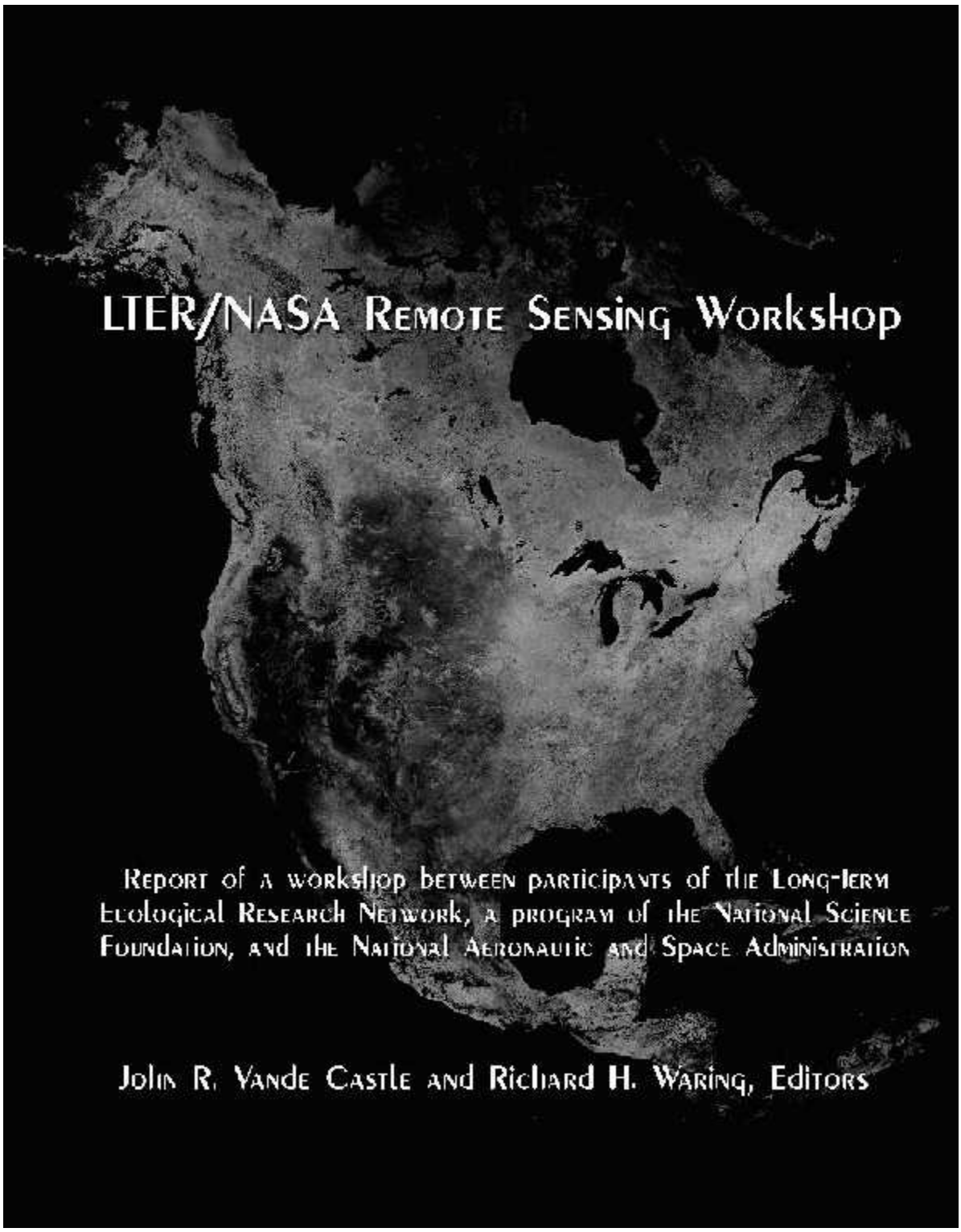
LTER/NASA Remote Sensing Workshop



Report of a workshop between participants of the Long-Term Ecological Research Network, a program of the National Science Foundation, and the National Aeronautic and Space Administration.

John R. Vande Castle and Richard H. Waring, Editors

Site: CPR Central Plains Experimental Range, Colorado

Site: CWT - Coweeta Hydrologic Laboratory, Georgia

Site: HFR - Harvard Forest, Massachusetts

Site: HBR - Hubbard Brook Experimental Forest, New Hampshire

Site: JRN Jornada Experimental Range, New Mexico

Site: KBS - Kellog Biological Station, Michigan

Site: KNZ - Konza Prairie Research Natural Area, Kansas

Site: LUQ - Luquillo Experimental Forest, Puerto Rico

Site: NIN - North Inlet LTER, South Carolina

Site: NTL - North Temperate Lakes, Wisconsin

Site: NWT - Niwot Ridge/Green Lakes Valley. Colorado

Loch Vale Watershed Study - Link with NWT Research

Site: MCM McMurdo Station, Antarctica

Site: PAL Palmer Station, Antarctic Peninsula

Site: SEV Sevilleta National Wildlife Refuge, New Mexico

Site: VCR Virginia Coast Reserve, Virginia

Associated NSF Programs: LMER

Executive Summary

A workshop with the goal of expanding collaboration between scientists at LTER sites and NASA researchers was held in November, 1992 at the Sevilleta National Wildlife Refuge in New Mexico. Scientists from both the ecological and remote sensing community participated, as did administrators from NSF and NASA. In addition, other members of the LTER community were called upon to document current and future interests for collaborative ventures. We report in this document the results of the workshop, including the additional information from LTER scientists requested by workshop participants.

This report contributes to expanding the collaboration by (a) identifying potential areas for mutual studies, (b) setting an agenda for advancing joint studies, and (c) indicating key individuals to contact.

As a result of the workshop, new instrumentation is proposed for LTER sites to improve the interpretation of remotely sensed data under changing atmospheric conditions. Specific areas of research collaboration and mutual data acquisitions were identified in the workshop. To initiate interaction beyond the workshop, NASA scientists and administrators were invited to participate in the LTER "All Scientists" meeting at Estes Park in September of 1993. NASA representatives requested attendance of LTER representatives in meetings for the testing of next generation satellite sensors, in particular of MODIS. Workshop participants requested further information to document special ecological interests of the LTER sites with regard to remote sensing, including use of Landsat Thematic Mapper data, and asked how additional satellite-derived data might be used by LTER investigators.

WORKSHOP PROCEEDINGS

LTER/NASA Workshop Background- John Vande Castle

This report is the result of a workshop held between representatives of the Long-Term Ecological Research Network (LTER) funded by the National Science Foundation (NSF) and the National Aeronautic and Space Administration (NASA), held November 11-13, 1992 at the Sevilleta LTER site in New Mexico. LTER participants included James Brunt, Warren Cohen, Jerry Franklin, Allen Hope, David Greenland, Jim Gosz, Bill Lauenroth, Tom Lillesand, Tad Crocker, Bruce Milne, Barbara Nolen, Greg Shore, Donna Koechner, John Vande Castle, and Carol Wessman. The NASA representatives included Robert Murphy, Diane Wickland, Chris Justice, Sam Goward, John Norman, Alfredo Huete and Dick Waring.

This workshop was a continuation of meetings held over the last few years between LTER and NASA representatives, including those between the Executive Committee of LTER and NASA in Washington D.C., and at the LTER "All Scientists" meeting at Estes Park in 1990. Steve Running met with the LTER Coordinating Committee (LTER/CC) in February of 1992 and received unanimous support for a LTER/NASA collaboration which was unanimously reaffirmed following a status update at the following July LTER/CC meeting. A pre-workshop meeting was held by Dick Waring, John Vande Castle, Steve Running and Warren Cohen in Seattle to discuss specific details to be addressed at this workshop. Directly after the workshop, topics to be addressed were communicated to representatives of each LTER, with responses from all LTER sites regarding their specific interest in this NASA/LTER interaction. These responses have been included in last section of this report.

