Overview of available data from the Svartisen subglacial laboratory and surrounding weather/discharge stations

Pierre-Marie Lefeuvre

September 2013

Table of Contents

Introduction

As part of the effort of data collection and sharing from the Stability and Variations of Arctic Land Ice (SVALI) project, we report data availability from the Svartisen Subglacial Laboratory (SSL) located in Northern Norway. This summary also includes some technical details and quality control of the datasets.

The construction of the Glomfjord hydro-power plant in the vicinity of the Svartisen Ice Cap has led to a long-term monitoring of the Saltfjellet-Svartisen hydrological system and in particular Engabreen, a maritime outlet glacier. Since 1992, the SSL built underneath the glacier has been the place of glaciological and hydrological investigations, in which the Norwegian Water Resource and Energy Directed (NVE – owner of the SSL) has largely contributed. Direct observations of the glacier bed are key to understand the relationship between the latter, subglacial hydrological changes and glacier surface dynamics. In this report, data from the SSL are presented with data from surface meteorological stations (Fig. 1), which primarily consist of physical parameters such as temperature, precipitation and discharge.

Figure 1: Approximate location of the Subglacial Laboratory and nearby meteorological stations

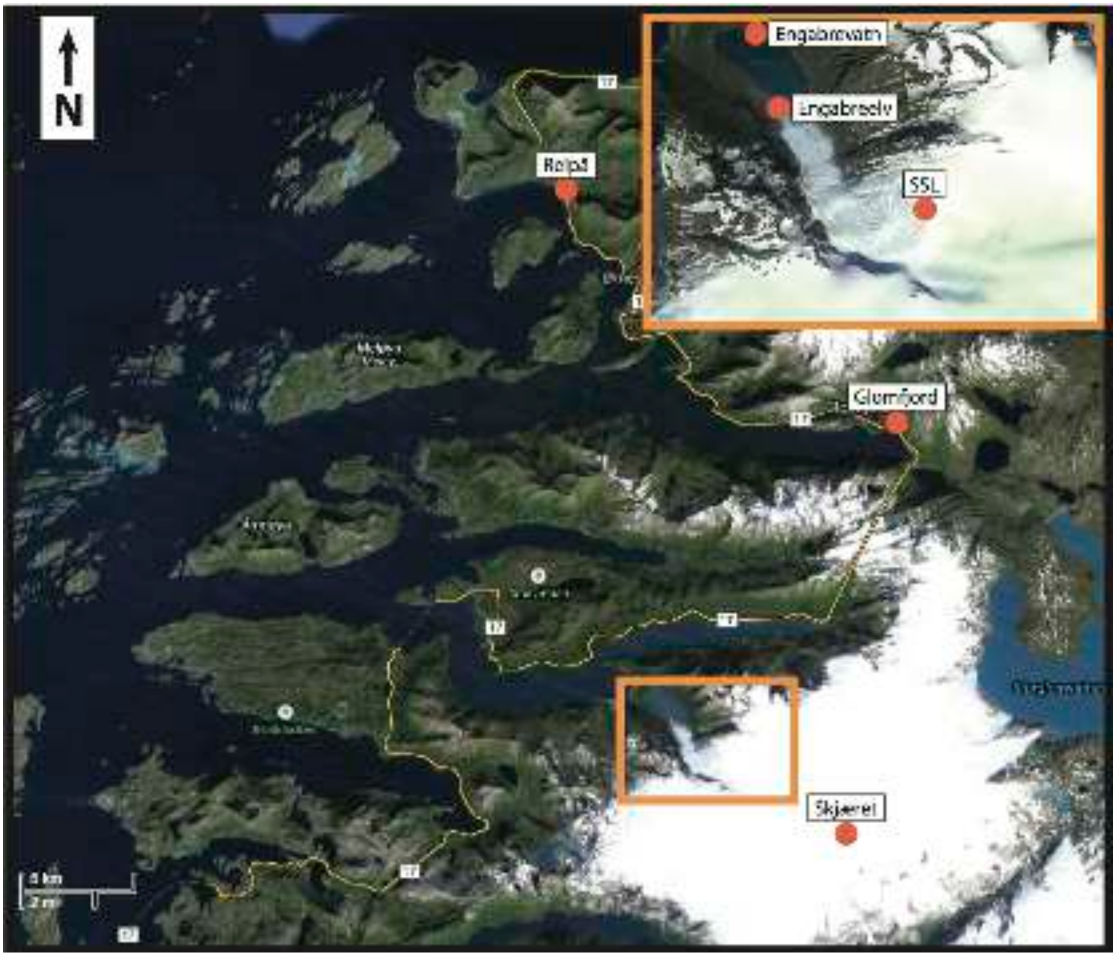
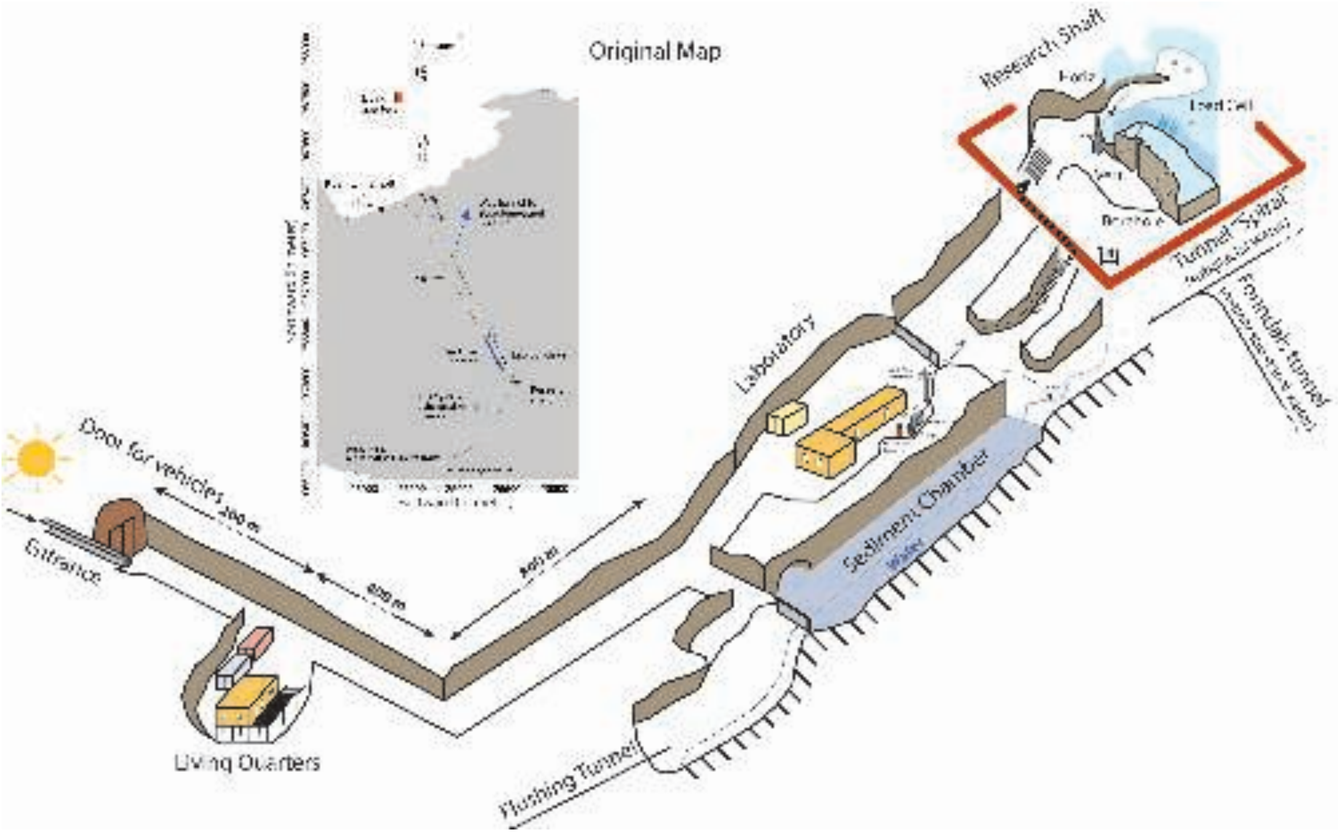


Figure 2: Original Map and Sketch of the facilities at the Svartisen Subglacial Laboratory.



