Database of Italian mountain glaciers

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Dendro Group (Riccardo Cerrato, Anna Coppola, Giovanni Leonelli, Manuela Pelfini, Valter Maggi, Mattia de Amicis, Paolo Cherubini, Hans Linderholm, Goteborg Univ, Björn Gunnarson, Stockholm Univ; e Italy 2K Eurocold Team)

SISC - Società Italiana per le Scienze del Clima - side event NextData, Bologna 27 ottobre 2017

WP 1.6: Risorse criosferiche montane

I ghiacciai alpini e la copertura nevosa sono indicatori molto sensibili ai cambiamenti climatici, e rappresentano un serbatoio di risorsa idrica fondamentale, in grado di rilasciare acqua di fusione nei periodi caldi, e tipicamente con precipitazione scarsa.

Questo WP è dedicato alle creazione di un database coerente, temporalmente e cronologicamente, di informazioni sui ghiacciai alpini nelle montagne italiane.

WP 1.6: Risorse criosferiche montane

- *Task 1*

Monitoraggio e censimento quantitativo dei ghiacciai alpini

dati quantitativi, georiferiti (e a data definita) di lunghezza, area, bilanci di massa, variazioni della *Equilibrium Line Altitude*; raccolta di materiale iconografico e fotografico / fotogrammetrico) in collaborazione con il Comitato Glaciologico Italiano.

Risultati attesi: Database delle risorse glaciali delle Alpi italiane

Task 2

Sviluppo e validazione di modelli concettuali e/o empirici della dinamica dei ghiacciai alpini. Equazioni di evoluzione dei vari ghiacciai alpini, suddivisi per macro-aree e geomorfologie specifiche.

Risultati attesi: modelli concettuali e/o empirici della risposta dei ghiacciai alla variabilità climatica

Minimal glacier model

assess glacier response to climatic fluctuations in the past or in the future

Minimal Glacier Model *(J.Oerlemans, 2008)*

Input: **Mass Balance** & **ELA**

Output: **Flow line lenght**

Boundary Condition:

$$B_S = W\beta(H_m + b_m - E)L$$

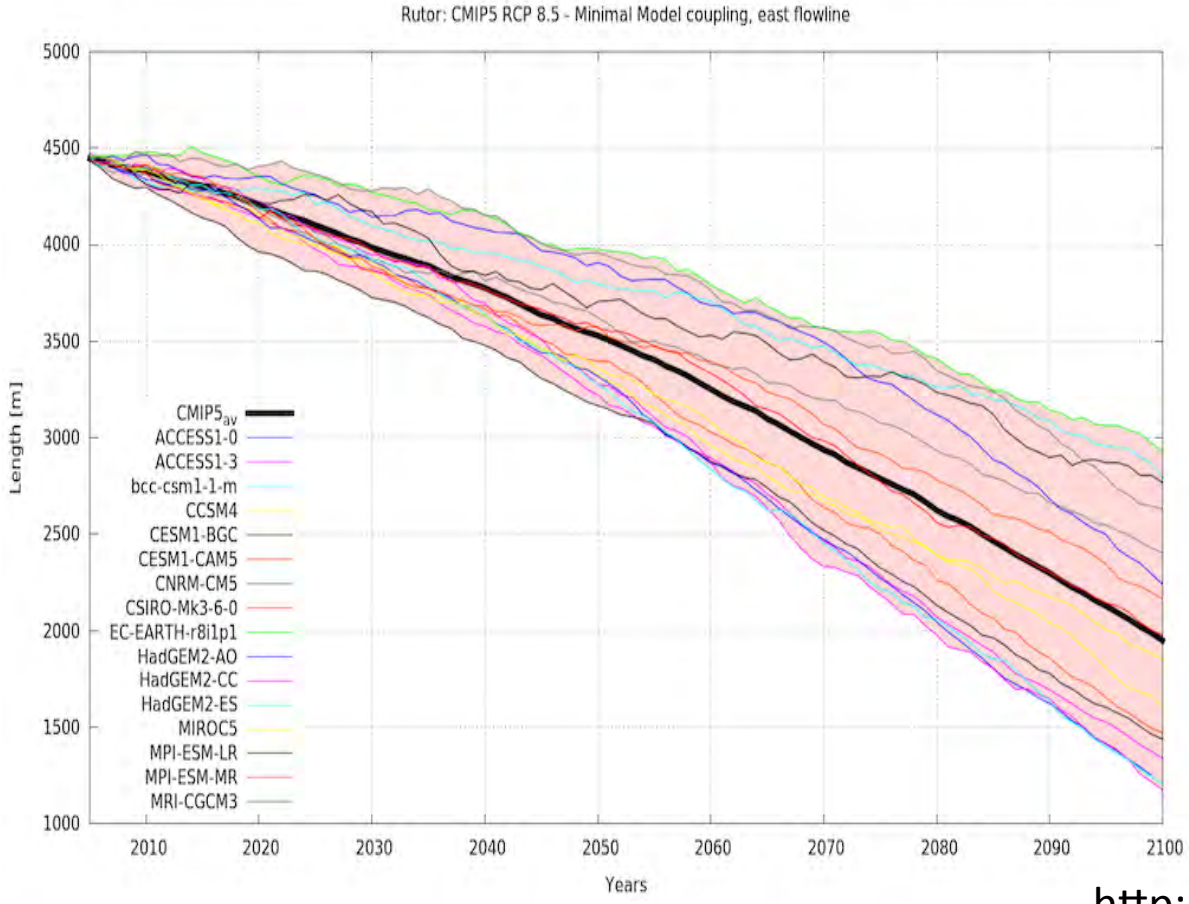
$$\frac{dL}{dt} = \left(\frac{3\alpha_m}{2(1+\upsilon s)} L^{1/2} - \frac{\alpha_m \upsilon}{(1+\upsilon s)^2} L^{1/2} \frac{\partial s_m}{\partial L} \right)^{-1} \frac{B_S}{W}$$

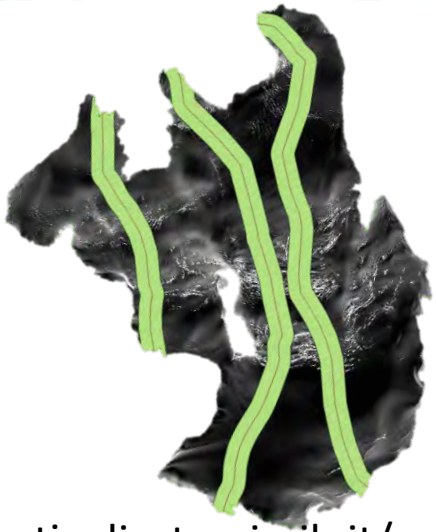
Model BC computable by GIS

Developed an iterative GIS module

All the module results are rely on DTM resolution!!

to **SPATIAL approach using GIS**





http://geomatic.disat.unimib.it/mgm

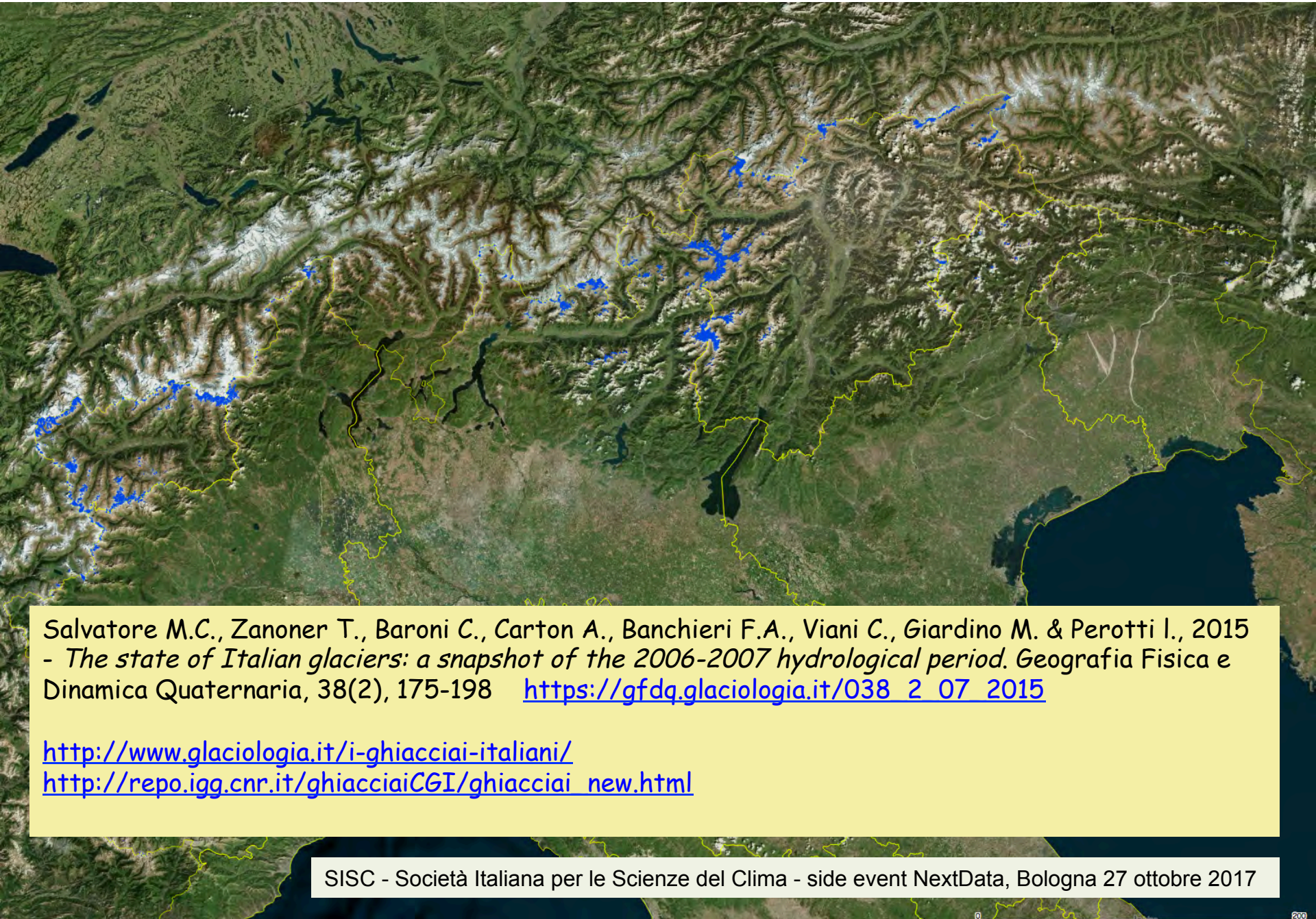
WP 1.6: Risorse criosferiche montane 23

- *Task 3*

stima dello stato e dei cambiamenti della copertura nevosa sulle montagne italiane (spessore e durata del manto nevoso, *Snow Water Equivalent*, precipitazione solida) mediante raccolta dei dati in situ da stazioni disponibili, immagini aeree e dati satellitari e di rianalisi.

→ **Vincenzo Levizzani CNR (FRMetS)**

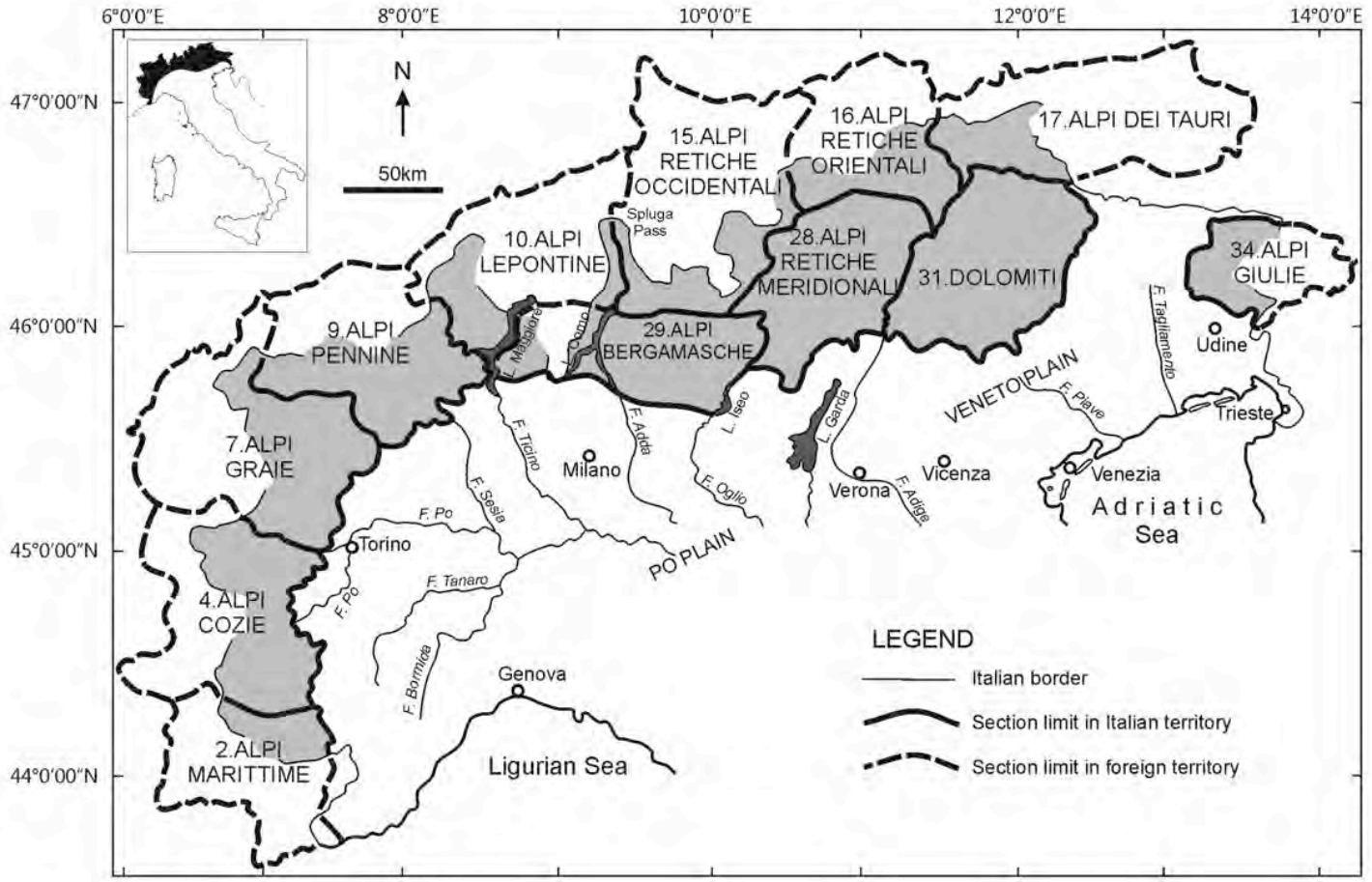
MOUNTAIN GLACIERS DATABASE: 2006-07.



