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Development of Case Studies of Regional Poor Air Quality Episodes (Ozone) as Tools for Air Quality Forecasting.

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1. Introduction

For the past two summers, undergraduate students and faculty at Plymouth State University have been conducting cases studies of the meteorological features associated with poor air quality episodes due to high concentrations of ozone. The goal of this project has been to provide a source of background information to meteorologists, many of whom lack expertise in this area, in order to help them to identify relevant synoptic patterns associated with elevated ozone levels. During the first year of the study, cases that affected the Northeastern United States were examined. Over the summer of 2006, the study was expanded to include regions of the United States east of the Rocky Mountains.

Five different regions were identified for these case studies: North Central; Midwest; Mid-Atlantic; Southeast; and South Central (Fig. 1) Regional boundaries were chosen using the National Weather Service regions as guidelines with sub-regions subjectively determined through consideration of climatological and topographical features. The method for determining poor air quality episodes as well as choosing the individual case studies will be presented in section 2. In many cases, “classic” poor air quality factors such as large areas of high pressure, calm winds, and clear skies were associated with each of the regions. However, this was not always the case. Analysis of each region showed that some “non-classic” elements could be identified in each region. Selected results demonstrating the “classic” and “non-classic” feature will be shown in section 3. Finally, the paper will finish with discussion and conclusion in section 4.

2. Identifying Regional Poor Air Quality Episodes

In order to examine the meteorology associated with an individual poor air quality episode, it was necessary to first determine criteria to identify regional poor air quality episodes and to then choose a case for analysis that was representative of these poor air quality events. Regional poor air quality episodes were determined by examining the 8 hour average ozone concentrations obtained from the Environmental Protection Agency (EPA) and from individual state air quality monitoring agencies for warm season months (April-October) for seven years (1999 - 2005). Data was collected only from the warm season since high ozone concentrations are primarily a warm season phenomena in most of the United States.

Definitions of a poor air quality episode were developed subjectively for each individual region. However in all regions, a poor air quality episode was defined such that most of the region experienced at least “moderate” air quality as defined by the EPA Air Quality Index (see Table 1), while a significant portion of the region (more than one urban area) experienced air quality that is “unhealthy for sensitive groups” or worse. As an example, a poor air quality episode for the Midwest region was defined as having at least one reporting station in each state with a “moderate” AQI and at least one reporting station in 3 different states reporting “unhealthy for sensitive groups” or worse.

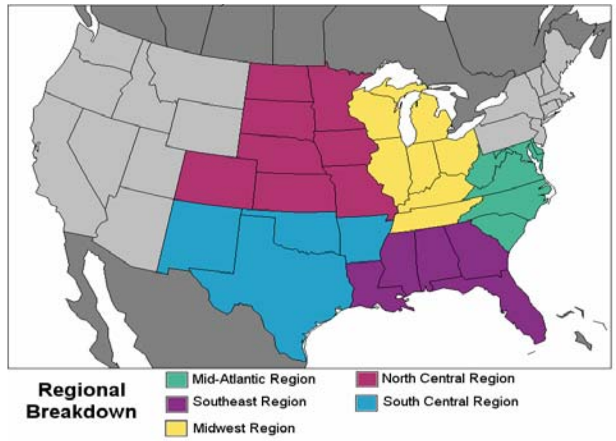

Figure 1. Regions for Poor Air Quality Case Studies

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AQI Category	8-hr concentration (ppb)
Good	0-64
Moderate	65-84
Unhealty for Sensitive Groups	85-104
Unhealthy	105-124
Very Unhealthy	125-374
Hazardous	> 374
Courtesy NOAA NWS	

Table 1. Relation between EPA Air Qualtiy Index and 8-hr ozone concentrations (ppb). (http://www.nws.noaa.gov/ost/air_quality/FAQs.htm)

Once the regional poor air quality episodes were identified in each region for the six year period, case studies were identified for analysis by examining the standard weather charts (surface, 850, 500 and 300 hPa) at 12Z on the date of the worst air quality reported for the event and comparing these to a composite analysis constructed with the NCEP/NCAR Reanalysis (Kalnay et al. 1996) at the NOAA Climate Diagnostics Center Web site (http://www.cdc.noaa.gov).

