INTEGRATED DATABASE FOR RAPID MASS MOVEMENTS IN NORWAY

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ABSTRACT: Rapid mass movements include all kinds of slides in geological material, snow or ice. Traditionally, information about such events is collected separately in different databases covering selected geographical regions and event types. In Norway the terrain is susceptible to all types of rapid mass movements ranging from single rocks hitting roads and houses to large avalanches and rockfalls where entire mountainsides collapse into fjords creating flood waves and endangering large areas. In addition, quick clay slides occur in desalinated marine sediments in south eastern and mid Norway. For the authorities and inhabitants of endangered areas, the type of threat is of minor importance and mitigation measures have to consider several types of mass movements. This demand asks for a national overview of all registered slide events that allows fast and easy access to the available data. Therefore an integrated national database for all types of rapid mass movements has been established. The database is built around individual slide events. Only three data entries are mandatory: Time, location and type of slide. The remaining optional information enables registration of detailed information about the terrain, involved materials and damages. Pictures, movies and other documentation can be uploaded into the database. A web based graphical user interface was developed allowing entry of new slides, editing and searching for slide events. An integration of the database into a GIS system is currently under development. Datasets from various national sources like the road authorities and the Geological Survey of Norway were imported into the database. Today, the database contains 22 000 slide events from the last five hundred years covering the entire country. A first analysis of the data shows that the most frequent slide type is snow avalanches and rockfalls followed by debris slides on third place. Most events are registered in the steep fjord terrain of the Norwegian west coast, but major slides are registered all over the country. Snow avalanches clearly account for most fatalities, while large rock slides causing flood waves and huge quick clay slides are the most severe single events. The quality of the data is strongly influenced by the personal engagement of local observers and varying observation routines. This database is a unique source for statistical analysis including, risk analysis and the relation between slides and climate.

KEYWORDS: Database, avalanche, mass movements, slide

1. INTRODUCTION

Large areas in Norway are exposed to all kinds of rapid mass movements. Snow avalanches threaten roads, railroads and settlements during winter time, while slushflows are active during early winter and spring. Rock fall and landslides can occur during the whole year, mainly in periods with heavy rains. Huge rock avalanches of several million cubic meters are a threat to many of the Norwegian fjords, where damage caused by flood waves can destroy tens of kilometers of shore line and single events have killed most Norwegians (Anda and Blikra, 1998)

During the last 150 years, approx. 2000 people have been killed by slides in Norway. Most of the fatalities occurred in homes and at work locations. Leisure time fatalities in snow avalanches have increased in recent years and now account for the majority of avalanche fatalities.

Systematic collection of slide events is crucial to establish a solid base for statistical and spatial analysis of slide events on every scale from local to national. There are two different approaches in registering slides. The first and mainly historically used method is the registration of active snow avalanche paths. Each path is identified and consecutive slides are associated with this snow avalanche path. The other approach is registering each slide

