GEO 809 Fachexkursion 2014-2015

Research and Monitoring of the Alpine Cryosphere in a Swiss Mountain Valley

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Samuel Nussbaumer
Michael Zemp

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## Participants 2015

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<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
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<td><a href="mailto:johannes.schindler@psi.ch">johannes.schindler@psi.ch</a></td>
</tr>
</tbody>
</table>
I. Administration

1. Maps
A  Eingang Forschungsstation
B  Sphinx-Observatorium
C  Wissenschaftliche Ausstellung
JUNGFRAUJOCH
TOP OF EUROPE
UNESCO Welterbe Schweizer Alpen

Zu den Höhepunkten im Leben jedes Schweizer zählt ein unvergesslicher Tagesausflug mit Europas höchsten elektrischen Eisenbahn zu den hochalpinen Wanderwelt auf 3454 Meter über Meer im UNESCO Welterbe Schweizer Alpen.


Weitere Informationen:
Kulturerbe Jungfraubahnen, Höhenweg 37, 3800 Interlaken
Telefon 033 828 72 33, info@jungfraubahnen.ch, www.jungfraubahnen.ch

3454 Meter über Meer
MEDIZINISCHE TIPPS
zum Ausflug aufs Jungfraujoch
ES GELTEN DIE FOLGENDEN EMPFEHLUNGEN

Höhenaufenthalt ohne Einschränkungen:
- Ein höheres Alter ist kein Hindernis für einen Aufenthalt in der Höhe.
- Bei medikamentös gut eingestellten Blutdruckpatienten ist der Höhenaufenthalt unbedenklich.
- Asthmakinder dürfen sich gewöhnlich in die Höhe begeben. Höhenlinderung ist nicht erforderlich.
- Epileptiker, die medikamentös gut eingestellt sind, dürfen sich der Höhe beugen.

Im Zweifelsfall ist eine vorgängige ärztliche Beratung angezeigt:
- Patienten nach einem orthogonalen Eingriff an den Hinterbeinen sollten nicht mehr als 3000 Meter über dem Meeresspiegel aufsteigen.
- Patienten mit Herzfehlern und einer eingeschränkten Pumpfunktion des Herzens (Herzinsuffizienz) sollten vor einer Aufzugsfahrt einen ärztlichen Befund aufweisen.

Höhenaufenthalt nicht empfohlen:
- Lungen- und Herzpatienten, die bereits in Ruhe oder beim Aufstieg Fieberschübe oder Atmungsstörungen haben, müssen von einem Höhenaufenthalt abgesehen werden.
- Patienten mit Angina pectoris oder schweren eingeschränkten Leistungsfähigkeit bei Herzinsuffizienz und Herzschwäche sollten nicht in große Höhen gehen.
- Herzhärtungsproblemen (Hypertonie) und Herzinsuffizienz unter medikamentöser Therapie sollten sich nicht in großen Höhen aufhalten.
- Patienten mit einem ausgeprägten Risikoprofil für kardiovaskuläre Erkrankungen (Hypertonie, Hämophilie, hochgradige Zuckerkrankung, hoher Blutdruck, Herzinsuffizienz) sollten vor einem Höhenaufenthalt einen ärztlichen Befund aufweisen.

WEITERE PRAKTISCHE TIPPS
- Bei Schlaflosigkeit empfiehlt sich ein abschirmender Nasensperrer vor einer Taufahrt, um Respiration durch fehlende Druckausgleich vorzubeugen.
- Mit einer extra Decke steht die Umgebungstemperatur. Deshalb ist bei Ausschlägen über 500 Meter auch im Sommer auf Wärmekleider zu achten.
- Die intensive Strahlung der Sonne bedeutet einen zusätzlichen Sonnenschutz der Haut und die Augen. Auf dem Gipfel sollte eine Sonnenbrille und der Sonnenschutz reichhaltiger sein.
- Im Gletscherplateau kann es bei Extremwetterbedingungen einen Sprung in den Frost zunehmen. Deshalb ist ein abnehmbarer Schneefell und eine warme Schneeschuhung zu empfehlen.
3. Contamination information research station Jungfraujoch

Internationale Stiftung
Hochalpine Forschungsstationen
Jungfraujoch + Gornergrat HFSJG
Sidlerstrasse 5
CH-3012 Bern

In der Sphinx sind empfindliche Messungen im Gange

Ihre Aktionen könnten die Qualität der laufenden Messungen auf Jungfraujoch gefährden

Bitte nehmen Sie sich etwas Zeit, um folgendes zu lesen:


Beispiele für problematische Geräte und Verbindungen sind Kühlboxen/Kühlschränke (Kühlmittel), Schaum (bautechnischer, Isolierschaum für Kühlboxen), Dosier-Inhalatoren (Asthma Sprays), Lösungsmittel (Anstrichmittel, Putzmittel), Brandschutzmaterialien und Feuerlöschmittel, alte Sportschuhe (Nike), Kalibrations-, Puffer-, und Träergase, welche für Messinstrumente benutzt werden, sowie Rauch (Zigaretten). Der Gebrauch dieser Substanzen ist im ganzen Sphinx-Bereich problematisch, namentlich in der Nähe von Lufteinlässen. Die Benutzung einiger dieser Substanzen ist nicht vermeidbar, wir sind Ihnen aber sehr dankbar, wenn Sie uns über eine mögliche Beeinträchtigung informieren.

Versuchen Sie generell, Ihre Anwesenheit auf der obersten Etage der Sphinx auf ein Minimum zu reduzieren, trotz der spektakulären Aussicht.

Es ist absolut verboten, auf den Terrassen zu rauchen (oder Feuer jeglicher Art zu entfachen), um Verfälschungen der Aerosol-Messungen zu vermeiden.
Die Stoffe in der untenstehenden Liste können problematisch sein.

**Fluorkohlenwasserstoffe (HFCs), halogenierte Fluorchlorkohlenwasserstoffe (HCFCs), Fluorchlorkohlenwasserstoffe (CFCs), perfluorierte Kohlenwasserstoffe, Halone, SF6** werden als Kühlmittel, Schäumungsmittel und Treibgas in Sprays benutzt, sowie in Feuerprüf- und Löschgeräten.

Kontakt: martin.vollmer@empa.ch

<table>
<thead>
<tr>
<th>Allgemeine Bezeichnung</th>
<th>Formel</th>
<th>Alternativbezeichnung</th>
<th>Gebrauch</th>
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<tr>
<td><strong>HFCs</strong></td>
<td></td>
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<tr>
<td>HFC-134</td>
<td>CH₃CF₂</td>
<td>Kühlmittel, Schaum</td>
<td></td>
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<tr>
<td>HFC-152a</td>
<td>CH₂CHF₂</td>
<td>Schaum</td>
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<td>CHF₂CF₃</td>
<td>Kühlmittel</td>
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<tr>
<td>HFC-143a</td>
<td>CH₂CF₂</td>
<td>Schaum</td>
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<tr>
<td>HFC-365mc</td>
<td>CH₂CF₂CH₂CF₃</td>
<td>Schaum</td>
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<td>HFC-245fa</td>
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<td>HFC-236fa</td>
<td>CF₂CH₂CF₃</td>
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<tr>
<td>HFC-227ea</td>
<td>CF₆CHFCCCF₃</td>
<td>Inhalatoren, Feuerlöscher-geräte, Kalibrationsgas für Trübungsmesser</td>
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<td>R-XXX, e. g. R-404, R-407 und ähnliche Mischung aus HFCs</td>
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<td>Kühlmittel</td>
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<td><strong>HCFCs</strong></td>
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<td>HCFC-22</td>
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<td>CH₂Cl₂F</td>
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<td>Kühlmittel</td>
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<td><strong>Halone</strong></td>
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<tr>
<td>H-1211</td>
<td>CBrClF₂</td>
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<td>H-1301</td>
<td>CBrF₃</td>
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<tr>
<td>H-2402</td>
<td>CBrF₂-CBrF₂</td>
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<tr>
<td><strong>PFCs und SF₆</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PFC-116</td>
<td>CF₆</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kohlenstoff-Tetrafluoride</td>
<td>CF₆</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schwefelhexafluorid</td>
<td>SF₆</td>
<td>Alle Sportschuhe, Kalibrationsgase, elektrischer Isolator</td>
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<td><strong>CFCs</strong></td>
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<tr>
<td>CFC-12</td>
<td>CCl₂F₃</td>
<td>F-12, R-12</td>
<td>Kühlmittel (alte Kühlschränke)</td>
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<td>CFC-11</td>
<td>CCl₃F</td>
<td>F-11, R-11</td>
<td>Schaum</td>
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<tr>
<td>CFC-113</td>
<td>CCl₂FCCCF₂</td>
<td>F-113, R-113</td>
<td>Reiniger für elektronische Komponenten, Laser</td>
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<tr>
<td>CFC-114</td>
<td>CCl₂CClF₂</td>
<td>F-114, R-114</td>
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<tr>
<td>CFC-115</td>
<td>CCl₂CF₂</td>
<td>F-115, R-115</td>
<td></td>
</tr>
<tr>
<td>Brommethan</td>
<td>CH₂Br</td>
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<tr>
<td>Methylchlorid</td>
<td>CH₃Cl</td>
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</tr>
<tr>
<td>Chloroform/Trichlormethan</td>
<td>CHCl₃</td>
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<tr>
<td>Trichlorethen/Trichlorethen</td>
<td>CH₃CCl₃</td>
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<tr>
<td>Kohlenstofftrichlormethan</td>
<td>CCl₃</td>
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<tr>
<td>Dichlormethan/Methylchlorid</td>
<td>CH₂Cl₂</td>
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<tr>
<td>Trichlorethen</td>
<td>CH₃CCl₂</td>
<td>TCE, Lösungsmittel</td>
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<tr>
<td>Perchlorethen</td>
<td>CCl₂CCl₂</td>
<td>PCE, Lösungsmittel</td>
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**Weitere wichtige Substanzen:**

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<th>Gebrauch</th>
<th>Kontakt</th>
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<tr>
<td><strong>Leicht flüchtige organische Stoffe (VOCs)</strong></td>
<td></td>
<td></td>
<td><a href="mailto:martin.vollmer@empa.ch">martin.vollmer@empa.ch</a></td>
</tr>
<tr>
<td>Butan</td>
<td></td>
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<tr>
<td>Pentan</td>
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<tr>
<td>Hexan/gesättigte Kohlenwasserstoffe</td>
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<tr>
<td>Xylo/Dimethy/benzol</td>
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<tr>
<td>Benzol/Benzene</td>
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<tr>
<td>Methylbenzol/Steinkohleiteröl/ Toluol</td>
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<tr>
<td>Isopren/Methylbutadien</td>
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<tr>
<td>Wasserstoff</td>
<td>H₂</td>
<td></td>
<td><a href="mailto:martin.steinbacher@empa.ch">martin.steinbacher@empa.ch</a></td>
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<tr>
<td>Kohlenmonoxid</td>
<td>CO</td>
<td>Zigarettenrauch, Kalibrations- und Puffergas</td>
<td><a href="mailto:martin.steinbacher@empa.ch">martin.steinbacher@empa.ch</a></td>
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<tr>
<td>Kohlendioxid</td>
<td>CO₂</td>
<td>Emissionen von CO₂, Verbrennung</td>
<td><a href="mailto:leuenberger@climate.unibe.ch">leuenberger@climate.unibe.ch</a></td>
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<tr>
<td>Methan</td>
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</tr>
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</table>

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**High Altitude Research Stations Jungfraujoch + Gornergrat**
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  leuenberger@climate.unibe.ch
II. Scientific paper abstracts 2015

1. Ice avalanches and Landslide on Grosser Aletschgletscher

Summary by Annelies Berger (annelies.berger@geo.uzh.ch) based on the following source:


The paper gives a detailed documentation of several ice avalanches on firn surface on the Grosser Aletschgletscher between the years 1968 and 1984. This events have in common, that they all show relatively large transport ways, but very low average slopes around 20° degree. It is obviously, that the large reach is not depending on the volume of the deposit (table 1). Consequently, the author wants document such ice avalanches on firn surface and achieve an explanation for their large transport paths. He provides a rule of thumb to estimate the ice avalanche reaches on firn areas, whereat it is not necessary to know the deposit volume. In addition, the paper shows shortly, that landslides may have same motion conditions on firn surfaces like ice avalanches.

