Automatic Weather Stations on Glaciers

Lessons to be learned
Extended abstracts

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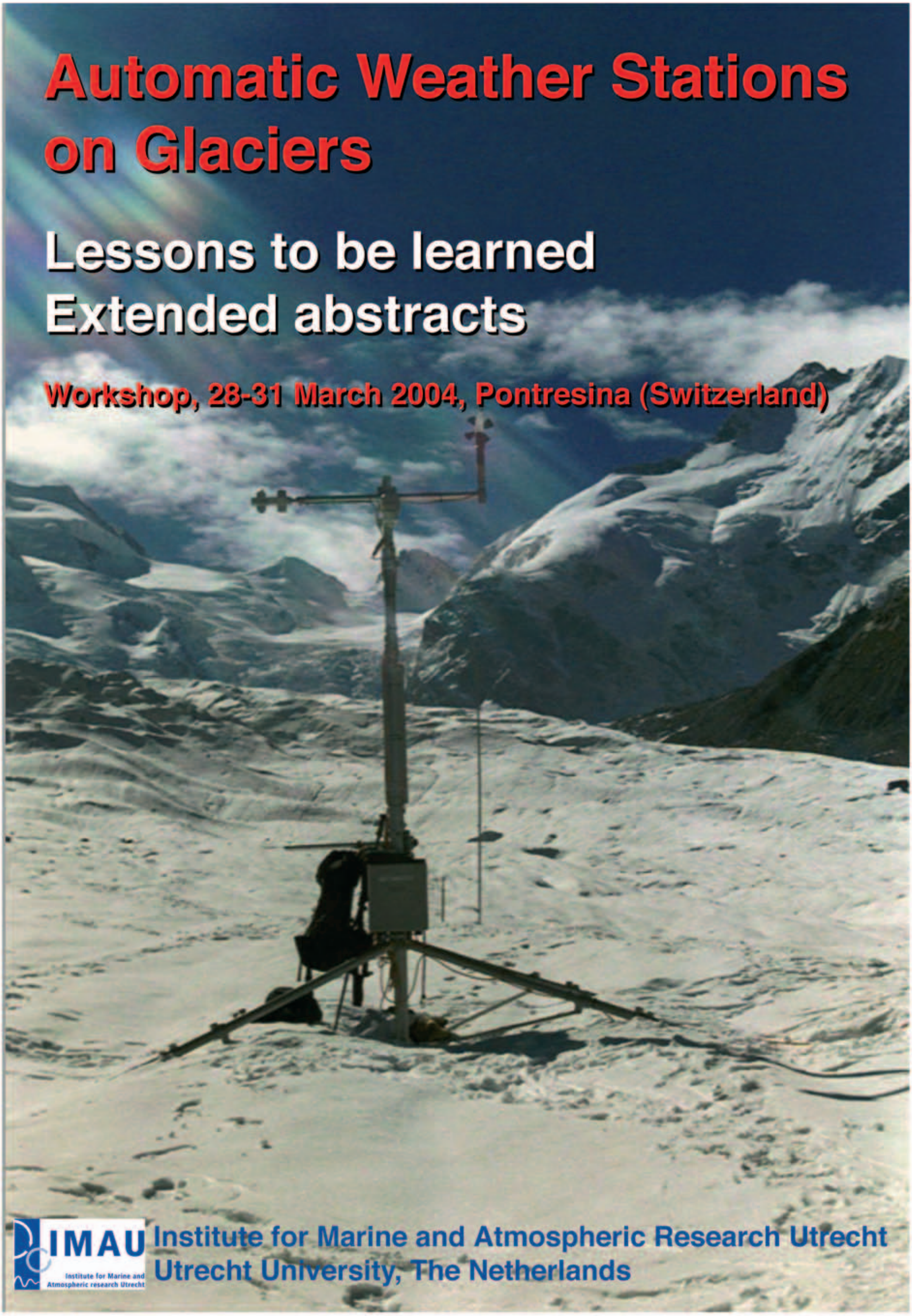

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HIGH-ELEVATION WEATHER STATIONS ON GLACIERS IN THE TROPICS AND THE HIGH ARCTIC

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Our climate research employing automatic weather stations (AWS) focuses on high-elevation glaciers at low latitudes, and on an ice cap at 81°N. Each AWS is designed to operate autonomously and continuously, for a multiyear period. The first of these was deployed in 1996, and two continue to operate in 2004. Design considerations, instrumentation and the performance of each station are illustrated and discussed.

