

# HYDROLOGICAL RESPONSE OF ANDEAN CATCHMENTS TO RECENT GLACIER MASS LOSS

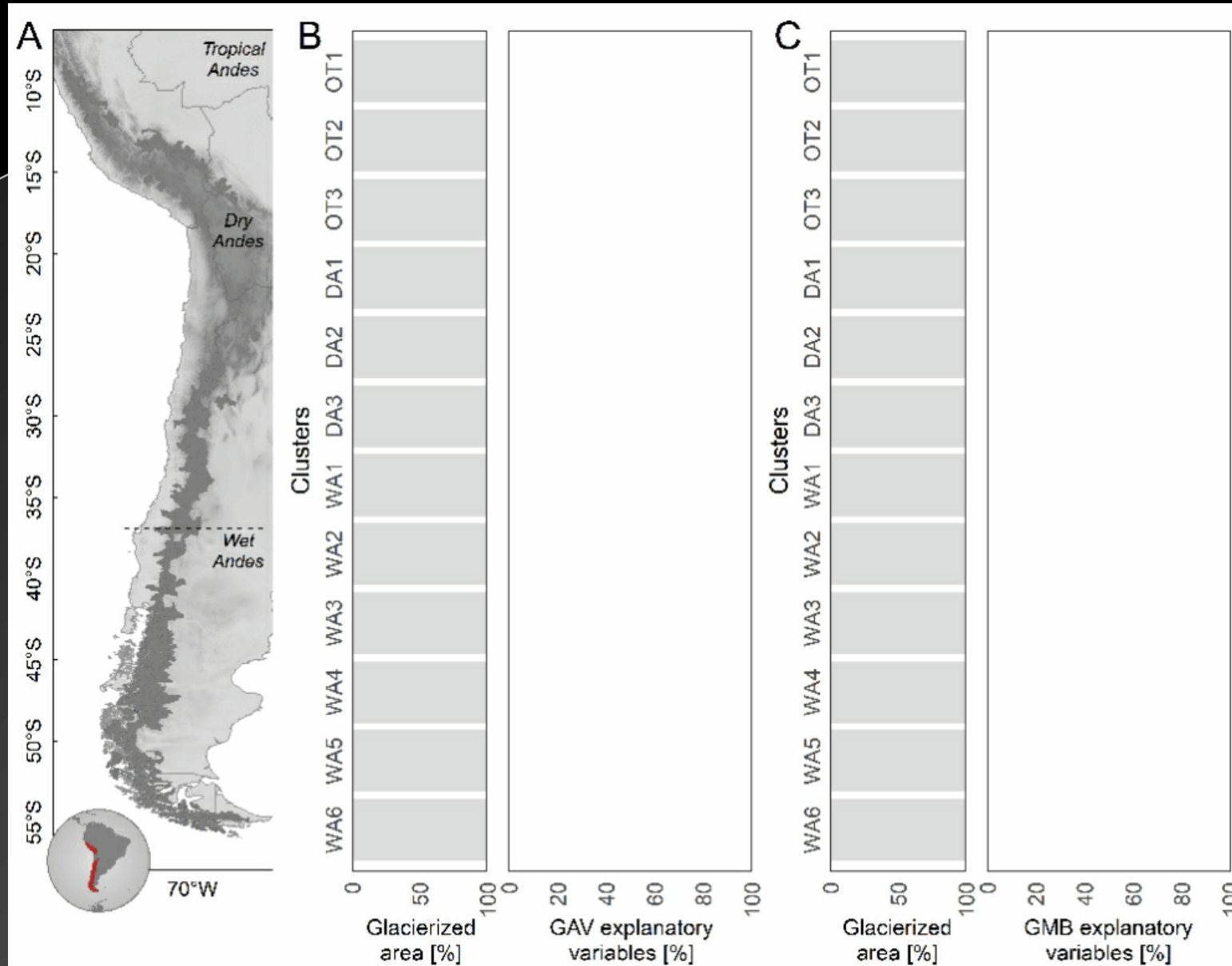
**Alexis Caro**<sup>1</sup>, Thomas Condom<sup>1</sup>, Antoine Rabatel<sup>1</sup>, Nicolas Champollion<sup>1</sup>, Nicolás García<sup>2</sup>

<sup>1</sup>Univ. Grenoble Alpes, CNRS, IRD, INRAE, Grenoble-INP, Institut des Géosciences de l'Environnement, Grenoble, France

<sup>2</sup>Glaciología y Cambio Climático, Centro de Estudios Científicos (CECs), Valdivia, Chile

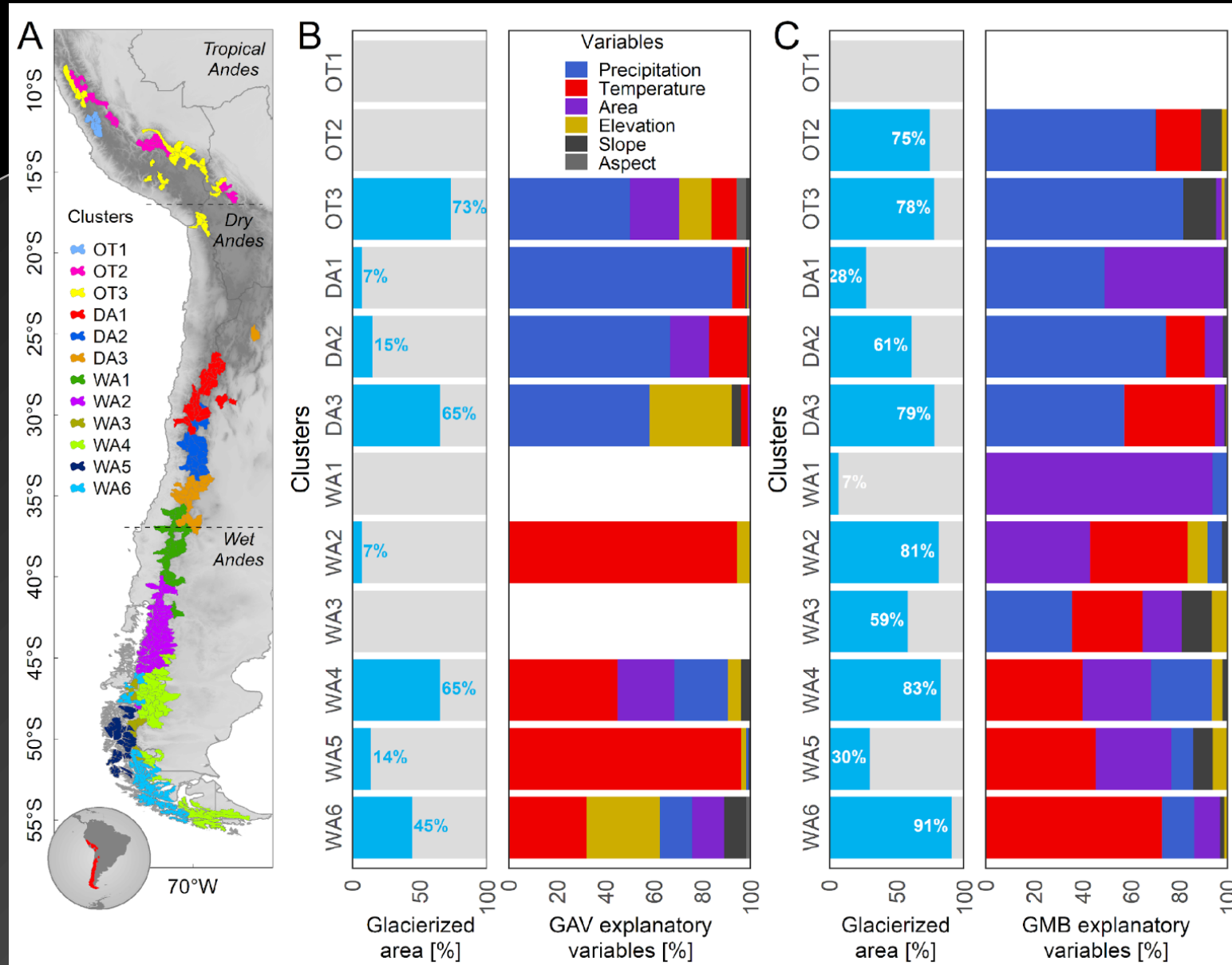


# Zonas glaciológicas asociadas al cambio glaciar reciente



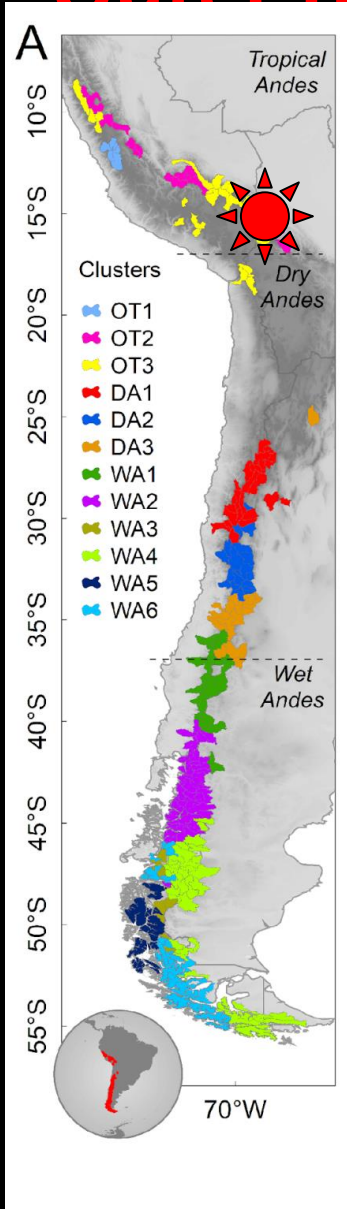
Caro A, Condom T and Rabatel A (2021) Climatic and Morphometric Explanatory Variables of Glacier Changes in the Andes (8–55°S). *Front. Earth Sci.*

# Zonas glaciológicas asociadas al cambio glaciar reciente



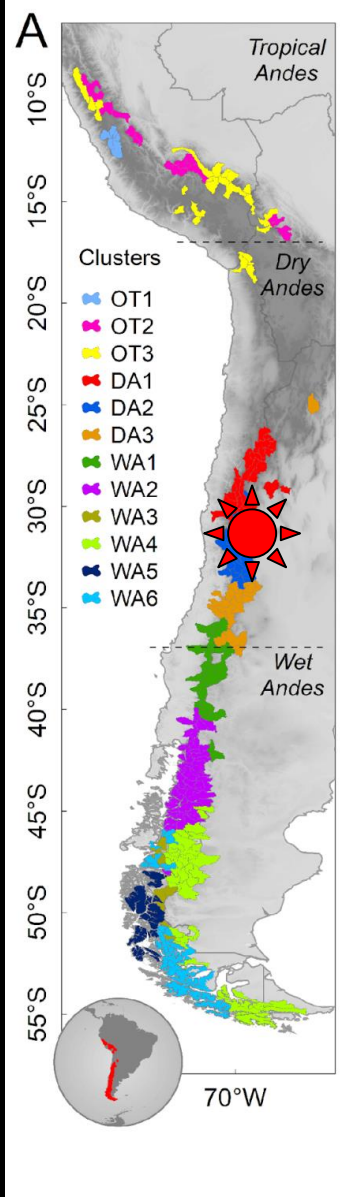
Caro A, Condom T and Rabatel A (2021) Climatic and Morphometric Explanatory Variables of Glacier Changes in the Andes (8–55°S). *Front. Earth Sci.*

# Outer tropics: Charquini Sur (16°S)



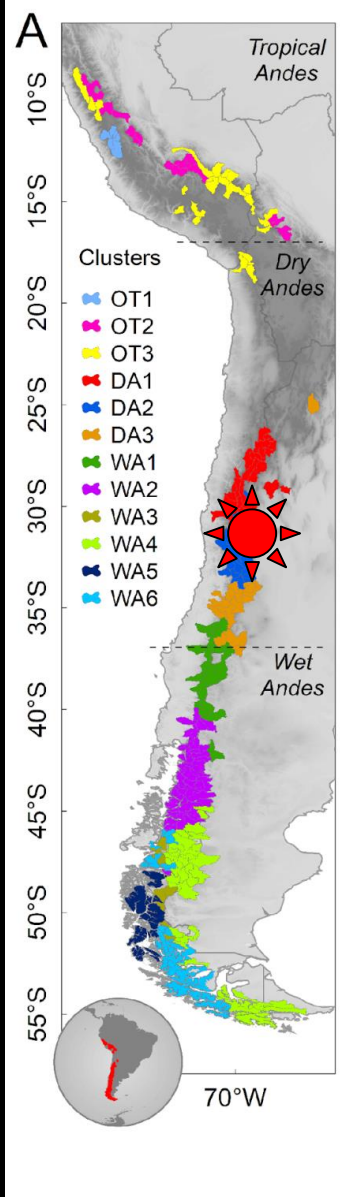
2016: Alexis Caro

# Dry Andes: Pirámide glacier (33°S)



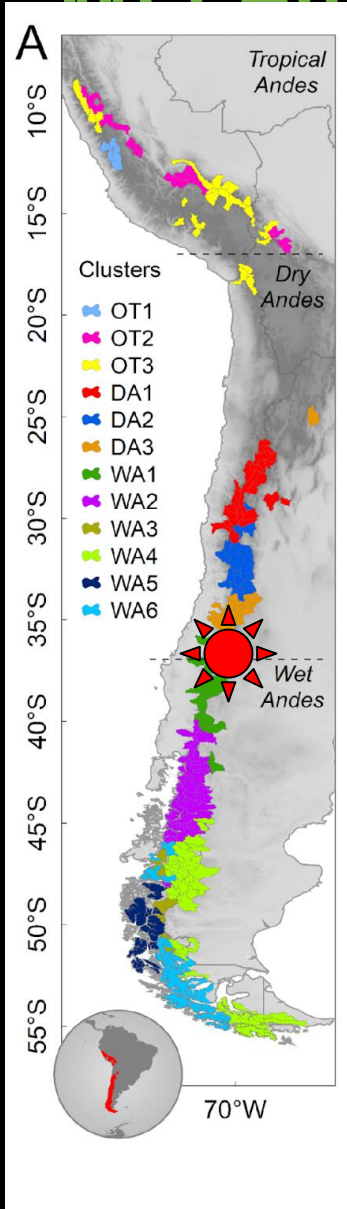
2018: Alexis Caro

# Dry Andes: Universidad glacier (34°S)



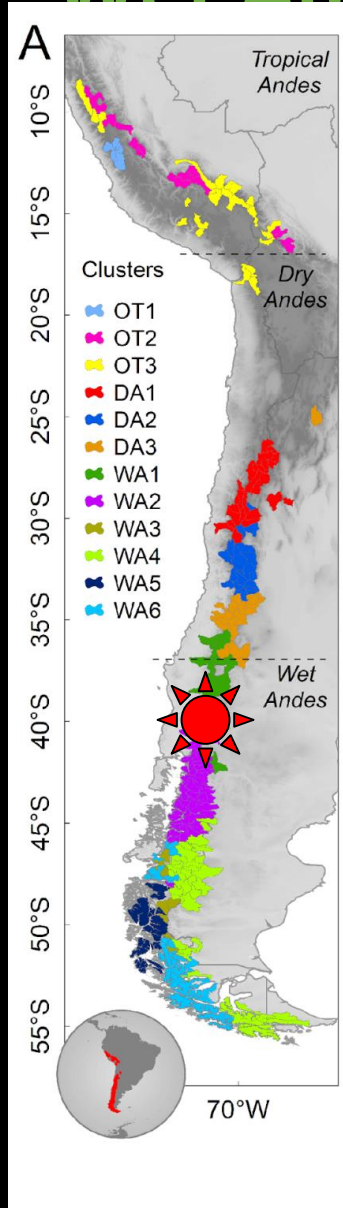
2018: Alfonso Fernández

# Wet Andes: Nevados de Chillán (37°S)



2012: Sergio Correa

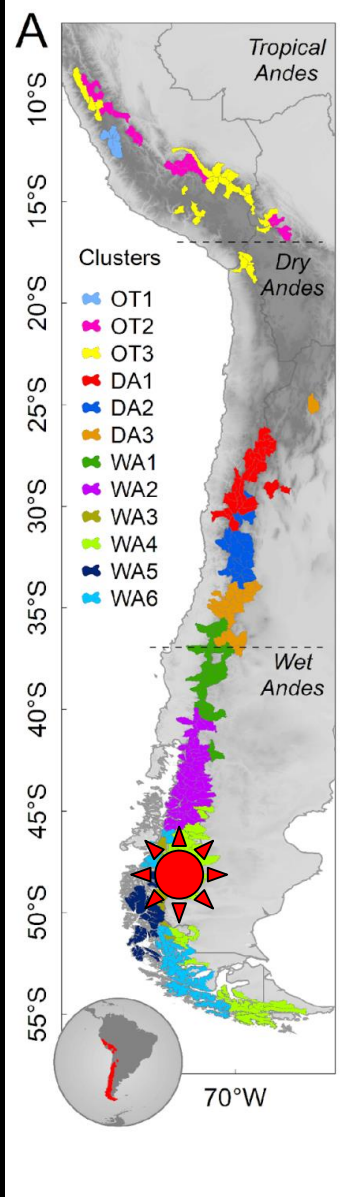
# Wet Andes: Mocho-choshuenco (40°S)



2013: Alexis Caro



# Wet Andes: Jorge Montt glacier (48°S)



2013: Francisca Bown

# Escorrentía glaciar

ej. Cuenca río Yeso (33°S)



# Escorrentía glaciar

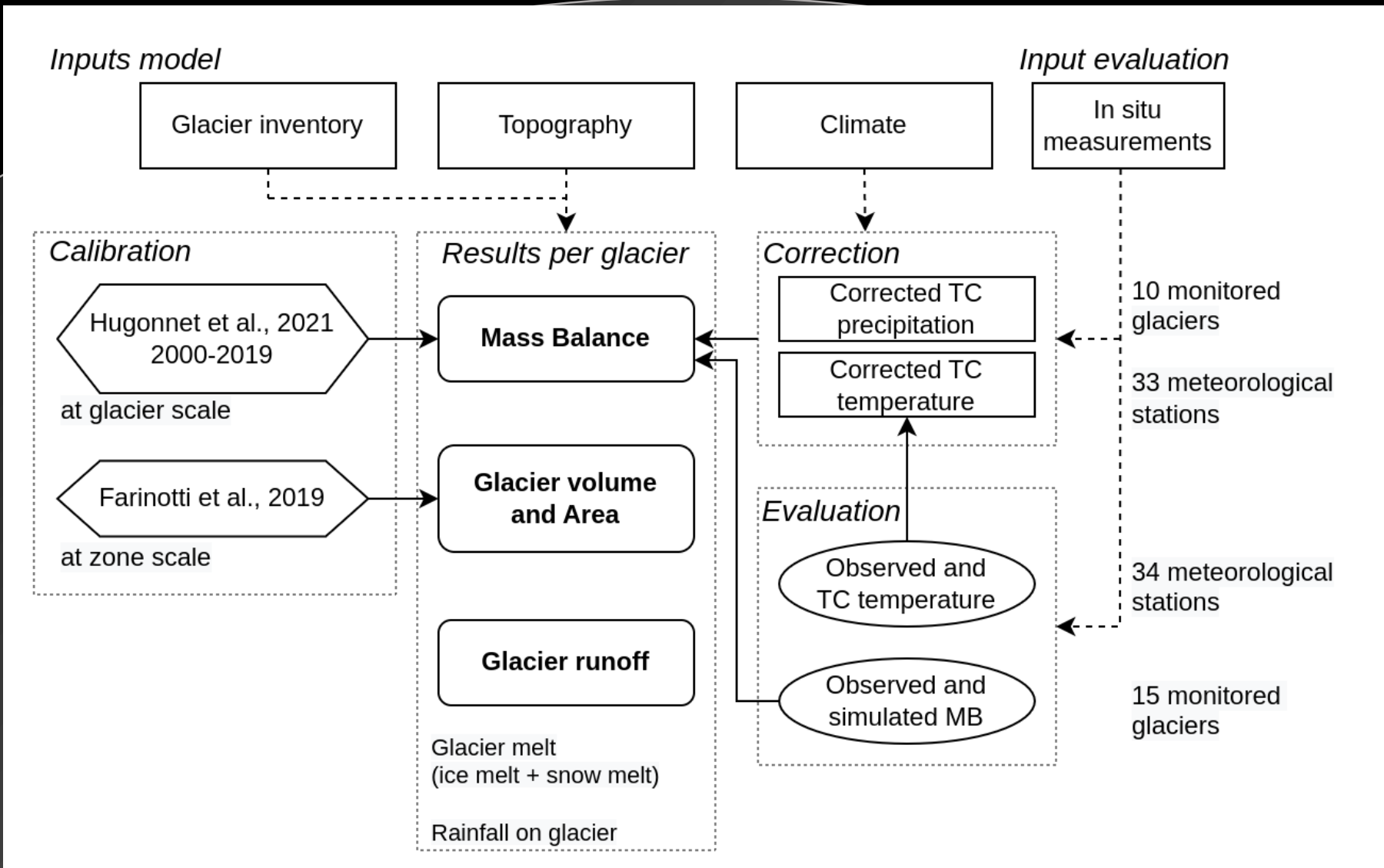
ej. Embalse El Yeso (33°S)



