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Application note

An improved evaporation dome for forest environments

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ABSTRACT

We describe an improved 'evaporation dome' for measuring ground evaporation in forests. We reduced the size of the dome to ease transport through rugged terrain and replaced the data-logger, notebook computer and lead-acid battery with the hand-held data acquisition and analysis tool, the Vernier LabQuest. This evaporation dome is a significant improvement on previous instruments because of its light-weight, ease of transport and deployment and low power consumption. The Vernier LabQuest enables graphing of data in real time and allows the user to perform quality checks and to calculate evaporation rapidly in the field, eliminating the need for further processing of data in the laboratory. The LabQuest is light and rugged, is self-powered with a long-lasting battery, and has four voltage input channels and two digital input channels. The relative humidity and temperature sensor we used occupied two voltage channels but the spare channels on the LabQuest could be used to expand the range of measurements made with the evaporation dome to include global solar radiation and soil temperature. We also redesigned the ventilation system such that air was well mixed to ensure a good response time in the temperature and humidity sensor, but that the boundary layer of the evaporating surface received minimal disturbance. In addition to making ground evaporation measurements practical in forests, the improved dome should also find application in agriculture and rangelands, owing to the greatly reduced health and safety concerns of deploying larger, heavier instruments.

1. Introduction

The purpose of this study was to design a practical instrument for measuring evaporation from the forest floor, based on existing versions of 'evaporation domes' used in agricultural landscapes and rangelands. These instruments measure evaporation from bare soil and litter based on the rate of increase of vapour density in a closed volume of air. Several versions of evaporation dome have been designed in past decades (Garcia et al., 2008; McJannet et al., 1996; McLeod et al., 2004; Stannard, 1988; Stannard and Weltz, 2007) but all have been large, heavy and cumbersome, and have relied on data-loggers interfaced to a notebook computer, both of which are powered by an external lead-acid battery. As a result these instruments have been difficult to transport, required more than one operator and were often impractical for use in field environments such as forest where trees, dense undergrowth, fallen logs and uneven ground can make passage difficult for such cumbersome instruments. The large size of existing domes can also make it difficult to find a sufficiently clear ground in forest to deploy the instrument. Previous versions have also typically required the operator to collect data in the field but analyse that data in the laboratory; hence, results were not immediately available for inspection in the field.

We sought to improve the design of evaporation domes, especially for use in forest, firstly by reducing its size but also by replacing the data-logger, notebook computer and lead-acid battery with the Vernier LabQuest (Vernier Software and Technology, LLC, Beaverton, OR, USA). The Vernier LabQuest is an inexpensive, light (350 g) and very mobile self-powered device that replaces the functions of a notebook computer and data-logger. The LabQuest can display temperature, humidity and calculated vapour density in real-time, and also has the capacity to quickly calculate evaporation directly in the field using built-in analysis tools. Full specifications for the LabQuest are available at the Vernier Software and Technology, LLC website (Vernier Software and Technology, 2011) but some key features are 416 MHz processor, four analogue and two digital ports with 12-bit A/D resolution, a 7 cm × 5.3 cm colour touchscreen with stylus, push button access to functions and navigation, on-screen keyboard, and rechargeable battery. The LabQuest is splash resistant, has an operating range of 0–70 °C and is of rugged construction, making it well-suited to field use. Built-in software allows data to be displayed as graphs, tables or meters, and it has many built-in functions for data analysis including curve-fitting. In the remainder of the paper we describe our improved evaporation dome and present some evaporation data obtained in natural forest using the improved dome.

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2. Design and construction of the improved evaporation dome

A hemispherical dome with diameter of 57.3 cm, height of 29 cm and a 2.5 cm flange was constructed from acrylic (Fig. 1a). The volume and area of the dome were 0.0545 m^3 and 0.258 m^2. The relatively small footprint of the dome made it easier to find suitable locations to place the dome in forest where understorey plants are common and the ground may be rough. Evaporation domes constructed for use in agricultural landscapes have generally been much larger. Foam rubber, which is compressed during measurements by placing a foot on the dome, was adhered to the flange to create a seal with the ground. A Monitor Sensors HT1 combined temperature and humidity probe (0–2.5 V output, 0.1% relative humidity and 0.01 °C temperature resolution) was mounted inside the dome through a cable gland such that the sensor head extended 15 cm into the dome (Fig. 1b). A small fan (eWatts 2213-1000 kV motor with 25 A electronic speed controller and GWS EP4025 propeller) was mounted at the apex of the dome and wired so that it drew air away from the evaporating surface towards the top of the dome and directly past the HT1 sensor head (Fig. 1b). This mounting minimised disturbance to the boundary layer of the evaporating surface while still providing good mixing of air within the chamber and a good response time of the temperature and relative humidity sensor. The fan system was capable of producing horizontal wind speeds at the surface of up to 1.0 m s^{-1}. We adjusted the speed controller such that the wind speed at the evaporating surface within the dome did not exceed 0.3 m s^{-1}, which was typical of field wind speeds at ground level using an impeller-type anemometer. Similar windspeeds have been observed at ground level in other forests (Hanson et al., 1993). The fan would run for at least a day on five AA batteries. For more open landscapes, larger windspeeds could be produced simply by fitting a larger propeller or a propeller with a larger pitch.

