Appendix C

Meteorological Considerations

Overview

We will present plots of rainfall precipitation, low, and high temperatures at three different time scales: monthly for two years previous to acquisition, seasonally with daily values throughout the fall, and “weekly” by showing data for ten days previous. The monthly scale is considered to be relevant for assessing annual effects. This scale will expose any drastic weather condition that could effect plant growth from the spring through the summer and into the fall. Because most pine trees keep their needles through two growing seasons and since the condition during both seasons can effect the amount of needle growth and needle-fall (Hennessey et al., 1992), data is given for two years prior to image acquisition. The main concern for the yearly scale data is to check for drought conditions together with temperature extremes. The seasonal time scale reveals daily conditions for each day from the first of September until the date of acquisition. This will help assess the fall condition which relate to leaf senescence and abscission (i.e. color change and falling off) (Wilson, 1984, p.122-123; Kozlowski and Pallardy, 1997, p. 56). Here the main concern is again difference in moisture conditions but now with particular attention to near or below freezing temperatures in only one of the images which could cause differences in deciduous leaf abscission (Kozlowski and Pallardy, 1997, p. 56; Goldfarb, 1997). Recall that the image acquisition ranges from November 20th to January 5 (see table 2.2). While most deciduous trees in North Carolina will have dropped their leaves by mid-November, warmer weather may result in certain Oaks having some leaves into December (Goldfarb, 1997). We will consider this fact when interpreting the Raleigh image in which Oak-Hickory is a major land cover type (Keys et al., 1995). The third
scale is to consider the 10 days proceeding the acquisition date for each satellite scene. This could help explain such things as puddles or moist soil if substantial rainfall had occurred some short time before the acquisition.

For each of the temporal scales we will present precipitation (in inches), high temperature, and low temperature (both in degrees Fahrenheit) and we will do so for each of the two study areas. Both visual inspection and statistical analysis were used to analyze the data. The statistical analysis will test the null hypothesis of no difference by checking if the mean of the difference is significantly different from zero. The first step for this test was to check for autocorrelation with each time series of difference data (see Brocklebank and Dickey, 1986, Chapter 1). This was done using the SAS™ “Autoreg” (autoregression) procedure. The software started with an autoregressive model with six lags and conducted backward elimination removing all lags, which were not significant at the 5% Alpha level. If any of the lag terms were significant, we used the test produced by the Autoreg procedure. For those data sets which had no significant lag terms we assumed there was no autocorrelation present and used the standard paired difference test produce the SAS™ “Reg” (regression) procedure (SAS, 1990, Chapter 36). The statistical analysis summary is given as a table below the corresponding plot of the actual data. For the test statistics with a p-value greater than .1 the two dates are considered to be equal. For a p-value between .05 and .1, is considered to be “borderline” and data whose p-value is less than .05 are considered to be different. After each plot and statistical summary, there is a brief interpretation of the possible effects that could be expected from the particular data shown on the plot.

Note: The data were obtained from the National Climatic Data Center (NCDC) through the North Carolina State Climate Office (climate@cyclone.meas.ncsu.edu). The names of the weather stations as listed by the NCDC are: Station 315830 MOREHEAD_CITY_2_WNW, Station 316108 NEW_BERN_FAA_AIRPORT, Station 314684 KINSTON_5_SE, and Station 317069 RALEIGH_DURHAM_WSFO_AP.
Coastal Area Weather Plots

The weather plots related to the coastal scene are from weather stations at Morehead City and Newbern, North Carolina. The locations of these stations are shown in figure C.1.

Figure C.1: Location of weather stations for the coastal study area.
While there is an exceptionally high amount of precipitation in August of 1987 and 1988, the precipitation was statistically equivalent. We believe there would not be any yearly growth differences caused by moisture conditions. In particular, there were no drought conditions in either year, a major factor in needle-fall (Hennessey, et al., 1992). There is the possible exception for April of 1994, for which little rain was reported at both stations: .4 inches from Morehead City, and .72 inches from Newbern. With this, and the heavier rains in 1987 and 1988, we may expect to find slightly more foliage in the 1988 coastal scene.
There is no statistical difference between the monthly low temperatures for the two time periods. The only element of this data which warrants consideration is the lower temperatures at the end of 1988. This will be considered more carefully in the analysis of the daily low temperatures for the fall.
Table C.4: Autocorrelation and Average Temperature Differences

<table>
<thead>
<tr>
<th>Location</th>
<th>Autocorrelation</th>
<th>Average difference significantly different than zero?</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morehead</td>
<td>None present</td>
<td>No</td>
<td>0.6071</td>
</tr>
<tr>
<td>Newbern</td>
<td>None present</td>
<td>No</td>
<td>0.2157</td>
</tr>
</tbody>
</table>

Figure C.4: Monthly average low temperature, coastal study area

Here we do not see any statistical or visual difference in the data. So the slightly dryer (though not statistically significant) weather observed for 1988 was not accompanied by particularly hot weather. This should help minimize the effect of a lack of moisture in the spring of 1988.
There is no statistical difference between the fall precipitation data for the two years. Also, nothing stands out on the graph. The general fall precipitation looks regular enough to accept that there will not be major differences in seasonal effects due to precipitation (note there is some difference in precipitation near the days of acquisition, this will be addressed in the discussion accompanying figure C.8).
**Figure C.6: Fall low temperatures, coastal study area**

