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J5.7 USING THE ABLE FACILITY TO OBSERVE URBANIZATION EFFECTS ON PLANETARY BOUNDARY LAYER PROCESSES

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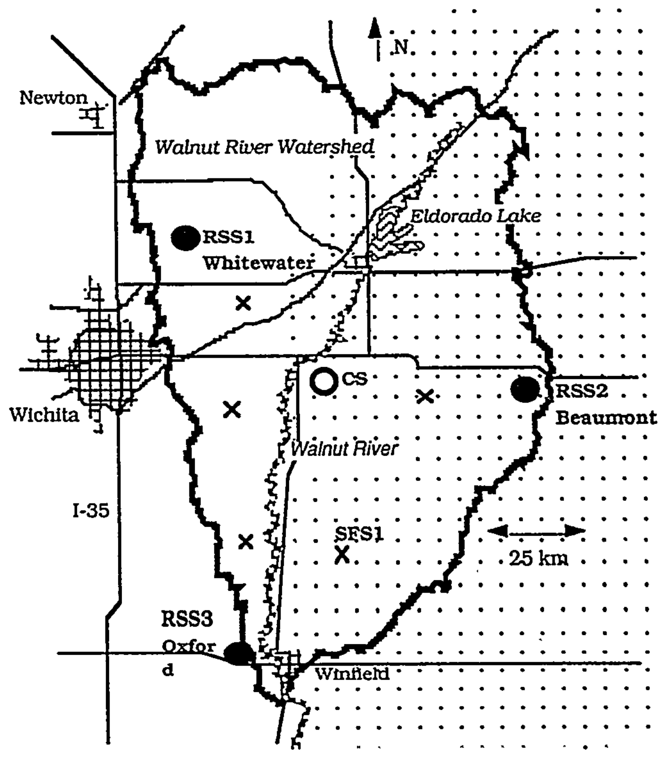
1. INTRODUCTION

The Argonne Boundary Layer Experiments (ABLE) facility, located in south central Kansas, east of Wichita, is devoted primarily to investigations of and within the planetary boundary layer (PBL), including the dynamics of the mixed layer during both day and night; effects of varying land use and landform; the interactive role of precipitation, runoff, and soil moisture; storm development; and energy budgets on scales of 10 to 100 km. With an expected lifetime of 10-15 years, the facility is well situated to observe the effects of gradual urbanization on PBL dynamics and structure as the Wichita urban area expands to the east and several small municipalities located within the study area expand. Combining the continuous measurements of ABLE with (1) ancillary continuous measurements of, for example, the Atmospheric Radiation Measurement (ARM) Program (Stokes and Schwarz, 1994), and the Global Energy Water cycle Experiment (GEWEX) (Kinster and Shukla, 1990) programs and with (2) shorter, more intensive studies within ABLE, such as the Cooperative Atmosphere-Surface Exchange Studies (CASES) Program, allows hypothesized features of urbanization, including heat island effects, precipitation enhancement, and modification of the surface energy budget partitioning, to be studied.

2. SITE DESCRIPTION

The ABLE site, located in Butler, Sedgewick, and Cowley Counties, lies within the northeastern quadrant of the ARM southern great plains Cloud and Radiation Testbed (CART) site (Fig. 1). The ABLE site covers an area approximately 80 km X 80 km, encompassing the lower half of the Walnut River watershed. The western edge of ABLE lies less than 10 km east of the eastern city limits of Wichita and includes the fringes of the Wichita urban area. The present configuration includes three remote sensing sites (RSS) located at the boundaries of the study area, a single surface flux site (SFS) located in the southeastern portion of ABLE above grassland, and a central site (CS), all of which have come into operation since July 1996. At least one additional SFS will be installed in 1998 above cropland, with an eventual total of five planned above varyious surface types.



CS: central site
RSS: remote sensing site
SFS: surface flux site

Figure 1. Map of the ABLE site. Hatched area to the east denotes rangeland or grassland. The remaining area is primarily cropland. The X's without labels are surface flux sites that have not yet been installed.

Each RSS includes a radar wind profiler (RWP) with radio acoustic sounding system

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(RASS) and a minisodar (MS) (Coulter and Martin, 1986) to provide complete wind profiles from 10 m to 4 km or more above the surface and virtual temperature profiles from 100 to 2500 m above the surface. Also included at each RSS is an automatic seather station (AWS) consisting of an instrumented 10-m tower to measure winds, temperatures, vapor pressure, and precipitation. Instrumentation at the RSSes and SFSes is summarized in Table 1. Locations of the sites are shown in Table 2.

The SFS consists of an AWS and eddy correlation instrumentation to measure the fluxes of temperature (sensible heat, H), moisture (latent heat, LE), momentum (u*), and carbon dioxide (F_{CO_2}). The EC instruments are mounted above a 2mtall mast to allow for flux measurements from any wind direction; thus, the requirements for an adequate SFS are often quite difficult to fulfill, particularly over cropland. The first SFS was located over grassland, which predominates in the eastern half of the region; the next SFS will be placed above cropland.

Table 1. ABLE instruments, their sites, measurement heights, and parameters measured.