During the recent decades, tourism attractions and sports like skiing or climbing in high mountain area are booming. This fact increases the risk in the context of ice avalanches, which overflow hiking tracks or damage infrastructure for example. So, it is relevant to estimate the ice avalanche motion to understand their behaviour. The author’s methods to document the ice avalanches are mainly field mapping using aerial photographs (1:10’000) and almost daily terrestrial photographs from the science station at the Jungfrau Joch. For special events like the ice avalanche in 1984 on the South of Mönch, he did ground surveying and used aerial photographs to map the event.

<table>
<thead>
<tr>
<th>Area</th>
<th>Date of fall</th>
<th>Date of photos</th>
<th>Reach (m)</th>
<th>Area of deposit (m²)</th>
<th>Volume of deposit (m³)</th>
<th>Estimated accuracy of volume value (±)</th>
<th>Average slope (α) (deg)</th>
<th>tan α</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Grosser Aletschgletscher and Mittelaletschgletscher:</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>South of Mönch</td>
<td>13. 8. 1980</td>
<td>620</td>
<td>40,000</td>
<td>88,000</td>
<td>50 %</td>
<td>17</td>
<td>0.31</td>
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</tr>
<tr>
<td>South of Mönch</td>
<td>15. 5. 1982</td>
<td>470</td>
<td>24</td>
<td>55</td>
<td>25 %</td>
<td>18</td>
<td>0.32</td>
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<tr>
<td>South of Mönch</td>
<td>5. 7. 1984</td>
<td>690</td>
<td>107,000</td>
<td>340,000</td>
<td>25 %</td>
<td>19</td>
<td>0.34</td>
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<tr>
<td>East of Jungfrau</td>
<td>4. 10. 1986</td>
<td>630</td>
<td>21,000</td>
<td>63,000</td>
<td>50 %</td>
<td>20</td>
<td>0.36</td>
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<td>East of Rottalhorn</td>
<td>11. 8. 1971</td>
<td>465</td>
<td>5,500</td>
<td>18,000</td>
<td>60 %</td>
<td>20</td>
<td>0.36</td>
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<td>East of Aletschhorn</td>
<td>6. 7. 1984</td>
<td>1060</td>
<td>175,000</td>
<td>350,000</td>
<td>50 %</td>
<td>21</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>On other glaciers:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brunegg Glacier, VS</td>
<td>6. 7. 1984</td>
<td>1300</td>
<td>200,000</td>
<td>300,000</td>
<td>70 %</td>
<td>20</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Festigletscher (1)</td>
<td>10. 9. 1971</td>
<td>525</td>
<td>31,000</td>
<td>47,000</td>
<td>50 %</td>
<td>17</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Marvine Glacier (2)</td>
<td>15. 7. 1983</td>
<td>2600</td>
<td>600,000</td>
<td>3,000,000</td>
<td>50 %</td>
<td>17</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Ice avalanche events on firn surface with small average slopes. Source: Alean (1984).

Table 1 shows the ice avalanches on firn surface on Grosser Aletschgletscher and Mittelaletschgletscher, which are documented in the paper. The study focus especially on the event of the 6th of July in 1984 at the southern hanging glacier of Mönch. The map of this event shows the five main sliding masses, which already contain nearly the half of the whole sliding volume. Two massive ice blocks are mapped too, which have an estimated volume of 1000 m³.
In addition, Alean illustrated two profiles through the avalanche deposit, figure 1 shows one of them.

The mean parameters to explain the ice avalanche motion are the internal and the sliding friction. For example, a high internal friction within a snow avalanche leads to high turbulences in the descending material, what is also visible on the form of rounded ice blocks, which collided with each other. This turbulence results in a high loss of kinetic energy, why the avalanche reaches are rather short. In case of ice avalanches with large reaches, the internal friction is low, there are little collisions of ice blocks and no dust is visible too. In this case, the sliding friction at the base between surface and avalanche is the dominant process, which decelerates the process. In order to consider this parameters, the author determine two main conditions for the development of large ice avalanche reaches on firn surface. Firstly, the vertical height should not be higher than a few tens of meters. Otherwise, the ice avalanche, which falls over a topographic step, gets a too high internal friction. Secondly, the firn surface terrain must be smooth and without crevasses, which can be filled with material.

If this conditions are given, the rule from Müller (in Heim 1932) can be applied to estimate the avalanche motion. It says, that “(...) the tangent of the average slope (α) of the block’s path is equal to the average coefficient of sliding friction” (Alean 1984). In case of the event of 6th july in 1984 the average slope was 19° degree, \(\tan(19°) = 0.34\). So, the avalanche reach is 2.9 times longer than the vertical height. Margreth and Funk pointed out in their study from 1999, that the average slope model is not detailed enough for hazard mapping. Even though the rule of thumb is just an approximation, it provides a useful estimation without need to know about the sliding volume of the ice avalanche.

![Figure 1](image)

Figure 1. Profile of the ice avalanche event of July 5th, 1984 at the South of Mönch with the illustration of the average slope \(\alpha\). Source: Alean (1984).

Reference:


Heim, A. (1932): Bergsturz und Menschenleben. Separatdruck der Vierteljahresschrift der Naturforschenden Gesellschaft in Zürich, Fretz und Wasmutz, Zürich
2. Modelling discharge of glacierized basins assisted by direct measurements of glacier mass balance

Summary by Michael FEHLMANN (michael.fehlmann@uzh.ch) based on the following source(s):


This paper discusses different approaches to model discharge for the Aletsch Glacier. In glacierized basins discharge not only depends on precipitation and on accumulation and melting of snow, but also on melting of ice from the glacier. Therefore, three conceptual models with different glacier melt routines are compared to each other. To validate these models, both discharge and glacier mass balance data are used. By including glacier mass balance data, it can be seen whether glacier melt is simulated accurately or is rather used to compensate for deficiencies of the input data or the model structure.

The three conceptual models used (HYMET, HBV, ETH) differ only in the way they model glacier melt at different elevations, while all models use more or less simple temperature index methods. The HYMET model uses the diurnal temperature range as an index for glacier melt, which is generally decreasing with increasing elevation. The HBV and the ETH model, on the other hand, use mean daily temperature values. The ETH model thereby includes a seasonally variable melt factor to account for the changing albedo of glacier ice during the year. The three models are applied to simulate glacier melt and river discharge for 19 hydrological years (1964/65 to 1982/83). For model calibration and validation, specific glacier mass balance was measured at different elevations during this period using ablation stakes in the accumulation area and snow pits in the accumulation area of the Aletsch Glacier.

The authors demonstrate with their study that glacier mass balance data greatly assists the modeller in defining optimal parameter values, which yield good simulations of both discharge and glacier mass balance. Furthermore, only by including such data in model validation possible shortcomings of the glacier melt routine can be revealed and different approaches can be compared. The comparison of three different approaches showed that the diurnal air temperature range (HYMET model) is a powerful variable to represent heat available for melt. However, better results are achieved when only including data for the four lowest elevation belts (*figure 1*). Regarding the HBV and the ETH model, it can be shown that the latter performs better and thus the inclusion of a seasonally variable melt factor is reasonable to reduce possible overestimations of fall melt runoff (*figure 2*).

Today, more complex (e.g. distributed, physically based) models can be applied to model discharge in glacierized basins. Where input data is sufficient, energy balance models can be applied to model glacier melt. However, the inclusion of additional data for model calibration and validation (e.g. mass balance data) is still a topic of recent research.
Figure 1. Comparison of measured specific glacier mass balance (1972/73) and 2 different ways of simulation using the HYMET melt model; (a) daily temperature range calculated separately for each elevation band (“previous runs”), (b) mean daily temperature range of the lowest 4 elevation belts applied at all levels. Source: Braun and Aellen (1990).

Figure 2. Performance of the HBV and the ETH snow and glacier melt models, 1977/78. Source: Braun and Aellen (1990).
3. Hazard assessment investigations in connection with the formation of a lake on the tongue of Unterer Grindelwaldgletscher, Bernese Alps, Switzerland

Summary by Anna HOLZBECHER (anna.holzbecher@geo.uzh.ch) based on the following source(s):


This paper explains the related processes to the development of the glacier lake on the tongue of Unterer Grindelwaldgletscher and presents the simulation results of future outburst floods and the corresponding estimated flood hydrographs. Furthermore it discusses the growing risk for Grindelwald and other communities downstream and proposes preventive measures.

Processes and evolution
The development of the glacier lake is a chain reaction and influenced by many factors. The destabilisation of the side walls due to the retreat of Unterer Grindelwaldgletscher leads to a high input of debris material on the glacier tongue (Schlossplatte and moraine are sliding down). As the debris layer thickens towards the glacier end, the glacier melt is reduced there and enhanced under thin debris layers upglacier. In consequence a depression forms on the tongue representing a basin for incoming meltwater. If the water cannot be drained fast enough a lake develops leading to even more melt as water can heat up above 0°C and transport the heat effectively through convection. Though, once a lake is present the enlargement of the depression and the lake is speeded up (Figure 2). A glacier lake can drain rapidly through dam failure by two mechanisms: the flotation of the ice dam or the enlargement of a small dam break into a channel. In this paper they conducted their modelling for the latter option.

Modelling
Werder et al. used Clarke’s model which includes also water temperature to model flood hydrographs. Following input parameters were needed in the model: geometry of the bed, ice and channel (determined with GPR and aerial photographs), hypsometry of the lake basin (derived from photogrammetry of the years 2000-2008 and extrapolated for the future), lake temperature and roughness of the channel which was derived from fitting the model to the monitored outburst flood in 2008 (Figure 1). Initial conditions are the water-level of the lake (measured with a pressure transducer installed in the lake) and the channel size. As boundary condition the water pressure at the glacier terminus must be defined.

Results and discussion
The results show a clear increase for future discharges between 2009 and 2014 and a decrease in advance warning times (Figure 4). Werder et al. also conducted a sensitivity analysis for the variation of the input parameters roughness and water temperature, the results can be seen in Figure 3. Furthermore, a damming effect of the narrow gorge Gletscherschlucht situated right below could be determined.

