Leveraging experimental catchment data for model verification- Andes

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INARCH Meeting October 15, 2024

ADVANCED MINING TECHNOLOGY CENTER
Ingeniería Civil
FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE
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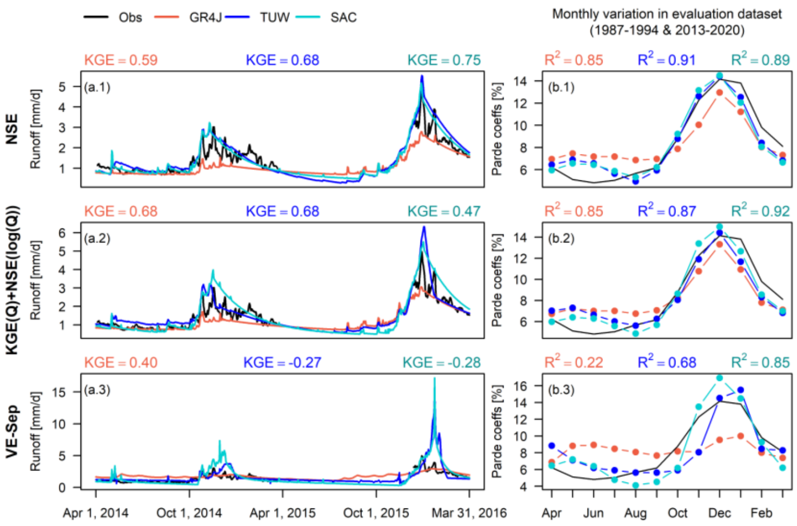
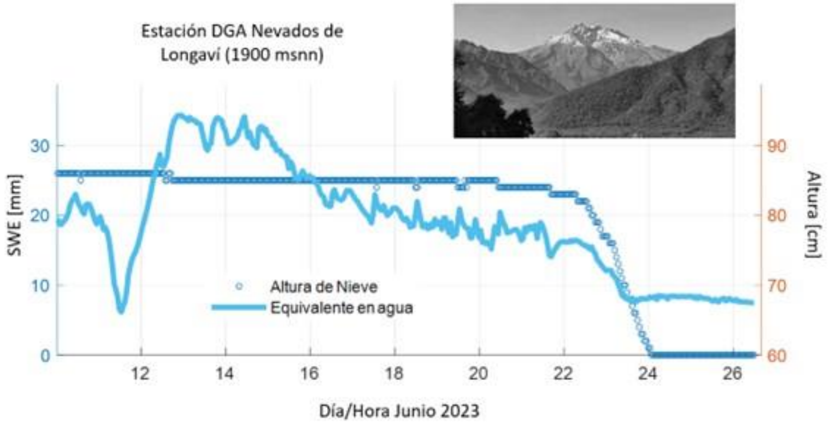
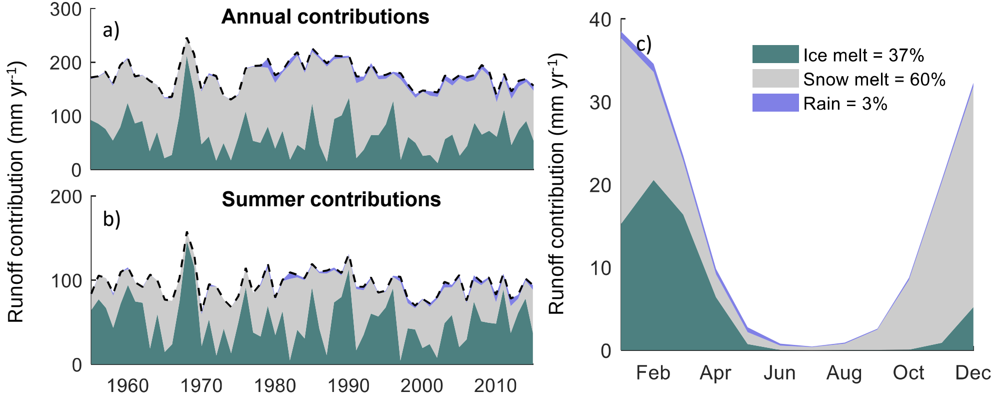
Motivation: the need to provide answers to specific questions



Seasonal streamflow forecasting (Araya et al., 2023)

Extreme event impacts





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

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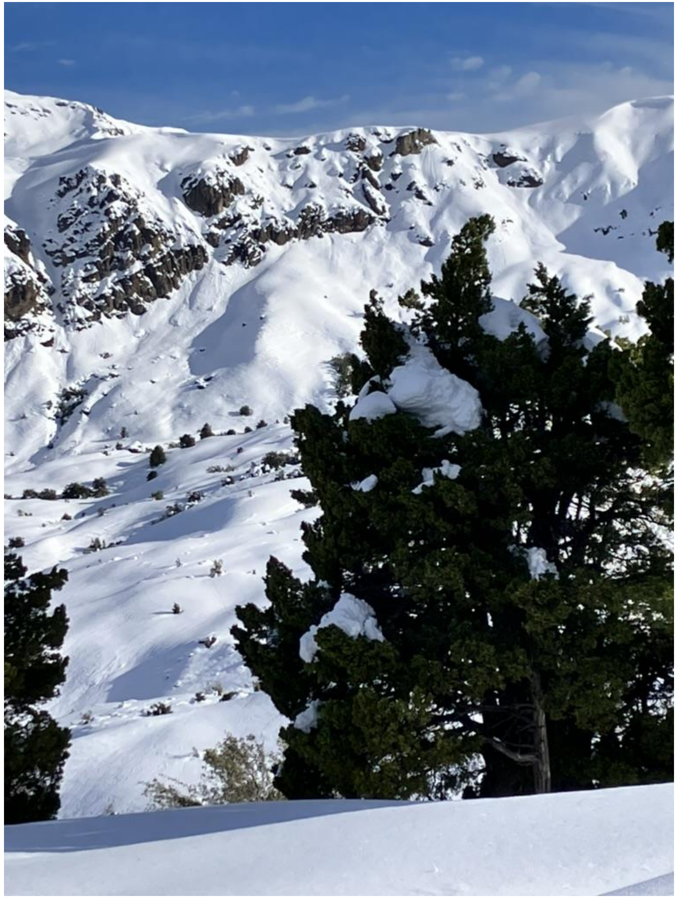
Reliable hydrological predictions in high-mountain areas remain an elusive objective

- Little to no observational meteorological networks
- Mountain precipitation unknown
- Limited remote-sensing capabilities
  - complex topography
  - cloudiness
  - high SWE accumulation
- Modeling parameterizations not yet fully tested in diverse geographic settings
- Feedback cycles: understanding and modeling
  - eg. glacier albedo
  - eg. marginal snowpacks



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What can we learn from alpine experimental catchments and research stations?

