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A modelling study of historical snow droughts in the extratropical Andes Cordillera and their hydrological implications

James McPhee, **Diego Hernandez-Neira**, Alonso Mejías, María Courard, Zelalem Tessema, Mohamed Ahmed, Alain Pietroniro, John Pomeroy.

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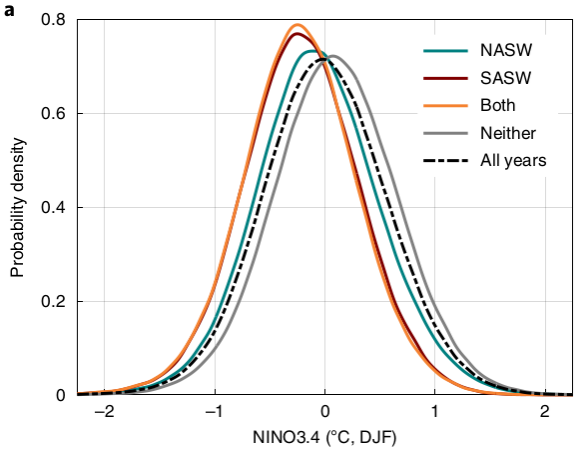
The 2010 megadrought in central Chile has no historical analogues in spatial and temporal extension (Garreaud et al.; 2017, 2019). It has been attributed to a joint anthropic effect and natural variability (Boisier et al., 2016; Garreaud et al., 2021).



NASW and SASW megadroughts coupling related to cold ENSO conditions during the past millennium (Steiger et al., 2021)

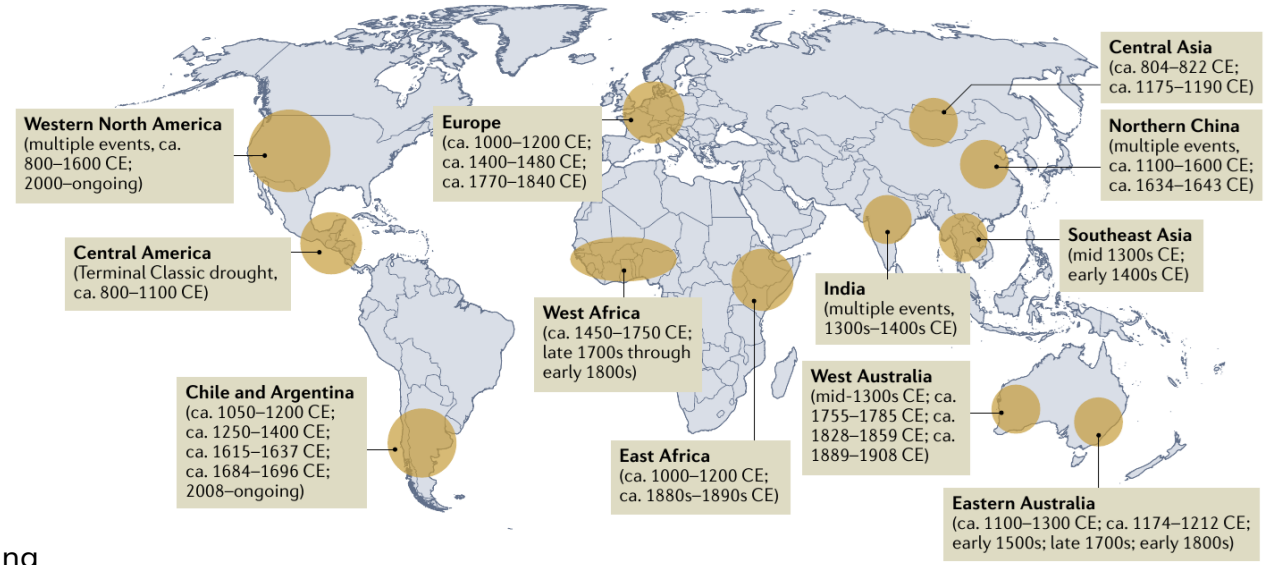
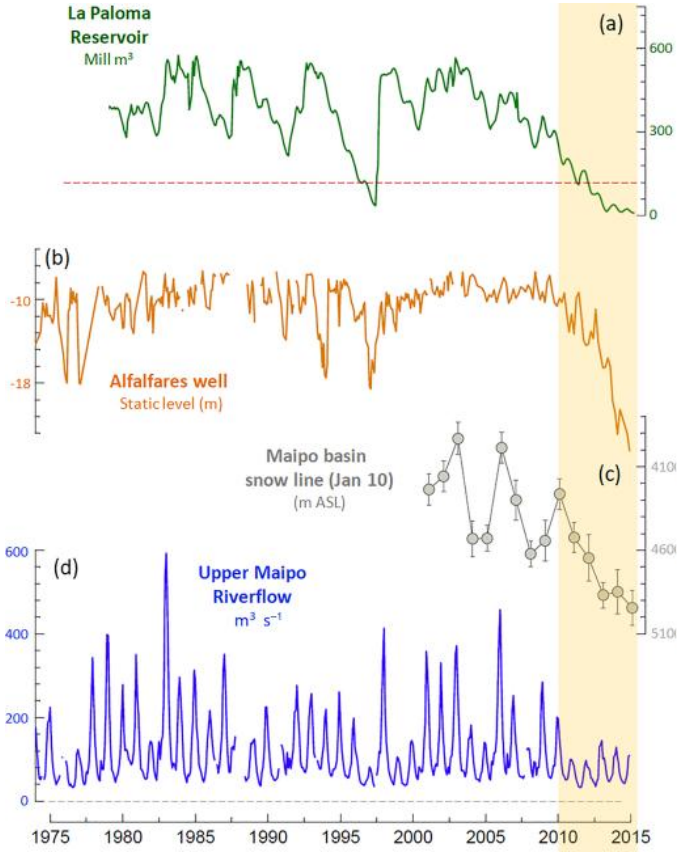


