**Igluna project: Glaciology research goals.** B. Albers[1], B. de Winter[2], M. Heemskerk[3], B. Foing[3,4,5] and the IGLUNA team[3]. [1] Vrije Universiteit Amsterdam, (Bram_Albers@hotmail.com). [2] Vrije Universiteit Amsterdam, (dewinterbram@hotmail.com). [3] Vrije Universiteit Amsterdam, [4] ESA ESTEC, [5] ILEWG

**Introduction:** The goal of IGLUNA is building a habitat in ice. This habitat should provide a foundation for a sustainable living in space [1]. The IGLUNA project is part of the ESA_lab and the Swiss Space Centre, which brings different student teams together from different disciplines to work on this project. The student group from the Vrije Univeriteit Amsterdam is developing the scientific research that can be applied inside the habitat. One major part of the Vrije Universiteit Science Experiments (VUSE) [2] is developing a system for chemical analysis of rock and ice samples. These research goals and analysis will be tested and implemented during the field campaign (17-30 June 2019) in a glacier nearby Zermatt in Switzerland.

**Ice Analysis:** The ice samples will be drilled by an ice bore developed by AMPEX [3]. The ice cores will be stored inside SMART-ICE Lab of the habitat. The temperature in this compartment is -4 degree Celsius. After the cores are split in two, One halve will be used to observe the annual stratification. This layering is an indication for the age of the glacier [4]. Each layer will be tested on four different measurements.

- First will every ice layer be melted and filtered. The residue consist of eolian transported material, including organic material (OM). The proportion OM will be measured in situ by visual observations and visual spectroscopy fluorescence. The residue of dust particle will be weighed and noted in a concentration (µg/cm$^3$). Dust concentration is an indication for the paleoclimate. A higher dust content indicate a colder climate, because when the temperature is lower, it is drier and therefore there is less vegetation. This results in a higher wind speed and dust flux [5].

- The meltwater of each layer will be captured and tested for the Electrical Conductivity (EC). The Electrical Conductivity of the meltwater, is an indicator for the amount of dissolved ions [6]. The higher the electrical conductivity the higher amount of ions. This amount is also a paleoclimate indicator. In a colder climates there are more aerosols deposited. This results in a higher aerosol content and electrical conductivity.

- In the same meltwater the acidity will be measured with a pH-meter. This will indicated the amount of $H^+$ in each ice layer. The degree of acidity is caused by the precipitation of snowfall. Due to the emission of greenhouse gasses, the acidity of precipitation is increasing [7]. When the ice core is drilled deep enough, there might be an rise in acidity, because of the main increase of greenhouse gases since 1950. Furthermore the acidity give more information about the dissolve ions in the glacier, which contribute to the EC written above.

After these measurements, the meltwater will be evaporated. All the dissolved ions and dissolved organic material will precipitate. This amount will also be weighted, and noted in a concentration (µg/cm$^3$). Again the proportion of OM will be measured by visual observations. Besides by adding hydrochloric acid it is possible to detect the present of carbonate.

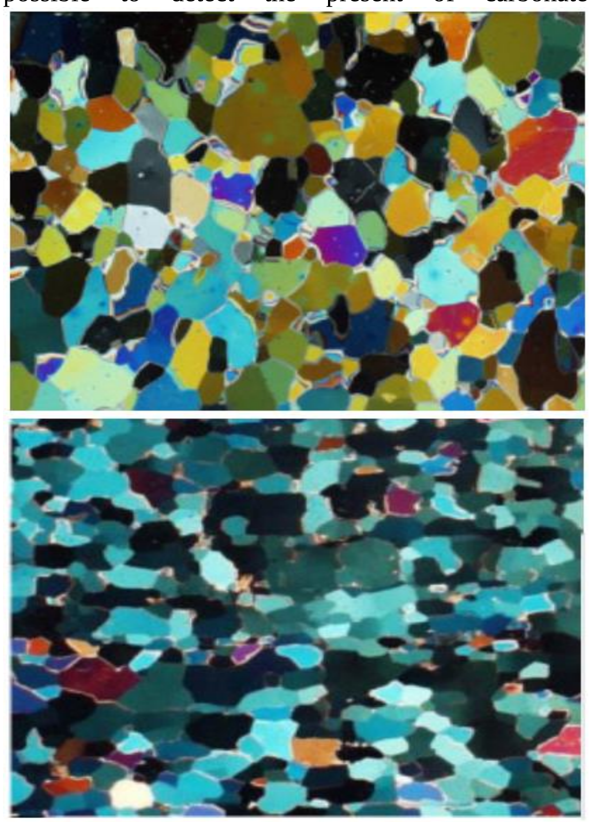

**Figure 1: Thin section of ice under a polarized microscope. The ice crystals in the upper photo are randomly orientated (different colors). The ice crystals in the lower photo are more deformed and have almost the same orientation (same color)[8].**

The other halve of the ice core will be used for making thin sections (~1 mm thick) perpendicular to the core, at different depths. Thin sections are made by melting a bigger ice sample to a thickness of 1 mm [9]. Two measurements will be made.

