Update of evapotranspiration dataset (HADES)

Seminar “Geodata Analysis and Modelling”

Institute of Geography

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Students:

Cristina Joss

15-113-426

cristina.joss@students.unibe.ch

Thierry Schilli

15-101-926

thierry.schilli@students.unibe.ch

Supervisors:

PD Dr. Andreas Paul Zischg

andreas.zischg@giub.unibe.ch

Dr. Pascal Horton

pascal.horton@giub.unibe.ch

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Goal

Current evapotranspiration raster dataset from HADES exhibits too high or low values for a certain land cover. Therefore, there is a need for identifying inaccuracies in the evapotranspiration dataset. This task was carried out within the framework of the "Geodataanalysis and Modelling" seminar. The main goal was to identify the errors using Python and ArcGIS, correct them and create a new evapotranspiration map.

Scientific Background

Evapotranspiration

Evapotranspiration refers to the process of evaporation of water, which takes place in two subprocesses. Plants absorb water through the roots and release it through the leaves, which is referred to transpiration. When water evaporates from the soil surface, it is called evaporation. The term evapotranspiration is the sum of transpiration and evaporation. We need to keep that definition in mind when we improve the evapotranspiration raster dataset. (Strahler et al. 2009)

Evapotranspiration model TRAIN

Our model is based on the evapotranspiration model TRAIN which "includes information from comprehensive field studies of evaporation and associated sub-processes and has been designed to simulate the spatial pattern of actual evapotranspiration" (Menzel 1999, S. 3). The original evapotranspiration dataset we refer to, is also based on TRAIN.

TRAIN's method for surface modelling of evaporation was calculated using complex water and energy flows. A series of input data was required for the calculation of the study area. Moreover, the dependence on temporal and spatial scales is pointed out. Conditions such as those of meteorology can only be considered marginally and were not taken into account in TRAIN's calculations (Menzel 1999). The same applies to the present work on the improvement of the evapotranspiration map.

The data sets for land use, which are variable in time, are of major application for the present study. Table 1 gives an overview of the different usage classes and the associated mean evaporation. In the cases of forest and agriculture, the evaporation height was additionally adjusted to the height. (Menzel 1999)

Class	Medium Evaporation (mm)
Forest (every altitude)	616
(600m)	712
(1800m)	523
Agriculture (every altitude)	436
(600m)	537
(1800m)	334
Settlement and industriy	434
Traffic area	199
Waters	901
Rock surface	234
Ice and firn surface	156
Total area Switzerland	**484**

Table 1: "Average annual evaporation in Switzerland, separated according to the most important land cover classes. For forests and agriculture, the mean values for individual altitude levels are also given" (Menzel 1999, P. 21).

Input data

The following datasets were provided to us for the project: raster of annual evaporation 1973-1992 (HADES), digital elevation model, and a land cover dataset consisting of glacier, water, wetland, rock, loose rock, forest, coniferous forest, deciduous forest, mixed forest, brush vegetation, grass and herb vegetation, agriculture and settlement zone (CORINE).

Method

For the methodological procedure the software ArcGIS was used on the one hand and PyCharm on the other hand. The Python script was edited in PyCharm, which was gradually read and applied in ArcGIS. The input data itself was imported into ArcGIS to provide an improved evapotranspiration map. The process from a currently error-prone evapotranspiration map from HADES to a revised map took place in numerous single steps. In order to fulfill our main goal of the project, creating an improved evapotranspiration map, a toolbox using python was created. The result was a whole, coherent script. As already mentioned, every step of the script was tested in ArcGIS. The following sections explain these steps (See Appendix).

At the beginning, the needed datasets were read into ArcGIS (Esri 2019). In a further step, the focus was on the projection of the raster data.