Initial interest in using remote sensing within the LTER Network began at the Sevilleta/LTER with a workshop in 1984 using Landsat-TM data for intercomparison of 4 LTER sites. A workshop in hosted by John Aber in November of 1989 resulted in a consensus of current remote sensing data needs for the LTER Network. This information was used for a funded proposal to NSF for a remote sensing data acquisition for LandsatTM, SPOT-HRV/pan and NHAP film data. Landsat and SPOT data are covered by a shared-license agreement for the proprietary data and are maintained on-line on the "LTERnet" file/communications server.

Background covering LTER research can be found in the publication "Franklin, J.F., C.S. Bledsoe, and J.T. Callahan. 1990. Contributions of the Long-Term Ecological Research Program. *BioScience* 40:7 509-523". More detailed Further information covering research at each of the LTER sites is available in the document "Long-Term Ecological Research in the United States: A Network of Research Sites" Martin, S. (ed.), 1991. (6th edition, revised), Long-Term Ecological Network Office, University of Washington, Seattle.

A GlobalScale Role for LongTerm Ecological Research Sites - Richard Waring

Over the last two decades, changes have been perceived at the global scale by depletion of stratospheric

ozone, increases in carbon dioxide and other trace gases in the atmosphere, and changes in the fraction of land covered by vegetation, surface waters, and ice. The LTER network, established during this period, provides a special reference. At these sites scientists are actively documenting what is present now, the historical rates of change, and how environmental conditions in terms of meteorology and atmospheric deposition have varied.

General Circulation Models (GCMs) provide a good point of reference for collaborations between LTER and NASA. GCMs are beginning to be coupled to large scale ecosystem models to generate estimates of the net exchange of CO_2, methane, water vapor, and energy between the land surfaces, sea surfaces, and atmosphere, integrated over periods of a month. At present, the grid scale for these models is typically 2.5^o X 2.5^o of latitude and longitude. Other models driven from satellitederived data are under development with matching resolution to the GCMs. Future models will have resolution of 1^o X 1^o or 0.5^o X 0.5^o and will contain nested higher resolution submodels. The generality and accuracy of all models will require continual testing over a range of sites. Research at LTER sites can provide validation for these and other more ecologically refined models.

The current GCMs predict meteorological conditions at 1720 layers through the atmosphere. At the ground level this translate into net radiation (derived from incoming short and long wave) and outgoing reflectance (mostly long wave, but off of snow and vegetation, 230% visible). The models also predict rainfall (precipitation), atmospheric humidity and temperature, and wind.

The characteristics of vegetation that most affect (interact) with the GCMs have to do with surface roughness (meaning height and density of vegetation), topographic conditions (affecting net radiation and roughness), and whether or not the vegetation is under droughtstress sufficient to limit transpiration and evaporation (so need for checking at some time the litter moisture and soil (or plant water stress). Unfortunately, all of the carbon and water models attempt to guess at the depth of rooting (and most fail) so where road cuts go through extensive transects of vegetation some real contribution could be made by providing better estimates of rooting depth under major vegetation types.

Clearly, this is a role for new studies on specific sites where physiological differences in response to humidity deficits or rooting depth might quantify relationships, but until such studies can be done, the GCM will make gross assumptions, like all vegetation is less than or more than 10 tall, has an albedo of 8-10%, and stores 15 cm of water in the rooting zone!

LTER sites could play a major role in the validation of GCMs, although the scale of research needs to be addressed as collaborations such as one between LTER and NASA proceed. A point made during the meeting was that this is meant to be a true collaboration, not be a simple data exchange exercise. LTER scientists and ecologists in general should not be expected to provide the data input needs for the GCMs or other models. The goal is to build Earth Systems Models of which GCMs are only a part.

LTER sites vary in form, from ecological reserves with protected boundaries, to sites where grazing, logging, farming, urban development and other activities are more intense. An opportunity exists, therefore, to compare the rates of "natural" against "management-induced" changes. In addition to documenting change in land cover, scientists at the LTER sites have knowledge of more subtle aspects of ecosystem function, often identifying the major factors involved in recycling nutrients, accumulation or loss of carbon, and the transport of water, soil, and others material from one ecosystem to another.

The LTER sites have, with the acquisition of more sophisticated computer systems, begun to register their data sets within a geographic frame of reference so that multiple sets of data may be compared for a specific area over time. NASA has an opportunity to provide the LTER sites with additional data sets from Landsat and NOAA satellites, as well as aircraft remote sensing data. To accurately interpret these satellitedata, the LTER sites should (1) be provided remote sensing data and model output for support of on-going field research. (2) be equipped with sun photometers to adjust observations for atmospheric absorption and scattering and (3) have fieldportable spectroradiometers to record the reflecting properties of major scene components. For the use of both these instruments, specialized training of

LTER personnel will be required.

In the development of the LTER network a means was established to store and distribute a large variety of well documented ecological data sets. This distribution system has grown to represent one of the largest store of computerretrievable ecological data in existence. We propose a coupling of conventional groundbased data and satellite data through a joint measurement plan and a linkage of information systems that will provide synergistic benefits to the ecological and remote sensing communities.

Each step along this interdisciplinary path from local understanding to globalscale inferences should bring more confidence in the reliability of remote sensing and the generality of biophysical and ecological models. Much data will be of common interest to LTER and NASAsupported scientists. Common interests will define priorities for documenting and sharing data sets. As scientists gain experience new data sets will be identified that should be incorporated in NASA or LTER data banks. Protocols for exchange of data between these two sources must be established, tested, and continually improved so that the detailed ecological knowledge obtained at the LTER sites contribute their full measure to our understanding of the Earth's biosphere.

H.J. Andrews Experimental Forest-Warren Cohen

Dr. Warren Cohen of AND/LTER gave background on the H.J. Andrews Experimental Forest and then talked about the remote sensing work done at the HJA and associated region, including spatial and spectral properties of forest stands. Warren then described the variety of remote sensing data and image types used as input for their research work. As background for scientists not familiar with the diversity of research interests within LTER, Warren provided specific details of conditions at the HJA:

The HJA is located in rugged terrain of central Oregon Cascade Range; 6400 ha, ranging from about 400-1600 m in elevation; maritime climate with mild, wet winters and cool, dry summers; annual precipitation of 2500 mm concentrated in winter, with deep snowpack above about 1000 m. The low and midelevation forests in the region are among the most productive in the world; average tree heights of primary forests are on the order of up to 75 m, with C storage of about 600 Mg/ha, much of it in fine and coarse woody debris. The HJA supports rich biological diversity, with more than 600 (species of) vascular plants, over 3400 arthropods, 20 reptiles and amphibians, 7 fish, 50 mammals, and 70 birds. Research roots extend back more than 40 years with primary emphasis of geomorphology vegetation stream interactions. Long-term records include climate, stream flow and chemistry, tree growth and mortality, fire history, and geomorphic and land use disturbance; currently, about 50 scientist, 25 graduate students, and 15 undergraduates use the site each year with over 100 research projects currently underway.

Research activities have as overall goal of developing concepts, hypotheses, models, and other techniques to evaluate effects of disturbances (natural and mancaused) on ecosystem structure, function, and species composition. Longterm studies fall into categories of characterization of disturbance regimes, understanding vegetation succession, arthropod ecology, young forest productivity, longterm site productivity, decomposition processes, and foreststream interactions. Much of the research at HJA is evolving towards addressing regional land use issues and on how regional land use affects ecosystem processes that may have significant impacts on the global climate.

Projects involving remote sensing rely on the characterization of the structure of individual forest patches and on forest fragmentation and landscape structure including research using processed imagery of brightness, greenness, and wetness indices. These, and normalized vegetation indices (NDVI) have been used to reduce the problems associated with topography in the region. Ground radiometer data has been collected of individual scene components, in addition to high spatial resolution digital aircraft data, and data from a camera mounted on a tethered blimp.

