AN INTRODUCTION TO INFLOW AVALANCHE DYNAMICS MEASUREMENTS USING THE SNOWBALL DEVICE

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ABSTRACT: The Snowball is a sphere with a diameter of 160 mm and with the density of flowing snow (about 300 kg/m^3), which was developed as an inflow measurement device for snow avalanches. It was designed by the AeroSpy Company (Linz, Austria) in collaboration with the BFW, Department of Natural Hazards and Alpine Timberline in 2009. The Snowball is equipped with several sensors: Orientation and acceleration of the device are determined by a gyroscope, magnetometers and accelerometers. The resulting 3D data is recorded with a sampling frequency of about 25 Hz. Additional information is provided by GPS sensors. A Recco Avalanche Rescue System ensures that the Snowball can be relocated and recovered after each experiment. We expect that the recorded data allows to reconstruct the trajectory of a particle embedded in an avalanche. This information can be used to characterize the avalanche dynamics along the track. Field experiments are carried out at the experimental avalanche test site Wattener Lizum near Innsbruck, Tyrol, Austria.

KEYWORDS: snow, avalanche, dynamics, inflow measurements

1. INTRODUCTION

In the last century, hazard mapping gained a high importance in the land use planning of alpine regions. For the design and construction of mitigation measures, sophisticated input data and a high level of expert knowledge is necessary. For this purpose, avalanche simulation models have become more and more important as a tool for decision makers. In the newest generation of avalanche models the evolution of snow velocity and flow height along the path can be described in three-dimensional terrain. With different physical and numerical approaches, various models have been developed, e.g. Sampl and Granig (2009), Christen et al. (2010). In each model, different parameters depending on avalanche type, path and snow properties have to be defined. The calibration of the models and its parameters is mostly based on back calculation of observed avalanches.

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The unknown rheological behavior of snow and the poor availability of measured data limits the prospects of a physical model calibration. Reports on runout length and deposit measurements are the most common avalanche data because of their destructive threat on man and property. The real time observation of snow avalanches is difficult because access, visibility, time of release and the instrumentation often restrict the possibilities of satisfying measurements.

More data and sophisticated knowledge concerning the complex internal structure of avalanches is provided by measurements of flowing snow. Experiments on snow chutes provide a deeper insight to the rheology of flowing snow on a small scale (Kern et al. (2004), Rognon et al. (2008)). Experiments on full size avalanches are performed in order to obtain a more accurate picture on snow avalanches. Full scale test sites (Issler (1999), Barbolini and Issler (2006)) equipped with a variety of observation methods and sensor types provide further information on snow avalanche dynamics. Pressures, velocity, flow height, mass evolution and further flow details are measured throughout the descent of an avalanche.

Figure 1: Exterior view of the Snowball. The sensors can be activated with a magnetic switch (bottom half of the sphere) from the outside without opening the ball in the held.

One may distinguish invasive and non-invasive measurement techniques. Invasive measurement technologies (load plates, optical sensors, capacities probes or pressure tubes) are placed at a fixed position in the avalanche path. If the avalanche interacts with the measurement device, data about the interior of the passing flow is recorded. Non-invasive technologies (radar, video, acoustic and seismic sensors) are placed outside the avalanche path and either measure the response of an actively emitted signal or passively measure a signal emitted by the avalanche itself.

Rammer et al. (2007) compared different velocity measurement methods. Front velocities measured with radar were found to be partly in good agreement with videogrammetric measurements. Optical velocity measurements at a fixed point in the avalanche path correspond to the radar measurements at a certain flow height near to the surface of the avalanche.

The availability of measuring data from the interior of an avalanche body throughout the complete descent of an avalanche is limited. In particular the velocity evolution of the deeper, dense flow layers in the avalanche can only be measured using sensors which are fixed in position. A new technique, independent of the position of the measurement device following the track of the avalanche would provide additional information on the velocity evolution and the internal structure of a snow avalanche.

Vilajosana et al. (2009) used wireless sensors equipped with several accelerometers in snow chute experiments. The wireless accelerometers were placed in the snow chute starting zone and traveled within the flow. Position and velocities could be determined and compared to video measurements. This study already showed the potential of inflow measurements in avalanche dynamics.

Adopting sensors which are used in navigation and remote sensing technologies to the needs of the challenging environment in a full scale snow avalanche is the object of the project 'Snowball'.

2. SNOWBALL

2.1. Measurement device

The Snowball shown in Figure 1, was designed by the AeroSpy Company (Linz, Austria) in collaboration with the BFW, Department of Natural Hazards and Alpine Timberline. The Snowball was especially constructed to suit the conditions existing in a snow avalanche: Its density and size are chosen in order to have similar properties as flowing snow within the dense part of an avalanche. The density of about 300 kg/m^3 is similar to the density in the deeper layers of an avalanche (Gauer et al. (2008)). The diameter of the hard sperical shell is 16 mm, representing an average size of a snow clod found in an avalanche (Bartelt and McArdell (2009)).

