Applications of spatial climate datasets in hydrology

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Spatial Climate Analyses for Switzerland

Workshop on MeteoSwiss grid data products and their use in practice

ETH Data Contact Point for MeteoSwiss

- Gridded Datasets
  - RhiresD, TabsD, TminD, TmaxD, SrelD, SISD (daily, monthly, annual)
  - Hourly incoming SW radiation SIS

- To-date 37 registered users for research at ETH (since July 2013)

- Typical applications:
  - input into earth system models
  - calibration/validation of models
  - weather generators and disaggregation of climate data
  - data analysis for many purposes

Use of gridded datasets in hydrology

- Advantages:
  - High spatial (km) and temporal (daily/hourly) resolutions
  - Long time series (1960s to today)
  - Convenient data structure (easy to use)

- Examples of case studies:
  - Snow cover distribution modelling in Switzerland
  - Disaggregation of climatic variables in complex topography
  - Forcing of hydrological models
  - Climate as a predictor for geomorphic processes

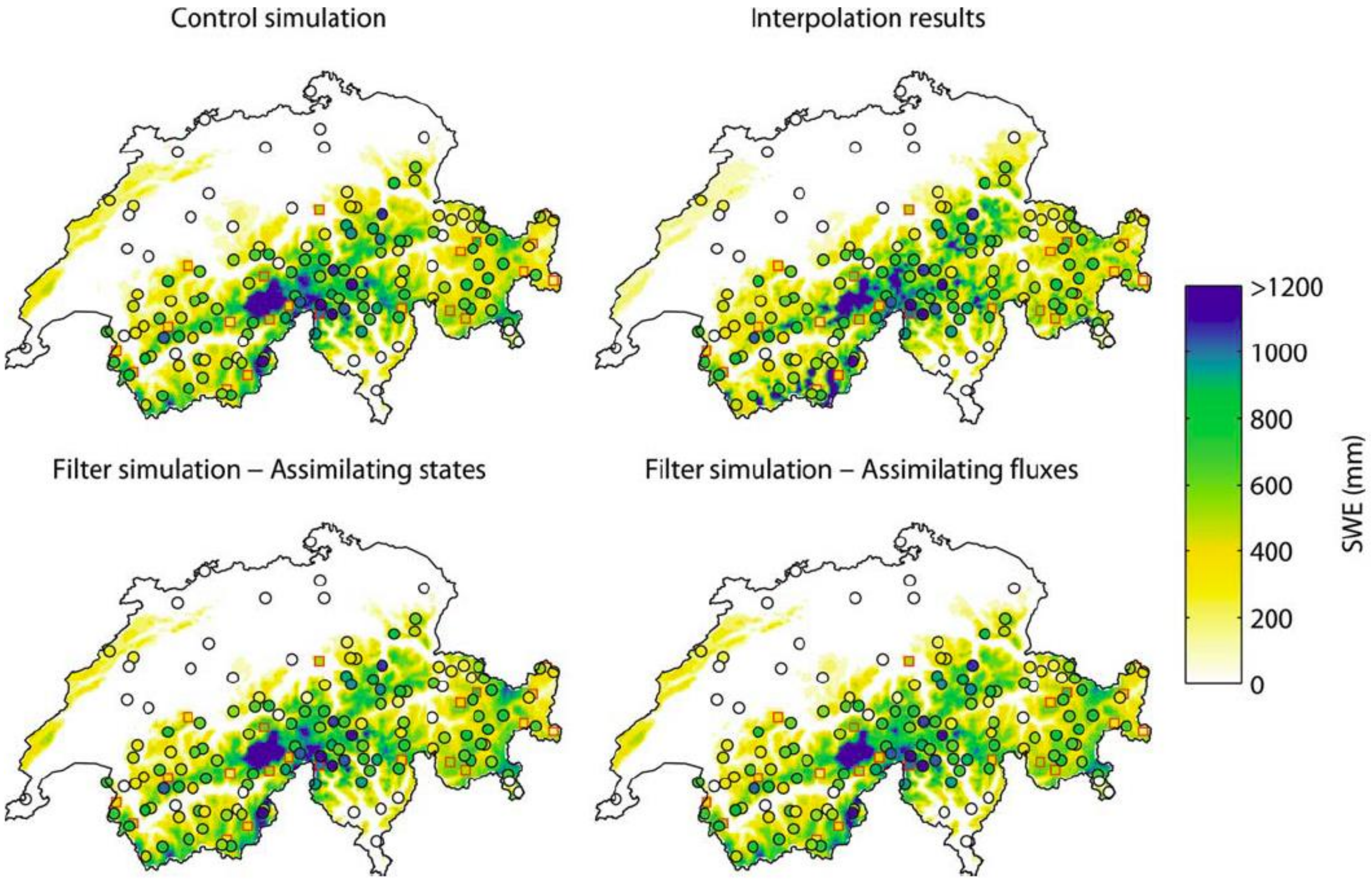
1. Snow cover modelling in Switzerland

Magnusson et al. (2014)

- Q: Does assimilation of point snow data improve predictions of snow cover dynamics?