LTER Climate Committee - David Greenland

Dr. David Greenland, chair of the LTER/Climate Committee provided valuable information on the status of measurements from LTER Meteorological Stations and their significance to remote sensing activities.

David handed out a pre-publication copy of a review of uses and needs for meteorological station measurements, (in press in *Progress in Physical Geography,* Vol. 17), as well as describing the status of meteorological station measurements which are standardized within the LTER Network. In particular, he described the various "levels" of measurements that are taken at the LTER sites (described in the LTER document "LTER Standardized Meteorological Measurements"). Of significance for this meeting, it was noted that a site may wish to upgrade their meteorological observations to become a "level 4" site (one of 3 levels of observation at which sites can choose to observe). A level four site would have instrumentation and observation protocol which would permit atmospheric corrections to remotely sensed data and to permit the running of basic biospheric-atmospheric models. In most cases some observations for a level four site are already being made at most LTER sites. The exception is that level four sites would be equipped with a sun photometer, to automatically track the sun during the daylight hours and provide data to be used for corrections due to atmospheric effects, especially to satellitederived data.

North Temperate Lakes LTER - Thomas Lillesand

Dr. Thomas Lillesand covered a number of points regarding the use of remote sensing, integrated Geographic Information System databases and integration of more conventional information into long-term ecological research programs. Representing the North-Temperate Lakes LTER site, Dr. Lillesand made a special point of demonstrating the potential of unplanned applications of data (including remote sensing). As an example, a simple measurement of lake-ice duration observed in a systematic and consistent manner, shows significant correlation with other indicators of regional climate change. Since remote sensing data available from operational weather satellites is able to be used in a similar manner, a standardized method can be used to extend such observations to other areas.

Vegetation indices, alpine environment and hyperspectral data - Carol Wessman

Dr. Carol Wessman, representing the Niwot Ridge LTER site, discussed the capabilities of high spectral resolution imagery for ecological analysis. These hyperspectral data offer the capability to address spectral mixture problems through spectroscopic techniques; broadband data such as TM and AVHRR can limit interpretation of reflectance information. For example, the alpine presents a particularly challenging test for commonly used vegetation indices. Confounding influences from a variable background, atmospheric attenuation and topographic influences cannot all be accounted for using a twoband ratio or the normalized difference vegetation index (NDVI).

These conditions are likely to be particularly influential in alpine regions due to the broad heterogeneity in vegetation distribution, the presence of variable background material (rocks and soil), and topographic influences. Adjustments of the NDVI can be made to account for firstorder soilvegetation interactions (i.e. soil brightness effects); but secondary soil variations due to soil optical properties require multiple spectral bands. Similarly, the heterogeneity of the alpine vegetationsoil surface will introduce a spectral variation that may confound analyses of pixelscale reflectance. This information is shown in figure 1.

The LTER Niwot Ridge alpine tundra site has an active remote sensing programwith current interest in sources of spectral variance in the alpine environment and the implications for satellite monitoring of alpine primary production. These vegetation studies are performed using the facilities at the Center for the Study of Earth from Space (CSES) within CIRES at CU and pursue current as well as future remote sensing capabilities. Preliminary work with SPOT imagery demonstrates the utility of remote sensing data for the evaluation of regional controls (temperature, wind, aspect) over alpine production. Time series of satellite data should elucidate the dynamics of the snow regime (spatial and temporal distribution of snow and snowmelt), a principal driver of biogeochemical processes in alpine environments. Groundbased spectrometry is being used to test the assumptions implicit in the satellite work; e.g. do measurements of productivity within a highly heterogeneous landscape scale linearly?

NASA and Landsat-TM data - Robert Murphy

Dr. Robert Murphy, NASA Branch Chief in Biogeochemistry and Geophysics, reviewed recently concluded negotiations with the EOSAT corporation that allows NASA to purchase a selected number of Landsat

(185 km X 185 km) scenes each year at better than a 50% discount. e.g. between $1500$2,000. Once purchased, these images may be distributed worldwide to global change researchers at the cost of reproduction (about $200 each). Related discussions are in progress with SPOT representatives, the French satellite corporation, that provides scenes with slightly better resolution than Landsat. With the launching of the Landsat-7 satellite (after Landsat-6 this year), control of the data will revert to NASA and all scenes acquired will be distributed at the cost of reproduction.

Dr. Murphy indicated that NASA was interested in offering coverage to all the designated LTER sites. He asked that each site consider: (1) the best season to acquire images, (2) document how such imagery will be processed for global change comparisons, and (3) indicate how acquisition of additional scenes might further research objectives.

Pathfinder Datasets - Chris Justice

Dr. Chris Justice from NASA's Goddard Space Flight Center, discussed some of the data products being prepared from present satellites and other sources that will be distribution online or reproduced on CDROM optical disks (at the cost of reproduction). Products include (1) NOAA daily weather satellite (AVHRR) coverage at 8 km X 8 km and 1km X 1 km scale, (2) Landsat coverage of North America for selected years, (3) digital elevations maps for each continent, and (4) integrated estimates of visible radiation derived from a variety of sensors.

Dr. Justice indicated that an advisory committee developing these products proposes to include representatives from the LTER community. Ecological insights are essential in designing and evaluating products and in testing the efficiency of various methods of distribution. NASA has already drawn heavily on the ecological community but the need for integration of sensor products increases the demand.

EOS - MODIS data - Alfredo Huete

Dr. Alfredo Huete, from the University of Arizona, is a member of the Earth Observing System (EOS) Team planning the NASA component of Mission to planet Earth. Planned improvement in sensor design will provide more accurate interpretations of ecologically important changes in the

Figure 1. Reflectance data were acquired across a transect of a Saddle Grid at the Niwot Ridge alpine landscape using a high spectral resolution field spectrometer. NDVI and second-derivative values were then calculated from these data. While the scales of these indices differ, the coefficients of variation (cv) for the transect suggest higher sensitivity to heterogeneity with the second derivative at 695nm (cv=0.35) than with the NDVI (cv=0.13). NDVI is influenced by highly reflecting soil and rock background, reducing its sensitivity to the highly variable plant cover prevalent in the alpine.

Earth's atmosphere and in the ocean and land ecosystems. An important new sensor for the ecological community has the acronym "MODIS" for ModerateResolution Imaging Spectroradiometer". Steve Running, Chris Justice, and Alredo Huete are members of a team testing models that simulate the capabilities of this instrument. Successful preparation for the use of MODIS data, which should be available beginning in 1998, is dependent on close cooperation with the ecological community associated with LTER sites to help test algorithms and provide insightful comments on test products now being generated. Table 1 and Figure 2 show data planned for MODIS research and planned products from MODIS.

Dr. Huete presented examples of how land cover types can be classified by dynamic changes occurring throughout the year as viewed from reflective measurements in the nearinfrared and red spectral regions. Additional differences in albedo, duration in snow cover, and thermal indices of drought can provide information on changing functional relationships associated with land cover types.

Satellite Sensors for Ecosystem Models - Sam Goward

Dr. Samuel Goward, University of Maryland, presented details on how present satellite sensors can drive

an ecosystem model (Steve Running's Forest BGC model). An example was given for a selection of forested sites in Oregon where data on net primary production, climate, and physiological state of the vegetation were available as part of a NASA supported study (with the acronym OTTER). Dr. Goward's analysis sets the upper limits on monthly photosynthesis as a product of the amount of light available and the fraction absorbed by vegetation. He then incorporates information from two thermal bands that further constrained photosynthesis as a function of freezing temperatures, extreme humidity deficits in the air, and extended periods of soil drought. Correlations with measured climatic variables, physiological state, and NPP were most encouraging. Trace-gas emissions from soil should also be correlated with the satellite derived estimates of litterfall and surface temperate and moisture status. The kind of dynamic analysis provided by satellite sensors described by Dr. Goward can be tested at LTER sites where NPP and climatic variables are being measured. Figure 3 shows an example of data used in the OTTER study.

