International Conference on Mountains and Climate Change
High Summit LECCO 2013

Climate change effect upon water resources in Northern Italy and the Alps

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Menu

- Motivation
- I-CARE project
- Hydrological changes in the Alps

- Future water resources- a case study

- Some conclusions

Motivation

Increase in surface temperatures has important consequences for the hydrological cycle in regions where water supply is currently dominated by melting snow or ice. In a warmer world, less winter precipitation falls as snow and the melting of winter snow occurs earlier in spring. Even with constant precipitation, these effects lead to a shift in peak river runoff to winter and early spring, away from summer and autumn when demand is highest. Where storage capacities are not sufficient, the winter runoff will be lost to the oceans. **With more than one-sixth of the Earth's population relying on glaciers and seasonal snow packs for their water supply**, the consequences of these hydrological changes for future water availability—predicted with high confidence and already diagnosed in some regions—are likely to be severe.

From: Barnett *et al.*, 2005, Nature 438, 303-309.

PNAS

Contribution potential of glaciers to water availability in different climate regimes

Georg Kaser, Martin Großhauser, and Ben Marzeion

Table 1. Climatological and geographical characteristics of the river basins shown in Figs. 1 and 2, sorted by the PIX

Basin name	Basin area, km²	Glacier area, km²	Glacier area, %	Population, 10^6	PIX, 10^6
Aral Sea	1,234,075	11,319	0.92	41.01	10.29
Indus	1,139,814	20,325	1.78	211.28	4.82
Ganges	1,023,609	12,659	1.24	[illegible]	2.40
Po	73,297	818	1.12	16.55	0.81
Rhone	97,702	1,162	1.19	10.12	0.57
Rhine	190,713	459	0.24	59.07	0.52
Yangtze	1,746,593	1,895	0.11	383.04	0.37
Brahmaputra	527,666	16,118	3.05	62.43	0.31
Danube	794,133	617	0.08	81.38	0.31
Tarim	1,053,180	20,494	1.95	9.22	0.30
Rio Santa	11,901	503	4.23	0.57	0.27
[illegible]	59,120	215	0.36	3.45	0.05
Huang[illegible]e	[illegible]702	17[illegible]	0.02	162.70	0.02
Indigir[illegible]	341,577	33[illegible]	0.10	0.04	0.00
Irrawa[illegible]	410,37[illegible]	2[illegible]	0.01	3[illegible]	0.00
Yukon [illegible]ver	830,25[illegible]	[illegible],07[illegible]	1.09	[illegible].13	0.00
Clutha [illegible]ver	17,18[illegible]	14[illegible]	0.86	0.03	0.00

ADAPTATION ??

Climate change in the Alps

Evidence from present knowledge indicates European Alps are undergoing **noticeable and measurable** transient climate change and their hydrological cicle is impacted

Thermal shift within Alps since 1980s, albeit sinchronous with global warming, seems at least twice as much global climate signal, and the Alps underwent more than 2°C increase of lowest temperatures dyring XX century, with substantially unchanged precipitation, but with a marked decrease of snowfall (*e.g.* Diaz & Bradley, 1997; Beniston, 2000; Beniston et al, 2003).

POLIMI & Climate change

2007-2009 CARiPANDA, Cambio climatico e risorsa idrica nel Parco Naturale dell'Adamello, Fondazione Cariplo.

2009-2010 Budget idrologica del ghiacciaio Dosdè (Valtellina, Italy). LEVISSIMA Italia.

2009-2010. IDRO-STELVIO. Una rete idrometrica per il Parco dello Stelvio, Finanziato sda Parco Stelvio.

2010-2012. SHARE-Stelvio. Un Parco – Osservatorio per lo studio dei Cambiamenti Climatici e Ambientali in alta quota. Finanz. Regione Lombardia.

2010-2013. Share-Paprika. Effects of climate change on water resources in the Karakoram range (Pakistan, Asia). EVK2CNR

2010-2013. SEED, Social, Economic and Environmental Development for the realization of Central Karakorum National Park (CKNP). EVK2CNR

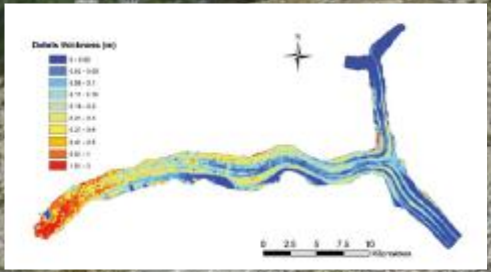
2011-2013. I-CARE. Impact of Climate change on Alpine water REsources: the case of Italy and Switzerland. 5x1000 Politecnico di Milano


PROGETTI DI RICERCA "5 PER MILLE JUNIOR" Anno 2009

Proposal:

I CARE

Impact of Climate change on Alpine water REsources: the case of Italy and Switzerland



I-CARE project

PROGETTI DI RICERCA "5 PER MILLE JUNIOR" Anno 2009

Proposal:

I CARE

Impact of Climate change on Alpine water REsources: the case of Italy and Switzerland

Google Earth 2008

Keywords: *climate change, alpine area, water resources*

Proposer:

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Duration: *24 months*

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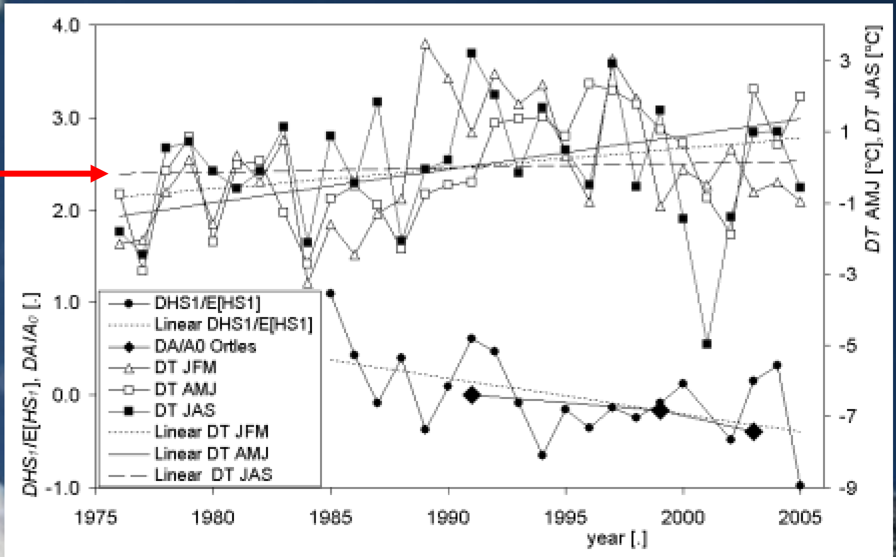
PROGETTI DI RICERCA "5 PER MILLE JUNIOR" *I CARE* 1

I-CARE (Impact of Climate change on Alpine water REsources: the case of Italy and Switzerland) project, awarded by Politecnico di Milano under the funding scheme 5xmille for outstanding young scientists, was aimed to investigate the observable impact of recent climate change in the Italian Alpine region with particular emphasis upon water resources, and to investigate prospective water-wise impact of expected climate change towards the end of the century.