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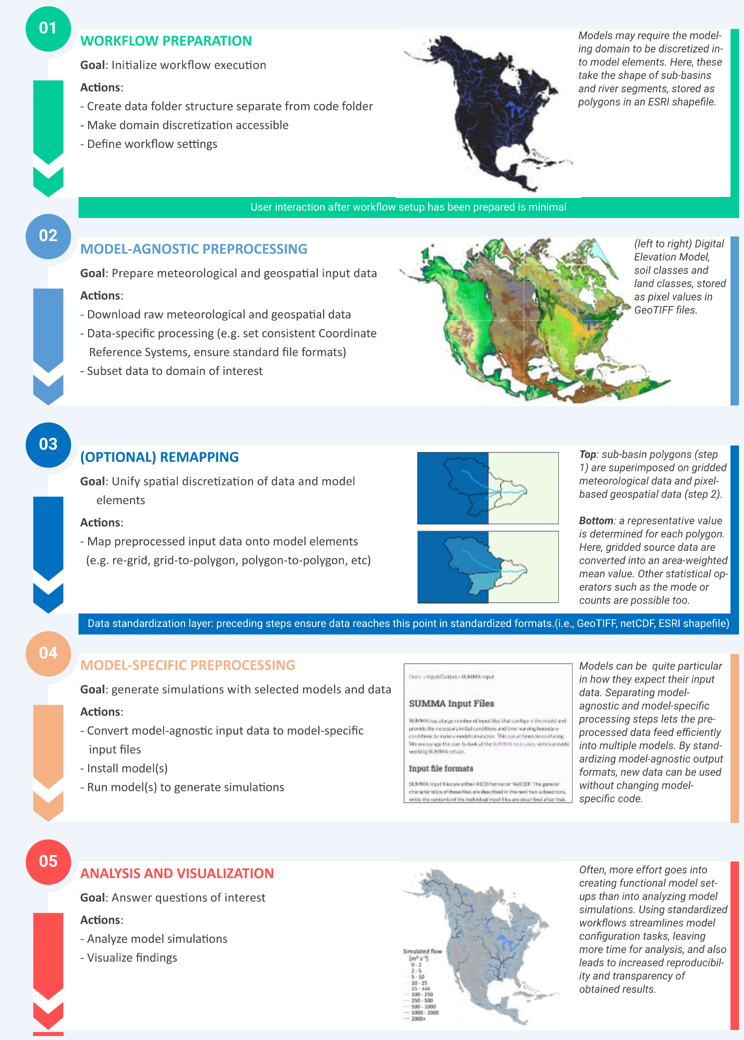
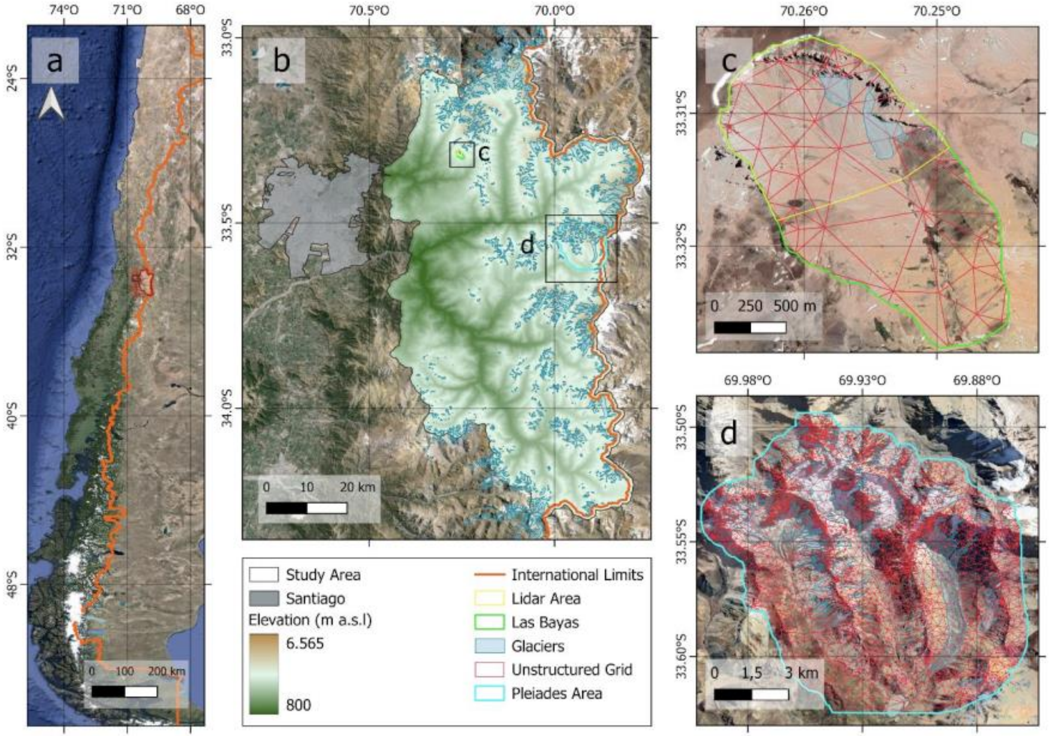
CWARHM Approach (Knoben et al. 2022)

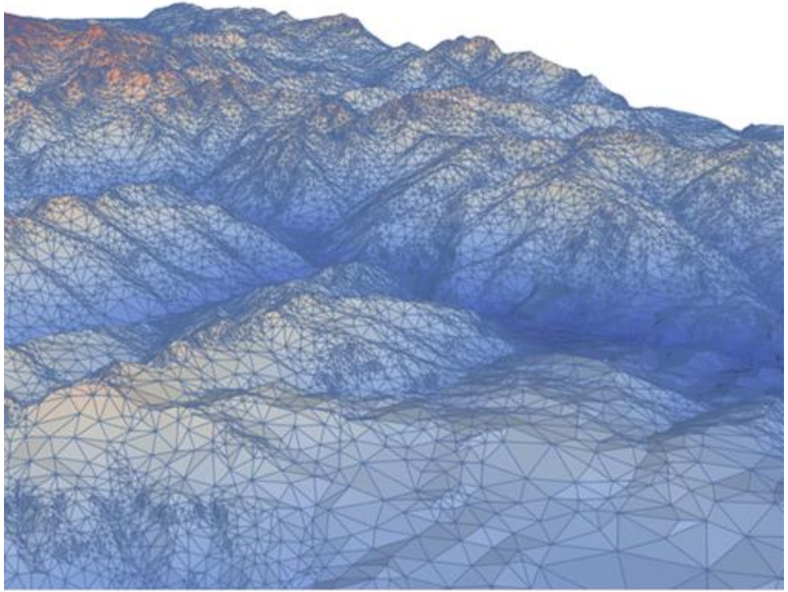
1. Workflow preparation: domain discretization in 1) TIN; 2) Grid; 3) HRU
2. Model-agnostic preprocessing
   a. NWP and reanalysis met forcings (ECMWF, ERA5-Land)
   b. Scaled station-based local gridded met. reference product (Álvarez-Garretón et al., 2018; Boisier, 2023) -> daily precipitation, max/min 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

