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Editorial

Advances in Evaporation and Evaporative Demand

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1. Introduction

The importance of evapotranspiration is well-established in various disciplines such as hydrology, agronomy, climatology, and other geosciences. Reliable estimates of evapotranspiration are also vital to develop criteria for in-season irrigation management, water resource allocation, long-term estimates of water supply, demand and use, design and management of water resources infrastructure, and evaluation of the effect of land use and management changes on the water balance.

The objective of the Special Issue "Advances in Evaporation and Evaporative Demand" was to define and discuss several related terms, including potential, reference, and actual evapotranspiration, and to present a wide spectrum of innovative research papers and case studies.

In this Special Issue there were eleven contributions that tackled the aforementioned goals.

2. Contributed Papers

The articles in this Special Issue address a wide variety of topics reflecting the challenges mentioned above ranging from urban hydrology to global evapotranspiration modelling:

The paper "**Determinants of Evapotranspiration in Urban Rain Gardens: A Case Study with Lysimeters under Temperate Climate**" [1] by Ahmeda Assann Ouédraogo, Emmanuel Berthier, Brigitte Durand and Marie-Christine Gromaire explores ET in urban rain gardens, a topic receiving more and more attention from both rain garden designers for a better consideration of ET in their designs and hydrology researchers for a more accurate description of the flux in the urban context. The city of Paris has instrumented eight rain garden lysimeters to obtain a better understanding and prediction of their hydrological behavior. In order to extrapolate on real situations, experimental rain gardens of reduced size and well-known structures were designed. Monitoring was carried out with lysimeters, i.e., mechanisms that enable the water balance components (exfiltration, water storage, etc.) to be observed, with measurements made by weighing variations in water content of the lysimeter. The aim was also to test different vegetation configurations and internal storage options, and to implement replicas in order to test the validity of the measurements. Thehe purpose of this study consists of three main points: estimating the actual evapotranspiration (ET) of these rain gardens at daily steps; assessing the impact of different configurations on ET fluxes; and comparing the actual ETs obtained from the lysimeters with reference to ET values, such as evaporation, from a pan evaporimeter and some models taken from the literature. The seasonal dynamics and the relative significance of each determinant of ET in the rain gardens were highlighted and the results could be used to investigate the modelling of hydrological processes in urban rain gardens.

The paper "**Stochastic Analysis of Hourly to Monthly Potential Evapotranspiration with a Focus on the Long-Range Dependence and Application with Reanalysis and Ground-Station Data**" [2] by Panayiotis Dimitriadis, Aristoteles Tegos and Demetris

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Koutsoyiannis, explores the stochastic structure of the potential evapotranspiration process, ranging from hourly to climatic scales, in terms of Hurst–Kolmogorov (HK) dynamics, which describes all the processes exhibiting the Hurst phenomenon (i.e., with a power-law autocorrelation function at large scales). They focused on the marginal structure of the PE process as fitted through the Pareto–Burr–Feller distribution. Both marginal and second-order dependence structures of the HK dynamics were estimated and compared to the ones identified from global-scale analyses in other key hydrometeorological processes that form the hydrological-cycle path driven by atmospheric turbulence, such as temperature, wind, solar radiation, and relative humidity. It was found that both the marginal probability distributions of PEV and PET are lighttailed when estimated through the Pareto–Burr–Feller distribution function. Additionally, the long-range dependence of both the PEV and PET was found to be of moderate strength, quantified through a Hurst parameter of 0.64 and 0.69, respectively. Both PET and PEV can be placed between the stochastic structures of temperature, relative humidity, solar radiation, and wind speed (i.e., strong LRD and light-to medium-tail) and the precipitation's structures (i.e., weak LRD and heavy tail).

