Case Study of the
June 22-28 $PM_{2.5}$ and Ozone Episode in the Midwest and Northeast United States

Jen Garlock
Timothy Dye
Sonoma Technology, Inc.

A week-long episode of high ozone and fine particulate matter ($PM_{2.5}$) levels affected the majority of the Midwest and Northeast United States from June 22 to 28, 2003. This summary and accompanying figures illustrate several important features of this episode. First, high levels of $PM_{2.5}$ did not always coincide with high levels of ozone. Second, as the weather systems and corresponding "polluted" air mass moved eastward, high $PM_{2.5}$ levels showed a one- or two-day lag behind peak ozone levels. The remainder of this case study describes these features.

High pressure increased in the Midwest on Saturday and Sunday (June 21-22) giving the region clear skies, a more stable atmosphere, weak winds, and increasing ozone concentrations (Figures 1a and 1b). Ozone levels reached Air Quality Index (AQI) category of Moderate over most of the Midwest, and areas of Michigan reached Unhealthy for Sensitive Groups (USG). $PM_{2.5}$ increased only slightly on Sunday and remained in Good and Moderate AQI categories.

USG ozone conditions became widespread over the Midwest on Monday (June 23) as the surface high remained over Illinois, Indiana, and Ohio (Figure 1c). The continued clear skies and light winds allowed ozone to build up. For the most part, $PM_{2.5}$ remained Moderate, with only a couple of sites reaching USG.

Tuesday and Wednesday (June 24-25) had the poorest air quality of the episode (Figures 1d and 1e). While Tuesday showed many areas with Unhealthy levels of ozone, $PM_{2.5}$ did not peak until Wednesday. Satellite imagery showed an approaching cold front moving through Wisconsin and Iowa. The satellite images and ozone maps showed a strong correlation between cloud cover and ozone levels. The position of the cold front (drawn on the $PM_{2.5}$ and ozone maps) with its increased winds and precipitation cleared out pollutants, as shown by the Good $PM_{2.5}$ AQI levels behind (northwest of) the front.

By Thursday (June 26), the cold front had progressed only through Illinois, where both $PM_{2.5}$ and ozone levels decreased drastically (Figure 1f). Ozone had also decreased to Good through Indiana where pre-frontal clouds reduced photochemistry, but $PM_{2.5}$ remained elevated. Meanwhile, in the Northeast, continued high pressure kept ozone levels in the USG and Unhealthy categories. $PM_{2.5}$ concentrations increased with most of the Northeastern $PM_{2.5}$ monitors reporting USG.

On Friday (June 27), a large improvement in both ozone and $PM_{2.5}$ conditions was evident for all but the coastal parts of the Northeast (Figure 1g). Initially a slow-moving system, the cold front picked up speed and swept from Illinois to central New York and Pennsylvania. Both ozone and $PM_{2.5}$ were decreased to Good levels, while coastal areas like Massachusetts, Connecticut, and New Jersey remained Unhealthy and USG for ozone and $PM_{2.5}$. The role of the cold front was critical for lowering $PM_{2.5}$ concentrations because it is the primary mechanism to replace the air mass over a region with clean air. For example, Figure 2 shows a 24-hour time series plot of surface weather and $PM_{2.5}$ conditions in Pittsburgh, Pennsylvania, on June 26 and 27. Notice that as the cold front moves through the region between 2:00 a.m. and 4:00 a.m., $PM_{2.5}$ concentrations begin decreasing. The cold front is marked in Figure 2 as the wind changed from south-southwesterly to westerly, and the dew point temperature began to decrease. The cleaner air mass behind the cold front resulted in $PM_{2.5}$ concentrations in the 10 $\mu g/m^3$ range.

Saturday (June 28) concluded the episode as all USG and Unhealthy levels of ozone and $PM_{2.5}$ cleared out (Figure 1h). The cold front cleared the Northeast, and all monitors for both pollutants reported Good or Moderate levels. The clouds, precipitation, increased wind speed, and cleaner northerly winds all provided a change in air mass and relief from the poor air quality.

