GLACIER SNOW/RAIN TRANSITION : THE IMPORTANCE OF ALBEDO

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AUDREY GOUTARD

- PhD student : started last october, supervised by Marion Réveillet, Fanny Brun and Delphine Six from IGE (Grenoble, France)

- Studies: Fundamental physics and then a master in Ocean , Atmosphere and Climate Sciences in Paris

- PhD subject : Impact of the snow/rain transition on glacier mass balances over the 21st century

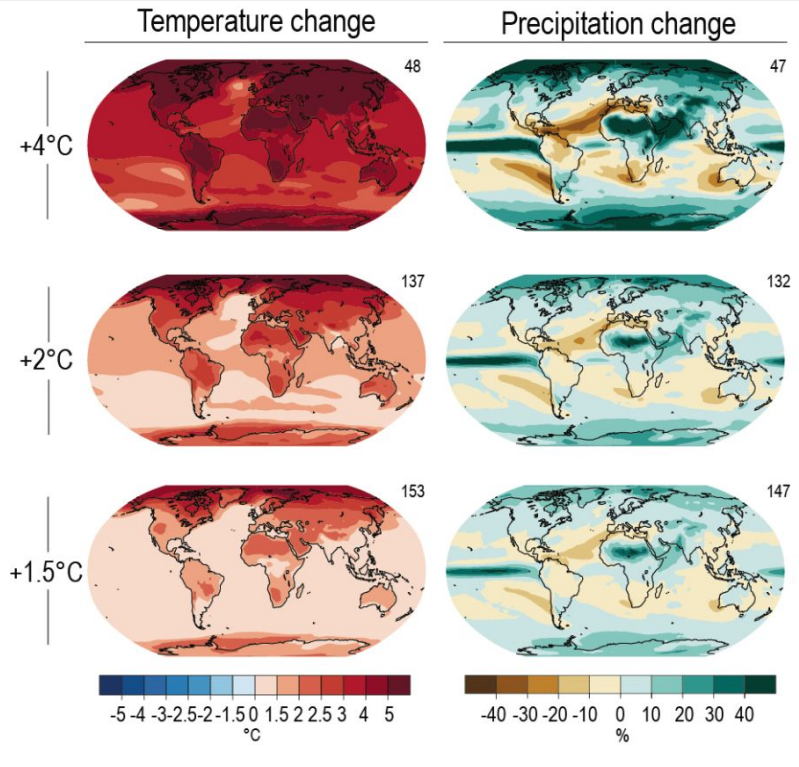

Figure 1 : Patterns of change in near surface temperature and precipitations, IPCC, 2021.

Temperature change

↓

Precipitation phase change

↓

Albedo change

↓

What impact on glacier mass balance ?

IMPACT OF THE SNOW/RAIN TRANSITION ON GLACIER MASS BALANCES OVER THE 21ST CENTURY

Providing refined **future glaciological projections** including feedback of **precipitation** and impacts of future **rain/snow transition** height in **3 different climate settings**

Argentière (France)

Zongo (Bolivia)

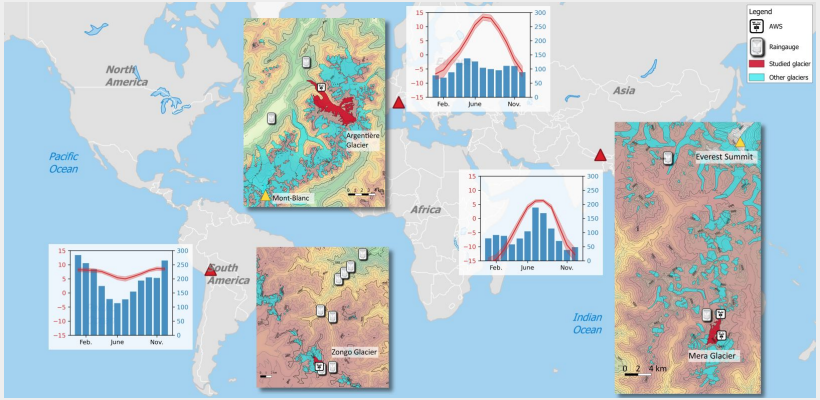

Figure 2 : Location of the three glaciers and the observation networks, ANR iFROG project by Fanny Brun.

Mera (Nepal)

DATA

Figure 3 : **Automatic weather station** on Zongo glacier (SAMA) located around 5050m high, measurement of albedo, temperature, humidity, wind, shortwave and longwave fluxes (in and out).