Werder et al. state clearly that without any preventive measures the risk of serious damage for downstream communities will grow. For this reason an early warning system was installed which would send a message to the person in charge of the regional natural hazard prevention
as soon as there would be a sudden drop in lake level. Furthermore, Bernese authorities also decided to build a drainage tunnel to keep a low water level in the lake.

Figure 1: Comparison of the measured and modelled outburst hydrographs in May 2008. (a) proglacial discharge, (b) lake discharge (note that when the $Q_{lake}$ time series stops, the lake is not empty yet). Model parameters: lake volume $0.75 \times 10^6$ m$^3$, lake water temperature $2.0 \; ^\circ$C, Manning channel roughness $0.025m^{-1/3}$ s. Source: Werder et al. (2009).

Figure 2: The gray-shaded area gives maximal lake extent for the years 2007 (a, 0.034 km$^2$), 2008 (b, 0.092 km$^2$) and 2009 (c, 0.136 km$^2$). The lake depth is given by the contour lines inside the lake area (interval 10 m). The centre of the lake is marked by a circle (identical to Fig. 5), the lake dam by a solid line and the glacier outline by a dashed line. Source: Werder et al. (2009).

Figure 3: The model sensitivity (a) to changes in Manning channel roughness $n_{man}$ and (b) to changes in the lake water temperature $T$. Left axis gives maximal discharge $Q_{max}$ and right axis advance warning time $\Delta t$. Source: Werder et al. (2009).

Figure 4: Predicted maximal discharge ($Q_{max}$) and advance warning time ($\Delta t$) for the years 2008–2014 assuming a completely filled lake basin and model parameters as used for Fig. 2. Source: Werder et al. (2009).
4. Modelling the retreat of Grosser Aletschgletscher in a changing climate

Summary by Alexandra KESSLER (ale.ke@bluewin.ch) based on the following source:


This paper compares various scenarios of glacier retreat of Grosser Aletschgletscher up to year 2100, using different climate scenarios on a three dimensional glacier dynamics model. Further, they analysed the difference in glacier retreat with various debris coverages.

Grosser Aletschgletscher is the largest glacier in the European Alps. To model its retreat, the surface mass balance and the glacier dynamics were included. To determine the surface mass balance, data from field data was used, involving point measurements in the accumulation zone, discharge measurements, meteorological time series and some measurement data from earlier studies. The glacier dynamics were derived from DEM’s, a bedrock map, and annual ice flow velocity measurements. Bed rock conditions were assumed to be twofold: frozen condition above 2400m a.s.l. and temperate below that threshold. Further the ice was assumed to be incompressible, isothermal and viscous.

Three different categories of climate scenarios were used: constant mean temperatures observed in the past, regional climate models and the linear increase towards 2° C (2DEG), the political goal. For each of the models a change in temperature for the year and season and a change in precipitation was determined (Table 1, Figure 1a). The constant temperatures category as four different submodells which encompass the extreme years of 2003 (warm = MY2003) and 1978 (cold = MY1978), further a 20 years period from 1989 to 2008 (MP20) and a 30 years period from 1961 to 1990 (MP30) were used to derive for each a mean temperature. The regional climate models from the ENSEMBLE project were calibrated against measurements of daily temperature and precipitation changes in the Aletsch region of the past and then extrapolated to the future (ENSmean). Upper (ENSmax) and lower (ENSmin) boundaries of the regional model were determined using global climate model.

The different climate scenarios do show that the Grosser Aletschgletscher is not in the equilibrium at the moment (Figure 1 b, c). Most of the scenarios do show a change in length, only the extreme year of 1978 had favourable conditions for the glacier. A fast retreat in almost all scenarios can be observed, because of positive feedback processes like forming of proglacial lakes and decreasing of glacier surface elevation due to melting.

Retreating glaciers can show an increase in debris coverage, due to instabilities and lateral spreading of middle moraines. An exponential decrease of melt with debris thickness was assumed. For the ENSmed model various debris coverage were included showing a less rapid glacier retreat.
Table 1. Applied changes for the different models: Change in mean annual air temperature $\Delta T_y$, summer temperatures from June to August $\Delta T_s$, and annual precipitation by 2100 from the period 1980 – 2009. RCM: regional climate model. Source: Jouvet et al. (2011).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>RCM/Considered period</th>
<th>$\Delta T_y$ $^\circ C$</th>
<th>$\Delta T_s$ $^\circ C$</th>
<th>$\Delta P$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSmed</td>
<td>MPM/CHAM, REMO</td>
<td>+4.3</td>
<td>+5.5</td>
<td>+1</td>
</tr>
<tr>
<td>ENSmin</td>
<td>SMICLCM, RCA</td>
<td>+2.9</td>
<td>+3.7</td>
<td>-4</td>
</tr>
<tr>
<td>ENSmax</td>
<td>ETHZ, HadCM3QO, CLM</td>
<td>+4.8</td>
<td>+7.7</td>
<td>-10</td>
</tr>
<tr>
<td>2015</td>
<td>-</td>
<td>+2</td>
<td>+2</td>
<td>0</td>
</tr>
<tr>
<td>MP20</td>
<td>October 1988-September 2008</td>
<td>+0.4</td>
<td>+0.5</td>
<td>-1</td>
</tr>
<tr>
<td>MP30</td>
<td>October 1960-September 1990</td>
<td>-0.6</td>
<td>-0.8</td>
<td>-5</td>
</tr>
<tr>
<td>MY1978</td>
<td>October 1977-September 1978</td>
<td>-0.9</td>
<td>-1.9</td>
<td>+11</td>
</tr>
<tr>
<td>MY2003</td>
<td>October 2002-September 2003</td>
<td>+1.4</td>
<td>+3.9</td>
<td>-15</td>
</tr>
</tbody>
</table>

Figure 1. a) change in mean annual air temperature over time. b) simulated change in glacier length for the different scenarios along the central flowline of Grosser Aletschgletscher. c) simulated change in total glacier volume for the different scenarios over time. Source: Jouvet et al. (2011)
5. Holocene glacier history from alpine speleothems, Milchbach cave, Switzerland

Summary by Chloé BOUSCARY (chloebouscary@wanadoo.fr) based on the following source:


The aim of this paper is to show that the timing and effects of changes in the mass balance of an alpine glacier can be successfully reconstructed by analyzing the physical-chemical properties of speleothems (stalagmites, stalactites) formed in caves adjacent to glaciers. Here, the experiment is done in the cave system of Milchbach adjacent to the Upper Grindelwald Glacier in the Swiss Alps.

Glaciers react sensitively to small modifications in meteorological parameters, and thus are useful to reconstruct climate changes. Because of its rapid response time to climate forcing (only about 12 years), the Upper Grindelwald Glacier has a high climate sensitivity that has led to many oscillations of the glacier tongue during the Holocene. To study these glacier fluctuations, Luetscher et al. explore a novel and continuous archive of glacier fluctuations with a new method based on speleothems.

As shown by the authors, there is a correlation between stratigraphic succession of fabrics of speleothems and elevation of the Upper Grindelwald Glacier. Therefore it is possible to reconstruct the mass balance by studying the petrography of stalagmites.

The stalagmites that can be found in Milchbach cave cover most of the Holocene, and so are well suited to record the fluctuations of the Upper Grindelwald Glacier during that period. These stalagmites show consistent petrographic and stable isotopic changes that can be linked to modifications in the cave environment as a result of the closing and opening of the cave entrances by the advance and retreat of the nearby glacier.

Columnar calcite fabrics are characteristic of a regular calcite precipitation, and hence of continuous water supply, and the absence of major seasonal temperature fluctuations. These layers have δ18O values of about −8.0‰ indicating that speleothems grew under quasi-equilibrium conditions (Figure 1). In an alpine cave environment, these conditions are in agreement with the presence of glacier ice sealing the entrances of the cave. The columnar calcite fabrics can thereby be associated with periods of glacier advances.

In contrast, bacterially mediated calcite preferentially precipitate under a transient hydrological regime, possibly resulting in periodic non-deposition. Stable data of these layers show depletion in δ18O of between 1 and 2‰ (Figure 1). These stromatolitic layers are typical for precipitation within caves overlain by an alpine soil cover and by vegetation, and so point to phases of glacier retreat and minima.

Hence, by analyzing the δ18O values of the fabric-layers of the speleothems and by dating them with U/Th analyses, it is possible to get an idea of the extent of the glacier at different periods.

In summary, Milchbach speleothems allowed the identification of 21 glacier retreats between 9.2 to 5.8 ka, and they also show that the amplitude of the oscillations of advance-retreat of the Upper Grindelwald Glacier varied over time (Figure 2).
Figure 1: Stable isotope fluctuations measured along the growth axis of stalagmite MB-6 and their correlation with petrography. Shifts towards depleted values are observed along organic-rich layers and in particular in bacterially mediated calcite layers (horizontal grey bars). DFT: distance from top.

Figure 2: Synthesis of Upper Grindelwald Glacier fluctuations interpreted from Milchbach speleothems (same petrographic legend as in Figure 1). The higher confidence of the interpreted fluctuations during the Early Holocene is shown by the dark blue curve. The interpreted fluctuations are compared with a) Phases of enhanced clastic sedimentation at Lake Le Bourget (France) interpreted from a curve of sediment reflectance (Debret at al., 2010), b) Lake level highstands in the Jura Mountains (Magny, 2004), c) Aletsch Glacier fluctuations (Holzhauser et al., 2005), d) Peat and wood remains found in sediments deposited at the front of retreating glaciers (Joerin et al., 2006, 2008), e) Intervals of glaciers advances in the Western (red) and Eastern Alps (brown) (e.g. Patzelt and Bortenschlager, 1973), and f) Fluctuations of the Kaunertal timberline (Nicolussi et al., 2005).
III. Additional scientific paper abstracts from the 2014 excursion

1. Modelling the trajectory of the corpses of mountaineers who disappeared in 1926 on Aletschgletscher, Switzerland

Summary by Florian DENZINGER (florian.denzinger@geo.uzh.ch) based on the following sources:


This paper uses a combined 3D surface mass balance and glacier dynamics model from Jouvet et al. 2011 to model the trajectory of the bodies of three mountaineers who disappeared on the Aletschgletscher in 1926. The presumable location of death was determined and further implications about the cause of death could be made. Another purpose of the study is a validation of the glacier flow model in the aforementioned study.

In March 1926 three brothers coming from Kippel ascended to Hollandiahütte over the Lötschenlücke. According to eyewitness reports and a note they set out for an excursion to Konkordiaplatz in the afternoon. The weather conditions changed drastically and a snowstorm lasting for the subsequent three days set in which later has been verified with mass balance measurements from Jungfraujoch. Search parties tried to find the mountaineers but were not successful. The cause of death remains unknown. On 27 June 2012, British mountaineers found human skeletons and mountaineering equipment in the ablation area of Aletschgletscher (Figure 1). A DNA analysis ordered at a later time proved it to be the three brothers. The location where the bones were found in 2012 was at 648°218/146°353 (in Swiss referential CH1903).