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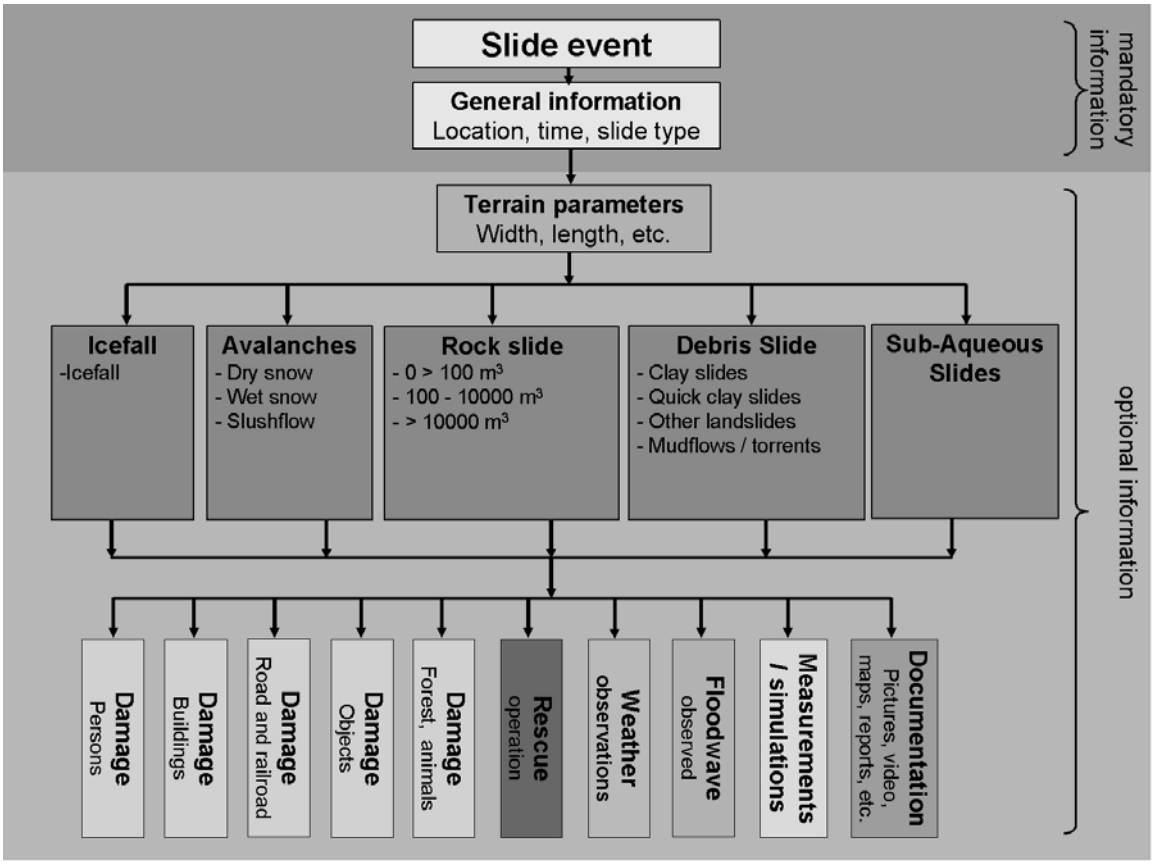

Figure 1: Structure of the slide database. The only mandatory data is the location, time and slide type. All other information is optional.

event as an independent occurrence that is identified by time, date and location.

The first approach was mainly chosen for snow avalanches. Snow avalanches may decend the same path every winter, such that the identification of the path is simple and new avalanches most likely will occur again at the same location. For other slide types such as rock fall and landslides, one event is often the only possible event at that exact location. No consecutive events are possible since the available materials are removed by the primary event. Consequently, here the second approach is more applicable.

Registers of slide events have been collected by different persons and institutions during the last 30 years. The objectives for these collections vary greatly from source to source. Usually, only one type of slide is included and only a short period of time or limited area is covered. Examples of such slide collections are the NGI snow avalanche collection of 200 extreme run out avalanches (Lied and Bakkehøi, 1980), the collection of 3600 damage slides at the Geological Survey of Norway (Furseth, 2003) and registrations by the Directorate of Public Roads.

A national database for all slide events was established within the GeoExtreme project (Blikra et al., 2004) which is a four year project to study the climate change effects on slide activity in Norway. The database should include all digitally tabulated slide events available in Norway. The objective of this database is to provide a national collection that gives an overview of historical slide events in Norway and can serve as the basis for statistical analyses and consulting work. The database should also include conclusive definitions of all involved parameters, based on national and international standards.

Table 1: Overview of the data sources used in the database.

Source	Type of slides	No. of slides	Time range
Road authorities	All types	ca. 15 700	1973 – 2004
NGI	Avalanches	ca. 2370	1973 – 2004
	Sub aqueous slides	ca. 30	- 8000 – 2004
	Quick clay slides	ca. 510	915 – 2002
	Landslides	ca. 90	2000
NGU	All types	ca. 3300	900 – 2004
Total	All types	ca. 22 000	

2. MATERIALS AND METHODS

4.1 The data

Avalanche paths have been registered in different collections in Norway since the 1930s (Ramsli, 1953). Usually one district or valley was mapped at a time and the data documented in maps and reports. The aim of this registration was to document where slides and avalanches could happen to avoid new development in exposed areas. This work has been continued with varying intensity until the early 1970s when the avalanche group at NGI was established. Earlier several 100 snow avalanches were registered in different municipalities (Ørsta, Stryn, Valldal).

The systematic registration of slide events affecting roads was started in 1973, the same year that the NGI research station in Grasdalen with daily observations started (Lied, 1993). The database collected by the Norwegian Directorate of Public Roads is today the biggest single collection including more than 15 000 slides of all types.

Since 1998 the Geological Survey of Norway has started the collection of historical damage slides. Furseth (2003) uses various sources such as interviews of locals, church registers and other archive materials to gather all possible information of slide events in Norway. More than 3000 slide events often with detailed information on date, location and kind of damage have been collected.

