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Methods for Evapotranspiration in Hydrological Models

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Abstract

Current evapotranspiration is a basic hydrologic cycle mechanism and is an only concept related to the balance of land surface water and land surface resources. A key role in simulating the hydrological effect of climate change is evapotranspiration, and an analysis of the methods of evapotranspiration measurement in hydrological models is important. This paper summarizes first the evaluation methods of evapotranspiration applied in hydrological models and then classifies them in their mechanisms into integrated conversion methods and classification methods. In hydrological models integrated converting methods are usually used and there are two differences: The first is the evaporation estimation of potential methods, while the second one defines the relation between the evaporation potential and actual evapotranspiration. In hydrological models simplified empirical procedures for the calculation of the potential and actual evapotranspiration are widely utilized due to greater information requirements of the Penman-Monteith process and the existing data uncertainty. Depending on the complexity of the hydrological model and on the significance and complexity of selecting the most suitable evapotranspiration methods, various evapotranspiration estimation methods are used. Finally, this paper illustrates the future development patterns of hydrological modelling approaches for estimating evapotranspiration.

Key words: Actual Evapotranspiration, Function of Soil Moisture, Hydrological Model, Integrated conversion methods, Potential Evaporation.

Introduction

Evapotranspiration is a mixture of two separate processes, by which water is lost from the soil by evaporation on the one hand and evapotranspiration from the crop by transpiration. It is a key water balance process and an important energy balance component. Its reliable estimation is not only vital to studying climate change and water resources assessment, but has a significant value for use in the management of crop water requirements, drought monitoring and forecasting, efficient development and use of water resources and so forth [1], [2]. Land evapotranspiration is transparent and difficult to measure and should be calculated and estimated. In 1694, a researcher used the evaporator for the first time in order to assess water surface evaporation. The researcher combined air temperature, wind and humidity to evapotranspiration and introduced the Dalton Evaporation Law that established the principle of evaporation for the basin with clear physical significance [3]. Methods of evaporation measurements include the hydrological method, the micro-meteorological method, the method based on plant physiology and the method of scintillometer (figure 1).

The hydrological approach is used to determine the whole basin or sub-basin evapotranspiration based on the principle of water balance[4], [5]. This system tests the evapotranspiration either over a large time scale, typically over the years or over a low, regional scale or point scale. In the analyzed area, the micro-meteorological method is based on an equation of energy balance or aerodynamic equations to determine evapotranspiration. The assumptions made of the micro-meteorological system in practice are however difficult to achieve, resulting in major errors (aerodynamic method, Bowen ratio energy balance method), and also in the complicated manufacture of instruments, contributing to maintenance problems and high costs[6], [7]. All these difficulties make it hard to popularize this method. The physiology of plants by way of the method of determining the consumption of water of plants decides their transpiration in the reservoir. This would be the case with the scintillometer technique[8], [9]. Evapotranspiration can be calculated by many techniques, including evaporation of the water surface through a variety of potential evapotranspiration and current evapotranspiration calculations, but the majority of them only look at evapotranspiration from a particular surface such as bare soil, water and vegetation thus ignoring the water balance. Such approaches do not find evapotranspiration to be a significant hydrologic cycle mechanism but a static amount to be measured. The recent development of remote sensing methods is able to estimate the evapotranspiration of the basin scale but due to technological restrictions; it's difficult to comply with the time requirements, usually instantaneously, besides being susceptible to external conditions[10]. The calculation of actual evapotranspiration on the basis of hydrological models examines water and energy factors and can be measured at various spatial and temporal scales so that outcomes can satisfy the demand for evaluation and control of water resources. There are many different types of methods for evaluation of the evapotranspiration on the basis of existing hydrological models. At the same time, their results are rarely compared in terms of accuracy. The following sections analyzes the examination modules for evapotranspiration based on the existing hydrological modeling, and analyze their differences according to their estimated principles. Finally, the forward development trends in hydrological models are forecast for the evapotranspiration estimation methods.

