GEOtop Users Manual

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Chapter 1

Introduction

1.1 What is GEOtop

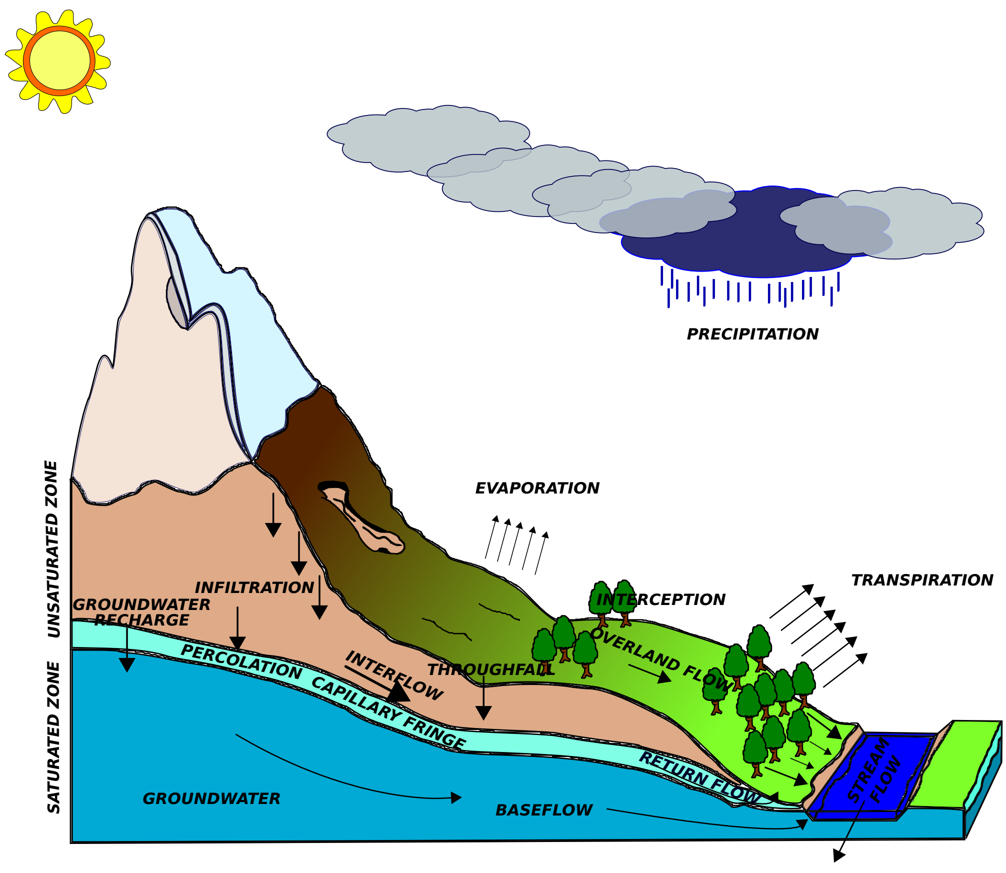


Figure 1.1: The water cycle

Many hydrological models, commercial and research research oriented, allow to analyze the water and energy exchanges between the soil and the low atmosphere. However, often the models treat accurately only some aspects of the water cycle, i.e. the run-off or the boundary layer, and study the other parts in an approximate way. GEOtop (*Rigon et al.*, 2006), on the other hand, is a physically based distributed hydrological model that analyzes the complete water cycle in a catchment. The model is conceived to deal with complex topographies, as it provides each grid point of the domain with the topographical characteristics of the basin (elevation, slope, aspect, shadow, sky view factor). The soil/rock thermal and hydraulic characteristics are given in input in form of maps, together with a vertical description of the layers to account for heterogeneous stratigraphies. The vegetation and soil cover features may also be specified in form of maps. The meteorological data, collected in one or more points in the catchment, are spatially distributed to each grid point thanks to the *Micromet* model (*Liston and Elder*, 2006). Then the model calculates the energy and mass balance in the catchment through a 3D solver for Richards' equation (*Endrizzi et al.*, submitted) and a 1D solver for the energy equation (*Dall'Amico et al.*, 2011a). The vegetation is treated according to a double layer scheme (*Endrizzi and Marsh*, 2010), that allows to separate the contribution of vegetation and of the surface on the turbulent fluxes. The snow module, originally implemented with a monolayer scheme (*Zanotti et al.*, 2004), now calculates accumulation and melting through a multilayer discretization of the snowpack (*Endrizzi*, 2007). Recently the model has been enriched with a *blowing snow* module, based on *Pomeroy et al.* (1993) e *Essery et al.* (1999) contributions, that allows to account the accumulation and scour due to the wind action. GEOtop represents a useful tool to simulate:

- the soil water content (*Gebremichael et al.*, 2009)
- the evaporation of the soil (*Bertoldi et al.*, 2006, 2010);
- the transpiration of the vegetation (*Endrizzi and Marsh*, 2010);
- the snow in a catchment (*Zanotti et al.*, 2004; *Endrizzi*, 2007; **?**; *Dall'Amico et al.*, 2011b);
- the surface temperature in a basin (*Bertoldi et al.*, 2010);
- the temperature in the soil/rock also under freezing conditions (*Dall'Amico*, 2010);
- the glacier mass balance (*Noldin et al.*, 2010);
- the water table and thaw depth interactions (*Endrizzi et al.*, submitted);
- and the water discharge in an outlet (*Rigon et al.*, 2006)

1.2 History

GEOtop concise history up to the first public release - by Riccardo Rigon

"*As scientists we are intrigued by the possibility of assembling our knowledge into a neat package to show that we do, after all, understand our science and its complex interrelated phenomena.*" (W.M., Kohler, 1969).

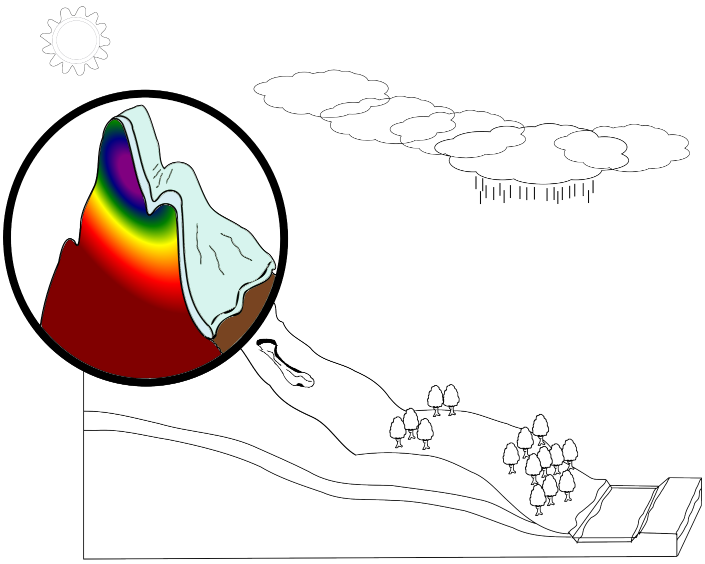


Figure 1.2: Cryosphere: snow, glacier, permafrost

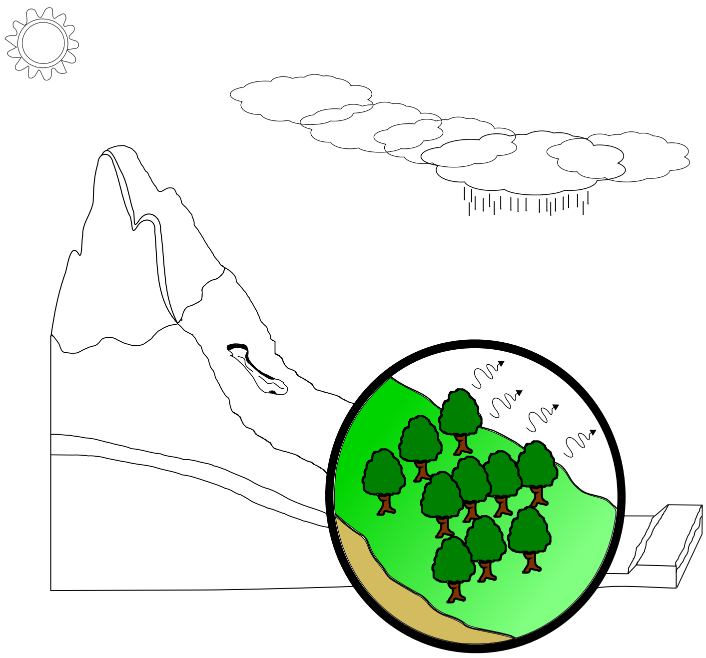


Figure 1.3: Vegetation and surface fluxes

1.2.1 GEOtop 0.5

The first version of GEOtop (0.5) was mostly financed by the Autonomous Province of Trento through the Serraia project and by the Italian Ministry of Research and University through the Cofin 1999 project. The very first step was due to the reading of the Entekhaby review of moddling the whole hydrological cycle [e.g. - Marani and Rigon (eds), 1997], and started with the master thesis of Paolo Verardo and his

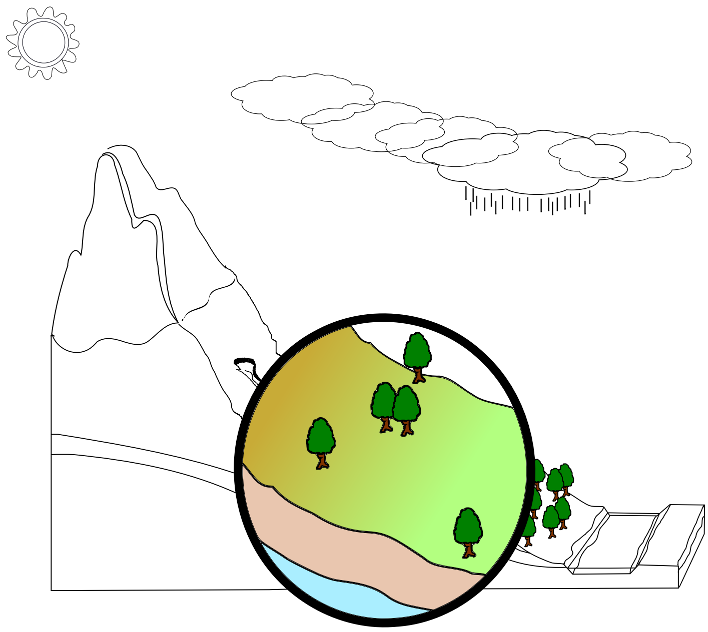


Figure 1.4: Soil: infiltration, water content, discharge

subsequent work in 1998. Around a year was spent to implement a decent model for evapotranspiration in a complex terrain environment, according to the Penman-Monteith (PM) schematization, and all the necessary incoming radiation treatments. Especially the view angle and the shadowing routine were delicate to implement. The problem of data assimilation and regionalization (at that time the only data we had were those coming from traditional hydro-meteorological stations and we do not have many of them) was face for the first time. Apart from the geomorphological data that we extract from DEMs (the ”sine qua non” basis of all the work) we had to regionalize: air-surface temperature (varying obviously with the elevation of the terrain), net radiation (that has to be first derived from that at the atmosphere top by the evaluation of an atmospheric thickness which has to be regionalized too) and wind speed. In sequence it was decided decided to use: kriging techniques and the hypothesis of adiabatic temperature profile (for air temperature); Brutsaert [1983] paper results (for atmosphere emissivity) and constant (or kriged) wind speed everywhere.

The heat conduction into the ground was parametrized as a linear combination of a sinusoidal function as Entekhaby suggested [1997] (this has been eventually changed). That work was also inspired by the routines of IPW (Image Processing Workbench) [Frew, 1990]. Actually it was tried to get IPW working: but its pervasive scripting base (scripting is good but there is a point after which it makes the code organization unclear), the discontinued support and ignorance of IPW code internals, led to built a new system from the scratch.

Despite of the approximations introduced, GEOtop 0.5 model worked fairly well in estimating the net longwave and shortwave radiation in any point across a basin and at any hour of the day, and could give also reliable estimates of the potential evapotranspiration on a daily basis. However to obtain the real evapotranspiration was a different question (and, obviously, to validate it, eve a different one). Marco Pegoretti

[1999] added to the evapotranspiration modules a rainfall-runoff model (temporary called GEOMODEL). The approach to the problem of rainfall-runoff was strongly influenced by the work of Rodriguez-Iturbe and Valdes [1979] and Gupta et al [1980], and I was reluctant to abandon the simplicity of a GIUH-based model in favor of a fully distributed model.

Of the many ideas behind the theory of the GIUH there is the observation that the river basin is a complex system (an interplay of hillslopes and channels) but, at least for the forecasting of floods, just a simple model works leading to the conclusion that dynamics works in simplifying statistically the complexity and the heterogeneity underneath.

The big problem in the GIUH approach however was (and is) the determination of the effective rainfall, i.e. the correct separation of surface runoff (interpreted as the cause of the flood surge) from subsurface flow (which must be actually treated separately and routed to the channels in a slower way), especially in dependence of storm events of diverse intensity, duration and inter-arrival time.

A model more or less contemporary to the GIUH is the TOPMODEL by Beven and Kirkby [1979]. It is based on the paradigm that runoff production is due to saturated areas (according to Dunne and Black, 1970). Thus, once one knows which areas are saturated and describes their growing during an event, the problem of the runoff coefficient is almost solved while routing of water to an outlet can be accomplished by some simple mechanism (the Muskingum-Cunge model at least in the original papers). Thus, an idea could have been to merge the best of the two formulations, the GIUH concept with the TOPMODEL. However the hypothesis on which the TOPMODEL has been based, mainly the stationarity of the hillslope subsurface fluxes, in one way simplifies the life of the modeler, but on the other is from many points of view a limitation which needs several work-around as described in Beven et al., [2002]. In fact, when the final goal is not simply the production of a well-fitted flood wave, but for instance the estimation of local soil moisture contents, the TOPMODEL fails to be precise enough [e.g., Grayson and Wilson, 2002].

Furthermore, the parameters entering the model become ”effective” parameters and lose their original physical significance (for instance, the hydraulic conductivity cannot be validated by local field measurements), and need to be ”calibrated” ex-post. Other limitations will be mentioned below when talking about the GEOTP 0.875 version. In any case, the TOPMODEL concept has been demonstrated to be a good tool to model floods in small-to -medium catchments, and has been considered the reference hydrological model for many of the researchers during the ’90s. The TOPMODEL’s ability to forecast floods derives also from its account (trivial indeed) of the topology and geometry of small- catchment flow paths: it was shown, in fact, that in small watersheds (up to at least 1000 square kilometers), hillslope residence time dominates the characteristic time of flood formation and that topology and geometry of river basins are sufficient with very minimalist dynamics to explain the shape of floods [Rinaldo et al, 1991; Rigon et al, 1996, Rinaldo et al., 1995, D’Odorico, 1996; D’Odorico and Rigon, 2003]. Thus, it was decided to build completely new subsurface and surface models, still driven by gravity (i.e. by slope as the TOPMODEL and not by the total hydraulic head) but, as a first approximation to the final wishes, introducing the buffer to cope with infiltration into the vadose zone. Subsurface flow was produced only by the saturated layer (including the capillary fringe), if present, and lateral surface runoff was routed as a kinematic wave (and through

Manning/Gauckler-Strikler equation for velocities).

In doing this, it was searched a better characterization of flow paths, with reference to the bedrock, instead of to the surface topography [see McDonnell et al., 1996]: this could be done by measuring soil depth or interpolating it for instance as in [Heimsath et al, 1997 or Roering et al, 1999; please see the overlooked Bertoldi et al, 2006 for the details].

In this separation of surface and subsurface fluxes, GEOtop 0.5 was similar to the grid bases THALES [Grayson et al., 1994a,1994b] or the more recent NEWTHALES. At first, the version of GEOtop by Verardo-Pregoretti-Rigon (GEOTOP 0.5) could work without an explicit channel routing assigning a locally variable roughness and hydraulic radius; usually, however, channels were determined by accurate topographic analysis and explicitly treated. Channels routing was performed by a GIUH theory as in Rinaldo et al [1995], where channel celerity and hydrodynamic dispersion were considered spatially uniform and constant in time.

Instead of the effective rainfall, the spatially an temporally distributed input to channels was produced by GEOtop, i.e. the GEOMODEL produced patterns of spatially distributed soil moisture, and these patterns were used to reduce the potential evapotranspiration to its real counterpart as described in Bertoldi et al., [2002].

1.2.2 GEOtop 0.75

(mostly financed by COFIN 2001, THARMIT Eu Project, CUDAM - CofinLab 2001, ASI 54/2000)

The use of PM equation for evapotranspiration was indeed unsatisfactory from many points of view. For instance, it depends on air temperature that was derived from interpolation, and it was envisioned that the parametrization of fluxes into the ground, sensitive both to the ground cover and to the water content, could be modeled directly, haven as a result that many of the variables and parameters that were known to be correlated were actually treated separately.

Thus, with the Master thesis of Giacomo Bertoldi[2000] wit was decided throw away the PM equation (actually we kept it for comparison), and to solve directly the energy balance in any point of the basin. This was the birth of GEOTOP 0.75 which is thoroughly documented in Bertoldi et al[2002a,b] and Rigon et al [2002]. It was actually a SVAT model plus an rainfall-runoff model coupled together. GEOtop needed several parameters to be run, however the modeling could have been considered parsimonious, if all the prognostic capabilities were to be considered. The user could switch-off the SVAT part and have a parametrically parsimonious rainfall-runoff model, or vice-versa she can switch-off the rainfall-runoff model and have a reasonably simple SVAT model. Large efforts were done in cleaning the old code and improving the input-outputs. Credits must be given to the work of Liang et al. [1994] with their work on VIC (which is however parametrized to work at much larger scales) and on Wigmosta et al. [1994] whose model is very similar to the version 0.75 of GEOtop (but was mostly a case of evolutionary convergence since the comparison came after the GEOtop implementation). From the beginning, the model was used to forecast the whole hydrological cycle, even if a reasonable snow modeling still had to arrive. We were looking also to other topics. Eco-hydrology was, in fact, a research thread whose seeds where already in Rodriguez-

Iturbe's mind when I was working with him at the Texas A&M University (1994-1996) and of which I was concerned from the beginning of the project.

Ecohydrology [Rodriguez-Iturbe, 2000] has roots in the work of Eagleson [1978, 2003], Phili, Brutsaert, Hillel [1990],s and others and is one of the hot issues in these hydrological decades [Rodriguez-Iturbe, 2000].

For validation of the modules, a key role in this had Tom Over who, besides giving a lot of suggestions making the concepts behind the model clear, suggested to use the South Great Planes 97 experiment data set, thing that we promptly did as it appears in the first journal paper about the model Rigon et al., 2006).

Based partially on GEOtop 0.75 (and on the subsequent GEOtop 0.875) came all the work by Reza Entezarolmahdi who tried first to create an automatic calibration system for the model. This actually used MOSC-EM [CITATIONS] which, however was never really integrated in the model. The work of Reza was really interesting for many point of view, but probably a little advanced with respect to times and finished to a dead-end from which we hope to resume it sometimes in the very next future.

1.2.3 GEOtop 0.875

(mostly financed by TIDE EU Project, CUDAM Cofinlab COFIN 2001, THARMIT EU project)

This version finally contained a snow accumulation and melt model (derived by the Utah Energy Balance -UEB- by Tarboton and Luce, [1992]) implemented by Fabrizio Zanotti [2003] with the help of Giacomo Bertoldi . It also included a post-processor, the S-FACTOR , which performed a landslide and debris-flow triggering implemented by Christian Tiso [2003] (eventually evaluated into GEOtop-SF by Silvia Simoni). Both the implementations were the outcome of two M.S. thesis. Snow-melting and soil freezing are essential components in the hydrological cycle of mountain catchments and cannot not be overlooked. Landslide and debris-flow triggering are also an issue with particular relevance in mountains areas, such that floods in mountain areas are usually the combined effect of large liquid and solid discharges whose effects cannot be separated: GEOtop with this version started to a tool for studying these phenomena.

However, with the version 0.875, we wanted to attack the problem of a sound hillslope-hydrology modeling.

So far, our understanding of mountain catchments in fact was based on hillslope hydrology, as reviewed for instance in Wipkey and Kirkby [1978], and the "perceptual" hillslope model that we had at that time derived from the assumption that it was possible to neglect the transients in the water fluxes [in the sense clarified in Iverson, 2000]; that topographic gradients dominate the hydrologic response; that hydraulic conductivity strongly decreases with depth in the soil and, not independently, that runoff occurs mostly owing to saturation excess. This last assumption in turn was based upon the results of a long series of experiments from the late seventies on by American geomormologists (Dunne, Black, Dietrich, Montgomery, Torres), and was supported by many others (among these: Moore, Grayson, Sivapalan, Wood). These experiments and subsequent research activities changed the belief spread by Horton that runoff was mostly due to the infiltration excess mechanism. Developing hydrological models based on saturation excess ideas (which involved further simplification) originated a series of rainfall-runoff models among which the already cited

TOPMODEL [Beven and Kirkby,1979; Sivapalan et al, 1991; Franchini et al, 1996] is the most successful product.

There are many aspects that could be improved with respect with that model. For instance, in characterizing the subsurface flow field more in terms of total head, even if in simplified form as in Iverson [2000], than in terms of the topographic gradient, as a first step toward the integration of the three dimensional Richards equation. These steps were implemented by the master thesis of Davide Tamanini [2003] that made GEOtop able to simulate transient subsurface flow, and both saturation excess and infiltration excess runoff. A first parameterization of the soil water retention curves was also implemented in the model. It is this code that was used in the first journal papers on GEOtop (Zanotti et al., 2004, Rigon et al., 2006, Bertoldi et al., 2006). Upon this code was based the work by Silvia Simoni, helped by Fabrizio Zanotti which produced the GEOtop-SF postprocessor that was able to estimate statistics of the stability of a hillslope. This work, in turn, produced Simoni Ph.D. thesis and Simoni et al., [2008].

In GEOtop 0.875 the integration of Richards equation followed a custom numerical scheme that was exceedingly complicate and non standard. Moreover, the integration scheme was not fully 3D, but could have been defined 2D + 1D, where "2D" stands for the lateral flow, obtained by using the Darcy Buckingham law, and 1D was the resolution of a one dimensional Richards equation. Despite these limitations, we could obtain reasonable reproduction of soil moisture distributions, good discharges at the outlet of basins, excellent reproduction of summer soil temperatures, and what we considered a good reproduction of turbulent heat and evapotranspiration exchanges.

1.2.4 GEOtop 0.9375

and subsequent version till the first public release (mainly financed by Projects with Servizio geologico PAT, progetto MORFEO by ASI, and EU IRASMOS and AQUATERRA projects)

The new development started with in mind that we had sooner or later to switch to a version of GEOtop with a full 3D integration of Richards equation.

However, the first new improvement of GEOtop was in the direction to include a multiple layer modeling of snow and a first core of the freezing soil subroutines. This was mainly accomplished during the Ph.S thesis of Stefano Endrizzi [2007], and greatly improved in his subsequent work at Saskatoon, working with Phil Marsh and Bill Quinton, and recently at Zurich University collaborating with Stephan Gruber.

Why complicating even more an already complex model? Moreover, why getting a new snow model, if the Utah energy balance seemed to work fine, as written in Zanotti et al., 2004? The rational behind this choice was essentially that the snow water equivalent was not enough for comparing snow measurement in the field with model outcomes. Clearly snow water equivalent (SWE) was enough just for those willing to cope with total water volume generated after snow melting, but not sufficient for studying and understanding the processes behind snowpack evolution and ablation. Nor even for having a reasonable estimate of soil temperature under the snow, and other interesting prognostics, like snow density.

However, Stefano's efforts were not limited to snow. He worked hard, for getting a consistent integrator of Richards equation, that he based on a Newton Krilov-method (Kelley, 2003). Besides he decided to change the surface water flow equation and numerics, by using the shallow water equation integrated with a robust but explicit method. This resulted in a very stable and reliable code that constitutes the core of the first public version of GEOtop. In fact Stefano decided to move from the the fraction of geometric series of $\sum_i (1/2)^i$ to the integer 1.

The collaboration of Stefano and Matteo Dall'Amico produced also a consistent integrator of the freezing soil moisture, after that Matteo, in his Ph.D thesis disentangled, at least for ourselves, a lot of thermodynamics (and together, we introduced a simple, and "normal" thermodynamic notation). This work has been documented in Dall'Amico et al., 2010 LINK, and produced a paper for The Cryosphere LINK.

1.2.5 Stefano Endrizzi's work

Up to version 0.875 version GEOtop was pretty much a home made effort, mainly pursued by Master and Ph.D students of Trento University. However, since then, either because the Ph.D students became doctors and spread around, and because other discovered the potential our work, GEOtop started to became really internationally used. Han Xunjun in China used GEOtop in his data assimilation system implementing an ensemble Kalman filter (in Python). The Lausanne group under the direction of Marc Parlange, within the collaboration of Silvia Simoni, and the direct coding efforts of Thomas Egger implemented a real time version of the model that is giving its results everyday (http://lsir-hydrosys01.epfl.ch:22006/). John Albertson and his group implemented an erosion module to be coupled with GEOtop. In Trento, a version of GEOtop, called GEOtop-EO implemented a prototype of infrastructure that includes besides the modeling core, a geographical database, with a raster service (built upon RAMADDA -LINK) and a visualization system based on JGrass. This was done for the project MORFEO (LINK). At Bolzano, in EURAC, Giacomo Bertoldi and Stefano Dallachiesa, endowed GEOtop with an external (so far) vegetation dynamical model (itself came from previous work by Albertson and Montaldo). Last, but not least, Mountain-eering made of GEOtop the center of its business plan, and supported the completion of the freezing soil module, and is going to develop a new NetCDF input/output system, and the creation of some data assimilation of snow measures.

Credits to work of the group of Lousanne should be given to have also included in GEOtop the METEO/IO environment which was the way to link the model to a real-time acquisition system. Stefano Endrizzi himself, when at Saskatoon, discovered the work of Liston and Elder [2006] with MICROMET, and included it in the GEOtop distribution with the permission of the Authors.

Also other player came to the game. Arpa Val D'Aosta decided to make of GEOtop the principal tool for doing analysis on snow and permafrost, and it is going to support its improvement and usability. The Karlshrue Institute of Technology in Garmisch-Partenkirchen (and particularly Prof. Harald Kunstmann, and coworkers) adopted for simulation for one of their TERENO experiment (LINK).

This, just to mention partial developments, not all of them yet flowed into the main version of the model. All of these efforts, in fact, could not being really unified in a single product.

1.2.6 GEOtop in Zurich

1.2.7 Future perspectives

So

So the questions for the future are:

how can we manage the future of this international crew, letting any single her freedom ? and making the whole community grow cooperatively ? how giving anyone the proper credits which are necessary to go ahead ? how maintain while moving on relevant pieces of software still available avoiding to wipe them out (as it happens for the PM coed, and more recently, with the former runoff-modules. to do a couple of examples ?

I gave already some possible direction (see for instance LINK) that derives from the issue raised by the work of Stefano Endrizzi and Hydrologis, and in an effort to unify all of my previous work lines.

However, this is not an aster I want to do by myself. The community around GEOtop must give its opinion. Because the only perfect model is the evolving one, since many contenders appear, our knowledge grows, and all of us work hard.

Relevant Literature

Chapter 2

Compiling Instructions

GEOtop runs properly under:

- Linux platform;
- Mac platform;
- Windows platform.

