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METEOROLOGICAL DATA STATIONS AT LONG-TERM ECOLOGICAL RESEARCH SITES

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ABSTRACT

Long-Term Ecological Research (LTER) sites have been designated in eleven ecosystems under the auspices of the National Science Foundation. Meteorological observations are part of the needed baseline data. An early accomplishment of this coordinated research program is a standard for LTER meteorological stations. National goals of the LTER program and the research objectives at each site are related in this report to specific needs for meteorological data that defined the concept and structure of the station standards. Each meteorological station must serve two purposes, support ongoing research at the site and provide climatic data for long-term studies and inter-site comparisons. The recommended standard is flexible. It establishes a core level of participation yet allows for considerable variation in data requirements of different ecosystems.

INTRODUCTION

The Long-Term Ecological Research (LTER) program was initiated by the National Science Foundation to secure well documented research sites that represent significant and distinctive ecosystems. LTER is a response to a desire by ecologists for a network of varied locations, managed for long-term ecological research, and providing continuing baseline collection and field facilities. These needs were identified in other programs such as the International Biological Program, the Experimental Ecological Reserve, and the Biosphere Reserve. The purpose of the LTER program of research is to define the patterns

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and discover the causes of long-term changes in ecological systems. Comparative ecological analyses are planned, thus data collected at the several sites must be compatible.

Participation in LTER is contingent upon a site's commitment to develop and sustain a core research program supported by on-going long-term data collection. Field sites and data must be available to collaborative scientists. Administration of a site may be shared between a government land holding agency and a university research group. National Science Foundation grant money characteristically supports only part of the activity at each site.

Each LTER site will have studies in five areas:

Primary Production--How is production distributed and controlled by physical and climatic features of site and by disturbances?

Populations of Representative Species--What are populations and causes of expansion or decline?

Organic Matter--What are the patterns and controls on accumulation in soils and sediments?

Inorganic Nutrients--What are patterns of input from atmosphere and movement through soil, ground, and surface waters?

Disturbance to Site--What have been the kinds and frequencies of natural and man-caused disturbances and each ecosystem's response to disturbances?

Ecological studies are typically site specific, which has an advantage of controlling the number of variables to be measured. LTER studies will extend theories and principles which have been learned and determine how they apply to a broad spectrum of conditions. Meteorological data will be required. Some ecological phenomena occur over long time scales and, thus, short-term studies cannot determine variability or stability of an ecosystem. Sites were selected based upon assurances of long-term continuity of management, availability of facilities to researchers, and upon presentation of proposals addressing pertinent questions in these study areas by competent scientists. In summary, the LTER program was designed to:

- produce and retain documented baseline data for solving long-term research and policy problems;
- develop standard intersite methodology for ecological research;
- assure long-term availability to the ecological research community of a coordinated network of research sites; and
- provide opportunities for a diversified group of investigators to concentrate and interrelate their specific studies on increasingly well documented ecosystems.

National Science Foundation issued an LTER program announcement in December 1979. The first six sites were funded in 1980, and five more sites were added in 1982 (Figure 1). All 11 sites have a research history, some exceeding 30 years duration, and they represent some of the principal ecosystems in the United