The lag in $PM_{2.5}$ concentrations behind ozone is illustrated in Figure 3. The plots show peak $PM_{2.5}$ levels occurring one to two days behind the peak ozone in most cities. There are two reasons for this. First, PM takes longer to build up than ozone. This is evidenced in the greater lags in Eastern cities where more buildup time transpired before the cold front passed. Second, ozone is more sensitive to meteorological conditions such as sunlight and winds than PM. This means that the ozone levels will respond more quickly to the incoming front, whereas PM will not show a significant change until a new air mass is present.

Meteorologically, it appears that both clouds and wind contributed to the lag in peak $PM_{2.5}$ behind peak ozone during this episode. The sunny skies and weak winds allowed ozone buildup beginning in the Midwest and spreading to the Northeast as the surface high expanded. $PM_{2.5}$ levels increased at nearly the same rate in the Midwest, but lagged behind ozone in Northeastern cities. As the front moved through, clouds shut down ozone production, which was followed by rain, higher winds, and northerly winds that cleared out $PM_{2.5}$ and the remaining ozone.

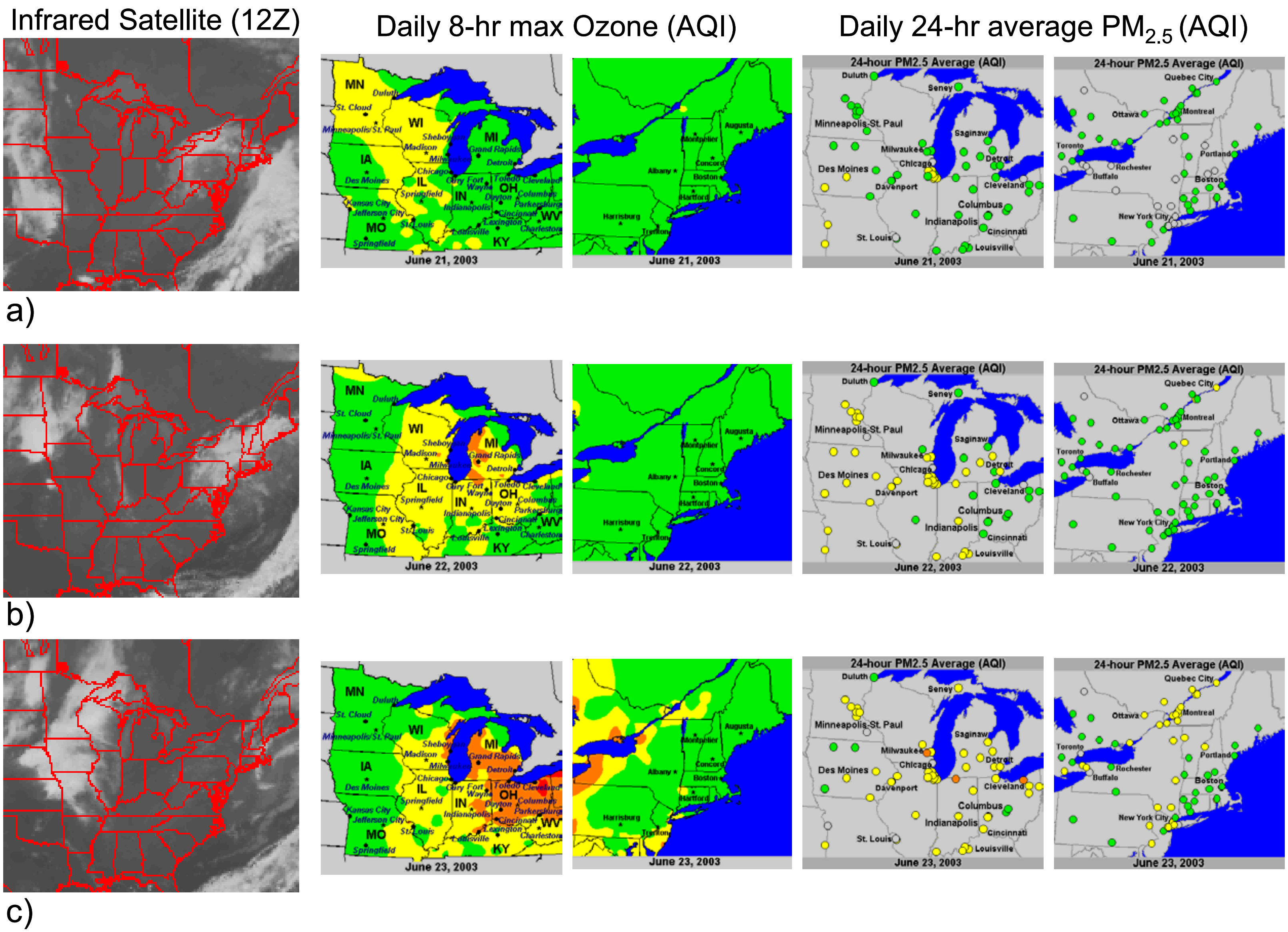

Figure 1a-c. Infrared satellite images at 12Z (0700 CDT), daily 8-hour maximum ozone maps (AQI), and daily 24-hour average $PM_{2.5}$ maps (AQI) for (a) June 21, 2003, (b) June 22, 2003, and (c) June 23, 2003. The position of the cold front has been included on the ozone and PM maps.