2.1 Compile GEOtop through a makefile

The GEOtop source code can be downloaded through a terminal (or command prompt if you are using Windows) by typing, as shown in *Figure* 2.1:

”svn co https://dev.fsc.bz.it/repos/geotop/trunk/0.9375KMacKenzie”

Figure 2.1: Download GEOtop source code through a terminal

The downloaded folder contains the folders:

- Debug: which contains the object file created during the compilation and the makefile
- geotop: which contains the code
- Libraries: which contains the support libraries

Open a terminal, go into the folder *Debug* by typing:

```
$ cd Debug
```

To compile GEOtop, type:

```
$ make all
```

The executable file *GEOtop1.2* is now created in the *Debug* folder.

Chapter 3

Basic theory

3.1 The calculation grid

3.1.1 Planar grid

The calculation domain is based on a fixed regular Cartesian grid that coincides with the DEM (Digital elevation model), as reported in Fig. 3.1, on which it is possible to extract the hydrological basin closed at a given outlet (Fig. 3.2). The X-axis coincides with the west-east direction and the Y-axis with the South-North direction, whereas the calculation grid size coincides with the pixel size (dX, dY) of the DEM.

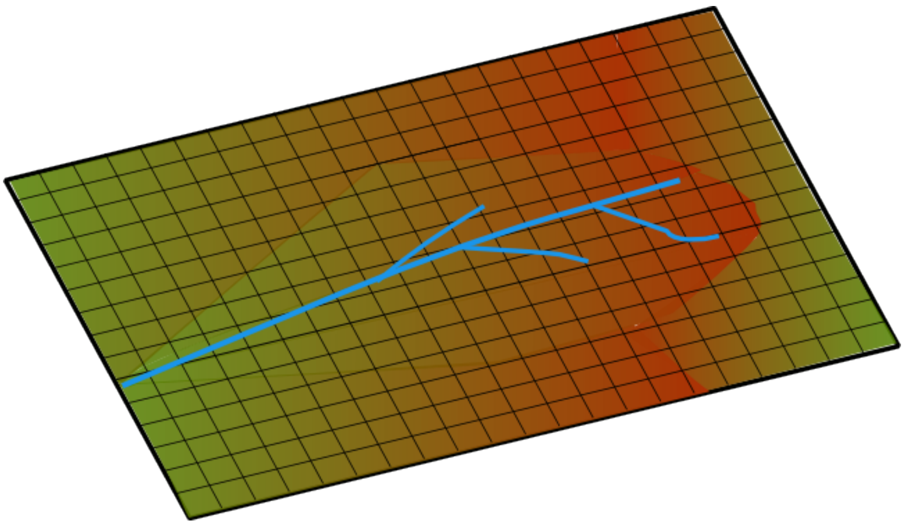


Figure 3.1: DEM of an the area of interest

3.1.2 Vertical grid

The Z-axis is vertical and oriented towards the center of the Earth. It is possible to define the number of layers along the z-axis and the discretization, i.e. the vector of layer depths (Fig. 3.3 left). Note that the layer depth be irregular (different layers of various depths) but uniform in all the domain and the layer numbering starts from the top to the bottom (Fig. 3.3 right). The calculation grid points coincide with the center of the cell (on the X-Y axis) and the center of the layer (on the X-Z axis). Table 3.1 reports and example of a vertical grid discretization characterized by 8 layers with irregular depths.

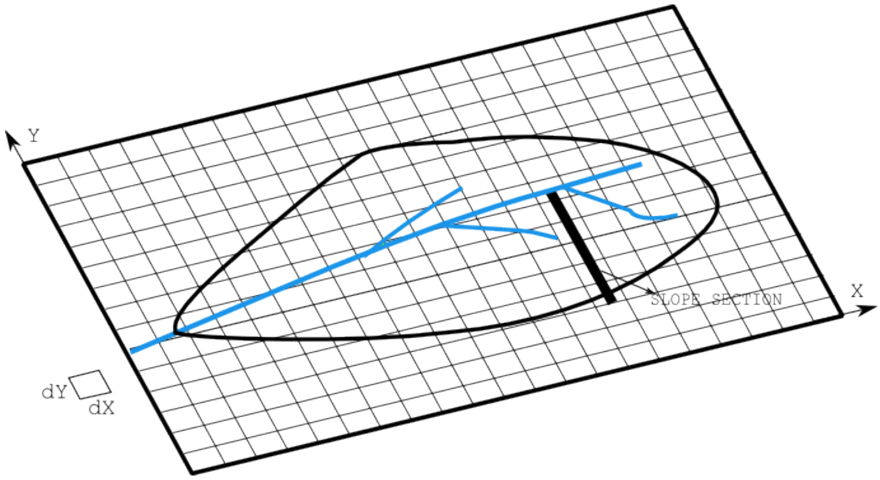


Figure 3.2: Calculation grid coinciding with the DEM. The hydrological basin (black line) and the river network (blue line) are present.

Layer ID	Depth (mm)
1	10
2	15
3	20
4	20
5	60
6	50
7	80
8	100

Table 3.1: Vertical grid discretization and layer depth

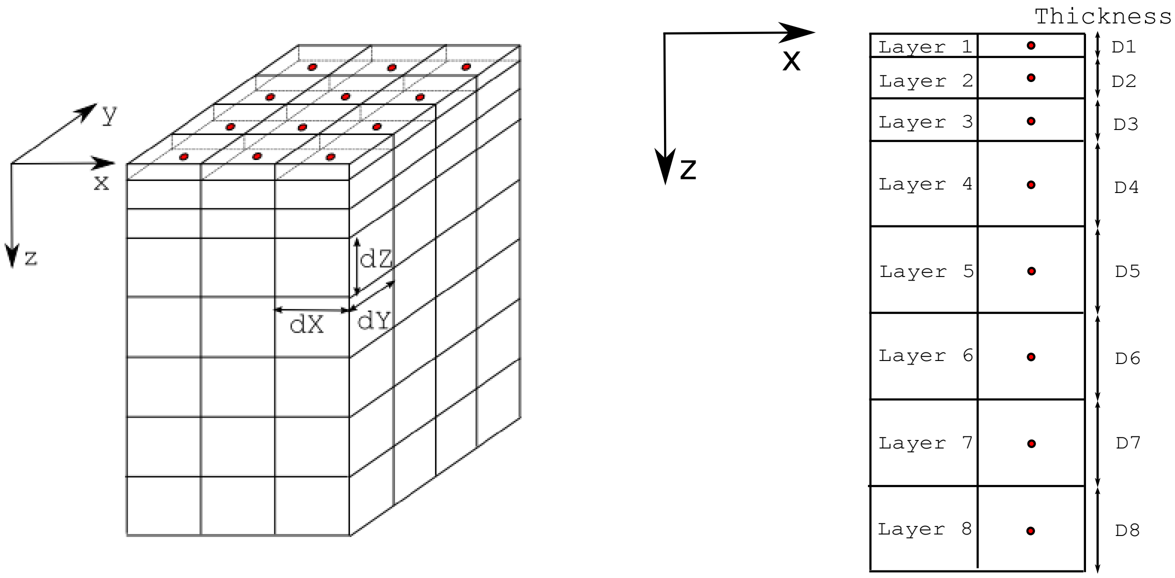


Figure 3.3: Left: three dimensional calculation grid. Right: discretization on the x-z plane. The red points, at the center of the cell, coincide with the calculation grid points

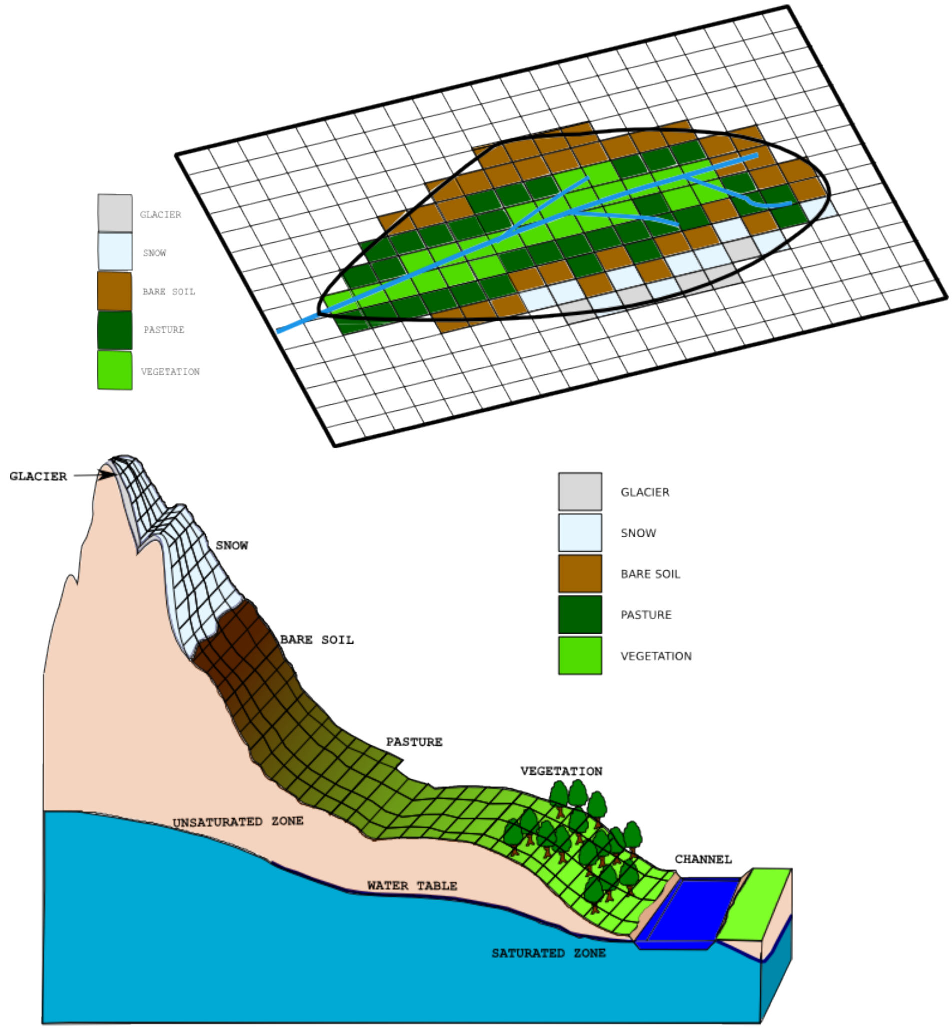


Figure 3.4: Top: Classification of a slope surface in a mountain basin on the basis of the land cover. Bottom: same classification for the entire basin.

3.2 The domain characterization

The domain characterization has the objective to determine:

- the land use i.e. vegetation, pasture, snow, glacier, forest etc. This map is usually called land cover
- the stratigraphical characteristics of the soil, i.e. 1 m of thick debris (gravel), 2 m of sand, 2 m of loam etc. in order to ease the guess of the hydraulic and thermal parameters of the soil. This map is usually called *soil type*.

3.2.1 Land cover

Let us define a slope on the DEM, as reported in Fig. 3.2: ideally it can be figured out as in Fig. 3.4: at the bottom left is located the channel, then towards the higher elevations one may found the vegetated area, pasture, bare soil, snow covered area and glacierized area. Fig. 3.4 on the top reports the slope surface discretization and classification, whereas on the bottom reports the land cover classification of the whole domain. In this example may be identified five classes of land cover: vegetated area, located near the main stream in the low elevated range; pasture area, located in the medium range elevations; bare soil area, located on the steepest part of the domain and at medium-high elevations; snow covered area, located at high elevation and finally the glaciarized area on the highest parts.

3.2.2 Soil type

Let us imagine to take a section of the slope and to classify the type of soil in terms of texture (debris, gravel, sand, loam, clay) and bedrock depth. Each classification number would correspond to a particular soil stratigraphy, defining the soil particles and depth of bedrock. Starting from these characteristics, one could derive the hydraulic and thermal parameters, according to **?** and **BLA BLA**. Fig. 3.5 reports the resulting map where each color corresponds to a given soil stratigraphy; the description of each type of soil stratigraphy is given in Table 3.2.

Stratigraphy ID	Layer ID involved	Soil texture
1	1, 2, 3	gravel
1	4, 5	clay
1	6, 7, 8	sand
2	1	clay
2	2, 3, 4	gravel
2	5, 6	clay
2	7, 8	sand
3	1, 2, 3, 4, 5, 6	clay
3	7	gravel
3	8	sand

Table 3.2: Soil type (stratigraphy) present in the domain

3.2.3 The final 3D calculation grid

The final calculation domain is reported in Fig. 3.6. At the top is represented a planar view of the basin with a detail on the soil discretization and stratigraphy; on the bottom, the slope profile is schematized: the surface is classified according to the land cover map, whereas the soil depth according to the soil type map. Please note tha the discretization on the Z axis is vertical and not normal to the slope.

3.3 The focus on some points

It is possible to select some points in the basin that deserve a special attention, i.e. for the presence of a measurement device or for civil protection reasons. These points may be located wherever in the domain area and may be classified according to topographic characteristics (elevation, slope, aspect), surface type (land cover) and soil stratigraphy (soil type). Table 3.3 summarizes the characteristics of the simulation points reported on Fig. 3.6. The point 1 is located at low altitude on the bottom valley, in a vegetated area near the channel. The point 2 is located slightly upwards on the pasture, the point 3 is at medium-high altitude, where no vegetation is present (bare soil). The point 4, at 2500 m altitude, is still snow covered and finally the point 5, at 3100 m, is characterized by the presence of a glacier. As far as the soil type is concerned, the slope is characterized by the stratigraphy 1 at low altitude near the channel, where the point 1 is located. Then, at medium-range altitude, it is characterized by the stratigraphy 3 (see points 2 and 3) and finally, at high elevations, by the stratigraphy 2 (points 5 and 6).
These points may be highlighted to run multiple 1D simulations (see Par. 4.2) or to print specific point results.

Point ID	Elevation (m a.s.l.)	Slope (°)	Aspect (° N)	Land cover	Soil type
1	1200	15	30	vegetation	1
2	1600	10	30	pasture	3
3	2200	20	15	bare soil	3
4	2500	25	0	snow	2
5	3100	25	0	glacier	2

Table 3.3: Topographic, land cover and soil type characteristics of the simulation points

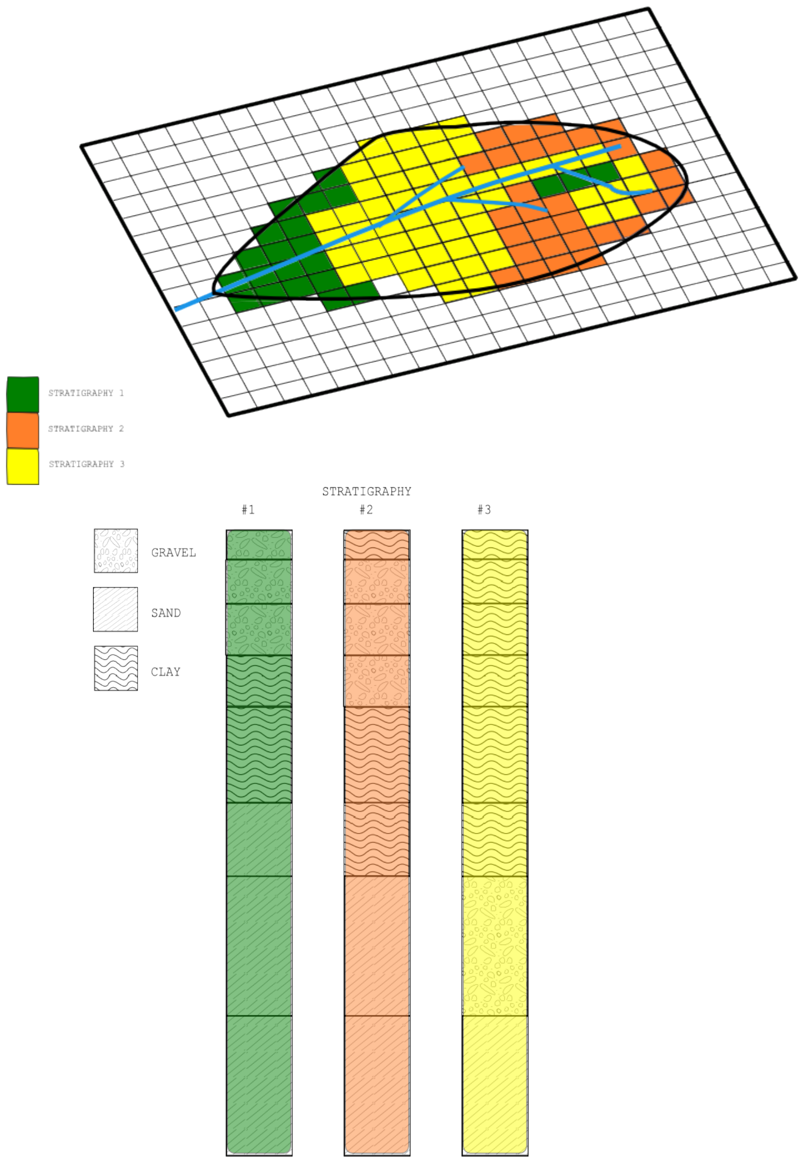


Figure 3.5: Domain characterization oriented to define the soil stratigraphy (soil type map).

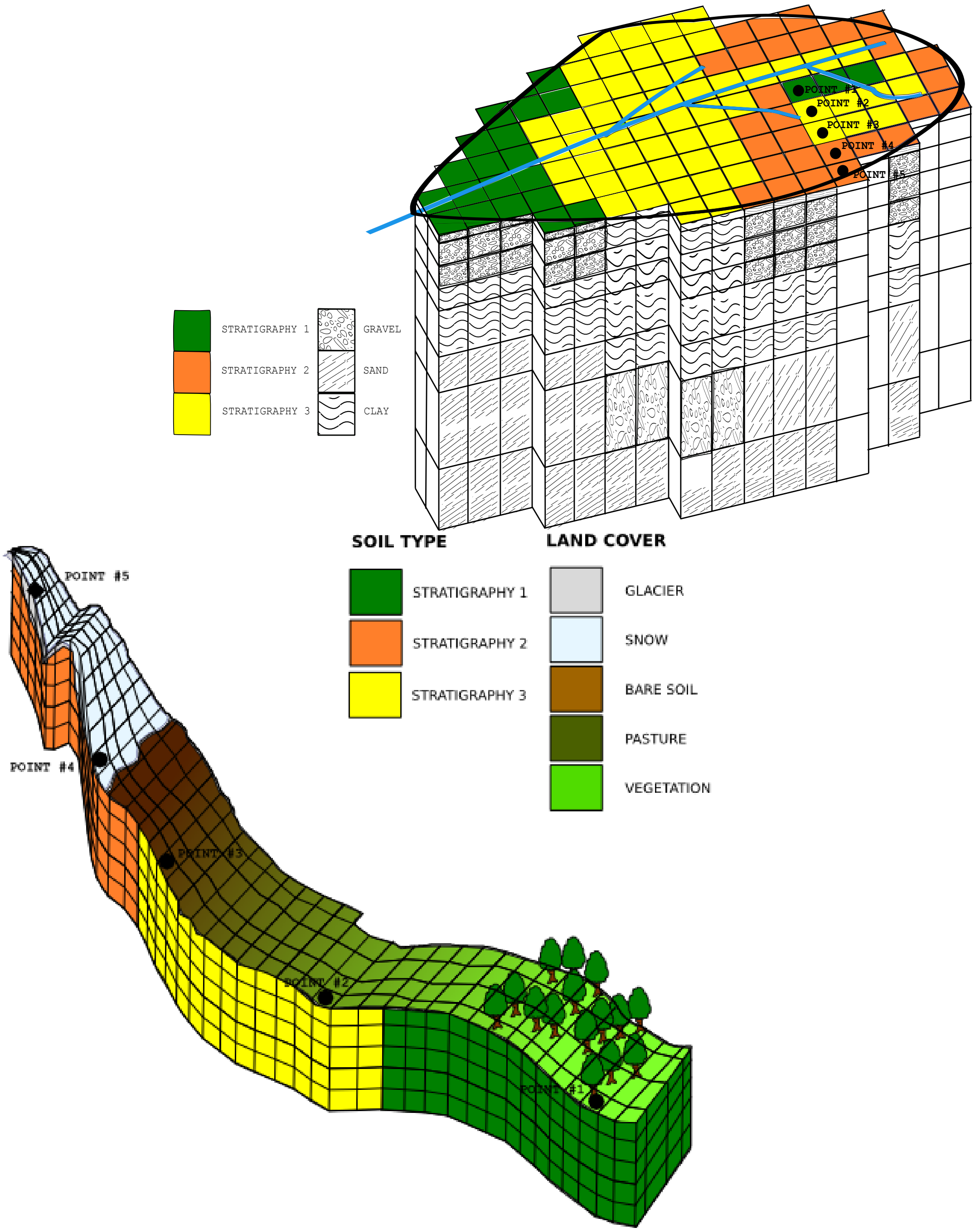


Figure 3.6: Domain characterization oriented to define the soil stratigraphy (soil type map).

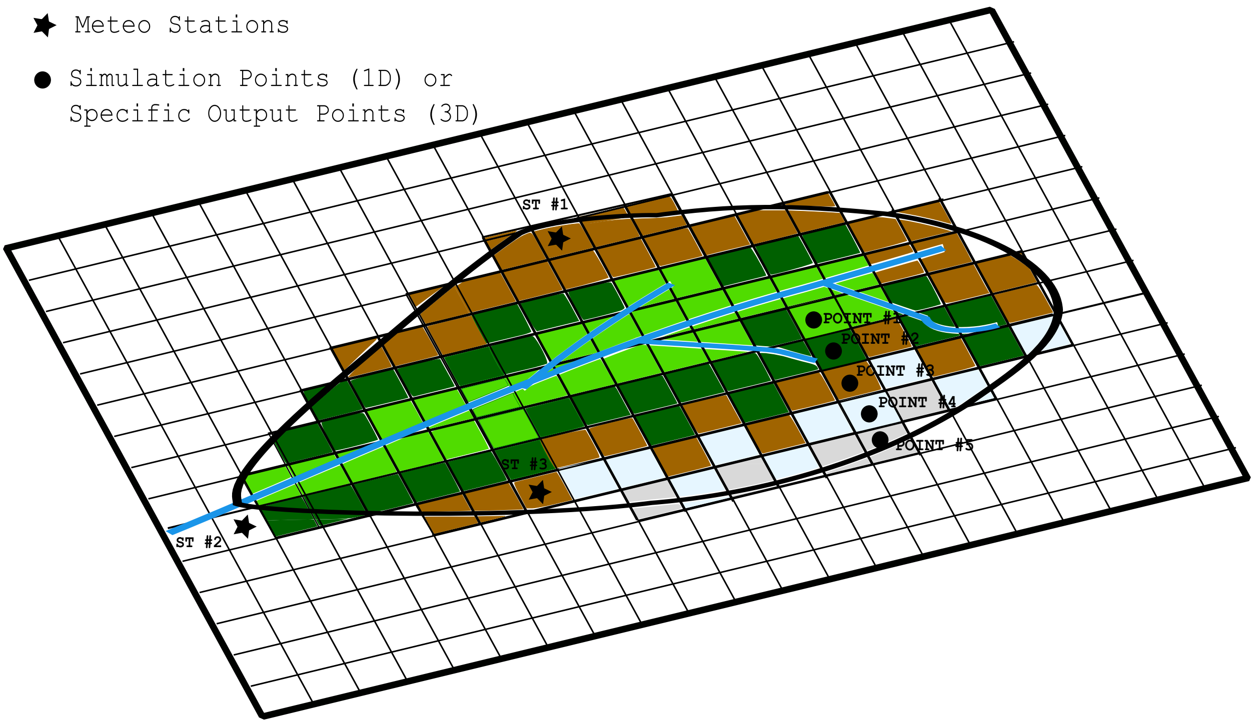


Figure 3.7: Planar view of meteo stations (ST) location in the domain area.

3.4 Meteorological forcing

The meteorological data represent the dynamic forcing that constrain the domain to evolve, under the constraints given by topography, the conservation laws and the boundary conditions. GEOtop may receive in input the meteorological data coming from several stations (the number of meteo stations is an input parameter).

3.4.1 Meteo station

In order to describe the characteristics of the meteo stations, it is requested to provide the following information:

- the number of meteo station;
- the coordinates (X, Y, Lat, Long) of each meteo station;
- the elevation;
- the sky view factor;
- the standard time difference (of the time records with respect to Greenwich Meridiam Time);
- the height of the wind speed and air temperature sensors.

Fig. 3.7 shows the planar view of the domain area where three meteo stations (ST) are present: ST1 is located on a high peak, ST2 is on the bottom valley and ST3 is on a medium altitude peak at the lefthand side of the river. The prospect view of the meteo stations is reported in Fig. 3.8. It is important to note the following: (i) the meteo stations may also be outside of the land cover map, however must be located inside the DEM area; (ii) the sky view factor of the meteo station depends on topography: whereas ST1 has no obstruction because of its high elevation, ST2 is characterized by a big obstruction given by the mountain ranges. Finally, the zoom in Fig. 3.8 reports a particular of the meteo station: the wind sensor height and the air temperature height must be specified in the model.

3.4.2 Meteo data

Each meteo station, according to the sensor installed, may measure different type of variables. The admitted input variables considered as meteorological forcing are:

1. precipitation intensity (mm h^{-1})
2. wind velocity (m s^{-1})
3. wind direction (°N)
4. windX and windY (m s^{-1}) (must belong to the same meteo station)
5. relative humidity (%)
6. air temperature (°C)
7. dew temperature (°C)
8. air pressure (bar)
9. short wave solar global radiation (W m^{-2})
10. short wave solar direct radiation (W m^{-2})
11. short wave solar diffuse radiation (W m^{-2})
12. short wave solar net radiation (W m^{-2})
13. long wave incoming radiation (W m^{-2})

The meteo variables have to be provided in the Meteo file, specified by the keyword *MeteoFile*. It is compulsory to add to the file the column of the date, given by the DD/MM/YYYY hh:mm format or by the Julian day. Figg. 3.9, 3.10 3.11 report an example of the time series that may be given in input.

