MAGNETIC CLASSIFICATION OF ACTIVE REGIONS*

SARA F. SMITH
(Lockheed Solar Observatory, Burbank, Calif., U.S.A.)

and

ROBERT HOWARD
(Mount Wilson and Palomar Observatories; California Institute of Technology, Pasadena, Calif., U.S.A.)

ABSTRACT

All the active regions observed on the Sun with the Mount-Wilson magnetograph between August 1959 and December 1962 have been given magnetic classifications in a system similar to the Mount-Wilson sunspot-classification scheme. The flare productivity of regions classified as unipolar, bipolar, and complex bipolar, as well as regions composed of multiple bipolar components has been studied. It has not been necessary to provide a classification corresponding to the γ class of sunspots. Although the relatively poor angular resolution employed in the magnetograms limits somewhat the accuracy of the data, it is clear that both complex bipolar regions and regions with multiple bipolar components produce more than three times the number of flares than the simple bipolar regions produce. The most flare-productive class of regions is the reversed polarity complex classification.

The statistical relation of the spot magnetic-field classification to the classification of the corresponding plage fields has been studied and found to be poor for these data.

The distribution of the magnetic regions in latitude shows that many of the regions with polarities reversed from the usual orientation are confined to the equatorial zone.

1. Introduction

In 1963, we began a project of studying and classifying magnetic regions and comparing these magnetic regions with sunspots, plages, and flares. The Mount-Wilson magnetograms used in this study were the whole disk daily maps made during the period August 1959 to December 1962. These magnetograms contain the longitudinal field component below about 100 gauss, and have a resolution of 23 sec of arc.

A system for classifying magnetic regions similar to the one we adopted for this work was devised independently by Martres, Michard, and Soru-Iscovici in 1966 based on observations made at Meudon. The Martres, Michard, and Soru-Iscovici system is surprisingly similar to ours, even though they were working primarily with magnetic-field measures of sunspots, and bright plage while we were working with magnetograms of plage and surrounding weaker fields.

Initially, we tried to adapt the Mount-Wilson classification system for sunspot groups to the weak fields observed on the magnetograms. After applying this system to

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several months of data, it became evident that the system did not adequately distinguish the situations observed in weak fields of low resolution. Therefore, a modified system employing new definitions was developed. All of the regions observed between August 1959 and December 1962 were studied using the modified sunspot group-classification system. After gaining additional familiarity with the characteristics of magnetic regions and their correspondence with plages, still other modifications to the classification scheme seemed to be desirable.

2. The Classification of Regions

The system which we discuss in this paper, we have found to be a practical one, although it is likely that we will make more modifications to it in the future. This system is described in Table 1 and illustrated in Figures 1 and 2. In this system all

Table 1

Magnetic Region Classifications

Designation	Definition
B	Simple bipolar region
BC	Simple bipolar region with one polarity partially encircling the opposite polarity
BS	A simple bipolar region with an area of opposite polarity embedded in one or both of the main bipolar components of the region
BY	Bipolar region with a peninsula of one polarity extending into the opposite polarity
BCS	Bipolar region with the characteristics of both a BC and a BS region.
BYS	Bipolar region with the characteristics of both a BY and a BS region.
BB	Two adjacent simple bipolar regions *not* clearly distinguishable as separate plages
BBC	A BB region with any of the C, Y or S characteristics
B–B	Two adjacent simple bipolar regions distinguished as separate plages
BCB	Two adjacent bipolar regions which were distinguished as separate plages but including any of the C, Y, or S characteristics
BBB	Three closely spaced B regions of any complexity
X	No classification given – poor data

Greek and lower-case letter designations have been replaced with Roman capital letters which are compatible with computer languages. In Figure 1, solid lines represent positive polarity and dashed lines represent negative polarity. In the upper left corner of the figure is an example of the most common class of magnetic region associated with plages. The letter designation is B meaning simple bipolar region. This class corresponds exactly to the Sn class in the Martres, Michard, Soru-Iscovici system (MMS). In the upper right of Figure 1, BC represents a bipolar region in which one polarity is partially encircled by the opposite polarity. This situation often occurs when a new region develops in a much older region and, therefore, corresponds most