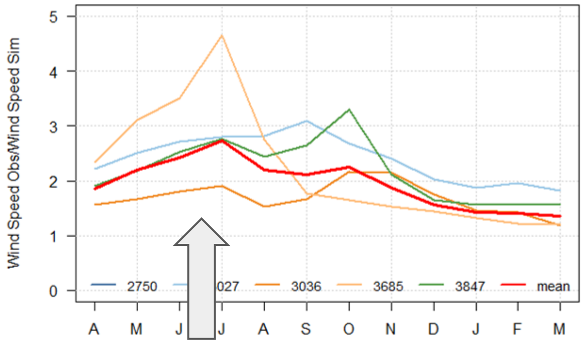
Min theoretical area (m²)	Max RMSE (m)	Number of triangles	Area range (m²)	Median area (m²)	Mean area (m²)	Mean resolution (m)
2 500	15	215 000	400 – 1 780 000	18 000	27 600	166



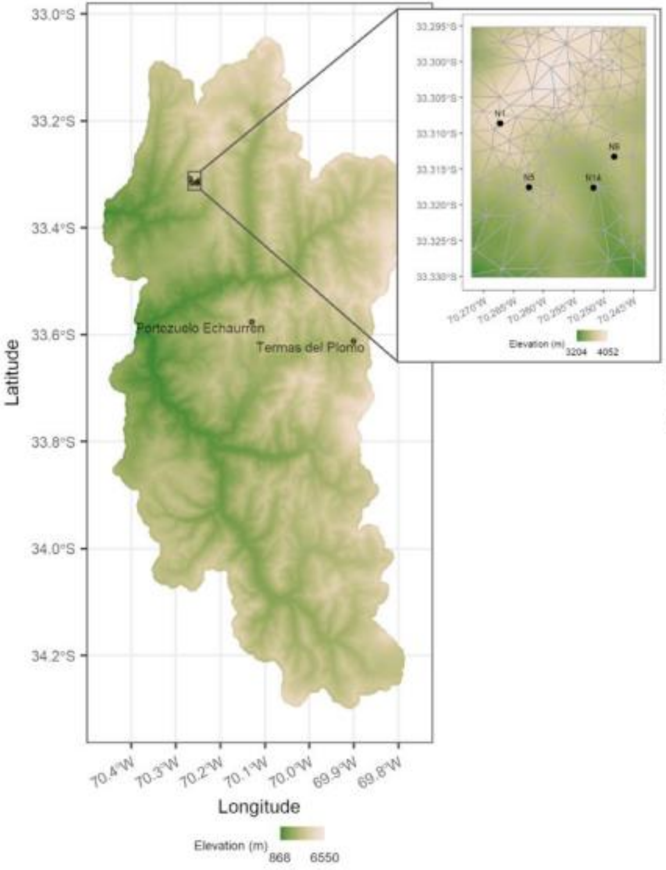


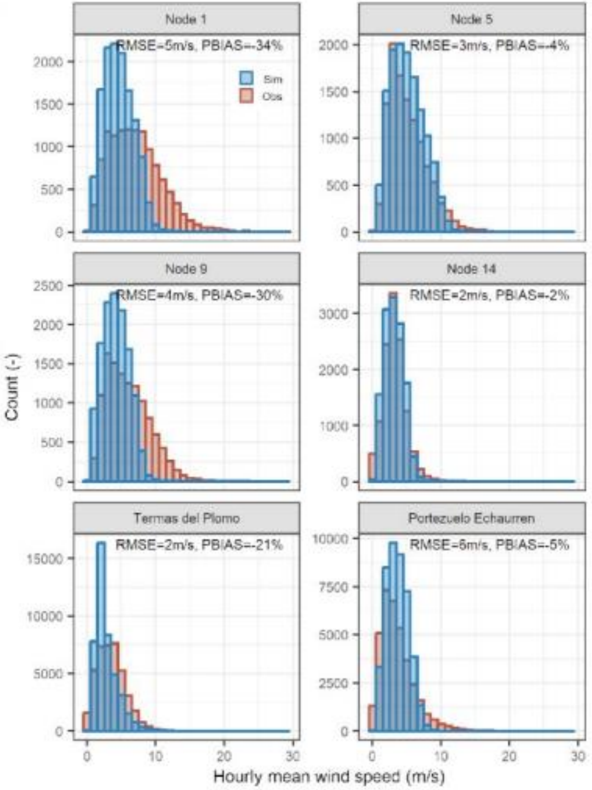
Local wind speed observations

Wind speed: monthly correction factor applied to NWP output (ECMWF)



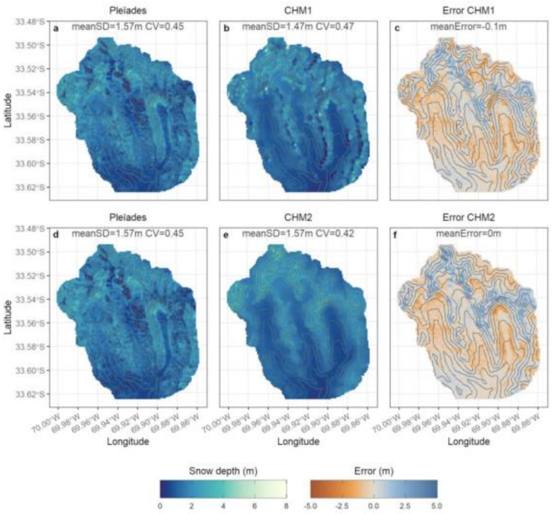
2-3 fold increase in w.s. during winter months.

