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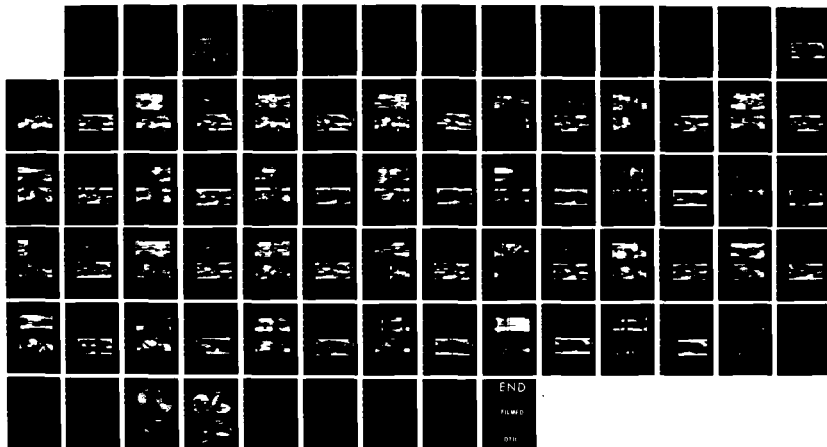
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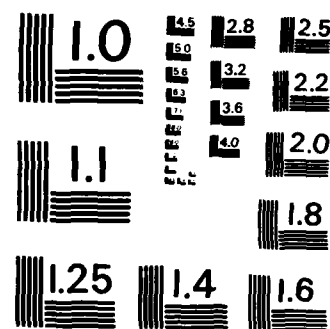
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NCAR/TN-251+STR  
NCAR TECHNICAL NOTE

March 1985

# Solar Coronal White Light, Fe X, Fe XIV and Ca XV Observations during 1984

## An Atlas of Synoptic Charts

D.G. Sime and  
R.R. Fisher, NCAR  
R.C. Altrock,  
Air Force Geophysical Laboratory

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## REPORT DOCUMENTATION PAGE

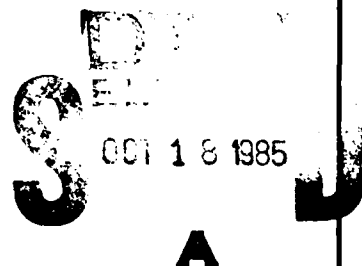
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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------|
| 1a. REPORT SECURITY CLASSIFICATION<br><b>Unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                    | 1b. RESTRICTIVE MARKINGS                                                                         |                             |
| 2a. SECURITY CLASSIFICATION AUTHORITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    | 3. DISTRIBUTION/AVAILABILITY OF REPORT<br>Approved for public release;<br>Distribution unlimited |                             |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                    | 5. MONITORING ORGANIZATION REPORT NUMBER(S)                                                      |                             |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S)<br><b>AFGL-TR-85-0234</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    | 7a. NAME OF MONITORING ORGANIZATION                                                              |                             |
| 6a. NAME OF PERFORMING ORGANIZATION<br><b>Air Force Geophysics Laboratory</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 6b. OFFICE SYMBOL<br>(If applicable)<br><b>PHS</b> | 7b. ADDRESS (City, State and ZIP Code)                                                           |                             |
| 6c. ADDRESS (City, State and ZIP Code)<br><b>Hanscom AFB<br/>Massachusetts 01731</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                    | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER                                                  |                             |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 8b. OFFICE SYMBOL<br>(If applicable)               | 10. SOURCE OF FUNDING NOS.                                                                       |                             |
| 8c. ADDRESS (City, State and ZIP Code)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                    | PROGRAM ELEMENT NO.<br><b>61102F</b>                                                             | TASK NO.<br><b>G3</b>       |
| 11. TITLE (Include Security Classification) <b>Solar Coronal White Light, Fe X, Fe XIV, and Ca XV Observations</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                    | PROJECT NO.<br><b>2311</b>                                                                       | WORK UNIT NO.<br><b>24</b>  |
| 12. PERSONAL AUTHOR(S) <b>During 1984<br/>D. G. Sime, R. R. Fisher, R.C. Altrock</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                    |                                                                                                  |                             |
| 13a. TYPE OF REPORT<br><b>REPRINT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 13b. TIME COVERED<br>FROM _____ TO _____           | 14. DATE OF REPORT (Yr., Mo., Day)<br><b>1985 October 7</b>                                      | 15. PAGE COUNT<br><b>71</b> |
| 16. SUPPLEMENTARY NOTATION<br><b>Reprinted from National Center for Atmospheric Research Technical Note Number TN-251+STR,<br/>Boulder, CO, March 1985</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                    |                                                                                                  |                             |
| 17. COSATI CODES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                    | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)                |                             |
| FIELD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | GROUP                                              | SUB GR.                                                                                          |                             |
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| 19. ABSTRACT (Continue on reverse if necessary and identify by block number)<br>Synoptic observations of the solar corona in white light and in three emission lines (Ca XV at 5964 Å, Fe XIV at 5303 Å, and Fe X at 6374 Å) were carried out during most of 1984 at the High Altitude Observatory's Mauna Loa Solar Observatory and at Sacramento Peak Observatory. These observations were partly in support of the scientific program of the repaired SMM spacecraft. The observations provide a record of the distribution of the density of the corona as well as the distribution and brightness of the hotter regions of the corona over the year. We present these data in the form of synoptic maps for each rotation during the year for the purpose of providing a context for the investigations which are to take place during the Joint Study of Coronal and Prominence Plasmas, organized by Goddard Space Flight Center/NASA. In this way, we propose both to describe the data coverage achieved and summarize the large scale properties of the corona in this late descending phase of the solar cycle. |                                                    |                                                                                                  |                             |
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> OTIC USERS <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    | 21. ABSTRACT SECURITY CLASSIFICATION<br><b>Unclassified</b>                                      |                             |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                    | 22b. TELEPHONE NUMBER<br>(Include Area Code)                                                     | 22c. OFFICE SYMBOL          |

March 1985

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## PREFACE

Synoptic observations of the solar corona in white light and in three emission lines ( Ca XV at 5964 Å, Fe XIV at 5303 Å, and Fe X at 6374 Å ) were carried out during most of 1984 at the High Altitude Observatory's Mauna Loa Solar Observatory and at Sacramento Peak Observatory. These observations were partly in support of the scientific program of the repaired SMM spacecraft. The observations provide a record of the distribution of the density of the corona as well as the distribution and brightness of the hotter regions of the corona over the year. We present these data in the form of synoptic maps for each rotation during the year for the purpose of providing a context for the investigations which are to take place during the Joint Study of Coronal and Prominence Plasmas organized by Goddard Space Flight Center/ NASA. In this way, we propose both to describe the data coverage achieved and summarise the large scale properties of the corona in this late descending phase of the solar cycle.

D. G. Sime, R. R. Fisher

and R. C. Altrock

March 1985.

High Altitude Observatory

and National Solar Observatory

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## I. INTRODUCTION

The purpose of this Note is to describe and present synoptic observations of the solar corona as a context for the detailed study of coronal and prominence plasmas. We present synoptic maps, from 1984, of the white light and emission line corona in a fashion which permits the easy comparison with other data sets so that the scientific potential of the data returned from the repaired SMM spacecraft can be enhanced.

The data consist of maps of the white light corona observed with the High Altitude Observatory's (HAO's) Mk-III K-coronameter on Mauna Loa and monochromatic data (Ca XV at 5964 Å (yellow), Fe XIV at 5303 Å (green), and Fe X at 6374 Å (red)) gathered with the photoelectric coronal photometer at the National Solar Observatory at Sacramento Peak (NSO). The white light data shows the overall distribution of density in the corona, and is reported here for the height of  $1.3 R_{\odot}$ . The emission line data, taken at a height of  $1.15 R_{\odot}$ , trace the distribution of coronal ions radiating at particular wavelength bands and as a result represent the distribution of material at particular temperatures. In general, this emission comes from regions of the corona with elevated temperatures; the red line from regions of about  $1.5 \times 10^6$  K, the green line from about  $1.8 \times 10^6$  K, and the yellow line from about  $5.0 \times 10^6$  K (Billings, 1966). Thus the brightest areas of the line emission are believed to trace out those parts of the corona heated by chromospheric active regions, although other features are also seen in these observations, including coronal holes. However, the overall relationship of structures seen in these lines to other coronal structures has never fully been examined. With this Note, we provide a tool to explore this relationship more completely.

The white light data from the Mk-III K-coronameter have been displayed in a series of atlases (eg., Fisher et al., 1982) which show the distribution of the coronal polarized brightness with position angle and time as a series of maps showing one Carrington rotation at time. Here we present, along with the white light observations and in the same format, the record of the distribution of the red, green and yellow line radiance in heliographic latitude and Carrington longitude.

## II. DESCRIPTION OF THE INSTRUMENTATION

The emission line data presented in this Note were gathered with the National Solar Observatory, Sacramento Peak, photoelectric coronal photometer operating on the 40 cm. coronagraph. Mica filters are used to isolate the emission lines. For the green line filter (5303 Å) the full width at half maximum (FWHM) is 0.65 Å, while for the red and the yellow (6374 and 5964 Å respectively), the FWHM are 0.73 and 0.65 Å. A piezo-electric modulator is used to chop between the central bandpass and the nearby continuum in order to remove the contribution of the continuum at this wavelength.

Data are collected by scanning a 1.1 arcmin. diameter aperture in position angle at one of a set of selected heights (.15, .35, .45 or .55  $R_{\odot}$ ) above the limb. Data are gathered at points separated by  $3^{\circ}$  in position angle. In this Note, we present only the data taken at 1.15  $R_{\odot}$ . The data are collected on magnetic tape for later analysis. At the time of these observations, the control of the instrument and of the data collection was handled by a PE 3220 computer. The instrument and its operation are described more fully by Fisher (1973) and Smartt (1982). An example of the data collected is shown in Fisher and Musman (1975).

The white light data were gathered using the HAO Mk-III K-coronameter on Mauna Loa. This instrument records 2-dimensional images of the distribution of coronal polarized radiance by scanning a radially aligned linear detector through position angle. Several data displays are available to the observer for the purposes of real time quality control, and the main data stream is captured on tape. This instrument and its operation have been described by Fisher et al. (1981).

### III. DATA REDUCTION AND PRODUCTS

Daily data scans have been examined for quality, and freedom from artifacts and then collected on tape for further processing. The contents of the emission line data tapes have then been reformatted to appear similar to the data collected by HAO's Mk-III K-coronameter. This allows easy application of much of the software written to manipulate and analyze the white light data. In particular, for this Note the data were then reduced to the synoptic map format by the algorithms originally developed for the HAO synoptic white light corona data collected at MLSO. These algorithms have been described by Garcia and Seagraves (1983). Here we discuss the three data products presented in this Note; the synoptic map, the SHELL, and the integrated brightness values.

The format of the synoptic map display is similar to that used in the recent Atlases of the white light data (Fisher et al., 1982). Each day's position angle scan from 0 to 180 degrees is assigned the Carrington longitude of the East limb of the sun for the time of the observation. The data are then inserted at the appropriate position in a rectangular grid representing solar latitude and longitude organized into Carrington rotations. Similarly, the other part of the scan, from 180 to 360 degrees, is used to construct a map based on observations of the West limb. The day number of limb passage for each observation is indicated below each map at the appropriate longitude, while days when no data are present are marked by a cross instead of a day number. For simplicity, only even day numbers are shown, although every day on which no data are available is indicated. Where data are absent, the contour plotting routine has been allowed to interpolate across the gap in order to preserve some indication of the nearby large scale structure. However, these periods should be used only with great caution and, especially when comparisons are made to other solar data, care should be taken to see that data actually exist.

The SHELL format provides a display of coronal data which perhaps makes the direct comparison with disc images easier. It is formed by projecting the synoptic map onto a spherical surface representing the height at which the data were taken. Thus the data appear as they would in the event that the corona could be observed against the disc instead of only at the limb. As with

the synoptic maps, use of the SHELLS involves an implicit assumption that the corona is stable from the time it is observed (at the limb) until the CMP date for the SHELL plot, and even up to the succeeding limb passage; a period of up to 14 days.

One other data product which has been of value in the past is the integrated brightness measure. This is simply the integral of the SHELL, and can be thought of as indicating the total brightness of the corona in the line observed (for the monochromatic data) or a measure of the total mass of the corona (in the case of the white light data). This represents an overall measure of the state of the corona and can be used as a global description of the evolution of the corona through the solar cycle (Fisher and Sime, 1984). It also represents the signal which would be observed if the solar corona was viewed unresolved, as from the vicinity of another star (Fisher et al, 1983).

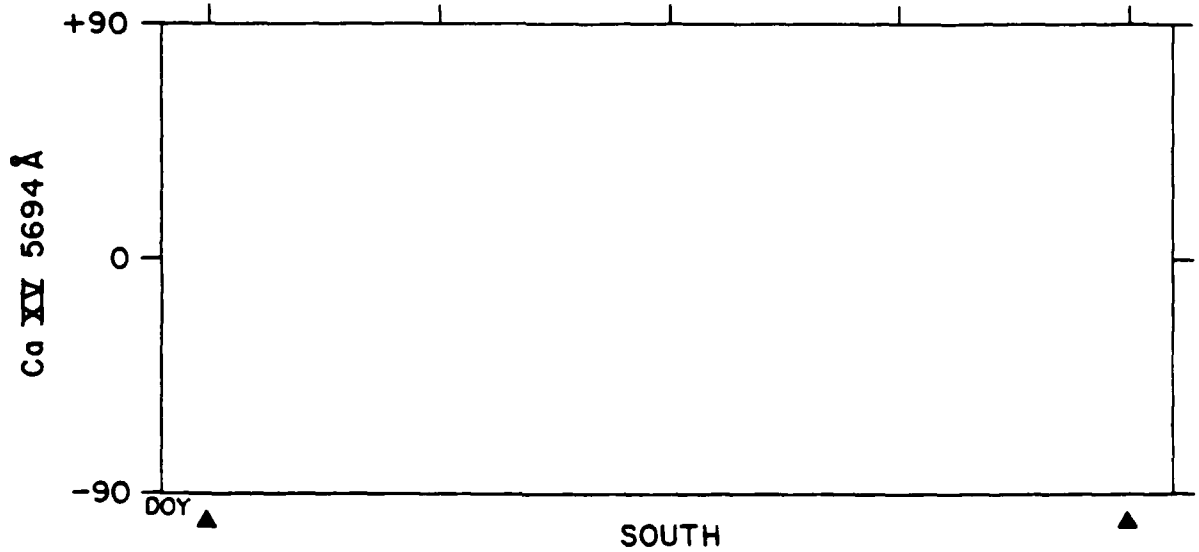
#### IV. SYNOPTIC MAPS OF THE GREEN LINE CORONA

The data are shown in this section as rectangular maps of each Carrington rotation from Jan 1984 (rotation 1744) to December 1984 (rotation 1756). On each page, the map of the yellow line observations is shown at the top, with the green line map below, followed by the red line data and finally, at the bottom of the page, the white light map. The emission line data are shown in millionths of the brightness of the center of the solar disc at the corresponding bandpass, while the white light data are shown as polarized brightness in units of  $10^{-8} B_{\odot}$ . On each page, a legend is shown which gives the values of radiance for each of the shading and contour levels shown on that page. Left hand pages show the data observed on the East limb, while data from West limb observations are shown on right hand pages.

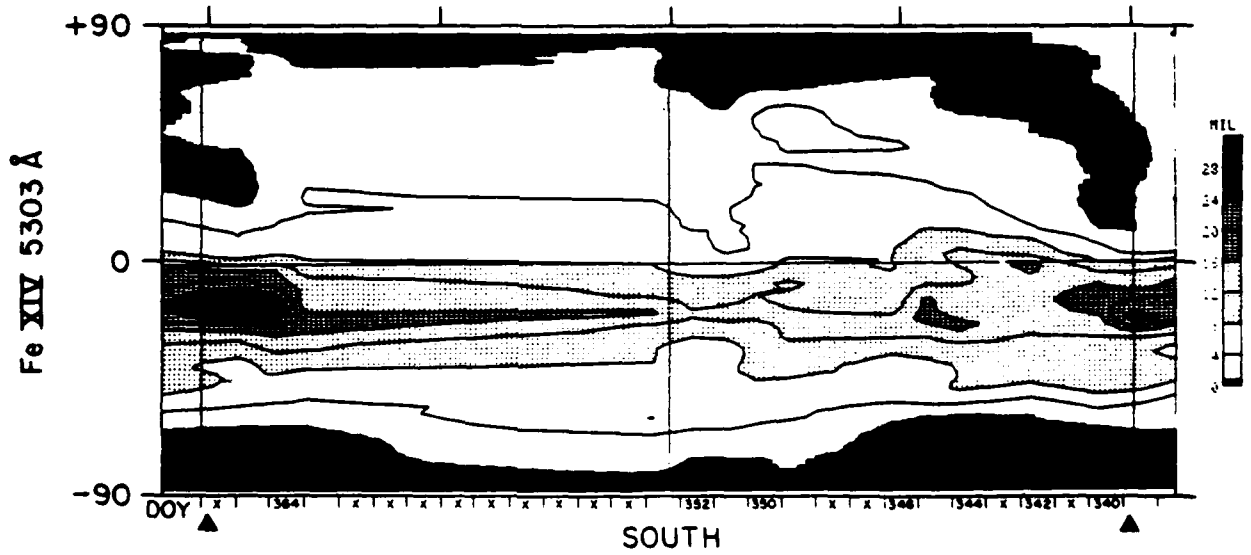
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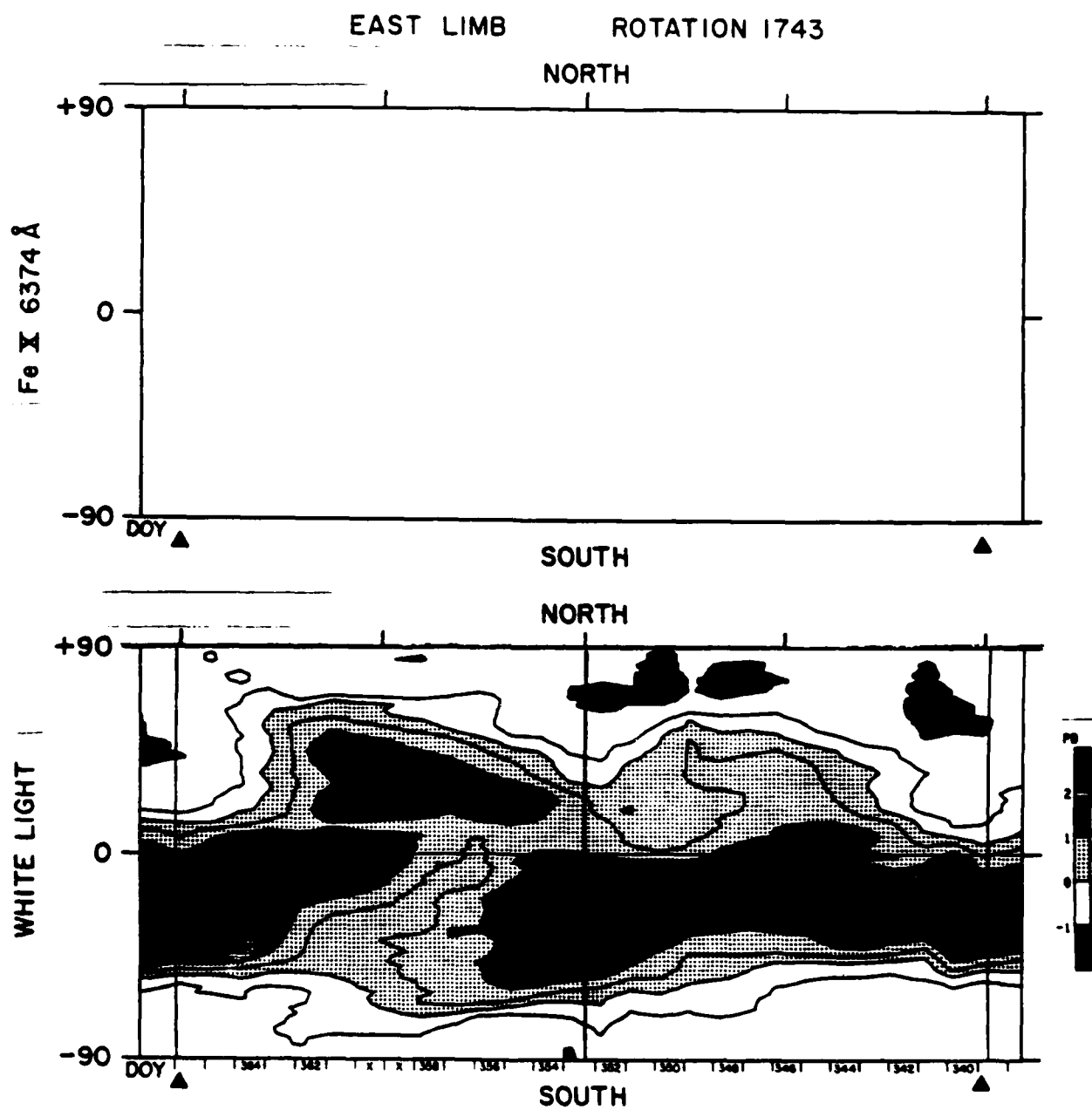
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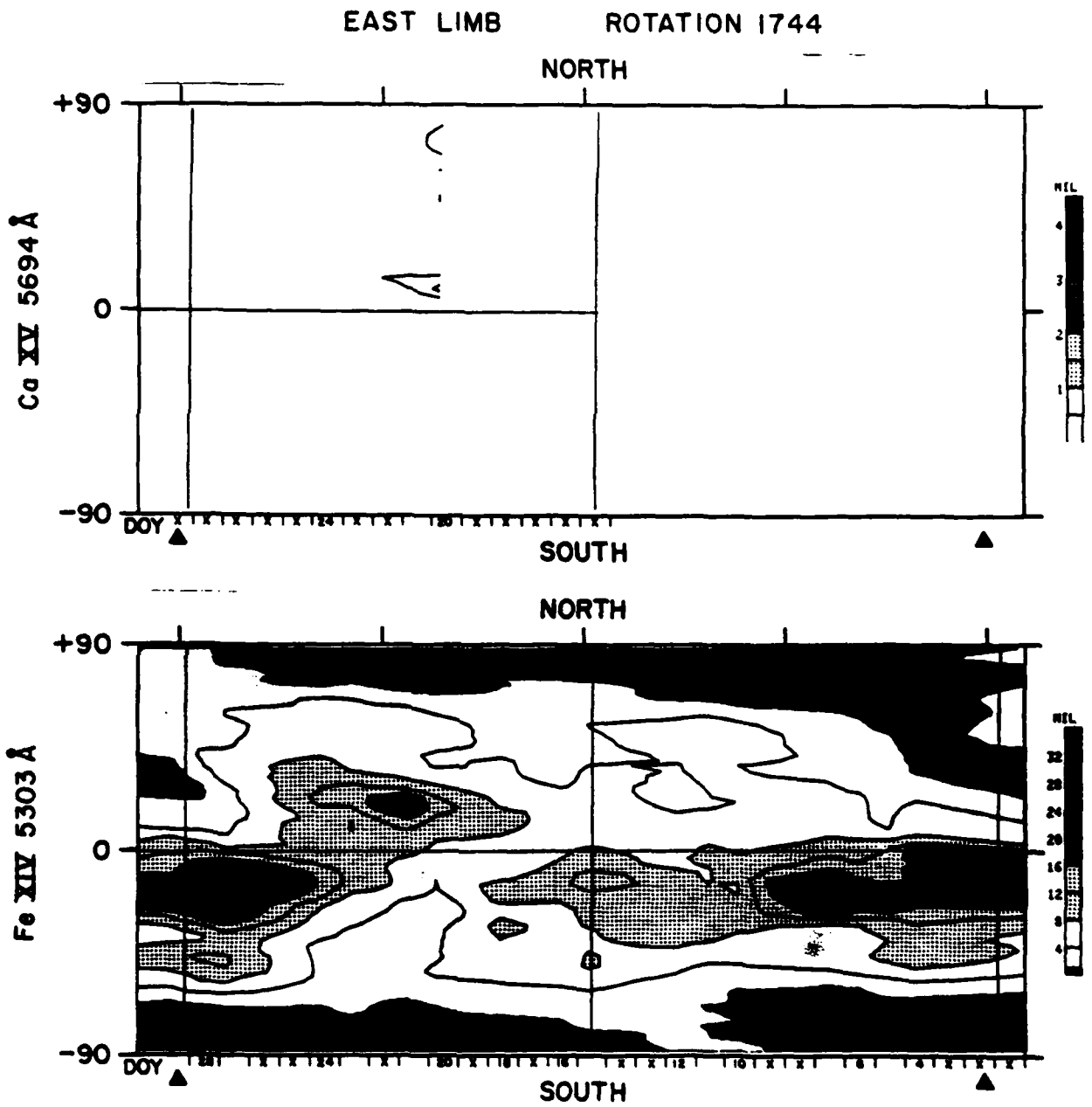
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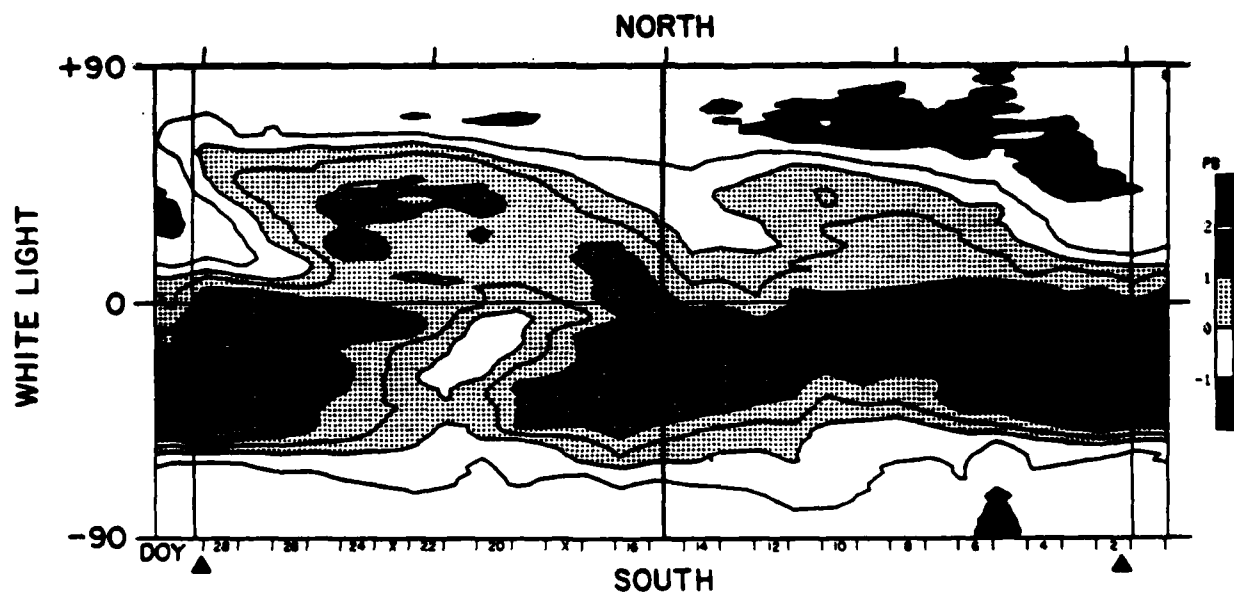
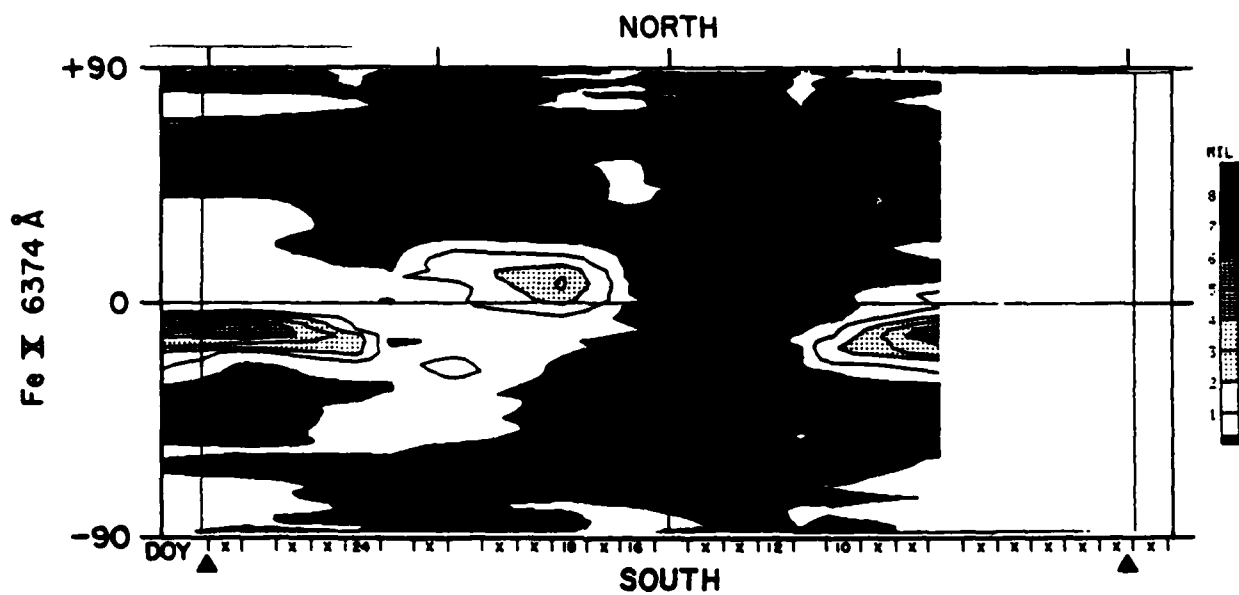


