Results of the 2006 Wēkiu Bug (*Nysius wekiuicola*) Surveys on Mauna Kea, Hawai‘i Island

Hawaii Biological Survey

Final Report **April 2007**

RESULTS OF THE 2006 WĒKIU BUG (NYSIUS WEKIUICOLA) SURVEYS ON MAUNA KEA, HAWAI‘I ISLAND

FINAL REPORT

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EXECUTIVE SUMMARY

As part of a continuing long-term study, the Hawaii Biological Survey of the Bishop Museum was contracted by the Office of Mauna Kea Management (OMKM) to continue its study of the distribution and habitat use of the wēkiu bug (*Nysius wekiuicola* Ashlock and Gagné), which is endemic to the Mauna Kea summit area. Two ten day field trips to study wēkiu bug ecology and distribution occurred in April and May 2006. Another week–long field trip was conducted in October 2006 to retrieve data from temperature loggers that had been installed various locations throughout the Mauna Kea summit in 2005.

Along with collecting wēkiu bug distribution and temperature data, a trapping study continued to determine whether current or historical trapping methods influence wēkiu bug catch effectiveness. Ethylene glycol traps (similar to traps used in earlier studies) and shrimp pitfall traps have been placed in a pairwise fashion at the summit of Pu‘u Hau Kea since 2002. In contrast to the pitfall trapping tests conducted since 2002 that had relatively similar results, ethylene glycol traps were much more effective, with 43 wēkiu bugs captured in glycol traps in both April–May 2006 as compared to only one captured in shrimp traps during the same time period. Because much of the snow had not melted by the end of April 2006, no wēkiu bugs were collected in any type of trap during the April testing. Because these results were so dramatic and the glycol traps have proven to be so effective, the pitfall trapping test has now been terminated.

In 2006 sample effort for wēkiu bugs reached an all time high, with 1048 trap days compared to the previous high of 911 trap days in 2005. The major findings of this study were that the snowy winter of 2005-2006 created ideal conditions for a long-lasting snowpack that appeared to provide favorable conditions for wēkiu bugs. It was previously postulated that an increased snowpack will favor wēkiu bugs because a long-lasting snowpack will provide greater long-term forage opportunities for the eolian drift insects preserved in the snow. Wēkiu bug captures from the 2006 field season appear to confirm this hypothesis, as a record number (114 individuals) were either observed or collected around snowbank areas.

We also found that wēkiu bug activity did not start until 10 days had elapsed after a large series of snow storms that ended on April 2, 2006. When we finally started observing wēkiu bugs on April 13, 2006 much of the snow had melted except for large patches around the summit areas. That none were collected in traps during our April 2006 field trip despite our intensive trapping and visual observations, indicating that wēkiu bugs remain inactive for some time after a period of heavy snow. The bugs must have penetrated fairly deep into the substrate to get away from the surface layer of snow that was over 2-3 m thick drifts in many summit areas.

During the 2006 field season, the nunatak hypothesis postulated by Porter and Englund (2006) for wēkiu bug distribution was successfully tested. This hypothesis states wēkiu bug distribution is related to topography, and that wēkiu bugs currently inhabit only areas of the summit that represented ice-free refugia inside the limit of the glacial ice cap that reached its maximum size about 20,000 years ago, and disappeared by about 16,500 years ago. By examining the geology of unsampled cinder cones, and also unsampled areas of previously sampled cones a predictive list was compiled for environmentally promising habitats to sample for additional bug populations. Several significant and new bug populations were found using these predictions, most notably in areas adjacent to the VLBA facility and areas around the adze quarry.

INTRODUCTION

As part of a continuing long-term study, the Hawaii Biological Survey of the Bishop Museum was contracted by the Office of Mauna Kea Management (OMKM) to study the distribution and habitat use of the wēkiu bug (*Nysius wekiuicola* Ashlock and Gagné), which is endemic to the Mauna Kea summit area. This study continues Bishop Museum wēkiu bug research that originated in the early 1980s (Howarth and Stone 1982), and resumed again in the late 1990s to the present (Howarth et al. 1999, Englund et al. 2002, Englund et al. 2005). To ensure the continued survival of this species, OMKM was interested in obtaining further information regarding wēkiu bugs in the alpine zone of Mauna Kea because so little is known about their life history, population status, and habitat requirements.

The objectives of the 2006 field season were to 1) survey for the presence or absence of wēkiu bugs at the summits of various pu‘u’s (cinder cones) located in the alpine zone of Mauna Kea, 2) determine the elevational and microhabitat distribution of wēkiu bugs on Mauna Kea, 3) assess whether different pitfall trapping methods used in earlier Bishop Museum studies provide comparable data in regard to wēkiu bug captures, 4) assess habitats among different elevations and cinder cone areas, 5) obtain microhabitat data in wēkiu bug habitat using temperature and relative humidity loggers, and 6) to test the wēkiu bug nunatak distribution hypothesis postulated in Porter and Englund (2006).

STUDY AREA

The overall study area for the 2006 field season has been thoroughly described in previous Bishop Museum reports and can be found in Howarth et al. (1982), Howarth et al. (1999), and Englund et al. (2002, 2005). The study area encompassed portions of the alpine zone of the Mauna Kea volcano (Figure 1), including both the Mauna Kea Science Reserve (MKSR) and the Mauna Kea Ice Age Natural Area Reserve (NAR). For the purposes of this study, we defined cinder cones as non-vegetated, dormant volcanic cones in the alpine zone above 9,600 ft (2,925 m). Elevations sampled using pitfall traps during the 2006 fieldwork study ranged from a maximum of 13,570 ft (4,137 m) at the Poi Bowl area below the Keck Observatory, to a low of 11,180 ft (3,402 m) in the northwestern summit area. Visual observations were made throughout the study area while hiking between sampling points.

Sample efforts in 2006 included an emphasis on sampling nunatak areas (summit cinder cone areas that stood above glaciated regions) as outlined in Porter and Englund (2006).

Unless otherwise stated, pu'u names were derived from USGS topographic quad maps. WGS 84 datum was used for recording GPS locations. Many pu'u have not yet been given official names, and when possible these cinder cones are identified by their altitude as stated on USGS topo maps. However, when no altitudes are given names of nearby landmarks or distinctive features were used. These names should not be viewed as official, but rather allow us to more easily identify specific areas of the vast summit region of Mauna Kea. Altitudes were determined using a combination of USGS 7.5 minute topographic quad maps and a handheld Suunto altimeter calibrated daily at Hale Pohaku.

METHODS

Wēkiu Bug Sampling

Sampling methodology consisted of three techniques: timed visual surveys mainly around snowbank areas, baited shrimp pitfall traps, and ethylene glycol pitfall traps. A detailed explanation of techniques for shrimp and ethylene glycol pitfall traps used in this study can be found in Englund et al. (2002). Individual pitfall trap locations were recorded with GPS (WGS 84 datum), as were locations where wēkiu bugs were visually observed. As in the 2002-2005 Bishop Museum studies, an efficiency test of the two main types of pitfall traps used in wēkiu bug surveys was conducted both in April and May 2006. The detailed protocol for the trap efficiency test can be found in Englund et al. (2002). As in previous studies, to ensure sampling was not just selective for known good wēkiu bug habitats pitfall traps were placed in a wide range of putatively suboptimal habitats, as well as potential habitat. Locations, elevations, cinder cone area and trap type can be found in Tables 1 and 2 for the April and May 2006 sampling. A total of 5 glycol and 5 shrimp pitfall traps were placed at Pu'u Hau Kea for 9 days in the months of April and May 2006 (Tables 1 and 2).

Temperature/Relative Humidity Probes

To obtain wēkiu bug microhabitat data in a wide variety of known and nearby suboptimal habitats (e.g., glaciated regions between cinder cones) 47 HOBO® Pro RH/Temp (Model H08-032-08) temperature probes were placed near the surface and buried 10 in (25 cm) into the substrate in 2006 (Table 8). Loggers were placed in a wide variety of other locations, in areas known to support high wēkiu bug densities, as well as areas where the bugs have not normally been captured (Figure 5).

These loggers record and store relative humidity and temperature data for a period of up to three years. It was necessary to provide a housing for the loggers to protect against contracting, expanding, and shifting substrates in the harsh environment of the Mauna Kea summit area. Following tests of various protective cases during the preceding study, PVC pipe caps with ventilation holes drilled in them were deemed to have the best protective qualities (Englund et al. 2005). The PVC cap fit snugly around the loggers, and was connected with stainless steel wire to protect the humidity sensor and prevent direct ground contact. Holes drilled in the cap also allowed drainage of any rainwater or snowmelt and provided air circulation. In areas of known wēkiu bug habitat (such as the summit of Puʻu Hau Kea or Puʻu Lilinoe) the loggers were placed in the exact locality where individual wēkiu bugs were observed or collected.

The first major logger installation was in December 2004, with paired loggers were placed just below the surface and covered with local substrate, and also buried approximately 10 in (25 cm) below the surface. Loggers were connected by approximately 3 ft (1 m) of stainless steel wire (also with flagging tape attached) to make future retrieval easier, as finding loggers was quite difficult because of their small size and high altitude effects (on researchers) within the study area.

A total of 9 pairs of loggers (18 total) were placed in a transect at Puʻu Hau Kea running through the summit cone area (Figure 6), starting at the bottom of the northwest rim and extending in a southeasterly direction into the cinder cone and down the slope to the bottom of the Puʻu Hau Kea cinder cone. These loggers recorded conditions within the Puʻu Hau Kea crater and outermost slopes, an area with some of the highest known wēkiu bug densities on Mauna Kea (Englund et al. 2002). Each logger pair consisted of one surface and one buried in the cinder to approximately 10-12 in (25-30 cm).

<u>Statistical Analysis for Temperature/Relative Humidity Data</u>

After temperature data were downloaded from the loggers to an excel spreadsheet, data were summarized and graphs and statistics were done with Sigma Plot version 10. We reduced the number of points per day (decreased the resolution) from 48 points per day (from 1 data point recording every 30 minutes) to 6 temperature/relative humidity points per day (1 every 4 hours) to better visualize and analyze the data. By doing this general trends in the data remained the same. Combined year–long data is graphed from a single temperature and relative humidity data (HOBO™) loggers collected and replaced in sequence in the exact location as the other, after replacement of loggers, with the loggers last replaced in October 2006. Both surface and subsurface loggers were placed at these locations. Due to apparent manufacturing or software errors, some of the loggers failed between the yearly data collection intervals and in 2005 this rate was at least 40%, while during the current study the failure rate decreased to around 10%. However, because the large number of data points for a single year made the graph busy and difficult to read, not all of these graphs are shown. Graphs with easily discernible relationships are shown in Appendix A as Figures 42-57.

The surface temperature (°C) and relative humidity (%) graphs (Figures 42–57) are indicative of slight but potentially important microclimate structure between areas. There are two sets of graphs with data displayed differently from identical locations. The first set of graphs includes Figures 7–41 that takes one daily mean temperature from the 48 daily readings (once every 30 minutes) for each logger, with the error bars indicating the standard deviation. Figures 7–41 have a single data point for each day, that is the combined mean for that day and the standard deviation is indicative of the variability for that day. The standard deviation of each mean is graphed and indicates the degree of variability within that day. Table 8 indicates the logger location in WGS 84 coordinates with pulled and replacement loggers for all of the sampled areas

For the second set of graphs (Figures 42-57), each graph encompasses 365 ± 3 days and each point is the mean of six points per day, with the x-axis of each graph starting at December 1, 2005 and ending on November 1, 2006. Actual logger points started on December 14, 2005 and ended on October 4, 2006. There are 2 y-axis scales per graph, with the left y-axis scale ranging from –10°C to 40°C, while the right y-axis indicates the relative humidity which to allow for better visualization purposes is from –20% to 110%.

Linear regressions were not used in 2006 because in contrast to the 6–month data set available in 2005, we had a full year of data and seasonal fluctuations in temperature would have invalidated a linear regression. In some sites we will have two years of nearly continuous data, which will be presented in next years' field trip report. At Pu‘u Hau Kea a transect of 18 surface and sub loggers placed at regular intervals up the sides of the cinder cone, down into the pit crater, and down the other side of the cone was made. Next years report will include a

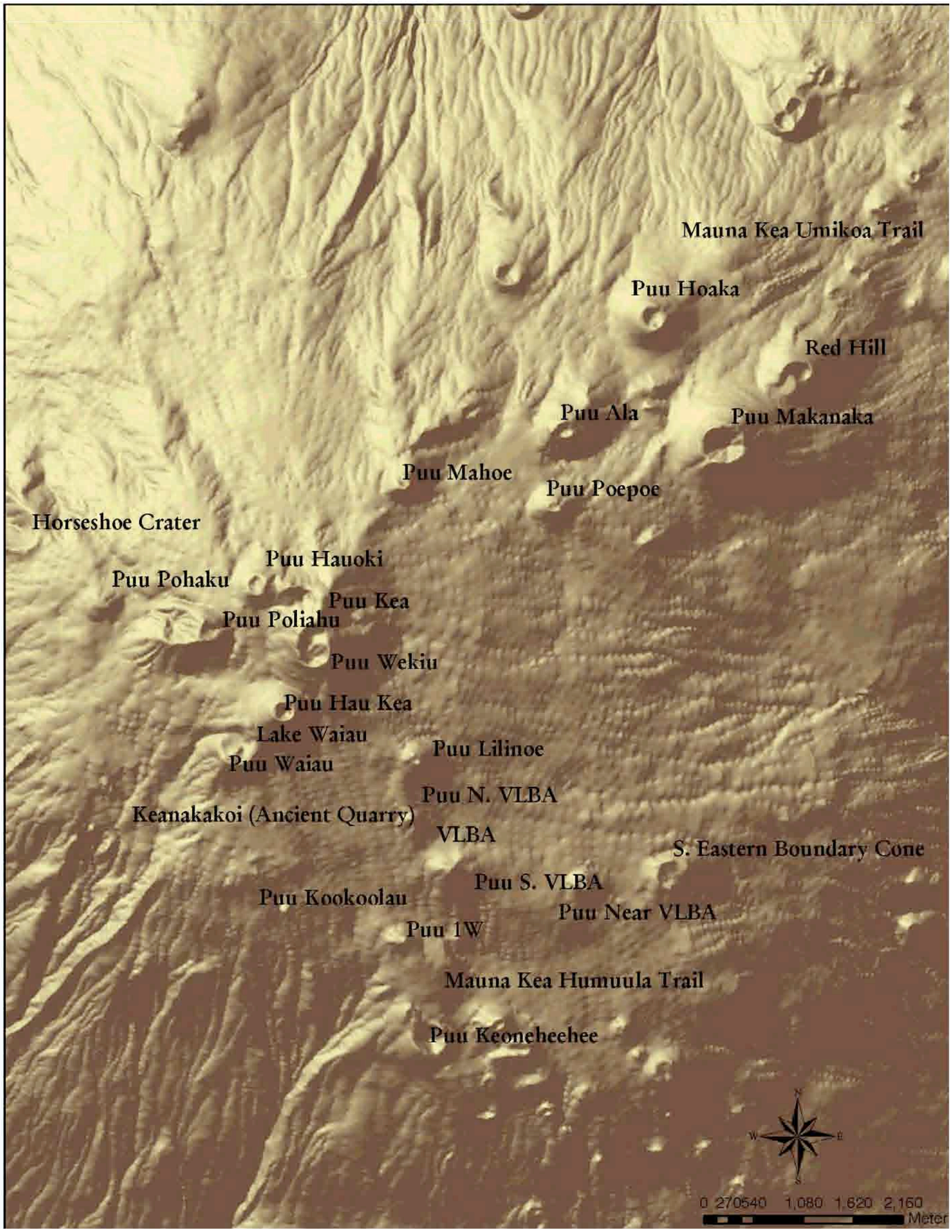

Figure 1. Overall study area and wēkiu bug sampling sites, and major sampling sites for 2006 fieldwork.

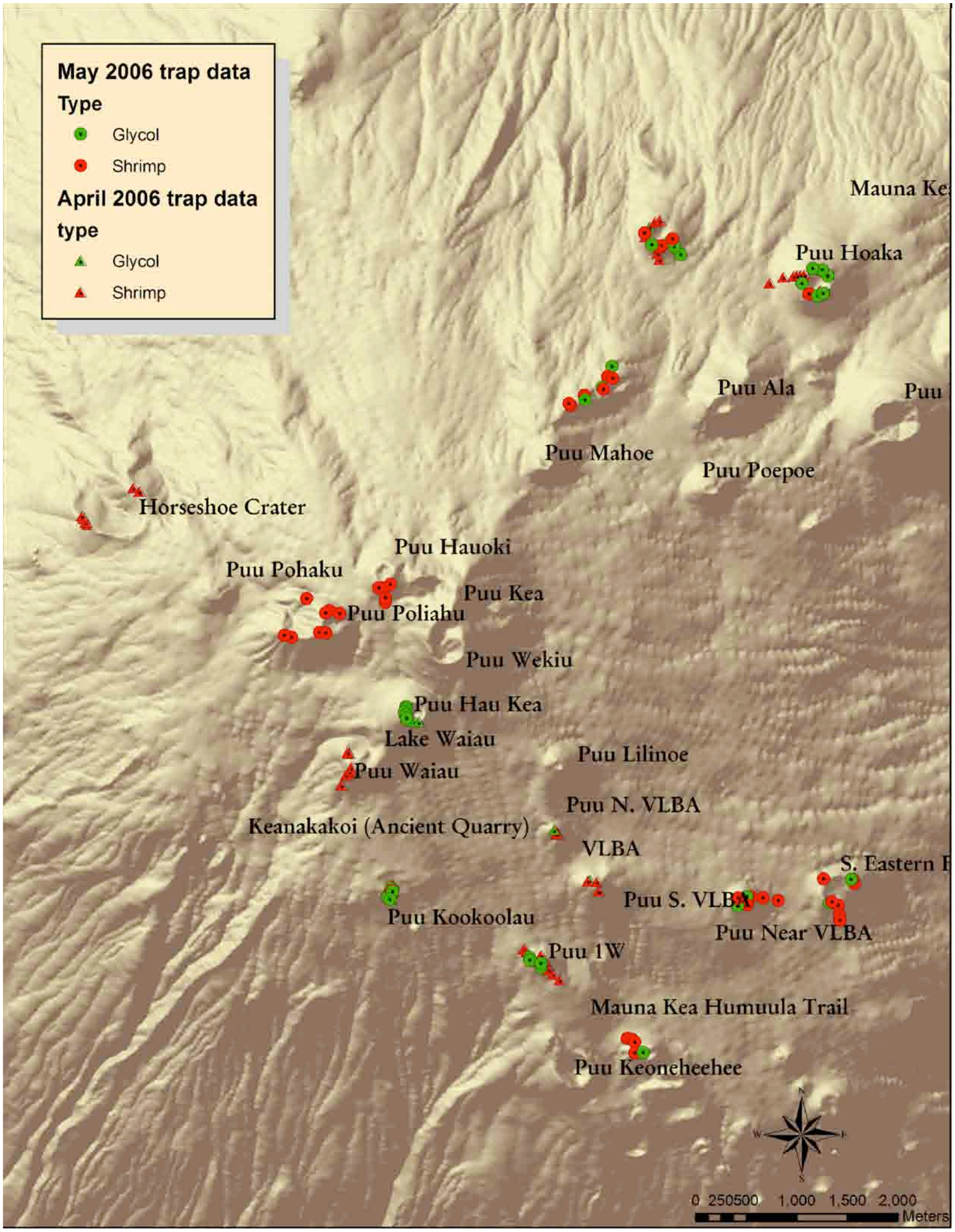

Figure 2. Overall study area and wēkiu bug sampling sites, and GPS waypoints at sample sites for 2006.

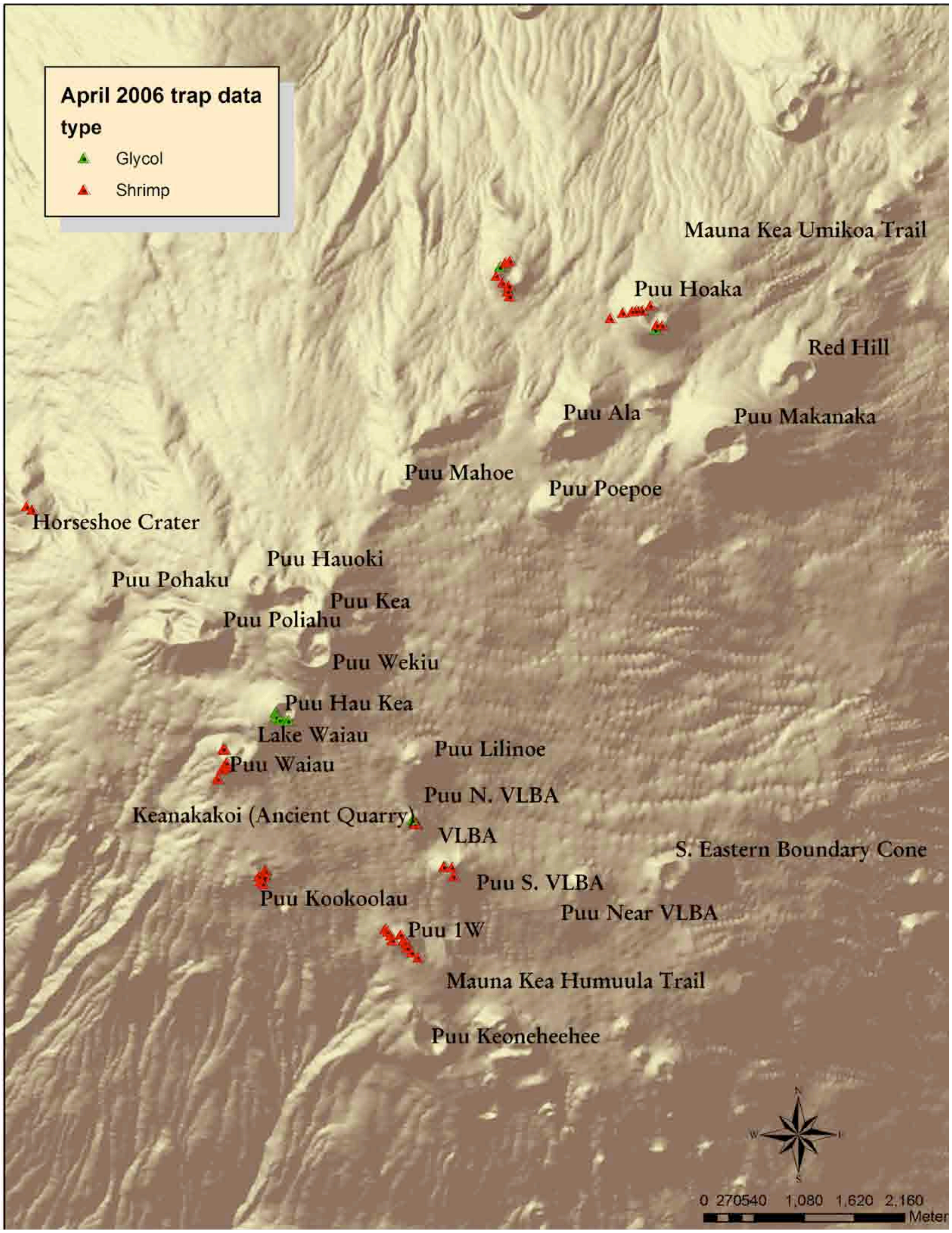

Figure 3. Trap type and locality information for April 2006.

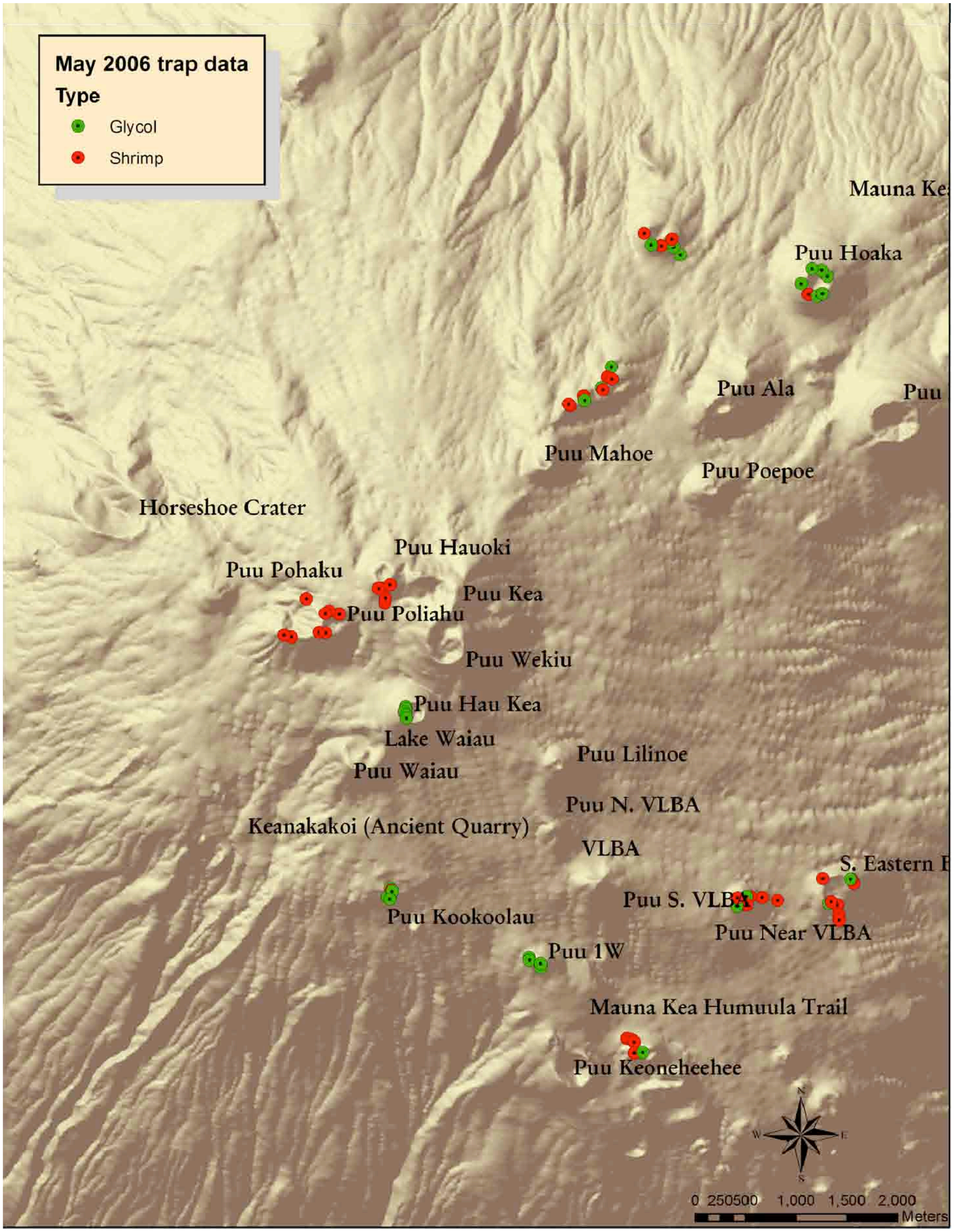

Figure 4. Trap type and locality information for May 2006.

