

*Glaciar
La Paloma*



Vulnerability and threats to snow and glaciers in the Southern Andes

Gino Casassa

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Glaciers, shown in red, v5 of the Randolph Glacier Inventory (Pfeffer et al., 2014). Yellow triangles represent WGMS glacier mass balance data obtained with the glaciological method 1.

Randolph Glacier Inventory v5 2015
29.333 km² 16.046 glaciers

Chile DGA Inventory Feb. 2014
23.459 km² 24.114 glaciers

N	NAME	ID WGMS	LAT. S	LON. W	COUNTRY	PERIOD	AREA [km ²]
1	LOS AMARILLOS	3904	29.29	69.99	Chile	2008-2012	0.95
2	AMARILLO	3905	29.30	70.00	Argentina	2008-2012	0.24
3	GUANACO ^a	3983	29.32	70.00	Chile	2004-2009	1.84
4	ESPERANZA ^a	3982	29.33	70.03	Chile	2004-2009	0.04
5	TORO 1 ^a	3980	29.33	70.01	Chile	2004-2009	0.07
6	TORO 2 ^a	3981	29.33	70.02	Chile	2004-2009	0.07
7	CONCONTA NORTE	3902	29.97	69.64	Argentina	2008-2012	0.08
8	BROWN SUPERIOR	3903	29.98	69.64	Argentina	2008-2012	0.19
9	PILOTO ESTE ^b	3589	32.22	70.05	Argentina	1980-2003	0.50
10	ECHAUREN NORTE	1344	33.57	70.13	Chile	1976-2013	0.40
11	MOCHO CHOSHUENCO SE ^c	3972	39.92	72.03	Chile	2004-2005	4.80
12	DE LOS TRES	1675	49.33	73.00	Argentina	1996-1998	0.97
13	MARTIAL ESTE	2000	54.78	68.40	Argentina	2001-2012	0.09
14	MARTIAL	917	54.78	68.42	Argentina	2000-2003	0.33

INVENTARIO NACIONAL DE GLACIARES

Inventario Nacional de
Glaciares

Marco Jurídico

Metodología

Provincias

Listado de Cuencas

Galería de Fotos

Prensa

Agradecimientos

Autoridades - Equipo Trabajo

Contactos



En Argentina los glaciares y otras crioformas cumplen un papel trascendente en el desarrollo regional y son componentes emblemáticos del patrimonio ambiental de la Cordillera de los Andes. Entre otros atributos, estos cuerpos de hielo son reconocidos como componentes cruciales del sistema hidrológico de montaña y como "reservas estratégicas" de agua para las zonas bajas adyacentes en gran parte de la diagonal árida del país.

Si bien la nieve que se acumula cada invierno en la Cordillera constituye la principal fuente de agua para

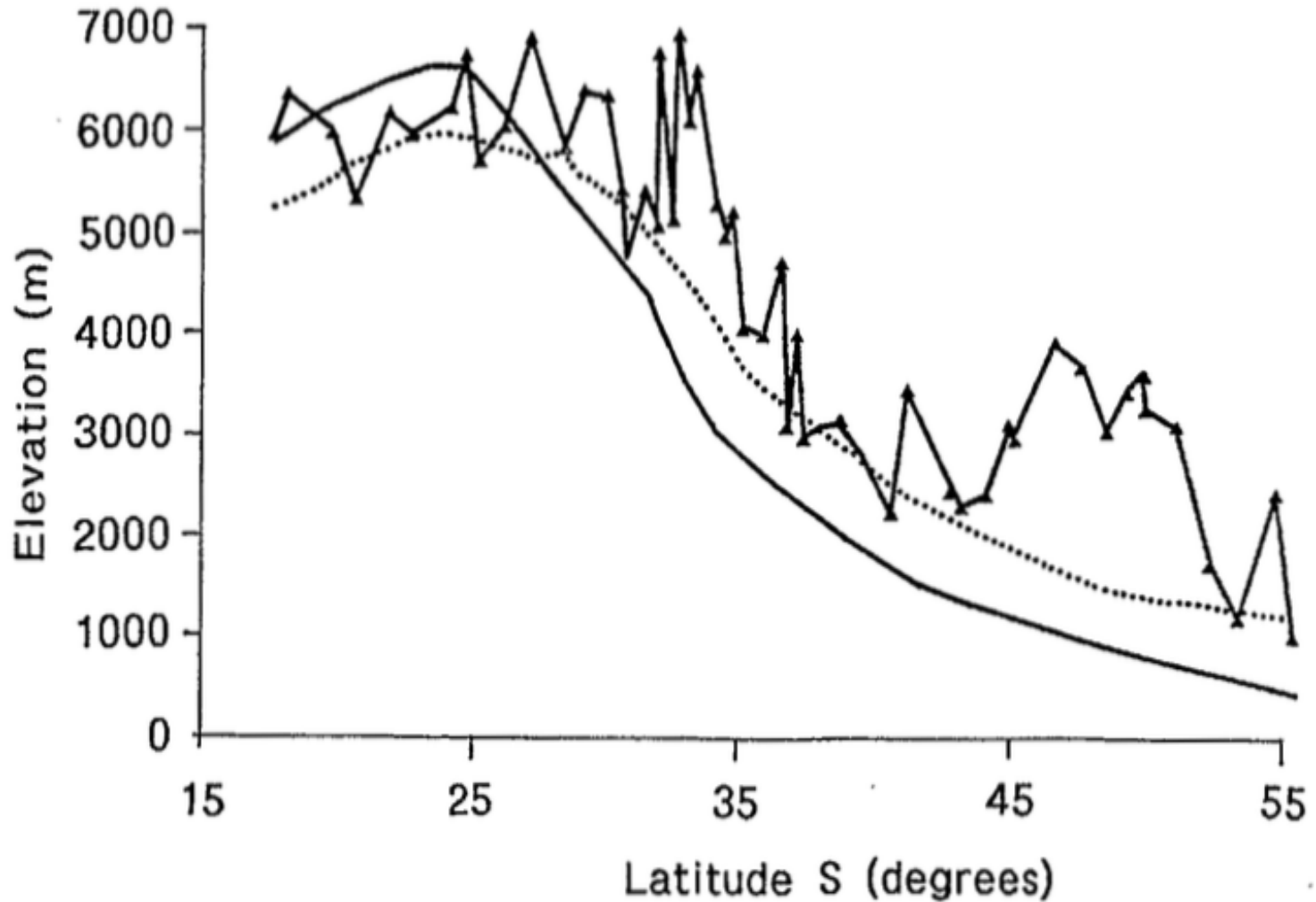
Ferri, L. 2015. The glacier inventory of the Central Andes of Argentina (31° - 35° S). AGU Fall Meeting, San Francisco, Abstract ID 73876.

8069 glaciers covering an area of 1768 km².

Debris-covered ice and rock glaciers represent 57% of the total inventoried area.

Gradual transition from debris-covered glaciers, in the upper part, to rock glaciers, in the lower sector.





Latitudinal variation of the approximate equilibrium line altitudes (ELAs) on the western (continuous line) and on the eastern Andes (dotted line), together with the highest elevation of peaks (line with triangles). The ELAs are adapted from the regional snowlines of Nogami (1972). (From Casassa et al., 1998)

Calentamiento del planeta

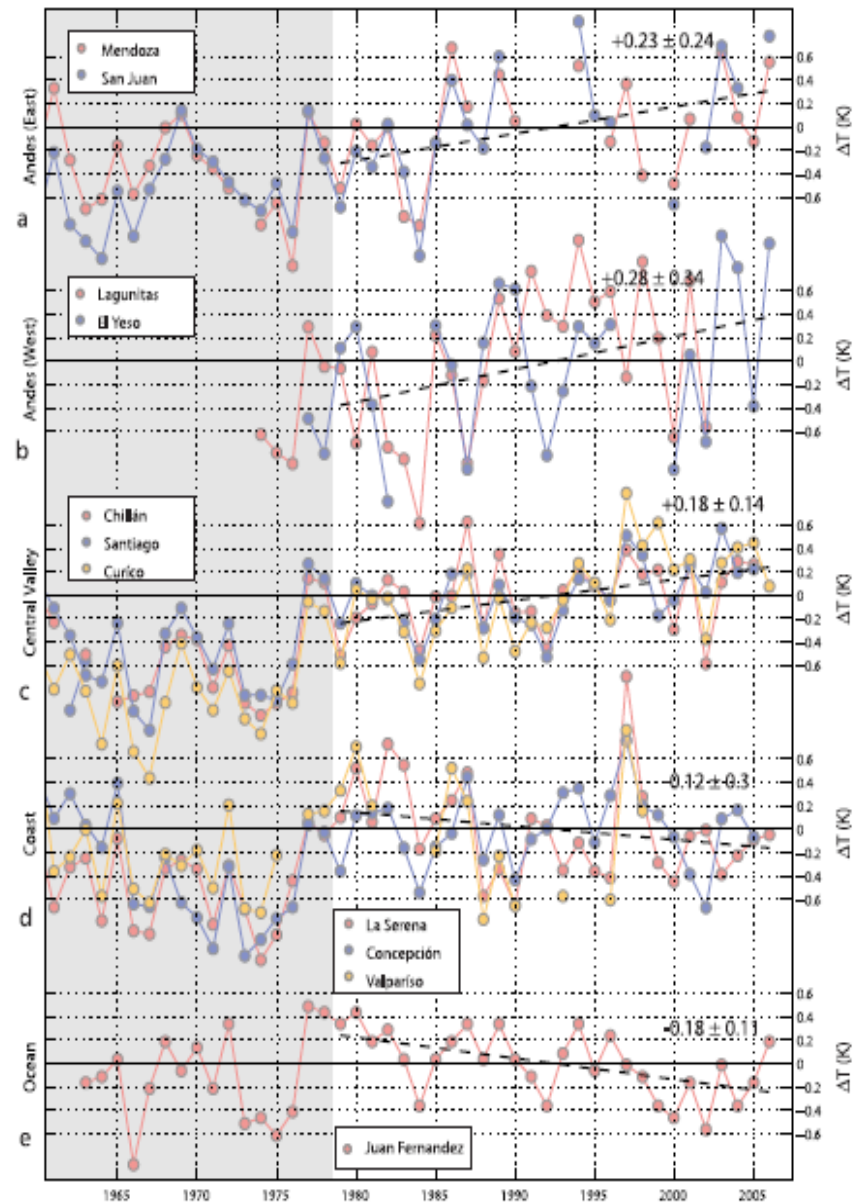
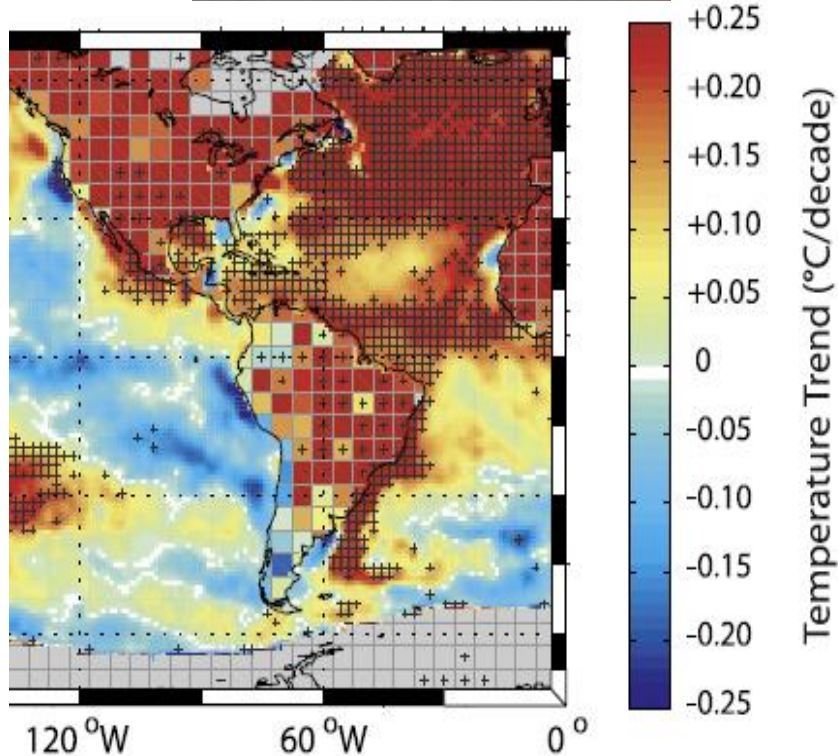