At least two case studies were subjectively chosen for each region: one that most closely resembled the composite analysis and one with the most extreme and widespread values of ozone concentrations. In the Southeast it was determined that the weather events could be sorted into two distinct composite types. In this case one representative case study was chosen for each type. Table 2 shows the dates chosen for each region. It should be noted that one remarkable episode (late June 2002) affected much of the central and eastern United States and was studied as a multi-region event.

3. Case Study Results

One of the reasons for examining regional poor air quality episodes is to allow meteorologists to compare and contrast the meteorological features associated with different regions. In this study, many meteorological factors were found to be similar across all regions for poor air quality associated with high ozone. These similarities are those that are "classic" features associated with textbook cases of poor air quality due to high ozone concentrations such as clear skies, large areas of surface high pressure, calm winds and a mechanism for limiting the vertical mixing of surface air (Jacobsen, 2002). Clear skies associated with large areas of high pressure allow the photochemical reaction that produces low-level ozone to be vigorous, while calm winds keep ozone (or its precursors) from being transported far their sources. Figure 2 indicates clear skies on June 23, 2002 over much of the southern Great Lakes for a case in the Midwest region where 8 hr ozone concentrations in Indiana an Ohio generally reached a peak higher than 85 ppb ("unhealthy for sensitive groups"). The corresponding surface analysis (Fig. 3) shows that an area of higher pressure was centered over Kentucky with light winds observed over the regions with poor air quality. However, even within these classic conditions, there is significant case-to-case and regional variability. For example, clear skies (Fig. 4) and calm winds associated with poor air quality in Mississippi and Louisiana in the Southeast region are not associated a center of surface high pressure. Instead, Fig. 5 indicates that the calm winds are associated with an area of higher pressure and weak pressure gradient.

Mid-Atlantic	June 23 – 28, 2003
	June 21 – 26, 2002
Southeast	September 7 – 13, 2002
	July 20 – 24, 2004
South Central	June 15 – 21, 2001
	June 20 – 26, 2002
North Central	June 21 – 26, 2002
	September, 3 – 10, 2002
Midwest	June 18 – 26, 2002
	June 21 – 26, 2003

Table 2. Dates of poor air quality case studies by region.

At the upper-levels nearly all of the poor air quality cases are associated with upper level ridging (see Fig. 6 from June 2002 for the North Central region for an example). Subsidence inversions associated with the sinking motion along and east of the upper-level ridge axis along with morning radiation inversions were also often contributors to poor air quality by limiting vertical mixing to a relatively shallow layer (see Fig. 7 for an example sounding from 2001 for the South Central region).

One other feature that was commonly observed between the cases was that the meteorological features associated with the poor air quality generally remained in place for several days. This allowed the ozone concentrations to generally build up for a couple of days. Also the areas of highest ozone concentrations slowly moved in response to the slow movement of meteorological features that contributed them. For example the poor air quality over Mississippi and Louisiana on September 10, 2002 (see above) were first observed over northern Georgia on September 8th as clear skies and surface ridging were located east of the Appalachian at that time (not shown).

