Distributed hydrological modeling in a mountainous snow dominated watershed with scarcity of hydropower data.

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Introduction and research need

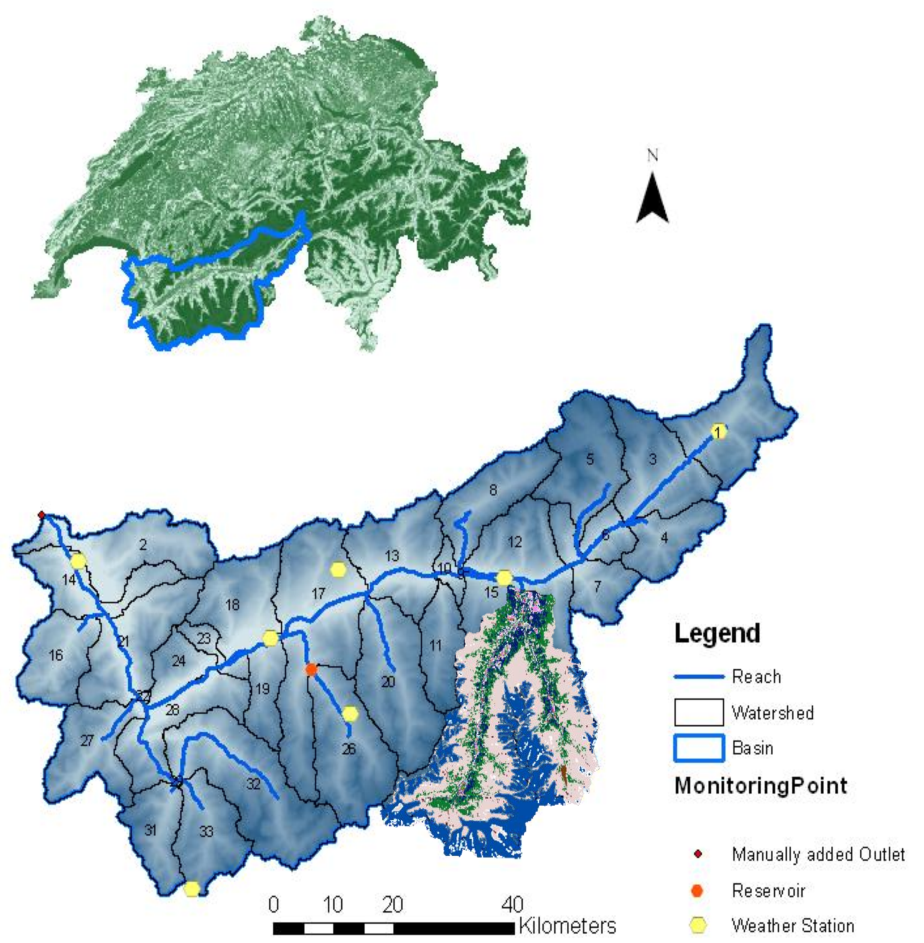
Complex physically-based distributed hydrological model requires detailed spatial and temporal datasets for better predictive model performance. Anthropogenic influence like hydropower installations makes modeling more challenging unless all the standard operation plans (SOP) is not given to the modeler.

Aims and Objectives

To develop a synthetic discharge dataset from hydropower stations based on available environmental variables

More specifically

- Reproduce discharge using hydrological model
- Forecast future water availability and related consequences using SWAT model.



Study area

- overall watershed area for upper Rhone 5000 Km^2
- area under consideration as Vispa valley 779 Km^2
- reservoir surface area (Mattmark) 1.76 Km^2
- net area where natural flow occurs 230 Km^2

18 percent of the land cover are glaciers and a major part of water is diverted to instantaneous basin through pumps for hydropower production.

