e2o_dstools Documentation

Release Test

Jaap Schellekens

January 09, 2015

CONTENTS

Note: This documentation is for version 0.1 of e2o_dstools, release Test This documentation was generated January 09, 2015

CHAPTER

ONE

INTRODUCTION

Note: A html version of this version of the documentation can be found at (http://wflow.googlecode.com/svn/tags/1.0RC6/doc/_build/html/index.html).

CHAPTER

TWO

THE RADIATION MODULE

2.1 Radiation correction on a digital elevation model

2.1.1 Introduction

In general evaporation amounts are determined for about 90% by radiation input. Radiation at the earth's surface is determined by the potential solar radiation at the edge of the earths atmosphere and the filtering within the atmosphere. The first component can be easily determined from equations. The reduction due to clouds etc can be estimated by incorporation short wave measurements but if these are not available cloud cover estimates can also be used. By combining this with a DEM radiation at the earths surface can be determined including the effects of aspect and shading.

2.1.2 Description

Adjusted after van Dam 2000

This section gives a short description. Another description can be found at http://re.jrc.cec.eu.int/pvgis/pv/solres/solres.htm.

Potential solar radiation is the radiation of an unobstructed or cloudless sky. The magnitude of the potential solar radiation depends on the position of the sun the solar altitude or solar angleduring the day, the inclination of the solar rays with the earth's surface, the amount of radiation at the outer layer of the earth's atmosphere, the transmissivity of the sky and the altitude of the earth's surface.

Solar declination is the annual fluctuation of the sun between the two tropics and varies between –23 and +23 degrees latitude. Solar declination is calculated per Day (Julian day number):

$$\delta = -23.4cos(360(Day + 10)/365)$$

The hour angle describes the movement of the sun around the earth in 24 hours, which equals 15 degrees longitude per hour (360 deg /24h). The hour angle n is calculated for each Hour (whole hour of the day):

$$n = (15\dot{H}our - 12)$$

The position or height of the sun above the horizon is called the solar altitude or solar angle. Solar altitude α (deg) is calculated for each location, determined by the location's latitude ψ (deg), declination and hour angle:

$$sin(\alpha) = sin(\psi)sin(\delta) + cos(\psi)cos(\delta)cos(n)$$

Solar azimuth is the angle between the solar rays and the North-South axis of the earth. Solar azimuth β_s (deg) is calculated by:

$$cos(\beta_s) = (sin(\delta)cos(\psi) - cos(\delta)sin(\psi)cos(n))/cos(\alpha)$$
$$forHour \leq 12 : \beta_s = \beta_s$$
$$forHour > 12 : \beta_s = 360 - \beta_s$$

Surface azimuth or aspect β_1 (deg) is the orientation of the land surface or slope to the North-South axis of the sun. Slope φ (deg) is the maximum rate of change in elevation.

The angle of incidence is the angle between the perpendicular plane of the incoming solar rays and the surface on which they are projected, defined by the aspect and slope of that surface. The angle of incidence ϑ (deg) is calculated with the solar angle α (deg), the slope of the land surface φ (deg), the azimuth of the sun β_s (deg) and azimuth of the land surface β_1 (deg):

$$cos(\vartheta) = cos(\alpha)sin(\varphi)cos(\beta_s - \beta_1) + sin(\alpha)cos(\varphi)$$

The second section of the radiation module calculates the potential solar energy. The amount of solar radiation that reaches the outer atmosphere is decreased by the travelling distance of the solar rays through the sky to the surface, the transmissivity of the sky and the cloud factor.

Solar energy at the outer layer of the atmosphere $Sout(Wm^2)$ is calculated by (Kreider & Kreith 1975):

$$S_{out} = S_c(1 + 0.034cos(360Day/365))$$

where $S_c(Wm^2)$ is the solar constant of 1367 Wm^2 (Duffie & Beckman 1991). The solar 'constant' is subject to much discussion. Gates (1980) gives a value of 1360 Wm^2. The NASA reports a value of 1353 Wm^2 (Jansen 1985), while Duncan et al. (1982) give a value of 1367 Wm^2. Monteith and Unsworth (1990) measured the highest value of 1373 W.m-2. The World Radiation Centre uses a value of 1367 Wm^2 (Duffie & Beckman 1991) and this value is also used in this study.

