P1.2 THE CHALLENGES OF FORECASTING AND NOWCASTING DURING JOINT URBAN 2003

Jeffrey B. Basara, Peter K. Hall Jr., R. Grant Stewart, Michael James, Ryan Barnes
Oklahoma Climatological Survey
University of Oklahoma

1. Introduction

During June and July 2003, Joint Urban 2003 (JU2003; the largest urban dispersion field experiment of its kind) was conducted in Oklahoma City. Scientists from across the United States and around the world converged on Oklahoma City to quantify airflows within the urban environment. Knowledge gained from JU2003 will greatly enhance the ability of emergency responders and city officials in the event that harmful contaminants are released within an urban setting (e.g., pollution, an industrial accident, or a chemical or biological attack).

To accomplish the goals of the experiment, extensive preparations were made over a period spanning nearly three years. Oklahoma City was chosen for a myriad of reasons which included a consolidated and well defined central business district of tall buildings, relatively flat terrain without large bodies of water bordering the city, predictable wind conditions for the study period, the gridded nature of the city streets, and the support of city officials for the project. Another main consideration for the selection of Oklahoma City was the extensive infrastructure of meteorological instruments in place in central Oklahoma.

Between the dates of 28 June and 31 July 2003, a vast array of instrument systems installed specifically for JU2003 collected high-resolution observations of meteorological variables in and around Oklahoma City. The instruments continuously gathered data from surface-based and tower-based measurements at ground level, on traffic poles, the sides of buildings, and on rooftops. Additional instruments were installed on the perimeter of the city to gather information on the vertical profile of wind speed, wind direction, and temperature.

However, to gather detailed information of how air moves through the urban canyon structures and into buildings, a special tracer (sulfur hexafluoride) was released when atmospheric conditions were suitable. During the course of the experiment, 10 tracer release studies that lasted approximately 8 hours (intensive observing periods; IOPs) were conducted and specialized instruments were deployed throughout the city to measure the concentration of the sulfur hexafluoride. The tracer experiments were very critical to the success of JU2003 because each release simulated how a contaminant would move through the city given certain atmospheric conditions.

2. The Forecast Problem

A key reason for the timing of JU2003 (i.e., late June-July) was the predictable nature of low-level wind conditions. Typically during the summer months, a mid tropospheric ridge develops over the Great Plains of the United States and mid-level winds weaken. As a result, low-level winds are most impacted by the position of the Bermuda high off the east coast of the United States. Because Oklahoma is located usually on the western periphery of the Bermuda high, the nature of surface winds are southerly during the June-July period. In addition, the propagation of surface frontal boundaries is limited during the summer months. As a result, the climatological pattern favored weak southerly winds with very minimal precipitation.

During JU2003, a number of portable sensors were deployed to detect the tracer released during the IOPs. The portable samplers, approximately 200 in all, were placed in the field before each IOP and returned to the laboratory for analysis upon the completion of the subsequent tracer release. In order to place all samplers in the correct positions before the beginning of an IOP, the experiment team needed approximately 24 hours of advanced notice concerning whether the atmospheric conditions were suitable for a tracer release.

The portable sensors were placed throughout Oklahoma City in 2 arrays dependent upon wind direction (Figs. 1a-b). Figure 1a shows a deployment of sensors consistent with southerly wind conditions while a deployment of sensors best suited for southeasterly winds is displayed in Figure 1b. Thus, the challenge to the forecasters was to identify the proper wind conditions 24-36 hours in advance of the tracer release, and provide guidance concerning the deployment of sensors (i.e., southerly winds or southeasterly winds). Once the tracer experiments were ongoing, the forecasting staff monitored weather conditions to ensure successful experiments as well as provide advanced warning in the event of inclement weather.

3. Retrospective Analysis

Prior to JU2003, a retrospective analysis of wind conditions during July was conducted using past climatological data. The results indicated that during any given year, wind conditions were

* *Corresponding author address:* Jeffrey B. Basara Oklahoma Climatological Survey, 100 E. Boyd St. Suite 1210, Norman, OK 73019, jbasara@ ou.edu

