The « SmartStake », a device for autonomous and real – time monitoring of glacier ablation

Antoine Rabatel, Romain Biron, Stéphane Gluck,
Delphine Six, *et al.*

© Antoine Rabatel, UGA

Institut des géosciences de l'environnement

WORLD METEOROLOGICAL ORGANIZATION
Weather · Climate · Water

Essential Climate Variables

An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate.

ECVs are identified based on the following criteria:

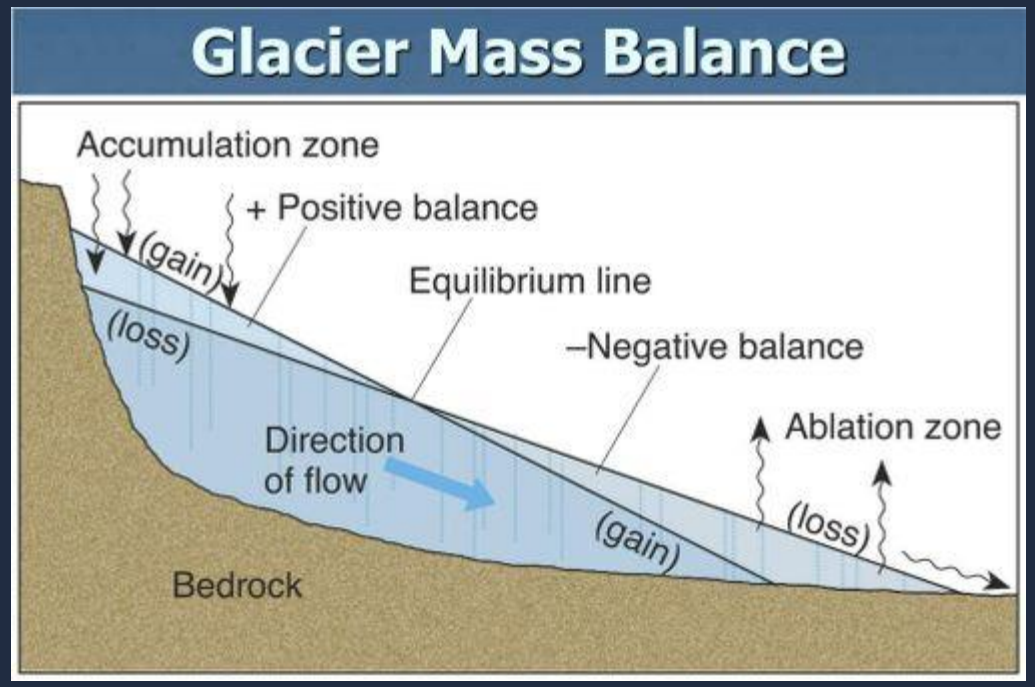
- **Relevance**: The variable is critical for characterizing the climate system and its changes.
- **Feasibility:** Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
- **Cost effectiveness:** Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage where possible of historical datasets.

Essential Climate Variables

Atmosphere · Land · Ocean · ECV data · Review of ECV Requirements · Dedicated ECV projects · ECV live monitoring

Definitions, **requirements**, and **network information** of ECVs are provided by the Global Observing Systems Information Center (GOSIC) or available as excel sheets for download: ECV-Land matrix