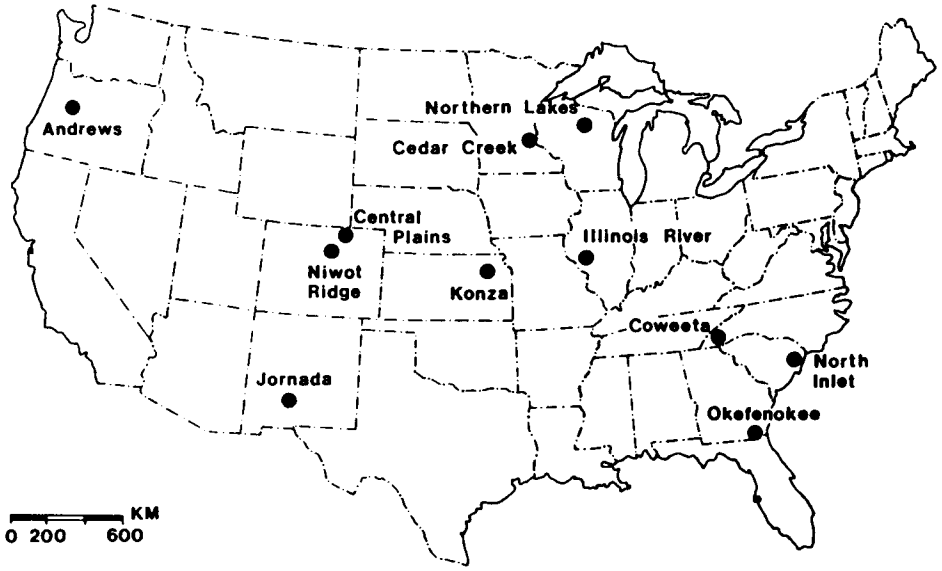

Figure 1. Long-Term Ecological Research sites span the United States from the Cascade Mountains in the West to the salt marshes of the East Coast and from the desertic basins of the Southwest to the Northern Lake country.

States (Table 1). Appendix I describes the sites and the focus of their meteorologically related research. In August 1981, the National Science Foundation funded a grant to encourage coordinated intersite research. That grant stimulated agreement on standardized meteorological measurements reported here. In addition, 13 multisite collaboration projects are proposed for the next 2 years. Twelve depend to some degree upon consistent meteorological data from all sites and one specifically calls for comparative meteorological studies.

PHILOSOPHY OF METEOROLOGICAL STANDARDS

The purposes for setting standards for the LTER sites were (1) to encourage the collection of certain basic meteorological data at all sites, (2) to assure compatibility of data among users, and (3) to define procedures for obtaining and reporting data which support research within and between sites and allow intersite climatological comparisons. Three constraints were recognized. First, the standards should not specify instruments or recording systems because advancing technology would outdate such decisions. Second, some meteorological variables should be

Table 1. LTER sites in 1983

Name	Institution	State
H.J. Andrews Experimental Forest	Oregon State University USDA, Forest Service	OR
Cedar Creek Natural History Area	University of Minnesota	MN
Central Plains Experimental Range	USDA, Agricultural Research Service Colorado State University	CO
Coweeta Hydrologic Laboratory	University of Georgia USDA, Forest Service	NC
Illinois River and Upper Mississippi River	State of Illinois Western Illinois University	IL
Jornada Experimental Range	New Mexico State University	NM
Konza Prairie Research Natural Area	Kansas State University	KA
Niwot Ridge, Mountain Research Station	University of Colorado	CO
North Inlet Marsh Hobcaw Barony	University of South Carolina	SC
Northern Lakes, Trout Lake Biological Station	University of Wisconsin	WI
Okefenokee National Wildlife Refuge	University of Georgia USDI, Fish and Wildlife Service	GA

Physiography and Elevation (m)	Biome	Climate
Mountain (445-1620)	Coniferous forest	Mild wet winter, warm dry summer
Glacial outwash plain (175-288)	Tall grass prairie, hardwood forest	Cold winter, hot summer, low year round precipitation
High plain (1650)	Short grass prairie	Cold winter, cool moist summer, moderate to high winds
Mountain (680-1592)	Deciduous forest	Moderate temperature, high year round precipitation
Large river (127-163)	Deciduous forest	Cool dry winter, wet warm summer
Basin and range (1318-1501)	Semidesert grassland	Mild dry winter, hot summer, intense variable summer precipitation
Dissected upland (366)	Tall grass prairie	Cold dry winter, warm moist summer
High mountains (2900-4060)	Alpine tundra, subalpine forest	Cold wet winter, cool dry summer
Coastal estuary (0-4)	Salt marsh	Maritime warm winter, hot summer
Glacial lakes (500)	Northern mixed forest	Cold wet winter, cool summer
Perched swamp (37)	Freshwater wetland	Subtropical high precipitation

measured at all sites but others are appropriate or useful only at certain sites or at specific times. And third, not all sites may be capable of making a major investment in a meteorological station.

To set useful standards while allowing flexibility, four levels of instrumentation and data summarization are specified. Requirements for the different levels are related so that a site may grow from one level of participation to the next without a break in data series. Distinctive attributes of the four levels are outlined in Table 2.