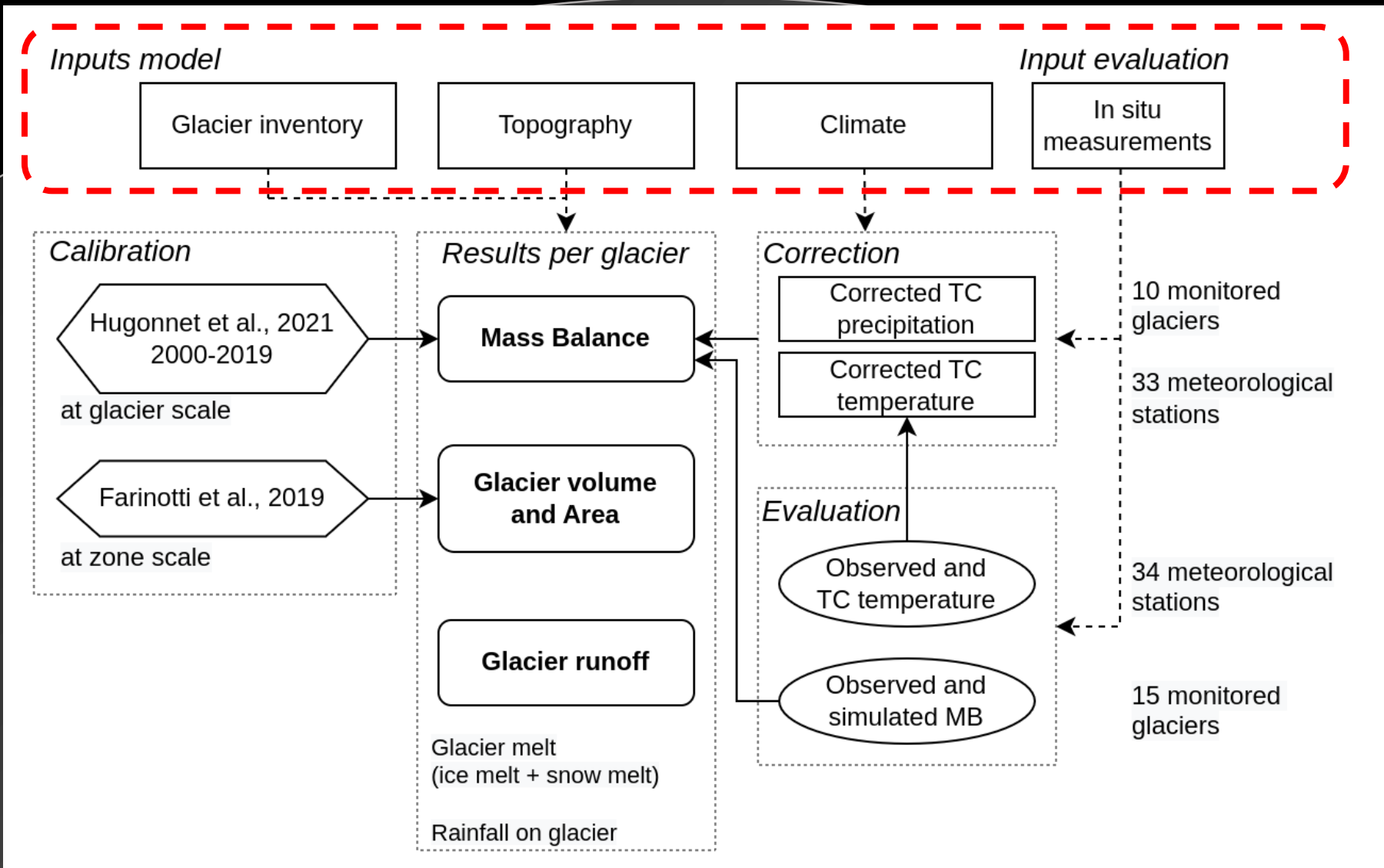
Echaurren Norte glacier

Bello, Yeso and  
Piramide glaciers

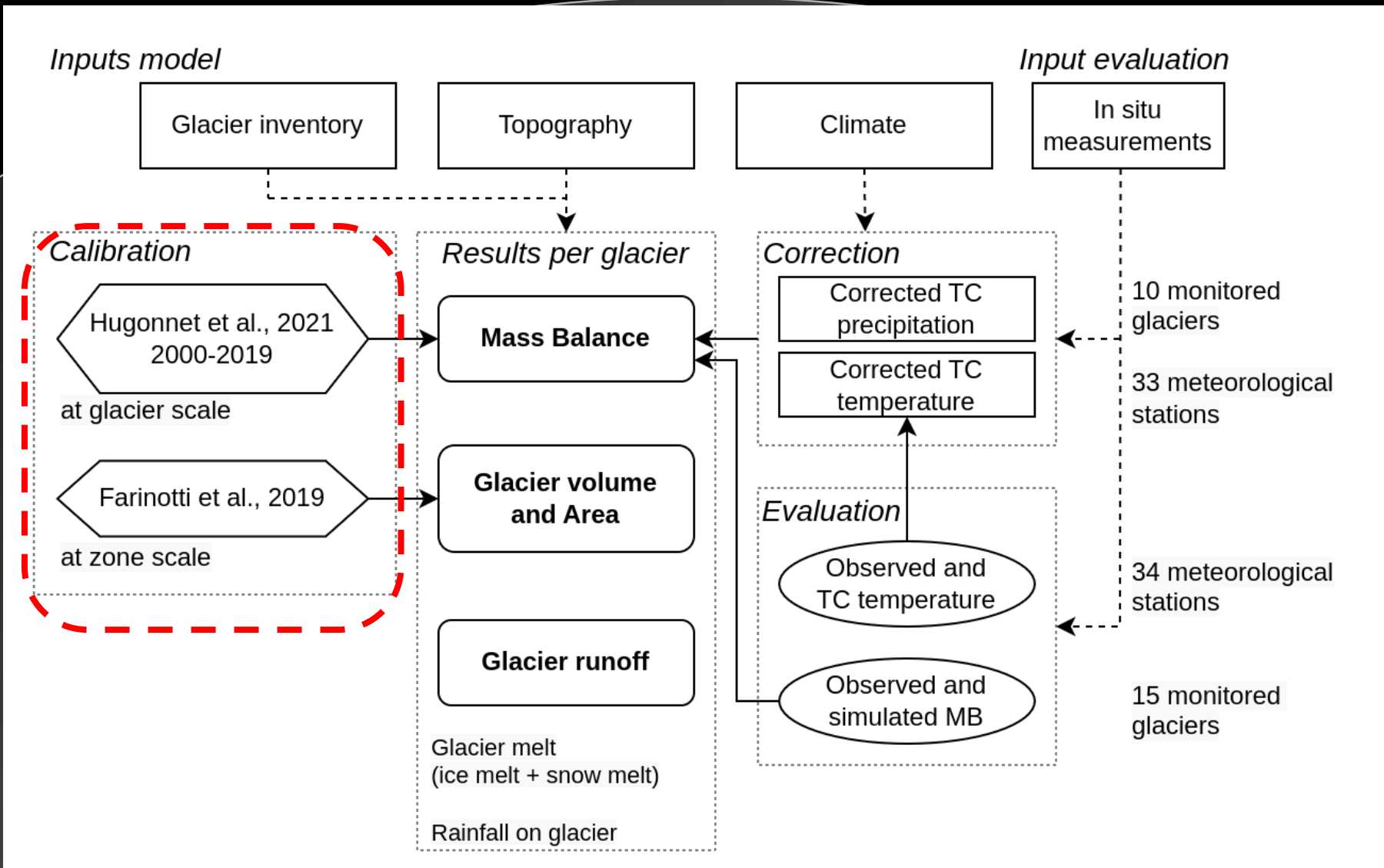
# Workflow



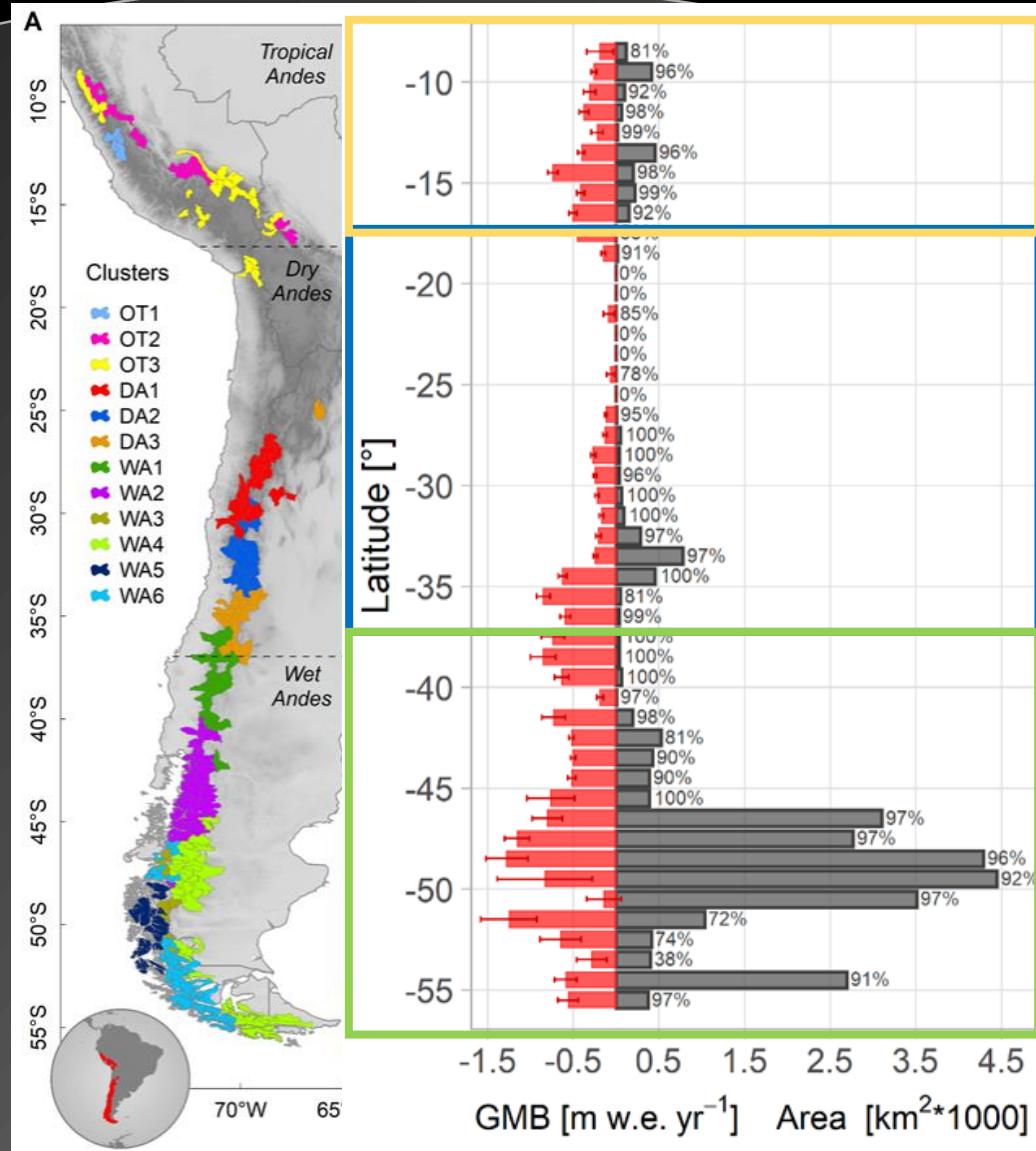
# Workflow



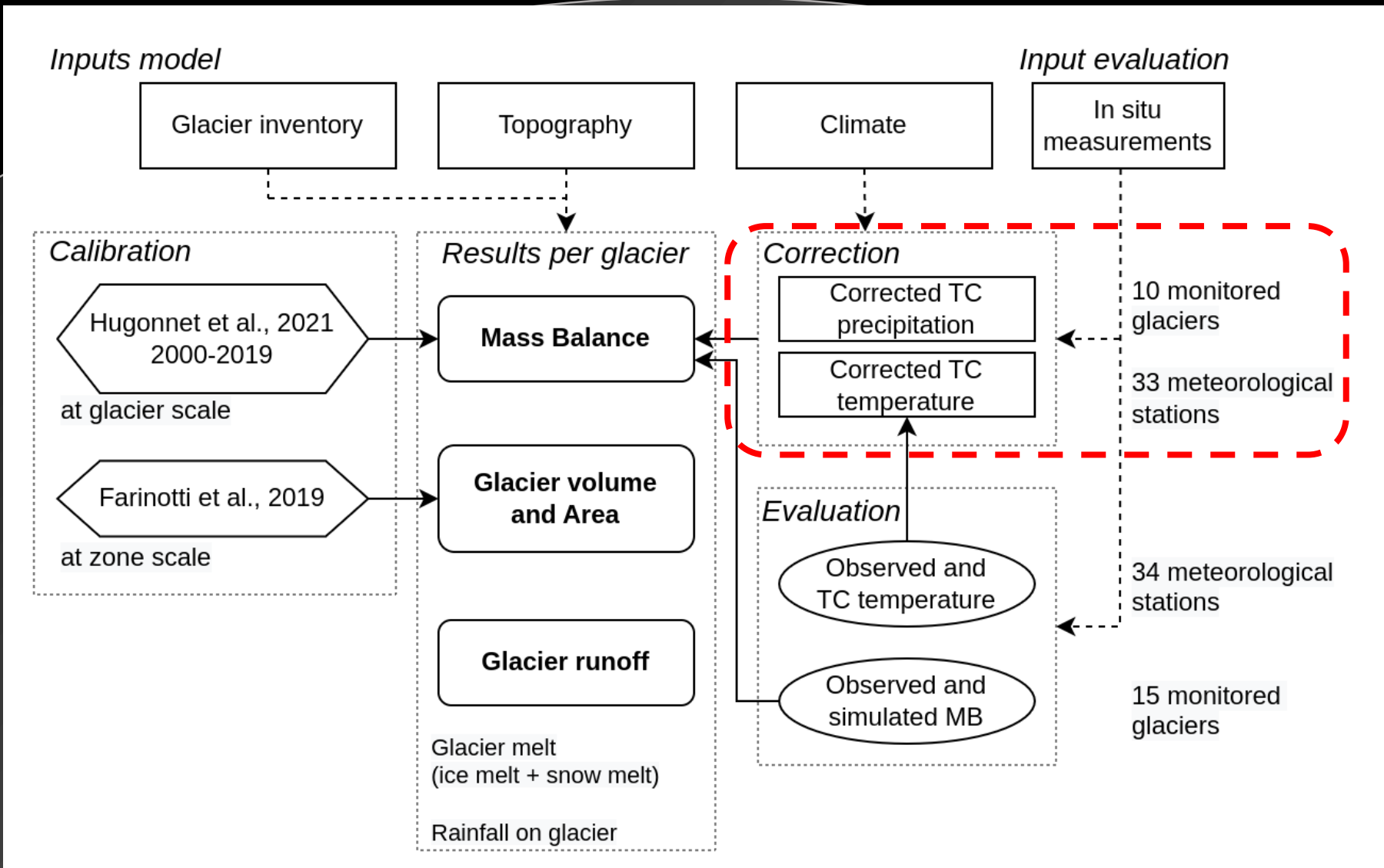
# Workflow



# Calibration: Geodetic mass balance (2000-2019)

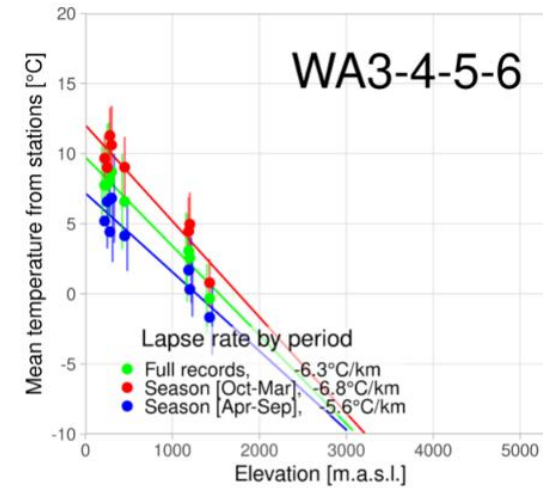
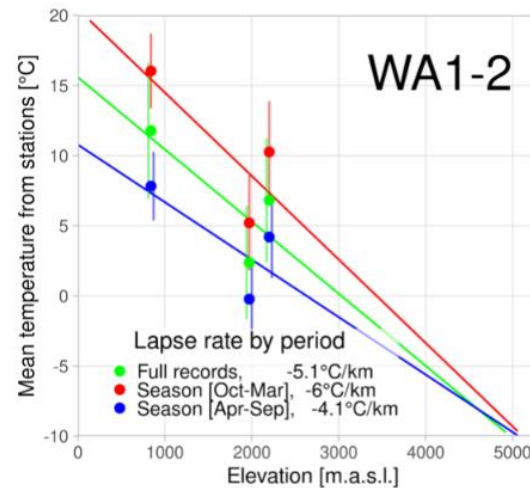
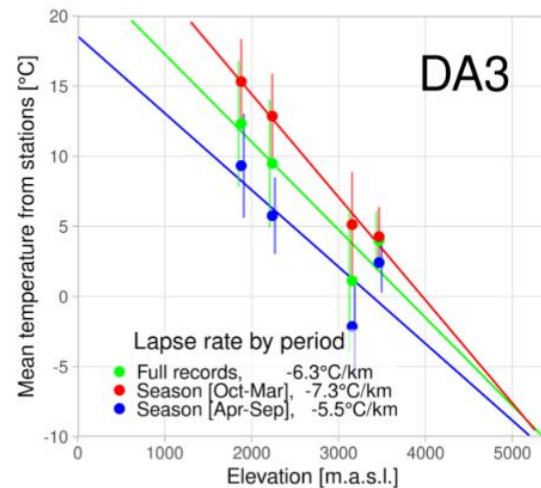
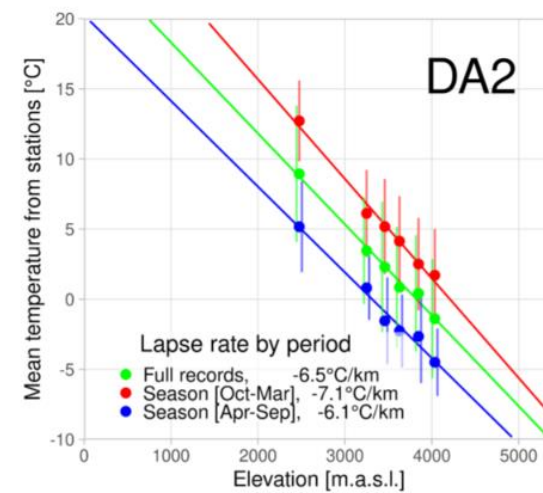
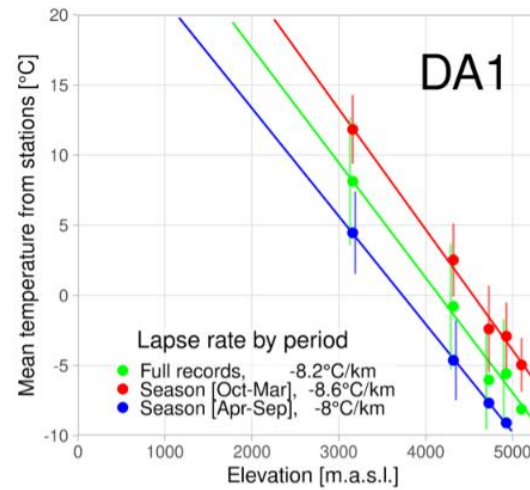
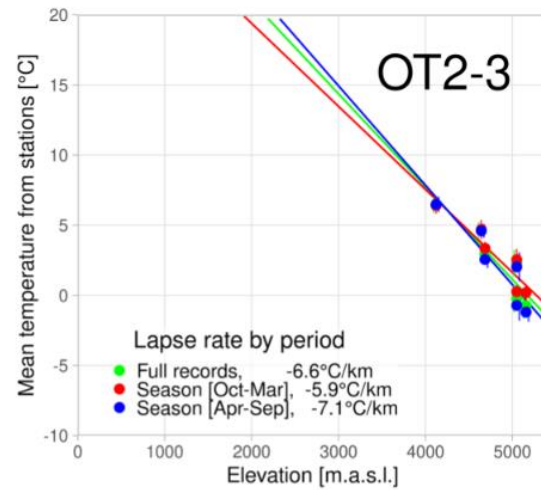


# Workflow

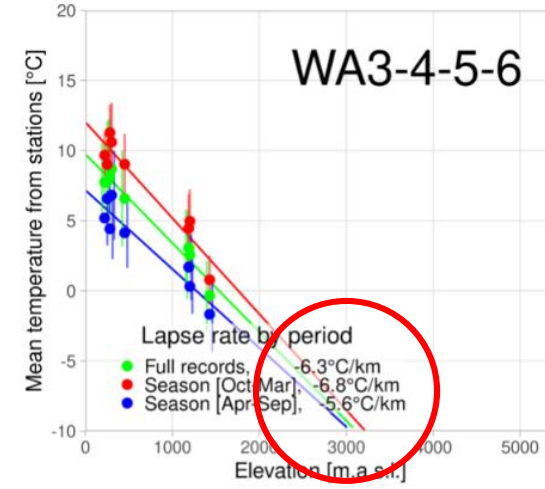
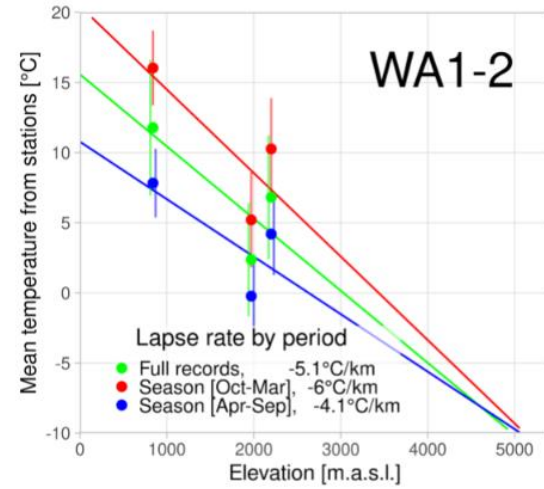
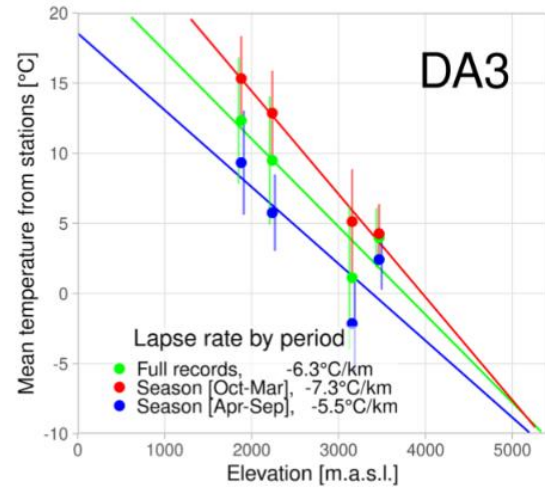
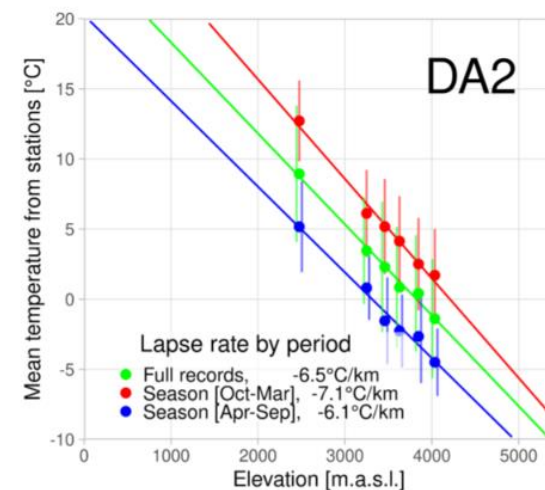
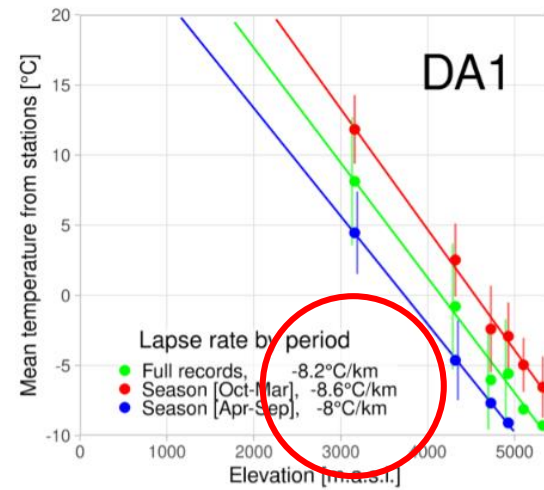
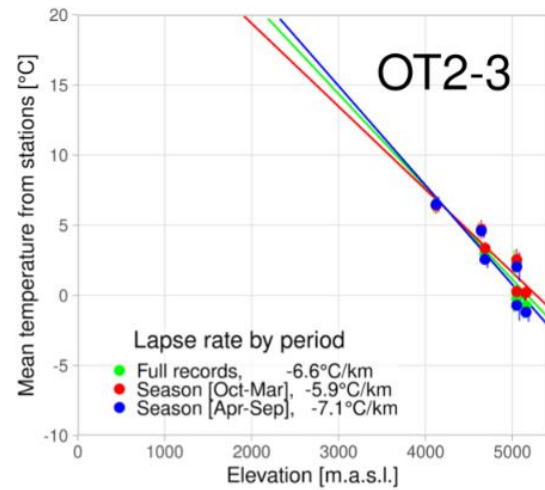