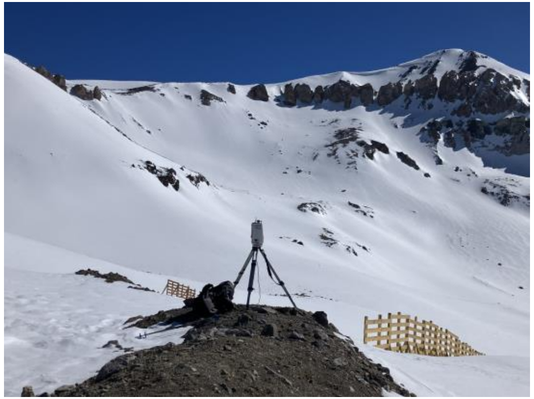




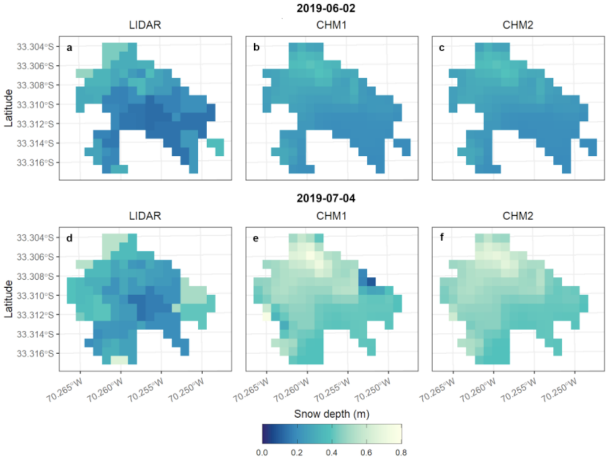
High-resolution snow depth

100 km2
Few acquisitions per season+
m-scale

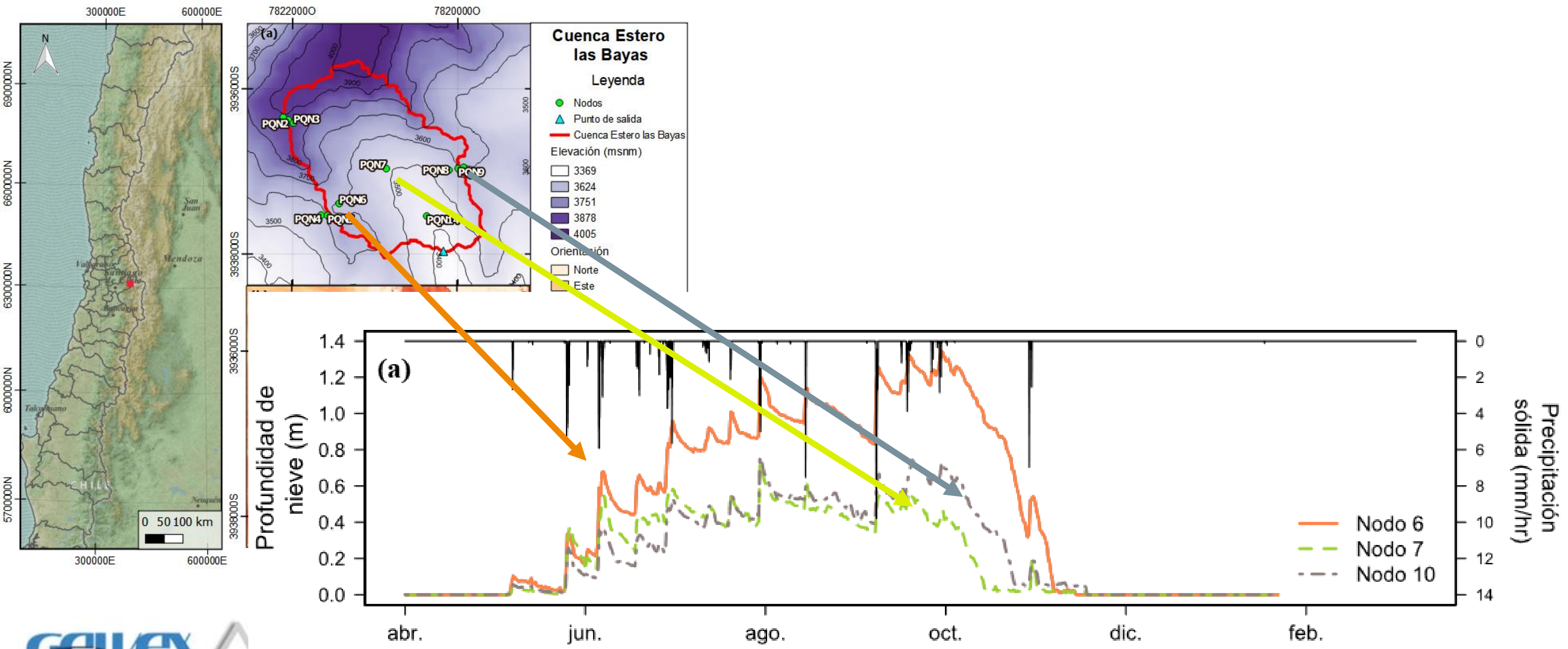




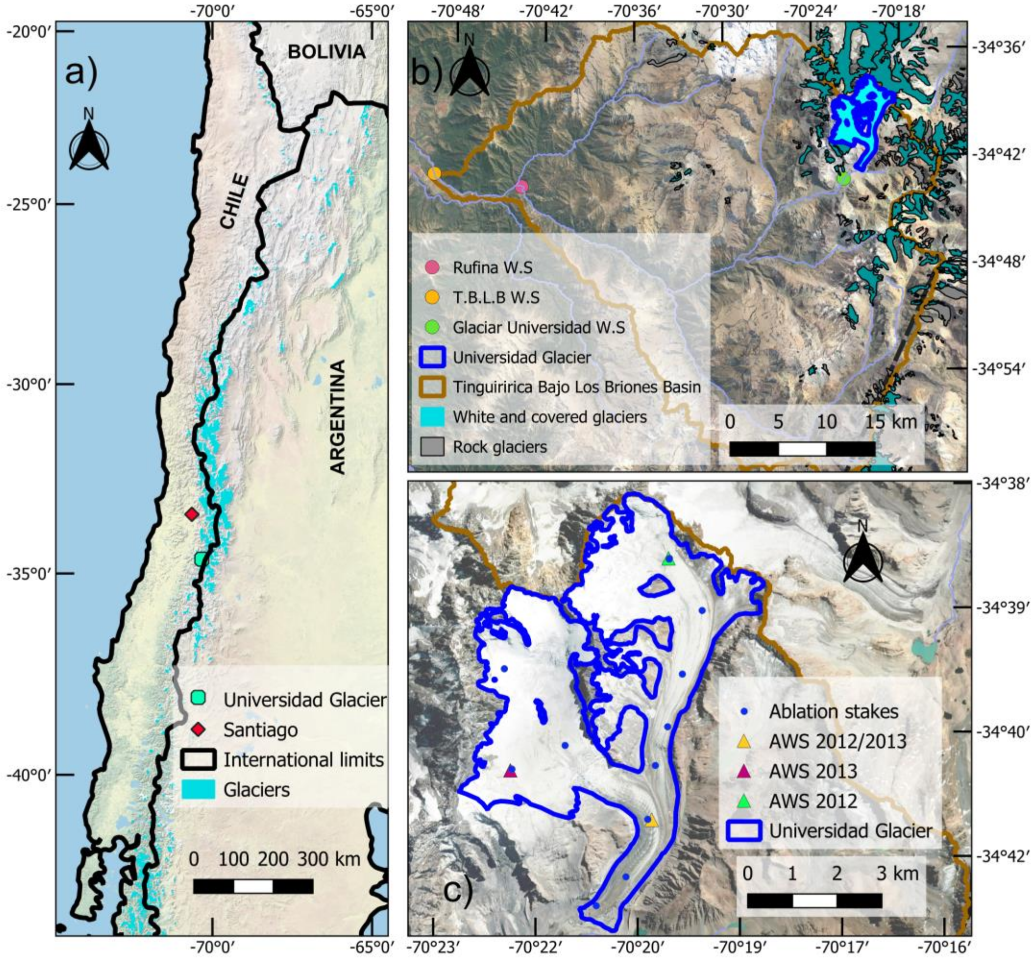
1 km2
Few acquisitions per season
cm-scale