Afterwards, DEM derivatives for slope and aspect had to be created. Again, a tool of ArcGIS was used, where the different derivates were classified by "reclassify". Five classes were created for slope and aspect. In the case of slope, the following subdivisions were made: 1 (0°-2°); 2 (2°-8°); 3 (8°-16°); 4 (16°-45°) and 5 (45°-90°). Aspect has the subdivisions: 1 (North: 0°-45°; 315°-360°); 2 (East: 45°-135°); 3 (South: 135°-225°) and 4 (West: 225°-315°); 5 (Flat Area: -1).

As a next step, the land cover dataset had to be merged into a new dataset, to be sure, which class reflects which cover. Due to similar evapotranspiration, the following land covers were merged into one class: Water and Wetlands; Rock and Loose Rock; Forest, Coniferous Forest, Deciduous Forest, and Mixed Forest.

The topography and the land cover data were then both combined into a single characteristics dataset. In order to assign an evapotranspiration map in a later step, classes had to be created for each combination of slope, aspect and landcover the following way:

$$(Aspect.tif \, * \, 100) \, + \, (Slope.tif \, * \, 10) \, + LandCover.tif \; = \; Characteristics.tif$$

with the key value xyz, where x = class of aspect, y = class of slope, z = land cover.

Afterwards, zonal statistics were made, which calculated the median of the original evapotranspiration values based on the characteristics. This is basically the new evapotranspiration dataset. For this step, the original evapotranspiration dataset had to be resampled into the resolution of the new one.
Now it was time to make a comparison between the new and the old evapotranspiration map. The threshold was defined as a 44% quantile, since the difference of the old and the new evapotranspiration value range expanded for 44 %. Every value of the original evapotranspiration dataset not fitting into the threshold was given the new value 1. All other pixel values were marked with the value of 0. Based on this raster, errors in the original dataset were replaced by the calculated new evapotranspiration dataset. In order to do so, the new dataset had to be resampled into the lower resolution of the original dataset.

Results

Python script

The edited script for the toolbox in ArcGis consists of several steps. At the beginning, the needed system modules are imported: arcpy and some submodules for the connection to ArcGIS and os for managing saving options. Then, parameter read ins are created to set the workspace and to read in the available input data into ArcGIS Moreover, a folder for the results needs to be created which may differ from the definition in the script. The specific projection can be chosen by the toolbox user. Subsequently, the creation of DEM derivates , slope and aspect, the reclassification of these and individual land covers takes place. According to that, classes were defined based on chosen thresholds. It is necessary to redefine those thresholds in case of other working topics. The last few steps regarding combination of the different rasters, zonal statistics, prepare raster for the update and the recalculation of a new evapotranspiration map are already explained in the methodological chapter.

Figure one shows the result of this methodological step. The errors marked with one are visible as red dots on the map. The distribution of those dots indicates that most errors were found in the Alps of Switzerland. In particular the canton of Tessin and Wallis are the most effected by those errors. In addition to this a closer look on the figure two has to be made. It shows additionally to figure one the landcover of a certain area on the map. Obviously in the Swiss Plateau where agriculture, settlement areas and Grass weren't that strong affected with errors. Whereas in regions with glacier, water and wetlands a great number of errors could have been discovered. In a further step the raster cells marked with