Light Aircraft Remote Sensing - Richard Waring

Dr. Richard Waring, NASA program scientist for Ecosystems and LandAtmosphere Interactions and co-director of the OTTER project, presented remotely sensed data collected from light aircraft over each of the OTTER sites in Oregon. All the basic remote sensing assumptions in Goward's satellitedriven model were confirmed with data collected by Rich McCreight, pilot and scientists in charge of the light aircraft One key point made in comparing nearground measurements with those derived from satellites was the importance of accounting for the changing absorbing properties of the atmosphere Examples of this are demonstrated in figure 4, showing intercepted radiation and NDVI data taken from aircraft and from a satellite.

NASA Field Programs - Diane Wickland

Dr. Diane Wickland, NASA Branch Chief of Ecosystems Dynamics, indicated that NASA would welcome the opportunity of developing additional field programs with LTER sites. She explained the various kinds of aircraft available to complement satellite coverage. The NASA aircraft are heavily committed, but as plans develop, they can be flown over LTER sites to meet specific objectives. As they return from planned missions they could also acquire data from LTER sites within their flight paths, weather permitting. Dr. Wickland charged the LTER group with querying their scientists to see what specific opportunities were available in the coming season as well as in future years.

Table 1 and Figure 2. Data to be acquired by the MODIS sensor and products planned from the project. The satellite-based sensor will provide 36 separate bands useful for distinguishing land, vegetation, ocean color, clouds, and numerous environmental variables.

Figure 3. An example of spectral data used in the OTTER study

Figure 4. The fraction of photosynthetically active radiation (IPAR) intercepted by forest canopies compares well with the normalized difference vegetation index (NDVI) measured from 300m (left) and from AVHRR satellite data (right).

To make full use of any remote sensing data, particularly in cases where change detection or environmental interpretation is of interest, some measure of atmospheric conditions is required. All NASA sponsored field experiments employ groundbased sun photometers to correct for variation in the spectral absorbing qualities of the atmosphere. Because the LTER sites are all interested in accurate assessment of change it would be desirable to station recording sun photometers at as many sites as possible.

In addition, Dr. Wickland and other NASA scientists indicated the desirability of characterizing the reflectance properties of major scene components at each of the LTER sites. A library of spectral reflectance properties can be assembled to allow calculation of shifts in the proportion of major vegetation units, soil, litter, and other scene components. These measurements require special instrumentation that can be brought to each LTER site. Workshops can be conducted to train local scientists. NASA scientists must rely, in any case, upon local expertise to identify key vegetation units,

soils, and the precise location of reference sites.

Ecosystem/Atmosphere Interactions - John Norman

Dr. John Norman, from the University of Wisconsin, provided insight into the kinds of vegetation and soil properties that affect ecosystem interactions with the atmosphere. Dr. Norman shared experiences in using micrometerological methods in a field study over the KONZA LTER site to calculate fluxes of water vapor and trace gases from ecosystems. He indicated how these calculations might be linked with conventionally measured climatic and structural variables. The LTER sites offer excellent potential for testing some important underlying assumptions in Global Circulation Models predicting climate change with increasing CO_2. For example, GCMs largely ignore surface roughness characteristics attributed to differences in the height and continuity of local vegetation and also assume equal water storage in the soil under adjacent vegetation types.

Workshop Recommendations

Information regarding data requirements and recommendations from the workshop were subsequently transmitted to LTER scientists. The responses and information from the LTER sites are included in this report.

I. Establish quality control teams- The need for such by GPS data as an example

II. Determine site characterization for remote sensing interpretation soil reflectance, emittance properties vegetation radiative properties

III. Meet requirements for providing sun photometers at LTER sites-MODIS team members (Huete and Justice) will coordinate in confirming availability of instrumentation.

IV. Identify best single, or multi-temporal acquisition date for Landsat-TM imagery over each LTER. (included in this report). This will be sent to Robert Murphy at NASA by John Vande Castle.

V. Notify Diane Wickland if LTER sites are interested in having airborne instrument Flights for specific objectives. Opportunities exists as part of other NASA missions, or as separate ventures.

VI. Notify Richard Waring if LTER sites have interest in lightaircraft coverage with video and other instruments.

VII. Determine if a multipleaircraft campaign might be justified for one or more LTER sites. John Vande Castle will communicate this possibility to LTER members and share response with Diane Wickland.

VIII. Have each LTER site identify what changes are of interest, the kind of satellite data required, and how data will be processed. This information will be helpful for NASA in planning. Consider pathfinder data sets as well as Landsat imagery.

IX. Discuss the possibility of proposing joint research to NSF and to NASA. What would each LTER group like to do, what kinds of instruments are required, etc. John Vande Castle can act as contact person.

X. Established guidelines and planning on how sites will use imagery (TM). Sketch out the possibilities for various interested LTER's. John Vande Castle will be the contact.

XI. Select LTER representatives for attending a MODIS team meeting in April. Alredo Huete will be responsible for arranging, and then contact John Vande Castle.

XII. Warren Cohen has John Price's program that produces Landsat and AVHRR acquisition date/time. This was provided to John Vande Castle. (This PC-based program has be placed on the LTERnet file server for sites to download).

XIII. Conduct a workshop to provide methodologies and information for ground spectroradiometer observations on LTER sites. Sam Goward and Carol Wessman are possible instructors/coordinators.

Items for the Sept 18-24 1993 Estes Park LTER "All Scientists" meeting Items for the Sept 18-24 1993 Estes Park LTER "All Scientists" meeting

The 1993 LTER "All Scientists Meeting " was seen as an excellent forum to continue a number of interactions between LTER and NASA scientists. The following were recommended as starting points:

- Sam Goward and Carol Wessman could demonstrate spectroradiometer use and output.
- Chris Justice could demonstrate an automated recording sun photometer.
- Posters could be prepared to explain the MODIS team objectives and capabilities, the advantages of sun photometer corrections to image analyses, environmental analysis from light aircraft, etc.
- Paired presentations with LTER and NASA scientists could be offered.
- A plenary speaker, could provide details on future plans, perhaps Waring, Wessman, or Running -representing people trained in both ecology and remote sensing.

Automatic sun photometer details.

There was much interest in use of sun photometers. Brent Holben (GSFS) provided the following details on the type of photometer that is under consideration for use.

The instrument requires a solid base such that there is no motion, which allows it to view the sky in precise increments from the sun. The tracking unit weighs about 5 kg and is 0.5 m high. The remaining components are smaller and are housed in a waterproof box(0.5x0.2 m). The basic instrument is designed to wake up at programmed intervals and view the sun and sky for retrieval of aerosol optical thickness, water vapor, ozone (maybe), particle size distribution, aerosol scattering phase function and single scattering albedo (maybe). The data are transmitted via satellite to a receiving station and analyzed in near real time. To take full advantage of the instruments capability an unobstructed view of the horizon from 10 to the zenith is best. This might not be possible, without relocation, at all sites, as a minimum of a 360 degree view of the horizon above 30 degrees is required for the size distribution and phase function retrievals (i.e. morning and afternoon observations). The sun observations require a clear view of the sun; the ideal is an observation hourly from sunrise to sunset.

The instruments are designed to run off a 12v battery charged by a solar panel. If local AC power is available so much the better.

As far as time required for maintenance, hopefully little is required. The instruments are fully automatic in terms of data collection, and sleeping between times of data acquisition. However weather, insects, birds and mammals could require some human interaction. Since these have not actually been tested over any length of time a cover could be placed over the instrument at night or during prolonged bad weather. During calibration events, perhaps a day might be required . If the instrument gets real sick and dies then it is anyone's guess.