Salvatore M.C., Zanoner T., Baroni C., Carton A., Banchieri F.A., Viani C., Giardino M. & Perotti l., 2015 - *The state of Italian glaciers: a snapshot of the 2006-2007 hydrological period*. Geografia Fisica e Dinamica Quaternaria, 38(2), 175-198 https://gfdq.glaciologia.it/038_2_07_2015

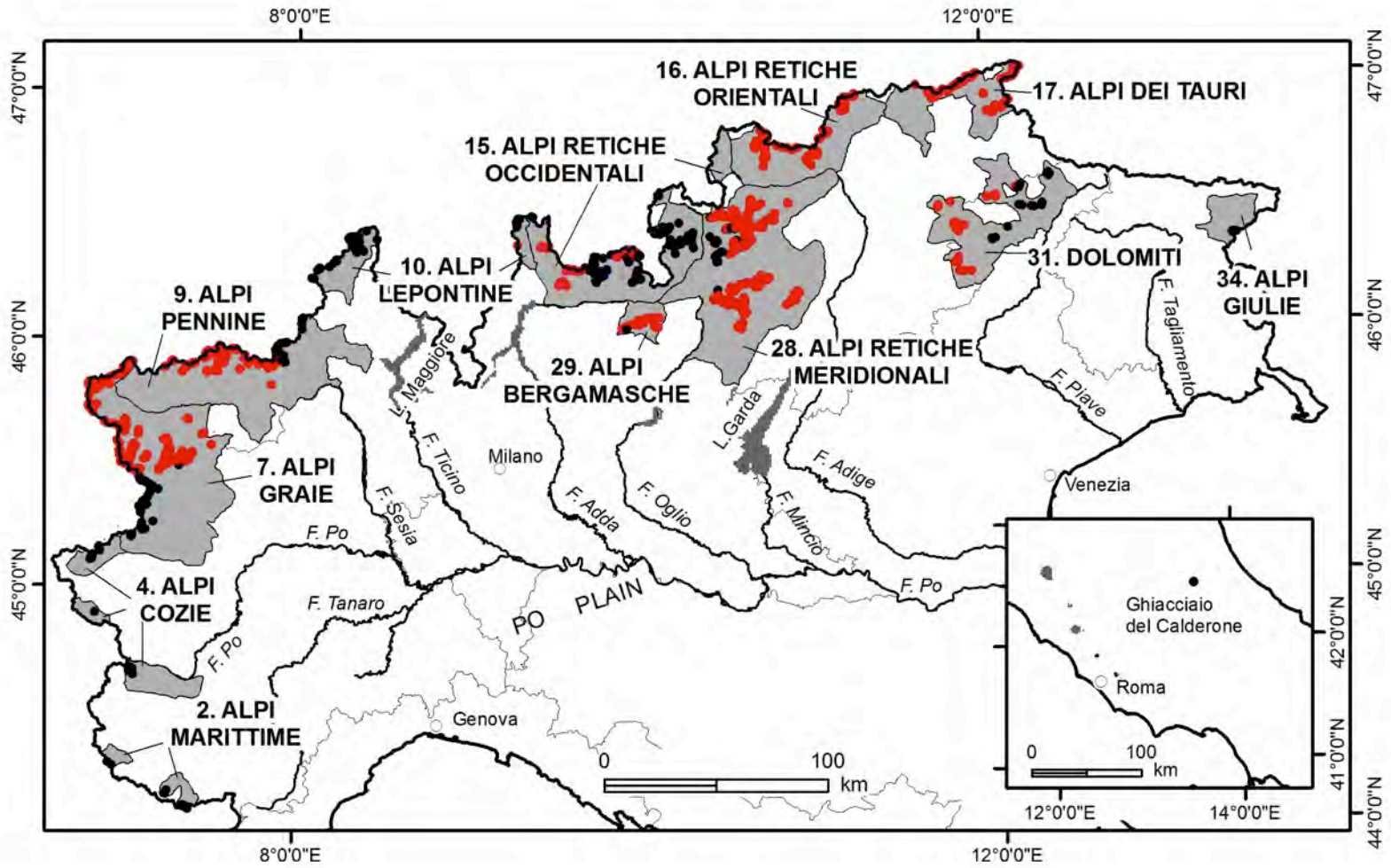
http://www.glaciologia.it/i-ghiacciai-italiani/
http://repo.igg.cnr.it/ghiacciaiCGI/ghiacciai_new.html

Salvatore M.C., Zanoner T., Baroni C., Carton A., Banchieri F.A., Viani C., Giardino M. & Perotti l., 2015 - The state of Italian glaciers: a snapshot of the 2006-2007 hydrological period. Geografia Fisica e Dinamica Quaternaria, 38(2), 175-198 https://gfdq.glaciologia.it/038_2_07_2015



Geographical setting of the Alps according to the International Standardized Mountain Subdivision of the Alps (ISMSA). The division and toponymy of the reliefs are shown at the section level. Only sections with glaciers are represented. Light grey indicates sections partially or completely within the Italian territory.

Salvatore et al. 2015

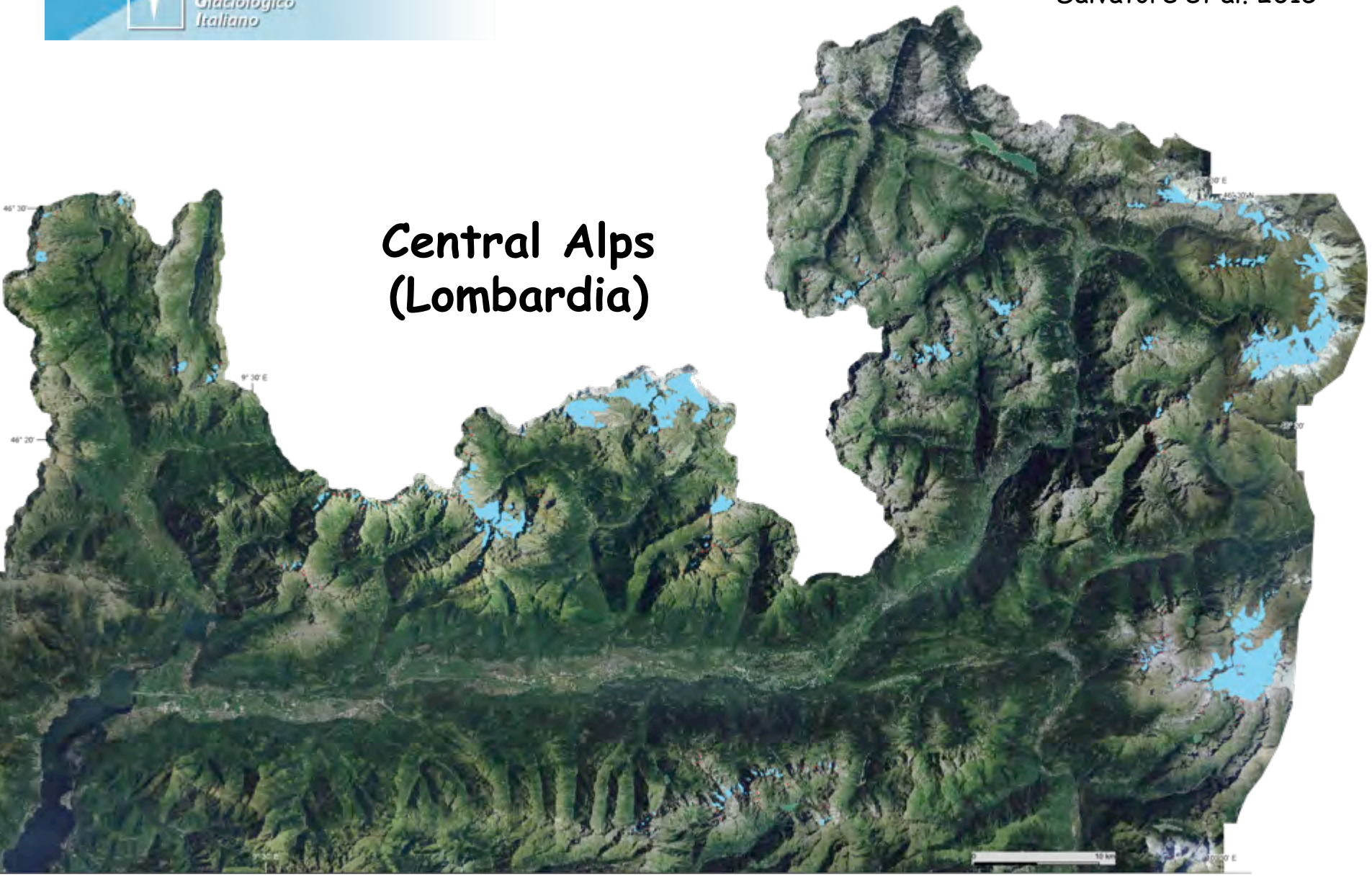


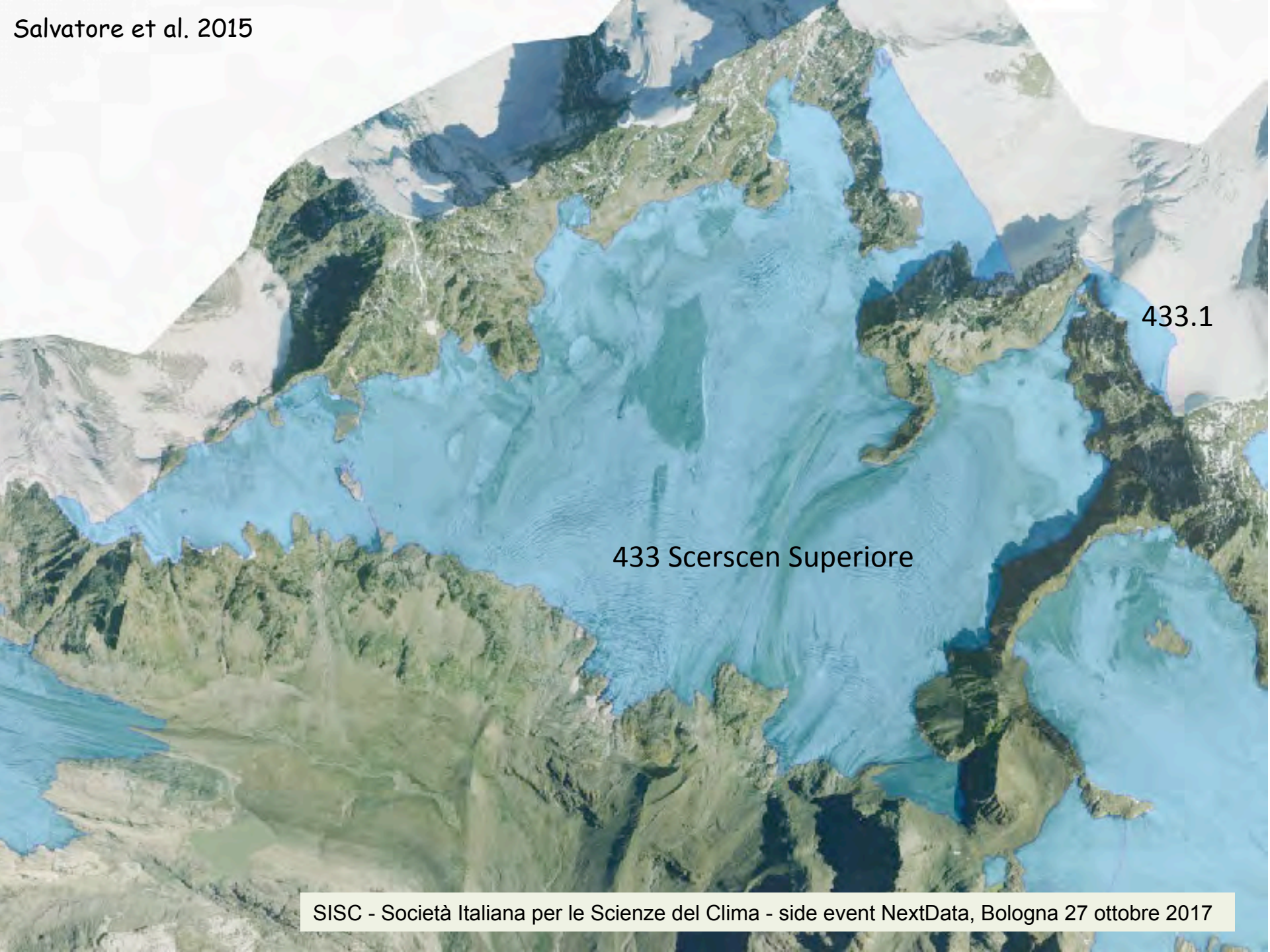
Location of Italian glaciers in 2006-2007, as detected from orthophotos provided by the National Geoportal of the Ministry of Environment and Protection of Land and Sea through the Web Map Service. Grey represents the ISMSA sections hosting glaciers in the Italian Alps. Red and black circles refer to glaciers detected in orthophotos taken in 2006 and 2007, respectively.

Comitato Glaciologico Italiano

Salvatore et al. 2015

Central Alps (Lombardia)




Salvatore et al. 2015
433.1
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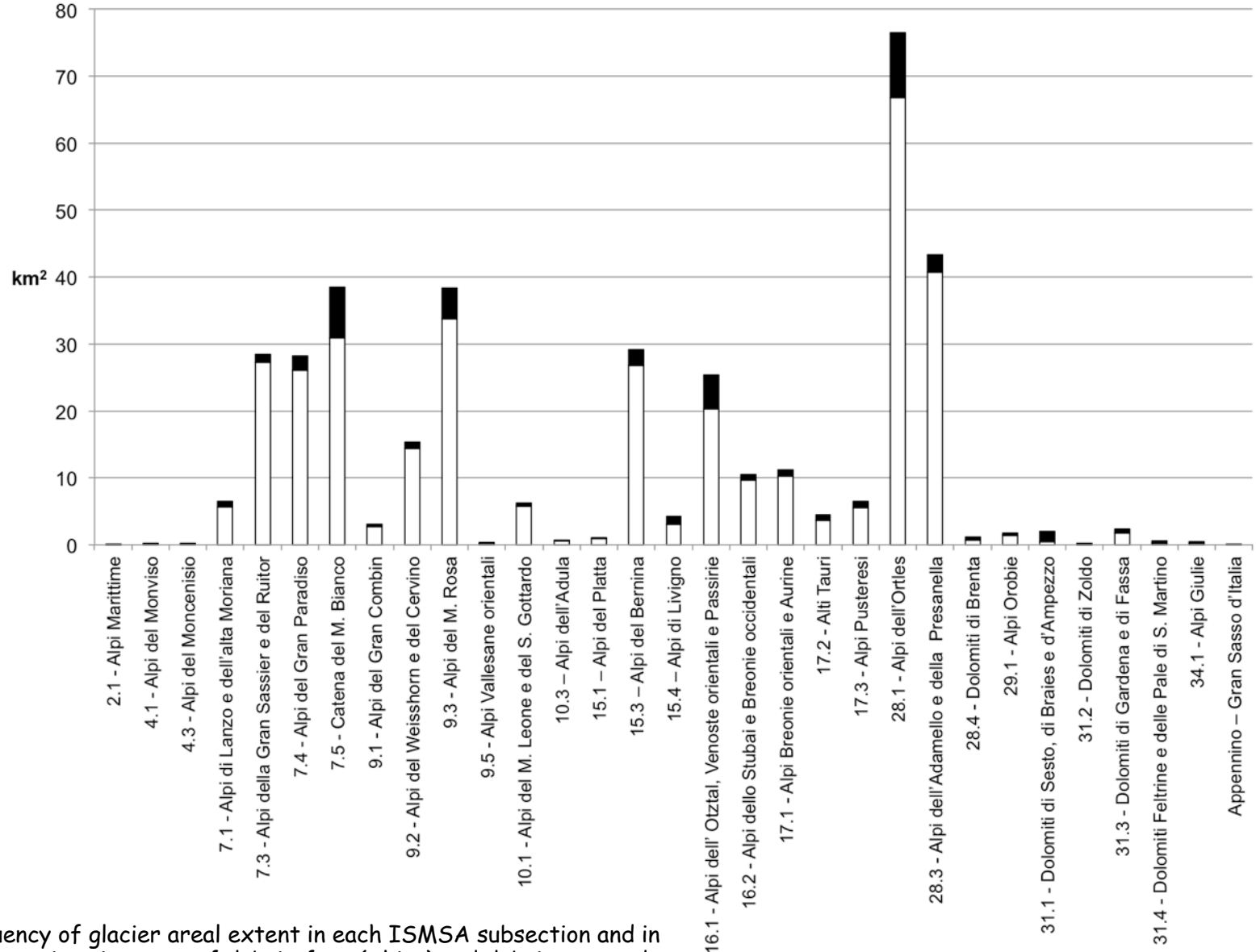
Attribute table related to 2006-2007 glaciers with morphometric and geographic data