Fig. 2 | **Common Era megadroughts.** Timing of Common Era (Year 1–present) regional megadroughts recorded in observations and the palaeoclimate record. Although there is variability in the timing and recurrence, the palaeoclimate record demonstrates that megadroughts are an intrinsic part of natural hydroclimate variability during the CE, affecting regions on every continent outside Antarctica.

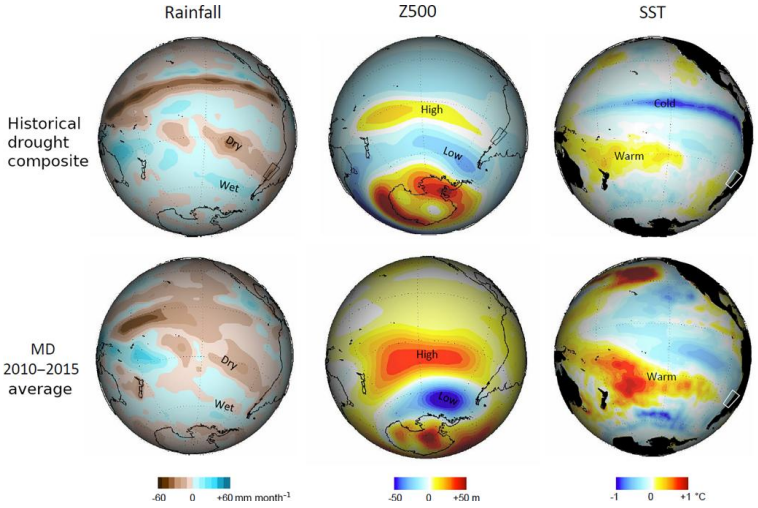
(Cook et al., 2022)



Garreaud et al. (2017)

- What are the dominant hydrological characteristics of snow droughts in the Mediterranean Andes?
- How might these characteristics evolve with climate change?

Garreaud et al. (2021)



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Modélisation Environmentale Communautaire – Surface and Hydrology (MESH) model

