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# Atlas of Simultaneous Occurrence of Different Cloud Types over the Ocean

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cumulus implies cirrus) and downward-directed (e.g. cirrus implies cumulus) contingency probabilities should be reasonably accurate. Maps of these quantities, as well as of the overall frequency of occurrence of each cloud type, of fog, and of clear sky, are presented at 15° latitude × 30° longitude resolution. These contingency probabilities should be useful for testing cloud-generation algorithms in general circulation models and for interpretation of cloud observations from satellites.

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*Reprint Edition 1990: Maps 20 and 22 for all seasons have been revised as described in the data tape documentation which is available from the Carbon Dioxide Information Analysis Center (CDIAC, MS-050, Oak Ridge National Laboratory, Post Office Box 2008, Oak Ridge, TN 37831-6050; tel. 615-574-0390; request Numeric Data Package NCP-026).*

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LIST OF CLOUD MAPS

The maps are contained in four separate sections: December, January, February (DJF); March, April, May (MAM); June, July, August (JJA); September, October, November (SON). Map numbers are consecutive within each section.

	Map numbers			
	DJF	MAM	JJA	SON
Number of synoptic cloud reports, in hundreds	I-1	II-1	III-1	IV-1
Number of observations of cloud types present, in tens				
Cirrus, Cirrostratus, Cirrocumulus (Ci/Cs/Cc)	I-2	II-2	III-2	IV-2
Altostratus, Altocumulus (As/Ac)	I-3	II-3	III-3	IV-3
Nimbostratus (Ns)	I-4	II-4	III-4	IV-4
Cumulus (Cu)	I-5	II-5	III-5	IV-5
Stratus, Stratocumulus (St/Sc)	I-6	II-6	III-6	IV-6
Cumulonimbus	I-7	II-7	III-7	IV-7
Percent of ship reports contributing to statistics of upper cloud levels:				
High cloud level	I-8	II-8	III-8	IV-8
Middle cloud level	I-9	II-9	III-9	IV-9
Frequency of occurrence of:				
completely clear sky	I-10	II-10	III-10	IV-10
sky obscured due to fog	I-11	II-11	III-11	IV-11
different cloud types:				
Ci/Cs/Cc	I-12	II-12	III-12	IV-12
As/Ac	I-13	II-13	III-13	IV-13
Ns	I-14	II-14	III-14	IV-14
Cu	I-15	II-15	III-15	IV-15
St/Sc	I-16	II-16	III-16	IV-16
Cb	I-17	II-17	III-17	IV-17

Contingency probabilities of the co-occurrence of coupled cloud types:

Season	Given cloud type	Probability that these are also present						
		Ci/Cs/Cc	As/Ac	Ns	Cu	St/Sc	Cb	NO*
DJF	Ci/Cs/Cc		I-24	I-26	I-28	I-30	I-32	I-18
MAM			II-24	II-26	II-28	II-30	II-32	II-18
JJA			III-24	III-26	III-28	III-30	III-32	III-18
SON			IV-24	IV-26	IV-28	IV-30	IV-32	IV-18
DJF	As/Ac	I-25		I-34	I-36	I-38	I-40	I-19
MAM		II-25		II-34	II-36	II-38	II-40	II-19
JJA		III-25		III-34	III-36	III-38	III-40	III-19
SON		IV-25		IV-34	IV-36	IV-38	IV-40	IV-19
DJF	Ns	I-27	I-35		I-42	I-44	I-46	I-20
MAM		II-27	II-35		II-42	II-44	II-46	II-20
JJA		III-27	III-35		III-42	III-44	III-46	III-20
SON		IV-27	IV-35		IV-42	IV-44	IV-46	IV-20
DJF	Cu	I-29	I-37	I-43				I-21
MAM		II-29	II-37	II-43				II-21
JJA		III-29	III-37	III-43				III-21
SON		IV-29	IV-37	IV-43				IV-21
DJF	St/Sc	I-31	I-39	I-45				I-22
MAM		II-31	II-39	II-45				II-22
JJA		III-31	III-39	III-45				III-22
SON		IV-31	IV-39	IV-45				IV-22
DJF	Cb	I-33	I-41	I-47				I-23
MAM		II-33	II-41	II-47				II-23
JJA		III-33	III-41	III-47				III-23
SON		IV-33	IV-41	IV-47				IV-23

\*NO = No Other Cloud

## 1. Introduction

It is a matter of synoptic experience that some types of clouds tend to appear together and other types tend to be somewhat mutually exclusive. The documentation of such information would be of importance in general circulation models involving cloud generation and in the detection of different cloud distributions from satellites. The problem of reporting cloud co-occurrences, however, is complicated by the fact that clouds occurring at the same time but at different levels in the atmosphere often overlap and thus are often hidden in line-of-sight observations either from the ground or from satellites.

Overall determination of the average co-occurrence of different cloud types can best be made from analysis of ground-based cloud observations. Although these have some shortcomings, to be discussed later, the principal advantages of ground-based observations (as opposed to satellite observations) are that they cover a time period of many years with unchanging reporting procedures and that ground observers can usually see individual clouds and can thus readily identify clouds by type. Satellite observations offer the potential for much greater temporal and geographical coverage of the earth, and satellites measure the cloud properties most relevant to the earth radiation budget. However, satellite cloud *type* identification is still in a state of development, especially regarding the detection of clouds smaller than the satellite's resolution, which is typically a few km (Coakley and Bretherton, 1982).

This report is one aspect of a larger project on the intercomparison of satellite and ground-based cloud observations (cf. Warren *et al.*, 1981) and on the geographical, seasonal, interannual and diurnal variation of

cloud amounts by type (in preparation). It is restricted to the analysis of surface synoptic reports from ships and covers most of the ocean area of the earth. Maps are presented which show the contingency probabilities of 6 cloud types (defined below) as well as the frequency of occurrence of each cloud type, of fog and of clear sky for the 4 meteorological seasons (DJF, MAM, JJA and SON). This atlas does not contain any information about cloud *amounts*.

The study required some decisions about the classification of cloud types and the choice of spatial and temporal resolution that would still result in representative values. These choices were motivated not only by meteorological judgment but also by the availability of sufficient numbers of ship observations. The basic study of cloud amounts referred to above has a 5° x 5° latitude/longitude resolution. However, sufficient ship observations were not available to construct an adequate contingency probability table at this resolution and a larger grid size was selected. Results are reported here for boxes of 15° x 30° ; map contours are based on one number in boxes of this size. Many of these boxes contain some land areas, but the values reported are *only for the ocean part of each box*. Similarly, the zonal average values tabulated in the atlas apply only to the ocean part of each latitude zone. The 15° latitude boundaries conveniently divide the globe into tropical, subtropical, lower midlatitude, upper midlatitude, and subpolar zones. Because the data source contains observations limited to the region 80°N - 70°S, the northernmost and southernmost zones are not 15° wide but cover instead the latitude intervals 60°-80°N and 60°-70°S, respectively. The 30° longitude spacing, beginning at Greenwich, generally separates the

eastern and western coastal oceans from the central ocean areas, in all oceans.

In this study individual contingency probabilities,  $P(A \Rightarrow B)$ , are computed, by which is meant: given type A, the probability that type B also occurs, where B can also be "no other" for the case that A occurs alone. In order for the probability values to be statistically meaningful, it is necessary that at least a certain minimum number of reports contribute to the computation of each value. A minimum number was selected that would be large enough to lead to a fairly smooth geographical variation of the probabilities (which suggests statistical reliability of individual probabilities) yet small enough so as not to unduly restrict coverage. *To compute  $P(A \Rightarrow B)$  it was required that of the times that A was present, it was possible in at least 50 individual synoptic reports to see whether B was also present.* (Further details and restrictions are described in Sec. 4e below). In general, the Northern Hemisphere oceans were very well sampled. The worst sampling was in the Antarctic Ocean during JJA and the ocean between Chile and New Zealand in all seasons.

It should be noted that the information contained in the contingency probability maps given in this report apply to an area the size of the ground observer's field of view, perhaps 20 km radius. All probabilities of the coexistence of different cloud types would of course be higher if expressed for a larger field of view but they would then be less representative of an individual meteorological condition.

## 2. Data Source

Twelve years of synoptic reports (1965-1976) from ships (about ten million total observations) were analyzed. These were the twelve best-sampled years in the Consolidated Data Set (Caton, 1978) of the U.S. Navy Fleet Numerical Oceanographic Center (FNOC) which is available on magnetic tapes from FNOC in Monterey, California.

Synoptic reports from ships are generally made every 6 hours: at 0, 6, 12, 18 GMT. From an analysis of the average frequency of cloud reports over the 24-hour period, no significant tendency for fewer observations at night was found. The analysis in this atlas does not cover diurnal variations of the co-occurrence probabilities. But, since there is essentially no diurnal sampling bias, the results should represent the daily mean, although a possible underestimate of cirrus by nighttime observers has been suggested (Riehl, 1947).

Over most of the ocean, there are insufficient observations to study details of the interannual variability of co-occurrence probabilities. Therefore, all observations are weighted equally in the analysis, irrespective of year. A 6 year subset of the twelve years was also analyzed and showed differences generally less than 0.01 from the 12-year set, but occasionally as large as 0.04 in the individual contingency probabilities. Differences in zonal averages were all smaller than 0.01. Spot checks of individual years in a few well-sampled boxes also showed interannual variations generally of a few percent or less.

### **3. Observer bias and fair-weather bias**

Cloud observations from transient ships are subject to biases due to the use of untrained observers (observer bias) and the possible attempt of ships to avoid storms (fair-weather bias). These biases have been discussed by Bunker (1976) and Quayle (1980), who compared observations from transient ships to those of nearby weatherships. We have taken the data source described by Quayle (1980) and determined the bias in total cloud amount, finding that cloud cover reports of stationary weatherships on average exceed those of nearby transient ships by about 2%. Only certain types of bias can affect the *co-occurrence* probabilities. The kind of *fair-weather bias* that could affect these results is a tendency of ships to avoid areas where certain combinations of clouds may be present. The kinds of *observer bias* that could affect the results are misclassification of cloud types and neglect to report a type that is present. This neglect sometimes occurs with thin Cs: a transient ship may report clear sky while a nearby weathership reports overcast Cs. It is difficult to quantify the effect that these biases could have on the computed contingency probabilities, because the data source available for estimating them (*simultaneous* observations by weatherships and nearby transients) is rather small. No attempt was made to correct for any of these biases when producing the maps.

### **4. Method of analysis**

Synoptic weather reports were read and decoded from the Fleet Numerical Oceanographic Center Consolidated Data Set for Dec. 1964 through Nov. 1976. (Dec. 1964 is included in the season "DJF 1965", for

example). These data contain reports made from ships between latitudes 80°N and 70°S. Each report contains coded information concerning total cloud amount (N), low cloud type (C<sub>L</sub>), middle cloud type (C<sub>M</sub>), high cloud type (C<sub>H</sub>), present weather (ww), and lower cloud amount. If information was lacking in a particular category, a slash was recorded by the observer. *In this discussion, a cloud type is either "reported present," "reported absent," or "unreported." "Unreported" means coded with a slash.*

*a. Assignment of cloud type categories*

The six cloud types chosen for the study include one high group, cirrus + cirrostratus + cirrocumulus (Ci/Cs/Cc); one middle-level group, altostratus + altocumulus (As/Ac); and four whose bases are lower than about 2 km: nimbostratus (Ns), cumulus (Cu), stratus + stratocumulus (St/Sc), and cumulonimbus (Cb). This grouping is partly motivated by the ground observer's more detailed recognition of the clouds closest to the ground. It is the same classification adopted by McDonald (1938), Telegadas and London (1954) and the International Satellite Cloud Climatology Project (WMO, 1980). This classification is somewhat arbitrary, and other classifications can be imagined. Grouping of the 27 types of the synoptic code (WMO, 1956) into these six types is given in Table I. (Henceforth in the text abbreviated notation is used, referring to the six types as Ci, As, Ns, Cu, St, Cb, and to "no other" as NO).

It should be noted that there is no single observer code which always means nimbostratus (Ns), but there are four codes each of which could possibly mean Ns (see Table 1). Therefore, when one of these four codes appeared, the present weather (ww) code (WMO, 1974) of the

**Table I.**

**Grouping of cloud types**

cloud types used in this paper	shorthand notation	observer codes included in each type <sup>1</sup>
Ci/Cs/Cc	Ci	C <sub>H</sub> 1-9
As/Ac	As	C <sub>M</sub> 1,3,4,5,6,8,9; C <sub>M</sub> 2,7 if not precipitating <sup>3</sup>
Ns <sup>2</sup>	Ns	If (precipitating) <sup>3</sup> and (C <sub>M</sub> 2,7 or C <sub>L</sub> 6,7)
Cu	Cu	C <sub>L</sub> 1,2
St/Sc <sup>4</sup>	St	C <sub>L</sub> 4,5,8; C <sub>L</sub> 6,7 if not precipitating <sup>3</sup> or if C <sub>M</sub> = 2,7
Cb <sup>5</sup>	Cb	C <sub>L</sub> 3,9

<sup>1</sup>C<sub>H</sub> = high cloud type; C<sub>M</sub> = middle cloud type; C<sub>L</sub> = low cloud type. The numbering scheme is defined in WMO (1956).

N=0 (clear) counts as a synoptic cloud report and is used in computing frequency of occurrence of cloud types but is not used in computation of contingency probabilities.

<sup>2</sup>Ns is also considered to be present when the cloud reports indicate "sky obscured" due to rain or snow (present weather code ww 50-89). If the report has both (C<sub>M</sub> = 2 or 7) *and* (C<sub>L</sub> = 6 or 7) with precipitation, this is counted as a co-occurrence of Ns with St. The present weather codes are defined in WMO (1974).

<sup>3</sup>"Precipitating" means present weather code 50-89.

<sup>4</sup>reports of "sky obscured due to fog" are excluded in the co-occurrence statistics (see text).

<sup>5</sup>Cb is also considered to be present when the cloud report indicates "sky obscured" and the present weather code is 90-99. This combination (which is quite rare) normally indicates a thunderstorm.

observation was checked, and it was required that rain or snow be occurring at the time of observation at the observer's location in order to designate that cloud as Ns. This means that Ns can only be reported present when it is directly above the observer. Also, it often happens that cloud types are unreported in the synoptic observation when the sky is "obscured" (N=9). In those cases the ww code was checked to find the reason for the obscuration. If the obscuration was due to rain or snow, the cloud was specified as Ns. These cases amounted to about 15% of all the Ns occurrences, so that a failure to take them into account would have resulted in a significant underestimate of the occurrence of Ns in some geographical regions. The sky is obscured due to fog in about 2% of all observations, and these observations were not used in computation of contingency probabilities. This is because co-occurrence probabilities involving fog are likely to be different from those involving other types of stratus. Since there is no information about middle and high clouds in a report of "sky obscured due to fog", the only effect of including fog as "stratus" in this study would be to increase artificially the probabilities  $P(C_i, A_s, N_s \Rightarrow St)$  and to decrease the probabilities  $P(C_i, A_s, N_s \Rightarrow \text{low clouds other than } St)$ . This is a consequence of the method of computation of contingency probabilities in the presence of obscured upper layers which is discussed below. The difference would amount to a few percent in the foggiest boxes and less than 1% in most cases.

*b. The fundamental principle*

It is important to be careful to avoid biases that are due to the observer's viewing position - in particular, the fact that higher clouds are only visible when the lower clouds are not overcast. To eliminate these

biases required a rather intricate analysis procedure which is described in Sec. 4d below.

*The fundamental principle used in this work is as follows: The probability  $P(L \Rightarrow U)$  of an upper cloud  $U$ , given a lower cloud  $L$ , is assumed to be the same when  $U$  cannot be seen (because  $L$  is overcast) as when it can be seen (when  $L$  is present but not overcast).*

Some such assumption (either this simple one or a more complicated extrapolation) is necessary because contingency probabilities must ultimately be computed from cases when at least 2 cloud types can be seen. This assumption becomes an issue only for the two higher types, As and Ci. (The low clouds can always be seen, and Ns can always be detected by the fact that it is raining or snowing.) To test this assumption, a number of well-sampled boxes, and the northern hemisphere as a whole, were examined, and  $P(L \Rightarrow U)$  was determined as a function of the amount of  $L$ , for  $L$  not overcast. Fig. 1 shows the results for the cases of  $P(\text{St} \Rightarrow \text{As or Ci})$  which are particularly important because of the large fraction of the reports in which St is overcast. The shape of the curve in Fig. 1a suggests no identifiable trend which could indicate that  $P(\text{St} \Rightarrow \text{As})$  differs significantly when St is overcast from when it is not. Furthermore, the mean of all non-overcast reports (the dashed line) is very close to the values for the higher amounts of St which would be expected to approximate more nearly the proper value for the overcast case. It is therefore concluded that the values obtained for  $P(\text{St} \Rightarrow \text{As})$ , on the basis of St present but not overcast, are reasonably representative of St overcast as well.

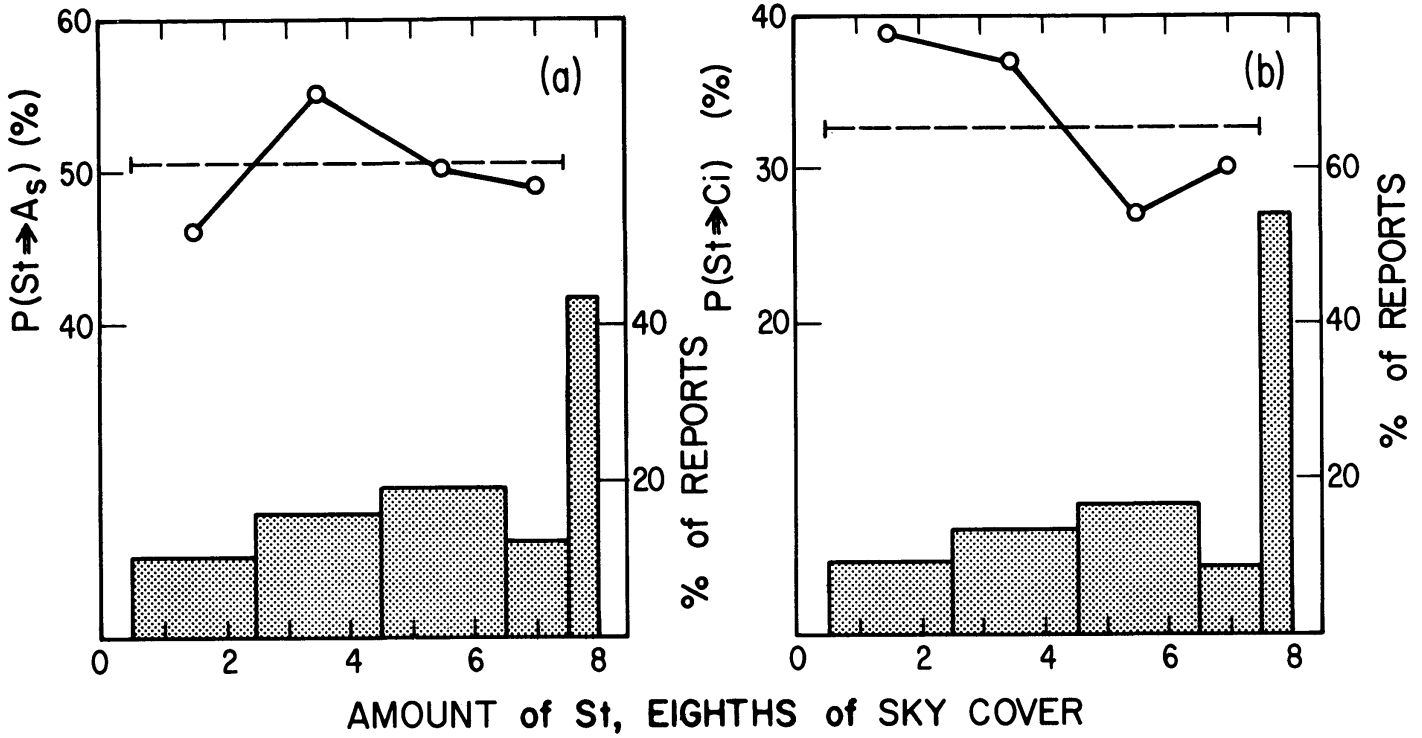


Fig. 1. Probability of occurrence of As(a) and Ci(b) with given amounts of St. Bars indicate the relative number of reports that contributed to each point. Dashed line represents the mean value of all reports contributing to the four points. (For Northern Hemisphere, MAM 1971)

The effect of the St amount on  $P(\text{St} \Rightarrow \text{Ci})$ , shown in Fig. 1b, is more difficult to interpret. The mean value differs by only a few percent from the 2 points for larger amounts of St but it is slightly higher than they are. Therefore the values reported may be slightly high, particularly in some geographical regions of strong subsidence where inversion-capped stratus is commonly unbroken.

The question does not arise with Cu because Cu is rarely reported as overcast; for Cb the extent of cover is likely to vary more with observer position relative to the cloud than with the size of the cloud. The probability of occurrence of Ci may depend on the amount of As. However, this is both difficult to ascertain (the As amount can only be determined from the coded report when low clouds are absent, possibly an unrepresentative subset of As) and any undercast extrapolation will lead to little error in  $P(\text{As} \Rightarrow \text{Ci})$  because As is overcast only 25% of the times that it occurs.

The probability of an upper level cloud, given a lower cloud, may be underestimated by this procedure if the upper cloud elements are typically as large as 1/8 of the sky, but less than 8/8, in cases where the lower cloud is nearly overcast: the window in the lower cloud could then be devoid of upper cloud in some cases when the upper cloud is not truly absent.

The fundamental assumption affects not only the probability  $P(\text{L} \Rightarrow \text{U})$  but also  $P(\text{U} \Rightarrow \text{L})$ , as shown in the following simplified example. Considering only Ns and Ci, suppose that on 5 observation days, Ci was present alone one time, a Ns overcast was present on 3 days, and on the fifth day Ns and Ci were both observed to be present (Ns was not

overcast). The computed probability  $P(Ns \Rightarrow Ci)$  is equal to unity in this hypothetical case. Now  $Ns$  was seen one-half of the time that  $Ci$  was observed, but the fundamental principle causes us to assume that  $Ci$  was also present on the three days of  $Ns$  overcast since  $P(Ns \Rightarrow Ci)=1$ . Therefore the  $P(Ci \Rightarrow Ns)$  is not 0.5 but rather 0.8, i.e.  $(3 + 1) / 5$ .

*c. Error checking and report selection*

Occasional reports contain obvious coding errors. These were corrected or discarded as appropriate. If  $N$  indicated a valid cloud amount other than zero but  $C_L$ ,  $C_M$  and  $C_H$  were each reported as zero, the report was not used (about 0.3% of all reports). If  $C_H$  was reported as visible while  $C_M$  was coded as a slash,  $C_M$  was reassigned as zero (about 0.5% of all reports). On some occasions, if the sky was overcast due to a low cloud, the observer may have put zeros into the report for  $C_M$  and  $C_H$  instead of slashes (about 2% of all reports). Such zeros were treated as slashes in this study.

When the sky was obscured ( $N = 9$ ), the present-weather code was checked for that observation. If  $ww$  indicated rain/snow or thunderstorm,  $C_M$  or  $C_L$ , respectively, were assigned as nimbostratus or cumulonimbus, respectively (see Table 1). If  $ww$  indicated fog, the report was counted so that the frequency of occurrence of fog could be computed, but no further use was made of the report in this study. Reports of sky-obscured due to reasons other than fog, rain, snow, or thunderstorm (about 2% of all reports) were discarded because no cloud information could be inferred from them.

After the above checks were made, if  $C_L$  was other than a slash

(more than 90% of the reports) and N was other than zero (approximately 95% of the reports are not clear skies), the report was used to compute cloud type contingency probabilities as described below. Consequently about 85% of all cloud reports in the data set were utilized. Cases of N=0 (clear sky) of course do not enter the computation of contingency probabilities but were counted so that frequencies of occurrence of the cloud types, clear sky and fog could be computed.

*d) Determination of cloud type contingency probabilities \**

This section describes how the "fundamental principle" was translated into the detailed logic of the computation.

Each report was examined for the occurrence of the six cloud types defined in Table 1, and the co-occurrences were counted and summed for the twelve years for each season for each of the 120 boxes defined between latitudes 80°N and 70°S. Table 2 shows a matrix of the contingency probabilities to be computed and summarizes the methods discussed in this section.

Because upper clouds (As and Ci) cannot be detected from surface observations when lower clouds are overcast, and because they also are sometimes simply not reported, counting is not straightforward for most contingency probabilities. To apply the "fundamental principle," the number of times that  $C_M$  and  $C_H$  are unreported (i.e. are coded with a slash) in the presence of each low cloud type must be counted. Similarly, given the presence of a middle cloud type, the number of times that  $C_H$  is unreported must also be counted. Fig. 2 is an aid to visualizing the various possibilities and shows the percentage of the reports used in this study that gave usable information for the various contingencies. These numbers show the percent of reports of a given lower cloud for which the indicated upper cloud was detectable. (The values shown in Fig. 2 are for global, annual, averages. While the pattern remains the same, the individual values may vary from box to box and season to

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\*The fine print in this section and the next contains details that are essential for computing the values shown on the maps. Readers at this point may wish to skip over the fine print, although those desiring to use the maps should consult it so as to understand fully the basis for their construction.

Table 2  
Categories of synoptic weather reports which contributed to computations of contingency probabilities.

	Ci	As	Ns	Cu	St	Cb	NO	f <sup>1</sup>
Ci	-	A	A	A	A	A	C	L
As	B	-	B <sup>2</sup>	A	A	A	C	L
Ns	B	B <sup>2</sup>	-	A	A <sup>3</sup>	A	C	L
Cu	B	B	B	-	X	X	B <sup>4</sup>	L
St	B	B	B	X	-	X	B <sup>4</sup>	L
Cb	B	B	B	X	X	-	B <sup>4</sup>	L

Given:

Codes (see text for details)

- A Both types were detectable, augmented by upper level unreported with lower cloud present
- B Both types were detectable (i.e. lower cloud not overcast)
- C All three levels were detectable
- L The level was detectable; includes clear sky
- X Mutually exclusive; not computable.

**Notes**

- 1 Overall frequency of occurrence
- 2 Ns and As co-occur only when  $C_M \neq 2, 7, /$  and  $ww =$  precipitation and  $C_L = 6, 7$ . Ns is always detectable when As is seen.
- 3 These types can be distinguished except when  $C_M = /$  and  $C_L = 6, 7$  with  $ww =$  precipitation.
- 4 Here B means, essentially, low and middle layers detectable.

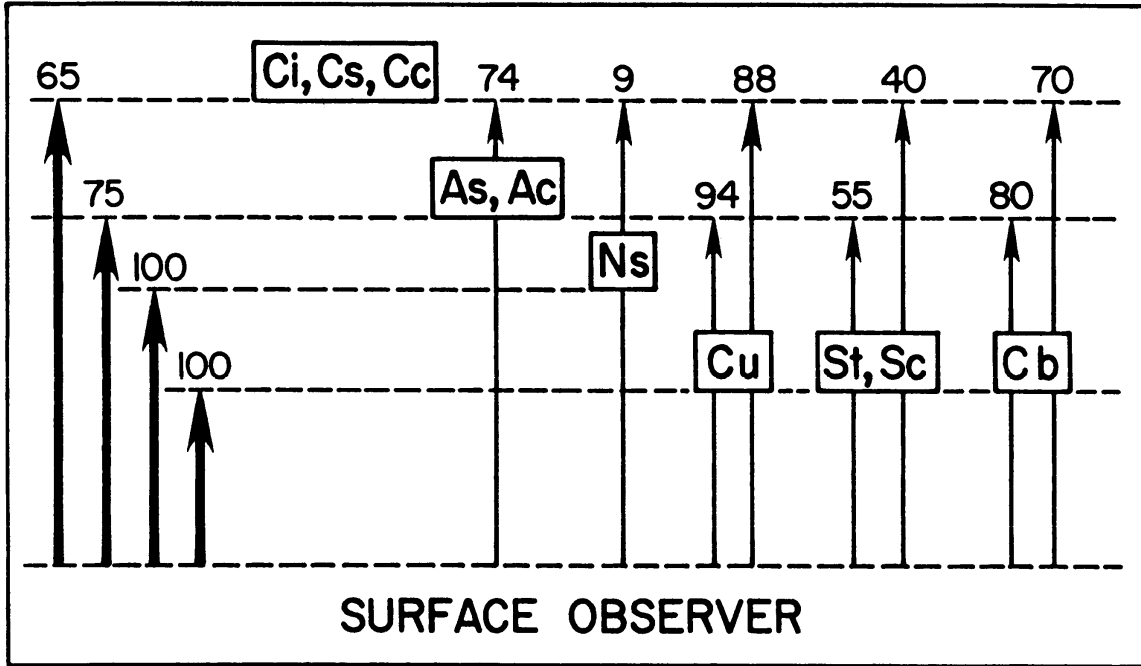


Fig. 2. Percent frequency with which observers reported upper levels seen through lower cloud types. Thick arrows on left give overall frequency of report of the *level* at head of arrow as seen through any (or no) lower cloud; on right is frequency of report of upper *levels* seen (whether an upper *cloud* was present or not) through particular lower cloud types. (Average of all seasons 1965-1976, global average).

season.) The number of times the upper level was unreported in the presence of a given lower cloud L is then multiplied by  $P(L \Rightarrow U)$  for the upper cloud, U, under consideration, as was shown in the simple example in Sec. 4b.  $P(L \Rightarrow U)$  is computed from the times when both levels could be seen and is assumed to be valid for the times when the upper level could not be seen. This gives a correction count which represents the times that the lower cloud occurred together with the upper cloud when the upper cloud was *present but not visible* and is added to the counts for computation of the probability  $P(U \Rightarrow L)$ . If this were not done, then in addition to the bias in  $P(U \Rightarrow L)$ ,  $P(U \Rightarrow St)$  would be artificially reduced relative to the probabilities  $P(U \Rightarrow \text{low other than St})$  because overcast conditions, and thus unreported upper-levels, occur more often with St than with the other low types.

(1) Computation of  $P(\text{lower} \Rightarrow \text{upper})$

The computation of  $P(L \Rightarrow U)$  from the times when both could be seen is accomplished by dividing the number of times the two cloud types were seen together, "number both seen" (NBS), by the number of times that the lower cloud was present and both levels could be observed. This number is given by the total number of times the given lower cloud was seen, "number lower seen" (NLS), minus the number of times that the upper cloud level was unreported in the presence of the lower cloud, "number upper unreported" (NUU). Thus,

$$P(L \Rightarrow U) = \text{NBS} / (\text{NLS} - \text{NUU}).$$

This category of computation is labeled as procedure B in Table 2.

(2) Computation of  $P(\text{upper} \Rightarrow \text{lower})$

For the converse computation of  $P(U \Rightarrow L)$ , consider first the numerator. The number of times both types were seen together (NBS) must be supplemented by the number of times both would have been seen together if the lower cloud were never overcast,  $P(L \Rightarrow U) \times \text{NUU}$ , as described above. In the denominator, the number of times that the upper cloud was seen, NUS, must be supplemented by the number of times it would have been seen if *none* of the lower clouds were ever overcast, "total number upper unreported" TNUU. TNUU is defined as  $P(Cu \Rightarrow U) \times \text{NUU}_{Cu} + P(St \Rightarrow U) \times \text{NUU}_{St} + P(Cb \Rightarrow U) \times \text{NUU}_{Cb}$ , and then

$$P(U \Rightarrow L) = \frac{\text{NBS} + P(L \Rightarrow U) \times \text{NUU}}{\text{NUS} + \text{TNUU}}.$$

This category of computation is labeled as procedure A in Table 2.

TNUU can be computed in this fashion only for Ns and As because for them all lower clouds are mutually exclusive and their effects are additive. For Ci, TNUU is instead approximated as  $f'(Ci) \times NHU$  where NHU is "number high unreported," the total number of times that the high level was unreported, and  $f'(Ci)$  is the frequency of occurrence of Ci computed from the times when the high level was visible (excluding cases of clear sky).

(3) Computation of  $P(\text{type} \Rightarrow \text{no other})$

The probability that an upper cloud type occurred alone,  $P(U \Rightarrow NO)$ , where U represents Ns, As or Ci, had to be computed from the reports in which all levels could be seen. (Note that this is a subset of the population of reports used for the computation of  $P(U \Rightarrow L)$  as described above.) This is straightforward for Ci which can only be detected when all levels are visible.  $P(As \Rightarrow NO)$  will be unknown only if As is seen while the high level is unreported. Nimbostratus can either be identified in the middle cloud group, in which case it will be unknown only if Ci is unreported, or it can be identified in the low cloud group in which case  $C_M$  may also be unreported. Since the latter case occurs frequently,  $P(Ns \Rightarrow NO)$  is computed predominantly from the times Ns was identified with the middle cloud group. This category of computation is labelled C in Table 2. For a given low cloud (not overcast), NO will be known if a middle cloud is present even if the high level is unreported, and will be unknown only if  $C_M=0$  while the high level is unreported. Since this latter case is rare,  $P(\text{low} \Rightarrow NO)$  was computed from essentially all reports (not overcast) and is therefore labelled as procedure B in Table 2.

Because the low cloud types are mutually exclusive, the sum  $P(U \Rightarrow NO) + \sum_{\text{low}} P(U \Rightarrow \text{low})$  for each of the upper types,  $U = Ci, As \text{ or } Ns$ , must properly be at most 1.0, but because  $P(U \Rightarrow NO)$  is computed from a somewhat different population than  $P(U \Rightarrow \text{low})$ , it is possible for the sum to be greater than 1.0. This occurs for less than four percent of the computed values and the excess may be a few percent. On those occasions that this does occur, the value used for  $P(U \Rightarrow NO)$  is  $1.0 - \sum_{\text{low}} P(U \Rightarrow \text{low})$ . Of the times that this adjustment must be made, it is usually for the case of As. Because  $P(As \Rightarrow NO)$  depends on  $P(As \Rightarrow \text{not } Ci)$  which is computed from the times when As was not overcast, the implication is

that Ci may occur somewhat more frequently when As is overcast than when it is not. Thus the values that are reported for  $P(As \Rightarrow Ci)$  may be somewhat low.

(4) Computation of  $f(\text{type})$

The frequency of occurrence,  $f$ , of a cloud type, was computed from the cases in which the type was detectable (including cases of clear sky). This is labelled L in Table 2. For low clouds (including Ns), this means *from all reports*. For As and Ci, however, it means from cases in which there was no undercast. No correction was made on the basis of  $P(L \Rightarrow U) \times NUU$  as was done for the contingency probabilities. Such a correction would have little effect on  $f(Ci)$ , because the most frequently occurring case of undercast is St, and  $P(St \Rightarrow Ci)$  is very similar to  $f(Ci)$ . In the case of As, such a correction might increase  $f(As)$  by 1-2%.

e) *Data sampling criteria*

In order that computed probabilities be statistically meaningful, some minimum number of cloud reports containing a given type of cloud must be required. The actual number selected was 50. If the number of observations of a given cloud type for a particular box was less than the specified minimum, no contingency probabilities were computed for that type for that box. Clearly, more frequently occurring cloud types have a better chance of having contingency probabilities computed for them. Observation of a co-occurrence requires that both cloud types be potentially visible. If a lower cloud is overcast so that an upper level is unreported, the number of reports from which that probability can be computed is reduced. The extreme example of this situation is  $P(Ns \Rightarrow Ci)$ . Ns is overcast about 90% of the time that it occurs (see Fig. 2), but the simultaneous occurrence of Ci can be determined only from the relatively few reports in which Ns was present but not overcast. In fact, this particular probability is likely not very reliable.

In addition to the requirement for a minimum number of reports, the number of reports contributing to the computation of a probability was required to be at least some small fraction (arbitrarily 2%) of the total number of observations of the given cloud type so that a measure of the minimum representativeness of the sample could be stated. For example, the high level is very frequently unreported when Ns is present. Suppose a box contained 10000 reports of Ns but the high level was unreported 9900 times. Then there

would be 100 reports from which  $P(Ns \Rightarrow Ci)$  could be computed. This number is greater than the minimum of 50 previously specified but since it is only 1% of the total number of  $Ns$  reports, the sample may not be representative of the whole. Had a larger criterion than 2% been chosen, fewer contingencies of the type  $P(Ns \Rightarrow Ci)$  would have been computed. However, no spatial discontinuity in the probability values resulted from using the 2% value.

Since  $P(U \Rightarrow L)$  is modified by the converse contingency  $P(L \Rightarrow U)$  as described above, the question arises as to how to handle the case in which a given upper cloud type  $U$  meets the minimum requirements for computation of  $P(U \Rightarrow L)$  while the converse contingency did not meet the minimums and was thus considered to be unreliable. It was decided to compute  $P(U \Rightarrow L)$  in this situation if the change produced in  $P(U \Rightarrow L)$  by the unreliable number  $P(L \Rightarrow U)$  was no greater than 5%. This situation arises most frequently with the co-occurrence of  $Ns$  and  $Ci$ ; thus  $P(Ci \Rightarrow Ns)$  is computed for more boxes than is  $P(Ns \Rightarrow Ci)$ .

## 5. Format of the maps

The atlas contains 47 maps for each of the four seasons. These maps show, for the ocean areas, the global distribution of the various quantities related to cloud types and co-occurrences, as discussed above, for the 12 year period (1965-1976).

Each section of the atlas includes the following maps:

- a) The total number of synoptic weather reports (tabulated in hundreds) which have information about cloud types, present or absent (Map 1). Such information may be an observation of a specific cloud type present ( $C_L$ ,  $C_M$ , or  $C_H$  code 1-9) or a cloud type inferred when the sky is obscured consistent with the ww report as shown in Table 1, or an observation of clear sky.

- b) The number (in tens) of times that each of the six cloud types was observed to be present (Maps 2-7).
- c) The fraction of reports (in percent) contributing to the statistics of middle or high cloud levels (Maps 8 and 9). This is the number of synoptic reports in which the middle (or high) level was not coded with a slash, divided by the total number of reports in which *any* cloud was reported present.
- d) The overall frequency of occurrence,  $f$ , (percent) of each cloud type as well as of fog and clear sky (Maps 10-17). It is simply the number of times the particular type was reported present, divided by the number of synoptic weather reports which contain information about that cloud level (i.e. in which that level was not coded with a slash). (That is,  $f$  is the fraction of times that the cloud type *was reported present* when *it was possible* to see whether it was present. The fraction of times that it was possible to see whether it was present is given in Map 8 or 9.) Values are tabulated for each box for which contingency probabilities involving that cloud type were computable, i.e., whenever the particular cloud type was reported present at least 50 times. (For Ci and As, this frequency was not adjusted by estimating the amount of higher cloud hidden behind a lower overcast. Such a correction would have little effect on the value of  $f$ , as discussed in Sec. 4d.)
- e) The probability,  $P$ , that given one of the six cloud types, no other cloud is present (Maps 18-23);

- f) The co-occurrence probabilities  $P$  for coupled cloud types (Maps 24-47). Some  $P$ -maps are absent simply due to the definitions of cloud types given in Table 1. For instance, the code allows only one low cloud type to be reported in a single observation so the co-occurrence probabilities of Cu, Cb, and St with each other are zero by definition.

Most of the maps are in two parts. One part shows computer-drawn contours while the other part gives the tabulated values for which these contours were drawn. Zonal average values for only the ocean part of the zone are printed along the right side of the digital maps. These result from averaging the values of all  $15^\circ \times 30^\circ$  boxes in the zone, each box weighted by the area of ocean it contains (obtained from Gates and Nelson, 1973). It should be noted that the contour maps contain no more information than the digital maps. They are shown only to illustrate the general patterns of the geographical variation of the quantities plotted. Attention is drawn to the following caveats concerning use of the maps:

- The contours are drawn to interpolate between the digital values as though the numbers were point values representing the centers of the box. This results in misleading contour lines in the neighborhood of coastlines. For example, the number plotted in the center of Australia applies only to the small ocean areas north of Australia. But the contour lines are drawn as though the number represented the geographical point where it is displayed.
- The contours should not be interpreted as giving more detail than the basic resolution of  $15^\circ \times 30^\circ$  as shown on the digital maps.

- Gradients shown by the contours in coastal regions are likely to be unrepresentative. This is especially obvious on the maps of "frequency of occurrence of completely clear sky." The only numbers greater than 5% are in coastal boxes, and it is likely that the gradient of this quantity is very steep near the coast, where incidently, shipping lanes are generally concentrated, with very low probability values in the open ocean. Yet the contour plot gives the impression of a smooth variation across the ocean.
- Since the data used for these maps are only from ships, each tabulated number, even though it is plotted in the center of its box (which may in some cases be on a coast or on land) *applies only to the ocean part of the box*. [The data set also contained ship observations from the Great Lakes and the Caspian Sea, which were not excluded from the analysis. However, the cloud observations from these inland waters do not dominate the statistics of their respective boxes because those boxes also contain considerable ocean area.]

Some of the co-occurrence maps are more precisely based than others. The definitions of Cu and Ci, for example, do not overlap, but the distinction between Ns and St is somewhat arbitrary. Thus, maps  $P(Cu \Rightarrow Ci)$  and  $P(Ci \Rightarrow Cu)$  will be more useful than the maps  $P(Ns \Rightarrow St)$  and  $P(St \Rightarrow Ns)$ . The maps for  $P(As \Rightarrow Ns)$  and  $P(Ns \Rightarrow As)$  are also of doubtful utility, since these two types can occur together only under the special conditions that Ns is assigned from the low group while in the middle level As is reported present.

Blanks occur on the maps where there were insufficient ship observations in the 12 years to obtain a statistically significant co-occurrence probability. In these locations, one can either interpolate between the values in neighboring boxes, if they are represented, or else take the *overall* frequency of occurrence from the f-maps by default.

In particular it will be noted that the maps of probabilities  $P(Ns \Rightarrow Ci)$  and  $P(Ns \Rightarrow NO)$  are rather empty in the Southern Hemisphere. This is because the number of synoptic cloud reports is generally much smaller for the Southern than Northern Hemisphere for all seasons and because there is a strong tendency for Ns to be overcast when it occurs. As a result, the number of observations of non-overcast Ns was often insufficient to obtain statistics of these probabilities in most of the Southern Hemisphere.

The numbers plotted on these maps are available on magnetic tape from the Data Support Group at NCAR.

## **6. Discussion**

The number of synoptic cloud reports in each  $15^\circ \times 30^\circ$  grid box, which provides the data base for the atlas, varies from a maximum of about 200,000 for a three-month summer period over 12 years in the North Atlantic (JJA) to near zero in the south polar regions during all seasons. The geographic pattern of the number of ship observations of various cloud types follows that for total synoptic cloud reports. It is obvious that the dominant shipping route patterns strongly influence the reliability of cloud statistics (as it does for all meteorological statistics based on surface based observations over the oceans). As already noted,

the sparsity of ship reports in the Southern Hemisphere mid-latitude and polar regions frequently preclude availability of the minimum number of observations necessary for cloud statistics computations.

The percentage of ship reports contributing to the statistics of middle or high cloud levels give an indication of the statistical reliability of the information presented on the co-occurrence probability maps. These values are less than 100 percent principally because of the presence of a lower overcast but also because of occasional neglect by observers to report anything but the lowest cloud level. For the middle cloud level the values decrease from near 90 percent at equatorial latitudes to about 60-70 percent at north and south polar regions. Analogous numbers for the high cloud level are about 80 percent and 30-40 percent for equatorial and polar regions, respectively. There are strong geographic variations in the percentage of ship reports giving information about high and middle level clouds, but no significant seasonal variation is apparent.

The maps show, that over the open ocean, the skies are completely clear only about 2-5 percent of the time except in coastal areas in the tropics and subtropics, associated with the subtropical anticyclones in those regions, where the frequency of cloudless skies may be as high as 30 percent off the West African coast and near 60 percent in the Arabian Gulf region. Sky obscuration over the ocean due to fog occurs only at subpolar and polar latitudes where it can reach up to 25 percent in the northwest Pacific during the summer (JJA).

Maps of the frequency of occurrence,  $f$ , of each cloud type are presented so that they can be compared with the contingency

probabilities of observed cloud-type couples. The zonal average values of  $f$  shown along the right side of the maps were used to prepare the plots of the average latitudinal variation of  $f$  shown in Fig. 3.

Both high and middle level clouds show relatively small variations with latitude but have maximum occurrence frequencies in the tropics and minima in the subtropics. Stratus and cumulus clouds, on the other hand, have large latitudinal differences. Their variations are compensatory. That is, cumulus is common where stratus is rare, and vice versa. Similar patterns, but with much lower occurrence frequencies, are also seen for Cb and Ns cloud types. Comparison of the frequency of occurrence maps indicates that middle and high clouds show a significant seasonal variation with maximum percent frequency of observations occurring during the summer months and with relatively small geographic variation. Low clouds, however, are strongly influenced by local thermal conditions, particularly near coastal regions. Cb and Cu have a maximum frequency of occurrence during the winter months in mid and polar latitudes and during summer months in tropical latitudes. Ns also shows a maximum during the winter at mid and polar latitudes of the Northern Hemisphere but no strong seasonal variation at other latitudes.

High and middle level clouds are seldom observed alone except near the coasts. This information could be useful for interpretation of satellite images. Cirrus or altostratus may be seen from above by satellite, but it is often not known whether another cloud is below. During all seasons the probability that Ci or As is alone is only 1-2% near the ITCZ, increasing to more than 20% at high latitudes where these clouds frequently represent the leading edge of extensive horizontal cloud

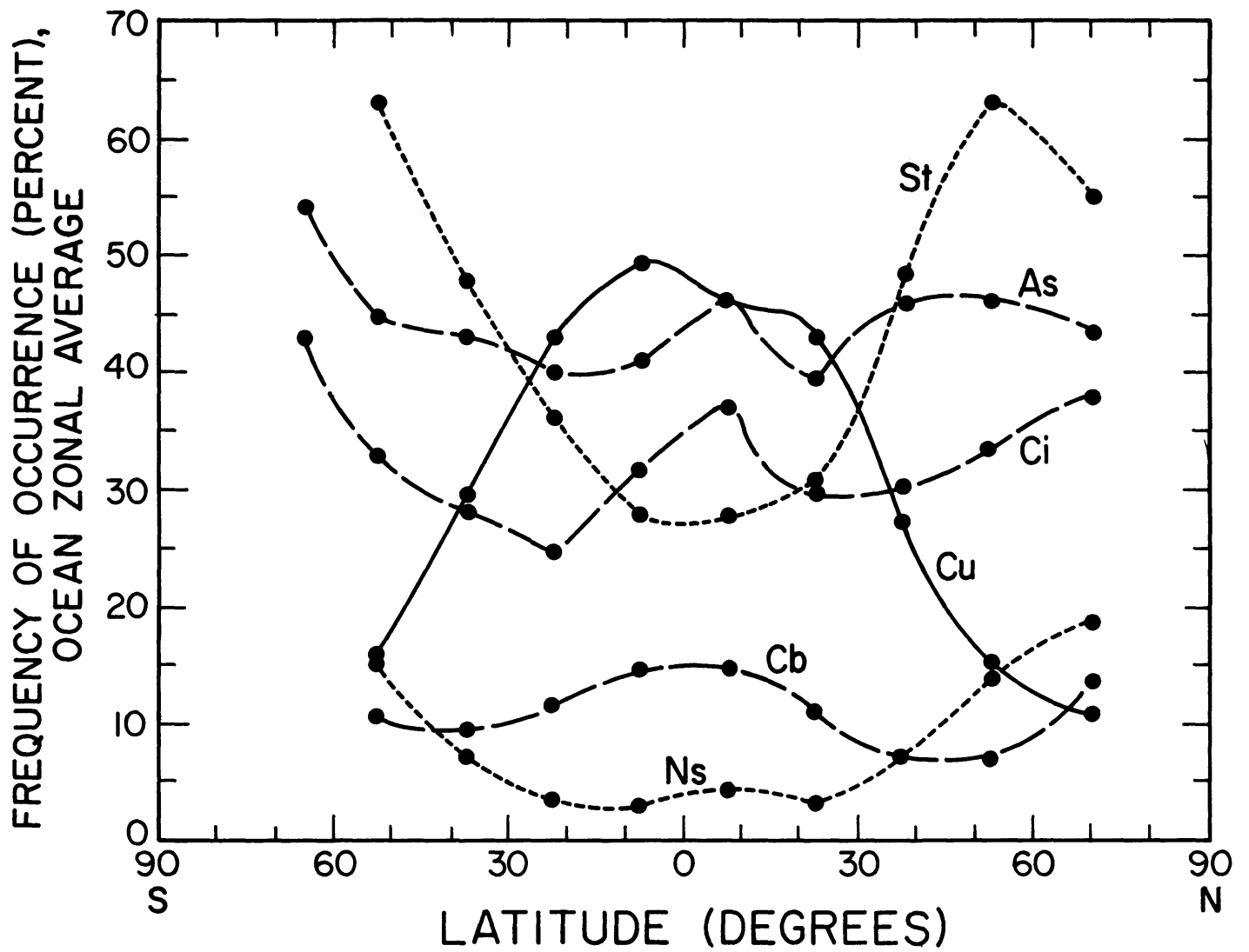


Fig. 3. Frequency of occurrence of each cloud type as a function of latitude, average of all four seasons.

systems. The highest values are in DJF along the Atlantic coast of North Africa and in the Arabian Sea, which are relatively free of all clouds during this season.

The results shown in the various contingency maps are summarized in Tables 3a-d where the zonal average values of the contingency probabilities are shown for four broad zones, 30° - 60° N, 0° - 30° N, 0° - 30° S, and 30° - 60° S. See also Warren et al (1982). For the different latitude zones, four numbers are given for each element of the table. They correspond to the four seasons as noted to the right of the table. The columns in the table give the probability of occurrence of a given cloud type together with other specified clouds. Also shown in the last column is the probability  $P(A \Rightarrow NO)$ , i.e., given cloud type A, the probability that no other cloud type is present. As discussed above, certain elements of the table are blank simply due to the definitions of cloud types given in Table 1; or, as in some cases involving Ns in the Southern Hemisphere, where the number of non-overcast observations was insufficient to satisfy the minimum criterion required for the contingency tabulation. The numbers in Table 3a-d are the result of averaging the values of all 15° x 30° boxes in the zone, each box weighted by the area of ocean it contains.

The contingency probabilities may be compared with the average overall frequency of occurrence of each cloud type (leftmost column). If the contingency probability  $P(A \Rightarrow B)$  is equal to the overall frequency of occurrence of B, then one may say that the value derived for  $P(A \Rightarrow B)$  could be due to chance and is probably not meteorologically associated, since, on average, B is no more or less likely when A is present than when

Table 3a  
 30° - 60° N OCEAN-AREA-WEIGHTED AVERAGE  
 CONTINGENCY PROBABILITY TABLE\*

Given cloud type	Frequency of occurrence (f)	Fraction of reports contributing to statistics of type	Probability that these are also present							
			Ci	As	Ns	Cu	St	Cb	NO	
Ci	.27	.50	-	.67	.16	.20	.49	.09	.10	DJF
	.33	.50	-	.62	.12	.19	.45	.06	.17	MAM
	.37	.52	-	.63	.09	.21	.45	.07	.16	JJA
	.31	.57	-	.66	.11	.26	.44	.09	.11	SON
As	.42	.65	.43	-	.01	.19	.62	.10	.08	DJF
	.45	.64	.46	-	.01	.18	.61	.08	.10	MAM
	.47	.64	.49	-	.01	.19	.61	.08	.10	JJA
	.44	.70	.46	-	.01	.23	.56	.10	.08	SON
Ns	.13	1.0	.34	.07	-	.02	.58	.02	.23	DJF
	.10	1.0	.40	.06	-	.01	.59	.03	.14	MAM
	.08	1.0	.43	.06	-	.02	.58	.02	.12	JJA
	.09	1.0	.40	.07	-	.02	.60	.03	.17	SON
Cu	.22	1.0	.25	.36	.01	-	-	-	.53	DJF
	.21	1.0	.30	.38	.01	-	-	-	.48	MAM
	.22	1.0	.36	.42	.01	-	-	-	.43	JJA
	.27	1.0	.29	.38	.01	-	-	-	.50	SON
St	.57	1.0	.25	.50	.15	-	-	-	.37	DJF
	.55	1.0	.29	.53	.13	-	-	-	.33	MAM
	.54	1.0	.33	.57	.10	-	-	-	.31	JJA
	.51	1.0	.28	.52	.12	-	-	-	.35	SON
Cb	.08	1.0	.28	.49	.03	-	-	-	.41	DJF
	.06	1.0	.32	.54	.03	-	-	-	.35	MAM
	.06	1.0	.42	.61	.03	-	-	-	.26	JJA
	.08	1.0	.35	.55	.03	-	-	-	.34	SON

\*"Ci" = Ci + Cs + Cc

"As" = As + Ac

"St" = St + Sc

"NO" = no other cloud

Table 3b  
 0° - 30° N OCEAN-AREA-WEIGHTED AVERAGE  
 CONTINGENCY PROBABILITY TABLE

Given cloud type	Frequency of occurrence (f)	Fraction of reports contributing to statistics of type	Probability that these types are also present							
			Ci	As	Ns	Cu	St	Cb	NO	
Ci	.27	.76	-	.66	.04	.42	.31	.13	.09	DJF
	.32	.78	-	.63	.04	.44	.27	.15	.10	MAM
	.39	.74	-	.68	.05	.42	.27	.20	.06	JJA
	.38	.76	-	.68	.04	.44	.26	.20	.05	SON
As	.39	.85	.45	-	.00	.37	.39	.15	.07	DJF
	.40	.86	.50	-	.00	.39	.36	.16	.07	MAM
	.49	.84	.54	-	.01	.37	.35	.20	.05	JJA
	.45	.85	.53	-	.01	.39	.34	.20	.04	SON
Ns	.04	1.0	.37	.13	-	.03	.64	.05	.20	DJF
	.03	1.0	.44	.13	-	.03	.62	.06	.16	MAM
	.04	1.0	.45	.15	-	.04	.59	.07	.14	JJA
	.04	1.0	.42	.14	-	.04	.60	.07	.15	SON
Cu	.45	1.0	.26	.33	.00	-	-	-	.56	DJF
	.47	1.0	.30	.34	.00	-	-	-	.52	MAM
	.44	1.0	.38	.41	.00	-	-	-	.43	JJA
	.47	1.0	.34	.38	.00	-	-	-	.47	SON
St	.30	1.0	.29	.54	.08	-	-	-	.37	DJF
	.28	1.0	.32	.54	.07	-	-	-	.36	MAM
	.30	1.0	.36	.60	.10	-	-	-	.30	JJA
	.28	1.0	.35	.58	.10	-	-	-	.32	SON
Cb	.10	1.0	.35	.55	.01	-	-	-	.35	DJF
	.12	1.0	.42	.56	.01	-	-	-	.32	MAM
	.16	1.0	.49	.61	.02	-	-	-	.26	JJA
	.15	1.0	.46	.60	.02	-	-	-	.28	SON

Table 3c  
 0° - 30° S OCEAN-AREA-WEIGHTED AVERAGE  
 CONTINGENCY PROBABILITY TABLE

Given cloud type	Frequency of occurrence (f)	Fraction of reports contributing to statistics of type	Probability that these types are also present							
			Ci	As	Ns	Cu	St	Cb	NO	
Ci	.33	.72	-	.65	.05	.45	.28	.18	.04	DJF
	.31	.74	-	.63	.04	.47	.26	.19	.05	MAM
	.22	.69	-	.65	.05	.41	.33	.16	.07	JJA
	.25	.67	-	.66	.04	.42	.34	.14	.06	SON
As	.43	.82	.48	-	.00	.39	.36	.19	.05	DJF
	.40	.83	.47	-	.00	.40	.34	.20	.05	MAM
	.38	.78	.37	-	.00	.35	.42	.17	.06	JJA
	.41	.76	.40	-	.00	.36	.42	.16	.06	SON
Ns	.04	1.0	.45	.14	-	.03	.65	.06	.11	DJF
	.04	1.0	.37	.14	-	.04	.62	.07	.15	MAM
	.03	1.0	.38	.15	-	.02	.68	.05	.18	JJA
	.03	1.0	.42	.14	-	.03	.68	.06	.14	SON
Cu	.48	1.0	.31	.36	.00	-	-	-	.50	DJF
	.49	1.0	.29	.33	.00	-	-	-	.53	MAM
	.45	1.0	.21	.31	.00	-	-	-	.60	JJA
	.45	1.0	.24	.33	.00	-	-	-	.55	SON
St	.30	1.0	.31	.55	.10	-	-	-	.34	DJF
	.28	1.0	.30	.53	.10	-	-	-	.37	MAM
	.35	1.0	.22	.50	.08	-	-	-	.42	JJA
	.36	1.0	.25	.52	.08	-	-	-	.39	SON
Cb	.14	1.0	.41	.58	.02	-	-	-	.30	DJF
	.15	1.0	.39	.55	.01	-	-	-	.32	MAM
	.12	1.0	.29	.54	.01	-	-	-	.37	JJA
	.11	1.0	.32	.56	.01	-	-	-	.34	SON

Table 3d  
30° - 60°S<sup>+</sup> OCEAN-AREA-WEIGHTED AVERAGE  
CONTINGENCY PROBABILITY TABLE

Given cloud type	Frequency of occurrence (f)	Fraction of reports contributing to statistics of type	Probability that these are also present							
			Ci	As	Ns	Cu	St	Cb	NO	
Ci	.31	.50	-	.62	.12	.24	.41	.07	.12	DJF
	.31	.52	-	.64	.11	.23	.43	.09	.12	MAM
	.26	.57	-	.65	.09	.21	.44	.13	.12	JJA
	.31	.54	-	.63	.08	.21	.44	.09	.15	SON
As	.47	.63	.43	-	.00	.23	.56	.08	.11	DJF
	.45	.63	.45	-	.01	.21	.55	.10	.11	MAM
	.40	.64	.42	-	.01	.18	.56	.14	.10	JJA
	.46	.62	.42	-	.01	.19	.59	.11	.10	SON
Ns	.11	1.0	-	.06	-	.01	.59	.02	-	DJF
	.11	1.0	-	.09	-	.01	.61	.02	-	MAM
	.08	1.0	-	.13	-	.01	.64	.03	-	JJA
	.09	1.0	-	.11	-	.01	.69	.02	-	SON
Cu	.26	1.0	.28	.40	.01	-	-	-	.47	DJF
	.26	1.0	.26	.37	.01	-	-	-	.52	MAM
	.25	1.0	.22	.32	.00	-	-	-	.58	JJA
	.24	1.0	.26	.38	.00	-	-	-	.50	SON
St	.54	1.0	.27	.51	.13	-	-	-	.35	DJF
	.54	1.0	.29	.49	.15	-	-	-	.38	MAM
	.54	1.0	.26	.46	.14	-	-	-	.42	JJA
	.56	1.0	.26	.51	.13	-	-	-	.36	SON
Cb	.07	1.0	.33	.55	.02	-	-	-	.34	DJF
	.10	1.0	.31	.52	.02	-	-	-	.37	MAM
	.13	1.0	.26	.46	.02	-	-	-	.43	JJA
	.09	1.0	.31	.55	.02	-	-	-	.35	SON

<sup>+</sup>Because of lack of observations in the Southern Ocean winter (see Map III-1), the JJA numbers in Table 3d apply not to 30° - 60°S but rather to 30° - 45°S

it is not. However, if the contingency probability  $P(A \Rightarrow B)$  is higher ( or lower) than the frequency of occurrence of B, the two cloud types are positively (or negatively) correlated. The table shows for example that  $P(Ci \Rightarrow As)$  is much larger than the overall frequency of occurrence of As, symbolized as  $f(As)$ , in all latitude zones for all seasons. These two types actually exhibit the strongest positive correlation of any two of the six types. By contrast, As and Cu are negatively correlated, particularly in low latitudes, indicating that these cloud types tend to be mutually exclusive. The negative correlation is likely due to the fact that Cu occurs in statically unstable air whereas As occurs in stable air.

Some of the other co-occurrence probabilities also show interesting latitudinal variations. For instance,  $P(Ci \Rightarrow St)$  shows a strong negative correlation at high latitudes, where  $f(St)$  is large. The correlation, however, is essentially zero at equatorial and subtropical latitudes. Also, Cb and Ci are uncorrelated at high latitudes but positively correlated in the tropics where the Ci often originates from the top of the Cb cloud. A similar contingency pattern is present for Cb and As.

Although there is relatively little seasonal variation in the co-occurrence of a number of the cloud types shown in Table 3, there are some notable and interesting exceptions. Given a low convective cloud type (Cu or Cb), the probability of Ci (or As) also being present is always higher during the summer than during the winter, with the seasonal variation being slightly larger in the Northern Hemisphere. A similar, large seasonal variation with a summer maximum is found for  $P(Cb \Rightarrow As)$  over most ocean areas. These are just a few of the most striking patterns that are readily apparent in the maps.

As indicated earlier, this atlas of cloud co-occurrences should aid analysts involved in the interpretation of satellite-derived cloud information and provide a guide for diagnostic or predictive models of the general circulation.

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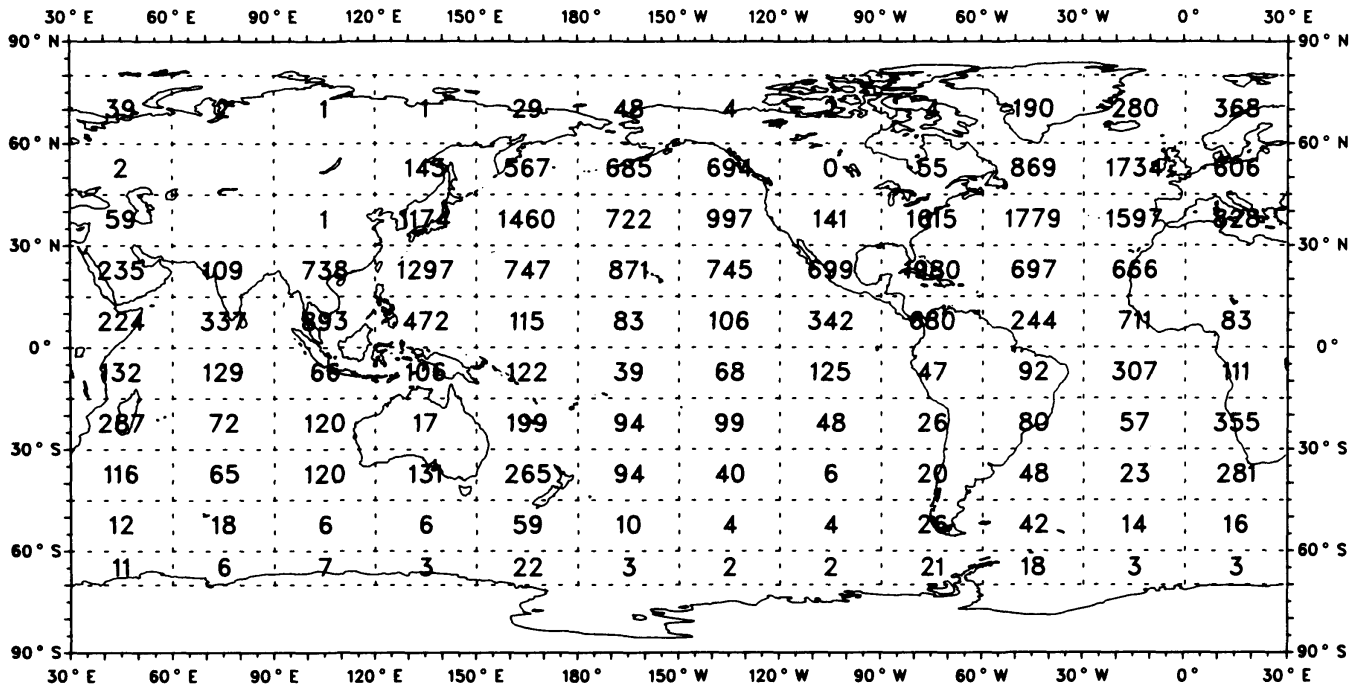
December, January, February

Map I-1

Number of Synoptic Cloud Reports from Ships, in Hundreds

DJF (1965-1976)

Ocean Areas Only

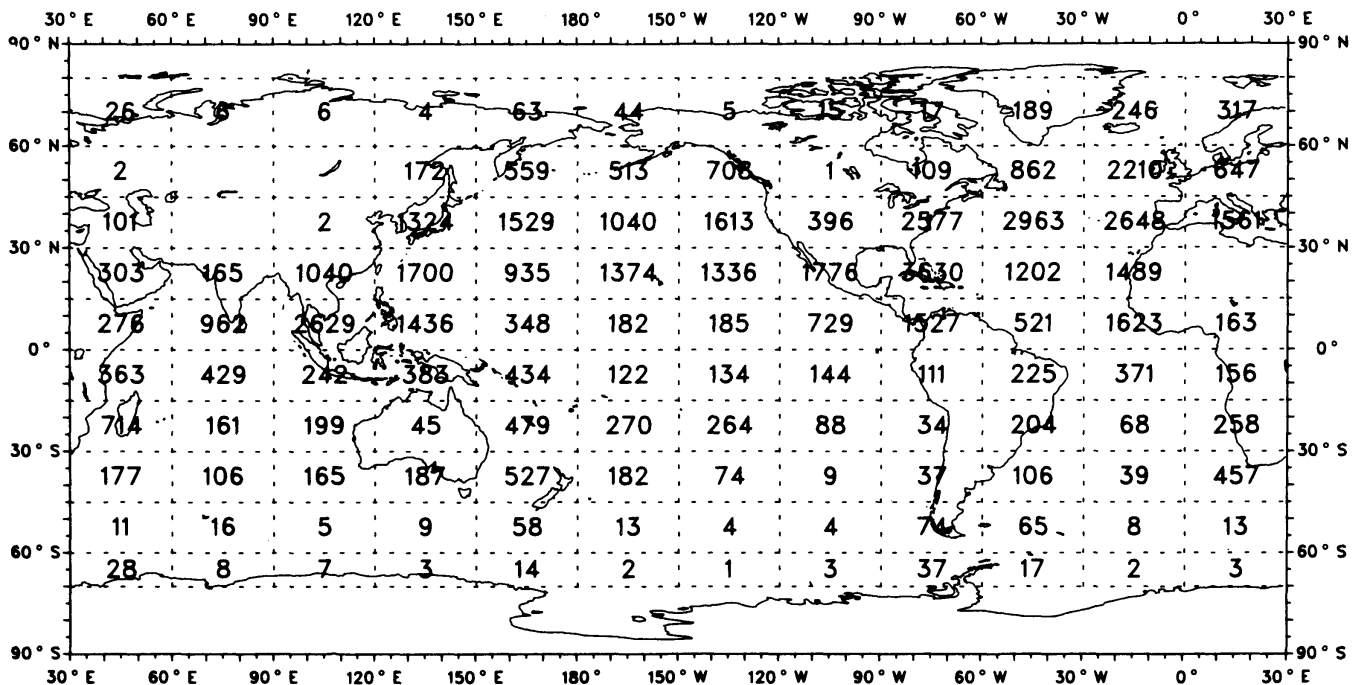


Map I-2

Number of Observations of Cirrus, Cirrostratus, or Cirrocumulus (N/10)

DJF (1965-1976)

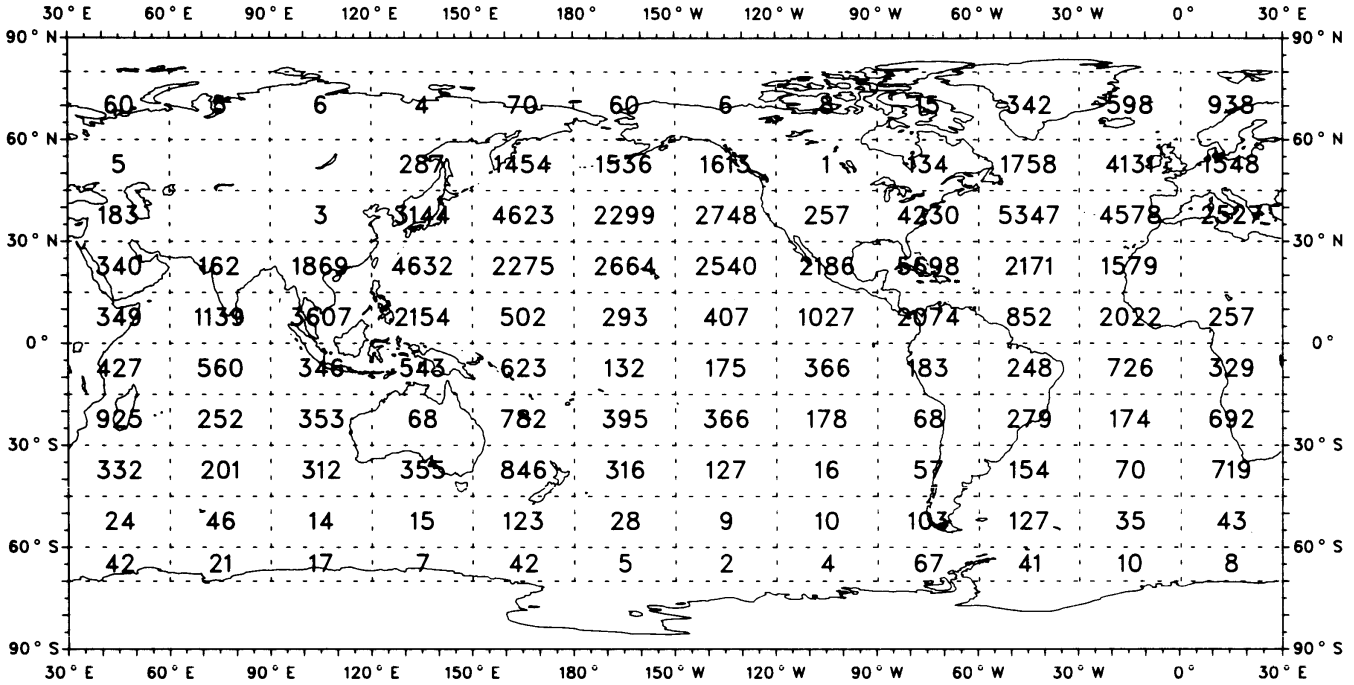
Ocean Areas Only



Number of Observations of Altostratus or Altocumulus (N/10)

DJF (1965-1976)

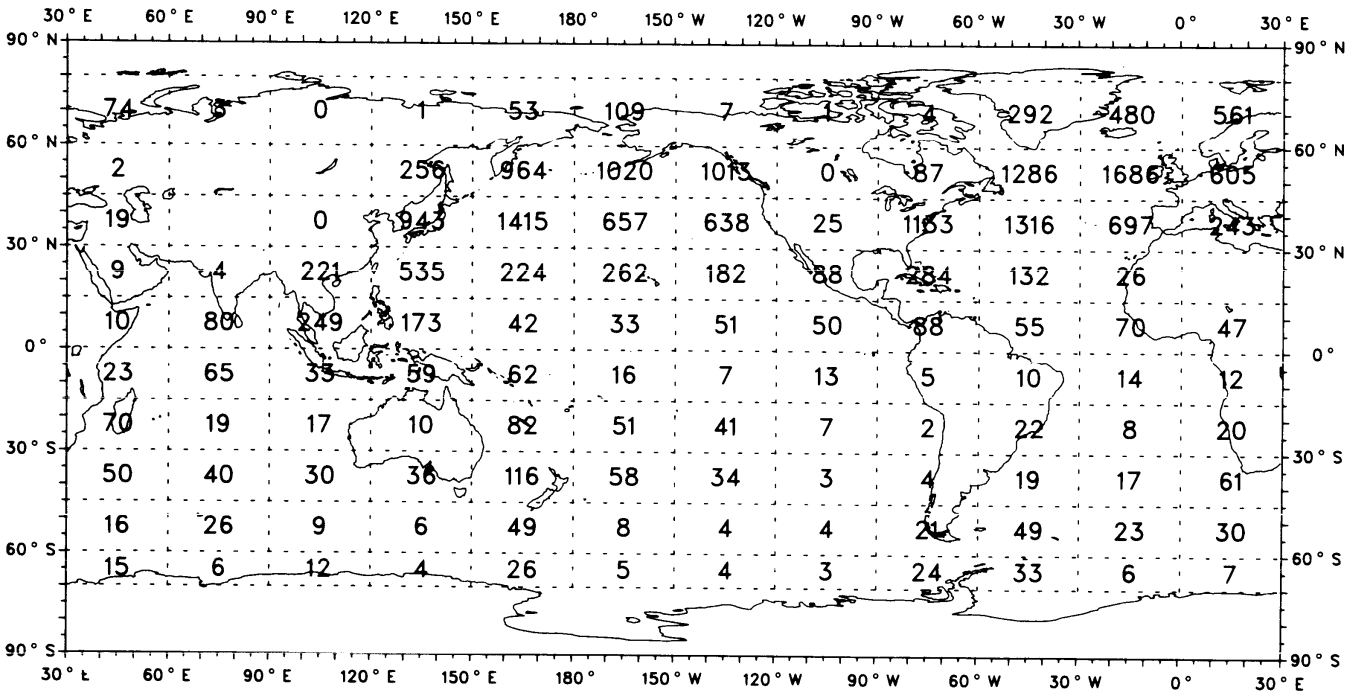
Ocean Areas Only



Number of Observations of Nimbostratus (N/10)

DJF (1965-1976)

Ocean Areas Only

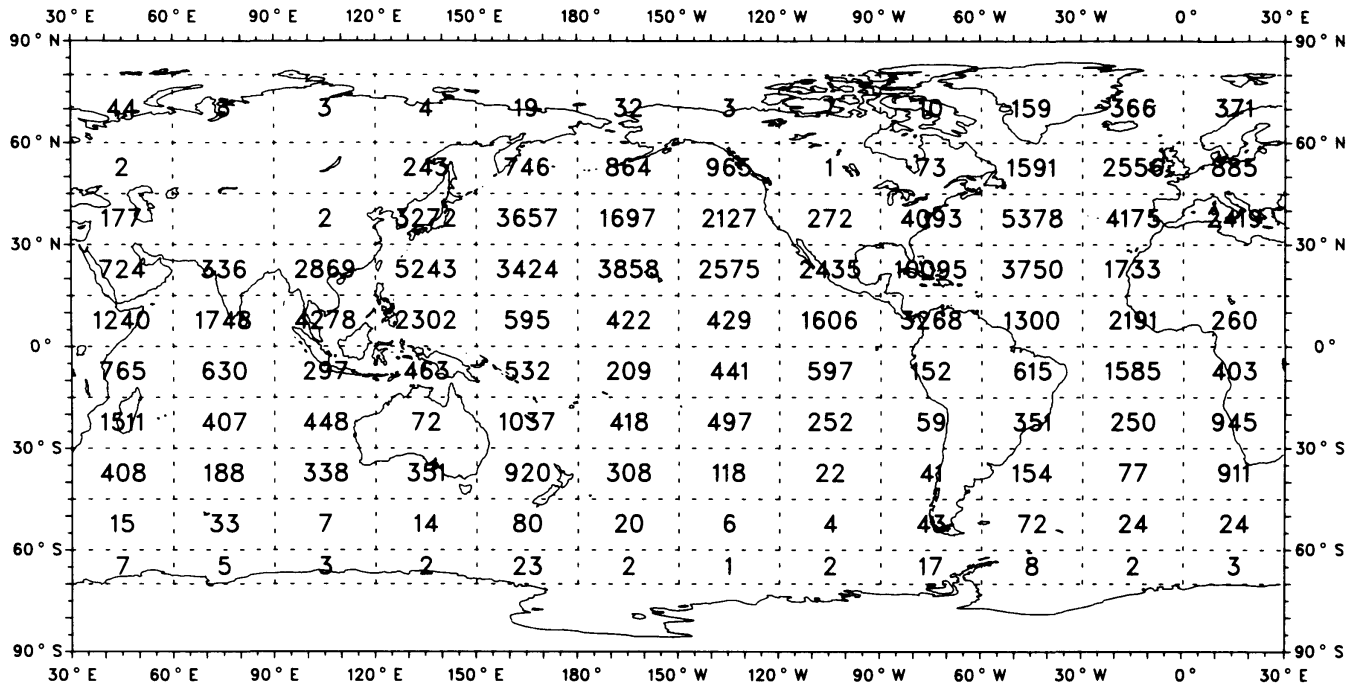


Map I-5

Number of Observations of Cumulus (N/10)

DJF (1965-1976)

Ocean Areas Only

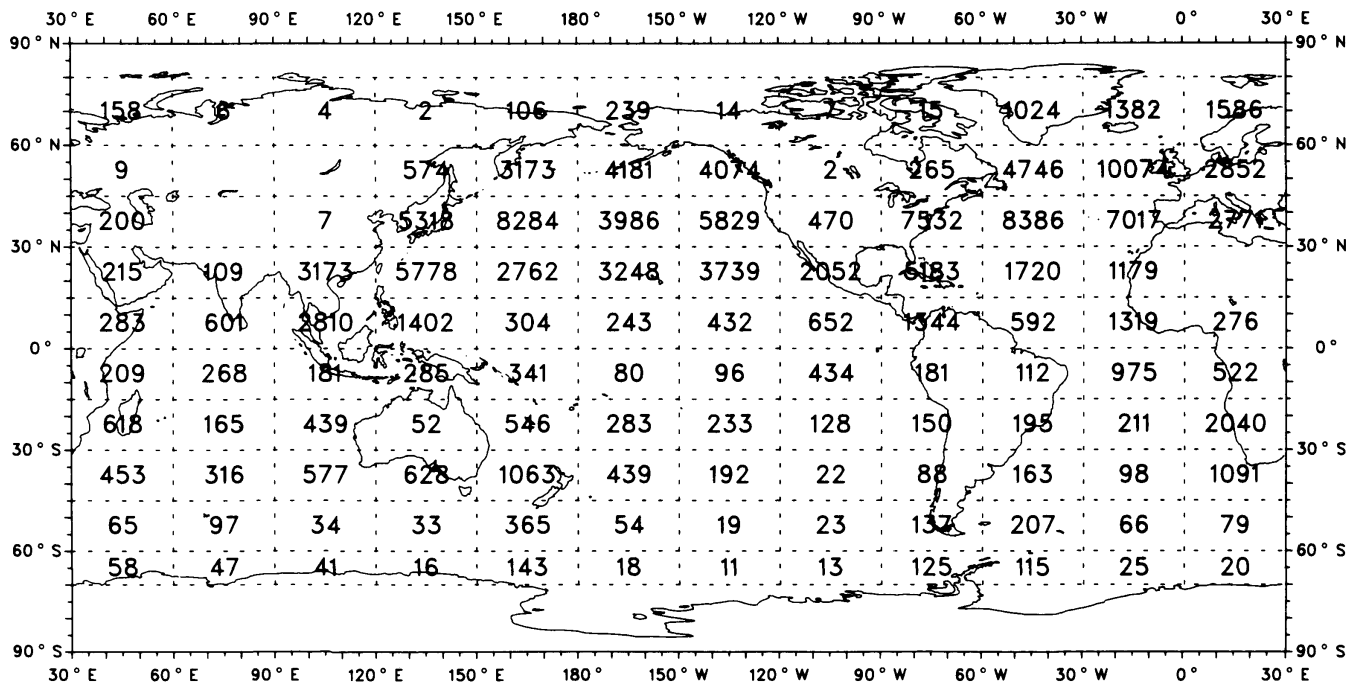


Map I-6

Number of Observations of Stratus or Stratocumulus (N/10)

DJF (1965-1976)

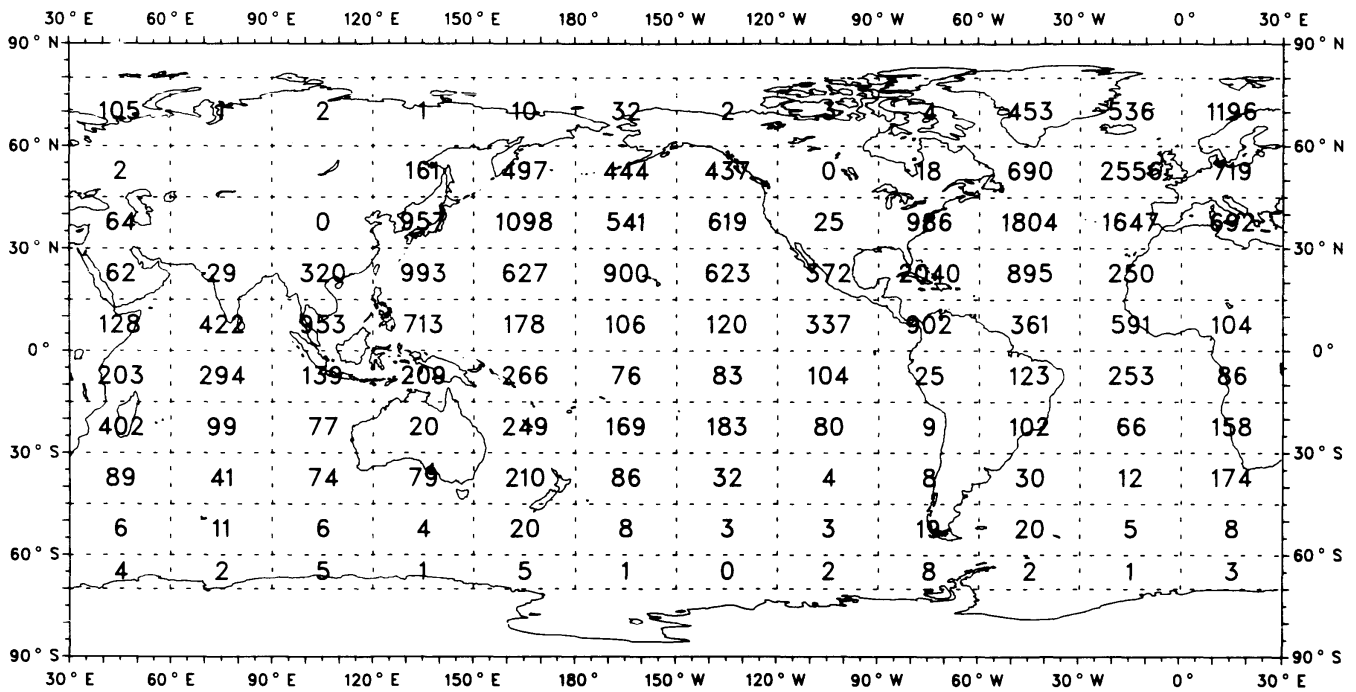
Ocean Areas Only



Number of Observations of Cumulonimbus (N/10)

DJF (1965-1976)

Ocean Areas Only

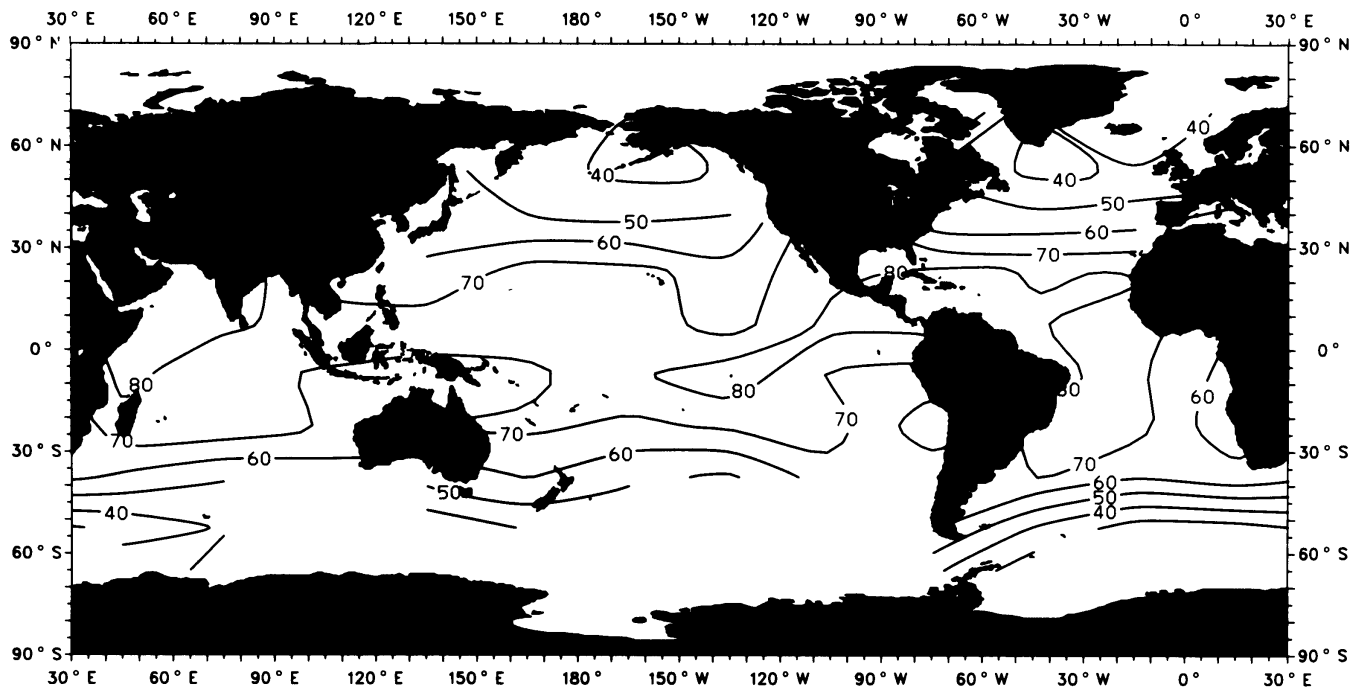


Map I-8

Percent of Ship Reports Contributing to Statistics of the High Cloud Level

DJF (1965-1976)

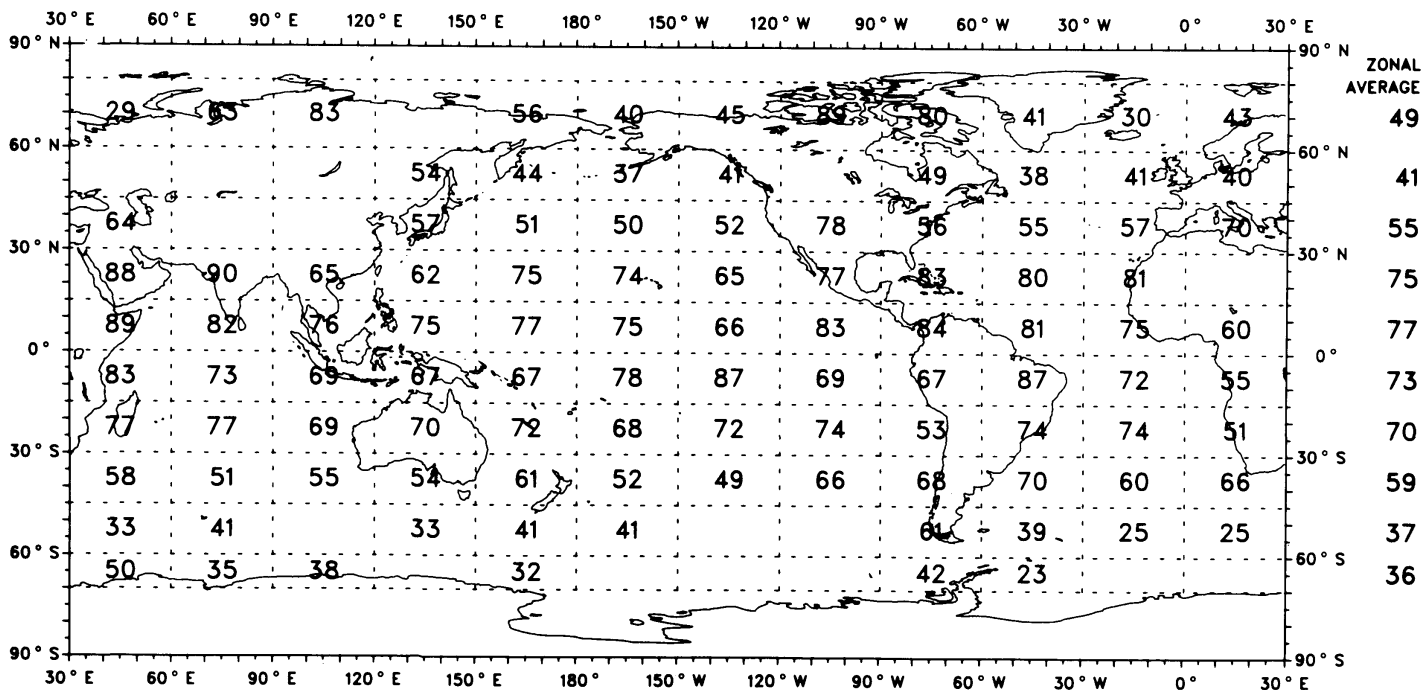
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the High Cloud Level

DJF (1965-1976)

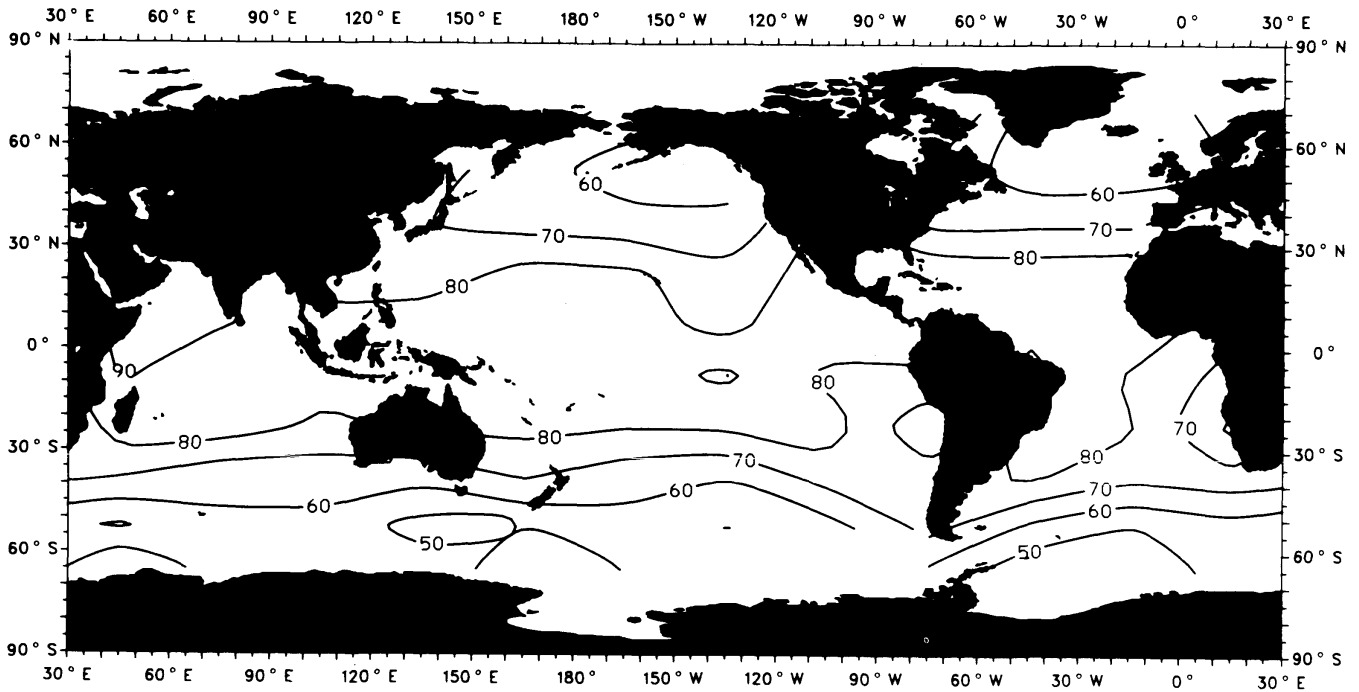
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

DJF (1965-1976)

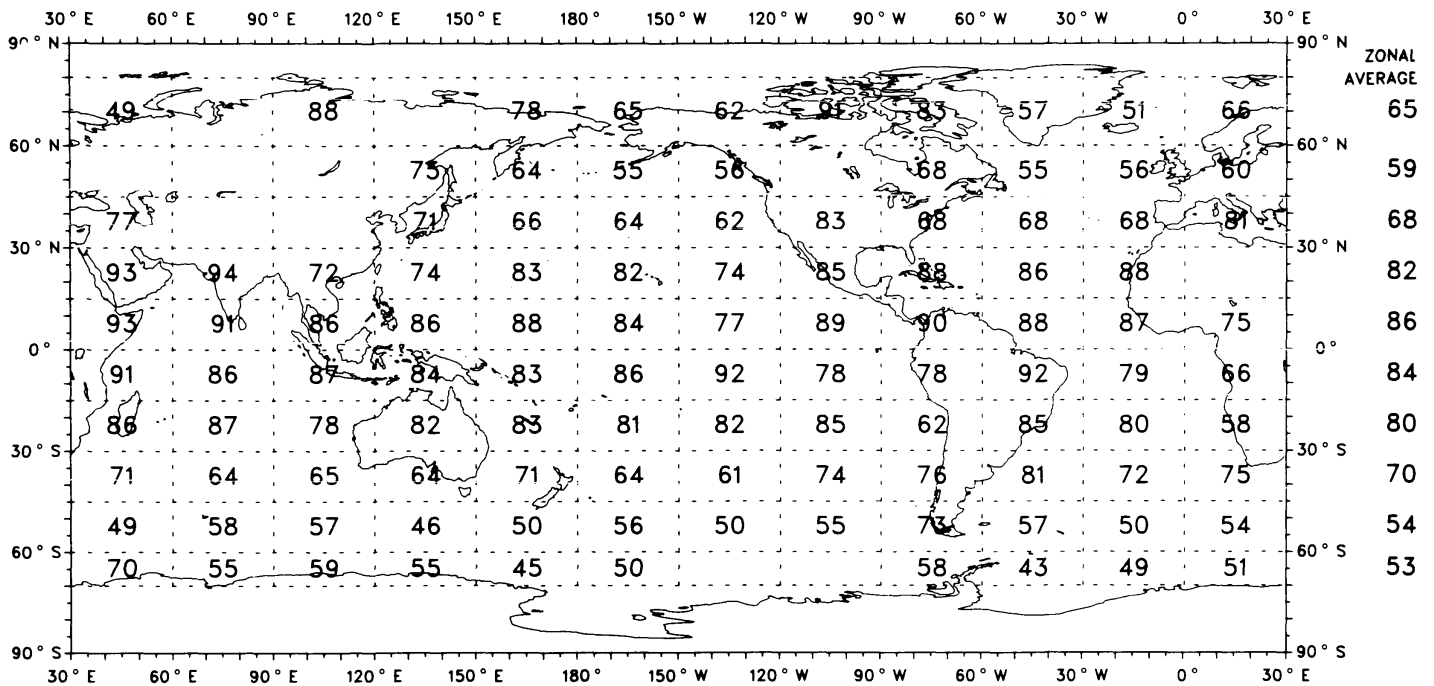
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

DJF (1965-1976)

Ocean Areas Only

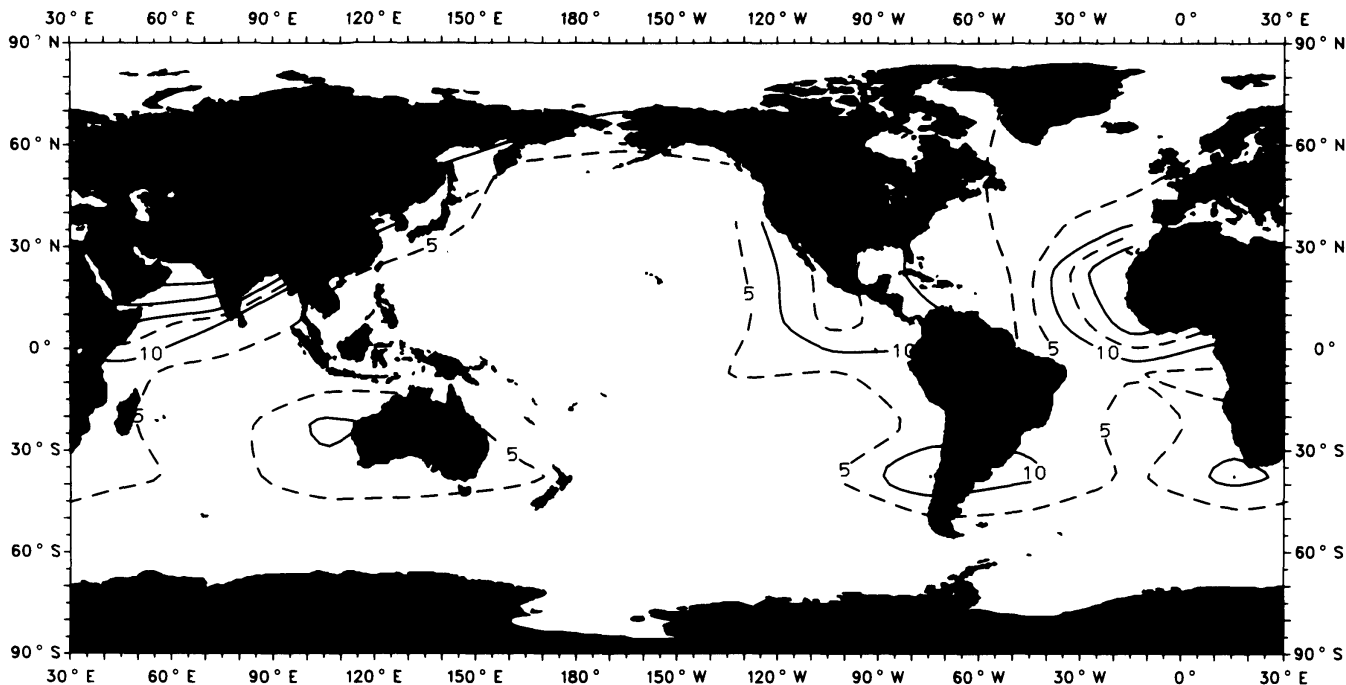


Map I-10

Frequency of Occurrence (Percent) of Completely Clear Sky

DJF (1965-1976)