Results of the 1991 LTER Remote Sensing Data Acquisition - John Vande Castle

A significant effort was made to acquire digital remote sensing data for each LTER site during 1991. Although a 30% cloud cover screen (10% for SPOT data) was initially used for data acquisition, almost

50% of the Landsat-TM data initially shipped, were returned due to excessive cloud cover over the sites. There was much less of a problem with SPOT data quality. The specific details of the acquisition have been published (Vande Castle, J.R., 1991. Remote Sensing and Modeling Activities for Long-Term Ecological Research. *Proceedings: GIS/LIS '91* 2:544-550). Both Landsat-TM and SPOT-HRV/pan data were acquired for each LTER site except the following: A single SPOT-HRV/XS scene was acquired for ARC/LTER since no other suitable data was available. No SPOT data (of any kind) exist archived, or were able to be acquired for PAL/LTER. One Landsat-TM scene (Nov of 1989) was acquired, the only usable scene in the Landsat-TM archive for PAL/LTER. No SPOT/pan data were able to be acquired for LUQ/LTER, a SPOT/XS scene was substituted, and the Landsat-TM scene acquired contained significant cloud cover over the site. Because of data quality in the Landsat-TM archive, a 1989 scene was selected for NWT/LTER and a January 1992 scene was selected for VCR/LTER. An additional SPOT/XS scene was acquired for both CPR/LTER and SEV/LTER. Many of these scenes have been classified for clouds,snow,water and shadow and processed to NDVI and VI by John Magnuson during his sabbatical at the LTER Network Office. These data are maintained in the optical disk archive at the Network Office.

Collaboration Information from LTER

During the LTER/NASA workshop, questions surfaced regarding specific interests and data needs of each LTER/site. A request was sent to each of the sites for information regarding what type of data would be useful at the site in a LTER/NASA collaboration, if they were interested in the installation of sun photometers, a Multi-Sensor Airborne Campaign (MAC), and specifically for verification of what Landsat-TM data the site was interested in.

A summary of the responses and conversations with LTER scientists show:

- acquiring sun photometers at their sites.
- Most sites need access to field spectroradiometers.
- Many LTER sites are interested in a Multi-sensor Airborne Campaign (MAC).
- Many sites are interested in acquiring a variety of remote sensing data in addition to Landsat-TM .
- Many sites are interested in medium, to large-scale intersite comparative research.

The edited responses provided by scientists at the LTER sites follow, with the primary source of the information following each section.

Site: AND - H.J. Andrews Experimental Forest, Oregon

Path 46, Row 29; Lat/Long: 44^{o}14'N / 122^{o}11'W

Preferred acquisition window: July 1-August 31

This site requests that the **scene NOT be shifted** (acquire p/r 46/29) for comparison with historical TM data already acquired by the site.

The AND (H.J. Andrews) LTER is extremely interested in a number of experimental remote sensing data sets. In particular, AVIRIS, TIMS, ASAS, and MODIS simulation data. HJA research can take full advantage of these data, for use in ecosystem models and purely remote sensing models (e.g., BRDF and mixture models). The products would be publications and improved understanding of the PNW ecosystem and how disturbances to the ecosystem effect global climate. The data would be used in a timely manner, and proposal could be developed to assure this. In particular, for Landsat TM data acquired for AND/LTER, over the next 4 years, AND will commit to evaluating stand and landscape structural changes, as well as disturbances such as logging, insects and wildfire events, over that time period. It is important

that the path/row are not altered, or scene shifted so that future acquisitions match previous TM data already acquired by the AND site and LTER Network Office

The AND/LTER is very interested in installation of sun photometers as part of the meteorological measurements (see details of climate committee) but funding for this is an important consideration.

Finally, a large amount of data are needed for validation of GCM and other data (presented at the workshop). The specific data requested needs to be defined and agreed to on a site-by-site basis. In addition, validation data need to be defined as discrete measurements or as spatially explicit data sets.

Information for AND/LTER from Warren Cohen

Site: ARC - Arctic Tundra, Alaska

Path 73, Row 12; Lat/Long: 68^{o}38'N / 149^{o}34'W

Preferred acquisition window: July 1-August 31

There is a real need for LANDSAT MSS data for the Toolik Lake site. Currently the site has none. Landsat-TM data are also needed, as no recent data exist in the archives. Other data are needed at different spatial and spectral scales. ARC/LTER now has, and are collecting over the next few years, data on distribution of vegetation and on distribution of plant biomass. Some plots in several different vegetation types are being studied for plant production each year. The data are now incorporated into a GIS for the Toolik Lake area. Either with LANDSAT or SPOT scenes, interpretation will be carried out for the distribution of vegetation (in fact, the detailed field data necessary for the interpretation have already been collected). The goal of the research is to construct a hierarchical GIS for the region.

AVIRIS overflight information is needed for the purpose of testing remote sensing techniques for measuring biomass, species composition, primary production, and canopy chemistry. The groundtruth data will be collected by Dr. Skip Walker (Univ. of Colorado) starting in the summer of 1993. He will utilize a handheld spectrophotometer for measurements of species, canopy chemistry and light, and biomass (similar to NDVI).

Information for ARC/LTER from John Hobbie

Site: BNZ - Bonanza Creek Experimental Forest, Alaska

Path 69, Row 15; Lat/Long: 64^{o}45'N / 148^{o}00'W

Preferred acquisition window: July 1-August 31

Difficult acquisition - very little data in archive

John Yarie suggests that TM data centered at site latitude would be most useful.

The BNZ/LTER needs AIRSAR data in the summer months there is a current proposal to JPL for these data, but it is difficult to say what will happen with that request. Also needed is current air photo coverage that will help with both vegetation monitoring and river dynamics research that is starting this year.

There is a potential for transect type studies between BNZ and ARC which would provide information on changes into the arctic tundra. Attention would be needed to decide what types of studies would be of greatest value. Another potential interest is to try and develop a set of maps or data sets that would represent Jenny's or Majors state factors. Some of the information is relatively easy to obtain especially in the area of topography, or vegetation distribution. Climate might represent the greatest problem. Current thoughts would be to use a series of AVHRR data sets to develop surface temperature data sets that could

be used to calculate growing degree day values. The intersite work could then revolve around the distribution of process controlling state factors across a range of sites that represent a large latitudinal transect. We could also do some analysis based on scale, noting differences in interpretations from an analysis of North America, to Alaska to BNZ. This type of analysis could also be tied to the results from the variability workshop held at the NTL/LTER.

Currently all AIRSAR data has been obtained by piggybacking on flights to look at sea ice. Hopefully this type of cooperation will continue. With an active SAR project we can reassure NASA that the data will be used for crosschecking with SAR or other remote sensing data.

We would like to see some AVIRIS data collected over the BNZ research sites. This would be very helpful in looking at the treatment effects that might be visible from low level aircraft data sets. Three years of chemistry data on these sites currently exist and BNZ would be willing to sample for analysis in calibrating AVIRIS type data. This would be very useful in determining what chemistry can be determined from these sensors.

BNZ would be very interested in cooperating on a multi-site project. BNZ feels that the site location would be necessary part of almost any multisite project that is related to vegetation used for global change issues.

BNZ is very interested in installing a sun photometer at the main weather station. There is some concern about its operation especially regarding power (battery probably essential) and how it might work in winter here how is it kept snowfree, for example.

