96-10

DRAFT

June 26, 1996

An Evaluation of the Ratio and Difference AVHRR Images: Examples Developed from 1992 and 1991 AVHRR Data

by
Paul Doraiswamy
USDA/ARS
and
Paul W. Cook
USDA/NASS

Introduction

As part of a continuing cooperative research project between USDA/ARS and USDA/NASS, an AVHRR difference image of the United States was developed to use biweekly composite images from the EROS Data Center in 1993. Each image product contained a color legend that provided information about the meaning of the five color ranges (see Table 1). Each range of color values provided a description relating the condition of vegetation within the United States compared with condition of the previous year. Earlier work had made possible comparing NOAA-11 AVHRR data for a four-year average or median value against the current year.

The launch of NOAA-14 in December 1994 prevented continuing the publication of the difference image products. First, the NOAA-14 data was not fully comparable with the NOAA-11 data so that NDVI values could not be computed using the same difference ranges as before. Also, NOAA-14 data could not be compared between years until an evaluation of the NDVI difference values had been conducted.

Although work is continuing to reestablish comparisons between multiple years, the current products compare only the years 1996 and 1995. Since evaluation of the difference image will not be complete until later this year, a new imagery product was introduced this year. This product was that of a ratio of the 1996 AVHRR Biweekly NDVI's to the corresponding 1995 AVHRR Biweekly period NDVI's.

Concerns about the Ratio Image

However, there are concerns about data integrity when taking "a ratio of ratios." Specifically, since the NDVI = (Band 2 - Band 1)/(Band 2 + Band 1), taking a ratio of the two years of data will form a "ratio of ratios."

Development of a legend for the ratio image has avoided assigning ranges a descriptive text relating to crop condition. The ranges of included ratio values are a percentage of the current year's NDVI in relation to the previous year's NDVI values. Seven ranges were chosen to accomplish this display (see Table 2).

Creation of the Difference and Ratio Images for 1992 and 1991

Rick Mueller created difference images and ratio images for 1992 versus 1991 at both the United States level and for the corn and soybeans states of Illinois, Indiana, Iowa, and Ohio for eleven consecutive biweekly AVHRR periods during 1992 and 1991 using Arc-Info. Although data was available for all the Biweekly periods during the two years, Periods 10, 12, 14, 16, and 18 are shown in the accompanying graphs contained AVHRR data from the available data for the crop growing season

The two years of 1991 and 1992 were chosen as the two years with the most stable AVHRR data available for the NOAA-11 data. Choosing stable years should provide the most stable comparisons of the ratio and difference images under the best of conditions. Counts were obtained within each of the ratio and difference values. Display of the data on one scale should aid in interpretation of the data.

Figures one through five display the ratio and difference counts (countr and countd, respectively) for Periods 10, 12, 14, 16, and 18 for the entire U.S. The remaining Figures 6 through 10 provide the counts of the ratio and difference images for four corn and soybeans States (Illinois, Indiana, Iowa, and Ohio).

Instability of the Ratio Image

The ratio image count values display three striking consistencies as the season progresses:

1) The number of counts near the median is always greater than the number of counts found in the maximum for the difference image,
2) The number of counts fluctuates greatly for as many as five values near the median for the ratio as opposed to the difference image that uniformly rises and falls as a normal distribution or as a skewed distribution, and
3) The ratio image generally, since so many pixels are concentrated near the median value, contains a smaller dynamic range of values that ranges between 10 and 25 counts over the periods under examination.

A more detailed examination of the graphs for each of the available periods should provide a better understanding of the above statements. The first group of five graphs show the entire U.S. image data counts for imagery data between 60 and 140. The remaining five graphs depict the same range of values between 60 and 140 for the regional corn growing states of Illinois, Indiana, Iowa, and Ohio. The meaning of the values does differ according to which process was used in comparing the two years of data. Ratio image values are an actual percentage comparing the later year with the earlier year. However, the difference values show the difference in raw values between NDVI values of 1992 minus the NDVI values of 1991.

U. S. Image and Four State Image Graphs

The choice of periods to examine in more detail was made to concentrate on the schedule of corn and soybeans planting, growth, development, and senescence. Although data are available for every Biweekly period of the two years, representative graphs of every other biweekly period should still provide sufficient detail to detect the characteristics of the two imagery products.

Selection of a uniform range was made to make the graphs of the periods more understandable. The actual range of values varied during each period, but the counts for values outside the range of 60 and 140 were insignificant. Often values outside this range would have as few as one or two counts. See Table 1 for a comparison of the dates for the two years.