The Svartisen Subglacial Laboratory

One of the subglacial intakes is currently used for scientific purposes and consists of a horizontal and a vertical research shaft (see Fig. 2 "Horiz." And "Vert."). From these entrances, an ice cave can be melted spraying hot-water provided by a hot-water drilling system of 600kW and two pumps. After more then 12 hours of work/melting a part of the bedrock can be cleared. Then, instruments can be placed to monitor the evolution of normal basal pressure, ice closure and furthermore samples of subglacial ice can be collected. The ice cave will close at a mean rate of 25 cm/day in each direction, leading to complete closure over three-five days. Finally, boreholes drilled from the research shaft through bedrock can be instrumented to measure water pressure at the glacier bed and basal sliding.

The research shaft is located under ~200m of ice giving a mean overburden pressure of about 1.8-1.9 MPa. The glacier base is composed of layers of debris-laden and debris-free ice. NVE's archives own a collection of pictures taken during previous fieldworks and workshops (1992-present), which provides numerous observations of basal ice. A more detailed description of the latter is included in internal reports and published work [Kohler, 1993; Hooke and Iverson, 1995; Jansson et al., 1996; Cohen, 1998, 2000; Jackson, 2000; Iverson *et al.*, 2003; Cohen et al., 2005]

Basal Pressure Time Series

Basal Pressure was measured using Load Cells (Fig. 3). These sensors consist of a plate, under which a wire under tension is attached to two vertical pins. The applied load causes the plate to bend and the distance between the screws increases changing the frequency at which the wire vibrates. The measured frequency has been calibrated to give normal pressure up to 9 MPa with an error of less than 1% for the total range, according to the manufacturer [GEONOR]. This Load Cell P-105 was originally created to measure uniform load such as water pressure on a dam wall. In the case of ice, this is only true when the glacier evenly rests on bedrock. However, rocks dragged at the bed, migration of meltwater channels and opening of cavities disturb the signal. Pressure variations in response to those phenomena are recurrent in summer and sporadic in winter as seen in Figure 5. Thus, winter records are more likely to represent the mean overburden pressure of the glacier and summer records, to reflect subglacial dynamics and hydrology.

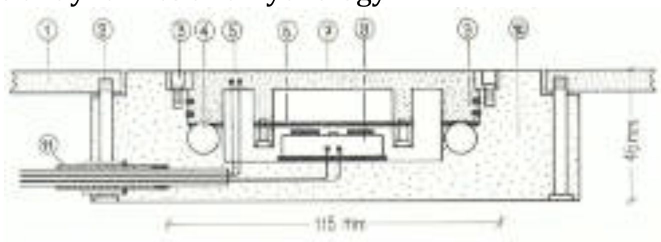


Figure 3: Sketch of Load Cell components

In 1992-1993, seven load cells were drilled into the bedrock: LC1e, LC2a, LC2b, LC4, LC6 and LC7. In 1997, LC97_1 and LC97_2 were installed and in 2012 were replaced with LC12_1 and LC12_2. The map in Figure 4 shows their location and that of the research shaft. The load cell LC01 added in 2001, failed to work after its first year. LC7, LC2a, LC97_2 and LC1e stopped working in 1996, 2008, 2010 and 2012, respectively.

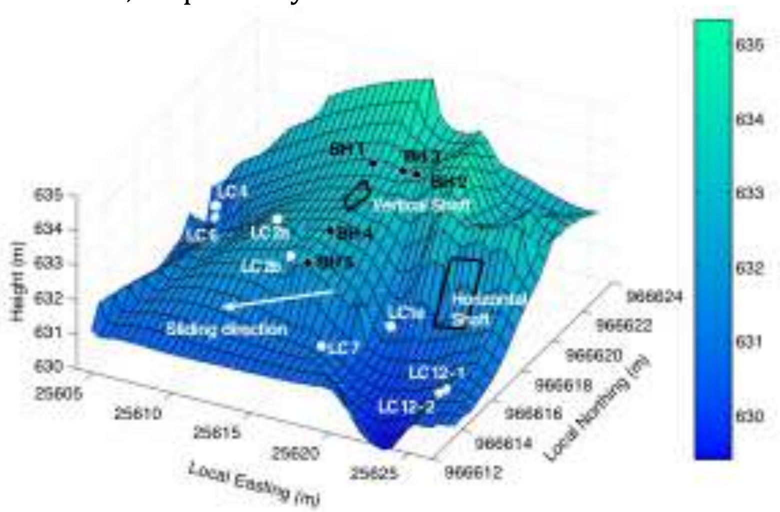


Figure 4: Digital Elevation Model of bedrock surrounding the Svartisen Subglacial Laboratory, which indicates location of Load Cells (LC - white), Rock Boreholes (BH - black), Shafts and Sliding direction.

The Time Series are not continuous, but span the period from late 1992 to 2013. Problems with batteries and data loggers caused most of the data gaps. Failure of the load cells could result from over-loading due to a rock passing over as seen on sensor 97_2, where evidence of gauging was visible. Connections with the datalogger can deteriorate over time as occurred with LC1e, which became loose due to work in the tunnel.