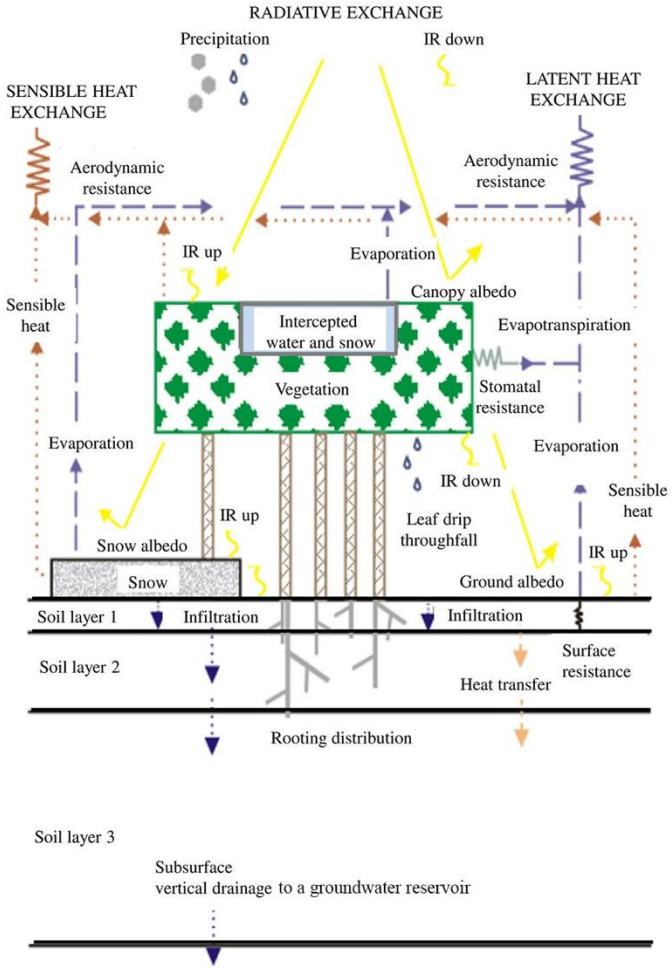
CLASS land surface scheme

MountainMESH: Sub-grid forcing scaling

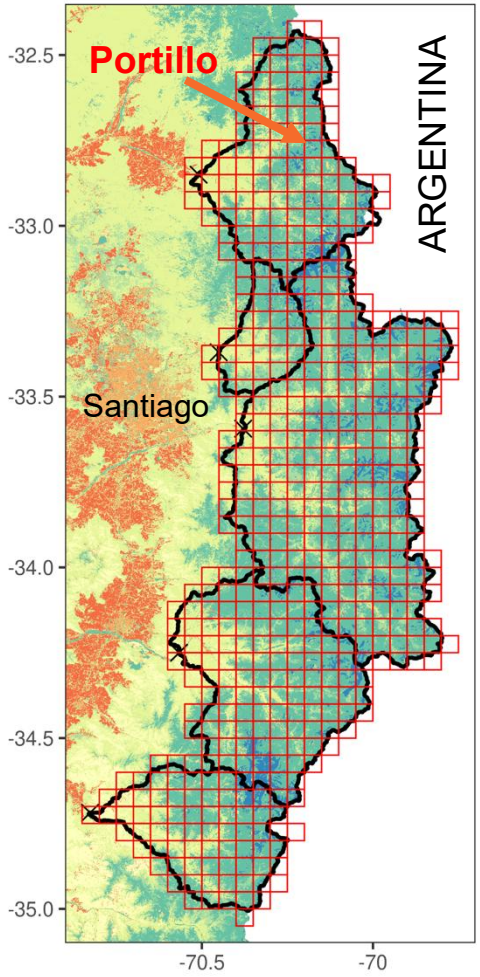
One-layer snow; three-layer soil; glaciers.