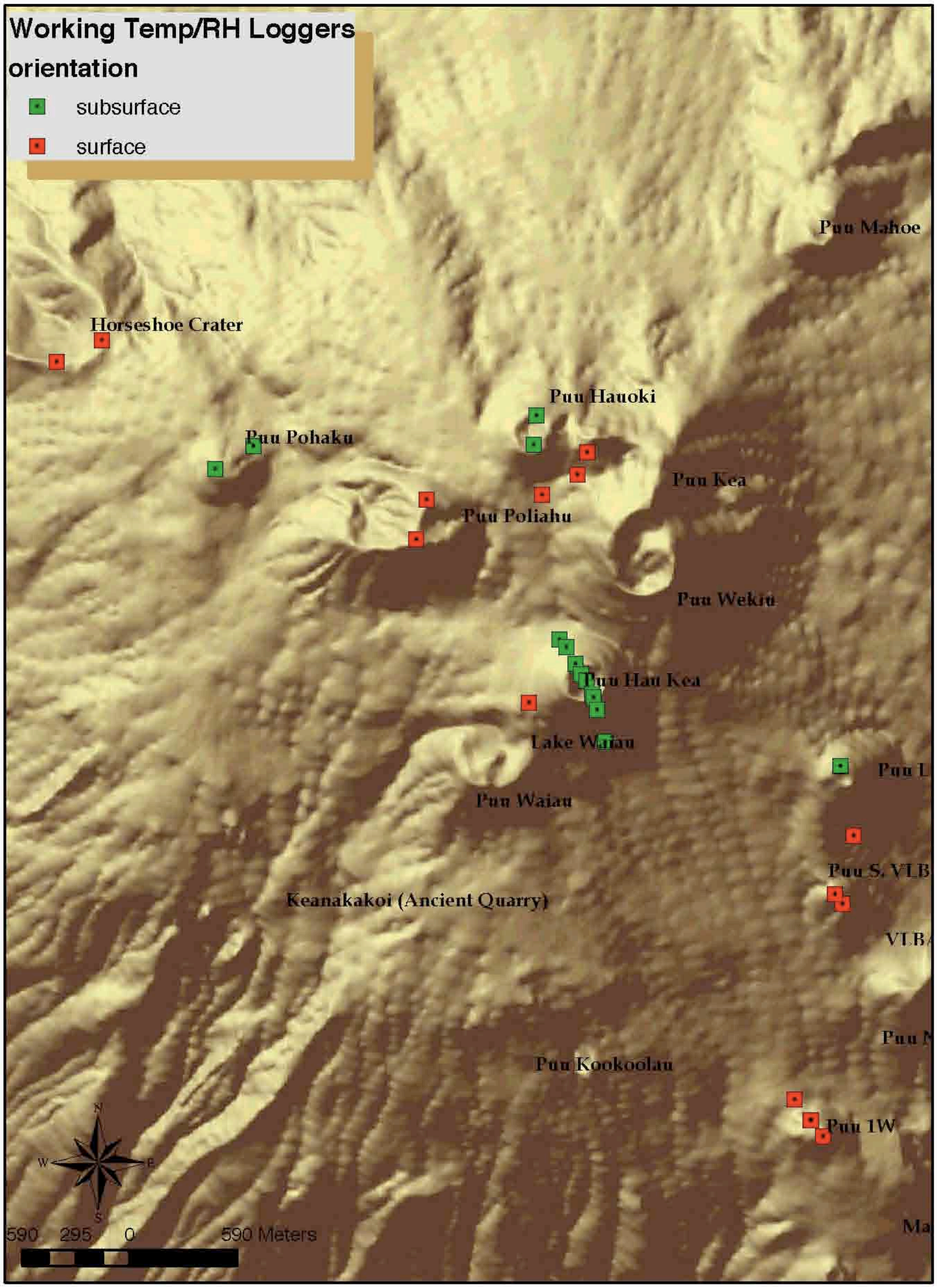

Figure 5. Temperature/Relative Humidity Data Loggers currently collecting data at the summit of Mauna Kea.

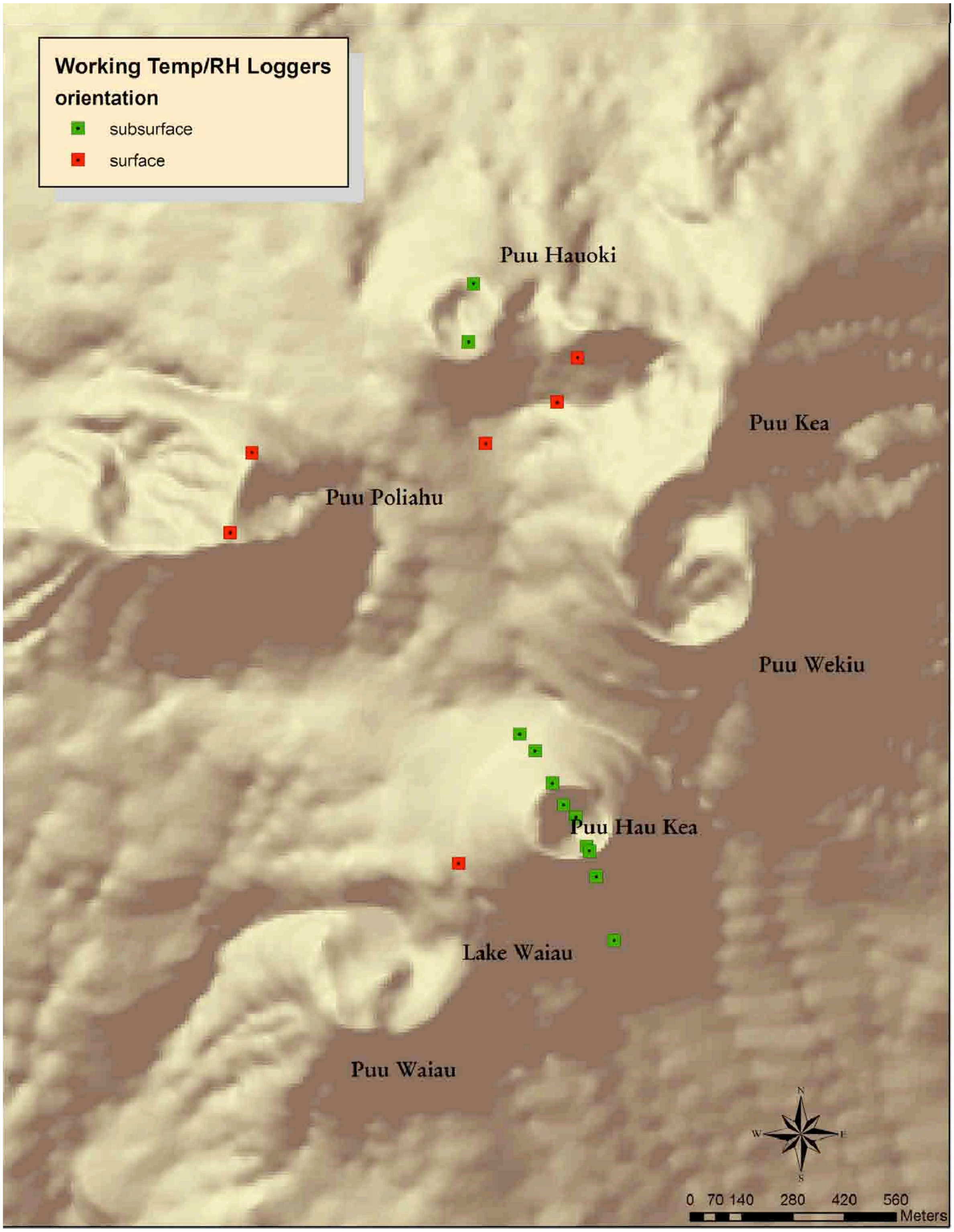

Figure 6. Close up of Temperature/Relative Humidity Data Loggers currently collecting data in the Pu'u Hau Kea region.

statistical analysis to assess if the observed temperature and relative humidity differences between the summit and base of Pu‘u Hau Kea are statistically significant.

RESULTS AND DISCUSSION

In 2006, the study period included two trips of 10 field days each in early April and early May, a one-day trip in June to recover a trap covered by snow in April–May, and a four-day trip in October to download and reinstall relative humidity and temperature loggers. The winter months 2005–2006 were particularly moist on the summit of Mauna Kea, and a nearly continuous series of wet weather events from February to April 2006 left a significant snow pack at the summit. National Weather Service information (from National Weather Service website at http://www.prh.noaa.gov/hnl/pages/events/weeksrain/weeksrainsummary.php) indicated that between February 19 and April 2, 2006 5 winter weather advisories, 2 winter storm watches (indicating snowfall of 2–5 inches), and 1 winter storm warning (indicating snowfall of 6 inches or more) were issued. This wet weather pattern was caused by a weakened jetstream in conjunction with a weak La Niña pattern, which kept storm systems locked into place as normal trade winds were much reduced. Moisture-rich Kona storms were created again and again by low pressure systems to the west which would weaken, then gain energy to create another storm. Strong southwest winds would dip as far south as 5 degrees north latitude and draw into the tropical equatorial moisture and transport it over the state (National Weather Service 2006). Not only did this result in heavy flooding throughout the state, but the summit of Mauna Kea was heavily hit by a series of snowstorms. Above 3,650 m (12,000 ft) the National Weather Service estimated 0.6–1.2 m (2–4 ft) of snow fell from February 19–April 2, 2006, and several times the snowfall was accompanied by strong winds resulting in snow drifts of greater than 2 m (6 ft). This actual snowfall total may be an underestimate, and recently raingage data from the Subaru facility has been found but not yet compiled that could lead to a more accurate compilation of snowfall totals at the summit area (Ryan Lyman, pers. comm.).

The snowy winter of 2005–2006 created ideal conditions for a long-lasting snowpack that appeared to provide favorable conditions for wēkiu bugs. It has been postulated that an increased snowpack will favor wēkiu bugs because a long-lasting snowpack will provide greater long-term forage opportunities for the aeolian drift insects that are preserved in the snow (Howarth and Stone 1982). Wēkiu bug captures from the 2006 field season appear to confirm this hypothesis, as a record number were either observed or collected around snowbank areas during this field season.

Tables 1 and 2 summarize trap locations by cinder cone, elevation, date set, trap type, and GPS coordinates. Overall 2006 sample effort was a total of 158 traps, with 70 shrimp and ethylene glycol pitfall traps emplaced in April and 88 in May. Summaries of the numbers of wēkiu bugs either observed or collected during 2006, and sample effort can be found in Tables 3–6.

Sample effort is defined by total trap days, which are the number of nights each baited shrimp or ethylene glycol pitfall trap was operating. Because of increasing field crew efficiency, pitfall trap effort in 2006 was the highest yet with 454 trap days in April and 594 trap days in May, for a total effort of 1048 trap days. This compares to 911 trap days in 2005, 274 trap days in 2004 (Englund et al. 2005) and 398 trap days in 2002 (Englund et al. 2002).

Trap Placements in Study Area

A total of 158 pitfall traps, built and emplaced according to protocols discussed in the Methods section, were set in various cinder cone areas at elevations from 3,505–4,172 m during fieldwork in April and May 2006 (Tables 1 and 2). Sampled areas included the main summit area including Pu‘u Hau Kea and the adjacent Pu‘u Waiau and Pu‘u Ko‘oko‘olau. For the first time traps were set for wēkiu bugs in the northeastern summit area around Pu‘u Hoaka, including the remote and difficult to access cinder cones around there and Pu‘u Mahoe. Traps were also placed in the lowest elevation areas that wēkiu bugs have been captured so far, the region south east of the VLBA facility. As much as possible trap placement in 2006 was a test of the nunatak hypothesis put forth by Porter and Englund (2006).

Wēkiu Bug Collections and Trapping Effectiveness

A total of 119 wēkiu bugs were observed or collected during the 2006 field year, with individuals collected from April to October (Table 3). Since 2002 (but not including the 2006 field season), a total of only 128 wēkiu bugs have been collected during Bishop Museum surveys, indicating that although locally common in a few areas, this species is at least cyclically rare throughout its overall range at the Mauna Kea summit. The main objective of current and previous wēkiu bug surveys has been to determine overall distribution and abundance of the bugs throughout their range; these data will ultimately aid in conservation planning.

In 2006, many more wēkiu bugs were collected during the May trip, with 101 individuals found as compared to only 13 during April (Table 5). It must be emphasized that during the April trip the 13 individuals were found (through visual observations) only on the last day of the field trip, despite similar efforts during the preceding ten days of that trip. The complete absence of wēkiu bugs except for the last day of the study appears to result from the fortuitous timing of the April field trip, as we started field work after the end of a long series of snow events. The last snow storm ended on the morning of 2 April, and our April sampling began the next day. Wēkiu bug activity did not start until 10 days had elapsed after the 2 April storms and by that time much of the snow had melted except for large patches around the summit areas. That none were collected in traps during April despite our intensive trapping and visual observations indicates that wēkiu bugs remain inactive for some time after a period of heavy snow. The bugs must have penetrated fairly deep into the substrate to get away from the surface layer of snow that drifted over 2–3 m deep in many summit areas.

There were more snow events between the April 2006 field trip which ended on 13 April, and the beginning of our next trip which started May 9th, as several glycol traps left in place during the April trip were completely covered with snow as late as until the end of the May field trip. For example, a gycol trap was placed at the summit of an unnamed pu‘u immediately north of the VLBA facility on the 9 April but could not be retrieved in May because high snow drifts completely covered much of the summit area of that pu‘u (Table 6).

Wēkiu bug activity was very high in May 2006, with a total of 101 bugs captured or observed during the May field trip (Table 6). In contrast to April 2006, wēkiu bugs were common throughout the May and found along the melting edges of snowbanks in various cinder cone areas (Table 6). One surprising finding was the lack of wēkiu bugs in apparently good habitats such as the remote Pu‘u Mahoe cone area. In 2006, wēkiu bugs were not collected here or at the nearby 11,989 pu‘u, despite ideal conditions at other areas of the summit. It is speculated that this northeast summit area is generally higher in elevation, and perhaps it had not enough time to warm up as compared to the lower elevation areas such as those around the VLBA.

Ethylene Glycol versus Shrimp Paste Pitfall Trapping Test

In contrast to the pitfall trapping tests conducted since 2002 that had relatively similar results, ethylene glycol traps were much more effective, with 43 captured in glycol traps in both April–May 2006, as compared to only one captured in shrimp traps during the same time period. Ethylene glycol traps (here after “glycol traps”) and shrimp pitfall traps have been placed in a pairwise fashion at the summit of Pu‘u Hau Kea since 2002, with traps placed approximately 5 m apart along the summit of this cinder cone. Because much of the snow had not melted by the end of April 2006, we no wēkiu bugs were collected in any type of trap during the April testing. As these results were so dramatic and the glycol traps have proven to be so effective that the pitfall trapping test has now been terminated. Because the trapping test results since 2002 have been relatively even and the current studies results were quite lopsided, there is no formula or correction factor that we can provide to adjust for glycol trapping test results conducted during earlier Bishop Museum tests in the 1980s (Howarth and Stone 1982), to compare to current pitfall trapping methods. It now can be said under that under certain conditions glycol traps are at least 40 times more effective than shrimp pitfall traps.

Optimal conditions in May allowed us to set alternating shrimp and glycol traps above and below thick snowbanks at the rim Pu‘u Hau Kea. Under these conditions wēkiu bugs were definitely more attracted to the glycol traps, confirming earlier hypotheses that lycosid spiders and other factors may limit the effectiveness of shrimp traps at certain times. Because the large native Mauna Kea lycosid is able to freely go in and out of the shrimp pitfall trap, it is possible they remove wēkiu bugs from the traps, or the bugs may be able to escape the cups when the sides become abraided by blowing sand particles. In any case, once the bugs and spiders go into the glycol they definitely do not escape, and counts in these traps are much more definitive. Also of note is the fact that far less shrimp bait is used in the glycol traps, with just a small amount of paste dabbed on the lip of the cup, as compared to the large amounts of rehydrated shrimp and shrimp paste used for the shrimp pitfall traps. It is possible that ethylene glycol itself or in combination with the other dead insects floating in the trap is also an effective attractant for the wēkiu bugs.

The May 2006 trap test on Pu‘u Hau Kea indicated that large numbers of wēkiu bugs can be collected in a short period of time, even when natural forage is plentiful in the adjacent snow banks. While the ethylene glycol pitfall traps outperformed the shrimp pitfall traps by a factor of 43-1 in May 2006, wēkiu bugs were not captured in either trap type during April sampling, likely because (as mentioned earlier) bugs were inactive after the long period of snow storms. Wēkiu bugs were apparently inactive for at least 10 days after the major snowstorm of ending April 2, 2006 around the summit, when much of the upper summit cinder cone areas were completely covered in snow.

Nunatak Hypothesis Test and New Wēkiu Bug Populations

Porter and Englund (2006) found that the distribution of wēkiu bugs is related to geomorphology: wēkiu bugs have been found predominantly on or near the crater rims of cinder cones that formed nunataks (ice-free areas rising above a surrounding glacier) during the last glaciation or that lay at the glacier limit. Of particular interest was the finding that wēkiu bugs are currently only inhabiting areas of the summit that lie within the limit of the glacial ice cap that reached its maximum size about 20,000 years ago, and disappeared by about 16,500 years ago. The highest cinder cones inside the ice limit rose above the glacier, forming nunataks in the summit region.

By analyzing historical wēkiu bug capture data, Porter and Englund (2006) found that the increasing altitude of such sites parallels the rise of the glacial-age snowline across the upper slopes of the mountain. The preferred habitat of the bugs was found to be on cinders and spatter near the unmodified crests of cinder cones; the crests of glacially overridden cones apparently lack suitable habitation sites. More significantly, wēkiu bug habitats were found by Porter and Englund (2006) to be concentrated on these cones in areas where seasonal snow remains longest, i.e., on north- and east-facing slopes and on slopes shaded by local topography. Such snow patches increase in number and area with increasing altitude above the limit of glaciation (3,800 m). Below the glacial limit, seasonal snow quickly disappears and wēkiu bugs have not been found. The moist margins of snow patches are places where eolian detritus is concentrated during ablation, thereby providing a rich source of food for wēkiu bugs.

Because an apparently convincing relationship between the glacial geology of the Mauna Kea summit region and wēkiu bug habitat use was found, Porter and Englund (2006) recommended on a geological basis several new areas to closely examine or resample for additional bug populations. By examining the geology of unsampled cinder cones and also unsampled areas of previously sampled cones in March 2006 (prior to the 2006 field season) a predictive list of environmentally promising habitats to sample was completed. The list emphasized nunataks and cinder cone areas close to nunataks, and areas near or within the glacial limit, as well as known areas of late-lying snow. This table has been updated with the results of the current 2006 field report, and several new wēkiu bug populations were found, most notably a significant population around cinder cones immediately adjacent to the VLBA facility and at Puʻu Koʻokoʻolau. Additionally, wēkiu bugs were caught consistently but only in one individual trap at a nunatak southeast of the VLBA facility that was pinpointed in Porter and Englund (2006). This nunatak was approximately 0.4 ha in size and was located at the very small outlying cone southeast of the VLBA facility (referred to as Puʻu 11,910 in Englund and Porter). Wēkiu bugs appear to be surprisingly restricted to non-glaciated habitats as they were not caught at traps in the glaciated regions of the same 11,910 cone, even though such areas were less than 20-30 m away.

Temperature RH/Loggers

Cinder cone areas where data loggers were installed and downloaded can be found in Table 8. Data were downloaded from the loggers in October 2006, and in contrast to last year the malfunction rate was greatly lowered from over 50% to around 10%. Downloaded data provides a unique wēkiu bug level representation of ground temperatures and ground humidities over a broad range of optimal and sub optimal habitats. Logger data illustrated in Figures 7–57 provides nearly a full calendar year of both winter and spring ground temperatures, with the first set of graphs (Figures 7–41) providing a summary of the mean daily temperature and standard deviation of the mean, and are useful in examining seasonal temperature trends and variability in daily temperatures. The second set of graphs (Figures 42-57) compiles 6 data points/day from temperatures taken every 4 hours. Not all loggers were included in the second set of graphs as the data were difficult to read in a graphical format due to the wide daily temperature variability at some locations.

Temperature data of interest in 2006 was the long period of time at the summit between the months of February to April when the loggers were buried with snow and had little daily variability. The spring months (mainly May to June) when wēkiu bugs are most active exhibited dramatic daily shifts in temperature. The summer months exhibited even greater daily variations.

Our statistical analysis will continue in next years' final report using a loess distribution to characterize the sigmoidal fluctuation of each area, and then compare that characterization to other areas on each cinder cone, and between the cinder cones.

Mauna Loa bug observations

The Mauna Loa bug (*Nysius aa* Polhemus) is the sister species to the wēkiu bug and is found only on the upper slopes of Mauna Loa. Because so little is known about this species a brief field reconnaissance trip to the Mauna Loa summit was undertaken during off days at Mauna Kea in April and May 2006 to learn more about this sister species to the wēkiu bug. Because it has been only sporadically collected, much less is known about the biology and ecological habits of the Mauna Loa bug, with fewer than 15 individuals collected prior to the current study (Bishop Museum Collection Data). Because they are apparently so closely related (Polhemus 1998) any ecological information on the Mauna Loa bug will lead to a greater understanding about wēkiu bug habitat requirements.

Thus, on 10 April and 13 May 2006, a series of shrimp pitfall traps were set and visual observations were made along the trail from above the parking lot of the Mauna Loa Observatory (MLO) (3,437 m) to the summit of Mauna Loa (3,964 m). The results (see Table 7) are of great interest because the Mauna Loa bug appears to be much more abundant within a broader range of habitat types than the wēkiu bug. For example, during the April 2006 sampling wēkiu bugs were entirely dormant for at least 10 days after a series of winter storms. In contrast, 13 Mauna Loa bugs were captured in just a matter of several hours during the same time period when wēkiu bugs were inactive. While wēkiu bugs have been captured almost entirely within non-glaciated portions at the upper summit area of individual cinder cones, Mauna Loa bugs have a much broader distribution. Only a few cinder cones are found around the Mauna Loa summit area; and all were formed after the Pleistocene glaciation that has so influenced the topography of Mauna Kea (Porter 2005). Thus nunatak habitats are entirely absent from Mauna Loa. This apparently does not adversely impact the highly adaptable Mauna Loa bug.

Mauna Loa bugs were most abundant in cinder habitats such as in 19.50543°N 155.57973°W in April 2006, or at 19.50520°N 155.57959°W in May 2006, and were less common (i.e., not observed at all) in pahoehoe habitats. Traps in and around aa lava flows generally had cinder nearby, where the adult and juvenile Mauna Loa bugs were common. In May, most Mauna Loa bugs were captured during visual observations by brushing away the top most 1.0–2.5 cm layer of cinder of which they were taking shelter under. Wēkiu bugs are usually observed moving fast on top of the substrate, while the Mauna Loa bugs seem to usually be underneath the top layer of substrate. Curiously few to no dead invertebrates were observed in the cinders where Mauna Loa bugs were abundant in May. Qualitatively, this observation was in contrast with high densities of freshly dead eolian detritus found in virtually all of the Mauna Kea cinder cone summits. The large native Lycosid spider was the only other major arthropod in found in abundance at the Mauna Loa summit. Only a few dead lady beetles (Coccinellidae) were observed in the cinders where the Mauna Loa bugs were found, along with a few dead Mauna Loa bugs (dead wēkiu bugs are almost never found). Further studies comparing the amount of forage available between Mauna Kea and Mauna Loa would be of great interest as there appeared to be relatively little for the Mauna Loa bugs to eat.

Table 1. Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in April 2006 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2006 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Hau Kea	1s	4–13 April	4,128 m	19.81395°N 155.47350°W	Shrimp
Pu‘u Hau Kea	1g	4–13 April	4,128 m	19.81395°N 155.47350°W	Glycol
Pu‘u Hau Kea	2s	4–13 April	4,127 m	19.81354°N 155.47342°W	Shrimp
Pu‘u Hau Kea	2g	4–13 April	4,127 m	19.81354°N 155.47342°W	Glycol
Pu‘u Hau Kea	3s	4–13 April	4,125 m	19.81324°N 155.47307°W	Shrimp
Pu‘u Hau Kea	3g	4–13 April	4,125 m	19.81324°N 155.47307°W	Glycol
Pu‘u Hau Kea	4s	4–13 April	4,119 m	19.81318°N 155.47256°W	Shrimp
Pu‘u Hau Kea	4g	4–13 April	4,119 m	19.81318°N 155.47256°W	Glycol
Pu‘u Hau Kea	5s	4–13 April	4,116 m	19.81316°N 155.47217°W	Shrimp
Pu‘u Hau Kea	5g	4–13 April	4,116 m	19.81316°N 155.47217°W	Glycol
Pu‘u Waiau	1	4–13 April	4,008 m	19.81023°N 155.47867°W	Shrimp
Pu‘u Waiau	2	4–13 April	4,008 m	19.81023°N 155.47867°W	Shrimp
Pu‘u Waiau	3	4–13 April	4,011 m	19.81033°N 155.47881°W	Shrimp
Pu‘u Waiau	4	4–13 April	4,016 m	19.80848°N 155.47862°W	Shrimp
Pu‘u Waiau	5	4–13 April	3,950 m	19.80740°N 155.47934°W	Shrimp
Pu‘u Waiau	6	4–13 April	3,992 m	19.80834°N 155.47891°W	Shrimp
Pu‘u Waiau	7	4–13 April	4,018 m	19.80868°N 155.47859°W	Shrimp
Pu‘u Waiau	8	4–13 April	4,038 m	19.80898°N 155.47844°W	Shrimp
Pu‘u Hoaka	1	5–12 April	3,689 m	19.85217°N 155.43436°W	Shrimp
Pu‘u Hoaka	2	5–12 April	3,712 m	19.85177°N 155.43506°W	Shrimp
Pu‘u Hoaka	3	5 Apr–10 May	3,712 m	19.85177°N 155.43506°W	Glycol
Pu‘u Hoaka	4	5–12 April	3,687 m	19.85222°N 155.43491°W	Shrimp
Pu‘u Hoaka	5	5–12 April	3,684 m	19.85413°N 155.43558°W	Shrimp
Pu‘u Hoaka	6	5–12 April	3,699 m	19.85361°N 155.43642°W	Shrimp
Pu‘u Hoaka	7	5–12 April	3,685 m	19.85356°N 155.43678°W	Shrimp
Pu‘u Hoaka	8	5–12 April	3,676 m	19.85357°N 155.43709°W	Shrimp
Pu‘u Hoaka	9	5–12 April	3,656 m	19.85349°N 155.43744°W	Shrimp
Pu‘u Hoaka	10	5–12 April	3,629 m	19.85337°N 155.43840°W	Shrimp
Pu‘u Hoaka	11	5–12 April	3,590 m	19.85282°N 155.43968°W	Shrimp
Glacier Cone	1	6–13 April	3,650 m	19.79300°N 155.46191°W	Shrimp
Glacier Cone	2	6–13 April	3,664 m	19.79274°N 155.46167°W	Shrimp
Glacier Cone	3	6–13 April	3,680 m	19.79237°N 155.46133°W	Shrimp
Glacier Cone	4	6–13 April	3,684 m	19.79193°N 155.46115°W	Shrimp
Glacier Cone	5	6–13 April	3,696 m	19.79196°N 155.45995°W	Shrimp
Glacier Cone	6	6–13 April	3,689 m	19.79247°N 155.46030°W	Shrimp
Glacier Cone	7	6–13 April	3,691 m	19.79167°N 155.45979°W	Shrimp
Glacier Cone	8	6–13 April	3,675 m	19.79119°N 155.45959°W	Shrimp
Glacier Cone	9	6–13 April	3,658 m	19.79076°N 155.45914°W	Shrimp
Glacier Cone	10	6–13 April	3,664 m	19.79026°N 155.45850°W	Shrimp
Pu‘u Ko‘oko‘olau	1	6–13 April	3,779 m	19.79857°N 155.47432°W	Shrimp
Pu‘u Ko‘oko‘olau	2	6–13 April	3,810 m	19.79844°N 155.47435°W	Shrimp
Pu‘u Ko‘oko‘olau	3	6–13 April	3,825 m	19.79819°N 155.47446°W	Shrimp
Pu‘u Ko‘oko‘olau	4	6–13 April	3,827 m	19.79792°N 155.47437°W	Shrimp
Pu‘u Ko‘oko‘olau	5	6–13 April	3,823 m	19.79751°N 155.47476°W	Shrimp

Table 1 (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in April 2006 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2006 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Ko‘oko‘olau	6	6–13 April	3,828 m	19.79800°N 155.47495°W	Shrimp
Pu‘u Ko‘oko‘olau	7	6–13 April	3,823 m	19.79728°N 155.47455°W	Shrimp
Horseshoe Crater	1	7–11 April	3,843 m	19.83336°N 155.49879°W	Shrimp
Horseshoe Crater	2	7–11 April	3,840 m	19.83368°N 155.49936°W	Shrimp
Horseshoe Crater	3	7–11 April	3,873 m	19.83034°N 155.50362°W	Shrimp
Horseshoe Crater	4	7–11 April	3,857 m	19.83053°N 155.50381°W	Shrimp
Horseshoe Crater	5	7–11 April	3,851 m	19.83088°N 155.50401°W	Shrimp
Horseshoe Crater	6	7–11 April	3,849 m	19.83111°N 155.50415°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	1	8–12 April	3,634 m	19.85481°N 155.45007°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	2	8–12 April	3,641 m	19.85532°N 155.45027°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	3	8–12 April	3,662 m	19.85585°N 155.45016°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	4 (4G)	8–12 April	3,672 m	19.85614°N 155.45079°W	Glycol
11,989 ft Pu‘u nr. Hoaka	5 (4S)	8–12 April	3,672 m	19.85614°N 155.45079°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	6 (5)	8–12 April	3,666 m	19.85681°N 155.45145°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	7 (6S)	8–12 April	3,653 m	19.85767°N 155.45111°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	8 (6G)	8–12 April	3,653 m	19.85767°N 155.45111°W	Glycol
11,989 ft Pu‘u nr. Hoaka	9 (7)	8–12 April	3,644 m	19.85810°N 155.45058°W	Shrimp
11,989 ft Pu‘u nr. Hoaka	10 (8)	8–12 April	3,628 m	19.85828°N 155.45010°W	Shrimp
Pu‘u N. VLBA	1	9–13 April	3,857 m	19.80329°N 155.45888°W	Shrimp
Pu‘u N. VLBA	2	9–13 April	3,860 m	19.80338°N 155.45897°W	Shrimp
Pu‘u N. VLBA	3	9 April–17 May	3,865 m	19.80368°N 155.45924°W	Shrimp
Pu‘u N. VLBA	4	9 April-2 June	3,865 m	19.80368°N 155.45924°W	Glycol
Pu‘u S. VLBA	1	9 Apr–11 May	3,809 m	19.79922°N 155.45583°W	Glycol
Pu‘u S. VLBA	2	9–13 April	3,808 m	19.79918°N 155.45599°W	Shrimp
Pu‘u S. VLBA	3	9–13 April	3,821 m	19.79911°N 155.45514°W	Shrimp
Pu‘u S. VLBA	4	9–13 April	3,816 m	19.79826°N 155.45496°W	Shrimp

Heather Laederich and Adam Vorsino sampling at summit of Pu‘u Hau Kea, 4 April 2006 (RAE photo).