The results presented here rely upon investigation carried out in partial fulfilment of I-CARE project.

Hydrological changes in the Alps

Snow cover



ORIGINAL PAPER

Evidence of climate change impact upon glaciers' recession within the Italian Alps

The case of Lombardy glaciers

G. Diolaiuti · D. Bocchiola · C. D'agata · C. Smiraglia

Article

The 1975–2005 glacier changes in Aosta Valley (Italy) and the relations with climate evolution

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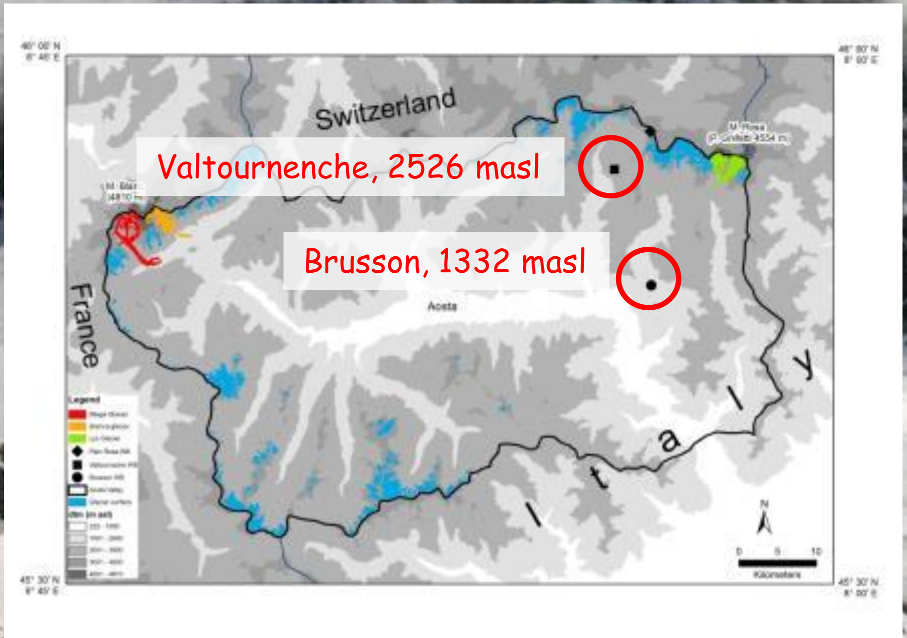
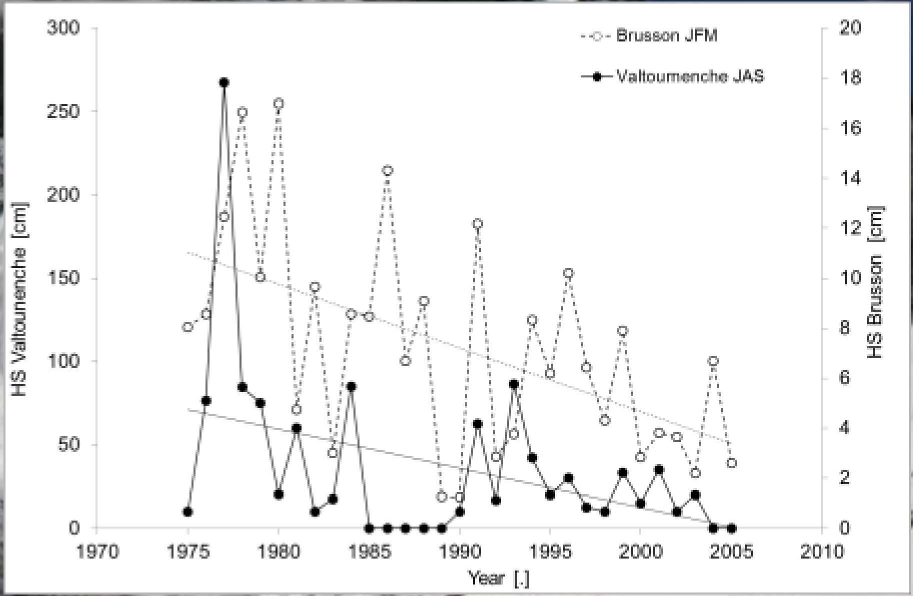
SAGE

