Towards a better understanding of snow surface temperature variability in mountain regions

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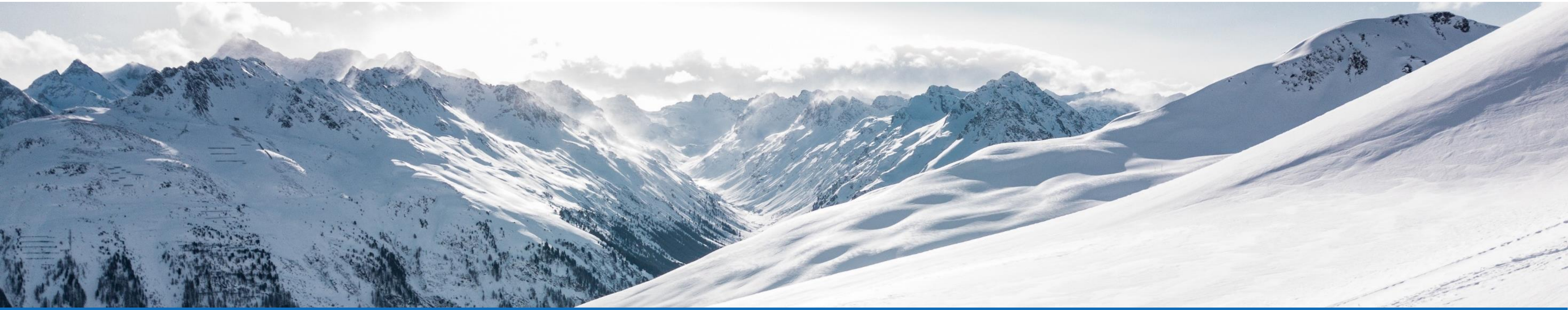


