Monitoring the active layer in Maritime and Peninsular Antarctica

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Abstract
This paper presents the active layer monitoring network in Maritime and Peninsular Antarctica established as part of the Brazilian activities for the IPY. Fifteen sites are already operating at King George and Livingstone Islands, and at the Antarctic Peninsula (Hope Bay). The sites consist of precision thermistors arranged as a vertical array with probes at different depths down to 1 meter. Soil moisture probes were placed at the bottommost layer at each site. All probes were connected to a Campbell Scientific CR 10 data logger recording data at hourly intervals. Soil chemical, physical, mineralogical and micromorphological characteristics are determined for each of the monitored sites using classical soil survey procedures. One year of data for four sites at the Keller Peninsula provide evidence of the effect of altitude. For all sites, the permafrost was expected to occur deeper than one meter from the surface. The highest site had the coldest temperature regime over the monitored period. Long term monitoring will allow a better understanding of the effects of climate change on the functioning of Antarctic terrestrial ecosystems.

Key Words
Climate change, permafrost, soils

Introduction

Cryosols are typical of polar and subpolar regions and have, as their main characteristic, the presence of permafrost. In Antarctica, there is still scarce data regarding permafrost distribution. The depth, distribution and overall characteristics of permafrost are the result of the thermal equilibrium between several environmental factors such as local climate, soil water content, and slope position.

In the current global warming scenario, permafrost studies are of special interest (Nelson and Anismov 1993; Ramos and Vieira 2003). The soil temperature regime is an important indicator of climatic regime, reflecting long term tendencies. The depth of frost penetration depends mainly on the intensity and duration of the cold, snow cover, precipitation and cloud cover. The continuous monitoring of soil temperature allows the identification of distinct events, such as the summer thaw period, of limited duration, and the longer winter period, during which temperatures remain below 0^oC (Guglielmin *et al.* 2008).

Maritime Antarctica has been increasingly recognized as a key region for monitoring climate change. Despite this recent interest, few investigations of thermal conditions of the active layer and permafrost in ice-free areas are based on continuous year-round measurements (Cannone *et al.* 2006; Ramos and Vieira 2003). Several international efforts are being made in order to fill this information gap and gather spatially distributed data to allow more robust and reliable analysis of the effects of climate change on active layer in Antarctica, such as the projects Thermal State of Permafrost (TSP) and Antarctic and Sub-Antarctic Permafrost, Soils and Periglacial Environments (ANTPAS) (Vieira *et al.* 2008).

The objective of the present work is to report the installation of active layer monitoring sites along a latitudinal and pedological gradient within the scope of the Brazilian funded IPY project entitled *Permafrost dynamics, characterization and mapping of Cryosols from Maritime and Peninsular Antarctica in a climate change scenario.* Data for 2008 is presented for four sites from Keller Peninsula

Methods

Monitoring sites are being installed at the most expressive ice-free areas at the South Shetlands Archipelago (King George, Livingstone and Deception Islands), as well as at the northernmost part of the Antarctica Peninsula and islands located in the Weddell Sea (Seymour and James Ross), constituting a latitudinal gradient with climatic and pedological differences.

The active layer monitoring sites consist of precision thermistors arranged as a vertical array with probes at different depths down to 1 meter. Soil moisture probes were placed at the bottommost layer at each site. All probes were connected to a Campbell Scientific CR 10 data logger recording data at hourly intervals
Soils chemical, physical, mineralogical and micromorphological characteristics were determined for each of the monitored sites using classical soil survey procedures (Simas *et al.* 2008). Soil samples are collected and submitted to laboratory analyses. General characteristics such as altitude, geomorphology, and vegetation type, were registered for each site. Additional soils were collected and analysed in order to characterize the main soil type for each ice-free area. Based on high resolution satellite images, soil maps were produced. Fifteen sites are in operation (Table 1) and four others will be installed in the near future in order to complete the network (Figure 1). Due to the proximity of the Brazilian Comandante Ferraz Station, which makes access to the systems easier, eight sites are located in Keller Penninsula, King George Island. For this area, it will be possible also to compare the effects of topography and different vegetation covers on the thermal dynamics of the soils. Apart from these, the following sites are already operating (Table 1): Livingstone Island (2 sites in Byers Peninsula), Antarctic Peninsula (one site in Hope Bay), King George Island (one site in Potter Peninsula and 2 sites in Fildes Peninsula).