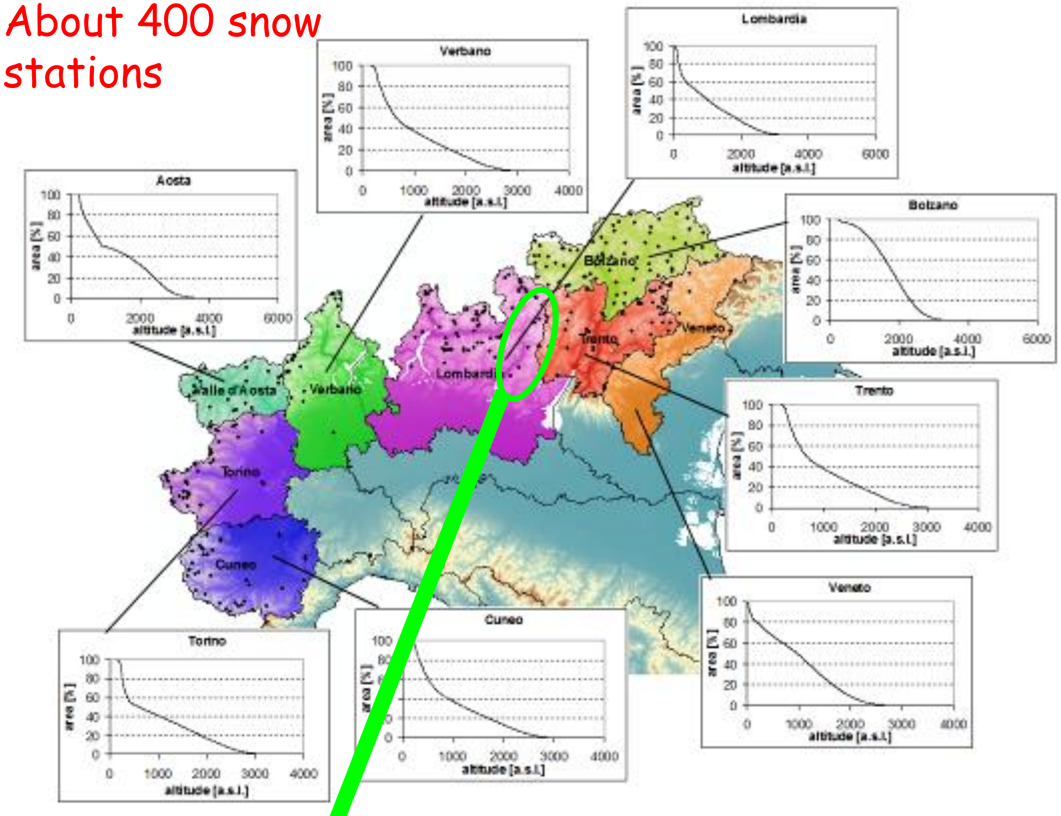


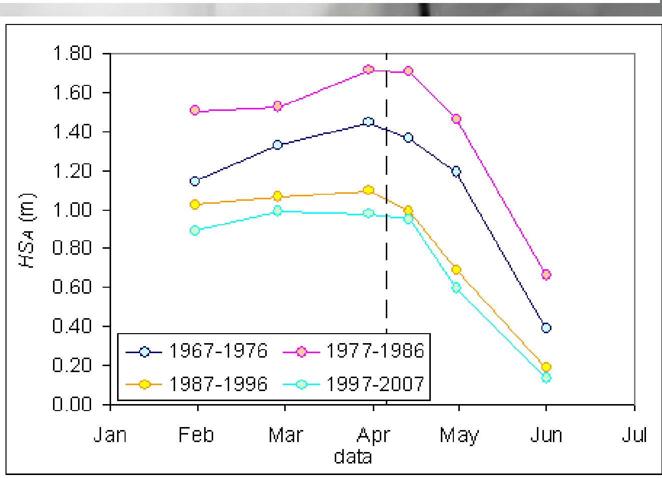


Hydrological changes in the Alps

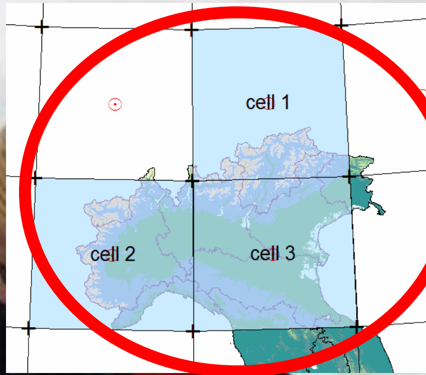
Snow cover

About 400 snow stations



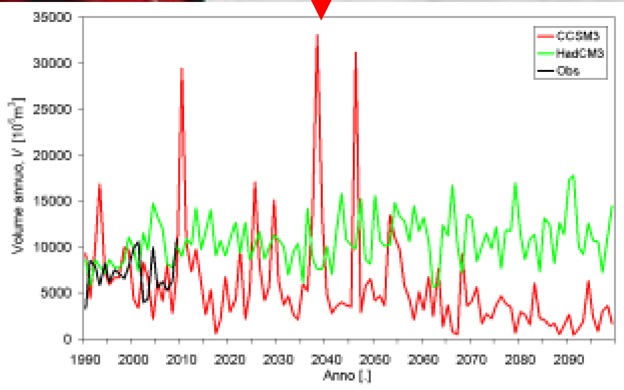


Snow regime variations



HadCM3

CCSM3




ORIGINAL PAPER

Evidence of climate change within the Adamello Glacier of Italy

Daniele Bocchiola · Guglielmina Diolaiuti

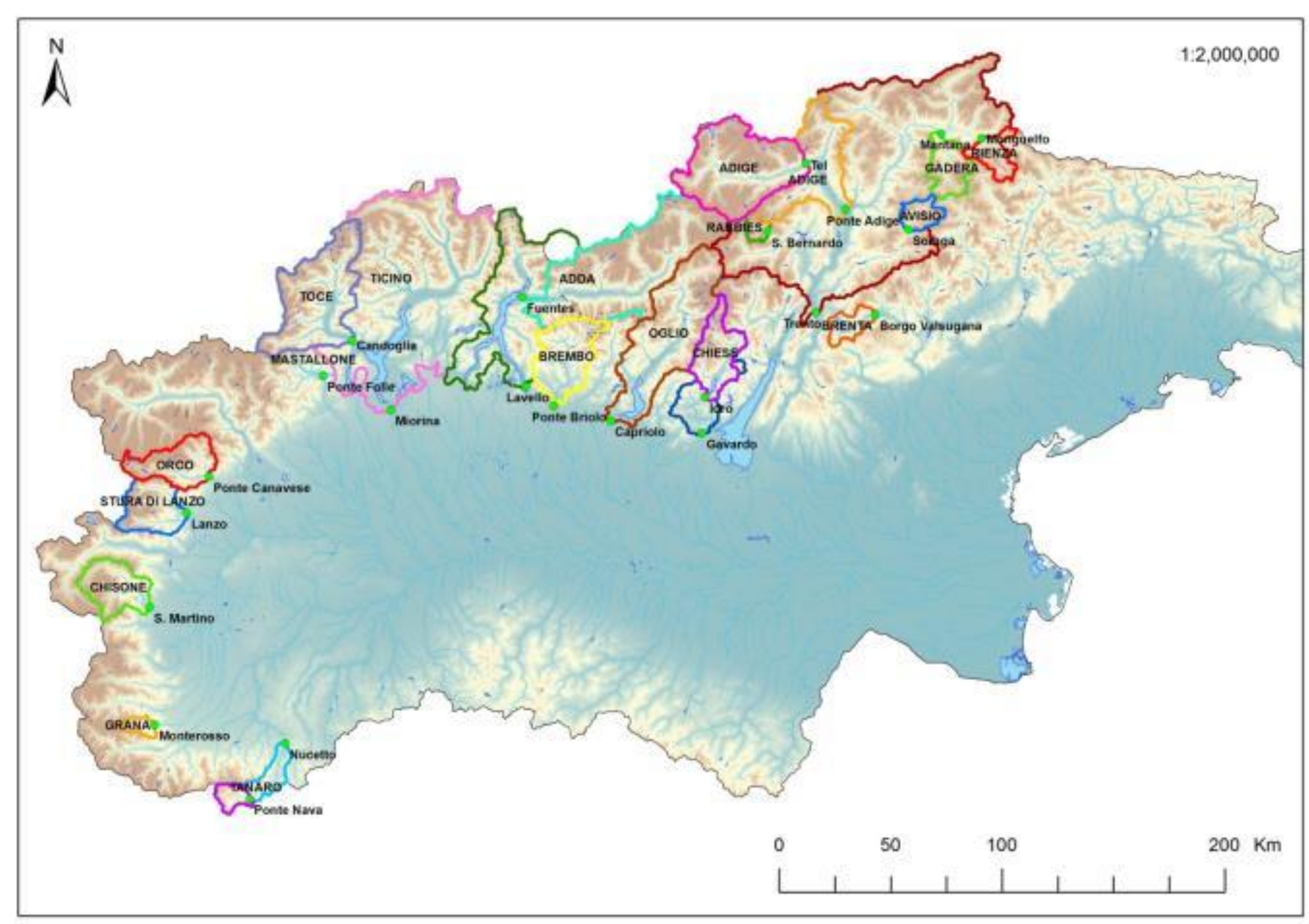

Cold Regions Science and Technology

Assessment of future snowfall regimes within the Italian Alps using general circulation models