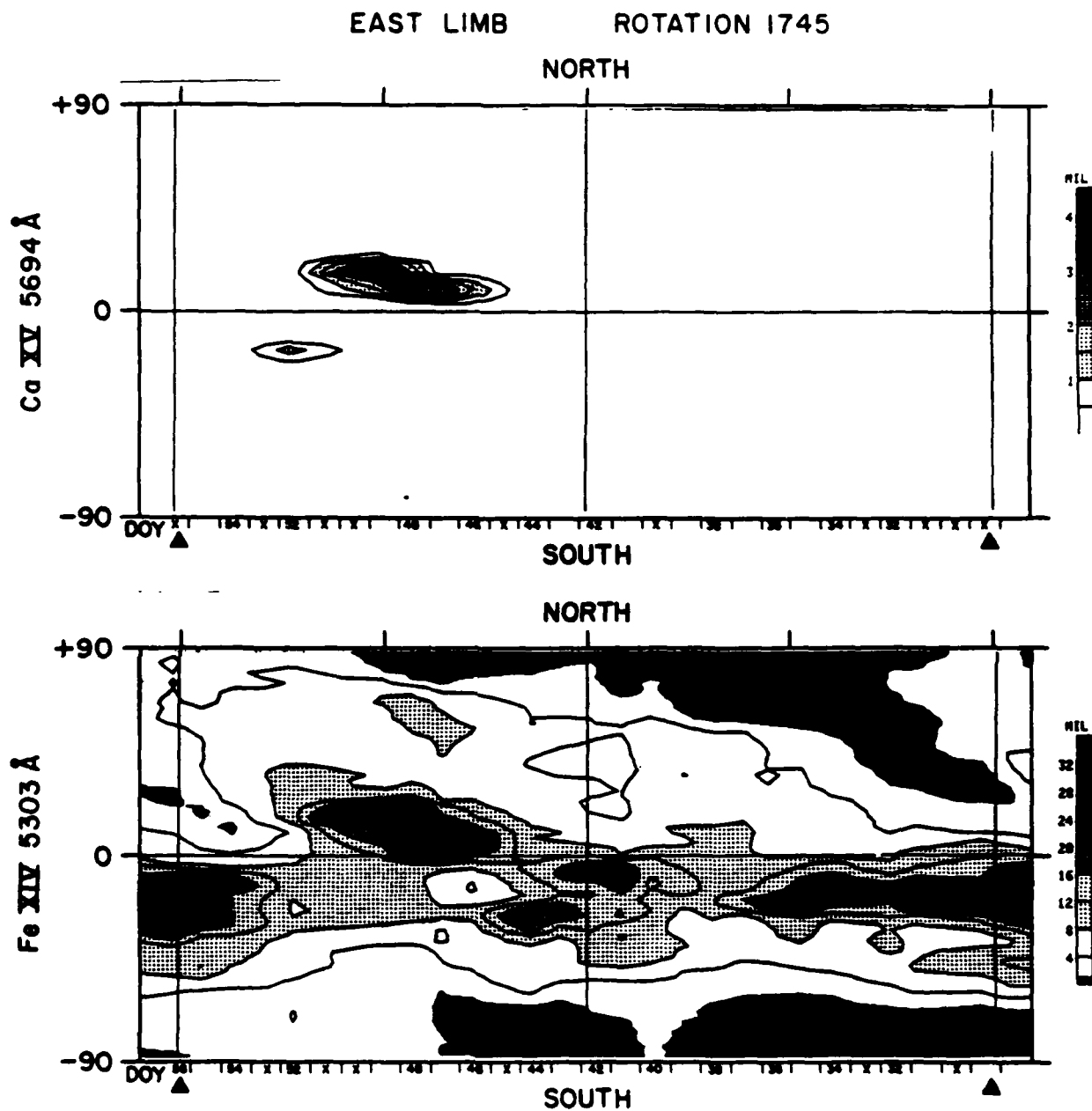


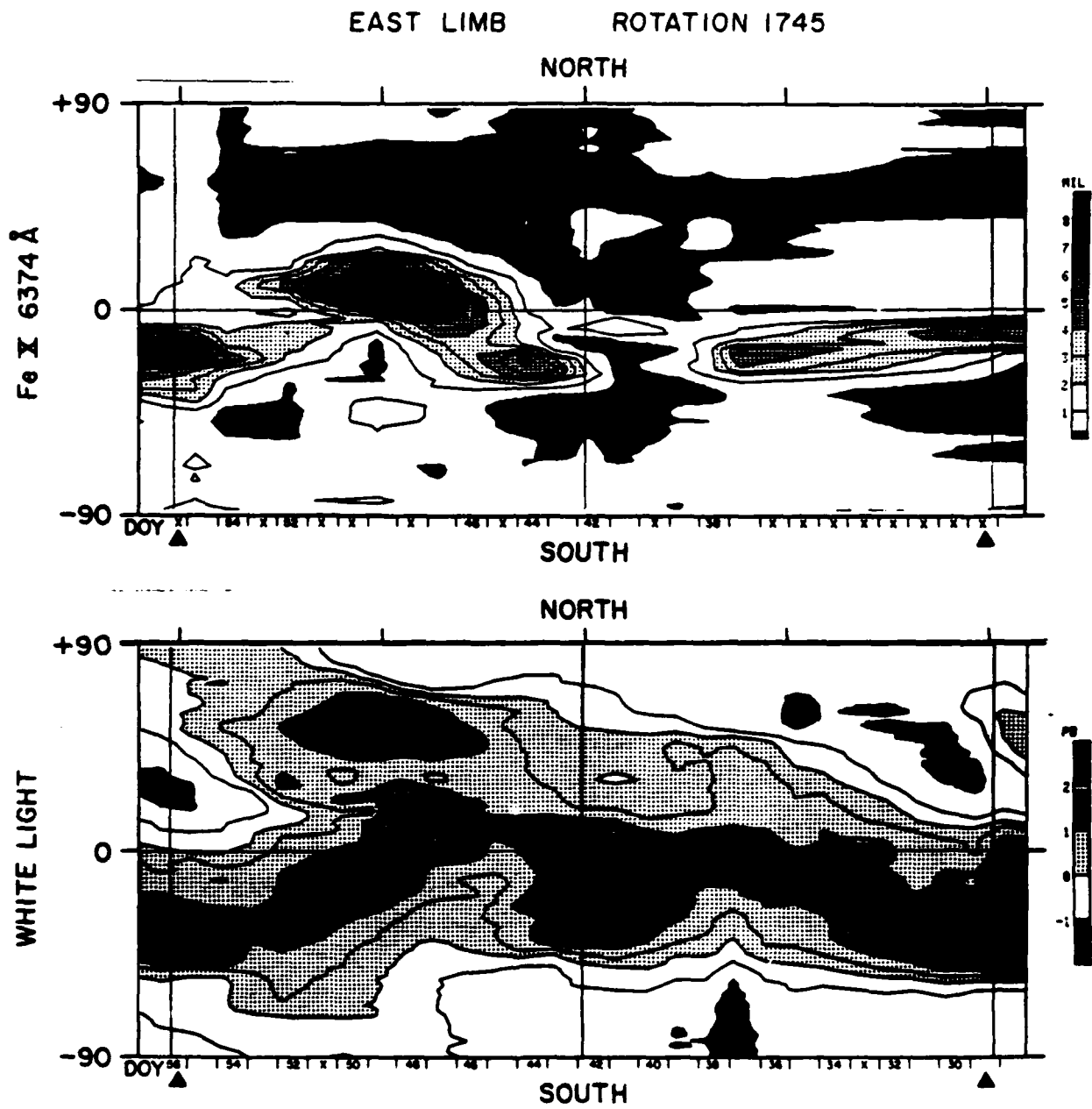


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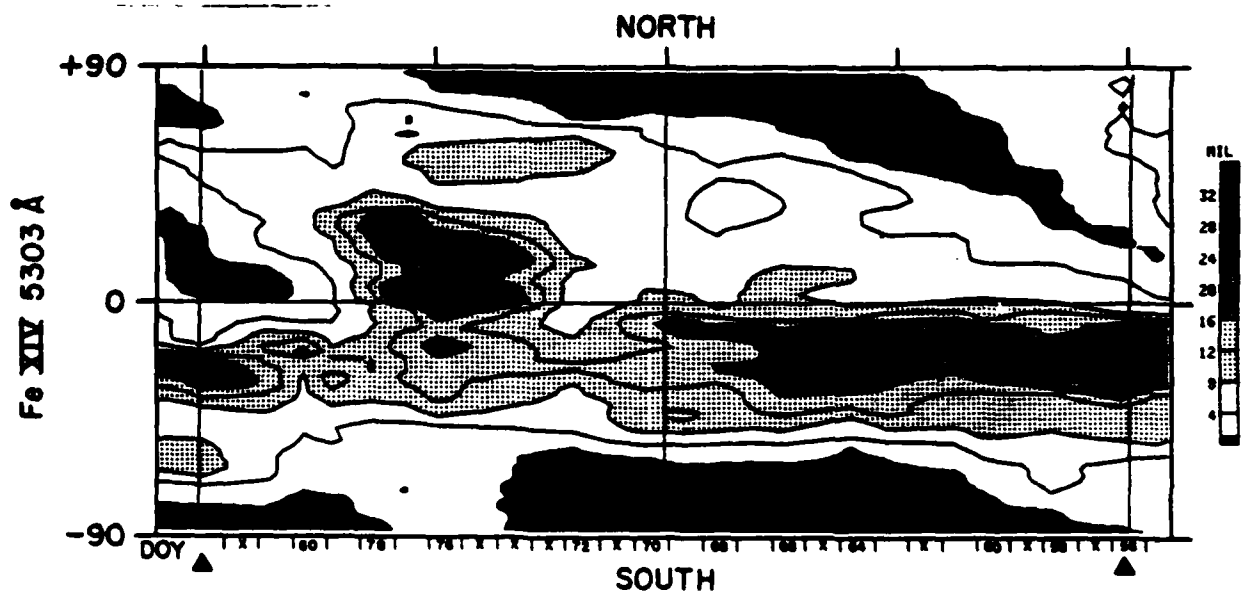
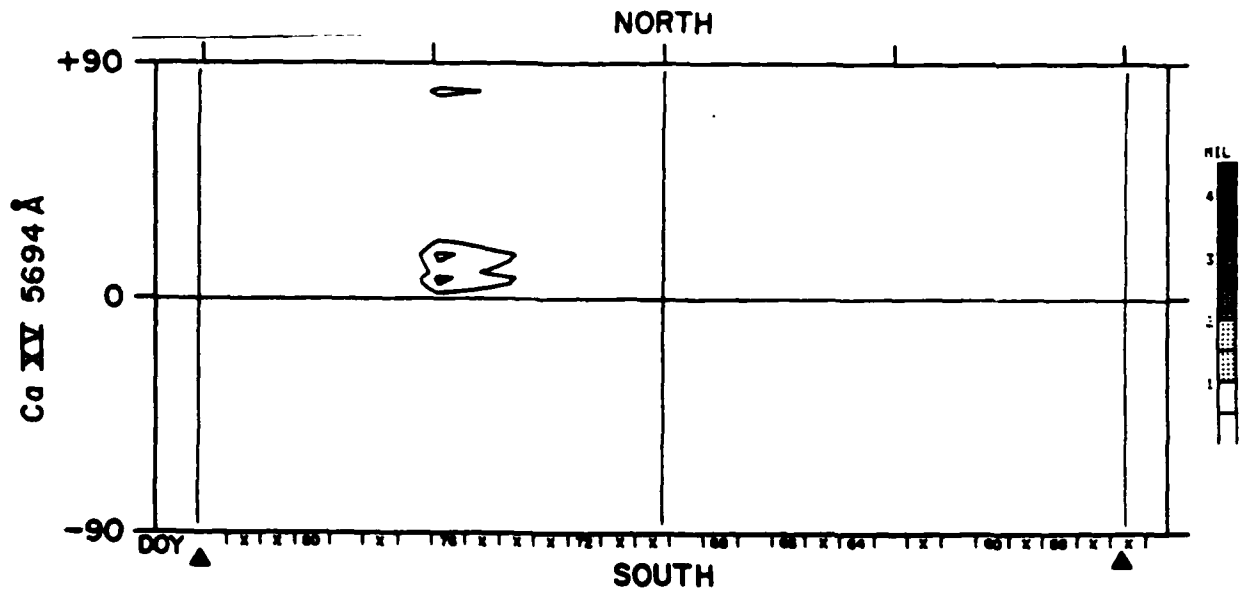


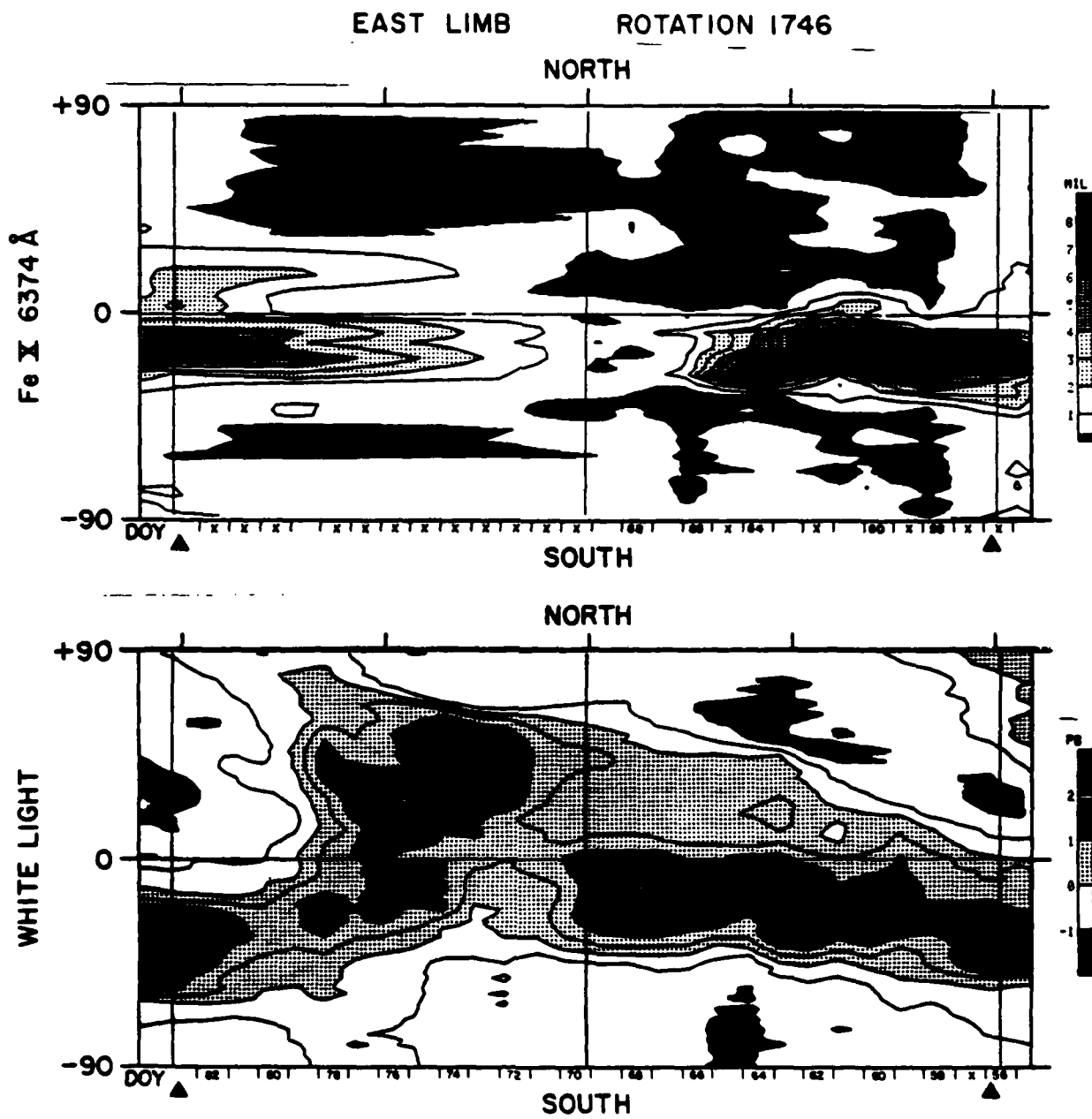




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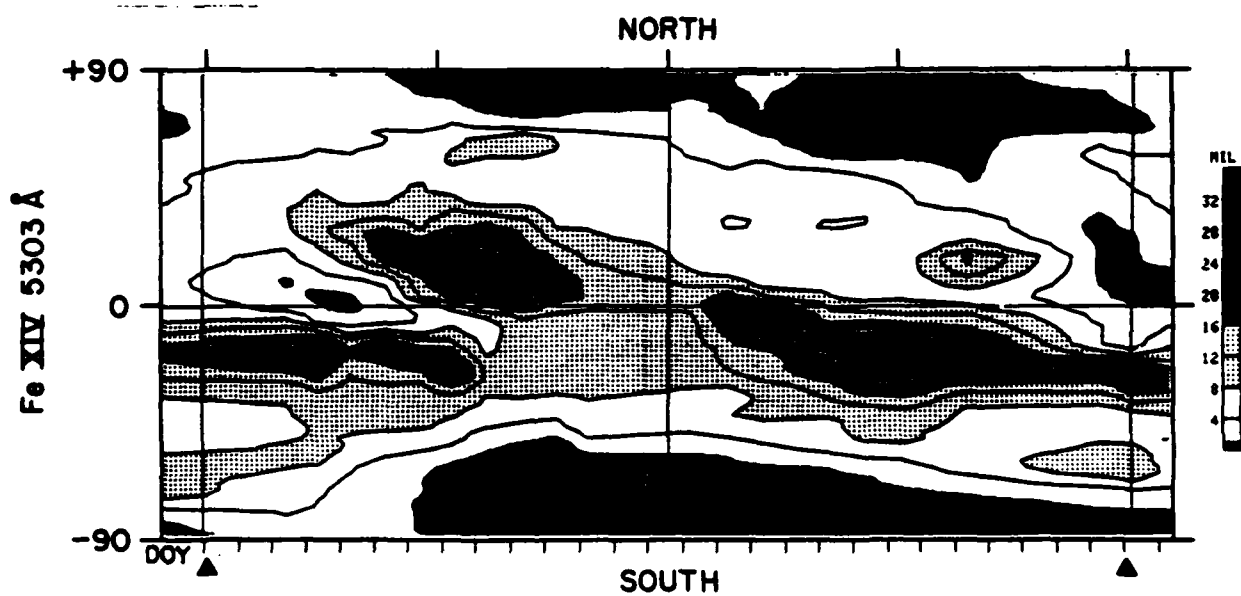
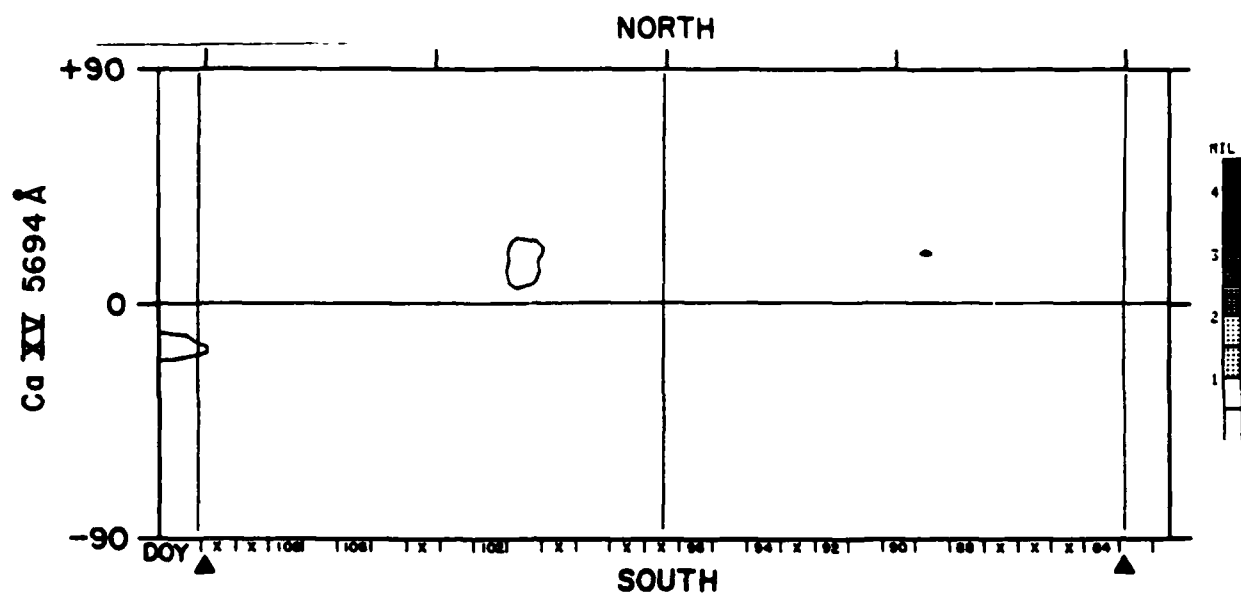
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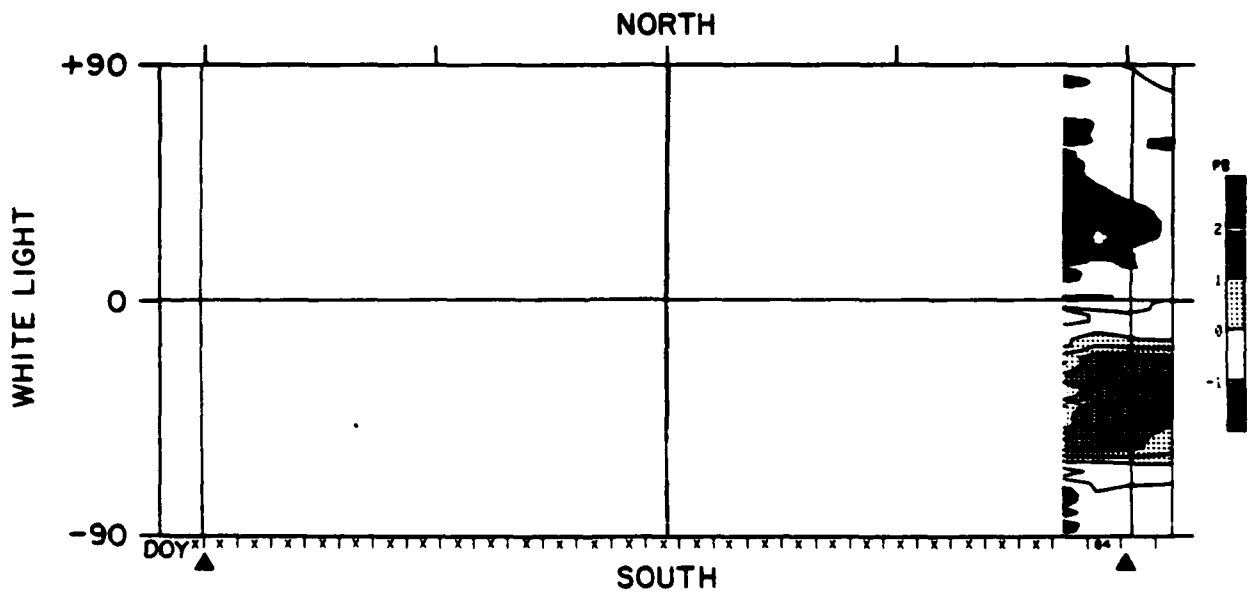
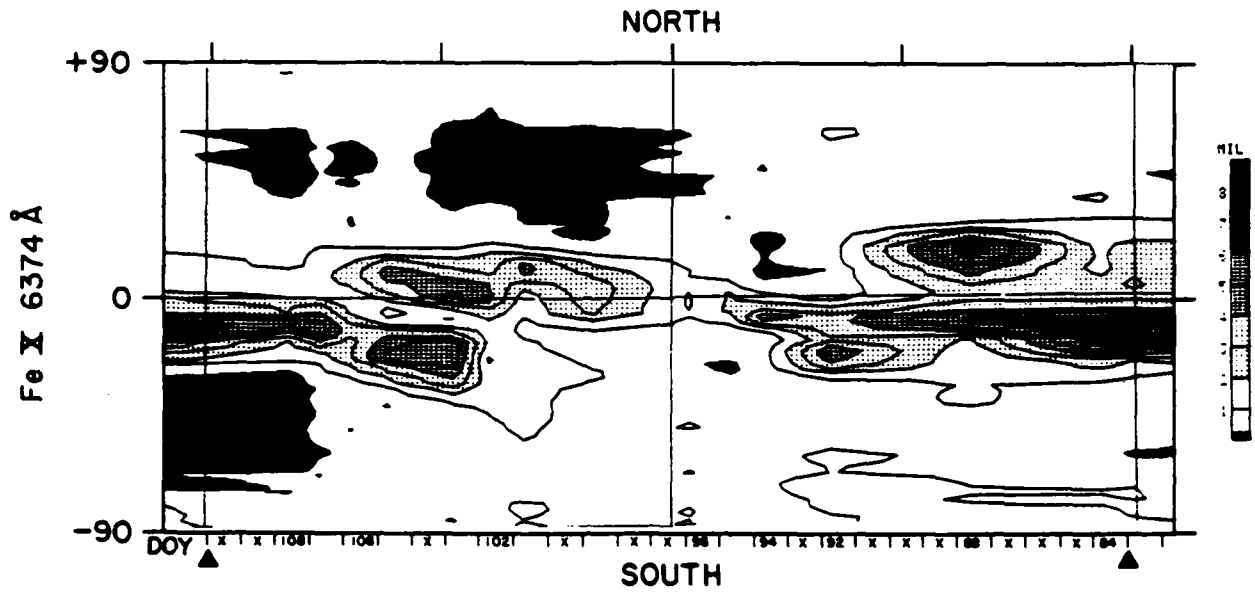


