Hydrological Prediction in High Mountains - Andes

The PWPi-Andes team
INARCH Meeting October 10, 2023

ADVANCED MINING TECHNOLOGY CENTER
Ingeniería Civil
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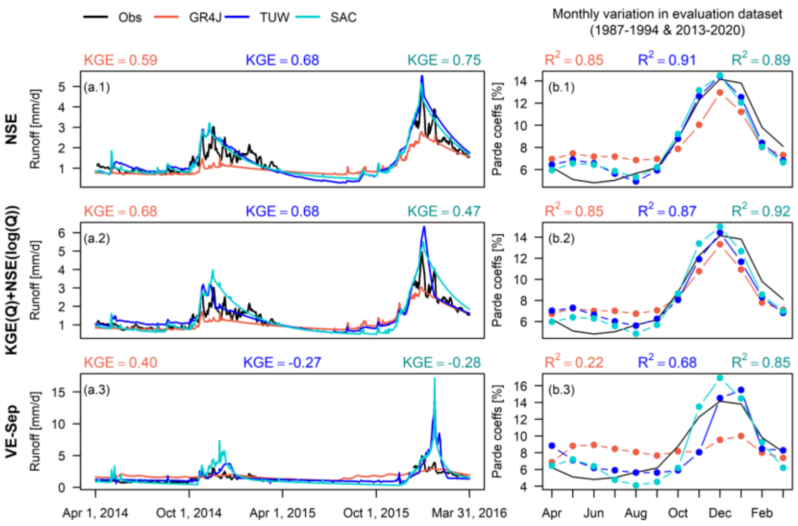
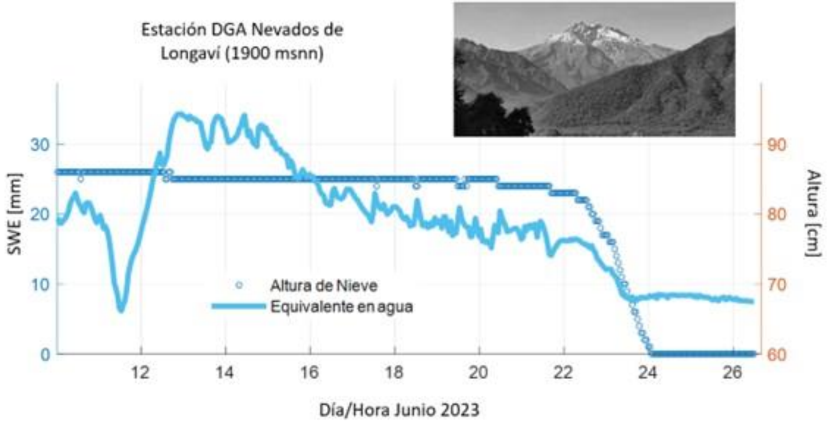
GWF
UNIVERSITY OF SASKATCHEWAN

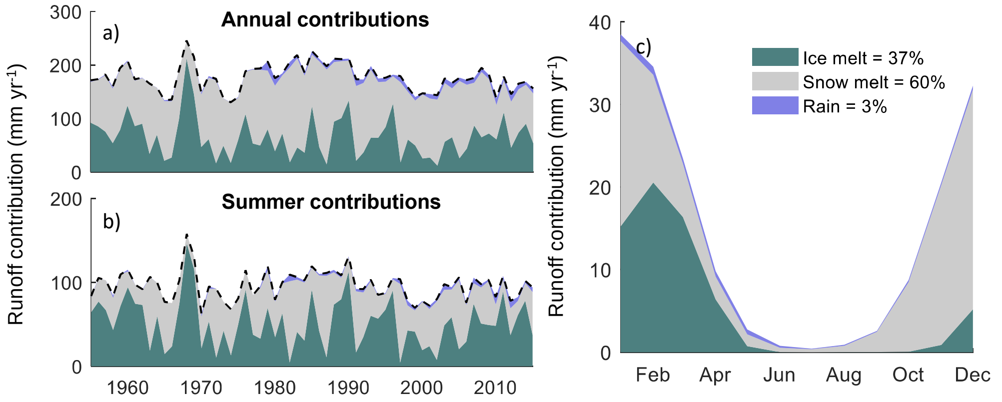
Motivation: the need to provide answers to specific questions



Seasonal streamflow forecasting
(Araya et al., 2023)

Extreme event impacts





Glacier influence on streamflow
(Ayala et al., 2020)

Sub-projects focusing on different ”flavors” of the overarching theme

SP-1. Regional snow simulation (Maria Courard).

Research question: What is the appropriate level of complexity in regional-scale snow water equivalent simulations in the Andes Cordillera?

SP-2. Drought propagation and process understanding in high mountain watersheds (Diego Hernández).

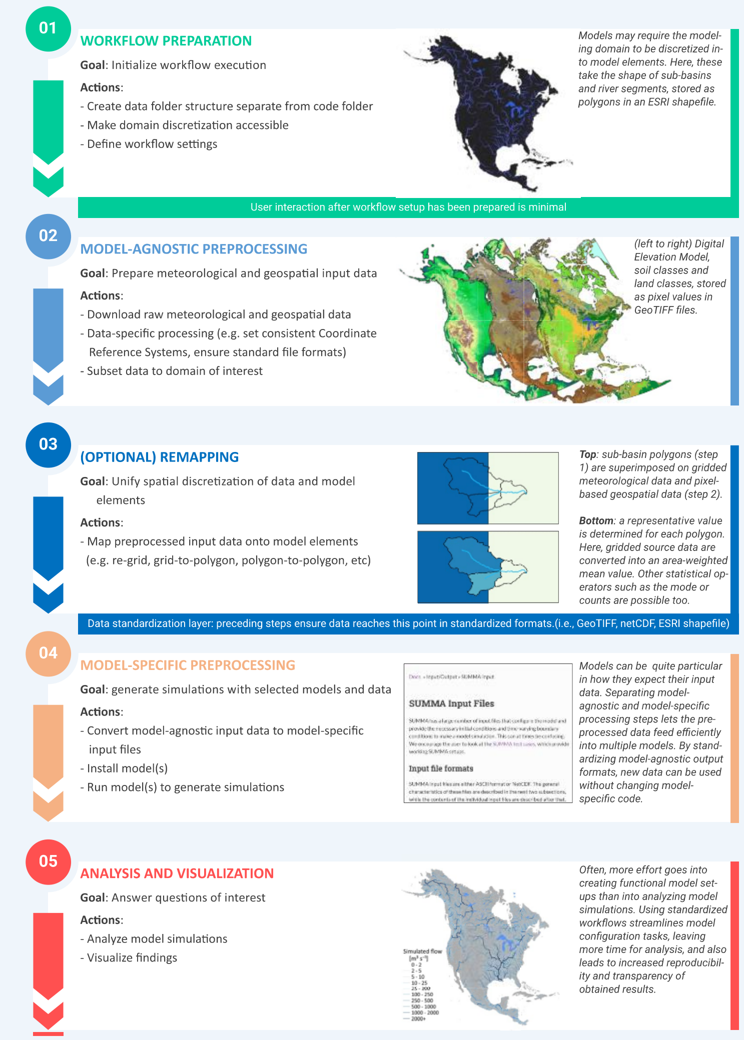
Research question: How do high mountain catchments respond to droughts of different characteristics?