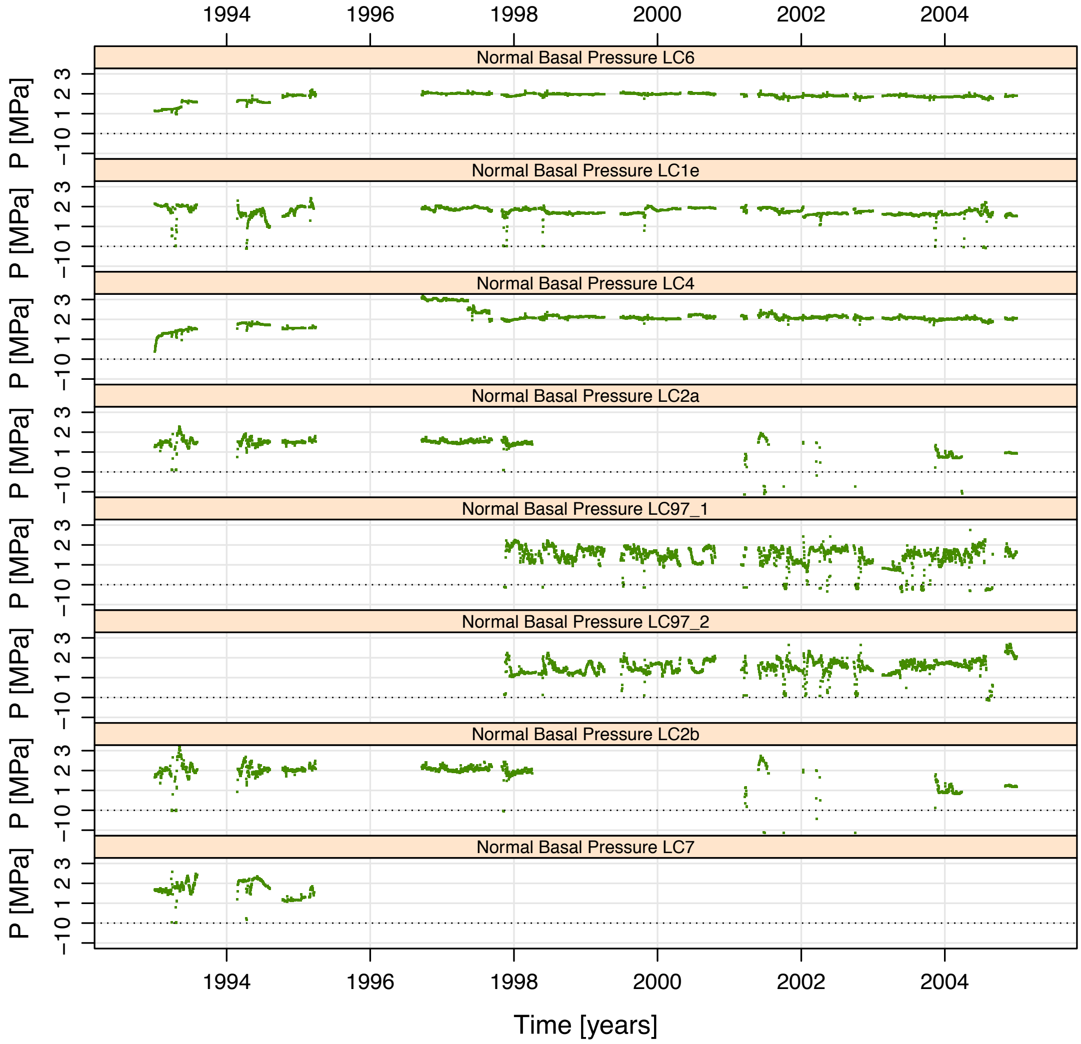


Figure 5: Normal Basal Pressure Time Series (green dots) and number of measurements per hour (orange lines) between 1998 and 2005.

Regarding the quality control, load cells sheltered from ice flow (e.g. LC4 and LC6) vary significantly less and present less noise as opposed to the rest of the sensors. For LC97_1 and LC97_2, negative pressure values were observed and can have several explanations. First, test of the load cells applying a force with a screw at one point of the load cell demonstrated that we could create negative values. While the load is concentrated on the edge of the uni-axial wire, the plate bends inward reducing the distance between the pins of the wire. The latter will therefore vibrate at a lower frequency than the frequency zero used in the calibration curve, giving apparent negative pressure.

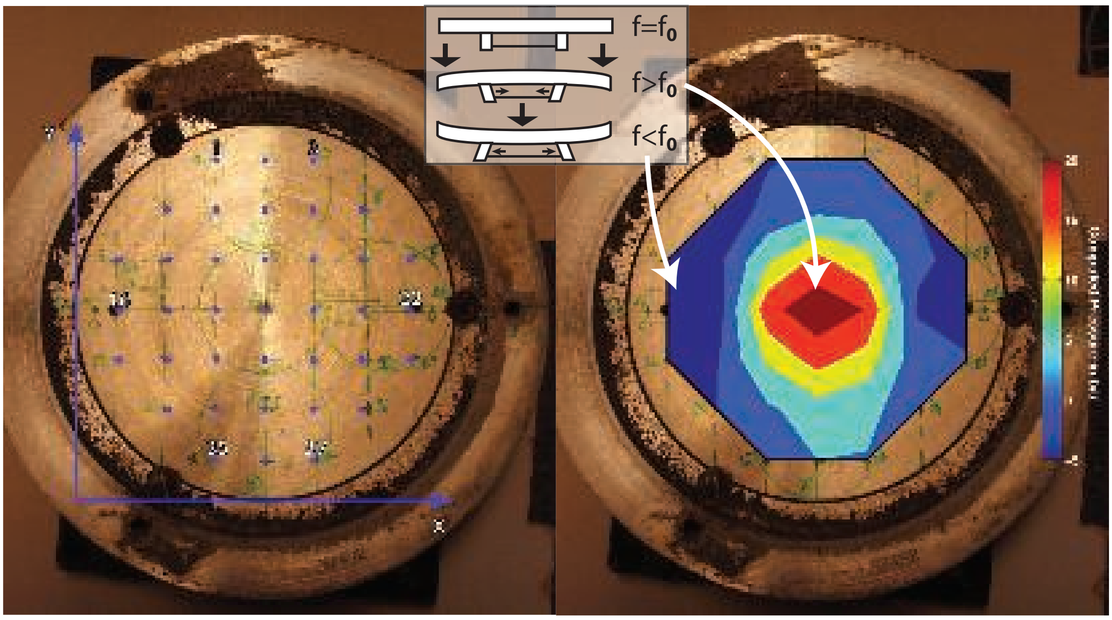


Figure 6: Test of Load Cell measurements. A load of 500kg is applied to defined points (left) and computed pressure [in bar] is shown on the right-hand side. Explanation of plate bending, frequency of the vibrating wire and negative pressure is explained on top.

Secondly, although DiBiagio, 2003 stated that hyperbolic drift of load cells is less than 1% over 27 years for laboratory conditions, a larger error could arise for in situ sensors that will bear much tougher conditions. This will lead to a change in the elasticity property of the wire and could reduce its frequency zero. A correction can only be applied if this frequency is measured during controlled unloading (e.g. melt of an ice cave). This is only possible for LC97_1 and LC97_2.

Despite non-continuous records, those time series are valuable due to their long time span and their high resolution (e.g. <=15 minutes interval). Variability can be smoothed in order to focus on understanding subglacial hydrological processes.

Pump Test Measurements

Instrumentation of the ice-bedrock interface is also possible from rock boreholes. These were drilled from the research shaft roof through bedrock to assess the distance from the ice during construction. There are five boreholes, from which water pressure and basal sliding can be measured.

For pump test experiments, packers are installed into the rock boreholes to seal the glacier bed from the research shaft. Onto those packers, pressure transducers are plugged and a valve can be used to control water flow or pressure as seen on Figure 6.