code	sub_code	wgi_code	max_elev	min_elev	tot_area	deb_area	exp_area	max_width	min_width	max_length	mean_or	mean_slope	date_	x_coord	y_coord	NOMEGRUPPO	SUPGRUP_N
219	0	IT4L01517011	4810	2279	6.382	0.419	5.963	1584.6	0.0	4093.1	SE	21	23082006	6.893	45.832	Monte Bianco	Massiccio del Monte Bianco
304	0	IT4L01502002	4334	2356	9.809	0.846	8.963	1963.5	0.0	5030.7	SW	21	4092006	7.833	45.909	Breithorn - Lyskamm	Gruppo del Monte Rosa i.s.a.
314	0	IT4L01042009	4297	2718	1.547	0.190	1.357	1292.9	58.4	2369.9	SE	34	4092006	7.891	45.919	Monte Rosa	Gruppo del Monte Rosa i.s.a.
299	0	IT4L01504005	4181	2925	0.946	0.038	0.908	781.0	0.0	2428.3	SW	27	4092006	7.788	45.914	Breithorn - Lyskamm	Gruppo del Monte Rosa i.s.a.
298	0	IT4L01504005	4039	2822	1.133	0.233	0.900	781.8	0.0	2778.5	SW	23	4092006	7.775	45.917	Breithorn - Lyskamm	Gruppo del Monte Rosa i.s.a.
129	0	IT4L01513007	4038	2813	1.766	0.034	1.732	1011.6	0.0	3117.9	NW	21	4092006	7.257	45.522	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
130	0	IT4L01513008	3864	3183	0.364	0.000	0.364	554.4	0.0	1640.1	NW	22	4092006	7.254	45.516	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
440	0	IT4L01123011	3850	2550	5.000	0.000	0.000	2200.0	0.0	5000.0	S	22	0	9.948	46.372	Bernina	Catena Bernina - Scalino
73	0	IT4L01451044	3849	3683	0.033	0.000	0.033	209.2	0.0	256.8	SE	33	4092006	7.273	45.514	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
128	0	IT4L01513006	3825	3050	1.166	0.027	1.139	1420.0	0.0	1265.9	W	31	4092006	7.262	45.536	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
329	1	IT4L01211026	3799	3682	0.020	0.000	0.020	281.9	0.0	110.8	E	33	6092007	7.896	45.982	Cima di Jazzi	Gruppo del Monte Rosa i.s.a.
113	0	IT4L01512023	3749	2961	1.202	0.013	1.189	887.6	0.0	2182.9	NE	20	4092006	7.280	45.540	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
490	0	IT4L01137003	3724	2866	1.029	0.257	0.772	590.3	158.7	2551.2	S	19	0	10.537	46.493	Ortles	Gruppo Ortles - Cevedale
301	0	IT4L01504007	3720	3018	0.343	0.036	0.307	571.7	0.0	1266.9	SW	28	4092006	7.788	45.905	Breithorn - Lyskamm	Gruppo del Monte Rosa i.s.a.
788	0	IT4L00112506	3711	2732	2.928	0.725	2.203	2839.7	0.0	3100.6	W	12	12092006	10.719	46.789	Palla Bianca	Catena Palla Bianca - Similaun
698	0	IT4L00102515	3696	2912	1.214	0.251	0.963	1447.8	0.0	2168.5	E	14	5092006	10.627	46.415	Cevedale	Gruppo Ortles - Cevedale
121	0	IT4L01512031	3692	2853	2.224	0.065	2.159	1760.3	0.0	3184.7	NE	15	21082006	7.274	45.597	Grivola Gran Serra	Catena del Gran Paradiso
329	0	IT4L01211014	3692	3299	0.073	0.000	0.073	247.1	0.0	329.2	E	31	6092007	7.898	45.982	Cima di Jazzi	Gruppo del Monte Rosa i.s.a.
74	0	IT4L01451045	3674	3533	0.037	0.000	0.037	175.9	0.0	268.7	SE	28	4092006	7.286	45.511	Gran Paradiso - Rocciaviva	Catena del Gran Paradiso
506bis	0	IT4L01137022	3673	2802	0.767	0.067	0.700	662.4	36.3	2029.8	NW	23	0	10.611	46.424	Ortles	Gruppo Ortles - Cevedale
507	0	IT4L01137023	3665	2970	1.057	0.025	1.032	779.2	25.8	2116.0	SW	18	0	10.607	46.413	Ortles	Gruppo Ortles - Cevedale
507.1	0	IT4L01137024	3664	2514	11.317	0.304	11.013	5559.9	297.4	3291.7	N	19	0	10.591	46.392	Ortles	Gruppo Ortles - Cevedale
510	1		3664	2514	11.317	0.304	11.013	5559.9	297.4	3291.7	NE	19	0	10.591	46.392	Cevedale	Gruppo Ortles - Cevedale
777	0	IT4L00112907	3650	2433	3.896	0.945	2.951	1489.1	0.0	4076.4	N	12	12092006	10.733	46.812	Palla Bianca	Catena Palla Bianca - Similaun
697	0	IT4L00102514	3644	2743	0.929	0.099	0.830	933.5	0.0	1583.4	E	21	5092006	10.638	46.406	Cevedale	Gruppo Ortles - Cevedale
693	0	IT4L00102510	3639	3299													
316	0	IT4L01042010	3613	2956	0.546	0.007	0.539	972.7	109.9	738.2	SW	18	4092006	7.910	45.921	Monte Rosa	Gruppo del Monte Rosa i.s.a.

WP2.1 - D2.1.A – Report on the Archives of mountain observation networks.

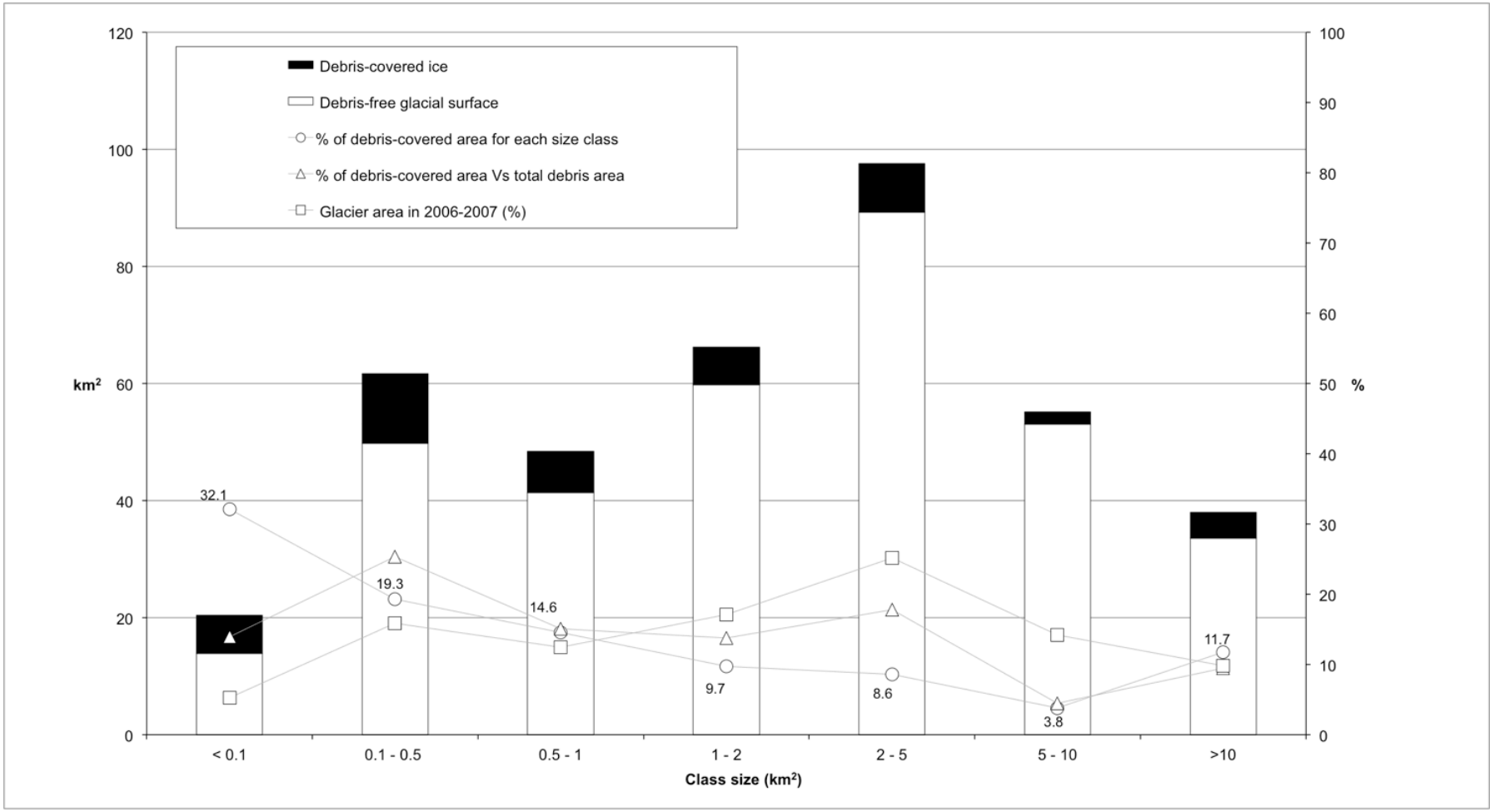
CODE ID	number assinged to the glacier as defined by the Italian Inventory (CGI-CNR, 1959-1962) or new code if glacier was not inventoried before.
SUB_CODE	number attributed to glaciers originated from fragmentation of wider body
WGI_CODE	ID number is assigned to the glacier as defined by the WGMS
TIME_STEP	Hydrological year of survey (yyyy)
MAX_ELEV	Maximum elevation of the highest point of the glacier in meters above sea level
MIN_ELEV	The minimum elevation of the lowest point of the glacier in meters above sea level
TOT_AREA	The total area of the glacier in a horizontal projection in square kilometers
DEB_AREA	Debris cover area in a horizontal projection in square kilometers
EXP_AREA	Debris free area in a horizontal projection in square kilometers
MAX_WIDTH	The maximum width of the glacier in a horizontal projection in kilometers
MIN_WIDTH	Minimum width of the glacier in a horizontal projection in kilometers
MAX_LENGTH	Maximum length of the glacier in kilometers measured along the main flowline in a horizontal projection
MEAN_OR	Mean orientation of the glacier using 8 classes centered on cardinal points (N, NW, W, SW, S, SE, E, NE).
OR_ACC	Mean orientation of the accumulation area using 8 classes centered on cardinal points (N, NW, W, SW, S, SE, E, and NE). FACULTATIVE
OR_ABL	Mean orientation of the ablation area using 8 classes centered on cardinal points (N, NW, W, SW, S, SE, E, and NE). FACULTATIVE
MEAN_SLOPE	Mean slope angle of glacier surface
DATE_	Orthophoto or satellite image acquisition data (ddmmyyyy)
X_COORD	The longitude of the glacier in decimal degrees East GW. Longitude is given to a maximum precision of 3 decimal places
Y_COORD	The latitude of the glacier in decimal degrees North. Latitude is given to a maximum precision of 3 decimal places
GL_NAME	Name of glacier following Italian Inventory (CGI-CNR, 1959-1992) or new name in case of fragmentation of glacial body or in case glacier was not inventoried before.
PRIMARY_CL	The primary classification of the glacier
FORM	The form of the glaciers

Salvatore et al. 2015



Frequency of glacier areal extent in each ISMSA subsection and in the Apennines in terms of debris-free (white) and debris-covered area (black). Values (km2) are indicated by numbers.

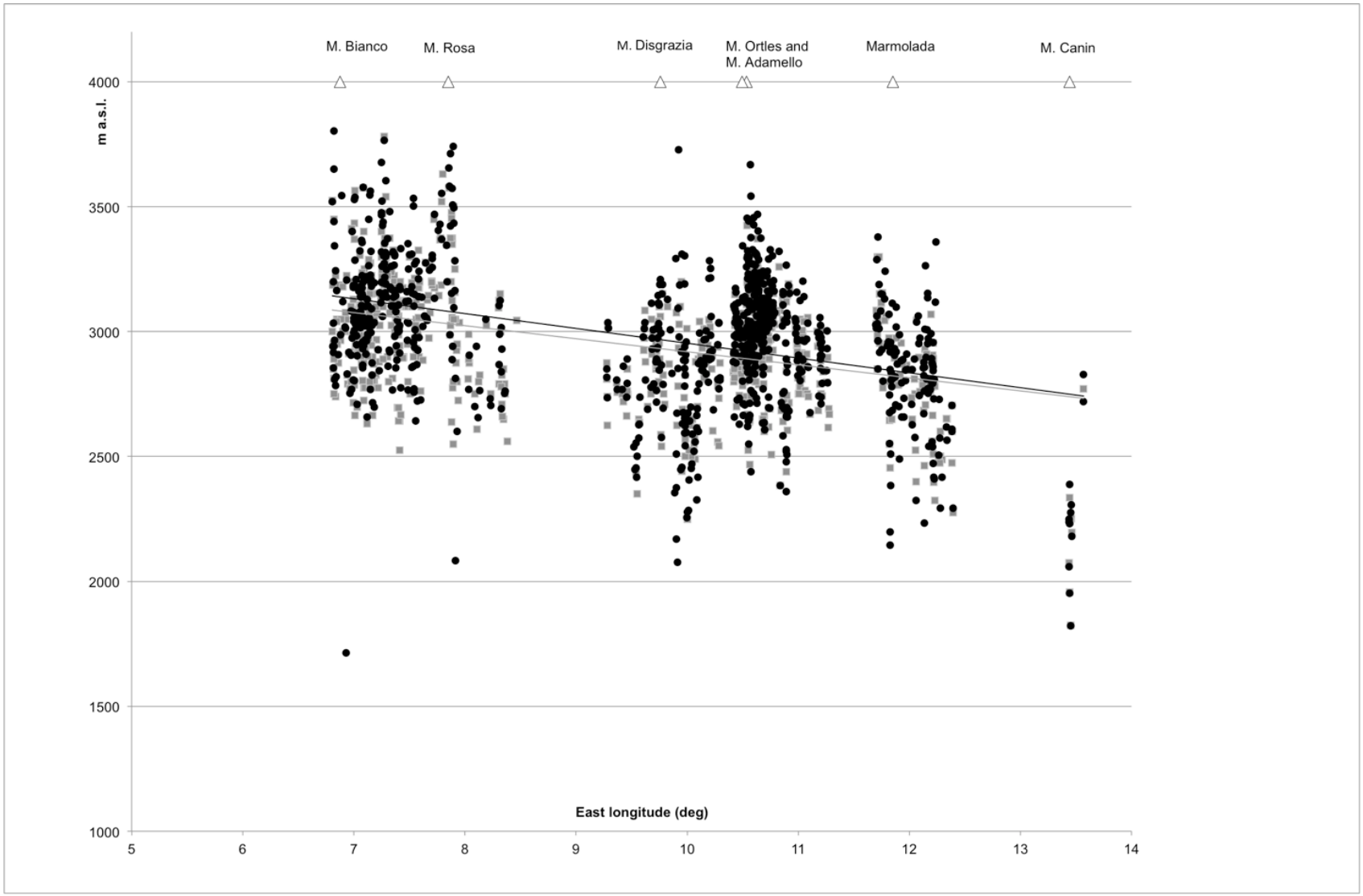
Salvatore et al. 2015



Number and areal frequency distribution of Italian glaciers in 2006-2007. Black stacks indicate the frequency of glaciers with debris cover.

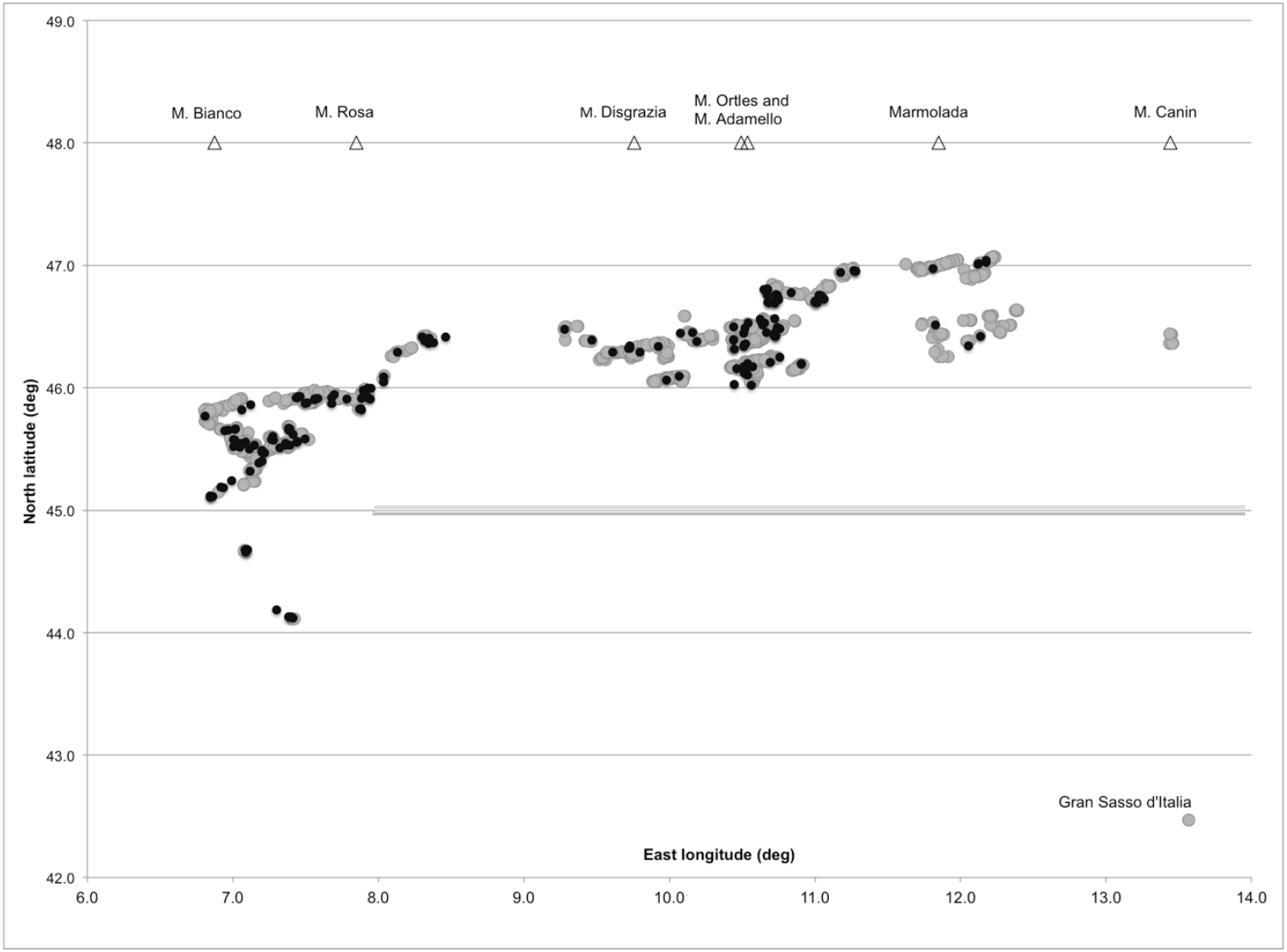
a) Areal extent (km^2) and percentage of glacier area for each size class (white square); percentage of debris covered area (circles) and percentage of debris covered area vs. total debris area for each class.