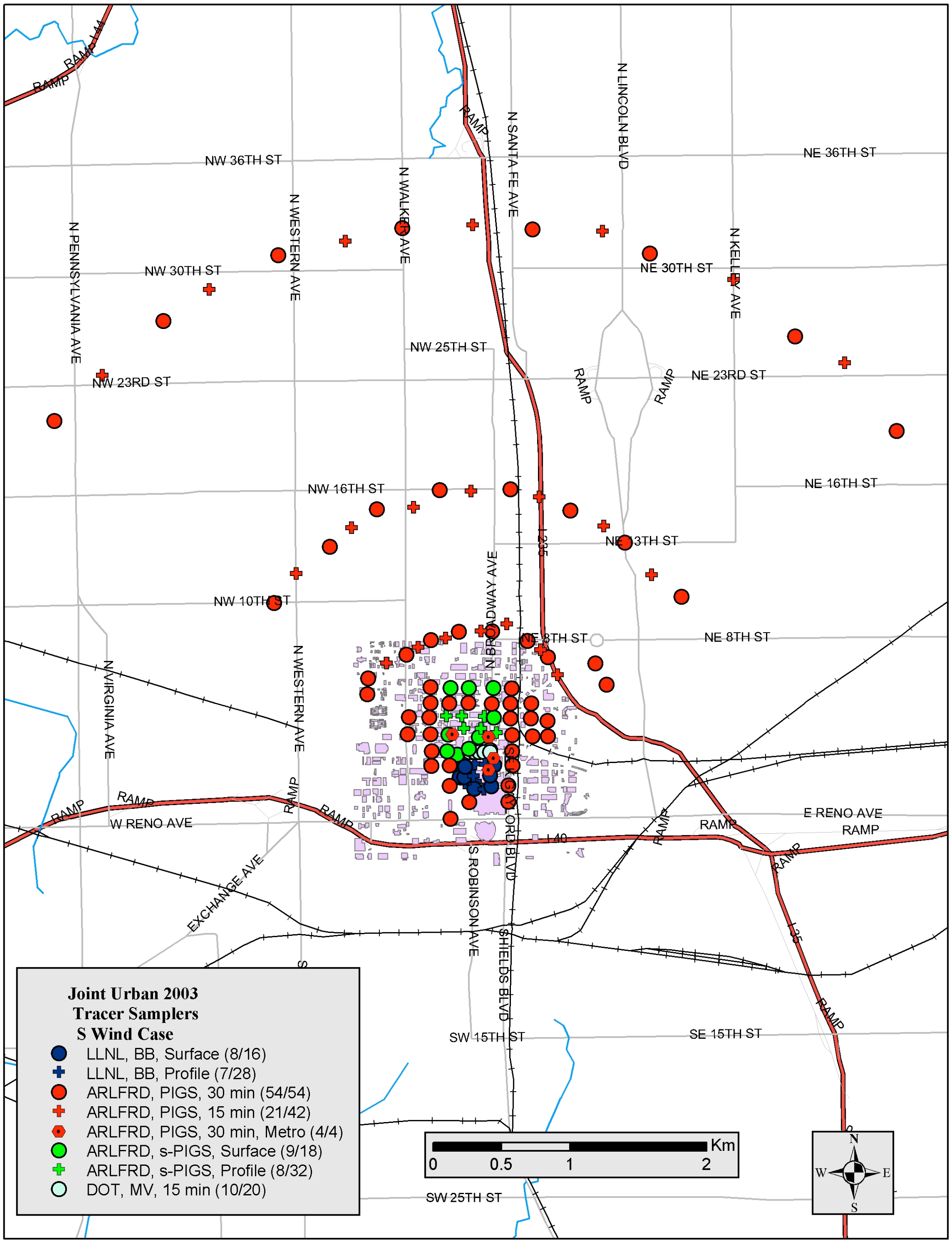

Figure 1a. The deployment of portable tracer samples for southerly wind conditions during JU2003.

