Technology Infusion for Atmospheric Boundary Layer Research: Observations and Experiments on Multi-scale Turbulence Phenomena

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Turbulence remains a key issue in atmospheric boundary layer (ABL) studies, given that most of the energy of ABL is pipelined into and dissipated through small-scale turbulence. While fluid dynamicists are still grappling with theoretical solutions of classical isotropic turbulence or simple canonical turbulent flows (not to mention the efficacy of Kolmogorov spectrum!), geophysicists are faced with the daunting task of parameterizing turbulence that carry heat, momentum and scalars in grid boxes of numerical models. Turbulent energy therein is not only cascading down the scales, but is also directly contributed by turbulence generated at sub-grid scales. This is particularly important near the ground where shear and buoyancy generated turbulence are vital and turbulence scales are relatively small. In light of outstanding theoretical difficulties, atmospheric observations and innovative controlled experiments play a crucial role in advancing our understanding of geophysical turbulence, and thus progress in measurement technologies, both in field and laboratory situations, is imperative for expanding the frontiers of turbulence research.

This presentation deals with a review of important ABL processes, their role in the production of and subsequent interactions with small-scale turbulence over various phases of the diurnal cycle, and the effects of complex topography, man-made elements and radiation inhomogeneities. Because of the high Reynolds numbers involved, ABL is also a platform for investigating fundamental concepts of turbulence as well as for eliciting of new flow phenomena. At the heart of such investigations is the versatile and state-of-the art instrumentation that can delve into processes of different scales and scale interactions. While leveraging or borrowing of existing technologies for ABL research can spark rapid progress, the importance of unique measurement concepts that allow probing into ABL over wide ranges of space-time scales cannot be overemphasized. Advances in Information Technology have also enabled the development of cyberinfrastructured test beds wherein a suite of instrumentation, models and high performance computing platforms can be melded to facilitate unprecedented information on ABL down to fine detail. Such platforms allow data collection from heterogeneous sensors, efficient transmission and storage of massive data sets, real-time event identification via data mining and aggregation, quality control, community access of data and even collaborative research.