Snow surface albedo changes in the last two decades across the South America (11°N-76°S): Some highlights revealed by satellite observations

Tomás R Bolaño-Ortiz[1], Maria Ruggeri[2], Lucas Luciano Berná Peña[1], S. Enrique Puliafito[1], and Francisco Cereceda-Balic[2]

[1]Mendoza Regional Faculty – National Technological University
[2]Universidad Técnica Federico Santa María

November 24, 2022

Abstract

Snow is among the most reflective of natural surfaces on Earth and in its reflectance, also known as snow surface albedo (SSA), a small SSA decrease can increase its absorption of solar energy. Also, climate models indicate that the reduction of SSA contributes to global warming and near-worldwide melting of cryosphere. The snowpack through South America (SA) is mainly associated to the Andes mountain range, which geologically extends 9000 km approx. from the tropical region (11°N) to the Antarctandes (76°S) in the Antarctic. There, snow is an important source of fresh water for more than 80 million people who live in the 9 countries where this mountain passes. In this study we have analyzed the SSA trend. For that, in accordance with the division proposed by Dussaillant et al. (2019), we have divided the study area into 8 zones: Inner Tropics (11°N-5°S), Outer Tropics (5°S-18°S), Desert Andes (18° S-31°S), Central Andes (31°S-37°S), North Patagonia (37°S-46°S), South Patagonia (46°S-54°S), Fuegian Andes (54°S- 56°S), and Antarctandes (63°S- 76°S). We used daily data of SSA available from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the NASA Terra and Aqua satellites for the last 20 years (Mar 2000 to Feb 2020). The results show that the greatest negative inter and intra-annual trends (i.e. is a decrease in SSA) during the last 20 years were observed in the Central Andes (April, -5.76%; $p < 0.001$), North Patagonia (Nov, -2.33%; $p < 0.05$) and Fuegian Andes (Oct, -1.73%; $p < 0.05$). While the greatest positive variations were detected in Antarctandes (May, 4.76%; $p < 0.001$), Fuegian Andes (Dec, 4%; $p < 0.05$), and Outer Tropics (Dec, 1.67%; $p < 0.01$). The highest SSA decrease observed in the Central Andes is consistent with previous studies carried out by the authors that have shown an association between light-absorbing particles with SSA decrease in various basins there. Our results could serve to better understand the radiative forcing changes generated in the SA cryosphere and its effects on climate change.

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AGU FALL MEETING
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C008 - Remote Sensing of the Cryosphere: Seasonal Snow II

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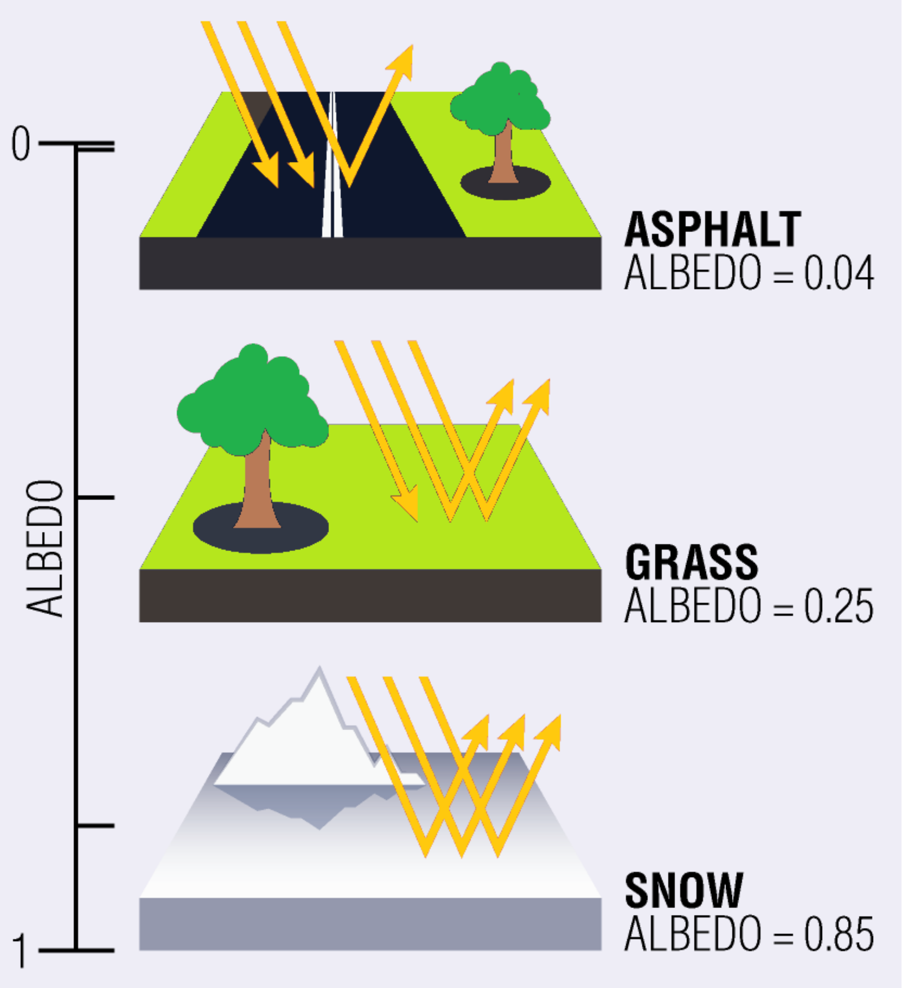
Snow surface albedo - SSA



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-> A small SSA decrease can increase its absorption of solar energy.

-> Climate models indicate that the reduction of SSA contributes to global warming and near-worldwide melting of cryosphere.

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-> The snowpack in South America is found mainly in the Andes Mountains.

-> This snowpack provides drinking water to more than 80 million people in 9 countries (*Molina et at.*, 2015).

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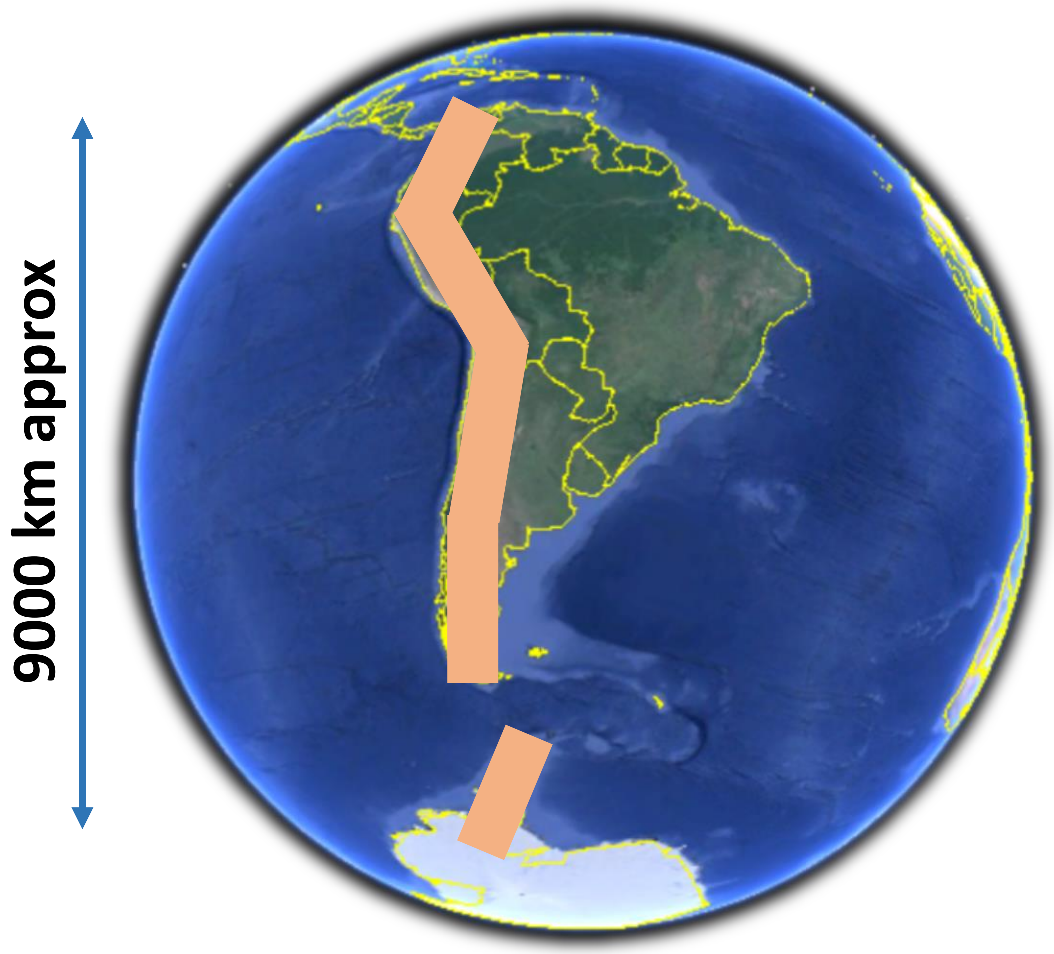

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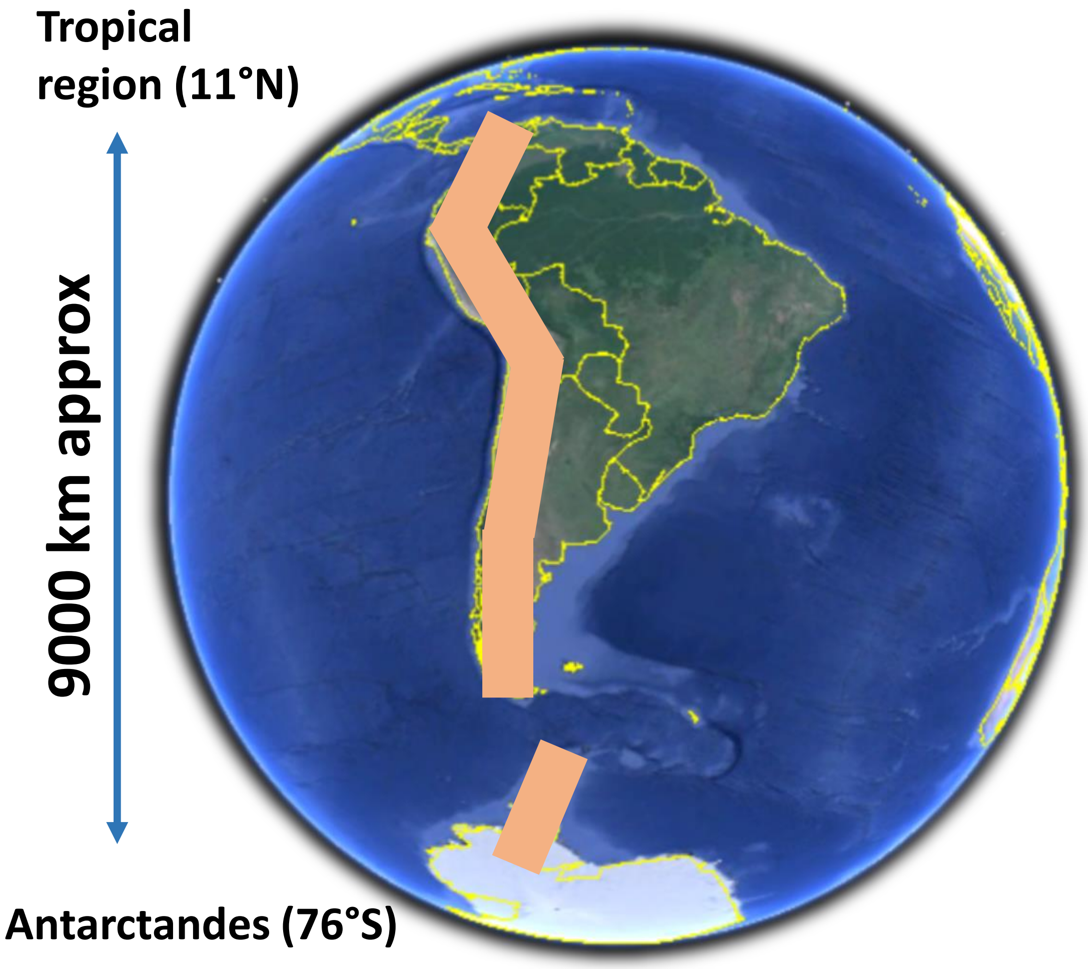

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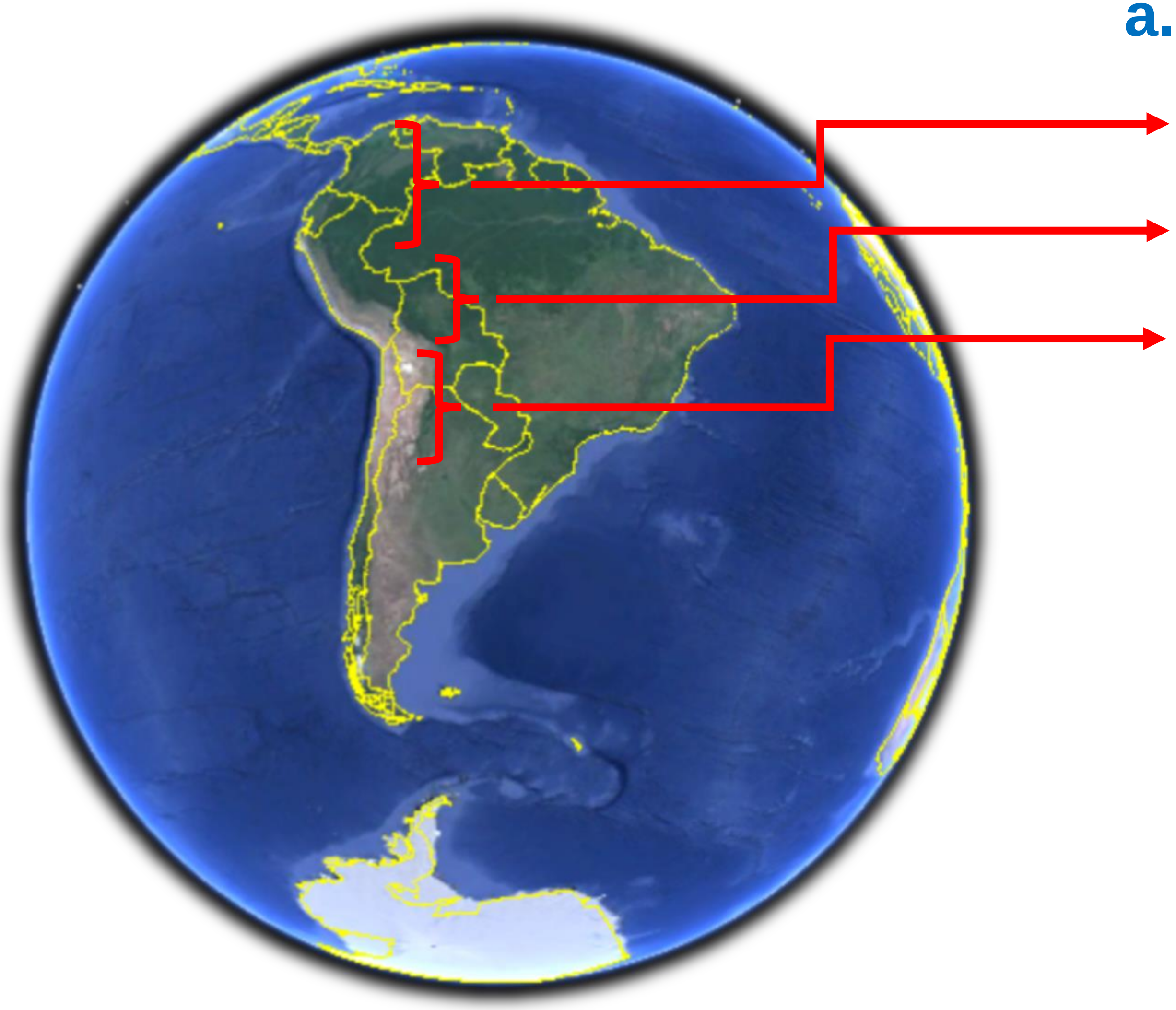

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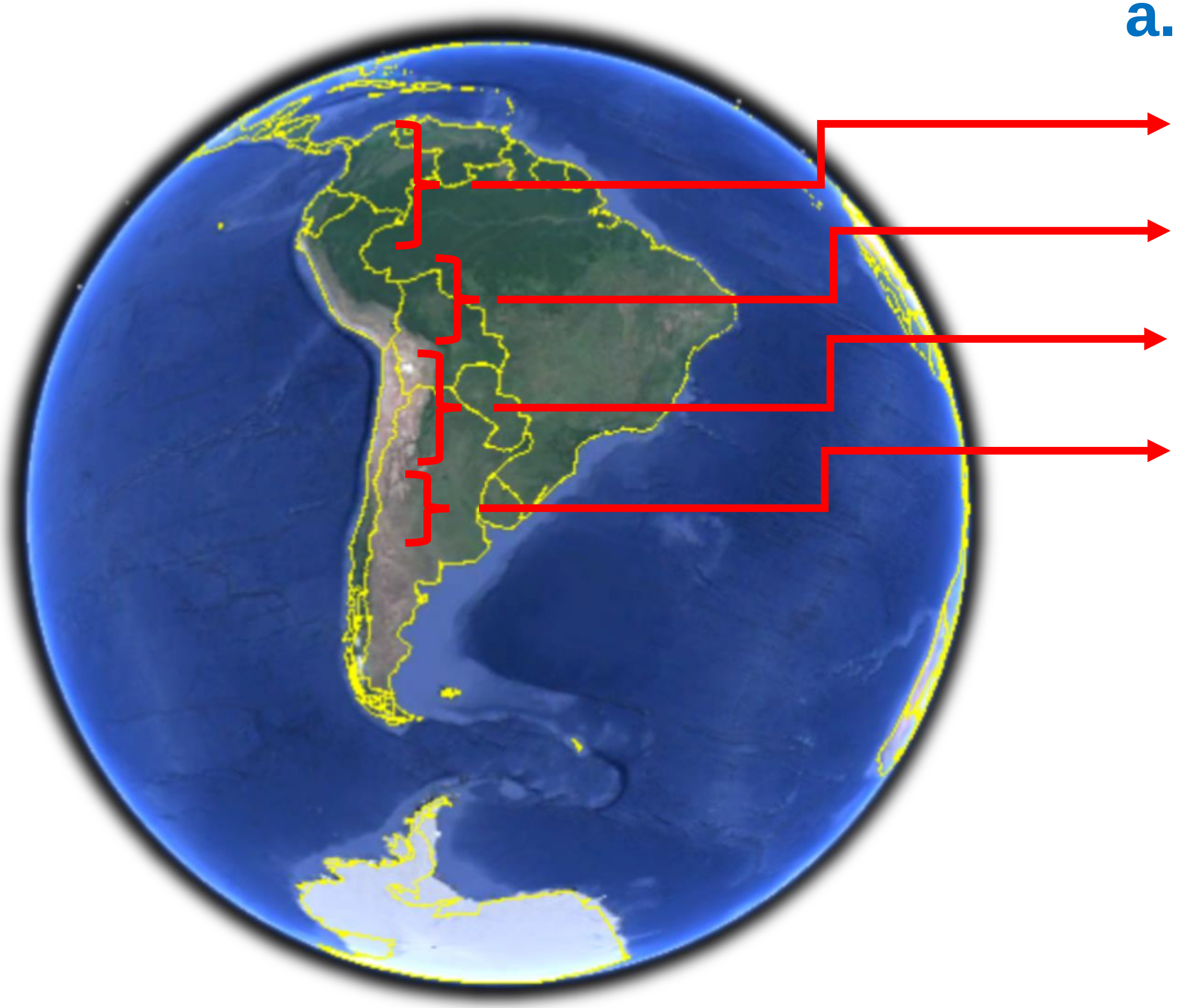

