University of Stuttgart

EGU2020-21740

Modeling spatial snow-cover distribution using snow-melt models and MODIS images

Dhiraj Gyawali [1*] and András Bárdossy[1]

dhiraj.gyawali@iws.uni-stuttgart.de

ENWAT

EGU European Geosciences Union

Background

Reliable representations of spatial distribution of snow and subsequent snow-melt are critical challenges for hydrological estimations, given their crucial relevance in mountainous regimes especially because of the high sensitivity to climate change.

Rationale

Relatively accurate physically based models are data intensive while in-situ measurements of snow-depth are prone to be non-representative due to local influences. Likewise, lack of snow-depth information and to some extent, cloud cover in the mountains limit the usage of Remote-sensing images in snow estimation.

Highlight of the work

- **Flexible methodology** incorporating available remotely-sensed images (MODIS Snow-cover products[2]) to calibrate simple distributed snow-melt models
- **Time-continuous spatial snow extent** in snow dominated regions
- Final validated spatial snow-distribution data can be, as a **stand-alone input**, coupled with distributed hydrological models to **improve the model predictions**.
- **Simplicity and transferability** across different geographical domains with reasonable precipitation and temperature data

[1] Institute for Modelling Hydraulic and Environmental Systems (IWS)
University of Stuttgart, Germany

Inputs

Meteorology : daily precipitation, daily (max, min, mean) temperatures, daily solar radiation

Topography : DEM, aspect and landuse

Snow information for calibration: MODIS Aqua and Terra imageries

Data preprocessing

Temperature: Daily External drift Kriging (elevation as a drift)

Precipitaiton: Daily External drift Kriging (directionally smoothed elevation as a drift) [3]

Cloud removal from MODIS images [4]

Model 1: Simple degree-day model, $SM_{grd,\,day} = ddf * (Tavg_{grd,day} - T\_threshold)$

Model 2: Incorporates precipitation induced melt

$$SM_{grd,\,dry\_day} = ddf * (Tavg_{grd,day} - T\_threshold)$$

$$SM_{grd,\,wet\_day} = (ddf_{grd,\,dry} + ddf_{wet} * (PCP_{grd,day} - Pcp_{thres})) * (Tavg_{grd,day} - T_{melt})$$

Model 3: Modifies Model 2 with distributed snowfall temperature

$$T_{sf,\,grd} = T_{sf\text{-}min} + (T_{sf\text{-}max} - T_{sf\text{-}min}) * \cos(aspect_{grd})^{PF}$$

Model 4: Modifies Model 2 with radiation

$$SM_{grd,\,cloudfree\_day}) = ddf_{grd,\,dry} * (Tavg_{grd,day} - T_{melt}) + ddf_{wet} * (PCP_{grd,day} - Pcp_{thres}) + (1-alb) * r\_ind * diff\_rad_{grd,day}$$

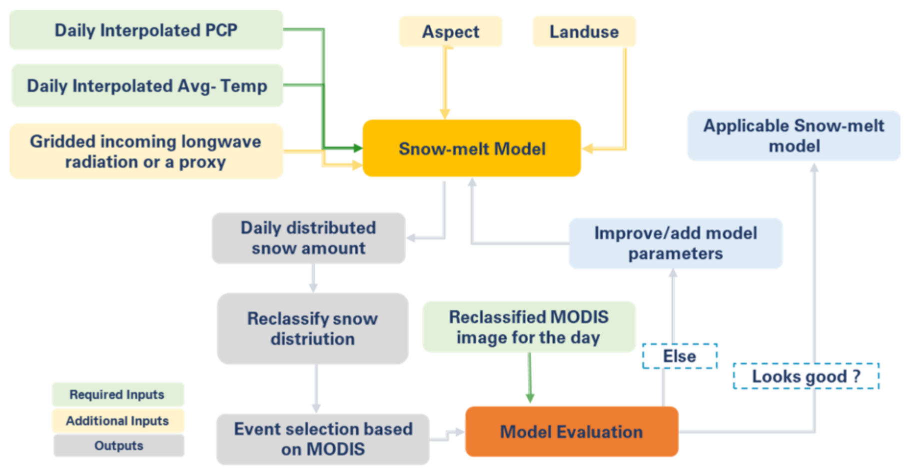
Model 5: Combines models 3 and 4

Daily snow balance:

$$SF_{grd\text{-}final,\,day} = SF_{grd,\,day} + SF_{grd,\,day-1} - SM_{grd,day}$$

where, Snow-melt (mm) is $SM_{grd} = \text{Max}(0, SM_{grd})$ when $T_{avg} > T_{threshold}$