SCRIVI CHE PUOI USARE -9999 E LUI USA IL DATO PRECEDENTE

3.4.3 Cloudiness

cloud transmissivity (-)
cloud factor (-)

3.4.4 Lapse rates

The meteorological variables are usually characterized by a gradient on elevation, known as "lapse rate". It represents the variation of the variable with elevation. GEOtop admits in input the a dynamic lapse rate that (variable in time) that, according to the elevation of the calculation grid node, modifies the value of the variable. The meteorological variable that admits a lapse rate are:

- lapse rate for precipitation (mm h^{-1} hm^{-1})
- lapse rate for air temperature (°C hm^{-1})
- lapse rate for dew temperature (°C hm^{-1})

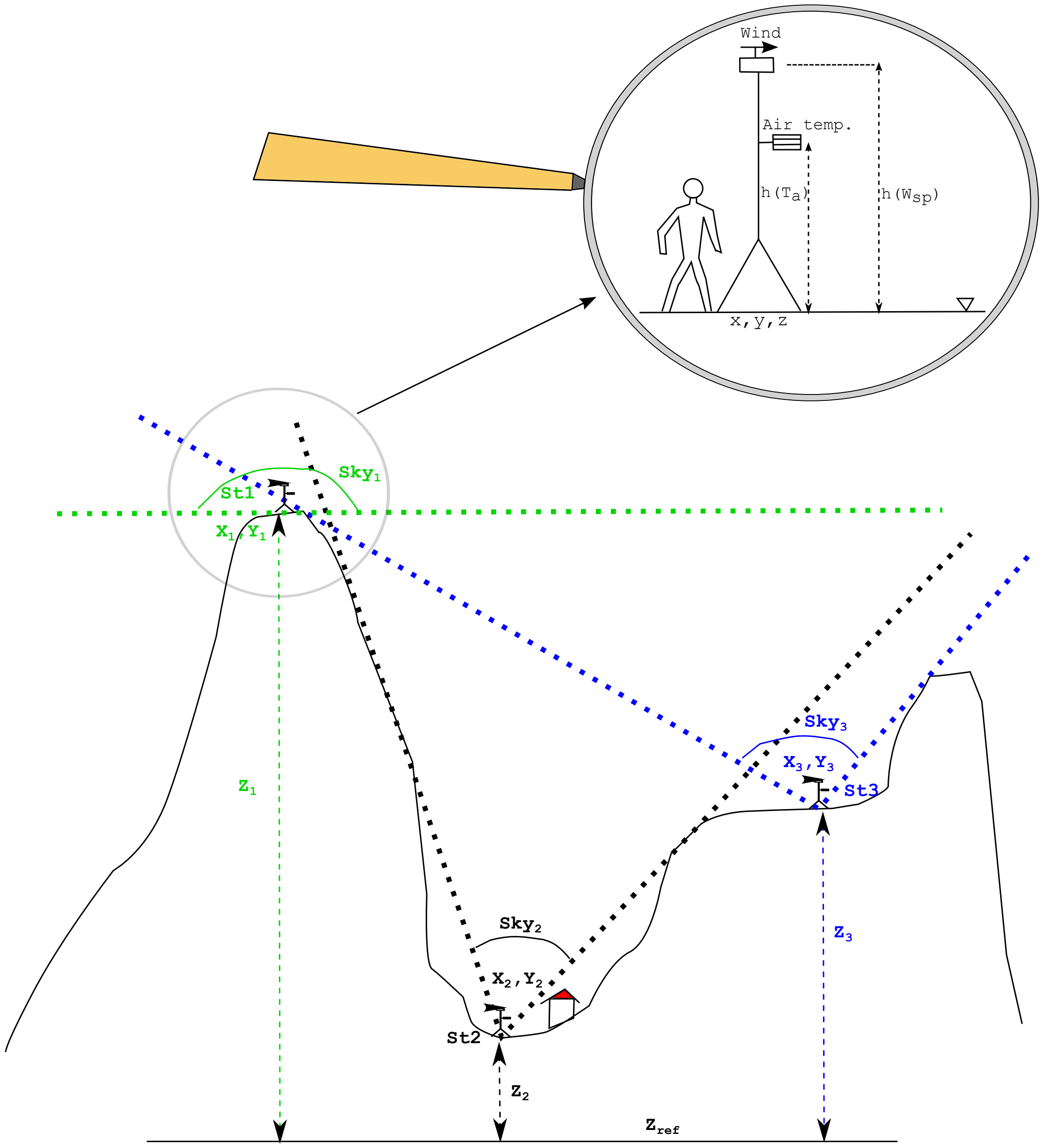


Figure 3.8: Prospect view of meteo station (ST) location in the domain area. X, Y, Z represent the east coordinate, north coordinate and elevation respectively. In the lence is reported a zoom of one meteo station: $h(T_a)$ and $h(W_{sp})$ represent the height of the air temperature and wind sensor respectively

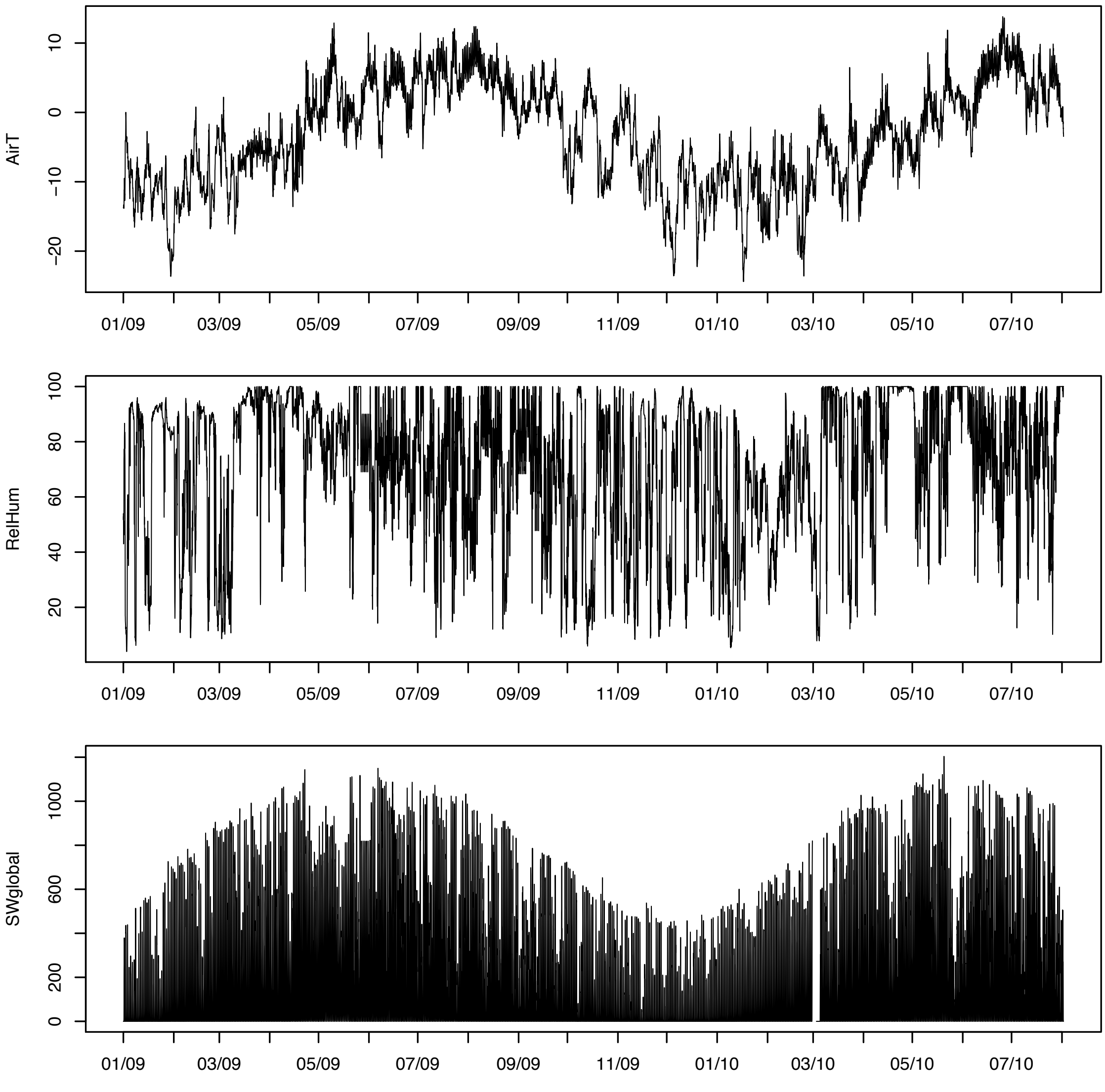


Figure 3.9: Meteo data measured in a meteo station. Top: air temperature (m s^{-1}); middle: relative humidity (%); bottom: short wave global radiation (W m^{-2})

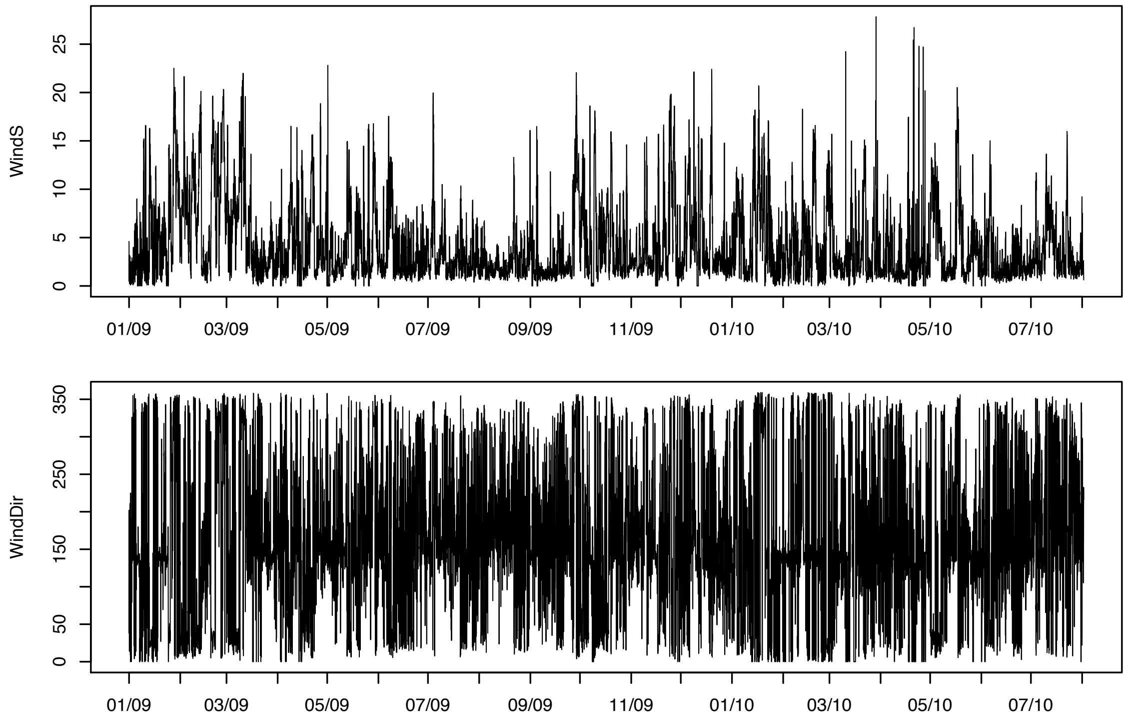


Figure 3.10: Meteo data measured in a meteo station. Top: wind speed (m s^{-1}); bottom: wind direction (° N)

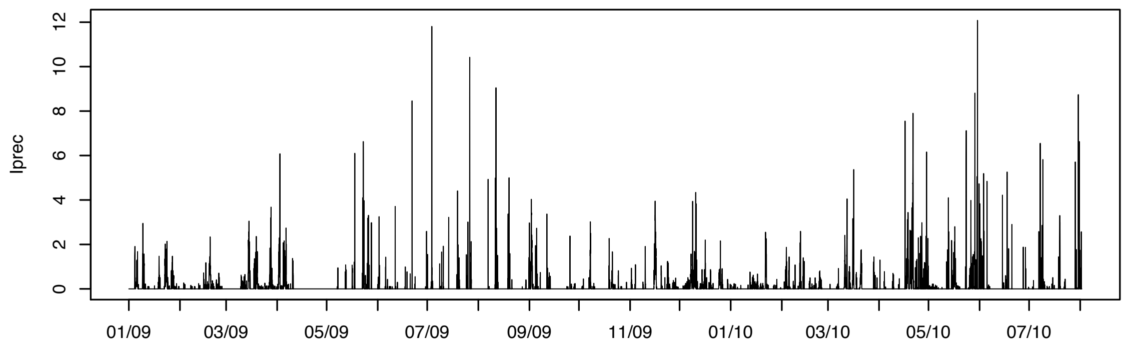


Figure 3.11: Meteo data measured in a meteo station: precipitation intensity (mm h^{-1})

Chapter 4

Simulation flow chart

This section is intended to provide a description of the simulation flow chart. In particular, a special focus will be given to the user's point of view (i.e. necessary input to provide and choices to make) when launching a simulation, and to the model point of view (i.e. calculation flow chart).

4.1 User point of view

The user that needs to fulfill a set of tasks in order to prepare the input necessary to launch a GEOtop simulation, as reported in Fig. 4.1.

Set general parameters The user must define the type of simulation (1D or 3D) and other general input.

Meteo station characterization The user must define the position and characteristics of the meteo stations.

Meteo data The user must define the meteorological forcing measured in each meteo station.

Topographic characterization The user must define the topographical characteristics of the domain area (i.e. elevation, aspect, slope, sky view factor, curvature).

Land cover characterization The user must define the surface type characteristics of the domain (often called "land use" or "land cover").

Soil type characterization The user must define the soil type characteristics of the domain area (i.e. soil texture, soil water retention curve etc.).

Initial conditions The user must define the initial temperature and water content in each cell of the domain.

Boundary conditions The user must define the behavior (fluxes) at the border domain.

Physical parameters The user must parametrize the various physical processes involved. In particular, the current version of GEOtop allow to specify the parameters typical of the following processes: glacier, snow, vegetation, soil/rock thermal, soil/rock hydraulic and discharge).

Output parameters The user must determine the desired information to be printed and the correspondent frequency.

4.2 1D simulations

Originally GEOtop was born as a hydrological model with the objective to produce maps of hydrological variables in a catchment. Later, thanks to the boost received by the permafrost community, it was adapted also to analyze single points located in extreme topographies. In these points, as outlined in Par. 3.3, for various reasons it may be interesting to produce 1D simulations. In fact 1D simulations are often useful as they allow to obtain results very rapidly and, in some cases, sufficiently reliable.

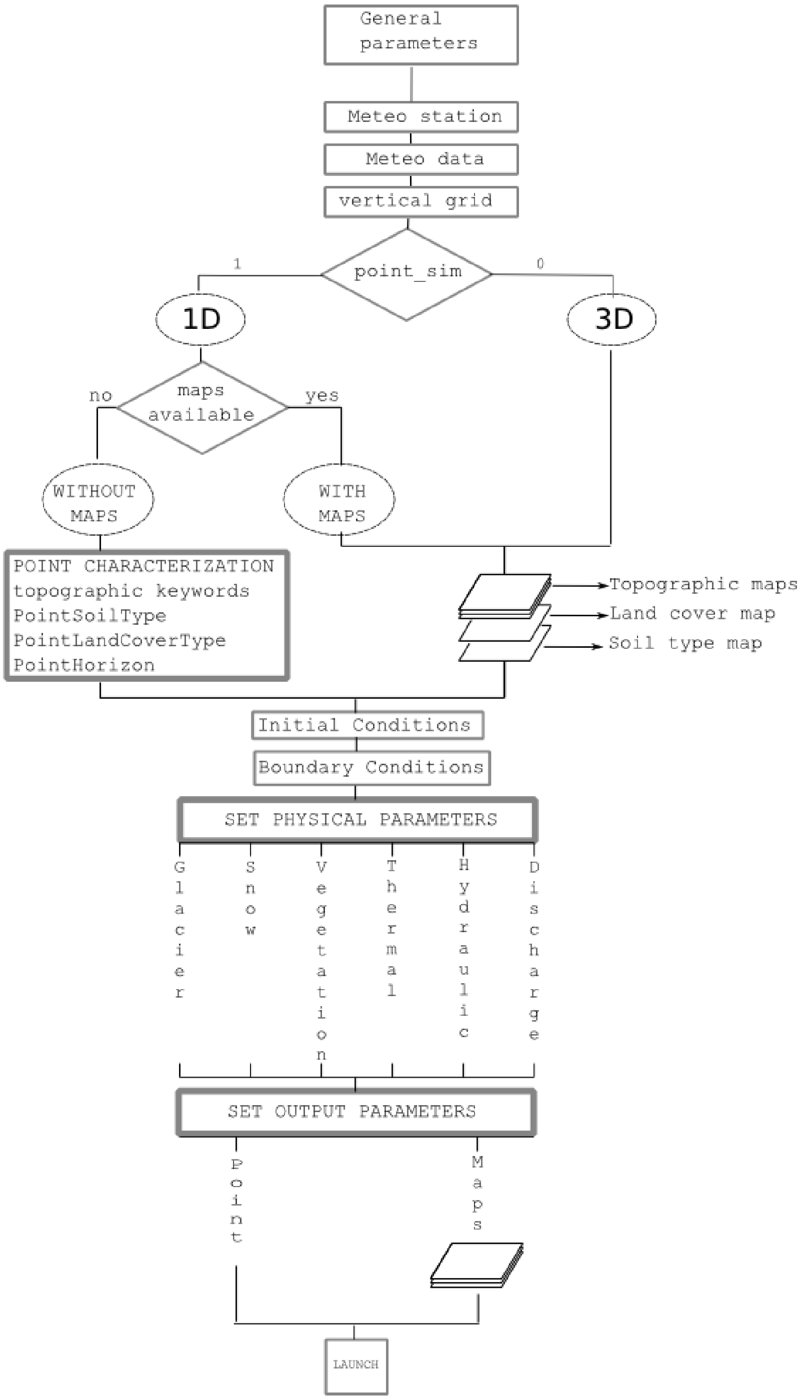
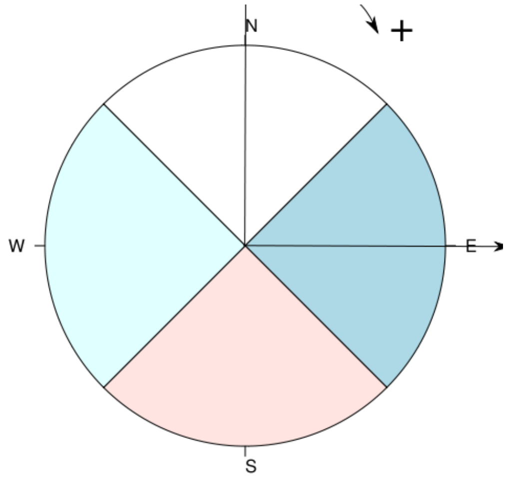


Figure 4.1: GEOtop flow chart: user point of view for preparing a simulation

4.2.1 Point horizon

In order to account for the topography visible by the simulation point, it is recommendable to provide the horizon file of the point. Every point $P(x, y, z)$ on the landscape, unless in the middle of a flat terrain, is surrounded by obstacles like mountains, buildings, trees. These objects, during the day, according to the elevation and position (azimuth) of the sun at a particular time in the year (julian day and day time), may produce a cast shadow on the point P that prevents the point from receiving direct solar radiation.
Thanks to proper cameras (e.g. fish-eye camera, see bottom of Fig. 4.1) or to GIS routines, it is possible to produce a file that outlines the angle height of the obstacles along a given azimuth direction. The *HorizonPointFile* allows to specify the horizon seen

HeaderHorizonAngle "azi"	HeaderHorizonHeight "hang"
45 °	0.00
135 °	10.00
225 °	30.00
315 °	5.00



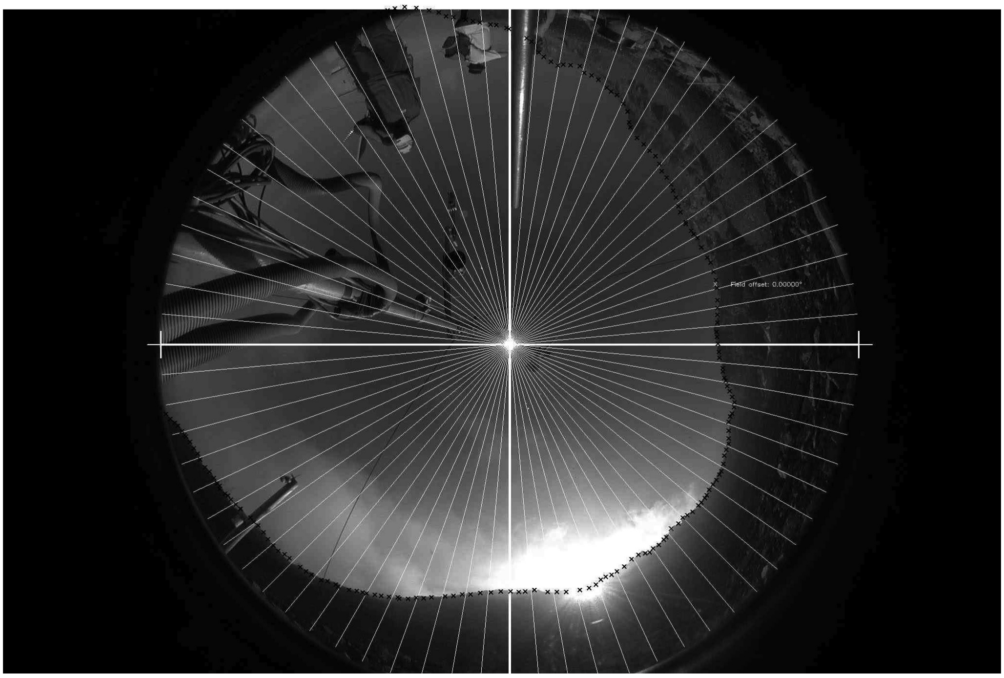


Table 4.1: Top: example of the default horizon file and of the corresponding azimuth classes. An example is given in Par. 5.2. Bottom: example of a fish-eye view from a point (courtesy of Stephan Gruber)

by a point P along a desired discretization of the azimuth. The file structure is thus a matrix whose first column represents the azimuth angle and the second column the elevation angle of the object height. The Table 4.1) reports the horizon file where the azimuth has been discretized in 4 parts. Note that the North direction must always be in the center of the slides in which the circle is divided. It is possible to increase the azimuth classes in order to provide a more detailed description of the obstacles height.
The horizon data may be specified in the following cases:

1. 1D simulations: since the topography is not provided, the user may provide the horizon file for every simulated point. Unless given, the model creates one assuming an overall flat terrain;

2. for meteorological stations: in this case it is needed to set the time when the sun is obscured by the obstacle; from that time onward the cloudiness calculation is no more carried by the ratio between actual and potential radiation, since the actual radiation would no longer provide a reliable value.

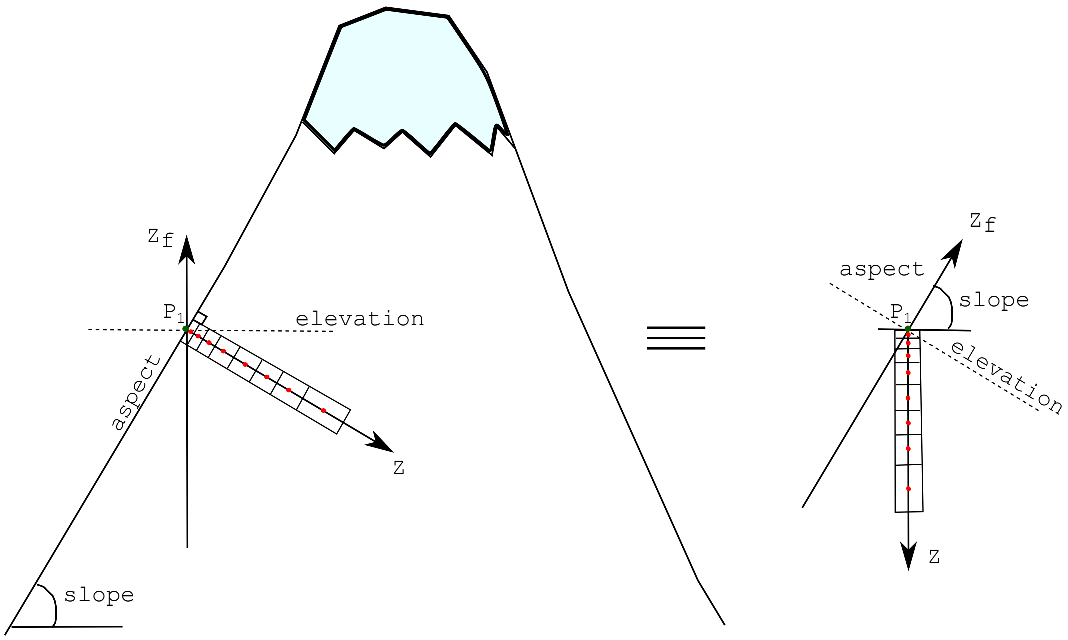


Figure 4.2: Scheme of a 1D simulation on steep topography typical of high mountain altitude

4.2.2 1D simulations: with or without maps

Let us suppose to select five points in the basin (see Fig. 3.6) where we want to run five 1D simulations. First of all it is necessary to provide the coordinates (X, Y) of the points, together with the average latitude and longitude of the area. In addition to that, it necessary to characterize the points by specifying the topography (elevation, aspect, slope, sky view factor, curvatures and the horizon), the soil type and land cover. This last information may be provided in two ways:

- **with maps**: the topographical, land cover and soil type maps are provided and the model, according to the coordinates of the points, automatically sets the topographical characteristics;
- **without maps**: the user has to specify all the characteristics of the points (e.g. see Table 5.3).

4.2.3 1D simulations in steep topography

The domain scheme of a 1D simulation at steep mountain topography is depicted in Fig. 4.2: the scheme is represented on the left: the axis of elevation Z_f is on the vertical direction and sets the elevation of the point on the surface, whereas the layers are located normal to the slope. If present, also the slope, aspect and horizon of the point P_1 may be specified. As the 1D representation is just an abstract sequence of layers of various depths located along on an imaginary line, one may think that the final scheme resembles what outlined on the right, where the elevation axis and the line Z axis form an angle complementary to the slope angle. Note that the Z axis does not coincide with the gravitational Z_f axis.

4.3 Model point of view

On the other hand, the model transforms the input given by the user into results, by solving the energy and mass balance in the calculation domain. As reported in Fig. 4.3, at the beginning of the simulation, GEOtop does the following activities:

1. Read input data In this phase, the model reads: (i) the keywords and parameters specified in *geotop.inpts* and other properly defined files; (ii) the topographic maps (elevation, aspect, slope, sky view factor, curvature), the land cover map (that coincides with the calculation mask), the map of soil type and, if available, the maps of initial conditions; (iii) reads the parameters (physical and output). If a parameter or a map is not specified with the proper keyword, it assumes the default value.

2. Create and initialize mesh As reported in Par. 3.1, it creates the calculation mesh according to the grid size of the land cover map and the vertical nodes spacing defined for the vertical grid. Then it initializes the temperature and water pressure head of each node with the initial conditions and sets the physical parameters according to what specified by the keywords.