- RhiresD and TabsD were used to calibrate a degree-day snowmelt model

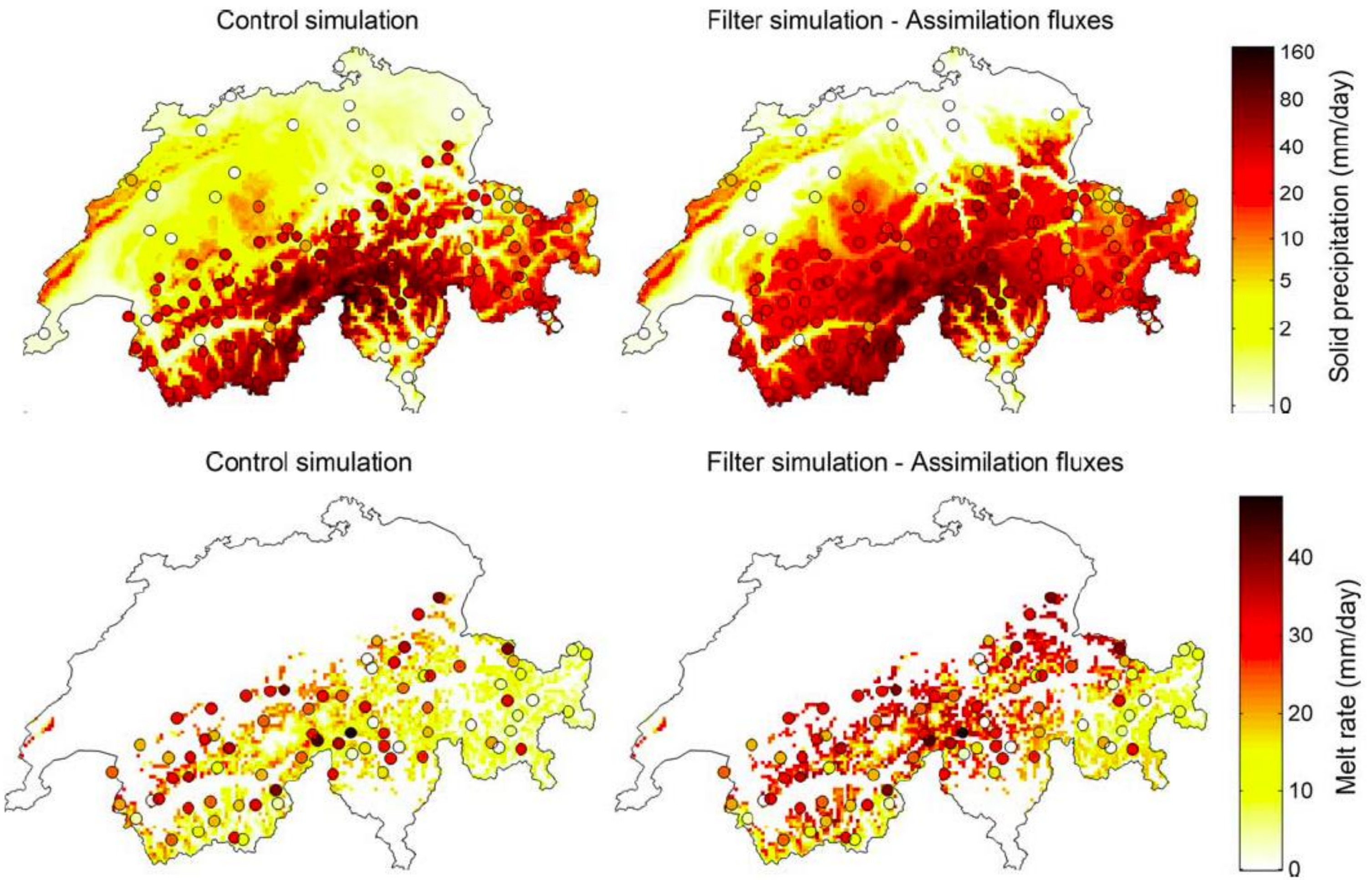
$$M = k(T - T^*)$$



1. Snow cover modelling in Switzerland

Magnusson et al. (2014)

- Spatially-distributed daily snowfall estimates (solid precipitation)
- Spatially-distributed estimates of daily snowmelt rates



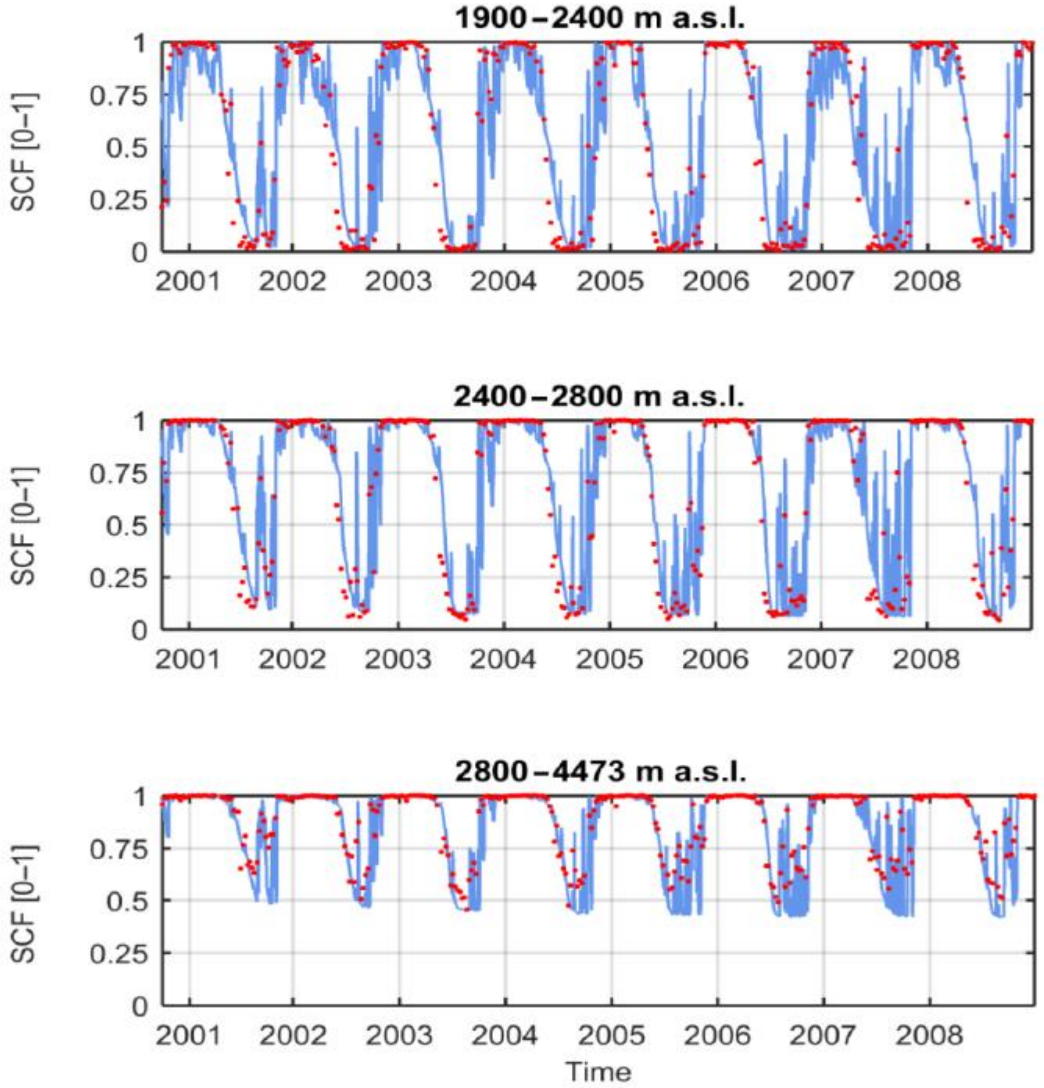
Magnusson, J., D. Gustafsson, F. Huesler, and T. Jonas (2014), Assimilation of point SWE data into a distributed snow cover model comparing two contrasting methods, *Water Resour. Res.*, 50, 7816–7835, doi:10.1002/2014WR015302.

1. Snow cover modelling in Switzerland

Costa et al. (2018)

- Q: What is the elevation dependence of snowmelt rates at a catchment scale (Rhone)

- A degree-day snowmelt model driven by RhiresD and TabsD calibrated with MODIS satellite data.