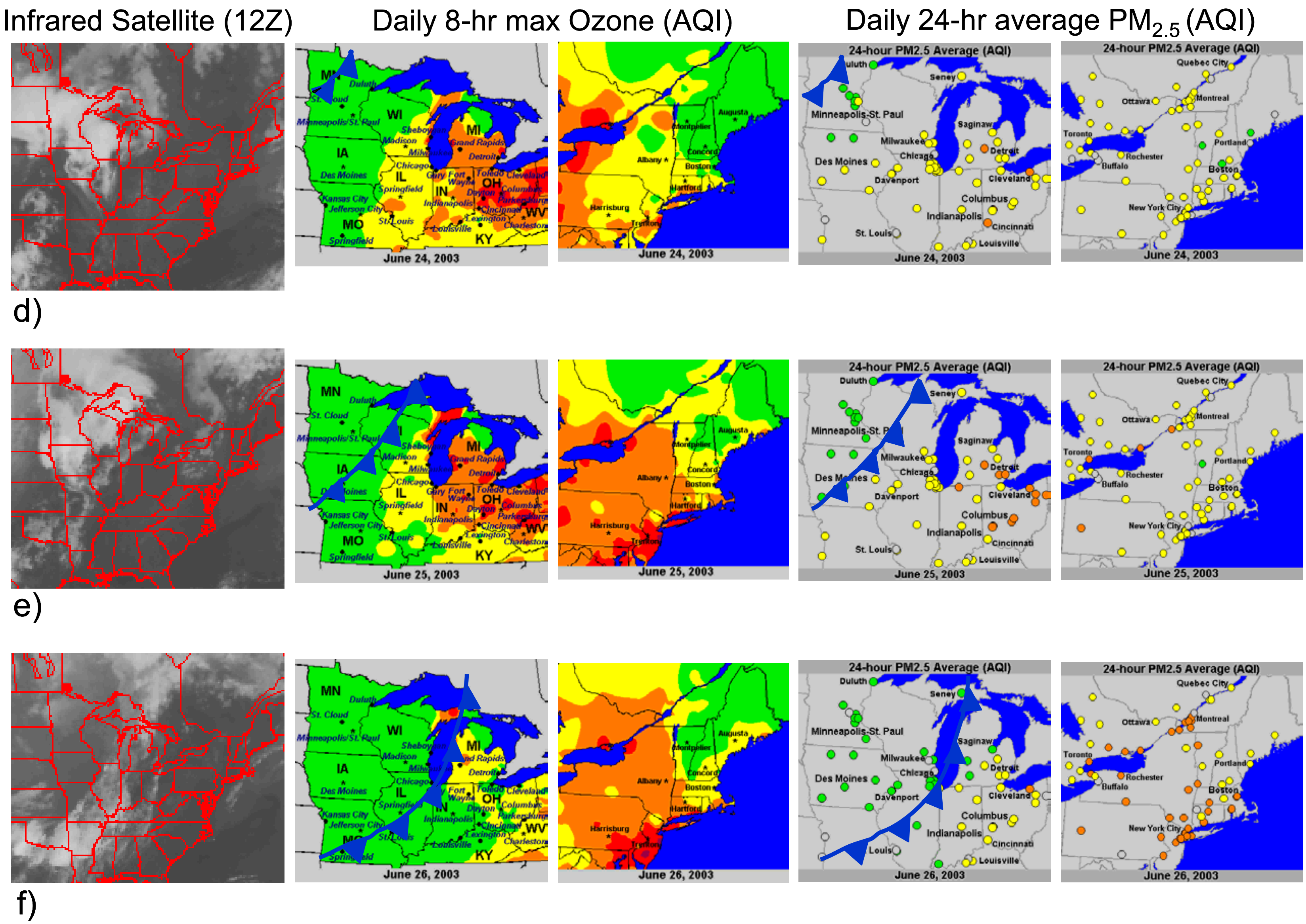

Figure 1d-f. Infrared satellite images at 12Z (0700 CDT), daily 8-hour maximum ozone maps (AQI), and daily 24-hour average $PM_{2.5}$ maps (AQI) for (d) June 24, 2003, (e) June 25, 2003, and (f) June 26, 2003. The position of the cold front has been included on the ozone and PM maps.

