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# CLIMSTAN
# STANDARDS FOR OBSERVATION AND ARCHIVING OF LTER CLIMATE DATA

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LAST UPDATED: 2/17/99

# METEOROLOGICAL OBSERVATION STANDARDS FOR LTER SITES

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## INTRODUCTION

Each LongTerm Ecological Research (LTER) site assumes an obligation to collect and make available data to characterize the ecosystem which the site represents. This document is the LTER guide for assembling meteorological data. All LTER sites and new LTER sites should consider following the procedures outlined here. This document defines, for the LTER program, the measurement and reporting standards for meteorological data. The standards are based on earlier LTER proceedures, the needs at existing LTER sites,

other standards existing in the literature, and the substantial experience of current LTER scientists.

### Objectives

The objectives of standardized meteorological measurements are:

1) establish baseline meteorological measurements to characterize each LTER site and enable intersite comparisons,

2) document for LTER objectives both cyclic and long-term changes in the physical environment,

3) provide a climatic history for each site's core research program to correlate with bioecological phenomena and to provide data for modeling,

4) provide a basis for coordinating specialized or short term meteorological measurements at two or more sites when such measurements are required for specific research problems.

We recognize that the rate of implementation of attaining these objectives is largely driven by the availability and cost of technology. Future technological advances will make the attaining of higher levels of participation easier but the ecological basis for the above objectives will remain essentially the same.

### Levels of Participation

The diversity of sites and their core research programs argue against a single inclusive set of standard measurements. Consequently, LTER meteorological measurements are grouped into five levels of standardized measurements, a plan which establishes degrees of uniformity for intersite comparative data yet allows flexibility for the site specific requirements of each core research program. This heirarchical principle has found considerable use in other areas of ecological work such as general classification studies. The committee recognizes that sites can have an observation program which falls between these levels. The levels are set up to facilitate interersite description. The five levels are:

Level 0: The entry level meteorological measurements of maximum and minimum temperature and precipitation amounts over 24 hour periods.

Level 1: A basic climatic station using standard measurements and instruments to measure temperature and precipitation on a continuous basis throughout the day. Data will be extracted for specific times or intervals to serve the climatological goals of objectives 1 and 2. All LTER sites must achieve Level 1.

Level 2: A research meteorological station having more intensive measurements in order to characterize in detail both long and short-term meteorological events affecting biological systems. These stations sense temperature, precipitation, and other variables on a continuous basis, may record observations digitally, and may have the capability to extract instantaneous observations or do integrations on a real time basis. Most LTER sites will seek to meet, and have met, Level 2 standards for some or all measurements.

Level 3: This includes a number of variables which we beleive it would be optimal for sites to record but for which funds may not be available and funding priorities must be set.

These variables include: Photosynthetically Active Radiation (PAR), Absorbed Photsynthetically Active Radiation (APAR), Soil temperature, Soil moisture, Atmospheric pressure, Vapor pressure.

Level 4: At various times, the research program at each LTER site may require additional specialized meteorological measurements directly related to local research needs. At the conceptual stage of a study, researchers will benefit from coordination, with other LTER groups where appropriate, in order to develop standardized techniques, identify mutual interests, and facilitate short term data collection and potential intersite comparisons.

The entry level, Level 0, is available for new sites to the LTER program. We regard the existence of this level as an interim measure only and sites are urged to proceed to the next levels as soon as possible and certainly within one year. Since technology is now easily available for level two observations, we consider level two to be the "standard" level for LTER sites.

Almost twenty years of experience has allowed us to understand how the hierarchy concept operates in practice and how we may use it better in the future. LTER sites make local decisions regarding levels of measurement implementations based upon individual site priorities. Productive site implementations relevant to the network of sites may be identified over time as emergent standards and can be considered when the level descriptions are reviewed. Periodic summary tables and reviews of all site implementations are beneficial and are recommended in the future and will be incorporated in future editions of this document and in other places when opportuinites arise. Such summaries and reviews provide a clear statement of the corporate priority decision making process of the network over time.

An initial summary of expectations at the levels mentioned above is as follows:

**Table 1: Summary of Variables Measured at Different Levels.**

| **Variable Included** | **Frequency of Observation** | **Method of Recording** |
|---|---|---|
| **Level 0** | | |
| Temp - max, min<br>Precip | Once per day | Non automated |
| **Level 1** | | |
| Temp - max, min, | More than once per | |

| | | |
|---|---|---|
| Precip | day | Automated - mechanical |
| **Level 2** | | |
| Temp - max, min, mean for 24 hrs<br><br>Precip<br><br>Wind speed and direction<br><br>Relative humidity<br><br>Global solar radiation | At least at synoptic times but prefereably hourly | Automated - electronic |
| **Level 3** | | |
| Various e.g.<br><br>PAR<br><br>APAR<br><br>Soil temperature<br><br>Soil moisture.<br><br>(follow new LTER book guidelines)<br><br>Vapor pressure<br><br>Atmospheric pressure | As appropriate | Usually automated |
| **Level 4** | | |
| Various e.g.<br><br>Gas exchange.<br><br>UVB<br><br>Sun photometer observations<br><br>Wet deposition observations | | |

Archiving of the data collected may be in any form at a site with the exception that sites are required to write their own filters to ensure that their data is compatible with the ClimDB data harvesting system described in other parts of this document (hyperlink). The concepts of filters and data harvesting are explained in the intersite data exchange part of this document.

**Designated Primary Observing Station**

It is common for LTER sites to develop more than one meteorological observing site. Extra sites may be used at any of the levels described here. However each LTER site should designate one observing station as its primary observing station. The primary observing station will be used for intersite studies unless there is some sound scientific reason for using another station at a site for such a study. In the latter case the reason for not using the designated station should be fully explained in the study.

**Station Site Selection**

The LTER meteorological station which is to be designated as the primary station should be located where surface measurements will record, as best as possible, representative conditions for the LTER site. A level area is more desirable than an unusual topographic setting. The station should not be on a slope, a ridge, or in a sheltered area unless such extreme positions are representative of the LTER site. Substations may be located to establish the range of conditions at a site.

The primary station should be located where surroundings are uniform. For example on a sod base at least 30 meters from hard surface areas such as asphalt or concrete and stations should be no closer to vertical obstructions (trees, buildings, etc.) than four times the height of the obstructions (USDC, 1989). At LTER sites with very tall trees this instruction may not be practical. Instead, the measurement site should be selected so that it has at least a 35 degree horizon i.e. no obstacles should be above 35 degrees on the local horizon. Similarly for lake and other aquatic sites it may be more expedient to record wind at a low level on or near the lake. In the case of the wind variable important local considerations will be permitted to take precedence over intersite standardization.

Exceptions to the all or parts of the above may be required by individual sites. The exceptions should be clearly outlined in the metadata provided with the LTER primary meteorological observing site.

**The Observation Record**

The original record of meteorological data for an LTER site will be retained. Entries in an Observation Record or log made when instruments are read, original chart recordings and printouts of electronic records, and in some cases, the records themselves, are examples of original records. Retention is important for verification of derived data because the Observation Record usually contains the comments necessary to establish the station history. Intersite reports are climatological summaries, and thus detailed data for onsite and intersite studies will be made only in the original record. Where possible, the original record will be available onsite to researchers from other sites for research activities requiring the primary record of meteorological data. It is recognized that it is not possible for all original electronic records to be retained since these data are often neccessarily transferred from one platform to another. In such cases the principle of keeping the original data should be maintained as much as possible. This, for example will require the provision of good metadata and data quality flags, including in some cases text notes, for data variables.