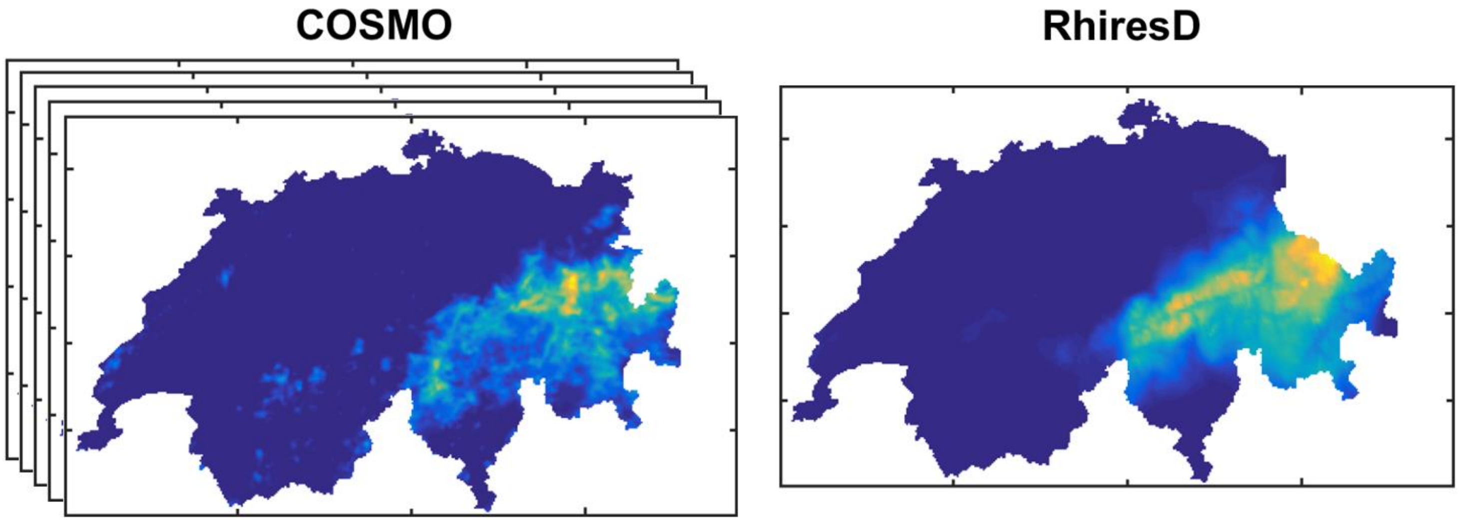
Costa, A., Molnar, P., Stutenbecker, L., Bakker, M., Silva, T. A., Schlunegger, F., Lane, S. N., Loizeau, J.-L., and Girardclos, S. (2018), Temperature signal in suspended sediment export from an Alpine catchment, *Hydrol. Earth Syst. Sci.*, 22, 509-528, https://doi.org/10.5194/hess-22-509-2018.

2. Disaggregation using gridded data

- Q: Can a higher spatial and temporal resolution be achieved by combining daily gridded data with other station/radar/NWP datasets?

- RhiresD+NWP (COSMO)
- RhiresD+stations (hourly)

- **CombiPrecip**
- **Ensemble RhiresD**

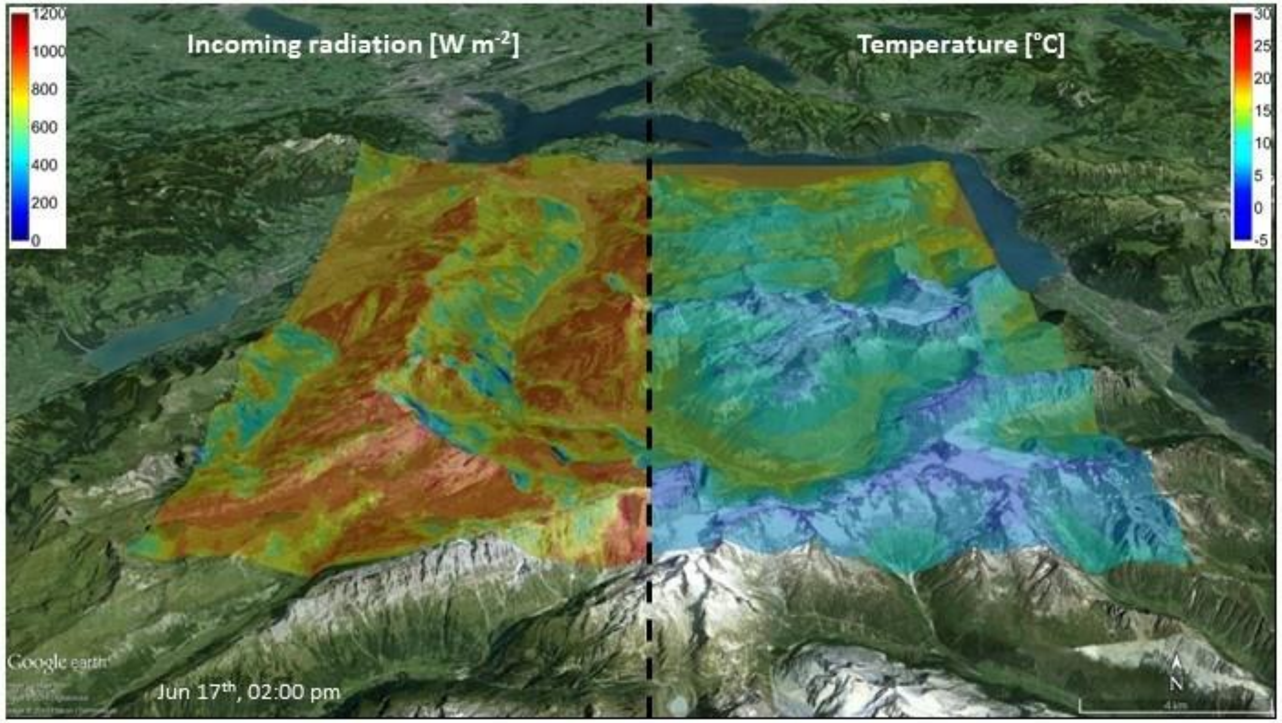


provided by T. Jonas (2018)

2. Disaggregation using weather generators

Peleg et al. (2017)

- Q: Can gridded data be used for the calibration of 2d stochastic weather generators which can be applied at very high spatial (100m) and temporal (mins) resolutions?



