TRENDS IN GLOBAL CIRRUS INFERRED FROM THREE YEARS OF HIRS DATA

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Abstract

Trends in global upper tropospheric semi-transparent cirrus cloud cover are beginning to emerge from a three year cloud climatology compiled using NOAA polar orbiting HIRS multispectral infrared data. Cloud occurrence, height, and amount have been determined with the CO2 slicing technique on the three years of data (June 1989 - May 1992). Annual, seasonal, and geographical trends of cloudiness are presented. To date, semi-transparent clouds are found in more than one third of the observations. Large seasonal changes are found in areas dominated by the ITCZ, the sub-tropical high pressure systems, and the mid-latitude storm belts. Semi-transparent clouds associated with these features move latitudinally with the seasons. More thin clouds (effective emissivity less than .50) are found in the tropics than in midlatitudes. Global average of all clouds (semi-transparent and opaque) is about 75%; more clouds are found over the oceans than over land.

1. Introduction

The CO2 slicing algorithm has been used to distinguish transmissive clouds from opaque clouds and clear sky in three years of HIRS (High resolution Infrared Radiation Sounder) multispectral observations. The algorithm has been described in previous the Technical Proceedings (Wylie and Menzel, 1991); the processing has not been altered during the three years. The CO_2 slicing algorithm calculates both cloud top pressure and effective emissivity from radiative transfer principles (Menzel et al , 1992, Eyre and Menzel, 1989, Menzel et al., 1989).

Effective emissivity refers to the product of the fractional cloud cover, N, and the cloud emissivity, E, for each observational area (roughly 30 km by 30 km). When NE is less than unity, HIRS may be observing broken opaque cloud (N<1, E=1), overcast transmissive cloud (N=1, E<1), or broken transmissive cloud (N<1, E<1). All of these possibilities are labelled as "cirrus" when NE<.95; when NE>.95 the cloud is labelled as opaque.

Briefly, the processing procedure is repeated here; more details can be found in the references above. HIRS data from NOAA 10, 11, and 12 were sampled as follows; only data with zenith angle less than 10 degrees were sampled for every third field of view (FOV) on every third line. With two satellites, about one half of the Earth is sampled each day. Morning orbits over land were rejected from the data. In the Arctic and Antarctic, the HIRS channels were inspected for the presence of surface temperature inversions which are assumed to be indicators of clear sky.

CO_2 slicing cloud top pressures are calculated when the cloud forcing (clear minus cloudy radiance is greater than the instrument noise level); otherwise the infrared window temperature is used to determine an opaque cloud top pressure. Fields of view are determined to be clear or cloudy if the moisture corrected 11.2 micron brightness temperature is within 2 degrees Kelvin of the known surface temperature (over land this is inferred from the NMC Medium Range Forecast (MRF) model analysis; over the oceans this is the NMC sea surface temperature analysis).

2. Global Cloud Statistics

A statistical summary of the global cloud observations from HIRS between June 1989 through May 1992 is shown in Table 1. Over 10 million observations were processed. Entries are believed to be accurate within 1%; values should be interpreted as +/-0.5% (for a discussion see Wylie and Menzel, 1991). High clouds above 400 mb comprised 22% of the observations. 27% of the observations were of clouds between 400 mb and 700 mb. Low clouds below 700 mb were found 27% of the time. Cloud free conditions were found 24% of the time. Cirrus clouds (observations with effective emissivities less than 0.95) were found in 40% of our observations; they ranged from 100 to 700 mb. Clouds opaque to infrared radiation (observations with effective emissivities greater than 0.95) were found 36% of the time. The global average cloud amount (global average of NE) was found to be 0.54.

The frequency of clouds over land was 66% versus 79% over oceans; the frequency of cirrus clouds over land was 37% versus 41% over oceans. Clouds above 500 mb preferred land over oceans (36% versus 34%). Thin clouds ($NE < 0.50$) preferred oceans over land (21% versus 17%).

Figure 1 shows the geographical distribution of cirrus clouds in summer and winter (darker regions indicate more frequent cloud occurrence). Winter refers to the months of December, January, and February; summer refers to June, July, and August. The seasonal summaries were compiled using a uniformly spaced grid of 2^o latitude by 3^o longitude. Each grid box for each season has at least 500 observations.