Also the Norwegian railroad administration operates their own slide registration. This data is currently not included in the database.

Recently, the GeoExtreme project offered funding for the digitization of older registration maps. This work will be continued in the upcoming years. An overview over the included datasets is given in Table 1.

It is an aim to include all available data into the present database and efforts are made to motivate private collections to be donated to the database. This poses partly large difficulties, since most collections have their own system for storing and defining the data.

4.2 Structure

The database is constructed for individual slide events. Only three parameters are mandatory: location, time, type of slide. All

Table 2: The available slide types and sub types used in the database.

Type	Subtype	Norwegian type	Norwegian sub type
Avalanche	Dry snow	Snøskred	Tørr snø
	Wet snow		Våt snø
	Slushflow		Sørpe
Rock slide	0 – 100 m^2	Steinskred	Steinsprang
	100 – 10 000 m^2		Steinskred
	> 10 000 m^2		Fjellskred
Debris slide	Clay slides	Løsmasseskred	Leire
	Quick clay slides		Kvikkleire
	Other debris slides		Løsmasse
	Mudflows / torrents		Flomskred
Icefall	No sub type	Isnedfall	
Sub-aqueous slide	No sub type	Undervannskred	

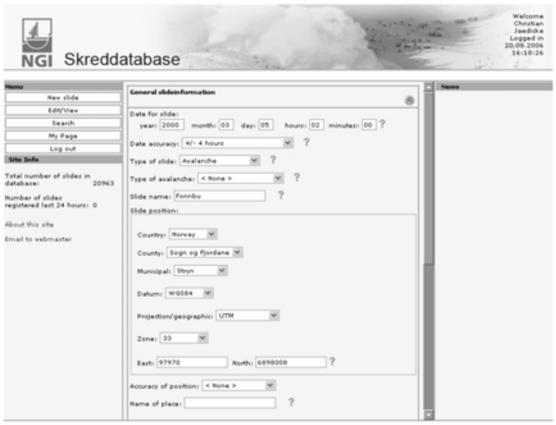

Figure 2: Screen plot of the registration page.

Figure 3: Screen plot of the search page.

other information is optional. The location is stored in projected geographical positions (UTM, WGS84). As date at least the year has to be given. If no date is known, the date is automatically set to 15 July. The data accuracy field is then set to “not known when during year”.

Other accuracy definitions can be chosen from a drop down menu, spanning from ± 5 minutes to ± 50 years. Substantial time has been used to define slide types and subtypes (Table 2) and it is our hope, that they will be accepted as a national standard.

The optional parameters are grouped in different classes (Fig. 1). General parameters include information that is available for any slide event type e.g. slope angle, slide geometry, name of municipality and county, etc.). More specific parameters depend on which slide type is reported. This class includes parameters such as geological setting, snow type, grain size, soil parameters and gives information about damages, rescue operations, victims and other effects of the slide (Fig. 1).

The optional parameters are grouped in different classes (Fig. 1). General parameters include information that is available for any slide event type e.g. slope angle, slide geometry, name of municipality and county, etc.). More specific parameters depend on which slide type is reported. This class includes parameters such as geological setting, snow type, grain size, soil type, water content etc. Secondary parameters give information about damages, rescue operations, victims and other effects of the slide (Fig. 1).

All text fields are connected to predefined lists, giving a range of possible values. Number fields are always followed by an accuracy field to be able to register the quality of the collected data. Wherever possible, parameters follow international standards. In total, 385 parameters are included in the database.

Table 3: Definition of the four quality levels of the slide events.

Level	Definition	Action
0	Registration not completed (Time or location or slide type not registered)	Slide is not accepted Slide will not be shown in lists and searches
1	Registration completed, not verified	Slide is accepted, editable for the user
2	Registration completed, verified, information missing	Slide is checked by the administrator More info can be added Slide is locked for editing by the user
3	Registration completed, verified, information complete	Slide is checked by the administrator All available information is included Slide is locked for editing by the user