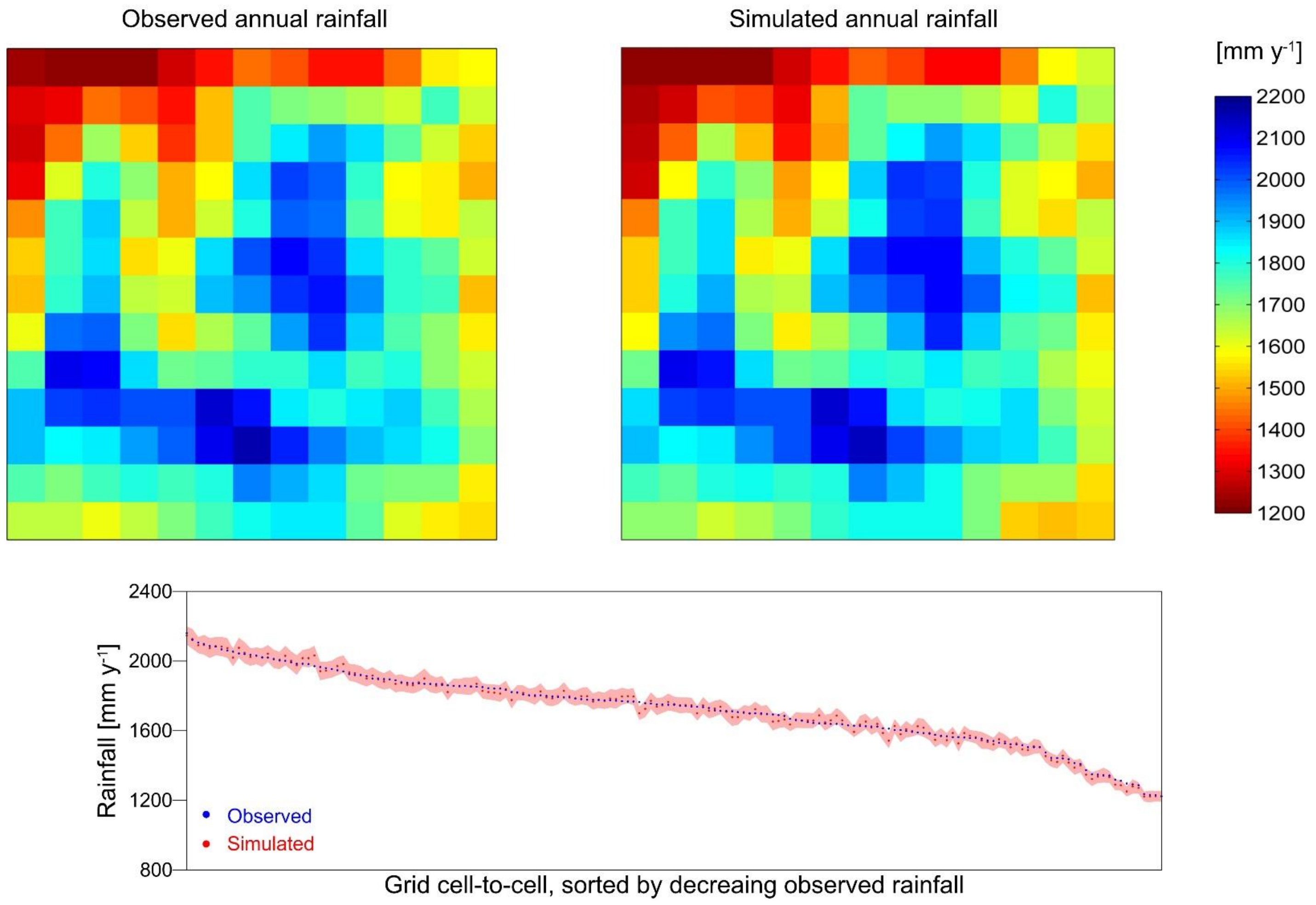
ENGELBERG VALLEY

Peleg, N., Fatichi, S., Paschalis, A., Molnar, P., and Burlando, P. (2017), An advanced stochastic weather generator for simulating 2-d high resolution climate variables, *J. Adv. Model Earth Syst.*, 9, doi:10.1002/2016MS000854.

2. Disaggregation using weather generators: precipitation

- Stochastic model for high resolution space-time rainfall fields is calibrated to reproduce coarser daily rainfall sums (RhiresD)

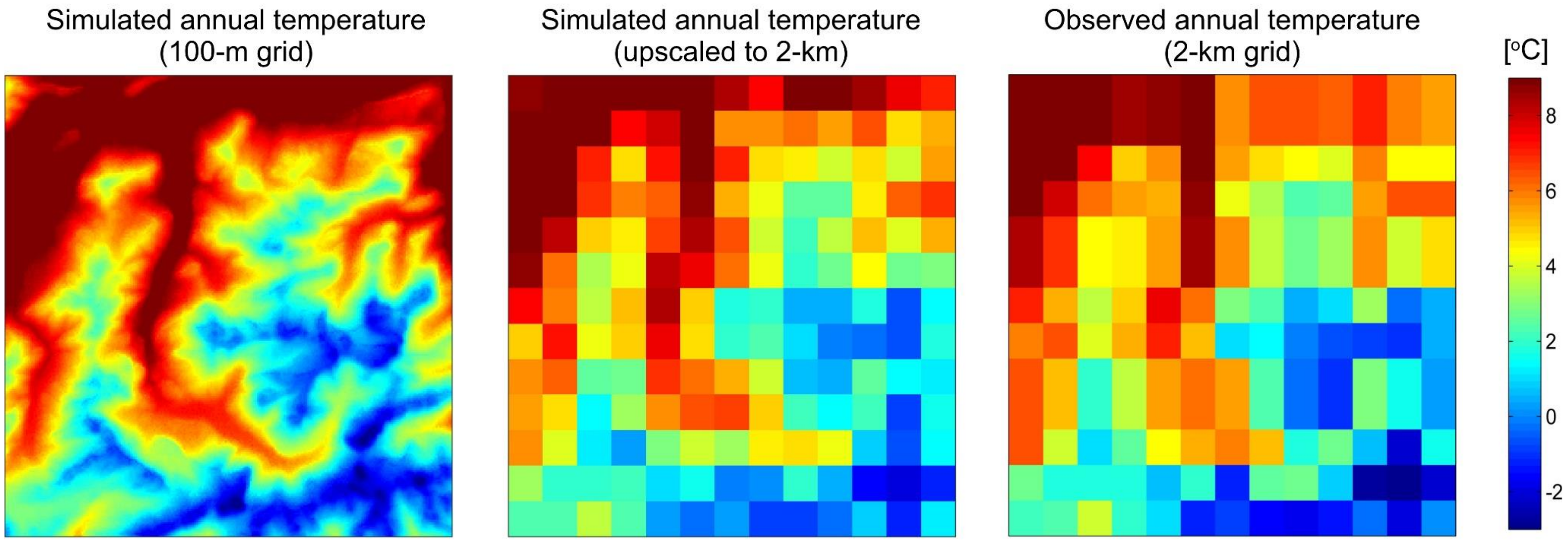
- STREAP storm structure derived from weather radar



Peleg et al. (2017)

2. Disaggregation using weather generators: air temperature

- Stochastic model for high resolution air temperature fields with elevation-dependence is calibrated to reproduce coarser daily temperature (TabsD)