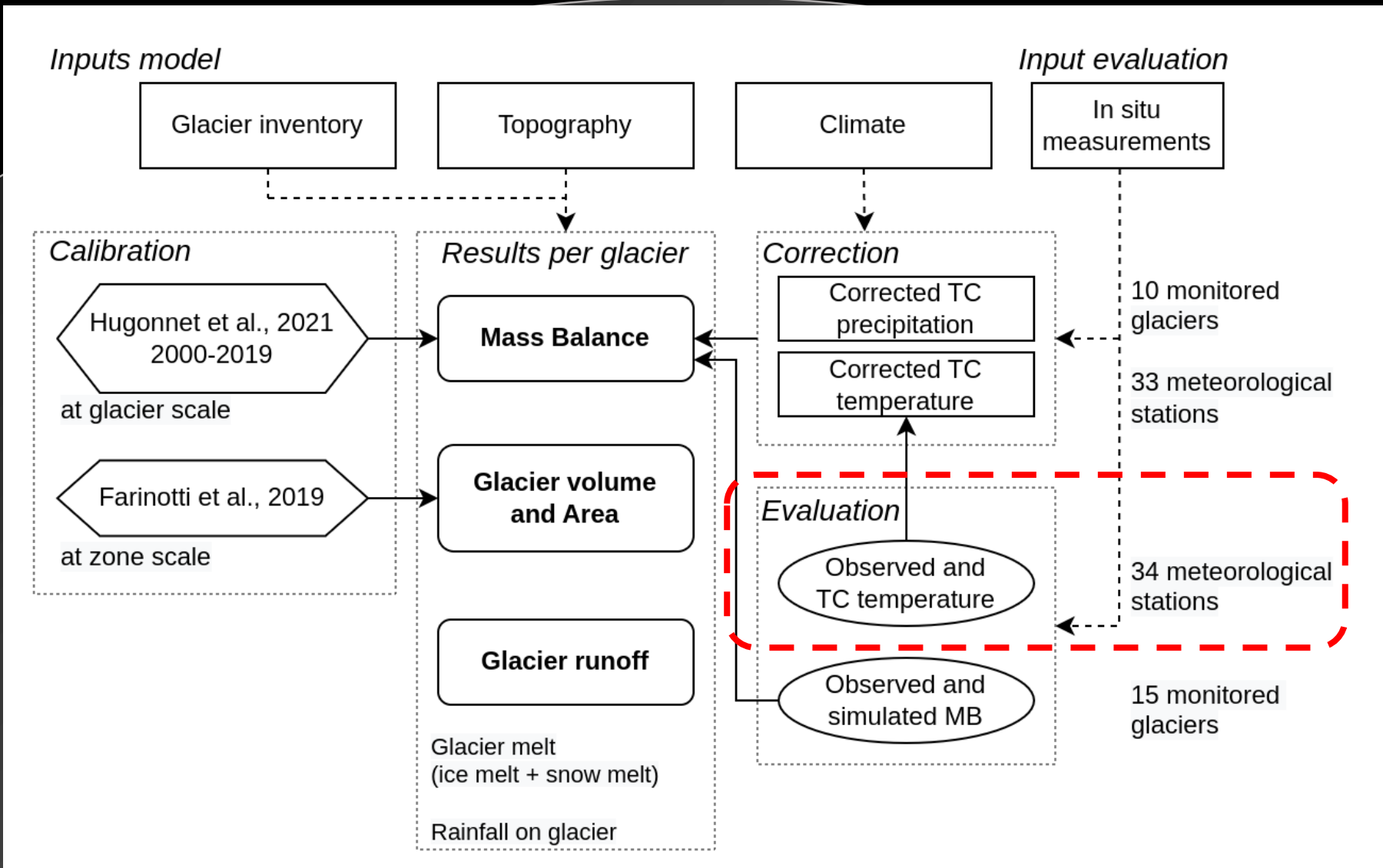
# Temperature correction: Temperature lapse rates



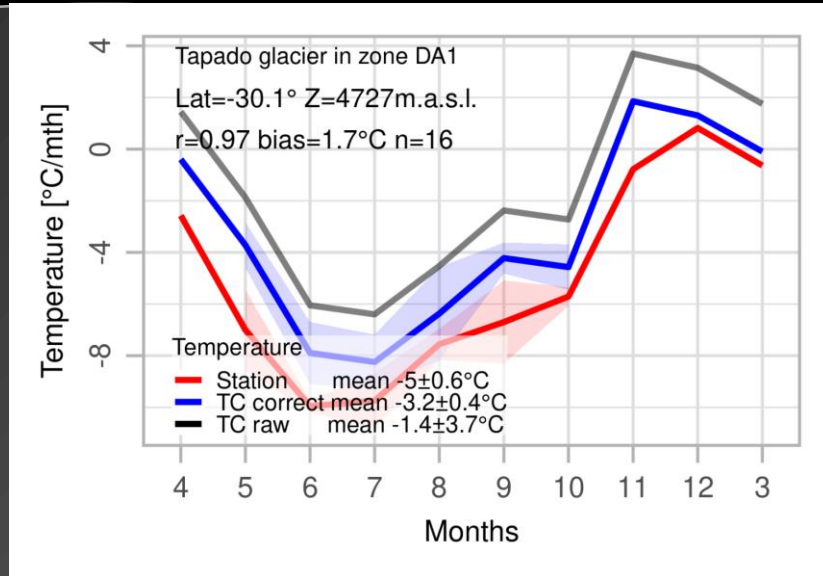
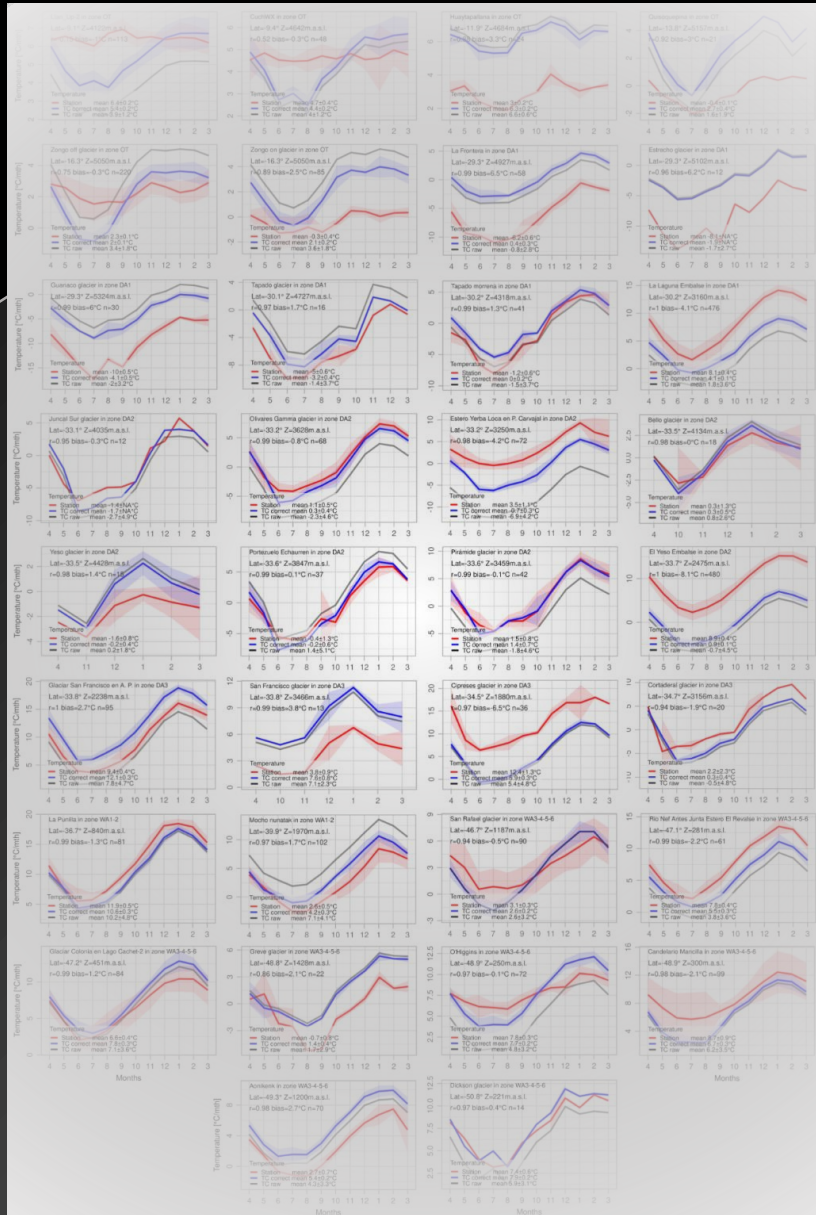
# Temperature correction: Temperature lapse rates



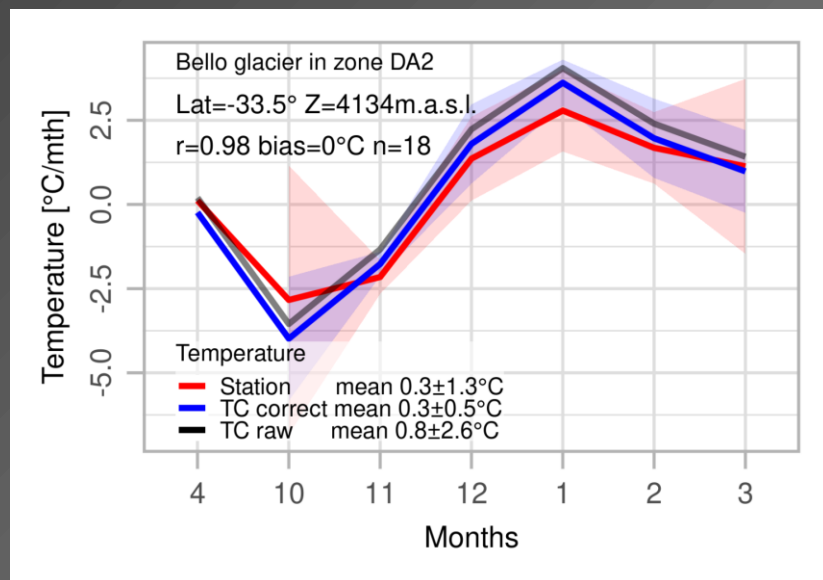
# Workflow



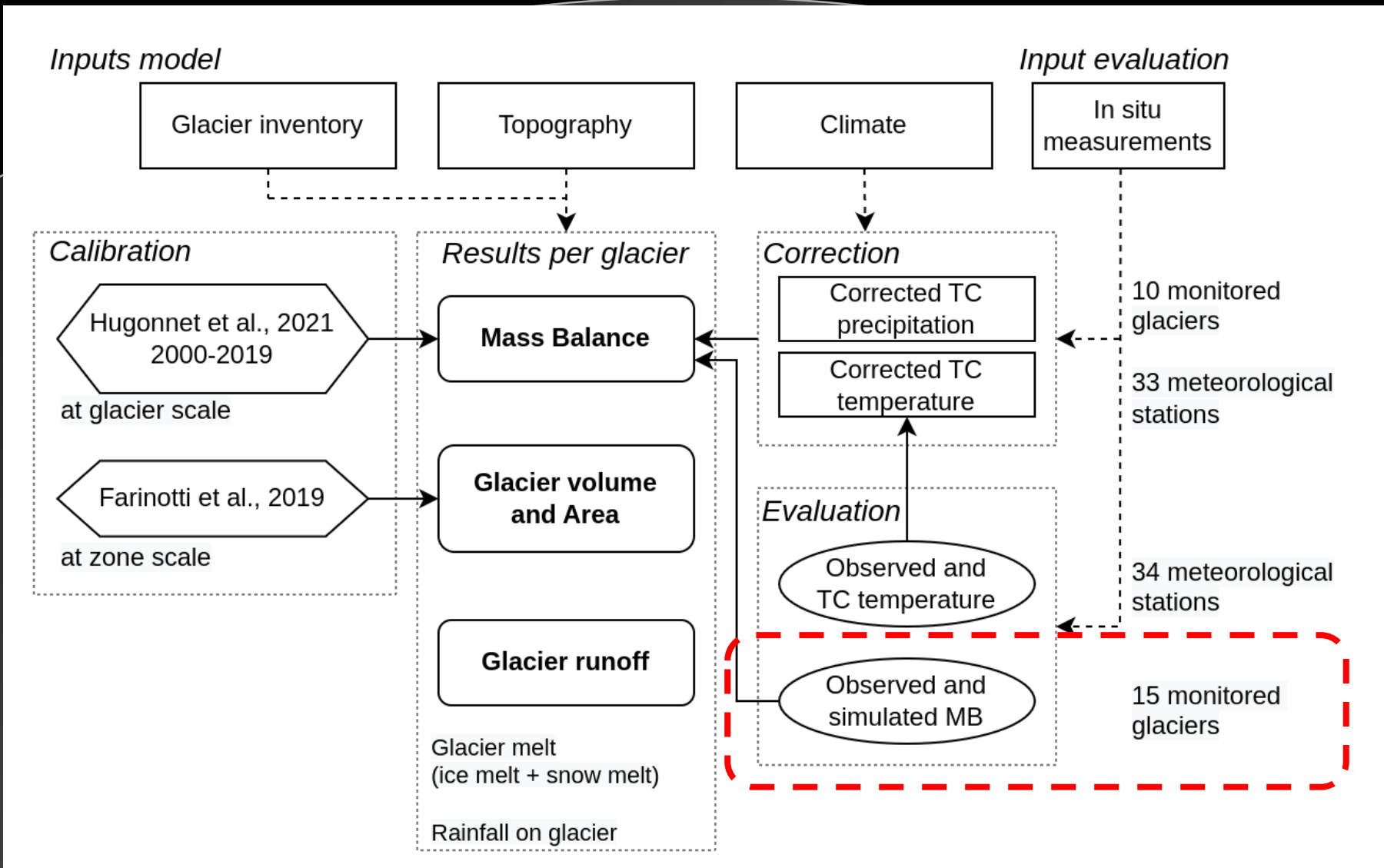
# Temperature evaluation: Dry Andes



bias = 0.2°C

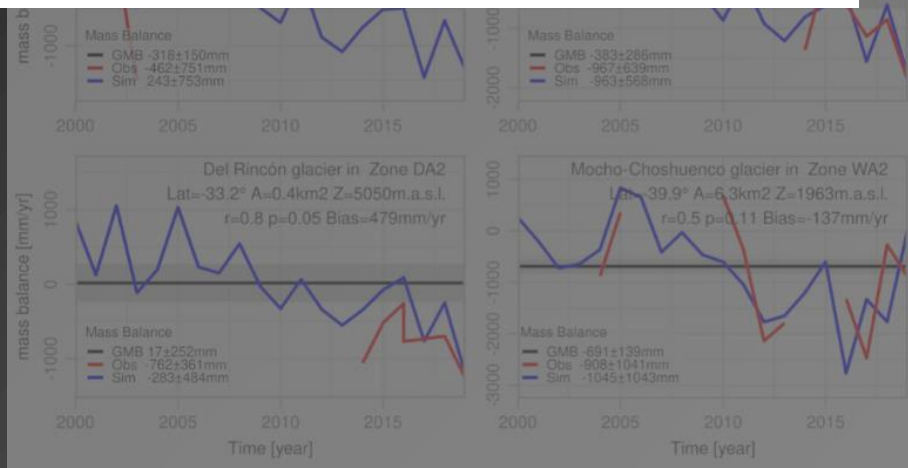
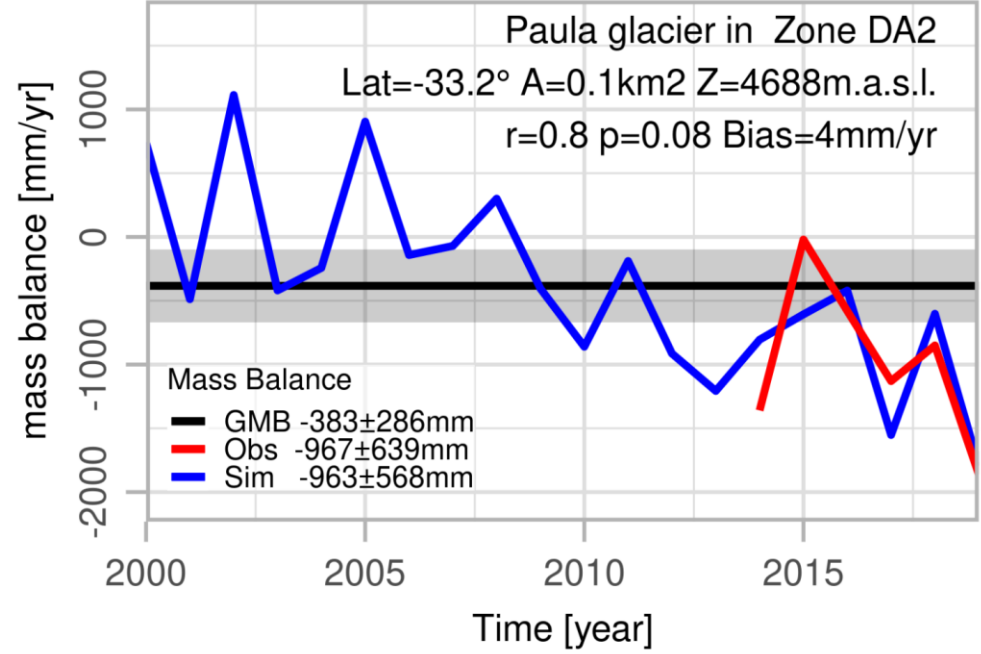
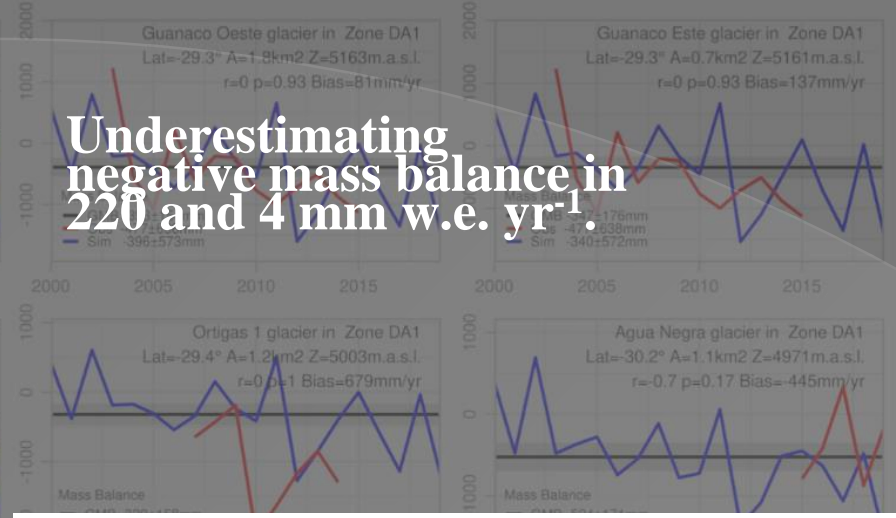
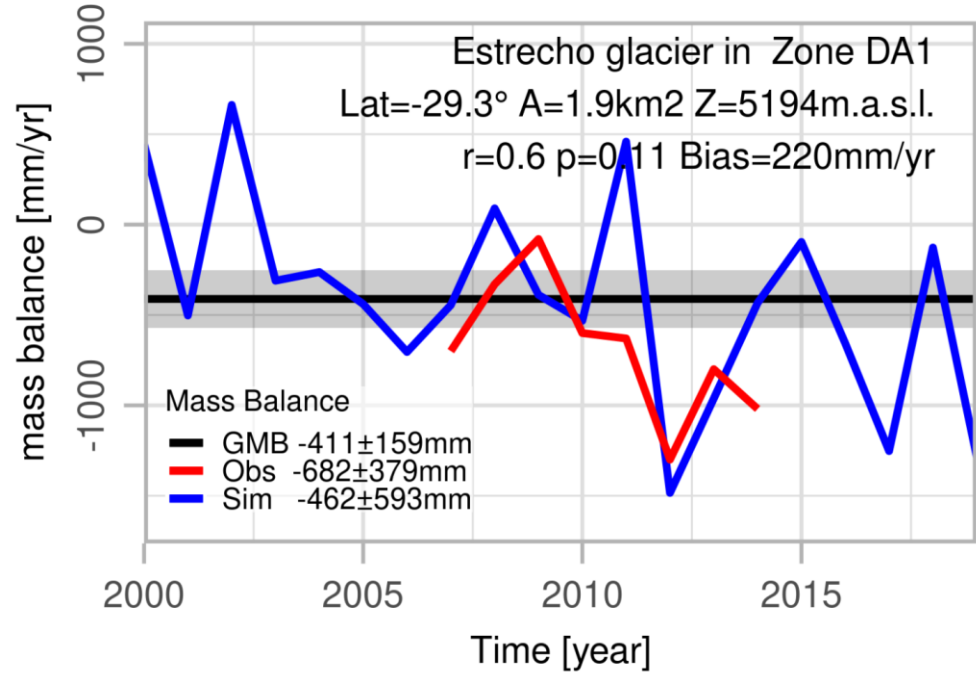


