ITEX CLIMATE STATIONS

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Preface

During the second ITEX meeting, held at the Danish Polar Center, Copenhagen, Denmark, February 5–6 1992, I was asked to prepare a manual for standardized ITEX climate stations suitable for all ITEX field sites. The resulting manual is based on the experiences from the Swedish ITEX site, Latnjajaure Field Station (LFS) in northernmost Swedish Lapland. At LFS we were running a well equipped automatic climate station plus a traditional manual weather station from June 12 to September 5 in 1991, and we will resume operation in April 1992. The climate station, which is more advanced than will be required for ITEX purposes, is the result of a meteorological long term experiment (five years, 1991–1995) and was designed by Dr. Björn Holmgren, chief meteorologist at the Abisko Scientific Research Station, Sweden. The present manual and report forms are based on our 1991 field work and data analysis, and also on the manual used within the Long Term Ecological Research project (LTER). I thank Dr. Halldor Thorgeirsson, Agricultural Research Institute, Reykjavik, Iceland, and participants of the 3rd ITEX workshop at Boulder, Colorado, 10 March 1992, for discussions and comments on the earlier version. Comments and suggestions for improvement of this manual are most welcome.

Boulder, March 10, 1992

Preface to Version 3.0

This revised version replaces version 2.0 (April, 1992); the chapter dealing with calculations of integrated radiation has been altered, growing degree days (GDD) has been added to the methods, and the monthly report form is fundamentally changed. Especially, I want to thank Barrie Maxwell, Canadian Climate Center, for critical reading of the last draft.

Göteborg, March 30, 1993.

Contents

Introduction

Each ITEX field site is obliged to install a climate station and to collect and communicate data from that station for common use within ITEX. The climate station level 1 (see below) is an absolute minimum in the initial phase at any field site, but installation of a level 2 station should be given high priority.

Objectives

The objectives of standardized meteorological and climatological measurements are: (1) to establish baseline measurements to characterize each ITEX field site and to enable intersite comparisons, (2) to document for ITEX objectives the long-term changes in the physical environment, and (3) to be able to correlate within- and among-year variations in snow-melt and plant response variables with the climatological variations of the site.

Levels of Participation

The diversity of sites with regard to length of vegetation season, accessibility, crew, energy sources, and funding argue against a single standard method. Therefore, ITEX climate recording methods are grouped in two levels (1 and 2) of standard measurements, and with several alternative solutions within level 2. Thus, there will be established degrees of uniformity for intersite comparative data, but with enough flexibility for site-specific requirements and constraints. All ITEX field sites are obligated to participate in the climate recording at *at least level 1 in the initial stage*, and establish level 2 measurements as soon as possible. Level 1 is a simple manual climate station equipped with maximum and minimum thermometers (in a shelter cage) and a precipitation gage, inspected every morning at 0700 hours normal time during the field season. Level 2 ITEX meteorology includes a data logger and several instruments; climate stations can be either entirely automatic or (preferably) a combination of manual and automatic recording. Thickness and duration of snow-cover should be monitored along permanent transects or at fixed points or plots at all ITEX sites, but methods need not be standardized due to environmental diversity among sites.

Selection of Climate Station Site

The climate station should be located where surface measurements are representatative for the ITEX site. Avoid unusual topographic settings, such as ridges or slopes. The station should be located within an area of uniform surroundings, and at least 30 m from larger buildings and rocks (as a rule, no closer than at least four times the height of the obstruction).

Comparison with Existing Meteorological Station

Co-operation should be established with the permanent meteorological station located closest to the ITEX site. From there, extract daily means for all parameters common to both the ITEX site and the weather station for the time period the climate station has been operating, and run simple regressions for all parameters. This procedure allows extrapolation of values for the ITEX site during periods when the climate station is not in operation. This is commonplace practice (see e.g., Inouye & McGuire 1991), and pilot studies from LFS show that errors are small early and late in the season (May and September).

