How short warm events disrupt snowcover dynamics
Example of a polar basin – Spitsberg, 79°N

Éric Bernard¹, Florian Tolle¹, Jean Michel Friedt², Christelle Marlin³, Madeleine Griselin¹
¹ CNRS UMR ThéMA, université de Franche-Comté, Besançon, France
² CNRS FEMTO-ST, université Franche Comté, Besançon, France
³ CNRS UMR IDES, université Paris -Sud, Orsay, France

RESUME : L’Arctique est un indicateur pertinent des changements climatiques. Les dynamiques nivologiques sont directement affectées mais le suivi des processus est rendu délicat par leur rapidité alors qu’ils correspondent à des éléments clef. Ces observations ont pu être conduites sur le glacier Austre Lovén (Spitsberg, Norvège – 79°N) pendant le programme hydro-sensors-FLOWS. Pour mieux comprendre l’impact de ces phénomènes, des observations à échelle spatio-temporelle extrêmement fine ont été menées. Un réseau d’échantillonnage dense (36 points répartis sur 4,5 km²) installé sur le glacier a permis de mesurer différents paramètres : manteau neigeux à plusieurs reprises, bilan de masse, températures au pas de temps horaire. De plus, un réseau de 6 stations photo automatiques permet la cartographie précise du manteau neigeux. Les résultats ont montrés que l’impact de courts événements chauds sur les dynamiques nivo-glaciologiques était capital. La tendance observée ets plus due à un manque de froid l’hiver qu’à un été trop chaud. Un été doux et sec aura une incidence minimale, alors qu’un hiver doux et très arrosé sera extrêmement néfaste aux basses altitudes alors qu’il participera à une importante recharge neigeuse en altitude, au-delà de l’isotherme 0°C.

MOTS-CLEF : Changements climatiques, Arctique, dynamiques nivologiques, géomatique.

ABSTRACT: Arctic is a reliable indicator of global climate changes. Snow dynamics are directly affected, and following processes becomes challenging: some fast but key events can be missed since they are short but significant. Such observations have been made in the Austre Lovén basin (Spitsbergen, Norway – 79°N) during the Hydro-sensor-FLOWS program. To better understand the impact of climate changes, one approach is to use a fine scale monitoring protocol based on a high density network of sampling points. This has been carried out for 5 years on the Austre Lovén glacier. Overall, 36 measurement points have been distributed at regular intervals over the 4.5 km² glacier surface. For each of these points the snow cover was measured several times and mass balance was yearly recorded. Furthermore, temperature is measured over a 20 sensors network on the glacier, and at last, a network of 6 automated digital cameras is used to map snowcover dynamics. Results show that there is a strong impact of short warm events on snow and ice dynamics. The observed trend is more due to lack of cold in winter than by excess of warm in summer. A meanly warm and dry summer will have few incidence, when a warm and watered winter could be seen as detrimental at low altitude as it will contribute to an important snow refill of the glaciers over the 0°C isotherm.

KEYWORDS: Climate change, Arctic, snow dynamics, geomatic.
the small glaciers are clearly retreating since the end of the Little Ice Age (Hagen et al., 2003).

Austre Lovénbreen is a 4.6 km² alpine type valley glacier located on the west coast of Spitsbergen, on the Brøgger peninsula (79°N, 12°E, Fig. 1), 6 kilometres far from Ny Alesund settlement. It’s a 7 km-long glacier from South to North, and its elevation extends from 50 to 550 m.a.s.l. The glacier area is surrounded by many sharp peaks, whose elevation reaches 876 m.a.s.l (Nobilefjellet). Its hydrological basin represent from about 10 km². It is a typical small arctic basin which is both exposed to sea and mountain influence.

2.2 Climatic condition

The Brøgger peninsula is subject to the influence of the northern extremity of the warm North Atlantic current along the west coast of Spitsbergen (Liestøl, 1993). The present climate at Ny Alesund, along the northern shoreline of the Brøgger peninsula is of polar oceanic climate type. Considering hydrological years (1st October of a given year to 30 September of the next year), the annual average air temperature is -5.77°C (1969-1998) for an average precipitation amount of 391 mm (1969-1998) (source DNMI at http://eklima.met.no). Over the period 1969 to 2010, these parameters display values increasing with time: +0.51°C per decade in temperature and +14 mm per decade in precipitation. However, the time-series may be separated into two distinct periods, which indicates a significant climate change at least from the late 90s.

- During the first 29 years (1969-1998), the mean value was -5.77°C. There was no significant temporal gradient (-0.02°C per decade) in comparison with the last 12 years (1998-2010).
- From 1998 until 2010, the air temperature significantly increased with time (annual gradient of +1.26°C per decade). This recent gradient is around 2.5 times the average one calculated for the whole period (1969-2010). The mean air temperature during this 12-years period is always above the 1969-1998 average value that is always above -5.77°C (Figure 2). The mean air temperature value is -4.20°C for 1998 to 2010 period.

3 METHODS AND DATA

A specific measurements network was implemented on the Austre Lovén glacier, so as to follow the hydro-nivo-glaciological process (Fig. 2). This network has been designed to provide the most accurate spatio-temporal survey.