A. Soncini, D. Bocchiola

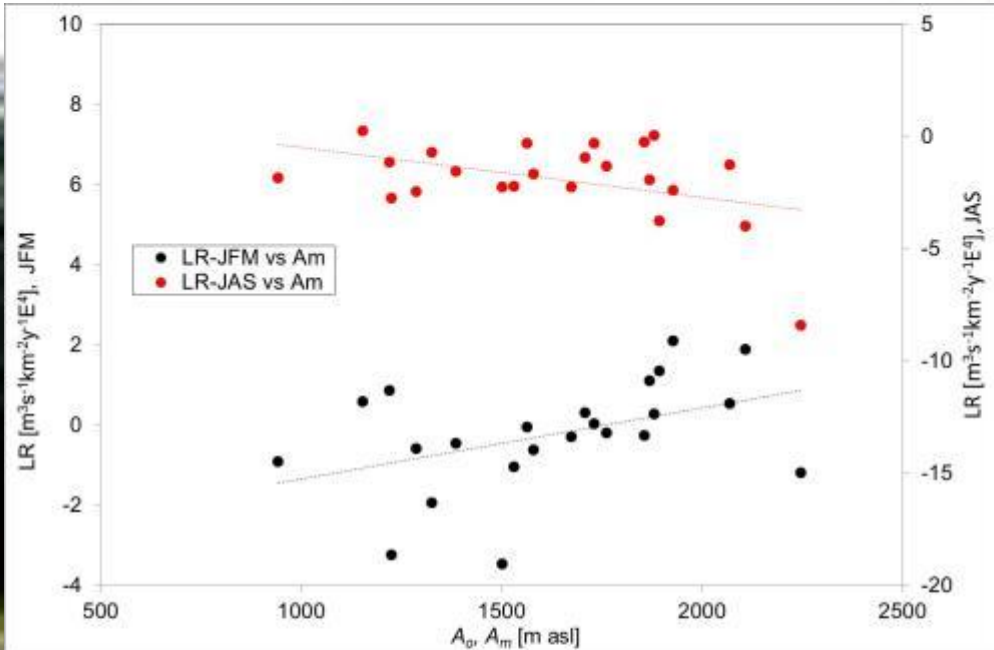
Hydrological changes in the Alps

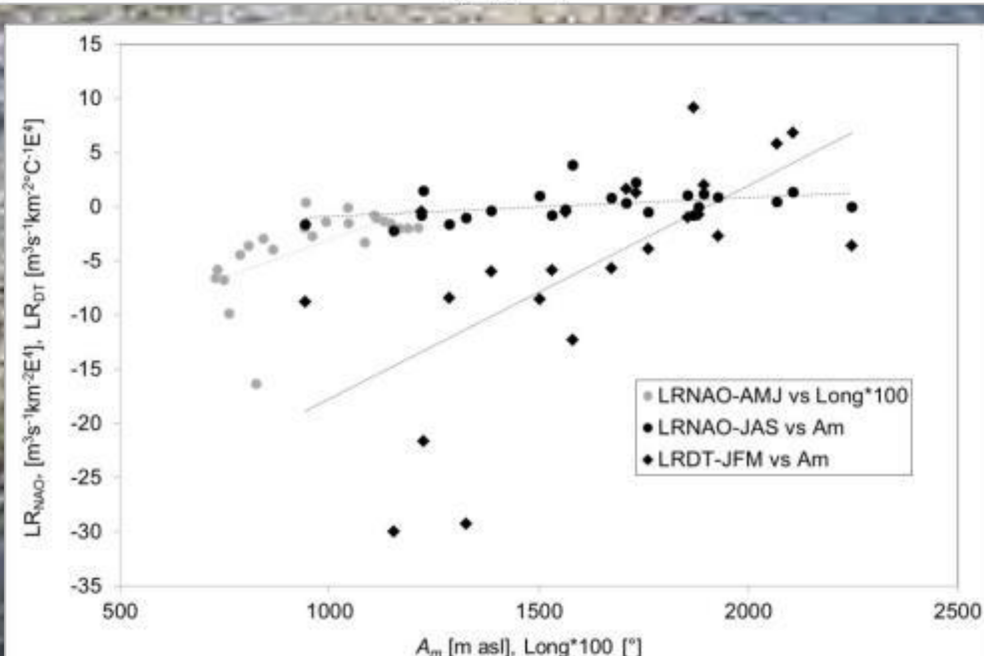
In stream water resources



We sistematically investigated long term (1921-2011, with variable length of data series) changes of yearly and seasonal discharges of 23 Alpine rivers in Northern Italy, to evidence non stationarity, and trends using linear regression, and Mann Kendall test, traditional and progressive.

Hydrological changes in the Alps   In stream water resources



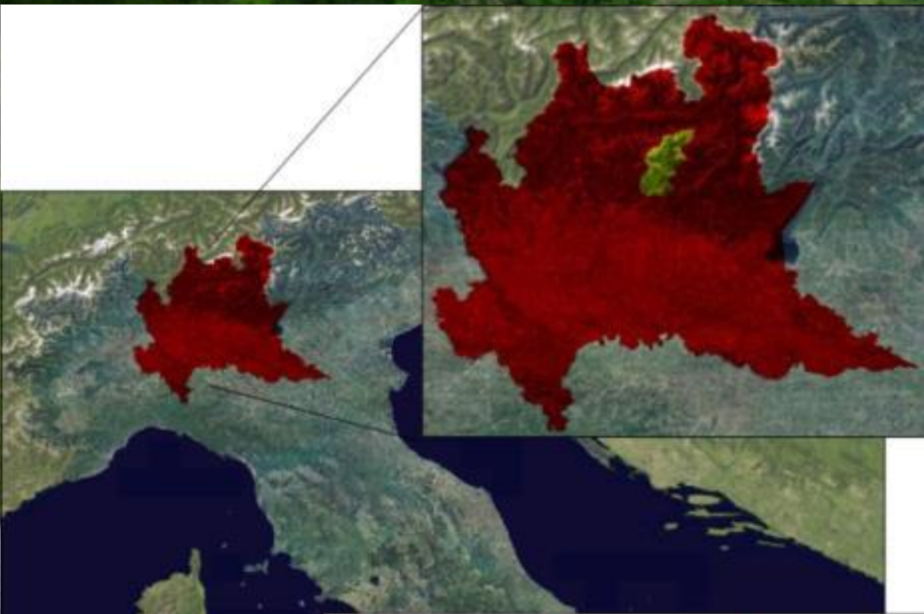


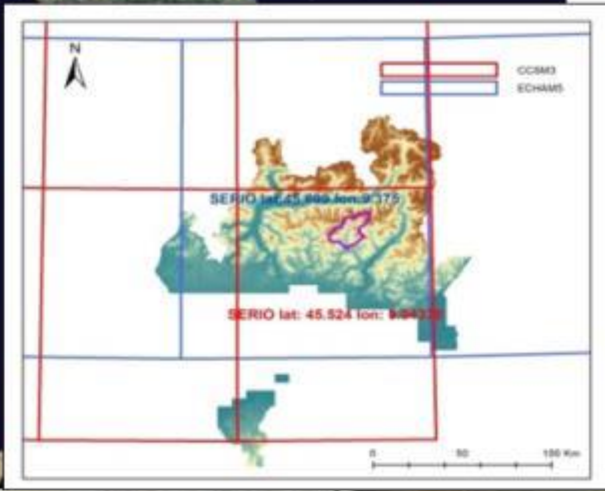
NAO and global thermal anomalies DT are correlated against the rate of variation of hydrological fluxes, with the intensity of correlation linked to altitude and longitude. The observed trends may be explained by:

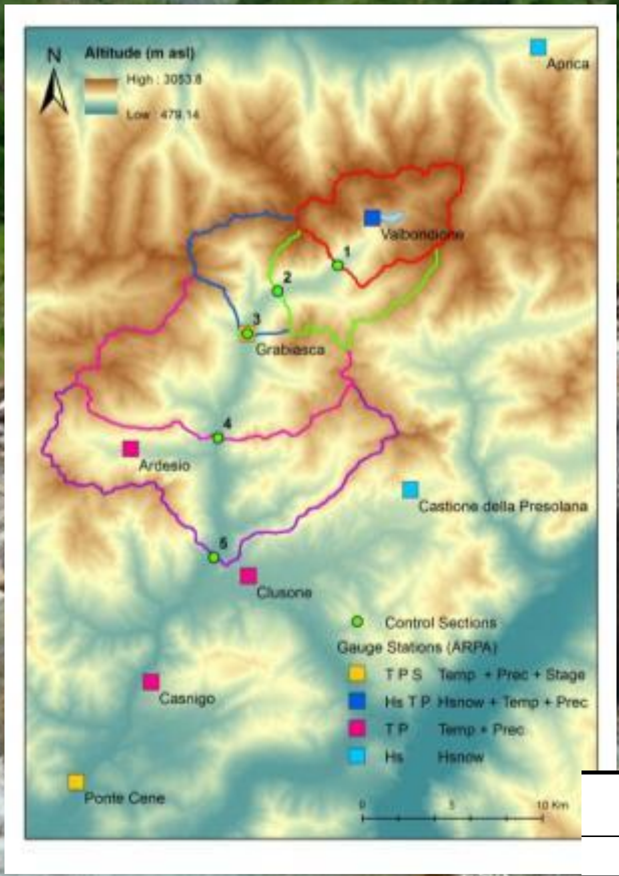
i) Trading of rainfall for snowfall during Winter, resulting into larger flows, and affecting more highest catchments and Northern areas,
ii) Lack of snow cover at thaw, and shrinking of ice covered areas, decreasing melt water deliver during Spring, and Summer, more evident at the highest altitudes, and
iii) Increase of evapotranspiration driven by temperature, leading to increased soil moisture uptake and decreased in stream fluxes at the intermediate altitudes.

Future water resources- a case study

The Serio river (ca. 92 km^2 in Grabiasca measured outlet)

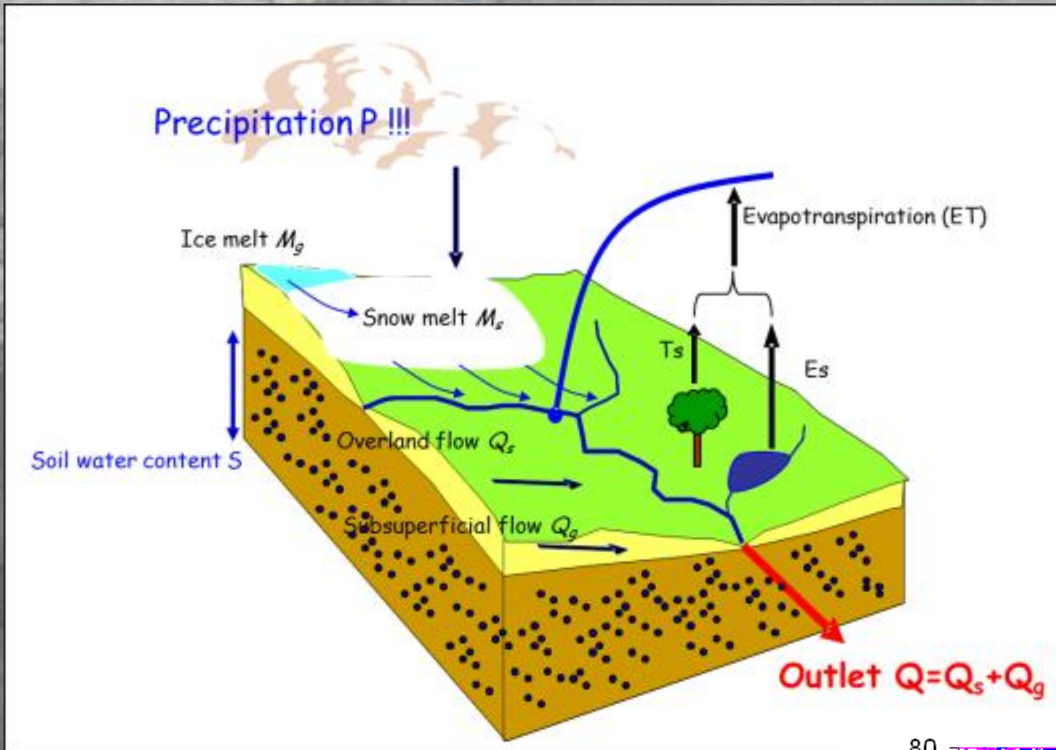






Gauge Stations	*A* [m asl]	*T*	*P*	*Hs*	*Q*
Valbondione	1802	x	x	x	-
Grabiasca	738	x	x	-	x
Ardesio	1002	x	x	-	-
Clusone	599	x	x	-	-
Casnigo	501	x	x	-	-
Ponte Cene	361	x	x	-	x
Castione della Presolana	1180	-	-	x	-
Aprica	1950	-	-	x	-