Observation Record

Original records (e.g., field record forms [Appendix II], THG charts, logger printouts) should be retained by the research group. Copies of month reports (Appendix III) shall be submitted to the ITEX secretariat as soon as possible after completion of a field season. For accuracy of reported values, see below Level 2 ITEX stations and in the examples (Appendix IV).

Level 1 ITEX Climate Stations

An ITEX site may choose to initiate meteorological measurements with Level 1 as a temporary expedient. A level 1 climate station is entirely manual, and consists of (1) a mercury maximum thermometer, (2) a spirit minimum thermometer, and (3) a precipitation gage. The thermometers should be installed in a shelter cage (Stevenson Screen) and the precipitation gage should be equipped with a conical shielding (see below Level 2 for details and installation recommendations). The following data shall be reported: daily values for precipitation (accuracy 0.5 mm) and type of precipitation (rain, snow, etc.), minimum, maximum, and mean temperatures (accuracy 0.1°C), and daily heat accumulation (see below); use ITEX monthly report form (Appendix III).

Level 2 ITEX Climate Stations

Instrumentation

All ITEX field sites should, as soon as possible, establish Level 2 measurements of climate, if possible on a continuous year-round basis. This climate station can be entirely automatic, but a combination with a manual station inspected twice a day is recommended during the vegetation period. In an ITEX Level 2 climate station the following parameters are to be measured:

1. Air temperature (sun protected at 1.5–2 m above ground)
2. Precipitation (0.5–1 m above ground)
3. Wind velocity (at 3.0 m above ground)
4. Global solar radiation
5. Relative humidity (at least during the vegetation period)

The Level 2 station requires a data logger. Configure it to store hourly means, and (if possible) also daily maximum and minimum records for all channels If the station is entirely automatic you will need a heating device for the precipitation bucket recorder; most loggers are equipped with a feed-back output which can be programmed to be triggered by, e.g., temperatures below freezing. Power supply for logger operations can be a problem in remote field sites; use 12 V car batteries which can be recharged by a portable gasoline generator or continuously charged by solar cells and/or wind generators. If year-round operation is attempted, note that solar cells will be out of activity from November until early March in the Arctic.

The heart of the manual part of a climate station is the traditional shelter cage or Stevenson Screen; wooden, white-painted, and ventilated. The shelter box itself should be at ca.1.5 m above ground, the door facing north (to avoid disturbance when inspecting instruments). The cage should contain:

a thermohygrograph (abbreviated THG) with seven-day drum rotation

a mercury maximum thermometer

a spirit minimum thermometer

a psychrometer (for calibration of the THG instrument)

The thermometers should be installed horizontally on hooks inside the cage. In the case of the maximum thermometer, the bulb end should be tilted somewhat downwards. During stormy weather it is advisable to inspect minimum and maximum thermometers more frequently than usual, since vibrations may drastically disturb the records. The THG instrument may be excluded at Level 2 if electronic air temperature logging is reliable and relative humidity of no interest for your site-specific purposes.

The manual part of the climate station also includes a precipitation gage. Install a standard non-recording gage, protected from wind by a shield or funnel-shaped shelter. Recording mechanical precipitation gages (e.g., Hellman apparatus) are difficult to use in the Arctic since they may become severely damaged when freezing with precipitation water in the bucket.

Soil and bedrock temperature probes are not included in the Level 2 design, since data is difficult to compare among sites if probes are not permanently installed at certain depths and soil types. However, soil temperature data may provide very interesting information for seasonal comparisons at any particular site. Note that soil temperature probes may require weeks (bedrock probes several months) after installation to attain stable values. If you have the opportunity to install soil temperature probes, place the sensors at a depth of 0 cm, 5, 10, 20, 40, and 80 cm.

Additional instruments, recommended but not required at the Level 2 ITEX meteorology, are electronic sensors for snow depth, precipitation, relative humidity, atmospheric pressure, wind direction, and photosynthetically active radiation (PAR).