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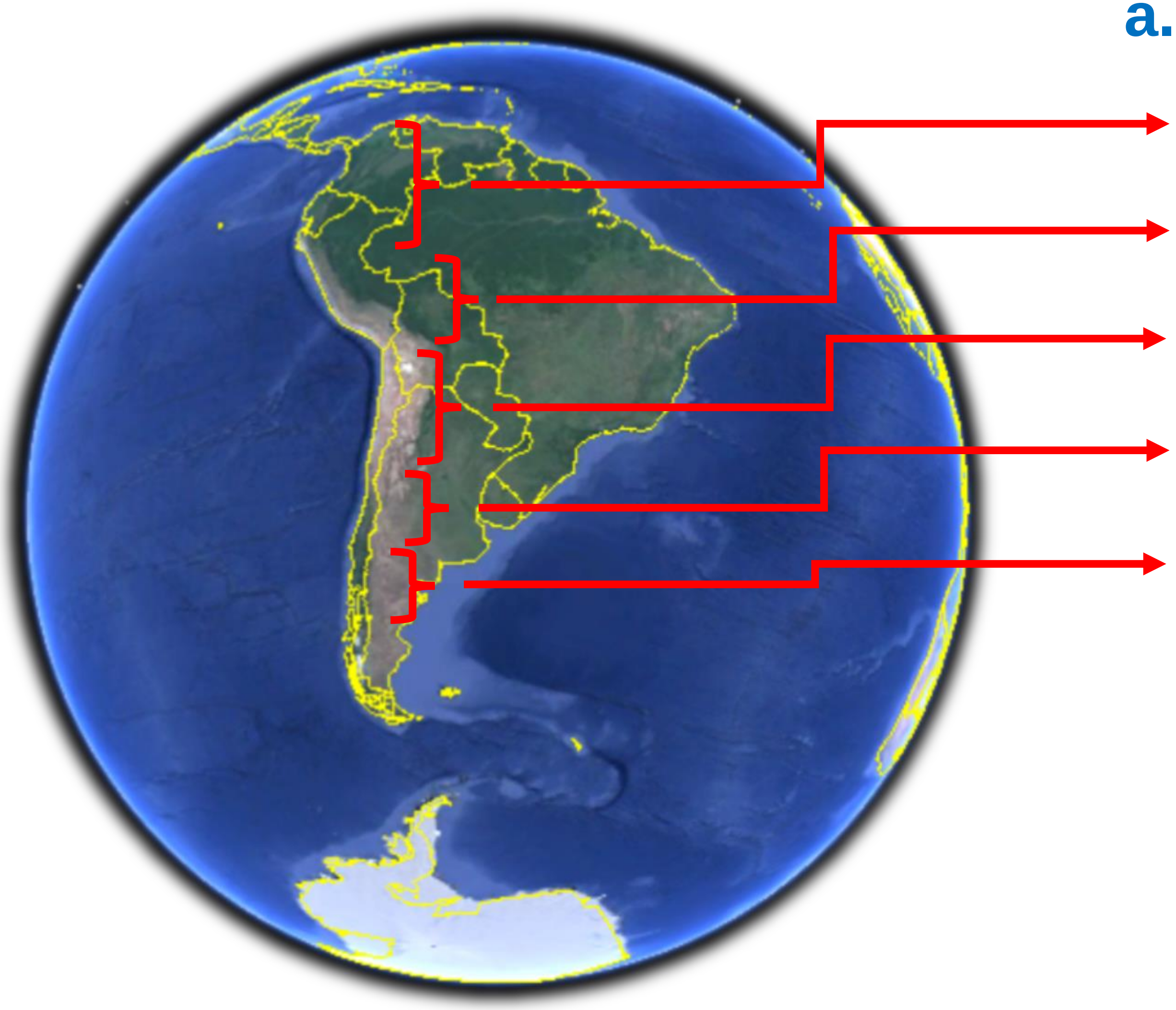

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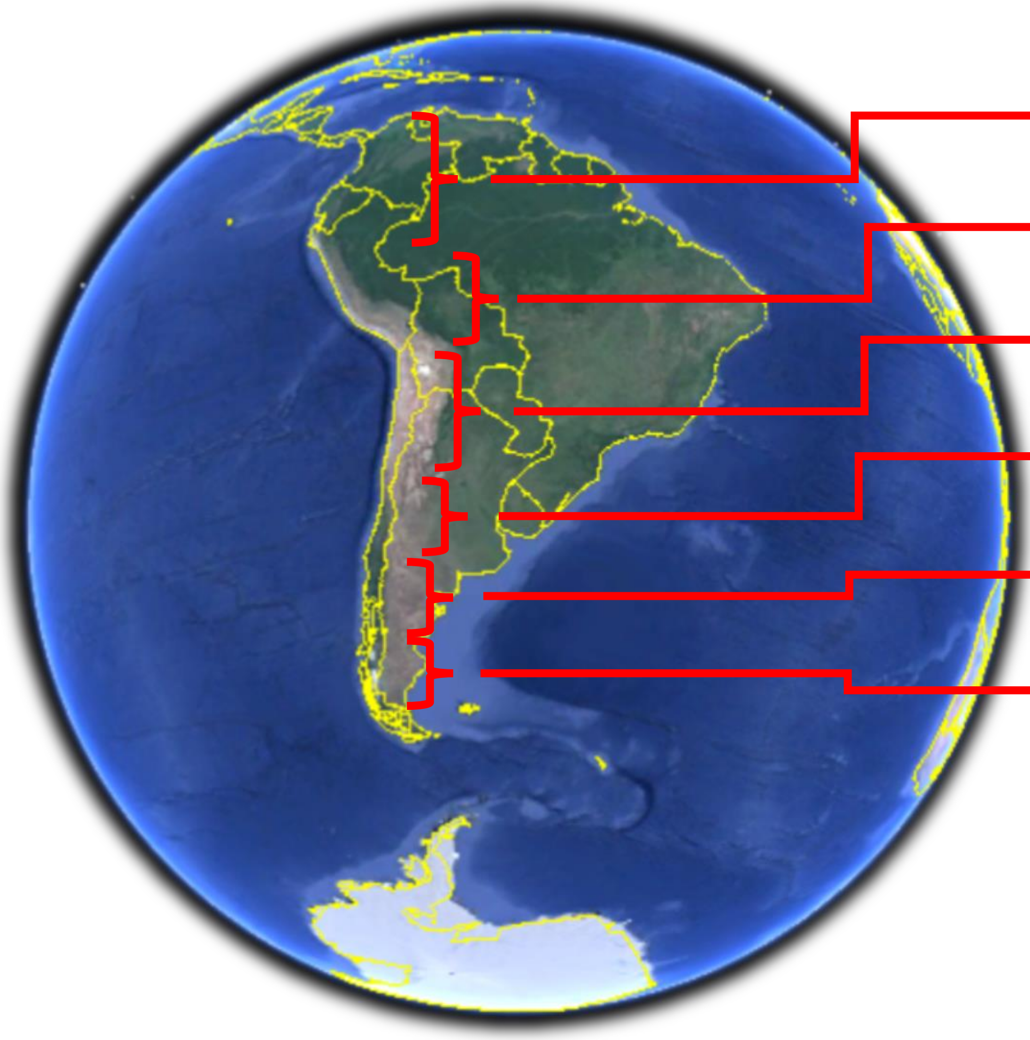

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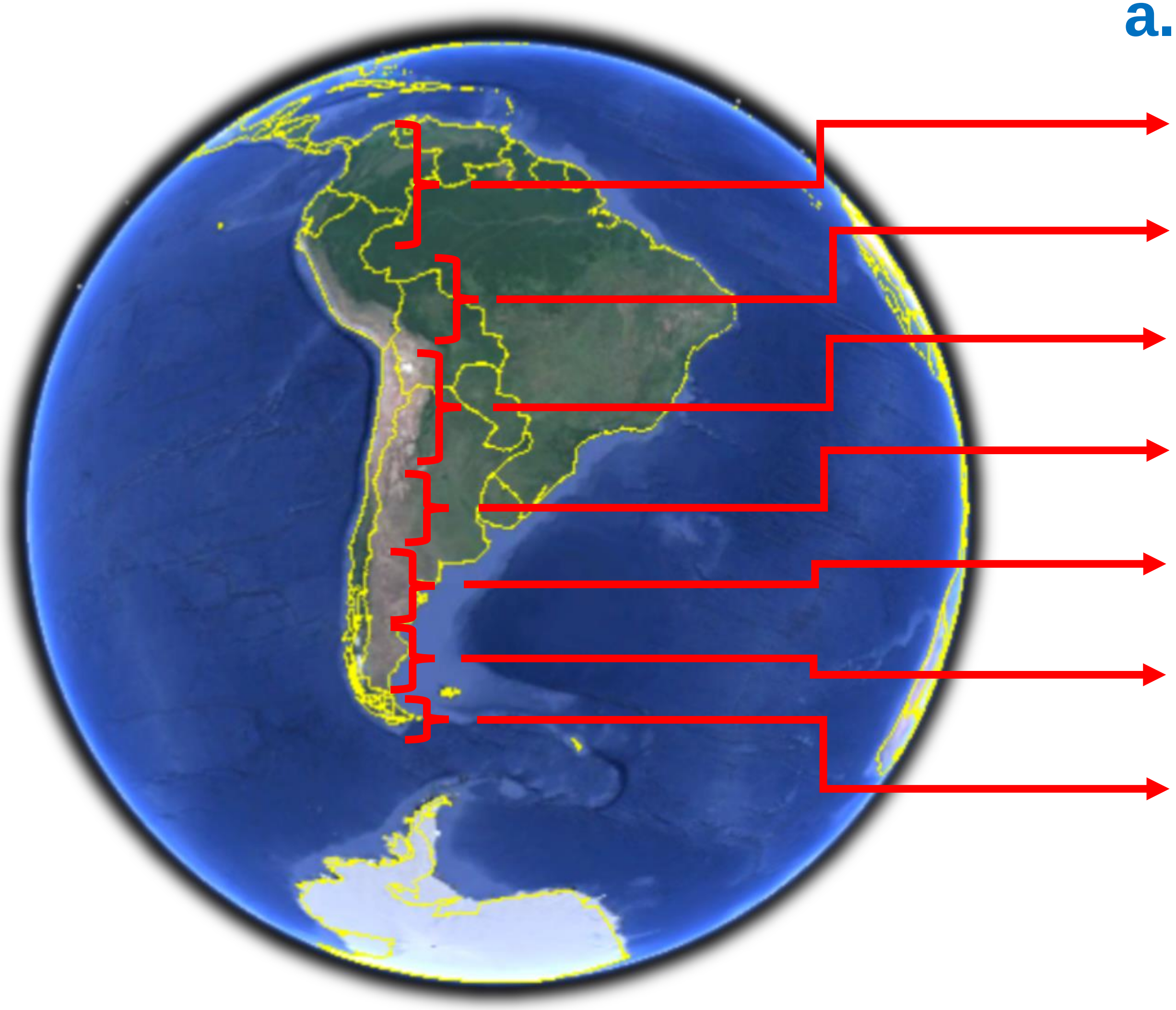

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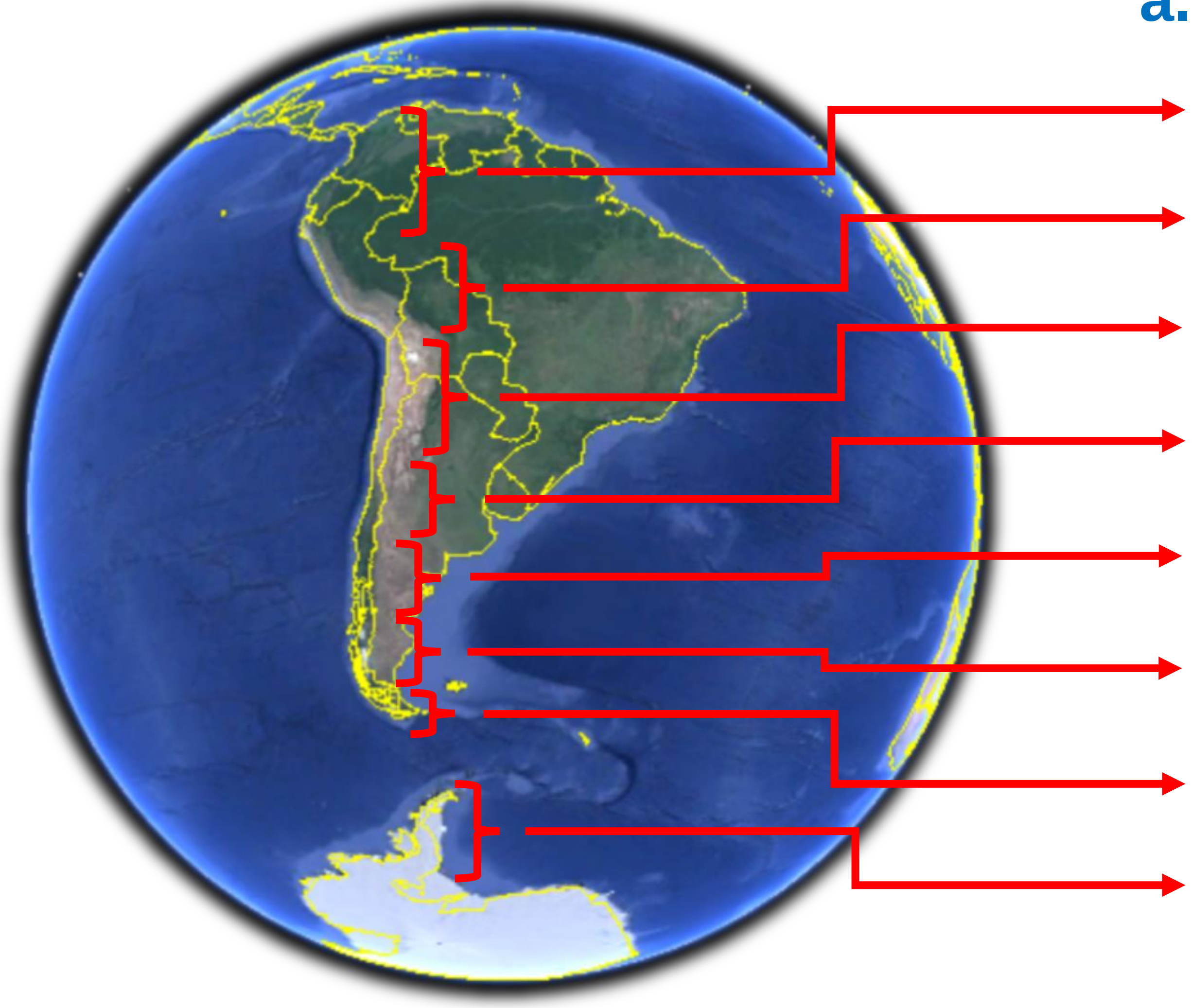

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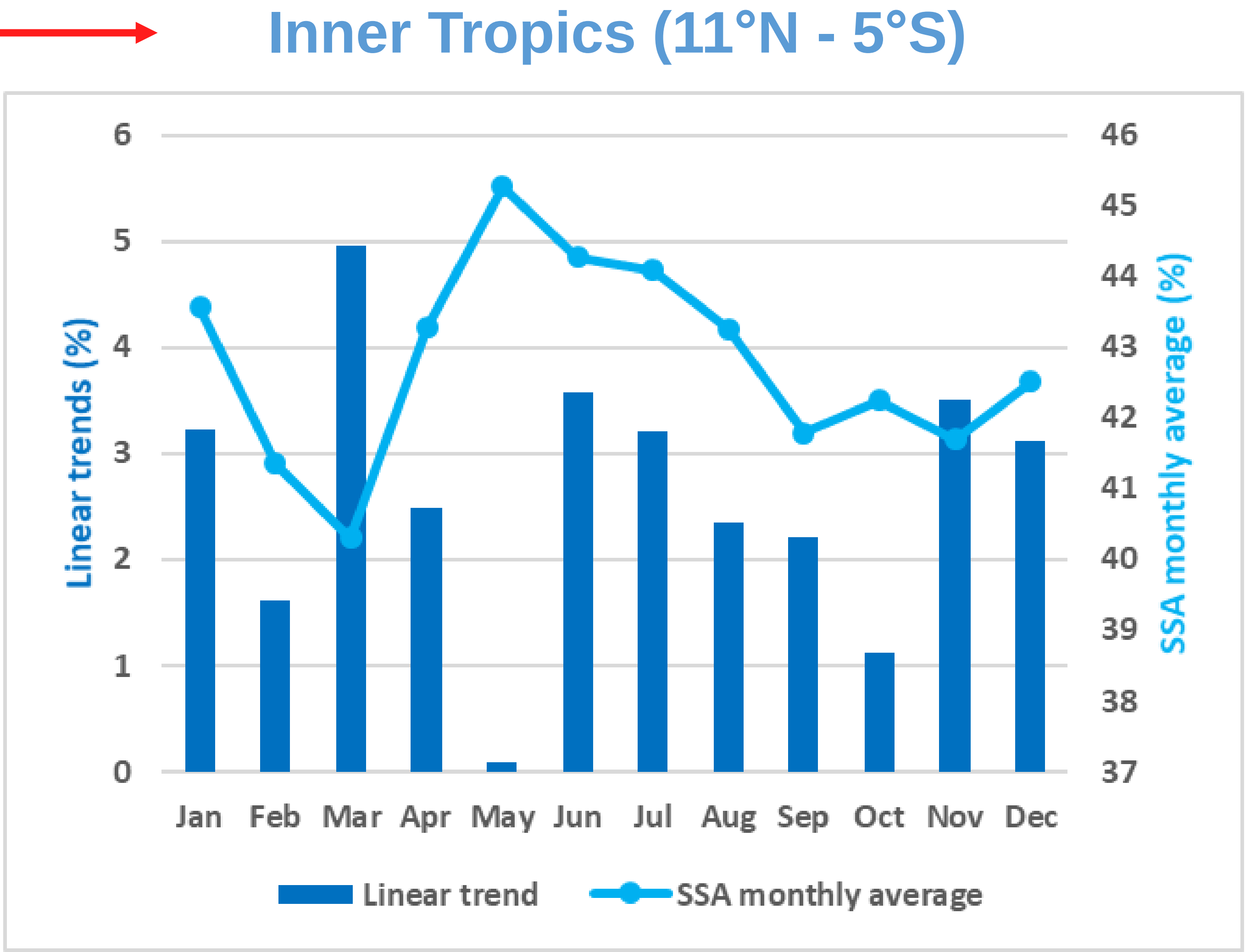
Methodology

b. A median trend procedure was applied using the Theil-Sen slope estimator (median trend) which has proven to be robust against outliers (Eastman, 2009), considering snow albedo data from March 2000 to March 2020, that is, 20 years.

c. The SSA monthly trend was estimated for each zone. Also, its SSA average.