# Workflow

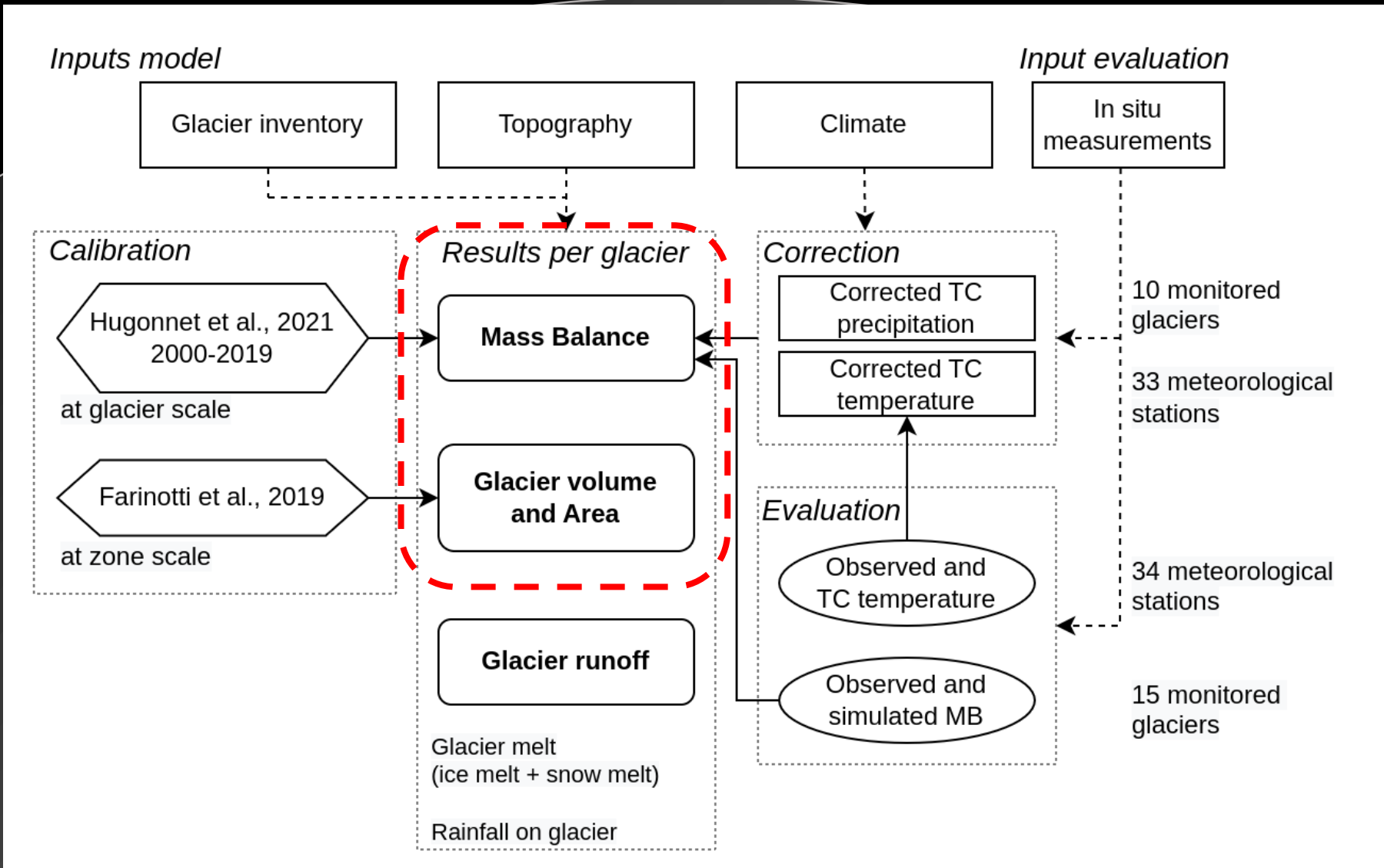


# Simulated mass balance evaluation: Dry Andes

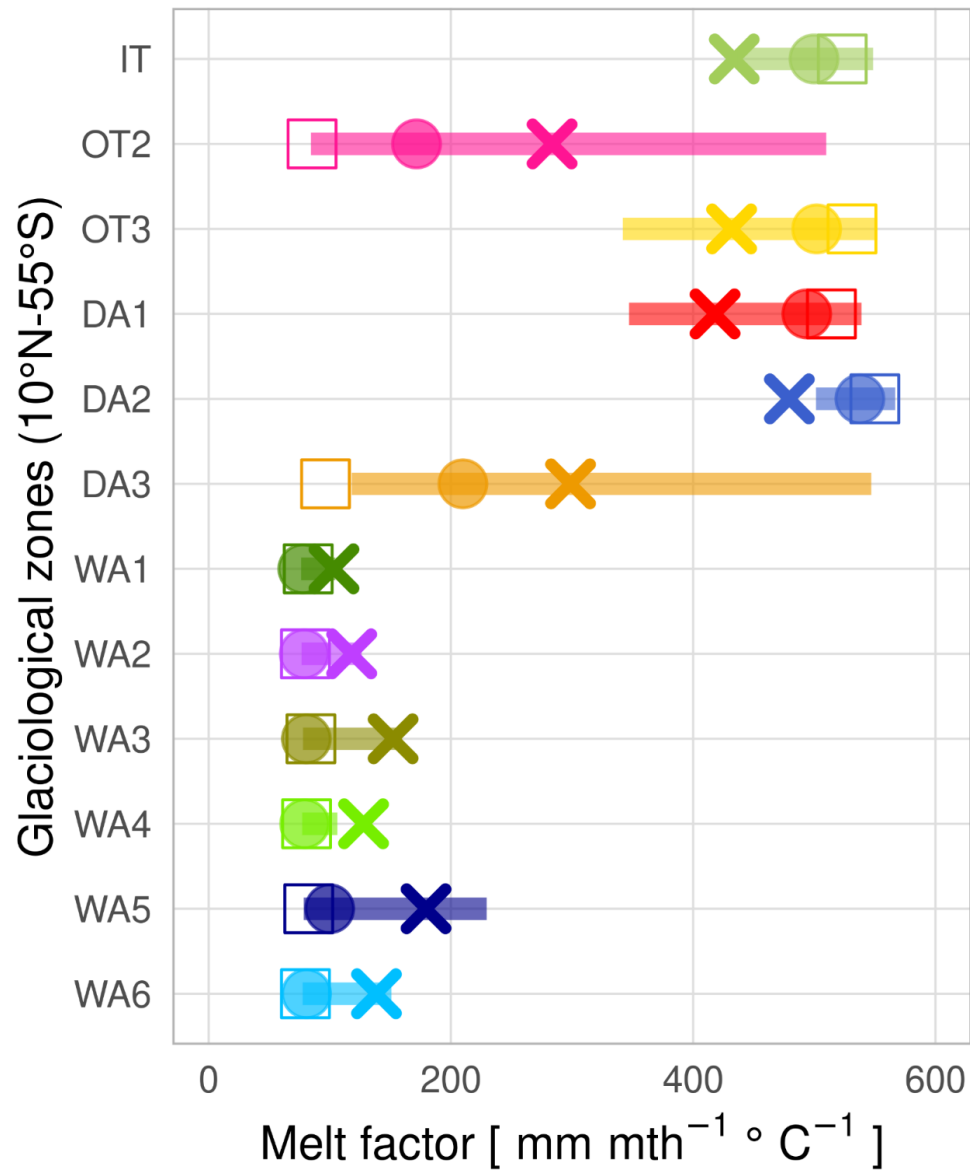
Underestimating negative mass balance in 220 and 4 mm w.e. yr<sup>-1</sup>.



# Workflow

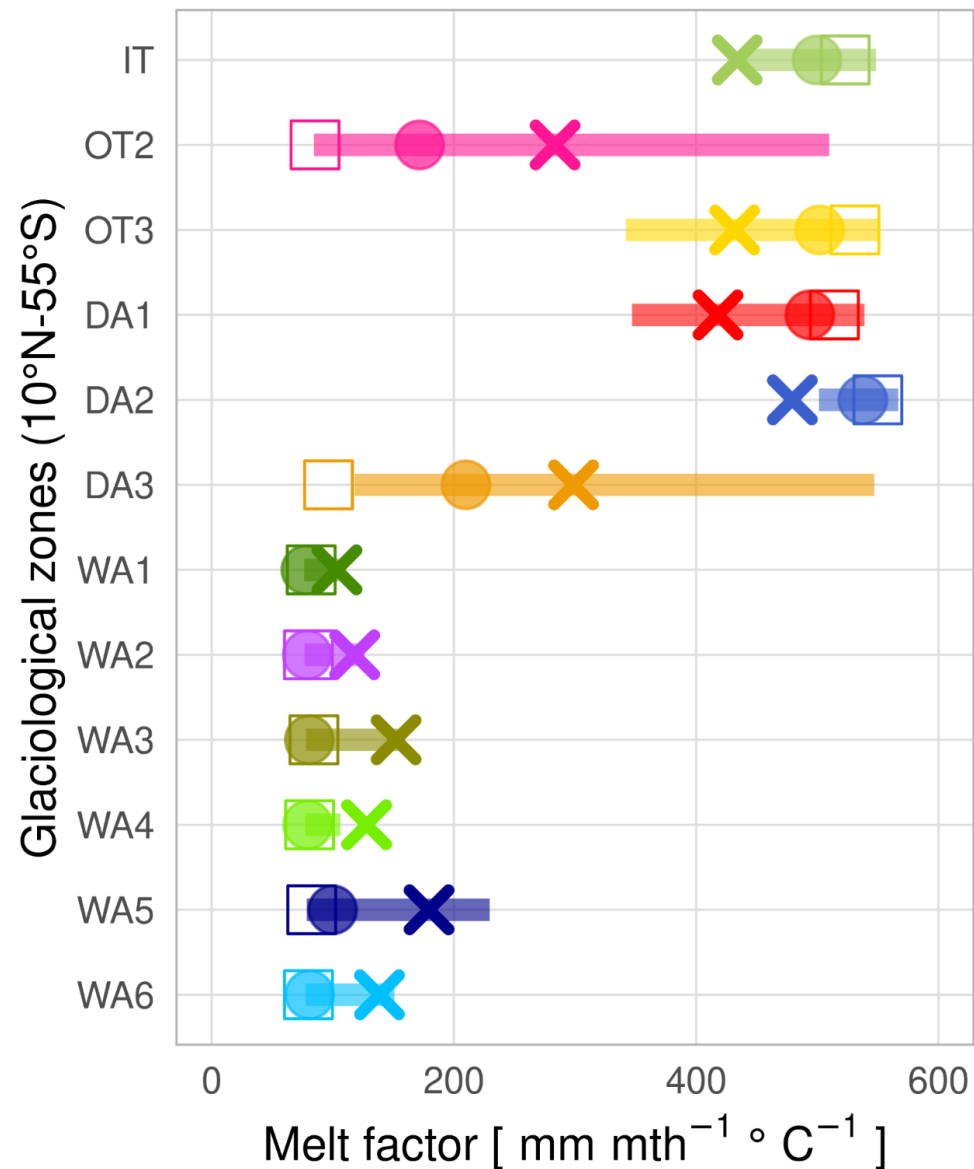


# Melt factors by glaciological zones





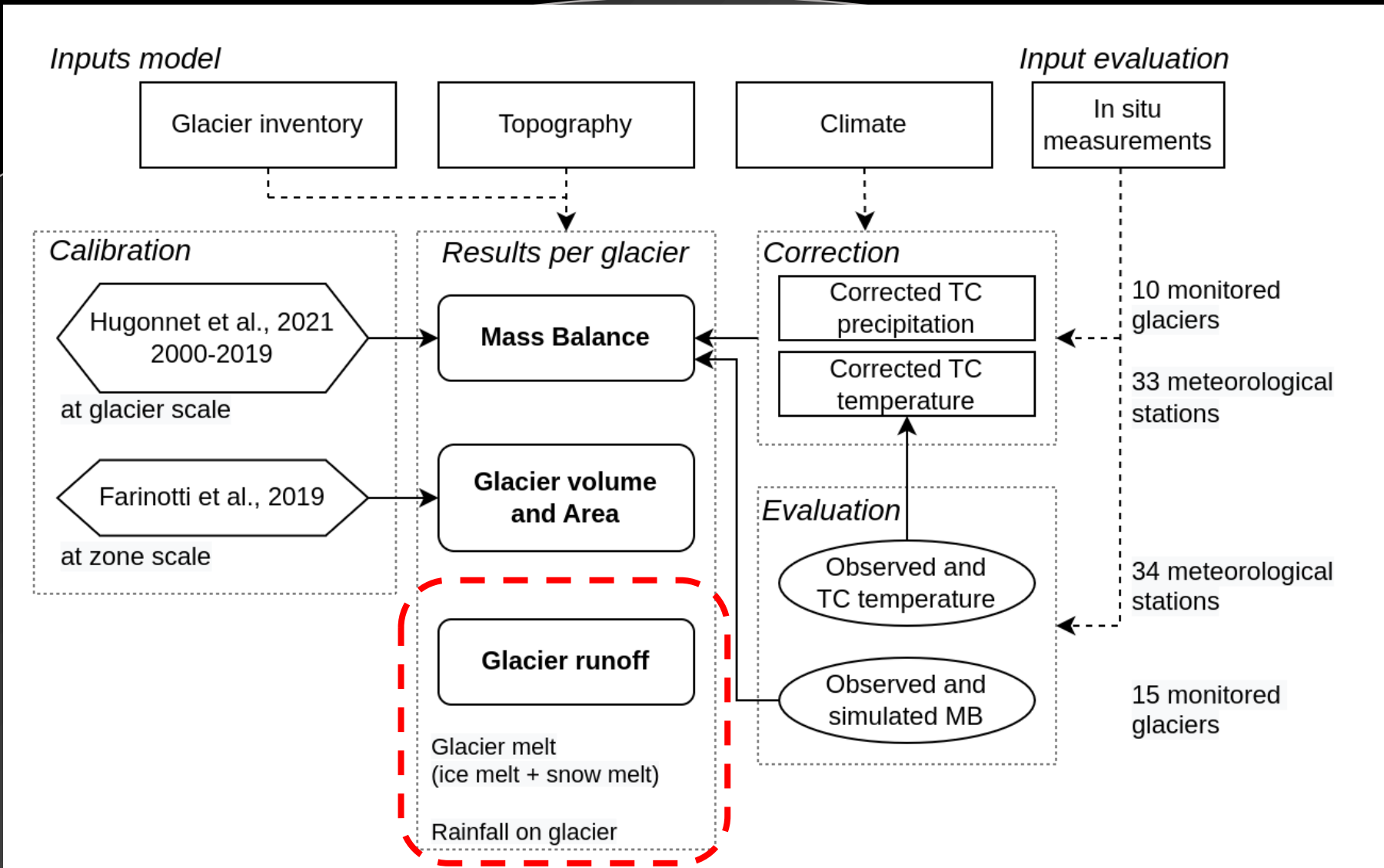
# Melt factors by glaciological zones



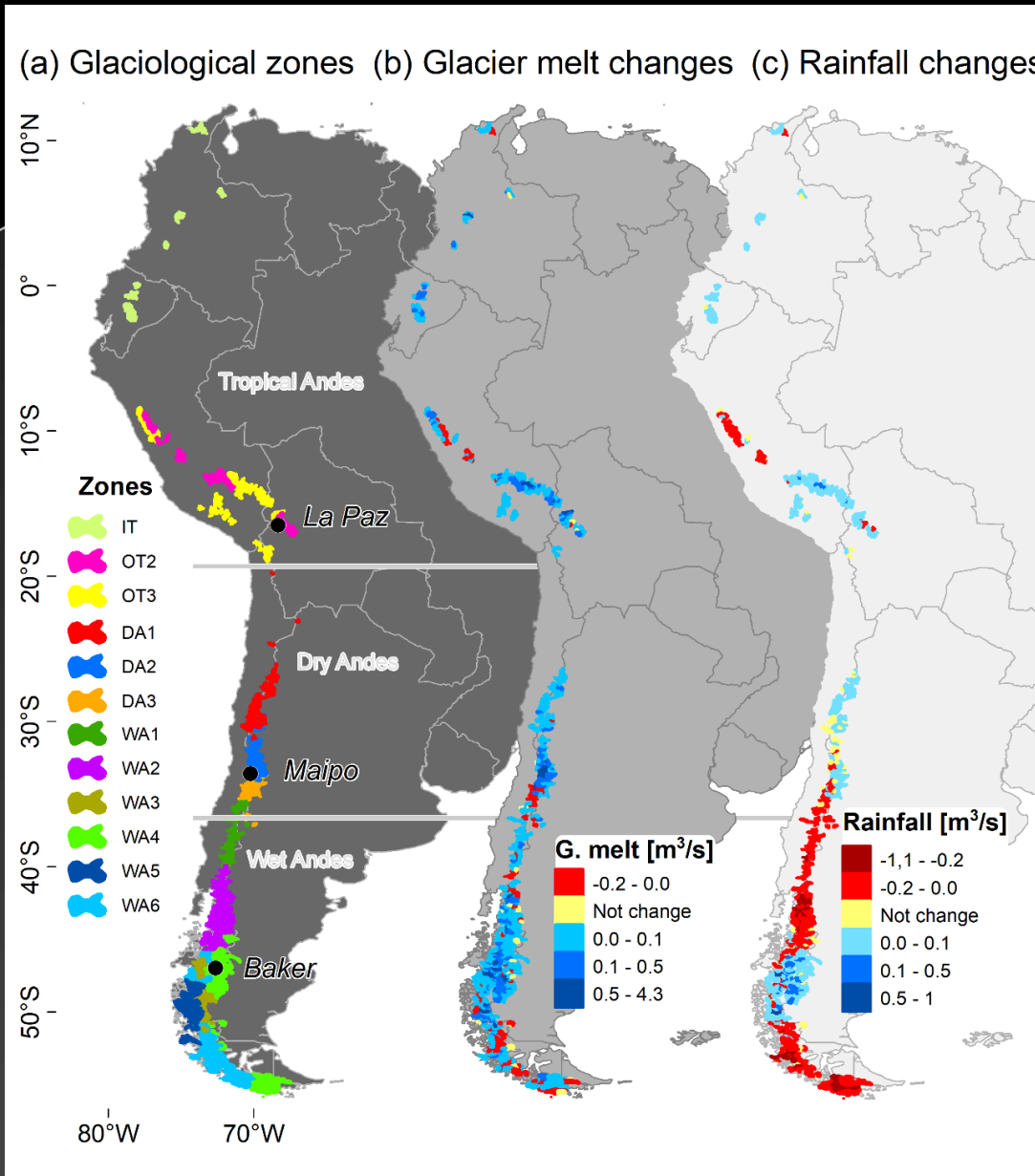
What does it mean?

- N° of months with  $T_{air} > T_{melt}$
- $T_{melt}$  value
- Climate dataset
- Mass balance calibration