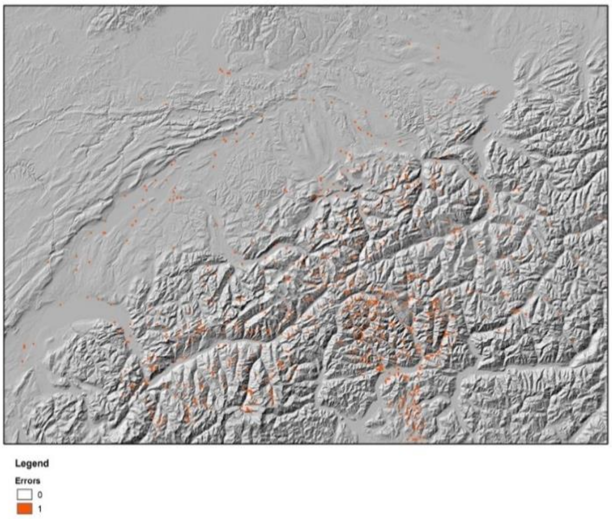

Figure 2:Map of Switzerland with marked Errors

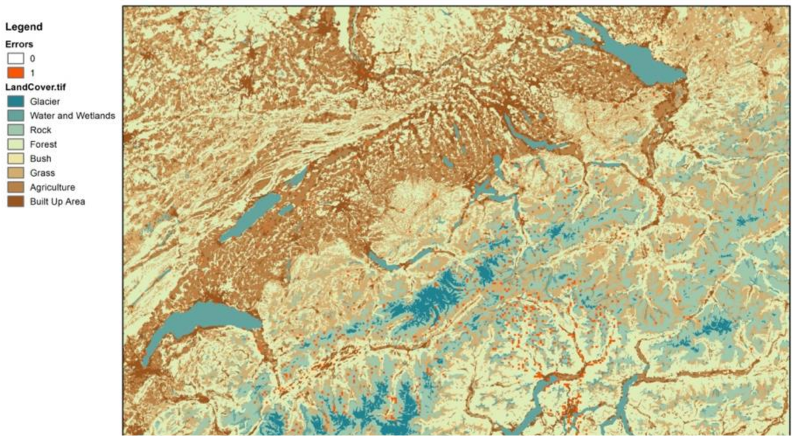

Figure 1: Map of Switzerland with marked errors and landcover

the value 1 had to be recalculated. At that time every component was ready to create a new evapotranspiration map.

Upgraded evapotranspiration map

Figure three shows the new evapotranspiration map. The evapotranspiration entities range from 191, as the lowest ones, until 883, as the highest entities. The high evapotranspiration values are mostly distributed in the Swiss Plateau and the low entities rather located in the Swiss Alps.

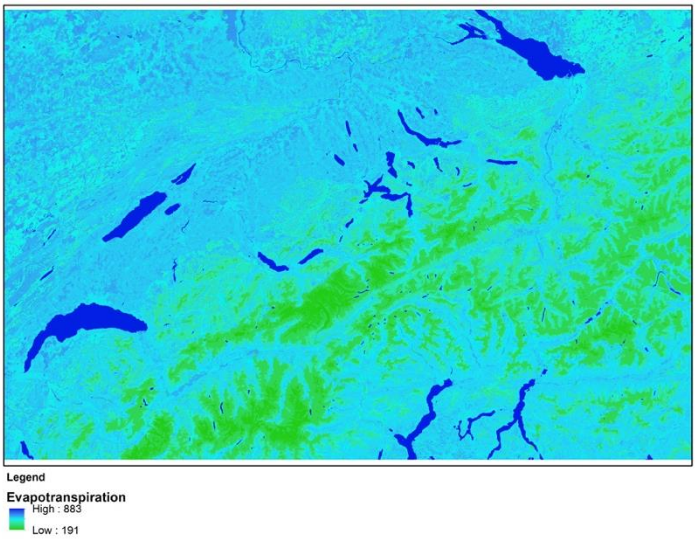

Figure 3:Evaportranspiration map based on land cover, topography, and the original values (resolution 25m).

Figure four was created by recalculating the errors and shows the updated evapotranspiration map. A wide range of entities are recognizable from 30 to 1028. Again the distribution of the higher values are spread in the Swiss Plateau and the lower one in the Swiss Alps.