Results



Inner Tropics (11°N - 5°S)
Linear trends (%)
SSA monthly average (%)
0
1
2
3
4
5
6
37
38
39
40
41
42
43
44
45
46
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Linear trend
SSA monthly average

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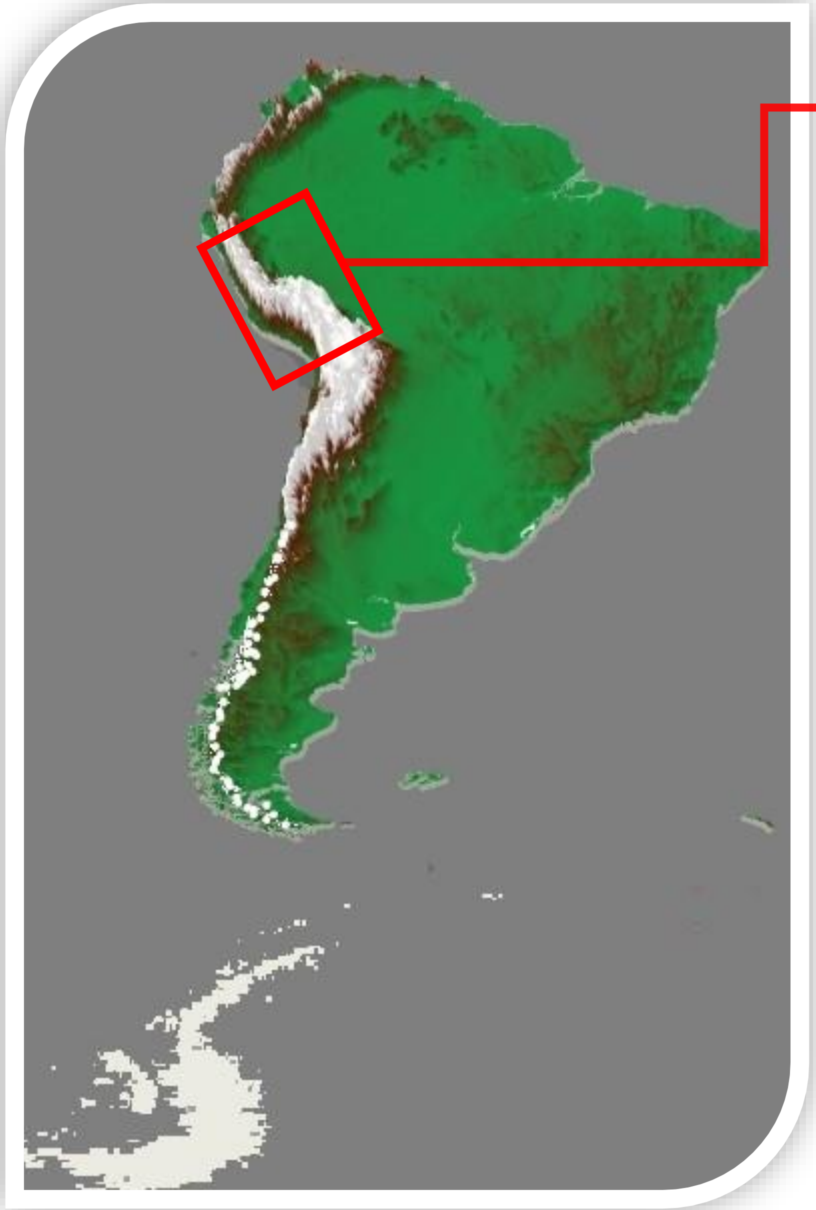
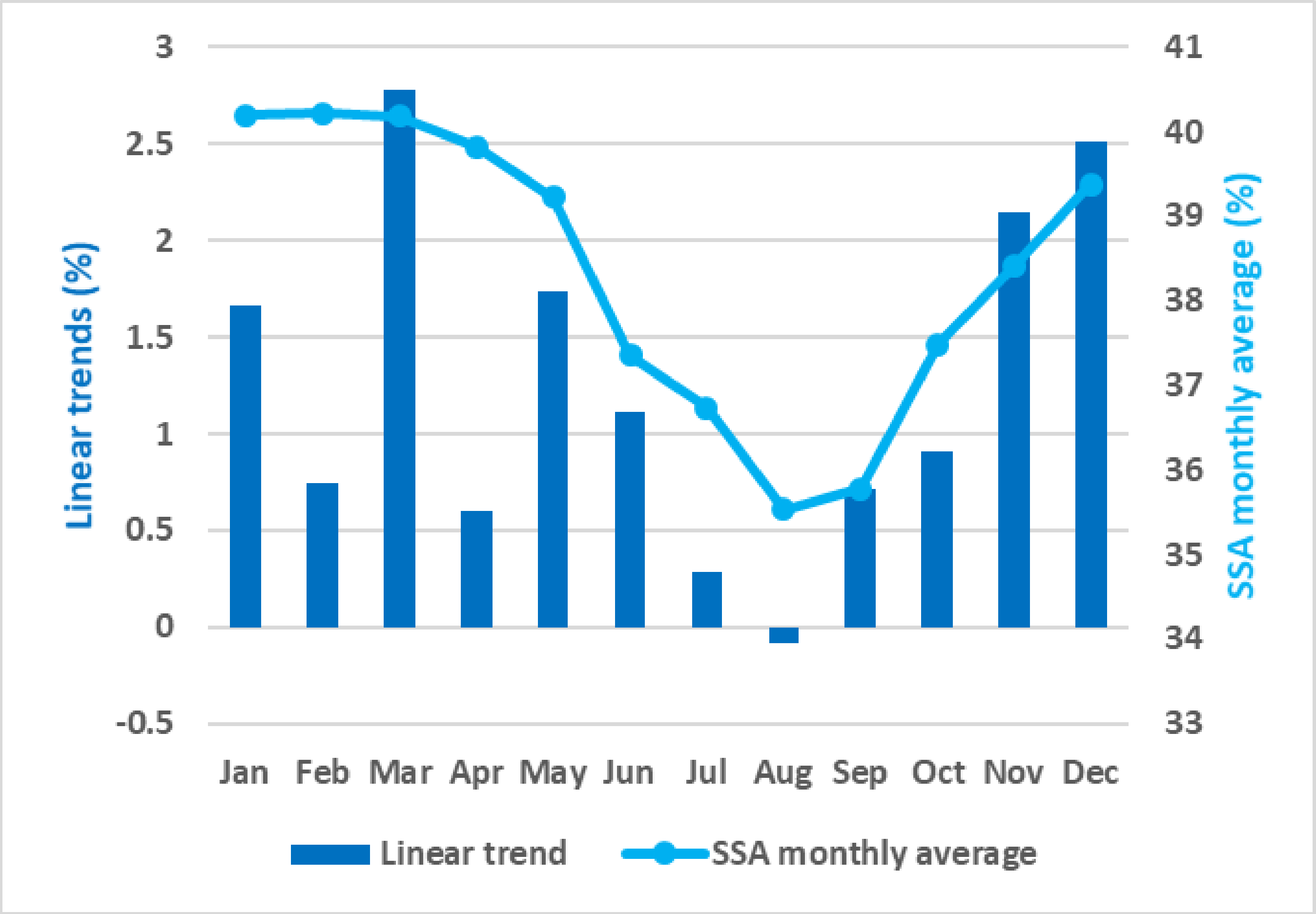


Outer Tropics (5°S - 18°S)



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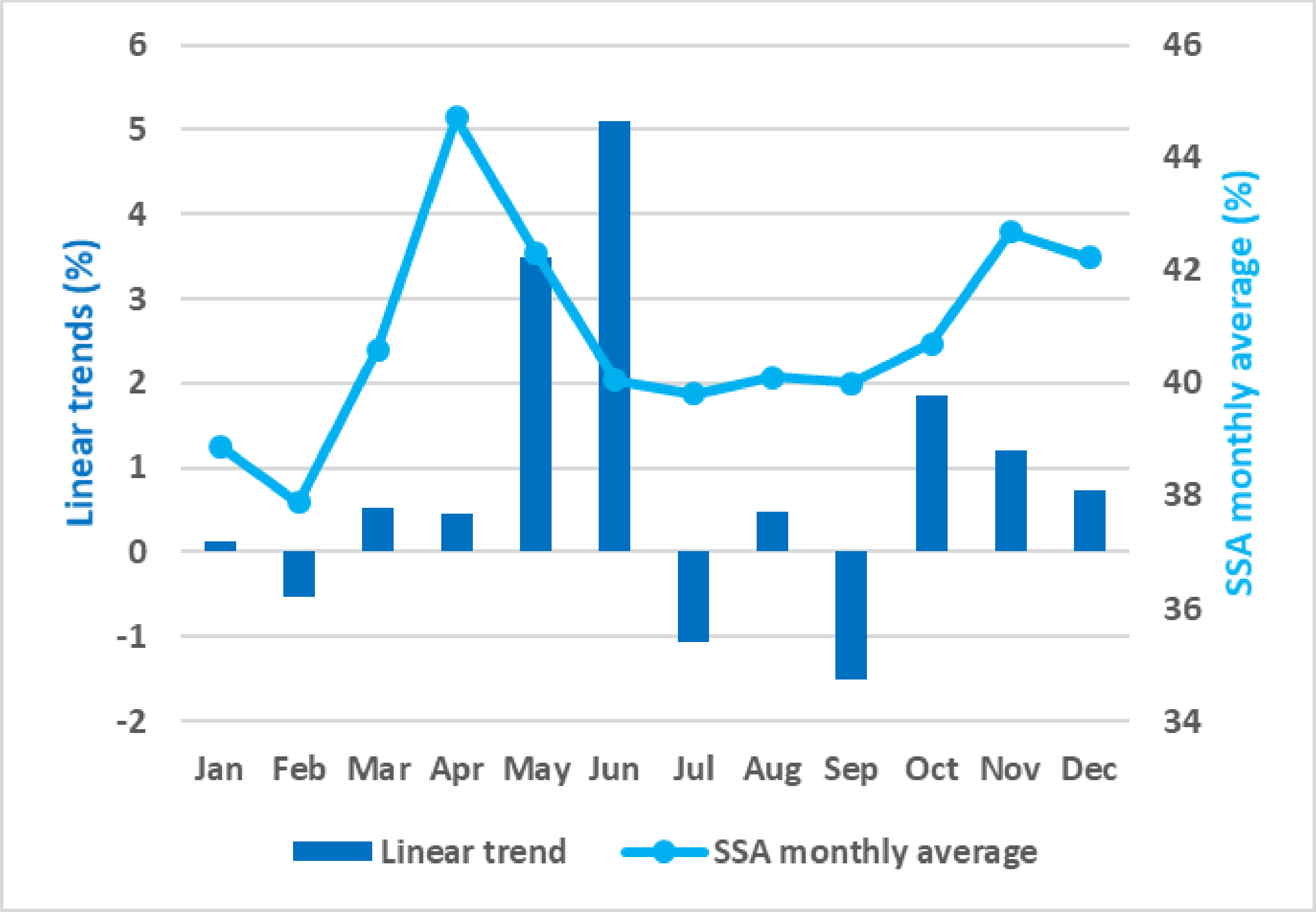
Desert Andes (18°S - 31°S)



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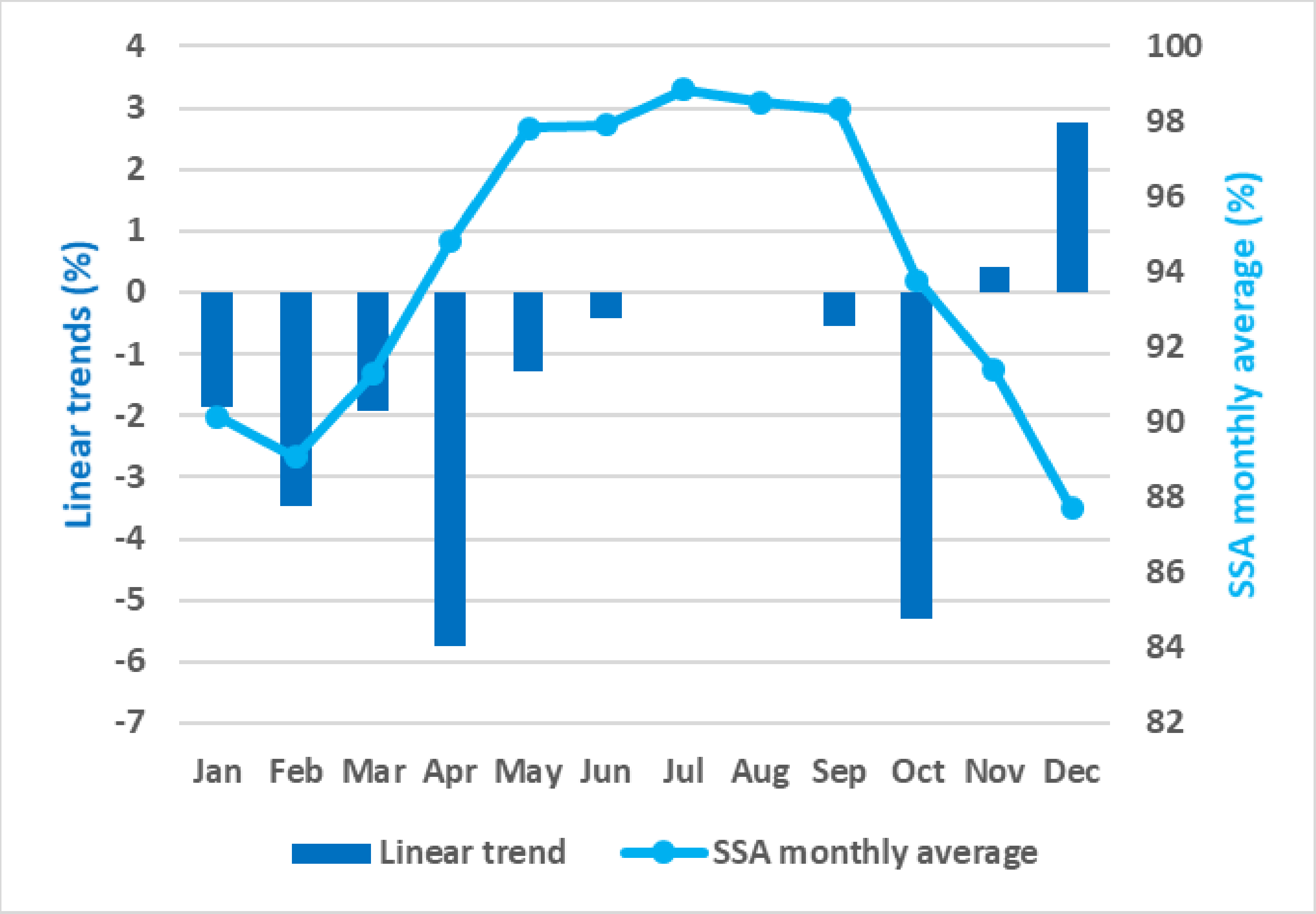
Central Andes (31°S - 37°S)