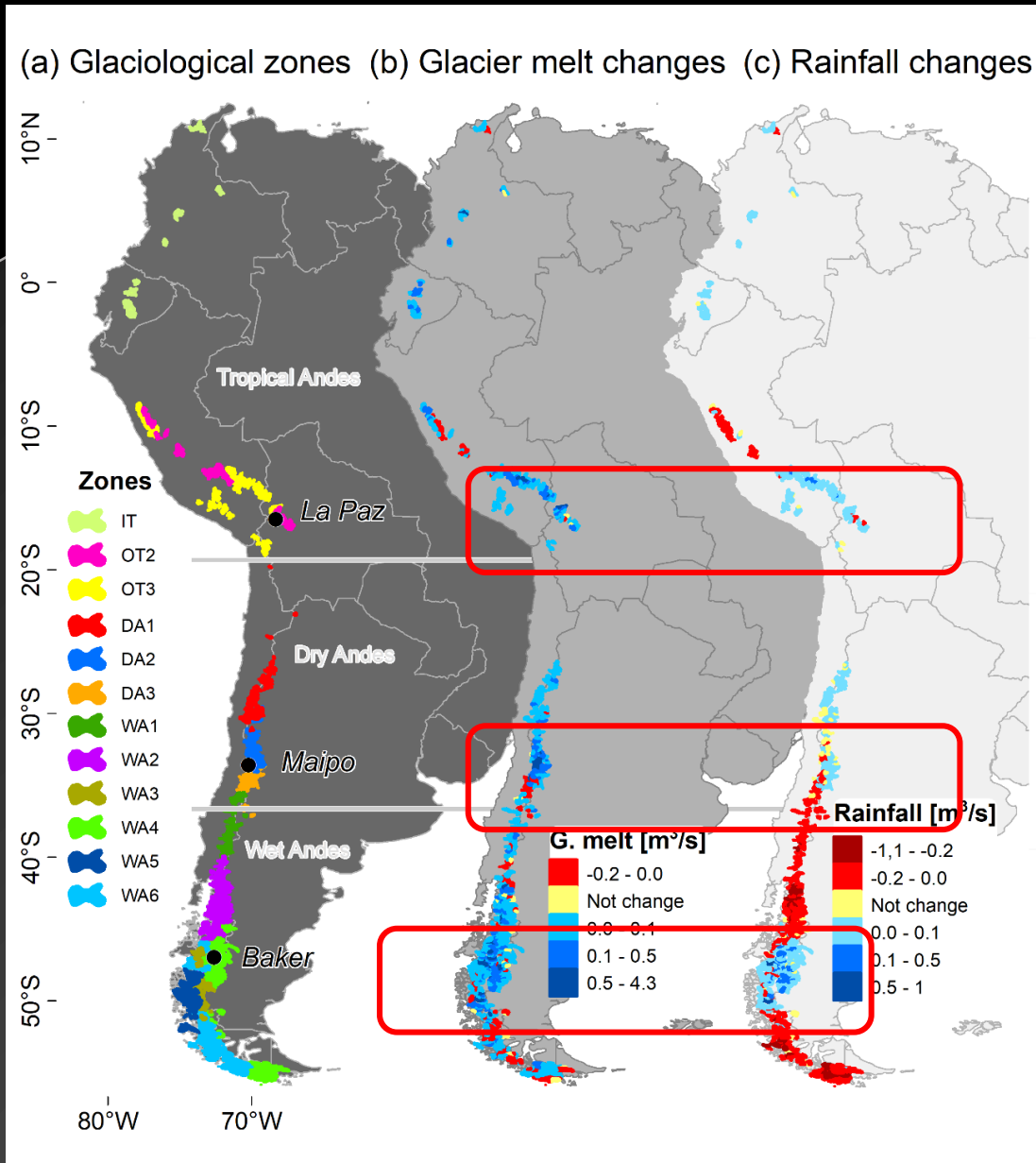
# Workflow



# Glacier runoff change between periodos 2000-2009 and 2010-2019



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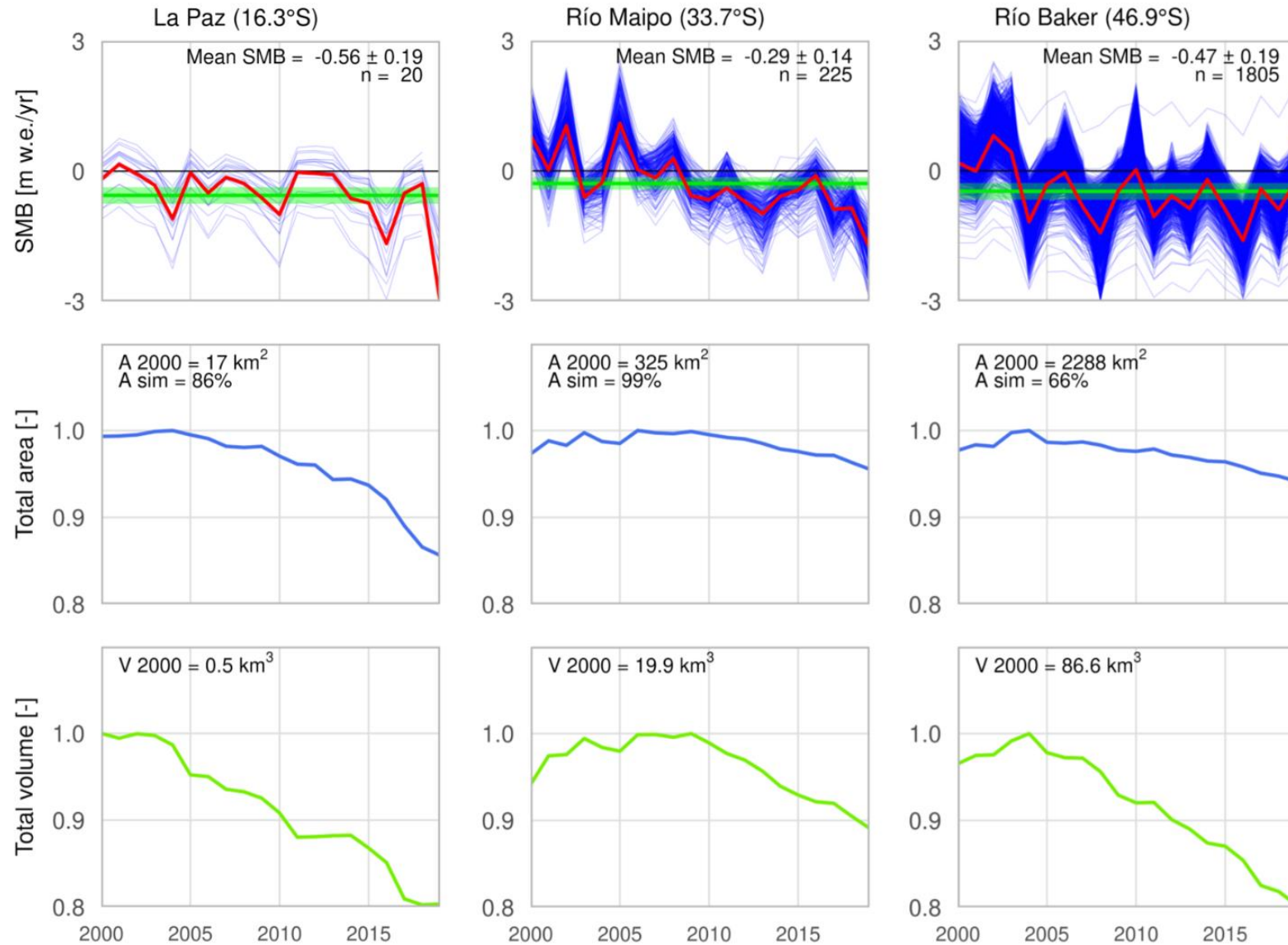


In 768 catchments

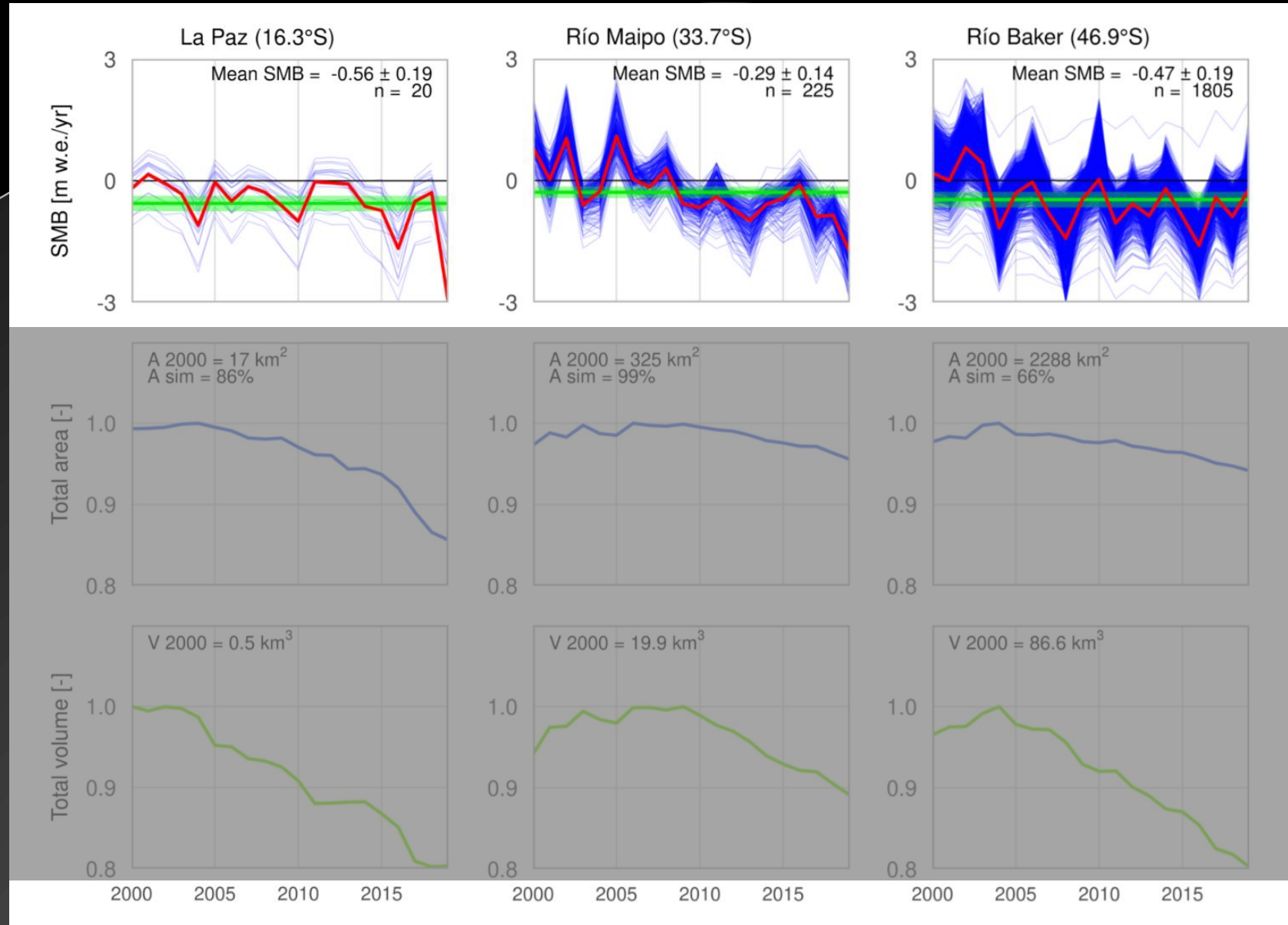
Glacier melt changes  
+12% in 84% of catchments

Rainfall on glaciers  
-2% in 41% of catchments

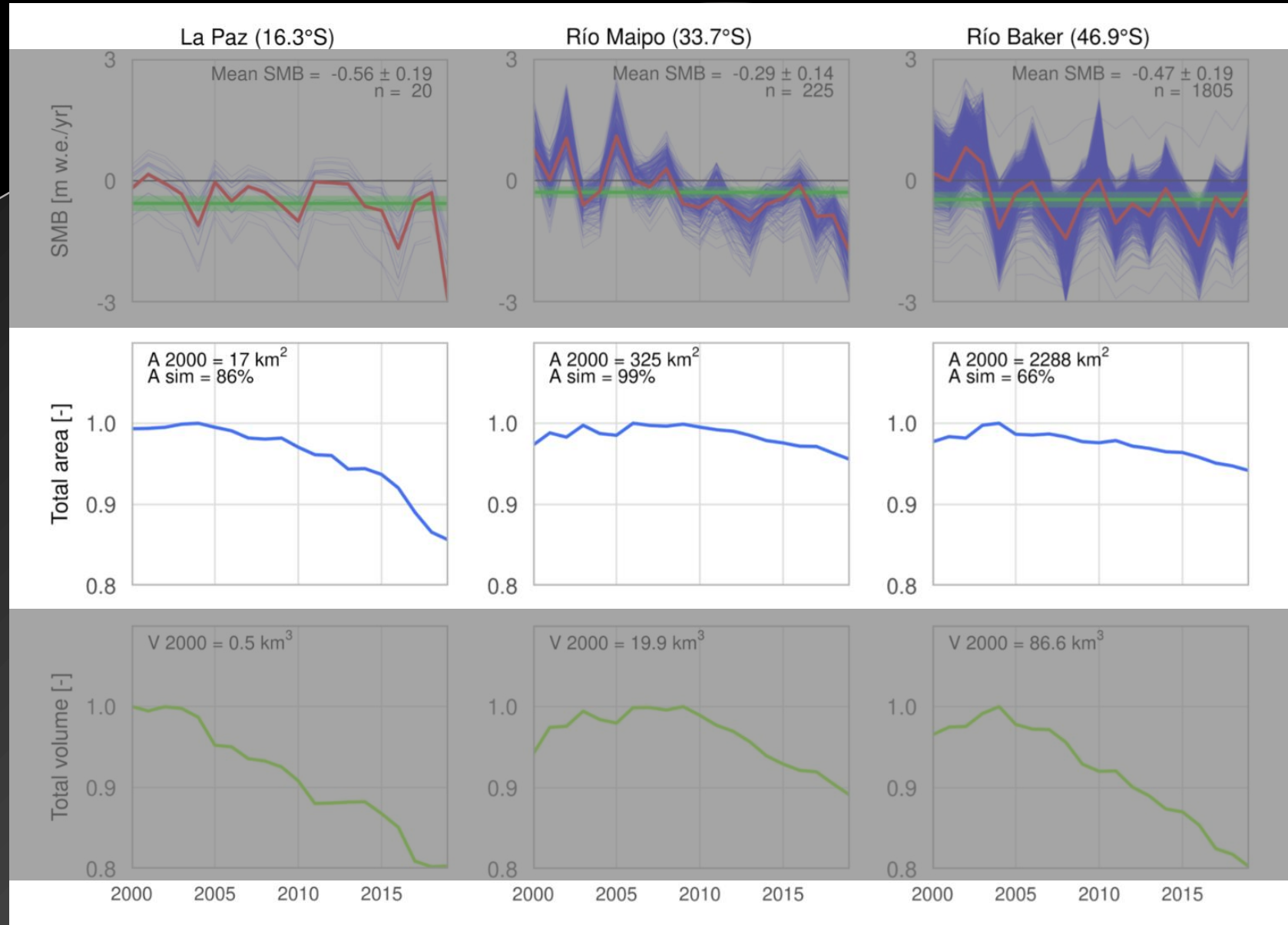
# Glacier changes in the selected basins: La Paz, Maipo and Baker



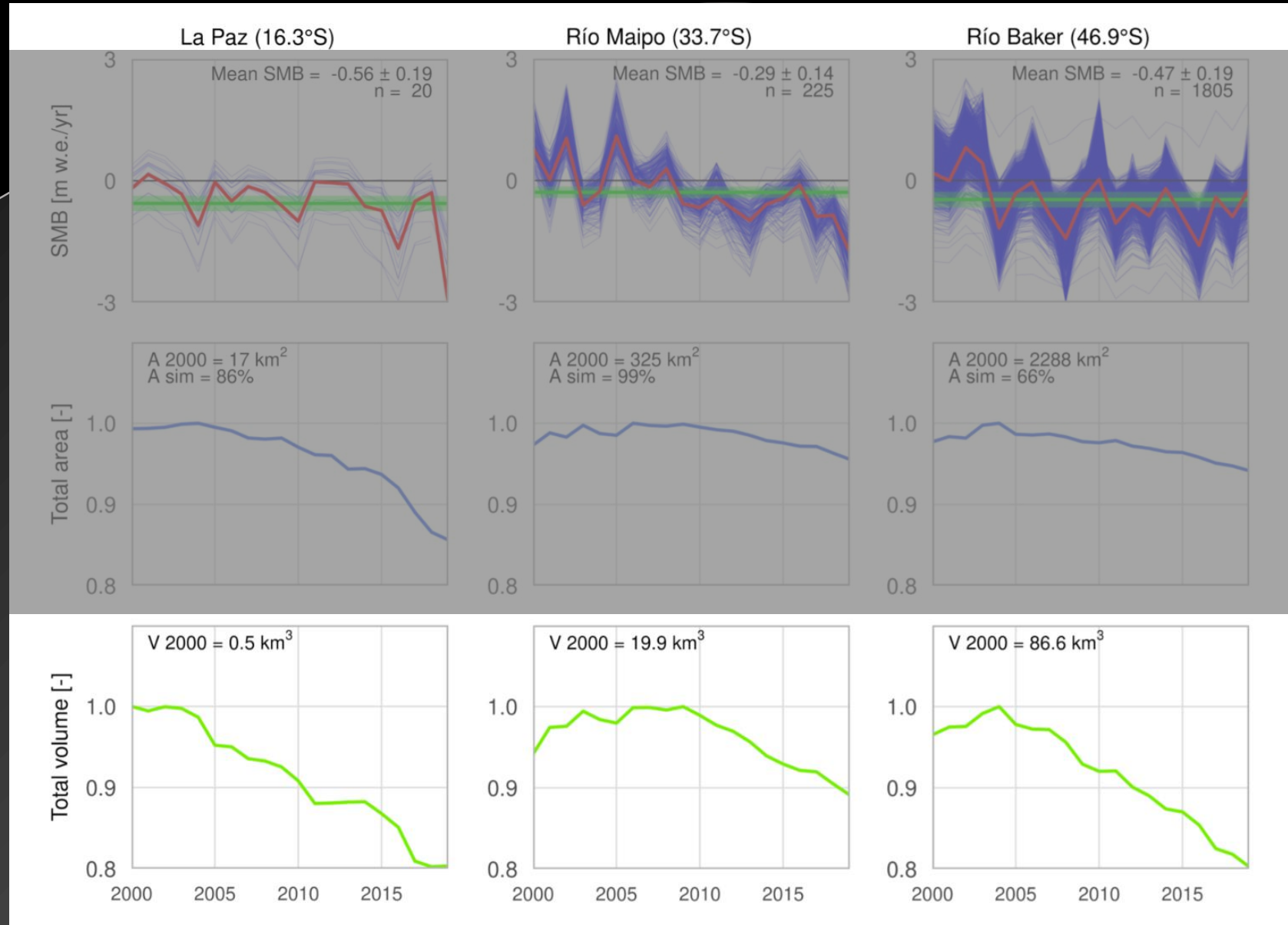
# Glacier changes in the selected basins: La Paz, Maipo and Baker



# Glacier changes in the selected basins: La Paz, Maipo and Baker

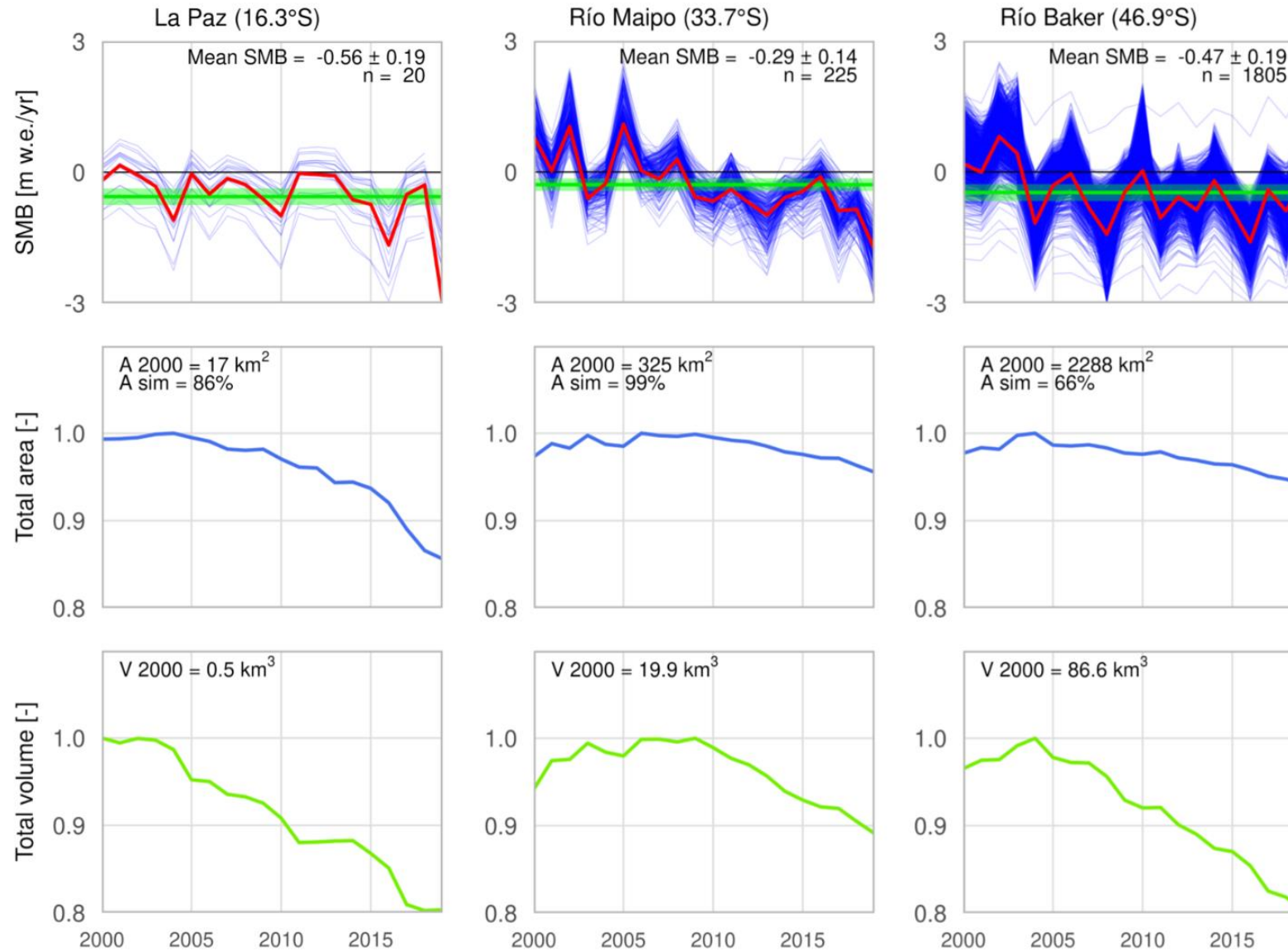


# Glacier changes in the selected basins: La Paz, Maipo and Baker

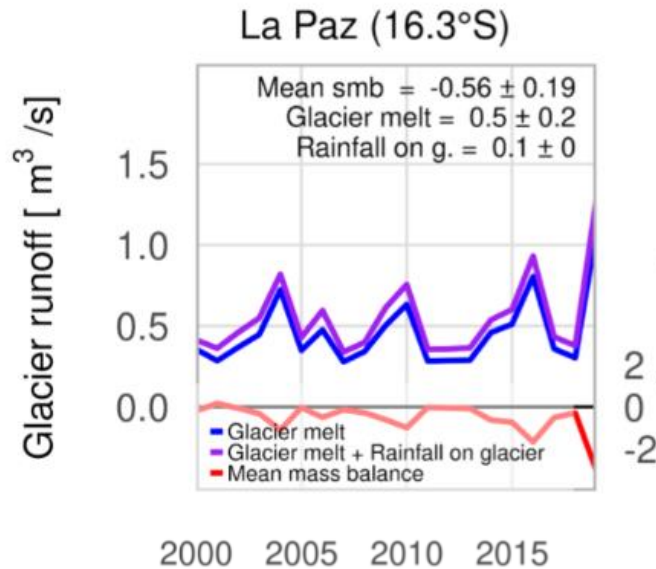




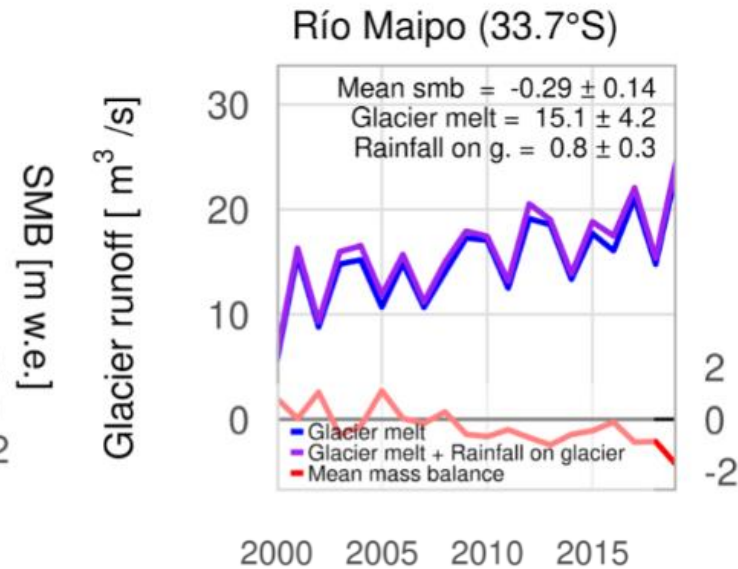
# Glacier changes in the selected basins: La Paz, Maipo and Baker