Table 2. Types of LTER meteorological stations

Level	Parameters	Interval	Remarks
0. Entry	Air temperature Precipitation	Daily	Temporary or satellite station
1. Basic	Air temperature Precipitation Vapor pressure Wind speed	Daily	Minimum standard station, use standard instruments
	Wind direction Solar radiation	Daily	Optional for Level 1
2. Research	All of the above	Hourly	Probably use electronic sensors and data logger
3. Supplemental	All of the above plus one or more: Snow depth Wind vector Partial spectrum radiation Soil temperature Water temperature Atmospheric pressure Evaporation Boundary layer fluxes or other variables	As required	Specialized measurement at some sites. May be continuing or short-term

Entry Level 0

Level 0 is the minimum station that will support beginning research activities and allow some intersite climatological comparisons. A Level 0 station could be a National Weather Service cooperative observer near the LTER site who measures and reports only air temperature and precipitation on a daily basis. Usual instrumentation is a nonrecording precipitation gage and maximum-minimum thermometers in a shelter with observations taken manually. It should be upgraded to Level 1 within 12 months.

Basic Level 1

The recommended minimum meteorologic effort for continuing participation in the LTER program is a Level 1 station on the site. The emphasis at this Level is on building a climatological data set from daily observations. This station is conceived to be economically achievable utilizing field-proven instrumentation of minimum complexity and maximum reliability. Measured elements include air temperature and vapor pressure, precipitation and wind speed. Wind direction and global solar radiation are recommended but optional. Data are summarized and reported for 24-hour intervals. A site with an established meteorological station probably begins at Level 1 or Level 2. A wide range of instrument types may be used at Level 1. The simplest station might consist of both nonrecording and recording precipitation gages, a shelter containing the maximum and minimum thermometers, a recording hygrothermograph, and a totalizing anemometer. Observations would be manual and extracted from charts. Sites could have several Level 0 or 1 meteorological stations at remote locations referenced back to a base station of higher level, but multiple stations are not required. The standards recognize that some Level 1 stations might be intermediate in sophistication or in the process of being upgraded to Level 2.

Research Level 2

The goal at Level 2 is to provide detailed meteorological data to support ecological research along with the basic goal of producing a climatologic data set. A Level 2 station measures and reports the same variables as Level 1 with the exception that wind direction and solar radiation are required. The interval for reported data is hourly and, thus, a Level 2 station may contain a data logger and electronic sensors instead of chart recorders.

Supplemental Level 3 Measurements

Level 3 is not a distinct level of sophistication above

Table 3. Current LTER site meteorologic stations

Site	Years of Record	Station Level	Precipitation			Temperature		
			Manual	Record	Snow	Air	Soil	Water
H.J. Andrews	31	3-	X	X	X	X	X	X
Cedar Creek	19	1-	X	X	X	X	X	
Central Plains	40	3	X	X	X	X	X	
Coweeta	48	3-	X	X		X	X	X
Illinois River	80+	3	X	X		X	X	
Jornada	68	3-	X	X		X	X	
Konza	11	2	X	X		X		
Niwot Ridge	31	1+		X	X	X		
North Inlet	10	3-	X	X		X		X
Northern Lakes	80+	2		X	X	X		X
Okefenokee	32	1±		X		X		

Level 2, but more a category of additional measurements to be made at Level 1 or 2 stations. Level 3 measurements may be continuing or short-term. LTER sites range from estuary to terrestrial, desert to temperate, and forest to alpine tundra. Certain meteorological data are needed at all these sites. Other variables such as evaporation, snow depth, atmospheric pressure, water and soil temperatures, wind vector analyses, or partial spectrum radiation flux are significant at some sites but inappropriate at others. Continuing measurement and reporting of meteorological variables not common to all sites would be specified at Level 3.

At various times, a site may require short-term specialized meteorological measurements such as deposition or turbulent transfer in the boundary layer or detailed micrometeorological observations within the biologically active surface. At the conceptual stage of a study, plans for special Level 3 meteorological measurements should be coordinated with other sites to develop standardized techniques, identify mutual interest, and

Humidity Dew Point	Wind Speed	Wind Direction	Radiation Solar	Radiation Net	Evap Pan	Atmospheric Pressure	Hourly Summary
X	X		X				X
	X	X	X			X	
X	X	X	X		X		X
X	X		X		X	X	X
X	X	X	X		X		X
X	X		X		X		X
X	X	X	X				X
X	X		X	X		X	
	X	X	X			X	X
X	X	X	X				X
	X	X		X	X		

facilitate short-term data collection and potential intersite comparisons.

For many LTER sites, atmospheric chemistry or hydrology measurements also will be made at or near the meteorological station. Other committees had the responsibility for setting standards for these measurements. Table 3 lists the meteorological elements measured at the LTER sites. At some sites, all measurements are made at a single station but many sites have measurements at several locations. The station levels shown in Table 3 are temporary because most LTER sites are in the process of developing or upgrading their meteorological stations. A plus or minus sign signifies that some measurement is extra or currently missing. The years of record include data from stations in or adjacent to the site which can be used to determine climatic values. The LTER station level classification does not apply to preexisting records.