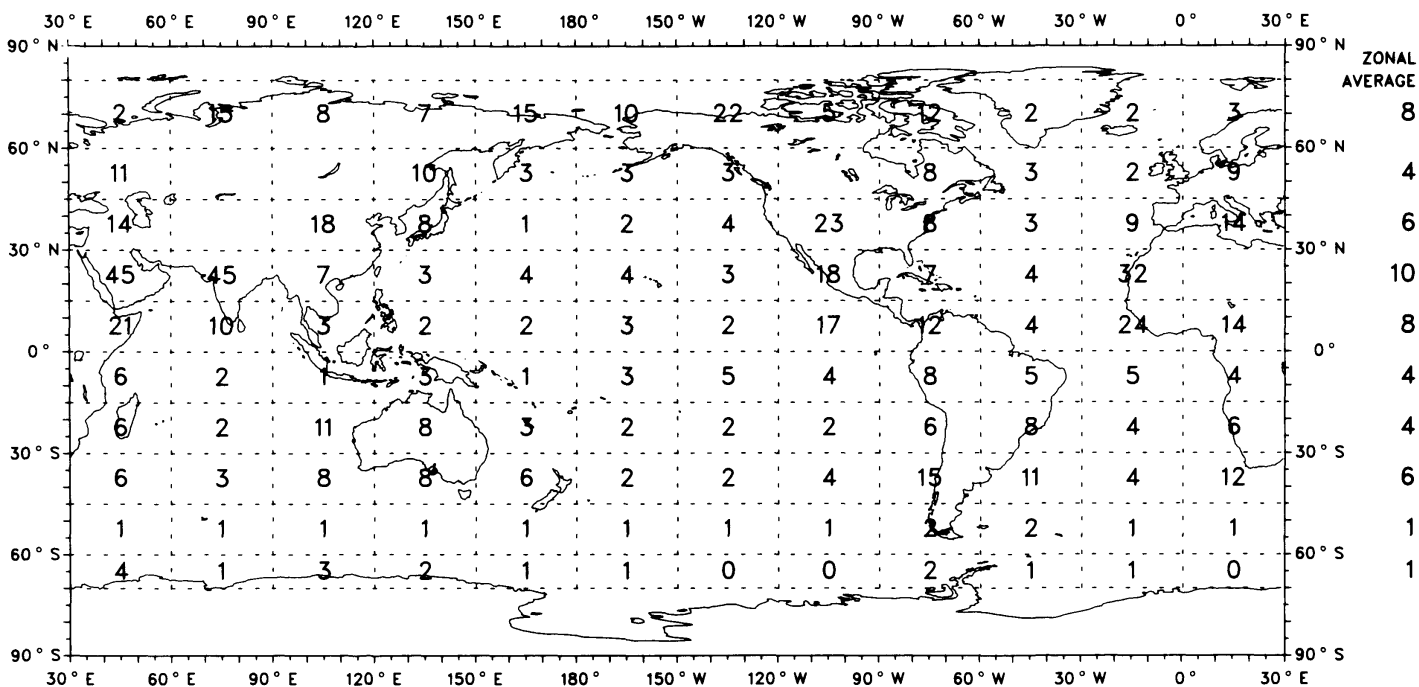
Ocean Areas Only



Frequency of Occurrence (Percent) of Completely Clear Sky

DJF (1965-1976)

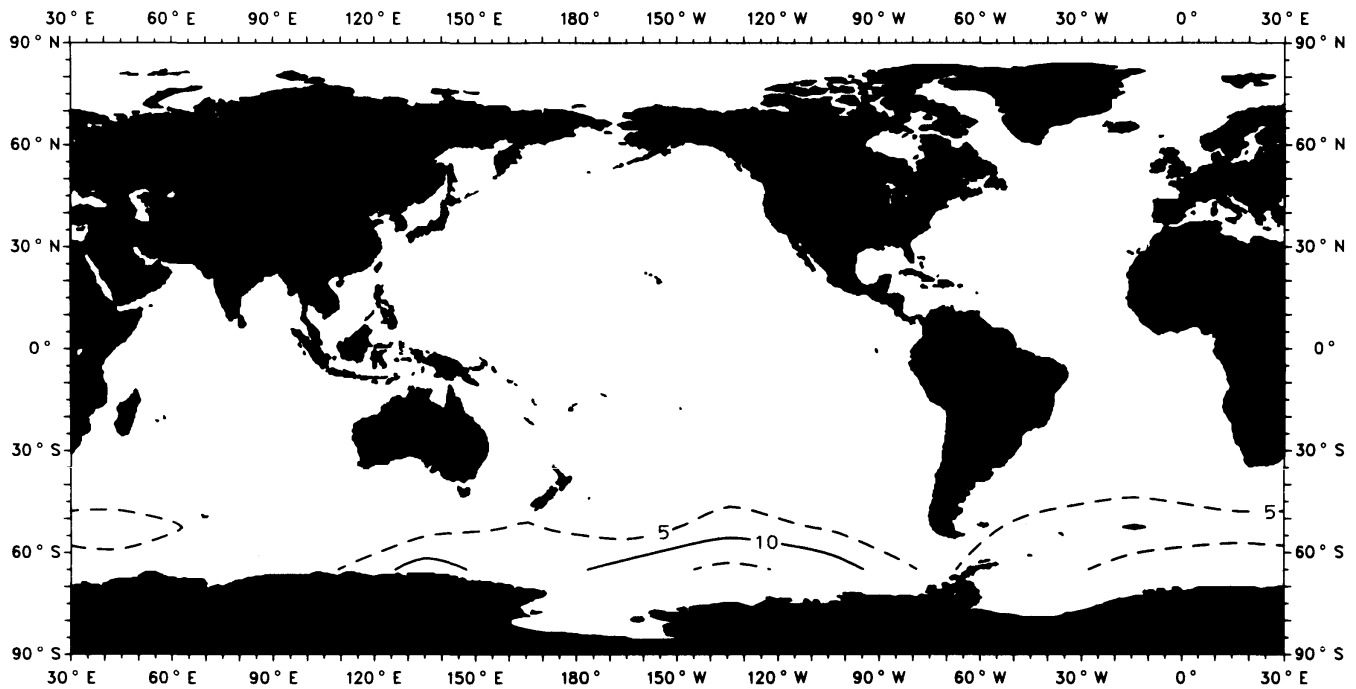
Ocean Areas Only



### Frequency of Occurrence (Percent) of Sky Obscured due to Fog

DJF (1965-1976)

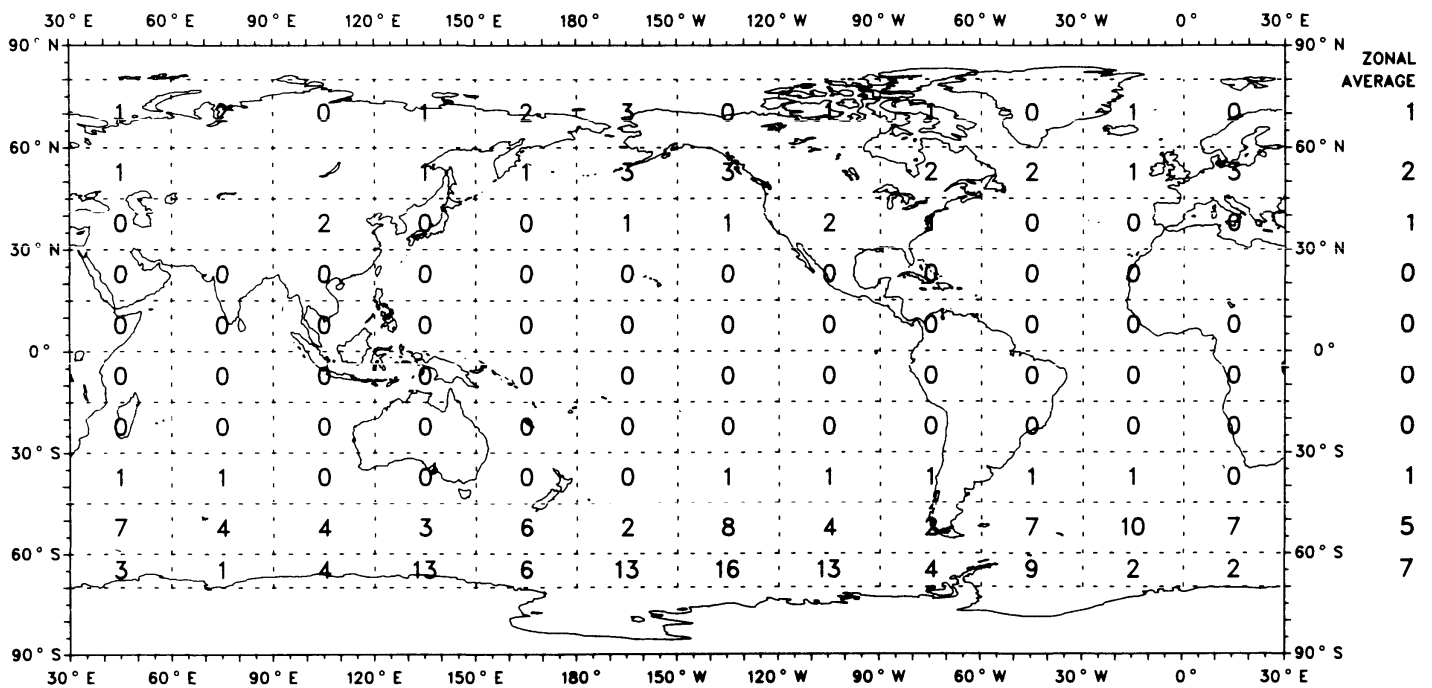
Ocean Areas Only



### Frequency of Occurrence (Percent) of Sky Obscured due to Fog

DJF (1965-1976)

Ocean Areas Only

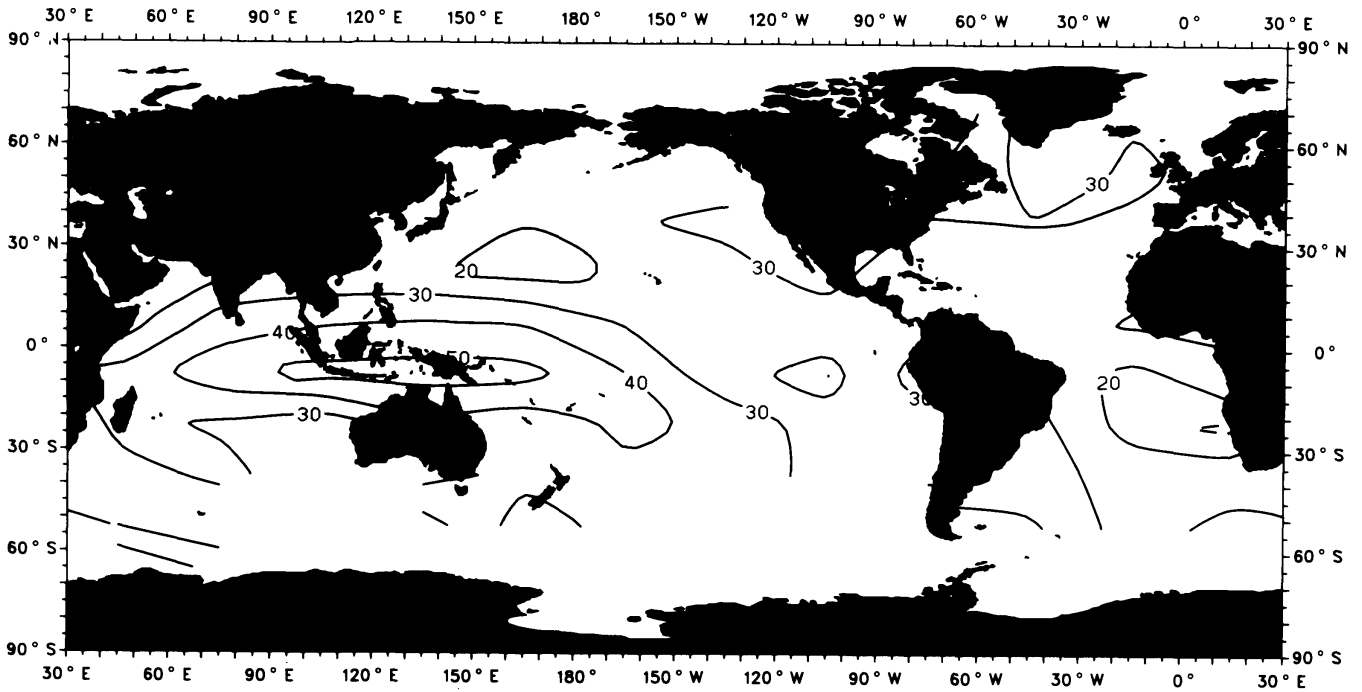


Map I-12

Frequency of Occurrence (Percent) of Ci/Cs/Cc

DJF (1965-1976)

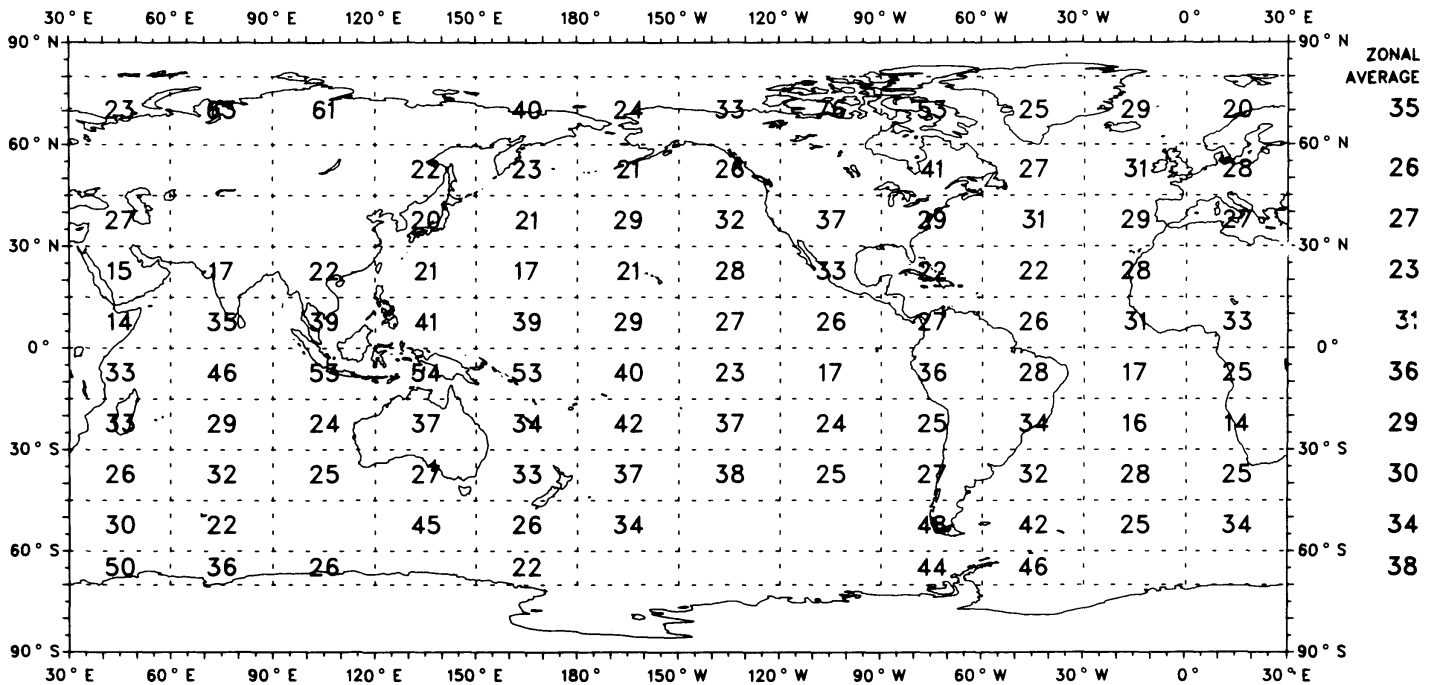
Ocean Areas Only



Frequency of Occurrence (Percent) of Ci/Cs/Cc

DJF (1965-1976)

Ocean Areas Only



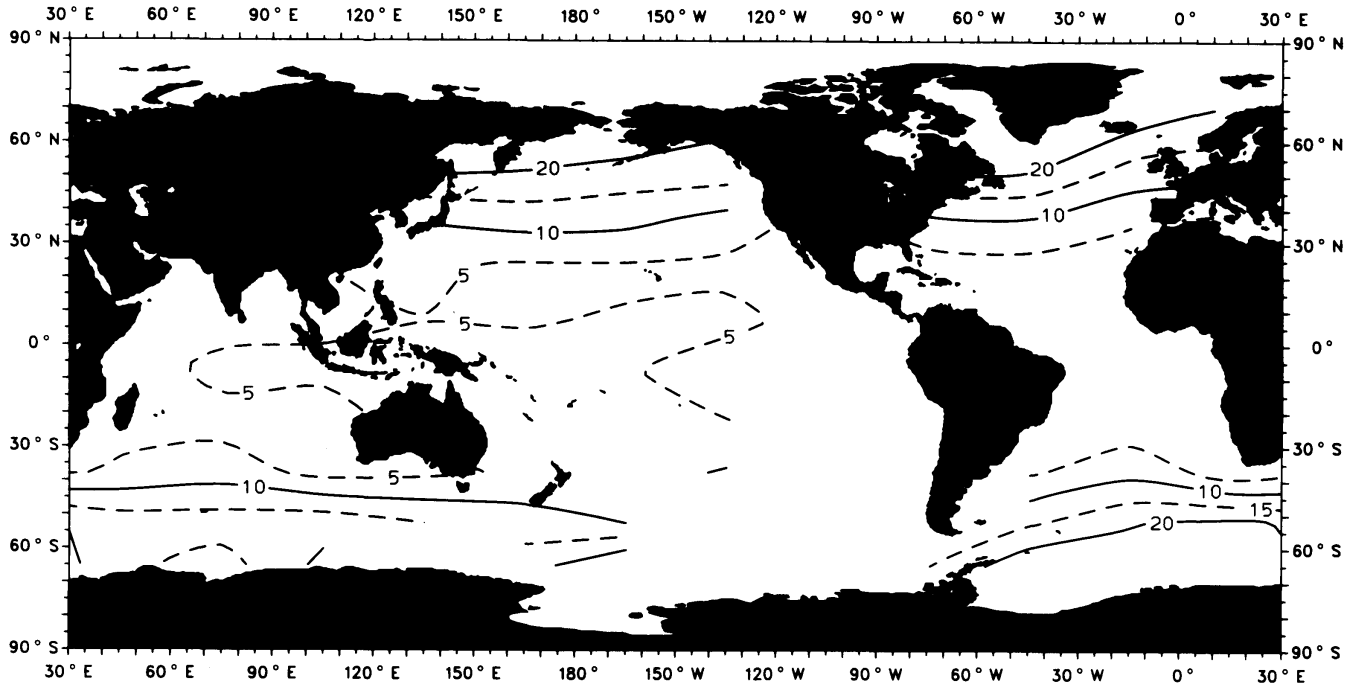


Map I-14

Frequency of Occurrence (Percent) of Nimbostratus

DJF (1965-1976)

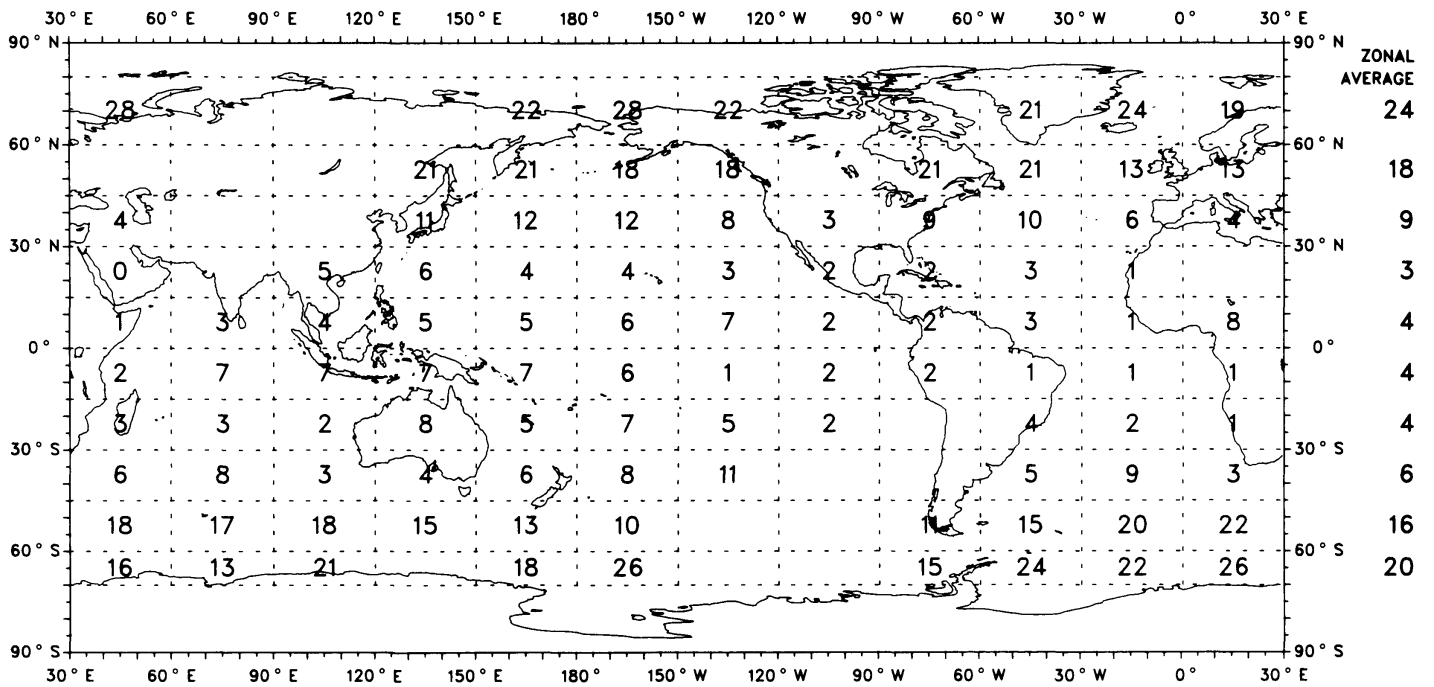
Ocean Areas Only



Frequency of Occurrence (Percent) of Nimbostratus

DJF (1965-1976)

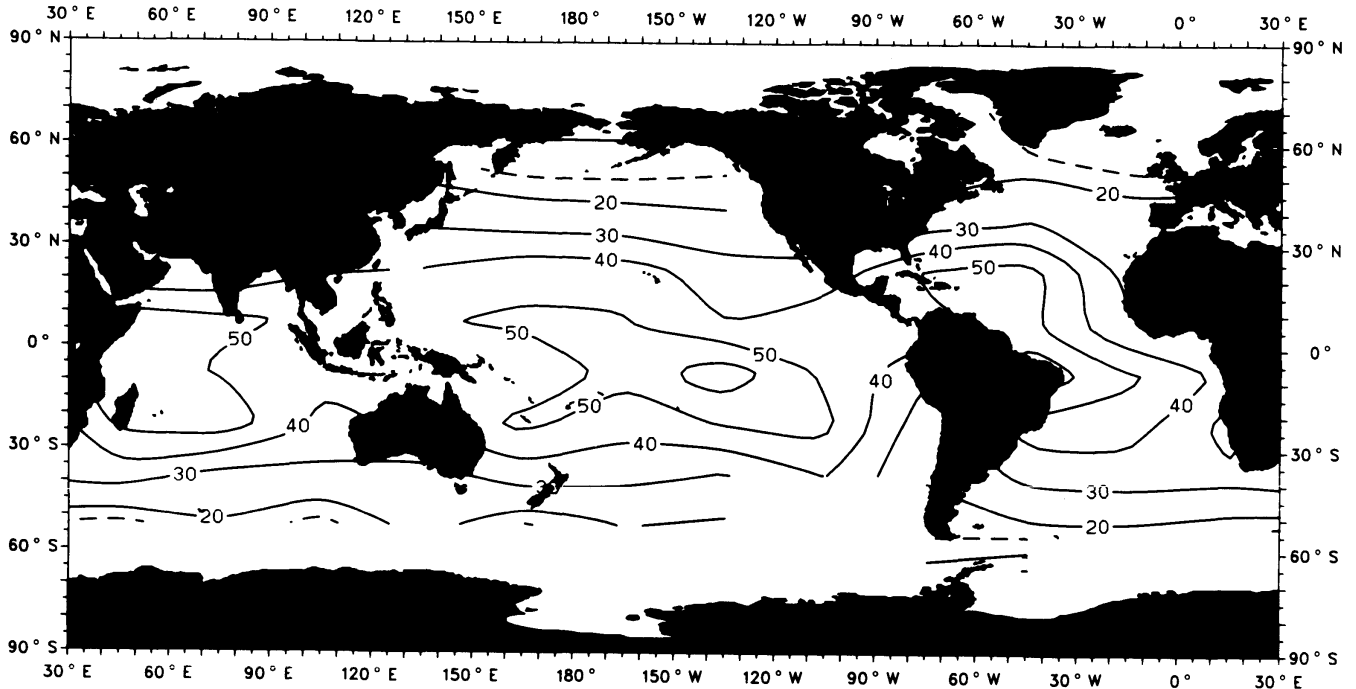
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

DJF (1965-1976)

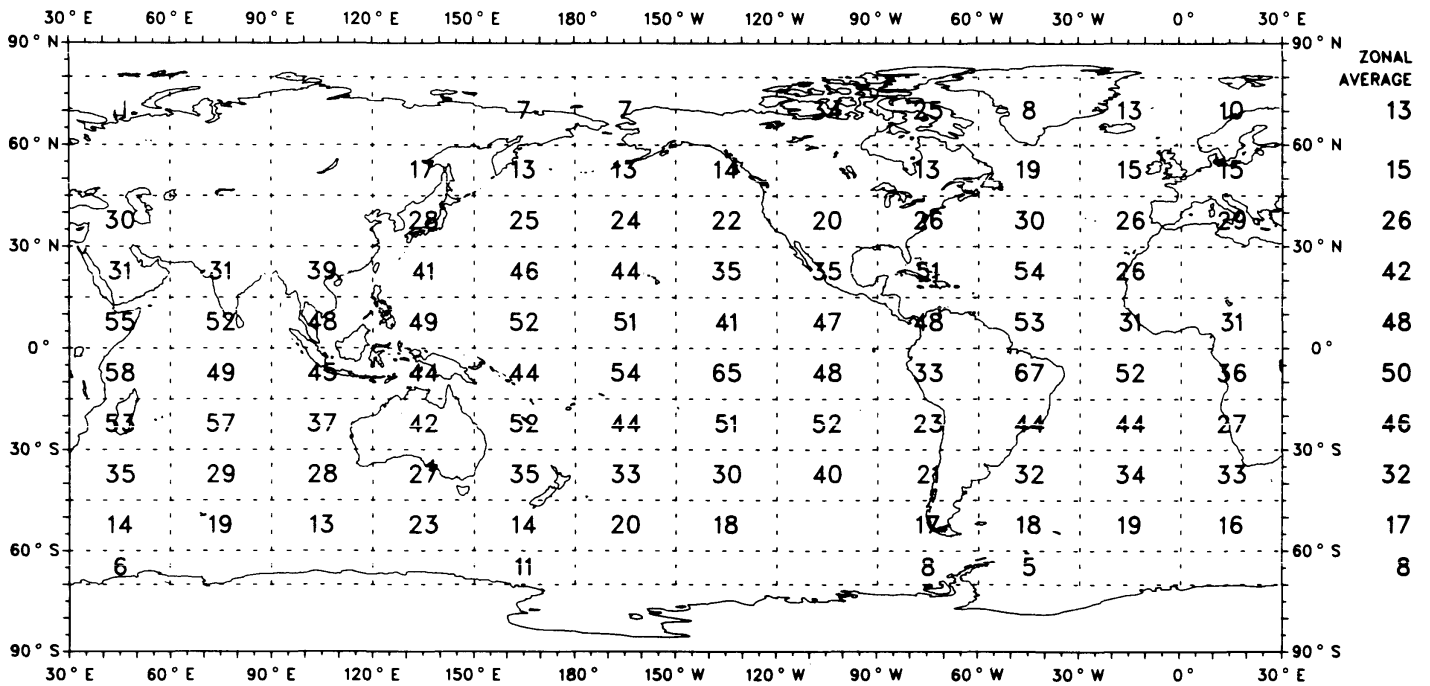
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

DJF (1965-1976)

Ocean Areas Only

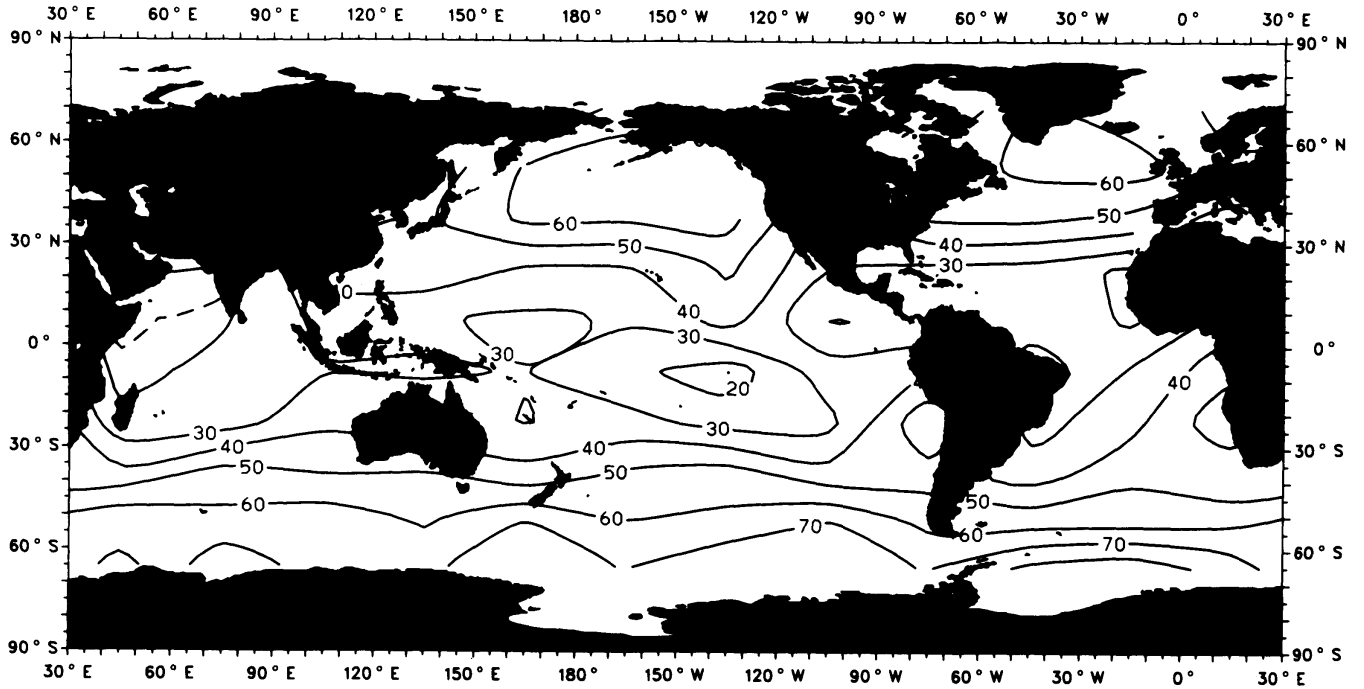


Map I-16

Frequency of Occurrence (Percent) of St/Sc

DJF (1965-1976)

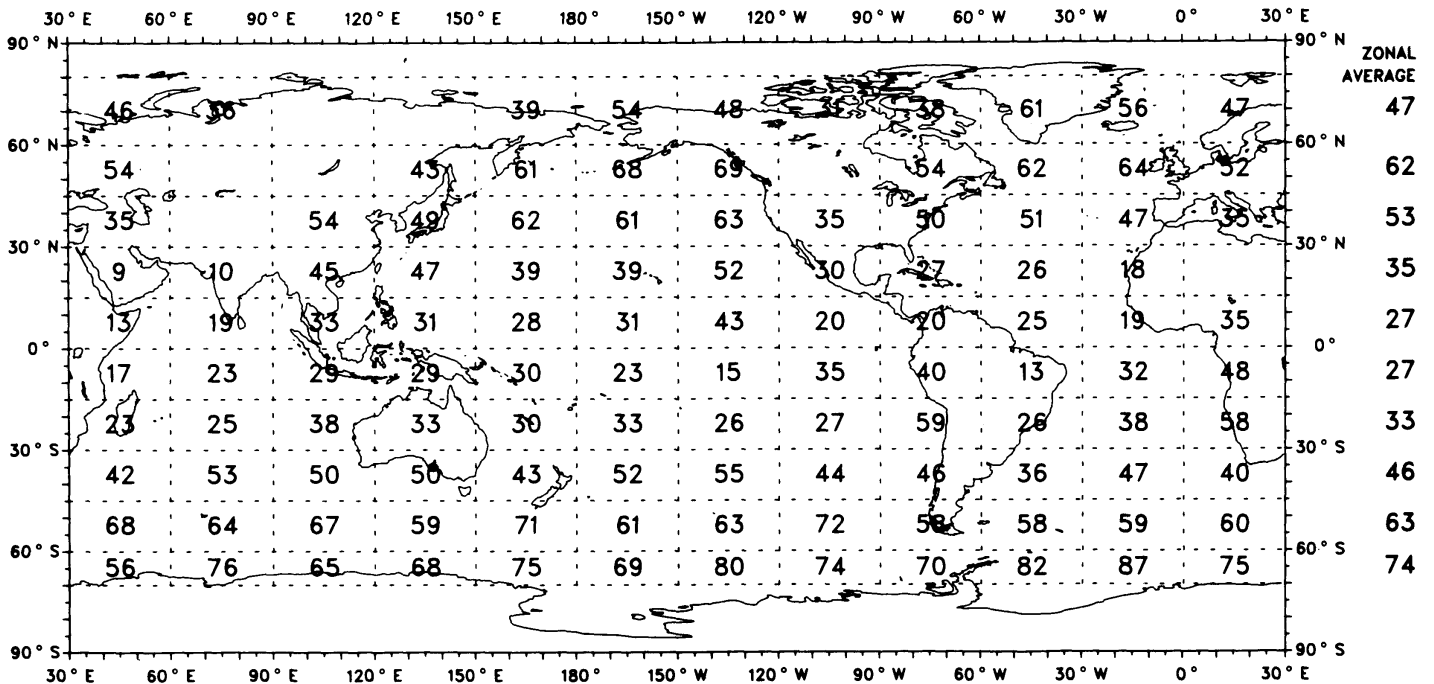
Ocean Areas Only



Frequency of Occurrence (Percent) of St/Sc

DJF (1965-1976)

Ocean Areas Only



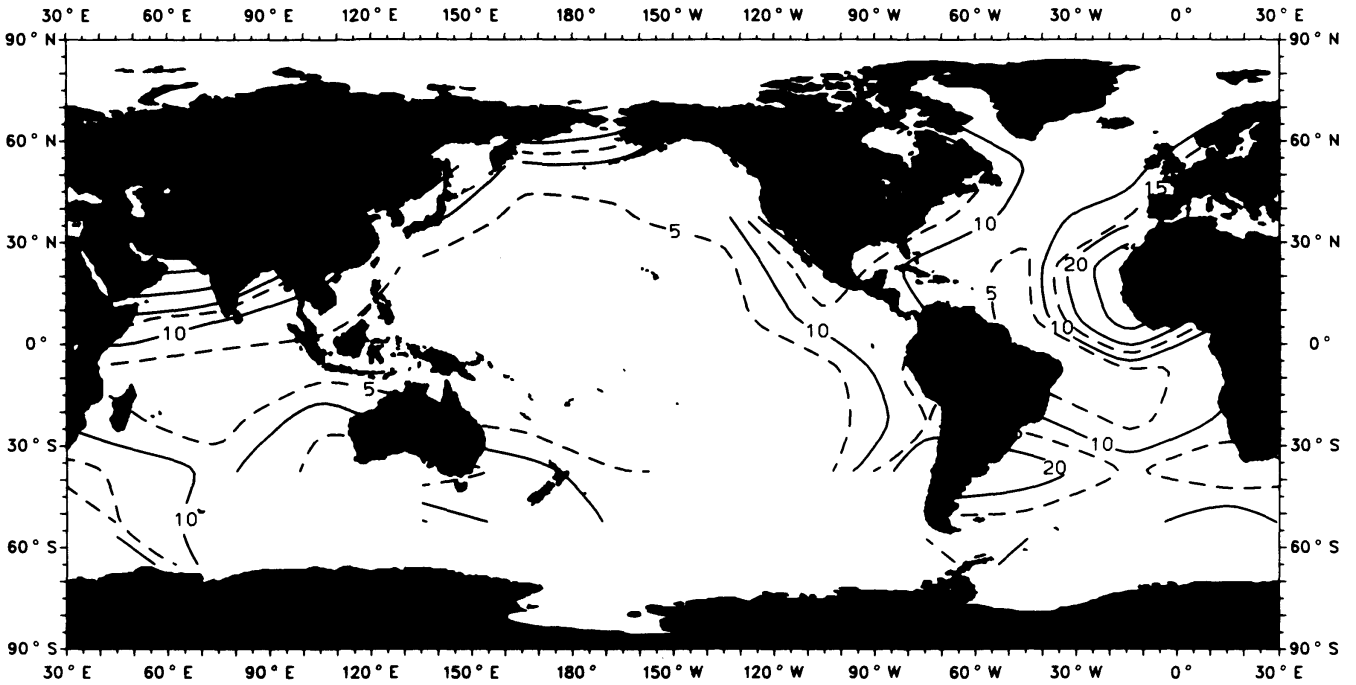


Map I-18

Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

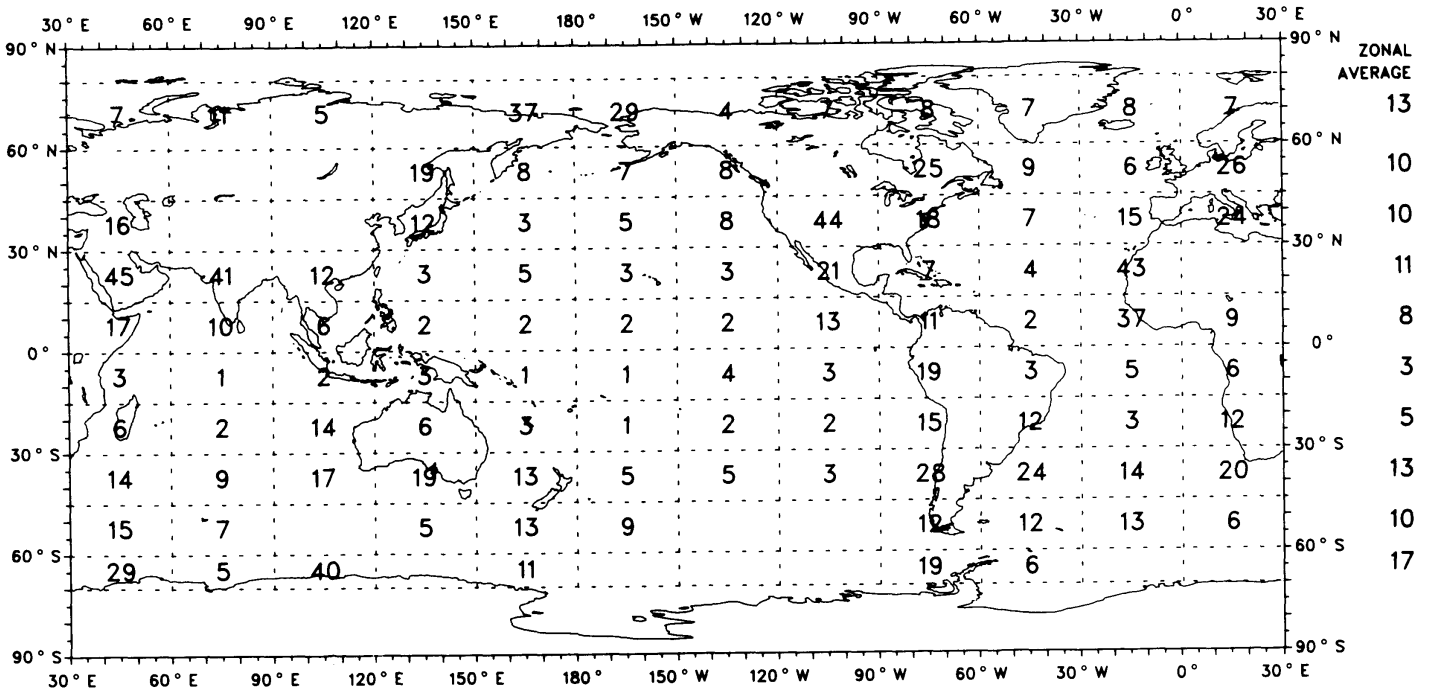
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

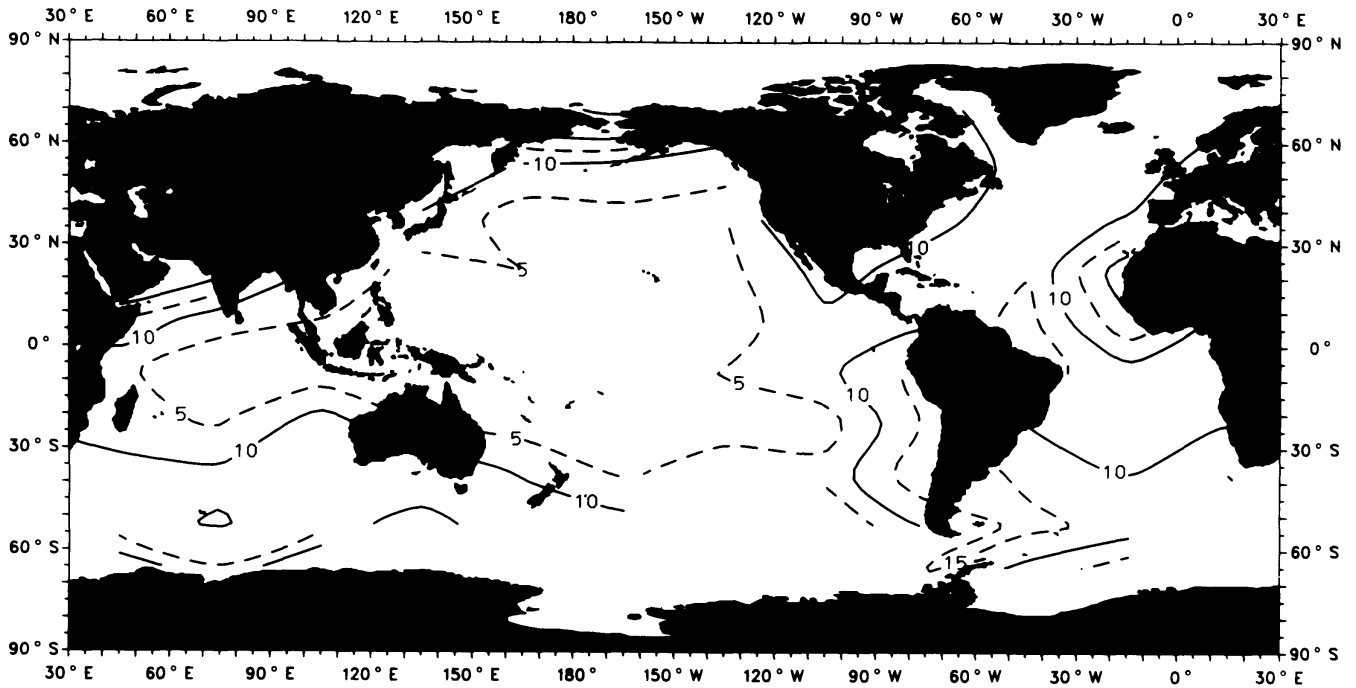
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

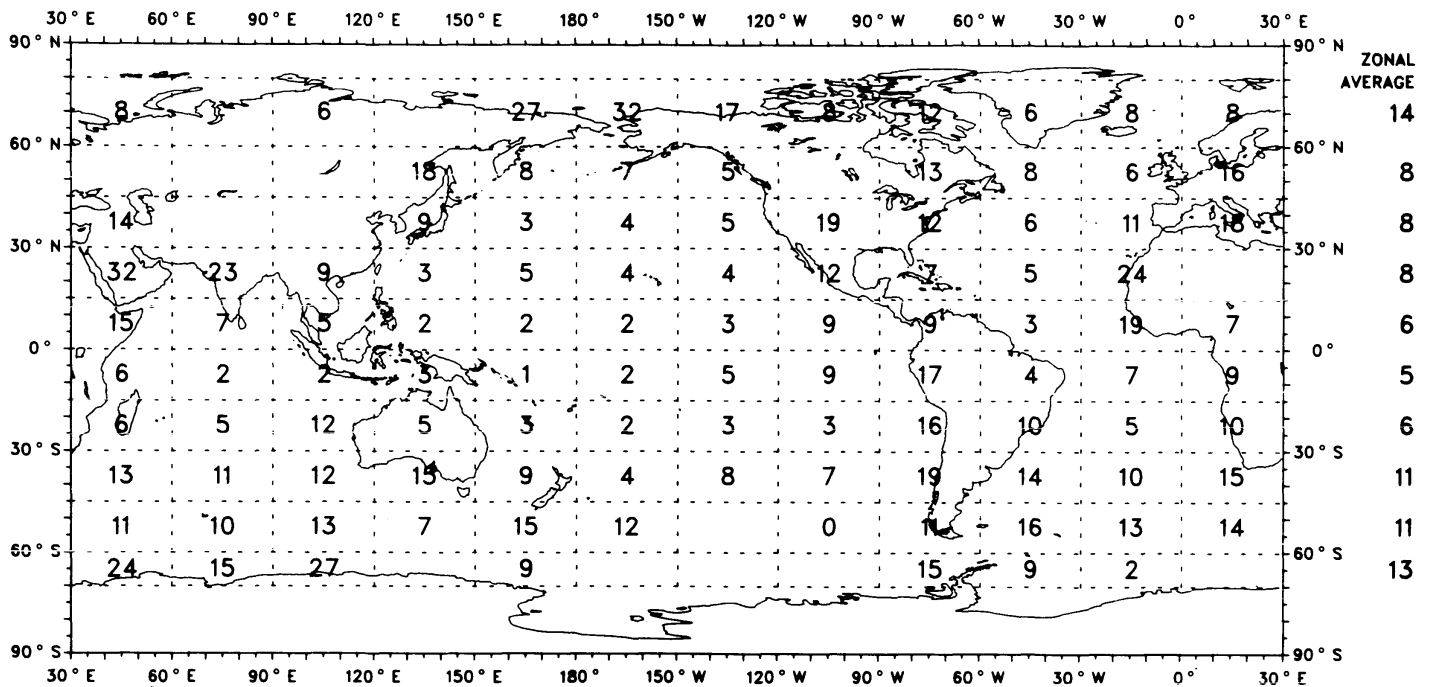
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

Ocean Areas Only

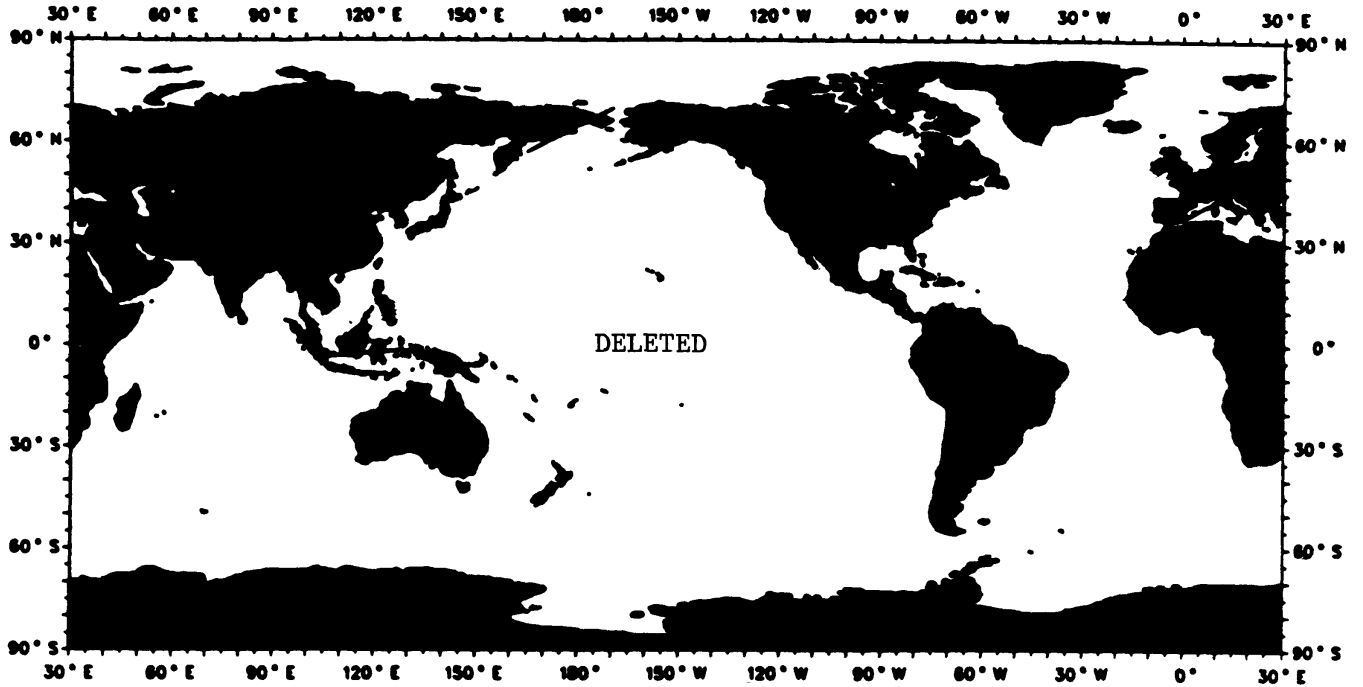


Map I-20

Given Nimbostratus, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

Ocean Areas Only

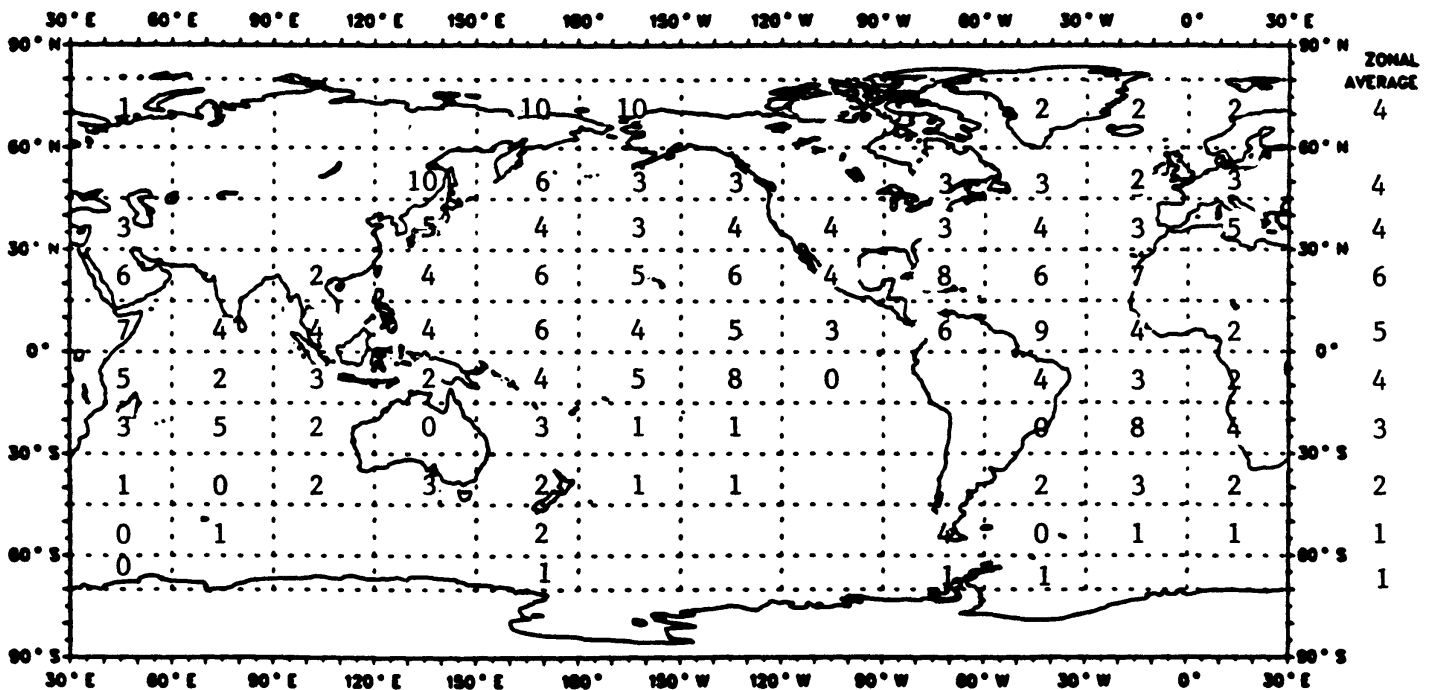


Given Nimbostratus, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

Revised 1988

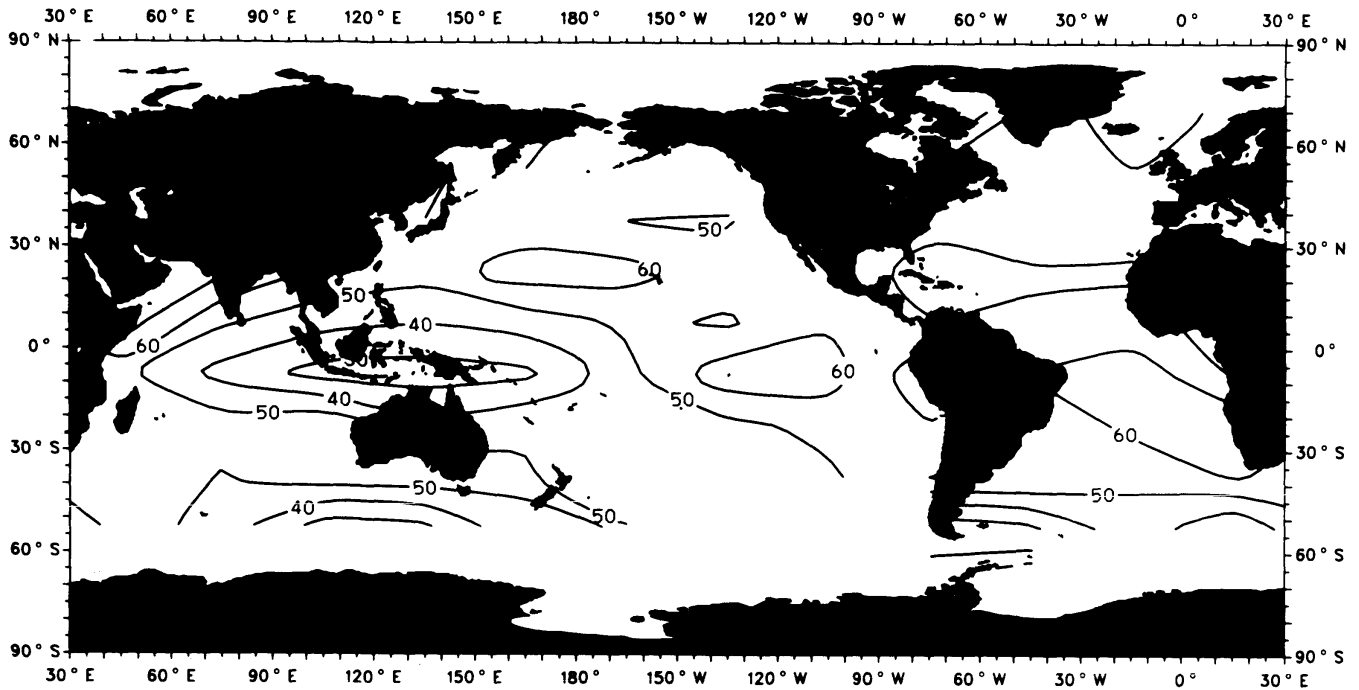
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

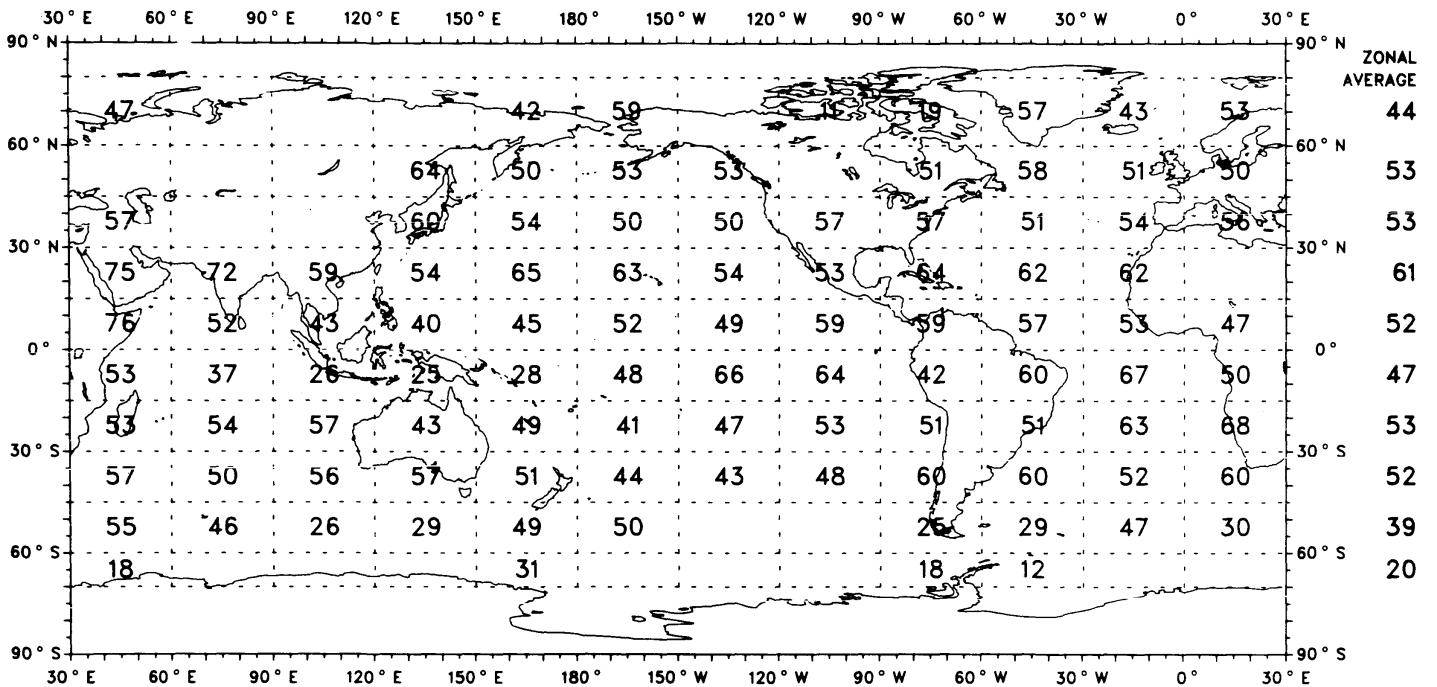
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

DJF (1965-1976)

Ocean Areas Only





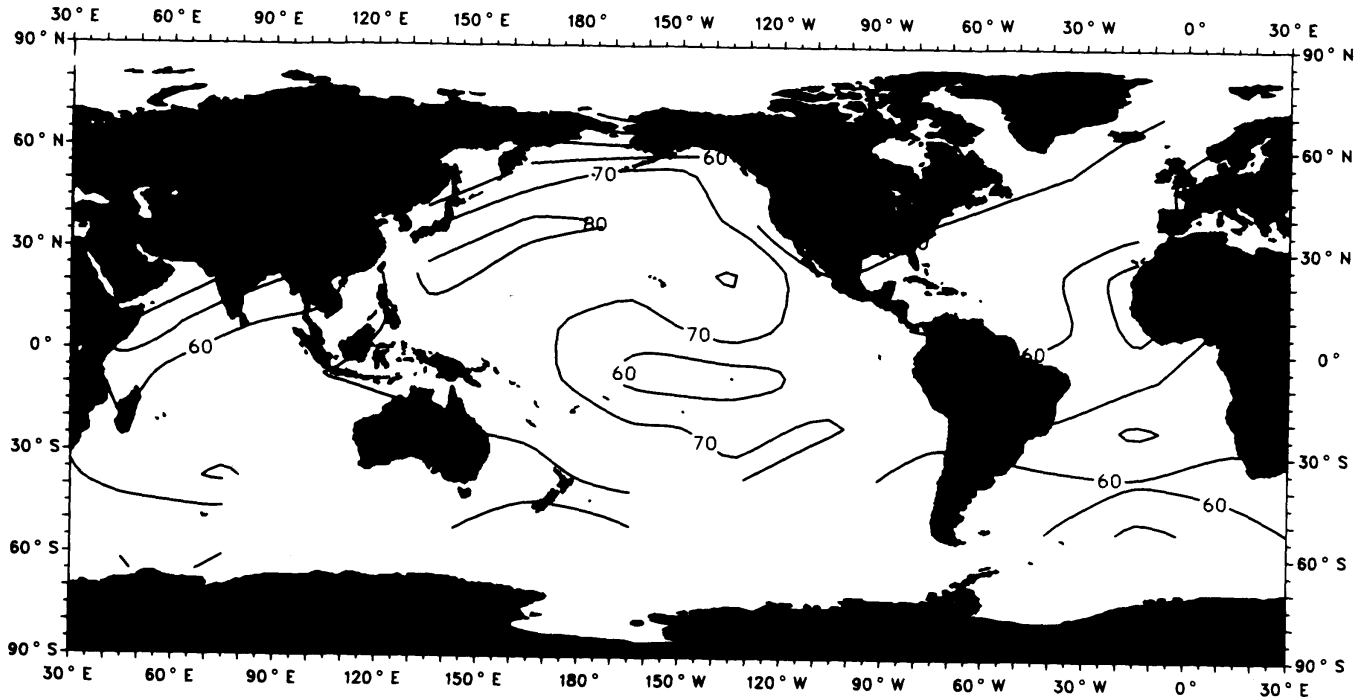


Map I-24

Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

DJF (1965-1976)

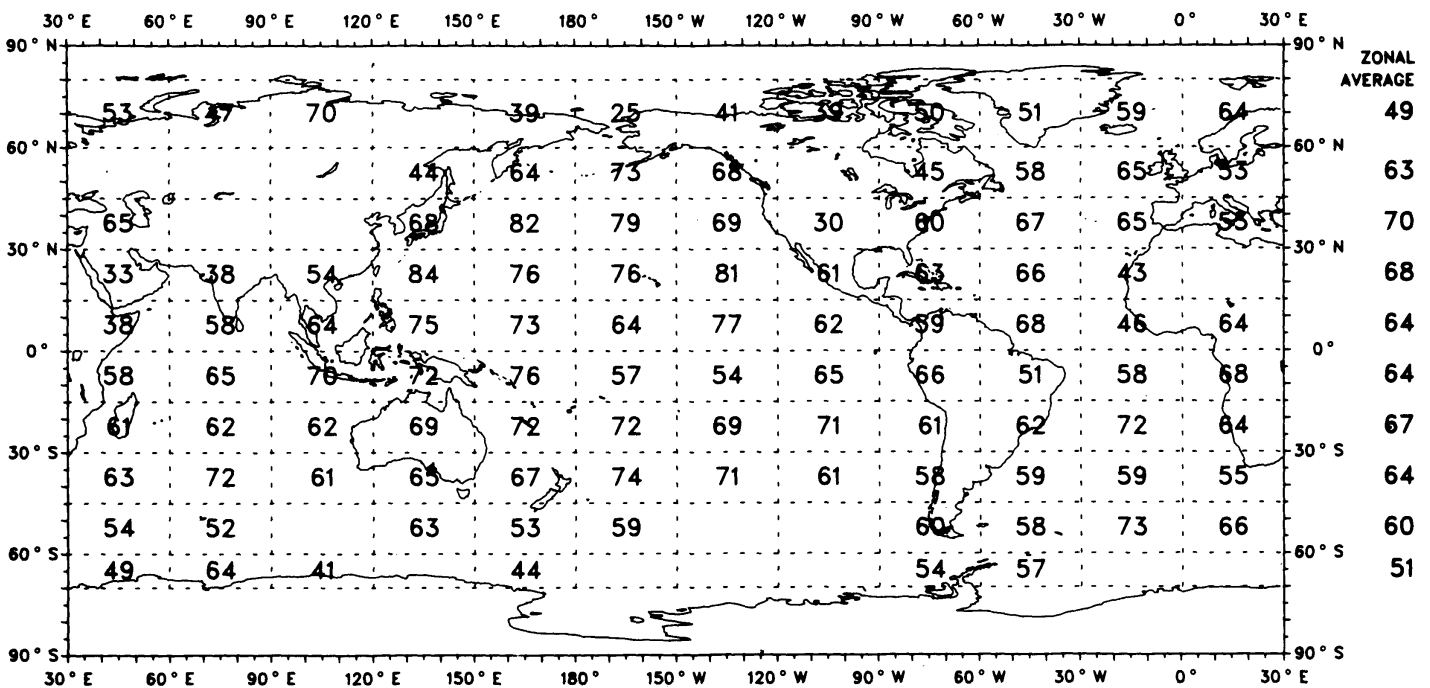
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

DJF (1965-1976)

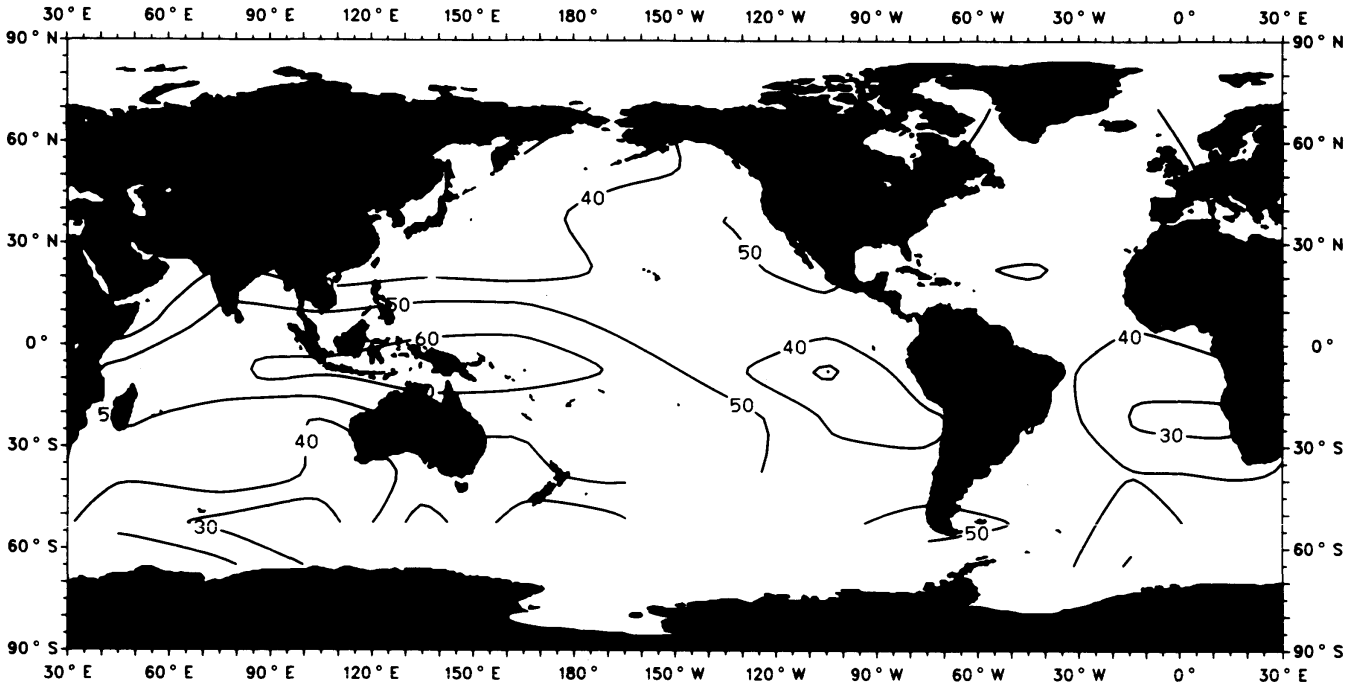
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

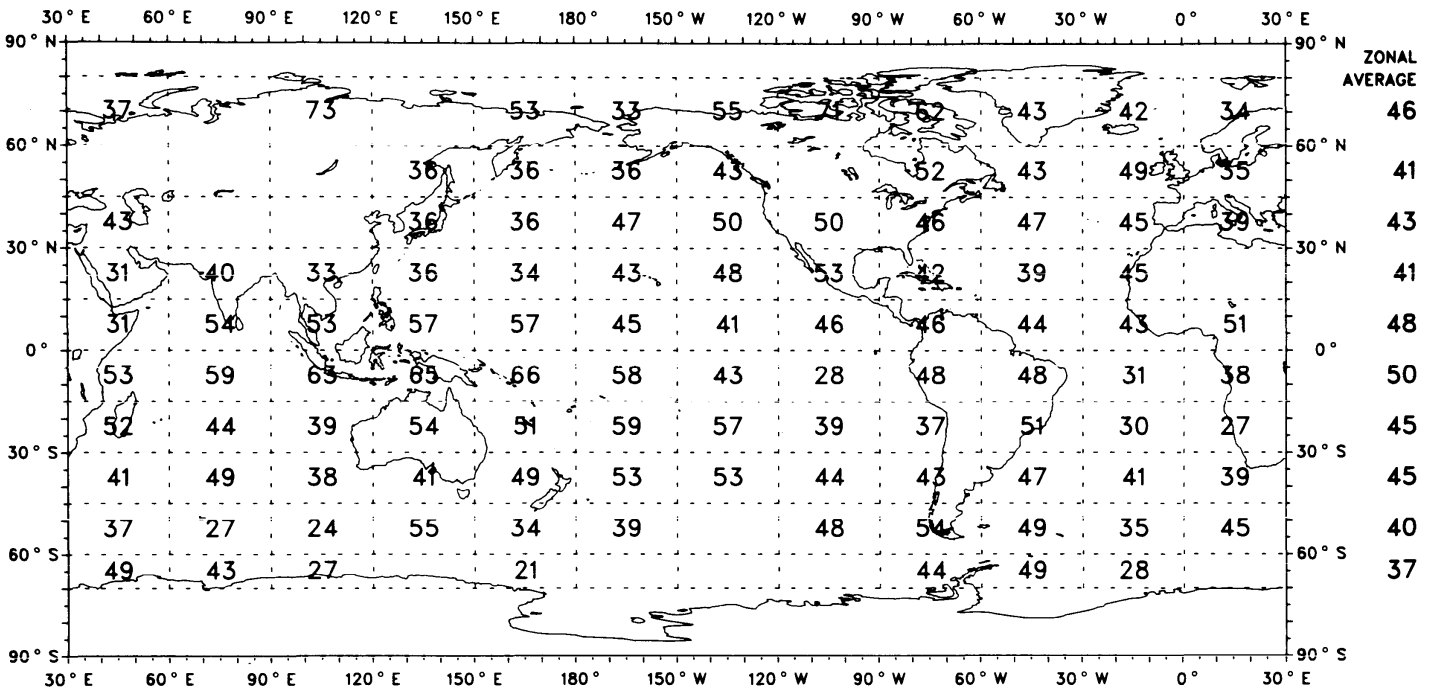
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

Ocean Areas Only





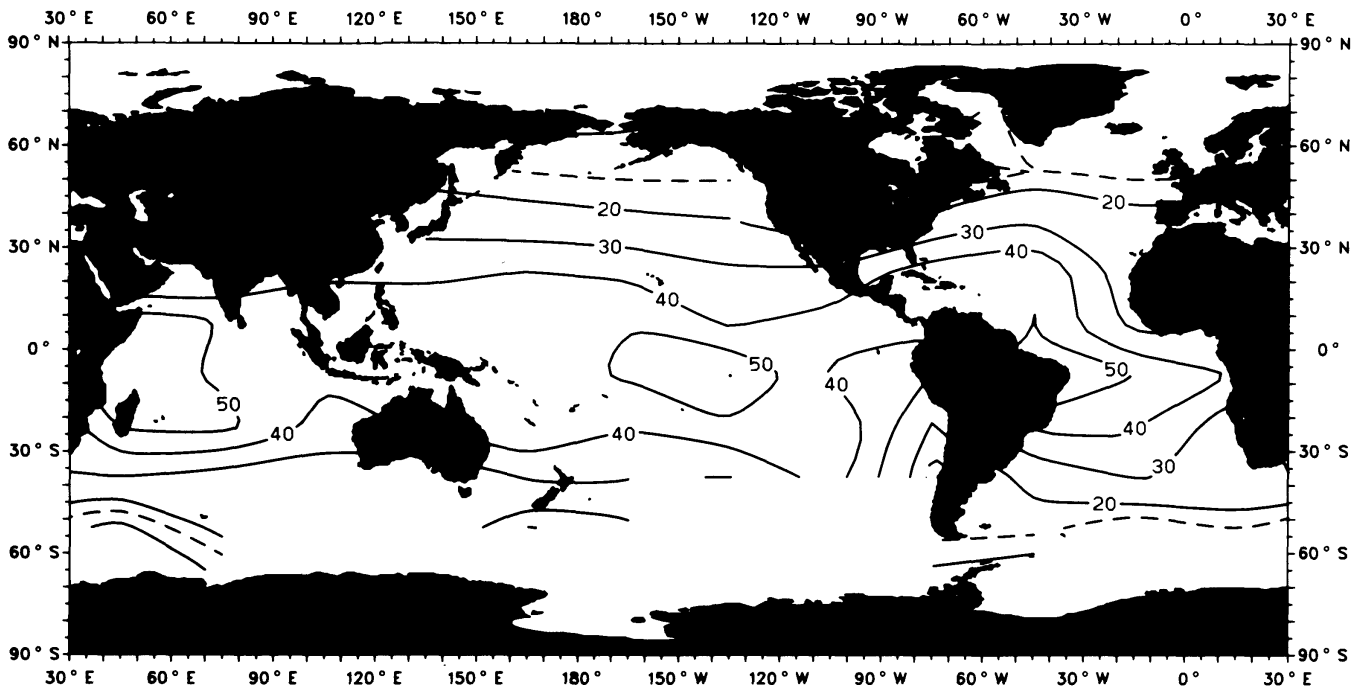


Map I-28

Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulus is Also Present

DJF (1965-1976)

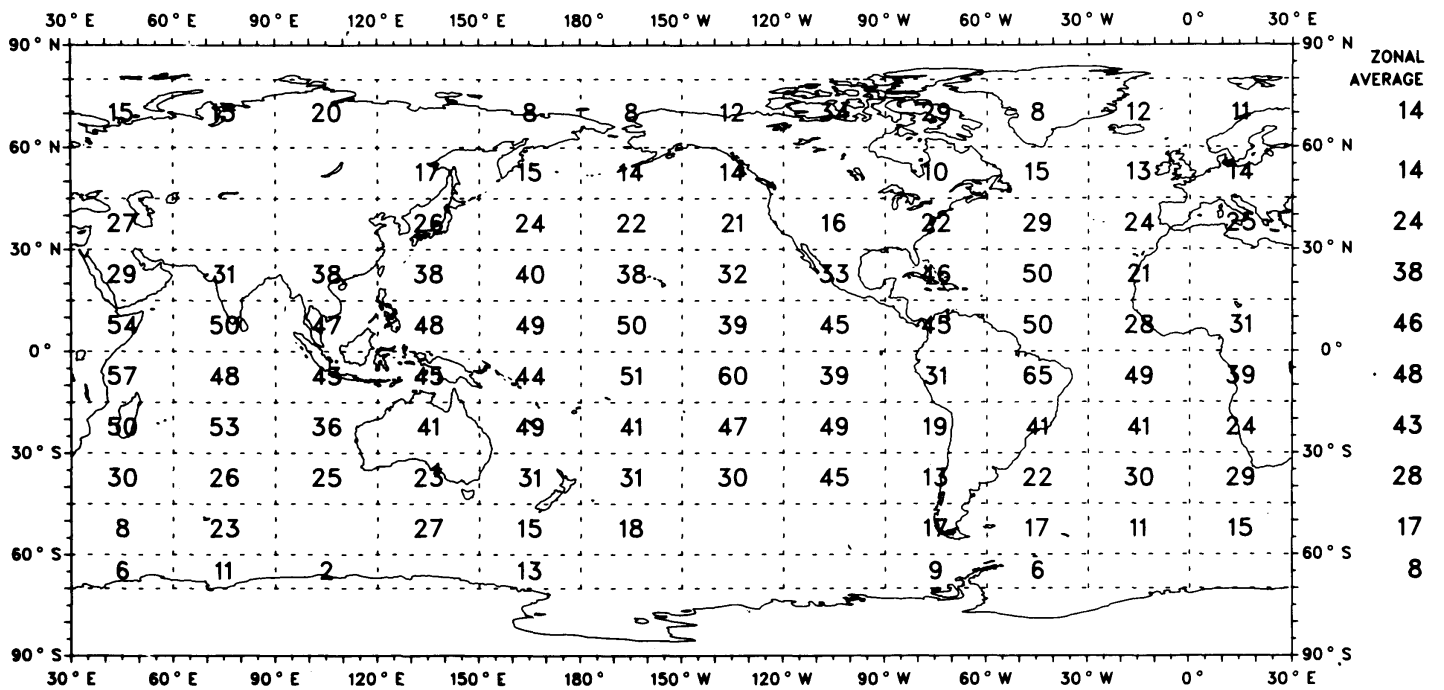
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulus is Also Present

DJF (1965-1976)

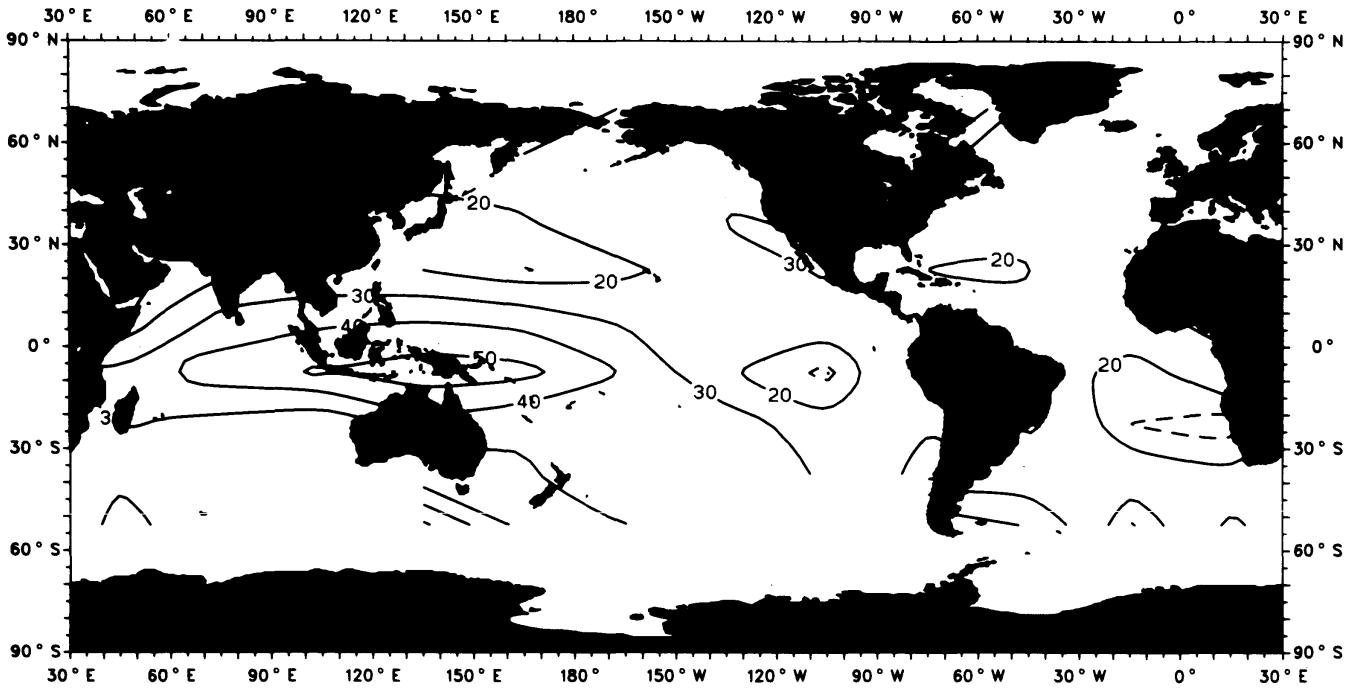
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

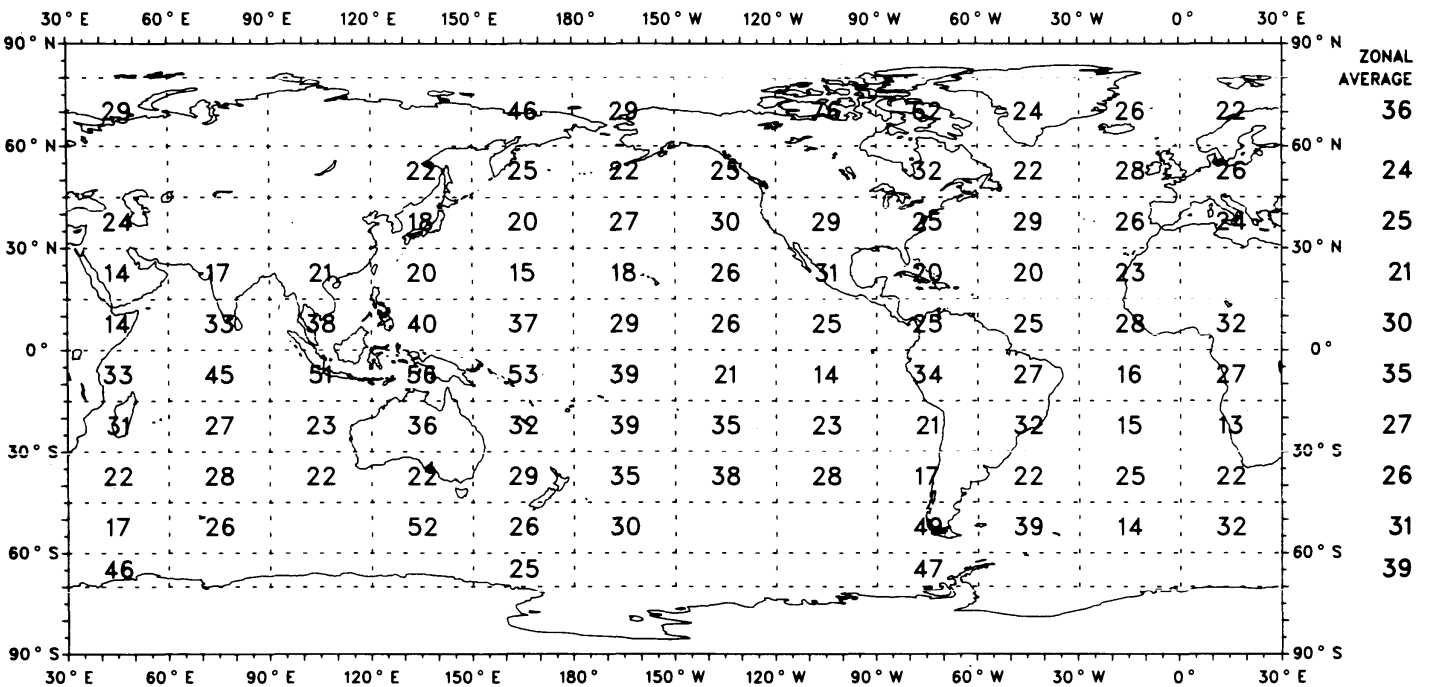
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

Ocean Areas Only

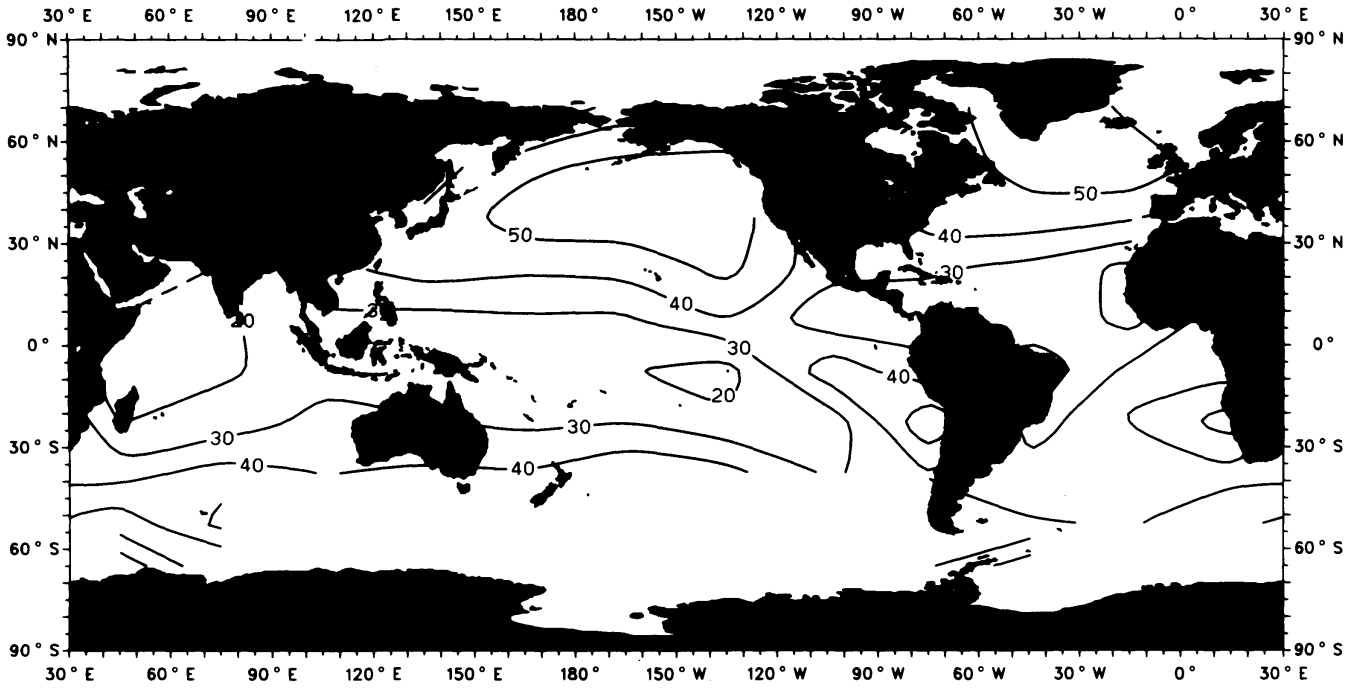


Map I-30

Given  $C_i/C_s/C_c$ , Probability (Percent) That  $St/Sc$  is Also Present

DJF (1965-1976)

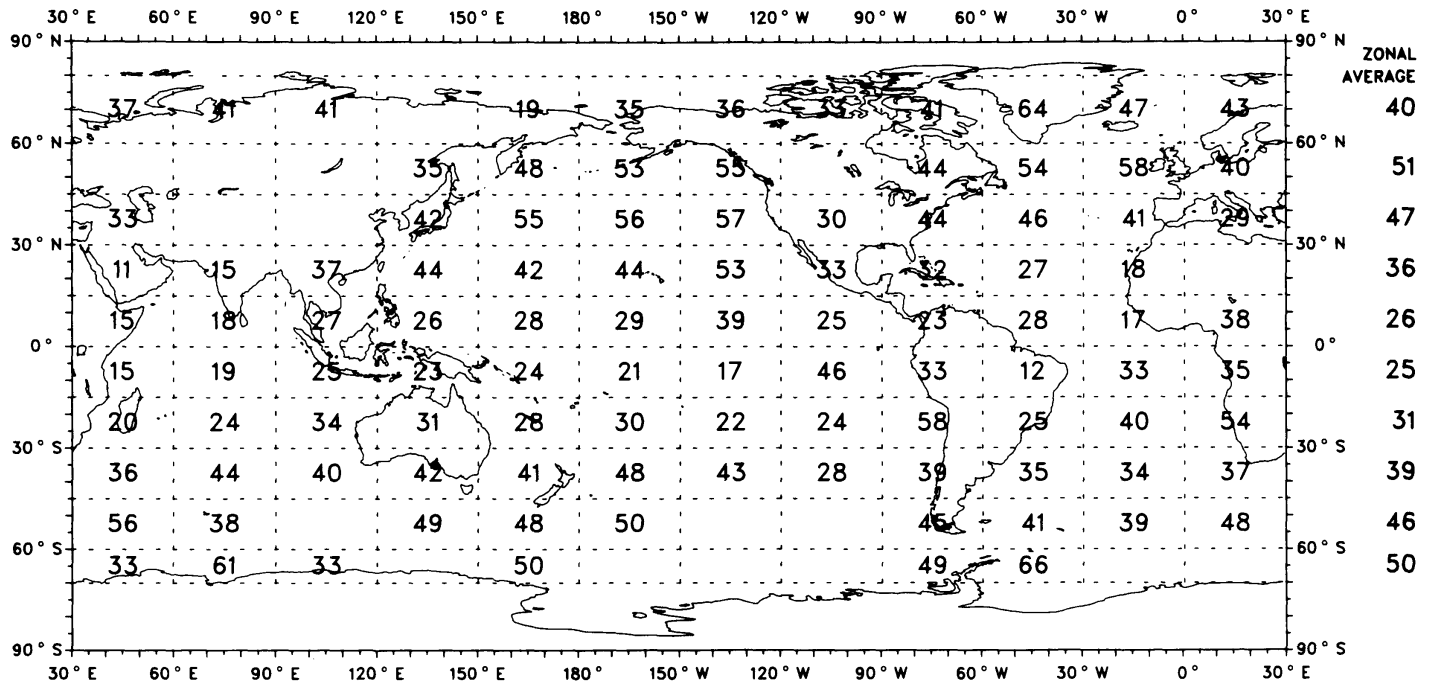
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That  $St/Sc$  is Also Present

DJF (1965-1976)

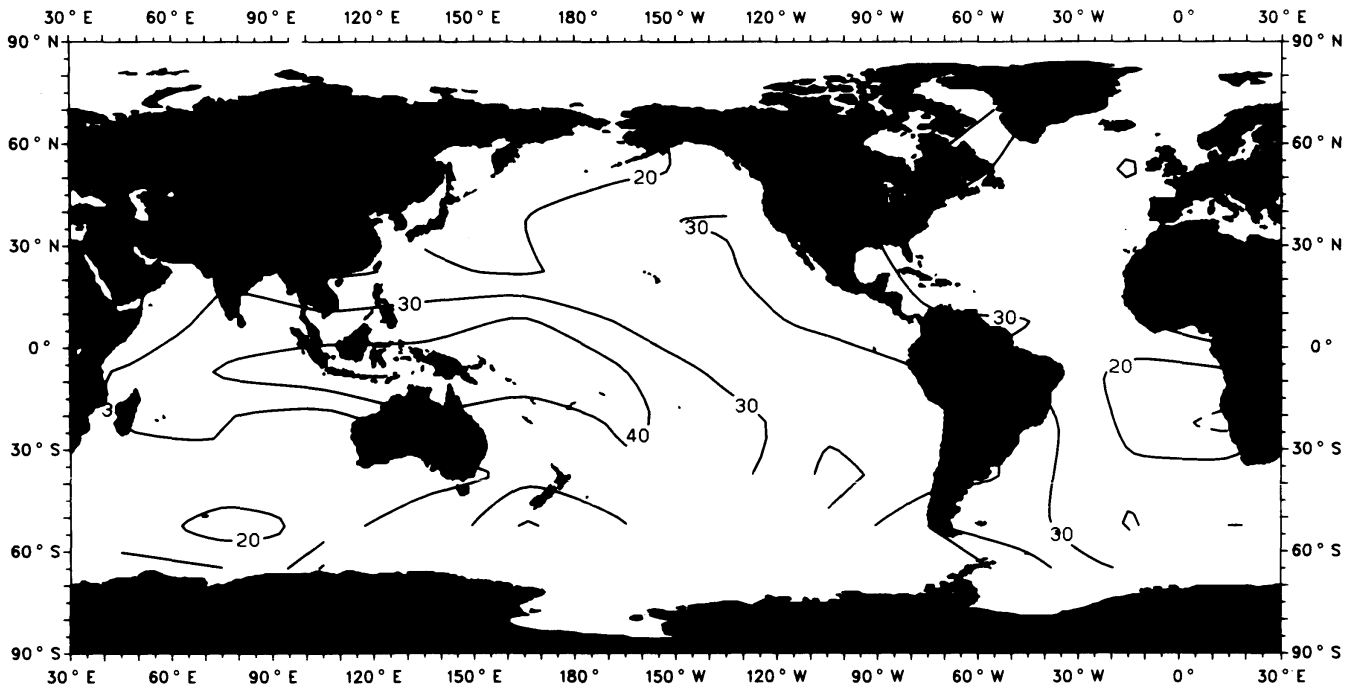
Ocean Areas Only



Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

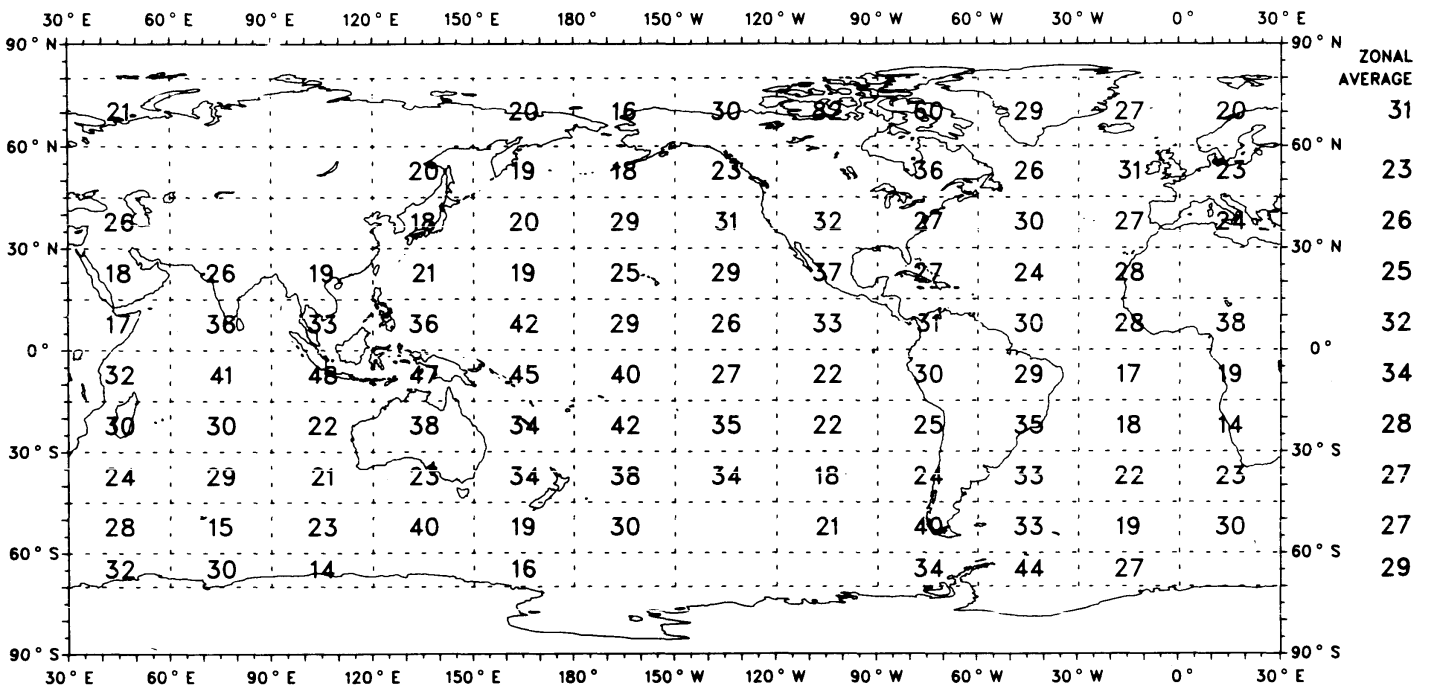
Ocean Areas Only



Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

Ocean Areas Only

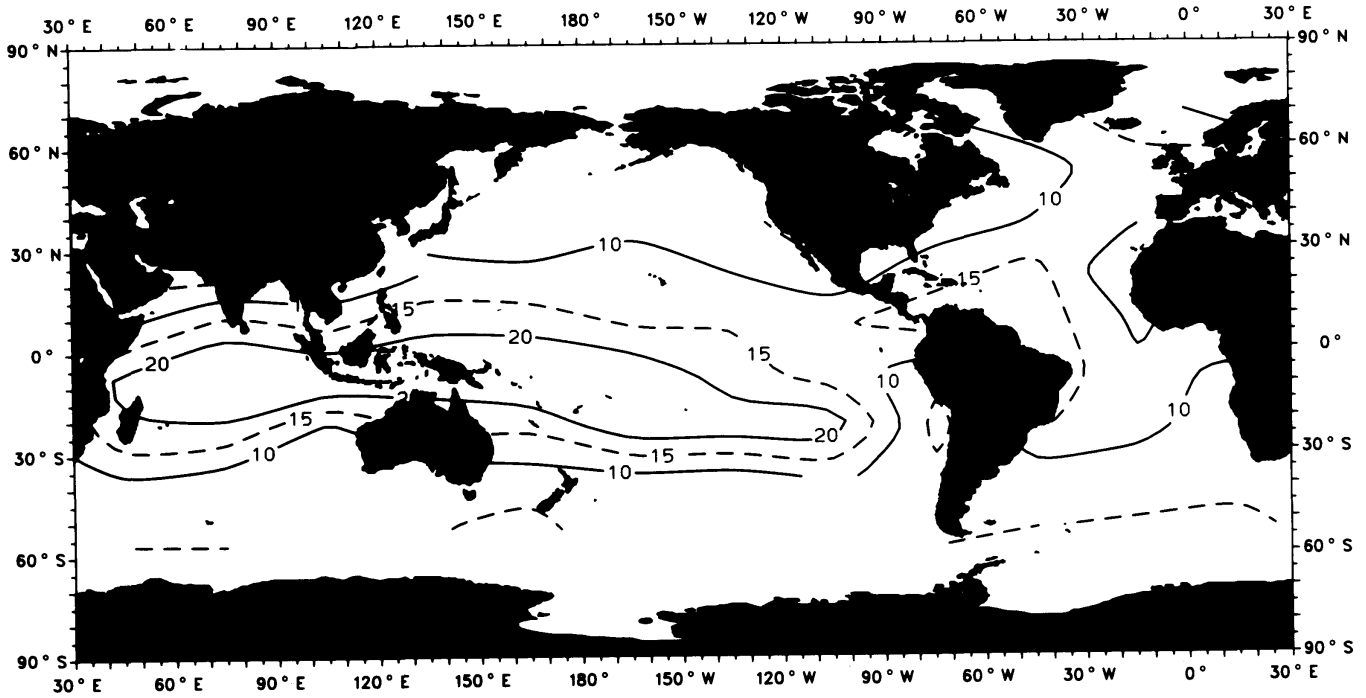


Map I-32

Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

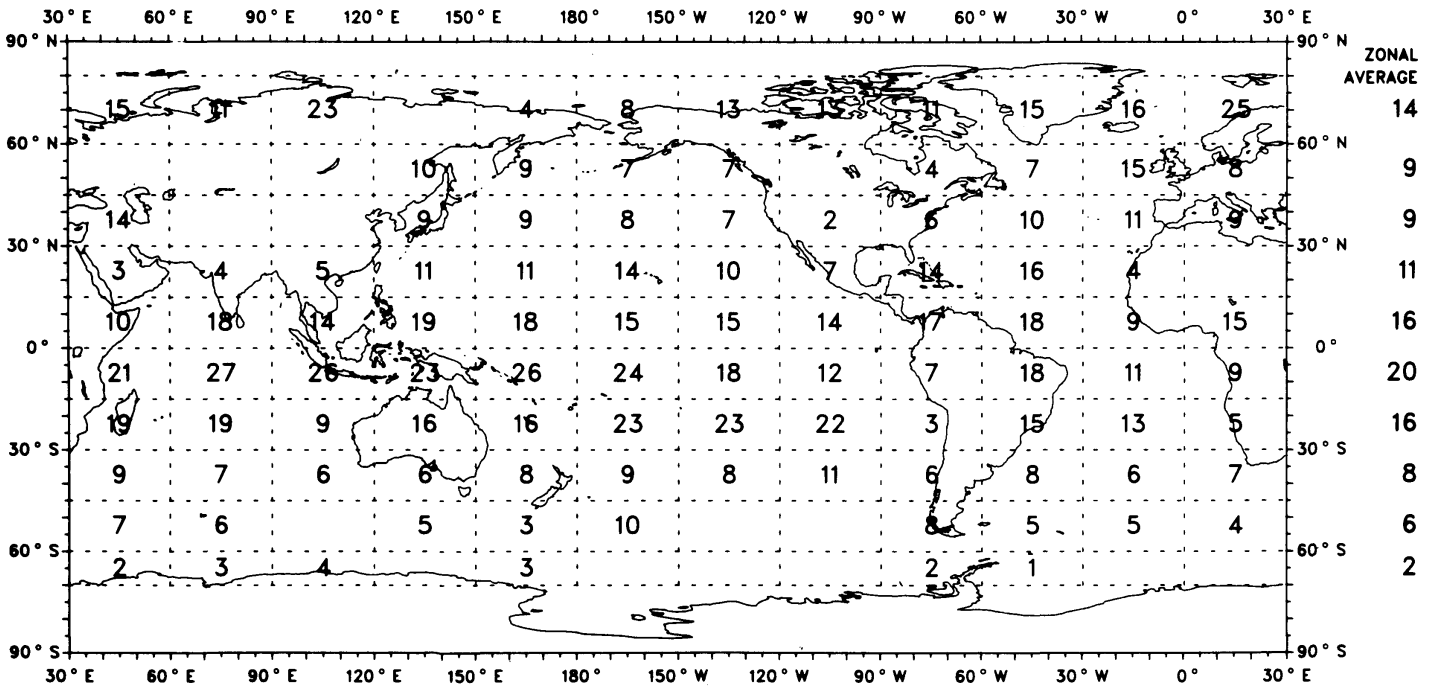
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