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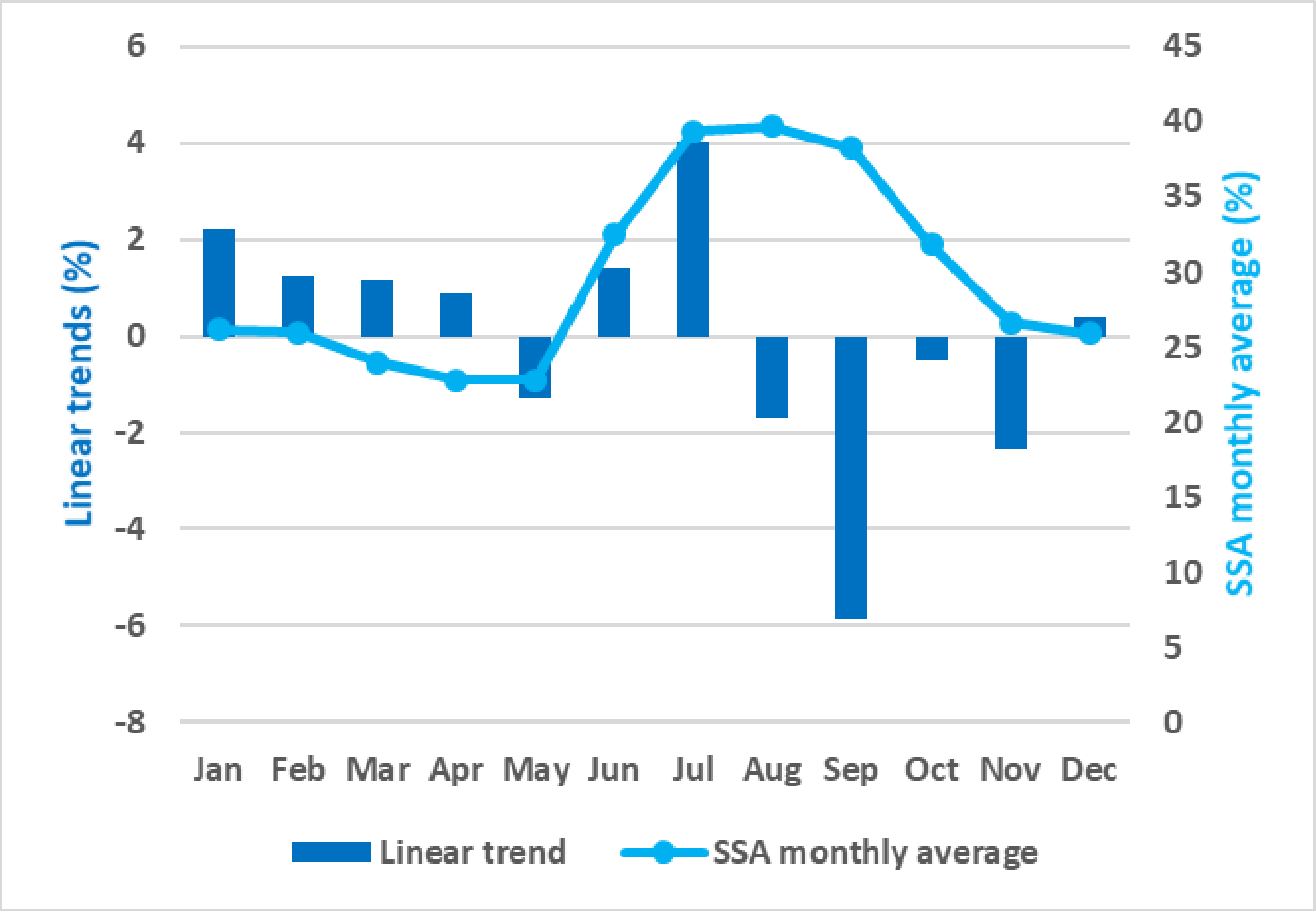
North Patagonia (37°S - 46°S)



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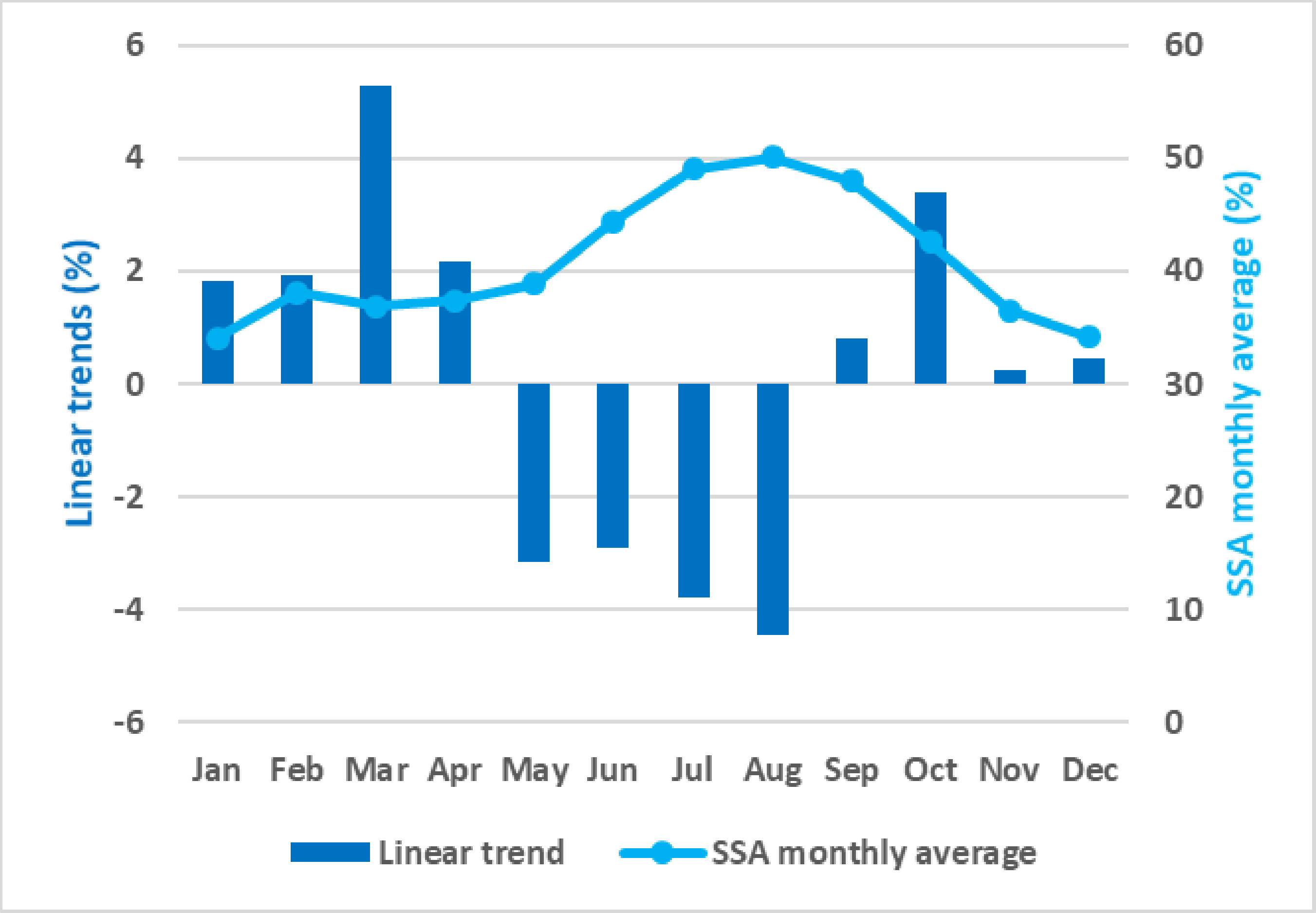
South Patagonia (46°S - 54°S)



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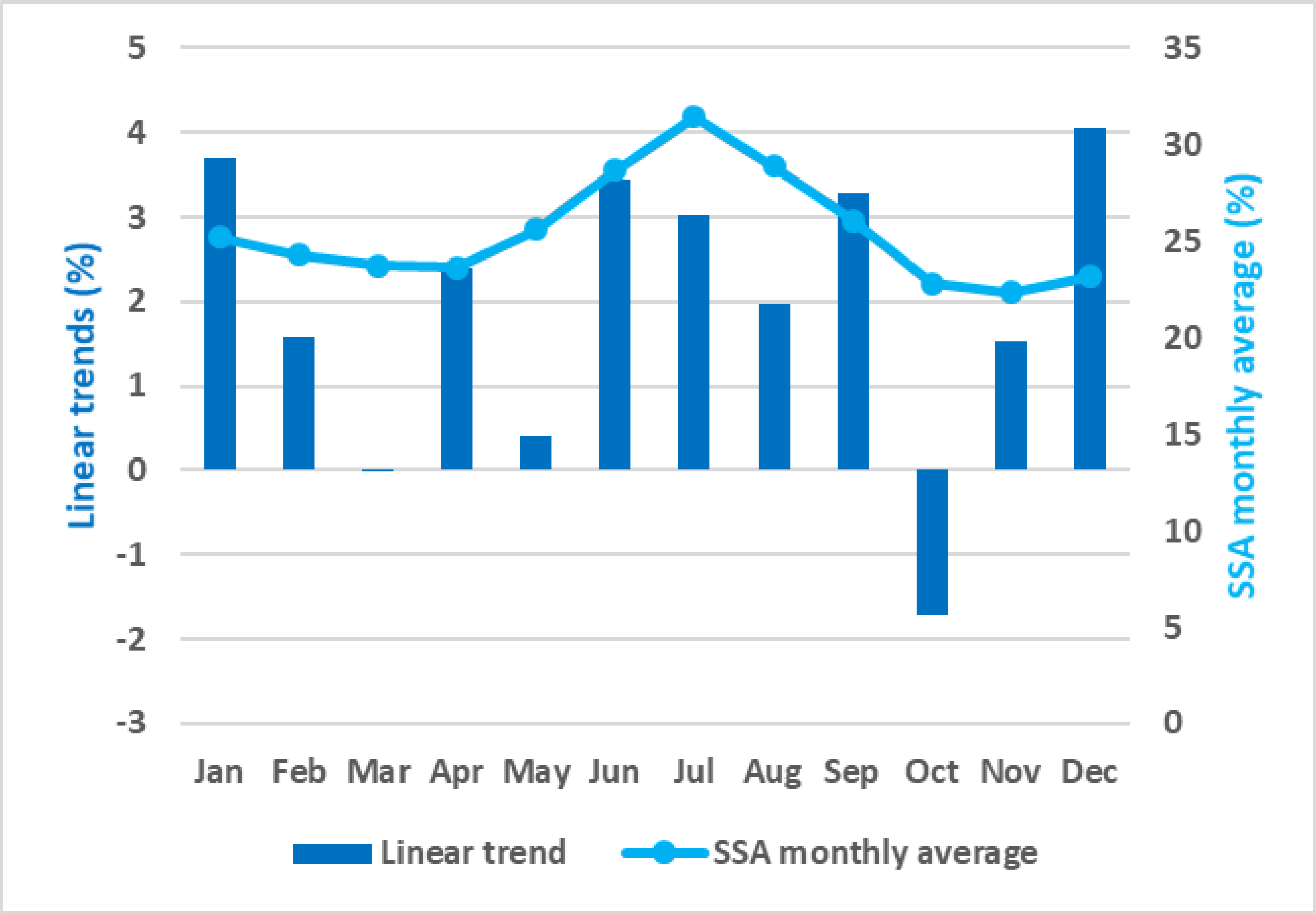
Fuegian Andes (54°S - 56°S)



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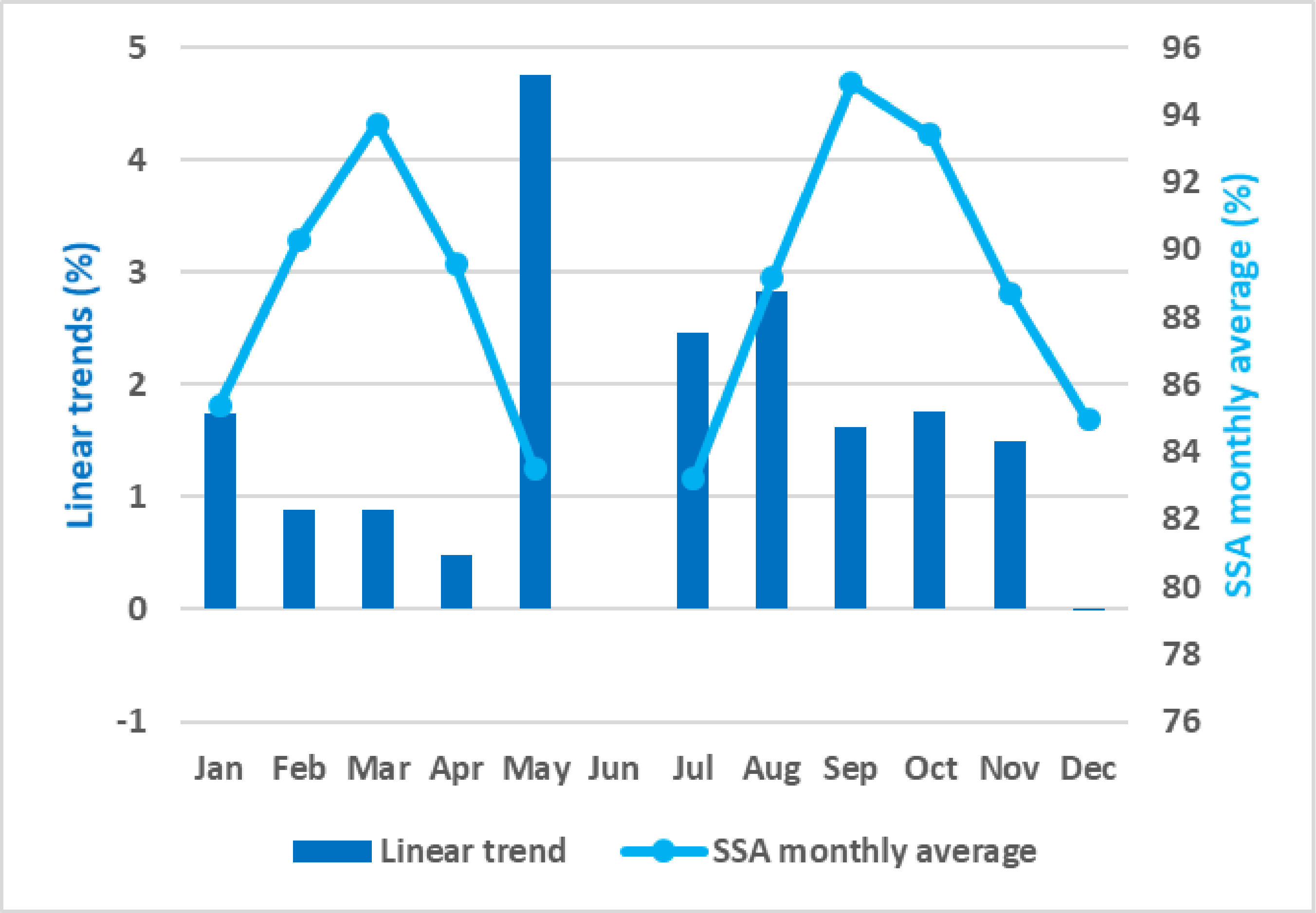
Antarctandes (63°S - 76°S)



Summary and outlooks

The greatest negative trends observed

The greatest positive trends observed

Better understanding of the radiative forcing changes generated in the cryosphere of South America and Antarctandes

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The greatest negative trends were observed in:

Central Andes (April, -5.76%; $p < 0.001$)

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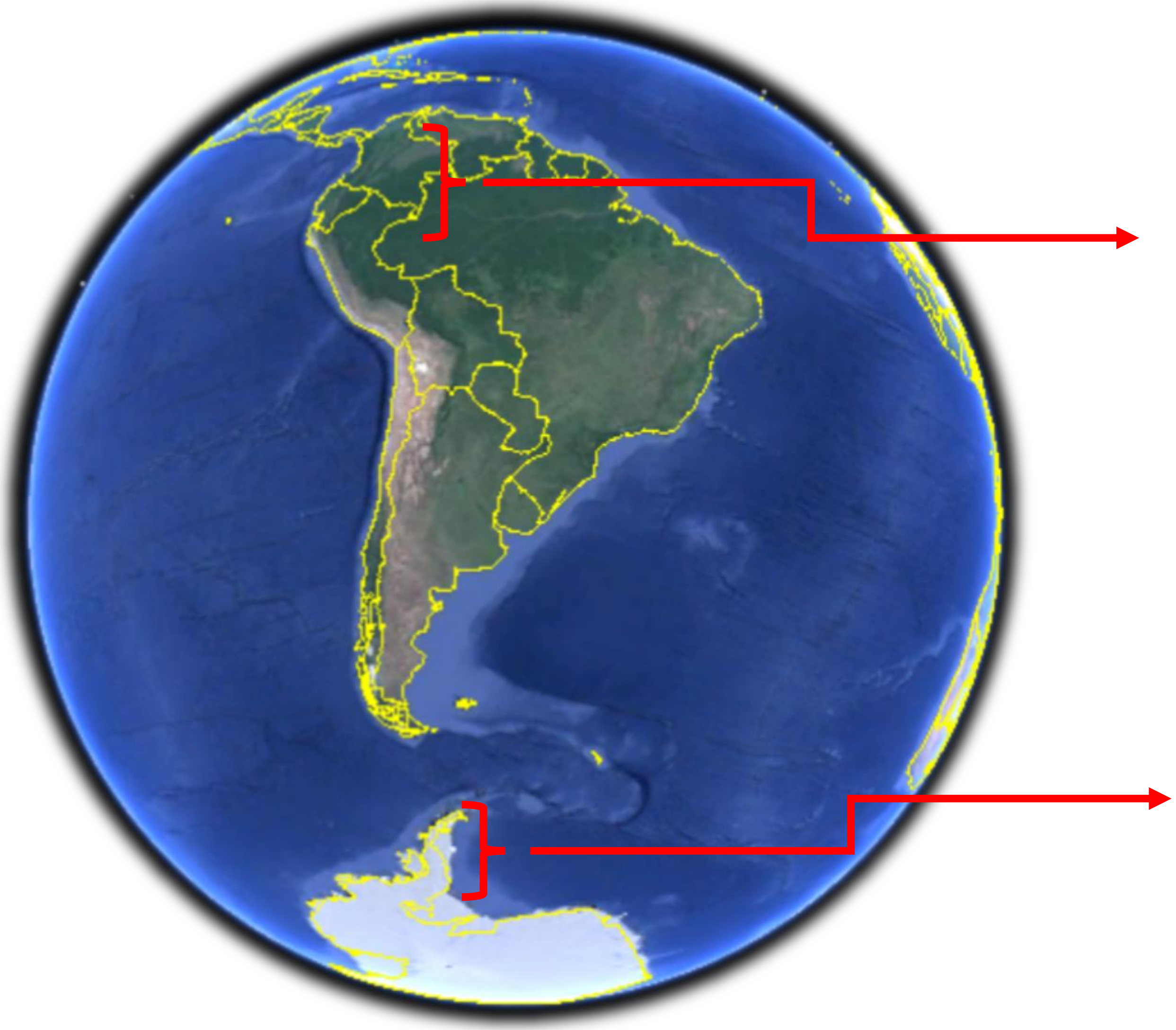