Streamflow routing

Bias-corrected ERA5Land forcing

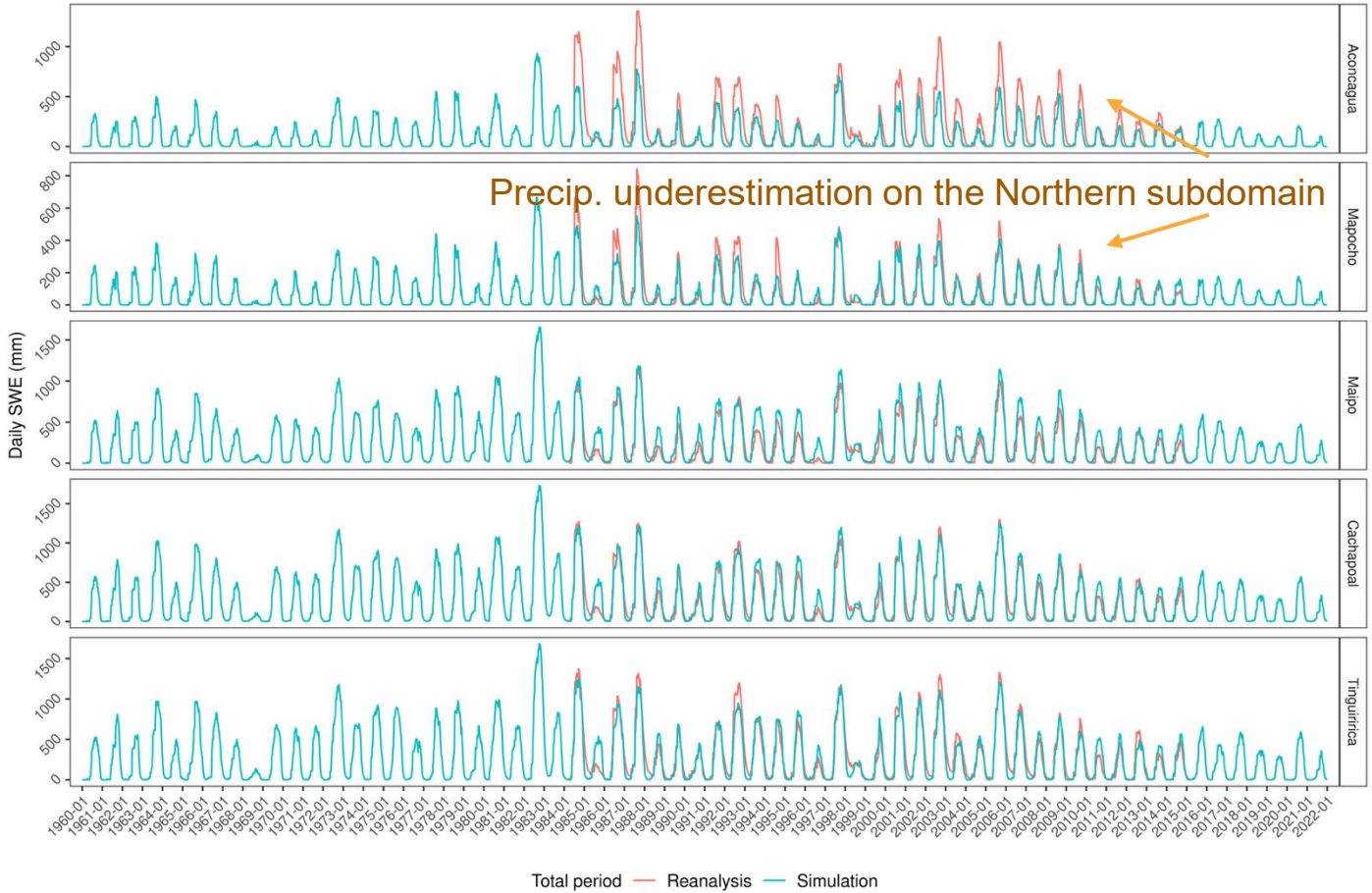


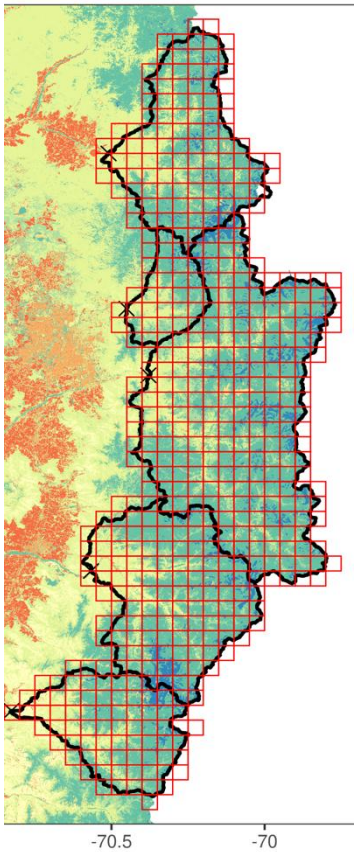
(Verseghy, 2012)



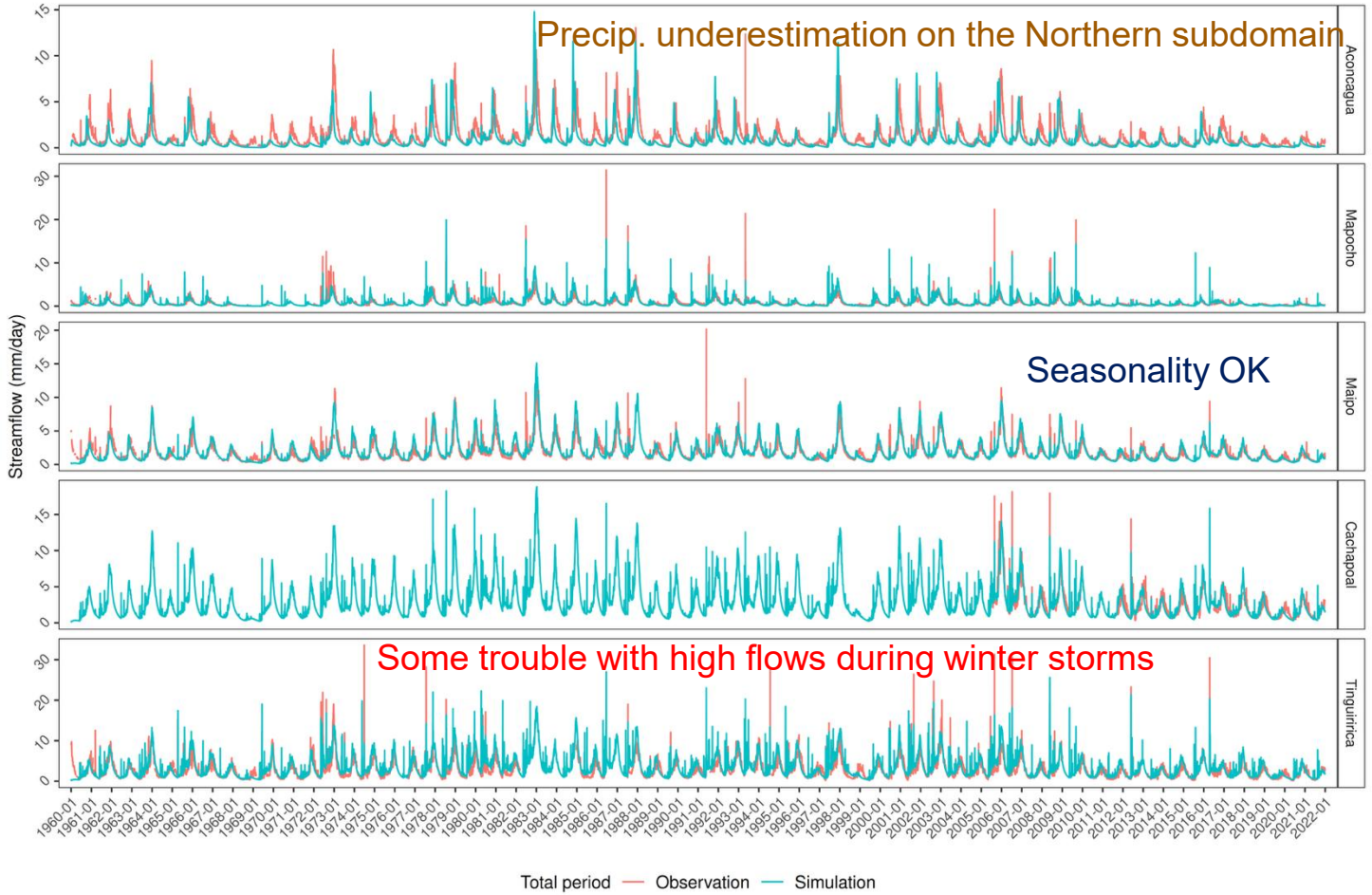
Glacier areas range from 2.9% to 11% of the watersheds. Bareland: from 57% to 68%.