Data Storage and Exchange

Regardless of the level of meteorological station, a log of observations and operations must be maintained. This permanent record may vary from National Weather Station Form E22 for reporting daily observations to a locally designed log of manual observations, check measurements, and instrument tests on a data logger system. The log will normally not be a data form that is exchanged but will be preserved and available for reference at the LTER site.

The content but not the format for data summaries is specified. Each site should produce monthly reports giving daily values and monthly totals and/or means and extremes of all variables appropriate for the level of station. In addition to paper reports, sites should maintain equivalent summarized data files in computer-accessible media (cards, tapes, or disks). Sites with Level 2 participation also will maintain computer-accessible files of calculated and summarized hourly values. Data in all reports and prepared files will be in metric units. Although data will be processed and available for ready exchange between LTER sites, large masses of information will not be automatically circulated. Data sharing will follow an individual request based on a specific need.

A Research Application

A goal of the National Science Foundation is to encourage intersite comparisons of ecosystems. The analysis of long-term climatic data sets is a multisite activity for 1983-85. Biological systems respond to threshold values or durations of a meteorological element or to specific interactions between two or more elements. Traditional expressions of climatic means and extremes are easy to calculate but may not relate to biological responses. A proposed first study will seek new expressions for precipitation data that better represent the driving functions of moisture input upon the variety of biological systems at the LTER sites.

APPENDIX

This section lists brief descriptions of the unique features of each LTER site and current research problems that have significant meteorologic emphasis. In addition to the studies listed, each site will (1) analyze available long-term meteorological records to define the climate of the research area, and (2) provide supporting meteorological data to other ecosystem research projects on the site.

H. J. Andrews Experimental Forest represents the densely forested part of the west side of the Cascade Mountains. The site consists of 6100 ha plus six smaller areas providing

examples of pristine old growth (400 + years) and mature (125 years) conifer forests, young managed forests, and aquatic habitats, primarily rapidly flowing mountain streams. Several remote meteorological stations are referenced to the main station at the lower end of the Experimental Forest. At 914 m elevation, measurements of horizontal and vertical wind flux, temperature, dewpoint, net radiation, and snow accumulation and melt are being made in clearcut and old growth forests. Studies will (1) evaluate effects of forest management practices on evapotranspiration, snowmelt, and turbulent exchange, (2) establish recovery rates of stream temperature with regrowth for several silvicultural regimes, and (3) examine spatial variation of precipitation and temperature in mountainous terrain to aid modeling of primary production.

Cedar Creek Natural History Area represents the varied ecosystems of the glacial outwash plain. Forty years of research has been done at this 2185 ha site, which consists of lakes, wetlands, grasslands, old fields, and forests including an undisturbed area. Agriculture is periodically terminated on a portion of the site to provide old field experimental areas for a range of known ages. Studies will (1) determine the influence of soil temperature upon the dynamics of the nitrogen cycle, and (2) evaluate and model, using climatic data, the water availability to plants in sandy soils.

Central Plains Experimental Range represents the short grass steppe of the high plains. Forty-four years of research by Government and university scientists on this 6280 ha area has emphasized livestock grazing. Facilities include a lysimeter installation. Studies will (1) determine the influence of rain, snowmelt, and evapotranspiration upon temporal and spatial variation of soil moisture, and (2) evaluate the influence of water and wind upon movement and deposition of soils and plant materials.

Coweeta Hydrologic Laboratory represents the humid temperate forests of the Appalachian Mountains and is one of the original experimental areas dedicated to the study of forest hydrology. Facilities have included 32 gaged watersheds and over 120 precipitation gages in the 2185 ha area. A base precipitation network had a density of 1 gage per 27 ha for 20 years. One main and three remote climatic stations are maintained. Studies will (1) observe and model changes in surface temperature (stream and soil) due to clearcutting a deciduous forest, (2) define links between year-to-year climatic variation and streamflow response with the aim of improving water yield predictions, and (3) investigate the processes that modify precipitation chemistry and affect stream solutions.

