Alpine glaciers disappearance tipping point: results from EURO-CORDEX models

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COACCH CO-DESIGNING THE ASSESSMENT OF CLIMATE CHANGE COSTS

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Introduction

The front variations of Alpine glaciers show a general retreat over the past 150 years. This glacier retreat, then, has a large impact on many regional sectors, such as hydroelectricity production, river runoff, and touristic sector. In the last decades, glacier retreat in the Alps has been extremely evident due to the pronounced temperature increase affecting these mountains.

Moreover, numerous model studies exhibit a high probability of occurrence of Alpine glacier disappearance by the end of the current century, especially under extreme future climate change conditions.

The Alpine glaciers disappearance is expected to largely influence the Alpine glaciers regions climate, especially in terms of water availability. For this reason, the occurrence of the Alpine glaciers disappearance is enumerated among the climate tipping point.

Alpine glaciers disappearance with other 3 climate tipping points and 9 socioeconomics tipping points are investigated in COACCH.

Given the reduced average glaciers dimension, high-resolution data are needed to investigate the occurrence and the potential impacts of this tipping point. Thus, the EURO-CORDEX dataset over the EUR-11 domain are analyzed in this study.

Models

1. RACMO22E
2. SMHI-RCA4
3. WRF331F

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Methodology

Glacier Length

Alpine glaciers differ under many characteristics:

- Elevation;
- mean aspect;
- length;
- shape.

Alpine Glaciers disappearance timing can, then, be simulated by means of a simplified dynamical glacier model:

minimal glacier model.

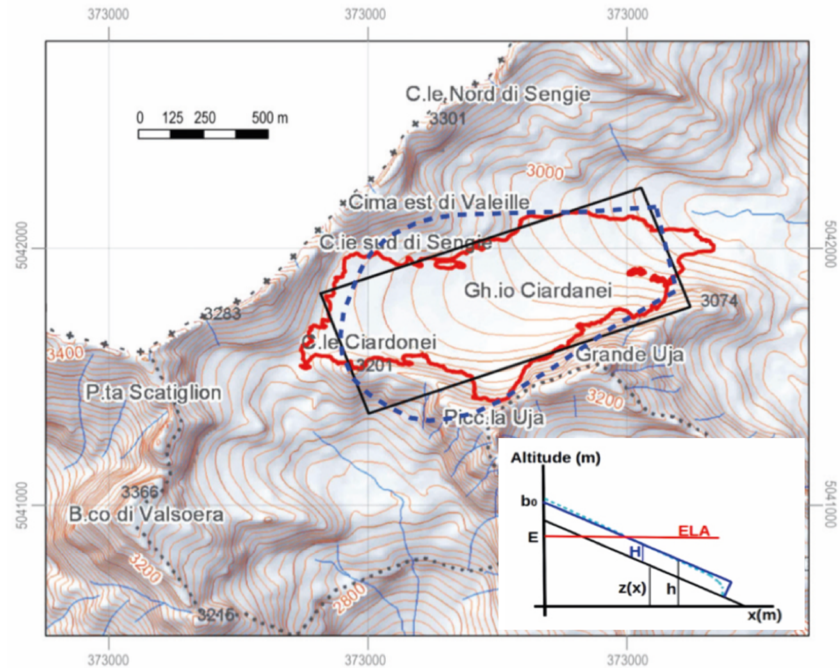

Figure: Schematic description of the minimal glacier model by Peano et al. 2016. Ciardoney glacier case. The simplified uniform width case is reported in black, while the red curve show the observed glacier shape. The small box exhibit the section of the simplified glacier geometry.

Surface mass balance

Accumulation

Use of snow precipitation from CORDEX data plus a refreezing factor.

Ablation

Positive Degree Day (PDD) method based on monthly temperature data

Glaciers

Synthetic glaciers in each RCM glacierized grid point are considered in the analysis:

- Small glaciers → initial length of 1000m
- Medium glaciers → initial length of 4000m
- Large glaciers → initial length of 10000m

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PDD Reeh (1991); Degree Day Factor Hock (2003); Minimal glacier model Peano et al (2016) and Oerlemans (2011)