June was Earth's warmest month, and 2015 is its warmest year so far

Enfriamiento regional en un planeta que se calienta

Falvey & Garreaud, JGR, 2009

Surface Temp. Trend (1979-2005)
Source: NCDC + HadISST



RESEARCH ARTICLE

10.1002/2015JD023126

Impact of the global warming hiatus
on Andean temperature

2015 JGR Atmospheres

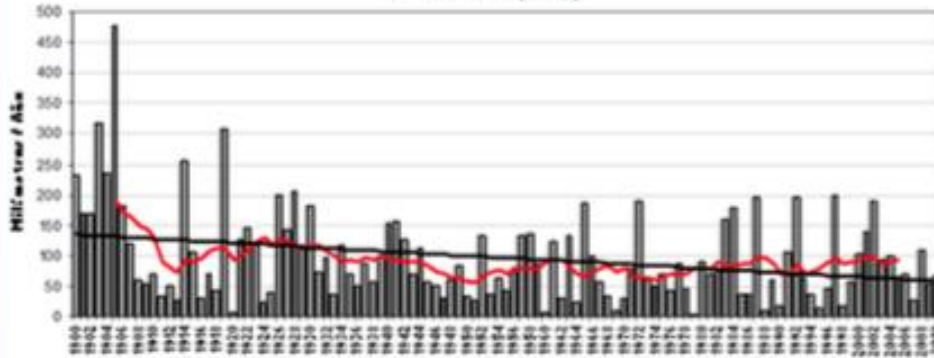
Key Points:

- Trends depend on latitude and choice

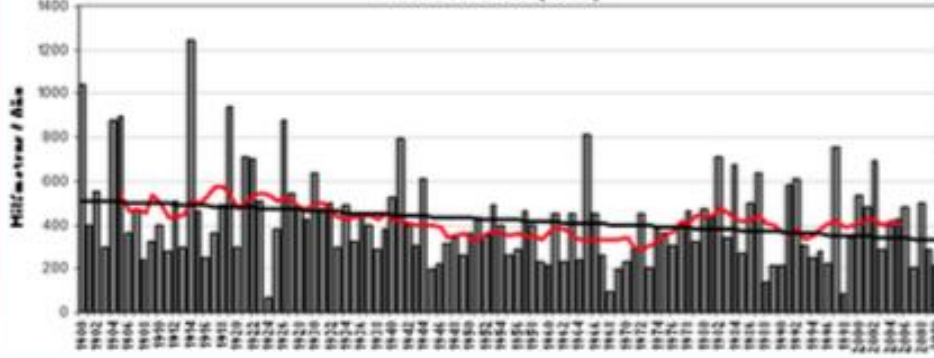
Mathias Vuille¹, Eric Franquist¹, René Garreaud², Waldo Sven Lavado Casimiro³, and Bolivar Cáceres⁴

Recent changes in Precipitation

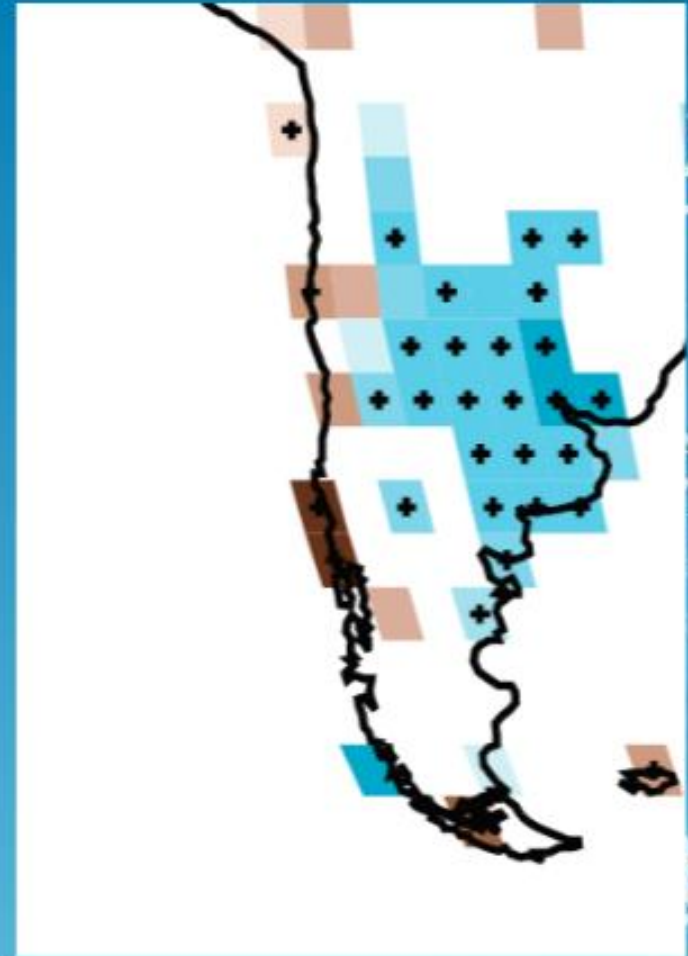
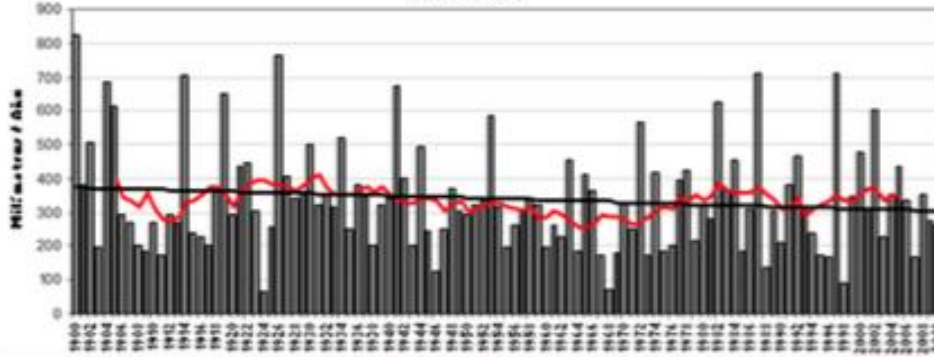
LA SERENA (30°S)



VALPARAISO (33°S)



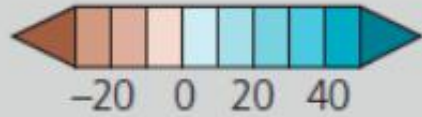
SANTIAGO



IPCC, 5AR WGII, 2014

Jorge Carrasco, pers. comm. 2015

Annual Precipitation Change

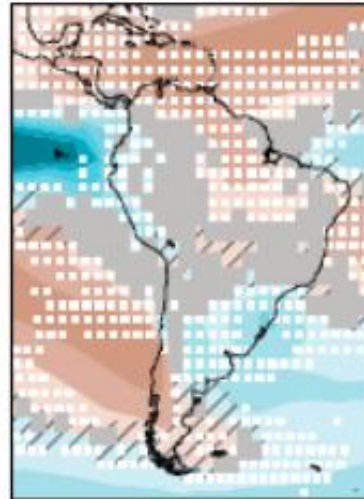


Difference from
1986–2005 mean (%)