Data used and sources

Data type	Data Source
Digital Elevation Model (DEM)	Swisstopo (grid cell: 25 m · 25 m) www.swisstopo.ch
Land use/cover	Swiss Federal Statistical Office (grid cell: 100 m · 100 m) http://www.bfs.admin.ch
Soil type	Swisstopo, soil potential map (vector data at 1:500'000 scale) www.swisstopo.ch
River & channel network	Swisstopo (vector data at 1:25'000 scale) www.swisstopo.ch
Hydrometeorlogic data (Precipitation, Temperature, Solar radiation, Wind speed , Relative humidity)	MeteoSwiss (weather station data) http://www.meteosuisse.admin.ch
River flows	Swiss Federal office for the environment (FOEN) http://www.hydrodaten.admin.ch/e/index.htm?lang=en

Methodology

Reservoir pre- and post- conditions were considered. At first stage, model was developed and calibrated based on historic climate and discharge data. Information obtained from this model was mostly which sub basin receive what amount of water. Later this information was implemented to transfer water from one sub basin to another. The snow melt algorithm for this study was considered as a linear function of the difference between the average snow pack-maximum air temperature and the base or threshold temperature for snow melt.

$$SNO_{mlt} = b_{mlt} \cdot sno_{cov} \cdot \left[\frac{T_{snow} + T_{mx}}{2} - T_{mlt}\right]$$

Where,

SNO_{mlt} = amount of snow melt on a given day (mm H_2O)
sno_{cov} = fraction of HRU area covered by snow
b_{mlt} = melt factor for the day (mm H_2O/day-^oC)
T_{snow} = snow pack temperature on a given day (^oC)
T_{mx} = maximum air temperature on a given day (^oC)
T_{mlt} = base temperature above which snow melt is allowed (^oC)

The melt factor is allowed to seasonal variation with maximum and minimum values occurring on summer and winter solstices

Model work

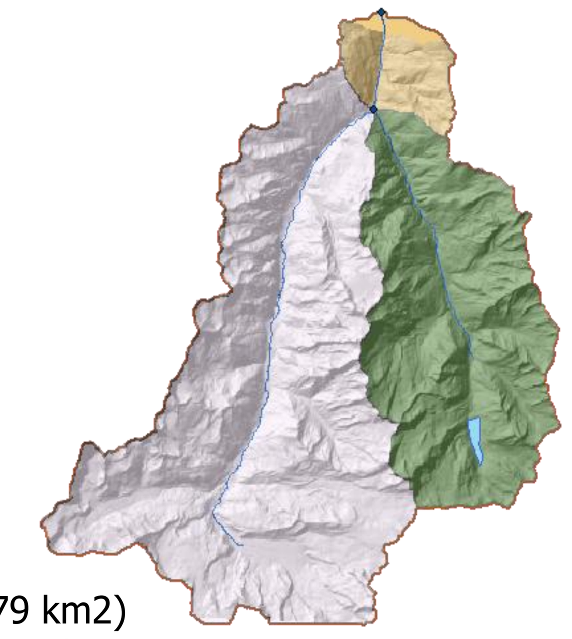
Model Interface: ArcSWAT 2009
Total year of study: 1997-2009
Warm up Period: 1997-2000
Calibration Period: 2001-2006
Validation Period: 2007-2009

Time step

Monthly Average
Daily Average

Model evaluation

Visually (graph fitting)
Statistically

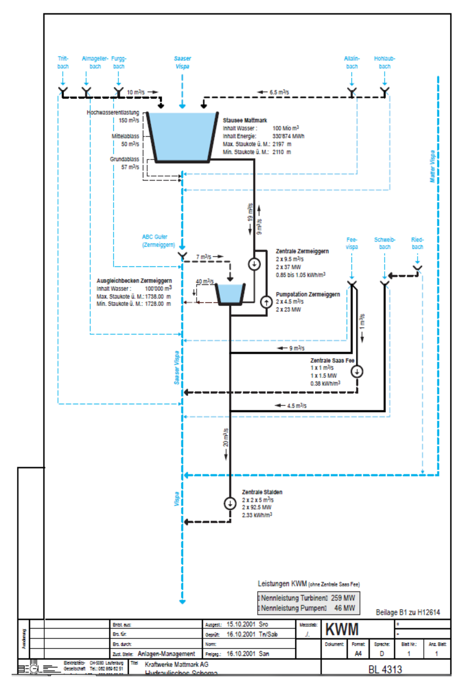


Effective area calculation

A1=Overall watershed area (779 km2)
A2=Net area responsible for providing water for Vispa
A3= Effective area
[A2/A3]=[519/230] i.e A3=0.412*A2

