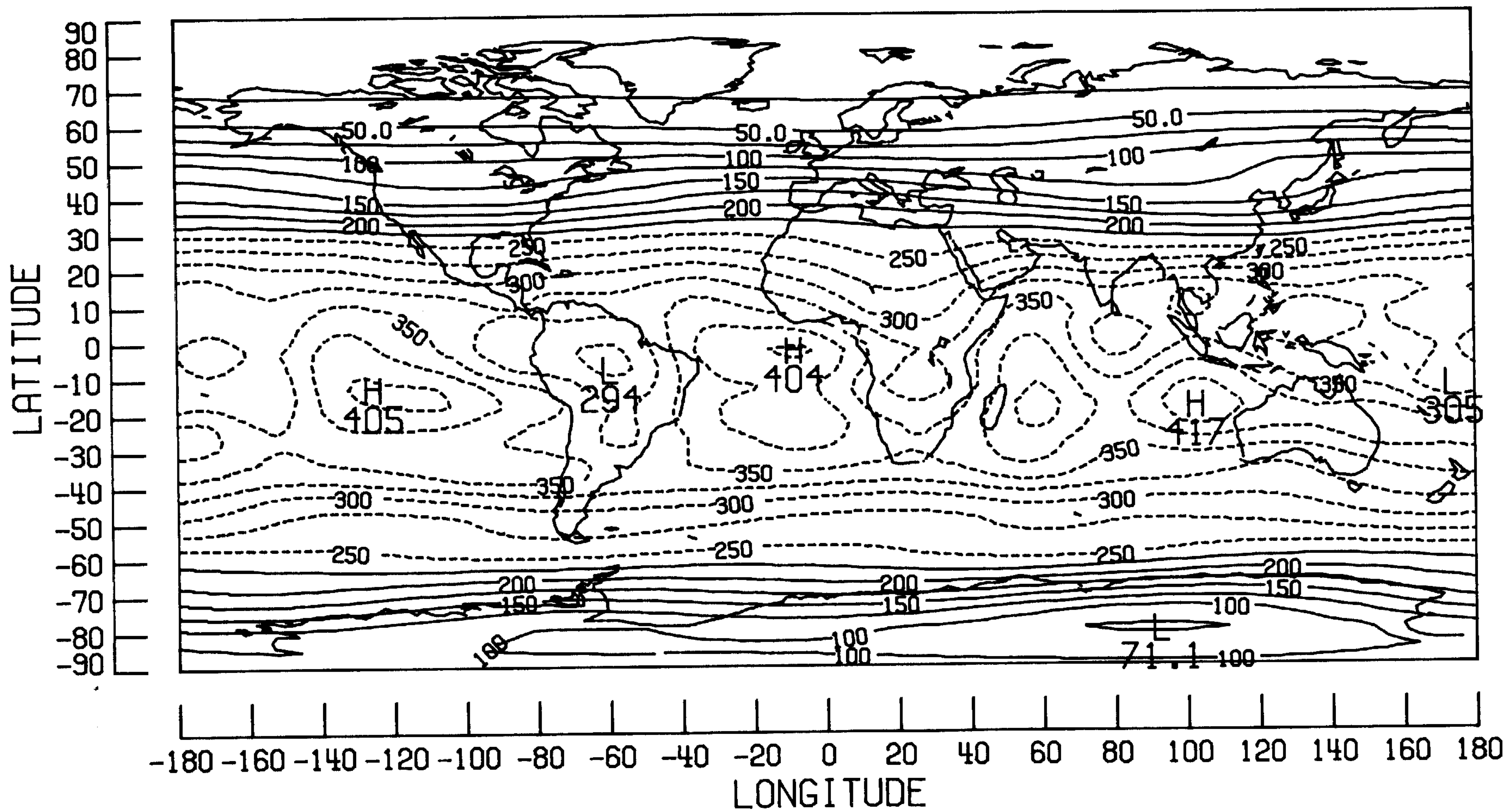

ABSORPTION W/(M*M)
JAN 1978