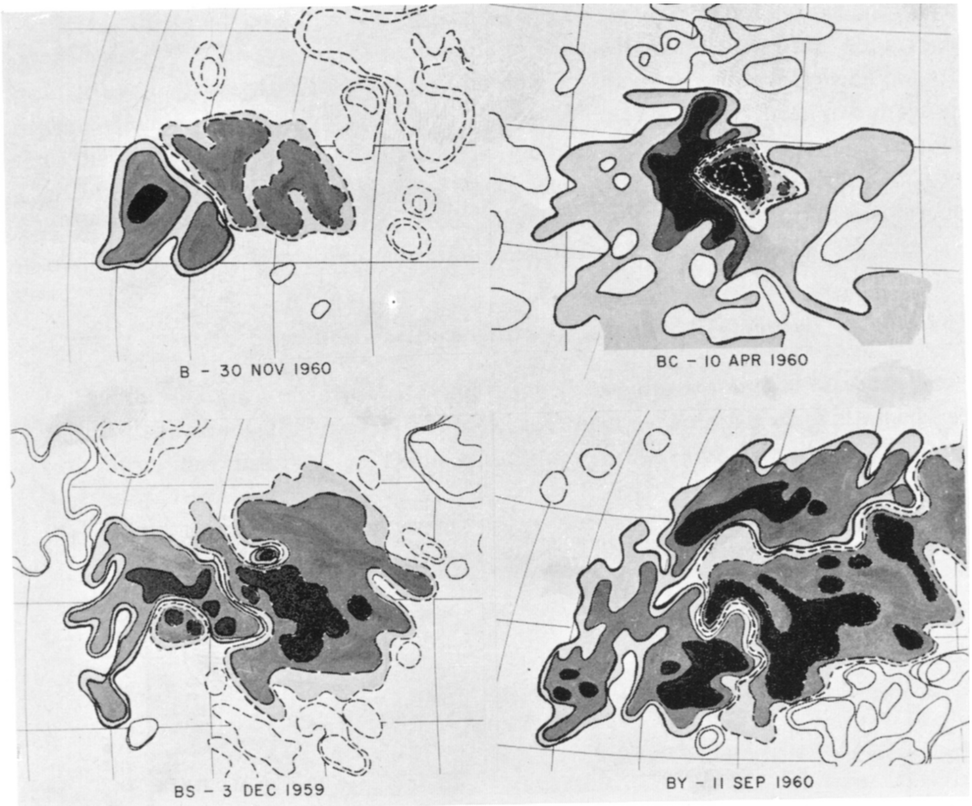

FIG. 1. *B = bipolar region; C = one polarity partially encircling opposite polarity; S = island of one polarity amidst opposite polarity; Y = a peninsula of one polarity extending into opposite polarity.*

closely to the Ca class in the MMS system. In the lower left of Figure 1, BS represents a bipolar region with one or more islands of opposite polarity in either the leading or following polarity of the region. This class is exactly analogous to the Cp class in the MMS system. The example of the BY class in the lower right of Figure 1 is a region in which a peninsula of one polarity extends into the opposite polarity. There is no exact equivalent for the BY class in the MMS system. We also use BCS and BYS designations to refer to a more complex situation. There are no counterparts for these in the MMS system.