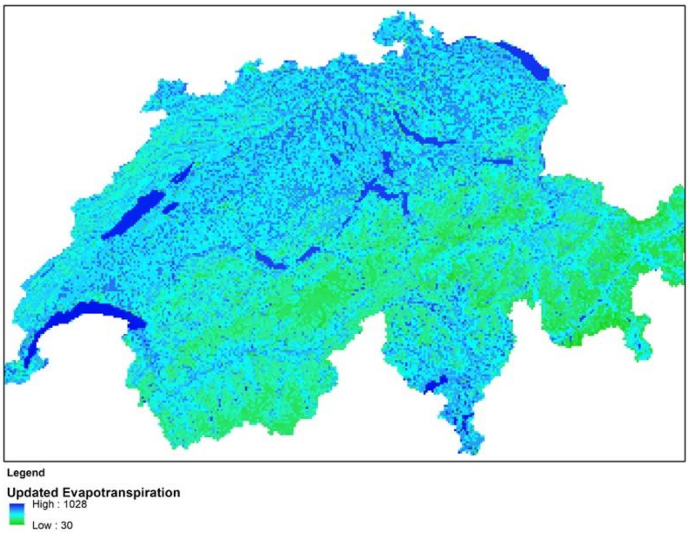

Figure 4:Updated evapotranspiration map (resolution 1000m).

Interpretation

The original evapotranspiration map (Figure three) compared with the updated evapotranspiration map (Figure four) shows differences regarding the range of evapotranspiration entities and the distribution of the values on the map.

A smaller range of entities in the recalculated evapotranspiration map than the error-prone map can be detected. The reason for this is that due to the choice of the median, the extreme values are filtered out and deleted from the range. This also results in a limitation of our approach, since it was not analyzed whether the extreme values represent false or correct information.

Analysis of new evapotranspiration raster

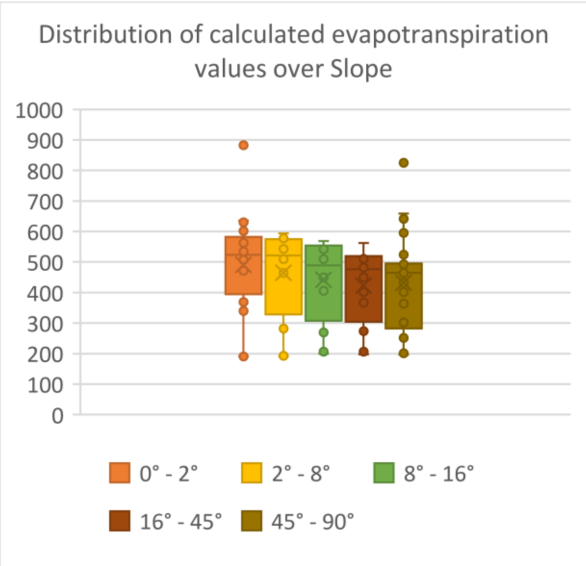

Figure 6: Boxplot of distribution of calculated evapotranspiration values over slope (own figure).

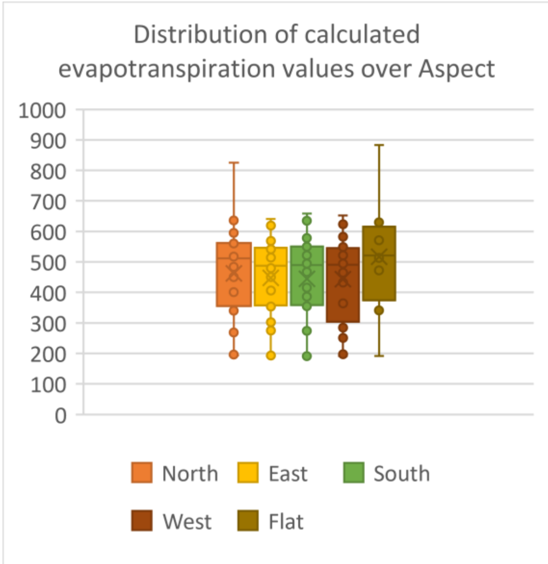

Figure 5: Boxplot of distribution of calculated evapotranspiration values over aspect (own figure).

Figure five and six show the distribution of the new calculated evapotranspiration raster over slope and aspect. Based on these two factors, it becomes apparent that most of the values are within the two quartiles. In addition, there are very few rough outliers. However, the quartiles are very far apart. This shows that both slope and aspect influence the evapotranspiration, but not very strongly.