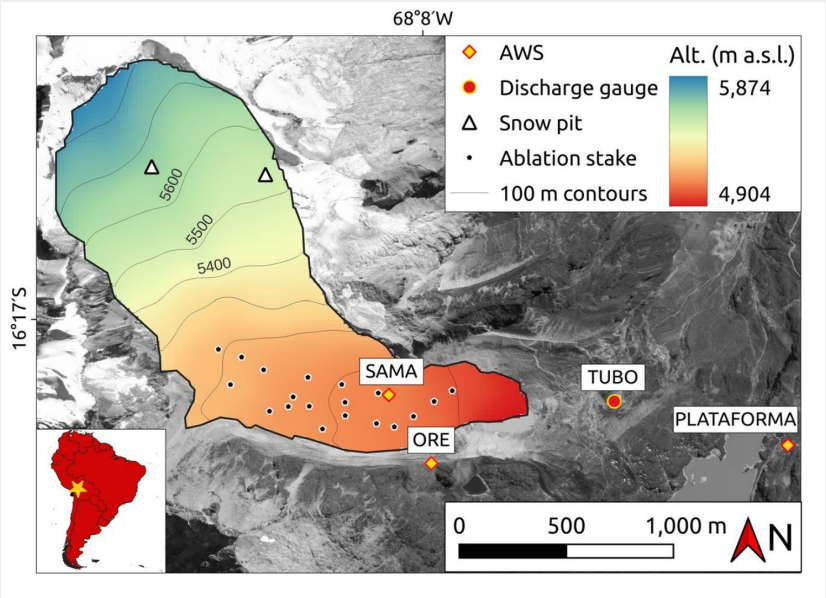

Figure 4 : Map of Zongo Glacier (Autin and al, 2022)

CROCUS

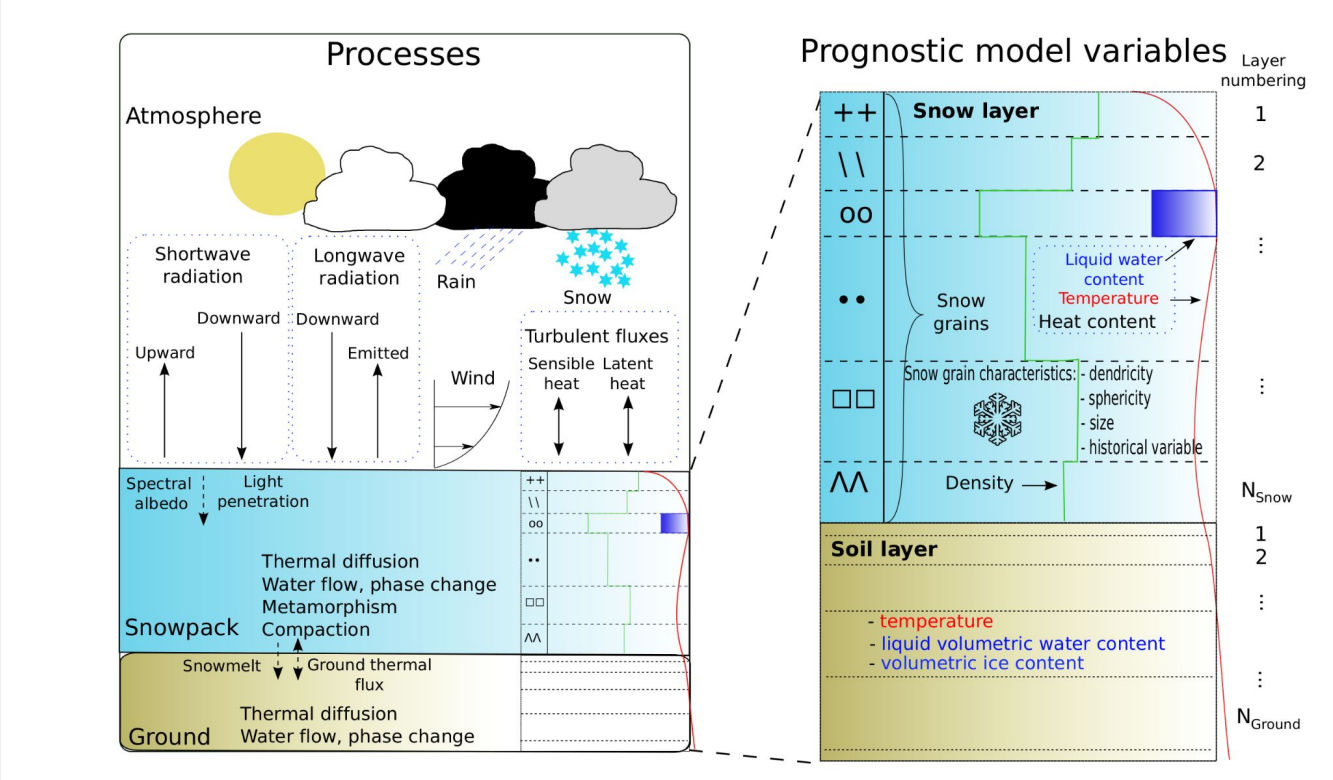

Figure 5 : Main physical processes of **snowpack model SURFEX/ISBA-Crocus** (Vionnet and al, 2012) also used for glacier mass balance modeling (Réveillet and al, 2018 & Lejeune and al, 2007).