Table 1. Dates of the AVHRR Biweekly Images for 1991 and 1992.

AVHRR Biweekly Images		
Period	**1991**	**1992**
10	June 7 - June 20	June 2 - June 25
12	July 5 - July 18	July 10 - July 23
14	August 2 - August 15	August 7 - August 20
16	August 30 - September 12	September 4 - September 17
18	September 27 - October 10	October 2 - October 15

Comparison of Figure 1. U. S. Image: Period 10 with Figure 6 Four State Image: Period 10

Both the U. S. Image and the Four State image for Period 10 show that the ratio image peaks at 100%, but the ratio image exhibits a smaller dynamic range than does the difference image. The U. S. Image ratio shows oscillations for values less than 100 while the Four state image shows oscillations immediately above and below 100%. The difference image for the Four state image is especially normally distributed. The U. S. Image difference counts clearly have a more normal distribution than do the ratio image counts, but not as smooth as those of the Four state area.

Comparison of Figure 2. U. S. Image: Period 12 with Figure 7 Four State Image: Period 12

The graph of the Period 12 U. S. Ratio and difference image counts show much similarity with the graph of the Period 10 U. S. Ratio and difference image counts graph. However, the Four State area ratio and difference image graph shows even more irregularity in the central part of the graph than does the Period 10 graph for the same Four State region

Comparison of Figure 3. U. S. Image: Period 14 with Figure 8 Four State Image: Period 14

Figure 3 presents a graph of the U. S. Ratio counts and U. S. difference image that is very much similar to the graphs of Periods 10 and 12. The irregularities for the ratio image are still near values that are less than 100%, however, the dynamic range is less than for the previous two periods. The Four state area exhibits even greater variability than did the previous two periods. Differences between counts exceed 20,000 for adjacent bins and can increase or fall in an irregular pattern for values near 100%. The difference image values are much more normally distributed and exhibit much more dynamic range and uniformity of response, particularly, above the values of 110.

Comparison of Figure 4. U. S. Image: Period 16 with Figure 9 Four State Image: Period 16

The U. S. image ratio and difference image graphs show similar characteristics for Figure 4 with those of previous periods. However, the number of irregularities is greater than for previous periods. The four states region continues the trend for even greater volatility in the ratio image counts with more values showing erratic shifts between adjacent values. Clearly, early September is a time that the ratio image does not portray well for the corn and soybeans regions.

Comparison of Figure 5. U. S. Image: Period 18 with Figure 10 Four State Image: Period 18

Late September is clearly a time that the difference image becomes less erratic, except that Figure 5 shows that 100% takes up nearly two million counts of the 13 million in the scene. Similarity between years must be improved during times of crop senescence so that the ratio image provides a more smooth transition between values. Figure 10 shows more smoothness for the Four State area as well than for earlier periods, but still not as regularly as for the difference image. The difference image values have more skew than do those of the other periods.

CONCLUSION

Selection of the years 1991 and 1992 was intended to provide AVHRR data of the greatest stability, since these two years had fewer crop trouble spots and extreme weather conditions than other available years of AVHRR data. The intent was to compare the capabilities of images generated by dividing one year by another and taking difference images of the two years. Two assumptions about the distribution of data were that (1) more normally distributed data provide a more easily interpreted and stable relationship to analyze and (2) erratic swings and reduced dynamic range of calculated reduce its effectiveness in interpreting changes between the provided data sets. Using these two criteria, the difference image clearly provides more stability for interpretation both at the U. S. Level, but particularly at the Four State regional level for Illinois, Indiana, Iowa, and Ohio.

Although the years of 1992 and 1991 are most likely for the NDVI values to exhibit the most stability, examination of additional years from the AVHRR sensor would be needed to establish the amount of non-normality that the ratio image might exhibit. Therefore, until further studies are completed, even the U. S. Level ratio image should be interpreted with some caution, particularly when examining the NDVI ratio values closest to 100%. The difference image would more likely provide a stable and more easily interpretable range of values, especially for those ranges of NDVI values most similar between the years.