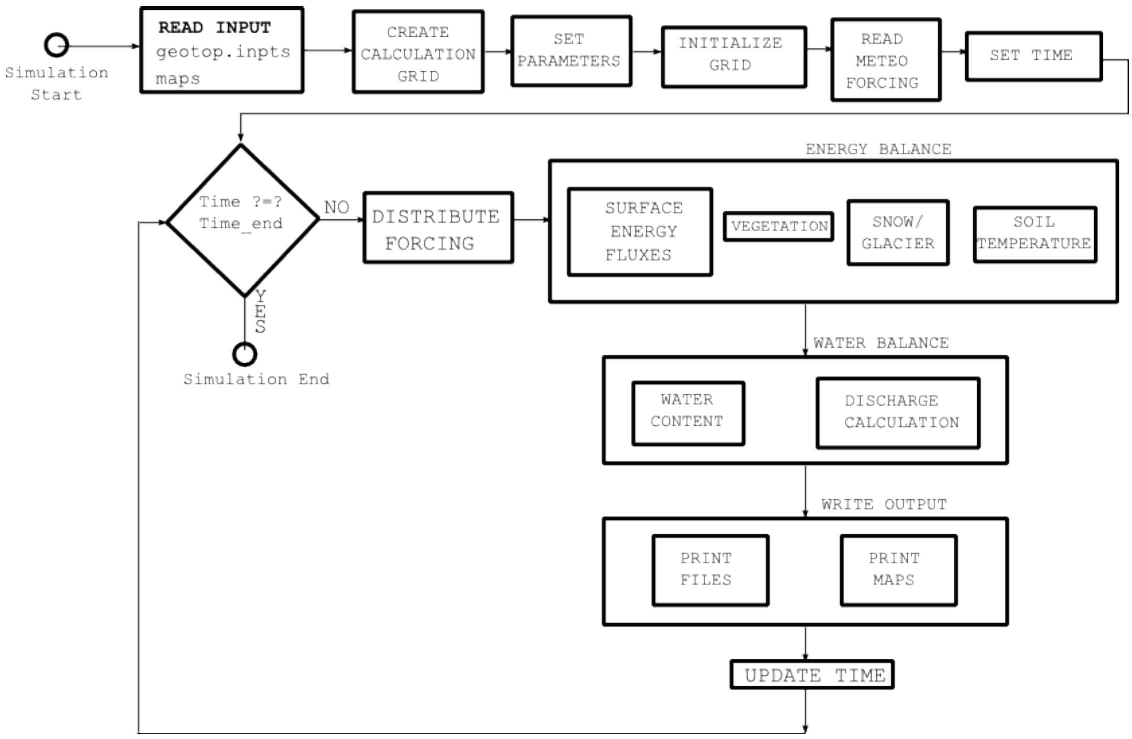


Figure 4.3: GEOtop flow chart: model point of view for accomplishing a simulation

3. Read meteo data During this phase it incorporates the meteorological data for each meteo station: these data represent the forcing that will drive the simulation, producing the dynamic boundary conditions for the surface nodes. Finally, GEOtop sets the initial simulation time to initialize the simulation counter: this will allow to compare the current simulation time with the expected simulation end time.

At this point begins the time loop for the calculation and the printing routines. In particular, at each calculation time step, GEOtop fulfills the following tasks:

1. Distribute meteorological forcing This allows to spatially distribute the meteorological forcing, measured in discrete meteo station, in all the calculation cells. This methodology is based on **LISTON**.

2. Energy balance In this phase the energy balance equation is solved. This encompasses the calculation of the surface energy fluxes, the vegetation module, the snow/glacier module and the routine the calculates the soil temperatures and ice content.

3. Water balance In this phase the mass balance equation is solved. This encompasses the calculation of the infiltration routine to determine the pore water pressure and water content through a 3D Richards solver. Eventually, the runoff and channel routing routines, based on a shallow-water solver, will allow to determine the discharge at the basin outlet.

4. Write output This phase is intended to print the point information and the maps according to the desired output frequency.

5. Update and check time This phase updates the time with the calculation time step and compares the new time with the simulation end time, to verify whether to stop the simulation or loop again. If the current simulation time SUPERA the end of the simulation, then the program stops and deallocates all the structures.

4.4 How to Run GEOtop

4.4.1 From Terminal

Open a terminal, go into the folder *Debug* by typing:

```
$ cd Debug
```

Write:

```
$ ./GEOtop1.2
```

Leave one space and type now the path to the folder where the simulation files are:

```
$./GEOtop_1.2 /Users/matteo/Duron/
```

Remember to put a"/" (slash) at the end and the type *Return*. The simulation should start.

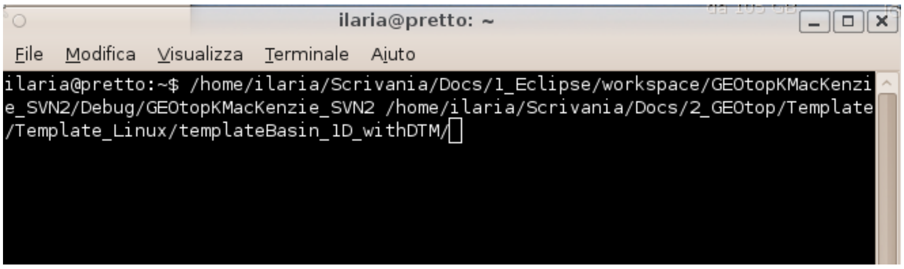


Figure 4.4: SVN

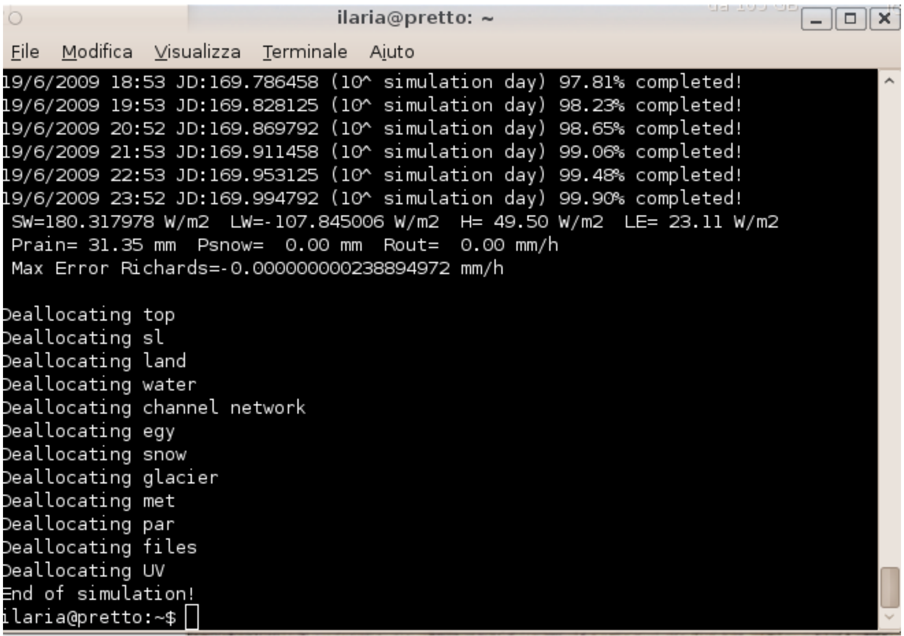


Figure 4.5: SVN

Chapter 5

I/O scheme: the keywords

GEOtop Input/Output (I/O) scheme is based on the keyword concept. Each parameter, concerning physical processes, output personalization, domain discretization and initial/boundary condition, is described by a keyword. The keywords may be classified according to the dimension (scalar or vector), type (numerical or string) and meaning (physical or boolean), as described in the Table 5.1.

	Scalar	**Vector**
Dimension	it refers to a single value, valid for the whole basin and during the entire simulation	it refers to more classes, layers or simulations. The vectors are composed just by numerical values (not strings).
	Numerical	**String**
Type	it is used to assign parameters	it is used to define maps, files or headers
	Physical	**Boolean**
Meaning	it is used to assign physical parameters	it is used to choose or reject an option in the parameterization process

Table 5.1: Keywords classification

The keywords may be used to describe both the input data and the output personalization. In particular, the keywords identify the following types:

1. **parameters**: they may be physical parameters, option parameters or output personalization;
2. **files**: they refer to input files, containing physical parameters, and output files containing the simulation results;
3. **maps**: they refer both to input maps, describing topographic features or soil characterization, and to output maps containing the simulation results;
4. **tensor**: they refer both to output maps containing the simulation results in each layer, or at specified depths, producing a 3D map;
5. **headers**: they refer to the column name of an input parameter or to the column name of an output result.

5.1 Keywords syntax

The main file where the keywords are defined is *geotop.inpts*. In this file, each line beginning with the character "!" is considered a comment, and therefore the following characters in the line won't be read.

```
! THIS IS a comment
```

In order to assign a value to the keyword, it is necessary to use the (character "="):

```
TimeStepEnergyAndWater = 3600
```

This instruction orders the model to assign 3600 to the keyword *TimeStepEnergyAndWater*. It is possible to assign a keyword a vector of numerical values by separating the components by the character “,”.

```
SoilLayerThicknesses=10, 15, 30, 50
```

This instruction assigns the keyword *SoilLayerThicknesses* a vector composed by 4 elements, namely: 10, 15, 30 and 50. It is not possible to assign a keyword a vector of strings.

5.1.1 Keywords definition

Readable characters

The numbers, the lower and upper case letters, the characters “.”, “-”, “+”, “/”, “:”, “[”, “\”, “]”, “∧”, “_”, and the separator characters will be referred to as “readable characters”. All the other characters, except for the assignation character (“=”) and the vector separator character (“,”), are not even read.

Strings or numerical keywords

The criterion used to distinguish whether an assignation is a string or numerical (be it single value or vector) is based on the **first readable character** after the field separator “=”, as explained in Table 5.2. As a consequence, it is not possible to assign string parameters that begin with a number or “+”, “-”, “.” (except “..”), because they will be considered numerical. Furthermore, the upper case letters are automatically converted in lower case, therefore all string keywords and parameters result to be case insensitive.

First character indicating a string keyword	**First character indicating a numerical keyword**
“/”	“+”
“:”	“-”
“[”	“E”
“\”	“e”
“]”	”.” (decimal separator)
“∧”	numbers
“_”	
“..”	
letters	
numbers	

Table 5.2: Character classification for strings and numerical

This means that the command lines:

```
TimeStepEnergyAndWater = 3600
```

and:

```
TimeStepEnergyAndWater = 3 this is the first figure 6 bla bla 0 micio bau 0 polenta
```

are actually equivalent, provided the first readable character is a number or “+”, “−”, “.” In addition, since the string are actually case insensitive, the command lines:

```
TimeStepEnergyAndWater = 3600
Time step energy and water = 3600
```

are also equivalent.

5.1.2 Dates and time

The dates in GEOtop are considered numerical parameters and are expressed in the “date12” format, namely using 12 figures as DDMMYYYYhhmm, where D = day, M = month, Y = year, h = hour (in 24 hours format). It is necessary to use 2 figures (not only one) for the minute, hours, month, and 4 figures for the year, otherwise the date will be misunderstood. An exception is made for the day which may also be represented by one figure. Since within a numerical value parameter, the characters different from numbers, “+”, “-”, “.”, and separators are not readable, provided they are not the first character, it is also possible to express the date12 format as DD/MM/YYYY hh:mm or DD MM YYYY hh mm, but not as DD-MM-YYYY hh:mm because ”-” makes changes to the meaning of a numerical value.

5.2 Keywords properties

The way the keyword are assigned is based on the following assumptions:

self explanatory The keyword is generally a “composed word” that aims at explaining its meaning just through the words that constitute it.
For example the keyword: *TimeStepEnergyAndWater* describes the calculation time step for the energy and water balance equations. The keyword: *SoilLayerThicknesses* outlines the layer thickness of the soil discretization.

tacit If not displayed, the parameter the keyword refers to will be initialized by the default value. Few parameters are mandatory (it will be remarked when this is the case), while most of them are not necessary to be assigned, and the corresponding line can be skipped or commented. The mandatory parameters are:

- *Latitude*
- *Longitude*
- integration time step for energy and water balance equation *TimeStepEnergyAndWater*
- Date and time of the simulation start in date12 format *InitDateDDMMYYYYhhmm*
- Date and time of the simulation end in date12 format *EndDateDDMMYYYYhhmm*

conservative The keywords allow to define the output files, maps and variables to be printed.
Only the output variables, maps and files that have been declared by the proper keyword will be printed in order to save memory and to keep the output simple.
For example, if one is interested in printing the incoming, outgoing and net shortwave radiation in a simulation point, may specify:

```
!=============================================================================
!   POINT OUTPUT COLUMN NUMBER
!=============================================================================
DatePoint = 1
AirTempPoint = 2
SurfaceEBPoint = 3
SWupPoint = 4
SWinPoint = 5
SWNetPoint = 6
SoilHeatFluxPoint = 7
LWinPoint=8
LWNetPoint=9
LWupPoint=10
```

In this way two output files will be created: “point.txt” (associated to the keyword *PointOutputFileWriteEnd*) and the file “soil-Tave.txt” associated to the keyword *SoilAveragedTempProfileFileWriteEnd*. The file “point.txt” will contain the results associated to the desired keywords at the specified column, i.e. the variable associated to the keyword *SWupPoint* will be printed in the column n. 2. Eventually, in case one wants to personalize the name of a output variable, it is necessary to flag the keyowrd *DefaultPoint=0* and then to specify the output keywords headers:

```
!=============================================================================
!   POINT OUTPUT HEADER
!=============================================================================
```

```
DefaultPoint = 0
HeaderDatePoint = "date"
HeaderSWupPoint = "SW out"
HeaderSWinPoint = "SW in"
HeaderSWNetPoint = "SW net"
```

In case one wanted to print the average temperatures of the soil:

```
!=============================================================================
!  OUTPUT FILES
!=============================================================================
PointOutputFileWriteEnd = "point"
SoilAveragedTempProfileFileWriteEnd = "soilTave"
```

In this case the file "soilTave.txt" will be produced, containing the temperatures at each layer. If one wanted to have the temperatures calculated at specified depths, one should write:

```
!=============================================================================
!  PERSONALIZED OUTPUT FILES
!=============================================================================
DefaultSoil = 0
SoilPlotDepths = 0.1, 0.5, 1, 2
```

In this case the file will contain the temperatures at 0.1, 0.5, 1.0 and 2.0 m.

self learning If the keyword represents a vector of length "l" and the input consists in a vector of length "m" with $m < l$, then the successive $l - m$ elements will be initialized equal to the element "l". For example, the keywords:

```
SoilLayerNumber=10
SoilLayerThicknesses=10, 15, 30, 50
InitSoilTemp=2
```

are interpreted as:

```
SoilLayerNumber=10
SoilLayerThicknesses=10, 15, 30, 50, 50, 50, 50, 50, 50, 50
InitSoilTemp=2, 2, 2, 2, 2, 2, 2, 2, 2, 2
```

organization The keywords may be assigned in the *geotop.inpts* file or in external files defined by proper keywords, in order to ease the organization of input. The keywords may also identify the name of files and headers to improve the output visualization. For example, let us assume to run a 1D simulation on eight points whose topographical and horizon (see Par. 4.2.1) characteristics are defined in Table 5.3.

Point	Elevation (m a.s.l.)	Slope (°)	Aspect (° N)	Horizon file
1	1600	10	0	1
2	2100	10	0	2
3	1600	30	0	1
4	2100	30	0	2
5	1600	10	180	1
6	2100	10	180	2
7	1600	30	180	1
8	2100	30	180	2

Table 5.3: Topographical characteristics of the simulation points

In order to provide these characteristics, one has two options. In the first option, one uses only the *geotop.inpts* file:

```
HorizonPointFile= "horfile"
HeaderHorizonAngle = "azi"
HeaderHorizonHeight = "hang"
PointElevation = 1600, 2100, 1600, 2100, 1600, 2100, 1600, 2100
PointSlope = 10, 30, 10, 30, 10, 30, 10, 30
PointAspect = 0, 180, 0, 180, 0, 180, 0, 180
PointHorizon = 1, 2, 1, 2, 1, 2, 1, 2
```

where the *HorizonPointFile* becomes (see Table 4.1):

```
azi, hang
45, 0
135, 10
225, 30
315, 5
```

Alternatively, in order to ease the comprehension, especially when the number of simulation points is high, one could define an external file (*PointFile*) containing the features of the points, where the name of the columns has been defined in *geotop.inpts* in the proper "header" keywords. This would result in:

```
HorizonPointFile = "horfile"
PointFile = "listpoints"
HeaderPointElevation = "ele"
HeaderPointSlope = "slp"
HeaderPointAspect = "asp"
HeaderPointHorizon = "hor"
HeaderHorizonAngle="azi"
HeaderHorizonHeight="hang"
```

and the correspondent *PointFile* would result in:

```
ID, ele, slp, asp, hor
1, 1600, 10, 0, 1
2, 2100, 30, 180, 2
3, 1600, 10, 0, 1
4, 2100, 30, 180, 2
5, 1600, 10, 0, 1
6, 2100, 30, 180, 2
7, 1600, 10, 0, 1
8, 2100, 30, 180, 2
```

Chapter 6

1D: domain definition and characterization

As pointed out in Fig. 4.1, the 1D simulation may defined in two ways:

1. with maps: in this case the user must provide also the topographical maps together with the land cover, the soil type and, if present, the initial conditions maps. Furthermore, the user must give in input also the coordinates of the simulation points (see Fig. 3.6 and 3.7). The model automatically extrapolates the information on the give points through the provided maps;
2. without maps: in this case, the user must provide all the necessary information about the topography, land cover and soil type of the simulation points.

In both cases the domain discretization along the Z coordinate (Fig. 3.3 on the right) must be properly defined as described in Table 6.1.

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
SoilLayerThicknesses	vector defining the thickness of the various soil layers. If not present, a column of 5 layers 100 mm thick will be assumed	mm		100	vec	num
SoilLayerNumber	number of soil layers (is calculated after the number of components of the vector SoilLayerNumber)	-		5	sca	num

Table 6.1: Keywords of parameters referred to soil layer

6.1 Without maps

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
PointLandCoverType	Land Cover type of the simulation point	-		NA	vec	num
PointSoilType	Soil type of the simulation point	-		NA	vec	num
PointElevation	elevation of the point of simulation	m a.s.l.		NA	vec	num
PointSlope	Slope steepness of the simulation point	degree		NA	vec	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
PointAspect	Aspect of the simulation point	degree		NA	vec	num
PointSkyViewFactor	Sky View Factor of the simulation point	-		NA	vec	num
PointCurvatureNorthSouthDirection	N-S curvature of the simulation point	m^{-1}		NA	vec	num
PointCurvatureWestEastDirection	W-E curvature of the simulation point	m^{-1}		NA	vec	num
PointCurvatureNorthwestSoutheastDirection	N-W curvature of the simulation point	m^{-1}		NA	vec	num
PointCurvatureNortheastSouthwestDirection	N-E curvature of the simulation point	m^{-1}		NA	vec	num
PointDrainageLateralDistance	Lateral Drainage distance of the simulation point	m		NA	vec	num
PointLatitude	Latitude of the simulation point	degree		NA	vec	num
PointLongitude	Longitude of the simulation point	degree		NA	vec	num
PointHorizon	number of the HorizonPointFile that describes the horizon of the simulation point	-		NA	vec	num

Table 6.2: Keywords of topographical, land cover and soil type characteristics that may be set in geotop.inpts. Each parameter may be give in input as a vector, each component representing a point. Otherwise the characteristics may be summarized in the file PointFile, each value corresponding to the proper header defined in Table 6.8.

Files

Keyword	**Description**
PointFile	name of the file providing the properties for the simulation point
HorizonPointFile	name of the file providing the horizon of the simulation point

Table 6.3: Keywords of files related to soil/rock spatial characterization for 1D simulation

Headers

Keyword	**Description**	**Associated file**
HeaderHorizonAngle	String representing the header of the column HorizonAngle of the HorizonPoint and HorizonMeteoStation files	HorizonPoint / HorizonMeteo-Station
HeaderHorizonHeight	String representing the header of the column HorizonHeight of the HorizonPoint and HorizonMeteoStation files	HorizonPoint / HorizonMeteo-Station
HeaderPointElevation	column name in the file PointFile for the elevation of the point	PointFile
HeaderPointSlope	column name in the file PointFile for the slope steepness of the point	PointFile
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Keyword	**Description**	**Associated file**
HeaderPointAspect	column name in the file PointFile for the aspect of the point	PointFile
HeaderPointSkyViewFactor	column name in the file PointFile for the sky view factor of the point	PointFile
HeaderPointCurvatureNorthSouthDirection	column name in the file PointFile for the N-S curvature of the point	PointFile
HeaderPointCurvatureWestEastDirection	column name in the file PointFile for the E-W curvature of the point	PointFile
HeaderPointCurvatureNorthwestSoutheastDirection	column name in the file PointFile for the NW-SE curvature of the point	PointFile
HeaderPointCurvatureNortheastSouthwestDirection	column name in the file PointFile for the NE-SW curvature of the point	PointFile
HeaderPointDrainageLateralDistance	column name in the file PointFile for the distance of lateral drainage	PointFile
HeaderPointHorizon	column name in the file PointFile that provides the number of the HorizonPointFile that describes the horizon of the simulation point	PointFile
HeaderPointLatitude	column name in the file PointFile for the latitude of the point	PointFile
HeaderPointLongitude	column name in the file PointFile for the longitude of the point	PointFile
HeaderPointID	column name in the file PointFile for the identification ID of the point	PointFile
HeaderCoordinatePointX	column name in the file PointFile for the x coordinate of the point	PointFile
HeaderCoordinatePointY	column name in the file PointFile for the y coordinate of the point	PointFile

Table 6.4: Keywords of headers that specify the soil/rock spatial characterization for 1D simulation

6.2 With maps

Maps

Keyword	**Description**
DemFile	name of the file providing the DEM map
SkyViewFactorMapFile	name of the file providing the sky view factor map
SlopeMapFile	name of the file providing the slope steepness map
RiverNetwork	name of the file providing the river network map
AspectMapFile	name of the file providing the aspect map
CurvaturesMapFile	name of the file providing the curvature map
LandCoverMapFile	name of the file providing the land cover map
SoilMapFile	name of the file providing the soil map

Table 6.5: Keywords of input file related to the domain

Files

Keyword	Description
PointFile	name of the file providing the properties for the simulation point

Table 6.6: Keyword of the file related to the spatial characterization of soil/rock properties. The parameters identified by the row index represent the value corresponding to the SoilMapFile map.

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
PointID	identification code for the point of simulation			NA	vec	num
CoordinatePointX	coordinate X if PixelCoordinates is 1, number of row of the matrix if PixelCoordinates is 0	m (according to the geographical projection of the maps)		NA	vec	num
CoordinatePointY	coordinate Y if PixelCoordinates is 1, number of column of the matrix if PixelCoordinates is 1	m (according to the geographical projection of the maps)		NA	vec	num
Latitude	Average latitude of the basin, positive means north, negative means south	degree	-90, 90	45	sca	num
Longitude	Average longitude of the basin, eastwards from 0 meridiane	degree	0, 180	0	sca	num

Table 6.7: Keywords of point characterization for the choice of points where to perform a 1D simulation

Headers

Keyword	Description	Associated file
HeaderPointID	column name in the file PointFile for the identification ID of the point	PointFile
HeaderCoordinatePointX	column name in the file PointFile for the x coordinate of the point	PointFile
HeaderCoordinatePointY	column name in the file PointFile for the y coordinate of the point	PointFile

Table 6.8: Keywords of headers that specify the soil/rock spatial characterization for 1D simulation

Chapter 7

3D: domain definition and characterization

7.1 Planar domain definition

Keyword	Description
DemFile	name of the file providing the DEM map
LandCoverMapFile	name of the file providing the land cover map

Table 7.1: Keywords of input file related to the domain

7.2 Z-coordinate domain definition

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
SoilLayerThicknesses	vector defining the thickness of the various soil layers. If not present, a column of 5 layers 100 mm thick will be assumed	mm		100	vec	num
SoilLayerNumber	number of soil layers (is calculated after the number of components of the vector SoilLayerNumber)	-		5	sca	num

Table 7.2: Keywords of parameters referred to soil layer

7.3 Topographical characterization

Keyword	Description
SkyViewFactorMapFile	name of the file providing the sky view factor map
SlopeMapFile	name of the file providing the slope steepness map
RiverNetwork	name of the file providing the river network map
AspectMapFile	name of the file providing the aspect map
CurvaturesMapFile	name of the file providing the curvature map
BedrockDepthMapFile	name of the file providing the bedrock depth map

Table 7.3: Keywords of input maps necessary to launch the 3D simulation

7.4 Land cover and soil depth characterization

Keyword	Description
LandCoverMapFile	name of the file providing the land cover map
SoilMapFile	name of the file providing the soil map

Table 7.4: Keywords of input maps necessary to launch the 3D simulation

Each land cover type may be characterized by parameters that define the influence on vegetation, soil surface and snow. Each soil type may be further described in the file *PointFile* (see Table 7.5) where each row index represents the value corresponding to the *SoilMapFile* map.

Keyword	Description
PointFile	name of the file providing the properties for the simulation point

Table 7.5: Keyword of the file related to the spatial characterization of soil/rock properties. The parameters identified by the row index represent the value corresponding to the SoilMapFile map.

It is also requested to provide a definition of the average latitude and longitude of the domain area, as specified in Table 7.8.

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
Latitude	Average latitude of the basin, positive means north, negative means south	degree	-90, 90	45	sca	num
Longitude	Average longitude of the basin, eastwards from 0 meridiane	degree	0, 180	0	sca	num

Table 7.6: Keyword of parameters describing the point characterization for 3D simulations

7.5 Output

It is possible to define some points where to obtain output information, as described in Par. 3.3. The parameters and headers to provide are specified in Table 7.7 and 7.8 respectively.

Keyword	Description	Associated file
HeaderPointID	column name in the file PointFile for the identification ID of the point	PointFile
HeaderCoordinatePointX	column name in the file PointFile for the x coordinate of the point	PointFile
HeaderCoordinatePointY	column name in the file PointFile for the y coordinate of the point	PointFile

Table 7.7: Keywords of header that specify the soil/rock spatial characterization for 3D simulation

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
PointID	identification code for the point of simulation			NA	vec	num
CoordinatePointX	coordinate X if PixelCoordinates is 1, number of row of the matrix if PixelCoordinates is 0	m (according to the geographical projection of the maps)		NA	vec	num
CoordinatePointY	coordinate Y if PixelCoordinates is 1, number of column of the matrix if PixelCoordinates is 1	m (according to the geographical projection of the maps)		NA	vec	num

Table 7.8: Keywords of point characterization for the choice of point outputs in 3D simulations

Chapter 8

General features

8.1 Input

8.1.1 File

Keyword	Description
TimeStepsFile	name of the file providing the integration time steps

Table 8.1: Keyword of file related to general input

8.1.2 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
FlagSkyViewFactor	If not present, the sky view factor can be calculated (=1), or just be considered only equal to 1 (=0)	-	0, 1	0	sca	opt
TimeStepEnergyAndWater	Integrations time step [s] for energy and water balance equation (mandatory)	s	0, inf	NA	vec	num
InitDateDDMMYYYYhhmm	Date and time of the simulation start in date12 format (mandatory)	format DDMMYY-hhmm	01/01/1800 00:00, 01/01/2500 00:00	NA	vec	str
EndDateDDMMYYYYhhmm	Date and time of the simulation start in date12 format (mandatory)	format DDMMYY-hhmm	01/01/1800 00:00, 01/01/2500 00:00	NA	vec	str
NumSimulationTimes	How many times the simulation is run (if >1, it uses the final condition as initial conditions of the new simulation)	-	0, inf	1	vec	num
StandardTimeSimulation	Standard time to which all the output data are referred (difference respect UMT, in hours): GMT + x [h]	h	0, 12	0	sca	num
PointSim	Point simulation (=1), distributed simulation (=0)	-	0, 1	0	sca	opt

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
RecoverSim	Simulation recovered (=number of saving point you want to start from), otherwise (=0)	-	0, 1	0	sca	opt
WaterBalance	Activate water balance (Yes=1, No=0)	-		0	sca	opt
EnergyBalance	Activate energy balance (Yes=1, No=0)			0	sca	opt
PixelCoordinates	Write 1 IF ALL point coordinates are in format (East, North) in meter, or if in format row and colums (r,c) of the dem map	-		1	sca	opt
SavingPoints		-		NA	vec	num
SoilLayerTypes	Number of types of soil types, corresponding to different soil stratigraphies	-		1	sca	num
DefaultSoilTypeLand	given a multiple number of type of soil, this relates to the default given to the land type type	-		1	sca	num
DefaultSoilTypeChannel	given a multiple number of type of soil, this relates to the default given to the channel type	-		1	sca	num

Table 8.2: Keywords for the general parameters settable in geotop.inpts

8.2 Output

8.2.1 Maps parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
FormatOutputMaps	Format of the output maps (=2 grass ascii, =3 esri ascii)	-	2, 3	3	sca	opt

Table 8.3: Keywords of general parameters regarding output options that may be set in geotop.inpts

Chapter 9

Meteo Forcing

9.1 Input

9.1.1 Files

Keyword	Description
MeteoFile	name of the file providing the meteo forcing data
MeteoStationsListFile	name of the file providing the Meteo Station list
LapseRateFile	name of the file providing the Lapse rate
HorizonMeteoStationFile	name of the file providing the horizon of the meteo station

Table 9.1: Keywords of files related to meterological forcing

9.1.2 Parameters for meteo station

Keyword	Description	M. U.	range	Default Value	Sca /Vec	File
MeteoStationsID	Identification code for the meteo station	-		NA	vec	MeteoStationsListFiles
NumberOfMeteoStations	MeteoStations ListFilesber of soil Meteo Stations (is calculated after the number of components of the vector NumberOfMeteoStations)	-		1	sca	MeteoStationsListFiles
MeteoStationCoordinateX	coordinate X of the meteo station	m		NA	vec	MeteoStationsListFiles
MeteoStationCoordinateY	coordinate Y of the meteo station	m		NA	vec	MeteoStationsListFiles
MeteoStationLatitude	Latitude of the meteo station	degree		Latitude	vec	MeteoStationsListFiles
MeteoStationLongitude	Longitude of the meteo station	degree		Longitude	vec	MeteoStationsListFiles
MeteoStationElevation	Latitude of the meteo station	m a.s.l.		0	vec	MeteoStationsListFiles

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Keyword	Description	M. U.	range	Default Value	Sca /Vec	File
MeteoStationSkyViewFactor	Sky view factor of the meteo station	-		1	vec	MeteoStationsListFiles
MeteoStationStandardTime	Time difference of the meteo records with respect to Greenwich Meridiam Time (GMT). Note that the CET, Central European Time, is GMT+1 for Standard Time and GMT+2 for Summer Time	h		Standard Time Simulation	vec	MeteoStationsListFiles
MeteoStationWindVelocitySensorHeight	Height of the wind velocity sensor of the meteo station	m a.g.l		10	vec	MeteoStationsListFiles
MeteoStationTemperatureSensorHeight	Height of the air temperature sensor of the meteo station	m a.g.l		2	vec	MeteoStationsListFiles

Table 9.2: Keywords for the description of the meteorological station. All values are numeric. Note that m a.s.l. stands for meters above the sea level and m a.g.l. stands for meters above the ground level.