Table 2. Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in May 2006 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2006 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Hau Kea	1s	9–17 May	4,129 m	19.81452°N 155.47333°W	Shrimp
Pu‘u Hau Kea	2s	9–17 May	4,121 m	19.81432°N 155.47331°W	Shrimp
Pu‘u Hau Kea	3s	9–17 May	4,128 m	19.81400°N 155.47348°W	Shrimp
Pu‘u Hau Kea	4s	9–17 May	4,126 m	19.81376°N 155.47327°W	Shrimp
Pu‘u Hau Kea	5s	9–17 May	4,131 m	19.81346°N 155.47322°W	Shrimp
Pu‘u Hau Kea	1g	9–17 May	4,129 m	19.81452°N 155.47333°W	Glycol
Pu‘u Hau Kea	2g	9–17 May	4,121 m	19.81432°N 155.47331°W	Glycol
Pu‘u Hau Kea	3g	9–17 May	4,128 m	19.81400°N 155.47348°W	Glycol
Pu‘u Hau Kea	4g	9–17 May	4,126 m	19.81376°N 155.47327°W	Glycol
Pu‘u Hau Kea	5g	9–17 May	4,131 m	19.81346°N 155.47322°W	Glycol
Pu‘u Ko‘oko‘olau	1	9–17 May	3,817 m	19.79747°N 155.47453°W	Shrimp
Pu‘u Ko‘oko‘olau	2	9–17 May	3,824 m	19.79747°N 155.47478°W	Glycol
Pu‘u Ko‘oko‘olau	3	9–17 May	3,820 m	19.79824°N 155.47450°W	Glycol
Pu‘u Ko‘oko‘olau	4	9–17 May	3,821 m	19.79806°N 155.47441°W	Shrimp
Pu‘u Ko‘oko‘olau	5	6 Apr–17 May	3,819 m	19.79798°N 155.47433°W	Glycol
Pu‘u Ko‘oko‘olau	6	6 Apr–17 May	3,819 m	19.79728°N 155.47455°W	Glycol
Glacier Cone	1	9–17 May	3,689 m	19.79224°N 155.46132°W	Glycol
Glacier Cone	2	9–17 May	3,688 m	19.79199°N 155.46129°W	Glycol
Glacier Cone	3	9–17 May	3,695 m	19.79138°N 155.46024°W	Shrimp
Glacier Cone	4	9–17 May	3,695 m	19.79138°N 155.46024°W	Glycol
Glacier Cone	5	9–17 May	3,698 m	19.79172°N 155.46024°W	Shrimp
Glacier Cone	6	9–17 May	3,698 m	19.79172°N 155.46024°W	Glycol
Far Pu‘u beyond VLBA	1	9–17 May	3,569 m	19.79748°N 155.43315°W	Shrimp
Far Pu‘u beyond VLBA	2	9–17 May	3,569 m	19.79748°N 155.43315°W	Glycol
Far Pu‘u beyond VLBA	3	9–17 May	3,565 m	19.79732°N 155.43231°W	Shrimp
Far Pu‘u beyond VLBA	4	9–17 May	3,557 m	19.79761°N 155.43292°W	Shrimp
Far Pu‘u beyond VLBA	5	9–17 May	3,583 m	19.79967°N 155.43376°W	Shrimp
Far Pu‘u beyond VLBA	6	9–17 May	3,569 m	19.79930°N 155.43082°W	Shrimp
Far Pu‘u beyond VLBA	7	9–17 May	3,582 m	19.79967°N 155.43102°W	Shrimp
Far Pu‘u beyond VLBA	8	9–17 May	3,524 m	19.79646°N 155.43219°W	Shrimp
Far Pu‘u beyond VLBA	9	9–17 May	3,518 m	19.79598°N 155.43214°W	Shrimp
Far Pu‘u beyond VLBA	10	12–17 May	3,582 m	19.79966°N 155.43115°W	Glycol
1st Pu‘u beyond VLBA	1	9–17 May	3,555 m	19.79766°N 155.43797°W	Shrimp
1st Pu‘u beyond VLBA	2	9–17 May	3,607 m	19.79790°N 155.43944°W	Shrimp
1st Pu‘u beyond VLBA	3	9–17 May	3,646 m	19.79797°N 155.44054°W	Shrimp
1st Pu‘u beyond VLBA	4	9–17 May	3,642 m	19.79799°N 155.44093°W	Shrimp
1st Pu‘u beyond VLBA	5	9–17 May	3,642 m	19.79799°N 155.44093°W	Glycol
1st Pu‘u beyond VLBA	6	9–17 May	3,654 m	19.79723°N 155.44090°W	Shrimp
1st Pu‘u beyond VLBA	7	9–17 May	3,652 m	19.79712°N 155.44177°W	Shrimp
1st Pu‘u beyond VLBA	8	9–17 May	3,652 m	19.79712°N 155.44177°W	Glycol
1st Pu‘u beyond VLBA	9	9–17 May	3,651 m	19.79784°N 155.44177°W	Live
Pu‘u Hoaka	1	10–16 May	3,662 m	19.85353°N 155.43414°W	Shrimp
Pu‘u Hoaka	2	10–16 May	3,662 m	19.85353°N 155.43414°W	Glycol

Table 2 (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in May 2006 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2006 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Puʻu Hoaka	3	10–16 May	3,694 m	19.85409°N 155.43468°W	Glycol
Puʻu Hoaka	4	10–16 May	3,690 m	19.85421°N 155.43561°W	Shrimp
Puʻu Hoaka	5	10–16 May	3,690 m	19.85421°N 155.43561°W	Glycol
Puʻu Hoaka	6	10–16 May	3,707 m	19.85284°N 155.43658°W	Shrimp
Puʻu Hoaka	7	10–16 May	3,707 m	19.85284°N 155.43658°W	Glycol
Puʻu Hoaka	8	10–16 May	3,706 m	19.85192°N 155.43591°W	Shrimp
Puʻu Hoaka	9	10–16 May	3,706 m	19.85192°N 155.43591°W	Shrimp
Puʻu Hoaka	10	10–16 May	3.712 m	19.85177°N 155.43506°W	Glycol
Puʻu Hoaka	11	10–16 May	3,700 m	19.85198°N 155.43457°W	Glycol
Puʻu Heather 11,989	1	10–16 May	3,615 m	19.85525°N 155.44804°W	Glycol
Puʻu Heather 11,989	2	10–16 May	3,644 m	19.85597°N 155.44868°W	Glycol
Puʻu Heather 11,989	3	10–16 May	3,664 m	19.85641°N 155.44905°W	Glycol
Puʻu Heather 11,989	4	10–16 May	3,657 m	19.85667°N 155.44885°W	Shrimp
Puʻu Heather 11,989	5	10–16 May	3,670 m	19.85606°N 155.44987°W	Shrimp
Puʻu Heather 11,989	6	10–16 May	3,666 m	19.85612°N 155.45078°W	Glycol
Puʻu Heather 11,989	7	10–16 May	3,663 m	19.85715°N 155.45149°W	Shrimp
Puʻu Heather 11,989	8	10–16 May	3,649 m	19.85198°N 155.43457°W	Glycol
Puʻu nr. Mahoe	1	10–16 May	3,831 m	19.84516°N 155.45439°W	Glycol
Puʻu nr. Mahoe	2	10–16 May	3,861 m	19.84425°N 155.45476°W	Shrimp
Puʻu nr. Mahoe	3	10–16 May	3,875 m	19.84408°N 155.45432°W	Glycol
Puʻu nr. Mahoe	4	10–16 May	3,878 m	19.84410°N 155.45432°W	Shrimp
Puʻu nr. Mahoe	5	10–16 May	3,896 m	19.84328°N 155.45526°W	Glycol
Puʻu nr. Mahoe	6	10–16 May	3,897 m	19.84312°N 155.45514°W	Shrimp
Puʻu nr. Mahoe	7	10–16 May	3,927 m	19.84253°N 155.45695°W	Shrimp
Puʻu nr. Mahoe	8	10–16 May	3,934 m	19.84213°N 155.45686°W	Glycol
Puʻu nr. Mahoe	9	10–16 May	3,939 m	19.84162°N 155.45821°W	Shrimp
Puʻu nr. Mahoe	10	10–16 May	3,939 m	19.84180°N 155.45839°W	Shrimp
Puʻu Poliahu	1	11–15 May	4,114 m	19.82274°N 155.47971°W	Shrimp
Puʻu Poliahu	2	11–15 May	4,146 m	19.82300°N 155.48067°W	Shrimp
Puʻu Poliahu	3	11–15 May	4,155 m	19.82276°N 155.48103°W	Shrimp
Puʻu Poliahu	4	11–15 May	4,173 m	19.82102°N 155.48158°W	Shrimp
Puʻu Poliahu	5	11–15 May	4,172 m	19.82098°N 155.48097°W	Shrimp
Puʻu Poliahu	6	11–15 May	4,116 m	19.82056°N 155.48419°W	Shrimp
Puʻu Poliahu	7	11–15 May	4,104 m	19.82073°N 155.48489°W	Shrimp
Puʻu Poliahu	8	11–15 May	4,083 m	19.82404°N 155.48282°W	Shrimp
Below Keck & Subaru	1	11–15 May	4,096 m	19.82378°N 155.47542°W	Shrimp
Below Keck & Subaru	2	11–15 May	4,113 m	19.82422°N 155.47540°W	Shrimp
Below Keck & Subaru	3	11–15 May	4,152 m	19.82509°N 155.47560°W	Shrimp
Below Keck & Subaru	4	11–15 May	4,152 m	19.82541°N 155.47495°W	Shrimp
Below Keck & Subaru	5	11–15 May	4,152 m	19.82508°N 155.47603°W	Shrimp
Puʻu 11,605	1	11–15 May	3,508 m	19.78514°N 155.45200°W	Shrimp
Puʻu 11,605	2	11–15 May	3,519 m	19.78504°N 155.45155°W	Shrimp
Puʻu 11,605	3	11–15 May	3,531 m	19.78481°N 155.45129°W	Shrimp
Puʻu 11,605	4	11–15 May	3,541 m	19.78385°N 155.45128°W	Shrimp
Puʻu 11,605	5	11–15 May	3,555 m	19.78390°N 155.45049°W	Glycol

Table 3. Wēkiu bug capture data from surveyed Mauna Kea cinder cones using visual collections, shrimp pitfall, and ethylene glycol pitfall traps in April, May, and October 2006.

Cinder Cone	2006 Capture Date	Trap #	Elevation	GPS Coordinates	Wēkiu #'s	Trap Type
Pu'u Hau Kea	Apr 13	Vis	4,124 m	19.81323°N 155.47220°W	1	Jesse
Pu'u Hau Kea	Apr 13	Vis	4,122 m	19.81330°N 155.47217°W	3	Heather
Pu'u Hau Kea	Apr 13	Vis	4,128 m	19.81327°N 155.47209°W	2	Heather
Pu'u S. VLBA	Apr 13	Vis	3,787 m	19.79994°N 155.45573°W	6	Ron/Adam
Pu'u N. VLBA	Apr 13	Vis	3,860 m	19.81323°N 155.47220°W	1	Jesse
April 2006 Subtotal					**13**	
Pu'u N. VLBA	11 May	Vis	3,852 m	19.80341°N 155.45871°W	3	Ron
Pu'u S. VLBA	12 Apr–11 May	1	3,809 m	19.79922°N 155.45583°W	9	Glycol
S.E. Boundary Cone	12 May	3	3646 m	19.79797°N 155.44054°W	2	Shrimp
S.E. Boundary Cone	12 May	5	3642 m	19.79799°N 155.44093°W	1	Glycol
Pu'u Hau Kea	12 May	2g	4121 m	19.81432°N 155.47331°W	2	Glycol
Pu'u Hau Kea	14 May	Vis	4,125 m	19.81469°N 155.47314°W	1	Jesse
Pu'u Hau Kea	14 May	Vis	4,124 m	19.81445°N 155.47327°W	2	Jesse
Pu'u Hau Kea	14 May	2g	4,121 m	19.81432°N 155.47331°W	4	Glycol
Pu'u Hau Kea	14 May	1g	4,130 m	19.81432°N 155.47331°W	1	Glycol
S.E. Boundary Cone #1	14 May	3	3,646 m	19.79797°N 155.44054°W	3	Shrimp
Below Keck & Subaru	15 May	4	4,152 m	19.82541°N 155.47495°W	2	Shrimp
Below Keck & Subaru	15 May	5	4,152 m	19.82508°N 155.47603°W	7	Shrimp
Below Keck & Subaru	15 May	1	4,096 m	19.82378°N 155.47542°W	10	Shrimp
Near road below Keck	15 May	3	4,164 m	19.82378°N 155.47542°W	3	Jesse
Pu'u N. VLBA	9 Apr–2 June	3	3,865 m	19.80368°N 155.45924°W	4	Glycol
Pu'u Hau Kea	17 May	2g	4,121 m	19.81432°N 155.47331°W	24	Glycol
Pu'u Hau Kea	17 May	4s	4,126 m	19.81376°N 155.47327°W	1	Shrimp
Pu'u Hau Kea	17 May	4g	4,126 m	19.81376°N 155.47327°W	12	Glycol
Pu'u Ko'oko'olau	17 May	1	3,817 m	19.79747°N 155.47453°W	1	Shrimp
Pu'u Hau Kea	17 May	vis	4,121 m	19.81432°N 155.47331°W	9	Heather/Ron
May 2006 Subtotal					**101**	
Pu'u Hau Kea	2 Oct 2006	vis	4,123 m	19.81370°N 155.47305°W	5	Ron
October 2006 Subtotal					**5**	
2006 Total					**119**	

Immature wēkiu bug preying on dead insects

Lycosa sp., endemic to the Mauna Kea summit (RAE photos)

Table 4. Results of Pu'u Hau Kea paired glycol and shrimp pitfall traps surveys during 4-13 April and 9-17 May 2006 (see Tables 1 and 2 for trap and GPS location information).

Trap Type	Trap #	# wēkiu bugs collected April	# wēkiu bugs collected May	# wēkiu bugs observed on caprock[1]	wēkiu Mortality (shrimp traps)
Ethylene Glycol	1g	0	1	0	n/a
Shrimp Pitfall	1s	0	0	0	0
Ethylene Glycol	2g	0	30	0	n/a
Shrimp Pitfall	2s	0	0	0	0
Ethylene Glycol	3g	0	0	0	n/a
Shrimp Pitfall	3s	0	0	0	0
Ethylene Glycol	4g	0	12	0	n/a
Shrimp Pitfall	4s	0	1	0	0
Ethylene Glycol	5g	0	0	0	n/a
Shrimp Pitfall	5s	0	0	0	0
Total Glycol		0	43	0	n/a
Total Shrimp		0	1	0	0

[1]Wēkiu bugs not collected within trap, but observed nearby around caprock near shrimp paste

Mating pair of Mauna Loa (*Nysius aa*) bugs

Mating pair of Wēkiu bugs (*Nysius wekiuicola*) (RAE photos)

Table 5. Summary of 2006 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using both shrimp pitfall and ethylene glycol pitfall traps in April 2006.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs visual observation only[1]	Trap Dates	Total Trap Days[2]
Pu'u Hau Kea	4,128 m	10	0	6	4–13 Apr	90
Pu'u Waiau	4,038 m	8	0	0	4–13 Apr	72
Pu'u Hoaka	3,712 m	11	0	0	5–12 Apr	77
Glacier Cone	3,696 m	10	0	0	6–13 Apr	70
Pu'u Ko'oko'olau	3,779 m	7	0	0	6–13 Apr	49
Horseshoe Crater	3, 873 m	6	0	0	7–11 Apr	24
11,989 ft Pu'u nr. Hoaka	3,672 m	10	0	0	8–12 Apr	40
Pu'u N. VLBA	3,865 m	4	0	1	9–13 Apr	16
Pu'u S. VLBA	3,821 m	4	0	6	9–13 Apr	16
Totals		70	0	13		454

[1]Number of wēkiu bugs hand collected around snowbanks and near traps during 20-30 minute trials by 2-3 observers, but not collected in traps. [2]Trap days = total nights x total traps per cinder cone.

Table 6. Summary of 2006 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using both shrimp pitfall and ethylene glycol pitfall traps in May 2006.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs visual observation only[1]	Trap Dates	Total Trap Days[2]
Puʻu Hau Kea	4,131 m	10	44	12	9–17 May	80
Puʻu Koʻokoʻolau	3,824 m	6	1	0	9–17 May	48
Glacier Cone	3,698 m	6	0	0	9–17 May	48
Far Puʻu beyond VLBA	3,583 m	10	0	0	9–17 May	80
S.E. boundary cone (1st Puʻu beyond VLBA)	3,654 m	9	6	0	9–17 May	72
Puʻu Hoaka	3,712 m	11	0	0	10–16 May	66
Puʻu Heather 11,989 ft	3,615 m	8	0	0	10–16 May	48
Puʻu nr. Mahoe	3,939 m	10	0	0	10–16 May	80
Puʻu Poliahu	4,173 m	8	0	0	11–15 May	32
Below Keck & Subaru	4,152 m	5	19	3	11–15 May	20
Puʻu 11,605	3,555 m	5	0	0	11–15 May	20
Puʻu N. VLBA	3,852 m	n/a	n/a	3	11 May	n/a
Puʻu S. VLBA	3,809 m	n/a (1 (glycol)	9	n/a	12 Apr–11 May	n/a
Puʻu N. VLBA[3]	3,865 m	n/a 1 (glycol)	4	n/a	9 Apr–2 June	n/a
Totals		88[3]	83	18		594

[1]Number of wēkiu bugs hand collected around snowbanks and near traps during 20-30 minute trials by 2-3 observers, but not collected in traps. [2]Trap days = total nights x total traps per cinder cone. [3]Glycol traps covered with snow drifts most of April/May 2006, not counted for trap days or traps total.

Table 7. Summary of Mauna Loa bug (*Nysius aa*) captures during brief field reconnaissance starting at MLO to Mauna Loa summit on 10 April and 13 May 2006.

General Location	2006 Date	Trap #	Elevation	Start Time/End Time of Trap	GPS Coordinates	Mauna Loa Bug #'s
Just above MLO	10 Apr	1a	3,419 m	1030-1830 hrs	19.53512°N 155.58151°W	1
Just above MLO	10 Apr	1b	3,419 m	1030-1830 hrs	19.53512°N 155.58151°W	0
Nr. trail-large cobble	10 Apr	2	3,800 m	1300-1740 hrs	19.51115°N 155.58395°W	0
Nr. trail-nr snow[1]	10 Apr	3	3,882 m	1320-1720 hrs	19.50543°N 155.57973°W	10
Nr. trail-nr snow[1]	10 Apr	Vis	3,882 m	1320-1720 hrs	19.50543°N 155.57973°W	3
April 2006 subtotal						**13**
Just Above MLO	13 May	1	3,437 m	1000-1704 hrs	19.53501°N 155.58150°W	0
Shelter Cave nr trail	13 May	2	3,662 m	1052-1630 hrs	19.52121°N 155.58308°W	0
Nr. trail-fine cinder[2]	13 May	3a	3,895 m	1200-1300 hrs	19.50520°N 155.57959°W	21
Nr. trail-fine cinder[2]	13 May	3b	3,895 m	1200-1300 hrs	19.50520°N 155.57959°W	14
Nr. trail-fine cinder[2]	13 May	Vis	3,895 m	1200-1300 hrs	19.50520°N 155.57959°W	15
By summit caldera	13 May	5	3,964 m	1400-1510 hrs	19.49359°N 155.57695°W	0
May 2006 subtotal						**50**

[1]90% gravel and 10% cobble substrate, 0.3 m from a 3m x 10 m snowbank. [2]Trapping and visual observations took place within a 30 m radius of this waypoint, on 5-25 mm fine cinder substrate.

Table 8. Temperature/Relative Humidity data loggers on the Mauna Kea installed in December 2004 or June 2005. Surface loggers at 0 cm, subsurface at 26 cm depth. *** = not working**

Date First Installed	#	Dec 2004	Logger # (June 05)	Log # (Dec 05) – Pulled Oct. 2006	Replacement Logger # (Oct 06)	Logger Placement	Elevation	Locality	GPS Coordinates (WGS 84)
14 Dec 2004	1	789564	789553	not replaced	792717	surface	3,902 m	Hau Kea (trail to Waiau)	19.81296°N 155.47545°W
3 Oct 2006	2	789564	defective, none	not replaced	792692	surface	3,950 m	Pu‘u Hau Kea (Keck side)	19.81615°N 155.47391°W
3 Oct 2006	3	792689	defective, none	not replaced	789544	subsurface	3,950 m	Pu‘u Hau Kea (Keck side)	19.81615°N 155.47391°W
14 Dec 2004	4		789559	792703	789552	surface	4,058 m	Pu‘u Hau Kea	19.81575°N 155.47351°W
14 Dec 2004	5		789545	789546	789565	subsurface	4,058 m	Pu‘u Hau Kea	19.81575°N 155.47351°W
14 Dec 2004	6	792737	754788	792702	789547	surface	4,096 m	Pu‘u Hau Kea	19.81496°N 155.47305°W
14 Dec 2004	7	792703	789561	792710*	792680	subsurface	4,096 m	Pu‘u Hau Kea	19.81496°N 155.47305°W
14 Dec 2004	8	792728	792694	792698	792728	surface	4,105 m	Pu‘u Hau Kea	19.81443°N 155.47275°W
14 Dec 2004	9	792691	754792	792708	792689	subsurface	4,105 m	Pu‘u Hau Kea	19.81443°N 155.47275°W
14 Dec 2004	10	792698	789549	792714	792694	surface	4,061 m	Pu‘u Hau Kea (crater bottom)	19.81413°N 155.47243°W
14 Dec 2004	11	792709	789562	754789	792723	subsurface	4,061 m	Pu‘u Hau Kea (crater bottom)	19.81413°N 155.47243°W
14 Dec 2004	12	792695	789544	792731	792741	surface[1]	4,081 m	Pu‘u Hau Kea	19.81342°N 155.47214°W
14 Dec 2004	13	792727	754787	792709	789562	subsurface	4,081 m	Pu‘u Hau Kea	19.81342°N 155.47214°W
14 Dec 2004	14	792735	754785	792738	789545	surface	4,126 m	Pu‘u Hau Kea (Hilo rim side)	19.81331°N 155.47206°W
14 Dec 2004	15	792688	792712	792732	789559	subsurface	4,126 m	Pu‘u Hau Kea	19.81331°N 155.47206°W
14 Dec 2004	16	792710	789552	792713	792701	surface	4,096 m	Pu‘u Hau Kea	19.81269°N 155.47188°W
14 Dec 2004	17	792715	792739	792684	754786	subsurface	4,096 m	Pu‘u Hau Kea	19.81269°N 155.47188°W
14 Dec 2004	18	792723	789565	792688	789558	surface	4,006 m	Pu‘u Hau Kea (Hilo side)	19.81112°N 155.47139°W
14 Dec 2004	19	792707	792706	792687	789561	subsurface	4,006 m	Pu‘u Hau Kea (Hilo side)	19.81112°N 155.47139°W
7 May 2005	20		792680	789561	not recorded	surface	3,989 m	Pu‘u Lilinoe	19.81008°N 155.45908°W
7 May 2005	21		792705	789549	792712	subsurface	3,989 m	Pu‘u Lilinoe	19.81008°N 155.45908°W
15 Dec 2005	22		792739	792694	789560	surface	3,843 m	Pu‘u Lilinoe	19.80664°N 155.45836°W
15 Dec 2005	23		792694	792739	792720	surface	3,843 m	Pu‘u Lilinoe	19.80664°N 155.45836°W
4 June 2005	24	792690	754791	792740	792715	surface	4,143 m	Pu‘u Hau Oki	19.82578°N 155.47539°W

[1]Surface logger was exposed, no rock cover (due to freeze/frost action)

[2]Surface loggers new as of December 2005, not installed in June

Table 8. Temperature/Relative Humidity data loggers on the Mauna Kea installed in December 2004 or June 2005. Surface loggers at 0 cm, subsurface at 26 cm depth. *** = not working.**

Date First Installed	#	Logger # (Dec 04)	Logger # (June 05)	Logger # (Dec 05) – Pulled Oct. 2006	Replacement Logger # (Oct 06)	Logger Placement	Elevation	Locality	GPS Coordinates (WGS 84)
4 June 2005	25	792686	789557	792717	792734	subsurface	4,143 m	Pu'u Hau Oki	19.82578°N 155.47539°W
4 June 2005	26	792702	729724	792723	792706	surface	4,139 m	Pu'u Hau Oki	19.82721°N 155.47528°W
4 June 2005	27	#7	792693	792686	792724	subsurface	4,139 m	Pu'u Hau Oki	19.82721°N 155.47528°W
4 June 2005	28	792734	789547	754786	792743	surface	4,097 m	Poi Bowl	19.82329°N 155.47491°W
4 June 2005	29	792731	789554	789558	792735[1]	surface	4,105 m	Poi Bowl	19.82433°N 155.47307°W
4 June 2005	30	792721	792741	792701	789543	surface	4,167 m	Poi Bowl	19.82543°N 155.47256°W
15 Dec 2005	31	792744	792691[2]	792691	792742	surface	4,009 m	Pu'u Pohaku	19.82548°N 155.49011°W
15 Dec 2005	32	792720	792690[2]	792690	754792	subsurface	4,009 m	Pu'u Pohaku	19.82548°N 155.49011°W
15 Dec 2005	33	792742	792736[2]	792736	792684	surface	4,055 m	Pu'u Pohaku	19.82434°N 155.49211°W
15 Dec 2005	34	792684	792730[2]	792730	792688	subsurface	4,055 m	Pu'u Pohaku	19.82434°N 155.49211°W
15 Dec 2005	35		754790[2]	754790	792731	surface	3,914 m	Horseshoe Crater	19.82953°N 155.50050°W
15 Dec 2005	36		754790[2]	754790	789546	surface	3,914 m	Horseshoe Crater	19.82953°N 155.50050°W
15 Dec 2005	37		789550	789550	792732	surface	3,924 m	Horseshoe Crater	19.83063°N 155.49815°W
15 Dec 2005	38		792695	792695	792738	surface	3,924 m	Horseshoe Crater	19.83063°N 155.49815°W
13 Dec 2005	39		792697	792697	754788	subsurface	4,154 m	Pu'u Poliahu	19.82298°N 155.48096°W
17 Dec 2004	40	#4 (754793)	792742	792742	792705	surface	4,154 m	Pu'u Poliahu	19.82298°N 155.48096°W
13 Dec 2005	41		792728	792728	789554	subsurface	4,175 m	Pu'u Poliahu	19.82101°N 155.48149°W
13 Dec 2005	42		792689	792689	789566	surface	4,175 m	Pu'u Poliahu	19.82101°N 155.48149°W
15 Dec 2005	43		n/a	754792	792693	surface	3,840 m	Pu'u North of VLBA	19.80324°N 155.45889°W
15 Dec 2005	44		n/a	754791	792733	surface	3,850 m	Pu'u North of VLBA	19.80372°N 155.45930°W
14 Dec 2005	45		n/a	792744	754787	surface	3,663 m	Pu'u by J. Burns road sign	19.79351°N 155.46120°W
14 Dec 2005	46		n/a	792721	792697	surface	3,702 m	Pu'u by J. Burns road sign	19.79250°N 155.46034°W
14 Dec 2005	47		n/a	754793	792702	surface	3,700 m	Pu'u by J. Burns road sign	19.79170°N 155.45973°W
16 Dec. 2004		792692	not replaced			subsurface	3,963 m	Pu'u Mahoe	19.83554°N 155.46239°W