Salvatore et al. 2015



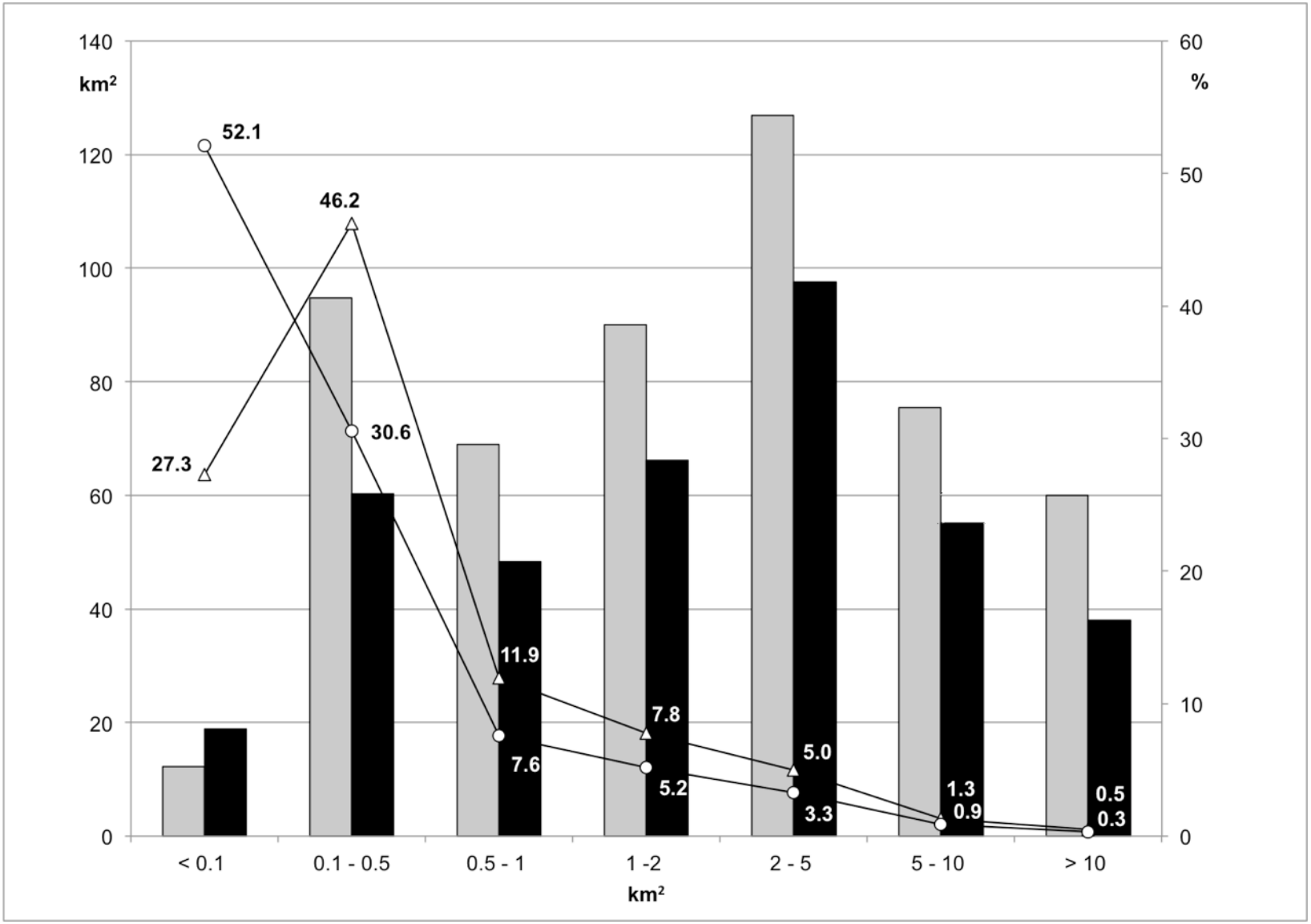
Altimetric distribution of mean elevation of Italian glaciers with respect to longitude in 2006-07 (black) and in the CGI Inventory (grey)

Salvatore et al. 2015



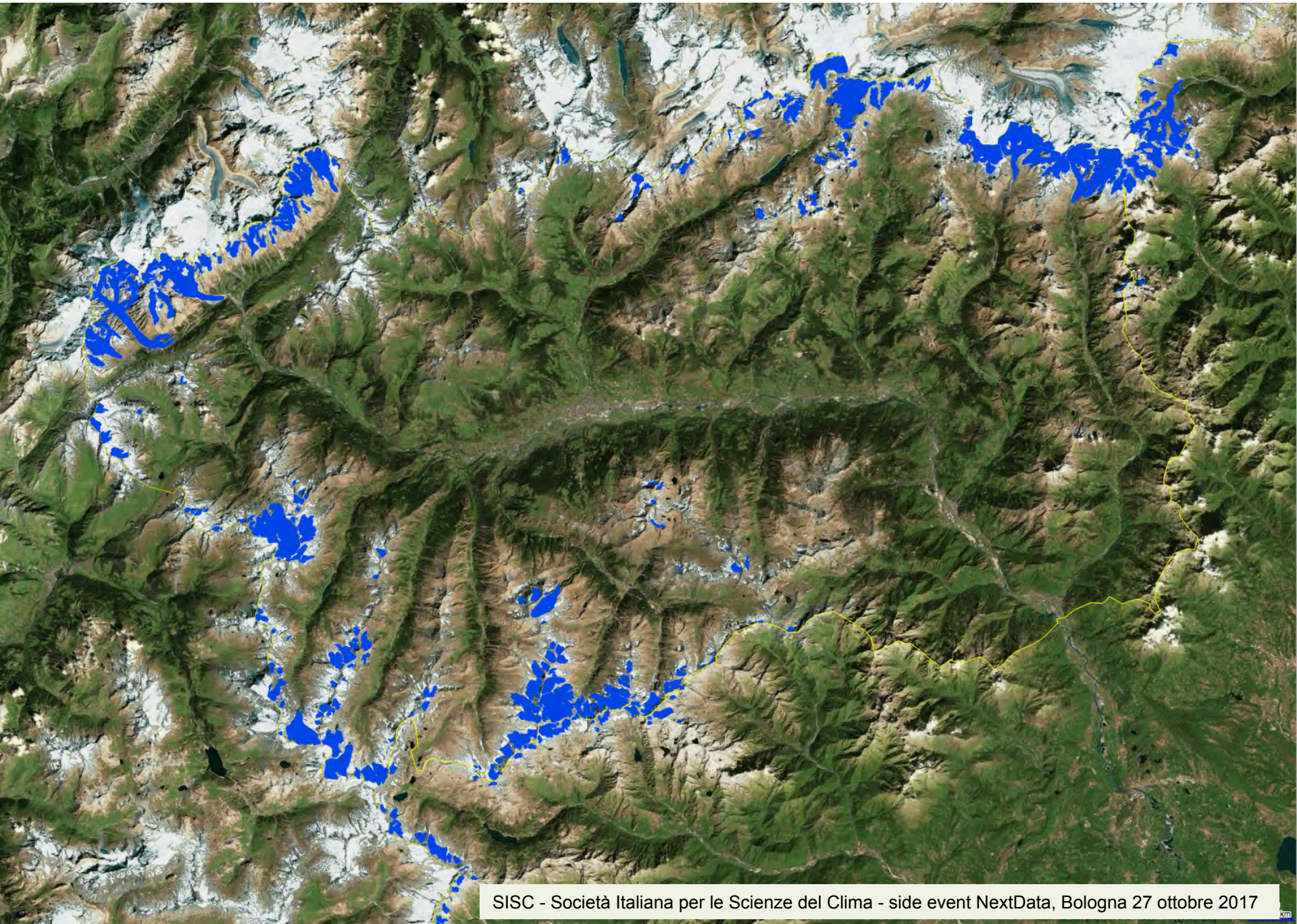
Snapshot of existing (in gray) and extinct (in black) Italian glaciers in 2006-2007 hydrological period (extint glaciers respect to 1957-58)

Salvatore et al. 2015

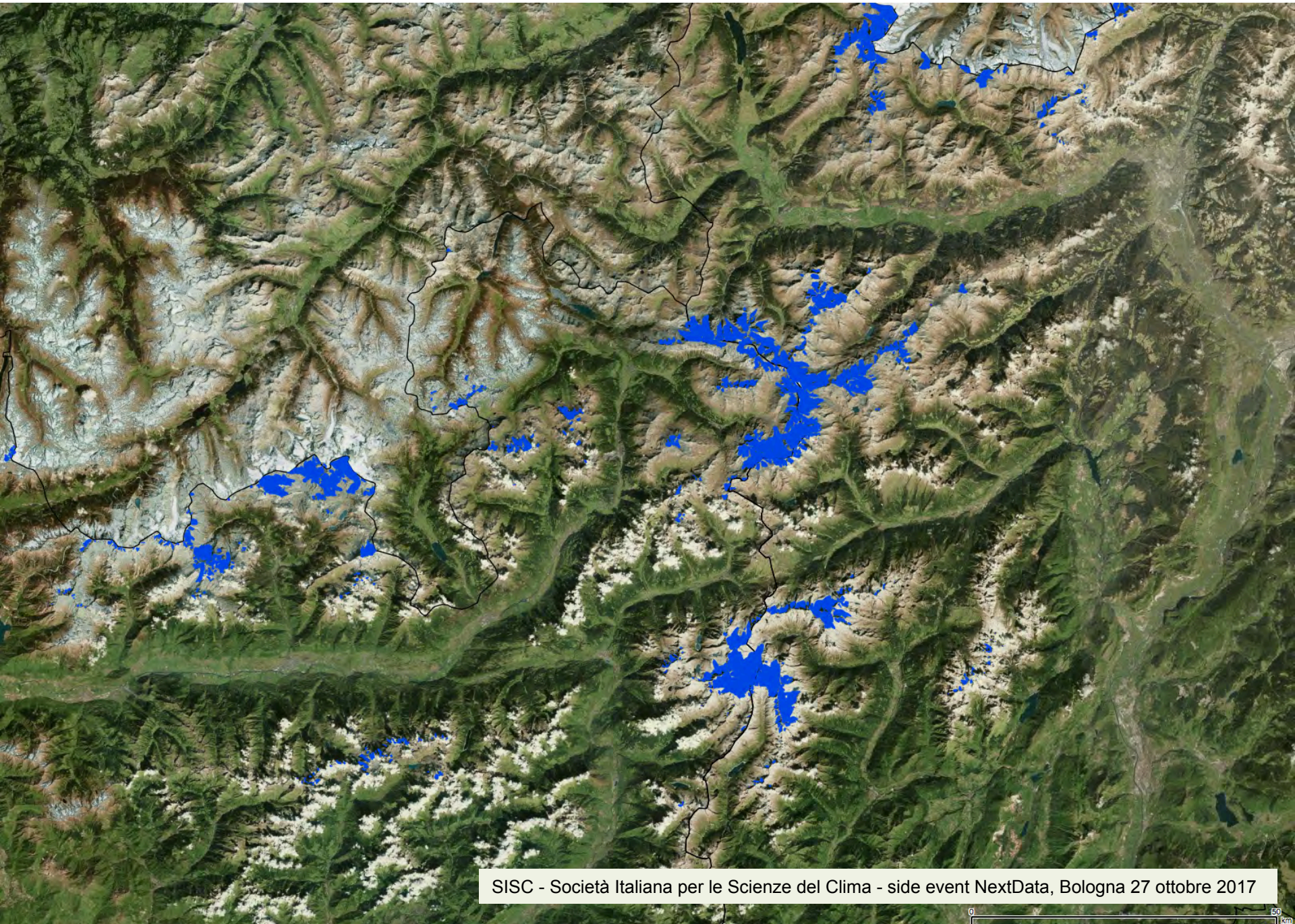


Comparison of areal frequency distribution and percentage of Italian glaciers in the 2006-2007 (black and circles, respec- tively) and 1957-1958 data (CGI Inventory, grey and triangles, respectively)

