Ice-mounted masts as platforms for micro-meteorological measurements on glaciers

Michael Winkler[1], Rainer Prinz[1], Lindsey Nicholson[1], Nicolas Cullen[2], Christophe Kinnard[3]

[1] Centre for Climate and Cryosphere, University of Innsbruck, Austria
[2] Department of Geography, University of Otago, New Zealand
[3] Centro de Estudios Avanzados en Zonas Áridas (CEAZA), La Serena, Chile

Introduction

Automated measurements of meteorological variables on glaciers are necessary for surface energy and mass balance studies. Typically, the instruments are mounted on tripods that are placed on the ice without additional securing devices (e.g. guy wires). We take the opportunity here to describe an alternative method, that involves using segmented masts that are drilled vertically into ice or snow covered glacial surfaces (Fig. 1). The presented system (or a version of it) was tested at the following sites: Kersten Glacier (Kilimanjaro, TZ), Lewis Glacier (Mt. Kenya, KE), Glaciar Shallap (Cordillera Blanca, PE), Glaciar Cerro Tapado (Coquimbo region, CL), Glaciar Guanaco, Glaciar Ortigas, Glaciarete Toro (all 3 sites Atacama region, CL), Brewster Glacier (NZ), and at various sites in Greenland.

Ice-mounted segmented mast design

The masts consist of aluminium (or steel) tube segments, each ca. 1 - 1.5 m long (**l** in Fig. 1A) with an outer diameter of ca. 50 mm and a wall thickness of ca. 4 mm. The segments are connected to each other through ca. 20 - 30 cm tubes with outer diameters equal to the inner diameter of the segments. They are fixed to both consecutive segments by high quality countersunk-head screws (Fig. 1B).

The combined mast is put into a hole drilled by an ice auger[1] or steam drill. The depth of the bore hole (**L** in Fig. 1A) very much depends on the ablation rate between consecutive maintenance visits; at least 1.5 m of mast should always be encased by ice. It is valuable to drill a second mast (Fig. 1A) to avoid turning of the whole station that can e.g. be caused by wind in the case that the mast is temporarily not frozen into the host ice and to block the bottom ends of the tube with a plug to prevent the mast from sinking into the ice under its own weight (Fig. 1C).

If a standard weather station tower must be used, the uppermost tube of the segmented mast can be equipped with a plate on top of which the standard mast can be mounted (Fig. 1E). This has proved to be a stable structure, but care should be taken concerning the color and size of the

[1] 48 mm outer diameter masts work e.g. perfectly with 51 mm Kovacs® ice augers.