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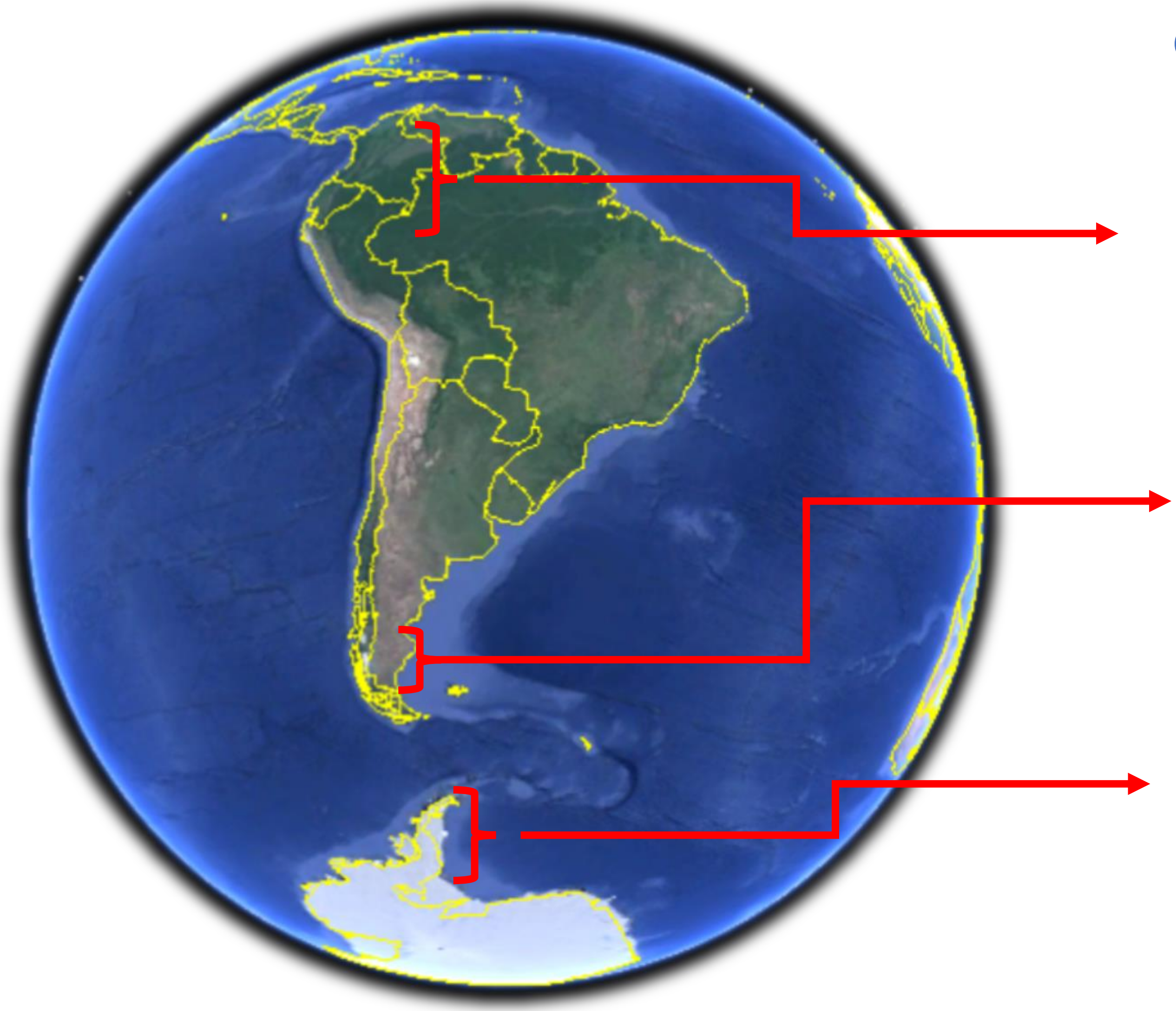

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Acknowledgment

- The National Agency of Scientific and Technological Promotion (ANPCyT) under project PICT 2016 1115. Argentina

- ANID FONDEF: ID19I10359 project from Ministerio de Ciencia, Tecnología, Conocimiento e Innovación. Chile

Thank you very much for watching this presentation

Any question or suggestion:

tomas.bolano@frm.utn.edu.ar

Furthermore, we see you again in live virtual presentation:

- **Session date and time:** Monday, 7 December 2020; 20:30 - 21:30 PST
- **Session number and title:** C008: Remote Sensing of the Cryosphere: Seasonal Snow II

Las Cuevas, Mendoza, Argentina
August 2019

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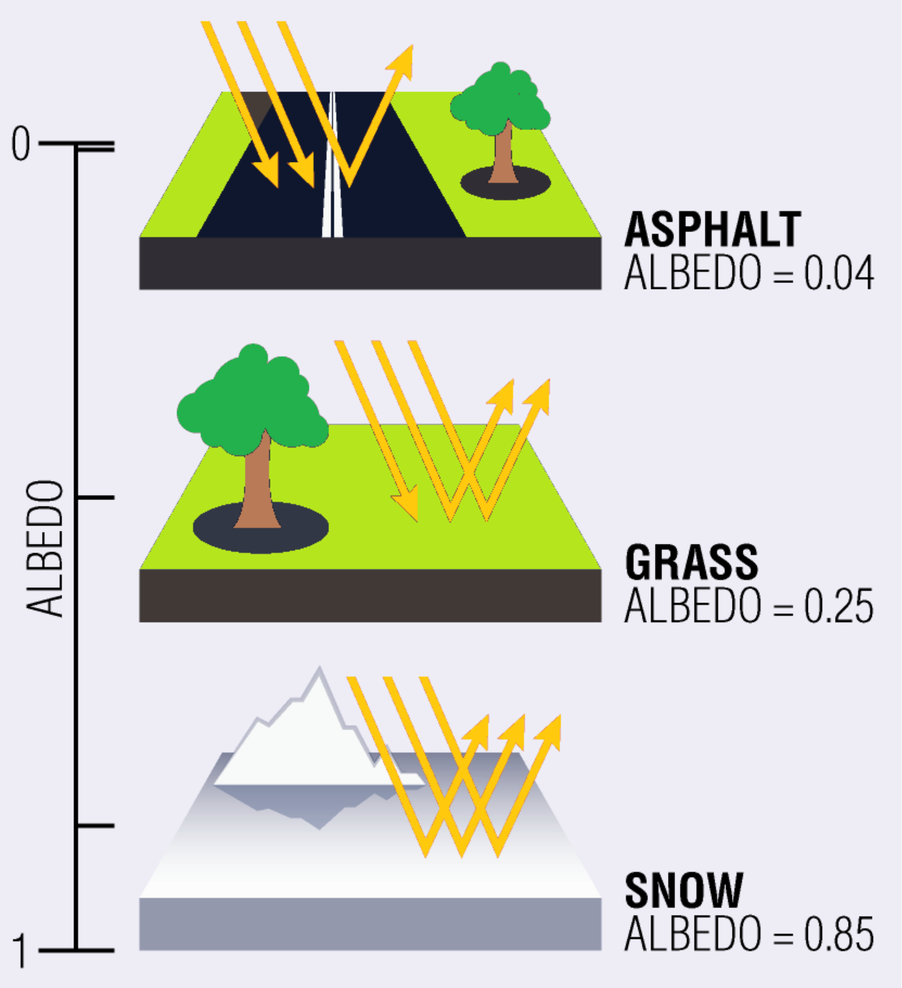

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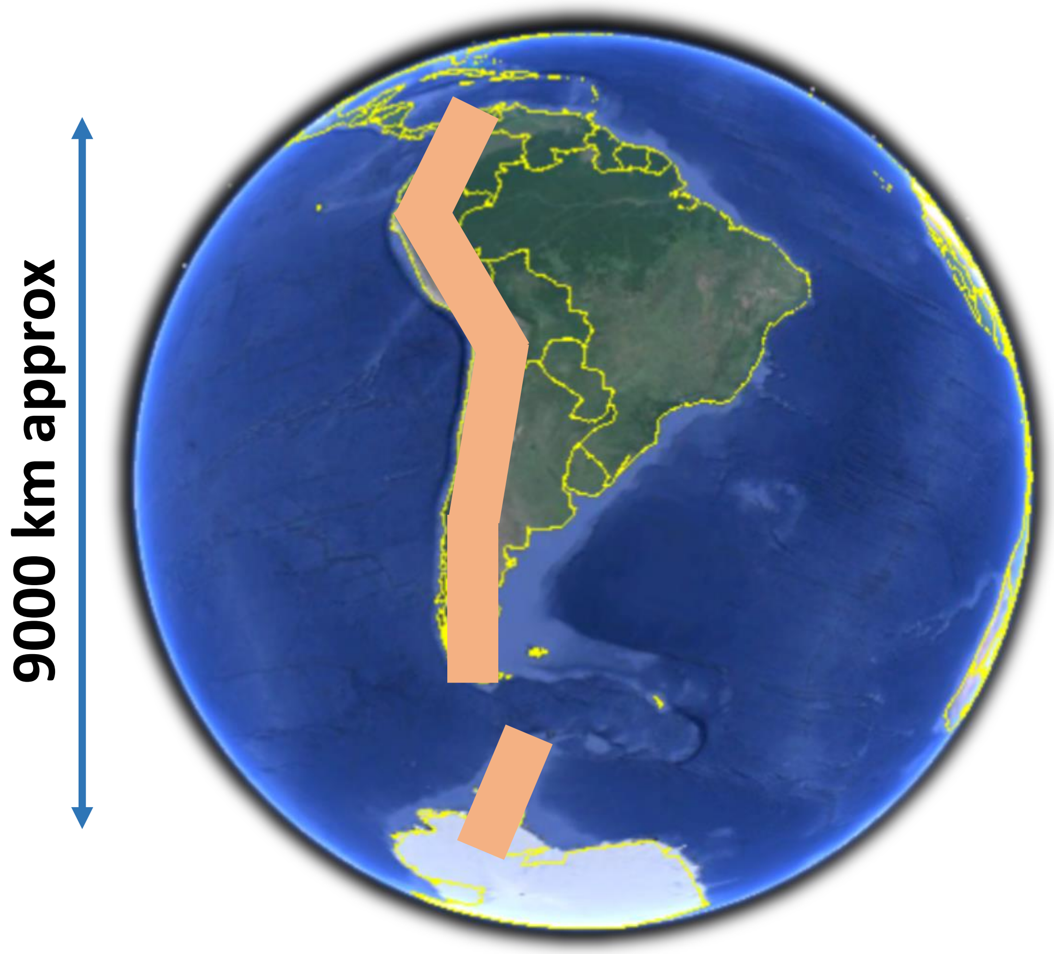

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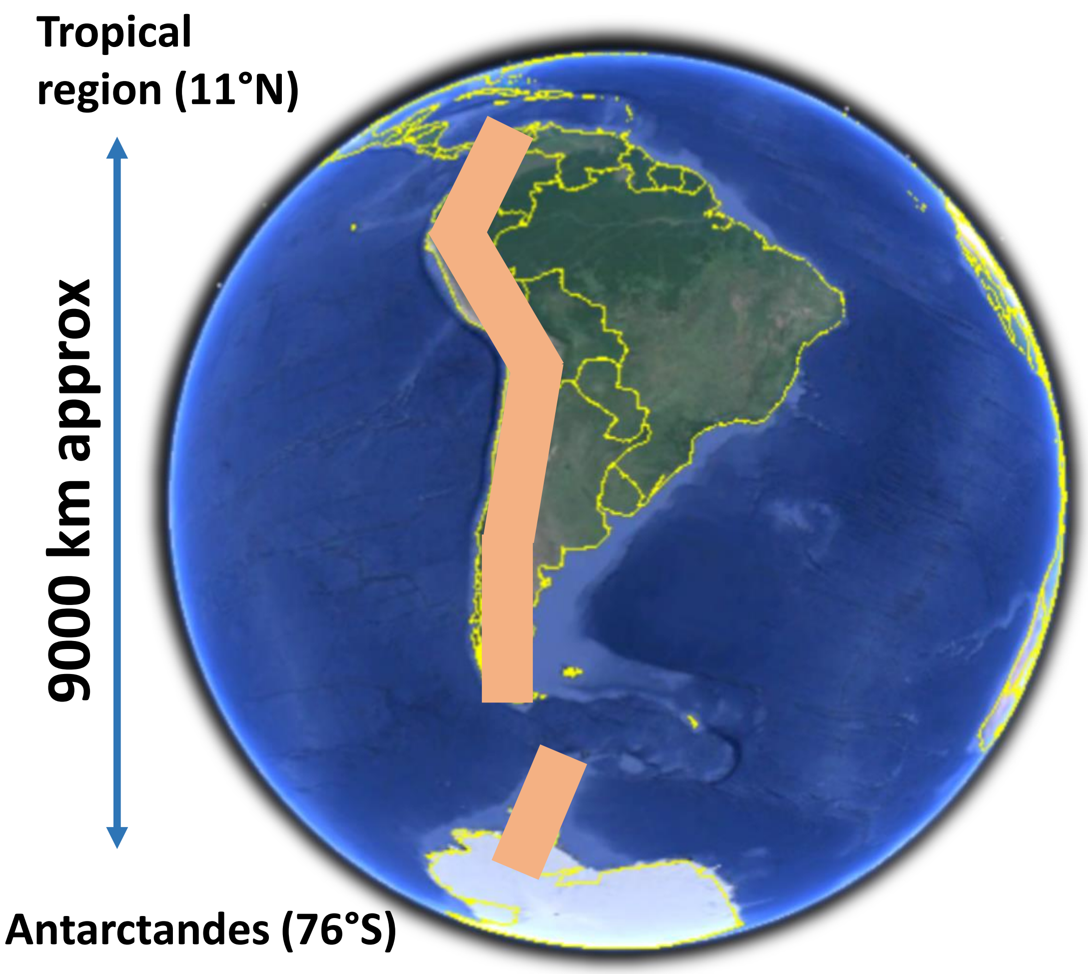

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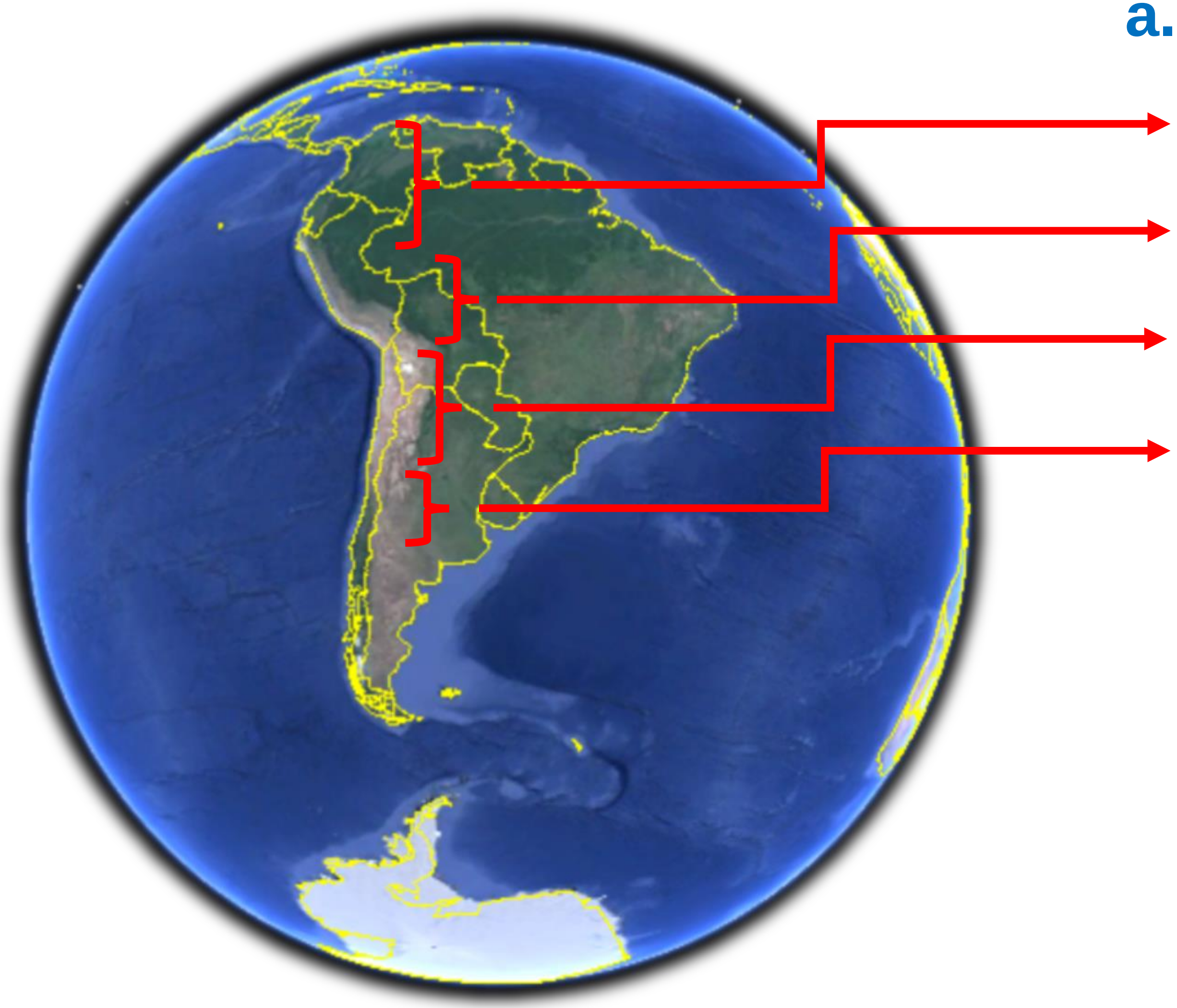
(*Dussaillant et at.*, 2019).