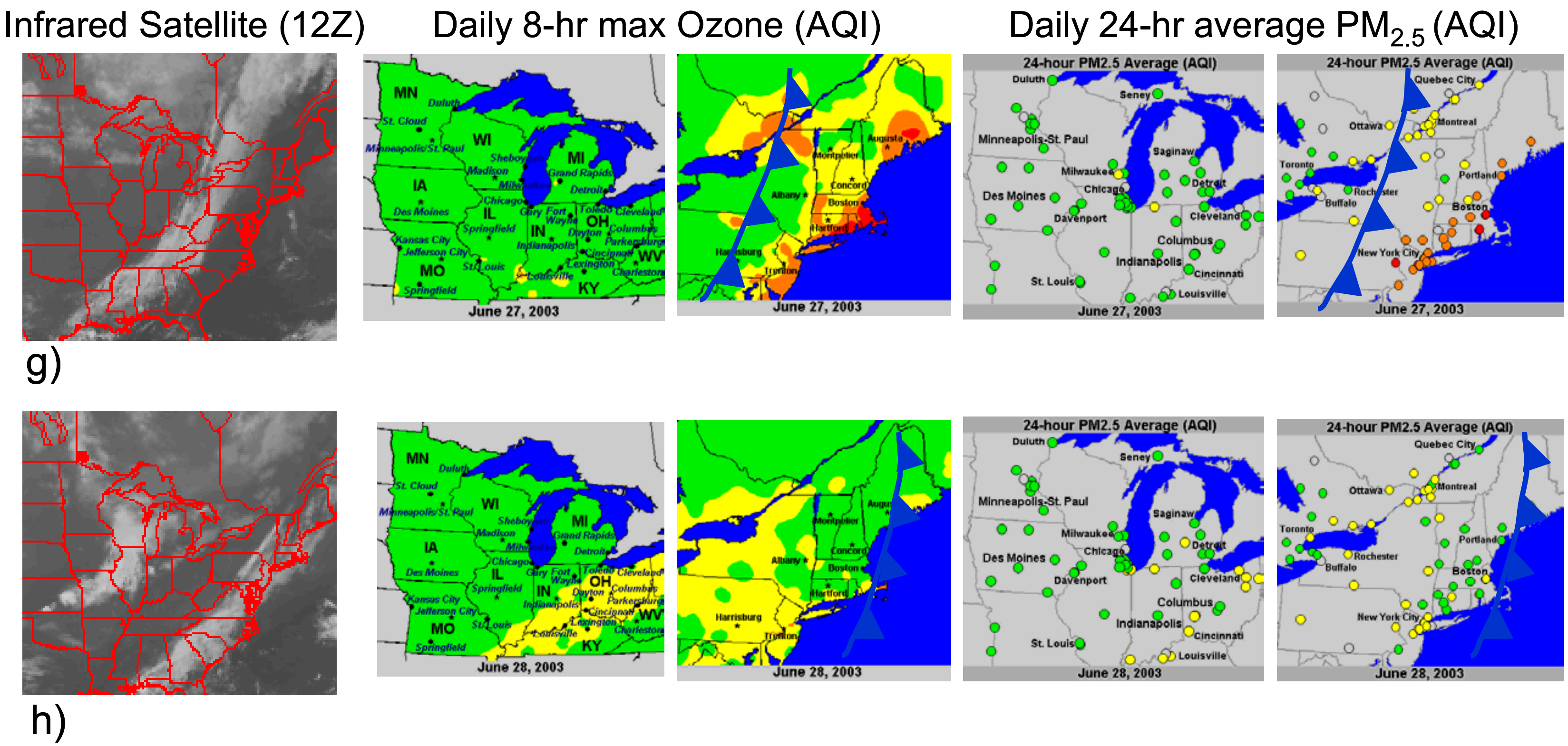

Figure 1g-h. Infrared satellite images at 12Z (0700 CDT), daily 8-hour maximum ozone maps (AQI), and daily 24-hour average $PM_{2.5}$ maps (AQI) for (g) June 27, 2003, and (h) June 28, 2003. The position of the cold front has been included on the ozone and PM maps.