LONGITUDE
LATITUDE

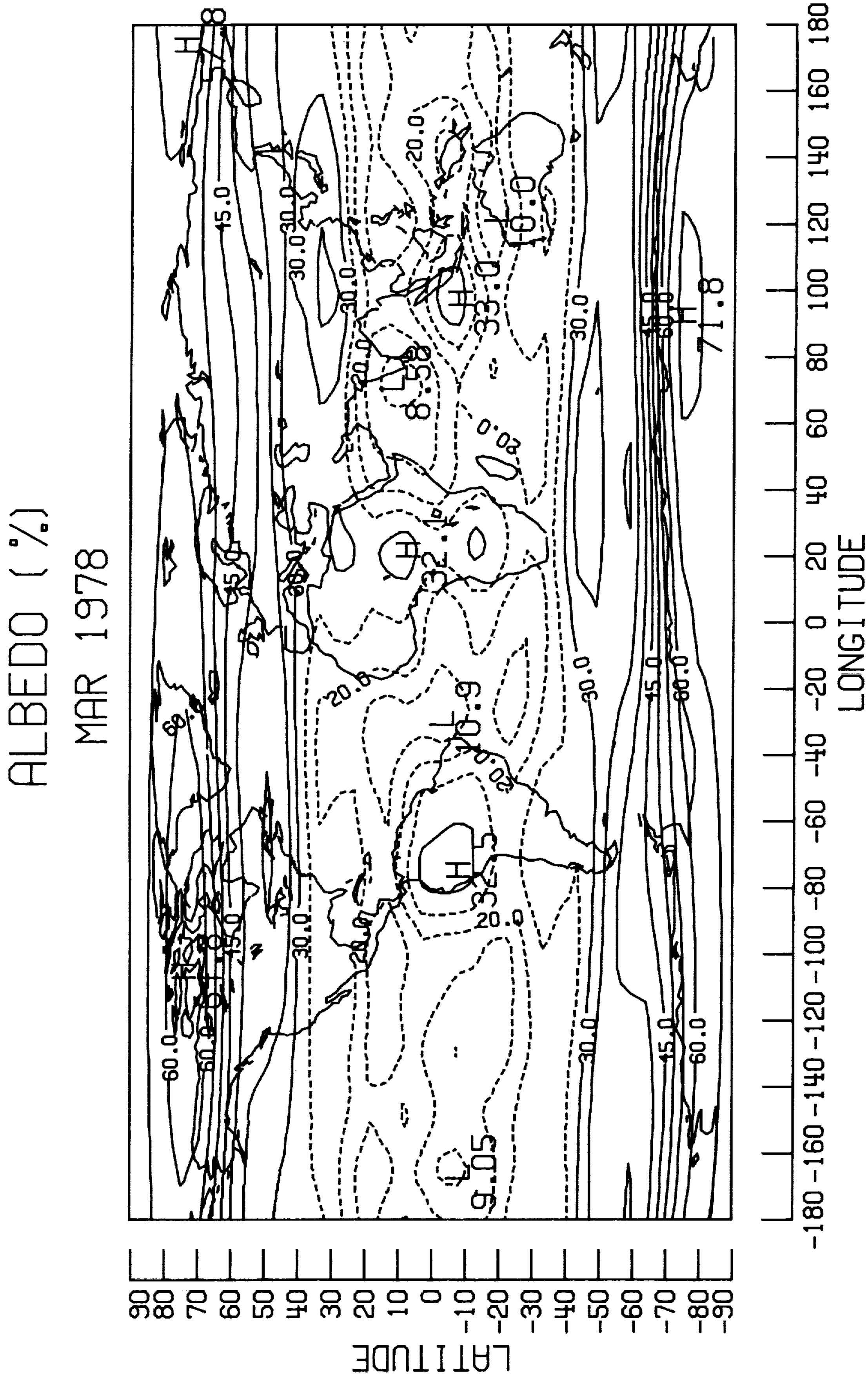
ALBEDO (%)