Mountain Glaciers Database - 1988-1989 – ALPI OCCIDENTALI



Mountain Glaciers Database 1988-1989 – ALPI CENTRALI



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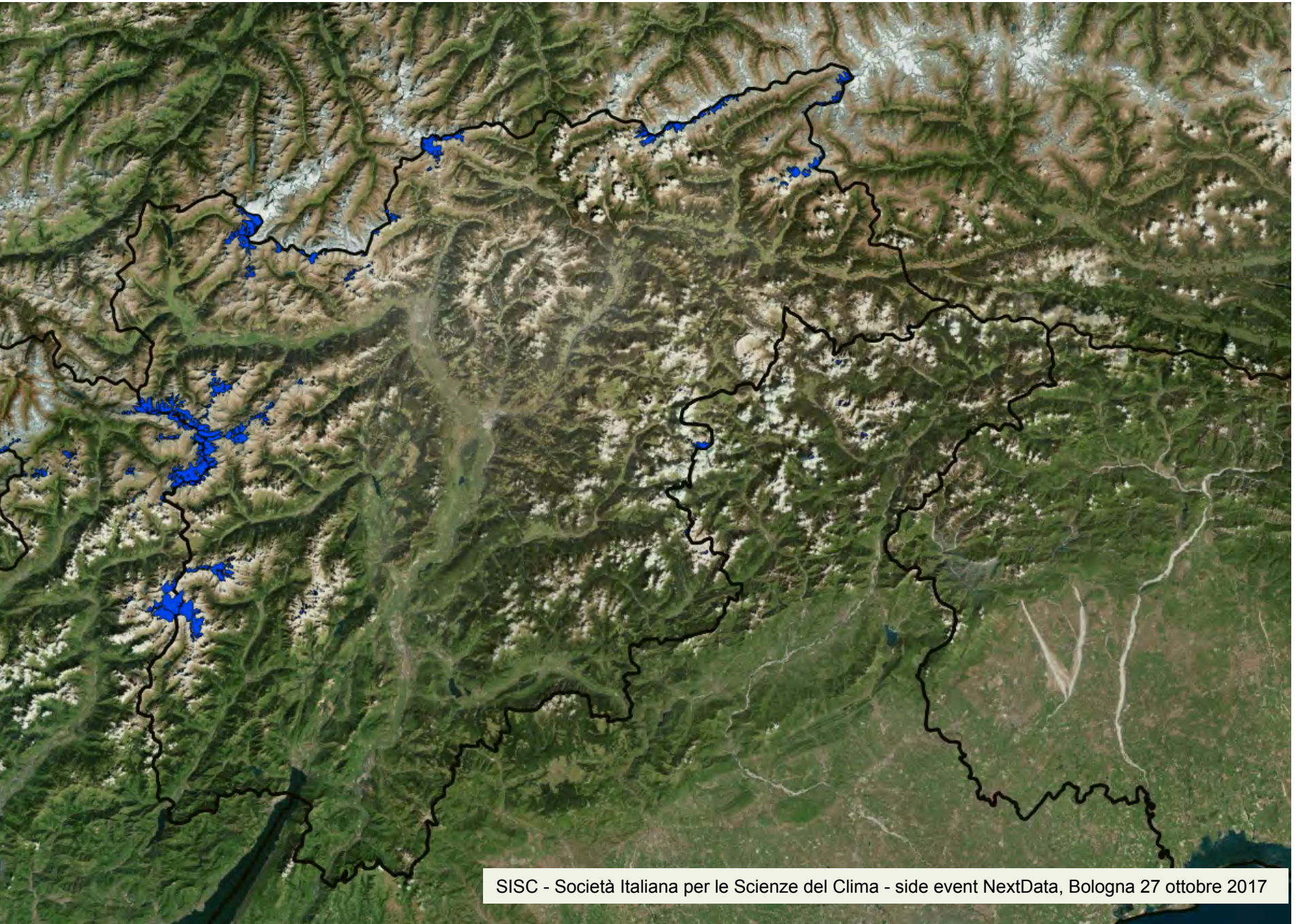
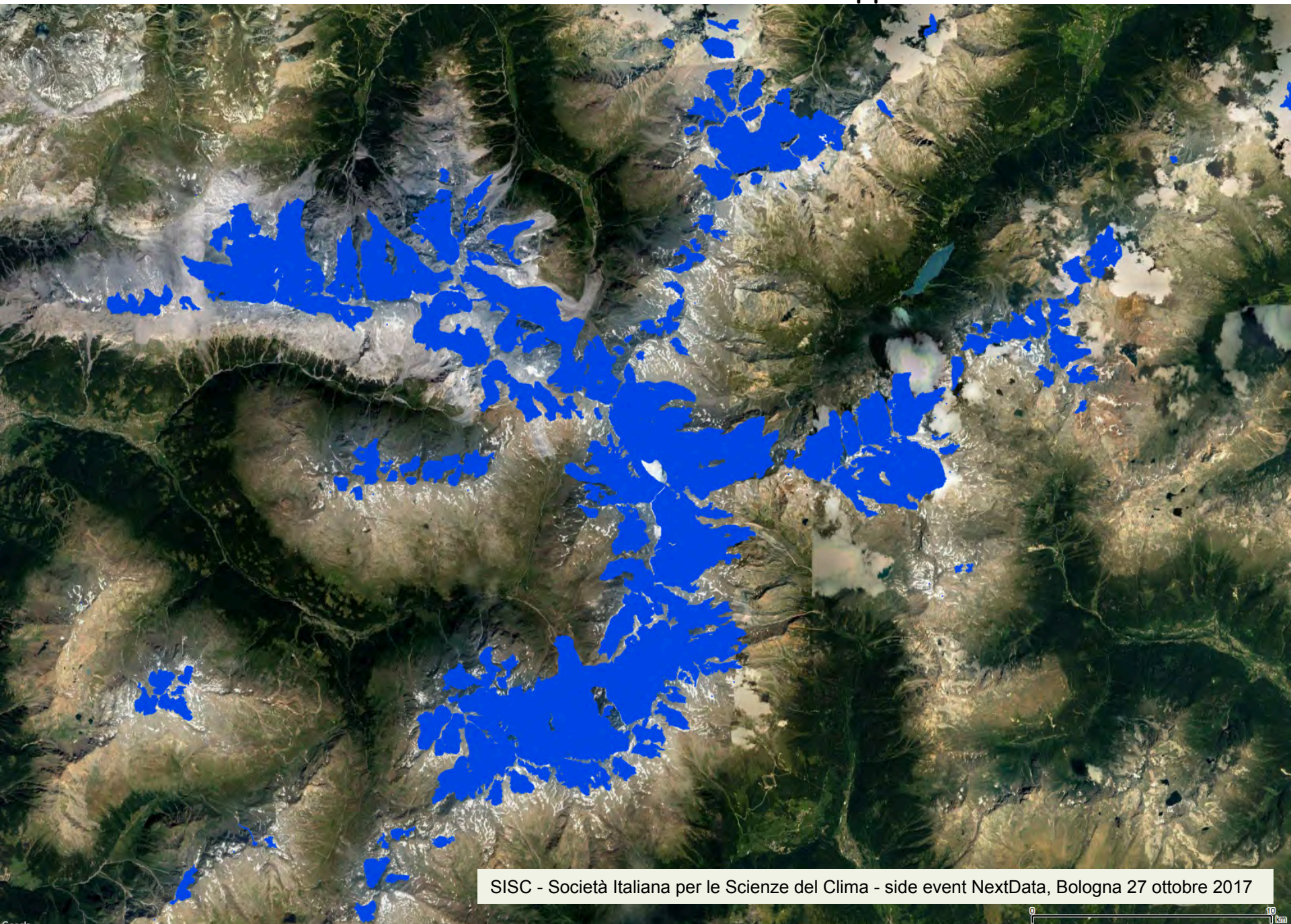
Mountain Glaciers Database 1988-1989 – ALPI ORIENTALI



Mountain Glaciers Database 1988-1989 – Gruppo Ortles-Cevedale



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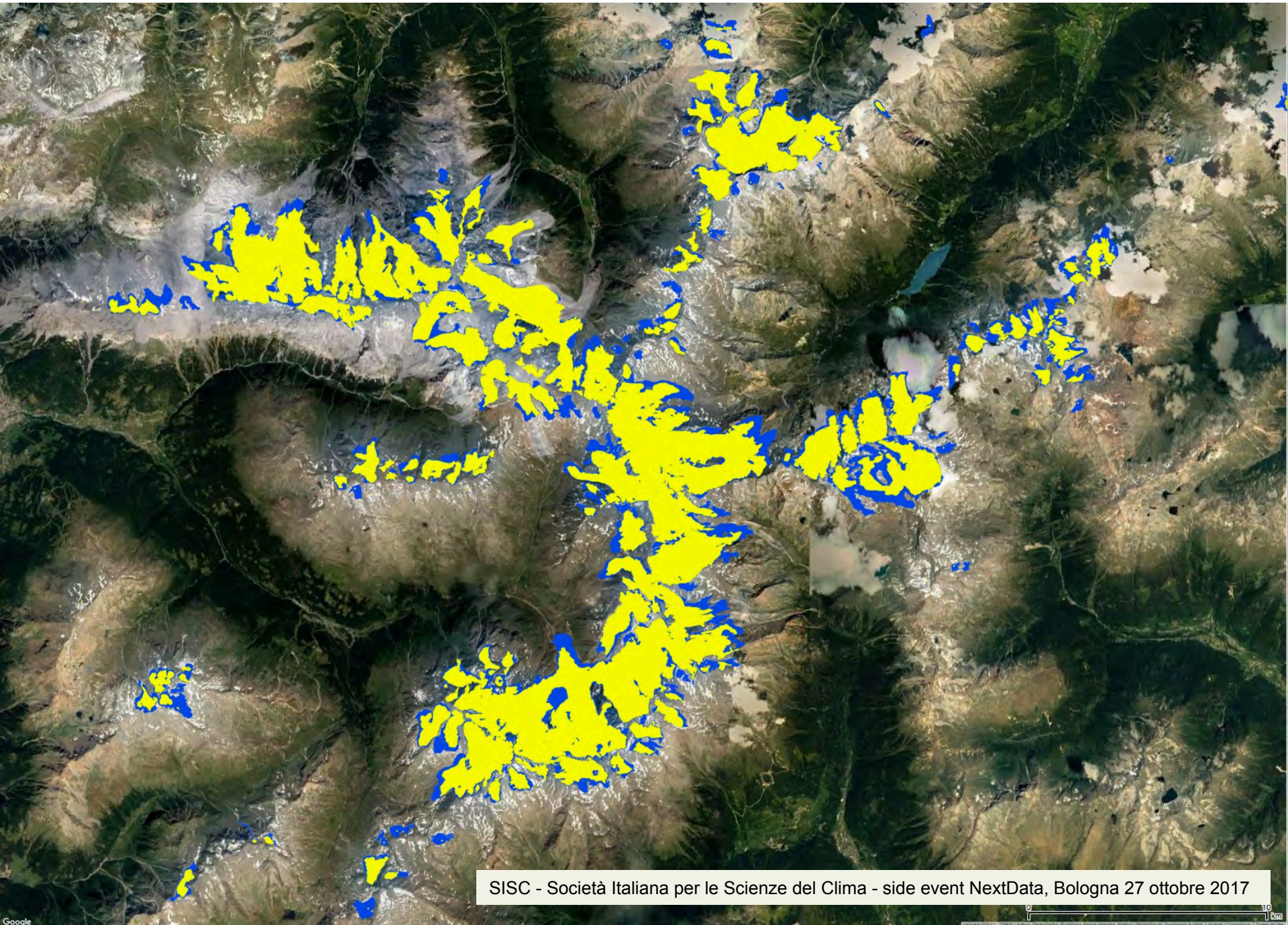
Mountain Glaciers Database 1988-1989 vs 2006-2007 – Gruppo Ortles-Cevedale



SISC - Società Italiana per le Scienze del Clima - side event NextData, Bologna 27 ottobre 2017

Attribute table related to 1988-89 glaciers with morphometric and geographic data

