The interest and difficulties to study marginal snowpacks

López-Moreno J.I.; Callow N.; McGowan H.; Webb, R.; Bilish, S.; Schwartz, A., Revuelto J.; Alonso-González E.; Deschamps, C.; Gascoin, S.

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Most of snow science has been conducted on cold, well-developed and seasonally persistent snowpacks:

they have the most influential role on planetary energy balance, strongly condition the hydrology, plant and animal phenology and the economy of the snow covered regions.

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https://doi.org/10.5194/hess-22-4891-2018

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Now you see it, now you don't: a case study of ephemeral snowpacks and soil moisture response in the Great Basin, USA

Rose Petersky[1] **and Adrian Harpold**[1,2,3]

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REVIEWS

Check for updates

A low-to-no snow future and its impacts on water resources in the western United States

Erica R. Siirila-Woodburn[1,9]✉, *Alan M. Rhoades*[1,9], *Benjamin J. Hatchett*[2], *Laurie S. Huning*[3,4], *Julia Szinai*[1,5], *Christina Tague*[6], *Peter S. Nico*[1], *Daniel R. Feldman*[1], *Andrew D. Jones*[1,5], *William D. Collins*[1,7] *and Laurna Kaatz*[8]

Ephemeral ⟷ Marginal snowpacks ⟷ Long lasting

1- Seasonal peak depths exceeding 1 meter are spatially limited and duration is restricted to the coldest months (60-120 days?)
2- High densification rates and a snow profile mostly exhibiting isothermal conditions
3- Several cycles of accumulation-ablation each snow season
4- They often exhibit a patchy and/or spatially variable distribution.

Marginal snowpacks should be found at elevations lying close to the 0ºC winter isotherm (also modulated by slope aspect): Across the world at moderate elevations and in mountain environments influenced by mild climates (sub-tropical and/or maritime influences).

Journal of Hydrometeorology

Volume 22: Issue 11

Editorial Type: Article

Article Type: Research Article

Revisiting the Global Seasonal Snow Classification: An Updated Dataset for Earth System Applications

Matthew Sturm[1] and Glen E. Liston[2]

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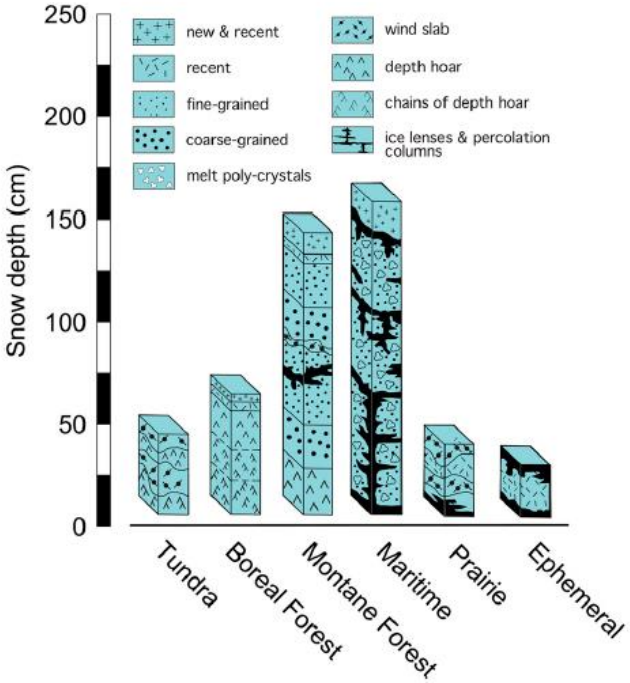
Published-online: 26 Oct 2021



er, snow depth and density statistics for each climate class (these data were adapted from
er of observations, SD = standard deviation, SWE = snow water equivalent depth.

	n	Depth (m)	Depth SD (m)	Density (kg m^{-3})	Density SD (kg m^{-3})	SWE (m)	SWE SD (m)
All data	25688	1.08	1.11	312	93	0.39	0.49
Tundra	31%	0.44	0.25	284	75	0.13	0.08
Boreal Forest	6%	0.60	0.23	217	56	0.13	0.06
Montane Forest	18%	1.30	0.83	335	86	0.46	0.36
Prairie	13%	0.89	0.73	312	85	0.30	0.31
Maritime	32%	1.77	1.50	343	101	0.68	0.67
Ephemeral	—	—	—	—	—	—	—

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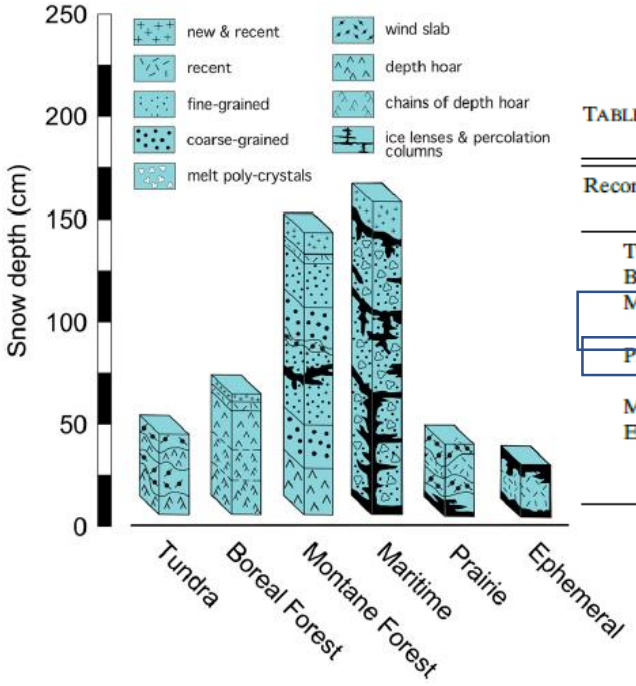

TABLE 4. Snow classification naming conventions, and a conceptual description of the general environment, properties, and geographic location associated with each snow class.

Recommended (adopted herein)	Sturm et al. (1995)	Physical environment	Snow property	Geographic description
Tundra	Tundra	Cold, windy	Shallow, hard wind slabs	High mountain and polar
Boreal Forest	Taiga	Cold, forested	Shallow, depth hoar	Subpolar
Montane Forest	Alpine	Warm, forested	Moderate depth, mixed types, warm snow	Mountains
Prairie	Prairie	Warm, windy	Shallow, soft wind slabs, some melting	Plains
Maritime	Maritime	Warm, high precipitation	Deep, wet	Coastal influence
Ephemeral	Ephemeral	Very warm	Always melting, intermittent, not persistent	Everywhere in autumn, always in temperate and subtropic locations

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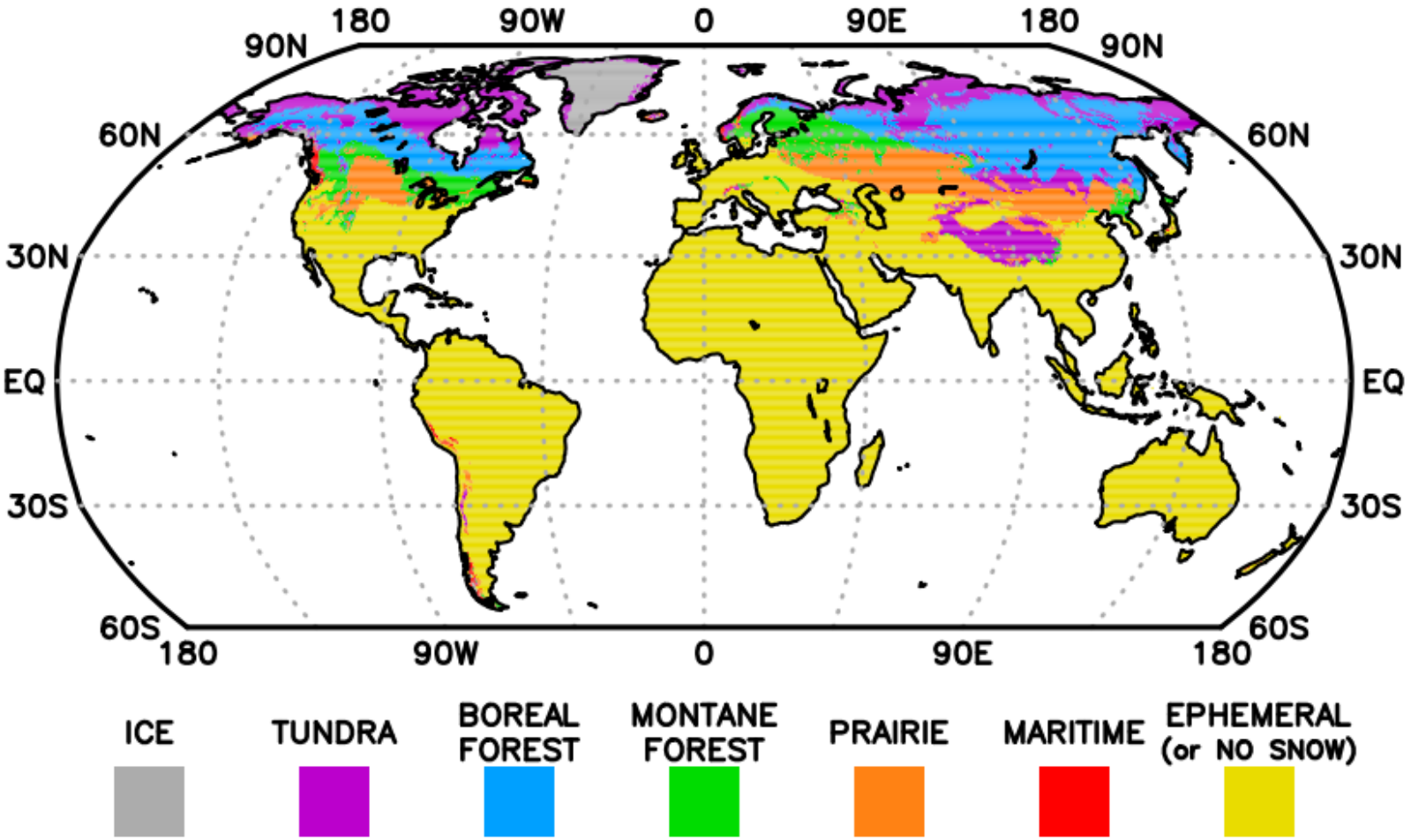