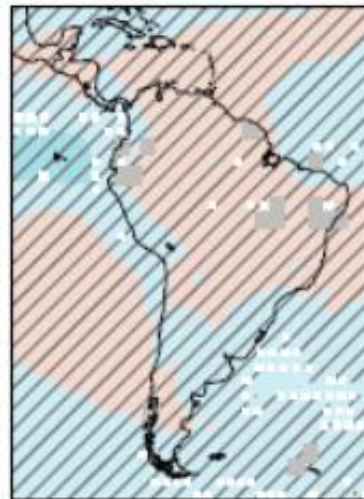
mid 21st century

late 21st century

RCP8.5

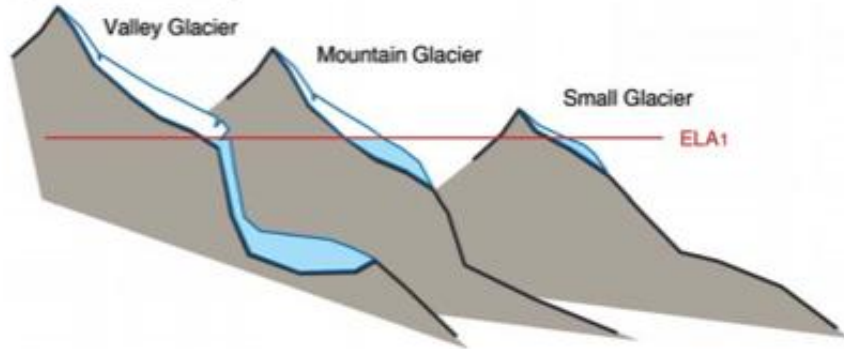


RCP2.6

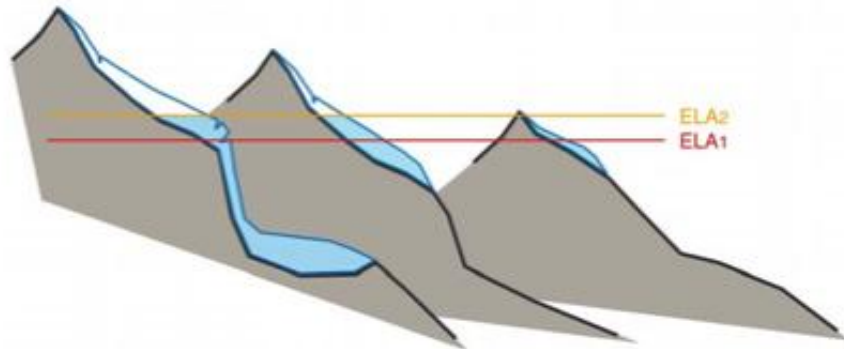


ELA RISE

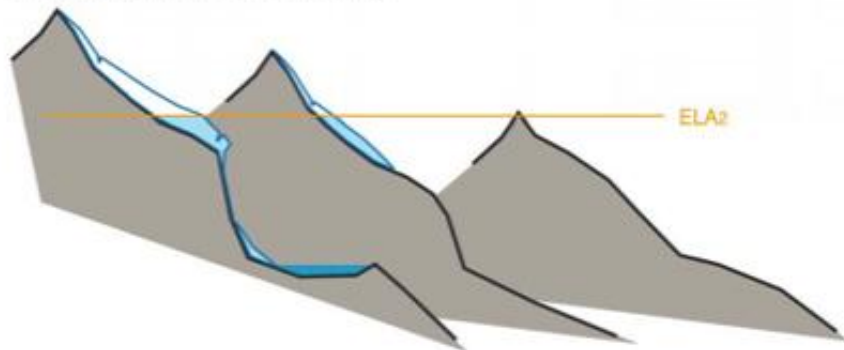
a) Before climate change



b) After climate change but before glacier readjustment



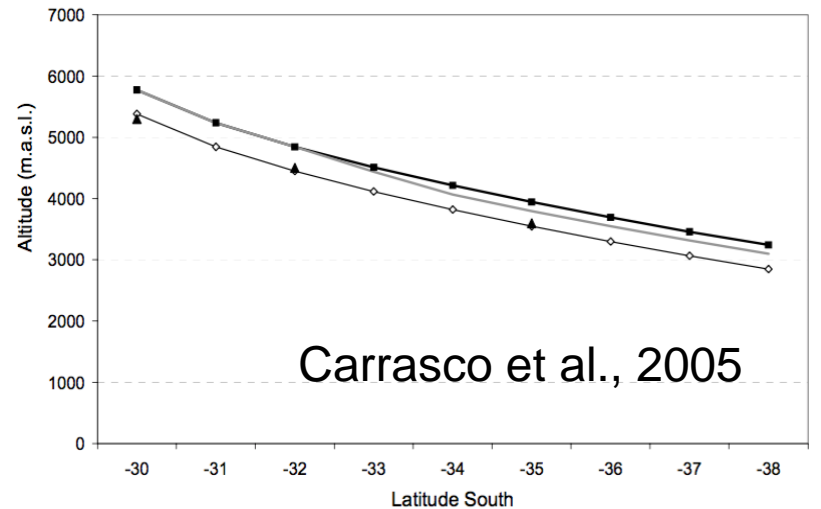
c) After readjustment to climate change



IPCC, 2013

COLD ICE

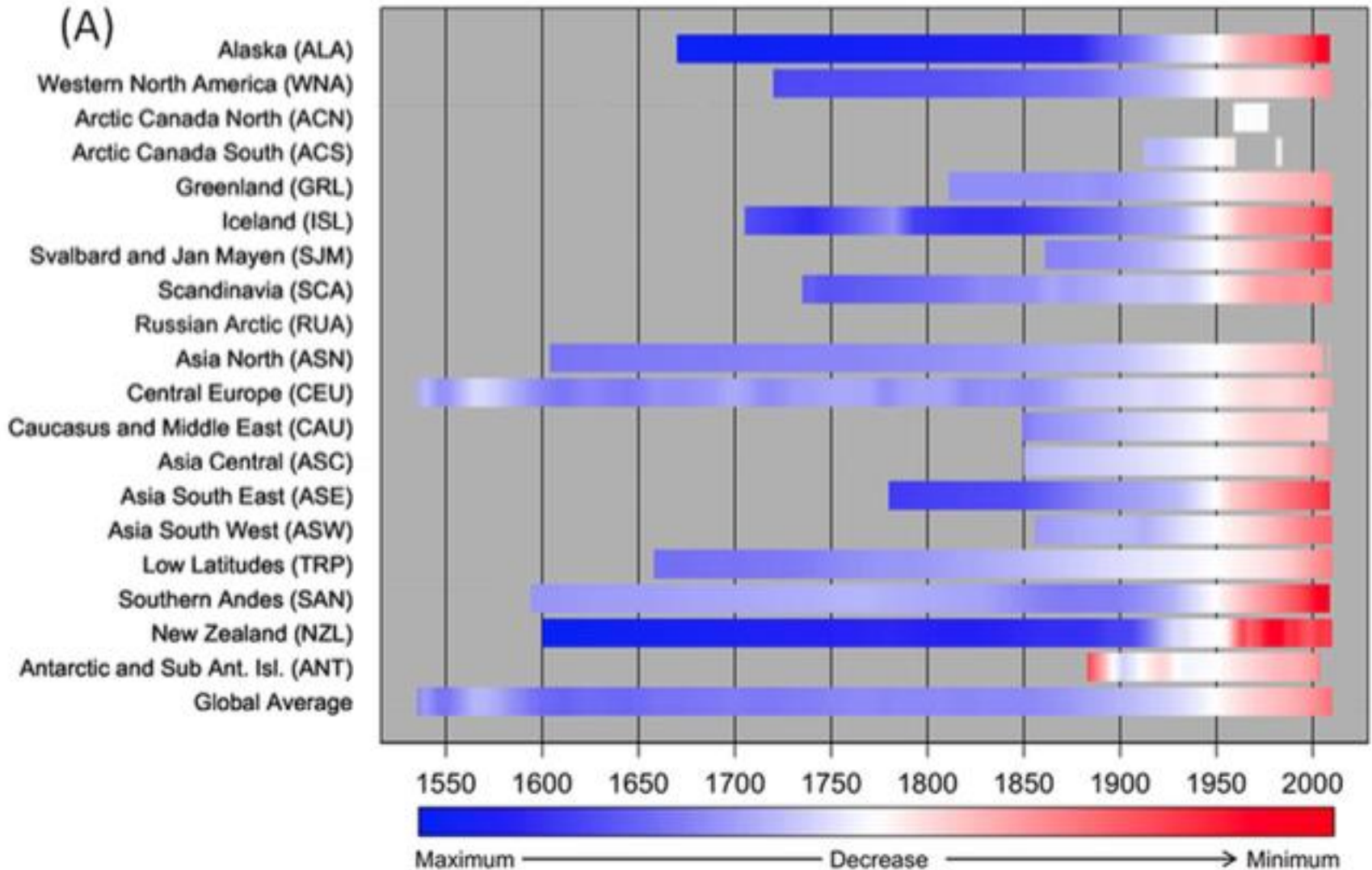
only restricted to highest summits



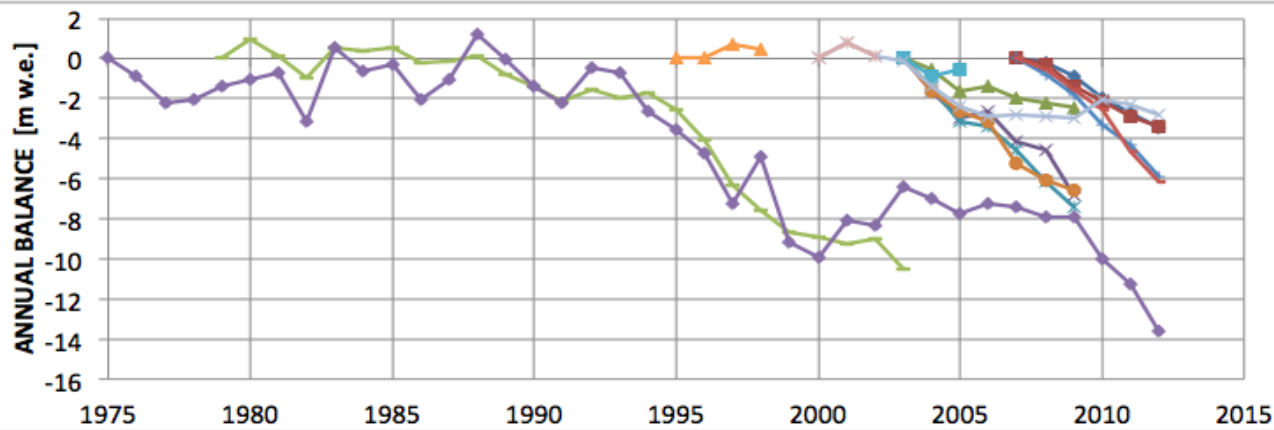
Carrasco et al., 2005

○ Present_ELAcc ■ ELA_A2_2070-2100 — ELA_B2_2070-2100 ▲ ELA_Obs (Present day)

