

Article

Modelling snowmelt runoff from tropical Andean glaciers under climate change scenarios in the Santa River sub-basin (Peru)

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Table S1. Characteristics of the six elevation zones extracted from the DEM of the Santa river sub-basin.

Zone	Elevation range (m)	Hypsometric altitude	Área (km ²)	Area (%)	Climatological station
A	1410–2300	2141.87	76.31	1.43	-
B	2300–3200	2843.61	645.45	12.11	Yungay
C	3200–4100	3730.57	1696.76	31.82	Recuay
D	4100–5000	4497.02	2446.71	45.89	Yanamarey
E	5000–5900	5242.05	449.67	8.43	Artesonraju AP2
F	5900–6766	6129.92	17	0.32	-

Table S2. Snow cover area in km² generated with MODIS10A1 sensor imagery every 1 days at GEE.

Date	Period in years / Glacier area (km2)																	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1-Jan		196.2	299.2	81.8	158.2	210.9	442.3	139.6	95.4	204	257.1	318.9	221.5	115.5	65.8	90.5	242.8	88.8
9-Jan		315.2	151.3	217.2	277.4	237.5	217.5	157.8	231.3	231	204.5	77.5	197.9	169.7	154.5	255.4	245.5	128.6
17-Jan		390.4	115.3	184.5	296.2	331.4	141	71.6	152.8	376.9	56.5	363.4	269.4	223.4	146.4	160.2	176.3	238.2
25-Jan		149.7	60.7	110.7	148.3	236	109.9	66.4	253.4	148.4	198.8	155.9	170.5	182.1	289.5	167.6	120	135.2
02-feb		260.8	229.4	75.2	76.3	179	18.8	161.8	158.1	157.7	188.1	170.1	350.1	123.3	135.9	260.9	82.8	131.9
10-feb		250	136.7	299.4	132.6	202.1	292.3	180.4	96.3	213.9	103.6	398.7	422.6	159.4	120.2	190.3	129.7	162.8
18-feb		192.4	89.1	206.3	262.2	216.3	228.5	248.7	227.9	153.1	158.8	103.9	123.6	112.2	92.6	284.8		193.6
26-feb	649	348.6	233.2	254.5	157.1	131.4	78.6	87.5	276	127.6	211.5	145.3	218.4	94.6	267.8	215.1	235.7	311.6
06-mar	551.8	184.5	232.9	92.7	51.8	165.6	46.2	112.4	406.9	143.5	44.4	322.7	170	154.8	212.2	141.7	150.6	137.1
14-mar	321.5	112.5	114.5	517.5	46.4	176	195	316.8	314.8	151.9	86.8	349.3	131.2	102.7	160.1	75.6	129.1	244.1
22-mar	527.9	281.9	226	105.6	81.7	48	156.1	200.7	48	252.8	174.2	177.3	187.2	342.8	157.5	273.4	143.4	161
30-mar	238.3	96.8	160.6	72.6	109	66.2	74.7	174.1	266.3	333.6	241.1	139.4	225.2	153.4	209.8	109.7	166.2	128.3
7-Apr	189.6	142.7	237.3	163.7	132.3	157.4		146.6	191	221.6	244	307.8	103.7	99.3	126.8	97.7	178.4	192.5
15-Apr	411.6	402.7	121	201.4	273.1	246.7	369	257.8	322.9	219.7	162.9	224.1	165.1	286.8	180.8	212.5	26.1	148.1
23-Apr	115.4	357.8	277.9	256	208.4	254.2		184.6	238.6	201.3	51.3	209.9	372.3	292.9	121.4	170.8	247.5	233.1
01-may	110.3	317	266.6	111.2	160.2	268.8		126	375.4	374.1	236.3	284	369.7	167.9	171.5	131.5	250.6	156.7
09-may	321	200.2	260.9	147.4	284.7	222.2	336.6	331.1	243.4	254.4	299.5	307.5	284.6	248	241.3	170.5	117.4	79.6
17-may	481	352.4	311.5	273.1	139	310.5	255.5	266	309.9	309.9	277.4	351	72	237.7	312.1	425.8	132.6	51.1
25-may	450.5	295.6	269	151	285.4	279.7	271.3	281.1	268.5	287.6	238.3	300.5	337.2	216.5	319.5	218.6	245.6	140.1
02-jun	232.4	210.7	244.3	297.3	263.7	257	71.6	330.7	348.3	265.7	171.8	303.8	265.4	203.7	275.6	247.7	185.7	305.2
