Our fundamental understanding of the boundary layer comes from measurements. Most measurements are made in the field, some are made in laboratory tank or wind tunnel simulations, and some are samples from numerical simulations. Theories and parameterizations, such as presented in earlier chapters, are valuable only if they describe the observed boundary layer behavior.

In this chapter we will outline the measurement categories, systems, field experiments, and techniques that are available to acquire a variety boundary layer data. Details of instrument design and operation will not be covered here, but they can be found in other references (see review by Lenschow, 1986).

10.1 Sensor and Measurement Categories

To make boundary layer measurements, we need three components: (1) a detector or sensor, (2) an encoder or digitizer, and (3) a data logger. Most detectors are devices for which the physical characteristics (size, resistance, etc) change as a function of the variable being measured. Thus, virtually all detectors are analog in nature, providing a continuously varying output as a function of continuously varying meteorological conditions. This output signal must then be sampled to produce a discrete digital record, using some sort of encoder or analog-to-digital converter. The resulting discrete series of data must be recorded, often on magnetic tape, magnetic disks, or optical disks. Instrument system or instrument package is the name given to the set of all three components listed above.

Additional components are also required: (4) an instrument platform, (5) a means of calibration, and (6) display devices. Platforms such as a tower or aircraft are
complex and expensive in their own right, and can often hold or carry many instrument systems. Power supplies, cooling, sheltering or shielding, and accommodations for humans are sometimes part of the platform. Calibration against known standards either should be performed periodically during the measuring program, or should be accomplished continuously as an intrinsic function of the sensor or instrument package. Uncalibrated data is worthless data. Finally, the measured values should be displayed on printers, plotters, or video displays in order to confirm the operation of the instrument. Display can be real time showing the raw or digitized values, pseudo-real-time (within 5 to 30 minutes) showing summary tables and average statistics, or daily post-processing. It would be embarrassing to perform a long field experiment only to discover in the post experiment analysis phase that all the data is bad, missing, improperly recorded or uncalibrated.

Boundary layer data are split into two categories: those obtained from **mean value** sensors, and those from **fast-response** sensors. Fast-response sensors are used for measuring the turbulent fluctuations, from which we directly calculate turbulence kinetic energies, fluxes, and higher moments. These instruments are often complex, delicate and expensive. In the surface layer, turbulent eddies are relatively small and short lived, requiring sensors that have faster responses than ones used to measure eddies in the middle or top of the convective boundary layer. At nighttime, turbulence is sometimes weaker, requiring sensitive sensors that have a good **signal-to-noise ratio**.

Fast-response instruments are also generally more costly to maintain, and require more expensive data logging equipment. The sensors are often small and delicate in order to achieve the fast response, and are thus vulnerable to damage by insects, precipitation, and mishandling. Either protective shrouds are needed, or replacements must be available. Since virtually all modern data logging is digital, the fast response signals are digitized at rates of once per second up to 50 or 100 times per second, resulting in data sets of thousands to hundreds of thousands of values for just a 20-minute record. The data logger must be able to ingest data at these high rates, and be able to store the large volume of data that accumulates.

If only mean values are required, then less-expensive, slower-response, more-durable instruments can be used. Based on profiles of mean variables, we can often indirectly calculate turbulence energies and fluxes. Most field experiments involve a mixture of mean and fast-response sensors, depending on the budget and the goals. Many of the fast-response sensors can also be used to find mean values, but not all.

**Direct sensors** are ones that are placed on some instrument platform to make **in-situ** measurements of the air at the location of the sensor. **Remote sensors** measure waves that are generated by, or modified by, the atmosphere at locations distant from the sensor. These waves propagate from the generation or modification point back to the sensor. **Active remote sensors** generate their own waves (sound, light, microwave), and have transmitter and receiver components. **Passive remote sensors** have only receiver components, and measure waves generated by the earth (infrared, microwave), the atmosphere (infrared), or the sun (visible).