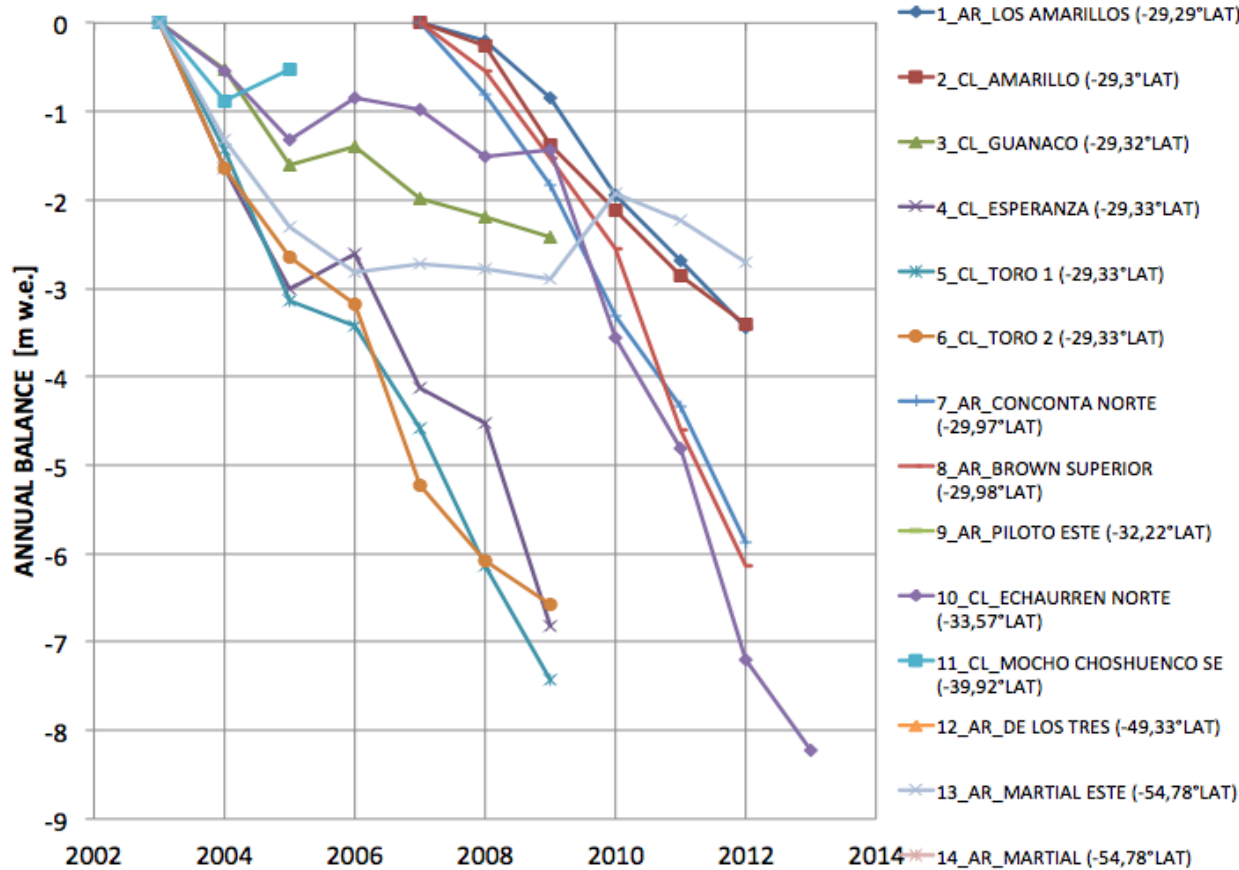
MEAN ANNUAL FRONTAL VARIATIONS OF GLACIERS



Zemp et al., 2015. WGMS



Cumulative net mass balance data for the 14 glaciers shown in Table 1 and Fig. 6. The data were obtained from WGMS (<http://wgms.ch/>, accessed August 2015).



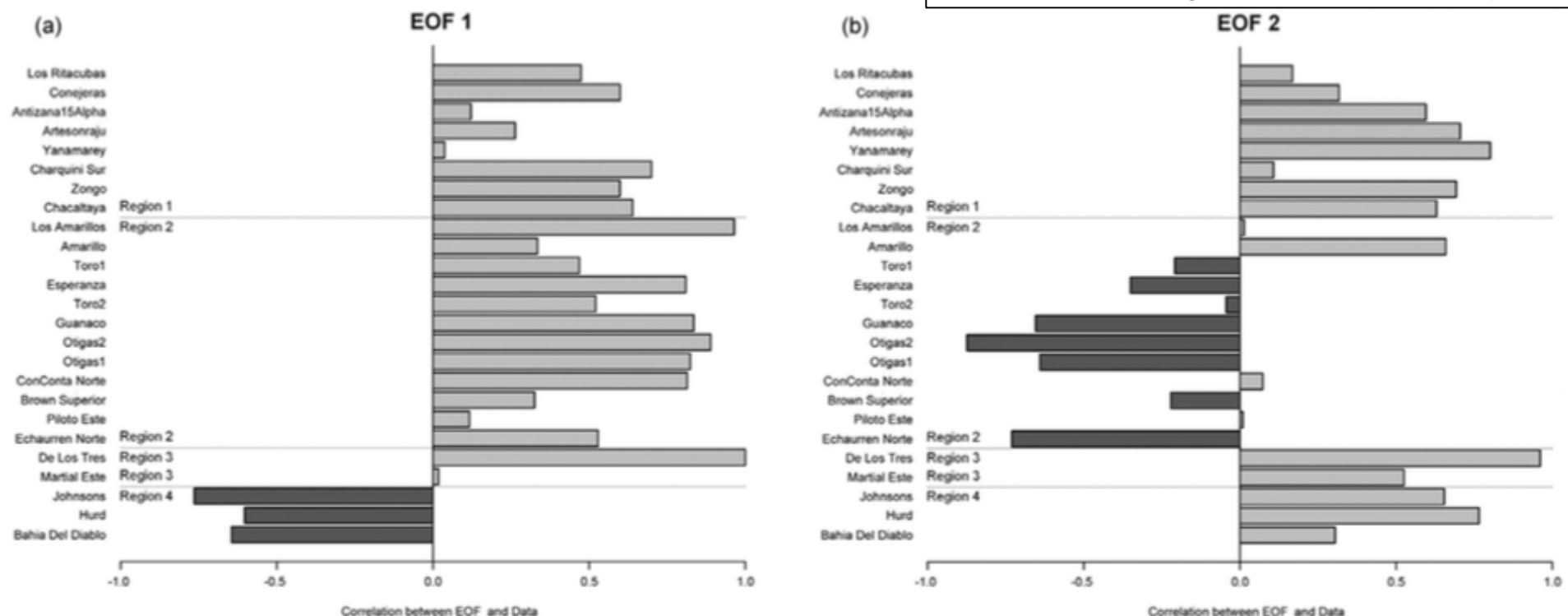
Mass loss and imbalance of glaciers along the Andes Cordillera to the sub-Antarctic islands



GPC, 2015

Sebastian H. Mernild ^{a,*}, Andrew P. Beckerman ^b, Jacob C. Yde ^c, Edward Hanna ^d, Jeppe K. Malmros ^{e,f}, Ryan Wilson ^a, Micheal Zemp ^g

Empirical Orthogonal Function analysis



Mean annual observed mass-balance B changed from -620 ± 390 (1993–2002) to -740 ± 240 kg m⁻² yr⁻¹ (2003–2012) and for this past decade showed a decrease in B from south to north.

These glaciers had a mean accumulation area ratio of 0.42, which is below the AAR value for glaciers in equilibrium, reflecting mean area and volume imbalances of 23% and 27%, respectively.