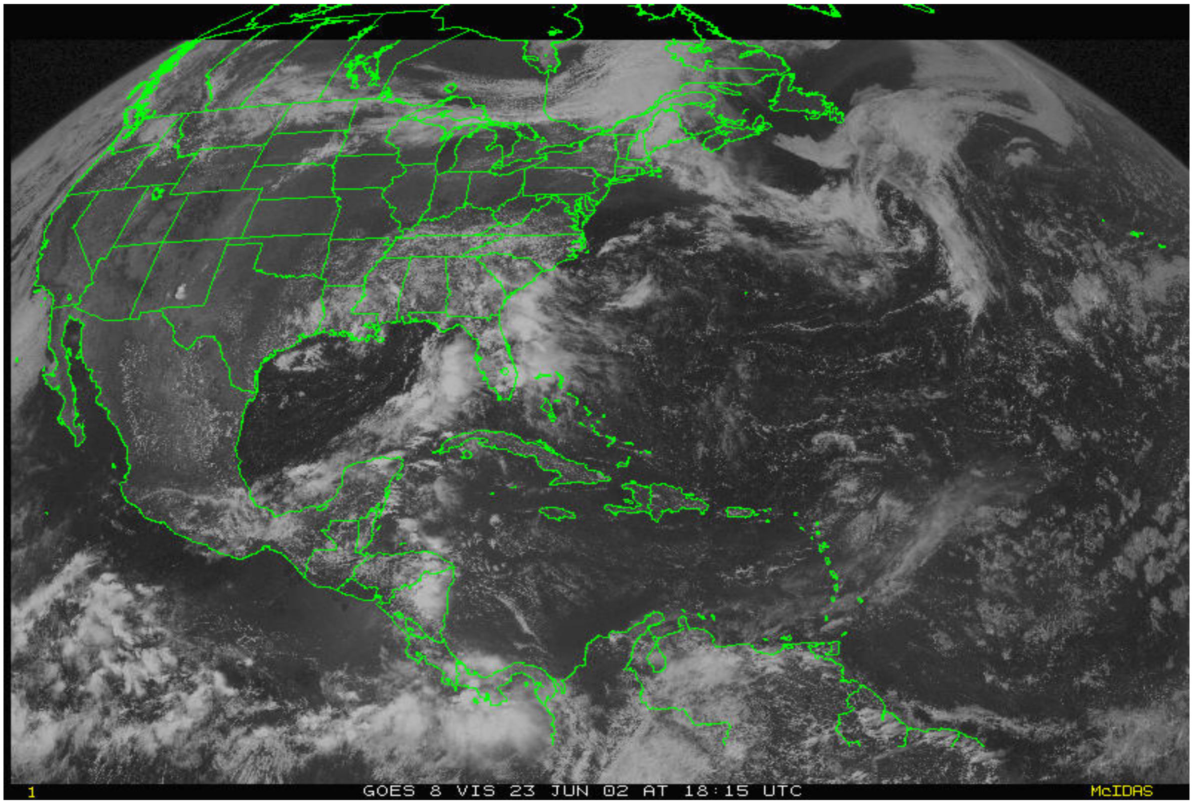

Figure 2. Visible satellite image, 1800 UTC 23 June 2002 (Image from NOAA National Climate Data Center).