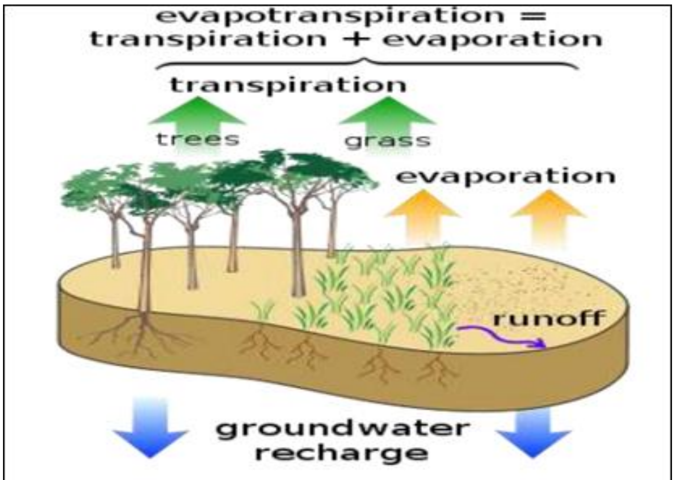

Figure 1: Evapotranspiration

1. Estimating Methods of Evapotranspiration In Hydrological Models:

Throughout hydrological models there are two classes of evaporating estimates: one evaluates water surface evaporation independently, transpiration and soil evaporation and then combines them into basin evaporation according to the pattern of land usage. The other estimates the potential evapotranspiration (ETp) first of all and then converts it into the actual evapotranspiration (ETa) applying function of soil moisture extraction. The first classification methods are referred to in this paper as classification methods, the second as integrated converting methods.

2. Reference Crop Evapotranspiration (ET0):

The amount of evapotranspiration from a reference surface not without water is regarded as evapotranspiration of reference crops and is referred to as ETo. A hypothetical reference plant for grass with special characteristics is the reference surface. Due to ambiguities in their meanings, the use of certain designations such as possible ET is highly discouraged. ETo is a climate parameter and it can be estimated from weather data. ETo describes the atmosphere's evaporating potential in a particular location and time of the year and does not take into account the crop characteristics and soil influences. The only factors affecting ETo are climate parameters.

3. Standard Conditions Crop Evapotranspiration (ETc):

The standard crop evapotranspiration, known as ETc, is an evapotranspiration of sick and well fertilised crops, which are cultivated in large fields and are grown under optimal soil water conditions and are fully produced in the given climatic conditions. From cool to warm medium temperature, ETc will be 1 to 9 mm / day. The amount of water required to cover the loss of the crop field is defined as the necessity for crop water. The values for crop evapotranspiration and crop water requirements are comparable, but the demand for crop water relates to the quantity of water to provide, while crop evapotranspiration refers to the water loss by evapotranspiration. The need for water irrigation is essentially the difference between the need for agricultural water and efficient precipitation. Additional water is also required for irrigation to leach salts and compensate for the non-uniformity of the application of water.

4. Differences between Integrated Methods Of Converting:

The following advantages of integral transforming approaches in evapotranspiration estimation are: they require few input variables, easy to use and have good adaptive abilities. They are therefore used extensively in hydrological models. Two differences found between the hydrological models: one is different mechanism of estimation of the potential evapotranspiration, usually used by researchers according to the availability of data; the other is divergent moisture extraction function of the soils which, in spite of the same basic format and differentiates significantly in complexity. The following sections discuss these two differences.

4.1. Function for Soil Moisture Extraction:

The actual evapotranspiration in conceptual hydrological models is focused upon the potential evapotranspiration and availability of water in soil. The soil moisture level is indicated by actual soil moisture divided by soil moisture capability. When the actual soil moisture content is higher than the soil moisture content of the evapotranspiration, evapotranspiration is limited to the conditions of the climate and water will evaporate at the most. Evapotranspiration decreases with reduced soil humidity until the actual soil humidity content is smaller than soil withering, or soil water reaches the largest deficit. Evapotranspiration is then constrained only by the supply conditions of water and by the levels in evapotranspiration to zero. The following is the basic formula of the soil moisture extraction function:

$$ETa = ETp\left(\frac{SMT}{SMC}\right)$$

Where actual soil moisture is SMT and soil moisture capacity is SMC.

In commonly used hydrological models, some researchers summarized soil moisture extraction functions. The actual evapotranspiration and evapotranspiration ratios change when there is water in the soil. Their relation indicates its format in relation to the type of soil and the Leaf Area Index (LAI), which is close to but hard to define the growth stage of vegetables.

