13.10 **CFD Simulations of Joint Urban Atmospheric Dispersion Field Study**

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1. INTRODUCTION

The application of Computational Fluid Dynamics (CFD) to the understanding of urban wind flow and dispersion processes has gained increasing attention over recent years. While many of the simpler dispersion models are based on a set of prescribed meteorology to calculate dispersion, the CFD approach has the ability of coupling the wind field to dispersion processes. This has distinct advantages when very detailed results are required, such as for the case where the releases occur around buildings and within urban areas. CFD also has great flexibility as a testbed for turbulence models, which has important implications for atmospheric dispersion problems.

In the spring of 2003, a series of dispersion field experiments (Joint Urban 2003) were conducted at Oklahoma City (Allwine, et. al, 2004). These experiments were complimentary to the URBAN 2000 field studies at Salt Lake City (Shinn, et. al, 2000) in that they will provide a second set of comprehensive field data for evaluation of CFD as well as for other dispersion models. In contrast to the URBAN 2000 experiments that were conducted entirely at night, these new field studies took place during both daytime and nighttime thus including the possibility of convective as well as stable atmospheric conditions. Initially several CFD modeling studies were performed to provide guidance for the experimental team in the selection of release sites and in the deployment of wind and concentration sensors. Also, while meteorological and concentration measurements were taken over the greater Oklahoma City urban area, our CFD calculations were focused on the near field of the release point. The proximity of the source to a large commercial building and to the neighboring buildings several of which have multi-stories, present a significant challenge even for CFD calculations involving grid resolutions as fine as 1 meter.

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A total of 10 Intensive Observations Periods (IOP's) were conducted within the 2003 field experiments. SF_6 releases in the form of puffs or continuous sources were disseminated over 6 daytime and 4 nighttime episodes. Many wind and concentration sensors were used to provide wind and SF_6 data over both long and short time-averaging periods. In addition to the usual near surface measurements, data depicting vertical profiles of wind and concentrations adjacent to the outside walls of several buildings were also taken. Also of interest were observations of the trajectory of balloons that were deployed close to the tracer release area. Many of the balloons released exhibit extremely quick ascents up from ground level to the top of buildings, thus implying highly convective conditions.

In this paper we will present some simulations that were performed during the planning of the field experiments. The calculations were based on two possible release sites at the intersections of Sheridan and Robinson, and Broadway and Sheridan. These results provided initial information on flow and dispersion patterns, which could be used to guide optimal placement of sensors at appropriate locations. We will also discuss results of more recent simulations for several releases in which reliable data is available. These simulations will be compared with the near field data taken from the wind sensors as well as the time-averaged data from the concentration sensors. Among the other topics discussed are initial and boundary conditions used in the simulations, adaptation of building GIS data for CFD modeling and analysis of field data.

2. MODELING APPROACH

The numerical model used in this study (FEM3MP) is an extension of a finite element model used to simulate heavy-gas dispersion. The model solves the time-dependent, incompressible Navier-Stokes equations using graded and distorted elements to represent the geometric complexities associated with buildings and other urban configurations. The coding structure of the model is based on an object-oriented approach with message passing for achieving parallelization. We have performed several planetary boundary layer simulations on LLNL's ASCI computers for up to 40 million gridpoints. For flexibility, the model contains a number of different RANS (Reynolds Averaged Navier-Stokes) turbulence closures; a K-theory model, buoyancy-extended k-epsilon, an advanced nonlinear eddy viscosity model, and a Large-Eddy Simulation (LES) model. The model also contains a number of physics submodels for simulating flow and dispersion within urban areas (Lee, et al., 2001)

3. MODEL RESULTS

As part of the pre-experiment planning activities, FEM3MP was initially used to simulate flows based on two release locations. Figure 1 shows the area of interest in downtown Oklahoma City. This preliminary calculation was performed within a 1 km x 1km domain at variable grid resolution. The initial plan was to initiate releases at two potential locations, near the intersections of Broadway and Sheridan, and Robinson and Sheridan. The red dots in fig. 1 depict the locations of the proposed concentration sensors and S1 and S2 are the source locations. The modeled buildings, with those buildings that exhibit low and narrow profiles filtered out, are shown in Fig. 2. The building database used in these initial calculations was relatively crude since each building was represented by a single averaged height. Thus buildings consisting of multiple structures with different heights were not delineated. Based on the climatological wind data for the summer months, the incoming mean wind was assumed to be from the south at 7 m/s.

