Sensitivity of European glaciers to precipitation and temperature – two case studies

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Introduction

Many studies have been carried out to investigate the relationship between climatic signals and variations of glaciers. Because the climate system can be regarded as non-linear, traditional linear statistical models cannot describe the full complexity of its behaviour.

Non-linear neural network models can be seen as new complementary statistical approaches for analyzing the complex climate-glacier relation and simulating glacier variations [2,4,5,6,7].

The study sites

	Lower Grindelwald Glacier	Nigardsbreen
Geographical coordinates	8°05′ E, 46°35′ N	7°08′ E, 61°45′ N
Length (km)	8.85	9.6
Surface area (km^2)	20.6	48.2
Elevation of head (meters asl.)	4107	1950
Elevation of terminus (meters asl.)	1297	355
Average height (meters asl.)	2840	1150
Equilibrium line altitude ELA (meters asl.)	2640	1560
Exposure	N–NW	E–SE
Average slope (%)	31.8	16.6
Firn fields	Ischmeer, Bernese Fiescher Glacier	

Fig. 1: Lower Grindelwald Glacier Bernese Alps, Switzerland [7]

Fig. 2: Nigardsbreen Western Norway [4]

Methods

A neural network aims at imitating the way our brain processes information. It consists of a set of highly interconnected units which process information as a response to external stimuli. Following a learning algorithm, the neural network model detects certain features of the data, which consist of input variables and desired output responses [4,5].

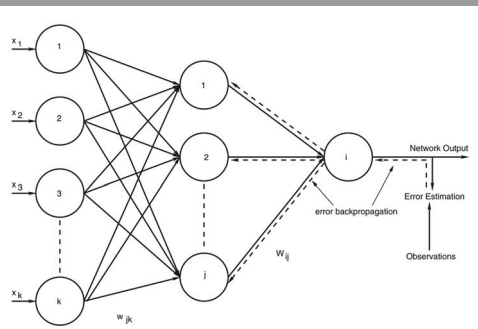

Fig. 3: The backpropagation network, a typical neural network model

The used non-linear backpropagation network has been trained with high resolution multiproxy reconstructions of temperature and precipitation (input data, [1,3]) and glacier length variations of the Alpine Lower Grindelwald Glacier, Switzerland, and Nigardsbreen, western Norway (output data, [4,6,7]).

The aim of this work is

- to **simulate future glacier length variations** of the Lower Grindelwald Glacier, Switzerland, forced by two different climate scenarios.
- to **study the relative importance of seasonal variations of temperature and precipitation on glacier fluctuations** of the Lower Grindelwald Glacier and Nigardsbreen.

Results

The model was forced with two regional climate scenarios of temperature and precipitation, derived from a probabilistic approach [2,4,6]:

- Scenario 1: no changes in temperature and precipitation compared to the 1970–2000 mean.
- Scenario 2: increasing temperatures (between +1.8°C and +2.7°C) and changing precipitation rates.

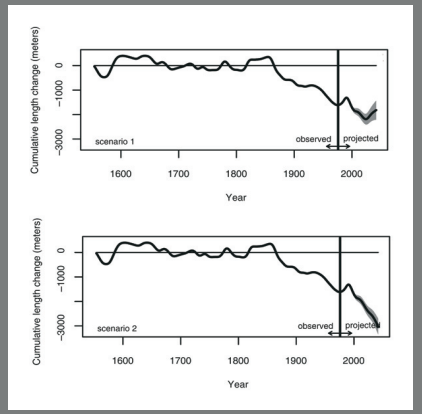

Fig. 4: Cumulative glacier length variations and simulations of the Lower Grindelwald Glacier for the 1550–2050 period

A sensitivity analysis of several advance and retreat periods of the Lower Grindelwald Glacier and Nigardsbreen was performed. It is based on the measurements of the effect that is observed in the output layer due to changes in the input data [2,4,6,7].

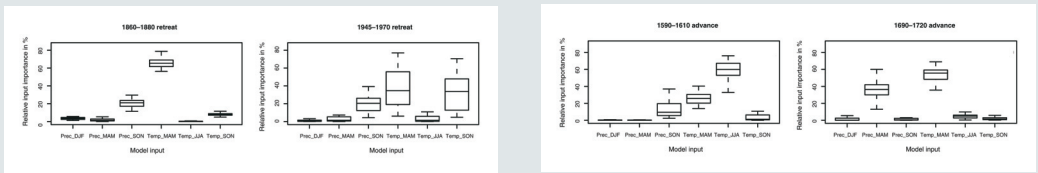

Fig. 5: Relative importance of climate input variables on length fluctuations of the Lower Grindelwald Glacier for four exemplary time periods

Conclusions

Using highly resolved temperature and precipitation reconstructions we could simulate future glacier length variations of the Lower Grindelwald Glacier. Both climate scenarios show a retreat of the glacier until the year 2025.
It has also been demonstrated that the relative importance of seasonal variations of temperature and precipitation has been variable in the past and that various combinations of temperature and precipitation characteristics have led to glacier advances and retreats. Precipitation plays an important role in the behaviour of Nigardsbreen. The Lower Grindelwald Glacier proved to be less sensitive to precipitation and more sensitive to temperature than Nigardsbreen.

References

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