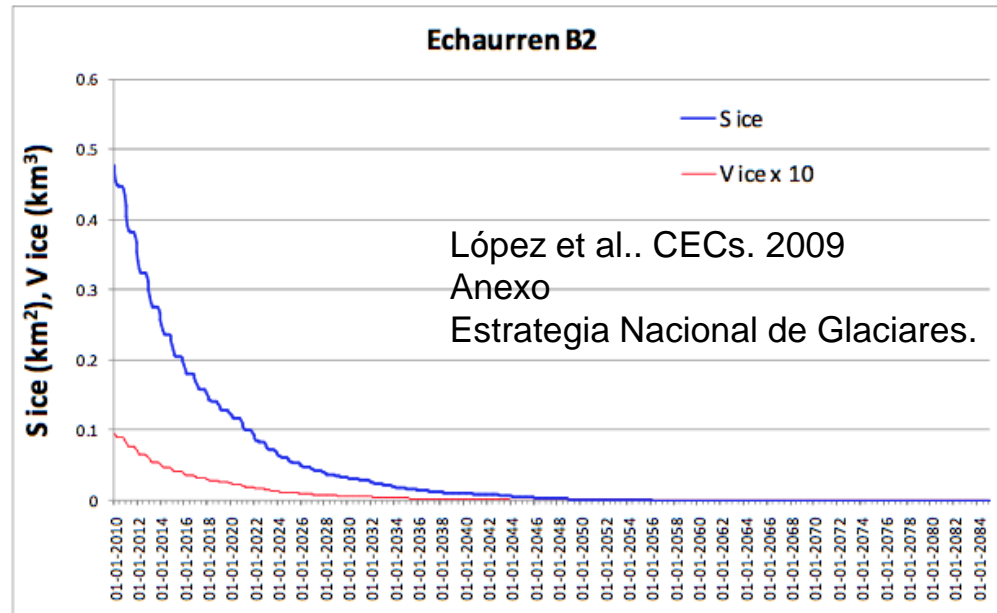
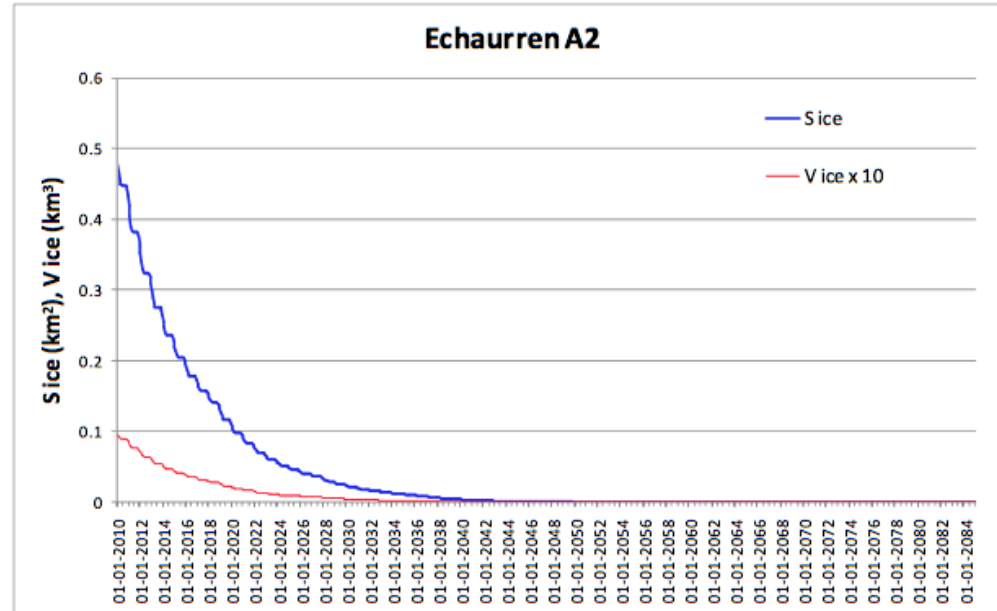
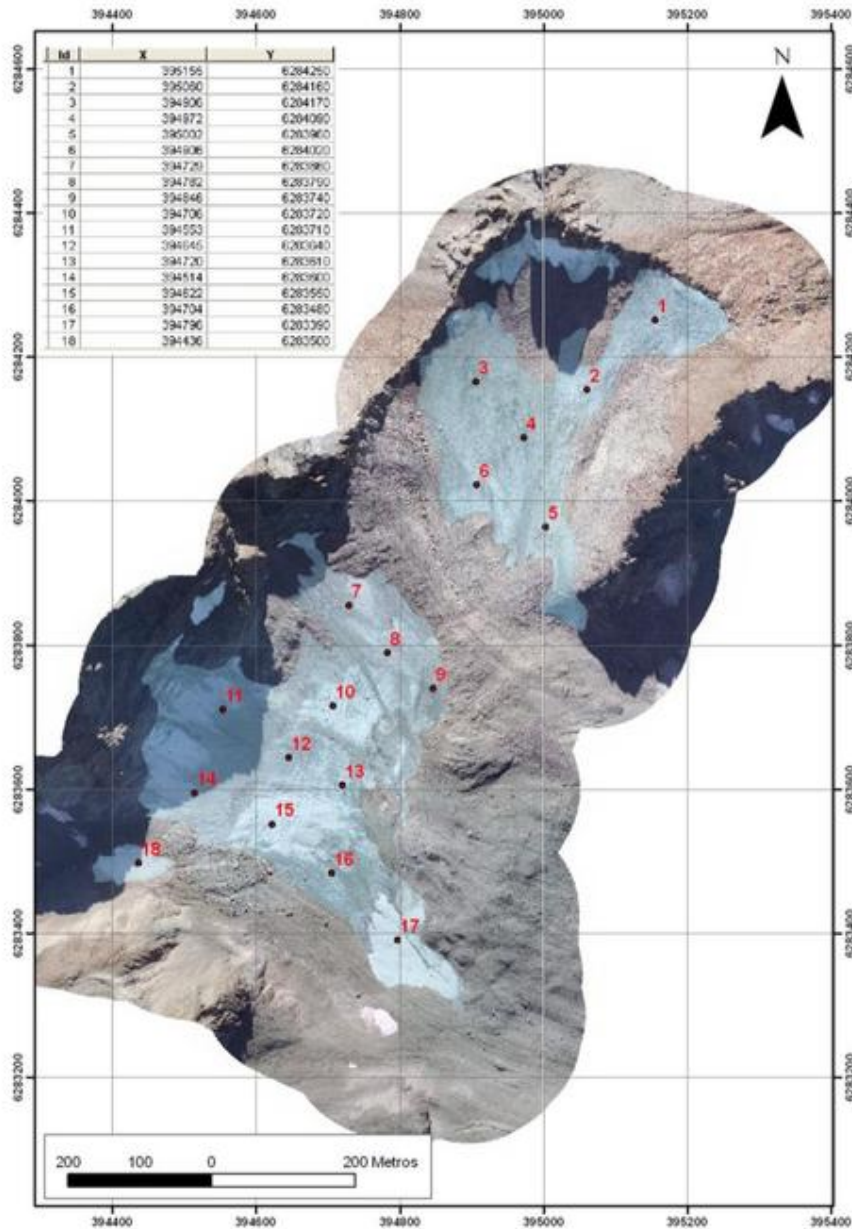
Glaciers in the northern part of Andes Cordillera are most out of balance with the present climate (33%), while glaciers on the sub-Antarctic islands are only slightly out of balance (4%).

Spatiotemporal cycle of B distinguishes glaciers on the sub-Antarctic islands from glaciers in the Andes. South America should be divided into three individual glacier regions, and not two regions as earlier stated.

Instantaneous response to ENSO, 8 year lag time to PDA

GLACIAR ECHAURREN

AREA 1975 0.4 km²
2014 0.2 km²



López et al.. CECs. 2009
Anexo
Estrategia Nacional de Glaciares.

Willis, M. J., A. K. Melkonian, M. E. Pritchard, and A. Rivera (2012), Ice loss from the Southern Patagonian Ice Field, South America, between 2000 and 2012, *Geophys. Res. Lett.*, 39, L17501, doi:10.1029/2012GL053136.

