A parameter optimization tool for evaluating the physical consistency of the plot-scale water budget of the integrated eco-hydrological model GEOtop in complex terrain

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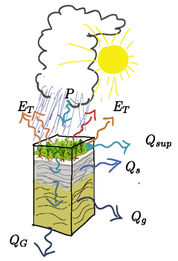
BACKGROUND



Integrated eco-hydrological models could be useful tools to:

- ✓ understand controlling factors;
- ✓ model climatic scenarios impacts;
- ✓ simulate different management strategies

Operational Limitations

Large uncertainties related to

- ✓ numerus model parameters;
- ✓ model boundary conditions;
- ✓ model structure / complexity.

➢ **Need of automatic model sensitivity and optimization tools**

AIMS

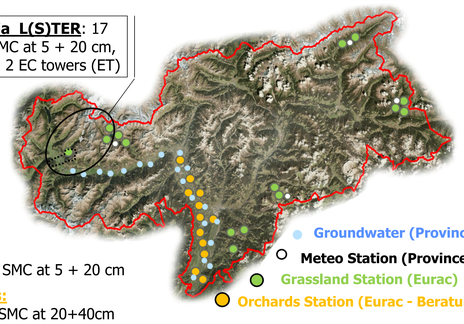
1. To present an approach for **improving calibration** of plot-scale soil moisture content (**SMC**) and evapotranspiration (**ET**).
2. To identify the **most sensitive parameters**
3. To identify **relevant factors** controlling temporal and spatial differences among sites.
4. To perform model sensitivity with respect to relevant **climatic/management scenarios**.

APPROACH

Ground observations

An unique micrometeorological, **ET** and **SMC** monitoring network has been installed in South Tyrol (Italy, Alps) representative of different land cover and topographic conditions [**1,2**] of **mountain regions**.

Matsch/Mazia L(S)TER: 17 stations, with SMC at 5 + 20 cm, meteo data and 2 EC towers (ET)



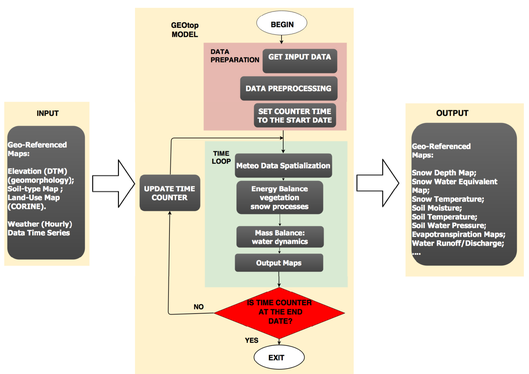
Grasslands:
15 stations, with SMC at 5 + 20 cm

Apple orchards:
12 stations with SMC at 20+40cm

Land use:	Grassland / Apple Orchards
Management:	Irrigated / Not Irrigated
Soil types:	Sand, silt, loam
Elevation:	200 – 2000 m a.s.l,
Slope:	0 – 30 deg
Aspect:	South/West – South/East
Groundwater:	<1 m - > 10 m
Bedrock depth:	20 cm - > 10 m

Hydrological modelling

The **GEOtop 2.0 integrated hydrological model** [**3,4**] was employed.

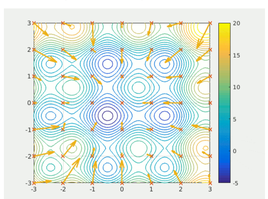


Modellig Approach

1. Selection of test stations.
2. Model sensitivity.
3. Model optimization.
4. Results consistency evaluation.
5. Scenarios selection.

Model sensitivity and optimization

- Development of an automatic model sensitivity and optimization tool: **GEOtopOptim**
- Published as a **R package** [**5**] on https://github.com/EURAC-Ecohydro/geotopOptim2.
- Based on the Particle Swarm Optimization approach ("hydroPSO" R package; [**6**]).
- MPI parallel implementation on the Vienna Scientific Cluster.



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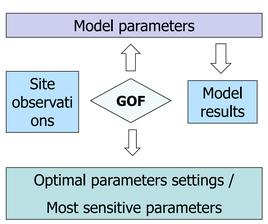


Methodological open issues

1. Choice of parameters to identify.
2. Optimization settings (# particles, # iterations …).
3. Choice of the target GOF function (RMSE, NSE, KGE).
4. Multi-target optimization (SMC at different levels, ET).
5. Temporal and spatial dependencies.

RESULTS

Parameters sensitivity

Latin Hypercube One factor At Time (**LHOAT**) parameters sensitivity on the GOF.

