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A Compact Ceilometer for Boundary Layer Height and Ceiling Retrievals for the Ameriflux Network

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The advent of sensor networks to gather atmospheric data for weather and climate forecasting on large spatial and temporal scales is crucial to the advancement of our understanding of many important processes that make up such predictive models. A prime example is the height of the atmospheric boundary layer (ABL). This is an important variable as it is used to parameterize boundary layer transport in numerical weather prediction models and boundary layer effects related to fluxes and concentrations of both trace gases and aerosols in inversion models. Increased knowledge of the boundary layer structure and the diurnal evolution of its height is the goal of recent activity in Europe to establish networks of aerosol profiling lidars and ceilometers to monitor boundary layer height, as well as other parameters. The value of these networks has led to the desire to add aerosol profiling ceilometers to the AmeriFlux network, especially to aid in regional flux monitoring efforts. Given that AmeriFlux sites utilize instrumented towers, whose automated sensors are exposed to the full range of weather and must operate often with limited electrical power, a new class of laser ceilometer is needed to add boundary layer height measurement capability to the AmeriFlux network.

The height of the ABL is used as a scale length in a variety of weather and climate models to predict vertical diffusion, turbulent mixing, convective transport, and even cloud formation at the top of the ABL. Despite its value, the ABL height is not well simulated in various global climate, regional air quality, and weather forecast models. Increasing the routine spatial and temporal measurement of the ABL and cloud base heights by adding ceilometers to the Ameriflux network would provide the data needed to advance understanding of the important transport and cloud formation processes in the ABL. Such a data input would help advance the capabilities of ABL models used in weather forecasting and climate prediction. Specifically it would aid in the refinement and development of regional CO_2 flux estimates.

We are developing an ultra-compact laser ceilometer for retrievals of both ABL height and cloud base height that is compatible with the demands imposed by the wide environmental conditions experienced by, and automated operation required of, site instrumentation throughout the AmeriFlux network. For deployment at an AmeriFlux tower site, substantial reductions in size, weight, and power are needed. Compact size, a high degree of ruggedization, and thermal management with a very small available power budget are similar to design restrictions placed on aircraft and spacecraft payloads. Our design for a compact ceilometer considers thermo-mechanical stability and thermal management in the entire environmental envelope as the foundation for the sensor design. Our design approach to a laser ceilometer utilizes a fiber laser operating at a wavelength of 1.55μm. A fiberized transmit and receive optical train has advantages over a free space train with respect to alignment stability under varying environmental conditions. It also has advantages with respect to the size, weight and power of the sensor and enables field replacement of crucial components without disturbing critical alignment. Operation at 1.55 μm has significant benefit for eye safe operation. The design fuses very compact fiber lasers, electronics fabrication techniques, and state-of-the-art thermal management techniques to develop a new class of ceilometer that will have the reduced size, weight, and power, as well as environmental stability, for routine, automated operation at AmeriFlux network sites.

We will review the elements of the design, including the coupled thermal, mechanical and optical modeling. We will review plans for system characterization, including accelerated thermal testing. Several engineering prototypes will undergo extensive demonstration at several AmeriFlux sites with site principal investigators.