FEB 1978



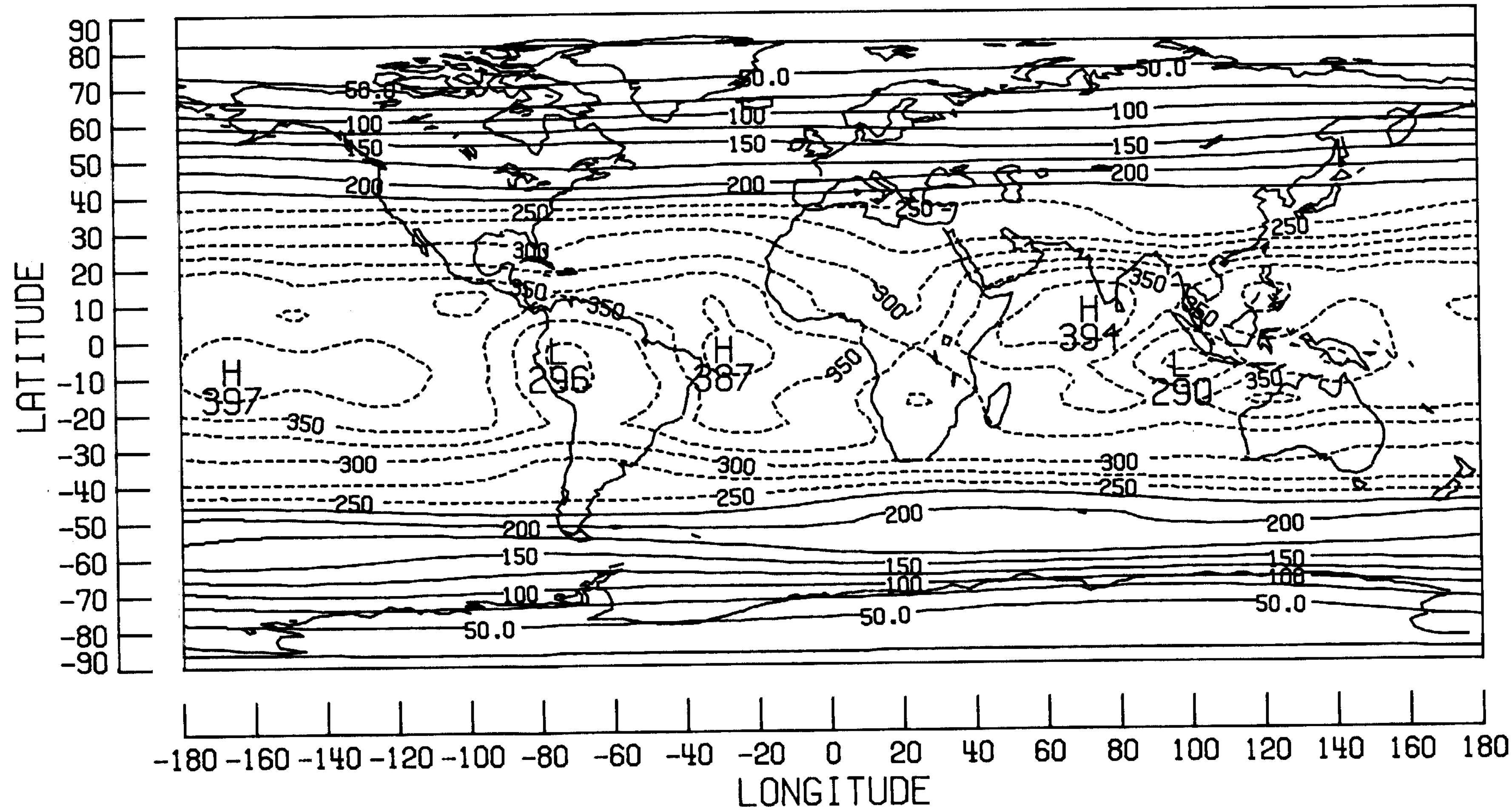
ABSORPTION W/(M*M)
