PhD Thesis Summary

SPECIFYING LAKE AND AREAL EVAPOTRANSPIRATION RATES IN HUNGARY

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Budapest, 2011


Preliminary research

Over land evaporation usually exceeds runoff. Within the hydrological cycle evaporation is an important, highly energy demanding physical phenomenon that is not only influenced by land use and climate change, but it also influences the latter significantly. Without reliable evaporation estimation, independent from other elements of the water-balance, it is not possible to gain better understanding the hydrological cycle and to improve hydrological and climate forecasts.

Recently there has been a renewed interest in Bouchet’s [10] complementary relationship since this is probably the only tool currently available to define areal evaporation based solely on widely accessible standard meteorological measurements. This theory constitutes the basis for the evaporation estimation model of Morton et al. [11], the so called WREVAP program.

In areal evapotranspiration estimation methods a general obstacle comes from the difficulty soil moisture can be assessed, especially at a large scale. Up to now, collecting such data has proved to be difficult and expensive.

At the beginning of the 2000 NASA launched two satellites into orbit: TERRA and AQUA. These two satellites provided new prospects in hydrology and within this, in evaporation estimation, since they started to measure several new variables that until then had not been possible at large spatial scales. Daytime surface temperature is one of these variables, playing an essential role in my PhD research. The soil moisture influences the surface temperature through evapotranspiration, hence measuring the surface temperature gives indirect information about the soil moisture, which can significantly promote hydrological investigations.
Objectives

One of my objectives was to demonstrate the detailed calculation method of net radiation because the Priestley-Taylor and Penman potential evaporation equations, which are integral in this thesis, and in Morton’s WREVAP program, are also in great part a function of it.

My research consists of two main parts: specifying lake and areal evaporation rates. I estimated the monthly evaporation rates of Lake Balaton and Lake Velencei. My aim was to provide a simply applicable alternative (by applying monthly weighting of the Priestley-Taylor and Penman equations) for the estimation formulae currently used for these two lakes, with the same or even higher accuracy. This part of the research was carried out within the CLAVIER (Climate Change and Variability) project funded by the European Union’s Sixth Framework Programme.

When estimating evapotranspiration, my goal was to establish a method applicable over Hungary utilizing the high (1x1 km) resolution surface temperature satellite measurements. The model, which was set up based on the above mentioned goals, makes it possible to estimate evapotranspiration on a monthly basis, covering whole country.
New scientific results

**Thesis statement 1:**

I demonstrated that by applying monthly weights for the Penman and Priestly-Taylor equations (i.e., the weighting method) open water evaporation can be simply estimated. [3–5]

The advantage of the combination method is that only basic meteorological data are needed for its application. I confirmed that the calibrated weighting factors are not sensitive to the position of the stations relative to the lake, i.e., whether they are taken from the upwind side (as it is prescribed for the Penman equation) or calculated as an average from the measurement sites around the lake.

The method was tested on Lake Balaton and Lake Velencei.

![Graph showing annual evaporation values of Lake Balaton in the verification period (odd years).]
Annual evaporation values of Lake Velencei in the calibration period (even years).

Thesis statement 2:

For the estimation of spatially changing areal evapotranspiration rates I introduced a linear transformation method based on MODIS data and Morton’s WREVAP program. [7–9]

The monthly changing linear transformation requires the specification of two anchor points: the temperature of the coldest pixel values together with their Priestley-Taylor evapotranspiration, and the averaged daytime surface temperature with the corresponding areal evapotranspiration rate provided by Morton’s WREVAP program. By fitting a line on these anchor points the areal evaporation of the cell with a given surface temperature can be determined. The basic requirement of this method is that surface conditions (net radiation and roughness) do not change significantly at a 1-km resolution.
Validation of the method was performed with the help of catchment water-balances and eddy-covariance measurements.

Validation of the evapotranspiration estimates with eddy-covariance data on a monthly basis, where n is the number of the months.
Regression plot of the evapotranspiration estimates against eddy-covariance and against catchment water-balance data at a multi-year basis in Hungary, where n is the number of the years.

Thesis statement 3:

As surface temperatures decrease with elevation, the transformation equations must be corrected. [7–9]

For application in Hungary, I delinated three elevation zones, to each of which I assigned a linear transformation that is characteristic for the centre of the zone. The actual linear equation estimating the evapotranspiration rate cell-by-cell arises from a linear interpolation of these transformations as a function of the cell elevation.

Validation of the transformation equation was performed with the help of catchment water-balance data and eddy-covariance measurements.
9-year averaged (2000-2008) mean annual evapotranspiration rates (mm).

9-year averaged (2000-2008) mean annual runoff rates (mm).
Possible use of thesis results

Accurate estimation of open water evaporation is indispensable for reservoir planning and sizing, and for the modification of lake water-balance components. An example for this is the consideration of water supplement to Lake Balaton in the early 2000’s.

Estimating evapotranspiration independently from other water-balance components plays an important role in calculating water budgets for watersheds where flow-rate measurements are missing. This is valid mostly for smaller catchments valid, where measurements are not or only irregularly carried out. Due to its high spatial resolution, the CREMAP model makes it possible to estimate annual mean runoff even for a watershed of only a few km² in area. The model can be successfully used also for the assessment of agricultural irrigation demand.

Future research possibilities

Further refinement of the weighting method could be achieved by specifying seasonally varying Priestley-Taylor parameter (α).

The evapotranspiration method in its present form is not recommended to be applied in mountainous areas of rugged terrain or in areas with strong surface albedo changes at a scale in excess of the 1-km resolution of the MODIS data. Research is currently undertaken to extend the method to conditions when the spatially constant net radiation requirement is violated. Employing high-resolution digital elevation models and MODIS surface albedo data, known changes in albedo as well as in mean surface slope and aspect among the MODIS cells can be accounted for in the transformation equations. Further research is required to investigate the effect of significant changes (i.e., an order of magnitude) in the momentum roughness height among the MODIS cells, and how to incorporate such effects in the present modeling framework.
List of publications related to the thesis:

Hungarian journal paper with review:


International journal papers:


Foreign-language paper in Hungarian journal:


Foreign-language book chapter:


Further references in the thesis