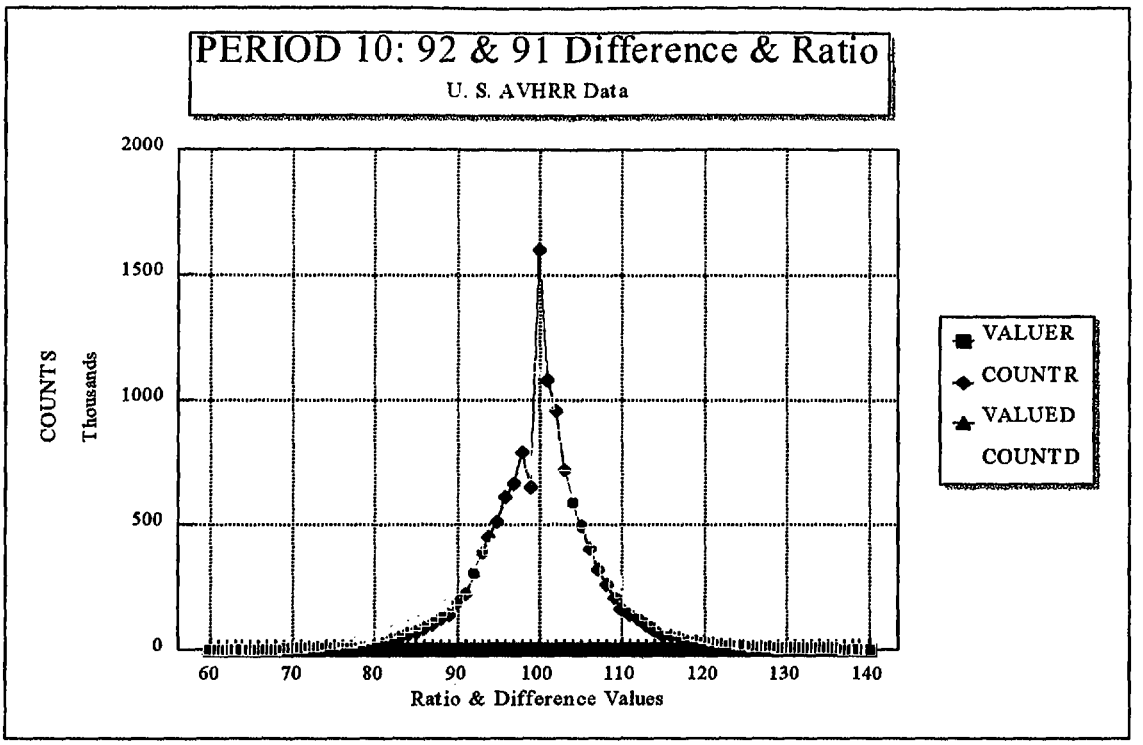

Figure 1. A Graph of Counts Comparing the Period 10 Ratio (COUNTR) with the Period 10 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images.

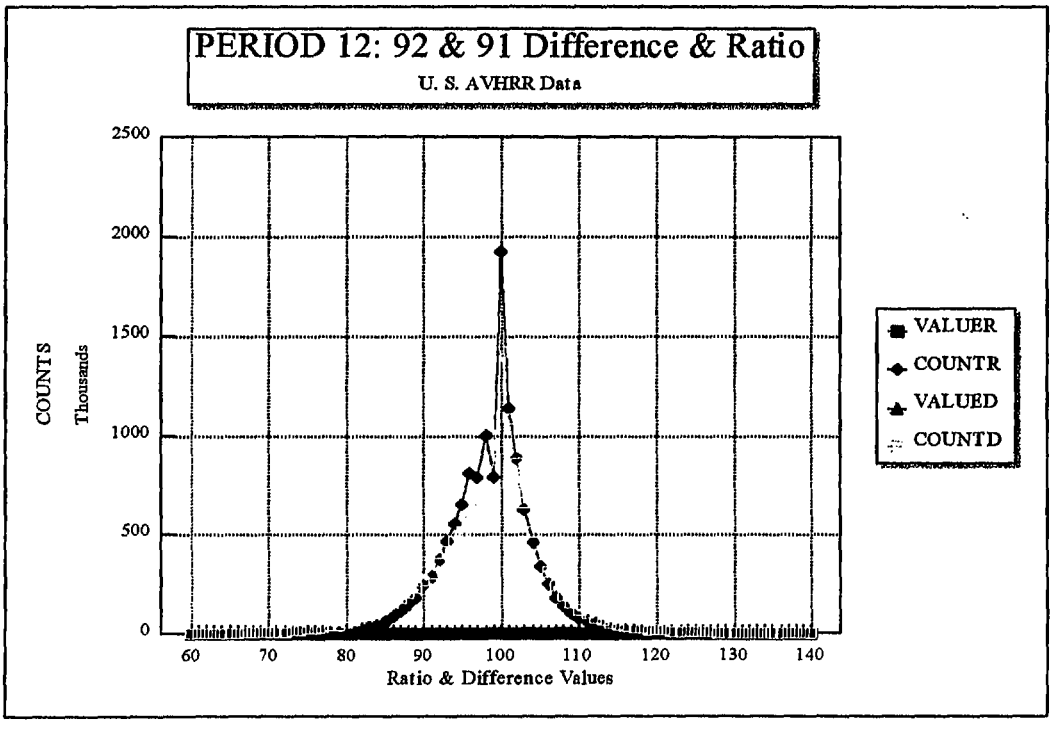

Figure 2. A Graph of Counts Comparing the Period 12 Ratio (COUNTR) with the Period 12 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images.