Providing refined **future glaciological projections** including feedback of **precipitation** and impacts of future **rain/snow transition** height in **3 different climate settings**

Better knowledge of **snow/rain transition**

Better knowledge of **albedo**

RAIN/SNOW TRANSITION

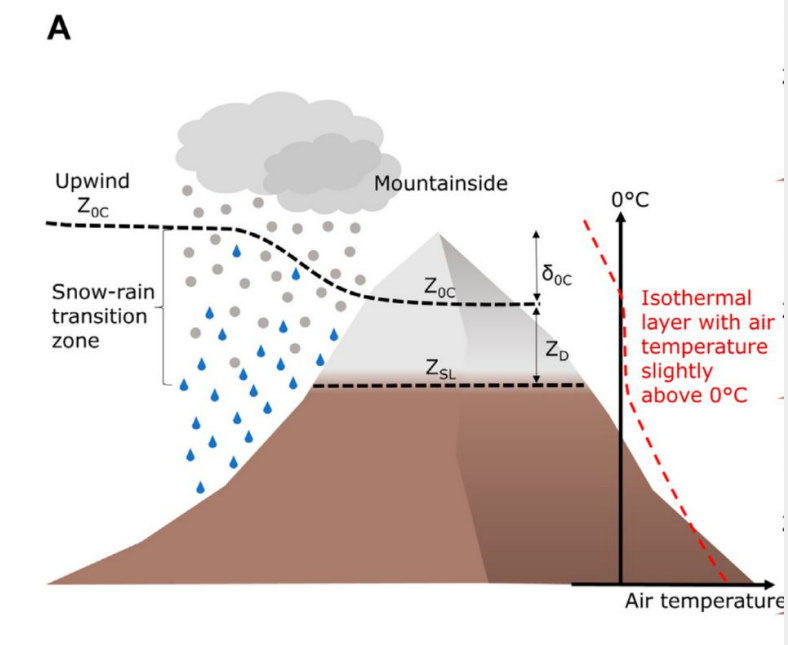

Figure 6 : **Terminology from Schauwecker et al. 2022,** black dashed lines show the altitude of the 0°C isotherm and the snowline

- Rain/snow transition ≠ snowline

- Rain/snow transition
  - Critical phenomenon
  - Definition not exact
  - Hard to measure → need MRR or disdrometer to determine the phase of the precipitation
- Snowline
  - Easier to measure with remote sensing
  - Limitations with cloud cover and satellite orbital period
  - Can use measures of albedo to retrieve the snowline

- Currently, studies investigating the snowline or snow/rain limit are very limited, especially in the Andes

ALBEDO

- Fraction of reflective radiation over total radiation
- For now, on the Zongo measurements of albedo are made locally (sensor at SAMA)

- Hard to know the altitude of the snowline with local measurements
- Important parameter in the model :
    - One of the most significant sources of melting energy
    - can vary a lot spatially

