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Supplement of

Hydrological response of Andean catchments to recent glacier mass loss

Alexis Caro et al.

Correspondence to: Alexis Caro (alexis.caro.paredes@gmail.com)

The supplementary material contains: Availability of data by glacier and catchment, data for evaluation and results, precipitation factor fit and climate correlations regarding annual mass balance.

1 Availability of data by glacier and catchment

Simulations in 786 Andean catchments are available. Each folder per catchment contains: glacier mass balance, area, volume, temperature, precipitation, glacier melt and rainfall on glaciers. These data were processed per glacier and per catchment at annual temporal resolution. In addition, glacier melt and rainfall on glaciers are available at a monthly time step per catchment. Data are available at glacier and catchment scale.

2 Climate evaluation

This section describes the data used to evaluate the TerraClimate dataset: temperature data recorded at meteorological stations in glaciers and outside them, lapse rate estimation per glaciological zone and the precipitation factors estimation.

2.1 Historical Climate data

In Table S1 are described the characteristics of 35 meteorological stations off and on glacier surface between 9°-51°S.

Table S1. Meteorological stations used to generate vertical temperature lapse rates and validate TerraClimate dataset on or near of glaciers across the Andes.

ID	Zone	Weather station name	Coordinates [°]		Elevation [m a.s.l.]		Surface	Range date		Reference
			Lat	Lon	Station	TC grid		start	end	
1	OT	Llan_Up-2	-9.05	-77.60	4122	4354	Off glacier	08/2006	06/2019	Mateo et al., 2022
2	OT	CuchWX	-9.41	-77.36	4642	4694	Off glacier	08/2013	12/2019	
3	OT	Huaytapallana	-11.93	-75.06	4684	4632	Off glacier	01/2018	12/2019	SENAMHI, 2022
4	OT	Quisoquepina	-13.80	-70.89	5157	5313	Off glacier	05/2015	12/2019	
5	OT	Zongo off glacier	-16.28	-68.14	5050	4836	Off glacier	10/1995	12/2018	GLACIOCLIM, 2022
6	OT	Zongo on glacier	-16.28	-68.14	5050	4836	On glacier	09/2004	08/2019	
7	DA1	La Frontera	-29.30	-70.01	4927	5074	Off glacier	01/2002	04/2007	Rabatel et al., 2011
8	DA1	Estrecho glacier	-29.30	-70.01	5102	5074	On glacier	04/2014	03/2015	Hernández et al., 2021
9	DA1	Guanaco glacier	-29.31	-70.00	5324	5074	On glacier	11/2008	04/2011	MacDonnell et al., 2013

10	DA1	Tapado glacier	-30.15	-69.92	4727	4502	Off glacier	05/2018	12/2019	CEAZA, 2022
11	DA1	Tapado morrena	-30.16	-69.91	4318	4502	Off glacier	11/2009	04/2013	DGA, 2022
12	DA1	La Laguna Embalse	-30.20	-70.04	3160	3434	Off glacier	01/1980	12/2019	
13	DA2	Juncal Sur glacier	-33.12	-70.11	4035	4189	Off glacier	01/2019	12/2019	
14	DA2	Olivares Gamma glacier	-33.16	-70.15	3628	4002	Off glacier	05/2014	12/2019	
15	DA2	Estero Yerba Loca en P. Carvajal	-33.22	-70.27	3250	4148	Off glacier	01/2012	12/2017	
16	DA2	Bello glacier	-33.53	-69.95	4134	4071	On glacier	11/2013	04/2018	
17	DA2	Yeso glacier	-33.53	-69.92	4428	4375	On glacier	11/2013	04/2018	
18	DA2	Portezuelo Echaurren	-33.58	-70.13	3847	3603	Off glacier	03/2016	12/2019	
19	DA2	Pirámide glacier	-33.59	-69.89	3459	3924	On glacier	11/2013	04/2018	
20	DA2	El Yeso Embalse	-33.68	-70.09	2475	2705	Off glacier	01/1980	12/2019	
21	DA3	G. San Franc. en A. P.	-33.75	-70.07	2238	2895	Off glacier	10/2011	12/2019	
22	DA3	San Francisco glacier	-33.80	-70.07	3466	3544	On glacier	11/2013	04/2015	
23	DA3	Cipreses glacier	-34.54	-70.42	1880	1961	Off glacier	11/2016	12/2019	
24	DA3	Cortaderal glacier	-34.66	-70.26	3156	3273	Off glacier	05/2018	12/2019	DGA, 2022
25	WA1-2	La Punilla	-36.66	-71.33	840	898	Off glacier	01/1980	10/1986	
26	WA1-2	Volcán Chillán	-36.89	-71.41	2200	-	Off glacier	03/2015	12/2019	
27	WA1-2	Mocho nunatak	-39.93	-72.01	1970	1523	Off glacier	05/2006	10/2014	Schaefer et al., 2017
28	WA3-4-5-6	San Rafael glacier	-46.70	-73.59	1187	1188	On glacier	07/2012	12/2019	DGA, 2022
29	WA3-4-5-6	Rio Nef A. J. E. El Revalse	-47.14	-73.09	281	551	Off glacier	01/2012	12/2017	
30	WA3-4-5-6	Glaciar Colonia en Lago Cachet-2	-47.20	-73.26	451	570	Off glacier	01/2011	12/2019	
31	WA3-4-5-6	Greve glacier	-48.83	-73.58	1428	1377	On glacier	10/2014	07/2016	

32	WA3-4-5-6	O'Higgins	-48.88	-72.74	250	699	Off glacier	01/2014	12/2019	
33	WA3-4-5-6	Candelario Mancilla	-48.93	-73.14	300	370	Off glacier	12/2004	12/2017	
34	WA3-4-5-6	Aonikenk	-49.29	-73.00	1200	1376	Off glacier	03/2014	12/2019	IANIGLA, 2022
35	WA3-4-5-6	Dickson glacier	-50.79	-73.14	221	529	Off glacier	11/2018	12/2019	CECs, 2018

2.2 Temperature lapse rates

In general, short air temperature records were observed on stations located over glaciers (Estrecho in 29°S, and Juncal Sur and Olivares in 33°S, over the 4000 m a.s.l.), whereas the longer records comes from stations located off glaciers (El Yeso Embalse in 33°S, La Laguna Embalse in 30°S and off Glacier Zongo in 16°S, over 2400 m a.s.l.). The short records are associated with recent dates before December 2019 and the longer ones start from 1980. The vertical temperature lapse rates were obtained using a minimum of 3 stations (cluster WA1-2) and a maximum of 8 meteorological stations (cluster WA3-4-5-6) at cluster scale (Figure S1).

