Climate-induced changes of the seasonal runoff behaviour in alpine catchments of the Swiss Alps and Southern Alps of New Zealand

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Subjects

Flow regimes describe the seasonal runoff behaviour of catchments. They are an integral expression of the existing climate conditions. Climate change leads to modified precipitation patterns, increased evaporation rates, reduced snow and ice storages, etc. These changes cause modifications of the seasonal runoff patterns. The runoff regimes were characterized by their dominating influence factor. Generally glacial, snow and rain fed regime types are distinguished.
This work targets to identify climate change induced runoff regime changes in the past for the whole spectrum of regime types (glacial, snow & rain regimes) in the montane area. To cover this spectrum the Swiss alps (glacial & snow dominated regimes) and Southern Alps of New Zealand (rain dominated regimes) were chosen as investigation areas.

Investigation Area / Methods

The runoff regime types of the Swiss alps and Southern alps of New Zealand were analyzed. The selection of the study sites was performed with regards of three criterias:

- As low as possible anthropogenic influence
- Adequate measurement series length
- Representative of the concerning regime type

In the Swiss alps four regime types are distinguished: glacial, glacionival, nivoglacial and nival alpine [1]. The runoff data of 22 catchments were examined (see Fig. 1).

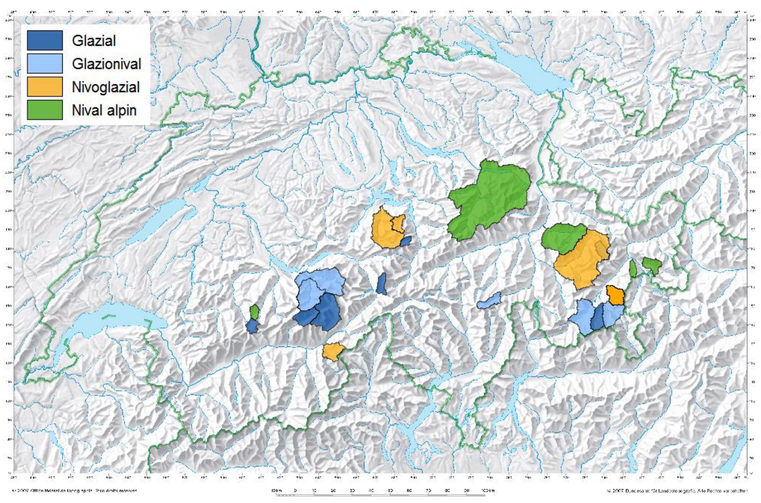

Figure 1: Study catchments of the Swiss alps

For the Southern alps of New Zealand eight different regime types can be found [2]:

- North-Western Catchments
- Nelson Marlborough Catchments
- East Coast Catchments
- Southland Catchments
- West Coast Catchments
- Central Main Divide Catchments
- Catchments South of the Main Divide
- Catchments North of the Main Divide

Figure 2 shows the location of the 24 chosen study sites.

To identify past changes in the seasonal runoff behaviour due to the climate change various statistical methods were applied:

- To detect trends into the runoff data the *Theil-Sen estimator* was applied. The estimator is robust against outliers and commonly used in hydrological studies [3]. To check for significance of the trends the *Mann-Kendall test* was selected.
- Seasonality changes in the peak runoff were identified using the seasonality calculation after *Bayliss and Jones* [4].
- The detection of possible tipping points was realised by the method after *Bai and Perron* [5].
- The correlation between two measurement series was determined with the *Spearman rank correlation coeffcient*. To assess the correlation the classification scheme after *Evans* [6] was used.
- The assessment of the year-to-year stability of the runoff regimes was performed by the entropy concept after *Krasovskaia* [7].