Figure 3 shows the steady-state wind field and dispersion pattern for a unit continuous source at the intersection of Robinson and Sheridan (S1). It is noteworthy that the spread of the dispersion pattern is biased towards the east of the downtown area due to the denser distribution of buildings to the east relative to the location of the source. One of the important issues in the pre-planning exercises was to estimate the path of the plume and how to optimize the deployment of sensors. A schematic showing the potential location of sensors is depicted in fig. 1. Results from the CFD model for the concentration time histories are given in fig. 4. The results clearly suggest that the high concentrations are along the urban canyon directly downwind of the release. Also, the high concentration areas are probably caused by the confluence of the released material due to the channeling around the street canyons close to the source. Fig. 5 and 6 depict the resulting surface wind and concentration pattern for the release at S2 (intersection of Broadway and Sheridan). In this case the dispersion pattern is fairly symmetrical around the plume centerline.

Additional, more detailed, comparisons are currently being performed with a new set of building GIS data which was provided by the University of Oklahoma. The new building data exhibits multi-structures within buildings and provides a more accurate representation of the areas around the releases. The initial efforts will be focused on IOP 3 in which the mean wind is essentially from the South as for the pre-experiment simulations. The results of these studies will be reported at the conference.

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4. REFERENCES

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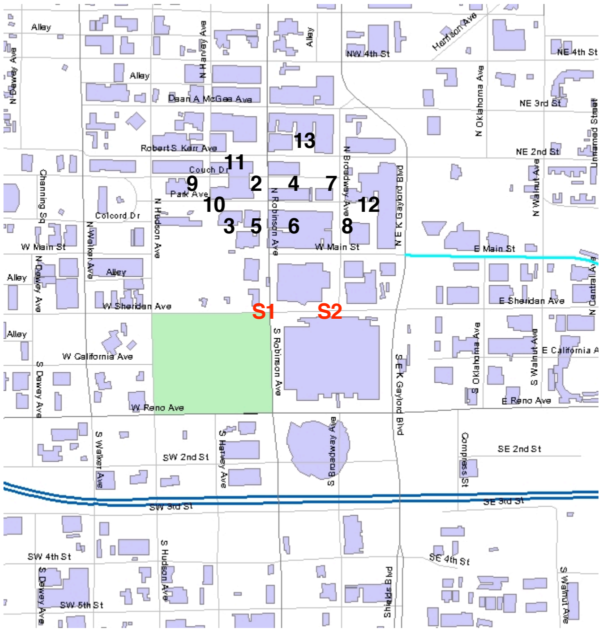

Fig.1: Building schematic of downtown Oklahoma City showing proposed source releases (S1, S2) and concentration sensor locations.

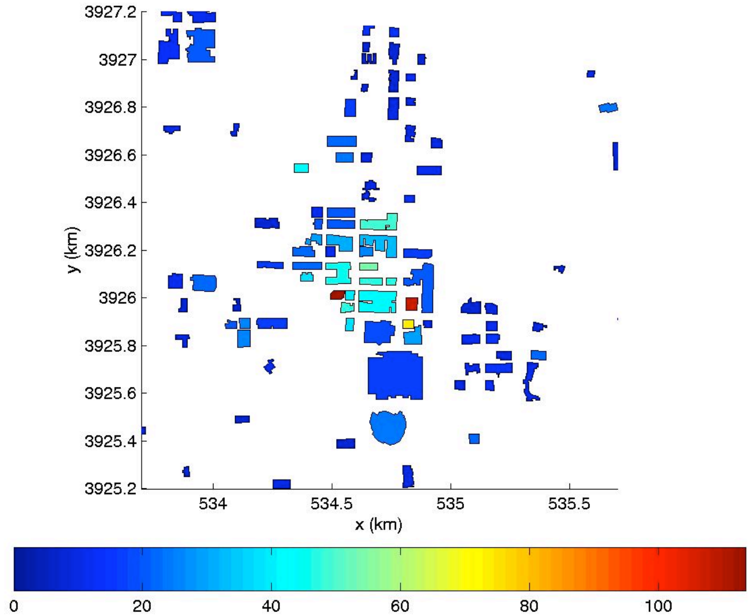

Fig.2: Modeled downtown area after filtering was performed on the building sizes. Color scale denotes building heights in meters.

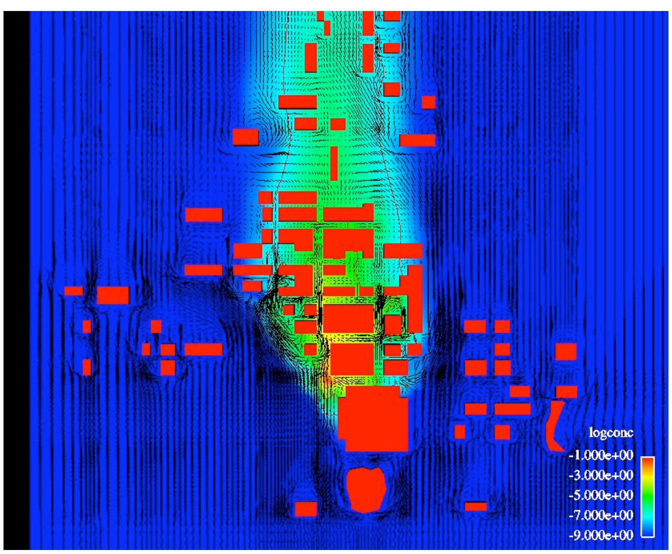

Fig.3: Surface wind vectors and steady state concentration pattern for release at S1.