All equipment (masts, shelter cage, etc.) must be carefully secured with steel wires, preferentially attached to the ground in the bedrock or in large rocks (some rock-drilling will thus usually be necessary). Check that all masts are absolutely vertical 3–4 times every season. Cables should be connected in bundles and protected against physical damage (e.g., by strong winds, grazing raindeer, stumbling polar bears, or clumsy scientists).

As soon as your ITEX climate station is installed, please submit a site description and operation program to the ITEX secretariat; photos will also be helpful.

Measurements

When using a combined manual/automatic climate station two daily observations are required (see Appendix III), at 0700 and 1900 hours normal time. Precipitation for the last 24 hours is recorded at the morning observation, and the gage is reset. Maximum and minimum thermometers are reset after the evening reading. The THG instrument (if present) should be calibrated using a psychrometer at least every time drum charts are replaced (once a week), but preferably twice a day. Temperature measurements from minimum and maximum thermometers, THG, and psychrometer should be taken with an accuracy of 0.1°C. Relative humidity should be recorded with an accuracy of 1 percent. Set time marks on drum chart by gently tapping the plotter arms from below.

In the automatic part of the station, the data logger shall measure air temperature at ca. 2.0 m above ground (the sensor sun-sheltered, preferably placed in the shelter cage of the manual station), global solar radiation, and wind speed (+ additional instruments). Configure the logger to store minute averages and to compress data to hour means and, if possible, hour maxima and minima for all instruments. Data derived from automatic stations should refer to diurnal periods 0–24 hrs normal time. Manual readings of maximum and minimum temperatures taken at 1900 hrs normal time will normally refer to the same time period, since temperature minimum usually occurs a few hours after midnight and maximum in early afternoon.

Temperature records from thermocouples and thermistors (usually logged with an accuracy of 0.01°C) should be reported with an accuracy of 0.1°C, global radiation with an accuracy of 1 W/m^2 (1W = 1J/s), integrated (mean) daily radiation effect (R) with an accuracy of 0.1 MJ/m^2, and wind speed with an accuracy of 0.1 m/s. Use the month report form (Appendix III) regardless of design of your Level 2 climate station. Notes on reading errors etc. should be put in the right margin of the report form or as footnotes. Day numbers (Julian dates; see Appendix I) should be used consistently in all ITEX reports.

Calculation of Daily Heat Accumulation and Degree Days

Daily temperature variation basically follows a sinusoidal function. The integrated daily temperature, i.e., the effective heat accumulation (H), therefore equals the daily mean temperature if there is no lower threshold value taken into account, or if the daily minimum temperature is above that threshold. Within ITEX climate monitoring the lower threshold is set to 0°C. Upper threshold values are not considered to apply in the Arctic. When summarized over a sequence of days, the cumulative heat accumulation units are called ”degree days above 0°C” or Thawing Degree Days (abbreviated TDD), and ”degree days above 5°C” or Growing Degree Days (GDD), respectively (Maxwell 1992). TDD has turned out to be the best measure for correlation with snow-melt, whereas GDD shows the best correlation with plant growth. Degree days should preferably be calculated from May 15 (day number 135) until the end of the vegetation period; use extrapolation from data collected from established nearby weather station if your ITEX climate station is not operating that early or late in the season.

The best measures of daily mean temperature will be obtained from automatically logged temperature data (stored as hourly means) as the mean of all 24 hour mean temperatures. Daily means may also be calculated from maximum and minimum (daily amplitude) only, but the temperature curve will often depart from the anticipated sinusoidal shape resulting in error of up to half a degree centigrade. Similarly, daily TDD and GDD values are preferably derived from hourly temperature means. Simply sum up the hourly means when values are above the set threshold (0° and 5°C, respectively), and divide the sum by 24.