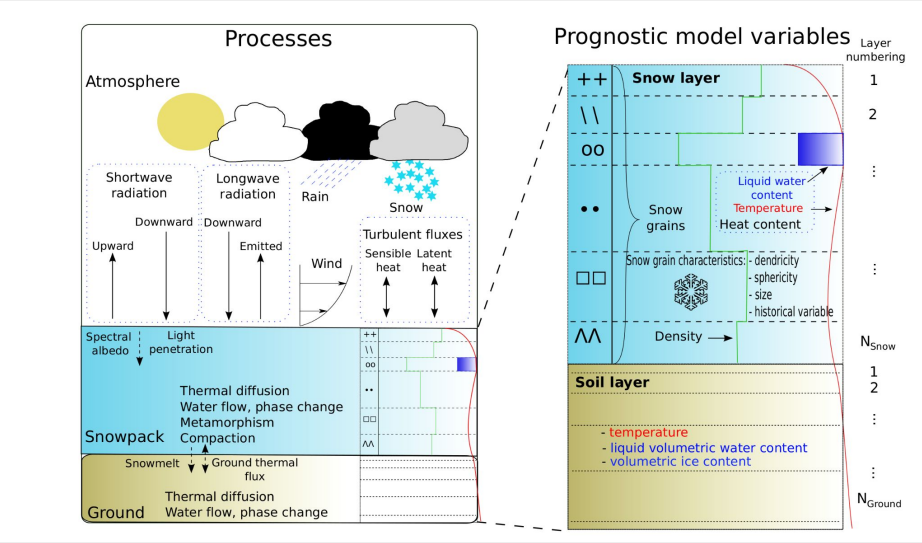

Figure 7 : Main physical processes of **snowpack model SURFEX/ISBA-Crocus** (Vionnet and al, 2012) also used for glacier mass balance modeling (Réveillet and al, 2018 & Lejeune and al, 2007).

ALBEDO

- To estimate snowline and better constrain the model → **Need spatialized albedo**

- Hard to have a spatialized albedo
    - Remote sensing methods
    - Limitations with cloud cover and satellite orbital period
    - Errors are more than 10% with remote sensing

- Development of other techniques to retrieve snow and ice albedo

DUMONT ET AL, 2012

Monitoring spatial and temporal variations of surface albedo on Saint Sorlin Glacier (French Alps) using terrestrial photography

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Abstract. Accurate knowledge of temperate glacier mass balance is essential to understand the relationship between glacier and climate. Defined as the reflected fraction of incident radiation over the whole solar spectrum, the surface broadband albedo is one of the most important variable in a glacier's mass balance. This study presents a new method to retrieve the albedo of frozen surfaces from terrestrial photography at visible and near infrared wavelengths. This method accounts for the anisotropic reflectance of snow and ice surfaces and uses a radiative transfer model for narrow-

The broadband bihemispherical reflectance of a surface (Bonnefoy, 2001) – referred to as albedo in the following – is defined as the fraction of the incident irradiance that is reflected by the surface over the whole solar spectrum. Thus, the albedo governs the amount of shortwave radiation that is effectively absorbed by the material. Since shortwave radiation plays a major role in the energy budget of temperate glaciers (Sicart et al., 2008; Slaymaker and Kelly, 2007, p. 57), the albedo is one of the leading variables controlling the energy balance (Six et al., 2009). Consequently, an accu-

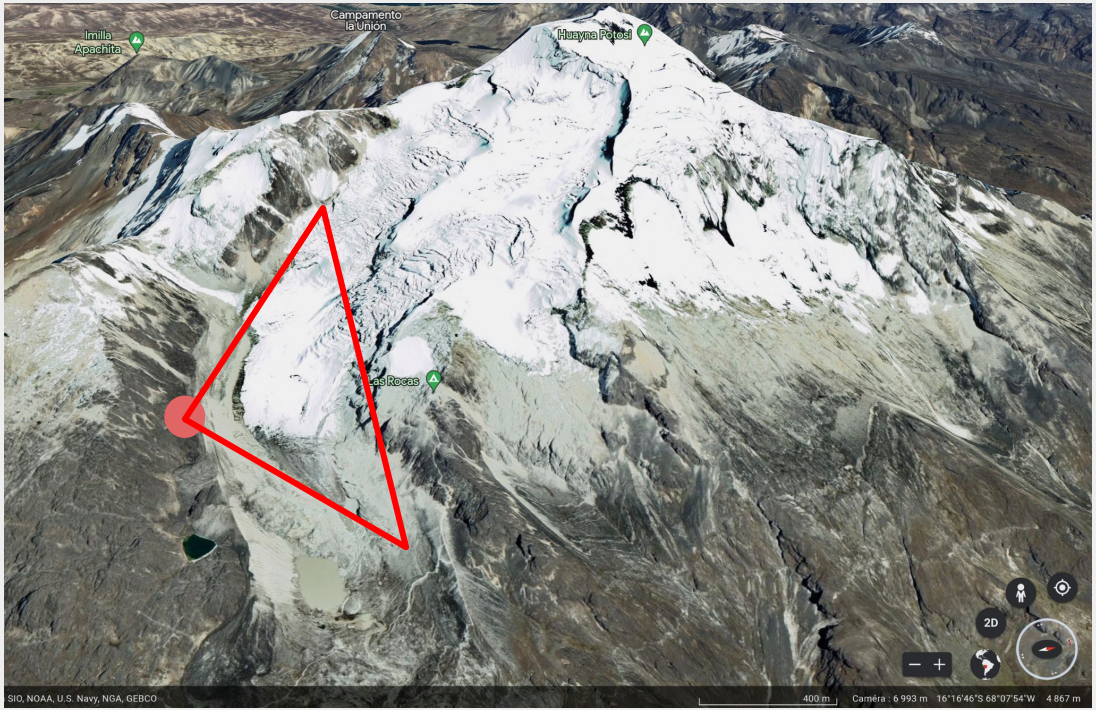
MONITORING SURFACE ALBEDO

- 2 cameras : visible and near infrared
- The whole glacier is captured several times a day