[1]Surface logger was exposed, no rock cover (due to freeze/frost action)

[2]Surface loggers new as of December 2005, not installed in June

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Summit of Pu‘u Hau Kea on April 4, 2006, after a major snowstorm showing an area of high wēkiu bug density. (RAE Photo)

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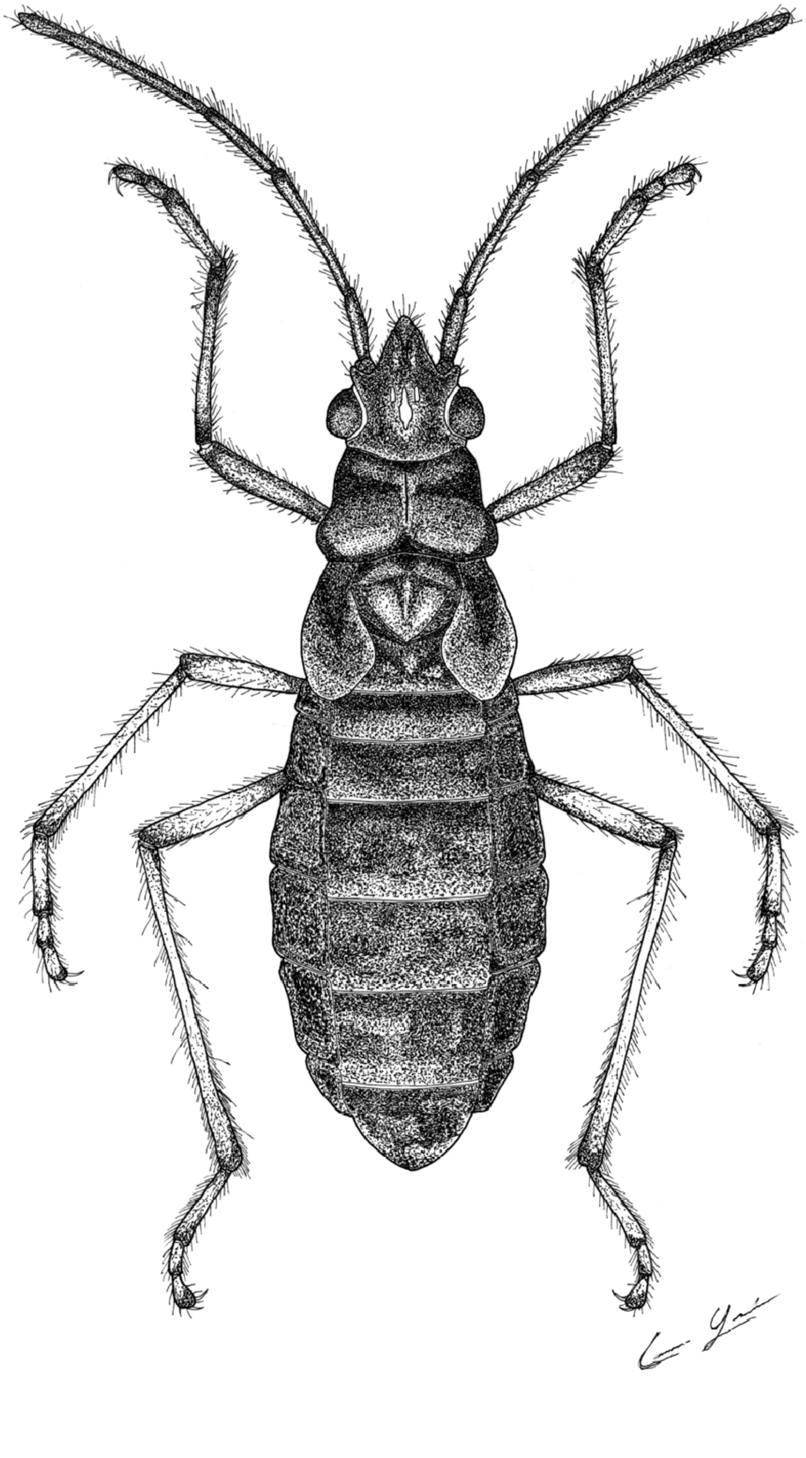

Wēkiu bug (*Nysius wekiuicola*) by Cameron Yasukawa.

APPENDIX A

Data Logger Graphs

Figures 7-41

Figures with averages 6 data logger readings per day (every 4 hours), for selected loggers

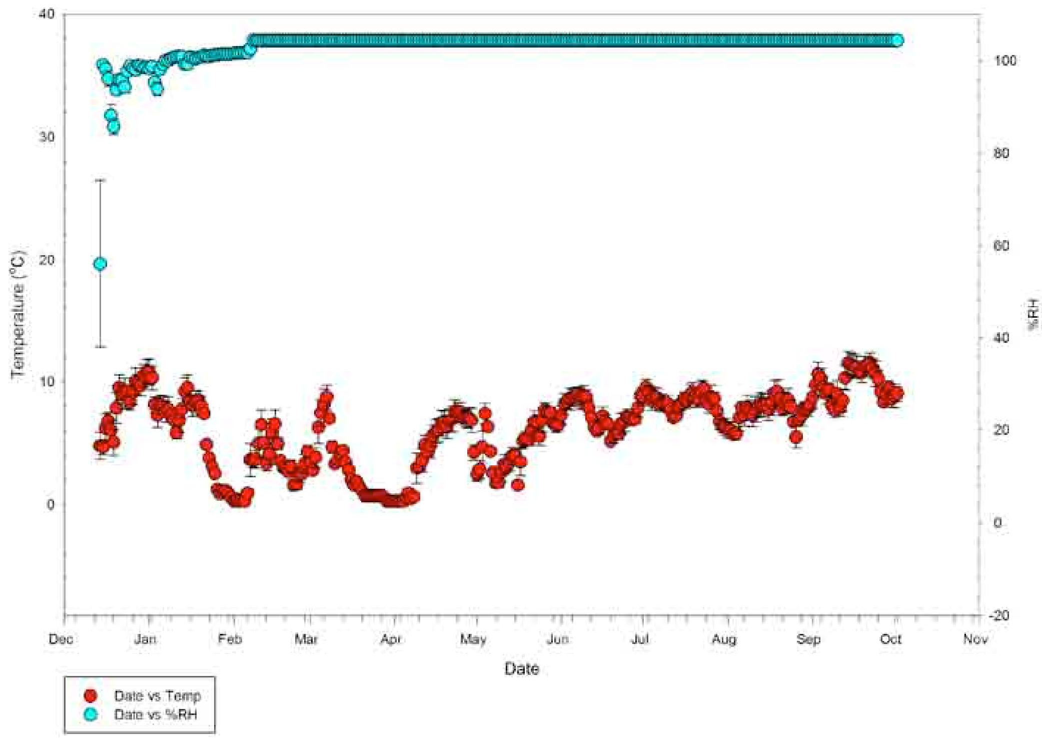

Figure 7. TEMP/RH Logger S/N#792684 Puu Hau Kea (4,096 m), SURFACE Dec. 2005–Oct. 2006.

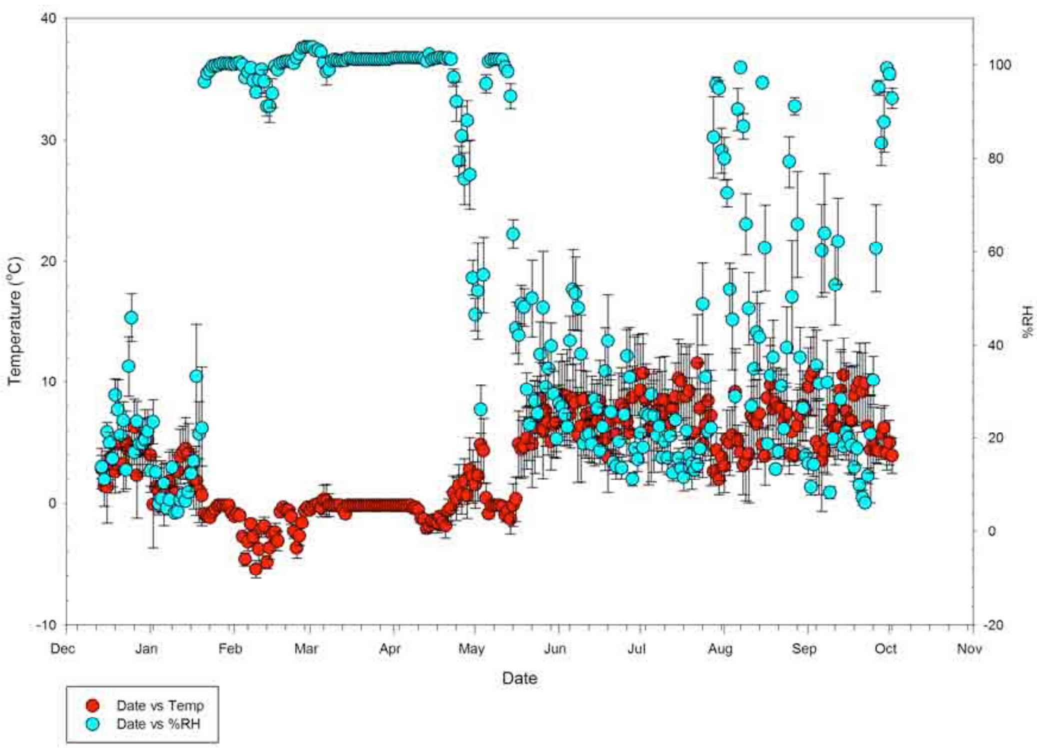

Figure 8. TEMP/RH Logger S/N#754789 Hau Kea cone (4,061 m), SUBSURFACE Dec. 2005– Oct. 2006.

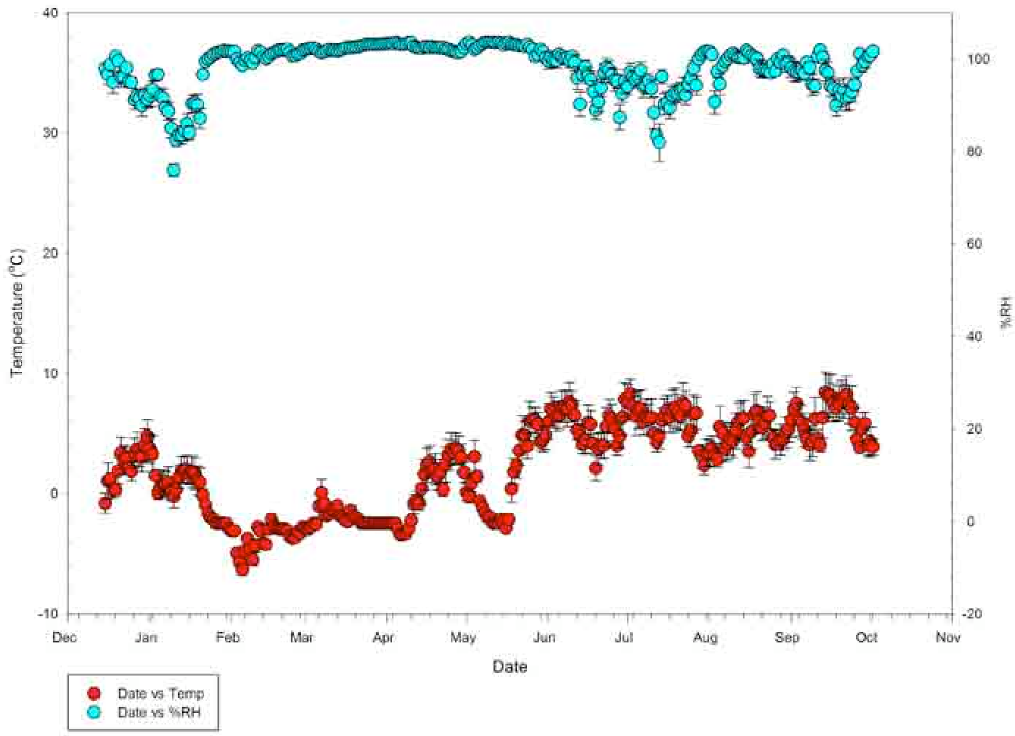

Figure 9. TEMP/RH Logger S/N#792732 Hau Kea (4,126 m), SUBSURFACE Dec. 2005– Oct. 2006.

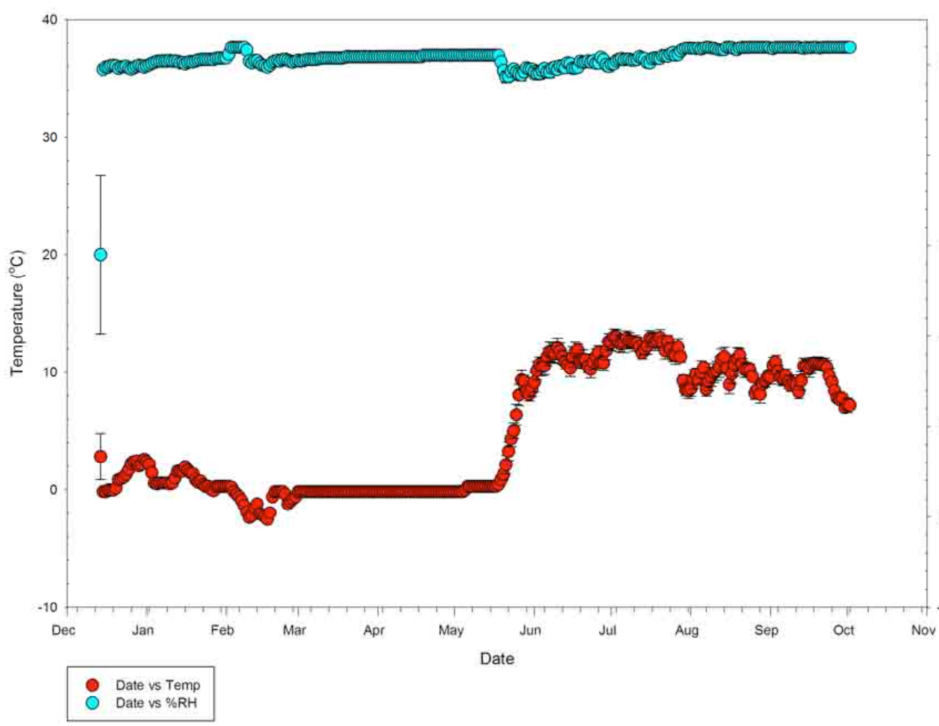

Figure 10. TEMP/RH Logger S/N#789546 Hau Kea (4,058 m), SUBSURFACE Dec. 2005– Oct. 2006.

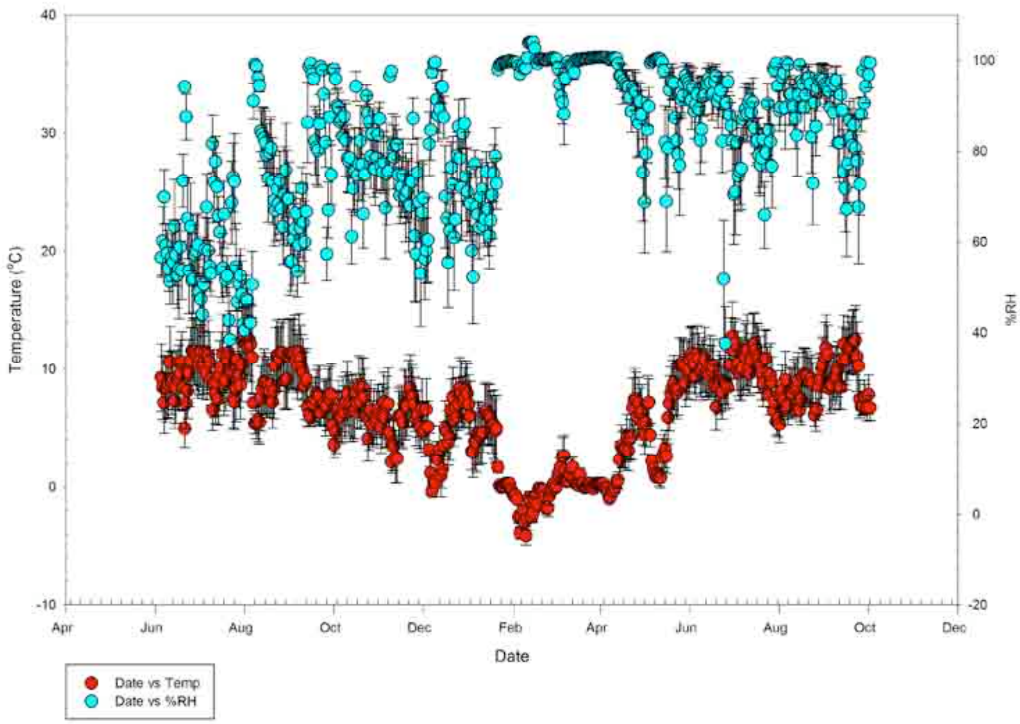

Figure 11. TEMP/RH Logger S/N#789553 Hau Kea base (trail to Lake Waiau) (3,902 m), SURFACE Dec. 2005– Oct. 2006.

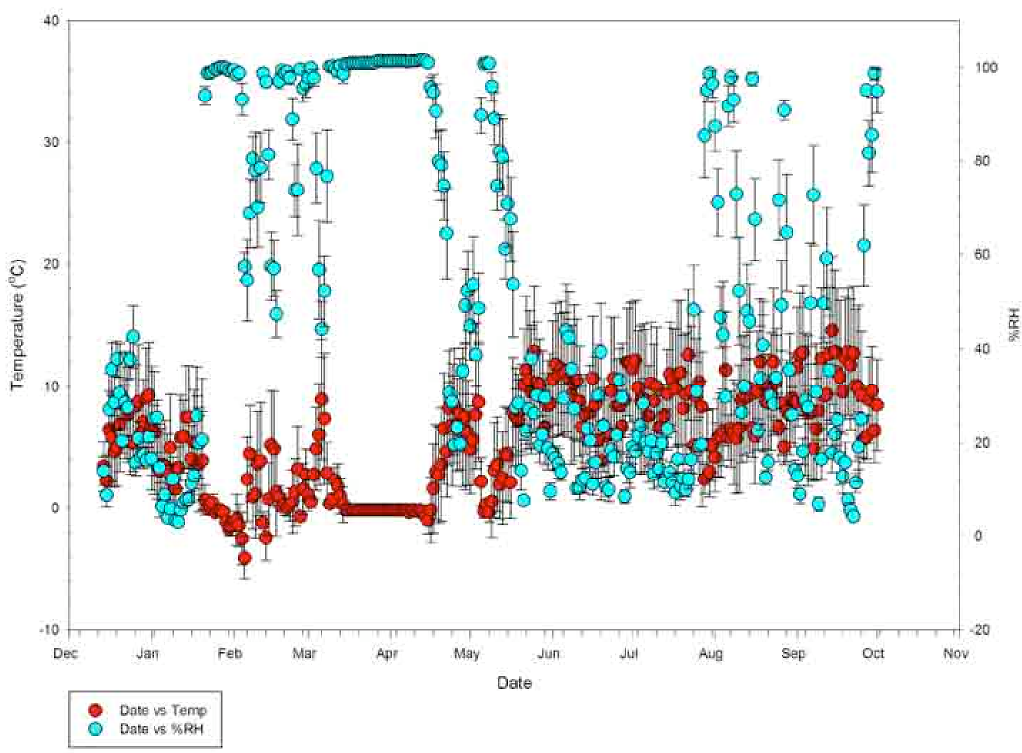

Figure 12. TEMP/RH Logger S/N#792698 Hau Kea (4,105 m), SURFACE Dec. 2005– Oct. 2006.

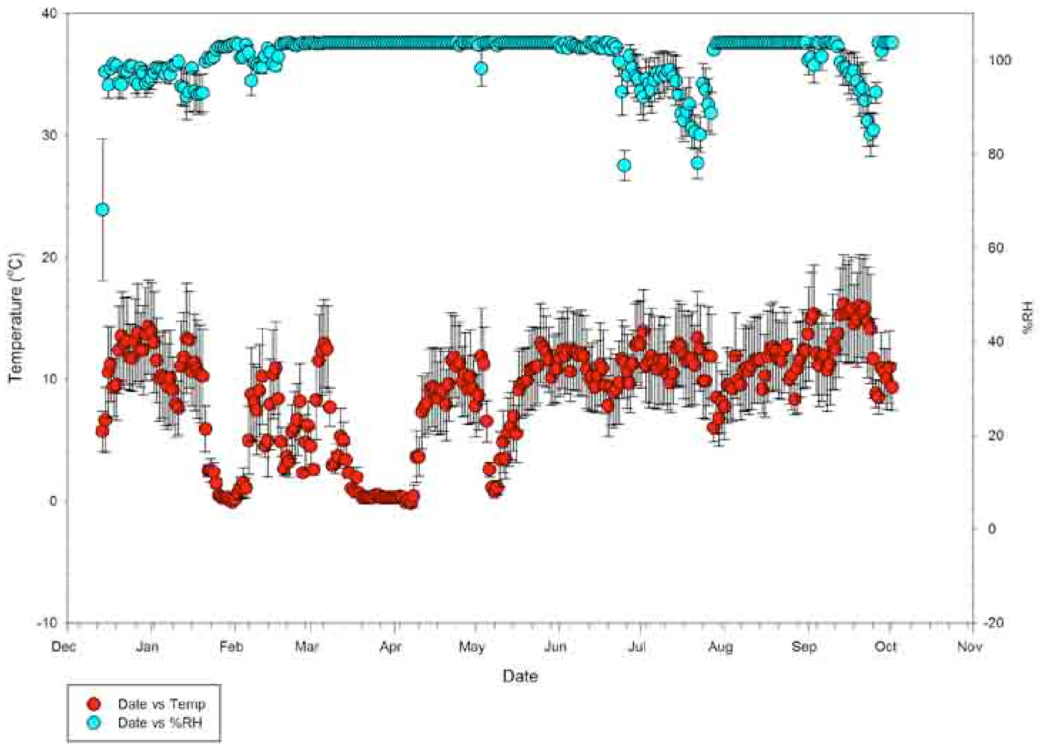

Figure 13. TEMP/RH Logger S/N#792688 Hau Kea (4,006 m), SURFACE Dec. 2005– Oct. 2006.

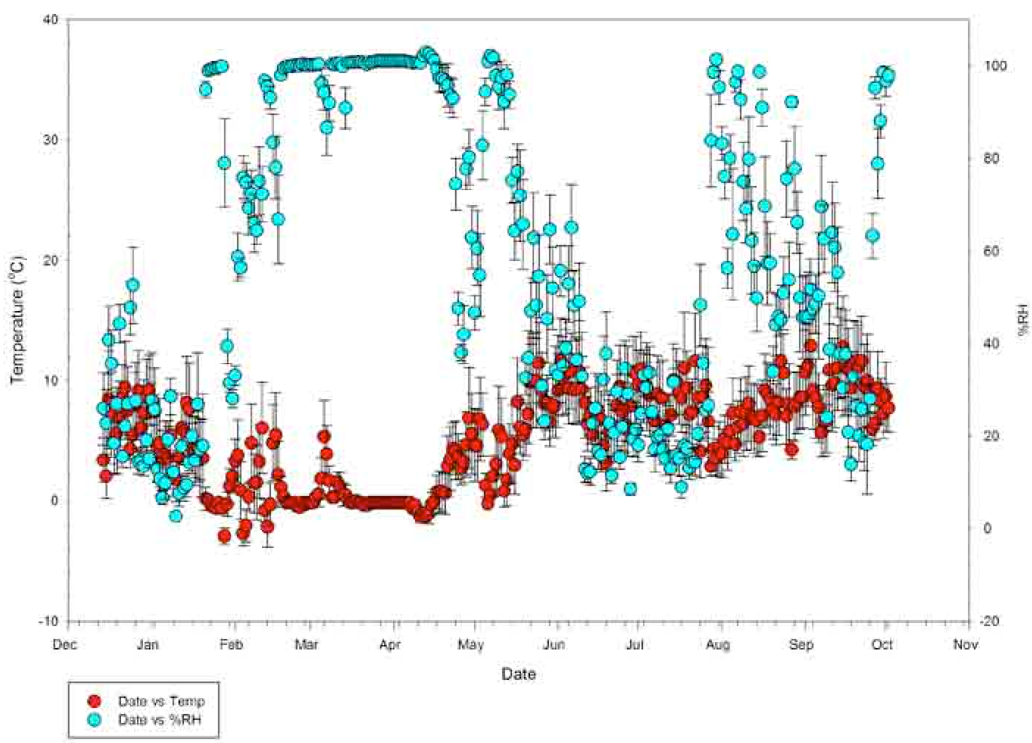

Figure 14. TEMP/RH Logger S/N#792702 Hau Kea (4,096 m), SURFACE Dec. 2005– Oct. 2006.

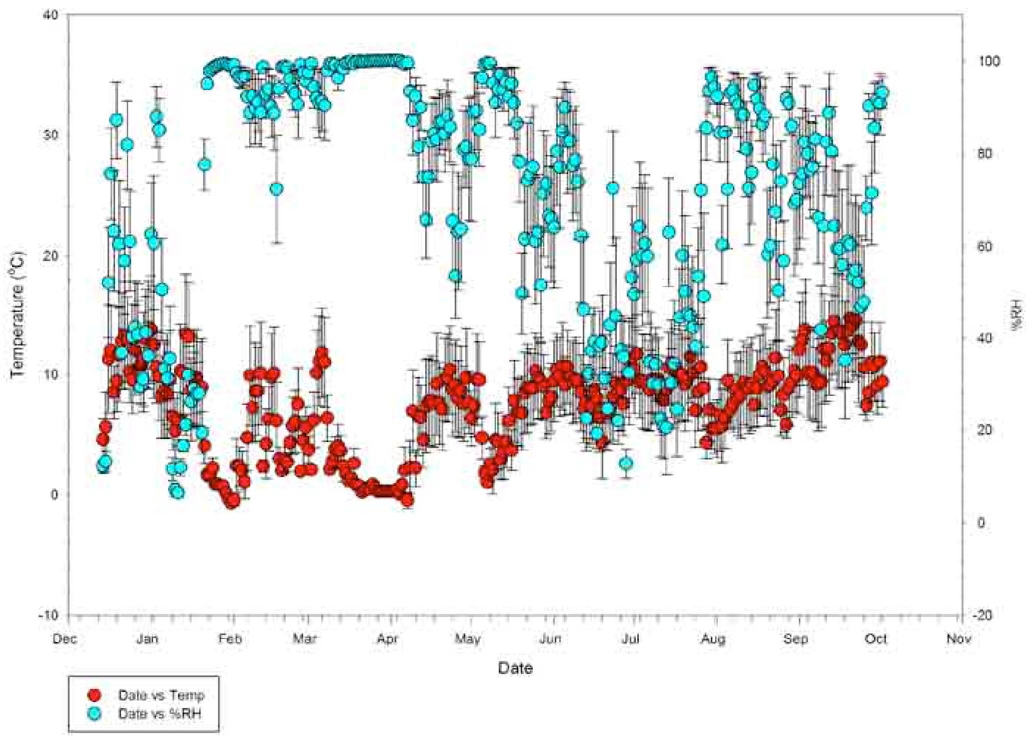

Figure 15. TEMP/RH Logger S/N#792713 Hau Kea (4,096 m), SURFACE Dec. 2005– Oct. 2006.