Information for BNZ/LTER from John Yarie

Site: CDR - Ceder Creek Natural History Area - Minnesota

Path 27, Row Row28; Lat/Long: 45^{o}24'N / 93^{o}12'W

Preferred acquisition window: July 1-August 31

(Note that CDR is not included in Row 29-previously requested by site)

At this time the primary remote sensing product that the CDR/LTER could put to immediate use would be **georeferenced** LandsatTM scenes. We have ongoing projects investigating landscape scale distributions of organic carbon in the standing biomass, forest floor, and soil which involve extensive field sampling at several hundred georeferenced sites. Although not part of our original proposal, we could evaluate the utility of Landsat imagery for discerning spatial patterns of vegetation and in some instances soils properties that may be associated with carbon distributions throughout the landscape. The imagery may also prove useful for mapping bogs in these landscapes. Although the preferred acquisition window for CDR is July1August 31, for our purposes, a **temporal sequence** of images throughout the growing season beginning in March and ending in October would be of more utility than a single summer image when tree canopy cover is at a maximum. The imagery would also be used as a reference for our vector based GIS applications

Information for CDR/LTER from Jay Bell

Site: CPR Central Plains Experimental Range, Colorado

Path 33, Row 32; Lat/Long: 40^{o}49'N / 104^{o}46'W

Preferred acquisition window: July 1-August 31

An important set of concerns for researchers working on the LTER project at the Central Plains

Experimental Range (CPER) is related to the question How well do ecosystems at the CPER represent the surrounding region ? (Burke, I.C. and W.K. Lauenroth. 1993. What do LTER results mean? Extrapolating from site to region and decade to century. Ecological Modelling [in press]). Two issues that arise immediately in any attempt to answer that question are (1) what is the current mix of land uses in the region, and (2) how is it changing through time? Because of their very different effects on ecosystem structure and function, the key land use types that need to be distinguished are cropland and rangeland. Decisions about land use are affected by both ecological and socioeconomicpolitical influences. Recently a federal program to reduce commodity surpluses has resulted in a large number of hectares of cropland being converted back to grassland by seeding with native species.

The relevance of our LTER research and our ability to make predictions about regional ecosystem behavior depend very heavily on our ability to monitor land use. Our simulation models require land use information as an input variable, and consequently our ability to simulate climate change or other changes in scenario is very closely tied to the accuracy of our representation of land use.

The remote sensing data that would be of most immediate benefit to the CPER\LTER project is Landsat-TM data, with which we could evaluate and update our geographic database on land use.

Additionally we are very interested in working with Carol Wessman from the Niwot Ridge LTER site to do comparative analyses of the two grassland types (tundra and shortgrass steppe) using AVIRIS data.

Information for CPR/LTER from William Lauenroth

Site: CWT - Coweeta Hydrologic Laboratory, Georgia

Path 18, Row 36; Lat/Long: 35^{o}00'N / 83^{o}30'W

Although the "summer" acquisition window of July 1-August 31 is generally preferred, the site **currently would like** a "winter" acquisition of December 1-March 1 to differentiate between conifer and deciduous vegetation..

1. Coweeta is interested in 3 remote sensing initiatives: A) temporal and spatial variation in canopy chemistry, B) landscapescale measurement of forest structural characteristics, and C) energy and mass flux estimates over broad spatial scales. Hence we are interested in the following types of data.

A) Temporal/Spatial Variation in Canopy Chemistry

Identical imaging spectrometer data (NASA ASAS/AVIRIS) at each site

Portable handheld spectroradiometer data for each of our canopy access sites

B) Landscapescale measurements of forest structural parameters

Full polarization SAR (NASA AIRSAR), multielevation/look angles

Satellitebased SAR (commercial products, e.g. Can. Rem. Sens. ERS1)

C) Energy and mass fluxes over broad spatial scales

The above data, plus TIMS data

Our interests are in relating the data from these airborne sensors to the canopy chemistry etc. data we're collecting on the gradient plots and in canopy towers.

2. We (and specifically Paul Bolstad) would be interested in working on an intersite/group project in conjunction with any planned initiatives. In addition, CWT is interested in any overflight data that NASA

could provide data on a "piggy-back" basis. This research would be related to the three initiatives described in part 1.

3. CWT is very interested in any MAC that might be initiated and want to participate in any planning session at the upcoming LTER AllScientists meeting.

4. CWT is interested in obtaining a sun photometer for correction of remote sensing data and would be willing to participate in this effort.

5. For Landsat-TM data, right now a dormant season acquisition (Dec Mar) would be best so evergreen cover (especially rhododendron) can be distinguished from other cover types. Thus CWT could gain more information from a winter acquisition rather than another summer acquisition, and then shift back to the summer on a regular basis. In a few years time, we may want another winter acquisition, but for now, one will do. There should be somewhat less cloud cover problems during winter, although sun angle may be a problem.

Information for CWT/LTER from Judy Meyer

Site: HFR - Harvard Forest, Massachusetts

Path 13, Row 30; Lat/Long: 42^{o}32'N / 72^{o}10'W

Preferred acquisition window: July 1-August 31

Can be acquired with HBR if scene shifted, but this would not be ideal.

The Harvard Forest LTER would like to have continuing coverage of Landsat-TM data as one of its more important datasets. The extent that the available data can be extended to include surrounding areas (e.g. all of New England, or the area between HFR and HBR) would increase its value. HFR has already had an AVIRIS (and data from instruments that fly with it) overflight since HFR is deeply involved in testing weather or not these data can measure canopy chemistry. Other NASA experimental instruments such as those used in a MAC, would involve additional work for the site. If properly funded, including the involvement of scientists working on such projects to date, NASA would benefit from a large amount of experience and ground data for instrument/model validation.

A sun photometer would be a great addition to the basic monitoring at all the LTER sites as well as important for research at the Harvard Forest. The effects of Global Change on radiation balance are not well known, and monitoring of radiation is minimal in the region. It would be a good thing to have these kind of continuous data available into the future.

Information for HFR/LTER from John Aber

Site: HBR - Hubbard Brook Experimental Forest, New Hampshire

Path 13, Row 29; Lat/Long: 43^{o}56'N / 71^{o}45'W

Preferred acquisition window: June 15-August 15

Path/Row 13/29 is the best for HBR acquisition although both HBR and HFR are covered if Row 29 is downshifted mid-way between the sites (placing HBR and HFR in the scene top 1/8 and bottom 1/8 respectively). There is also need for consideration of site-specific details (in more than just the HBR scene) such as the small HBR watershed and larger PemiMerrimack drainage under investigation by HBR researchers.

Remote sensing research expectations in the HBR LTER are high , but funding levels for data acquisition extremely low (all data made available by LTER/NASA interactions would be valuable). Although funds for

data are limited, available data would be utilized. Technology supplements from NSF to the LTER program enabled the HBR/LTER to install GISrelated equipment and software. With the current 6-year NSF grant there is some funding to support fte technician types, supplies, computer costs, travel.

HBR would like to receive historical and contemporary TM data for the site and larger watershed (PemigewassetMerrimack Rivers) area. Path/row 13/29 includes HBR in the extreme SE corner and excludes most areas of interest to the east and south of the HB and larger watersheds. P/R 13/30 may be best, but this would risk losing the watershed off the NW corner. HBR already has '84 and '91 images, and would like a longitudinal sequence for intervening years, and new images perhaps on an annual or biennial basis.

The HBR/LTER has three major remote sensingrelated objectives using TM data, and imaging spectrometer data if these data could be provided: (1) evaluate the relationship between spectral indices and forest canopy structure and stress (nutrient, moisture), (2) develop image segmentation measures for classifying vegetation and land cover types in the northern hardwood ecosystem using an image texture algorithm recently developed by Bill Philpot here at Cornell, and (3) map land cover dynamics in the PemiMerrimack drainage in relation to stream water chemistry. A tremendous forest inventory data set exists for control and manipulated subwatersheds in the HB basin. Two indices of choice would be NDVI and GEMI (a nonlinear index developed to monitor global vegetation from satellites by Pinty and Verstraete, accepted for publication in *Vegetatio*). Researchers would conduct tests to determine which index better predicts physionomics and floristics of forest canopies in the region. The same inventory data set would be used to evaluate the performance of the texture algorithm for improving image segmentation and classification accuracy in the HB and PemiMerrimack basins. If we were to attack the land cover dynamics for the larger watershed, we would also need TM for 12/30 plus 12/31 (scene shift). At this time we don't have a big demand for coarse resolution NOAA/AVHRR NDVI data although these data would allow collaboration with de HBR/LTER for a broad view of the northeast ecosystem.