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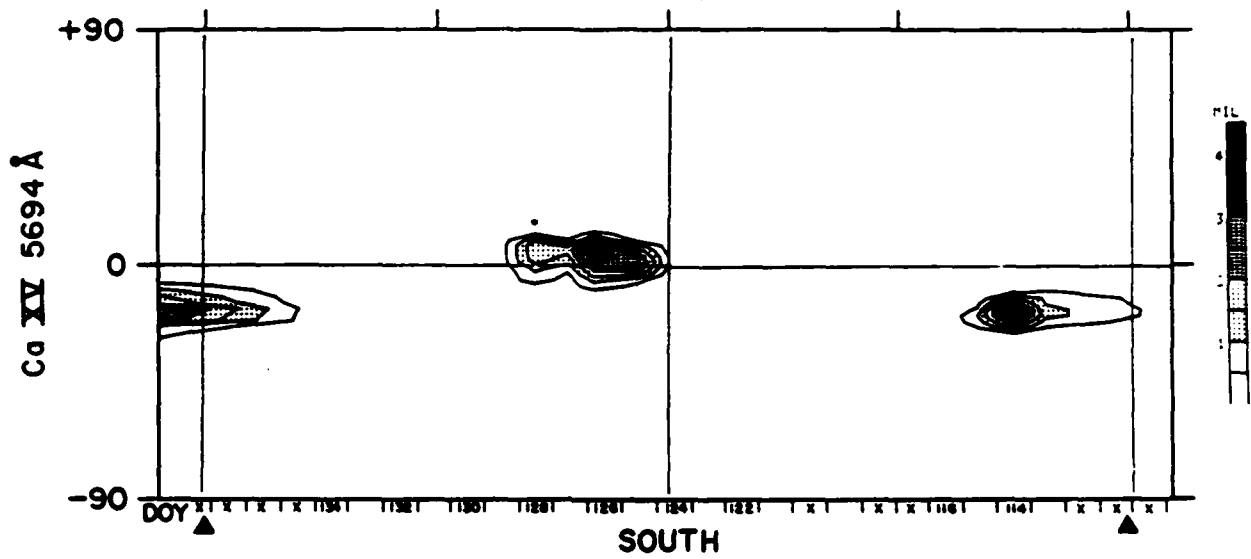
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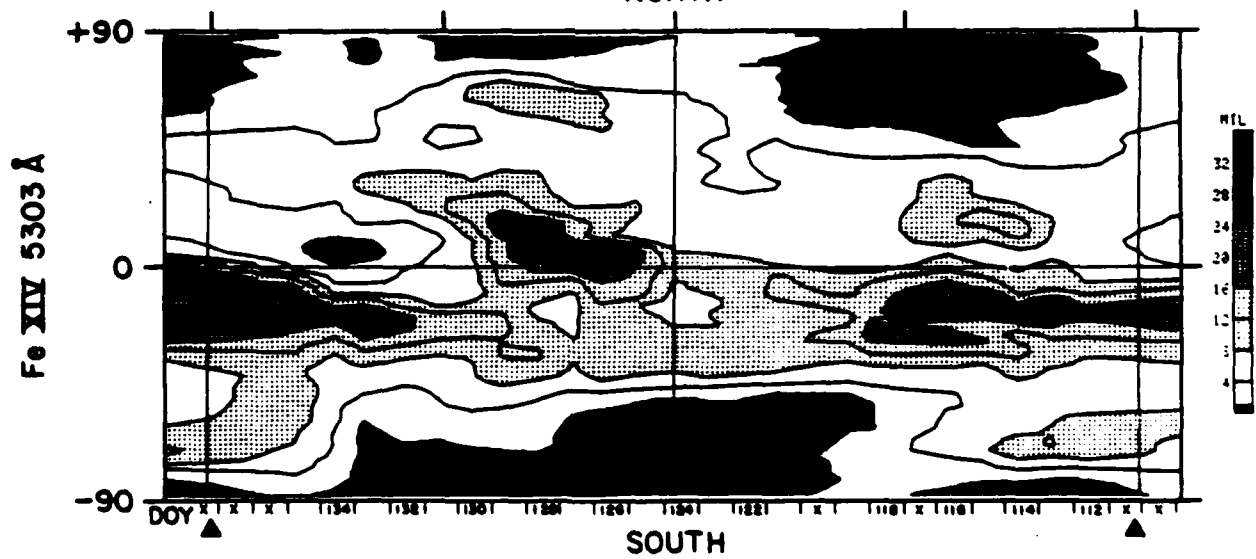
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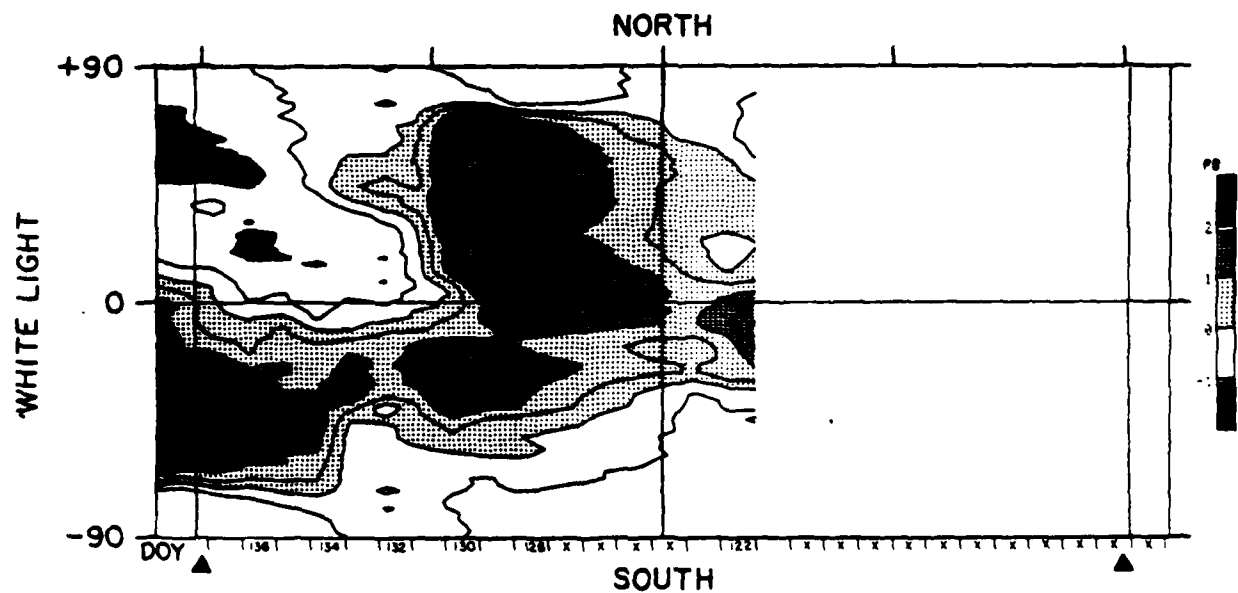
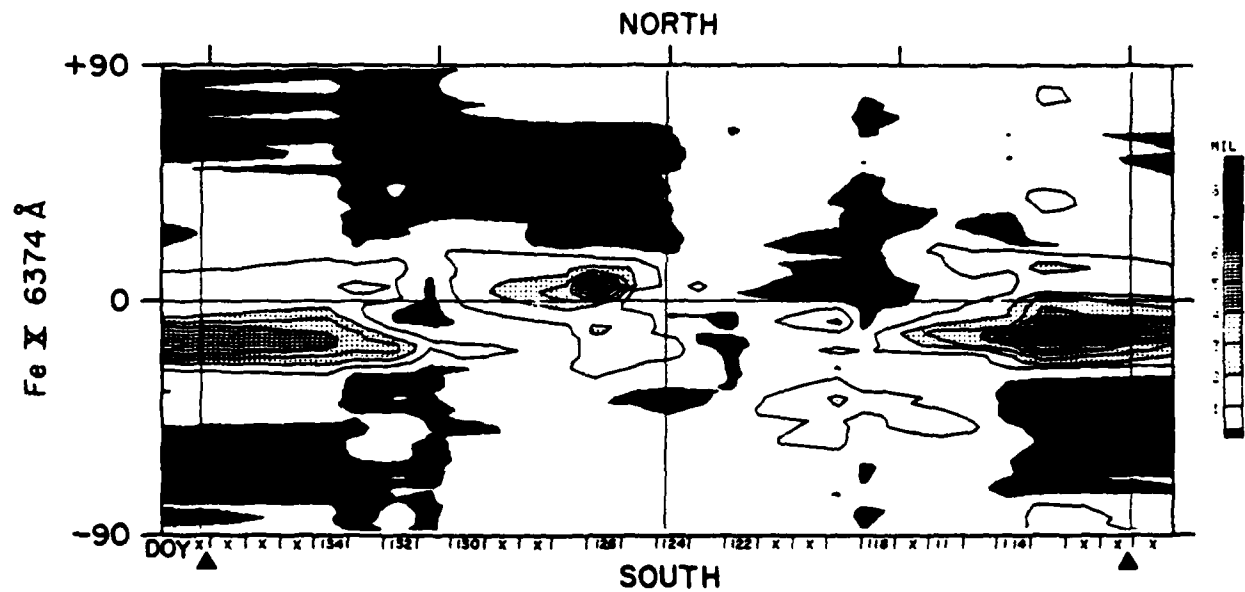
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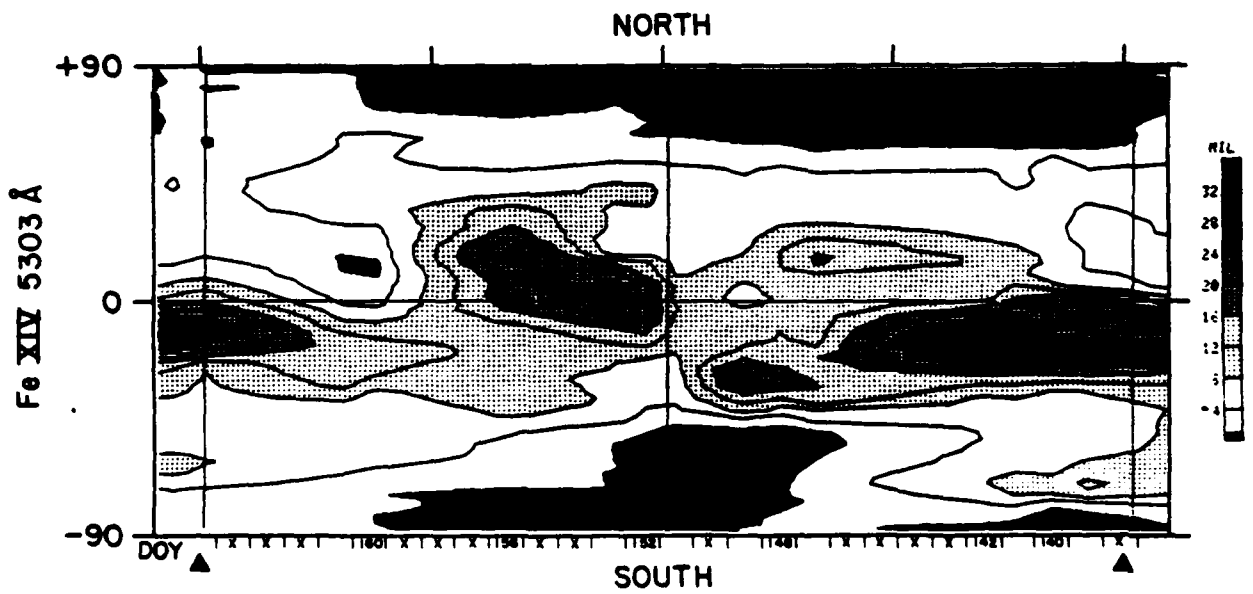
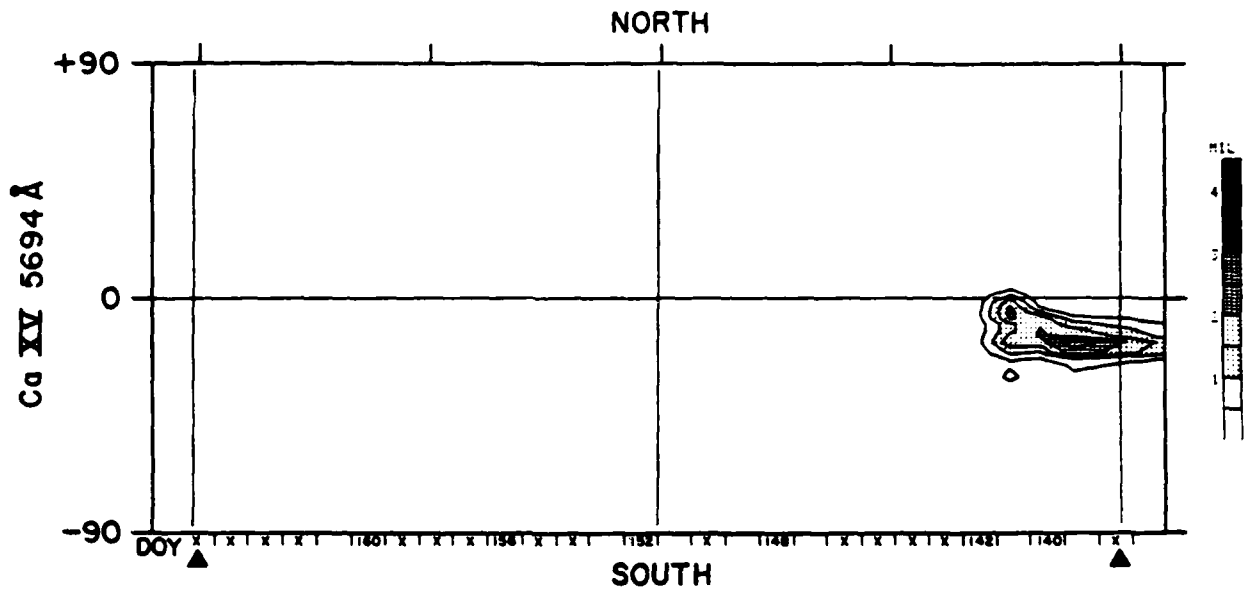
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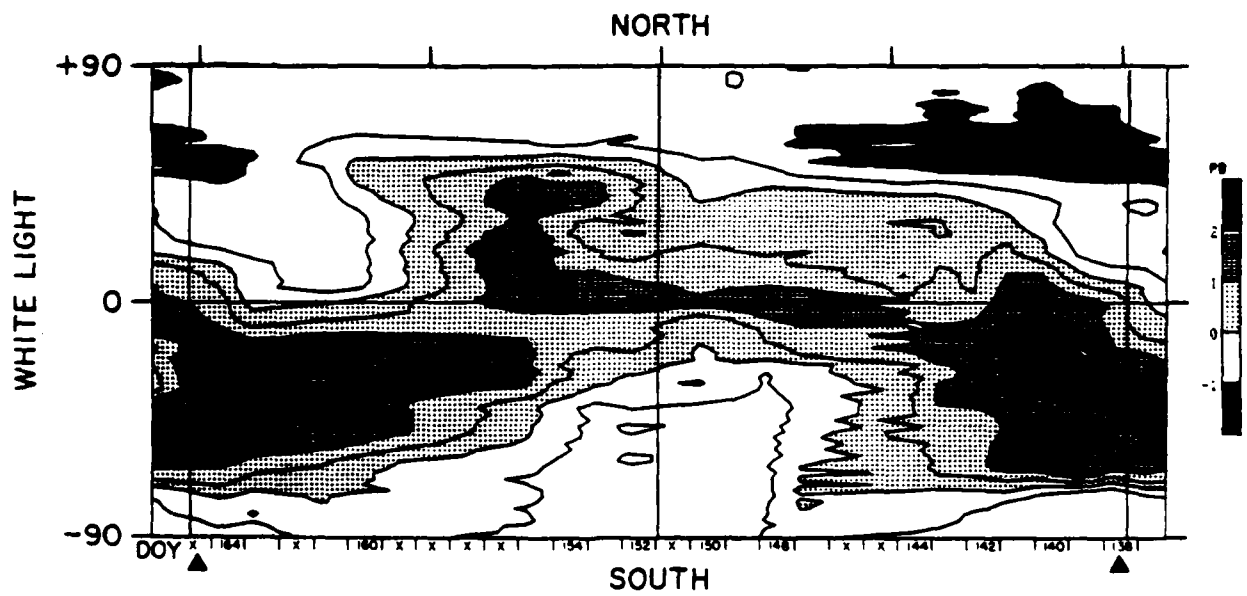
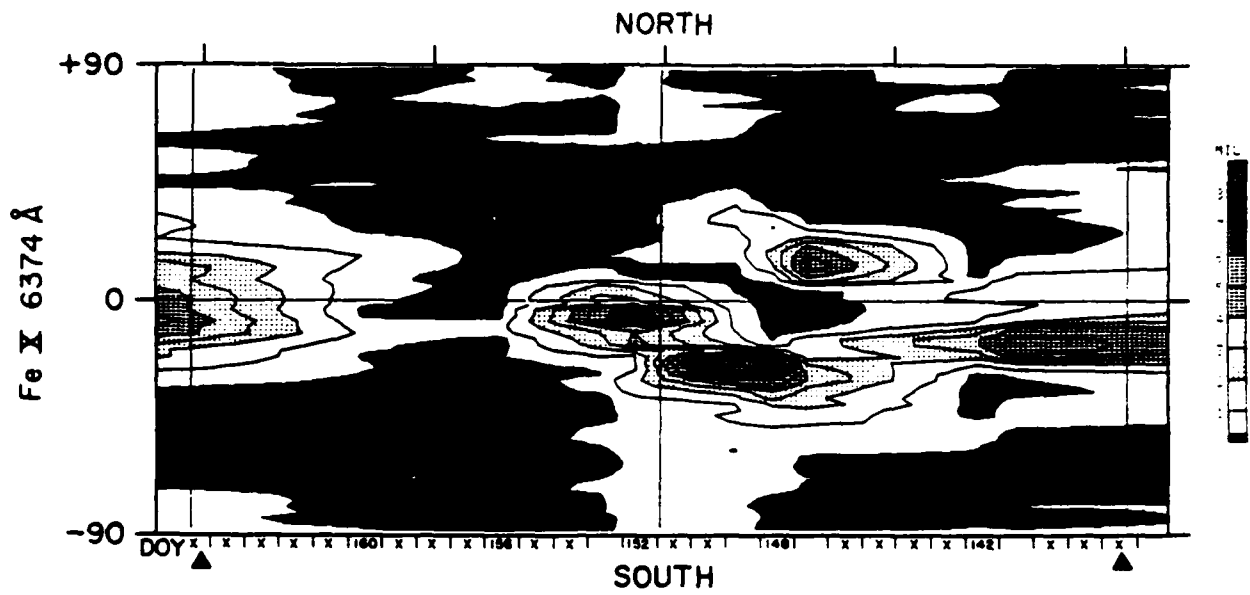
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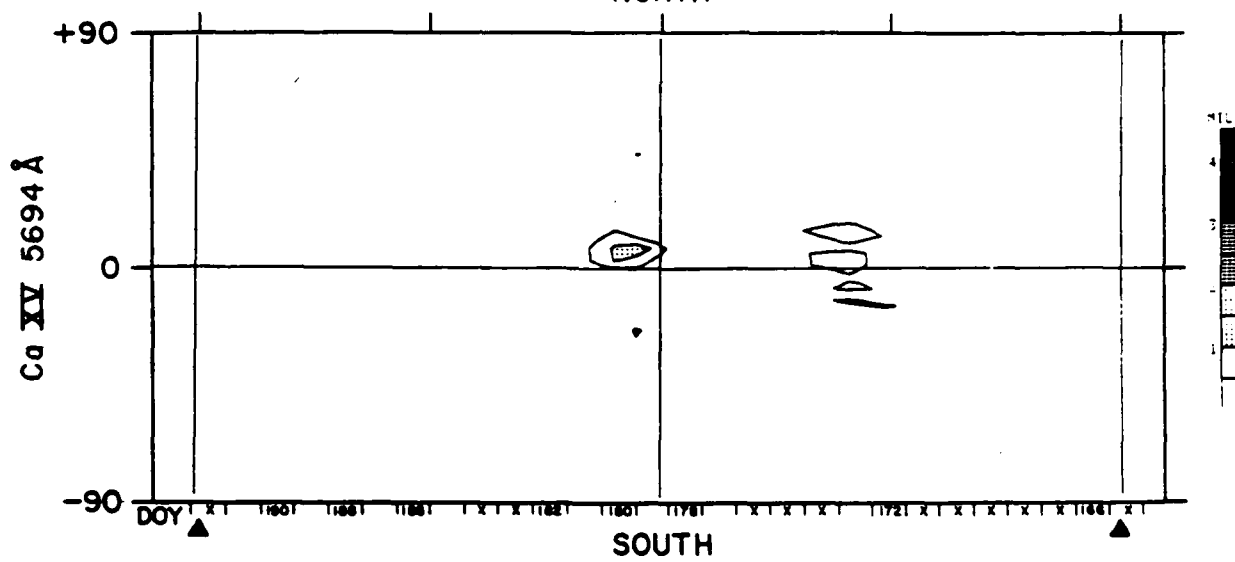
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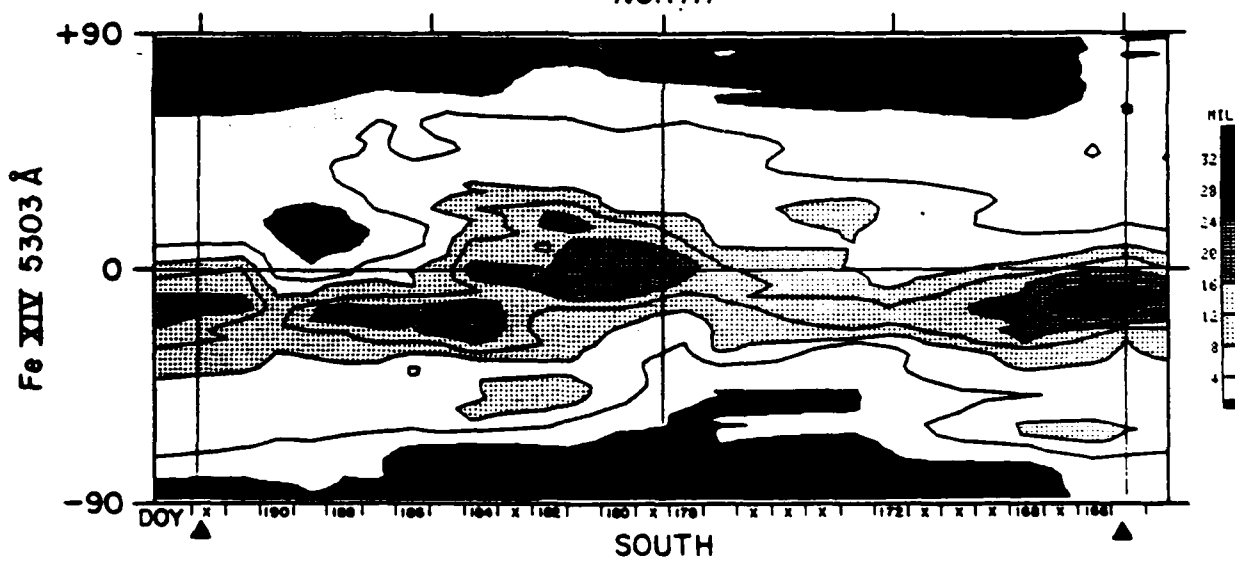


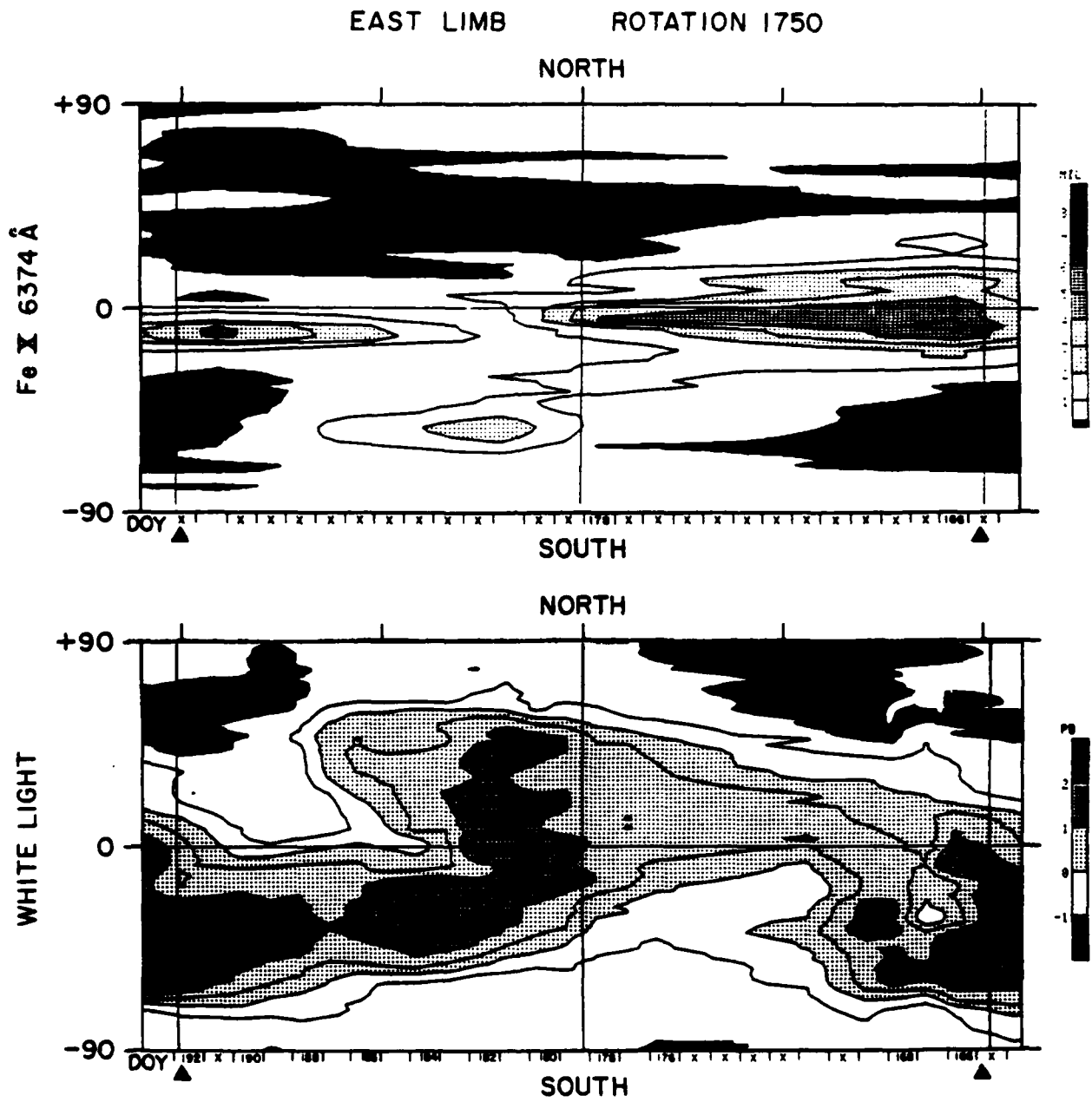
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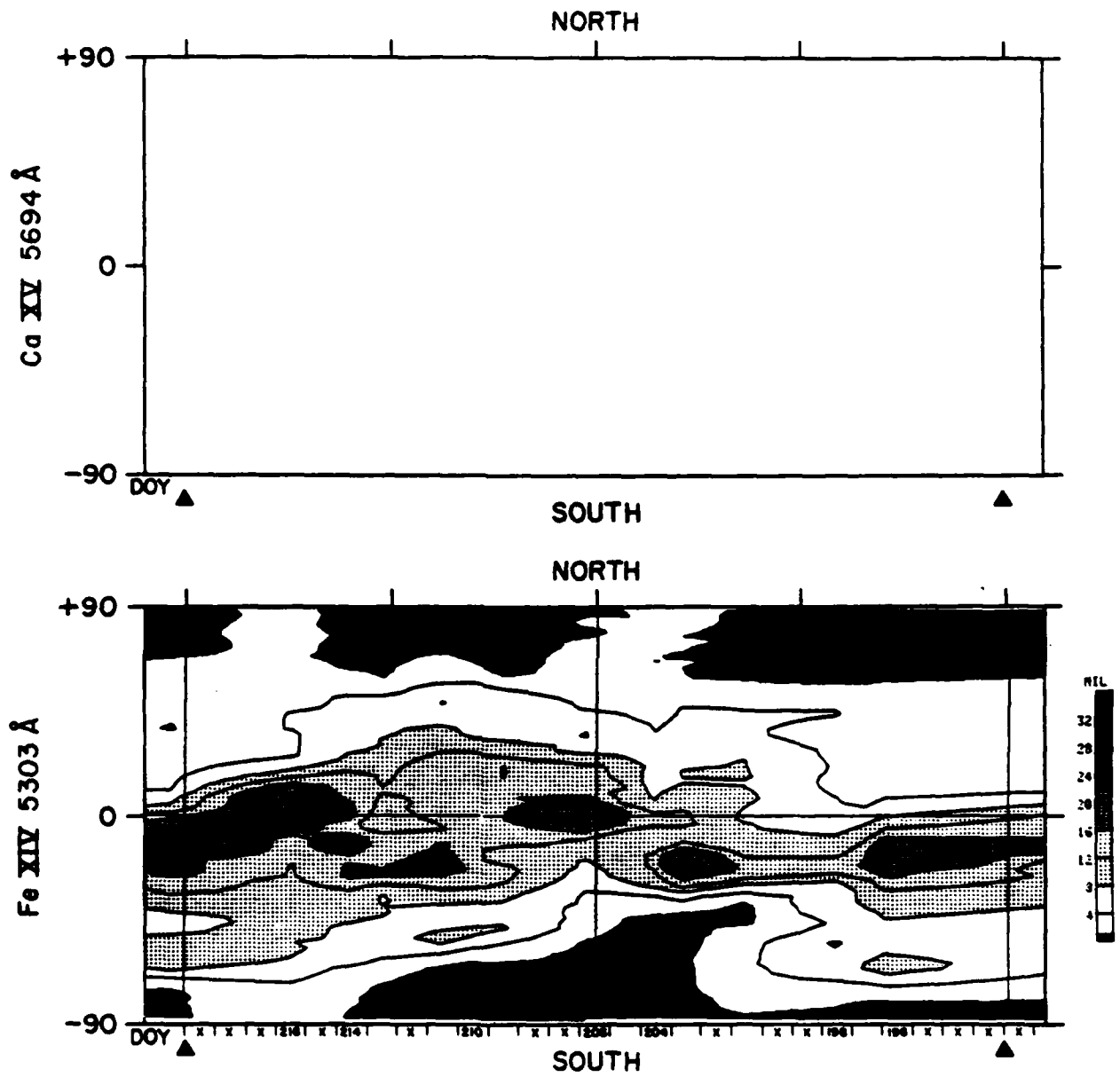
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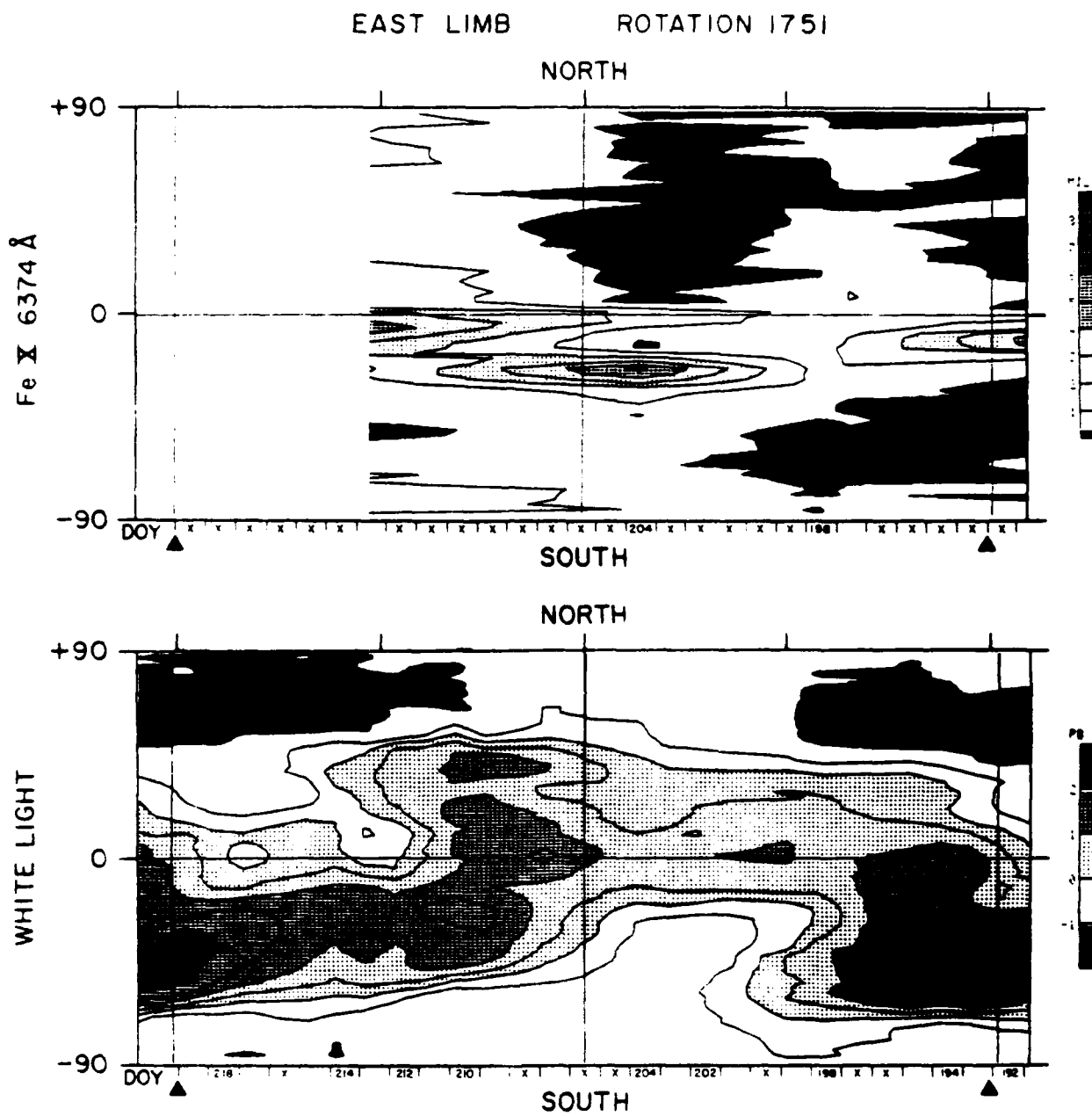




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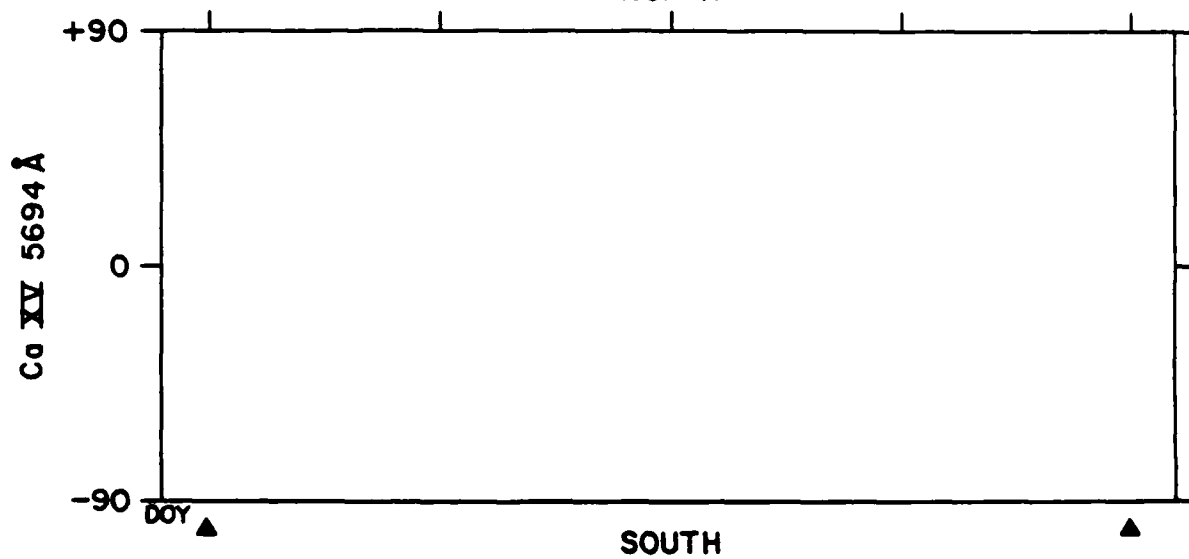