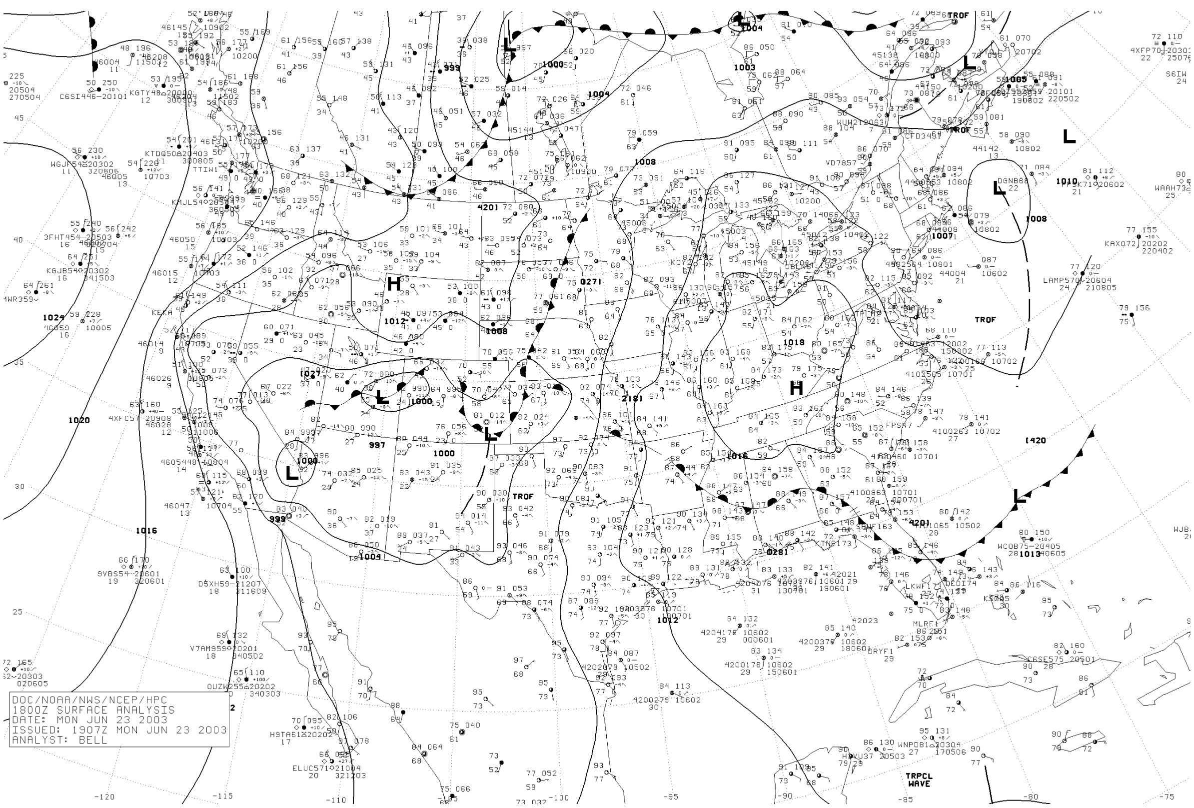

Figure 3. NCEP Surface Analysis 1800 UTC 23 June 2002 (Chart from NESDIS-SRRS)