The major features of the three year summary have not changed appreciably from those reported in the two year summary (Wylie and Menzel, 1991). The ITCZ is readily discernible as the band of more frequent cirrus cover (darker band in the tropics); the mid-latitude storm belts are also evident. The ITCZ is seen to move north with the sun. The subtropical high pressure systems are also apparent as the band of less frequent cirrus cover (white band in the subtropics). Cirrus clouds are less (more) frequent in the winter (summer) season in both hemispheres. Over the Indonesian region the ITCZ expands in latitudinal coverage from winter to summer. In the central Pacific, the ITCZ shows both a southern and northern extension during the winter months.

In the southern hemisphere, the eastern Pacific ocean off of South America and the eastern Atlantic ocean off of Africa remain relatively free of cirrus cloud throughout the year. The southern hemispheric storm belt is evident throughout the year. In the northern hemisphere mid-latitude storm belts, the frequency of cirrus clouds increased during the winter with the strengthening of the Alleutian Low in the north Pacific and the Icelandic Low in the north Atlantic. The North American cirrus cloud cover shows little seasonal change agreeing with the GOES/VAS analysis (Menzel et al., 1992). Large convective development occurs during the winter (southern summer) in South America and Africa which is readily apparent through increased occurrence of high cirrus clouds.

3. <u>Trends in the Three Years</u>

Table 2 shows the progression from year 1 (June 89 - May 90) to year 2 (June 90 - May 91), and then from year 2 to year 3 (June 91 - May 92). Thin clouds refers to NE < .5, thick to .95 > NE > .5. The change from year 1 to year 2 is imperceptible. The change from year 2 to year 3 is large and very obvious; cloud cover increased by 2% with opaque clouds decreasing by 7% and cirrus increasing by 9%. Cirrus appears much more frequently in the year 3 data than in previous years; conversely opaque cloud appears much less frequently. The probability of clear sky remains stable.

Figure 2a shows the geographical distribution of the difference in the probability of cirrus occurring summer 1990 minus summer 1989. The differences greater than 12% are scattered about, with no discernible pattern. Coherent changes are apparent only in the Timor Sea (off the northwest coast of Australia) with a decrease of cirrus and in the Pacific Ocean east of Papua New Guinea with a increase of cirrus. Figure 2b shows the corresponding difference for winter 1990 minus winter 1989 (winters are indicated by the year of the first month in the time interval, so that winter 1989 refers to December 1989 through February 1990). Again there is not very much difference. The only features are the increase of cirrus in the Coral and Timor Seas (representing a westward shift from Fig 2a), and the decrease of cirrus in the Indian Ocean west of Australia (representing a westward shift from Fig 2a). Figure 2c shows the corresponding difference for summer 1991 minus summer 1990. A change in cirrus coverage from the previous years summer is obvious. Coherent increase of cirrus greater than 12% is apparent in the ITCZ, in the southern midlatitudes, in the Indian Ocean, and in eastern Africa. Decrease of cirrus is indicated in the higher latitudes of the southern hemisphere. Finally Figure 2d shows the corresponding difference for winter 1991 minus winter 1990. The global increase in cirrus has become even more pronounced, especially in the central Pacific Ocean, in the Indian Ocean, and the northern hemisphere midlatitudes.

The explanation for this increase in global cirrus cloud cover is not readily apparent. However, there were two 1991 phenomena that may be related. Mt. Pinatubo erupted in June 1991 causing aerosol optical thicknesses to increase by factors of four or five in the following months and foreshadowing global cooling of about .5 C (Stowe et al., 1992). In late 1991 and early 1992 warm episode conditions intensified in the eastern equatorial Pacific (El Nino) causing positive sea surface temperature anomalies greater than 2 C (NOAA, 1992). The relationship, if any, between these events and the change in cloud cover (increase in global cirrus cloud, corresponding decrease in global opaque cloud) will require more study.

5. Conclusions

There continues to be a global preponderance of semi-transparent high clouds, presumed to be cirrus; 40% on the average for the three years covered by June 1989 to May 1992. In the ITCZ a high frequency of cirrus (greater than 50%) is found at all times; a modest seasonal movement tracks the sun. Large seasonal changes in cloud cover occur over the oceans in the storm belts at midlatitudes; the concentrations of these clouds migrated north and south with the seasons following the progressions of the subtropical highs (anticyclones). More cirrus is found in the summer than in the winter in each hemisphere.

