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A Comparison of ASCE and FAO56 Reference Evapotranspiration at Different Subdaily Timescales: a Numerical Study

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Introduction: Subdaily estimates of reference evapotranspiration (ET_o) are needed in many applications such as dynamic agro-hydrological modeling. The ASCE and FAO56 Penman–Monteith models (ASCE-PM and FAO56-PM, respectively) has received favorable acceptance and application over much of the world, including the United States, for establishing a reference evapotranspiration (ETo) index as a function of weather parameters. In the past several years various studies have evaluated ASCE-PM and FAO56-PM models for calculating the commonest hourly or 15-min ET_o either by comparing them with lysimetric measurements or by comparison with one another (2, 3, 5, 9, 10, 11, 16, 17, 19). In this study, sub-daily ETo estimates made by the ASCE-PM and FAO56-PM models at different timescales (1-360 min) were compared through conduction of a computational experiment, using a daily to sub-daily disaggregation framework developed by Parchami-Araghi *et al.* (14).

Materials and Methods: Daily and sub-daily weather data at different timescales (1-360 min) were generated via a daily-to-sub-daily weather data disaggregation framework developed by Parchami-Araghi *et al.* (14), using long-term (59 years) daily weather data obtained from Abadan synoptic weather station. Daily/sub-daily net long wave radiation (R_{nl}) was estimated through 6 different approaches, including using two different criteria for identifying the daytime/nighttime periods : 1) the standard criteria implemented in both ASCE-PM and FAO56-PM models and 2) criterion of actual time of sunset and sunrise in combination with 1) estimation of clear-sky radiation (R_{so}) based on the standard approach implemented in both ASCE-PM and FAO56-PM models (1st and 2nd R_{nl} estimation approaches, respectively), 2) integral of the R_{so} estimates derived via a physically based solar radiation model developed by Yang et al. (25), YNG model, for one-second time-steps (3rd and 4th R_{nl} estimation approaches, respectively), and 3) integral of the calculated R_{nl} based on R_{so} estimates derived via YNG model for one-second time-steps (5th and 6th R_{nl} estimation approaches, respectively). The capability of the two models for retrieving the daily ET_o was evaluated, using root mean square error RMSE (mm), the mean error ME (mm), the mean absolute error ME (mm), Pearson correlation coefficient r (-), and Nash–Sutcliffe model efficiency coefficient EF (-). Different contributions to the overall error were decomposed using a regression-based method (7).

Results and Discussion: Results showed that during the summer days, 24h sum of sub-daily radiation and aerodynamic components of ET_o and the estimated ET_o derived from both models were in a better agreement with the respective daily values. The reason for this result can be attributed to the nighttime value of cloudiness function (*f*) and the longer nighttime during the cold seasons. Because the nighttime values for *f* are equal the *f* value at the end of the previous daylight period until the next daylight period. The difference between sub-daily ET_o derived from the ASCE-PM and FAO56-PM models during the day and night was highly dependent on the wind speed. In case of both models, daily aerodynamic component of ET_o ($ET_o^{d,aero}$) were reproduced more efficiently, compared to radiation component ($ET_o^{d,rad}$). Except in the case of 6th R_{nl} estimation approach, FAO56-PM model (with a mean model efficiency (MEF) of 0.9934 to 0.9972) had better performance in reproducing the daily values of ET_o (ET_o^{d}), compared to ASCE-PM model (with a MEF of 0.9910 to 0.9970). The agreement between 24h sum and daily values of aerodynamic component had a lower sensitivity to the adopted time-scale, compared to the radiation component. Compared to the FAO56-PM model the performance of the ASCE-PM model in reproducing the $ET_o^{d,rad}$, $ET_o^{d,aero}$ and ET_o^{d} had higher sensitivity to the approach utilized for calculation of R_{nl} and hence, to the uncertainty of net radiation. Results showed that a smaller time step does not necessarily leads to an improvement in agreement between 24h sum of subdaily and daily values of ET_o. Deficiency of the standard daytime/nighttime identification criteria resulted in a higher daily averaged

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daytime (1.3831 to 1.6753 h) used in cloudiness function calculations, compared to the respective value used in calculations of the radiation and aerodynamic components. In order to estimate the sub-daily ET_o under climatic condition of the studied region, the use of ASCE-PM model based on the 6th R_{nl} estimation approach, $(ASCE\text{-}PM)_6$, with a MEF of 0.9970 is preferred, compared to other studied alternatives. Another advantage of the $(ASCE\text{-}PM)_6$ and $(FAO56\text{-}PM)_6$ models is their computational efficiency in case of their implementation in hydrological models.

Keywords: Disaggregation, Evapotranspiration, ASCE Penman-Monteith, FAO-56 Penman-Monteith