An Evaluation of the Effect of Meteorological Variables for the Estimation of Evapotranspiration

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1. Introduction

The hydrologic cycle can be evaluated with respect to the surface energy balance, as thermal energy from solar radiation is absorbed and transformed into either sensible or latent heat. Improved knowledge of the surface energy exchange is paramount for understanding the water balance. Identifying the important meteorological variables on evapotranspiration in 21 meteorological measurement locations in South Korea is the major consideration of this study. Meteorological and flux data (net radiation, air temperature, wind speed, and relative humidity) measured from 21 locations in South Korea by Korea Meteorological Adminstration (2000) for last 10 years were used to study the significance of major variables on Penman evapotranspiration estimation.

2. Methods

Meteorological data used in this study were collected over 21 locations in South Korea by Korea Meteorological Adminstration (KMA) for last 10 years. Using mean values of four meteorological factors for the period from January 1, 1991 to December 31, 2000 values of the relative sensitivity were calculated, and error analysis was performed. The meteorological data include air temperature (T_a, °C), wind speed (u_2, m/s), relative humidity (RH, %), and solar radiation (K, $MJ/m^2 \cdot day$).

Relative sensitivity was examined to compare the importance of four meteorological and flux variables (net radiation, wind speed, air temperature, and relative humidity) on Penman potential evapotranspiration (PET) estimation. Since the structure of the Penman model was formulated from consideration of physical principles, it was expected to provide a realistic sensitivity of the meteorological factors in controlling the evaporation process.

3. Analysis and Results

3.1 Sensitivity Analysis

Since the structure of the Penman model was formulated from consideration of physical principles, it was expected to provide a more realistic indication of the relative sensitivity of the meteorological factors in controlling the evaporation process. The study results show that

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on the whole, solar radiation is the most sensitive meteorological factor and wind speed is the least sensitive meteorological factor for most of measurement locations.

The sensitivity of evapotranspiration rates to changes in humidity is less in the inland areas than in the coastal areas. Due to the storage and release of heat, one would expect such a body of water to significantly influence evapotranspiration rates. The availability of water vapor serves as a barrier to increased evapotranspiration rates and thus, variation in the level of humidity greatly influences variation in computed evapotranspiration rates.

For measurement locations located in the comparatively southern part of Korean Peninsula, such as Busan, Jeju and Gosan, variation in temperature produce the greatest variation in evapotranspiration rates. The temperature relative sensitivity values of 0.538, 0.562 and 0.575 are an indication of the great influence of temperature variation on computed evapotranspirationj rates. Air temperature and wind speed are the most sensitive meteorological factors for Gosan. This simultaneous increase in sensitivity of wind speed and temperature in Gosan could be an indication of an increase of the sensible heat flux density.

3.2 Monthly Variation of Relative Sensitivity

Using the relative sensitivity values obtained from 21 locations, cluster analysis was performed, and five locations which have most significant difference were selected and their monthly relative sensitivity values were analyzed. In this study, 5 representative locations could be selected when they are clustered into five clusters, and the selected locations was used for monthly variation of relative sensitivity. The selected locations are Dagoanryeong, Wonju, Busan, Gwangju, and Gosan.

The influence of the meteorological factors on estimated rates of evapotranspiration varies with the time of year. Using the Penman model and monthly values of the four meteorological factors for each month, the relative sensitivity values were derived for Dagoanryeong, Wonju, Busan, Gwangju, and Gosan. Temperature is the most sensitive meteorological factor in Daegoanryeong and Wonju during the winter period (December and January). On the other hand, temperature is the most sensitive meteorological factor in Busan, Gwangju and Gosan during the summer period (July and August). Relative humidity is the most sensitive meteorological factor in most of the measurement locations during the winter period (December and/or January). Solar radiation is the most sensitive meteorological factor in most of the measurement stations for all months. Therefore, accurate estimation of evapotranspiration rates in all the measurement stations depend primarily on the solar radiation. Wind speed is the most sensitive meteorological factor in Daegoanryeong, Wonju, Gosan and Busan during the winter period.

