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Technical Note

Inter-annual and spatial variability of Hamon potential evapotranspiration model coefficients

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SUMMARY

Monthly calibrated values of the Hamon PET coefficient (*C*) are determined for 109,951 hydrologic response units (HRUs) across the conterminous United States (U.S.). The calibrated coefficient values are determined by matching calculated mean monthly Hamon PET to mean monthly free-water surface evaporation. For most locations and months the calibrated coefficients are larger than the standard value reported by Hamon. The largest changes in the coefficients were for the late winter/early spring and fall months, whereas the smallest changes were for the summer months. Comparisons of PET computed using the standard value of *C* and computed using calibrated values of *C* indicate that for most of the conterminous U.S. PET is underestimated using the standard Hamon PET coefficient, except for the southeastern U.S.

1. Introduction

Potential evapotranspiration (PET) provides an estimate of the climatic demand for water. PET is energy limited since the definition of PET assumes an unending supply of water (Wilm and Thornthwaite, 1944). PET is an integral part of water balance computations and of climatic indices such as aridity indices (Budyko, 1948; Thornthwaite, 1948; Willmott and Feddema, 1992; Arora, 2002; Weiskel et al., 2014). Temperature based PET models have been used for over 50 years and have been applied in a wide range of climatic and physiographic regions. These models have been applied widely because they only require mean monthly temperature as input and these data are readily available for long time periods and for many locations across the globe. Although temperature-based PET models are empirical and do not include representation of many physical processes, they have been found to provide reliable estimates of monthly and annual PET for many locations (Lu et al., 2005; Federer et al., 1996; Vörösmarty et al., 1998; Hay et al., 2011).

Thornthwaite (1948) provided one of the best known and widely used methods to compute PET. Thornthwaite's method required monthly temperature and mean monthly daylength as inputs to the equations. Hamon (1961) presented a PET model that was developed based on measurements of PET published by Lowry and Johnson (1942) and Thornthwaite (1948). The Hamon PET model was developed as an improvement of the well-known Thornthwaite PET model and included the effects of saturation vapor density on PET. In 1963 Hamon provided a slightly updated version of his model (Hamon, 1963).

The Hamon PET equation is simple and does not explicitly include the effects of humidity, wind speed, and land cover on PET. However, because the Hamon equation only requires inputs of monthly temperature it can be widely applied in both time and space. Additionally, although conceptually simple, the Hamon PET equation has been evaluated and compared with a number of other models and is considered to provide reliable monthly PET estimates (Lu et al., 2005; Federer et al., 1996; Vörösmarty et al., 1998). In a study of five PET models for use with global water balance models, Federer et al. (1996) found that estimates of PET from the Hamon model agreed with estimates from other models across a wide range of climates. In addition, Vörösmarty et al. (1998) compared 11 different PET models for a wide range of climatic conditions across the conterminous U.S. and found that the Hamon model was comparable to more input-detailed models.

The Hamon model includes an empirically determined model coefficient that remains constant for all applications. Some studies have shown that improved PET estimates are obtained using the Hamon model if a correction factor is applied (Sun et al., 2008).

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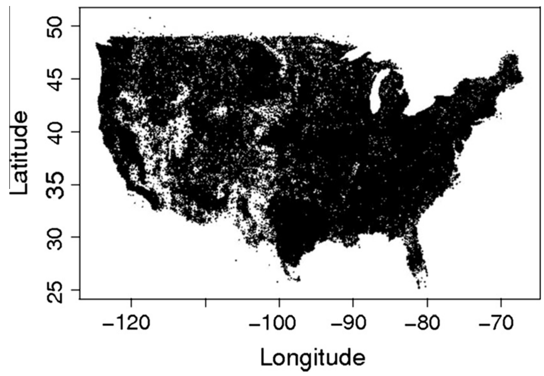

Fig. 1. Map of the centers of hydrologic response units.

Instead of applying a correction factor, a better approach may be to use Hamon PET coefficients that vary by month and by location. The objectives of this study are to (1) determine useful Hamon PET coefficients for each month and for locations across the conterminous U.S., and (2) examine the effects of varying monthly coefficients on PET estimates.

2. Data and methods

The original Hamon (1961) monthly PET model is,

$$PET = CD^2P_t/100 \quad (1)$$

where PET is in inches day, C is an empirical dimensionless coefficient equal to 0.55, D is the possible hours of daylight in units of 12 h, and P_t is the saturated water vapor density at the daily mean temperature in grams per cubic meter (Hamon, 1961). By multiplying by 25.4 and the number of days in a month provides Hamon PET estimates in millimeters per month.