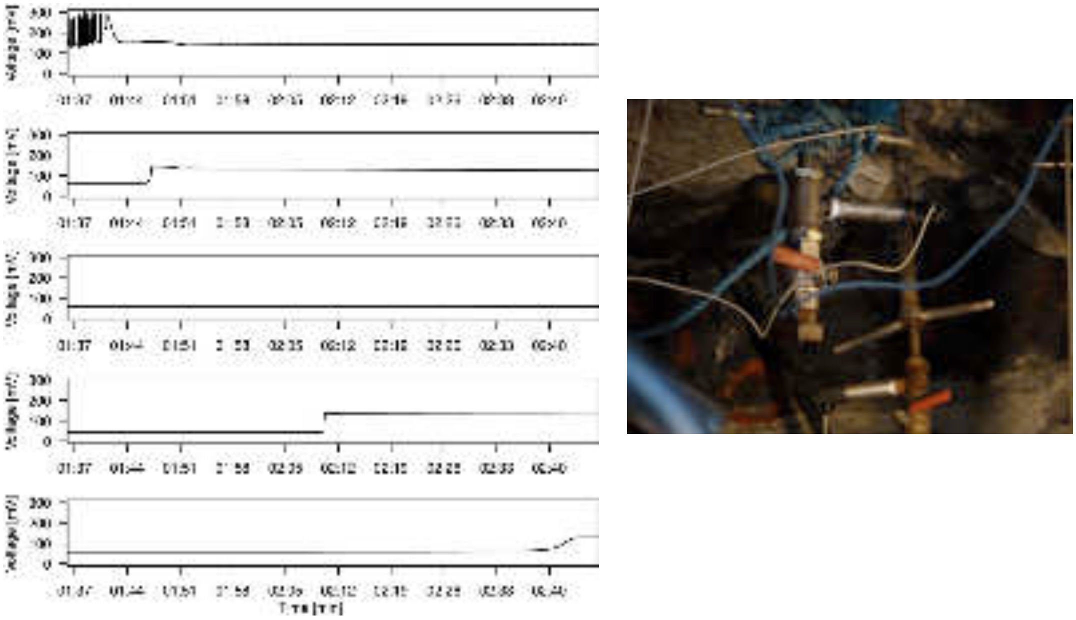


Figure 7: Pump Test Experiment showing connection (voltage increase) between BH1 (Top graph.) and three out of four boreholes. The picture shows packers installed in rock boreholes to which were plugged pressure transducers wired to a CR10 data logger.

A pump test starts with injection of water in one borehole, usually BH1, using a High-pressure Low-volume pump (e.g. Kärcher©). Pressurisation is needed to reach the mean overburden pressure, which is about 1.9 MPa, so that water can flow at the ice-bedrock interface. Measured water pressure confirms this threshold at which pressure stops building up and water leaks out of the borehole. Repeated injections lead to ice melting and formation of small channels. At that point, the Kärcher© cannot sustain the discharge and water pressure decreases. It is therefore replaced with the Low-Pressure High-volume pump. Following this transition, the four other boreholes show increase in water pressure if a connection occurs. The timing gives the level of connectivity of the subglacial hydrological system, which depends on its stage of development. This evolution usually occurs throughout the spring and summer with increasing surface melt and precipitation.

Published data (Lappegard et al., 2006) are available for further analysis. These pump tests took place for a couple of days in May 1998, March 2001, March 2002 (x2), July 2002 (x2), May 2003 (x3) and November 2003. Two additional experiments were undertaken in 2012 to complete a new dataset.

Basal Sliding

After clearing the rock boreholes of ice and debris, instrumentation of the glacier bed is done in order to measure basal sliding. A simple drag spool setup is used and is composed of an anchor attached to a wire. This wire turns a wheel, whose rotation changes the resistivity of a potentiometer and so the measured voltage. Calibration is computed prior to their installation by pulling the wire at a known distance interval and recording the resulting voltage. Finally, the time derivative of the wire length gives basal velocities.

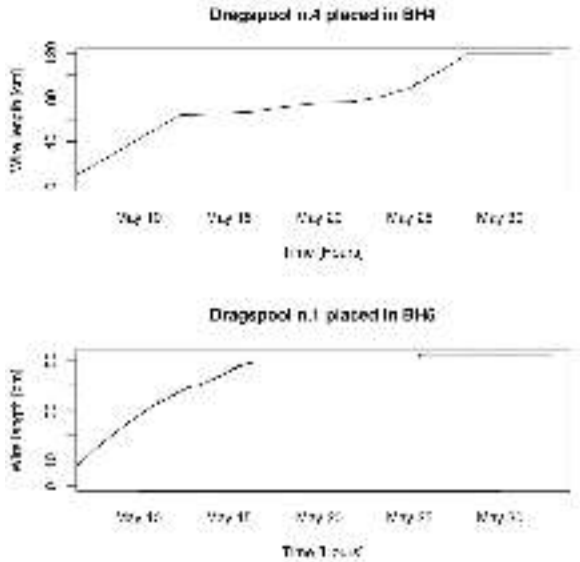


Figure 8: Dragspool time evolution. The wire length increases as the ice pulls the anchor.

The measurement period usually spans a couple of weeks and the data show little noise, but complex and fast changes. Their interpretation is difficult as it depends on the location of the anchor and the way the ice deforms. The anchor may be either at the interface or in the basal ice and both these options need to be considered [Cohen, 1998].

Measurements were performed in November 1997, November 2003, April 2006 [Lappegard, not published, lasted for several weeks], 2000 and 2003 [Cohen et al., 2005, uncertain time span].

Subglacial Discharge

Due to the low elevation of the tongue of Engabreen, meltwater for hydropower purposes is captured from subglacial intakes drilled up to the base of the glacier. A vast tunnel network has been drilled under Svartisen and redirects meltwater to Storglomvatnet reservoir. During late spring and summer, the large subglacial intakes, gateways to the glacier sole, largely contribute to its input. Discharge is monitored in Fonndals tunnel (Fig. 2) at two stations “Crump” and “Fjellterskel”, where the origin of the water is mainly sub-aerial. This mixes with subglacial water from “Spiral tunnel” in the sediment chamber. The difference in discharge measured at both stations gives an estimate of subglacial discharge at an altitude of 600 m. Groundwater contribution to the measured discharge is assumed to be negligible, based on observations of water flow into the tunnel system through fractures.

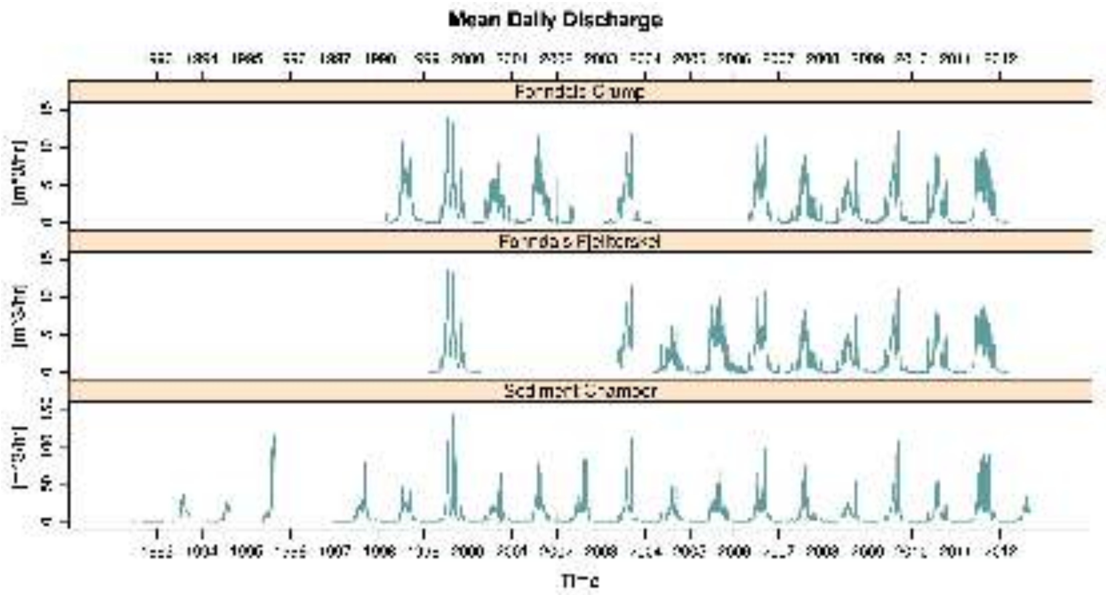


Figure 9: Mean Daily Discharge from the tunnel network nearby the Svartisen Subglacial Laboratory.

The original hourly discharge is not continuous and has some artefacts such as data shifts and peaks. Hydrologists at NVE have only undertaken for the daily dataset quality control, corrections as well as interpolations. Although useful, hourly discharge is more interesting to analyse its relation to diurnal pressure events observed in the load cell records.

