Acoustic Tomography Techniques for Observing Atmospheric Turbulence

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Like ultrasonic anemometer-thermometers in widespread usage today, acoustic tomography uses travel-time observations between different source/receiver pairs to determine wind velocity and temperature. The fundamental distinction is that tomography regards the wind and temperature fields as varying in space, rather than constant values at a “point”. The travel-time data are used to constrain an inverse reconstruction of the fields through which the signal have propagated. To date, all operational tomography arrays for the atmosphere have been designed to image surface-layer turbulence. Transducer heights a few meters above the ground, 20-100 propagation paths, signal frequencies in the range 100-1000 Hz, and horizontal dimensions of about 100 m are typical. These design characteristics are driven by instrumentation constraints as well as the desire to model the acoustic propagation with straight, geometric rays. The path-averaging inherent to the acoustic travel-time observations emphasizes large-scale structure in the flow, which may be advantageous in applications such as (1) imaging the four-dimensional velocity and temperature fields of near-ground turbulence and gravity, (2) efficient validation of large-eddy simulation closure models, and (3) improvement of passive localization of sound sources by compensating for atmospheric refraction. Different inverse algorithms for reconstruction of temperature and velocity fields are discussed, including stochastic inversion (SI) and a recently developed time-dependent stochastic inversion (TDSI). Issues in the inversion formulation, such as incorporation of *a priori* assumptions regarding the correlation function of the turbulence, are discussed. We demonstrate TDSI by reconstructing temperature and wind velocity fields from acoustic tomography experiments carried out at the University of Leipzig, Germany. A new, 3D tomography array has been constructed Boulder Atmospheric Observatory and became operational in March 2008. Some preliminary results are given. Acoustic tomography may be considered as part of a general trend in atmospheric observations toward data assimilation and inverse reconstructions based on large quantities of disparate sensor data.