The Snowball is equipped with an internal measurement unit (IMU). The IMU consists of various sensors and measurement devices. The interior of the ball is shown in Figure 2.

The absolute orientation of the ball and its orientation are measured using a gyroscope and a magnetometer. The gyroscope provides information on the angular velocities of the Snowball. The magnetometer works like a three-dimensional compass. By considering the strength of the Earth's magnetic field, the absolute orientation can be determined. Three accelerometers are used to measure the change of the velocity and the forces acting on the ball. The resulting data is recorded with a sampling frequency of about 25 Hz. Furthermore, the Snowball is equipped with a GPS unit.

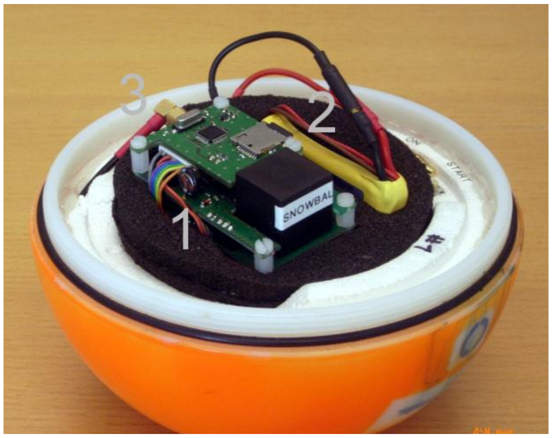

Figure 2: (1) IMU, Internal Measurement Unit equipped with several sensors. (2) Power supply. (3) GPS antenna.

2.2. Experimental method

In a field experiment, the Snowball is placed in the potential release zone. After artificial release the measurement device moves and deposits as a part of the avalanche body. Throughout the descent of the avalanche the variety of sensors provide three-dimensional information about accelerations, rotation and orientation. During the avalanche descent the GPS reception and accuracy are limited. For the IMU no data link is necessary throughout the experiment. The Snowball can operate for several hours logging the raw data on an internal hard drive. A Recco Avalanche Rescue System ensures that the Snow-ball can be relocated in the avalanche deposit and recovered after each experiment.

2.3. Data analysis

We expect that the recorded data allows to recon-struct the trajectory and velocity of a particle embed-ded in an avalanche. Thus the characteristics in-side the avalanche can be analyzed with respect to time and space along the complete avalanche path. Additionally to the trajectory and velocity evolution information on rotations could serve as an indicator for the internal turbulent structure of the deeper layers of an avalanche.

The additional GPS data can be used to determine start and deposition position of the ball which is important for the comparison with the model results. Furthermore the GPS data can serve as a reference for the calibration and IMU data verification.

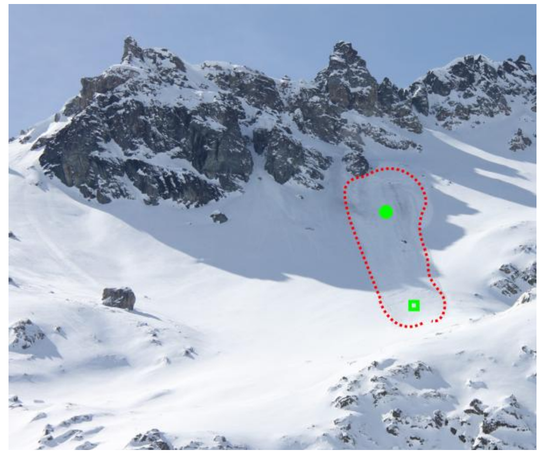

Figure 3: Experimental site, Wattener Lizum near Innsbruck, Aus-tria. Red dotted line marks the avalanche outline. The release position (green circle) of the Snowball and the deposit on position (green square) are shown.

3. FIRST EXPERIENCE

The Wattener Lizum near Innsbruck, Tyrol serves as an avalanche test site of the BFW. Experiments are performed regularly using radar measurements and laser scanning (Sailer et al. (2008)). First ex-perience was gained with the measurement device in winter 2009/2010 at the test site. The Snowball was placed in the release zone at a height of about 2500 m, see Figure 3. A small snow slab was released and the avalanche stopped quickly. The Snowball was deposited shortly after the release (150 m height difference). Due to the short track no significant data could be recorded.

4. OUTLOOK

Recording data of layers inside a snow avalanche along the whole path can give new insights into the structure and dynamic behavior of avalanches. The combination of the different sensor measurements to determine the position and orientation of the Snow-ball are promising.
In connection with radar measurements through-the-depth information concerning the flow velocity can be obtained along the complete avalanche path. Radar and Snowball measurements are not restricted to a particular test site which allows a high mobility and measurements at multiple locations. Further experiments are planned on various test sites with the Snowball measurement device in the upcoming winter.

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