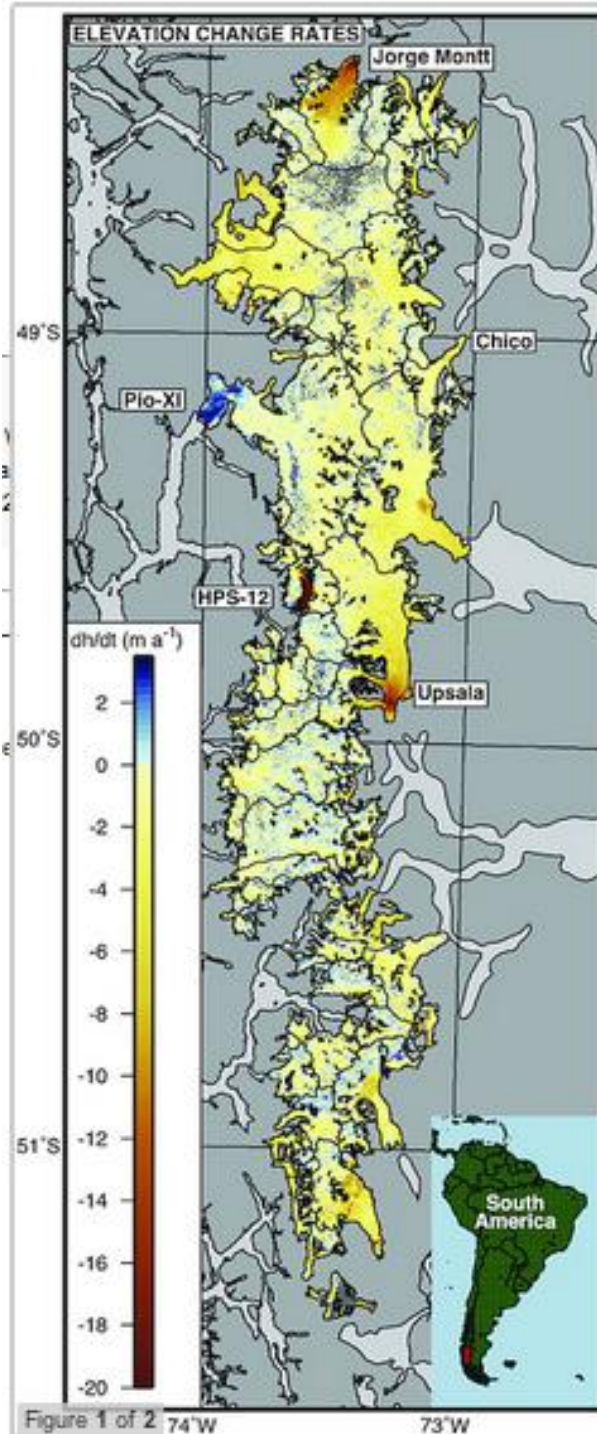


Figure 1 of 2

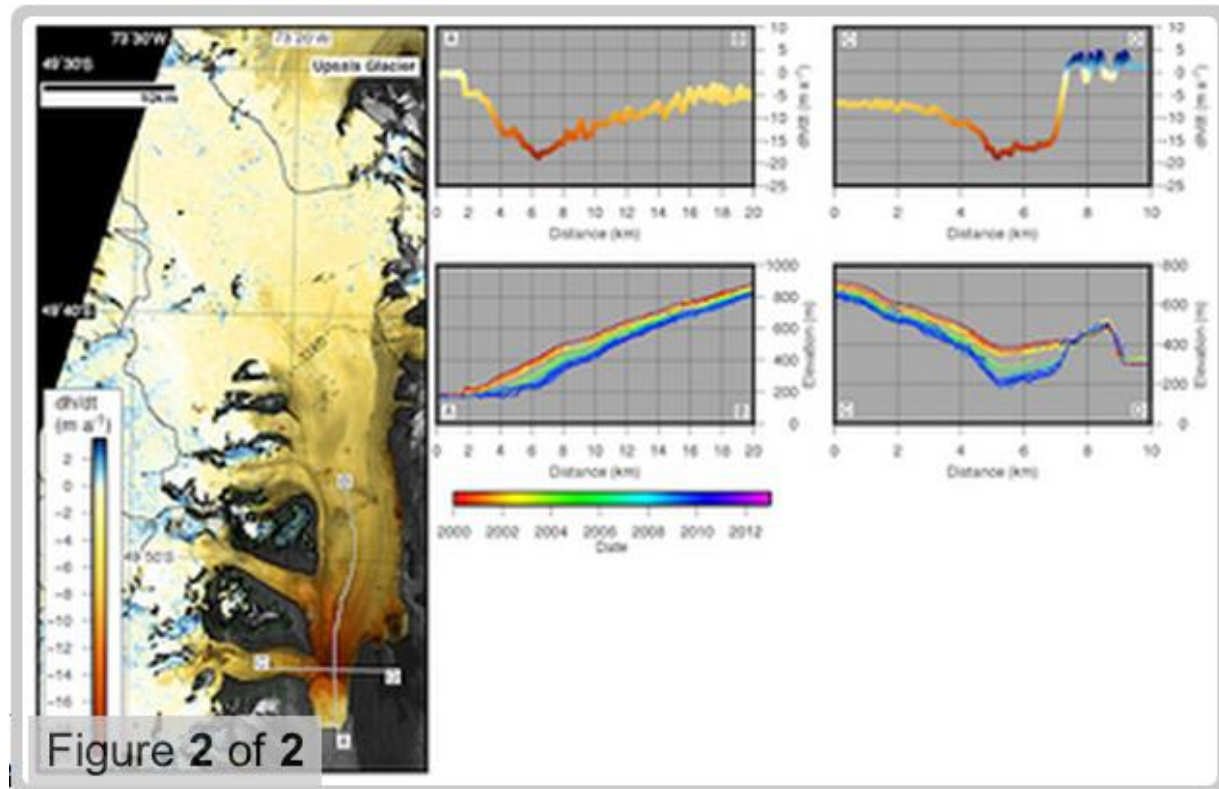
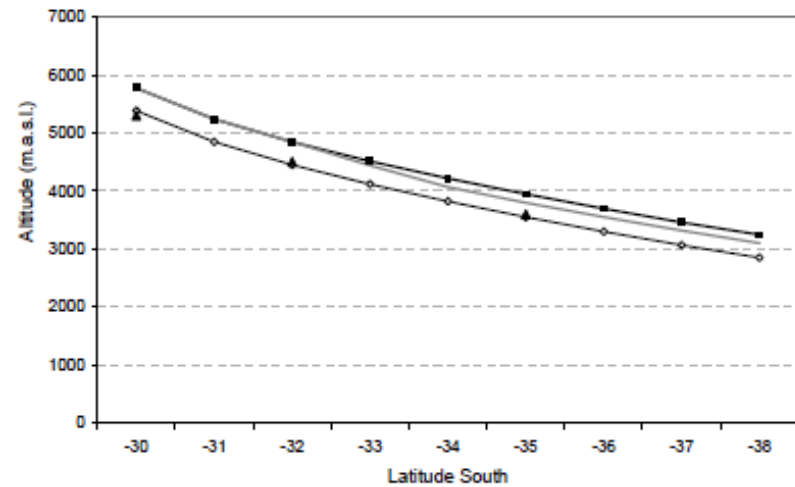


Figure 2 of 2

DEPORTES INVERNALES



ASCENSO DE LA LÍNEA DE NIEVES

Carrasco et al., 2005

Mc HARVILLE
Cartoonists/illustrators



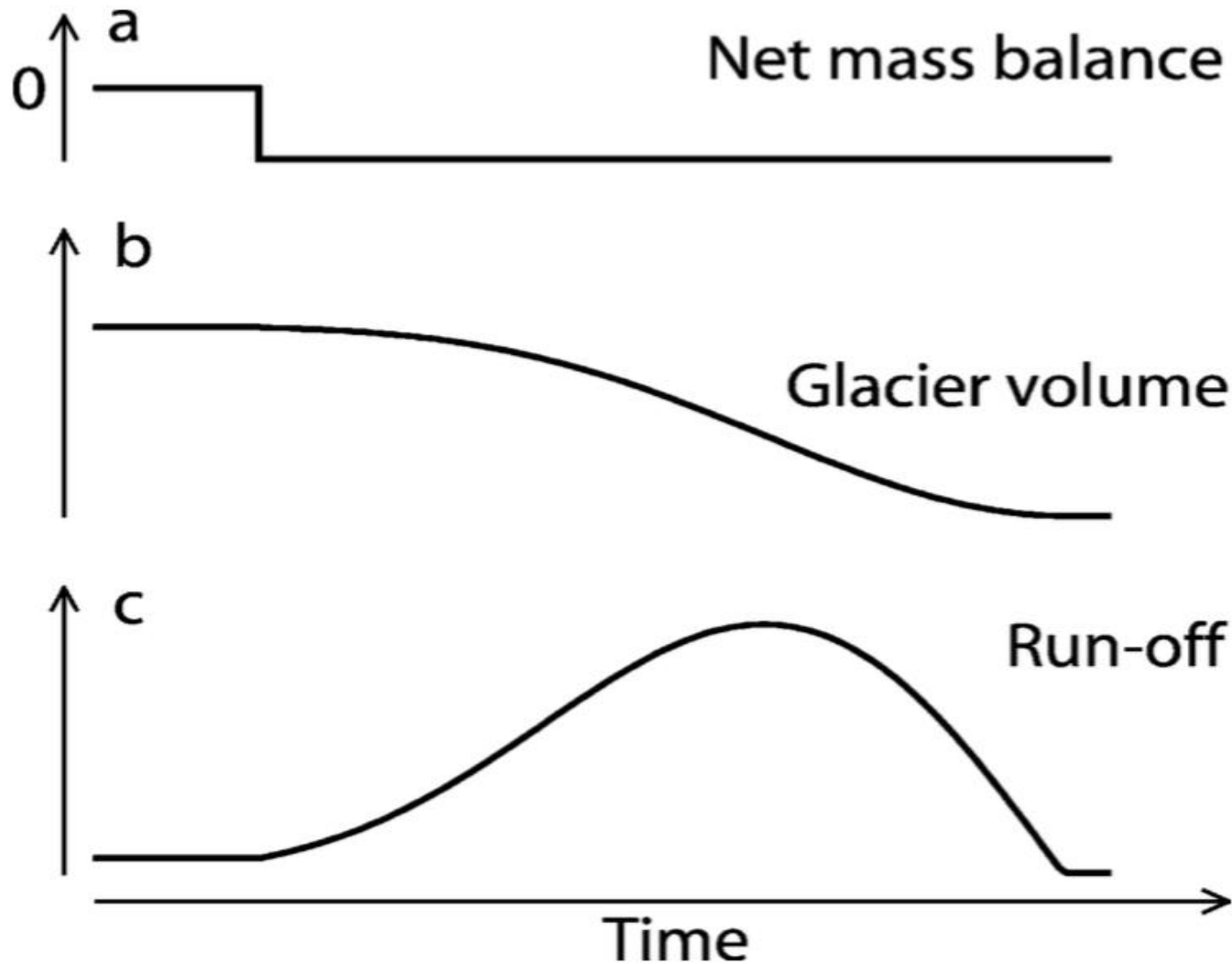
WATER RESOURCES



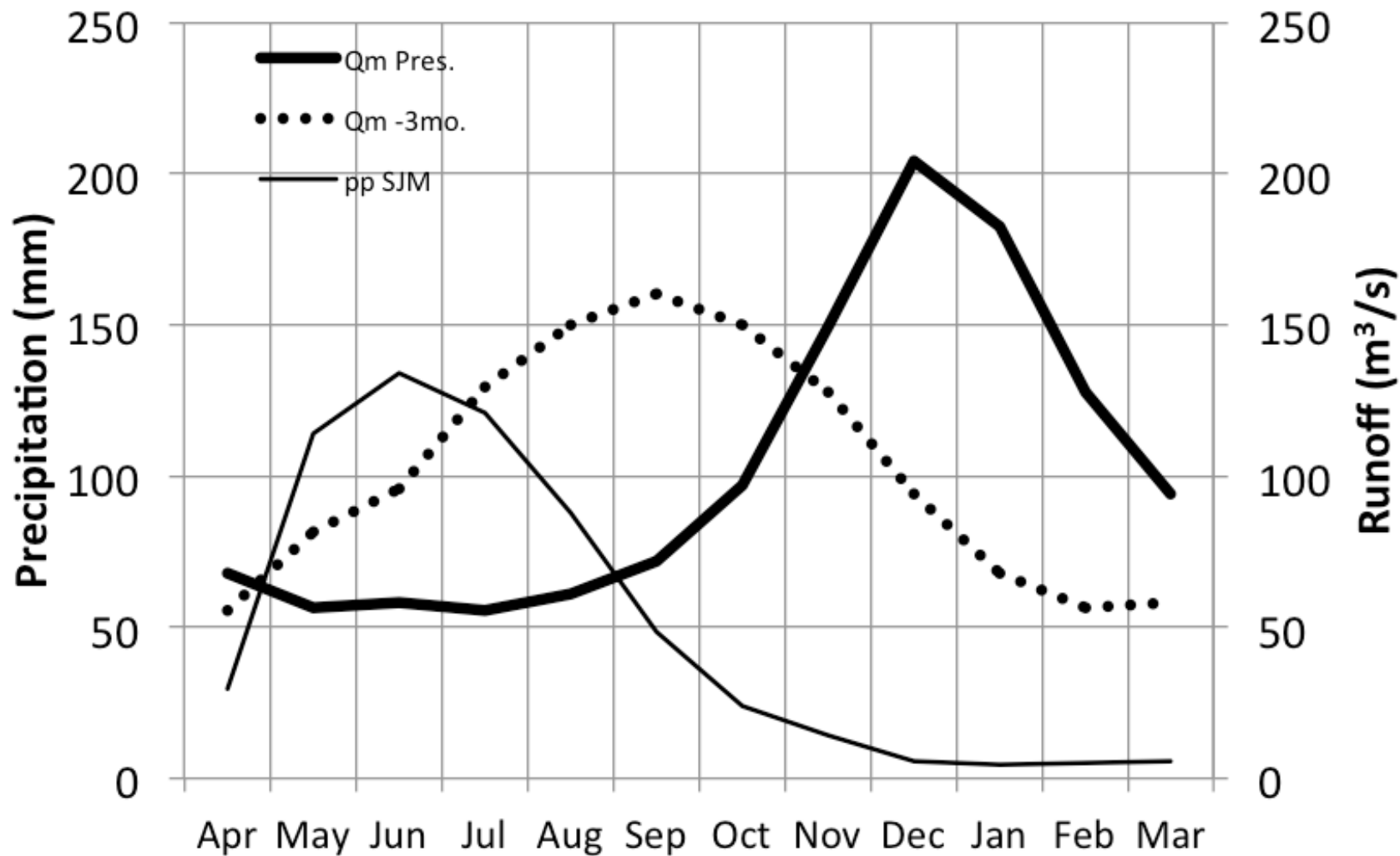
Greenland moulin

Steffen et al.