Hamon (1963) provided a slightly modified version of his PET model. The updated model is,

$$PET = CDP_t \quad (2)$$

where in the 1963 version of the model, $C = 0.0065$. The difference in C is due to additional testing by Hamon (1963) and because the values are not divided by 100 as in Eq. (1).

Both models have the same form, use the same variables, and provide similar PET estimates. We used both the Hamon (1961, 1963) versions of the model, but because the results were so similar we only present the results using the 1963 model in this paper. The calibrated Hamon coefficients for the 1961 and 1963 models can be downloaded from ftp://brrftp.cr.usgs.gov/pub/mows/data/hamonCoef/.

Mean monthly measured free-water surface (FWS) evaporation for 1956 through 1970 from Farnsworth et al. (1982) were used for calibration of the Hamon PET model. The FWS data are considered representative of mean monthly measured PET (Farnsworth et al., 1982). These data were digitized and interpolated to a 5-km (km) by 5-km grid by the National Weather Service.

PET was computed using monthly temperature data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) data set (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu). The PRISM data set provides monthly temperature and precipitation data for the conterminous U.S. on a 4-km by 4-km grid for the period 1895 to present. The

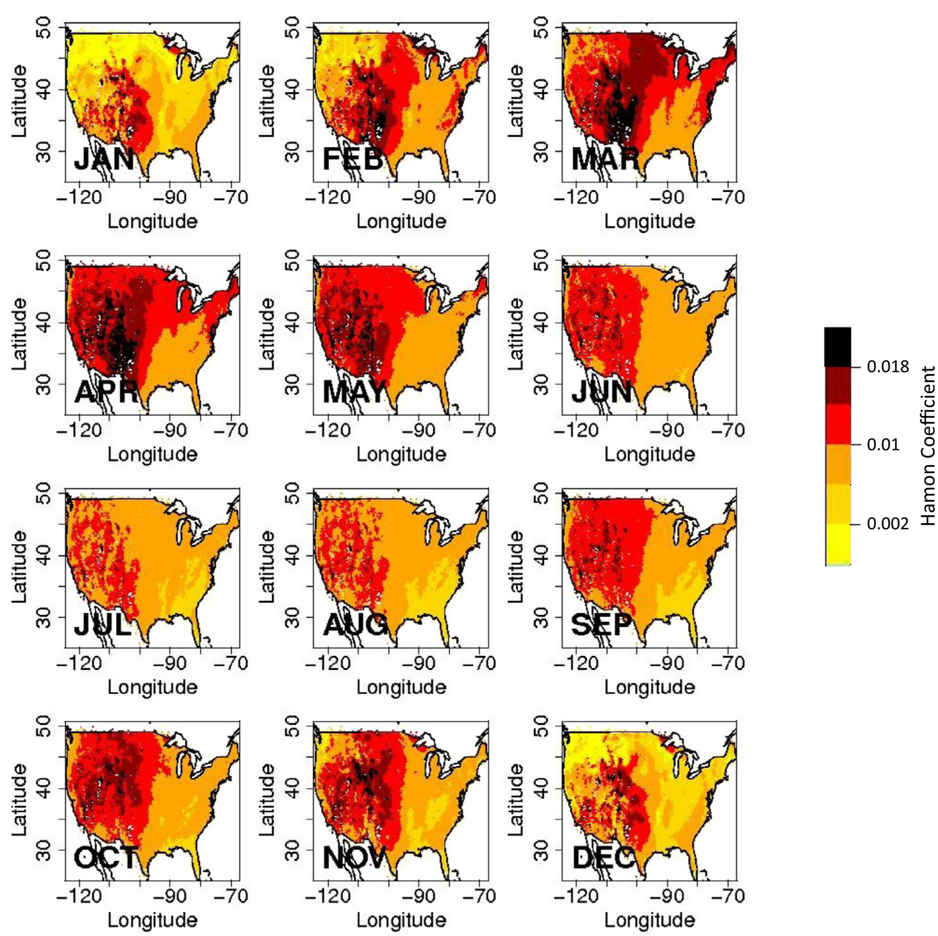

Fig. 2. Monthly Hamon potential evapotranspiration model coefficients determined through calibration.