SP-3. Glaciohydrology and global change in the extratropical Andes Cordillera (Alonso Mejías).

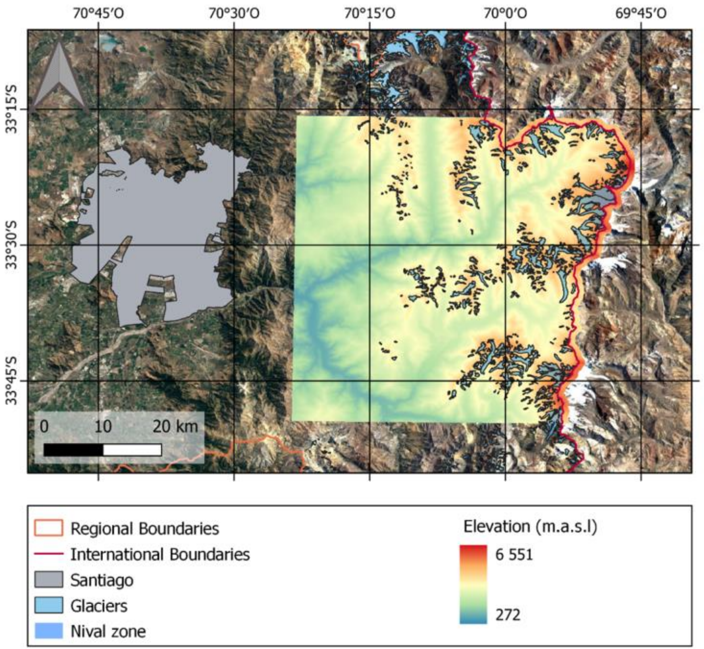
Research question: What are the expected hydrological impacts of projected glacier retreat in the extratropical Andes at the watershed scale?

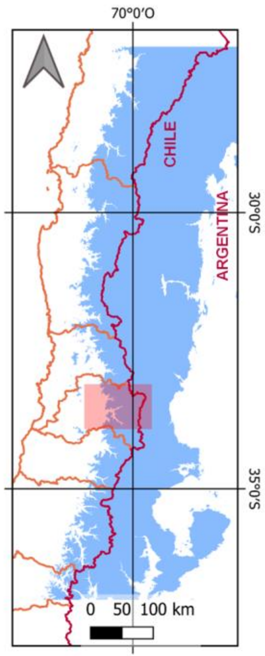
CWARHM Approach (Knoben et al. 2022)

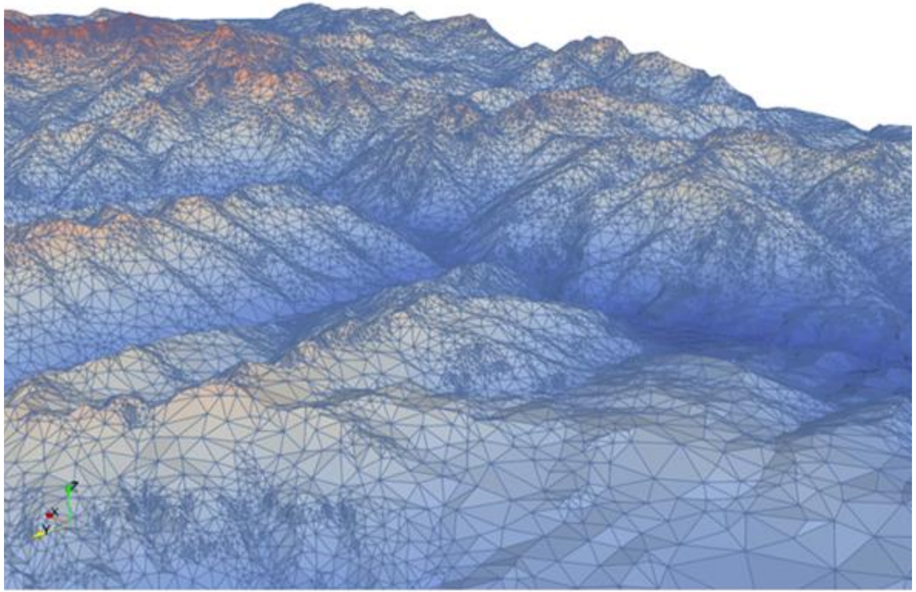
1. Workflow preparation: domain discretization in 1) TIN; 2) Grid; 3) HRU
2. Model-agnostic preprocessing
   a. NWP and reanalysis met forcings (ECMWF, ERA5-Land)
   b. Scaled station-based local gridded met. reference product (Álvarez-Garretón et al., 2018; Boisier, 2023) -> daily precipitation, max/min air temperature
   c. Downscaling of a. based on b.
3. Remapping of preprocessed forcings to model elements
4. Model-specific preprocessing
5. Visualization and analysis