4.2. Methods of Estimation For Potential Evapotranspiration:

Potential evapotranspiration is a significant input in the simulation of the hydrological cycle. The use of different methods to measure possible evapotranspiration impacts the precision of simulation of a particular hydrological model. There are many different types of models for evapotranspiration. The effect of various possible evapotranspiration calculating methods on the HBV model simulation precision was analyzed by researchers. They found that the Penman method with temperature adjustment improved the precise simulation; however, the results obtained were better with the Priestley-Taylor method. Therefore, the Priestley-Taylor method was the best method, improving the negative evapotranspiration in winter by taking soil heat flux into consideration. Based on their mechanisms, the possible methods for estimating evapotranspiration can be categorized into strength, temperature and mass transference methods. The equation of energy uses the idea of energy balance as an approximation of evapotranspiration potential.

5. Factors Affecting Evapotranspiration:

The factors which affect evaporation and transpiration are the crop characteristics, weather parameters, management and environment.

- Weather parameters: Evapotranspiration's major weather parameters are, air temperature, radiation, wind speed and humidity. A reference crop evapotranspiration (ETo) represents the atmosphere's evaporational power. The evapotranspiration of the reference crop reflects the evapotranspiration from standard vegetation.
- Crop factors: When assessing the evapotranspiration of crops grown in large, well-managed fields, the type of crop, variety and stage of development should be considered. For various crop types varying ET levels in different environmental conditions result in different transpiration resistance, crop roughness, crop height, reflection, crop rooting and ground cover characteristics.
- Environmental and Management conditions: The crop development can be limited and the evapotranspiration reduced due to factors such as poor soil fertility, soil salinity, limited fertilizer application, presence of impenetrable or hard soil horizons, absence of control over diseases and pests and soils.

The ground cover, soil water and plant density content must also be addressed in determining ET. The impact of the soil water content on ET is mainly calculated by the extent and the soil type of the water deficit. On the other hand, there will be too much water that damages the root and restricts dramatically water absorption by inhibiting respiration.

6. Development Trends:

Hydrological model simulates and simplifies the interconnections between elements of the water cycle. On the one side, the rules of the hydrological cycle are tested through hydrological models. Therefore, an attempt is made to approximate mechanisms of the real hydrologic procedure through a variety of experiments and mathematics equations that more precisely reflect them and to build more complex models such as the SHE model. On the other side, models are created for solving an existing problem that is embedded in specific conditions to find a simple and efficient solution to reduce the complexities of small procedures. The emerging pattern in hydrological models of evapotranspiration prediction methods is compatible with the above-mentioned directions, whereas the integrated converting methods focus on the straightforward relationship between evapotranspiration changes, the classification methods are designed to develop into more complex mechanisms, with complex equations that describe the amount of water in all types of evapotranspiration and conversion of energy. Therefore, it is possible to illustrate two main trends in the methods of evaporation assessment: first, in order to simplify its practice and second, in terms of its increasing complexity.

Conclusion

In the water balance Evapotranspiration plays a key role. Evapotranspiration consumes the water from plant interception, soil water and surface water. According to statistics, evapotranspiration in humid areas represents approximately 50% of annual precipitation and around 90% in arid regions. Actual evapotranspiration observations are highly complicated and vulnerable to external factors influencing, so indirect estimation methods are often employed. Estimates of actual hydrological cycle simulation evapotranspiration are of great importance for adaptive maintenance of water resources under a changeable climate. There is however various methods focused on hydrological equations to measure the evapotranspiration. The following approaches are examined:

- Firstly, the paper examined the methods used in hydrological models for estimating evapotranspiration. Based on their features the classification aggregation methods and the combined conversion methods were classified into two groups. Next, they evaluate various types of evapotranspiration and then get the evapotranspiration in the basin based on the patterns of land usage. The latter converts possible evapotranspiration according to the soil moisture content into real evapotranspiration. In order to assess potential evapotranspiration and the extraction of soil humidity, the differences exist between the integrated conversion methods. This paper outlines 14 feasible forms of measurement approaches for evapotranspiration and 12 types of extraction features.
- There are certain uncertainties regarding input, output and layout of hydrological models, and there are high data criteria for the scientifically dependent Penman-Monteith process. It severely impairs the accuracy of the calculations of the hydrological cycle. They must therefore explore further how consistent theoretical evapotranspiration estimation calculations for various hydrological models and soil moisture extraction functions can be used to common their uncertainty.
- In the context of the models, this paper offers two key recommendations for the creation of them, namely the sophistication of methods for the measurement of evapotranspiration in the hydrological model and the simplification in the field of research.

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