FEB 1978

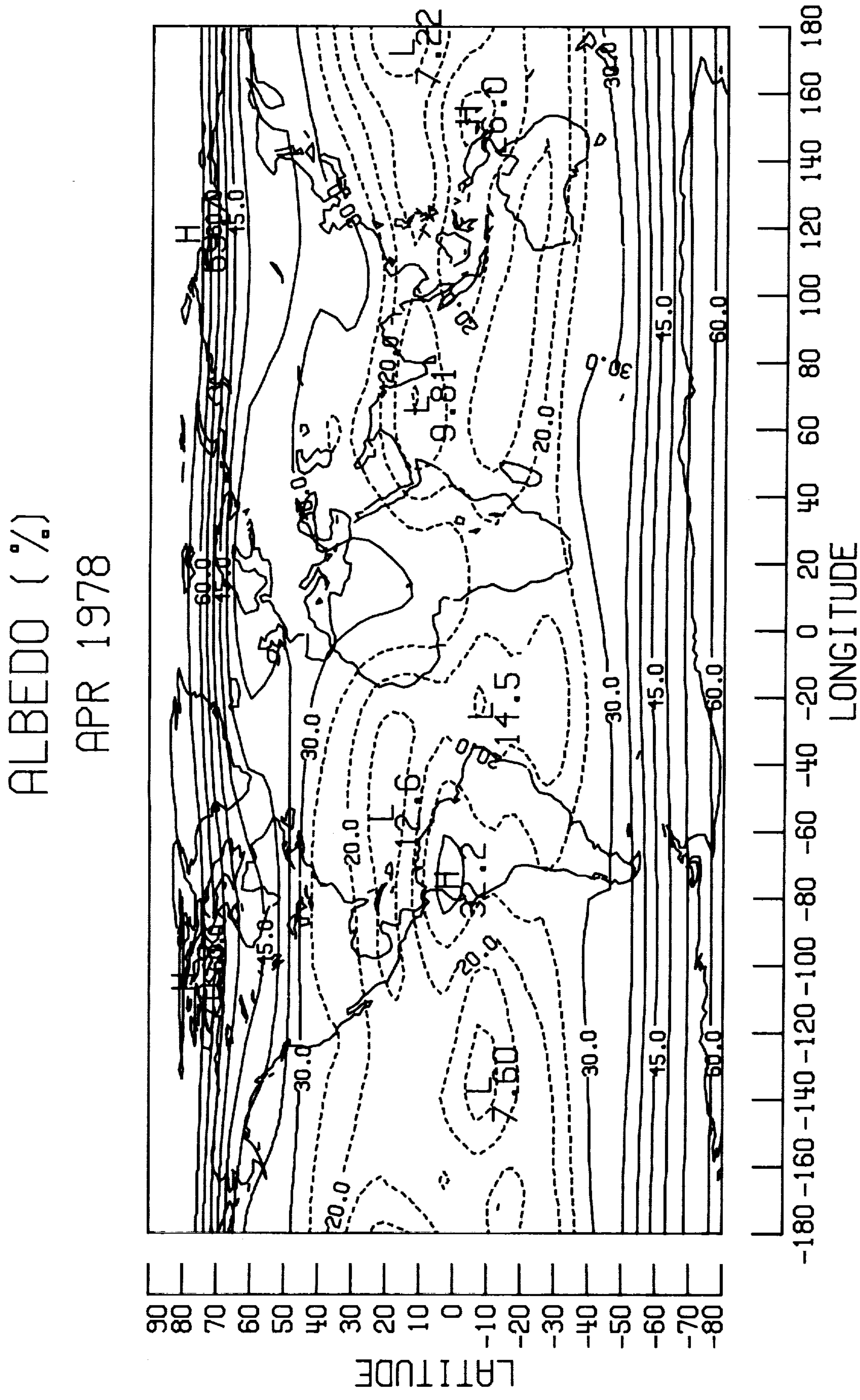


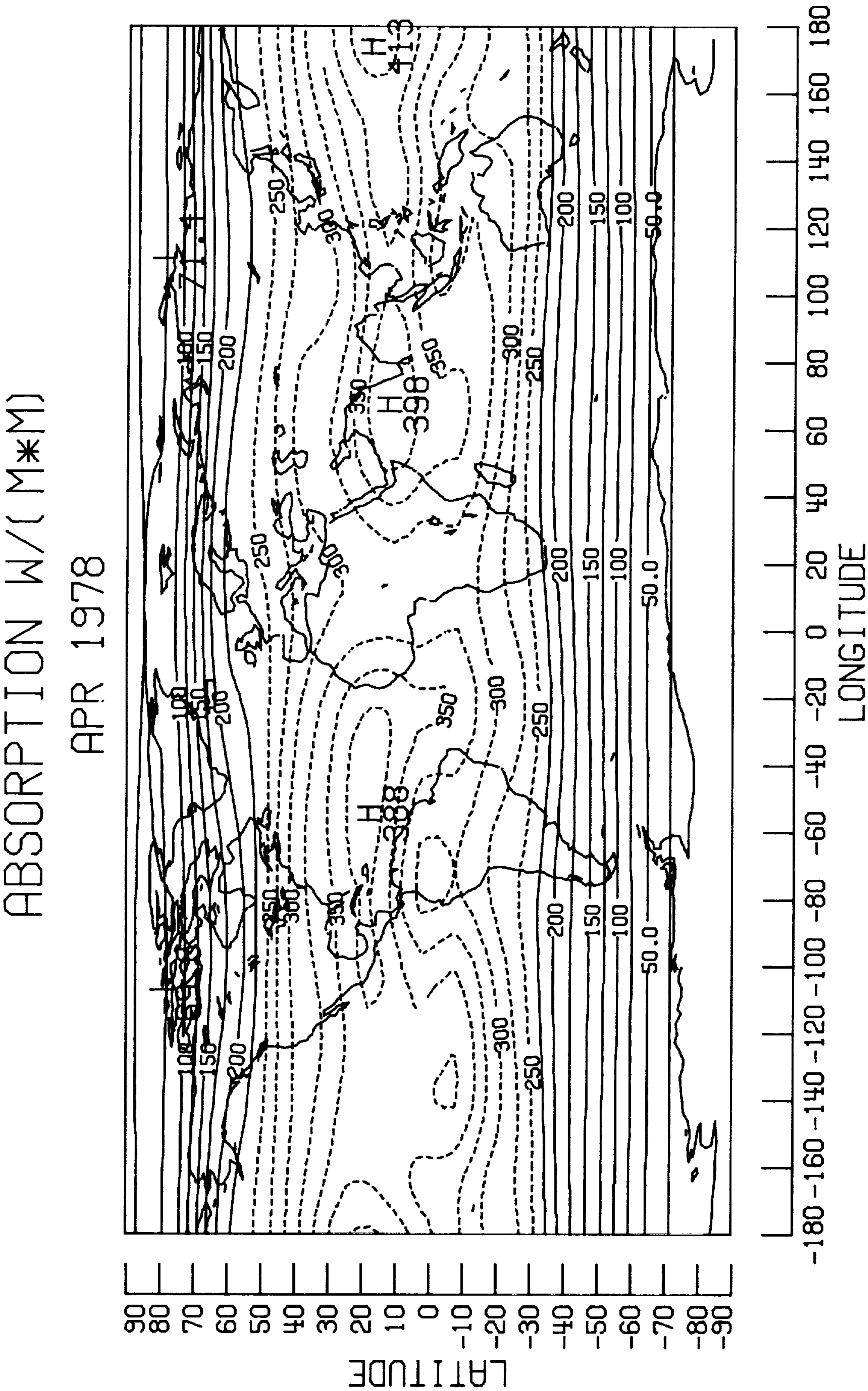

ALBEDO (%)
MAR 1978
LONGITUDE
LATITUDE

ABSORPTION W/(M*M)