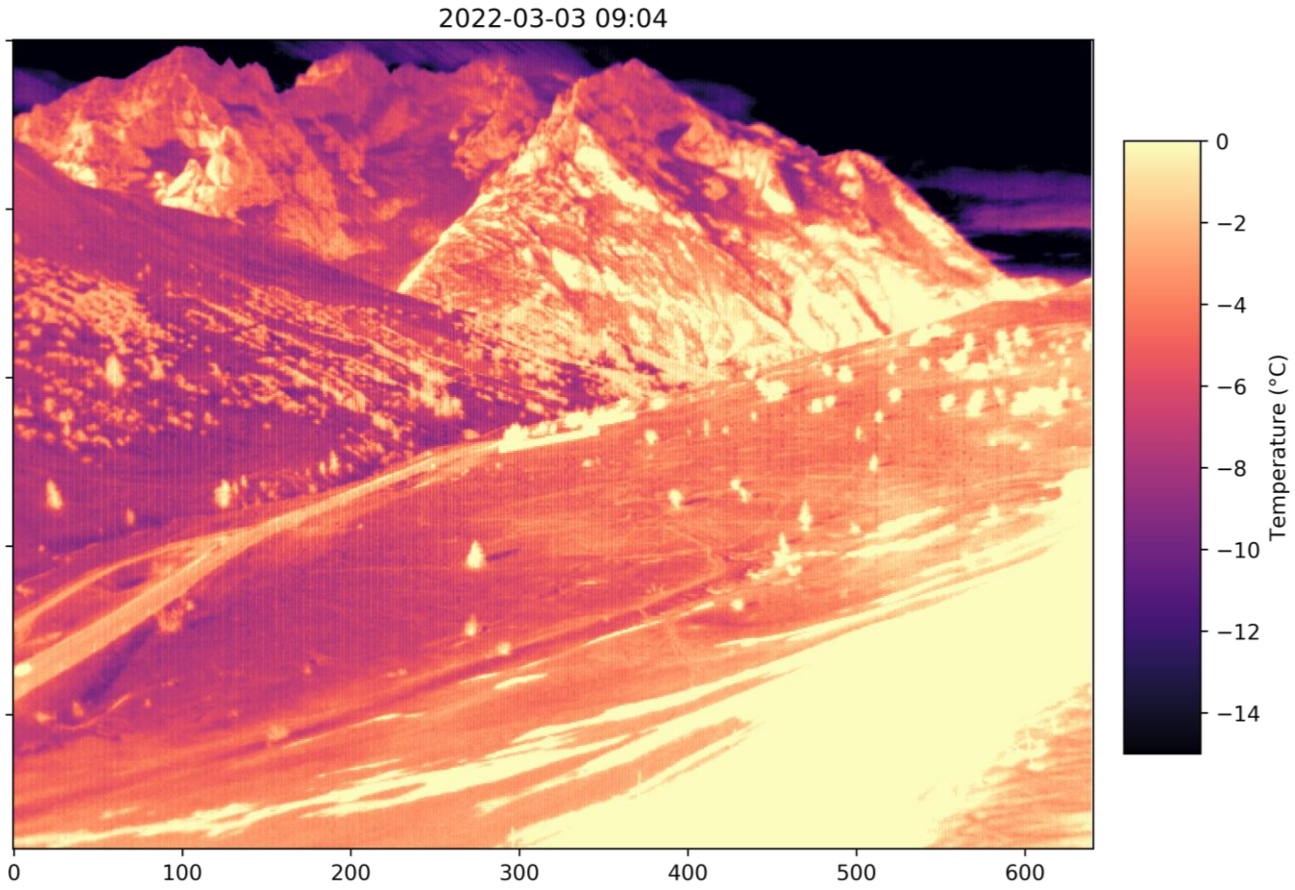
Snow surface temperature – relevance

- It determines the evolution of the optical and microstructural properties through feedback loops with the albedo

- It is a result of the surface energy budget

  → complex energy budget over complex terrain

  → **complex T_S distribution over complex terrain**



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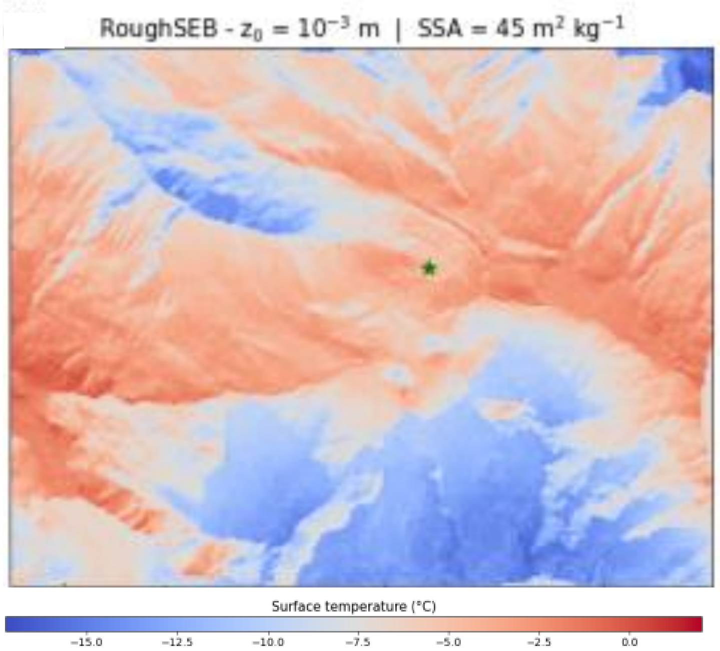
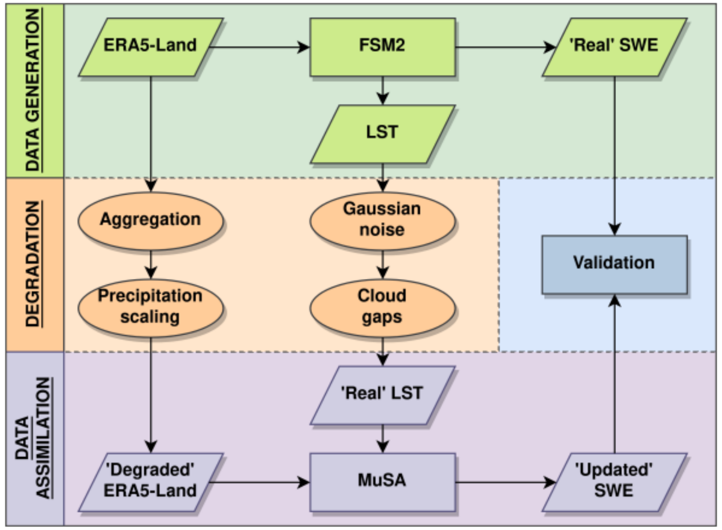
Snow surface temperature – three outlooks

Observations	Modeling	Data assimilation





Data assimilation

Observing System Simulation Experiment

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Synthetic surface temperature data