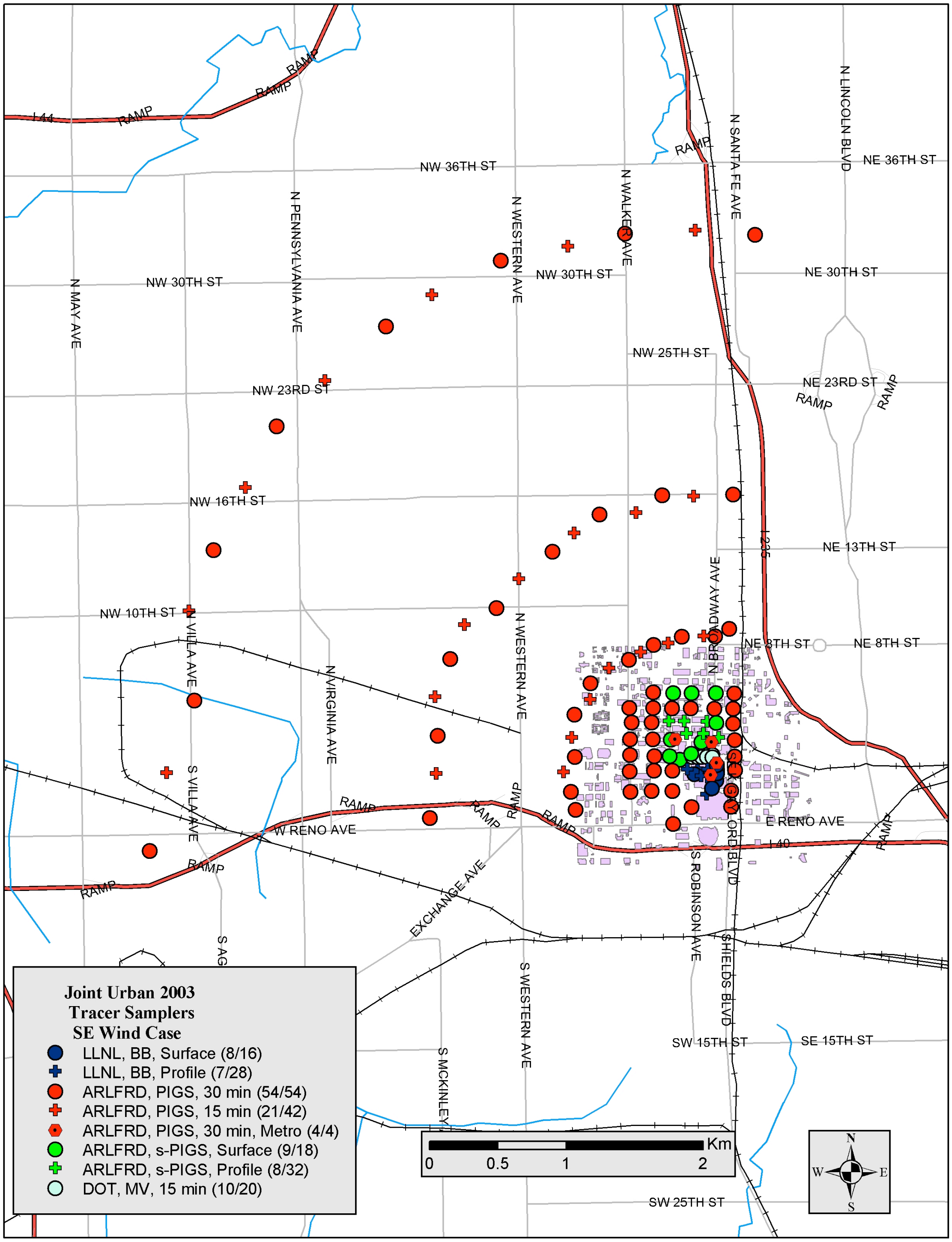

Figure 1b. The deployment of portable tracer samplers for southeasterly wind conditions during JU2003.

favorable for achieving the overall goal of the experiment: 10 IOPs. However, the number of favorable cases per year varied greatly. Further analysis revealed the greatest factor that dictated the speed and direction of the low-level wind conditions besides the low-level Bermuda high was the juxtaposition of the mid-tropospheric ridge that develops over the central United States during the summer months.

Two distinct scenarios were identified that impacted the number of possible IOP cases observed in the retrospective study. First, when the mid-tropospheric ridge axis was positioned overhead or to the east of Oklahoma City, the southerly winds at the surface were reinforced. Thus, central Oklahoma experienced persistent southerly winds suitable for IOP conditions. In addition, the low-level wind conditions were quite easy to identify at an extended time interval (e.g., 1-4 days in advance).

A second, and quite different scenario existed when the mid-tropospheric ridge was positioned to the west of Oklahoma City. In this case, mid-tropospheric conditions resulted in northwesterly flow aloft over the plains of the United States. As a result, the conditions aloft favored the development and maintenance of a surface ridge to the east of the Rocky Mountains. With each surface ridge that developed in this scenario, a surface front or wind shift would push into Oklahoma which replaced the southerly winds with northerly or easterly winds that were unfavorable for IOP conditions.

IOP	30 Hour Verification	AVN	AVN Error	Eta	Eta Error	NGM	NGM Error
1	100	170	70	150	50	170	70
2	210	180	30	190	20	190	20
3	180	190	10	180	0	200	20
4	190	200	10	200	10	230	40
5	170	180	10	180	10	190	20
6	200	180	20	190	10	190	10
7*	190	170	20	160	30	140	50
8*	150	150	0	130	20	160	10
9*	150	150	0	140	10	170	20
10*	180	150	30	50	130	10	170

Table 1. Wind direction in degrees from true north observed at the KOKC ASOS station and the 30-hour forecast values and error for the AVN, Eta, and NGM numerical weather prediction models.