The solar radiation energy that reaches the earth's surface is decreased due to the length of the air mass it has to pass through and the transmissivity τ (% or fraction) of the sky. The radiation flux through a hypothetical plane normal to the beam ($S_{nor}Wm^2$) is given by (Gates 1980):

$$S_{nor} = S_{out}\tau^{Mh}$$

in which Mh (% or fraction) is the relative path length of the optical air mass at altitude h (m). Transmissivity (τ) is usually between 0.5 and 0.8, but can be as low as 0.4 in the tropics (Whitmore et al. 1993), but mostly a value of 0.6 is used (Gates 1980). To calculate the relative path length of an optical air mass at altitude h (m), the relative path length of an optical air mass at sea level M0 (% or fraction) is corrected for the atmospheric pressure at altitude h. Mh (% or fraction) is calculated using (Kreider & Kreith 1975):

$$Mh = M_0 P_h/P_0$$

in which P_h/P_0 (mbar.mbar-1) is an atmospheric pressure correction. The relative path length of the optical air mass at sea level M0 is obtained by (Kreider & Kreith 1975):

$$M_0 = \sqrt(1299 + (614sin(\alpha))^2) - 614sin(\alpha)$$

The atmospheric pressure correction P_h/P_0 is written as (List 1984):

$$P_h/P_0 = ((2880.0065h)/288)^5.256$$

The incoming radiation normal to the beam Snor must be corrected by the orientation and slope of the surface, defined by the angle of incidence ϑ, to calculate the incoming radiation Sdir (Wm^2) on the earth's surface:

$$S_dir = S_norcos(\vartheta)$$

Direct light is scattered in the atmosphere. This daylight scattering or diffuse radiation is approximately 15% of direct radiation (Gates 1980). A more accurate empirical estimation for diffuse radiation Sdif (Wm^2) in a clear not dust-free sky reads as (Liu and Jordan in Gates 1980):

$$S_dif = S_out(0.271 - 0.294\vartheta^{Mh}sin(\alpha)$$

During daylight when the sun is above the horizon, it is assumed that all cells receive the same amount of diffuse radiation. Total incoming radiation Sin (Wm^2) is the sum of direct and diffuse radiation:

$$S_in = S_dir + S_dif$$

Total incoming radiation Sin as calculated with the above is actually a radiation flux for that moment. In the procedure given above, radiation is calculated per time step. If this amount of radiation is used in a water balance model, the amount of radiation and therewith the amount of evapotranspiration will be overestimated or under estimated, depending on the time of the day and the position of the sun.

Most of the work done for the shading is implemented in the pcraster horizontan function.

2.2 How to use the maps generated to correct model incoming radiation from models or measurements

The paragraph below is adapted from the r.sun grass manual:

The real-sky irradiance/irradiation are calculated from clear-sky raster maps by the application of a factor parameterizing the attenuation of cloud cover. Examples of explicit calculations of this parameter can be found in Becker (2001), Kitler and Mikler (1986). However, the cloudiness observation by a meteorological service routine is usually prone to subjective errors and does not describe sufficiently the physical nature and dynamic spatial-temporal pattern of different types of cloud cover. Therefore, a simpler parameter has to be used. The solutions for horizontal and inclined surfaces are slightly different. For the assessment of global irradiance/irradiation on a horizontal surface under overcast conditions Gh the clear-sky values Ghc are multiplied by clear-sky index kc (Beyer et al 1996, Hammer et al 1998, Rigollier et al. 2001):

$$Gh = Ghckc$$

The index kc represents the atmospheric transmission expressed as a ratio between horizontal global radiation under overcast and clear-sky conditions. For a set of ground meteorological stations the clear-sky index can be calculated from measured global radiation Ghs and computed values of clear-sky global radiation Ghc:

$$kc = Ghs/Ghc$$

As an alternative the kc can be derived also from other climatologic data (e.g. cloudiness, cf. Kasten and Czeplak 1980). The raster maps of kc must be then derived by spatial interpolation. The kc can be calculated directly as a raster map from short-wave surface irradiance measured by satellites. This method is based on the complementarity between the planetary albedo recorded by the radiometer and the surface radiant flux (Cano et al 1986, Beyer et al 1996, Hammer et al 1998). To compute the overcast global irradiance/irradiation for inclined surfaces, Gi the diffuse Dh and beam Bh components of overcast global radiation and of the clear-sky index kc have to be treated separately as follows from the following equations:

$$Dh = Dhckdc$$

$$Bh = Bhckbc$$

The ratio of diffuse to the global radiation Dh/Gh for clear and overcast skies changes according to the cloudiness. In Europe the Dh/Gh values are typically in interval 0.3-1.0 (Kasten and Czeplak 1980). The underlying physical processes are quite complicated and computationally represented only by empirical equations (cf. Scharmer and Greif, 2000, Kasten and Czeplak 1980, Hrvol' 1991). However, for many meteorological stations, besides the global horizontal radiation Ghs, the diffuse component Dhs is either measured or calculated from cloudiness, sunshine or other climatologic data. The raster map of Dhs/Ghs can be derived from the point values by spatial interpolation.