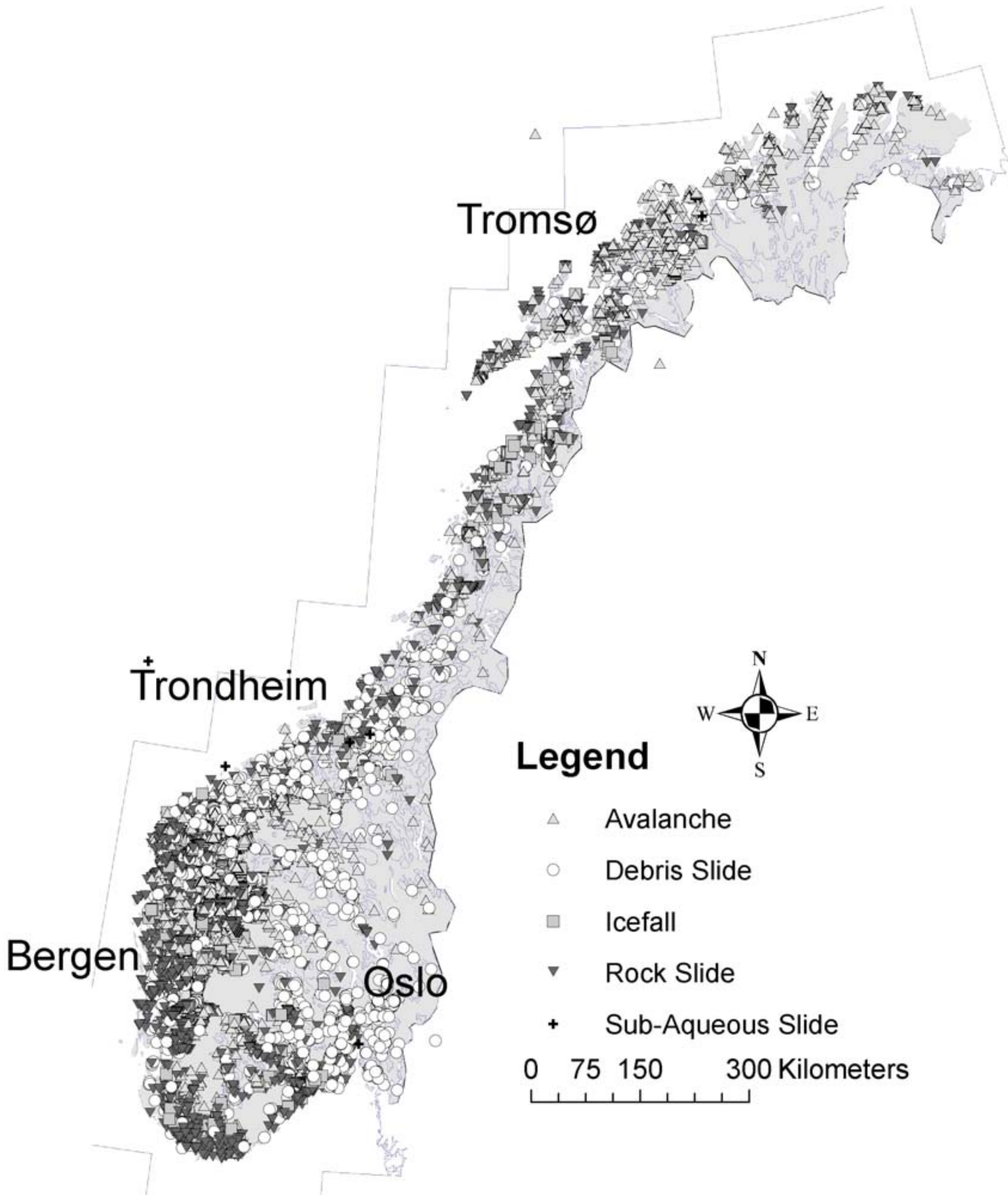

Figure 4: Map of Norway showing slide events classified by slide type.

The data quality can vary considerably depending on the source of the data, the person doing the registrations and the local conditions during the registration. Therefore, each slide can have one of four quality levels (Table 3). New entries will be continuously evaluated by the database administrator who checks the correctness of the registration. If all available data are included in the registration, the status is increased to level two or three. Now, the slide is locked for editing from the user and only the administrator can do further edits. The administrator is also the only person to delete data from the database (status is set to zero).

The database is implemented in an Oracle base and the user interface is web-based.

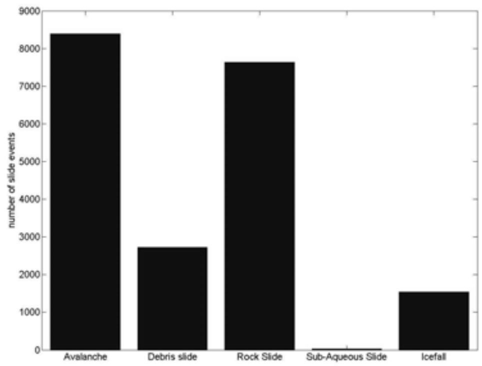

Figure 5: Type of all avalanches in the database.

