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# Contribution of statistical modeling to the understanding of the mass balance of a small arctic glacier

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## 1. Introduction

Today, most of the studies on Arctic glaciers mass balance are performed using global scale datasets (satellite images, airborne data...). However, monitoring at local scale is necessary to analyze, understand and validate arctic glaciers dynamics.

Operating a statistical model is a new approach in our work that enables us to combine most of the available data on the studied glacier. It helps having a synoptic point of view on annual and interannual causes of the variability of the Austre Lovén mass balance.

The Austre Lovénbreen has been systematically instrumented and monitored since 2007 thanks to a succession of research programs (Sensor-Flows, Cryo-Sensors and PRISM)

## 2. Objectives

The work described here aims at better understanding how contrasted climatic and snow conditions in recent years do constrain, sometimes unexpectedly, mass balance dynamics.

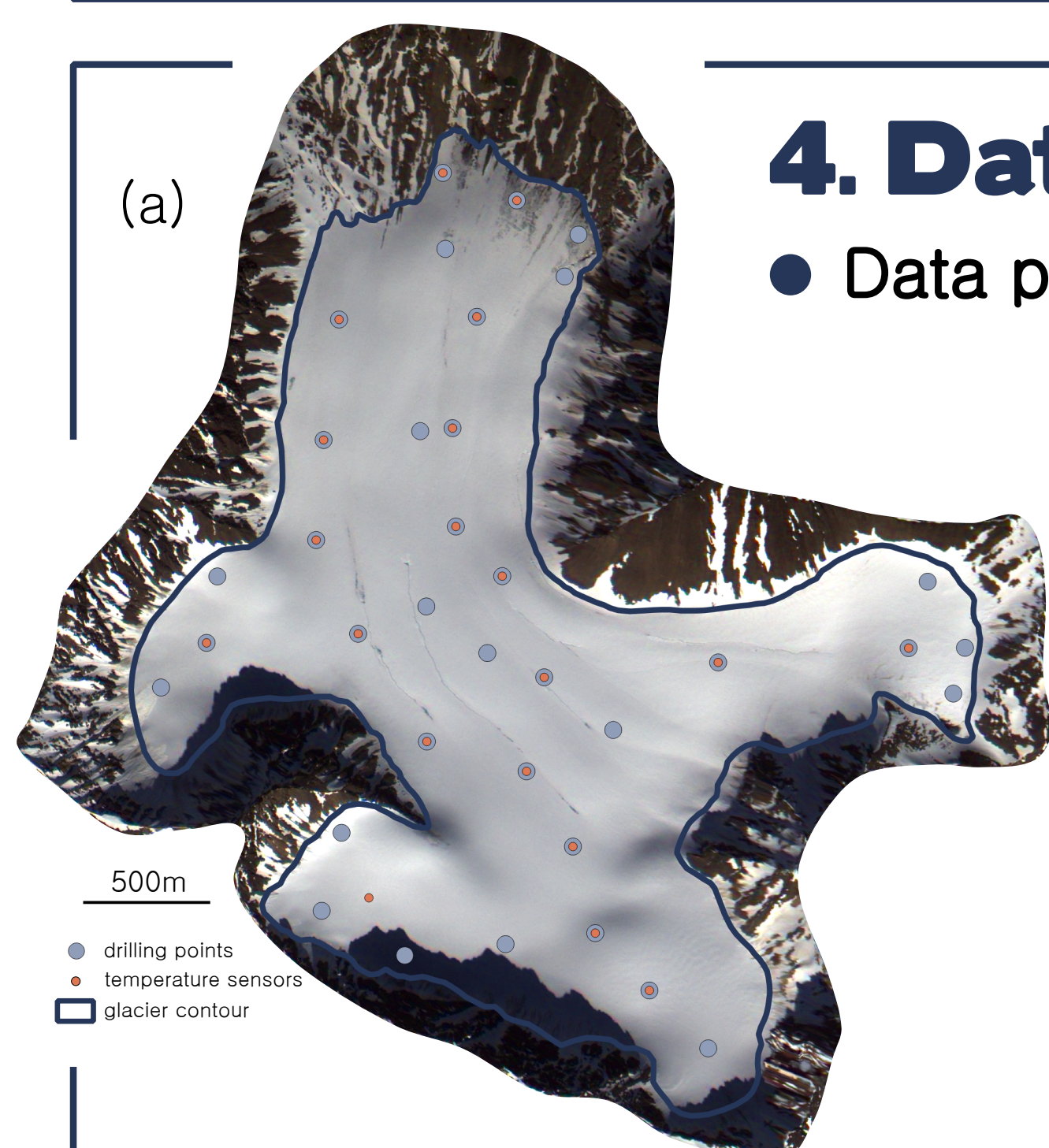
Objectives are (i) to identify factors and combination of factors affecting annual mass balance and (ii) to reveal trends over time and space.