9.1.3 Headers for meteo station

Keyword	Description	Associated file	type (file, header)
HeaderIDMeteoStation	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationCoordinateX	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationCoordinateY	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationLatitude	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationLongitude	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationElevation	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationSkyViewFactor	column name in the file MeteoFile	MeteoFile	header
HeaderMeteoStationStandardTime	column name in the file MeteoFile	MeteoFile	header

Table 9.3: Keywords of headers that specify the meteo station characteristics

9.1.4 Parameters for meteo forcing

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Associated file
Vmin	Minimum wind velocity (too low wind speeds may create numerical problems)	m s^{-1}	0, 100	0.5	sca	geotop.inpts

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Associated fie**
RHmin	Minimum relative humidity (too low relative humidities may create numerical problems)	%	0, 100	10	sca	geotop.inpts
RainCorrFactor	correction factor precipitated rain	-	1 , 2	1	sca	geotop.inpts
LapseRateTemp	Lapse rate of air temperature with elevation	°C km^{-1}		NA	vec	LapseRate File
LapseRateDewTemp	Lapse rate of dew temperature with elevation	°C km^{-1}		NA	vec	LapseRate File
LapseRatePrec	Lapse rate of precipitation with elevation	mm h^{-1} km^{-1}		NA	vec	LapseRate File

Table 9.4: Keywords for the description of the meteorological data. All values are numeric.

9.1.5 Headers for meteo forcing

Each meteo variable must be identified by a header in the *MeteoFile* and the header name may be identified by the keywords specified in Table 9.5.

Keyword	**Description**	**Associated file**	**M.U. of the data**
HeaderDateDDMMYYYYhhmmMeteo	column name in the file MeteoFile for the variable DateDDMMYYYhhmmMeteo	MeteoFile	DD/MM/YYYY hh:mm
HeaderJulianDayfrom0Meteo	column name in the file MeteoFile for the variable julian day from 0	MeteoFile	day
HeaderIPrec	column name in the file MeteoFile for the variable precipitation	MeteoFile	mm h^{-1}
HeaderWindVelocity	column name in the file MeteoFile for the variable wind speed	MeteoFile	m s^{-1}
HeaderWindDirection	column name in the file MeteoFile for the variable wind direction	MeteoFile	°N
HeaderWindX	column name in the file MeteoFile for the variable wind X	MeteoFile	m s^{-1}
HeaderWindY	column name in the file MeteoFile for the variable wind Y	MeteoFile	m s^{-1}
HeaderRH	column name in the file MeteoFile for the variable Relative humidity	MeteoFile	%
HeaderAirTemp	column name in the file MeteoFile for the variable Air Temperature	MeteoFile	°C
HeaderDewTemp	column name in the file MeteoFile for the variable Dew temperature	MeteoFile	°C
HeaderAirPress	column name in the file MeteoFile for the variable Air Pressure	MeteoFile	mbar
HeaderSWglobal	column name in the file MeteoFile for the variable SW global	MeteoFile	W m^{-2}
HeaderSWdirect	column name in the file MeteoFile for the variable Swdirect	MeteoFile	W m^{-2}
HeaderSWdiffuse	column name in the file MeteoFile for the variable Swdiffuse	MeteoFile	W m^{-2}
HeaderCloudSWTransmissivity	column name in the file MeteoFile for the variable transmissivity of SW through cloud	MeteoFile	-
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Keyword	Description	Associated file	M.U. of the data
HeaderCloudFactor	column name in the file MeteoFile for the variable cloud factor	MeteoFile	-
HeaderLWin	column name in the file MeteoFile for the variable LW in	MeteoFile	W m^{-2}
HeaderSWnet	column name in the file MeteoFile for the variable SW net	MeteoFile	W m^{-2}
HeaderDateDDMMYYYYhhmmLapseRates	column name in the file LapseRate-File for the variable Date	LapseRateFile	DD/MM/YYYY hh:mm
HeaderLapseRateTemp	column name in the file LapseRate-File for the variable air temperature	LapseRateFile	see LapseR-ateTemp
HeaderLapseRateDewTemp	column name in the file LapseRate-File for the variable dew tempera-ture	LapseRateFile	see LapseRat-eDewTemp
HeaderLapseRatePrec	column name in the file LapseRate-File for the variable precipitation	LapseRateFile	see LapseR-atePrec

Table 9.5: Headers of meteorological forcing (meteo data - character)

9.2 Spatial distribution of meteorological forcing

9.2.1 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Num / Opt
Iobsint	Let Micromet determine an appropriate ”radius of influence” (=0), or define the ”radius of influence” you want the model to use (=1). 1=use obs interval below, 0=use model generated interval.	-		1	sca	opt
Dn	The ”radius of influence” or ”observa-tion interval” you want the model to use for the interpolation. In units of deltax, deltay.	-		1	sca	num
SlopeWeight	Weight assigned to the slope (as tangent when it is <1) in the spatial distribution of the wind speed	-	0 - 1	0	sca	num
CurvatureWeight	Weight assigned to the curvature (as sec-ond derivative of the topographic surface) in the spatial distribution of the wind speed. Valid slope and curve weights val-ues are between 0 and 1, with values of 0.5 giving approximately equal weight to slope and curvature. The suggestion is that slopewt and curvewt be set such that slopewt + curvewt = 1.0. This will limit the total wind weight to between 0.5 and 1.5 (this is not stricktly required)	-		0	sca	num
SlopeWeightD				0	sca	num
CurvatureWeightD				0	sca	num
SlopeWeightI				0	sca	num
CurvatureWeightI				0	sca	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Scalar / Vector**	**Num / Opt**

Table 9.6: Table of spatial distribution method parameters (numeric)

9.3 Output

9.3.1 Point

File

Keyword	**Description**
PointOutputFile	name of the output file providing the Point values
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end

Table 9.7: Keywords of output files to visualize meteorological forcing on the simulation points

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
DefaultPoint	0: use personal setting (see Table of headers), 1:use default headers	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of the output for specified grid points (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
PsnowPoint	column number in which one would like to visualize the Psnow_over_canopy[mm]	-	1, 76	-1	sca	num
PrainPoint	column number in which one would like to visualize the Prain_over_canopy[mm]	-	1, 76	-1	sca	num
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Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
PsnowNetPoint	column number in which one would like to visualize the Psnow_under_canopy[mm]	-	1, 76	-1	sca	num
PrainNetPoint	column number in which one would like to visualize the Prain_under_canopy[mm]	-	1, 76	-1	sca	num
PrainOnSnowPoint	column number in which one would like to visualize the Prain_rain_on_snow[mm]	-	1, 76	-1	sca	num
WindSpeedPoint	column number in which one would like to visualize the Wind_speed[m/s]	-	1, 76	-1	sca	num
WindDirPoint	column number in which one would like to visualize the Wind_direction[deg]	-	1, 76	-1	sca	num
RHPoint	column number in which one would like to visualize the Relative_Humidity[-]	-	1, 76	-1	sca	num
AirPressPoint	column number in which one would like to visualize the Pressure[mbar]	-	1, 76	-1	sca	num
AirTempPoint	column number in which one would like to visualize the Tair[°C]	-	1, 76	-1	sca	num
TDewPoint	column number in which one would like to visualize the Tdew[°C]	-	1, 76	-1	sca	num
TsurfPoint	column number in which one would like to visualize the Tsurface[°C]	-	1, 76	-1	sca	num

Table 9.8: Table of point output (numeric)

Headers

Keyword	Description	Output file
HeaderDatePoint	column name in the file PointOutputFile for the variable DatePoint	PointOutputFile
HeaderJulianDayFromYear0Point	column name in the file PointOutputFile for the variable JulianDayFromYear0Point	PointOutputFile
HeaderTimeFromStartPoint	column name in the file PointOutputFile for the variable TimeFromStartPoint	PointOutputFile
HeaderPeriodPoint	column name in the file PointOutputFile for the variable PeriodPoint	PointOutputFile
HeaderRunPoint	column name in the file PointOutputFile for the variable RunPoint	PointOutputFile
HeaderIDPointPoint	column name in the file PointOutputFile for the variable IDPointPoint	PointOutputFile
HeaderCanopyFractionPoint	column name in the file PointOutputFile for the variable CanopyFractionPoint	PointOutputFile
HeaderPsnowPoint	column name in the file PointOutputFile for the variable PsnowPoint	PointOutputFile
HeaderPrainPoint	column name in the file PointOutputFile for the variable PrainPoint	PointOutputFile

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Keyword	Description	Associated file
HeaderPrainNetPoint	column name in the file PointOutputFile for the variable PrainNetPoint	PointOutputFile
HeaderPrainOnSnowPoint	column name in the file PointOutputFile for the variable PrainOnSnowPoint	PointOutputFile
HeaderWindSpeedPoint	column name in the file PointOutputFile for the variable WindSpeedPoint	PointOutputFile
HeaderWindDirPoint	column name in the file PointOutputFile for the variable WindDirPoint	PointOutputFile
HeaderRHPoint	column name in the file PointOutputFile for the variable RHPoint	PointOutputFile
HeaderAirPressPoint	column name in the file PointOutputFile for the variable AirPressPoint	PointOutputFile
HeaderAirTempPoint	column name in the file PointOutputFile for the variable AirTempPoint	PointOutputFile
HeaderTDewPoint	column name in the file PointOutputFile for the variable TDewPoint	PointOutputFile
HeaderTsurfPoint	column name in the file PointOutputFile for the variable TsurfPoint	PointOutputFile

Table 9.9: Table of meteorological parameters (character)

9.3.2 Maps

Map names

Keyword	Description
SurfaceTempMapFile	name of the output file providing the surface temperature map
PrecipitationMapFile	name of the output file providing the precipitation map
AirTempMapFile	name of the output file providing the Air temperature map
WindSpeedMapFile	name of the output file providing the Wind Speed map
WindDirMapFile	name of the output file providing the Wind Direction map
RelHumMapFile	name of the output file providing the Rel. Humidity map
SpecificPlotSurfaceTempMapFile	name of the output file providing the surface air temperature map at high temporal resolution during specific days
SpecificPlotWindSpeedMapFile	name of the output file providing the wind speed map at high temporal resolution during specific days
SpecificPlotWindDirMapFile	name of the output file providing the wind direction map at high temporal resolution during specific days
SpecificPlotRelHumMapFile	name of the output file providing the relative humidity map at high temporal resolution during specific days

Table 9.10: Keywords of names of meteorological forcing maps

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec
OutputMeteoMaps	frequency (h) of printing of the results of the meteo maps	h		0	sca

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**
SpecialPlotBegin	date of begin of plotting of the special output	format DDMMYY hhmm	01/01/1800 00:00, 01/01/2500 00:00	0	vec
SpecialPlotEnd	date of end of plotting of the special output	format DDMMYY hhmm	01/01/1800 00:00, 01/01/2500 00:00	0	vec

Table 9.11: Keywords for parameters of printing details for meteo maps

Chapter 10

Glacier

10.1 Input

10.1.1 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
IrriducibleWatSatGlacier	irreducible water saturation for glacier	-		0.02	sca	num
MaxWaterEqGlacLayerContent	maximum water equivalent admitted in a snow layer			5	sca	num
MaxGlacLayerNumber	maximum layers of snow to use (suggested >5)			0	sca	num
ThickerGlacLayers	Layer numbers that can become thicker than admitted by the threshold given by MaxGlacLayerNumber (from the bottom up). They can be more than one			Max Glac Layer Number/2	vec	num

Table 10.1: Keywords of glacier input parametrs configurable in geotop.inpts file.

10.2 Output

10.2.1 Point output

Files

Keyword	Description
GlacierProfileFile	name of the output file providing the glacier instantaneous values at various depths
GlacierProfileFileWriteEnd	name of the output file providing the glacier instantaneous values at various depths written just once at the end
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end

Table 10.2: Keywords of file related to glacier

Headers

Keyword	Description	Associated file
HeaderDateGlac	column name in the file GlacierProfileFile for the variable Date	GlacierProfileFile
HeaderJulianDayFromYear0Glac	column name in the file GlacierProfileFile for the variable Julian Day from 0	GlacierProfileFile
HeaderTimeFromStartGlac	column name in the file GlacierProfileFile for the variable Time from start	GlacierProfileFile
HeaderPeriodGlac	column name in the file GlacierProfileFile for the variable Simulation period	GlacierProfileFile
HeaderRunGlac	column name in the file GlacierProfileFile for the variable Run	GlacierProfileFile
HeaderIDPointGlac	column name in the file GlacierProfileFile for the variable IDPoint	GlacierProfileFile
HeaderTempGlac	column name in the file GlacierProfileFile for the variable temperature	GlacierProfileFile
HeaderIceContentGlac	column name in the file GlacierProfileFile for the variable ice content	GlacierProfileFile
HeaderWatContentGlac	column name in the file GlacierProfileFile for the variable liquid content	GlacierProfileFile
HeaderDepthGlac	column name in the file GlacierProfileFile for the variable Depth	GlacierProfileFile

Table 10.3: Keywords of the personalized header for the file GlacierProfileFile

Keyword	Description	Associated file
HeaderGlacDepthPoint	column name in the file PointOutputFile for the variable GlacDepthPoint	PointOutputFile
HeaderGWEPoint	column name in the file PointOutputFile for the variable GWEPoint	PointOutputFile
HeaderGlacDensityPoint	column name in the file PointOutputFile for the variable GlacDensityPoint	PointOutputFile
HeaderGlacTempPoint	column name in the file PointOutputFile for the variable GlacTempPoint	PointOutputFile
HeaderGlacMeltedPoint	column name in the file PointOutputFile for the variable GlacMeltedPoint	PointOutputFile
HeaderGlacSublPoint	column name in the file PointOutputFile for the variable GlacSublPoint	PointOutputFile

Table 10.4: Keywords of the personalized header for the file PointOutputFile

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
DefaultGlac	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
GlacPlotDepths	depths of the glacier where one wants to write the results	-		NA	vec	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
DateGlac	column number in which one would like to visualize the Date12 [DDMMYYYYhhmm]	-		-1	sca	num
JulianDayFromYear0Glac	column number in which one would like to visualize the JulianDayFromYear0[days]	-		-1	sca	num
TimeFromStartGlac	column in which one would like to visualize the TimeFromStart[days]	-		-1	sca	num
PeriodGlac	Column number to write the period number	-		-1	sca	num
RunGlac	Column number to write the run number	-		-1	sca	num
IDPointGlac	column number in which one would like to visualize the IDpoint	-		-1	sca	num
WaterEquivalentGlac	column number in which one would like the water equivalent of the glacier	-		-1	sca	num
DepthGlac	column number in which one would like to visualize the depth of the glacier	-		-1	sca	num
DensityGlac	column number in which one would like to visualize the density of the glacier	-		-1	sca	num
TempGlac	column number in which one would like to visualize the temperature of the glacier	-		-1	sca	num
IceContentGlac	column number in which one would like to visualize the ice content of the glacier	-		-1	sca	num
WatContentGlac	column number in which one would like to visualize the water content of the glacier	-		-1	sca	num

Table 10.5: Keywords defining the column number where printing the desired variable in the GlacierProfileFile

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
DtPlotPoint	Plotting Time step (in hour) of the output for specified pixels (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12 [DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
GlacDepthPoint	column number in which one would like to visualize the glacier depth [mm]	-	1, 76	-1	sca	num
GWEPoint	column number in which one would like to visualize the glacier water equivalent [mm]	-	1, 76	-1	sca	num
GlacDensityPoint	column number in which one would like to visualize the glacier density [kg m^{-3}]	-	1, 76	-1	sca	num
GlacTempPoint	column number in which one would like to visualize the glacier temperature [°C]	-	1, 76	-1	sca	num
GlacMeltedPoint	column number in which one would like to visualize the glac_melted [mm]	-	1, 76	-1	sca	num
GlacSublPoint	column number in which one would like to visualize the glacier sublimated depth [mm]	-	1, 76	-1	sca	num

Table 10.6: Keywords defining the column number where to print the desired variable in the PointOutputFile

10.2.2 Map Output

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
DefaultGlac	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
GlacPlotDepths	depths of the glacier where one wants to write the results	-		NA	vec	num
OutputGlacierMaps	frequency (h) of printing of the results of the glacier maps	h		0	sca	num

Table 10.7: Keywords of frequency for printing glacier output maps

Chapter 11

Snow

11.1 Input

11.1.1 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
RoughElemXUnitArea	Number of roughness elements (=vegetation) per unit area - used only for blowing snow subroutines	Number m^{-2}	0, inf	0	sca	num
RoughElemDiam	Diameter of the roughness elements (=vegetation) - used only for blowing snow subroutines	mm	0, inf	50	sca	num
AlphaSnow	Alpha (SNTHERM parameter) for the freezing characteristic soil for snow, the bigger, the steeper the curve around 0 degrees	-		1.00E+05	sca	num
ThresTempRain	dew or air temperature above which all precipitation is rain	°C		3	sca	num
ThresTempSnow	dew or air temperature below which all precipitation is rain	°C		-1	sca	num
DewTempOrNormTemp	Use dew temperature (1) or air temperature (0) to discriminate between snowfall and rainfall	-	1 or 0	0	sca	opt
AlbExtParSnow	albedo extinction parameter (aep): if snow depth < aep, albedo is interpolated between soil and snow	mm		10	sca	num
FreshSnowReflVis	visible band reflectance of fresh snow	-		0.9	sca	num
FreshSnowReflNIR	near infrared band reflectance of fresh snow	-		0.65	sca	num
IrriducibleWatSatSnow	Irreducible water saturation. It is the ratio of the capillarity-hold water to ice content in the snow.	-	0.02 - 0.07	0.02	sca	num
SnowEmissiv	snow long wave emissivity	-		0.98	sca	num
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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
SnowRoughness	Roughness length over snow	mm		0.1	sca	num
SnowCorrFactor	correction factor on fresh snow accumulation			1	sca	num
MaxSnowPorosity	maximum snow porosity allowed. This parameter prevents excessive snow densification	-		0.7	sca	num
DrySnowDefRate	snow compaction (% per hour) due to destructive metamorphism for snow density< SnowDensityCutoff and dry snow	-		1	sca	num
SnowDensityCutoff	snow density cutoff to change snow deformation rate	kg m^{-3}		100	sca	num
WetSnowDefRate	enhancement factor in presence of wet snow	-		1.5	sca	num
SnowViscosity	snow viscosity coefficient **(kg s m**$^{-2}$) at T=0 C and snow density=0	N s m^{-2}		1.00E+06	sca	num
FetchUp	scaling fetch in case snow wind transport in increasing [m]	m		1000	sca	num
FetchDown	scaling fetch in case snow wind transport in decreasing [m]	m		100	sca	num
BlowingSnowSoftLayerIceContent	Snow depth (in ice water equivalent), the averaged density of which is used for blowing snow wind thresholds	kg m^{-2}		0	sca	num
TimeStepBlowingSnow	Time step [s] at which the Prairie Blowing Snow Model is run	s		TimeStep Energy AndWater	sca	num
SnowSMIN	minimum slope [degree] to adjust precipitation reduction	degree		30	sca	num
SnowSMAX	maximum slope [degree] to adjust precipitation reduction	degree		80	sca	num
SnowCURV	shape parameter for precipitation reduction (if <0 the adjustment is not applied)	-		-200	sca	num
MaxWaterEqSnowLayerContent	maximum water equivalent admitted in a snow layer	kg m^{-2}		5	sca	num
MaxSnowLayerNumber	maximum layers of snow to use (suggested >10)			10	sca	num
ThickerSnowLayers	Layer numbers that can become thicker than admitted by the threshold given by MaxSnowLayerNumber (from the bottom up). They can be more than one			Max Snow Layer Number/2	vec	num
BlowingSnow	Activate blowing snow module (yes=1, no=0)	-		0	sca	opt
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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
PointMaxSWE	Max snow water equivalent that can be reached in the simulation point	kg m^{-2}		NA	vec	num
SnowAgingCoeffVis	reflectance of the new snow in the visible wave length	-		0.2	sca	num
SnowAgingCoeffNIR	reflectance of the new snow in the infrared wave length	-		0.5	sca	num

Table 11.1: Keywords of snow input parameters configurable in geotop.inpts file.

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
ThresSnowSoilRough	Threshold on snow depth to change roughness to snow roughness values with d0 set at 0, for bare soil fraction	mm	0, 1000	10	vec	num
ThresSnowVegUp	Threshold on snow depth above which the roughness is snow roughness, for vegetation fraction	mm	0, 20000	1000	vec	num
ThresSnowVegDown	Threshold on snow depth below which the roughness is vegetation roughness, for vegetation fraction	mm	0, 20000	1000	vec	num

Table 11.2: Keywords of snow characteristics that may be set in geotop.inpts. Each parameter may be given in input as a vector, each component representing the value corresponding to the LandCoverMapFile value identified by the vector index

11.2 Output

11.2.1 Point output

Files

Keyword	**Description**
SnowProfileFile	name of the output file providing the snow instantaneous values at various depths
SnowProfileFileWriteEnd	name of the output file providing the snow instantaneous values at various depths written just once at the end
SnowCoveredAreaFile	Name of the output file containing the percentage of the area covered by snow
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end

Table 11.3: Keywords of file related to snow / glacier

Headers

Keyword	**Description**	**Associated file**
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Keyword	Description	Associated file
HeaderDateSnow	column name in the file SnowProfileFile for the variable Date	SnowProfileFile
HeaderJulianDayFromYear0Snow	column name in the file SnowProfileFile for the variable Julian Day from 0	SnowProfileFile
HeaderTimeFromStartSnow	column name in the file SnowProfileFile for the variable Time from start	SnowProfileFile
HeaderPeriodSnow	column name in the file SnowProfileFile for the variable Simulation period	SnowProfileFile
HeaderRunSnow	column name in the file SnowProfileFile for the variable Run	SnowProfileFile
HeaderIDPointSnow	column name in the file SnowProfileFile for the variable IDPoint	SnowProfileFile
HeaderTempSnow	column name in the file SnowProfileFile for the variable temperature	SnowProfileFile
HeaderIceContentSnow	column name in the file SnowProfileFile for the variable ice content	SnowProfileFile
HeaderWatContentSnow	column name in the file SnowProfileFile for the variable liquid content	SnowProfileFile
HeaderDepthSnow	column name in the file SnowProfileFile for the variable Depth	SnowProfileFile

Table 11.4: Keywords of the personalized header for the file SnowProfileFile

Keyword	Description	Associated file
HeaderPsnowNetPoint	column name in the file PointOutputFile for the variable PsnowNetPoint	PointOutputFile
HeaderSnowDepthPoint	column name in the file PointOutputFile for the variable SnowDepthPoint	PointOutputFile
HeaderSWEPoint	column name in the file PointOutputFile for the variable SWEPoint	PointOutputFile
HeaderSnowDensityPoint	column name in the file PointOutputFile for the variable SnowDensityPoint	PointOutputFile
HeaderSnowTempPoint	column name in the file PointOutputFile for the variable SnowTempPoint	PointOutputFile
HeaderSnowMeltedPoint	column name in the file PointOutputFile for the variable SnowMeltedPoint	PointOutputFile
HeaderSnowSublPoint	column name in the file PointOutputFile for the variable SnowSublPoint	PointOutputFile
HeaderSWEBlownPoint	column name in the file PointOutputFile for the variable SWEBlownPoint	PointOutputFile
HeaderSWESublBlownPoint	column name in the file PointOutputFile for the variable SWESublBlownPoint	PointOutputFile

Table 11.5: Keywords of the personalized header for the file PointOutputFile

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt

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Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
DefaultSnow	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
SnowPlotDepths	depths of the glacier where one wants to write the results	-		NA	vec	num
DateSnow	column number in which one would like to visualize the Date12 [DDMMYYYYhhmm]	-		-1	sca	num
JulianDayFromYear0Snow	column number in which one would like to visualize the JulianDayFromYear0[days]	-		-1	sca	num
TimeFromStartSnow	column in which one would like to visualize the TimeFromStart[days]	-		-1	sca	num
PeriodSnow	Column number to write the period number	-		-1	sca	num
RunSnow	Column number to write the run number	-		-1	sca	num
IDPointSnow	column number in which one would like to visualize the IDpoint	-		-1	sca	num
WaterEquivalentSnow	column number in which one would like the water equivalent of the snow	-		-1	sca	num
DepthSnow	column number in which one would like to visualize the depth of the snow	-		-1	sca	num
DensitySnow	column number in which one would like to visualize the density of the snow	-		-1	sca	num
TempSnow	column number in which one would like to visualize the temperature of the snow	-		-1	sca	num
IceContentSnow	column number in which one would like to visualize the ice content of the snow	-		-1	sca	num
WatContentSnow	column number in which one would like to visualize the water content of the snow	-		-1	sca	num

Table 11.6: Keywords defining the column number where printing the desired variable in the SnowProfileFile