These data show a statically significant difference with the temperatures from 1988 being lower. Of particular interest is that the 94 data, acquired on November 20, was before any frost. In contrast, the 1988 scene was acquired on December 5 -- after ten days (not in a row) had low temperatures below or near 30. As stated above, most vegetation should have already gone through its leaf senescence and abscission. However, the statically significant difference and the temperature going below freezing ten times prior to the 1988 image and not once for the 1994 image, we may expect addition vegetation present in the 1994 image.
As with the yearly high temperature, there is no statistical difference between the data sets and there are no particularities in the graph. There should be no difference caused by fall high temperatures.
There is no statistical difference for these data. However, we see that for the four days before the acquisition of the 1994 scene there had been rain recorded at both weather stations. These moist conditions may be visible on the soil (Drury, 1990, p. 35) and will need to be considered in the change detection. The extreme amount of rain observed at the New Bern station seven days previous to the 1988 scene acquisition was on November 28th and is also observed at the Raleigh weather station for that same date (see figure [mat].18). Since the Morehead station, which is near the coast, showed only slight precipitation, the precipitation observed on this date was probably the result of a cold frontal event which did not advance to the shore (Lundberg, 1997). However, with the six dry days which followed, it seems like rain induced moisture conditions will not be present in the 1988 scene.
Figure C.9: Ten days previous low temperatures, coastal study area

Here we see extremely statistically different data. This further supports the notion discussed with the plot of the fall low temperature. The 1988 scene had colder weather prior to image acquisition. Again, the result may be less vegetation for the 1988 scene.
Figure C.10: Ten days previous high temperatures, coastal study area

As with the previous figure, this data also shows the weather in 1988 to be significantly colder than in 1994. So these data also indicate that there may be more vegetation present in the 1994 scene.
Raleigh Area Weather Plots

The following weather plots are from the weather stations at Raleigh-Durham airport, North Carolina. The location of the station is shown in figure C.11.

Figure C.11: Location of the weather station for the Raleigh study area.
Month

Precipitation (Inches)

Raleigh - '93-'94
Raleigh - '87-'88

Autocorrelation | Average difference significantly different than zero? | p-value
---|---|---
None present | No | 0.5944

Figure C.12: Monthly Precipitation for Raleigh study area

This data show no difference in monthly average precipitation with no particular extremes within the data. We would not expect any seasonal effects due to moisture conditions.
### Figure C.13: Monthly average low temperature, Raleigh study area

Here, although the data look similar, we see there is a statistically significant difference between the two dates. Namely, there are lower temperatures for the 1987–1988 date. There is little practical difference in that there is no extreme low temperature. However, as we see for the last three months, there were cooler conditions for the fall of 1988 that may have effected the leaf senescence and abscission (Wilson, 1984, p. 122-123; Kozlowski and Pallardy, 1997, p. 56). Figure C.16 and the discussion thereafter consider the cooler 1988 weather in more detail.
The statistical analysis and well as appearance of the monthly high temperatures is similar to the monthly low temperature. Likewise, as there is no extremes in high temperature, the most significant aspect of these data is the cooler temperature in the fall of 1988. This will be discussed further with figure C.17.
The plot of daily precipitation as well as the statistical analysis does not show any particular differences between the two years.

**Figure C.15: Fall precipitation, Raleigh study area**

<table>
<thead>
<tr>
<th>Autocorrelation</th>
<th>Average difference significantly different than zero?</th>
<th>p -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None present</td>
<td>No</td>
<td>0.2795</td>
</tr>
</tbody>
</table>
Figure C.16: Fall low temperatures, Raleigh study area

As hinted to by the monthly data, we can observe from the plots and gather from the statistical significance that the fall weather was cooler in 1988. However, because the 1994 scene was not acquired until January 5th, 1995, all leaf abscission would have occurred by this time -- even with a mild fall. Unlike the 1994 coastal image, there were several days in which the low temperatures went below freezing. So, although there is a statistically significant difference between low temperature for the two years, because of the later acquisition of the “1994” image, it seems that this difference will have minimal effect on the reflectance value for the image.
Figure C.17: Fall high temperatures, Raleigh study area

Similar to the fall lows, we see that the fall high temperatures were lower in 1988. Again, we believe the acquisition date of January 5th is late enough to negate the effect of a warmer fall.
Figure C.18: Ten days previous precipitation, Raleigh study area

Here we see the same rainfall event that was observed at the Newbern station. For the coastal scene this event occurred seven days previous to image acquisition, for the Raleigh scene it occurred five days previous. However, unlike the 3 inches observed at Newbern, less than an inch was observed at the Raleigh station. We believe the five days with no precipitation gave sufficient time to remove any of the soil moisture conditions that may have resulted from the rain event. Also there is not statistical difference between the two data sets. We believe the daily precipitation just before image acquisition will not effect the spectral response for the Raleigh area images.
Figure C.19: Ten days previous low temperatures, Raleigh study area

These data show a statistical difference that contradicts the results from the fall data. (See figure C.16 and the discussion that follows.) Here the low temperatures were lower in 1994. This is because these data are for “days previous” which is relative to the date of acquisition. Here we see that the days before the “1994” image acquisition were indeed cold. This supports the discussion which followed figure C.16 in that the important thing in the interpretation of that data set was the late acquisition of the “1994” scene.
Figure C.20: Ten days previous high temperatures, Raleigh study area

As in figure C.19 we have cooler temperatures in 1994. As discussed in the proceeding figure, while the fall of 1988 was somewhat warmer, the days just prior to image acquisition show cool temperatures for 1994 as well.
Conclusions based on weather data

Considering those data from the coastal area, it appears that the 1994 scene will contain more moist or wet areas and the year had, at least until the time of acquisition. There was a rather mild fall in 1994 compared to 1988, which had significantly cooler weather including ten days with low temperature below freezing. For the 1994 scene in general it is likely that the bare ground will appear darker and there may be more vegetation due to the warmer weather.

Considering the Raleigh area, although these weather data also show a warmer fall in 1994 the later acquisition date for the “1994” image (January 5th, 1995) should reduce the effects as manifest in the image. The precipitation data suggest dry conditions for both images.