Acoustic Sensor To Measure Wind Velocity And Snowdrift For Snow Avalanche Forecasting

Vincent CHRITIN, Thierry Melly

IAV Engineering - Noise Vibration Control & Acoustic Systems
PSE/A, EPFL - 1015 Lausanne - Tél + 41 21 693 46 26
Fax + 41 21 693 83 93 - vincent.chritin@epfl.ch

Abstract. Wind can create even greater unstable accumulations of snow in mountainous areas than heavy snowfalls. But knowing wind conditions is not sufficient to predict these accumulations because their formations also depend on the snow quality of the snowpack surface upwind of the release zone. Consequently, assessment of snowdrift is required to improve avalanche forecasting. In accordance with this assumption, a new acoustic sensor was developed. The sensor includes a mechanical part designed to form a closed acoustic enclosure. The acoustic enclosure contains a microphone connected to an electrical amplifying and filtering device. Because the output information delivered by the instrument is proportional to the wind velocity and to the flux of solid particles (ice grains) drifted by the wind, the instrument is called an *anémo*driftometer. Prototypes of the instrument were first tested in a wind-tunnel and then at an experimental site in the Alps. Then an operational version, called Flow*Capt*, was developed and connected to the automatic weather station at 2700m in the Aminona ski resort (Switzerland). During the winter, snowdrift is recorded on the test site along with other meteorological parameters, and avalanche activity, to provide extensive on-site calibration and testing of the sensor. The experiment demonstrates that the instrument is a useful component of the avalanche forecasting chain.

Keywords: acoustics, sensor, avalanche forecasting, snowdrift.

1. Snowdrift: a capital information for avalanche forecasting

Wind can create even greater unstable accumulations of snow in mountainous areas than heavy snowfalls. But knowing wind conditions is not sufficient to predict these accumulations because their formations also depend on the snow quality of the snowpack surface all around measurement stations : at a given place, effective snowdrift will require high wind velocities, while for another snow pack snowdrift will already occur at low wind velocities. Knowing snowdrift by direct measurements is subsequently of high importance for avalanche forecasting (fig. 1).

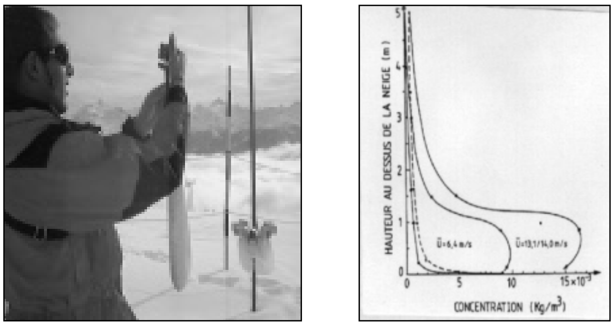

Fig. 1 : Left - On the field, snowdrift is measured periodically by security patrollers, with the so-called Manual Driftometer. This simple instrument makes possible quantitative snowdrift assessments, but it requires the presence of a human observer on the sites. Compared to this method, the new acoustic sensor gives the possibility of continuous and automatic recording of snowdrift. Right - Typical snowdrift profile, From Föhn (1980).

2. Principle of the acoustic *anémo*driftometer

The so-called Flow*Capt*™ acoustic *anémo*driftometer determines both wind velocity and snow particles flux. The detection principle is based on mechanical-acoustical coupling. The sensor is composed of closed pipes containing electro-acoustic transducers and a powering, filtering and amplifying unit. When the sensor is placed into a snow particles flux, the particles shock the sensor pipes, inducing acoustical pressure (fig. 2). The pressure is picked-up by piezo-electric microphones. The electrical outputs are filtered and time-averaged in given frequency ranges to provide a signal proportional to particles flux Q (kg.m^2.s^{-1}). The formal relation between the measured acoustic pressure and the snow particles flux Q requires the determination of the mechanical-acoustical coupling equations for the sensor, according to suitable hypothesis about particle impacts. The wind velocity is determined on a similar principle : the wind interacts with the body of the sensor and generates acoustic pressure into the air enclosures (fig. 3). Suitable sensitivity can be obtained optimising the body shape and structure to the expected wind velocities.