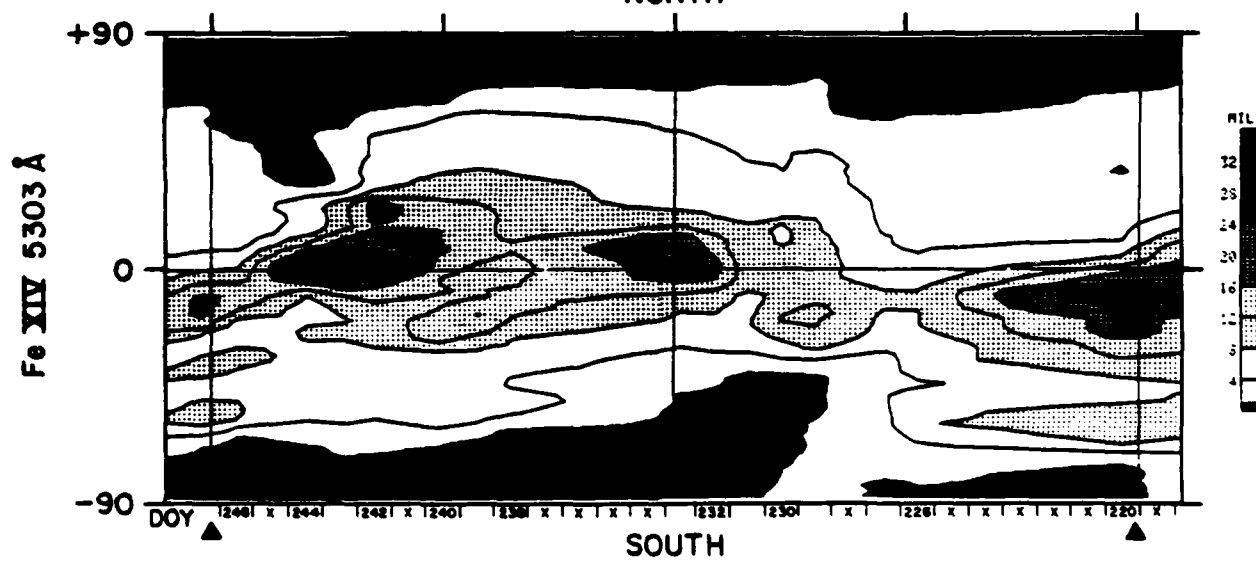
EAST LIMB

ROTATION 1752

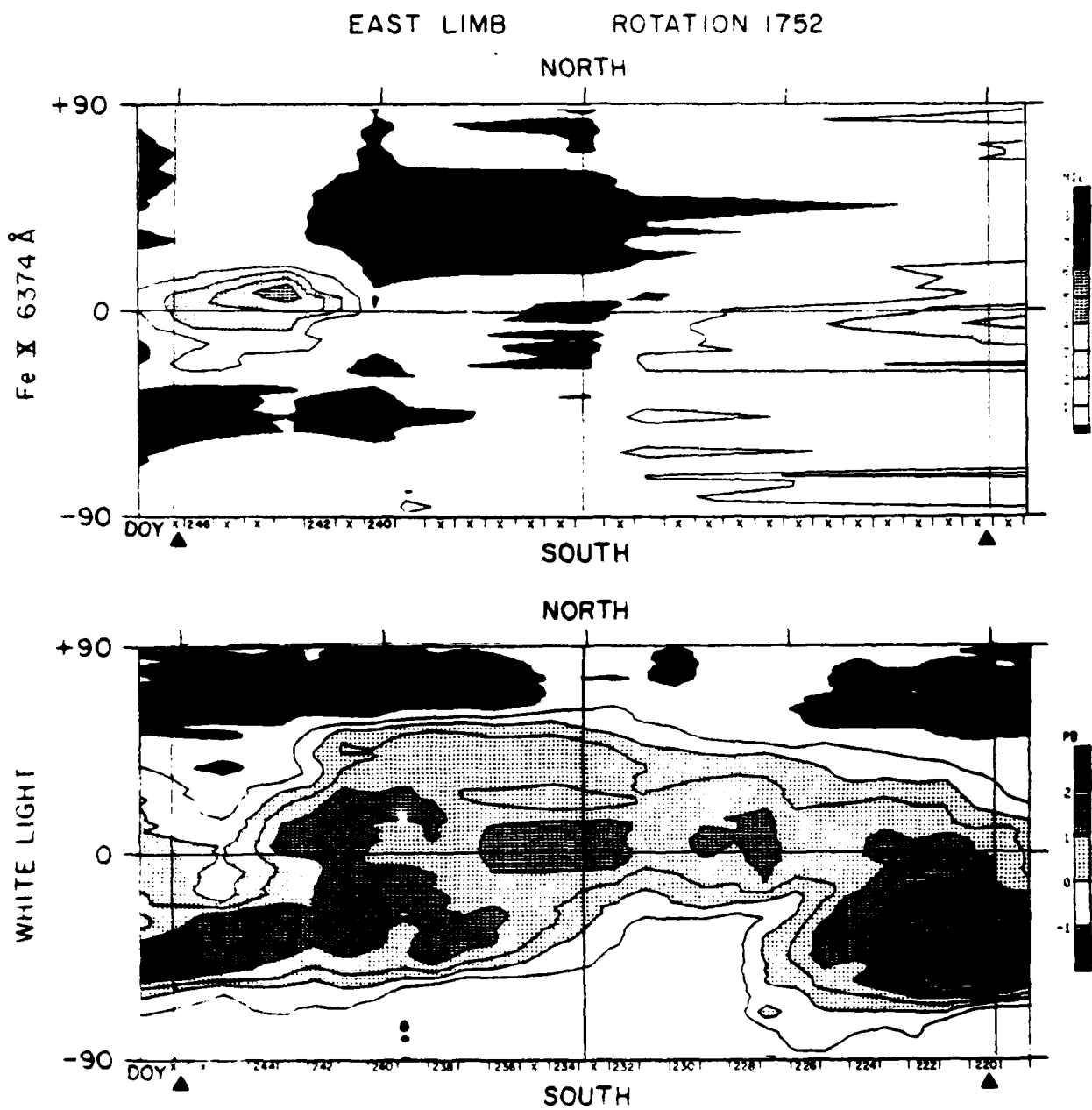
NORTH



NORTH







ROTATION 1753

**NORTH**

Ca XV 5694 Å

**+90**

O

-90

DOY ▲

**SOUTH**

**NORTH**

**Fe XIV 5303 Å**

**+90**

0

-90

DOY \*

**SOUTH**

**WIL**

32

38

24

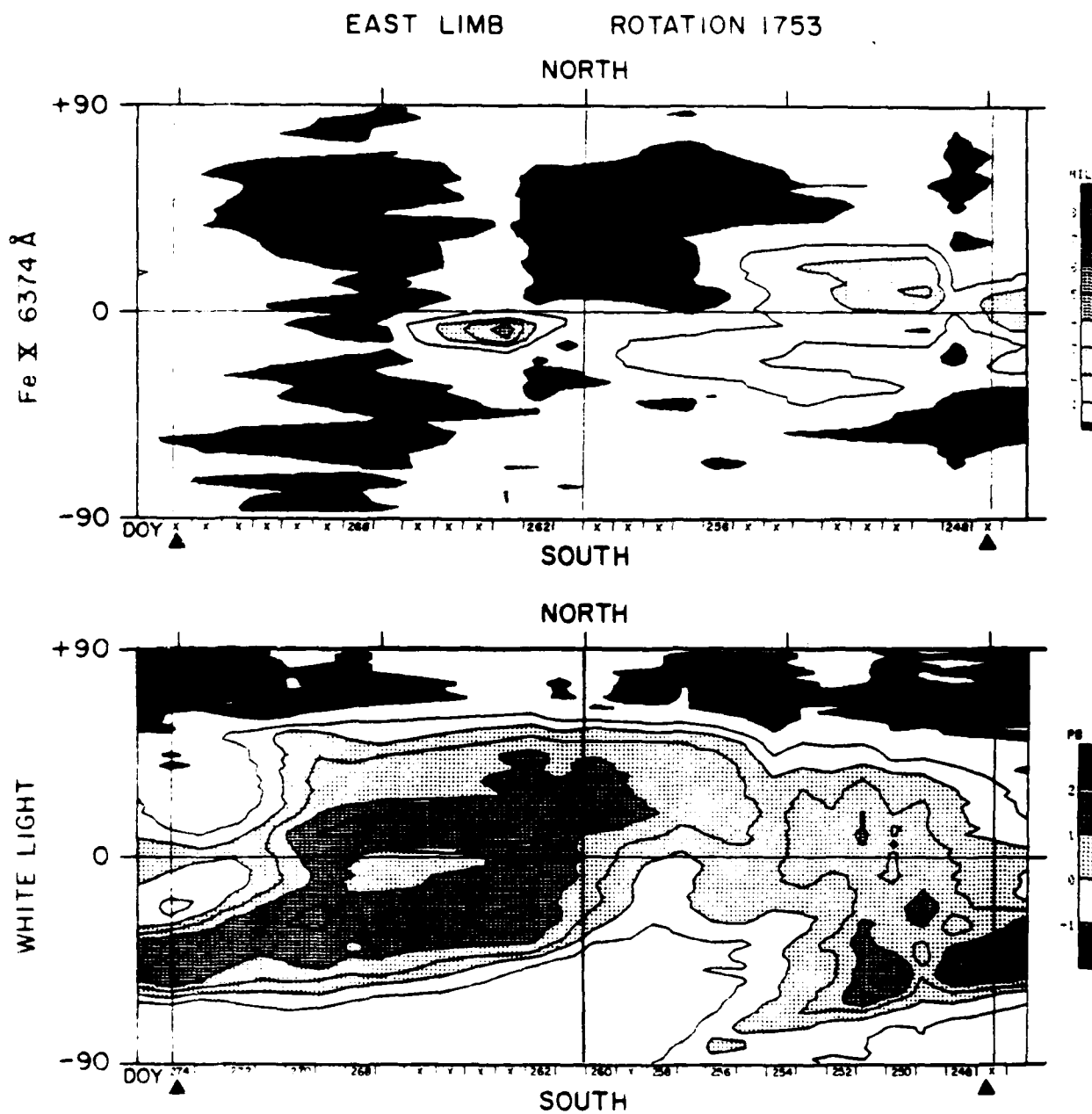
28



12

٥٠

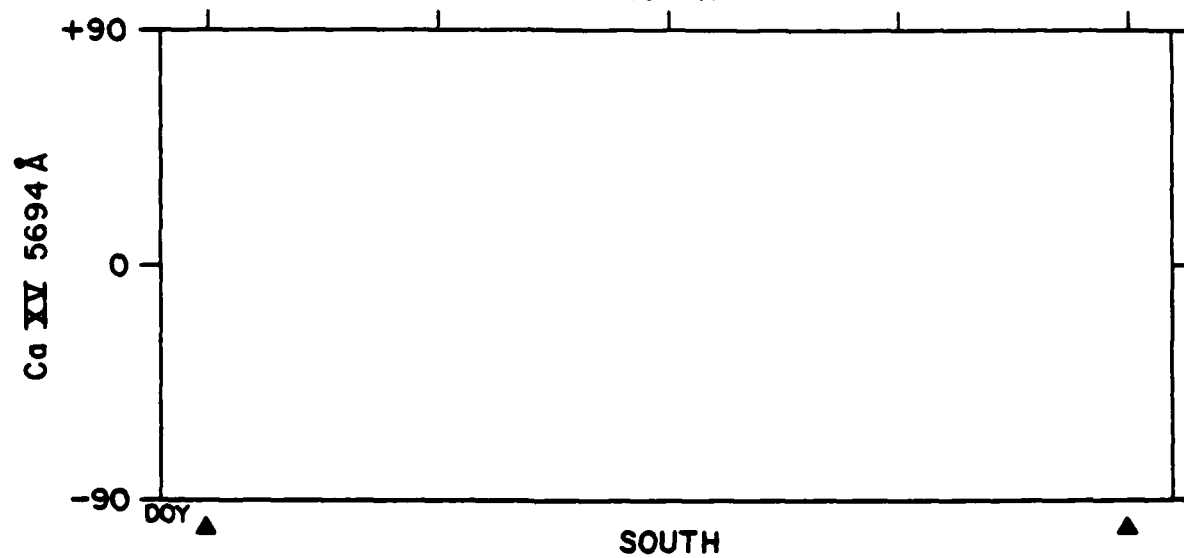
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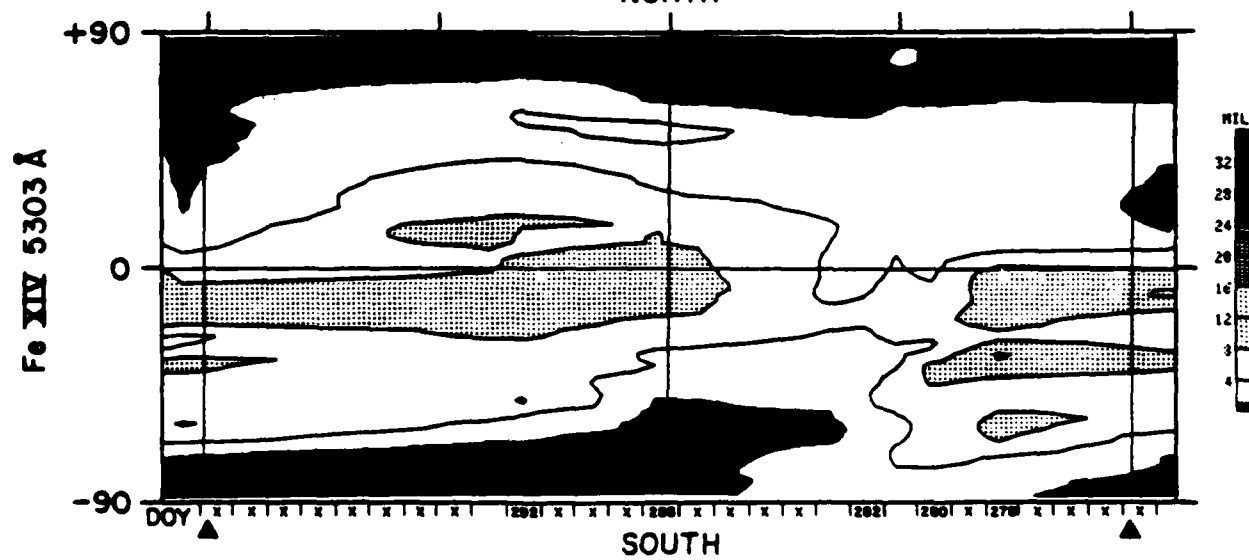
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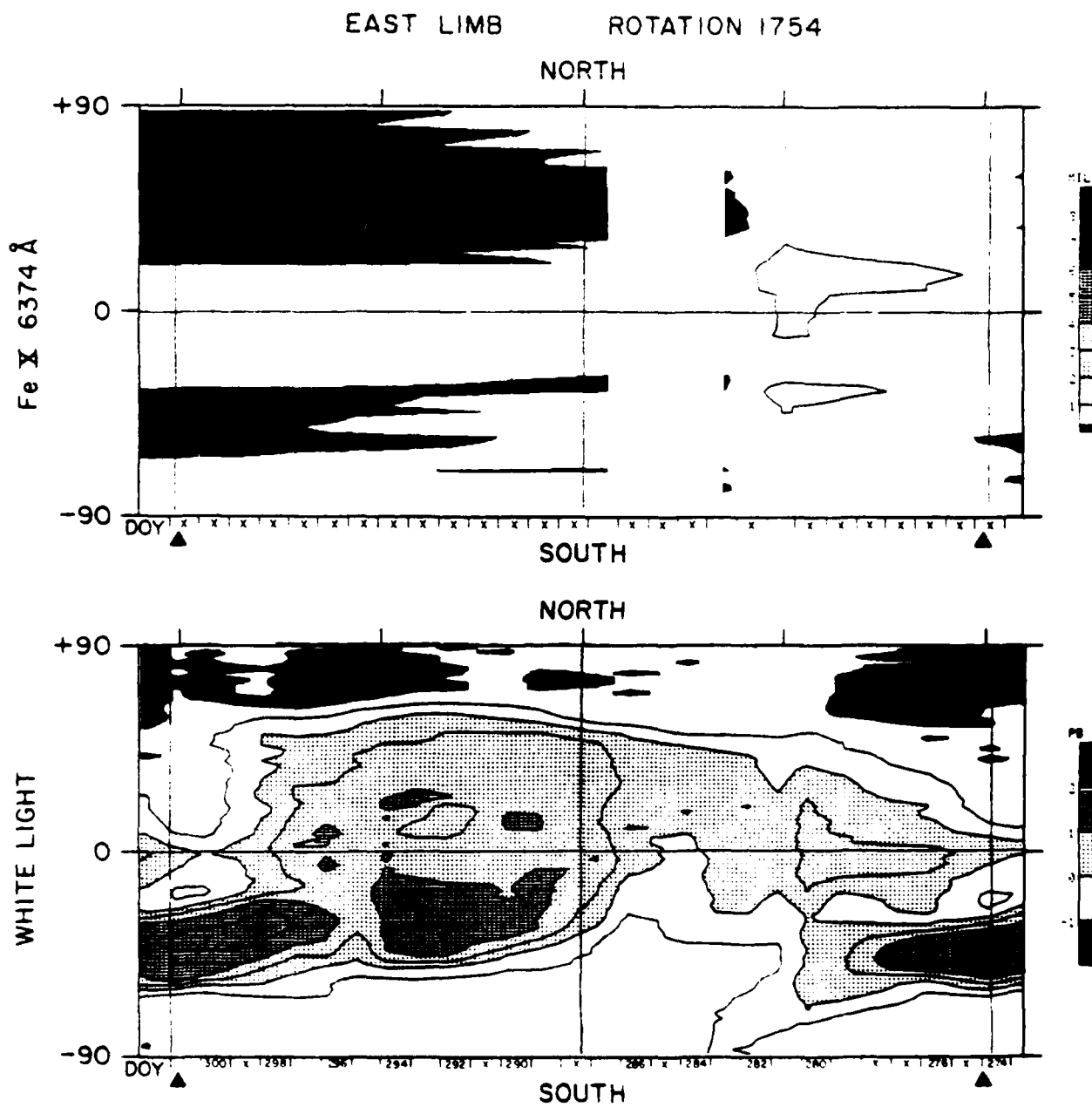
ROTATION 1754

NORTH



NORTH

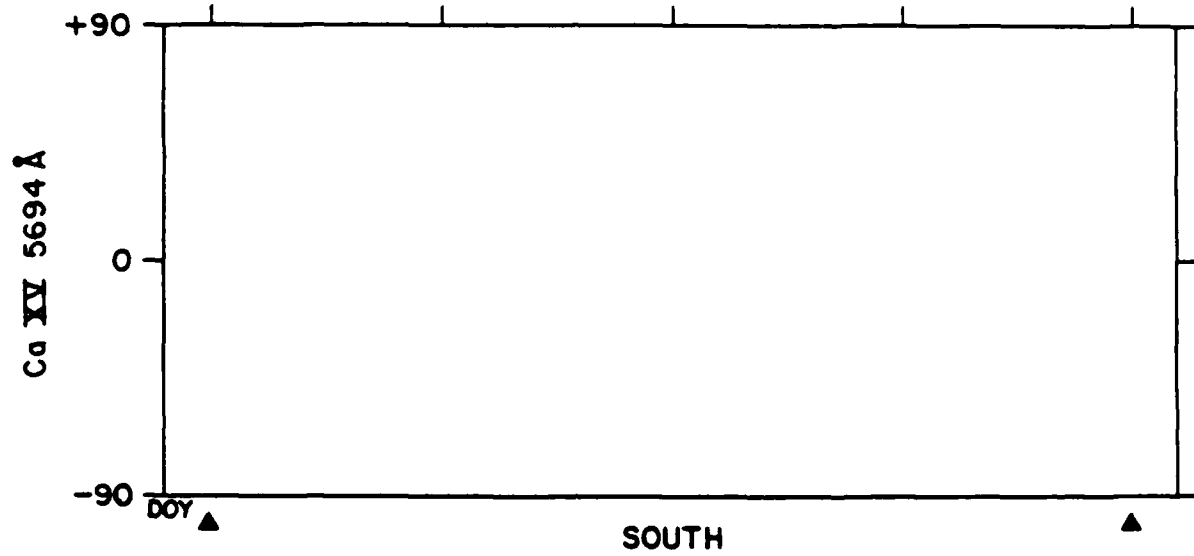




EAST LIMB

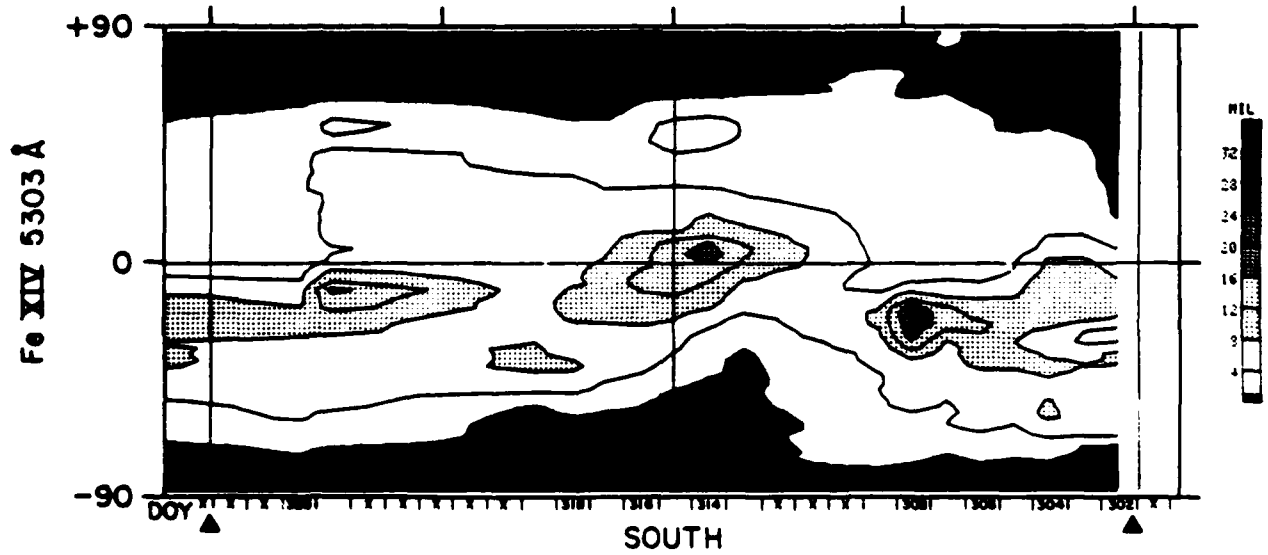
ROTATION 1755

NORTH



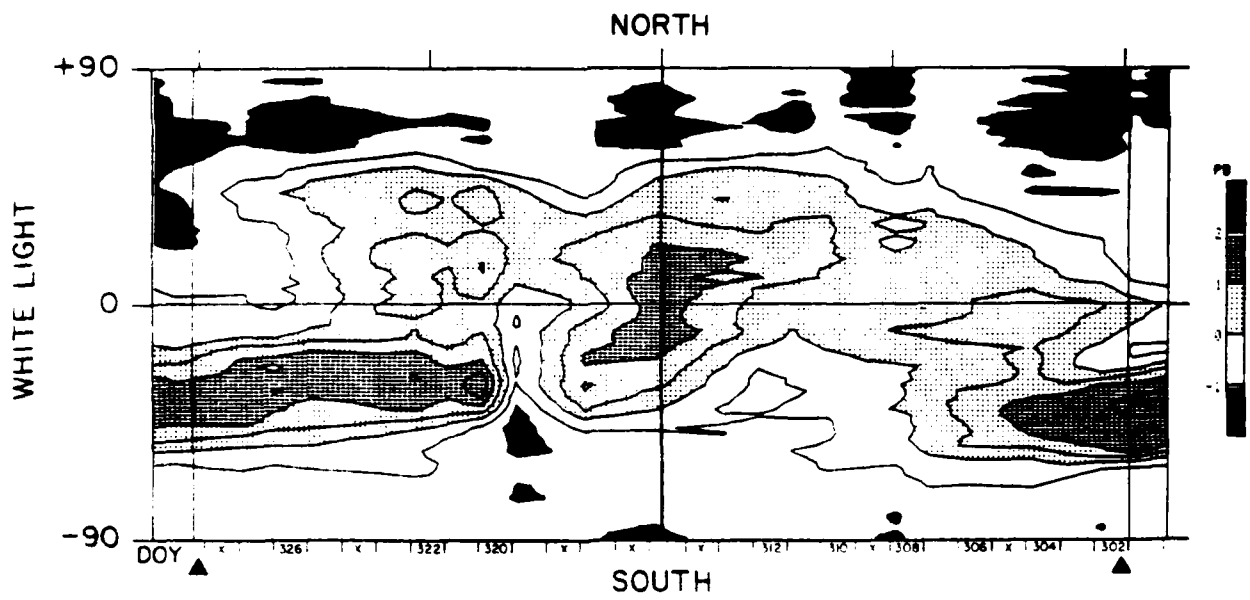
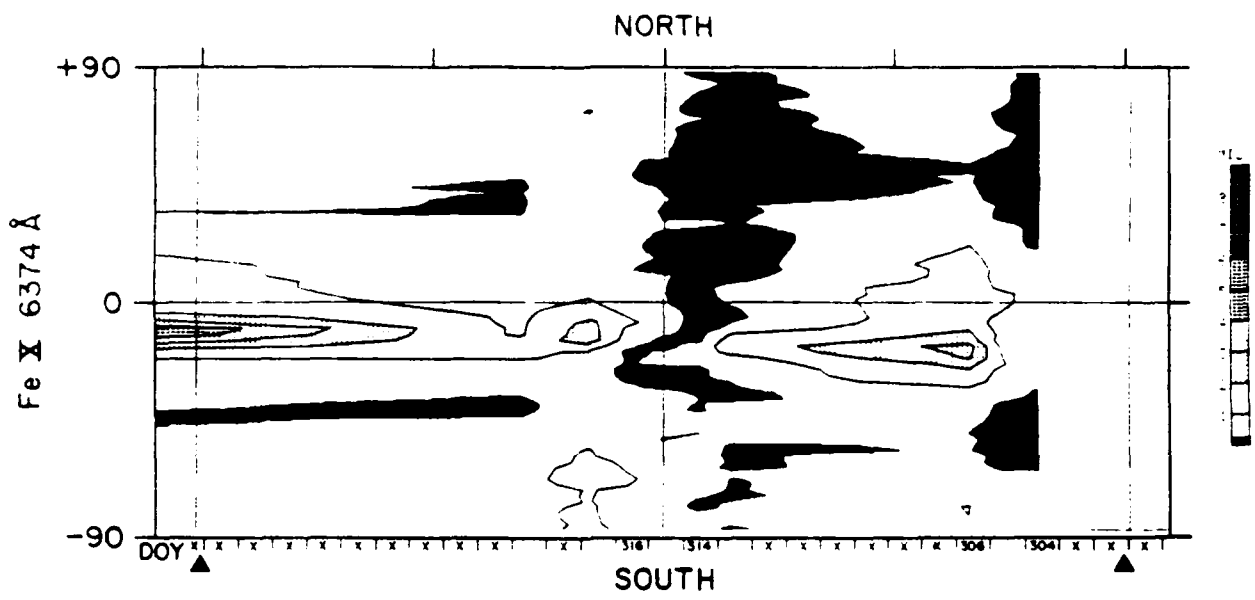
SOUTH