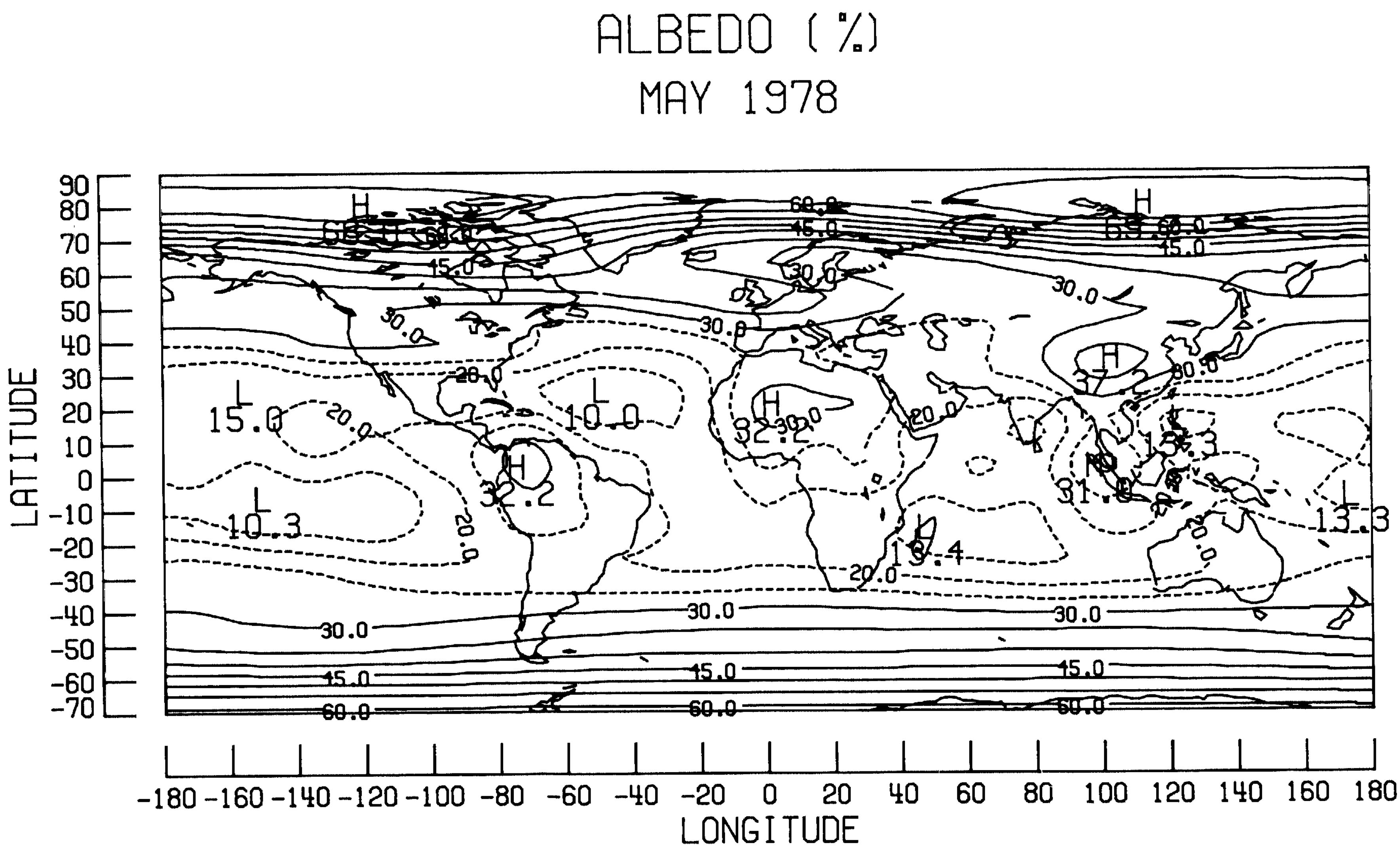
MAR 1978

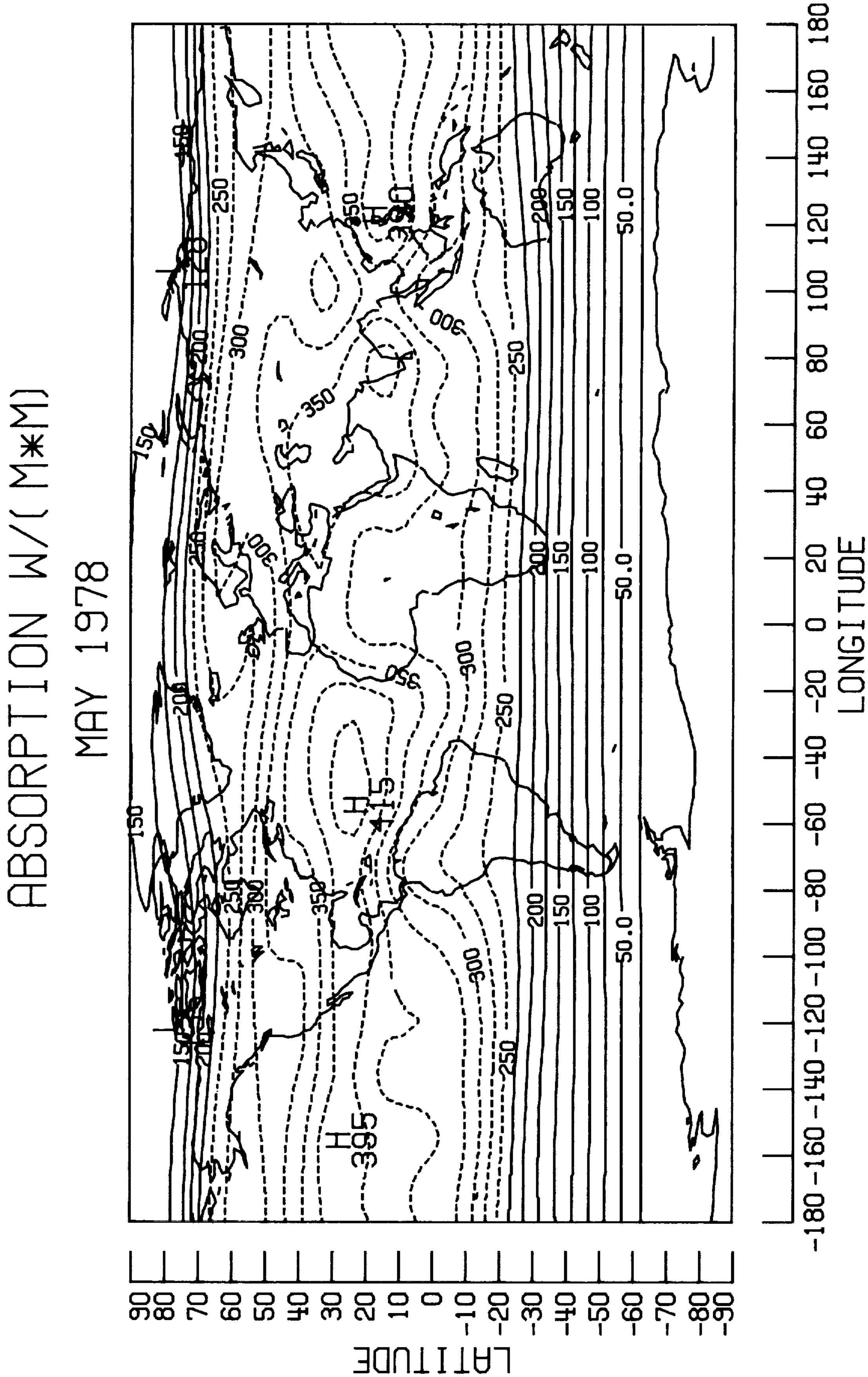



ALBEDO (%)
APR 1978
LATITUDE
LONGITUDE
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180



ABSORPTION W/(M*M)
APR 1978
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 -90
H 398
H 388
H 413


ALBEDO (%)
MAY 1978
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
15.0
10.3
10.0
32.2
30.0
20.0
45.0
60.0
13.4
31.8
13.3


ABSORPTION W/(M*M)
MAY 1978
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 -90
H
395
H
415
H
380
50.0
100
150
200
250
300
350

NASA National Aeronautics and Space Administration

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15. Supplementary Notes

G. Louis Smith and T. Dale Bess: Langley Research Center, Hampton, Virginia.
David Rutan: PRC Kentron, Inc., Aerospace Technologies Division, Hampton, Virginia.

Atlas of Nimbus 7 data for November 1978 to October 1985 is presented in NASA RP-1231, 1990.

16. Abstract

An atlas of monthly mean global contour maps of albedo and absorbed solar radiation is presented. The atlas is based on 35 months of continuous measurements from July 1975 to May 1978. The data were retrieved from measurements made by the shortwave wide-field-of-view radiometer of the first Earth radiation budget (ERB) instrument, which flew on the Nimbus 6 spacecraft in 1975. Profiles of zonal mean albedos and absorbed solar radiation are presented. These geographical distributions are provided as a resource for 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.

17. Key Words (Suggested by Authors(s)) Earth radiation budget Albedo Nimbus 6 Wide-field-of-view radiometer Shortwave radiation Satellite radiation measurements		18. Distribution Statement Unclassified—Unlimited Subject Category 47	
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