Stochastic analysis of mountain glacier dynamics

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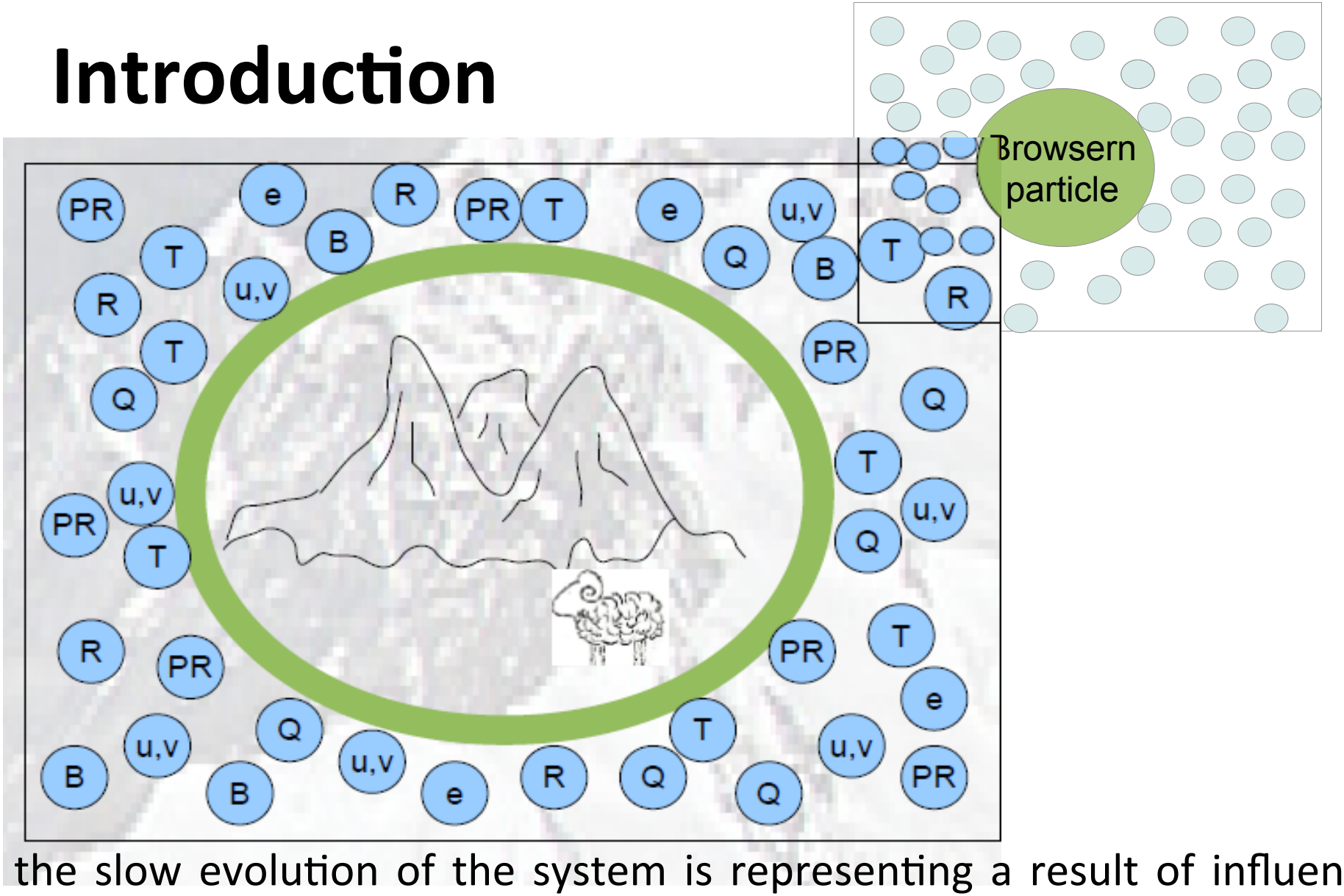
Introduction



If the slow evolution of the system is representing a result of influence of random processes (independent in time), it is base to use stochastic differential equations. In this work, the theory of Brownian motion was applied to describe dynamics of a mountain glacier as a response to changes in annual atmospheric conditions.