NORTH



EAST LIMB

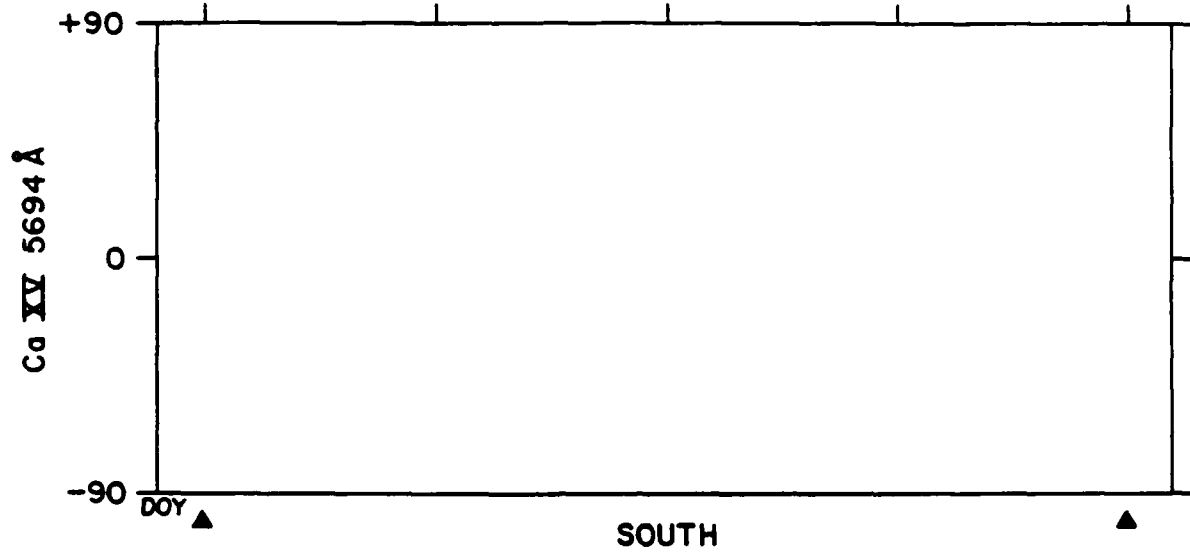
ROTATION 1755



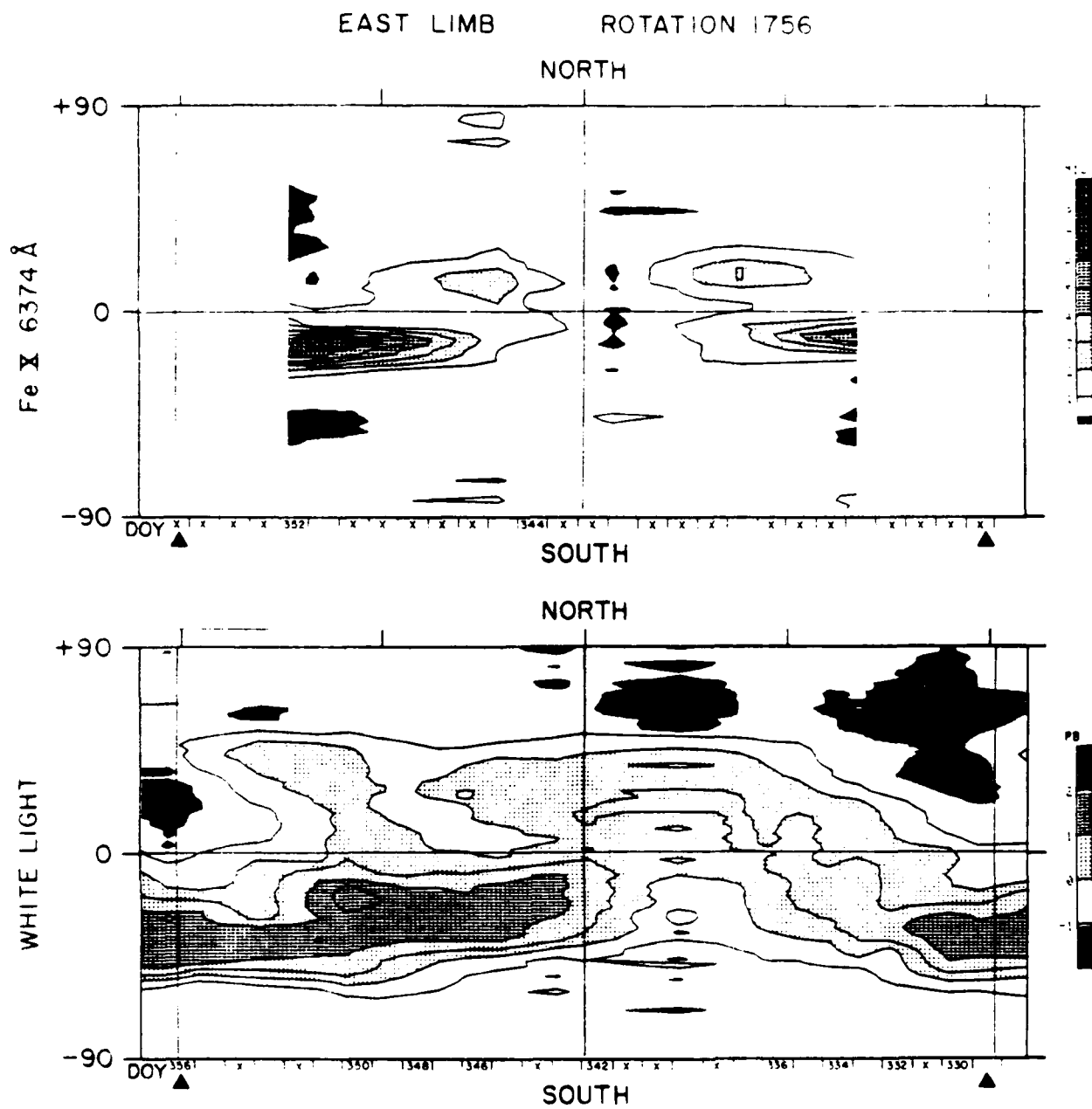
EAST LIMB

ROTATION 1756

NORTH



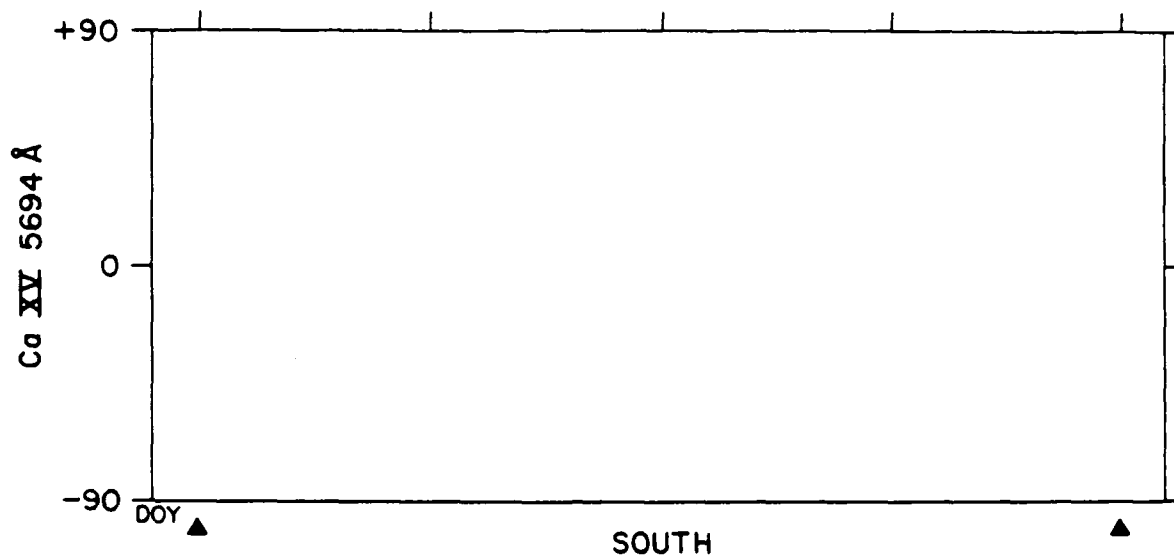




WEST LIMB

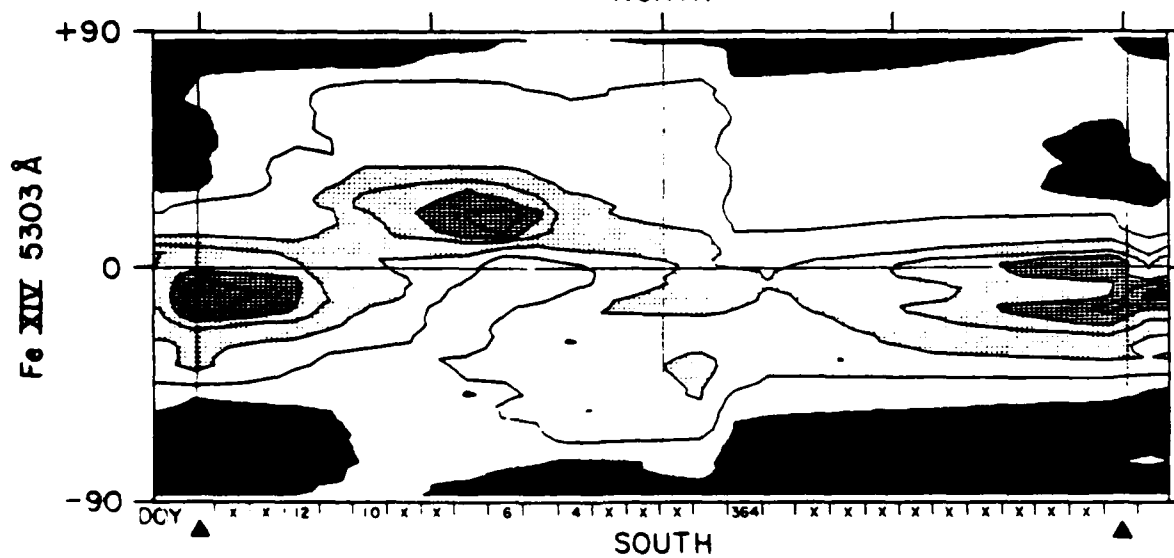
ROTATION 1743

NORTH



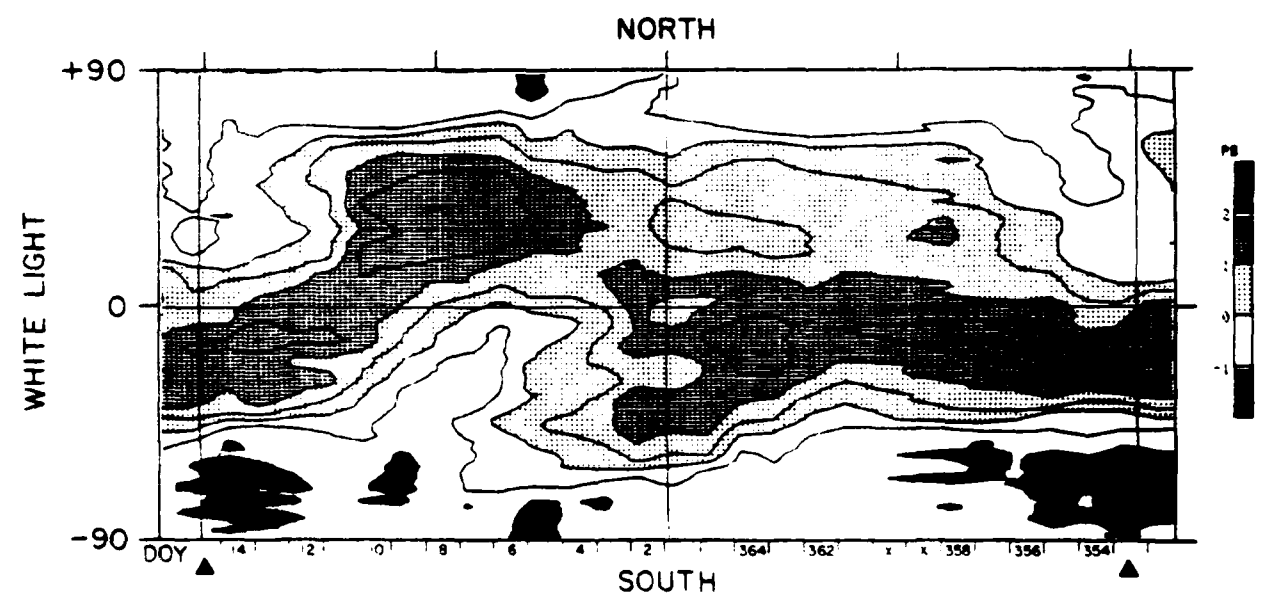
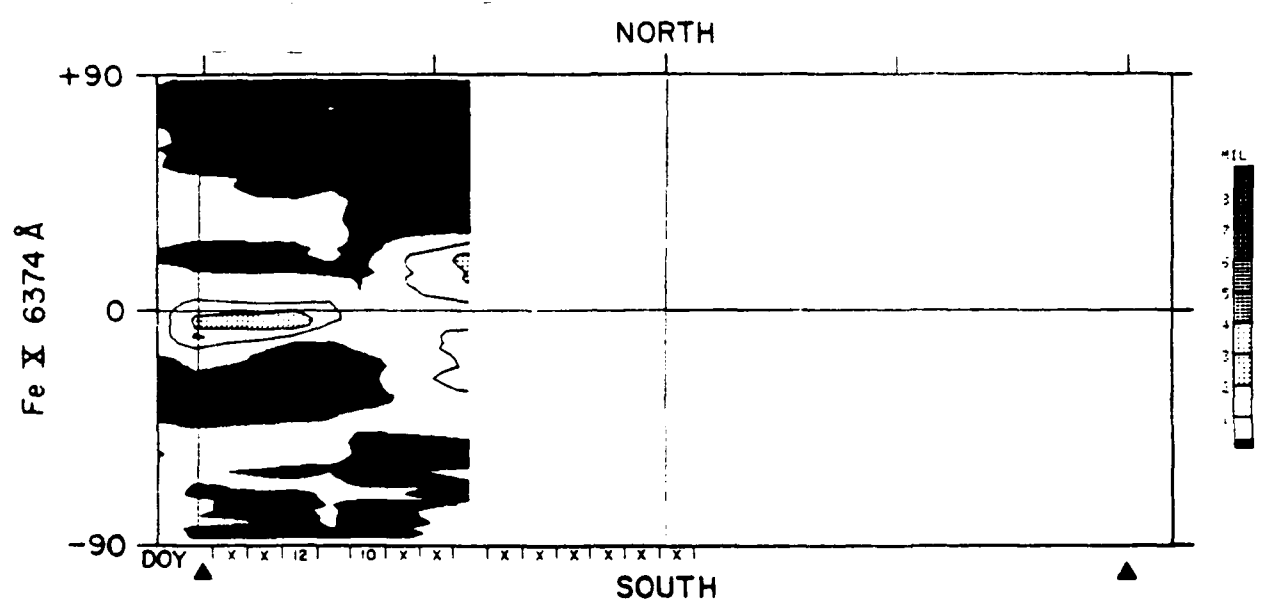
SOUTH

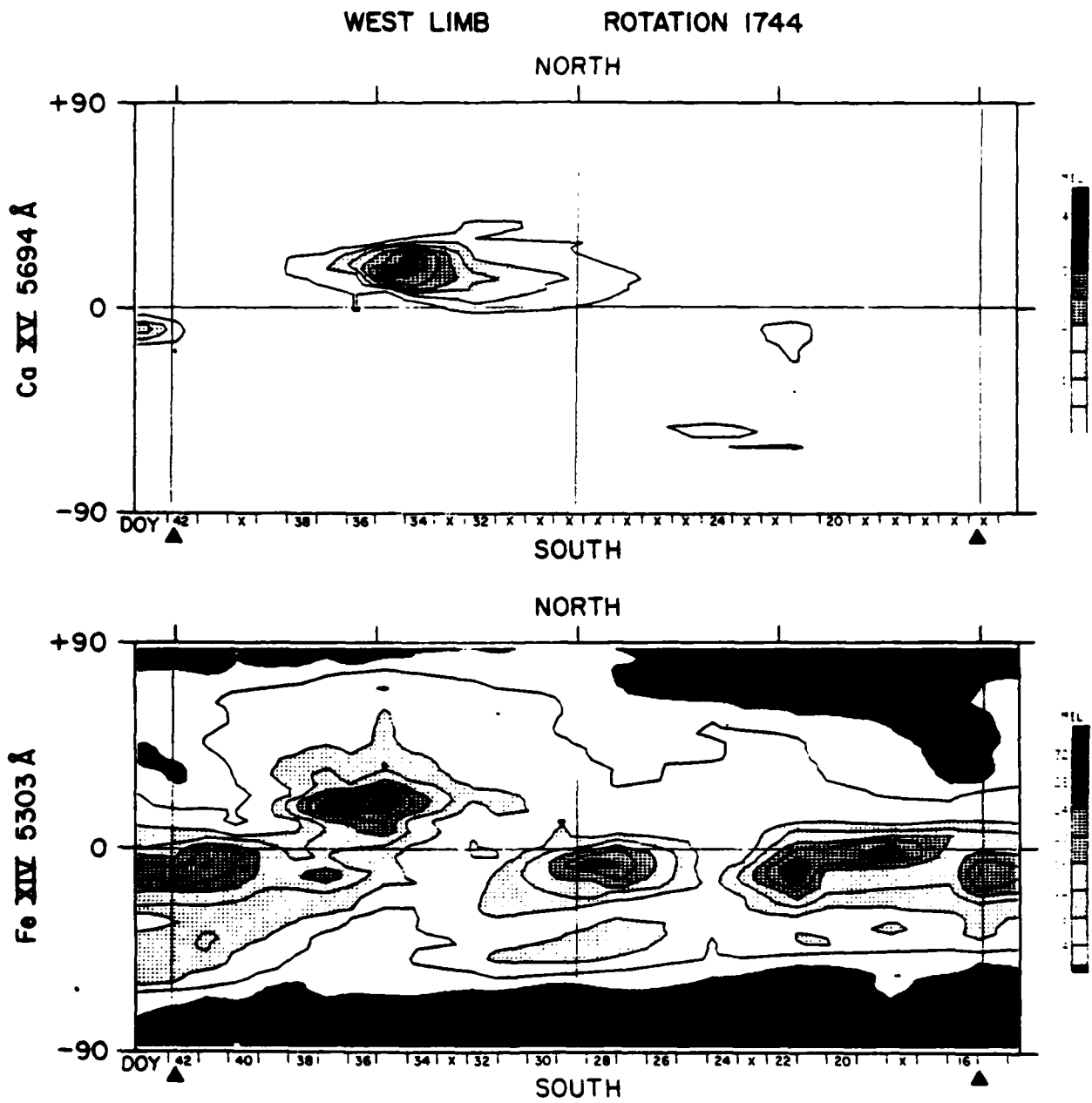
NORTH



WEST LIMB

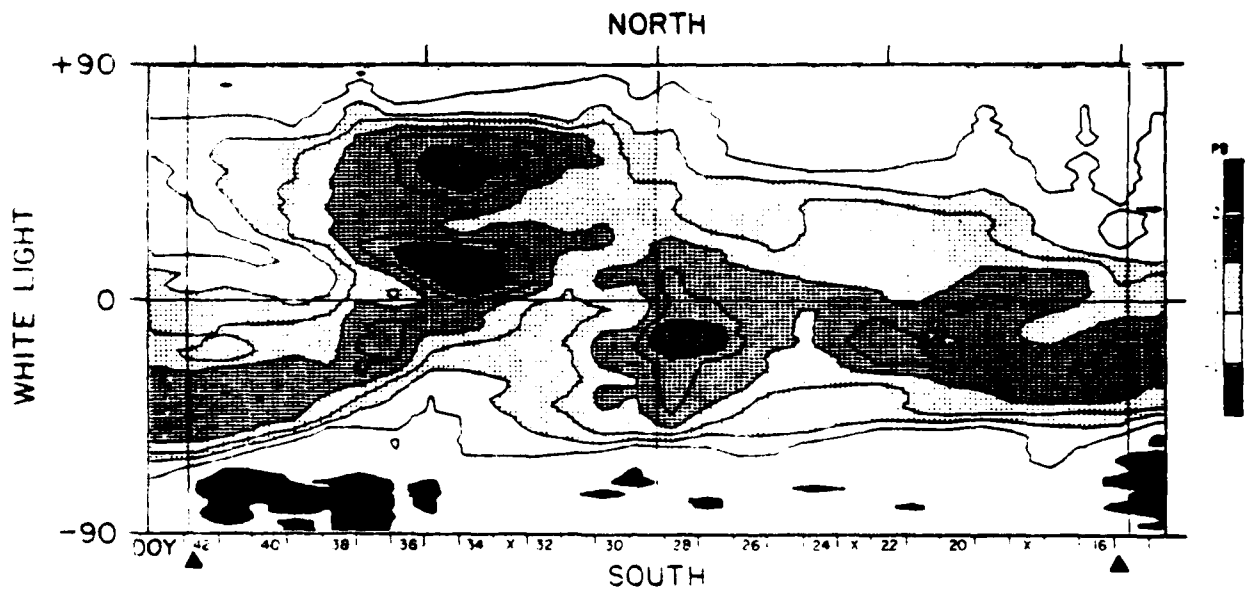
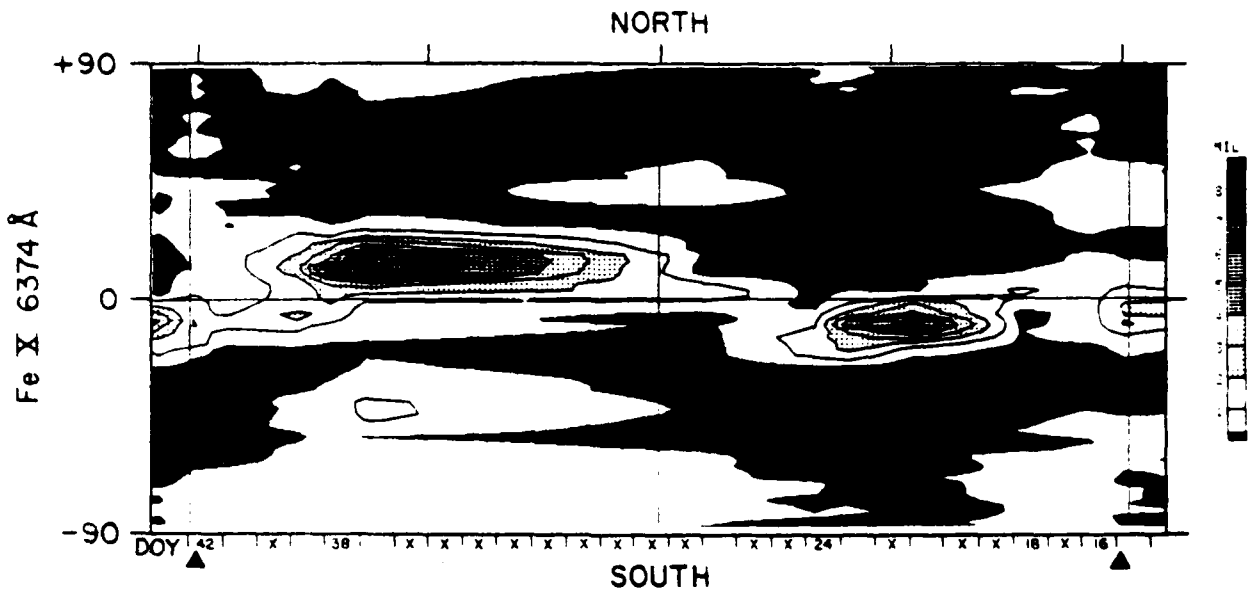
ROTATION 1743

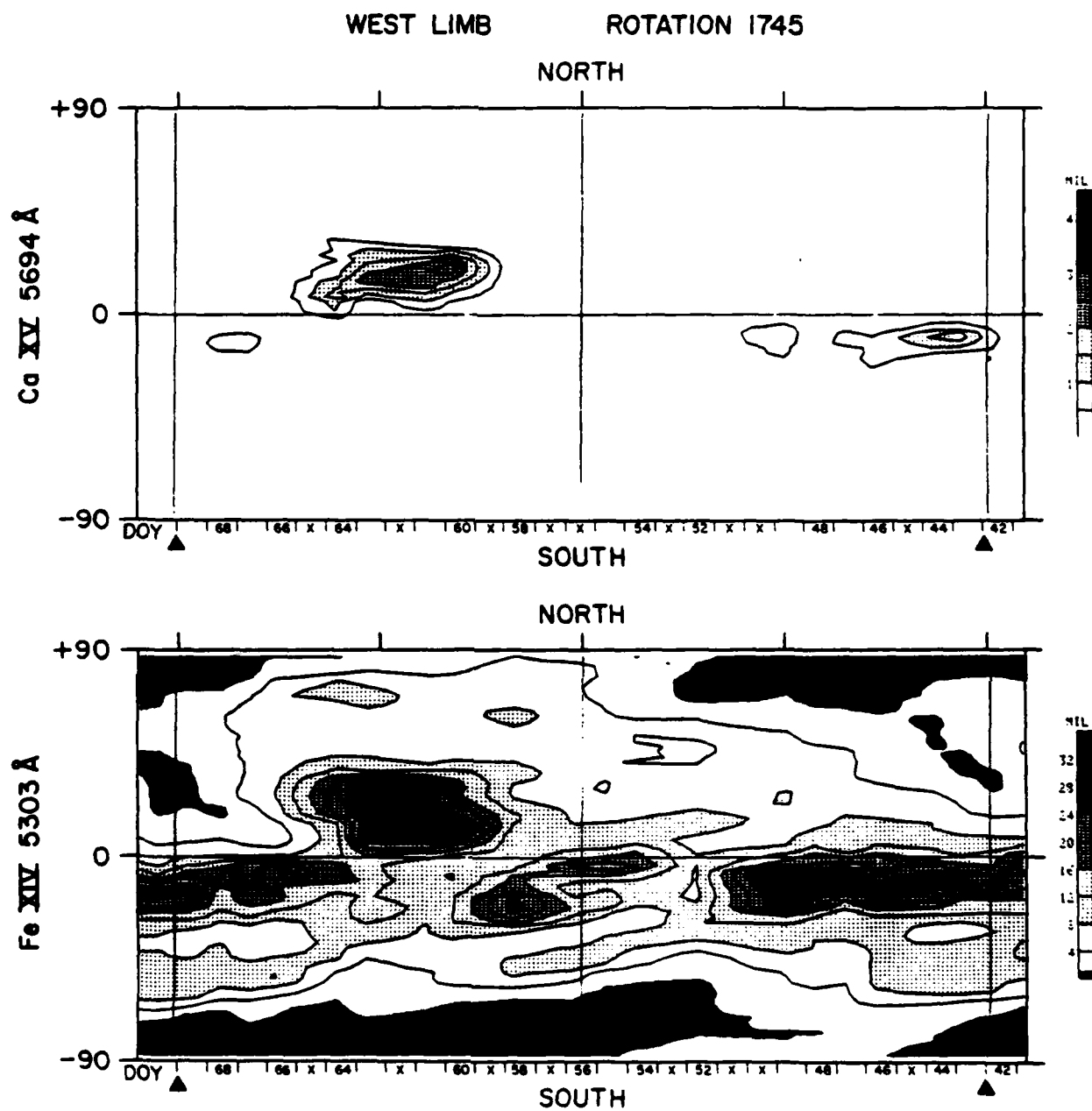




WEST LIMB

ROTATION 1744

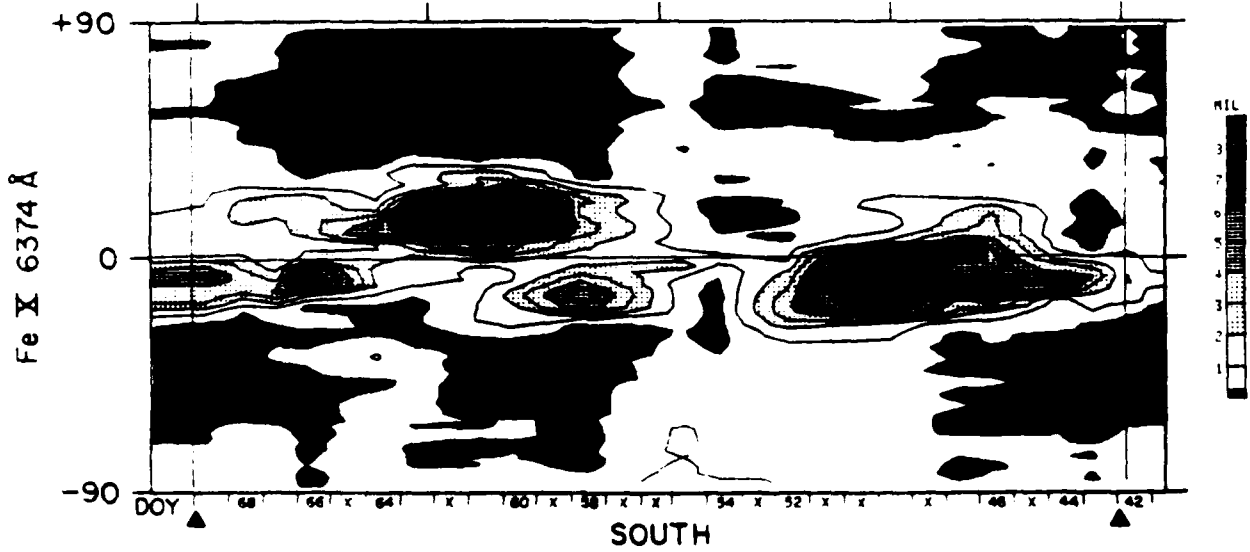




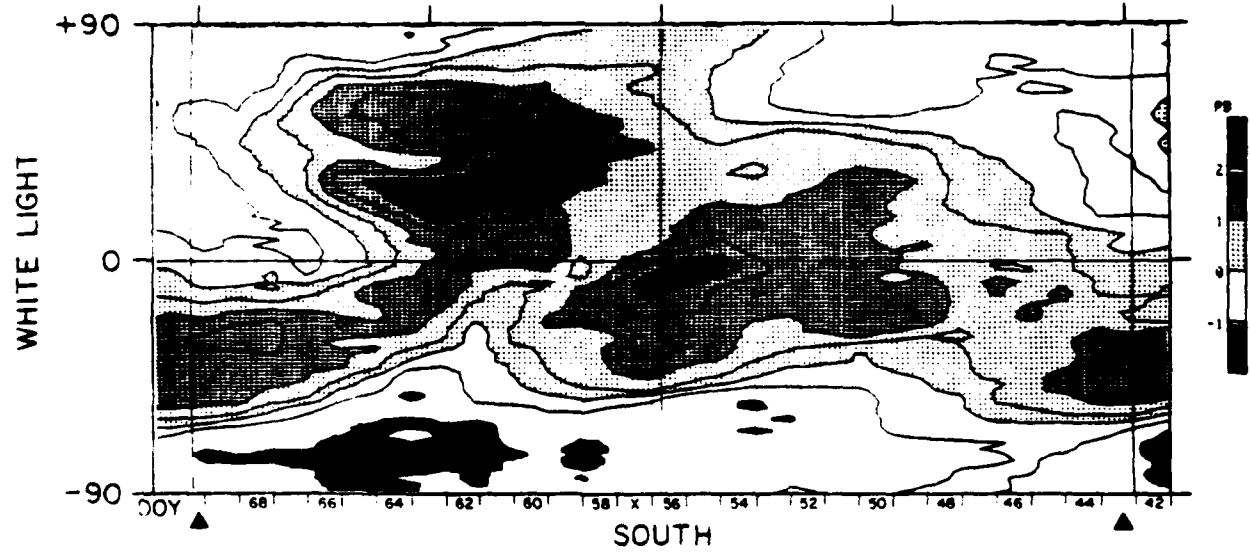
WEST LIMB

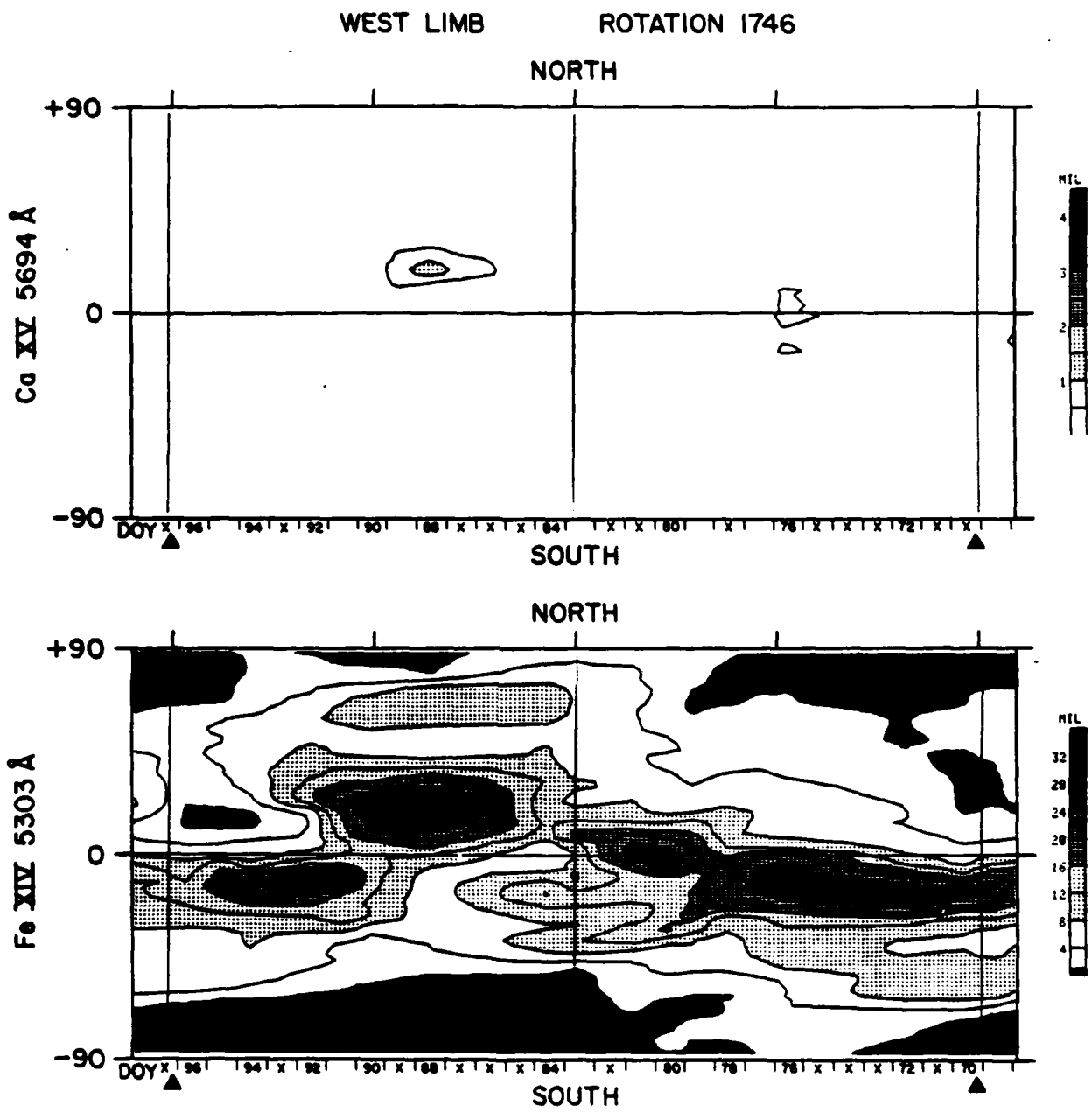
ROTATION 1745

NORTH

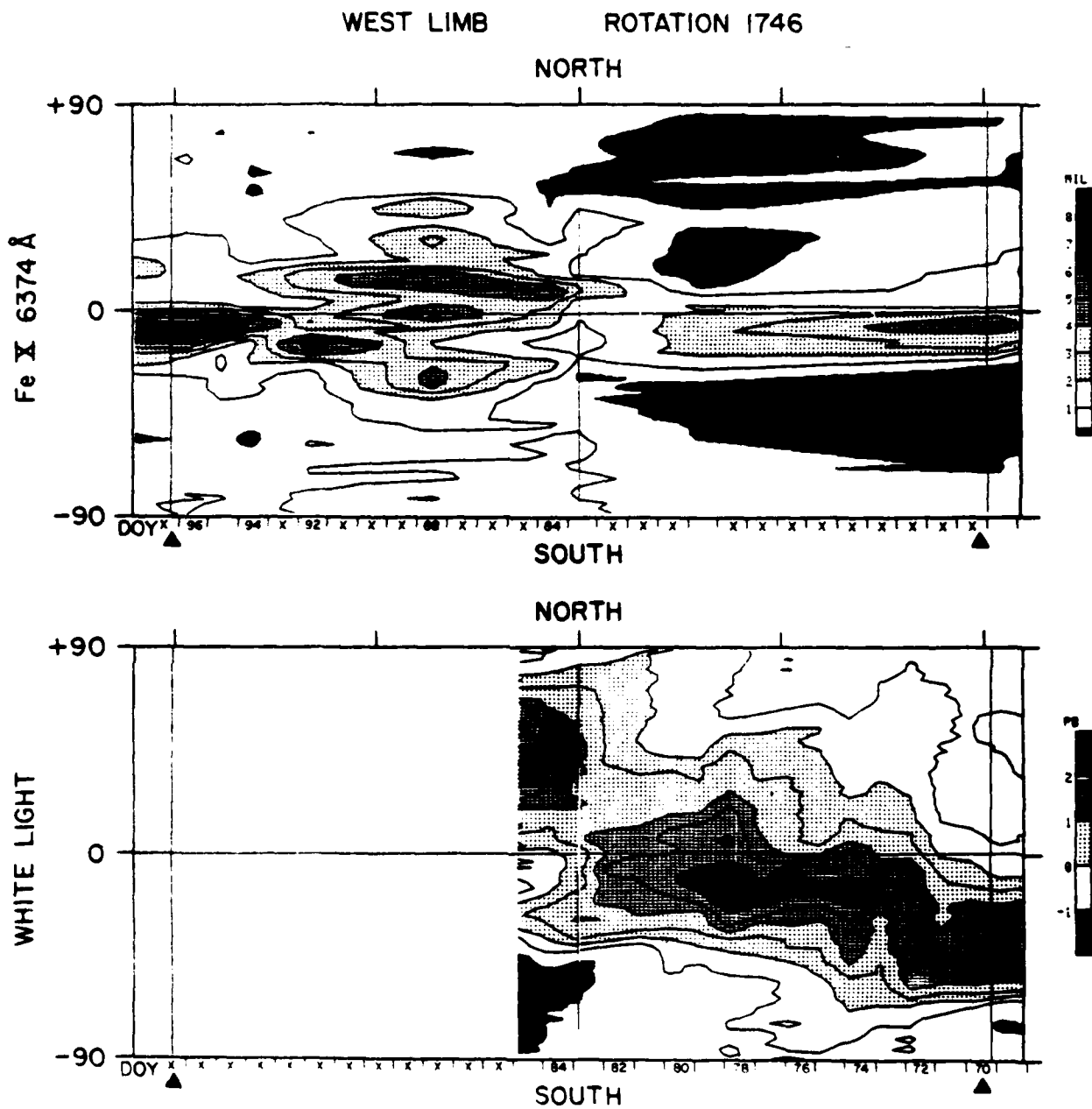


NORTH



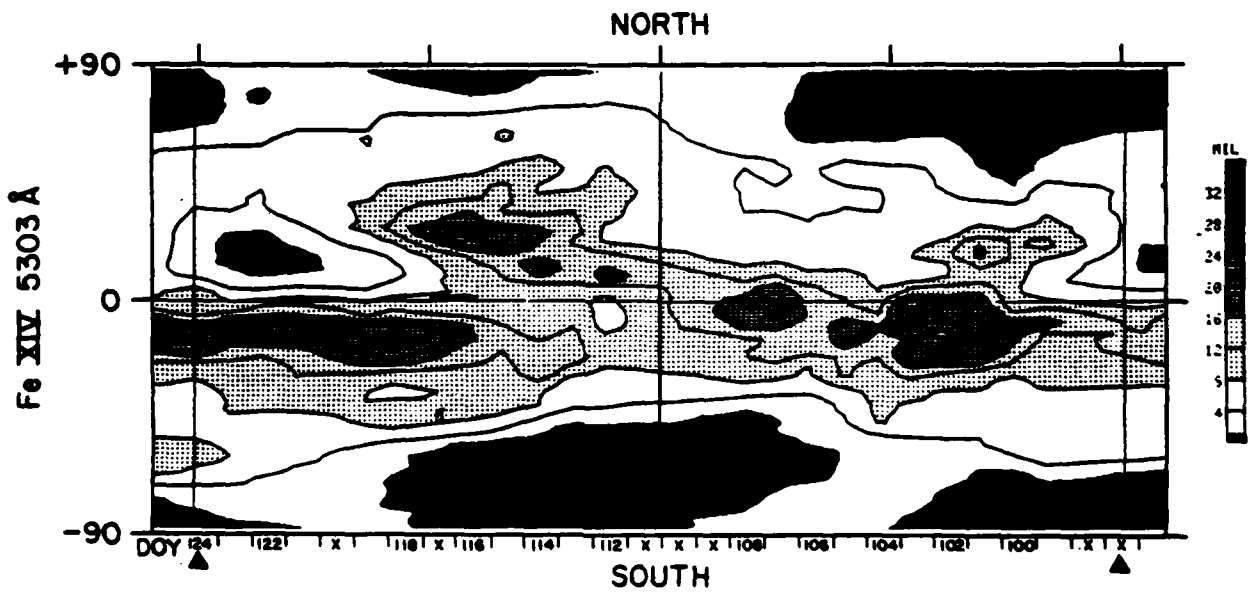
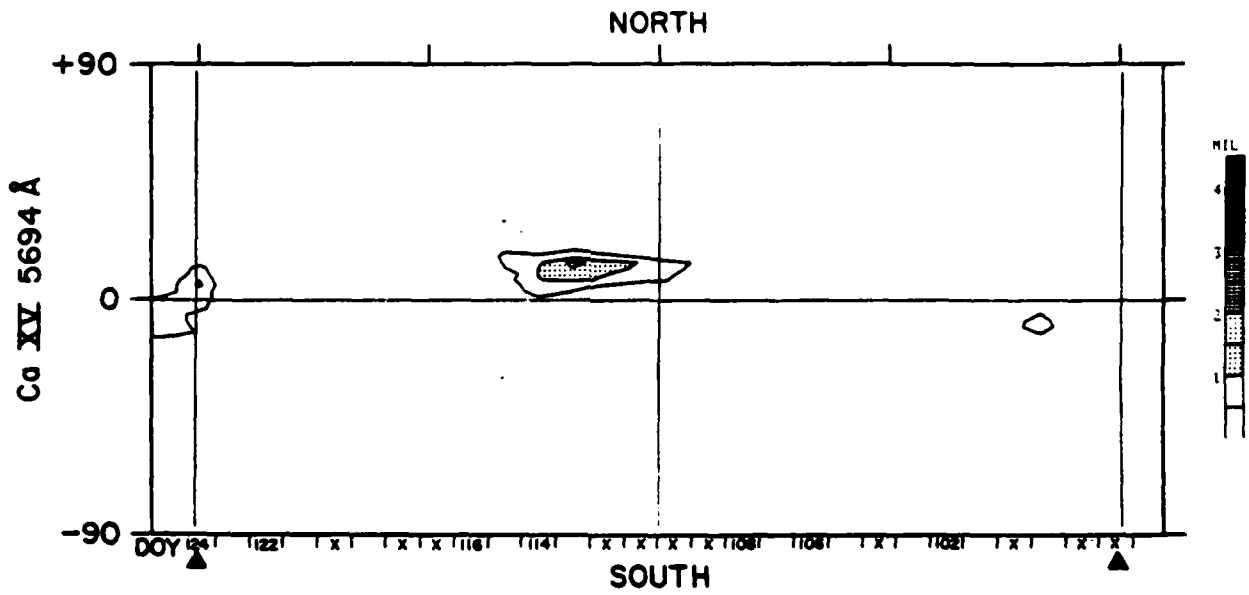