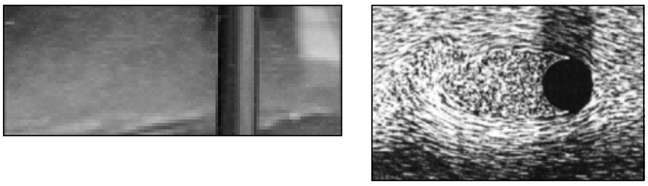

Fig. 2 : Left - Saltation ice particles shocking a pipe. (from V. Chritin). Right - Visualisation of a turbulent flux around a cylindrical obstacle. (from H. Werlé, ONERA).

Because snowdrift happens during windy periods, it is necessary that the sensor strongly discriminates wind from snowdrift. This property can be obtained by an appropriate design of the mechanical-acoustical coupling. With no mobile components and full protected transducers (microphones inside closed cavities), the Flow*Capt* is very suitable for stringent topographical and climatic environments.

3. Prototyping of the *anémo*driftometer

Theoretical and experimental campaigns have been carried-out at the Swiss Federal Institute for Technology (EPFL) to develop Flow*Capt* prototypes (fig. 3).

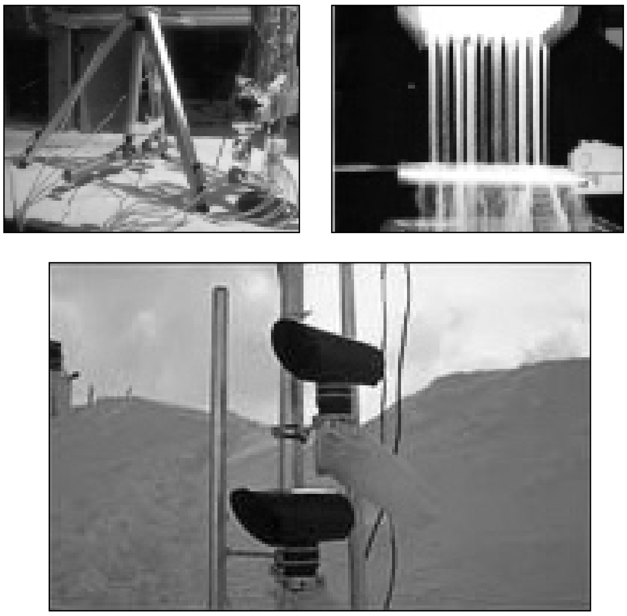

Fig. 3: Top left - Prototypes tested in wind tunnel, at LASEN-EPFL. The acoustic response of cylindrical and spherical forms excited by wind were characterised in the 0 - 12.5 m/s range (from Th. Castelle). Top right - Calibration with controlled particles flux on test-bench, at LEMA-EPFL. (from Th. Melly). Bottom - Prototype tested at Anzère ski resort (2400 m).

Results obtained from the on site validation experiments carried-out with a reference *anémo*meter (fig. 4) and a reference snowdrift measuring device (fig. 5) show good accordance.

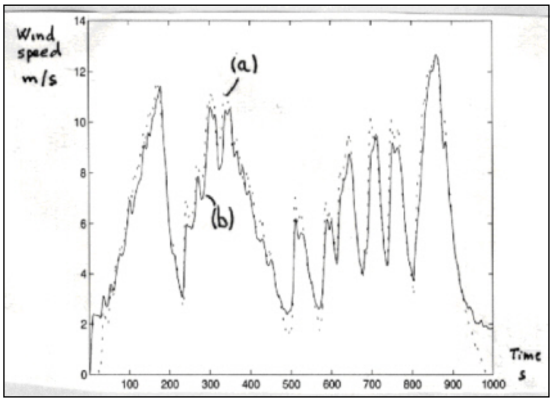

Fig. 4: Wind velocity measurements in wind tunnel.
(a) Calibrated MiniAir5™anémometer response
(b) FlowCapt prototype response.