Disturbance of natural flow through pumping using pipe network

Soil sample were taken from field in order to calibrate soil parameters



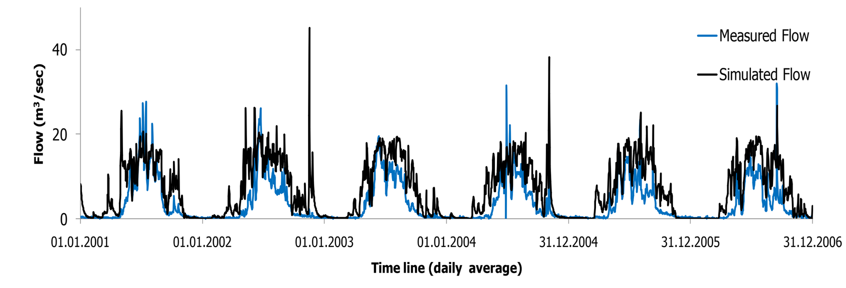
Hydropower Scheme KW Mattmark

Optimized parameter

Parameter	Description	Range	Optimized value
SFTMP	Snowfall temperature [◦C]	−5,+5	1.221
SNOEB	Initial snow water content [mm]	0, 300	150
SMTMP	Snow melt base temperature [◦C]	−5,+5	2.823
TIMP	Snow pack temperature lag factor [–]	0, 1	0.032
SMFMN	Melt factor for snow on December 21st [mm H2O/◦C day]	0, 10	4.825
SMFMX	Melt factor for snow on June 21st [mm H2O/◦C day]	0, 10	3.319
SNOCOVMX	Minimum snow water content that corresponds to 100% snow cover [mm]	0, 500	300

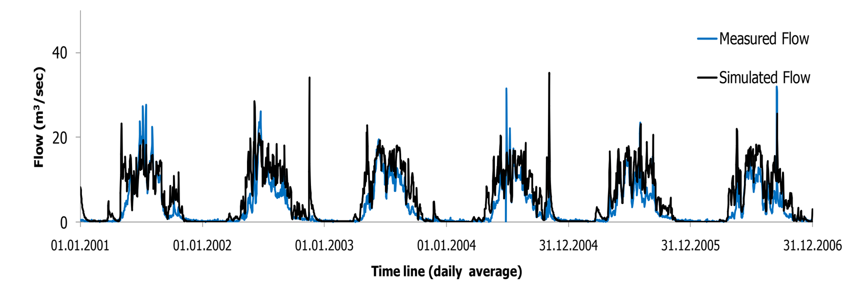
Results

Simulated flow plotted against measured flow for the calibrated period. Model performance evaluated using Nash and Sutcliffe Efficiency (NSE)

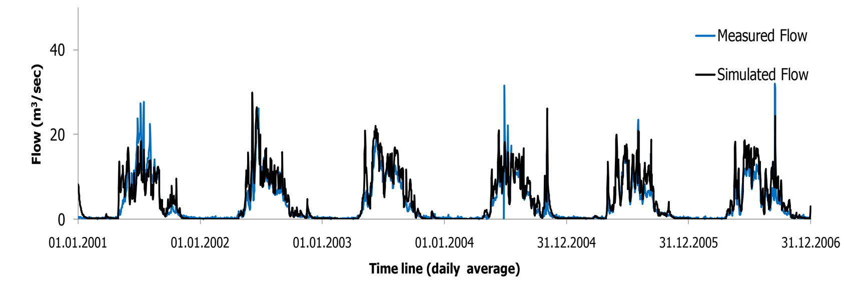


Discussion

First simulation with systematic overestimation and influence of additional peaks by the simulated flow. NSE obtained -0.08



Simulation after parameter optimization and estimated water transaction based on environmental signals. NSE obtained 0.49



Final simulation with real discharge data from the hydropower release. Additional peaks no longer appear NSE obtained 0.76

Conclusion

Sound agreement was obtained between observed and simulated discharge with hydrological model. Methodology is valid only if historical data are available for considering pre- and post- reservoir operation. Parameter sensitivity plays an important role for higher model efficiency.

Future work

- Implement climate driven scenarios
- Implement socio-environmental scenarios
- Implement energy driven scenarios

References

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Verbunt, A., Zwaaftink, M.G., Gurtz, J., 2005. The hydrologic impact of land cover changes and hydropower stations in the Alpine Rhine basin. Ecological Modelling, 187(1): 71-84

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