Another picture is shown in figure seven on land cover: the quartiles, but also the whiskers, are much closer together. Glaciers, agriculture and built up areas in particular show very precise results. This means that it is especially in these areas that land cover significantly influences evapotranspiration. The outliers around 800 and 900 can also been seen in the upper figures. This probably concerns pixels, which still have overlaps with water bodies with very high evapotranspiration values even in the 25 m resolution.

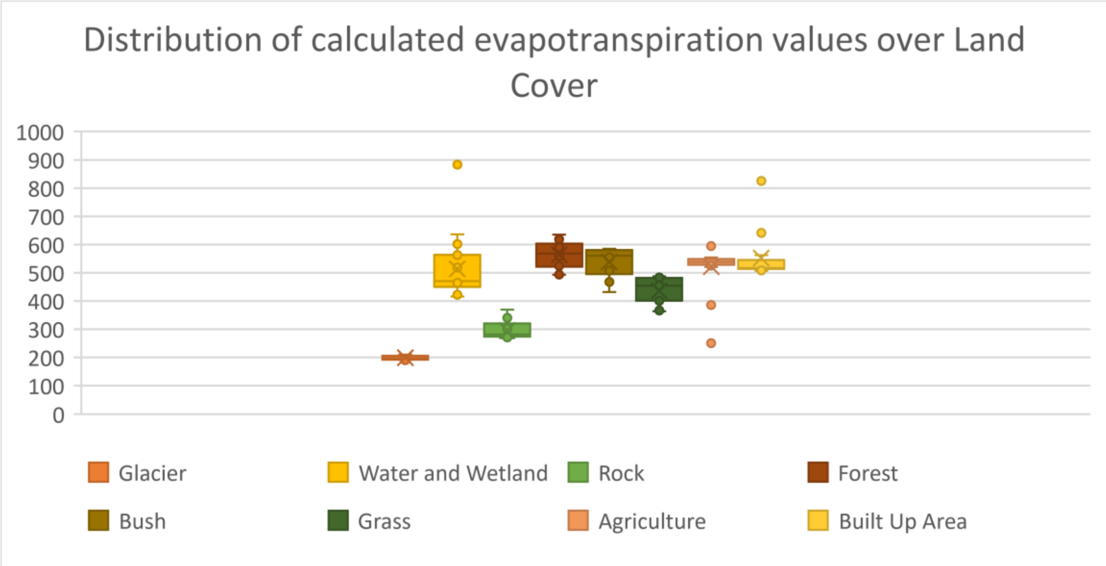

Figure 7: Boxplot of distribution of calculated evapotranspiration values over land cover (own figure).

Challenges

Our first approach in order to identify inaccuracies was divided into two ideas. Firstly, the existing evapotranspiration raster should be transformed into a matrix. Second, the inaccuracies should be recognized with a for/in-loop programmed in a python script and additionally a neighborhood-analysis should be conducted. These two steps should be applied in PyCharm. During the process of our project we decided to work with a GIS software. Therefore, we did not have to transform our raster model into a matrix, because we conducted every step in ArcGIS, where it was possible to work directly with rasters. Instead of a loop-function in python a script for a toolbox in ArcGIS was created. The reason for this was the ease of use with the existing data, as well as the application of the script for further work.

Discussion

The original goal was to scale the different layers, as well as the map to be created, down to a higher resolution of 250m * 250m. However, this did not make sense, as we could not create a higher resolution of the content itself. For this reason the resolution of the original dataset of 1km * 1km was maintained. Hence, the new evapotranspiration dataset based on land cover, topography and the median of the original one is available in a 25m resolution.

With regard to the different land coverages, it has to be mentioned that only one general forest was taken into account. However, there are different types of forest, which also have different effects on the evaporation

Outlook

The python script for calculating a new evapotranspiration map was conducted for applying it with only ArcGIS. In order to use it with other programs like QGIS, an adaptation will be needed. Our new evapotranspiration map can be used for the Hades website. Before doing it the script has to be analyzed regarding mistakes of our choice of the median and classifications.