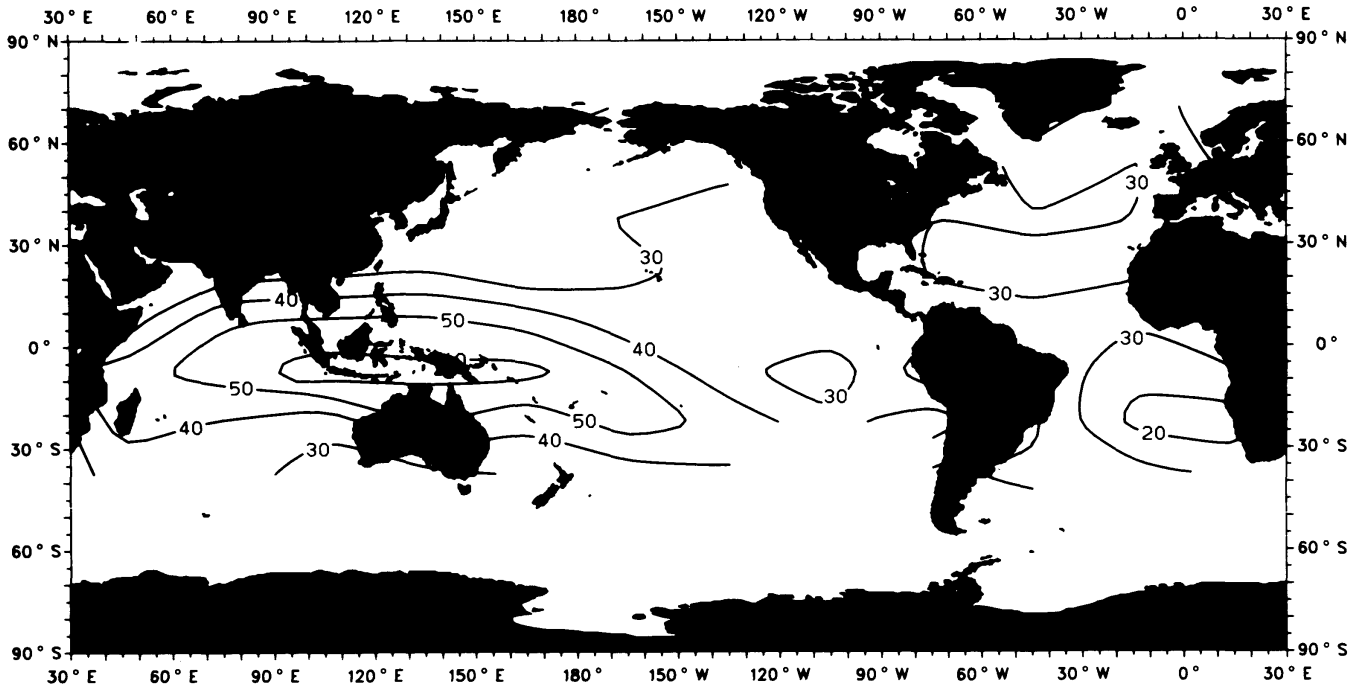
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

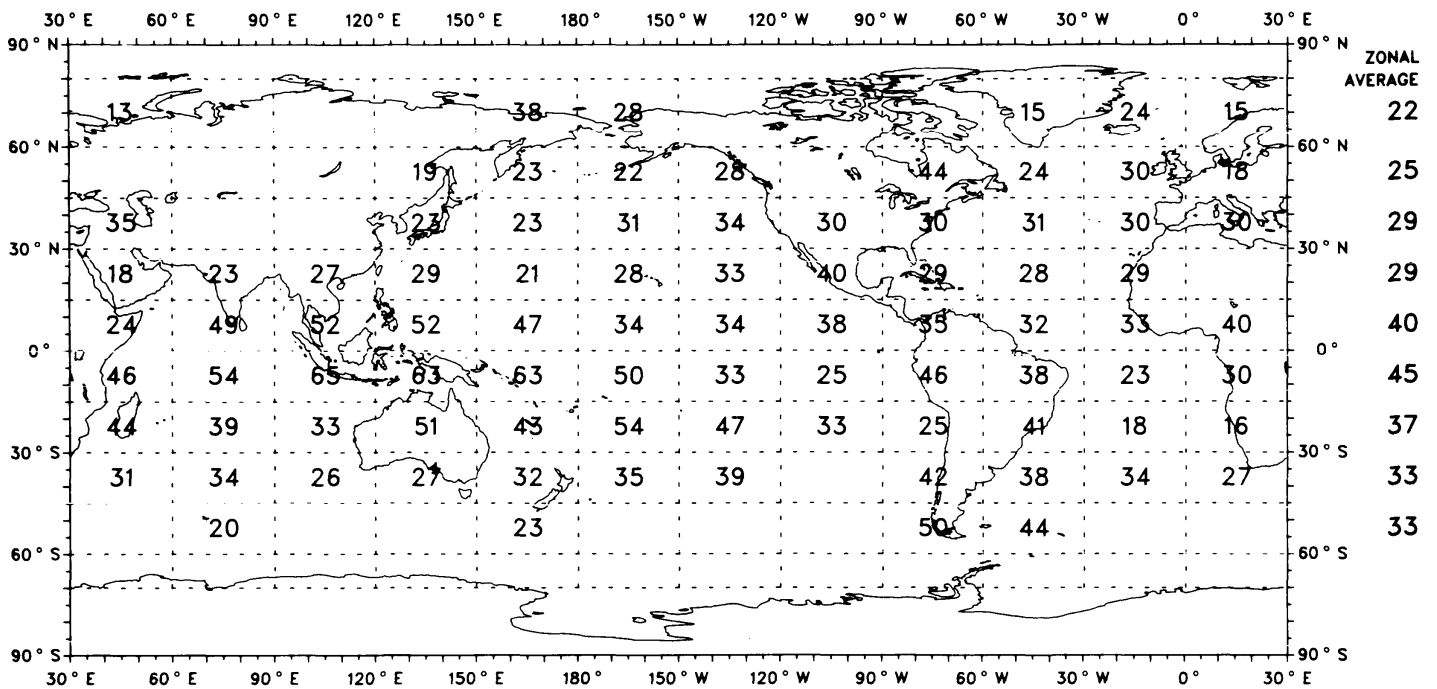
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

DJF (1965-1976)

Ocean Areas Only

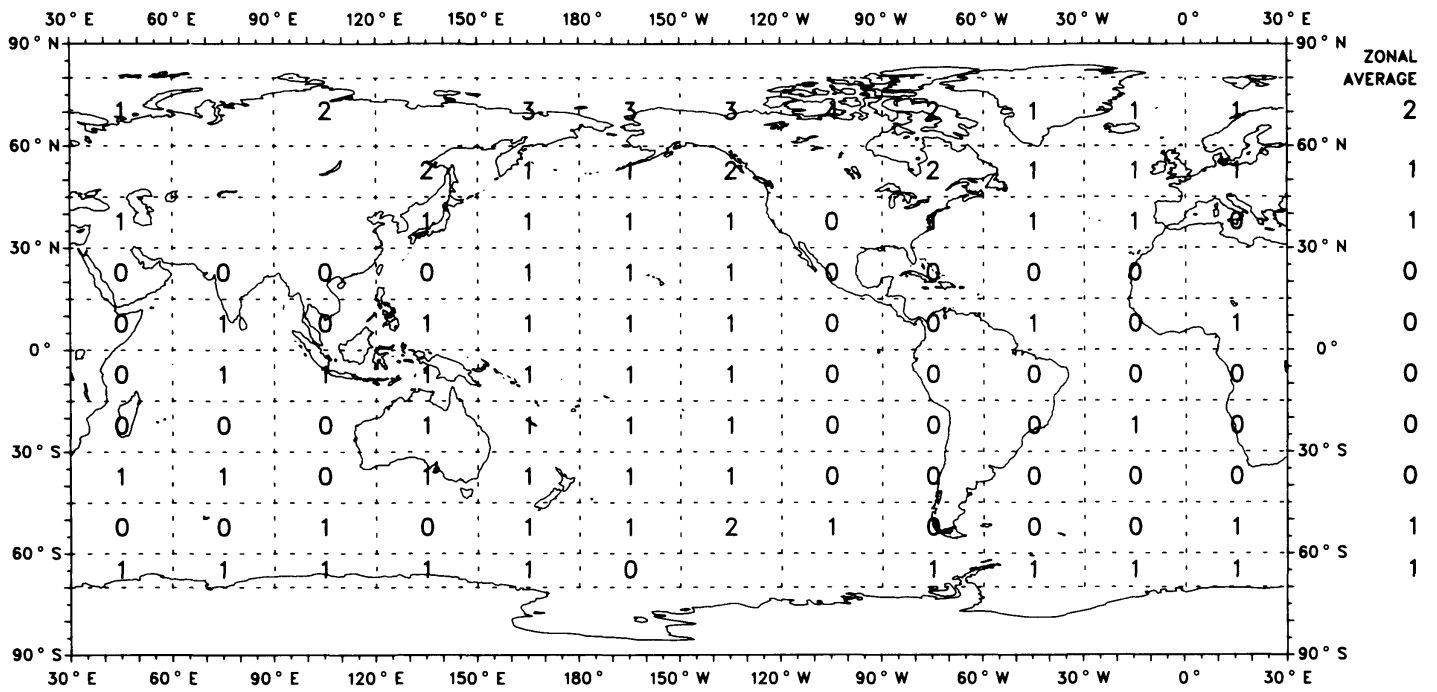


Map I-34

Given As/Ac, Probability (Percent) That Nimbostratus is Also Present

DJF (1965-1976)

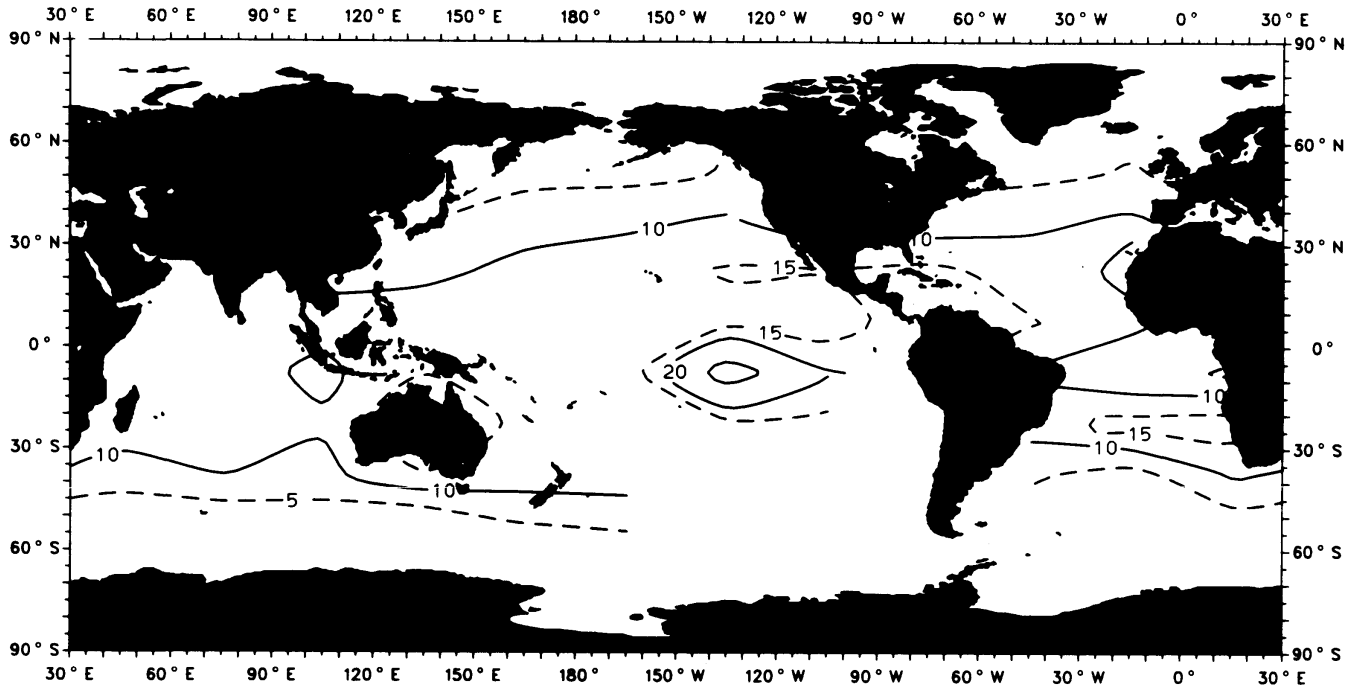
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

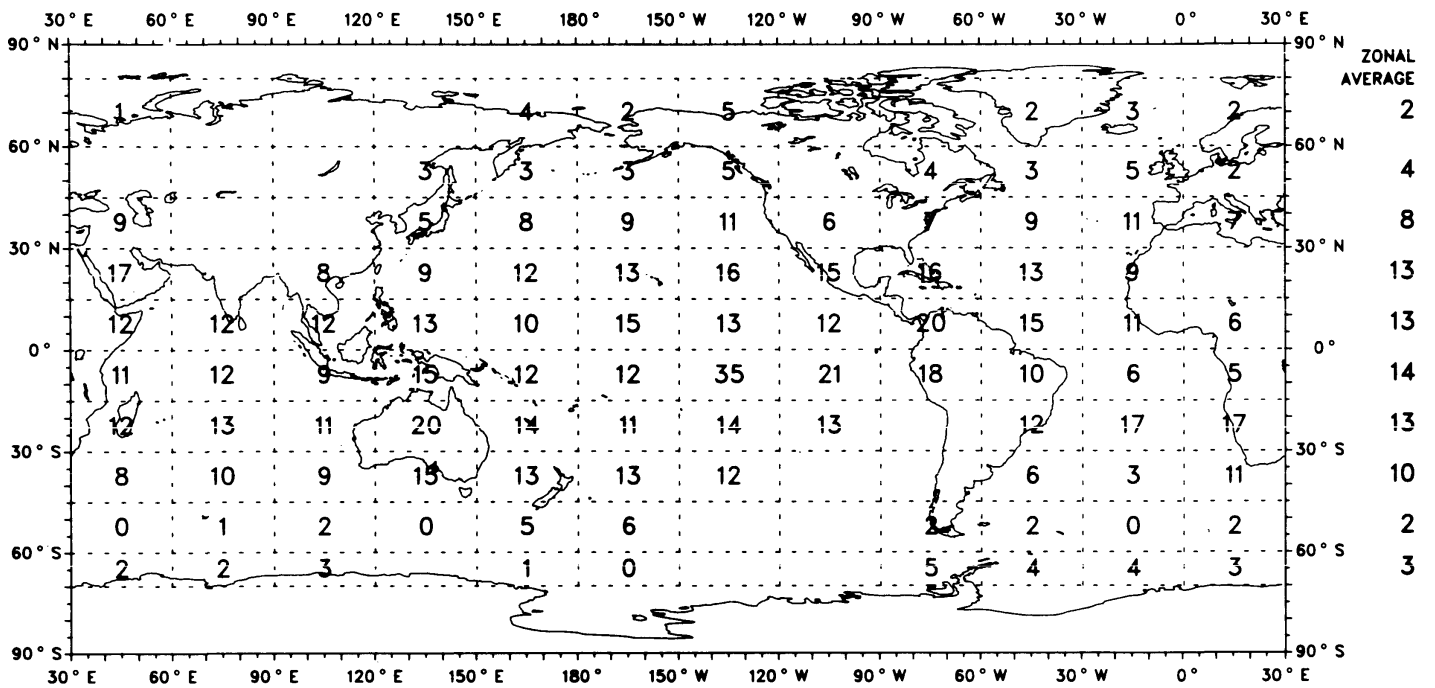
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

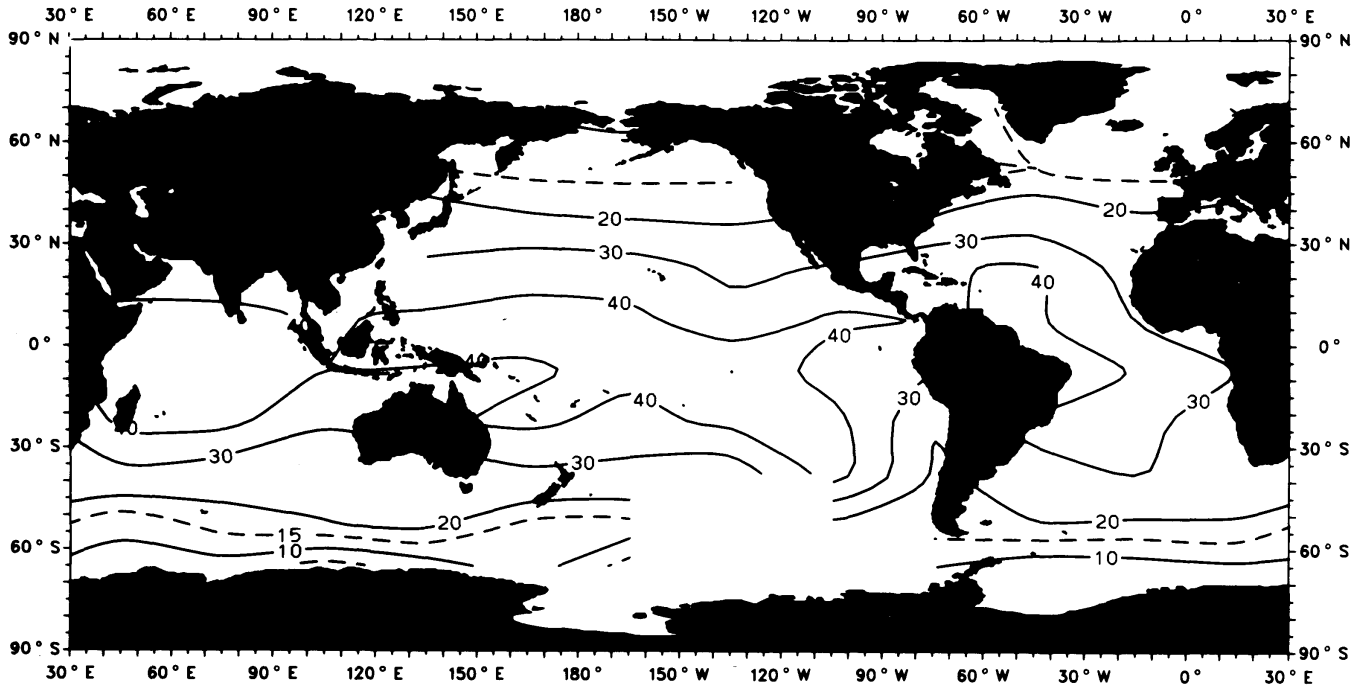
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulus is Also Present

DJF (1965-1976)

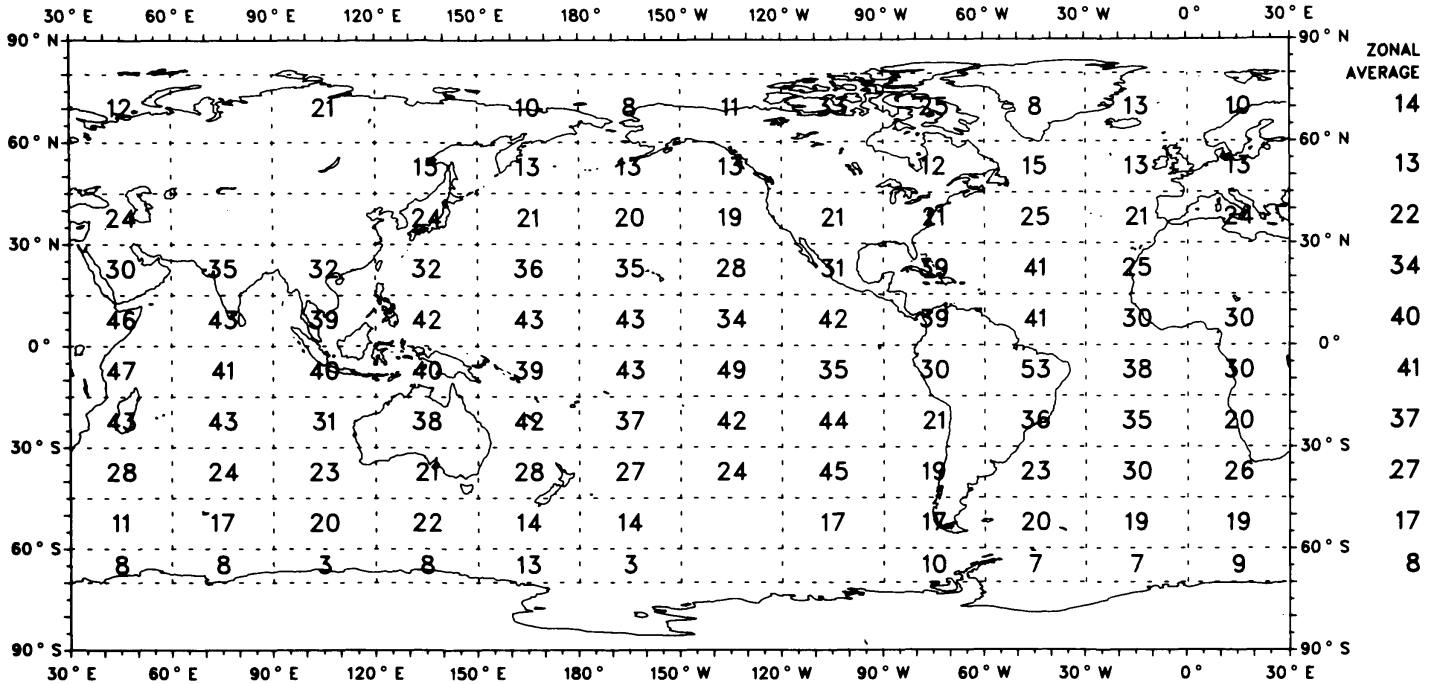
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulus is Also Present

DJF (1965-1976)

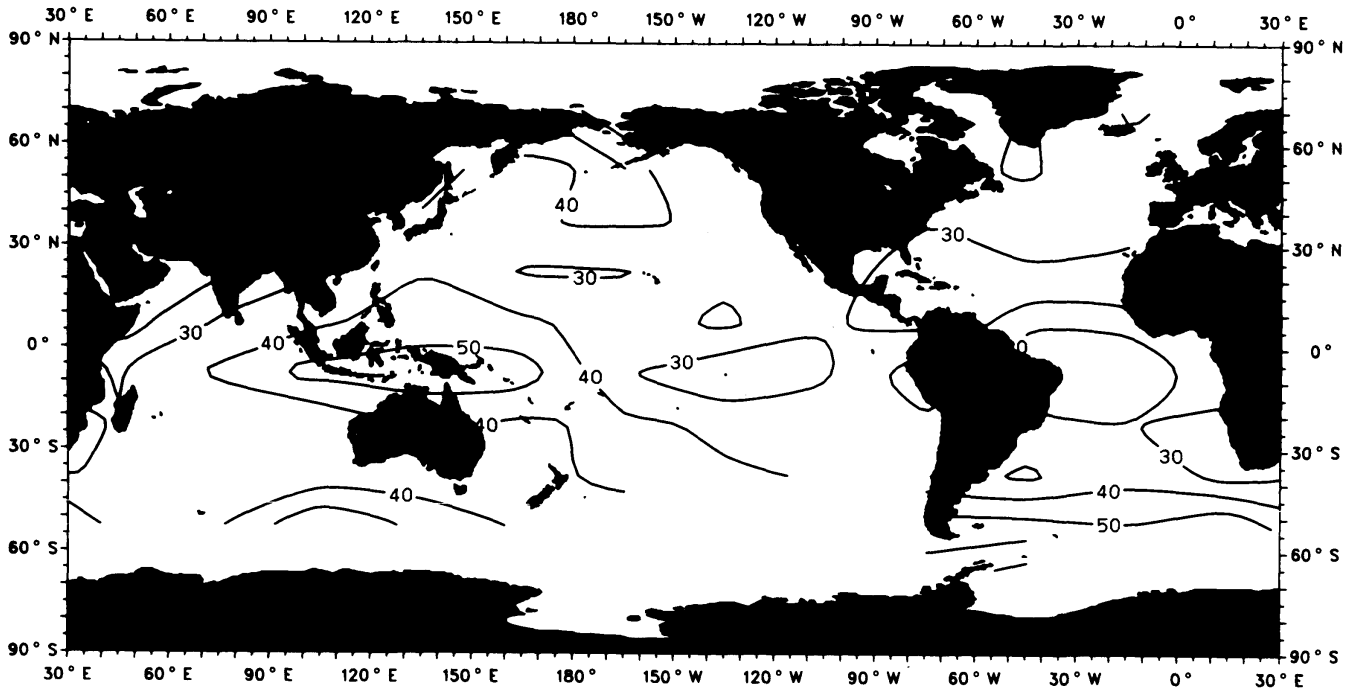
Ocean Areas Only



Given Cumulus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

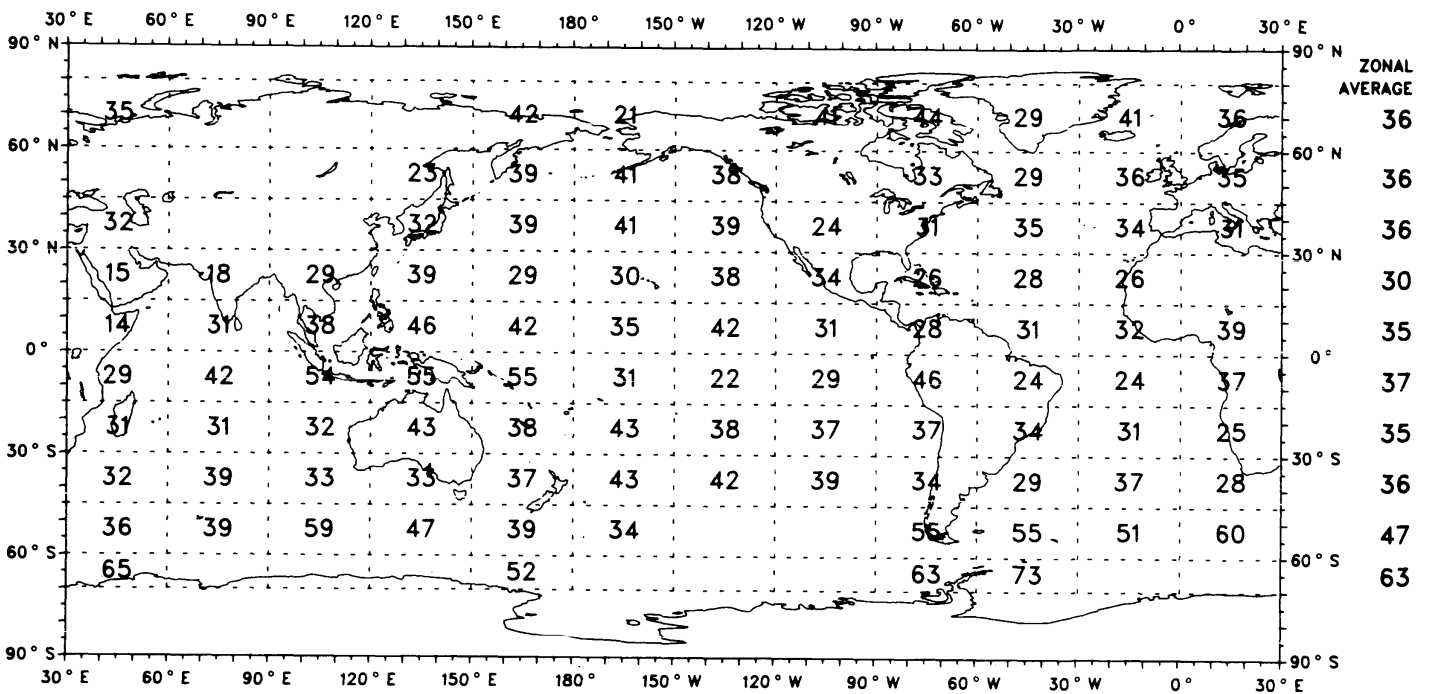
Ocean Areas Only



Given Cumulus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

Ocean Areas Only

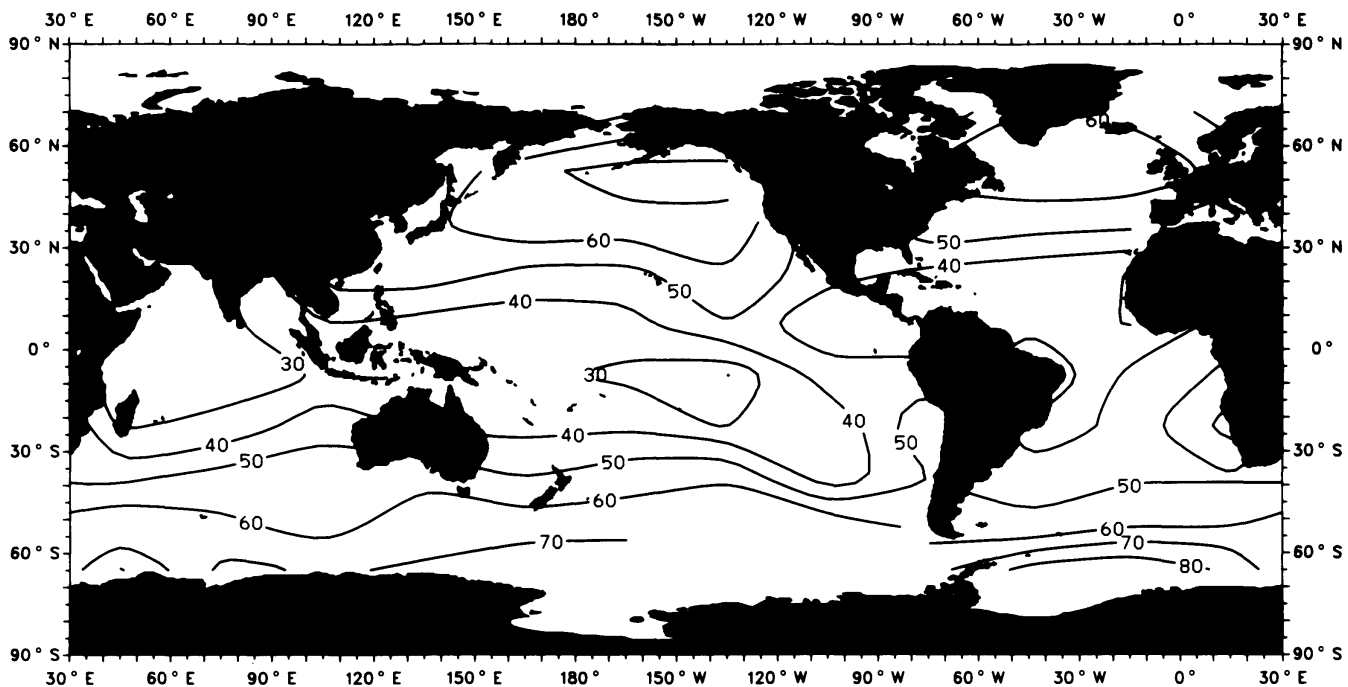


Map I-38

Given As/Ac, Probability (Percent) That St/Sc is Also Present

DJF (1965-1976)

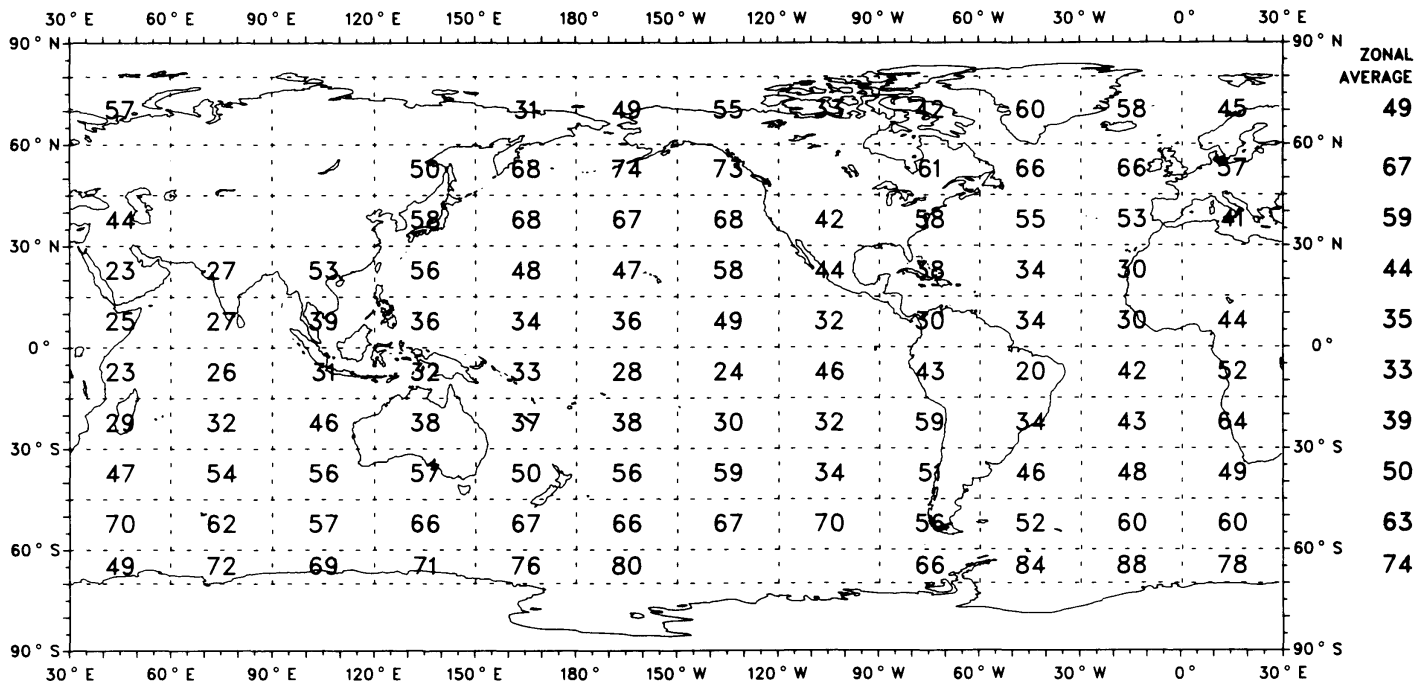
Ocean Areas Only



Given As/Ac, Probability (Percent) That St/Sc is Also Present

DJF (1965-1976)

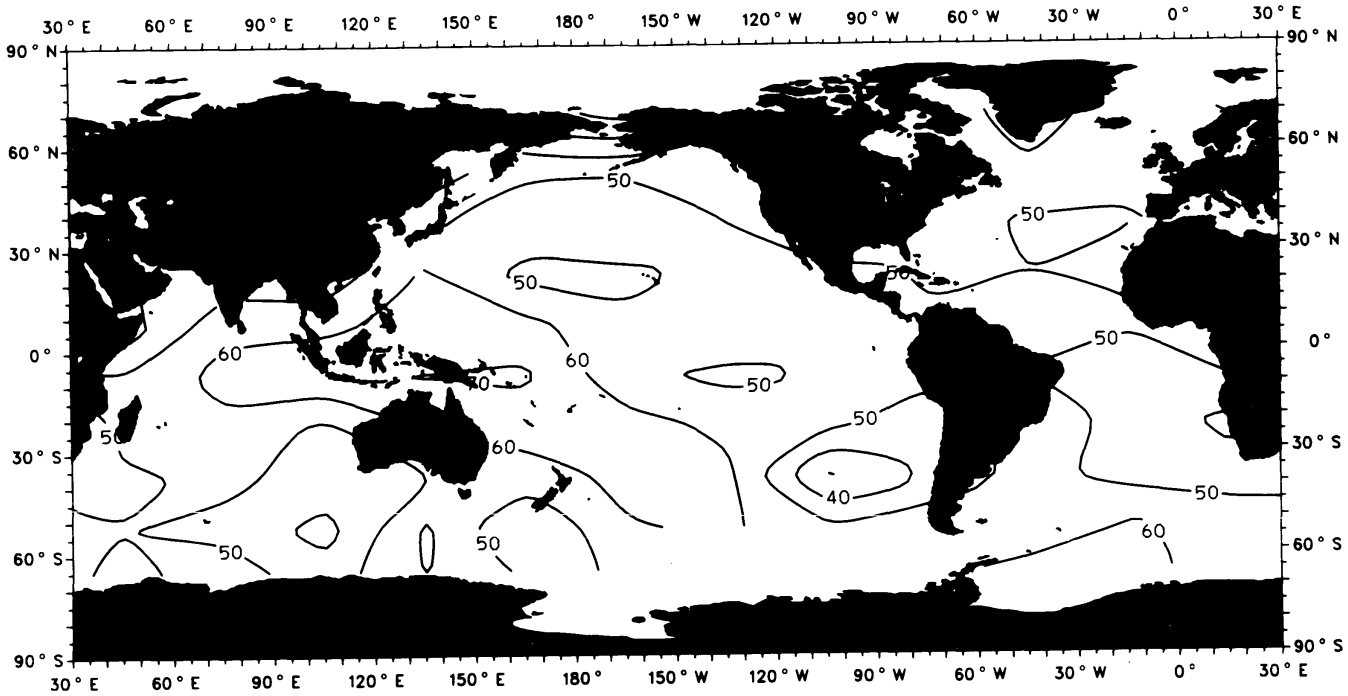
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

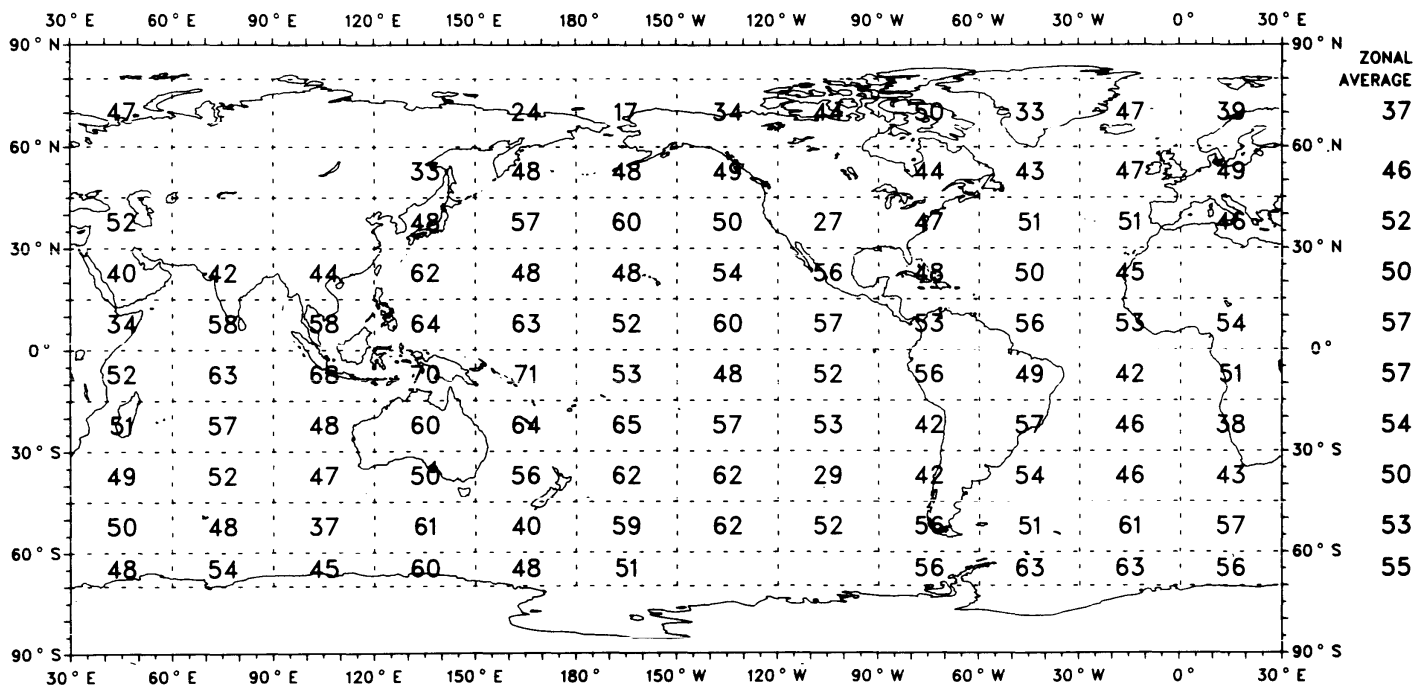
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

Ocean Areas Only

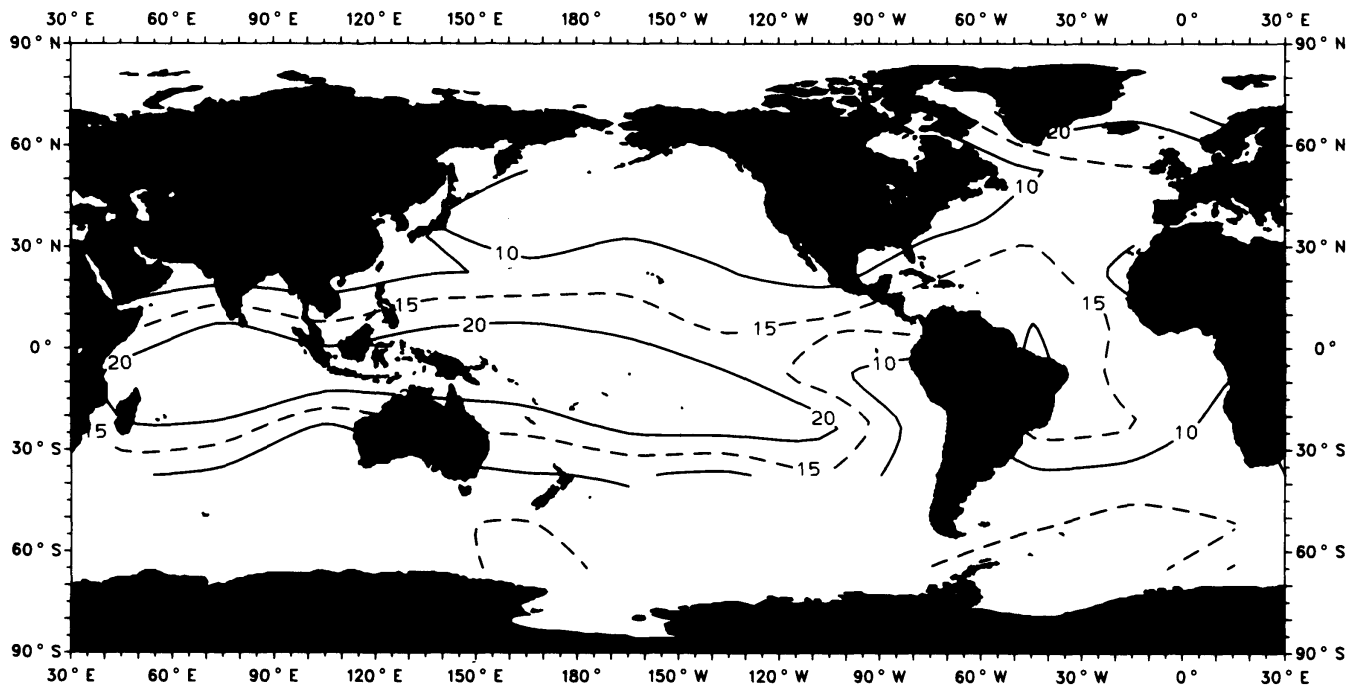


Map I-40

Given As/Ac, Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

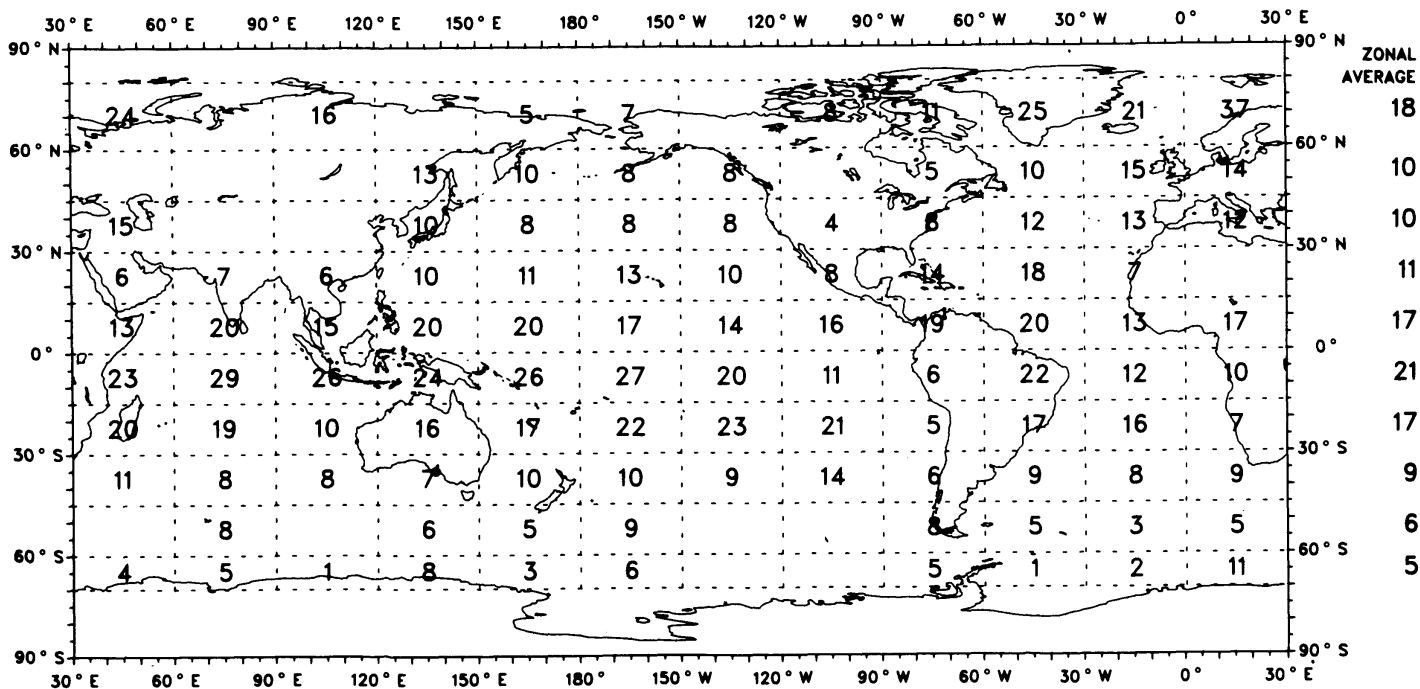
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

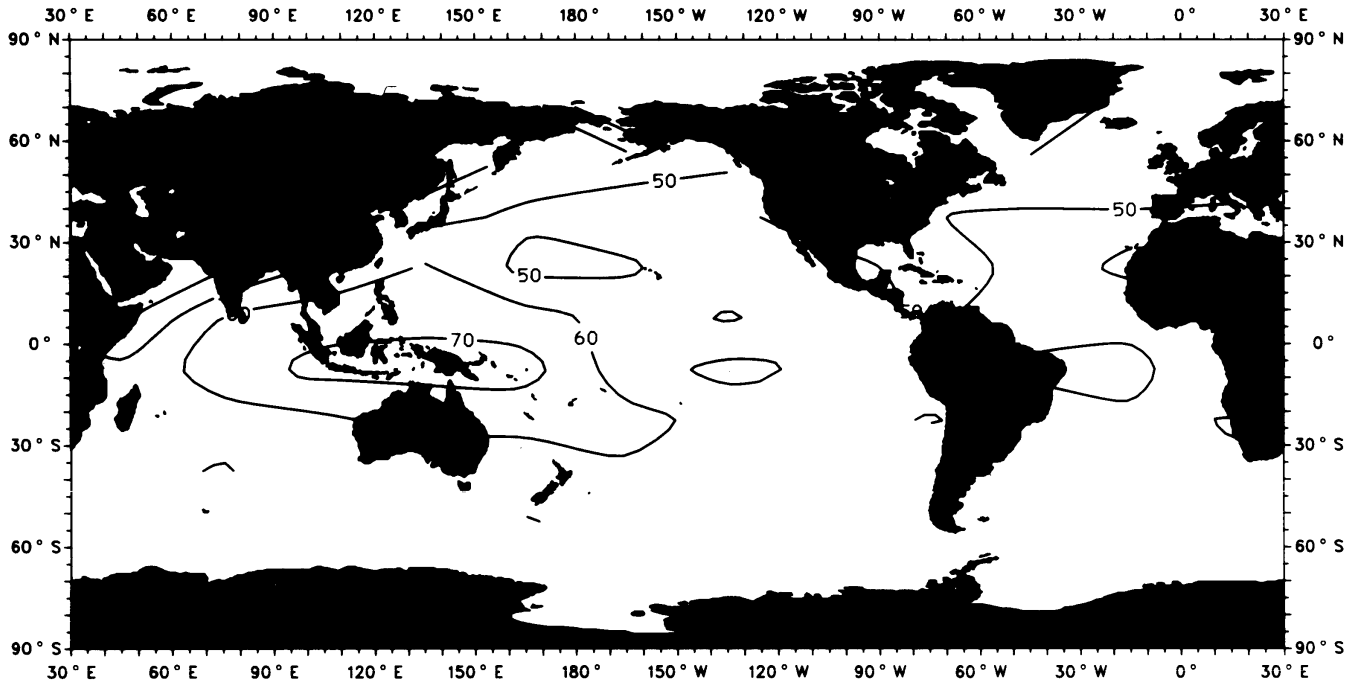
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

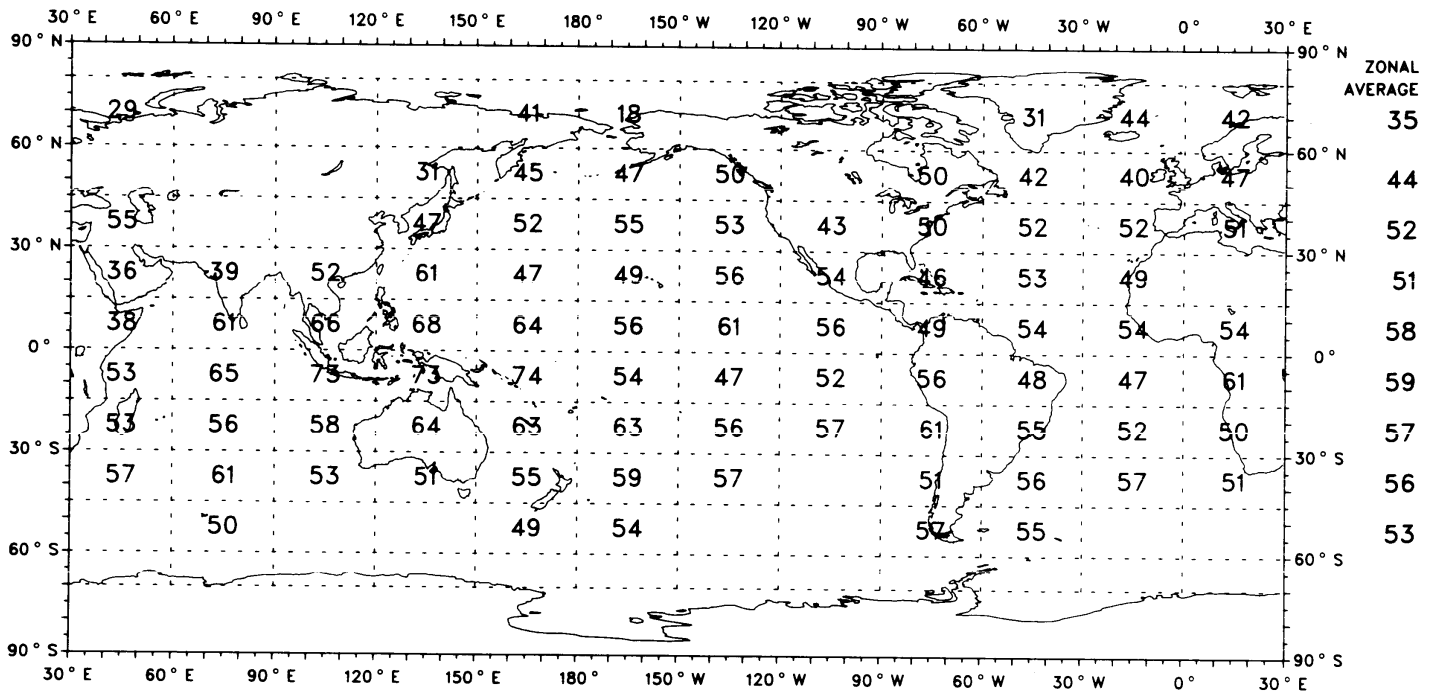
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That As/Ac is Also Present

DJF (1965-1976)

Ocean Areas Only

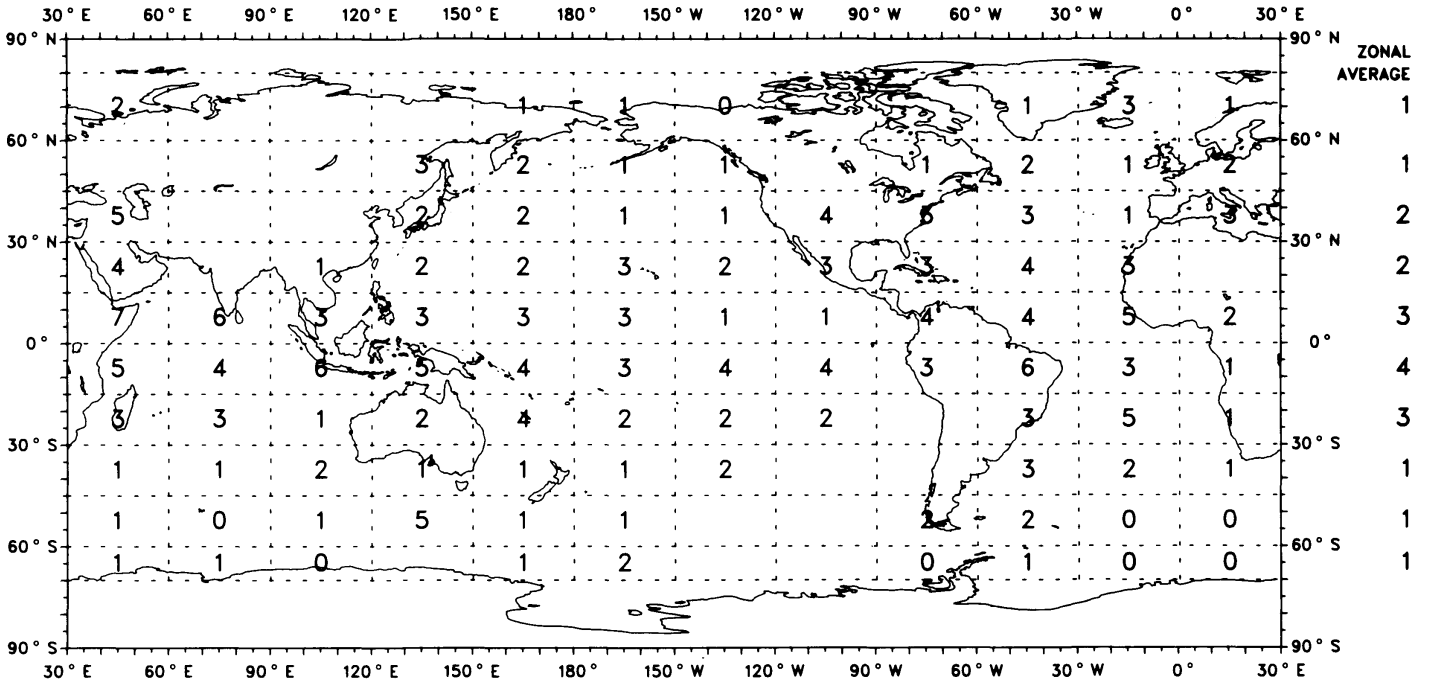


Map I-42

Given Nimbostratus, Probability (Percent) That Cumulus is Also Present

DJF (1965-1976)

Ocean Areas Only

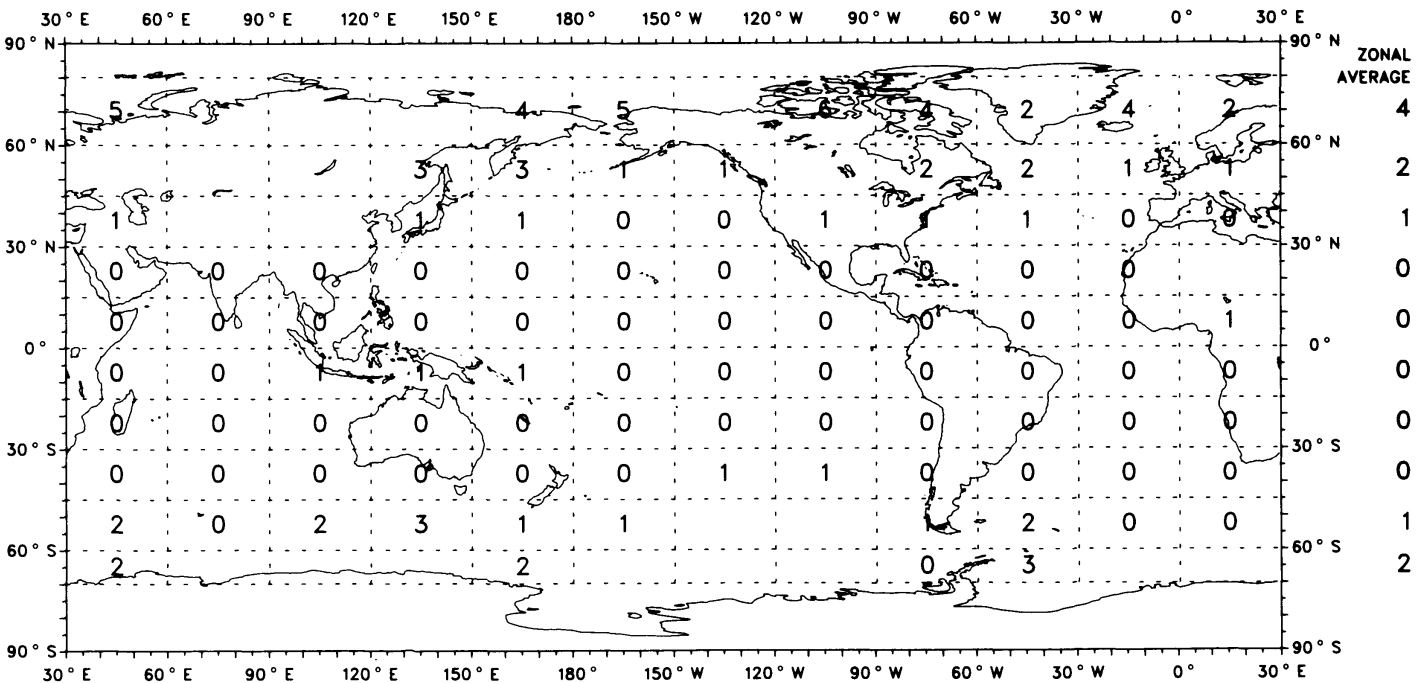


Map I-43

Given Cumulus, Probability (Percent) That Nimbostratus is Also Present

DJF (1965-1976)

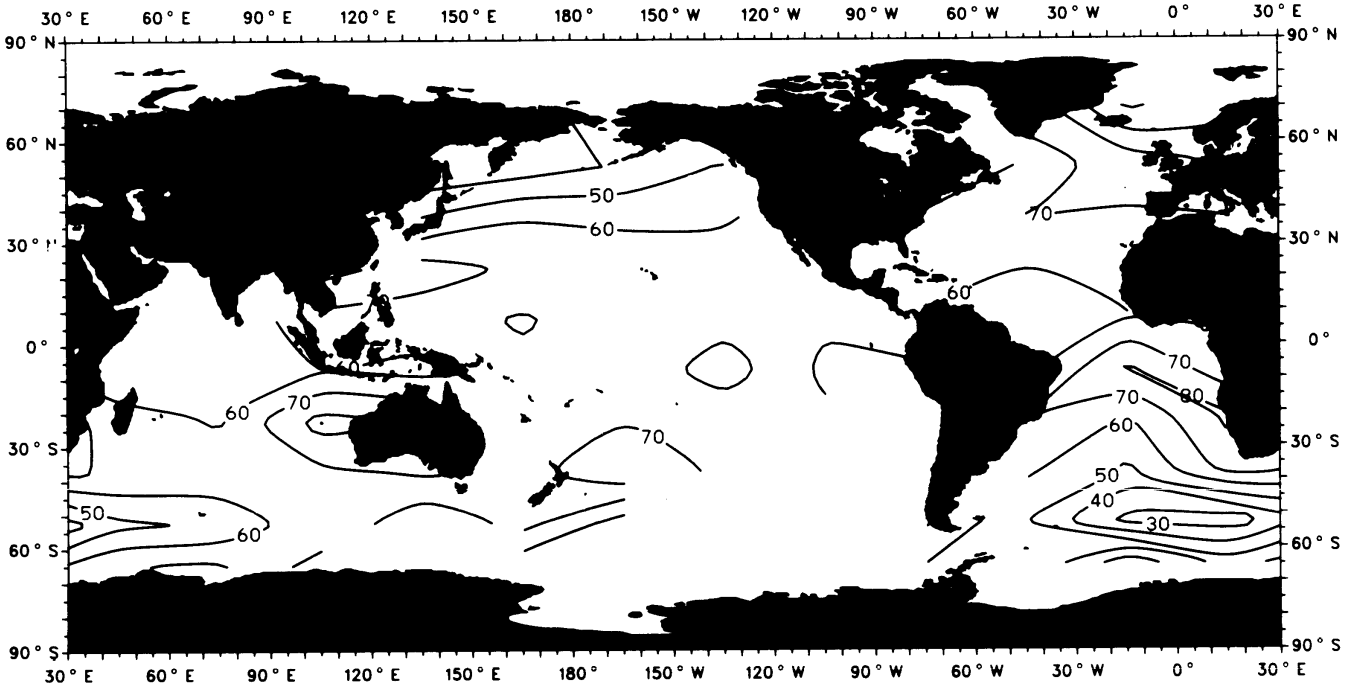
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That St/Sc is Also Present

DJF (1965-1976)

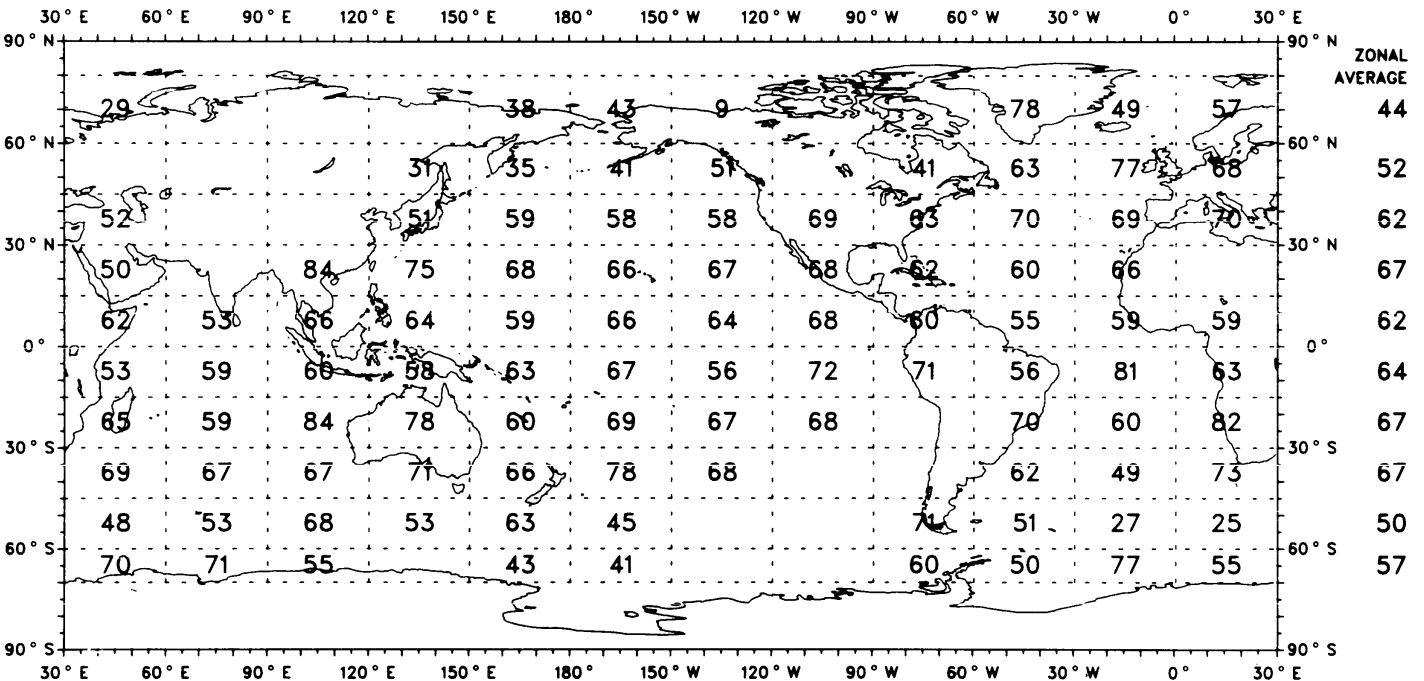
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That St/Sc is Also Present

DJF (1965-1976)

Ocean Areas Only

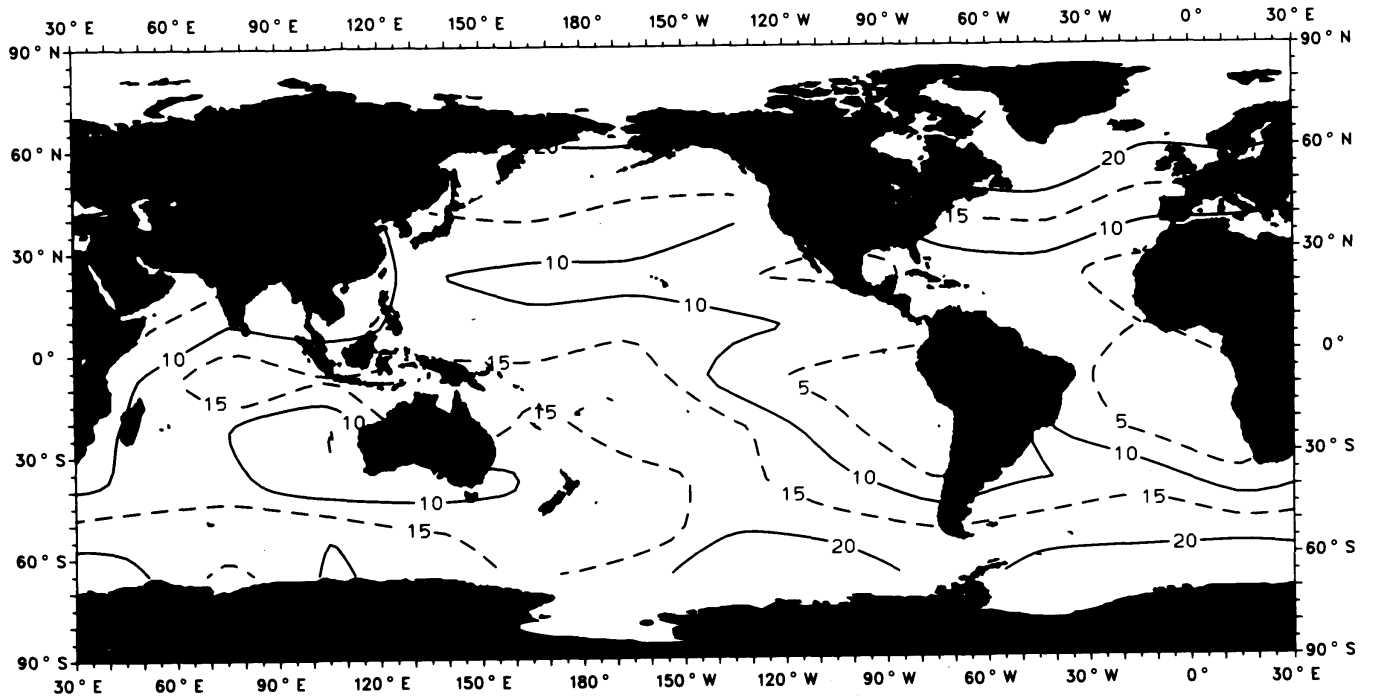


Map I-45

Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

DJF (1965-1976)

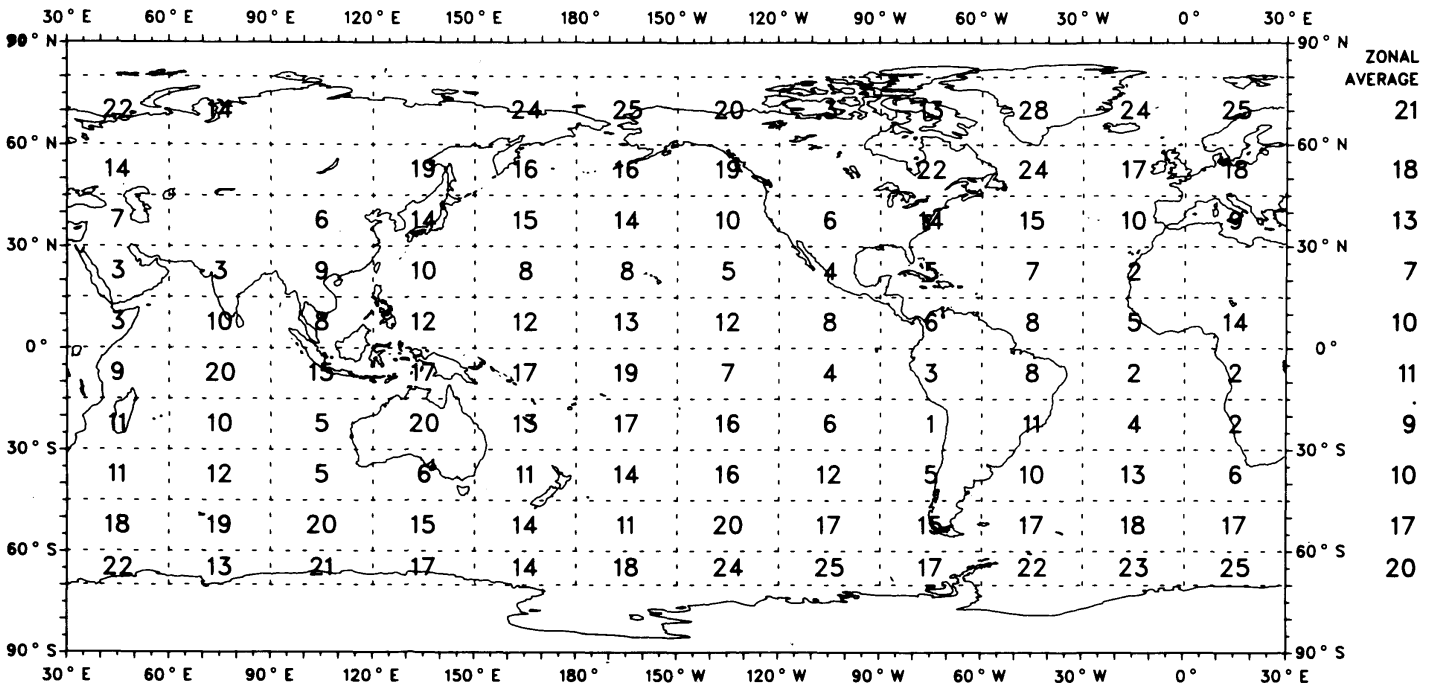
Ocean Areas Only



Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

DJF (1965-1976)

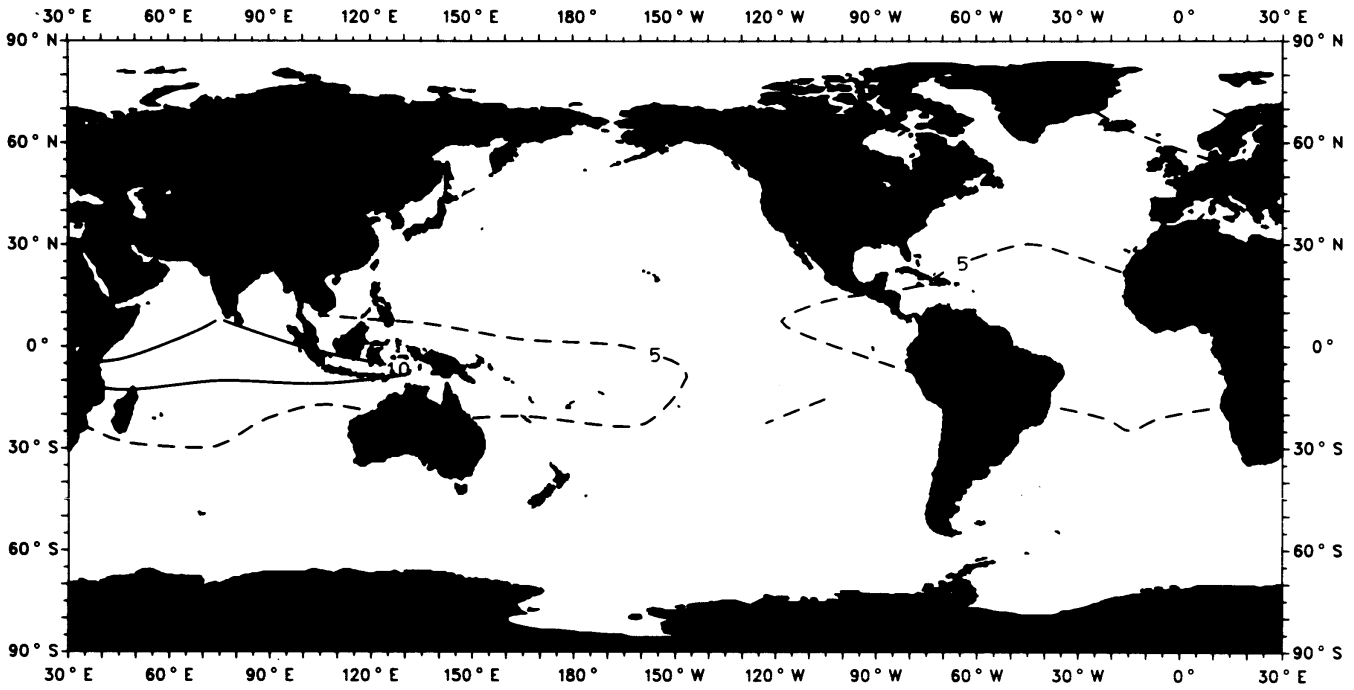
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

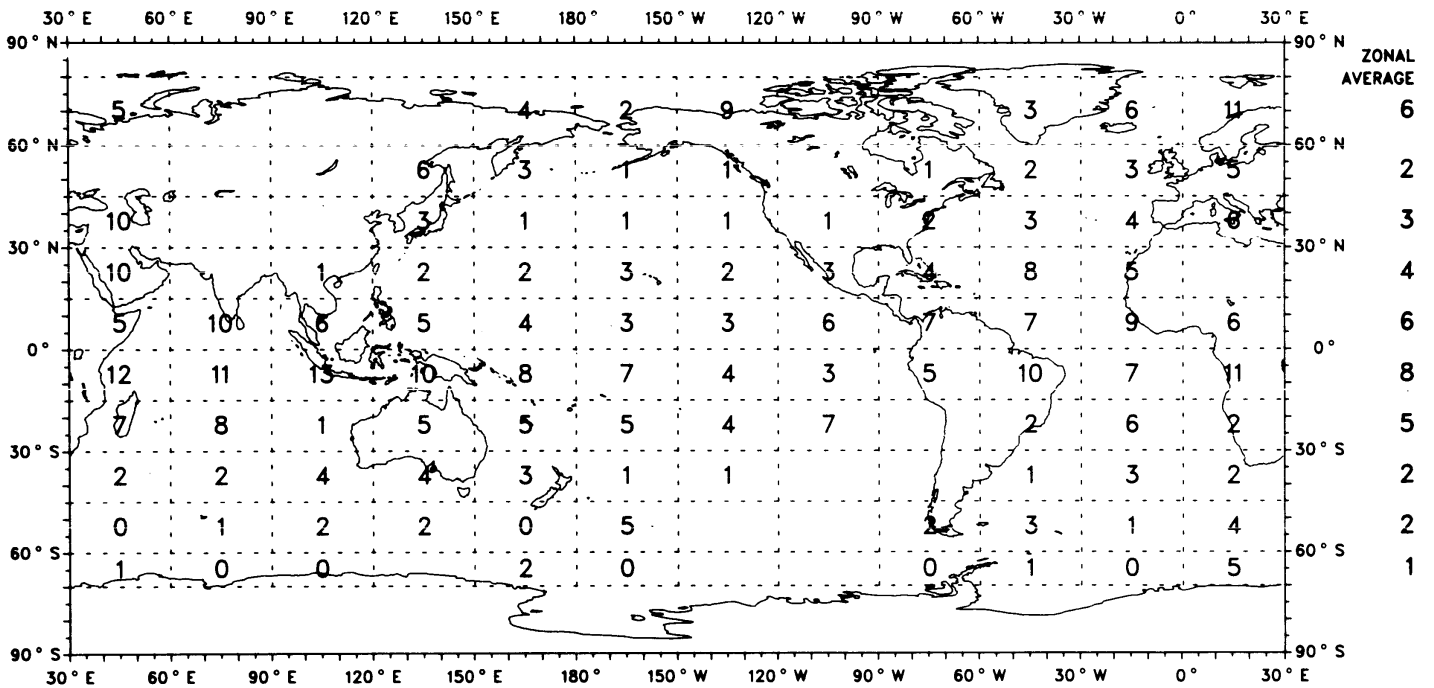
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

DJF (1965-1976)

Ocean Areas Only

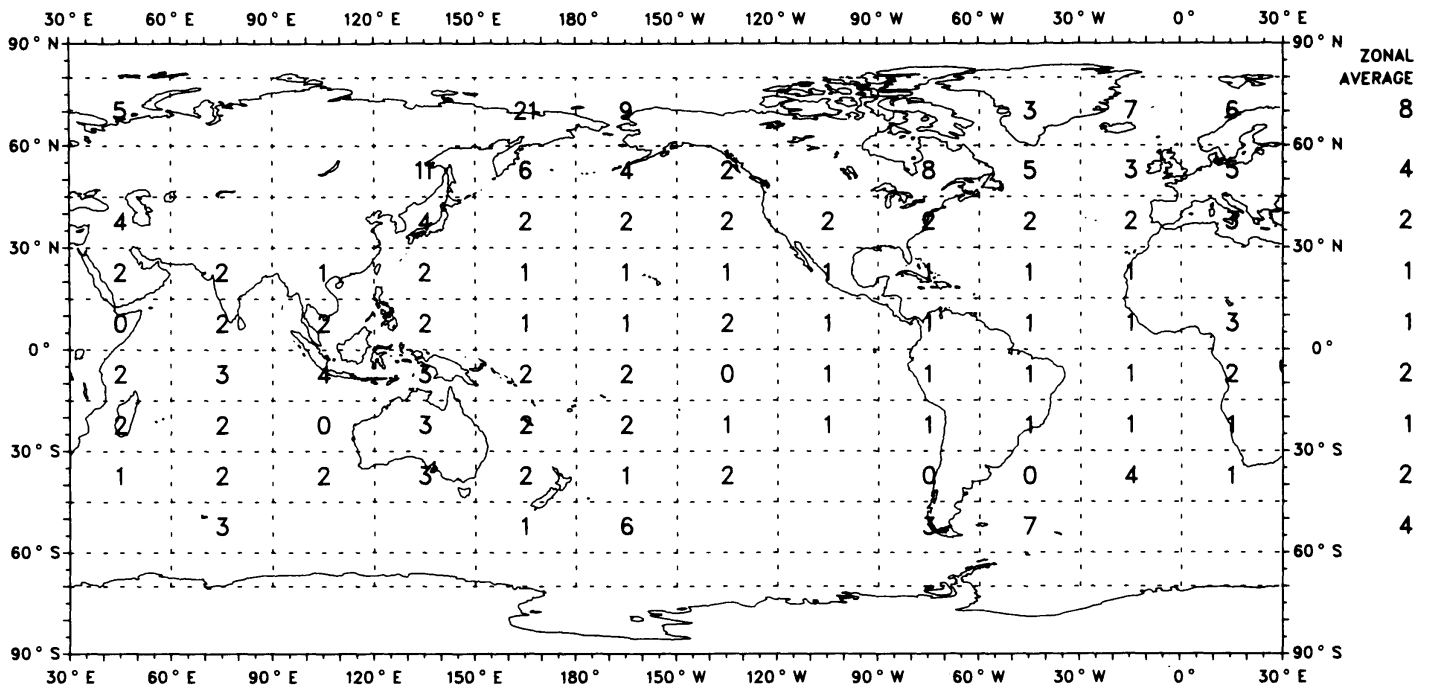


Map I-47

Given Cumulonimbus, Probability (Percent) That Nimbostratus is Also Present

DJF (1965-1976)

Ocean Areas Only



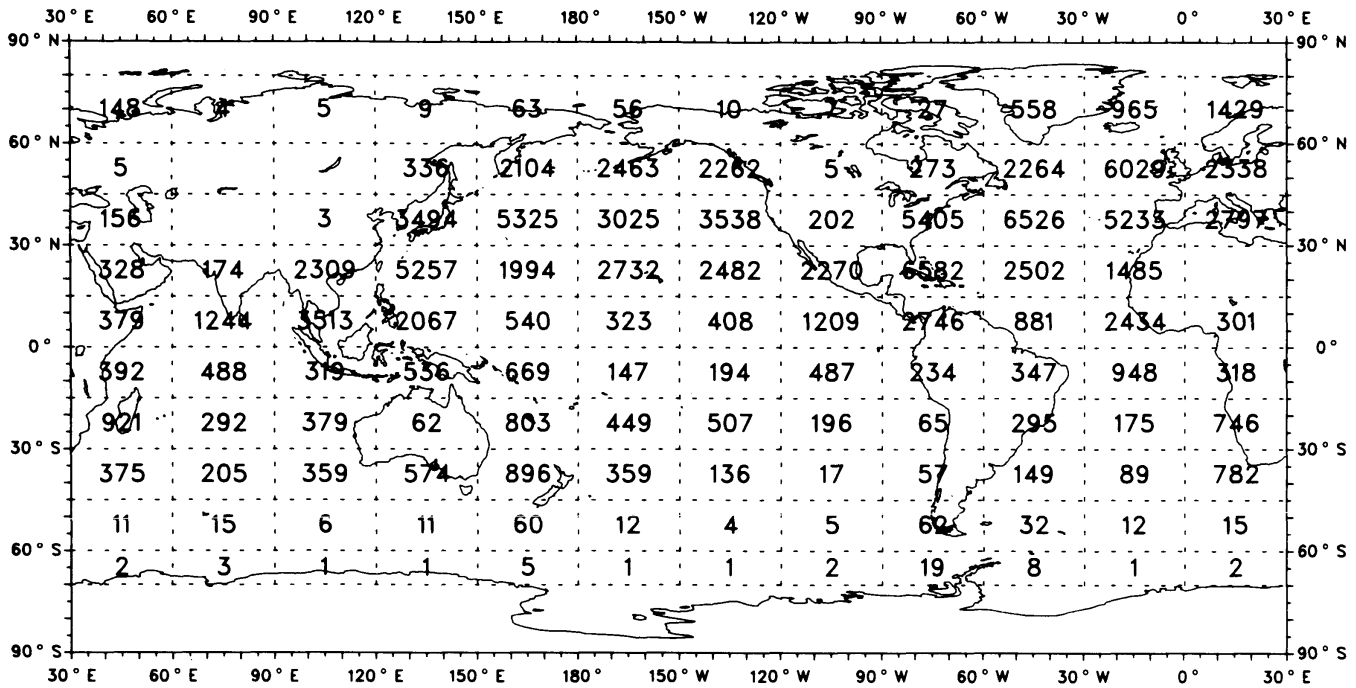
March, April, May



Number of Observations of Altostratus or Altocumulus (N/10)

MAM (1965-1976)

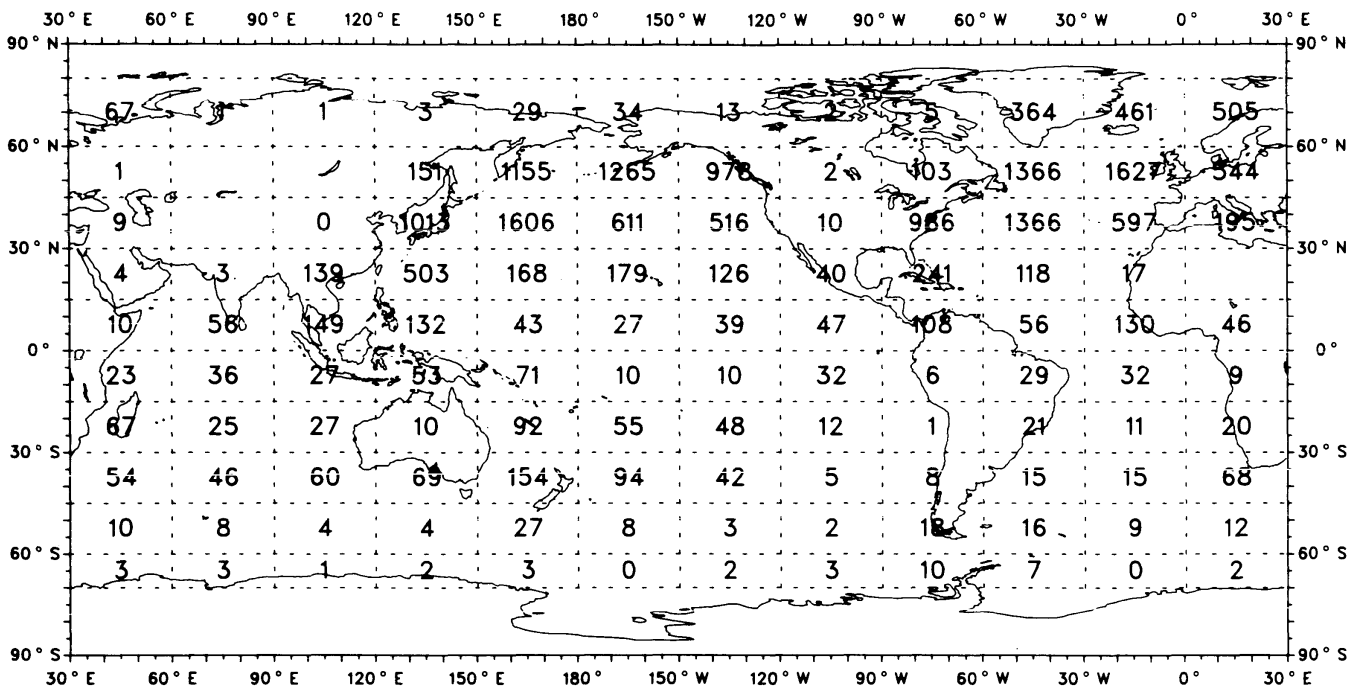
Ocean Areas Only



Number of Observations of Nimbostratus (N/10)

MAM (1965-1976)

Ocean Areas Only

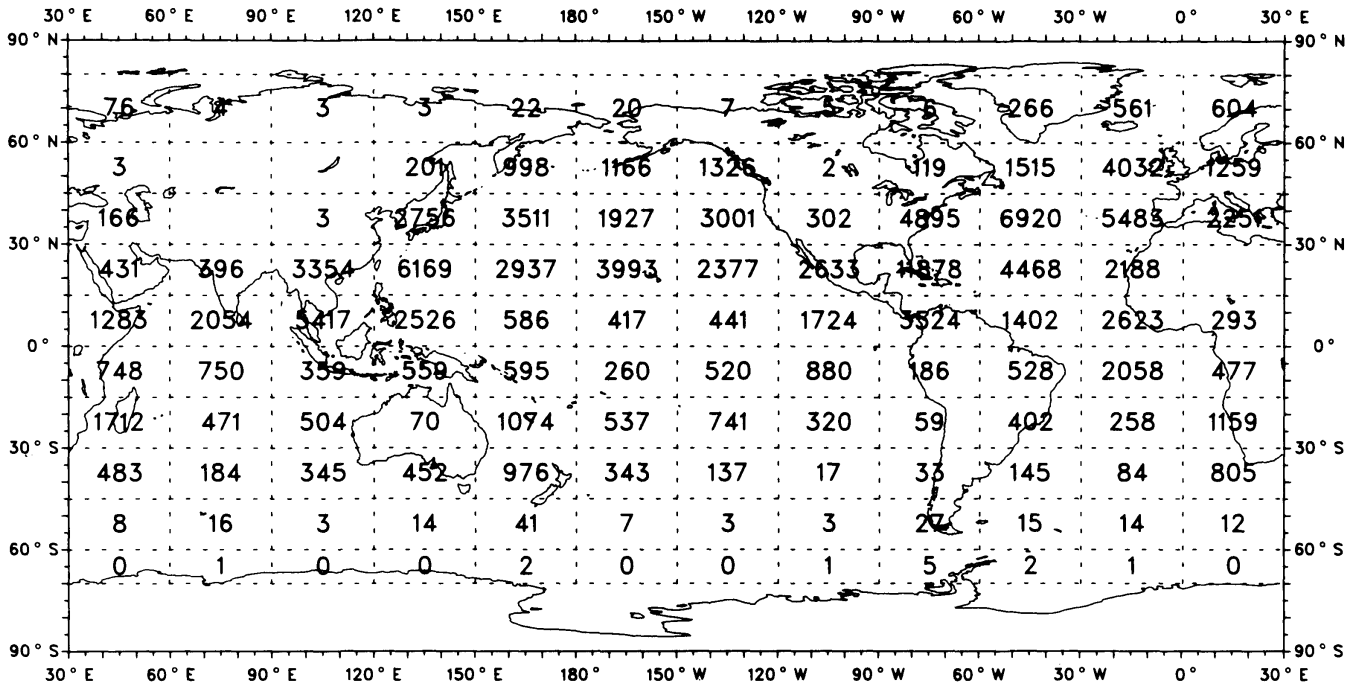


Map II-5

Number of Observations of Cumulus (N/10)

MAM (1965-1976)

Ocean Areas Only

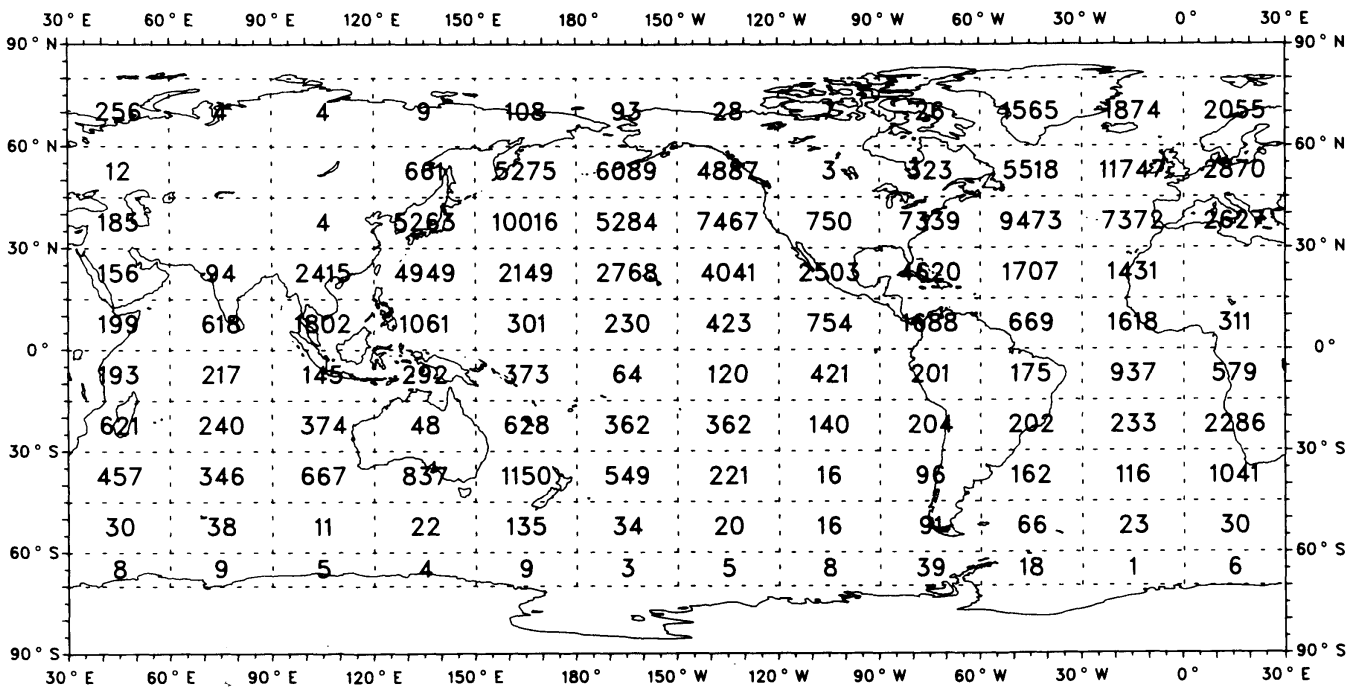


Map II-6

Number of Observations of Stratus or Stratocumulus (N/10)

MAM (1965-1976)