Figure 2 shows three examples of 'multiple bipolar regions'. These are two or more bipolar regions which are sufficiently close together that at least at some time during the disk passage, they are considered to be one plage. In the upper left BB represents two simple bipolar regions. In the upper right BBB is used to designate three or more regions of any degree of complexity found in B, BC, BS, and BY regions. In the lower left BBC refers to a double bipolar complex region, also with any of the degrees of

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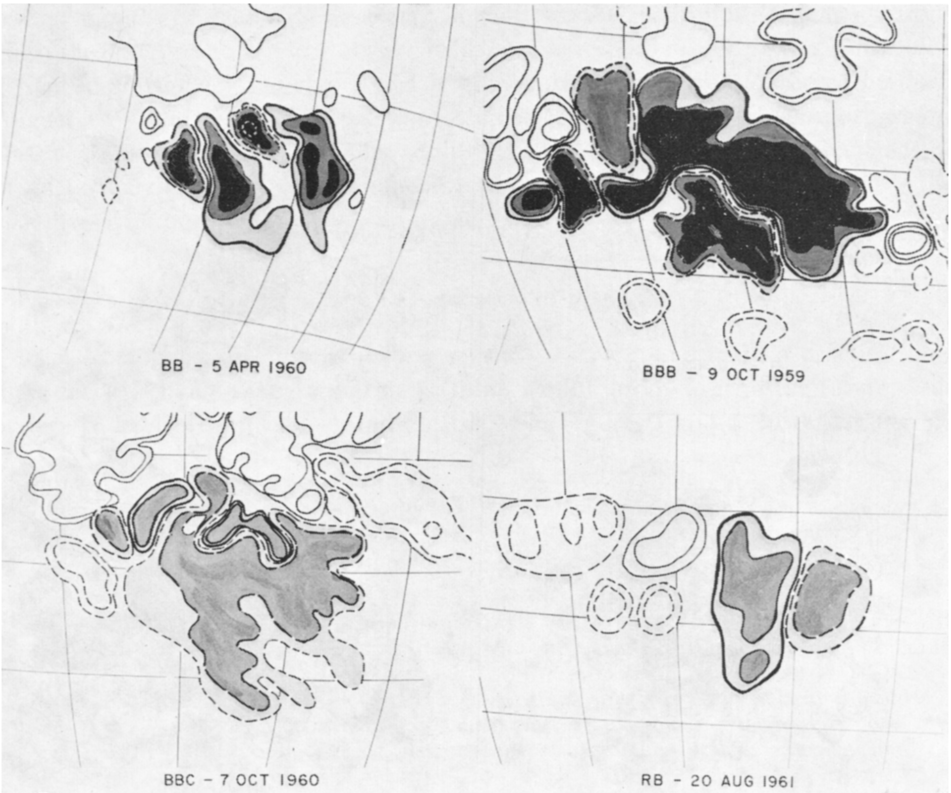

FIG. 2. *BB* = *two adjacent bipolar regions; BBB* = *three adjacent bipolar regions; BBC* = *two adjacent bipolar regions more complex than a BB region; RB* = *reversed polarity simple bipolar region. All of these regions appeared in the Southern Hemisphere.*

complexity as in the examples in Figure 1. Lastly, in the lower right RB stands for a simple reversed polarity magnetic region. All of the regions in Figure 2 are Southern-Hemisphere regions so that the interchanged polarities of this region are shown in comparison with the normal configuration for this hemisphere and solar cycle. Reversed polarity regions appear to be similar to all other regions except for this polarity reversal. Reversed polarity regions may be of any degree of complexity. They were isolated in this classification system by placing an R in front of the regular classification.

In addition to these classes of magnetic regions there are also positive and negative 'A' regions or areas of single polarity. In all known cases these regions are simply old remnants of bipolar regions. An 'A' region as defined here is an isolated feature of one polarity and bears no relation to the UM regions observed on synoptic charts. Also, a large number of regions were classified as X to indicate the classification was unknown because of poor data.

The MMS system contains two classes, Si and Cγ, which are not equivalent to any of the classes in our system. Si represents regions whose polarities are abnormally inclined such as those in which the leading polarity is North of the following polarity instead of West of the following polarity. This would be a good addition to our system since these regions would consist of an intermediate class between B and RB regions. The Cγ class in the MMS system is a region, like the Mount-Wilson γ class of sunspots, having the polarities very mixed. Since we have several more classes for describing complex configurations we find no need for such complex γ class.