FIG. 6. Global snow classification. Antarctica is mostly Ice and therefore not shown.

1. They have **specific needs to be monitored and modeled**

More spatial and temporal resolution is required, errors assumed in deep and long lasting snowpacks may be unnaceptable in marginal snowpacks

2. Snowpacks are likely to be **highly vulnerable to climate warming** due to the mild temperatures and isothermal characteristics.

We hypothesize that many of the current marginal snowpacks will disappear or shift to an ephemeral state

However it is not measured yet their sensitivity to climate warming and this preliminary hyphothesis needs to be further checked

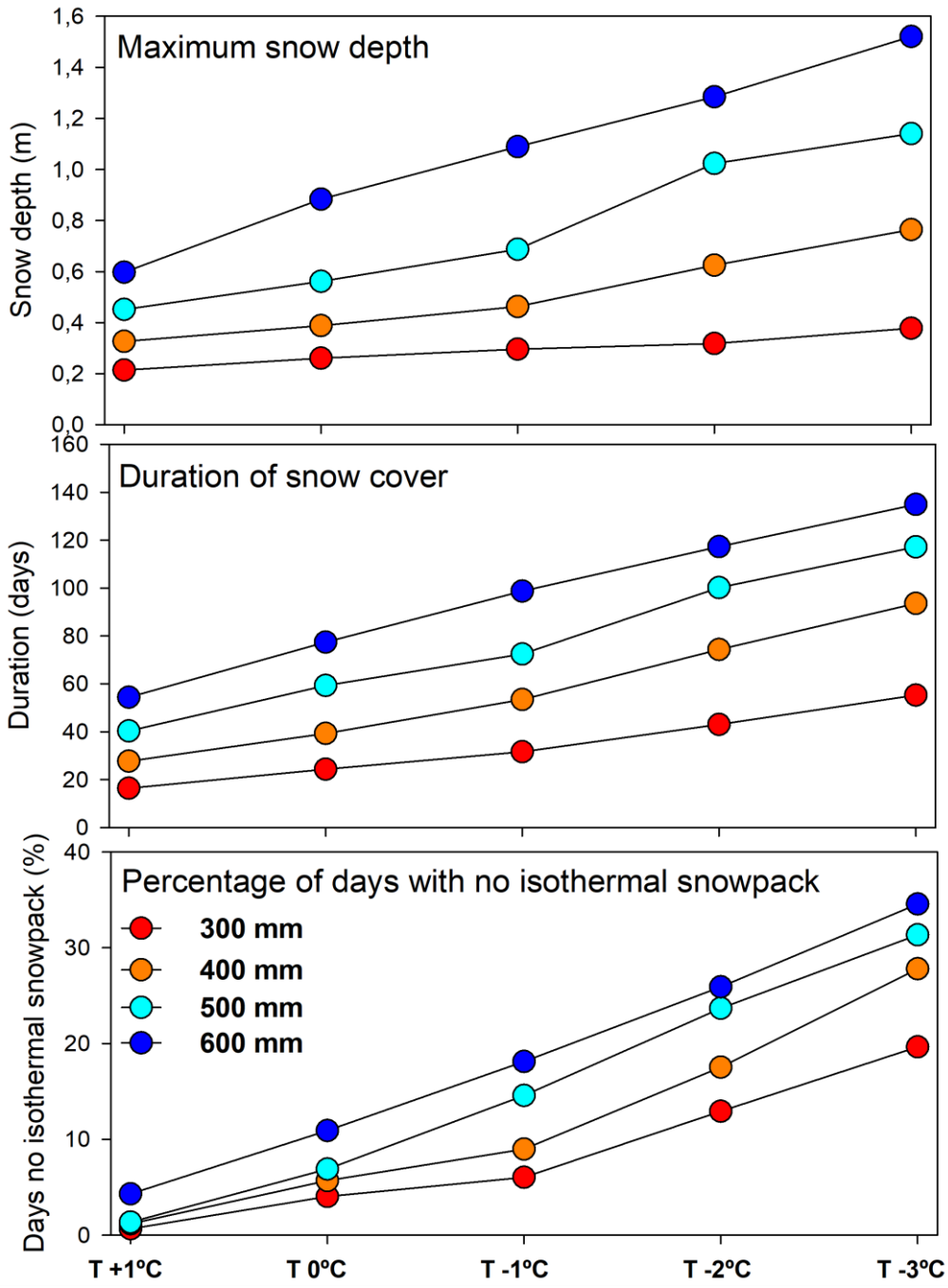
3. Even if the duration and depth of marginal snowpacks is moderate, several studies have shown their role on natural processes: i) water availability, ii) plant and animal phenology, iii) exchange of gases between soils and atmosphere, iv) nutrient cycle, etc

They have not been quantified yet: how much snow is necessary to have an unequivocal imprint on environmental processes?

1. Definition and climatic conditions to find marginal snowpacks

SNOWY MOUNTAINS (Australia)