**Intersite Exchange of Data**

Each site must make available data from levels 0, 1, and 2 as soon as possible after collection and quality control has been done. LTER data exchange files may be a subset of the total data collected at a site. Information collected as part of a specific study at a single site may be reserved by the scientist until the results are analyzed and reported. However all data must meet the NSF mandated regulations for being made accessible to the public. Data will be processed and available for exchange between LTER sites through the ClimDB data base system described in a separate part of this document. Data should be used on a user beware basis. Although every effort has been made for quality control and the identification of questionable data, it is still possibe that errors of various kinds may be contained within the data. Users are especially encouraged to read the metadata files associated with the data of interest to them. If any possible errors are found users should contact the site contact person.

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## LEVEL 0 METEOROLOGY

Level 0 Meteorology is strictly manual daily reporting. A site may choose to initiate meteorological measurements with Level 0 as a temporary expedient. An existing Cooperative Observer station for the National Weather Service might be used as a proxy until the LTER site can establish its own station.

### Instrumentation

Temperature instrumentation (Table 2) will consist of maximum and minimum thermometers mounted in a National Weather Service type instrument shelter. The installation of the instrument shelter and thermometers will follow the guidelines of the National Weather Service for Cooperative Observer Stations (USDC, 1989). When NWS standards for electronic temperature measurements at cooperative observer stations are established, these will also be acceptable guidelines for LTER sites.

The nonrecording precipitation gage (Table 2) should be located no nearer the instrument shelter than twice the height of the instrument shelter. At exposed windswept sites a windshield may be required for the precipitation gage. The gage must be elevated above maximum snow depth, and, if possible, operation should continue during freezing weather. These considerations are covered in the Observing Handbook No. 2 (USDC, 1989) which is the guideline document for the precipitation gage.

### Measurements

Daily observation of precipitation and temperature is necessary at level 0 (Table 2). All daily meteorological measurements and comments on station operation will be entered into a Permanent Observation Record or log which is the official data source for calculated values appearing in LTER intersite reports. Observations made early in the morning are interpreted as representing conditions on the previous day. We suggest observations be made between 0500 and 0900 hours. The observation time should be as consistent as possible from day to day and should be noted in the observation log. This specification of observation time is important since daily, monthly or longer mean temperatures, calculated from daily maximum and minimum values, may be biased by the time of observation by as much as 2 or 3°C compared to the midnight to midnight reading (Baker, 1975, Karl et al. 1986).

### Reporting

A monthly intersite report for Level 0 meteorology (Table 3) will consist of daily values for maximum, minimum and average daily temperature and total precipitation. Monthly means for maximum, minimum and average daily temperature will be calculated along with total monthly precipitation. Maximum and minimum temperatures will be reported in degrees Celsius. The daily mean air temperature will be the average of the maximum and minimum temperatures. Daily precipitation will be reported as mm of water and the water equivalent depth of snow will be recorded (USDC, 1989).

**Table 2. Level 0 Meteorological Station Equipment**

| Equipment | Specifications |
|---|---|
| Maximum and Minimum Thermometers | National Weather Service type maximum and minimum thermometers mounted on a support in the shelter. |
| Shelter | Cotton Region type, medium size (20x30x32 inch box). |
| Precipitation Gage | Capacity of measuring tube is 2 inches (~50 mm) of<br><br>rainfall with overflow capacity of 7 inches (~180 mm).<br><br>Funnel to measuring tube area ratio is<br><br>10:1 so that 1 mm of rain produces a 10 mm depth for measurement to the nearest 0.10 cm. Where data are taken from NWS Coop stations measurement may be to the nearest 0.25cm. |

**Table 3. Level 0 Meteorological Measurements**

| Variable | Frequency of Observation | Observation Record Entry |
|---|---|---|
| MaxMin Temperature | Daily | Daily |
| Precipitation | Daily | Daily |

**Table 4. Level 0 Meteorological Summaries.**

| Variable | Determination | Units | Values |
|---|---|---|---|
| Temperature | Observation | Degrees Celsius | Daily Maximum<br>Daily Minimum |
| | Daily Mean | Degrees Celsius | Daily sum of the two Max Min values divided by two |
| | | | Monthly sum of the |

| | | | |
|---|---|---|---|
| | Monthly Mean | Degrees Celsius | MaxMin values per day divided by two<br><br>divided by the number of days in the month. |
| Extreme Temperature | Extracted from the Observation Record | Degrees Celsius | Monthly maximum and Monthly Minimum of the MaxMin Thermometers |
| Precipitation | Daily total precipitation | mm | Daily total |
| | Monthly Total Record | mm per month | Summation of daily |

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**LEVEL 1 METEOROLOGY**

Level 1 Meteorology involves continuous recording by a mechanical recorder. Sometimes, an LTER site will begin its direct meteorological reporting at Level 1. Level 1 is still regarded as interim, however; all sites should eventually maintain a Level 2 meteorological station (next main section).

**Instrumentation**

The instruments required for a Level 1 station (Table 5) contain some which record continuously. Other instruments are identical to those used for level 0 Table 2.

**Table 5. Level 1 Meteorological Station Equipment**

| Equipment | Specifications |
|---|---|
| Maximum and Minimum Thermometers | National Weather Service type maximum and minimum thermometers mounted on a support in the shelter for the mercury maximum thermometer and the spirit minimum thermometer. |
| Shelter | Cotton Region type, medium size (20x30x32 inch box). |
| Precipitation Gage | Capacity of measuring tube is 2 inches (~50 mm) of<br><br>rainfall with overflow capacity of 7 inches (~180 mm). Funnel to measuring tube area ratio is 10:1 so that 1 mm of rain produces a 10 mm depth for measurement to the nearest 0.10 cm. Where data are taken |

| | |
|---|---|
| | from NWS Coop stations measurement may be to the nearest 0.25cm. |
| Thermograph | Air temperature measured with bimetallic strip. Continuous record on a seven day drum rotation. |
| Recording Precipitation Gage | NADP Station, weighing pan or tipping Gage bucket gage |

Installation of the instrument shelter, air thermometers and preciptation gage should follow the NWS guidelines for Cooperative Observer Stations (USDC, 1989). When NWS standards for electronic temperature measurements at cooperative observer stations are established, these will also be acceptable guidelines for LTER sites. The level 1 site has much the same instrumentation as the level 0 site (Table 2).

**Measurements**

Maximum and mininum temperatures for the calendar day are extracted from a strip chart. Total precipitation is computed from a continous chart and checked against the totalizing precipitation gage.

**Preprocessing**

Relatively little preprocessing at the site is required for Level 1 (and Level 0) data.

*Temperature*

- Maximum: Directly measured, reported in degrees Celsius

- Minimum: Directly measured, reported in degrees Celsius

- Mean: computed as average of Maximum and Minimum

*Precipitation*

- Liquid: Directly measured, reported as mm of water

- Frozen: computed as water equivalent (USDC, 1989), reported as mm of water.

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**LEVEL 2 METEOROLOGY**

Level 2 Meteorology entails hourly, or at least synoptic (four times daily at 0000, 0600, 1200, and 1800 hr GMT), reporting throughout a day. This reporting is necessarily automated. A day is defined as a 24-hour period from local midnight to midnight as measured by standard time in the time zone.

*An established LTER site is expected to maintain at least one Level 2 meteorological station for intersite comparison and standardization purposes.*

In addition to basic climatic parameters obtained at a Level 1 station, a Level 2 station obtains the more detailed meteorological data appropriate for a research site. Table 6 lists the variables to be recorded at Level 2. All variables except radiation should be recorded at least at synoptic times but preferably hourly.