Surface Meteorological and Discharge Stations

The Norwegian Water Resources and Energy Directorate (NVE) operates three meteorological/discharge stations in the vicinity of Engabreen: Engabrevatn, Engabreelv and Skjæret (Fig. 1). Through the Norwegian Meteorological Office's website eKilma.no, long-term air temperature and precipitation are available for two locations: Glomfjord and Reipå (Fig. 1).

Engabreelv

Monitoring of the proglacial stream started in 1993 in the mean time than the construction of the intakes and the tunnel network. The re-advance of the glacier Engabreen led to the rapid removal of this station in 1997 before the frame got destroyed by the glacier. For that period, the quality of the data is not excellent and care must be taken during its analysis. In Spring 2012, this discharge station was re-installed close to its former location at the pro-glacial stream 800 m from the glacier snout. The current measurements have high temporal resolution and disturbances are only seen during events of ice formation in the river. The current calibration curve is a composite of measurements from the 1990s and 2012-13. It assumes that the profile did not change over time, which might not be correct. Future measurements will affine the calibration curve.

Engabrevatn

The water level of the pro-glacial lake, Engabrevatn has been monitored since 1969-70. The water from the lake flows into the fjord through a unique outlet stream and measurements of its discharge at that point are used to create the calibration curve. The record is nearly continuous and the resolution has passed from sub-daily to hourly with regular interval in 1994. Its temporal evolution mimics the pro-glacial discharge and very good agreement can be reached when there is no rain and little snow. In that case, the glacier Engabreen is the major contributor to changes in lake level. When comparing overlapping pro-glacial and lake discharge, a slight delay of a few hours is observed. Knowing this delay, the discharge for Engabrevatn could be used as a replacement for the discharge at the pro-glacial stream.

For the last two years, an additional sensor has recorded air temperature at the same site. In combination with air temperature from Skjæret, we would obtain an estimate of the local lapse rate, which can be used for assessing ice melt.

Skjæret

Skjæret is an Automatic Weather Station installed on a nunatak of the Svartisen Ice Cap at an elevation of 1364m. Despite a harsh environment, the air temperature record is of rather good quality. It extends from 1995 to present. Other data such as precipitation, radiation, moisture content, wind speed and direction are also available.

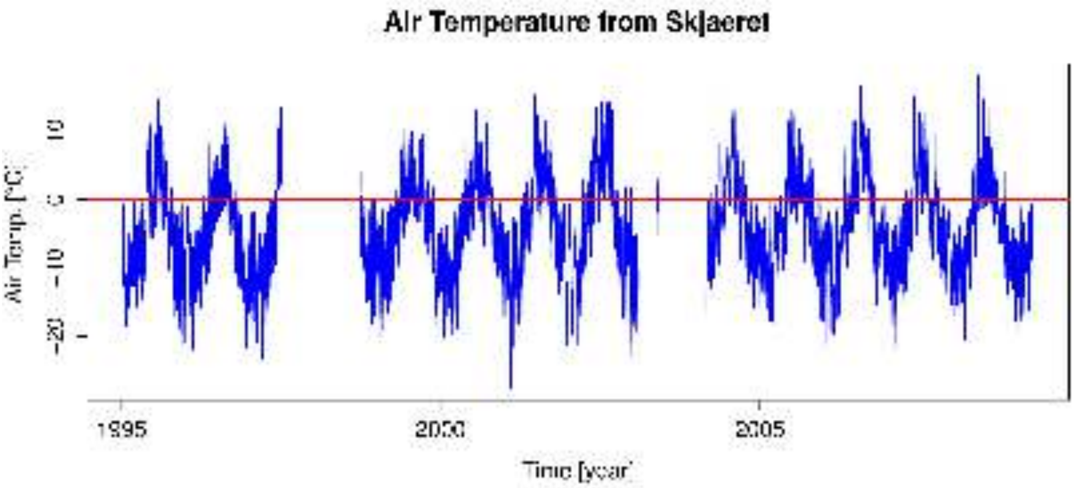


Figure 10: Air temperature for Skjæret.

Glomfjord and Reipå

Very little information is accessible regarding these stations in eKlima.no. Nevertheless, they are/were the sole meteorological stations providing long-term precipitation and air temperature data. Glomfjord is located about 20 km North of Engabreen and has the longest temperature record nearly covering the whole study period (1992 to 2010). On the other hand, its precipitation data stops earlier in 2005 than in Reipå. Although Reipå extends these observations from 1995 to present, the uncertainty related to its distance from Engabreen (>30 km) must be taken into account in any analysis.

Additional Data

Aerial photos of the lower part of Engabreen exist for some years as presented on Figure 12. Those records in addition to laser point measurements of the snout from a fixed point provide information on glacier front evolution for the last 25 years. This effort is part of a long-term mass balance program (<1970) using classic glaciological methods (i.e. stakes). Furthermore, laser scans of the glacier surface were collected in 2000, 2002, 2003, 2008 and 2013. However, Zempf *et al.* [2013] showed that the estimate of mass change from both methods is not consistent. The glaciological record is currently under revision.

Surface velocities of the glacier tongue were measured for a few weeks in 1994 and 1997 using markers installed on the glacier surface to track glacier motion [Kohler, 1998]. In May 2011, differential GPS were installed above the icefall and recorded a spring speed-up event (2 weeks) [Christianson, 2012]. Finally, Jackson et al. [2005] published annual velocity variations for 2000-2003.

Conclusion

Comparisons of the different data mentioned above will help identifying the cause of changes at the glacier bed. Figure 11 offers an example of the possibility of the gathered dataset.