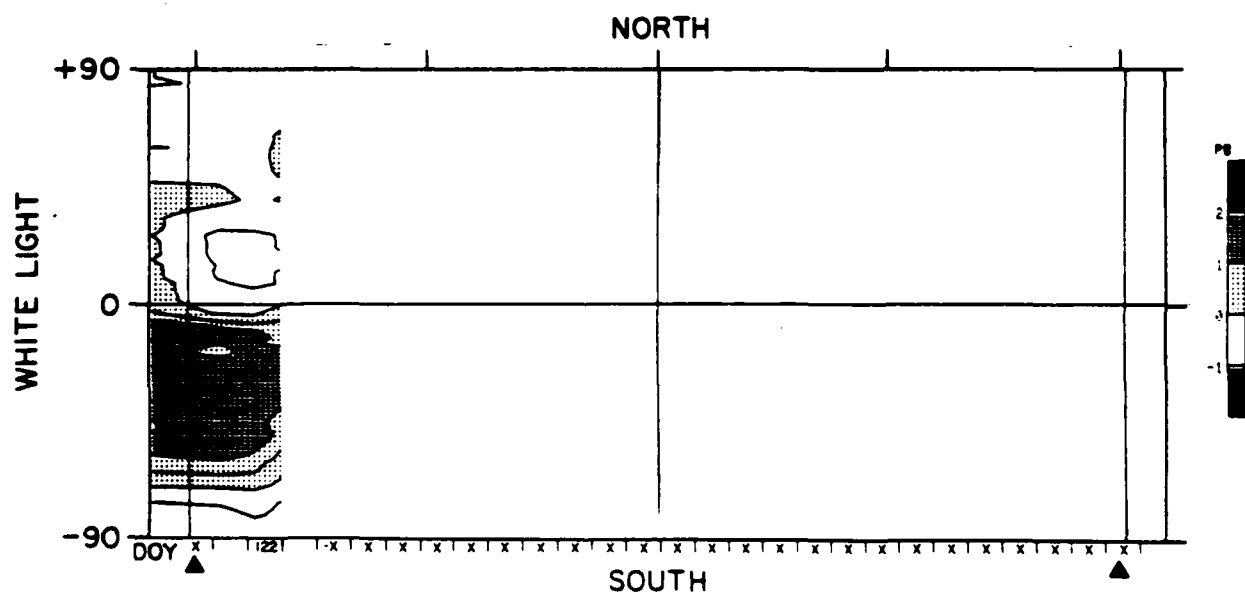
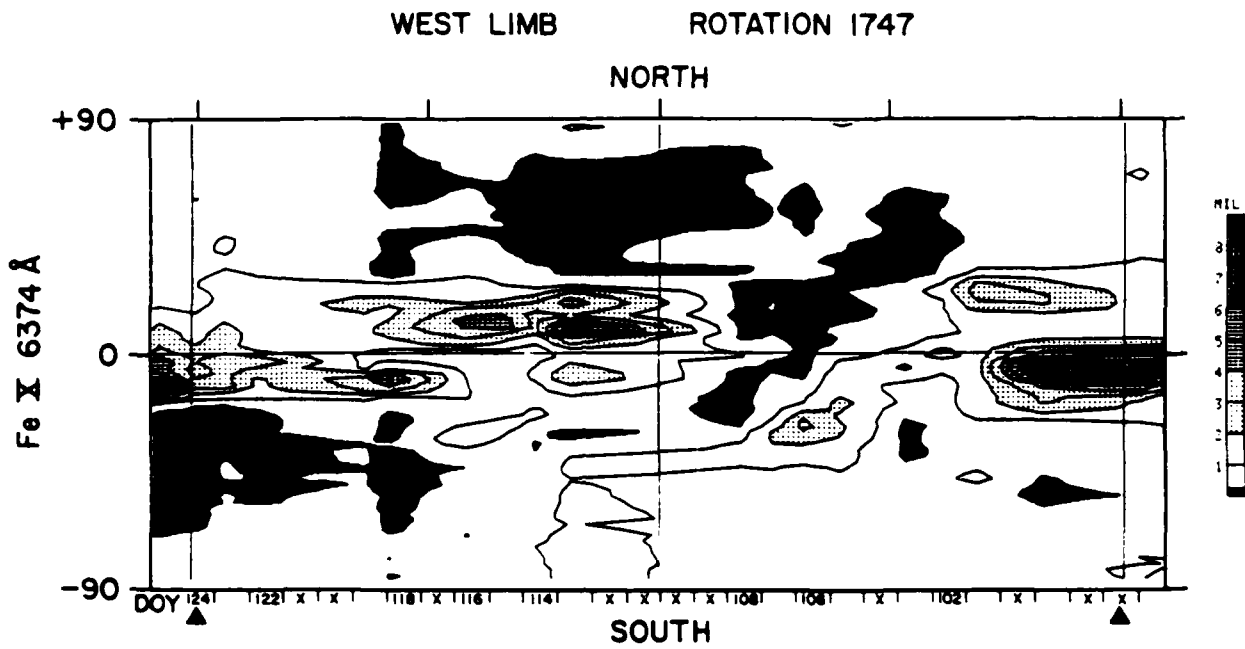


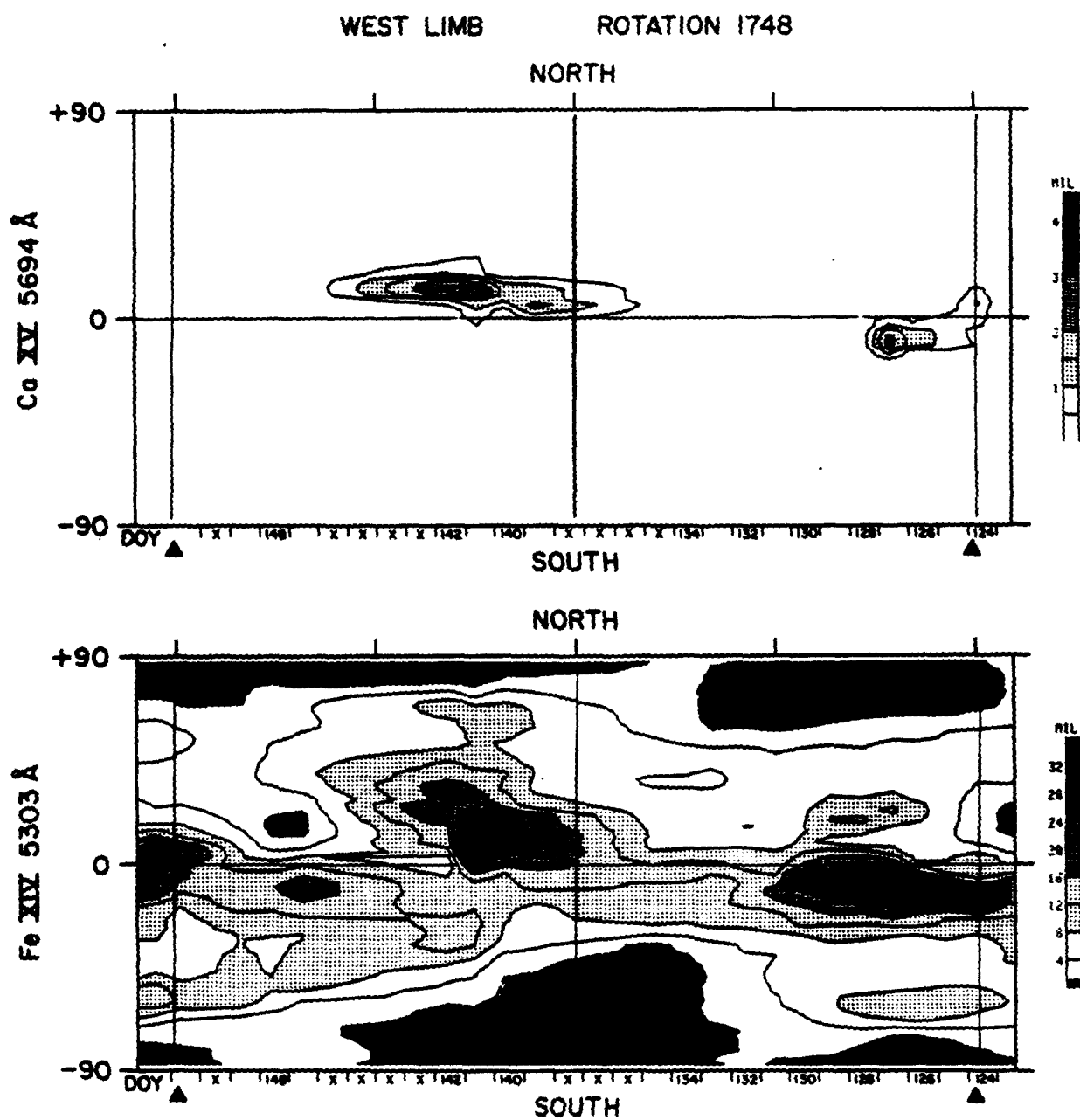


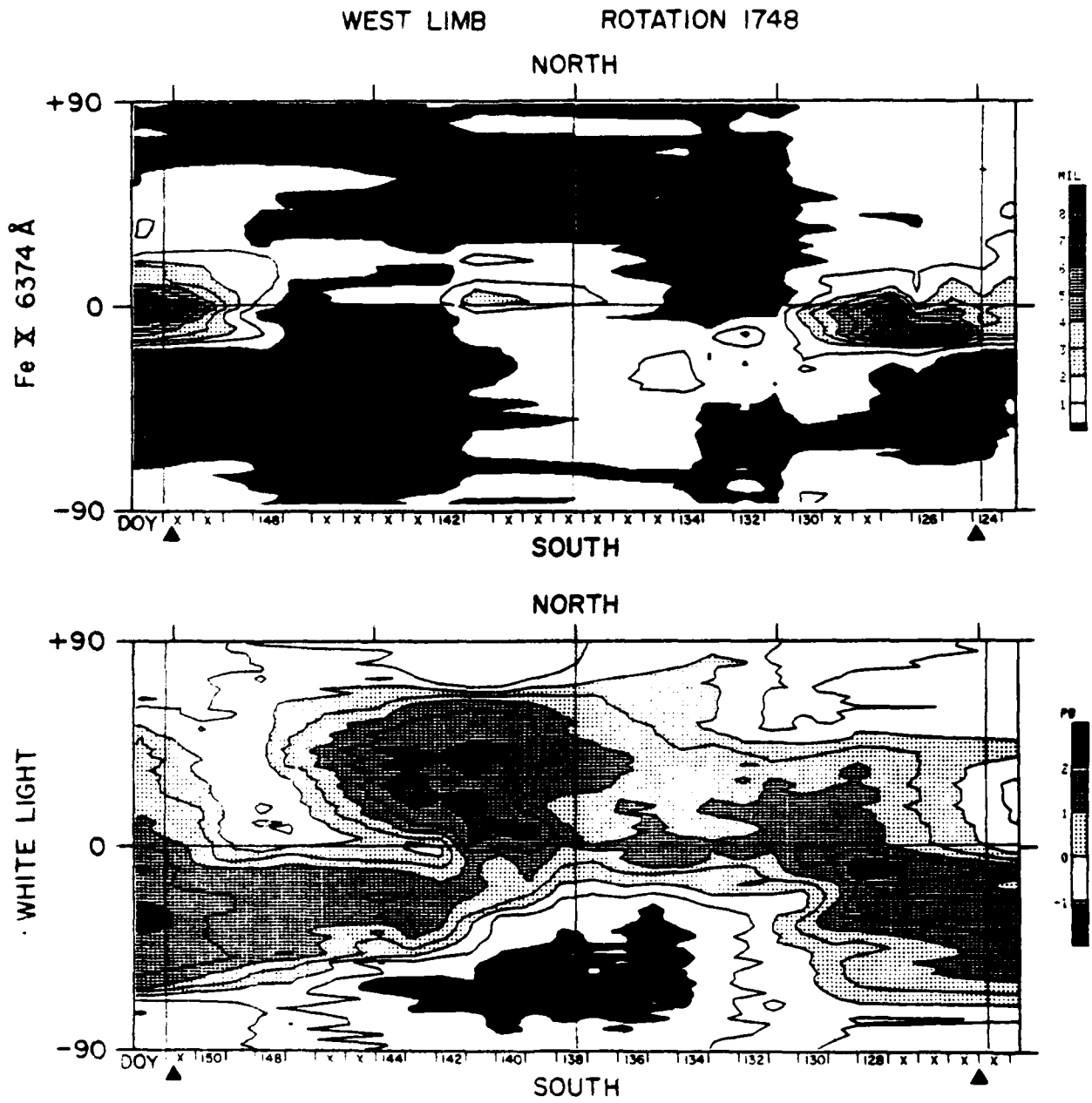
WEST LIMB

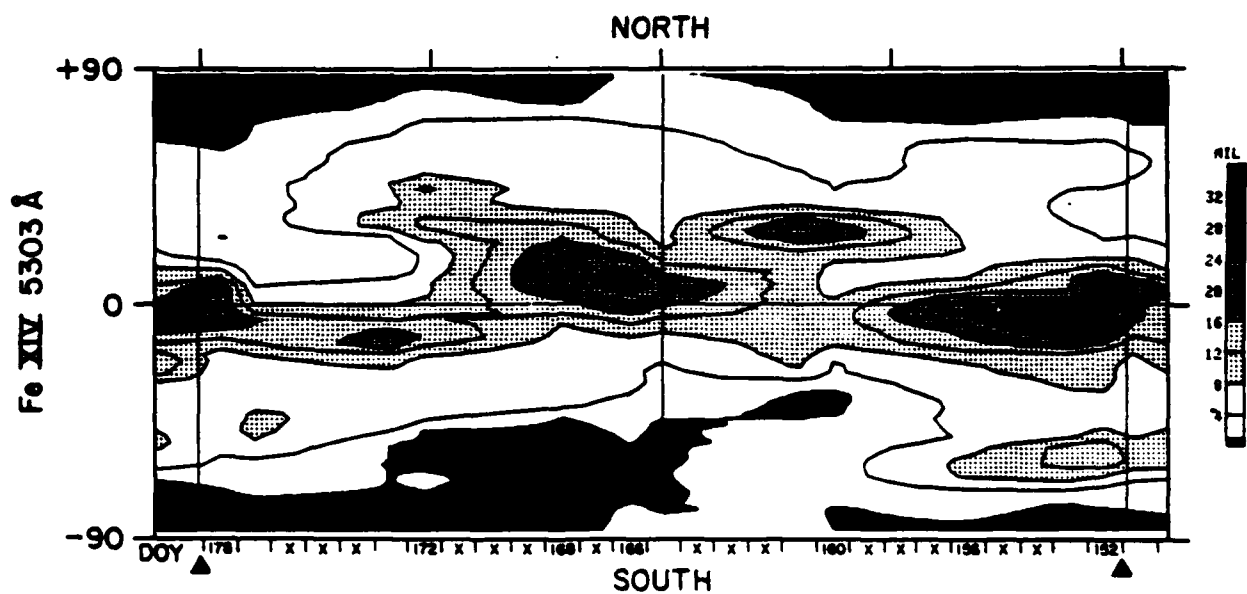
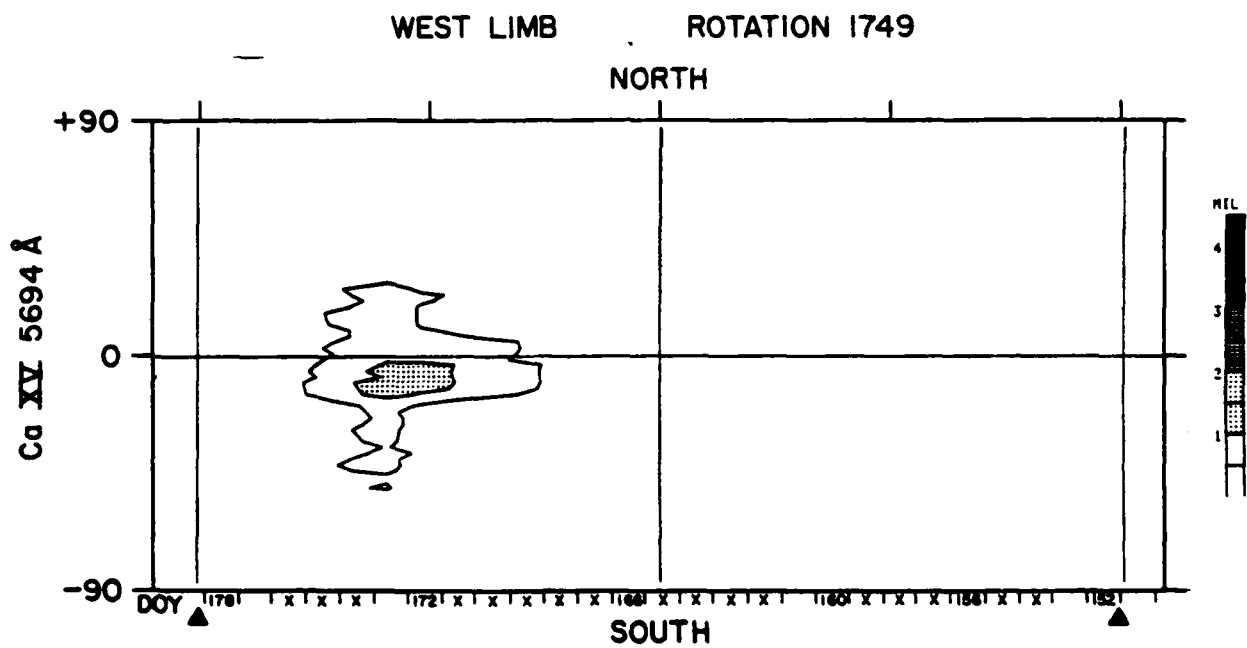
ROTATION 1747