A numerical 3D ice motion model fed with historical data, climate data, surface mass balance data and DEM data has been used to compute the flow trajectory of the bodies. Normally this method is used to date ice. The bodies were transported downwards over a 10.5 kilometre trajectory. They lost approximately 800 meters in altitude (Figure 2). Until the mid 1980ies the bodies submerged into the ice, whereas at the confluence at Konkordiaplatz the corpses started to emerge again to the surface combined with a faster flow speed. As a result of sensitivity analysis, a rectangle of approximately 1600x300 meters, which represents ca. 0.6% of the whole glacier area of Aletschgletscher, could be identified. According to the authors the most probable cause of death were disorientation in the severe and long-lasting weather conditions and a subsequent freezing to death.

This model could be a useful tool for police work and object reappearance prediction modelling which could be particularly interesting with the linked effects of global warming (e.g. Dakota location on Gauligletscher).
Figure 1: Modelled trajectory of the corpses flow path overlain on a topographic map. Different decadal positions are indicated as black points. The black rectangle marks the confidence of the reconstructed immersion location. The Hollandia hut is marked with a star.

Figure 2: Elevation, velocity and position of the modelled trajectory
2. Glaziologie - Annäherung an 3500 Jahre Gletschergeschichte

Summary by Ladina GLAUS (ladina.glaus@geo.uzh.ch) based on the following source:

Zumbühl, H. J. & Holzhauser, H. (2007). Glaziologie – Annäherung an 3500 Jahre Gletscherge-

The chapter of this book summarises the changes of the “Aletschglacier” as well of the “lower Grindelwaldglacier” in the last 3500 years. It presents different indications, as fossil and soil, historical documents and other discoveries, which give a conclusion for the retreat and advancements, as well as the extent of the glacier in the last centuries.

The “Aletschglacier” with its length of 23 km and an area of 81.7km² is the largest glacier in the Alps and further one of the most beautiful. The glaciers collecting basins is fed by the mountains Jungfrau, Mönch and gross Fiescherhorn. Regarding the history of the glacier, there is a significant fluctuation seen. During the Bronze Age, the glacier was even shorter then nowadays. An advance of the glacier occurred around 600-650 B.C. and reached a similar extent as in 1850/60. Knowledge about this length changes are won by age dating of fossil wood, found in the thawing glacier tongue.

Due to a hindered access to the glacier, the first documentation by humans is derived from late 19th century. The view from Belalp was recorded on postcards in 1890. Pictures made by Frédéric Martens show the maximal extent in 1859/60.

Figure 1: Retreat and advance periods of the Aletschglacier (Zumbühl, H. J. & Holzhauser, H. 2007)
The “lower Grindelwald glacier” is shorter than the “Aletsch glacier” with a length of 8.85 km and an area of 20.6 km². The tongue consists of a confluence of two glaciers, the lower Ischmeer, and Berner Fieschenglacier. Nowadays, the first one does not feed the glacier anymore. In contrary to the Aletschglacier, the locals came much earlier in contact with the glacier, as the tongue almost advanced in the 18th century town to the valley floor and breaking off of seracs as well as ice avalanches shook the village.

Fossil soils, wood pieces and good historical documentations enable a reconstruction of the past 3200 years of the glacier. Advances of the glacier happened in the 12th/11th the century B.C., 8th-6th century B.C., 527-578 A.D., 820-834 A.D., 1088-1137 A.D. and around 1338 and 1600 A.D. Moraines document the extent of the glacier during those time periods. Three maximum extend of the glacier were reached in 1778/79, 1820/22, 1855/56 during Little Ice Age. Since the little ice age, the glacier lost 0.42 m/y, what means a reduction of 5.5 km² for the area and a lost in volume of 1.56 km³ (1860-2004). Today, the tongue is inactive.

Paintings of the glacier go back to the 17th/18th century. Matthäus Merian made a beautiful etching in 1642. Caspar Wolf (1735-1783) documented the glacier even during winter season. He was one of the most famous landscape painters (Fig. 2). The new technical improvement of photography in the 19th century helped to give a more exact documentation.

Figure 2: left: Albrecht Kauw, 1669. Advance of lower (cutout from panorama of Grindelwald). Right: Caspar Wolf, ca. 1778. View from Bänisegg to Schreckhorn and part of Ischmeer of the lower Grindelwald glacier (Zumbühl, H. J. & Holzhauser, H. 2007).

As a conclusion it can be said that both glaciers show in their history sensible reactions to climate changing. Different findings as fossil wood help for age dating and reconstruction of the glaciers advances and retreats. Historical documentation further show maximal extends of the two glaciers, as well as the retreat since last little ice age.
3. A high-resolution air chemistry record from an Alpine ice core: Fiescherhorn glacier, Swiss Alps

Summary by Jacqueline HUBER (jhuber@access.uzh.ch) based on the following source:


This paper briefly summarises the results of chemical analyses of environmentally relevant species performed on an ice core from Fiescherhorn glacier (3890 m a.s.l.). Even though most of the attention has been paid to the ice cores from polar ice sheets regarding paleoclimatic and atmospheric information, alpine glaciers can significantly contribute to the understanding of the atmospheric cycle of species with short atmospheric lifetimes.

In 1989 a drilling was performed on the Fiescherhorn glacier, which is probably the only site in the north of the main Alpine chain applying the requirements of an environmental archive. Especially due to the possibility of linking the ice core data to long-term meteorological and air quality measurements from the nearby high-alpine research station Jungfraujoch (3450m a.s.l.), assuming that the atmospheric concentrations are comparable. The 77-m-long ice core revealed high annual net accumulation rate (1.4m water equivalent on average) and therefore enabled the reconstruction of high-resolution environmental records. First, it allowed dating the ice core by annual layer counting of the seasonally varying singles of the tritium concentration and the isotopic ratio $\delta^{18}O$, revealing the time period 1946-1988. Second, high-resolution chemical concentration records were accessible, corresponding to the chemical snow composition at Fiescherhorn. Dominating anthropogenically derived secondary aerosols such as sulphate ($SO_4^{2-}$), ammonium ($NH_4^+$) and nitrate ($NO_3^-$) as well as mineral dust components such as calcium ($Ca^{2+}$), characterize this site as a relatively unpolluted continental site.

The secondary aerosols $SO_4^{2-}$, $NH_4^+$ and $NO_3^-$ show seasonal variations corresponding to the seasonalites of tritium and $\delta^{18}O$. The production of $SO_4^{2-}$, $NH_4^+$ and $NO_3^-$ via gas-to-particle conversion takes place in the atmospheric boundary layer (ABL). As in winter the high-alpine sites are decoupled from the ABL the lowest values occur in winter and higher values in summer.

Annual averages were calculated to derive a concentration trend (Figure 1). $SO_4^{2-}$, $NH_4^+$ and $NO_3^-$ show an increasing trend from 1946, reaching a maximum in 1975, followed by a decreasing trend until 1988. This expresses the increased anthropogenic emissions until 1975 and the following emission reductions in western Europe. The chloride (Cl-) and sodium (Na+) values increased around 1965 and remained constant at this higher level, implying more and stronger sea-salt-transporting weather conditions. The mineral dust components ($Ca^{2+}$, $K^+$, $Mg^{2+}$) do not show a significant trend. Neither does $\delta^{18}O$ supporting the statement above, that the observed concentration changes are not caused by varying precipitation characteristics but caused due to changing emissions and ambient air conditions.

Comparing the $SO_4^{2-}$ records with the direct atmospheric measurements derived on the Jungfraujoch from 1973-1988 showed good agreement (correlation coefficient $r^2=0.41$) (Figure 2). These direct measurements also enabled to calibrate the Fiescherhorn $SO_4^{2-}$ ice record.
Figure 1: Concentration records (annual averages) of $\text{SO}_2^{4-}$, $\text{NH}_4^+$, $\text{NO}_3^-$, $\text{Cl}^-$, $\text{Na}^+$, $\text{Ca}^{2+}$, $\text{K}^+$ and $\text{Mg}^{2+}$ as well as $\delta^{18}$O (with the corresponding annual layer thickness). Dashed curves represent smoothed values to guide the eye.

Figure 2: (top) Annual $\text{SO}_4^{2-}$ averages determined in the Fiescherhorn ice core (solid line) and atmospheric samples from the Jungfraujoch (dashed line) from 1974-1988. (bottom) Scatterplot of the annual averages with the resulting linear regression line ($r^2=0.41$).
4. Reconstruction of ice-volume changes in Unterer Grindelwald Glacier

Summary by Paribesh PRADHAN (paribesh.pradhan@uzh.ch) based on the following sources:


These two papers briefly summarize different approaches which were used for the reconstruction of the Unterer Grindelwald glacier in the Swiss Alps. The first paper by Daniel Steiner et. al. gives a scientific view on reconstruction of Unterer Grindelwald and Unteraar glaciers based on historical texts and pictorial sources such as paintings, maps and photographs since mid-fourteenth century. It also presents a chronicle on evolution of glaciology, glacier monitoring in the Swiss Alps and contributions made by early glaciologists like Louis Agassiz also known as the father of glaciology. The second paper by Andreas Bauder et. al. gives an account of ice-volume changes in 19 glaciers selected from Switzerland including Unterer Grindelwald based on Digital Elevation Model (DEM) data since the end of Little Ice Age i.e. 1850 A.D.

The Unterer Grindelwald glacier (latitude 46°35'N, longitude 8°05'E) shown in figure 1 is one of the well documented glaciers located at the Bernese Alps in Switzerland due to the low position of its terminus and its easy accessibility. This valley glacier is 8.85 km long covering an area of 20.6 km² with Ischmeer glacier in the east and the Berner Fiescher glacier in the west that also joins to form its tongue. The equilibrium line altitude of the Unterer Grindelwald glacier is at 2,640m.

The historical records like paintings, maps and photograph that is available for the Unterer Grindelwald glacier give a very detail picture of glacial fluctuation in the Swiss Alps during Late Holocene allowing scientist to reconstruct ice volume changes further into the past than it would have been possible with the use of direct measurements alone. In fact, a temporal resolution of decades or even individual years glacier time series could be reconstructed using such methodology as illustrated in figure 3. It shows the cumulative length fluctuation of Unterer Grindelwald glacier from 1535 A.D. until 1983 A.D. while table 1 in figure 2 shows the changes in glacier parameters between 1860 A.D. and 2004 A.D. The scientific investigation based on these evidences and comparing them with old topographic map show that Unterer Grindelwald glacier retreated relatively slowly during the first period after mid-nineteenth-century maximum extent but then accelerated during 1861-70 period. The DEM models generated from digital stereophotogrammetry by Bauder et. al. 2007, and its comparisons show similar rate of thickness change of -0.42 m per year since their mid-nineteenth-century maximum extent. Figure 3 illustrates the advancing and recession period of Unterer Grindelwald glacier very well with exception of some anomalies.
When the topographic characteristics of the Unterer Grindelwald Glacier was compared for the period of 1860/61/72 and 2004 as illustrated in figure 4, the length of the glacier had decreased by 1.95 km, the elevation of the terminus of the glacier retreated to 1297 m.a.s.l from 972 m.a.s.l and the surface area had also decreased by 5.5 km² which is approximately -20%. The overall mass loss is -1.56 km³ ice which is equivalent to -1.4 km³ water assuming ice density to be 0.9 kg m⁻³.

