



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

F. Parchami-Araghi¹ - S. M. Mirlatifi^{2*} - Sh. Ghorbani Dashtaki³ - A. Sadeghi Lari⁴

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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 (ET_o) 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 ET_o 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

1, 2- Ph.D. Student and Associate Professor, Department of Irrigation and Drainage Engineering, Tarbiat Modares University, Tehran

(*-Corresponding Author Email: mirlat_m@modares.ac.ir)

3- Associate Professor, Department. of Soil Science, Shahrekord University, Shahrekord, Iran

4- Assistant Professor, Department of Water Engineering, Hormozgan University, Bandar Abbas, Iran

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-PM)₆, with a MEF of 0.9970 is preferred, compared to other studied alternatives. Another advantage of the (ASCE-PM)₆ and (FAO56-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