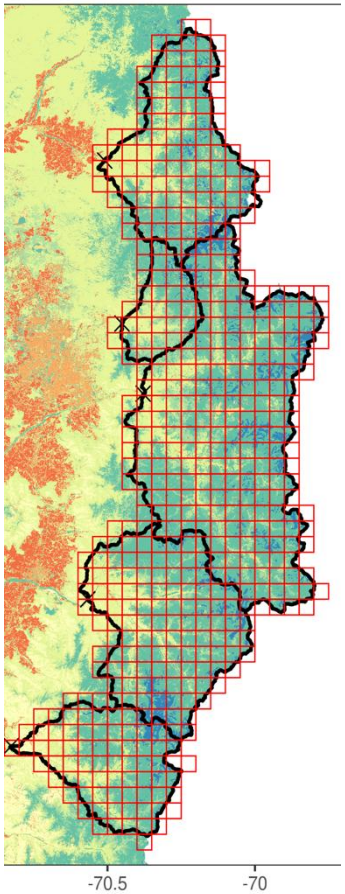
Model evaluation: SWE



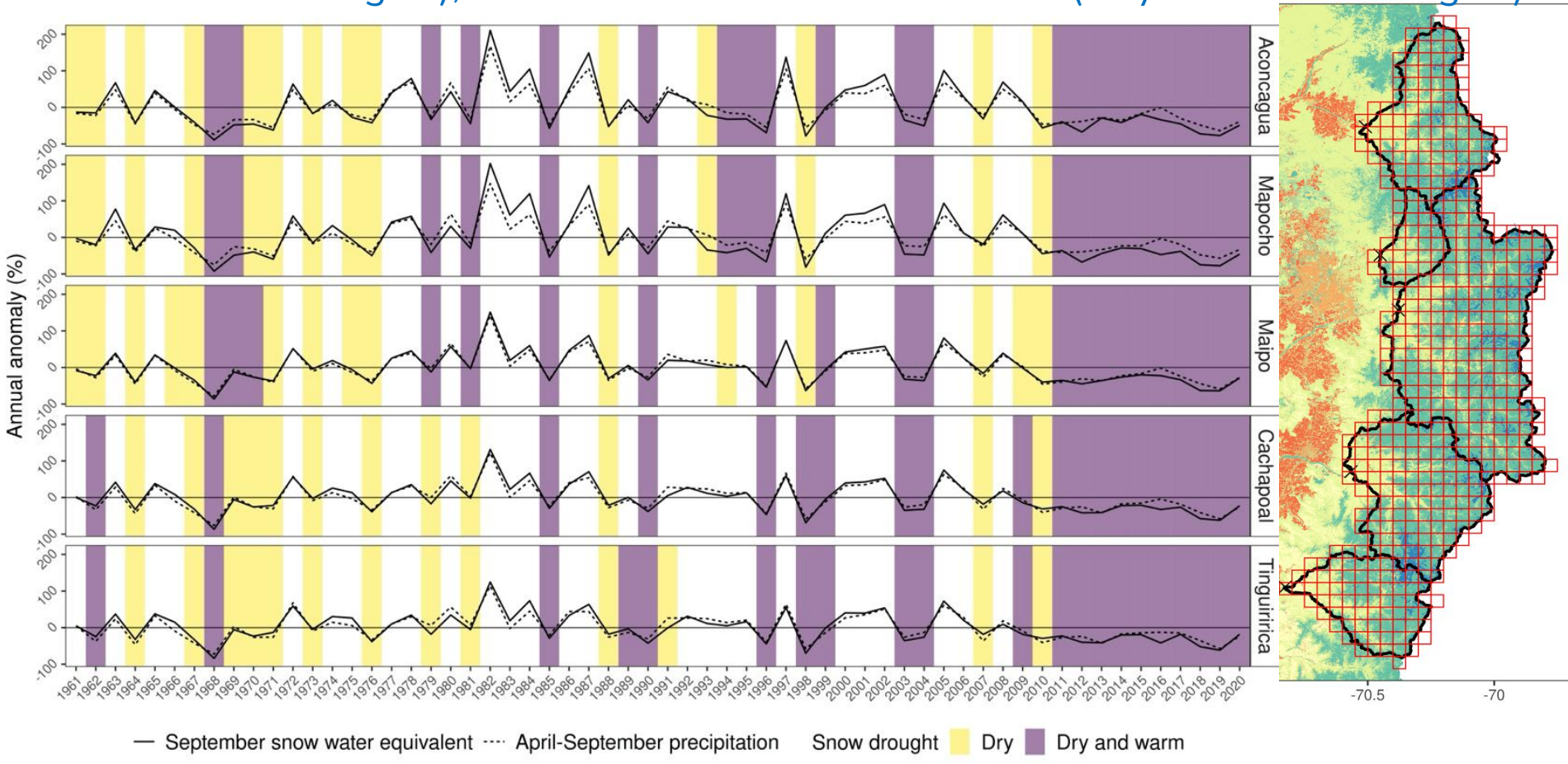


Model evaluation: streamflow