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
DefaultPoint	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of the output for specified pixels (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
SnowDepthPoint	column number in which one would like to visualize the snow_depth[mm]	-	1, 76	-1	sca	num
SWEPoint	column number in which one would like to visualize the snow_water_equivalent [mm]	-	1, 76	-1	sca	num
SnowDensityPoint	column number in which one would like to visualize the snow_density[kg/^{3}]	-	1, 76	-1	sca	num
SnowTempPoint	column number in which one would like to visualize the snow_temperature[°C]	-	1, 76	-1	sca	num
SnowMeltedPoint	column number in which one would like to visualize the snow_melted[mm]	-	1, 76	-1	sca	num
SnowSublPoint	column number in which one would like to visualize the snow_subl[mm]	-	1, 76	-1	sca	num
SWEBlownPoint	column number in which one would like to visualize the snow_blown_away[mm]	-	1, 76	-1	sca	num
SWESublBlownPoint	column number in which one would like to visualize the snow_subl_while_blown [mm]	-	1, 76	-1	sca	num

Table 11.7: Keywords defining the column number where printing the desired variable in the PointOutputFile

11.2.2 Map Output

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
DefaultSnow	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
SnowPlotDepths	depths of the glacier where one wants to write the results	-		NA	vec	num
OutputSnowMaps	frequency (h) of printing of the results of the snow maps	h		0	sca	num

Table 11.8: Keywords of frequency for printing snow output maps settable in geotop.inpts

Chapter 12

Vegetation

12.1 Input

12.1.1 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
VegHeight	vegetation height	mm	0, 20000	1000	vec	num
LSAI	Leaf and Stem Area Index $[L^2/L^2]$	-	0, 1	1	vec	num
CanopyFraction	Canopy fraction [0: no canopy in the pixel, 1: pixel fully covered by canopy]	-	0, 1	0	vec	num
DecayCoeffCanopy	Decay coefficient of the eddy diffusivity profile in the canopy	-	0, inf	2.5	vec	num
VegSnowBurying	Coefficient of the exponential snow burying of vegetation	-	0, inf	1	vec	num
RootDepth	Root depth (it is used to calculate root_fraction for each layer, it must be positive)	mm	0, inf	300	vec	num
MinStomatalRes	Minimum stomatal resistance	s m^{-1}	0, inf	60	vec	num
VegReflectVis	Vegetation reflectivity in the visible	-	0, 1	0.2	vec	num
VegReflNIR	Vegetation reflectivity in the near infrared	-	0, 1	0.2	vec	num
VegTransVis	Vegetation transmissimity in the visible	-	0, 1	0.2	vec	num
VegTransNIR	Vegetation transmissimity in the near infrared	-	0, 1	0.2	vec	num
LeafAngles	Departure of leaf angles from a random distribution (1 horizontal, 0 random, -1 vertical)	-	-1, 0, 1	0	vec	opt
CanDensSurface	Surface density of canopy	kg m^{-2} LSAI^{-1}	0, inf	2	vec	num

Table 12.1: Keywords of vegetation characteristics that may be set in geotop.inpts. Each parameter may be given in input as a vector, each component representing the value corresponding to the LandCoverMapFile value identified by the vector index

12.2 Numerics

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Logical / Numeric
CanopyMaxIter	Max number of iterations for (vegetation energy balance equation)			3	sca	num
LocMaxIter	Max number of iterations for the calculation of the within-canopy Monin-Obukhov length (vegetation energy balance equation)	-		3	sca	num
TsMaxIter	Max number of iterations for the calculation of canopy air temperature (vegetation energy balance equation)	-		2	sca	num
CanopyStabCorrection	Use of the stability corrections within canopy (=1), otherwise (=0)	-		1	sca	opt
BusingerMaxIter	Max number of iterations for Monin-Obulhov stability algorithm -Businger parameterization (surface energy balance equation)	-		5	sca	num

Table 12.2: Keywords of input numeric parameters for the energy equation regarding vegetation routines settable in geotop.inpts

12.3 Output

12.3.1 Point

Files

Keyword	Description
TimeDependentVegetationParameterFile	name of the file providing the time dependent vegetation parameters
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end

Table 12.3: Keywords of file related to vegetation

Headers

Keyword	Description	Associated file
HeaderTvegPoint	column name in the file PointOutputFile for the variable TvegPoint	PointOutputFile
HeaderTCanopyAirPoint	column name in the file PointOutputFile for the variable TCanopyAirPoint	PointOutputFile
HeaderLSAIPoint	column name in the file PointOutputFile for the variable LSAIPoint	PointOutputFile
Headerz0vegPoint	column name in the file PointOutputFile for the variable z0vegPoint	PointOutputFile
Headerd0vegPoint	column name in the file PointOutputFile for the variable d0vegPoint	PointOutputFile
HeaderEstoredCanopyPoint	column name in the file PointOutputFile for the variable EstoredCanopyPoint	PointOutputFile

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Keyword	Description	Associated file
HeaderSWvPoint	column name in the file PointOutputFile for the variable SWvPoint	PointOutputFile
HeaderLWvPoint	column name in the file PointOutputFile for the variable LWvPoint	PointOutputFile
HeaderHvPoint	column name in the file PointOutputFile for the variable HvPoint	PointOutputFile
HeaderLEvPoint	column name in the file PointOutputFile for the variable LEvPoint	PointOutputFile
HeaderHgUnvegPoint	column name in the file PointOutputFile for the variable HgUnvegPoint	PointOutputFile
HeaderLEgUnvegPoint	column name in the file PointOutputFile for the variable LEgUnvegPoint	PointOutputFile
HeaderHgVegPoint	column name in the file PointOutputFile for the variable HgVegPoint	PointOutputFile
HeaderLEgVegPoint	column name in the file PointOutputFile for the variable LEgVegPoint	PointOutputFile
HeaderEvapSurfacePoint	column name in the file PointOutputFile for the variable EvapSurfacePoint	PointOutputFile
HeaderTraspCanopyPoint	column name in the file PointOutputFile for the variable TraspCanopyPoint	PointOutputFile
HeaderWaterOnCanopyPoint	column name in the file PointOutputFile for the variable WaterOnCanopyPoint	PointOutputFile
HeaderSnowOnCanopyPoint	column name in the file PointOutputFile for the variable SnowOnCanopyPoint	PointOutputFile
HeaderQVegPoint	column name in the file PointOutputFile for the variable specific humidity near the vegetation	PointOutputFile
HeaderLObukhovCanopyPoint	column name in the file PointOutputFile for the variable LObukhovCanopyPoint	PointOutputFile
HeaderWindSpeedTopCanopyPoint	column name in the file PointOutputFile for the variable WindSpeedTopCanopyPoint	PointOutputFile
HeaderDecayKCanopyPoint	column name in the file PointOutputFile for the variable DecayKCanopyPoint	PointOutputFile

Table 12.4: Keywords of the personalized headers for the PointOutputFile

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
DefaultPoint	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of the output for specified pixels (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num

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Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
TvegPoint	column number in which one would like to visualize the Tvegetation[°C]	-	1, 76	-1	sca	num
TCanopyAirPoint	column number in which one would like to visualize the Tcanopyair[°C]	-	1, 76	-1	sca	num
CanopyFractionPoint	column number in which one would like to visualize the Canopy_fraction	-	1, 76	-1	sca	num
LSAIPoint	column number in which one would like to visualize the LSAI[m^2/m^2]	-	1, 76	-1	sca	num
z0vegPoint	column number in which one would like to visualize the z0veg[m]	-	1, 76	-1	sca	num
d0vegPoint	column number in which one would like to visualize the d0veg[m]	-	1, 76	-1	sca	num
EstoredCanopyPoint	column number in which one would like to visualize the Estored_canopy[W/m2]	-	1, 76	-1	sca	num
SWvPoint	column number in which one would like to visualize the SWv[W/m^2]	-	1, 76	-1	sca	num
LWvPoint	column number in which one would like to visualize the LWv[W/m^2]	-	1, 76	-1	sca	num
HvPoint	column number in which one would like to visualize the Hv[W/m^2]	-	1, 76	-1	sca	num
LEvPoint	column number in which one would like to visualize the LEv[W/m^2]	-	1, 76	-1	sca	num
HgUnvegPoint	column number in which one would like to visualize the Hg_unveg[W/m^2]	-	1, 76	-1	sca	num
LEgUnvegPoint	column number in which one would like to visualize the LEg_unveg[W/m^2]	-	1, 76	-1	sca	num
HgVegPoint	column number in which one would like to visualize the Hg_veg[W/m^2]	-	1, 76	-1	sca	num
LEgVegPoint	column number in which one would like to visualize the LEg_veg[W/m^2]	-	1, 76	-1	sca	num
TraspCanopyPoint	column number in which one would like to visualize the Trasp_canopy[mm]	-	1, 76	-1	sca	num
WaterOnCanopyPoint	column number in which one would like to visualize the Water_on_canopy[mm]	-	1, 76	-1	sca	num
SnowOnCanopyPoint	column number in which one would like to visualize the Snow_on_canopy[mm]	-	1, 76	-1	sca	num
QVegPoint	column number in which one would like to visualize the specific humidity near the vegetation (grams vapour/grams air)	-	1, 76	-1	sca	num
QCanopyAirPoint	column number in which one would like to visualize the specific humidity at the canopy-air interface (grams vapour/grams air)	-	1, 76	-1	sca	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
LObukhovCanopyPoint	column number in which one would like to visualize the LObukhov-canopy[m]	-	1, 76	-1	sca	num
WindSpeedTopCanopyPoint	column number in which one would like to visualize the Wind_speed_top_canopy [m/s]	-	1, 76	-1	sca	num
DecayKCanopyPoint	column number in which one would like to visualize the Decay_of_K_in_canopy[-]	-	1, 76	-1	sca	num

Table 12.5: Keywords defining the column number where to plot the desired variable in the PointOutputFile

12.3.2 Map Output

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
OutputVegetationMaps	frequency (h) of printing of the results of the vegetation maps	h		0	sca	num

Table 12.6: Keywords of frequency for printing vegetation output maps settable in geotop.inpts

Files

Keyword	**Description**
CanopyInterceptedWaterMapFile	name of the output file providing the canopy intercepted water map
SpecificPlotVegSensibleHeatFluxMapFile	name of the output file providing the vegetation sensible heat flux map at high temporal resolution during specific days
SpecificPlotVegLatentHeatFluxMapFile	name of the output file providing the vegetation latent heat flux map at high temporal resolution during specific days
SpecificPlotNetVegShortwaveRadMapFile	name of the output file providing the vegetation Swnet flux map at high temporal resolution during specific days
SpecificPlotNetVegLongwaveRadMapFile	name of the output file providing the vegetation Lwnet map at high temporal resolution during specific days
SpecificPlotCanopyAirTempMapFile	name of the output file providing the canopy air temperature map at high temporal resolution during specific days
SpecificPlotVegTempMapFile	name of the output file providing the vegetation temperature map at high temporal resolution during specific days
SpecificPlotAboveVegAirTempMapFile	name of the output file providing the above vegetation air temperature map at high temporal resolution during specific days

Table 12.7: Keywords of file related to vegetation (map)

Chapter 13

Surface Fluxes

13.1 Input

13.1.1 Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Logical / Numeric**
LWinParameterization	Which formula for incoming long-wave radiation: 1 (Brutsaert, 1975), 2 (Satterlund, 1979), 3 (Idso, 1981), 4(Idso+Hodges), 5 (Koenig-Langlo & Augstein, 1994), 6 (Andreas & Ackley, 1982), 7 (Konzelmann, 1994), 8 (Prata, 1996), 9 (Dilley 1998)		1, 2, .., 9	9	sca	opt
MoninObukhov	Atmospherical stability parameter: 1 stability and instability considered, 2 stability not considered, 3 instability not considered, 4 always neutrality			1	sca	num
Surroundings	Yes(1), No(0)	-		0	sca	opt
NumLandCoverTypes	Number of Classes of land cover. Each land cover type corresponds to a particular land-cover state, described by a specific set of values of the parameters listed below. Each set of land cover parameters will be distributively assigned according to the land cover map, which relates each pixel with a land cover type number. This number corresponds to the number of component in the numerical vector that is assigned to any land cover parameters listed below.	-	1, inf	1	sca	num

Table 13.1: Keywords of parameters regarding the surface energy fluxes calculation

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
SoilRoughness	Roughness length of soil surface	mm	0, 1000	10	vec	num
SoilAlbVisDry	Ground surface albedo without snow in the visible - dry	-	0, 1	0.2	vec	num
SoilAlbNIRDry	Ground surface albedo without snow in the near infrared - dry	-	0, 1	0.2	vec	num
SoilAlbVisWet	Ground surface albedo without snow in the visible - saturated	-	0, 1	0.2	vec	num
SoilAlbNIRWet	Ground surface albedo without snow in the near infrared - saturated	-	0, 1	0.2	vec	num
SoilEmissiv	Ground surface emissivity	-	0, 1	0.96	vec	num

Table 13.2: Keywords of land cover characteristics affecting surface energy fluxes that may be set in geotop.inpts. Each parameter may be given in input as a vector, each component representing the value corresponding to the LandCoverMapFile value identified by the vector index

13.2 Numerics

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Scalar / Vector**	**Logical / Numeric**
BusingerMaxIter	Max number of iterations for Monin-Obulhov stability algorithm -Businger parameterization (surface energy balance equation)	-		5	sca	num

Table 13.3: Keywords of input numeric parameters for the energy equation regarding vegetation routines settable in geotop.inpts

13.3 Output

13.3.1 Point

Files

Keyword	**Description**
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end

Table 13.4: Keywords of file related to point output variables

Headers

Keyword	**Description**	**Associated file**

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Keyword	**Description**	**Associated file**
HeaderSurfaceEBPoint	column name in the file PointOutputFile for the variable SurfaceEBPoint	PointOutputFile
HeaderSoilHeatFluxPoint	column name in the file PointOutputFile for the variable SoilHeatFluxPoint	PointOutputFile
HeaderSWinPoint	column name in the file PointOutputFile for the variable SWinPoint	PointOutputFile
HeaderSWbeamPoint	column name in the file PointOutputFile for the variable SWbeamPoint	PointOutputFile
HeaderSWdiffPoint	column name in the file PointOutputFile for the variable SWdiffPoint	PointOutputFile
HeaderLWinPoint	column name in the file PointOutputFile for the variable LWinPoint	PointOutputFile
HeaderLWinMinPoint	column name in the file PointOutputFile for the variable LWinMinPoint	PointOutputFile
HeaderLWinMaxPoint	column name in the file PointOutputFile for the variable LWinMaxPoint	PointOutputFile
HeaderSWNetPoint	column name in the file PointOutputFile for the variable SWNetPoint	PointOutputFile
HeaderLWNetPoint	column name in the file PointOutputFile for the variable LWNetPoint	PointOutputFile
HeaderHPoint	column name in the file PointOutputFile for the variable HPoint	PointOutputFile
HeaderLEPoint	column name in the file PointOutputFile for the variable LEPoint	PointOutputFile
HeaderQSurfPoint	column name in the file PointOutputFile for the variable specific humidity near the soil surface	PointOutputFile
HeaderQAirPoint	column name in the file PointOutputFile for the variable specific humidity of the air	PointOutputFile
HeaderLObukhovPoint	column name in the file PointOutputFile for the variable LObukhovPoint	PointOutputFile
HeaderSWupPoint	column name in the file PointOutputFile for the variable SWupPoint	PointOutputFile
HeaderLWupPoint	column name in the file PointOutputFile for the variable LWupPoint	PointOutputFile
HeaderHupPoint	column name in the file PointOutputFile for the variable HupPoint	PointOutputFile
HeaderLEupPoint	column name in the file PointOutputFile for the variable LEupPoint	PointOutputFile

Table 13.5: Keywords defining the headers to personalize for the output related to surface flux in the PointOutputFile

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
DefaultPoint	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of THE OUTPUT FOR SPECIFIED PIXELS (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
TsurfPoint	column number in which one would like to visualize the Tsurface[°C]	-	1, 76	-1	sca	num
SurfaceEBPoint	column number in which one would like to visualize the Surface_Energy_balance [W/m^2]	-	1, 76	-1	sca	num
SoilHeatFluxPoint	column number in which one would like to visualize the Soil_heat_flux[W/m^2]	-	1, 76	-1	sca	num
SWinPoint	column number in which one would like to visualize the SWin[W/m^2]	-	1, 76	-1	sca	num
SWbeamPoint	column number in which one would like to visualize the SWbeam[W/m^2]	-	1, 76	-1	sca	num
SWdiffPoint	column number in which one would like to visualize the SWdiff[W/m^2]	-	1, 76	-1	sca	num
LWinPoint	column number in which one would like to visualize the LWin[W/m^2]	-	1, 76	-1	sca	num
LWinMinPoint	column number in which one would like to visualize the LWin_min[W/m^2]	-	1, 76	-1	sca	num
LWinMaxPoint	column number in which one would like to visualize the LWin_max[W/m^2]	-	1, 76	-1	sca	num
SWNetPoint	column number in which one would like to visualize the SWnet[W/m^2]	-	1, 76	-1	sca	num
LWNetPoint	column number in which one would like to visualize the LWnet[W/m^2]	-	1, 76	-1	sca	num
HPoint	column number in which one would like to visualize the H[W/m^2]	-	1, 76	-1	sca	num
EvapSurfacePoint	column number in which one would like to visualize the Evap_surface[mm]	-	1, 76	-1	sca	num
LEPoint	column number in which one would like to visualize the LE[W/m^2]	-	1, 76	-1	sca	num
QSurfPoint	column number in which one would like to visualize the specific humidity at the surface (grams vapour/grams air)	-	1, 76	-1	sca	num
QAirPoint	column number in which one would like to visualize the specific humidity at air (grams vapour/grams air)	-	1, 76	-1	sca	num
LObukhovPoint	column number in which one would like to visualize the LObukhov[m]	-	1, 76	-1	sca	num
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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
SWupPoint	column number in which one would like to visualize the SWup[W/m^2]	-	1, 76	-1	sca	num
LWupPoint	column number in which one would like to visualize the LWup[W/m^2]	-	1, 76	-1	sca	num
HupPoint	column number in which one would like to visualize the Hup[W/m^2]	-	1, 76	-1	sca	num
LEupPoint	column number in which one would like to visualize the LEup[W/m^2]	-	1, 76	-1	sca	num

Table 13.6: Keywords defining which parameter to print on the PointOutputFile

13.3.2 Maps

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec
OutputSurfEBALMaps	frequency (h) of printing of the results of the Surface energy balance maps	h		0	sca

Table 13.7: Keywords for parameters of printing details for surface energy balance maps

File

Keyword	Description
RadiationMapFile	name of the output file providing the Radiation map (all the type of radiations)
NetRadiationMapFile	name of the output file providing the Net Radiation map
InLongwaveRadiationMapFile	name of the output file providing the LW Radiation map
NetLongwaveRadiationMapFile	name of the output file providing the Net LW Radiation map
NetShortwaveRadiationMapFile	name of the output file providing the Net SW Radiation map
InShortwaveRadiationMapFile	name of the output file providing the Swin Radiation map
DirectInShortwaveRadiationMapFile	name of the output file providing the Swdir Radiation map
ShadowFractionTimeMapFile	name of the output file providing the map of the fraction of Shadow in the time
SurfaceHeatFluxMapFile	name of the output file providing the Surface heat flux map
SurfaceSensibleHeatFluxMapFile	name of the output file providing the Surface sensible heat flux map
SurfaceLatentHeatFluxMapFile	name of the output file providing the Surface latent heat flux map
SpecificPlotSurfaceHeatFluxMapFile	name of the output file providing the surface heat flux map at high temporal resolution during specific days
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Keyword	**Description**
SpecificPlotTotalSensibleHeatFluxMapFile	name of the output file providing the total sensible heat flux map at high temporal resolution during specific days
SpecificPlotTotalLatentHeatFluxMapFile	name of the output file providing the total latent heat flux map at high temporal resolution during specific days
SpecificPlotSurfaceSensibleHeatFluxMapFile	name of the output file providing the surface sensible heat flux map at high temporal resolution during specific days
SpecificPlotSurfaceLatentHeatFluxMapFile	name of the output file providing the surface latent heat flux map at high temporal resolution during specific days
SpecificPlotIncomingShortwaveRadMapFile	name of the output file providing the Swin flux map at high temporal resolution during specific days
SpecificPlotNetSurfaceShortwaveRadMapFile	name of the output file providing the surface Swnet flux map at high temporal resolution during specific days
SpecificPlotIncomingLongwaveRadMapFile	name of the output file providing the Lwin flux map at high temporal resolution during specific days
SpecificPlotNetSurfaceLongwaveRadMapFile	name of the output file providing the surface Lwnet map at high temporal resolution during specific days

Table 13.8: Keywords of output map files related to surface fluxes settable in geotop.inpts

13.4 Values of reference

Surface description	*roughness z_0 [mm]*	*Reference*
Mud flats, ice	0.01	*Sutton* (1953)
Smooth tarmac	0.02	*Bradley* (1968))
Large water surfaces	0.1 - 0.6	Numerous references
Grass (lawn up to 1 cm)	1	*Sutton* (1953)
Grass (artificial, 7.5 cm high)	10	*Chamberlain* (1966))
Grass (thick up to 10 cm high)	23	*Sutton* (1953)
Grass (thin up to 50 cm)	50	*Sutton* (1953)
Trees (10-15 m high)	400-700	*Fichtl and McVehil* (1970)
Large city	1650	*YAMAMOTO and SHIMANUKI* (1964)

Table 13.9: Example of roughness parameters for various surfaces *Brutsaert* (1982)

Radiative proprieties of natural materials p.13 Boundary Layer Climates - T.R.Oke
Example of roughness parameters for various surfaces - Evaporation into the Atmosphere, Wilfried Brutsaert, 1984

Surface	*Remarks*	*Albedo* α	*Emissivity* ε
Soil	Dark, wet	0.05 -	0.98 -
	Light, dry	0.40	0.90
Desert		0.20 - 0.45	0.84 - 0.91
Grass	Long (1.0 m)	0.16 -	0.90 -
	Short (0.02 m	0.26	0.95
Agrigultural crops,		0.18 -	0.90 -
tundra		0.25	0.99
Orchards		0.15 - 0.20	
Forest			
Deciduos	Bare	0.15 -	0.97 -
	Leaved	0.20	0.98
Coniferous		0.05 - 0.15	0.97 - 0.99
Water	Small zenith angle	0.03 - 0.10	0.92 - 0.97
	Large zenith angle	0.10 - 1.00	0.92 - 0.97
Snow	Old	0.40 -	0.82 -
	Fresh	0.95	0.99
Ice	Sea	0.30 - 0.45	0.92 - 0.97
	Glacier	0.20 - 0.40	

Table 13.10: Radiative proprieties of natural materials

Surface description	*z_0(cm)*	*Reference*
Mud flats, ice	0.001	Sutton (1953)
Smooth tarmac	0.002	Bradley (1968)
Large water surfaces	0.01 - 0.06	Numerous references
Grass (lawn up to 1 cm)	0.1	Sutton (1953)
Grass (artificial, 7.5 cm high)	1.0	Chamberlain (1966)
Grass (thick up to 10 cm high)	2.3	Sutton (1953)
Grass (thin up to 50 cm)	5	Sutton (1953)
Trees (10-15 m high)	40-70	Fichtl and McVehil (1970)
Large city	165	Yamamoto and Shimanuki (1964)

Table 13.11: Example of roughness parameters for various surfaces (Evaporation into the Atmosphere, Wilfried Brutsaert, 1984)

Chapter 14

Soil/Rock Infiltration

14.1 Input

14.1.1 File

Keyword	**Description**	**Associated file**	**type (file, header)**
SoilParFile	name of the file providing the soil parameters	/	file

Table 14.1: Keywords of file related to soil and rock parameters

14.1.2 Headers

Keyword	**Description**	**Associated file**
HeaderPointSoilType	column name in the file PointFile for the soil type of the point	PointFile
HeaderSoilDz	column name in the file SoilParFile for the layers thickness	SoilParFile
HeaderNormalHydrConductivity	column name in the file SoilParFile for the normal hydraulic conductivity	SoilParFile
HeaderLateralHydrConductivity	column name in the file SoilParFile for the lateral hydraulic conductivity	SoilParFile
HeaderThetaRes	column name in the file SoilParFile for the residual water content	SoilParFile
HeaderWiltingPoint	column name in the file SoilParFile for the soil wilting point	SoilParFile
HeaderFieldCapacity	column name in the file SoilParFile for the field capacity	SoilParFile
HeaderThetaSat	column name in the file SoilParFile for the saturated water content	SoilParFile
HeaderAlpha	column name in the file alpha parameter of Van Genuchten	SoilParFile
HeaderN	column name in the file N parameter of Van Genuchten	SoilParFile
HeaderV	column name in the file V parameter of Van Genuchten	SoilParFile
HeaderSpecificStorativity	column name in the file specific storativity	SoilParFile

Table 14.2: Keywords of headers related to soil

14.1.3 Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
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Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
FrozenSoilHydrCondReduction	Ω: Reduction factor of the hydraulic conductivity in partially frozen soil ($K = K_{no\_ice} * 10^{\Omega Q}$, where Q is the ice ratio	-	0, 7	2	sca	num

Table 14.3: Keywords for the description of soil

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
NormalHydrConductivity		mm s^{-1}		1.00E-04	vec	num
LateralHydrConductivity		mm s^{-1}		1.00E-04	vec	num
ThetaRes		-		0.05	vec	num
WiltingPoint		-		0.15	vec	num
FieldCapacity		-		0.25	vec	num
ThetaSat		-		0.5	vec	num
AlphaVanGenuchten		mm^{-1}		0.004	vec	num
NVanGenuchten		-		1.3	vec	num
VMualem		-		0.5	vec	num
SpecificStorativity		mm^{-1}		1.00E-07	vec	num

Table 14.4: Keywords of soil input parameters settable in geotop.inpts

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
FrozenSoilHydrCondReduction	Reduction factor of the hydraulic conductivity in partially frozen soil ($K = K_{no\_ice} * 10^{impedenceQ}$, where Q is the ice ratio	-	0, 7	2	sca	num
PointSoilType	Soil type of the simulation point	-		NA	vec	num
NormalHydrConductivityBedrock		mm s^{-1}		1.00E-04	vec	num
LateralHydrConductivityBedrock		mm s^{-1}		1.00E-04	vec	num
ThetaResBedrock		-		0.05	vec	num
WiltingPointBedrock		-		0.15	vec	num
FieldCapacityBedrock		-		0.25	vec	num
ThetaSatBedrock		-		0.5	vec	num
AlphaVanGenuchtenBedrock		mm^{-1}		0.004	vec	num
NVanGenuchtenBedrock		-		1.3	vec	num
VMualemBedrock		-		0.5	vec	num
SpecificStorativityBedrock		mm^{-1}		1.00E-07	vec	num

Table 14.5: Keywords of soil input parameters settable in geotop.inpts

Numerics

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Logical / Numeric
RichardTol	Absolute Tolerance for the integration of Richards' equation on the Euclidean norm of residuals (mass balance)	mm	1E-20, inf	1.00E-08	sca	num
RichardMaxIter	Max iterations for the integration of Richards' equation (mass balance equation)	-	1, inf	100	sca	num
RichardInitForc	Initial forcing term of Newton method (mass balance equation)	-		0.01	sca	num

Table 14.6: Keywords of input numeric parameters for the energy and mass balance equation settable in geotop.inpts