Langevin equation

Equations of the minimal glacier model (author: J.Oerlemans, 2008) were transformed into a Langevin equation (the glacier length change was considered as the "slow" variable; the mass balance change (expressed as variations of the ELA) as the "fast" variable:

$$dW/dt = -\lambda W + \eta$$

«slow» variable

«fast» variable (influence of random processes)

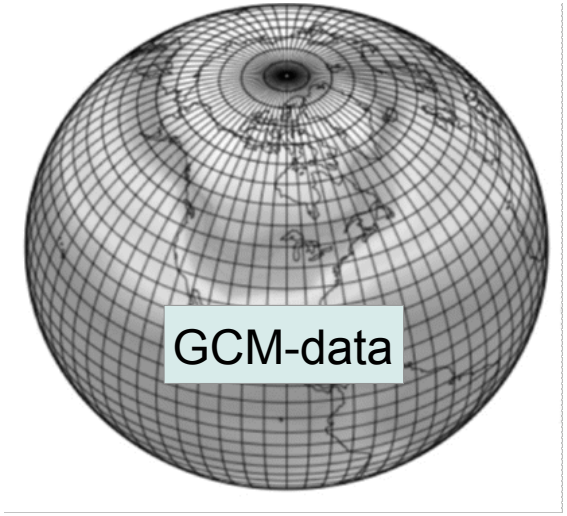
$$d\Delta y/dt = -(2ay_0 - b)\Delta y - cE_0\Delta E$$

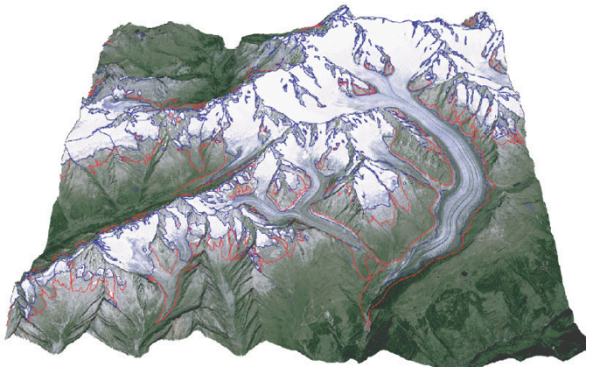
$(2ay_0 - b) = 50$ *years,* the characteristic time of the system

$y = \sqrt{L}$ (L - glacier length)

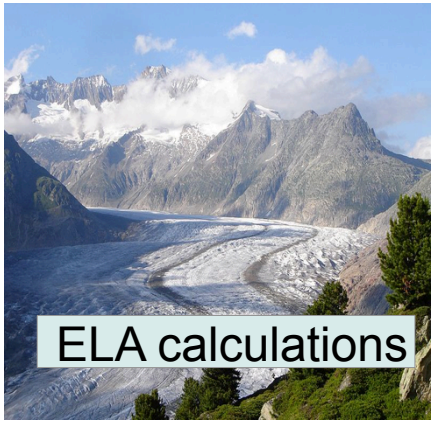
E - equilibrium line altitude (ELA)