Methodology



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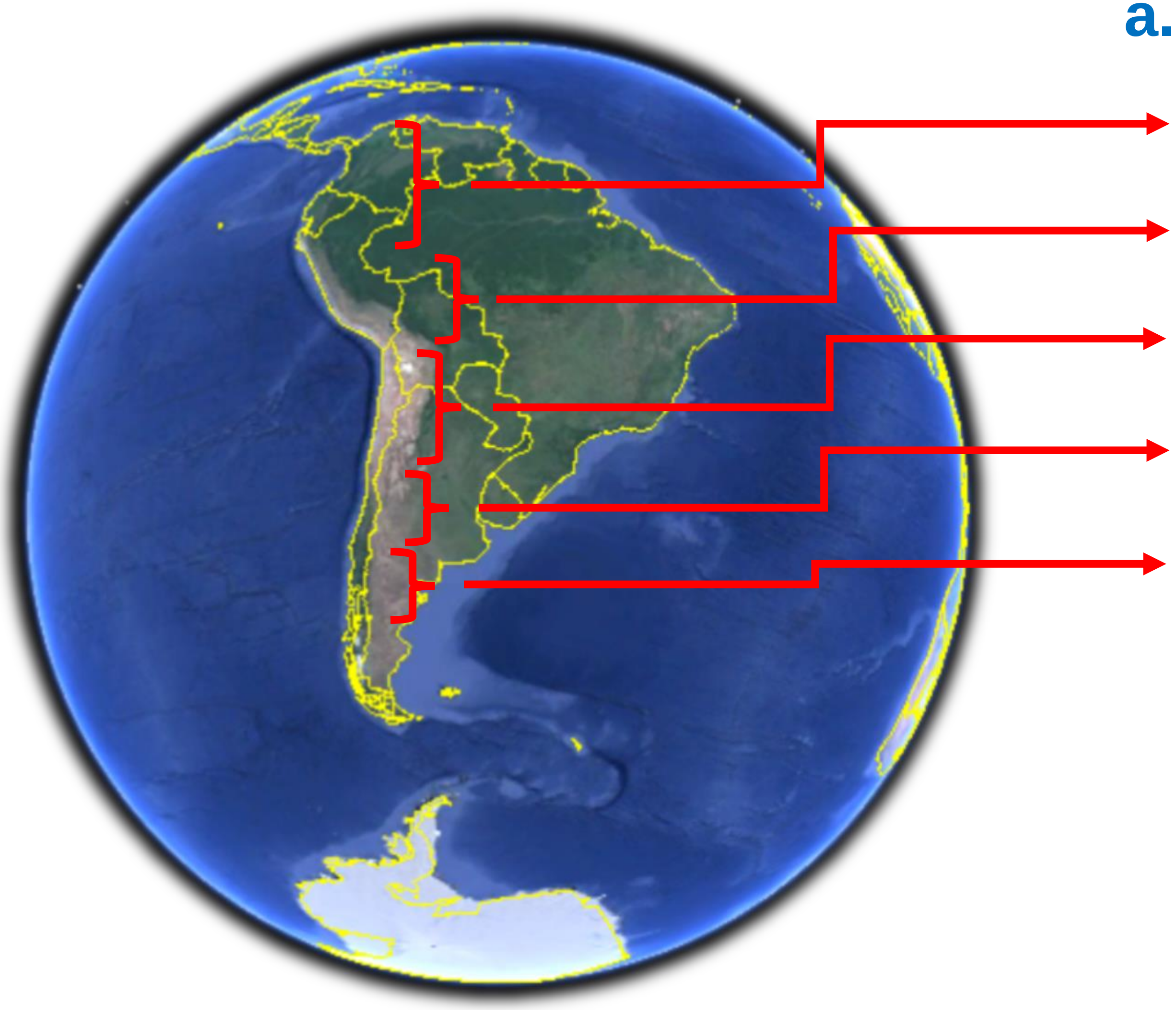

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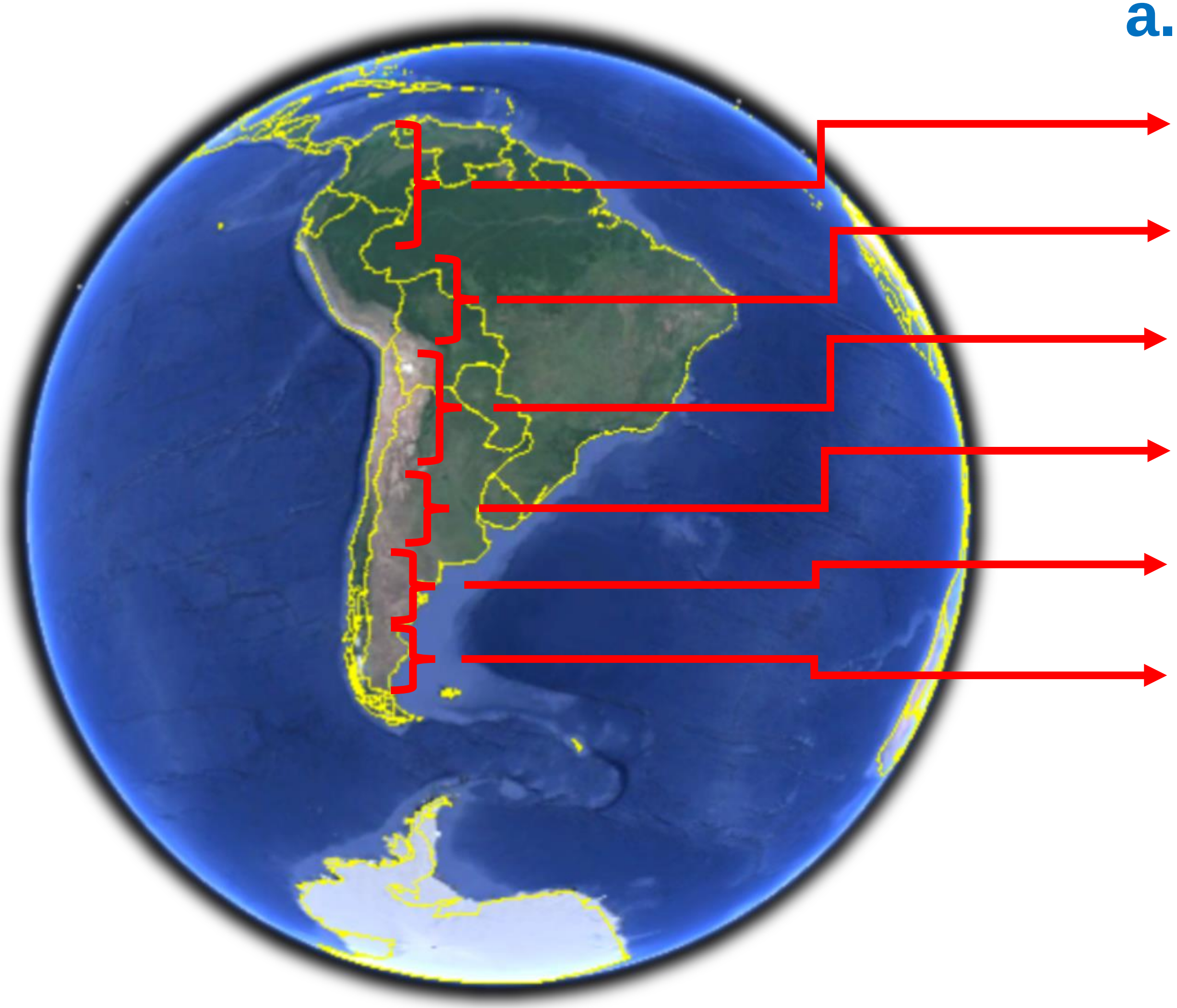

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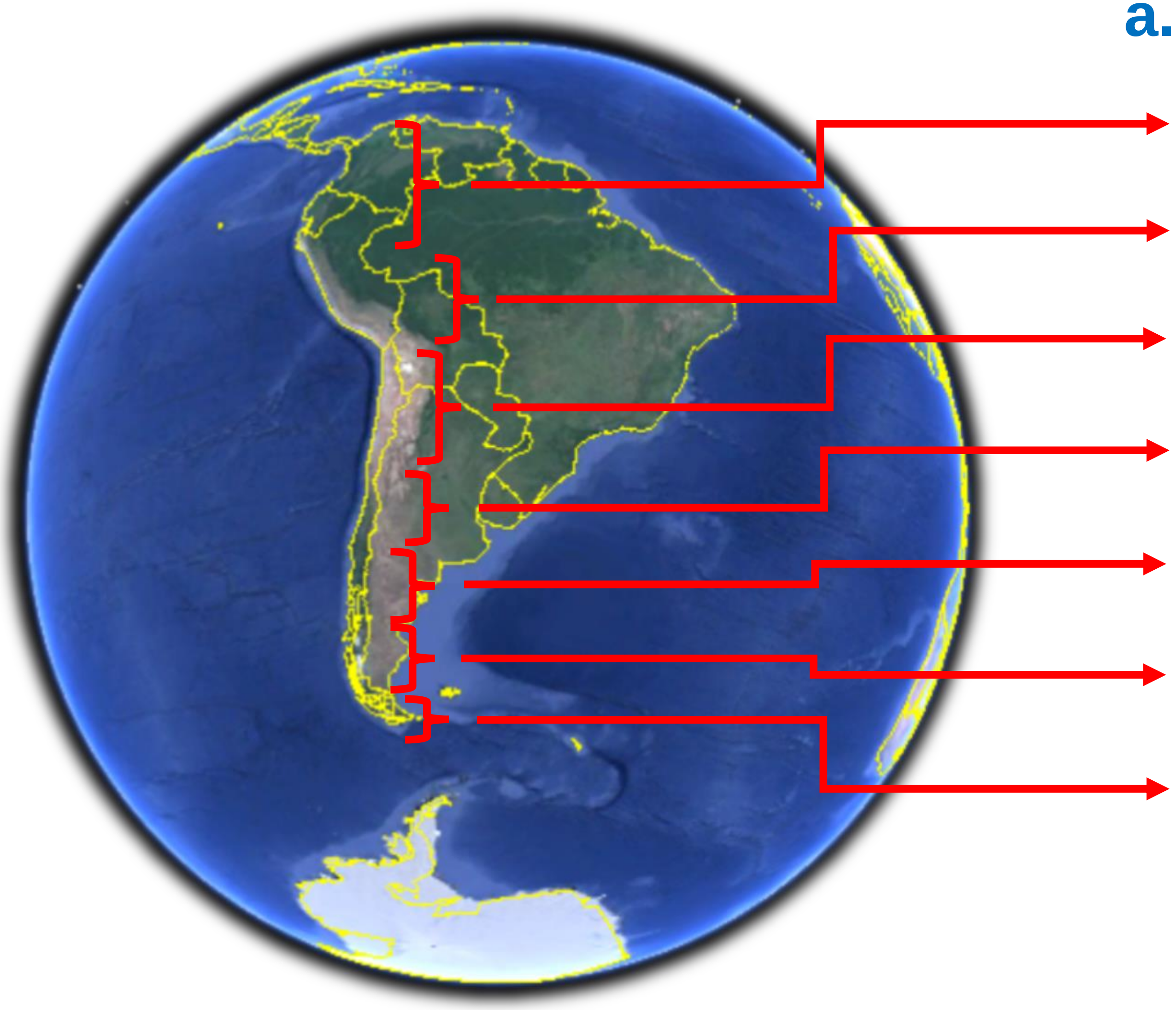

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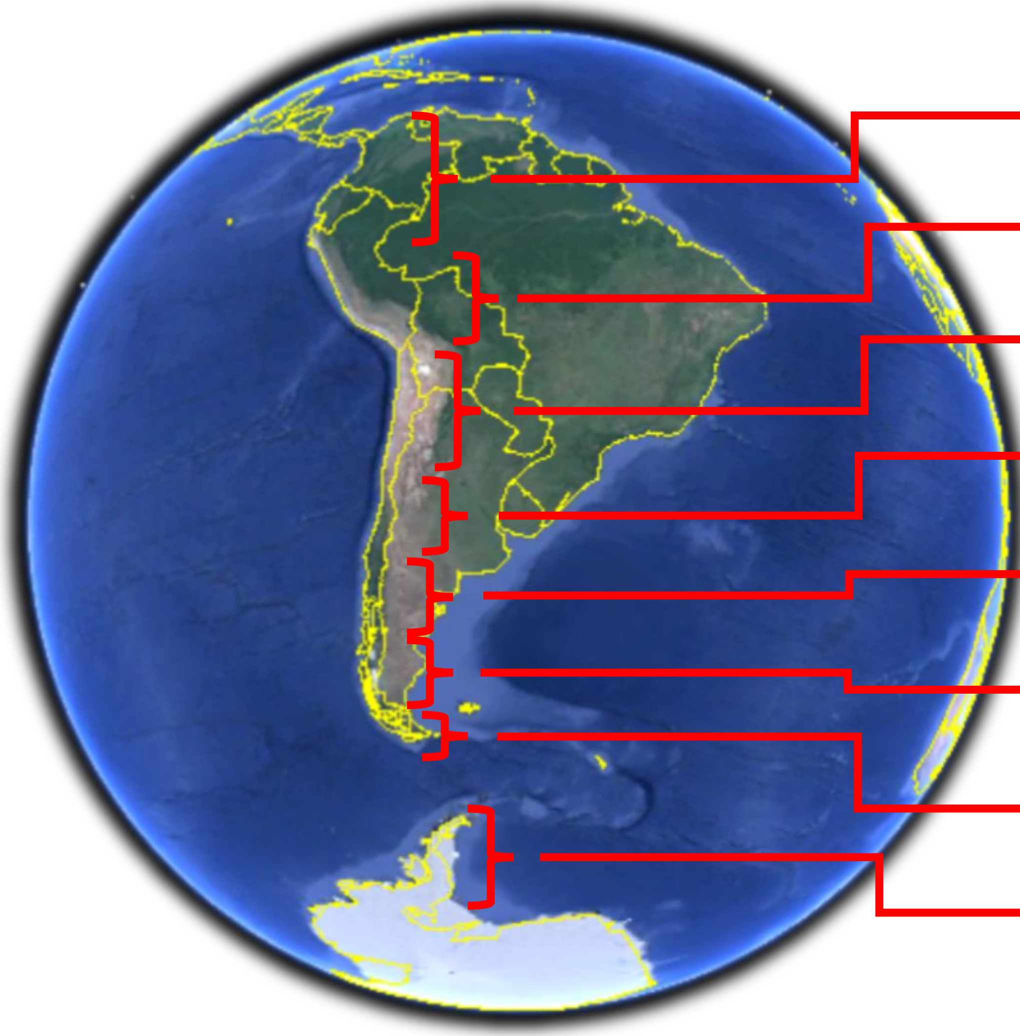

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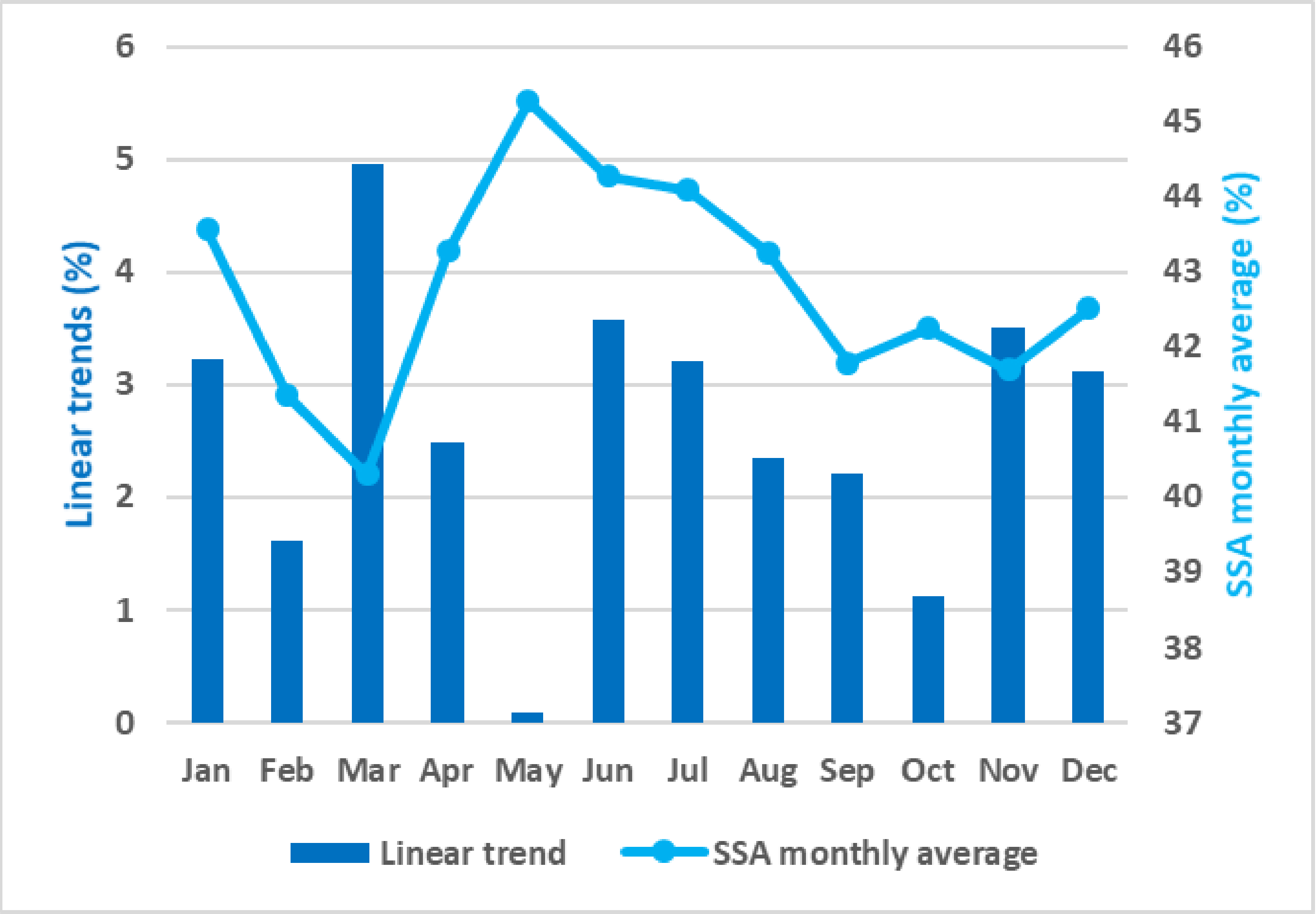
Methodology

b. A median trend procedure was applied using the Theil-Sen slope estimator (median trend) which has proven to be robust against outliers (Eastman, 2009), considering snow albedo data from March 2000 to March 2020, that is, 20 years.

c. The SSA monthly trend was estimated for each zone. Also, its SSA average.