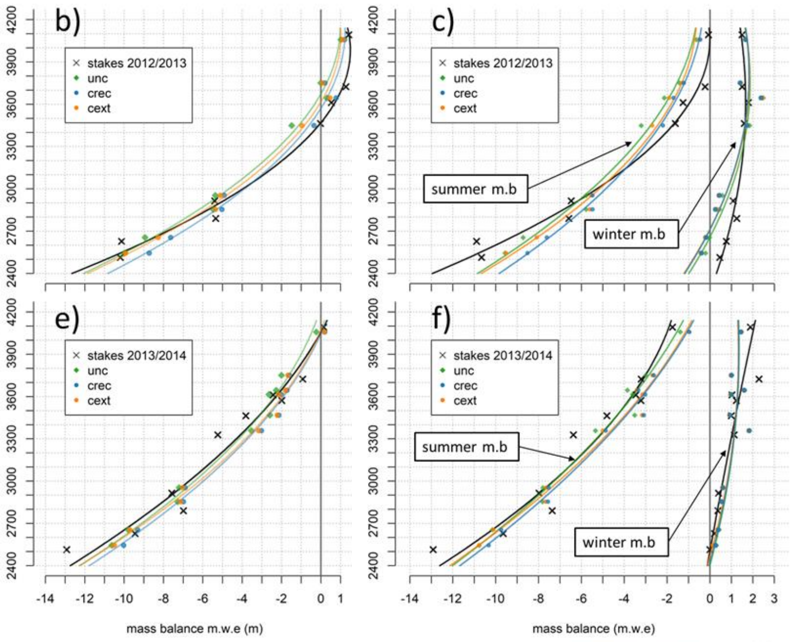
Continuous snow depth



SP-3. Glaciohydrological impacts with CRHM



Just a few ablation measurements allow to identify strengths and weaknesses



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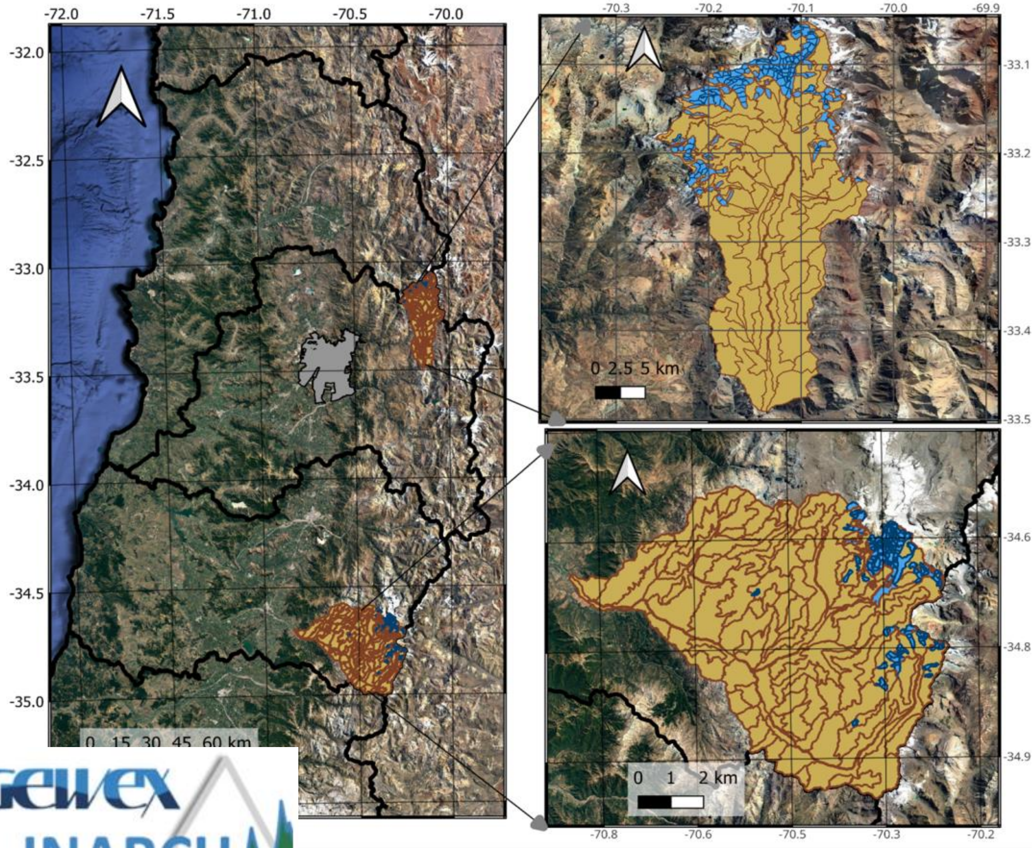