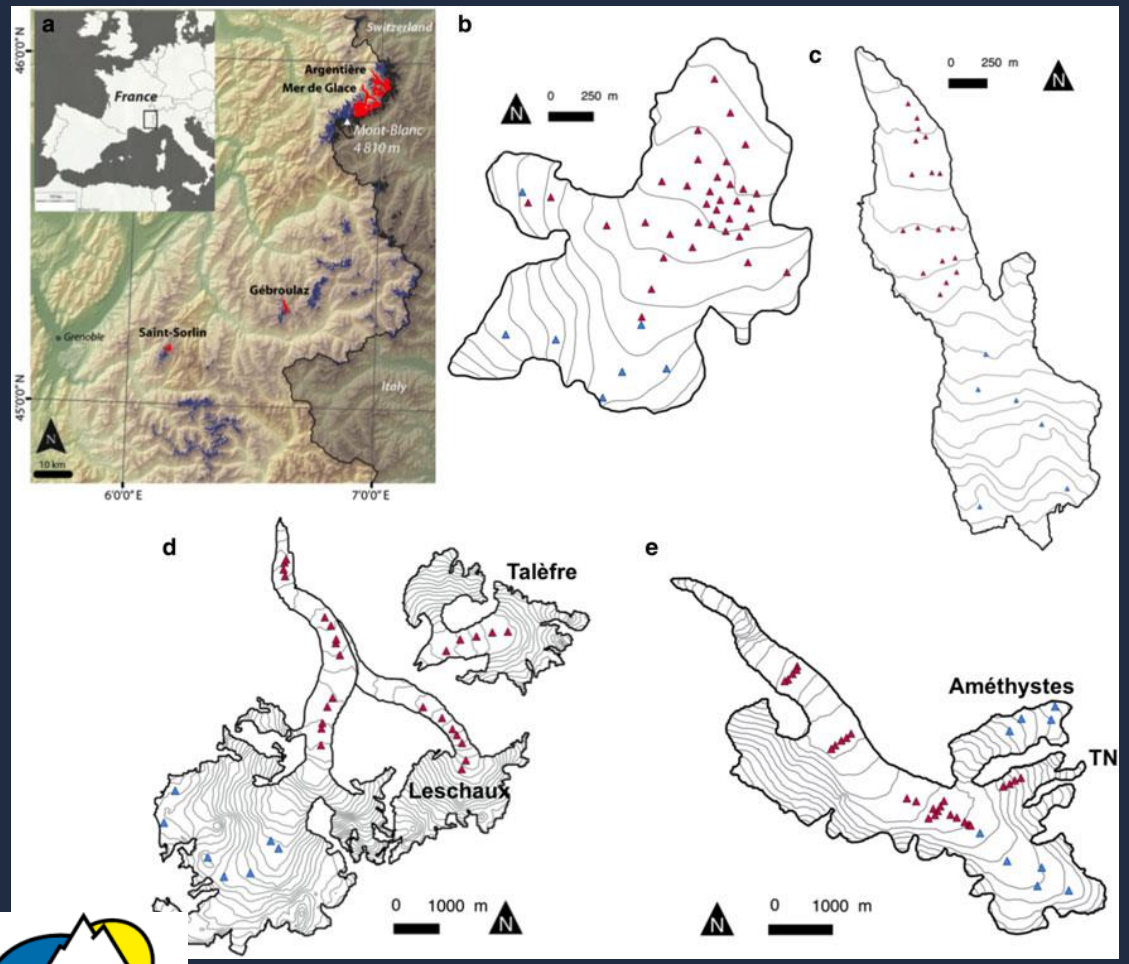
ECV	Products
Hydrosphere	
River Discharge	River discharge; Water Level; Flow Velocity; Cross-section
Groundwater	Groundwater volume change; Groundwater level; Groundwater recharge; Groundwater discharge; Wellhead level; Water quality
Lakes	Lake water level; Water Extent; Lake surface water temperature; Lake ice thickness; Lake Ice Cover; Lake Colour (Lake Water Leaving Reflectance)
Soil Moisture	Surface soil moisture; Freeze/thaw; Surface inundation; Root-zone soil moisture
Cryosphere	
Snow	Area covered by snow; snow depth; snow water equivalent
Glaciers	Glacier area; Glacier elevation change; Glacier mass change
Ice Sheets and ice shelves	Surface Elevation Change;Ice velocity;Ice mass change;Grounding line location and thickness
Permafrost	Thermal State of Permafrost; Active Layer Thickness



Glacier surface mass balance

- **Accumulation** *(solid precipitation, snow drift, avalanches, internal refreezing)*
- **Ablation** *(melting, sublimation, calving)*

⇒ Point measurements at the glacier surface



© Bruno Jourdain, UGA

© Romain Biron, IRD

Ablation measurements

Stakes inserted in the ice

⇒ Depend on the availability of an operator (and on weather conditions!)