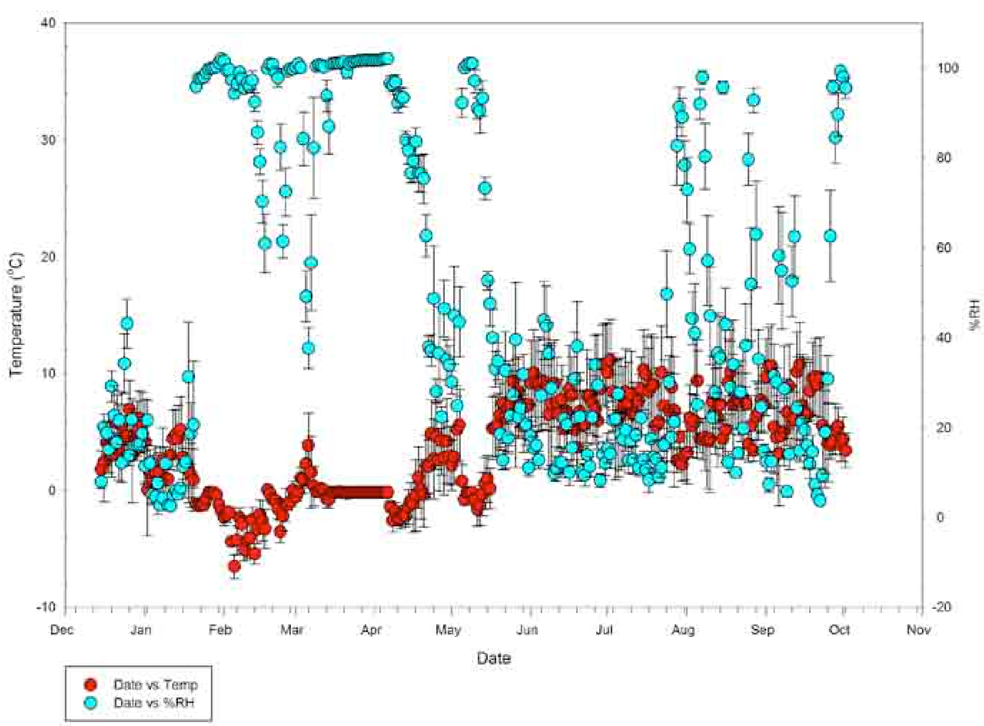

Figure 16. TEMP/RH Logger S/N#792714 Hau Kea crater bottom (4,061 m), SUBSURFACE Dec. 2005–Oct. 2006.

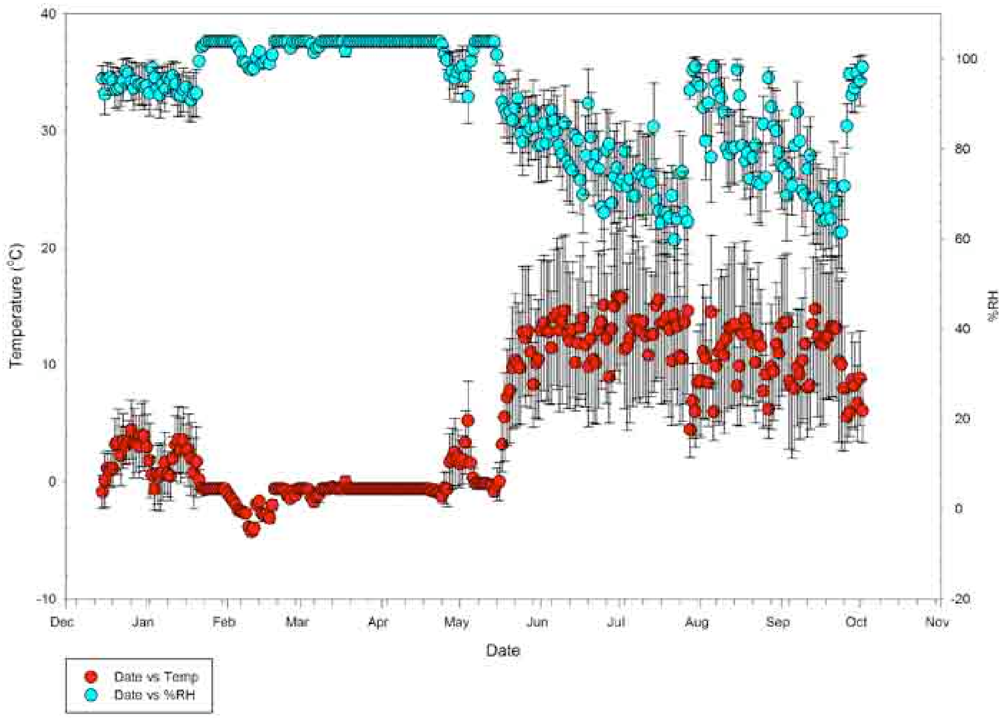

Figure 17. TEMP/RH Logger S/N#792731 Hau Kea (4,081 m), SURFACE Dec. 2005– Oct. 2006.

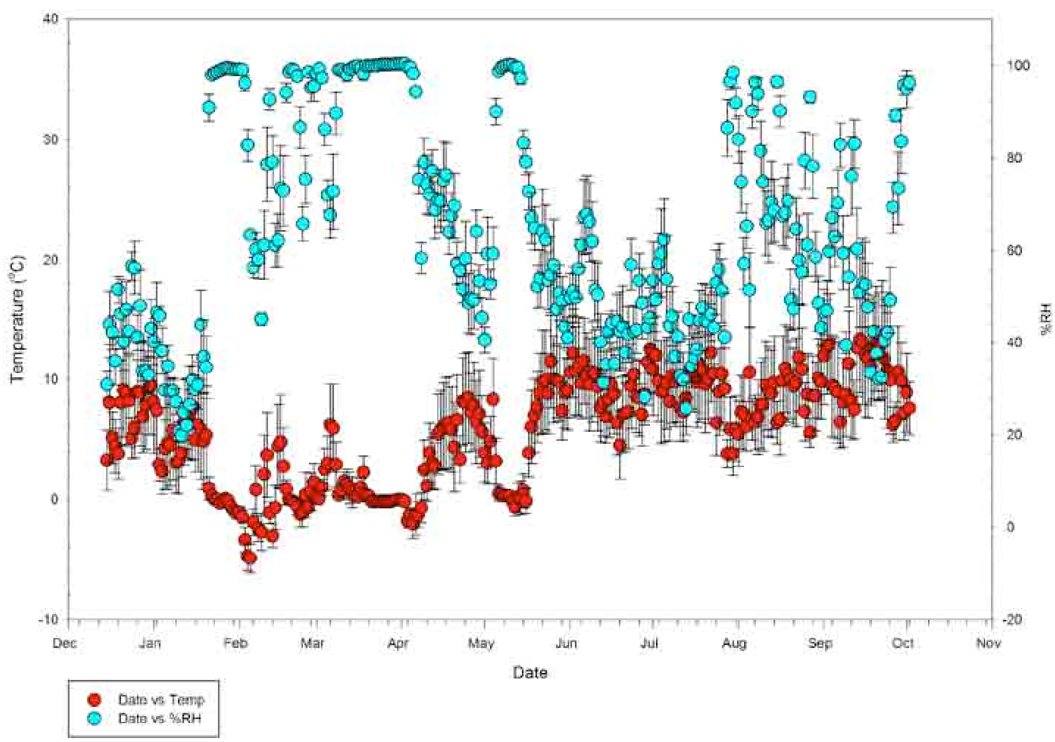

Figure 18. TEMP/RH Logger S/N#792738 Hau Kea (4,126 m), SURFACE Dec. 2005– Oct. 2006.

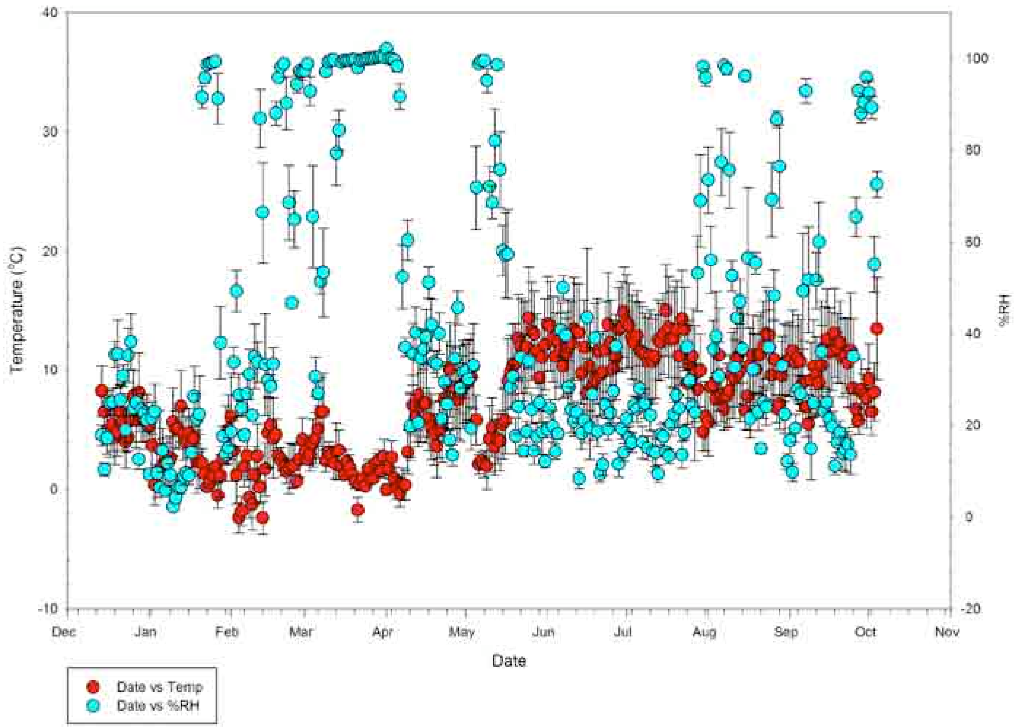

Figure 19. TEMP/RH Logger S/N#754790 Horseshoe Crater (3,914 m), SURFACE Dec. 2005– Oct. 2006.

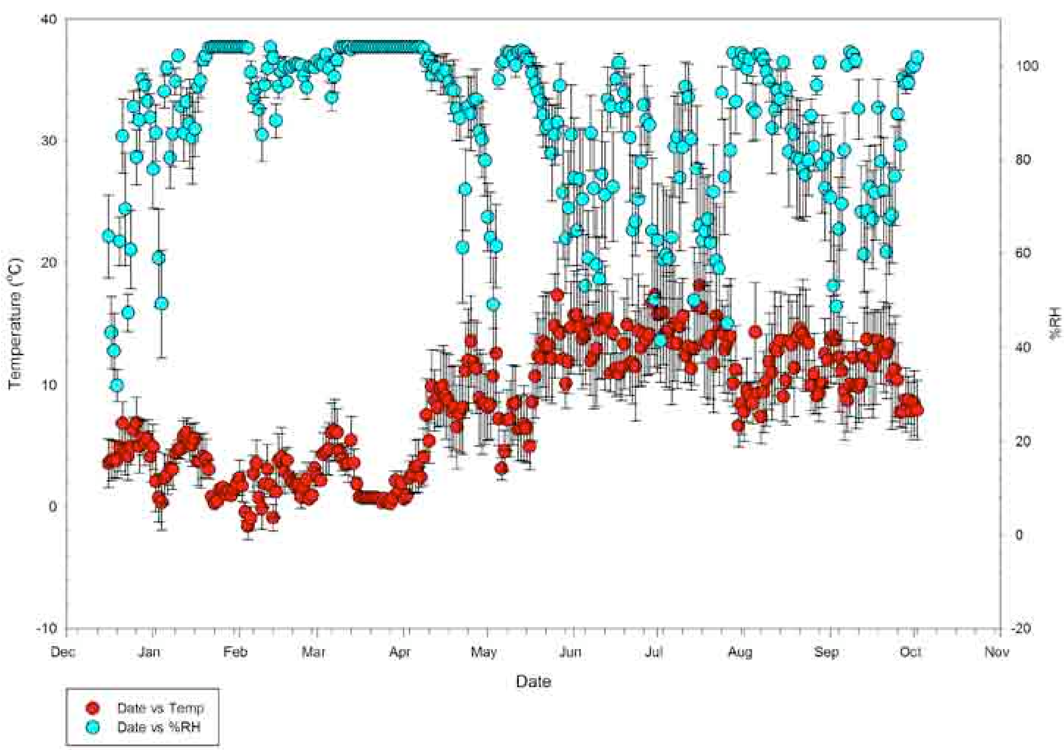

Figure 20. TEMP/RH Logger S/N#789550 Horseshoe Crater (3,924 m), SURFACE Dec. 2005– Oct. 2006.

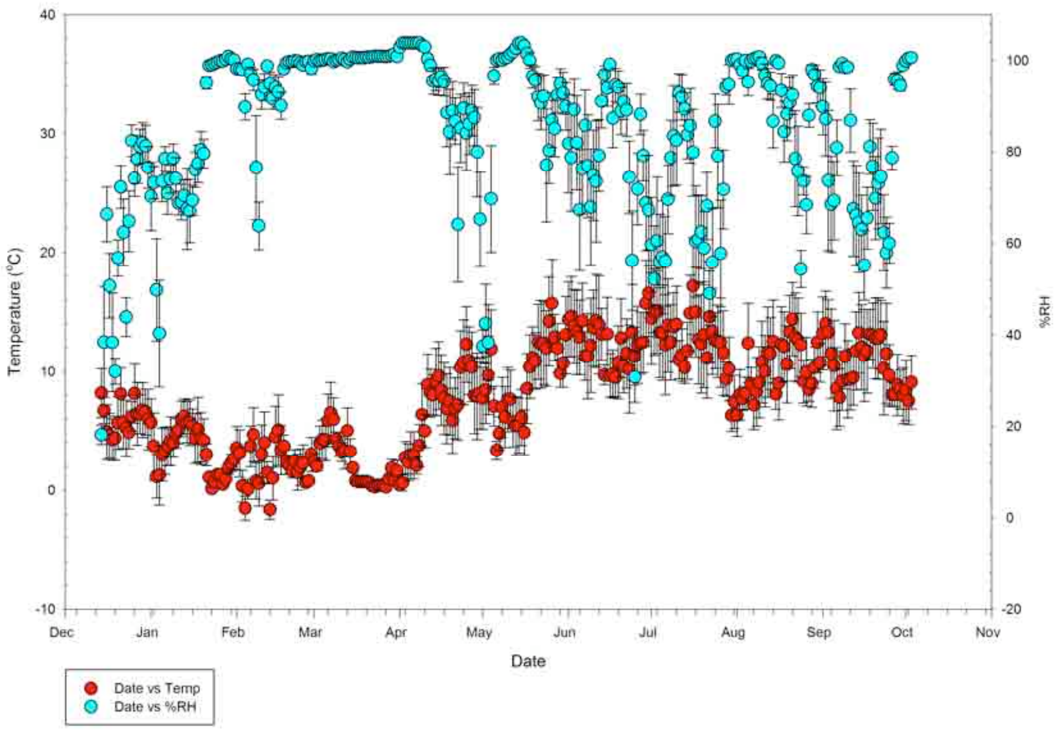

Figure 21. TEMP/RH Logger S/N# 792695 Horseshoe Crater (3,924 m), SURFACE Dec. 2005– Oct. 2006.

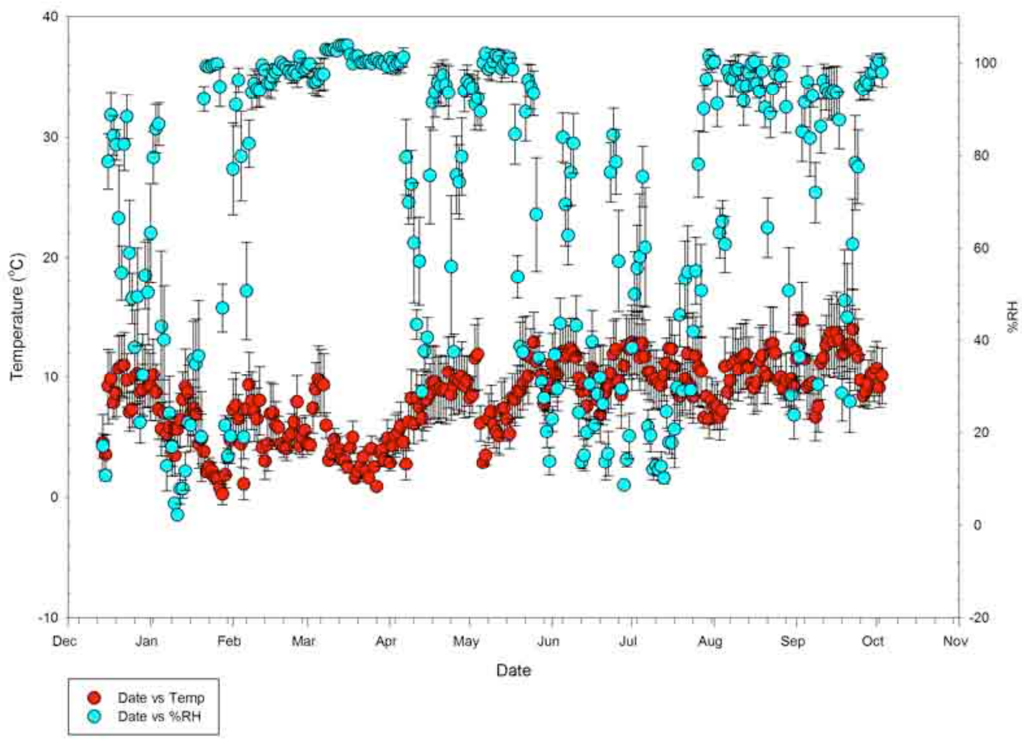

Figure 22. TEMP/RH Logger S/N# 754793 John Burns Cone (3,700 m), SURFACE Dec. 2005– Oct. 2006.

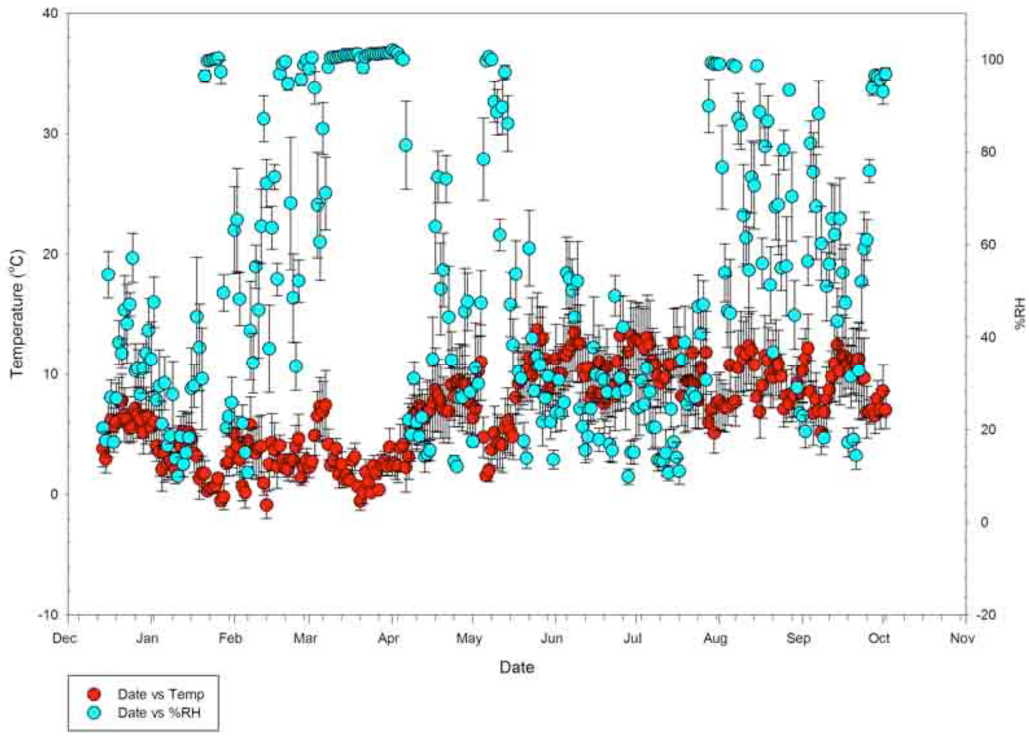

Figure 23. TEMP/RH Logger S/N# 792721 John Burns Cone (3,702 m), SURFACE Dec. 2005– Oct. 2006.

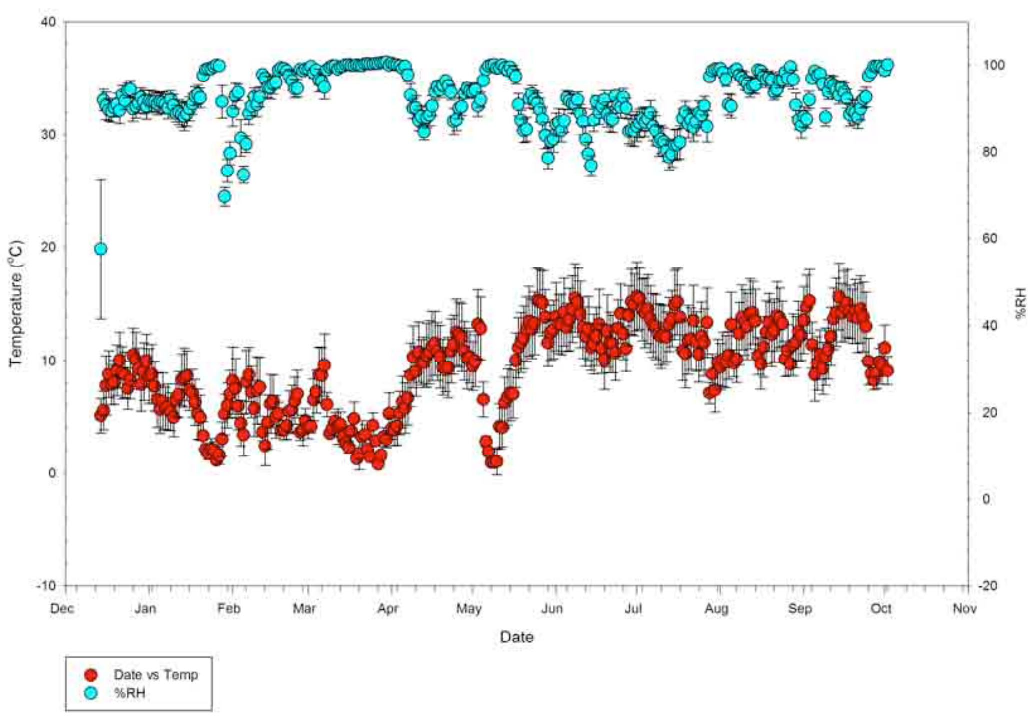

Figure 24. TEMP/RH Logger S/N# 792744 John Burns Cone (3,663 m), SURFACE Dec. 2005– Oct. 2006.

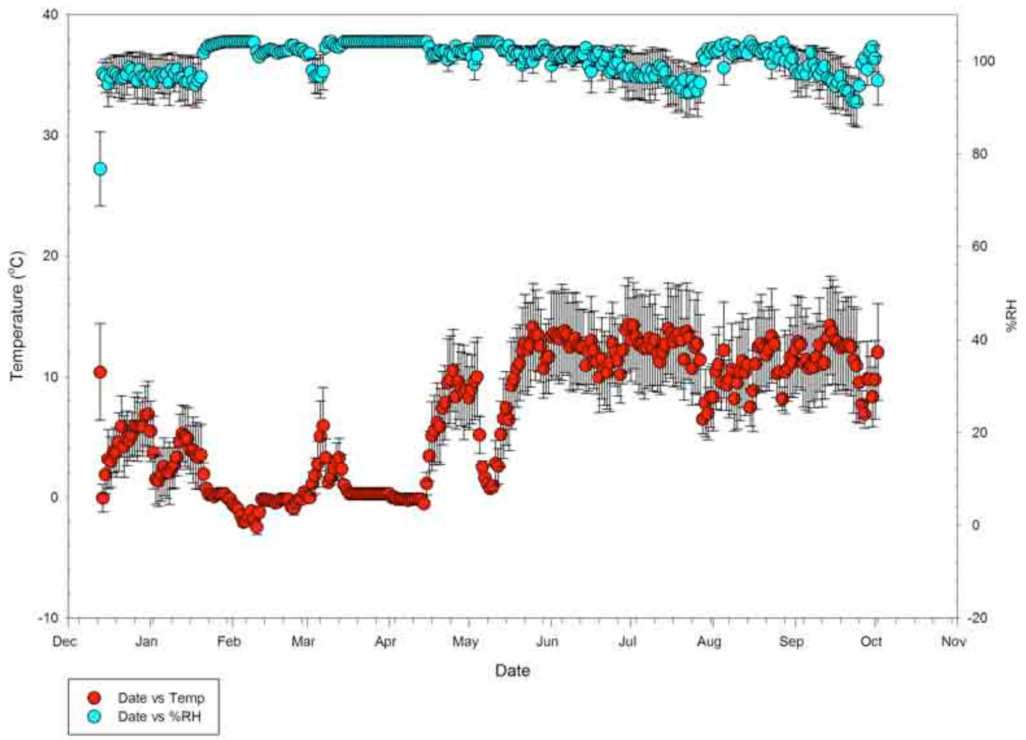

Figure 25. TEMP/RH Logger S/N# 754786 lower Poi Bowl (4,097 m), SURFACE Dec. 2005– Oct. 2006.

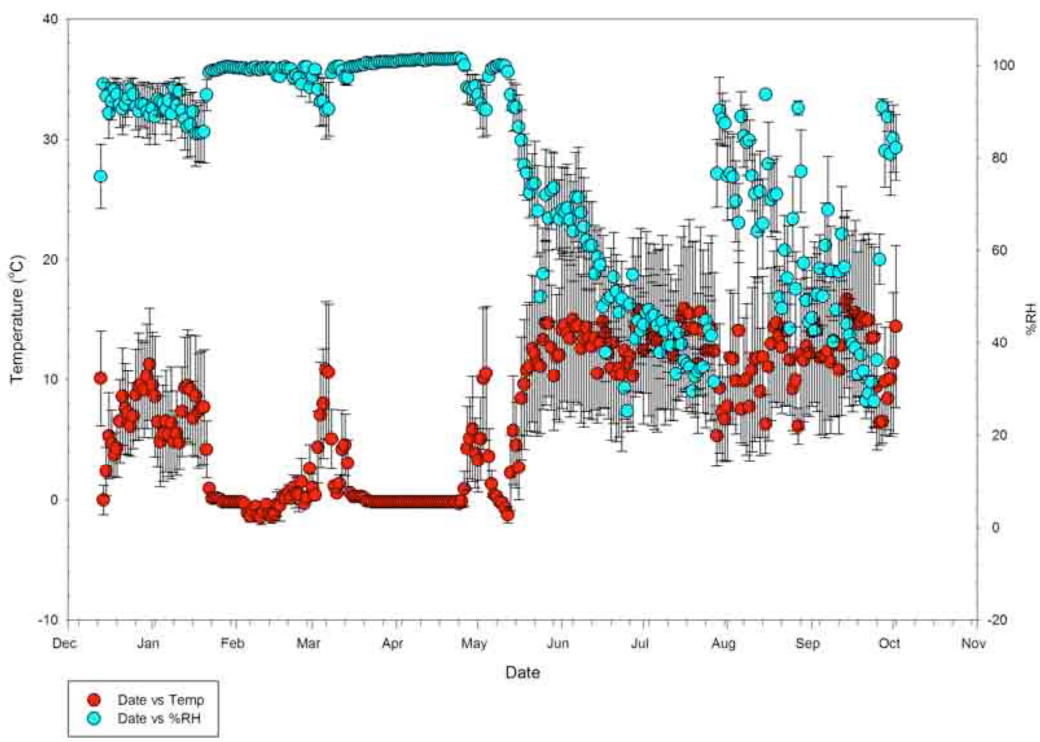

Figure 26. TEMP/RH Logger S/N# 789558 mid Poi Bowl (4,105 m), SURFACE Dec. 2005– Oct. 2006.