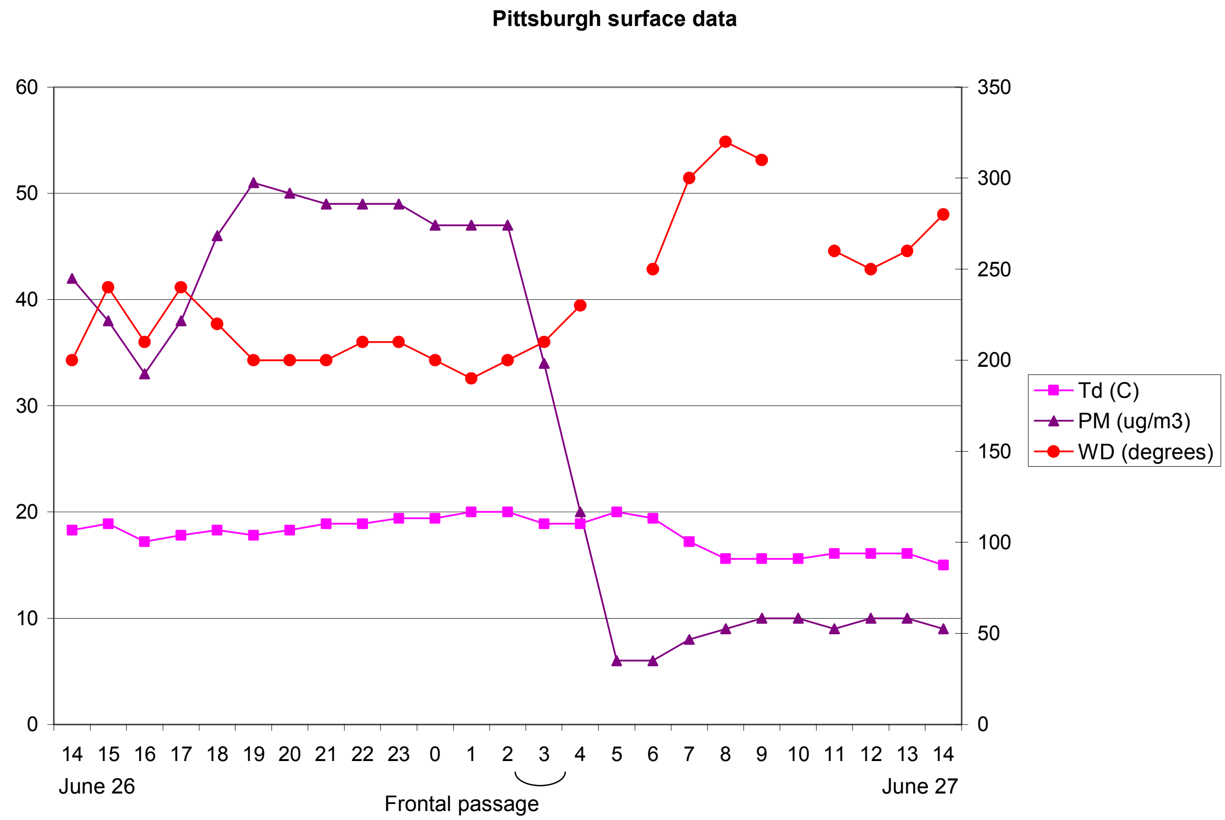

Figure 2. 24-hour time series of surface data in Pittsburgh from June 26, 2003, 14Z (0900 CDT) to June 27, 2003, 14Z. The plot shows wind direction, dew point, and PM concentrations before, during, and after frontal passage.