IOP	30 Hour Verification	AVN	AVN Error	Eta	Eta Error	NGM	NGM Error
1	9	10	1	10	1	12	3
2	9	5	4	6	3	9	0
3	17	17	0	13	4	15	2
4	15	15	0	14	1	15	0
5	8	5	3	12	4	8	0
6	12	9	3	8	4	9	3
7*	5	5	0	5	0	5	0
8*	14	8	6	7	7	9	5
9*	9	7	2	6	3	7	2
10*	6	5	1	4	2	6	0

Table 2. Wind speed in knots observed at the KOKC ASOS station and the 30-hour forecast values and error for the AVN, Eta, and NGM numerical weather prediction models.

4. Forecast Challenges

4.1 *The Large-Scale Weather Patterns*

As noted in Section 3, two distinct atmospheric scenarios existed in the retrospective analysis that could aid or hinder the operations during JU2003. Unfortunately, the large-scale weather pattern that consistently occurred during JU2003 was the scenario in which the mid-tropospheric ridge axis was located to the west of Oklahoma City. As such, periodic surface boundaries pushed into central Oklahoma throughout the experiment and the southerlies needed for IOP operations were periodically replaced by northerly or easterly winds.

4.2 *The Diurnal Cycle of Wind Direction*

Hall and Basara (2004) noted that the diurnal oscillation of wind direction during JU2003 was significant. For example, the mean wind direction during the period varied between 160 degrees just before sunrise (1200 UTC) to nearly 210 degrees by midday (1800 UTC) to nearly 150 degrees just after sundown (0200 UTC). In addition, the mean wind speed increased from just 7 knots just before sunrise (1200 UTC) to nearly 13 knots by 1600 UTC.

The daily oscillation of wind conditions posed a serious challenge for forecasters. First, borderline conditions favorable for IOPs were highly scrutinized due to the nearly 60-degree window of wind direction likely to exist during the 8-hour lifetime of an IOP. In addition, once IOP conditions were identified, the deployment of the field sensors dictated very specific wind conditions. However, the difference between the deployment schemes in Figures 1a and 1b was just 45 degrees while the mean diurnal cycle of wind direction was approximately 60 degrees. Thus, wind conditions could initially be favorable for one deployment, but with a diurnal shift in wind direction, become unfavorable for that deployment scheme.