14.2 Output

14.2.1 Point output

Files

Keyword	Description
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end
SoilLiqWaterPressProfileFile	name of the output file providing the Soil/rock instantaneous liquid water pressure head values at various depths
SoilLiqWaterPressProfileFileWriteEnd	name of the output file providing the Soil/rock instantaneous liquid water pressure head values at various depths written just once at the end
SoilTotWaterPressProfileFile	name of the output file providing the Soil/rock instantaneous total (water+ice) pressure head values at various depths
SoilTotWaterPressProfileFileWriteEnd	name of the output file providing the Soil/rock instantaneous total (water+ice) pressure head values at various depths written just once at the end
SoilLiqContentProfileFile	name of the output file providing the Soil/rock instantaneous liquid water content values at various depths
SoilLiqContentProfileFileWriteEnd	name of the output file providing the Soil/rock instantaneous liquid water content values at various depths written just once at the end
SoilAveragedLiqContentProfileFile	name of the output file providing the Soil/rock average (in DtPlotPoint) liquid water content values at various depths
SoilAveragedLiqContentProfileFileWriteEnd	name of the output file providing the Soil/rock average (in DtPlotPoint) liquid water content values at various depths written just once at the end

Table 14.7: Keywords of output file related to soil

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
DefaultSoil	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
SoilPlotDepths	depth at which one wants the data on the snow to be plotted	m		NA	vec	num
DateSoil	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-		-1	sca	num
JulianDayFromYear0Soil	column number in which one would like to visualize the JulianDayFromYear0[days]	-		-1	sca	num
TimeFromStartSoil	column number in which one would like to visualize the time from the start of the soil	-		-1	sca	num
PeriodSoil	Column number to write the period number	-		-1	sca	num
RunSoil	Column number to write the run number	-		-1	sca	num
IDPointSoil	column number in which one would like to visualize the IDpoint	-		-1	sca	num

Table 14.8: Keywords defining the column number where to print the desired variable in the output files for the soil variables

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
DefaultPoint	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of the output for specified pixels (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
WaterTableDepthPoint	column number in which one would like to visualize the water_table_depth [mm]	-	1, 76	-1	sca	num

Table 14.9: Keywords defining the column number where to print the desired variable in the PointOutputFile

14.2.2 Map Output

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
OutputSoilMaps	frequency (h) of printing of the results of the soil maps	h		0	sca	num

Table 14.10: Keywords of frequency for printing soil output maps

14.2.3 Map names

Keyword	Description
SoilMapFile	name of the file providing the soil map
FirstSoilLayerLiqContentMapFile	name of the map of the liquird water content of the first soil layer
LandSurfaceWaterDepthMapFile	name of the map of the water height above the surface
WaterTableDepthMapFile	name of the output file providing the Water table depth map
SpecificPlotSurfaceWaterContentMapFile	name of the output file providing the surface water content map at high temporal resolution during specific days

Table 14.11: Keywords of print output maps for soil and rock thermal and hydraulic variables

14.2.4 Tensor names

Keyword	Description
SoilLiqContentTensorFile	Name of the ensamble of raster maps corresponding to the liquid water content of each layer (if PlotSoilDepth≠0 it writes the value at the corresponding depths)
SoilLiqWaterPressTensorFile	Name of the ensamble of raster maps corresponding to the water pressure of each layer (if PlotSoilDepth≠0 it writes the value at the corresponding depths)

Table 14.12: Keywords of print output tensor maps for soil and rock thermal and hydraulic variables

Chapter 15

Soil/rock temperature

15.1 Input

15.1.1 File

Keyword	**Description**	**Associated file**	**type (file, header)**
SoilParFile	name of the file providing the soil parameters	/	file

Table 15.1: Keywords of file related to soil and rock parameters

15.1.2 Headers

Keyword	**Description**	**Associated file**
HeaderPointSoilType	column name in the file PointFile for the soil type of the point	PointFile
HeaderSoilDz	column name in the file SoilParFile for the layers thickness	SoilParFile
HeaderKthSoilSolids	column name in the file thermal conductivity of the soil grains	SoilParFile
HeaderCthSoilSolids	column name in the file thermal capacity of the soil grains	SoilParFile

Table 15.2: Keywords of headers related to soil

15.1.3 Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
ThermalConductivitySoilSolidsBedrock	thermal conductivity of the bedrock	W m^{-1} K^{-1}		2.5	vec	num
ThermalCapacitySoilSolidsBedrock	thermal capacity of the bedrock	J m^{-3} K^{-1}		1.00E+06	vec	num

Table 15.3: Keywords of soil input parameters settable in geotop.inpts

Numerics

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Logical / Numeric
HeatEqTol	Max norm of the residuals (energy balance equation)	J m^{-2}		1.00E-04	sca	num
HeatEqMaxIter	Max number of iterations (energy balance equation)	-		500	sca	num

Table 15.4: Keywords of input numeric parameters for the energy equation settable in geotop.inpts

15.2 Output

15.2.1 Point output

Files

Keyword	Description
PointOutputFile	name of the file providing the properties for the simulation point
PointOutputFileWriteEnd	name of the output file providing the Point values written just once at the end
SoilTempProfileFile	name of the output file providing the Soil/rock instantaneous temperature values at various depths
SoilTempProfileFileWriteEnd	name of the output file providing the Soil/rock instantaneous temperature values at various depths written just once at the end
SoilAveragedTempProfileFile	name of the output file providing the Soil/rock average (in DtPlotPoint) temperature values at various depths
SoilAveragedTempProfileFileWriteEnd	name of the output file providing the Soil/rock average (in DtPlotPoint) temperature values at various depths written just once at the end
SoilIceContentProfileFile	name of the output file providing the Soil/rock instantaneous ice content values at various depths
SoilIceContentProfileFileWriteEnd	name of the output file providing the Soil/rock instantaneous ice content values at various depths written just once at the end
SoilAveragedIceContentProfileFile	name of the output file providing the Soil/rock average (in DtPlotPoint) ice content values at various depths
SoilAveragedIceContentProfileFileWriteEnd	name of the output file providing the Soil/rock average (in DtPlotPoint) ice content values at various depths written just once at the end

Table 15.5: Keywords of output file related to soil

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Str / Num / Opt
DefaultSoil	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
SoilPlotDepths	depth at which one wants the data on the snow to be plotted	m		NA	vec	num
DateSoil	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-		-1	sca	num
JulianDayFromYear0Soil	column number in which one would like to visualize the JulianDayFromYear0[days]	-		-1	sca	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
TimeFromStartSoil	column number in which one would like to visualize the time from the start of the soil	-		-1	sca	num
PeriodSoil	Column number to write the period number	-		-1	sca	num
RunSoil	Column number to write the run number	-		-1	sca	num
IDPointSoil	column number in which one would like to visualize the IDpoint	-		-1	sca	num

Table 15.6: Keywords defining the column number where to print the desired variable in the output files for the soil variables

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
DefaultPoint	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotPoint	Plotting Time step (in hour) of the output for specified pixels (0 means the it is not plotted)	h	0, inf	0	vec	num
DatePoint	column number in which one would like to visualize the Date12[DDMMYYYY hhmm]	-	1, 76	-1	sca	num
JulianDayFromYear0Point	column number in which one would like to visualize the JulianDayFromYear0[days]	-	1, 76	-1	sca	num
TimeFromStartPoint	column number in which one would like to visualize the TimeFromStart[days]	-	1, 76	-1	sca	num
PeriodPoint	column number in which one would like to visualize the Simulation_Period	-	1, 76	-1	sca	num
RunPoint	column number in which one would like to visualize the Run	-	1, 76	-1	sca	num
IDPointPoint	column number in which one would like to visualize the IDpoint	-	1, 76	-1	sca	num
ThawedSoilDepthPoint	column number in which one would like to visualize the thawed_soil_depth [mm]	-	1, 76	-1	sca	num

Table 15.7: Keywords defining the column number where to print the desired variable in the PointOutputFile

15.2.2 Map Output

Parameters

Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Str / Num / Opt**
OutputSoilMaps	frequency (h) of printing of the results of the soil maps	h		0	sca	num

Table 15.8: Keywords of frequency for printing soil output maps

15.2.3 Map names

Keyword	Description
SoilMapFile	name of the file providing the soil map
FirstSoilLayerTempMapFile	name of the map of the temperature of the first soil layer
FirstSoilLayerAveragedTempMapFile	name of the map of the average temperature of the first soil layer
ThawedDepthMapFile	name of the output file providing the Thawed soil depth map
FrostTableDepthMapFile	name of the output file providing the Frost table depth map

Table 15.9: Keywords of print output maps for soil and rock thermal and hydraulic variables

15.2.4 Tensor names

Keyword	Description
SoilTempTensorFile	Name of the ensamble of raster maps corresponding to the temperature of each layer (if PlotSoilDepth≠0 it writes the value at the corresponding depths)
SoilAveragedTempTensorFile	Name of the ensamble of raster maps corresponding to the average temperature of each layer (if PlotSoilDepth≠0 it writes the value at the corresponding depths)
IceLiqContentTensorFile	Name of the ensamble of raster maps corresponding to the average ice content of each layer (if PlotSoilDepth≠0 it writes the value at the corresponding depths)

Table 15.10: Keywords of print output tensor maps for soil and rock thermal and hydraulic variables

Chapter 16

Discharge at the outlet

16.1 Input

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
SurFlowResLand	(C_m): coefficient of of the law of uniform motion on the surface ($v_{sup} = C_m \cdot h_{sup}^{\gamma} \cdot i_{DD}^{0.5}$), γ defined below	$m^{1-\gamma}$ s^{-1}	0.01, 5.0	0.5	sca	num
SurFlowResExp	(γ): Exponent of the law of uniform motion on the surface $v = C_m \cdot h_{sup}^{\gamma} \cdot i^{0.5}$	-	0.25 - 0.34	0.67	sca	num
ThresWaterDepthLandDown	h_{sup}: Threshold below which C_m is 0 (water does not flow on the surface)	mm		0	sca	num
ThresWaterDepthLandUp	h_{sup}: Threshold above which C_m is independent from h_{sup} (= fully developed turbulence)	mm		50	sca	num
SurFlowResChannel	Resistance coefficient for the channel flow (the same γ for land surface flow is used)	$m^{1-\gamma}$ s^{-1}		20	sca	num
ThresWaterDepthChannelUp	h_{sup} Threshold above which C_m is independent from h_{sup} (= fully developed turbulence).	mm		50	sca	num
RatioChannelWidthPixelWidth	Fraction of channel width in the pixel width	-		0.1	sca	num
ChannelDepression	Depression of the channel bed with respect to the neighboring slopes. It is used to change between free and submerged weir flow model to represent to surface flow to the channel	mm		500	sca	num
MinSupWaterDepthLand	minimum surface water depth on the earth below which the Courant condition is not applied	mm		1	sca	num
MinSupWaterDepthChannel	minimum surface water depth on the channel below which the Courant condition is not applied	mm		1	sca	num

Table 16.1: Keywords on input parameters to describe surface water flow on land and channel

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Logical / Numeric
MinTimeStepSupFlow	minimum integration time step for the integration (surface flow equation)			0.01	sca	num

Table 16.2: Keywords of input numeric parameters for the surface water balance equation settable in geotop.inpts

16.2 Output

16.2.1 Point

Files

Keyword	Description
DischargeFile	name of the file providing the discharge values at the outlet

Table 16.3: Keywords of file related to point output variables

Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
DtPlotDischarge	Plotting Time step (in hour) of the water discharge (0 means the it is not plotted)	h	0, inf	0	vec	num

Table 16.4: Keywords defining which parameter to print on the DischargeFile

Chapter 17

Basin synthetic outputs

17.1 Output

17.1.1 Files

Keyword	Description
BasinOutputFile	name of the output file providing the Basin values
BasinOutputFileWriteEnd	name of the output file providing the Basin values written just once at the end

Table 17.1: Keywords of file name for the synthetic basin outputs

17.1.2 Parameters

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
DefaultBasin	0: use personal setting, 1:use default	-	0, 1	1	sca	opt
DtPlotBasin	Plotting Time step (in hour) of THE basin averaged output (0 means the it is not plotted)	h	0, inf	0	vec	num
DateBasin	column in which one would like to visualize the Date12 [DDMMYYYYhhmm]	-	1, 24	-1	sca	num
JulianDayFromYear0Basin	column in which one would like to visualize the JulianDayFromYear0[days]	-	1, 24	-1	sca	num
TimeFromStartBasin	column in which one would like to visualize the TimeFromStart[days]	-	1, 24	-1	sca	num
PeriodBasin	column in which one would like to visualize the Simulation_Period	-	1, 24	-1	sca	num
RunBasin	column in which one would like to visualize the Run	-	1, 24	-1	sca	num
PRainNetBasin	column in which one would like to visualize the Prain_below_canopy[mm]	-	1, 24	-1	sca	num
PSnowNetBasin	column in which one would like to visualize the Psnow_below_canopy[mm]	-	1, 24	-1	sca	num

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Keyword	**Description**	**M. U.**	**range**	**Default Value**	**Sca / Vec**	**Log / Num**
PRainBasin	column in which one would like to visualize the Prain_above_canopy[mm]	-	1, 24	-1	sca	num
PSnowBasin	column in which one would like to visualize the Prain_above_canopy[mm]	-	1, 24	-1	sca	num
AirTempBasin	column in which one would like to visualize the Tair[°C]	-	1, 24	-1	sca	num
TSurfBasin	column in which one would like to visualize the Tsurface[°C]	-	1, 24	-1	sca	num
TvegBasin	column in which one would like to visualize the Tvegetation[°C]	-	1, 24	-1	sca	num
EvapSurfaceBasin	column in which one would like to visualize the Evap_surface[mm]	-	1, 24	-1	sca	num
TraspCanopyBasin	column in which one would like to visualize the Transpiration_canopy[mm]	-	1, 24	-1	sca	num
LEBasin	column in which one would like to visualize the LE[W/m^2]	-	1, 24	-1	sca	num
HBasin	column in which one would like to visualize the H[W/m^2]	-	1, 24	-1	sca	num
SWNetBasin	column in which one would like to visualize the SW[W/m^2]	-	1, 24	-1	sca	num
LWNetBasin	column in which one would like to visualize the LW[W/m^2]	-	1, 24	-1	sca	num
LEvBasin	column in which one would like to visualize the LEv[W/m^2]	-	1, 24	-1	sca	num
HvBasin	column in which one would like to visualize the Hv[W/m^2]	-	1, 24	-1	sca	num
SWvBasin	column in which one would like to visualize the SWv[W/m^2]	-	1, 24	-1	sca	num
LWvBasin	column in which one would like to visualize the LWv[W/m^2]	-	1, 24	-1	sca	num
SWinBasin	column in which one would like to visualize the SWin[W/m^2]	-	1, 24	-1	sca	num
LWinBasin	column in which one would like to visualize the LWin[W/m^2]	-	1, 24	-1	sca	num
MassErrorBasin	column in which one would like to visualize the Mass_balance_error[mm]	-	1, 24	-1	sca	num

Table 17.2: Keywords of print parameters to personalize the BasinOutputFile

17.1.3 Headers

Keyword	**Description**	**Associated file**
HeaderDateBasin	column name in the file BasinOutputFile for the variable DateBasin	BasinOutputFile
HeaderJulianDayFromYear0Basin	column name in the file BasinOutputFile for the variable JulianDayFromYear0Basin	BasinOutputFile
HeaderTimeFromStartBasin	column name in the file BasinOutputFile for the variable TimeFromStartBasin	BasinOutputFile
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Keyword	Description	Associated file
HeaderPeriodBasin	column name in the file BasinOutputFile for the variable PeriodBasin	BasinOutputFile
HeaderRunBasin	column name in the file BasinOutputFile for the variable RunBasin	BasinOutputFile
HeaderPRainNetBasin	column name in the file BasinOutputFile for the variable PRainNetBasin	BasinOutputFile
HeaderPSnowNetBasin	column name in the file BasinOutputFile for the variable PSnowNetBasin	BasinOutputFile
HeaderPRainBasin	column name in the file BasinOutputFile for the variable PRainBasin	BasinOutputFile
HeaderPSnowBasin	column name in the file BasinOutputFile for the variable PSnowBasin	BasinOutputFile
HeaderAirTempBasin	column name in the file BasinOutputFile for the variable AirTempBasin	BasinOutputFile
HeaderTSurfBasin	column name in the file BasinOutputFile for the variable TSurfBasin	BasinOutputFile
HeaderTvegBasin	column name in the file BasinOutputFile for the variable TvegBasin	BasinOutputFile
HeaderEvapSurfaceBasin	column name in the file BasinOutputFile for the variable EvapSurfaceBasin	BasinOutputFile
HeaderTraspCanopyBasin	column name in the file BasinOutputFile for the variable TraspCanopyBasin	BasinOutputFile
HeaderLEBasin	column name in the file BasinOutputFile for the variable LEBasin	BasinOutputFile
HeaderHBasin	column name in the file BasinOutputFile for the variable HBasin	BasinOutputFile
HeaderSWNetBasin	column name in the file BasinOutputFile for the variable SWNetBasin	BasinOutputFile
HeaderLWNetBasin	column name in the file BasinOutputFile for the variable LWNetBasin	BasinOutputFile
HeaderLEvBasin	column name in the file BasinOutputFile for the variable LEvBasin	BasinOutputFile
HeaderHvBasin	column name in the file BasinOutputFile for the variable HvBasin	BasinOutputFile
HeaderSWvBasin	column name in the file BasinOutputFile for the variable SWvBasin	BasinOutputFile
HeaderLWvBasin	column name in the file BasinOutputFile for the variable LWvBasin	BasinOutputFile
HeaderSWinBasin	column name in the file BasinOutputFile for the variable SWinBasin	BasinOutputFile
HeaderLWinBasin	column name in the file BasinOutputFile for the variable LWinBasin	BasinOutputFile
HeaderMassErrorBasin	column name in the file BasinOutputFile for the variable MassErrorBasin	BasinOutputFile

Table 17.3: Keywords of headers to personalize the column names of the BasinOutputFile

Chapter 18

Boundary and Initial Conditions

18.1 Boundary Conditions

18.1.1 Energy balance equation

Dirichlet

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
ZeroTempAmplitDepth	Zero annual amplitude depth (ZAA): depth at which the annual temperature remains constant. It is used as the bottom boundary condition of the heat equation. The Zero flux condition can be assigned setting this parameter at a very high value	mm		1.00E+20	sca	num
ZeroTempAmplitTemp	Temperature at the depth assigned above	$^{\circ}$C		20	sca	num

Table 18.1: Keywords of boundary condition for the energy balance equation

Neumann

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
BottomBoundaryHeatFlux	Incoming heat flux at the bottom boundary of the soil domain (geothermal heat flux)	W m^{-2}		0	sca	num

Table 18.2: Keywords of boundary condition for the energy balance equation

18.1.2 Water balance equation

Neumann

Keyword	Description	M. U.	range	Default Value	Sca / Vec	Log / Num
FreeDrainageAtBottom	Boundary condition on Richards' equation at the bottom border (1: free drainage, 0: no flux)	-	0,1	0	sca	num
FreeDrainageAtLateralBorder	Boundary condition on Richards' equation at the lateral border (1: free drainage, 0: no flux)	-	0,1	1	sca	num
PointDepthFreeSurface	depth of the trench that simulates the drainage of a soil column through a weir. The deeper the trench, the higher the drainage. Valid in 1D simulations	mm		NA	vec	num

Table 18.3: Keywords of boundary condition for the energy balance equation

18.2 Initial Conditions

18.2.1 Snow

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Log / Num
InitSWE	Initial snow water equivalent (SWE) - used if no snow map is given	kg m^{-2}		0	sca	num
InitSnowDensity	Initial snow density - uniform with depth	kg m^{-3}		200	sca	num
InitSnowTemp	Initial snow temperature - uniform with depth	°C		-3	sca	num
InitSnowAge	Initial snow age	days		0	sca	num

Table 18.4: Keywords for the input of initial conditions

18.2.2 Glacier

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Log / Num
InitGlacierDepth	Initial glacier depth - used if no snow map is given	mm		0	sca	num
InitGlacierDensity	Initial glacier density - uniform with depth	kg m^{-3}		800	sca	num
InitGlacierTemp	Initial glacier temperature - uniform with depth	°C		-3	sca	num

Table 18.5: Keywords for the input of initial conditions

18.2.3 Soil / Rock

Water balance equation

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Log / Num
InitWaterTableHeightOverTopoSurface	initial condition on water table depth (positive downwards from ground surface). Used if InitSoilPressure is void	mm		0	sca	num
InitSoilPressure		mm		NA	vec	num
InitSoilPressureBedrock		mm		NA	vec	num

Table 18.6: Keywords for the input of initial conditions

Energy balance equation

Keyword	Description	M. U.	range	Default Value	Scalar / Vector	Log / Num
IInitSoilTemp		°C		5	vec	num
InitSoilTempBedrock		°C		5	vec	num

Table 18.7: Keywords for the input of initial conditions settable in geotop.inpts

Chapter 19

Templates

In order to introduce the user to a first use of the model, two examples are provided to illustrate how to start a simulation and obtain results. The key ideas embedded in the input-out structure are flexibility and self-explanatory names for variables and files.

All input-output parameters and the simulation control parameters are given in the itgeotop.inpts file. A log-file is generated as a track of the simulation, it summarizes the parameter set chosen for the simulation and the time evolution, i.e. the percentage of simulation completed and the amount of time required to complete it. If the simulation is long or convergency problems are encountered, this file can be very large. If the simulation is completed a *SUCCESSFUL-RUN* empty file is created, alternatively a *FAILED* file is printed out. If the simulation is rerun new files are generated and old files are renamed with .old

Default values are assigned to several variables, assuming the simulation is 3D, if the users wants to change the default status, appropriate flags need to be assigned.

19.1 1D simulation

Some processes are mainly 1-dimensional, therefore they can be investigated using GEOtop in a simplified manner. In such a way the computational domain is reduced to one vertical column aligned to a Cartesian grid. Processes related to soil temperature and snow profiles can be studied in one dimension.

Input-output and controlling simulation parameters are assigned in the *geotop.inpts* file, together with the keyword specific for the 1D simulation. In order to traduce a real case study into a scheme that can be handed by the model, the following elements have to be set:

- computational domain;
- initial conditions;
- boundary conditions;
- meteorological forcing;
- soil and snow thermic parameters.

The **computational domain** is set assigning the number of layers and their thickness in the SOIL PARAMETERS block (SoilLayerThicknesses).

The **initial conditions** can be assigned to soil, snow, watertable, ice and bedrock (Table 19.1). Initial conditions on soil temperature are assigned through the InitSoilTemp parameter in the SOIL PARAMETERS block, the initial conditions on snow are assigned through four parameters initial snow water equivalent (InitSWE), initial snow density (InitSnowdensity), initial snow temperature (InitSnowTemp), initial snow age (InitSnowAge). The initial watertable height can be defined through the InitWaterTableHeightOverTopoSurface parameter, which takes negative value if the soil in unsaturated and 0 if it is saturated. Initial condition on ice depth, temperature and ice density can be set through the corresponding parameters InitGlacierDepth, InitGlacierDensity and InitGlacierTemp.

Dirichlet **boundary conditions** are assigned at the bottom boundary of the computational domain by setting the depth at which the temperature fluctuation due to external forcing is zero (ZeroTempAmplitDepth) and providing the constant temperature at such a depth (ZeroTempAmplitTemp). Both parameters can be found in the ENERGY BALANCE PARAMETERS block. Boundary conditions for the mass balance (Richards equation) are set by default to no flux (as reported in the log-file).

Meteorological forcing are assigned through the meteo-file, the horizon meteo-file and some parameters which specify the characteristic of the meteorological station and the sensor height in the METEO PARAMETERS block. There is one horizonmeteo file per meteorological station; they can be present to improve the shadow calculation. It describes the obstacles around the station in terms of two angles; one describes the angle on an horizontal plane between the North and the object; the other angle describes the height of the object along the vertical plane.

	Physical variables	Parameter name
Soil	soil temperature soil pressure	InitSoilTemp InitSoilPressure
Snow	snow water equivalent snow density snow age	InitSWE InitSnowDensity InitSnowAge
Ice	ice depth ice density ice temperature	InitGlacierDepth InitGlacierDensity InitGlacierTemp
Water	watertable depth water pressure within the bedrock temperature of the bedrock	InitWaterTableHeightOverTopoSurface InitSoilPressureBedrock InitSoilTempBedrock

Table 19.1: Synoptic table of the initial conditions

Soil and snow thermic parameters are assigned for each layer in the SOIL and SNOW block through several parameters such as soil thermal conductivity and capacity (ThermalConductivitySoilSolids, ThermalCapacitySoilSolids). In addition, land cover characteristic are given in the LAND COVER PARAMETERS block.

19.1.1 Parameter file: *geotop.inpts*

Parameters are organized in 10 blocks; they can be flags which enable or disable functionalities in the simulation, keywords or values. The 10 blocks are listed in the followings:

1. Base Parameters (Table 19.2). This block contains 4 parameters which define the integration interval, the simulated time through the initial and end dates and whether the simulation has to be run more than one time; 3 flags defining whether the water and/or the energy balance calculations have to be switch on (1) and whether the simulation is 1D. The default case is 3D simulation which corresponds to setting the *PointSim* to 0 or, alternatively, not using it. The last two parameters are defined by the users.
2. Input files and Headers (Table 19.3). This block contains the keywords which define the column names for some input files, such as the meteo file, the horizon meteo file and the list point file.
3. Meteo Parameters: define the characteristics of the meteorological station/s. (Figure 19.1)
4. Energy Balance Parameters (Table 19.4). These parameters are necessary to solve the energy balance equation.
5. Water Balance Parameters (Table 19.4). These parameters are necessary to solve the Richards equation.
6. Land Cover Parameters (Table 19.5). These parameters allow for the surface roughness, reflectivity and emissivity characterization.
7. Soil Parameters (Table 19.6). These parameters allow the user to characterize the soil both in terms of geometry (number of layers and thickness) and hydraulic properties (van Genucten [1980] parameters).
8. Snow Parameters (Table 19.7). These parameters allow for snow characterization.
9. Output in a Point and Output Time Series (Figure 19.3) allow the user to define which output has to be printed and in which format.

For additional details see Tables ... Add REF to keyword table.

Parameter / Keyword / Flag	value
TimeStepEnergyAndWater	3600
InitDateDDMMYYYYhhmm	12/07/2010 00:00
EndDateDDMMYYYYhhmm	15/08/2010 23:00
NumSimulationTimes	1
WaterBalance	1
EnergyBalance	1
PointSim	1
StandardTimeSimulation	0
DtPlotPoint	1

Table 19.2: Base Parameters.

Parameter / Keyword / Flag	value
PointFile	”listpoints”
HeaderPointElevation	”ele”
HeaderPointSlope	”slp”
HeaderPointAspect	”asp”
HeaderPointSkyViewFactor	”sky”
HeaderPointMaxSWE	”swe”
MeteoFile	”meteo”
HeaderDateDDMMYYYYhhmmMeteo	”date”
HeaderWindVelocity	”WindS”
HeaderWindDirection	”WindDir”
HeaderWindX	”WindX”
HeaderWindY	”WindY”
HeaderRH	”RelHum”
HeaderAirTemp	”AirT”
HeaderSWglobal	”SWglobal”
HeaderIPrec	”Iprec”
HeaderCloudSWTransmissivity	”CloudTrans”
HorizonMeteoStationFile	”horizonmeteo”
HeaderHorizonAngle	”Angle”
HeaderHorizonHeight	”Height”

Table 19.3: Input files and headers

Energy balance		Water balance	
Parameter / Keyword / Flag	value	Parameter / Keyword / Flag	value
LWinParameterization	9	FrozenSoilHydrCondReduction	2
MoninObukhov	1	RichardTol	1.E-8
HeatEqTol	1.E-5	RichardMaxIter	500
HeatEqMaxIter	500	RichardInitForc	0.01
ZeroTempAmplitDepth	20100		
ZeroTempAmplitTemp	-1.25		

Table 19.4: Parameters used for solving the energy balance and Richards equation.