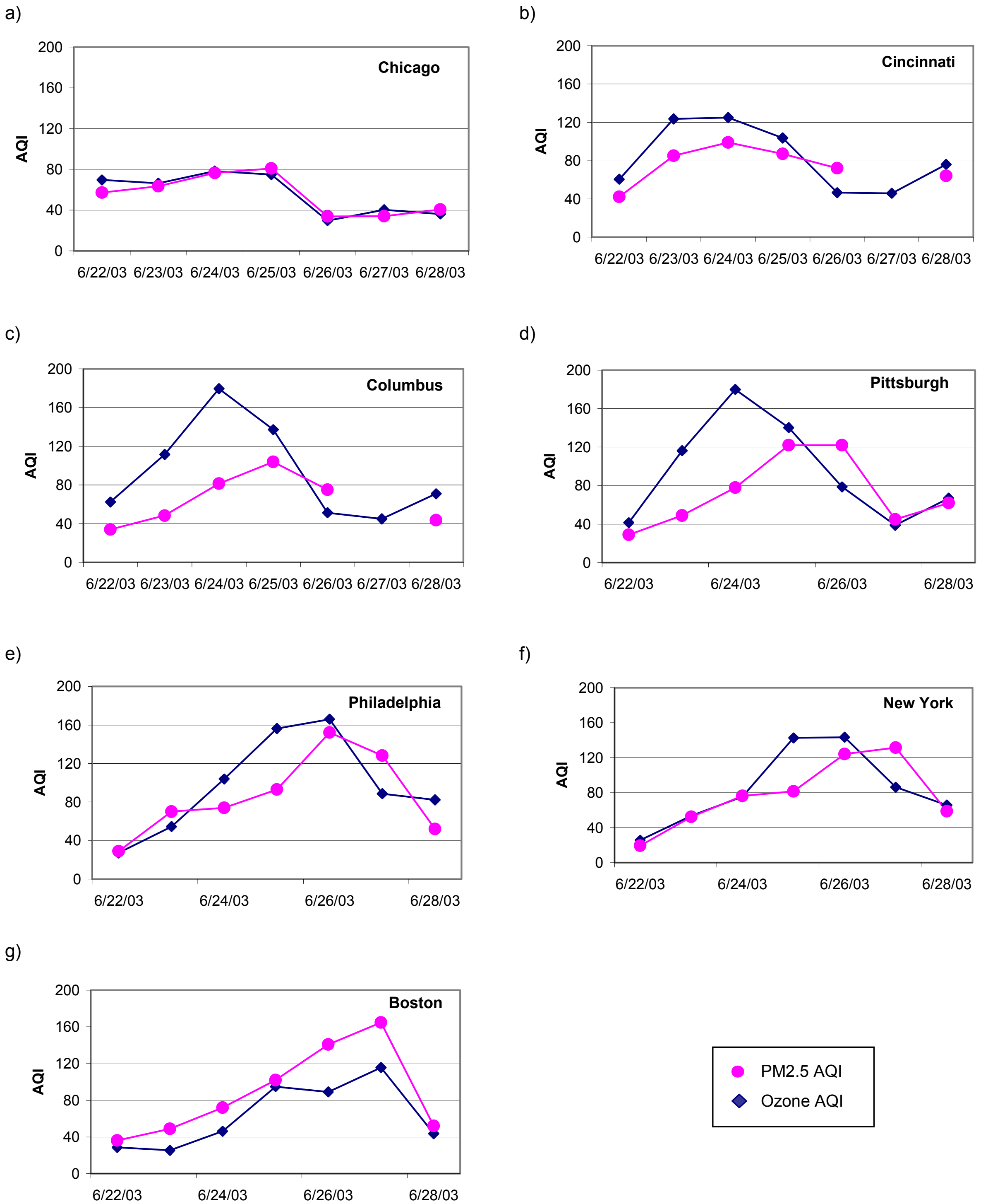

Figure 3. Daily ozone and $PM_{2.5}$ AQI levels from June 22 to June 28, 2003, for (a) Chicago, (b) Cincinnati, (c) Columbus, (d) Pittsburgh, (e) Philadelphia, (f) New York, and (g) Boston.