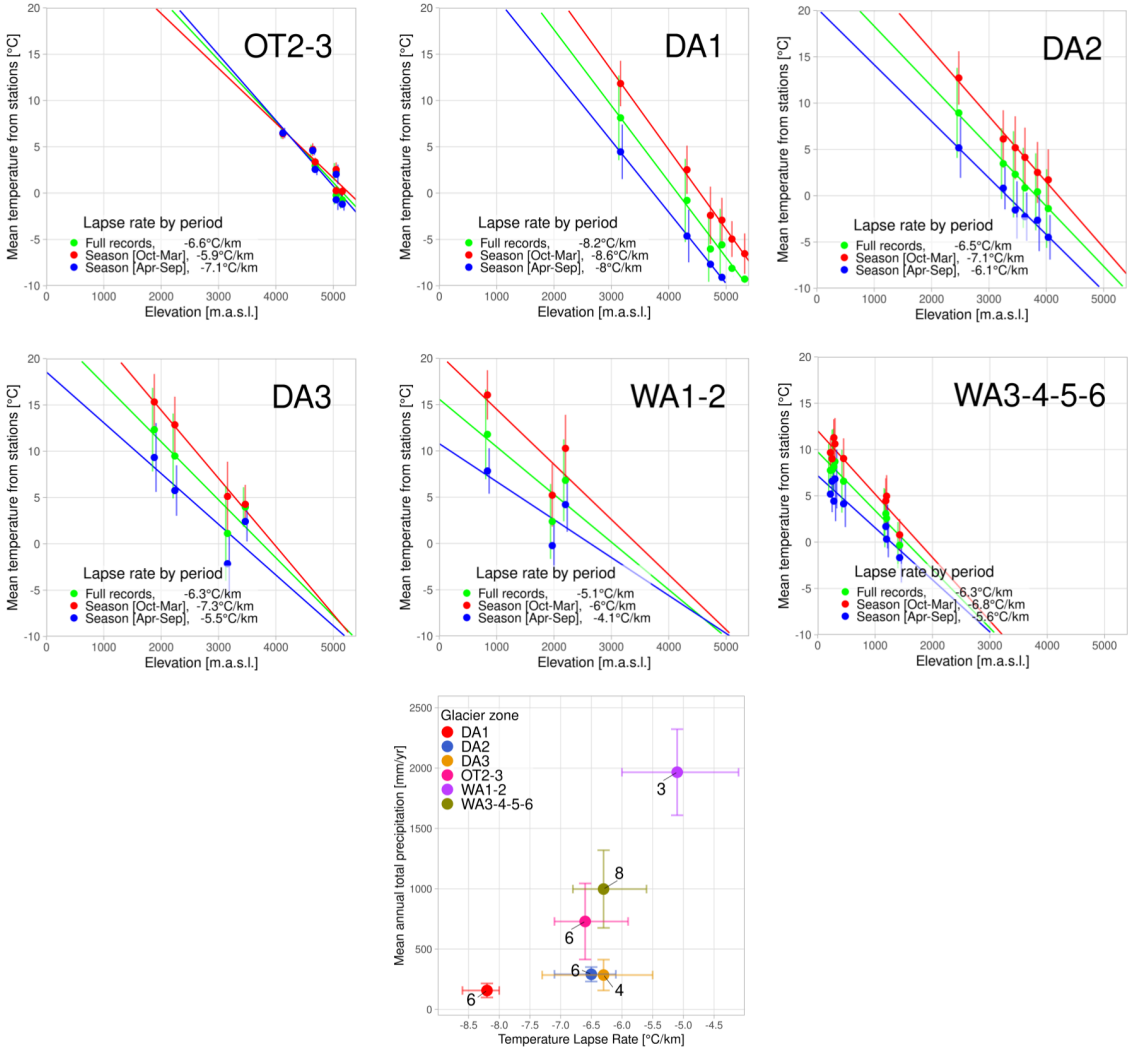

Figure S1. Temperature lapse rates at glaciological zone scale using meteorological records at monthly time step from 1980 to 2019.

2.3 Historical assessment of TerraClimate

In this section, the TerraClimate temperature was evaluated regarding meteorological station measurements (Table S1). Table S2 shows the temperature assessment results in 35 weather stations before and after the application of the lapse rate per glaciological zone, whereas, Figure S2 displays the monthly evaluations.

Table S2. TerraClimate temperature assessment regarding observations before and after temperature lapse rate application. The assessment was made using weather station elevations.

ID	Zone	Weather station name	Weather Station [°C]		Corrected TerraClimate [°C]		Raw TerraClimate [°C]		N° of Months
			Mean	SD	Mean	SD	Mean	SD	