## 4. Data & method

### 4. Data & method

#### • Data preparation

A rich measurement network (a) :  
 - 20 temperature sensors (b)  
 - 42 drilling points (snowpack monitoring)  
 - 37 ice stakes (mass balance monitoring)  
 - precipitation extrapolation from the Ny Alesund station (altitudinal gradient applied, Bernard, 2011).



(b) 1. temperature sensor, 2. PICO drill, 3. ablation stake

In a different way as usually done, we used the Kemp REGR technique (1983) to reconstruct temperatures (c).

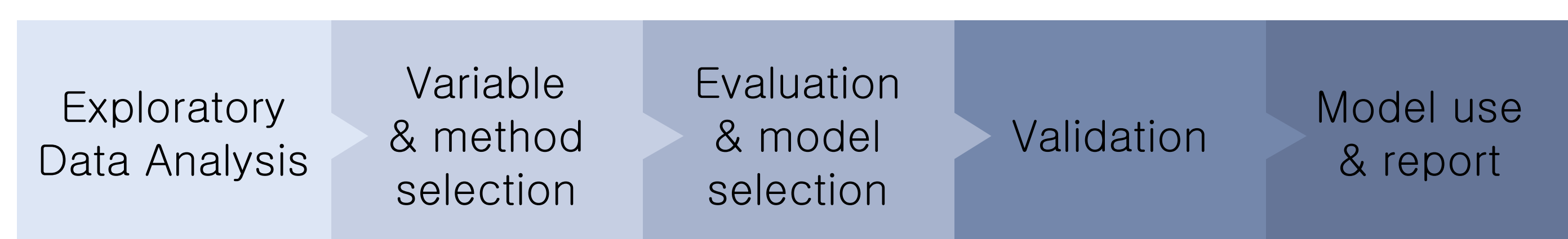
$$T_{ijkn} = \sum_{1 \leq m \leq M} W_m (a_{jkm} + b_{jkm} T_{ijkm}) \quad \text{where} \quad W_m = r^2_{jkm} \left( \sum_{1 \leq p \leq M} r^2_{jknp} \right)^{-1}$$

(c) REGR : the weighting functional values (W) are proportional to the square of the between station correlation

From punctual information to a 10k points grid (20x20m) for a better spatialization of phenomena. A geostatistical interpolation (krigeage) were done using the LISQS software (prototype developed in Théma lab.).

#### • Data preparation

A tool : explanatory modeling (d) :