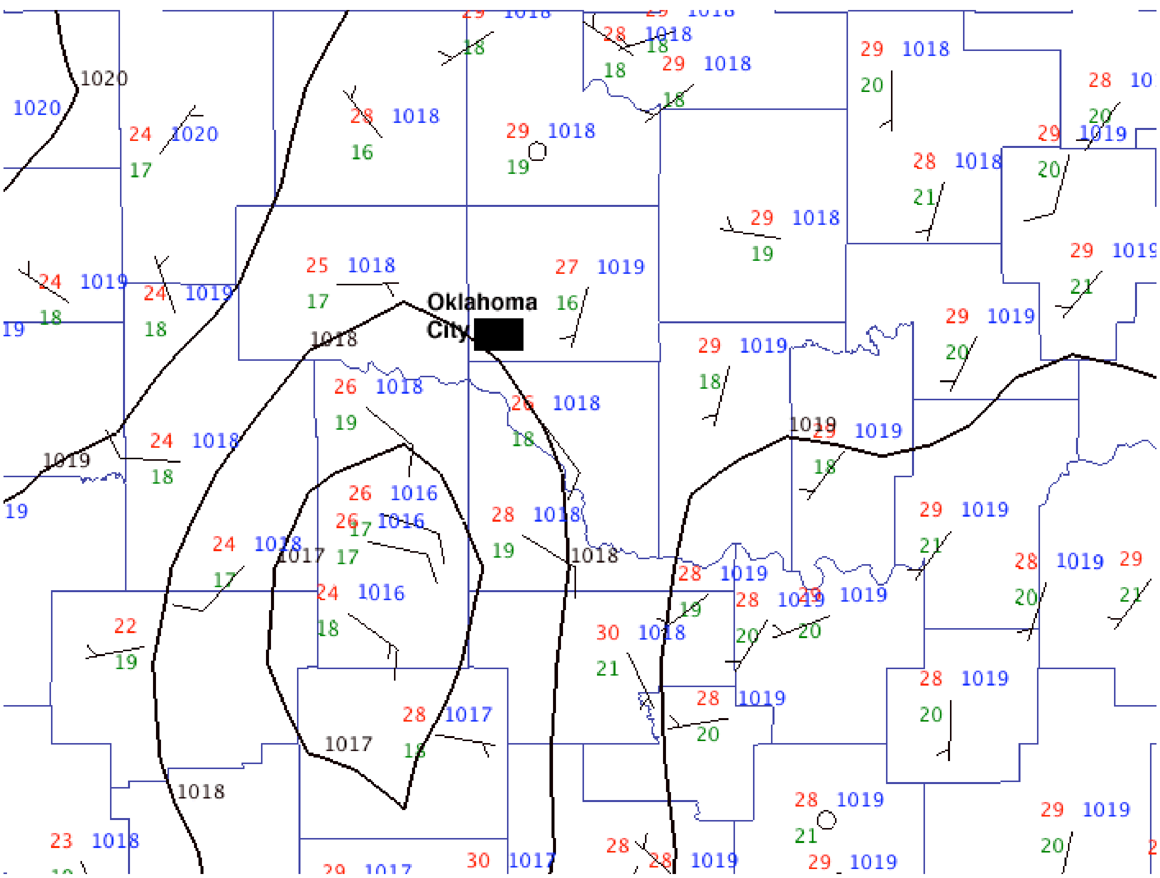

Figure 2. Surface conditions at Oklahoma Mesonet sites at 1730 UTC on 29 June 2003. Temperature in Celsius is in red, dew point temperature in Celsius is in green, pressure reduced to sea level in millibars is in blue, and the contours represent pressure contoured at 1 mb increments.