1	OT	Llan_Up-2	6.4	0.2	5.4	0.2	3.9	1.2	113
2	OT	CuchWX	4.7	0.4	4.4	0.2	4	1.2	48
3	OT	Huaytapallana	3	0.2	6.3	0.2	6.6	0.6	24
4	OT	Quisoquepina	-0.4	0.1	2.7	0.4	1.6	1.9	21
5	OT	Zongo off glacier	2.3	0.1	2	0.1	3.4	1.8	220
6	OT	Zongo on glacier	-0.3	0.4	2.1	0.2	3.6	1.8	85
7	DA1	La Frontera	-6.2	0.6	0.4	0.3	-0.8	2.8	58
8	DA1	Estrecho glacier	-8.1	NA	-1.9	NA	-1.7	2.7	12
9	DA1	Guanaco glacier	-10	0.5	-4.1	0.5	-2	3.2	30
10	DA1	Tapado glacier	-5	0.6	-3.2	0.4	-1.4	3.7	16
11	DA1	Tapado morrena	-1.2	0.6	0	0.2	-1.5	3.7	41
12	DA1	La Laguna Embalse	8.1	0.4	4.1	0.1	1.8	3.6	476
13	DA2	Juncal Sur glacier	-1.4	NA	-1.7	NA	-2.7	4.9	12
14	DA2	Olivares Gamma glacier	1.1	0.5	0.3	0.4	-2.3	4.6	68
15	DA2	Estero Yerba Loca en P. Carvajal	3.5	1.1	-0.7	0.3	-6.9	4.2	72
16	DA2	Bello glacier	0.3	1.3	0.3	0.5	0.8	2.6	18
17	DA2	Yeso glacier	-1.6	0.8	-0.2	0.4	0.2	1.8	15
18	DA2	Portezuelo Echaurren	-0.4	1.3	-0.2	0.6	1.4	5.1	37
19	DA2	Pirámide glacier	1.5	0.8	1.4	0.7	-1.8	4.6	42
20	DA2	El Yeso Embalse	8.9	0.4	0.9	0.1	-0.7	4.5	480
21	DA3	G. San Francisco en A. P.	9.4	0.4	12.1	0.3	7.8	4.7	95
22	DA3	San Francisco glacier	3.8	0.9	7.6	0.8	7.1	2.3	13
23	DA3	Cipreses glacier	12.4	1.3	5.9	0.3	5.4	4.8	36
24	DA3	Cortaderal glacier	2.2	2.3	0.3	0.4	-0.5	4.8	20
25	WA1-2	La Punilla	11.9	0.5	10.6	0.3	10.2	4.8	81
26	WA1-2	Volcán Chillán	6.8	4.4	-	-	-	-	-
27	WA1-2	Mocho nunatak	2.6	0.5	4.2	0.3	7.1	4.1	102
28	WA3-4-5-6	San Rafael glacier	3.1	0.3	2.6	0.2	2.6	3.2	90
29	WA3-4-5-6	Rio Nef Antes Junta Estero El Revalse	7.8	0.4	5.5	0.3	3.8	3.6	61
30	WA3-4-5-6	Glaciar Colonia en Lago Cachet-2	6.6	0.4	7.8	0.3	7.1	3.6	84

31	WA3-4-5-6	Greve glacier	-0.7	0.8	1.4	0.4	1.7	2.9	22
32	WA3-4-5-6	O'Higgins	7.8	0.3	7.7	0.2	4.8	3.2	72
33	WA3-4-5-6	Candelario Mancilla	8.7	0.9	6.7	0.3	6.2	3.5	99
34	WA3-4-5-6	Aonikenk	2.7	0.7	5.4	0.2	4.3	3.3	70
35	WA3-4-5-6	Dickson glacier	7.4	0.6	7.9	0.2	5.9	3.1	14