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Data assimilation

↓

Snow Water Equivalent (SWE) estimation

→ **Expected improvement of SWE estimations passing from the revisit time of Landsat 8/9 (16 days) to the one of Trishna (3 days)**

EGUsphere

Alonso-González et al. 2022, Improving numerical snowpack simulations by assimilating land surface temperature

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Modeling

RoughSEB model : computation of the surface temperature based on the closure of the surface energy budget

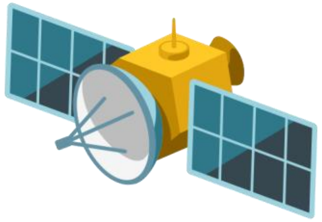
- Accurate computation of the radiative fluxes based on a **ray-tracing model**
- **Decametric resolution** to represent surface topography

The Cryosphere

Robledano et al. 2022,
Modeling surface temperature and radiation budget of snow-covered complex terrain

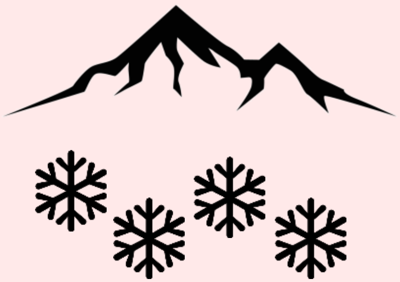
POSTER ID:258 – Ghislain Picard et al.
Modeling the surface temperature of snow-covered mountainous areas at the spatial resolution of Trishna, SBG and LSTM

Observations – instruments



Landsat 8/9
Ecostress

Extensive measurements of T_S



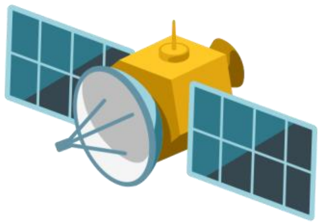
Relatively coarse resolution

Contribution of the atmosphere

Emissivity variations

Revisit time + clouds

Observations – instruments



Landsat 8/9
Ecostress

Uncooled
Thermal infrared
(TIR) cameras

Extensive measurements of T_S

Relatively coarse resolution

Contribution of the atmosphere

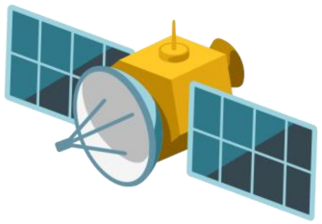
Emissivity variations

Revisit time + clouds

+ resolution
+ atmospheric contribution
+ insights into the role of emissivity
+ continuous measurements

- overall instability and T_{int} dependency of the camera's accuracy → **TIR radiometers**

Observations – instruments



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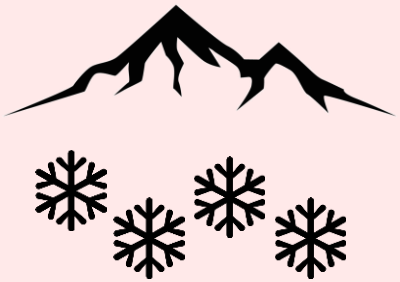