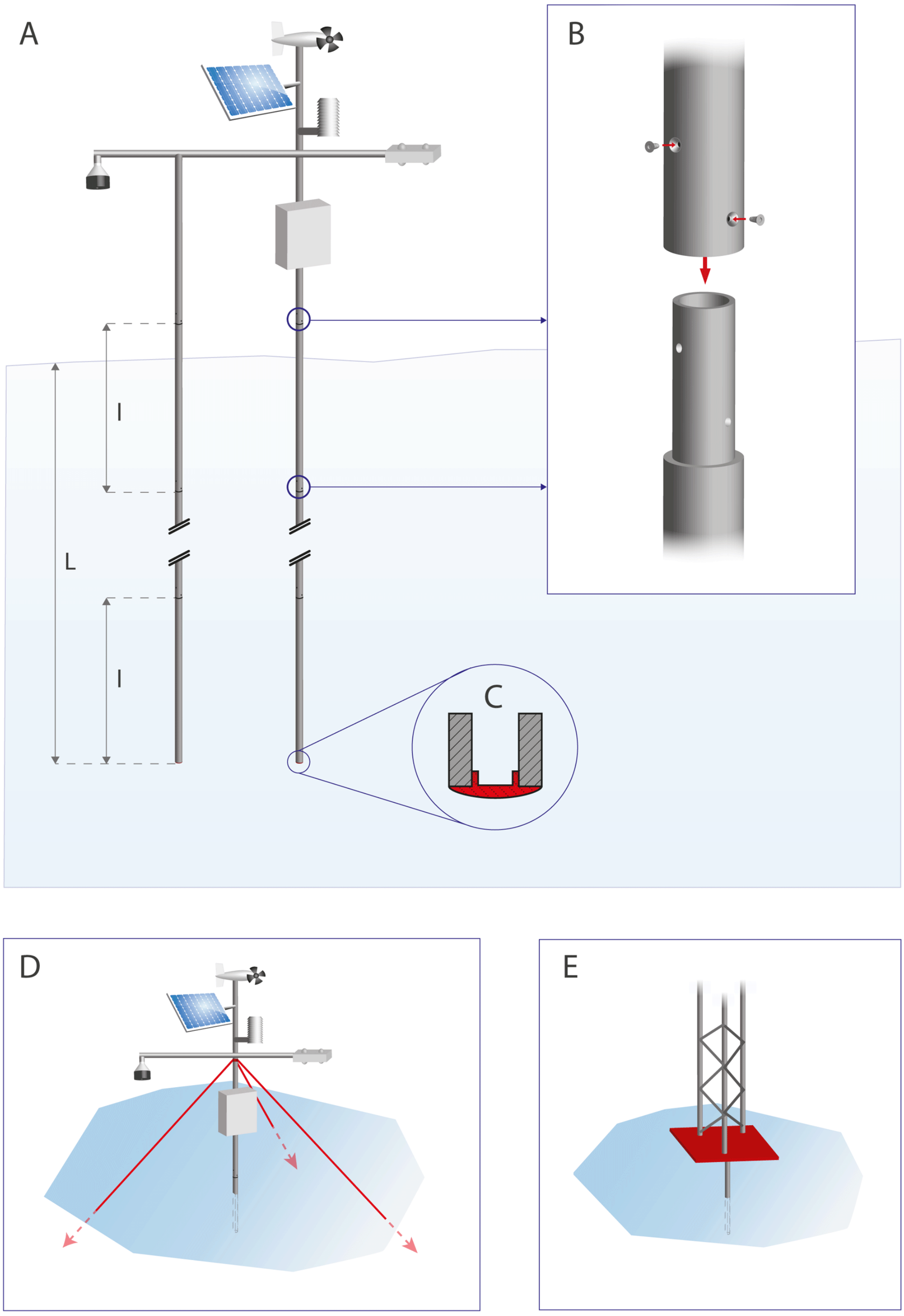

Figure 1. Segmented mast drilled vertical into the ice.

mounting plate, to minimise the influence of the plate on the meteorological measurements made. Additionally, the (single) mast can be braced with guy wires (Fig. 1D). A good way to fix the wires is by drilling holes in extension of the wires, plunging the wires into the holes and partly filling the holes with water. After the water is frozen, the wires can be tautened and the holes can be filled up completely. This guy line style was more successful than guy lines on traditional peg anchors as the pegs melt out and regular visits are needed to tension the wires correctly. Incorrectly tensioned guy lines can often be the cause of rather than the cure for station tilting!

Advantages of the ice-mounted segmented mast system

1. The mast stays vertical assuring levelled sensors, a necessary requirement especially for measuring radiative fluxes, wind speed and wind direction. Tilt due to ice flow was never experienced by the authors but could be an issue on fast flowing, shallow glaciers. Particularly, over rough and rapidly changing glacier surfaces, tripod masts can become tilted or even fall over. Corrections can be made using inclinometers but uncertainties remain.
2. There is no need for a separate construction carrying the sonic sensor that measures ablation. When tripod masts are used there always has to be a separate construction drilled into the ice where the sonic ranger is mounted on. In case the ice-mounted construction can be prevented from melting into the ice, it makes a second mast superfluous (and also the messy cables between the two constructions).

Three more positive attributes of the drilled-in mast are that (i) manufacturing is cheap and easy and can be done by any skilled craftsmen even in developing countries, (ii) the segmented design allows quick extension or shortening of the mast according to accumulation or ablation situations without demounting the sensors, and (iii) dividing the mast's load (about 12 kg at 6 m length for the aluminium construction) to several field personal allows alpine style expeditions that access remote areas by foot to be carried out.

Restrictions of and recommendations for the ice-mounted segmented mast system

There is only one disadvantage of the described system (compared to the usage of a tripod mast) that directly affects the measurement quality. Ablation continuously changes the height of the sensors above the ice surface, which means that data from different periods cannot necessarily be compared to each other. However, the sonic sensor provides height data for correction. All the other restrictions mentioned in the following are technical ones.

Mast segment connections differing from Figure 1B were also tried, with moderate success. E.g. tubes with threads that can be screwed onto each other turned out to be weak and difficult to handle. The connection presented in Figure 1B actually strengthens the junction between two tube segments. Still, there are also problems with the Figure 1B - solution because the screws can break during opening because of the cold and from corrosion. It is suggested to use only two high quality screws per connection.

The drilled-in mast systems can only be applied at sites where the amount of mass turn over and the maintenance interval fit together, e.g. at sites with low mass turn over or at frequently visited glaciers. A second mast pole (or even a third, see Jarosch et al. "A versatile tower platform for glacier instrumentation: GPS and Eddy Covariance Measurements" in this issue) not only prevents rotation of a station but also gives it more stability (Fig. 1A). More than one mast can also be helpful on highly penitented glacier surfaces where unpredictable and locally high rates of surface lowering can cause the masts to melt out earlier than predicted.

As a rule of thumb, the weather station's center of gravity should never be more than 3 m above the ice surface and the mast should always be deeper in the ice than one tube segment length (at least 1.5 m). Guy wires avoid failures of the system during strong winds (Fig. 1D), but in most of the locations this mast type has been deployed in these were not necessary, and instead, at sites that are expected to experience high winds simply increasing the diameter of the mast is sufficient to resist high winds.