Errors in micro-meteorological estimates of reference crop evaporation due to advection

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Abstract

Micro-meteorological methods including the Bowen ratio, infrared thermometry, the Penman-Monteith equation and eddy correlation measurements were used to determine reference crop evaporation, Eo, under conditions of limited fetch. The accuracy of these methods was compared with lysimetrically measured values of Eo.

Advected heat flux density was determined from measurements of net radiation, soil heat flux density, the Bowen ratio and reference crop evaporation Eo.

It was shown that the experimental site was subject to advective influences brought about by limited fetch. A mean hourly advection of 301 $W \cdot m^{2}$ was obtained from 75 hourly sets of experimental data.

The index of agreement, SI, was used to determine the accuracy of estimates of Eo using micro-meteorological techniques under limited fetch conditions. The Penman-Monteith equation compared best with lysimeter observations, with an SI value of 0,95 when daylight values were considered. This is followed by SI values of 0,77; 0,88; 0,70 and 0,49 respectively for the Bowen ratio; the energy balance equation (EBE) and infrared thermometry; the EBE and sensible heat measurements and eddy correlation measurements.

Introduction

Accurate estimation of atmospheric evaporative demand, AED, is indispensable for crop-related evaporative studies. De Jager and Van Zyl (1989) formulated AED mathematically as:

$$AED = kcEo \qquad (1)$$

where:

kc = evaporation coefficient (dimensionless) composed of soil and plant components
Eo = evaporation from a reference crop (mm-h')

Reference crop evaporation, Eo, is defined by Doorenbos and Pruitt (1977) as the rate of total evaporation of an extended surface of an 80 mm to 150 mm tall grass cover of uniform height actively growing, completely shading the ground and not deficient of water or nutrient.

AED is defined as the water vapour transfer to the atmosphere required to sustain the energy balance of a given vegetative surface (crop), in its present growth stage, when the water status of its root zone permits unhindered plant evaporation and the water status of the top 150 mm of soil equals its current value (De Jager and Van Zyl, 1989).

It is clear from Eq. 1 that the accuracy of AED depends entirely upon the accuracy of the evaporation coefficient for the relevant crop growth stage and the value of Eo.

Numerous climatological methods of estimating Eo exist in the literature (Bowen, 1926; Thornthwaite and Holzman, 1939; Penman, 1948; Thornthwaite, 1948; Blaney and Criddle, 1950; Swinbank, 1951: Makkink, 1957; Slatyer and McLlroy, 1961; Jensen and Haise, 1963; Monteith, 1963, 1964; Van Bavel, 1966; Tanner, 1967; Priestley and Taylor, 1972; Caprio, 1974; Hargreaves, 1974; Idso et al., 1975; Idso et al., 1977; Linacre, 1977; Allen, 1986; Choudhury et al., 1986; Van Zyl and De Jager, 1987).

Perhaps the most fundamental methods of determining Eo are those derived directly from the surface energy balance equation, EBE, and the eddy correlation technique, EC.

Methods derived from the EBE relevant to this study are:

- EBE and Bowen ratio (Bowen, 1926)
- EBE and infrared thermometry, IRT (Choudhury et al., 1986)
- Penman-Monteith equation, PME (Thorn, 1975)
- EBE and sensible heat flux density, C (Thorn, 1975). C can be obtained from eddy correlation measurements.

In many applications in arid to semi-arid regions Eo is measured in a lysimeter over small grass-covered areas. The question therefore arises: how does advected energy influence the above-mentioned methods in such limited fetch situations. This formed the overall object of this investigation.

Specific objectives were to:

- determine the accuracy of Eo estimated using the Bowen ratio, IRT, PME, C, and EC by comparison with lysimeter observations; and
- determine advected heat flux density using surface energy balance, Bowen ratio and lysimeter observations.

Materials and methods

Method

It was decided to investigate the influence of advection upon micro-meteorological estimates of Eo under limited fetch conditions. The latter were produced by making measurements near the middel of a short grass-covered area, which was approximately 80 m x 80 m in size (see Fig. 1). Four of the micro-meteorological techniques examined involved modifications of the energy balance equation. These were derived using:

- the Bowen ratio;
- an infrared thermometer for determining sensible heat, IRT;
- a combination method (Penman-Monteith equation, PME); and
- a sonic anemometer and fine-wire-thermocouple for determining sensible heat flux, C.

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Received 15 November 1991; accepted in revisedform 2 July 1992.