A STREAMLINED COLLECTOR FOR PRECIPITATION (ASCOP)

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Introduction

Conventional precipitation gages with a cylindrical shape are a barrier in the wind field and cause the air flow to separate from the rim, to alter its direction and to accelerate as it passes over the opening (Sevruk et al.; 1989). The consequence of this aerodynamic blockage is a deficiency in catch, because the trajectories of hydrometeors are deflected away from the opening. The problem increases in severity as windspeed increases and as the falling speed of the precipitation decreases. Thus, undercollection is greatest at high windspeeds, and for snow and fine rain as opposed to larger sized raindrops.

The aerodynamic performance of exposed precipitation collectors depends on their relative depth, the ratio of depth to radius (aspect ratio), the size and shape of the rim (Sevruk et al., 1989) and upon other details of their shape. Reducing the depth of the collector reduces the displacement and acceleration of the flow over the opening, by reducing the aerodynamic blockage caused by the collector (Hall et al., 1992). If a precipitation collector is to make use of reduced depth in order to improve the flow characteristics over the opening, it must be quite shallow. The aspect ratio would need to be below 0.25 and preferably below 0.1 (meaning: for a 20 cm diameter collector, the depth should be below 10 cm, preferably below 4 cm). The aspect ratio of ASCOP is 0.66 (with a wind shelter that reduces cooling), compared to 3.79 of the Austrian standard gage (Paar AP 23).

The precipitation collectors presented here are instruments for the measurement of all forms of precipitation with collector and container separated in order to reduce the aerodynamic blockage of the collector. By applying the principles of an airfoil or wing design, it is possible to redistribute the disturbances between the upper and lower surfaces of the collector, thus minimizing those over the opening. Acceleration takes place under the collector (there must be an acceleration associated with the barrier in the airflow) and the flow field remains almost unaffected above the opening. The goal is that the trajectories of snowflakes above the opening are not altered by the existence of the gage.

Materials and Methods

The design of a perfect precipitation collector must consider several criteria. It must be capable of collecting and storing snow at least until it has melted. The orifice opening must be a defined, effective size and must have special aerodynamic characteristics, these being small vertical displacement and acceleration of the wind flow over the opening. The separation of the boundary layer on the collector surface should be horizontal across the opening. A wind-driven circulating flow in the collector must be eliminated and the collector must be as shallow as possible. The last design feature is based upon aerodynamic considerations and is associated with practical difficulties (e.g. ineffective drainage and limited storage capacity). Thus, deeper collectors are preferred for practical reasons although their aerodynamic performance is not as good (see fig.2).

The design of the collectors was based upon flow simulation of ideal inviscid flow over a Karman - Trefftz airfoil profile (Wiesinger 1993a). In any real fluid, viscosity is present which produces boundary layers, turbulence and separation. Often, however, in the majority of the flow field, viscous effects are small and the flow can be modelled as inviscid, assuming ideal flow. For shapes such as airfoils which are rounded and not too thick, inviscid analysis typically yields very accurate predictions of the velocity field and surface pressure.

The design of ASCOP is also based on investigations and experiences made with similar prototypes (Wiesinger 1993a,b) in Japan. Alterations were made with the installation of a central heating unit, the use of other materials such as carbon fibre and aluminum instead of polyacetal and wood. Moreover the orifice area has been reduced to 200 cm^2, because experiences from field testing in Japan did not reveal any significant differences in performance between collectors with sizes between 250 and 750cm^2.

ASCOP is being manufactured as both, a heated winter version with overflow drainage system that keeps a heated water bath with a constant level inside the collector (fig.2), as well as a summer version without water bath which drains via a funnel and tube into a container. The two versions can be exchanged very simply. The water bath inside the container improves the aerodynamic performance, prevents collected snow of being blown out and reduces evaporation which usually occurs when funnels are heated. This evaporation amount can be in the order of 20% of collected snow. A thin layer of oil prevents evaporation of the collected precipitation. We use LV/SM 1036 (manufactured by the Austrian ÖMV) which is a synthetic ester with a density of 0.83 g/ml (at +15°C), a point of congelation of -60°C and viscosities of 130 and 600 centistokes at 0°C and -20°C, respectively. 600 centistokes (at -20°C) corresponds to the state of a standard transmission oil at room temperature.