The changes in cirrus cloud cover from year 1 to year 2 were insignificant, but the changes from year 2 to year 3 were very noticeable. Opaque cloud cover reduced by 7% globally, while cirrus cloud cover (most of it having effective emissivity less than 0.50) increased by 9%. While 1991 saw the eruption of Mt. Pinatubo and a significant El Nino event in the eastern Pacific, the explanation for this change in global cloud cover is not yet understood.

Acknowledgments

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Table 1: HIRS three year global cloud statistics (June 1989 to May 1992). The frequency of cloud observations for different heights and effective emissivities. Percentages are of the total number of observations, clear and cloudy combined. Clouds were not detected in 24% of the observations.

	ALL CLOUDS	EFFECTIVE EMISSIVITY				
LEVEL		<0.25	<0.50	<0.75	<0.95	>0.95
<200 mb	3%	1%	0%	0%	1%	1%
<300 mb	10	2	2	2	2	2
<400 mb	9	2	2	2	2	1
<500 mb	11	3	2	3	2	1
<600 mb	8	1	2	3	1	1
<700 mb	8	1	1	2	1	3
<800 mb	8	0	0	0	0	8
<900 mb	12	0	0	0	0	12
<1000 mb	7	0	0	0	0	7
Total	76%	10%	9%	12%	9%	36%

Table 2a: The change in HIRS global cloud cover from year 1 (June 1989 to May 1990) to year 2 (June 1990 to May 1991). Numbers are frequency of cloud cover in year 2 minus the frequency of cloud cover in year 1; negative numbers indicate a decrease in cloudiness while positive numbers indicate an increase.

	EFFECTIVE EMISSIVITY		
LEVEL	thin<0.50	thick>0.50	opaque>0.95
hi < 400 mb	0	1	0
mid <700 mb	0	0	-1
low <1000 mb	0	0	0
Total	0%	1%	-1%

Table 2b: The change in HIRS global cloud cover from year 2 (June 1990 to May 1991) to year 3 (June 1991 to May 1992). Numbers are frequency of cloud cover in year 3 minus the frequency of cloud cover in year 2.

	EFFECTIVE EMISSIVITY		
LEVEL	thin<0.50	thick>0.50	opaque>0.95
hi < 400 mb	4	1	-1
mid <700 mb	3	1	-1
low <1000 mb	0	0	-5
Total	7%	2%	-7%