Hydrological model



vater content
 precipitation (rain and snow)
ting from snow
ting from glacier
potranspiration
-superficial discharge

ormation:
discharge
soil water content

ETP= potential evapotranspiration rate
R_a= total incoming extraterrestrial solar
radiation

$$_g \quad \left(S_{Max} \right)$$

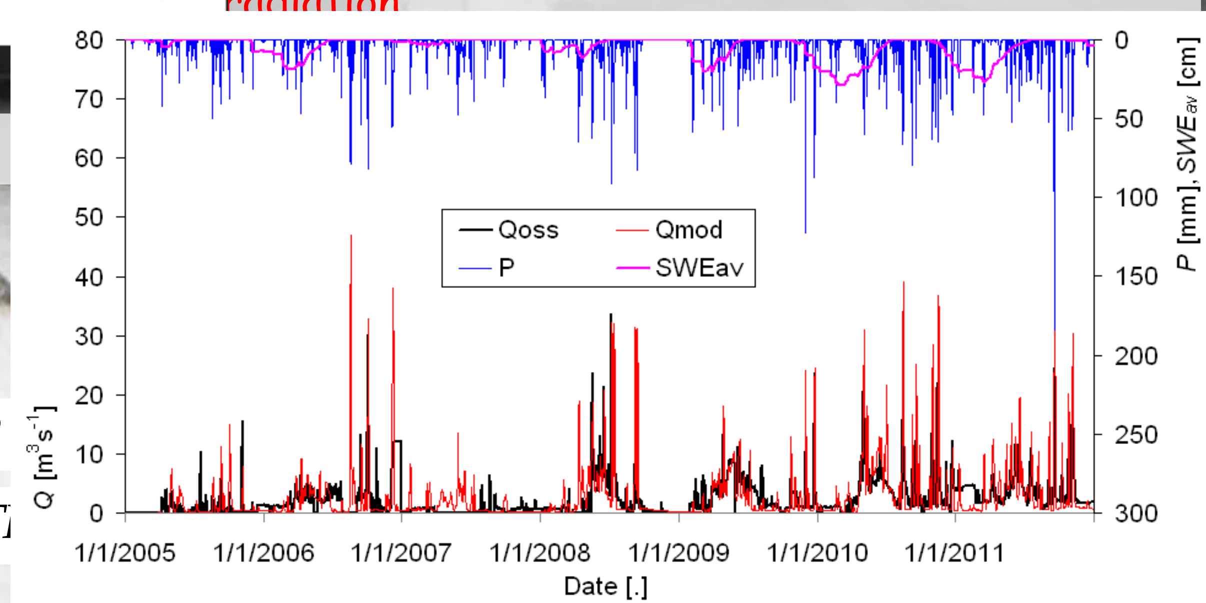
Power law for sub-superficial discharge

K= saturated permeability
k= scaling exponent

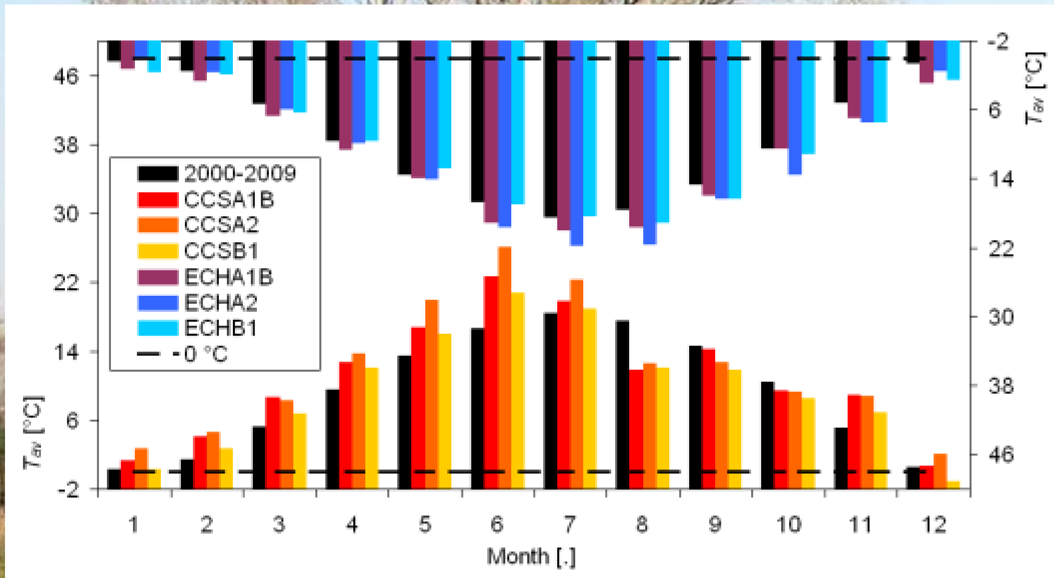
$$ET = Es + Ts$$

$$Es = \alpha(\theta)\, ETP$$

$$Ts = \beta(\theta)\, ETP$$



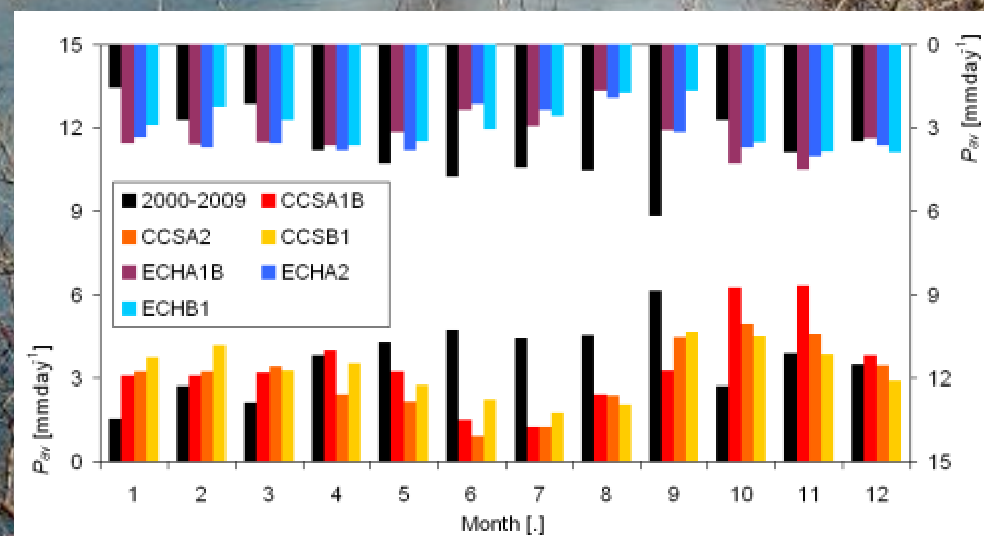
Climate scenarios 2045-2054 (vs 2000-2009)



