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Sensor Web in Antarctica: Developing an intelligent, autonomous platform for locating biological flourishes in cryogenic environments. K.A. Delin[1], R.P. Harvey[2], N.A. Chabot[2], S.P. Jackson[1], Mike Adams[2], D.W. Johnson[1], and J.T. Britton[1] [1]Jet Propulsion Laboratory, M/S 306-336, 4800 Oak Grove Drive, Pasadena, California 91109-8099 (kevin.delin@jpl.nasa.gov), [2]Department of Geological Sciences, Case Western Reserve University, Cleveland OH 44106-7216 (rph@cwru.edu).

Introduction: The most rigorous tests of the ability to detect extant life will occur where biotic activity is limited by severe environmental conditions. Cryogenic environments are among the most severe- the energy and nutrients needed for biological activity are in short supply while the climate itself is actively destructive to biological mechanisms. In such settings biological activity is often limited to brief flourishes, occurring only when and where conditions are at their most favorable. The closer that typical regional conditions approach conditions that are actively hostile , the more widely distributed biological blooms will be in both time and space. On a spatial dimension of a few meters or a time dimension of a few days, biological activity becomes much more difficult to detect.

One way to overcome this difficulty is to establish a Sensor Web[1] that can monitor microclimates over appropriate scales of time and distance, allowing a continuous virtual presence for instant recognition of favorable conditions. A more sophisticated Sensor Web, incorporating metabolic sensors, can effectively meet the challenge to be in "the right place in the right time". This is particularly of value in planetary surface missions, where limited mobility and mission timelines require extremely efficient sample and data acquisition. Sensor Webs can be an effective way to fill the gap between broad scale orbital data collection and fine-scale surface lander science.

We are in the process of developing an intelligent, distributed and autonomous Sensor Web that will allow us to monitor microclimate under severe cryogenic conditions, approaching those extant on the surface of Mars. Ultimately this Sensor Web will include the ability to detect and/or establish limits on extant microbiological activity through incorporation of novel metabolic gas sensors. Here we report the results of our first deployment of a Sensor Web prototype in a previously unexplored high altitude East Antarctic Plateau "micro-oasis" at the MacAlpine Hills, Law Glacier, Antarctica.

The Test Site: While there are myriad terrestrial locations and environments that can serve as analogs to sites of interest on Mars, The Dry Valleys in the McMurdo Sound region of the Transantarctic Mountains are among the most commonly mentioned. Snow-free through most of the year, with active periglacial features such as ice covered lakes and ephemeral streams, the Dry Valleys serve as an accessible Mars analog site for many studies (*e.g.* [2]). However, in several ways the Dry Valleys are simply too hospitable to be considered the best available Mars surface analogs. In the height of the summer, air temperatures in the Dry Valleys often exceed freezing, with rock surface temperatures reaching 10°C or higher. Surface runoff becomes significant, and ephemeral streams fill to significant levels. Proximity to the Ross Sea provides significant input of precipitation and ocean-derived organic material to local biotic systems. Subsequently, while the Dry Valleys are an incredibly useful analog to Mars surface conditions, they have served as host to active macro- and microscopic biological communities throughout the recent past, at a level far beyond that considered possible at the Martian surface.

While the Dry Valleys are the largest and most accessible dry deserts in Antarctica, many smaller dry deserts exist with more inhospitable (and thus more Mars-like) climatic conditions. Along the western edge of the Transantarctic Mountains, immediately adjacent to the East Antarctic Icesheet, plateau ice is diverted into glacial channelways as it plunges eastwards and downhill to the Ross Sea. These diversions, in concert with the general deflation of the icesheet over the past 20,000 years, have created great numbers of small, isolated snow-free areas. Because of their isolation, the vast majority of these sites remain unvisited and unstudied. Typically these regions are moraines or nunataks with a surface composed of loose glacial debris (of local origin) or alluvium a few centimeters thick over either bedrock or ice. The climatic conditions in these areas are much harsher than typically seen in the Dry Valleys because of their altitude and exposure to the cold, dry katabatic winds blowing from the interior of the icesheet. The result is that typical yearly temperatures average –40°C or colder, the dry, thin and cold air keeps liquid water essentially unstable year-round. The katabatic winds severely limit transport of organic material from the Ross Sea, and the surficial UV flux in the Antarctic springtime is among the highest anywhere on the globe. While there are clearly some major differences between Earth and Mars, the conditions prevalent in these high altitude snow-free regions more closely approach those of the Martian surface than any other sites on our planet. Yet even in these hostile regions, life is not absent. Within a given snow-free area, microclimates exist that can foster biological activity, perhaps only for days or hours in a given year. Given favorable geomorphology to provide some protection from the katabatic winds, and a mild