⇒ The measure is a cumulative value over several days/weeks/months (between two field campaigns)

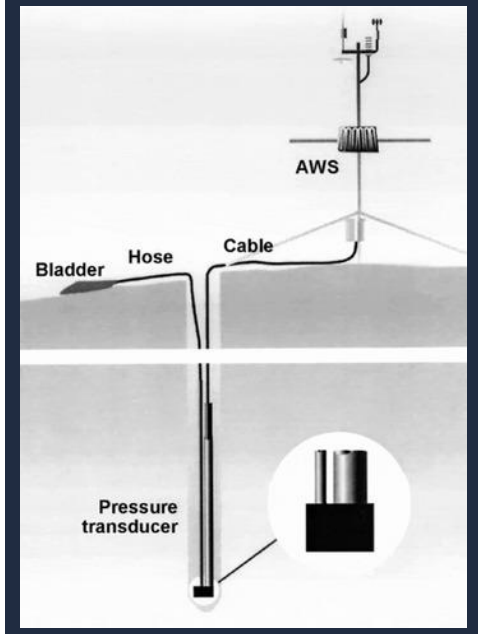
Need to go towards:

- Continuous/real-time measurement
- Autonomous
- Remote transmission

A need: real-time and automonous measurements

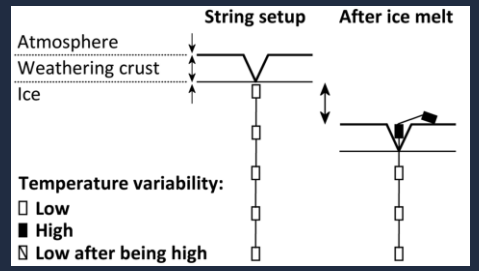
“Emerging” methods

Boggild *et al.*, 2004
Pressure transducers



Hulth, 2010
Draw-wire sensor

Carturan et al., 2019
Thermistors chain



Landmann *et al.*, 2021
Camera + graduated stake

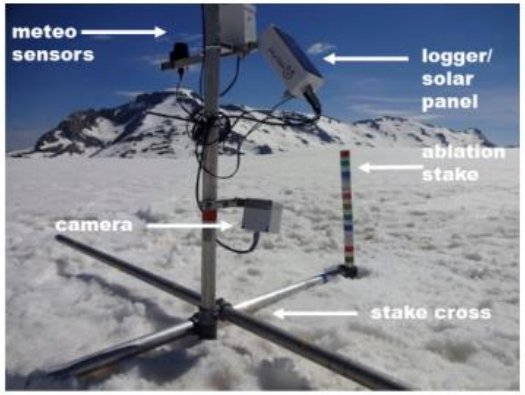


Figure 2. The camera setup used to obtain daily estimates of glacier point mass balance. Here, the camera has just been mounted on the snow-covered surface of Glacier de la Plaine Morte (19 June 2019).

Ialongo *et al.*, 2021
Light sensors

Needs *vs.* advantages of the chosen technology

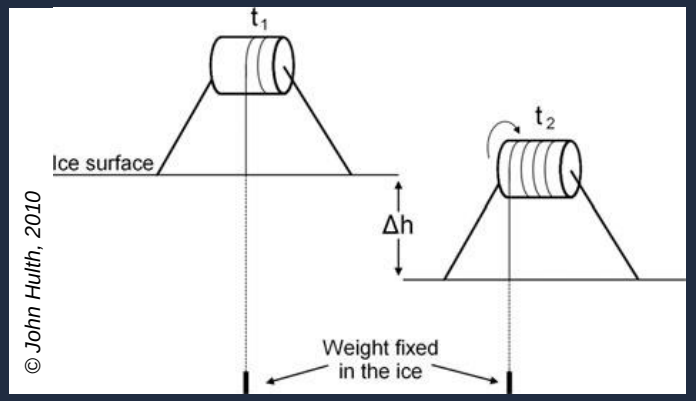
Autonomous measurement for ablation of several meters per season *(=> no stake in the ice)*