SP-1. Regional Snow Modeling with CHM

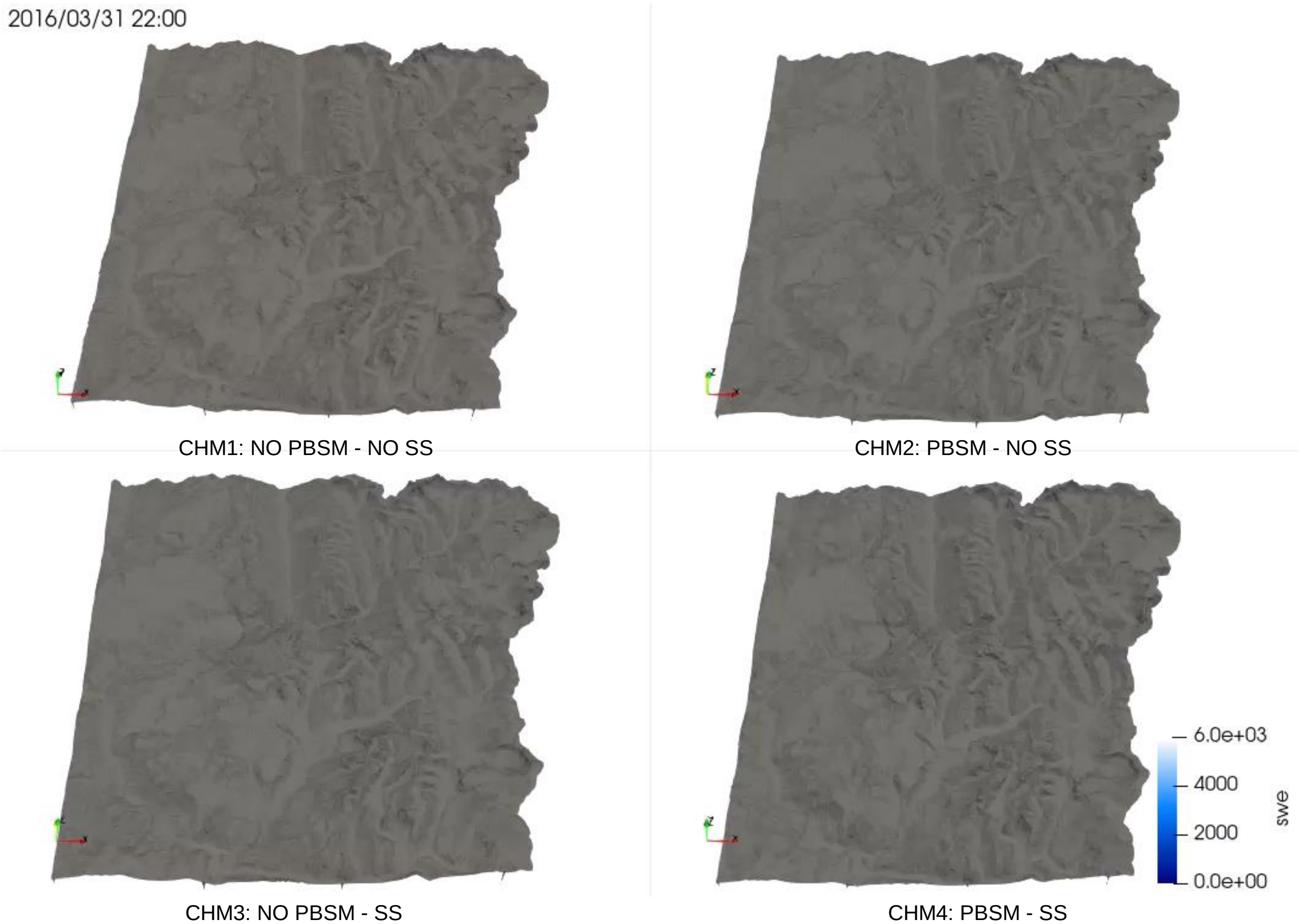


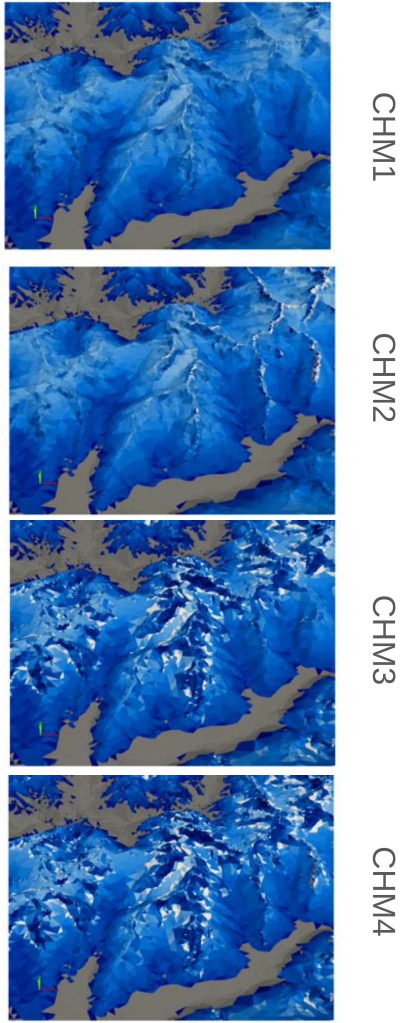




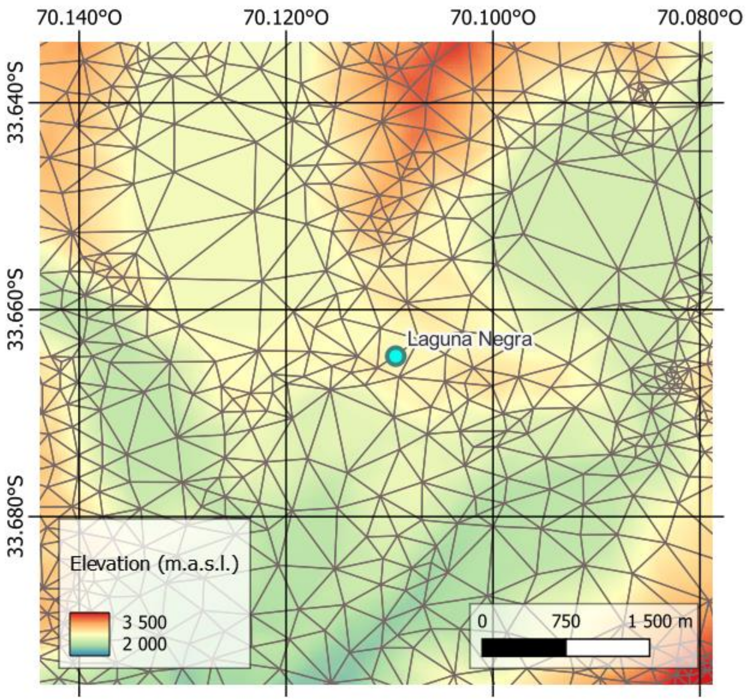
Area (km²)	Annual pp (mm)	Mean annual temp (°C)	Number of triangles	Area range (m²)	Mean area (m²)	Mean resolution (m)	Cores/Run time (1 WY)
~ 3 200	600	4	~ 100 000	400 - 700 000	32 000	180	22/ ~1hr30