The paper "**Precipitation and Potential Evapotranspiration Temporal Variability and Their Relationship in Two Forest Ecosystems in Greece**" [3] by Stefanos Stefanidis and Vasileios Alexandridis, aimed to investigate temporal variability and detect trends in drought conditions in two different types of forest ecosystems using long–term timeseries meteorological data from mountainous meteorological stations. For this purpose, the ratio of precipitation to potential evapotranspiration was used as a proxy indicator for the evaluation of drought conditions at different timescales (annual/seasonal). The Mann–Kendal and Sen's slope methods were applied in order to evaluate the significance and magnitude of the tendency, and to identify the time of abrupt changes. The results indicated that humid conditions prevail in both forest areas and that dry conditions occur in summer. The examined parameters present significant variability between seasons, following the Mediterranean climate pattern. The trend analysis showed that the reported upward and downward trends in Aridity Index are, in general, statistically insignificant, and the magnitude of the trend is considered negligible.

The paper "**Evaluation of Evaporation from Water Reservoirs in Local Conditions at Czech Republic**" [4] by Eva Melišová, Adam Vizina, Martin Hanel, Petr Pavlík and Petra Šuhájková, aimed to explore the relationships for the calculation of evaporation from water surface in the Czech Republic using reanalyzed climate data and the constructed linear models (LM) and random forest models (RFM) for the calculation of evaporation. The main objective of the evaporation estimation from the water surface was to derive a universal relationship for the whole territory of the Czech Republic. The derivation of the relationship for evaporation was based on the multiple linear regression method, where the values of the dependent variable (evaporation) were sought, based on two or more variables (predictors: air temperature, surface temperature, wind speed, surface net solar radiation, dew point, surface pressure, dew point, altitude, latitude, longitude and calculated humidity). The construction of the models was performed (i) manually, where the evaluation was perfomed using the AIC parameter and the quantile–quantile was used for visual diagnostics, (ii) using stepwise regression, where the predictorswere entered sequentially and models from one to X-selected variables were generated. Random forest regression was used to account for non-linear relationships. Linear and random forest regression models were cross-validated and evaluated using criterion functions (R^2, RMSE, MAE and RERR). Finally, 3(+1) LM models and 3 RF models were selected. It turned out that geomorphological information (elevation and location) appeared more in the manually derived models than in the to models constructed using the stepwise regression method. In the comparison between linear models (LM) and random forest models (RFM), LM was found to have much more variability in the outcome compared to the RFM. Among the best models that were evaluated by linear regression, models LM1 from the manual linear regression group and LM12 from the stepwise regression group were used. Model LM1 was selected as the best model among the six predictors. The LM1 model can be replaced by an alternative model LM12 which also performed satisfactorily in terms of four predictors.

The paper "**Integrating Drone Technology into an Innovative Agrometeorological Methodology for the Precise and Real-Time Estimation of Crop Water Requirements**" [5] by Stavros Alexandris, Emmanouil Psomiadis, Nikolaos Proutsos, Panos Philippopoulos, Ioannis Charalampopoulos, George Kakaletris, Eleni-Magda Papoutsi, Stylianos Vassilakis and Antonios Paraskevopoulos, aimed to present a new methodology and the equipment used in the assessment of crop water stress by spatial measurements of canopy temperature, air temperature, and relative humidity from sensors incorporated into an unmanned aerial vehicle (UAV) from a pilot implementation in a potato cultivation field. The functionality of the proposed system was certified (accuracy of the UAV path and flight altitude, reliability of the aerial data acquisition system, communication stability between UAVs and ground base). Their findings indicated that the canopy temperatures derived from the ground meteorological station, the onboard aerial micrometeorological system, and the portable IRT radiometers produced a suitable thermal image from the surface of the crop. The subsystems can be useful for supporting applications that are significant for irrigation water management and programming, such as irrigation alerting and scheduling, crop surveillance, and irrigation water management. However, the authors state that more efforts are necessary to make these technologies more user-friendly and available for all end users, covering different advantages for a precise crop water stress evaluation.