Framework



Model Evaluation

1. Snow-detection threshold definition
   - If If $snow_{grd,\,model} >= sno\_th$, corresponding grid value= 1
   - $snow_{grd,\,model} < sno\_th$, corresponding grid value = 0
2. Reclass MODIS snow cover composite as:
   - *No Snow = 0, Snow (1-100) = 1*
3. Model Evaluation based on a Brier Score:

$$\mathbf{BS} = \frac{1}{N}\sum_{t=1}^{N}(f_t - O_t)^2$$, where, f_t = modeled output, o_t = observed values

4. Evaluation of outputs based on HBV flow simulation

EGU2020-21740

Modeling spatial snow-cover distribution using snow-melt models and MODIS images

University of Stuttgart
Dhiraj Gyawali [1*] and András Bárdossy[1]
dhiraj.gyawali@iws.uni-stuttgart.de

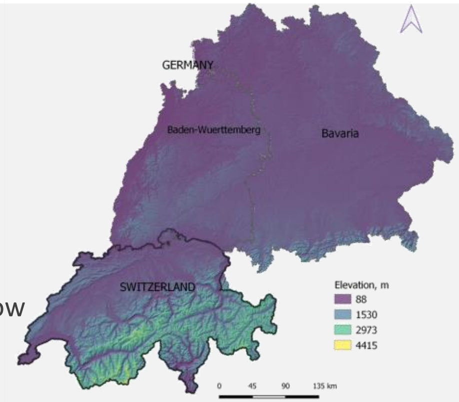
Study Area

a. Baden-Wuerttemberg and Bavaria in Germany :

characterized by intermittent snow

b. Switzerland:

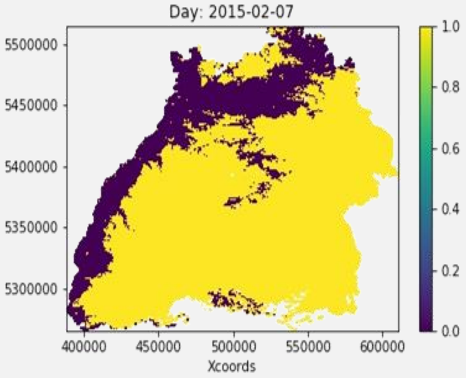
characterized by partly long duration snow