Limited energy consumption *(without a solar panel = better)*

Low volume of data to be remotely transmitted *(e.g. LoRa or satellite)*

Direct and unambiguous measurement *(low level of on-board and post processing)*

Structure strong enough to be buried under several meters of snow during the accumulation season



© John Hulth, 2010

© Romain Biron, IRD

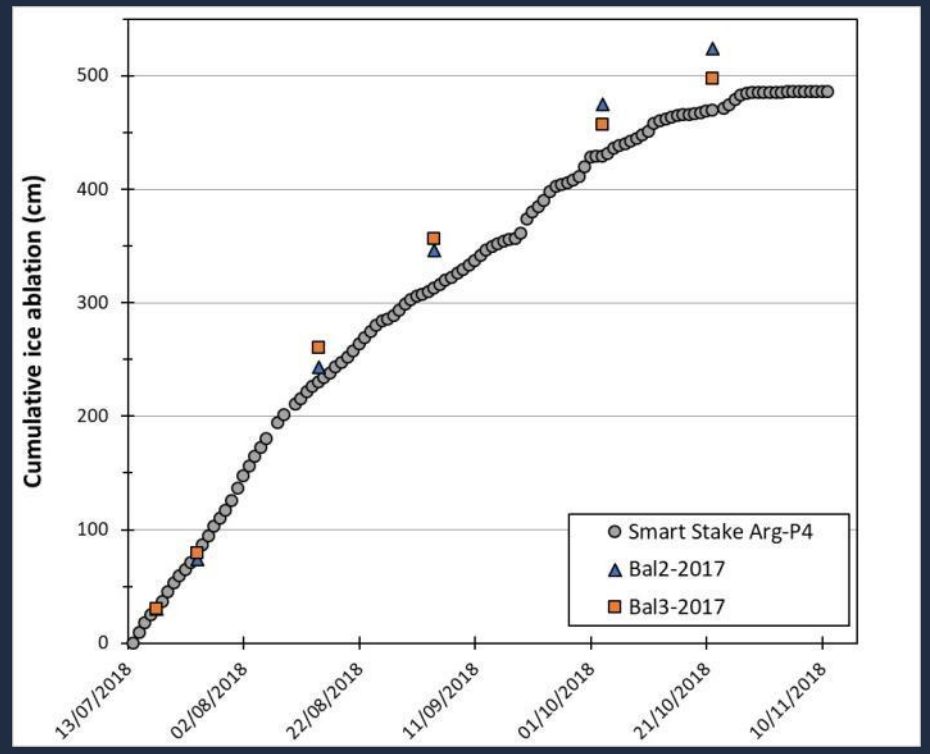
© Romain Biron, IRD

Results of the first prototypes

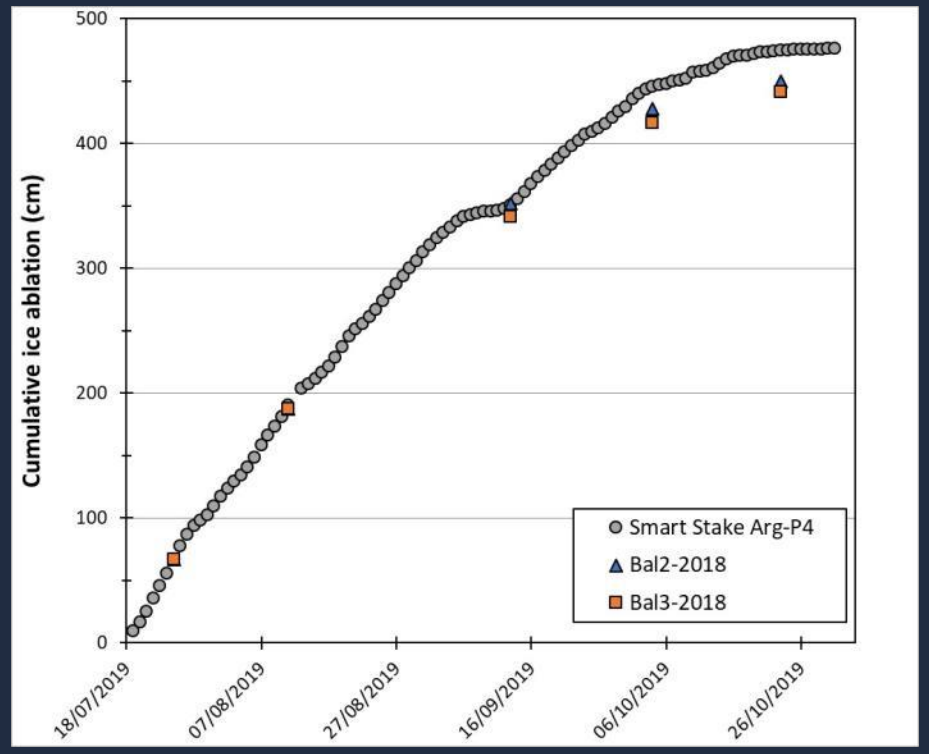
Daily melt on *Glacier d'Argentière* *(z= 2400 m a.s.l.)*

Comparison with 2 « classical » stakes in the vicinity (10 to 50 m apart)