- First the grain size of the ice crystals will be determined. The grain size is an indication for the age of the glacier. Ice crystals grow with age, and larger ice crystals indicate older ice crystals [8]. We expect that the grain size will increase with depth.

- Secondly, the thin section of ice will be observed by polarized light. Ice crystals are changed in position due to the stress in the glacier. This is visible with the different colors of the ice crystals [figure 1]. By rotating the thin section in three directions, it is possible to ‘blackens’ the ice crystals. This is an indication, that the ice crystal is parallel to the surface or perpendicular to the incoming light. Furthermore this is physical the most ideal situation by stress. The position of several ice crystals will be mapped in a stereo net. Eventually, a concentration of poles will indicate the main stress direction on the ice sample [6]. When this techniques is applied at different depths it is possible to construct a spatial pattern.

At last the temperature of the ice will be measured at different depths. It is possible to determine the effect of the atmospheric temperature on the ice and how deep this atmospheric influence goes. Also it is an indication for how close the ice is to melting.

The temperature, grain-size and the stress directions analyses can be used to divide the glacier in different phases [6].

**Instruments:** For the described research objects, several instruments are required. An ice lighter will be used to distinguish the different ice layer. Ice layers that contain less debris absorb more light than layers with more debris [4]. For melting and filtering each individual layer, a heater and many filters are required. The heater can also be used to evaporate the dissolved particles and making thin-sections. Because the weight of the residue and evaporated ions is very low, an accurate balance is needed. An EC-meter and a pH-meter are necessary for measuring the EC and the pH-value. The thin sections will be observed under a polarized microscope. This microscope will also be used to detect organic material. To determine the deformation of the ice. At last a thermistor string is required to measure the temperature at several depths.

**Field Campaign:** The exact location of the field campaign is in the Glacier Palace, in the south of Switzerland. The Glacier Palace is located in the Upper Theodul glacier at 3810 meter high near the peak of the Klein Matterhorn [figure 2] [10]. The habitat is located in the accumulation zone of the glacier, at the southern part of the Alps. This might result in a clear annual ice layering and dust sources from the south (e.g. the Sahara desert, Mediterranean sea and the Po valley). However the deformation of ice-crystals might be limited, because of the relatively young accumulation. Also the grain size of ice crystals will be less developed. The ice flow of the glacier is to the north, so we expect the main stress direction on the ice-crystals in this direction. Besides the vertical stress will increase with depth. At last we expect at this location to distinguish two facies [6].

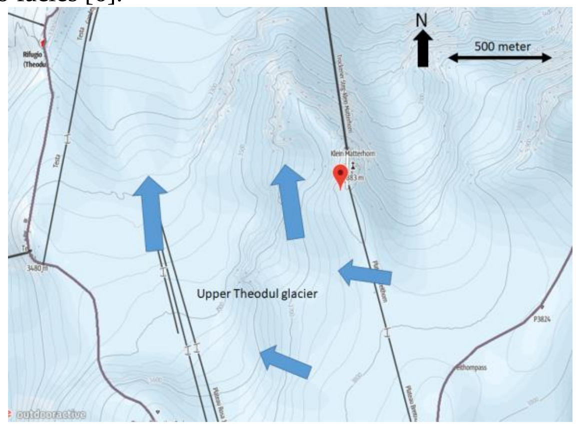


**Figure 2: Overview field campaign location. Red dot: habitat location. Blue arrows: the ice flow direction.**

**Acknowledgements:** I would like to thank prof. Bryn Hubbard, dr. Simon Cook, dr. Harold Lovell and dr. Heïdi Sevestre for sharing their experience and tell me more about glaciology. At last I would like to thank the IGLUNA team for their support and collaboration.

**References:**

[1] Swiss Space Centre (2018), Igluna. https://www.spacecenter.ch/igluna/

[2] De Winter, B. (2019) LPSC50, #1588

[3] AMPEX (2018), The Aachen modular planetary exploration system. https://www.ampex-igluna.com/

[4] A. Svensson (2018). The visual stratigraphy of the ice. http://www.iceandclimate.nbi.ku.dk/research/drill_analysing/cutting_and_analysing_ice_cores/visual_stratigraphy/

[5] D. R. Muhr (2012). The geologic records of dust in the Quaternary, Chap. 8, Sec. 3

[6] B. Hubbard and N. Glasser (2005). Field techniques in glaciology and glacial morphology, Chap. 3, Sec. 4.3 and 4.6

[7] J. Ruggaber (2016). What is acidic snow? https://www.quora.com/What-is-acid-snow

[8] A. Svensson (2018). Ice crystal structure. http://www.iceandclimate.nbi.ku.dk/research/flowofice/ice_crystal_structure/

[9] S. J. Cook et al. (2016). Geomorphological Techniques, Chap. 3, Sec. 4.1

[10] Zermatt Matterhorn (2018). Glacier palace. https://www.zermatt.ch/en/Media/Attractions/Glacier-palace