The ratio of collector height to its radius has a considerable effect on the flow field. With deeper collectors, the velocity above the collector is lower than the free-stream and the velocity gradients around the collector are larger as opposed to a shallower collector. With decelerated flow over the orifice the collector might actually collect more snow per area than is actually accumulating. Likewise the angle of attack influences the distribution of flow speeds. For a collector which has a ratio of height / radius equal 0.613, the flow speed above the center of the orfice is 0.75 when the angle of attack is zero (horizontal flow, fig.1). It is 0.6 when the flow comes from 10 degrees above the horizontal and 0.93 when it comes 10 degrees from below the horizontal plane (Wiesinger 1993b).

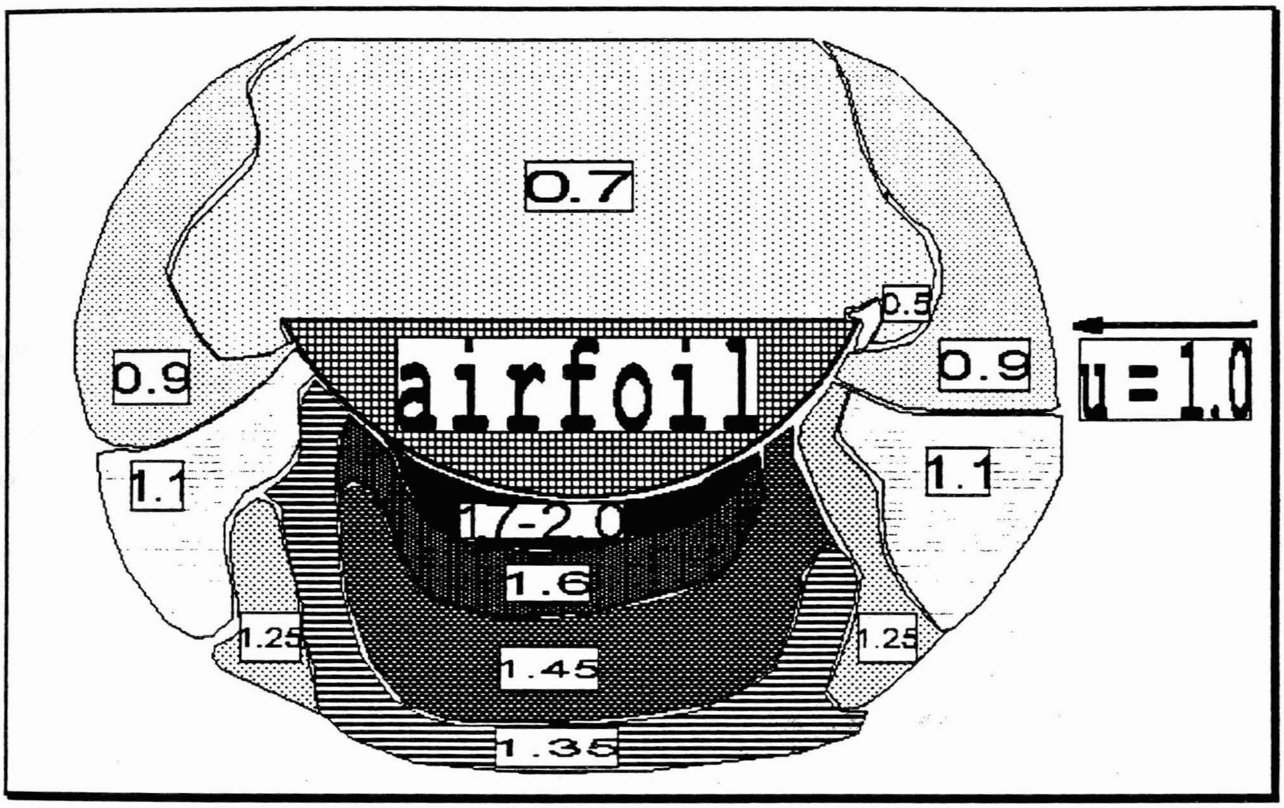

Fig. 1: Velocity distribution of the airflow along a Karman Trefftz airfoil profile as a percentage of the flow speed of the free stream which has a similar shape as the ASCOP, but does not have an inwardly turned lip. The simulation is made for ideal inviscid flow. The angle of attack is zero (horizontal flow) and the velocity of the free stream (u) is 1.0. The ratio H/R (0.613) is the collector height / radius of collector. The ratio H/R for the ASCOP used in this study is 0.66 (and is 0.58 for the summer version without wind shelter).

Results