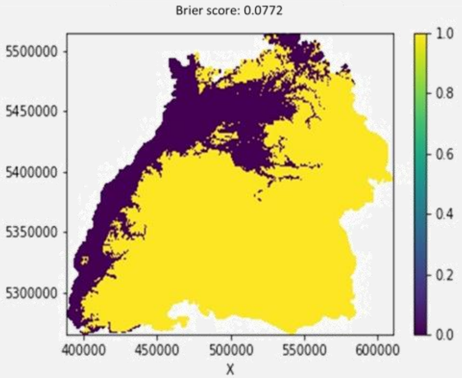
Results

Comparison of simulated snow distribution with MODIS

Baden-Wuerttemberg



MODIS

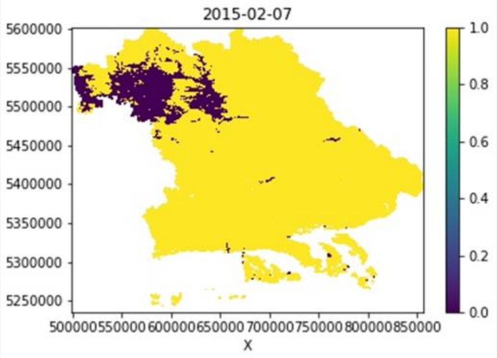


Model 4

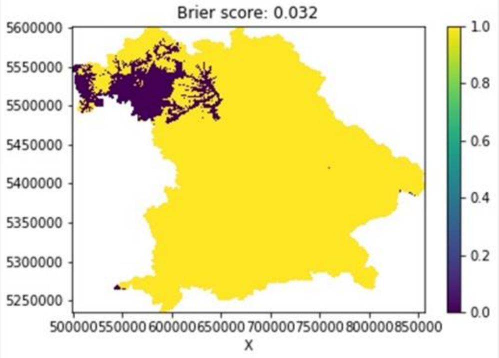
Simulated

Results

Bavaria

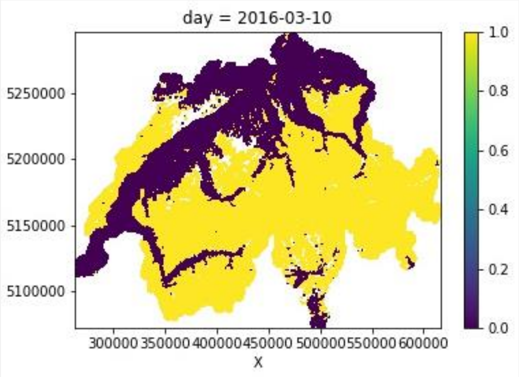


MODIS

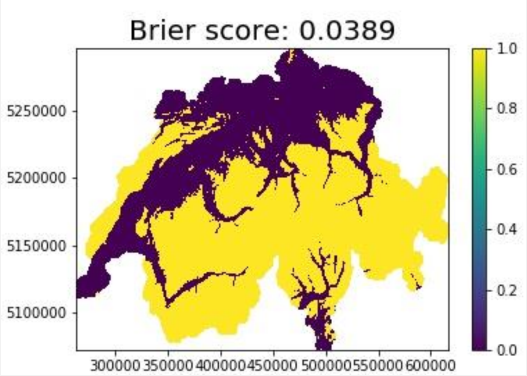


Simulated

Switzerland



MODIS



Simulated

University of Stuttgart

EGU2020-21740

Modeling spatial snow-cover distribution using snow-melt models and MODIS images

Dhiraj Gyawali [1*] and András Bárdossy[1]

dhiraj.gyawali@iws.uni-stuttgart.de

ENWAT

EGU European Geosciences Union

Results

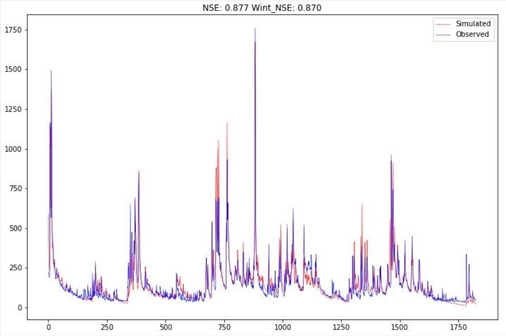
Performance evaluation of the snow-model outputs in HBV

a. **Basic HBV** model with snow component is used as a reference

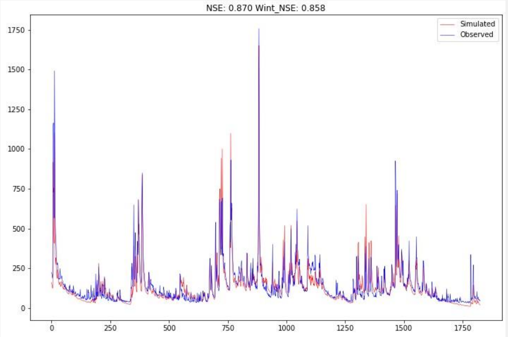
b. Melt water outputs are fed into a HBV module without the snow-component (henceforth referred as '**Liquid HBV**') to compare the impacts on the resulting flows

c. Nash-Sutcliffe efficiencies (NSE) for the whole time series as well as Winter period are evaluated.