Another important distinction of Level 2 meteorological systems is the capability for continuous, unattended operation, as required by the periodic (hourly or synoptic) measurements. The relatively low cost of so-called electronic data loggers makes automatic recording an especially attractive method for handling the additional recording requirements of a Level 2 station. Most LTER sites have already acheived this level of observation.

**Instrumentation**

Level 2 instrumentation makes periodic measurements of maximum, minimum and (separately) mean air temperature, precipitation (as water-equivalent), wind (speed and direction), relative humidty, and global solar radiation, as summarized in Table 6. The air temperature and precipitation sensors at a Level 2 station are often are more sensitive and need to be exposed in a different manner than those at a Level 1 station. Some "packaged" meteorological stations come with masts and equipment enclosures that obviate the need for the **standard NWS-type shelters and other equipment described in sections 2 and 3 above.**

**Table 6. LEVEL 2 Meteorological Station**

| Equipment | Specifications |
|---|---|
| Temperature sensors and Maximum and Minimum Thermometers | Electronic temperature sensors backed up for calibration purposes by National Weather Service type maximum and minimum thermometers mounted on a support in the shelter for the mercury maximum thermometer and the spirit minimum thermometer or simple mercury in glass thermometers. |
| Shelter | Appropriate shield for electronic sensor or Cotton Region type, medium size (20x30x32 inch box). |
| Precipitation Gage | Capacity of measuring tube is 2 of<br><br>rainfall with overflow capacity of 7.<br><br>Funnel to measuring tube area ratio is 10:1 so that 1 mm of rain produces a 10 mm depth for measurement to the nearest 0.10 cm. Where data are taken from NWS Coop stations measurement may be to the nearest 0.25cm. |
| Recording Precipitation Gage | NADP Station, weighing pan or tipping Gage bucket gage |
| Electronic Relative Humidity sensor | |
| Hygrothermograph | Air temperature measured with bimetallic strip. Relative humidity measured by human hair bundle. Continuous record on a seven day drum rotation. |

| | |
|---|---|
| Portable Psychrometer | Electric fandriven drywet bulb psychrometer to be used as calibration check device for the recording hygrothermograph |
| Totalizing Anemometer | Activated at wind speeds 1 m/sec (2 mph) |
| Recording Wind Vane | Direction divided into 8 (45 deg sectors) or measuring by degree. |
| Recording Pyranometer | Capable of recording total global (direct and diffuse) radiation on a daily basis. |

The nonrecording precipitation gage should be located no nearer the instrument shelter than twice the height of the instrument shelter. At exposed windswept sites, a windshield may be required for the precipitation gage. The gage must be elevated above maximum snow depth, and, if possible, operation should continue during freezing weather.

The recording precipitation gage may be either a weighing or tipping type gage. Gages should record to at least 0.5 mm (0.02inch) unless a NWS recommended Fisher Porter gage or gage from an elctronic data logger system, is used. Both standard and recording precipitation gages will be maintained at the same site. Recording gages will be impractical for some LTER sites in winter unless exposure and servicing can be provided in deep snow and the gage heated. It is a common acceptable practice to use a mixture or any combination of antifreeze, alchohol and oil, in the storage container of the raingage in order to use the instrument in the winter time. The water equivalent depth of snow will be recorded (USDC, 1989).

Both precipitation gages should not be closer to trees, buildings or the instrument shelter than twice the height of the obstruction. Standards for precipitation measurement given in for lower levels also apply.

The hygrothermograph will not be needed if an electronic relative humidity sensor is available. But note comments elsewhere concerning the calibraation of such sensors.

The anemometer should be located away from obstructions which would interfere with wind flow over the instrument. The anemometer will be mounted with the cups at 10 meters (Note this is a change from the first edition of the standards). Maintenance on the bearings and spindle will be performed twice yearly as recommended in the Observer Handbook No. 2 (USDC, 1989) or the instrument manufacturers manual. Wind travel may be accumulated by an internal counter or at a separate recorder. The optional wind direction variable will require a recording system. Level 2 stations require increased reliance upon recording instruments. The individual LTER site may elect to install a data logging system rather than separate recorders.

The global incoming radiation sensor must be fully exposed to the sky in all directions (not shaded by vegetation, buildings, or topography). An exception may be made if all of an LTER site is similarly shaded by topographic obstacles. A fully exposed sensor is preferable because the data have wider application and the effect of shading can be subtracted from full sky data. The sensor should be inspected daily, the glass kept clean, and the sensor and recorder recalibrated every 18 months.

**Measurements**

Level 2 measurements are to be made hourly, or at least synoptically, and reported daily. Synoptic observation times are well defined by the WMO as being 0000, 0600, 1200, annd 1800 GMT. Hourly times should always be referenced to local standard time, not daylight-savings time or other special times which may be in effect at a site.

**Table 7 LEVEL 2 Meteorological Measurements**

| **Variable** | **Determination** | **Units** | **Values** |
|---|---|---|---|
| Mean Temperature | Daily sum of 24 hourly observations divided by 24 | Deg C | Daily mean |
| | Monthly sum of daily means divided by the number of days in the month | Deg C | Monthly mean |
| Extreme temperatures | Largest and smallest absolute values from the electronic observation record. | Deg C | Monthly max<br>Monthly min<br>Daily max<br>Daily min |
| Relative humidity | Daily sum of 24 hourly observations divided by 24 | % | Daily mean |
| | Monthly sum of daily means divided by the number of days in the month | % | Monthly mean |
| Precipitation | Daily total precipitation | mm | Daily total |
| | Summation of daily record per month | mm | Monthly total |
| Wind speed | Summation of wind travel per day divided by the number of seconds in a day | m/sec | Daily mean |
| | Summation of daily means divided by the number of days in the month | m/sec | Monthly mean |
| | Instantaneous direction taken each hour | | |

| | | | |
|---|---|---|---|
| Wind Direction | Most frequent daily per month<br>For data logged recordings record vector mean wind direction (See appendix 4) | 45 deg sector<br>45 deg sector<br>1 deg | Most frequent daily<br>Most frequent monthly<br>Mean daily |
| Global solar radiation | Daily total<br>Monthly mean of daily total | MJ/sq. m<br>MJ/sq.m | Daily totals<br>Monthly means |

**Preprocessing**

Substantial preprocessing, including quality control, at the site is required for Level 2 data.

Assuming hourly data are summaries of short time interval observations, air temperature and relative hmidity data should include the instantaneous maximum and minimum and 60 minute average for each variable where available. Precipitation and solar radiation should be hourly totals. These hourly measurements are a minimum and additional parameters may need to be recorded at some sites.

*Wind*

The preprocessing of the wind data is complex. Observers using elctronic data processing eqipment should follow the suggestion provided in Appendix 4. Total wind travel, observed for a 24 hour period, will be converted to mean daily wind speed in meters per second. Where calm wind conditions are the rule, listing of minimum wind speed may be omitted. At sites using data loggers the proceedure for obtaining daily mean wind values is outlined in Appendix 4. At sites experiencing diurnal wind shifts, the report may list day and night means in addition to a single 24 hour mean. Wind direction may be recorded as an instantaneous observation once an hour (or as the most common direction in a five minute interval at times when the direction is highly variable) or summarized as the mean direction for each hour. As a minimum, direction will be listed for eight points plus the calm condition. Where measured, wind direction will be reported as the number of hourly observations in each of 8 directions, plus calm, for each 24 hour period, for example:

| Date | N | NE | E | SE | S | SW | W | NW | Calm |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 1 | 3 | 5 | 6 | 2 | 3 | 0 |
| 2 | 1 | 1 | 2 | 4 | 5 | 7 | 2 | 1 | 1 |
| 3 | 0 | 2 | 1 | 3 | 6 | 2 | 3 | 2 | 2 |

Where data loggers are used vector mean wind direction may be computed and reported following the guidlines suggested in Appendix 4. Whichever method is chosen should be noted in the metadata for the variable.