In the present paper we present soil temperature from 13/03/2008 to 10/01/2009 for sites 1, 4, 6 and 8, in Keller Peninsula which form an altitudinal sequence developed from basaltic-andesitic materials. All four sites are devoid of vegetation. According to the Ferraz Station metereological data air temperature varied from -14^{o}C to +5^{o}C in the studied period, with mean value of -1^{o}C.

Table 1 – Sites in operation.

Site	UTM (21 E)		UTM	Altitude	Location
	E	N	Fuse	(m)	
1	427137	3115583	21 E	28	Keller
2	426511	3115084	21 E	34	Keller
3	426610	115905	21 E	259	Keller
4	426663	3116587	21 E	196	Keller
5	426004	3116940	21 E	45	Keller
6	424084	3116257	21 E	31	Keller
7	426174	3115459	21 E	89	Keller
8	427053	3115790	21 E	49	Keller
9	426431	3115419	21 E	112	Keller
10	413784	3096573	21 E	70	Potter
11	871370	3080448	21 E	65	Fildes
12	865940	3077672	21 E	95	Fildes
13	441165	3109959	21 E	85	Lions Rump
14	598797	3053099	20 E	108	Byers
15	499560	2969987	21 E	50	Hope Bay

Results
The dataset shows clear differences between soil temperature variations for the studied sites (Table 2). Site 1, presented the coldest regime as shown by the highest number of days with mean temperature <=0^{o}C and lowest mean temperature values. April marked the beginning of continuous freezing for all monitored layers, and Site 1 was the first to present all layers in continuous freezing and the last to start thawing. Site 3 was the first to start the continuous thawing, starting at October 18th. At the other sites, continuous thawing of the surface layer starts in November. The bottommost layer at Site 1 starts continuous thawing only in the beginning of January.

All monitored layers at the four sites presented positive temperature during part of the year, indicating that the permafrost occurs at deeper layers (Figure 2). The bottommost layer at Site 1 presented the lowest maximum temperature (1^{o}C) and presented only 34 days in which the mean temperature was > 0^{o}C.

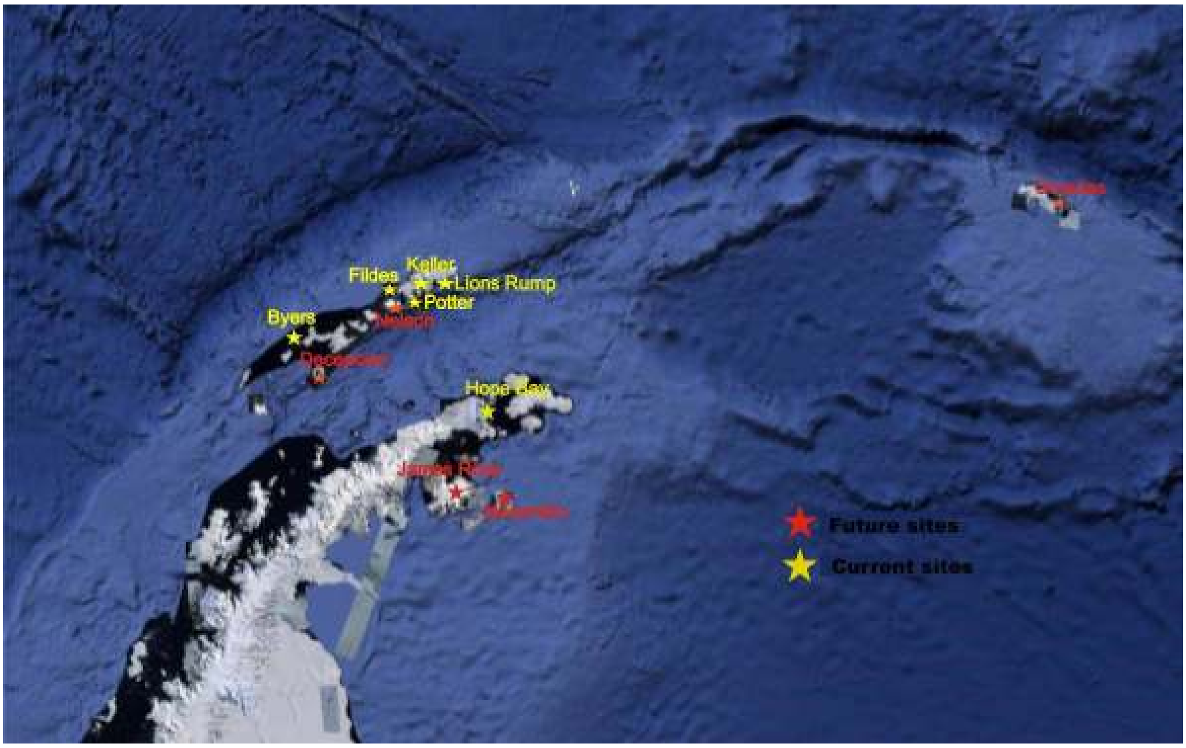

Figure 1. Current and future sites for long term monitoring of active layer in ice-free areas of Antarctic Region 8.