3. Statistical Characteristics of Magnetic Regions

In Figure 3 is shown the distribution of magnetic regions among the various classes. All the classifications discussed in this paper are the most complex class attained by a region during one disk passage. Positive and negative A regions are the most numer-

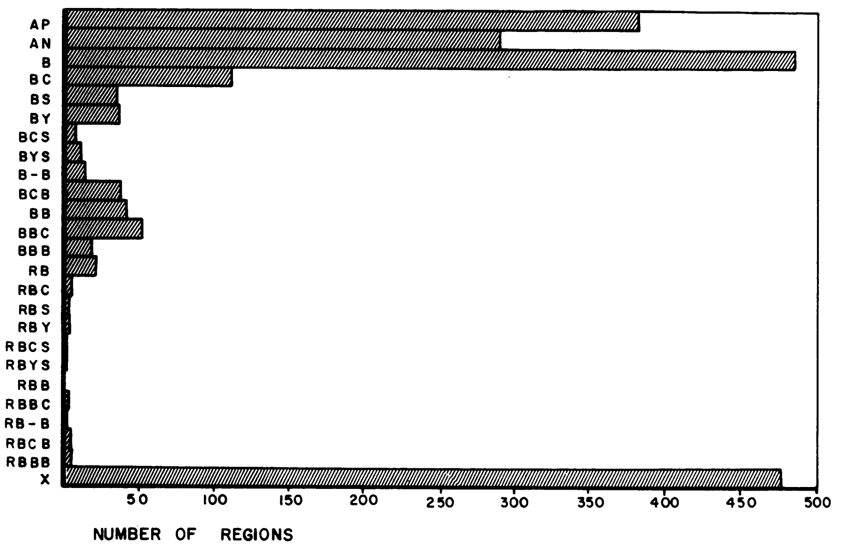

FIG. 3. *Distribution of magnetic regions by classification. Simple bipolar regions, B and BC, are the most common classes of young regions. AP and AN regions are remnants of old bipolar regions. Reversed polarity regions begin with R. X refers to regions not classified because of poor data.*

ous. Next in frequency are simple bipolar regions, B and BC. The complex regions BS, BY, BYC, and BCS comprise only 10% of the entire sample of over 1600 regions classified other than X or A, and are outnumbered by regions composed of multiple bipolar units which comprise 19% of the sample. Least frequent are reversed polarity regions which altogether comprise less than 5% of the sample.

In Figure 4, we compare the relative distribution of sunspot groups with the distri-

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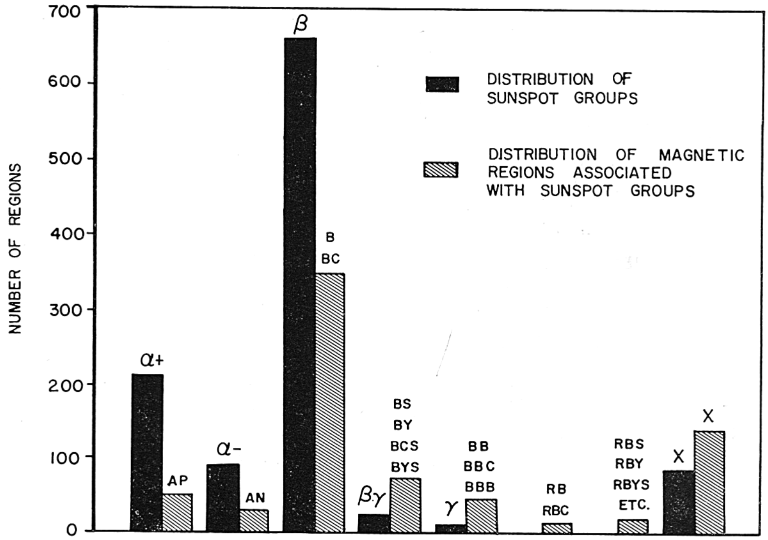

