ACTIVE LAYER PROTOCOL

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Introduction

The active layer, the zone of annual freezing and thawing between the atmosphere and permafrost, is the locus of several important sets of dynamic processes, including biological, pedologic, geomorphic, biogeochemical, and hydrologic. Despite its importance to a wide variety of physical and biological investigations, information about development of the active layer has rarely been collected in a systematic, standardized fashion over large areas.

Ideally, active layer data should be collected at regular intervals from the time of snowmelt until the annual freezeup. These data should be collected to obtain a statistical characterization of active layer thickness in representative terrain and vegetation types, on an interannual basis. The ITEX experiments offer excellent opportunities to obtain long-term records of active layer fluctuations in response to climate and soil factors. Similar goals exist in other international activities, including those of the International Permafrost Association (IPA) and its working groups on Permafrost and Global Change and Periglacial Processes and Environments (see the IPA News Bulletin Frozen Ground, no. 16, December 1994).

The majority of the historical record on thaw depth (at least in the North American Arctic) has been obtained using small-diameter metal rods to probe for the bottom of the active layer. Other methods include frost tubes (Mackay 1973, Rickard and Brown 1972) and measuring and recording ground temperatures; both approaches yield high-quality data, but are necessarily restricted in their ability to provide spatial information. Physical probing has the advantage of being the most practical, low-cost method of nondestructive and areally extensive data collection. However, in coarse and bouldery soils, and in deeper active layers (>1.5 m), probing becomes impractical and other methods should be considered.

Sampling Design

Active layer thickness is known to vary substantially over very short distances. Sampling design is rarely treated explicitly in publications describing studies of thaw depth in the Arctic, but appears to have involved two commonly used methods: 1) linear transects, with measurements made at equal intervals; and 2) unspecified "random" selection of measurement locations. The potential exists for several types of inaccuracy in collecting active layer data using transects, equally spaced observations, and purely random methods. Transects may not be aligned with environmental gradients, leading to erroneous conclusions about spatial patterns of thaw depth and fallacious inferences about environmental controls. In the presence of such spatial regularities as patterned ground, equally spaced observations may lead to serious under- or over-estimates of active layer thickness. Probing locations chosen using a purely random design generally do not provide good areal coverage, and may be difficult to locate. A standardized set of measurements, obtained using an explicitly spatial sampling design, yields information useful for examining interrelations between physical and biological parameters. Grids measuring from 100 to 1000 meters on a side are adequate under most circumstances for making estimates of active layer thickness in representative vegetation.

Extensive experimentation, both in the field and through simulation, indicates that the most effective and economical sampling design is the systematic stratified unaligned (SSU) sampling scheme advocated by Berry and Baker (1968), Iachson (1985) and several other workers, including the comprehensive treatise by Thompson (1992). Validation of the design's effectiveness in the context of active layer variation was demonstrated for northern Alaska in a thesis by Fagan (1995). The SSU design is relatively easy to implement in the field using either pacing or more precisely measured distances to locate individual sampling points. It also provides excellent areal coverage and avoids problems that might otherwise be introduced by the presence of such spatial regularities as sorted or nonsorted patterned ground.

The SSU design, implemented on a series of grids, is consistent with recommendations proposed by the International Permafrost Association for the Circumarctic Active Layer Monitoring program (CALM). For ITEX purposes, the grids should be sampled once each year, at the end of the summer, although more frequent sampling is desirable to gain information about the relation of thaw progression to climate and phenology.

Recommended Procedures

A two-level, active layer measurement program at all ITEX sites is recommended. Level 1 measurements consist of monitoring active layer thickness with a metal rod in close proximity to each ITEX site and an associated grid. Level 2 measurements involve permanently installed devices using a combination of frost tubes and data loggers.

The Level 1 measurement program provides information about the rate and maximum depth of thaw in and around ITEX open-top chamber (OTC) sites. Measurements are made with a thin, rigid metal rod (less than 1 cm in diameter) calibrated in centimeter increments, and pushed vertically into the soil to the depth at which ice-bonded soil provides firm resistance. When removing the rod, extreme care should be taken to prevent disturbance to the soil and

vegetation. The Level 1 program consists of three parts. Two data forms for use in the field are provided as Appendices (See data forms in appendicies VI and VII).

