Regional Evaluation of Evapotranspiration in the Everglades

U.S. Department of the Interior—U.S. Geological Survey

What and Why

Understanding the water budget of the Everglades system is crucial to the success of restoration and management strategies. Although the water budget is simple in concept, it is difficult to assess quantitatively. Models used to simulate changes in water levels and vegetation resulting from management strategies need to accurately simulate all components of the water budget.

One of the most important components of the Everglades water budget is evapotranspiration (ET). ET is water removed from the surface and soils by direct evaporation and plant transpiration. In South Florida, ET rates may exceed 40 in/yr (inches per year) on the average; during dry years, the ET could exceed rainfall (about 50 in/yr). Thus, most of the water that falls on the land surface as rainfall is returned to the atmosphere by ET. Despite the importance of ET in the Everglades water budget, our knowledge of ET is, at present, only semi-quantitative. Recent advances in instrumentation and measurement techniques have made it possible to continuously measure ET, so that an accurate evaluation of ET in the Everglades can be made.

In 1995, a study to measure and model ET in the Everglades (fig. 1) was begun as part of the South Florida Ecosystem Program (McPherson and others, 1995). The principle objective of the study is to develop an understanding of ET within the Everglades drainage unit, excluding forested agricultural and brackish environments. To achieve this, a network of eight ET-measurement sites was established, representing the various types of hydrologic and vegetative environments. Continuous measurement of ET at these sites for at least a 2-year period (October 1995 through September 1997) will be used to develop regional models of ET that can be used to estimate ET at other times throughout the Everglades.

This fact sheet describes the basic principles of ET measurement, and the locations and features of the ET stations operated as part of this study.