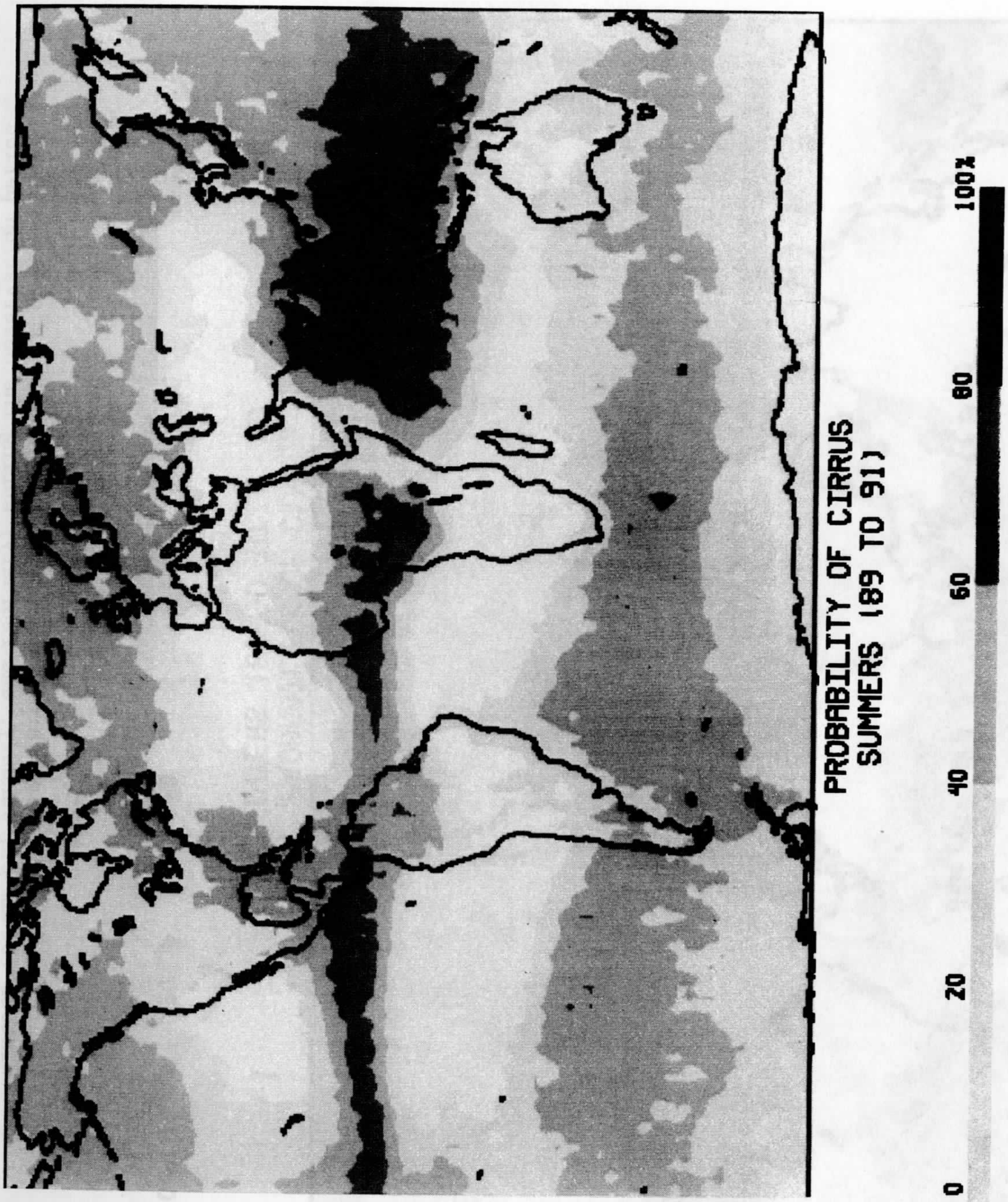

Figure 1: (a) The geographic frequency of transmissive clouds for the summers (June, July, August) during the observation period June 1989 to May 1992. The left margin of the figure coincides with the International Date Line.