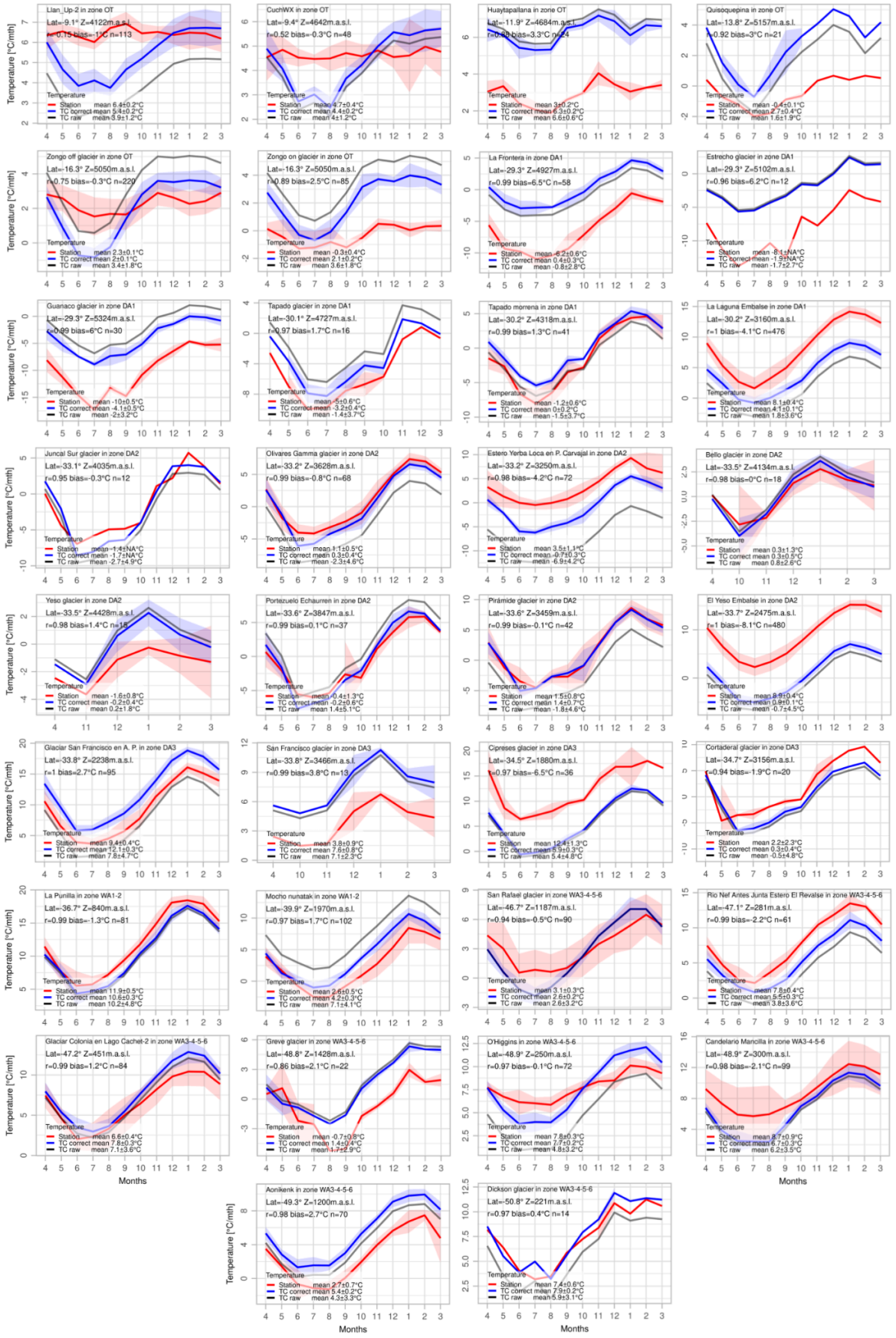
Llan_Up-2 in zone OT
Lat=-9.1° Z=4122m.a.s.l.
r=0.15 bias=-1°C n=113
Temperature
Station mean 6.4±0.2°C
TC correct mean 5.4±0.2°C
TC raw mean 3.9±1.2°C
CuchWX in zone OT
Lat=-9.4° Z=4642m.a.s.l.
r=0.52 bias=-0.3°C n=48
Temperature
Station mean 4.7±0.4°C
TC correct mean 4.4±0.2°C
TC raw mean 4±1.2°C
Huaytapallana in zone OT
Lat=-11.9° Z=4684m.a.s.l.
r=0.99 bias=3.3°C n=24
Temperature
Station mean 3±0.2°C
TC correct mean 6.3±0.2°C
TC raw mean 6.6±0.6°C
Quisoquepina in zone OT
Lat=-13.8° Z=5157m.a.s.l.
r=0.92 bias=3°C n=21
Temperature
Station mean -0.4±0.1°C
TC correct mean 2.7±0.4°C
TC raw mean 1.6±1.9°C
Zongo off glacier in zone OT
Lat=-16.3° Z=5050m.a.s.l.
r=0.75 bias=-0.3°C n=220
Temperature
Station mean 2.3±0.1°C
TC correct mean 2±0.1°C
TC raw mean 3.4±1.8°C
Zongo on glacier in zone OT
Lat=-16.3° Z=5050m.a.s.l.
r=0.89 bias=2.5°C n=85
Temperature
Station mean -0.3±0.4°C
TC correct mean 2.1±0.2°C
TC raw mean 3.6±1.8°C
La Frontera in zone DA1
Lat=-29.3° Z=4927m.a.s.l.
r=0.99 bias=-6.5°C n=58
Temperature
Station mean -6.2±0.6°C
TC correct mean 0.4±0.3°C
TC raw mean -0.8±2.8°C
Estrecho glacier in zone DA1
Lat=-29.3° Z=5102m.a.s.l.
r=0.96 bias=6.2°C n=12
Temperature
Station mean -8±1±NA°C
TC correct mean -1.9±NA°C
TC raw mean -1.7±2.7°C
Guanaco glacier in zone DA1
Lat=-29.3° Z=5324m.a.s.l.
r=0.99 bias=6°C n=30
Temperature
Station mean -1±0.5°C
TC correct mean -4.1±0.5°C
TC raw mean -2±3.2°C
Tapado glacier in zone DA1
Lat=-30.1° Z=4727m.a.s.l.
r=0.97 bias=1.7°C n=16
Temperature
Station mean -5±0.6°C
TC correct mean -3.2±0.4°C
TC raw mean -1.4±3.7°C
Tapado morrena in zone DA1
Lat=-30.2° Z=4318m.a.s.l.
r=0.99 bias=1.3°C n=41
Temperature
Station mean -1.2±0.6°C
TC correct mean 0±0.2°C
TC raw mean -1.5±3.7°C
La Laguna Embalse in zone DA1
Lat=-30.2° Z=3160m.a.s.l.
r=1 bias=-4.1°C n=476
Temperature
Station mean 8.1±0.4°C
TC correct mean 4.1±0.1°C
TC raw mean 1.8±3.6°C
Juncal Sur glacier in zone DA2
Lat=-33.1° Z=4035m.a.s.l.
r=0.95 bias=-0.3°C n=12
Temperature
Station mean -1.4±NA°C
TC correct mean -1.7±NA°C
TC raw mean -2.7±4.9°C
Olivares Gamma glacier in zone DA2
Lat=-33.2° Z=3628m.a.s.l.
r=0.99 bias=-0.8°C n=68
Temperature
Station mean 3.1±0.5°C
TC correct mean 0.3±0.4°C
TC raw mean -2.3±4.6°C
Estero Yerba Loca en P. Carvajal in zone DA2
Lat=-33.2° Z=3250m.a.s.l.
r=0.98 bias=-4.2°C n=72
Temperature
Station mean 3.5±1.1°C
TC correct mean -0.7±0.3°C
TC raw mean -6.9±4.2°C
Bello glacier in zone DA2
Lat=-33.5° Z=4134m.a.s.l.
r=0.98 bias=0°C n=18
Temperature
Station mean 0.3±1.3°C
TC correct mean 0.3±0.5°C
TC raw mean 0.8±2.6°C
Yeso glacier in zone DA2
Lat=-33.5° Z=4428m.a.s.l.
r=0.98 bias=1.4°C n=16
Temperature
Station mean -1.6±0.8°C
TC correct mean -0.2±0.4°C
TC raw mean 0.2±1.8°C
Portezuelo Echaurren in zone DA2
Lat=-33.6° Z=3847m.a.s.l.
r=0.99 bias=0.1°C n=37
Temperature
Station mean -0.4±1.3°C
TC correct mean -0.2±0.6°C
TC raw mean 1.4±5.1°C
Pirámide glacier in zone DA2
Lat=-33.6° Z=3459m.a.s.l.
r=0.99 bias=-0.1°C n=42
Temperature
Station mean 1.5±0.8°C
TC correct mean 1.4±0.7°C
TC raw mean -1.8±4.6°C
El Yeso Embalse in zone DA2
Lat=-33.7° Z=2475m.a.s.l.
r=1 bias=-8.1°C n=480
Temperature
Station mean 8.9±0.4°C
TC correct mean 0.9±0.1°C
TC raw mean -0.7±4.5°C
Glaciar San Francisco en A. P. in zone DA3
Lat=-33.8° Z=2238m.a.s.l.
r=1 bias=2.7°C n=95
Temperature
Station mean 9.4±0.4°C
TC correct mean 12.1±0.3°C
TC raw mean 7.8±4.7°C
San Francisco glacier in zone DA3
Lat=-33.8° Z=3466m.a.s.l.
r=0.99 bias=3.8°C n=13
Temperature
Station mean 3.8±0.9°C
TC correct mean 7.6±0.8°C
TC raw mean 7.1±2.3°C
Cipreses glacier in zone DA3
Lat=-34.5° Z=1880m.a.s.l.
r=0.97 bias=-6.5°C n=36
Temperature
Station mean 12.4±1.3°C
TC correct mean 5.9±0.3°C
TC raw mean 5.4±4.8°C
Cortaderal glacier in zone DA3
Lat=-34.7° Z=3156m.a.s.l.
r=0.94 bias=-1.9°C n=20
Temperature
Station mean 2.2±2.3°C
TC correct mean 0.3±0.4°C
TC raw mean -0.5±4.8°C
La Punilla in zone WA1-2
Lat=-36.7° Z=840m.a.s.l.
r=0.99 bias=-1.3°C n=81
Temperature
Station mean 11.9±0.5°C
TC correct mean 10.6±0.3°C
TC raw mean 10.2±4.8°C
Mocho nunatak in zone WA1-2
Lat=-39.9° Z=1970m.a.s.l.
r=0.97 bias=1.7°C n=102
Temperature
Station mean 2.6±0.5°C
TC correct mean 4.2±0.3°C
TC raw mean 7.1±4.1°C
San Rafael glacier in zone WA3-4-5-6
Lat=-46.7° Z=1187m.a.s.l.
r=0.94 bias=-0.5°C n=90
Temperature
Station mean 3.1±0.3°C
TC correct mean 2.6±0.2°C
TC raw mean 2.8±3.2°C
Rio Nef Antes Junta Estero El Revalse in zone WA3-4-5-6
Lat=-47.1° Z=281m.a.s.l.
r=0.99 bias=-2.2°C n=61
Temperature
Station mean 7.8±0.4°C
TC correct mean 9.5±0.3°C
TC raw mean 3.8±3.6°C
Glaciar Colonia en Lago Cachet-2 in zone WA3-4-5-6
Lat=-47.2° Z=451m.a.s.l.
r=0.99 bias=1.2°C n=84
Temperature
Station mean 6.6±0.4°C
TC correct mean 7.8±0.3°C
TC raw mean 7.1±3.6°C
Greve glacier in zone WA3-4-5-6
Lat=-48.8° Z=1428m.a.s.l.
r=0.86 bias=2.1°C n=22
Temperature
Station mean -0.7±0.9°C
TC correct mean 1.4±0.4°C
TC raw mean 1.7±2.9°C
O'Higgins in zone WA3-4-5-6
Lat=-48.9° Z=250m.a.s.l.
r=0.97 bias=-0.1°C n=72
Temperature
Station mean 7.6±0.3°C
TC correct mean 7.7±0.2°C
TC raw mean 4.8±3.2°C
Candelario Mancilla in zone WA3-4-5-6
Lat=-48.9° Z=300m.a.s.l.
r=0.98 bias=-2.1°C n=99
Temperature
Station mean 8.7±0.9°C
TC correct mean 6.7±0.3°C
TC raw mean 6.2±3.5°C
Aonikenk in zone WA3-4-5-6
Lat=-49.3° Z=1200m.a.s.l.
r=0.98 bias=2.7°C n=70
Temperature
Station mean 2.7±0.7°C
TC correct mean 5.4±0.2°C
TC raw mean 4.3±3.3°C
Dickson glacier in zone WA3-4-5-6
Lat=-50.8° Z=221m.a.s.l.
r=0.97 bias=0.4°C n=14
Temperature
Station mean 7.4±0.6°C
TC correct mean 7.9±0.2°C
TC raw mean 5.9±3.1°C
Temperature [°C/mth]
Months