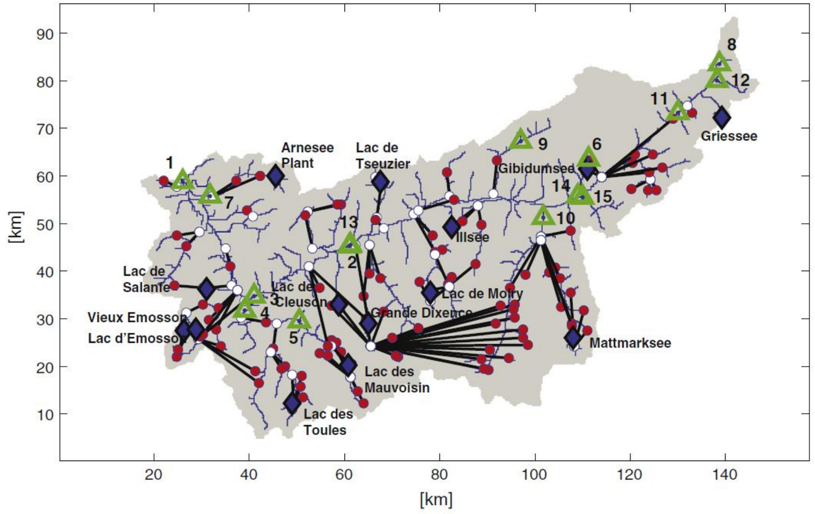


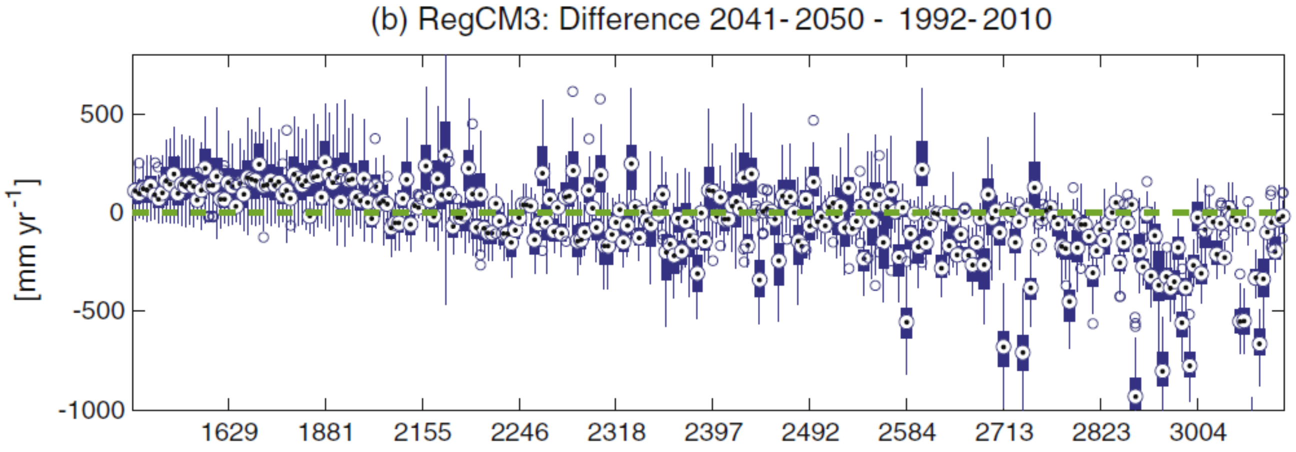
Peleg et al. (2017)

3. Forcing of hydrological models

Fatichi et al. (2015)

- Disaggregated climate (RhiresD) to hourly resolutions is key for physically-based hydrological modelling of complex watersheds (incl. anthropogenic impacts and climate change), Rhone Basin





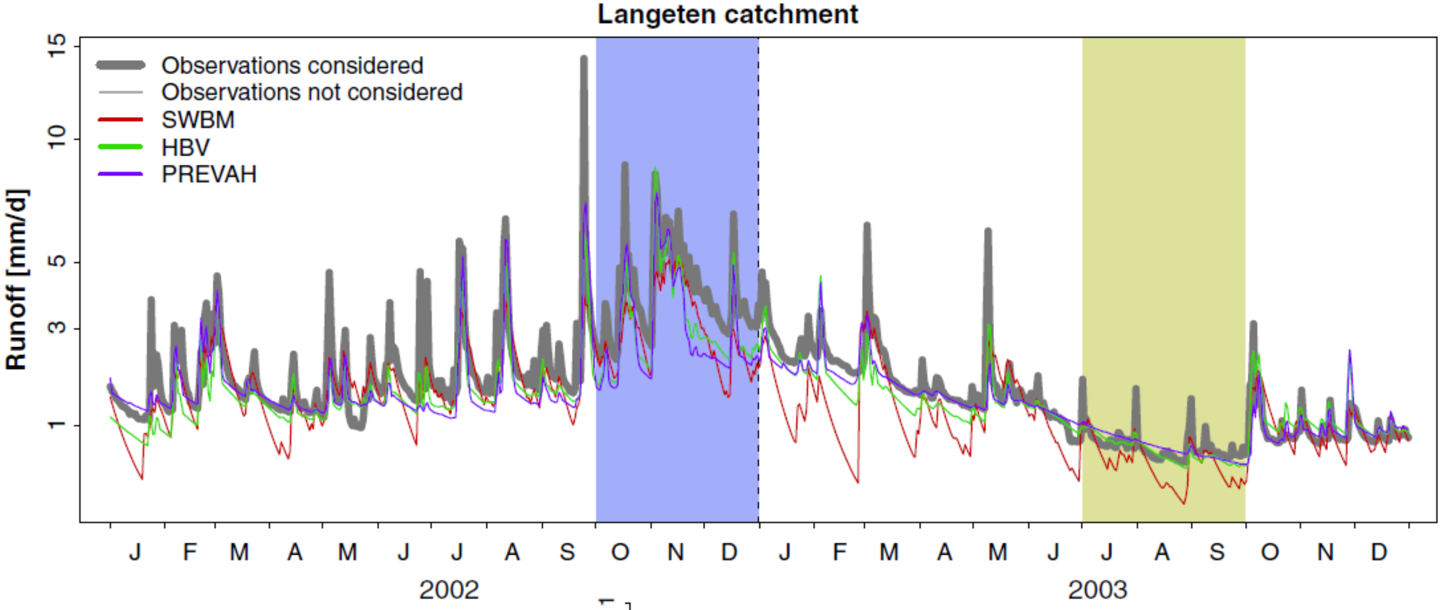
Fatichi, S., Rimkus, S., Burlando, P., Bordoy, R., and Molnar, P. (2015), Elevation dependence of climate change impacts on water resources in an Alpine catchment, *J. Hydrol.*, 525, 362-382, doi:10.1016/j.jhydrol.2015.03.036.

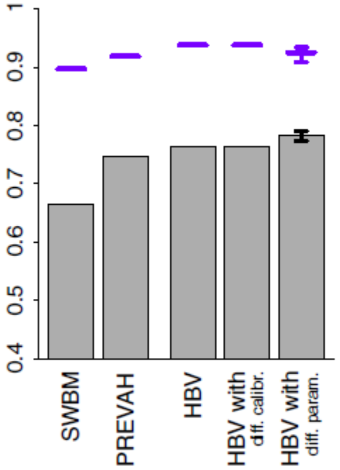
3. Forcing of hydrological models

- Q: What is the advantage of using the MeteoSwiss gridded products to force hydrological models?

- consistent spatial distribution
- allows comparison of models

Orth, R., Staudinger, M., Seneviratne, S.I., Seibert,J., and M. Zappa (2015), Does model performance improve with complexity? A case study with three hydrological models, *J. Hydrology*, 523, 147-159, doi:10.1016/j.jhydrol.2015.01.044.