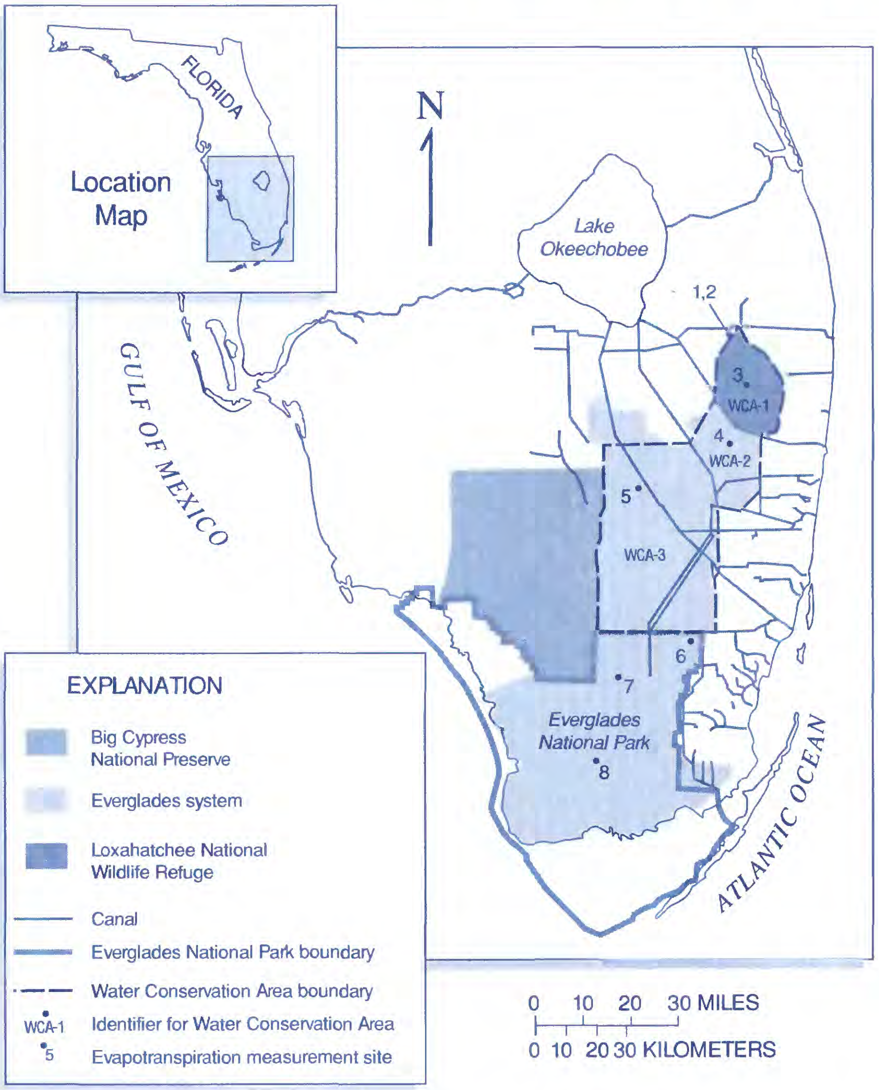

Figure 1. The Everglades and locations of evapotranspiration (ET) stations.

How

Methods of measuring evapotranspiration generally are divided into two categories: water budgeting and energy budgeting. The former method relies on accurate accounting of water flow into and out of a control area. Accurate determination of flow components is difficult in much of the Everglades due to low hydraulic gradients and sheet flow conditions. Therefore, water budgeting was not used in this study.

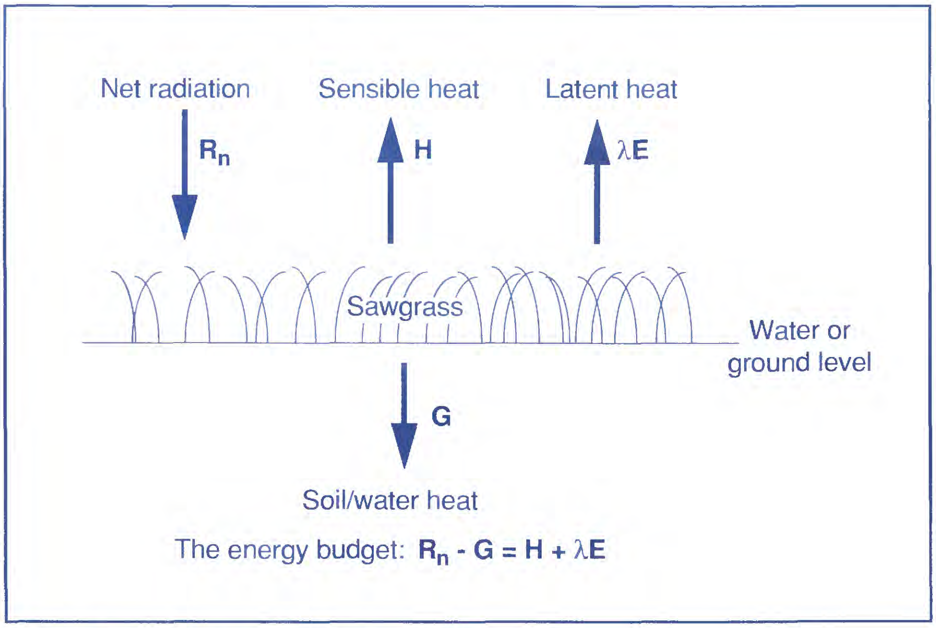

Figure 2. Energy budget during daytime heating.

Energy budget methods rely on an accurate accounting of energy to and from the land surface and generally assume one-dimensional energy flow. Because the energy needed to evaporate water is relatively large (about 580 calories per gram), ET, or latent heat, can represent a significant component of the energy budget (fig. 2). Net radiation (R_n) is the difference between incoming shortwave (solar) radiation and outgoing shortwave and longwave radiation, sensible heat (H) is the energy transported from the land surface by air movement (convection), latent heat (λE) is the energy transported away from the surface by evaporating water, and soil/water heat (G) is the heat that goes into changing the temperature of the soil or the water standing on the land surface. Any of these components may reverse in direction—for example, latent heat is added to the surface by condensation (dew formation), and net radiation is directed upward at night.