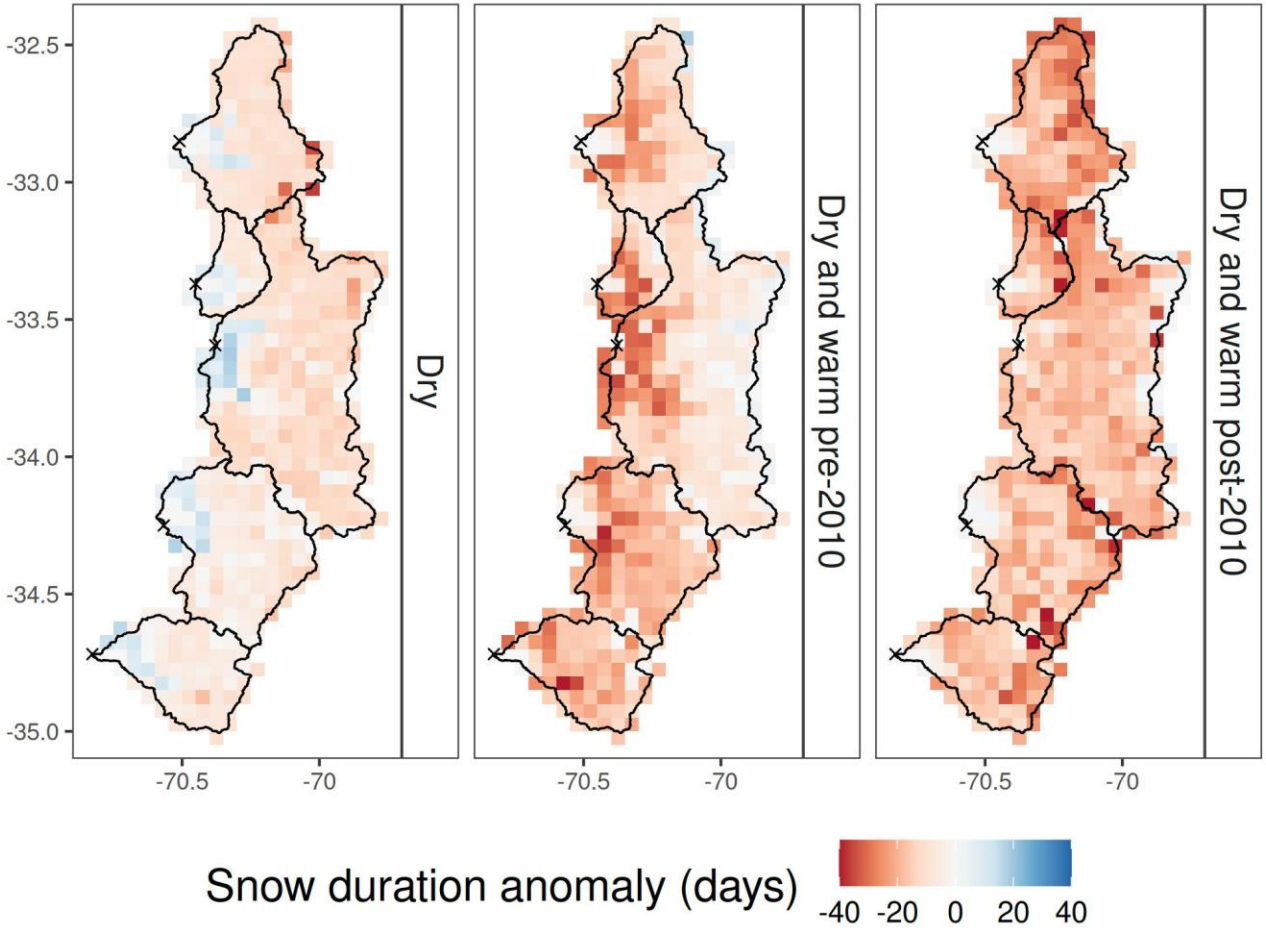


Snow drought either associated with precipitation deficit (“dry drought”), or also concurrent with ΔTJJA > 0 (“dry and warm drought”)