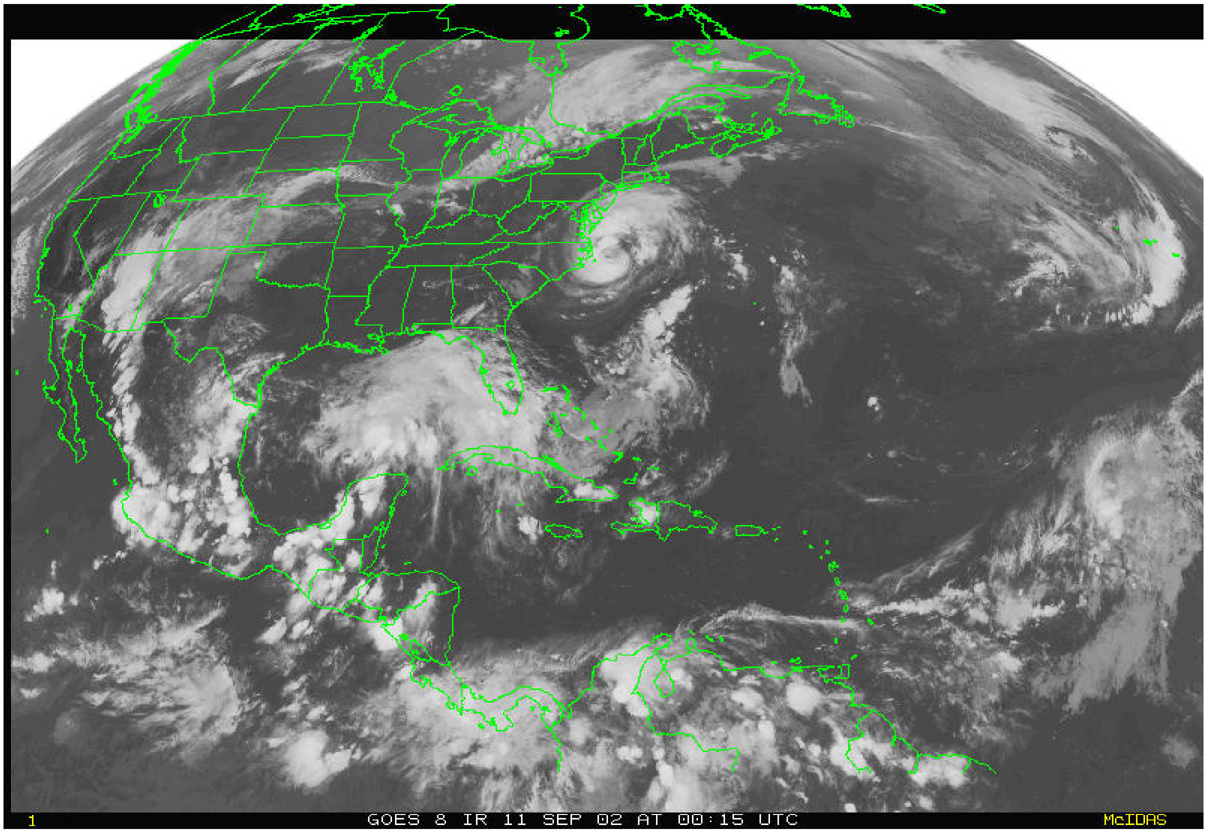

Figure 4. Infrared satellite image. 0000 UTC 11 September 2002

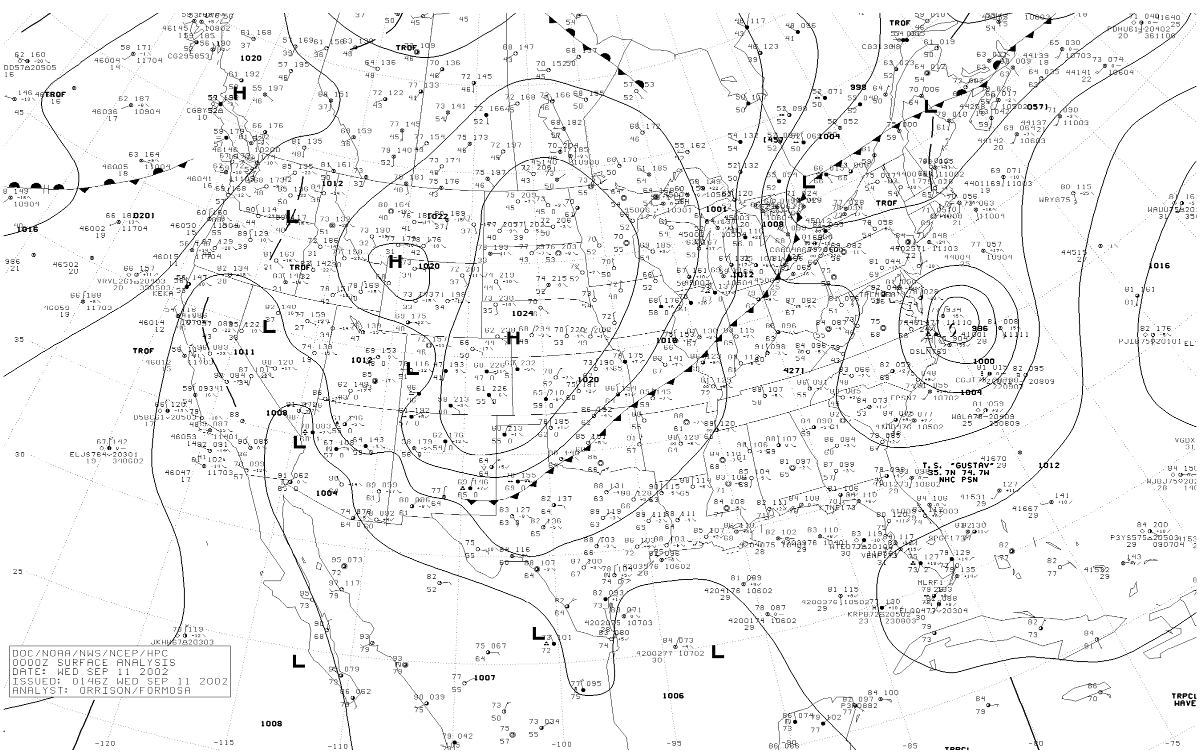

Figure 5. NCEP Surface analysis: 0000 UTC September 11, 2002.