Univ. Colorado



Melt of the “deglaciation discharge dividend” (Collins, 2008) until a maximum peak level is attained, subsequently decreasing when the glacier is not able to sustain such large melt water production due to its reduced size, until finally the discharge drops to the base flow level when glacier extinction is reached.



Hypothetical shift from a glacio-nival regime to a more nivo-pluvial regime at Maipo River at El Manzano station (850 m asl), central Chile, as a response to a future warming scenario under constant annual precipitation, which is consistent with model predictions (e.g. Serrano, 2014).

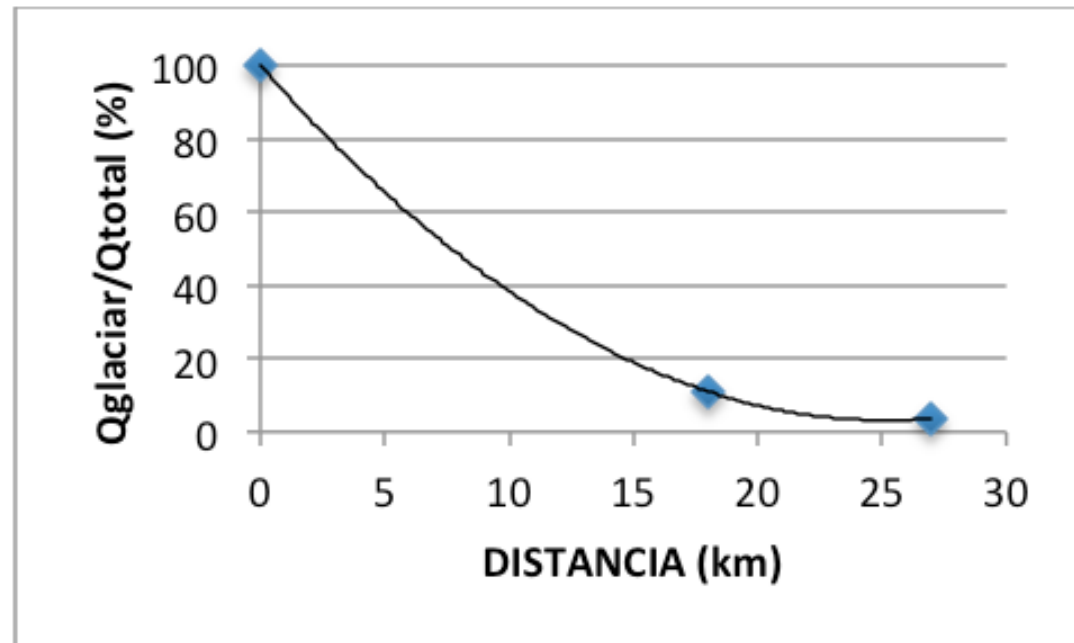
Contribución hídrica de glaciares en el estero Yerba Loca y su extrapolación a la cuenca del río Maipo

Gino Casassa^{1,2}, Ashley Apey¹, Martín Bustamante¹, Cedomir Marangunic¹, Carlos Salazar³ y Diego Soza¹

Cuenca	%Q50 %anual	%Q95 %anual	%Q50% marzo	%Q95% marzo	%Q marzo 2015
	%	%	%	%	%
Yerba Loca a.j. San Fco.	11,0	21,0	50,9	72,3	81,5
<u>Mapocho Los Almendros</u>	3,6	11,9	32,4	56,9	46,4
<u>Maipo El Manzano</u>	6,2	12,3	34,1	55,5	55,4

Proporción en % del caudal de derretimiento glaciar (esencialmente hielo) simulado (Tabla 3) respecto de los caudales de excedencia de Tabla 4 y de los caudales DGA de marzo 2015.

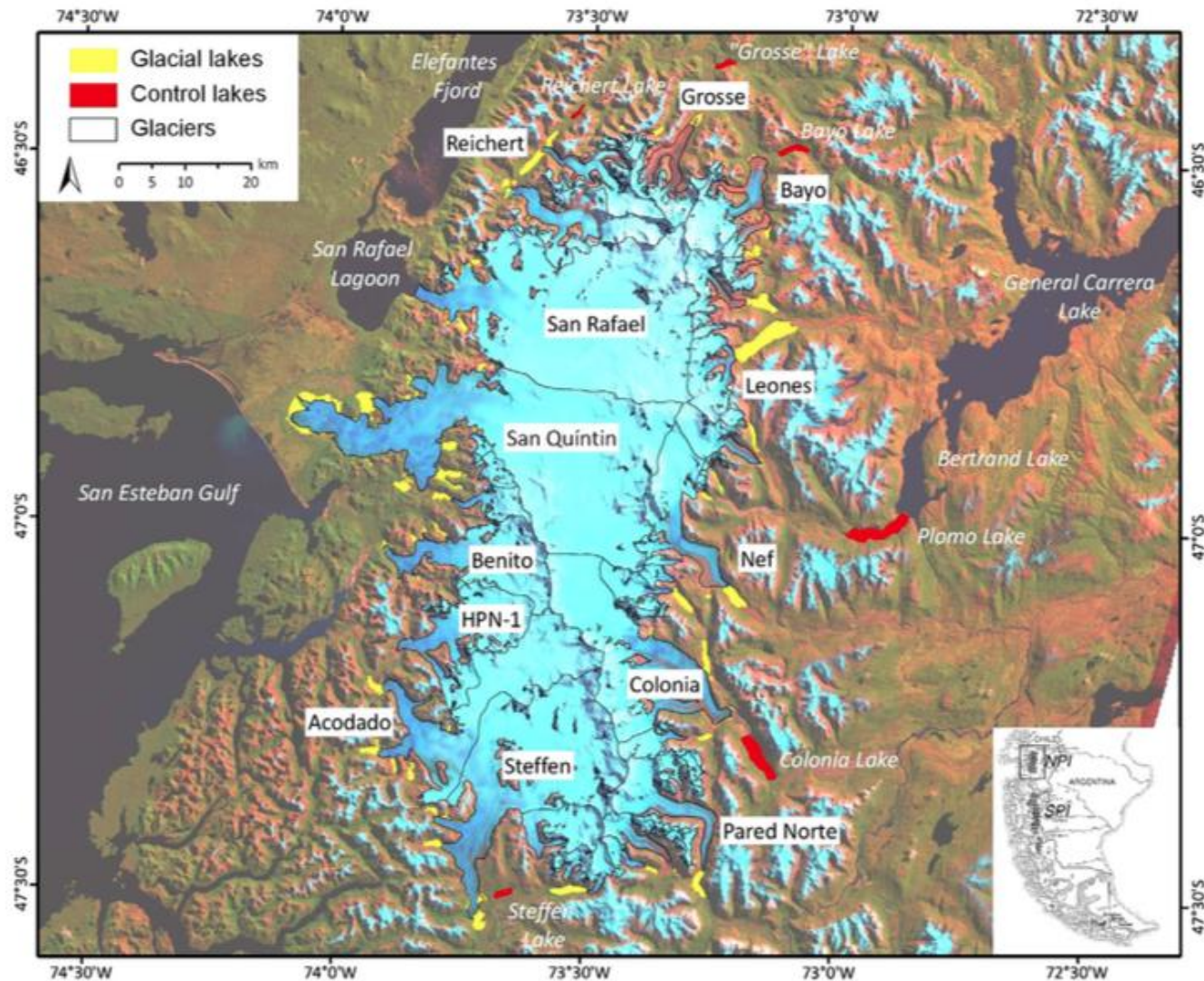
% de aporte hídrico de los glaciares respecto de los caudales promedio anuales (probabilidad de excedencia del 50%) para el Estero de Yerba Loca, en función de la distancia relativa a los glaciares.



Evolution of glacial lakes from the Northern Patagonia Icefield and terrestrial water storage in a sea-level rise context

Thomas Loriaux*, Gino Casassa
GPC, 2013

Increase of glacial lake area of 66 km²
between 1945 and 2011



FUENTES DE MATERIAL PARTICULADO

DARKENING PEAKS Glacier Retreat, Science, and Society



- Fuentes naturales cercanas (avalanchas, saltación, reptación, suspensión)
- Fuentes naturales lejanas (p.ej. polvo de zonas desérticas (Atacama, Patagonia, Sahara, Asia central), ceniza volcánica))
- Fuentes antrópicas cercanas (p.ej. tráfico en caminos de tierra, actividades mineras, etc.)
- Fuentes antrópicas lejanas (grandes metrópolis, industrias, etc.)