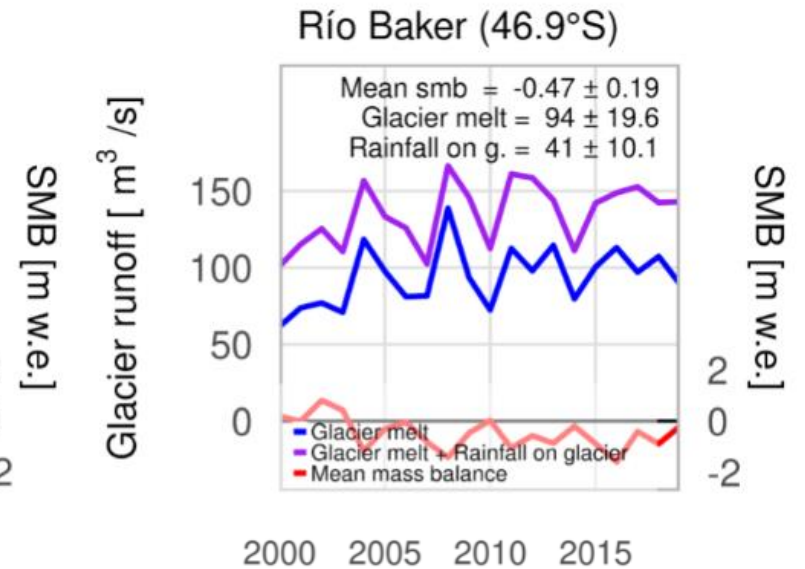
# Glacier runoff changes in the selected basins: La Paz, Maipo and Baker



Glacier melt +20%  
 Rainfall +15%

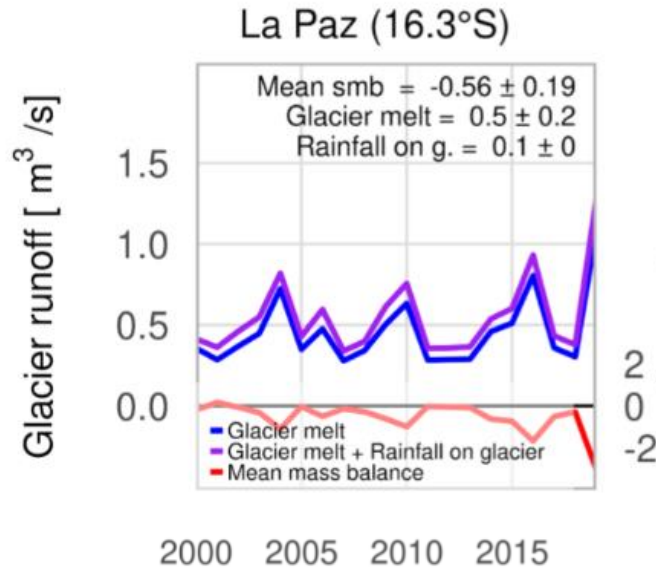


Glacier melt +37%  
 Rainfall +2%

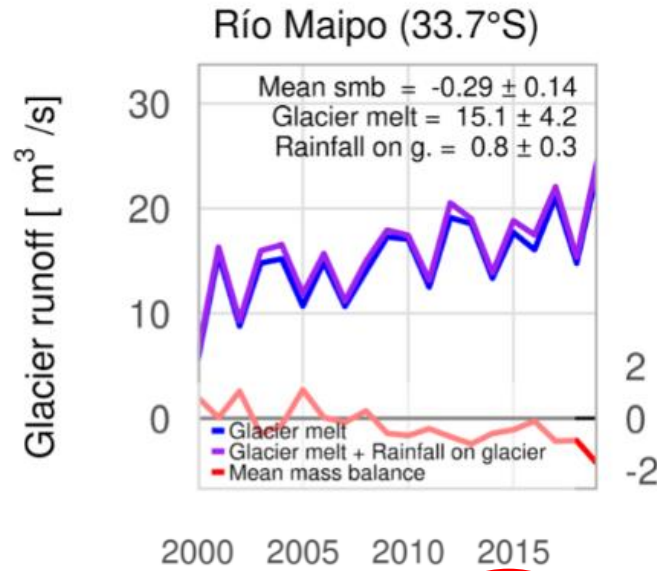


Glacier melt +10%  
 Rainfall +11%

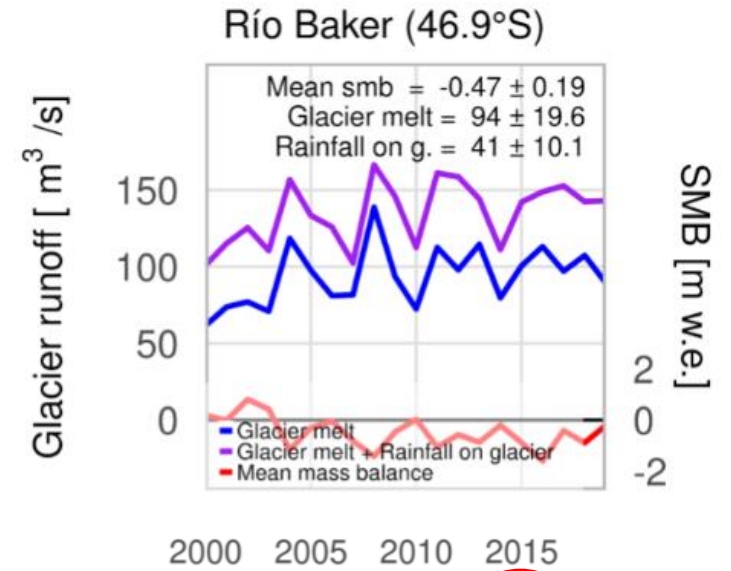
# Glacier runoff changes in the selected basins: La Paz, Maipo and Baker



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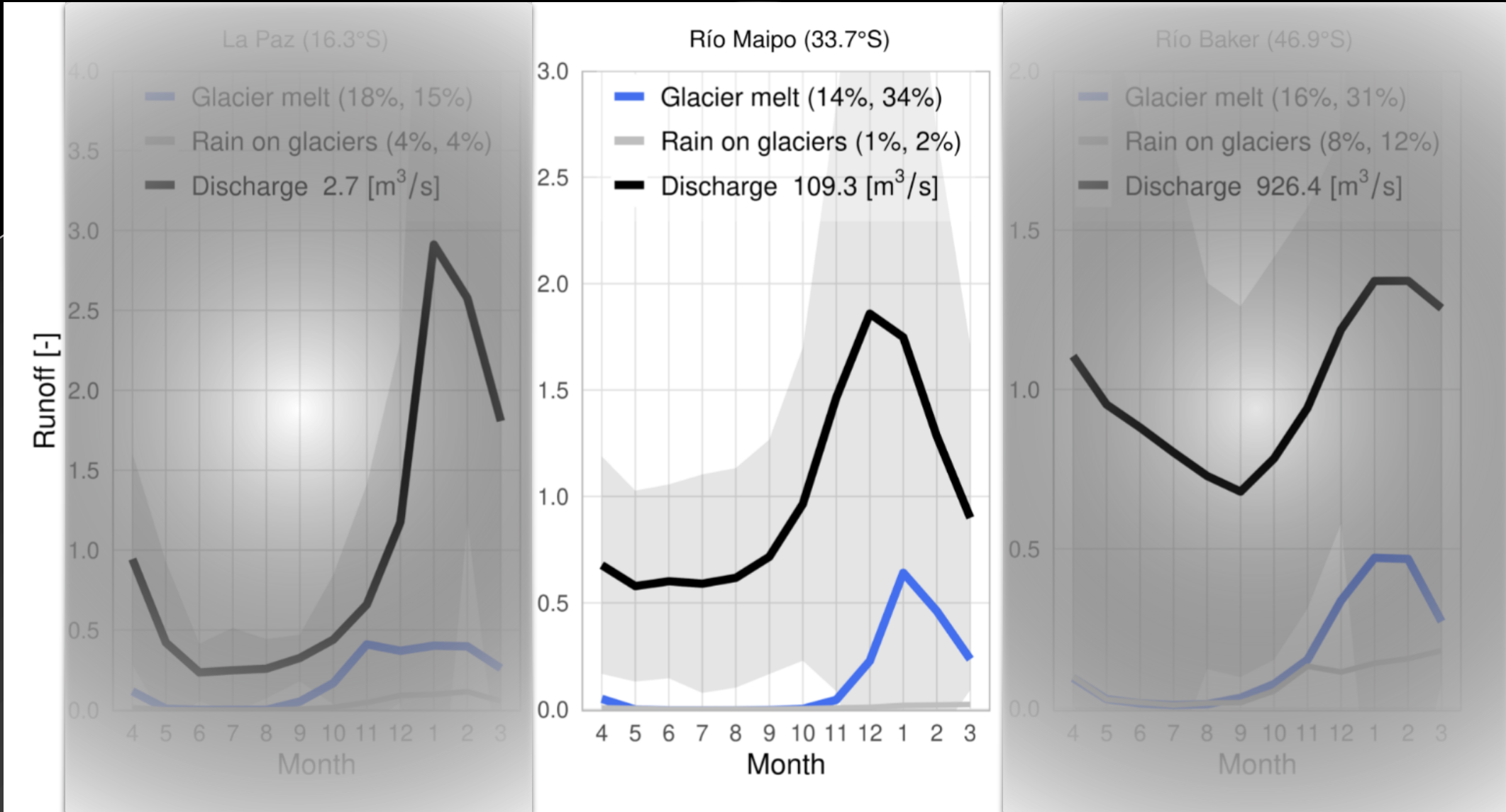


Glacier melt +37%  
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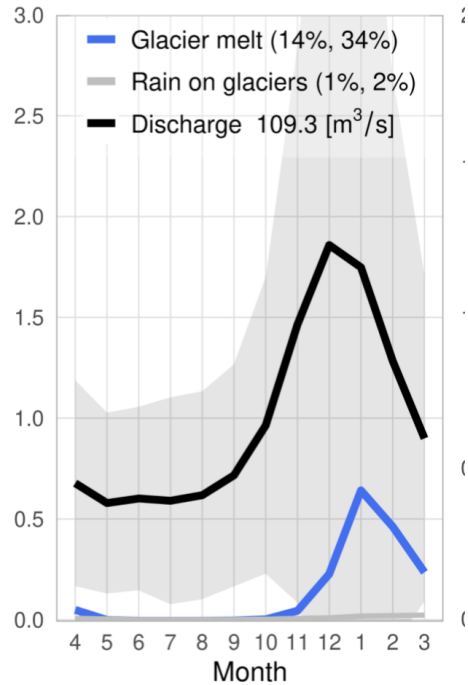
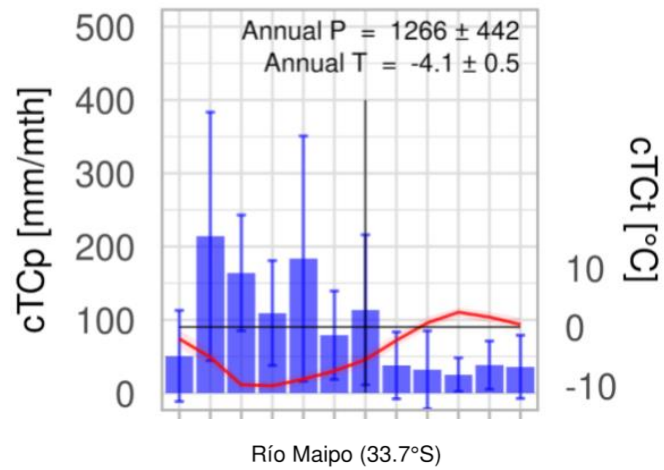


Glacier melt +10%  
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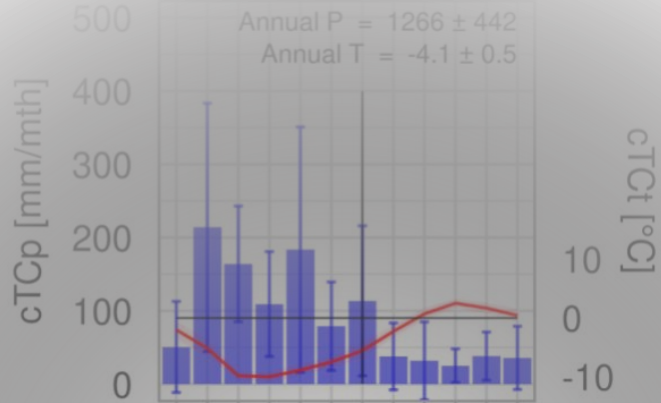
# Glacier runoff changes in the Maipo catchment



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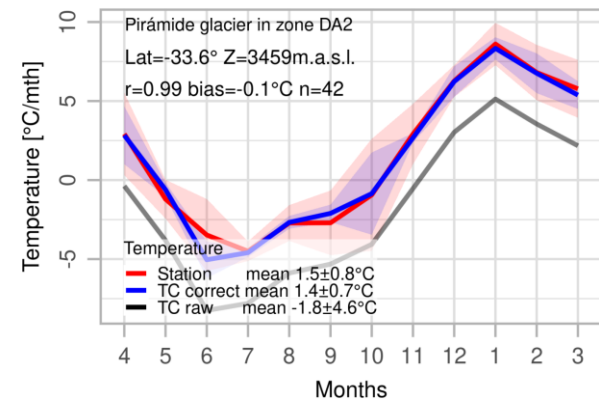
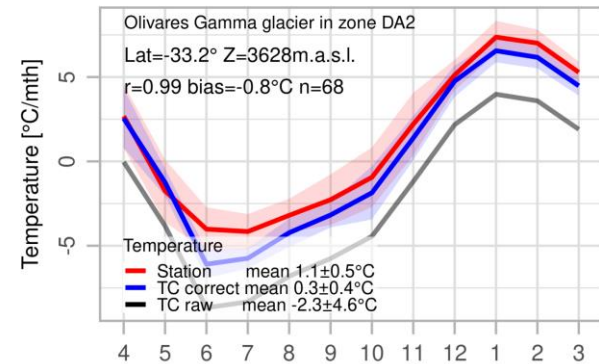
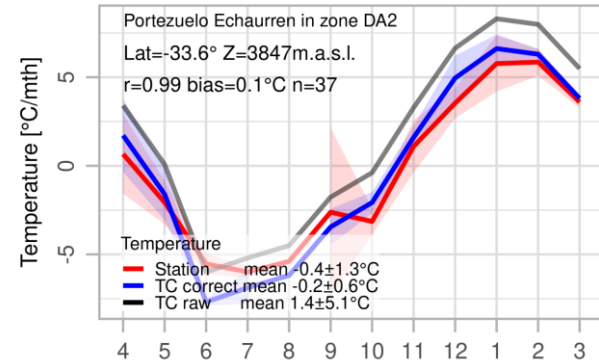
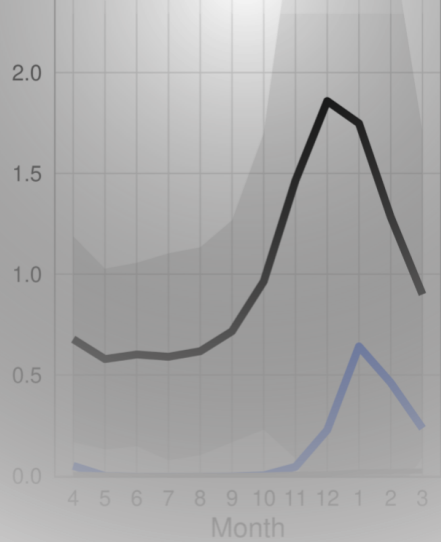


# Glacier runoff changes in the Maipo catchment

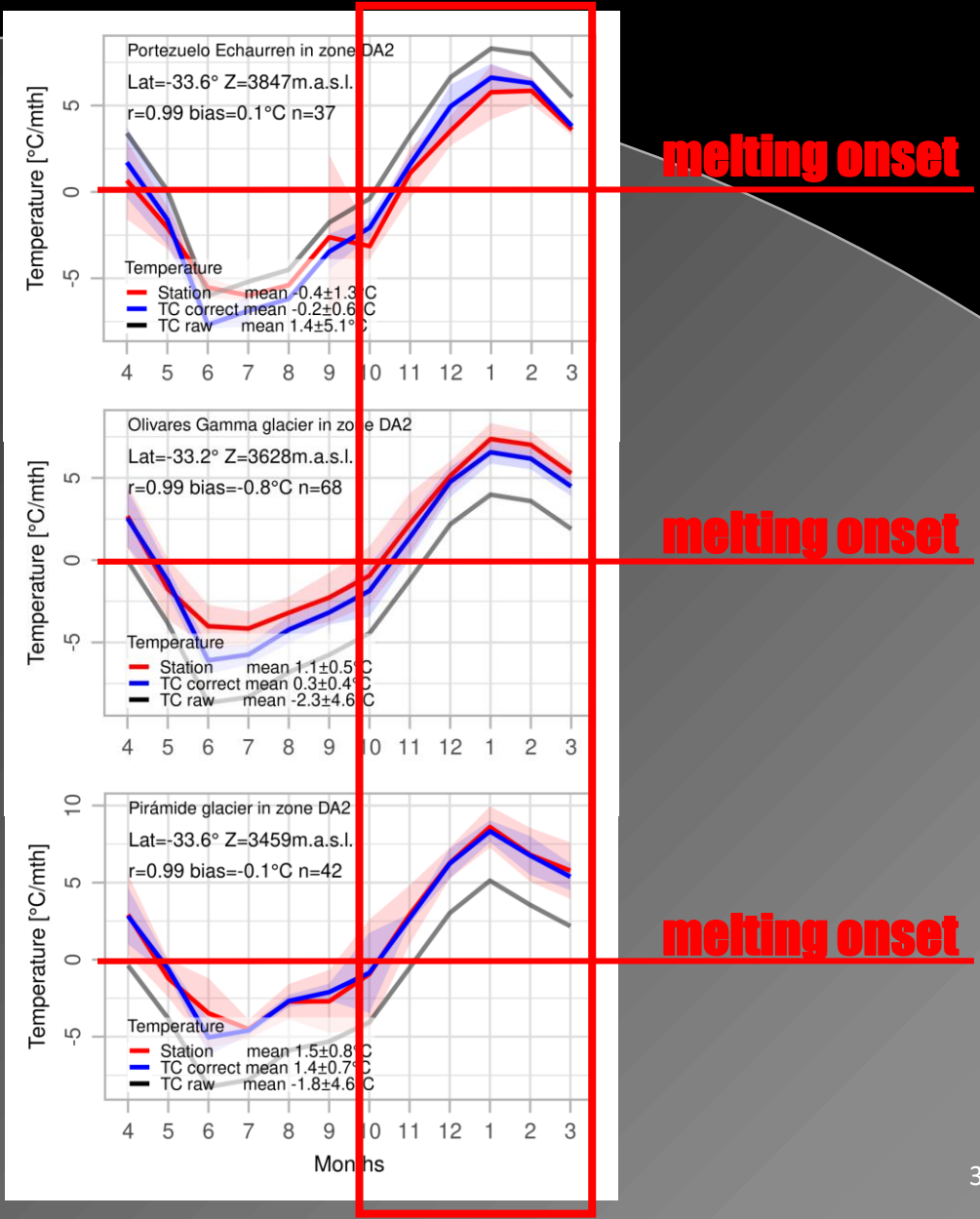
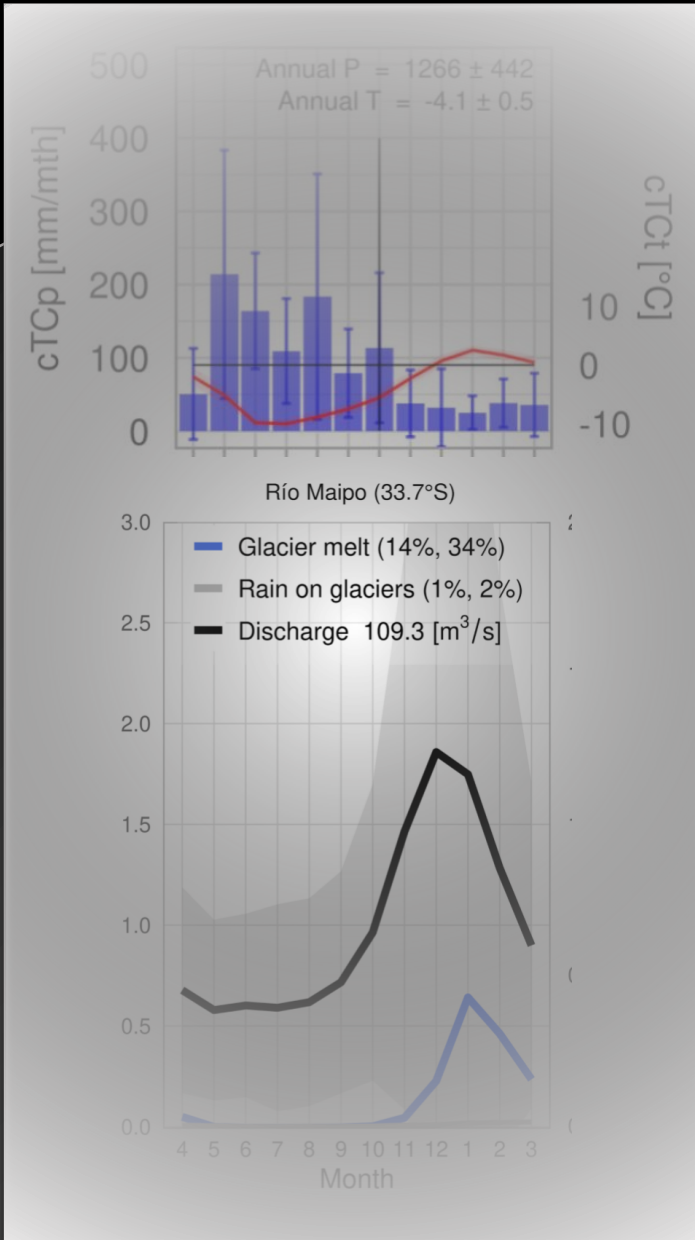


Río Maipo (33.7°S)

- Glacier melt (14%, 34%)
- Rain on glaciers (1%, 2%)
- Discharge  $109.3 \text{ [m}^3\text{/s]}$



# Glacier runoff changes in the Maipo catchment



# Conclusions

93% of the catchments show a decrease in glacier area and volume between the periods 2000-2009 and 2010-2019,