10-jun	392	280	263.7	289	254.7	281.1	360.3	279.7	312.3	315.6	264.3	266.3	258.2	223.7	236.8	259.3	216.5	272.4
18-jun	362.5		237.9	303.1	246.5	253.2	278.6	174.8	326.4	236.4	147.2	285	263.6	231	258.2	287.1	227.6	243.4
26-jun	432.3	73.2	250	262.7	104.2	245.2	282.8	281.9	357.2	316.7	255.7	301.8	269.7	295.3	222.2	298.9	232.2	267.6
04-jul	334.6	220.6	204.3	236.2	160.3	252.3	281.9	255.9	306.8	291.1	249	296	314.2	251.5	227.5	282.9	198.7	218.8
12-jul	366.7	253.2	270	306.5	233.4	263.9	290	236.8	307.2	282.6	129.1	263.6	305.4	264.2	253.8	311	246.4	283.7
20-jul	290	318	324.1	234	233.9	261.8	232.5	222.8	249.5	212.2	267.9	292.4	320.5	272.5	259	254.2	234.5	251.6
28-jul	297.1	348.9	284.3	31.1	303.8	263.8	266.7	280.9	268.8	324.5	227	285.7	265.3	285.7	296.4	309.6	222.4	267.5
5-Aug	481.8	292.8	293.3	258.5	279.8	177.7	205.6	221.2	159.7	249	234.1	276.6	307.7	249.6	152.1	250.3	196.7	243.7
13-Aug	323	255.2	119.3	290.3	252.2	245.6	106.7	252.1	258.7	308.4	203.2	246.6	258.7	268.9	282.2	265.4	179.3	231
21-Aug	264.1	291.5	108.8	214.9	260.2	210.4	136.8	278.9	220.3	263.5	207.3	222	243.9	128.2	261.1	172.1	203.3	197.9
29-Aug	249.3	310.3	253.8	212.1	174.5	178.9	236.7	163.3	259.1	168.9	57.6	233.4	210.8	295.3	214.7	252.5	150.1	176.7
06-sep	244.7	162.8	231.4	220	192.9	111.5	259.8	81.7	195.6	313.5	242.2	130.7	283.9	247.3	116.4	148.9	170.7	50.3
14-sep	103.3	155.3	144.3	220.9	319.7	231	235.6	196.7	125.6	213.6	211.5	116.3	218.6	201	223.9	218.5	143	232.1
22-sep	175.4	135.8	218.6	274.7	195.6	206.9	209.1	138.7	198.2	100.7	105.9	88.7	42.4	169.7	142.9	56.7	37.1	150.9
30-sep	219.2	263.5	73.9	216.2	73.5	25.6	202.8	238.3	90	113	183.7	105.7	209.8	74.5	144.6	199.6	73.5	195.4
08-oct	237.2	105.8	148.3	205.1	254.7	263.5	273.1	302.2	137.3	108.8	115.3	263.4	119.2	63	39.3	208.7	220.1	153.1
16-oct	235.2	185	137	168.2	70.6	70.1	286.3	187	263.6	52.4	154.7	221.8	22.4	141	118.4	81.3	146.5	67
24-oct	273.8	78.6	41	119.2	144.6	195.7	218	114.2	72.4	283.7	116.2	57	106.5	140.6	195.6	103	129.7	140.6
01-nov	306.6	341.9	310.5	224.2	51.3	141	179	289.5	102.4	295.2	184.9	139.4	114.6	281.6	70.4	229.5	152.6	200.9
09-nov	297.2	147.3	118.9	211.9	262.3	243.3	83.1	199.9	138.5	227.8	90.1	127.7	172.8	147.3	144.9	91.8	194.5	170.6
17-nov	208.8	104	36	247.6	337.5	291.3	185.3	108.4	116	160.5	372.3	54.7	194.2	279.5	304.5	231.1	199.3	201.8
25-nov	42.2	308.8	103.4	62.3	181.2	249.6	206.9	278.5	74.4	229	156.4	188.9	208.4	220.7	82.2	81.7	69.5	161.4
3-Dec	89	111.9	207.1	238.2	212.5	149.7	123.5	267.6	324.8	54.4	133.7	67.1	78.8	316.1	138.2	300.3	188	176.5
11-Dec	409.4	303.7	151.3	63.2	179.7	39.7	107.7	73.5	298.1	200.7	134.9	139.6	184.1	215.4	192.4	130.7	163	175.7
19-Dec	99.4	264.4	259.3	131	354.4	158.7	85.2	171.4	252.1	167.7	116.8	347.2	168.6	271.3	214.2	86	123.5	192.4
27-Dec	197	297.3	117.7	126	41.9	294.5	176.7	157.1	229.8	289.4	228.7	196.3	160.7	112.7	175	244.4	135.8	187.1
Mean	295.7	237.1	194.5	199.7	193.9	206.6	205.0	202.1	227.6	226.3	182.5	222.3	216.5	202.9	189.7	201.2	170.2	184.3
Max.	649	402.7	324.1	517.5	354.4	331.4	442.3	331.1	406.9	376.9	372.3	398.7	422.6	342.8	319.5	425.8	250.6	311.6