Streamlined precipitation collectors are less affected by wind than gages with a cylindrical shape. They show a catch much closer to that of the references, which are protected against wind, than common gages of cylindrical shape. The improved performance can be seen in fig.3., where the accumulation of precipitation with time is plotted. The Paar is a cylindrical, heated gage with tipping buckets. The period was featured by strong winds (fig.4) and snowfall. The ASCOP caught 45 % more snow than the cylindrical gage during this storm.

A standard, which measured the true snowfall, was not available. Measurements from the snow board were equally affected by wind, and therefore unuseful as standards. For cases of rainfall, where falling speeds of raindrops are about ten times higher than those of snowflakes (Wiesinger 1993b), the differences in catch are within 10 %.

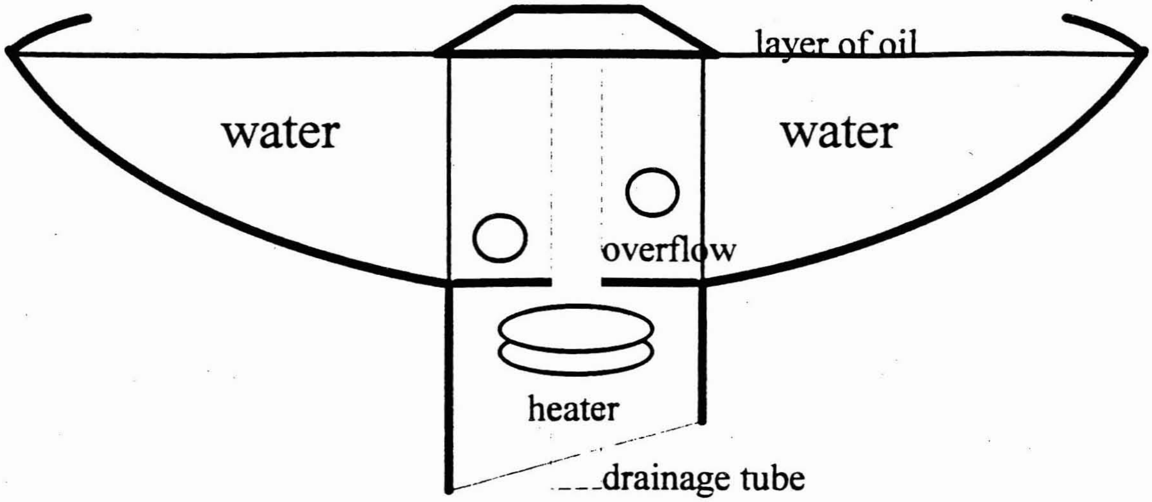

Fig.2: Cross sectional view of ASCOP. The collector is filled with water which is protected against evaporation by a thin layer of oil. The overflow-heater unit in its center prevents oil from flowing down and prevents the drainage system from obstruction by contamination, and it heats the liquid when the temperature gets close to freezing. A drainage tube made from Teflon drains liquid from the collector when precipitation is added. The liquid is collected in a container which rests on electric weighing scales.