We selected two of the basins with the largest glacier area in the extratropical Andes: Rio Olivares (-33.49°) and Tinguiririca Bajo los Briones (-34.72°)

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

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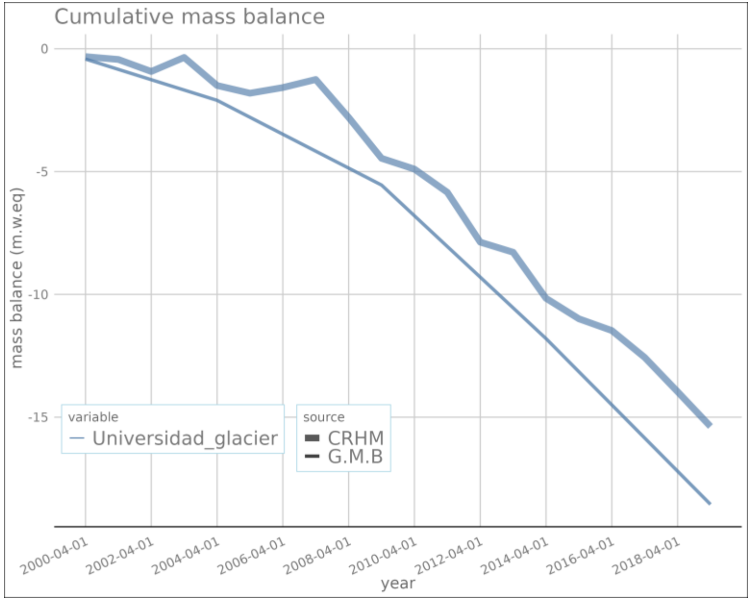
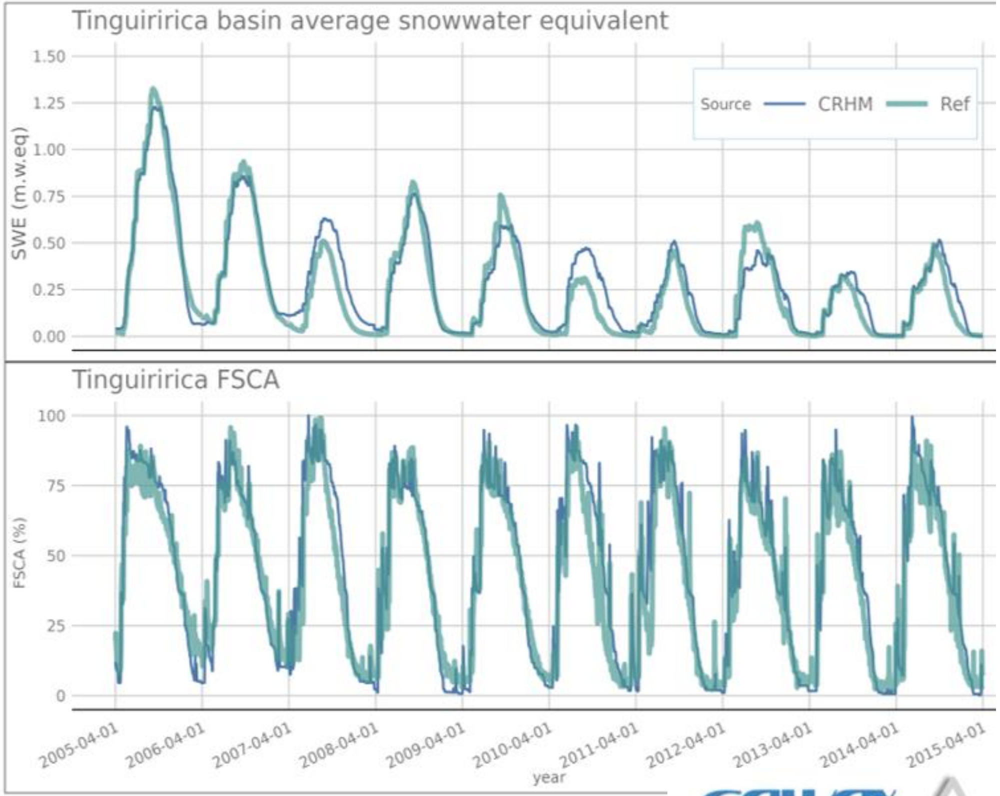
SP-3. Tinguiririca basin evaluation





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

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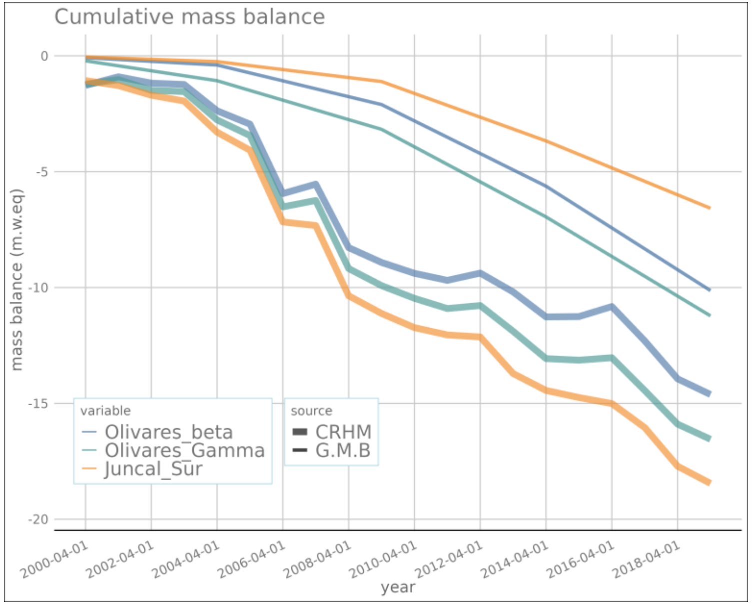
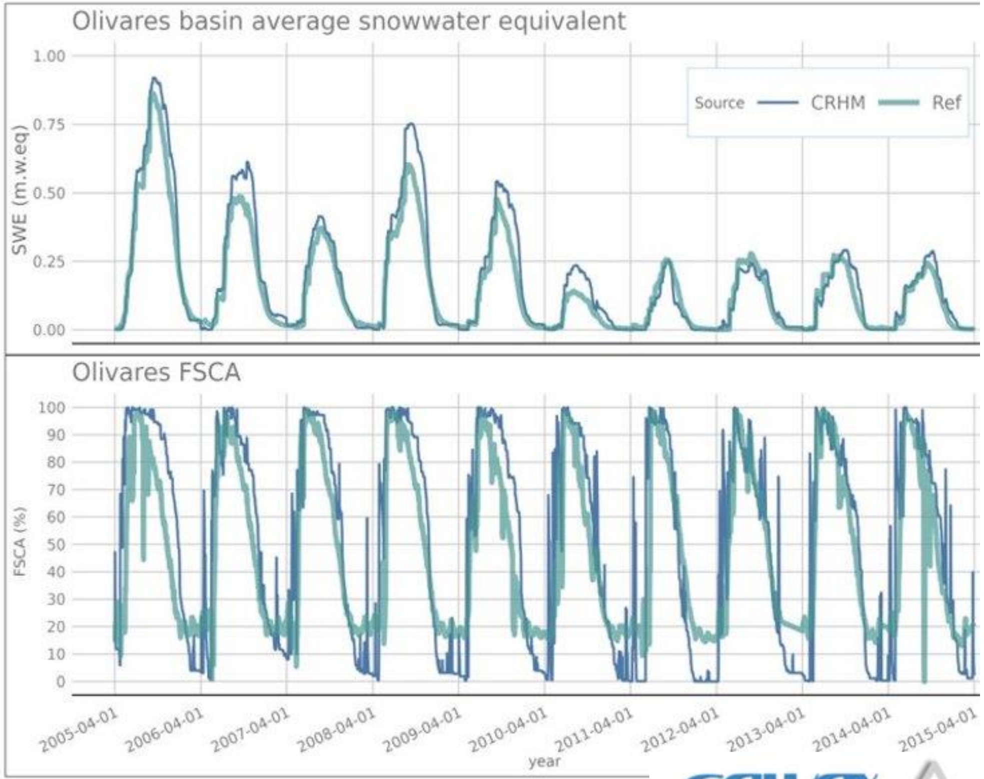
SP-3. Olivares basin evaluation (parameters from Tinguiririca)