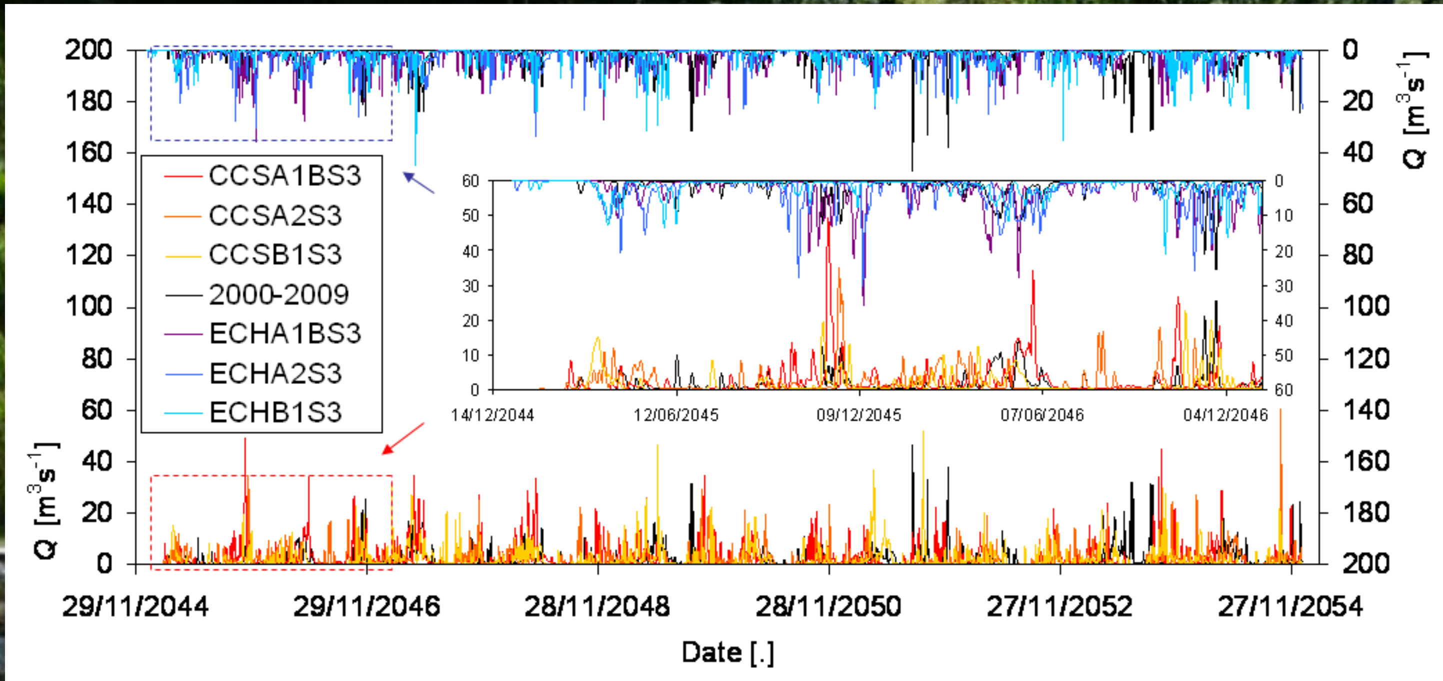
Average monthly temperatures during 2045-2054, vs 2000-2009, Grabiasca (738 masl)

Variable	Description	Values			
	CCSM3	CO	CCSA1B	CCSA2	CCSB1
P_{CUM} [mm]	Total yearly precipitation	*1344*	*1255*	*1103*	*1192*
T_{av} [°C]	Temperature Grabiasca	*9.4*	*11.3*	*11.6*	*10.0*
ET_{av} [mm]	Mean yearly evapotranspiration	430	364	360	350
SWE_{av} [mm]	Mean daily snow water equivalent	45.8	29.5	23	44.6
Q_{av} [m^3s^{-1}] S1	Mean in stream discharge	1.01	1.24	1.05	1.18
Q_{av} [m^3s^{-1}] S2	Mean in stream discharge	1.61	1.98	1.66	1.87
Q_{av} [m^3s^{-1}] S3	Mean in stream discharge	2.16	2.65	2.22	2.50
Q_{av} [m^3s^{-1}] S4	Mean in stream discharge	3.85	4.75	3.95	4.45
Q_{av} [m^3s^{-1}] S5	Mean in stream discharge	5.46	6.76	5.57	6.29
	ECHAM5	CO	ECHA1B	ECHA2	ECHB1
P_{CUM} [mm]	Total yearly precipitation	*1344*	*1200*	*1188*	*1068*
T_{av} [°C]	Temperature Grabiasca	*9.4*	*10.8*	*11.2*	*10.5*
ET_{av} [mm]	Mean yearly evapotranspiration	430	415	397	395
SWE_{av} [mm]	Mean yearly snow water equivalent	45.8	25.9	37.9	25.6
Q_{av} [m^3s^{-1}] S1	Mean in stream discharge	1.01	1.13	1.12	0.98
Q_{av} [m^3s^{-1}] S2	Mean in stream discharge	1.61	1.79	1.78	1.54
Q_{av} [m^3s^{-1}] S3	Mean in stream discharge	2.16	2.39	2.38	2.05
Q_{av} [m^3s^{-1}] S4	Mean in stream discharge	3.85	4.23	4.23	3.61
Q_{av} [m^3s^{-1}] S5	Mean in stream discharge	5.46	5.97	5.98	5.06

Average monthly precipitation during 2045-2054, vs 2000-2009, Grabiasca (738 masl)

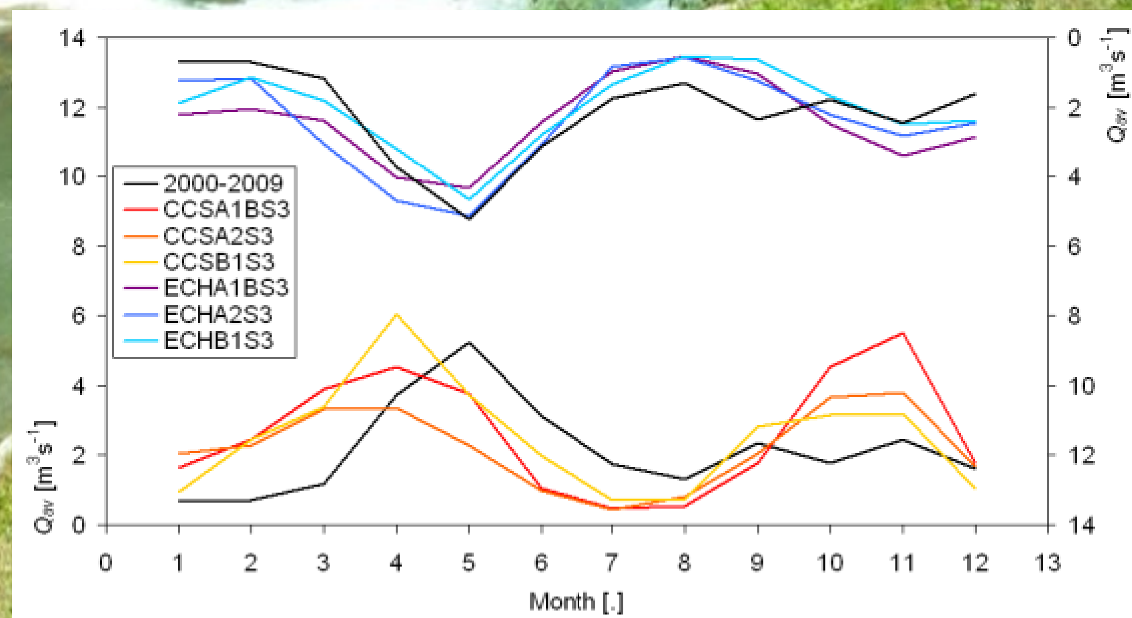


Hydrological scenarios 2045-2054 (vs 2000-2009)