Attributes of 1988-89_Ghiacciai_UO_PI_MOD

FID	Shape	JOIN_COUNT	TARGET_FID	JOIN_FID	ID	CODE	SUB_CODE	WGI_CODE	TIME_STEP	MAX_ELEV	MIN_ELEV	TOT_AREA	DEB_AREA	EXP_AREA	MAX_WIDTH	MIN_WIDTH	MAX_LENGTH	MEAN_OR	OR_ACC	OR_ABL	MEAN_SLOPE	DATE_	X_COORD	Y
0	Polygon	0	0	0	0	364	0	IT4L01113002	1989			0.167109780690249						NE				03081989		
1	Polygon	0	0	0	0	365	0	IT4L01113003	1989			0.760118010173453						NE				03081989		
2	Polygon	0	0	0	0	366	0		1989			1.249280813154 6E-03						E				03081989		
3	Polygon	0	0	0	0	367	0	IT4L01113004	1989			3.066705464464 56E-*						E				03081989		
4	Polygon	0	0	0	0	367.1	99		1989			4.747149624982 74E-*						E				03081989		
5	Polygon	0	0	0	0	368	0	IT4L01113005	1989			9.984577130108 06E-*						NE				03081989		
6	Polygon	0	0	0	0	369	0	IT4L01113006	1989			0.159792465767332						SE				03081989		
7	Polygon	0	0	0	0	370	99		1989			9.833308139745 55E-*						SE				03081989		
8	Polygon	0	0	0	0	371	0	IT4L01113007	1989			0.26311989735693						SW				03081989		
9	Polygon	0	0	0	0	372	0	IT4L01113008	1989			7.844143529059 93E-*						SW				03081989		
10	Polygon	0	0	0	0	373	0	IT4L01113009	1989			0.149207525471354						NW				03081989		
11	Polygon	0	0	0	0	374	99	IT4L01113010	1989			1.176522406442 17E-*						N				03081989		
12	Polygon	0	0	0	0	374	99	IT4L01113010	1989			2.727723178214 91E-*						N				03081989		
13	Polygon	0	0	0	0	375	0	IT4L01111001	1989			1.236067977508 49E-*						SW				03081989		
14	Polygon	0	0	0	376	376	0	IT4L01111002	1989			0.390355733583351						W				03081989		
15	Polygon	0	0	0	377	377	99	IT4L01111003	1989			0.135759533051877						NW				03081989		
16	Polygon	1	658	58	662	378	0	IT4L01111004	1989			0.112824082545779						NW				26091988		
17	Polygon	0	0	0	378	379	0	IT4L01111005	1989			0.146194464868455						NE				26091988		
18	Polygon	0	0	0	380	380	0	IT4L01111006	1989			6.459652016312 67E-*						N				26091988		
19	Polygon	0	0	0	0	380.0	99		1989			1.864029280245 22E-*						N				26091988		
20	Polygon	0	0	0	999	382	99	IT4L01111011	1989			4.400688869282E-03						NW				26091988		
21	Polygon	0	0	0	383	383	0	IT4L01104002	1989			4.627069198660 89E-*						N				26091988		
22	Polygon	0	0	0	0	383.0	99	IT4L01104001	1989			2.531043184988 66E-*						N				26091988		
23	Polygon	0	0	0	382	383.2	99	IT4L01104003	1989			5.528438088643 06E-*						N				26091988		
24	Polygon	0	0	0	0	383.3	99	IT4L01104004	1989			1.824643941786 24E-*						NE				26091988		
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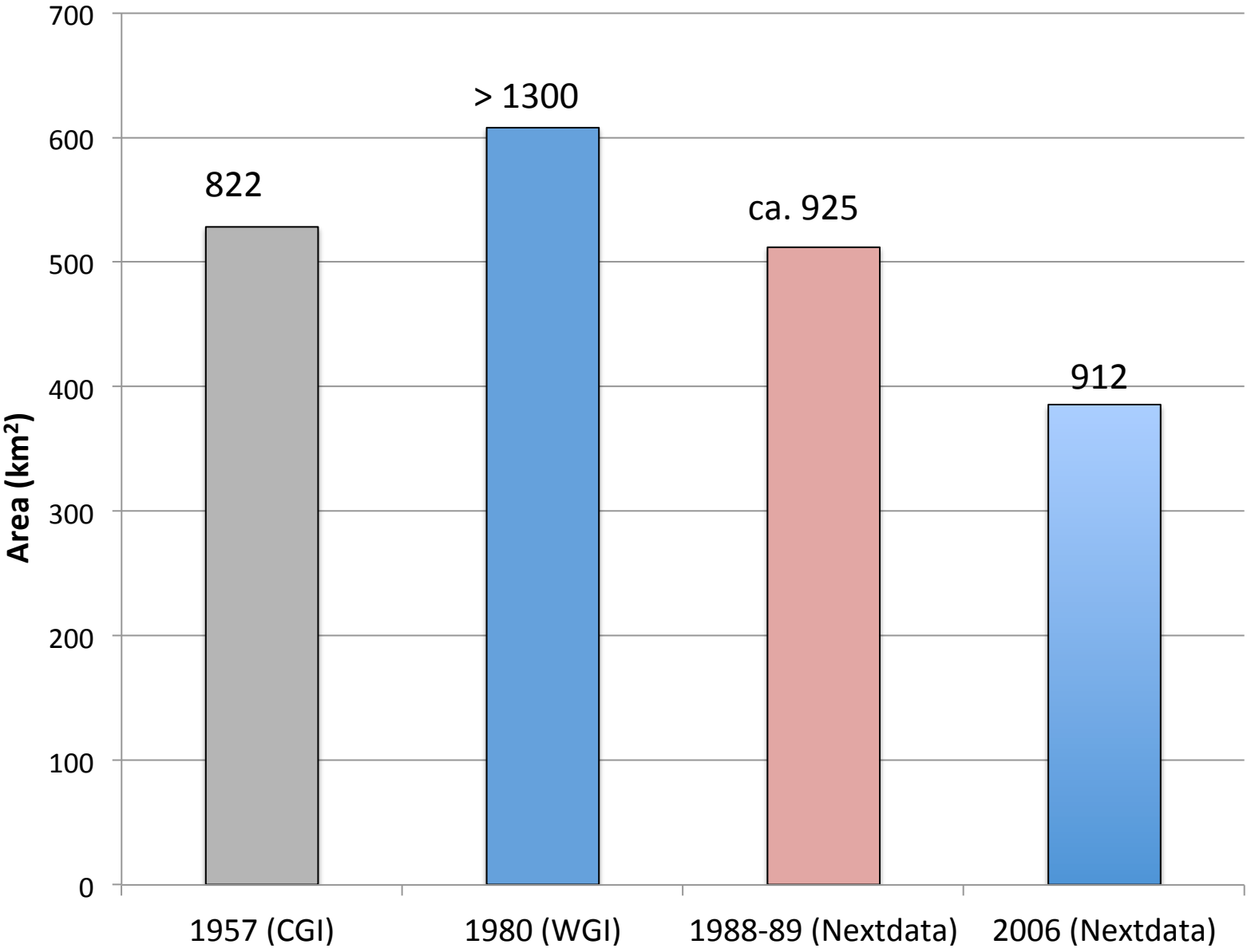
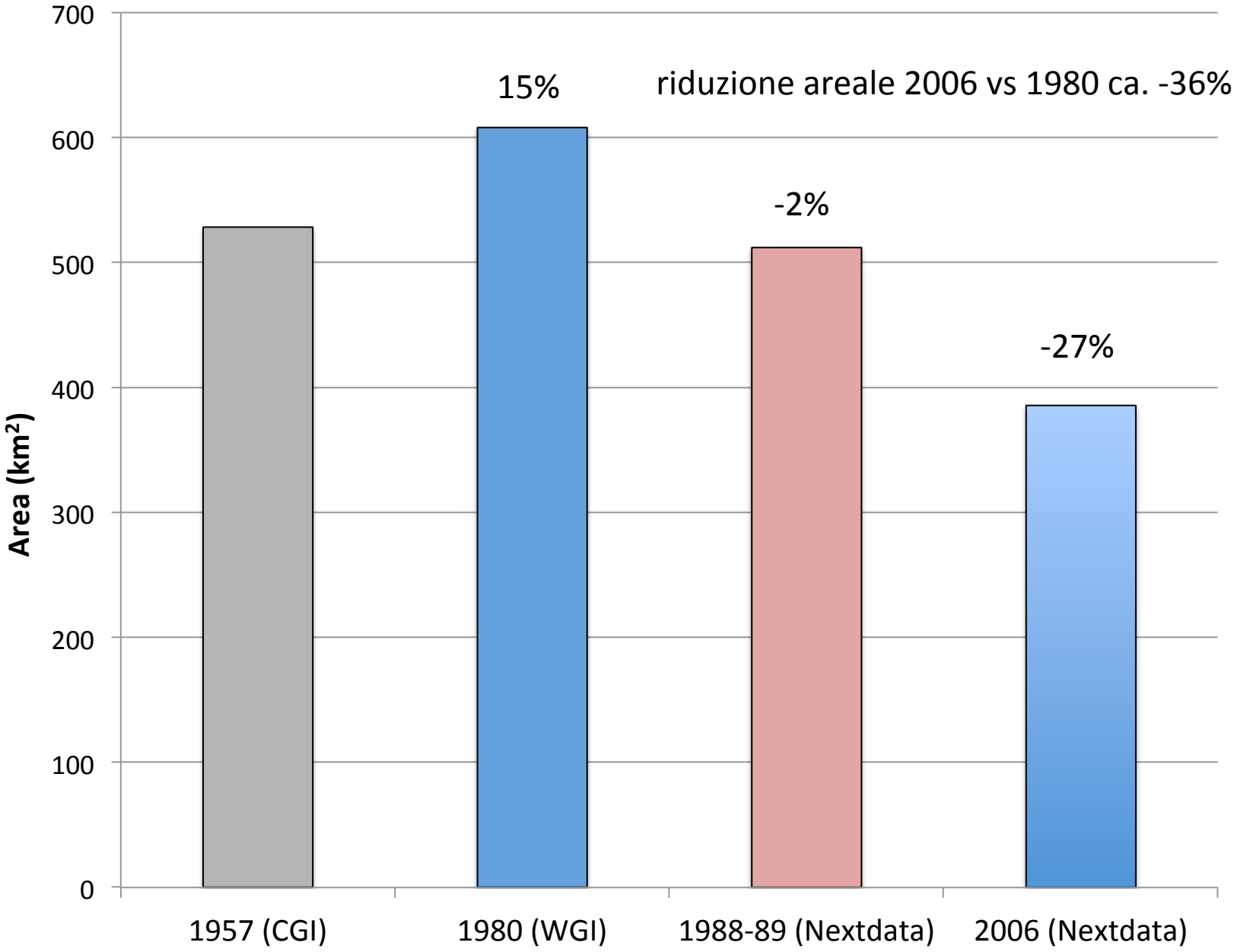
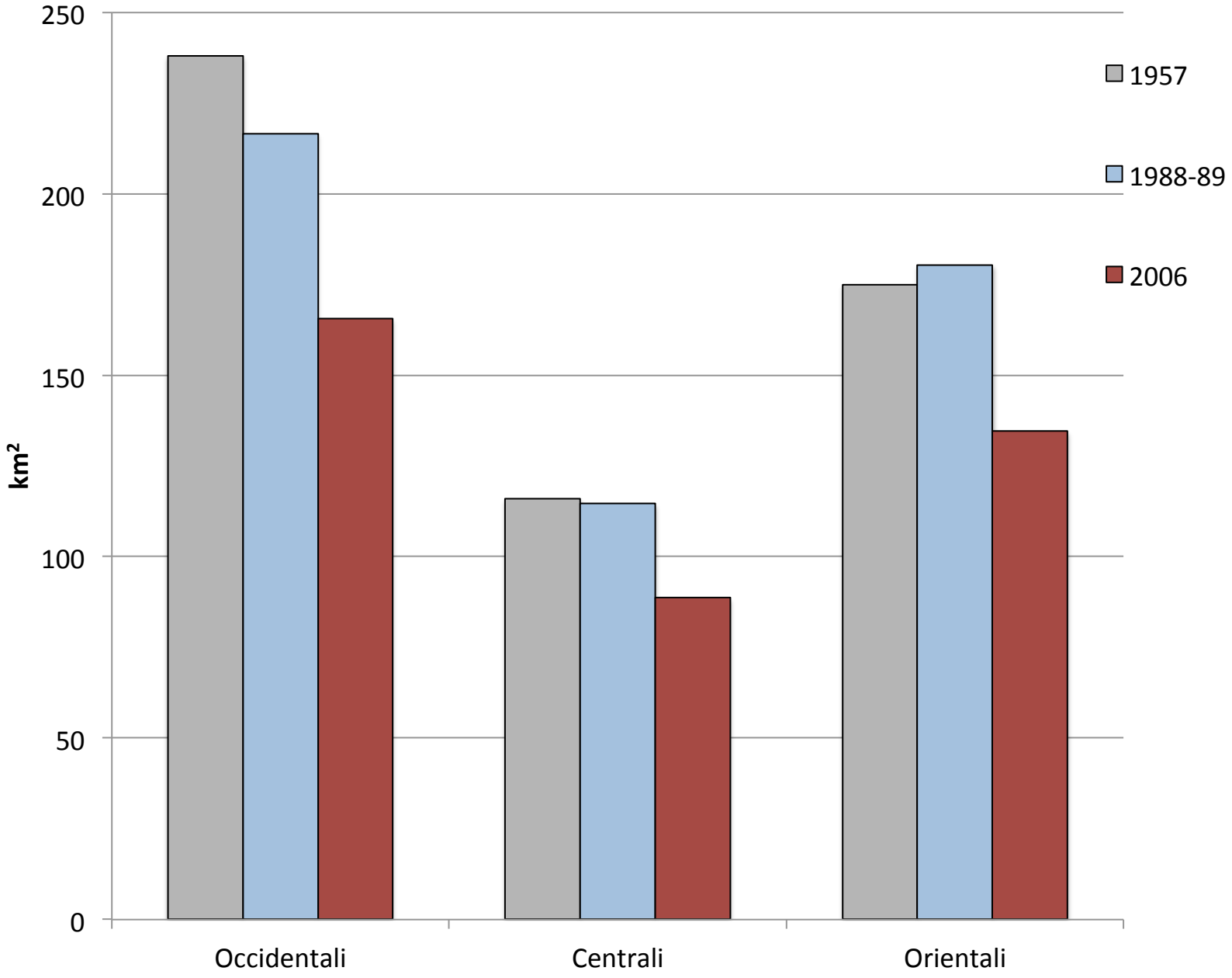
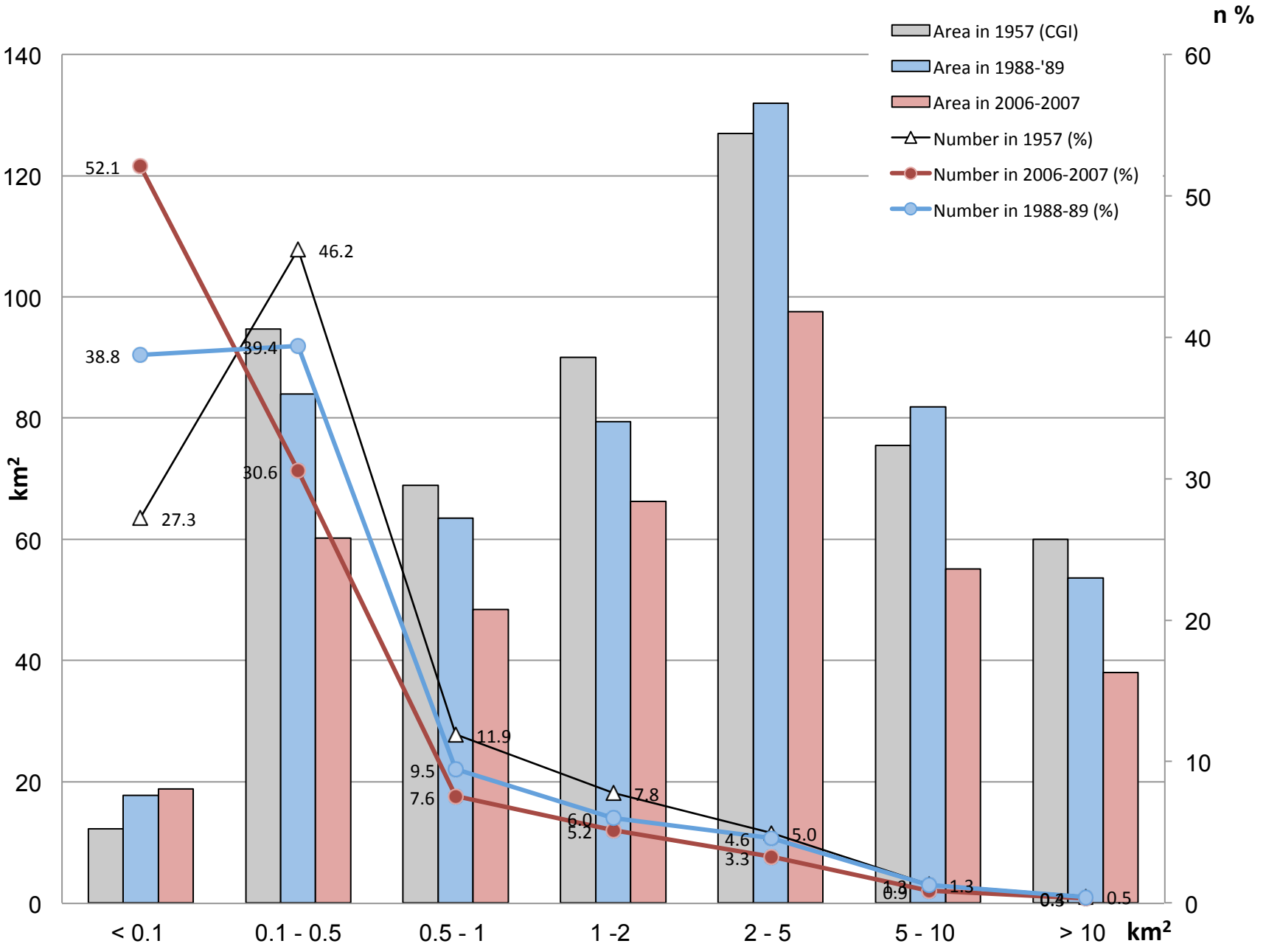
Italian Glaciers database - ALCUNE CONSIDERAZIONI….

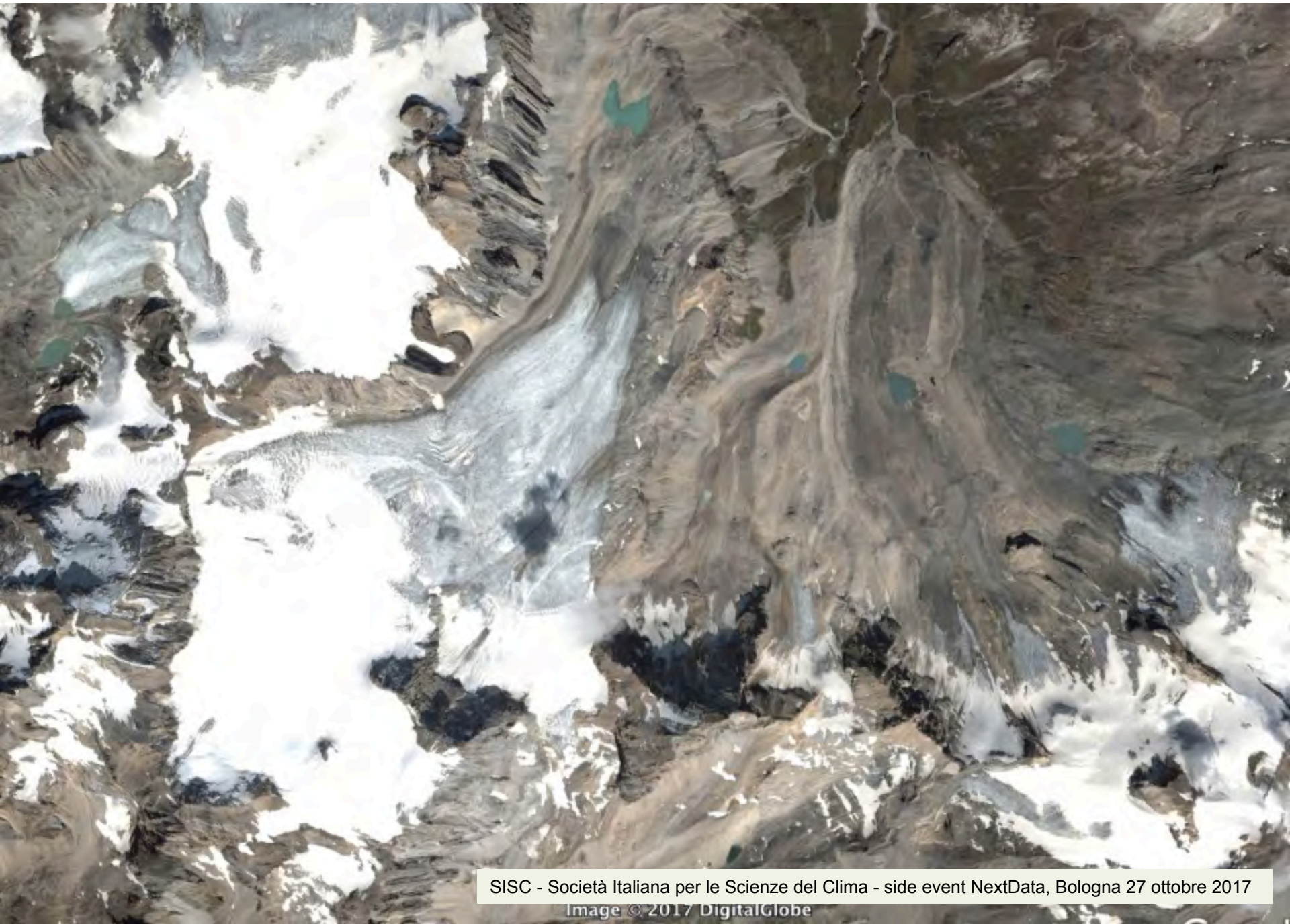



700
600
500
400
300
200
100
0
Area (km²)
15%
riduzione areale 2006 vs 1980 ca. -36%
-2%
-27%
1957 (CGI)
1980 (WGI)
1988-89 (Nextdata)
2006 (Nextdata)


250
200
150
100
50
0
km²
1957
1988-89
2006
Occidentali
Centrali
Orientali


n %
Area in 1957 (CGI)
Area in 1988-'89
Area in 2006-2007
Number in 1957 (%)
Number in 2006-2007 (%)
Number in 1988-89 (%)
km²
140
120
100
80
60
40
20
0
60
50
40
30
20
10
0
52.1
38.8
39.4
46.2
27.3
30.6
11.9
9.5
7.6
7.8
6.0
5.2
5.0
4.6
3.3
1.3
1.3
0.5
< 0.1
0.1 - 0.5
0.5 - 1
1 -2
2 - 5
5 - 10
> 10
km²