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

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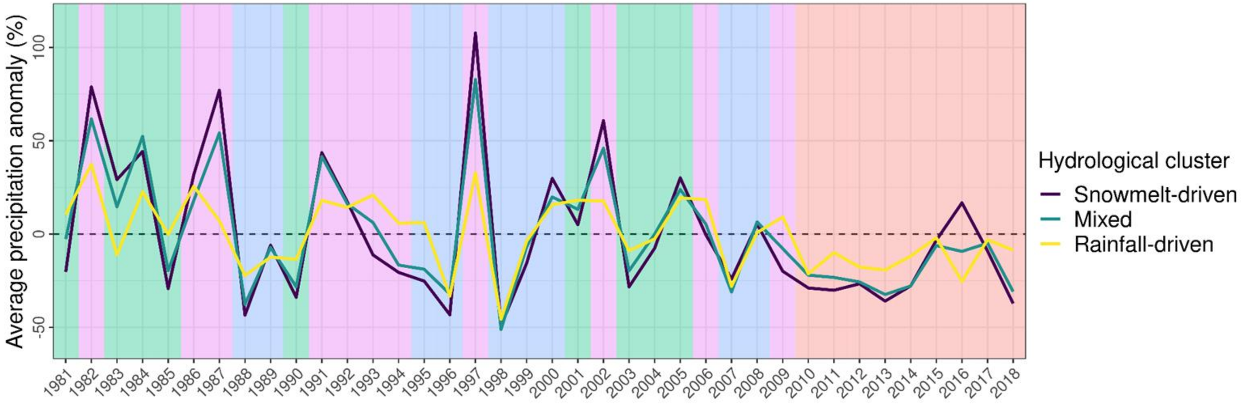
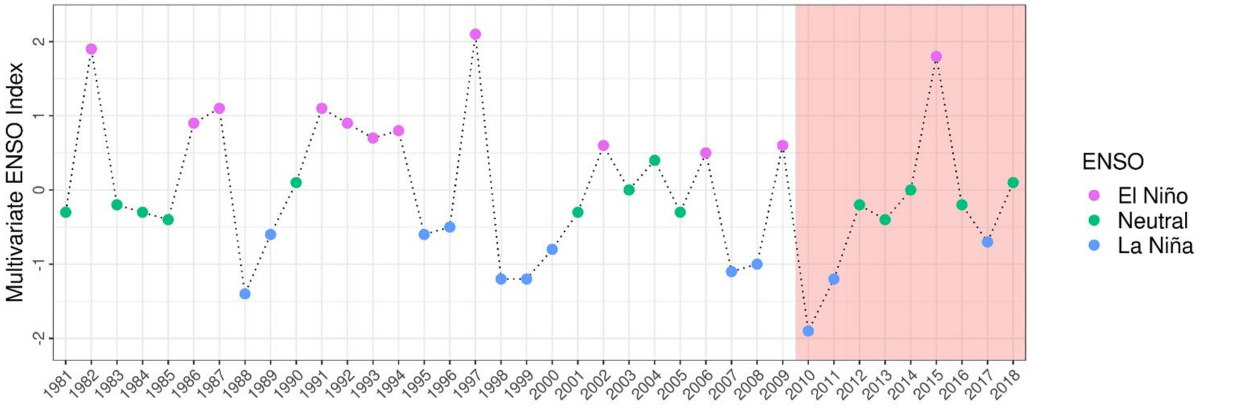
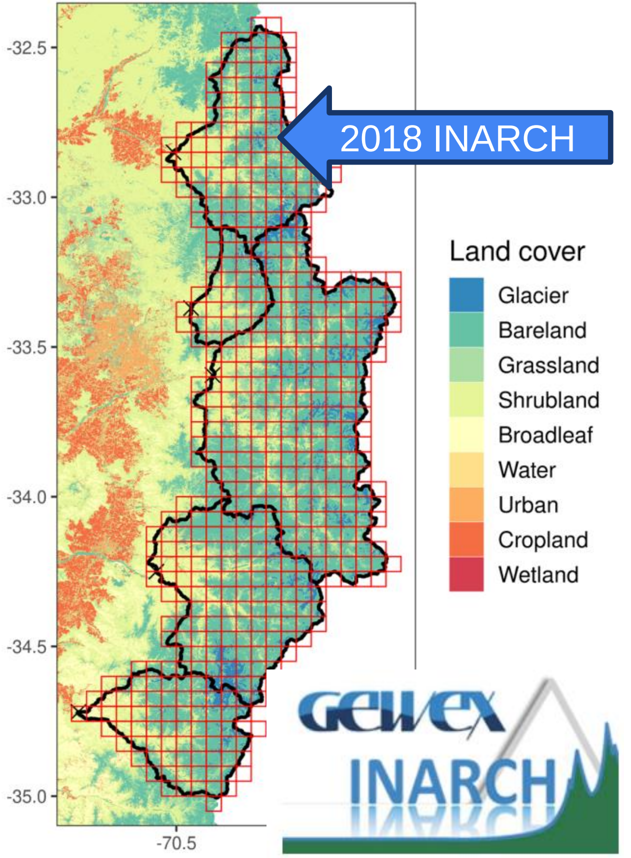
SP-2. Drought impacts with MESH

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.