Figure 3: Unterer Grindelwald Glacier (http://map.geo.admin.ch)

<table>
<thead>
<tr>
<th>Glacier</th>
<th>Area* (km²)</th>
<th>Investigated period</th>
<th>Number of DEMs</th>
<th>Volume change (10⁹ m³ a⁻¹ w.e.)</th>
<th>Net balance (10⁹ m³ a⁻¹ w.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allalin</td>
<td>9.680</td>
<td>1932–2004</td>
<td>7</td>
<td>-0.108</td>
<td>-0.13</td>
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<tr>
<td>Basòdino</td>
<td>2.201</td>
<td>1929–2002</td>
<td>7</td>
<td>-0.061</td>
<td>-0.25</td>
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<tr>
<td>Chessjen</td>
<td>0.195</td>
<td>1879–2004</td>
<td>7</td>
<td>-0.037</td>
<td>-0.34</td>
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<tr>
<td>Clariden</td>
<td>5.127</td>
<td>1936–2003</td>
<td>4</td>
<td>-0.040</td>
<td>-0.20</td>
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<tr>
<td>Corbassière</td>
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<td>1877–2003</td>
<td>4</td>
<td>-0.421</td>
<td>-0.15</td>
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<tr>
<td>Gîetro</td>
<td>5.549</td>
<td>1934–2003</td>
<td>5</td>
<td>-0.068</td>
<td>-0.09</td>
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<tr>
<td>Gorner</td>
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<td>1931–2003</td>
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<td>-1.694</td>
<td>-0.27</td>
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<tr>
<td>Gries</td>
<td>5.264</td>
<td>1884–2003</td>
<td>9</td>
<td>-0.621</td>
<td>-0.59</td>
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<tr>
<td>Großer Aletsch</td>
<td>83.015</td>
<td>1880–1999</td>
<td>5</td>
<td>-4.858</td>
<td>-0.42</td>
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<td>Hohlaub</td>
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<td>1879–2004</td>
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<td>-0.094</td>
<td>-0.23</td>
</tr>
<tr>
<td>Limnern</td>
<td>2.415</td>
<td>1876–1977</td>
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<td>-0.129</td>
<td>-0.38</td>
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<tr>
<td>Plattalva</td>
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<td>Rhone</td>
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<td>1874–2000</td>
<td>6</td>
<td>-0.588</td>
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<tr>
<td>Schwarzberg</td>
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<td>1879–2004</td>
<td>7</td>
<td>-0.136</td>
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<tr>
<td>Seeowejnen</td>
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<td>1956–2004</td>
<td>4</td>
<td>-0.021</td>
<td>-0.17</td>
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<td>Silvretta</td>
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<td>1893–2003</td>
<td>7</td>
<td>-0.085</td>
<td>-0.20</td>
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<tr>
<td>Trit</td>
<td>15.315</td>
<td>1861–2003</td>
<td>8</td>
<td>-0.680</td>
<td>-0.27</td>
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<tr>
<td>Unteraar</td>
<td>22.727</td>
<td>1880–2003</td>
<td>7</td>
<td>-1.729</td>
<td>-0.44</td>
</tr>
<tr>
<td>Grindelwald</td>
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<td>1861–2004</td>
<td>4</td>
<td>-1.560</td>
<td>-0.39</td>
</tr>
</tbody>
</table>

*Area at the end of investigated period.

Figure 4: Volume change and net balance of glaciers based on DEMs evaluation by Bauder et. al. 2007
Figure 5: Cumulative length variations of (a) the Unterer Grindelwald Glacier from 1535 to 1983, relative to the 1600s max. extent (b) the Unteraar Glacier from 1719 to 2004 relative to 1871 according to Steiner et. al. 2008

Figure 6: Topographical characteristics of the Unterer Grindelwald Glacier in 1860/61/72 and 2004 according to Steiner et. al. 2008

<table>
<thead>
<tr>
<th>Topographical Characteristics of the Unterer Grindelwald Glacier in 1860/61/72 and 2004</th>
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<tbody>
<tr>
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<tr>
<td>Length (measured along the longest flowline 1; see Figure 6.10)</td>
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<tr>
<td>Elevation of head (Mönch)</td>
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<tr>
<td>Elevation of terminus</td>
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<tr>
<td>Surface areaa</td>
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<tr>
<td>Estimation of equilibrium line altitude (accumulation area ratio = 0.67)</td>
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<tr>
<td>Average slope in %</td>
</tr>
<tr>
<td>Average slope in degrees</td>
</tr>
<tr>
<td>Exposure</td>
</tr>
<tr>
<td>Absolute ice volume change 1860/61/72–2004</td>
</tr>
<tr>
<td>Average thickness change rate 1860/61/72–2004</td>
</tr>
</tbody>
</table>

*Note: The calculations are based on digital elevation models for 1861 and 2004 (Table 6.2, a).

*Including all subglaciers connected with major streams in 1860/61/72.

Both these studies had some limitations and errors. The spatial distribution of thickness changes on the Unterer Grindelwald Glacier showed some surprising patterns attributed to less accuracy of the data for Steiner’s study. Likewise, Bauder’s values on ice volume change and net balance also had some errors possibly resulting from error in map survey, inaccuracy of contour line evaluation or photogrammetric analysis and error due to interpolation on a regular grid. However, both studies showed a net volume change of -1.56 km³ ice losses and net balance of -0.39 to -0.42 m per year.
5. Collapse at the eastern Eiger flank in the Swiss Alps

Summary by Annette RAMP (annette.ramp@uzh.ch) based on the following source:


Gebiet
Die Studie konzentriert sich auf den Felssturz an der Eiger Ostflanke in den Schweizer Alpen (Fig.1a). Durch den Rückgang des unteren Grindelwaldgletschers (Fig. 1c) wurde der Fels nicht weiter komprimiert und dadurch wurde die 2 Millionen m$^3$ jurassischer Kalkstein instabil was schliesslich zu dessen Zusammenbruch führte.


Ereignis
Am 10. Juni 2006 wurde erstmal ein Felssturz von mehreren Hundert m$^3$ an der Eiger Ostflanke beobachtet, zuerst eine Hangbewegung und dann wie zwei steile 250m lange Risse aufgingen. (Fig. 1b und 1c). Einen Monat später am 12. Juli wurde ein Laserscanner montiert um das Felsgleiten zu überwachen. Zusätzlich wurde über mehrere unterschiedlich lange Zeiträume TLS Punktwolken aufgenommen. Deren Vergleich zeigt die Instabilität und Verschiebung der Fels-
masse, ausserdem lässt sich so das Volumen des Felssturzes berechnen. In den ersten Tagen der Beobachtung bewegten sich der Heckblock mit einer Geschwindigkeit von 80cm/Tag und der Frontblock mit 20cm/Tag, was sehr ungewöhnlich für einen Felsrutsch ist. Am nördlichen Frontblock konnten mit dieser Methode regelmässig Felsstürze aufgezeichnet werden (Felssturzvolumen 2'530m³ zwischen 11 und 13 Juli 2006 und 430m³ in den nächsten 24h). Ein Pfeiler (Fig. 1b blaue Line) zeigte signifikant höhere bewegungsraten, bis zu 125 cm/Tag (Fig. 2a) was zu dessen Zusammenbruch und schliesslich zum Zusammenbruch des ganzen nördlichen Blocks am 13.Juli 2006 führte. Die Hangbewegungen gingen trotzdem weiter aber langsamer (15-60cm/Tag), trotzdem konnten keine weiteren Felsstürze in den nächsten Monaten beobachtet werden. Auch im Winter 06/07 bewegte sich die Felsmasse an der Eiger Ostflanke weiter mit bis zu 1,5 cm/Tag.


Diskussion
Die Bruchstelle an der Ostflanke ist tektonischen Ursprungs, die Öffnung ist jedoch klar auf den Rückzug des Gletschers (Fig. 1c) und auf den Zusammenbruch des mittleren Pfeilers zurückzuführen. Der Auslöser für den Felssturz war wahrscheinlich ein erhöhter Wasserdruck auf die Gleitflächen infolge von Schneeschmelze und erhöhten Niederschlägen im Frühjahr und im Sommer 2006, was ein üblicher Auslösefaktor für solche Ereignisse ist. Der Heckblock begann schnell weg zu brechen, Photographien zeigen, das er deswegen immer wie mehr in kleinere Blöcke auseinander brach. Diese verhielten sich mehr wie körniges Material als wie ein intakter Felsblock. Diese Zerstörung des Heckblocks führte zu einem Massenverlust und vielleicht dadurch zu einem Anstieg der Wasser-Permeabilität, was wiederum zu einem tieferen Porenwasserdruck entlang der basalen Bruchfläche führte. Diese Kombination von Massenverlust und verringertem Porenwasserdruck könnte die beobachtete Verlangsamung der Fliessgeschwindigkeit im Sommer 06 und Winter 06/07 erklären. Dass die Bewegungsgeschwindigkeit im Sommer 07 wieder anstieg könnte durch die Veränderte Struktur der Bruchfläche und durch den angestiegenen Porenwasserdruck durch Schmelzwasser ausgelöst worden sein.
6. Assessment of the hazard potential of ice avalanches using remote sensing and GIS-modelling

Summary by Noah ZELTNER (noah.zeltner@uzh.ch) based on the following source:


This paper briefly summarises a systematic approach to quickly detect the hazard potential of ice avalanches based on statistical parameters, geographic information system (GIS) modelling techniques and remote sensing. It validates the approach with a case study out in the Bernese Alps and discusses the achieved results, illustrating technical problems and proposing further improvements.

Due to intensification of human activities leading to acceleration of environmental changes in high mountain areas integrative and extensive decision support with application of monitoring systems and models are needed. Corresponding techniques to assess an area-wide detection of potential hazard of ice avalanches have not yet been evolved. Salzmann et al. (2004) evaluated a three-step methodology to get a quick idea of potentially dangerous regions of a broad area (in this case the Swiss Alps).

![Flowchart of the three-level downscaling strategy for detecting ice avalanche hazard potentials](source)

Figure 1: Flowchart of the three-level downscaling strategy for detecting ice avalanche hazard potentials. Source: Salzmann et al. (2004)
The method presented in this paper follows a three-level downscaling strategy in which each level consists of GIS and remote sensing approaches to gain or evaluate data. The first step includes a detection of glaciers with a critical slope factor based on empirical rules. The second models (a) potential runout path(s) and improvement of image resolution for a better assessment of potential hazard zones. In a third step detailed investigations of the preserved areas are tried to be made by calling in high resolution DTM and terrain analyses (e.g. geomorphologic structures). The declared goal of the authors is not to get lost in detailed investigation of a certain area but almost the contrary. The chain reactions and disaster combinations often require an integrative overview rather than investigation of isolated processes. Due to that, Salzmann et al. (2004) tried to strengthen the model by implementing some statistical parameters to simplify and generalize the selection of potentially dangerous glacier and related hazards (e.g. avalanche starting conditions, slope and basal ice temperature, runout distances or average slope of a mass fall event).

Several additional problems and further thoughts are mentioned. In regard of the eventual hazard potential of an ice avalanche event other effects of the chain reaction can easily be forgotten. While the actual flow part of an ice avalanche is modeled as described above the assessment of the potential impact of the powder snow part is not known or at least not easily determinable (Figure 2).