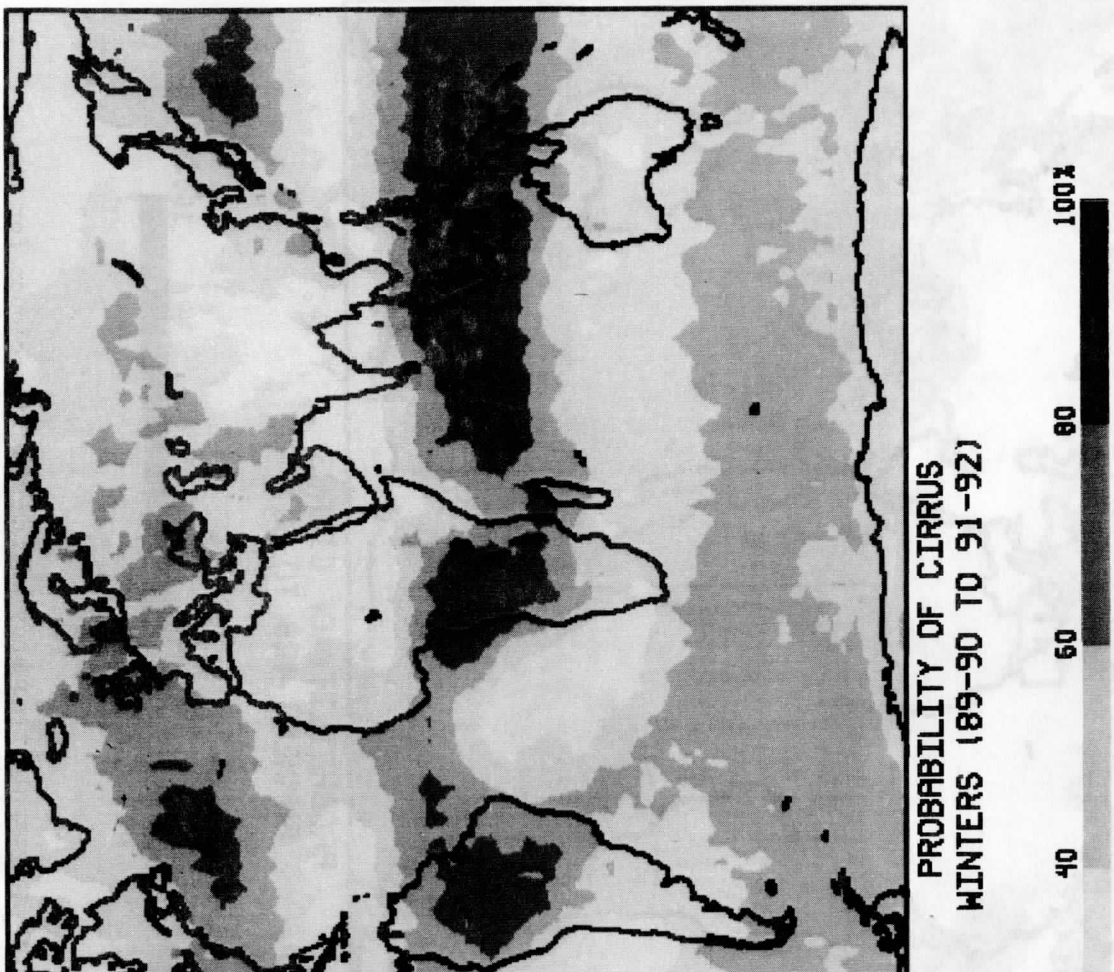

Figure 1: (b) The geographic frequency of transmissive clouds for the winters (December, January, and February) during the observation period June 1989 to May 1992.