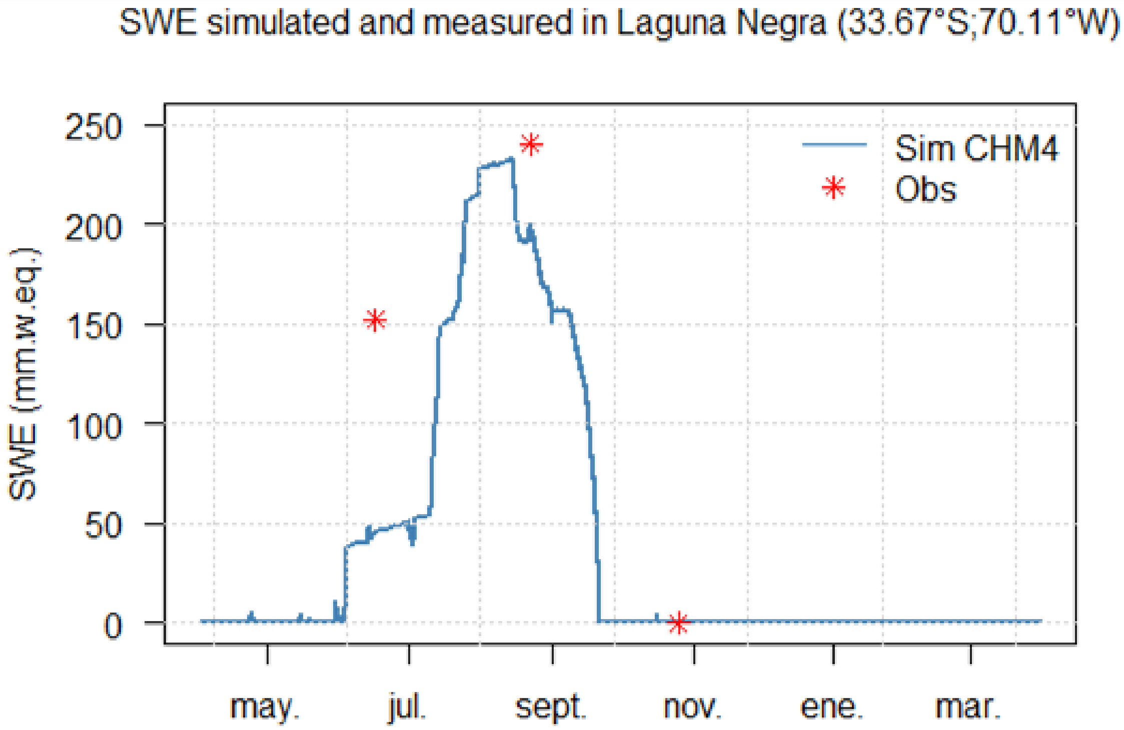
SP-1. Regional-scale SWE Results with CHM





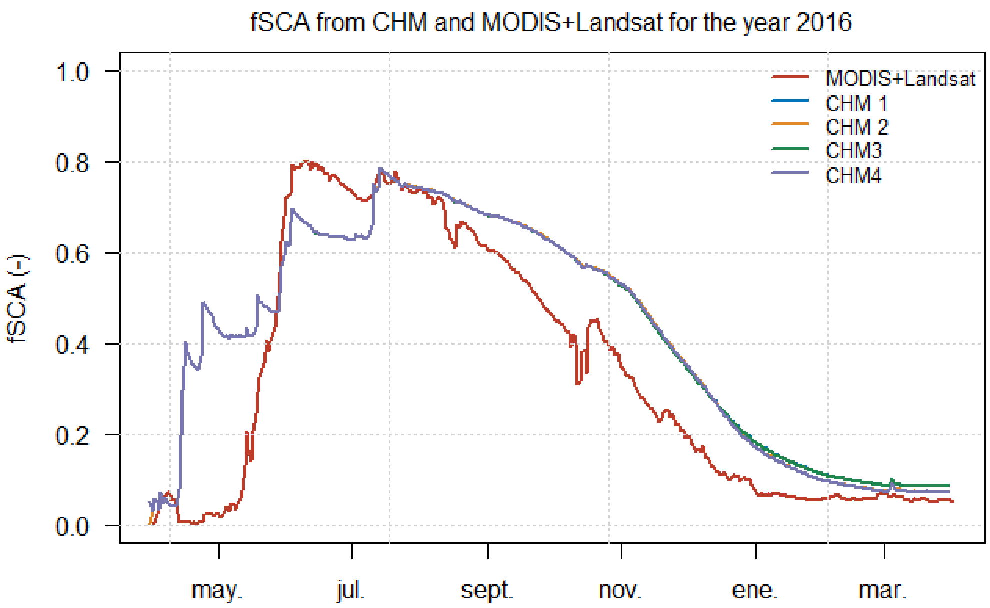
SP-1. Point-scale SWE Results

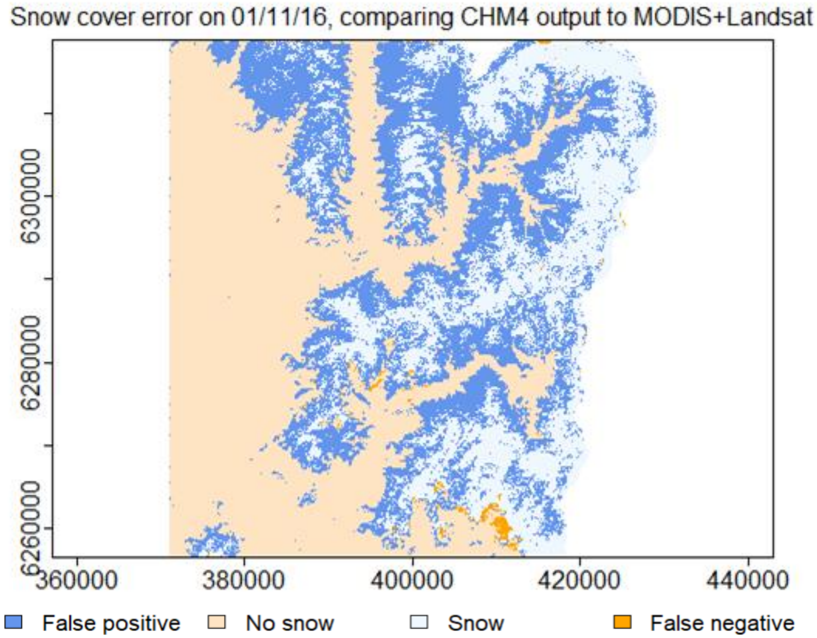




- Comparison with manual snow surveys during accumulation season, peak SWE and end of snow season.
- SWE underestimation during the accumulation season.
- Correct representation of peak SWE.