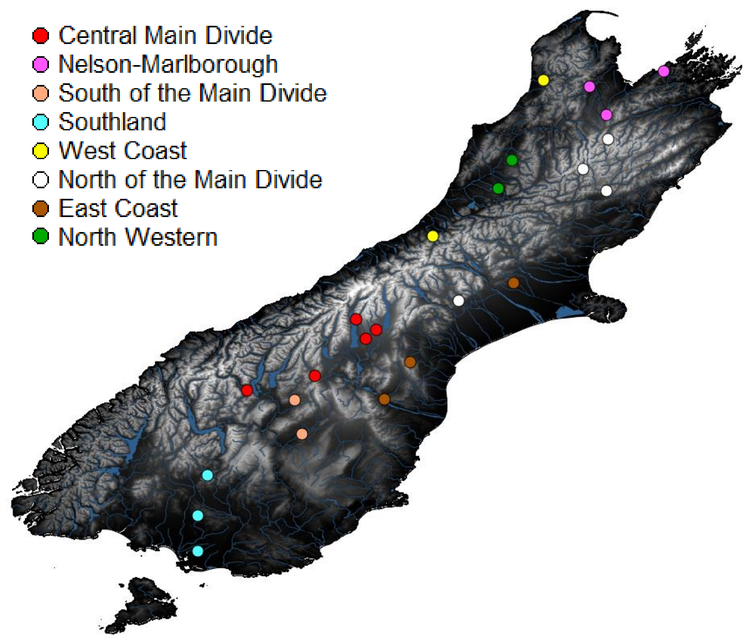

Figure 2: Study catchments of the South Island of New Zealand

Results

The results show that the runoff regimes of both investigation areas are affected by the effects of climate change.
Especially the glacial and/or snow dominated runoff patterns experienced marked changes. The melting period moved forward due to the earlier onset of the snow melting. The warmer temperatures led to an increased glacial melting and a temporally rise of the meltwater. For some Swiss catchments the peak of the meltwater passed already through because of the reduced glaciers.
In general the Swiss runoff regime types experience a shift towards the lower regime type. For example for the glacial catchments a shift towards the glacio-nival runoff pattern was observed. Figure 3 illustrates this shift for the stations Lonza-Blatten and Rhone-Gletsch by showing the approximation of the August and July discharge, which indicates a decline of the glacial component in favor of the nival component.
In the Southern alps of New Zealand an increase of the annual runoff was observed, except for the east coast catchments. Seasonally considered all catchments, except the east coast catchments, experienced an increase of the spring and winter runoff and a decrease of the summer and autumn runoff due to the climate warming. For the east coast catchments climate change led to a decrease of the annual runoff because of reductions of the spring and winter runoffs. The summer and autumn discharge kept nearly unchanged.

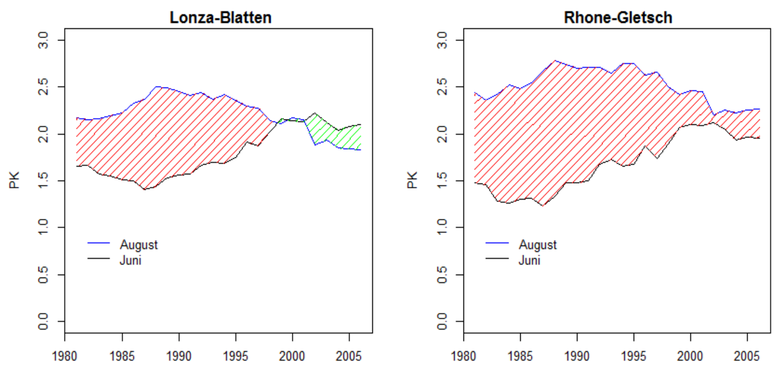

Figure 3: Temporal development of the August and July Pardé coefficients for the stations Lonza-Blatten and Rhone-Gletsch between 1981 and 2010.

The effects of climate change on the seasonal runoff patterns of the Southern Island of New Zealand are strongly superimposed by the El Niño Southern Oscillation (ENSO). Figure 4 illustrates the summer runoff of the Mataura-Parawa, the summer precipitation of Invercargill and the ENSO between 1955 and 2010. A remarkable negative correlation between the ENSO (SOI) and the precipitation/runoff is shown.

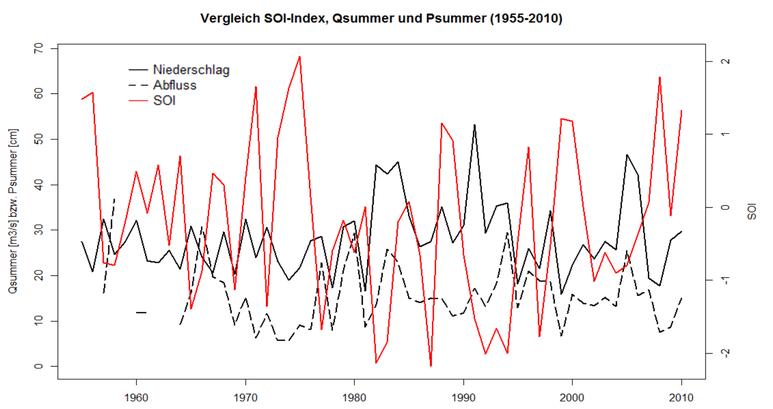

Figure 3: Temporal development of the ENSO, summer precipitation (Invercargill) & summer runoff (Mataura-Parawa) between 1955 and 2010.

Conclusions

This master thesis was able to show that the climate warming affects the runoff regimes of both investigation areas: the Swiss alps and the Southern alps of New Zealand.
But the maritime island-environment of New Zealand leads to to a much higher rain domination and superimposition by the prevailing atmospheric circulation patterns than the continental climate of the Swiss alps.
Thus the evidence of changes in the seasonal runoff patterns due to the climate change is much more difficult for the runoff regimes of the Southern alps than for the Swiss alps.
Nevertheless especially the glacial and nival dominated regime types of both investigation areas showed similar climate-induced changes in the seasonal runoff patterns.

Literature: [1] Weingartner & Aschwanden (1992): *Abflussregimes als Grundlage zur Abschätzung von Mittelwerten des Abflusses*. HADES, Tafel 5.2, Bern. [2] Grüter, E. (1996): *Flow regimes of rivers dreining the Southern Alps in New Zealand: classification and regionalisation*. Universität Bern. [3] Huxol, S. (2007): *Trendanalyse von Zeitreihen der Komponenten des Wasserkreislaufs im Einzugsgebiet der Dreisam zur prozessorientierten Beurteilung hydrologischer Klimafolgen*. Diplomarbeit. Institut für Hydrologie der Albert-Ludwigs-Universität Freiburg i.Br. [4] Köplin, N. (2012): *Hydrological impacts of climate change in Switzerland during the 21st century.* Inauguraldissertation. Philosophisch-naturwissenschaftliche Fakultät der Universität Bern. [5] Bai, J. & Perron, P. (1998): Estimating and Testing Linear Models With Multiple Structural Changes, In: *Econometrica*, 66, 47-78. [6] Evans, J. D. (1996): *Straightforward statistics for the behavioral sciences*. Pacific Grove: Brooks/Cole Publishing. [7] Krasovskaia, I. (1995): Quantification of the stability of river flow regimes. In: *Hydrological Sciences – Journal des Sciences Hydrologiques*, 40(5), 587-598.

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