Figure S2. Monthly TerraClimate temperature and temperature records comparison in 34 weather stations on and near of glaciers across the Andes.

2.4 Precipitation factor fitting

The results of the precipitation factor adjustment in 18 glaciers along the Andes are presented in Table S3. Despite the Pf estimation in Tropical Andes we used Pf = 1, due high precipitation overestimation observed after ran the simulations.

Table S3. Standard deviation of annual mass balance for observed and simulated glaciers.
Orange color shows high SD differences whereas the blue color show close SD between mb observed and simulated.

RGIv6.0 id	Name	Pf	LR [°C/km]	Sim mb mean [mm w.e.]	Sim mb sd [mm w.e.]	Obs mb mean [mm w.e.]	Obs mb sd [mm w.e.]	Start year	End year	Glaciological zone	Final Pf
RGI60-16.01339	Antisana 15 Alpha	1	-6.6	-114	540	-511	490	2000	2019	IT	1
RGI60-16.01355	Conejeras	1	-6.6	-1971	1628	-3300	1587	2006	2019	IT	
RGI60-16.00532	Charquini Sur	4	-6.6	-437	138	-918	1055	2003	2018	OT	1
RGI60-16.00543	Zongo	4	-6.6	-472	352	-248	520	2000	2018	OT	
RGI60-16.01447	Chacaltaya	2.4	-6.6	219	620	-1314	616	2000	2008	OT	
RGI60-16.02086	Yanamarey	4	-6.6	-1073	411	-1078	728	2005	2019	OT	
RGI60-16.02444	Artesonraju	1	-6.6	-469	759	-828	610	2005	2019	OT	
RGI60-17.00466	Azufre	4	-6.5	-2562	421	-2955	499	2018	2019	DA3	4
RGI60-17.02128	Martial Este	2.3	-6.4	-281	576	-183	569	2001	2019	WA3-4-5-6	2.3
RGI60-17.12440	Mocho-Choshuenco	4	-6.5	-1003	1008	-908	1041	2004	2019	WA2	4
RGI60-17.13715	Echaurren	4	-6.9	-517	760	-832	1356	2000	2019	DA2	1.9
RGI60-17.14203	Piloto Este	1.9	-6.9	237	742	-463	751	2000	2003	DA2	
RGI60-17.14642	Agua Negra	3.2	-8.2	-850	493	-383	492	2015	2019	DA1	2.8
RGI60-17.14868	Guanaco Oeste	1.1	-8.2	-376	400	-619	396	2004	2015	DA1	

RGI60-17.14872	Toro 2	4	-8.2	-73	401	-1097	626	2004	2009	DA1
RGI60-17.14874	Esperanza	4	-8.2	-171	455	-1137	962	2004	2009	DA1
RGI60-17.14887	Amarillo	3.8	-8.2	-380	842	-295	1665	2008	2019	DA1
RGI60-17.14889	Los Amarillos	4	-8.2	-199	297	-296	1100	2008	2019	DA1

3 Mass Balance evaluation

This section describes the data used to evaluate the simulated mass balance regarding observations.

