Towards Decadal Hydro-Glaciological Forecasts for the Hydropower Sector

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Introduction

Hydropower and **water resources management** are an important issue in most countries of the world, included Switzerland. **Numerical models** are currently produced to understand climate with different tools and methods in order to simplify reality while reducing uncertainties [2]. After Fukushima accident in 2011, the **"Energy Strategy 2050"** has been developed. Many institutions are currently involved in studying how to shift towards a more sustainable energy production system. The relation between hydrology and glaciology has been studied and it's mainly due to the following **factors**: influence of glacier extent and glaciers and presence of lakes.

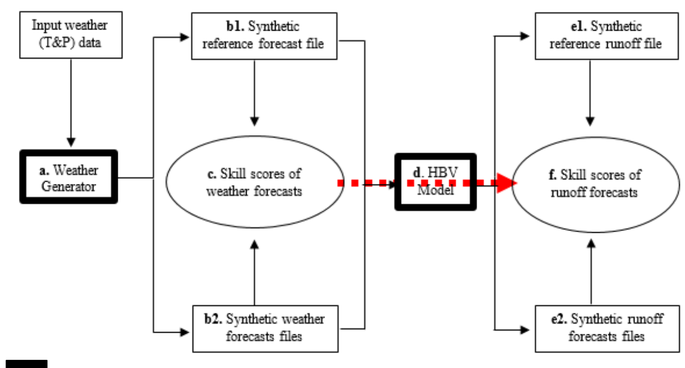
Objectives and purposes

This work is part of a larger project of forecasts accuracy assessment for the Swiss hydropower energy sector. A study of how accuracy transfers from meteorological forecasts to hydrological runoff has been performed [1] [3].

Three research questions have been answered:

1. *How can skill (or accuracy) transfer from meteorological to runoff forecasts be assessed?*
2. *How does a shrinking glacier influence skill transfer?*
3. *Which hydrological compartments do affect skill transfer the most and which are the main physical factors involved?*

Methodology



Skill Score name	Mathematical formula	Variability range
Root Mean Square Error (RMSE)	$\sqrt{\frac{1}{N}\sum_i^t (f_i - o_i)^2}$	0 (best score) < RMSE < ∞ (worst score)
Reduction of Variance (RV)	$1 - \frac{\frac{1}{N}\sum (f_i - o_i)^2}{var_r^2}$	-∞ (worst score) < RV < 1 (best score)
Correlation Coefficient (CC)	$\frac{\frac{1}{N}\sum_i^N (f_i - \bar{f}) * (o_i - \bar{o})}{sd_f * sd_o}$	-1 (worst score) < CC < 1 (best score)

B

Figure 1 - (A) Description of the project methodology and all its most important procedural steps; (B) Skill scores used for the quantification of decadal forecasts. Skill scores are calculated between the forecast (f) and the observed values of the reference (o) time-series at a daily temporal range for each lead time. "Var" indicates the variance and "sd" the standard deviation. "N" relates to the total number of lead times.