(d) Steps in the statistical modeling process

Variable to explain : mass balance

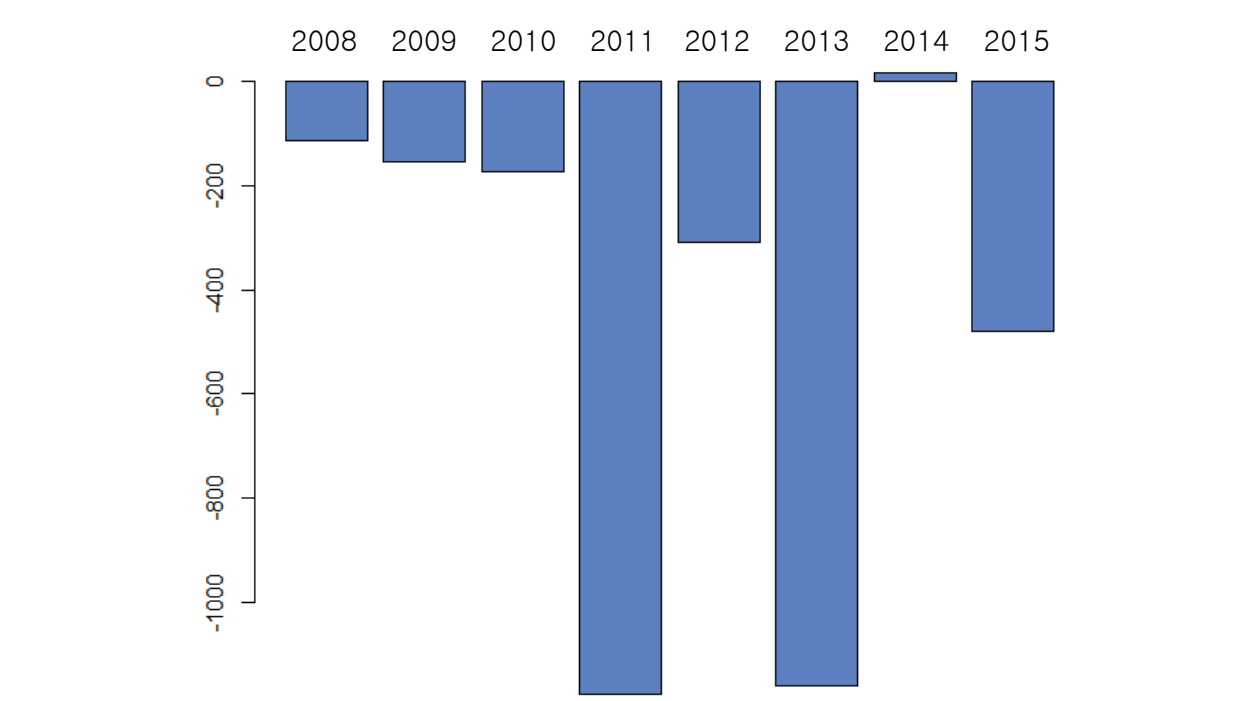
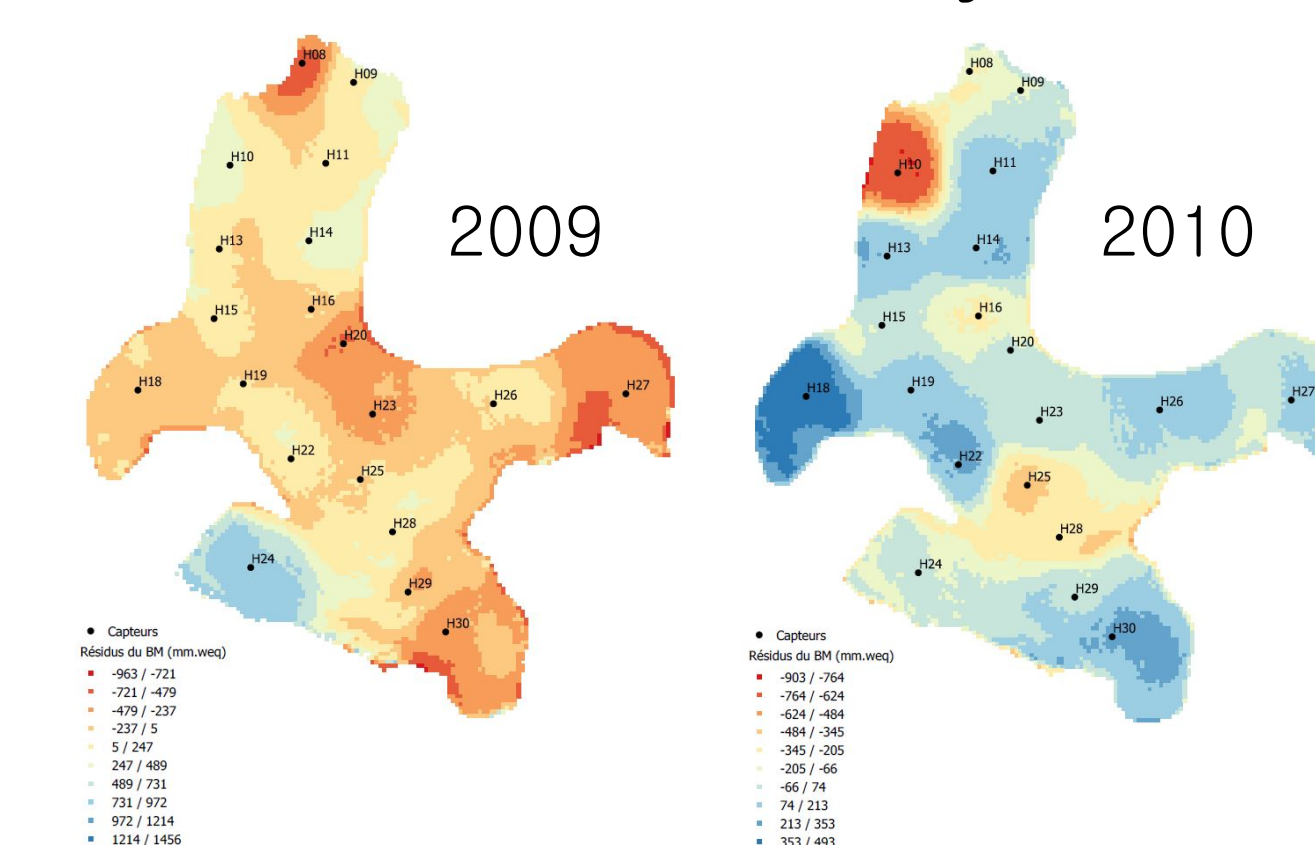
Explicative variables :  
 - cumulative thawing degree-days (base 0°C and 5°C)  
 - liquid precipitations (winter / summer)  
 - snow accumulation