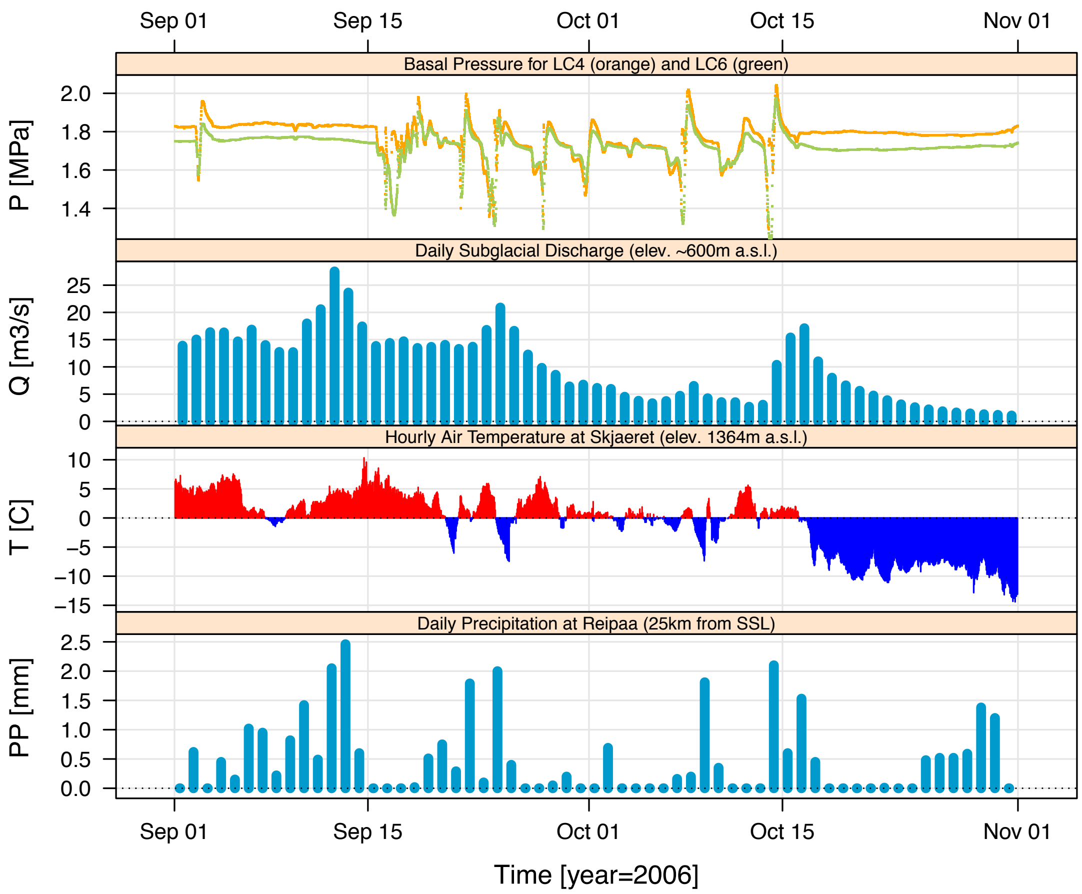
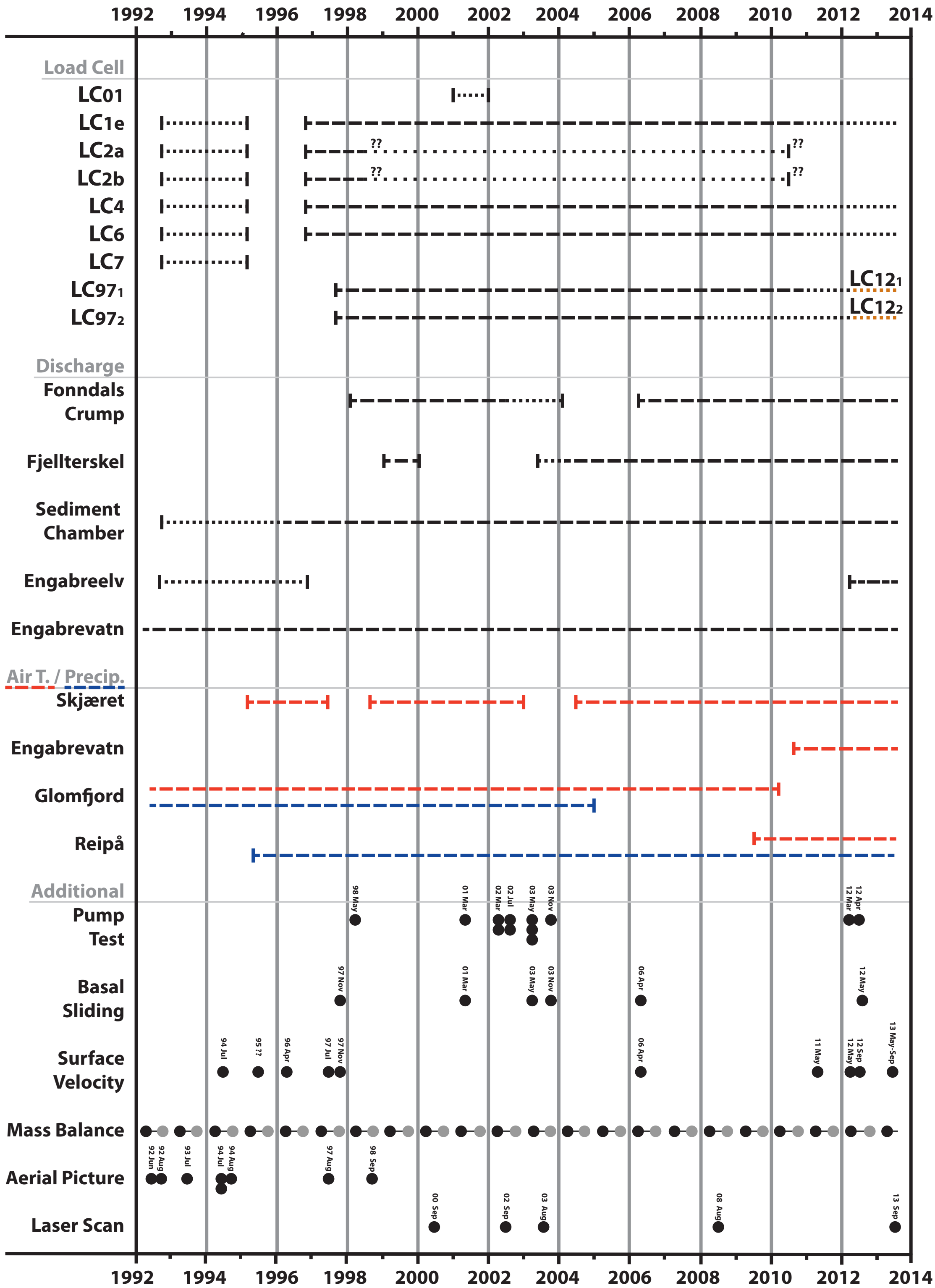


Figure 11: Time Evolution for the September and October 2006 of Normal Basal Pressure, Subglacial Discharge, Air Temperature and Precipitation.

Final Summary



Annexe I: Publications & Reports related to the SSL and Engabreen (Chronological Order)

Christianson, K. 2011. *Geophysical exploration of glacier basal processes and grounding line dynamics*. Ph. D. thesis, Pennsylvania State University, USA.

Barnett M. 2010. Implementation of In-Field Life Detection and Characterisation Techniques in Icy Environments. *Ph.D. thesis.* Cranfield University.

Dubnick, A., J. Barker, M. Sharp, J. Wadham, G. Lis, J. Telling, S. Fitzsimmons and M. Jackson. 2010. Characterisation of dissolved organic matter (DOM) from glacial environments using total fluorescence spectroscopy and parallel factor analysis. *Annals of Glaciology*, 51(56), 111-122.

Moore, P.L., K.A. Christianson, N.R. Iverson, J. Winberry, D. Cohen, S. Anandakrishnan, M. Mathison and M. Jackson. 2010. Glacier Seismicity and Basal Sliding: Field Experiments at Engabreen, Norway. *Eos Trans.* AGU, Fall Meeting 2010, Abstract C43A-0527.

Jackson, M. and T. Haug. 2008. Glaciodyn activities on and under Engabreen. Extended abstracts, *Workshop on the dynamics and mass budget of Arctic glaciers/GLACIODYN (IPY) meeting, 28 January-1 February 2008, Obergurgl, Austria. 62-64.*

Iverson N.R., D. Cohen, T.S. Hooyer, J.F. Thomason and M. Jackson. 2008. Frictional Slip Resistance at Glacier Beds due to Rock Debris, Norway. *Eos Trans.* AGU, *89*(53), Fall Meeting Suppl., Abstract C23B-01.

Wadham, J.L., M. Tranter, A. Hodson, M. Skidmore, P. Wynn and M. Jackson. 2008. What lies beneath? New perspectives on the deep icy biosphere, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract B52B-07.

Barnett, M.J., D.C. Cullen, J. Telling, J.L. Wadham, J. Holt and M. Sims. 2007. Detection of Microbial Life in Glacial Samples - Laboratories Studies and Development for Field Use, *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract C33B-03.

