Development of a NYC Meteorological Network with Emphasis on Vertical Wind Profiles in Support of Meteorological and Dispersion Models

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A permanent New York City (NYC) meteorological network (NYC MetNet) is being established with some of the equipment used in the Urban Dispersion Program[1] (UDP) along with a variety of ancillary instrumentation. The UDP, originally led by Pacific Northwest National Labs, with strong support from Brookhaven National Labs, was a multi-year program that began during early 2004. More than 25 organizations and as many as 250 people participated in the UDP. Participants ranged from national laboratories and agencies, universities, and private industry to, a host of NYC agencies. The program was aimed at investigating air flow and atmospheric dispersion through the heavily urbanized NYC borough of Manhattan and exploring the performance of a variety of air dispersion modeling strategies at both street level and urban level. Two field campaigns in March 2005 (MSG05) and August 2005 (MID05) involved the release and the dispersion monitoring of tracer gases. Some key meteorological instruments were used in and around Manhattan to provide wind, temperature, pressure, humidity and rainfall rate measurements. The usefulness of these measurements in assessing emergency management capabilities were sufficient to begin the task of obtaining continuous measurements and thereby begin to establish NYC MetNet. The recent deployment of a radar wind profiler (RWP) to provide a profile of winds routinely up to 2.5 km, and the development of a Doppler lidar for simultaneous aerosol and wind measurements will enhance the network.

The equipment transferred from the UDP include two building-top weather stations in midtown Manhattan, two building top sonic detection and ranging (SODAR) instruments for measuring winds to ~200 m above the building in 10 m steps, and one radar wind profiler (LSC) for measuring winds to ~2,500 m above the building in 60 m steps. The installations of the equipment has been hardened and the data is being integrated with a host of existing equipment, including two direct detection Lidars, a Ceilometer, a 3 Wavelength Nephelometer, PM samplers, a direct broadcast satellite receiving station for NASA's MODIS (TERRA and AQUA satellites) and GOES-12 imager data, a CIMEL radiometer and linkage to a network of other radiometers and lidars. At even a larger scale of integration, partnerships with neighboring universities are being pursued for the development of an urban ocean and atmospheric observatory.

Besides using the wind profiles to characterize dispersion for hazard management purposes, a combination radar profilers and lidar-aerosol wind profilers can benefit a variety of meteorological applications. Providing measurements relating to the vertical structure of the atmosphere is a key aspect to this network of instruments. This information is very important to understand some of the complex meteorological dynamics in a heavily urbanized environment. The lidars, SODAR and the radar wind profilers provide this valuable vertical structure information.

Convective mixing height has been a relevant parameter for climate, urban heat island and conventional dispersion models studies, and becomes even more important in advanced models where the intensity of turbulence under convective conditions is assumed to be strongly related to boundary layer (BL) height. Mixing layer depth (Planetary Boundary Layer (PBL) height) determines the vertical extent of the volume into which pollutants disperse. Models have difficulty getting mixed layer height correct and hence can lead to very large errors in the concentrations of fine particulate matter that are known to cause health issues (particulate matter standard with 2.5 microns (PM2.5)).

Ground based lidar backscatter intensity provides fine resolution of time-height data that is very useful in revealing the daily cycle of convective boundary layer (CBL) growth and collapse[2]. As an illustration of this, figure 1(a) plots the CCNY lidar backscatter measurements. In particular, we observe two distinct aerosol layers during the morning PBL. Both layers merged at approximately 13:00 and separated in the late afternoon. When the CCNY lidar PBL height measurements are overlaid onto Congestion Mitigation and Air Quality Modeling System (CMAQ) predicted PBL height (black) values, we see that the CMAQ model is tracking only the lower branch of the PBL curve and is not taking into account the persistent PBL fragments which have not dissipated from the night before. Therefore, CMAQ underestimates the PBL height in comparison to the lidar measurements, which leads to a diurnal overestimation of the PM2.5 mass concentration as observed in simultaneous TEOM-CMAQ measurements (Fig. 1b). The dip in the PBL curve which is attributed to a sea breeze effect (based on near surface temperature readings) is not resolved by the CMAQ modeling.

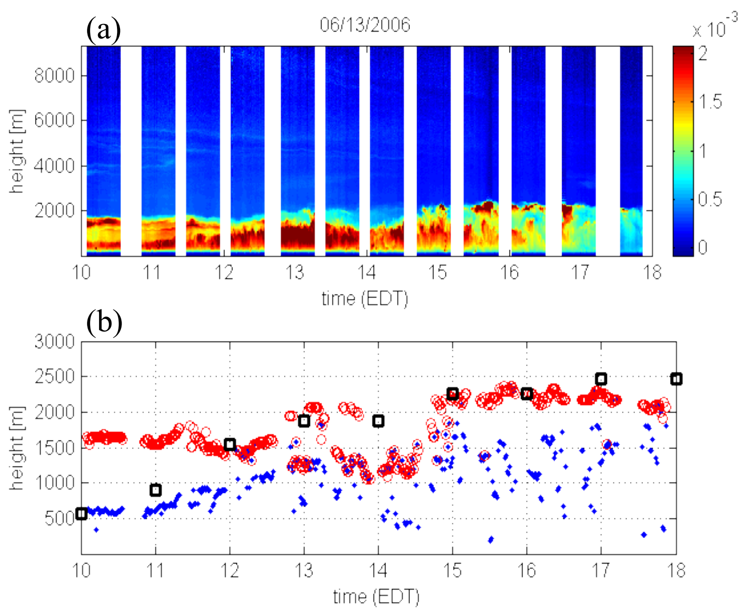

Fig.1 (a) Lidar backscatter image of June 13, 2006 at CCNY; (b) Temporal development of the boundary structure derived from lidar backscatter data and PBL heights predicted by CMAQ model (black).

