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Novel Non-Contact Integrated Air Thermometer Hygrometer Anemometer with Rapid Response

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Accurate, fast and simultaneous air temperature and humidity measurements in the atmospheric boundary layer are of critical importance to understanding the exchange of energy and matter between the ecosystem and the atmosphere. The construction and the design rationale of a novel, integrated instrument, combining an acoustic thermometer, ultrasonic anemometer and an infrared gas analyzer, capable of rapid, accurate in-situ temperature, humidity and 3D wind measurements are described. A 400kHz ultrasonic pulse is transmitted across a fixed 0.1 m path to determine speed of sound and a mid-infrared 2.7 micron optical beam passes through a co-located 0.16 m sensing path to simultaneously determine the water vapor density. The compact size and the spatial integration of the sensors offer many advantages. Speed of sound can be corrected for humidity effects in real time so that accurate air temperature can be computed at fast sample rates without the need for data post-processing. The air temperature measurements are further compensated for changes of acoustic path length due to cross-wind, so accuracy can be maintained under a wide span of wind conditions. The performance of the combined sensor is evaluated in a laboratory environmental chamber in a temperature range of -30 to +50 degrees C and humidity range between -60 to +40 degrees C dew point. Results show an accuracy of 0.3 degrees C and a resolution of 0.002 degrees C over the entire test range. Furthermore, a field inter-comparison with a temperature probes in an aspirated shield demonstrate good agreement for most conditions, but revealed errors in the temperature probe due to solar radiation and evaporative cooling. The immunity to solar radiation and the rapid response of the non-contact thermometer makes an ideal instrument for evaluation of the frequency response and the performance of aspirated resistance thermometers.