Modeling method : multiple linear regression

Best models were selected each year using the Akaike's Information Criterion (AIC) and the field knowledge. Each model was then validated according to a residual analysis. Fitting a statistical model is a long iterative process.

## 5. Preliminary results

### • Model residuals analysis



(e) Mass balances of the Austre Lovén from 2008 to 2015. 2014, the only positive mass balance recorded so far

Model that trend to exaggerate extremely low mass balance values (e.g 2013) whereas it is a pretty good estimator of "normal" mass balances (e.g 2009).

### • Focus on 3 different years

2009 : a "normal" year

2013 : a very bad year

2014 : a positive year

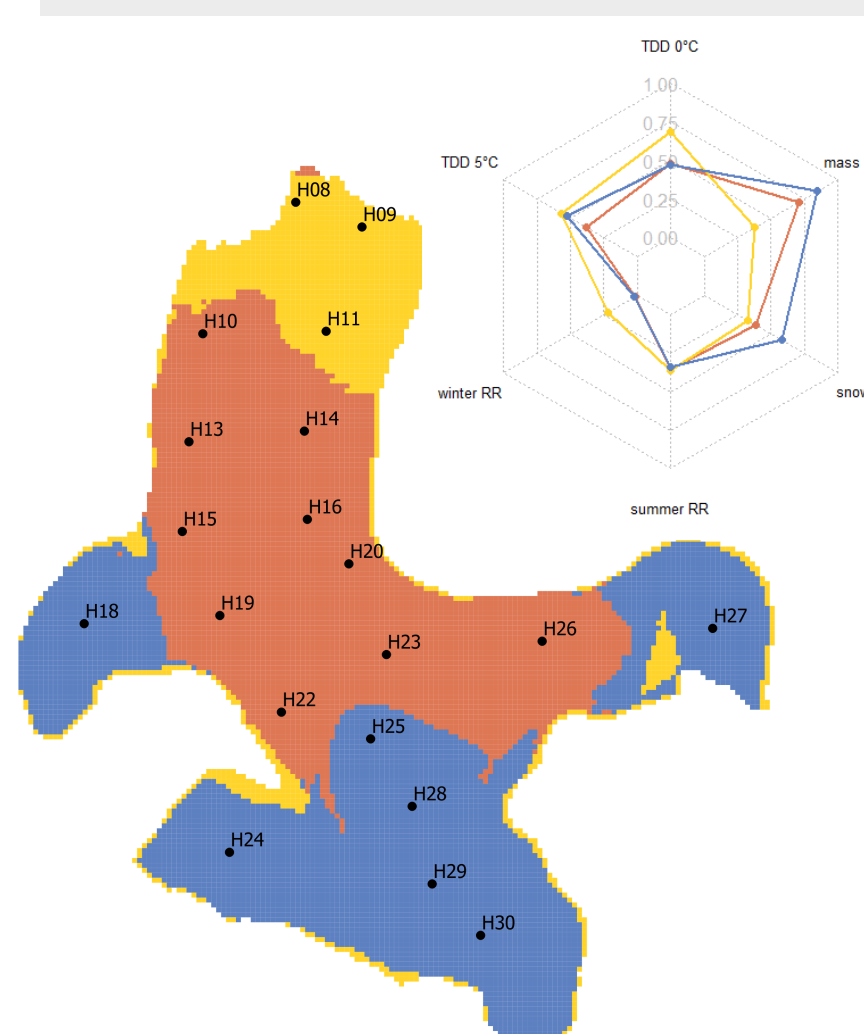
Which variable is most important ?

