Involvement of the SOERE CRYOBS-CLIM (CRYosphere, an OBServatory of the CLIMate – IR OZCAR) in snow and ice related hazards prevention in an Alpine context

Delphine Six (Univ. Grenoble Alpes / IGE)
Florence Naaim (Univ. Grenoble Alpes / Irstea)
Philippe Schoeneich (Univ. Grenoble Alpes, IGA)
Samuel Morin (Meteo France, CNRM-CEN)

And CRYOBS-CLIM team
Outlines of the presentation

✓ What is the Cryosphere?
✓ What are the snow and ice related hazards?
✓ What is CRYOBS-CLIM?
✓ What is our contribution to hazard prevention?

Conclusions
What is the Cryosphere?

• The Cryosphere is the frozen part of the earth system
• It exists at all latitudes and altitudes on land and sea and in the air for some portion of year (50% of the land surface (Vaughan et al., 2013)
• All continents are at some risk from cryospheric hazard

UNEP 2007
Small and large, fast and slow

**Small and rapid**: Ice/snow/rock avalanche

**Large and rapid**: domino effect

**Small and slow**: formation of lakes,...

**Slow at continental to global scales!**
- Sea-level rise related to melting of ice sheet
- Seasonality of runoff and freshwater supply linked to snowfall/snow cover duration and disappearance of glaciers
SOERE CRYOBSCLIM

CRYosphere, an OBServatory of CLIMate

Long term observatory (in-situ data with remote observations and modeling) of the terrestrial cryosphere (mountain glaciers, polar ice-sheets, seasonal snow cover and mountain permafrost)

located worldwide (at high latitudes and altitudes)

to address major societal issues such as water resources, ice-related hazards, atmospheric processes,

in a context of climate change

(European Alps, tropical Andes, Himalayas, Antarctica, Svalbard), 53 people, 8 laboratories, 1300 k€
The monitoring and research topics consist in documenting and studying:

- Ice, water, and vapor mass fluxes
- Radiative and turbulent energy fluxes
- Internal state of subsurface systems and the resulting continental water mass storage
- Ice dynamics and related consequences on ice flow
Snow and ice related hazard within CRYOBS-CLIM

Focus on the Alps

Three examples:
- Glacier (Outburst flood)
- Permafrost (Rockglacier collapse)
- Snow (Avalanche)
The 1892 catastrophe

• 175 fatalities

Outburst flood from Tête Rousse Glacier

Rupture of an interglacial cavity in Glacier de tête Rousse

The 1892 catastrophe

- 175 fatalities
- 200,000 m$^3$ of water + ice
- 800,000 m$^3$ of sediment

The cavity was formed from a crevasse that was filled and enlarged by melt water.
Mass balance reconstruction (red curve) using meteorological dataset and mass balance from Glacier d’Argentière (green curve)

- The origin of the meltwater reservoir was more likely a supraglacial lake formed before 1878 during a period of negative mass balance.
- Following a period of positive mass balance after 1878, the lake was hidden until the outburst flood of 1892.

Datasets of cryospheric components over large time periods are essential. It helps stakeholder to understand past trajectories and to anticipate the future.

Rockglaciers show different reactions to climate change:
- a normal behavior,
- a strong acceleration (crevasses, and scars)
  the collapse

Monitoring of selected cases allows to get a better understanding of the processes.

Rockglacier collapse

Inventory of destabilized rockglaciers

- Based on survey of destabilization features
- Velocity changes estimated from orthophoto comparisons

Over 20 potentially hazardous rockglaciers could be identified, and field surveys were initiated in 2017 on a few of them.
Complete the extraction process by filling in the blanks with relevant information from your source, such as names, dates, and specific details about rockglacier events.
The evaluation of avalanche release conditions constitutes a great challenge for risk assessment.

The spatial variability of snowpack properties has an important impact on snow slope stability and thus on avalanche formation.
Avalanche forecast – Snowpack model

Crocus

- A snow pack model used to compute the time evolution of the vertical profile of the physical properties of snow

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Figure: The variables considered.

CROCUS analysis provides an index for avalanche release which is used in avalanche bulletin


Detailed evaluation (snow depth, snow water equivalent (SWE), basal runoff, surface temperature and albedo, and profiles variables such as temperature, density, liquid water content and snow type)

- Weekly measurements of snowpack properties,
- Daily meteorological and snowpack conditions since 1960 (hourly measurements since 1993)

Avalanche forecast – Drifting snow model

Blowing snow events strongly affect the local evolution of the avalanche danger!
Avalanche forecast – Drifting snow model

Col du Lac Blanc (2700 m)

- Intensive measurements of wind, drifting snow and snow properties have been collected at the Col du Lac Blanc since 1990.

Avalanche forecast

Highly instrumented measurement campaigns are also essential. The calibrated models with in situ data allow to extend the knowledge acquired at local sites both in space and time.
Message to take home

✓ The Cryosphere is an important part of the CZ.
✓ It affects half of the land surface
✓ The datasets at the core of the SOERE CRYOBS-CLIM are often unique in the world
✓ Ice and snow related hazards from local to global scale are a constitutive part of CRYOBS-CLIM tasks (..., sea-level rise, seasonality of runoff and freshwater supply,..)
✓ Long term monitoring and highly instrumented measurement campaigns are essential.
ANY QUESTIONS?

Don’t be frozen by the subject
<table>
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<tr>
<th>Ice on Land</th>
<th>Percent of Global Land Surface&lt;sup&gt;a&lt;/sup&gt;</th>
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<tr>
<td>Antarctic ice sheet&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.3</td>
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<td>Greenland ice sheet&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.2</td>
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<tr>
<td>Glaciers&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.5</td>
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<tr>
<td>Terrestrial permafrost&lt;sup&gt;f&lt;/sup&gt;</td>
<td>9–12</td>
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<tr>
<td>Seasonally frozen ground&lt;sup&gt;g&lt;/sup&gt;</td>
<td>33</td>
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<tr>
<td>Seasonal snow cover</td>
<td>1.3–30.6</td>
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<td>(seasonally variable)&lt;sup&gt;i&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Northern Hemisphere freshwater (lake and river) ice&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1.1</td>
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<tr>
<td>Total&lt;sup&gt;h&lt;/sup&gt;</td>
<td>52.0–55.0%</td>
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A blowing snow scheme has been implemented into the operational chain for avalanche hazard.

- Amount of snow redistributed in saltation and turbulent suspension
- Sublimation loss
- Mechanical evolution of snow grains

Avalanche forecast – Drifting snow model

From data to model and back to data

Rockglacier collapse

Col du Lou rockglacier serve as model for the identification of other potential destabilized rockglaciers.

Field surveys were initiated in 2017 on a few of them.

Datasets of cryospheric components over large time periods are essential. It helps stakeholder to understand past trajectories and to anticipate the future.