Italian Glaciers database - NUOVI DATI 2015 …. In progress

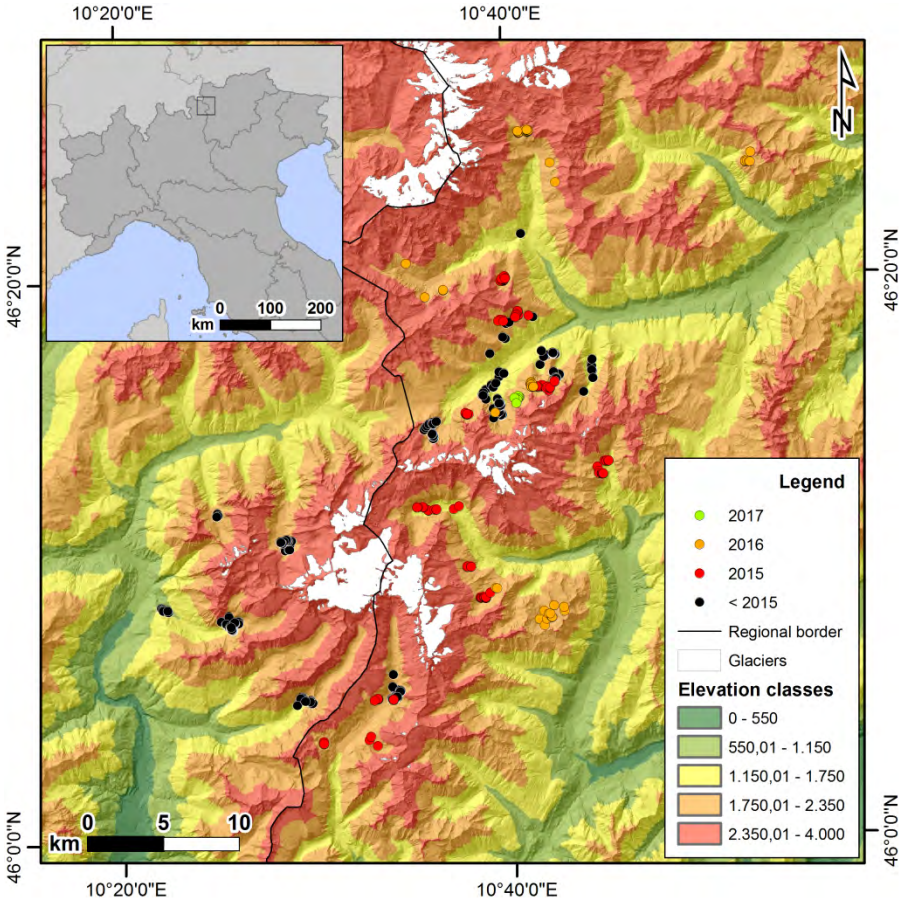


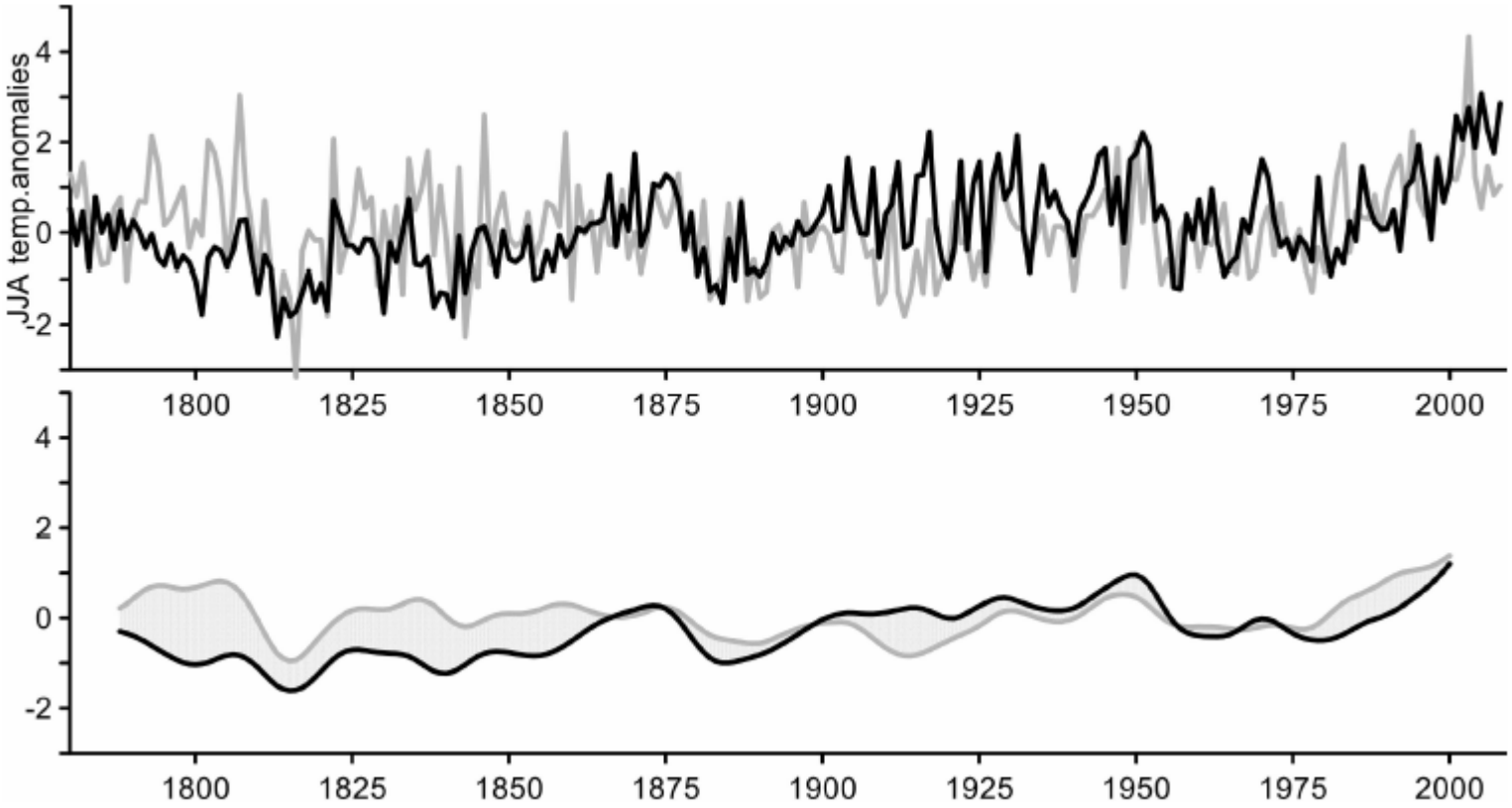
Multi-species and multi-approach tree-rings analysis for reconstructing alpine glaciers mass balance and climatic changes in the Raethian Alps during the last millennium

Laboratorio di Dendrocronologia DST - Università di Pisa

Total collected individuals:
511

- *European larches* (*Larix decidua* Mill.):
  408
- Swiss stone pine (*Pinus Cembra* L.):
  26
- Norway spruce (*Picea abies* H.Karst.):
  77

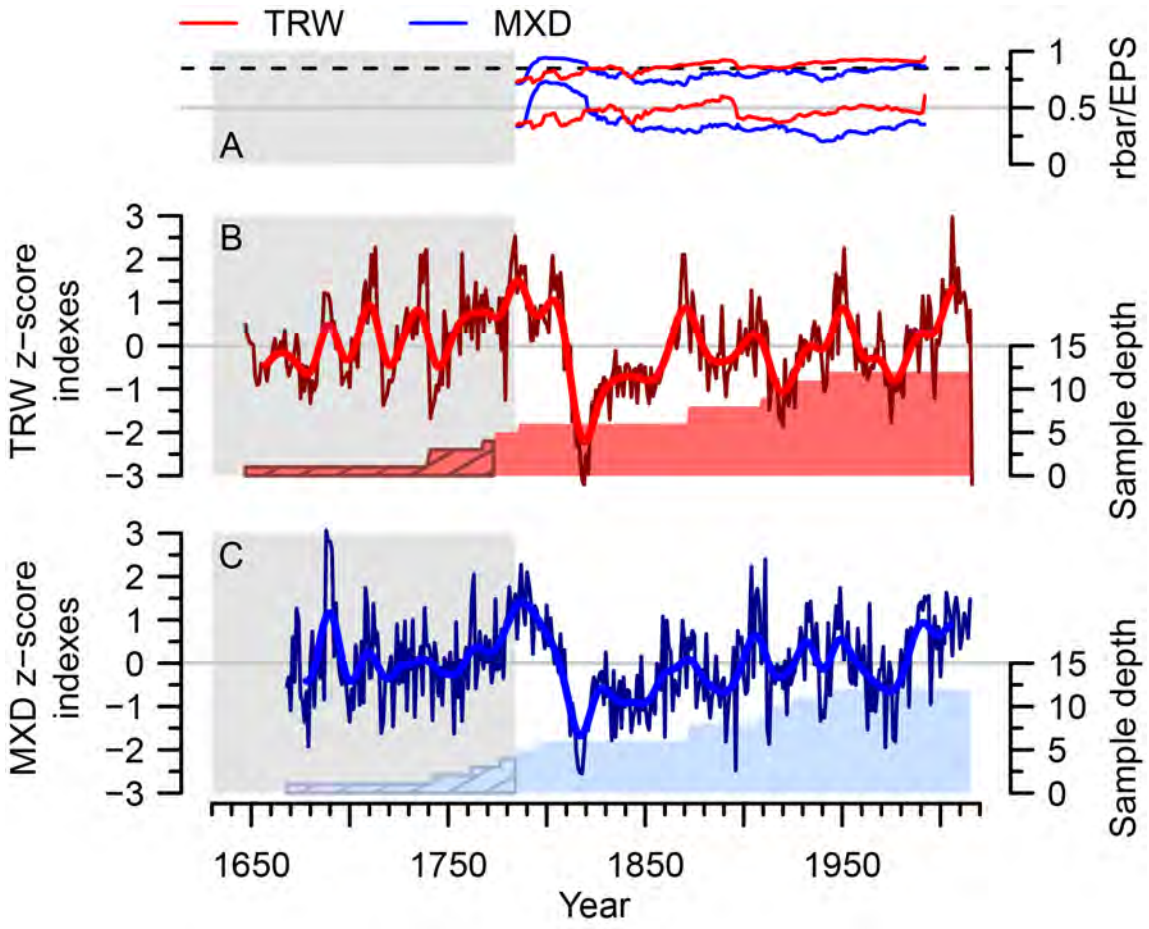




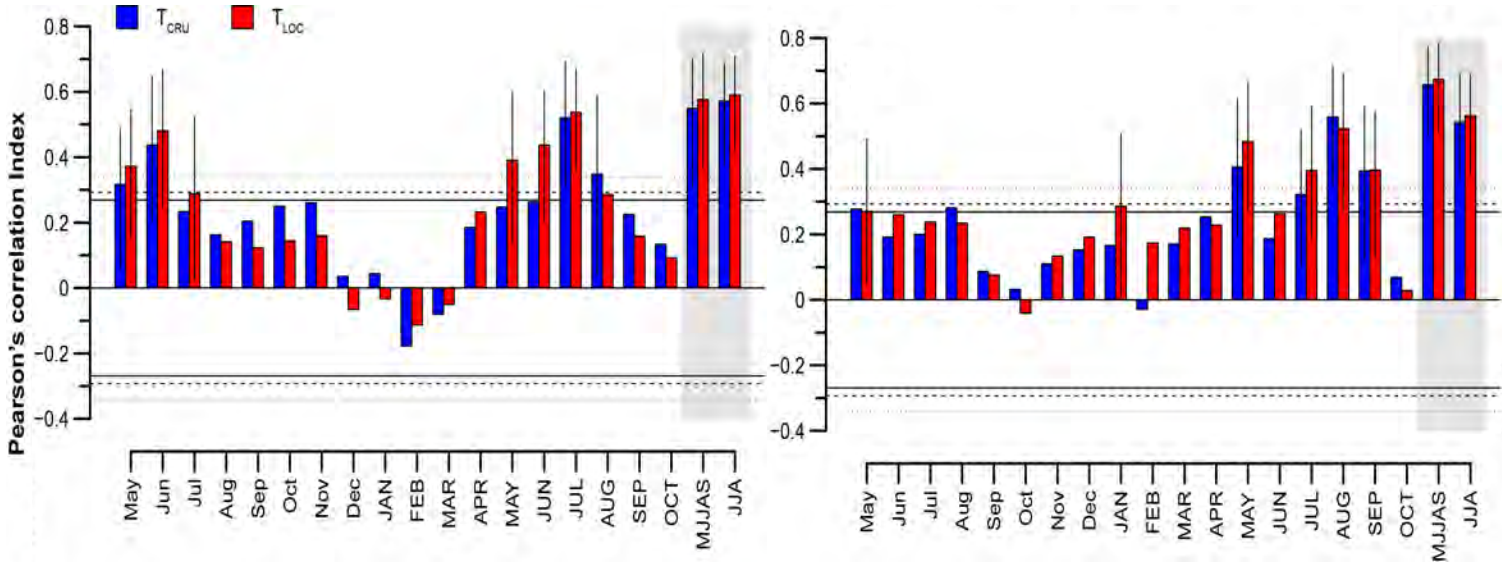
Comparison of the Adamello-Presanella Tree-ring with reconstruction of June to August temperature anomalies (black) with the HISTALP June to August mean temperatures (1780-2008, grey) for unfiltered series (top) and after filtering with a 20-yr low-pass filter (bottom).

Coppola, A., Leonelli, G., Salvatore, M. C., Pelfini, M., and Baroni, C.: Tree-ring–based summer mean temperature variations in the Adamello–Presanella Group, Clim. Past, 9, 211–221, 2013 doi:10.5194/cp-9-211-2013

This new approach will help to enhance the summer temperature reconstructions obtained before by less conservative approach. This will retain more climatic variability.



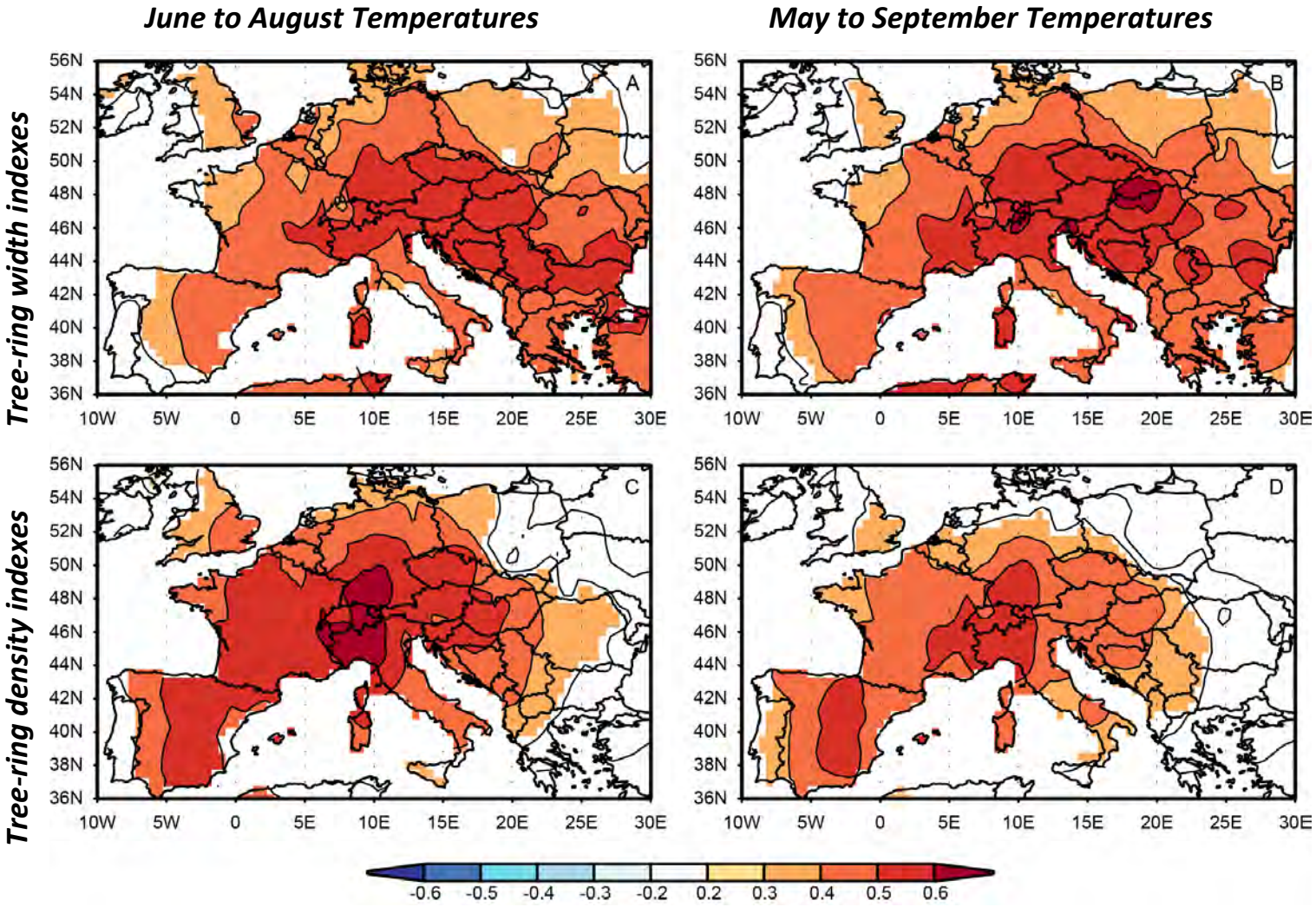
Using a multi-methods approach it was possible to create new chronologies considering the middle and long term variability… (Cerrato et al. in progress)