The Bowen-ratio energy budget method (Bowen, 1926) was selected for use in the Everglades because relatively inexpensive instrumentation for continuous measurement of actual ET is available. The method has been previously used at other locations in Florida (Bidlake, 1993). When using this method, R_n and G are monitored at 15-minute intervals using thermopile and thermocouple sensors. The difference between R_n and G is the energy transported upward by H and λE, but the relative magnitudes of H and λE cannot be determined from energy-budget data alone. The Bowen ratio (B) is the ratio of H to λE. It can be shown that B is also a function of measured vertical differences of temperature and vapor pressure in the air, or

$$B = \gamma \times \Delta T / \Delta e$$

where γ is a weak function of air temperature and barometric pressure (roughly a constant), ΔT is the temperature difference between two points at different heights above the land surface, and Δe is the vapor pressure difference between the same two points. The energy budget can then be written in terms of the Bowen ratio to solve directly for latent heat, as:

$$\lambda E = (R_n - G) / (1 - B).$$

Two types of stations are being used to monitor the components of the energy budget. One type, shown in figure 3, is used at locations where plant transpiration could be an important part of the total ET. This type of station features a pair of movable air temperature and humidity sensors for measuring ΔT and Δe. These sensors are mounted on an exchange mechanism so that the sensor positions are reversed every 15 minutes. This reversal of position makes it possible to eliminate the effect of sensor bias on the difference measurements and is necessary to measure accurately the small differences in temperature and humidity that occur over the 3 - to - 5-ft vertical distance. The effect of sensor bias is removed from the 30-minute average by simply averaging the differences measured during two succesive 15-minute intervals.

The other type of monitoring station is much simpler in operation and is used where permanent areas of open water occur with little emergent vegetation, so that plant transpiration is an insignificant part of the total ET. At such open-water stations, the same Bowen-ratio principle is used to partition the energy flux into convective and evaporative components. However, the temperature and vapor pressure differences can be measured from water to air, rather than within the air. Since the water-to-air differences are much greater than differences in the air over similar distances, the effect of air and vapor pressure sensor bias is insignificant. Therefore, the sensor exchange mechanism is not required, and only one vapor pressure sensor is needed. Vapor pressure at the water surface can be calculated from the water temperature.

Data are recorded at 15-minute intervals at all of the stations used in vegetated areas, and at 30-minute intervals at the open-water stations. Some of the types of data recorded at the ET stations are not used in determination of ET but are needed in models of ET, or in general interpretation of the data. Multiple sensors are used for soil data because of the heterogeneous nature of soils, and the average of the soil heat fluxes is used in the energy balance. A summary of the types of data that are recorded is given in the table to the right of this column.

Where

The chief consideration for selecting the ET sites was to have a network of sites representative of the ecosystems of the Everglades system in terms of plant communities, duration of water inundation, and geographic coverage. Other factors were security and logistics. Sites in areas that are open to hunting and air boating were located in relatively remote locations and not on major air boat trails. In the following list, map numbers correspond to numbers on the location map (fig. 1).

Data type	Number of sensors at each site	
	Vegetated sites	Open-water sites
Rainfall	1	1
Wind direction	1	1
Wind velocity	1	1
Incoming solar radiation	1	1
Net solar radiation	2	1
Water level	1	1
Soil temperature	3	0
Soil heat flux	3	0
Water temperature	3	3
Air temperature	2	1
Moisture content of air	2	1
Moisture content of soil	3	0

