# A versatile tower platform for glacier instrumentation: GPS and Eddy Covariance Measurements

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## Introduction

Deploying a high accuracy, kinematic GPS on a glacier to measure surface movements over time creates specific demands on the design of the mounting platform. First, the platform must be anchored directly to the ice surface to ensure that the GPS device actually measures ice deformation. Second, accumulation throughout the winter season dictates that the instrument must be mounted at a certain height above the ice surface to avoid burial by snow. Third, to ensure a direct coupling between the instrument and the ice surface, a very rigid mounting structure is required, which minimizes the interference of structural instabilities (e.g. vibration or swaying) with the measurement of ice surface motion. Finally, the design should be easily expandable, modular, only require off-the-shelf components, allow for easy assembly in the field, and require a minimum of custom fabrication.

## Tower Design and Assembly

Inspired by the requirements layed out in the introduction, we describe the design of our tower platform which was initially intended for GPS measurements. We also present the utilization of the tower for eddy covariance measurements. As the main building material for the tower we choose 1 1/2" IPS (48 mm outer diameter) aluminum tubing, which fits perfectly into bore holes from a standard ice auger, is structurally very rigid, and readily available. To create a rigid structure, we connect tube segments of different length with standard industrial fittings as displayed in Figure 1. The following parts are required for building the basic tower:

- 3 x 4 m, 1 1/2" IPS aluminum tubing as anchors (vary these depending on ablation).
- 3 x 2-3 m, 1 1/2" IPS aluminum tubing for tower (vary these depending on accumulation).
- 9 x 0.5 m, 1 1/2" IPS aluminum tubing for cross bracing.
- 3 x NuRail® #70-8 connectors to couple anchors to tower.

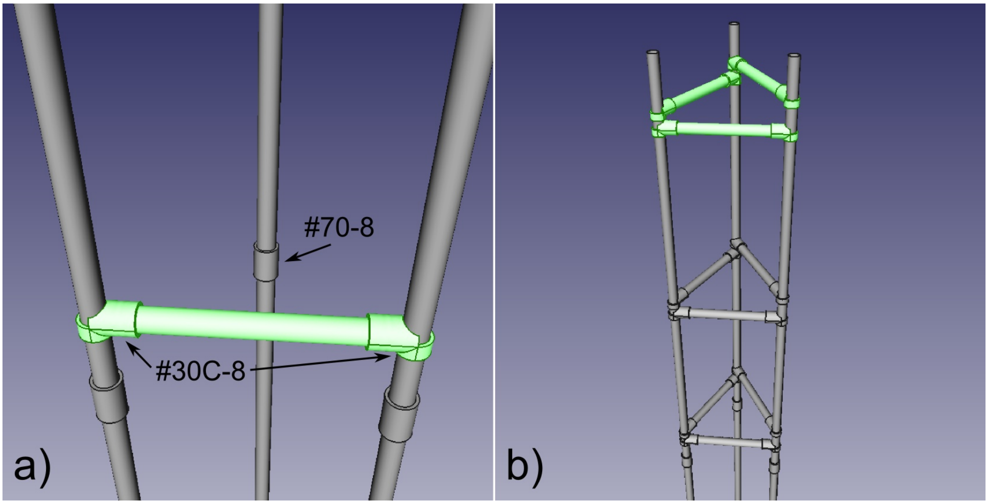


**Figure 1.** A cross brace element of the tower is displayed in (a) and the whole tower setup in (b).

- 9 x NuRail® #30C-8 connectors for cross bracing.

Additionally one can use:

- 3x NuRail® #40-8 flanges to mount the custom top antenna plate.
- 4x NuRail® #7-8 crosses to mount the solar panel.

The vast amount of readily available industrial connectors allows for flexible design solutions, which should be suitable for many glaciological solutions. Assembly of the tower in the field is straight forward and one can use our routine as a guideline:

- Drill three holes vertically in the ice, which fit the three anchor poles and use an assembled cross brace (Fig. 1a) as a distance template between the holes. A water level designed to mount on pipes proved itself to be very useful for vertical drilling.
- Add the three #70-8 connectors to the anchors and mount the three tower poles.
- Use one set of #30C-8 connectors and a 0.5 m pipe segment to build a cross brace.
- Slide three cross braces onto the tower poles to create one level of cross bracing.
- Add three levels of cross bracing to the tower.
- Additionally add a custom top plate and/or the solar panel mounts (#7-8 in our case).