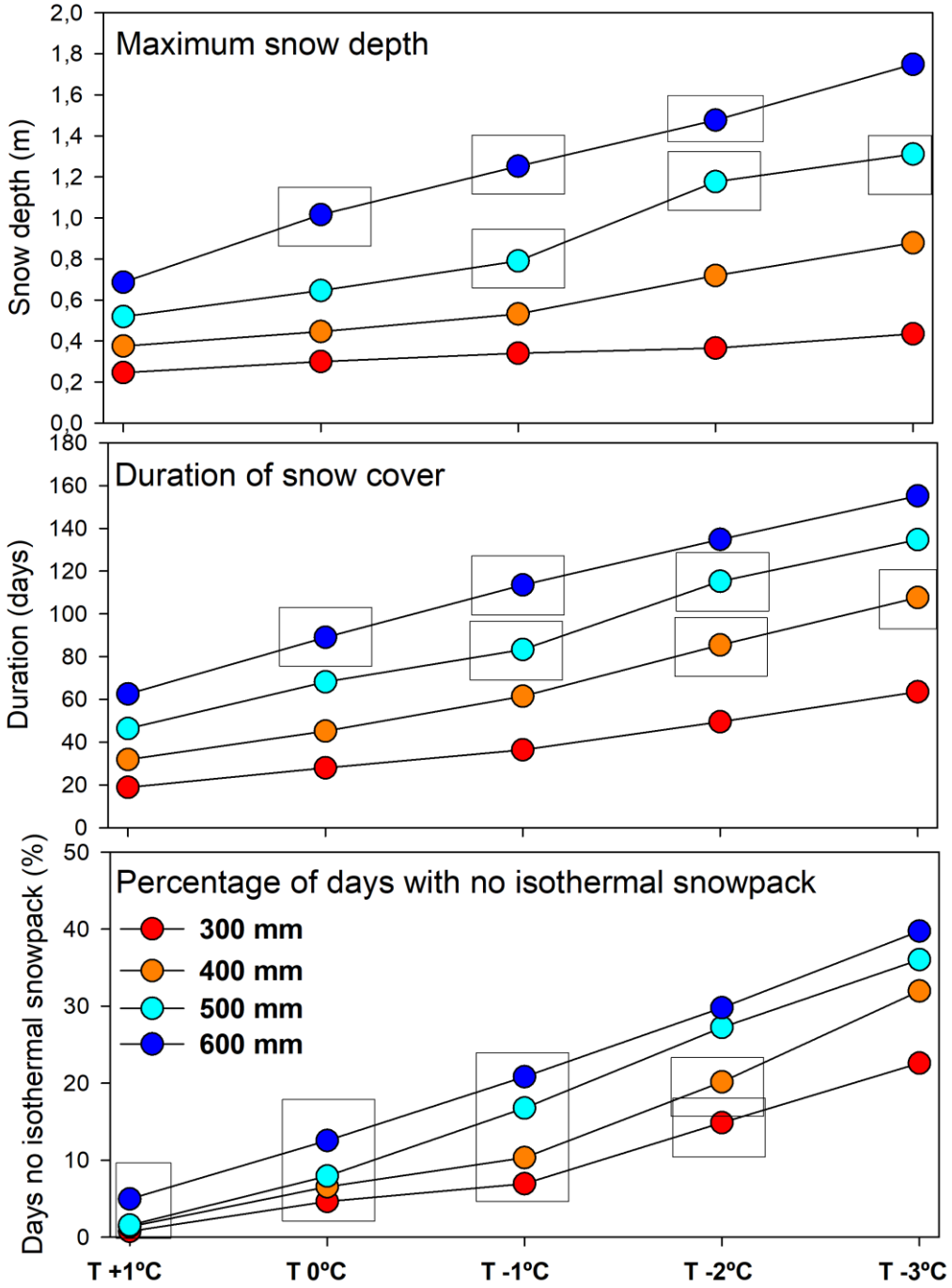
Simulated (with FSM) long-term average (1999-2020) annual maximum snow depth, duration of the snow cover and % of non isothermal snowpack) in the Snowy Mountains using as forcing Era-land data escaled to DJFM temperature and precipitation ranging from +1 to -3ºC and from 300 to 600 mm



1. Definition and climatic conditions to find marginal snowpacks

Maximum annual snow depth: 80-150cm
Snow cover duration: 60 – 120 days
% no isothermal snowpack: <15%

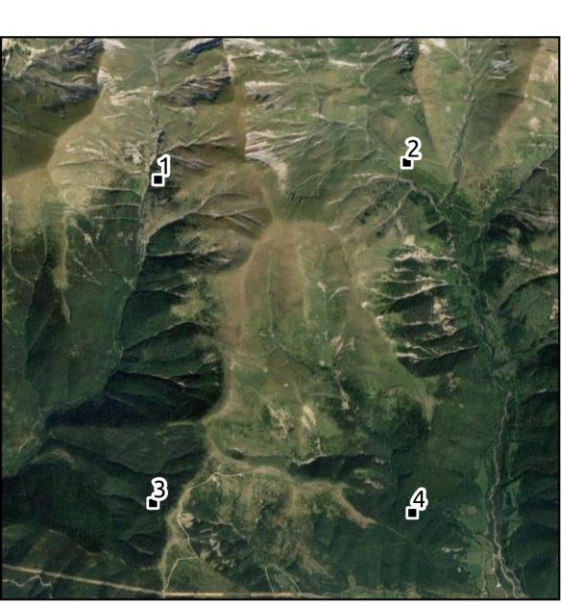
T0ºC P600mm
Tº-1C P500 and 600mm
T-2ºC P400mm

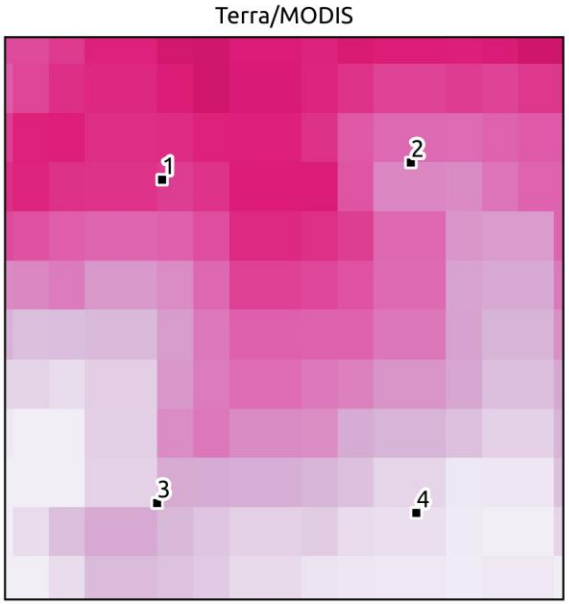


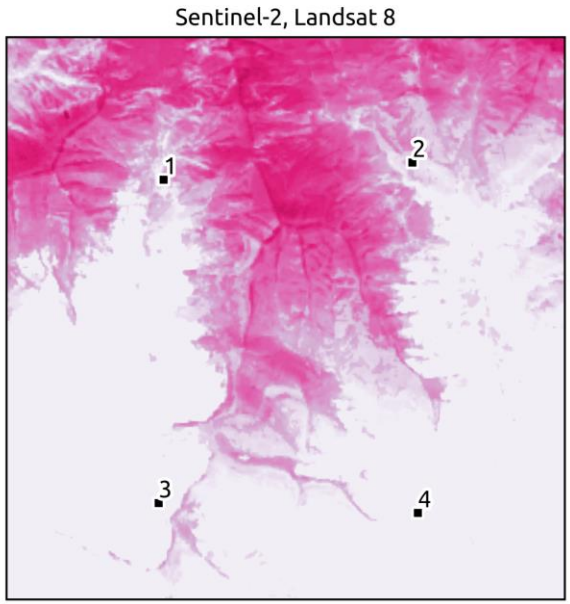
2. Specific needs to observe and simulate marginal snowpacks

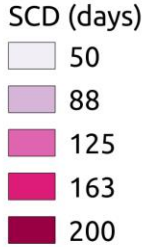
Average annual snow cover duration 2017-2021. Cotefablo pass (Spanish Pyrenees)

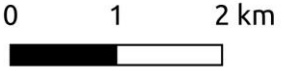
(Mod/Sen2-Landsat)				
Point	3	4	1	2
2017	162/110	164/64	138/68	102/81
2018	134/110	86/79	45/72	25/88
2019	171/0	96/0	62/3	38/13
2020	114/0	90/0	95/11	77/10
Average	**145/53**	**109/36**	**85/39**	**60/48**