Relatively coarse resolution

Contribution of the atmosphere

Emissivity variations

Revisit time + clouds

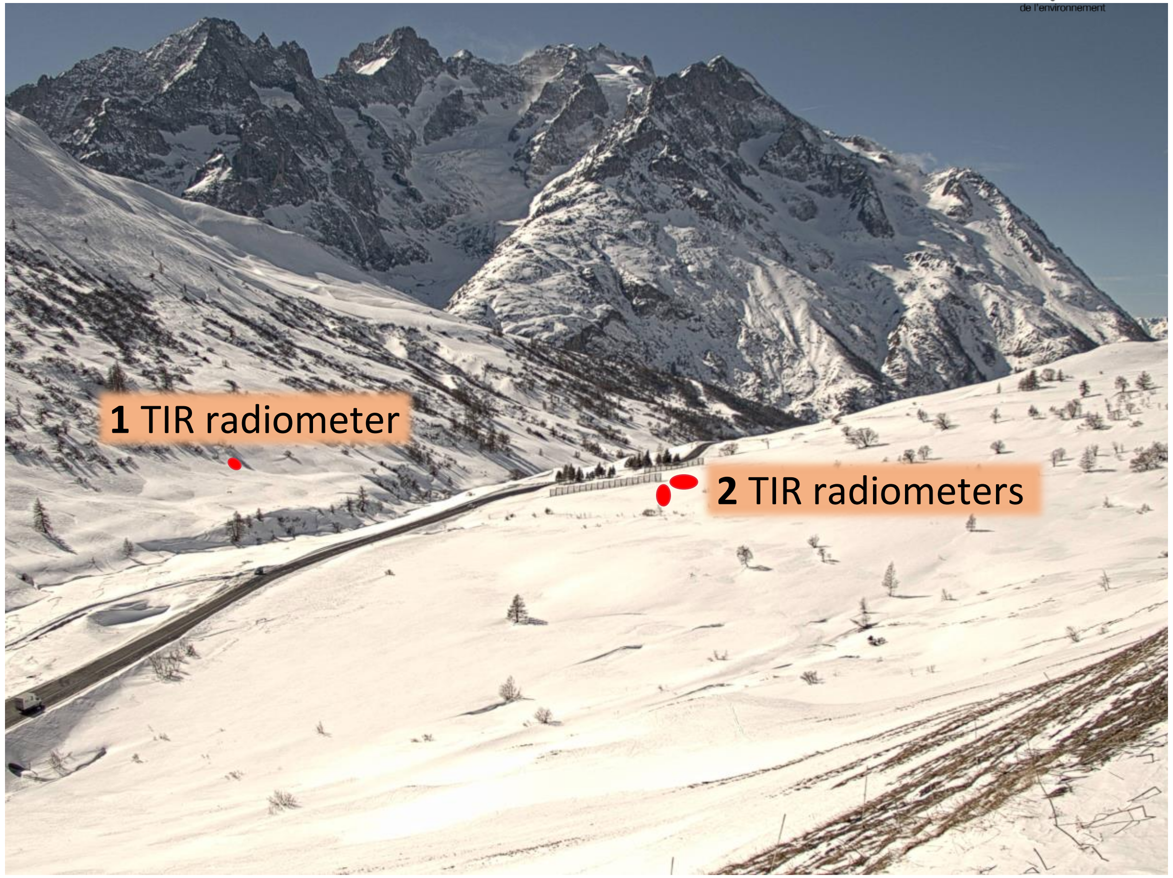
- \+ resolution
- \+ atmospheric contribution
- \+ insights into the role of emissivity
- \+ continuous measurements

\- overall instability and T_{int} dependency of the camera's accuracy → **TIR radiometers**

GOAL : obtain accurate measurements of the snow surface temperature using TIR cameras

Observations – measurement sites

Col du Lautaret, French Alps



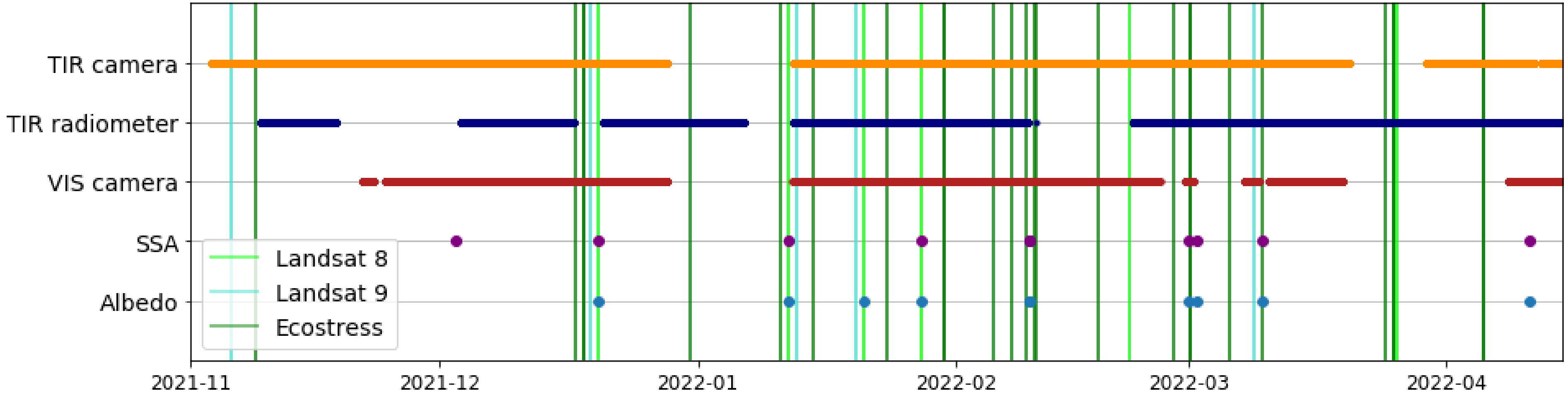
Pic du Midi, Pyrenees

Observations – 2021-2022 campaign

Data acquired during the winter of 2021-2022:

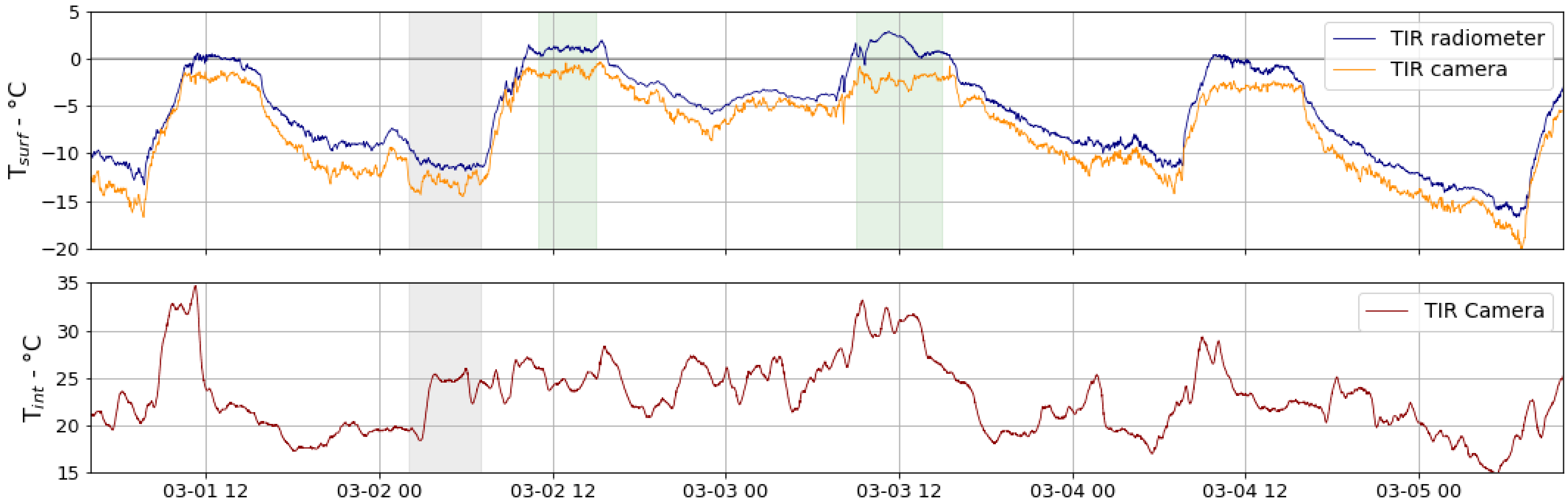
- **TIR camera** 230 days
- **TIR radiometers** 150 days
- **Visible camera** 133 days

- **Landsat 8/9** 17 cloudless TIRS images (daytime)
- **Ecostress** 26 cloudless TIRS images
- **Albedo** 10 measurements
- **Grain size** 10 measurements



Observations – T_S intercomparison

Temporal comparison between TIR camera and TIR radiometer:

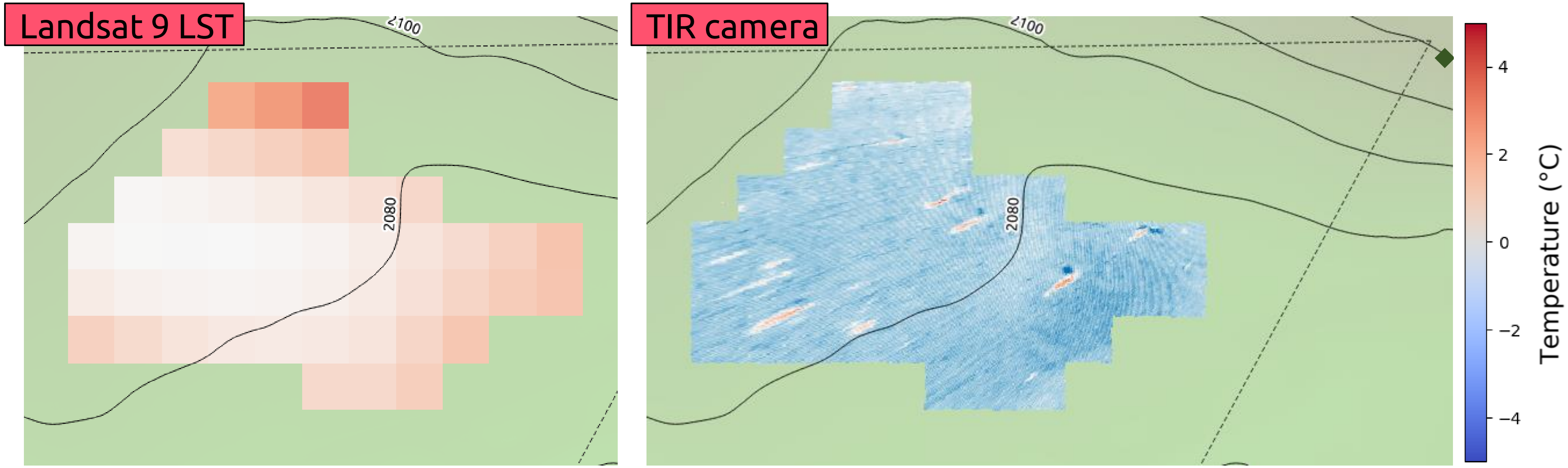


- Noise related to the internal temperature variations of the camera
- Inaccuracy of temperatures measured by the radiometer

On average $\mathbf{T_{cam} - T_{rad} = -2.1\ °C}$

Observations – T_S intercomparison

Spatial comparison between TIR camera and Landsat 9 LST in the presence of surface melt :



$T_{Landsat}$ = +0.77±0.67 °C

T_{camera} = -1.97±0.67 °C

Conclusion of the inter-comparison: **significant bias >1°C** between camera and radiometer measurements

Observations – critical issues

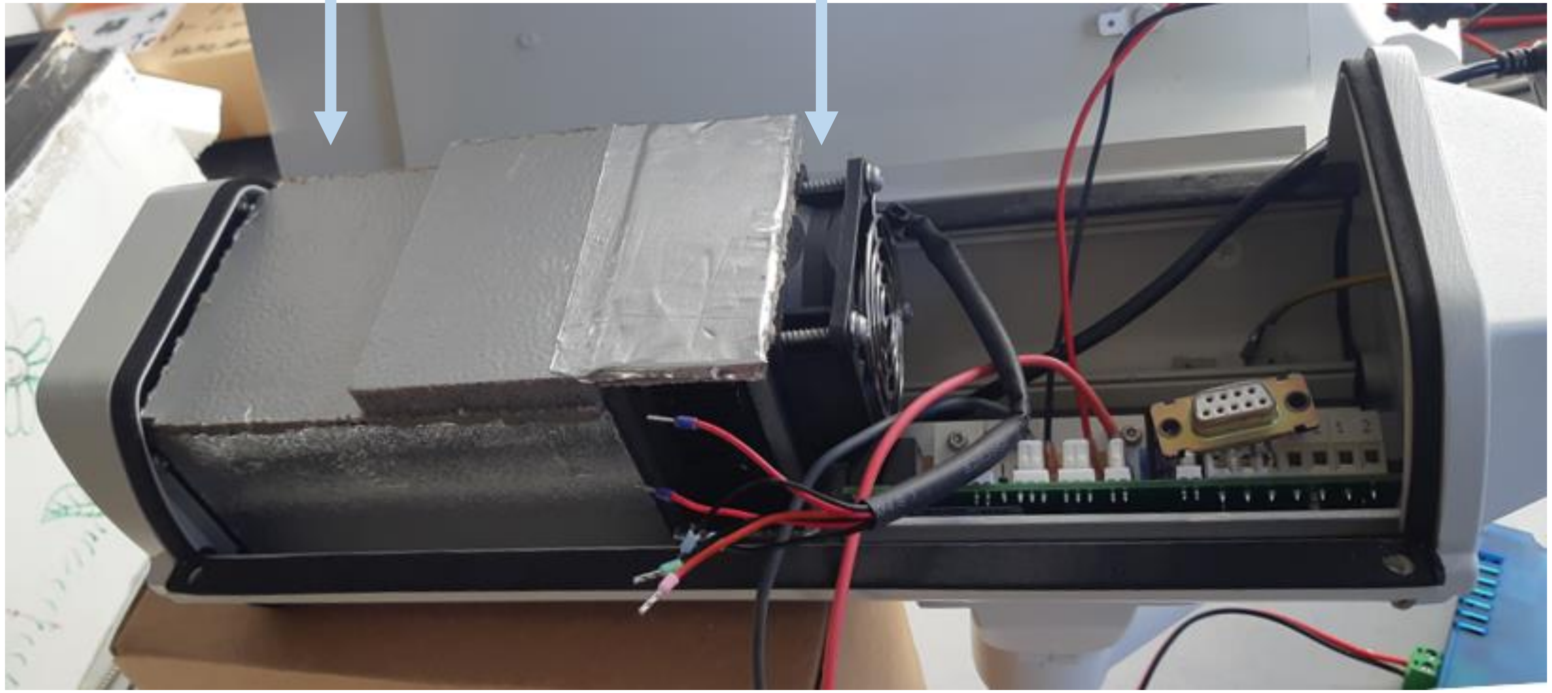
Problem 1	Inaccurate ground truth → **radiometers replaced by higher quality ones**
Problem 2	High noise caused by the instability of the internal temperature of the camera
Problem 3	Lack of a precise characterization of the camera window