FIG. 4. *Distribution of magnetic regions associated with sunspots compared to the distribution of sunspots. Sunspot classes do not correspond exactly to the magnetic-region classes. It is evident, however, that the magnetic regions contain a larger percentage of complex regions than the sunspot data.*

bution of only those magnetic regions associated with sunspot groups. In this graph the magnetic regions are combined into the categories which most nearly correspond to the sunspot-group classifications. For the classes $\alpha+$, $\alpha-$ and β, the sunspot regions far outnumber the magnetic regions of similar class which are associated with sunspots. However, in all of the complex classes, the complex magnetic regions outnumber the complex sunspot groups. There were no sunspots groups classified as reversed for an entire disk passage during this period. It is evident from this graph that there is not a 1:1 correspondence between sunspots classes and magnetic regions classes.

A great many magnetic regions are associated with more than one sunspot group. The actual correlation between sunspots and magnetic regions is depicted in Figures 5 and 6. First, in Figure 5, we consider those cases in which there was only one sunspot group per magnetic region. On the horizontal axis in Figure 5, the sunspot classes are shown in five groups. β, βp, and βf are all simple bipolar regions. Because there are so few $\beta\gamma$ and γ spot groups we consider them together as complex sunspot groups. $\alpha+$ and $\alpha-$ are considered together as unipolar sunspots. There were no reversed polarity spots in this sample even though there were 37 reversed polarity magnetic regions. Lastly, there are some classified as X for unknown because of lack of data.

On the vertical axis is the distribution of sunspot classes among similar groupings of the magnetic region classes. The primary reason for this arrangement is to show that the correlation between sunspot classification and magnetic-region classifi-

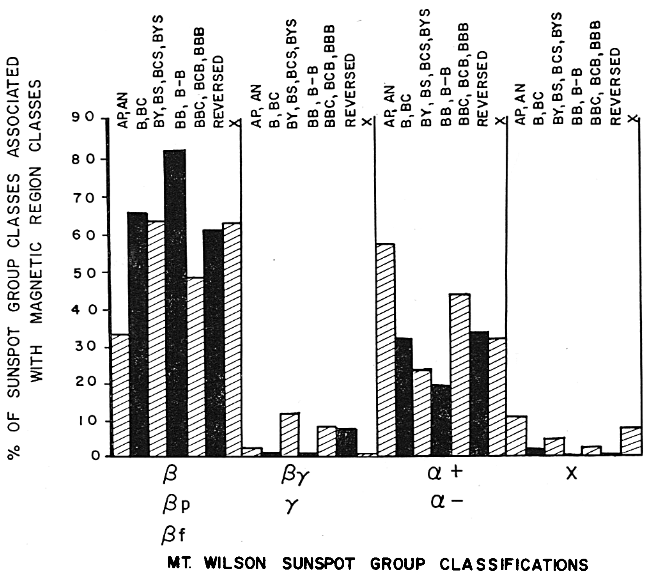

FIG. 5. *Distribution of sunspots groups among groups of magnetic-region classes for only those cases in which one sunspot group corresponded to one magnetic region. Complex sunspot groups tend to be associated with complex magnetic regions but the converse is not true.*