Additional to that, problems with the base data accuracy can occur since different types of software can result in different parameterizations of initial values, because the application of this specific method is not made for other areas as remote high mountain areas, where it is difficult to find suitable Ground Control Points to orthorectify satellite images or simply due to the fact that the topography of the runout zone can change a lot during the year (e.g. snowfall) what makes assumptions even more difficult without having detailed in-situ information about a single glacier area.

Looking forward, Salzmann et al. (2004) see lots of potential in using similar satellite data with higher resolutions of complete areas of the world with ASTER and SRTM.

Figure 2: Comparison of modeled runout paths (Gutz Glacier, Bernese Alps, Switzerland). The underlying hazard map was produced by the Swiss Federal Institute for Snow and Avalanche Research (SLF) (S. Margreth, unpublished data), and the overlays are modeled runout paths using the method proposed here.
IV. Scientific and socio-cultural topics 2015

1. Geologie der Jungfrau Aletsch Region

Zusammenfassung von Annelies Berger (annelies.berger@geo.uzh.ch) basierend auf:


2. High altitude research station Jungfraujoch

Summary by Michael FEHLMANN (michael.fehlmann@uzh.ch) based on the following source(s):

High altitude research stations Jungfraujoch & Gronergrat, www.ifjungo.ch (13.06.2015).
Institute for atmospheric and climate science, www.iac.ethz.ch (13.06.2015).
ICOS-CH, icos-switzerland.weebly.com/jungfraujoch.html (13.06.2015).

At the high altitude research station Jungfraujoch (3500 m a.s.l.) extensive and successful scientific activity takes place since 1931. As soon as the railway to Jungfraujoch was completed in 1912 researchers began to profit from the possibilities offered at this exceptional site and discussions started about the construction of a scientific station. The idea was mainly pushed by meteorologists and astronomers but later extensive research started in various fields, which could profit from the location in an unspoiled high alpine environment (e.g. physiology, meteorology, glaciology, radiation, astronomy, and cosmic rays).

The scientific infrastructure consists of two buildings, the research station and the Sphinx observatory (figure 1). The research station provides room for a maximum of 12 researchers, who can live at the station for 2-3 weeks during measurement campaigns. It therefore contains ten bedrooms, a living room, a kitchen, a bathroom and also provides water, electricity and internet access. However, during most of the time researcher only come for short visits to check or calibrate measurement devices. The Sphinx observatory, which was completed in 1937, includes an astronomical and a meteorological cupola and several laboratories. It has become a symbol of scientific activity at Jungfraujoch for millions of tourists.

Highlights of past research were mainly achieved in the fields of meteorology and astronomy. For example, research on cosmic rays provided basic results closely related to two Nobel prices in physics (Blackett 1948; Powell, 1950). In 1962, two German physicists were able to make the first absolute measurements of the solar constant due to the excellent transparency of the atmosphere above Jungfraujoch. And after a solar flare in 1982, the presence of high energy solar neutrons in the Earth's atmosphere could be proved for the first time. During the past decades, several changes of the research emphasis have occurred at the station, from glaciology and medicine towards cosmic rays and astrophysics and finally towards astronomy. In the past few years, environmental sciences have appeared more in the forefront.

One example of recent research in environmental sciences at Jugfraujoch is the measurement programme relevant for the international carbon observation system (ICOS). ICOS is a European research infrastructure, which provides harmonized and high precision scientific data on carbon cycle and greenhouse gas budget. In this context, meteorological advection patterns are routinely determined at Jungfraujoch with back-trajectory-analysis (figure 2).
Figure 1. Infrastructure at the Jungfraujoch (from left to right): Restaurant "Top of Europe", research station, Sphinx rock with observatory. Source: www.ifjungo.ch (13.06.2015).

Figure 2. The back-trajectory plot provides a perspective view of back-trajectories initialized at the given site and followed 10-days backward in time. Different colours indicate different initial altitudes. Traveling times along the trajectory are marked by filled circles (24 h) and crosses (12 h). Source: icos-switzerland.weebly.com/ jungfraujoch.html (13.06.2015).
3. Old "Walser" trails – the upper Lauterbrunnen valley

Summary by Anna HOLZBECHER (anna.holzbecher@geo.uzh.ch) based on the following source:


The history of the Lauterbrunnen valley, a trough valley situated in the Bernese Alps northwest of the famous mountain peaks Eiger, Mönch and Jungfrau and at the border to the canton of Valais is closely linked to the Walser. The Walser were originally Alemannic peasants which migrated around 1000 A.D. from the Berner Oberland to the Valais and settled around the upper stream of the Rotten. Later, in the 12. and 13. century, a great part of them migrated again, especially to the east where they built Walser colonies in the Grison regions Vals, Obersaxen, Davos and many more (Figure 1). However, a part of them, those living in the Lötschental situated south of the Lauterbrunnen valley, moved north and there are strong evidences that they came to and lived in the Lauterbrunnen valley. As a reason for the migration historians consider the severe scarcity of land in the Valais because it is proved that settlements were built even on very exposed sites which were abandoned later on.

The question which way the Walser took to arrive in the Lauterbrunnen valley cannot be answered with certainty. The saga says they crossed the approximately 3000m high Wetterlücke or the equally high Petersgrat both covered by glacier ice and populated in this way the upper Lauterbrunnen valley. However, historians consider also the route via Lötschenlücke, Kiental and Sefinenfurgge as a possible way even though it represents a great contour.

Before the arrival of the Walser the upper Lauterbrunnen valley was not populated. Once arrived, Walser families founded various settlements such as Ammerten, Sichellauenen, Trachsellauenen, Schiirboden, Gimmelwald or Mürren, all situated in the upper valley part. Of course, Walser also settled down in Lauterbrunnen and Wengen, though in the lower valley, where they mixed up with the local population.

The great part of the Walser were peasants which practiced livestock farming. Depending on the season they moved with their cattle and families either up or down the mountain though they practiced what we understand today under Alpwirtschaft. The most important alps were the Busen- and the Sefinenalp. As some of the Walser joined in a rebellion which was linked to the secularisation of church properties in the valley after the reformation of 1526 the government of Berne gave 100 Kuhrechte on the Sefinenalp to the loyal village Unterseen which partly belonged to the Walser before. Their existence was now threatened even more than in the past. These circumstances as well as the fact that Walser families moved back to the catholic Valais after reformation and also the Little Ice Age set in around 1500 accompanied by longer winters and accumulation of avalanches and moreover the pest which took many lives in the 17th century in the Lauterbrunnen valley – all these factors led to a depopulation of the upper Lauterbrunnen valley and the abandonment of settlements situated there.

And which evidences can be found today that indicate the past presence of the Walser in the Lauterbrunnen valley? Strong indicators are the dialect as well as the architecture of houses and the spatial division of settlements which all resemble to what can be heard or observed in the Valais. A special architectural element which is typical for the Valais and can be found in Gimmelwald is the Zange – a longitudinal vertical baulk meant as reinforcement of the block wall (Figure 2). But also archaeological findings of house fundament or an axe in Untern Ammerten show that the upper Lauterbrunnen valley had to be populated once. Another strong prove for the presence of Walser in the region are all kind of written documents such as judge-
ments of the Chorgericht, sale documents or Tauf- and Totenrödel where Walser family names appear. Only those allow a more detailed reconstruction of the past.

Figure 1: Walser settlement areas. Source: Waibel, M & Waibel, E.A. (2007).


4. Mountaineering in the Jungfrau – Aletsch region

Summary by Alexandra KESSLER (ale.ke@bluewin.ch) based on the following sources:


http://www.jungfraualesch.ch/de.htm Stand: 14.6.15

http://www.aletscharena.ch/sites/de/aletscharena/destination/unesco_welterbe.html Stand: 14.6.15


http://www.beatenbergbilder.ch/home/reportage_32_eigernordwand.htm Stand: 14.6.15

One of the first signs of mountaineering in the Jungfrau – Aletsch region is the erection of the hotel Rosenlaui at the Grosse Scheidegg in 1773. It has been built to accommodate wealthy tourists, exploring the mountains. In 1811, the Jungfrau summit was climbed, the first 4000 in the Swiss Alps. In the following years other mountains in the same regions were climbed, along with which visitors from far and wide came (Staeger 2012). English nobility declared the Alps as the playground of Europe. Thus 1863 the SAC in Switzerland was founded opposing against ‘The Alpine Club’ in London (Baer 1999).

In the late 19th, early 20th century, the Jungfrau – Aletsch region was industrialized. The area was connected with railway lines and soon several projects were planned to make the mountain tops easier to reach. Realised projects are the train to the Kleine Scheidegg and ultimately to the Jungfraujoch, and the first cablecar to the Enge at the Wetterhorn which had to be teared down due to reclining demand. A project which has not been put into reality was a cog railway from Brig to Lake Märjelen and then a cable car over the Aletsch to the Jungfrau. Also a prolonging of the existing railway and cablecar route were never realised. During the 1st and 2nd world war, tourism declined, however winter tourism emerged (Staeger 2012).

In 2001, the Jungfrau – Aletsch region 828 km² (www.aletscharena.ch), consisting of 25 communities has been accepted as a UNESCO world heritage site. The region does fulfil three criteria where only one has to be met: scientific interest, biological and ecological diversity and the regions importance in European culture (literature, art, mountaineering and tourism) (www.jungfraualetsch.ch).

One of the most famous ascends in this region was and is the north face of the Eiger. For a long time the route was impossible to climb, due to poor material and climate conditions (avalanches, low temperatures and wind). The first attempt in 1911 reached the station of the Jungfrau train at the Eiger. A second attempt in 1934 ended in the falling of a crewmember and the roped party had to be rescued from the train station at the Eiger. The third attempt in 1935 ended deadly as the two mountaineers were surprised by a snowstorm the location called since the ‘Todesbiwak’. In the fourth attempt in 1936 two groups started to climb up at the same time. Reaching a difficult point they joined. While reaching the same point as the group in 1935 one companion was injured and they decided to go down again from the ‘Todesbiwak’ (death bivouac). Due to increased icing, they were not able to return but died having been surprised by an avalanche and waiting for help. In 1937 yet another attempted ascend had to be terminated, but they were the first to survive the descent from the ‘Todesbiwak’. In spring 1938 another two mountaineers died at an attempt of descending (www.wikipedia.org).