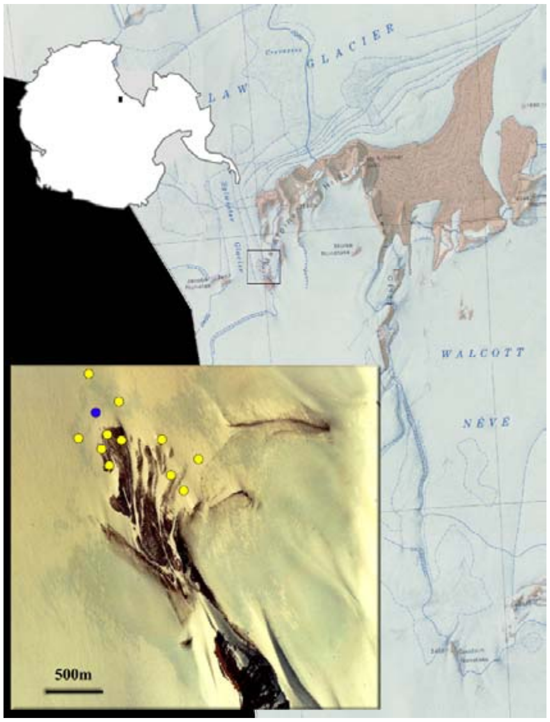

Figure 1. Location of Antarctic Sensor Web test site. Continental outline in upper left shows general area of larger map; insert in lower right is an aerial photograph of deployment area at the western end of the MacAlpine Hills. Colored circles showing locations of individual pods, with the location of "mother pod" shown in blue. Background map from USGS Antarctic series Buckley Island quadrangle map.

day or two each year that allows the rocks and regolith to warm in the sun, "micro-oases" develop where minor amounts of liquid water can persist , perhaps only for a few days in a given decade [3]. Although the volume of liquid water available is many orders of magnitude lower than that seen in the Dry Valleys, and rock temperatures above 0°C may occur for only hours a year, these conditions are still sufficient to foster sporadic flourishes of biological activity. However, the variability of conditions at these sites means that very subtle differences may be enough to control whether biological activity can be supported or not.

By coincidence, these areas often lie adjacent to Antarctic meteorite recovery sites; the same climatic features that support the development of snow-free regions on local bedrock and moraines contribute to the formation of meteorite stranding surfaces, such as exposure to the katabatic winds, high altitude, and high sublimation rates [4]. The main target of the 2002-2003 Antarctic Search for Meteorites (ANSMET) field season, the MacAlpine Hills, offered us an excellent opportunity to test the ability of the Sensor Web to monitor a rapidly changing microclimate. Moraines and nunataks in this area create small "micro-oases" where solar heating of exposed rocks are partially isolated from the surrounding East Antarctic icesheet.

Deployment: The Sensor Web chosen for deployment consisted of 14 self-contained, battery-powered pods equipped with solar panels for augmented energy harvesting, internal temperature sensors, external combined temperature and relative humidity sensors, and dual "remote" external temperature sensors on 3-5 m cable. Each pod is also equipped with small radio antennae that allow wireless communication with all other pods in range[1]. Three of the pods had special roles; two had limited sensor capability and served purely as communications relays, while a third served as the "mother pod". This pod was connected by cable to a robust laptop that continuously downloaded data from the Sensor Web. All the pods were deployed on either bamboo poles or tripods so that their onboard sensors record temperatures at approximately 1 m above the local surface.

With the exception of the mother pod (located near camp to allow connection to the laptop), pod locations were chosen with both science and web performance in mind. Our major goal for this deployment was to observe the "heat island" affect associated with the moraine by simultaneous monitoring air, snow, ice, "soil" and bedrock temperatures across the study area. With this in mind, pods were located in all of these environments surrounding the northern end of a moraine adjacent to camp. To ensure system redundancy, all pods had at least 2 neighbors within communication range.

Initial deployment of the pods and activation of the Sensor Web took place on 12/21/02 and it ran uninterrupted until deactivated on 1/12/03. Data rate for the entire Sensor Web system was one reading every 5 minutes per sensor (with some pods recording as many as 5 channels). All pod batteries remained fully charged throughout the deployment as a result of the 24 hour sun, and only one pod suffered a "failure", failing to return data during the last 90 hours of the deployment. Internal temperature of the pods have ranged between –19° and –5° C, consistent with local air temperatures and showing minor but visible diurnal variations. External sensor data has not yet been fully analyzed. Sensors in snow show good isothermal behavior, varying less than 4° C over the course of the deployment, while sensors in moraines and bedrock have recorded temperatures with dramatic variations over many tens of degrees. This high variability is expected in an environment where solar warming can be immediately followed by intense radiative cooling in localized shadows.

Implications: The Sensor Web proved robust and a superb tool for investigating microclimate in cryogenic conditions. The sensor package deployed for this test was necessarily limited; for future deployments we hope to use these climatological variables to activate sensors capable of directly detecting the presence of liquid water and metabolic products such as CO_2 and CH_4.

References: [1] Delin (2002) *Sensors* **2**, 270-285. [2] Doran et al. (1998) *J. Geophys. Res. E* **103**, 28,481-28,493. [3] Harvey (1989) *Meteoritics* **24**, 275. [4] Harvey, this volume.

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