with all identified variables  $R^2=0.68$   
 1. winter liquid precipitation  $R^2=0.64$   
 2. snow accumulation  $R^2=0.65$

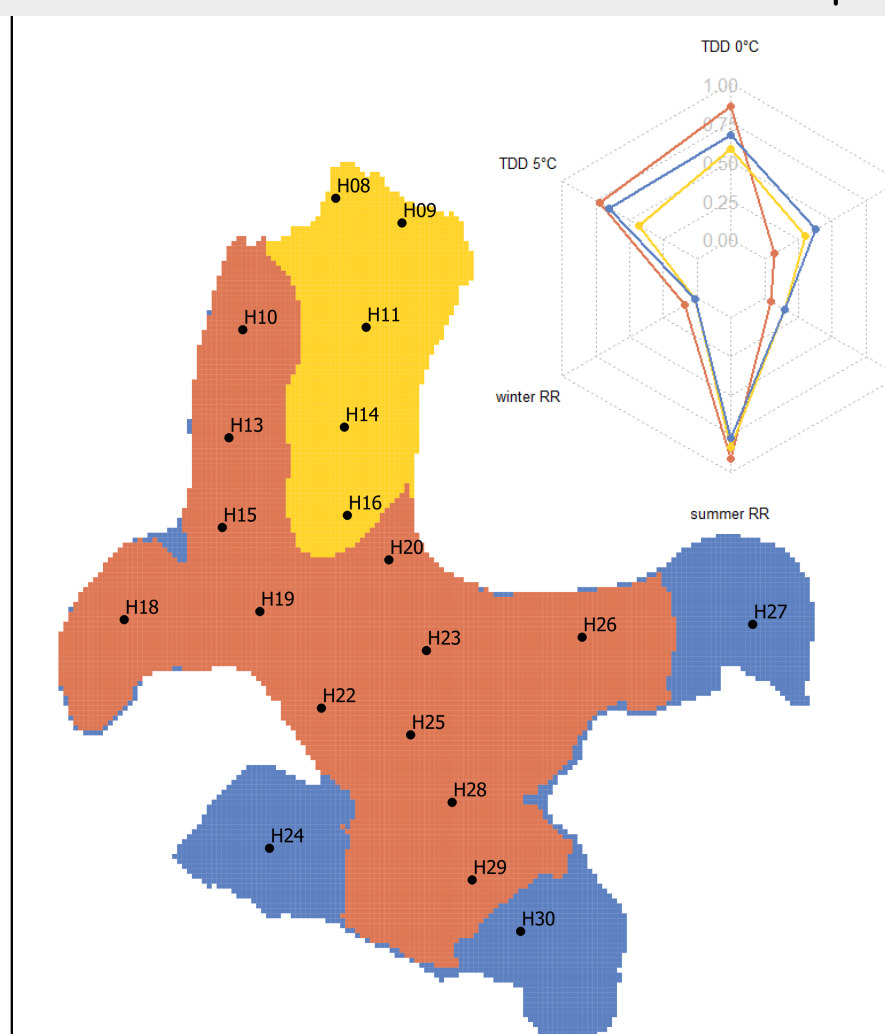
with all identified variables  $R^2=0.80$   
 1. snow accumulation  $R^2=0.66$   
 2. cumulative TDD base 0°C  $R^2=0.72$

with all identified variables  $R^2=0.94$   
 1. snow accumulation  $R^2=0.73$   
 2. summer liquid precipitations  $R^2=0.75$