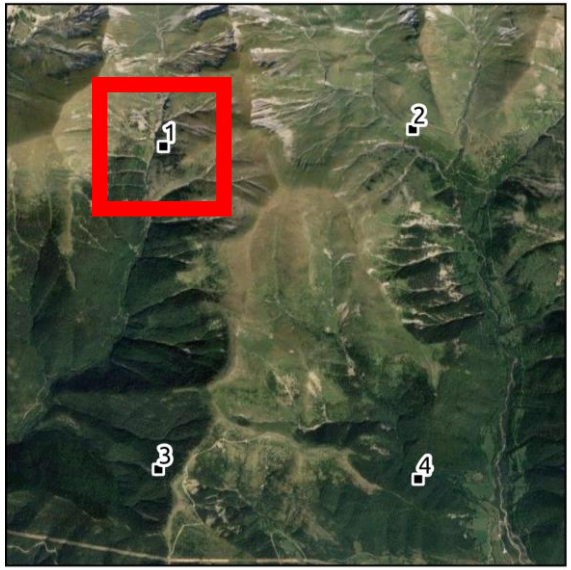


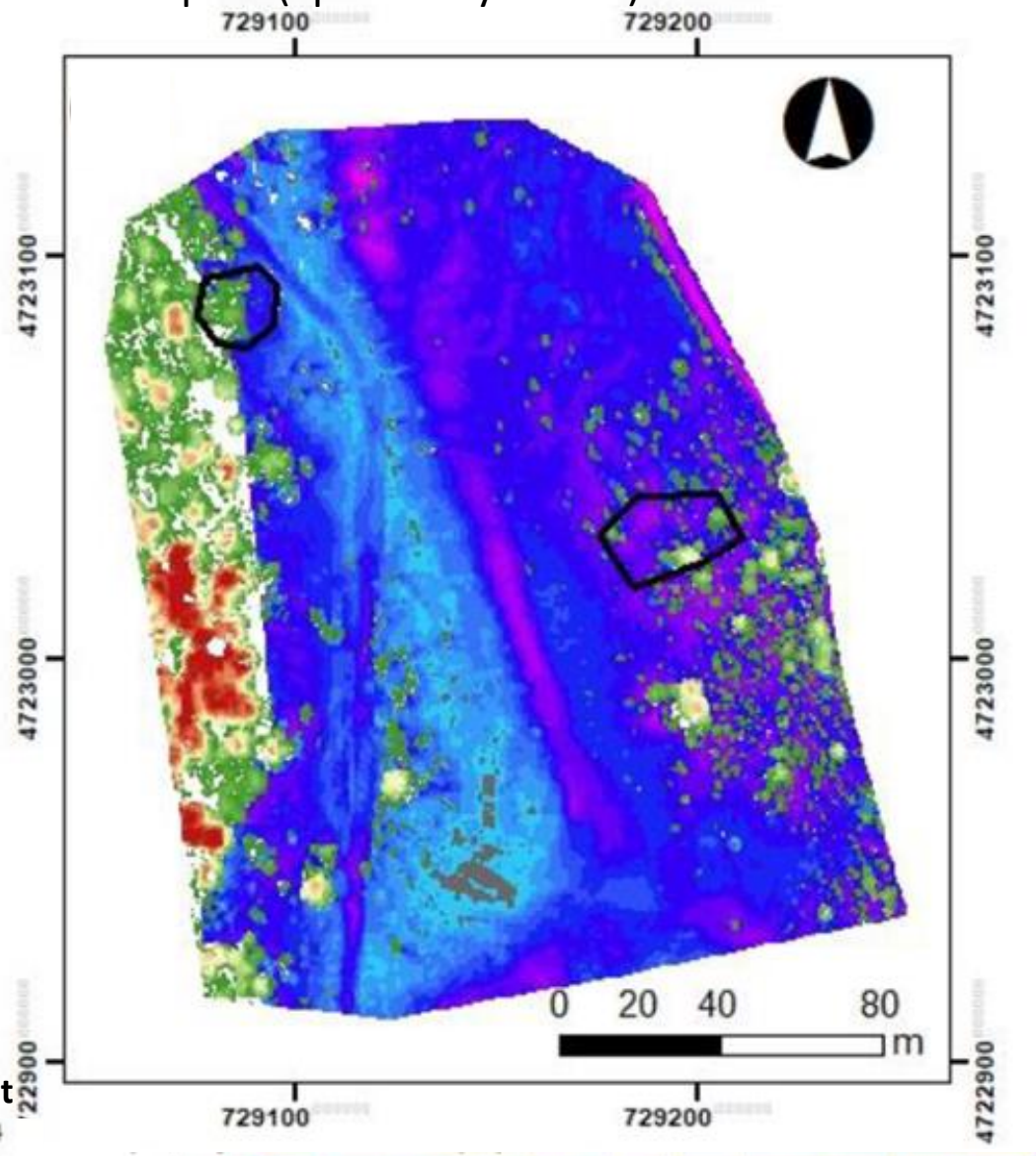




2. Specific needs to observe and simulate marginal snowpacks

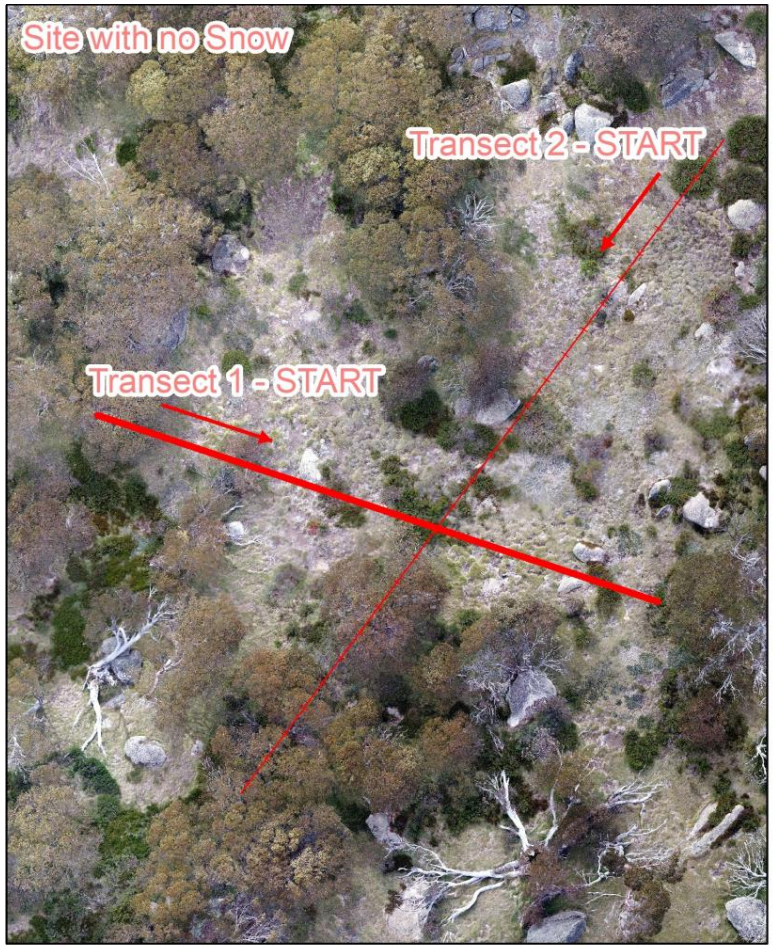
Snow depth in point 1 with SfM from UAV. Cotefablo pass (Spanish Pyrenees)

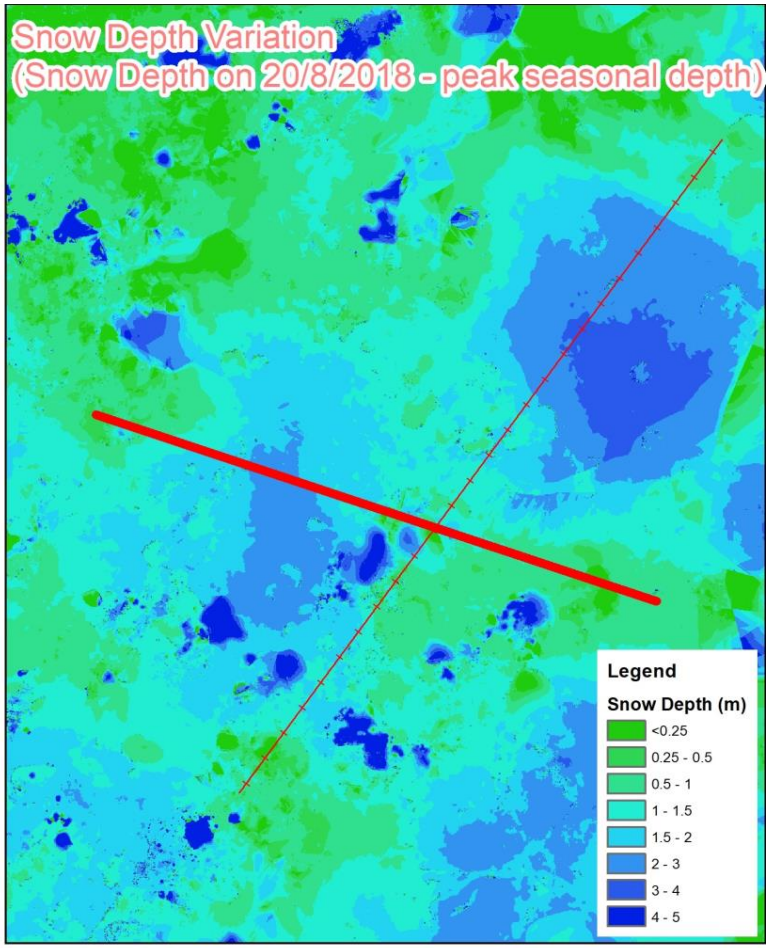


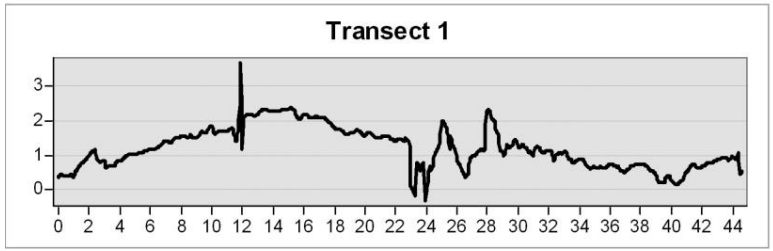


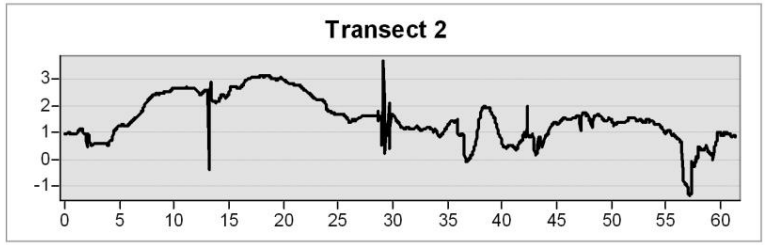
2. Specific needs to observe and simulate marginal snowpacks