*Precipitation*

Because the standard precipitation gage is considered the more accurate, the recording gage values are adjusted to equal the standard gage total. Daily precipitation will be reported in millimeters for the LTER site reports. Hourly precipitation totals will be tabulated and available at each site but not included in intersite reports.

*Relative Humdity*

The electronic sensor or hygrothermograph will provide a continuous record of temperature and relative humidity. The hygrothermograph record should be adjusted to read within 1 deg C of the maxmin thermometers. The accuracy of the hygrograph response to relative humidity will be verified using a portable psychrometer which draws a constant air stream over wet and dry bulb thermometers. The relative humidity reading of hygrograph and psychrometer will be compared at high and low relative humidities. The use and adjustment of the hygrothermograph are discussed in Field Manual for Research in Agricultural Hydrology Chapter 3 (Brakensiek, Osborn and Rawls, 1979) which serves as the guideline document for the hygrothermograph.

*Global Solar Radiation*

Global solar radiation may be integrated by the data logger. Total global incoming solar radiation will be reported in MJ/sq. m/day. More on this topic is provided in Appendix 1.

*Additional Considerations*

Because of their complexity, sensors in Level 2 systems typically require periodic calibration. Suggested methods of calibration are provided below.

No specific Level 2 meteorological equipment is recommended by the committee since each site should be free to select its own system. However, the selected system should be able to, at a minimum:

1) make the indicated measurements at hourly (or at least synoptic) intervals,

2) record the measurements for periodic collection, either by direct media transfer or by telemetry

3) translate and relay the recorded measurements on command in suitable form to an to an external computer.

The following are some criteria that LTER sites may use for selecting automated meteorological systems:

1) Components of a system must be physically and electrically compatible. Response speed and signal level of sensor and recorder must match to avoid degrading raw data. Recorder and translator must match to avoid losing data. Unless the user is prepared to assume system design responsibility, components should be bought from a single supplier who guarantees system compatibility.

2) The recorded data should be accessible in the field for checks and calibration as well as being easily translatable to a record which can be read and processed by computer for summary reporting, and further analysis.

3) The system should be able to operate during expected environmental conditions. Estimate climatic extremes at your site and specify that the equipment will operate within these limits. Components that seem particularly susceptible to cold (less than minus 10 deg.C) and

moisture (RH greater than 90%) conditions include hard copy paper printers and cassette recorders. Modems are more reliable if a phone line can reach a station. Cellular phones and telemetering systems have also proved reliable in extreme conditions.

4) Be sure that the manufacturer can provide fast service and backup for your equipment and/or have two or more compatible systems to interchange components. If components are interchanged make sure intercalibration factors are available. Budget for repairs and recalibrations.

Although the LTER program does not endorse any particular manufacturer of electronic data sensing and recording instrumentation, it is noted that a large number of LTER sites use equipment made by Campbell Scientific inc, of Logan Utah; accordingly, Apppendix 2 includes a typical configuration from this manufacturer. Other manufacturers may be able to provide similar, acceptable systems

All original data records (tapes, charts, etc) should be kept, and the earliest listing of raw electronic data should become part of the permanent record for the site.

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## LEVEL 3 METEOROLOGY

Level 3 includes a number of variables which we beleive it would be optimal for sites to record but for which funds may not be available and for which funding priorities must be set.

These variables include: PAR, APAR, Soil temperature, Soil moisture, [for soil moisture and temp data take guidance from new LTER book on soil mesurements - Phil Roberstson (KBS) Editor] Atmospheric pressure, Vapor pressure.

### Instrumentation

PAR and APAR are two variables commonly used in ecological models. The instruments are essentially radiometers.

The measurement of soil temperature and moisture will be described by an LTER publication on soil measurement by Robertson et al. (Details of the exact citation will be added when they are available). Soil temperature should be measured at depths copatible with the Robertson work

Atmospheric pressure can be measured by electronic sensors which will attach to a data logger. Vapor pressure may be derived using tables (e.g. Marvin, 1941) and values of the air temperature, relative humidity, and atmospheric presure.

### Measurements

Photosynthetically active radiation (PAR) and Absorbed Photosynthetically active radiation (APAR) should be measured in a similar way to radiation. electronic integrators can accumulate the energy input and display daily or hourly period totals or provide input to a data logger. We reccomend 15 minute integrations of these variables.

Soil moisture and temperature should be measured hourly but this instruction may be changed pending the Robertson LTER book on soil measurement procedures.

Vapor pressure may be derived at hourly intervals using hourly measurements of relative humidity and temperature. A single instantaneous observation of air pressure will be appropriate for this calculation. The computation is explained in Appendix 3

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## LEVEL 4 METEOROLOGY

### General

Level 4 meteorology concerns additional specialized measurements directly related to local site specific research needs. Because a wide variety of such needs exist, the topic can be treated in only a general manner here. Persons interested undertaking specialized studies should contact investigators already performimg them to obtain advice and coordinate methodology. Climate Committee members may be able to help with advice on investigators to contact.

If funds are available we recommend that sites consider making obervations of wet deposition, atmospheric transmissivity and Ulltra Violet B (UVB) radiation. UVB measurements may be important in detecting long-term trends in this variable. Such changes might be expected in association with changes in the amount of stratospheric ozone and excessive UVB can have potentially harmful effects on plants and animals If sites are interested in this or other questions related to UVB then it should be measured. However this is an expensive task. Broad band UVB measuring systems currently cost about $5000 while multispectral instrument systems may cost $25,000. Persons interested in such measurements will get useful advice from the USDA UVB Monitoring Program at http://uvb.nrel.colostate.edu/UVB/

Sun photometer observations. The National Aeronautical and Space Administration (NASA) has developed an instrument called a sun photometer. This instrument tracks the sun during the day and measures the components of the transmissivity of the atmosphere. The measurements are designed to be used to give greater accuracy in the interpretation of satellite imagery. The sun photometer measurements are potentially useful in obtaining some elements of the surface radiation balance.

Wet deposition observations should be patterned after the wet deposition measurements made in the National Atmospheric Deposition Program (NADP). The NADP program uses an instrument to measure separately both wet and dry deposition. We recommend only the former be used since the latter may be unreliable. Wet deposition is distinguished from bulk deposition because the latter measures both wet and dry deposition in the same receptacle.

### The National Atmospheric Deposition Program (NADP)

The National Atmospheric Deposition Program is a cooperative research program of the state agricultural experiment stations and other federal, state, and private research organizations. Its aim is to determine both the composition and amount of atmospheric deposition and its distribution on a national scale in order to assess the magnitude of the effects... (NADP, 1984). The NADP program is now called the National Atmospheric Deposition Program / National Trends Network (NADP/NTN). Look for more information at http://nadp.sws.uiuc.edu and see also http://btdqs.usgs.gov/acidrain/ .

Some LTER sites already participate in the NADP. The LTER climate committee endorses all the practices already in place for the standardization of NADP measurements. These practices are reported in the documents NADP Site Selection and Installation Manual, NADP Instruction Manual On Site Operations, and Field Operations Manual.

The NADP is now closed to the establishment of any new sites. Any LTER sites that are interested in making atmospheric deposition measurements should use the same sample collectors (Aerochemetrics Model 201) used in the NADP program. These are available from Aerochemetrics Ltd. 6832 SW 81 Street, Miami, Florida 33143. Investigators should also follow, as closely as possible, the same laboratory analytical methods used in the NADP program. Details of these may be obtained from the NADP documents NADP Quality Assurance Plan : Deposition Monitoring and CAL Analytical Methods Manual. Copies are available from Dr. Van Bowersox, Illinois Water Survey, 2204 Griffith Drive, Champaign, IL 61820 which is the location of the Central Analytical Laboratory (CAL) of the NADP.