Cullen, D.C., J.L. Wadham, R. Pancost, S. Kelly, M.J. Barnett and M. Jackson. 2007. *In Situ* ATP Bioluminescent Measurements in Subglacial Environments – The Engabreen Glacier in the Norwegian Arctic, *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract C33B-02

Iverson, N.R., T. S. Hooyer, U. H. Fischer, D. Cohen, P. L. Moore, M. Jackson, G. Lappegard, and J. Kohler, 2007. Soft-bed experiments beneath Engabreen, Norway: Regelation infiltration, basal slip, and bed deformation, *Journal of Glaciology*, 53, 323-341.

Cohen, D, T. S. Hooyer, N. R. Iverson, J. F. Thomason and M. Jackson. 2006. Effects of water pressure fluctuations on quarrying: subglacial experiments using acoustic emissions. *Geophysical Research Abstracts, Vol. 8, 02784.*

Cohen D., T.S. Hooyer, N.R. Iverson, J.F. Thomason and M. Jackson. 2006. Role of transient water pressure in quarrying: a subglacial experiment using acoustic emissions. *Journal of Geophysical Research.*, **111**, F03006, doi:10.1029/2005JF000439.

Jackson, M. and H. Elvehøy. 2006. Engabreen – mass balance results and the Svartisen subglacial laboratory. Extended abstracts, *Workshop and GLACIODYN planning meeting, 29 January-3 February 2006, Obergurgl, Austria,* 52-53.

Lappegard G. 2006. Subglacial stress bridging around low-pressure channels. *Journal of Geophysical Research Earth Surface* Submitted*.*

Lappegard G, J. Kohler, M. Jackson and J.O. Hagen. 2006. Characteristics of subglacial drainage systems deduced from long-term load-cell measurements at Engabreen, Norway. *Journal of Glaciology,* vol. 52, No. 176, pp. 137 – 148.

Lappegard G. 2006. Basal hydraulics of hard-bedded glaciers: observations and theory related to Engabreen, Norway. *Ph.D. thesis.* University of Oslo.

Cohen D., N.R. Iverson, T.S. Hooyer, U.H. Fischer, M. Jackson and P. Moore. 2005. Debris-bed friction of hard-bedded glaciers. *Journal of Geophysical Research*, 110, doi:10.10297/2004JF000228.

Hooyer T.S., D. Cohen, N.R. Iverson, J.F. Thomason and M. Jackson. 2005. A quarrying experiment beneath a thick valley glacier: role of transient water pressure. *Geological Society of America Abstracts with Programs* 37(5).

Iverson N.R., D. Cohen, T.S. Hooyer, J.F. Thomason and M. Jackson. 2005. Effects of Water-Pressure Fluctuations on Glacial Erosion: a Quarrying Experiment Beneath Engabreen, Norway. *Eos Trans.* American Geophysical Union, Fall Meeting 2005, abstract #H51G-0442.

Lappegard G and J. Kohler. 2005. Determination of basal hydraulic systems based on subglacial high-pressure pump experiments. *Annals of Glaciology,* 40, 37-42.

Lappegard G and J. Kohler. 2005. Stress-bridging around low-pressure subglacial channels . *Geophysical Research Abstracts.* Vol 7, 08882.

Cohen D., N.R. Iverson, T.S. Hooyer, U.H. Fischer, M. Jackson and P. Moore. 2004. Debris-bed friction of hard-bedded glaciers. *Eos Trans. AGU,* 85(46) Fall Meet. Suppl., Abstract C34A-03.

Cohen D., N.R. Iverson, T.S. Hooyer, U.H. Fischer, M. Jackson and P. Moore. 2003. Importance of debris-bed friction in resisting sliding of a hard-bedded glacier. *Geophysical Research Abstracts.* Vol 5, 01220 (invited).

Fischer U. H., N.R. Iverson, T.S. Hooyer, D. Cohen, M. Jackson and J. Kohler. 2003. The role of subglacial sediment in glacier dynamics. *Mitteilungen der VAW, Nr. 180.* International Glaciological Symposium: Milestones in physical glaciology - from the pioneers to a modern science, 13-20, Zürich, Switzerland, February 14, 2003.

Iverson N.R., D. Cohen, T.S. Hooyer, U.H. Fischer, M. Jackson, P.L. Moore, G. Lappegard, and J. Kohler. 2003. Effects of basal debris on glacier flow. *Science*, 301 81-83.

Iverson N.R., D. Cohen, T.S. Hooyer, U.H. Fischer, M. Jackson, P.L. Moore, G. Lappegard, and J. Kohler. 2003. Bed-Deformation Experiments beneath a Thick Temperate Glacier. *GSA Abstracts* 35(6), Annual Meet. Suppl. Abstract 122-8 (invited).

Hooyer T.S., N.R. Iverson, D. Cohen, U.H. Fischer, M. Jackson, P.L. Moore, G. Lappegard, and J. Kohler. 2002. Motion of a Temperate Glacier over Hard and Soft Beds: Subglacial Experiments at Engabreen, Norway. *Eos Trans. AGU,* v. 83 Fall Meet. Suppl., Abstract.

Iverson N.R., T.S. Hooyer, U.H. Fischer, D. Cohen, M. Jackson, P.L. Moore, G. Lappegard, and J. Kohler. 2002. Bed-Deformation Experiments beneath a Thick Temperate Glacier. *Eos Trans. AGU,* v.83 Fall Meet. Suppl., Abstract.

Jackson M. and L. Ruffles. 2000. Water Pockets in the Basal Ice of Engabreen, Northern Norway. *Eos Trans. AGU,* 83 Fall Meet. Suppl., Abstract v. 81(48), H61G-07.

Jackson M. 2000. Svartisen Subglacial Laboratory, NVE Document 14, 27 pp.

Cohen D., R. LeB. Hooke, N.R. Iverson and J. Kohler. 2000. Sliding of ice past an obstacle at Engabreen, Norway. *Journal of Glaciology*. 46, 599-610.

Cohen D. 2000. Rheology of ice at the bed of Engabreen, Norway. *Journal of Glaciology.* 46, 611-621.

Cohen D. 1999. Measurement of water content at the base of Engabreen, Norway. *Eos Trans. AGU,* v.80 Fall Meet. Suppl., Abstract.

Lappegard G. 1999. Subglacial Pressure Variations beneath Engabreen. Cand. Sci. Thesis. University of Oslo.

Ruffles L.M. 1999. In-situ investigations of subglacial hydrology and basal ice at Svartisen Glaciological Observatory, Norway. PhD. Thesis. University of Wales, Aberystwyth.

Cohen D. 1998. Rheology of Basal Ice at Engabreen, Norway. *Ph.D. thesis.* University of Minnesota.

Kohler J. and 9 others. 1998: Effect of a Controlled Discharge Pulse on the Subglacial Drainage System and Ice Flow at Engabreen, Northern Norway. *Eos.* (*Abstract). v. 79(45),* p. 274.

Kohler J. 1998: The Effect of Subglacial Intakes on Ice Dynamics at Engabreen. *HB-Rapport* 12/98.

Lappegard G., J. Kohler and J.O. Hagen. 1998: Subglacial Pressure Variations beneath Engabreen, Northern Norway. *Eos. (Abstract). v. 79(45),* p.310.

Cohen D., N.R. Iverson, R.LeB. Hooke, J. Kohler and H. Elvehøy. 1997. Basal ice rheology of flow past an obstacle at the bed of Engabreen, Norway. Eos. (Abstract). v. 78(46), p.229.

Cohen D., N.R. Iverson, R.LeB. Hooke, J. Kohler and H. Elvehøy. 1996. A study of the flow of ice past an instrumented obstacle at the bed of Engabreen, Norway. *Eos. (Abstract). v.77(46),* p. 193.