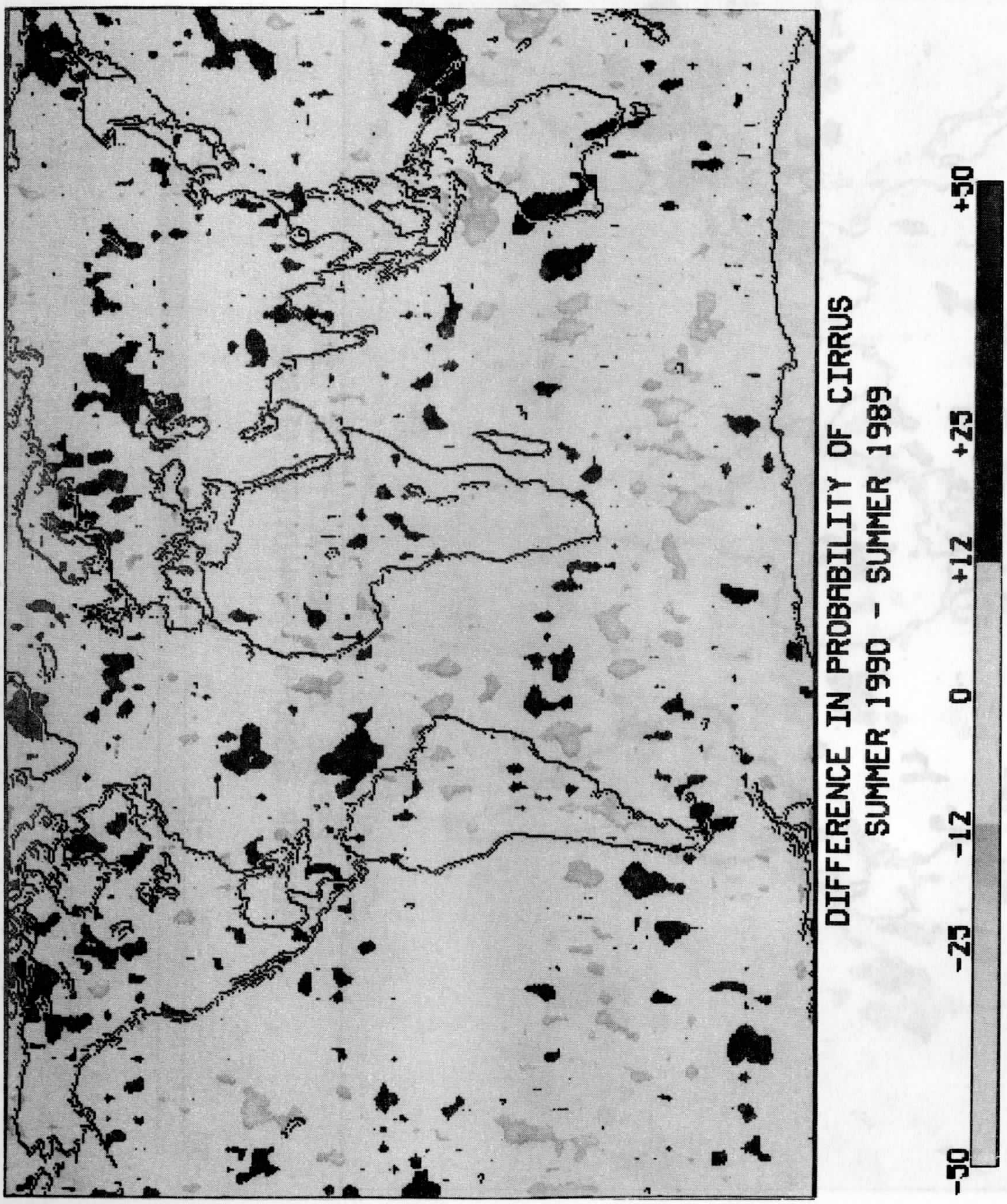

Figure 2: (a) The geographical distribution of the difference in the probability of cirrus occurring summer 1990 minus summer 1989. Summer includes June, July, and August.

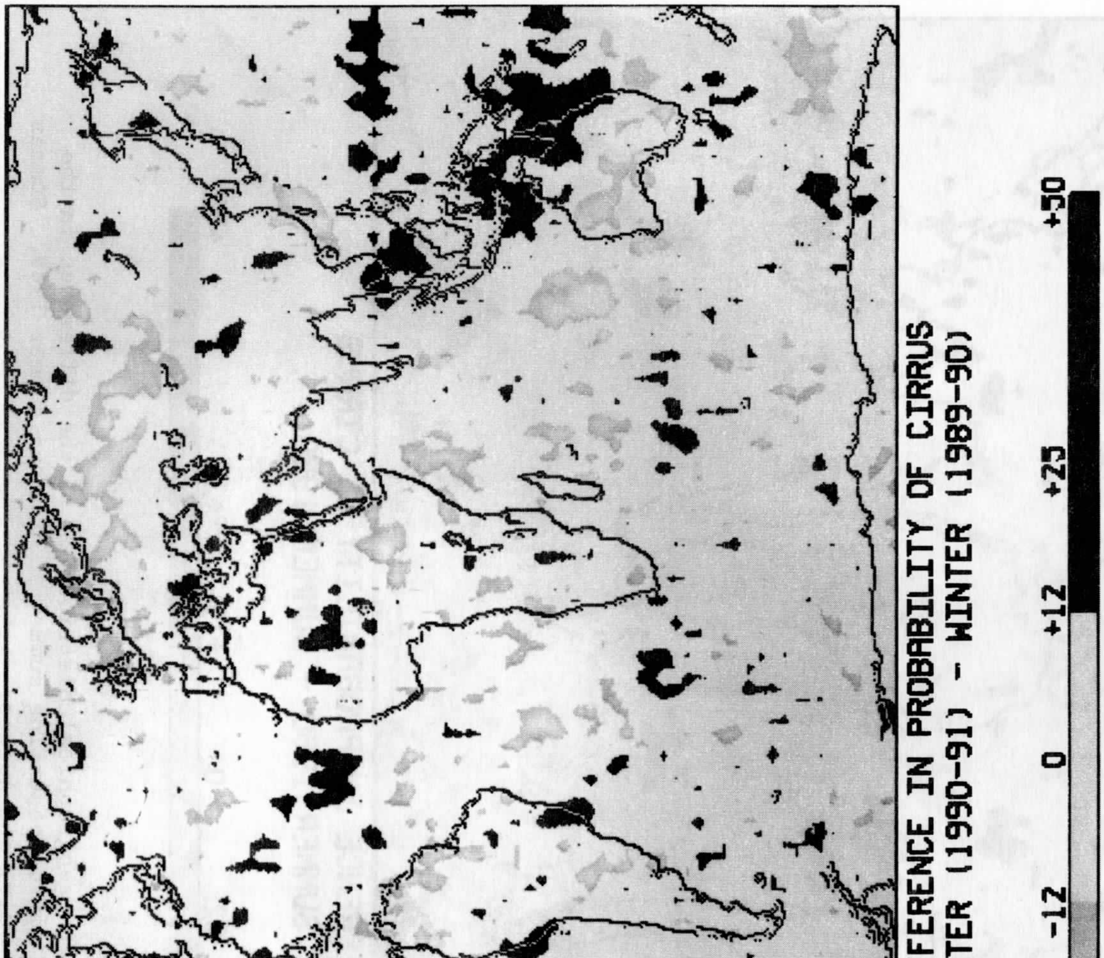

Figure 2: (b) The geographical distribution of the difference in the probability of cirrus occurring winter 1990 minus winter 1989. Winter includes December, January, and February and is labeled by the year associated with the month of December.