**Standardization of Specialized Measurements.**

Owing to the large variety of specialized measurements that might be undertaken at LTER sites the Climatology Committee does not specify procedures but does make two recommendations:

First, where any specific future intersite study is anticipated the investigators are strongly urged to plan the experiment in such a way that instrumentation and methods are identical at the sites involved. The climate committee would be able to give advice on experimental design.

Second, investigators using specialized meteorological measurements must pay special attention to reporting the accuracy and precision of their observations. This will enable future studies to determine whether intersite comparisons fall within or outside of measurement error. Statements of accuracy and precision should address all parts of the following definitions which have been provided by the National Atmospheric Deposition Program (NADP, 1984. p38):

*Accuracy:* A measure of the degree of conformity of the mean value, obtained by using a specific method or procedure, with the true value. The concept of accuracy includes both bias (systematic error) and precision (random error).

*Precision:* The degree of agreement of repeated measurements of a homogeneous sample by a specific procedure, expressed in terms of dispersion of the individual values about the mean value.

The LTER Climate Committee endorses the precision and accuracy values suggested by the North Central Region of the Agricultural Climate Committee and advises LTER sites to attempt to meet these standards. They are as follows:

**Table 7. Precision and Accuracy of Measurements.**

| **Measurement** | **Precision** | **Accuracy** |
|---|---|---|
| Temperature | 0.1 deg C | 0.25 deg C |
| Radiation | 1%/100 KJ | 5% |
| Wind Speed | 0.1 m/s | 5% |
| Wind direction | 1 deg | 2 deg |
| Precipitation | 1 mm | 5% |

| | | |
|---|---|---|
| Relative humidity | 1% | 5% |

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## CALIBRATION

In order to maintain a high degree of accuracy in the measurements of climate parameters it is essential that instruments be checked and calibrated on a regular basis. The frequency and need for calibration depend upon the variable being measured and the type of sensor and method of recording being used. The use of electronic data loggers that can run for weeks or months without needing any technician attention make it especially important that a regular schedule of checking data and a set calibration schedule be followed. We recommend the following procedures for the various levels of measurement.

### Level 0

*Air temperature*

It is expected that at this level mercury and alcohol glass thermometers will be used. These thermometers are calibrated and tested by the manufacturer and have proved to be reliable over long periods of time. They should be used for checking and calibration of both chart and electronically gathered data at higher levels.

*Precipitation*

Standard rain gages that are measured manually with a measuring stick are calibrated by the manufacturer and need no further calibration.

### Level 1

*Air temperature*

At this level it is expected that air temperature will be recorded by either a thermograph or by an electronic data logger.

Thermograph:

For the thermograph chart temperature should be checked with a glass thermometer at each visit to the station and the maximum and minimum temperatures should be checked between chart and thermometer readings whenever the chart is replaced. When necessary adjustments can be made manually to the thermograph.

Data logger:

The data logger temperature reading should be checked against the mercury or alcohol thermometers at each visit to the site. Any sensor that deviates from the thermometer reading should be replaced and sent back to the manufacturer for calibration.

*Precipitation*:

It is expected that a manual precipitation gage will be used at this level (see level 0)

### Level 2

*Temperature:* Same as for level 1

*Precipitation*:

At this level it is expected that precipitation will be recorded with a data logger with either a tipping bucket (using an event recorder) or by a weighing bucket (using a pressure transducer) precipitation gage.

Tipping bucket:

Manufacturer’s instructions for calibrating this instrument should be followed before this instrument is placed in the field. The instrument should be recalibrated on a seasonal or more frequent schedule.

As an additional check weekly or monthly cumulative amounts should be checked against a manual precipitation gage at the site.

Weighing bucket:

A series of calibration weights and the procedure for calibrating this instrument are provided by the manufacturer. The instrument should be calibrated seasonally.

As an additional check this instrument should also be checked against a manually read precipitation gage on a regular (weekly or monthly) basis.

*Relative Humidity*:

It is assumed that at this level RH will be recorded electronically, usually in a unit that includes both temperature and relative humidity sensors.

Relative humidity readings should be checked on a regular basis using an aspirated pschycrometer. Replacement units for the RH chip are usually available from the manufacturer.

*Windspeed*:

Windspeed calibration is made by the manufacturer. Manufacturer’s instruction for recalibration frequency and bearing replacement should be followed. Where available windspeed can be checked locally in a wind tunnel.

*Wind direction*:

Initially wind direction must be established using a compass and following the manufacturer’s instructions. Wind direction should be checked on a regular schedule by comparing instant logger readings with the actual direction shown by the sensor’s vane.

*Solar radiation*:

It is expected that a LI-COR pyranometer or similar sensor will be used at this level for recording global radiation. Each sensor is given a calibration factor by the manufacturer which needs to be programmed in to the data logger. Manufacturers recommend recalibration on an annual or biannual schedule. it is important that this recommended schedule be followed as these sensors do need frequent recalibration. This calibration can usually be provided by the manufacturer.

**Level 3 and Level 4**

The specialized sensors used at these more complex levels of climate parameter recordings will all need some level of calibration on a wide variety of schedules A few examples are given below.

Wet deposition:

The NADP (National Atmospheric Deposition Program) has a rigorous program for calibration of instruments and sample analysis. Sites recording wet deposition on their own should try to follow the NADP standards.

Sun Photometer:

Sites participating in the NASA sun photometer program should have the instruments calibrated by NASA on a regular schedule provided by NASA.

Soil Temperature sensors:

Soil temperature sensors should be calibrated against known temperatures before being placed in the soil. It is recommended that these sensors be tested again when they are removed from the soil. Experience has shown that these sensors may fail or drift significantly over long periods. The data should be carefully monitored and any irregularity noted. A regular schedule of tasting and replacement of the soil temperature sensors should be established for long term monitoring sites. [In the future this information will be made compatible with the Robertson et al. book on soil observation processes].

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## Appendix 1 - Measurement of Solar Radiation

The Climate Committee does not advocate the use of any particular sensor for the measurement of solar radiation. Solar radiation is considered here to be both direct and diffuse radiation originating from the sun and having wavelengths between 0.15 and 3.0

micrometers. This radiation is commonly called shortwave radiation as oppose to longwave radiation (or infrared radiation 3.0 to 100 micrometers) which is emitted by the Earth and the atmosphere. We present examples of the types of instrument which are used at LTER site. Some sites use a LI-COR Silicon Pyranometer for solar radiation measurement. Other sites use Kipp and Zonen radiometers with a CM5 thermopile or a CM3 pyranometer while still other sites use radiometers from the Eppley Company. There are also other manufacturers of solar radiometers. As in other situations the more expensive equipment generally provides greater accuracy. Our experience has shown that most of the radiometers mentioned above are reliable. Users should pay attention to the need for careful siting (preferably with no obstruction of the horizon) and leveling of the sensors and make every effort to keep the surface of the sensor free from dust, ice and other forms of water. We choose not to suggest the measurement of other components of the radiation balance at level 2, such as longwave radiation flows, because such measurements are either expensive or labor intensive or both.