Jansson P., J. Kohler and V.A. Pohjola. 1996. Characteristics of Basal Ice at Engabreen, Northern Norway. *Annals of Glaciology, No. 22,* pp. 114-120. *[NVE Meddelelse nr. 93].*

Hooke R.LeB. and N.R. Iverson 1995: Grain-size distribution in deforming subglacial tills: role of grain fracture. *Geology. v. 23(1),* pp. 57-60. [1]

Kohler J and J. Bogen. 1994. Målinger på og under Engabreen. *HB-Notat 1/94.*

Kohler J. 1994. Tracing at Engabreen. *HB-Notat 23/94.*

Kohler J, V. Pohjola and P. Jansson. 1994. Subglacial experiments at Engabreen, northern Norway. *Eos. (Abstract). v. 75(44),* p. 227.

Kennett M.I. and J. Kohler. 1993. Channel networks under Svartisen, Norway: a comparison of GIS modelling and tracer results. *Eos. (Abstract). v. 74(43),* p. 255.

Kohler J. 1993: Engabreen subglacial observatory: fieldwork report, March 1993: *HB-Notat 11-93.*

Kohler J. 1993: Tracing at Engabreen-August 1993: *HB-Notat 17-93.*

Kohler J and N.R. Iverson 1993: Subglacial experiments at Engabreen, northern Norway. *Eos. (Abstract). v. 74 (43),* p.263.

Kennett M. 1988: Dybdemålinger og forsøk på lokalisering av subglasiale elveløp på Engabreen 1987. *VHB Notat Nr. 8/88.*

Annexe II: Log sublab

Date Arrival	Date Departure	Tunnel Horiz.	Tunnel Vert.	Pump test	Basal Sliding	Work
11/11/2012	17/11/2012					Melted horizontal tunnel to prepare creep closure experiment and installed dragspool.
17/08/2012	05/09/2012					Set up strain diamond with GPSes, pro-glacial station (conductivity + fluorescence + temperature).
06/05/2012	15/05/2012					Discharge measurements with propeller (fail), installation of pro-glacial discharge station, check GPSes.
02/05/2012	05/05/2012					Basal sliding and checking packers, Check top GPSes
13/04/2012	20/04/2012					Pump test, Melting of horizontal ice tunnel, Bedrock Mapping, Test creep closure measurements with Kinect, Set out GPS on glacier surface (4 + 1 base) Subglacial Workshop.
18/03/2012	27/03/2012					Pump test, Melting of horizontal icetunnel to reach first load cells 97_1 and 97_2, Mapping of the bedroc. Download discharge data.
31/10/2011	04/11/2011					Melted out a tunnel. Lots of local precipitation (flood warnings for area) and hit a subglacial drainage channel.
01/08/2011	01/08/2011					Seismic maintenance
18/05/2011	26/05/2011					
29/04/2011	13/05/2011					Melted out long tunnel up above research shaft. Closed about 10. May. Pump experiments
07/05/2011	07/05/2011					Visit to the tunnel, and they had a workshop at the brestue.
01/08/2010	01/08/2010					
01/06/2010	01/06/2010					
01/04/2010	01/04/2010					
01/03/2010	01/03/2010					
17/11/2009	19/11/2009					Electrical maintenance and improvements to pump system electricals by Meløy Elektro.
17/11/2009	20/11/2009					Work with sediment project in tunnel, maintenance and testing of instruments by Iowa State and ETH
01/03/2009	01/03/2009					Work with sediment project in ice tunnel, Cranfield sampled in ice tunnel, spiral and elsewhere, subglacial workshop as part of Glaciodyn.
01/11/2008	01/11/2008					
01/05/2008	01/05/2008					Work in horizontal tunnel and on the glacier. Set out GPS, geophones and radar reflectors at three points on the glacier. Terrestrial Radar Test.
01/11/2007	01/11/2007					Work in horizontal tunnel and Fonndalstunnel, as well as sampling in spyletunnel.
01/05/2007	01/05/2007					Measure strain network of 9 stakes on the glacier tongue. GPS measurements of stakes 34, 18 and 17 over ca. 10 days.
01/10/2006	01/11/2006					Opened horizontal tunnel.
01/04/2006	01/04/2006					Opened horizontal tunnel, and took basal ice samples. Water sampling in the spiral. Snow and water sampling in Fonndalstunnelen. Set up five GPS receivers on glacier tongue and on plateau.
01/09/2005	01/09/2005					Routine visit, downloaded Pressure Data.
01/03/2005	01/03/2005					Routine visit, downloaded Presure Data.
01/11/2004	01/11/2004					Opened horizontal tunnel, and took basal ice samples. Water sampling in the spiral. Snow and water sampling in Fonndalstunnelen.
23/03/2004	07/04/2004					Installation of erosion panel, and related pump experiments; Sampling of meltwater and ice in tunnels, including up the spiral. Also melting of pro-glacial river. Horizontal shaft was opened up and melted up to the instrument.
03/03/2004	01/03/2004					– routine visit, didn't download data.
06/11/2003	13/11/2003					Pump experiment. Opened horizontal tunnel, Replaced one load cell.
01/09/2003	01/09/2003					Downloaded data, dismantled drag spools and downloaded data.
01/07/2003	01/07/2003					Routine visit, downloaded Pressure Data.
09/05/2003	16/05/2003					Pump experiments; Drag spools set up.
31/03/2003	05/04/2003					Took down friction panel and replaced load cells in panel.
01/02/2003	01/02/2003					Fixed problem with datalogger (Knut).
01/02/2003	01/02/2003					Tried to fix problem with datalogger.
01/09/2002	01/09/2002					Downloaded data; discovered problem with data logger – no data being saved.

02/07/2002	07/07/2002					Pump experiments.
04/04/2002	21/04/2002					Installation of till prism; instrument in vertical shaft.
16/03/2002	22/03/2002					Pump experiments.
01/03/2001	01/03/2001					Installation and re-excavation of till prism; instrument in vertical shaft – high pressure pump experiments. Installation of new pump.
01/10/2000	01/10/2000					Vedlikehold av utstyr - – samlet morene stoff.
01/08/2000	01/08/2000					Downloaded Pressure Data.
01/05/2000	01/05/2000					Routine visit, downloaded Pressure Data.
01/10/1999	01/10/1999					Tookwater- ice samples from horizontal shaft - water chemistry. Downloaded Pressure Data.
01/09/1999	01/09/1999					Visit with students, downloaded Pressure Data.
01/08/1999	01/08/1999					Overview for Kjell Repp and Agnar Ås
01/05/1999	01/05/1999					Routine visit, downloaded Pressure Data.
01/02/1999	01/02/1999					Discharge station Fonndalstunnelen; Download Pressure Data.
01/09/1998	01/10/1998					PumpTest and downloaded Pressure Data.
01/05/1998	01/05/1998					Pumpt Test. Routine visit, downloaded Pressure Data. Water chemistry.
01/04/1998	01/04/1998					Installation of Crump-overflow in Fonndsatunnelen for discharge measurements.
01/11/1997	01/11/1997					Rheology of Basal Ice. Measure Water Pressure in Boreholes. In-situ investigations of subglacial hydrology and basal ice. Installation of 2 load cells. Downloaded Pressure Data.
01/07/1997	01/07/1997					Effect of large, controlled discharge pulse on subglacial hydrology and ice flow. Water Chemistry. Downloaded Pressure Data.
01/03/1997	01/03/1997					Researcher visit, downloaded Pressure Data.