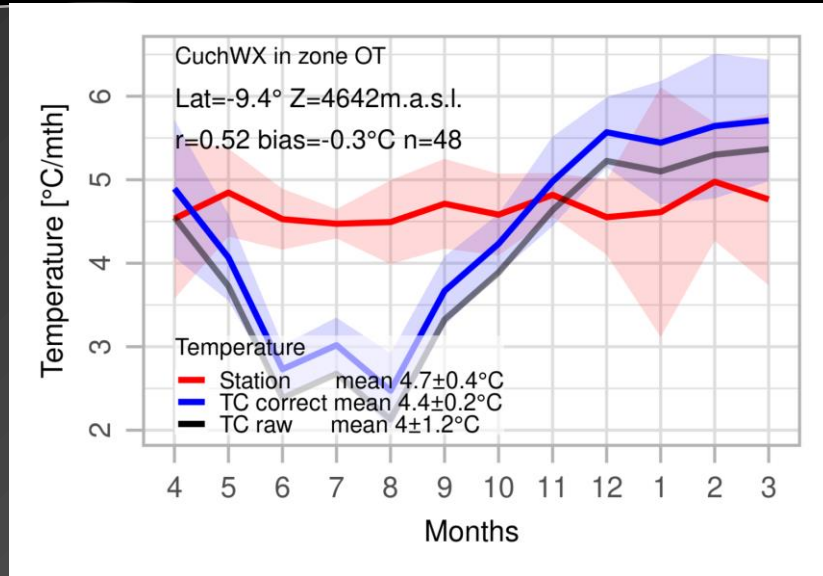
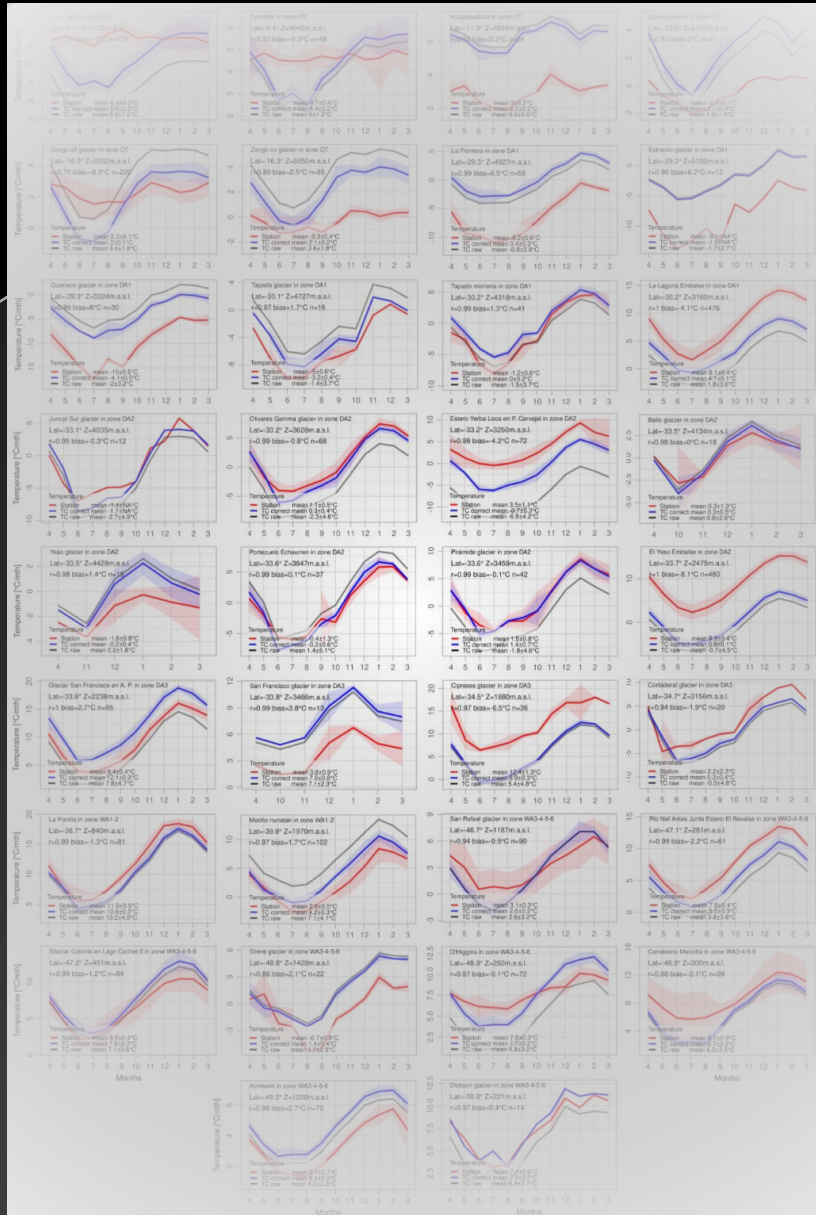
Largest percentage increment of glacier runoff in the Tropical Andes and Dry Andes (> 62%). Despite this, the increase in the Inner Tropic and Dry Andes 1 zones corresponds to the lowest absolute glacier runoff amounts across the Andes.

The three selected catchments display consistent results with previous studies and in situ observations. The larger glacier contributions to the catchment was quantified for the Baker (43%) and Maipo (36%) catchments during the summer season (January-March). Whereas, the larger glacier contribution to the La Paz catchment (45%) was estimated during the transition season (September to November).

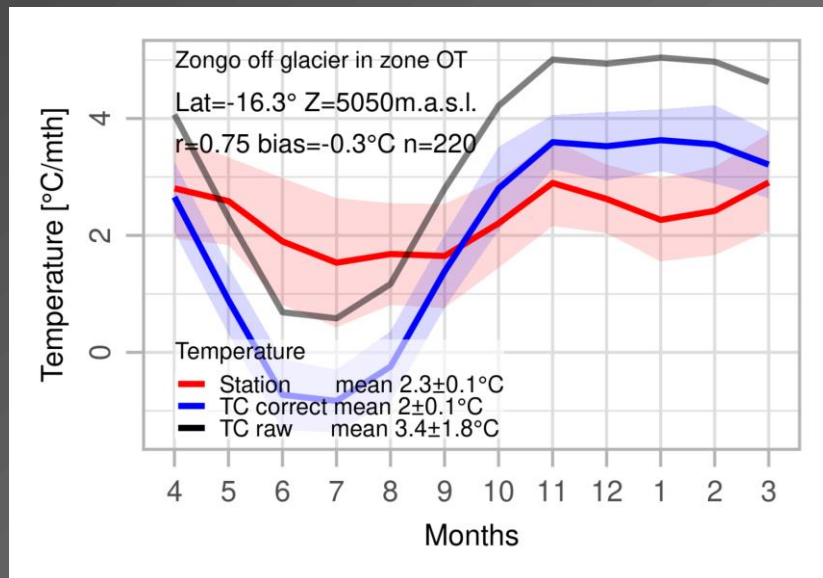


# Supplementary

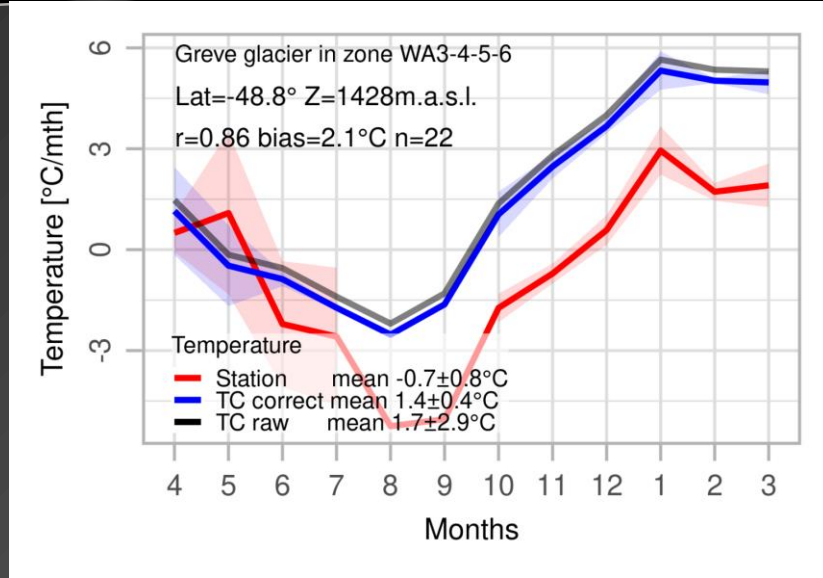
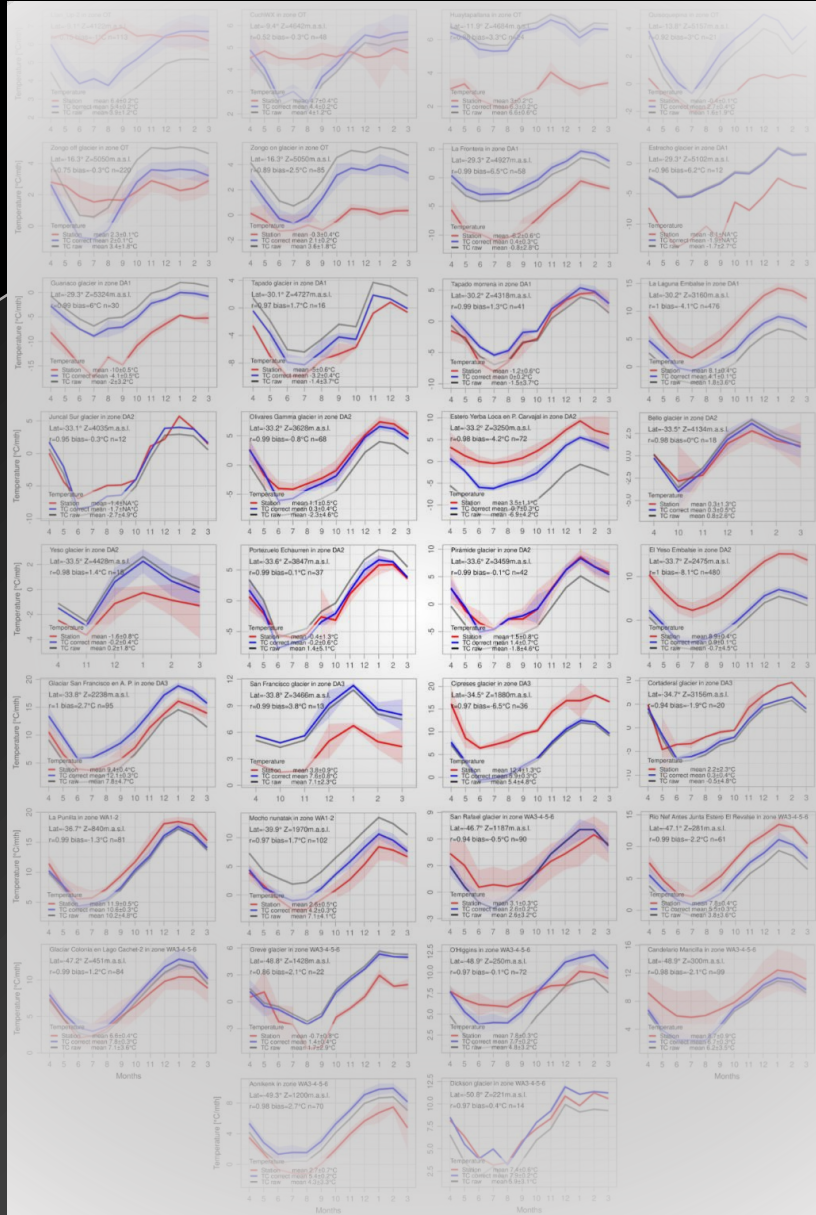
# Temperature evaluation: Tropical Andes



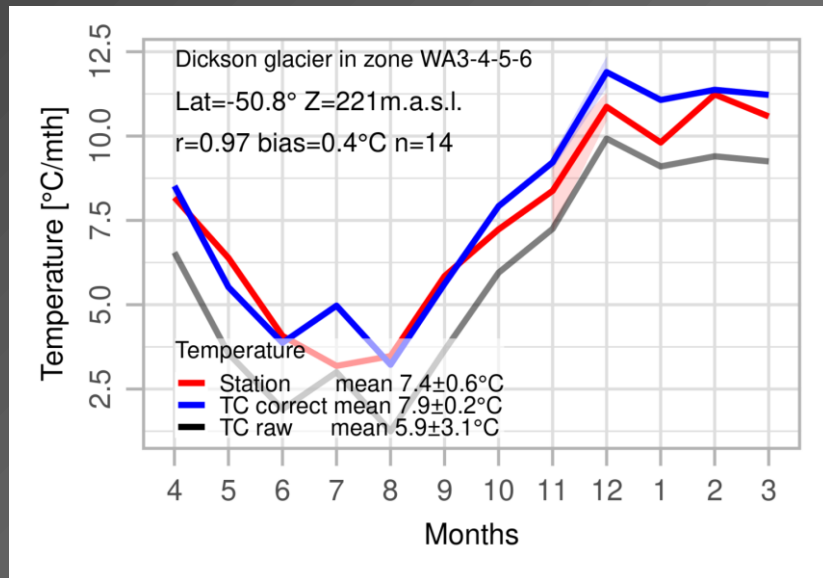
bias = 2.1°C



# Temperature evaluation: Wet Andes

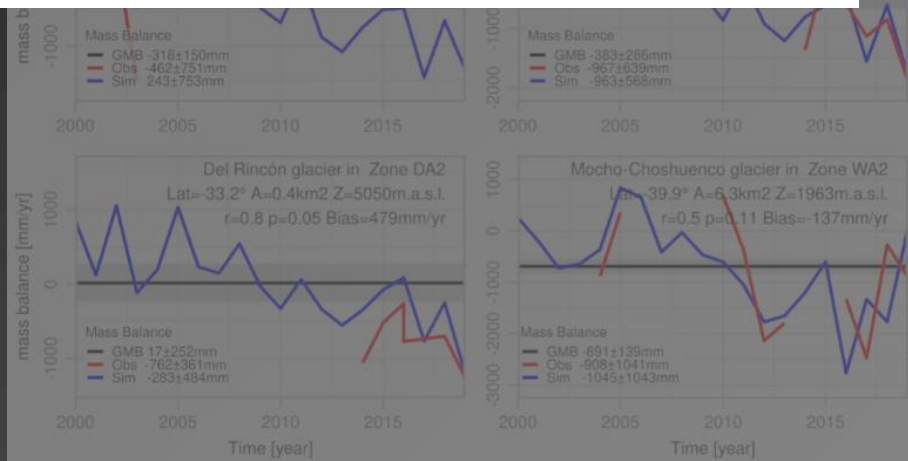
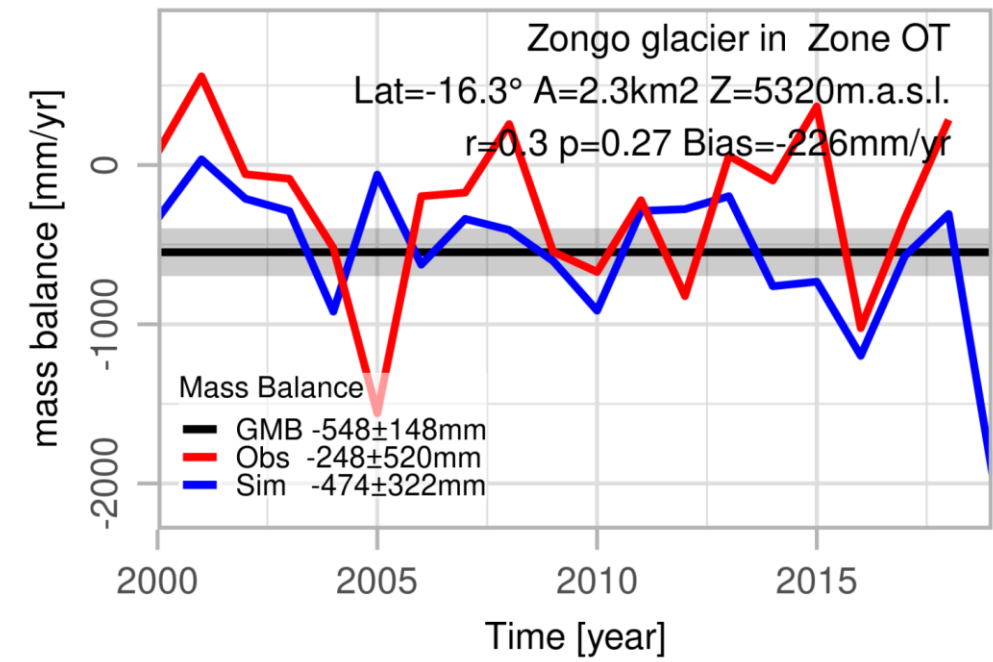
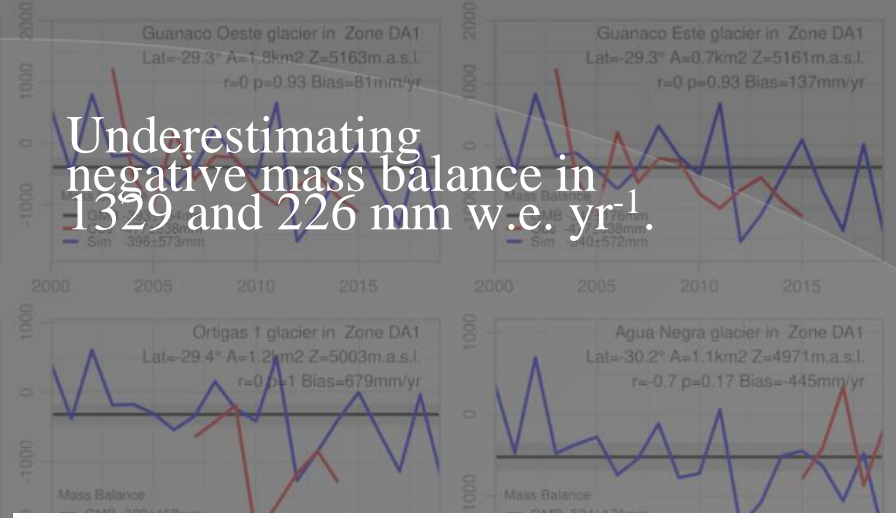
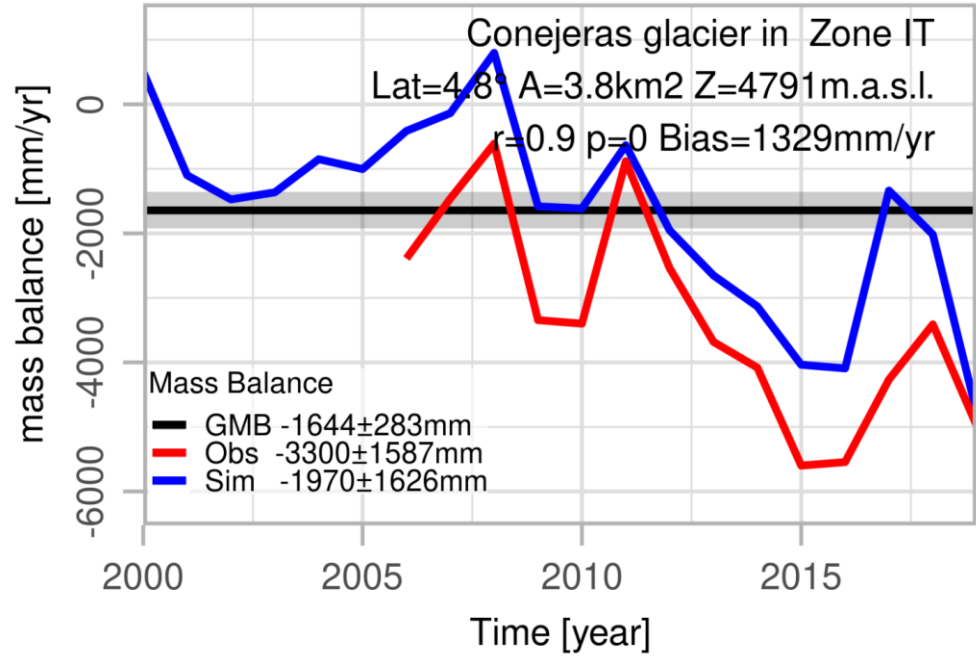