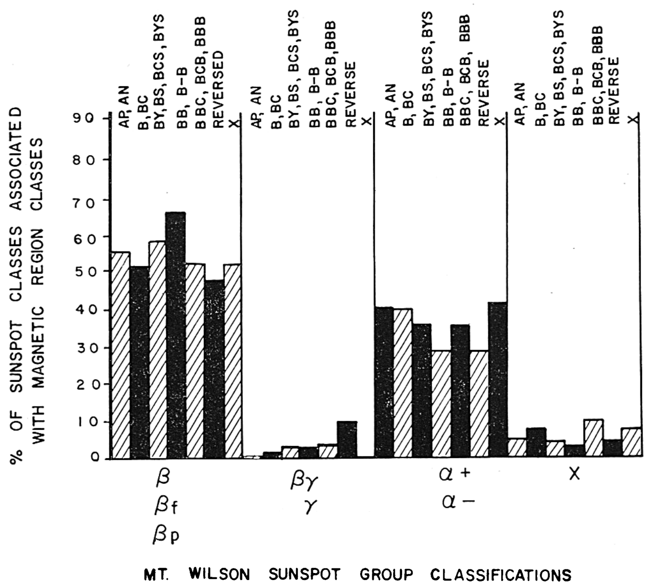

FIG. 6. *Distribution of sunspot groups among groups of magnetic regions for those cases in which more than one sunspot group corresponded to one magnetic region. The correlation between sunspot classification and magnetic-region classification is seen to be poor.*

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cation is poor. Excluding the 'A' magnetic region classification, approximately 60% of the sunspots groups associated with any magnetic region class are simple bipolar groups; approximately 30% are unipolar spots groups; and 10% or less are complex sunspot groups. The large number of AP and AN regions among the β-sunspot classes may also be due in part to instrumental errors.

In addition, in Figures 5 and 6, there are a few significant details. Although the number of complex sunspot groups, $\beta\gamma$ and γ, is relatively small, it is clear that these groups are almost invariably associated with complex magnetic-region classes, rather than with the simple classes labeled AP, AN, B, or BC. When we consider the cases as in Figure 6 in which more than one sunspot group is associated with one magnetic region, the degree of correlation is even less, as is evidenced by the more uniform height of each bar within each sunspot group. The sunspot group classes are averages for a complete disk passage. The magnetic-regions classes are the most complex class for a complete disk passage of the features. A preferable way to make such a correlation would be to use daily classifications rather than single values for a disk passage.

Figure 7 shows the distribution of flares of various importances among the magnetic-regions classifications. In this figure, flare productivity represents the total number of flares of each importance per region, where it is understood that one region represents

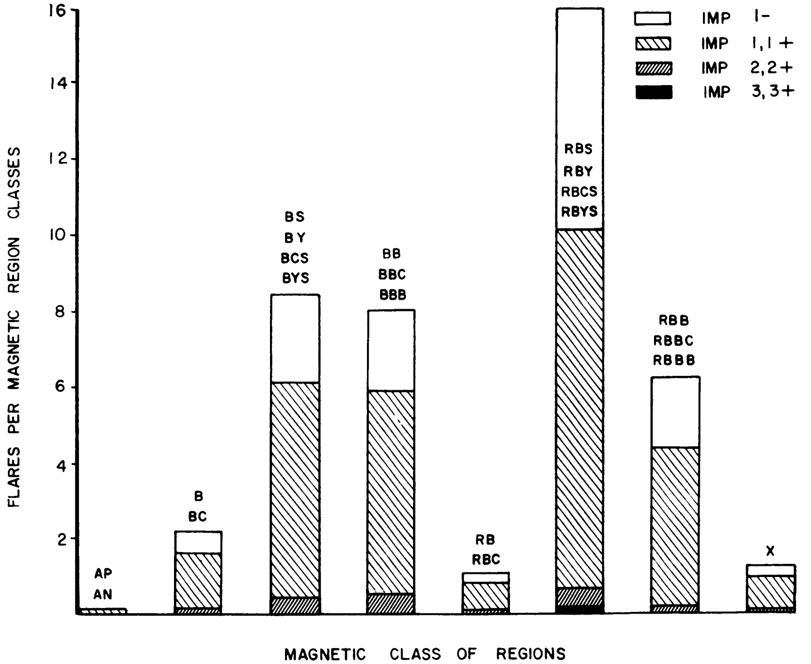

FIG. 7. *Complex reversed polarity magnetic regions were the most flare-productive regions during this period, Aug. 1959 to Dec. 1962. All complex regions were three times as flare productive as simple bipolar regions B, BC, and RB, RBC.*

one disk passage of a magnetic feature. Only the importance-I flares can be considered to be a reliable statistical sample. Most important to note in this figure is that the reversed polarity complex regions are by far the most flare-productive region classification. This gives us another important parameter in the search for tools for flare prediction. Also important are the complex bipolar regions and multiple bipolar regions which are seen to be approximately three times as flare productive as simple bipolar regions.