Snow depth transects in Snowy Mountains (Australia)







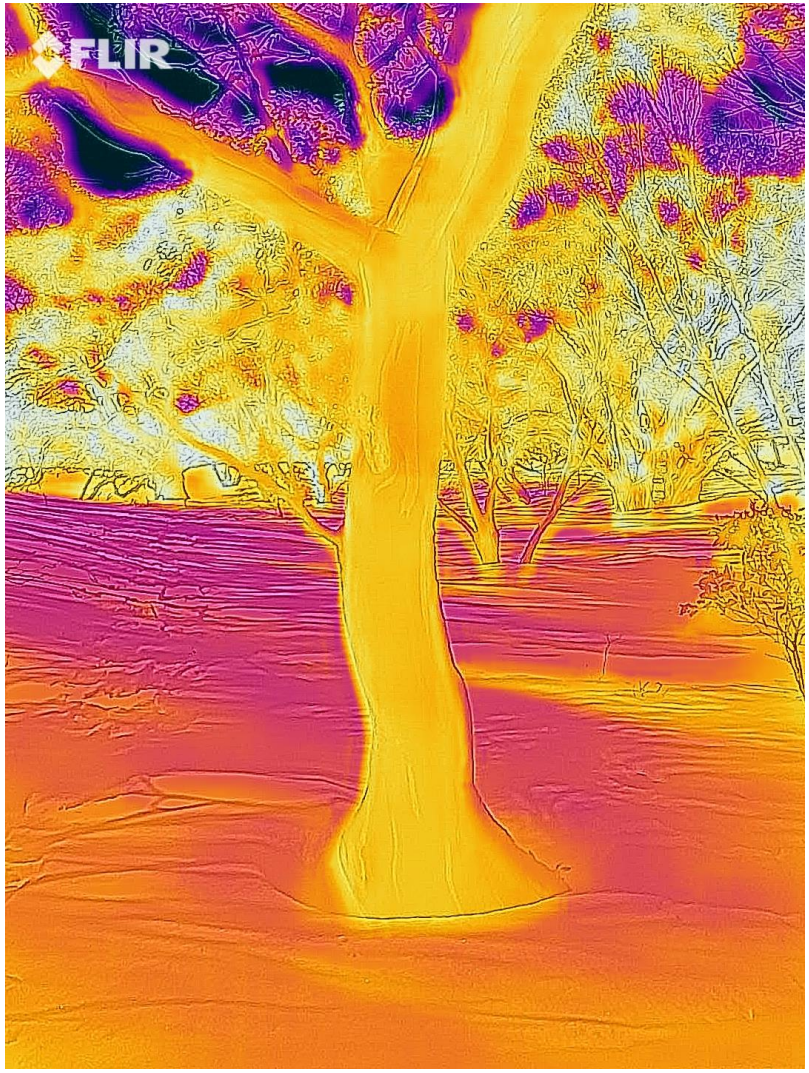


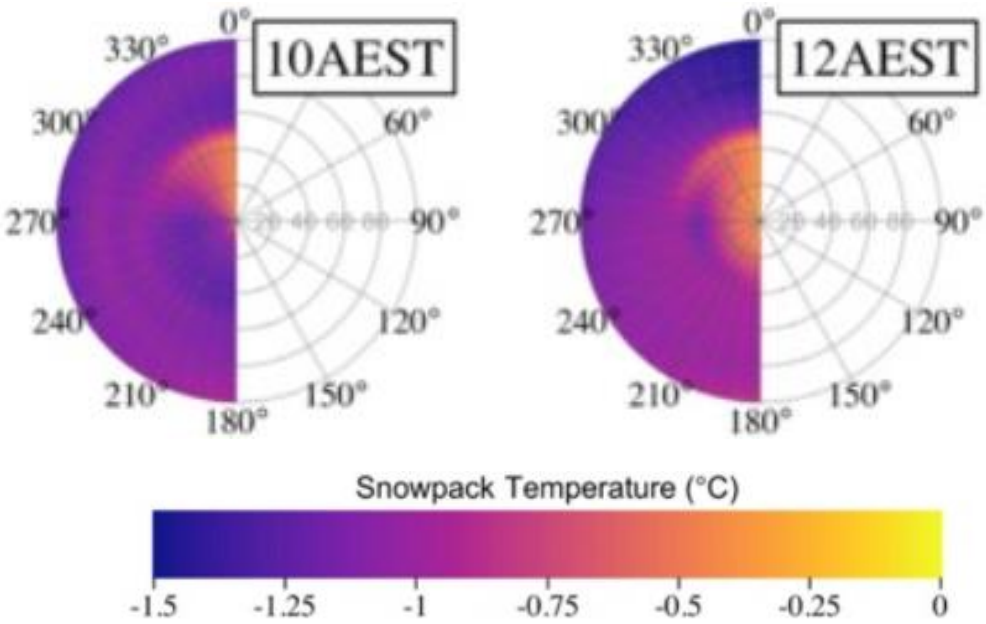
2. Specific needs to observe and simulate marginal snowpacks

Interaction with shrubs: i.e. *Buxus sempervivens*, *Juniperus comunis* and *Echinospartum horridum*

2. Specific needs to observe and simulate marginal snowpacks

Thermal emission from vegetation





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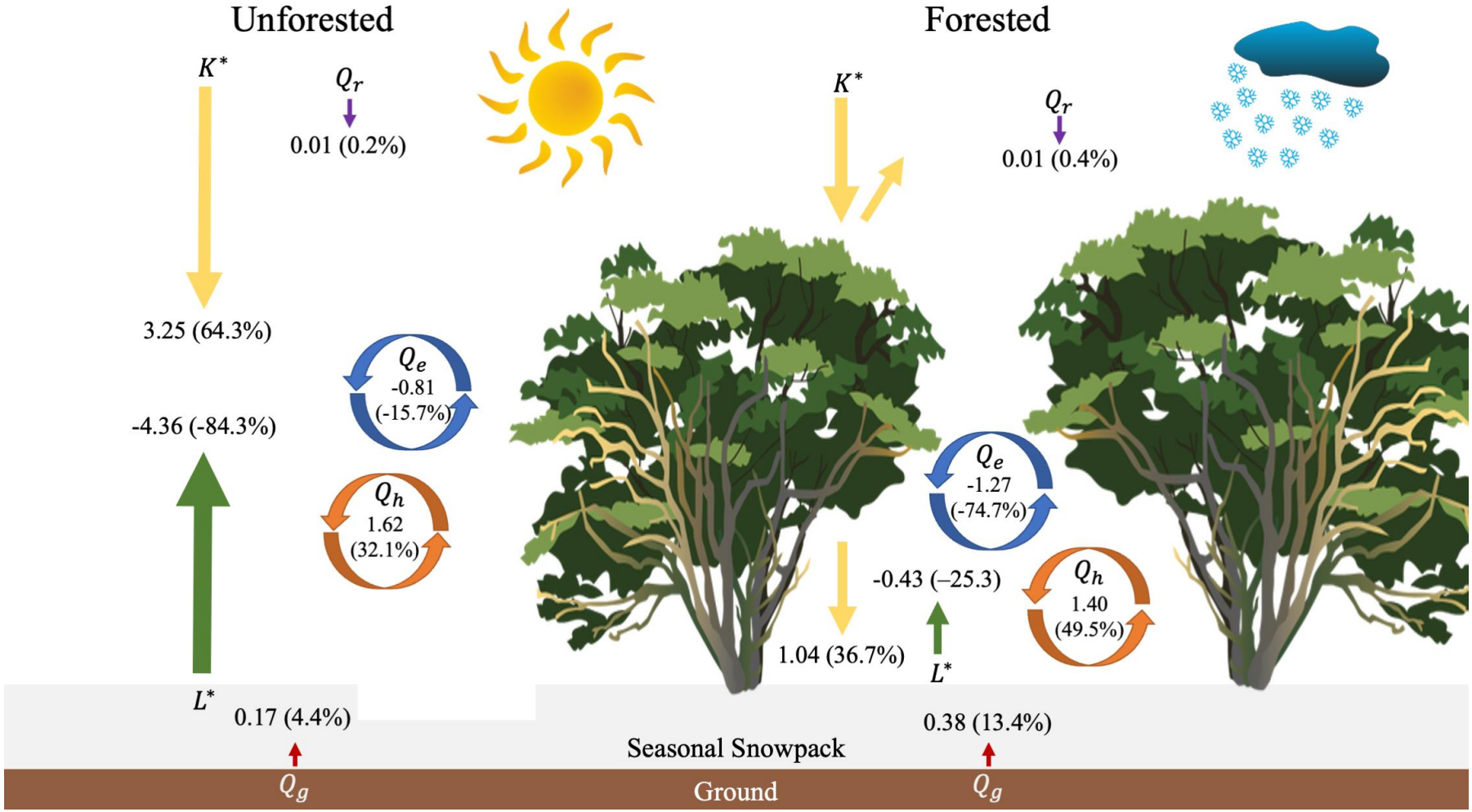