Experiences from Japan (Wiesinger 1993b) showed that streamlined collectors catch comparable amounts as the WMO Double Fence International Reference gage, however, Yang (WMO 1992) showed that even this method of measuring solid precipitation is deficient.

The overflow-heater unit is capable of keeping the water bath liquid down to -25°C at a windspeed of 11 km/h with relatively low power consumption. The evaporation protecting oil in use (LV/SM 1036) does not evaporate by itself, and prevents evaporation of water over 100 days at laboratory temperatures between 30 and 50°C completely.

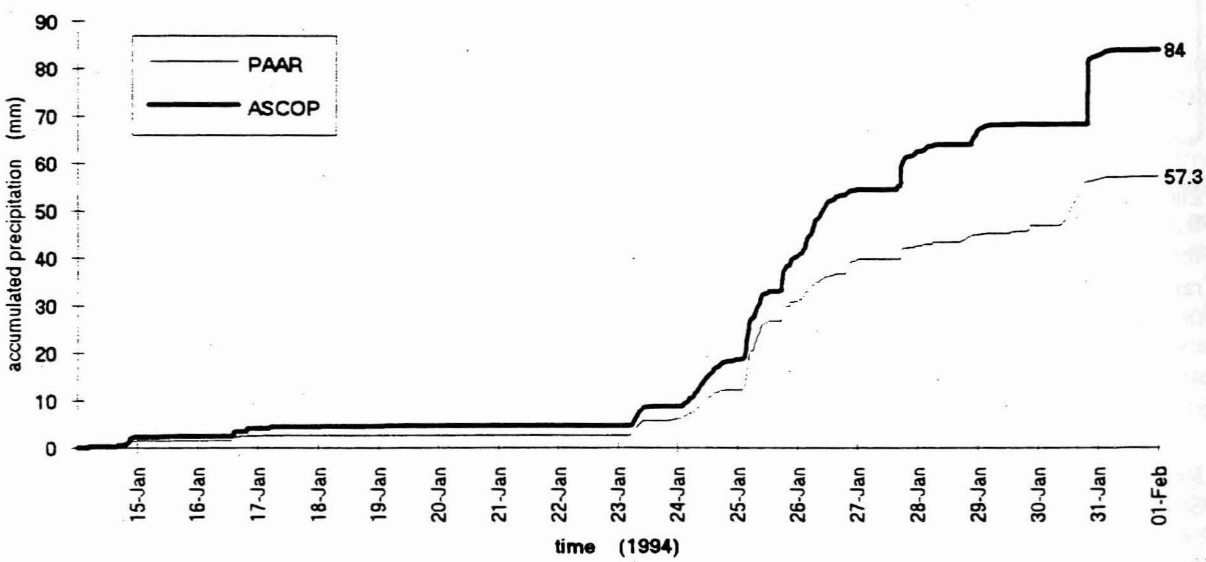

Fig.3: Comparison of two different precipitation gages during a windy and snowy period at Hochkar / Austria. PAAR is a conventional type gage, cylindrical in shape, heated and equipped with tipping buckets. ASCOP is streamlined, heated and equipped with electric weighing scales.