If logger data are not available, daily mean temperature from the manual climate station is calculated as half the sum of maximum and minimum temperatures (i.e., 0.5[Tmax + Tmin]). During a day when temperature never rises above 0°C, H of course equals zero. If, however, the maximum temperature is over 0°C but minimum temperature is below 0°C (a common situation in arctic climate stations), a correction is needed since the preset threshold value cuts off the sine curve, leaving the area below the curve smaller than that above it. In this case, the following calculation shall be used (formulas extracted from Watanabe, 1978):

(1) **D = Tmax — Tmin**
(D = difference between maximum and minimum temperature; daily amplitude)

(2) **p = (Tmax — k) / D**
(p = difference ratio, k = threshold value [0 or 5])

(3) Look up the **p** value in Table 1 below and find the corresponding **h** value

(4) **H = h x D**

Table 1. Parameters for rapid calculation of effective heat units (from Watanabe, 1978).

p	h	p	h	p	h	p	h	p	h
0.01	0.00	0.21	0.04	0.41	0.12	0.61	0.22	0.81	0.35
0.02	0.00	0.22	0.04	0.42	0.12	0.62	0.22	0.82	0.35
0.03	0.00	0.23	0.05	0.43	0.13	0.63	0.23	0.83	0.36
0.04	0.00	0.24	0.05	0.44	0.13	0.64	0.24	0.84	0.37
0.05	0.00	0.25	0.05	0.45	0.13	0.65	0.24	0.85	0.38
0.06	0.01	0.26	0.06	0.46	0.14	0.66	0.25	0.86	0.38
0.07	0.01	0.27	0.06	0.47	0.14	0.67	0.25	0.87	0.39
0.08	0.01	0.28	0.06	0.48	0.15	0.68	0.26	0.88	0.40
0.09	0.01	0.29	0.07	0.49	0.15	0.69	0.27	0.89	0.41
0.10	0.01	0.30	0.07	0.50	0.16	0.70	0.27	0.90	0.41
0.11	0.02	0.31	0.08	0.51	0.16	0.71	0.28	0.91	0.42
0.12	0.02	0.32	0.08	0.52	0.17	0.72	0.28	0.92	0.43
0.13	0.02	0.33	0.08	0.53	0.17	0.73	0.29	0.93	0.44
0.14	0.02	0.34	0.09	0.54	0.18	0.74	0.30	0.94	0.45
0.15	0.03	0.35	0.09	0.55	0.18	0.75	0.30	0.95	0.45
0.16	0.03	0.36	0.10	0.56	0.19	0.76	0.31	0.96	0.46
0.17	0.03	0.37	0.10	0.57	0.20	0.77	0.32	0.97	0.47
0.18	0.03	0.38	0.10	0.58	0.20	0.78	0.32	0.98	0.48
0.19	0.04	0.39	0.11	0.59	0.21	0.79	0.33	0.99	0.49
0.20	0.04	0.40	0.11	0.60	0.21	0.80	0.34	1.00	0.50

Calculation of Integrated Global Solar Radiation

On a clear day, the influx of global solar radiation, measured in W/m^2, is described by a sine function, although often somewhat more leptokurtic than the daily temperature curve. In the daily solar radiation curve, there is no lower threshold value to consider. However, distortions caused by fog, clouds, topography, etc., are common, and the simple calculation of the mean radiation (0.5[Rmax + Rmin]) is a poor estimate, especially during intermittent cloudy conditions. Rmin is mostly close to zero or, in late summer, even slightly negative, and can thus be neglected. At each ITEX site carrying out Level 2 climate recording, the relation between daily mean and the optimum solar radiation hour mean should be calculated. This equation can then be used when records (hourly means) are missing in order to extrapolate daily mean from the optimum value alone. For the Latnjajaure Field Station, daily mean radiation equals roughly 0.3 x Rmax.

Integrated radiation (effect) over a day is obtained as follows. The daily mean radiation should be multiplied by 0.0864 ($24x3600x10^{-6}$) to obtain a value for the total energy influx during the day (R), expressed in MJ d^{-1} (1W = $1Js^{-1}$); see Barry 1992 for more information. Since recording of global radiation requires a data logger anyhow, the best measure of integrated radiation is obtainedfrom the mean of all 24 hourly mean values from 0000 to 2300 hours. As in the case of integrated temperature (degree days), the cumulative record should preferably commence on May 15 (day number 135; see above).

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