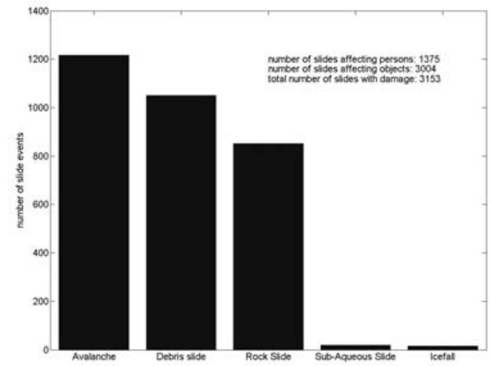

Figure 6: Type of avalanches causing damages and affecting persons.

4.3 Graphical user interface

The graphical user interface to the database is programmed in .NET and available online as an interactive webpage.

All users have to register and can access the database with user name and password. This allows the administrator to identify the user. Further, creation and editing of slides is logged. The users can have the status of layman, expert or administrator, where layman is default. Expert and administrator status is only given to persons known to the administrator of the database. A personalized page allows changes in personalia and preferences.

Different pages can be accessed after the login. Registration of new slides is the center of the solution. Here all parameters for a new slide event can be entered. The form is built in a modular hierarchy. On the first page, the mandatory parameters (time, location, type) are entered together with a list of ten yes/no questions regarding the occurrence of waves etc., all of which are No by default (Fig. 2).

The remaining registration is based on the selection made on the first page. The user is guided through a series of pages, starting with the general terrain parameters and slide specific parameters. The following pages only appear if the user has ticked of for Yes on the first page. For example a page for the registration of damage on buildings only appears if “building affected” is ticked off on the first page. The very last registration page offers the possibility to enter a free text in addition to all other information. This is to motivate the user to categorize their information instead of writing a report.

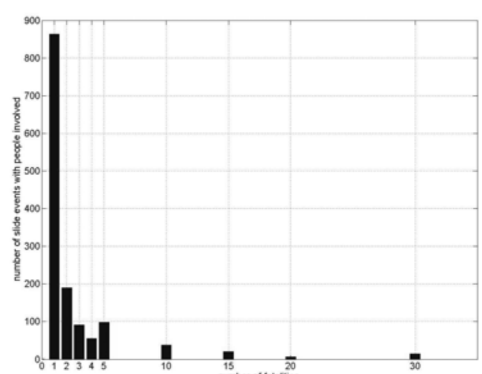

Figure 7: Number of fatalities in a single event.

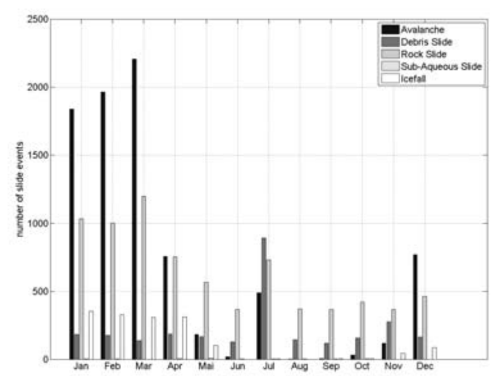

Figure 8: Annual distribution of slide type.

Fast and effective registration of new slides is an important aim. The first page with the mandatory parameters should be filled in within one minute. To assist this, drop down menus with pre-defined values are used wherever applicable. All number values are followed by an accuracy estimate that is also pre-defined in drop down menus. If available, files like pictures, movies, documents and modeling results can be uploaded to the database (Fig. 1).

Different lists allow the user to view and access existing data. Currently, three basic lists are available, “all slides”, “my slides” and “last 20 slides”. The list shows the slide name, name of the user who registered the slide and the registration date. Each user can edit their own slides and view all other slides. Additionally, the administrator can use this list to change the slide status and delete slides.

An important reason for establishing the database is the need to search the collected data for slides of certain types, in different time spans etc. The search page (Fig. 3) allows searching for all 385 parameters in the database. All parameters can be combined creating custom search strings. The results can be listed online or be exported to TXT or EXCEL files. A graphical presentation of the location of the data on a map is currently under development.