3.1 Mass balance observations

In table S4 are described the characteristics of 15 monitored glaciers with mass balance measurements located between 5°N-55°S. We filtered glaciers with mass balance observations with a greater geodetic mass balance error that its mass balance estimation from Hugonnet et al.(2021) between 2000-2019, such as Chacaltaya (RGI60-16.01447; -0.16±0.17 m w.e.), Los Amarillos (RGI60-17.14889; -0.14±0.15 m w.e.), Toro 2 (RGI60-17.14872; -0.13±0.19 m w.e.), Antisana 15 Alpha (RGI60-16.01339; -0.11±0.12 m w.e.). As well as, very small monitored glaciers like Esperanza glacier (RGI60-17.14874; 0.1 km^2).

Table S4. In situ glaciological mass balance measurements on 15 glaciers used to validate OGGM simulated mass balance across the Andes

N°	Zone	Glacier name	Coordinates [°]		Elevation [m a.s.l.]	Glacier area [km^2]	RGIv6.0 id	Mass balance observation references
			Latitude	Longitude				
1	IT	Conejeras	4.8	-75.4	4791	3.8	RGI60-16.01355	WGMS, 2021
2	OT	Zongo	-16.3	-68.1	5320	2.3	RGI60-16.00543	
3	DA1	Guanaco Oeste	-29.3	-70	5163	1.8	RGI60-17.14868	
4	DA1	Guanaco Este	-29.3	-70	5161	0.7	RGI60-17.14869	
5	DA1	Amarillo	-29.3	-70	5174	0.4	RGI60-17.14887	
6	DA1	Estrecho	-29.3	-70	5194	1.9	RGI60-17.14892	
7	DA1	Ortigas 1	-29.4	-70.1	5003	1.2	RGI60-17.14849	
8	DA1	Agua Negra	-30.2	-69.8	4971	1.1	RGI60-17.14642	
9	DA2	Piloto Este	-32.6	-70.1	4481	2.9	RGI60-17.14203	
10	DA2	Paula	-33.2	-70.3	4688	0.1	RGI60-17.13879	Marangunic et al., 2021
11	DA2	Paloma Oeste	-33.2	-70.3	4408	0.6	RGI60-17.13882	
12	DA2	Paloma Este	-33.2	-69.7	4762	0.6	RGI60-17.13883	

13	DA2	Del Rincón	-33.2	-70.1	5050	0.4	RGI60-17.13887	
14	WA2	Mocho-Choshuenco	-39.9	-72	1963	6.3	RGI60-17.12440	WGMS,2021
15	WA4	Martial Este	-54.8	-68.4	1091	0.7	RGI60-17.02128	

3.2 Superficial mass balance assessment

In this section, the results of simulated mass balance evaluation from OGGM regarding in situ measurements are presented. Table S5 shows the results of the evaluation in 15 Andean glaciers. The results of annual mass balance differences and cumulative mass balance differences per glacier are displayed in Figure S3 and Figure S4.

Table S5. OGGM mass balance evaluation on 15 glaciers using in situ measurements from the Tropical Andes to the Wet Andes (2000-2019)

N°	Zone	Glacier name	MB Obs [mm]	MB Sim [mm]	MB Hugonnet et al. 2021 2000-2019 [mm]	Date range	Person corr	p-value	r^2	RMSE [mm]	bias [mm]
1	IT	Conejeras	-3300±1587	-2196±2582	-1644±283	2006-2019	0.9	0	0.8	704	1104
2	OT	Zongo	-248±520	-471±299	-548±148	2000-2018	0.3	0.22	0.1	484	-224
3	DA1	Guanaco Oeste	-477±638	-396±573	-393±154	2003-2015	0	0.93	0.0	613	81
4	DA1	Guanaco Este	-477±638	-340±572	-347±176	2003-2015	0	0.93	0.0	613	137
5	DA1	Amarillo	-295±1665	-345±663	-204±168	2008-2019	0	0.89	0.0	1592	-50
6	DA1	Estrecho	-682±379	-462±593	-411±159	2007-2014	0.6	0.11	0.4	281	220
7	DA1	Ortigas 1	-1036±630	-358±549	-320±158	2007-2014	0	1	0.0	589	679
8	DA1	Agua Negra	-383±492	-828±455	-524±171	2015-2019	-0.7	0.17	0.5	303	-445
9	DA2	Piloto Este	-462±751	243±753	-318±150	2000-2003	0.8	0.21	0.6	395	706
10	DA2	Paula	-967±639	-963±568	-383±286	2014-2019	0.8	0.08	0.6	384	4
11	DA2	Paloma Oeste	-1217±913	-1102±500	-589±237	2014-2019	0.7	0.1	0.5	564	114
12	DA2	Paloma Este	-1090±1102	-876±498	-288±183	2015-2019	0.8	0.08	0.7	542	214
13	DA2	Del Rincón	-762±361	-283±484	17±252	2014-2019	0.8	0.05	0.7	191	479
14	WA2	Mocho-Choshuenco	-908±1041	-1045±1043	-691±139	2004-2019	0.5	0.11	0.3	833	-137
15	WA4	Martial Este	-183±569	-280±560	-236±224	2001-2019	0.5	0.02	0.3	472	-98