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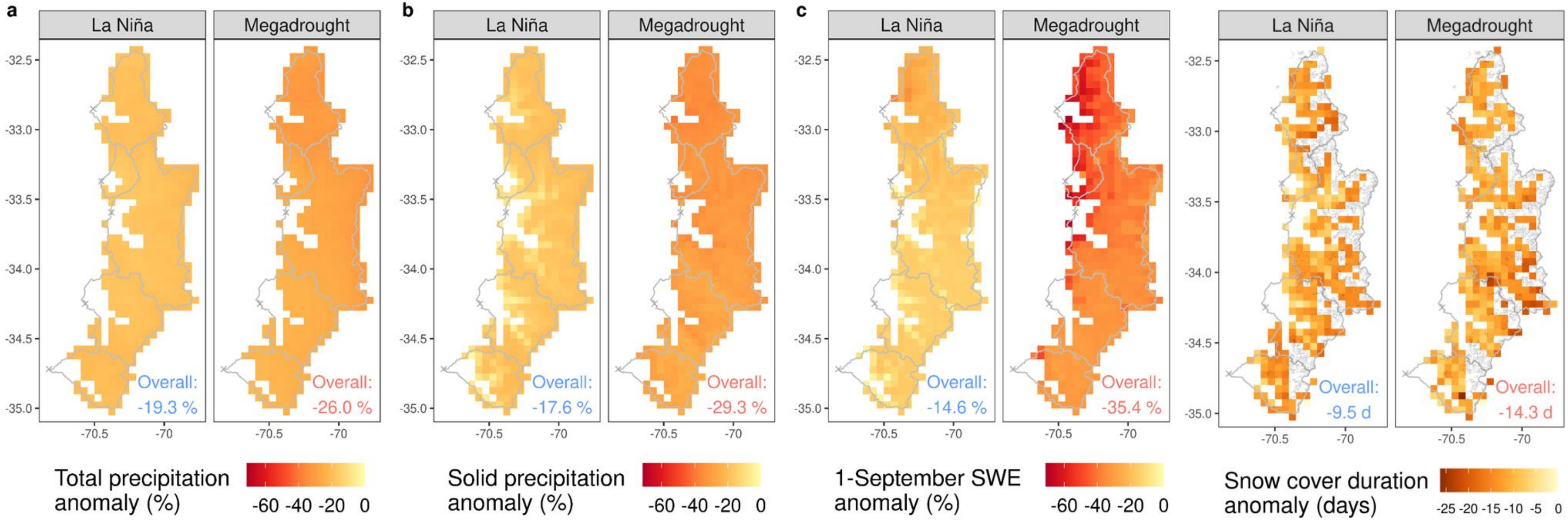

From total precipitation to solid precipitation and then snow accumulation, the deficit amplifies for the megadrought but softens for La Niña years (in %).

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

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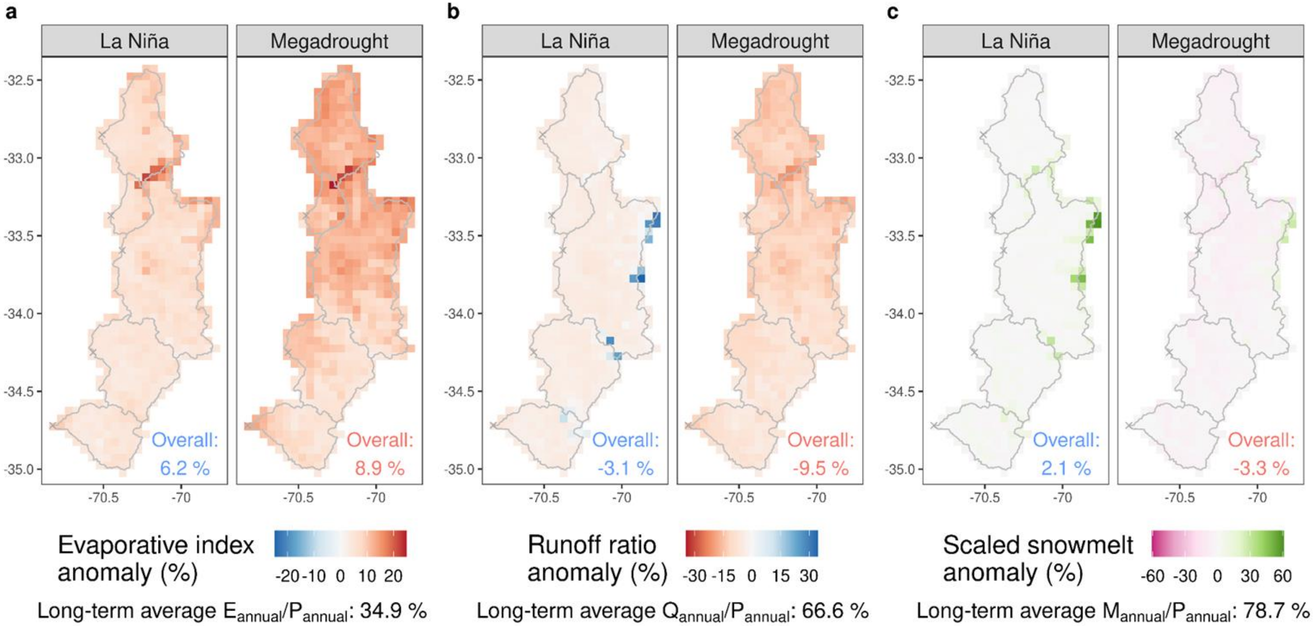

These three variables are already scaled by annual precipitation and could be interpreted as efficiencies.

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

Summary and perspectives

- Physically based modeling tools offer the opportunity to assimilate data from diverse sources
- Experimental catchments are key to test hydrological hypotheses and identify avenues for improvement in hydrological predictions
- Combination of defensible models + assimilation of remote/in-situ data emerging as desirable strategy for timely hydrological predictions for social preparedness.

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