Observations – critical issues

Problem 2 High noise caused by the instability of the internal temperature of the camera

Insulated camera

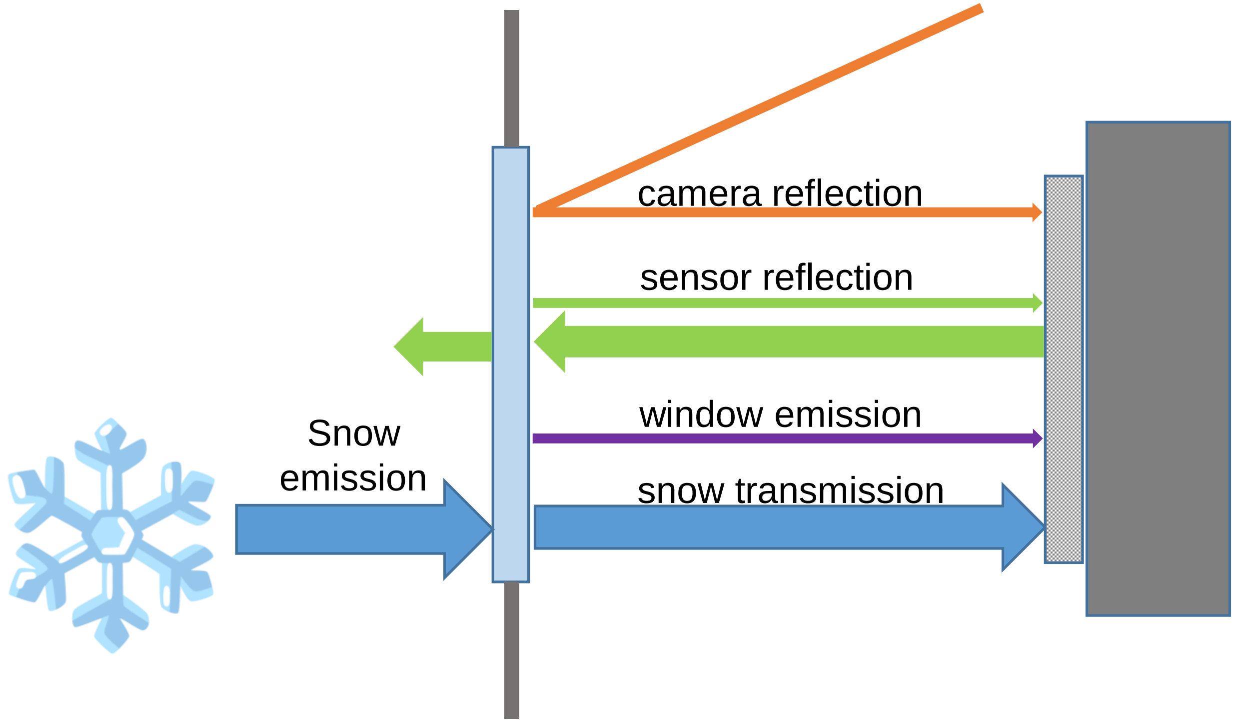
Peltier unit



Internal temperature
variations of 0.8°C
for external temperatures
between -10°C - 15°C
in lab conditions