References

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Appendix

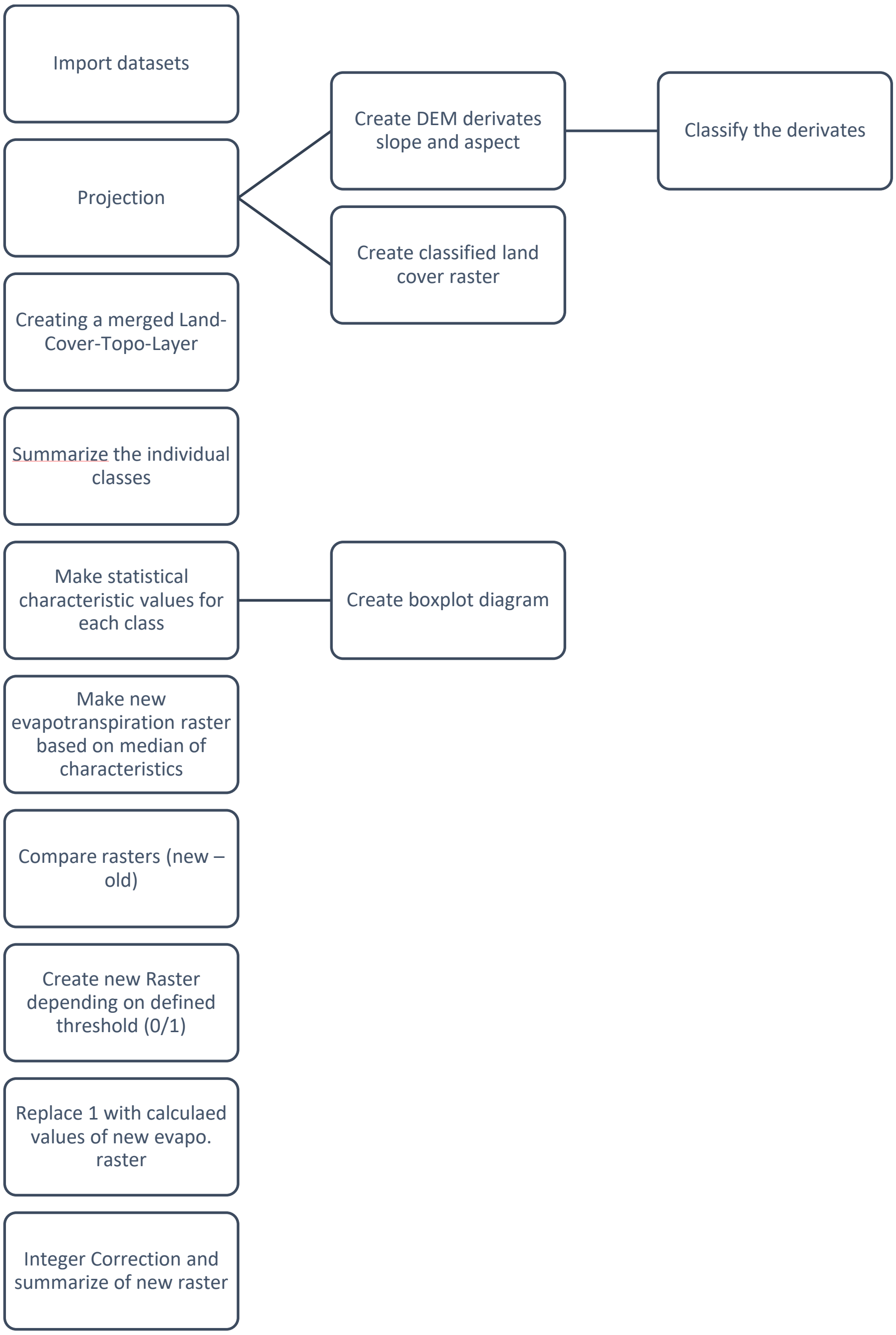

Figure 8: Workflow