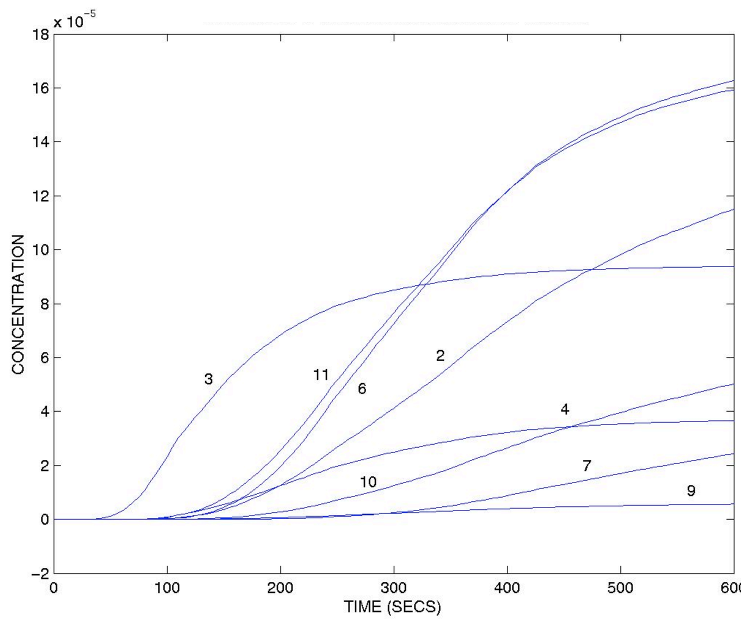

Fig.4: Surface concentration time histories from the S1 release at the various downwind locations

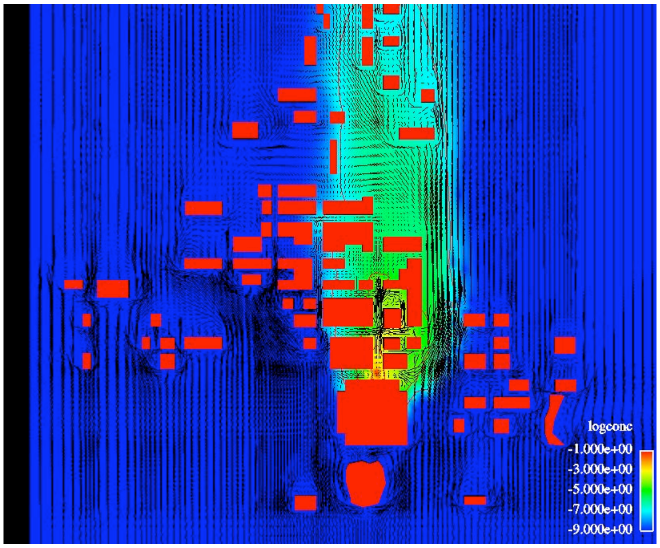

Fig.5: Surface wind vectors and steady state concentration pattern for release at S2

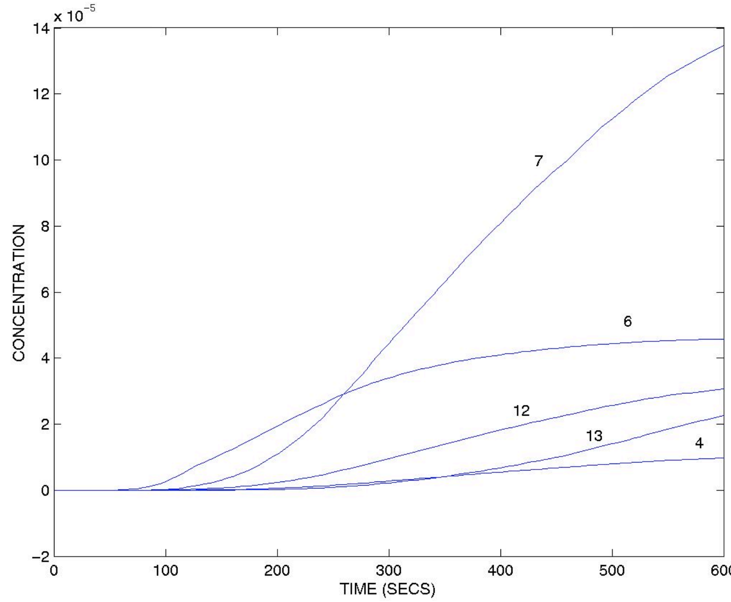

Fig.6: Surface concentration time histories from the S2 release at the various downwind locations