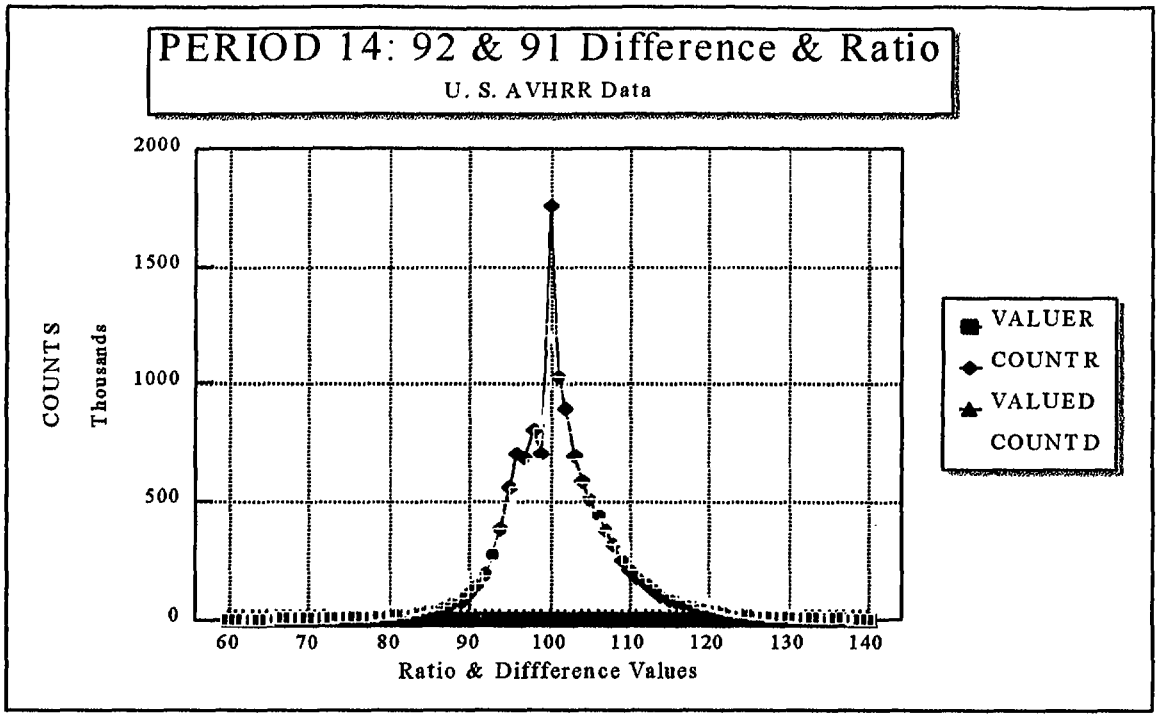

Figure 3. A Graph of Counts Comparing the Period 14 Ratio (COUNTR) with the Period 14 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images.