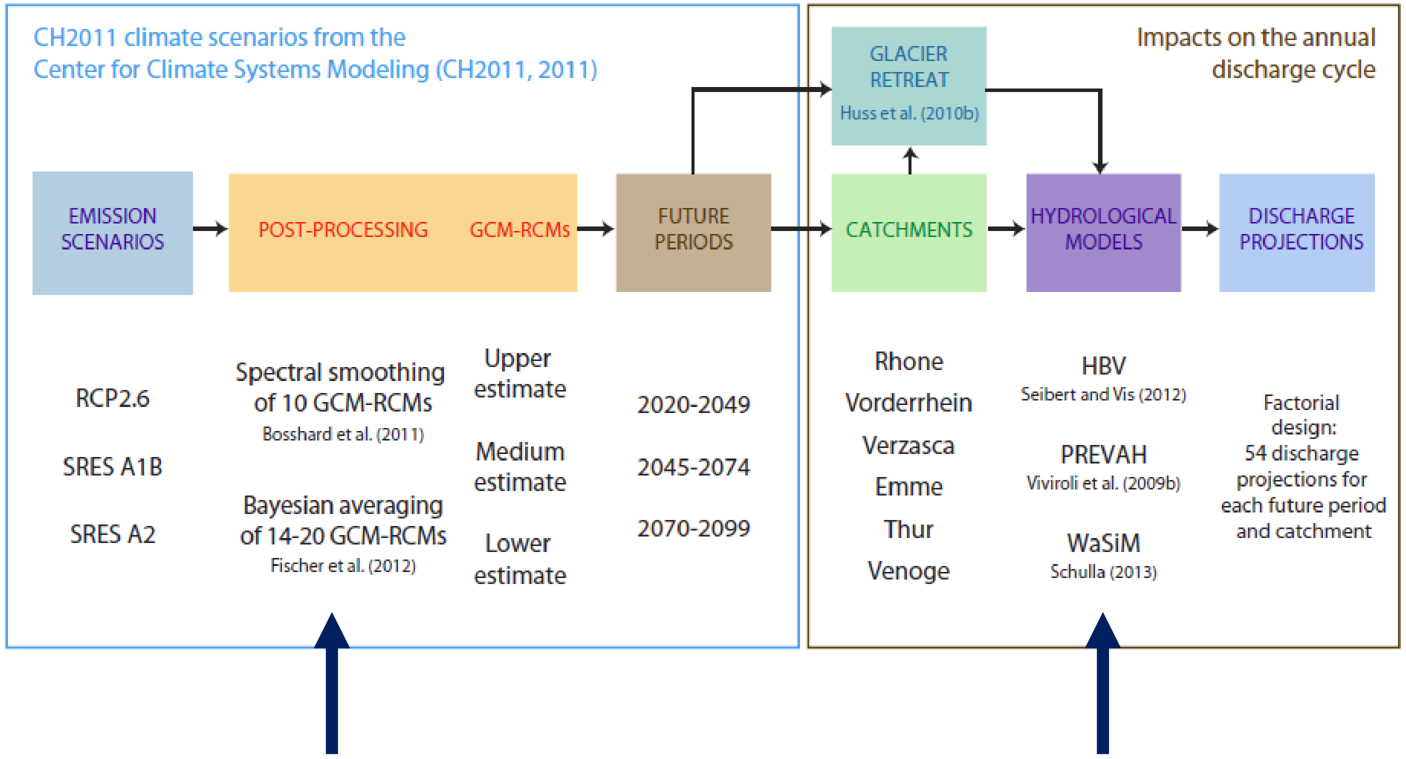
Orth et al. (2014)

3. Forcing of hydrological models in CC impact studies

Addor et al. (2014)

- Q: Where are MeteoSwiss gridded data used in hydrological climate change impact studies ?

- future climate scenarios
- model calibration



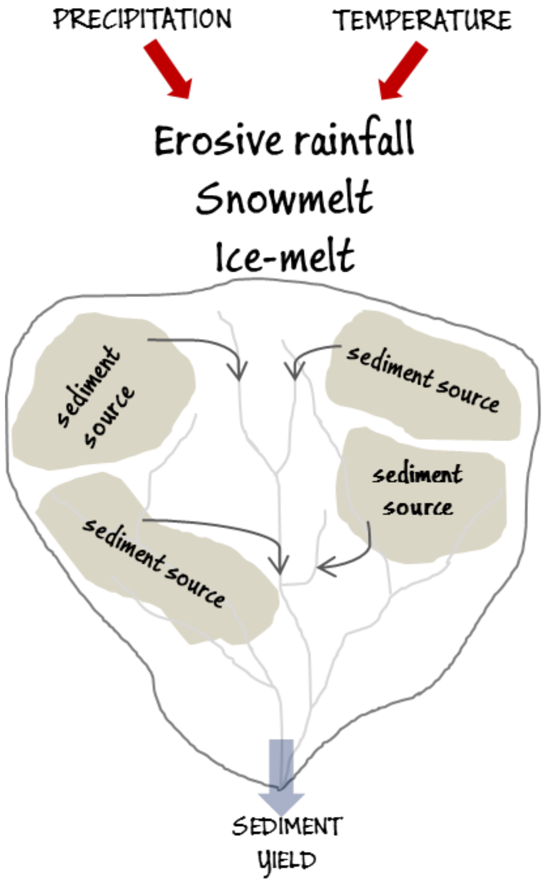
Addor, N., O. Roessler, N. Koeplin, M. Huss, R. Weingartner, and J. Seibert (2014), Robust changes and sources of uncertainty in the projected hydrological regimes of Swiss catchments, *Water Resour. Res.*, 50, 7541–7562, doi:10.1002/2014WR015549.

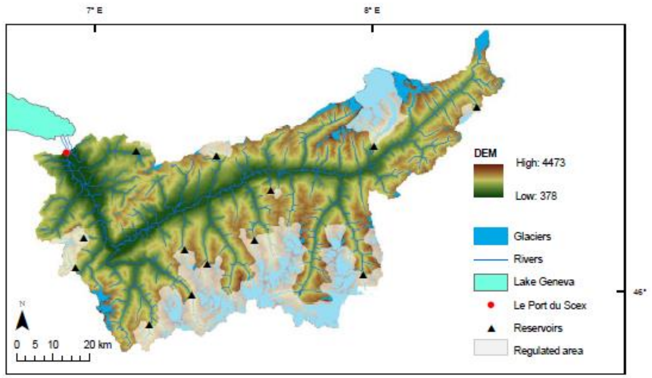
4. Climate and geomorphic processes: sediment sources

- Q: Can gridded climatic variables be used to identify the hydroclimatic forcing of fine sediment sources?

- RhiresD and TabsD used to estimate basin-wide erosive rainfall, snowmelt and icemelt and combined in a multivariate regression model with suspended sediment concentration (Porte du Scex)