Consecutively, the raster maps of diffuse and beam components of the clear sky index can be computed:

$$Dh = GhDhs/Ghs$$
$$Bh = Gh\check{}Dh$$
$$kdc = Dh/Dh$$
$$kbc = Bh/Bhc$$

where subscript s is meant to distinguish data measured on meteorological stations Bhs and Dhs from the estimated values Bh, and Dh.

2.3 Implementation

Usage:

```
e2o_radiation -D DEM [-O outputdir][-S start day][-E end day]
          [-M][-x lon][-y lat][-h][-l loglevel][-T minutes]

-D DEM Filename of the digital elevation model
-O outputdir (default is . )
-S Startday - Start day of the simulation (1 Jan is 1)
-E EndDay - End day of the simulation
-T minutes - timeresolution in minutes (60 default is 1 hour)
-M The DEM xy units are in metres (instead of lat/lon)
-x longitute of the map left (if map xy in metres)
-y lattitude of the map bottom (if map xy in metres)
-l loglevel Set loglevel (DEBUG, INFO, WARNING,ERROR)
-s start hour (per day) of the calculations (default =1)
-e end hour (per day) of the calculations (default = 23)
-h This information
```

The program produces the following map stacks, one for each day of the year:

```
COR00000.??? - Total clear sky radiation on DEM
SUN00000.??? - Nr of time intervals a pixel was in the sun
FLAT0000.??? - Total clear sky radiation on a flat surface
CORDIR00.??? - Direct clear sky radiation on DEM
FLATDIR0.??? - Direct clear sky radiation on a flat surface
```

`e2o_dstools.e2o_radiation.`**`GenRadMaps`**(*SaveDir*, *Lat*, *Lon*, *Slope*, *Aspect*, *Altitude*, *DegreeDem*, *logje*, *start=1*, *end=2*, *interval=60*, *shour=1*, *ehour=23*)

Generates daily radiation maps for a whole year. It does so by running correctrad for a whole year with hourly steps and averaging this per day.

`e2o_dstools.e2o_radiation.`**`correctrad`**(*Day*, *Hour*, *Lat*, *Lon*, *Slope*, *Aspect*, *Altitude*, *Altitude_UnitLatLon*)

Determines radiation over a DEM assuming clear sky for a specified hour of a day

Variables

- **Day** – Day of the year (1-366)
- **Hour** – Hour of the day (0-23)
- **Lat** – map with latitudes for each grid cell
- **Lon** – map with longitudes for each grid cell
- **Slope** – Slope in degrees
- **Aspect** – Aspect in degrees relative to north for each cell

- **Altitude** – Elevation in metres
- **Altitude_Degree** – Elevation in degrees. If the actual pcraster maps are in lat lon this maps should hold the Altitude converted to degrees. If the maps are in metres this maps should also be in metres

Return Stot Total radiation on the dem, shadows not taken into account

Return StotCor Total radiation on the dem taking shadows into acount

Return StotFlat Total radiation on the dem assuming a flat surface

Return Shade Map with shade (0) or no shade (1) pixels

`e2o_dstools.e2o_radiation.`**`detRealCellLength`**(*ZeroMap*, *sizeinmetres*)

Determine cellength. Always returns the length in meters.

`e2o_dstools.e2o_radiation.`**`lattometres`**(*lat*)

” Determines the length of one degree lat/long at a given latitude (in meter). Code taken from http:www.nga.mil/MSISiteContent/StaticFiles/Calculators/degree.html Input: map with lattitude values for each cell Returns: length of a cell lat, length of a cell long

`e2o_dstools.e2o_radiation.`**`main`**(*argv=None*)

Perform command line execution of the model.

CHAPTER THREE

EXAMPLES AND TESTS

CHAPTER

FOUR

FAQ

CHAPTER

FIVE

RELEASE NOTES

CHAPTER

SIX

INDICES AND TABLES

- *genindex*
- *modindex*
- *search*

CHAPTER

SEVEN

REFERENCES

CHAPTER EIGHT

TODO

[CQFLOW] Köhler, L., Mulligan, M., Schellekens, J., Schmid, S. and Tobón, C.: Final Technical Report DFID-FRP Project no. R7991 Hydrological impacts of converting tropical montane cloud forest to pasture, with initial reference to northern Costa Rica.,, 2006.

PYTHON MODULE INDEX

e