System	Sites	Measurement heights(m)	Parameters measured[a]
RWP	RSS1, 2, 3	100-4000 every 60	s, d, snr, T_v
MS	RSS1, 2, 3	10-200 every 5	s, d, snr
AWS[b]	RSS1, 2,3		s, d, e, P
	SFS1	10	
	CS		
EC[b]	SFS1	2.5	H, LE, u*, s, d, F_{CO_2}

[a] Parameters measured and not defined in the text include wind speed (s), wind direction (d), virtual temperature (Tv), vapor pressure (e), pressure (P), and signal-to-noise ratio (snr)

[b] weather stations and eddy correlatoion stations will also be located at future flux sites.

Table 2. site locations and instruments

Site	Lat (deg)	Lon (deg)	Height (m ASL)	Instrument systems
RSS1	37.850	97.187	420	RWP, MS, AWS
RSS2	37.627	96.538	478	RWP, MS, AWS
RSS3	37.273	97.095	360	RWP, MS, AWS
SFS1	37.521	96.855	408	EC, AWS
CS	37.626	96.882	400	AWS

A network of 45 rain gauges was installed by Oregon State in the northwest quadrant of the ABLE area, in the Towanda river basin University during the first intensive measurement period of CASES in April-May, 1997. The rain gauge network will remain in place for long-term studies and is being augmented with a soil moisture measurement system that samples soil moisture profiles by using time-delay refractometers at 16 locations within a 100 m X 100 m area.

Data from each of the sites (not including the rain gauge network) are collected by data link every hour at the CS near Augusta, Kansas (Fig. 1). The CS will also be the location of a rawindsonde system, a ceilometer, and an AWS, to be installed in the next year. The CS will also contain prepared locations (power, computer hookups, etc.) for additional instruments brought to the site by researchers, either for comparison with site measurements or to complement the array of instruments already present.

The data are immediately displayed for quality control upon arrival at the CS. Next, the data are compressed and simultaneously sent to Argonne National Laboratory, where they are processed and placed on the Internet, available for public inspection and retrieval by interested users within two hours of the time of measurement.

3. Urban Influences

The Wichita metropolitan area is expected to expand eastward during the next decade; thus, it could have a noticeable effect on the dynamics and structure of the PBL, particularly in the northwestern portion of ABLE.

3.1 Urban Heat Island

Increased temperatures, particularly during nighttime, are a well-known result of metropolitan development. The ratio of artificial to natural surfaces increases, reducing the available soil moisture; in addition, many of the artificial surfaces are vertical structures that tend to absorb infrared radiation from neighboring structures. A long-term trend in the difference between maximum and minimum temperatures in the western portion of the ABLE site might result from the influences of a urbanization. Such a trend might have a bearing on the recent observation that much of the increase in measured temperatures over the Earth's surface arises from increases in minimum temperatures during nighttime, because some of the measurement sites were once rural and have become less so.

3.2 Precipitation

Because Wichita is often upwind of the northern part of the ABLE site, urban modification of precipitation patterns might already be taking place over portions of ABLE . The placement of the dense rain gauge network is well suited for monitoring changes in such effects as the metropolitan area expands. Storm development could be affected; thus, the coverage by several next generation radar (NEXRAD) facilities over the area can be most useful in these determinations.

3.3 Runoff

Increased runoff would be an expected result of urban expansion in this region, as the areal extent of soil and vegetated surfaces decreases This result might have effects on the water table, on runoff in the urbanized subbasins, and even in the entire basin of the Walnut River watershed, which encompasses the ABLE site. Hydrologic studies as part of the CASES effort could examine changes in runoff amounts as Wichita expands eastward.

3.4 Mixed-layer height

Increases in the height of the mixed layer over urban areas are well known: less evaporation over artificial surfaces leads to dryer air (Chandler, 1967; Sisterson and Dirks, 1978) and increased sensible heat flux, which in turn is the principal driving force in the growth of the mixed layer during daytime (Boers et al., 1984). The increased heat flux causes more entrainment of dry air above the mixed layer in a positive feedback to mixed-layer growth (Spangler and Dirks, 1974). The degree to which these processes affect the growth of the mixed layer downwind of Wichita is already a study of interest to ABLE. As the metropolitan region grows, the changes in downwind effects on mixed layer height should be detectable.

The nighttime boundary layer should also be affected. Increased surface temperatures would tend to decrease the stability of the layer; however, warm advection from Wichita above a shallow local surface layer might tend to increase the stabilitiy. The depth of the nocturnal boundary layer affects the development of the nocturnal jet: the height of the jet maximum is often located near the top of the surface based temperature inversion (Blackadar, 1959). In the Plains region, the nocturnal jet is frequently very strong and well established, particularly with south or southwest synoptic flow, when it is often associated with the rapid transport of moisture from the Gulf of Mexico to the northern Plains which can initiate thunderstorms. Nocturnal wind maxima are not limited to southerly wind directions; they can develop with winds from any direction (Lettau, 1979; Sisterson et al., 1983)

The effects listed above will not be immediately obvious from data on a daily basis. Serious, detailed analyses will be required to adequately understand the effects of urban areas on the PBL. Additional instruments supplied for short- or long-term studies by government and university scientists will be useful for understanding these long-term effects.

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