To complement satellite images, 6 automated digital camera-based have been installed. This setup, thanks to which oblique view pictures are gathered with high time and spatial resolution (the pixel size is at worst 0.46 m X 0.46 m considering the lens aperture), covers 96% of the glacier surface. We have selected the acquisition of 3 images every day at a fixed hour set to 7h, 11h and 15h UTC (corresponding to 8/12/16h (mean solar time at this longitude). Hence, weather permitting, a daily coverage of the glacier condition is guaranteed by this instrument network, providing a perfect complement to spaceborne satellite imagery whose availability is strongly dependent on weather conditions and satellite programming over the region of interest.
A network of 20 air temperature logger is distributed over the whole surface of the glacier (Fig. 1). This network gives the hourly temperature during all the year, on each of these points. This allows to calculate the thermal state of the glacier (hourly, daily or monthly depending on process studied) both giving a value for the whole surface and spatializing the information by interpolating data (Bernard et al., 2011). This data processing gives the possibility of observing each warm event, whatever their duration is. In addition, we can determine which part of the glacier is concerned by those specific events.

Concerning the precipitations, data used are those of Ny Alsund meteorological station, 6 km far from the glacier. Sensors on the glacier do not yield good results because of field conditions.

4 RESULTS

4.1 First observations

Results show that there is a strong impact of short warm events on snow and ice dynamics. Indeed, the last 5 years exhibit some clues to understand some key processes.

This short period belong to a hot decade which affects Svalbard: the observed trend is more due to lack of cold in winter than by excess of warm in summer. Observations at a local scale show the main impact of liquid precipitations on snowcover dynamics and then on glacier’s behaviour each season. The result is complex: a meanly warm and dry summer will have few incidence on the glacier mass balance, when a warm and very dry winter could be seen as detrimental at low altitude as it will contribute to an important snow refill of the glaciers over the 0°C isotherm.

4.2 Glacier thermal state

We note that, with the exception of warm events, there is no positive thermal state before May 1st. Regarding the thermal state of the glacier, a day can display both positive and negative temperatures, both temporally as spatially during all the year. These alternations continue late in the season, and full positive thermal state (on a daily scale of the glacier), does really install only during the first half of June.
season is in average warmer in 2008-2009 (0.8 °C) than in 2009-2010 (0.6 °C).

If it is difficult to identify clear trends, however, we note that the thermal summer, with temperatures significantly and sustainably positive, usually begins in mid-June to end during the first week of September.

### 4.3 Importance of winters

Winter is characterized by the occurrence of warm events: accompanied by precipitation, they have a major impact on the snowcover and therefore on glacier’s accumulation.

Winter 2008-2009 shows a significant temperature oscillation with many very cold peaks, reaching almost the -30 °C in January 2009. Between January and the end of May, when the thermal state rises very sharply (up from -20 °C to +2 °C), there are five peaks with minimum located between -20 °C - 25 °C. This winter is thus punctuated with six warm events, resulting from a sharp rise in temperatures. For each of these events, the period above 0 °C is extremely short (1.5 days on average), and temperatures drop as quickly as they are rose. It is an outstanding phenomenon, since the amplitudes of the thermal states are always above 15 °C.

Winter 2009-2010 has similarities with the previous season. The most important cold peak is also involved January. However, this winter is less cold, but mostly warm events are much more counted. Between November and May, there are indeed nine warm events that follow each time an extremely sharp rise in temperatures.

The thermal behaviour of the winter is not linear, but marked by extreme fluctuations in temperature. This could be nothing if it appears during dry conditions, unlike precipitations occur.

### 5 DISCUSSION

#### 5.1 Brutality of temperature fluctuations

To demonstrate this particularity, we can take the example of November 26th 2009 (Fig. 4). The details of the hourly evolution of the thermal state reveals fluctuations in the 0 °C isotherm.

![Figure 4. Daily thermal state and its Daily temperature sudden variation.](image)

It is thus noted that the glacier was left entirely in positive values for nearly two hours, which is sufficient to initiate melting dynamics. Such event, which creates circulation of liquid water within the snowcover, is causing crusts found in the stratigraphic profiles. In addition, melt accompanied by rain greatly reduces mass and thickness of the snowcover.

#### 5.2 Winter short warm events

Let’s take the example of one warm event that occurred on January 15, 2010. This one was particularly representative.

Although the daily thermal states of January 15 and 16 are negative (about -0.6 °C), there is a relatively large area of the glacier (22 and 24%) in positive values. On this part of the glacier, heavy precipitations are probably rainfall, with consequences on snowcover, which could completely disappear. Following the refreezing observed on the following days, a large amount of the precipitation could be found in the form of melt-freeze crust in the snowcover.
5.3 Visual results

According to the camera network, the figure 6 shows one of the many impacts of warm events accompanied by rain. This was observed at the late October, when winter seemed to be installed. It took just a few hours of huge rainfall occurred simultaneously with an important rise of temperature to destroy completely the snowcover. This warm event lasted less than a day: thermal state was significantly negative before and after this event.

6 CONCLUSION

Despite of a general climatic trend along an hydrological year, short warm event observed and described above could show reversing effects on snowcover over a period of only a few days or sometimes a few hours.

7 REFERENCES