SP-1. Snow Covered Area

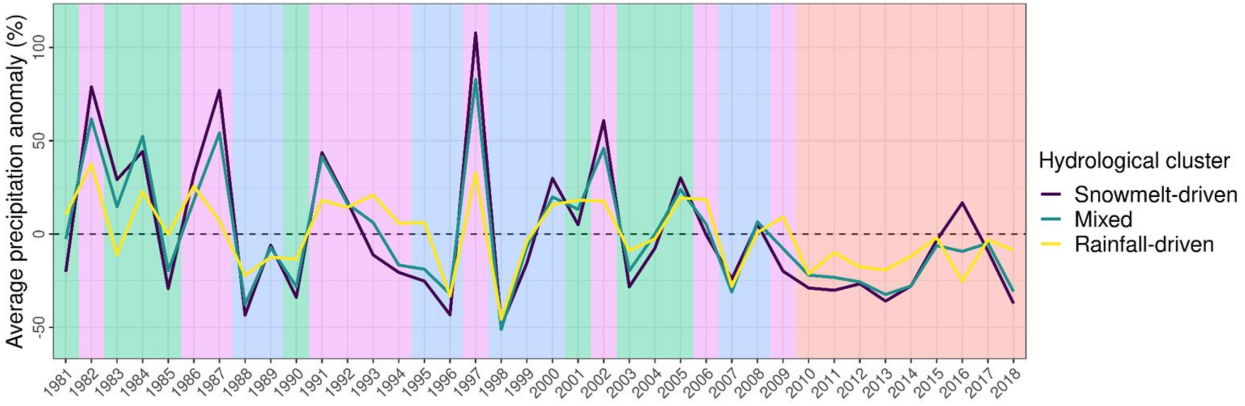


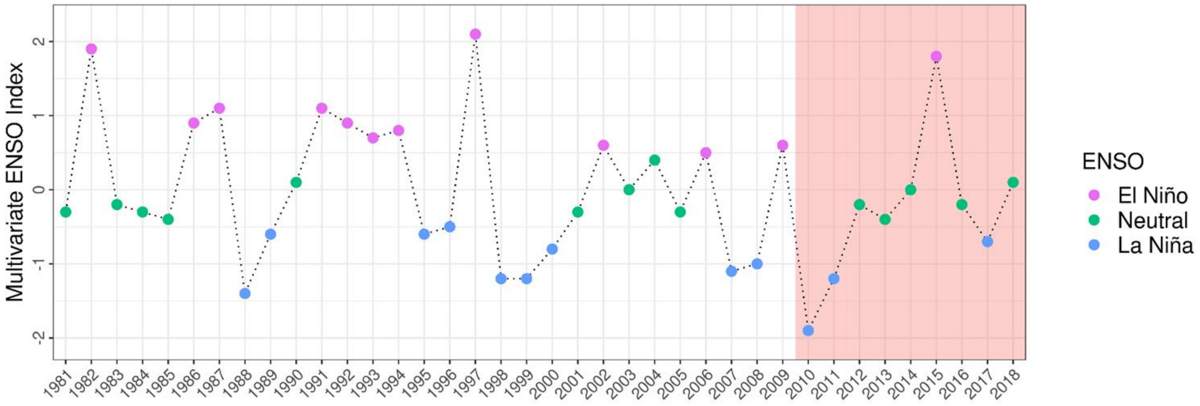


Model	RMSE	Mean error	R^2
CHM1	0.15	0.12	0.81
CHM2	0.15	0.12	0.80
CHM3	0.15	0.12	0.81
CHM4	0.15	0.11	0.80

General overestimation of snow covered area, except during june-july.
Performance metrics over the whole area show no differences between models.

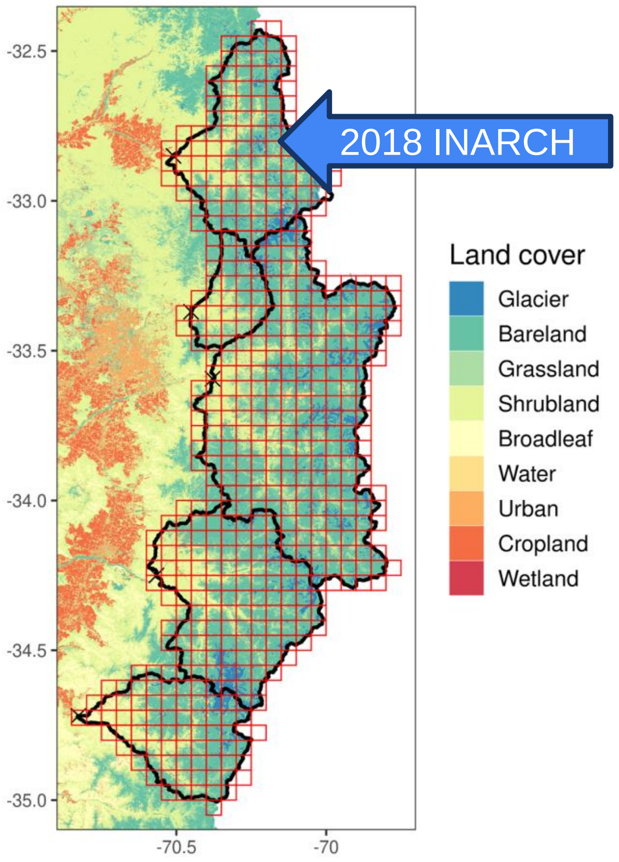
SP-2. Drought impacts with MESH





Dominant land cover classes:

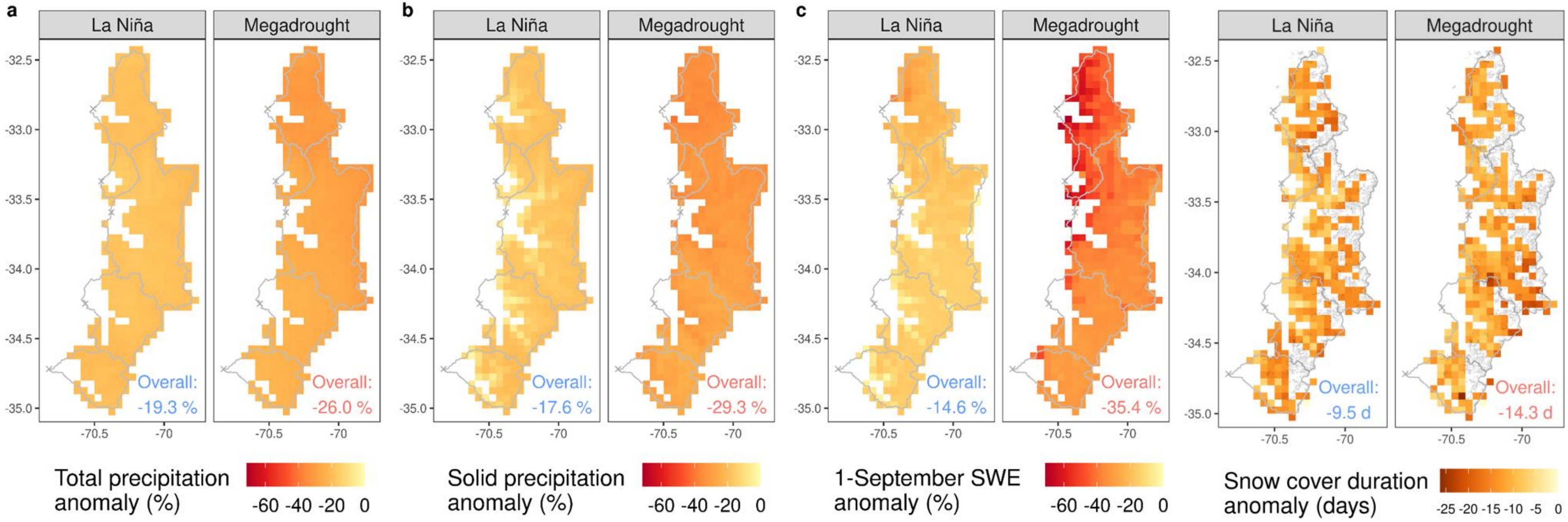
Bareland:	57 to 68 %
Shrubland:	9 to 20 %
Grassland:	4 to 22 %
Glacier:	3 to 11 %



Water years are classified into El Niño, Neutral, La Niña, and Megadrought.

Setup: 5 x 5 km grid cells, GRUs defined by land cover and aspect, MMESH enabled.

SP-2. Drought impacts with MESH

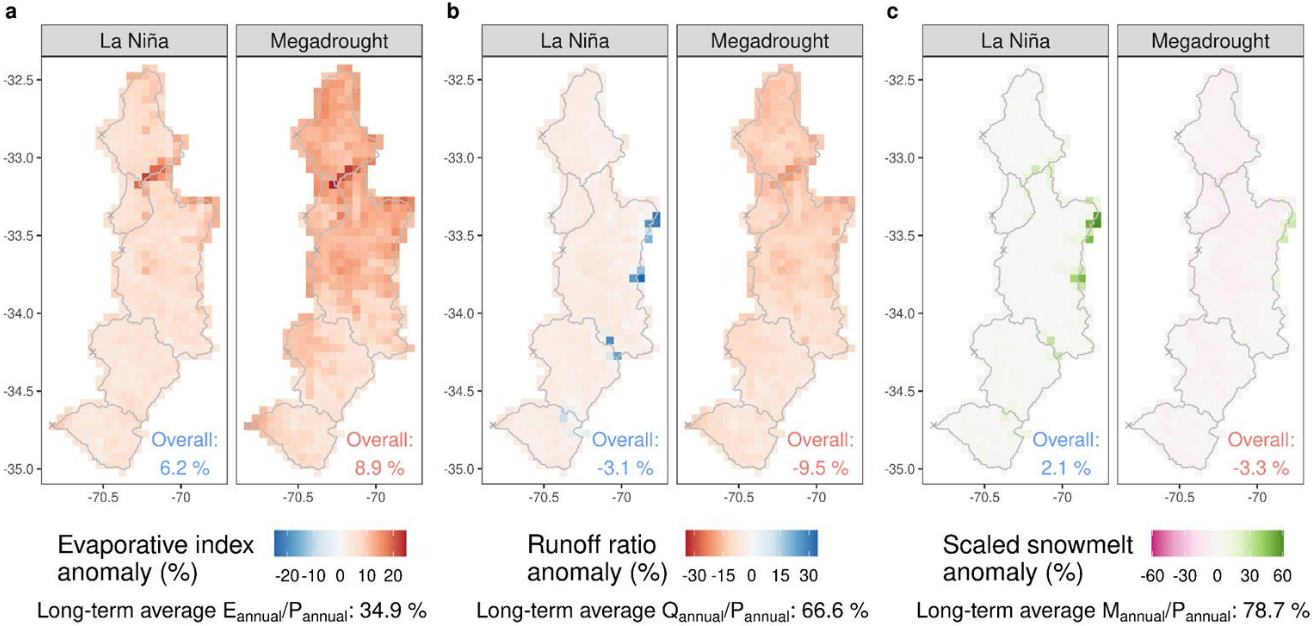


From total precipitation to solid precipitation and then snow accumulation, the deficit amplifies for the megadrought but softens for La Niña years (in %).

This modulation is possibly related to the seasonal temperature anomalies (LN and MD capture well-defined meteorological signatures).

Average anomalies		
Variable	**La Niña**	**Megadrought**
Precipitation (%)	-19.3	-26
Storms temperature (°C)	-0.3	0.2
Temperature JJA (°C)	-0.3	0.2
Temperature OND (°C)	0.2	0
Temperature JFM (°C)	-0.3	0.5

SP-2. Drought impacts with MESH



These three variables are already scaled by annual precipitation and could be interpreted as efficiencies.