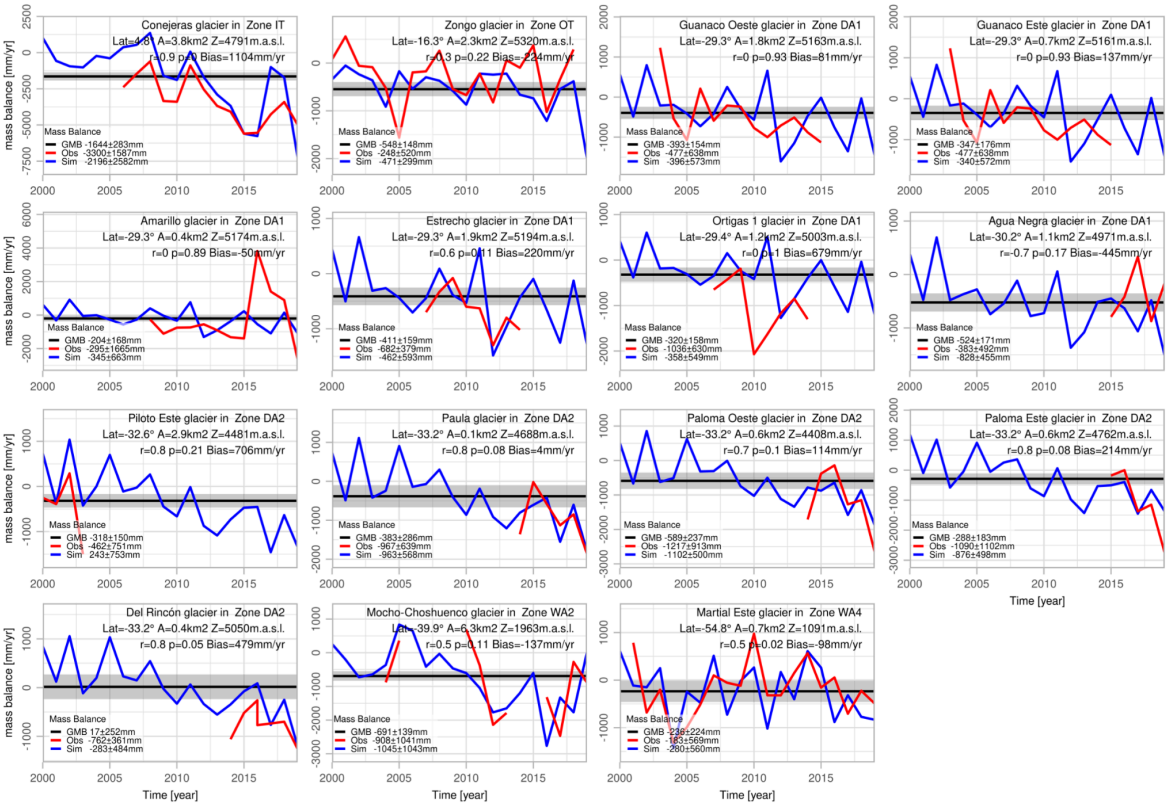

Figure S3. Annual mass balance differences between OGGM simulations and observations on 15 glaciers across the Andes (2000-2019).

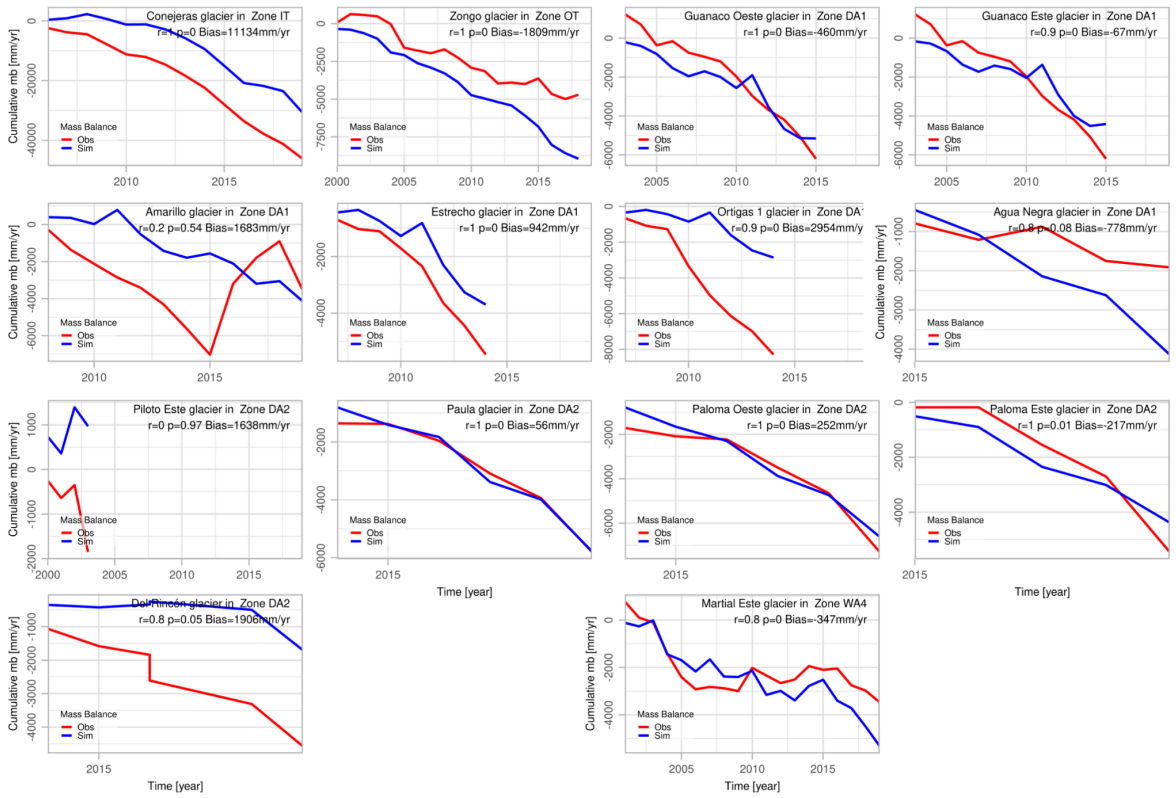

Figure S4. Cumulative mass balance differences between OGGM simulations and observations on 14 glaciers across the Andes (2000-2019).