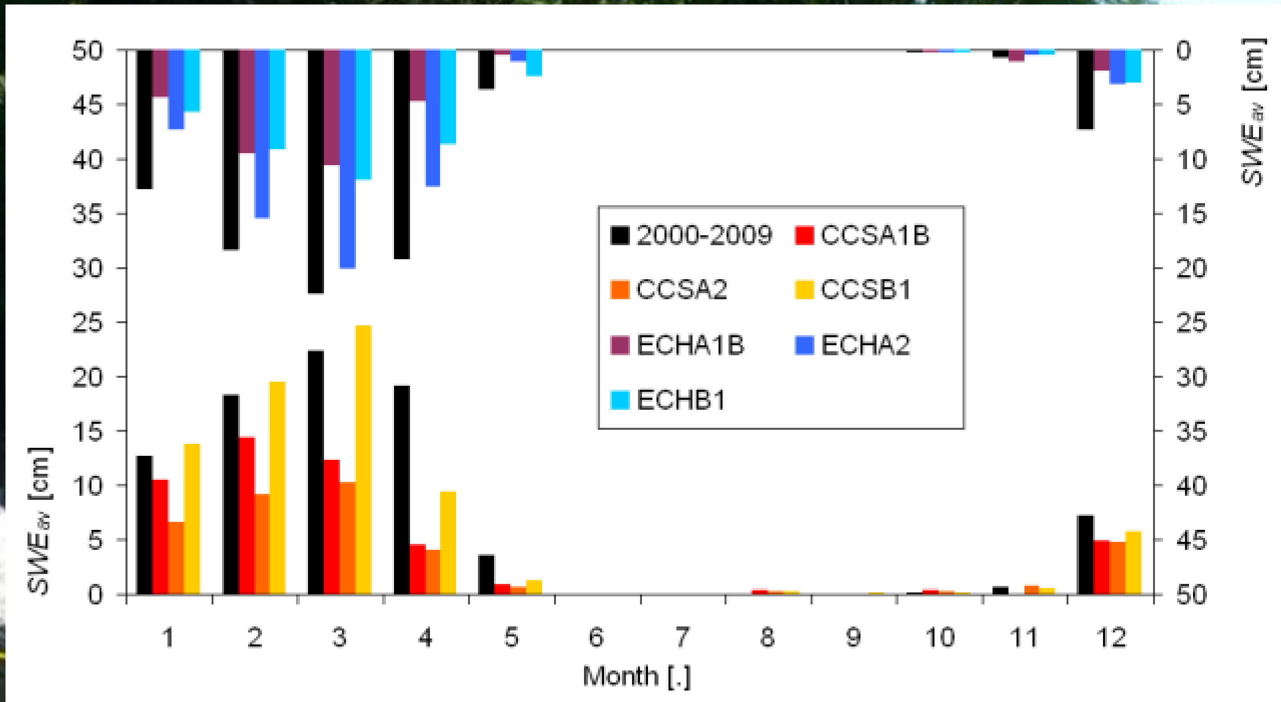
Daily discharges during 2045-2054, vs 2000-2009, Grabiasca (738 masl)

Daily discharges during 2045-2054, vs 2000-2009, Grabiasca (738 masl)

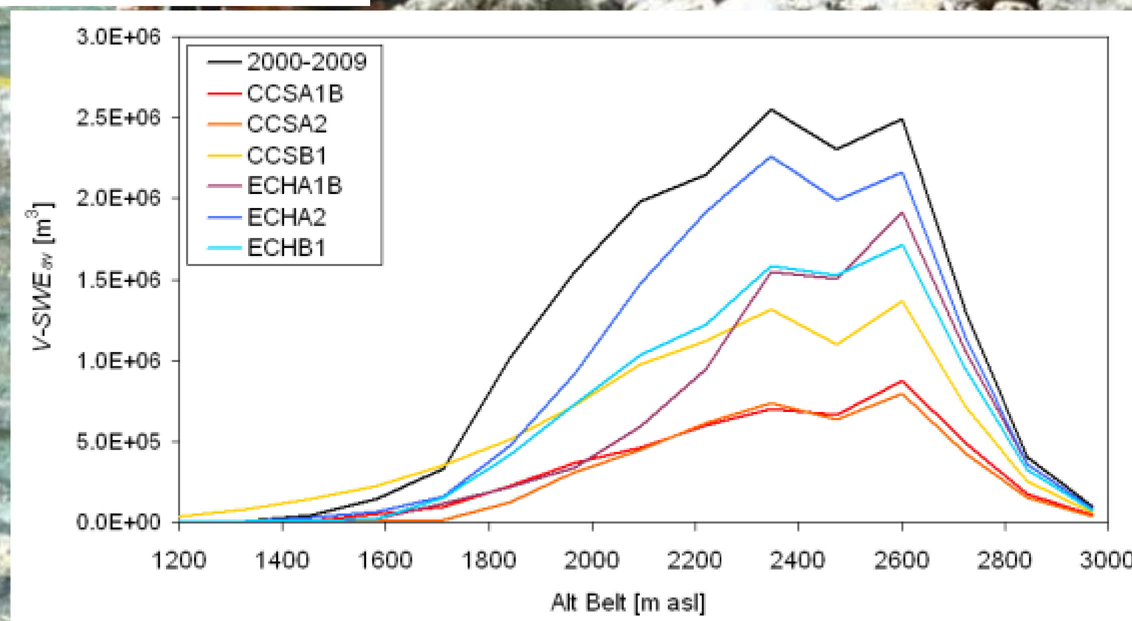


Snow cover scenarios 2045-2054 (vs 2000-2009)

Mean monthly snow water equivalent on the ground at 2000 m asl.



Mean monthly volume of water under snow form V-SWE, within each altitude belt.



Conclusions (so to speak !!)

- Recent studies provided clues of modified hydrological cycle in the Alps of Italy.

- Decreased snow and ice coveras per increased temperatures, may have resulted into increased Fall and Winter floods, and subsequently earlier melt and decreased instream flows in Summer.

- Projected hydrological behavior until half century of instream flows for a some case study catchments in the Alps (e.g. Serio, Oglio) displays potentially enhanced trends as reported above, and noticeable shifts of hydrological cycle, with potential fallout upon the riverine environment.

- Future snowline will likely be uplifted, and snow water decreased substantially.

Attend the posters:

1) Soncini, A. et al., Future hydrological regimes under climate change scenarios in the Upper Indus Basin: the case study of the Shigar river. Session: Water

2) Paramithiotti, V. et al., Assessing hydrologic components of a glaciated catchment in the central Himalaya. Session: Cryosphere.