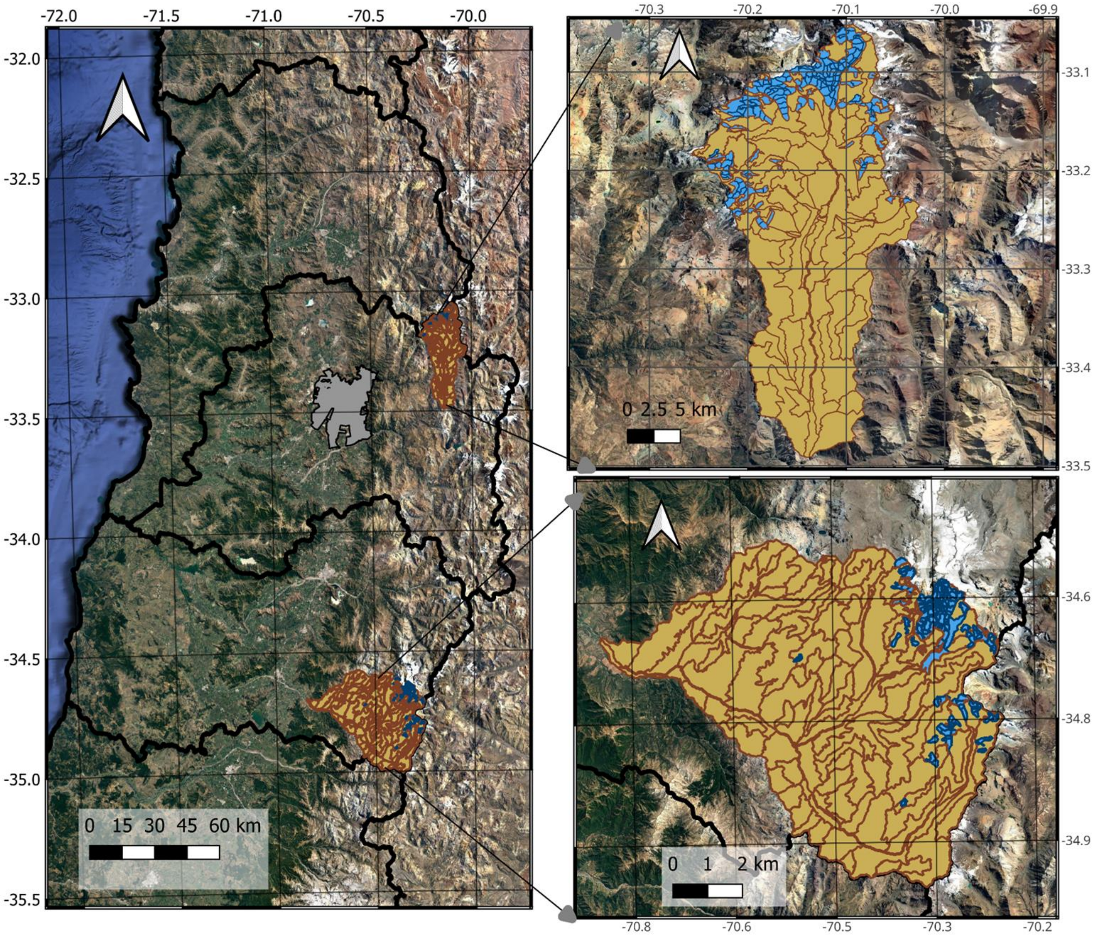
The MD depicts less efficiency in producing snowmelt (compared to the long-term average) and producing runoff (compared to LN), and more efficiency in producing evaporation.

Glacier GRU variables:

Long-term average	Annual contribution: $Q_{glacier}$ to Q (%)	Summer contribution: $Q_{glacier}$ to Q (%)
Aconcagua	3.6	7.8
Mapocho	2.8	5.9
Maipo	6	16
Cachapoal	7.8	23.2
Tinguiririca	5.8	20.3

Average anomaly	Annual $Q_{glacier}$, compared to long-term average (%)		Summer $Q_{glacier}$, compared to long-term average (%)	
	LN	MD	LN	MD
Aconcagua	-39	-80	-66	-84
Mapocho	-36	-77	-64	-83
Maipo	-22	-49	-37	-53
Cachapoal	-22	-34	-46	-43
Tinguiririca	-22	-32	-50	-45

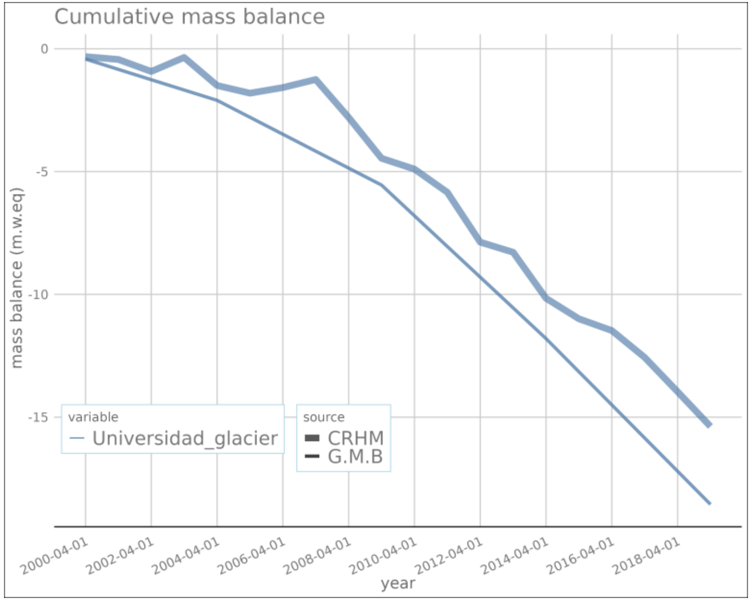
SP-3. Glaciohydrological impacts with CRHM