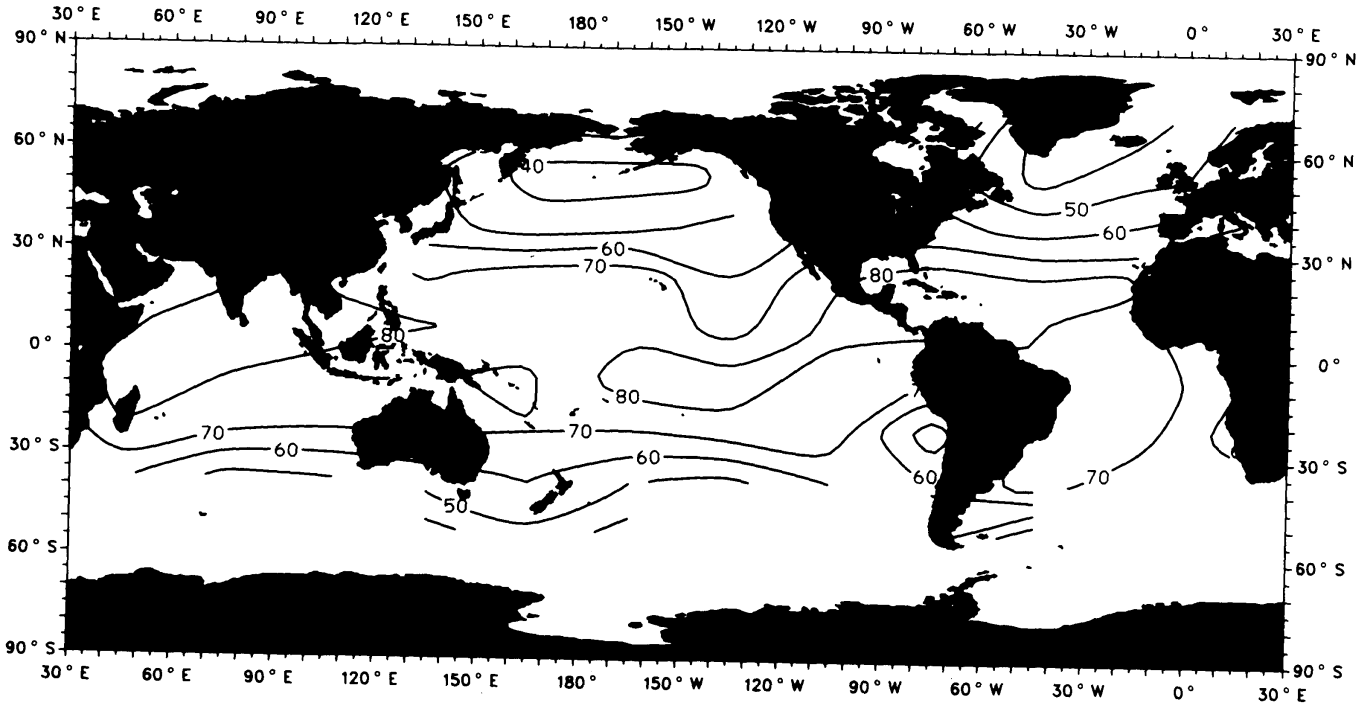
Ocean Areas Only





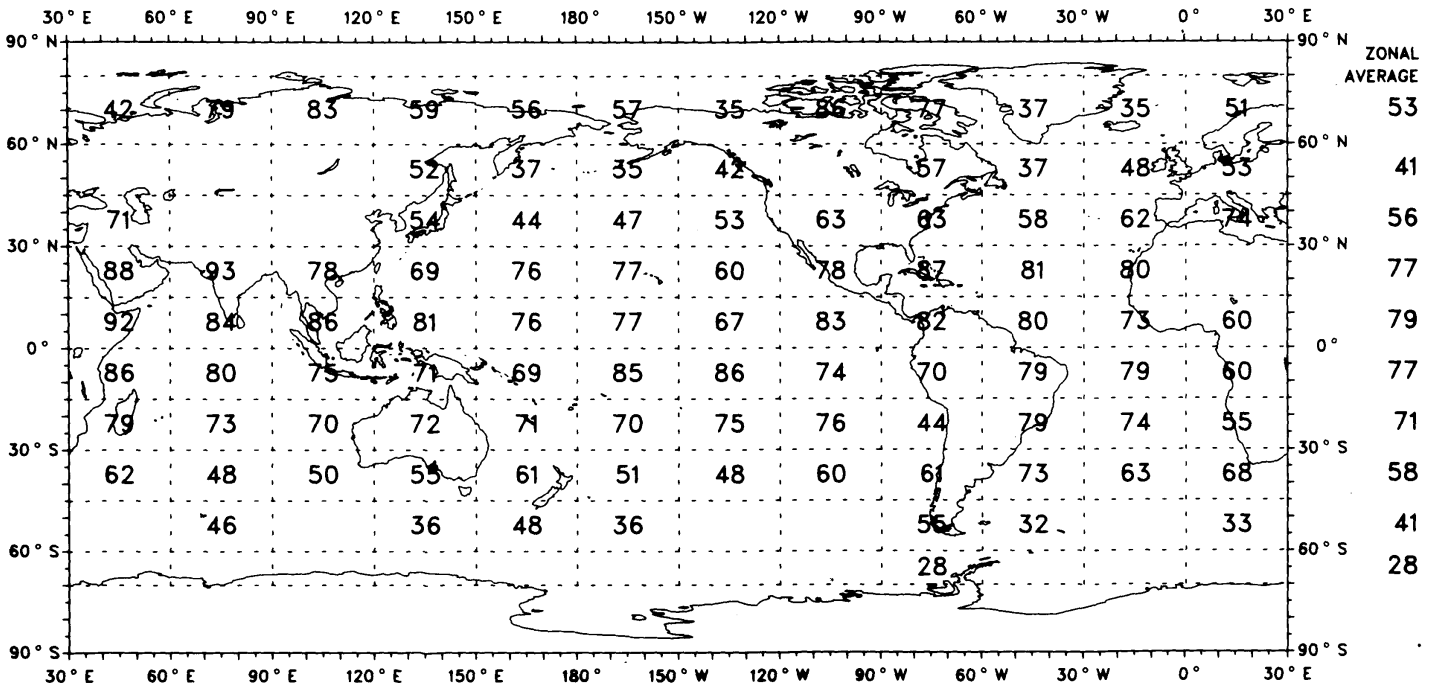
Map II-8

Percent of Ship Reports Contributing to Statistics of the High Cloud Level  
 MAM (1965-1976) Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the High Cloud Level

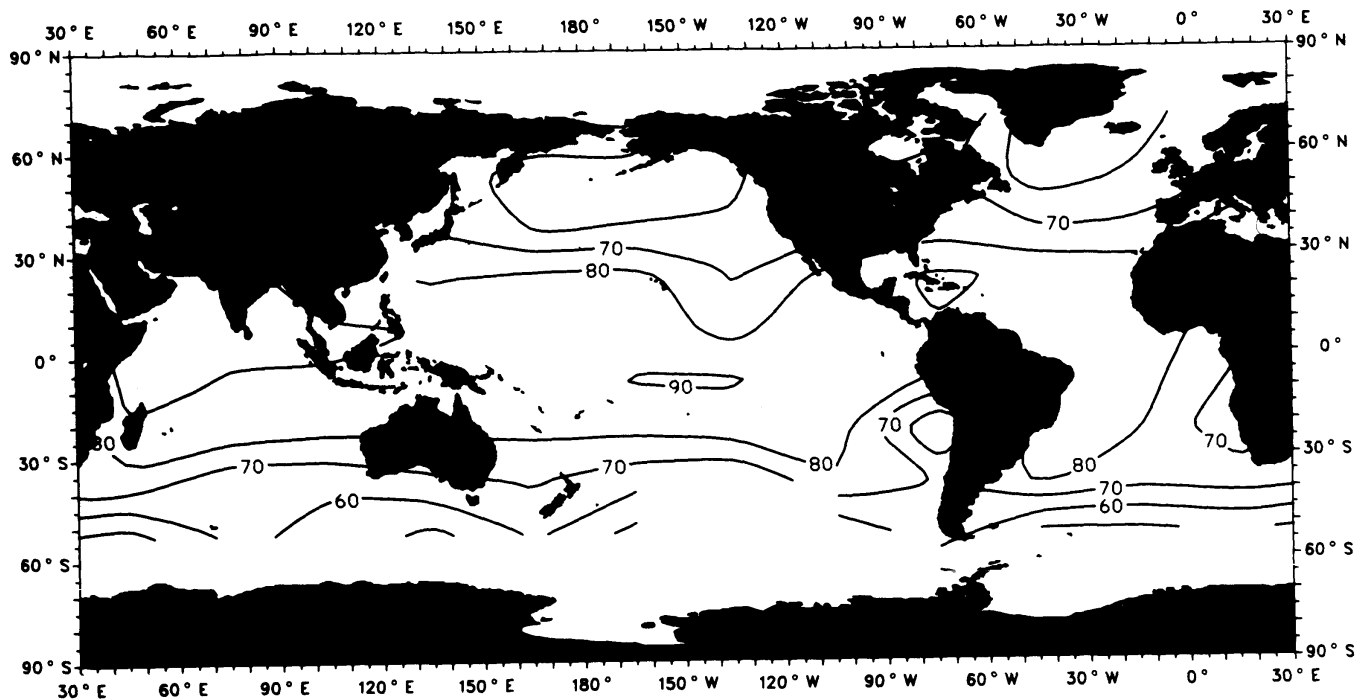
MAM (1965-1976) Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

MAM (1965-1976)

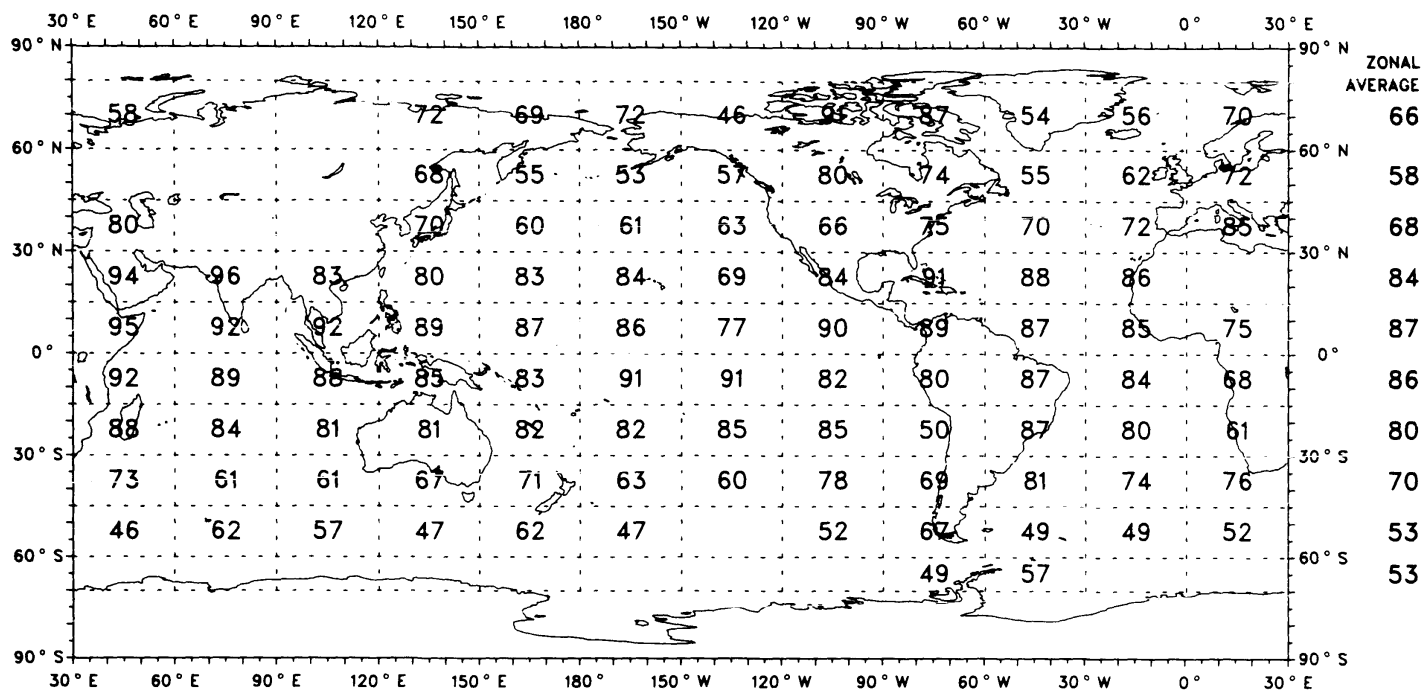
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

MAM (1965-1976)

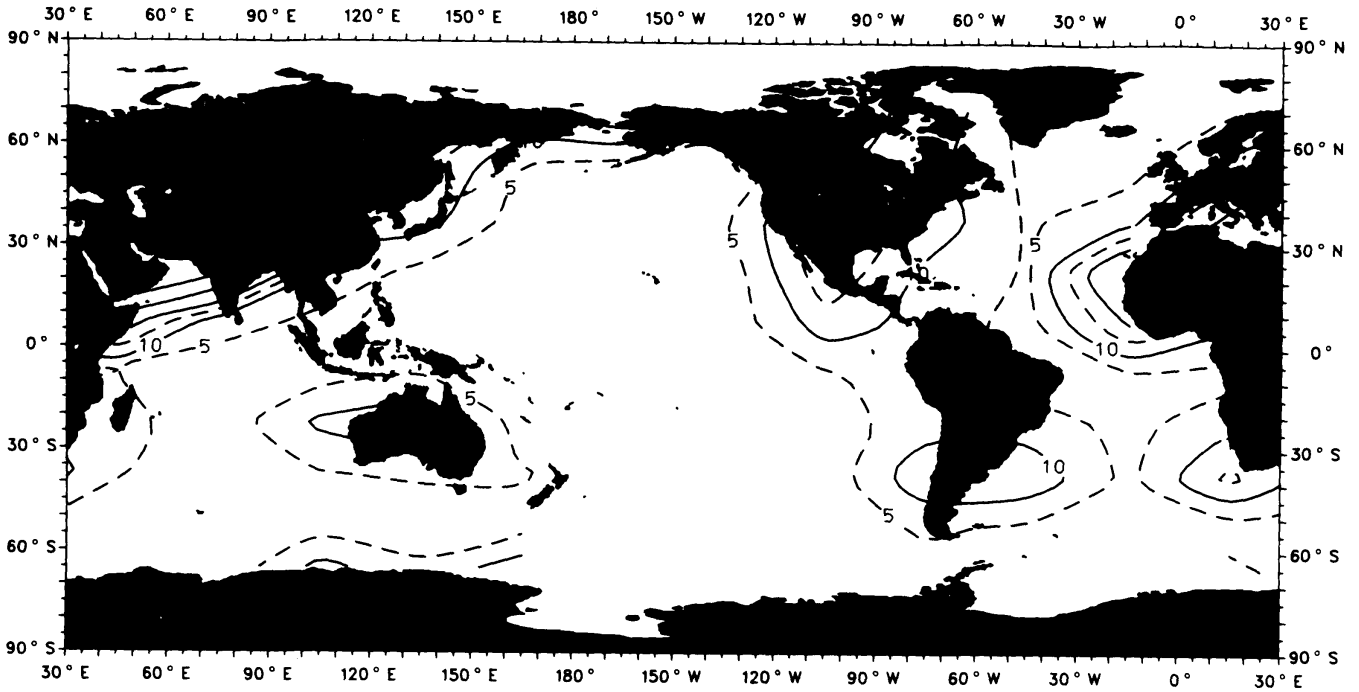
Ocean Areas Only



Frequency of Occurrence (Percent) of Completely Clear Sky

MAM (1965-1976)

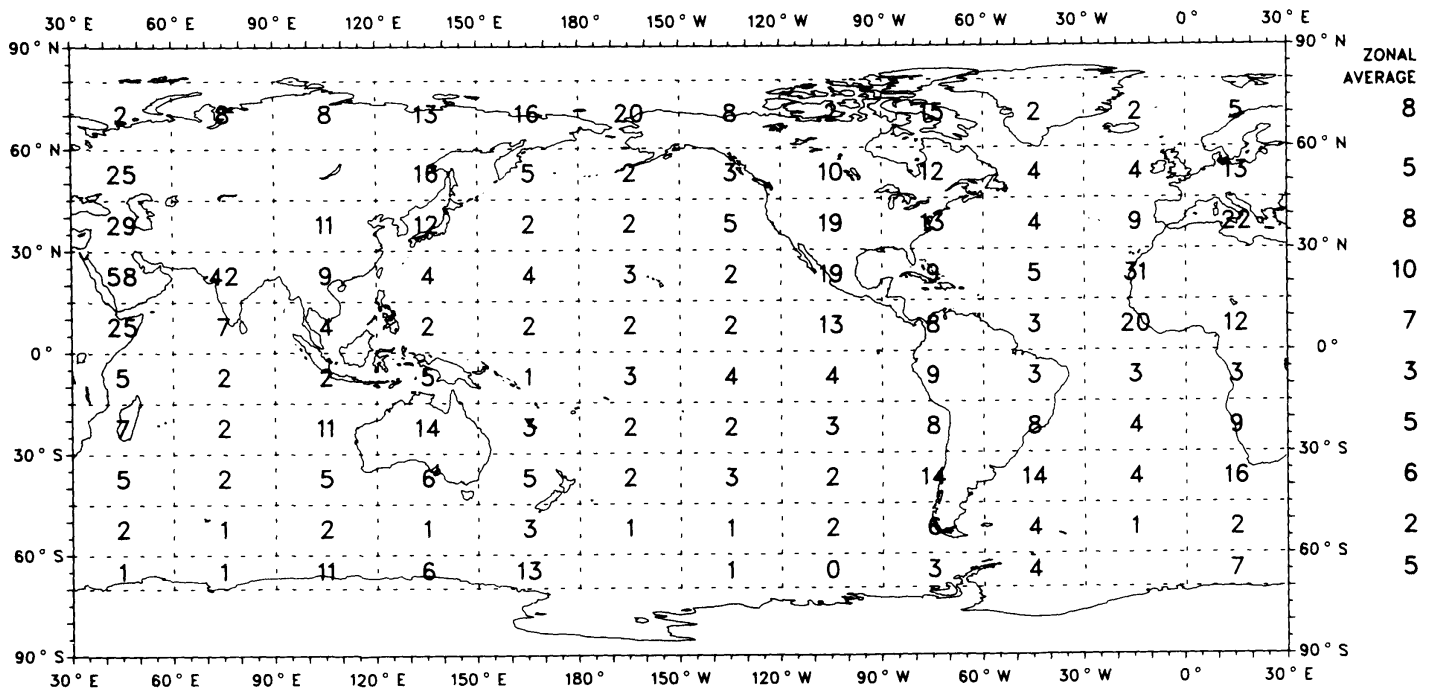
Ocean Areas Only



Frequency of Occurrence (Percent) of Completely Clear Sky

MAM (1965-1976)

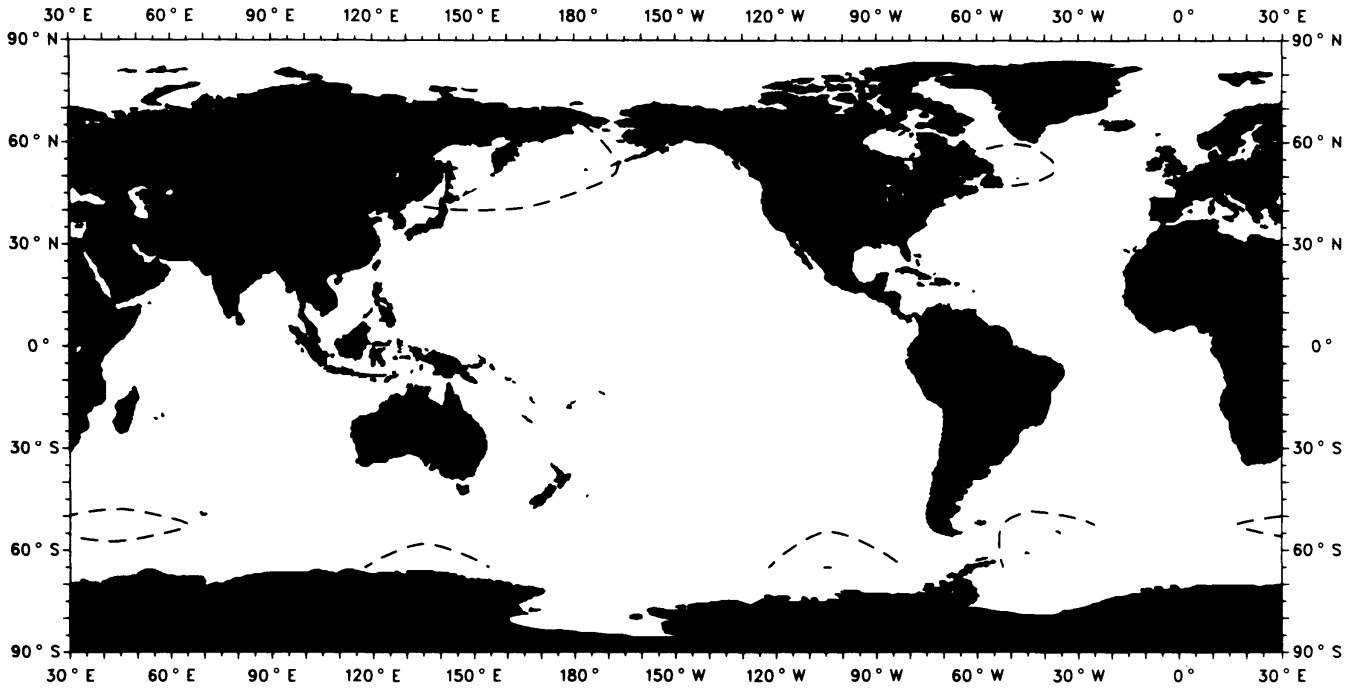
Ocean Areas Only



Frequency of Occurrence (Percent) of Sky Obscured due to Fog

MAM (1965-1976)

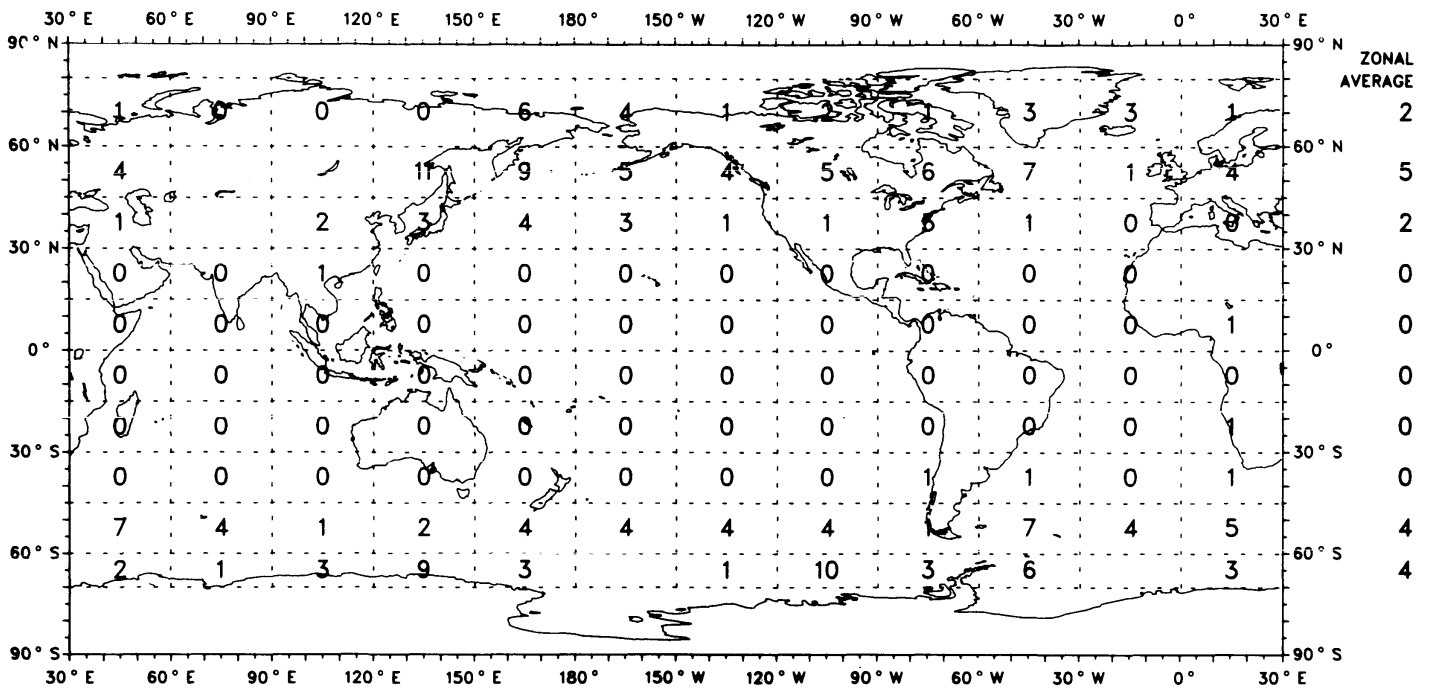
Ocean Areas Only



Frequency of Occurrence (Percent) of Sky Obscured due to Fog

MAM (1965-1976)

Ocean Areas Only

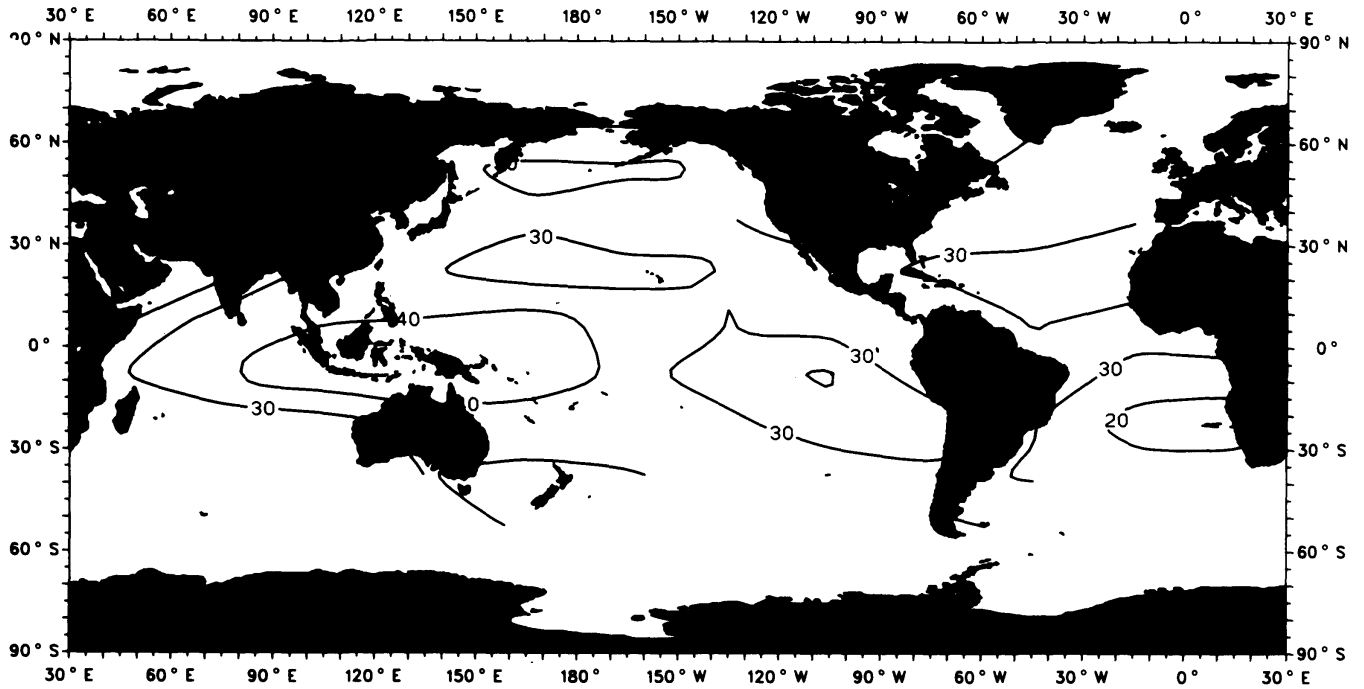


Map II-12

Frequency of Occurrence (Percent) of Ci/Cs/Cc

MAM (1965-1976)

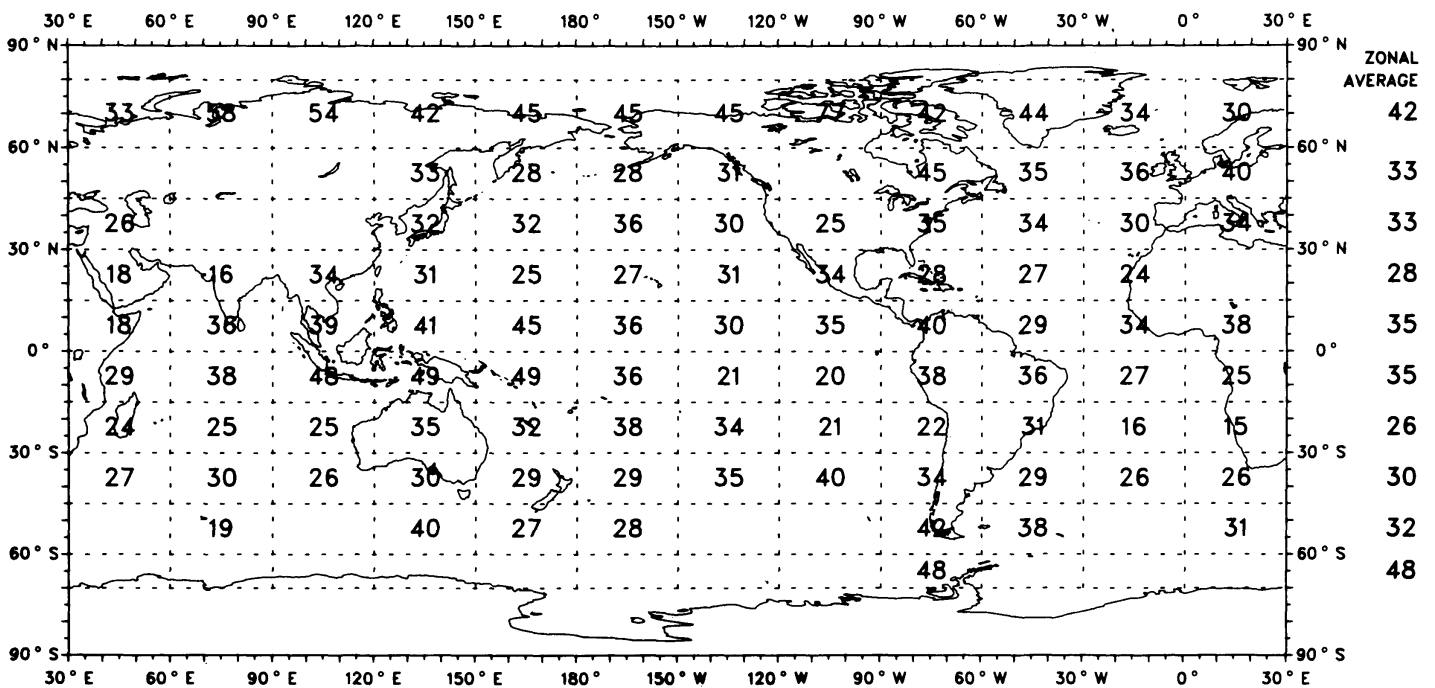
Ocean Areas Only



Frequency of Occurrence (Percent) of Ci/Cs/Cc

MAM (1965-1976)

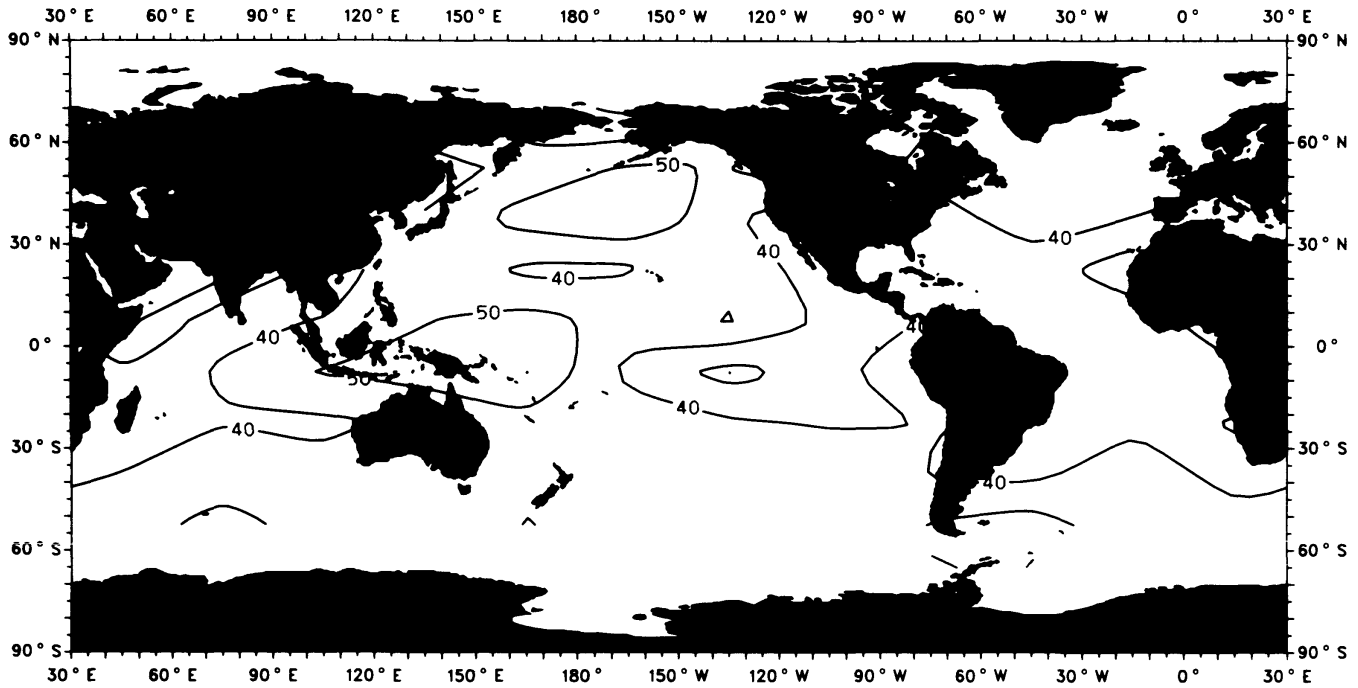
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

MAM (1965-1976)

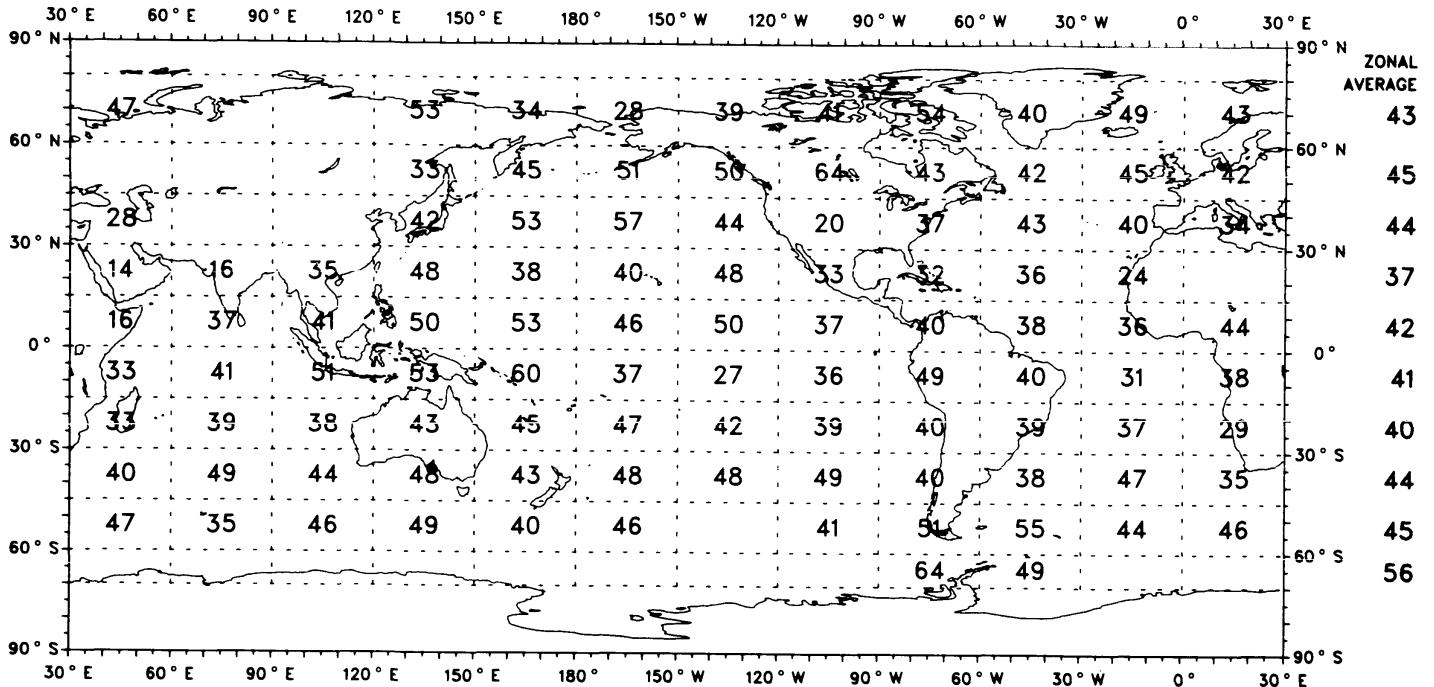
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

MAM (1965-1976)

Ocean Areas Only

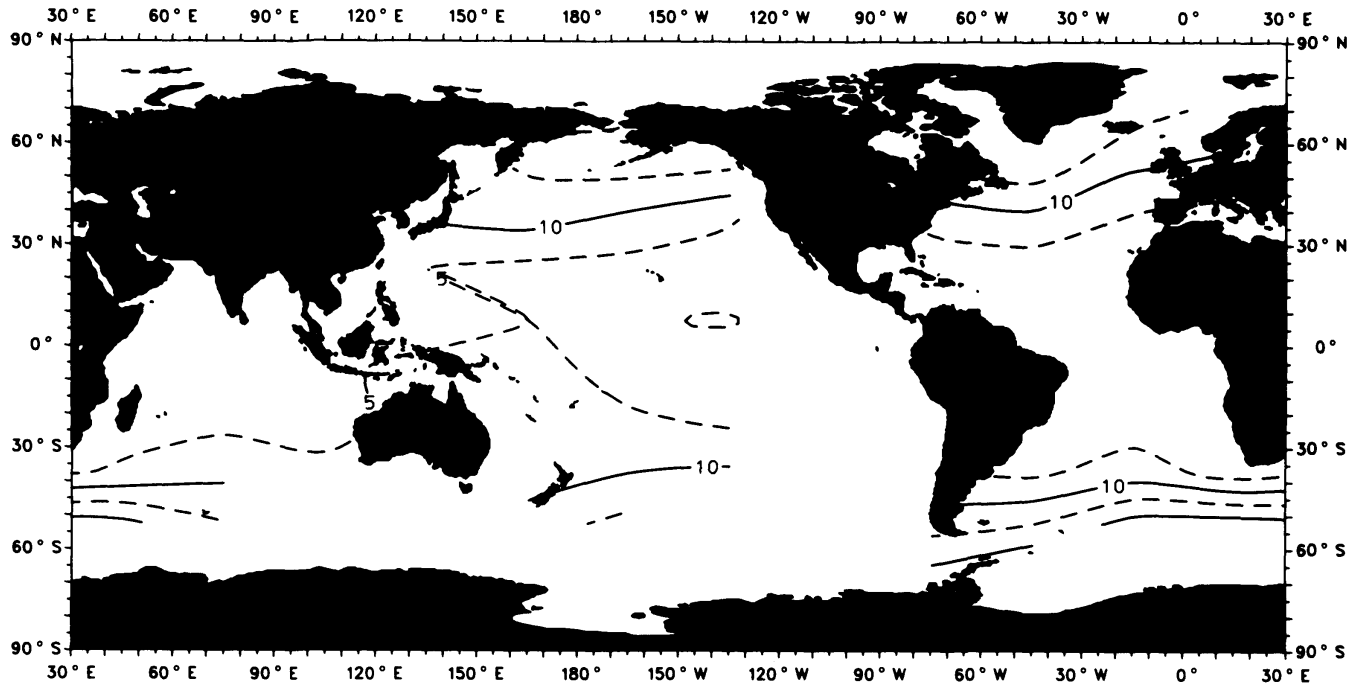


Map II-14

Frequency of Occurrence (Percent) of Nimbostratus

MAM (1965-1976)

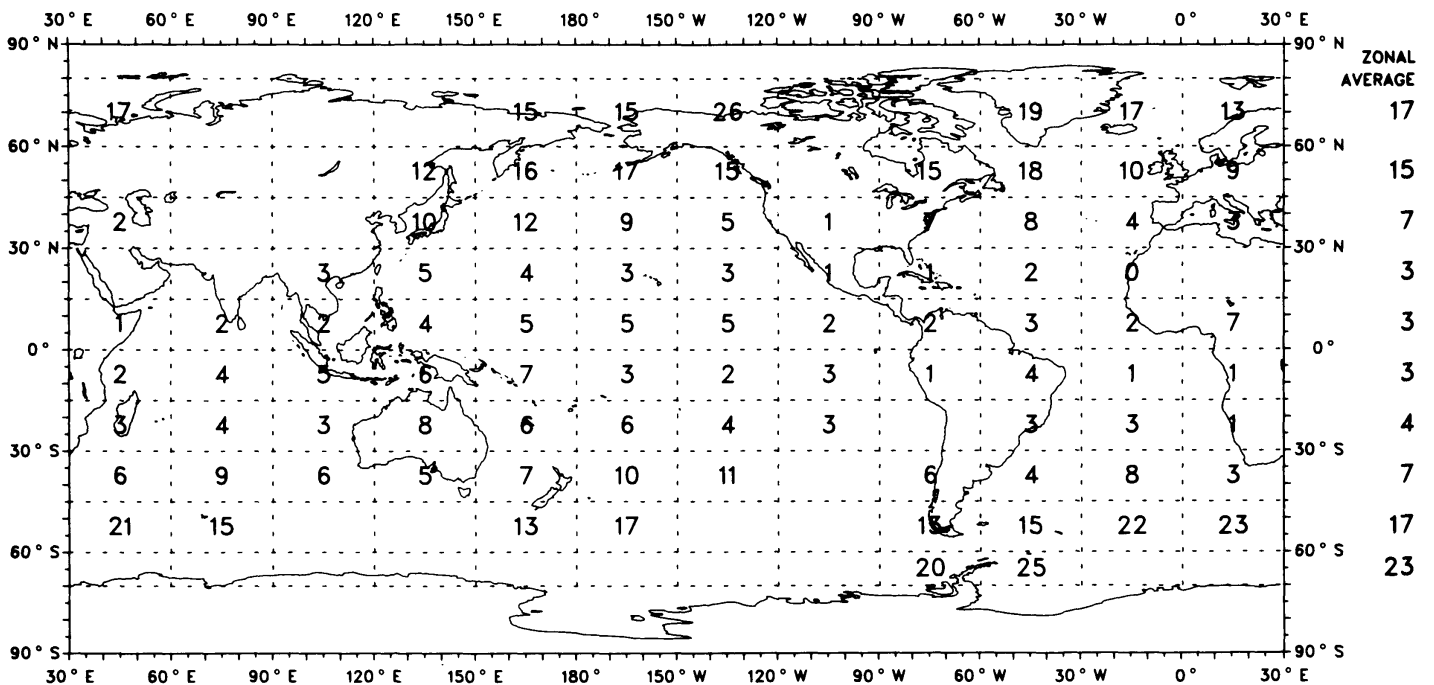
Ocean Areas Only



Frequency of Occurrence (Percent) of Nimbostratus

MAM (1965-1976)

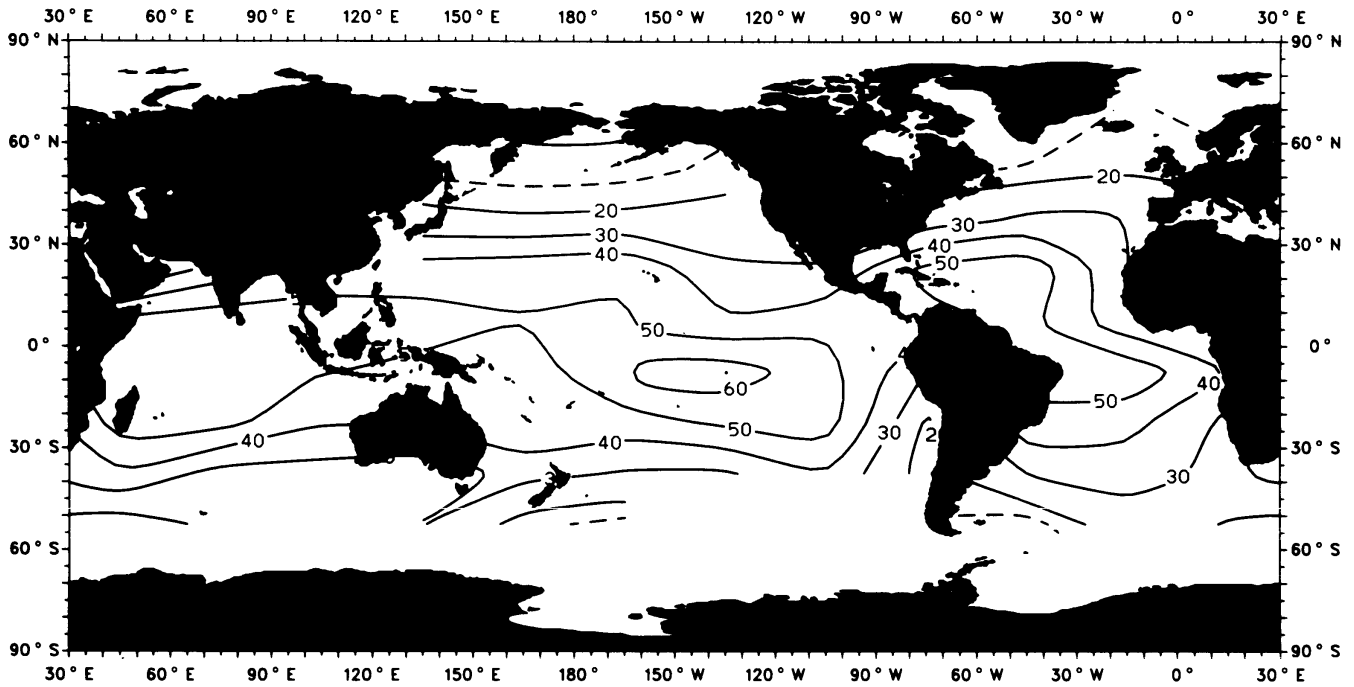
Ocean Areas Only



### Frequency of Occurrence (Percent) of Cumulus

MAM (1965-1976)

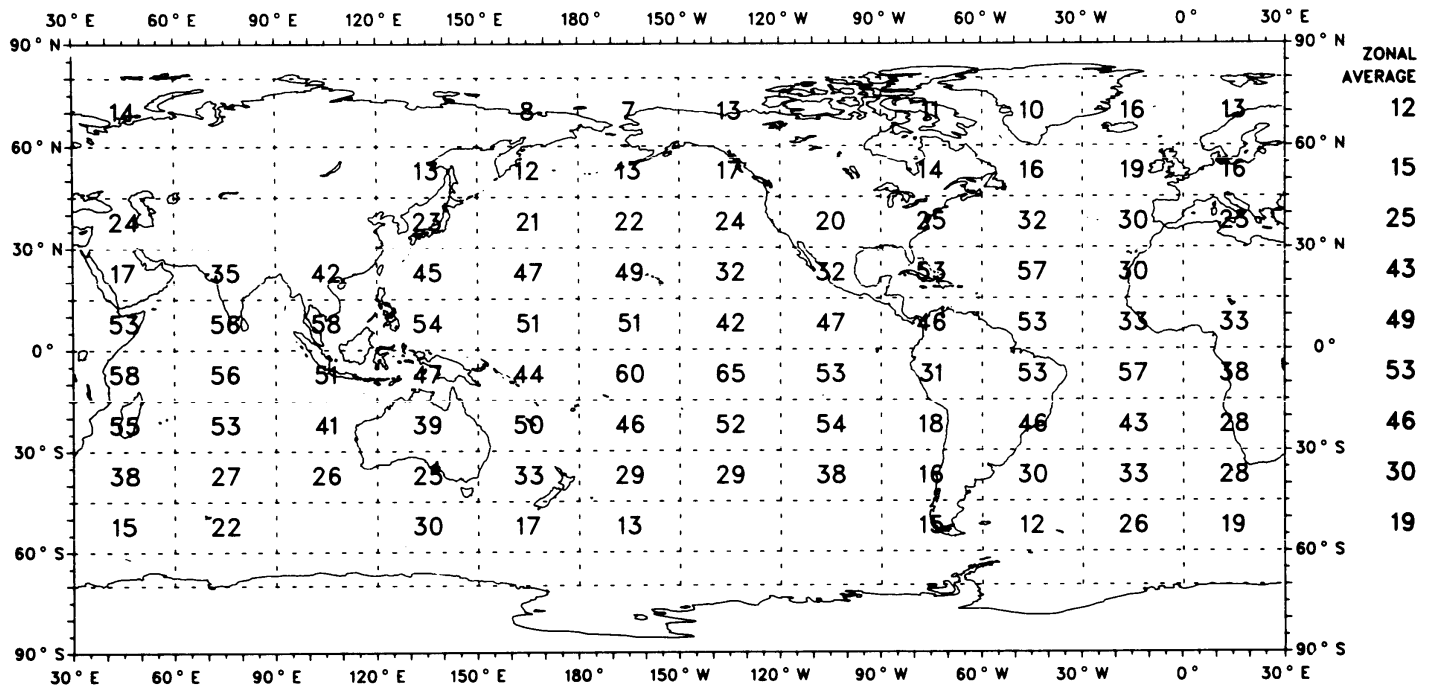
Ocean Areas Only



### Frequency of Occurrence (Percent) of Cumulus

MAM (1965-1976)

Ocean Areas Only

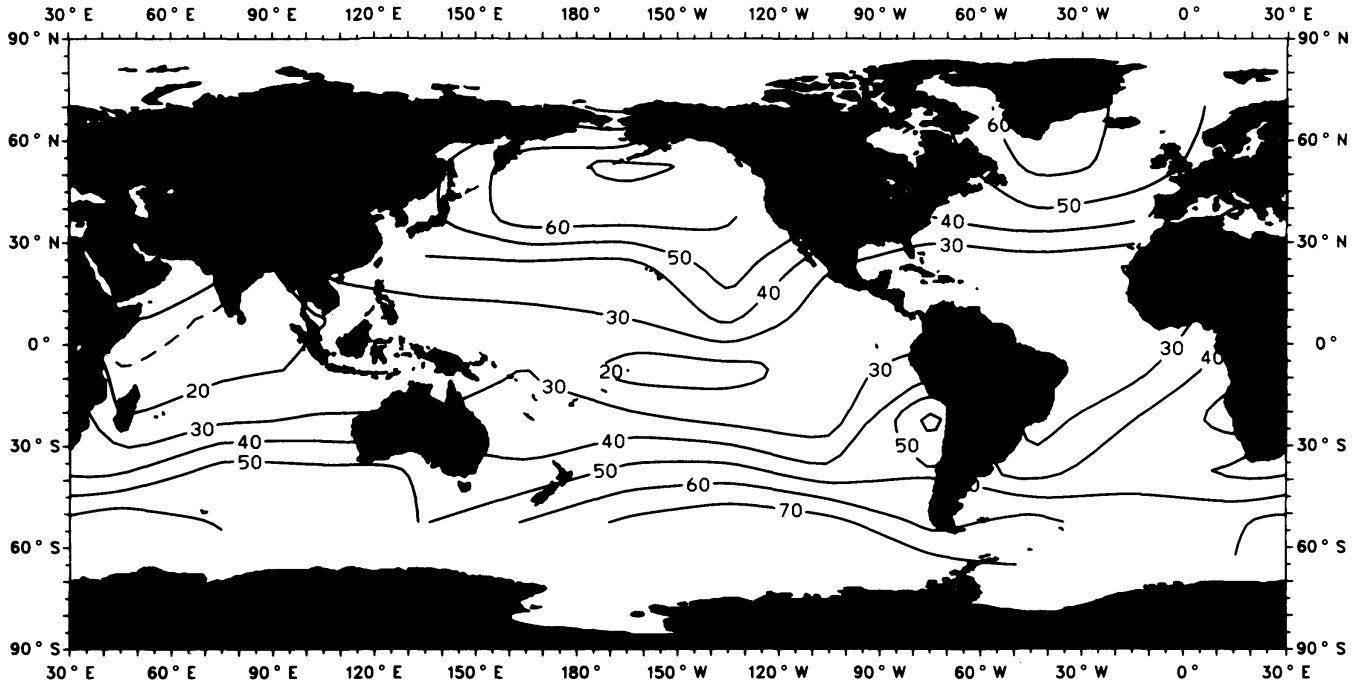


Map II-16

Frequency of Occurrence (Percent) of St/Sc

MAM (1965-1976)

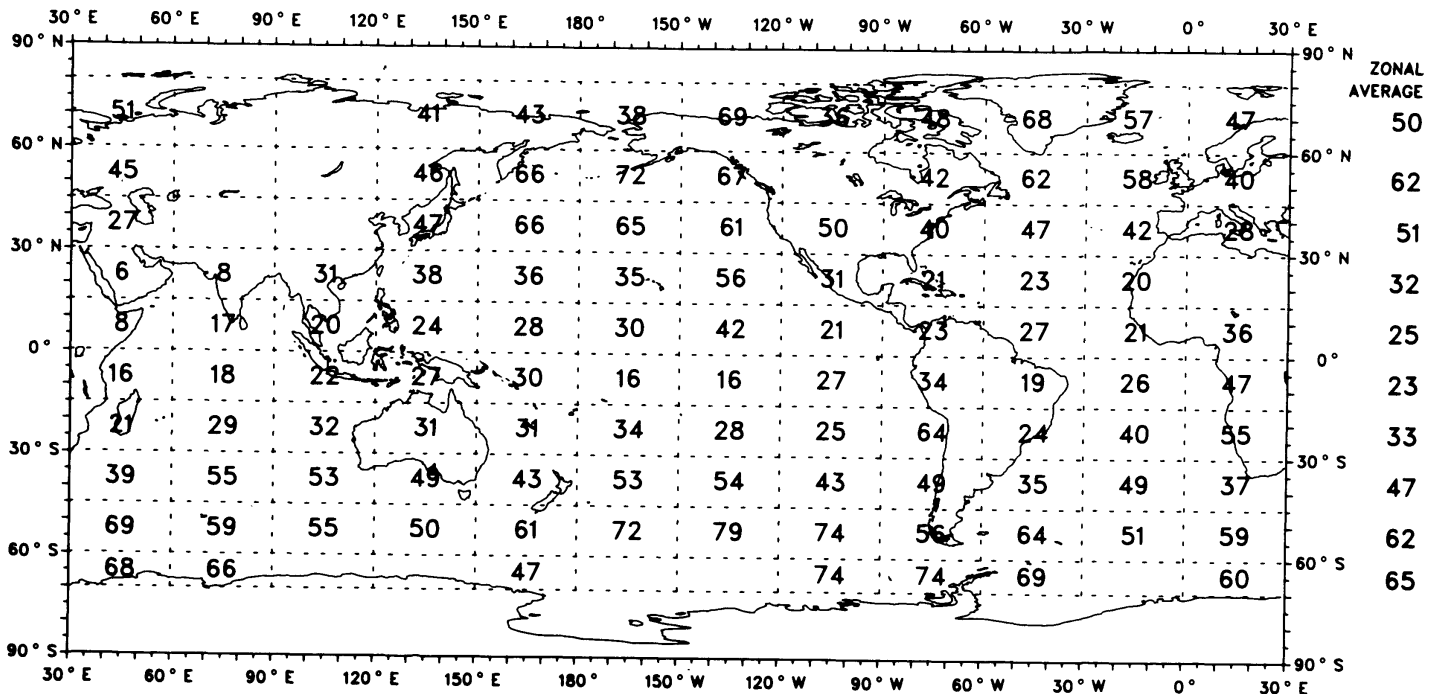
Ocean Areas Only



Frequency of Occurrence (Percent) of St/Sc

MAM (1965-1976)

Ocean Areas Only



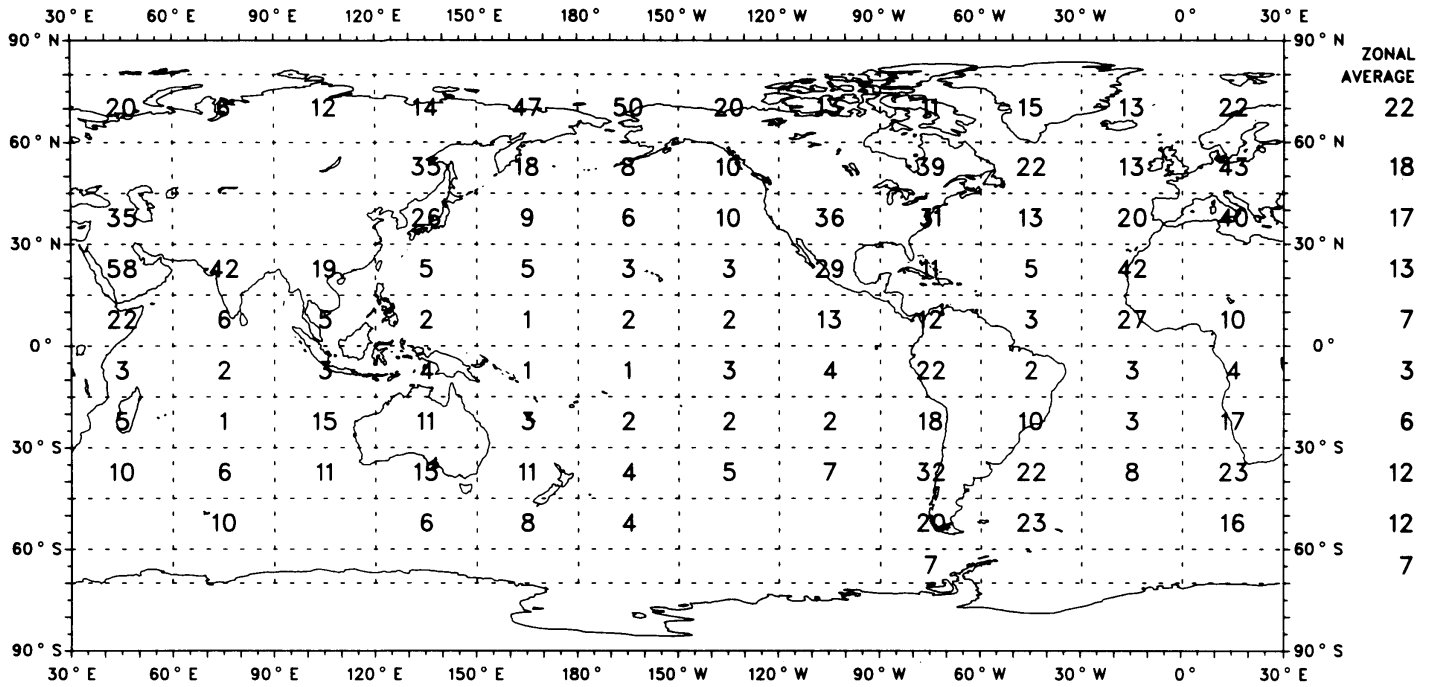


Map II-18

Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

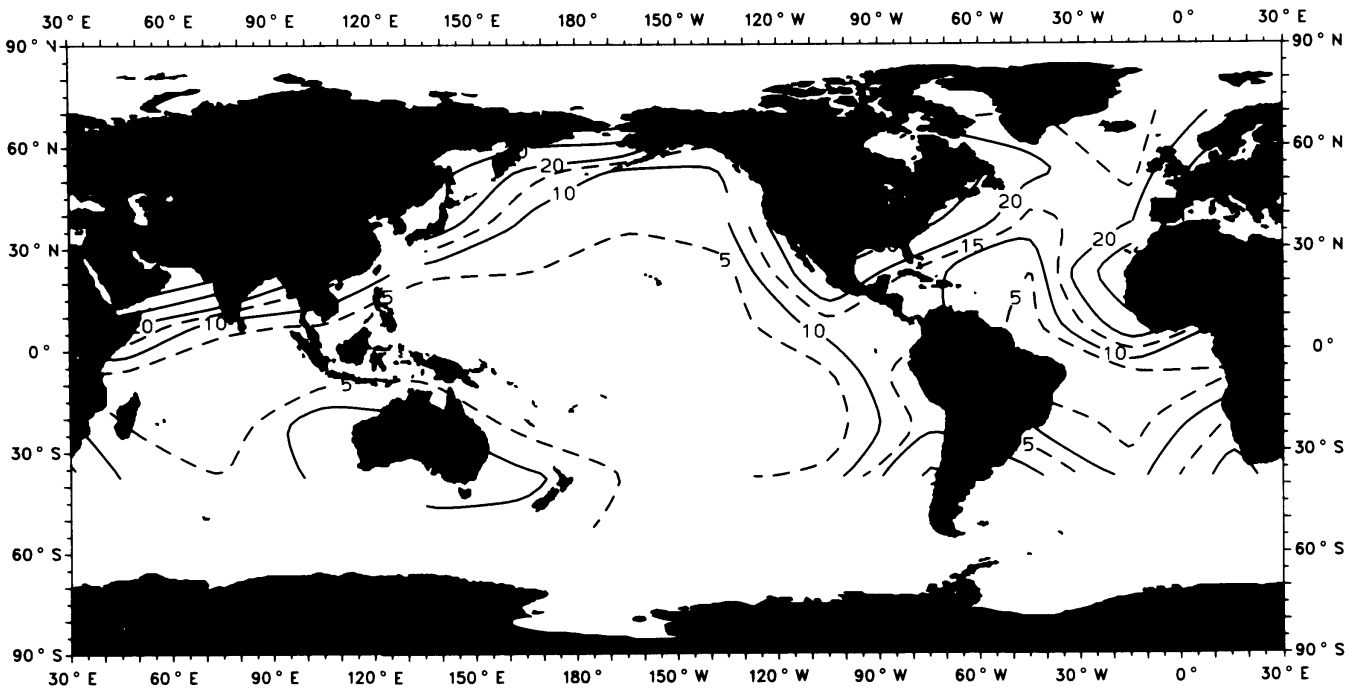
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

Ocean Areas Only



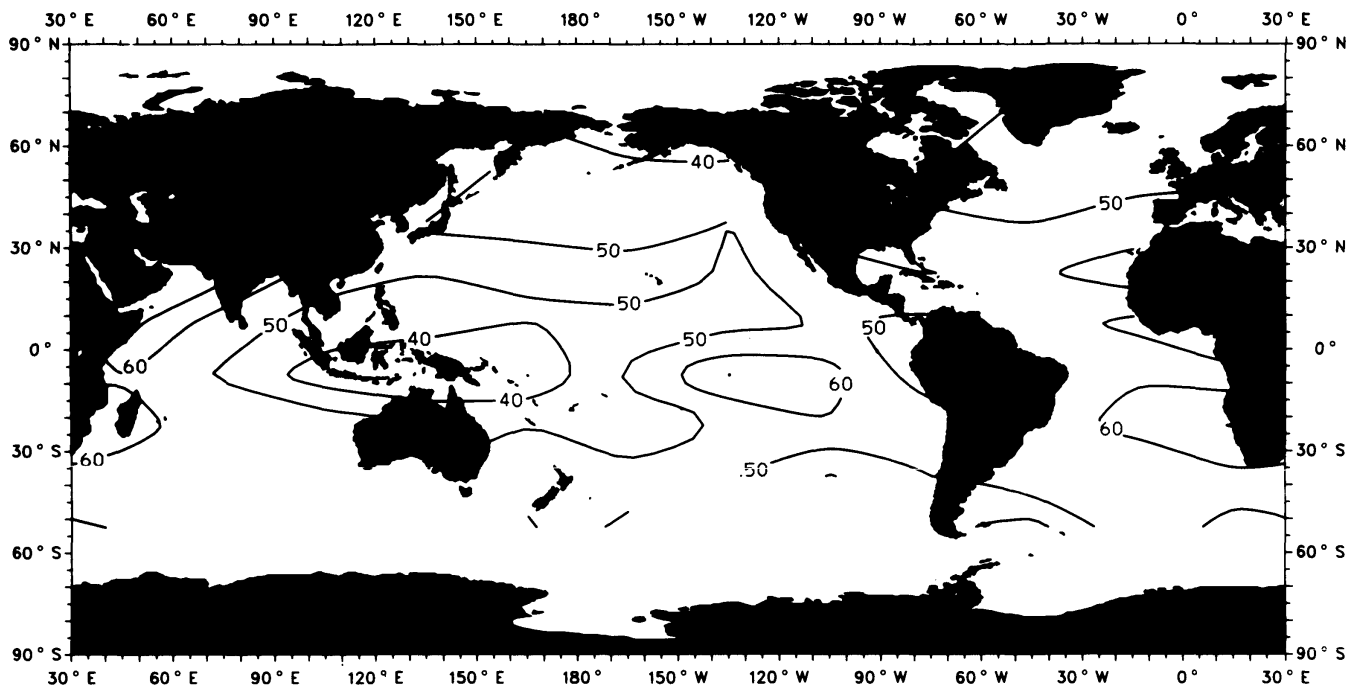




Given Cumulus, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

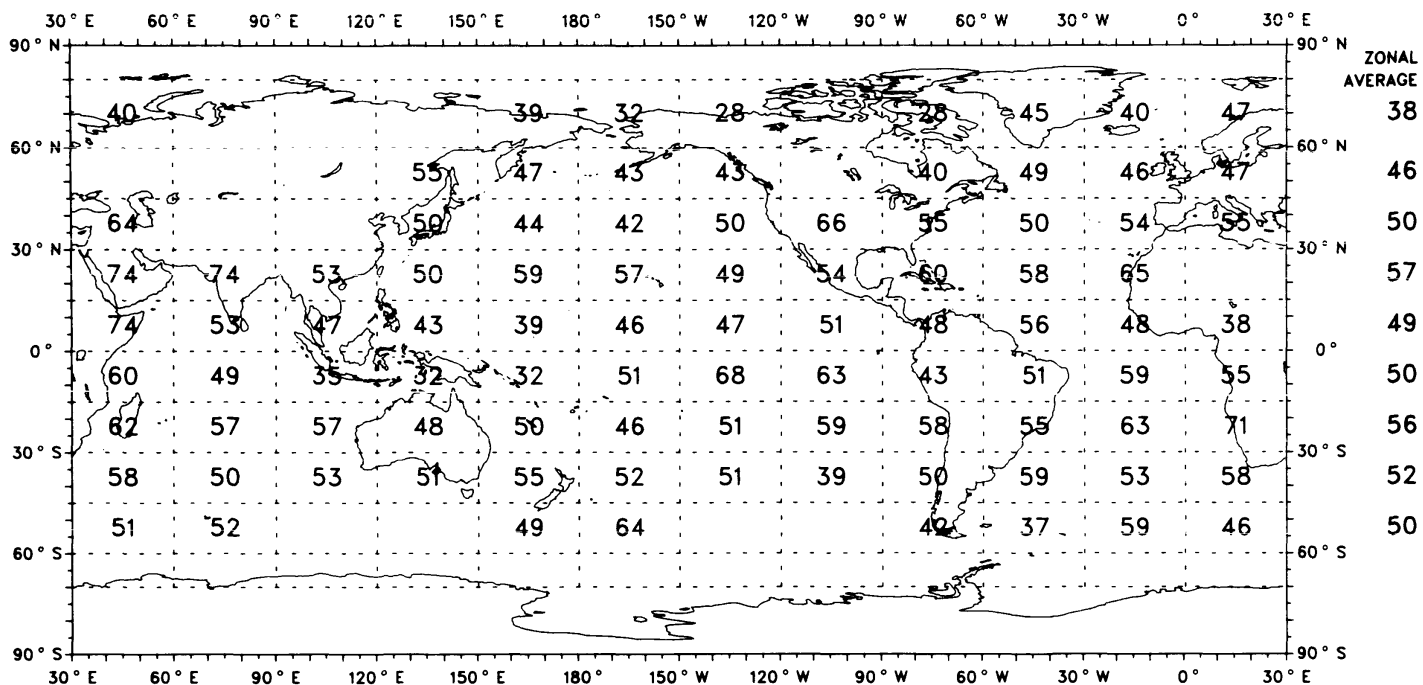
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

Ocean Areas Only

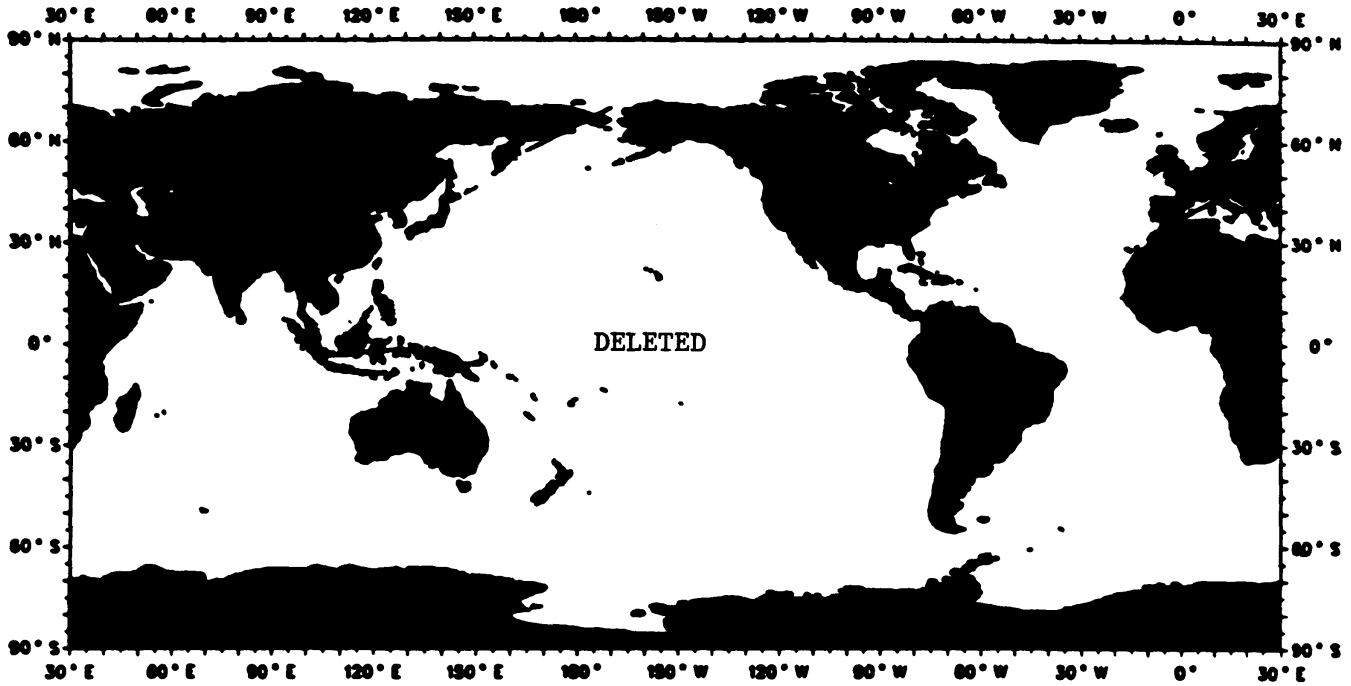


Map II-22

Given St/Sc, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

Ocean Areas Only

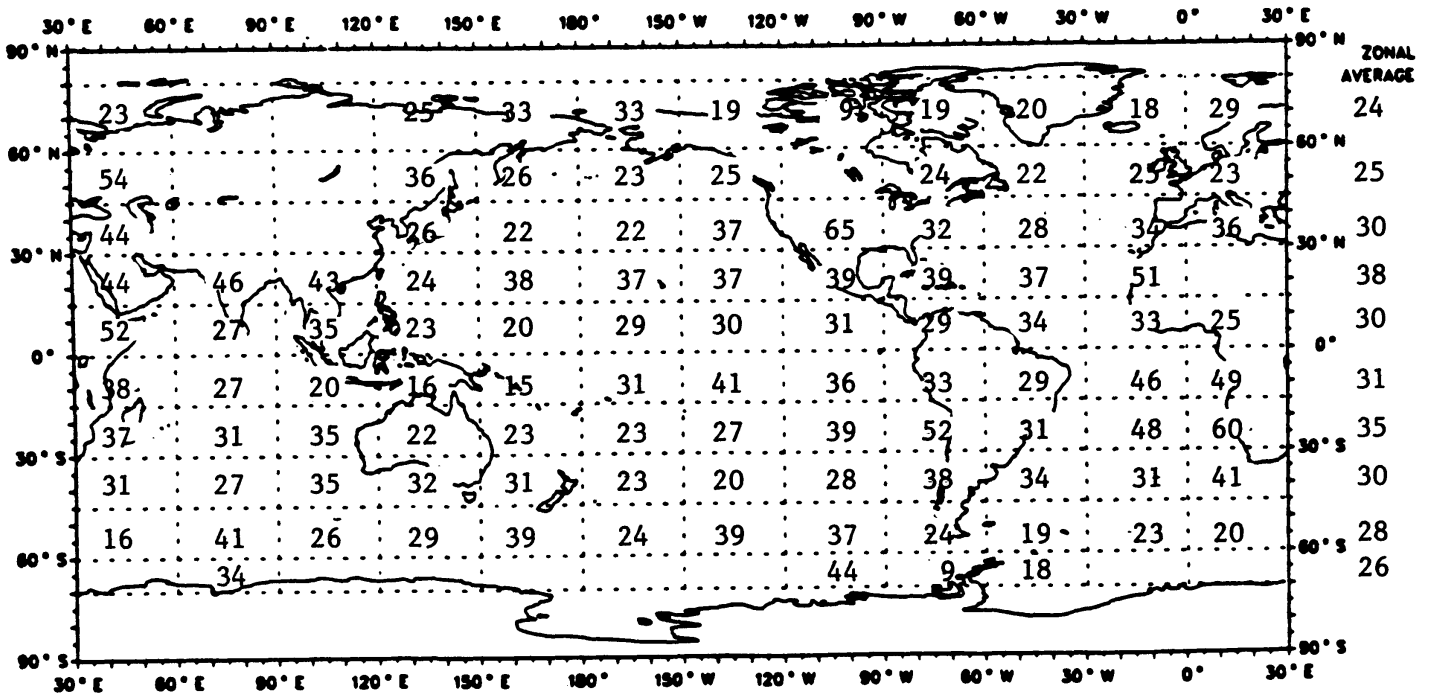


Given St/Sc, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

Revised 1988

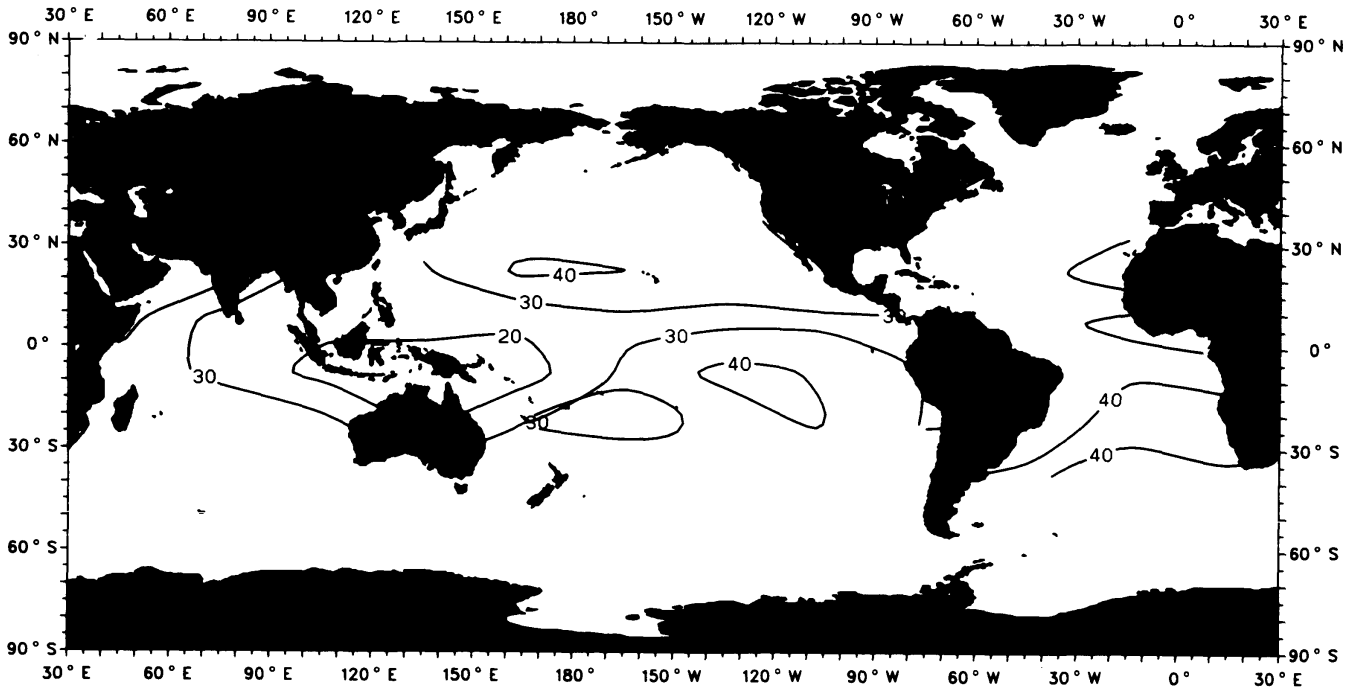
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

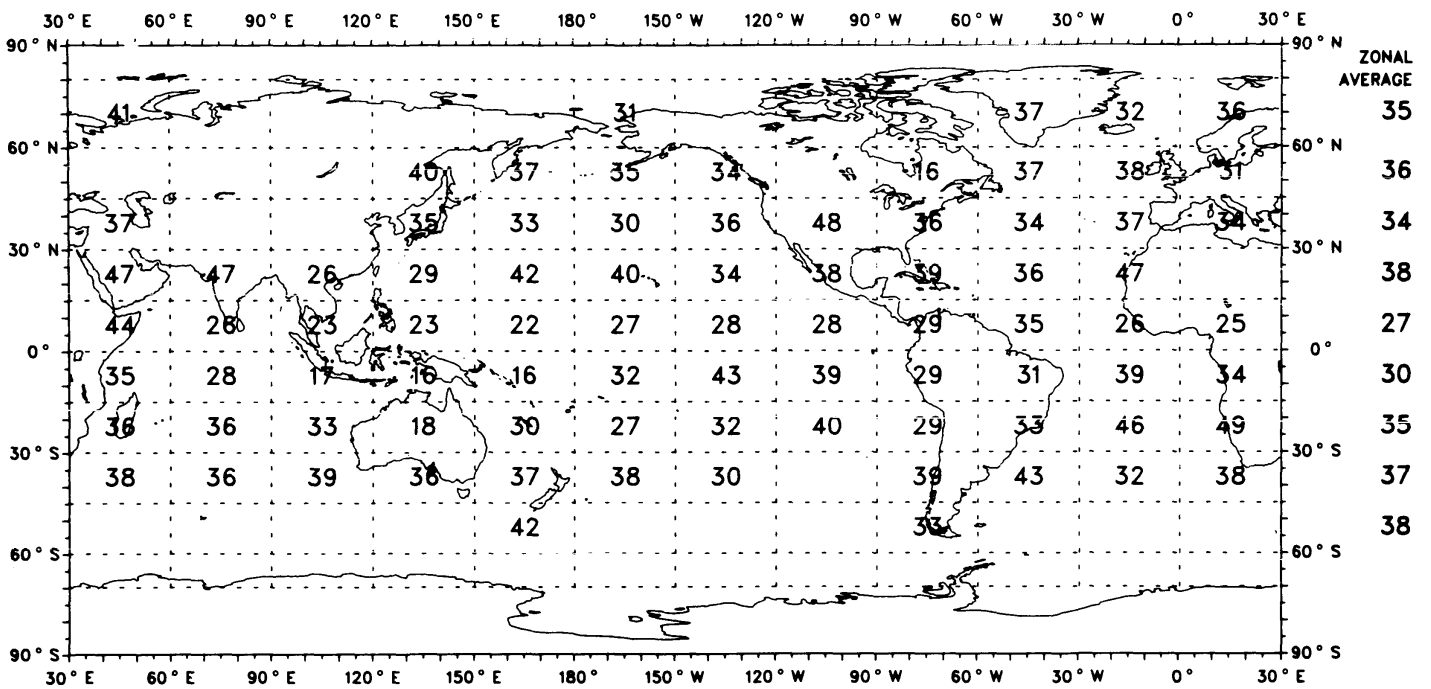
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That No Other Cloud Is Present

MAM (1965-1976)

Ocean Areas Only

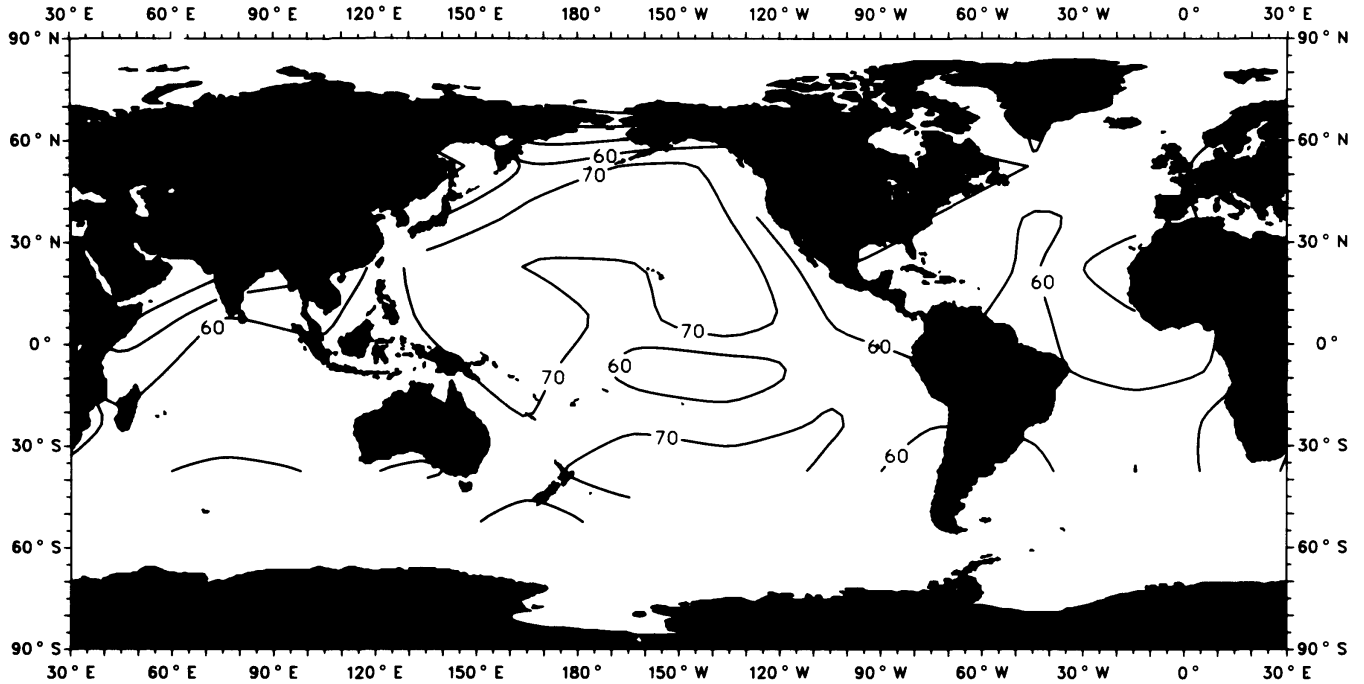


Map II-24

Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

MAM (1965-1976)

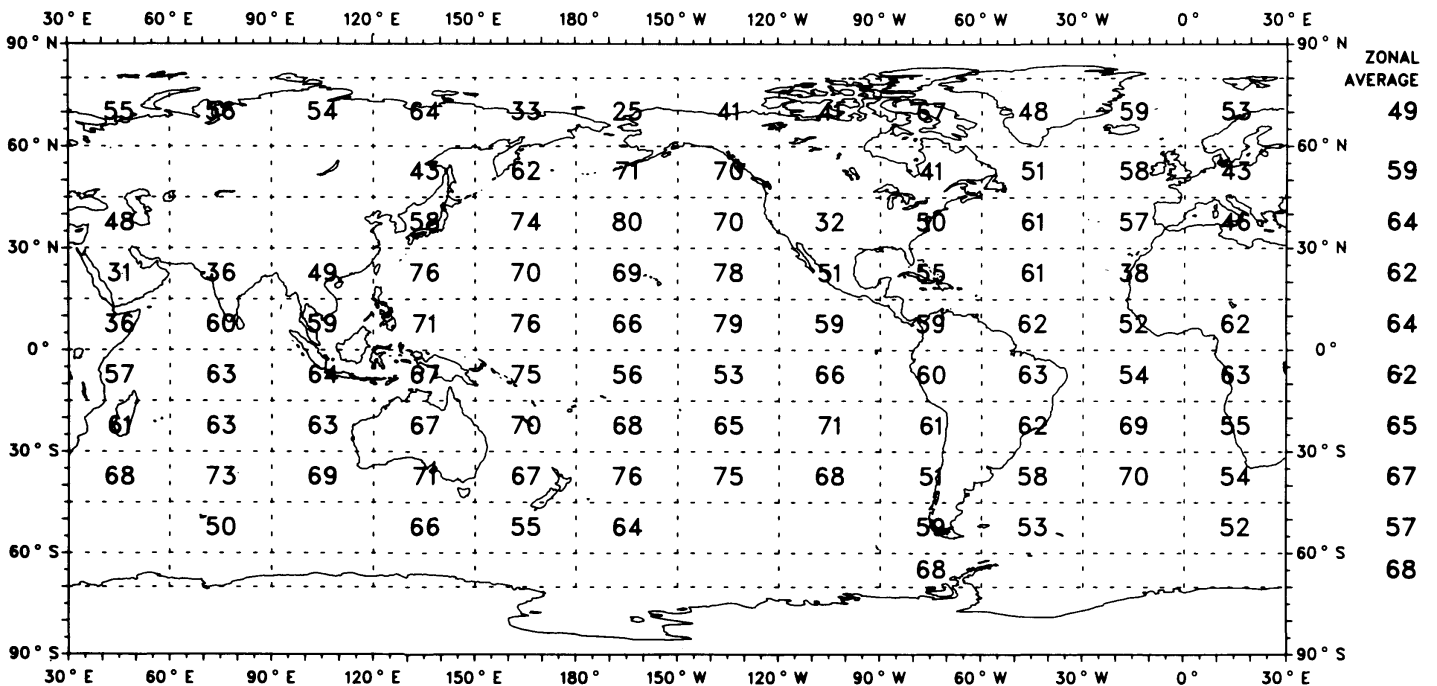
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

MAM (1965-1976)

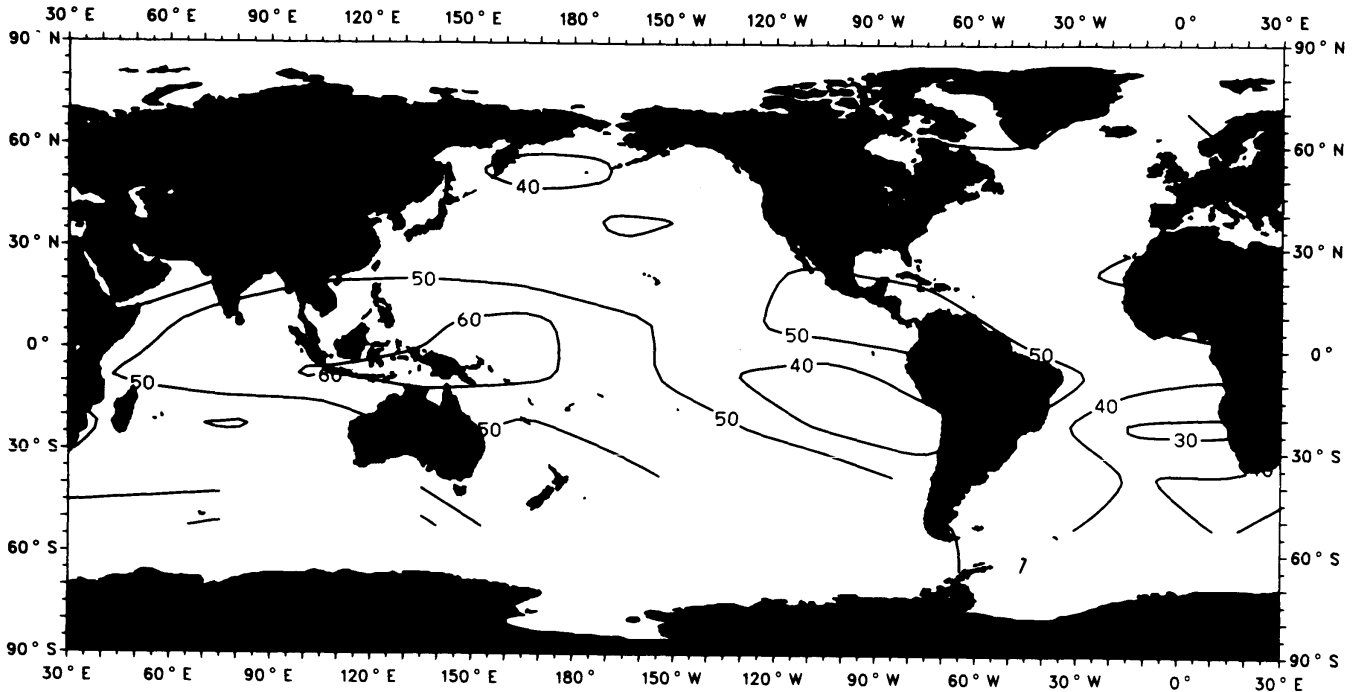
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

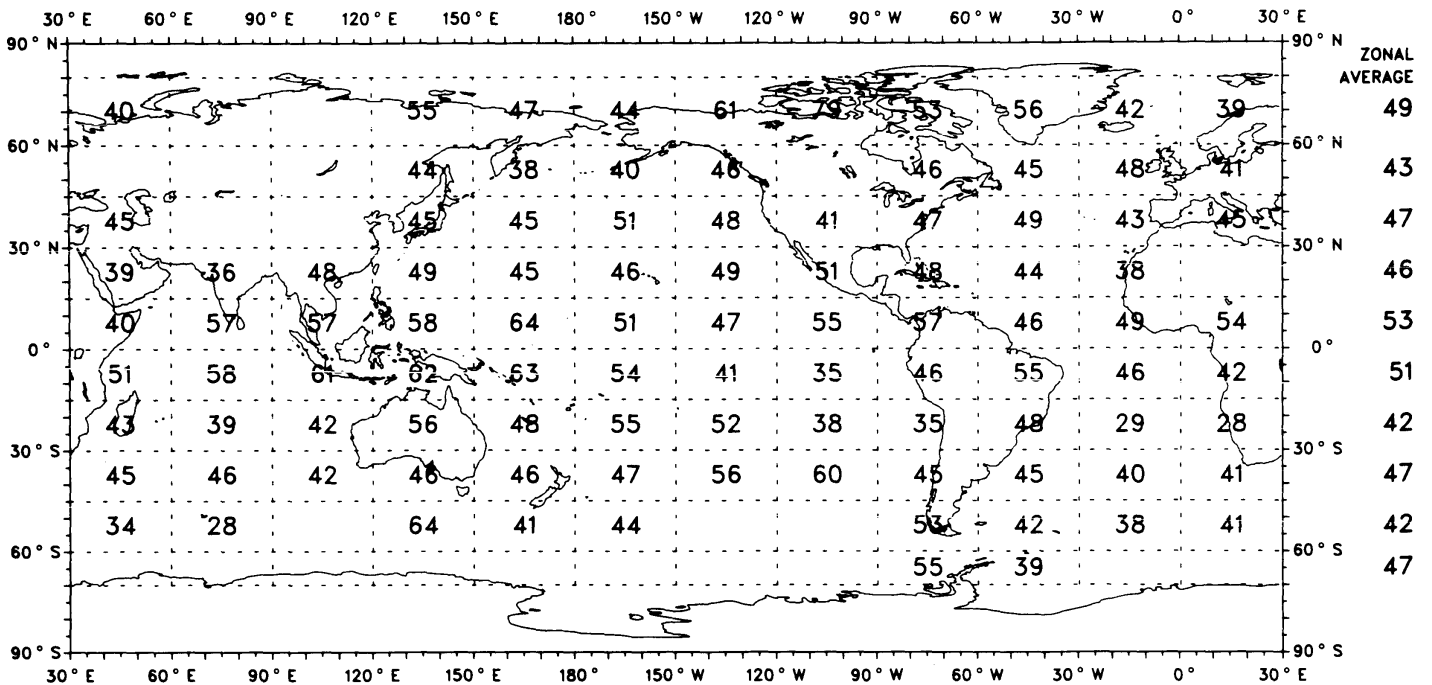
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

Ocean Areas Only





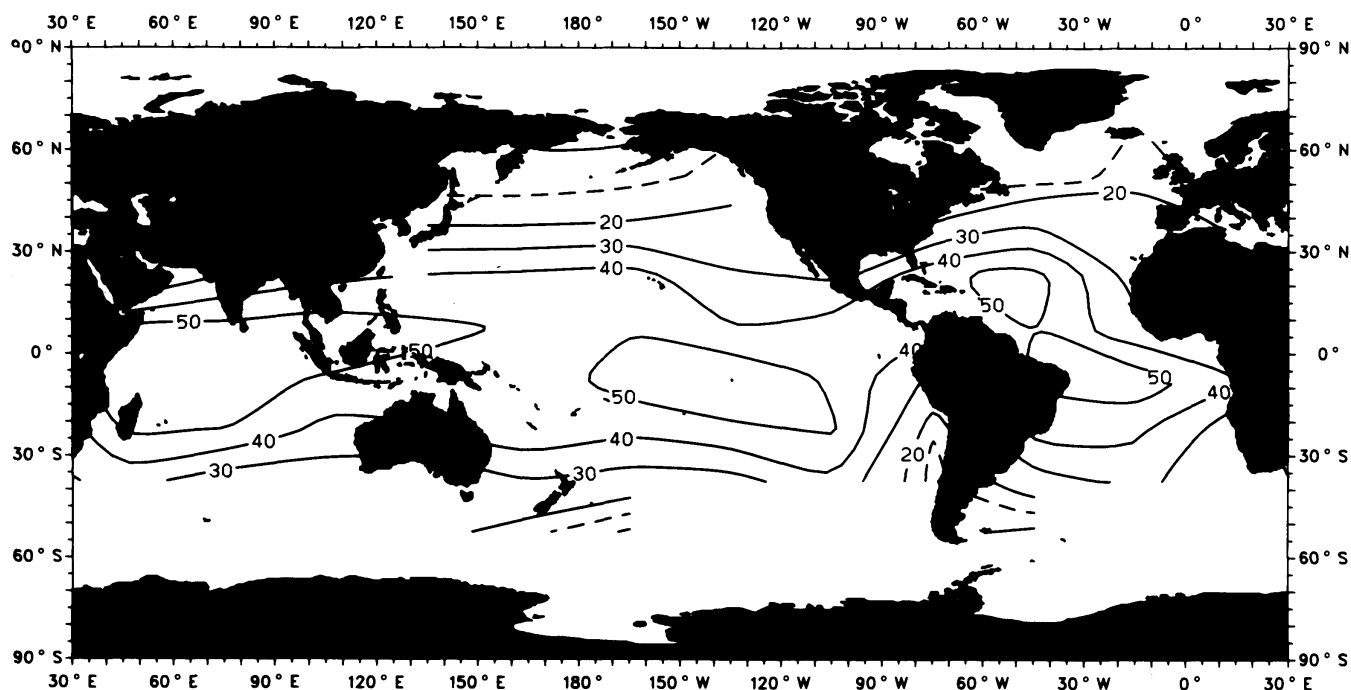


Map II-28

Given Ci/Cs/Cc, Probability (Percent) That Cumulus is Also Present

MAM (1965-1976)

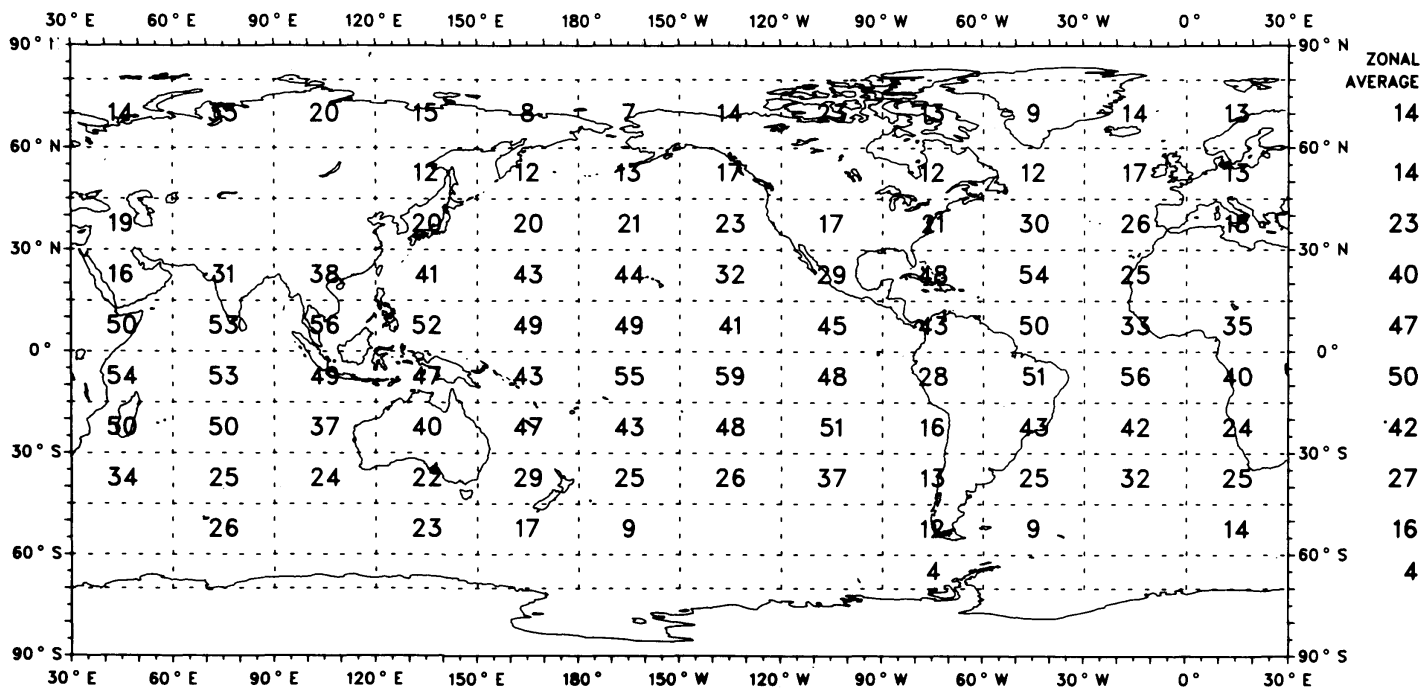
Ocean Areas Only



Given Ci/Cs/Cc, Probability (Percent) That Cumulus is Also Present

MAM (1965-1976)