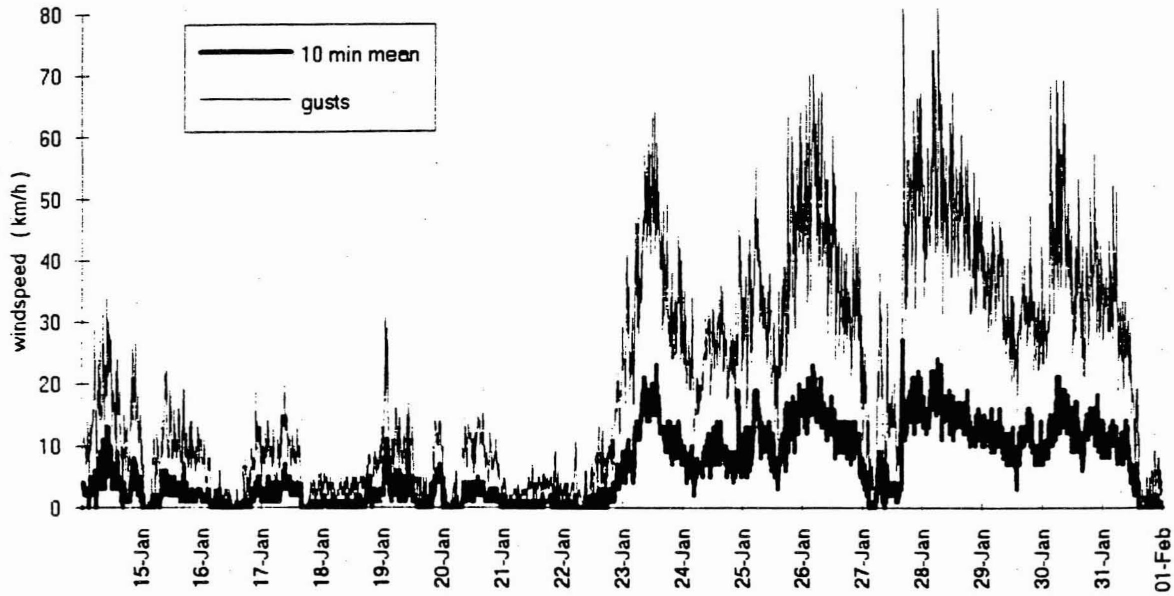

Fig.4: Windspeeds at Hochkar / Austria from 14 January until 1 February 1994.

Conclusions

The gages of aerodynamical superior performance (ASCOP) can be automated and combined with any system of measurement, but only accurate and reliable systems are appropriate. The simplest way is the collection of water in a sealed container that is weighed. With this method evaporation losses are very small and the instrumentation for the collection of rain is comparatively cheap. Thus, this "low tech" instrument is useful for studies on the aerial distribution of rainfall where many accurate gages at a low cost are required. The use of high performance weighing scales appears to be the most reliable method, if a continous data set is needed. With this method evaporation losses are eliminated.

The ASCOP-winter version is not as simple as the ASCOP-summer version since it needs a power line for the melting of the snow. If electricity is available, the instrument serves well as a collector of rain and snow, even at windy sites. However, the careful selection of a site for precipitation measurement, which is representative and not extremely wind exposed, is still required.

Acknowledgements

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References

Hall, J.D., Irwin, J.G., Stone, B.H. and Upton, S.L.(1992): Aerodynamic considerations in precipitation collector design. National Measurement System Symposium, Airborne Pollutants Measurement, March 17-18, 1992, Warren Spring Lab., Stevenage, U.K.

Sevruk, B., Hertig, J.-A. and Spiess, R. (1989): The effect of precipitation gauge orifice rim on the wind field deformation as investigated in a wind tunnel. Atmospheric Environment, Vol. 25 A, No. 7. p.1173-1181.

Wiesinger, T. (1993a): Improved design of precipitation gages based on aerodynamic principles. in: Precipitation Measurement & Quality Control, Sevruk, B. & Lapin, M. eds., Proc. of the Int. Symposium on Precipitation and Evaporation, Bratislava 1993, Vol.1, p.143-147.

Wiesinger, T. (1993b): Accurate measurement of snowfall - development of two innovative precipitation gages based on the analysis of existing errors. Dissertation, University of Vienna, Institute of Meteorology and Geophysics, 230pp.

WMO (1992): International Organizing Committee for WMO Solid Precipitation Measurement Intercomparison, 6th Session, Toronto, 14-18 Sept. 1992, Final Report, CIMO/C-SPR-0C6. 162pp.