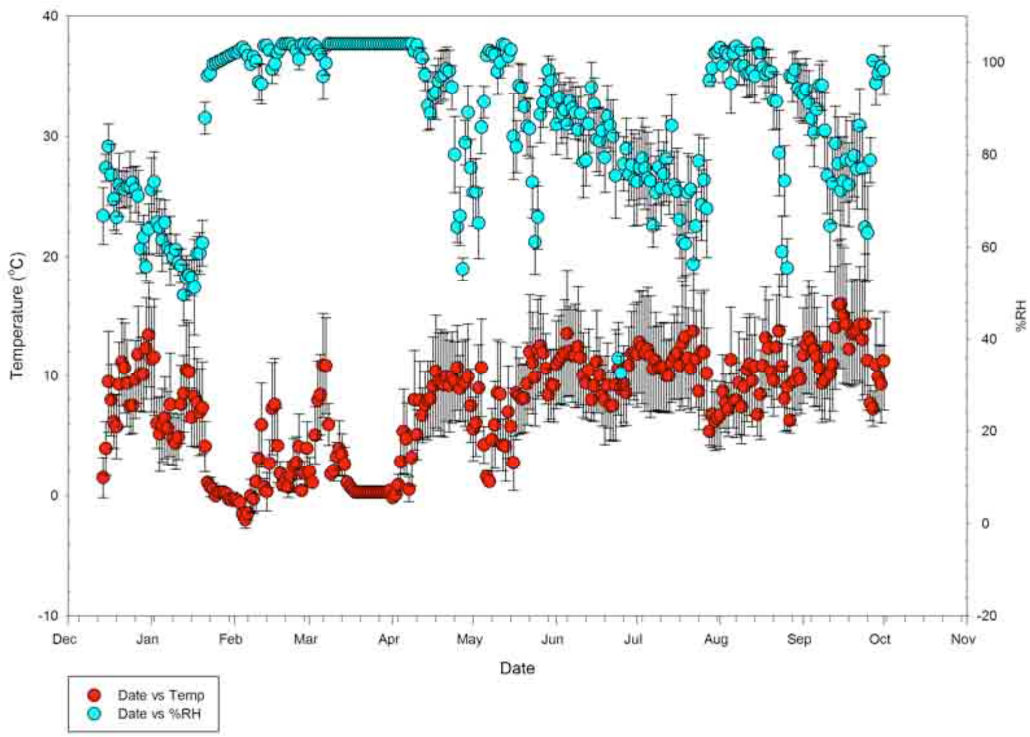

Figure 27. TEMP/RH Logger S/N# 792701 upper Poi Bowl (4,167 m), SURFACE Dec. 2005– Oct. 2006.

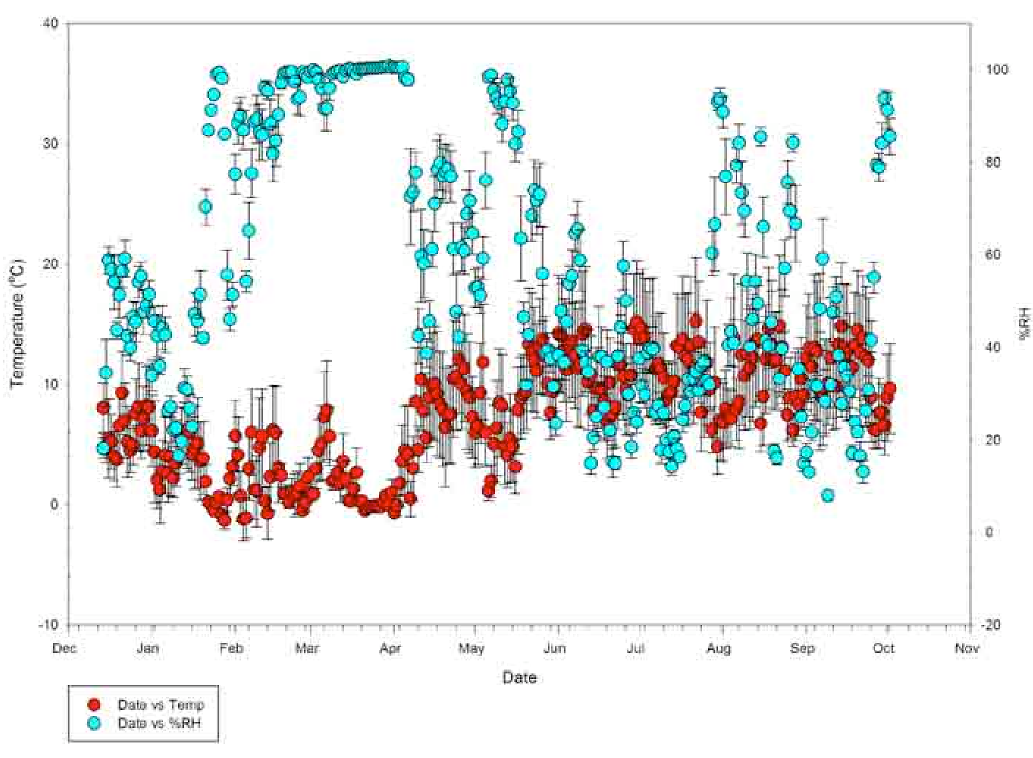

Figure 28. TEMP/RH Logger S/N#792736 Pohaku (4,055 m), SURFACE Dec. 2005– Oct. 2006.

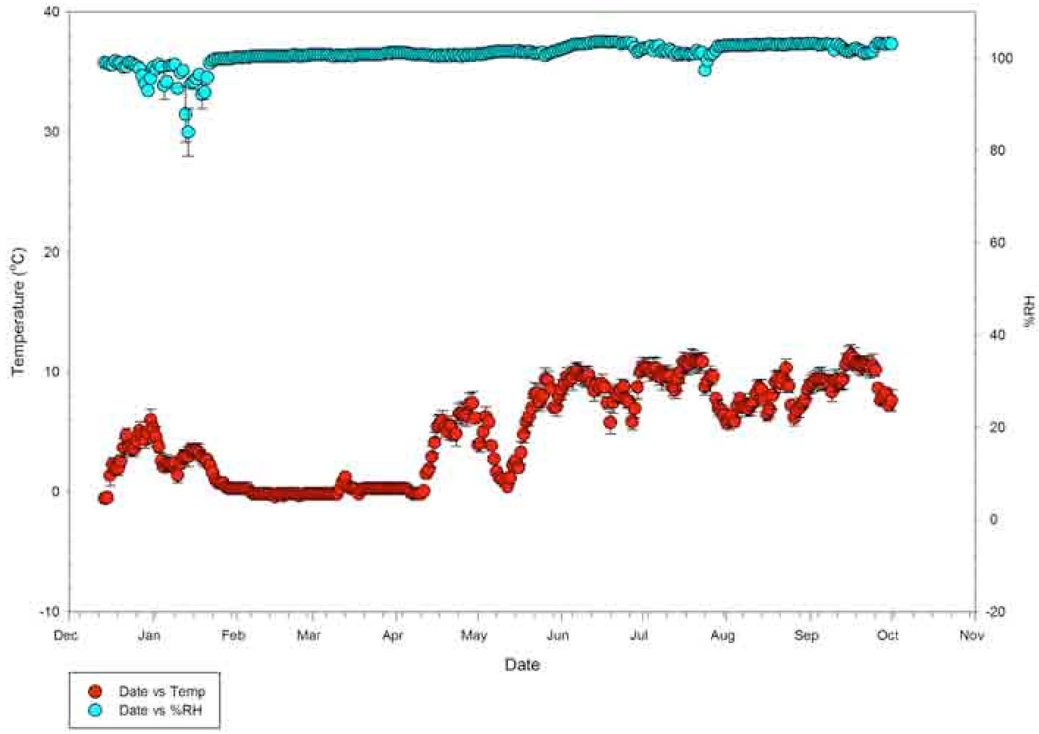

Figure 29. TEMP/RH Logger S/N#792686 Hau Oki (4,139 m), SUBSURFACE Dec. 2005– Oct. 2006.

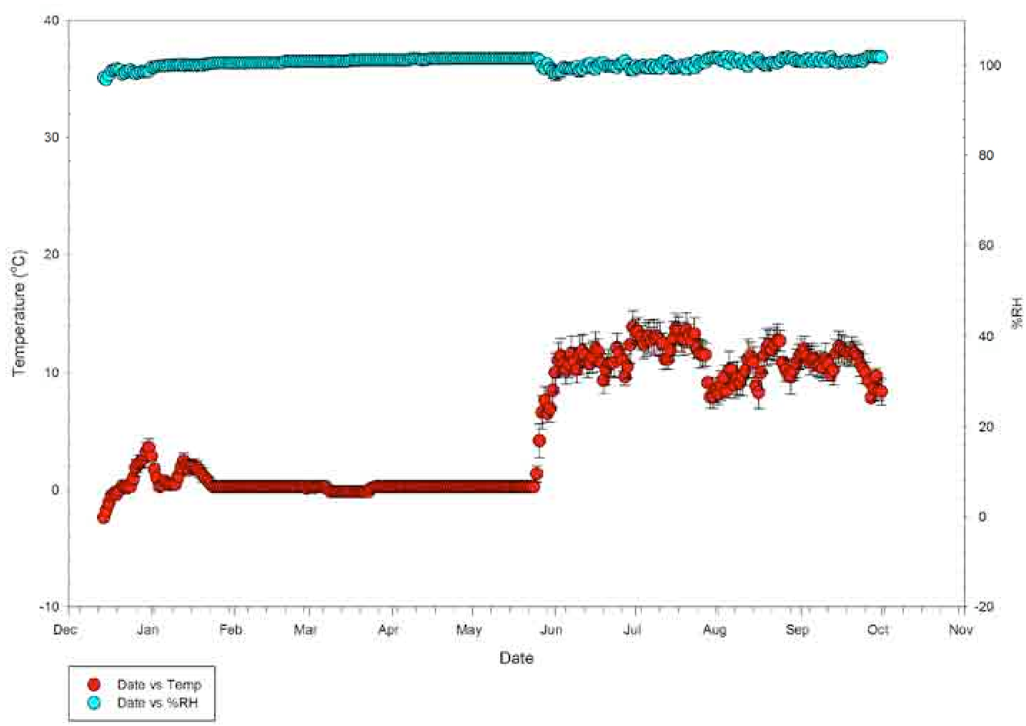

Figure 30. TEMP/RH Logger S/N#792717 Hau Oki (4,143 m), SUBSURFACE Dec. 2005– Oct. 2006.

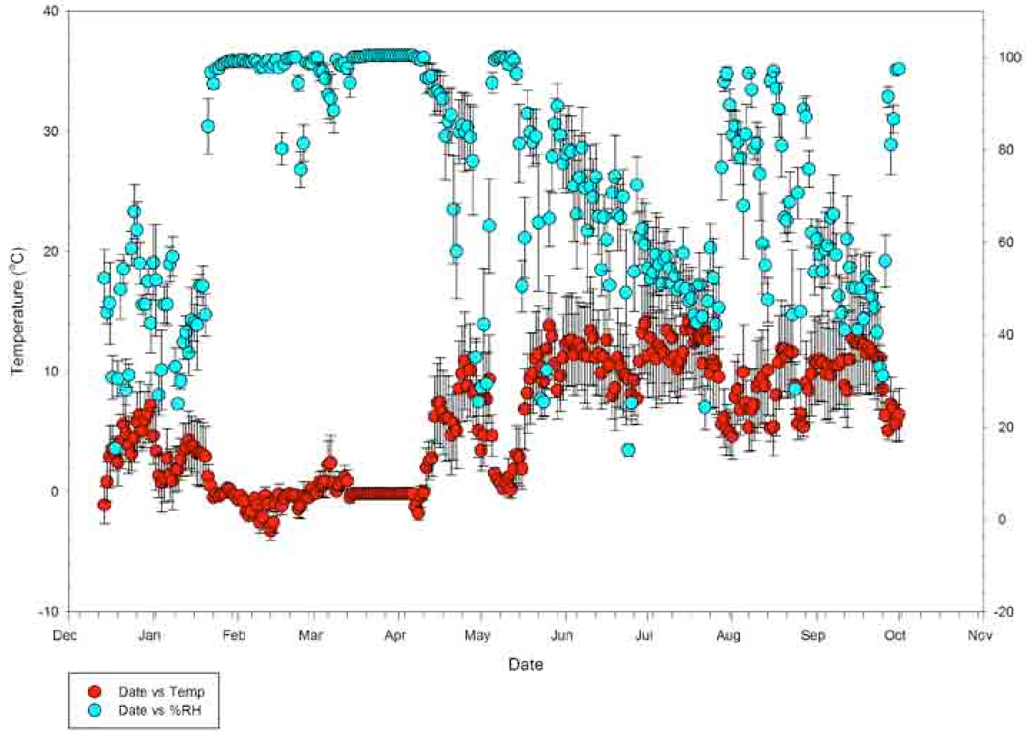

Figure 31. TEMP/RH Logger S/N#792723 Hau Oki (4,139 m), SURFACE Dec. 2005– Oct. 2006.

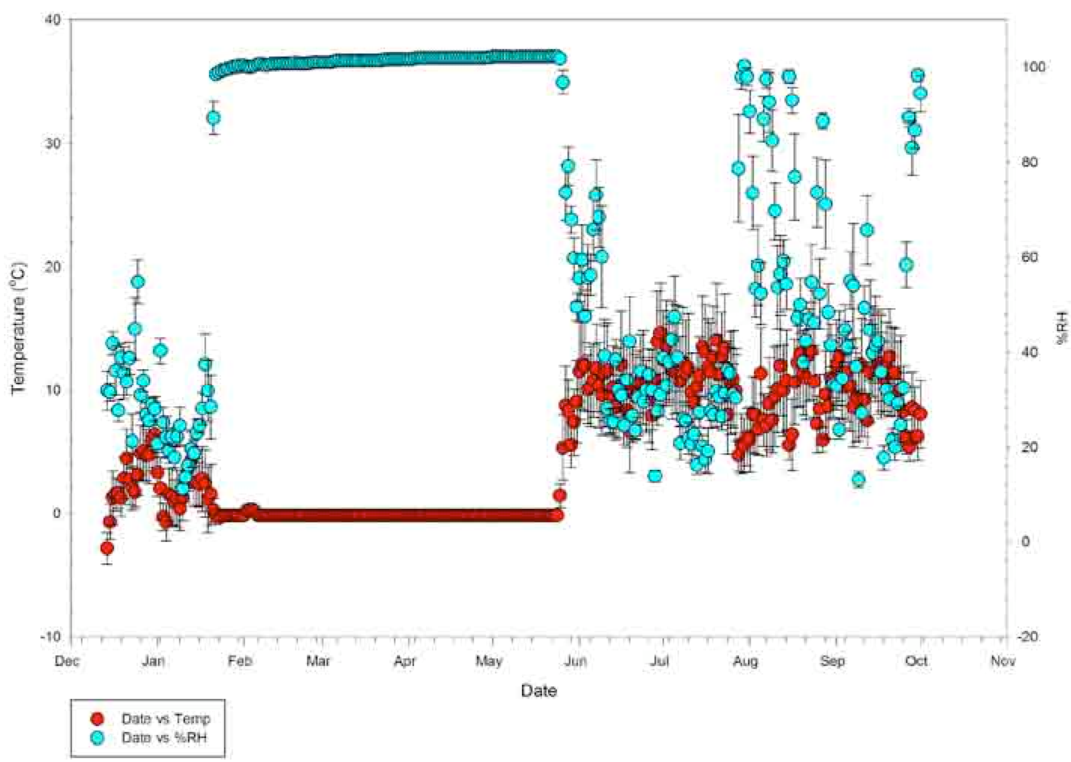

Figure 32. TEMP/RH Logger S/N#792740 Hau Oki (4,143 m), SURFACE Dec. 2005– Oct. 2006.

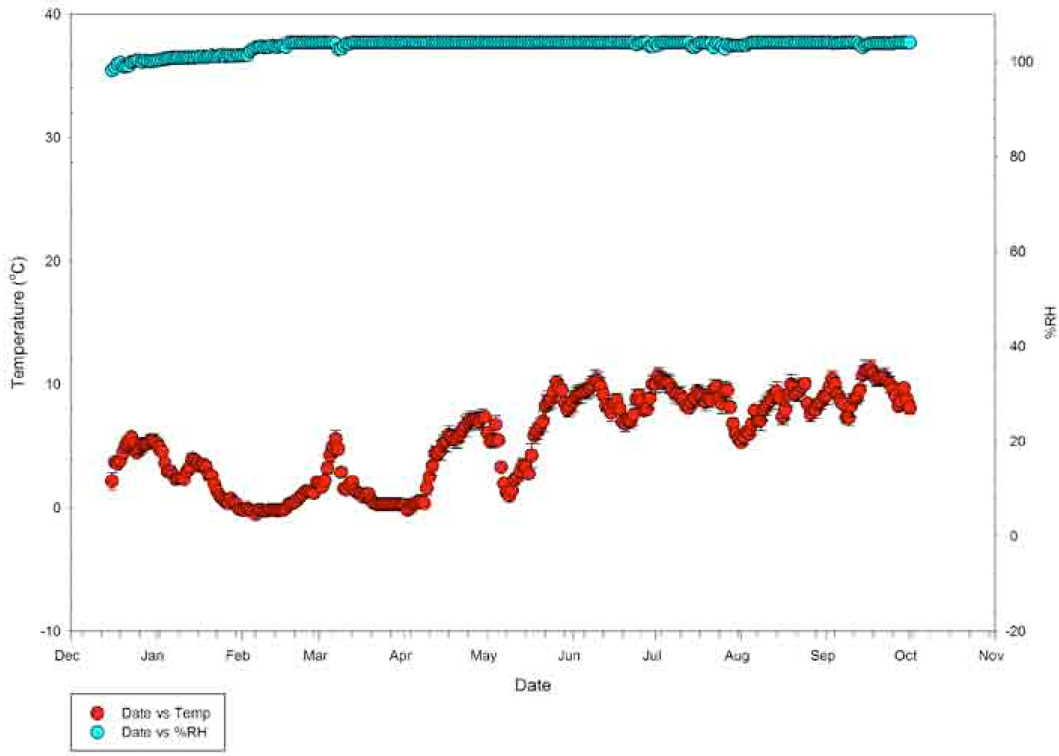

Figure 33. TEMP/RH Logger S/N#789549 Lilinoe (3,989 m), SUBSURFACE Dec. 2005– Oct. 2006.

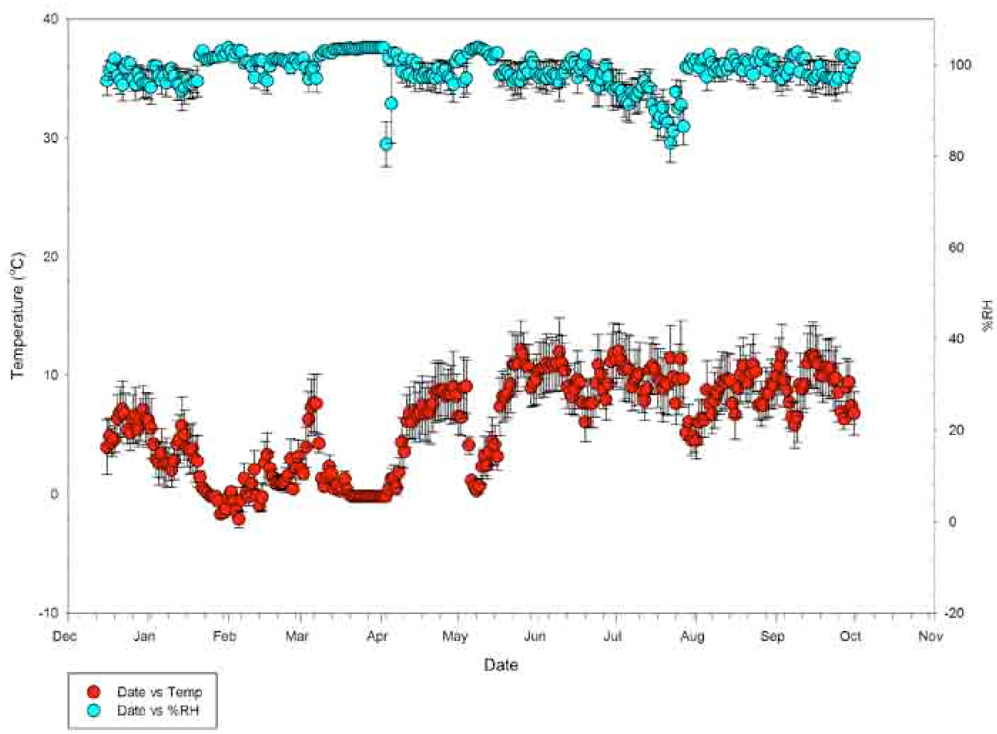

Figure 34. TEMP/RH Logger S/N#789561 Lilinoe (3,989 m), SURFACE Dec. 2005– Oct. 2006.

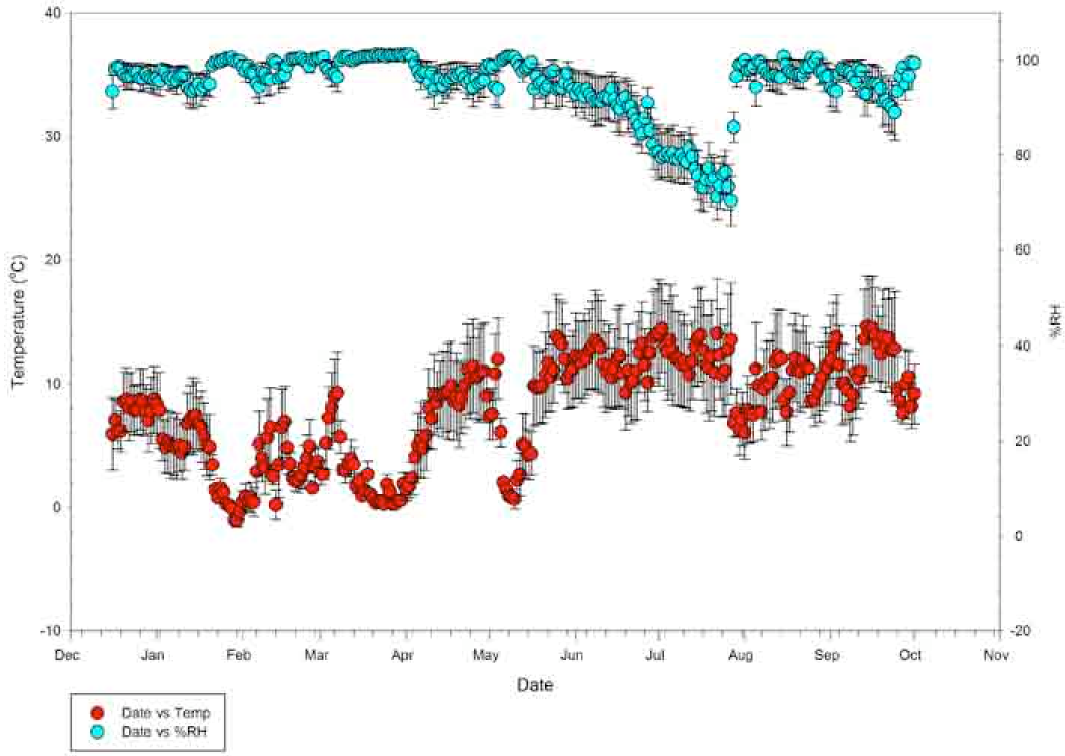

Figure 35. TEMP/RH Logger S/N#792694 Lilinoe (3,843 m), SURFACE Dec. 2005– Oct. 2006

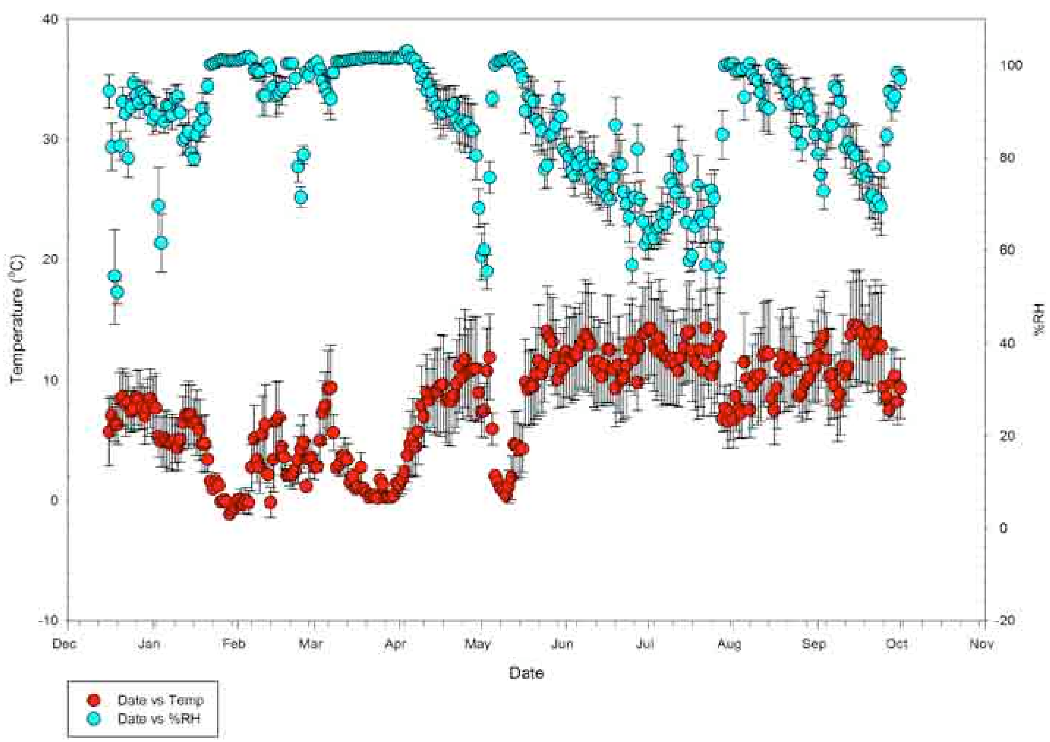

Figure 36. TEMP/RH Logger S/N#792739 Lilinoe (3,843 m), SURFACE Dec. 2005– Oct. 2006

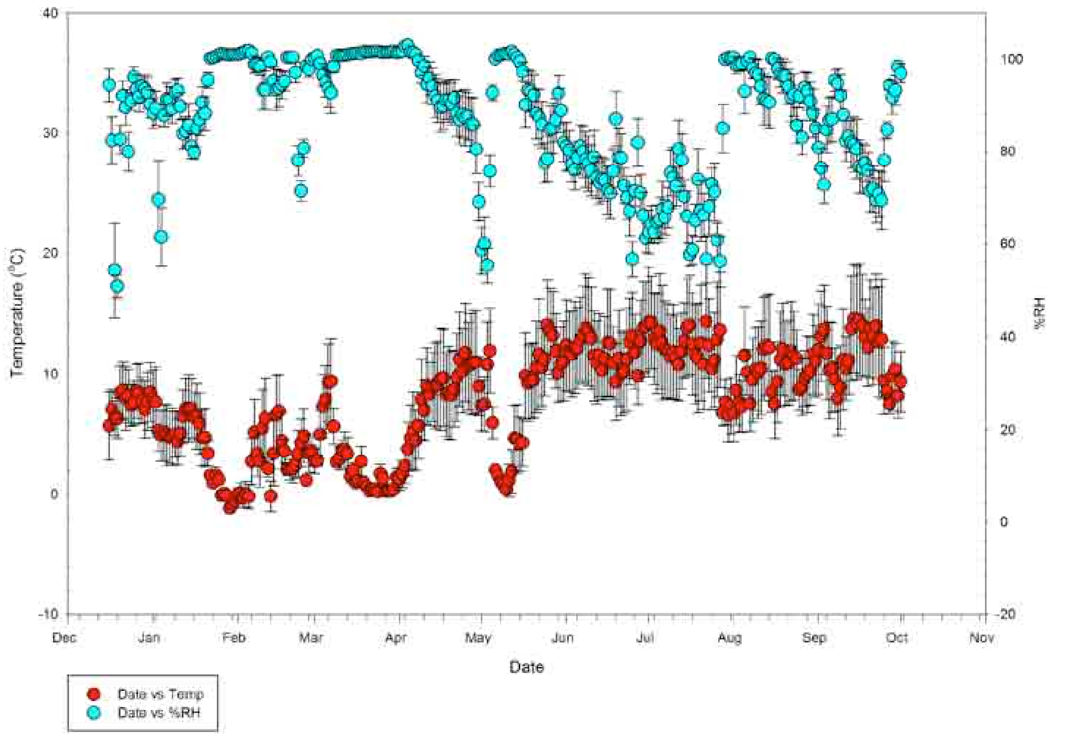

Figure 36. TEMP/RH Logger S/N#754791 Pu'u N. of VLBA (3,850 m), SURFACE Dec. 2005– Oct. 2006.