The finished tower can now be instrumented and auxiliary booms can be easily mounted to the rigid structure. Resetting of the tower after a year in the field is simple. One can just unmount the tower from the anchors by opening the #70-8 connectors and the anchors can be re-drilled or one

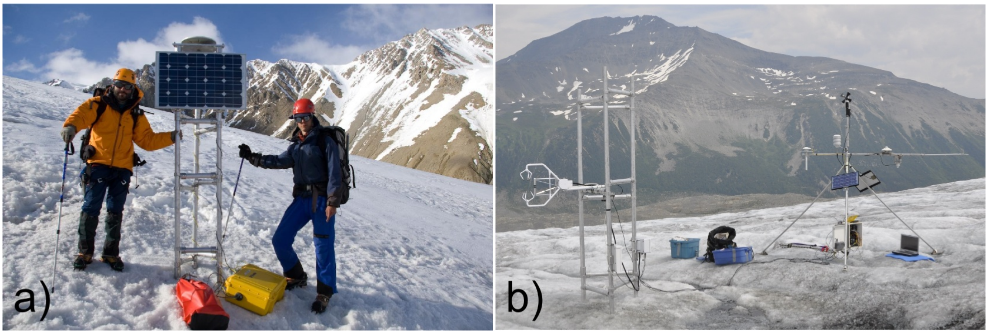


**Figure 2.** GPS tower setup located in Kluane National Park (a) and the eddy covariance setup at Castle Creek Glacier (b).

uses another set of anchor poles to set up the tower beside the old location. Normally two sets of anchor poles are sufficient as the old anchors normally melt out of the ice over the next year.

For GPS applications in Kluane National Park (see Fig. 2), we did not find the need to plug the anchor poles to prevent sinking over time, but this depends on the load of the tower and could easily be done. For the eddy covariance application, large cork stoppers were inserted into the end of the anchor poles and secured with tape. As the poles were inserted into water-filled holes, it became necessary to cut holes into the cork to allow water and air pressures to equilibrate.

## GPS Application

Our tower design is used to measure surface movements on a glacier (60°49'20" N, 139°7'26.8" W) in the Kluane National Park, Yukon, Canada, instrumented with Trimble® R7 receivers together with Zephyr Geodetic antennae, which are mounted with a custom made top plate onto our towers (cf. Fig. 2a). To provide power for a year round operation of the instruments, we use 100 Ah deep-cycle AGM batteries at each tower which are recharged by 50 W solar panels. This setup allows us to measure for 6 hrs each day (9 am to 3 pm local time) at a 1 Hz sampling rate. We limit the measurement time because of little sunlight and cold air temperatures during the winter months which both have negative effects on the battery charge. With this setup several instruments have been measuring glacier motion continuously since 2008 at the field site of G.E. Flowers and C.G. Schoof. So far we have not encountered major difficulties or design flaws during the 3 years of operation.

## Eddy Covariance Application

In the summer of 2010, this tower design was tested as a mounting platform for open path eddy covariance (OPEC) measurements on Castle Creek Glacier (53°2.2' N, 120°24.4' W) in the Cariboo Mountains of British Columbia, Canada. A sonic anemometer (CSAT-3) and krypton hygrometer (KH-

20) were installed on the tower structure, with an initial height of 1.86 m above the ice surface. The CSAT-3 was oriented to minimize turbulence with the tower structure, with the x-axis perpendicular to the dominant down-glacier (katabatic) wind direction. OPEC measurements were collected at a frequency of 20 Hz, and stored on a 2 GB compact flash card using a Campbell® Scientific SC-115 flash storage attachment on the CR1000 datalogger. Near-continuous measurements were collected between August 2$^{nd}$ and August 10$^{th}$, before power issues interrupted the datalogger operation. Two 10 W solar panels were used to trickle charge the 12 V batteries, but cloudy conditions during the observation period limited the battery recharge. Voltages dropped below 10.5 V during the night of August 10$^{th}$, 11$^{th}$ and 12$^{th}$, and the datalogger function stopped completely on August 13$^{th}$. Despite the power supply issues, very useful data has been collected and the tower proved itself to be a very stable mounting platform for eddy covariance measurements over a glacier surface. At a sampling frequency of 20 Hz, the flash card memory allows for approximately 30 days of observations. At high-melt locations, this may be the limit that the tower can be left unattended. For long term measurements we suggest to use 100 Ah deep-cycle AGM batteries and 40-50 W solar panels, which should allow for an operation of the instruments for several months.

## Conclusions

We found the above described tower design to be very suitable for GPS and eddy covariance measurements above glacier surfaces. The design is readily available, only uses off-the-shelf components and can be easily modified to be suitable for many other glaciological applications. Finally, we hope others find this design useful for mounting their instruments and we would be delighted to answer questions or discuss the design further via email.