Table 2. Temperature data for the different soil layers at Sites 1, 2, 3 and 4, Keller Peninsula.

	Site 1 - 196 m.a.sl.				Site 2- 49 m.a.s.l.			Site 3 - 34 m.a.s.l.			Site 4m – 28 m.a.s.l		
Depth of sensor (cm)	10	33	56	78	10	51	92	10	45	80	10	44c	99
days <=0°C	243	242	254	278	209	211	218	196	197	182	234	197	248
days >0°C	69	70	58	34	103	101	94	116	115	130	78	115	64
Min T°C.	-8	-7	-6	-5	-8	-6	-5	-8	-6	-5	-6	-4	-3
Max T°C.	5	4	2	1	6	4	3	7	5	4	5	4	2
Mean	-2	-2	-2	-2	-1	-1	-1	-1	-0	-0	-0	-0	-0
Stand. Dev.	3	2	2	2	3	2	2	3	3	2	2	1	1
Isothermal days	64	60	93	95	52	77	98	42	73	92	98	130	149
Start continuous freezing	8/04	9/04r	13/04	11/04	9/04	26/04	28/04	9/04	15/04	19/04	9/04	19/04	17/04
Start continuous thawing	22/11	27/11	20/11	5/01	10/11	20/11	2/12	18/10	6/11	17/11	21/11	29/11	21/11

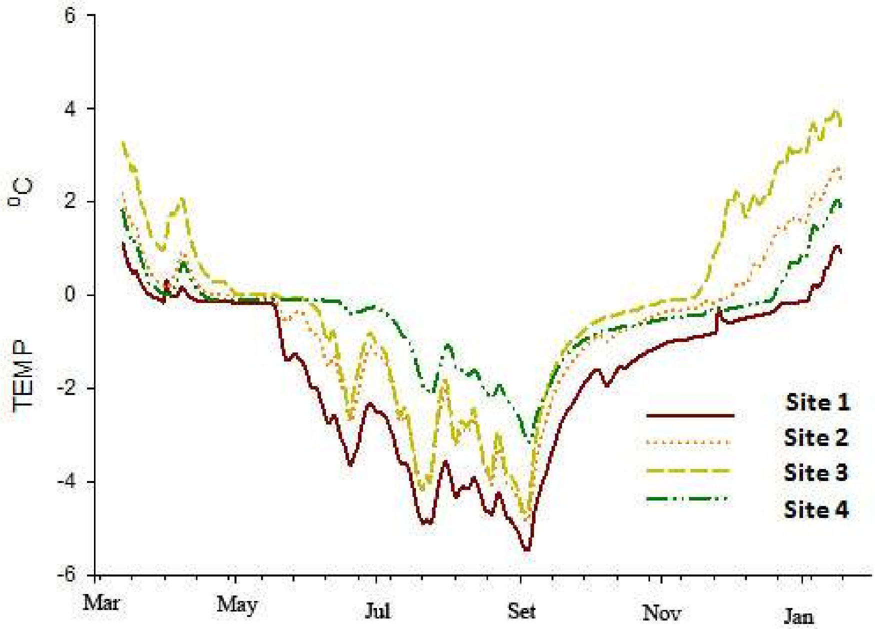

Figure 2. Mean daily temperature for the bottommost layer of Sites 1, 2, 3 and 4, Keller Peninsula, evidencing that at all Sites temperatures were above zero during part of the monitored period.

Conclusion

This initial data set allows only a preliminary interpretation of the temperature variation for the studied sites and no major conclusions are possible at this moment. Anyhow, the data evidences the effect of altitude in soil temperature, indicating that at higher altitudes the permafrost table is closer to the surface and that the permafrost table starts deeper than one meter from the surface at the studied sites. Nevertheless, these results are extremely important for future evaluation of soil temperature. In January 2010, data for the other operating sites will be downloaded as well as a second year data for the sites at Keller Peninsula. As more the spatial and temporal variation. Long term monitoring will allow a better understanding of the effects of climate change on the functioning of Antarctic terrestrial ecosystems. This will allow a better understanding of the general temperature pattern along the studied transect.

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