OTC Measurements:

In each of at least 25 OTCs, active layer thickness should be measured at the center point within one day following the onset of snow free conditions. At the beginning of the growing season (first two weeks), measurements should be made daily or at two-day intervals. Thereafter, measurements should be made once during midseason, and again at the end of summer. Data can be recorded and average values computed on the OTC/Control active layer form provided in the appendix to this manual.

Control Measurements:

A total of 100 points per sample period are to be probed in areas immediately surrounding the OTC controls. In the case of 25 OTC sites, four measurements of thaw depth should be made at each control, at approximately seven-day intervals. If there are between 25 and 50 OTCs per site, three measurements per control are adequate. If 50 or more OTCs are available, two measurements per control are adequate. The specific point locations to be probed can be varied slightly from week to week to prevent any cumulative effect from minor disturbances. Care should be taken to prevent disturbance by trampling during the repeated measurements. The control measurements will provide the basis for comparison with the seasonal OTC measurements at each site. The total of at least 100 points at weekly intervals will provide a basis for intersite comparison and an assessment of seasonal progression. Data can be recorded and average values computed on the OTC/Control active layer form provided in the appendix to this manual.

Standard Grid Measurements:

At least one 100 m grid should be positioned to incorporate as many OTC locations as practical. At ITEX sites with widely dispersed OTCs, additional or larger grids may be established. Measurements are made once each summer, at the latest date possible, but prior to the annual freezeup. More frequent measurements are highly desirable, and can be made as time and resources permit.

Step 1:

Establishment of Grid. The SSU sampling design is implemented for a 100 m grid by dividing the area of interest into 100 square subareas (strata), each 10 m on a side. The grid can be established to a sufficient degree of accuracy using compass and pace methods. Mark the four outer corners of the grid with wooden stakes or metal rods that will remain in place permanently. If Global Positioning System (GPS) equipment is available, the locations of these markers should be recorded with the best accuracy possible. Grid intersections can be marked permanently with a series of wooden stakes, which can also serve as sites for supplemental snow, soil or vegetation observations.

Step 2:

Selection of Sampling Locations Within Grid. A standardized set of measurement points, located within the grid cells according to the SSU design, appears on the gridded data form (see appendix to manual) and is used to establish the sampling points. The intersection of the row and column coordinates within each cell represents the sampling location within that unit, and can be located precisely using a steel tape, or with accuracy to about one meter by pacing from the southwest corner of the grid cell. A permanent marker should be placed at each sampling point to insure measurements are made at the same location in subsequent years. The gridded data form can be used with a clipboard for recording thaw-depth measurements in the field and computing the average value per sample interval. If a sampling location is found to be inaccessible or under a water body, this grid cell may be permanently eliminated from consideration.

Step 3:

Measurement. Standing at a sampling location, the observer inserts a metal rod to the depth of resistance and records the value directly on the gridded data form (see appendix). If time permits recording two measurements per site is desirable, as it provides a measure of the robustness of the sample. Such duplicate measurements should be made 1 m apart. If for some reason (e.g., a subsurface stone) the observer considers an observation to be unrepresentative or biased, replacement should be made by turning to the opposite direction (rotating 180) and making another measurement. If a complicating influence (e.g., areas of stony material) extends over the area surrounding the sample location, the observer should move in 1 m increments toward the southwest corner of the grid until its effects can no longer be discerned. The marker for that stratum should be moved to the new location.

Level 2 measurements apply to a limited number of permanent measurement devices installed at OTC sites or landscape or vegetation units representative of the ITEX site. Level 2 measurements have two components:

Frost Tubes:

When read periodically, frost tubes provide information about seasonal progression of thaw and maximum seasonal thaw. A first-year pilot effort will be

made in 1995-96 by providing a limited number of prefabricated frost tubes for use at selected ITEX sites. The location of the frost tubes should be inside the perimeter of the ITEX grid. The exact position of a single frost tube should be determined at the end of the first summer of active layer measurements by selecting a point having the mean active layer depth for the entire grid. Installation details, including observational details, will be provided to those users at a later date.

Soil Temperature Recorders:

Soil temperature can be incorporated into instrumentation currently in use at specific ITEX sites, or can employ miniature data loggers, such as the HOBO manufactured by Onset Computer Corporation (Pocasset, Massachusetts, USA). Soil temperature in OTCs and control sites should be recorded at approximately one- hour intervals, measured at a sensor depth of 15 cm, on a seasonal or annual basis (in the case of the HOBO miniature data logger the time interval is 1.2 hours). Soil temperature data should be summarized using temperature conventions employed in the ITEX Climate Station report forms.

References

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