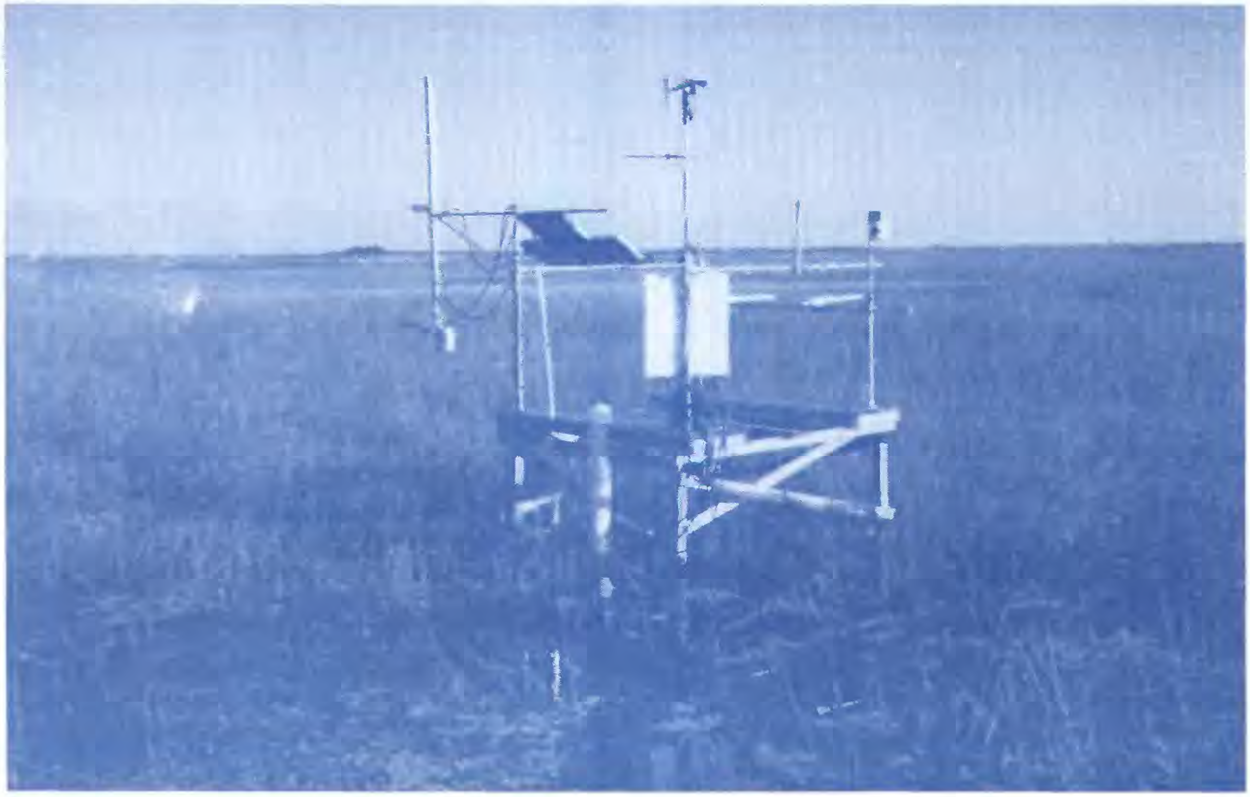

Figure 3. Evapotranspiration (ET) site 7.

Map number	Site name	Area[1]	Community	Lat-long	Comments
1	Enr - cattail	Enr	Cattails	263910 0802432	Never dry
2	Enr - open	Enr	Open water	263740 0802612	Never dry
3	Site 7	Lox	Open water	263120 0802013	Never dry
4	F4	WCA2	Dense sawgrass	261900 0802307	Dry part of some years
5	Camp23	WCA3	Medium sawgrass	261541 0804356	Dry part of most years
6	Nesrs3	Enp	Medium sawgrass	254450 0803007	Never dry
7	P33	Enp	Sparse sawgrass	253655 0804211	Never dry
8	Old Inghram Hw	Enp	Sparse rushes	252112 0803807	Dry part of every year

[1]Enr, Everglades Nutrient Removal project area; Lox, Loxahatchee National Wildlife Refuge; WCA, Water Conservation Area; Enp, Everglades National Park

When

The total length of the ET evaluation project is 5 years. The project began in fiscal year (FY) 1995 with site selection and equipment installation. Data collection will continue through FY 1996 and 1997. Development of site models and a regional model of ET will proceed through FY 1998. The study will end in FY 1999.

References

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Bowen, I.S., 1926, The ratio of heat losses by conduction and by evaporation from any water surface: Physical Review, 2nd series, v. 27, no. 6, p. 779-787.

McPherson, B.F., Higer, A.L., Gerould, Sarah, and Kantrowitz, I.H., 1995, South Florida ecosystem program of the U.S. Geological Survey, FS-134-95, 4 p.

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