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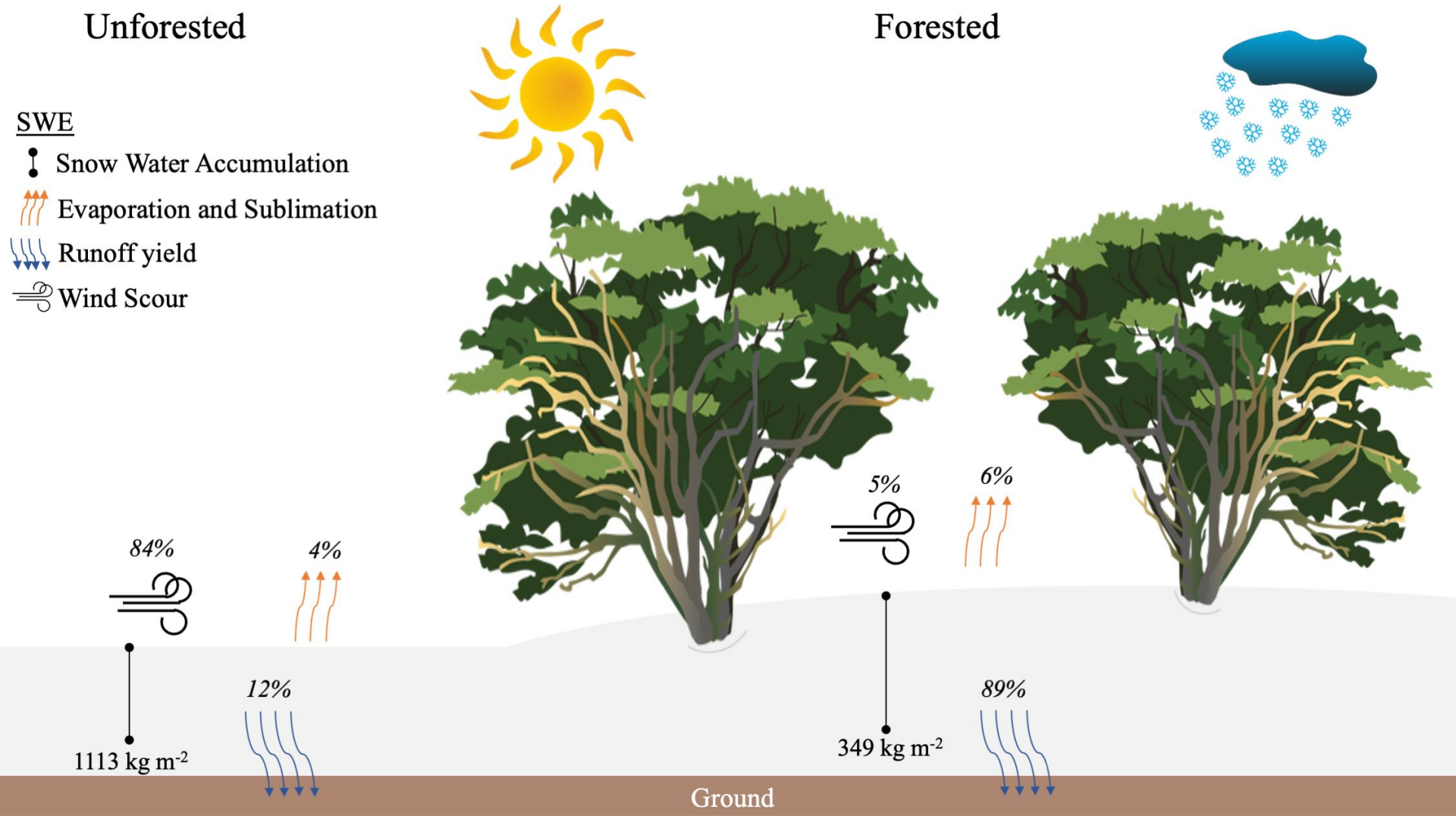
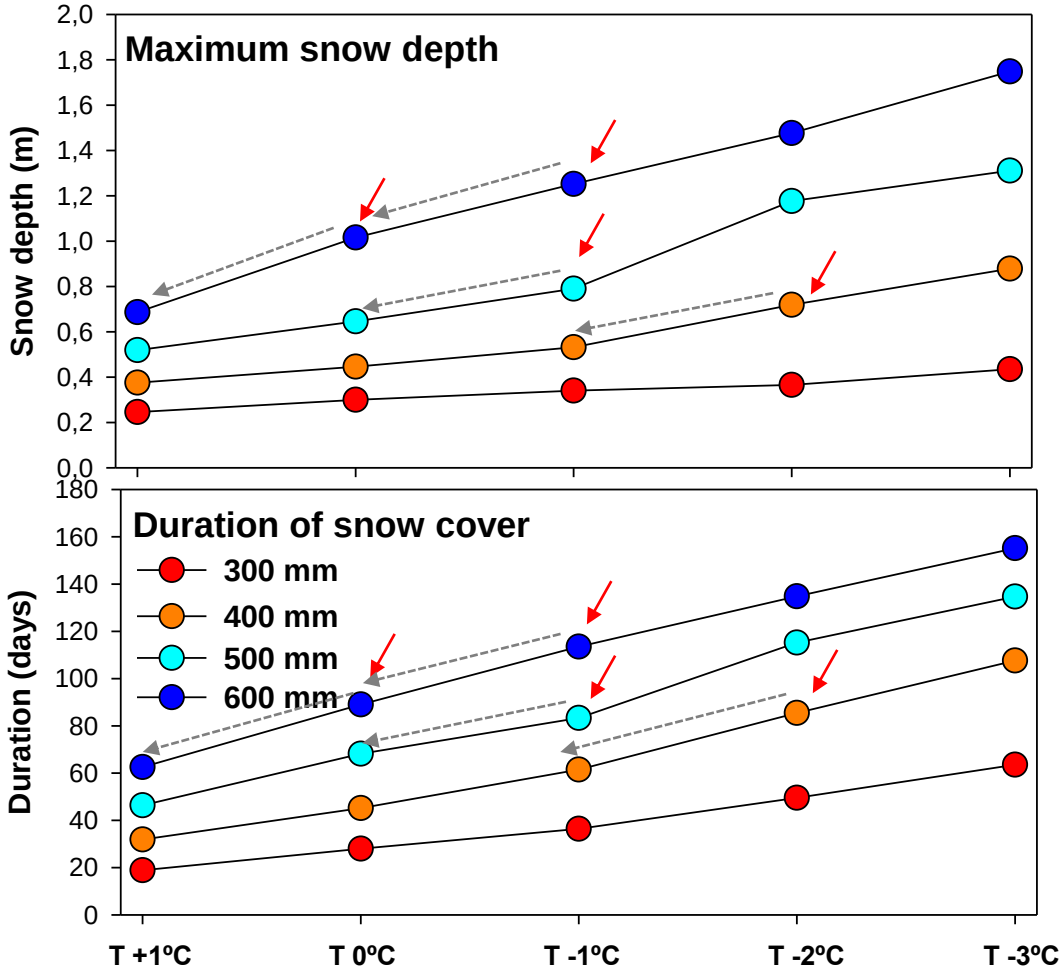