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**Appendix 2 - Components of a Typical Level 2 Meteorological Site**

The following is one example of the basic components of a data logger system from Campbell Scientific, Inc. and their approximate 1997 costs that would comprise an electronic data sensing and logging system acceptable for level 2 meteorology. The list is given as an example only. It includes some items that will not be needed at certain sites and does not include extra items that may be needed to meet the specialized needs of other sites.

| | | |
|---|---|---|
| LOGGER | | |
| CR21XL logger | | $2,100 |
| SENSORS | | |
| Vasaila Temp/humidity probe | | $480 |
| Texas Electronics Tipping bucket rain gage | | $295 |
| Met One Wind speed and direction | | $800 |
| Vasaila Barometric Pressure | | $540 |
| LI-COR Pyranometer | | $260 |
| 2 Soil Temperature probes | | $100 |
| | | |
| TOWER & ACCESSORIES | | |
| 10 meter tower & mounts | $515 | |
| base | $75 | |
| grounding | $30 | |
| guy kit | $145 | |
| anchors | $95 | |
| 2 cross arms @ $120 | $240 | |
| radiation shield and cross arm | $220 | |
| LI-COR levelling for x arm mount | $80 | |
| Total tower | $1,400 | $1,400 |
| | | |
| ENCLOSURE FOR LOGGER | | $295 |
| | | |
| OTHER POSSIBLE ACCESSORIES | | |
| Solar panel | | $265 |
| Phone modem system | | $650 |
| Multiplexor | | $725 |
| | | |
| TOTAL | | $7,910 |

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**Appendix 3 - Estimationof Vapor Pressure**

Actual vapor pressure in millibars may be calculated for each of the two daily observation points as:

Actual vapor pressure = {Relative humidity/100}*saturation vapor pressure at air temperature.

The latter may be obtained from tables (Marvin, 1941).

or

Actual vp = saturation vapor pressure at dewpoint temperature, where saturation vapor pressure in millibars:

$e = 6.1121 \exp(17.368\, T / (238.88 + T))$

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**Appendix 4. Measurement of Wind Speed and Direction**

Wind Speed and Wind Direction [txt with sub&superscripts in same line]

Wind speed is sensed by an anemometer and customarily measured by counting pulses representing total wind travel during the sampling scan interval. Thus, speed is total travel over scan duration and is a mean, not instantaneous value, for that interval of time.

si = wind speed [m/s] = wind travel [distance] / sampling interval [time]

The scalar mean wind speed (i.e., without regard to direction), Smean, produced by a data logger at the end of the output period is:

Smean = sum(si / N) (1)

where N = number of sampling intervals in an output period. Note that any maximum wind speed selected by a data logger from all si in an output period is NOT an instantaneous peak wind speed but an average for the duration of the scan interval. If peak winds are an important parameter to be measured, then the logger should be programmed for short scan intervals, i.e. an interval less than typical wind gust duration. The maximum sampling rate of the data logger or the response time of the anemometer will determine the shortest sampling interval over which speed can be determined.

Anemometers are available which produce a continuous voltage signal proportional to wind speed. Cost and maintenance of sensitive models of these instruments may limit their use in climate stations. Valid peak wind speed can be defined by this type of anemometer if the signal is recorded continuously or sampled frequently.

Wind direction is customarily measured by a wind vane which is decoded by the logger into azimuth (az) from north so that N is 0 degrees (or 360 degrees), E is 90 degrees, S is 180 degrees, and W is 270 degrees.

Alternatively, wind speed and direction can be sensed by a two-propeller anemometer, usually facing North and East, measuring two components of wind. The resultant wind speed is:

si = (ni2 + ei2)1/2 (2)

where ni and ei are the instantaneous north and east components of wind speed (if ni or ei are negative they reprsent wind flux from the opposite direction, south or west). If this calculation is done at scan time, the scalar mean wind speed for a logger output period is as in equ. (1). The instantaneous wind direction from a two-propeller anemometer is:

azi = arctan(ei / ni) (3)

Obviously, ni and ei must be checked for the zero condition. Note that a simple mean of wind directions will yield invalid results. As an extreme example, the mean of four observations of wind directions near North at 357 degrees, 3 degrees, 358 degrees, and 2 degrees would compute as South or 180 degrees. The best way to obtain mean wind direction is therefore to compute the mean wind direction from the sums of the components:

Azmean = arctan(sum[ei] / sum[ni]) (4)

Some data loggers have the capability to compute vector mean wind velocity and vector mean wind direction over an output period from the scan interval observations of wind speed and direction. In addition to the scalar mean wind speed, the logger internally calculates the vector mean wind velocity from computed orthogonal components of the observed wind vectors. The vector mean wind velocity is always less than or equal to the scalar mean wind speed. The orthogonal components are calculated by the logger using equ. (5) and (6) from the scan interval observations of speed and direction. The logger averages direction over the output period as in equ. (4) and averages velocity as in equ. (7).

If the data logger does not have a routine for averaging vectors from anemometer and vane sensors, the orthogonal components for each scan interval may be calculated as:

ni = si cos(azi) and (5)

ei = si sin(azi) . (6)

The vector mean wind velocity would be computed for an output period, similar to equ. (2):

Vmean = (sum[ni2] + sum[ei2])1/2 (7)

and the vector mean wind direction computed by equ. (4).

If a data logger is not used or one is used that can not compute wind speed and direction vectors, mean wind direction might be approximated by recording the prevailing wind direction at observation time or by recording the wind direction at the time of maximum wind speed within each sampling period.

Wind direction is meaningless during calm periods, i. e. when wind speed is recorded as zero or within the sensitivity error band of the anemometer. For data systems using the wind vector calculation, the calm period wind directions are reduced to insignificant fractions of the output period vector mean direction. However, the negligible wind speeds for calm periods should and do contribute to both the scalar mean wind speed and vector mean wind velocity.

A useful option available with some data loggers is to output the standard deviation of the wind directions observed over the sampling output period. A climatic station representing a site or time period characterized by variable and non-persistent wind directions will record a larger standard deviation than the case where wind blows from a consistent direction. Thus, the standard deviation provides another quantifiable measure of the climate characteristics of a site in addition to its statistical values.

Aggregation rules:

When wind speed is aggregated to represent longer time periods, e. g. averaging hourly into daily periods or daily into monthly means, computing the mean of the scalar mean wind speeds will be valid. However, to average the wind vector, all vector mean wind velocity and direction pairs must be converted to rectangular coordinates using calculations similar to equ.(5) and (6) and the longer time period vector means of velocity and direction computed from the orthogonal values similar to equ. (7) and (4). This is the only valid method to compute the vector means. The daily mean of the hourly standard deviations would be the square root of the mean of the hourly deviations squared:

SDmean = (sum[SD2] / N)1/2 (8)

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# Glossary of Climatology/Climate Data Terms

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ABSOLUTE TEMPERATURE - Temperature measured in Kelvin.

ADVECTION - Energy or mass exchange by horizontal mass movement

ADIABATIC - A change of state without transfer of energy across system boundaries.

AIR MASS - A widespread body of air approximately homogenous in its properties

ALBEDO -the reflectivity of a body integrated over the solar spectrum. May be expressed as time averaged or instantaneous values. Instantaneous values are similar to reflectance measurements in remote sensing.

ANEMOMETER - Instrument for measuring wind velocity. Most common type uses cups attached to axles which rotate horizontally.

ANNUAL FLOOD - Highest flow point on a stream during any calender or water year.

ANOMALY - Deviation from a normal or average value.

ARIDITY - the degree to which air lacks effective moisture. Opposite of humidity

ASPECT - compass azimuth to which a slope faces. Ranges from 0° to 360°.

BAR - basic unit of pressure, equal to $10^6$ dyne/$cm^2$ or 29.5 in/Hg.

BAROMETER - instrument for measuring pressure

BIOCLIMATIC - pertaining to the effect of climate on life.

BOWEN RATIO - the ratio of energy flux as sensible heat to energy flux as latent heat.

BPI PAN - A type of evaporation pan. See Pan evaporation.