Study sites

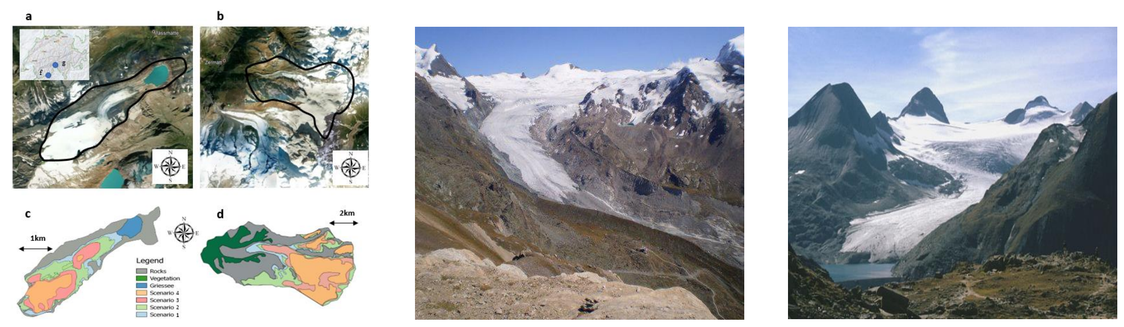
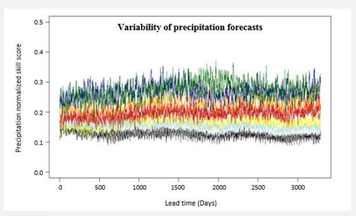
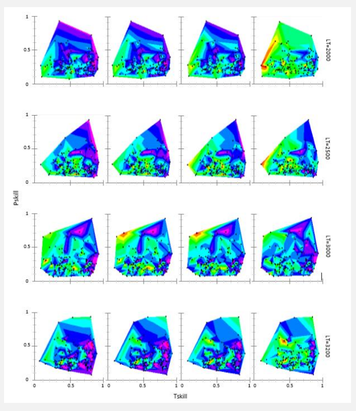
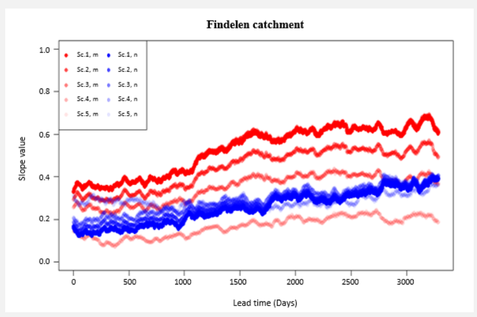


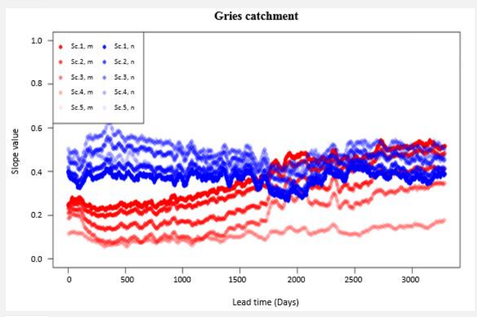
Figure 2 - (A) Geographic situation of Gries and Findelen catchments: satellite representations including outlines, surface type and glacier extent for different scenarios. In the localization map of the two catchments, "f" indicates the Findelen catchment, while "g" represents the Gries catchment. Pictures of (B) Findelen and (C) Gries hydrological catchments.