Parameter / Keyword / Flag	value
SoilRoughness	100
ThresSnowSoilRough	5
AlbExtParSnow	3
SoilAlbVisDry	0.5
SoilAlbNIRDry	0.5
SoilAlbVisWet	0.5
SoilAlbNIRWet	0.5
SoilEmissiv	0.96

Table 19.5: Land cover characterization parameters

Parameter / Keyword / Flag	value
SoilLayerTypes	1
InitWaterTableHeightOverTopoSurface	-3000
SoilLayerThicknesses	100,100,100, ...
InitSoilTemp	0.34, 0.15, -0.03, ...
VerticalHydrConductivity	0.0001
ThetaRes	0
ThetaSat	0.2,0.2,0.2,0. ....
AlphaVanGenuchten	0.0436,0.0436,0.0436, ...
NVanGenuchten	1.51,1.51,1.51, ...
ThermalConductivitySoilSolids	2.3
ThermalCapacitySoilSolids	2.3E+06 ...

Table 19.6: Soil characterization parameters

Parameter / Keyword / Flag	value
FreshSnowReflVis	0.96
FreshSnowReflNIR	0.72
BlowingSnow	0
InitSWE	0
InitSnowDensity	180
InitSnowTemp	-3
InitSnowAge	0
NumMaxSnowLayers	5
InfiniteSnowLayer	3
MinLayerThicknessSnow	5, 30, 120, 5, 5
MaxLayerThicknessSnow	20, 100, 10000, 100, 50
RainCorrFactor	1
SnowCorrFactor	1.6
SnowSMIN	25
SnowSMAX	70
SnowCURV	-150
DewTempOrNormTemp	0.65
ThresTempRain	2
ThresTempSnow	-1
SnowEmissiv	0.94
SnowRoughness	0.1
FreshSnowReflVis	0.9
FreshSnowReflNIR	0.65
IrriducibleWatSatSnow	0.02
MaxSnowPorosity	0.7
DrySnowDefRate	1
SnowDensityCutoff	100
WetSnowDefRate	1.5
SnowViscosity	1.E6
AlphaSnow	1.E2

Table 19.7: Snow characterization parameters

19.1.2 Input files

The input files required to run a 1D-simulation in addition to the *geotop.inpts* file are the followings:

- meteo file;
- horizon meteo file;
- list point.

The **meteo file** contains a time series of meteorological data. If data for more stations are available, one meteo file per station needs to prepared before a simulation can be run; the same holds for the horizionfile. Using the meteo parameters in the *geotop.inpts* file the user can specify the number of stations and their characteristics, e.g. location, elevation, sky view factor, time shift with respect to UTC if any and sensors height. In case of more stations, scalar values are substituted by vectors (Figure 19.1). For flexibility purposes the user can specify the columns name of the meteo file through the keywords provided in the Input files and Header block in the *geotop.inpts* file, as shown in Figure 19.2. The quoted names to the right can be changed at the user's convenience. The same concept applies to the horizon meteo and list point files, whose column names can be defined through appropriate keywords (Figure 19.2).

The **horizon file** it describes the obstacles around the station in terms of two angles; one describes the angle on an horizontal plane between the North and the object; the other angle describes the height of the object along the vertical plane.

The **list point** file describes the morphological features of the points where the simulation is performed. If more than one point are listed in this file the simulation is run simultaneously run at multiple points. The features that have to be provided for each point are the point identification number, the elevation, the local slope, the aspect and the sky view factor.

```
!==================================================
!  METEO PARAMETERS
!==================================================
NumberOfMeteoStations =1
Latitude = 45.55000
Longitude= 7.41000
MeteoStationElevation = 3100
MeteoStationSkyViewFactor = 1
MeteoStationStandardTime = 0
MeteoStationWindVelocitySensorHeight = 3
MeteoStationTemperatureSensorHeight = 3
```

```
!==================================================
!  METEO PARAMETERS
!==================================================
NumberOfMeteoStations =3
Latitude = 45.55000,45.15000,45.85000
Longitude= 7.41000,7.11000,7.21000
MeteoStationElevation = 3100,2900,2000
MeteoStationSkyViewFactor = 1,1,1
MeteoStationStandardTime = 0,0,0
MeteoStationWindVelocitySensorHeight = 3,7,5
MeteoStationTemperatureSensorHeight = 3,2,2
```

Figure 19.1: Example of meteo parameter sets, for one station on the left, for 3 station on right.

19.1.3 Output files

The number and the type of output that GEOtop prints out can be decided by the user through the DefaultPoint parameter. If this is set to 1, GEOtop prints out all possible output, as listed in Table ... Add REF to keyword table; alternatively, the user can specify which output wants GEOtop to print by setting the DefaultPoint parameter to 0. In this case the headers of the wanted output have to be specified as well (Figure 19.3). This section of the parameter file allows the user to change the column name and position in the output files by using the appropriate keyword. e.g. IDPointPoint will be printed on column 4 and labeled *chose a name*. In the example shown in Figure 19.3, 22 columns will be printed into the file named point, as specified by the PointOutputFileWriteEnd keyword. This name can be defined by the user. In the presented example two are the output files *point.txt* and *soiTave.txt*. This is an option that can be decided by the users and additional files can be printed on demand.

```
!======================================================
!  INPUT FILES and HEADERS
!======================================================

PointFile = "listpoints"
HeaderPointElevation      = "ele"
HeaderPointSlope          = "slp"
HeaderPointAspect         = "asp"
HeaderPointSkyViewFactor = "sky"
HeaderPointMaxSWE    = "swe"

MeteoFile = "meteo"
HeaderDateDDMMYYYYhhmmMeteo = "date"
HeaderWindVelocity = "WindS"
HeaderWindDirection = "WindDir"
HeaderWindX = "WindX"
HeaderWindY = "WindY"
HeaderRH = "RelHum"
HeaderAirTemp = "AirT"
HeaderSWglobal = "SWglobal"
HeaderIPrec = "Iprec"
HeaderCloudSWTransmissivity = "CloudTrans"

HorizonMeteoStationFile = "horizonmeteo"
HeaderHorizonAngle = "Angle"
HeaderHorizonHeight = "Height"
```

Figure 19.2: Input file Headers block in the *geotop.inpts* file

```
!==================================================
! OUTPUT in a POINT
!==================================================
DefaultPoint = 0
DatePoint = 1
JulianDayFromYear0Point = 2
RunPoint = 3
IDPointPoint = 4
HeaderIDPointPoint="chose a name"
AirTempPoint = 5
HeaderAirTempPoint = "TempAria"
SurfaceEBPoint = 6
SnowDepthPoint = 7
SWEPoint = 8
SnowMeltedPoint = 9
SWupPoint = 10
SWinPoint = 11
SWNetPoint = 12
SoilHeatFluxPoint = 13
TsurfPoint = 14
WindSpeedPoint = 15
PsnowPoint=16
PrainPoint=17
LWinPoint=18
LWNetPoint=19
LWupPoint=20
HupPoint=21
LEupPoint=22
!==================================================
!  OUTPUT TIME SERIES
!==================================================
! File with the errors and warnings MANDATORY
PointOutputFileWriteEnd = "point"
SoilAveragedTempProfileFileWriteEnd = "soilTave"
```

Figure 19.3: Output blocks in the *geotop.inpts* file defining column header and their position in the output file

19.2 3D distributed simulation

GEOtop can reproduce physical processes which are mainly characterized by 3D-dynamics, such as snow melt in mountainous area, atmosphere-vegetation interactions and soil-atmosphere interaction (in bare soil), infiltration, water redistribution through the soil and stream discharge generation (Figure 19.4). Such processes required the topography of the study area to be given as input to the model and mass balance equation to solved in three dimensions (energy balance equation is solved 1D given the prevailing vertical fluxes to horizontal). GEOtop uses a 3D-structured grid as shown in Figure 19.5. In addition, to investigate interactions between atmosphere and vegetation, and between soil and atmosphere, distributed information on landcover and soil type are required.

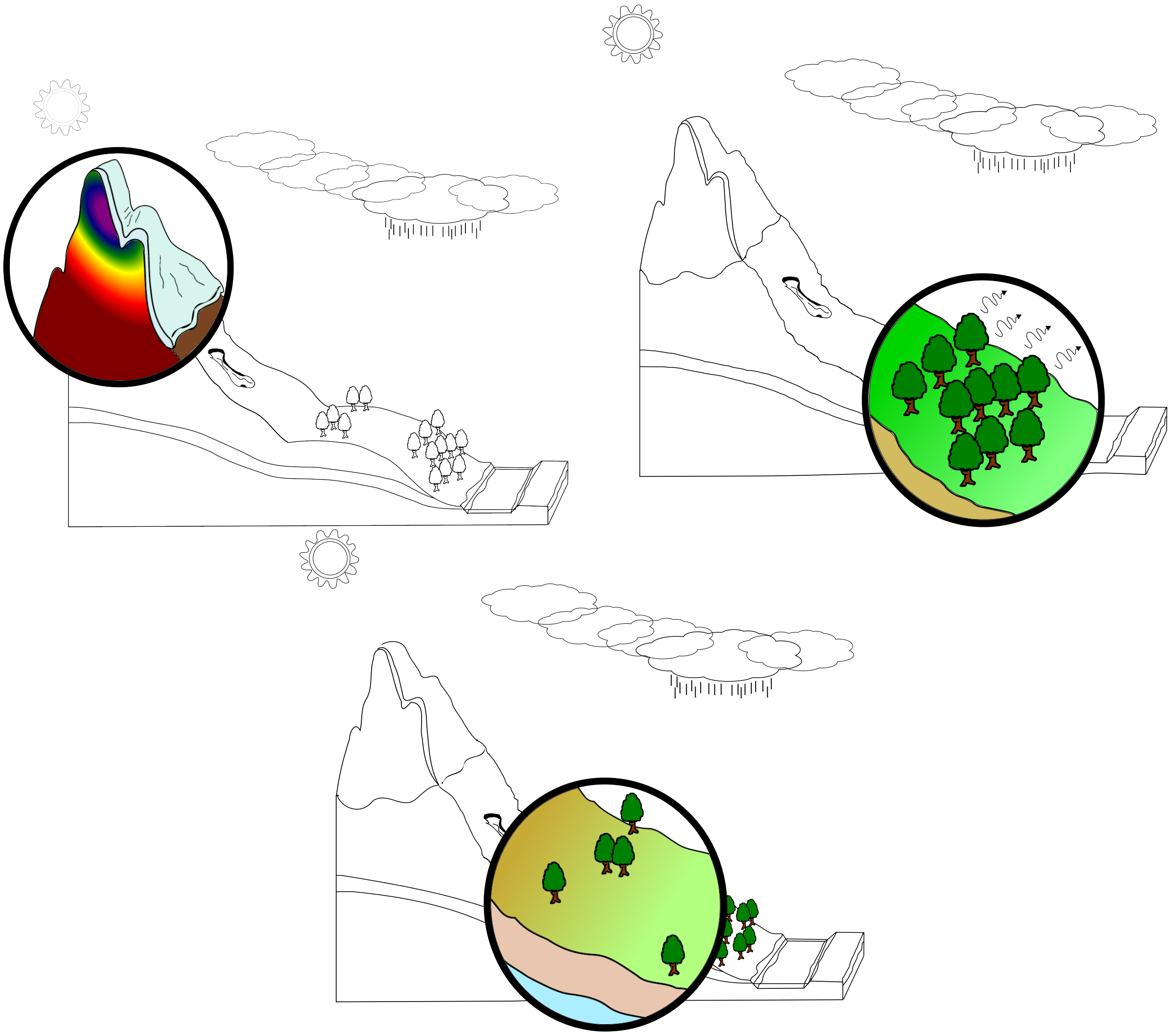

Figure 19.4: Physical processes typical of mountain hydrology which can be reproduced using a distributed, 3D model, such as GEOtop.

The example presented refers to a 2 day-run on a 0.7 km^2 alpine watershed. Data from only one station were available for this catchment. Soil type and landcover data were derived from satellite images and soil characterization (geomechanical properties and lithologic profiles) were derived from extensive field campaigns. In this respect GEOtop is a tool to handle post-processed Earth Observation (EO) data and distributed field data. The goal of this template is to show how the user can set up a distributed simulation.

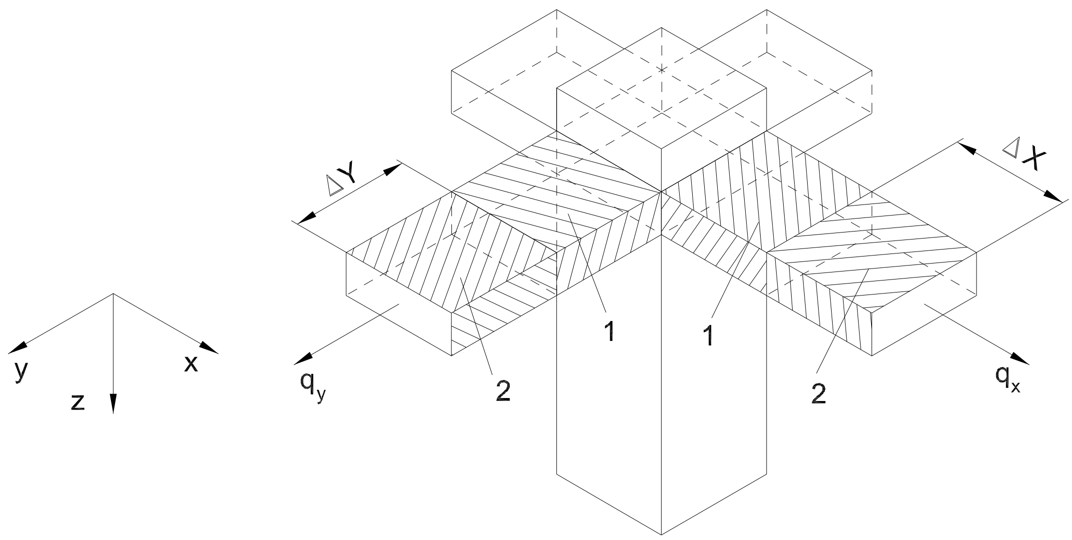

Figure 19.5: 3-dimensional grid structure implemented in GEOtop to solve the mass balance equation.

19.2.1 Parameter file

The structure of the parameter files is analogous to what previously illustrated for the 1D case with few additional keywords and parameters which need to be add in order to print out distribute and aggregated results, such as maps and stream flow, see Table 19.8. The *DtPloDischarge* parameter specifies the print out stream discharge time series time step in hours (1), the *OutputSoilMaps* parameter specifies the print out time step for the stream discharge time series (24 hours). The barycentric latitude and longitude for the watershed has to supplied.

Parameter / Keyword / Flag	value
TimeStepEnergyAndWater	3600
InitDateDDMMYYYYhhmm	12/07/2010 00:00
EndDateDDMMYYYYhhmm	15/08/2010 23:00
NumSimulationTimes	1
WaterBalance	1
EnergyBalance	1
Latitude (avg)	46.3
Longitude (avg)	11.7
StandardTimeSimulation	0
DtPloDischarge	1
DtPlotPoint	1
DtPlotBasin	1
OutputSoilMaps	24
OutputSnowMaps	24
OutputSurfEBALMaps	24
OutputMeteoMaps	24

Table 19.8: Base Parameters for a 3D simulation. Units are specified in Table ADD REF TO KEYWORD TABLE

Raster file maps name have to be specified in the File names and Header parameters section as shown in Table 19.9. The number of available meteorological stations and their characteristics have to be specified in the appropriate parameter section.

Parameter / Keyword / Flag	value
PointFile	”listpoints”
HeaderPointElevation	”ele”
HeaderPointSlope	”slp”
HeaderPointAspect	”asp”
HeaderPointSkyViewFactor	”sky”
HeaderPointMaxSWE	”swe”
MeteoFile	”meteo”
HeaderDateDDMMYYYYhhmmMeteo	”date”
HeaderWindVelocity	”WindS”
HeaderWindDirection	”WindDir”
HeaderWindX	”WindX”
HeaderWindY	”WindY”
HeaderRH	”RelHum”
HeaderAirTemp	”AirT”
HeaderSWglobal	”SWglobal”
HeaderIPrec	”Iprec”
HeaderCloudSWTransmissivity	”CloudTrans”
DEMfile	”dem”
LandCoverMapFile	”landcovermapfile”
SkyViewFactorMapFile	”0sky”
SlopeMapFile	”0slope”
AspectMapFile	”0aspect”
CurvaturesMapFile	”0curvature”
SoilMapFile	”soiltype”
SoilParFile	”soil/soil”

Table 19.9: Input files and headers for a spatially distributed simulation.

The number of landcover and soil type categories have to be specified in the appropriate parameter section. In case the soil in the watershed is not homogeneous, the number of different soil type can be assigned to the SoilLayerTypes parameter (see Table 19.10) and a description for each soil type has to be provided. This is done through files stored in a user defined path specified by the keyword *SoilParFile* (Table 19.9). Soil characterization files must contain information on the layer thickness, hydraulic conductivity, residual and saturated moisture content etc. as specified by the keywords in Table 19.10.

In addition to what already said for the 1D case, distributed **Initial conditions** (IC) can be assigned using raster maps associated with a specific keyword which specifies the path to the file. E.g. the IC on the water table depth can be assigned through the keyword *InitWaterTableHeightOverTopoSurfaceMapFile*, the IC on initial snow height and initial ice depth can be assigned through the keywords *InitSnowDepthMapFile* and *InitGlacierDepthMapFile*.

In addition to what already said for the 1D case, lateral **boundary conditions** can be assigned through the keyword *FreeDrainageAt-LateralBorder*.

Parameter / Keyword / Flag	value
SoilLayerTypes	28
InitWaterTableHeightOverTopoSurface	-1000
InitSoilTemp	5
ThermalConductivitySoilSolids	2.5
ThermalCapacitySoilSolids	2.3E6
HeaderSoilDz	”Dz”
HeaderLateralHydrConductivity	”Kh”
HeaderNormalHydrConductivity	”Kv”
HeaderThetaRes	”res”
HeaderFieldCapacity	”fc”
HeaderThetaSat	”sat”
HeaderAlpha	”a”
HeaderN	”n”
HeaderSpecificStorativity	”SS”

Table 19.10: Soil characterization parameters for a 3D simulation

```
!================================================
!  OUTPUT TIME SERIES
!================================================
DischargeFile = "tabs/discharge"
PointOutputFile = "tabs/point"
SnowProfileFile = "tabs/snow"
BasinOutputFile = "tabs/basin"
SoilAveragedTempProfileFile = "tabs/soilTave"

SoilAveragedTempTensorFile = "maps/T"
SoilLiqContentTensorFile = "maps/thetaliq"
IceLiqContentTensorFile = "maps/thetaice"
LandSurfaceWaterDepthMapFile = "maps/hsup"
SurfaceHeatFluxMapFile = "maps/EB"
SurfaceSensibleHeatFluxMapFile = "maps/H"
SurfaceLatentHeatFluxMapFile = "maps/LE"
SurfaceTempMapFile = "maps/Ts"
SoilLiqWaterPressTensorFile = "maps/pressure"
ThawedDepthMapFile = "maps/thawed"
WaterTableDepthMapFile = "maps/watertable"

SWEMapFile= "maps/SWE"
SnowDepthMapFile = "maps/snowdepth"

PrecipitationMapFile = "maps/Prec"
AirTempMapFile = "maps/Ta"
WindSpeedMapFile = "maps/WindSpeed"
WindDirMapFile = "maps/WindDir"
RelHumMapFile = "maps/RH"
```

Figure 19.6: Keyword setting for output files.

The raster maps and input files which are strictly required to run a distributed simulation are the following:

19.2.2 Input maps and files

- Digital Elevation Model DEM.
- Landcover map
- Soiltype map and a file characterizing each different soil type (Figure 19.8).
- Time series of meteorological forcing.

To improve the quality of the simulation additional raster maps derived from geomorphological analysis of the DEM can be supplied. These maps detail the morphology of the watershed allowing for more reliable calculations. These maps are: slope and aspect maps, curvatures along specified directions and a drainage direction map. They can by computed through sounded hydrological routines such as the Horton Machines ADD REFERENCES.

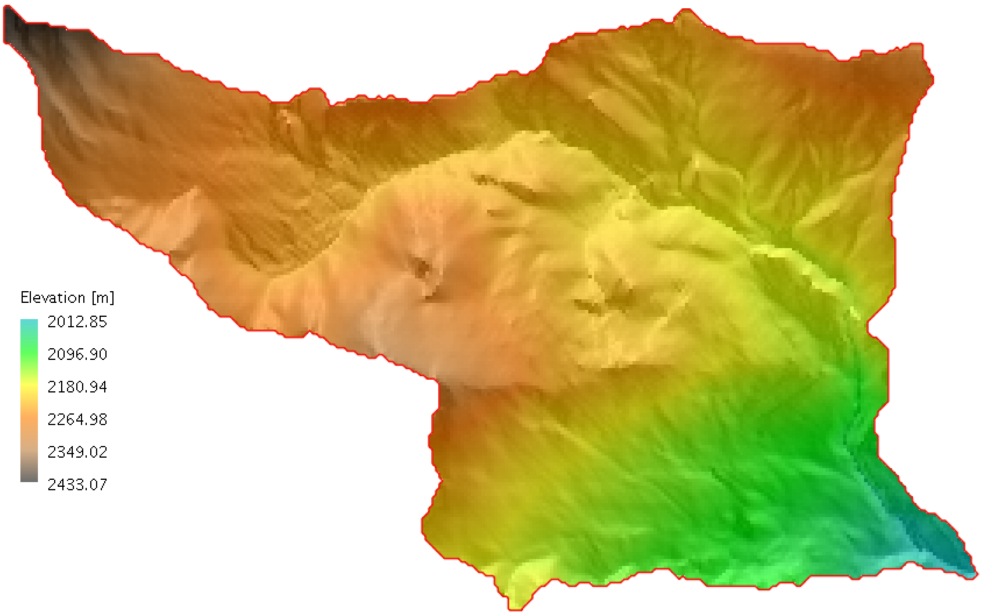

Figure 19.7: Digital elevation map of the investigated watershed.

```
Dz,Kh,Kv,res,fc,sat,a,n,SS
280,1.00E-07,1.00E-07,0,0.03,0.06,0.004,1.3,1.00E-06
500,1.00E-07,1.00E-07,0,0.03,0.06,0.004,1.3,1.00E-07
2000,1.00E-07,1.00E-07,0,0.03,0.06,0.004,1.3,1.00E-
```

Figure 19.8: Example of a soil type characterization file

The map resolution play an important role on the computational time therefore a trade-off between precision and the computational time has to be defined by the users. As a figure, the DEM used in this example is 5m resolution and counts 55648 cells in total.

19.2.3 Outputs

GEOtop can yield two types of different outputs:

- raster maps
- time series (discharge, air temperature, evaporation, latent heat fluxes, etc.....) at specific points (Figure 19.10).

The output raster maps (Figure 19.9) have to be specified by the user through appropriate keywords in the parameter file (see Table 19.9), in addition, their output frequency has to be assigned through the *OutputXXXMaps* parameter.

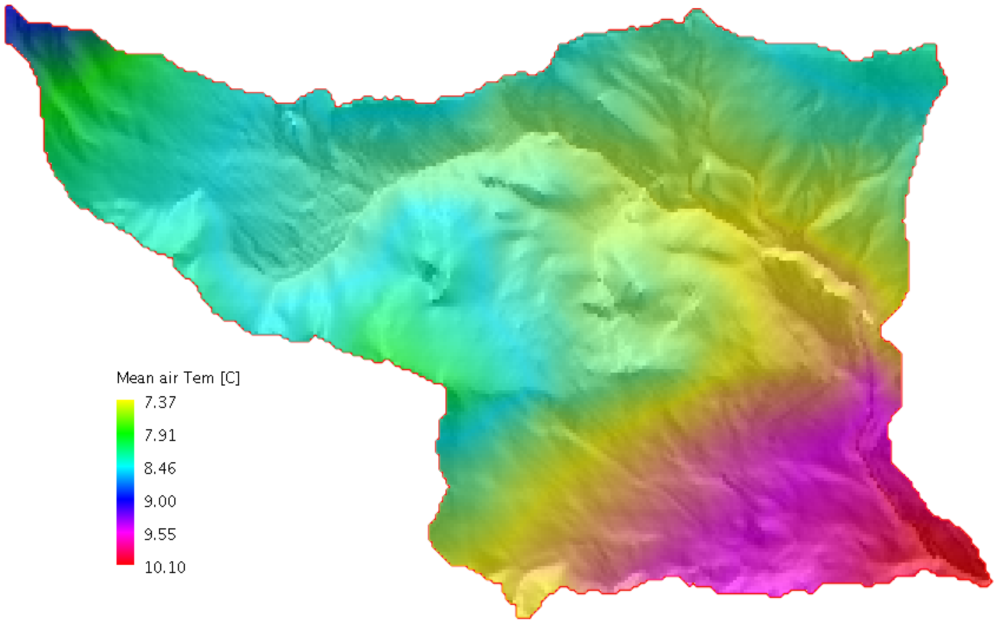

Figure 19.9: One of the many distributed output, the mean air temperature

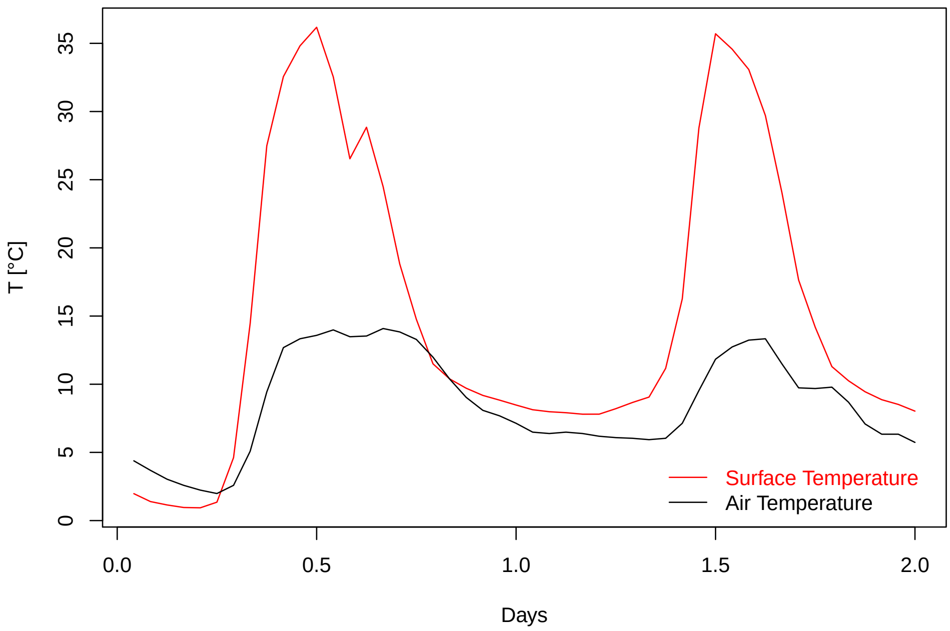

Figure 19.10: Two day-time series of mean air temperature output for a specified point

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