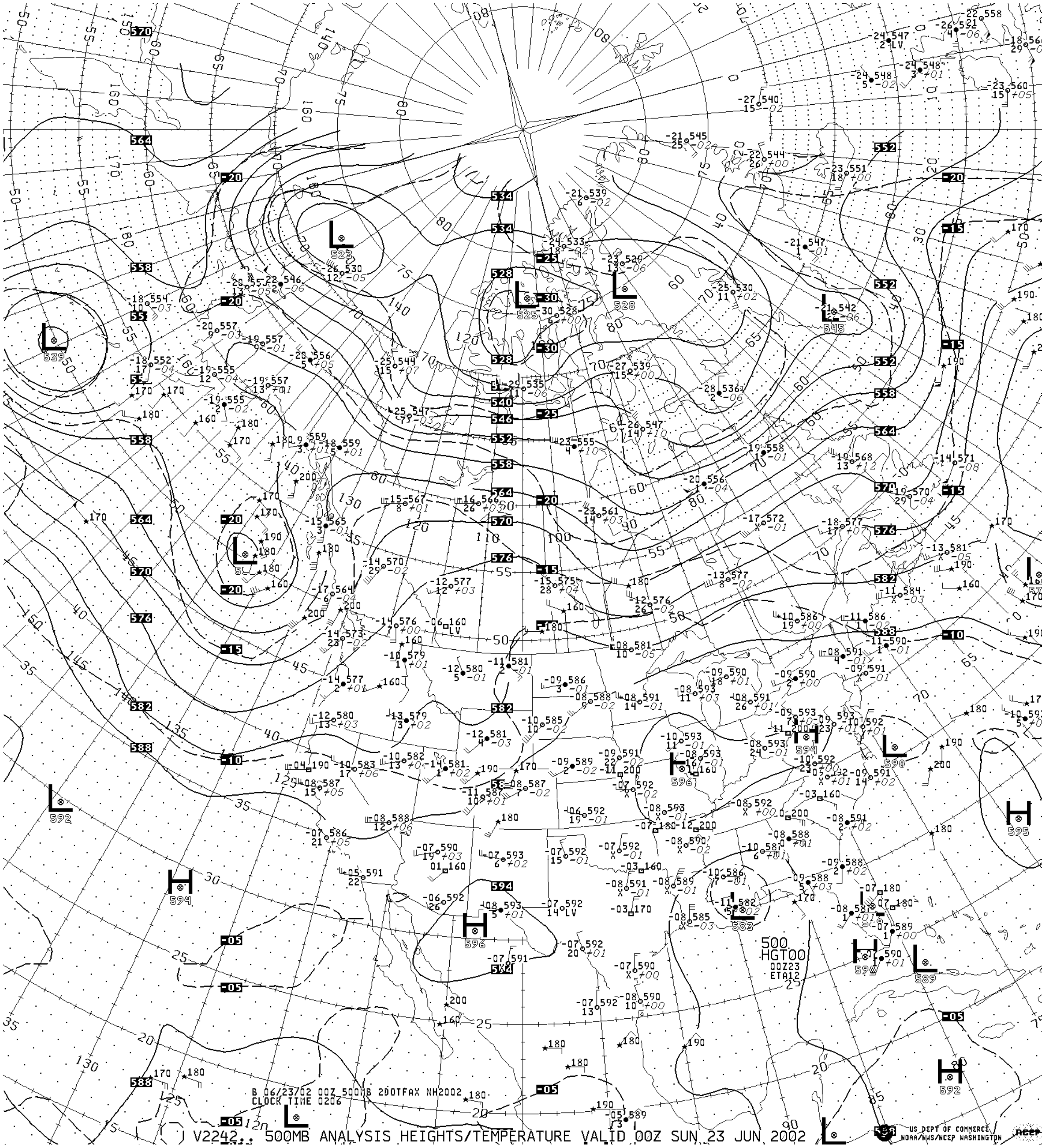

Figure 6. 500 mb Heights (solid, every 6 dam) and Temperature (dashed, every 5 C): 0000 UTC 23 June 2002.