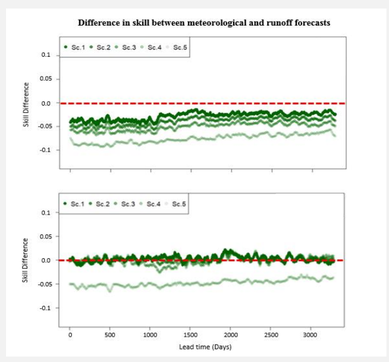
Results and outcomes

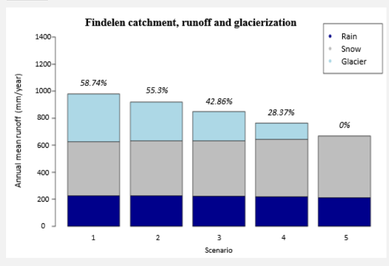


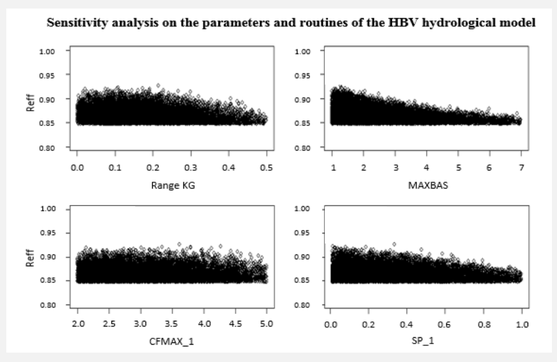












Scenario	Gries catchment						Findelen catchment					
	RMSE	RMSE	RV	RV	CC	CC	RMSE	RMSE	RV	RV	CC	CC
	m	*n*	*m*	*n*	*m*	*n*	*m*	*n*	*m*	*n*	*m*	*n*
1	0.38	0.37	0.35	0.38	0.35	0.02	0.53	0.25	0.48	0.25	0.31	0.01
2	0.34	0.40	0.31	0.41	0.34	0.02	0.53	0.26	0.49	0.26	0.30	0.01
3	0.27	0.46	0.24	0.48	0.32	0.03	0.44	0.27	0.38	0.26	0.30	0.01
4	0.20	0.51	0.17	0.52	0.28	0.03	0.35	0.30	0.28	0.28	0.31	0.01
5	0.12	0.45	0.09	0.41	0.33	0.02	0.17	0.28	0.12	0.24	0.33	0.00

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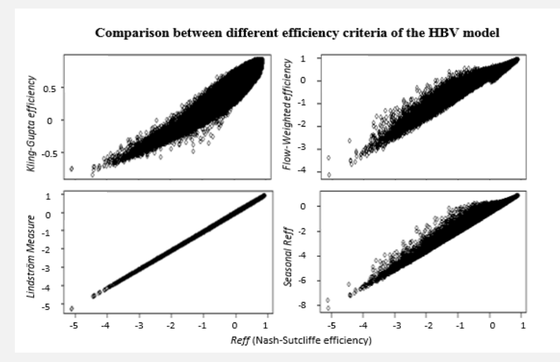

Scenario	Findelen, static glacier routine		Findelen, dynamic glacier routine		Gries, static glacier routine		Gries, dynamic glacier routine	
	Reff	*Qsim*	*Reff*	*Qsim*	*Reff*	*Qsim*	*Reff*	*Qsim*
1	0.7632	915.71	0.8053	978.79	0.8429	2648.21	0.8417	2640.06
2	0.7543	854.36	0.7986	920.35	0.8320	2456.02	0.8313	2448.86
3	0.7099	754.84	0.7956	849.18	0.8199	2145.42	0.8223	2142.22
4	0.6404	636.72	0.7780	765.02	0.7941	1867.15	0.8003	1867.32
5	0.4007	472.67	0.5879	666.13	-0.3438	1691.88	-0.4761	1706.86

J

Figure 3 - Presentation of the project's results. (A) Normalized precipitation skill scores where each coloured line corresponds to a forecast set; (B) Interpolation of skill scores to study the relation between temperature, precipitation and runoff forecasts accuracy; (C-D) Parameters to indicate the impact of a shrinking glacier on skill scores for the two catchments; (E) Difference in skill between meteorological and runoff forecasts over all lead times; (F) Representation of the three main components of simulated runoff: rain, snow, glacier melt; (G) Parameters of the HBV model which show the highest contribution to model efficiency; (H) Variability of slope parameters for all skill scores and for both catchments; (I) Correlation between some efficiency criteria of the model; (J) Variability of model efficiency by modifying the glacier routine of the model.

Conclusions & summary

- Temperature forecasts have a larger influence on runoff predictions than precipitation in the **Findelen** catchment with a higher glacierization
- For the **Gries** catchment, precipitation has the highest impact on runoff (due to higher temperatures and to model's parameters)
- Explanations of the difference → higher temperatures could led to a higher precipitation influence on skill transfer; uncertainties derived from calibration
- Variability with the different **glacierization scenarios** → increase of P influence in case of reduced glacierization, influence of temperatures and topography / morphological features, meteorological input data came from GERM glaciological model
- Shift from a glacier-dominated regime to a precipitation-dominated regime, lakes as storage sources, variability of PET-snow cover, no differences changing model's routine

References & Acknowledgements

References

[1] Ailliot P., Allard D., Monbet, V. & Naveau, P. 2015. Stochastic weather generators: an overview of weather type models. *Journal de la Société Française de Statistique* 156: 101-113.

[2] Beven, K. 2012. *Rainfall-Runoff Modelling (2nd edition).* Wiley-Blackwell Editors, Lancaster University, UK.

[3] Hamill, T.M. & Juras J. 2006. Measuring forecast skill: is it real skill or is it the varying climatology? *Quarterly Journal of the Royal Meteorological Society* 132: 2905-2923.

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