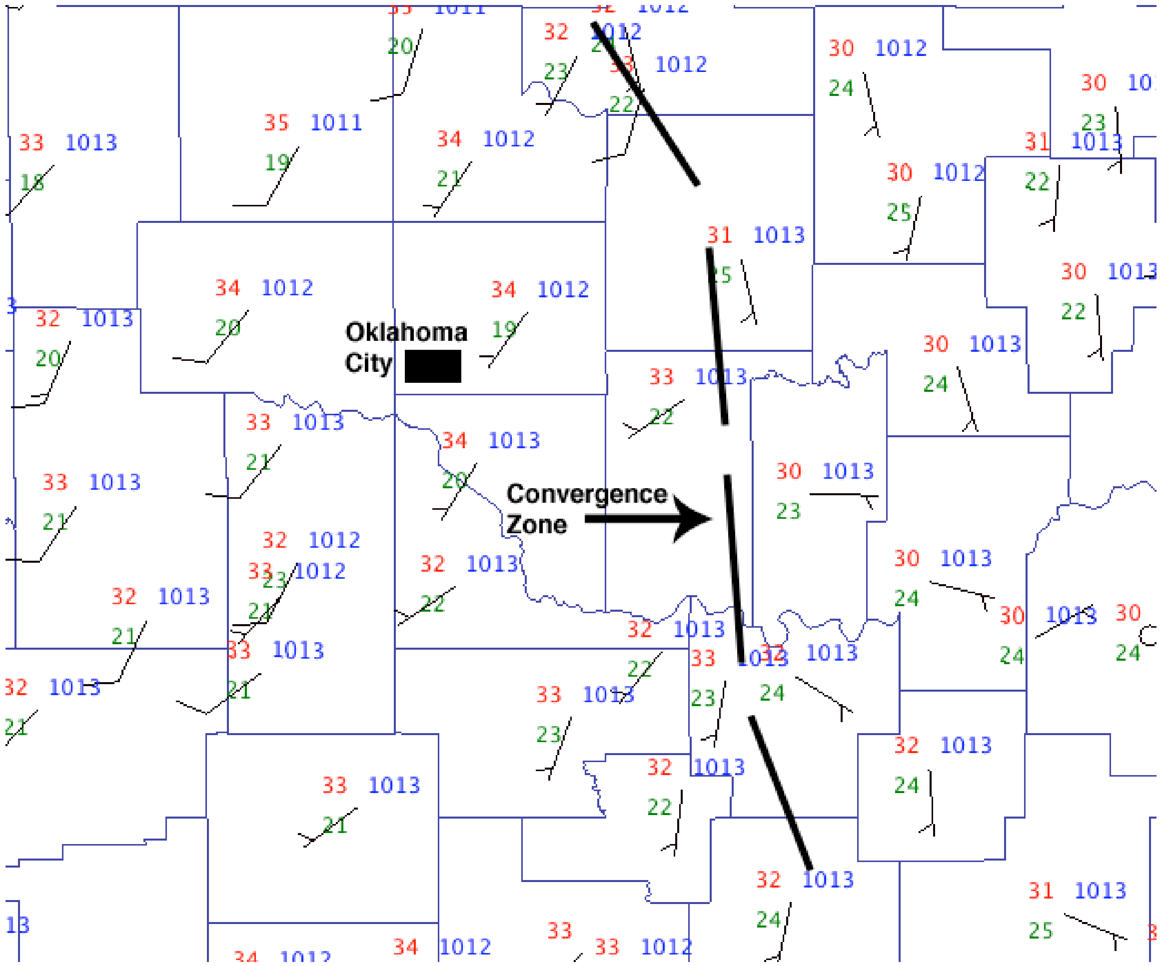

Figure 3. Surface conditions at Oklahoma Mesonet sites at 1730 UTC on 2 July 2003. Temperature in Celsius is in red, dew point temperature in Celsius is in green, pressure reduced to sea level in millibars is in blue, and the contours represent pressure contoured at 1 mb increments.

4.3 *Numerical Model Guidance*

The main challenge facing forecasters during JU2003 was identifying very specific wind conditions 24-36 hours in advance. Numerical weather prediction models are particularly helpful in providing guidance for extended periods. As such, three models (the Eta, AVN, and NGM) were employed in the forecasting of low-level wind conditions during JU2003.

Tables 1 and 2 show the forecasted values of wind speed and direction by the NWP models for days in which an IOP occurred. Specifically, the 30-hour forecast is compared with the actual observations at the KOKC ASOS site just southwest of the central business district of Oklahoma City. While some errors were quite small, others were quite large. In particular, the minimum wind direction error for the models was 50 degrees and as large as 70 degrees during the IOP 1. Typically, however, the errors in wind directions were generally less than 40 degrees. Nevertheless, the errors combined with the diurnal oscillation of wind direction resulted in actual conditions that were significantly different than those forecasted.

4.4 *Mesoscale Phenomena*

During JU2003, the forecast staff closely monitored atmospheric conditions during each IOP. On numerous occasions, mesoscale phenomena impacted the low-level wind condition. For example, during IOP 1, a mesoscale convective complex (MCC) developed in southwest Kansas during the overnight hours on 28 June 2003, and propagated into western Oklahoma. While the convection did not directly impact Oklahoma City, a mesoscale surface low remained following the dissipation of the MCC (Fig. 2). As the meso-low propagated to the southeast during the day, the surface winds backed from southwest to easterly in just 5 hours and IOP 1 was halted during the late afternoon.

A second example is shown for 2 July 2003 (IOP 2). In this case a mesoscale convergence zone generated by differential surface heating developed just east of Oklahoma City. As a result, to the west of the boundary, the surface winds veered significantly to the southwest in response to the mesoscale feature, while to the east of the convergence zone, the surface winds were southeasterly (Fig. 3). Unfortunately, the portable sensors were deployed for southeasterly wind conditions and much of the tracer was advected off of the sampling grid.

Because the success of each tracer release hinged on wind speed and direction, and because mesoscale phenomena threatened IOP operations, it was critical for the operational staff to have real-time data at a scale of the features impacting the low-level atmosphere across Oklahoma. A key tool utilized by the forecast team during IOP operations was the Oklahoma Mesonet (Brock et al. 1995), a network of 115 automated weather stations in Oklahoma. The dense number of sites combined with frequent updates (every 15 minutes compared to every hour at ASOS sites) allowed the staff meteorologists to monitor mesoscale conditions that would otherwise not be detected.