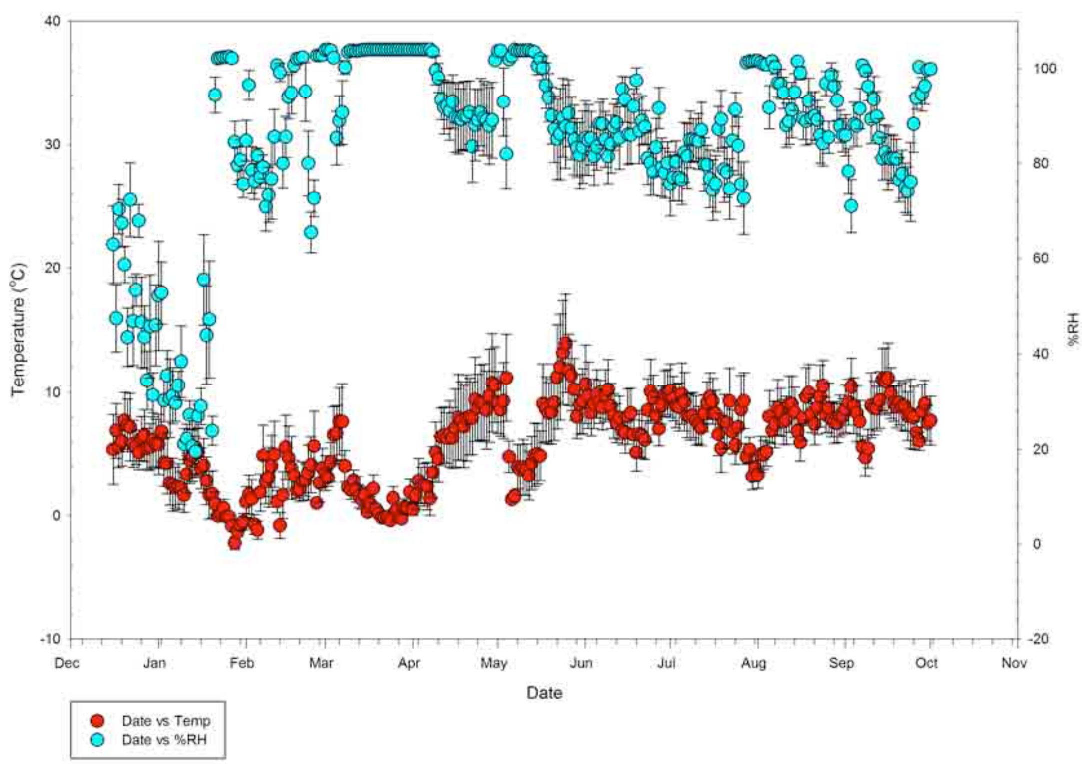

Figure 37. TEMP/RH Logger S/N#754792 Pu'u N. of VLBA (3,840 m), SURFACE Dec. 2005– Oct. 2006.

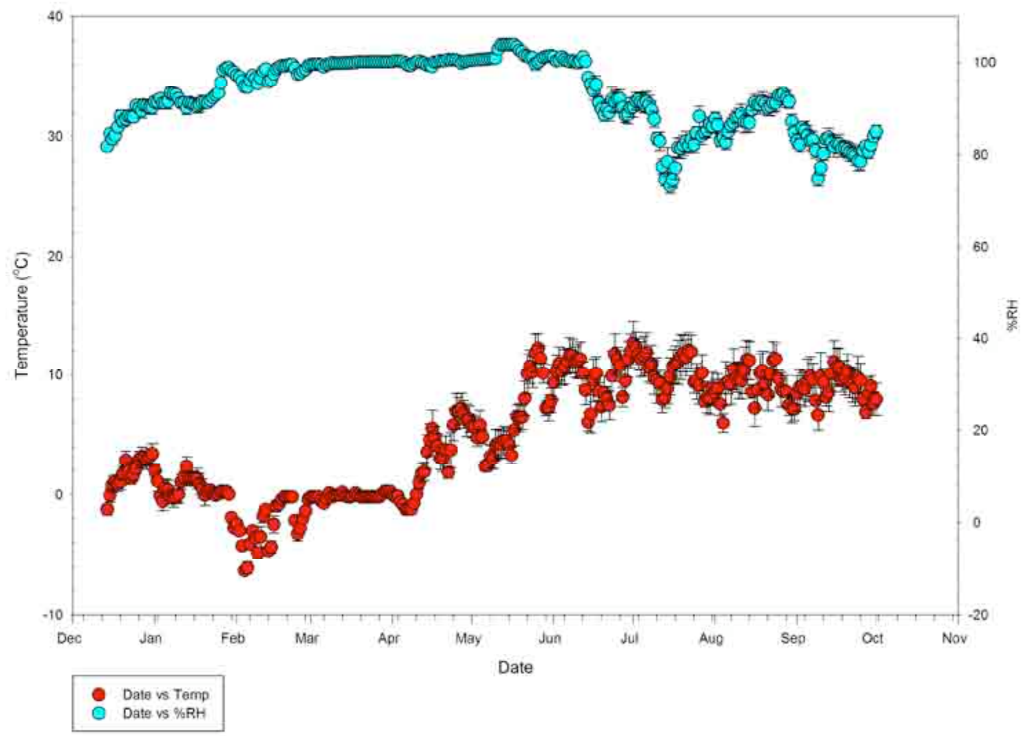

Figure 38. TEMP/RH Logger S/N#792697 (4,154 m), Poliahu SUBSURFACE Dec. 2005– Oct. 2006

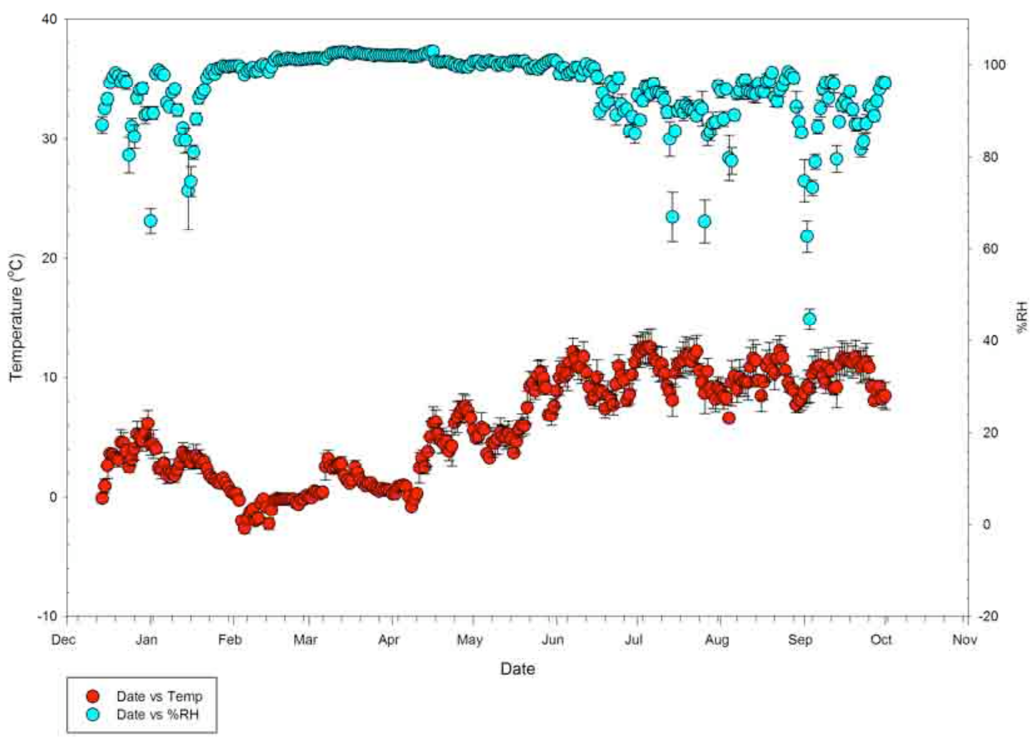

Figure 39. TEMP/RH Logger S/N#792728 (4,175 m), Poliahu SUBSURFACE Dec. 2005– Oct. 2006.

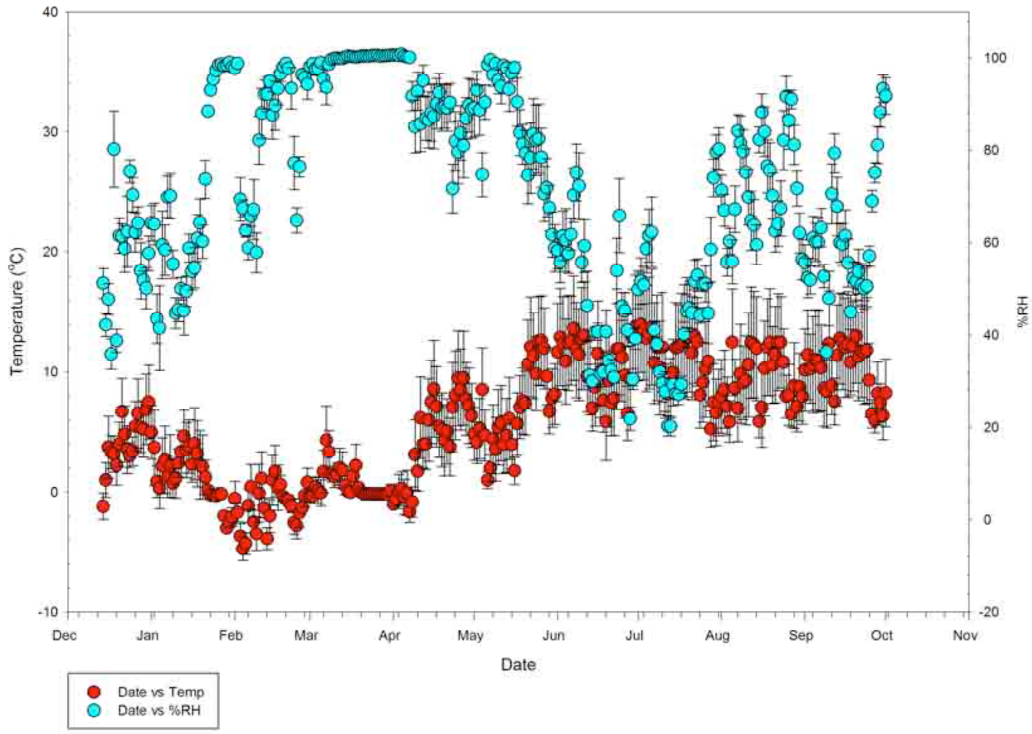

Figure 40. TEMP/RH Logger S/N#792689 (4,175 m), Poliahu SURFACE Dec. 2005– Oct. 2006.

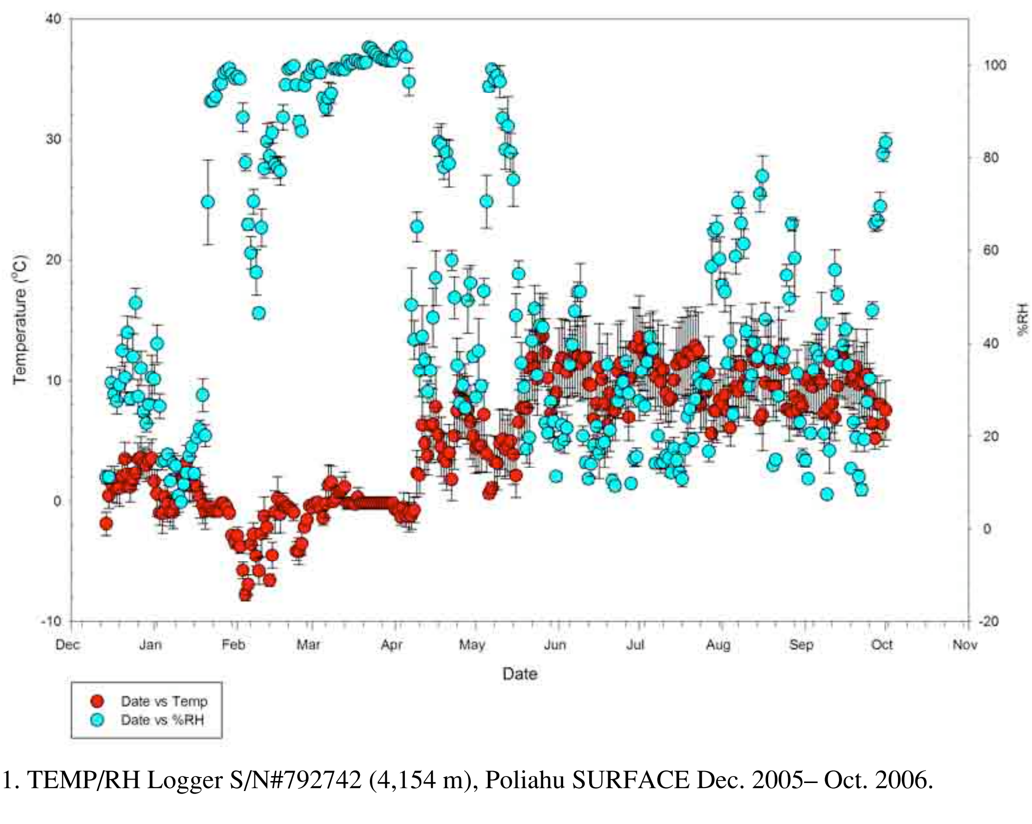

Figure 41. TEMP/RH Logger S/N#792742 (4,154 m), Poliahu SURFACE Dec. 2005– Oct. 2006.

Figures 42–57

Figures with data logger readings per day (every 4 hours), for selected loggers

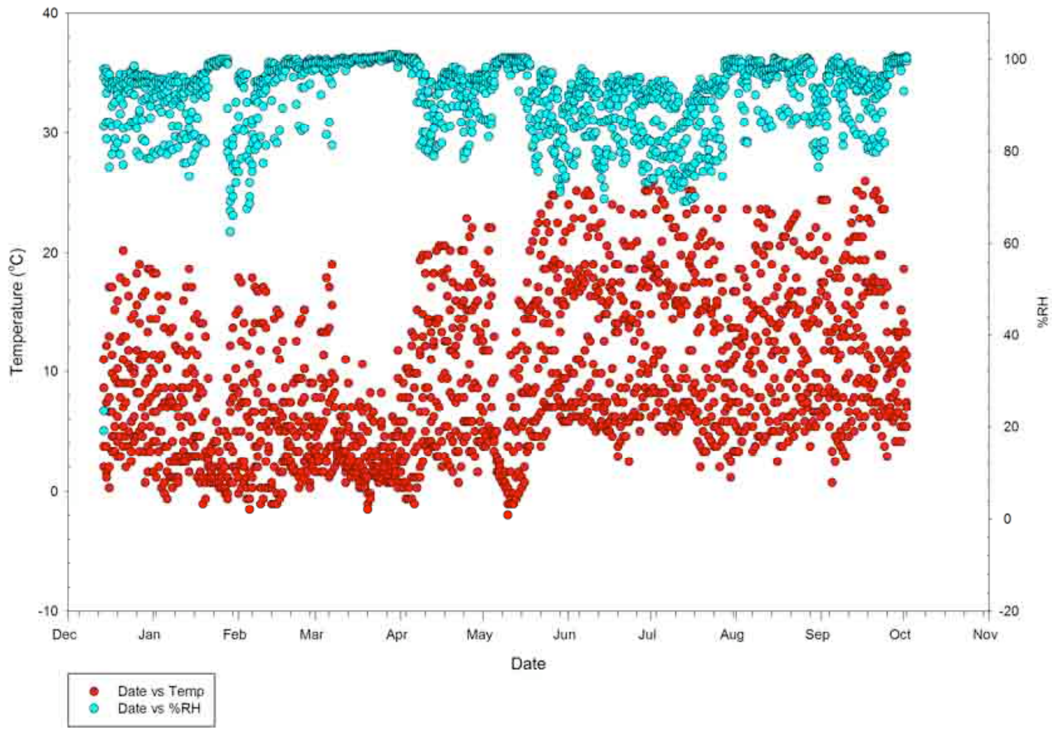

Figure 42. TEMP/RH Logger S/N#792444 John Burns cone (3,663 m), SURFACE Dec. 2005– Oct. 2006.

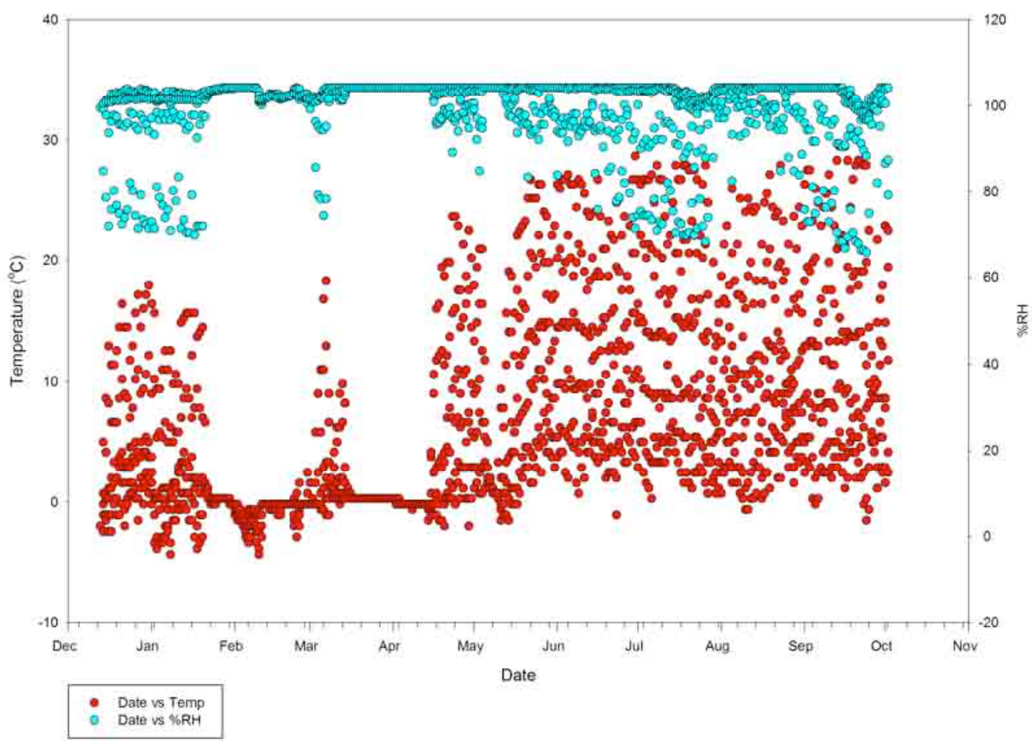

Figure 43. TEMP/RH Logger S/N#754786 Poi Bowl (4,097 m), SURFACE Dec. 2005– Oct. 2006.

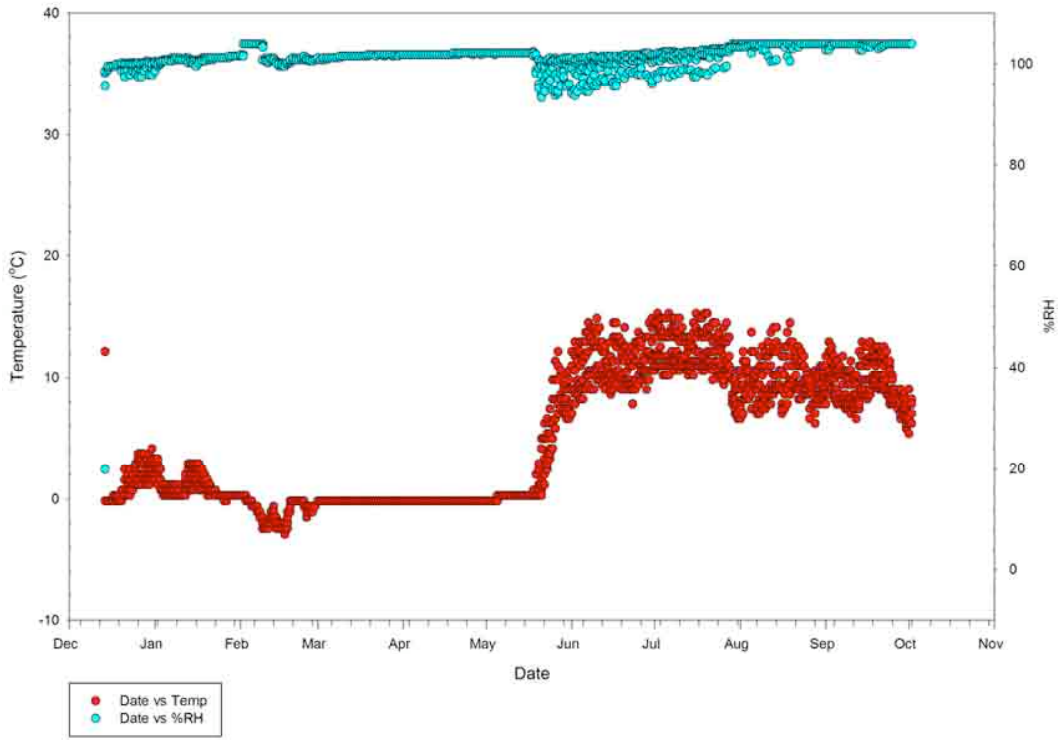

Figure 44. TEMP/RH Logger S/N#789546 Hau Kea (4,058, m), SUBSURFACE Dec. 2005– Oct. 2006.

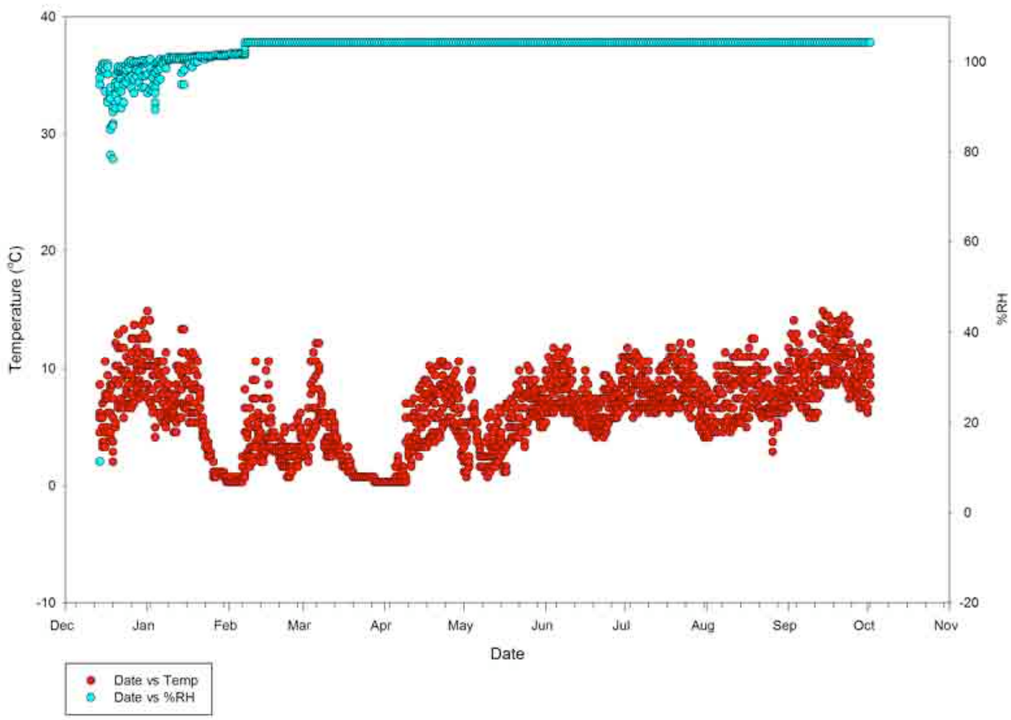

Figure 45. TEMP/RH Logger S/N#792684 Hau Kea (4,096 m), SUBSURFACE Dec. 2005– Oct. 2006.

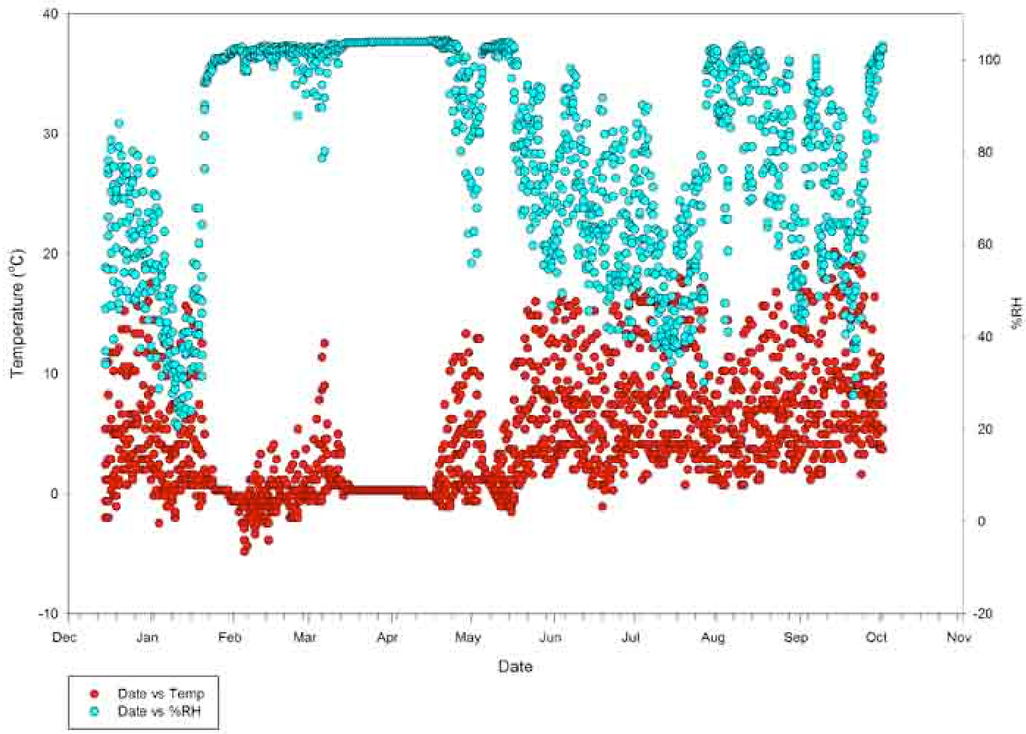

Figure 46. TEMP/RH Logger S/N#792708 Hau Kea (4,105 m), SUBSURFACE Dec. 2005– Oct. 2006.