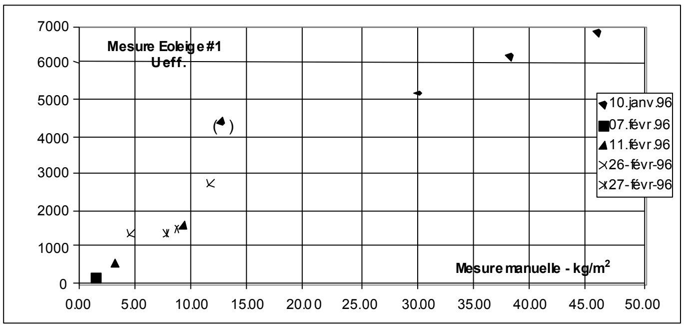

Fig. 5: Comparison of snowdrift measured by the FlowCapt prototype (Eoleige) and a Manual Driftometer.

On the basis of the obtained results, the industrial development of the Flow*Capt* began. A particular attention was paid on the calibration, reliability and temperature deviation to ensure precise quantitative snowdrift information. The sensitivity of the sensor to wind velocity is calibrated in a wind-tunnel, by comparison with reference *anémo*meters. To calibrate snowdrift, no reference instrument exists. Thus, it is necessary to define a specific method to find the calibration parameters under various conditions (fig. 6): (1) sensitivity measurements in bench tests, with controlled particles flux (2) continuous meteorological and snowdrift measurements for two winters on a test site (3) comparison of the Flow*Capt* response to Driftometer indexes during storms.

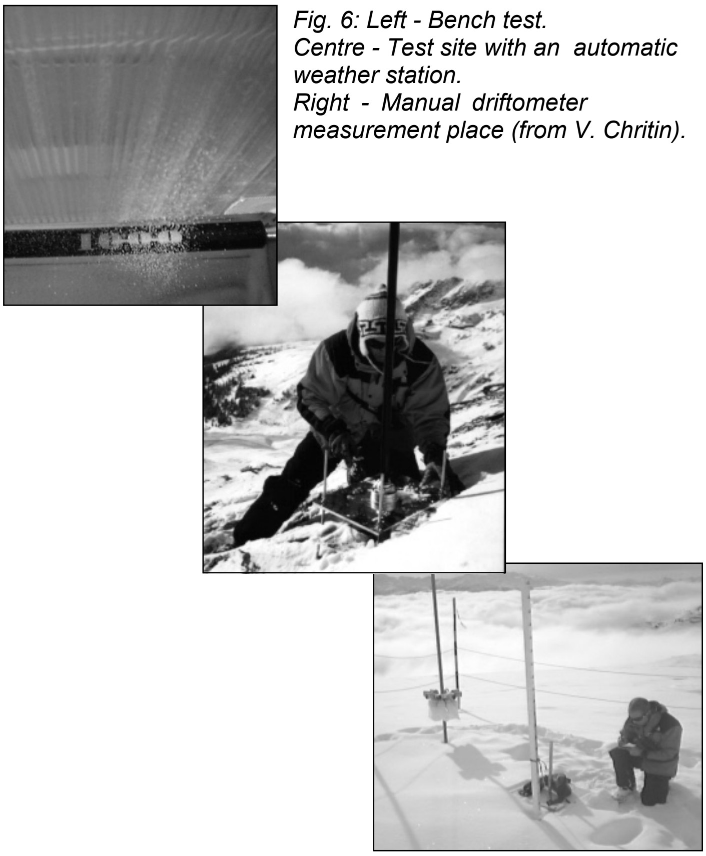

Fig. 6: Left - Bench test.
Centre - Test site with an automatic weather station.
Right - Manual driftometer measurement place (from V. Chritin).