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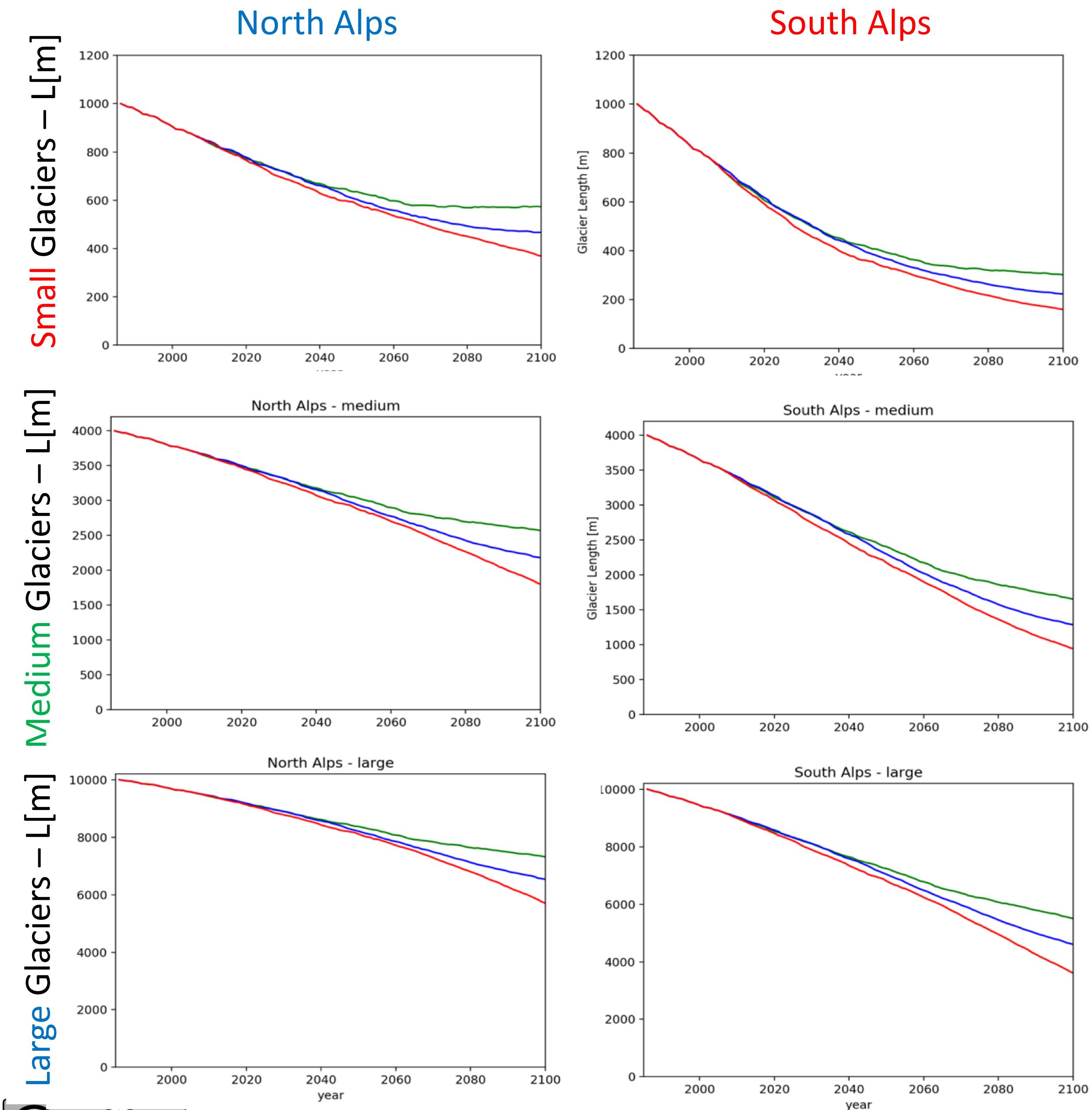
Results – synthetic glacier retreat



Glacier size	Scenario	NA	SA	Alps
Small	RCP 2.6	32%	52%	36%
	RCP 4.5	51%	68%	57%
	RCP 8.5	58%	78%	65%
Medium	RCP 2.6	3%	10%	5%
	RCP 4.5	16%	37%	23%
	RCP 8.5	22%	45%	30%
Large	RCP 2.6	0%	0%	0%
	RCP 4.5	3%	8%	5%
	RCP 8.5	6%	13%	8%

Table: Percentage of synthetic glaciers simulated to disappear by the end of the 21st century

All glacier will reach half their initial length by end of century in southern Alps, only under RCP8.5 it will occur in Northern Alps;

RCP2.6 shows possible glacier retreat stabilization around 2080s.

Small glaciers show high probability of disappearance by end of the century.

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Figure: Multi-model mean synthetic Glacier length change. North Alps – South Alps distinction set at 45.5N