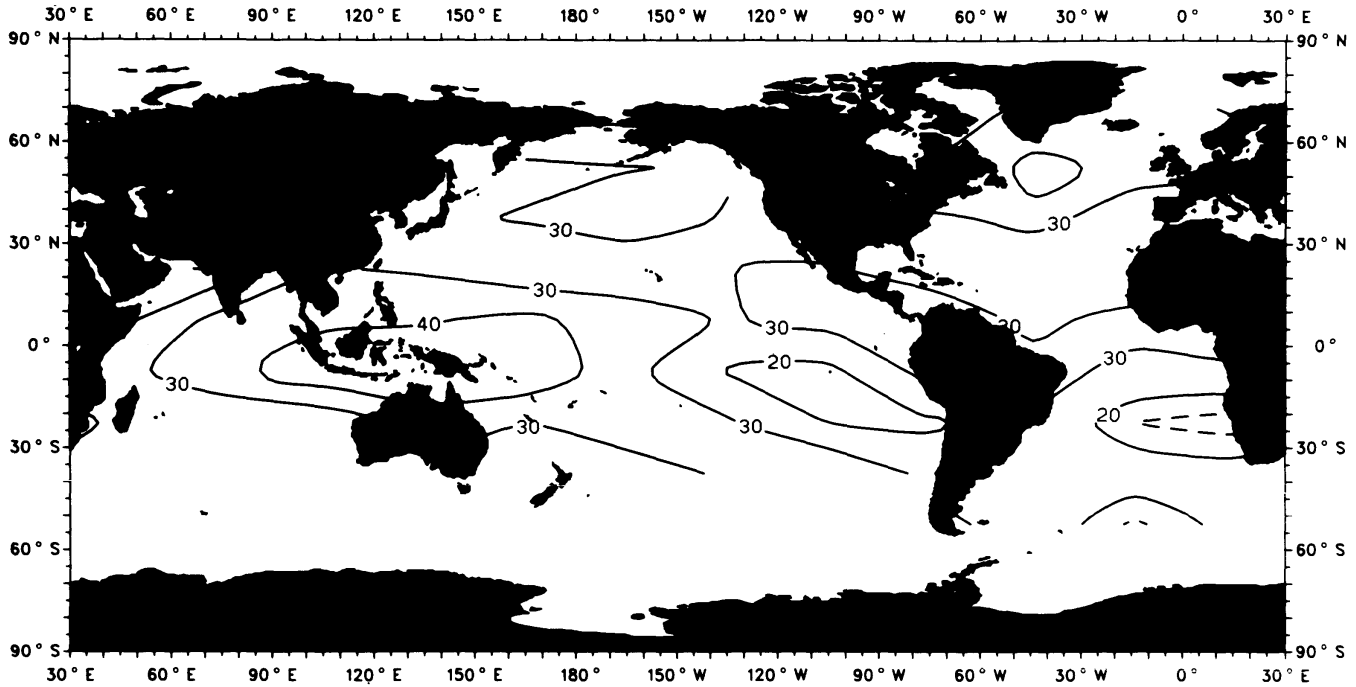
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

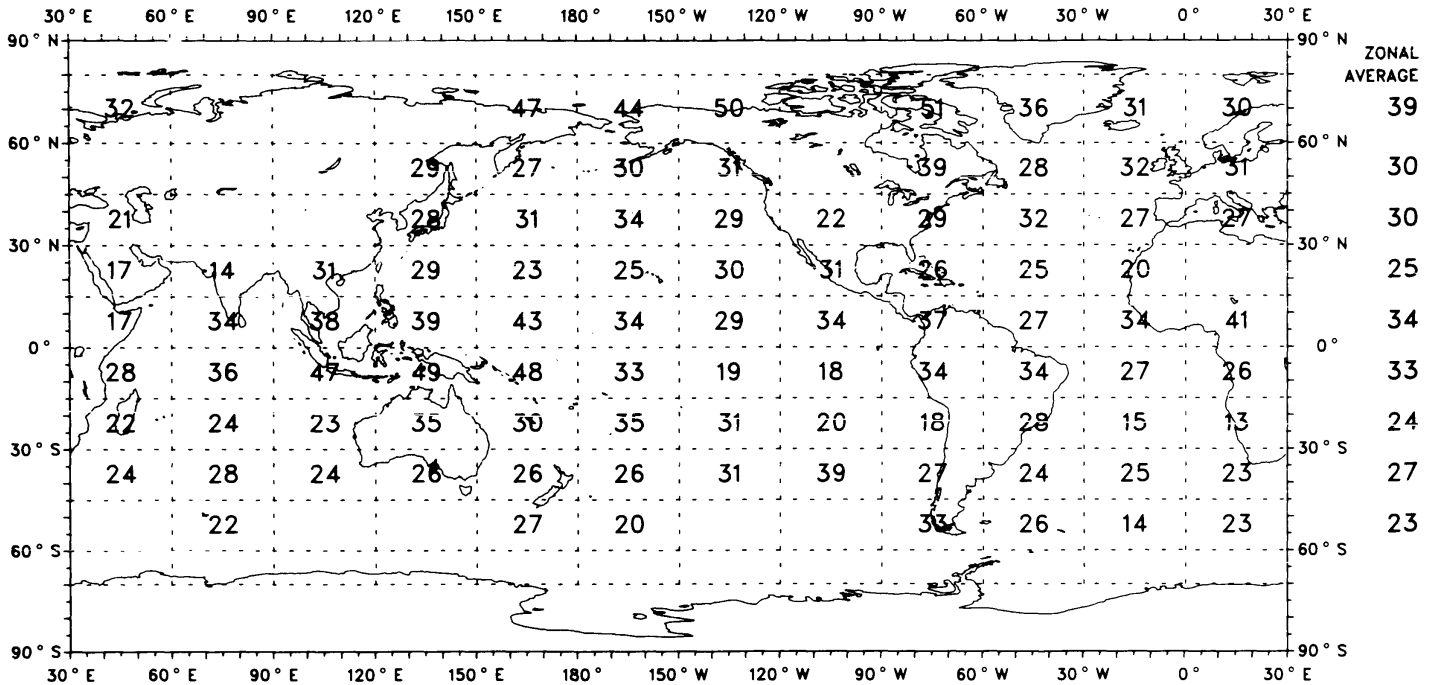
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

Ocean Areas Only

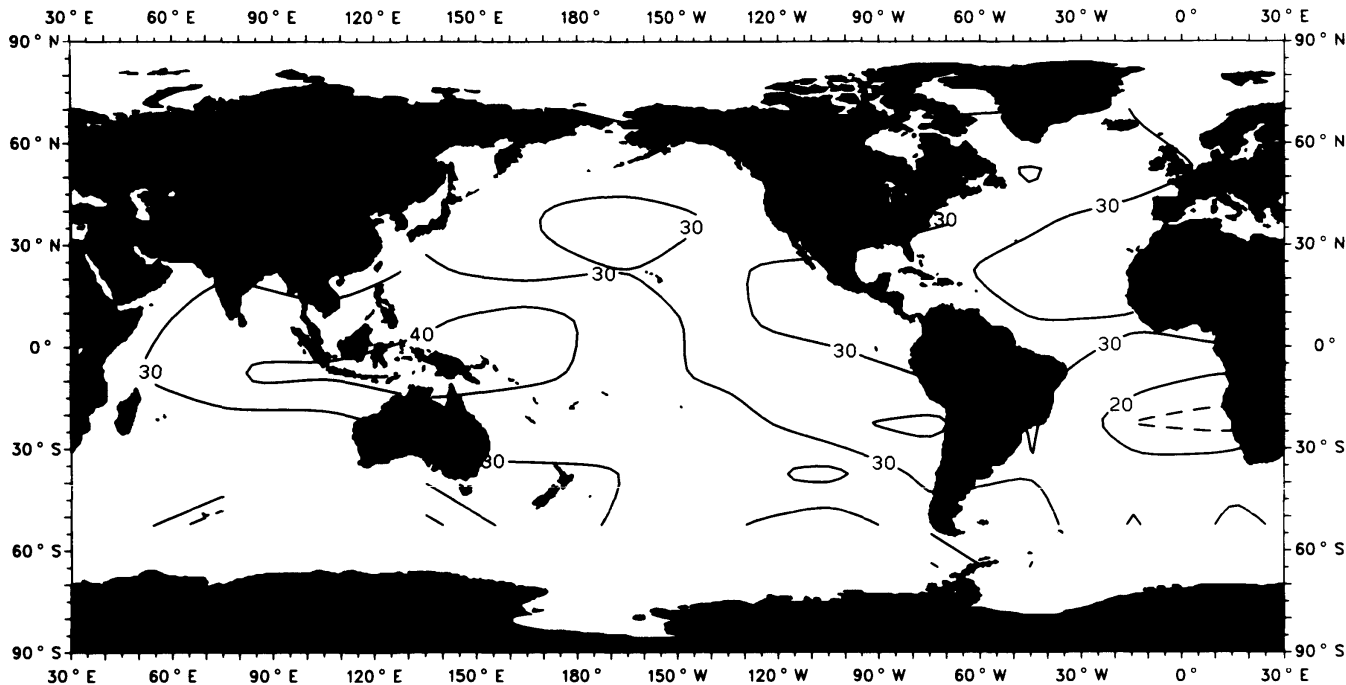




Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

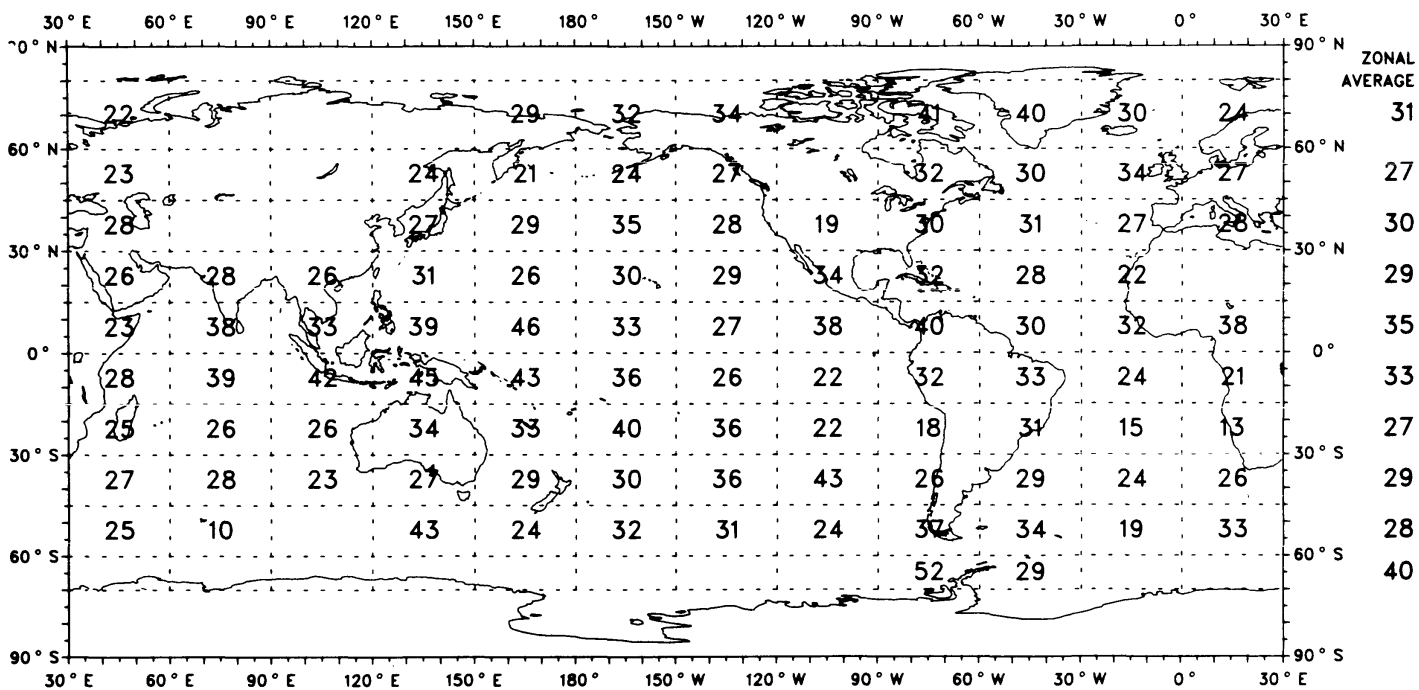
Ocean Areas Only



Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

Ocean Areas Only

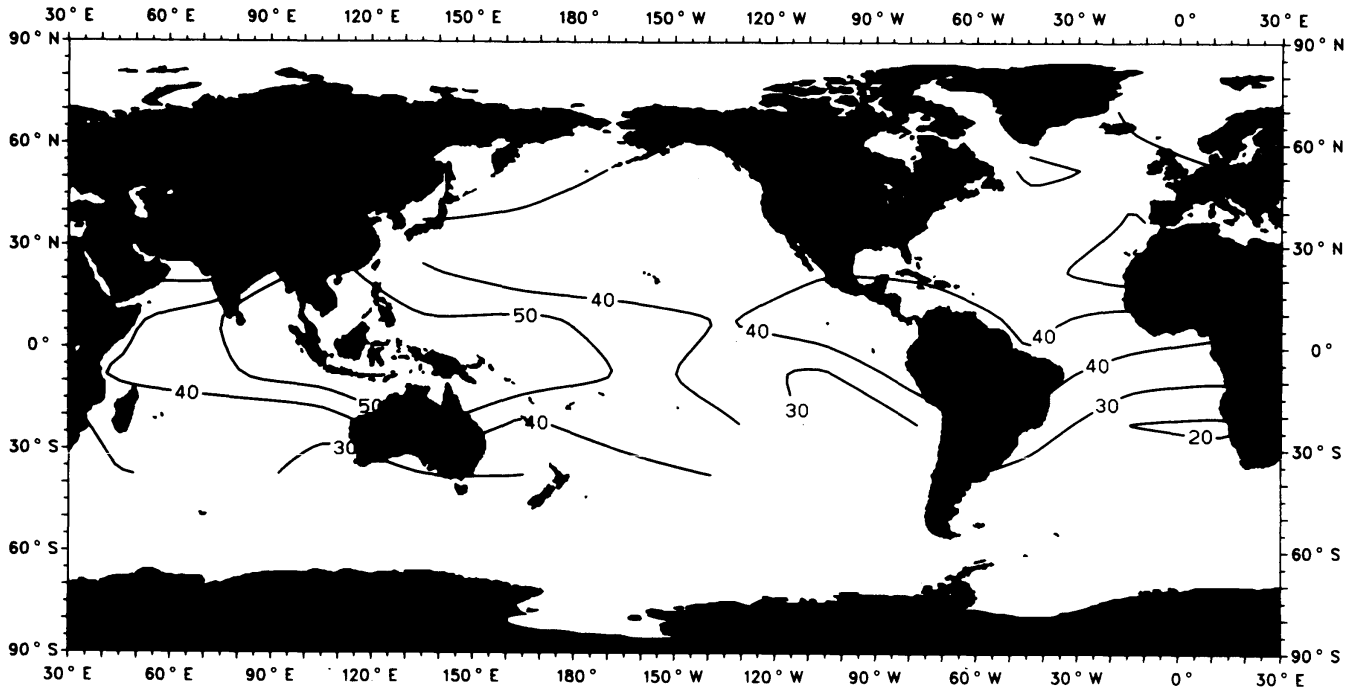




Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

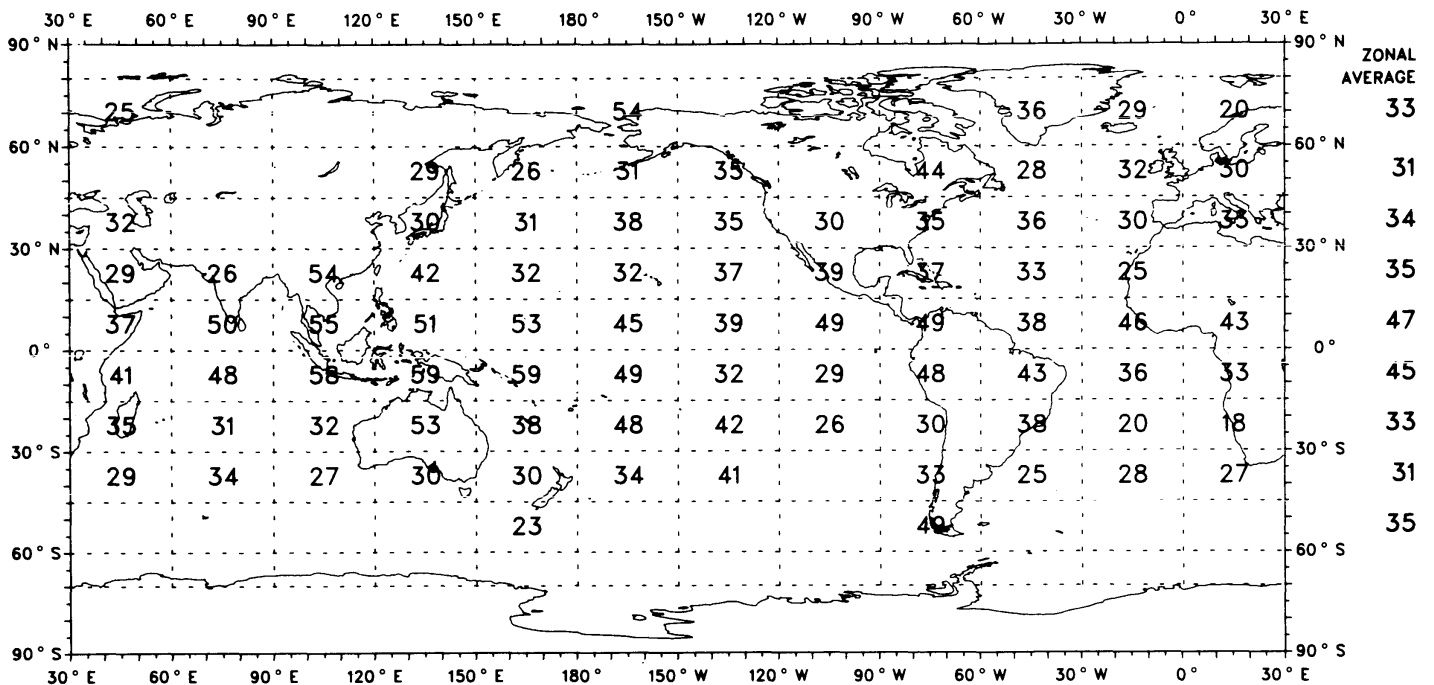
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

MAM (1965-1976)

Ocean Areas Only

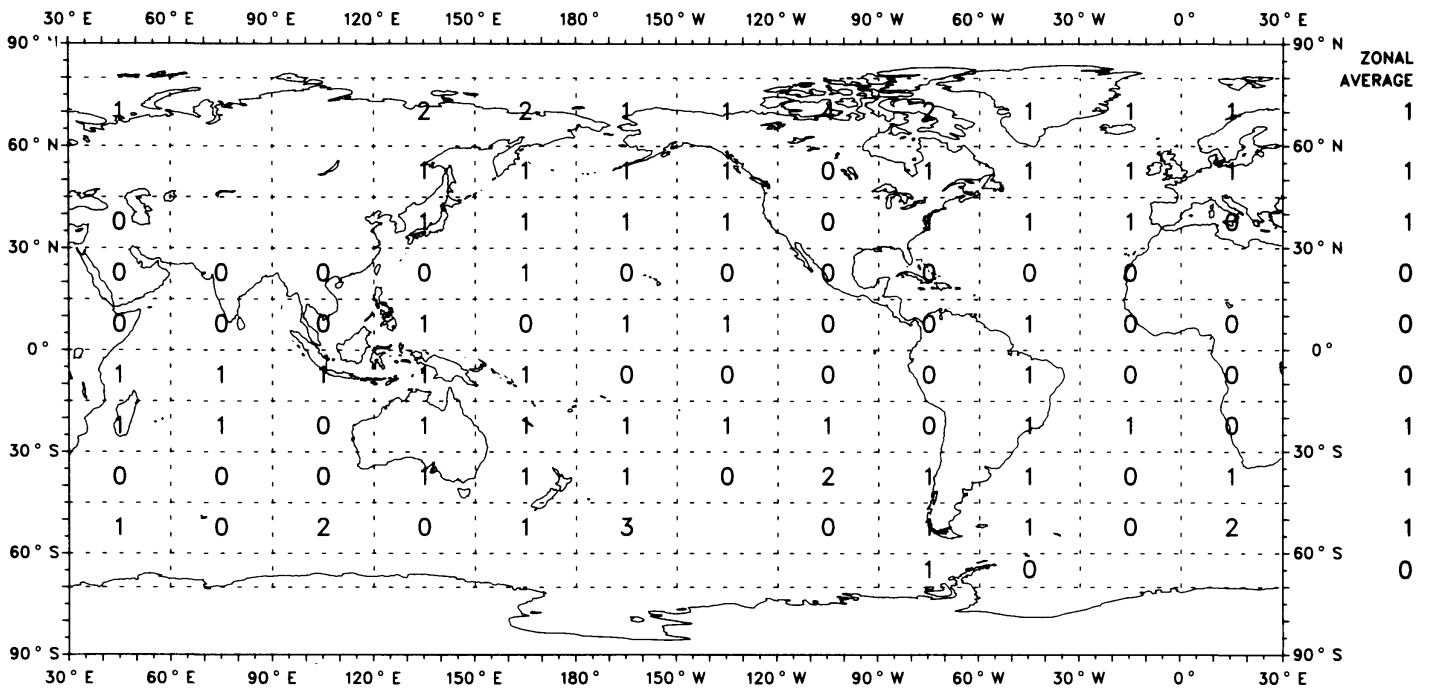


Map II-34

Given  $A_s/A_c$ , Probability (Percent) That Nimbostratus is Also Present

MAM (1965-1976)

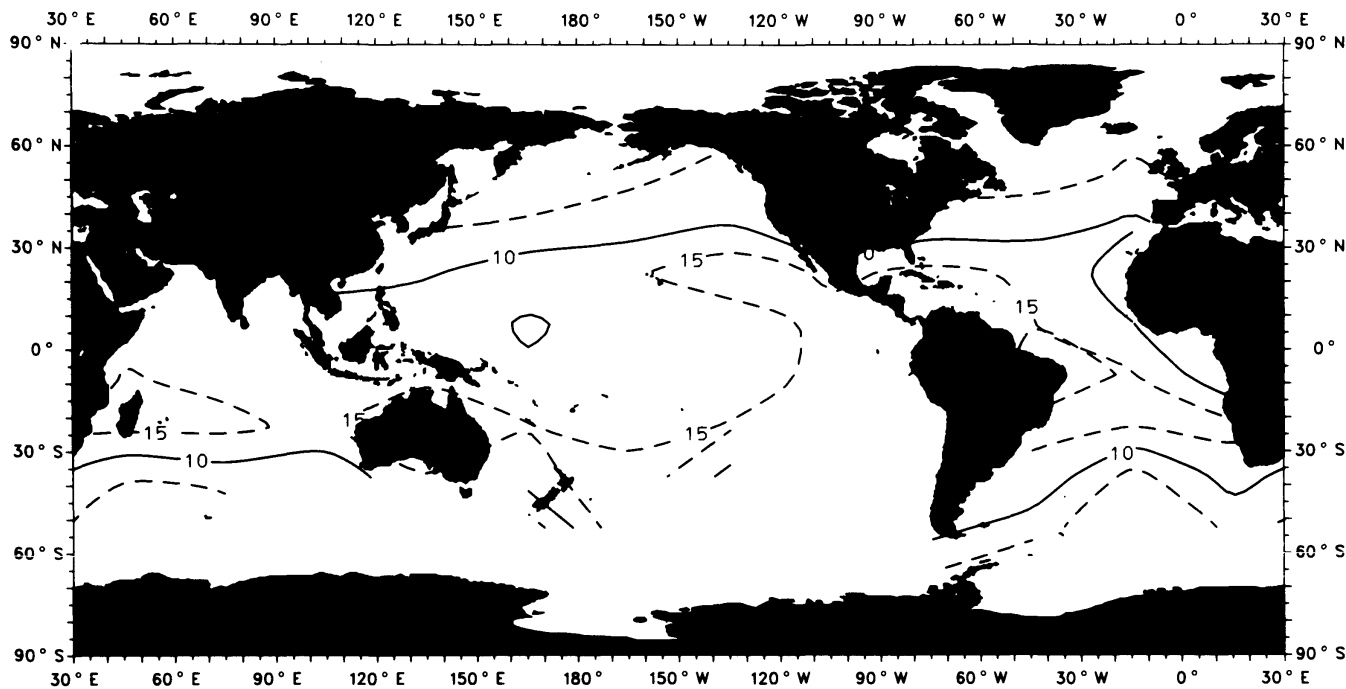
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

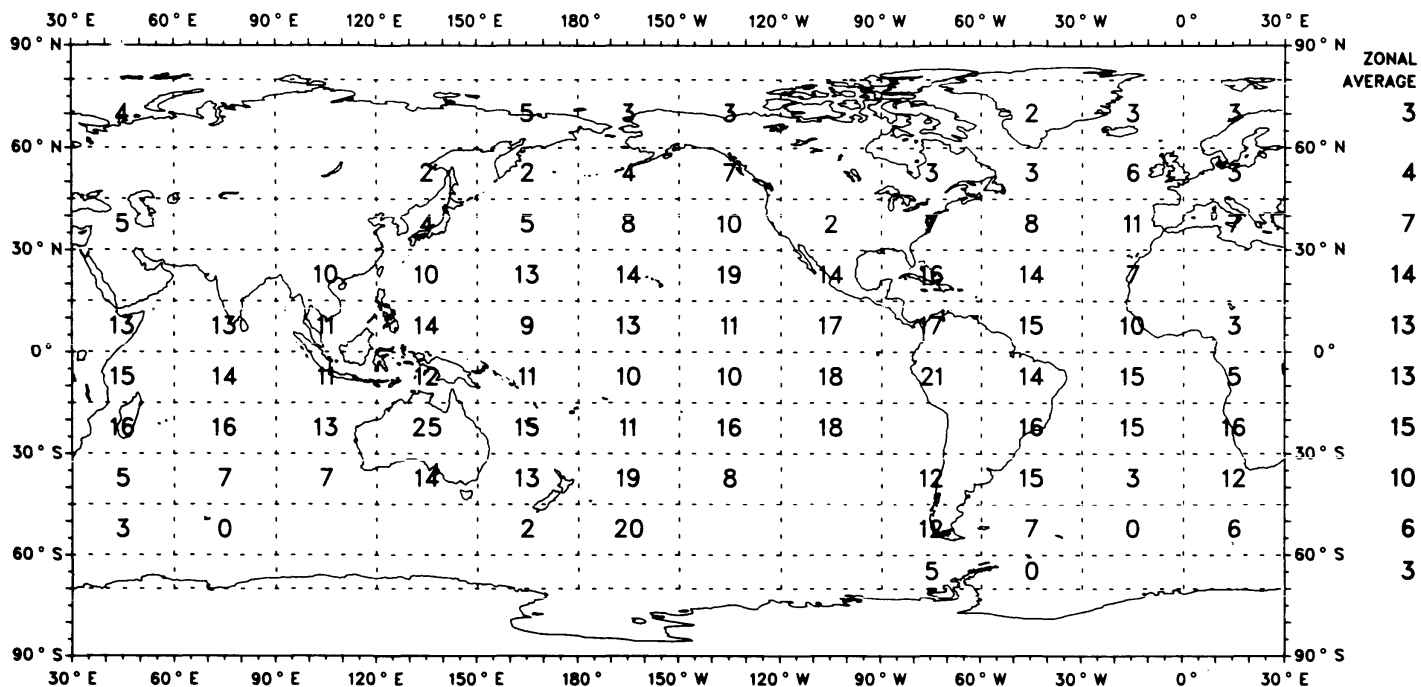
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

Ocean Areas Only

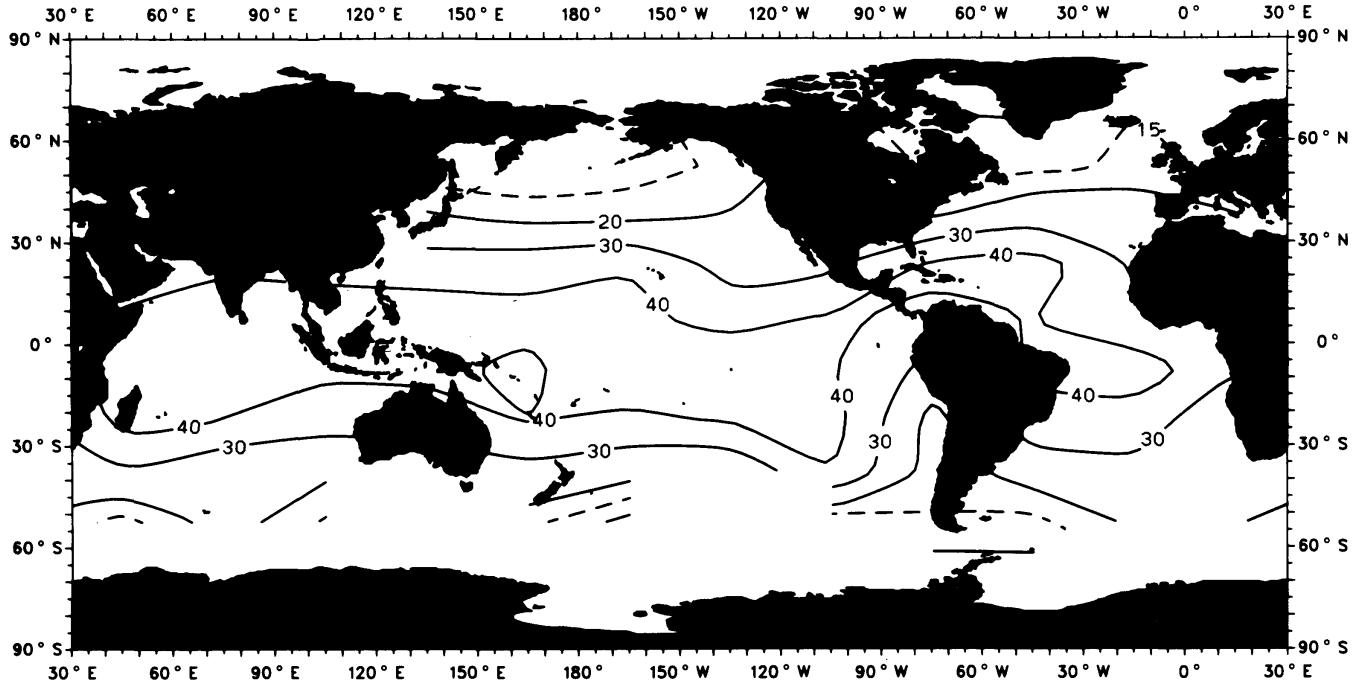


Map II-36

Given As/Ac, Probability (Percent) That Cumulus is Also Present

MAM (1965-1976)

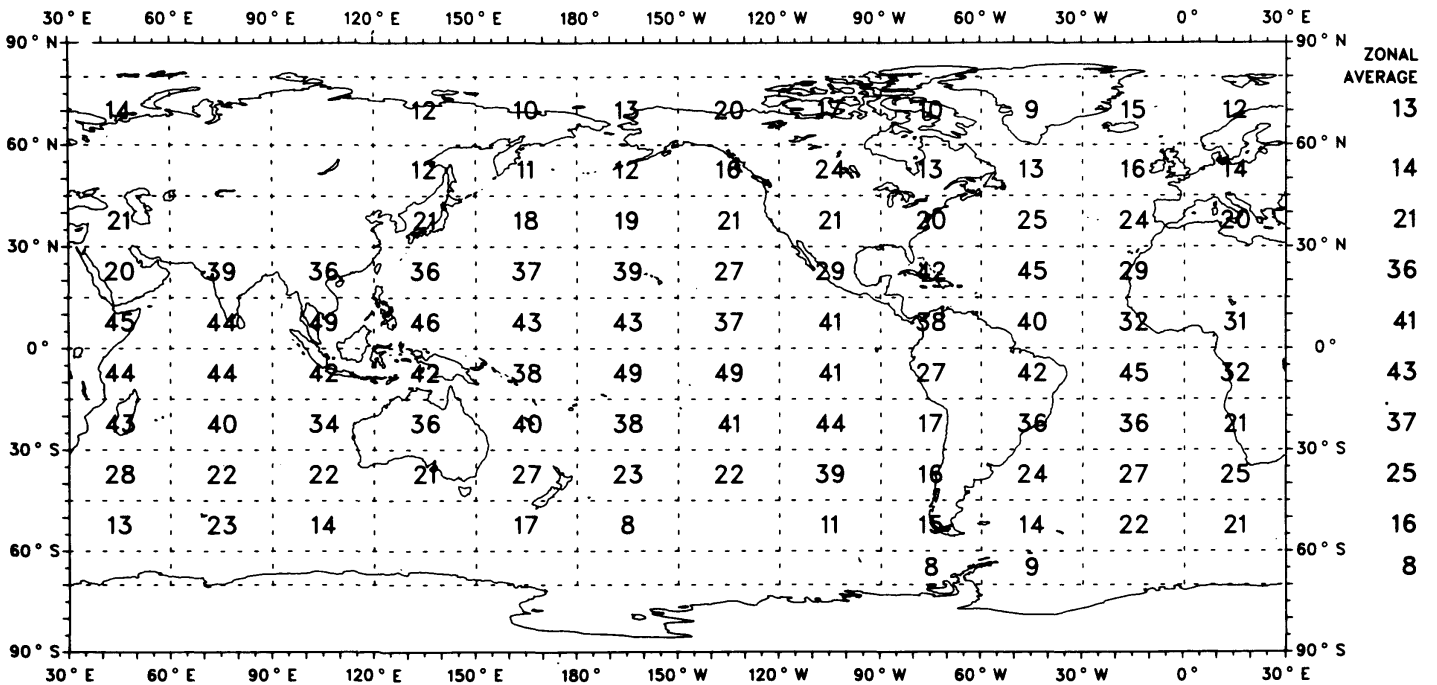
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulus is Also Present

MAM (1965-1976)

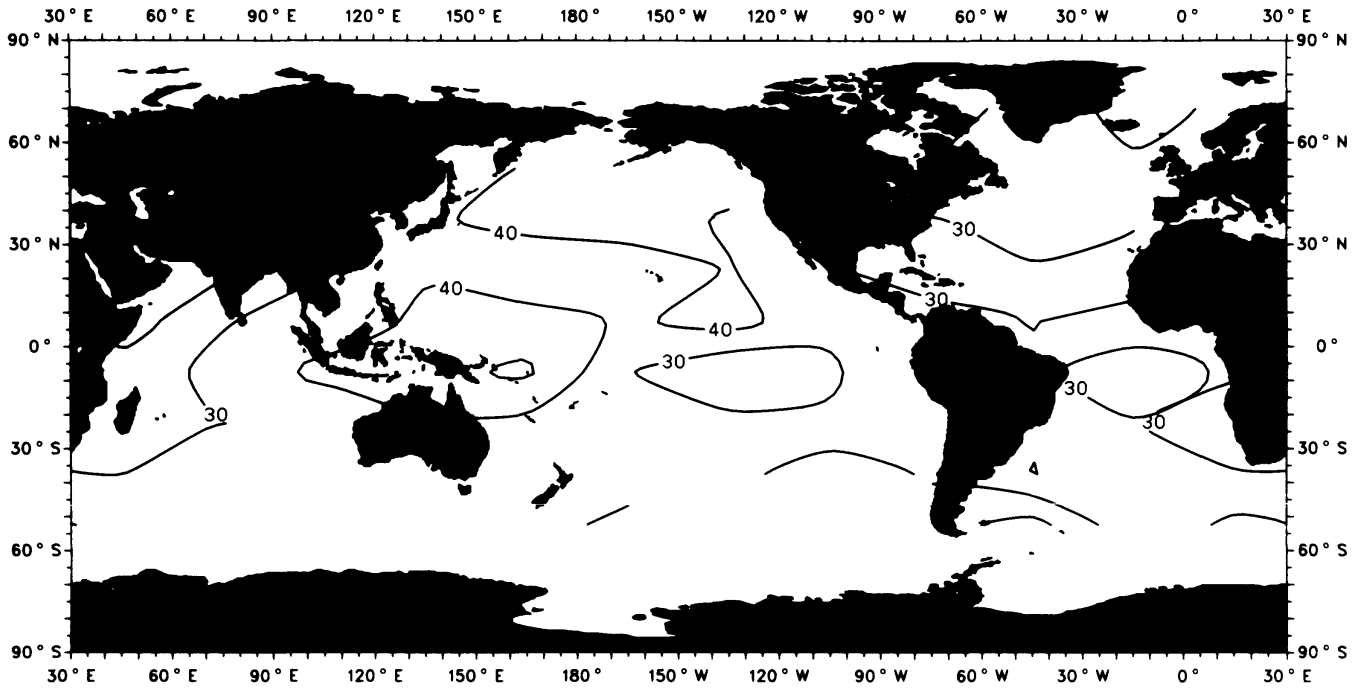
Ocean Areas Only



Given Cumulus, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

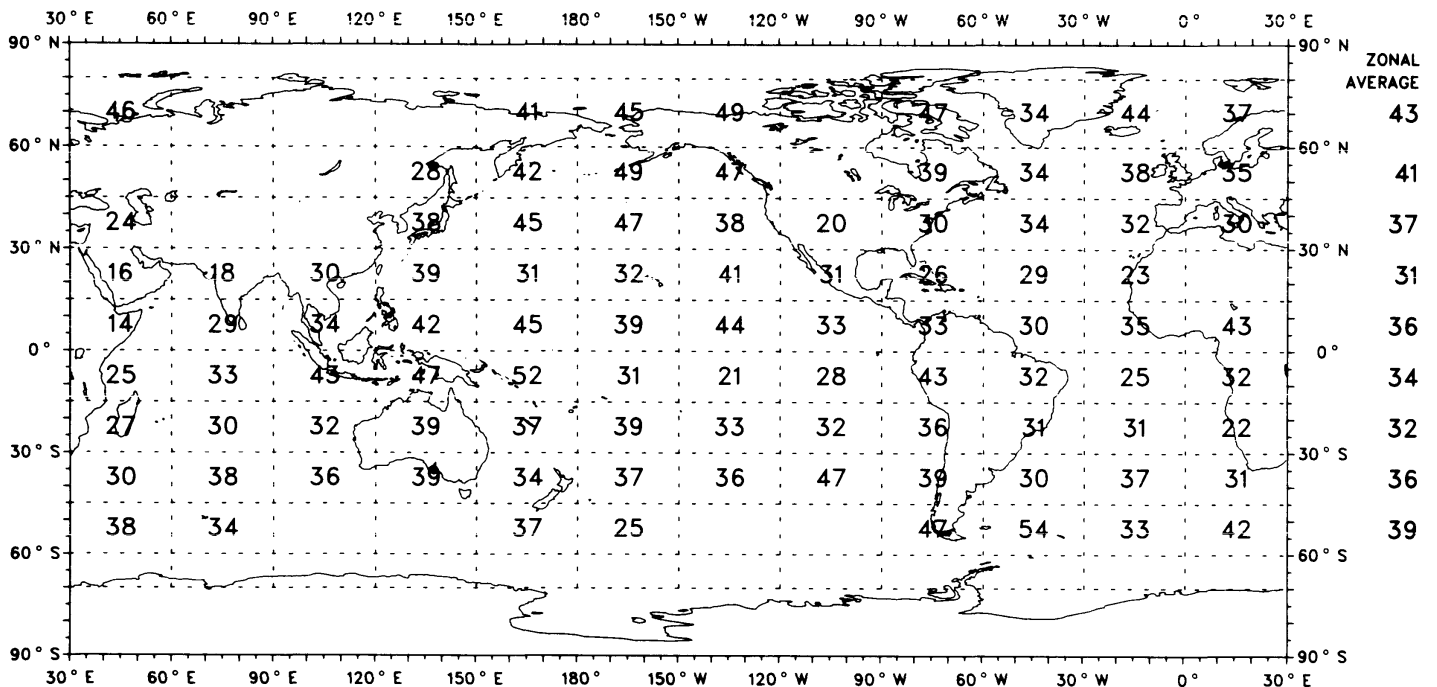
Ocean Areas Only



Given Cumulus, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

Ocean Areas Only

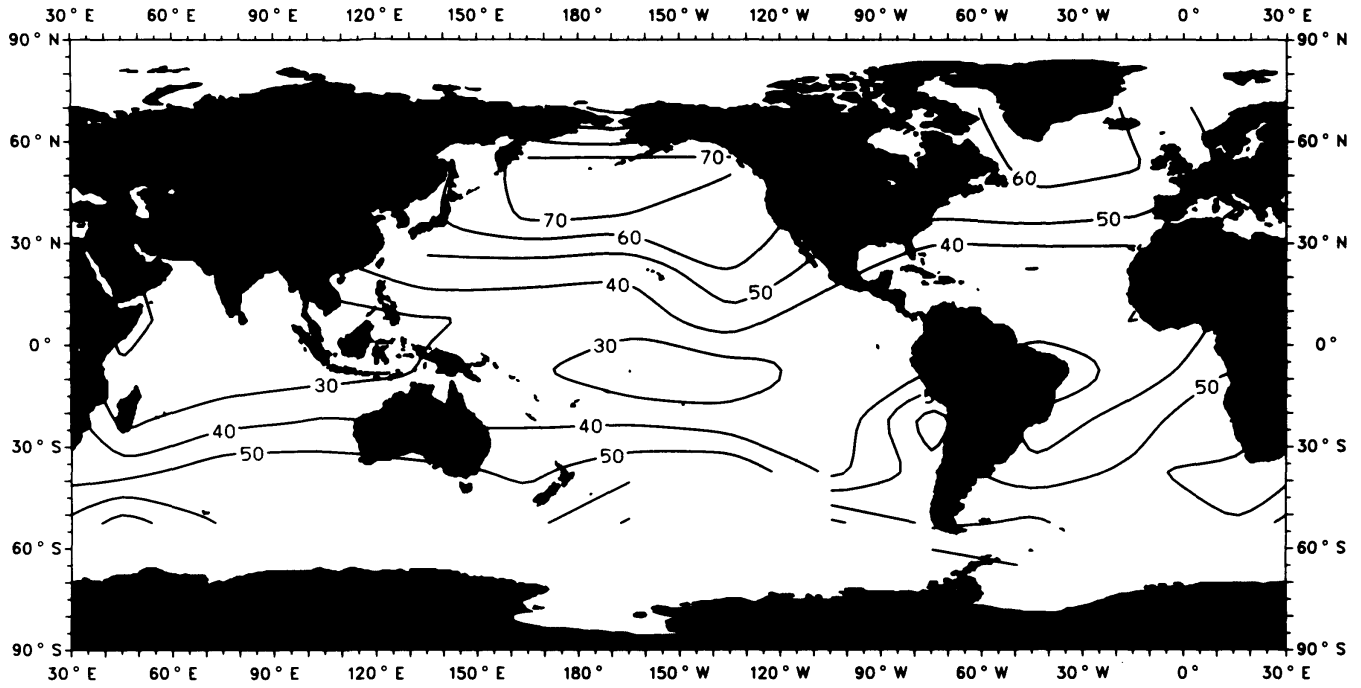


Map II-38

Given As/Ac, Probability (Percent) That St/Sc is Also Present

MAM (1965-1976)

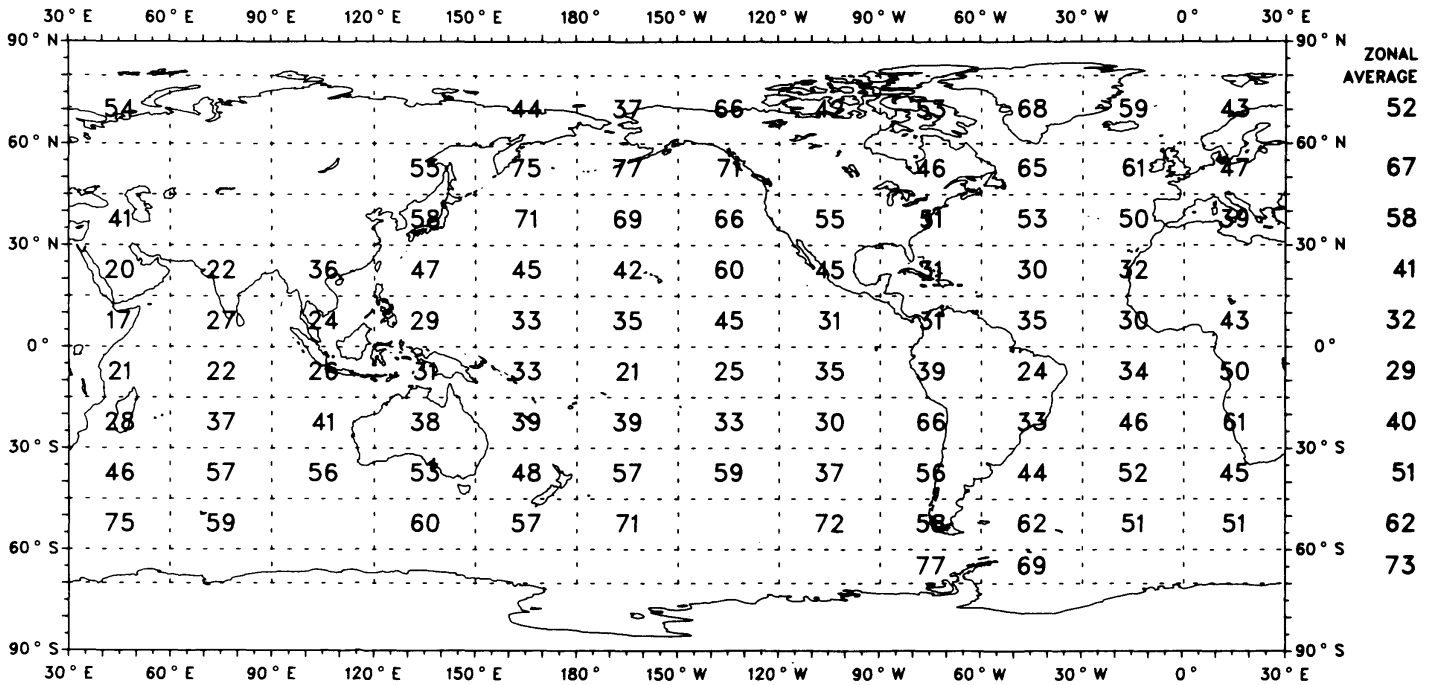
Ocean Areas Only



Given As/Ac, Probability (Percent) That St/Sc is Also Present

MAM (1965-1976)

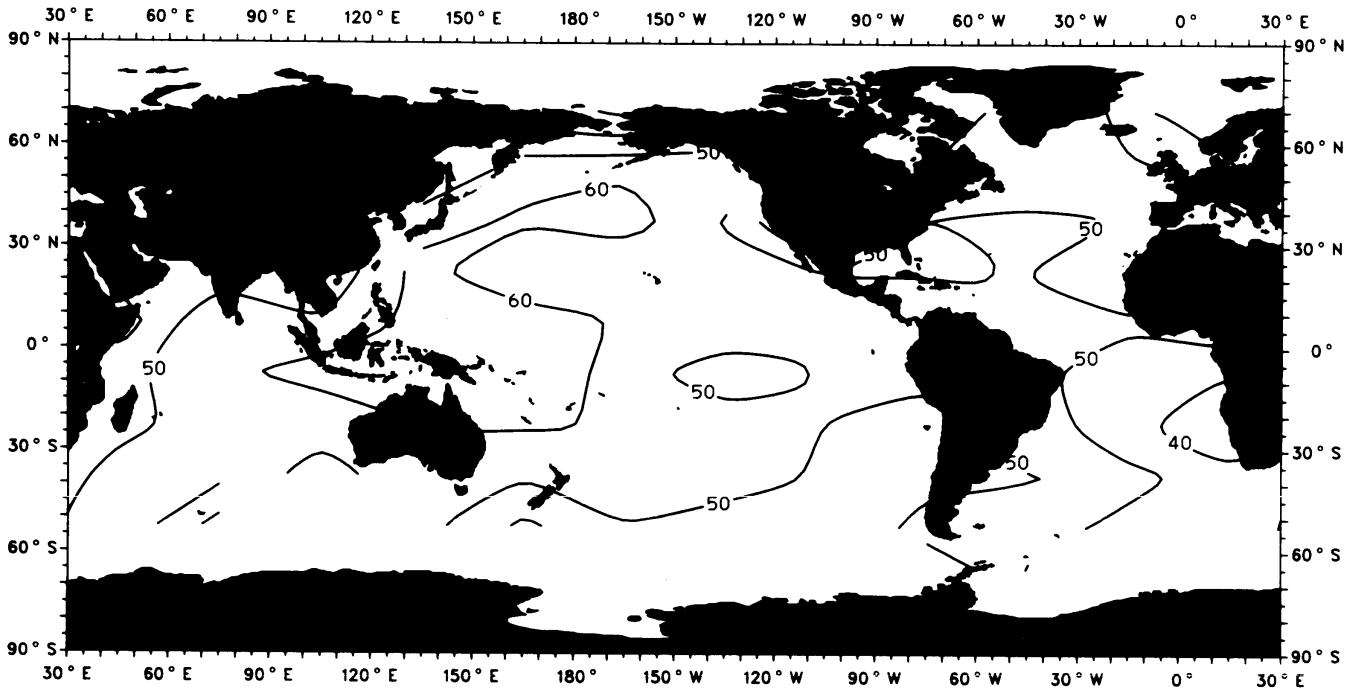
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

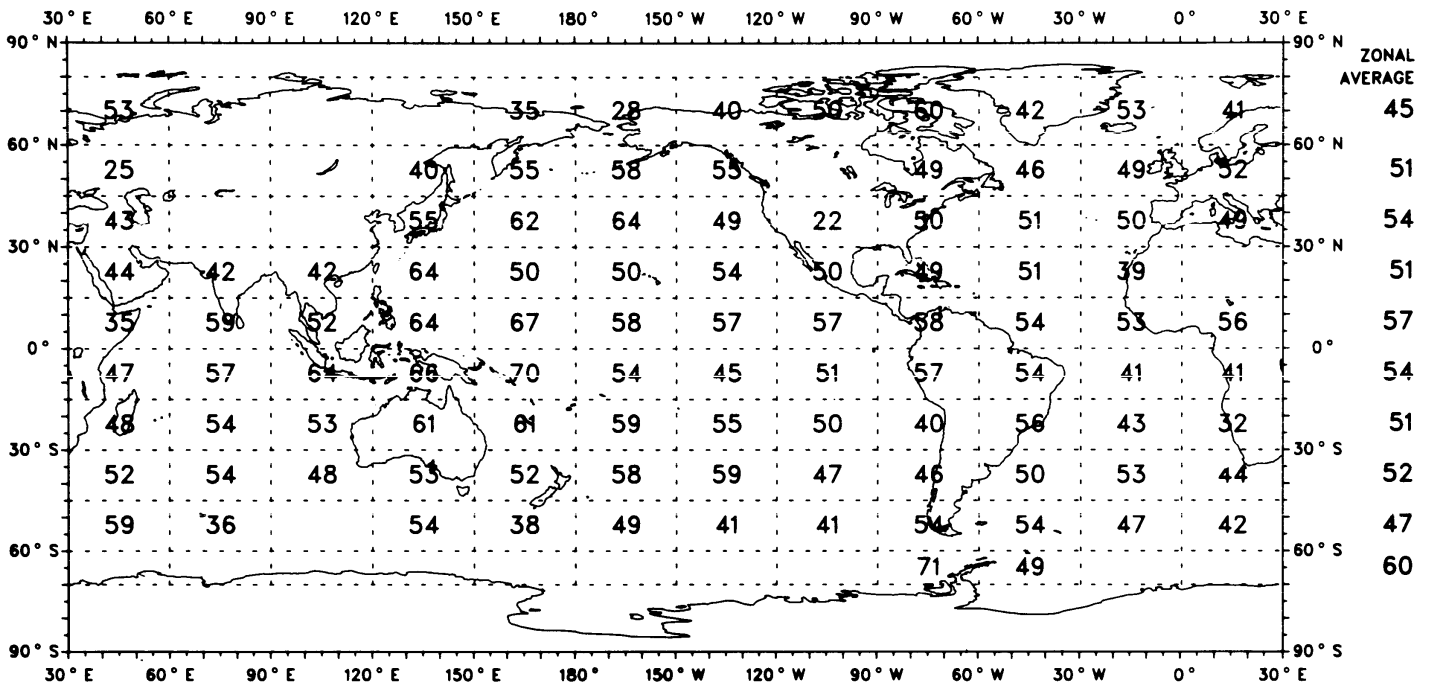
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

MAM (1965-1976)

Ocean Areas Only

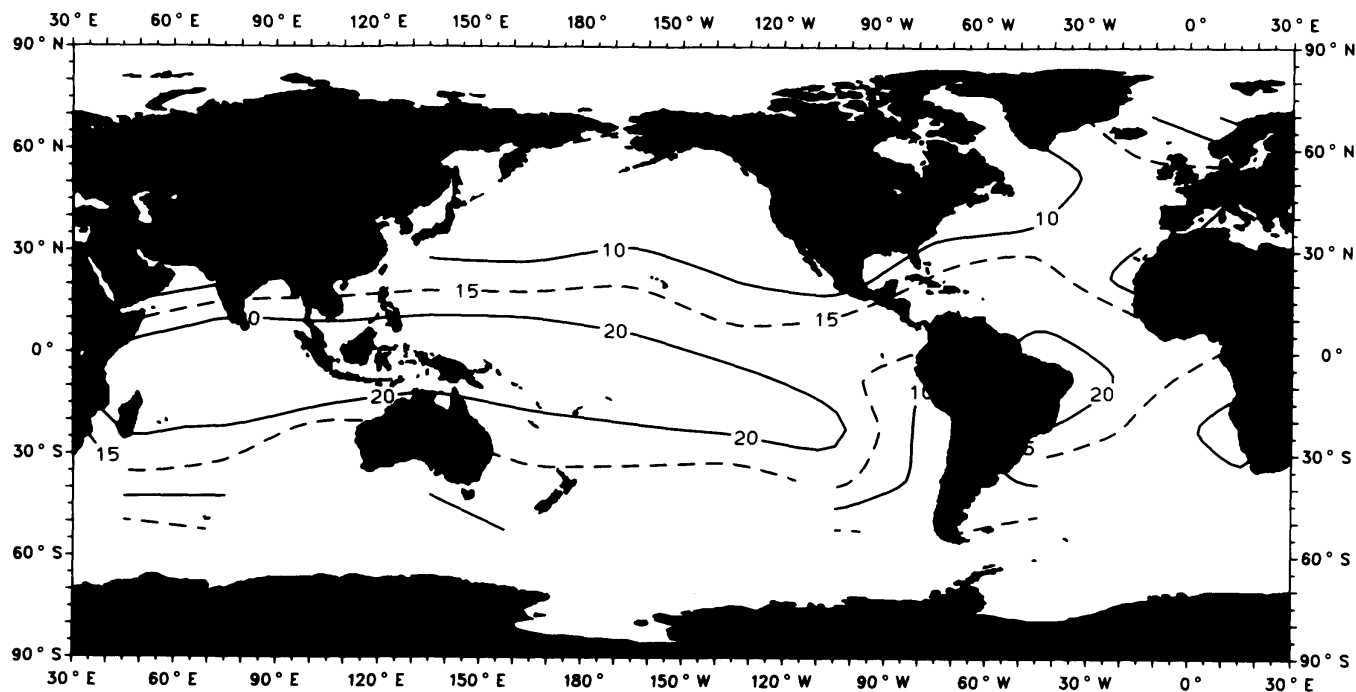


Map II-40

Given As/Ac, Probability (Percent) That Cumulonimbus is Also Present

MAM (1965-1976)

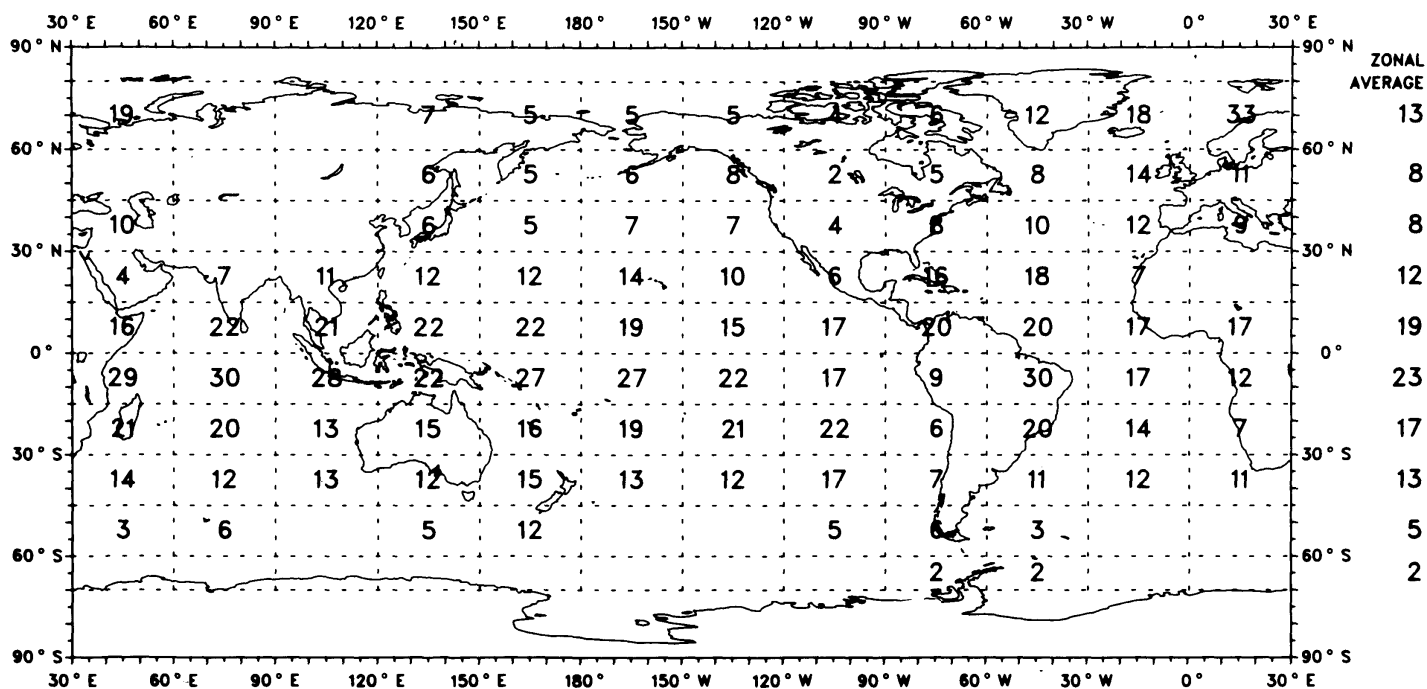
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulonimbus is Also Present

MAM (1965-1976)

Ocean Areas Only







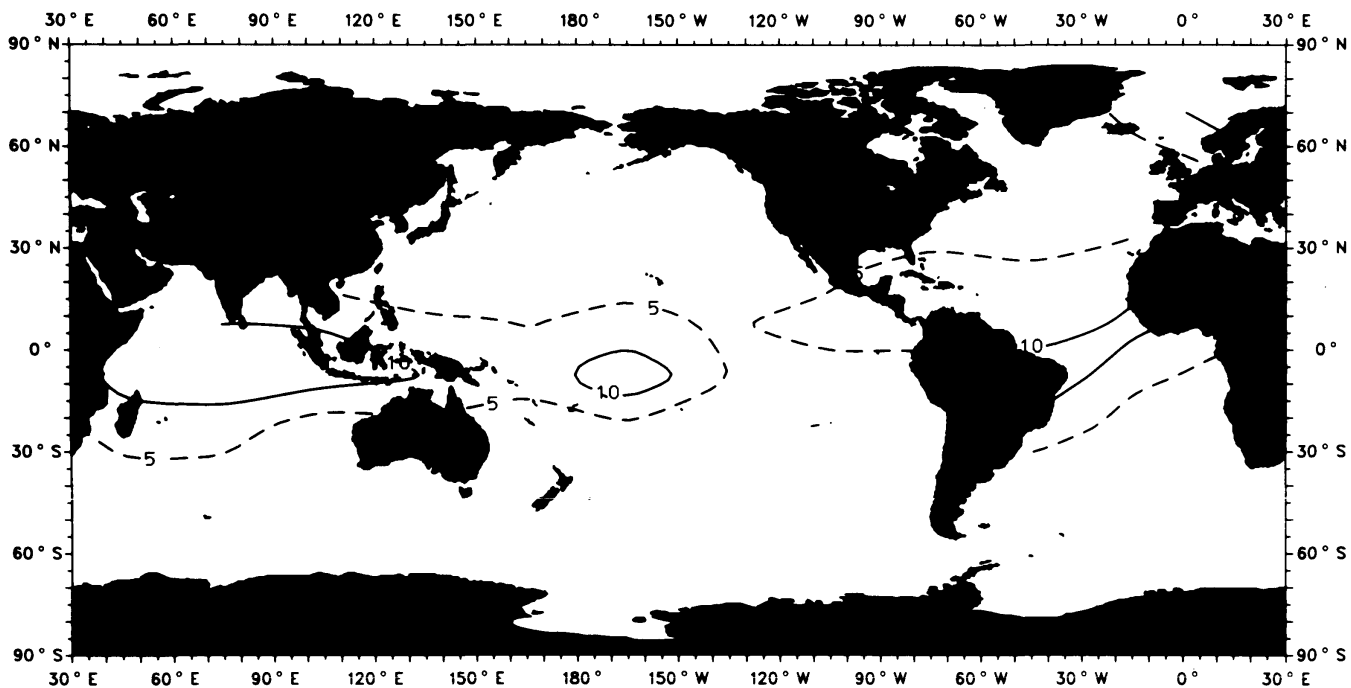




### Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

MAM (1965-1976)

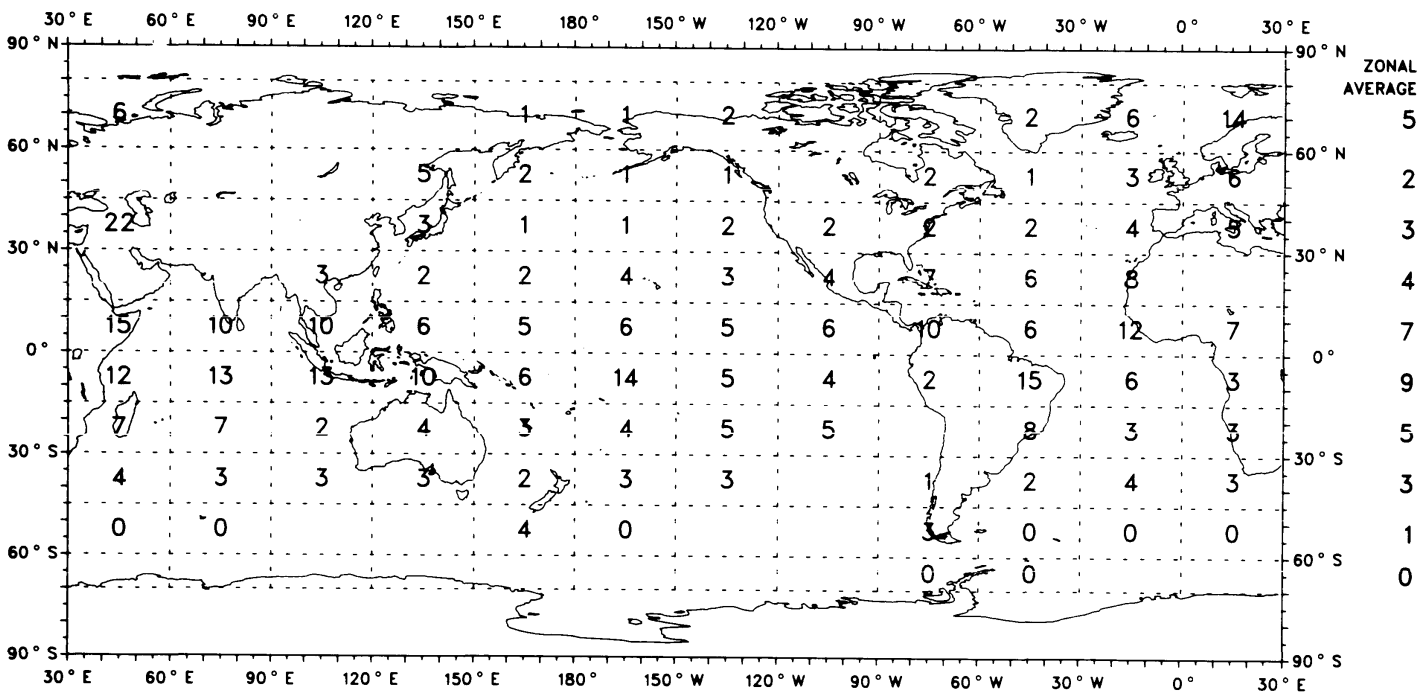
Ocean Areas Only



### Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

MAM (1965-1976)

Ocean Areas Only

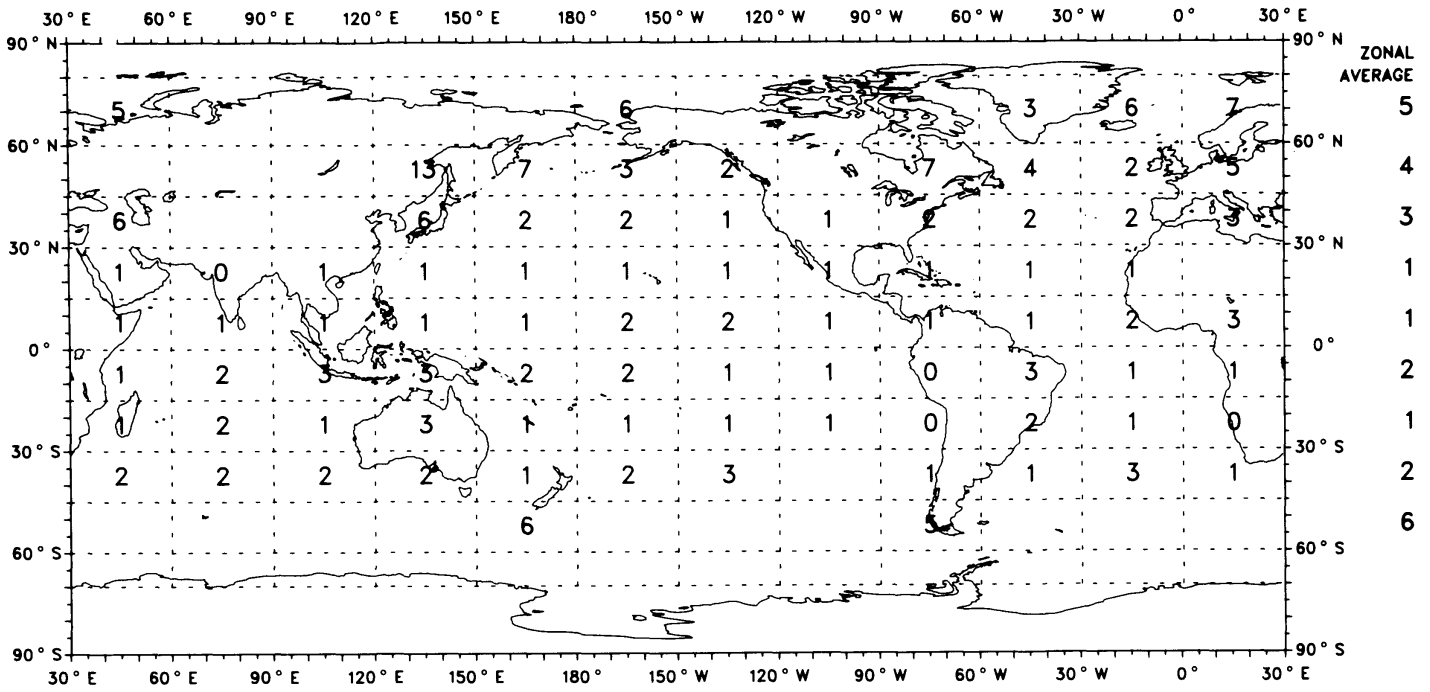


Map II-47

Given Cumulonimbus, Probability (Percent) That Nimbostratus is Also Present

MAM (1965-1976)

Ocean Areas Only



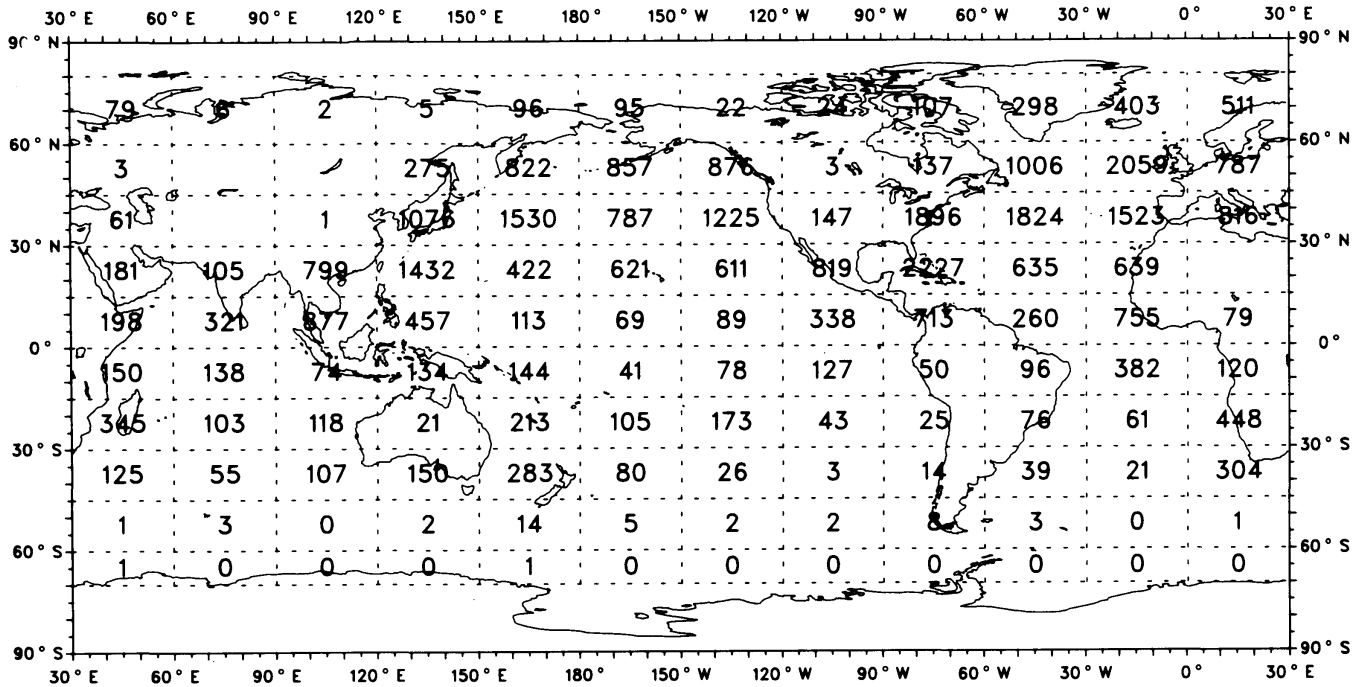
June, July, August

Map III-1

Number of Synoptic Cloud Reports from Ships, in Hundreds

JJA (1965-1976)

Ocean Areas Only

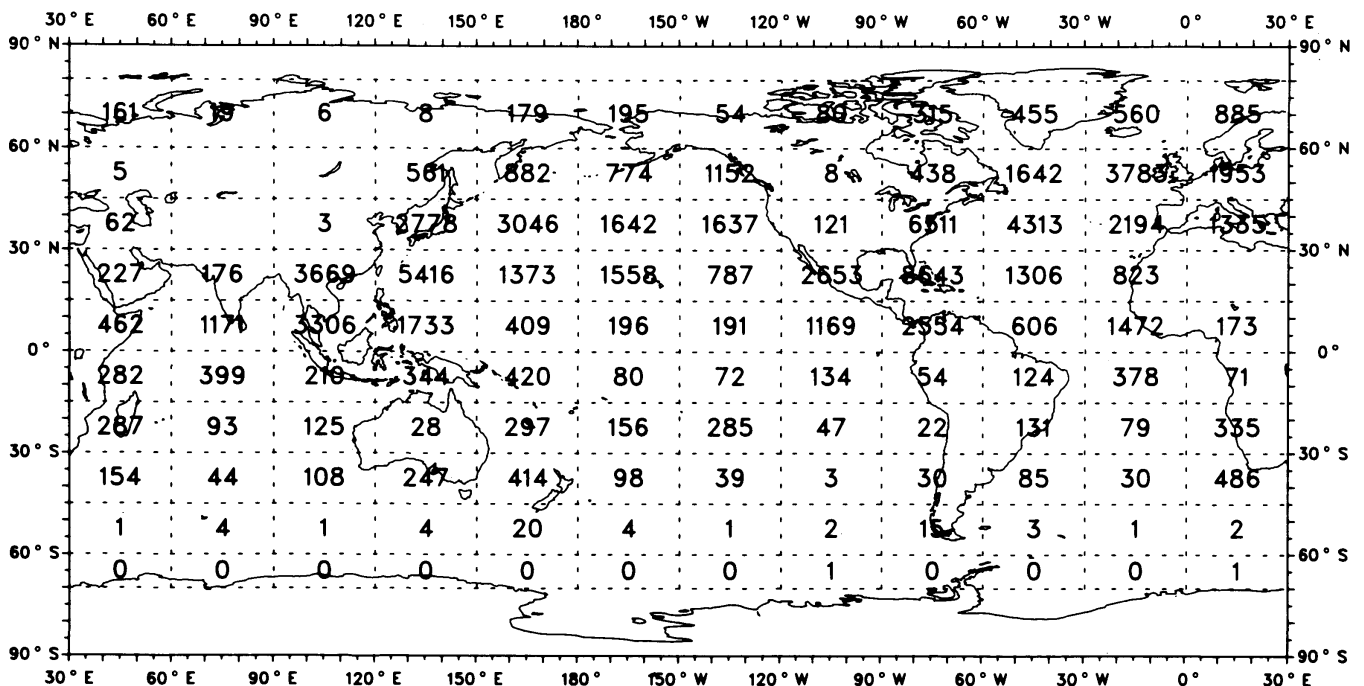


Map III-2

Number of Observations of Cirrus, Cirrostratus, or Cirrocumulus (N/10)

JJA (1965-1976)

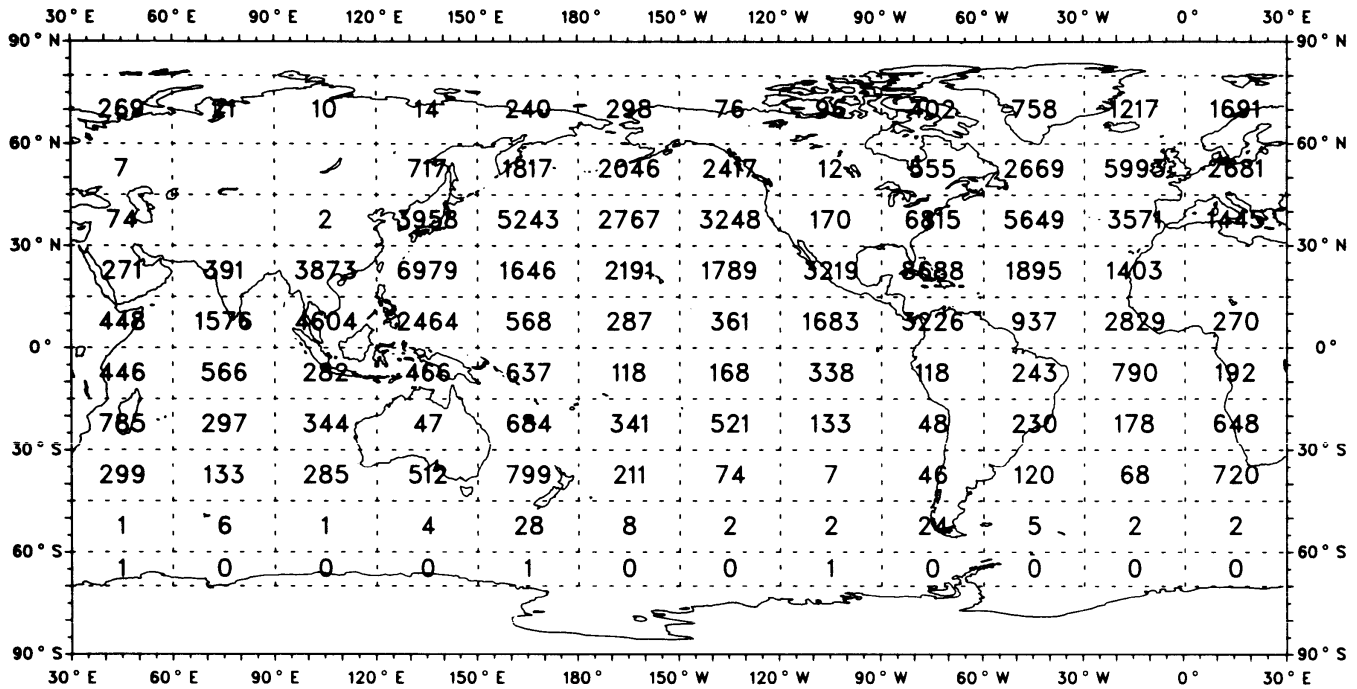
Ocean Areas Only



Number of Observations of Altostratus or Altocumulus (N/10)

JJA (1965-1976)

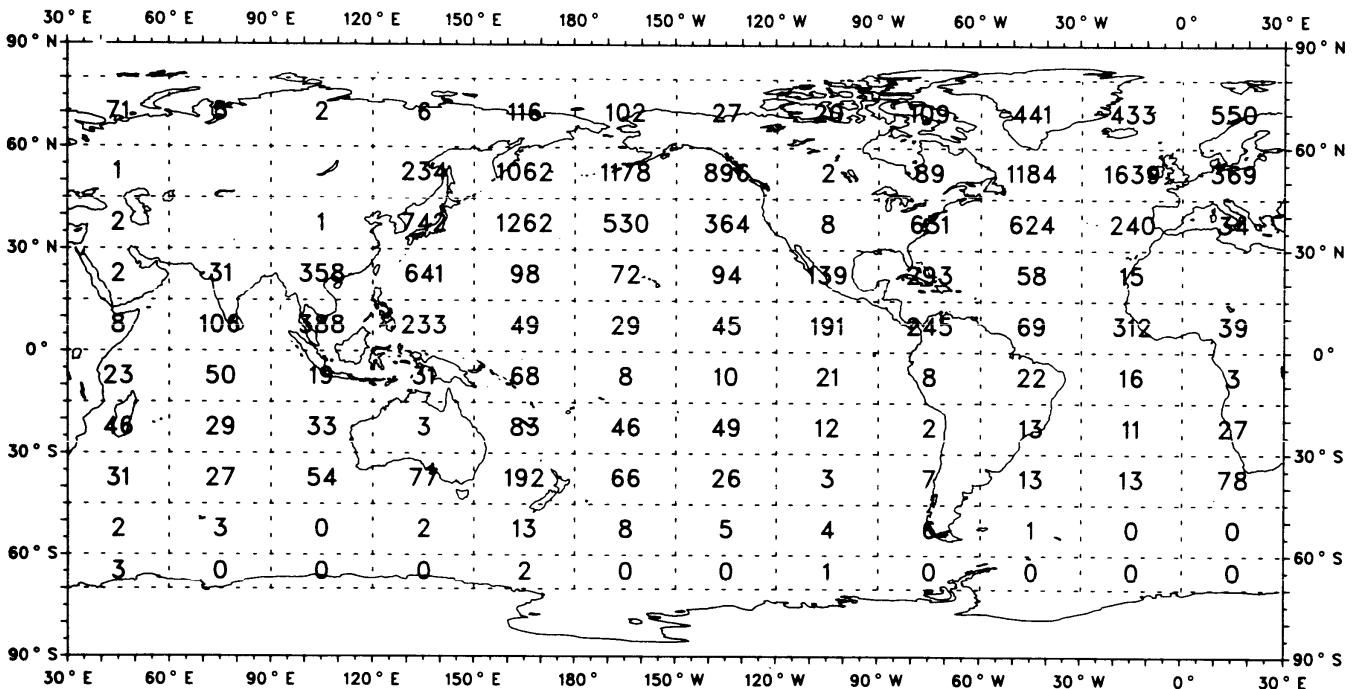
Ocean Areas Only



Number of Observations of Nimbostratus (N/10)

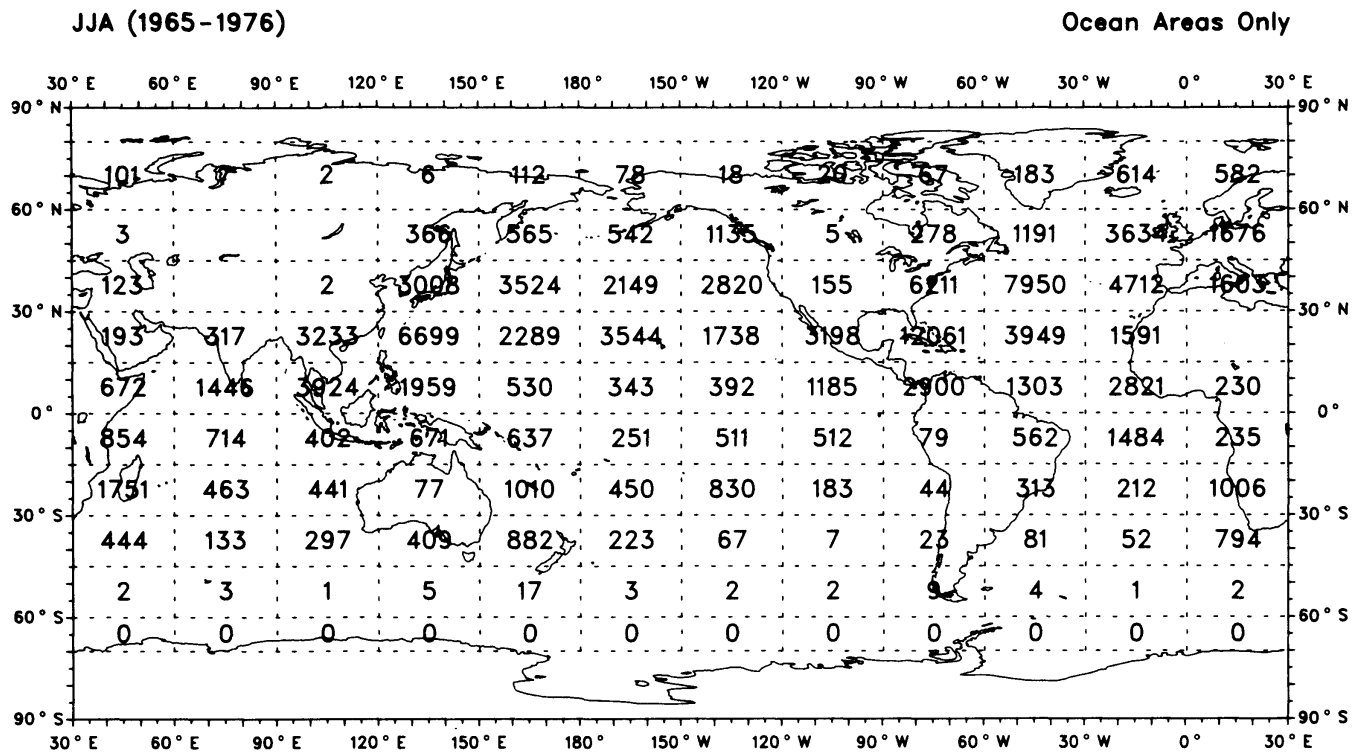
JJA (1965-1976)

Ocean Areas Only



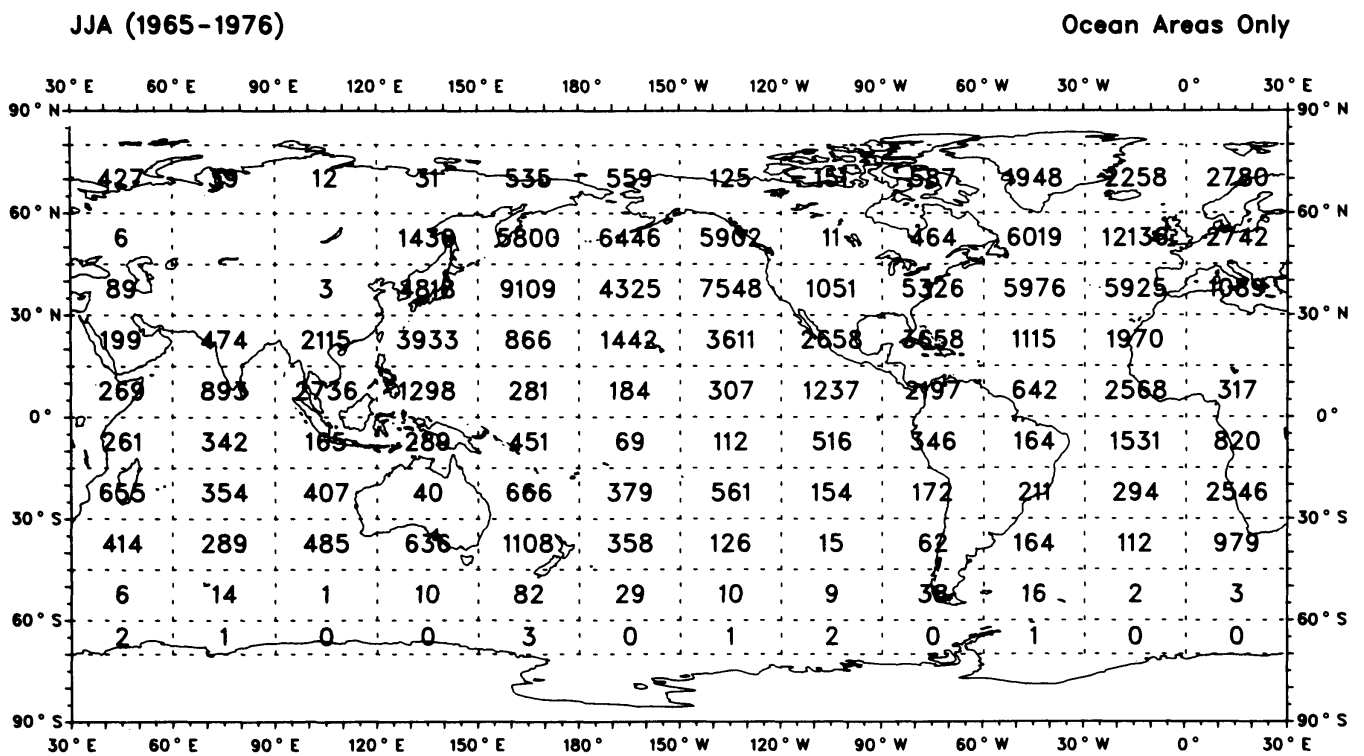
Map III-5

Number of Observations of Cumulus (N/10)



Map III-6

Number of Observations of Stratus or Stratocumulus (N/10)



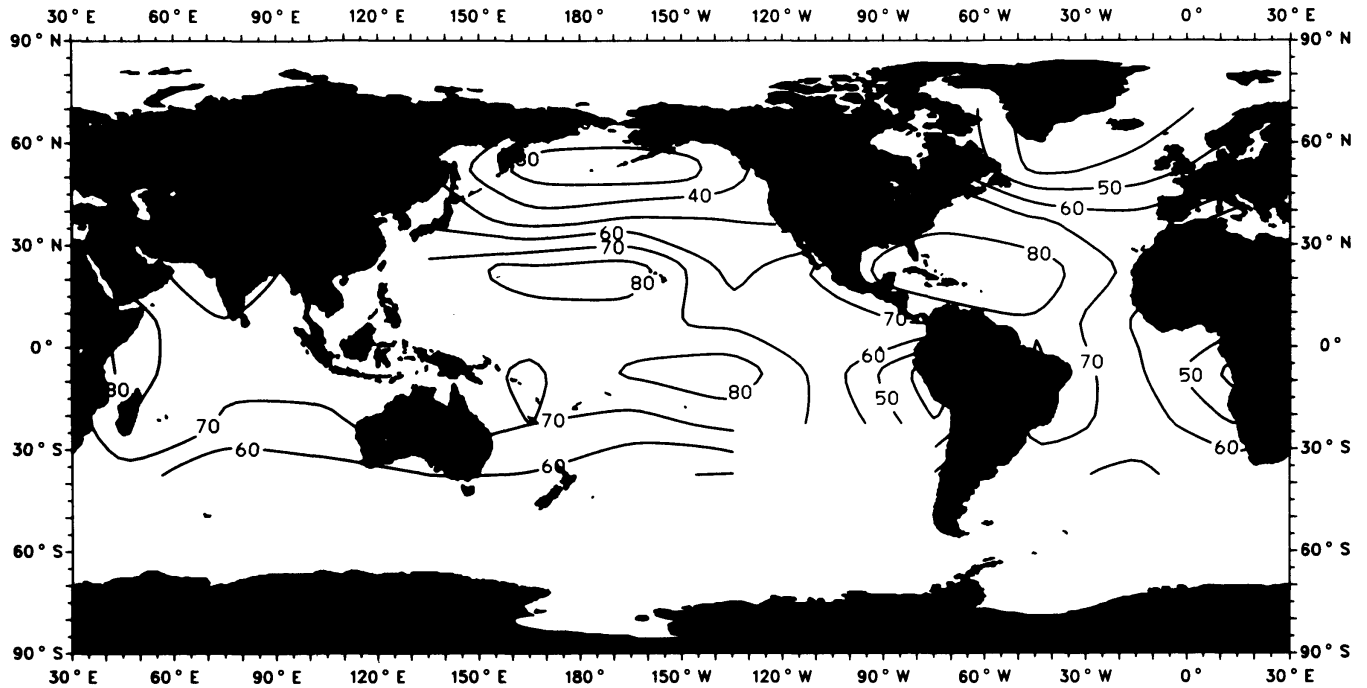


Map III-8

Percent of Ship Reports Contributing to Statistics of the High Cloud Level

JJA (1965-1976)

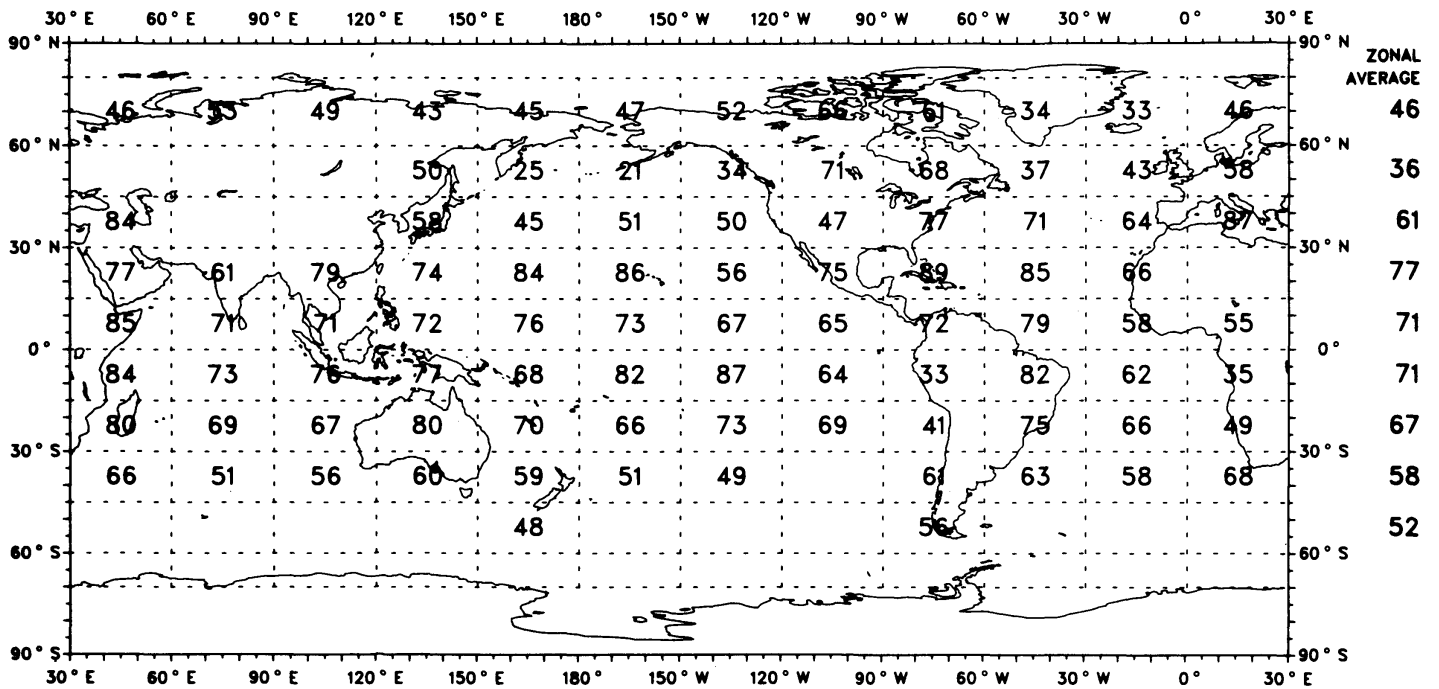
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the High Cloud Level

JJA (1965-1976)

Ocean Areas Only



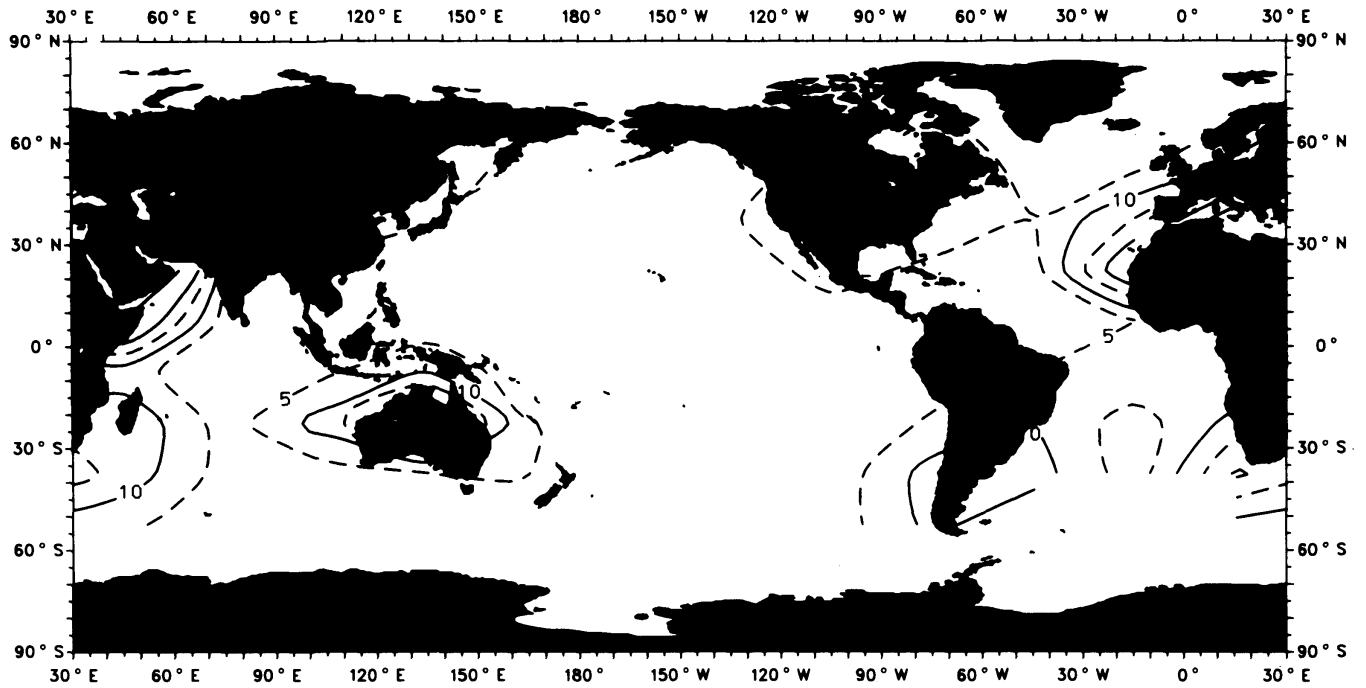


Map III-10

Frequency of Occurrence (Percent) of Completely Clear Sky

JJA (1965-1976)

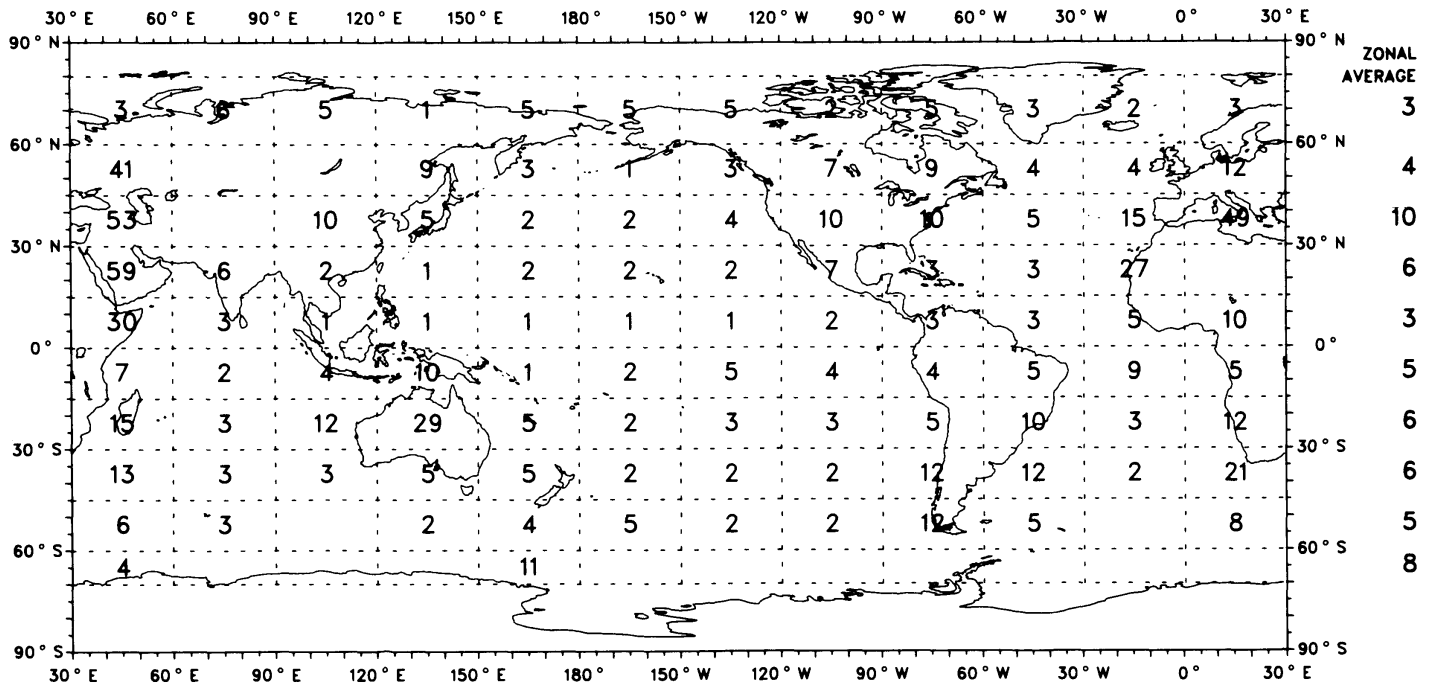
Ocean Areas Only



Frequency of Occurrence (Percent) of Completely Clear Sky

JJA (1965-1976)