For air temperature, solar radiation and wind speed during the winter period, Daegoanryeong and Wonju show extremely high relative sensitivity values compared with other months. Thus, variations in PET rates during the winter period in Daegoanryeong and Wonju appear to be controlled by four meteorological factors (temperature, humidity, solar radiation and wind speed). For Busan and Gwangju, air temperature is the most sensitive factor in the estimation of Penman PET during the summer period. On the other hand, humidity, solar radiation and wind speed are the sensitive meteorological factors during the winter period. For Gosan, air temperature and solar radiation are the sensitive factors during the summer period but humidity and wind speed are the sensitive factors during the winter period. Thus, changes in air temperature and solar radiation become less important during the

winter period while the influence of humidity and wind speed increases significantly during the winter period.

3.3 Error Analysis

The potential evapotranspiration errors for 21 geographic locations are given in Table 1. The evapotranspiration error values indicate that the meteorological factor measurement error is very small compared with the mean daily evapotranspiration. The largest error is about 3 percent of the daily evapotranspiration. As indicated by the values in Table 1, the presence of error in the meteorological data would have only a minor effect on computed evapotranspiration estimates.

Table 1. Potential error in evapotranspiration estimates resulting from error in meteorological data

Location	Error in Evapotranspiration Estimates (mm/day)				Mean Daily Evapotranspiration (mm/day)
	ΔT_a	ΔRH	ΔK	Δu_2	
Daegoanryeong	0.031	-0.014	0.111	0.041	1.648
Gangreung	0.037	-0.008	0.137	0.071	2.217
Chuncheon	0.035	-0.006	0.132	0.047	1.799
Wonju	0.034	-0.005	0.136	0.049	1.754
Seoul	0.033	-0.008	0.122	0.066	1.861
Incheon	0.039	-0.010	0.144	0.057	2.209
Suwon	0.031	-0.007	0.121	0.056	1.656
Seosan	0.037	-0.009	0.139	0.050	2.043
Cheongju	0.036	-0.008	0.137	0.060	2.004
Daejeon	0.037	-0.007	0.145	0.058	2.141
Chupungryeong	0.034	-0.010	0.127	0.057	1.926
Andong	0.039	-0.007	0.148	0.058	2.190
Pohang	0.041	-0.009	0.150	0.072	2.513
Daegu	0.039	-0.009	0.142	0.074	2.294
Busan	0.042	-0.012	0.147	0.069	2.508
Jinju	0.039	-0.007	0.151	0.059	2.283
Jeonju	0.033	-0.007	0.129	0.056	1.819
Gwangju	0.038	-0.009	0.144	0.059	2.209
Mokpo	0.045	-0.015	0.159	0.060	2.777
Jeju	0.040	-0.014	0.139	0.060	2.437
Gosan	0.045	-0.027	0.139	0.047	2.591

ΔT_a : Expected measurement error of air temperature (℃); ΔRH : Expected measurement error of relative humidity (%); ΔK : Expected measurement error of solar radiation ($MJ/m^2 \cdot day$); Δu_2 : Expected measurement error of wind speed ($m/\sec$)

4. Conclusions

Mean values of four meteorological factors(air temperature, wind speed, relative humidity and solar radiation) measured over 21 locations in South Korea for 10 years were used for analyses of relative sensitivity and error. The study results show that on the whole, solar

radiation is the most sensitive meteorological factor and wind speed is the least sensitive meteorological factor for most of measurement locations. The sensitivity of evapotranspiration rates to changes in humidity is less in the inland areas than in the coastal areas. Due to the storage and release of heat, one would expect such a body of water to significantly influence evapotranspiration rates. For measurement locations located in the comparatively southern part of Korean Peninsula, variation in temperature produce the greatest variation in evapotranspiration rates.

Using the relative sensitivity values obtained from 21 locations, cluster analysis was performed, and five locations which have most significant difference could be selected and their monthly relative sensitivity values were analyzed. Solar radiation is the most sensitive meteorological factor in most of the measurement stations for all months. Therefore, accurate estimation of evapotranspiration rates in all the measurement stations depend primarily on the solar radiation.

The evapotranspiration error values indicate that the meteorological factor measurement error is very small compared with the mean daily evapotranspiration. The largest error is about 3 percent of the daily evapotranspiration.

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