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Measurements of Evaporation From Open Water Using Scintillometry

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The use of scintillometers to determine sensible and latent heat flux is becoming increasingly common due to their ability to quantify convective fluxes over distances of hundreds of meters to several kilometers. The majority of investigations using scintillometry to determine energy fluxes have been above land surfaces but in this paper we consider determination of fluxes from a water body.

Rather than providing a direct estimate of sensible heat flux, scintillometry characterizes the turbulence intensity within the atmosphere by measuring the structure parameter of the refractive index ( ). It is then possible to use to determine the sensible heat flux using Monin-Obukhov Similarity Theory (MOST), site specific meteorological measurements and the Bowen ratio. The Bowen ratio is the ratio of sensible to latent heat flux and is used in scintillometry calculation procedures to correct for the effect of humidity on scintillations, thereby enabling calculation of the structure parameter of temperature ( ) which is central to determination of the sensible heat flux (Wesely, 1976).

A commonly used methodology for determining the Bowen ratio in scintillometry relies on balancing the energy budget by redistributing the available energy across fluxes of sensible and latent heat. This methodology, which is referred to as the 'Bowen ratio closure method', relies on accurate specification of net radiation and changes in heat storage. The changes in heat storage for a soil surface are relatively small, however, the changes in heat storage for a water body represent a much bigger component of the available energy and, therefore, present a large potential source of error in calculations. Variation in water temperature both spatially and with depth complicates estimation of water body heat storage. The problems in representing water body heat storage changes means that an alternative calculation procedure for the Bowen ratio is required if scintillometry is to be used for reliably estimating fluxes from open water.

In this paper we propose and test a new scintillometer calculation methodology which does not rely on measurements of water temperature or water body heat storage for determining the Bowen ratio. The concepts behind the approach were first put forward by Vercauteren et al. (2009) who estimated evaporation using measurements of sensible heat flux from an eddy covariance system, air temperature, humidity and wind speed. The approach is based around linearization of the Bowen ratio, which is a common assumption in models such as the Penman's model and its derivatives.

This methodology has been tested by comparison with eddy covariance measurements and through comparison with alternative scintillometer calculation approaches which are commonly used in the literature. Comparison of evaporation estimates from the eddy covariance system and the scintillometer showed excellent agreement across a range of weather conditions and flux rates, giving a high level of confidence in scintillometry derived evaporation rates. The proposed approach produced better estimates than other scintillometry calculation methods because it does not rely on measurements of water temperature or water body heat storage. The proposed methodology requires less instrumentation than alternative scintillometer calculation approaches and the spatial scale of required measurements are arguably more compatible. In addition to scintillometer measurements of the structure parameter of the refractive index of air, the only measurements required are atmospheric pressure, air temperature, humidity and wind speed at one height over the water body.

Vercauteren, N., Bou-Zeid, E., Huwald, H., Parlange, M.B., Brutsaert, W., 2009. Estimation of wet surface evaporation from sensible heat flux measurements. Water Resour. Res. 45.
Wesely, M.L., 1976. The Combined Effect of Temperature and Humidity Fluctuations on Refractive Index. J. Appl. Meteorol. 15(1) 43-49.