The paper "**Estimation of Daily Potential Evapotranspiration in Real-Time from GK2A/AMI Data Using Artificial Neural Network for the Korean Peninsula**" [6] by Jae-Cheol Jang, Eun-Ha Sohn, Ki-Hong Park and Soobong Lee, developed a model that estimates the daily PET based on ANN using the GEOstationary Korea Multi-Purpose SATellite 2A (GEO-KOMPSAT 2A, GK2A). The objective was to retrieve real-time daily ET with a spatial resolution of 1 km for hydrological resource monitoring on the Korean Peninsula. To reflect the complex relationships and nonlinearity between the GK2A-derived data and ET, the precipitation and digital elevation data were used as input for the ANN. Daily PET from KMA were used as reference data for the ANN model training. The accuracy of the model was verified by comparing the modeled data with the ET from in-situ measurements of the KMA and National Institute of Forest Science (NIFoS). In comparison with the station-derived PM-ET, the ANN-based derived PET showed high accuracy, while validating the spatial distribution and the ANN model-estimated daily PET showed high accuracy at all KMA stations. Additionally, the derived PET models performed particularly better than the Terra/MODIS PET product for the eastern coastal region of the Korean Peninsula, where the elevation changes dramatically.

The paper "**Simplified Interception/Evaporation Model**" [7] by Giorgio Baiamonte, explored the rainfall partitioning in net rainfall and evaporation losses by the canopy, using a very simplified sketch of the interception process, which combines a modified exponential equation from the literature (Merrian model), accounting for the antecedent volume stored on the canopy, and a simple power-law equation to compute the evaporation by the wet canopy. Even though the considered approach is far from the physically based approaches, the latter may require many parameters that are not easy to determine. It is shown that the simplified parsimonious approach may lead to a reasonable quantification of this important component of the hydrologic cycle, which can be useful when a rough estimate is required, in the absence of a detailed characterization of the canopy and of the climate conditions. It is also shown that the Merrian model can be derived by considering a simple linear storage model. The application of the suggested procedure was performed for faba bean cover crop, which was described according to the general lengths of four distinct growth stages considered in FAO56, whereas LAI and interception capacity were obtained from the literature. Since few are parameters required, this simple approach could be applied at large scale when a rough estimate of evaporation loss by wet canopy is necessary, in the absence of a detailed characterization of canopy and climate.

The paper "**Sensitivity of the Evapotranspiration Deficit Index to Its Parameters and Different Temporal Scales**" [8] by Frank Joseph Wambura, investigated the sensitivity of the evapotranspiration deficit index (ETDI) to its parameters, and to data at different temporal scales. The parameter sensitivity test revealed that ETDI is less sensitive when the (a, b)-parameters range from (0.1, 1.8) to (0.5, 1.0) inclusive, and more sensitive when they approach (0.9, 0.2). Since the ETDI is sensitive to different parameter combinations, the selection of an optimal parameter combination might rely on information from specific locations. Moreover, an optimal parameter combination can also be obtained when ETDI is calibrated against other drought indices or durations of historically severe drought events. The temporal scale sensitivity test at the twelve points in the river basin showed that the number of drought events, the total drought durations, and durations per event decrease as the temporal scale increases. Therefore, small temporal scale ET data are highly recommended to increase the accuracy of ETDI-based drought characteristics.

The paper "**Estimation of Reference Evapotranspiration Using Spatial and Temporal Machine Learning Approaches**" [9] by Ali Rashid Niaghi, Oveis Hassanijalilian and Jalal Shiri, investigated the effect of different input combinations of meteorological data on the accuracy of daily ETo estimation in subhumid climate using gene expression programming (GEP), support vector machine (SVM), multiple linear regression (LR), and random forest (RF) methods. They compared the spatial and local prediction capabilities of the different machine learning (ML) techniques in ETo estimation and evaluated the performance of the models based on the various study years and meteorological stations. The comparison of the performance accuracy of the applied models revealed that the RF model was, in general, the best for all combinations among the four defined models, in general. The LR, GEP, and SVM models were improved when a local approach was used, except for the RF model, which was less accurate with a local approach. The radiation-based combination was the most accurate predictor among all models tested. The results showed that due to the flat topography of the study area with high wind speeds during the growing season, the inclusion of the wind used as a parameter to build the model architecture and estimate the ETo could increase the accuracy of the prediction. In addition, it might be more practical to apply the spatial RF model for stations with missing meteorological data without the need for local training. The recommended application of spatial RF using radiation combination allows for a more reliable estimate of ETo to fill the missing values for more precise water management purposes.