Std-chronology **Mxd-chronology**

…but that retain more short term variability, permitting to reconstruct with more detail the climatic parameter (Cerrato et al. in progress)

Obtained results are valuable at regional scale, resulting of extremely interest for all the European scientific community (Cerrato et al. in progress)



Dendroclimatologia — ricostruzione del clima

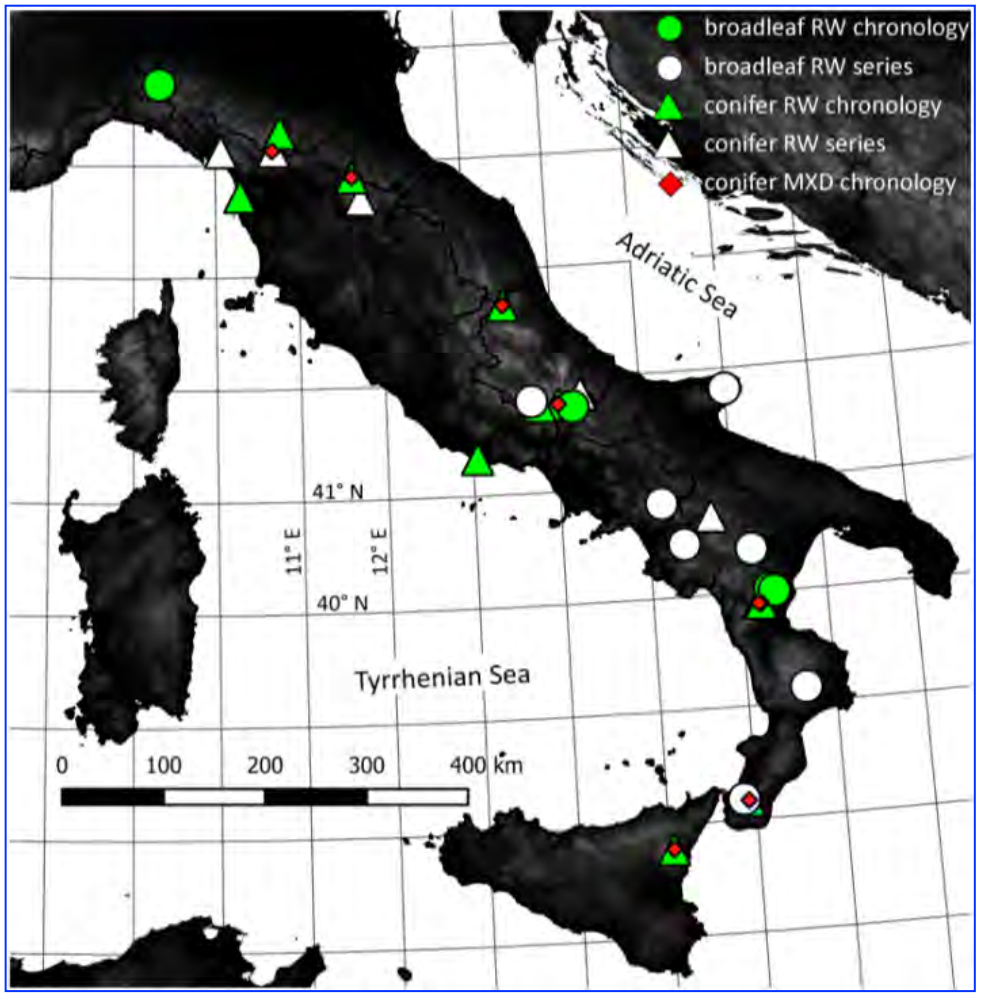
- Messa a punto di un metodo per la ricostruzione climatica sulla base degli alberi più sensibili al clima.

- Ricostruzione delle temperature medie estive per una regione 1°lat. x1° long. fortemente glacializzata delle Alpi centrali comprendente i Gruppi: Silvretta (Switzerland), Ötztaler-Venoste Alps (Austria & Italy), Bernina (Switzerland & Italy), Ortles-Cevedale (Italy) Adamello-Presanella (Italy). Anni 1565-2010. — (Leonelli et al., 2016, Climatic Change).

- Ricostruzione delle temperature di fine estate (Agosto-Settembre) per l'Italia peninsulare dal 1700 basata sulla densità massima del legno.

- L'analisi di sensitività climatica per siti Appenninici indica un ruolo anche delle precipitazioni tardo estive

- La ricostruzione è stabile nel tempo, migliora alcune ricostruzioni effettuate per il NE Mediterraneo ed è comparabile negli andamenti con altre ricostruzioni effettuate in Grecia.



(Leonelli et al., 2017 Climate of the Past)

Dendroclimatologia — ricostruzione del clima

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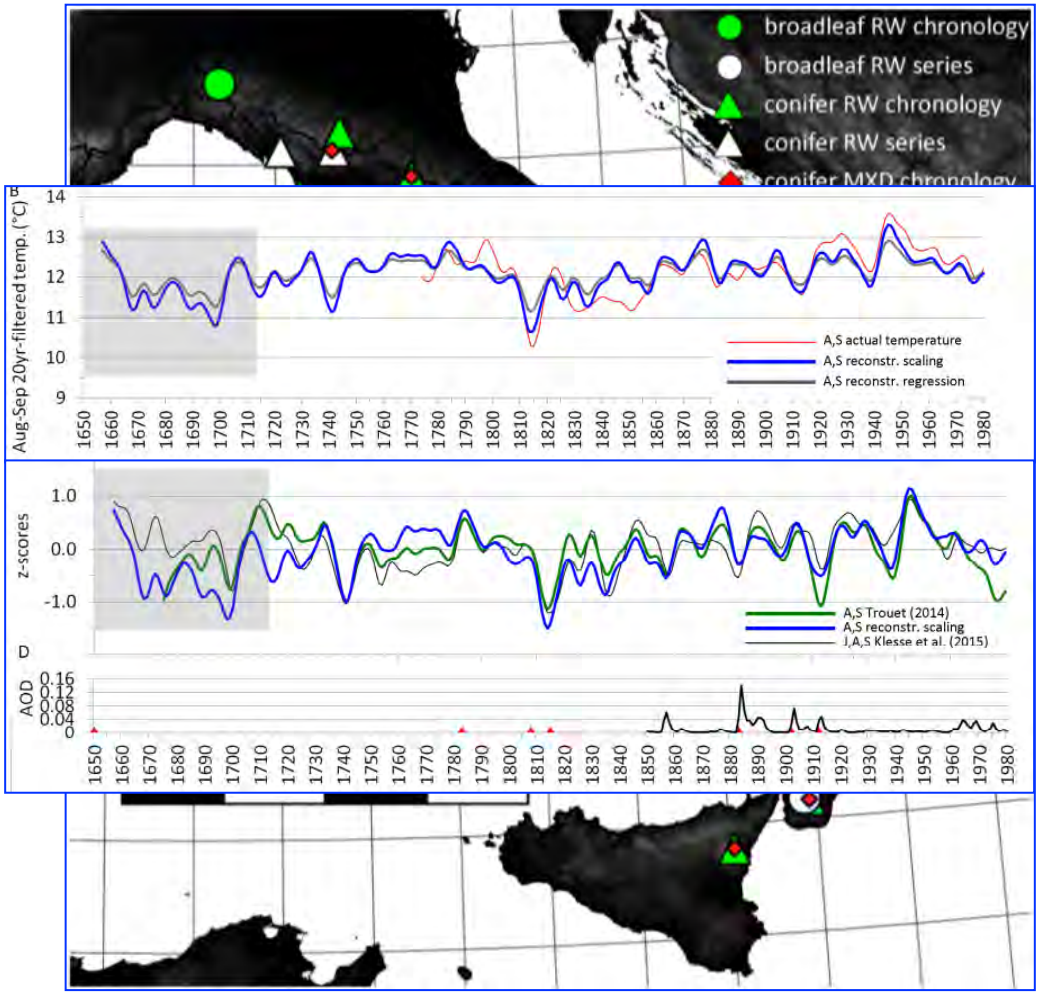
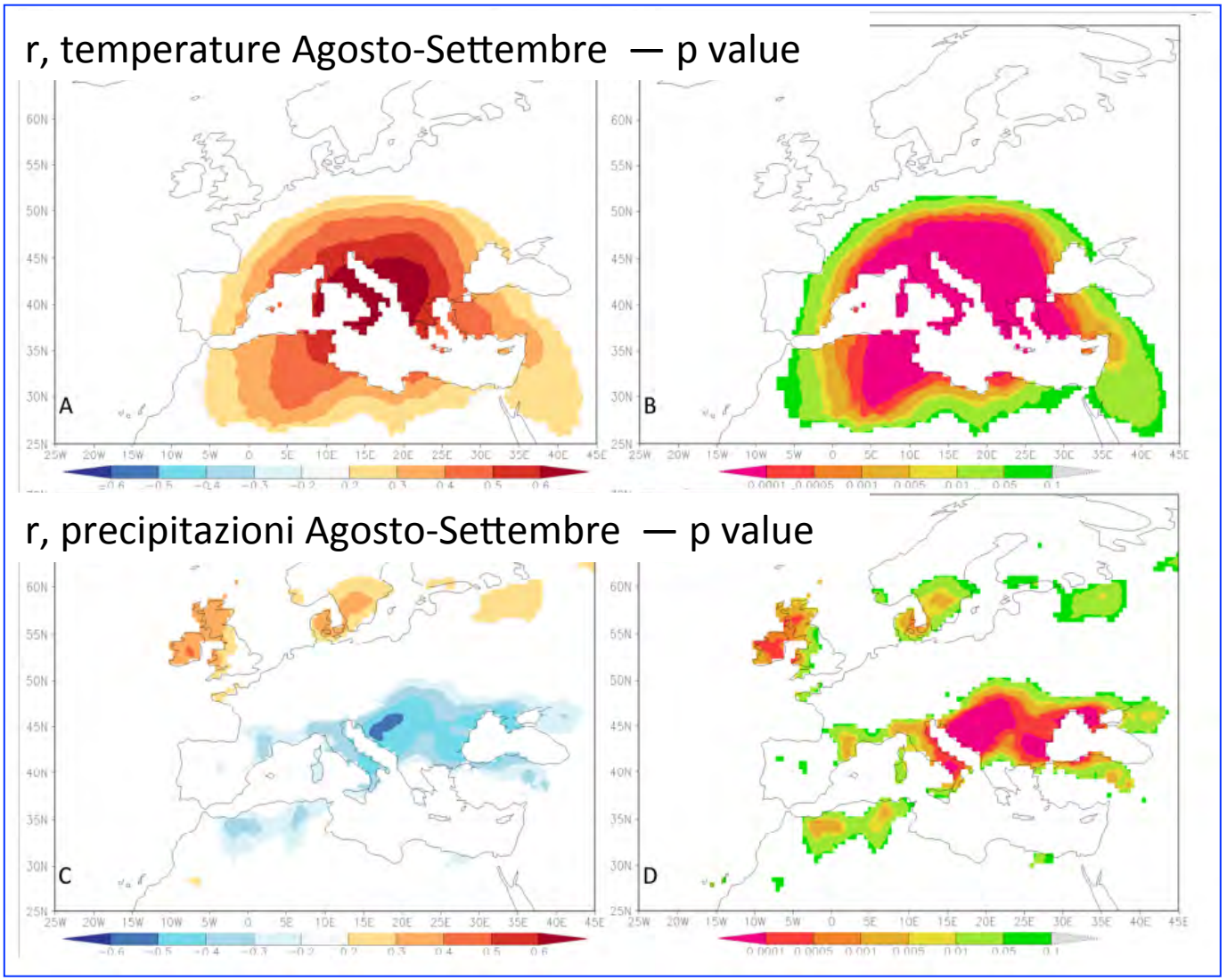


(Leonelli et al., 2017 Climate of the Past)

Dendroclimatologia — ricostruzione del clima

- La validazione spaziale indica l'areale di competenza della ricostruzione effettuata per le temperature di Agosto-Settembre
- Indica inoltre la presenza di un dipolo con il nord Europa per quanto riguarda il segnale delle precipitazioni



(Leonelli et al., 2017 Climate of the Past, in press)

Dendroclimatologia — dendroisotopi

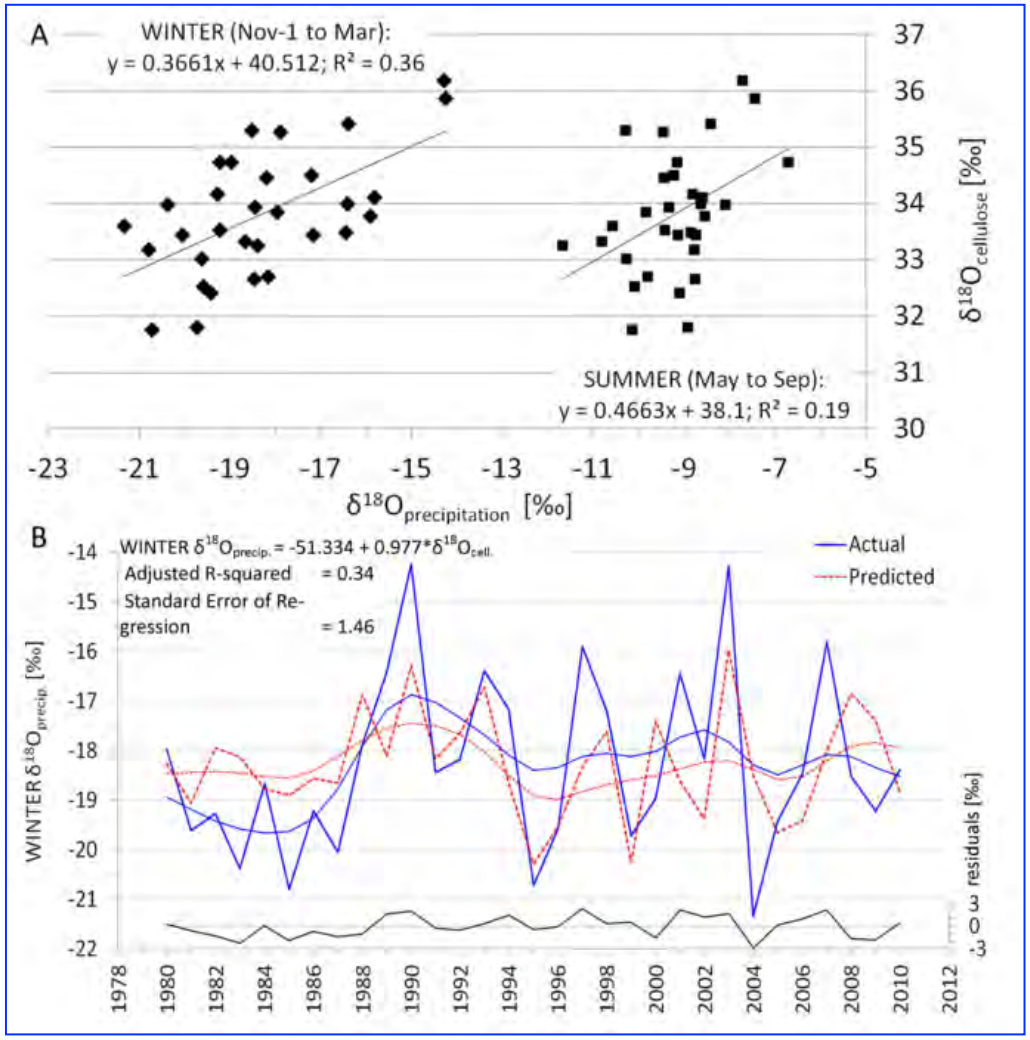
Area proglaciale del Ghiacciaio dei Forni (SO)

Analisi dei segnali isotopici $\delta^{13}C$ e $\delta^{18}O$ registrati negli anelli di accrescimento degli alberi che crescono in valli glaciali in relazione alle variabili climatiche e al segnale isotopico delle precipitazioni.

Individuato il ruolo determinante delle precipitazioni invernali (nevose) nell'influenzare il segnale isotopico del $\delta^{18}O$ degli anelli di accrescimento

Prima ricostruzione del segnale isotopico del $\delta^{18}O$ nelle precipitazioni invernali

Effettuato campionamento acque correnti e acqua nel suolo, per meglio comprendere i meccanismi alla base del frazionamento isotopico, confronti con più siti dalle Alpi



(Leonelli et al., 2017 Science of the Total Environment)