Fuentes antrópicas lejanas (ciudad de Santiago)

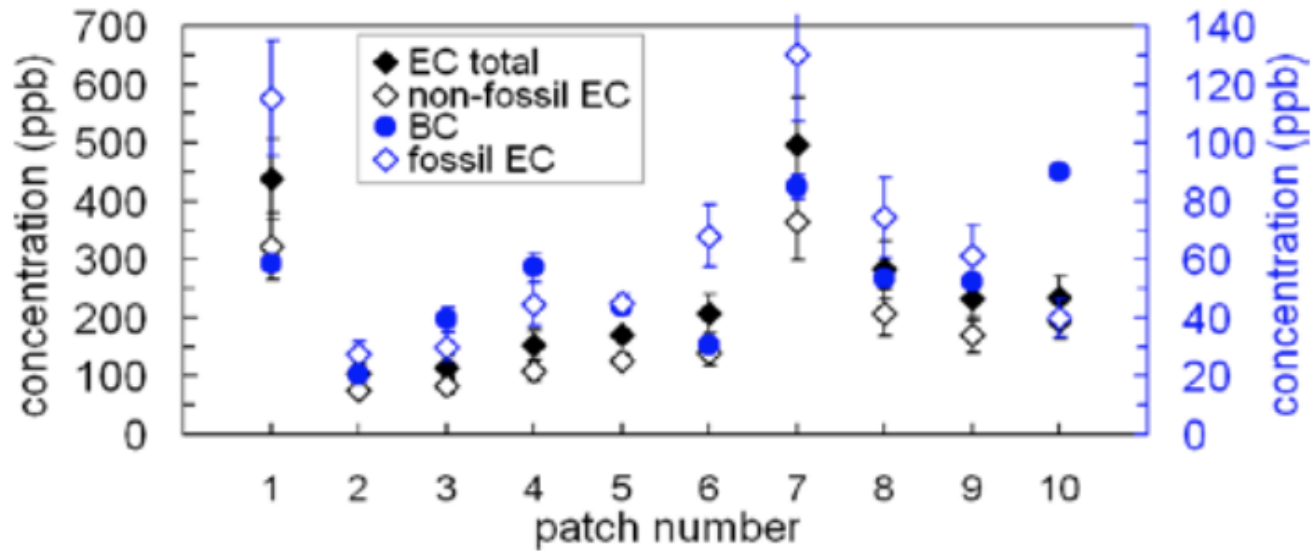
Fotografía del Cajón de Yerba Loca del 10 Enero 2014, con humo de incendios forestales provenientes principalmente de Melipilla.



Steve Warren



Fig. 2: EC and BC in samples from Olivares Beta glacier. Note the 5 times higher concentrations in total EC (left axis) compared to BC (right axis), while fossil EC and BC are of similar magnitude (right axis).





Impact of Santiago de Chile urban atmospheric pollution on anthropogenic trace elements enrichment in snow precipitation at Cerro Colorado, Central Andes

F. Cereceda-Balic^a, M.R. Palomo-Marín^b, E. Bernalte^b, V. Vidal^a, J. Christie^a, X. Fadic^a, J.L. Guevara^{a,1}, C. Miro^c, E. Pinilla Gil^{b,*}

^a Centro de Tecnologías Ambientales, Universidad Técnica Federico Santa María, Av.

^b Departamento de Química Analítica, Facultad de Ciencias, Universidad de Extrema

^c Departamento de Física Aplicada, Universidad de Extremadura, Campus Universita

Winter snow precipitation in the Central Andes mountain range enrichment of anthropogenic elements. The preliminary results obtained sources by exploiting chemical information collected in the snow.

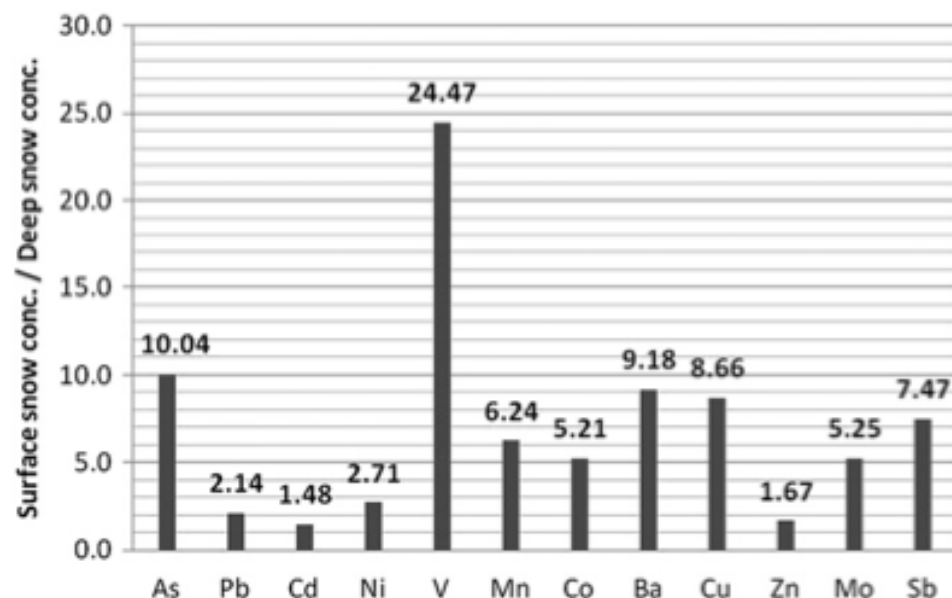


Fig. 4. Elemental concentration ratios (surface vs deep) in snow at Cerro Colorado (2008 and 2009 sampling campaigns).

~68% DEBRIS-COVER INCREASE IN PATAGONIA 1944-2014

Farías, 2015, DGA

- + albedo feedback
- effect thick debris

DEGLACIATION EFFECT

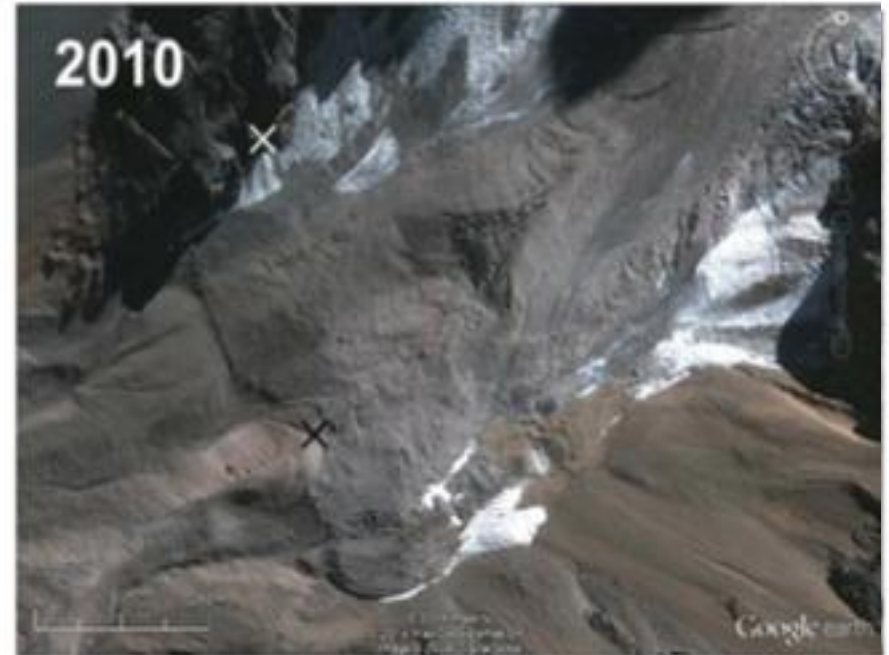
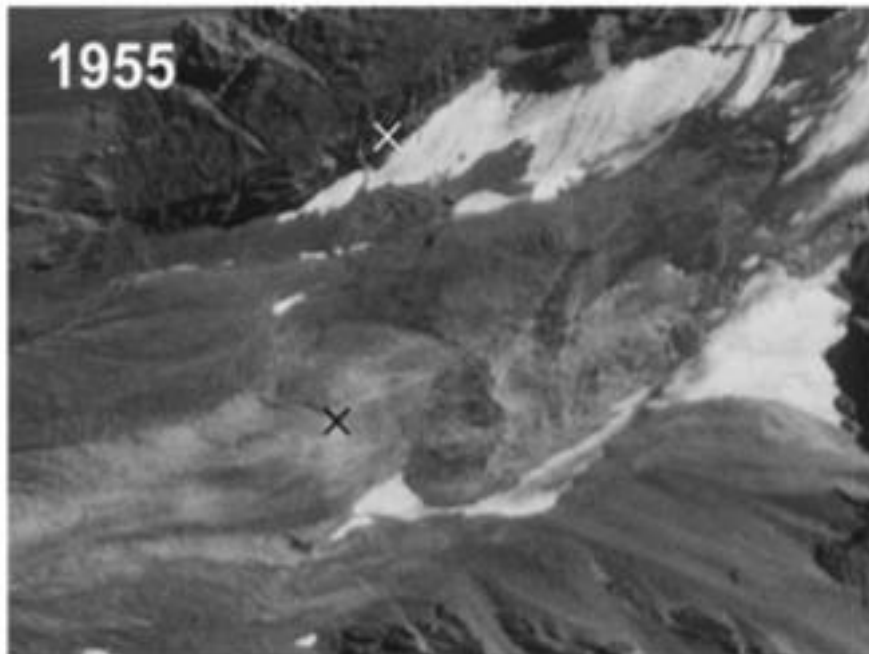


Nef Glacier
NPI
Patagonia

Reconsidering the glacier to rock glacier transformation problem: New insights from the central Andes of Chile

Sébastien Monnier ^{a,*}, Christophe Kinnard ^b

Geomorphology 238 (2015) 47–55



CONCLUSIONES

El aumento de temperatura en el último siglo, principalmente causado por el efecto invernadero, ha resultado en una reducción de la criosfera a nivel global, incluyendo los glaciares de los Andes del Sur.

Sequía en Chile centro-norte en los últimos años.

A mediano-largo plazo el rol de los glaciares y la nieve en el balance hídrico será cada vez menor.

Ante la dificultad de mitigar (reducción de gases de efecto invernadero, control de la contaminación (efecto albedo), uso de fuentes de energía renovables), no queda más de ADAPTARSE a un planeta más cálido.

Legislar (en Chile) e implementar de manera óptima el sistema de EIA en Chile y Argentina respecto de la criosfera.

Necesidad de estudios más detallados!

GÉNESIS: “Señorear sobre la Tierra” = DESARROLLO SUSTENTABLE!
La supervivencia del ser humano Y de los glaciares....