4. Pilot installation at Aminona

In December 1997, Flow*Capt* has been installed on a Swiss standard automatic remote station (Gubler, 1996), at Aminona ski resort (Switzerland). The station is located at an altitude of 2700m on a south facing slope of Mt. Bonvin. Values are recorded every minute (time constant = 1s). Snowdrift is integrated from ground to 1m and between 1m and 1.2 m (fig. 7). The upper sensor additionally measures wind speed.

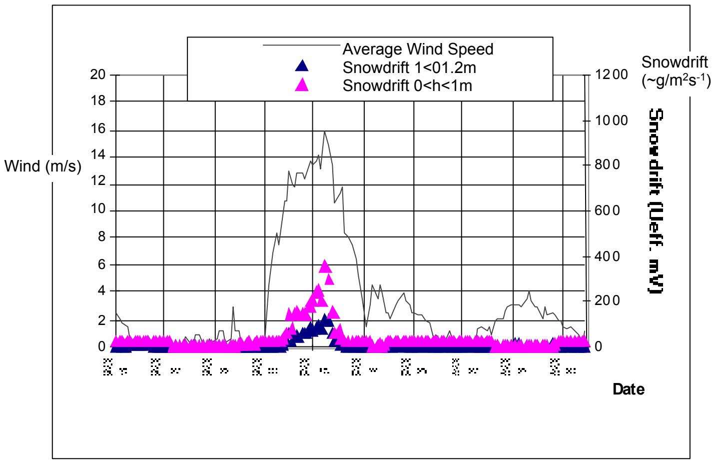

Fig. 7: Wind and snowdrift recorded at Aminona ski resort, between January 24th and 26th, 1998.

The station (fig. 8) is equipped with a set of sensors and a number of features that allow for a significant improvement of the assessment of the actual local avalanche danger. The expert local forecasting software NivoLog™ uses the measured snowdrift data to analyse the avalanche release probability in all sectors of the Aminona ski resort.

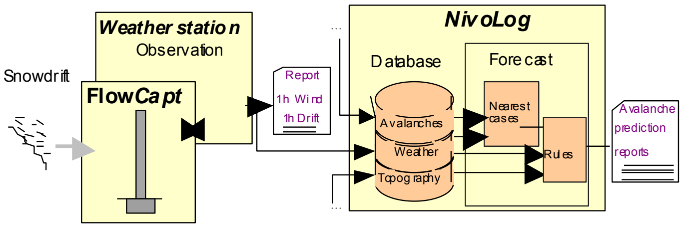

Fig. 8: The sensor is used in connection to an automatic weather station. Snowdrift information is recorded into a database and computed by an expert system to analyse the avalanche release probabilities.

5. Conclusion

The Flow*Capt* acoustic sensor is the first operational automatic *anémo*driftometer. Connected to weather stations, it provides automatically quantitative snowdrift measurements, which are significant data to predict avalanches. Its acoustical principle, with no mobile components and reliable mechanical part, makes it suitable for applications in stringent environments.

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References

- Chritin (V.), 1998, Flowcapt : un capteur dans le vent, ANENA revue n°81, march 98, pp 13 - 15.
- Bolognesi (R.), 1996, The Driftometer, Proc. of The Int. Snow and Science Workshop, Banff, Canada.
- Bolognesi (R.), Daultier (J.-M), Naaim (F.), Ousset (F.), 1995, Une évaluation quantitative du snowdrift pour la prévision locale des avalanches, ANENA Revue n°69, march 95.
- Castelle (Th.), 1994, Transport de neige par le vent en montagne : approche expérimentale du site du col du lac blanc, PhD Thesis 1303, Génie civil EPFL.
- Gubler (H.), 1996. Remote Avalanche Warning-, Alarm- and Control Systems, Fundamentals, Applications and Experience. Proc. Of the Int. Snow Science workshop, pp 165-172, Banff,Canada.
- Schmidt (R. A.) et al., 1984, Comparison of snow drifting measurements at an alpine ridge crest, Cold Regions Science and Technology, Vol. 9, pp 131-141.