Agricultural Water Management 130 (2013) 168–177

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Simulation of evaporation, coupled liquid water, water vapor and heat transport through the soil medium

S.A. Banimahd, Sh. Zand-Parsa*

Irrigation Department, Agricultural College, Shiraz University, Shiraz, Iran

ARTICLE INFO

Article history:
Received 17 September 2012
Accepted 23 August 2013
Available online 28 September 2013

Keywords:
Soil temperature
Soil water content
Water vapor
Simulation
Evaporation

ABSTRACT

In this research, the model of SWCT (soil water content and temperature) was developed for simulation of fluxes of soil water (liquid water and water vapor) and heat. The governing equations for water and heat fluxes were solved using numerical finite difference method. Soil water content and temperature were numerically solved using a fully explicit method. The measurement devices of temperature sensors and TDR probes (for measuring water content) were installed at soil depths of 0.05, 0.35, and 0.5 m, at the selected site. The novelty of this study was the simulation of actual evaporation from the soil surface using the Penman–Monteith's equation, in which the value of saturated air vapor pressure was substituted by actual soil vapor pressure at the surface layer. This novelty allowed estimation of the actual evaporation rate based on soil water content and temperature and meteorological data. Simulated water contents followed reasonably well the measured values at three soil depths during the simulation period. Soil water content and temperature were numerically simulated using the SWCT model with coupling liquid water, water vapor, and heat transport and provided reasonably good results with the values of RMSE less than 0.017 $cm^3\,cm^{-3}$ and 2.2 °C, respectively.

The sensitivity analysis of the simulated soil temperatures were accomplished by changing radiation, input data of air temperatures and initial soil temperatures by ±20% and ±10% of measured values and the maximum values of RMSE changed by 65.7%, 140.3% and 190.7%, respectively. The results showed that air temperature, solar radiation, and initial soil temperature must be measured or predicted with high accuracy in order to produce low error values.

1. Introduction

The arid or semiarid regions occupy more than half of the global land areas. Soil water content and temperature affect biological activities, seed germination and plant growth in surface soil layers. They also affect water and nutrition absorption and solute transport in soil. Furthermore, vapor concentration between liquid water around the soil particles and seeds is important for germination of seeds (Wuest et al., 1999). Scarcity of water resources in arid and semiarid regions is a great concern for human activities. Many researchers have reported that desertification has been increasing as a result of climate changes (such as global warming) and human activities (Verstraete and Schwartz, 1991; Puigdefabregas, 1995; Warren, 1996). Understanding the basis of heat and water fluxes between air and soil surface is important for monitoring heat fluxes, evaporation and transpiration. As a result, continuous monitoring of soil water content and soil temperature is very important in fields such as agronomy and hydrology, which are significantly improved by a good knowledge of soil water content and temperature.

Soil water and heat fluxes can be defined by measuring soil water content and temperature in different soil layers continuously. Current techniques for detecting both soil water content and temperature such as gamma attenuation, soil heat flux, time-domain reflectrometry (TDR) and ground penetration radar (GPR) are expensive and time consuming. An alternative to the laborious and expensive field measurements is to develop a model that simultaneously simulates water flow and heat transport in unsaturated soils, and quantifies soil water content and soil temperature dynamics, particularly in relation to mass and energy transfer near the soil surface. However, the drawbacks of simulation models are their requirements for measured/predicted parameters of atmosphere, water and soil variables. Also, it is needed to predict or measure initial and boundary variables related to soil, water and atmosphere.

Philip and de Vries (1957) provided a mathematical description of liquid water and vapor fluxes in soils under both pressure head of soil water (isothermal) and soil temperature (thermal) gradients. Their theory was used in the classical simulation models, developed as well as applied by many investigators (Nassar and Horton, 1997;

* Corresponding author. Tel.: +98 9173154861.
E-mail address: zandparsa@yahoo.com (Sh. Zand-Parsa).

0378-3774/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.agwat.2013.08.022