Table S3. Values of the climatic variables of precipitation, temperature, SCA and discharge for the SRM from 2005 to 2009.

Climate station	Snow Cover Area				Discharge—three station			
	Correlation Method				Correlation Method			
	DCCA	Pearson	Kendall	Spearman	DCCA	Pearson	Kendall	spearman
Precipitation								
Recuay	−0.71	−0.32	−0.32	−0.44	0.57	0.37	0.37	0.50
Yungay	−0.56	−0.34	−0.34	−0.45	0.67	0.48	0.47	0.61
Yanamarey	−0.04	−0.33	−0.27	−0.37	0.86	0.44	0.32	0.43
Artesonraju_AP2	−0.64	−0.43	−0.31	−0.44	0.38	0.47	0.43	0.61
Temperature								
Recuay	−0.67	−0.33	−0.23	−0.34	−0.19	0.12	0.23	0.35
Yungay	0.15	0.00	−0.02	−0.02	0.81	−0.10	−0.01	−0.01
Yanamarey	−0.09	0.18	0.13	0.20	−0.81	−0.24	−0.14	−0.21
Artesonraju_AP2	−0.30	−0.07	−0.05	−0.08	−0.41	0.12	0.19	−0.76
Discharge	−0.07	−0.32	−0.28	−0.42				

Table S4. Monthly average discharge under climate change scenario RCP 4.5.

Months	Actual	Simulated		
		RCP 4.5 -30	RCP 4.5 - 50	RCP 4.5 - 80
January	139.8	152.4	151	139.8
February	150.4	143.4	127.7	132.4
March	338.7	370.1	367	356.3
April	224.4	204.5	201.7	196.2
May	74.3	44.6	45	44.7
June	24.7	21.5	18.7	19.8
July	27.1	37	38.6	37.3
August	21.6	23.8	22.1	21.8
September	31	37.6	36.4	40.5
October	51.6	69.7	67.4	64.6
November	62.7	63.4	61.6	53.3
December	78.6	80.5	78.7	79.4

Table S5. Monthly average discharge under climate change scenario RCP 8.5.

Months	Actual	Simulated		
		RCP 8.5 - 30	RCP 8.5 - 50	RCP 8.5 - 80
January	139.8	102.1	144.1	196
February	150.4	138.8	136.6	164.1
March	338.7	337	332.5	338.5
April	224.4	211.4	204.2	192
May	74.3	66.5	63.8	63.6
June	24.7	19.6	24.8	18.1
July	27.1	35.2	30	27.5
August	21.6	18.5	22	20.9
September	31	34.3	30.7	41.2
October	51.6	65.8	52.4	53.1
November	62.7	58	58.9	45.1
December	78.6	86.6	65.2	65.0