It’s first successful ascend was in 1938, accomplished by Anderl Heckmair and his crew (red route picture 1). Heckmair started along two other groups into the wall. Due to bad weather he
descended again to start again the other day. The other two groups stayed in the wall. Heckmair profited from the steps forced into the snow and better material, especially crampons, one the group did not even have them. One of the other group had to descend, the other joined after an avalanche nearly killed them all. After 3 days they reached the summit (www.wikipedia.org). Some firsts and fastests of the north face of the Eiger (www.wikipedia.org): In 1936 the first solo ascending succeeded on the normal Heckmair route by a Swiss mountaineer. The first winter ascend was in 1978 by a Japanese who needed six days. The fastest climbing of the north facing wall in 2008 was the Swiss Ueli Steck who needed only 2 hours and 48 minutes without securing rope in winter. Only Daniel Arnold, also Swiss was 20 minutes faster, however he climbed in summer. The fastest roped party needed in 2011 4h 25 min. The first women climbing the north face in 4 days was the German Daisy Voog in 1964.

picture 1: different routes leading to the peak of the Eiger through the north face of the Eiger: Blue: 1966 John Harlin direct route; Red: Heckmair route, normal route 1) Hinterstosser Quergang, 2) first ice field, 3) second ice field, 4) Todesbiwack, 5) Bügeleisen, 6) third ice field, 7) ramp, 8) Götterquergang, 9) Spinne (die weisse Spinne), 10) Gipfeleisfeld; yellow: 1969 Japanese direct route; green: 1976 Czechs direct route.
Source: http://www.beatenbergbilder.ch/home/reportage_32_eigernordwand.htm, Stand 14.6.15
5. Flora and Fauna of the Jungfrau-Aletsch Region

Summary by Chloé BOUSCARY (chloebouscary@wanadoo.fr) based on the following sources:


The Jungfrau-Aletsch region is located in the south-central Swiss Alps, and has nine peaks higher than 4000 m. 80% of the region is covered by glaciers and barren rocks, the rest of the area is composed of 6% of forest, 5.2% of alpine meadow, and 8% of scrub. Even if the region is not really hospitable, a flora and a fauna representative for the Alpine high mountains have adapted to this difficult environment and can be found in these marvelous landscapes.

In term of vegetation, there is a marked difference between slopes exposed to the south, and to the north, respectively northern and southern slopes of the mountains. The southern slopes are warmer and drier (side of the sun) than the northern ones, and the limits of altitudinal zonation of vegetation are situated 200m higher (figure 1). On the north side, forests at lower elevations consist of broadleaved species such as beech, ash, alder, elm and birch. The south side is too dry for beech, so the dominant specie is the Scots pine, nowadays gradually replaced by the downy oak better suited to the almost Mediterranean habitat. On the northern side the subalpine zone is dominated by Norway spruce with mountain ash, silver birch, sycamore maple and stone pine, and on the southern side, by more continental species such as European larch. Above the timberline are vast areas of rhododendron scrub, alpine grassland and tundra vegetation and, on the dry southern slopes, steppe grasslands, gradually passing to bare rocks.

Figure 1: Altitudinal zonation of vegetation (www.jardinalpindulautaret.fr, 13.07.2015), but in the rocky steppes of the Valais, the zonation might be higher because it is an inner Alpine dry valley with shallow nutrient-poor soils, aridity, wind and sun that preserved plants from the steppes of eastern Europe and the Mediterranean arrived shortly after the retreat of the glaciers 10000 years ago at the end of the last Ice Age.
Along with the climatic conditions (rain and snowfall, temperature, sunlight and wind) and the topography (slope, altitude), the type of soil (crystalline, granite and gneiss, or limestone) is very important to determine which plants grow where. Some plants, such as the quintessential alpine flower, the edelweiss (see to the left), and also the alpine aster and the yellow bellflower, contain active agents able to neutralise the ions contain in chalky soils and so are more common in areas where the substrate is limestone. As for the stinking primrose, the trumpet gentian and the yellow alpine pasqueflower, they prefer silicate bedrocks. Some plants can adapt to two soils, like for the alpenrose where the substrate is crystalline, and the hairy alpenrose where it is limestone. In the Aletsch region, glaciers has deposited chalky material from the Jungfrau massif on top of the crystalline bedrock, enabling chalk-loving plants like the mountain avens to grow among the glacier forelands.

This varied flora is part of the habitats of animals that live in the region. The fauna of the Jungfrau-Aletsch region is typical of the Alps, with a wide variety of species including 271 vertebrates, 42 mammals, 99 birds, 8 reptiles, 4 amphibians, 7 fish, 97 molluscs and more than 979 insects. In total, around 1250 species have been recorded.

Among all these species, it is common to see birds such as eagles, kestrel, chough, black grouse, snow finch, wallcreeper, lammergeyer, pygmy owl and various woodpecker species. But the most majestic of these birds is the Golden eagle (see to the left), with a wingspan up to three meters. Other spottable animals are green lizards, snakes (the bite of an Adder or a European asp can cause serious health problems), goats, sheep, chamois, alpine ibex, red deers, the reintroduced lynx, and small mammals such as mountain hares, foxes, ermines, marmots …

The ibex, the Golden eagle, the lynx and the wolf (among other species) were exterminated in Switzerland. Today, thanks to reintroduction programs, they have reappeared in the Alps. But contrary to the reintroduction of the ibex (see to the right) that was a success - there are nowadays around 40000 ibex in the Alps, with 15000 of them in Switzerland -, the reintroduction of the large predators that are the lynx (see to the left) and the wolf is not always welcome. Lynx were released back into the wild in Switzerland in the 1970s, while the wolf has returned as part of a Europe-wide migration. Since then, opinions are divided: some are encouraging this reintroduction for the enrichment of the fauna and the protection of the flora it provide, but owners of livestock fear for their sheep and goats, saying that the return of the wolf puts their existence at risk.

Today, the Swiss Alps Jungfrau-Aletsch region is inscribed as a UNESCO World Heritage Site under Natural Criteria for its geological and geomorphological significance, and biological and ecological diversity, and the region is categorized under the ‘IV Protected Landscape’ by the IUCN, which means that habitats or species management areas may exist as a fraction of a wider ecosystem or protected area and may require varying levels of active protection. Thanks to this designation, the abundant variety of habitats and living species are being actively conserved and protected.
V. Additional scientific and socio-cultural topics from the 2014 excursion

1. Swiss Alps Jungfrau-Aletsch: UNESCO World Natural Heritage Site

Summary by Paribesh PRADHAN (paribesh.pradhan@uzh.ch) based on the following sources:


The Swiss Alps Jungfrau-Aletsch formerly also known as Jungfrau-Aletsch-Beitschhorn was inscribed on the World Heritage List under the natural criteria in 2001. It was later extended to the World Heritage Site inscribed under Natural Criteria for its geological and geomorphological significance, biological and ecological diversity and unsurpassed beauty. The IUCN management has categorized this region under its ‘IV Protected Landscape’.

The Swiss Alps Jungfrau-Aletsch lies in south-central Switzerland in the Bernese Alps of the central European Highlands (biogeographical province), on the border between Cantons of Valais and Bern, 25 km south of Interlaken and 20 km north of Brig. This natural heritage site covers the entire Aar massif from the Gasterntal in the west to the Grimselsee in the east. It also includes catchments of Aletsch, Aar and Grindelwald glaciers as shown in figure 1. As the center of all this is Konkordiaplatz which is the tourist’s and researcher’s hub for this region.

This World Heritage Site covers a total area of 82,388 ha and it is the largest glaciated area in the Alps making it also one of the greatest watersheds of Europe. The presence of U-shaped valleys, valley glaciers, cirques, horn peaks and moraines in the region illustrate this fact. Of its 82,388 ha, 56% lies within the Canton of Valais and 44% lies within the Canton of Bern to its north. The area covered by glaciers is around 35,000 ha including five of the seven longest glaciers in Switzerland thus making this site the largest continuous area of ice in the Alps. The altitude variation ranges from 809 m.a.s.l to 4,274 m at Finsteraarhorn. 50% of the total area of the Swiss Alps Jungfrau-Aletsch lies above 2,600 m with ELA at 2,700 m on the northern slopes and 2,900 m on the southern slopes. The Aletsch Glacier that lies in this region also shown in figure 2 is the largest and longest in western Eurasia with an area of 96 km² and length of 23.3 km. When ice thickness of Aletsch Glacier was measured at Konkordiaplatz in 1991, it was found to be of 900 m height because of the overdeepening of the bedrock. It is the only other place outside the polar icecaps where such huge thickness of ice exists. The Fiesch Glacier is the second longest and third largest glacier in Europe with length of 15.1 km. This site also hosts 9 peaks that are above 4,000 m namely - the Finsteraarhorn, Aletschhorn, Jungfrau, Mönch, Schreckhorn, Gross & Hinter Fiescherhorn, Gruenhorn and Lauteraarhorn.
80% of the Swiss Alps Jungfrau-Aletsch World Heritage Site constitute of glaciers and barren rock while 6% is forested, 5.2% is alpine meadow, and 8% is scrub. Steep north-facing slopes dictate the physiography of this region. The southern ones are relatively gentle in comparison. The distribution and diversity of vegetation in the region vary according to slope, aspect and elevation, and there is a marked difference in vegetation between the northern and southern slopes; meaning that forests on the north side at lower elevations consist of broadleaved species such as beech, ash, alder, elm and birch while on the south side which is relatively very dry consists of Scots pine. One can find rhododendron scrub, alpine grassland and tundra vegetation above the timberline. On the xeric southern slopes, steppe grassland is extensively present. Some 1800 species of plants and 700 mosses have been documented in this designated area. This region also hosts wide species of fauna such as ibex, lynx, red deer, roe deer, chamois and marmot along with various species of reptiles and amphibians. Birds like golden eagle, kestrel, chough, ptarmigan, black grouse, snow finch, wallcreeper, lammergeier, pygmy owl and various woodpecker species can also be found. In terms of numbers, 1250 species of animals including 271 vertebrates and 979 insects have been recorded in this region.

Evolutionary records suggest human intervention in this landscape some 3400 years ago sufficed by archeological evidence that this area was inhabited by Celts Romans and Alemans in the dry Valais. The site itself is not inhabited by people except for summering shepherds; the population of the surrounding valley at present is 35,100 with tourism and agriculture as their primary source of income. Tourism in this region flourished in early 19th Century after the first successful summit of Jungfrau in 1811 and Finsteraarhorn in 1812. The tourist season was basically only in summer during its early years but later after 1930s winter sports became popular in this region. The Jungfrau railway built between 1870 and 1912 changed definition of accessibility in such harsh terrain and increased the influx of tourists by multitudes. Today, this region is a bit overcrowded with the influx of mass tourism, and therefore, the intervention of humans and climate change pose major challenge as well as threat to this region.
2. Glaciers and Summits of the Jungfrau-Aletsch Region

Summary by Jacqueline HUBER (jhuber@access.uzh.ch) based on the following sources:


The impressive but barely touched high-mountain landscape of the Jungfrau-Aletsch Region between the Bernese Oberland and the Rhone Valley is a highly glaciated part of the Alps including one of the most famous mountain range of the world: Eiger, Mönch and Jungfrau. There are nine peaks over 4 000 m in this region (Figure 1): Finsteraarhorn (4274m), Aletschhorn (4193m), Jungfrau (4158m), Mönch (4099m), Schreckhorn (4078m), Gross Fiescherhorn (4049m), Hinter Fiescherhorn (4025m), Grünhorn (4044m) and Lauteraarhorn (4042m) [3]. The numerous glaciers are a crucial contribution to the fascination and uniqueness of this region, even more in the age of climate change.

The steep, humid and cool north side, containing several glaciers including the lower and upper Grindelwald glacier, is in the catchment of the Aar, running into the North Sea via the Rhine. The gentler, warmer and drier south-facing side, the inner Alpine valley of the Valais, drains into the Rhone feeding into the Mediterranean [1].