We investigated the latitude dependence of regions of various classifications. Some of these results are shown in Figure 8. A feature to note is the distribution of reversed polarity regions relative to B regions. The mean latitude in the North or the South for the reversed regions is definitely shifted toward the equator. The preponderance of Northern-Hemisphere regions is reflected in all of the magnetic classes except for the

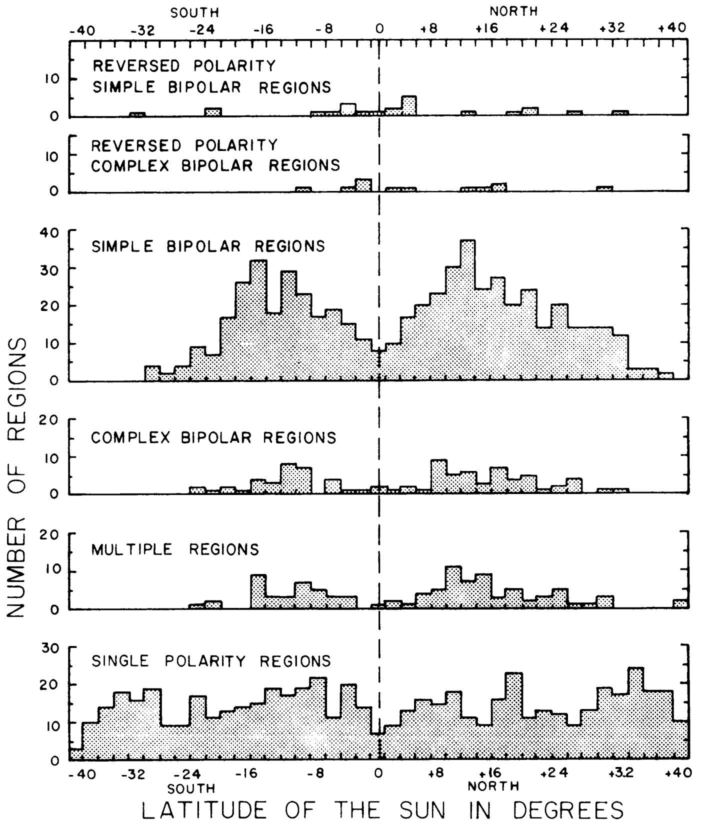

FIG. 8. *Distribution of magnetic regions on the sun, Aug. 1959 – Dec. 1962. Reversed polarity magnetic regions are the only class of magnetic regions which tend to occur most frequently within 10° of the solar equator.*

A (unipolar) regions. 'A' regions have a uniform distribution which extends to higher latitudes than the distribution of sunspots.

It should be noted again that the classifications given in this paper are maximum-complexity classifications for the disk passage of the regions. It would be better to study flare productivity and sunspot correlations using *daily* magnetic-region classifications. We plan further studies using more recent magnetic-field data which are of better quality.

References

Martres, M.J., Michard, R., Soru-Iscovici, I. (1966) *Ann. Astrophys.* **29**, 245.

DISCUSSION

Bumba: Does your classification system contain the stage of evolution of active regions, for example the maximum stage?

Sara Smith: This classification system is based only on the appearance of regions and not on the way regions evolve. Since the classifications were assigned for each day's observations, the evolution of regions can be studied using these classifications. However, the diagrams in this paper employ the most complex classification attained during each disk passage of all regions observed during the period August 1959 to December 1962.

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