Neckar catchment in Baden-Wuerttemberg



'Liquid' HBV

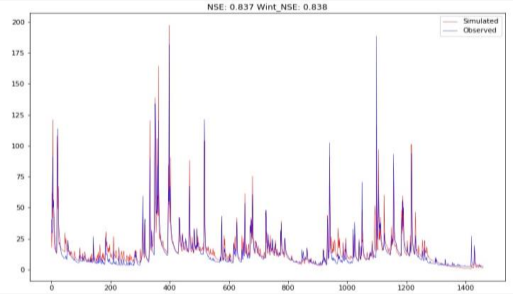


Basic HBV

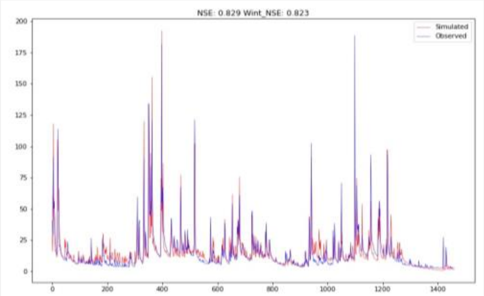
Models	NSE	Winter NSE
Basic HBV	0.870	0.858
Liquid HBV	0.877	0.870

Observed Flows, cumecs
Simulated Flows, cumecs

Horb catchment in Baden-Wuerttemberg



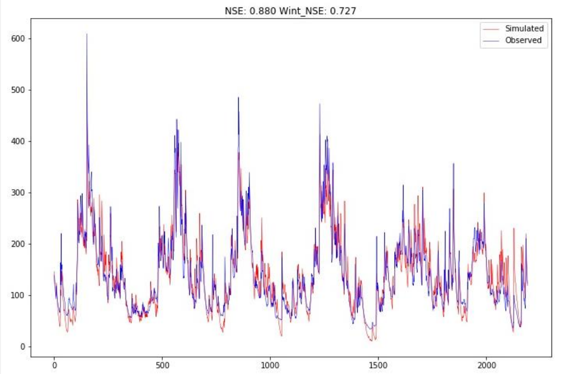
'Liquid' HBV



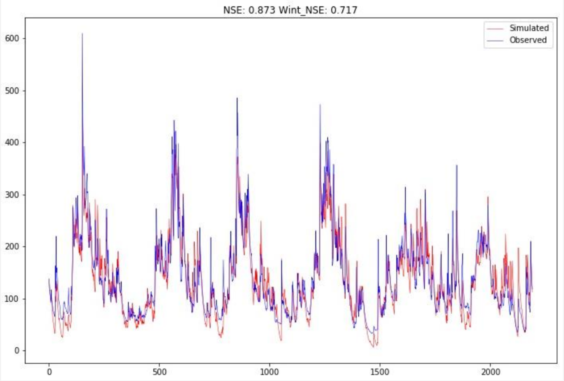
Basic HBV

Models	NSE	Winter NSE
Basic HBV	0.829	0.823
Liquid HBV	**0.837**	**0.838**

Reuss catchment in Switzerland



'Liquid' HBV



Basic HBV

Models	NSE	Winter NSE
Basic HBV	0.873	0.717
Liquid HBV	**0.880**	**0.727**

University of Stuttgart

EGU2020-21740

Modeling spatial snow-cover distribution using snow-melt models and MODIS images

Dhiraj Gyawali [1*] and András Bárdossy[1]

dhiraj.gyawali@iws.uni-stuttgart.de

ENWAT

EGU European Geosciences Union

Concluding remarks

- Results suggest good agreement with MODIS data and the parameters show relative stability across the time domain at the same sites and are transferrable to other regions
- Calibration using readily available images used in this method offers adequate flexibility, albeit the simplicity, to calibrate snow distribution in mountainous areas across a wide geographical extent with reasonably accurate precipitation and temperature data.
- Improvement in HBV model performance is also observed.

LHG ENWAT

University of Stuttgart

CC BY

References:

2 Hall, D. K., G. A. Riggs, and V. V. Salomonson. 2006. MODIS/Terra Snow Cover 5-Min L2 Swath 500m. Version 5. Boulder, Colorado USA: NASA National Snow and Ice Data Center Distributed Active Archive Center. http://dx.doi.org/10.5067/ACYTYZB9BEOS.

3 Bárdossy, A. and Pegram, G..2013. Interpolation of precipitation under topographic influence at different time scales, Water Resources Research, Vol. 49, 4545–4565, doi:10.1002/wrcr.20307, 2013

4 Gafurov, A. and Bárdossy, A. 2009. Cloud removal methodology from MODIS snow cover product, Hydrol. Earth Syst. Sci., 13, 1361–1373, https://doi.org/10.5194/hess-13-1361-2009, 2009.