4 Morphometric and climate variables associated to catchments with glacier melt and rainfall on glaciers changes

Table S6. Mean morphometric and climate variables on glacierized catchments with glacier melt and rainfall on glaciers changes between periods 2000-2009 and 2010-2019

Change in contribution	Latitude median [°]	Elevation [m a.s.l.]	Area [km^2]	Slope [°]	Aspect mode [°]	Temperature (change) [°C]	Total precipitation (change %) [mm yr^{-1}]	Nº of catchments
Glacier melt								
Increase	-46	2404±1637	0.9±3.3	25±7	120	-0.1 (0.4)	2550 (-8)	661
Reduction	-52	1737±1319	0.5±2	24±7	126	0.6 (0.3)	2929 (-14)	95
Not change	-44	1944±1146	0.2±0.3	27±7	110	0.4 (0.4)	2929 (-10)	30
Rainfall on glaciers								
Increase	-46	2691±1734	1±3.8	25±7	138	-0.6 (0.4)	1843 (-4)	403
Reduction	-44	1898±1339	0.7±2.3	25±8	110	1.2 (0.3)	3773 (-11)	322

Not change	-33	3881±1548	0.5±1.7	26±8	141	-2.1 (0.4)	1547 (-10)	61

5 Climate correlations regarding annual mass balance

Figure S7 shows statistically significant correlations (p-value < 0.05) between mean annual temperature and precipitation with the mean annual simulated mass balance in the period 2000-2019 at catchment scale across the Andes. The mean temperature correlation in 729 catchments was -0.74±0.1, while we estimated a mean precipitation correlation in 600 of -0.7±0.1. The high correlations of precipitation and mass balance in the Dry Andes and precipitation and mass balance in the Wet Andes are similar as expected from the Caro et al. (2021) estimation.

Table S7. Mean annual temperature and precipitation correlations regarding mean annual simulated mass balance per glaciological regions across the Andes

Glaciological region	Temperature mean correlation	Precipitation mean correlation	Temperature N° of catchments	Precipitation N° of catchments
Tropical Andes	-0.87±0.1	0.65±0.1	183	16
Dry Andes	-0.63±0.1	0.75±0.1	131	136
Wet Andes	-0.72±0.1	0.69±0.1	415	448

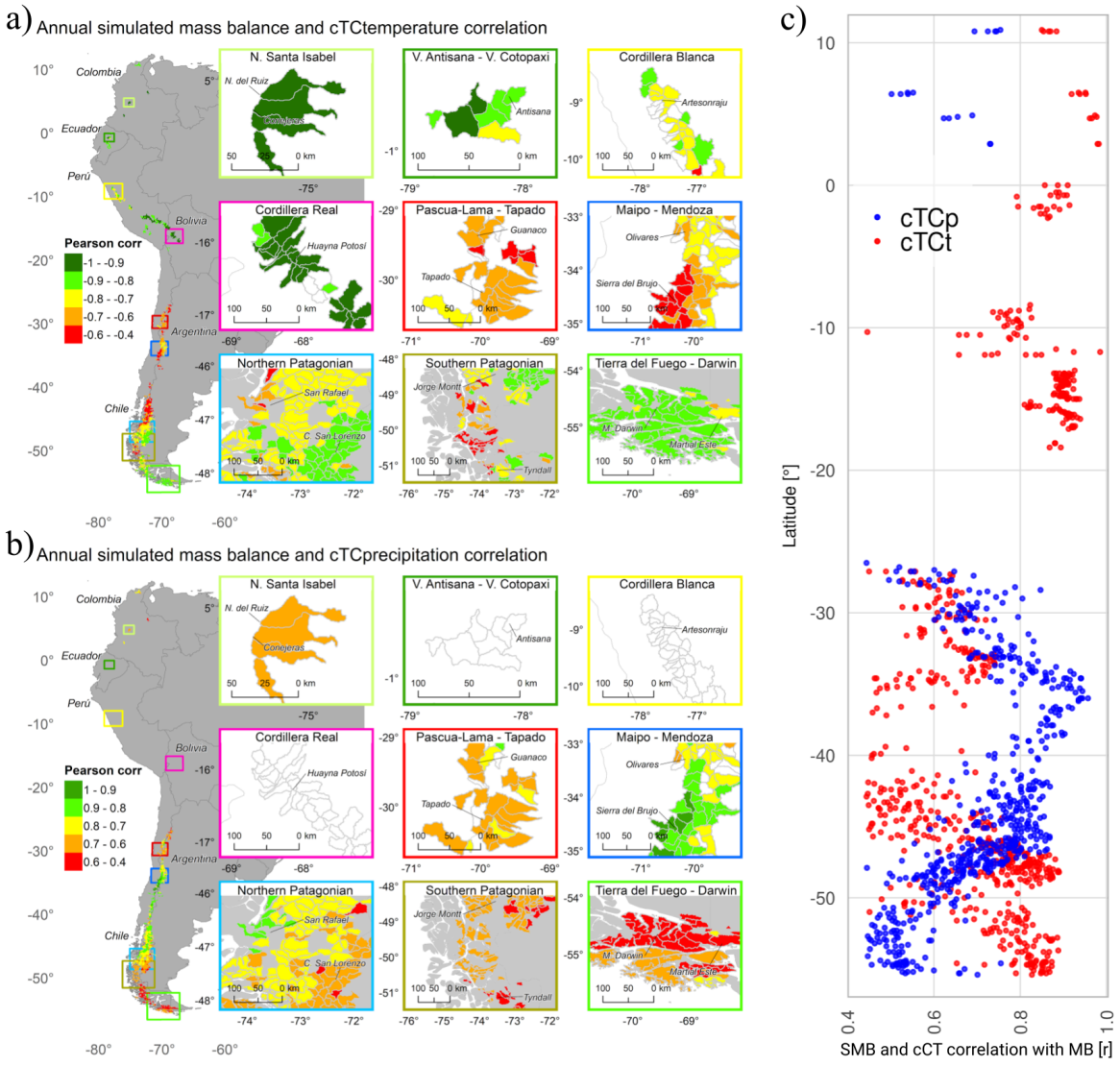

Figure S5. Correlations between annual corrected temperature and precipitation with simulated annual mass balance for the period 2000-2019 at catchment scale. Correlations are presented by a) temperature and b) precipitation considering some interesting catchments across the Andes. c) Correlations are present to temperature (cTCp) and precipitation (cTCp), where the negative correlation of temperature was escalated to positive values for easier comparison with precipitation correlation. Mean values were extracted from each simulated glacier inside 729 catchments for temperature and 600 catchments for precipitation, considering statistically significant correlations in the 786 simulated catchments (< 0.05).

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