The paper "**Evapotranspiration Trends and Interactions in Light of the Anthropogenic Footprint and the Climate Crisis: A Review**" [10] by Stavroula Dimitriadou and Konstantinos G. Nikolakopoulos, reviewed emerging ET trends over the latest decades in areas with different environmental conditions in the context of the ongoing climate change. Additionally, they focused on critical components such as the anthropogenic impact on ET and, the mechanisms in which ET participates in forest land-cover and wildfires, croplands (irrigation and cultivation practices), groundwater (quantity and quality), and ambient air. Five broad conclusions were deducted: First, Mediterranean climate regions (MCRs) appear to be vulnerable to the impacts of the ongoing increase in ET, especially during summertime, due to the ongoing precipitation shifting in winter and the air temperature warming (especially the rise in the minimum air temperature values) which is expected to be more severe in MCRs such as Southern Europe, in the summertime. Air temperature is considered a proxy of the energy state of the system. In water-limited areas, evaporative fractions can serve as a water-stress indicator. Second, the ET in tropical forests plays a rather beneficial role since it moderates the flooding risk during the wet season resulting in a net cooling effect. Third, in semi-arid to arid areas, an increase in ET and especially of evaporation constitutes an important problem due to sustained baseflow recessions which exacerbate the limited water availability. In these drought-prone areas, ET exacerbates soil salinization. Fourth, the relationship between ET and wildfires is of major importance. The impacts are site-specific and climate, and fire-severity-dependent. The hydrological processes may be altered if a critical amount of canopy loss occurs (e.g., 20% for semi-arid regions, 45% for tropical forests) occurs. Concurrently, the Reference evapotranspiration could serve as a fuel aridity measure to assess forest fire risk. Fifth, along with climate change, the consequences of human activity such as air pollution (aerosols, CO_2 emissions), land use/land cover shifting to agricultural uses with intensive productivity practices, large reforestation implementation, and large constructions (e.g., dams, dense and high urban buildings) have substantially changed the actual evapotranspiration rates during recent decades. Via the human footprint, the interpretation of the evaporation paradox has been made plausible.

Finally, Aristoteles Tegos, Nikolaos Malamos and Demetris Koutsoyiannis in their paper "**RASPOTION—A New Global PET Dataset by Means of Remote Monthly Temperature Data and Parametric Modelling**" [11], introduced a new monthly global PET dataset, named RASPOTION, by implementing the Parametric model with remote sensing data of mean air temperature, provided by a recent remote mean temperature dataset from 2003 to 2016. The dataset was validated with in situ samples (USA, Germany, Spain, Ireland, Greece, Australia, China) and by using spatial Penman–Monteith estimates in England. Overall, for the majority of the Earth's surface, RASPOTION constitutes a reliable monthly PET dataset, freely available to scientists across different research disciplines in order to assist scientific studies into the global hydrological cycle and decisions for both short- and long-term hydro-climatic policy actions.

3. Conclusions

Since we have been conducting research in the field of evaporation assessment for more than a decade and considering the remaining challenges within evaporation assessment research, this SI was a great opportunity to discover and promote new trends in evaporation analysis.

The state-of- the art review study research presented by MchMahon et al. [12] identifies six areas for further research which are: (i) hard-wired potential evaporation estimates; (ii) estimating evaporation without wind data; (iii) estimating evaporation without at-site data; (iv) dealing with an environment undergoing climate: increasing annual air temperature but decreasing pan evaporation rates; (v) daily meteorological data averaging over 24 h or day-light hours only; and (vi) finally, uncertainty in evaporation estimates. In addition to the above key research topics advanced remote sensing techniques can be further support the water engineering and scientific community and some featured papers with modern views have been presented in our SI along with the key outstanding issues presented above.

As Guest Editors, we are sharing our enthusiasm with the successful completion of the SI and we trust that the selected research papers will be a valuable contribution to the domain of geosciences in the years to come.

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