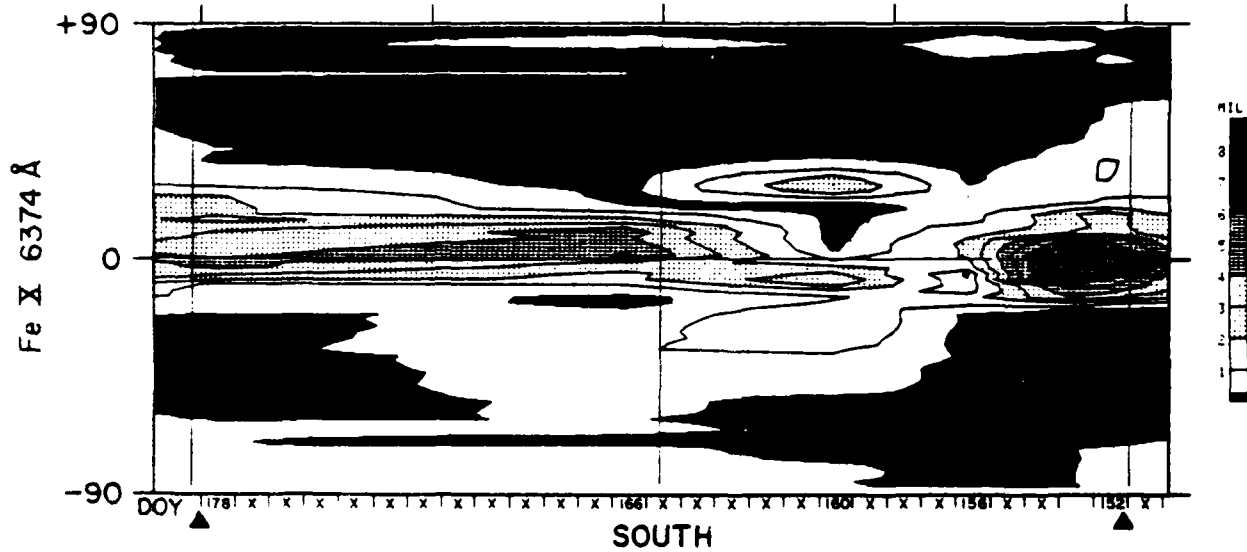




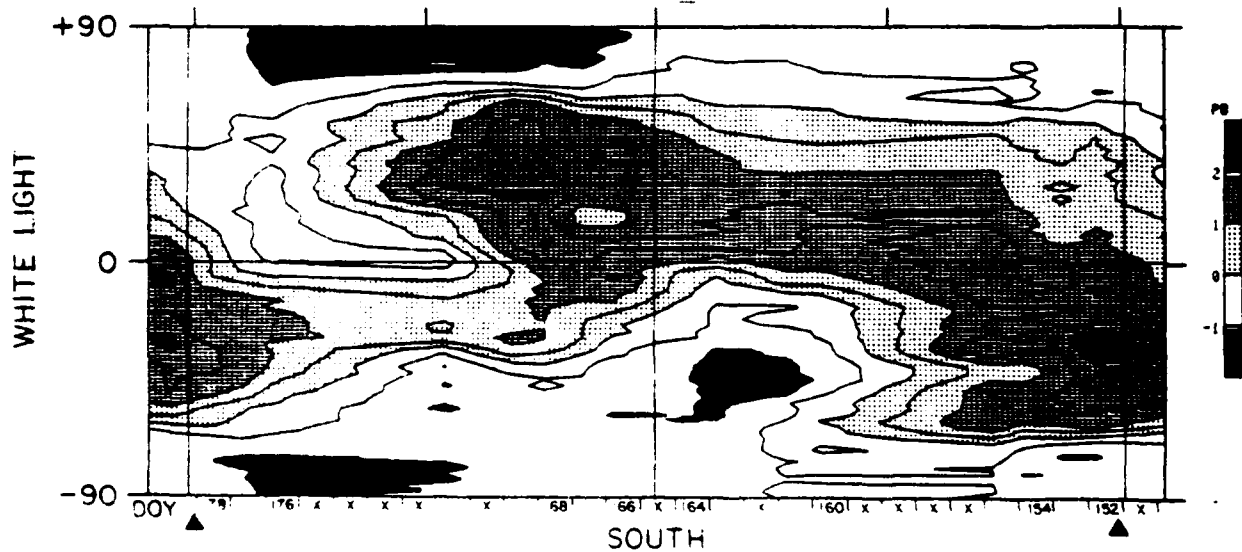


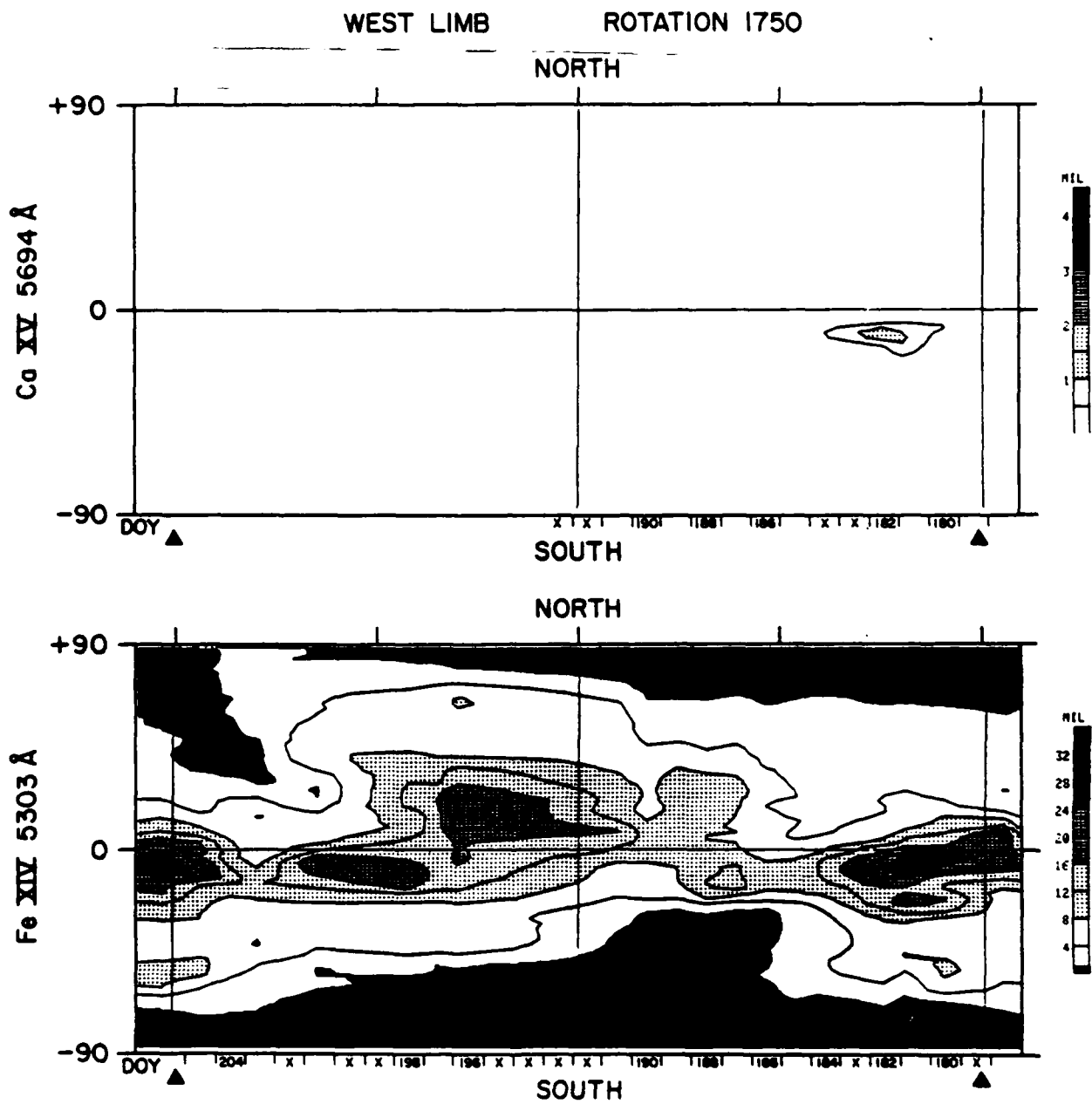
ROTATION 1749

NORTH

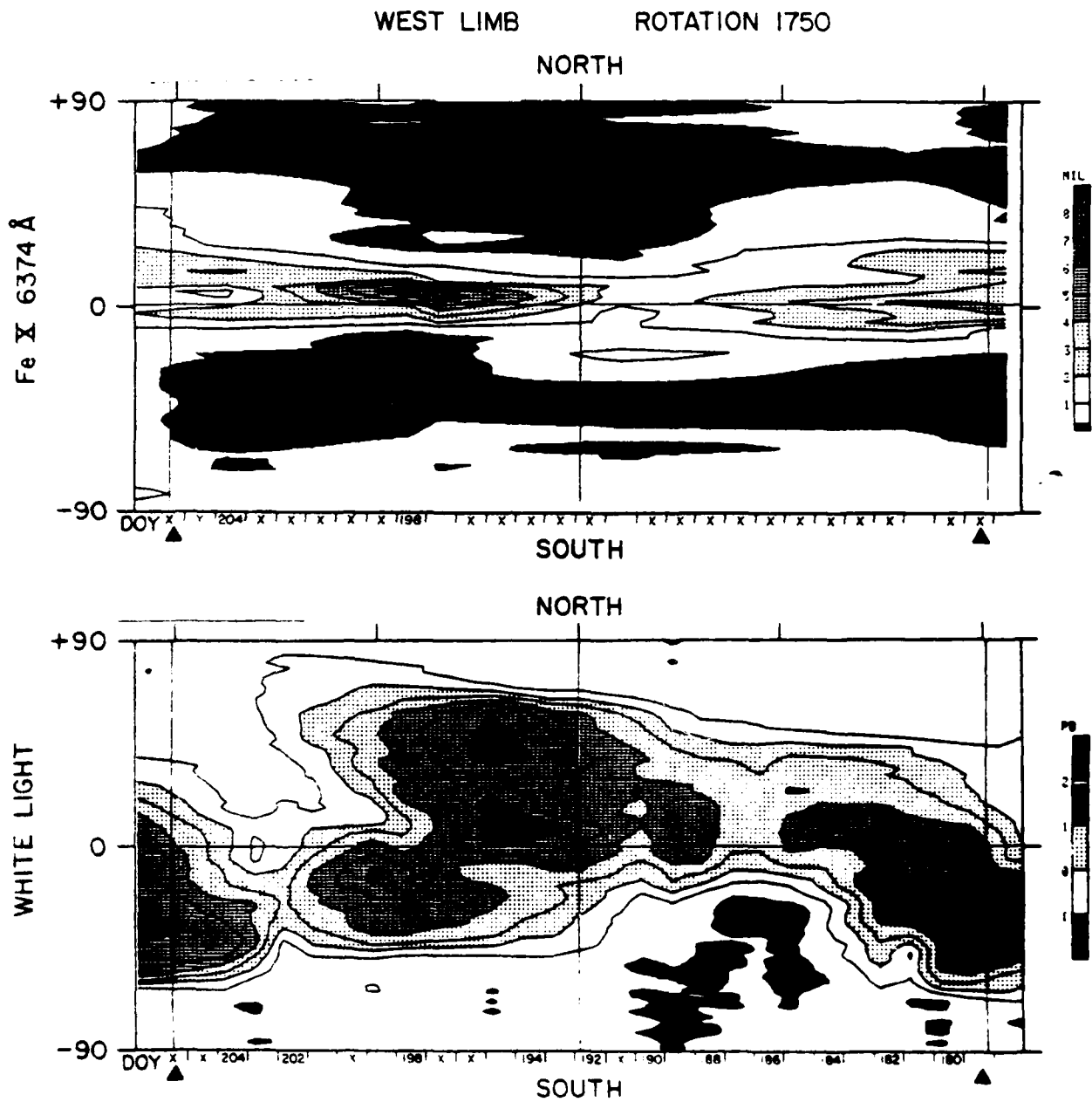


**NORTH**

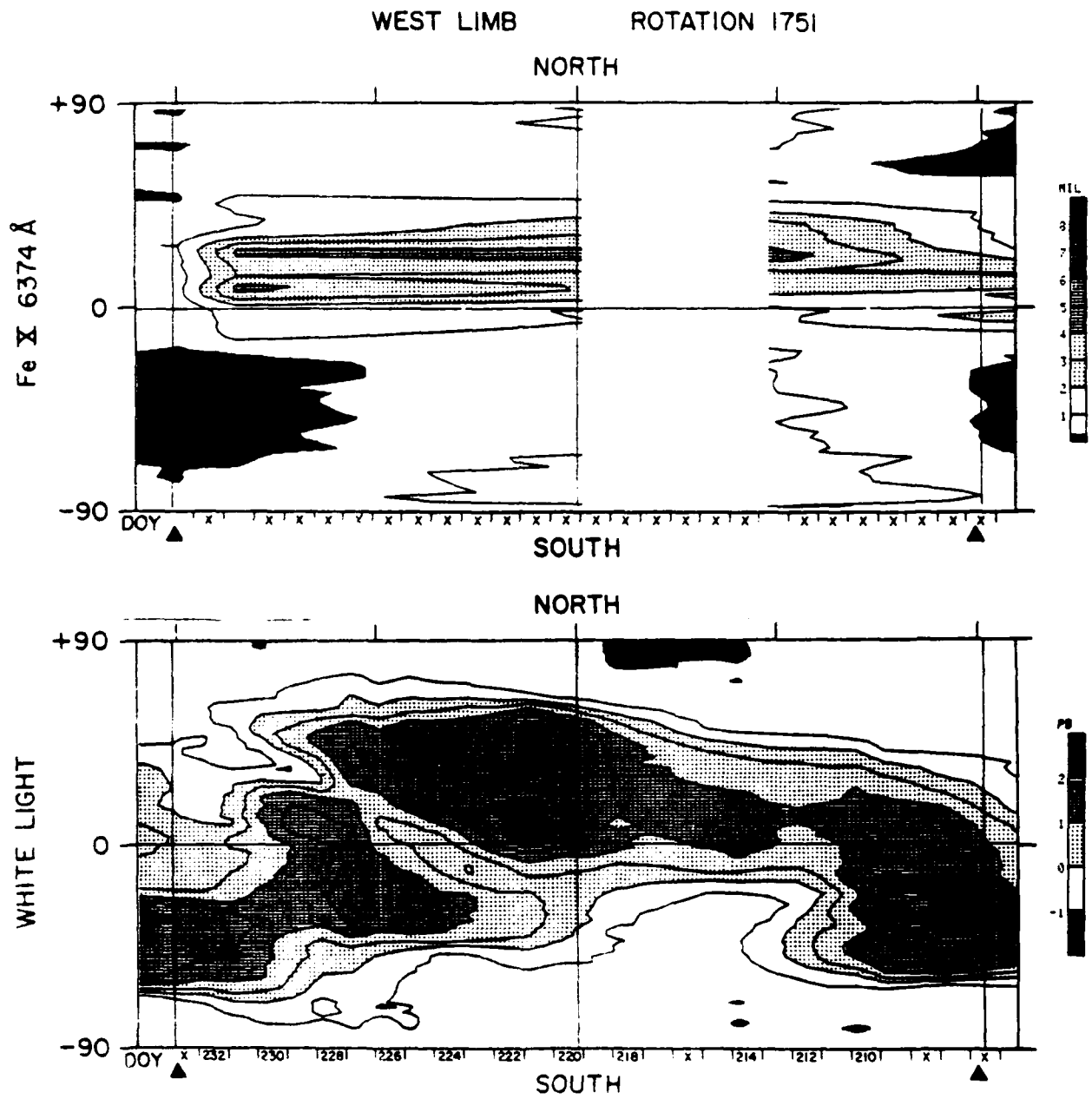


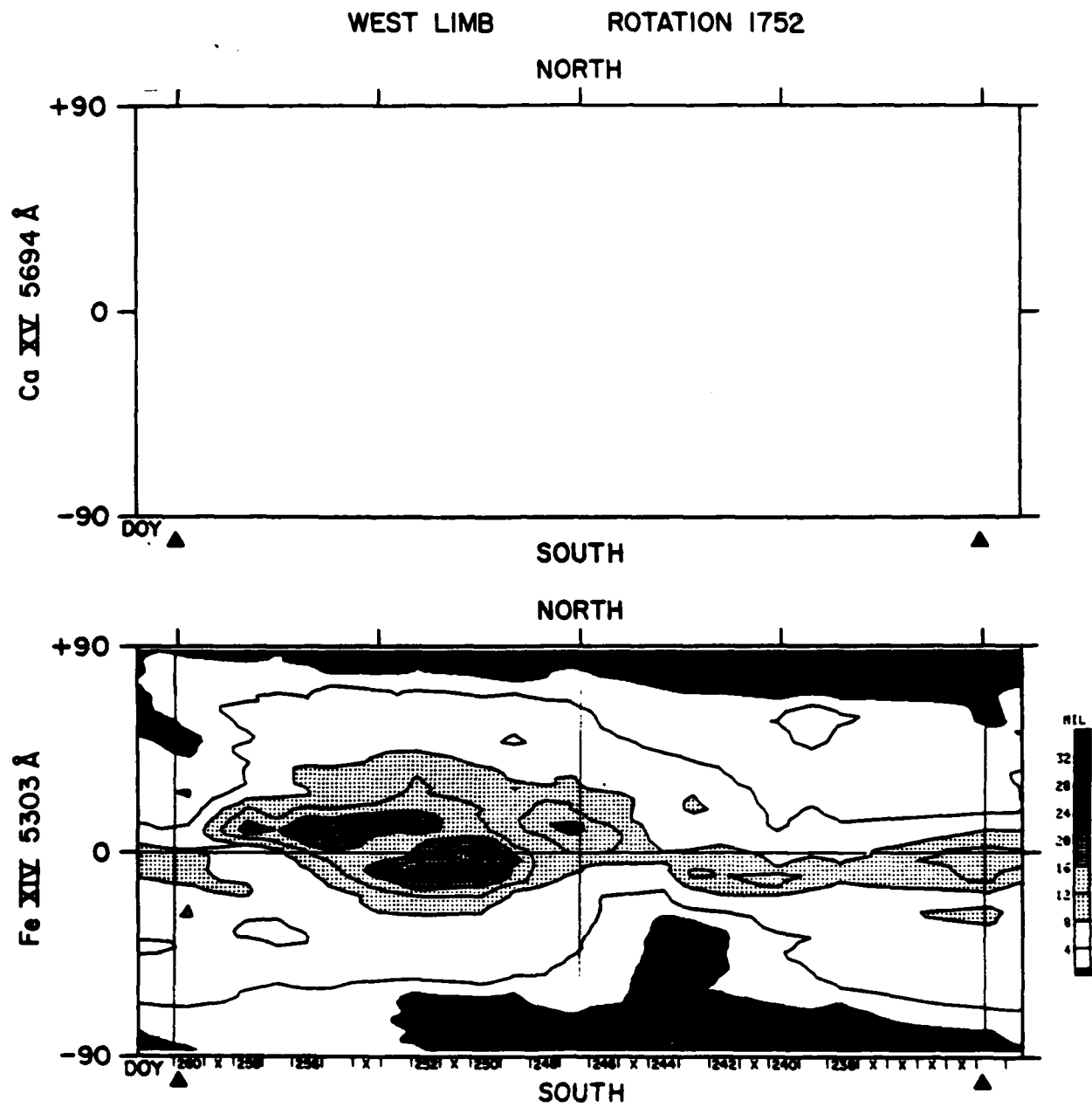


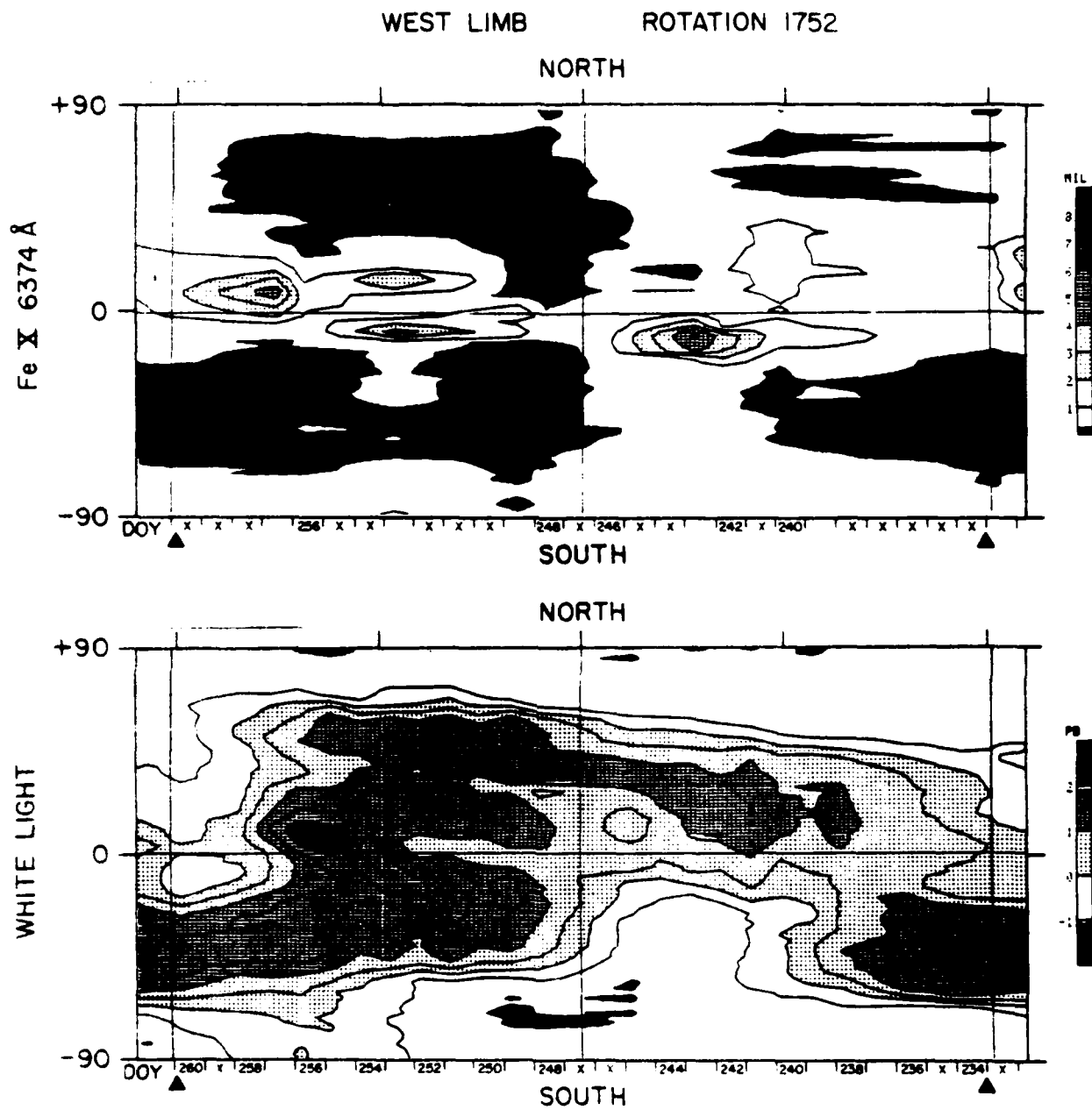


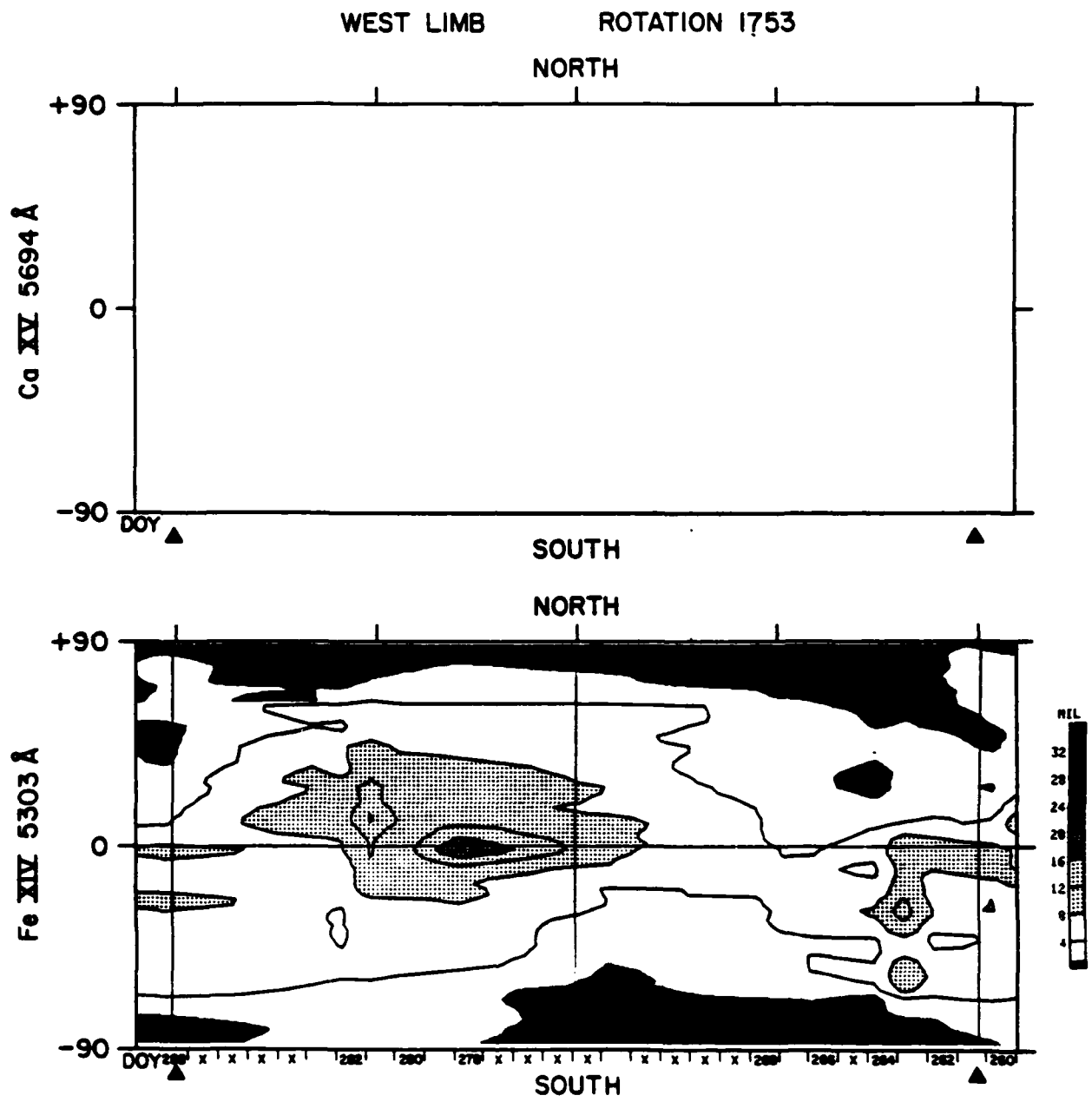






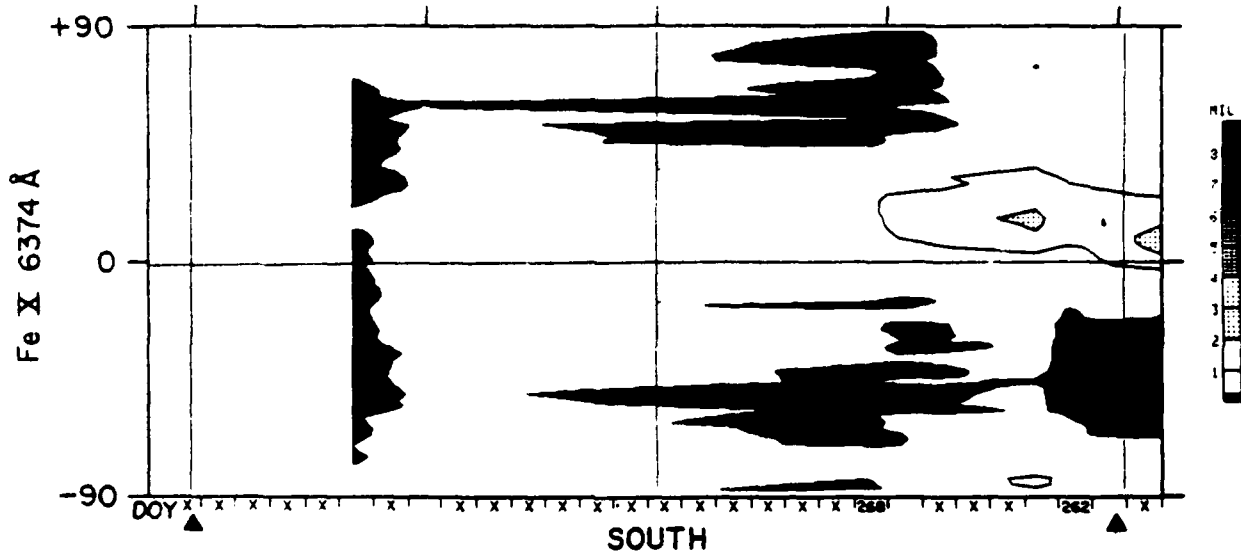




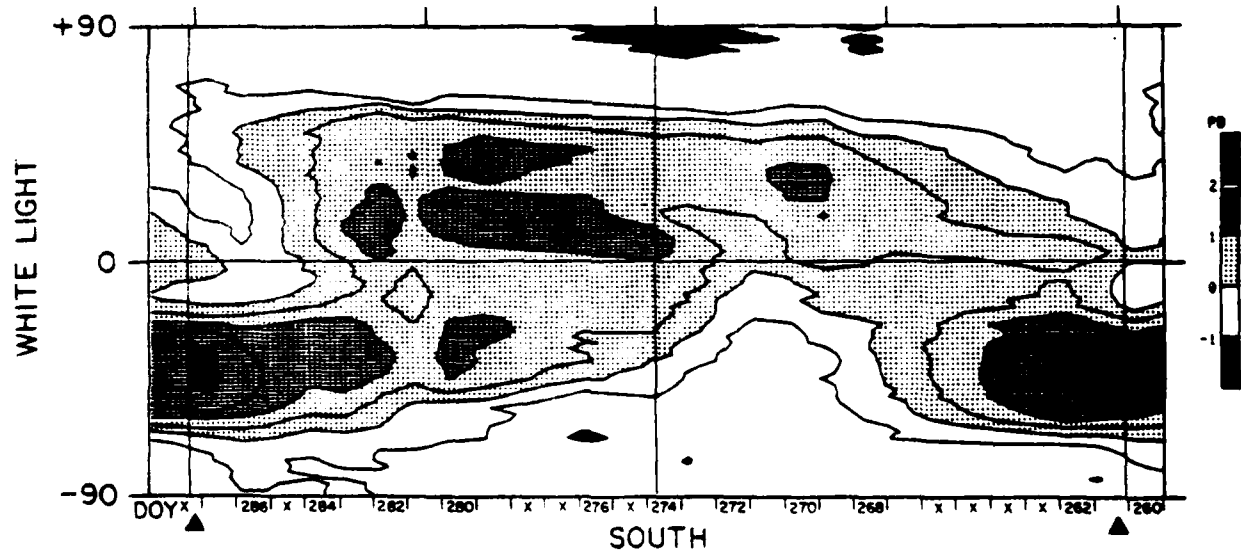


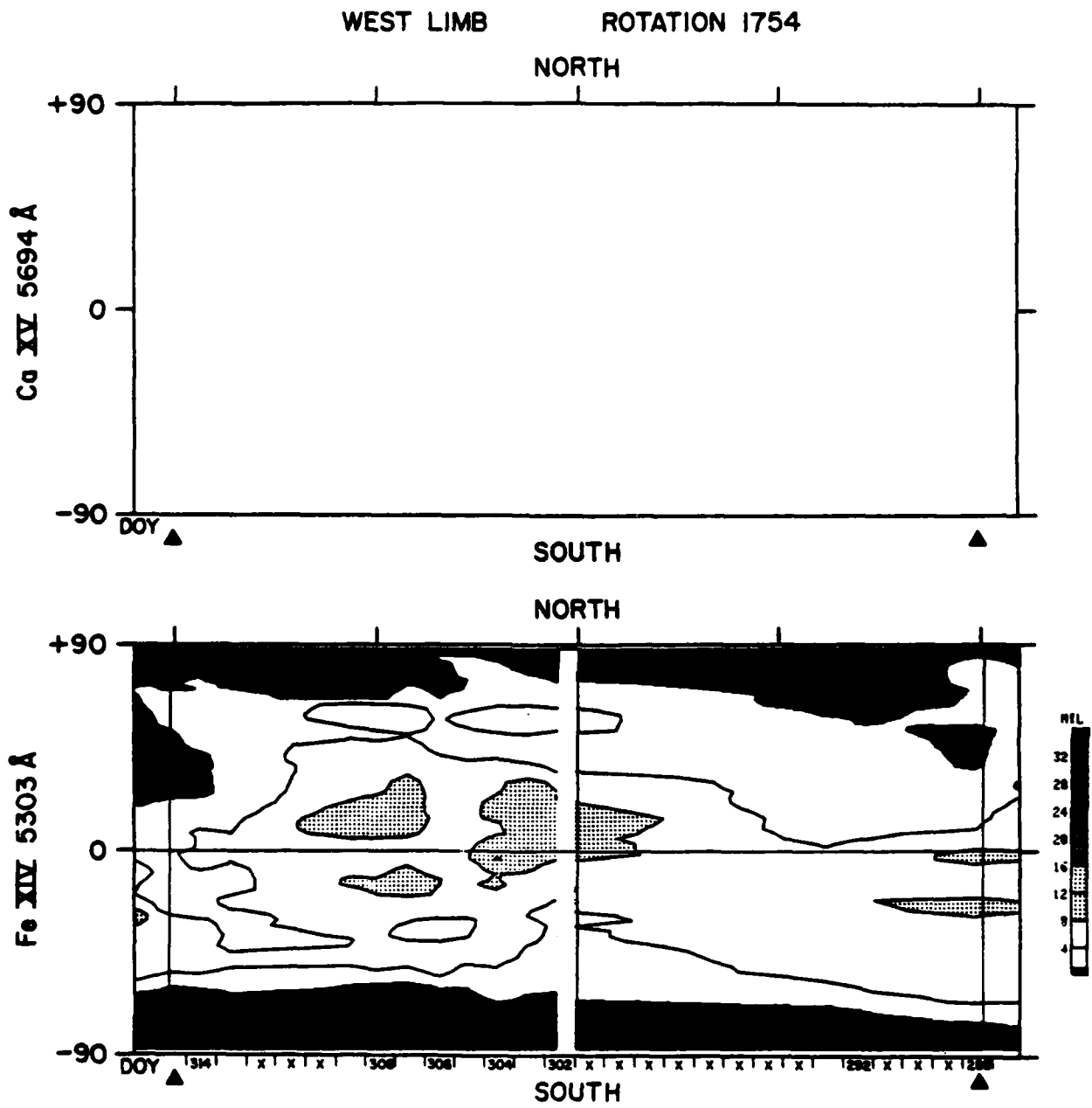
ROTATION 1753

NORTH



**NORTH**

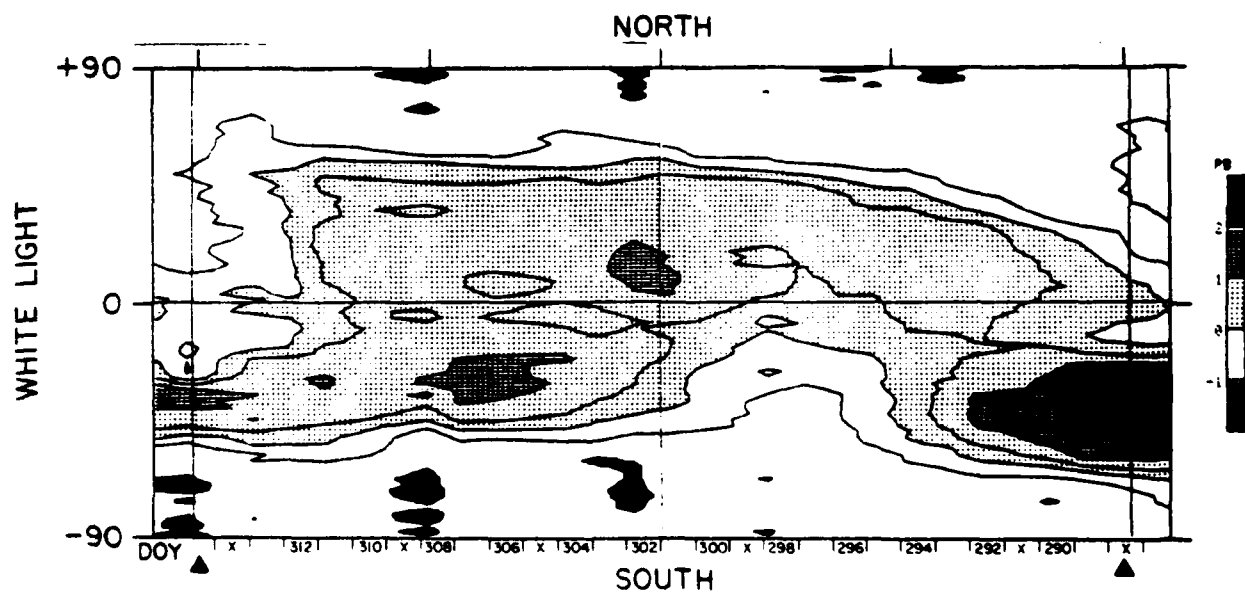
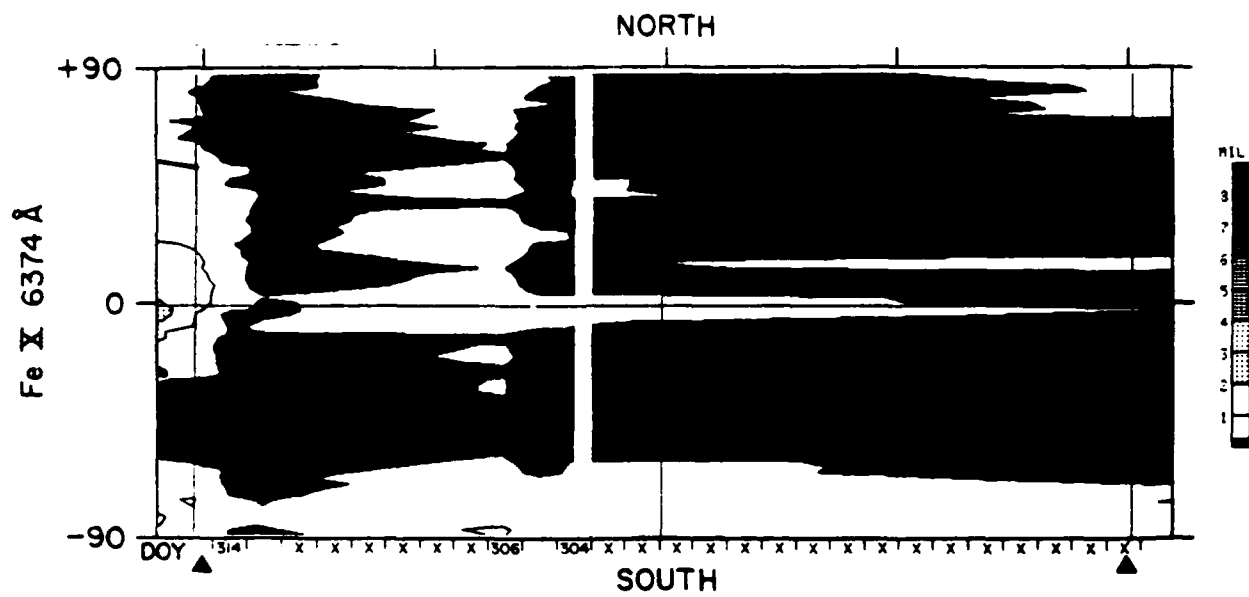


