



MILAGRO Measurement Campaign over Mexico City Metropolitan Area

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About half of the world's population now lives in urban areas because of the opportunities for better jobs, access to city services, cultural and educational activities, and a desire for more stimulating human interaction. At the same time, many of these urban centers are expanding rapidly, leading to the growth of cities and megacities, which are defined as metropolitan areas with populations exceeding ten million inhabitants. Population growth and increasing industrialization have inevitably resulted in a higher demand for energy, greater use of fossil fuels, and more emission of pollutants into the atmosphere. As a result, air pollution has become not only one of the central environmental problems of the century, but also presents serious health consequences to people and economic costs to society.

The main pollutants emitted into the atmosphere in megacities are carbon dioxide, sulfur oxides, nitrogen oxides, carbon monoxide, volatile organic compounds, metal oxides, and atmospheric particles (aerosols) mostly consisting of soot or black carbon, sulfates, nitrates, and organic matter. Currently, the use of fossil fuels in transportation, the generation of electricity, and industrial processes represent the primary sources of pollutant emissions. Once released into the atmosphere, pollutant gases and aerosols are mixed into and transported throughout the atmosphere without regard to geopolitical frontiers, until they are removed by physical and chemical processes. In many cases, the pollutants can undergo chemical and physical transformations that are driven by sunlight leading to the formation of oxidants and secondary aerosol species. The length of time that the pollutants remain in the atmosphere and the meteorology determine the range of their impacts.

These exported primary pollutants and their reaction products have the potential to

affect human health and ecosystems on large geographic scales, and additionally can affect atmospheric visibility, weather systems and precipitation, and global climate. The geographic re-distribution of pollutants, the evolution of their chemical, physical, and optical properties, and the mechanisms for their eventual removal from the atmosphere are very complex and obviously important, yet only partly understood at the present time.

MILAGRO (Megacity Initiative: Local and Global Research Observations) is the first international effort to study the impact of a megacity on air quality. The Mexico City Metropolitan Area (MCMA) - the second largest megacity in the world - was selected as the initial case study for MILAGRO. Previous research on air pollution associated with the MCMA provided a framework for planning of future field studies, particularly the MCMA-2003 Campaign. Specifically, it showed that the atmosphere of the MCMA contains high level of aerosols and is extremely active photochemically; it is ideally suited for understanding the atmospheric chemistry of tropical megacities.

More than 150 institutions from Mexico, United States and Europe participated, and over 450 investigators and technicians from 30 different nationalities participated in the MILAGRO campaign in March 2006, organized under four components:

(1) MCMA-2006 (México City Metropolitan Area - 2006) - examine emissions and boundary layer concentrations within México City, the exposure patterns and effects on human health and the evaluation and design of policies intended to reduce pollutant levels. (2) MAX-Mex (Megacity Aerosol Experiment in México City) - examine the properties and evolution of aerosols and gas-aerosol interactions in the immediate urban outflow. (3) MIRAGE (Megacity Impacts on Regional and Global Environments) - examine the evolution of the México City plume on larger regional scales. (4) INTEX-B (Intercontinental Chemical Transport Experiment - Phase B) - study the evolution and transport of pollution on global scales.

The scientific protocol consisted of a month-long series of carefully coordinated observations of the chemistry and physics of the atmosphere in and near México City, using a wide range of instruments at ground sites, on aircraft and satellites, complemented by meteorological forecasting and numerical simulations. Together, these research observations provide the most comprehensive characterization of México City's urban and regional air pollution.

The MILAGRO participants worked side-by-side to collect the data during the observational phase in March 2006, and will continue to collaborate over the next several years to interpret the results. Additionally, MILAGRO has created a vigorous educational program with the participation of many students from universities in México and other countries, and by organizing lecture series, tours, and exhibits for the gen-

eral public. This talk will describe the driving forces behind the formation and growth of megacities, impacts of emissions and the ambient concentration of pollutants on the health of the populations, visibility, ecosystems, climate change, and global pollutant transport. The comprehensive measurements that took place during the MILAGRO Campaign and some preliminary results as well as some anticipated results will be presented. The impact of new science on the megacity air pollution problem would be brought in with regard to potential improvements in monitoring, in the use of air quality models to make predictions of the consequences of emission sources, to enable better strategies to reduce emission, and to improve control strategy evaluation. In conclusion, megacities present a major challenge for the global environment. Air pollution has serious impacts on public health, causes urban and regional haze, and has the potential to contribute significantly to climate change. Air pollution science has progressed steadily in recent decades due to improvements in the ability to measure pollutants, precursors, and reactive intermediates. This information has facilitated the development of improved computer models of the complex photochemistry that forms O₃, other oxidants, and secondary PM. These scientific advances motivate further research to gain a better understanding of how air pollution is formed in megacities and how best to control it. Field measurement campaigns such as MILAGRO focused on the characterization of the outflow of air pollutants from megacities will provide insights on their regional and global impacts.