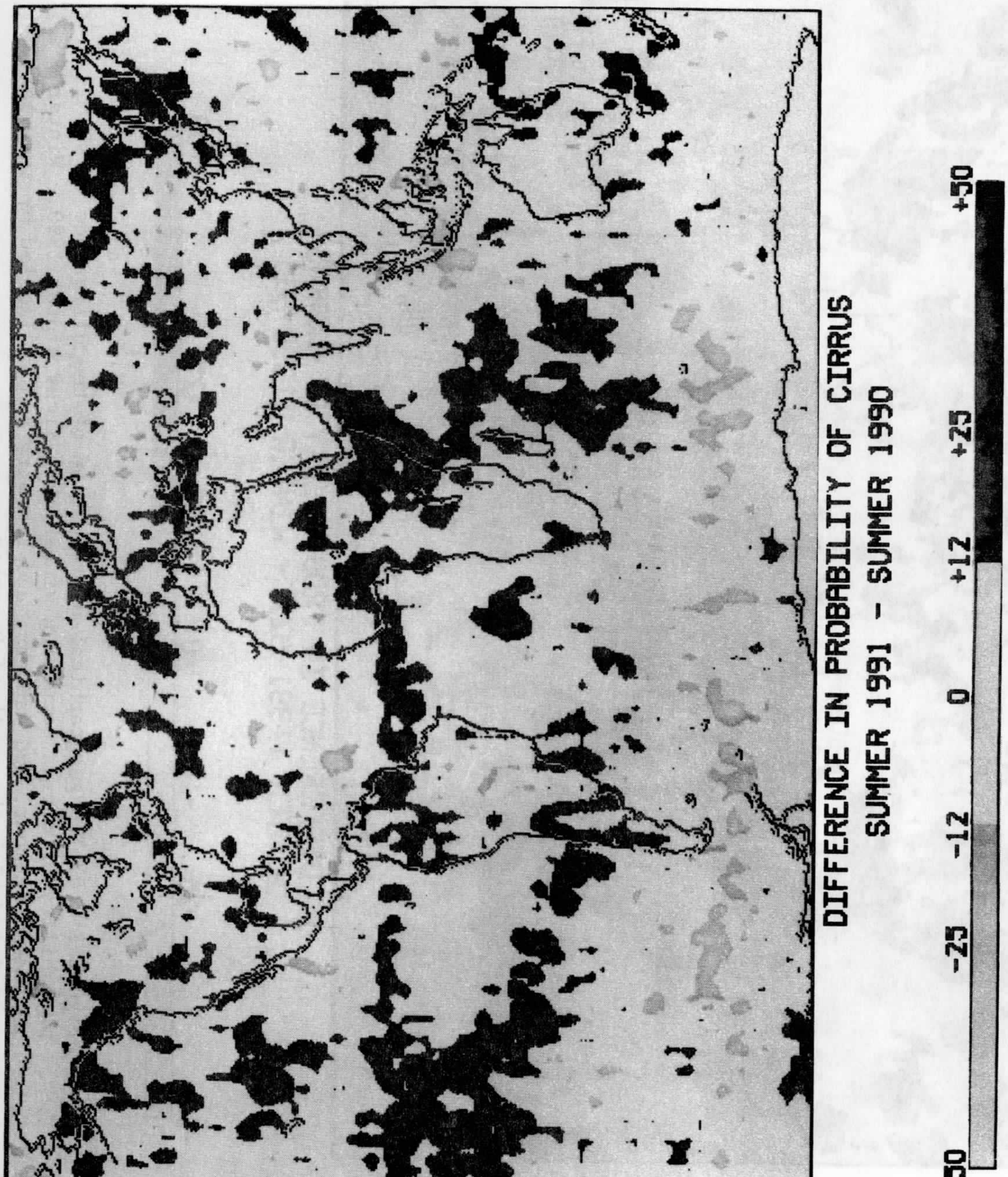

Figure 2: (c) The geographical distribution of the difference in the probability of cirrus occurring summer 1991 minus summer 1990. Summer includes June, July, and August.