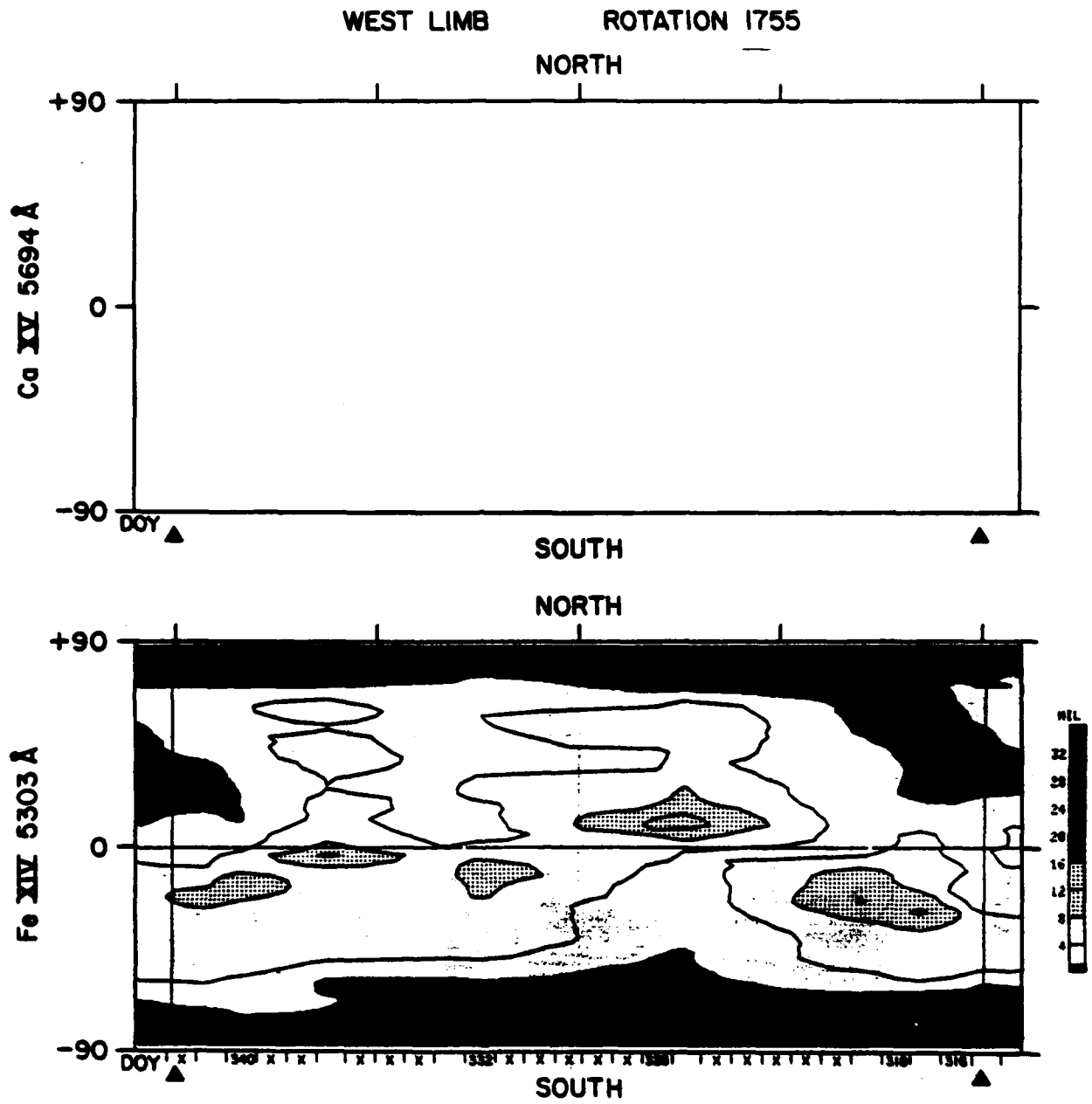


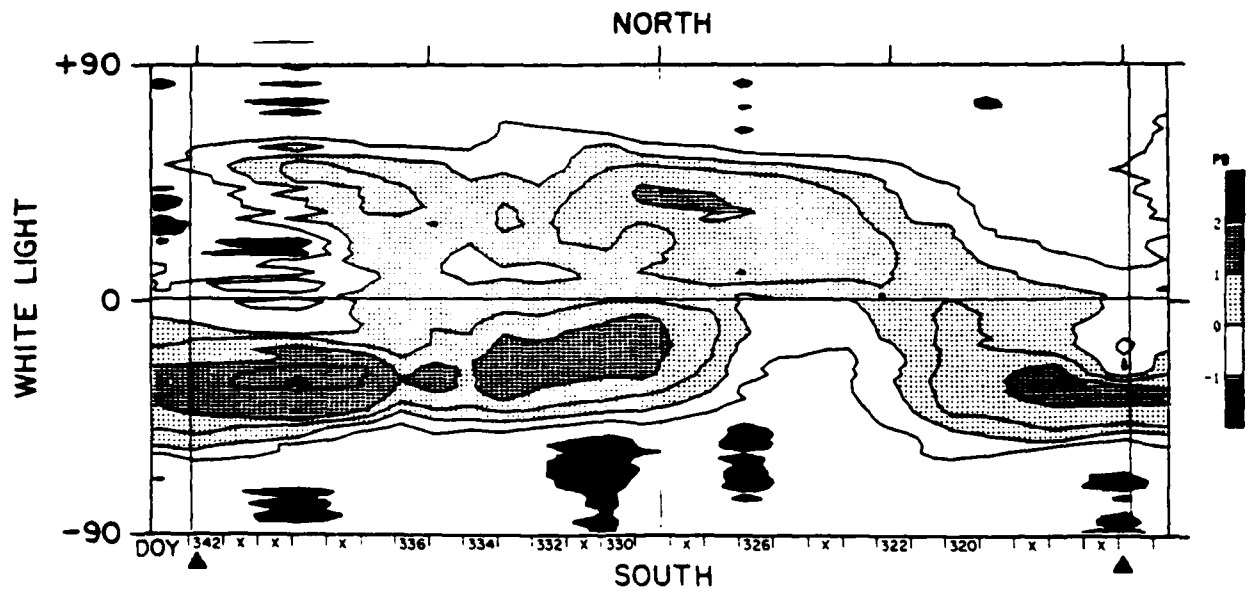
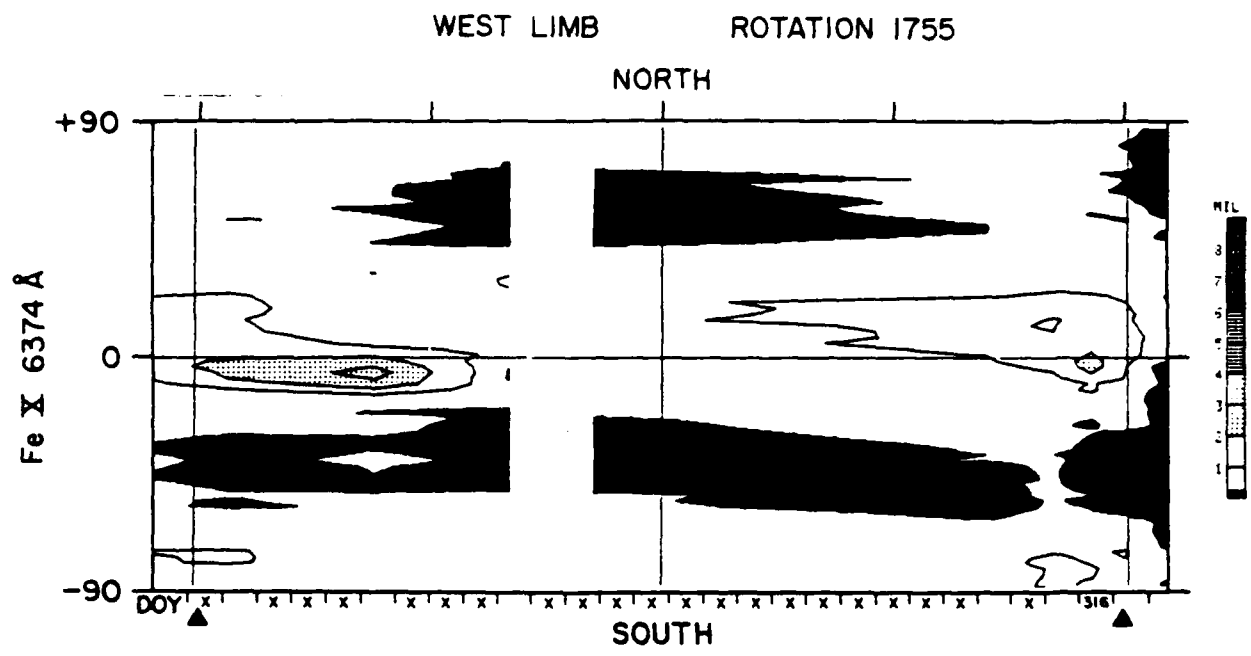


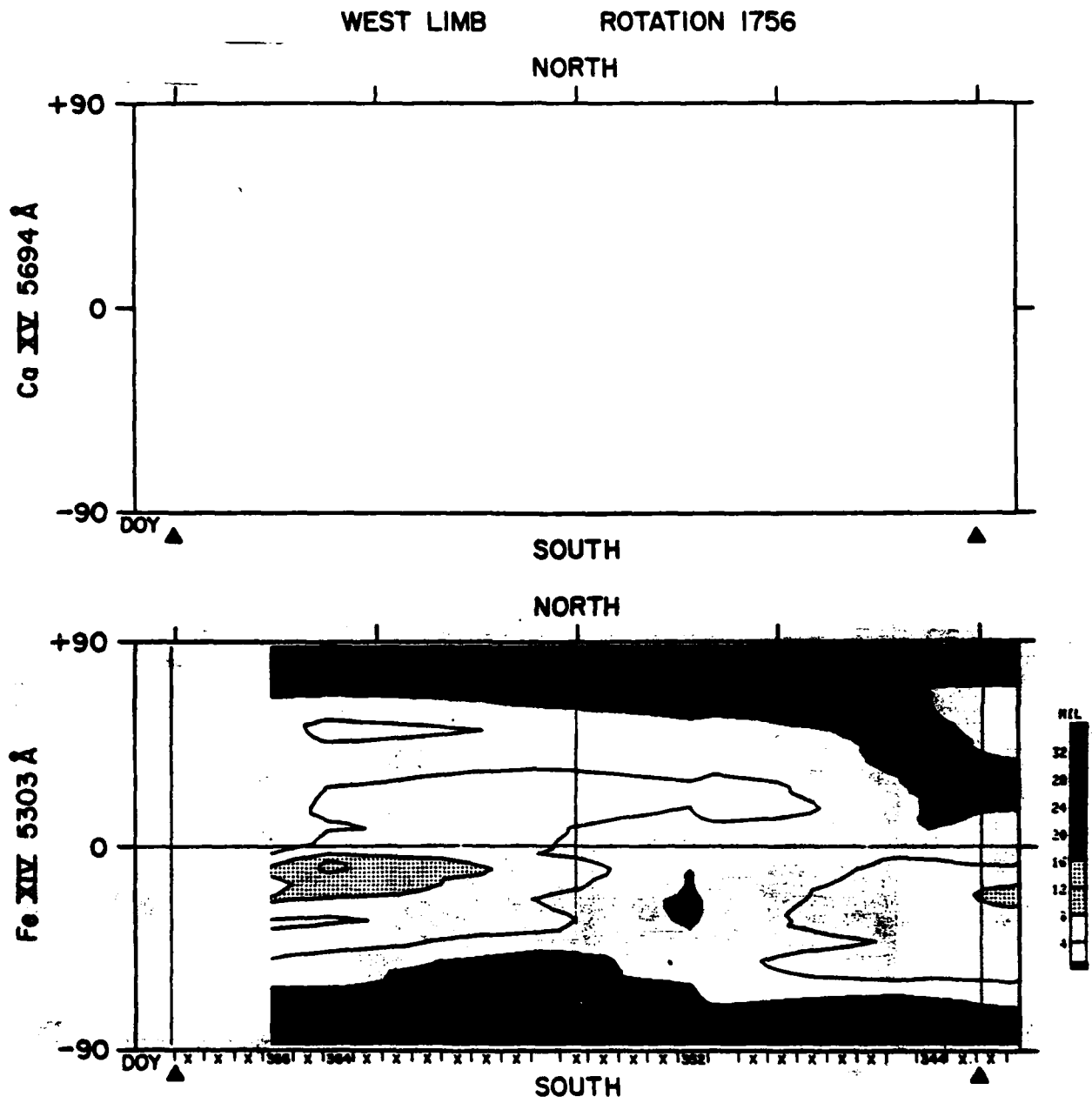
WEST LIMB

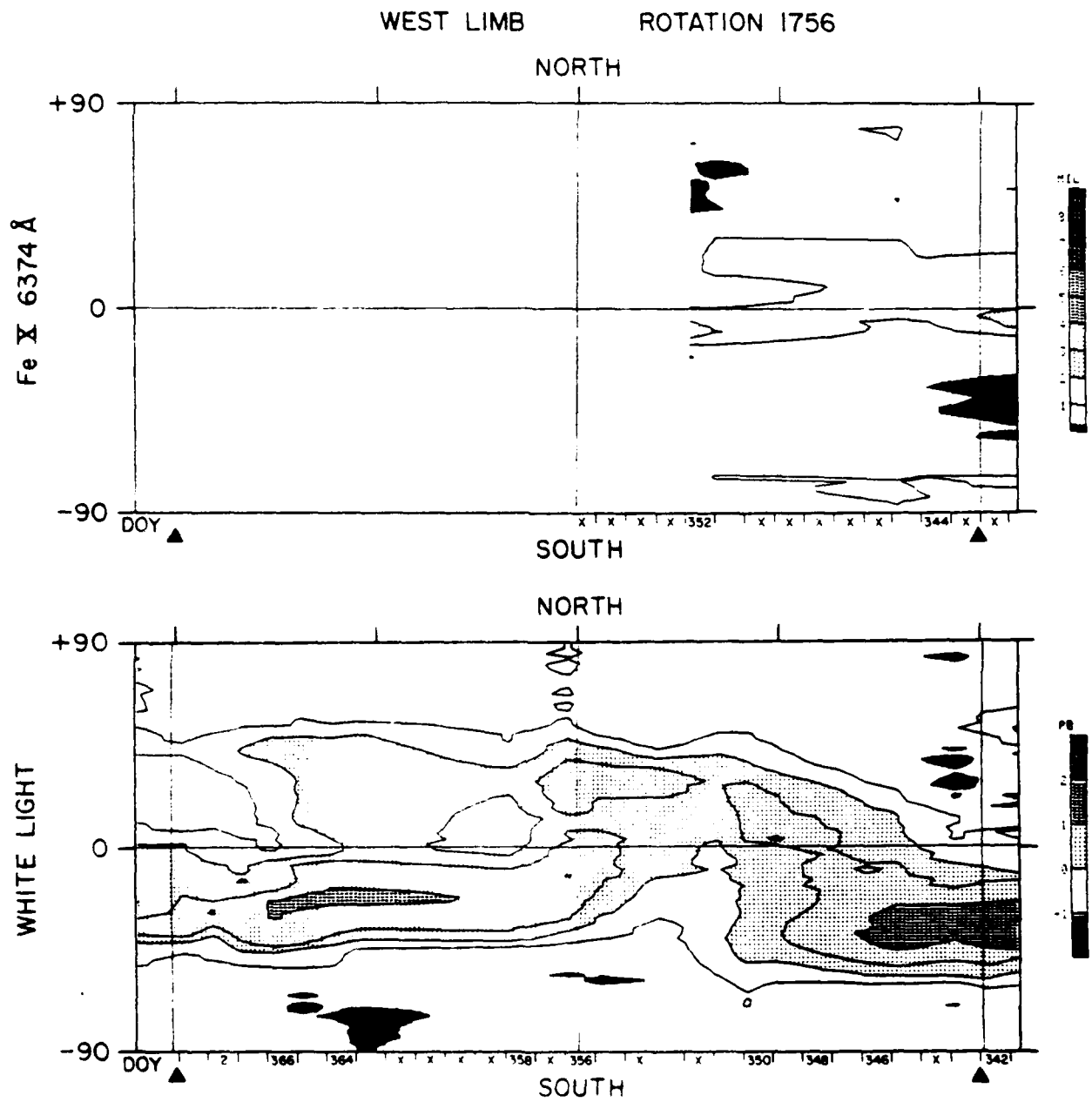
ROTATION 1754











## V. VARIATIONS OF THE LARGE SCALE CORONA IN 1984

Throughout the year of 1984, including the operations period of SMM II, a pronounced change in the distribution of coronal material can be traced by inspection of the synoptic charts for the three emission lines and the white light. We shall discuss the coronal situation as was documented at the beginning of the year and then comment on the general evolution away from this initial state.

At the beginning of this period, the gross morphology was relatively simple. Enhanced density regions (West limb: DOY 62 and DOY 84) were separated by almost 180 degrees of longitude, the one at DOY 62 extended from near to the equator upward to a rather high solar latitude, approximately N60. The other dense region was found on the opposite side of the sphere, extending from the equator southward to approximately S60. Thus, when viewed by the coronagraphic instruments, C/P on SMM, and the ground based emission line and white light photometers, the rotating corona appears as a tilted dipole configuration with a relatively large angle of inclination.

Following some fifty to seventy degrees of Carrington longitude, or about four to six day's rotation, to the east of the large scale hemispheric enhanced density regions were two persistent coronal holes (West limb: DOY 69 and DOY 84), located about 180 degrees of longitude apart from each other, and extending from polar regions toward the equator. These low density regions generally did not extend to any significant distance (if at all) across the solar equator, in contrast to the shape of the coronal hole, CH1, observed during the Skylab epoch (1973-74).

This general condition of the corona, present at the beginning of 1984, was found to be reasonably stable during the first half the the year. There is obvious variation of the detailed structure of the two hemispheric enhancements from east limb to west limb, but the general location and amplitude of the observed coronal signals remained, more or less, constant. A similar configuration was not observed at the corresponding phase of the last solar cycle, although the coronal hole configurations are somewhat like those observed during rotation 1598 in 1973.

This pattern began to alter over the period DOY 180 to DOY 230. The northward and southward extents of the enhanced regions tended to recede toward the solar equator. That is, the

amount of apparent "tilt" of the dipole rotated from approximately 60 degrees in early 1984 to about 30 degrees at the end of the year. At the same time the maximum amplitude of the signals detected from the hemispheric enhancements decreased, causing a reduction in the integrated white light and green line parameters (see section VII). Thus, in the broadest possible view of the variation in the corona, a steady decrease in both the latitudinal extent and density of the enhanced regions was observed as the year progressed.

An interesting effect was noted in the observations of Ca XV ( $\log T = 6.6$ ). During the first half of the year, regions detected near the solar equator were evidently over active regions. These higher temperature features had a characteristic persistence of one or two rotations, and seemed to have longitudinal extent somewhat greater than one would expect from the size of the associated  $H_{\alpha}$  active regions. Unfortunately, few yellow line observations in the second half of the year prevent further analysis of the variation of these types of features.

## VI. SHELL PLOTS OF THE CORONA

Sample SHELL plots of the corona are shown for the three emission lines and for the white light observations made between DOY 121 and DOY 135, 1984. Each day's data have been projected onto a sphere and rotated to the visible disc. Thus the observations taken on DOY 128 are shown projected onto the longitude at Central Meridian on this day. If the corona is stable during this period, the coronal data can thus readily be compared with disc observations of this date. The example shown here emphasizes both the similarities and considerable differences in the corona seen at the various wavelengths. These can be generated for specific intervals of interest; they are offered to demonstrate their availability and their value when adequate coverage in all four data sets is achieved. Requests for data in this format should be addressed to the Mauna Loa Solar Observatory, attention C. Garcia.

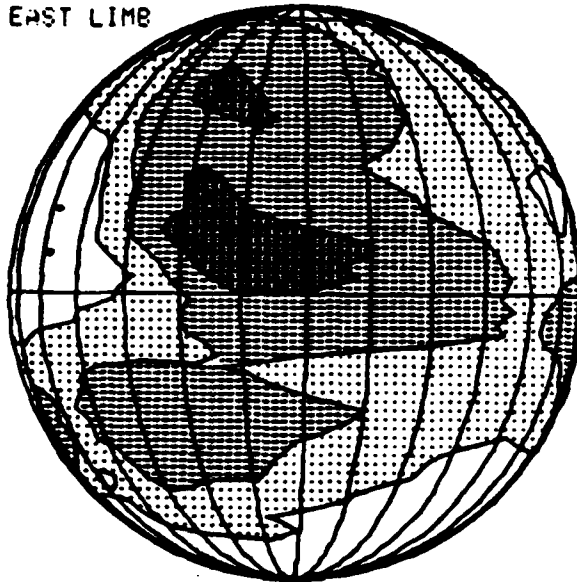
On each page, two sets of data are shown, the white light (inner corona) and the yellow line, then the red line and the green line. Four diagrams are shown on each page. The SHELL on the left represents the East limb observations rotated onto the hemisphere facing the earth, while the righthand SHELL displays West limb data rotated as if on to the hemisphere away from the earth.



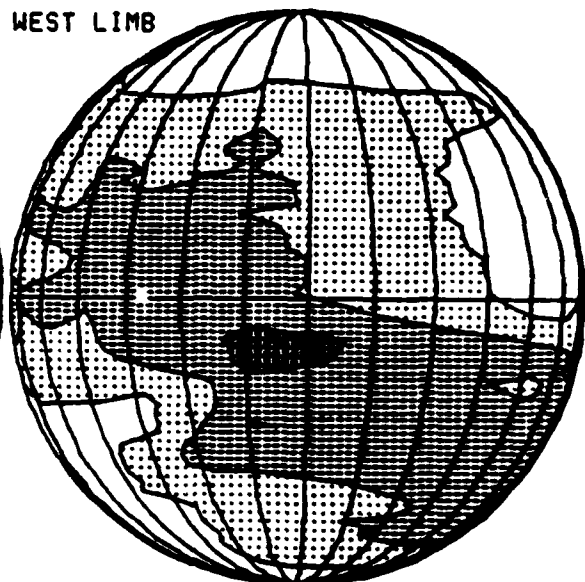
DOY 135.0 1984 INNER CORONA NCAR-HAO-MLSO



EAST LIMB



WEST LIMB



135.0

128.2

121.4

135.0

128.2

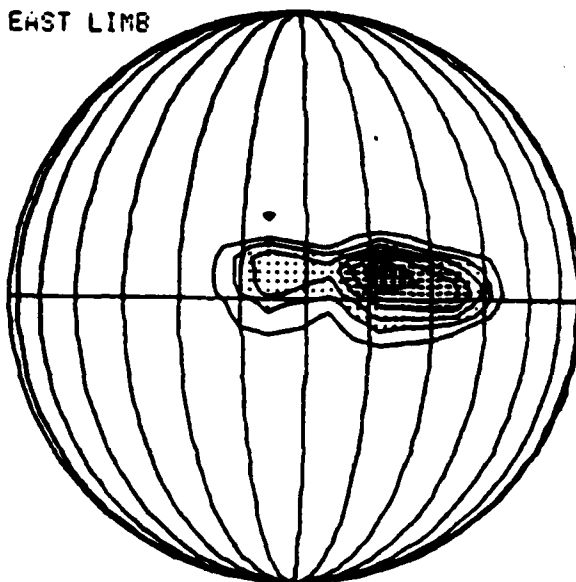
121.4

DOY 135.0 1984 YELLOW CORONA LINE  
SACRAMENTO PEAK OBSERVATORY

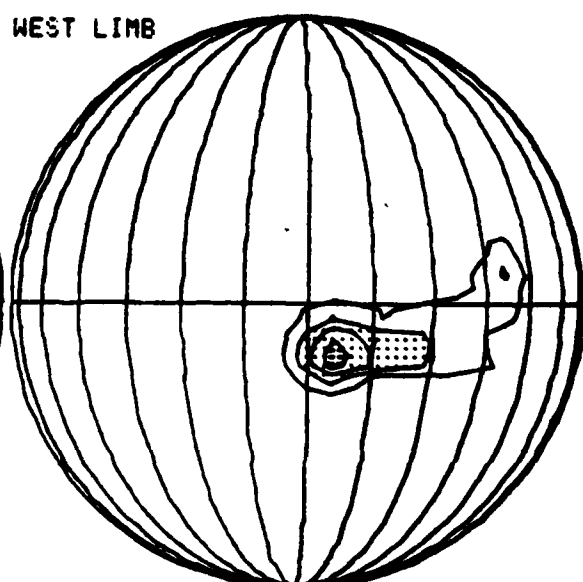
RADIUS 1.13



EAST LIMB



WEST LIMB



135.0

128.2

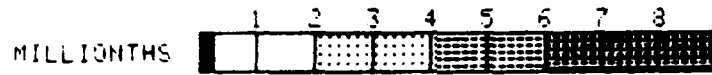
121.4

135.0

128.2

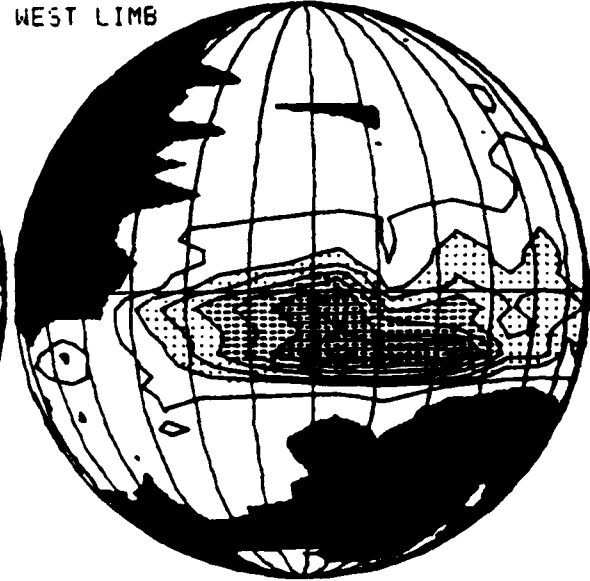
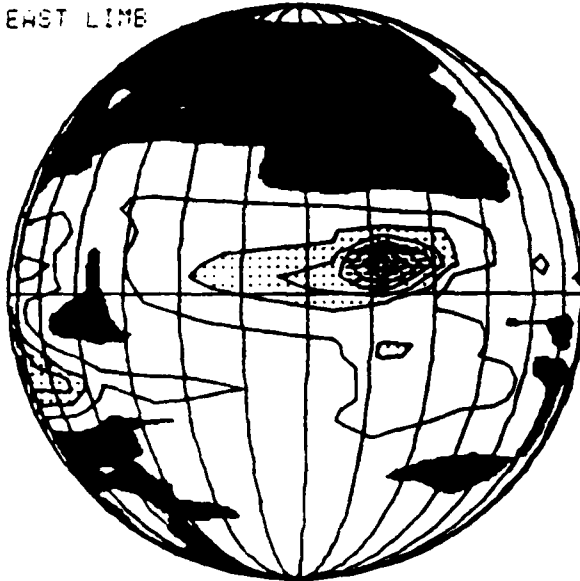
121.4

DOY 135 0 1984 RED CORONA LINE RADIUS 1 15  
SACRAMENTO PEAK OBSERVATORY



EAST LIMB

WEST LIMB



135 0

128 2

121 4

135 0

128 2

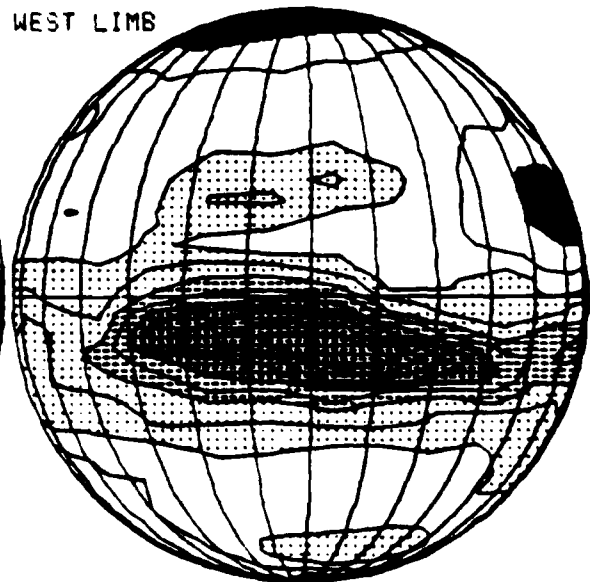
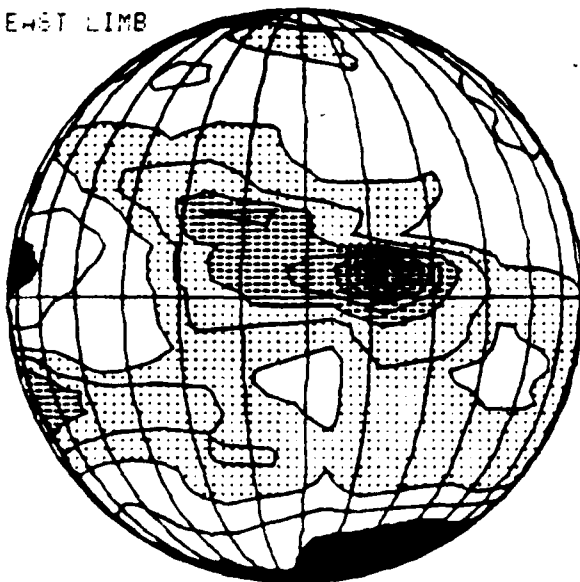
121 4

DOY 135 0 1984 GREEN CORONA LINE RADIUS 1 15  
SACRAMENTO PEAK OBSERVATORY



EAST LIMB

WEST LIMB



135 0

128 2

121 4

135 0

128 2

121 4

## VII. INTEGRATED MEASURES OF THE CORONA

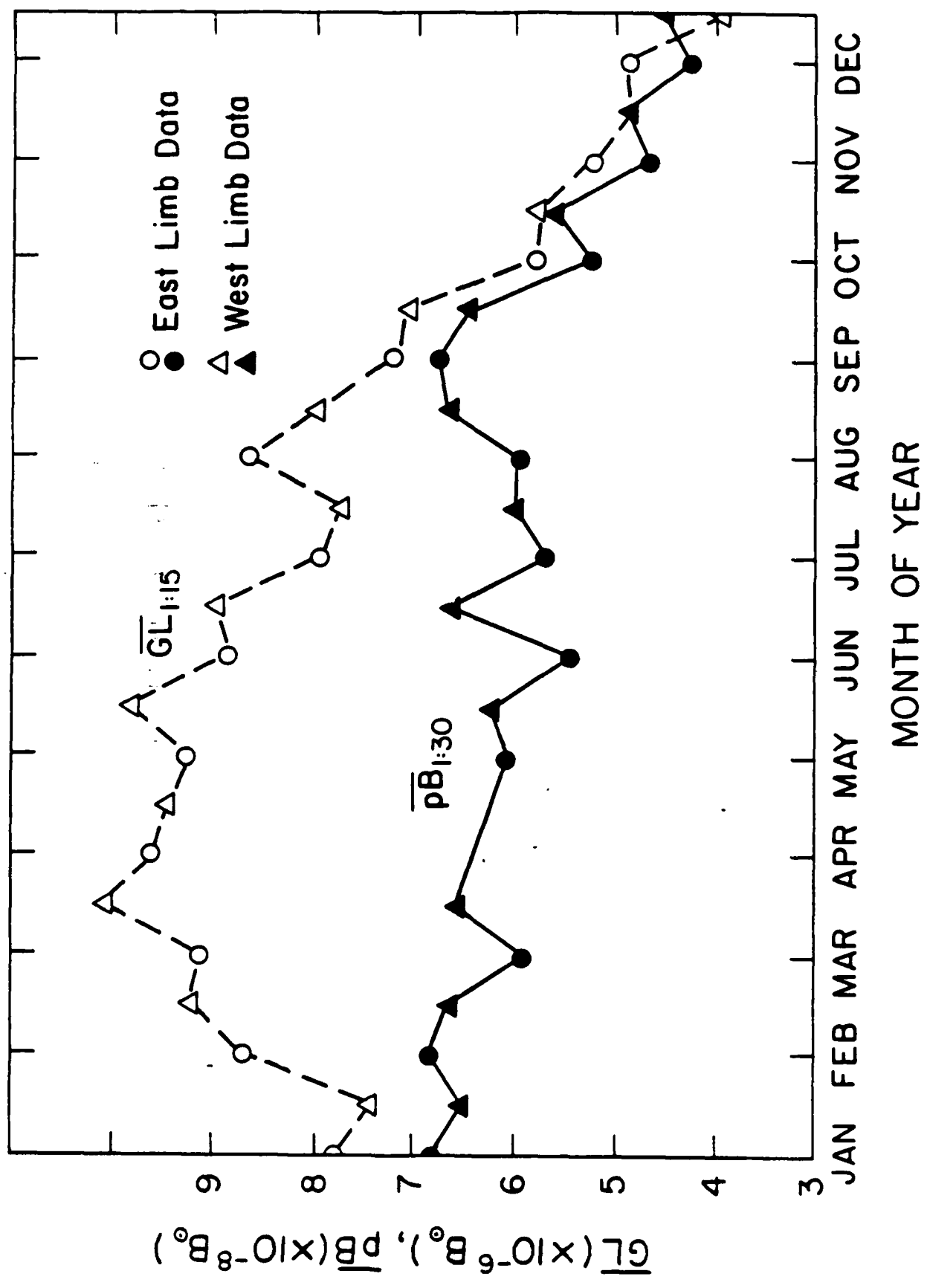
The variation in the overall state of the corona can be indicated qualitatively by the use of the integrated coronal brightness. This has been shown (Fisher et al, 1983) to describe quite well the state of activity of the sun. It has also been shown ( in the case of the white light data) that monthly average values vary over the solar cycle with the monthly average sunspot number according to a linear relation:

$$pB = 2.66 + 0.018 R_I$$

where  $R_I$  is the international sunspot number. Over the last two solar cycles, the range of values for  $pB$  was from 2.66 to about 5.8 .

The monthly average values for  $pB$  are shown opposite for 1984. The values are given for both the East and West limb data, thus providing a temporal resolution of about two weeks. The integrated value of the white light polarized radiance decreased steadily throughout the year, but it is still not quite as low as was observed at the previous minimum. Also shown are the integrated green line data. These show a similar decline at the end of the year, although there may be a local maximum occurring about March or April. This might be interpreted as a slight increase of smaller scale solar activity which did not influence the large scale structure of the corona as detected by the white light observations. A study of the detailed relationship of the white light to the green corona is in progress.

1984  
YEARLY VARIATION OF WHITE LIGHT AND  
GREEN LINE MONTHLY INTEGRATED INDICES



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### ACKNOWLEDGMENTS

The emission line data described in this Note were collected with support provided by the United States Air Force. Assistance in data reduction has been provided by Howard DeMastus, Cheryl Brown-Hill, and John Cornett. The National Solar Observatory is a division of the National Optical Astronomical Observatories, operated by The Associated Universities for Research in Astronomy (AURA). The High Altitude Observatory is a division of the National Center for Atmospheric Research (NCAR). Both AURA and NCAR are sponsored by the National Science Foundation. Helpful comments on the manuscript were provided by R. H. Munro. C. Rasmussen of the NCAR publications office provided editorial assistance.

**END**

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