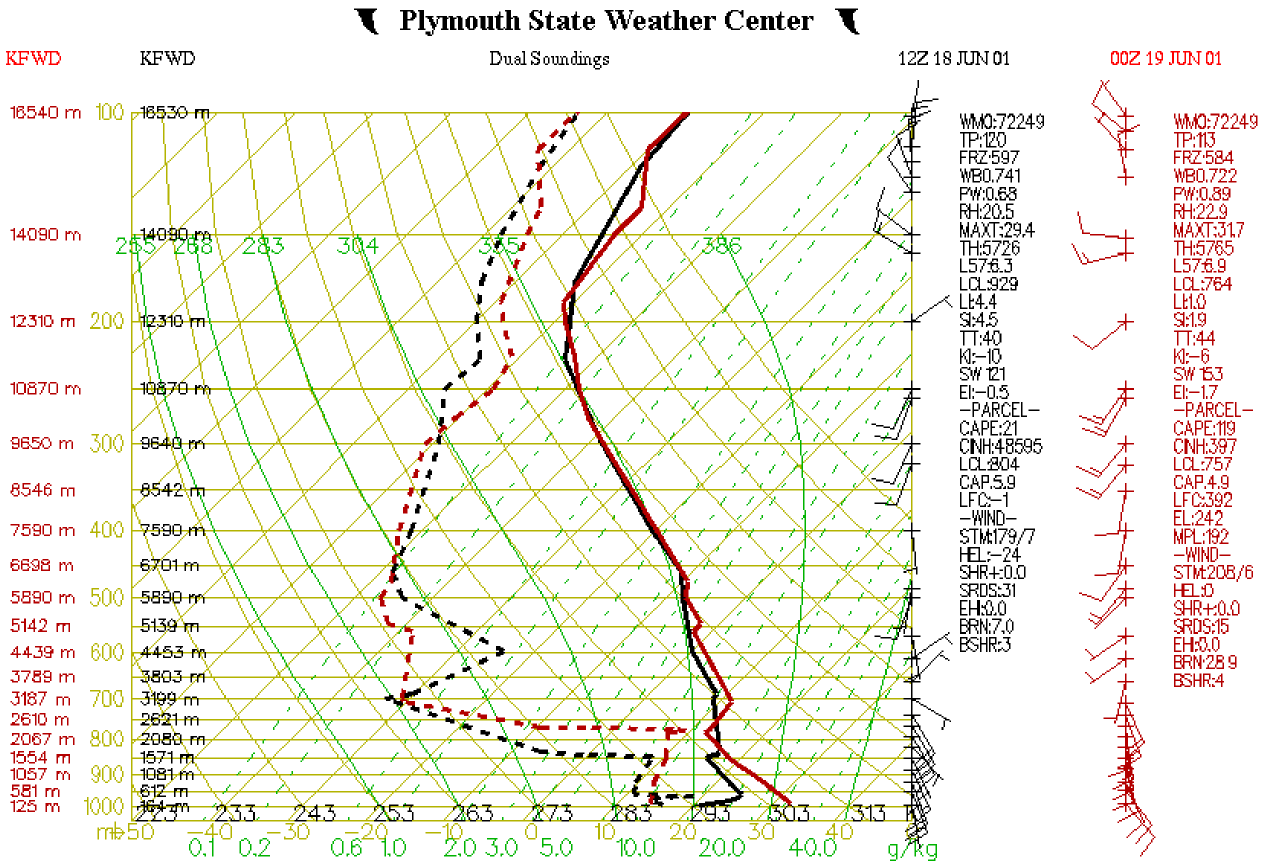

Figure 7: Dual soundings of Fort Worth, TX on June 18, 2001 at 12Z and June 18, 2001 at 00Z.

While many of the cases exhibited “classic” textbook meteorological features, a few of the case showed some interesting other features. For example, most of the poor air quality cases in the Mid-Atlantic region feature clear skies, upper-level ridging, and subsidence inversions. However, the major feature in the surface sea-level pressure field is a lee trough (not shown). In general the lee trough forms in response to weak westerly downslope flow from the Appalachian Mountains. It has been hypothesized that the lee trough may act to increase ozone concentrations along the trough axis through weak convergence.

4. Concluding Discussion

In this paper we have examined the meteorological features associated with regional poor air quality episodes with high ozone concentrations. For the most part the case studies from each have classic meteorological features associated with poor air quality such as large areas of surface high pressure, clear skies, calm winds, upper-level troughs and subsidence inversions. Subtle differences have been noted for each region, such as the lee trough often observed in poor air quality episodes in the Mid-Atlantic region. Due to space limitations we could not present the detailed case analyses from each region here. In the future the full case study analyses for each region will be available on a web site as well as in individual PDF files.

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Climate Diagnostics Center – http://www.cdc.noaa.gov

NOAA/NCDC – http://www.ncdc.noaa.gov

NESDIS/SRRS - http://nomads.ncdc.noaa.gov:9091/ncep/NCEP