The Great Aletsch glacier is the largest and widest glacier in the Alps (length of 22.6 km, area of 81.7 km²). The firn basins Grosser Aletschfirn, Jungfraufirn, Ewigschneefälde and Grüneeggfirn (from west to east) converge at the Konkordiaplatz, where the ice is 900m thick. It is also a scientific object. First glaciological experiments were done by Alfred Escher in 1841 when he monitored ablation between June and August [2].

During the maximum extent of the last glacial Period, the Würm glacial period 24 000 years ago, the Fiescher glacier, the Great Aletsch glacier and the Rhone glacier covered most of Switzerland and thus all of the Valais. Only the highest peaks were not covered by this ice blanket, e.g. the Finsteraarhorn and the Aletschhorn. The Ice Age ended 11 700 years ago due to significant climate warming: the Holocene began. Notoriously, the glaciers melted and retreated. Irregular alternating warm and cold periods some of them leading to advancing glaciers, depositing several moraine embankments [2].
Figure 1: Glaciers and peaks of the Jungfrau-Aletsch region [2].
3. Konkordia Alpine Hut

*Summary by Daniela MÜLLER (daniela.mueller@geo.uzh.ch) based on the following sources:*

www.konkordiahütte.ch (accessed: 14.05.14)

The Konkordia Alpine Hut is situated at the edge of the Konkordiaplatz about 200 meters above the glacier in the Bernese Alps. The hut is located at a height of 2850 meter above sea level and has capacity for 155 guests. It has an opening period from March to May and July to September and the current owner is the SAC section of Grindelwald.

The first hut was built in 1877 approximately 50 meters above the glacier. There was space for 20 guests and the cost for one night was 50 Rappen. It was financed by the SAC and Emil Cathrein, owner of the Jungfrau Hotel at the Eggishorn. The SAC section Monte Rosa was in charge of the newly built hut at this time. Due to the big amount of mountaineers and the lack of clarity who has to pay for important maintenance works, Emil Cathrein decided to build the Pavillon Cathrein just a few meters above the first hut. At this time food and fuel was transported on foot from the Hotel Jungfrau to the hut.

To improve the situation at the Konkordiaplatz, the newly founded SAC section of Grindelwald wanted to build a new hut. Because the central committee in Geneva didn’t adjudge the project enough money, Gustav Hasler the president of the section Grindelwald offered to pay for the construction costs. The Haslerhütte was built in 1908 and Gustav Hasler gave the hut as a present to his SAC section. In 1946 the SA section Grindelwald bought the Pavillon Cathrein for 45’000 Swiss francs and was henceforward owner of all three huts at the Konkordiaplatz. Due to glacier melt the path to the Huts got longer year by year and the bergschrund had to be traversed by ladders. After a big rockfall event in 1965, the path had to be relocated and to reach the alpine huts mountaineers had to traverse a 60 meters high rock face with nine ladders with total 200 steps and two bridges. In 1967 the Pavillon Cathrein was modified for roughly 134’000 Swiss francs and in 1976 the upper hut was renovated for about 230’000 Swiss francs. In 1980 the first solar plant was established to provide electricity for the hut telephone. In 1985 more solar panels got installed and henceforth electricity was available for the lighting of the hut. Moreover a tank of 70’000 litre for the storage of fresh water was installed. In 1996 another big renovation took place. For approximately 2 million Swiss francs the hut got enlarged and reached its current capacity of 155 guests.

Due to the further retreat of the Aletschgletscher, the rock is going to destabilise more and is therefore a risk for mountaineers. The path to reach the Konkordia hut gets longer every year and because of the thickness loss of the glacier new steps have to be added from time to time.
Figure 1: The Haslerhütte in 1908

Figure 2: The Konkordia Alpine Hut
4. Vulnerability of Grindelwald to natural hazards – avalanches, rock fall, floods

by Patrick BAER (patrick.baer@geo.uzh.ch) based on the following sources:


Jungfraubahnh: http://www.jungfrau.ch/en/tourism/news-events/v-cableway/the-v-cableway-project/ (access 12.06.2014)

Gletschersee Grindelwald: http://www.gletschersee.ch/index.cfm/treeID/27 (access 12.06.2014)

Grindelwald as a high mountain village is particularly exposed to natural hazards. The hazard map provided by the cantonal authorities shows a complex situation with several different hazards affecting the same areas (Fig. 1). A detailed investigation shows that the occurring hazards can be distinguished into three different categories: Gravitational hazards (rock falls and avalanches), landslides and flooding events.

Gravitational hazards mainly affect remote areas of the village. All the hazard zones related to these events are situated in south-east, east and north-west boundary areas of the community, where few residential buildings are present. Only the residual risk zone for rock falls is designed larger taking a big rock fall event from the Hörnli ridge north face into account. For avalanche hazards, several smaller but remote avalanche tracks are in the red zone. Only the area of Milibach in the north-east, which is situated in the potentially disastrous Wetterhorn avalanche track, consists of a larger yellow zone also including several residual buildings.

Landslide hazards are mainly determined in the smooth north faces and affecting a large number of residual buildings. This slope is critical for landslides because the topography is parallel to the geological layering, which enhances sliding activities.

The most important hazards are flooding and debris flow events. On one hand, an important part of the village, Grindelwald Grund, which includes most of the major infrastructure, is located close to the Lütschine river and on the other hand, several small streams with debris flow potential lead through residential or important touristic areas. Also past events were mostly related to flooding: For example in 2005, not only Grindelwald Grund has been flooded, but also the valley downstream, which led to the isolation of Grindelwald for approximately two days (authorities of Grindelwald 2005). Furthermore, the hazard related to the Grindelwald glacier lake is distinguished as a flood hazard (c.f. Werder et al. 2010).

Since flooding currently is the highest risk, great efforts have been made to reduce the threat for Grindelwald Grund: A 8.5 Mio CHF project, which currently is under construction, will protect the infrastructure of Grindelwald Grund. At the same time, authorities of Grindelwald are working on a new infrastructure concept since the current road and railway infrastructure is too small for the present amount of tourists. Furthermore, the Jungfraubahnh AG is planning a new V-shaped cable car connection from Grindelwald Grund to Männlichen and to station Eigergletscher called “V-Cableway Project”, which is planned to open service in 2016 (Jungfraubahnh). With this additional infrastructure and thus a rising number of tourists, also the situation in Grindelwald Grund will change: The already limited space will be used with higher density,
more daily tourists are expected and therefore, damage potential will be higher. In order to protect infrastructure as well as tourists, mitigation projects like the flood protection project in Grindelwald Grund are inevitable.

Figure 1: Combined hazard map for Grindelwald, including rock fall, avalanche, flood and debris flow, landslide. Red, blue, yellow: Different hazard zones. Brown: Area outside the area of investigation. (Source: Geoportal canton of Berne www.apps.be.ch)

Figure 2: Hotspots of Risk in Grindelwald: Mainly infrastructures along the Lütschine river (railway tracks, train stations, cantonal road, cable car station). Furthermore, two campsites are distinguished as hotspots of risk due to their position (left: In the red hazard zone on a debris fan; right: On the valley floor near the Schwarze Lütschine) and the poor protection of people living in tents compared to people living in houses or hotels.
5. Climate change and implications for winter tourism in the Jungfrau-Aletsch region

Summary by Noah ZELTNER (noah.zeltner@uzh.ch) based on the following sources:


In this summary I will discuss the consequences of CC for the sector of tourism in the Jungfrau-Aletsch region. Overall, why should tourism care about climate change?

It will surely influence the touristic conditions in terms of e.g. warmer temperatures, higher snowlines or/and more extreme weather conditions. These effects can have an impact in positive and negative ways. How tourism will look in a few decades is hard to tell but there will be implications of climate change with strong consequences on the development of tourism.

**Negative effects**

For the negative effects one could name the decreasing snow security, deglaciation processes, permafrost degradation, extreme weather conditions and changes in landscape.

According to Müller et. al. (2007) there will be an increase of snow line of about 350m until the year of 2050. Due to warmer temperatures the length of snow cover and the number of days with snow fall will decrease. This will pose a danger for skiing areas situated in lower places of the Alps (Bürki, 1995). As this is an ongoing process this could hit - even though with some delay - the relatively high situated region of Jungfrau. Deglaciation processes will change the conditions as it will reduce the touristic attraction of a region. In combination with permafrost degradation this will lead to processes of destabilization where touristic infrastructure will be affected (e.g. mountain railway stations and their pillars) and rock fall will increase. More often occurring extreme weather conditions will cause problems too. Hot waves can lead to aridity and strong precipitation events will increase hazard potential in high mountain areas quite strongly. Last but not least, climate change will leave its marks in many locations but especially in regard of glaciers, vegetation and soil and fauna. All in all, it is clear that alpine locations are highly vulnerable to changes of these conditions due to their (economical) dependence on tourism.

Although negative effects might be more obvious there are also chances coming out of these implications of climate change. Summer tourism will be getting higher priority as there could be a major shift to the warmer months of the year. The heat period of 2003 can act as a good example for that. In addition to that, alps could have a revival of the wellness sector of the 20th century as the swiss alps could somehow build a refugium and hidaway of the southern blazing heat (Müller, 2007). Further adaptations in the touristic activity offers of a region will be needed.

A good example of handling the changing conditions is the newly developped “climate guide” of the Jungfrau region. It is offering several guided paths over the whole area where climate change is happening and is visible to the naked eye. On one side it serves as a new model of tourist attraction. On the other side it is kind of a mitigation process and is making people aware of what the implications of climate change are.
Adaptation strategies

Assimilation can be grouped in first technological and second business-related strategies (Scott and McBoyle, 2007). On the technological side there is the already widespread and commonly used snowmaking although it raises more and more questions the sustainability of this adaptation strategy and its environmental impact. Besides that, slope development and operational practices can include protection of glaciers with land contouring or smoothing ski slopes to be more efficient when using snowmaking. While not yet really used in Europe cloud seeding is sometimes used in North America and Australia to produce artificial precipitation.

On the business-related side there is the possibility to merge to bigger ski conglomerates to act more efficiently and on a larger scale. In the case of the Jungfrau region one could think of merging with other Bernese ski resorts although Jungfrau already is quite a big resort relatively to other Swiss resorts. This would reduce the amount of money to be spent for the strategies mentioned above. Additionally, models of revenue diversification and marketing incentives are in practice to attract more tourists in particular regions. Lastly, financial sector is getting on the train of climate change implications as well providing snow insurances and weather derivative products to ski resorts under certain conditions (Scott and McBoyle, 2007). In combination with building ski conglomerates this could be a good protection method for bad winters.

It is hard to predict how touristic landscape will look like in Swiss Alps over the next coming decades, especially as the different mitigation possibilities won’t match every region equally good and in the end will proof their usability only while practising. Although climate change will cause a lot of problems to deal with it can offer some chances to profit as the Jungfrau region is showing with the “climate guide” also available as an application for smartphones.

Figure 1: Deglaciation of Triftgletscher from 1948-2006 causing a loss of attractiveness and an increasing hazard potential leading to higher risks for the touristic area. (source: www.gletscherarchiv.de)

Figure 2: “climate guide” application of the Jungfrau region.