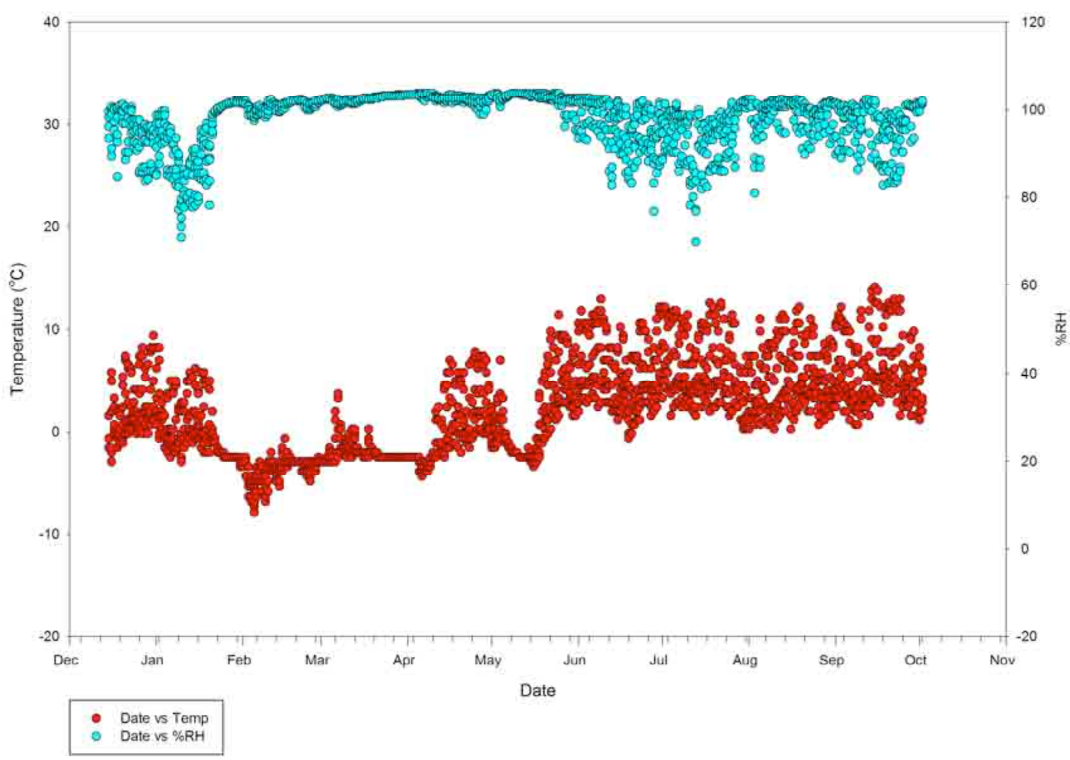

Figure 47. TEMP/RH Logger S/N#792732 Hau Kea (4,126 m), SUBSURFACE Dec. 2005– Oct. 2006.

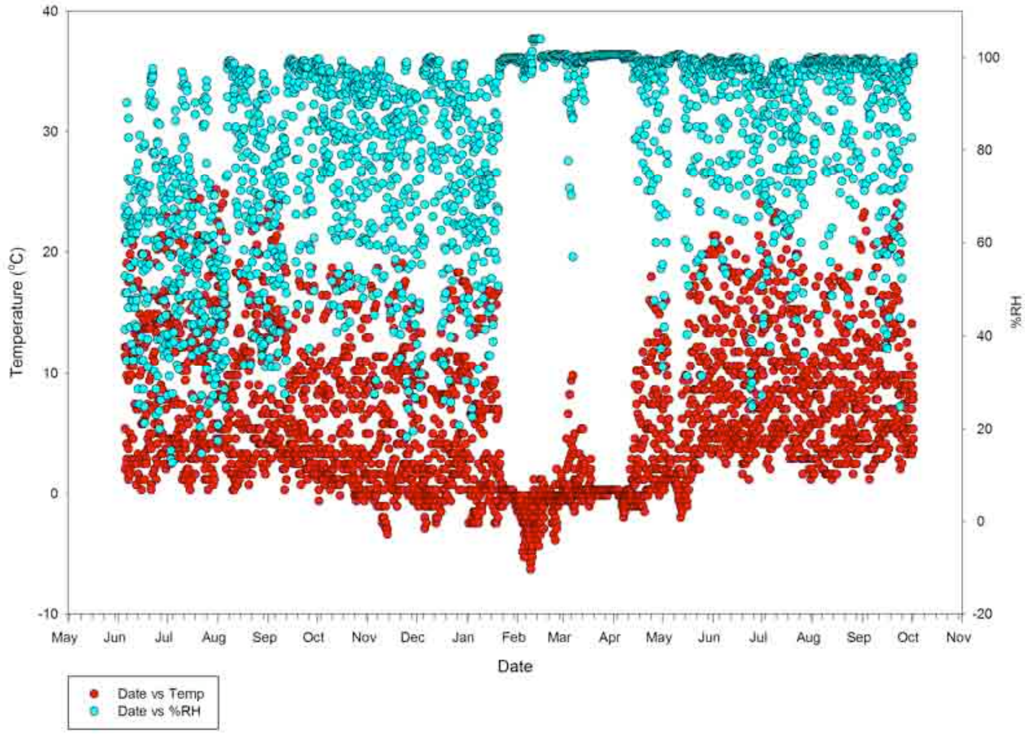

Figure 48. TEMP/RH Logger S/N#789553 Hau Kea base (trail to Lake Waiau) (3,902 m), SURFACE Dec. 2005–Oct. 2006.

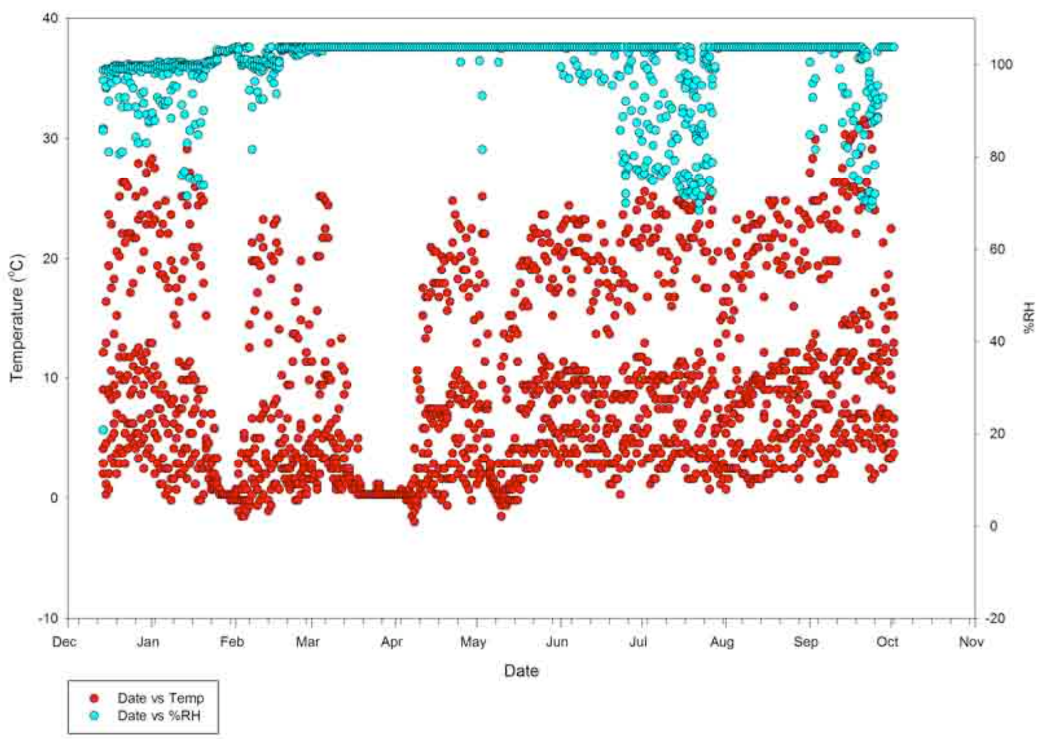

Figure 49. TEMP/RH Logger S/N#792688 Hau Kea (Hilo side) (4,006 m), SURFACE Dec. 2005– Oct. 2006.

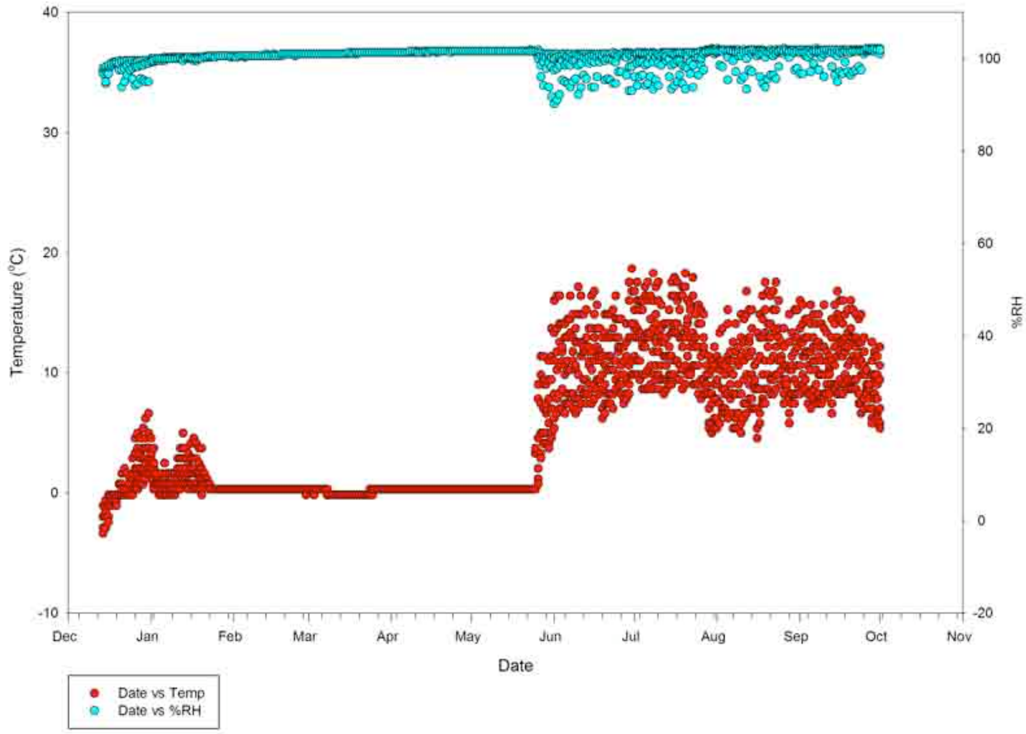

Figure 50. TEMP/RH Logger S/N#792717 Hau Oki (4,143 m), SUBSURFACE Dec. 2005– Oct. 2006.

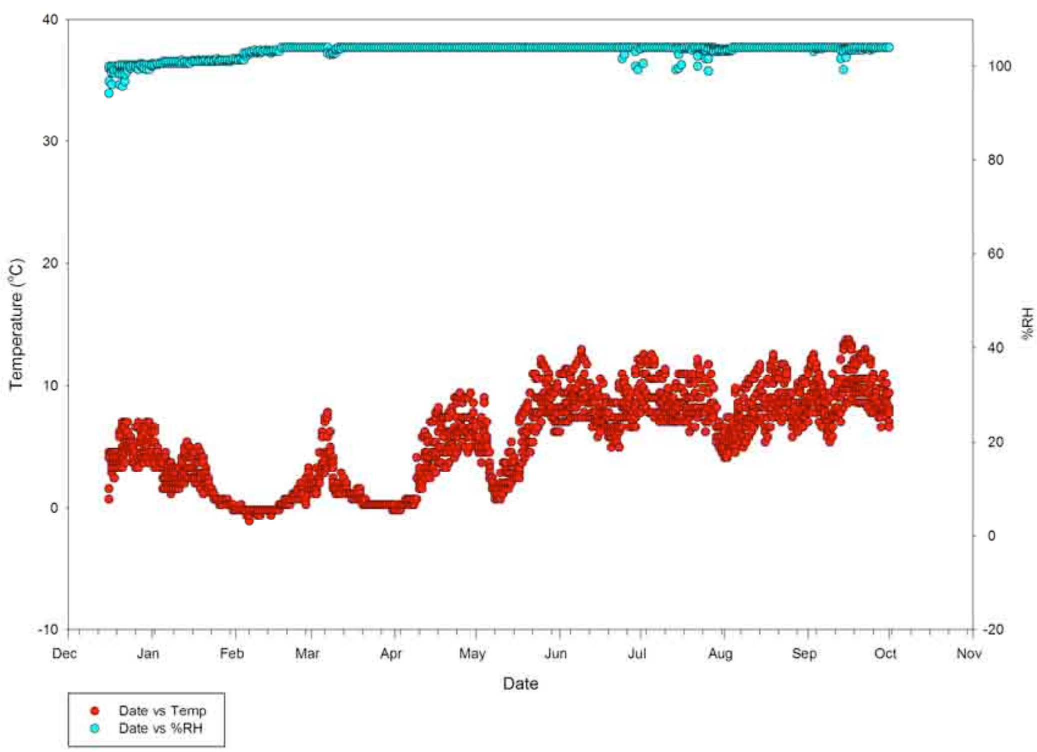

Figure 51. TEMP/RH Logger S/N#789549 Lilinoe (3,989 m), SUBSURFACE Dec. 2005– Oct. 2006.

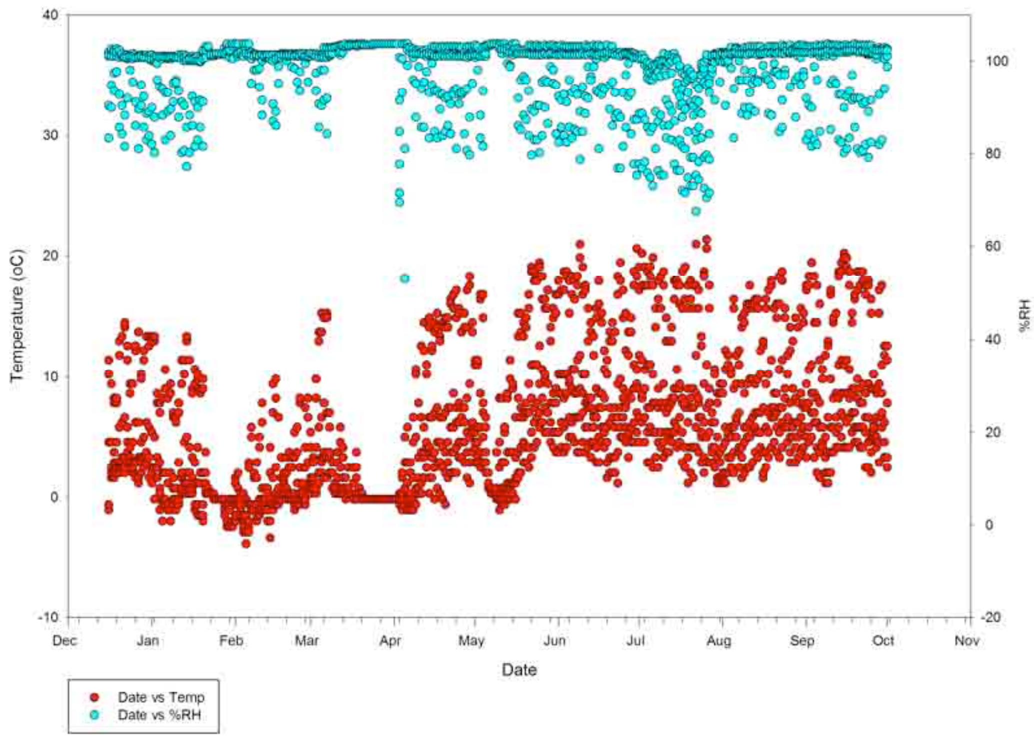

Figure 52. TEMP/RH Logger S/N#789561 Lilinoe (3,989 m), SURFACE Dec. 2005– Oct. 2006.

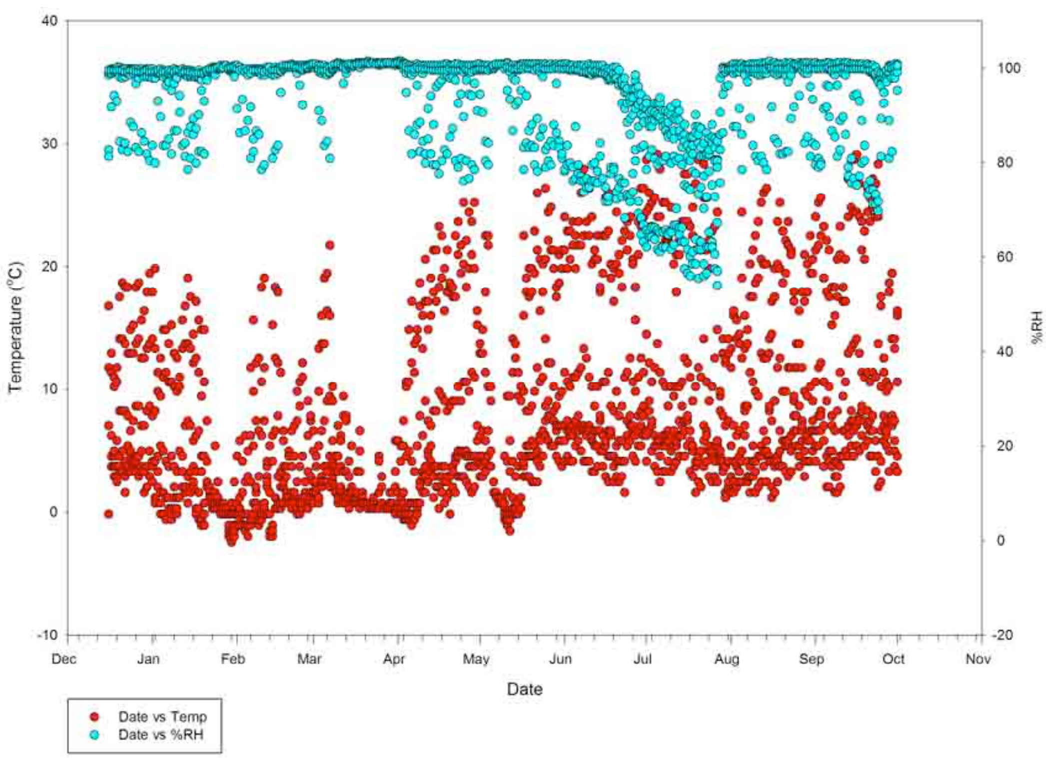

Figure 53. TEMP/RH Logger S/N#792694 Lilinoe (3,843 m), SURFACE Dec. 2005– Oct. 2006.

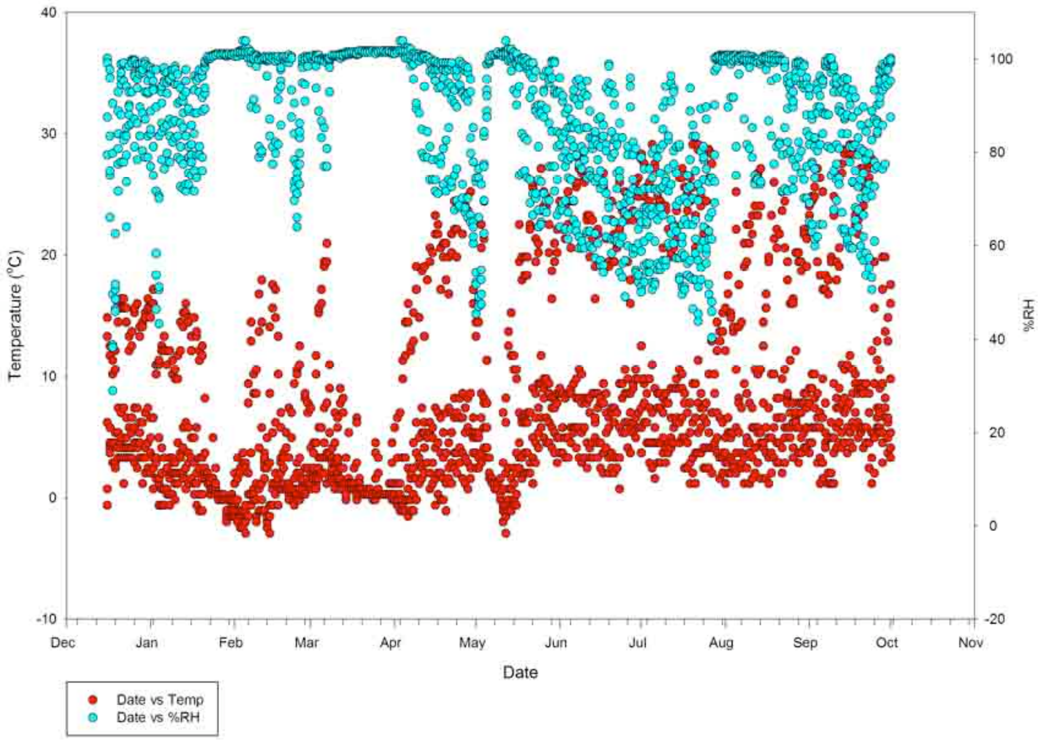

Figure 54. TEMP/RH Logger S/N#792739 Lilinoe (3,843 m), SURFACE Dec. 2005– Oct. 2006.

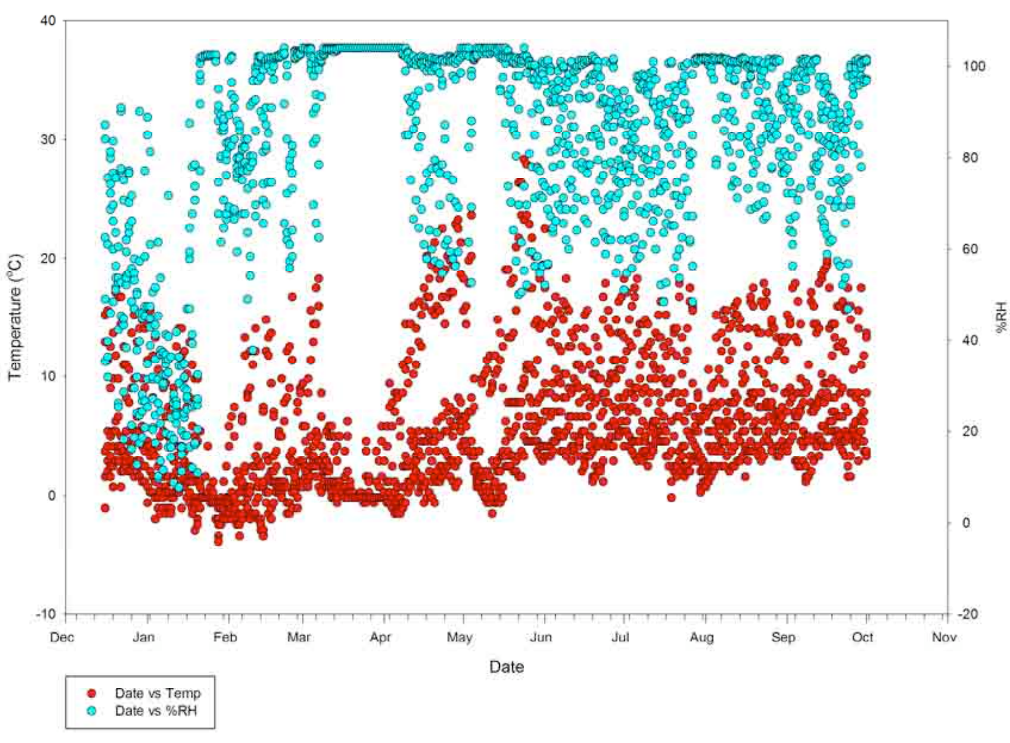

Figure 55. TEMP/RH Logger S/N#754792 Pu‘u N. VLBA (3,840 m), SURFACE Dec. 2005– Oct. 2006.

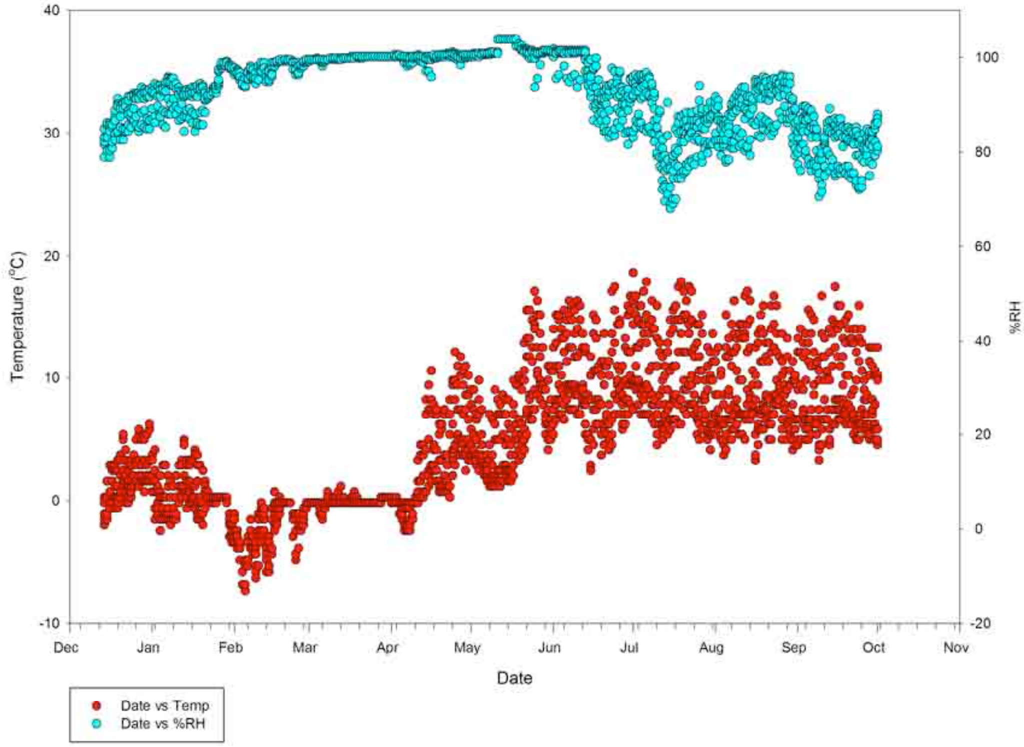

Figure 56. TEMP/RH Logger S/N#792697 Poliahu (4,154 m), SUBSURFACE Dec. 2005– Oct. 2006.

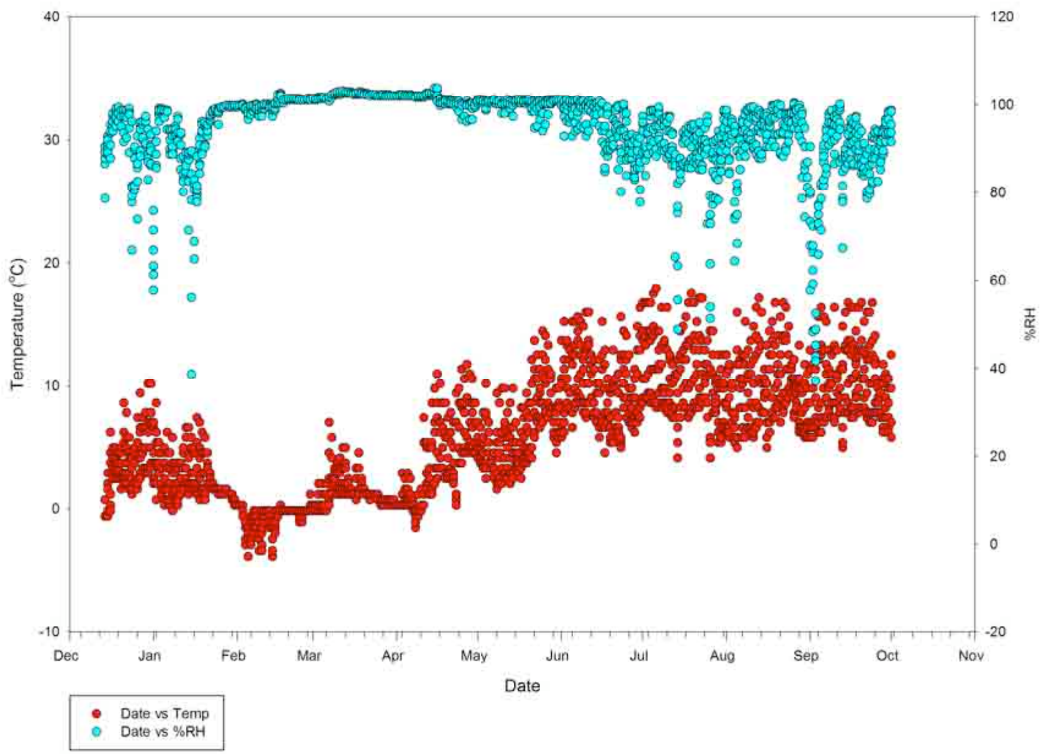

Figure 57. TEMP/RH Logger S/N#792728 Poliahu (4,175 m), SUBSURFACE Dec. 2005– Oct. 2006.