BULK DENSITY - In soil, the mass of the solids divided by the volume of the solids and voids.

CLASS A PAN - Also called a standard pan. A type of evaporation pan. See Pan evaporation.

CLIMATOLOGICAL OBSERVATION - Strictly speaking, this requires the following data to be evaluated at least once daily: maximum temperature, minimum temperature, total precipitation since the previous report.

CONVECTION - Mass movements in a fluid or gas resulting in a mixture of properties within the fluid or gas. Generally assumed to be vertical motion.

DAILY MEAN - average value of a climatic element over a 24-hour period. Daily means recorded using special-purpose maximum/minimum thermometers are called TRUE DAILY

MEANS.

DAY - There are a surprising large number of definitions for a day. Most relevant to climate measurement is the difference between a mean solar day and a civil day. MEAN SOLAR DAY is derived from the apparent solar day (interval of time required for the sun to cross a specific meridian), modified by the equation of time. The CIVIL DAY is a mean solar day modified to make time keeping practical.

DEGREE - unit of temperature

DEGREE DAY - A measure of departure of the mean daily temperature from a given standard or threshold. The departure can be positive with respect to the threshold, as in cooling degree days, or negative, as in heating degree days or frost degree days. Degree days are generally allowed to accumulate over a season. GROWING DEGREE DAY - As above, the threshold temperature is generally defined by the vegetation types, e.g. 4 °C for C3 grasses, for 7 °C C4 grasses, etc.

DEW - water deposited on vegetation or other surface by condensation.

DEW POINT - temperature to which air must be cooled at constant pressure and water vapor content for saturation to occur.

DROUGHT - a period of abnormally dry weather sufficiently prolonged for the lack of water to cause hydrological imbalance.

DRY BULB THERMOMETER - a thermometer which directly measures air temperature. Contrast with wet bulb thermometer.

EVAPOTRANSPIRATION - combination of EVAPORATION (loss to the atmosphere from a free water surface, rocks, bare soil, or intercepted water), and TRANSPIRATION (water loss from the surface of plants). Can also be conceptualized as an exchange of energy, see Latent Heat. POTENTIAL EVAPOTRANSPIRATION - evaporation from a short, green well-watered crop which exerts negligible resistance to the flow of water.

FETCH - distance downwind to a change in surface cover or surface property.

FIELD CAPACITY - The percentage of soil moisture held with water potential less than -1/3 bar. A measure of the greatest amount of water that a soil can store under conditions of complete wetting followed by free drainage.

FIRST ORDER STATION - a climate station where automatic or hourly readings of pressure, temperature (including min/max), humidity, sunshine, wind, and precipitation are made.

FREEZING INDEX - number of degree days above and below 0 °C between the highest and lowest points of the cumulative degree-days time curve for one freezing season.

FREEZING SEASON - time interval between the highest point and the succeeding lowest point on the time curve of cumulative degree days above and below 0 °C.

FROST DAY - an observational day on which frost occurs.

GROWING SEASON - the period of the year during which the temperature of vegetation is sufficiently high to allow plant growth, generally considered to be the time between successive occurrences of some index temperature. 10 °C is often used as an index, as is annual mean temperature for a given location.. EFFECTIVE GROWING SEASON - length of growing season which prevails in 80% of all years.

HUMIDITY - a measure of water vapor in the air.

ABSOLUTE HUMIDITY - ratio of mass of water vapor to volume of air and water vapor

RELATIVE HUMIDITY - ratio of humidity present in a volume of air to the amount it could hold if saturated. A temperature dependant quantity.

HYDROLOGIC YEAR - see WATER YEAR

HYGROMETER - instrument which measures water vapor content of the atmosphere

INSTRUMENTAL CORRECTION - difference between the readings of a given instrument and those of a standard instrument.

INSOLATION - solar radiation received at the Earth's surface

KELVIN - a unit of the absolute temperature scale. Zero Kelvin is absolute zero.

LANGLEY - unit of energy per area equal to one calorie per square centimeter. Superseded by the SI unit $Wm^{-2}$ but still commonly encountered.

LAPSE RATE - Rate of temperature change with height.

LATENT HEAT - strictly speaking, energy consumed in a phase change. In climatological usage, the energy transported to the atmosphere from the surface by the evaporation of water.

MEAN TEMPERATURE - average temperature of the air given a specified time period, usually a day, month, or year. Also called TRUE MEAN TEMPERATURE

MIXING RATIO - the mass of water vapor to the mass of dry air, a measure of humidity

NORMAL - in climatology, mean values over a specified period, usually thirty years.

OBSERVATIONAL ERROR - difference between an observed value and its true value. Can be subdivided into SYSTEMATIC ERROR (a series of measurements with similar error), RANDOM ERROR, and MISTAKES (widely discrepant readings, usually the result of error by the observer).

PAN EVAPORATION - water loss to the atmosphere as measured from a standard pan.

PAN COEFFICIENT - quantity which relates pan evaporation to actual evapotranspiration. Specific to various vegetation or crop types.

PRECIPITATION GUAGE - a device for measuring the amount of precipitation. A rain gauge should have uniform cross sectional area and be sited away from obstructions. Precipitation gauges often have shields to prevent wind from biasing the data.

PSYCHROMETER - a type of hygrometer utilizing either a wet bulb/dry bulb thermometer combination or a piezoelectric resistance element.

PYRANOMETER - a device for measuring incoming solar radiation. Measures both direct and diffuse insolation, although it is possible to modify the instrument to measure only diffuse irradiance by addition of a shadow band.

PYRGEOMETER - measures longwave radiation

PYRHELIOMETER - similar to a pyranometer but measures only direct insolation

RAIN DAY - in U.S. usage, a day with some measurable precipitation

RANGE - difference between the maximum and minimum value of a measurement

RADIOSONDE/RAWINSONDE - an instrument package attached to a balloon for making upper atmosphere measurements. The rawinsonde includes wind measurement instruments.

SENSIBLE HEAT - an exchange of energy causing a rise in temperature

SHELTER - housing for instruments.

SOIL HEAT FLUX - Flow of heat into or out of a soil, the product of the soil temperature gradient times the thermal conductivity of the soil. Expressed in $Wm^{-2}$.

SOIL TEXTURE - The distribution of particle sizes within a soil. Texture classes are SAND (particle size range 0.05 - 2.0 mm), SILT (particle size range 0.002 - 0.05 mm), CLAY (particle size < 0.002 mm), or LOAM (a soil of mixed texture).

SOIL WATER CONTENT - The amount of liquid water or water vapor contained in the soil matrix. Can be expressed as VOLUMETRIC units (volume of water per unit volume of soil) or GRAVIMETRIC units (mass of soil moisture per unit mass of soil).

SOIL WATER POTENTIAL - The mechanical work necessary to transfer a unit of soil solution from a standard or reference state (where potential = 0) to the situation of interest. This term is also frequently used to describe the concentration gradient of soil moisture between two locations separated either vertically or horizontally, or both.

SPECIFIC - observation made per unit of mass. For example, specific heat is the heat required to raise one unit of mass one degree of temperature. See specific humidity.

STANDARD - an index or hypothetical value or distribution of some quantity. E.g. standard pressure is 1000 mb.

STATION - a meteorological or climatological measurement site.

SYNOPTIC - in meteorology, an observation or forecast occurring simultaneously over a wide area.

TEMPERATURE EFFICIENCY INDEX - long range efficiency of temperature in promoting plant growth. The sum of all 12 monthly temperature efficiency ratios.