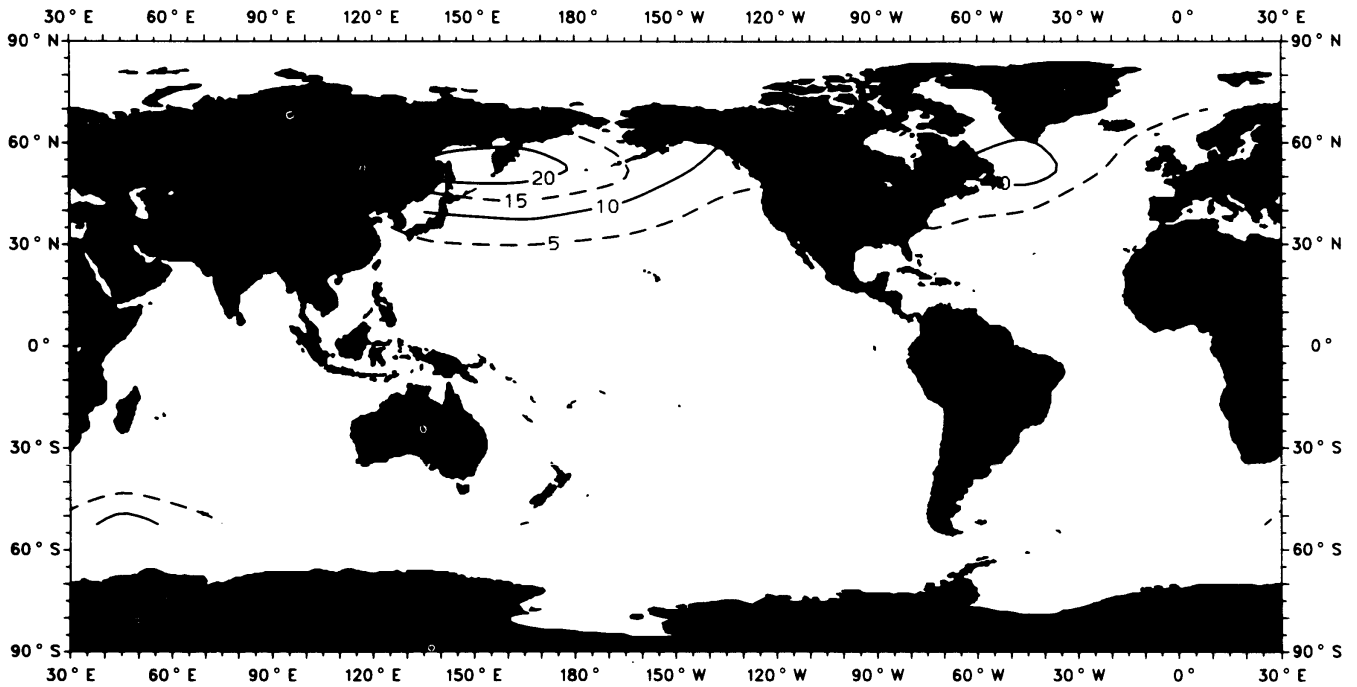
Ocean Areas Only



Frequency of Occurrence (Percent) of Sky Obscured due to Fog

JJA (1965-1976)

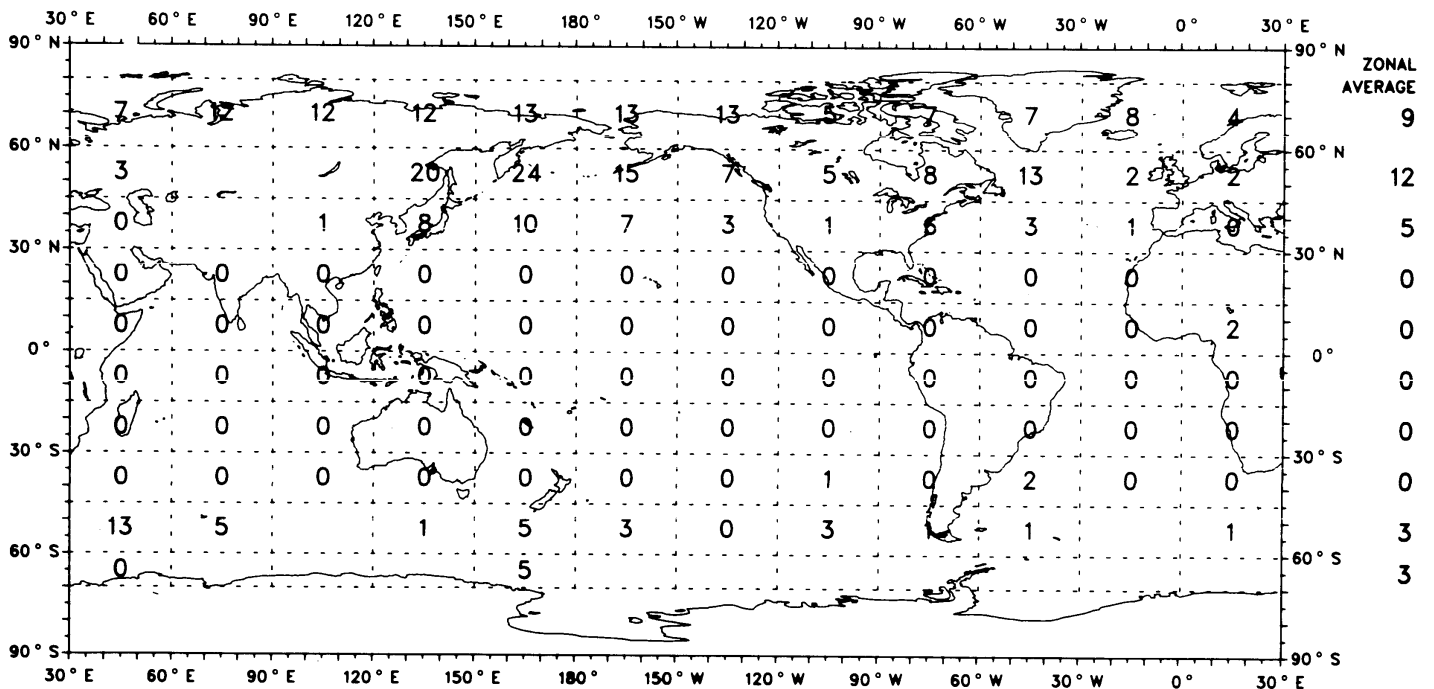
Ocean Areas Only



Frequency of Occurrence (Percent) of Sky Obscured due to Fog

JJA (1965-1976)

Ocean Areas Only

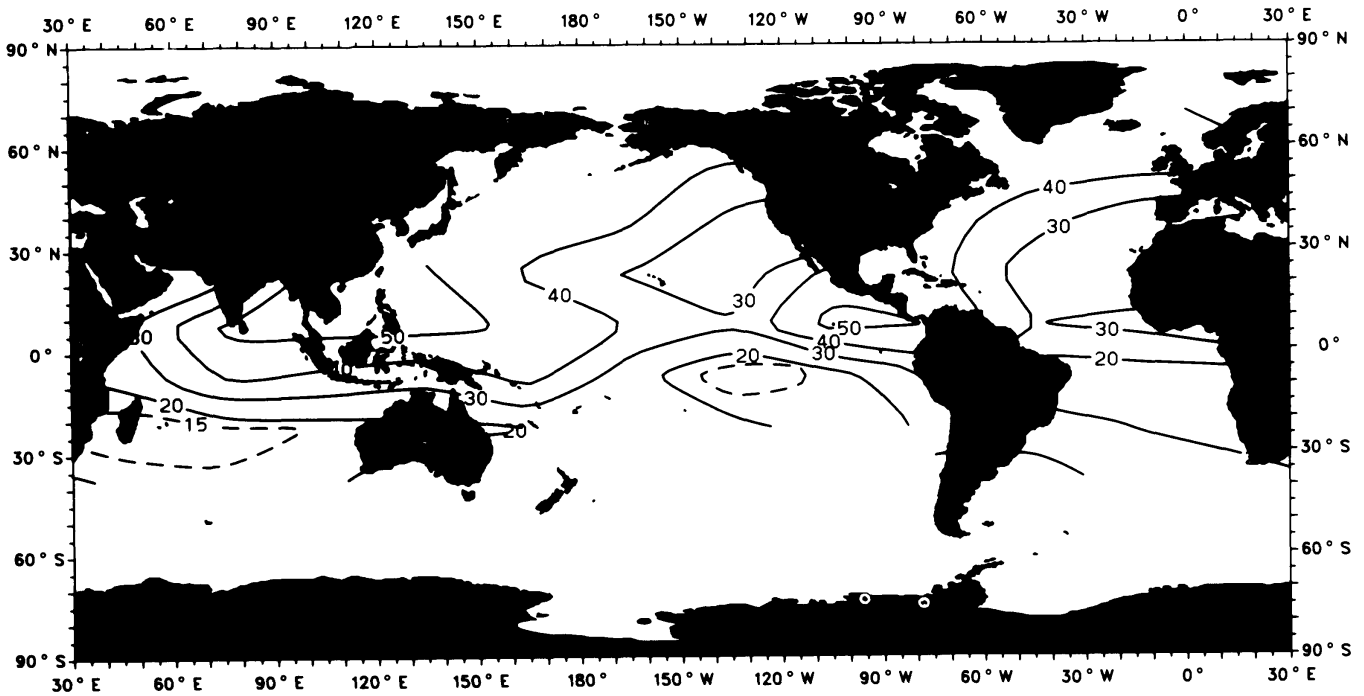


Map III-12

Frequency of Occurrence (Percent) of Ci/Cs/Cc

JJA (1965-1976)

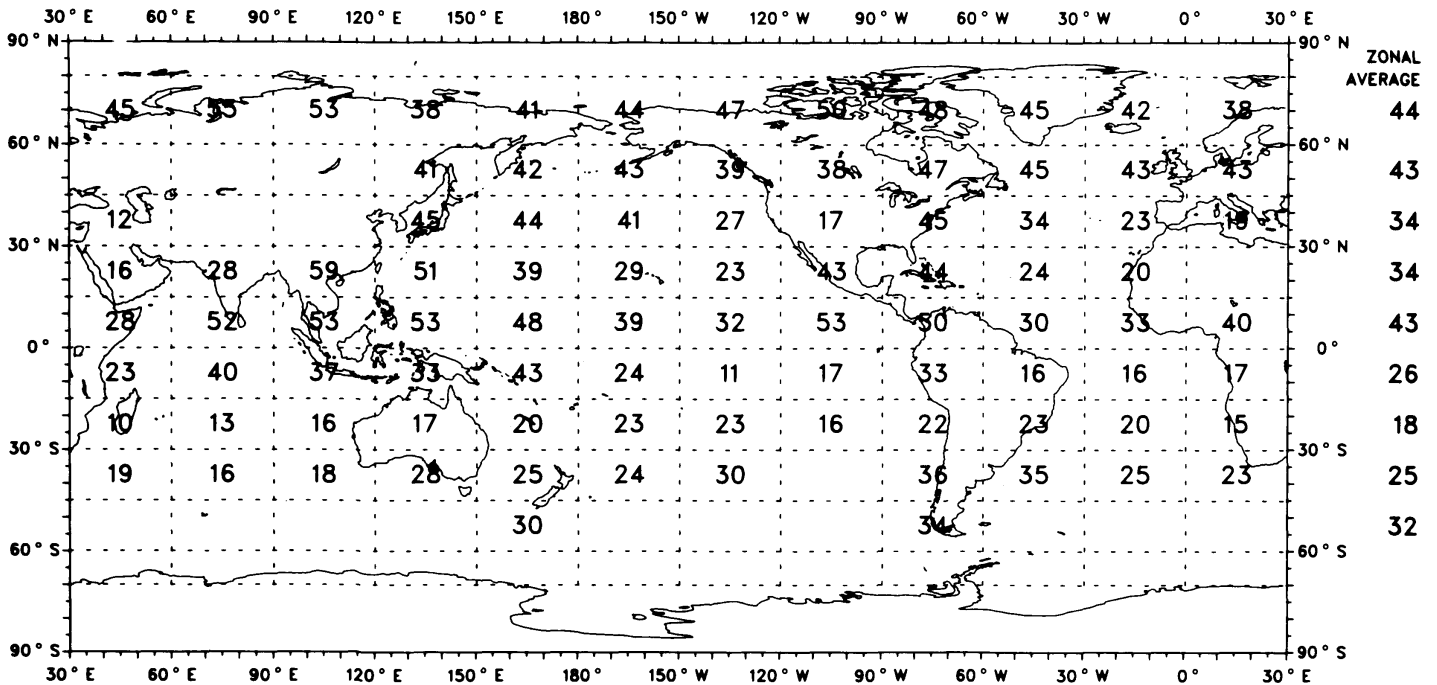
Ocean Areas Only



Frequency of Occurrence (Percent) of Ci/Cs/Cc

JJA (1965-1976)

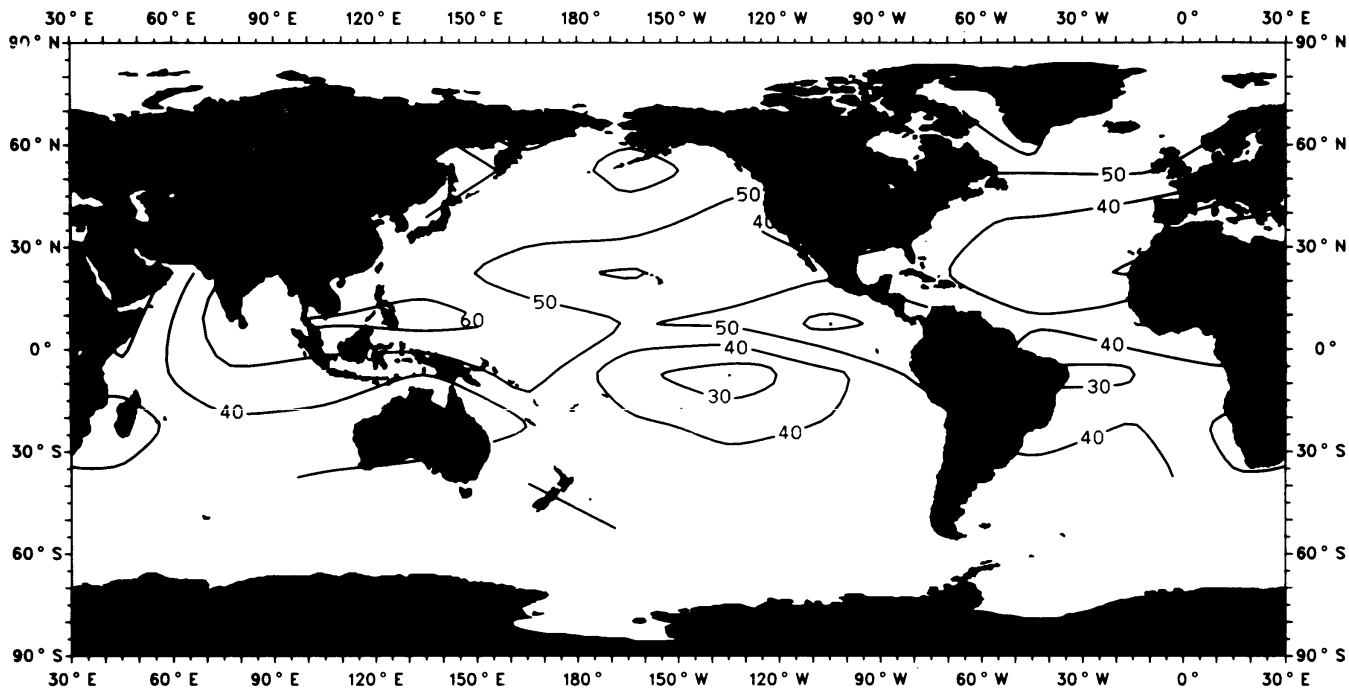
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

JJA (1965-1976)

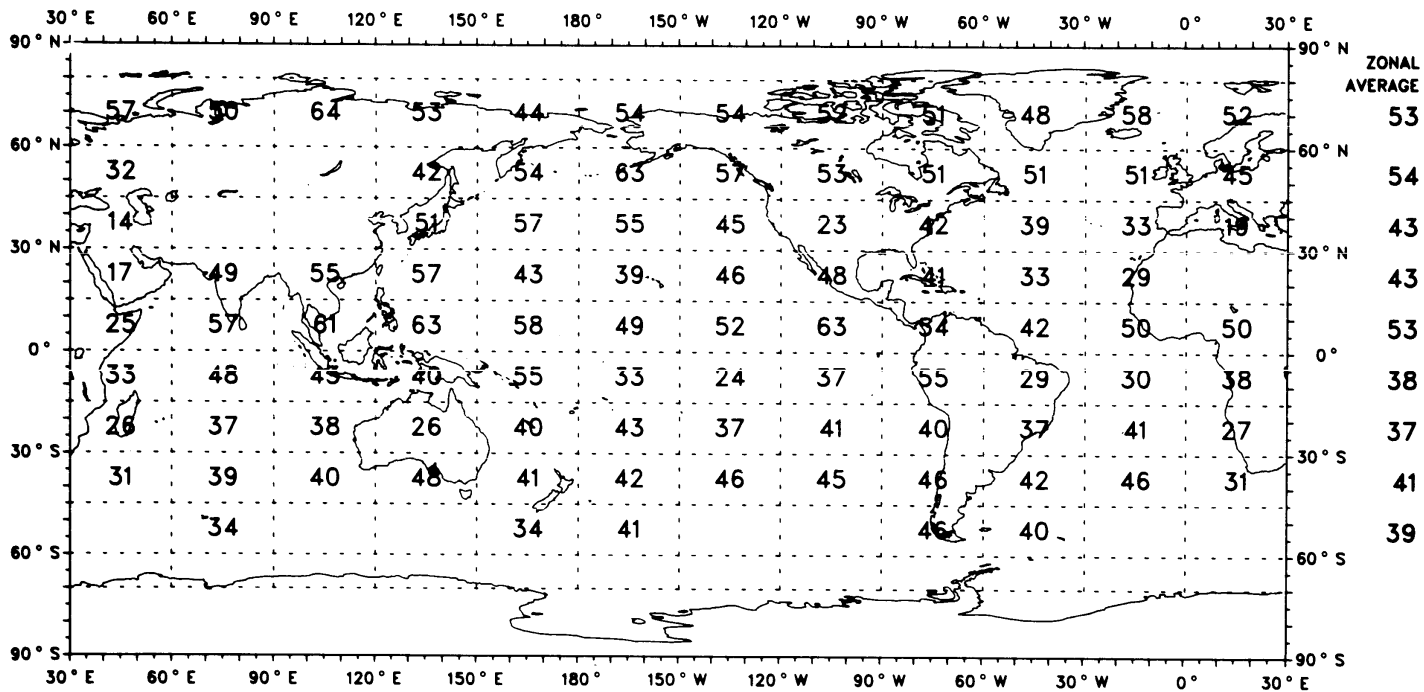
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

JJA (1965-1976)

Ocean Areas Only

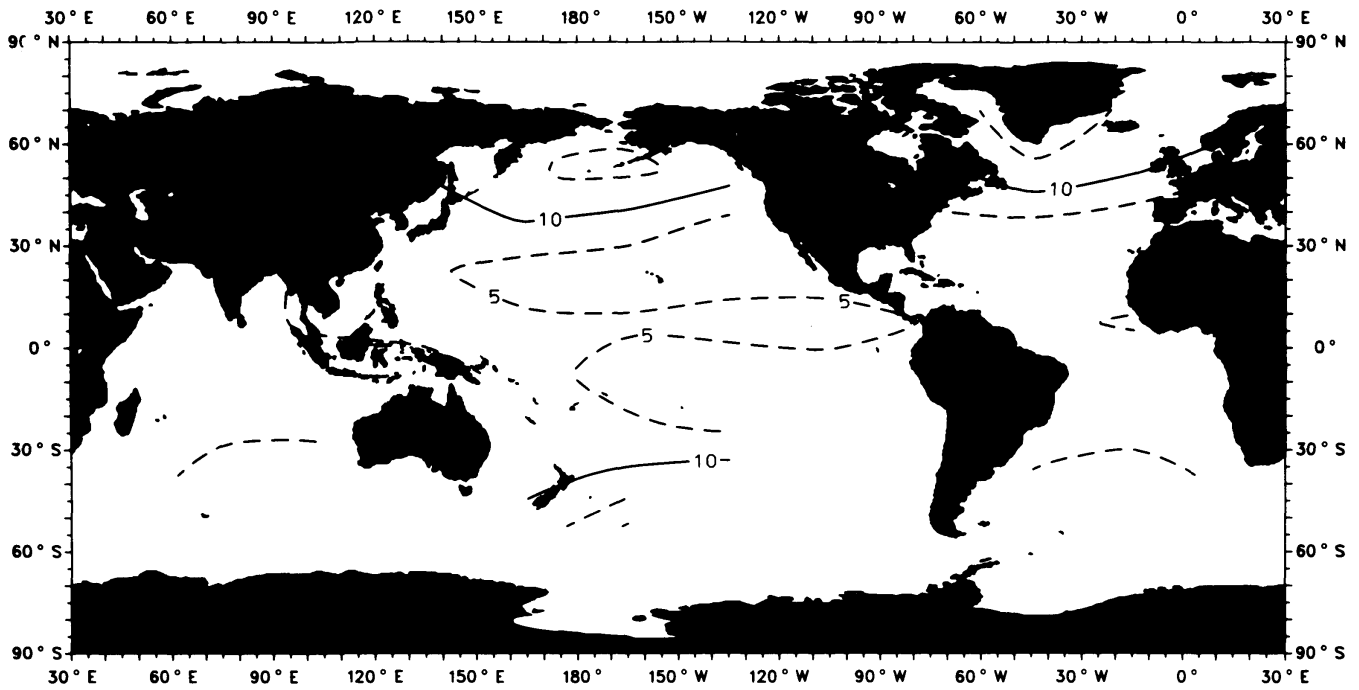


Map III-14

Frequency of Occurrence (Percent) of Nimbostratus

JJA (1965-1976)

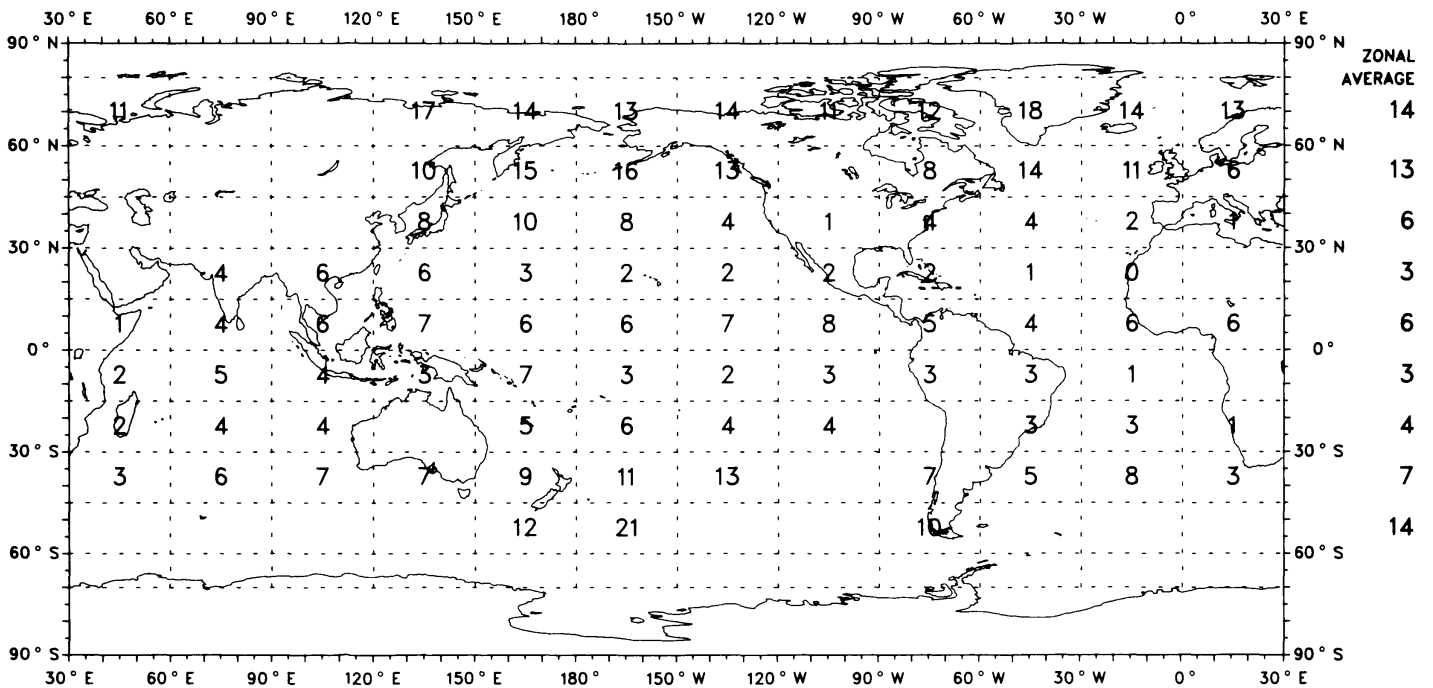
Ocean Areas Only



Frequency of Occurrence (Percent) of Nimbostratus

JJA (1965-1976)

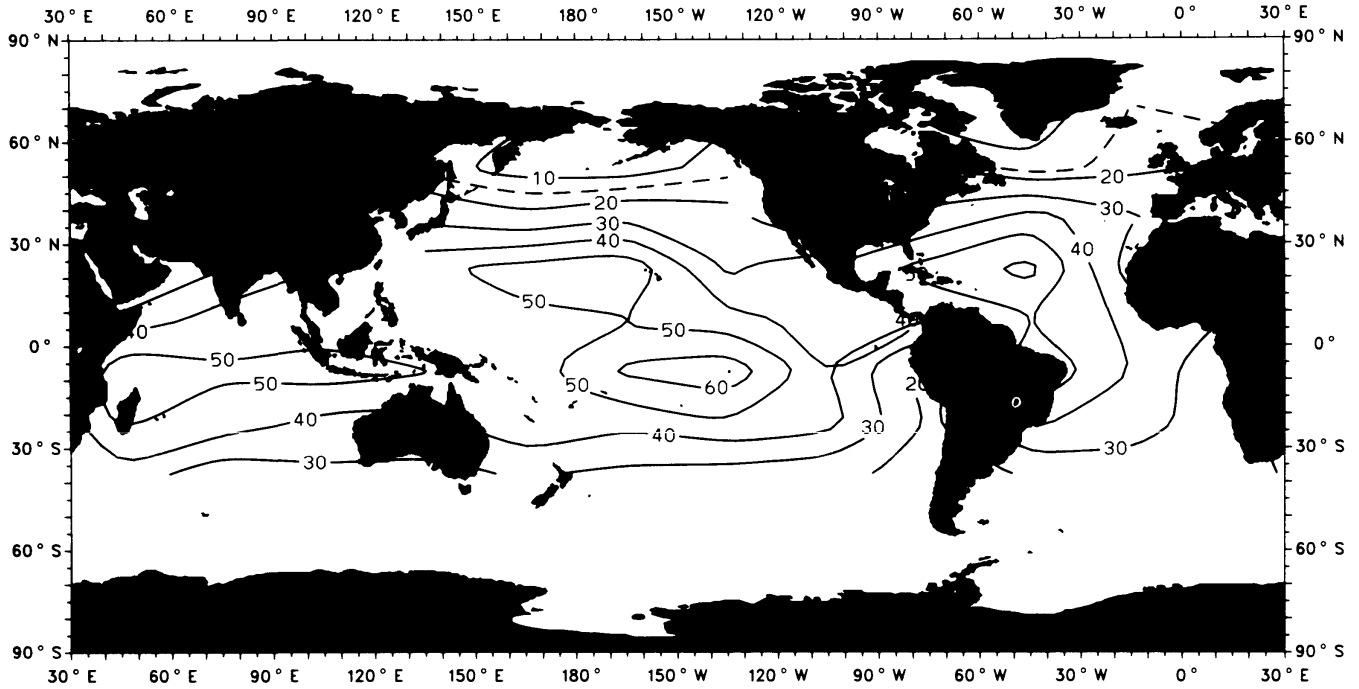
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

JJA (1965-1976)

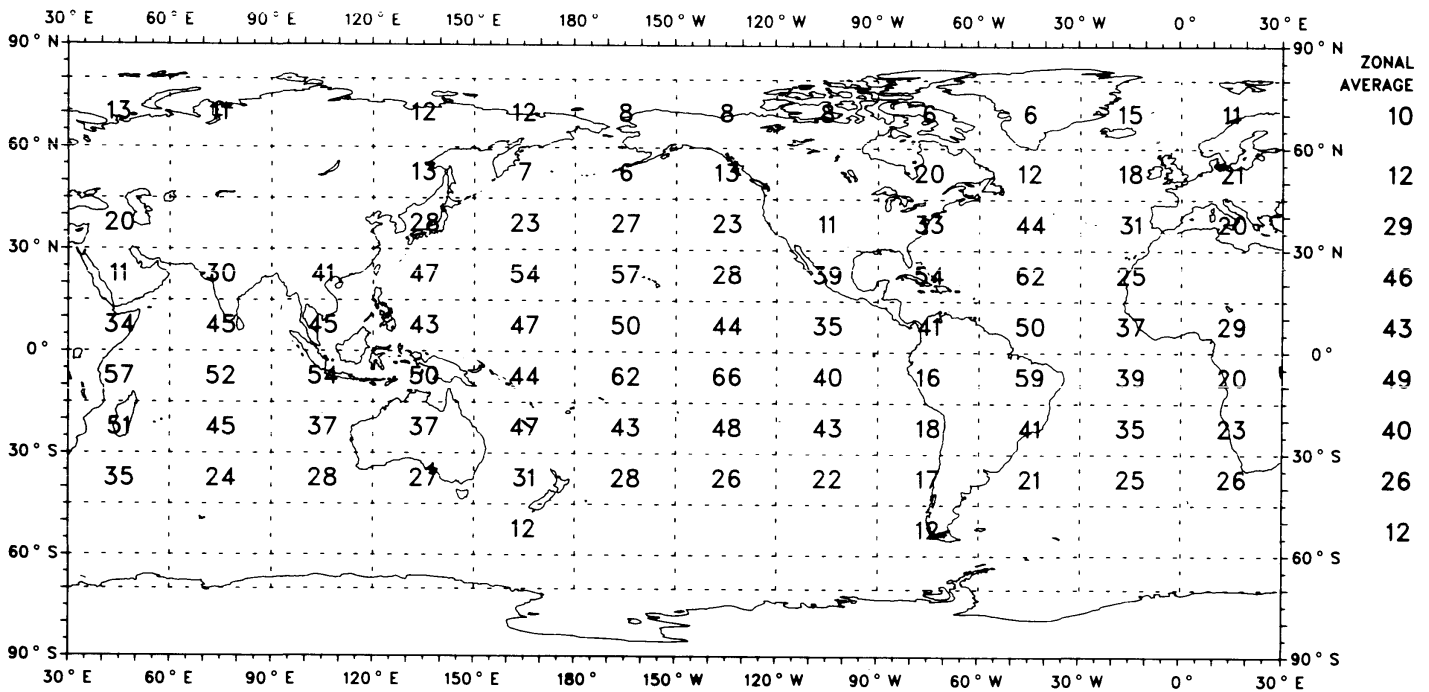
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

JJA (1965-1976)

Ocean Areas Only

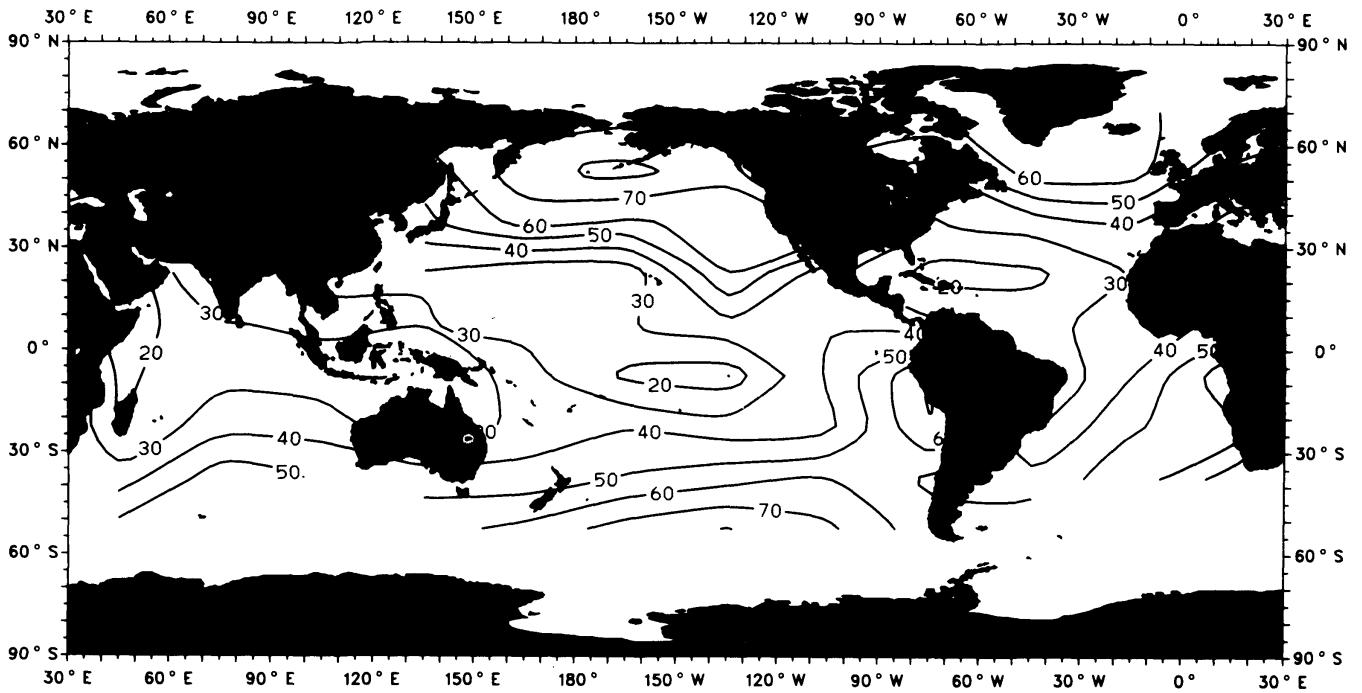


Map III-16

Frequency of Occurrence (Percent) of St/Sc

JJA (1965-1976)

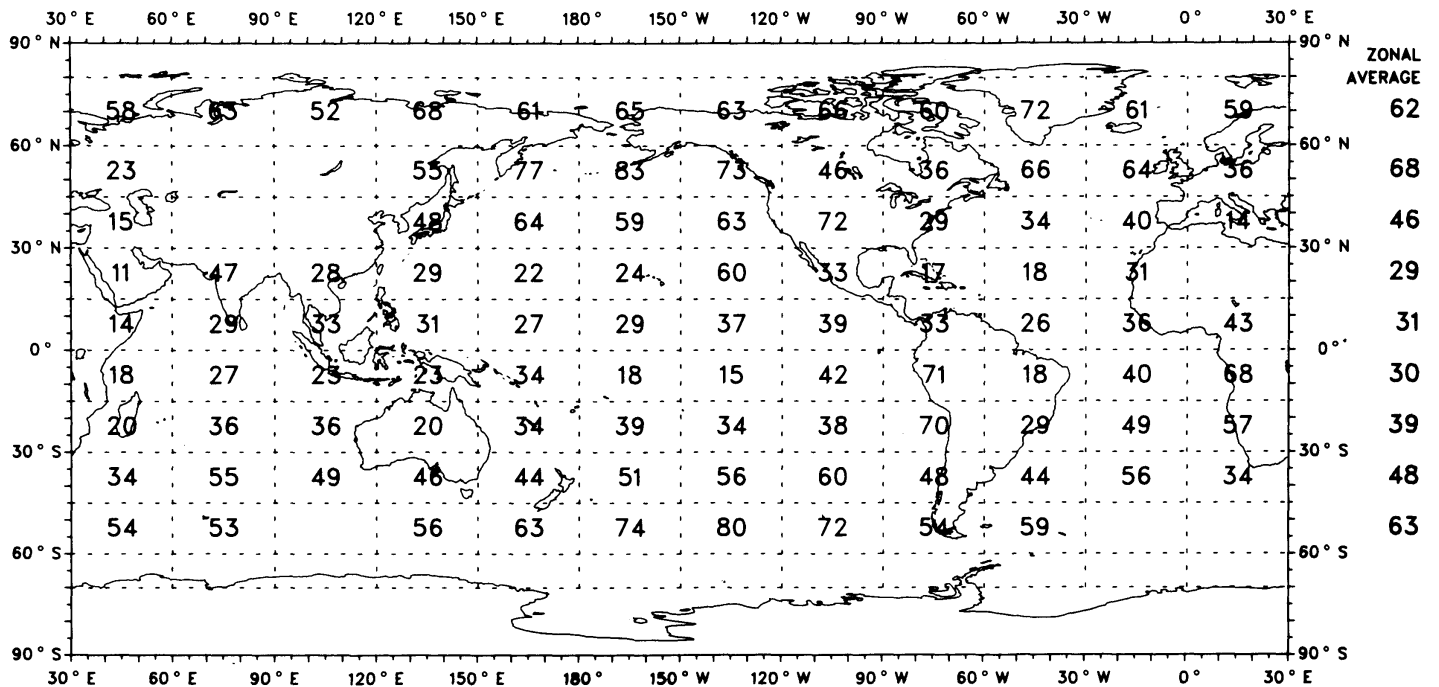
Ocean Areas Only



Frequency of Occurrence (Percent) of St/Sc

JJA (1965-1976)

Ocean Areas Only



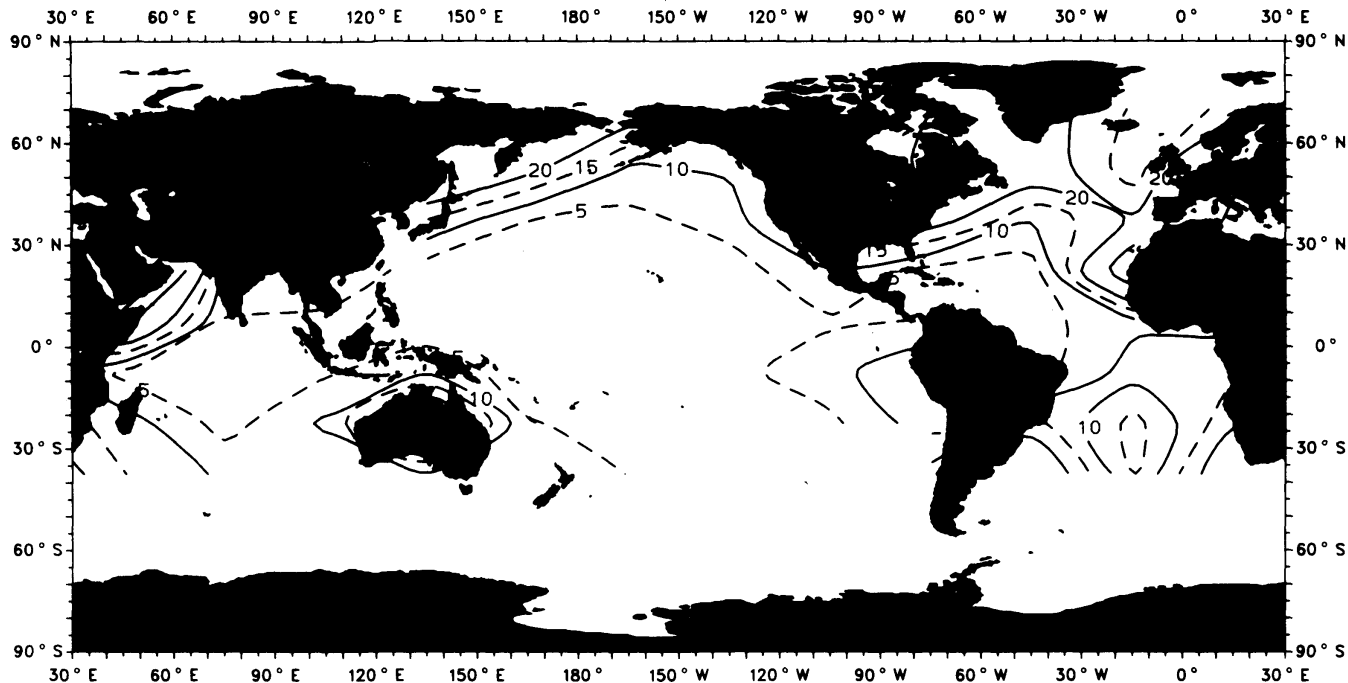


Map III-18

Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

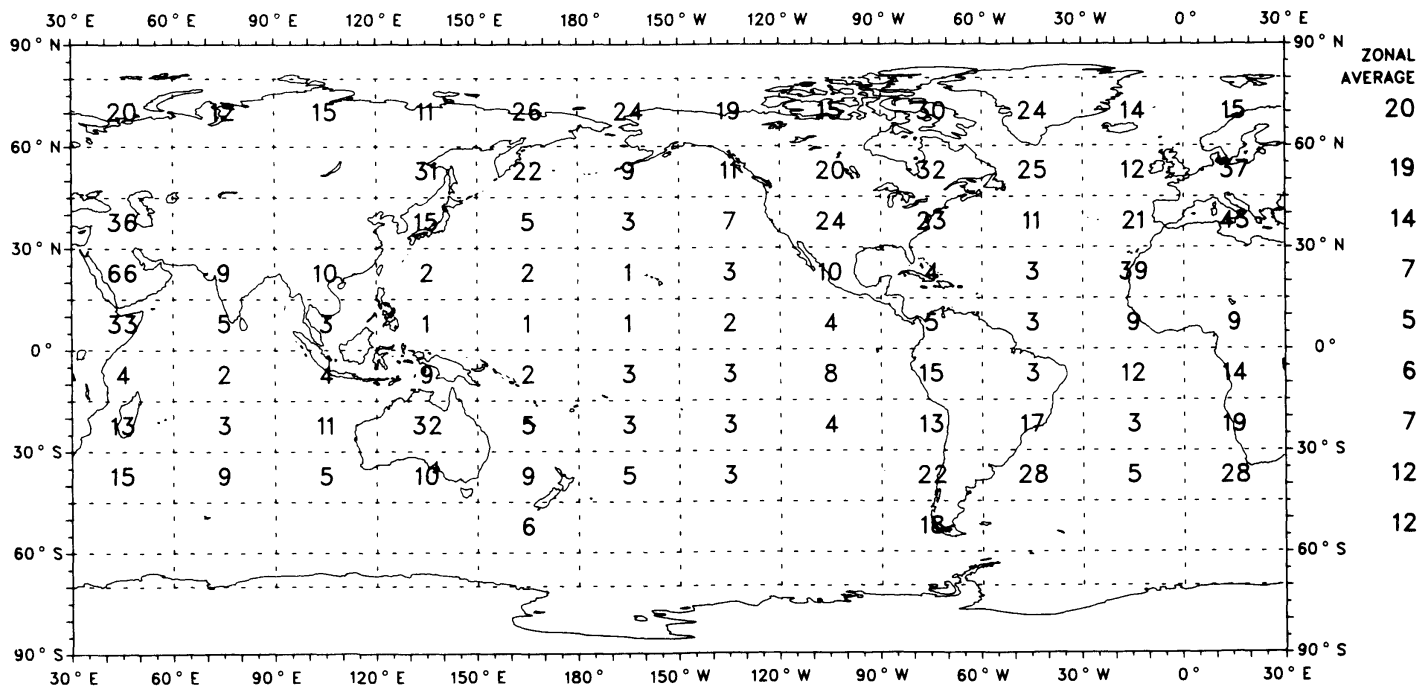
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

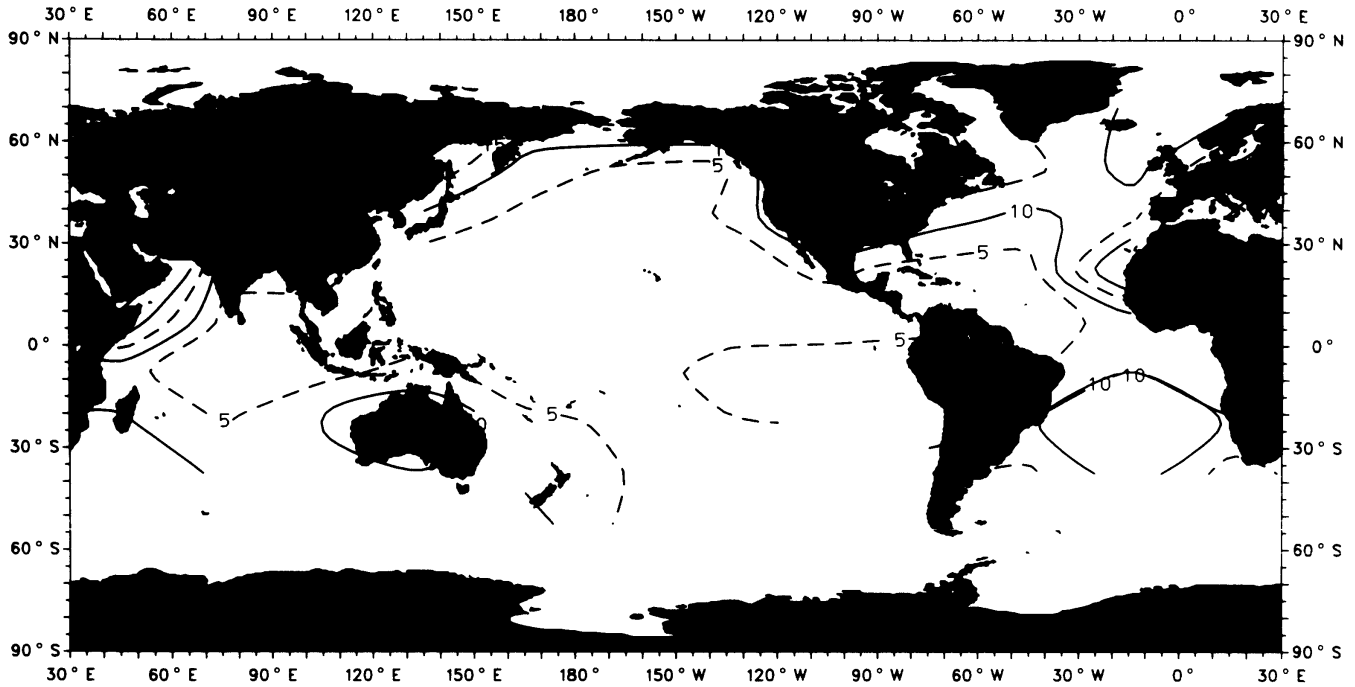
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

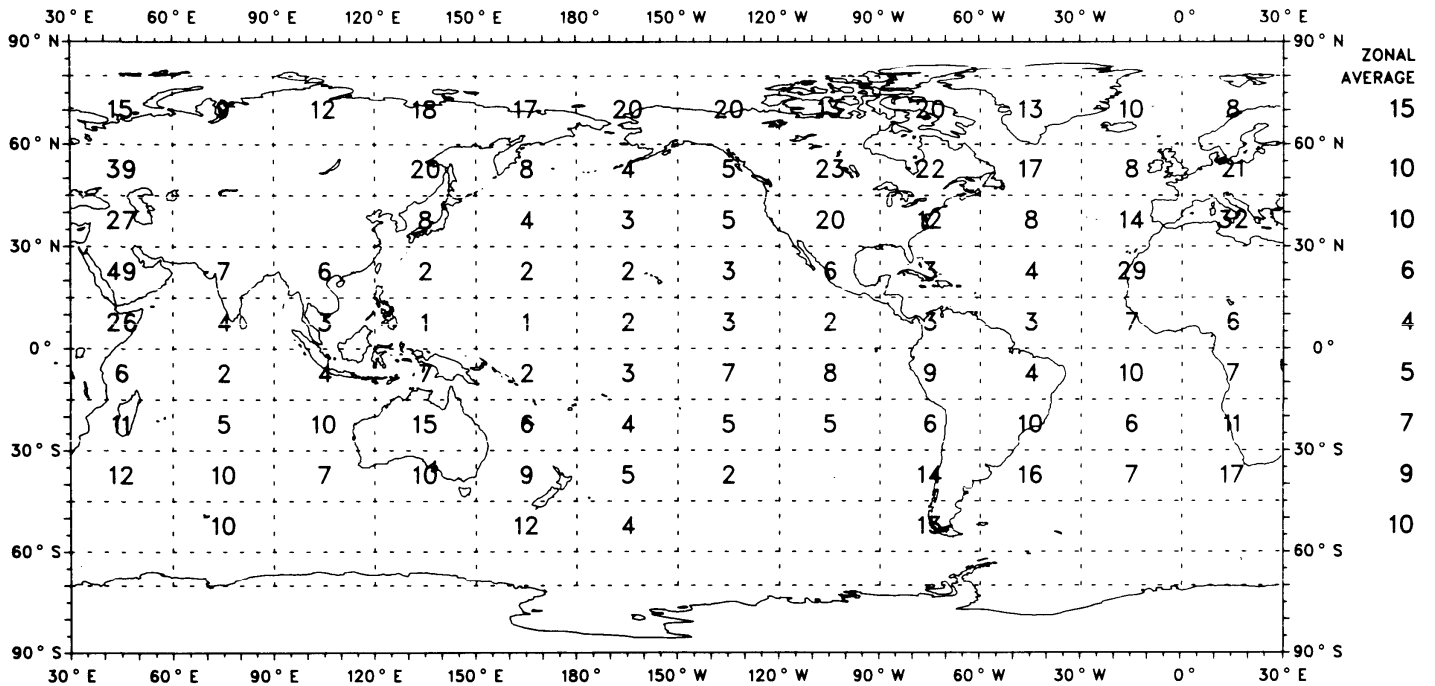
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

Ocean Areas Only

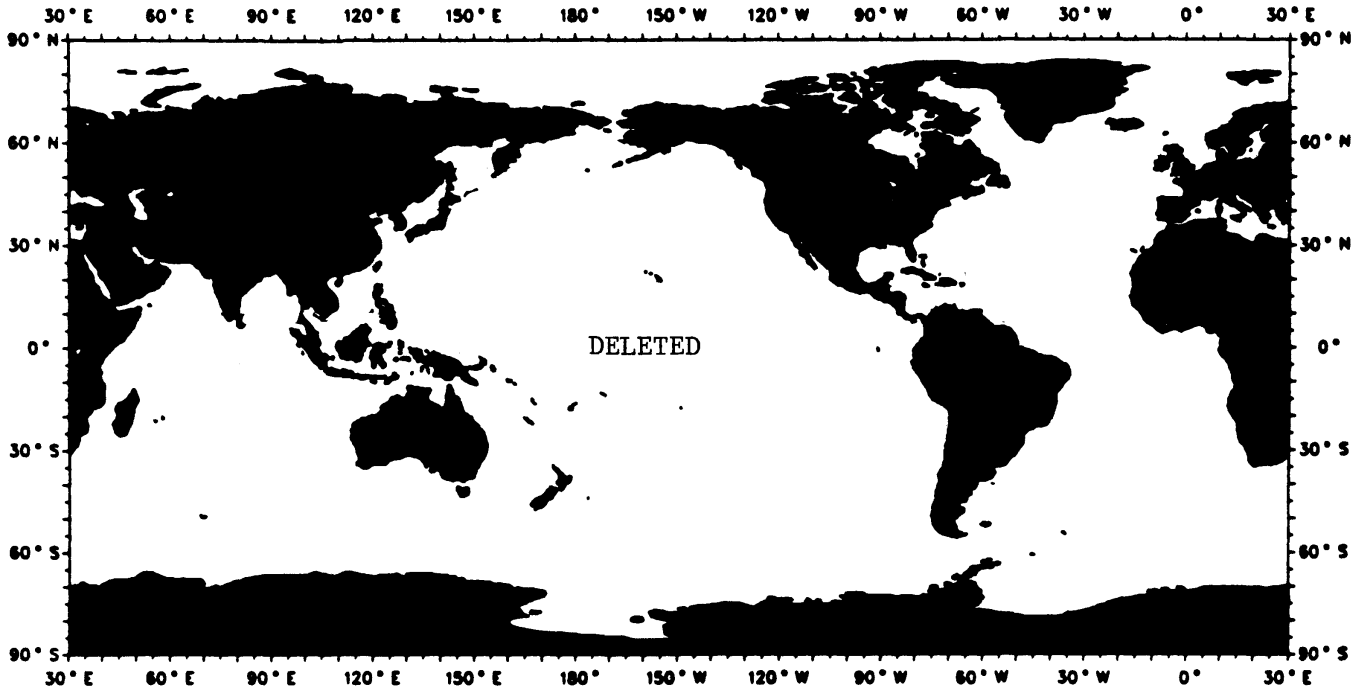


Map III-20

Given Nimbostratus, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

Ocean Areas Only

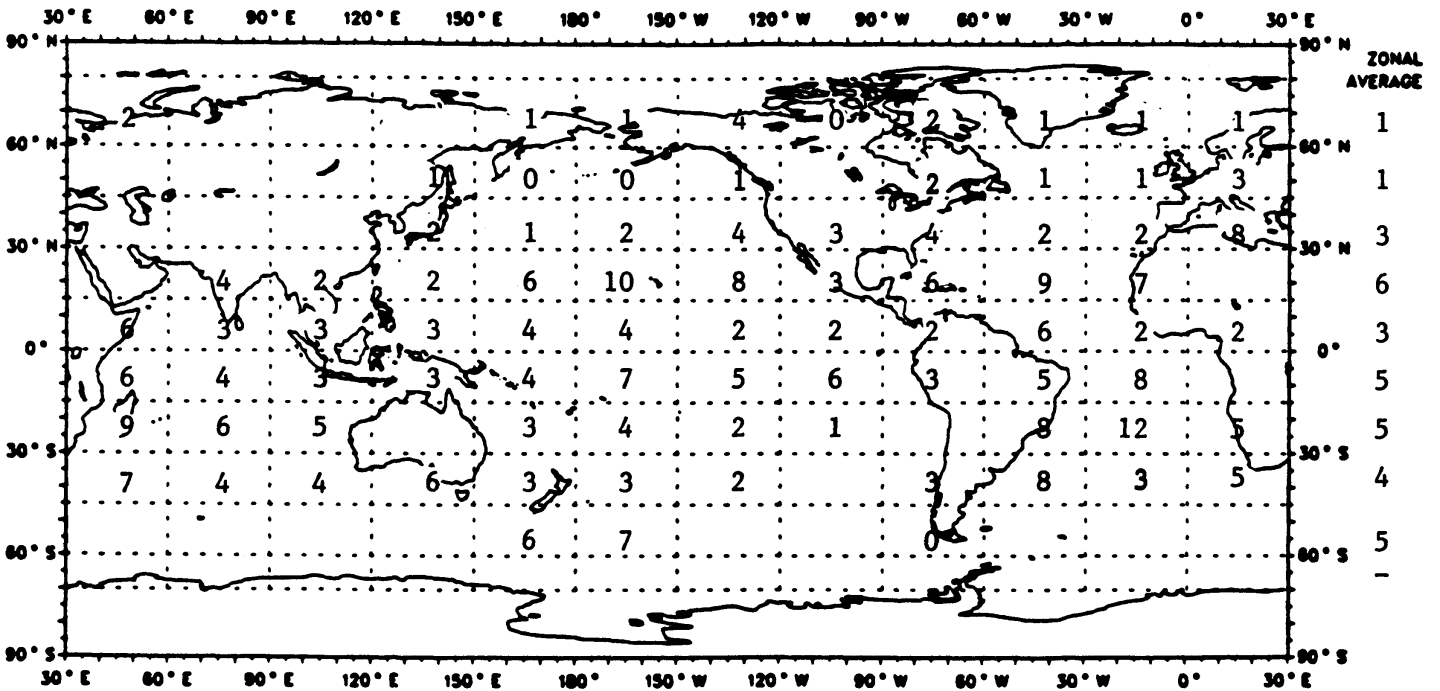


Given Nimbostratus, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

Revised 1988

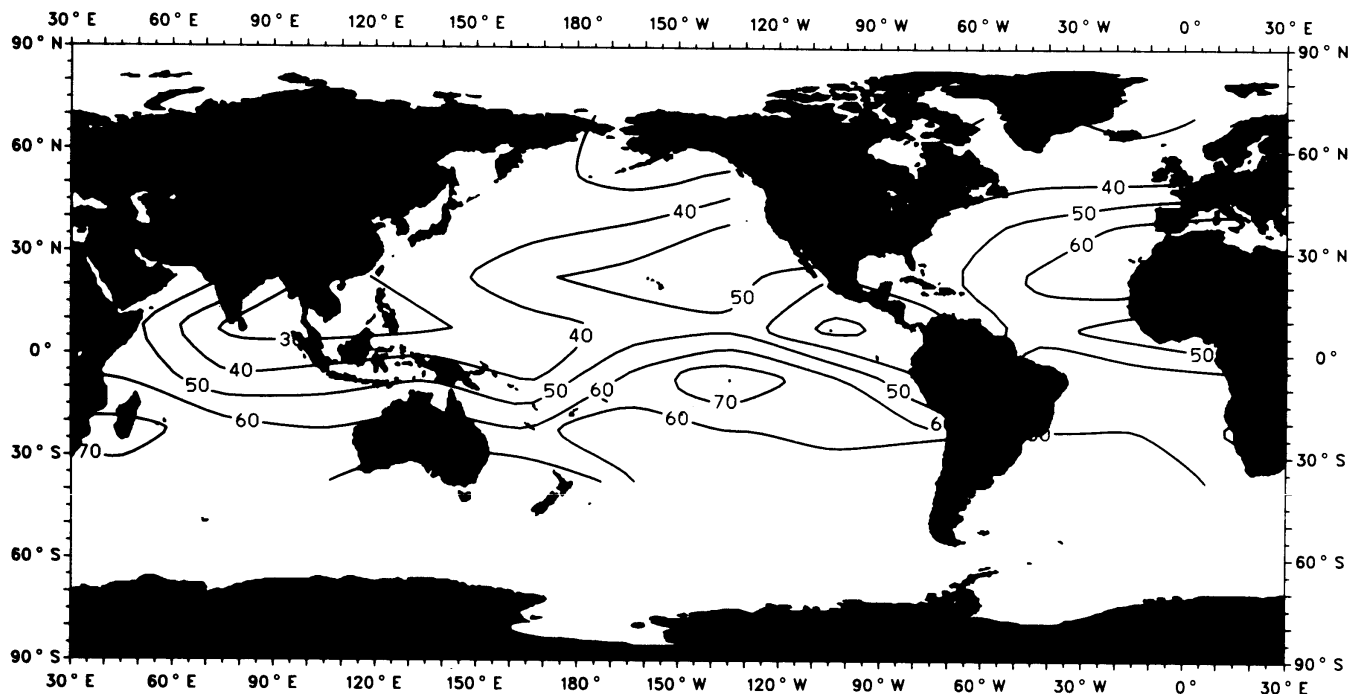
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

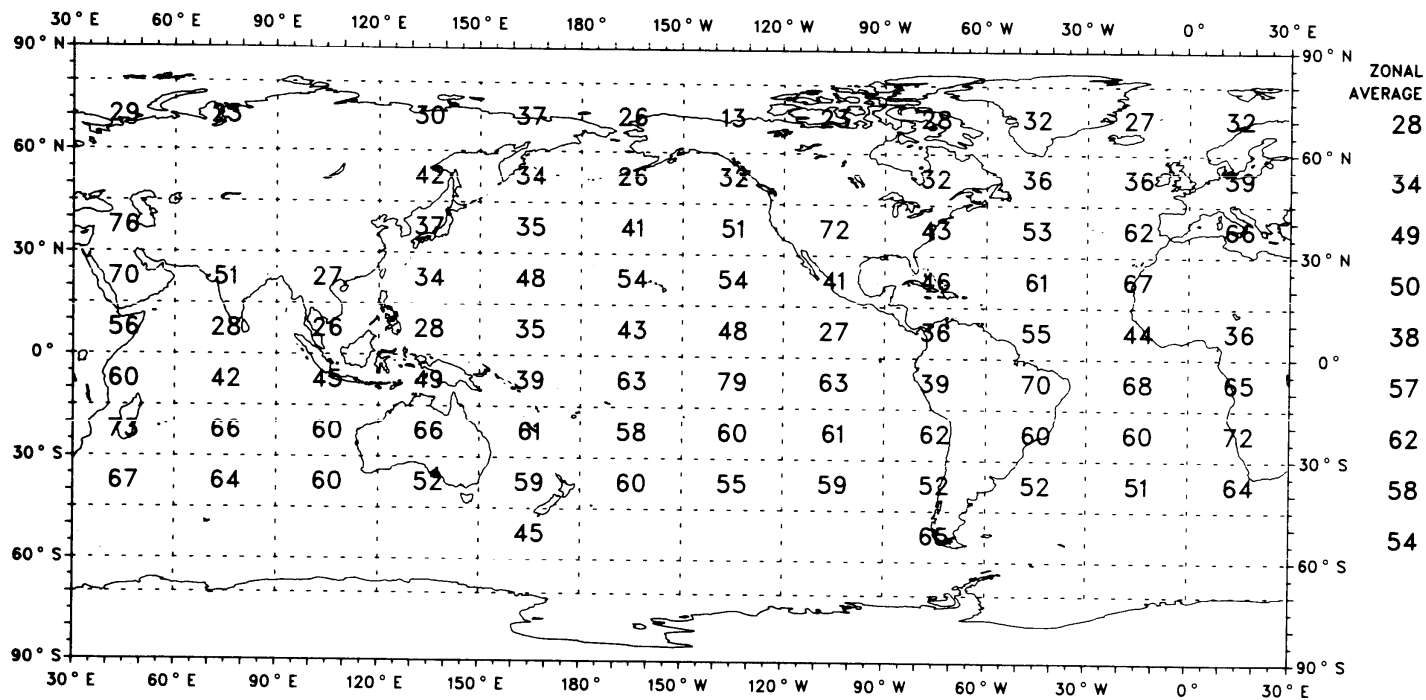
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

Ocean Areas Only



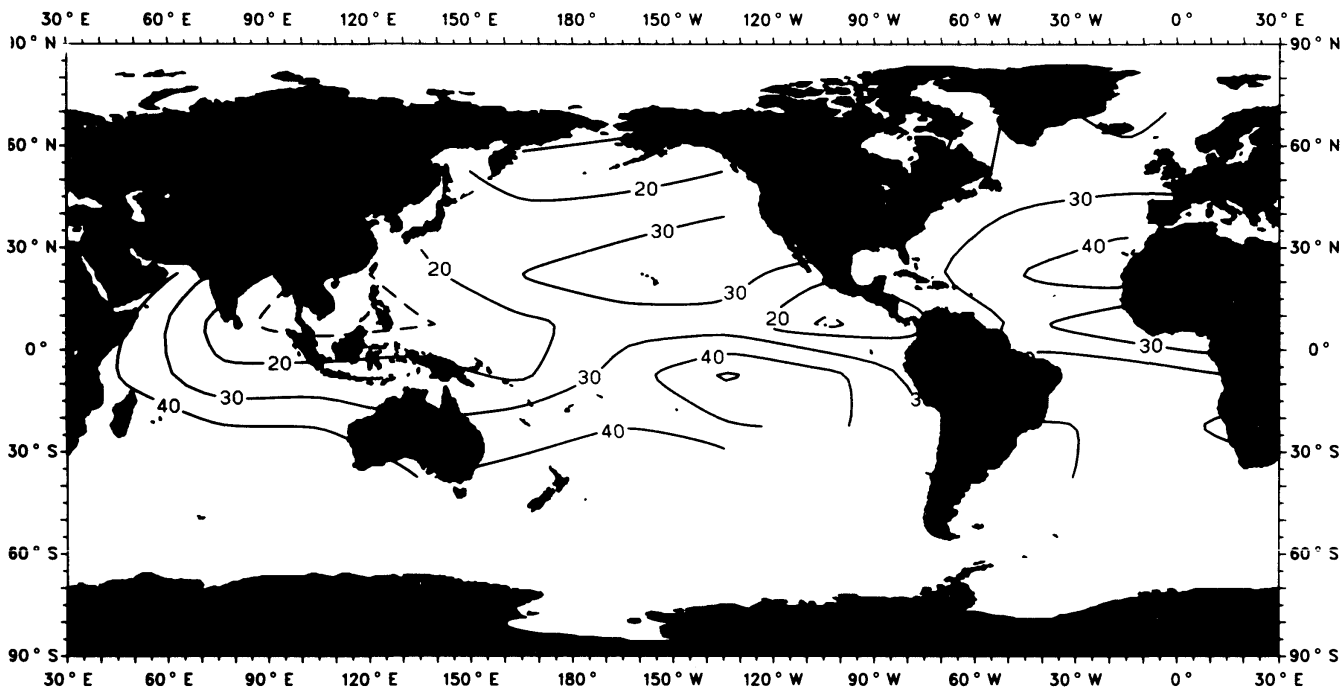


Given Cumulonimbus, Probability (Percent) That No Other Cloud Is Present

Map III-23

JJA (1965-1976)

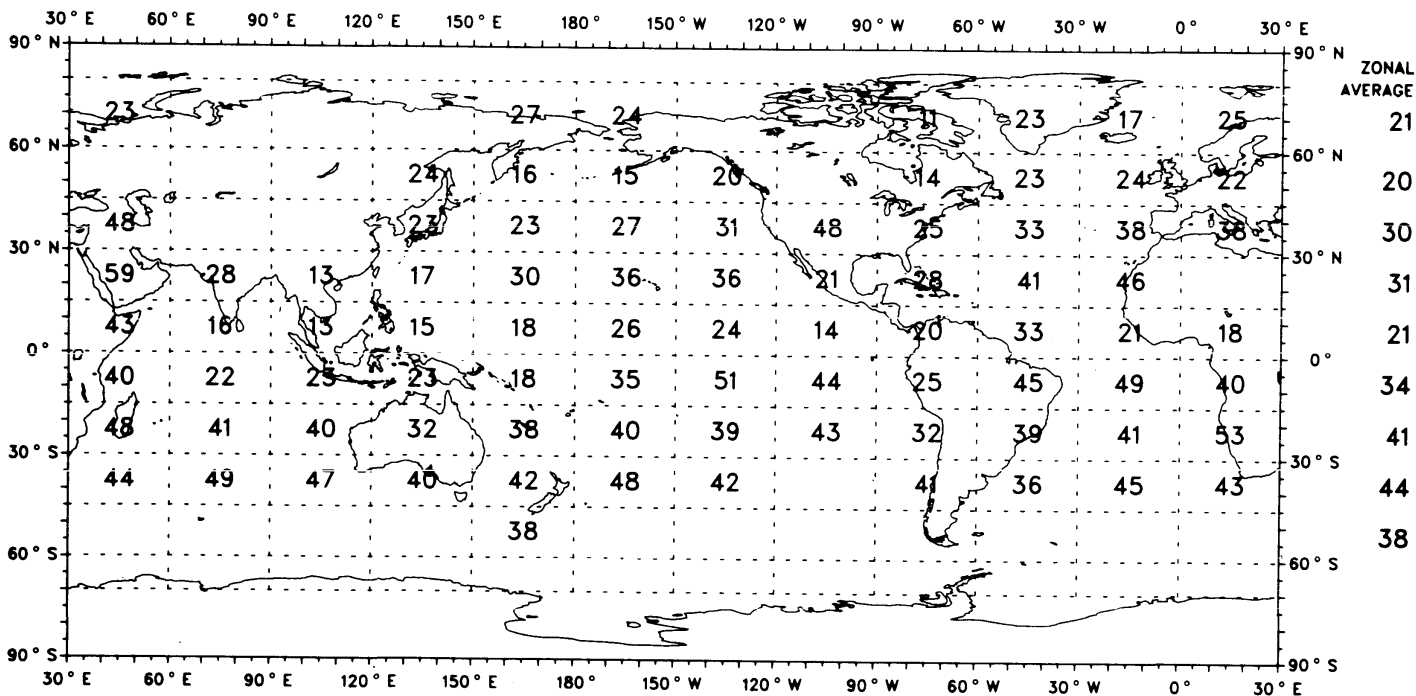
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That No Other Cloud Is Present

JJA (1965-1976)

Ocean Areas Only

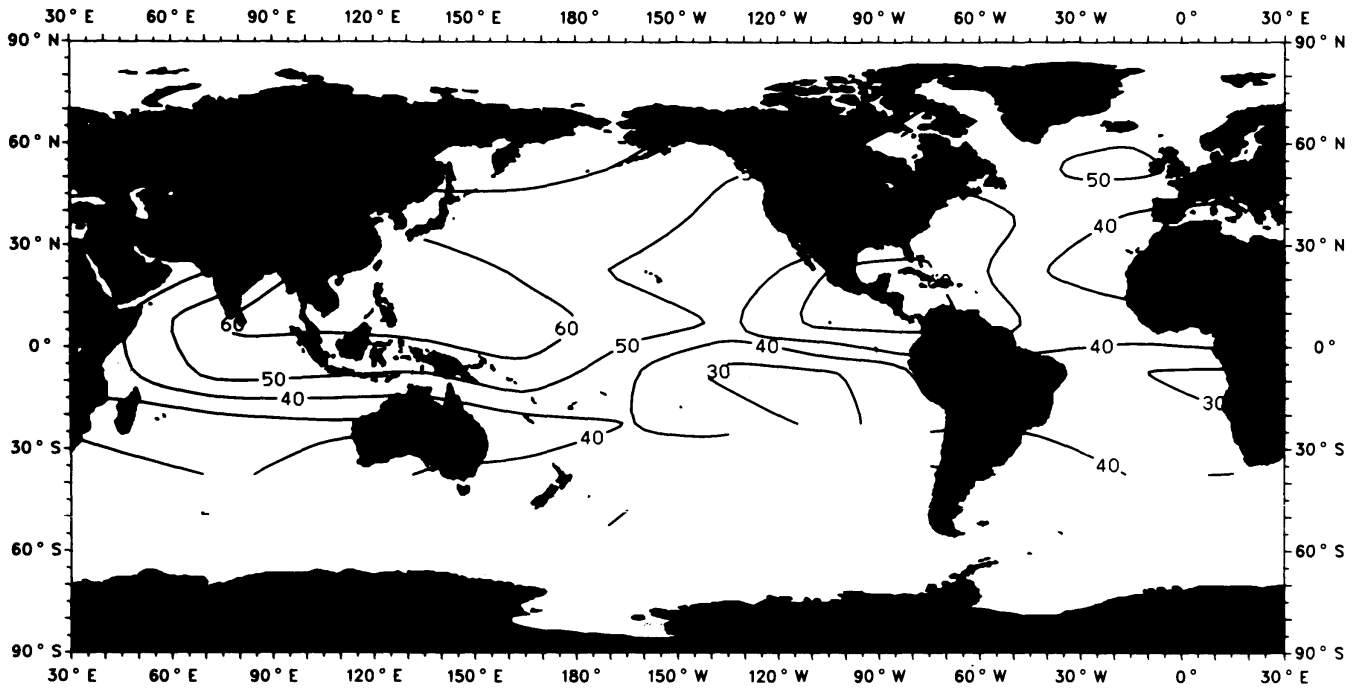




Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

JJA (1965-1976)

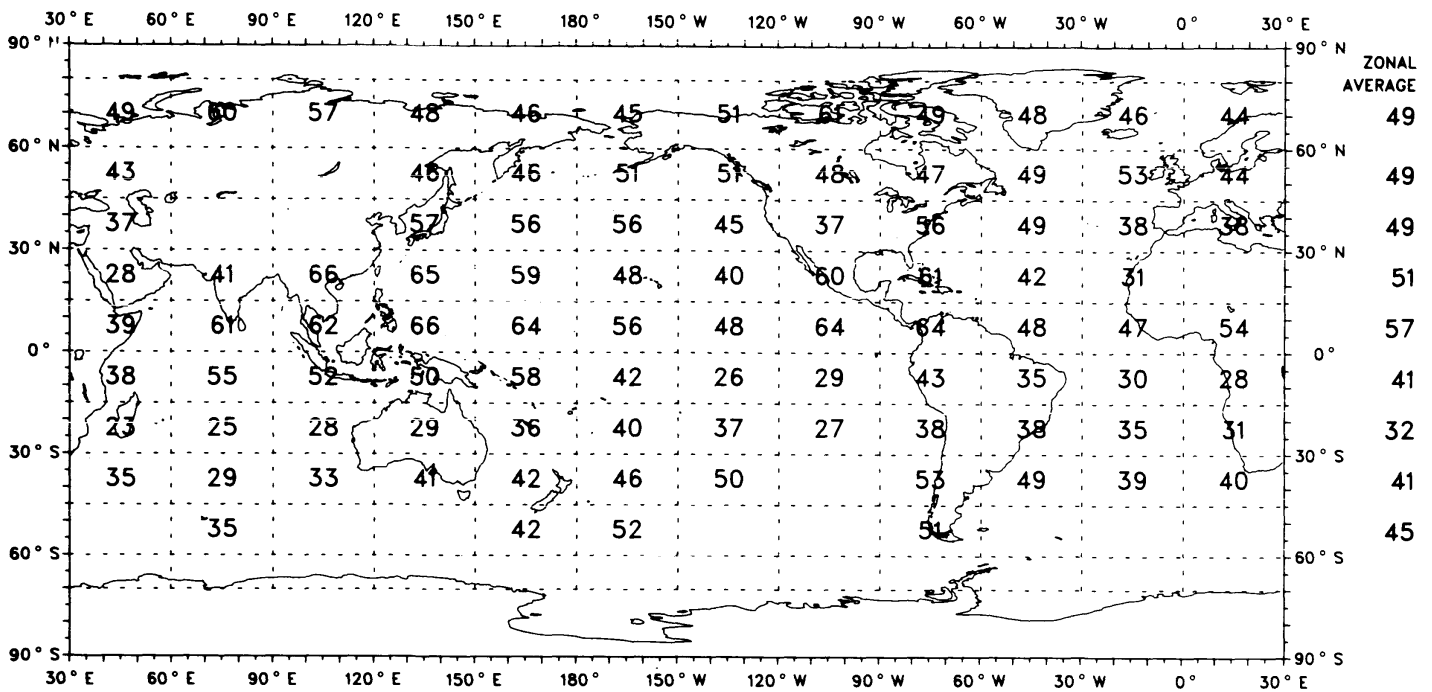
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

JJA (1965-1976)

Ocean Areas Only

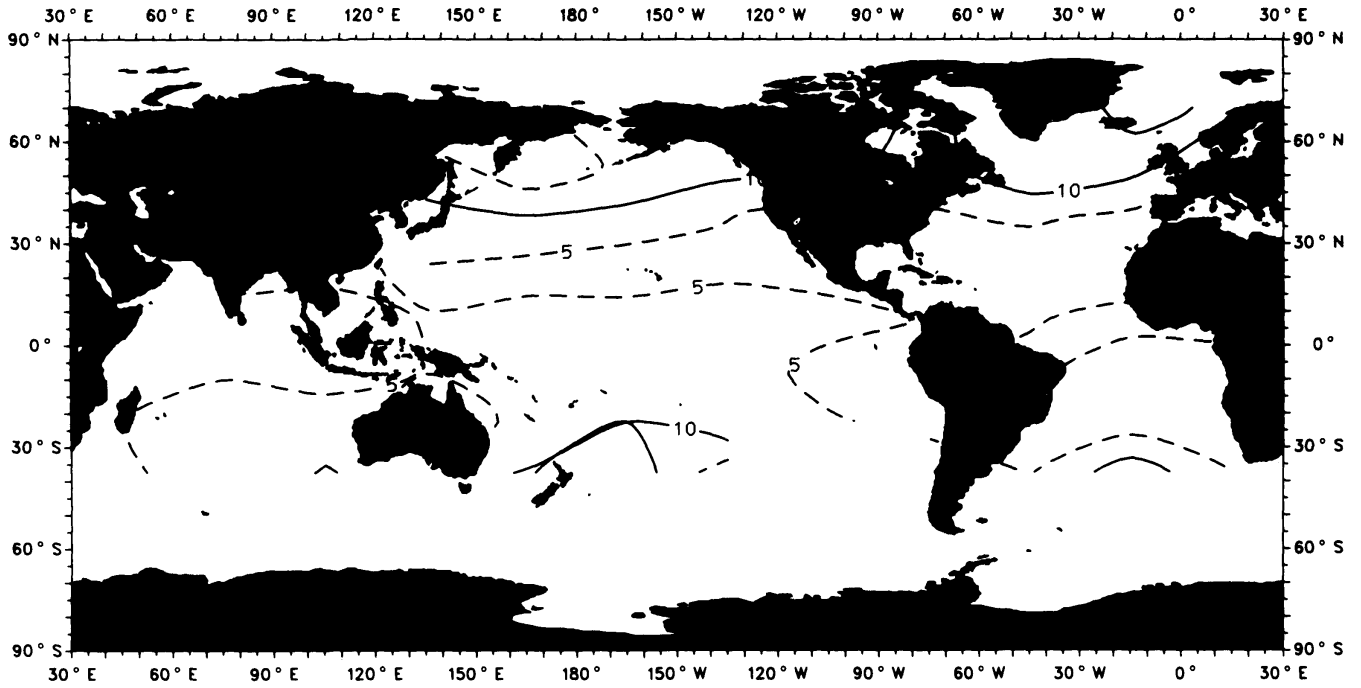


Map III-26

Given  $C_i/C_s/C_c$ , Probability (Percent) That Nimbostratus is Also Present

JJA (1965-1976)

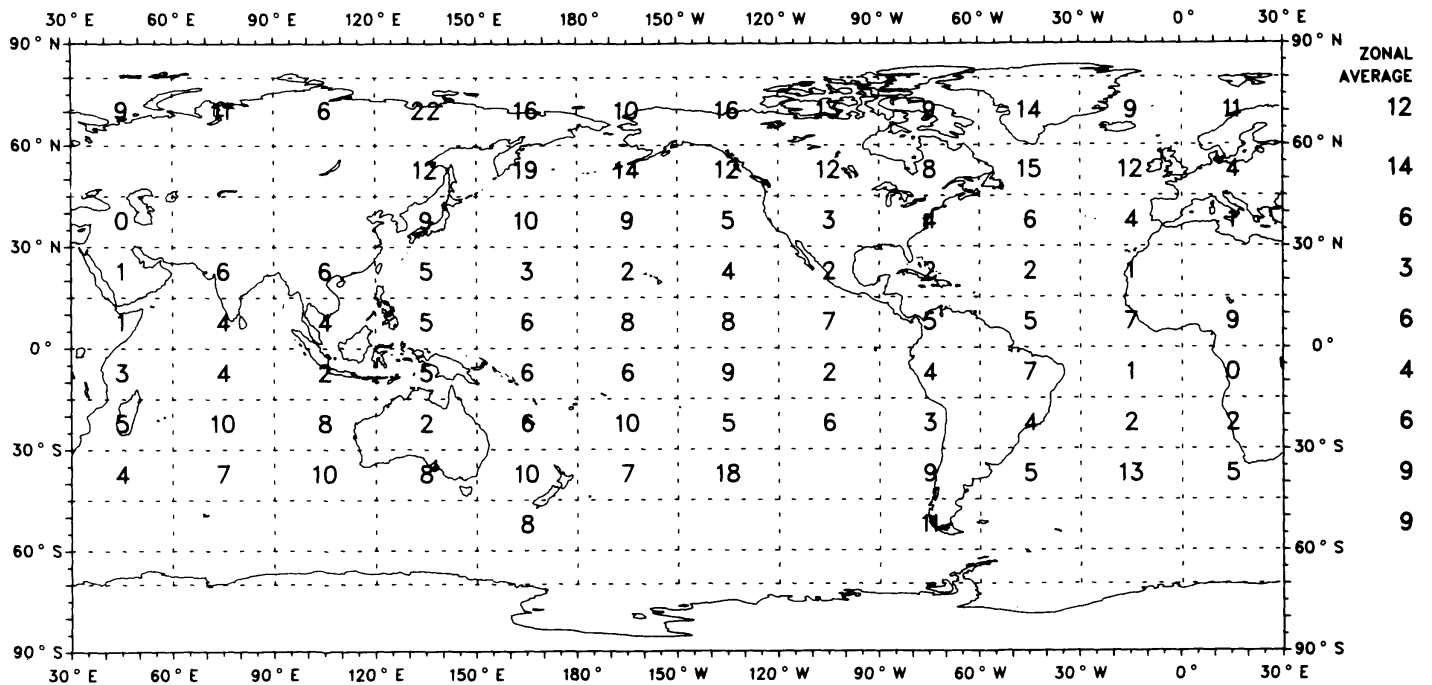
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Nimbostratus is Also Present

JJA (1965-1976)

Ocean Areas Only







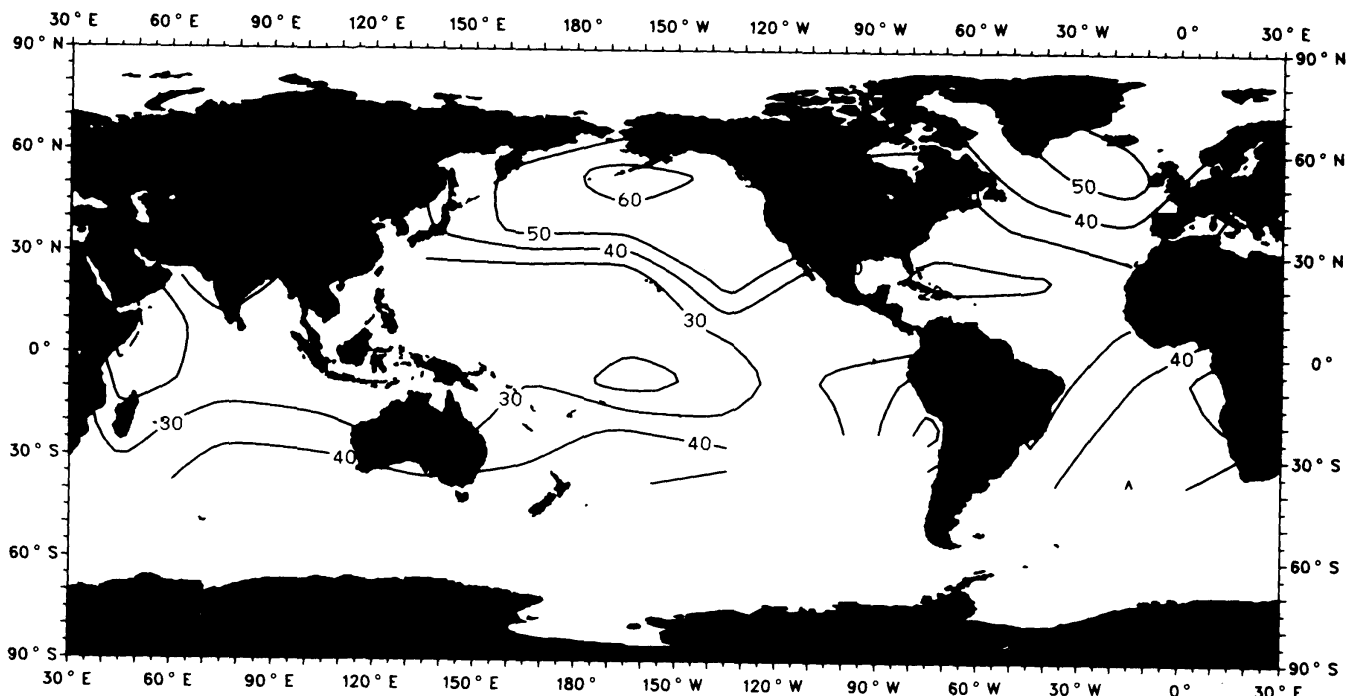


Map III-30

Given Ci/Cs/Cc, Probability (Percent) That St/Sc is Also Present

JJA (1965-1976)

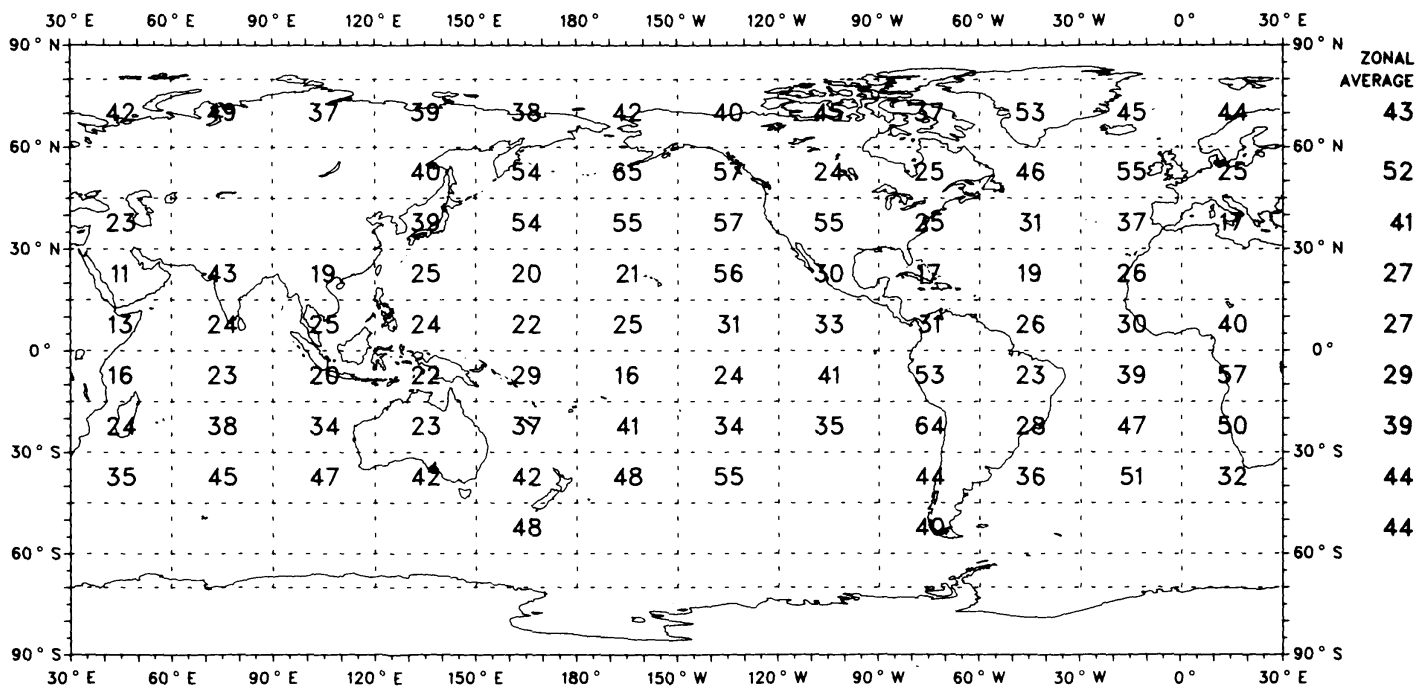
Ocean Areas Only



Given Ci/Cs/Cc, Probability (Percent) That St/Sc is Also Present

JJA (1965-1976)

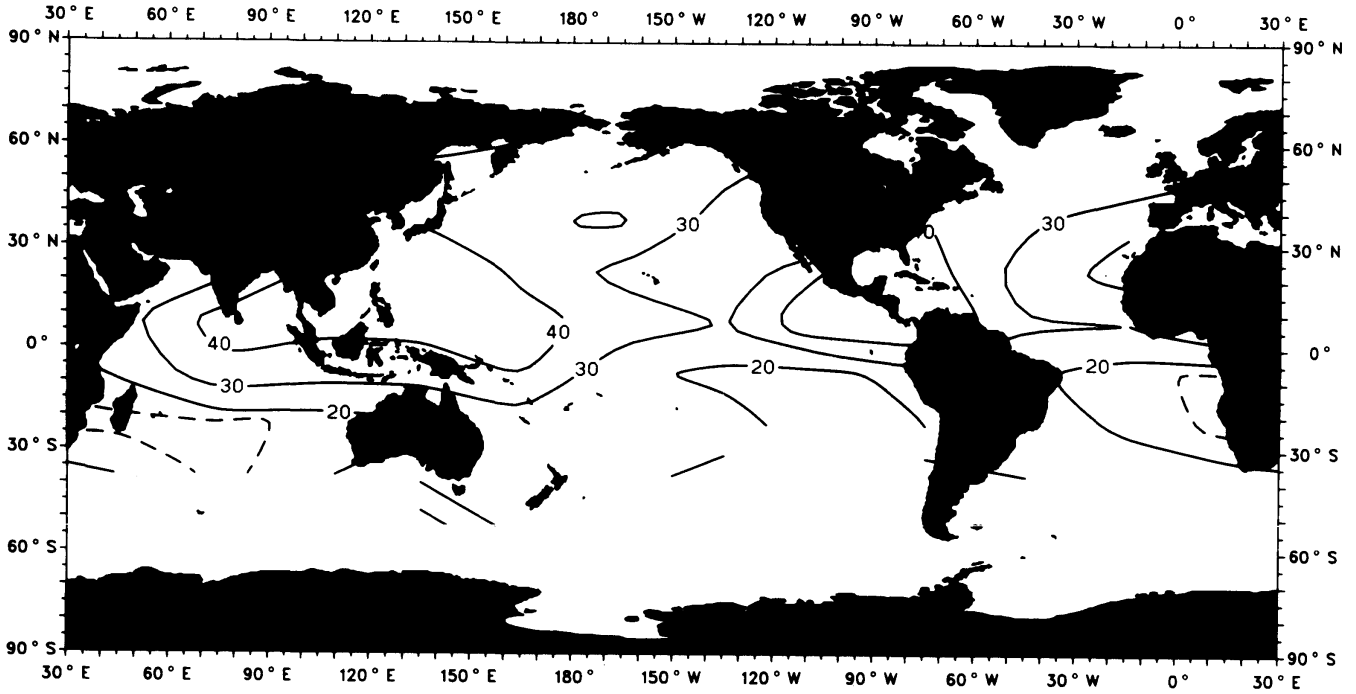
Ocean Areas Only



Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

JJA (1965-1976)

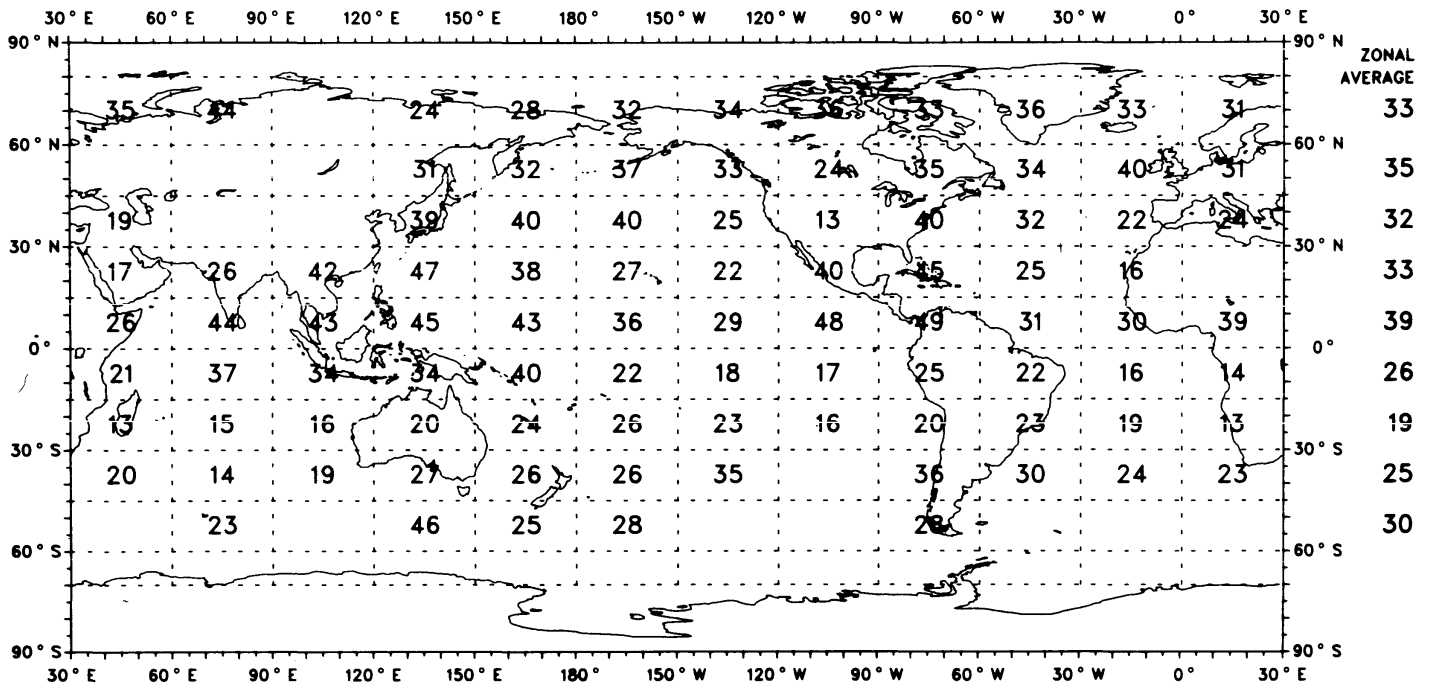
Ocean Areas Only



Given St/Sc, Probability (Percent) That Ci/Cs/Cc is Also Present

JJA (1965-1976)

Ocean Areas Only

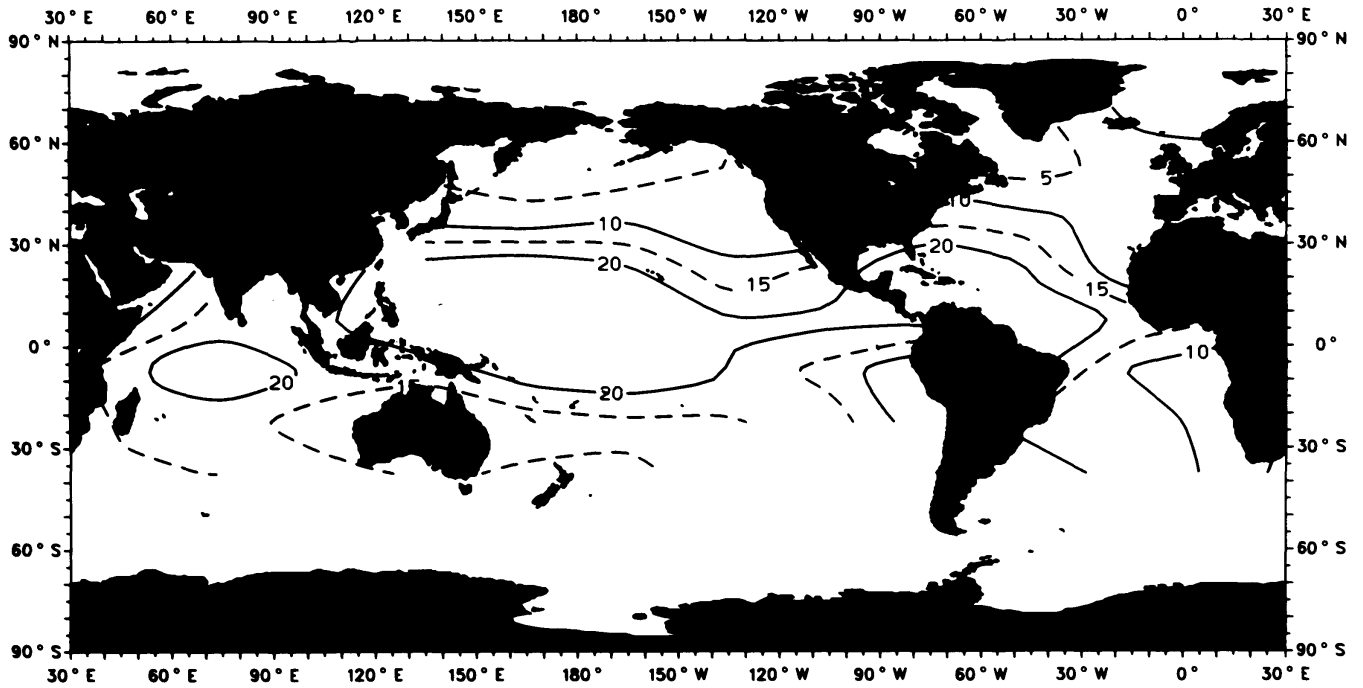


Map III-32

Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present

JJA (1965-1976)

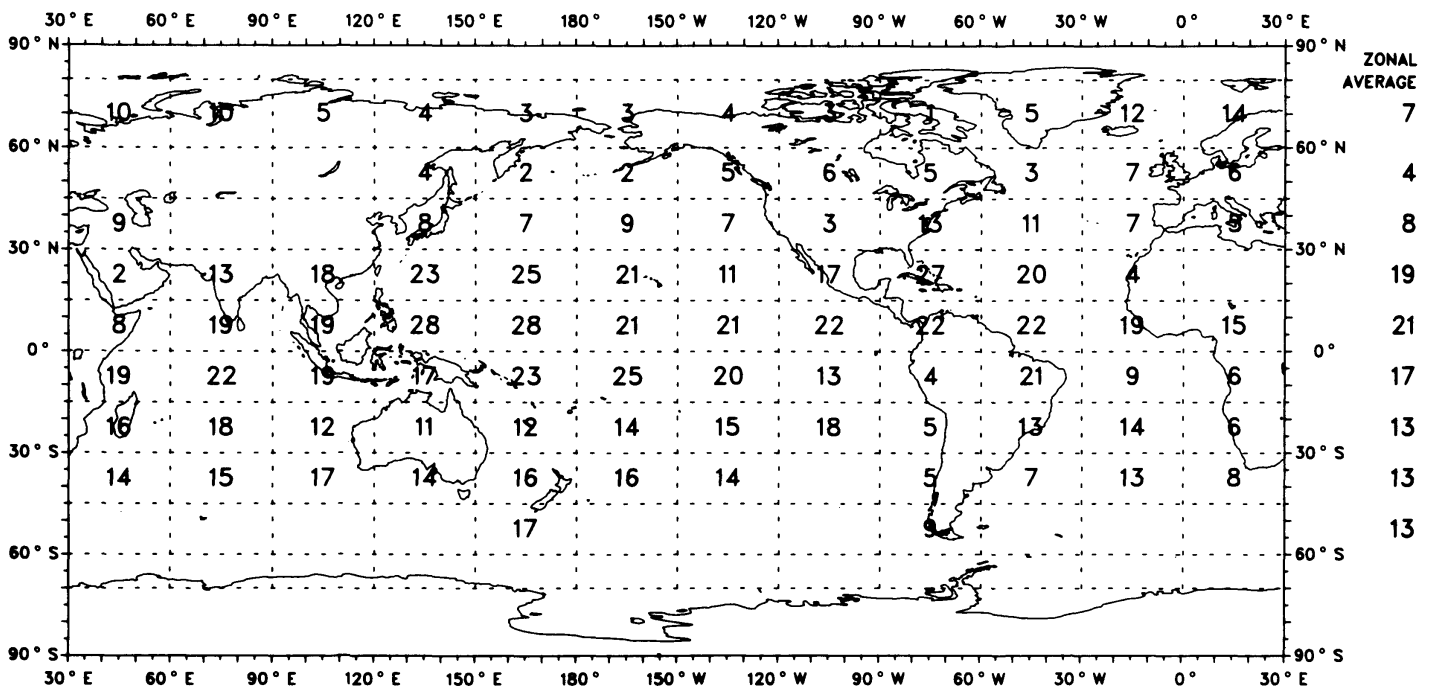
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present