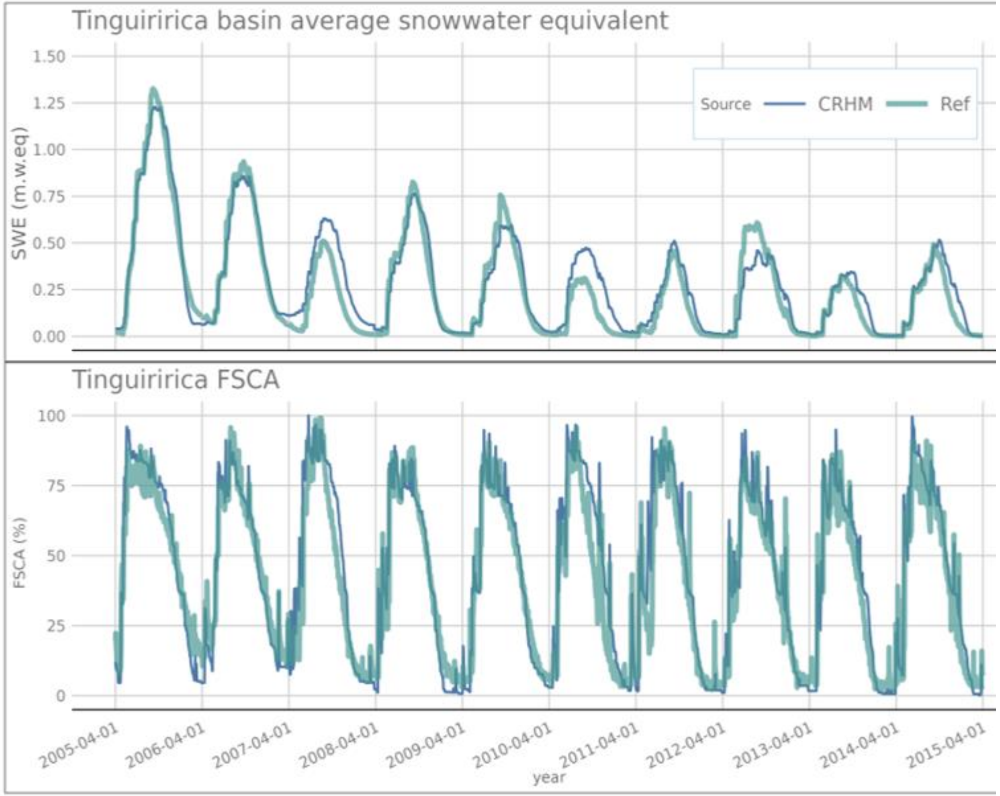


We selected two of the basins with the largest glacier area in the extratropical Andes: Rio Olivares (-33.49°) and Tinguiririca Bajo los Briones (-34.72°)

Basin	Area (km^2)	Glacier area (km^2)	Annual pp (mm)	Mean temp (°C)
Olivares River	542	73	455	2.8
Tinguiririca Bajo los Briones	1438	66	1418	4.2

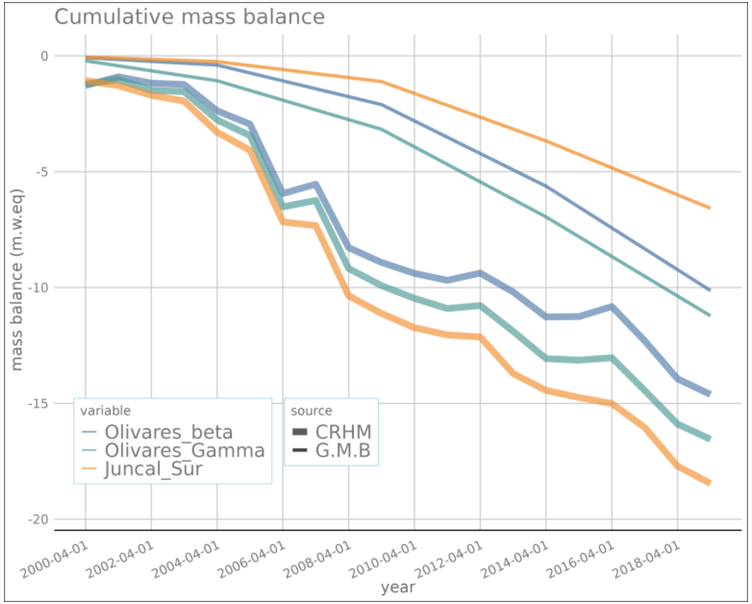
SP-3. Tinguiririca basin evaluation

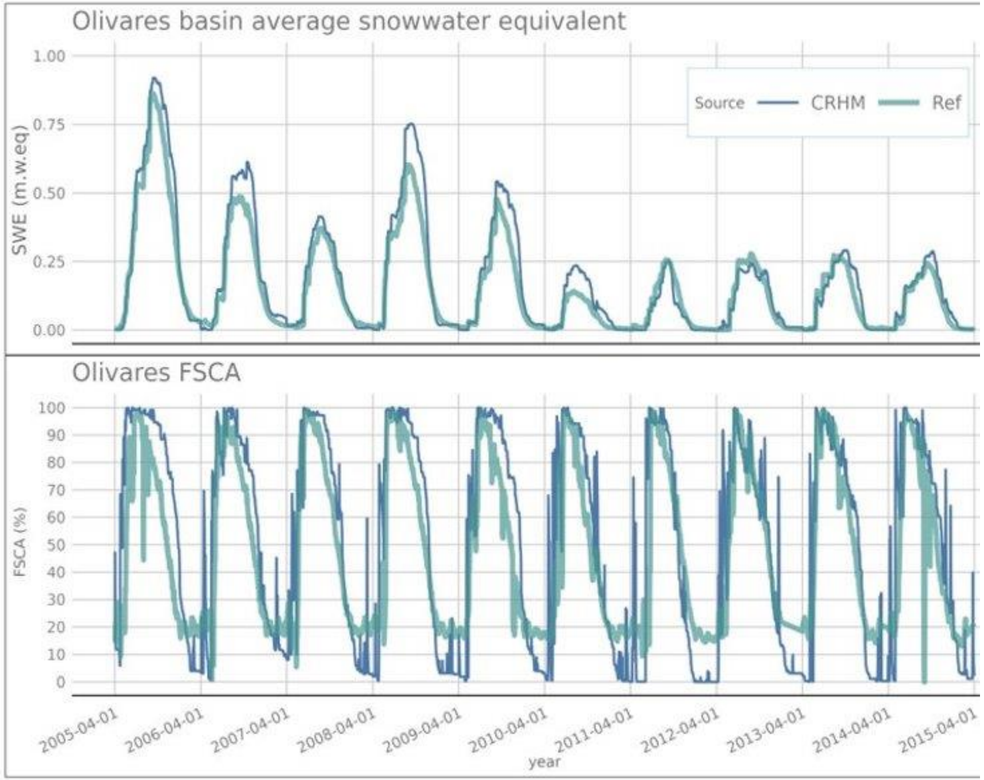




Variable	RMSE	R2	KGE	r pearson	α	β
SWE (m.w.eq)	0.10	0.90	0.85	0.96	0.91	1.11
FSCA (%)	9.86	0.85	0.89	0.95	1.06	1.08

SP-3. Olivares basin evaluation (parameters from Tinguiririca)





Variable	**RMSE**	**R2**	**KGE**	**r pearson**	**α**	**β**
SWE (m.w.eq)	0.08	0.80	0.85	0.96	1.15	1.23
FSCA (%)	19	0.70	0.70	0.87	1.25	1.09

Summary and perspectives

- Snow regional modelling CHM: proposal for full Andes implementation submitted Oct 5th 2023
- MESH implementation: model calibration to follow
- CRHM implementation: Better constrain MB+EB -> climate change scenarios
- Experimental catchments:
  - Maintenance and repairs planned for summer 2024 at Las Bayas (8) and Valle Hermoso (7)
  - Expansion of Las Bayas