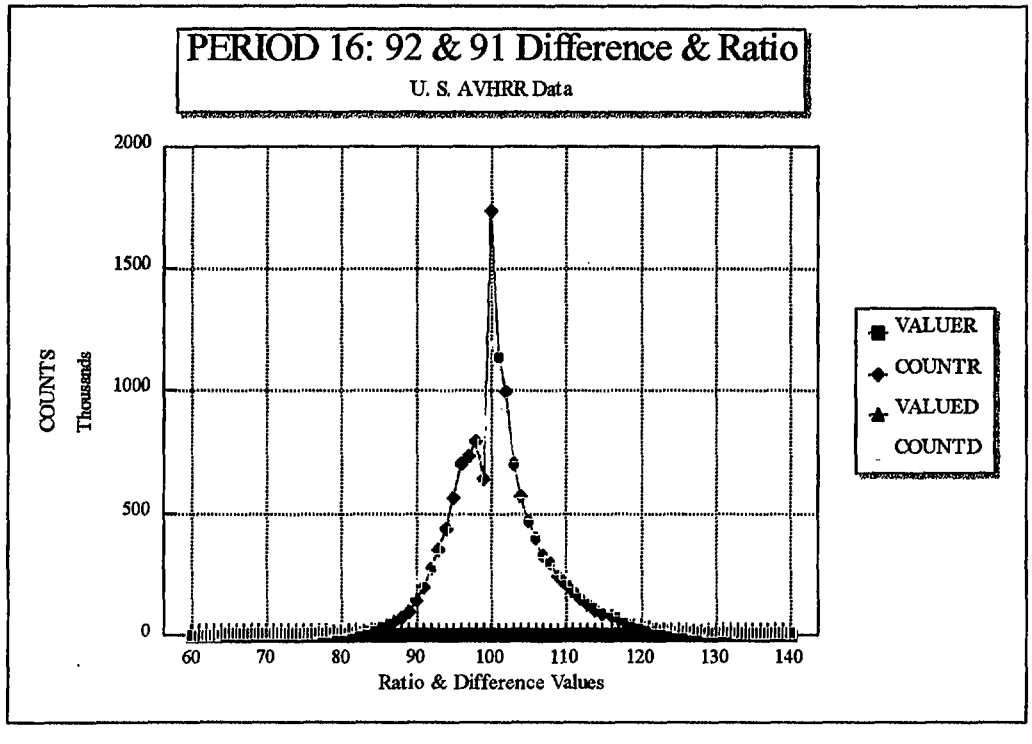

Figure 4. A Graph of Counts Comparing the Period 16 Ratio (COUNTR) with the Period 16 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images.

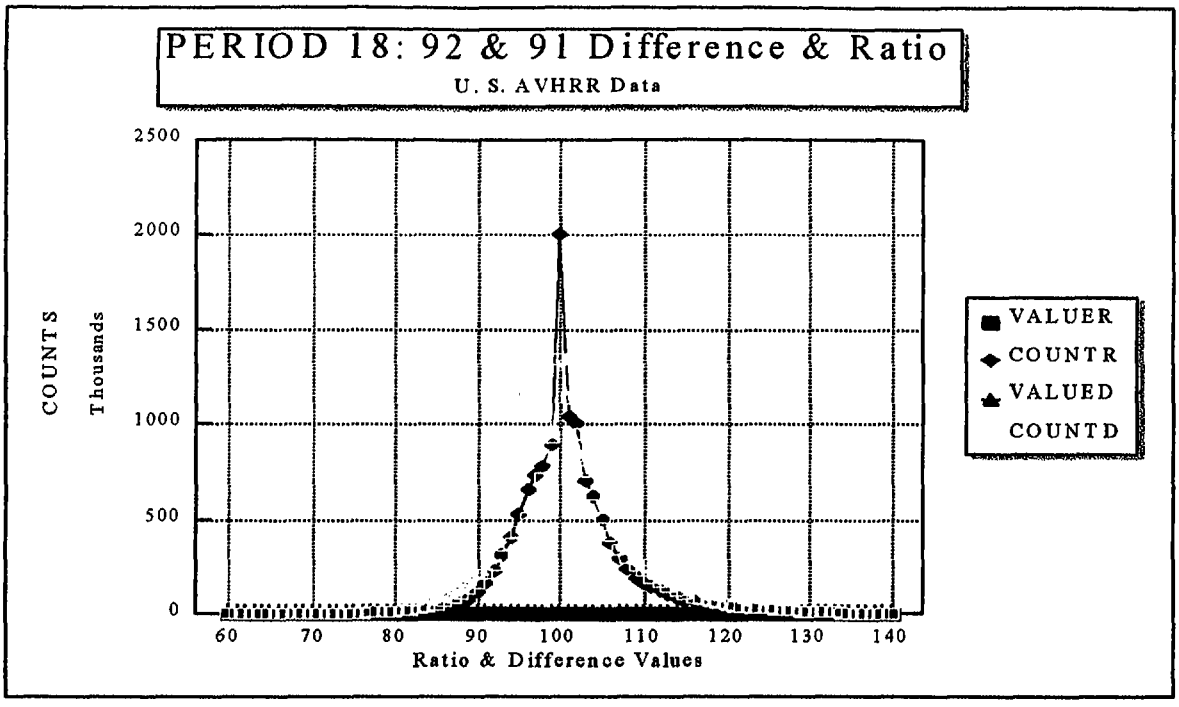

Figure 5. A Graph of Counts Comparing the Period 18 Ratio (COUNTR) with the Period 18 Difference Image (COUNTD) for the 1992 vesus the 1991 AVHRR Biweekly Composite Images.