Illinois River and Upper Mississippi River represent the aquatic and terrestrial ecosystems of large rivers and their flood plains. Studies starting in the 1890's provide data that predates the influence of large impoundments and present-day urban pollution. Research focuses on an older impoundment on each river

and a new impoundment just below the confluence of the two rivers. Terrestrial sites include a range of human impact zones such as levee, agricultural, park, and wildlife reserve lands. Meteorological data will be obtained from National Weather Service stations distributed over these large watersheds. In general, the ecosystem stability is more strongly influenced by annual flooding than individual meteorological events. Studies will use long-term climatic records with tree ring and sediment analyses to estimate river flow and climatic histories for the presettlement period.

Jornada Experimental Range and New Mexico State University Ranch represent the semidesert grassland of the basin and range portion of the Southwestern United States. The combined lands total over 104,000 ha and reach from the flood plain of the Rio Grande River to the crest of the San Andreas Mountains and include an interior basin without a drainage outlet. Research focuses on effects of grazing with some exclosures ungrazed since 1927. Intense but variable precipitation is sampled by a 75-gage network plus a new 100-gage transect. Studies will (1) demonstrate that climatic controls of decomposition rates of surface litter are modulated by soil depth, (2) define spatial variability of precipitation and soil temperature and its influence on soil moisture along two parallel 3-km transects extending down a rocky mountain slope to an ephemeral dry lake, and (3) determine the effect of climatic variables on movement by water vapor diffusion of percolated precipitation stored in subsoil back into the root zone.

Konza Prairie Research Natural Area is a rare undisturbed example of the tall grass or bluestem prairie which once covered about 7 percent of the conterminous United States. This ecosystem, which is intermediate between the short grass prairie and deciduous forest, has been managed since 1972 to represent presettlement conditions; treatments include fire at various intervals. Oak forest is limited to the moist riparian sites of this dissected terrain. Studies will characterize the episodic nature of precipitation and drought typical for this site and relate climate, fire, and grazing effects to species composition and plant production.

Niwot Ridge site includes areas representing alpine tundra, subalpine forests, high meadows, and glacial lakes and streams adjacent to the Mountain Research Station of the Institute of Arctic and Alpine Research. The climatic station network is based on a transect of sites installed in 1952 over a range of elevations. The main LTER station at Saddle is in the tundra on a broad ridge at 3536 m elevation. A summertime instrument array on a 100 m transect adjacent to the station measures wet and dry bulb temperature at two levels, wind velocity at four levels, net radiation and soil heat flux. Studies will (1) investigate airflow and potential for pollutant transport into high elevation land, and (2) observe and model surface energy flux over tundra and relate this to occurrence of various vegetation forms.

North Inlet site represents significant areas of the Atlantic Coastline with barrier islands, salt marshes, and tidal estuaries grading into pine forest. This estuarian ecosystem interfaces with the ocean and influences the productivity of ocean life. The 7085 ha Hobcaw Barony has been maintained in an undisturbed state since 1907 and became the research site of the Belle Baruch Institute for Marine Biology and Coastal Research in 1969. The climatic station is at the end of a pier in the salt marsh and connected by 1-km long cable to data processing facilities in the field lab. Studies will evaluate the effects of wind, precipitation, and hydraulics in controlling daily variations of nutrient content of water with the goal of explaining population dynamics and productivity of tidal waters.

Northern Lakes site represents one of the largest concentrations of lakes in the world. Within 10 km of the Trout Lake Biological Station are 68 named and 28 unnamed lakes. Research is focused on 5 lakes near the Wisconsin-Michigan border and the larger Lake Mendota near Madison. Lake research dates from 1924 and climatological data from nearby stations date from the 1890's. Research sites include adjacent bogs and conifer and deciduous forests. Studies will (1) extend knowledge of the thermal behavior of lakes in response to meteorological events and as an indicator and integrator of climate, (2) relate year-to-year variations in precipitation to chemistry of surface and subsurface waters and productivity of phytoplankton, and (3) determine how variability of wind, water level, and heat input in lakes affect the year-to-year stability of ecosystem structure through changing populations of certain fishes.

Okefenokee National Wildlife Refuge is in one of the largest freshwater wetland ecosystems in the United States. The 378,100 ha watershed is 46 percent swamp, and includes open water, emergent marsh weeds and grasses, emergent shrubs, cypress swamps, and forested islands. These interrelated ecosystems are strongly affected by water level as determined by rainfall within the watershed. Ecological research includes a strong interest in systems modeling. Studies will determine the effects of climatic patterns upon stability of biotic populations.