$$SSC = a_1 ER^{b_1} + a_2 SM^{b_2} + a_3 IM^{b_3} + a_4 HP^{b_4}$$

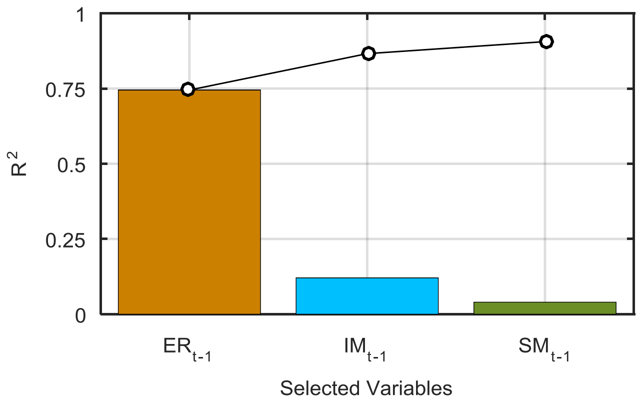




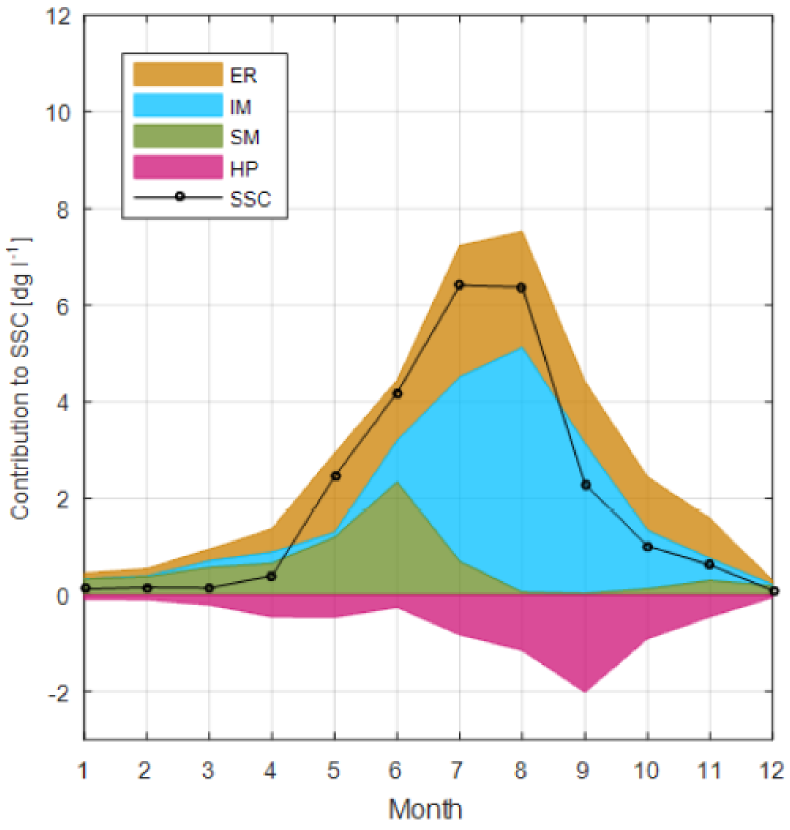
Costa et al. (2018)

4. Climate and geomorphic processes: sediment sources

- Hydroclimatic triggering of suspended sediment load can be quantified
- Erosive rainfall predicts variability in SSC, glacially eroded sediment is most important for total SS load



Costa et al. (2018)

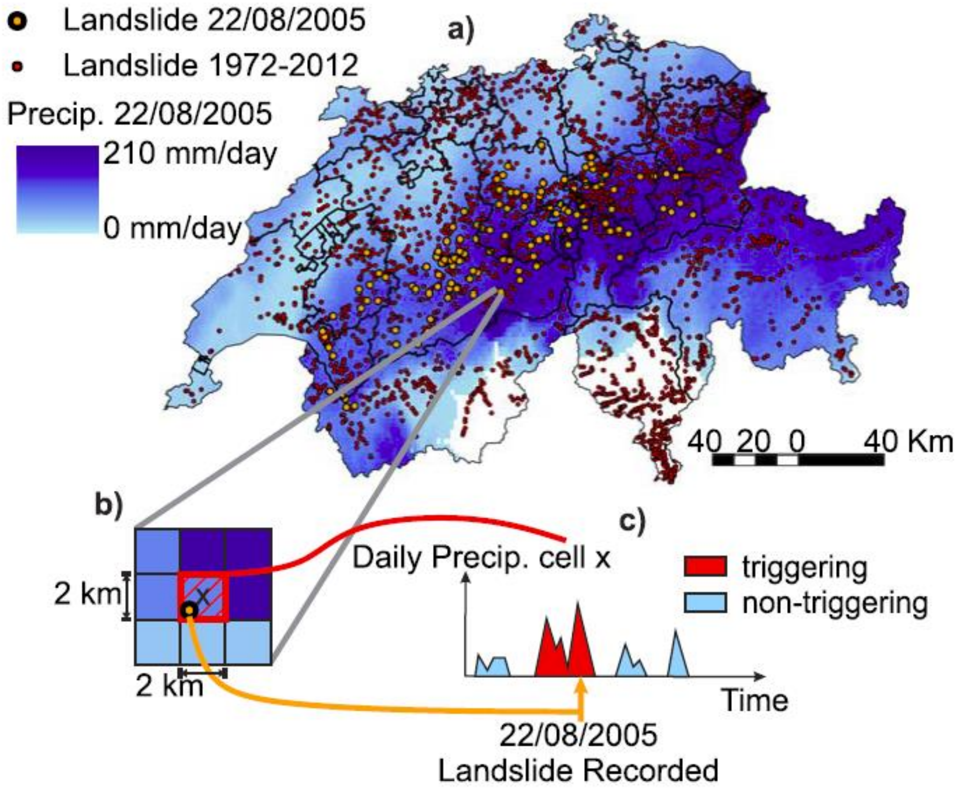


Costa, A., Anghileri, D., and Molnar, P. (2018), Hydroclimatic control on suspended sediment dynamics of a regulated Alpine catchment: a conceptual approach, *Hydrol. Earth Syst. Sci.*, 22, 3421-3434, https://doi.org/10.5194/hess-22-3421-2018.

4. Climate and geomorphic processes: landslides

- Q: Can landslide occurrence in Switzerland be predicted from daily gridded rainfall?
- How much rain is needed to have landslides?
- RhiresD was used to derive storm events and combined with the WSL landslide damage database (2300 events), 1972-2012

Leonarduzzi et al. (2017)