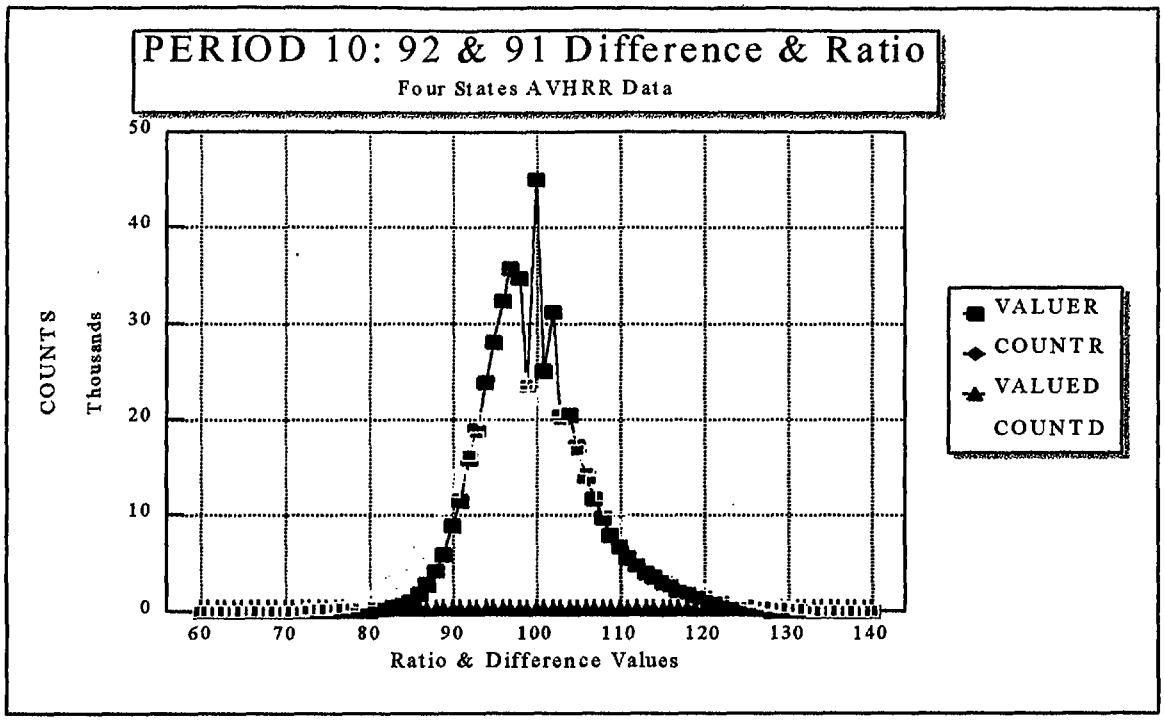

Figure 6. A Graph of Counts Comparing the Period 10 Ratio (COUNTR) with the Period 10 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images for Illinois, Indiana, Iowa, and Ohio (Four States).