Sensitivity for Montacini P2 pasture site with respect to **SMC** @ 5 cm

Ranking Nmbr	Parameter Name	Relative Importance Norm.
1	SOIL__N	0.3135
2	SOIL__ThetaSat	0.2727
3	SOIL__LOG10_NormalHydrCond	0.1222
4	SOIL__LOG10_Alpha	0.0988
5	SCALAR__SoilEmissiv	0.0860
6	SOIL__ThetaRes	0.0477
7	SCALAR__CanopyFraction	0.0126
8	SCALAR__SoilAlbNIRWet	0.0114
9	SCALAR__SoilAlbNIRDry	0.0103
10	SCALAR__SoilAlbVisDry	0.0079
11	SCALAR__SoilAlbVisWet	0.0069
12	SCALAR__SoilRoughness	0.0048
13	SCALAR__LSAI	0.0031
14	SCALAR__RootDepth	0.0005

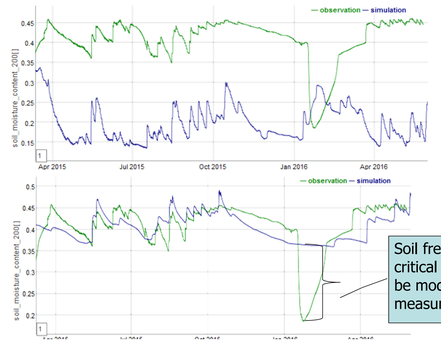
Sensitivity for Montacini P2 pasture site with respect to **SMC** @ 5 cm and **ET**

Ranking Nmbr	ParameterName	Relative Importance Norm.
1	SCALAR__CanopyFraction	0.2543
2	SOIL__ThetaSat	0.1823
3	SOIL__LOG10_Alpha	0.1695
4	SOIL__N	0.1667
5	SCALAR__SoilEmissiv	0.0704
6	SOIL__LOG10_NormalHydrCond	0.0613
7	SCALAR__SoilAlbNIRDry	0.0196
8	SCALAR__SoilAlbNIRWet	0.0143
9	SCALAR__SoilAlbVisDry	0.0121
10	SOIL__ThetaRes	0.0116
11	SCALAR__SoilAlbVisWet	0.0097
12	SCALAR__LSAI	0.0091
13	SCALAR__SoilRoughness	0.0084
14	SCALAR__DecayCoeffCanopy	0.0035

➢ **Soil parameters** are the most sensitive.
➢ **ET** optimization most sensitive to **vegetation dynamic** (Canopy Fraction).

Model optimization

Example of **optimization** results (DOMEF 1500 meadow site, GOF RMSE for SMC 5 cm)



Original Simulation
RMSE 0.21
PBIAS% -47.5
KGE -0.17
NSE -14.45

100 Iterations
512 Particles
RMSE 0.04
PBIAS% -0.4
KGE 0.42
NSE 0.35

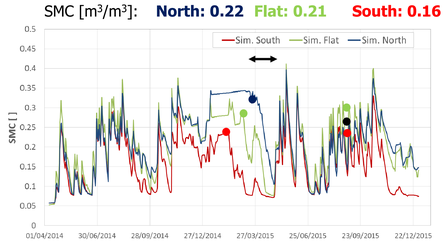
➢ Using a higher particles # and lower iterations # allows an efficient use of the cluster without loosing effectiveness.

Environmental factors sensitivity

Topographic properties

- North aspect, slope 30°;
- Flat;
- South aspect, slope 30°;

SMC [m^3/m^3]: **North: 0.22** **Flat: 0.21** **South: 0.16**

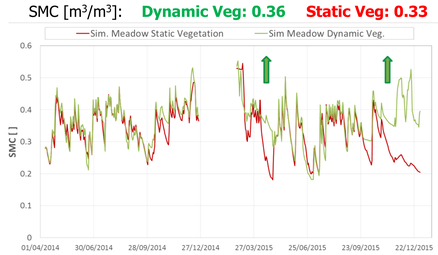


The effect of slope/aspect on SMC is seasonally-dependent. Aspect influences **snow cover** duration and **radiation** (ET). Steep slopes influence net precipitation and lateral water distribution.

Model´s processes representation sensitivity

Dynamic vegetation: time-variable LAI, canopy fraction and height

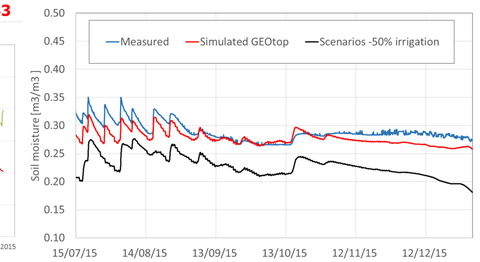
SMC [m^3/m^3]: **Dynamic Veg: 0.36** **Static Veg: 0.33**



Vegetation dynamic has an impact on SMC, especially in spring and autumn.

Management scenarios sensitivity

Reduction of 50 % in irrigation frequency
Latsch (BZ, Italy) apple orchard.



Models application for evaluating plants water stress conditions.

CONCLUSION & OUTLOOK

Conclusions:

- ➢ Development of automatic optimization tool for the GEOtop hydrological model.
- ➢ The method allows to identify most sensitive model parameters and critical processes in the model and/or in the observations.
- ➢ Optimization settings and specific sites properties control optimization performances.
- ➢ Using a higher particles # and lower iterations # allows an efficient parallel use of the cluster without loosing effectiveness.

Outlook:

- ➢ Model optimization for all experimental sites.
- ➢ Cross-sites parameter sensitivity.
- ➢ Seasonal temporal analysis.
- ➢ Optimal model parameters identification.
- ➢ Multi-objective optimization rules (ET, SMC, ...)
- ➢ Production of optimal irrigation scenarios.

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