Methods: from GCM to ELA





Downscaling meteoparameters to Aletschgletscher area

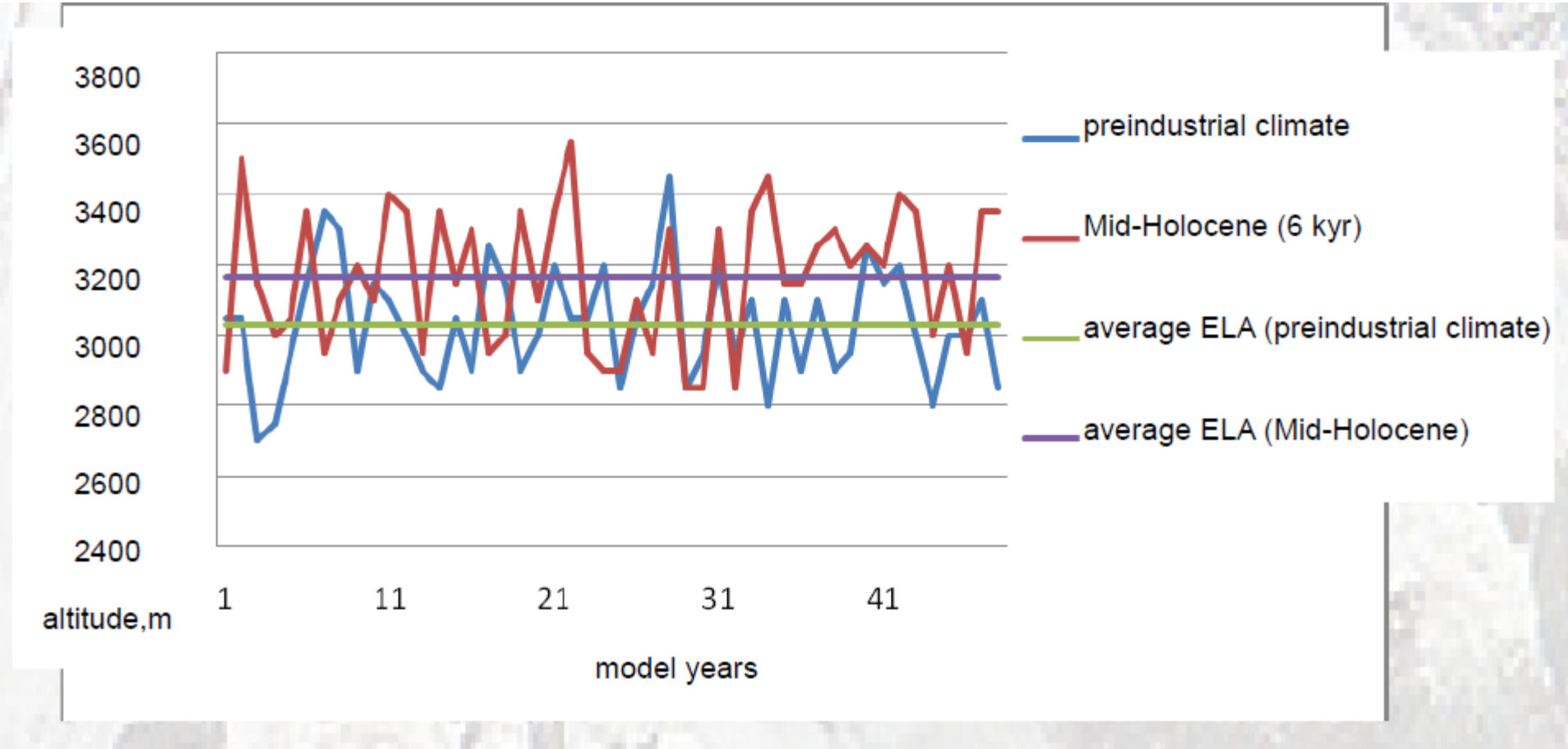


The research object:

Great Aletsch Glacier (*Grosser Aletschgletscher*), valley glacier

Location: 46°22'32'' N 8°04'38''E, Switzerland, Bernese Alps

Results



Aletschgletscher's ELA was calculated for two climatic periods - pre-industrial and Holocene optimum (the results of the project 2 PMIP (Paleoclimate Modeling Intercomparison Project, http://pmip2.lsce.ipsl.fr/) was used (CNRM,UBRIS,MRI)

Conclusions

- scale of the glacier length fluctuations caused by climate variability (within a climatic period with fixedboundary conditions) was calculated (20 m). Measured changes of Aletschgletscher's length during the 20th century exceed the received values. It means that observed changes can't be interpreted as a standard deviation of the glacier length in stationary conditions, and it should be treated as superposition of long and unidirectional climate change (in this case warming) and random influences caused by interannual variability of meteorological conditions;
- scale of climatic changes (Holocene - pre-industrial, 21-19 centuries) are similar