JJA (1965-1976)

Ocean Areas Only







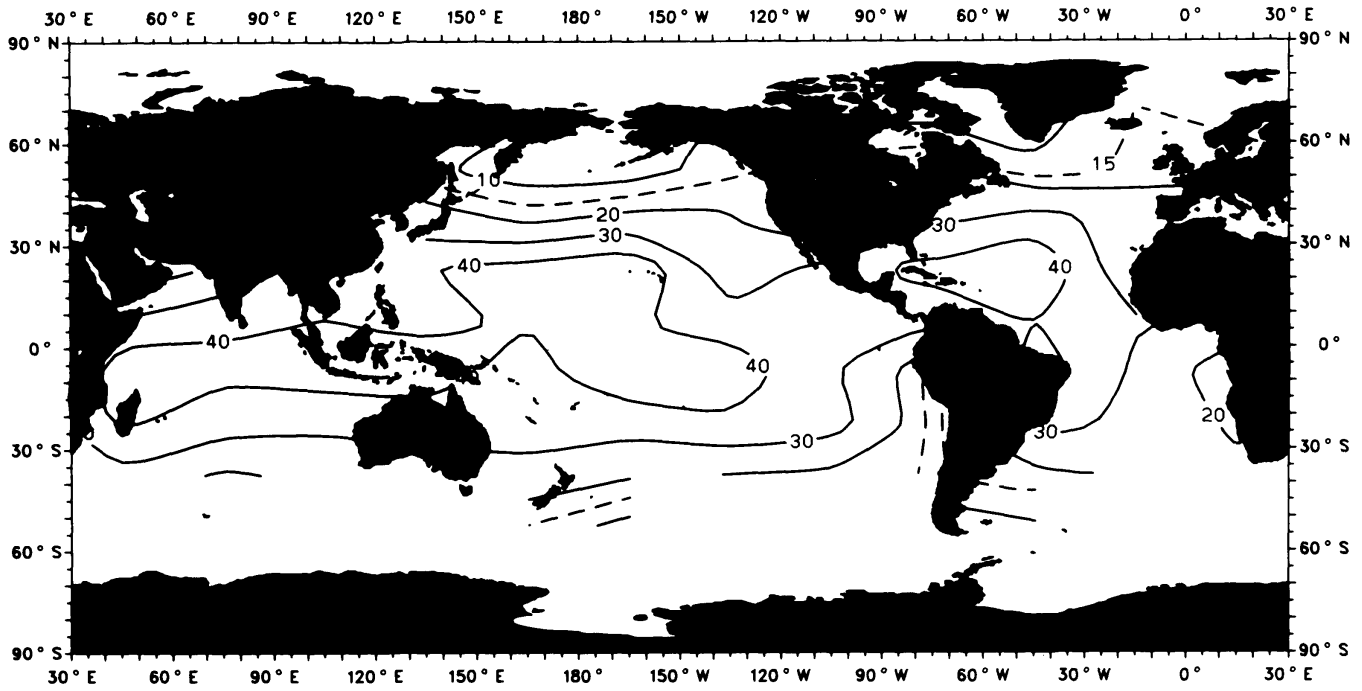


Map III-36

Given As/Ac, Probability (Percent) That Cumulus is Also Present

JJA (1965-1976)

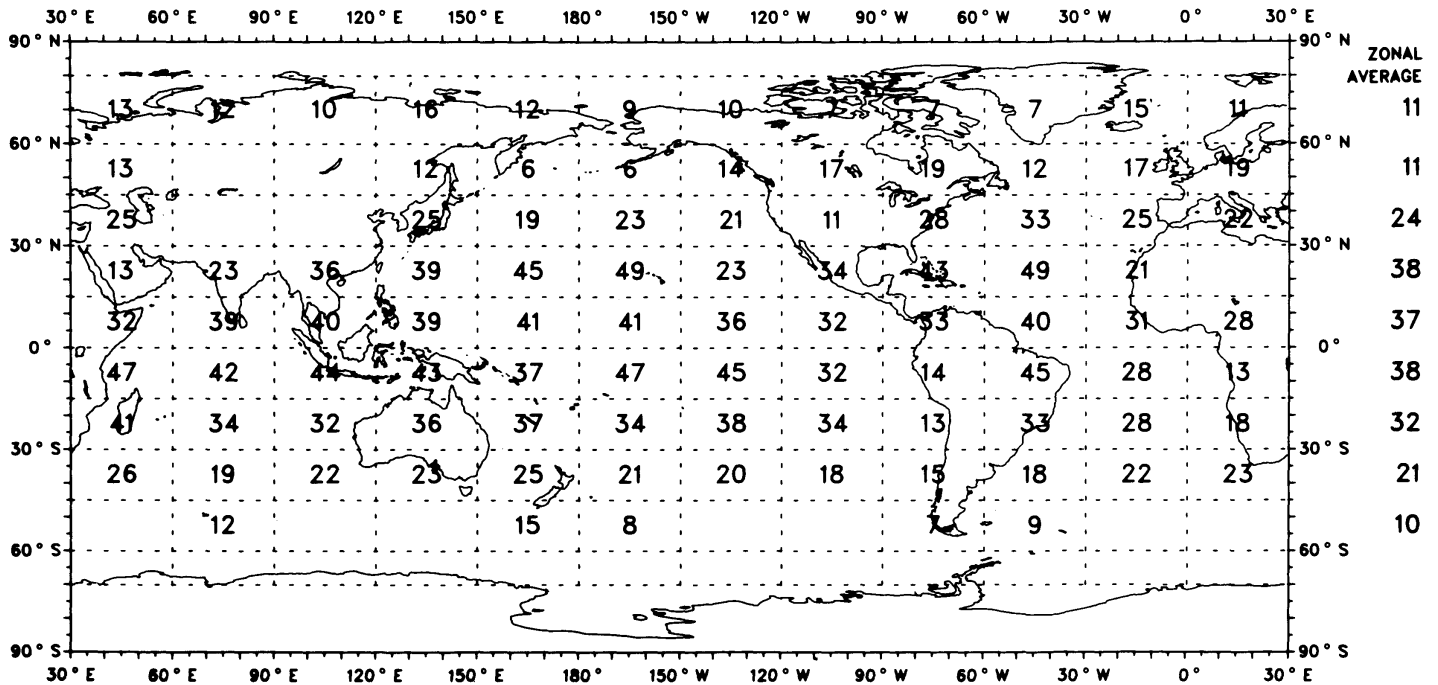
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulus is Also Present

JJA (1965-1976)

Ocean Areas Only



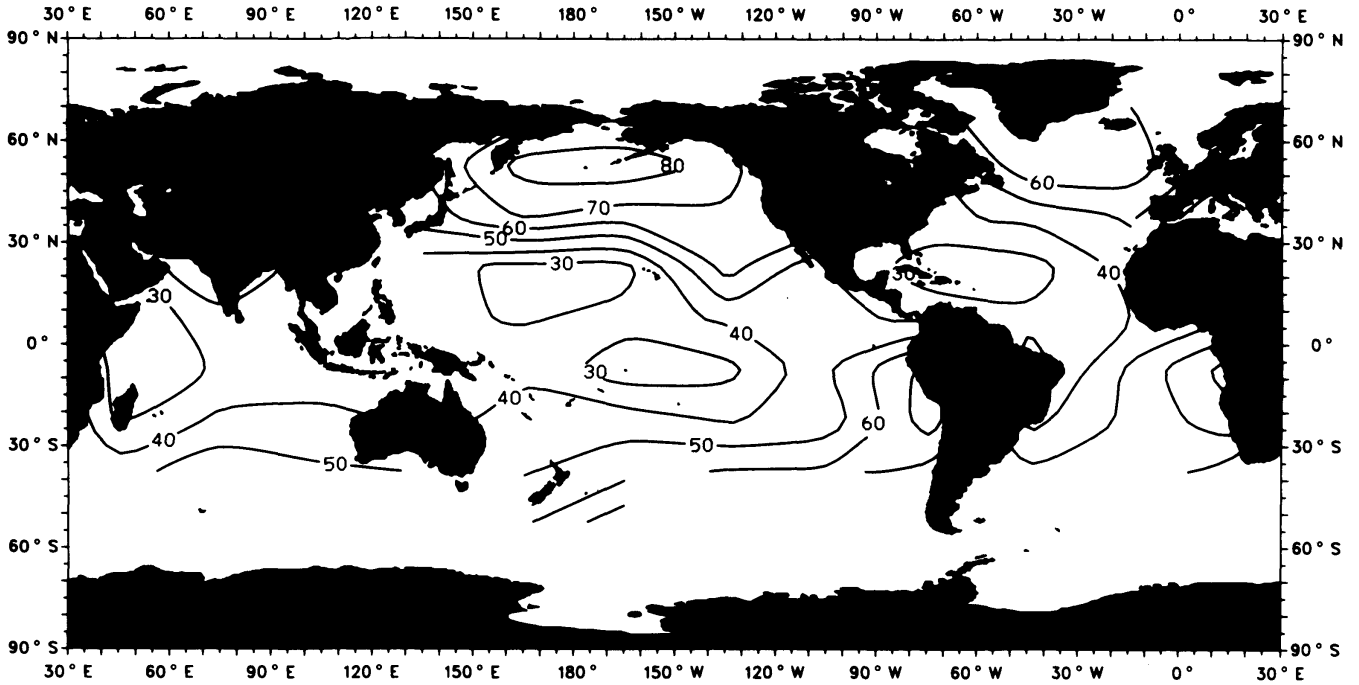


Map III-38

Given As/Ac, Probability (Percent) That St/Sc is Also Present

JJA (1965-1976)

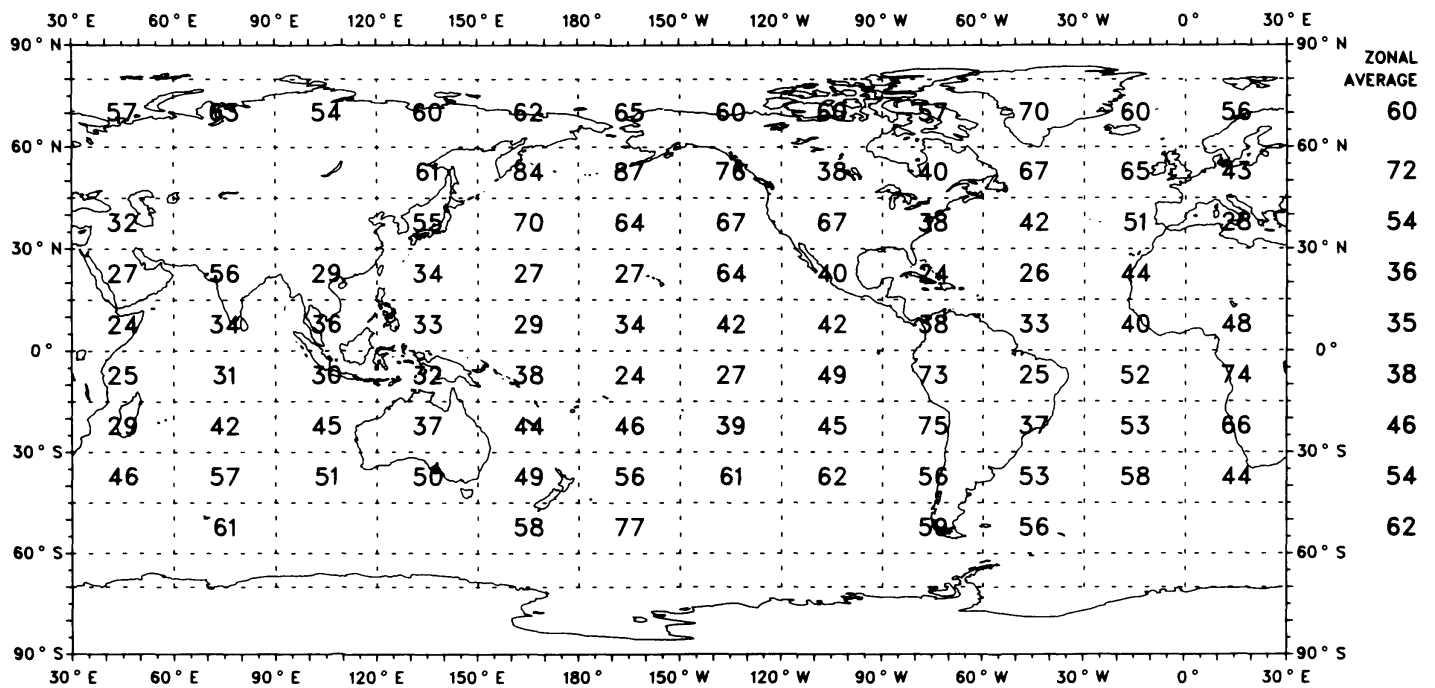
Ocean Areas Only



Given As/Ac, Probability (Percent) That St/Sc is Also Present

JJA (1965-1976)

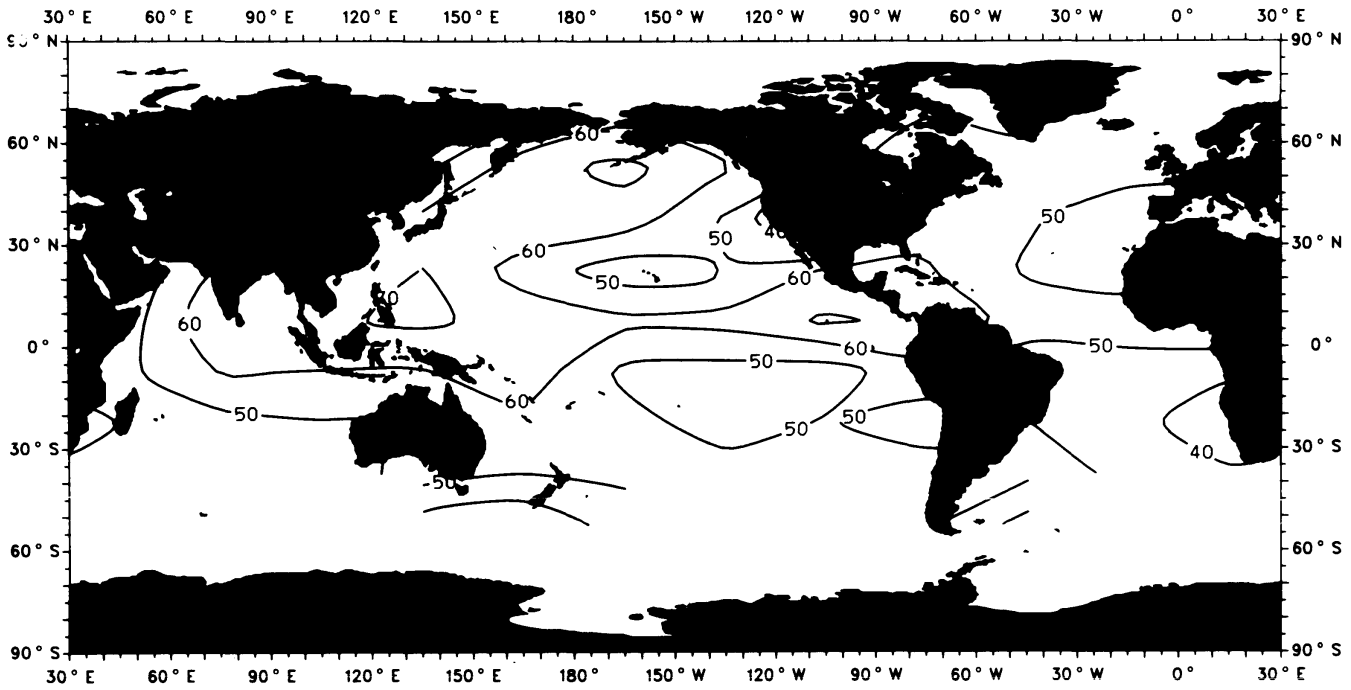
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

JJA (1965-1976)

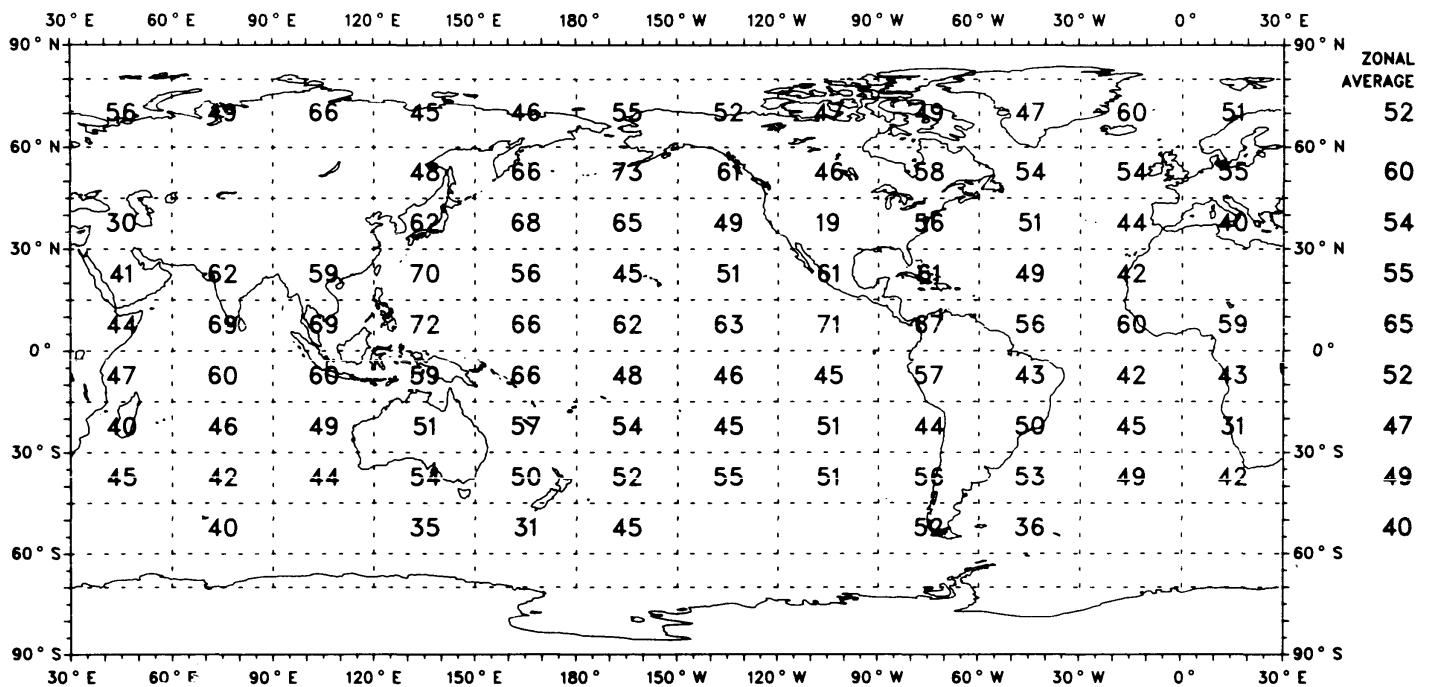
Ocean Areas Only



Given St/Sc, Probability (Percent) That As/Ac is Also Present

JJA (1965-1976)

Ocean Areas Only









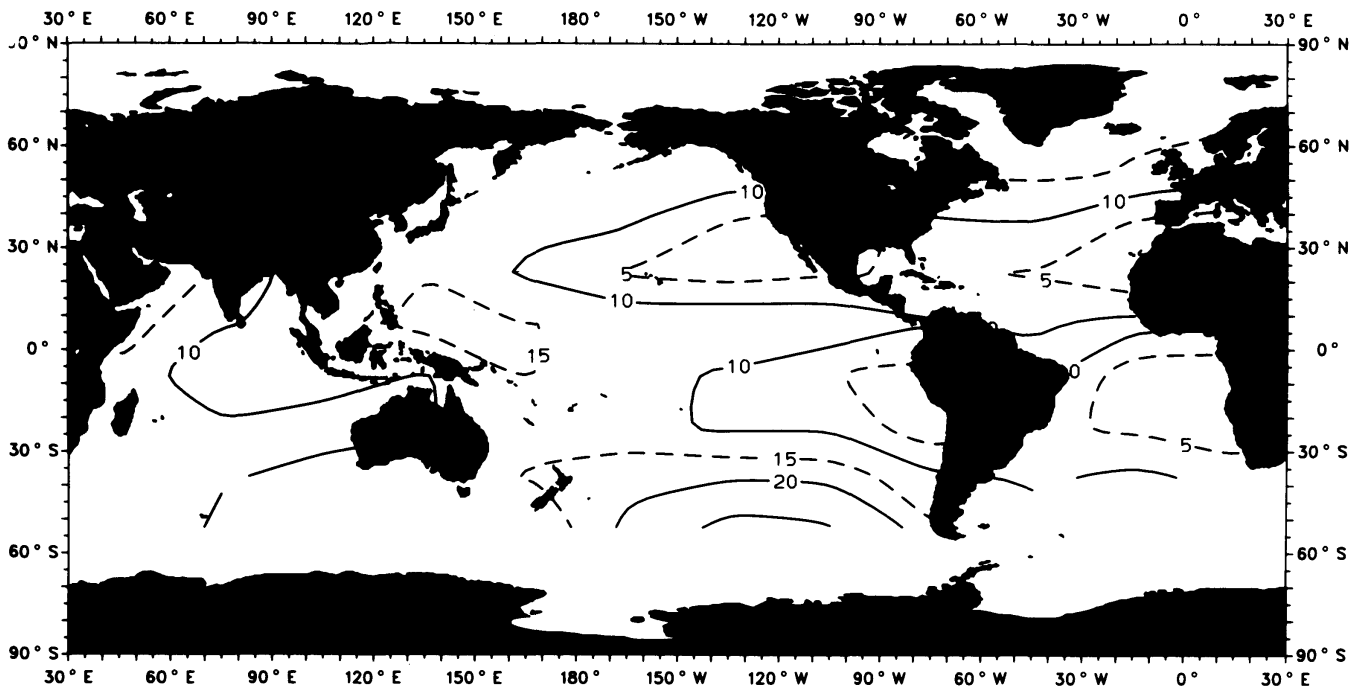


Map III-45

Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

JJA (1965-1976)

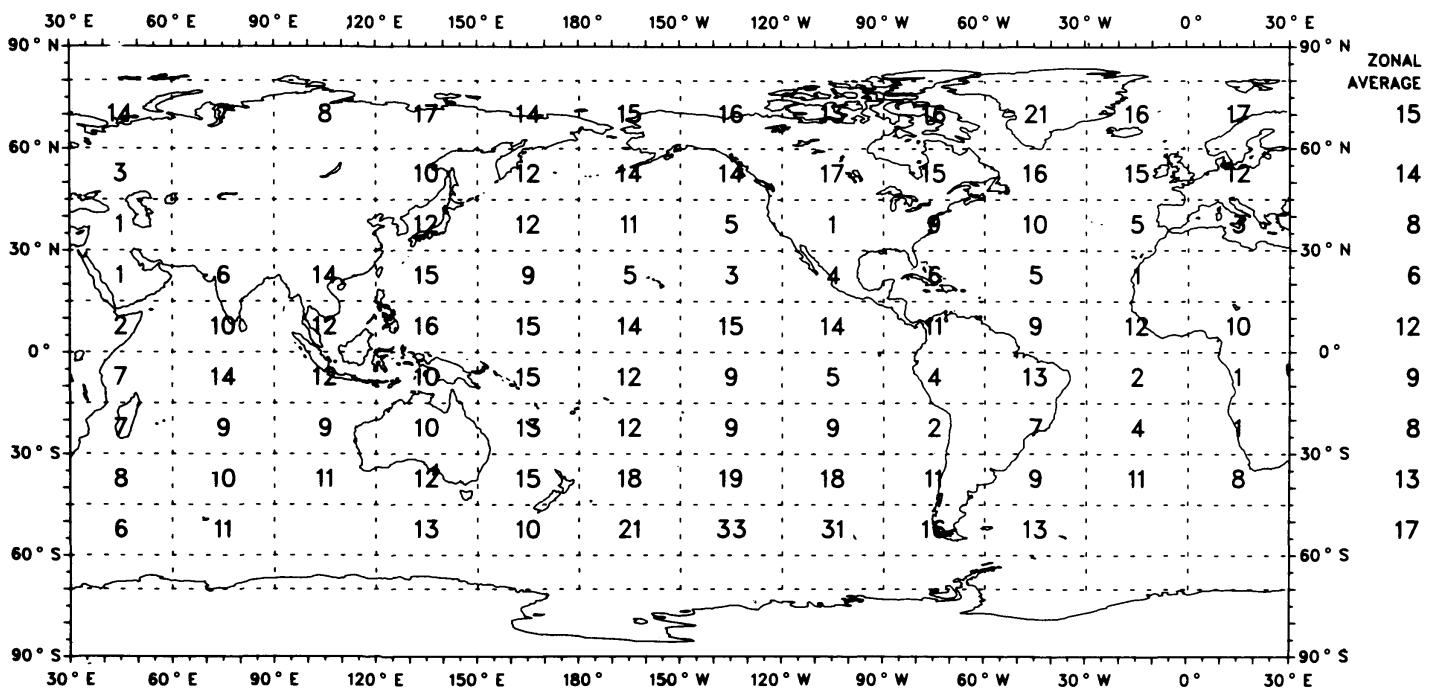
Ocean Areas Only



Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

JJA (1965-1976)

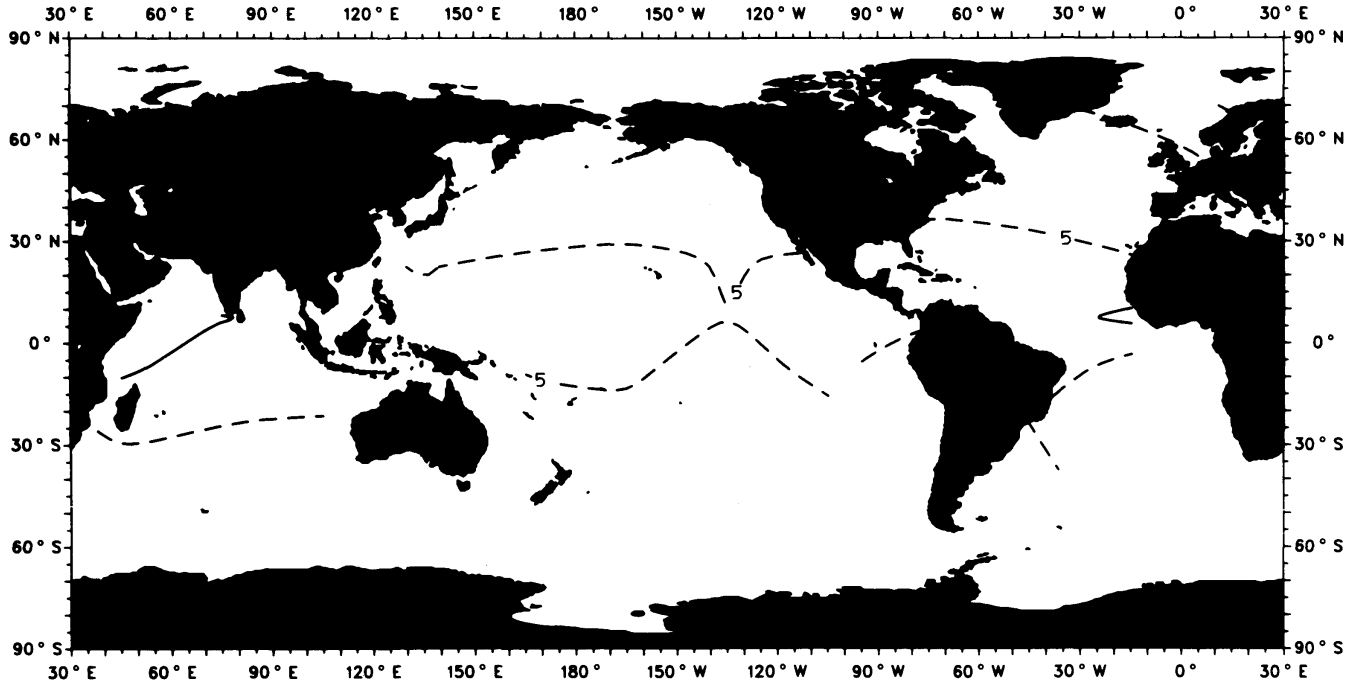
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

JJA (1965-1976)

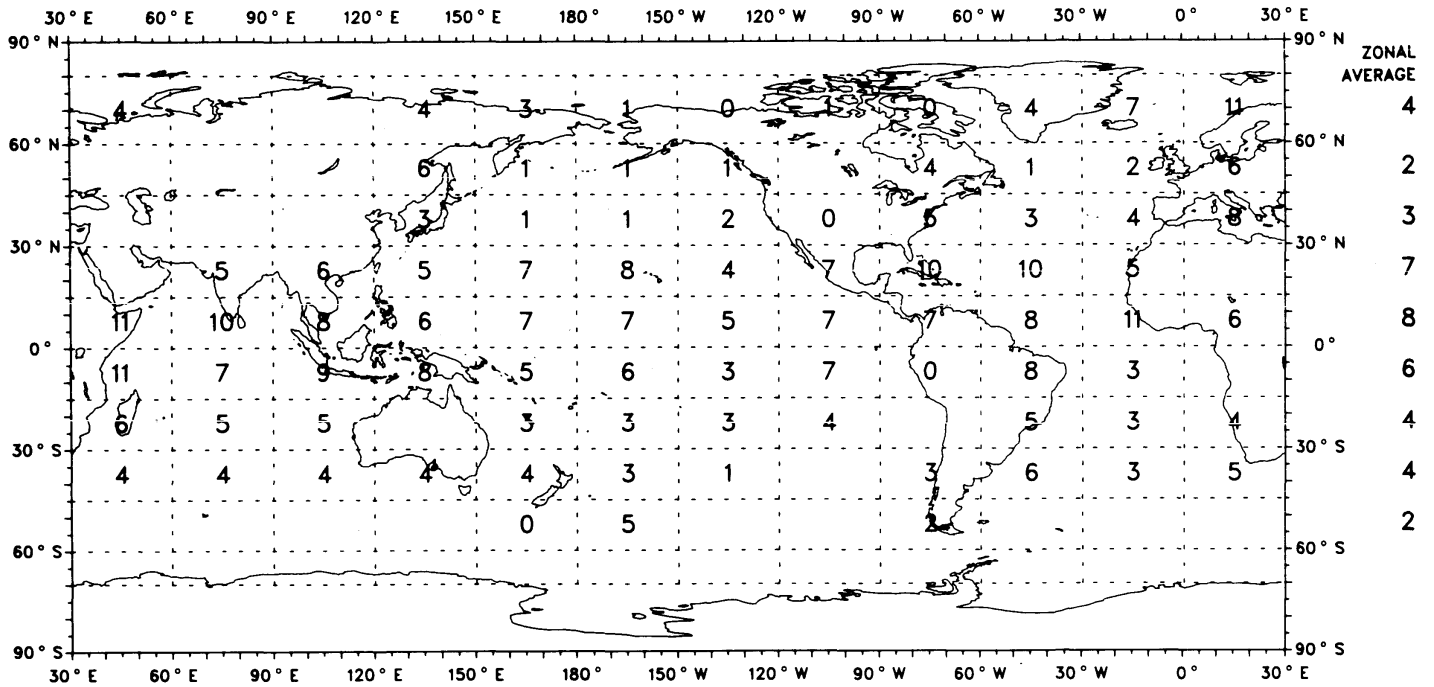
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That Cumulonimbus is Also Present

JJA (1965-1976)

Ocean Areas Only





September, October, November



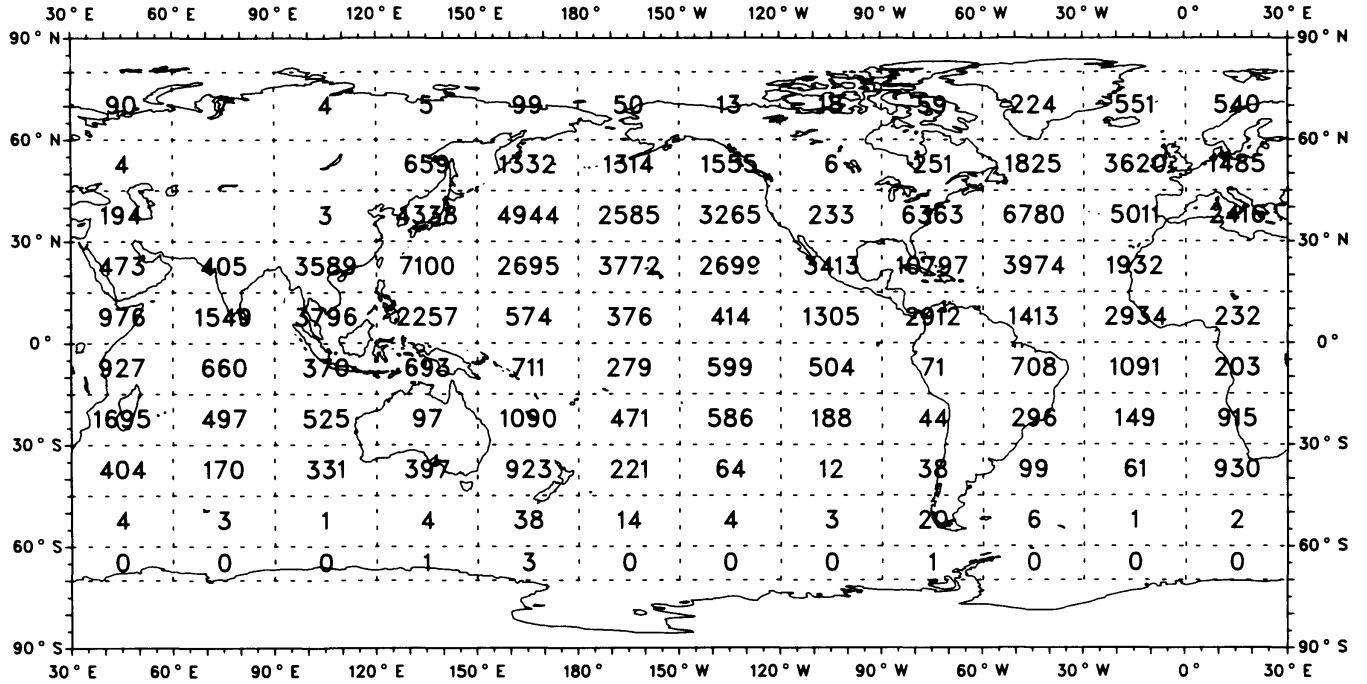


Map IV-5

Number of Observations of Cumulus (N/10)

SON (1965-1976)

Ocean Areas Only

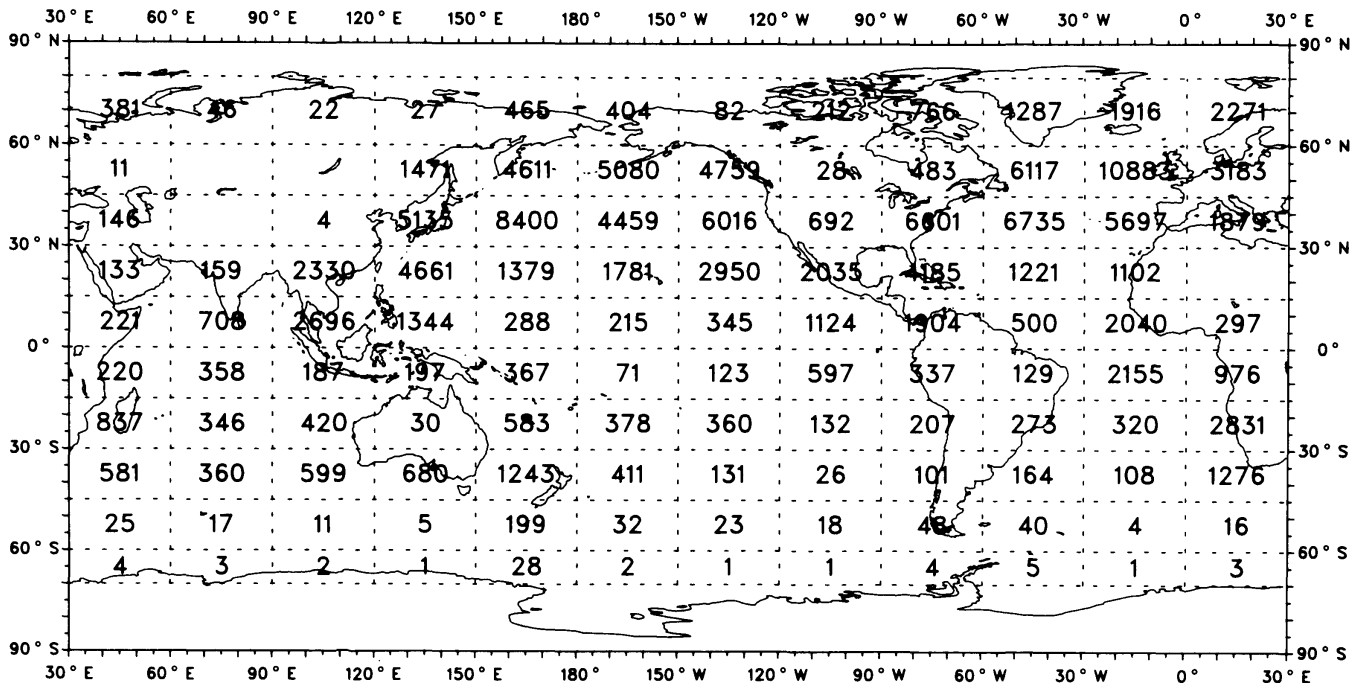


Map IV-6

Number of Observations of Stratus or Stratocumulus (N/10)

SON (1965-1976)

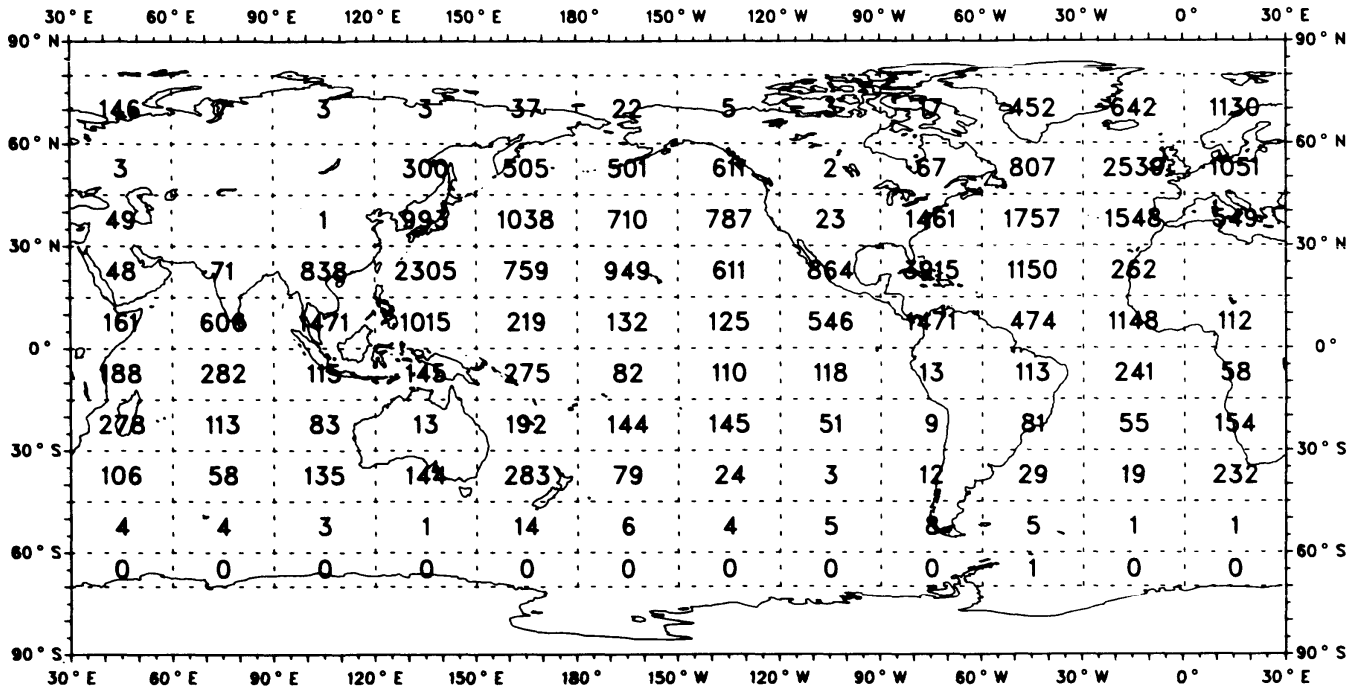
Ocean Areas Only



Number of Observations of Cumulonimbus (N/10)

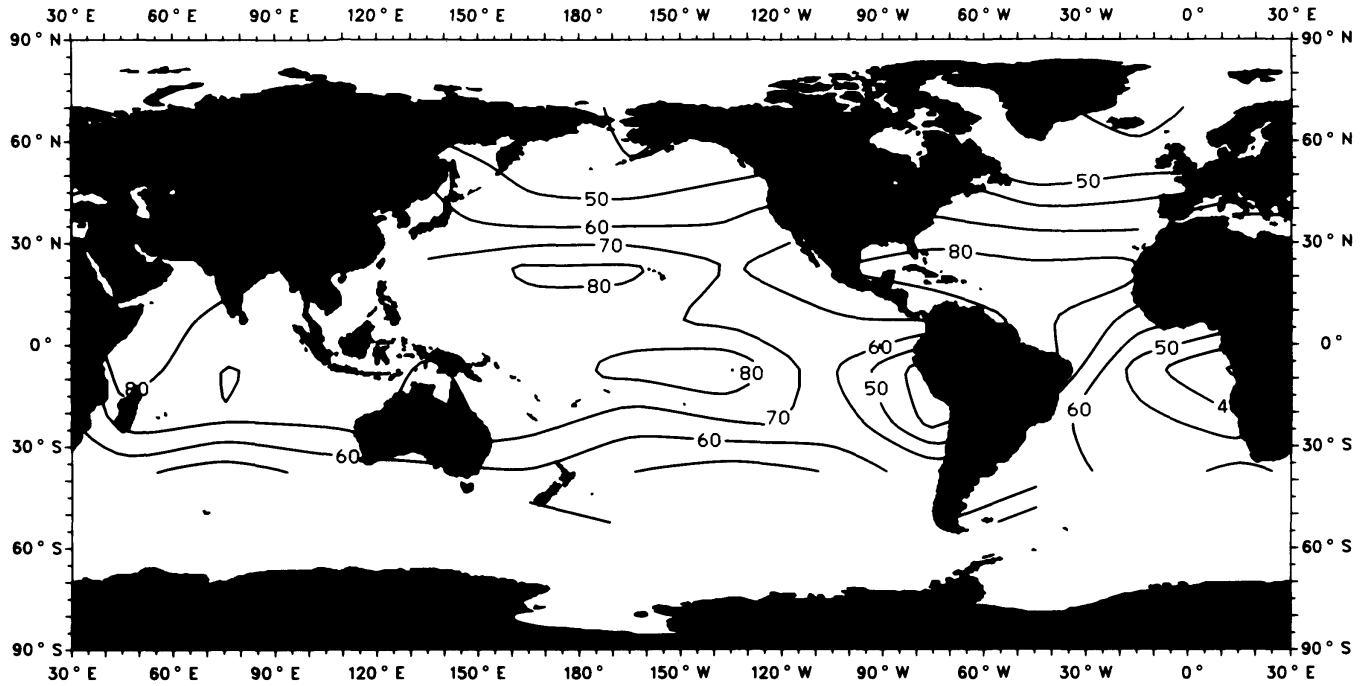
SON (1965-1976)

Ocean Areas Only



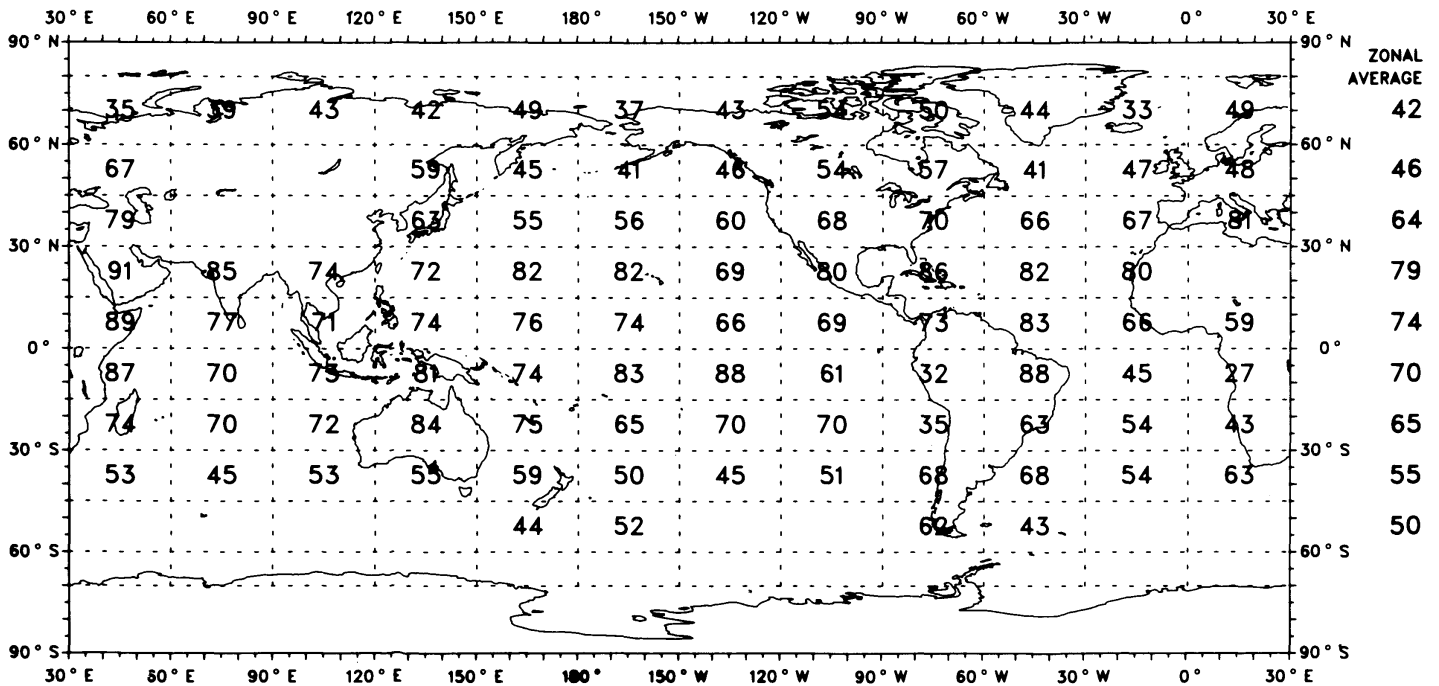
Map IV-8

Percent of Ship Reports Contributing to Statistics of the High Cloud Level  
SON (1965-1976) Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the High Cloud Level

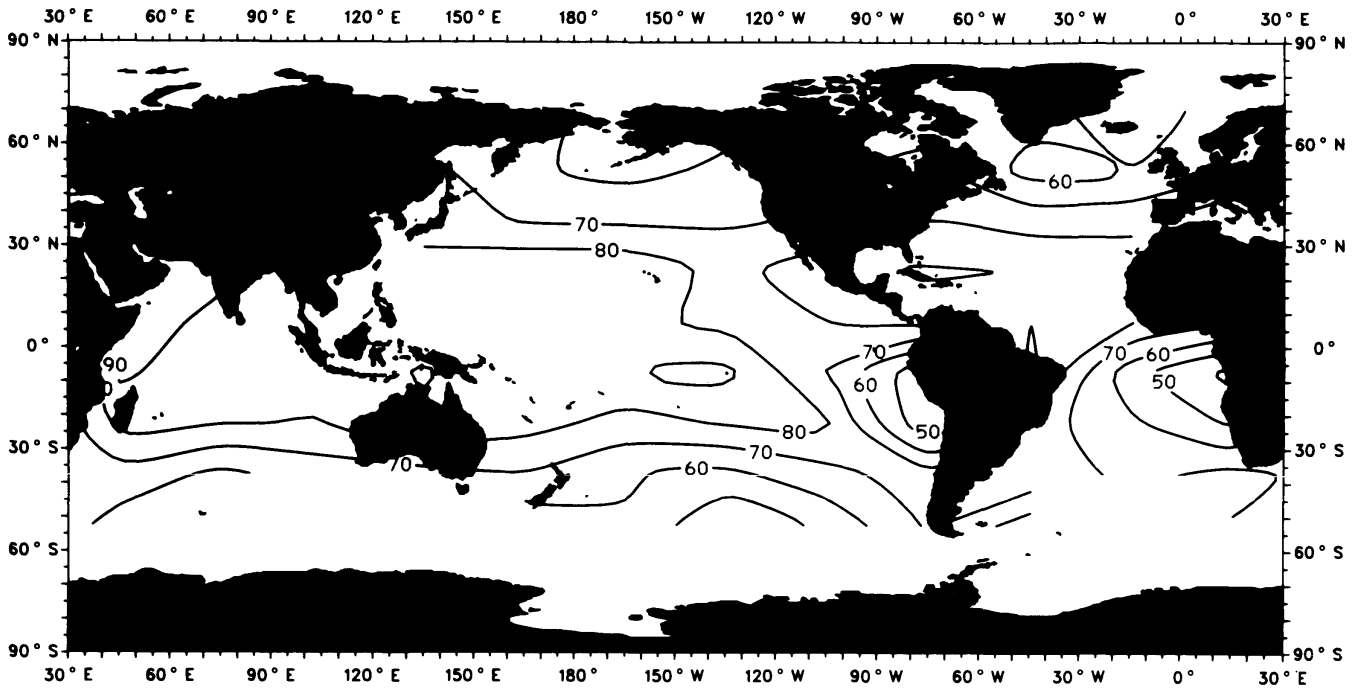
SON (1965-1976) Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

SON (1965-1976)

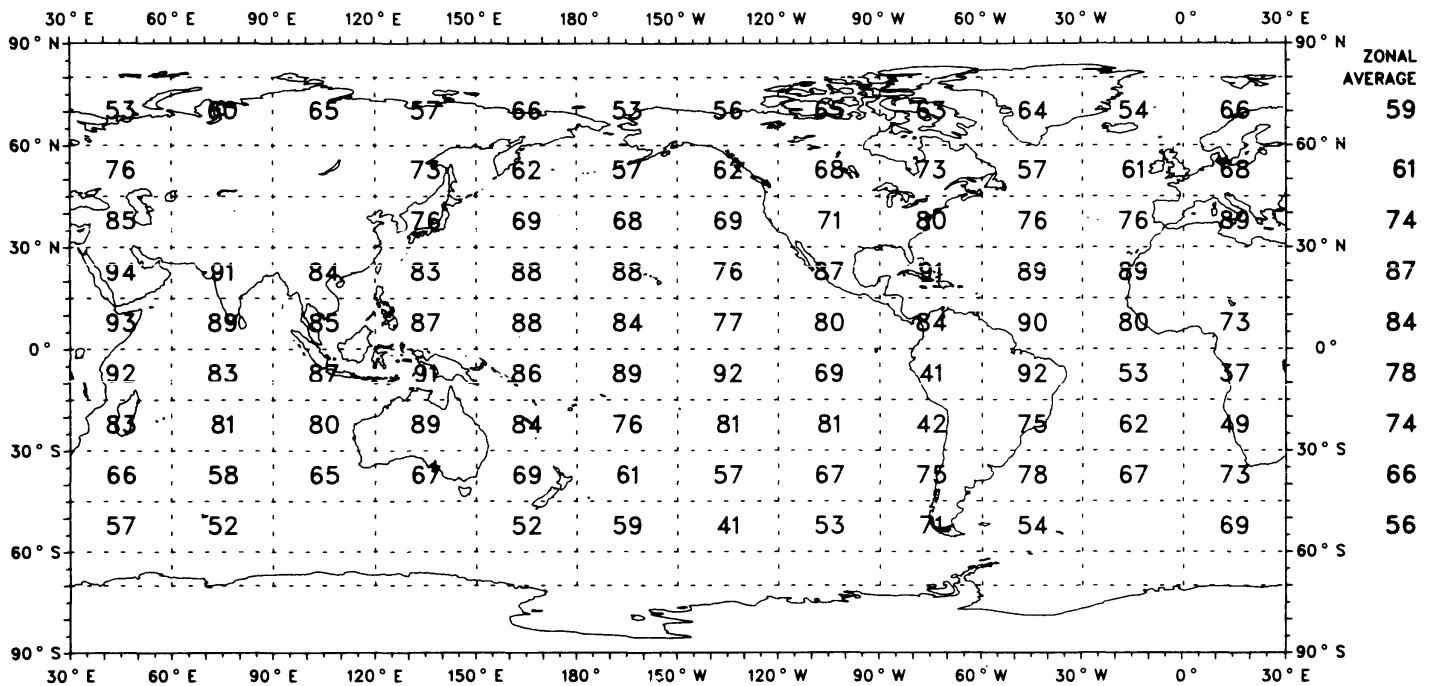
Ocean Areas Only



Percent of Ship Reports Contributing to Statistics of the Middle Cloud Level

SON (1965-1976)

Ocean Areas Only

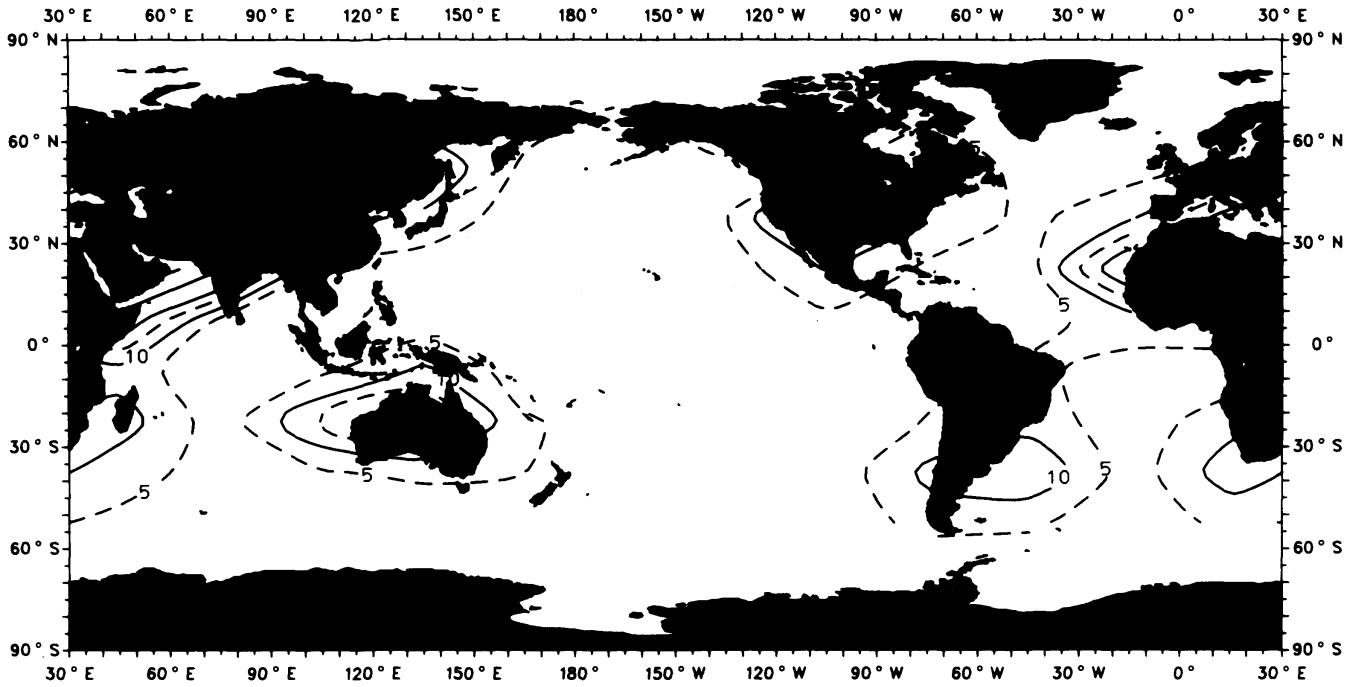


Map IV-10

Frequency of Occurrence (Percent) of Completely Clear Sky

SON (1965-1976)

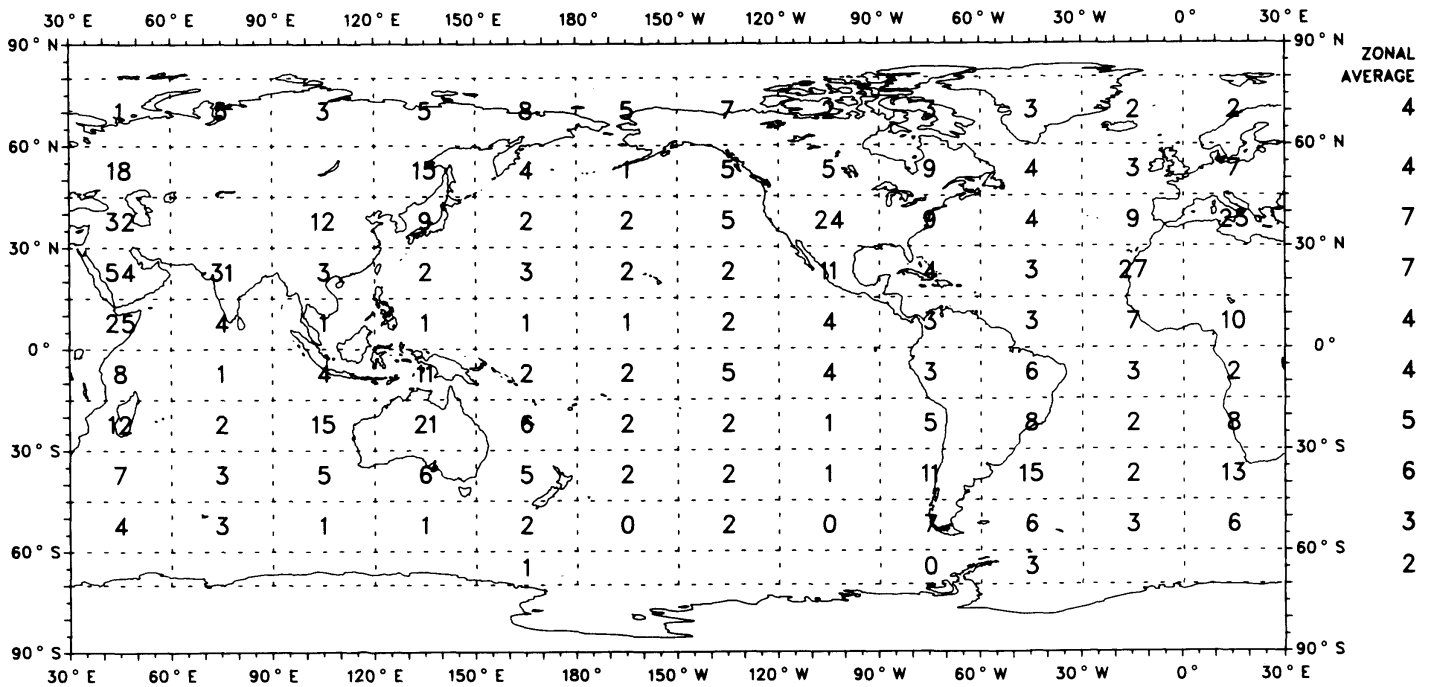
Ocean Areas Only



Frequency of Occurrence (Percent) of Completely Clear Sky

SON (1965-1976)

Ocean Areas Only



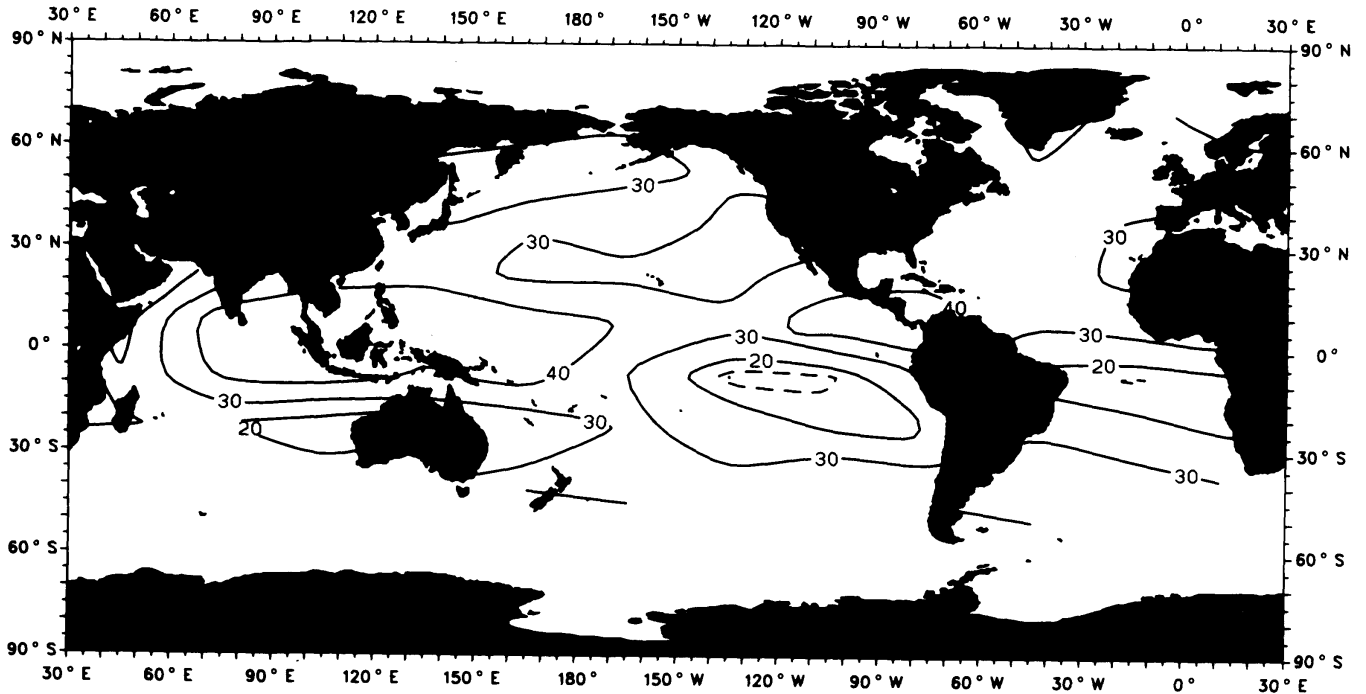


Map IV-12

Frequency of Occurrence (Percent) of Ci/Cs/Cc

SON (1965-1976)

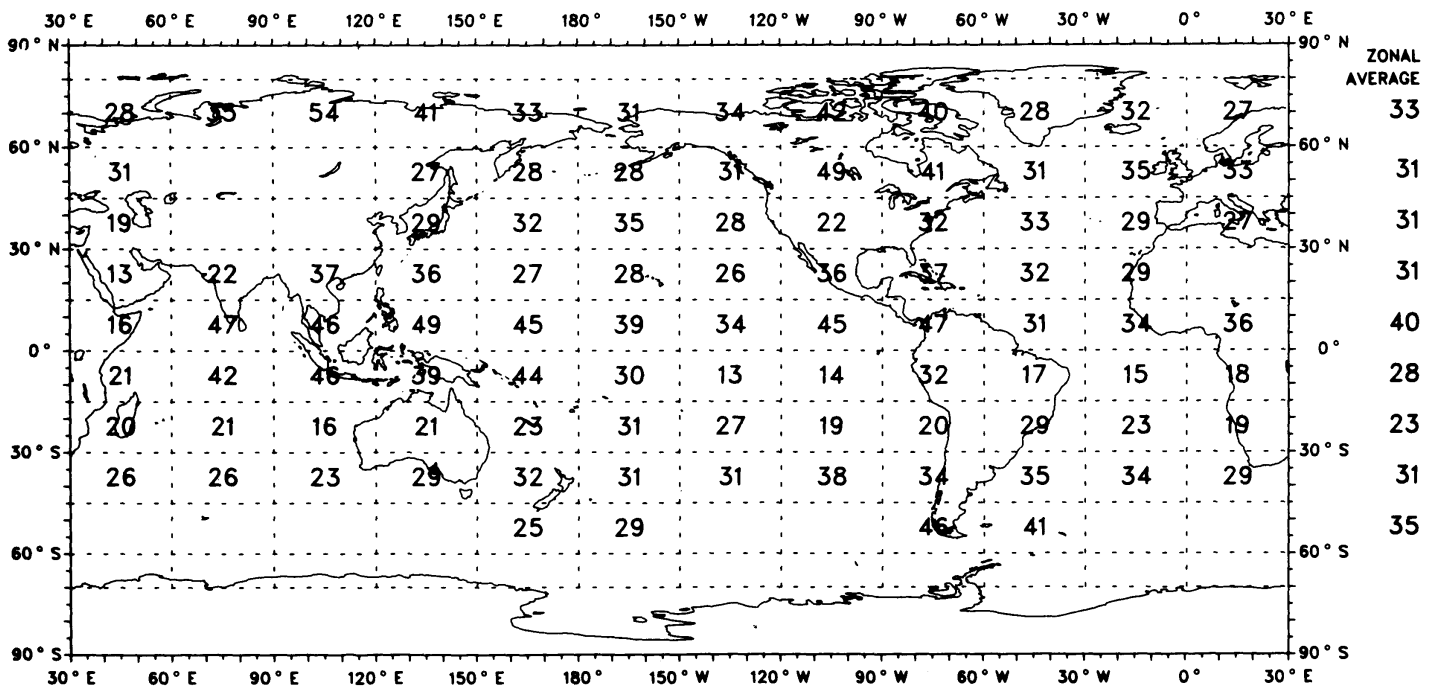
Ocean Areas Only



Frequency of Occurrence (Percent) of Ci/Cs/Cc

SON (1965-1976)

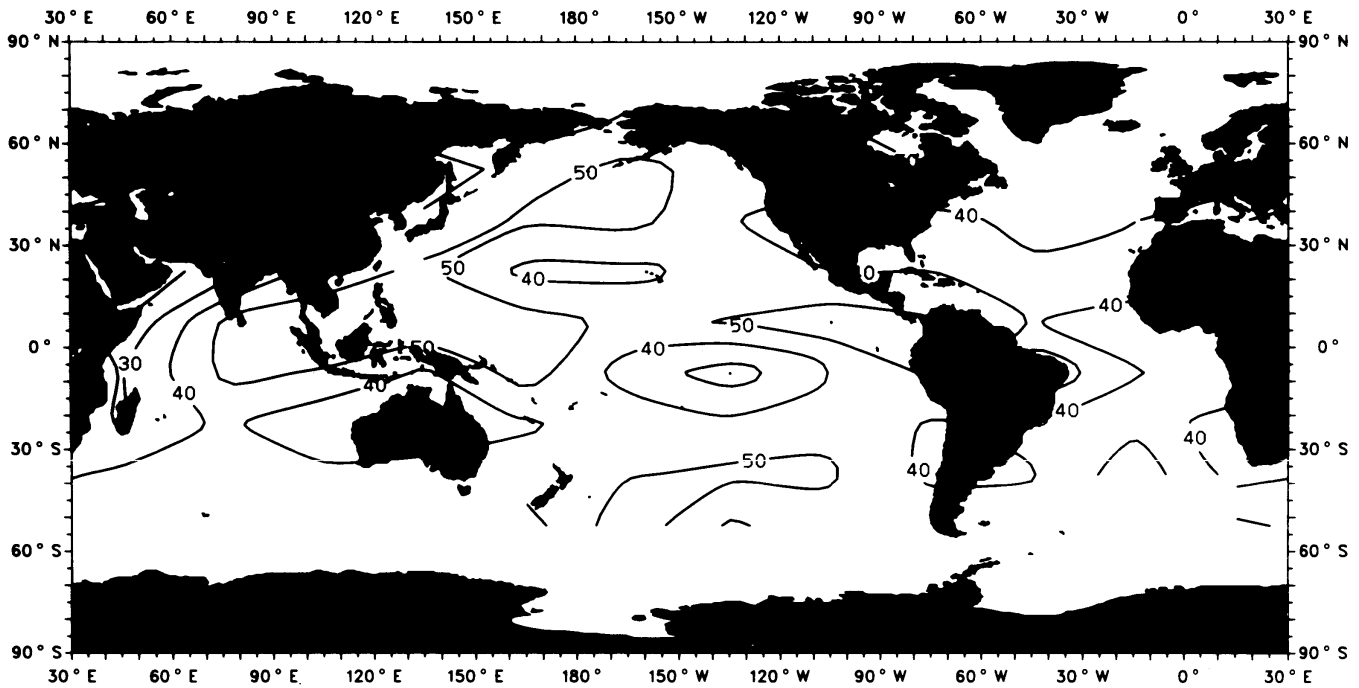
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

SON (1965-1976)

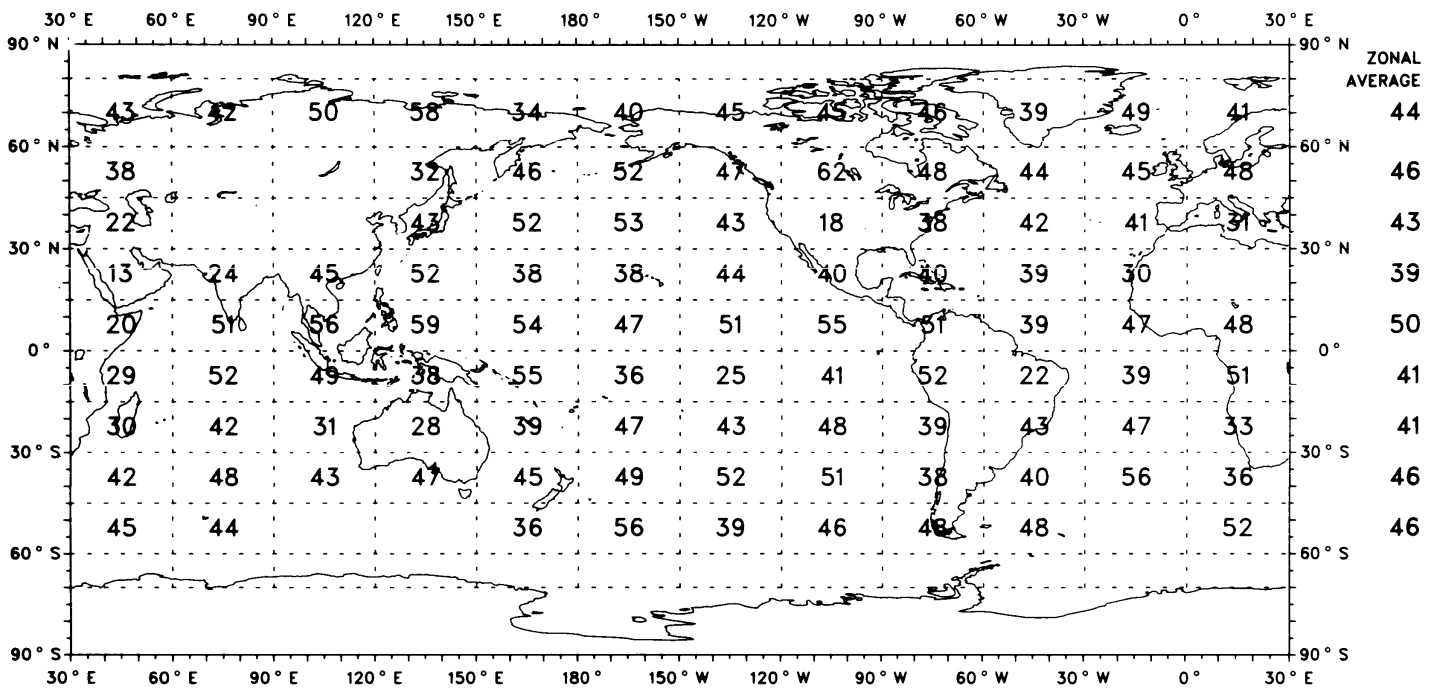
Ocean Areas Only



Frequency of Occurrence (Percent) of As/Ac

SON (1965-1976)

Ocean Areas Only

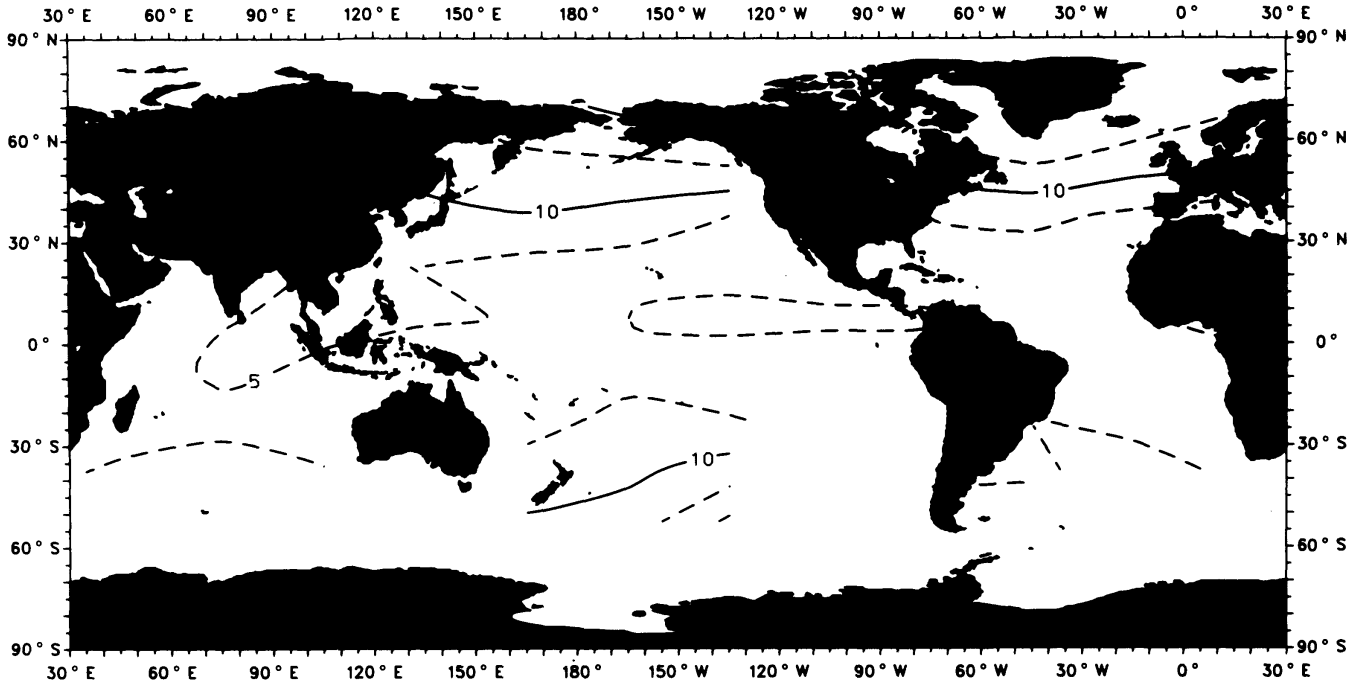


Map IV-14

Frequency of Occurrence (Percent) of Nimbostratus

SON (1965-1976)

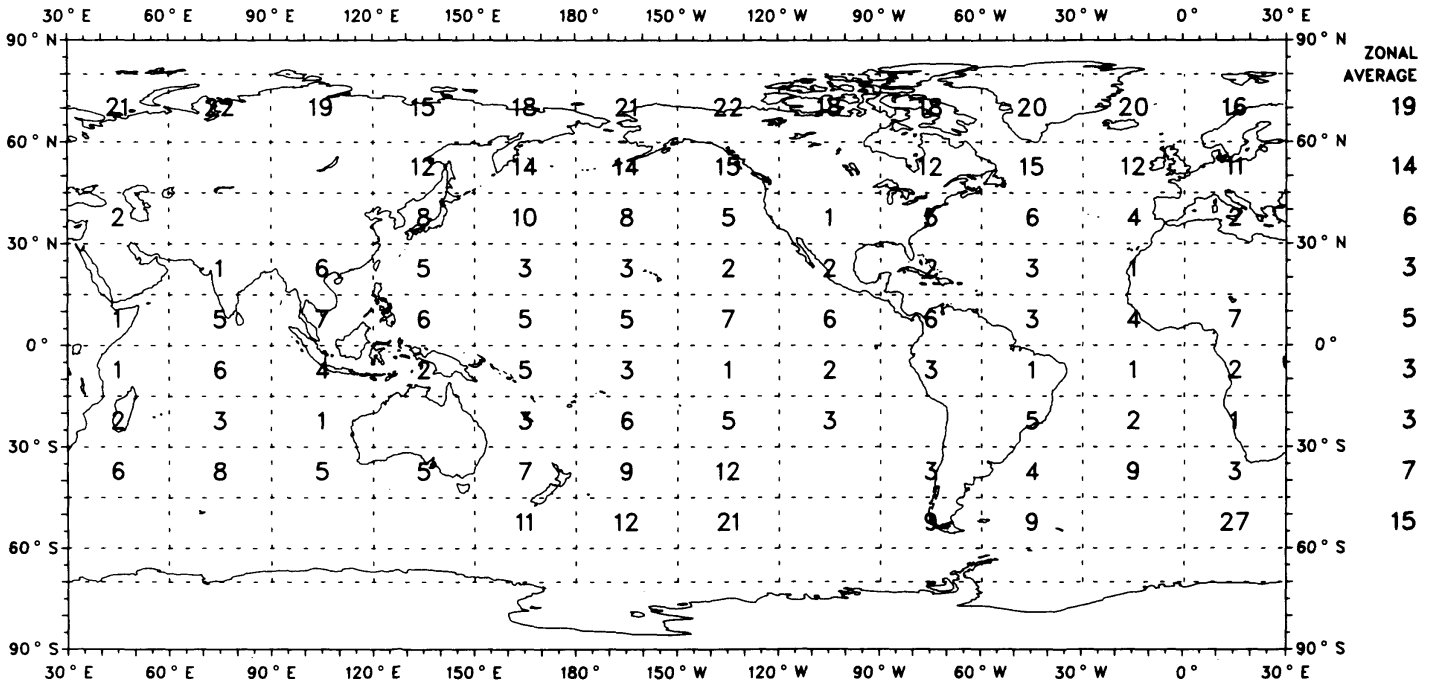
Ocean Areas Only



Frequency of Occurrence (Percent) of Nimbostratus

SON (1965-1976)

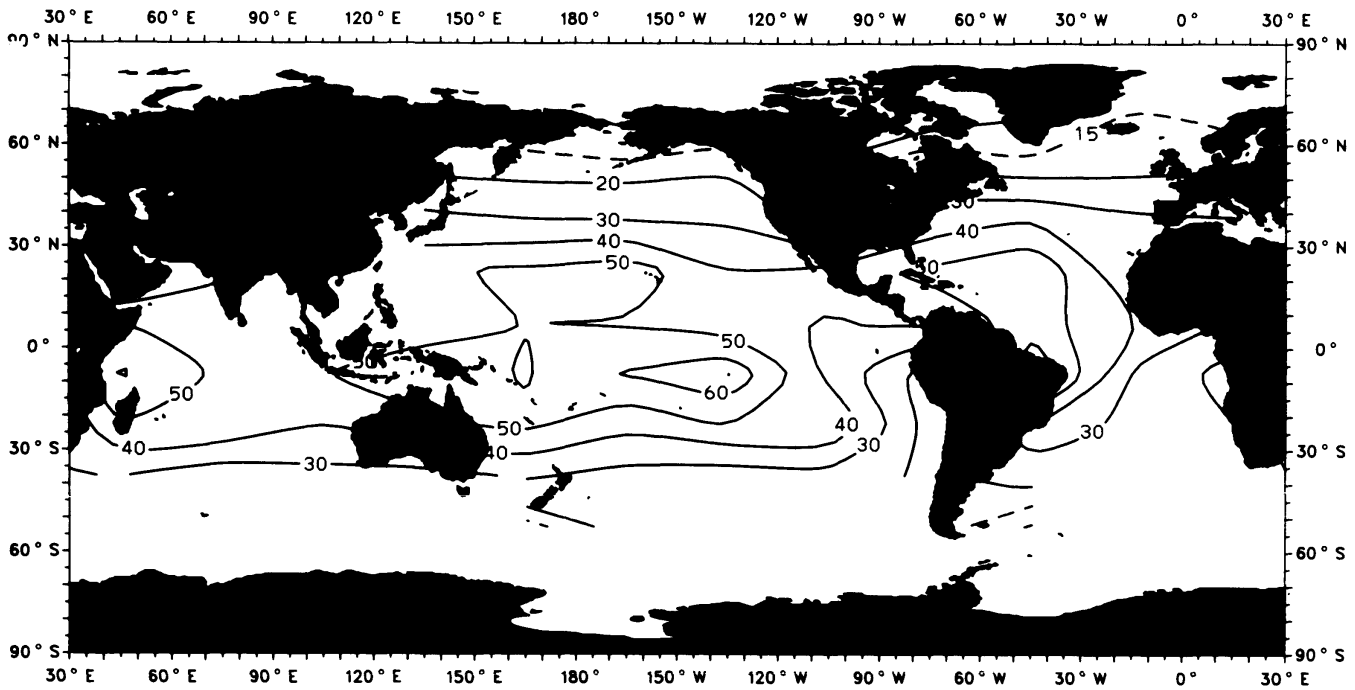
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

SON (1965-1976)

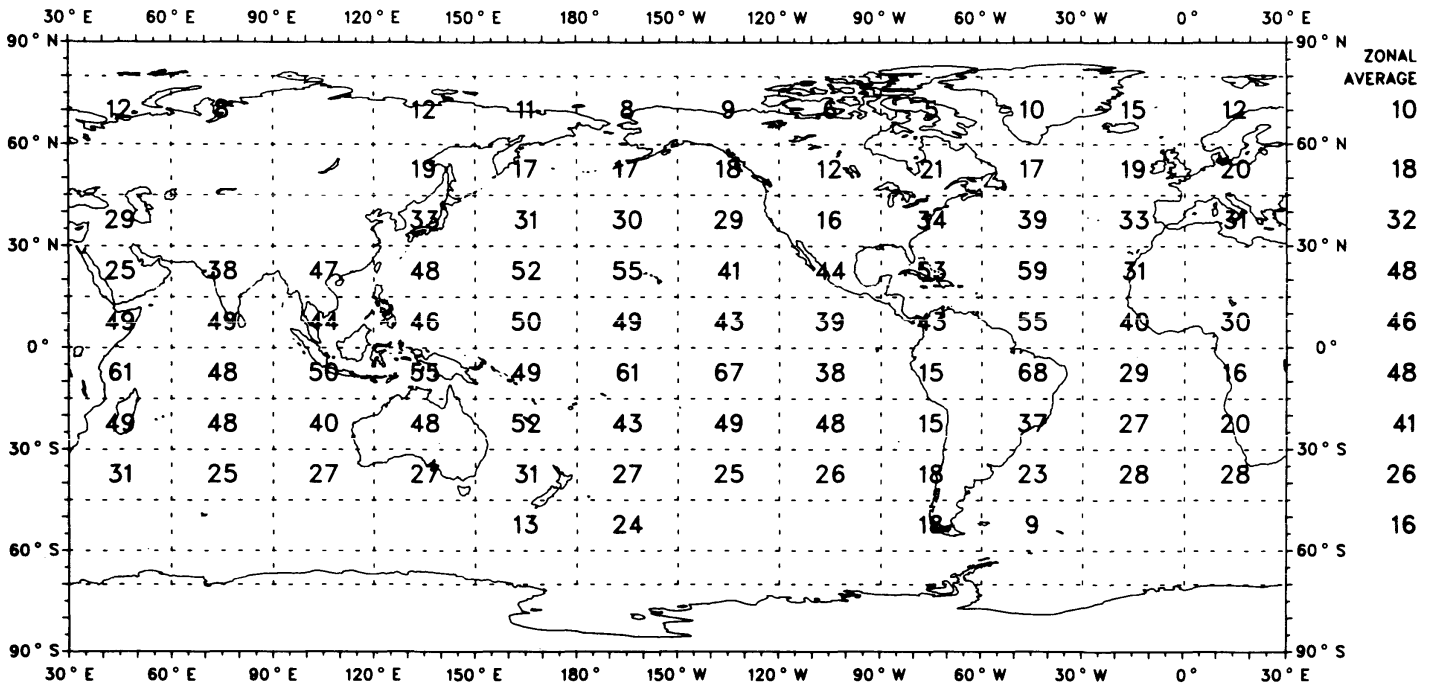
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulus

SON (1965-1976)

Ocean Areas Only

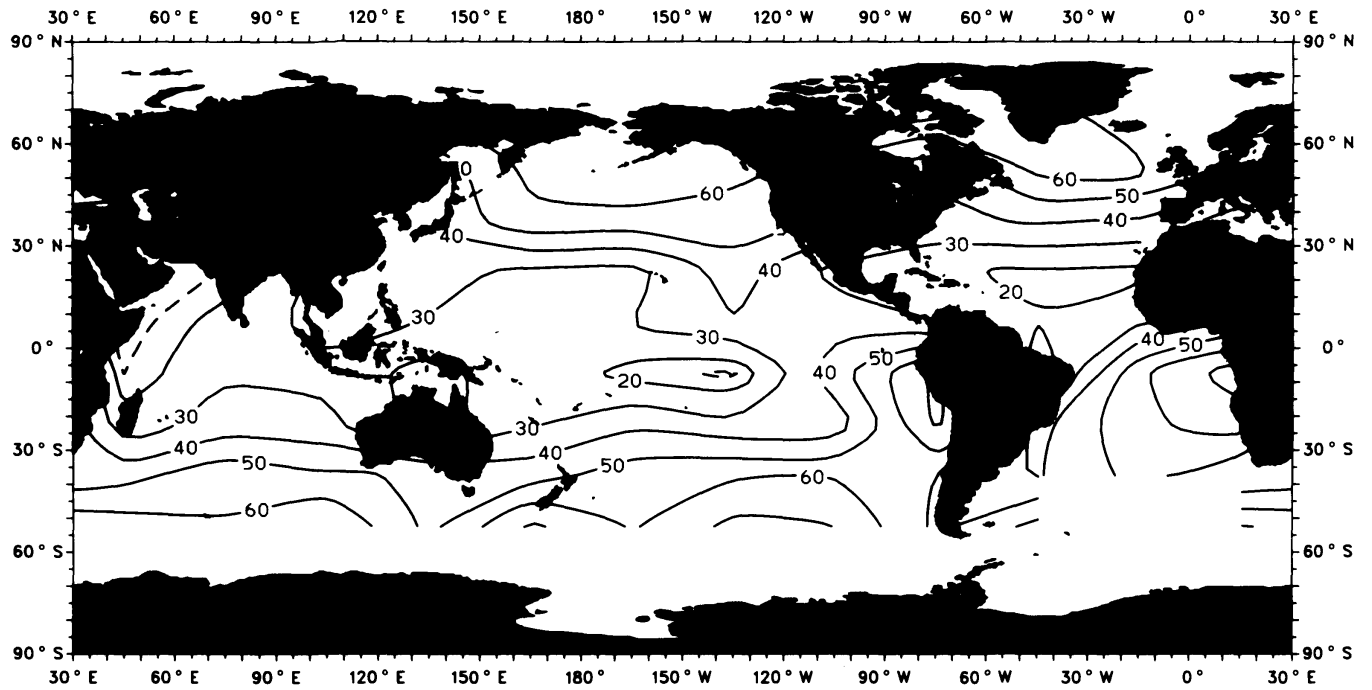


Map IV-16

Frequency of Occurrence (Percent) of St/Sc

SON (1965-1976)

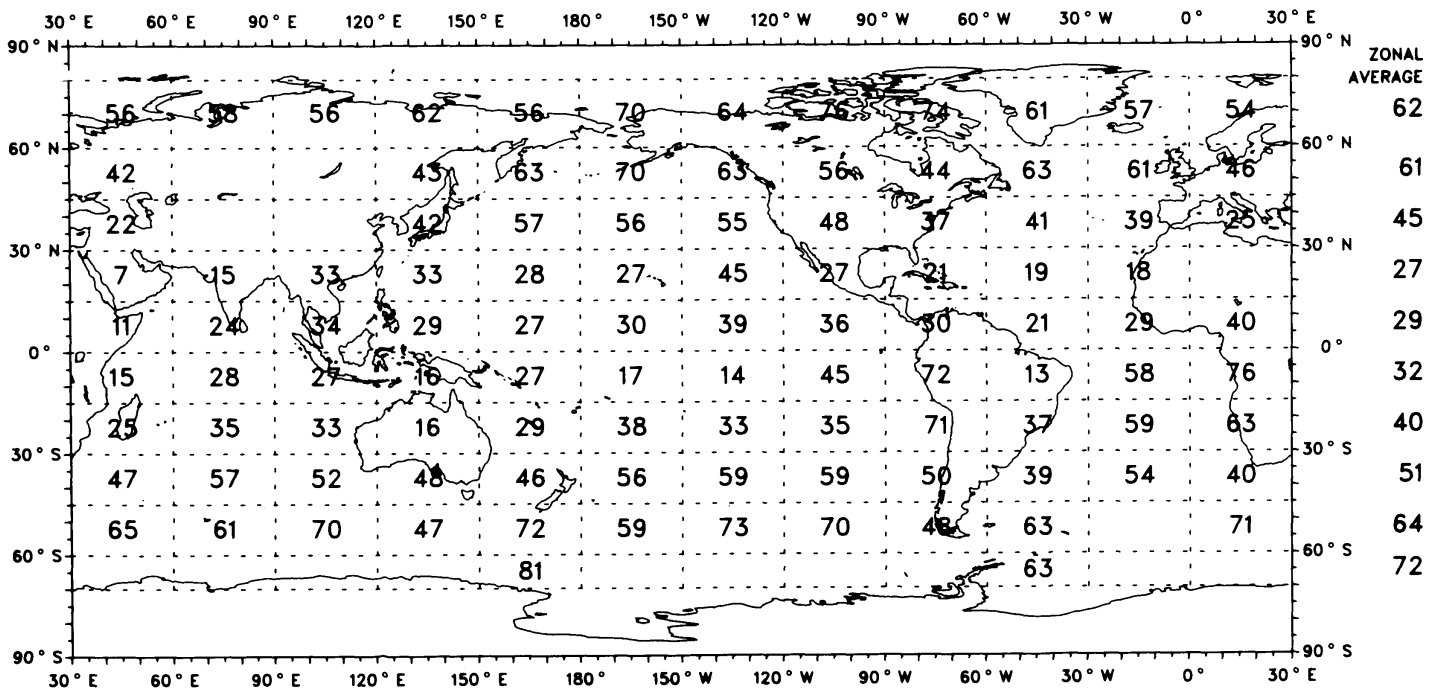
Ocean Areas Only



Frequency of Occurrence (Percent) of St/Sc

SON (1965-1976)

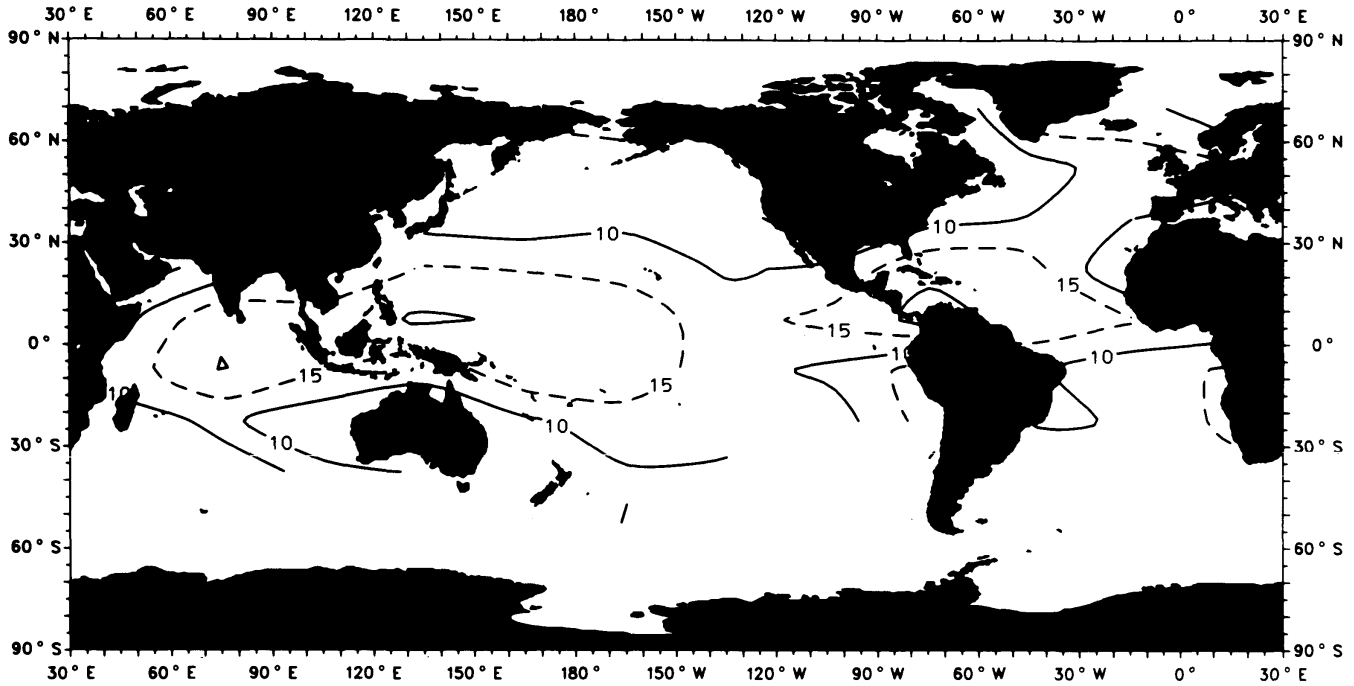
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulonimbus

SON (1965-1976)

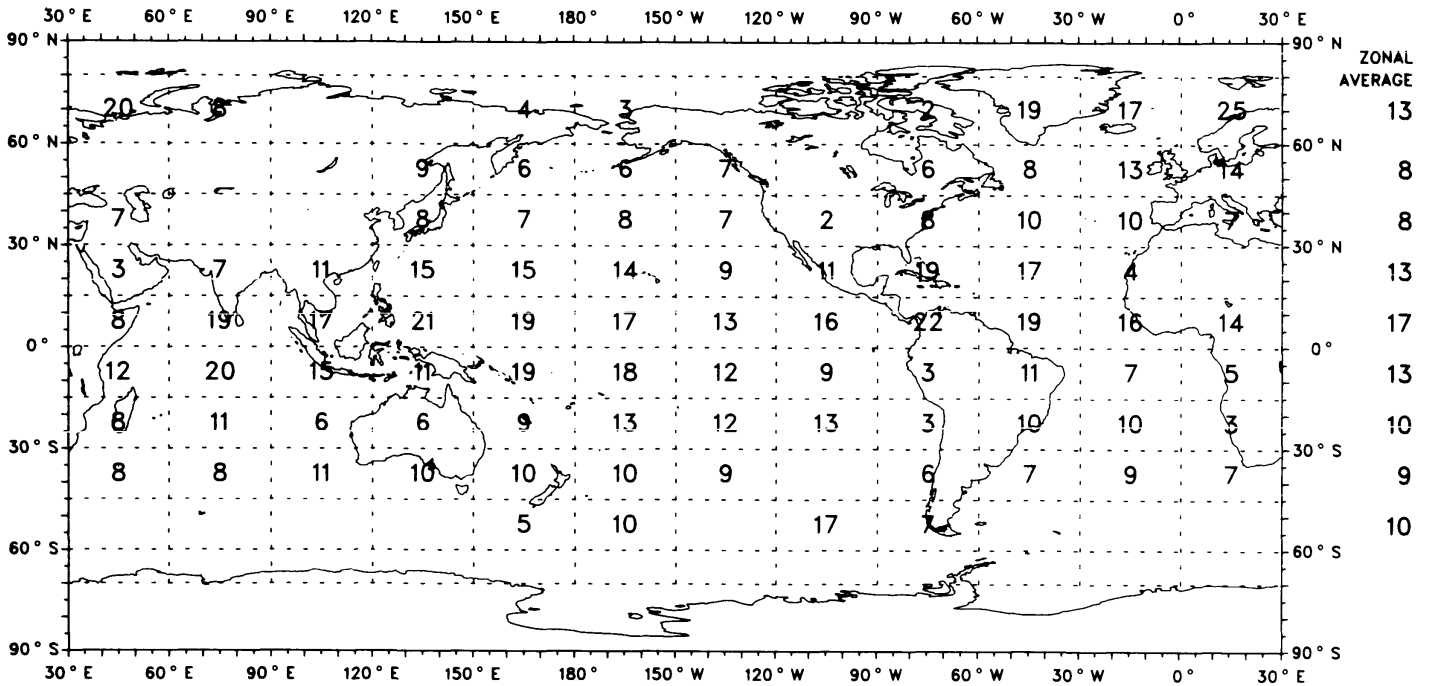
Ocean Areas Only



Frequency of Occurrence (Percent) of Cumulonimbus

SON (1965-1976)