The HT1 sensor was interfaced to a Vernier LabQuest (Fig. 1c) that also provided the 5 V power supply to the HT1. Two of the LabQuest's four analogue channels were used by the HT1 sensor (Fig. 1d). The calibration parameters of the HT1 sensor were stored in the LabQuest configuration such that actual temperature and humidity could be displayed on the LabQuest in real time. The LabQuest can sample up to 100,000 times per second but we used the recommended sampling rate of once per second for temperature and humidity sensors. The *Table Menu* has the option of creating *Manual* and *Calculated Columns*, which are constants input by the user (such as the volume and area of the dome) or calculated variables based on sensor measurements and/or other constants and variables. Using this feature we programmed the LabQuest to calculate Kelvin temperature, saturation vapour pressure, vapour pressure, and vapour density (the files are available from the author upon request). The LabQuest was setup to graph vapour density (g m^{-2}) versus time (min), in real time, after the *Collect* button was pressed (Fig. 1e). The Y-axis range can be specified manually or allowed to autoscale as data are collected. When data collection ceased (sampling duration was 0.4 min or 25 s) the curve was analysed using the LabQuest's built-in analysis tools, which displayed the linear regression line, the coefficient of determination, the root mean-square-error, and the slope and intercept (Fig. 1e). The LabQuest is able to fit many other types of curves but only linear curve fitting was relevant to our application. The

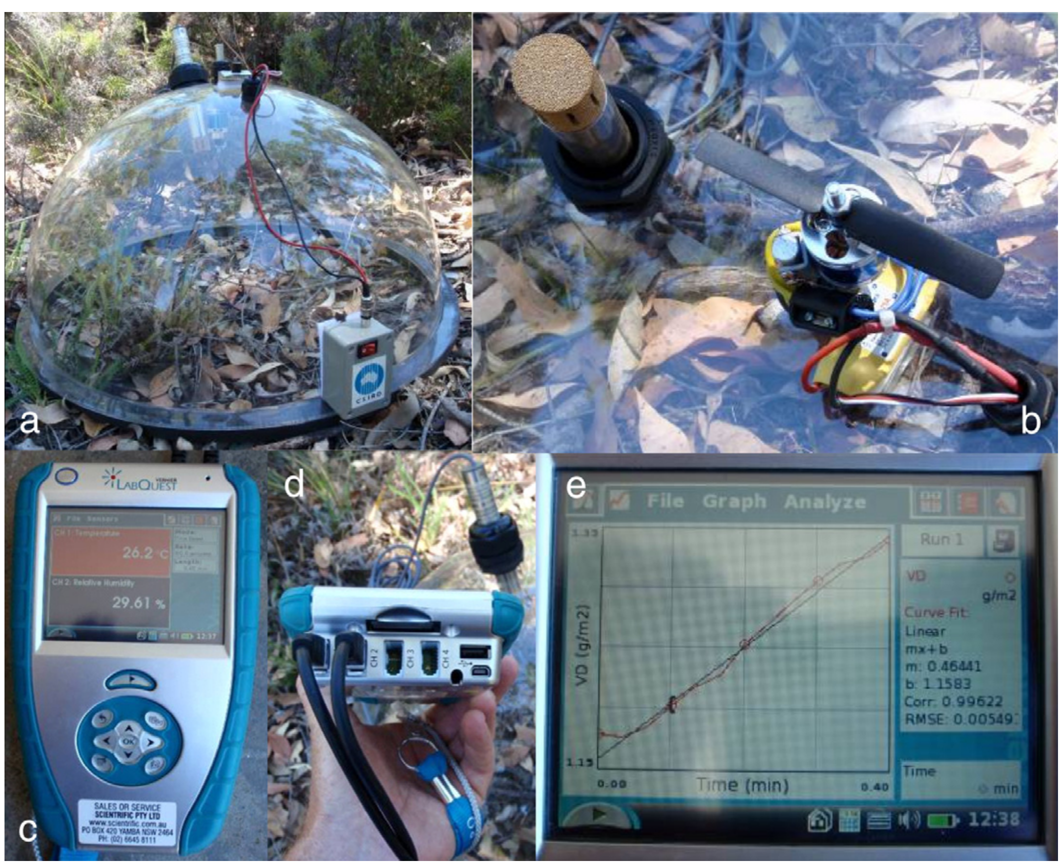

Fig. 1. (a) The acrylic dome with battery case, temperature/humidity sensor and fan speed controller externally visible. (b) The underside of the dome showing the fan motor, fan and temperature/humidity sensor. (c) Front view of the Vernier LabQuest displaying temperature and relative humidity. (d) Analogue channel inputs, USB slot, SD card slot and micro-USB slot on the rear of the LabQuest. (e) Closeup of the touch-screen of the LabQuest displaying field data through which a regression line has been plotted; the slope (m) was 0.46 g m^{-2} s^{-1}.