

Concept paper: Assessment of soil temperature

In contribution to ACT. 3.2 (WPT2) – Operational criteria and constraints for shallow geothermal systems in the Alpine environment.

Introduction

The underground temperature is one crucial parameter for the evaluation of operational criteria and constraints for shallow geothermal systems (ACT 3.2). The assessment of underground temperature can be divided in two parts. One is dealing with the shallow seasonally influenced soil layers and the other part takes care of the deeper structures, where the seasonal influence on the temperature can be neglected, but the geothermal gradient becomes important. Different methodologies have to be applied for the assessment of underground temperature in these two areas. This paper deals with the assessment of the seasonal variable temperatures of the very shallow layers.

	Shallow ~(0 – 10 m)	Deep ~(10 – 100+ m)
Medium	Soil	Rock
Energy source	Sun, climate	Geothermal heat flux
Numerical model type	Transient	Steady-state
Data source	Weather service, soil sciences	Geology
Possibility for calibration	Measurements, monitoring	Existing data, if any (tunnels, deep wells, ...)

Assessment of soil temperatures

SoilTempSimV3B is a one-dimensional simulation model for calculating soil temperatures on a daily time step basis. The model allows inclusion of ground coverage by biomass or a snow layer and accounts for the freezing/thawing effect of soil water in its calculations. Required inputs for the model are, on the one hand, time-dependent data such as daily mean, maximum and minimum air temperatures, global solar radiation, total aboveground biomass, snow (as snow water equivalent), actual daily evapotranspiration and daily values of the pore volume of the soil (which can vary due to soil cultivation) and volumetric soil water content at all relevant depths, and on the other hand, configuration and parameterisation data that is regarded as time-independent, such as soil composition (sand, clay and organic fraction), annual mean air temperature, and some empirical parameters. As output the model will deliver daily mean,

maximum and minimum soil temperatures and volumetric ice content (during freezing periods) for all the desired depths. The calculation is carried out one-dimensional (multiple depths at one surface location). To extend the results in the three-dimensional space, input data has to be present as raster datasets, the model is then run for each rasterpoint.

Summary of input data

The most critical input parameters and data are described in this section. For a full description of Input data please refer to the [SoilTempSim manual](#).

Data	Type	Availability	Provider	Editing effort	Comment
<i>Soil convection heat transfer coefficient</i>	Surface property	?	BOKU?	?	Literature values?
<i>Foliage emissivity</i>	Surface property	?	BOKU?	?	Herb et al 2006
<i>Sand content</i>	Soil property	~	E-BOD, BOKU?, Quarterary Geologists?	Low-medium	Sand and clay ratios are used for calculation of thermal conductivity of the soil. Values must be derived from soil type.
<i>Clay content</i>	Soil property	~	E-BOD, BOKU?, Quarterary Geologists?	Low-medium	
<i>Porosity</i>	Soil property	-	E_BOD, BOKU?	?	
<i>Soil moisture</i>	Climatic / Soil property	-	ZAMG, BOKU?	High	Have to be derived from Climatic input data
<i>Air temperature (daily min/max/mean)</i>	Climatic property	+	ZAMG	Low	ZAMG raster datasets
<i>Radiation (daily sum)</i>	Climatic property	+	ZAMG	?	Recalculation for inclined surfaces
<i>Snow cover</i>	Climatic property	+	ZAMG	Low	
<i>Total aboveground biomass</i>	Bio-climatic property	?	BOKU?	?	Literature values for Grassland available?
<i>Evapotranspiration (daily sum)</i>	Bio-climatic property	?	BOKU?	?	Literature values?

Climatic input data

All necessary Climatic data can be obtained as grid datasets from the Austrian Weather service (ZAMG).

Needed datasets: SPARTACUS, WINFORE, SNOWGRID, APOLIS.

Air temperatures: min/max from SPARTACUS; mean air temperature not available(?).

Soil moisture and evapotranspiration: Must be derived from SPARTACUS (precipitation) and WINFORE (Water balance Information),

Snow cover: Snow water equivalent is available from the SNOWGRID dataset.

Radiation: The daily sum of solar irradiation can be calculated from the APOLIS dataset by ZAMG.

Soil material properties

The soil material properties are basically reduced to three input parameters, namely the content of sand and clay and the total soil porosity. The remaining volume $[1 - (V_{\text{CLAY}} + V_{\text{SAND}} + V_{\text{POR}})]$ is assumed to be organic fraction. These properties are used by the model internally to calculate the soils thermal conductivity. The desired input parameters must be derived from the soil type, available for permanently settled areas from the online portal [e BOD](#). Data from e-BOD is only valid for the uppermost layer (up to ~1m depth), data from Quaternary geological mapping could be used to close data gaps.

Model validation

The soil temperature model has to be validated using soil temperature measurements. Deployment of up to five temperature monitoring stations is planned in the framework of field campaigns, one Weather monitoring station operated by ZAMG (Austrian weather service) will be equipped with soil temperature sensors in 10, 20 and 50 cm depth.

Monitoring stations

The monitoring equipment consists of multiple digital thermometers (Dallas Instruments DS 18B20 one wire protocol) attached to a three-pin cable and a datalogger device based on the Arduino micro controller board. The soil temperature will be logged in defined time intervals (e.g. 3h) and stored on a micro-sd card.

Installation proposal

Model results

Inquiry for ZAMG Support (Input data preparation)

Data	Dataset	Resolution x,y	Resolution time	Comments, open questions
<i>Temperature data Min Max Mean</i>	SPARTACUS	1 km	Daily values	Mean temperature available?
<i>Precipitation</i>	SPARTACUS	1 km	Daily sum	Needed for soil moisture calculation?
<i>Water balance</i>	WINFORE	1 km	Daily balance	Needed for soil moisture calculation?
<i>Snow Water Equivalent</i>	SNOWGRID	100 m	15 min (orig)	Daily mean values should be sufficient
<i>Radiation</i>	APOLIS	100 m	15 min	Daily sum of radiation onto the real surface needed (not horizontal)

Inquiry for BOKU Support (Input data processing and model support)

The service description includes (a) support for installation and if necessary adoption of SoilTempSimV3B on a PC at GBA and (b) processing of input data provided by ZAMG and GBA.

SoilTempSimV3B should be installed on a PC at the Geological Survey and ...

Consultancy and assistance for data preparation

Data	Derived from dataset(s)		
<i>Soil convection heat transfer coefficient</i>	?		
<i>Foliage emissivity</i>	?		
<i>Sand content</i>	e-BOD, Quarternary Geology (GBA), field campaign (GBA)		
<i>Clay content</i>			
<i>Porosity</i>			
<i>Soil moisture</i>	SPARTACUS, WINFORE (?)		
<i>Total aboveground biomass</i>	Literature?		
<i>Evapotranspiration (daily sum)</i>	SPARTACUS, WINFORE (?)		

Support for implementation of SoilTempSimV3B