bias =  $0.2^\circ\text{C}$



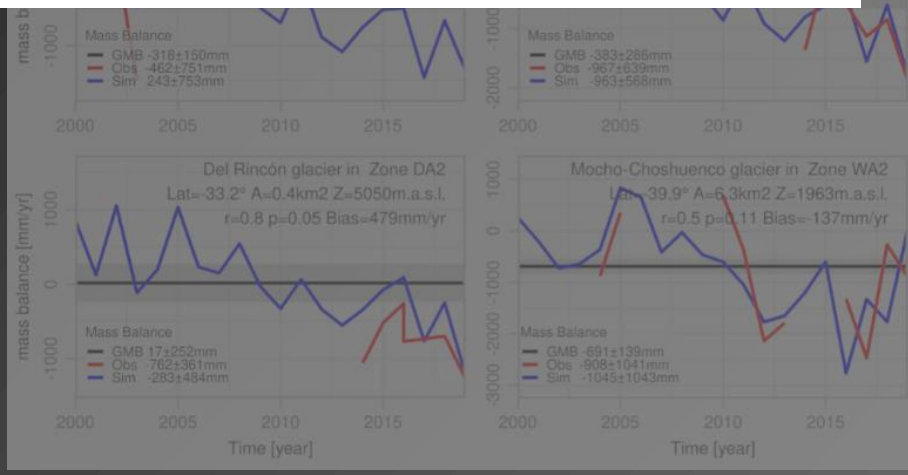
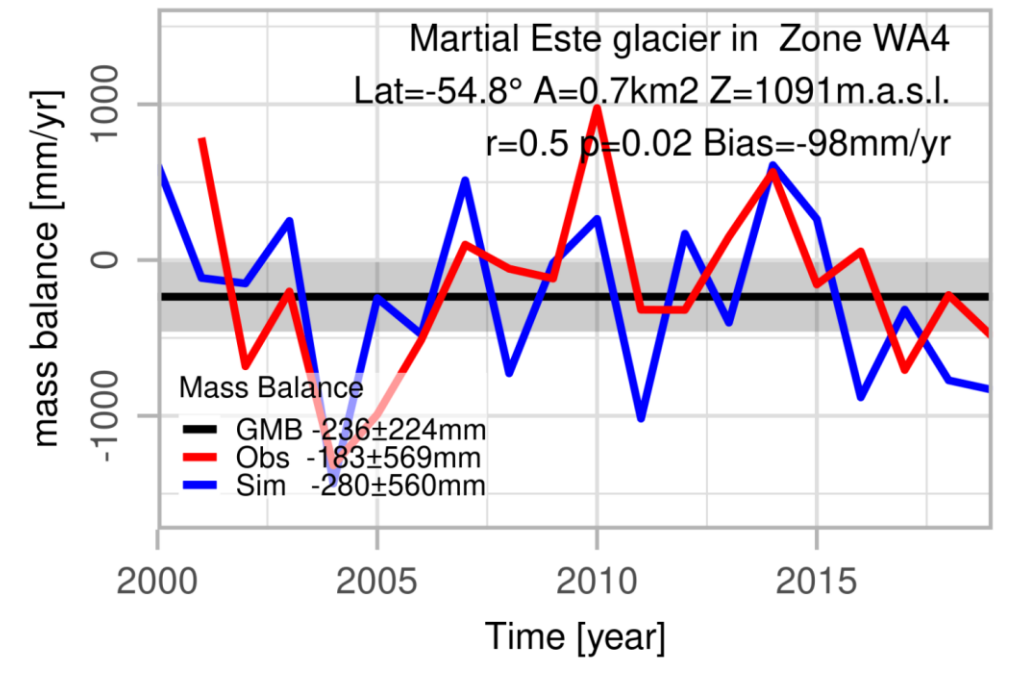
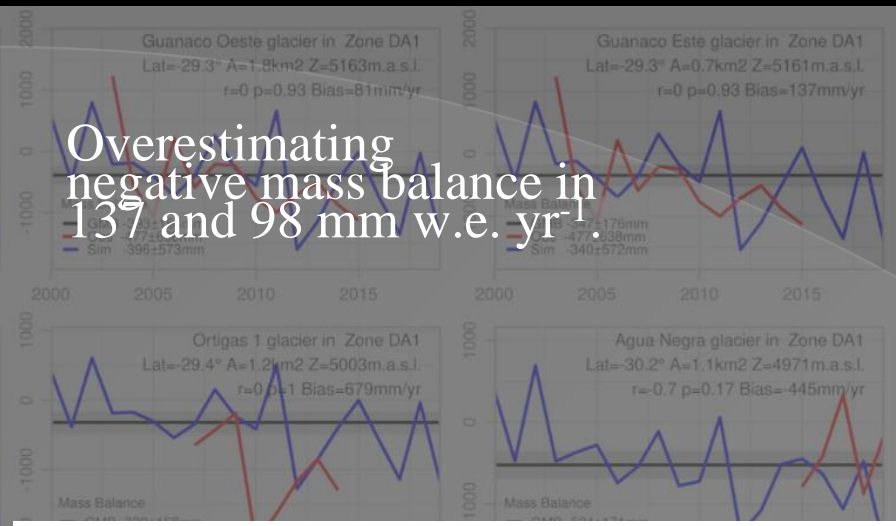
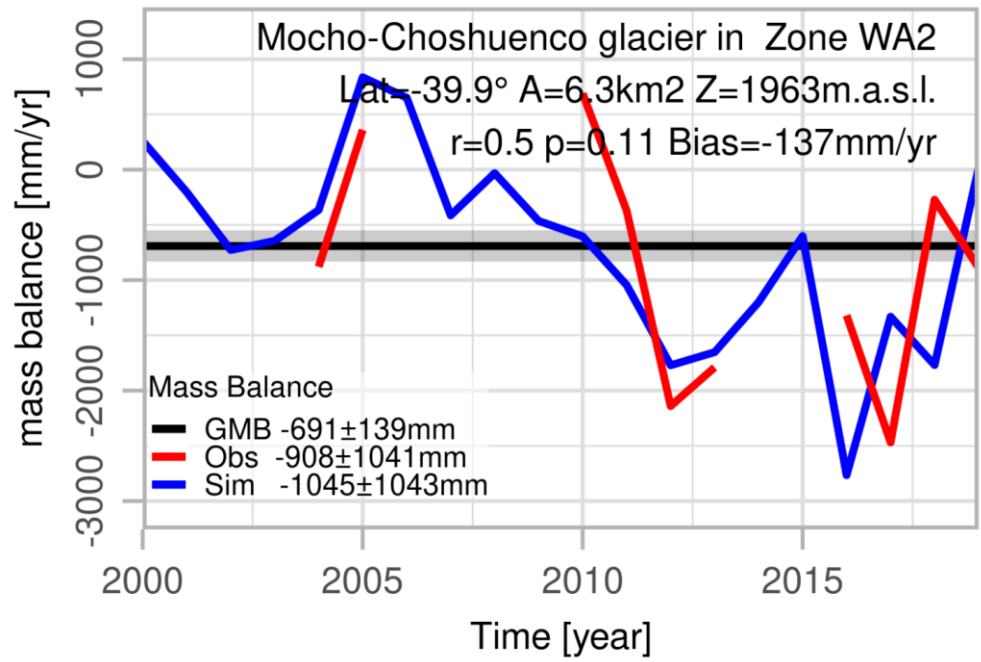
# Simulated mass balance evaluation: Tropical Andes

Underestimating negative mass balance in 1329 and 226 mm w.e. yr<sup>-1</sup>.

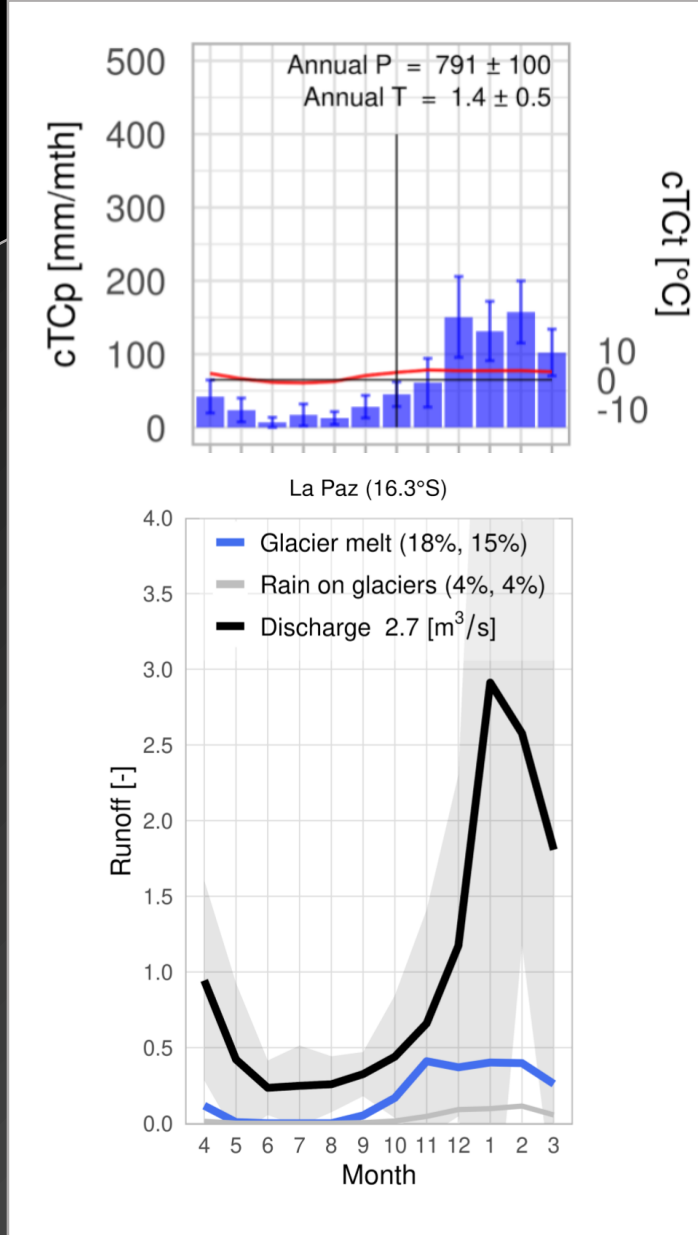


# Simulated mass balance evaluation: Wet Andes

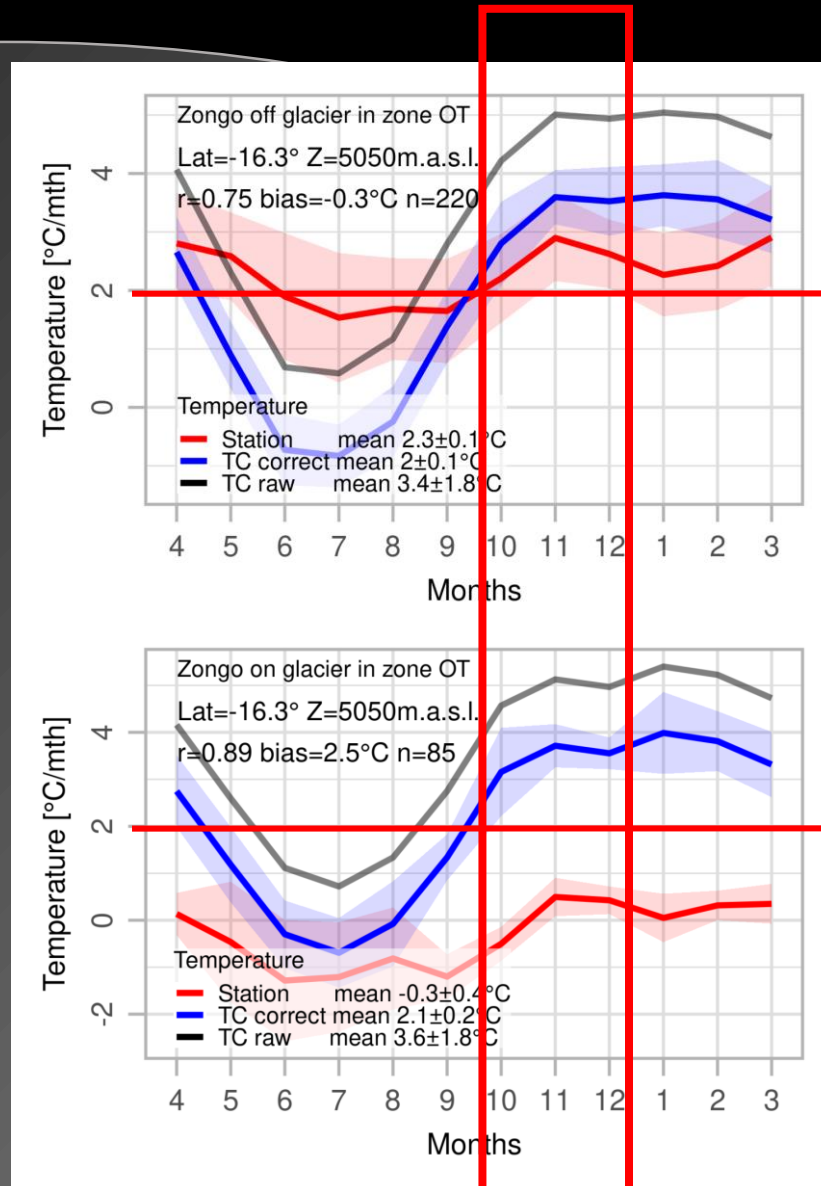
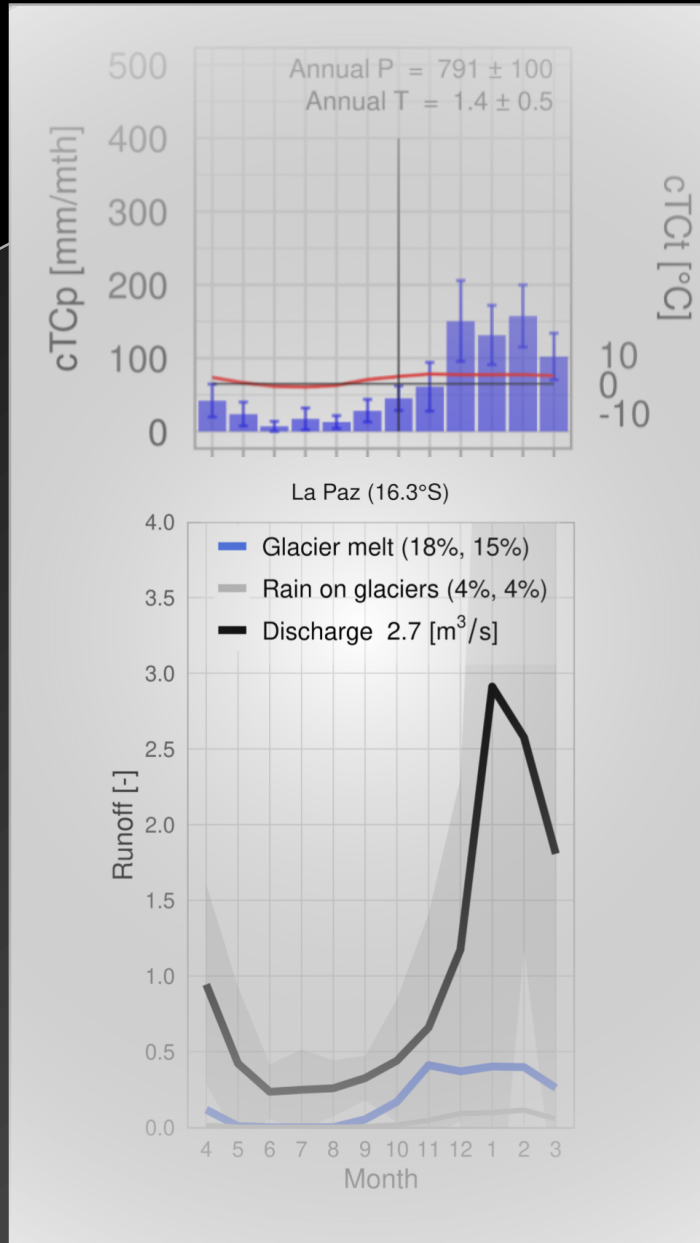
Overestimating negative mass balance in 137 and 98 mm w.e. yr<sup>-1</sup>.



# Glacier runoff changes in the La Paz catchment



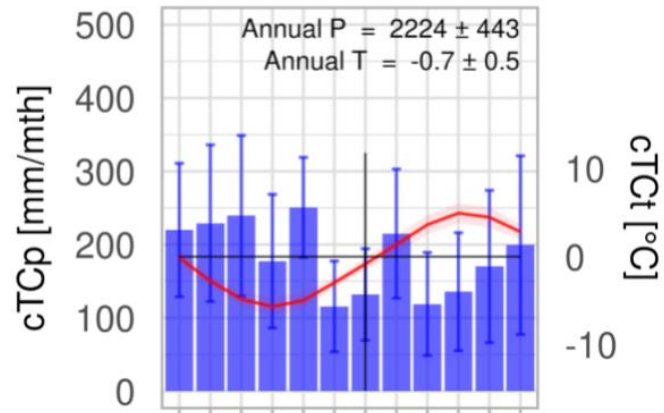
# Glacier runoff changes in the La Paz catchment



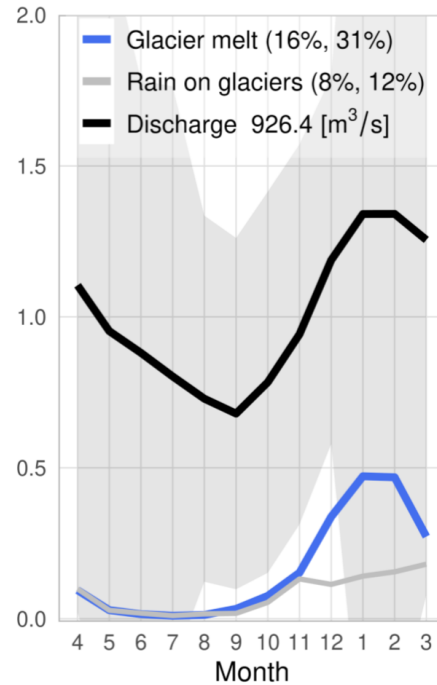
melting onset

melting onset

# Glacier runoff changes in the Baker catchment

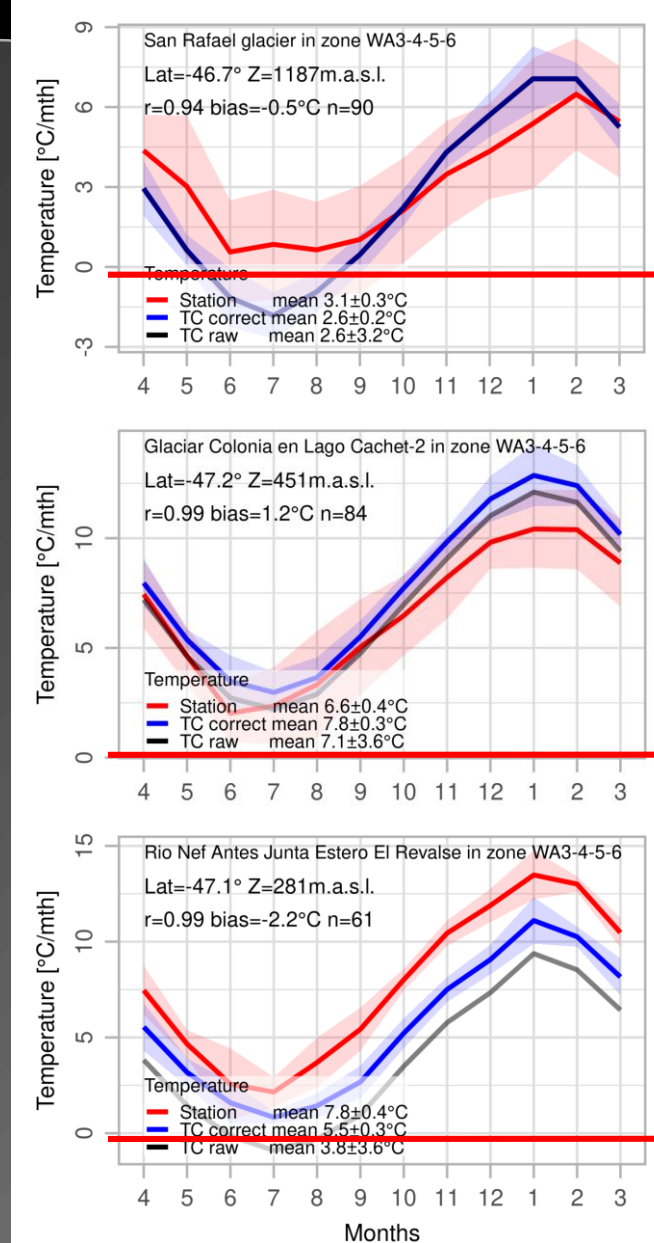
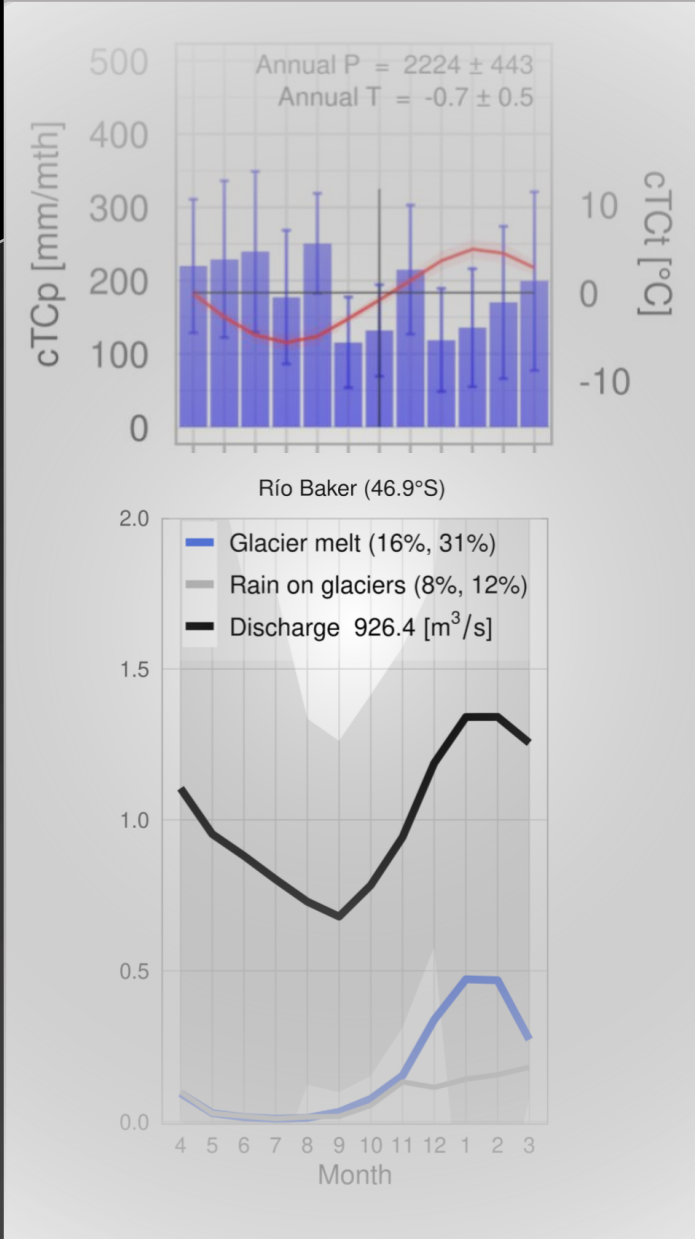


Rio Baker (46.9°S)





# Glacier runoff changes in the Baker catchment



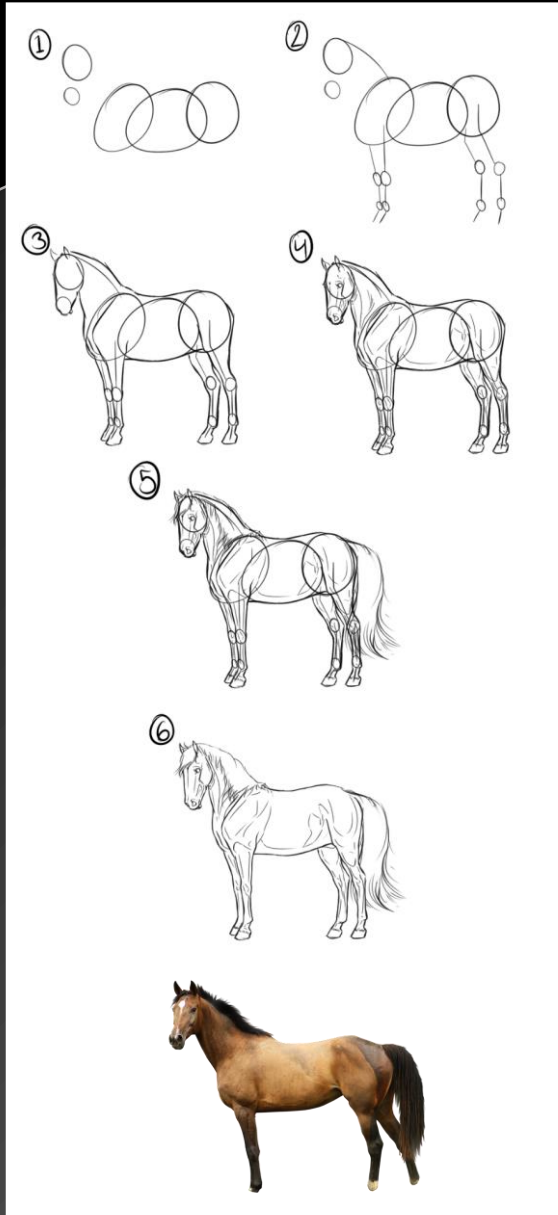
**melting onset**

**melting onset**

**melting onset**

# Glacier simulation

Procesos de la simulación



# Glacier simulation

Procesos de la simulación