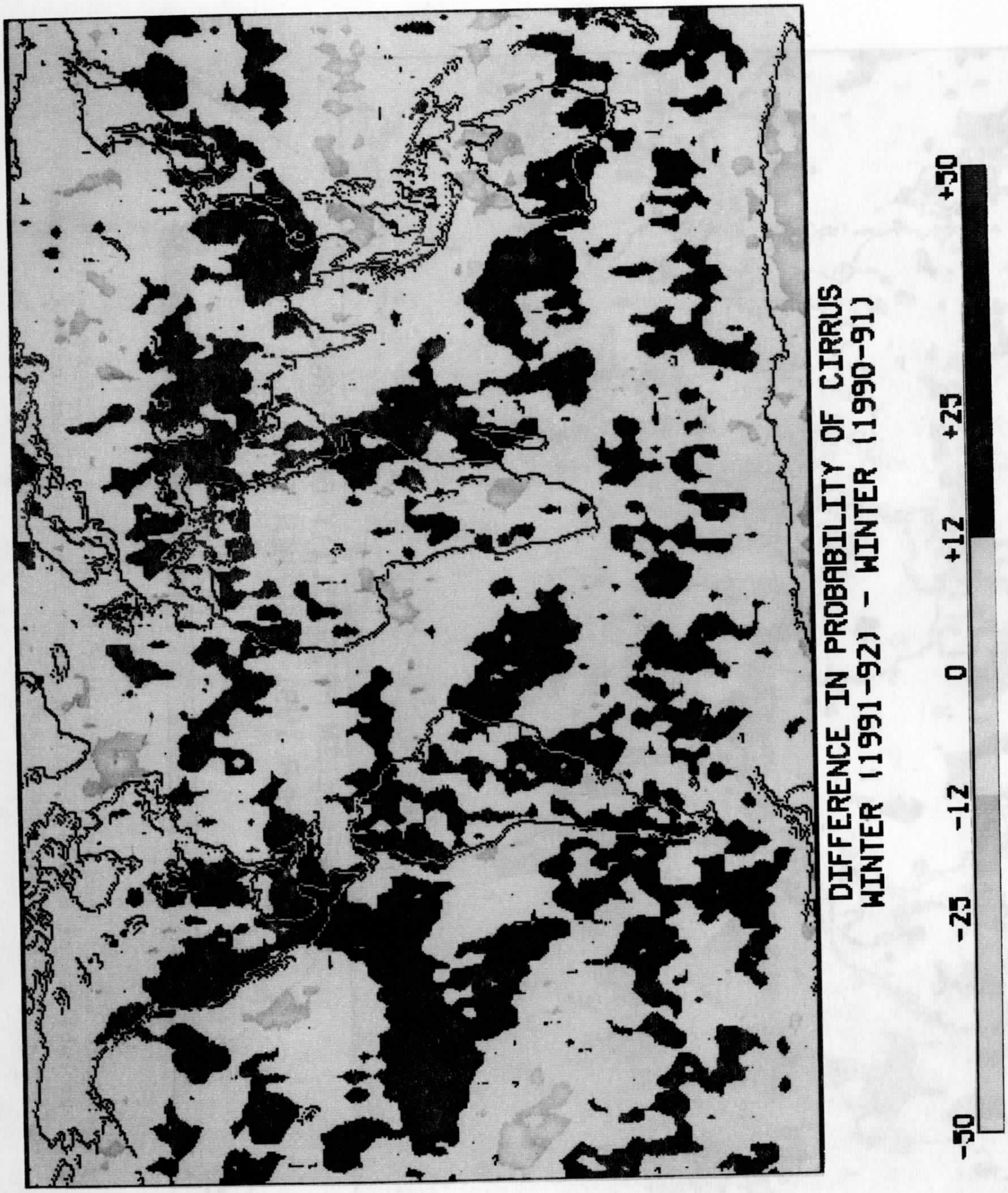

Figure 2: (d) The geographical distribution of the difference in the probability of cirrus occurring winter 1991 minus winter 1990. Winter includes December, and January, and February and is labeled by the year associated with the month of December.

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