The HBR/LTER would be very interested to submit intersite research proposals, perhaps along the lines outlined in the preceding paragraph, including how the two spectral indices perform over the diverse ecosystems and land cover conditions of the LTER sites. The same interest exists to see how the indices perform interseasonally as well.

The HBR/LTER is interested in NASA "piggyback" arrangements, but current funding cannot assure NASA that the data will be processed and used in a timely fashion. HBR is especially interested in improving knowledge and proficiency in processing and analyzing imaging spectrometer data, particularly for small plots in the HBR watershed where a wealth of field data exist.

HBR is quite interested if a MAC can be initiated, especially in coordination with HFR/LTER research (including that of John Aber).

As a further commitment to any LTER/NASA interaction, Steve De Gloria from HBR/LTER is interested in working on intersite research resulting from the LTER/NASA collaboration, perhaps on a sabbatical basis.

Information for HBR/LTER from Steve De Gloria.

Site: JRN Jornada Experimental Range, New Mexico

Path 33, Row 37; Lat/Long: 32^{o}30'N / 106^{o}45'W

Preferred acquisition window: April 21 - June 1

Second Preference Sept 21-Oct 21

Third preference Feb 1 - March 7

The above windows correspond with net primary productivity harvest.

Note that acquisition on same path as SEV is preferred. SEV acquisition date preference is similar (less restricted) to JRN for all 3 acquisition windows! JRN scene includes White Sands and is 1 row south of SEV.

The JRN/LTER is very interested to acquire Landsat-TM data at multiple times per year, on a seasonal basis. In addition the site is interested in any possibility to acquire coarse-resolution AVHRR data as well as high spatial/spectral resolution AVIRIS data.

In exchange for data acquisition, JRN/LTER would use the data for:

-vegetation classification

comparison of sites with regard to the spectral vegetation index (and assumed association with biomass/production)

-response to climatic controls

-comparison of observed phenological change patterns within sites to the patterns observed regionally

comparison of time trajectories of spectral vegetation indices for different landscape units

JRN/LTER is interested in submitting proposal for intersite research, with SEV and others, especially in relation to the previously described research.

JRN/LTER is interested in any NASA overflight piggybacking especially in using AVIRIS data for an intersite project to improve land cover classification using spatial mixing techniques.

If a MAC could be coordinated for 1995 JRN would be very interested in working with data such as that within a transect including JRN, SEV, CPR, and NWT.

JRN is interested in acquiring an automated sun photometer.

Information for JRN/LTER by Barbara Nolen

Site: KBS - Kellog Biological Station, Michigan

Path 21, Row 31; Lat/Long: 85^{o}24'W / 42^{o}24'N

Preferred acquisition window: July 1-August 31

KBS is very interested in acquiring Landsat TM data for 1992, ideally in the preferred "window" as well as additional 2 scenes, a month apart, or if not available in 1992, for other years. In addition, KBS is interested in acquiring an array of imagery at different resolutions including AVHRR, SPOT (pan and XS), and higher spatial/spectral resolution data (AVIRIS etc.) as near as possible to the same time period as other available data.

KBS would like to submit an intersite proposal including other LTER's with agricultural land associated with them. We would conduct a land use analysis.

KBS is interest in any piggy-pack data opportunities, although more specific information on what data could be acquired is needed. The higher resolution imagery would benefit the site and the investigations.

KBS again would be interested in a MAC, but more information is needed by the site regarding what is involved and what can be expected from the imagery.

A sun photometer would be an excellent addition to the new LTER climate station.

Information for KBS/LTER from Stuart Gage

Site: KNZ - Konza Prairie Research Natural Area, Kansas

Path 28, Row 33; Lat/Long: 39°05'N / 96°35'W

Preferred acquisition window: July 1-August 31

Secondary acquisition window May 20 - June 14

KNZ is interested in "regular" Landsat-TM data for any/all scale up procedures currently underway. Coupled to this, high spectral, high spatial resolution, multitemporal (intraseasonal) imagery would allow Konza to develop techniques for monitoring seasonal fluxes of aboveground living and dead biomass and associated physiological responses (e.g., evapotranspiration), foliar nitrogen, and largescale estimates of trace gas flux. Early season data (during the period of rapid growth and when differences between burning regimes are greatest) would be more useful than late season data. Such data also would be useful in monitoring the effects of grazers on primary production and plant species composition. Multitemporal imagery would also allow more detailed investigation the effects of precipitation distribution within the growing season on production responses in relation to other constraints (e.g., light and nitrogen limitation) and reflectance characteristics of vegetation.

KNZ is also very interested in using handheld radiometers to increase our spatial and temporal coverage of Konza Prairie.

KNZ is interested in working on intersite research projects involving programs mentioned previously.

Small intersite campaigns/'piggyback' flights:

Konza already has in place large scale experimental manipulations involving fire, grazing, and water additions. Additional flights or intersite campaigns would allow us to superimpose shorterterm manipulations (e.g., nitrogen addition, varying grazing intensity or duration) on longterm manipulations. But, KNZ would like time to "carefully" plan any other experiments. More information is needed regarding how these data can/need to be processed. In particular if NASA is able to pre-process the data (i.e. georeferenced to something), they will be used!

KNZ would be interested in a MAC, especially investigating other grasslands sites, i.e. Jornada, Cedar Creek, CPER and Sevilleta.

KNZ is very much interested in obtaining sun photometer instrumentation.

For Landsat-TM acquisitions, the July 1-August 31 window is best, but if other data are available, KNZ would like late May through early June as a second choice. In addition, it should be noted the substantial remote sensing datasets already acquired for KNZ during the FIFE program. John Briggs can be contacted for further information at the site, and the FIFE CDROM datasets are distributed through NASA's Pilot Land Data System. Most of the "point" data is on-line (via Internet) as well as available on CDROMs. Both PLDS and FIFE user support are handled by Jim McManus (mcmanus@pldsg3.gsfc.nasa.gov 3012863135)

Information for KNZ/LTER from John Briggs

Site: LUQ - Luquillo Experimental Forest, Puerto Rico

Path 4, Row 47(48); Lat/Long: 18°18'N / 65°47'W

Preferred acquisition window: ALL

Very difficult acquisition due to cloud cover at time of overpass, although tropical location allows for year-around acquisition. Path location permits 100x100 km subscene with slight downshift centered at Latitude 18°18'N in path 47

LUQ would like a semireliable source of images, at least one a year acquired either from satellite or aircraft platforms. The data would be used to track short term changes in vegetation recovery after hurricane Hugo and to scale up ground measurements.

LUQ would be interested in an appropriate intersite proposal, but would like to hear more about the possible range of topics. LUQ is interested in having data from piggybacked flights. However, the amount of processing required must be considered. It would be very useful to have complete sets of all the data already acquired by NASA from aircraft that has never been decomped made available. There is considerable info from PR that will never see the light of day unless preprocessing is performed on the data by NASA.

LUQ would like to install a sun photometer.

As mentioned before, LUQ would be very interested in obtaining data that would be generated by a MAC, and is interested in pursuing this in discussions at the LTER All Scientists meeting.

Satellite data acquisition at LUQ would be made easier, if a way could be found to acquire data after tropical storms pass to the north of the island or when weak winter frontal systems move in from the north. A more rapid response for acquisitions from EOSAT or SPOT would be useful here.

In addition, Bob Waide suggested that an idea of Jim Gosz, to make groundbased air concentration measurements using LIDAR could perhaps be something that could be pursued at LTER sites with NASA's cooperation.

Information for LUQ/LTER from Bob Waide

Site: NIN - North Inlet LTER, South Carolina

Path 16, Row 37; Lat/Long: 33°30'N / 79°13'W

Preferred acquisition window: July 1-August 31

Current plans will discontinue funding for activities at NIN after 1993.