The SODAR, mounted on a midtown high rise is shown in figure 2a. The RWP mounted on the roof of the Liberty Science Center (Jersey City, NJ) is shown in figure 2b. SODAR profilers as well as radar wind profilers can be very useful for obtaining BL information. Turbulence in the outer SODAR Boundary Layer (SBL) often is intermittent and patchy, making it very difficult to measure the height up to which turbulence extends. The other problem is that the backscatter intensity, on which mixing height estimation from SODAR data in the SBL usually relies, depends not only on turbulent fluctuations of the refractive index but also on its mean gradient. In this case, the mixing height determined from the SODAR output maybe the top of the stable layer which has developed due to radiative cooling rather than the top of the mixing layer. With two closely located yet spatially distinct SODARs in the network, an additional verification of BL height is possible. Regarding obtaining BL information from the single RWP in NYC MetNet, spectral measurements of velocity as well as signal to noise ratios would be useful and it would be beneficial to have a nearby profiler to which we can compare both our measurements. A profiler, located 27 miles southwest of midtown Manhattan in New Brunswick, NJ, has been in operation for decades. This profiler is operated by the Rutgers University Department of Environmental Sciences (c/o Bob Porcja and Barbara Turpin) and the New Jersey Department of Environmental Protection (c/o Charles Pietarinen). As an initial comparison of the performance from these two profilers, figure 3 shows quiver plots of the wind vectors. Note that the directions of the arrows indicate the horizontal wind direction where north is the direction out of the page, east is to the right, west is to the left and south is into the page. Although these figures indicate there is similar behavior, it is the differences in these profiles that will provide important information regarding urban heat island effects and boundary layer heights.


Fig.2a SODAR mounted on a NYC high rise


Fig. 2b RWP mounted on the Liberty Science Center

Comparing two wind profilers October 11th 2008

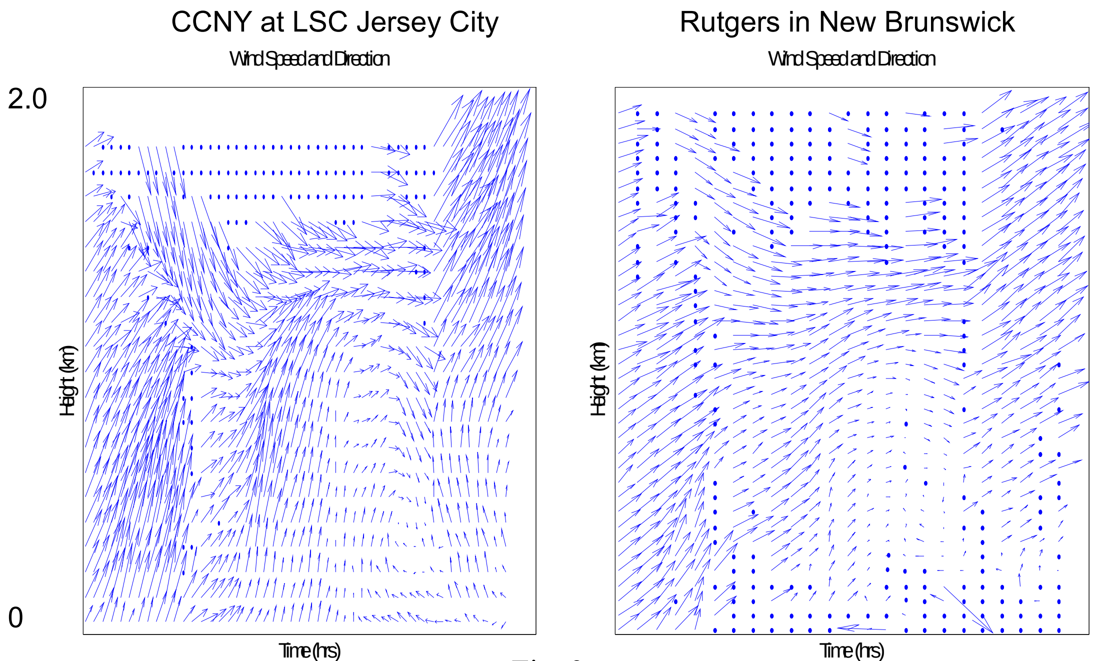

Fig. 3

The presentation will provide an update on installation upgrades and operations of the NYC MetNet. Besides providing an important service to the New York City metropolitan area by supplying useful and timely air transport information, the network may act as a test bed for advanced studies of the dispersion of air particles under complex conditions with applications ranging from social concerns to military operations and government planning. To enhance the network's reach and performance, we have made a number of upgrades and preliminary tests for new installations.

Acknowledgement

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[1] K.J. Allwine, K.L. Clawson, J.E. Flaherty, J.H. Heiser, R.P. Hosker, M.J. Leach, and L.W. Stockham, “URBAN DISPERSION PROGRAM: URBAN MEASUREMENTS APPLIED TO EMERGENCY RESPONSE” Seventh Symposium on the Urban Environment 10-13 September 2007 San Diego, CA

[2] J.Y. Ku, C. Hogrefe, G. Sistla, S.Chaw, L. Charles, B. Gross “Use of lidar backscatter to determine the CBL heights in New York City, NY” 5th Annual CMAS Conference, October 16-18, 2006 Chapel Hill, NC