Ocean Areas Only

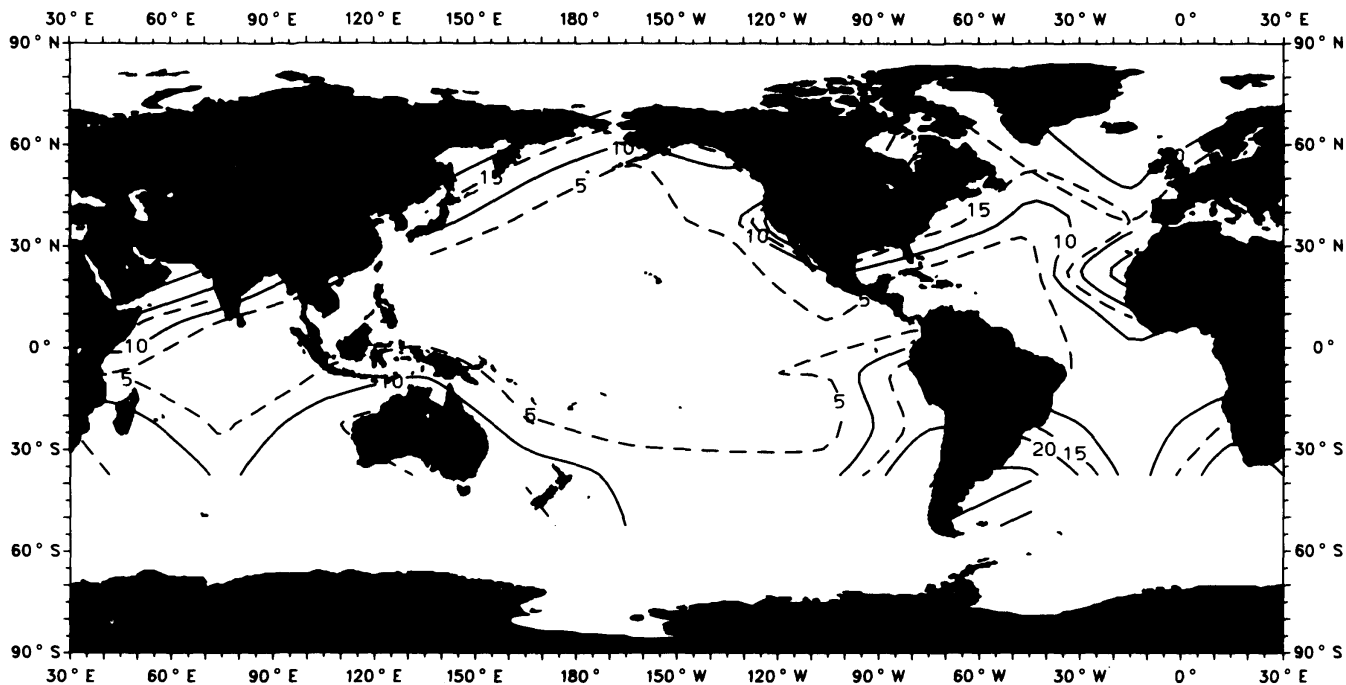


Map IV-18

Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

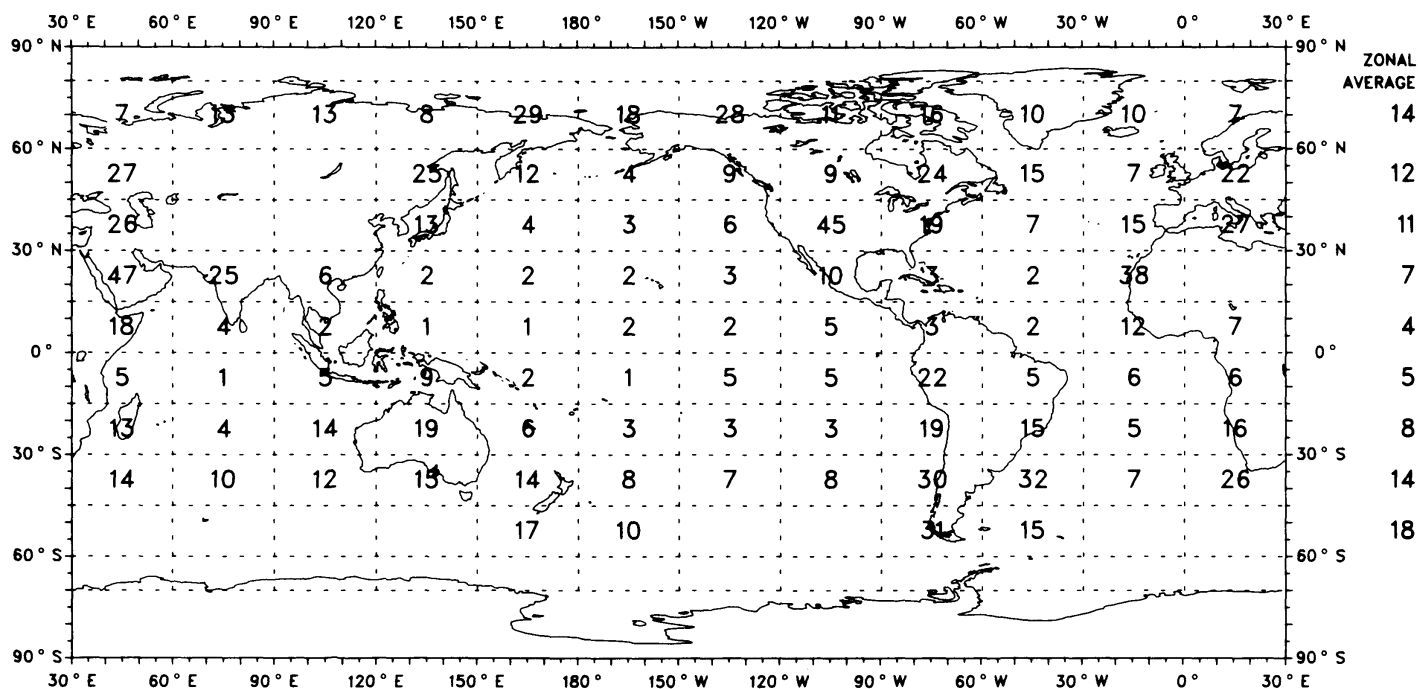
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

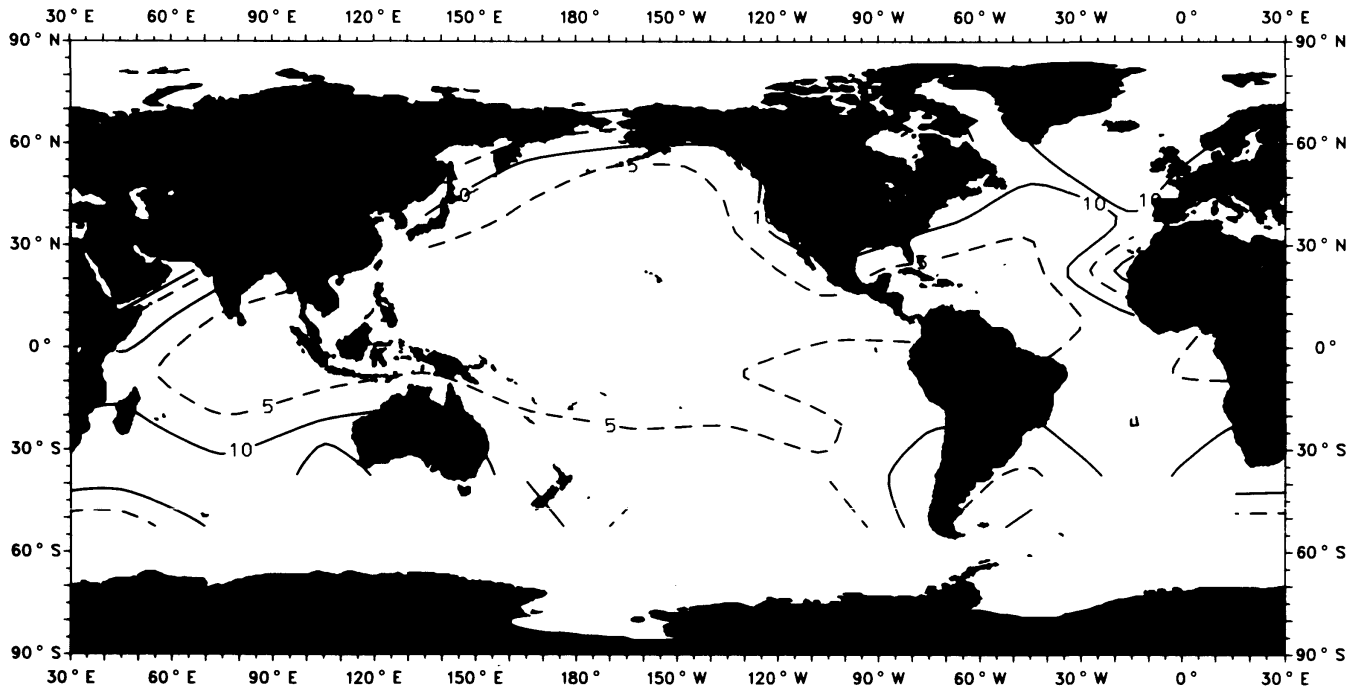
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

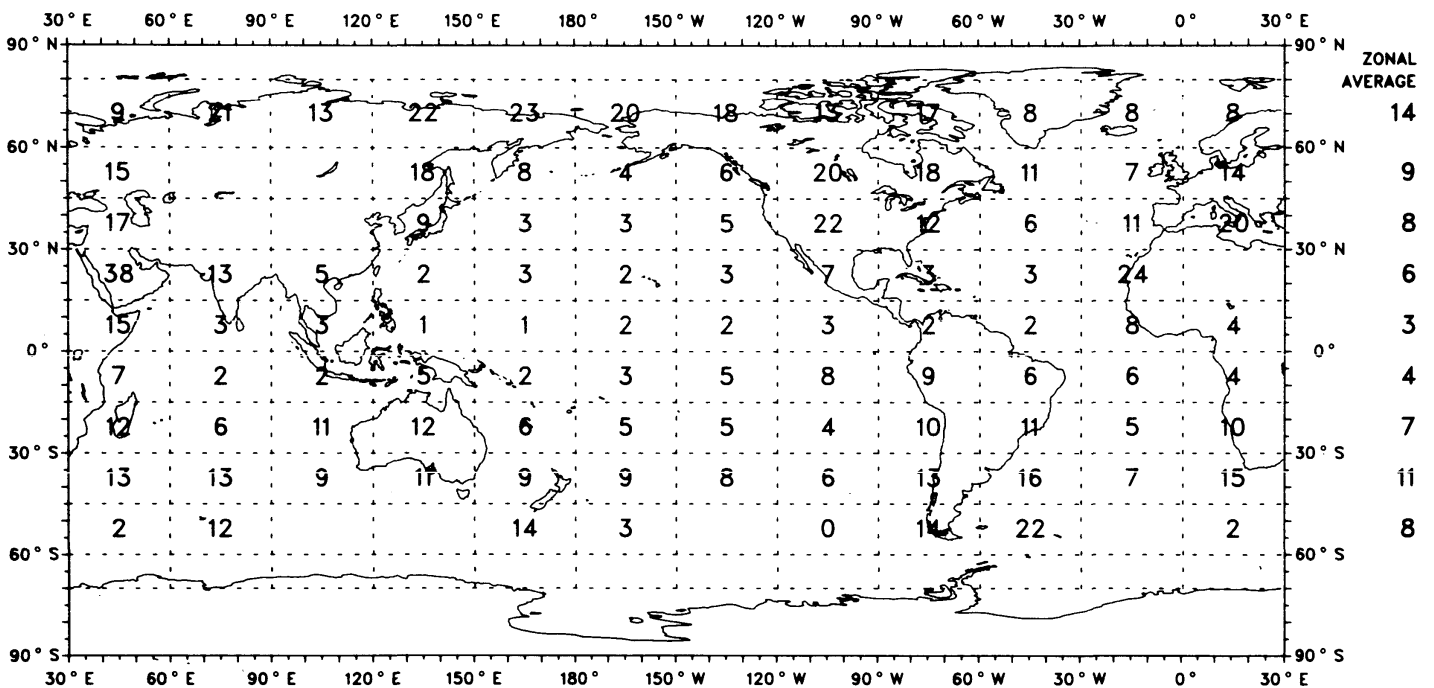
Ocean Areas Only



Given As/Ac, Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

Ocean Areas Only

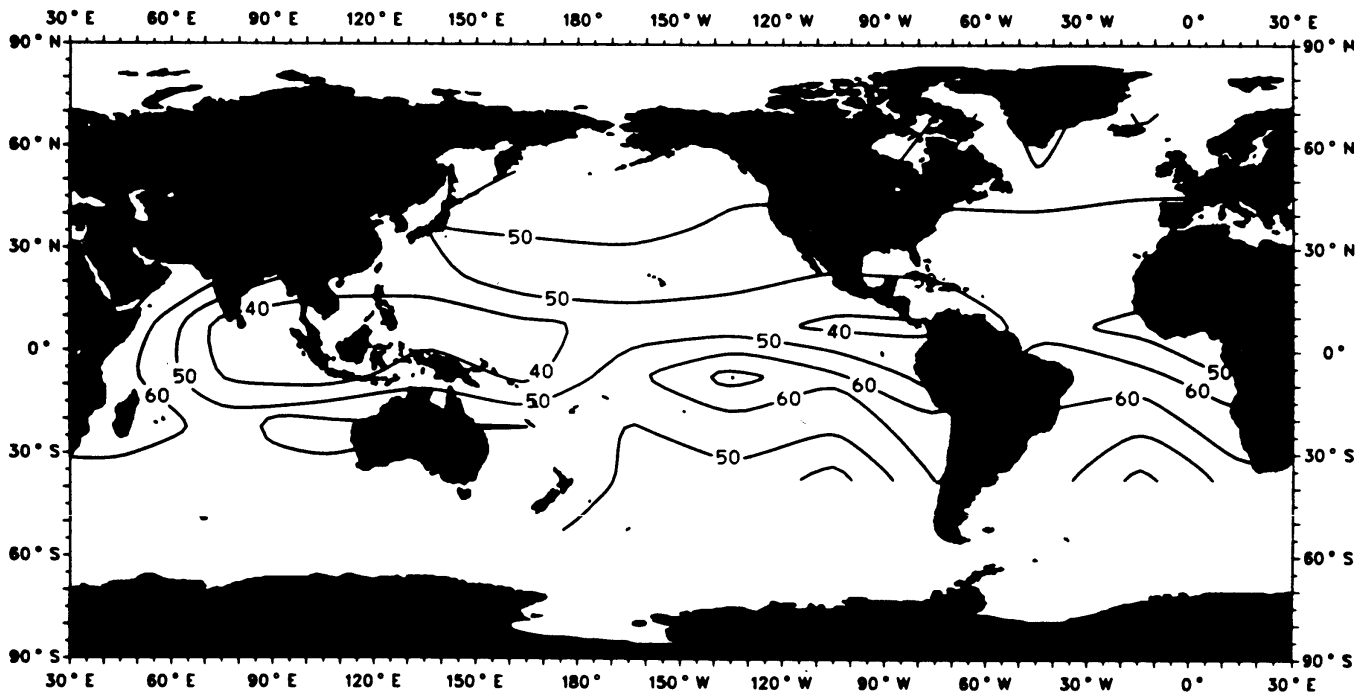




Given Cumulus, Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

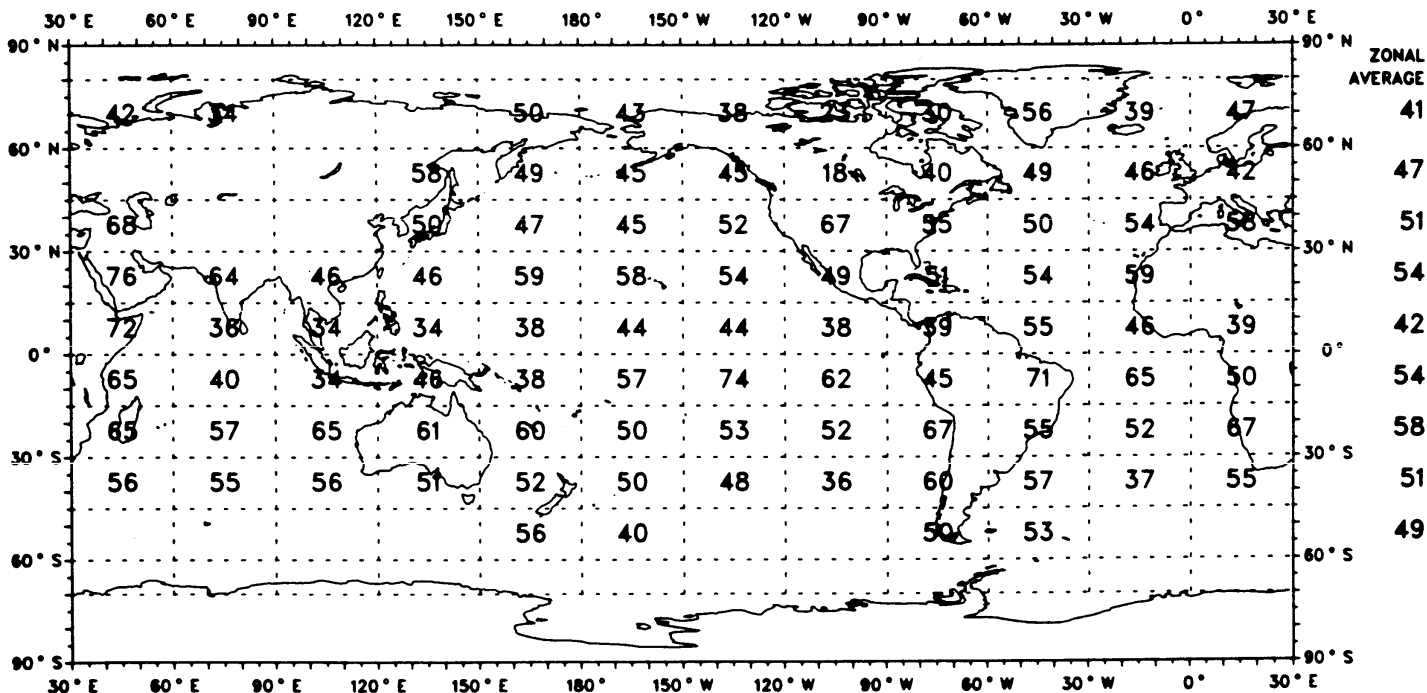
Ocean Areas Only



Given Cumulus, Probability (Percent) That No Other Cloud Is Present

SON (1965-1976)

Ocean Areas Only





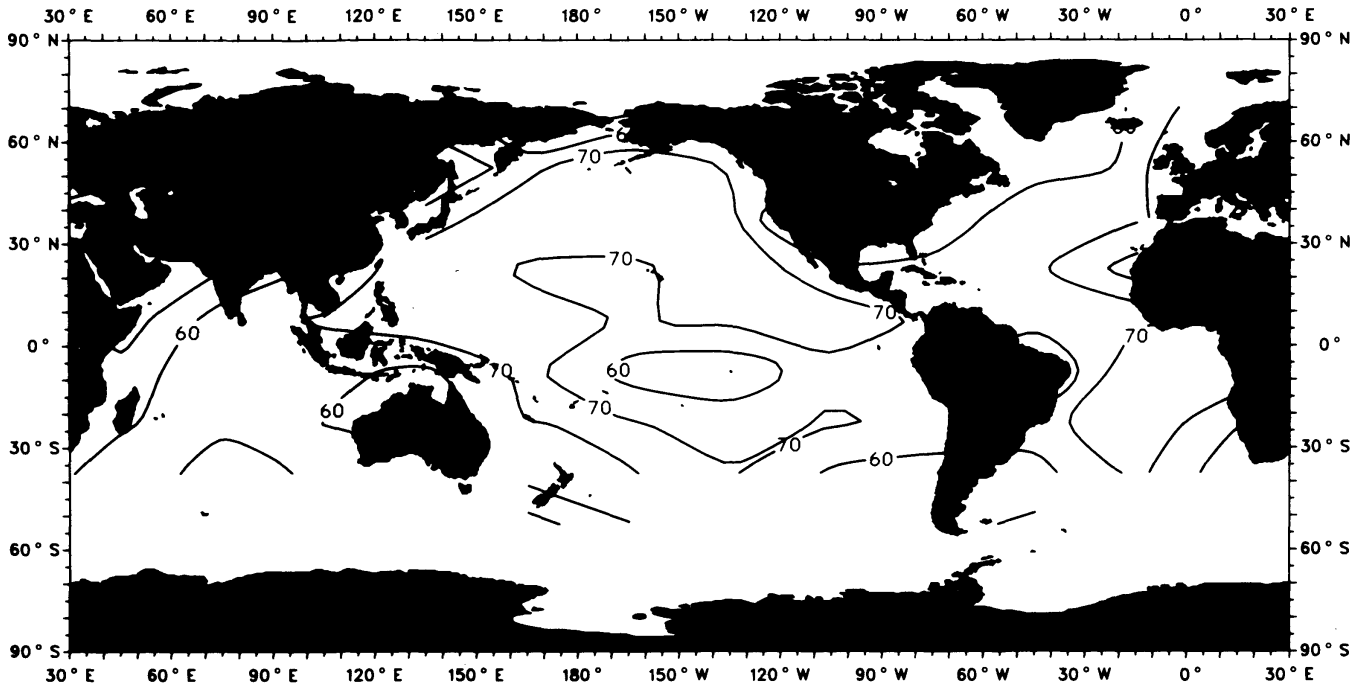


Map IV-24

Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

SON (1965-1976)

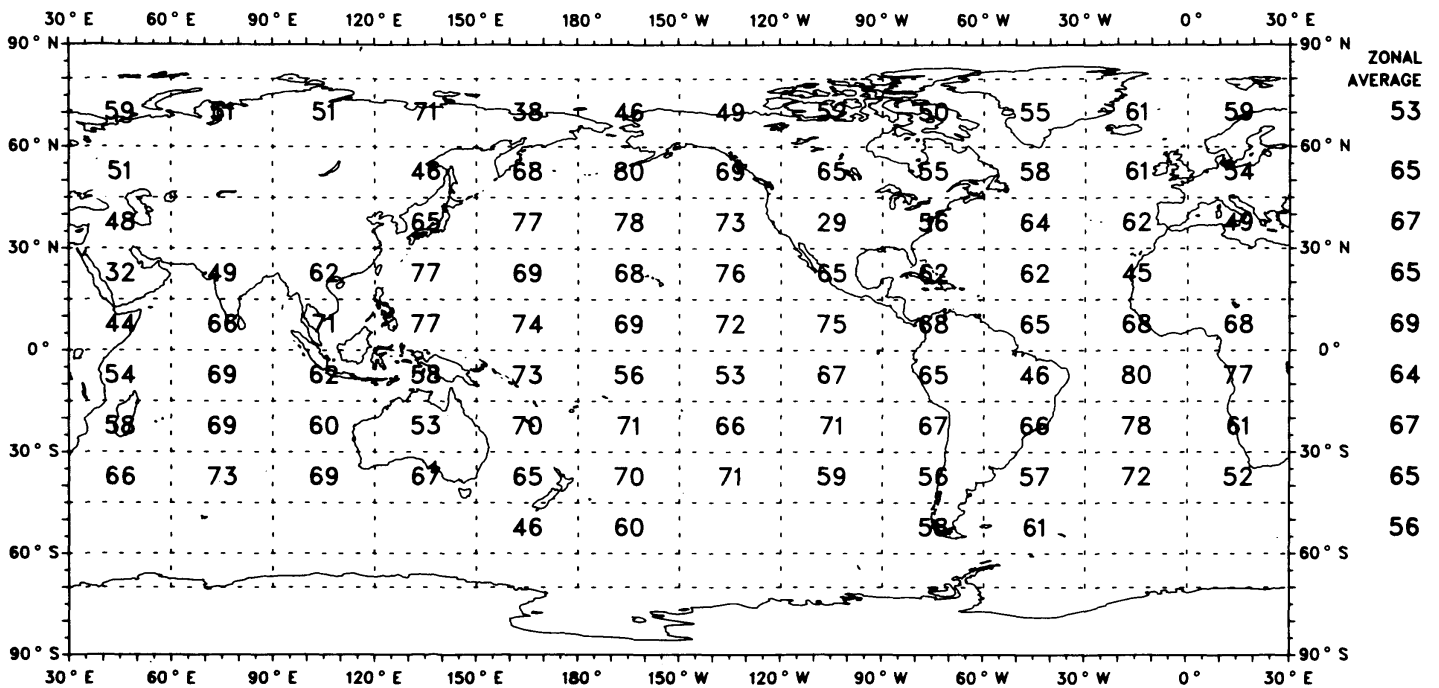
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That  $A_s/A_c$  is Also Present

SON (1965-1976)

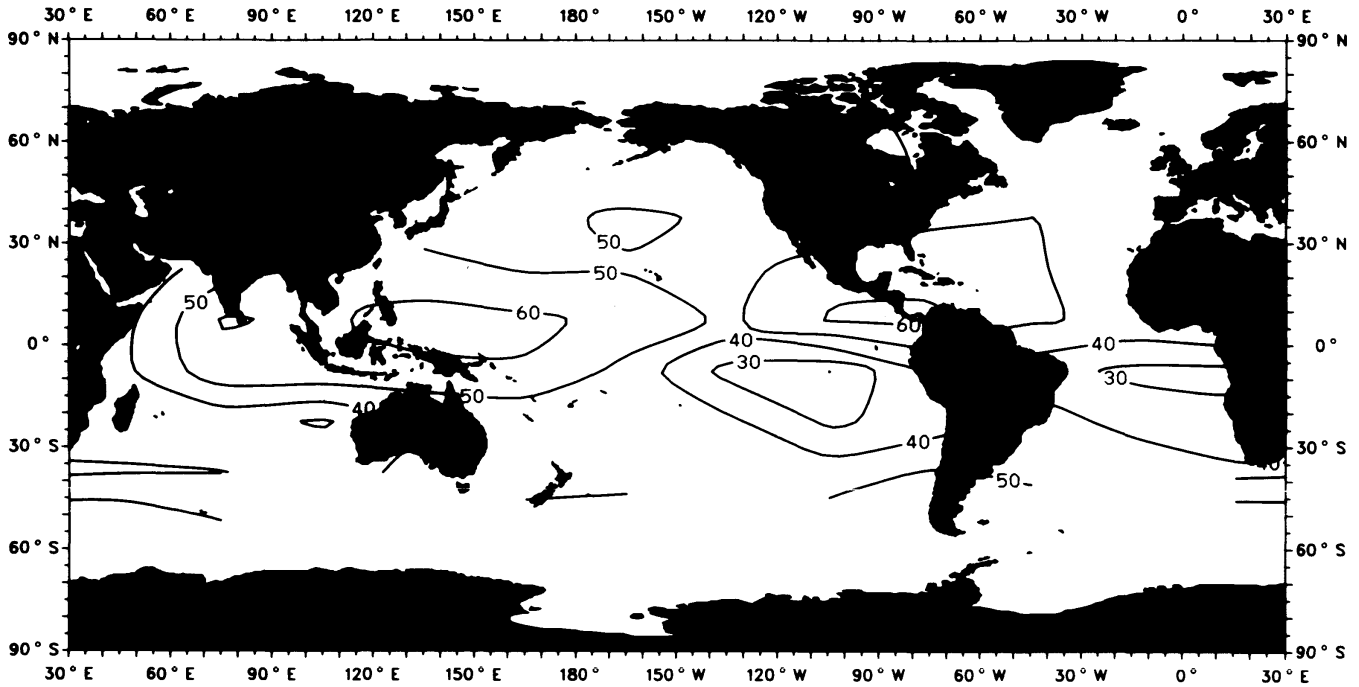
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

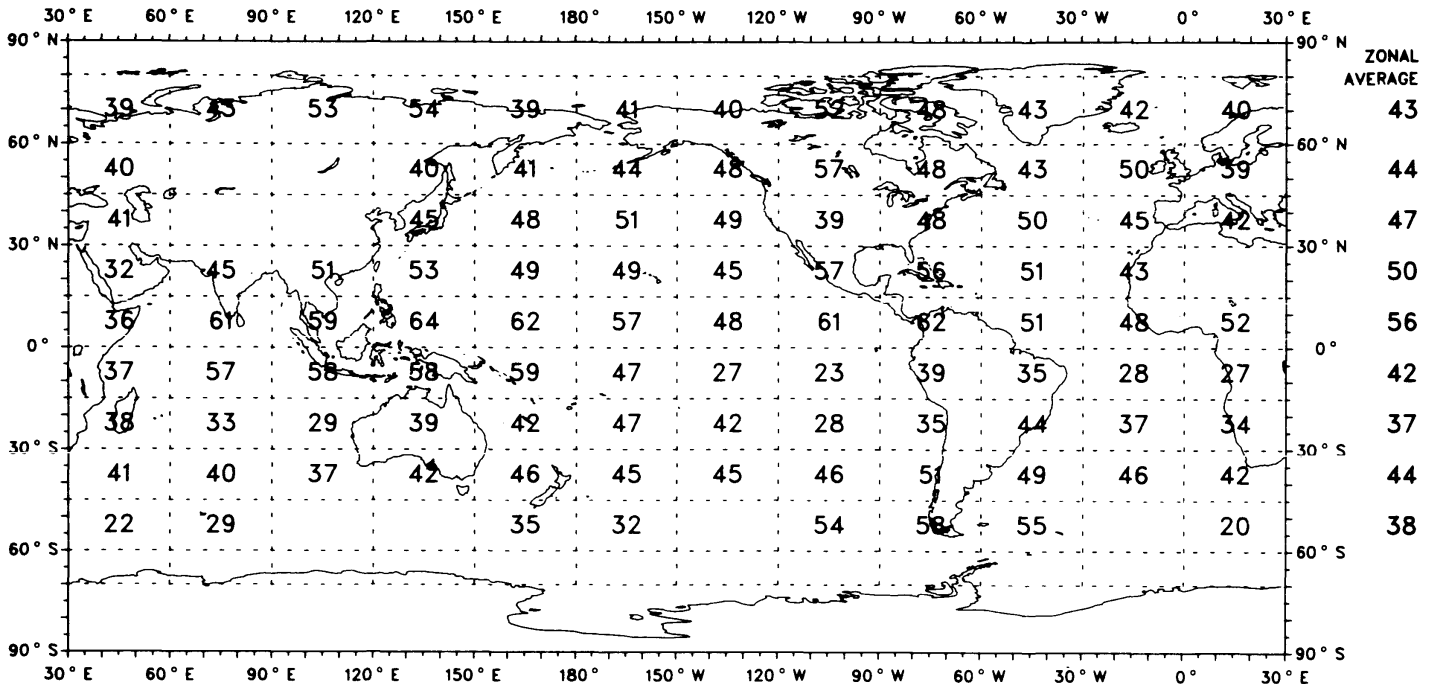
Ocean Areas Only



Given As/Ac, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

Ocean Areas Only





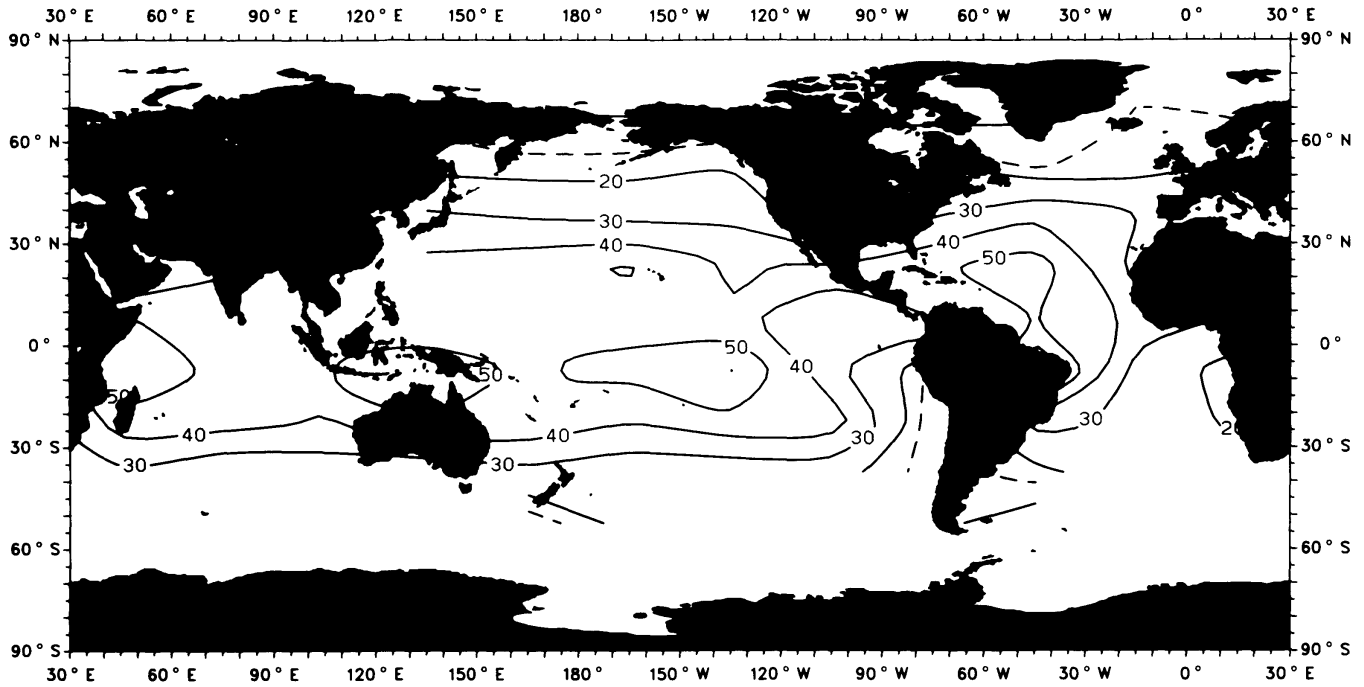


Map IV-28

Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulus is Also Present

SON (1965-1976)

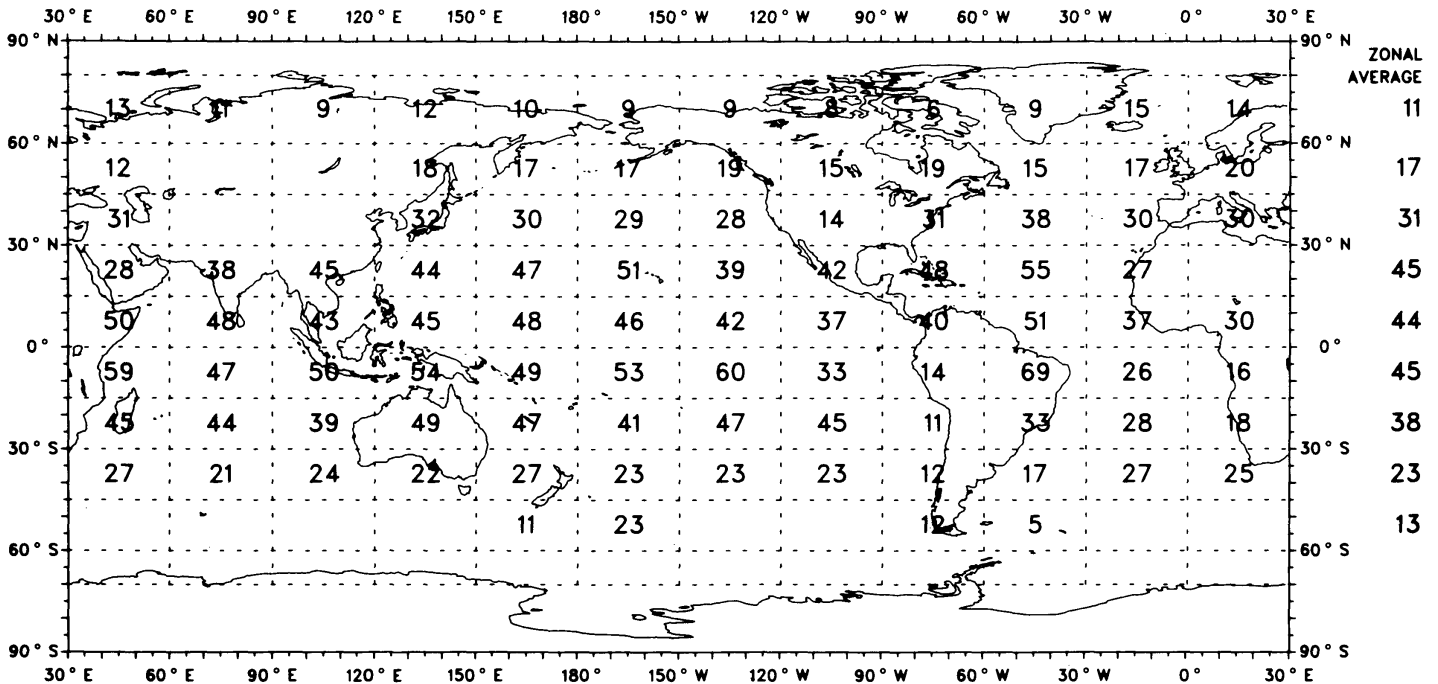
Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulus is Also Present

SON (1965-1976)

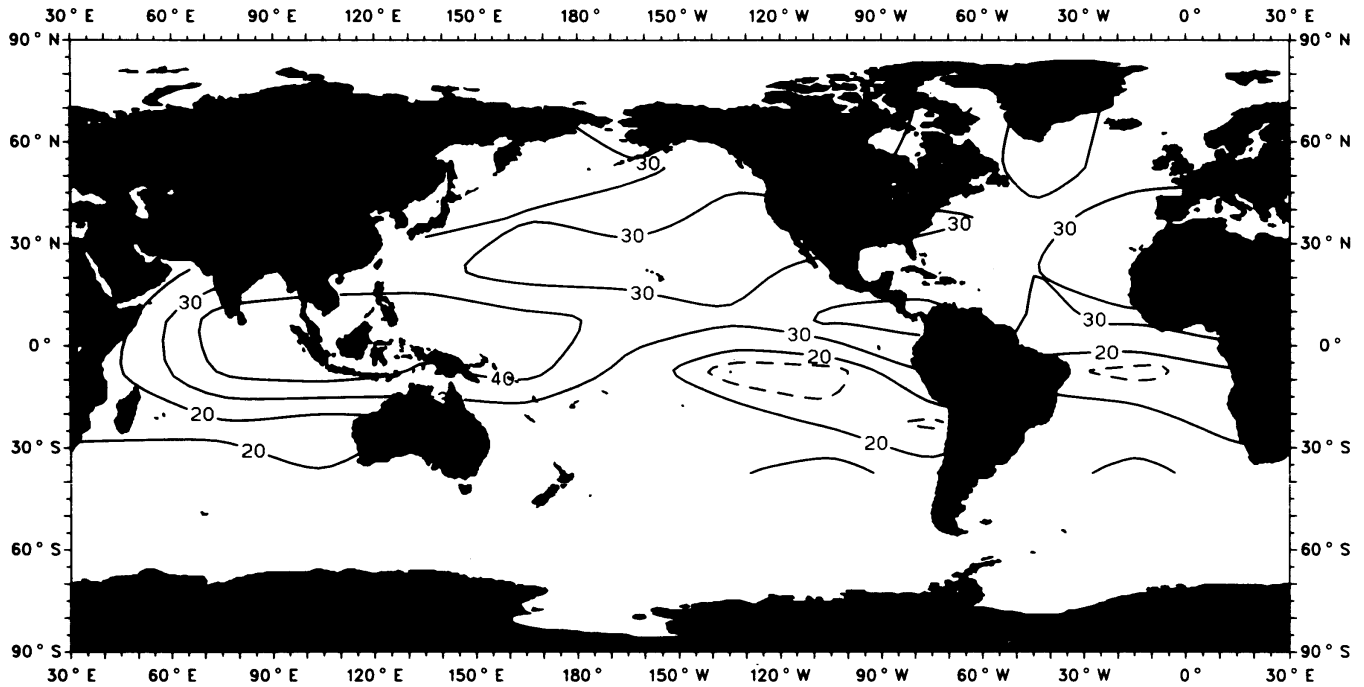
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

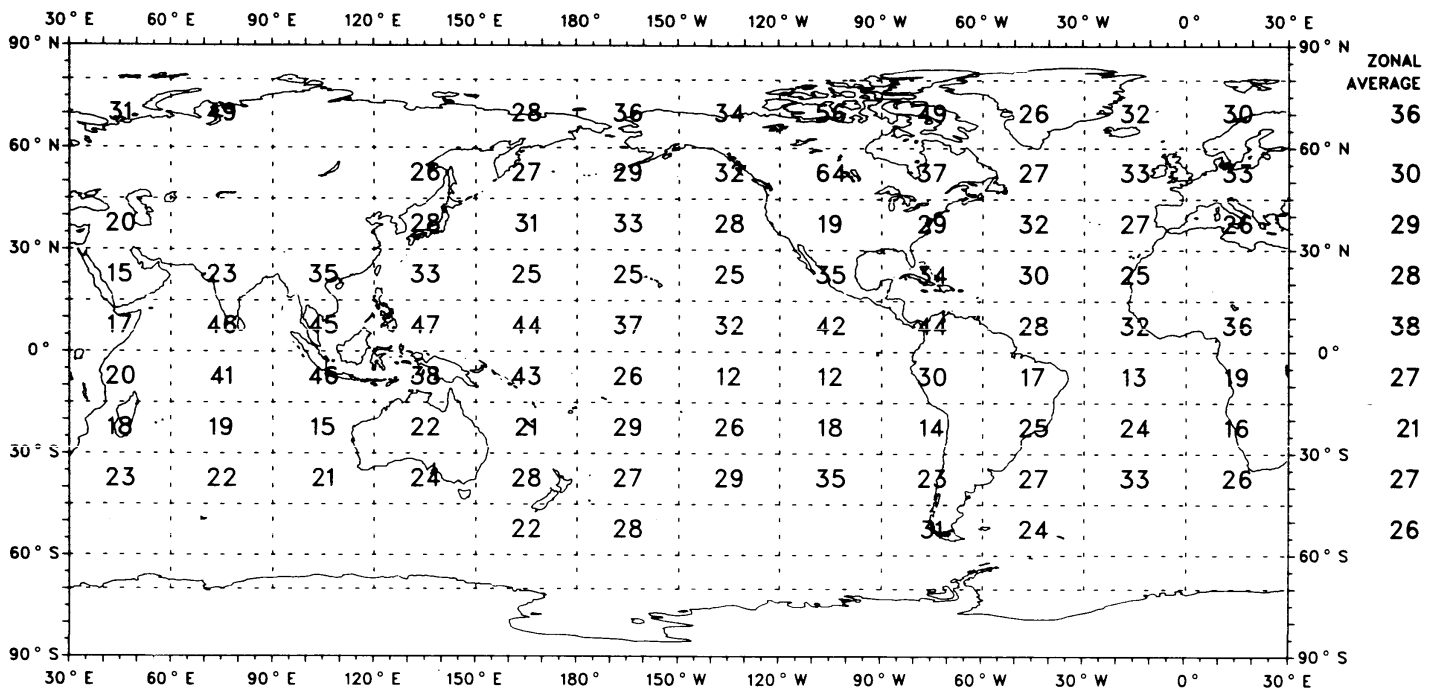
Ocean Areas Only



Given Cumulus, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

Ocean Areas Only

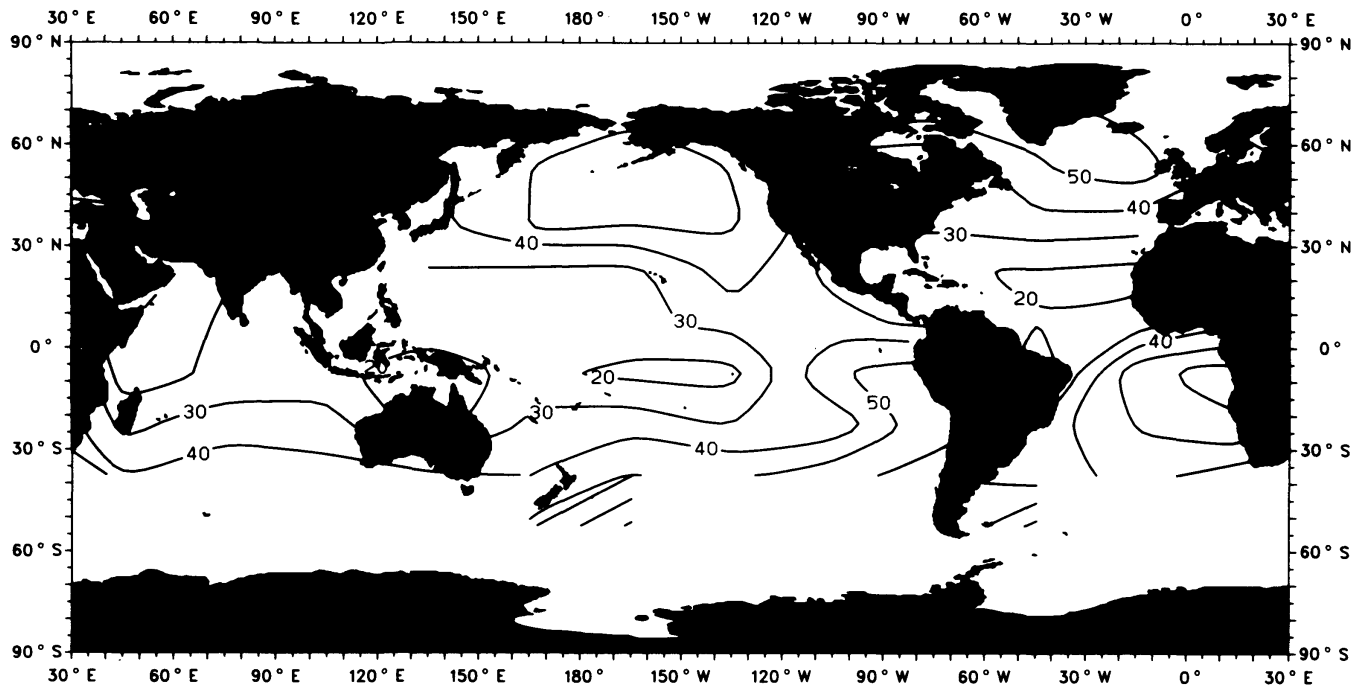


Map IV-30

Given Ci/Cs/Cc, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

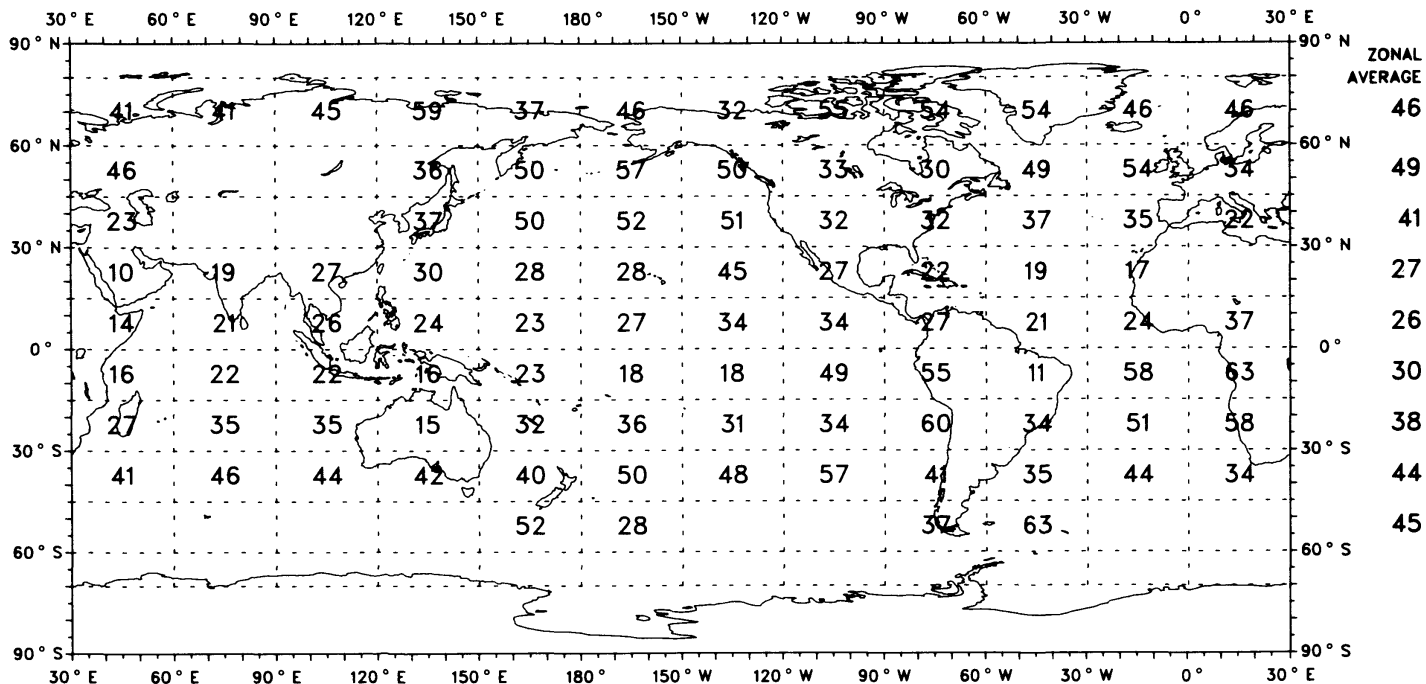
Ocean Areas Only



Given Ci/Cs/Cc, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

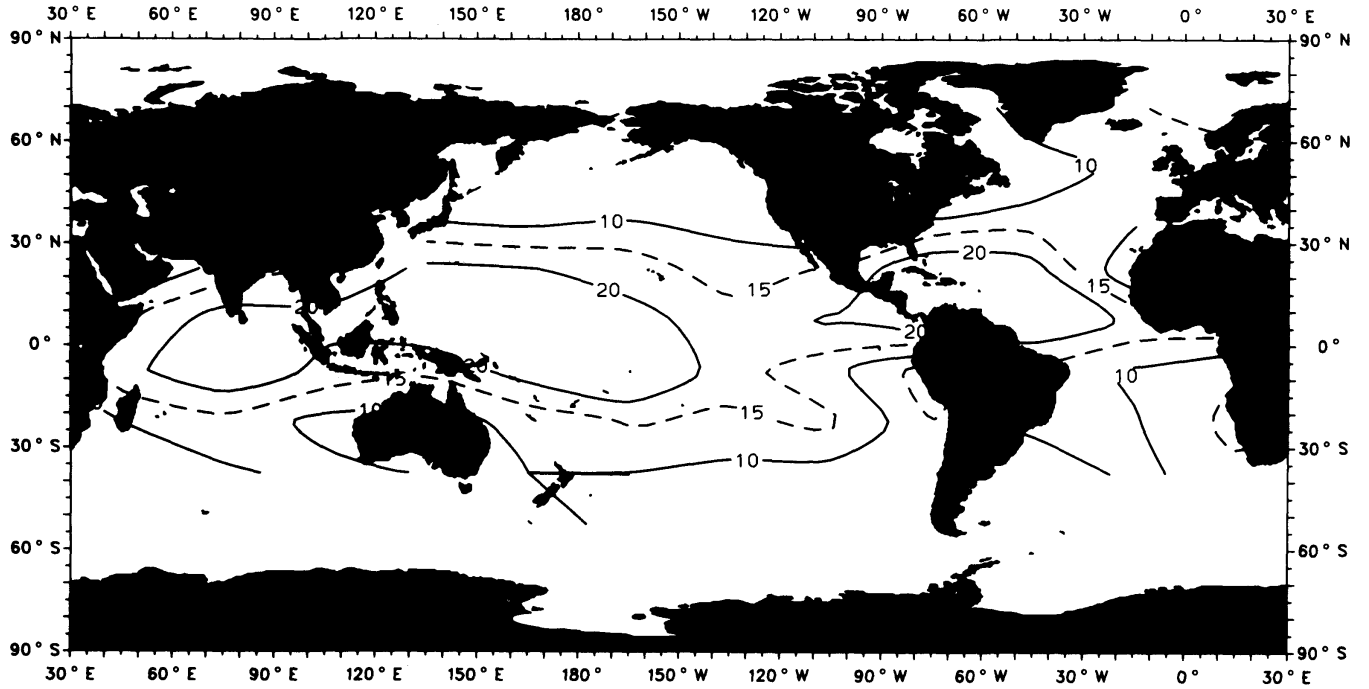
Ocean Areas Only





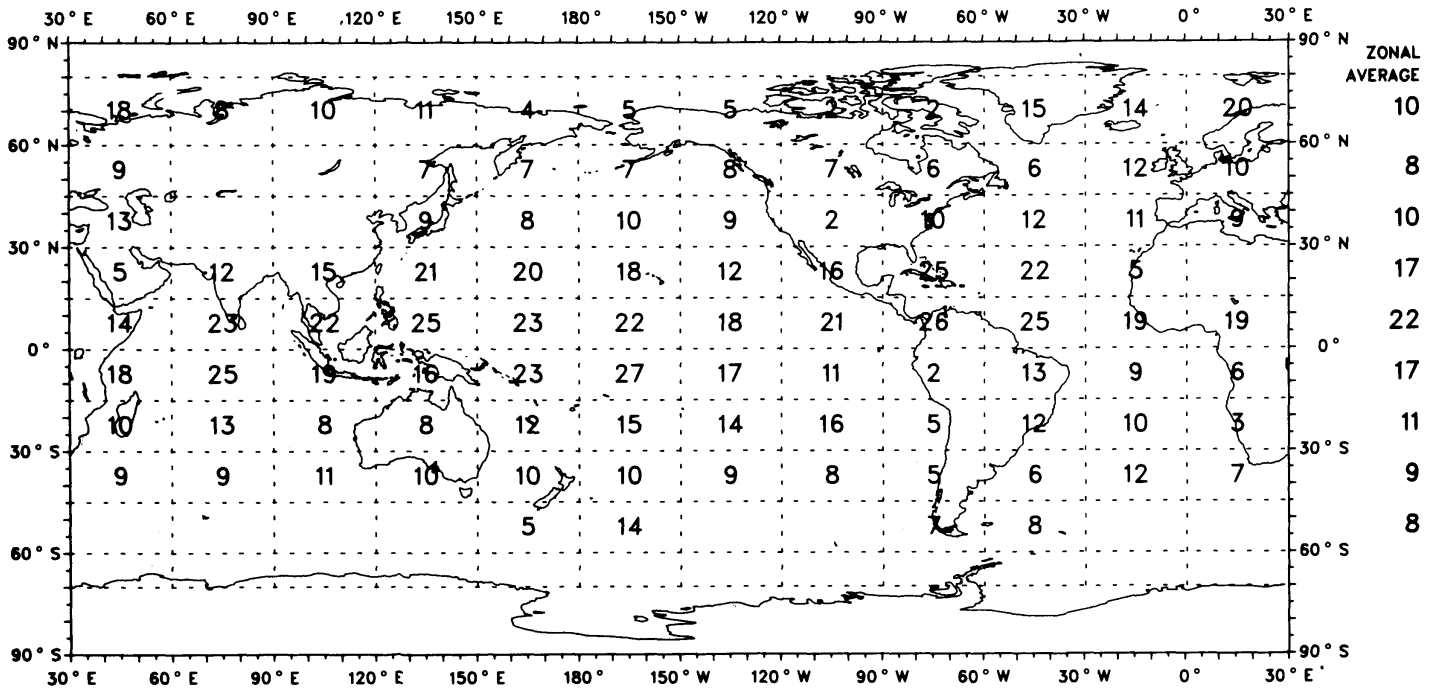
Map IV-32

Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present  
SON (1965-1976) Ocean Areas Only



Given  $C_i/C_s/C_c$ , Probability (Percent) That Cumulonimbus is Also Present

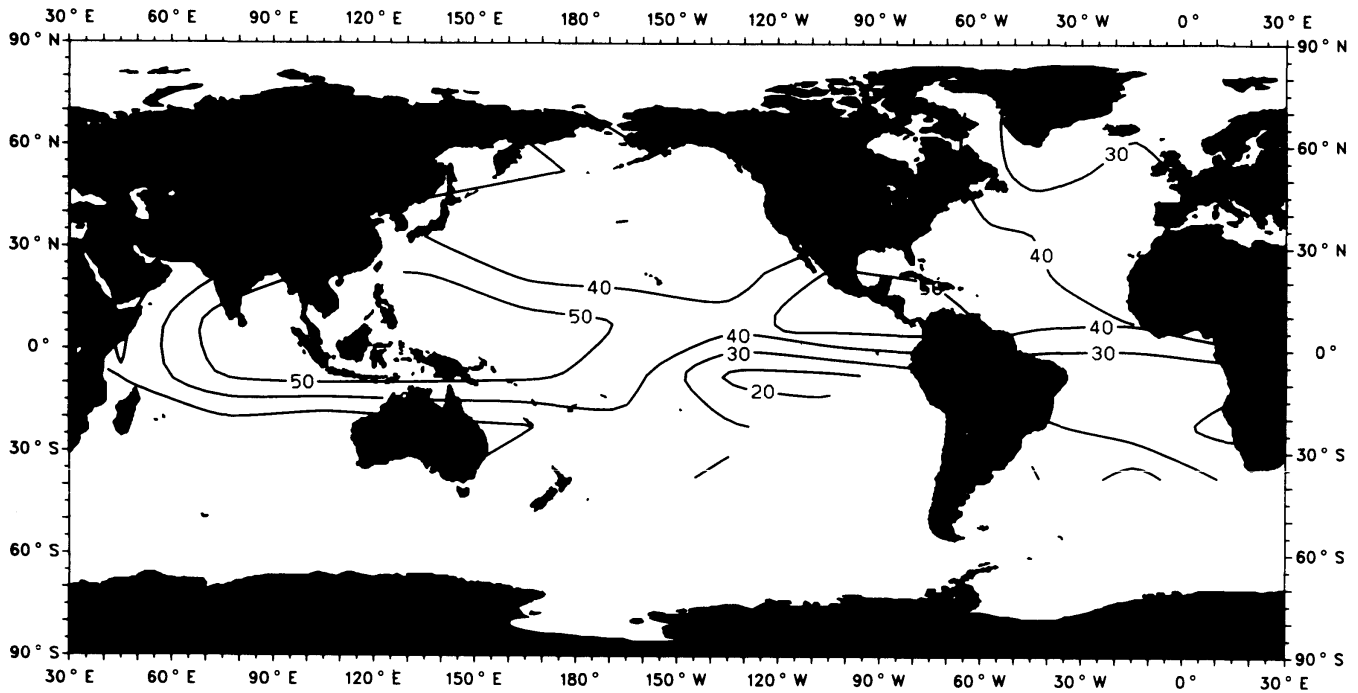
SON (1965-1976) Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

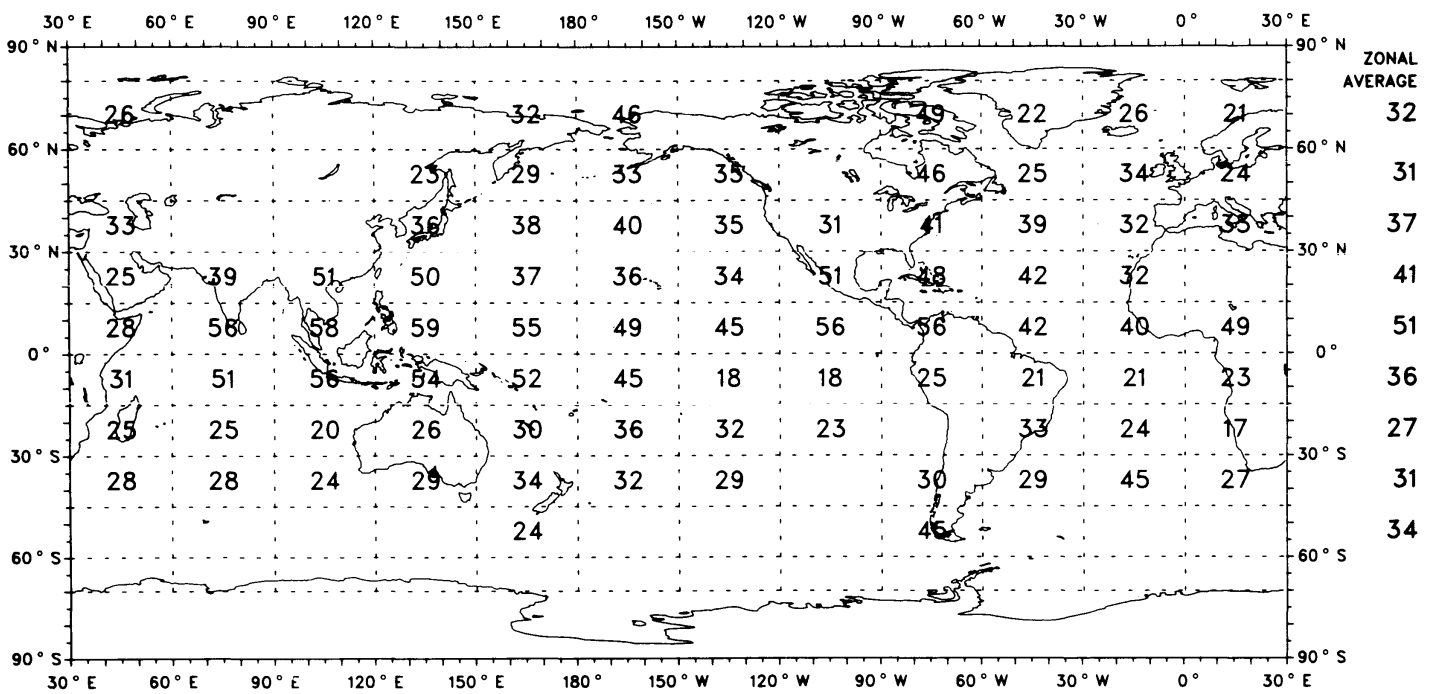
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That Ci/Cs/Cc is Also Present

SON (1965-1976)

Ocean Areas Only





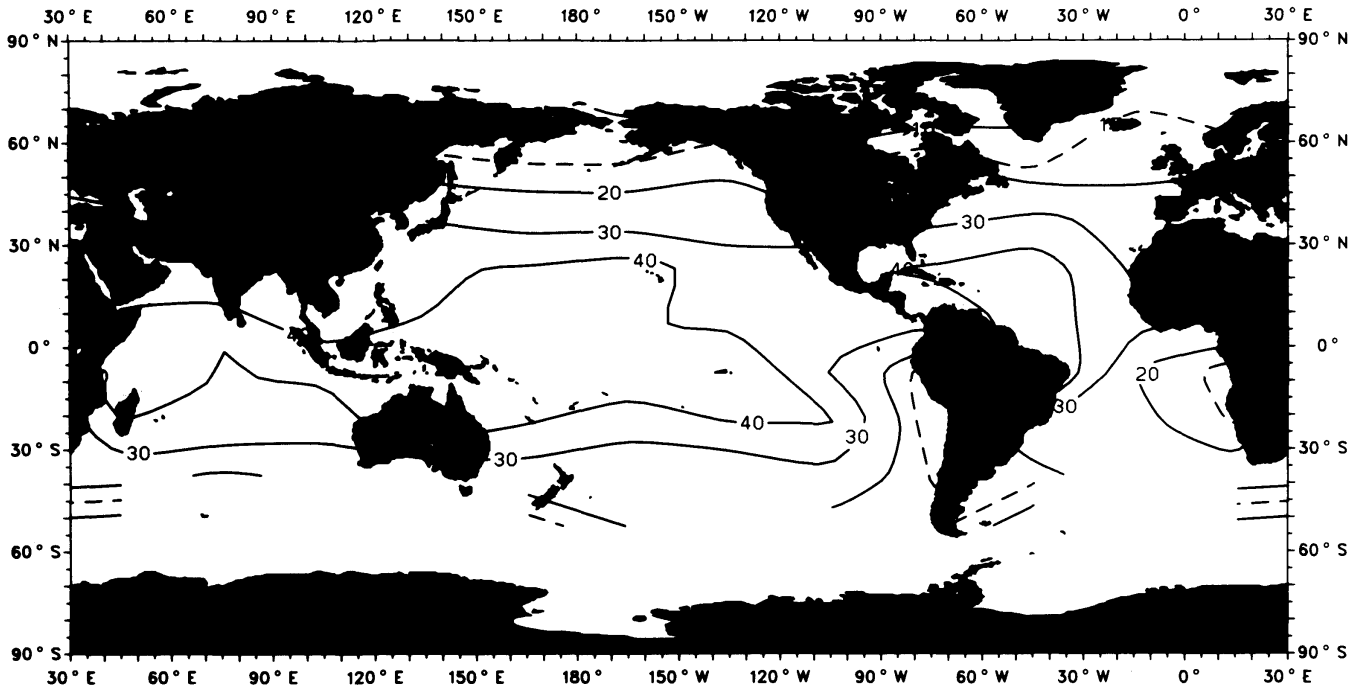


Map IV-36

Given As/Ac, Probability (Percent) That Cumulus is Also Present

SON (1965-1976)

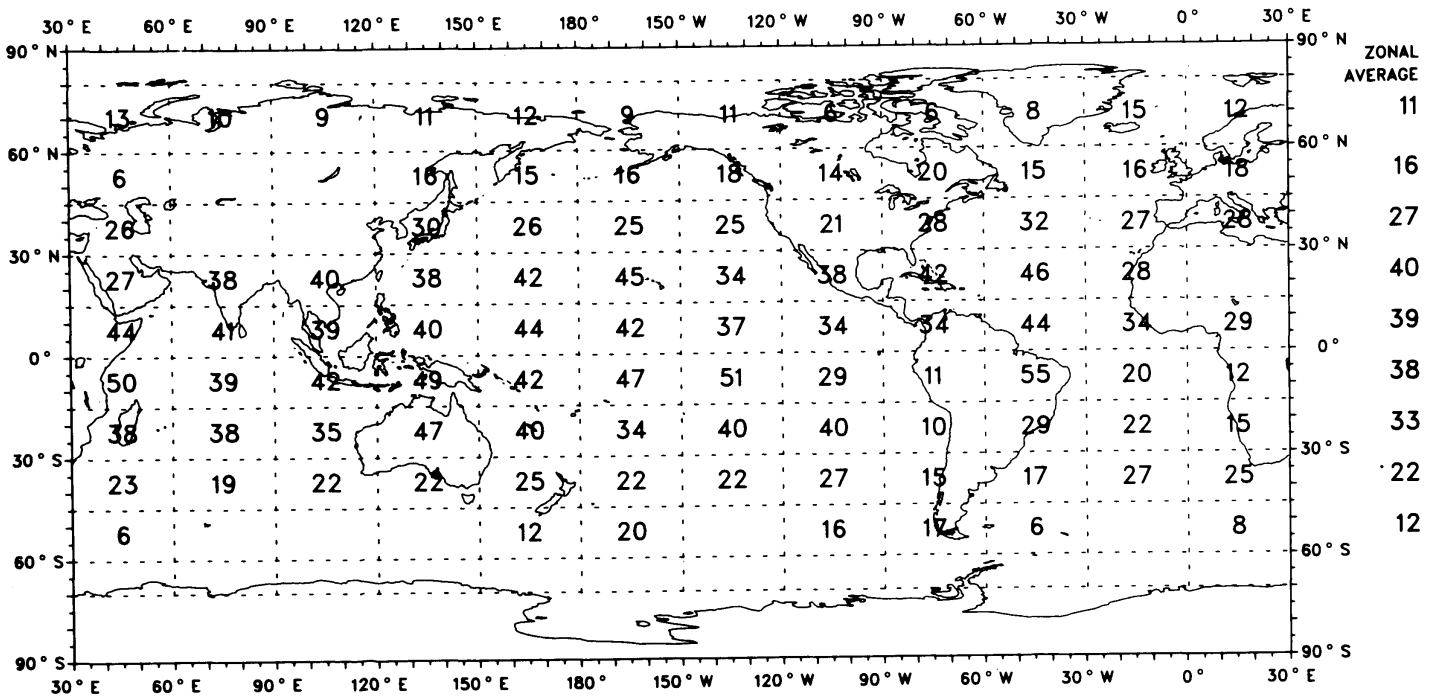
Ocean Areas Only



Given As/Ac, Probability (Percent) That Cumulus is Also Present

SON (1965-1976)

Ocean Areas Only



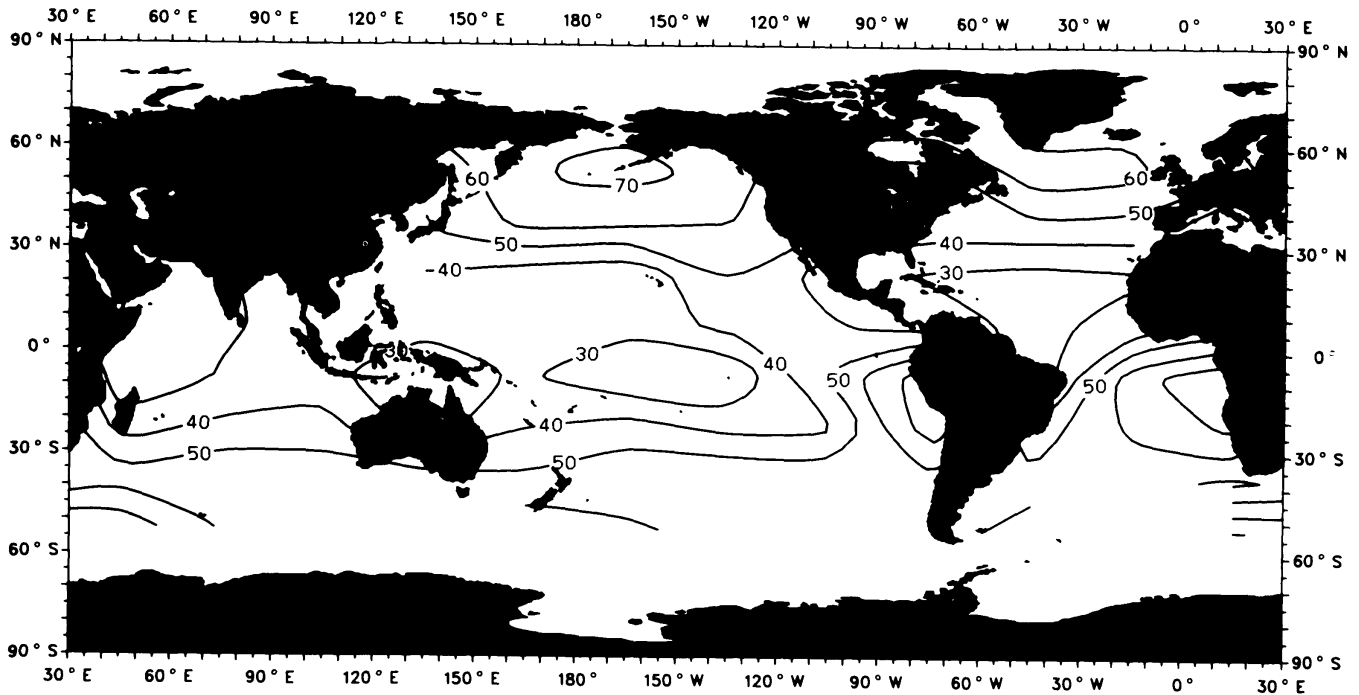


Map IV-38

Given As/Ac, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

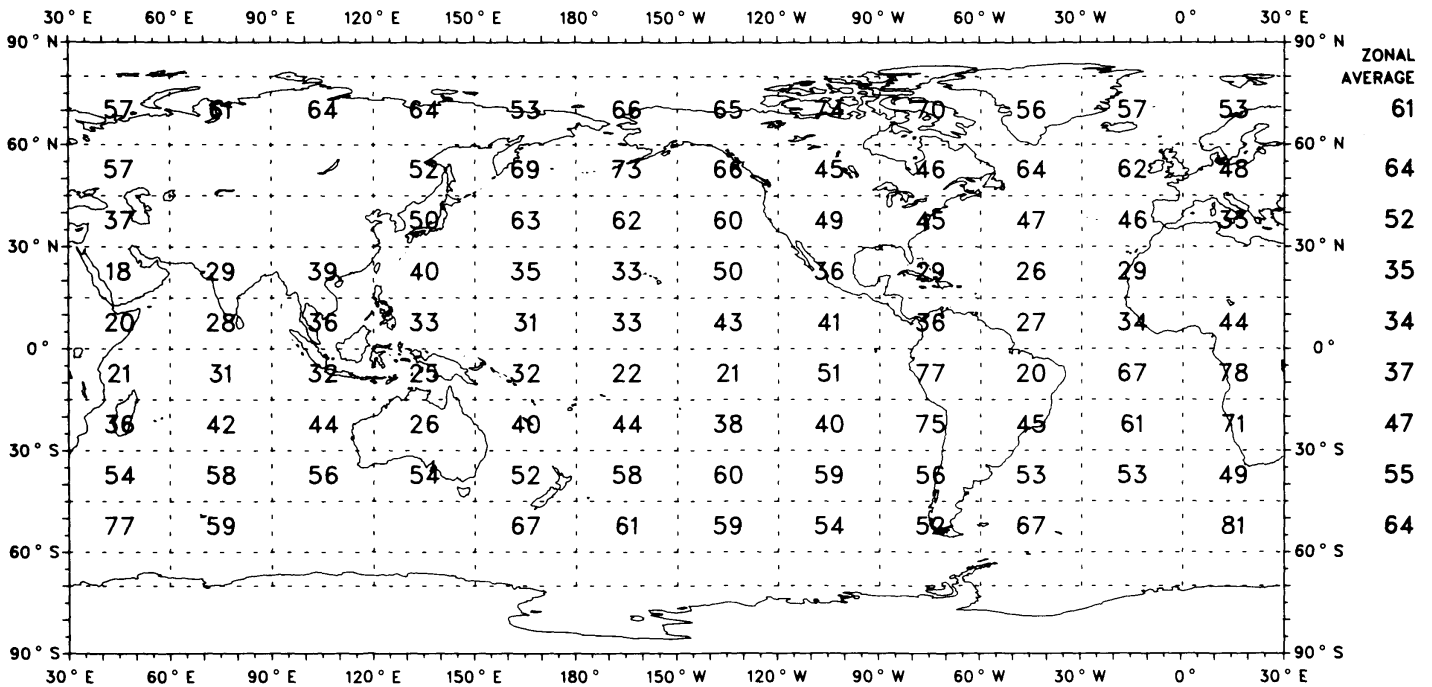
Ocean Areas Only



Given As/Ac, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

Ocean Areas Only



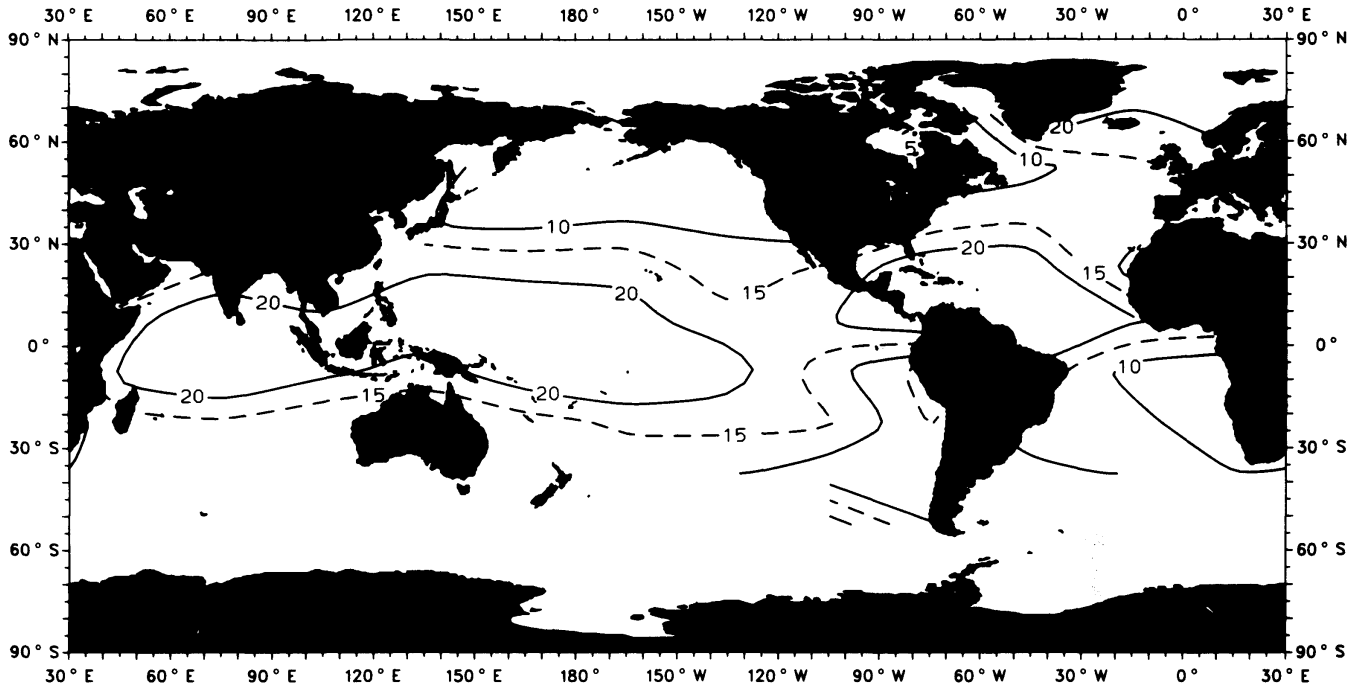


Map IV-40

Given  $A_s/A_c$ , Probability (Percent) That Cumulonimbus is Also Present

SON (1965-1976)

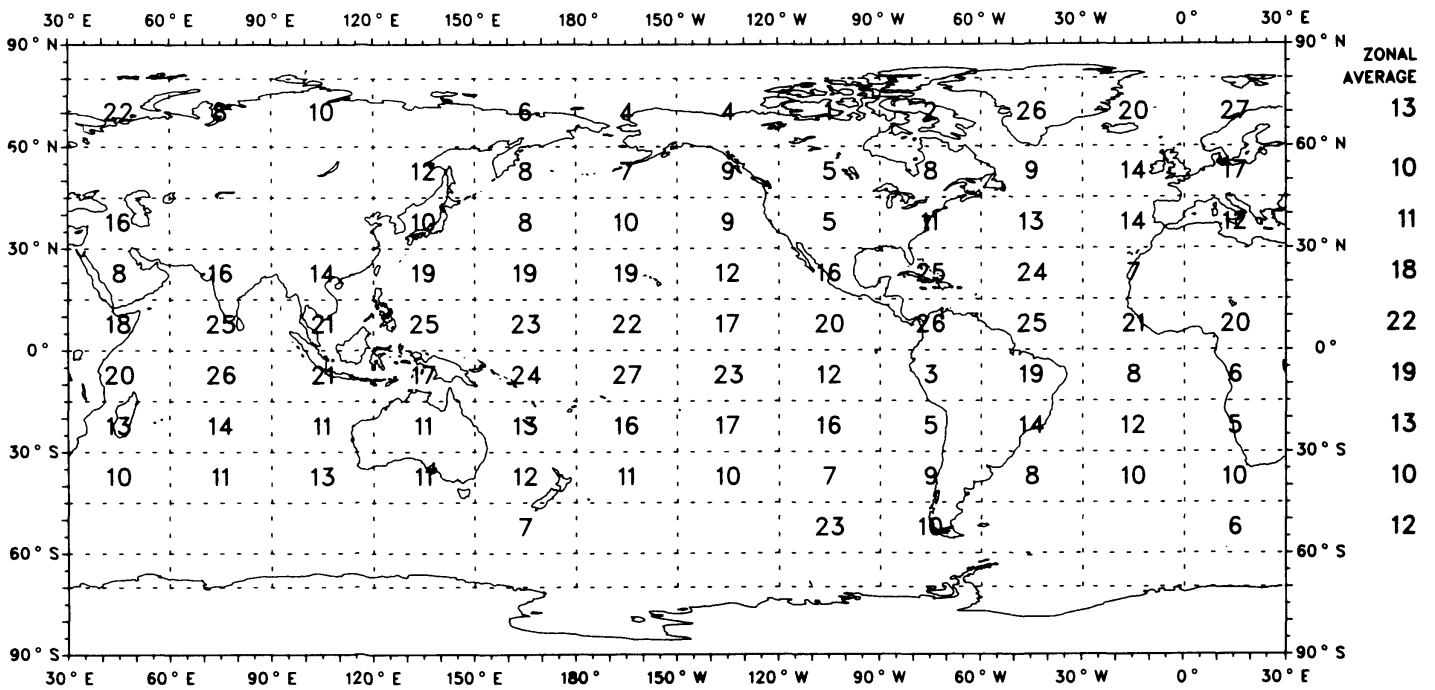
Ocean Areas Only



Given  $A_s/A_c$ , Probability (Percent) That Cumulonimbus is Also Present

SON (1965-1976)

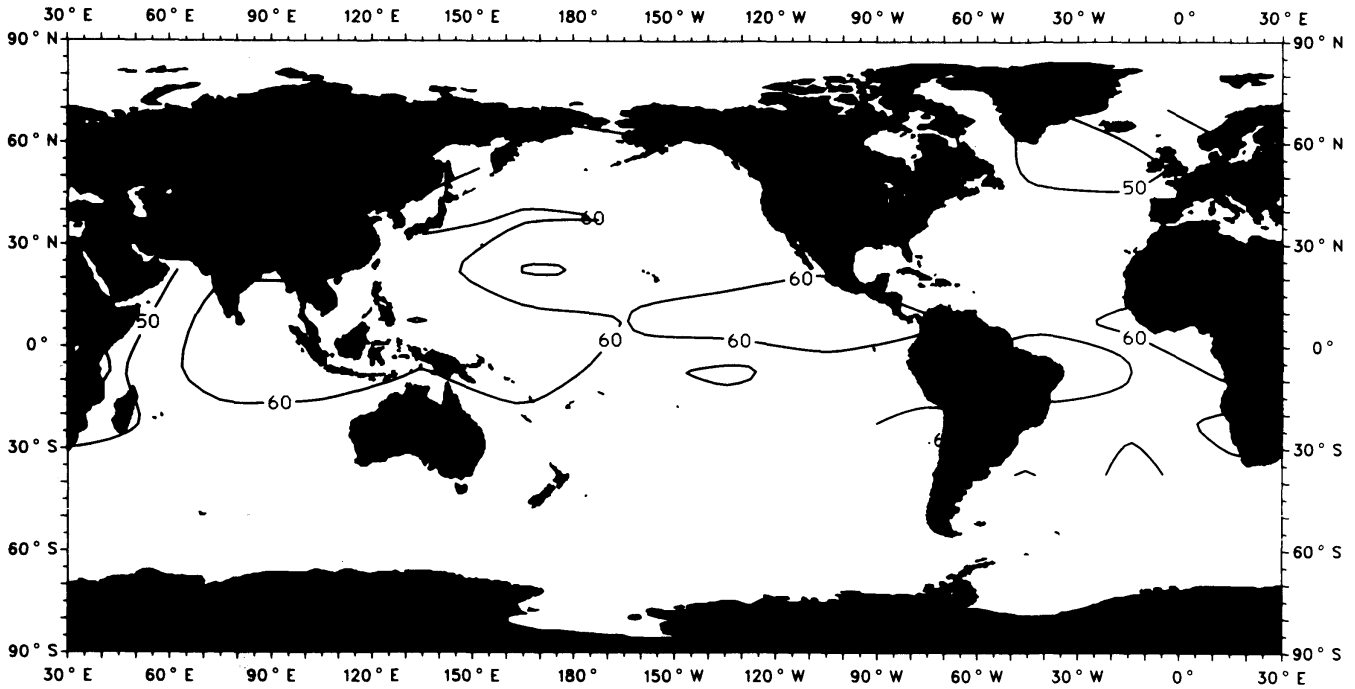
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That As/Ac is Also Present

SON (1965-1976)

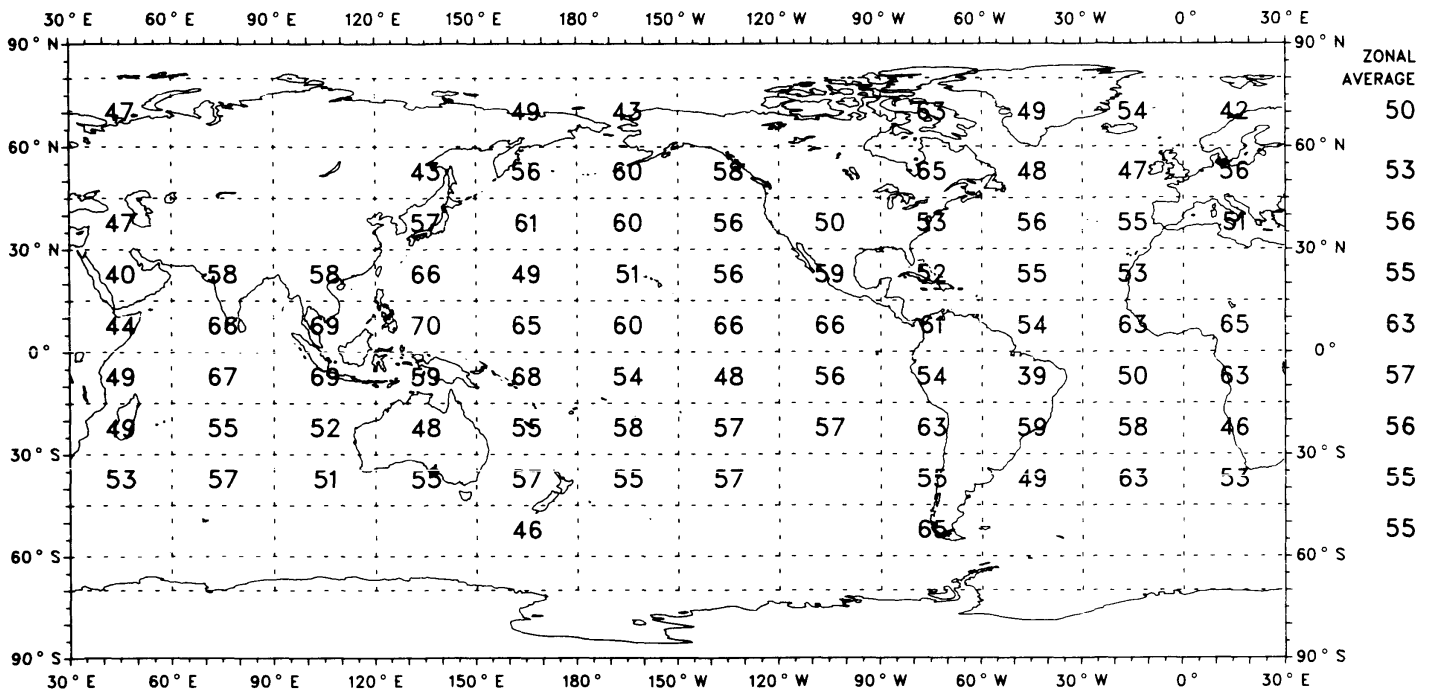
Ocean Areas Only



Given Cumulonimbus, Probability (Percent) That As/Ac is Also Present

SON (1965-1976)

Ocean Areas Only

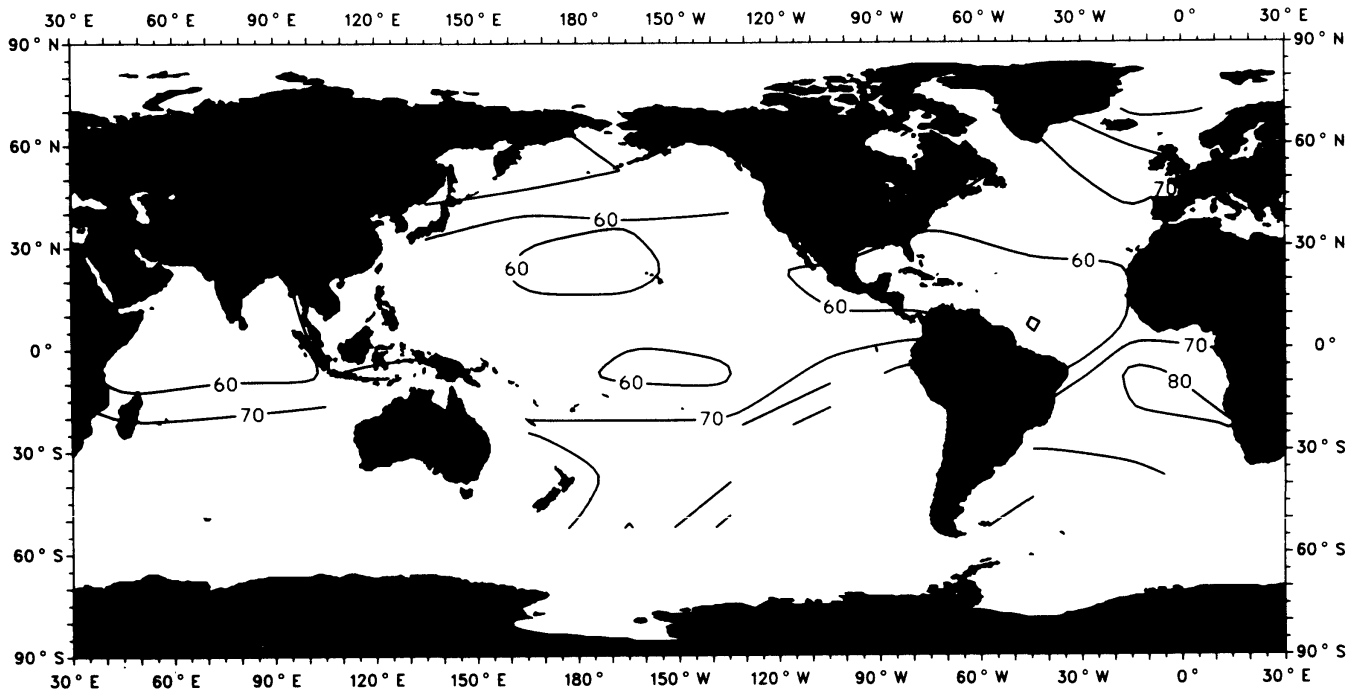




Given Nimbostratus, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

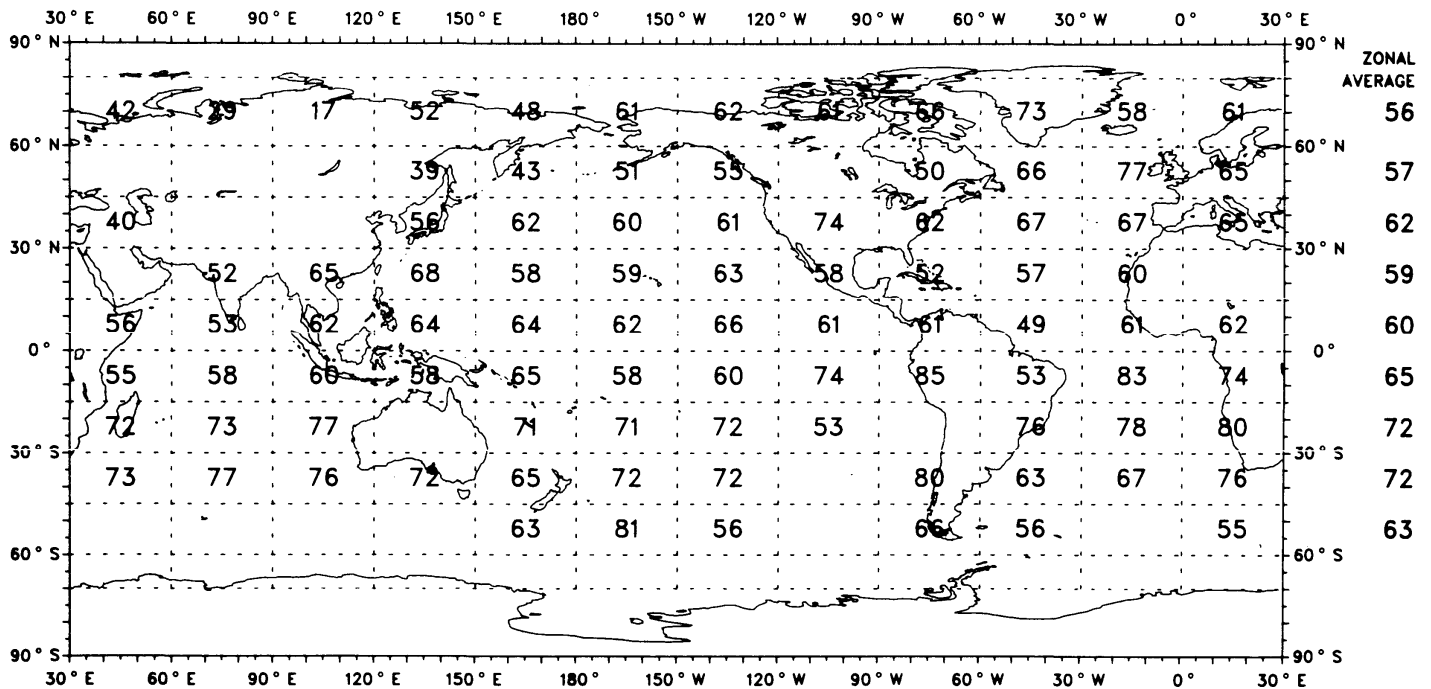
Ocean Areas Only



Given Nimbostratus, Probability (Percent) That St/Sc is Also Present

SON (1965-1976)

Ocean Areas Only

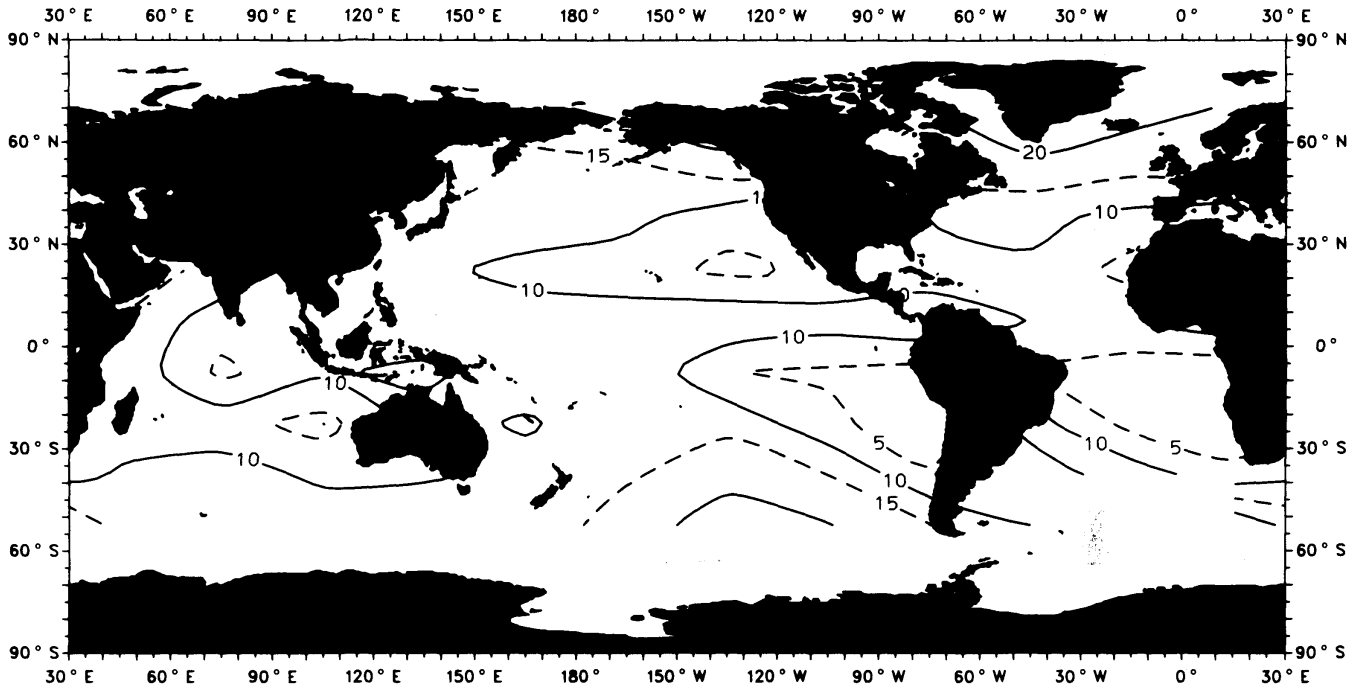


Map IV-45

Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

SON (1965-1976)

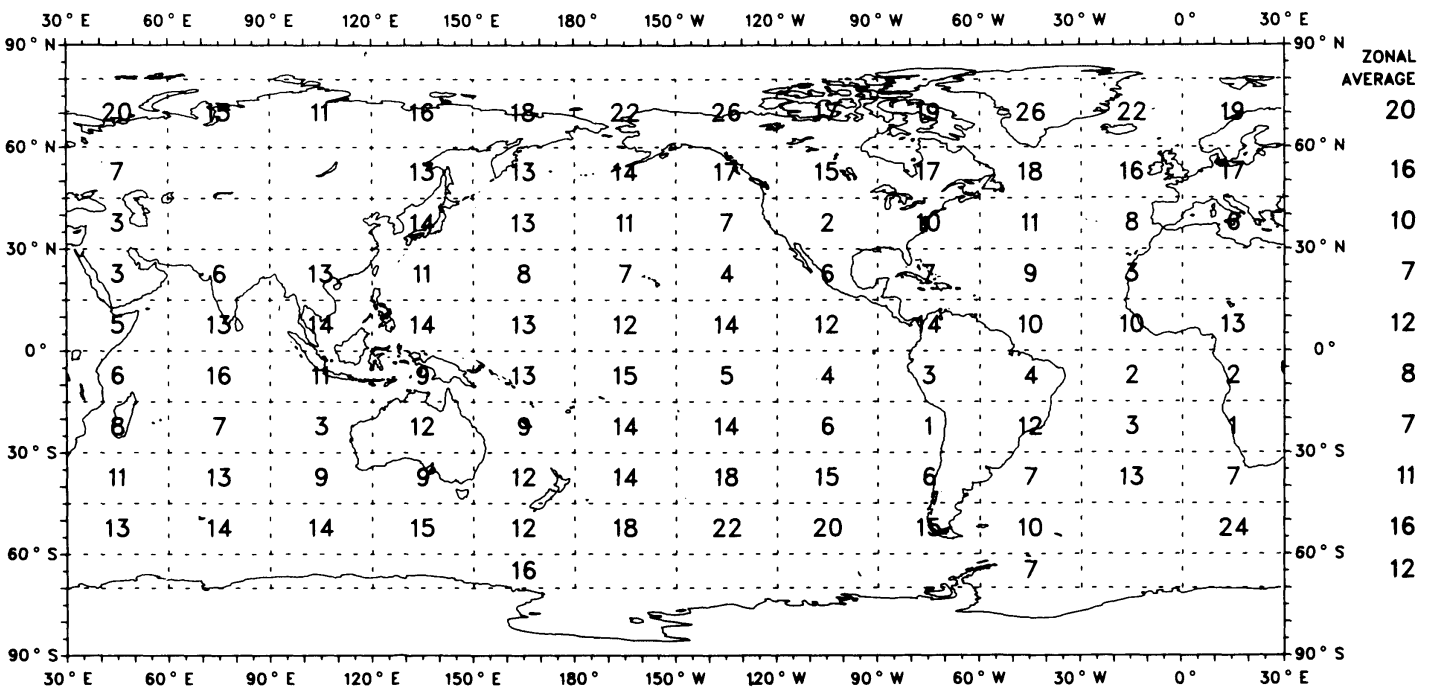
Ocean Areas Only



Given St/Sc, Probability (Percent) That Nimbostratus is Also Present

SON (1965-1976)

Ocean Areas Only





Map IV-47

Given Cumulonimbus, Probability (Percent) That Nimbostratus is Also Present

SON (1965-1976)

Ocean Areas Only