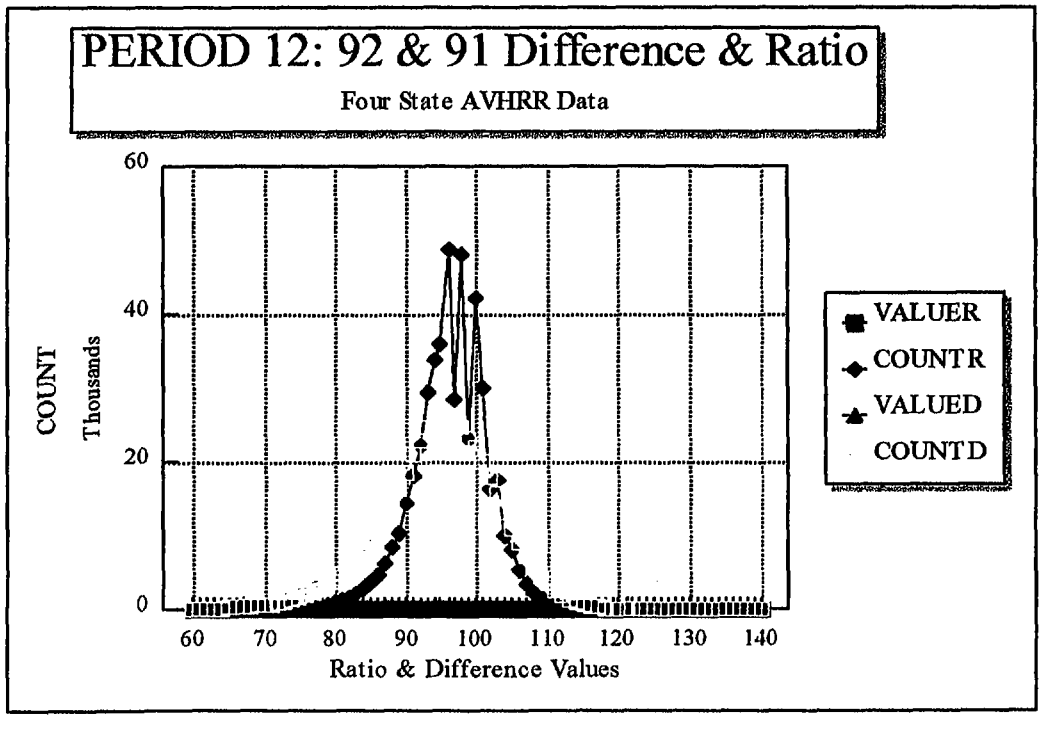

Figure 7. A Graph of Counts Comparing the Period 12 Ratio (COUNTR) with the Period 12 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images for Illinois, Indiana, Iowa, and Ohio (Four States).

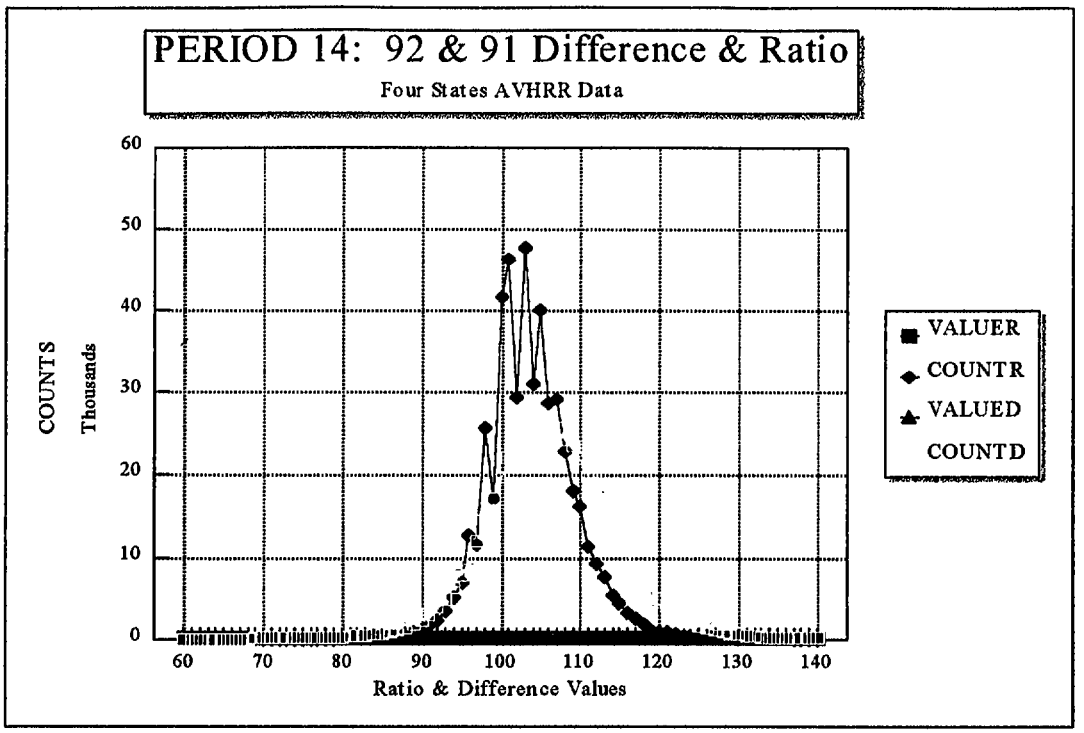

Figure 8. A Graph of Counts Comparing the Period 14 Ratio (COUNTR) with the Period 14 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images for Illinois, Indiana, Iowa, and Ohio (Four States).