Results

Inner Tropics (11°N - 5°S)



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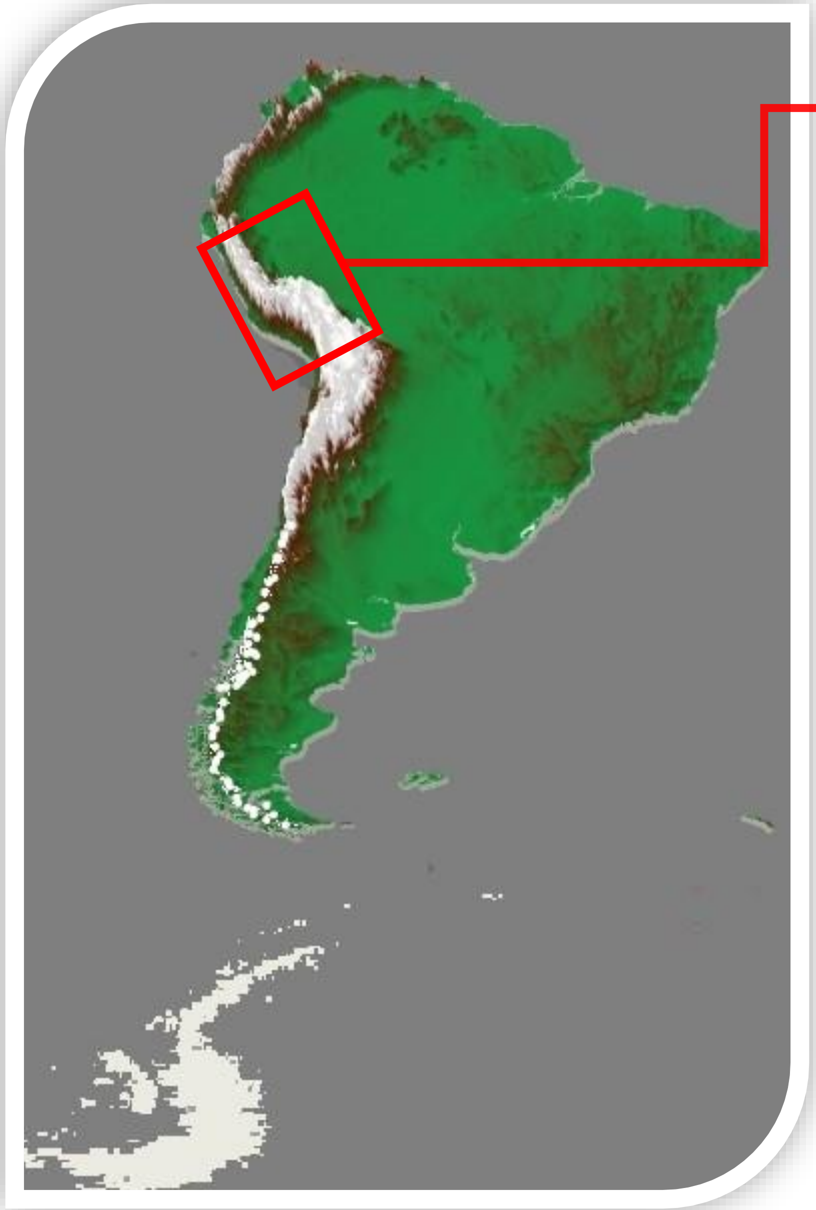
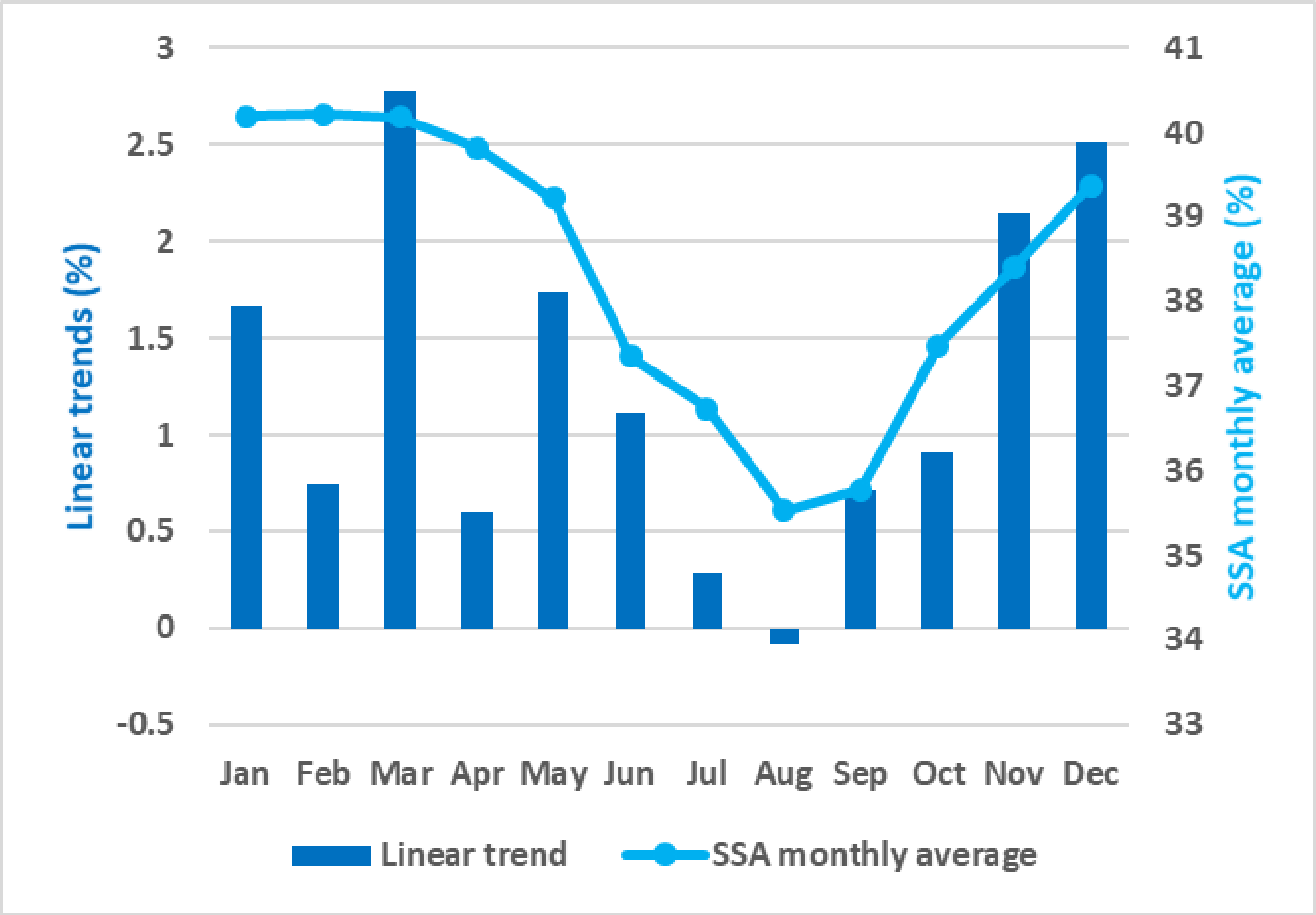
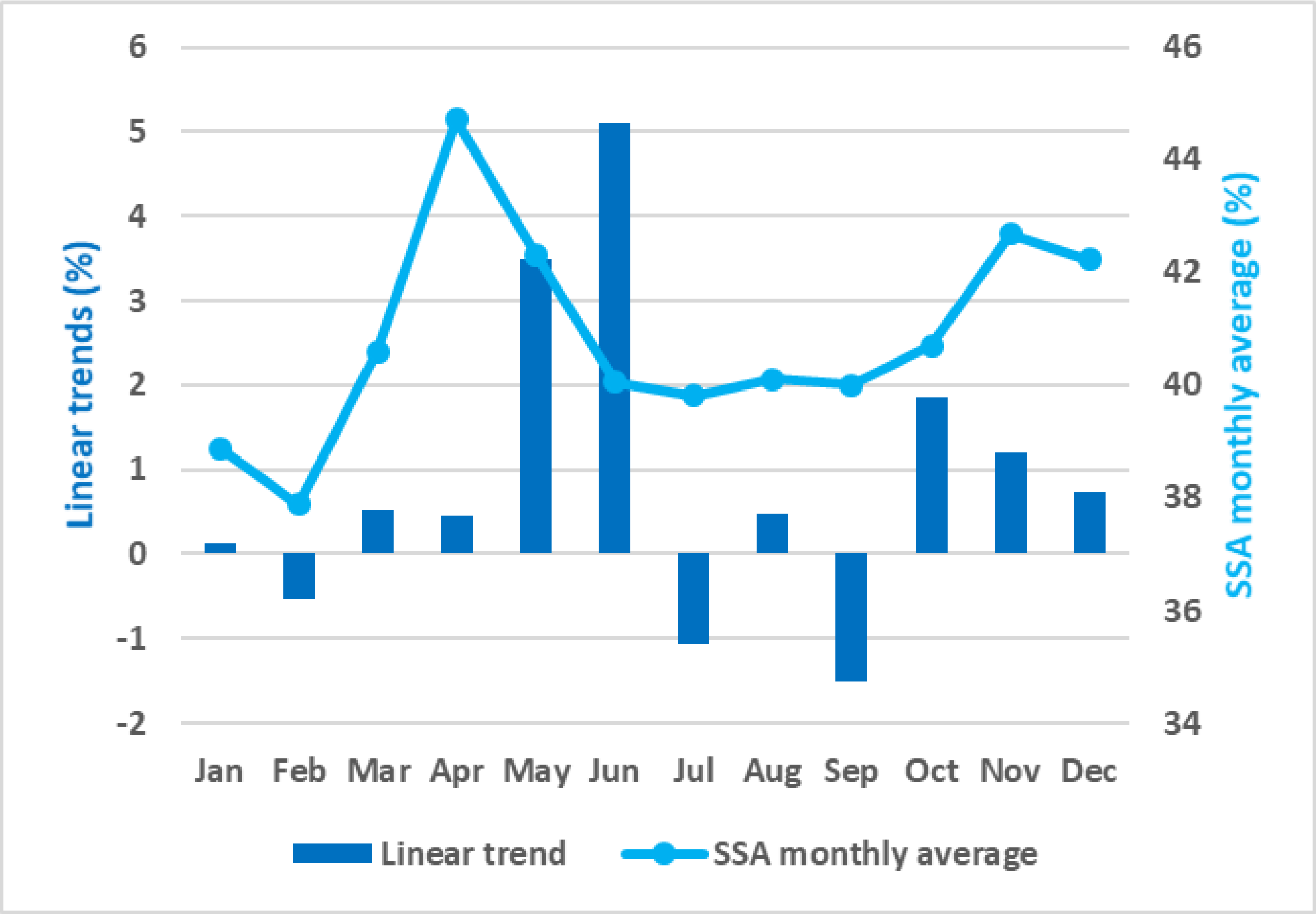


Outer Tropics (5°S - 18°S)



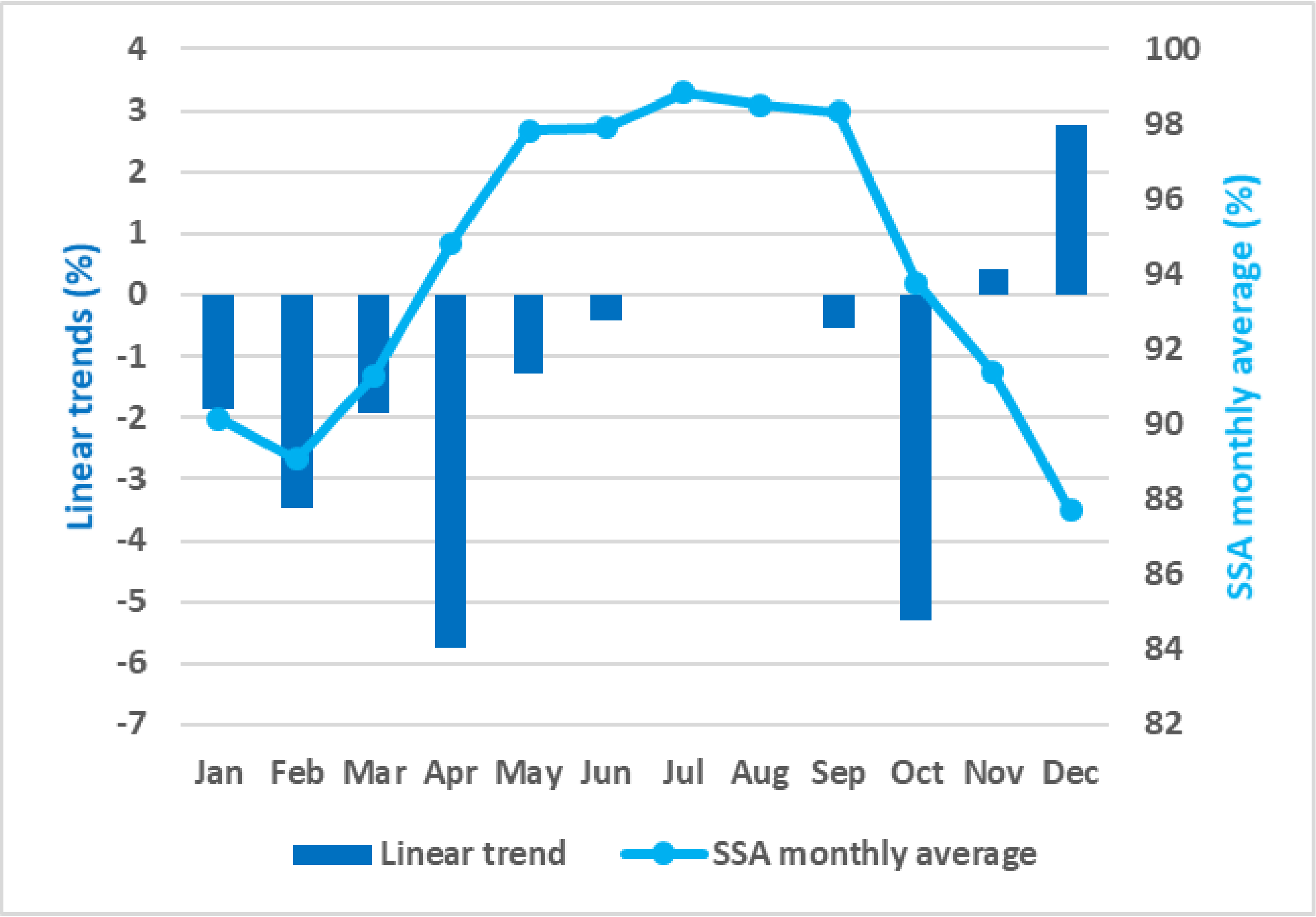
Results

Desert Andes (18°S - 31°S)



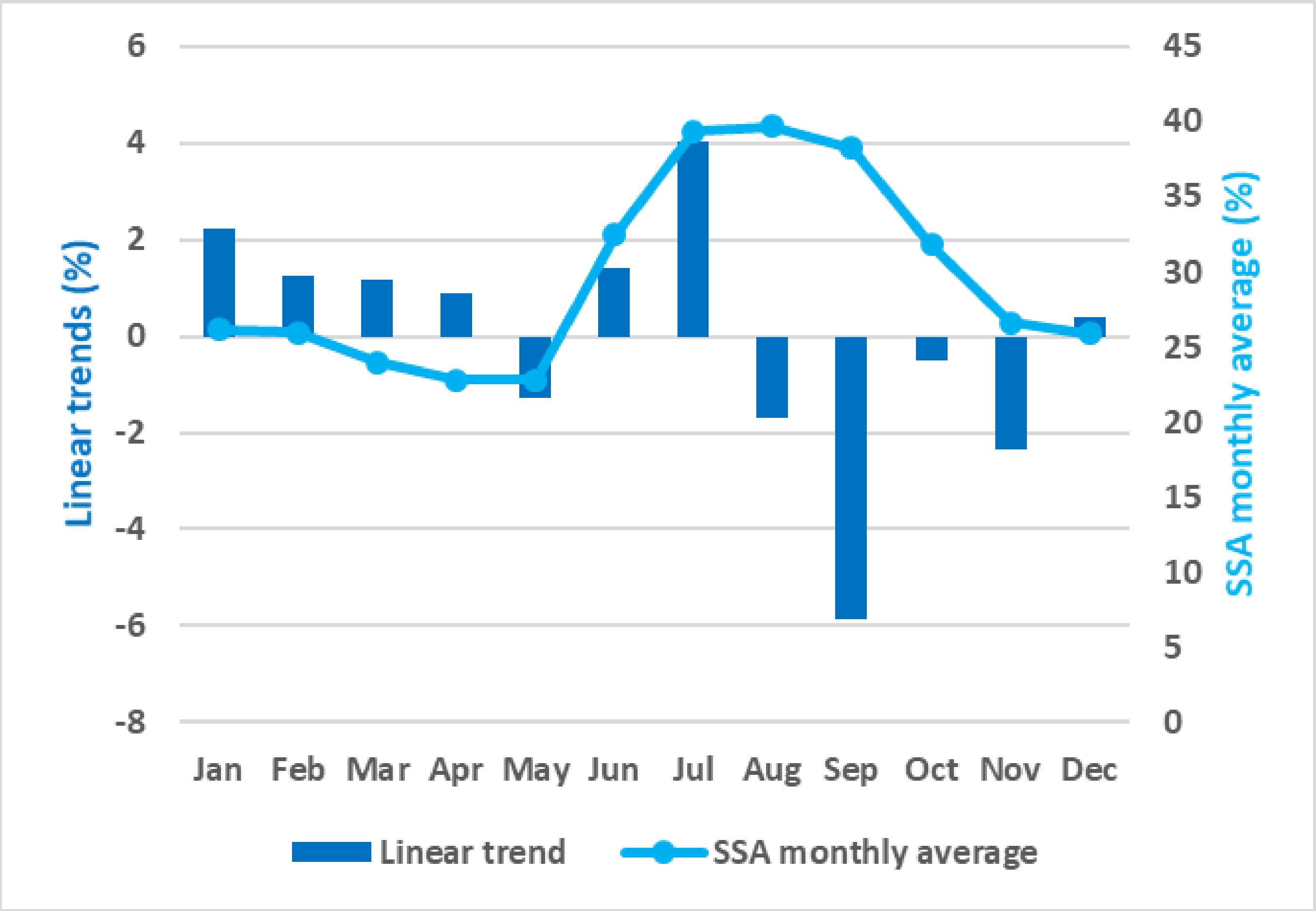
Results

Central Andes (31°S - 37°S)