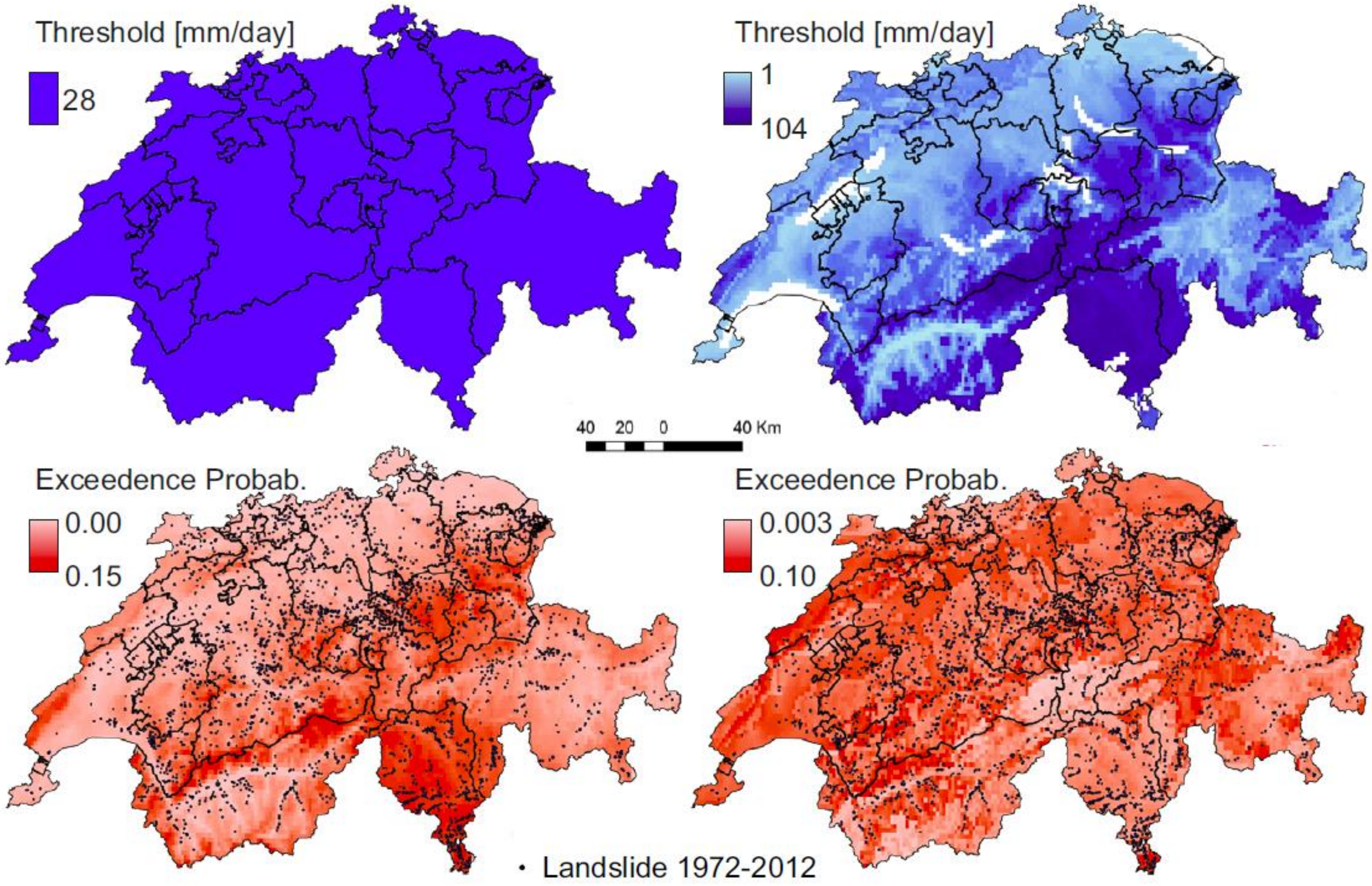


4. Climate and geomorphic processes: landslides

Leonarduzzi et al. (2017)

- Daily rainfall threshold amounts were objectively defined for Switzerland

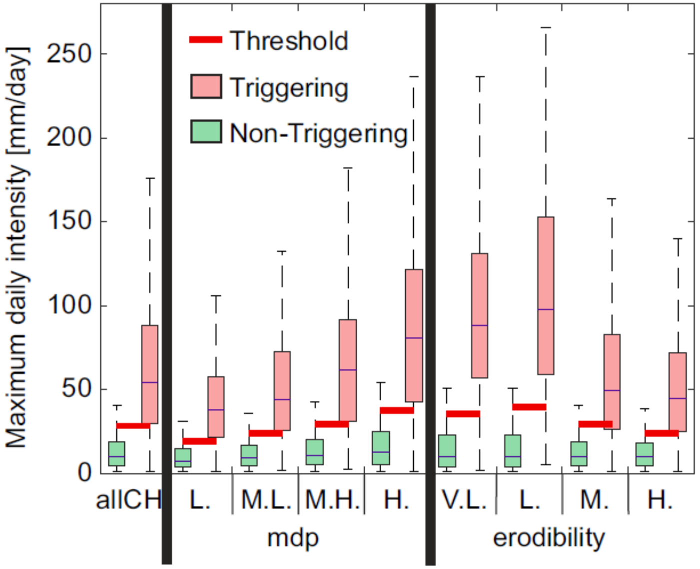
- Additional factors are local susceptibility (soil erodibility, vegetation cover, slope, etc.)

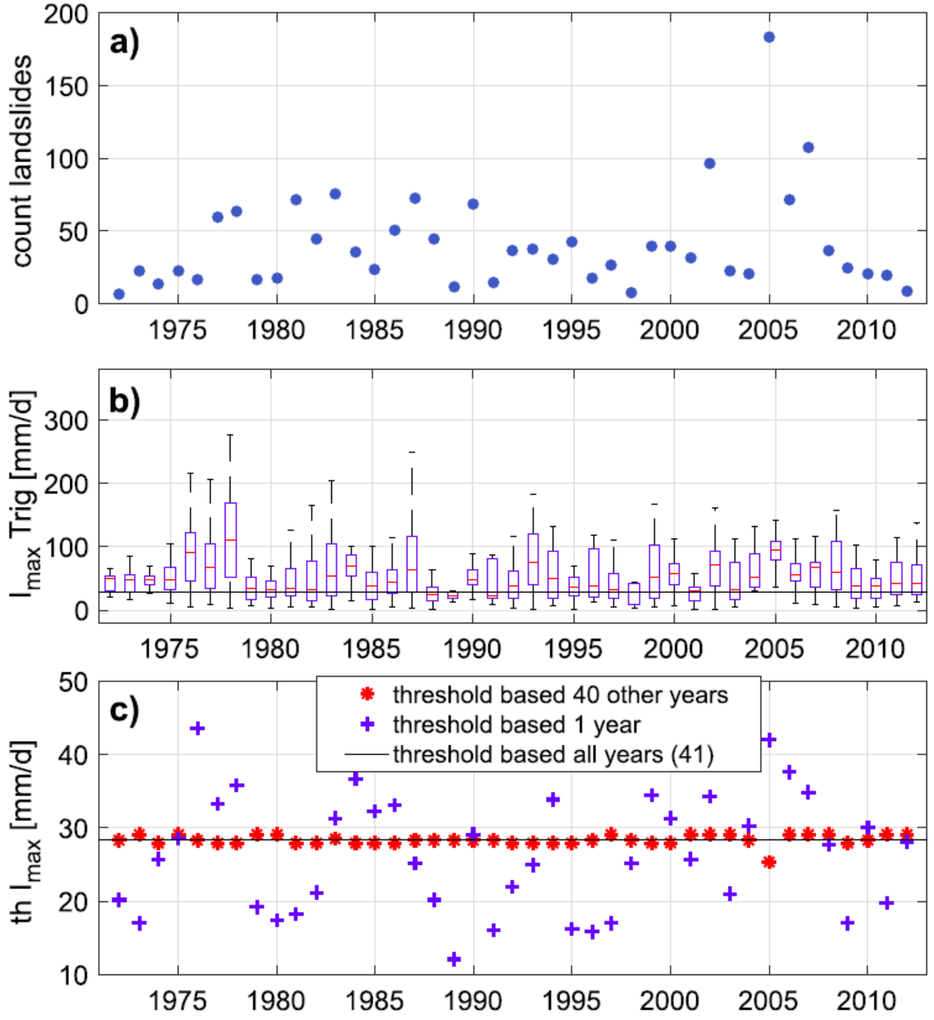


4. Climate and geomorphic processes: landslides

Leonarduzzi et al. (2017)

- Soil erodibility is a significant predictive factor
- Individual years with large events (storms) are important for the threshold assessment





Leonarduzzi, E., P. Molnar, and B. W. McArdell (2017), Predictive performance of rainfall thresholds for shallow landslides in Switzerland from gridded daily data, *Water Resour. Res.*, 53, doi:10.1002/2017WR021044.

Messages from the hydrological applications

- Hydrological processes have **high spatial variability**
  - spatially distributed climatic variables are needed for their prediction
  - homogeneity in time is required for studies of change
  - consistency between precipitation and temperature is needed (snow)

- What are the **necessary resolutions** for hydrological studies
  - water balance studies at large catchment scales: km-day sufficient
  - event analyses: meter-min more suitable

- Quantifying **uncertainty in hydrological predictions** is key
  - ensembles needed to study inherent climate variability
  - provide uncertainty bounds on all estimates

Other potential applications

- Study of any elevation-dependent process (e.g. tree-line)
- Weather conditioning of biological processes (fauna and flora)
- Spatial patterns of species habitat/migration
- Tourism potential in Switzerland (summer/winter)
- Infrastructure management (roads/railways)

- Severity of historical droughts & heatwaves
- Solar radiation potential
- Wind potential (new dataset needed)
- Quantifying water resources/deficits (also urban scale)
- Natural hazards and warning systems (landslides, avalanches,…)

Thank you for your attention

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