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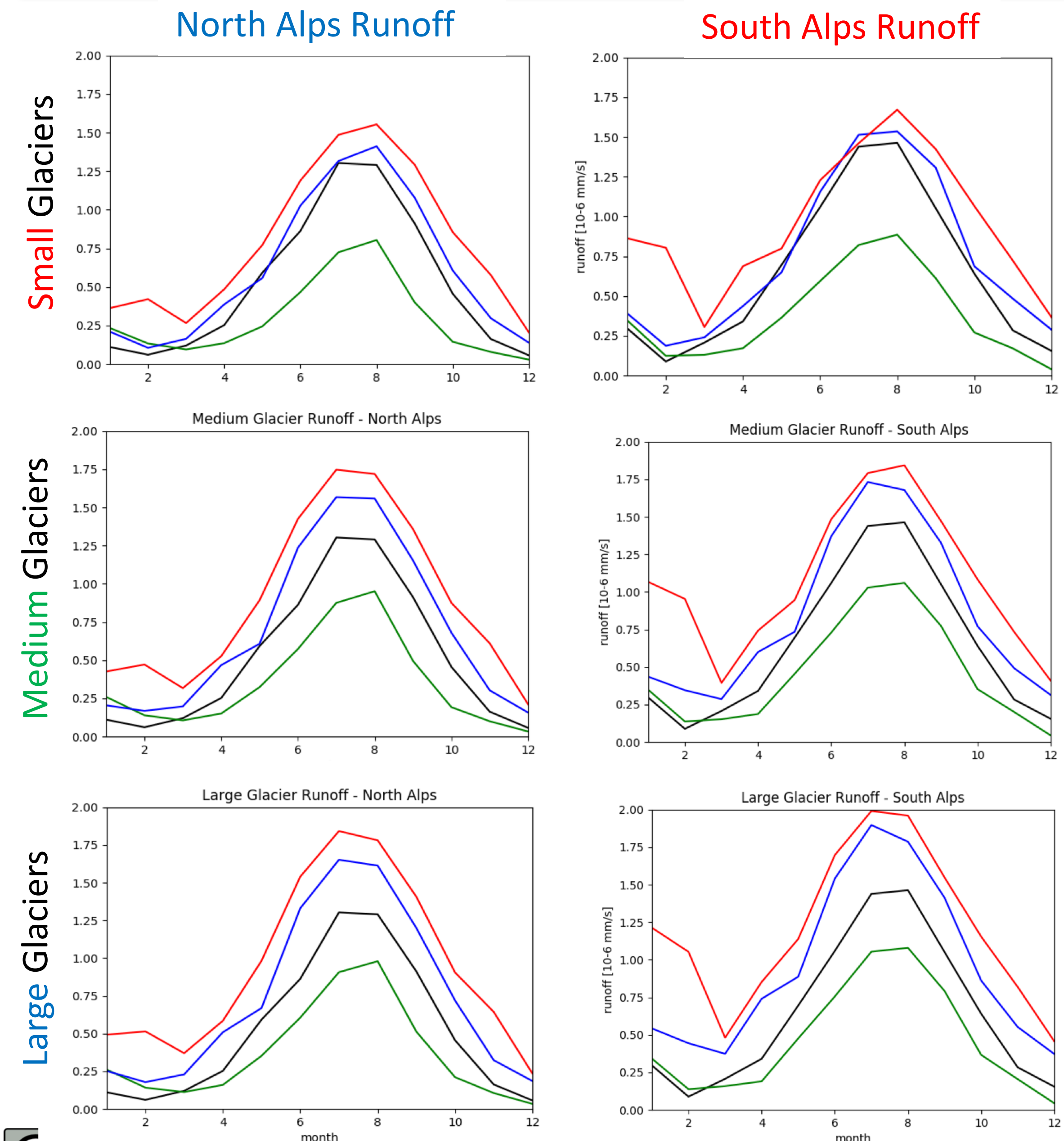
Results – synthetic glacier retreat



Changes in seasonal cycle of glacier runoff composed by:

1. liquid precipitation falling on glacier;
2. glacier ablation;

Note: glacier runoff values are computed only in grid cell where glacier length is higher than zero.

RCP2.6 shows a reduction in glacier runoff by the end of the century compared to 1986-2005;
RCP8.5 and RCP4.5 show higher glacier runoff values.

Figure: Seasonal cycle of the total runoff over glaciers in 2081-2100 as represented by glacier models forced by RCMs following different scenarios (RCP2.6/RCP4.5/ RCP8.5 as green/blue/red line , respectively) compared to 1986-2005 historical period (black line). Units are in 10^{-6} mm/s.

1986-2005 | 2081-2100 RCP2.6 | 2081-2100 RCP4.5 | 2081-2100 RCP8.5

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North Alps – South Alps distinction set at 45.5N

Conclusions

- Alpine glacier disappearance tipping point is expected to occur by the end of the century only under RCP 8.5 scenario and in particular for small glaciers;
- Under RCP 2.6 scenario glacier length is expected to reach a new equilibrium state for all glaciers length category;
- Independently from initial glacier length, alpine glaciers are expected to halve by the end of the century in the Southern Alps under RCP 8.5;
- North Alps region exhibits smaller changes compared to South Alps region;
- Glacier runoff seasonal cycle shows a lengthening of the runoff season towards late summer and beginning of autumn;
- A doubling of glacier runoff is expected at the end of the century under RCP 8.5, while increase of about 1.5 times are simulated under RCP 4.5;
- RCP 2.6 scenario shows values of glacier runoff equal to 0.8 times the historical (1986-2005) values.
- Outlook: increase the synthetic glaciers size categories, and account for glacier runoff and simulated local soil-runoff.

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