Snow pillow measurements in Norway

Snow pillows in Norway

As 50% of annual precipitation falls as snow in Norway access to real time snow data is of great importance. Snow data is primarily used for hydropower planning (98.3% of total energy production) and flood forecasting.

NVE has from 1967 built a network of 24 automatic snow pillow stations.

- Site altitudes 30-1200 meters a.s.l.
- Annual SWE\text{max} 200-1700 mm
- Latitude 58°N – 79°N

NVE snow stations will have at least one 2.5 m\text{2} white PVC pillow filled with ethanol or glycol, with two pressure sensors and ultrasonic snow depth sensors. Data transfer is via cellular networks and the stations run on solar power.

Bridging / pressure relief

Norwegian winter climate

- **Western part** - relatively mild winters, with rain on snow causing multiple crust layers in snow pack. Bridging problems almost every year.
- **East and Northern parts** - Stable, cold winter conditions. Precipitation only as snow at high altitudes. Snow pillows works generally well. Less stable at lower altitudes - bridging problems occasionally.

Snow bridge detection

- Unexpected decrease in SWE are assumed to be bridging effects. Snow on top of pillows were dug off and put back to break any snow bridges within the snow packs. SWE readings got back to expected levels, corresponding to manual measurements.
- One way of investigating bridging effects without changing the snow pack is to have a standard size snow pillow on top of a larger snow scale. This will be tested for the winter 2010/11.

Overcoming bridging problems

- By increasing size, the bridging errors are assumed to be reduced. Tests are being conducted using 4 squared pillows of all together 25 m\text{2} at two stations.
- The heat capacity and heat transfer properties of pillows change the natural thermodynamics. To mitigate this, a 25 m\text{2} wooden snow-scale with 0.5m air underneath is being tested at one station.
- On two sites hard tops of waterproof plywood are added to the flexible PVC pillows to avoid pressure relief from partly compressed areas on the pillows.
- … or replace pillows all together! In the 2010/2011 season passive gamma sensor is tested as an alternative to pillows. This sensor type is non-contact, do not measure pressure and hence will not be affected by bridging problems.

NVE has established a test site for snow gauging equipment (*Filefjell Snow Science Site*) with focus on bridging problems and gauging methodology comparison. The site is equipped with a full meteorological station, soil- and groundwater monitoring and radiometric measurements.

All of NVE’s data are freely available to researchers, and we are eager to cooperate with other institutions.
Snowpack dynamic responses were measured through the depth adjacent to the Bridger Bowl Ski Area during the 2010 winter. Six field experiments (11 detonations) were conducted at a site:

**Project Goals:**

1. Develop a field-portable instrumentation suite capable of capturing snow dynamic response and air blast overpressure.
2. Measure the effect of blast range on snowpack response.
3. Measure the shock attenuation through the snow depth.
4. Measure the effect of explosive placement relative to the snow surface and explosive size.
5. Measure changes in snow pack response when subjected to repeated explosive shots at the same location.

**Project Overview:**
Six field experiments (11 detonations) were conducted at a site adjacent to the Bridger Bowl Ski Area during the 2010 winter. Snowpack dynamic responses were measured through the depth and at two ranges with various explosives and placements.

- 0.9kg and 1.8kg charges of Pentolite cast boosters
- Three locations with respect to the snow surface
- 1m suspended, surface, and buried

In each test, six dual-axis accelerometers were placed at various distances from the blast to capture the dynamic response of the snowpack, at 3m and at 7m from the blast site. A pressure transducer was placed at 7m in order to capture the over-pressure of the shockwave.

**Methods:**

- Six dual-axis accelerometers placed throughout the depth of the snowpack, at 3m and at 7m from the blast site. A pressure transducer was placed at 7m in order to capture the over-pressure of the shockwave.

**Data Collection:**

- National Instruments USB-9221 Instrumens Data Acquisition System & notebook computer to record transducer signals
- Labview v8.6 data collection rate was 5000 Hz
- Sampling rate based on: 1) Nyquist theorem sampling rate considerations; 2) transient and relatively high-frequency acceleration signal components; 3) capture acoustic signals throughout the dynamic range of the air pressure sensor
- 7.2 amp-hour sealed 12 volt battery-powered sensors
- 30 m power cable to a junction box cabled to sensors
- Junction box directed 12-VDC to the microphone and also housed a 5 VDC voltage regulator for the accelerometers.
- 13 channels of data signals routed through the junction box and 30 m cable to data acquisition system

**Results:**

- **Snow pit data recorded in the 120cm profile:**
  - Rounds, p=273 kglm², down to 65cm below surface
  - Ice crust 65cm below surface
  - Depth hoar, p=223 kglm², below ice crust
- **Two tests:**
  - 0.9kg explosive followed by 1.8kg explosive, both suspended 1m above the surface
  - Acclerometers placed at 20, 50 and 90cm depths (from top)
- **Two sets:**
  - 3m and 7m from charge
- **Air overpressure sensor placed 7m from explosives**
- **Vertical acceleration responses from first of two explosive charges are shown below in Figure 7**

**Conclusions:**

A method for measuring the dynamic response of snow due to an explosive charge was designed, built and field tested in 2010.

- Vertical and radial accelerations due to the explosive blast were recorded at 6 locations within the snowpack for each test
- Air overpressure was measured before, during and after explosive shockwave passage

**References:**


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