Using Remote Automatic Weather Stations to Determine Evapotranspiration

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Efficient water management has become increasingly important as the world struggles to feed growing populations and as climate change places increasing pressure on those regions that already suffer from water shortages and drought. The increased frequency of extreme weather events also contributes to the growing pressure on water resources such as lake and reservoir water levels and river discharge. According to the United Nations, water usage has grown at more than twice the rate of population increase over the past century. In 2006, it was calculated that more than 1.4 billion people live in river basins where water use exceeds minimum recharge levels. Around 70 percent of freshwater usage is for irrigation, 20 percent for industry, and 10 percent for domestic use. Globally, irrigated agriculture accounts for around 20 percent of cultivated land but contributes 40 percent of total food production (FAO 2012). The agricultural and horticultural industries consume enormous quantities of water, so the challenge is to use the correct amount of water to maximize production without waste. To achieve this, it is necessary to determine the volume of water that is required by a specific crop as it grows. This information can then be utilized to manage irrigation.

Evapotranspiration

Evapotranspiration is an important component of the water cycle (Figure 1). It is the sum of evaporation and plant transpiration from the Earth’s surface to the atmosphere. Evaporation is the movement of water to the air from sources such as the soil, plant canopies, and water bodies. Transpiration is the movement of water within a plant and the subsequent loss of water as vapor through the stomata in leaves. The energy that drives these processes comes from solar and terrestrial radiation. The rate is influenced by a complex interaction of many factors, including the topography, geology, and botany of the area, the moisture content of the soil, the moisture availability to vegetation, and the local weather. As many of these factors vary throughout each day and with the seasons, the rates are continually changing at any given site. This means it is not possible to measure evapotranspiration directly.

Conventional Evaporation Station

An evaporation pan is a practical way to measure the loss of water from a small water surface. However, this is not a direct measurement of part of the natural evapotranspiration process. A conventional station consists of a Class A evaporation pan, a stilling well, a mechanical micrometer to record daily evaporation from a water-filled tank, an anemometer, and a floating water temperature sensor. In addition, precipitation is measured by a manual...
check gauge, which provides daily precipitation data for inclusion in the evaporation model (Figure 2).

Evaporation rates from lakes, soil surfaces, and vegetation will be different from a pan and therefore have to be determined using empirical methods. For example, consider a pan of water in the middle of a lake versus a pan of water in the middle of a field or a parking lot. The moist air from the surrounding lake will decrease the diffusion gradient between the pan and the overlying air, when compared to the pan in a field with much dryer overlying air. The evaporation pan on land will overestimate the actual lake evaporation. To correct for this, a standard pan coefficient of 0.7 is multiplied times the pan evaporation to more closely approximate lake evaporation.

Scheduled maintenance on conventional precipitation networks can result in data availability as low as 68 percent, whereas immediate reactive maintenance work can improve data availability to 85 percent. However, this means that 15 percent of the precipitation data would have to be interpolated from neighboring sites and maintenance costs would be relatively high. Frequent rain gauge maintenance is needed due to environmental deposits such as leaves, dust, bird excrement, and small animals penetrating the mechanism and/or blocking the funnel.

For most lake associations working to determine a water budget for their lake, the conventional evaporation station as described above is often sufficient.

Compact Weather Sensor System

It is possible to measure meteorological parameters automatically and to calculate evaporation based on the measured values for wind run, temperature, humidity, global radiation, and precipitation. The automatic weather station (for delivering the required data) consists of a 2m mast to measure wind, temperature, humidity, and global radiation, with a solar power package and a data logger with remote transmission unit (Figure 3). In addition, a precipitation gauge is equipped with a windshield to improve catching efficiency at low precipitation rates and to reduce the effect of wind.

Figure 2. Example of a conventional measuring station: anemometer, rain gauge, and Class A evaporation pan with stilling well, mechanical micrometer, and floating water temperature sensor.

Figure 3. Automatic weather station with Lufft sensor suite and Adcon remote transmission unit, also showing OTT Pluvio2 rain gauge with wind shield to improve catching efficiency.

The system consists of a Lufft WS501 meteorological sensor suite measuring wind direction and speed, air temperature and relative humidity, barometric pressure (optional), global radiation, and precipitation, connected to an Adcon A753 datalogger with integrated GPRS communication, a base station A850 Telemetry Gateway (which can manage from one to 500 stations) and the software package addVANTAGE Pro 6.3, a data visualization, processing
and distribution platform. This station is designed to WMO (World Meteorological Organization) guidelines with a 2m tripod mast and can be operated in a variety of modes. If external power (by battery or mains power supply) is available, the WS501 unit can be freely configured to read wind speed up to ten times per second, delivering WMO-compliant wind gust and average readings. All other sensors would normally be read once per minute and the results aggregated into ten-minute averages. If no external power is available, and the whole system is being powered by the internal battery of the Adcon remote telemetry unit (RTU), which in turn is charged by a small solar panel in DIN A5 format, the Lufft WS501 will read all parameters once per minute and aggregate these readings over a ten-minute interval.

These ten-minute aggregates, as stored by the Adcon RTU, are automatically transmitted to the A850 base station at user-definable intervals, for example, once every ten minutes or once per hour or once every four hours. The transmission interval is usually determined according to the availability of power.

Data stored in the A850 are handled by the addVANTAGE Pro 6.3 software. This fully integrated, browser-based software package contains a variety of processing extensions, one of which calculates evapotranspiration according to the modified Penman-Monteith equation. A further extension is available to convert these figures through a wide range of crop tables into crop-specific evapotranspiration. The results of the computation can be displayed in tabular and graphical format (Figure 4), and can be accessed by web browser via a PC or through Livedata, a software module designed for smartphones. This module offers a wide variety of display options, ranging from a 24-hour to an annual view – as shown in the screenshots above.

Maintenance Issues
In operational precipitation networks, there is a direct relationship between the uncertainty of measurements and maintenance issues: Relatively low levels of maintenance work lead to higher uncertainty in measured data. With low power consumption and a very low maintenance requirement, the OTT Pluvio² precipitation monitor addresses the problems associated with more traditional monitors. The addition of Pluvio² to a weather station with sensors for wind, temperature, humidity, global radiation, and barometric pressure substantially lowers maintenance costs and improves the suitability of the station for remote monitoring applications.

Conclusion
In the past, real-time calculation of evapotranspiration has been limited by power, telecoms availability, a high maintenance requirement – or a combination of these. However, by combining Adcon communications and data management with computation in an automatic weather station complete with a low-maintenance OTT Pluvio² rain gauge, farmers and horticulturalists will be able to make substantial improvements to the efficiency with which they manage irrigation water.

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