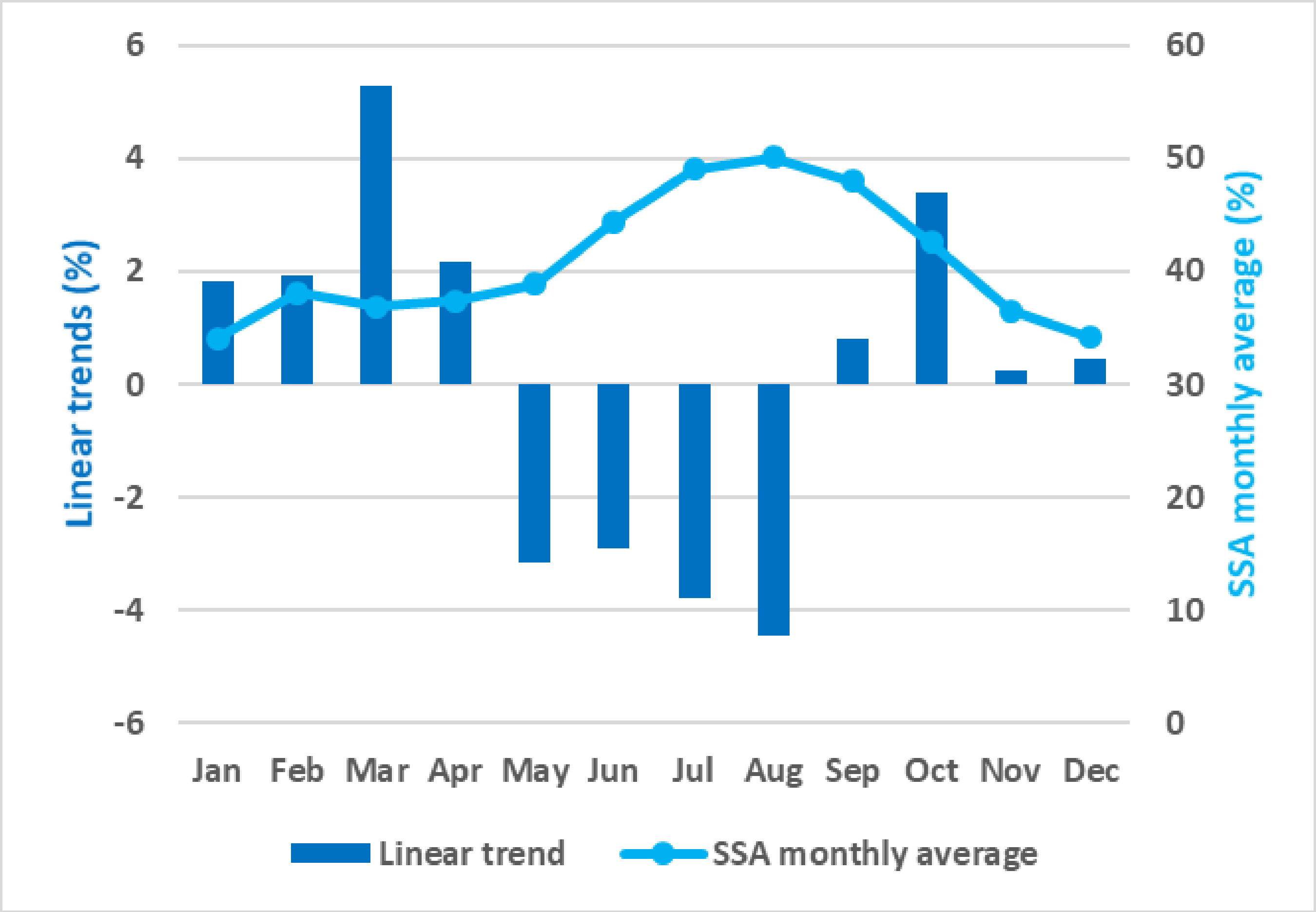
Results

North Patagonia (37°S - 46°S)



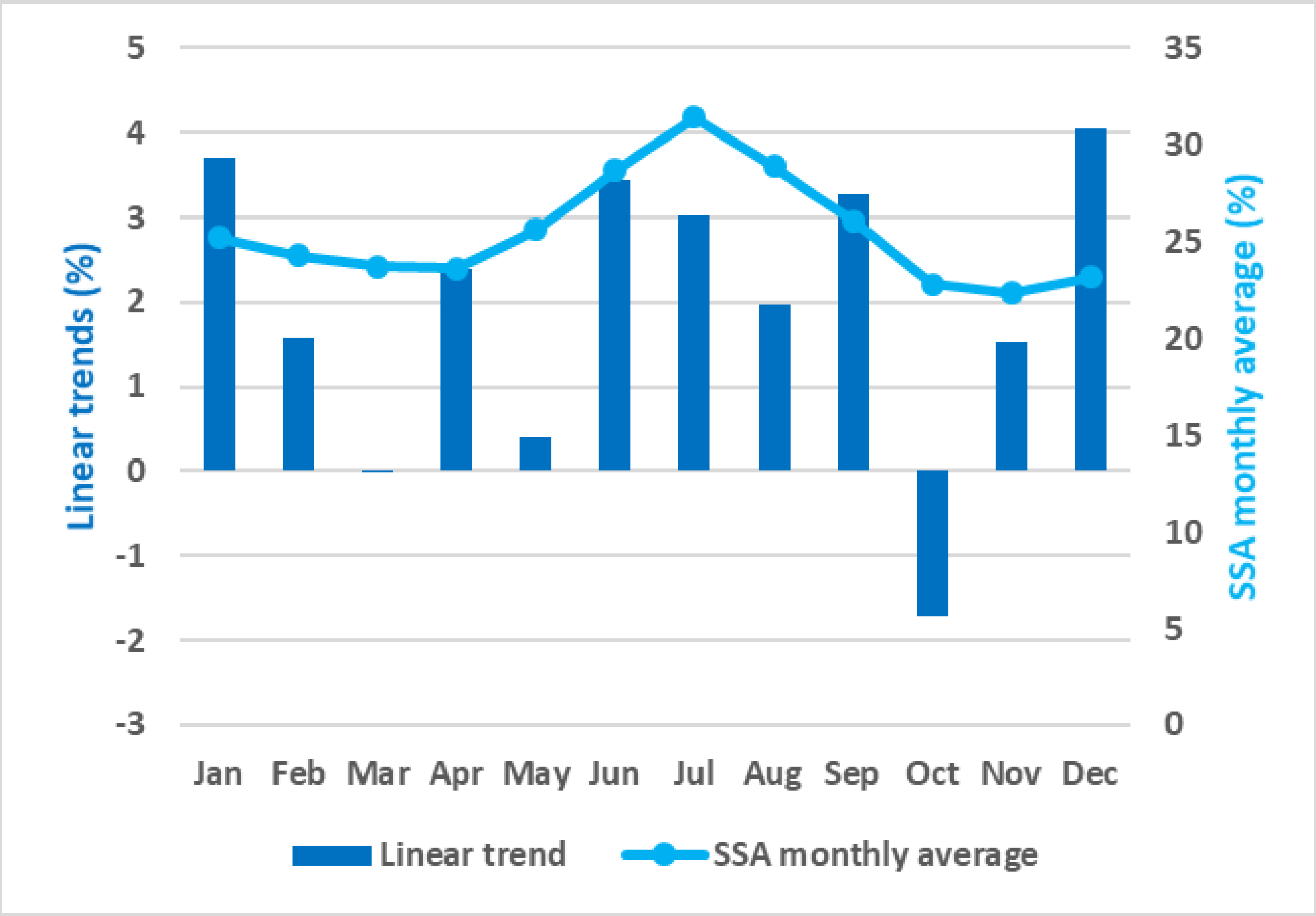
Results

South Patagonia (46°S - 54°S)



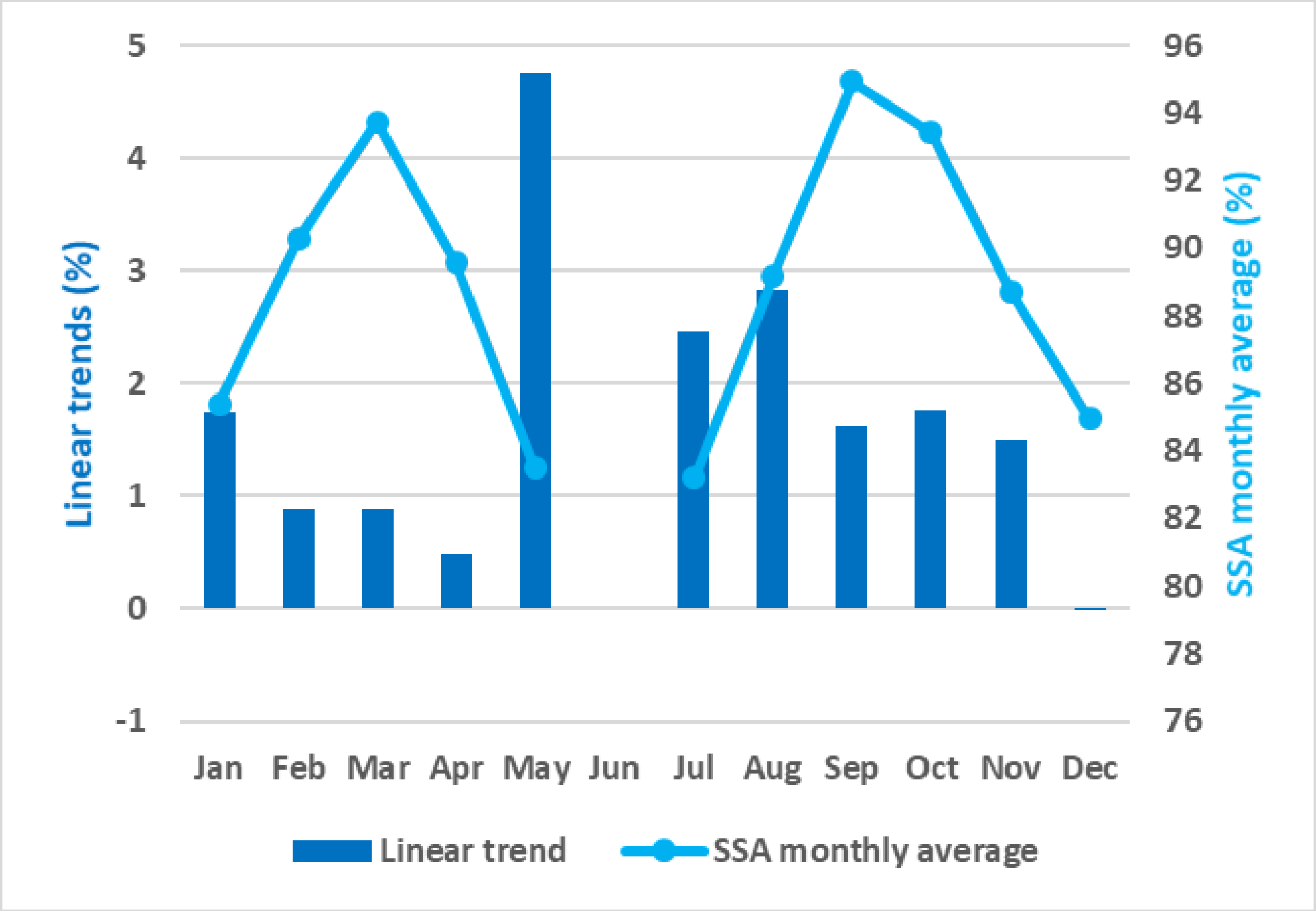
Results

Fuegian Andes (54°S - 56°S)



Results

Antarctandes (63°S - 76°S)



Summary and outlooks

The greatest negative trends observed

The greatest positive trends observed

Better understanding of the radiative forcing changes generated in the cryosphere of South America and Antarctandes

Summary and outlooks

The greatest negative trends were observed in:

Central Andes (April, -5.76%; $p < 0.001$)

North Patagonia (Nov, -2.33%; $p < 0.05$)

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South Patagonia (Mar, 5.3%; $p < 0.05$)

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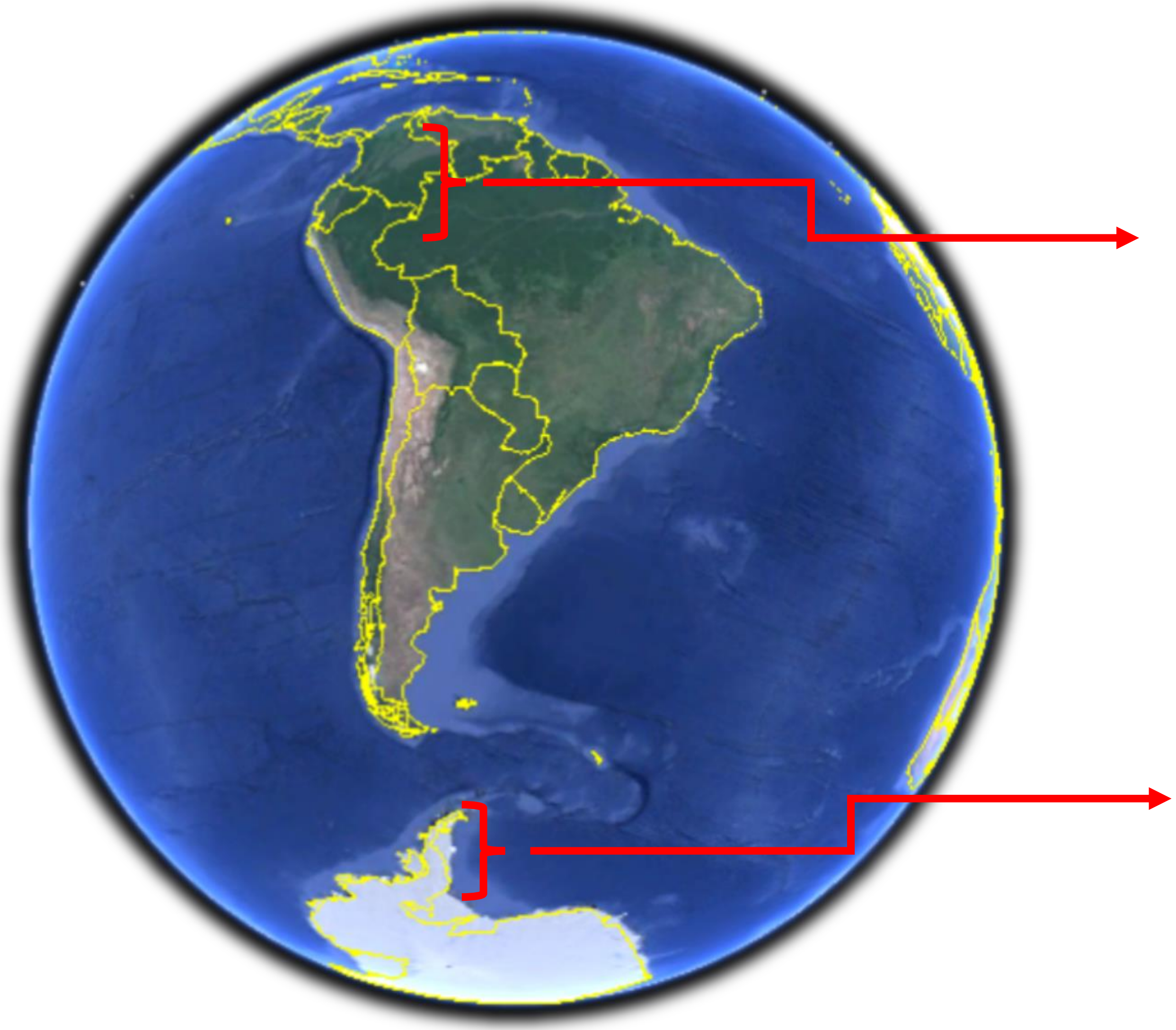

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Acknowledgment

- The National Agency of Scientific and Technological Promotion (ANPCyT) under project PICT 2016 1115. Argentina

- ANID FONDEF: ID19I10359 project from Ministerio de Ciencia, Tecnología, Conocimiento e Innovación. Chile

Thank you very much for watching this presentation

Any question or suggestion:

tomas.bolano@frm.utn.edu.ar

Furthermore, we see you again in live virtual presentation:

> **Session date and time:** Monday, 7 December 2020; 20:30 - 21:30 PST
>
> **Session number and title:** C008: Remote Sensing of the Cryosphere: Seasonal Snow II

Las Cuevas, Mendoza, Argentina
August 2019