- Based on Corripio (2004) and Sirguey et al (2009) : different surfaces reflect different amounts of radiation in the visible and near-infrared wavelengths → can distinguish snow from ice
- Pros and cons :
  - takes into account topography
  - does not take into account anisotropy of the surface
  - need at least one measurement in the field
  - clear sky conditions

MONITORING SURFACE ALBEDO

- 2 cameras : VIS and NIR
- Covering a large part of the glacier
- Some limitations on the location



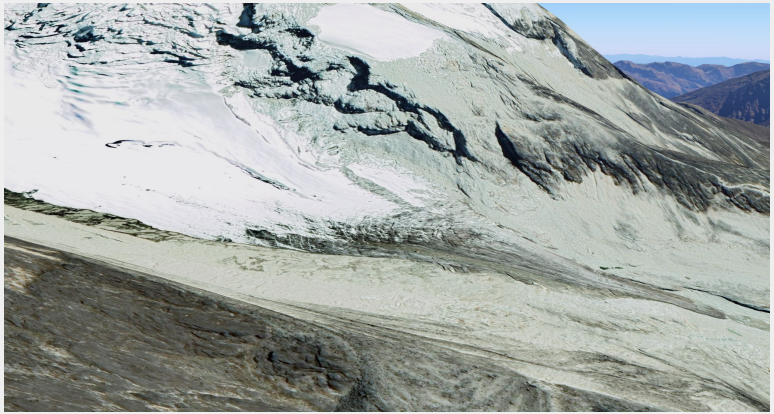
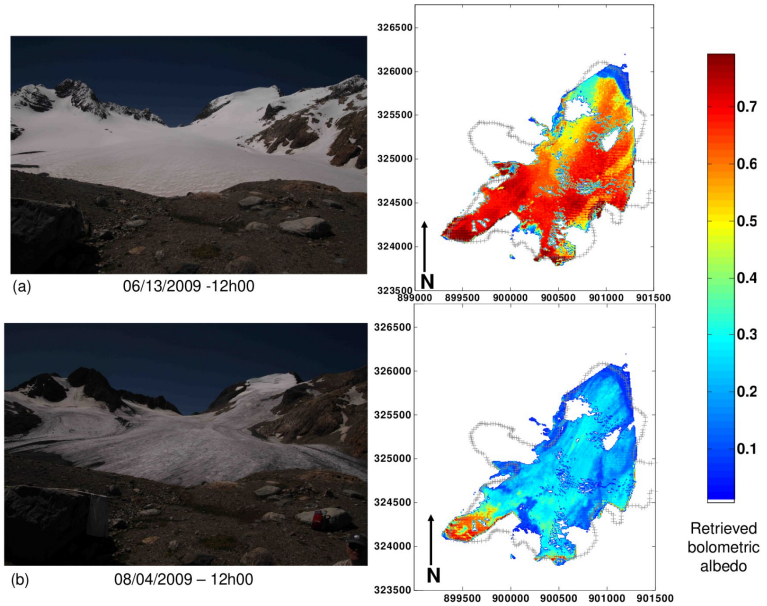


Figure 8 : Map of the **Zongo glacier** from above (left) and the view from the **possible location of the cameras** (right), Google Earth.

EXPECTED RESULTS



- Spatialized albedo over the glacier
  - better constrain the model (ex. puddle at the surface)
  - better knowledge of the impact of rain on snow events on the albedo

- Visible camera can give information about the weather on the glacier :
  - might see rain on snow events
  - help to distinguish rain and snow for some specific events

Figure 9 : Visible photography of the Saint Sorlin Glacier (left) and the **derived albedo map** (right) on 13 June 2009 12:00 LT (a) and 4 August 2009 12:00 LT (b), from *Dumont et al, 2012*

PERSPECTIVES

- Better knowledge of phase of precipitations on the Zongo glacier :
    - help to understand the impact of rain on the surface mass balance
    - help to refine modelisation and future projections

- In general for my PhD :
    - improve the physics of the model to better represent the future of rainfall on and in the glacier
    - work on the two other sites and compare them in order to know which area is the most impacted by the elevation of the rain/snow transition

THANK YOU !