3. Sensitivity of marginal snowpacks to climate warming

Highly vulnerable to climate warming

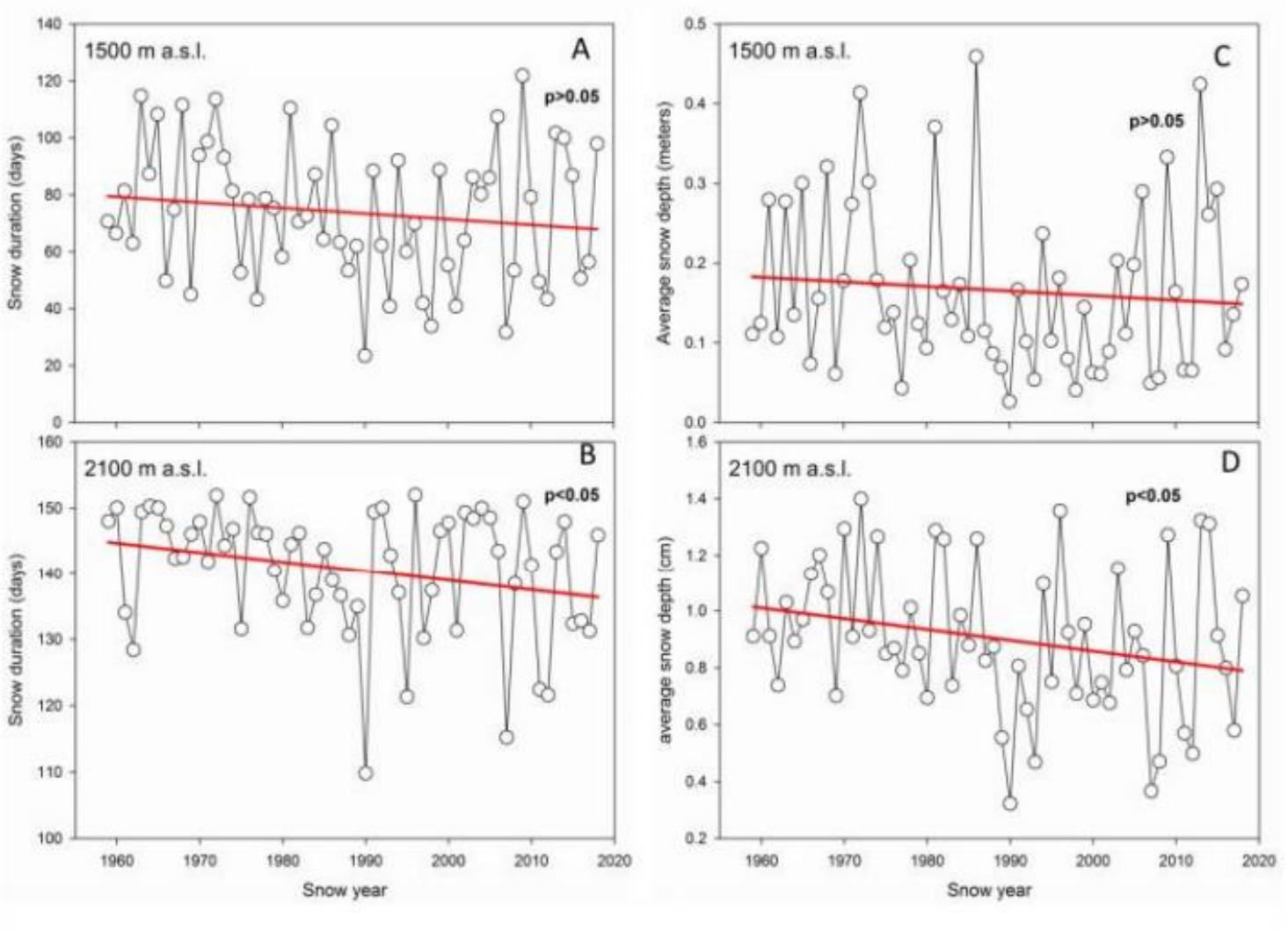


Marginal snowpacks
T0ºC P600mm
Tº-1C P500 and 600mm
T-2ºC P400mm

1ºC of warming implies a reduction of 27% of peak snow depth and 26 days in snow cover duration for marginal snowpacks

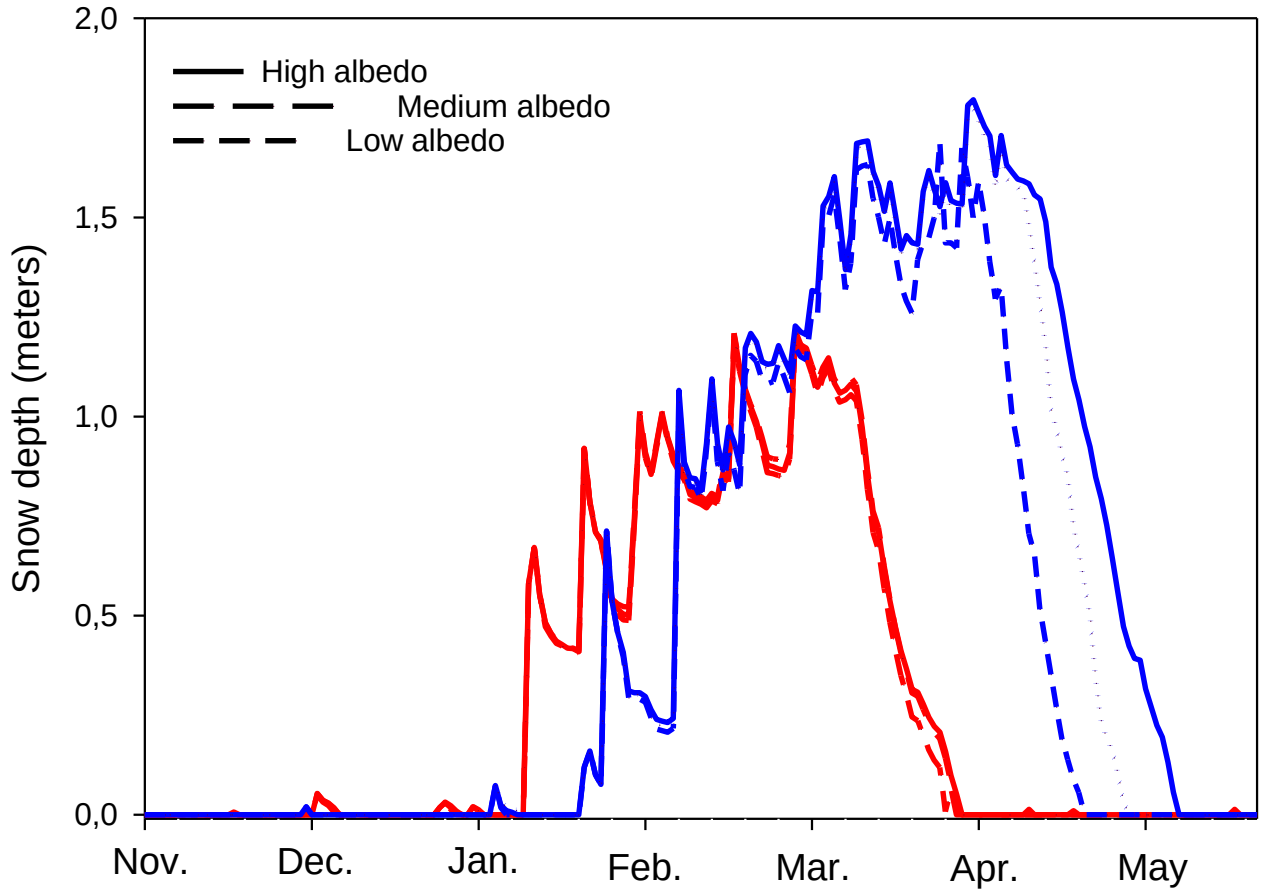
3. Sensitivity of marginal snowpacks to climate warming

Trends (1950-2019) in snow duration (left) and snow depth (right) at 1500 m a.s.l. (upper) and 2100 m (lower)