2018 ablation season



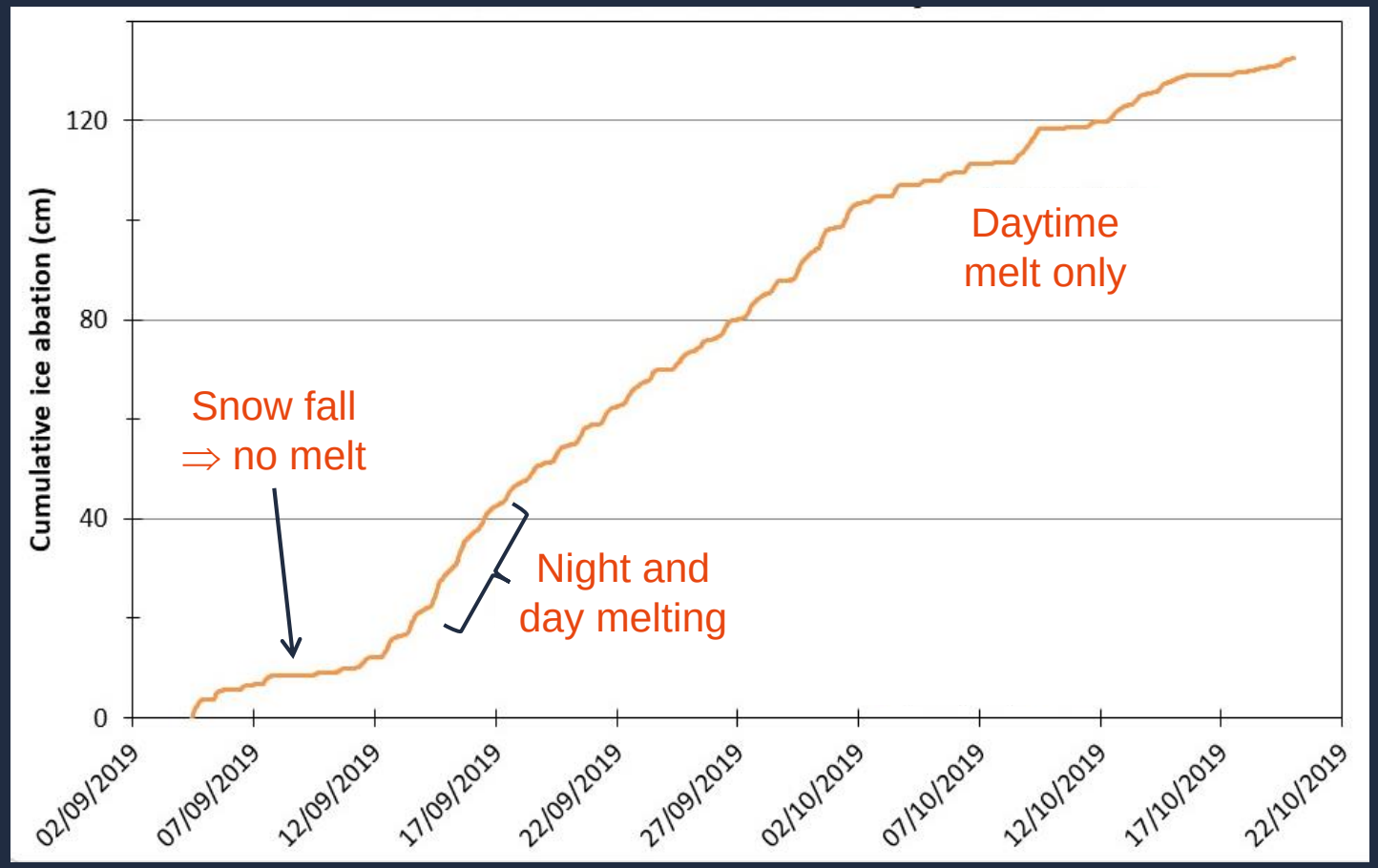
2019 ablation season



Results of the first prototypes

½ hourly cumulative melt on *Glacier d'Argentière* *(z= 2400 m a.s.l.)*

2019 September 4th to September 20th

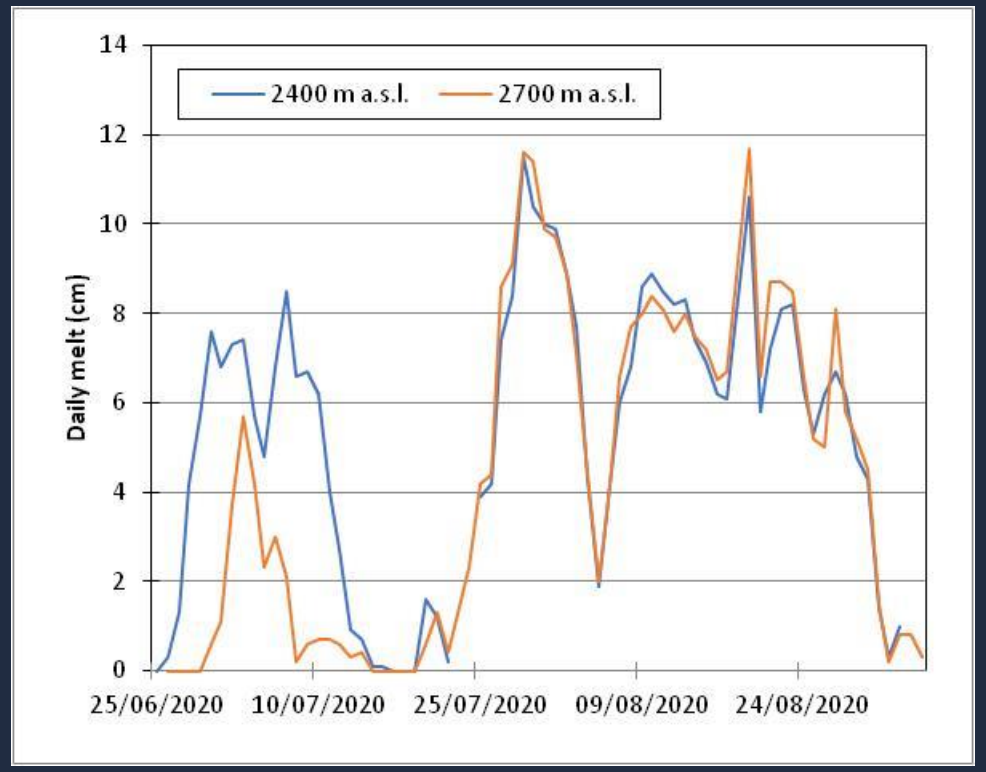


Results of the first prototypes

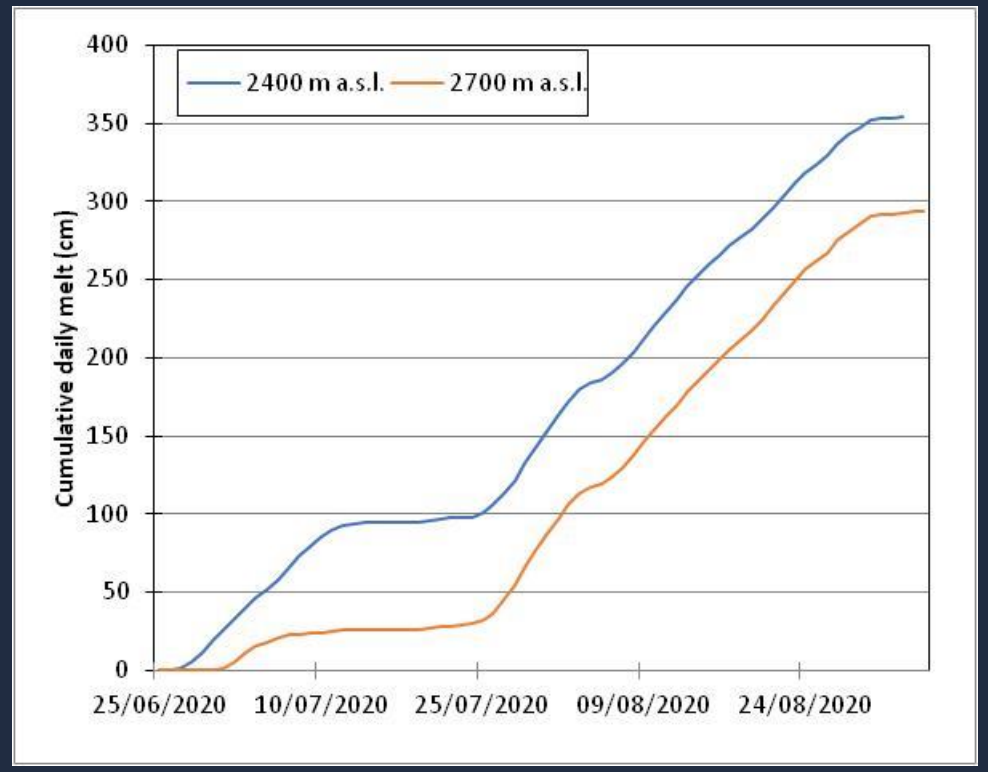
Daily melt on *Glacier d'Argentière* *(z= 2400 & 2700 m a.s.l.)*

Summer 2020 from June 25th to Sept. 4th

Day-to-day variability



Cumulative daily melt



Next steps

From a scientific point of view

Quantify the surface energy balance (automatic weather station settled at 2400 on Argentière during summer 2021)

⇒ Characterize the temporal variability of melt conditions
⇒ Focus on night-time melt

From a technical point of view

Partnership with A2 Photonic Sensors to further develop the SmartStake

From a monitoring point of view

Partnership with the World Glacier Monitoring Service for a widespread deployment on the WGMS reference glaciers

Thank you for your attention

antoine.rabatel@univ-grenoble-alpes.fr