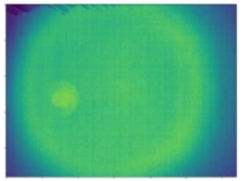
Observations – critical issues

Problem 3 Lack of a precise characterization of the camera window



Window transmission curve

Camera measurements of a blackbody source →



Characterisation of the window with TIR radiometers

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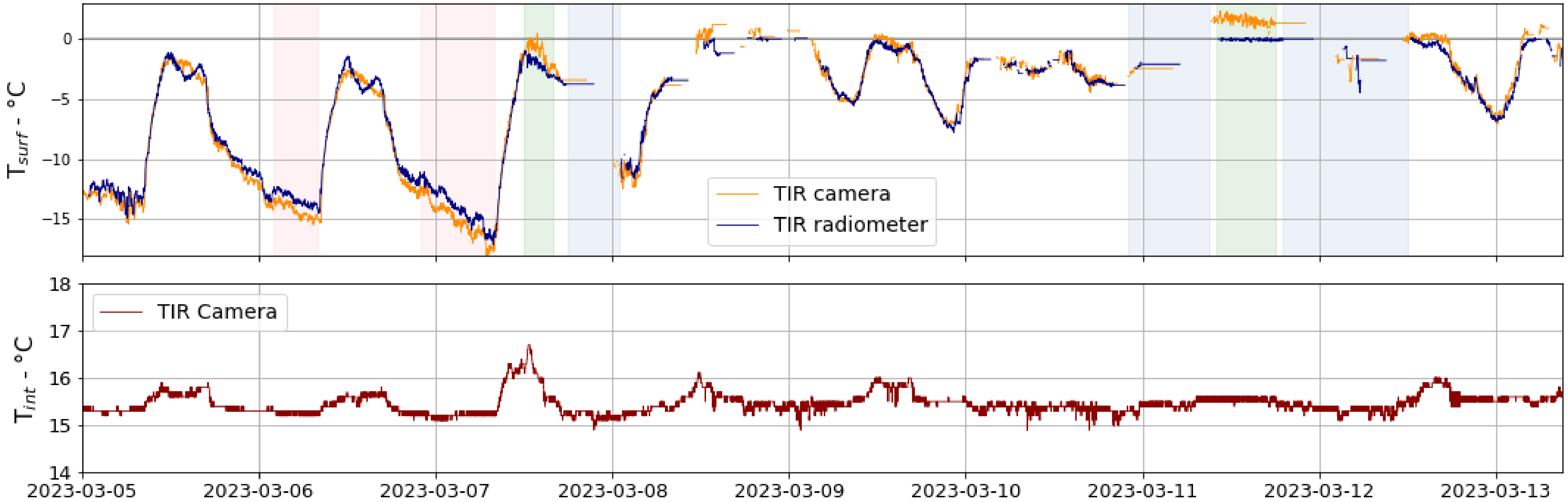
Camera window model

Observations – 2022-2023 campaign

Comparison between TIR camera and TIR radiometer **after application of the window model** :



- Clouds / fog → excluded data
- Temperature overshoots → overheating?
- Temperature undershoot

Emissivity?

Atmosphere?

On average T_{cam} - T_{rad} **well below 1.0 °C**

Take home message

Conclusions

1. Internal temperature stabilisation and camera characterisation lead to a **absolute accuracy of ≈ 1°C** of an uncooled thermal infrared camera

2. A rich and **unprecedented dataset** of accurate snow surface temperature was built → **soon published**

Take home message

Conclusions

1. Internal temperature stabilisation and camera characterisation lead to a **absolute accuracy of ≈ 1°C** of an uncooled thermal infrared camera

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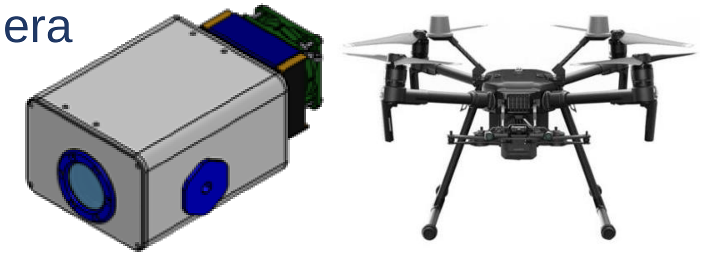
Perspectives

1. Validation for:

- satellites: **cal/val of Trishna, LSTM, SBG**
- models: RoughSEB POSTER ID:258
- assimilation experiments

2. Insights into the contributions of the **atmosphere** and **emissivity** of snow over complex terrain

3. **Drone flights**: preliminary tests with a stabilized TIR camera



Thank you