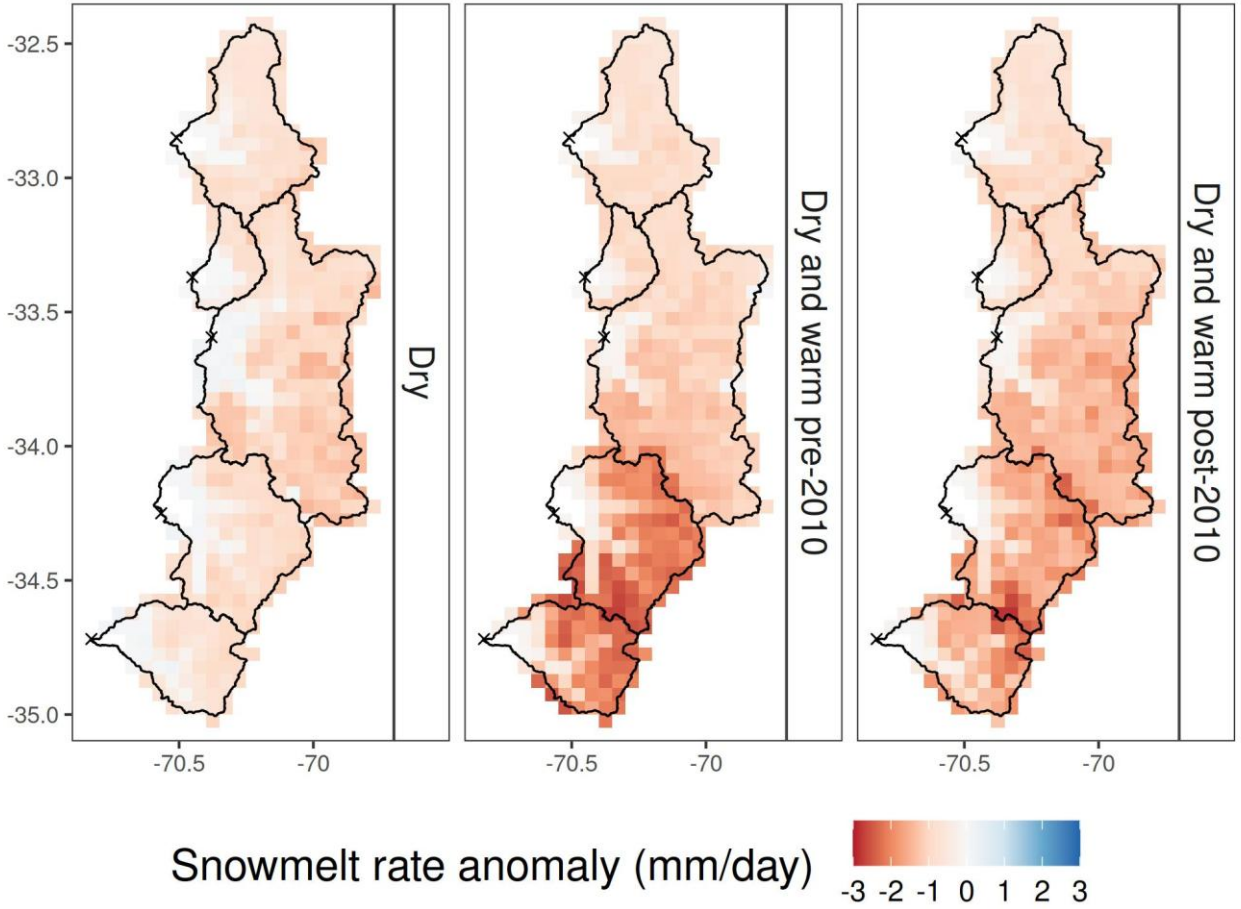


Different patterns of snow cover duration reduction before and after 2010

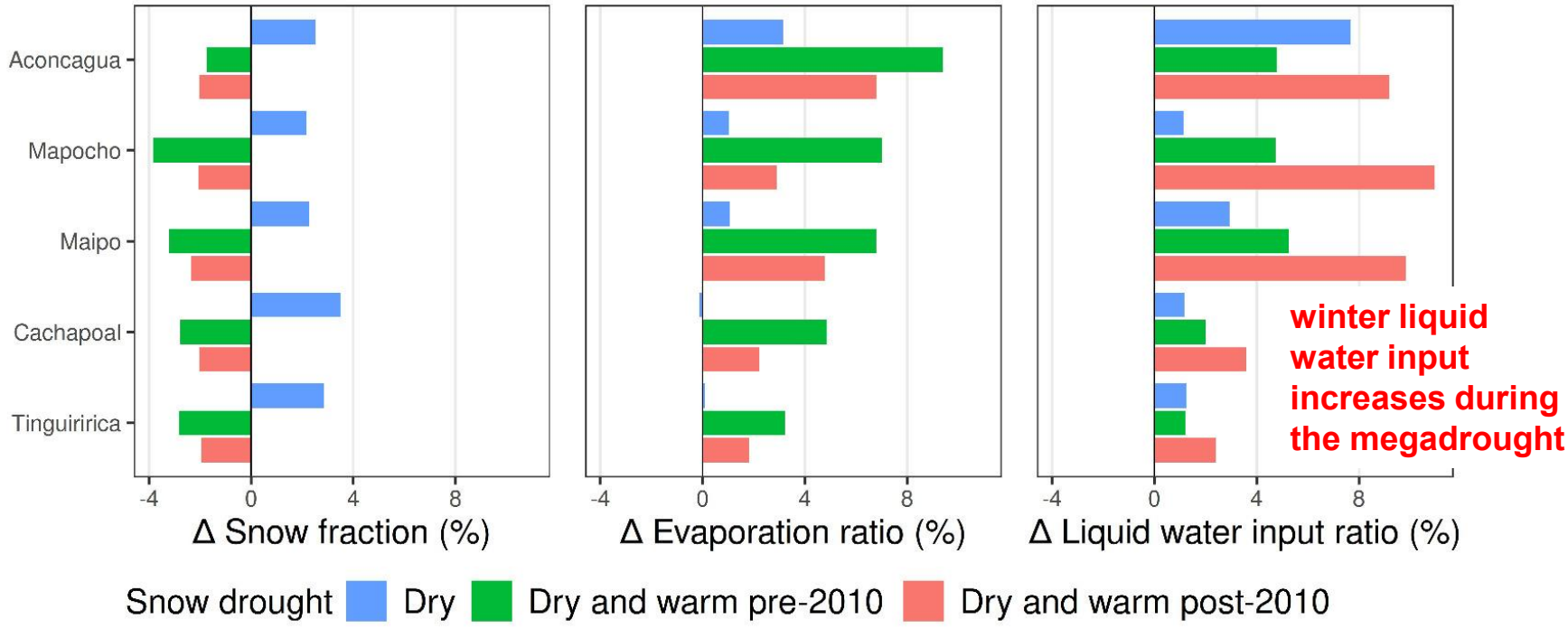
Dry droughts show smaller effect on snow cover duration