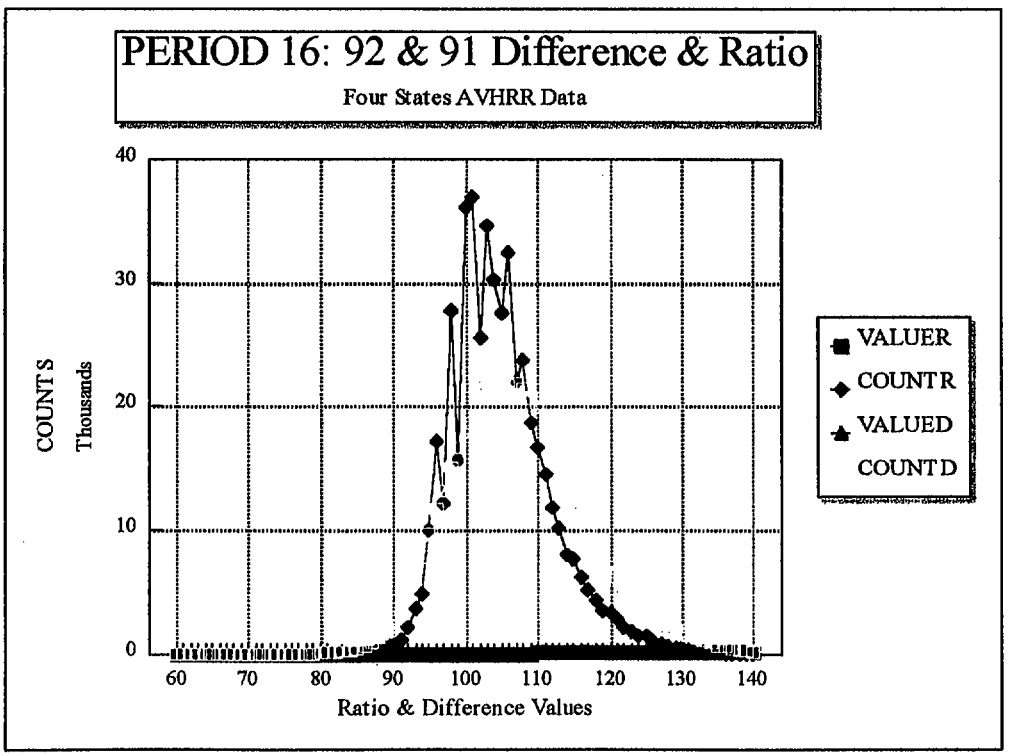

Figure 9. A Graph of Counts Comparing the Period 16 Ratio (COUNTR) with the Period 16 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images for Illinois, Indiana, Iowa, and Ohio (Four States).

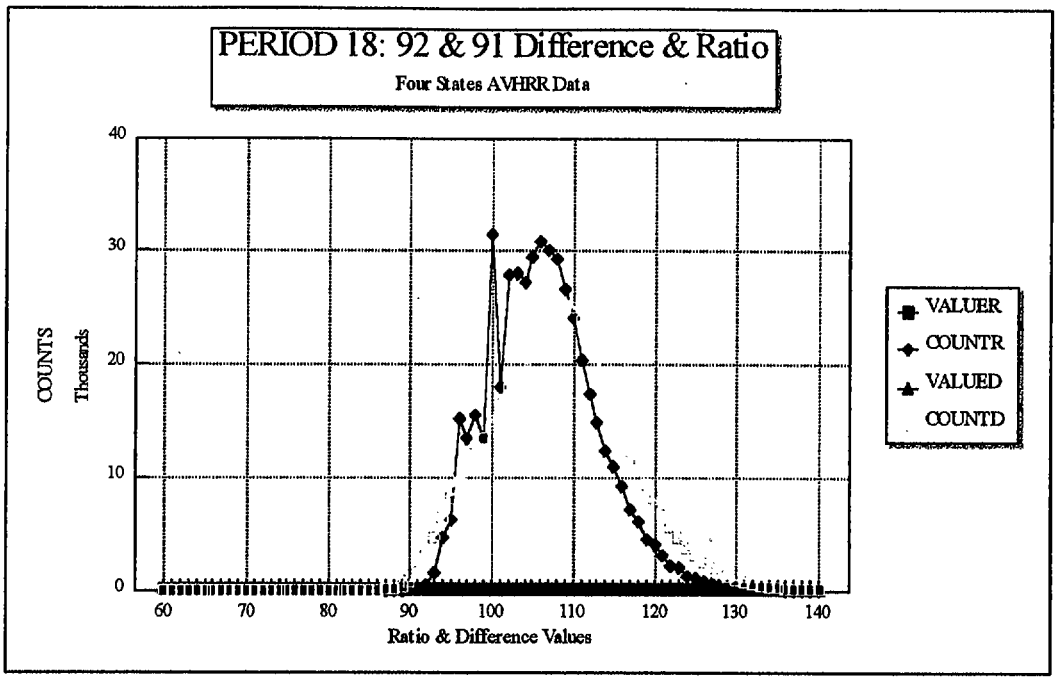

Figure 10. A Graph of Counts Comparing the Period 18 Ratio (COUNTR) with the Period 18 Difference Image (COUNTD) for the 1992 versus the 1991 AVHRR Biweekly Composite Images for Illinois, Indiana, Iowa, and Ohio (Four States).