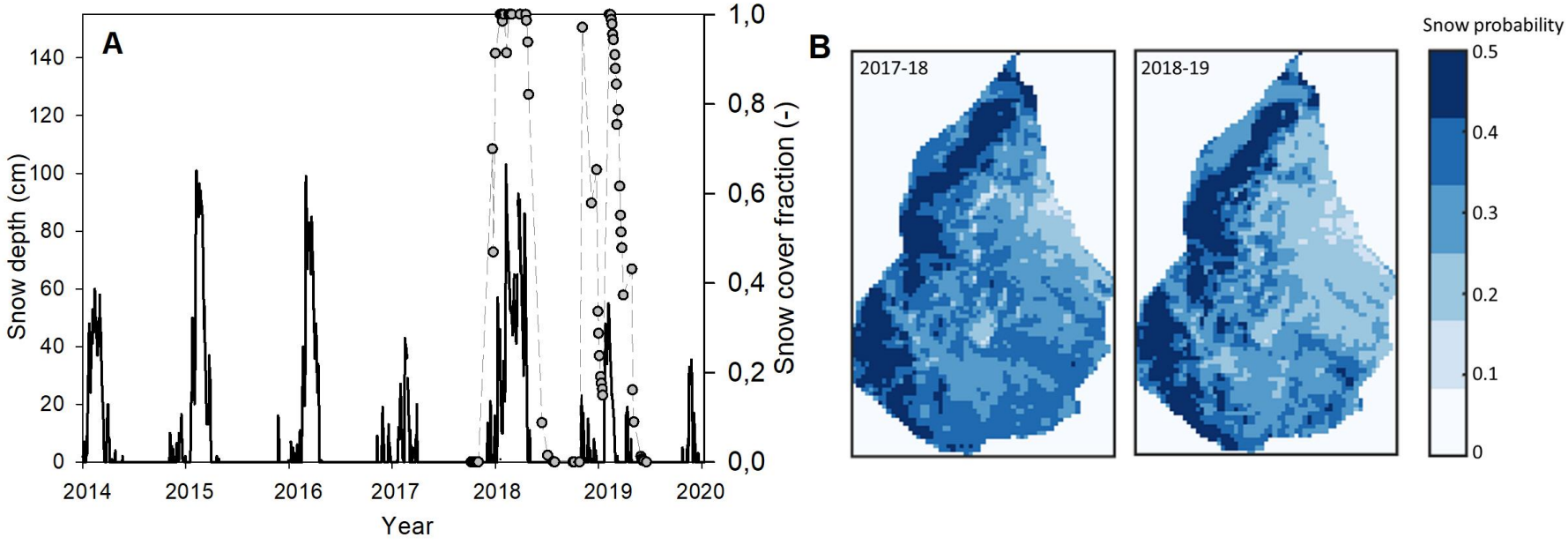
3. Sensitivity of marginal snowpacks to climate warming

Effect of changing snow albedo for long lasting (blue) and marginal snowpack (red) simulated in the Atlas mountains



4. Influence of marginal snowpacks on natural systems

Snow depth series and snow probability for Sentinel-2 in mountains of Peñalara (Central Spain): 2017-18 consolidated snowpack; 2019-2020 marginal snowpack



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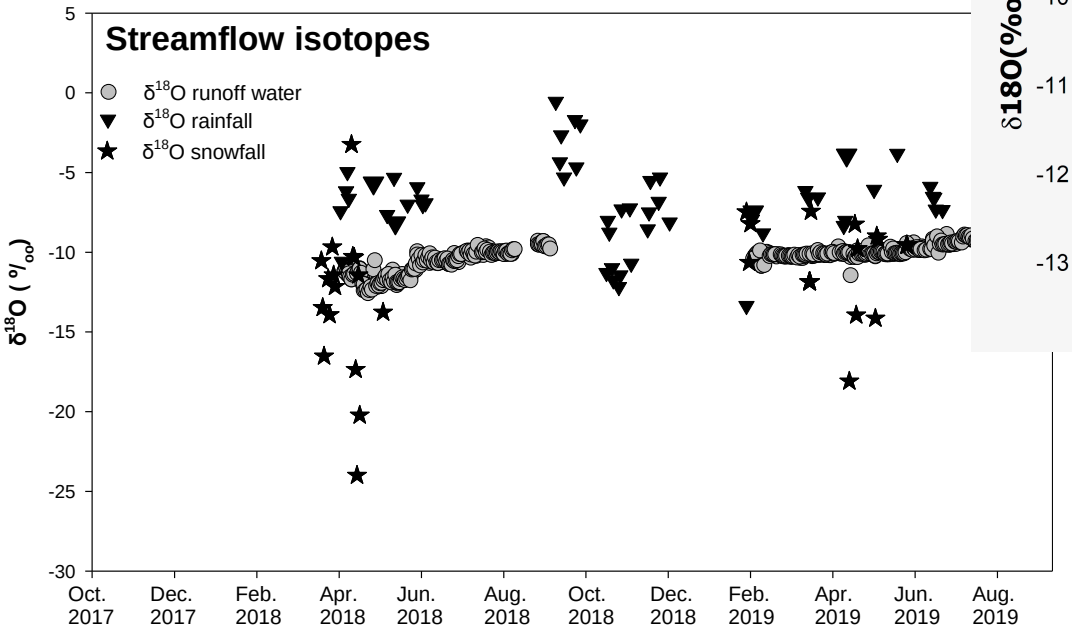
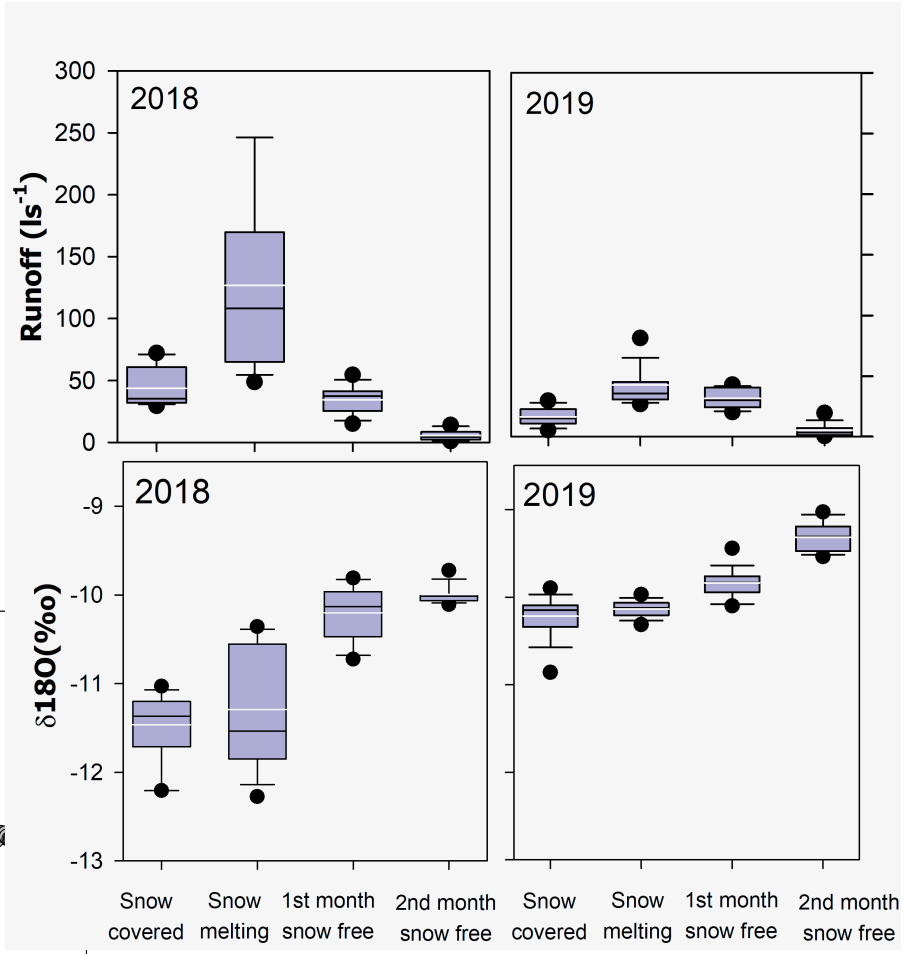
Runoff and O18 isotopes in Peñalara basin





Conclusions

- Marginal snowpacks must occupy large extensions in the world, but it is not found yet as a widely recognized snow type or snow environment.
- Preliminary results shows they can be found in areas with DJFM temperature between 0 and -2ºC, with the need of incresing precipitation as temperature is warmer.
- High resolution products products are necessary to capture their very large spatial variability
- The patchy nature of these snowpacks, the important ground heat fluxes and the frequent interaction with vegetation* need consideration for modelling.

  *vegetation that has not been analyzed to the date
- The isothermal characteristics of marginal snowpacks makes to hypothetize that any change in the incoming energy (temperature, radiation balance, etc) may strongly affect the mass balance; However as it develops only during the coldest moths the response may be more subtle than expected.

-The analyses on how marginal snowpacks affect natural systems are still to be done…..
How much snow and for how long on the ground is necessary to have an unequivocal impact?

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