Snow droughts associated with **lower melt rates** overall

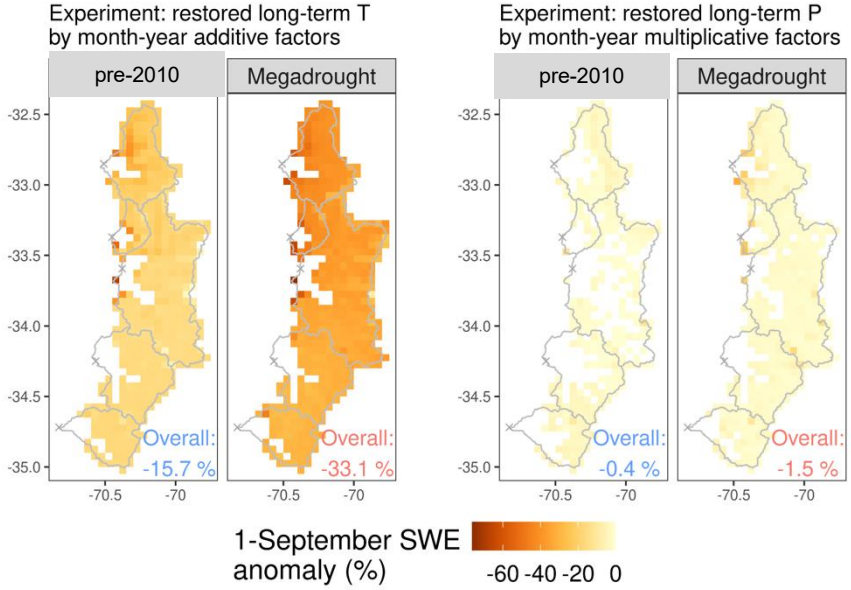


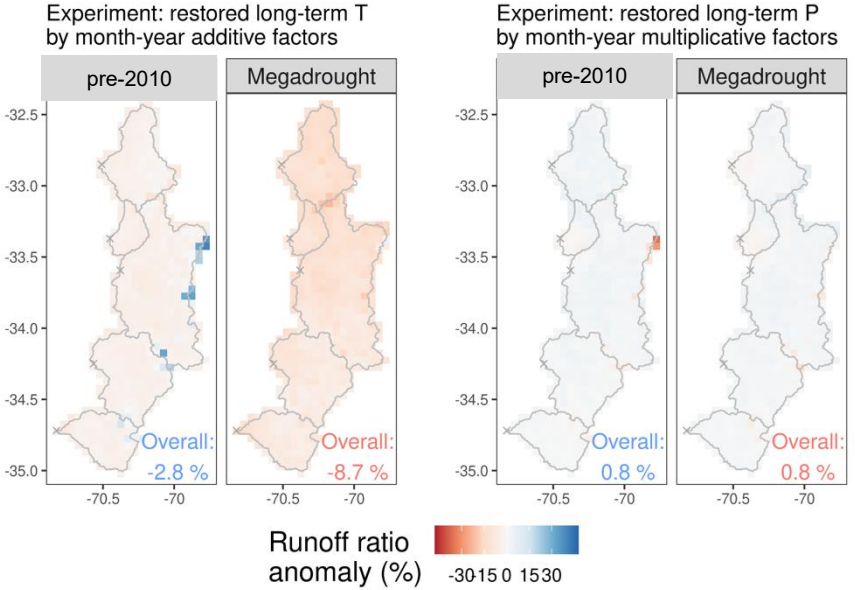
Fall and Winter (Apr-Sep) anomalies: less snow fraction, more evaporation, more liquid water input to the soil during dry and warm droughts.



winter liquid water input increases during the megadrought

Differences in propagation and efficiency are explained by precipitation anomaly (and secondarily by temperature anomaly).





1-September SWE anomaly (%)		
Experiment	**Pre-2010**	**Megadrought**
Control	-14	-33.5
Restored T	-15.7	-33.1
Restored P	-0.4	-1.5
Restored P-T	-0.8	0.3

Runoff ratio anomaly (%)		
Experiment	**Pre-2010**	**Megadrought**
Control	-2.4	-8.7
Restored T	-2.8	-8.7
Restored P	0.8	0.8
Restored P-T	0.8	0.9

Conclusions

- Since the end of the twentieth century, "dry and hot" droughts predominate.
- "Dry and warm" droughts induce 20-40 days shortening in snow cover.
- 20-50% amplification in SWE anomaly with respect to Pp.
- Lower average melt rate: greater impact in area south of 34°S -> LWII increase -> EI increase.
- Attribution highlights precipitation effect. Implications for climate change adaptation on this region.

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THANK YOU FOR YOUR ATTENTION!

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