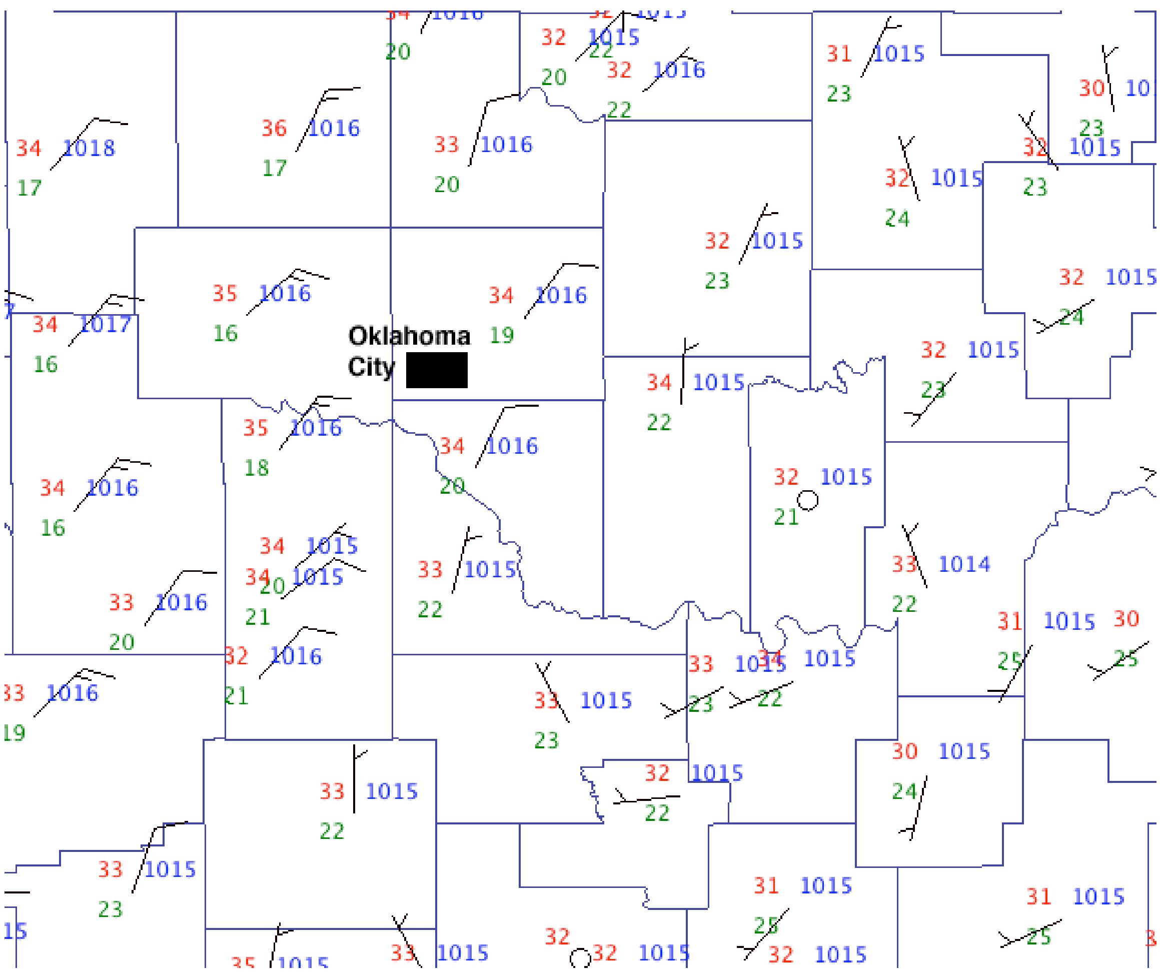

Figure 4. Surface conditions at Oklahoma Mesonet sites at 1800 UTC on 10 July 2003. Temperature in Celsius is in red, dew point temperature in Celsius is in green, pressure reduced to sea level in millibars is in blue, and the contours represent pressure contoured at 1 mb increments.