Four high-elevation AWS sites coincide with locations from which ice core records were obtained. Nevado Sajama is in the Cordillera Occidental of Bolivia (Figure 1, left-hand image; 18°06'S, 68°53'W and 6542 m), where an ice core was obtained in 1997 (*1*). Our station operated for four years (*2–6*). Also in Bolivia, we deployed a station in the Cordillera Real at 16°39'S, 67°47'W at 6265 m on Nevado Illimani (*7*) near the site of 1999 ice core drilling (*8–10*). A new station is currently operating on Quelccaya Ice Cap in Perú (13o 56'S, 70o 50'W and 5670 m), where long ice cores were drilled in 1983 and again in 2003. In Africa on the Northern Icefield of Kilimanjaro (3°04'S, 37°21'E and 5794 m), an AWS has operated continuously since 2000 (*11–16*). Our high-latitude site was on the Murray Ice Cap, northern Ellesmere Island (81°21'N, 69°15'W) at an elevation of 1,100 m. Here, an additional AWS on a 10-meter tower operated seasonally through three summers (Figure 1, right-hand image). Measurements were undertaken at this site to better understand glacier-climate interactions, and areal changes in glacier extent through time (*17–19*).

Figure 1: AWS on Sajama (left), Quelccaya Ice Cap (center), and Murray Ice Cap (right).

Design concerns and considerations for the Sajama AWS included uncertainty about the magnitude and inter-annual variability of wet-season accumulation, high wind speed during the winter, and visitation by climbers. Of these, only the magnitude of precipitation presented a significant problem, due to sensor burial and tensioning of guy-wire cables. Additional issues included unreliable GOES telemetry and electrical activity apparently associated with blowing snow and/or convection.

The Illimani AWS design was similar to that on Sajama. Site location was compromised to prevent interference from climbers, leading to unrepresentative temperature measurement and enhanced snow accumulation. High precipitation associated with anomalously low sea surface temperatures in the equatorial Pacific Ocean created hazardous conditions for personnel in September 1999 (7), and prevented visitation of the station in October 2000 and October 2001. Sometime prior to November 2001, accumulation buried the entire AWS and the station has not been recovered. GOES telemetry was also unreliable on Illimani, and on one occasion lightening or stray electrical activity seriously damaged the electronics.

Quelccaya Ice Cap's high accumulation rate (2–5 m; L. Thompson, 2003 pers. comm.), dictated a AWS design in which all sensors were initially 4.5 m above the snow surface (Figure 1). Lightning protection was also incorporated into the design. Shortly after deployment, telemetry via an improved, High Data Rate GOES transmitter ceased. The station will be visited late in March to collect data (hopefully) and ascertain whether the transmitter failed or vandalism occurred.

The AWS design for Kilimanjaro was done without knowledge of the current horizontal surface mass balance regime. Visitation by climbers on this popular mountain was also a concern. Telemetry using Argos was added after the first year, which has performed flawlessly. Excellent overall reliability of the station is aided by low air humidity and high solar radiation (Figure 2), and we therefore hope to continue measurements for the balance of the decade, to better understand the glacier's response to inter-annual climate variability.

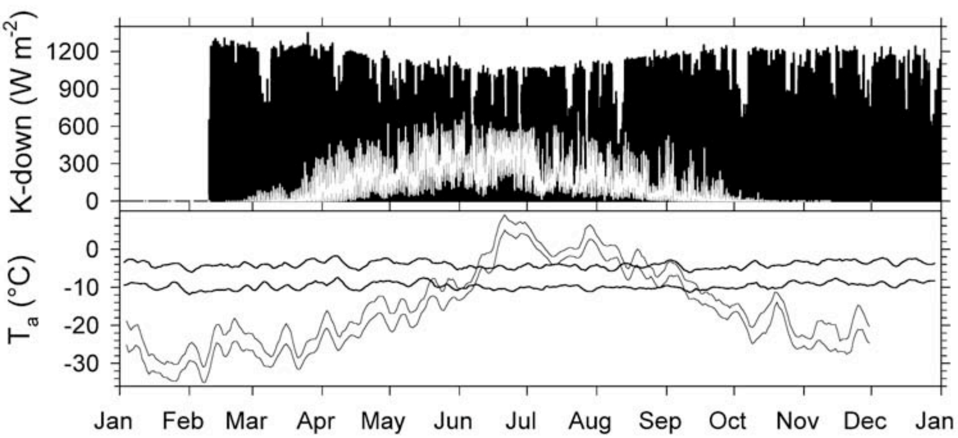

Figure 2: Contrasting seasonality at two AWS sites, with implications for instrumentation and power budgets. Upper panel is global solar radiation (hourly) on Kilimanjaro (black lines) and on Murray Ice Cap (white lines). Lower panel illustrates max/min daily temperatures for the same sites; Kilimanjaro is shown as the darker line.

Design considerations for the AWS on Ellesmere Island were very different from those for the low-latitude sites, due in part to the extreme difference in climate seasonality (Figure 2). At this latitude, virtually no solar radiation receipt for five months each year limits the availability of power. Riming of sensors is problematic through all seasons but winter, but was greatly reduced on radiometers by ventilation. Animal visitation presents a challenge to arctic AWSs, even on glaciers, and at this site a persistent fox eventually penetrated our defenses.

All of these AWS have some components in common, and some are unique. Our experience with the reliability of specific electronics and instruments are also discussed.

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