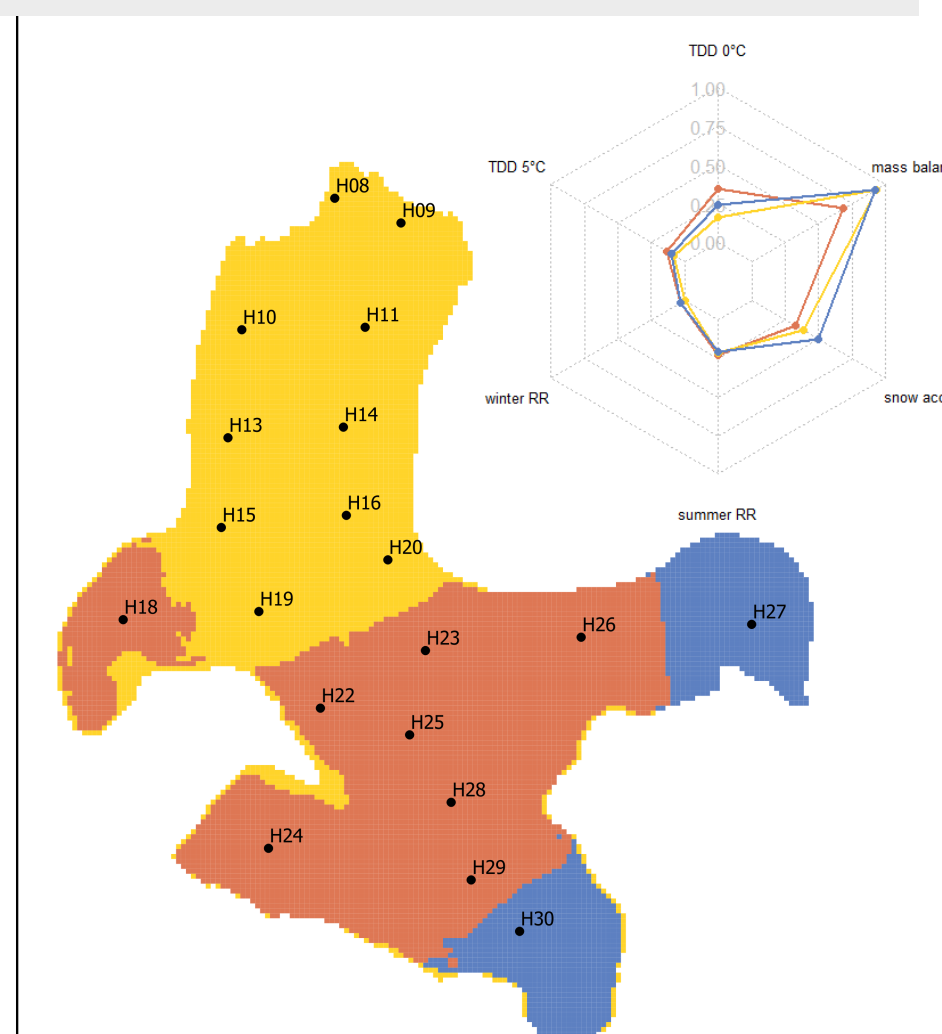
Similar individuals over space



Thermal and winter liquid precipitations gradient prioritized to define classes.



Greater distinction between right and left bank of the front than usual. Emphasize of cirques due to temperature and snow accumulation variables.



Good repartition of snow accumulation over the glacier leading to an homogenisation of classes and a positive m.b.

Which variable is most important in each pixel ? >>>> coming soon...

notes : there is no link between classes of the same color between year. To allow comparisons, the scale is the same for each radar.

## 6. Discussion and future work

The explanatory model and geomatic treatments are designed to help understand mass balance behavior at a local scale over the Austre Lovén. It is an original approach integrating lots of different measured variables. Fitted models seem pretty good at explaining the reasons of mass balance variability even though it is weaker

for extrem years. Preliminary results show that the glacier's organization is well represented by the model with a front which register the strongest changements whereas cirques are more preserved. The most important variables enhanced each year are coherent. Future work will focus on defining this for each pixel of the glacier.