TEMPERATURE EFFICIENCY RATIO - departure of normal monthly temperature above 0 °C divided by 4, i.e. (T-0)/4

THAWING INDEX - number of degree days above and below freezing between the lowest and highest points on the cumulative degree day time curve

THAWING SEASON - the period of time between the lowest and succeeding highest points on the time curve of cumulative degree days above and below 0 °C.

THERMISTOR - a temperature measurement device composed of solid semiconductors with a negative linear resistance response to temperature change

THERMOCOUPLE - a temperature sensor which converts thermal energy directly into electrical current.

VAPOR PRESSURE - the partial pressure exerted by the water molecules in mixed gas. A measure of humidity.

WATER YEAR - any twelve month period, usually selected to begin or end during a dry period, used as a basis for analyzing hydrological data. In the U.S., the water year is commonly 1 Oct - 30 Sept.

WATT - a unit of power equal to 1 joule per second. A watt per square meter is the standard unit of radiant flux density in the SI system.

WET BULB - either a thermometer with a saturated wick covering its bulb, used along with a dry bulb thermometer to measure relative humidity, or the temperature an air parcel would obtain if cooled adiabatically to its saturation point.

WILTING POINT - The soil moisture potential at which a plant begins to lose turgor and exhibit adaptive mechanisms in response to water stress, e.g. leaf rolling, stomatal closure.

WIND VANE - arrow like instrument used to indicate wind direction

WIND VECTOR - vector describing the combined direction and velocity of the wind. WIND ROSE - a graph of wind vectors over time VECTOR MEAN WIND - the vector average of wind over time.

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# AUTHORSHIP AND DEVELOPMENT OF DRAFT STANDARDS FOR OBSERVATION AND ARCHIVING OF LTER CLIMATE DATA

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This document is the result of the cooperative effort of many LTER groups and individuals.

The document primarily results from a meeting held at Sevilleta LTER, NM Oct. 2-5, 1997 called

LTER Climate Observations and Format Standards Meeting (CLIMSTAN)

The participants at the meeting are listed here .

The original (1986) meteorological observation standards document was developed by the individuals and 1986 Climate Committee who are listed at the front of the document itself.

The revised (1997) version of the observation standards is mainly the work of Karen Baker, David Greenland, Jordan Hastings, Lloyd Swift Jr., and Les Viereck (listed alphabetically). (Greenland - Editor)

The Intersite Climate Data Base section of the document was mainly the work of Barbara Benson, Caroline Bledsoe, Darrell Blogett, Doug Goodin, Don Henshaw, Bill Lauenroth, Doug Moore, Robin Stubbs, and Lloyd Swift Jr. (listed alphabetically). (Goodin and Henshaw - Co - editors).

The Glossary was mainly the work of Doug Goodin.

All parts of the document were reviewed by the full membership of the 1997 Climate Committee and 1997 Data Managers Committee.

### Climate Committee 1997
### AND Arthur McKee and David Greenland
### ARC John Hobbie
### BNZ Les Viereck and Phyllis Adams
### CDR Johannes Knops
### CWT Lloyd Swift Jr.
### HFR Emery Boose
### HBR Amy Bailey
### JRN Vince Gutschick
### KBS James Crum and Stuart Gage
### KNZ John Briggs and Doug Goodin

**LUQ Robert Waide and Doug Schaefer**
**NWT Mark Losleben and Tim Seastedt**
**NTL John Magnuson, Dale Robertson and John Lenters**
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**PAL Ray Smith, Karen Baker and Robin Ross**
**SEV Doug Moore, Cliff Dahm and Jim Gosz**
**SGS Timothy Kittel and Bill Parton**
**VCR Bruce Hayden**
**Data Managers Committee 1997**
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AND Susan Stafford,Don Henshaw, Gody Spycher
ARC James Laundre, John Hobbie
BAL Christopher Steele, Timothy Foresman
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SGS Chris Wasser
VCR John Porter

## ClimDB+ Mailing List Members

Barbara Benson (NTL) established an extended group list for persons who will be testing and contributing to the ClimDB system and are interested in issues related to intersite climate database development. The mailing list is called ClimDB+ and as of November, 1997 included the following persons:

AND Arthur McKee, David Greenland, Susan Stafford,Don Henshaw, Gody Spycher
ARC John Hobbie, James Laundre
BAL Christopher Steele, Timothy Foresman
BNZ Les Viereck, Phyllis Adams, Darrell Blodgett
CAP Peter McCartney
CDR Johannes Knops, Clarence Lehman
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HBR Amy Bailey
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JRN Vince Gutschick, Ken Ramsey, John Anderson, Barbara Nolen
KBS Phil Robertson, Stuart Gage, Kay Baergen, SHalstead

KNZ John Briggs, Doug Goodin
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MCM Berry Lyons, Denise Steigerwald
NET James Brunt, Caroline Bledsoe
NTL John Lenters, Barbara Benson, Robin Stubbs
NWT Mark Losleben,Tim Seastedt, Michael Hartman
PAL Ray Smith, Karen Baker
SEV Doug Moore, Jim Gosz, Gregg MacKeigan
SGS Bill Lauenroth, Chris Wasser
VCR Bruce Hayden, John Porter

## Prefaces to Editions of the Observation Standards

### PREFACE TO 1986 EDITION

Following the initial establishment of the Long Term Ecological Program (LTER) a Meteorological Committee was organized under the cochairpersonship of Dr. Harvey L. Ragsdale and Dr. Lloyd W. Swift of the Coweeta LTER site. The other committee members were Drs D. Bark (Konza), D. Greenland (Niwot), B.J. Kjerfve (North Inlet), and A. McKee (Andrews). Using some of the original planning documents of the LTER program (TIE, 1979), site specific material (e.g. Waring et al., 1978), National Weather Service and World Meteorological Organization documentation (WMO, 1970,1971, USDC, 1970), and the experience of the committee, the first part of a document outlining the standardization of LTER meteorological measurements was completed. The majority of the work was performed by Drs. Ragsdale and Swift and the first three sections of the present document is largely due to their efforts. Drs. Swift and Ragsdale subsequently described the status of meteorology within LTER in an overview document (Swift and Ragsdale, 1985). In 1985, the committee was reestablished by the central coordinating committee of LTER as a climate committee whose tasks are to complete the present document and to prepare a climatic description of the LTER sites. This manual has been reviewed by all members of the LTER Climate Committee and represents the approved procedures for the operation of the the LTER climatology program at the time of writing. Changes and additions to the contents of this manual will be supplied to site principal investigators when appropriate. It should be noted that the reference USDC 1970 supplied with hardbound versions of the manual is currently under revision by the National Weather Service and a new version of this will be available from the NWS within the next two years.

David Greenland.
Niwot Ridge/Green Lakes Valley Site
University of Colorado.
June 1986

### PREFACE TO 1997 EDITION

Expansion of the LTER Network, advances in technology, the need for greater specification of climate data format, and members of the LTER Coordinating Committee demanded a revised version of the Meterological Standards Document. The LTER Network Office funded a meeting where much of the work on revision and data format standardization was accomplished. The meeting was held at the Sevilleta site between October 2 -5, 1997. At the meeting were representatives of the Climate Committee, the Data Managers Committee, and LTER climate data users. A list of persons who contributed at the meeting is given here . Following the meeting a draft of the revision was reviewed by members of the full Climate Committee after which the document was submitted for approval by the LTER Coordinating Committtee.

David Greenland.
Andrews and Niwot Ridge/Green Lakes Valley Site
University of North Carolina.
October 1997.

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*Last Updated 2/17/99 David Greenland. greenlan@email.unc.edu*

# Participants

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Return to authorship document

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Oct 2-5, 1997, Sevilleta. NM.

**THE PARTICIPANTS IN CLIMSTAN MEETING WERE**:

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