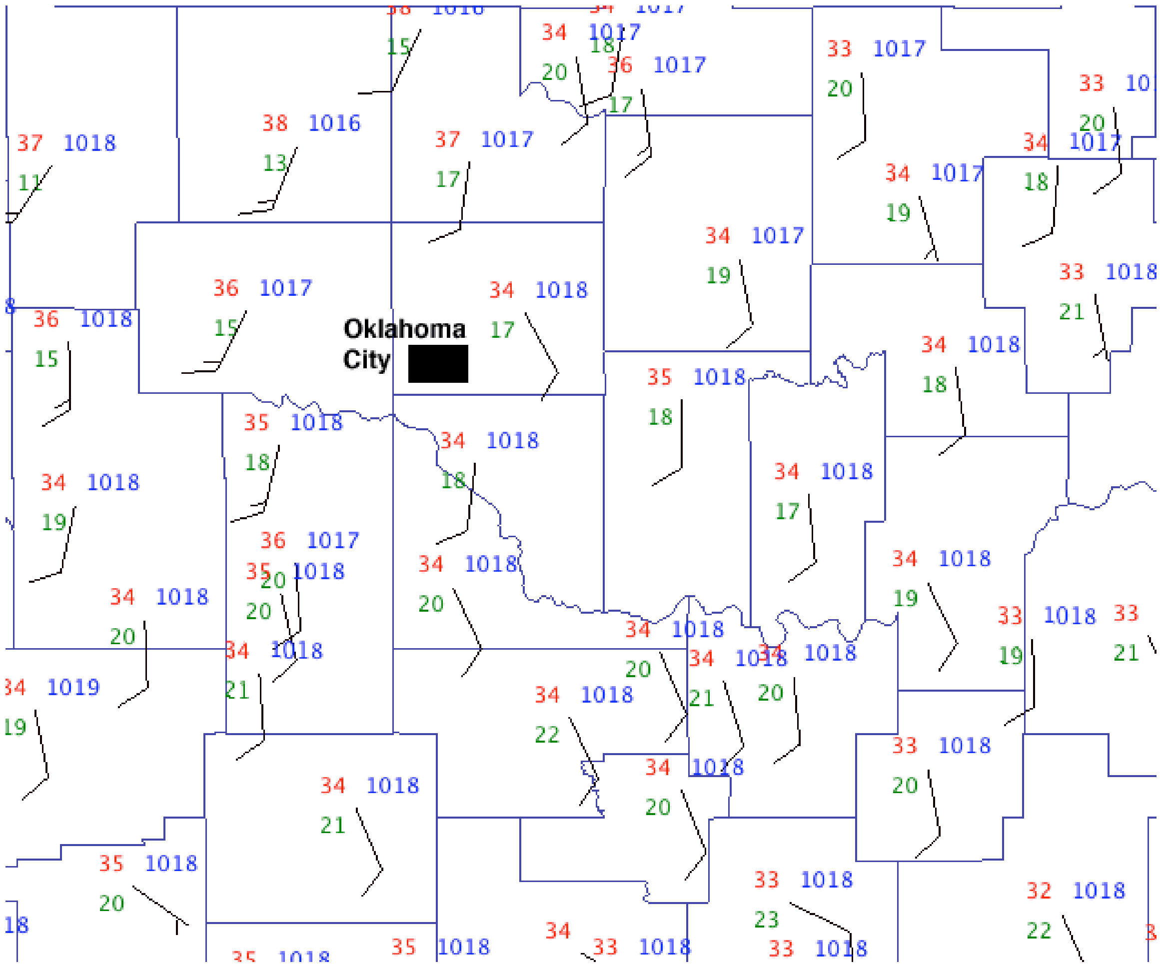

Figure 5. Surface conditions at Oklahoma Mesonet sites at 1800 UTC on 11 July 2003. Temperature in Celsius is in red, dew point temperature in Celsius is in green, pressure reduced to sea level in millibars is in blue, and the contours represent pressure contoured at 1 mb increments.

4.5 *Missed Opportunities*

At times during JU2003, atmospheric conditions were quite favorable for IOP operations. However, a number of opportunities were missed due to various circumstances. For example, on 10 July, a surface front pushed through Oklahoma City and the surface winds became northerly (Fig. 4). Because the NWP guidance predicted easterly winds and because of the ambient northerly wind on the day of the forecast, the forecast team decided that 11 July was not favorable for IOP operations. However, by 1200 UTC on 11 July, the winds had returned to a southeast direction, and by 1800 UTC, nearly ideal conditions for IOP operations existed (Fig. 5).

5. Conclusions

The results of JU2003 will have a significant impact on emergency preparedness in Oklahoma City, cites across the United States, and cities around the world in the event that harmful contaminants are released into the atmosphere. In addition, the wealth of information gathered during the experiment will aid in the increased understanding of urban meteorology. It is expected that scientists and students will investigate the data collected during JU2003 for the next decade or so.

Preliminary results from this study demonstrate that forecasting conditions for the tracer experiments during JU2003 was quite challenging. A major complicating factor was the nature of the forecasts that included very specific wind conditions at a time interval of 24-36 hours. Furthermore, natural factors such as the diurnal cycle of wind speed and direction, the juxtaposition of the mid-tropospheric ridge, and mesoscale phenomena directly impacted the accuracy of the forecasts during JU2003. Fortunately, JU2003 was very successful and all 10 IOPs were accomplished. However, the success of the experiment would not have been possible, in part, without the skilled forecasters who continuously monitored atmospheric conditions on behalf of the experiment team.

6. Acknowledgements

This study was made possible, in part, by funding from the Defense Threat Reduction Agency. The authors would like to thank Dr. Jerry Allwine for the use of Figures 1a and 1b.

7. References

Brock, F. V., and coauthors, 1995: The Oklahoma Mesonet: A technical overview, *J. Atmos. Oceanic Technology,* **12**, 5-19.

Hall, P. K. Jr., and J. B. Basara, 2004: Statistical analysis of numerical model output used for forecasting during Joint Urban 2003. Symposium on “Planning, Nowcasting, and Forecasting in the Urban Zone”, Seattle, WA., this issue.