5. RESULTS

Currently, 22 000 slides are included in the slide database. Figure 4 shows a map with slide events listed as slide type. The majority of the slides are registered by the road authorities. This can easily be seen as the slide events follow the main roads in Norway. The spatial distribution is mainly limited to the valleys with population and infrastructure. In the coastal districts snow avalanches and rock falls dominate. The inland features more debris slides and only a limited number of rock fall events. Debris slides rarely occur north of the city of Trondheim. In total numbers, most slide events are snow avalanches, followed by rock slides (Fig. 5).

Most fatalities and damages by slide events in Norway are caused by snow avalanches, followed by debris slides (Fig. 6). It is obvious from Figure 7, that most events only cause one fatality. Catastrophic events with 20 or more fatalities are exceptional and occur only very seldom.

An annual distribution of the different slide types (Fig. 8) shows that the highest snow avalanche activity can be expected from December to April. An exception is the increased activity in July. Debris slides activity is equally distributed throughout the year with a peak in July. The rock slide activity is highest in the winter months January to April, but also here a peak occurs in July.

Dividing the slide events into the Norwegian districts show that most slide events occur on the west coast and least in eastern Norway. It also shows that the registration of slides is limited in some districts even if the topography would indicate a higher amount of slides in these areas.

6. DISCUSSION

The attempt to establish a nationwide slide database meets limitations. Traditionally, each scientific and administrative organization establishes their own database strongly designed to serve their specific field of interest and use. Additionally the way of thinking about geo-referenced data has changed significantly during the last years. Therefore, the construction of a homogeneous dataset of historical slide events seems to be an impossible task.

Regarding the new database presented in this paper the following points can be noted: Firstly, the data are irregularly distributed in both time and space. The number of observations has strongly increased since the 1970’s, when the first systematical observations were started. Still, data is missing for considerable periods. From the raw data it is obvious that the amount of data collected as well as the data quality depends on the personal enthusiasm of the observers. Therefore, some districts show very limited or no registrations, even if the terrain suggests a high slide activity.

Historical slides before the 1960s are mostly limited to events with fatalities and / or considerable damage. This limitation makes analyzing slide frequencies difficult. Such an analysis requires a comparable data collection routine for a period of at least 100 years. Also, the earliest avalanche and slide mapping studies focused only on the detection of active slide paths, not on identification of exact dates for individual slides. Mostly, data are only collected in and close to infrastructure and settlements. Events in uninhabited terrain are seldom registered, again limiting the possibility for frequency and spatial distribution analysis.

Secondly, the collected parameters are very different from source to source. Each collection has a different focus, leading to a large variation. The required minimum information for a dataset to be included in the present database is time, location and slide type. Luckily, additional common parameters could be found that allow for a wider analysis of the data. For future work with the database, all parameters from the included datasets were incorporated in the database.

For any statistical analysis, the question whether the fact that no slide is registered in a certain area at certain time means that no slide occurred in nature is of high importance. This question clearly can be answered with no. The number of real and unregistered slides most likely exceeds the registered slides by several orders of magnitude. Still, one can assume that the large events with several fatalities and considerable damage are included in the database.

Despite these limitations, the database is of high value a wide range of analysis. The spatial distribution shows which slide type dominates in which part of the country. Also, the annual distribution shows the influence of the weather on the different slide types. The peak of debris slides in July for example is easily explained with convective precipitation and thunderstorms in the warm summer month. Equally, the high rock fall activity in winter could be explained with the increased number of frost cycles.

The most valuable application is the use of the data in statistical and GIS analysis where climate and topographical data is included. This type of analysis allows for establishing relationships between weather and slide events, slide type and topographical or geological conditions and also consequence analysis for infrastructure. An example of such an application is given in Kronholm et al. (this volume).

7. CONCLUSIONS

The national slide database for Norway offers a unique national collection that incorporates all currently available slide registers in Norway. The data quality is generally high, but limitations exist mainly in the spatial and temporal distribution of the data. The database gives a good overview over slide events in Norway, giving information from most exposed areas, regional distribution of slide types and annual distributions. A graphical user interface was developed to allow a wide range of users to register and view slide events. Statistical analyses based on the database are possible and show interesting results. The no-slide events are the insecure factor. It is obvious that the registered number of slides is a subset of a much larger number of real slides that are never registered.

To improve the data quality in the future, data have to be collected more systematically. The user interface will also offer short field questionnaires that can be used during field campaigns for later registration on the database web side. The database will be developed further with both new slide events and historical slides that are digitized from the archives of the national organizations.

7. ACKNOWLEDGEMENTS

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