Site: NTL - North Temperate Lakes, Wisconsin

Path 25, Row 28; Lat/Long: 46°00'N / 89°40'W

Preferred acquisition window: July 1-August 31

For Landsat-TM, the keyword here is regular. As lead p.i. John Magnuson points out,a minimum of **annual** summer scenes is needed. LAI/biomass work would infer earlyJuly to mid August preference for the acquisition window. But, at least early on, seasonal coverage would be good to have as well. The UW Environmental Remote Sensing Center is ready to process any scenes that could be provided over the next few years. In addition, scenes covering the Madison Lakes could be included since these are part of NTL's research program. Interests in processing these data range from lake ice phenology, to hydrologic modelling, to forest structure and function, to water quality, to regional land cover analysis, and beyond.

NTL is in the process of acquiring ERS1 data to assess their applicability to the NTL site. There is also a potential for the Canada Center for Remote Sensing (CCRS) to fly some (if not all) of Tom Gower's plots

with the airborne radarsat simulator this summer. Ideally, NTL could pull together a minicampaign of TM data, radarsat simulation data, and ERS1 data, nearly simultaneously with Gower's ground measurements.

NTL is interested in potential piggy-pack data acquisitions with past experience involving AIS1 data (a student is currently analyzing TIMS data as well). These efforts would require a strong NASA commitment beyond provision of the data. The hardware, software, and "grayware" requirements of analyzing simulator data are often monumental especially with the difficulty in correcting the radiometry and geometry of data from such flights (often departing substantially from the satellite counterparts). If NTL can substantively cooperate with NASA scientists and/or access NASA facilities, NTL would like to obtain AVIRIS and MODIS simulator data for the site.

NTL would like to participate in a 1995 MAC, but would also like to have something started before then - perhaps starting small with one or two sites between now and then.

Now for other datahere is a challenge for NASA and the whole Pathfinder concept. NTL would like to see some input into the PATHFINDER program since both the MSS and AVHRR PATHFINDER pilot programs are emphasizing interannual NDVI change detection to the exclusion of nearly everything else most notably changes in seasonal snow and ice cover. Perhaps winter scenes could be processed as well. To extend ongoing research, NTL would like to access all archives of Landsat, AVHRR, and GOES data during the "ice season" along a latitudinal gradient from Wisconsin into Canada. Again, NTL wants to do this ASAP, not several years out.

Sun Photometers/Spectroradiometers instrumentation seems to fall in the department of a network activity. There is certainly value in collecting such data irrespective of their use for atmospheric correction of remotely sensed images. Such data collected by a distributed network such as LTER would probably be valuable for colleagues in atmospheric science as well. Bundled with this whole business is NASA's potential help in the field of radiometry as well. Decades out we may well wish we'd measured ground reflectance at the time of acquisition of at least some of our scenes.

In addition, NTL is interested in the whole matter of remote sensing and NASA collaboration. However, we should to be cautious about overselling (or overbuying) our favorite technologies within the network. Throwing data at a site without the requisite personnel support will serve nobody well. Similarly, answering "yes" to everything NASA is prepared to offer should only be done with great thought, not just because the data are "free." At the same time, this endeavor must have a planning horizon beyond NASA. This is not to diminish NASA's key importance. Rather, its simply to say that there are SPOTs, JERSs, ERSs, etc., etc, not to mention international intersite research as well.
Information for NTL/LTER from Thomas Lillesand

Site: NWT - Niwot Ridge/Green Lakes Valley. Colorado

Path 34, Row 32; Lat/Long: 40o03'N / 105o37'W

Preferred acquisition window: July 1August 31

Difficult acquisition due to cloud cover at overpass time

Niwot Ridge landscape and regional studies use the facilities at the Center for the Study of Earth from Space (CSES) within CIRES at CU to pursue current as well as future remote sensing capabilities. The resources at CSES were established for indepth analysis of imaging spectrometry and its application to earth system science. A NASA/LTER program that would provide aircraft data, particularly AVIRIS imagery, in the Niwot region would be directly applicable to ongoing spectrometry work in the alpine and would greatly assist extrapolations from point measurements in a heterogeneous ecosystem to the regional level. Collaborative remote sensing studies are being established between the CPR and NWT sites for comparative studies of the Central Plains grasslands and the cold grasslands of the Rocky Mountain alpine. The proximity of these sites, spatially as well as ecologically, increases their value to a

NASA/LTER collaboration (e.g. a 1995 MAC). Moreover, an overflight of the Loch Vale site in Rocky Mountain National Park, in conjunction with the NWT/CPR overflights, would add substantially to studies of the grassland/front range ecosystem.

Acquisition of temporal sequences of TM imagery would broaden studies of regional dynamics in vegetation production and snow regimes. A research interest relevant to NASA/LTER interactions concerns the measurement of snow properties. A collaborative link between NASA and LTER programs would enhance the ability to measure snow covered areas (AVIRIS, HIRIS, LANDSAT, and AVHRR) snow water equivalence (AirSAR), and various energy balance components. The NWT

EOS IDS grant ("Hydrology, hydrochemical modeling, and remote sensing in alpine basins", PI Jeff Dozier) is currently collaborating with the NWT and Loch Vale projects.This is a good example where a more formal relationship between NASA and the LTER projects would be beneficial for both parties.

The NWT/LTER (Niwot RidgeGreen Lakes Valley) is a good place to calibrate remotely sensed images with a pixel resolution around 2030 m. The ability to scale up to the regional area of the Colorado Front Range is presented through collaborative work with the NPS and USGS at Loch Vale in Rocky Mountain National Park and with the USFS RMRFES at the Glacier Lakes site in the Snowy Range of WY.

In addition, the following publications are directly related to continuing efforts with the LTER NASA collaboration:

Duguay, C.R. in press. Modeling the radiation budget of alpine snowfields with remotely sensed data: Model formulation and validation. Annals of Glaciology.

Duguay, C.R. and E.F. LeDrew. 1991. Estimating surface reflectance and albedo over rugged terrain from Landsat5 Thematic Mapper. Arctic and Alpine Research 23: 213223

Duguay, C.R. and E.F. LeDrew. 1991. Mapping surface albedo in the east slope of the Colorado Front Range with Landsat5 Thematic Mapper. Photogrammetric Engineering and Remote Sensing 58: 551558.

Information for NWT from Carol Wessman, Tim Seastedt and Mark Williams

Loch Vale Watershed Study - Link with NWT Research

Loch Vale Watershed scientists are in their second year of a global change research project that tests simulation results against abundant field data for mesoscale atmospheric, biogeochemical process, and hydrologic models. The models, RAMS, CENTURY, and the RHESSys structure that includes ForestBGC and TOPMODEL, are linked to allow assessment of possible consequences of regional climate change, determined from double CO_2 GCM model output. The modeling exercises will be conducted at increasingly larger spatial scales, beginning with 7 km^2 Loch Vale Watershed, to 200 km^2 Big Thompson Drainage in Rocky Mountain National Park, to the entire Colorado Front Range, including Niwot Ridge. Some modeling of both Loch Vale and Niwot Ridge has already begun.

A proposal is currently pending with NOAA to enlarge the study basin to cover the entire South Platte River Basin, and to dynamically link RAMS with RHESSys. Our plans to scale up fit in very well with ideas for an intersite multisensor airborne campaign. If we have TM and aircraft data available for the South Platte, we can compare them to AVHRR data for the same region. This will be valuable for evaluating scaling issues and the comparability of different sensors collecting similar types of information. We already have plans to acquire the AVHRR data from USGS/EROS Data Center, and when available, from the NASA/EOS Pathfinder (mid1993). CoPrincipal Investigators in these projects include Steve Running, Ramakrishna Nemani, Larry Band, Roger Pielke, Tim Kittel, Bill Parton, Dennis Ojima, Tom Kirchner, Jill Baron. Remotelysensed data will be extremely valuable for allowing either data acquisition from larger spatial scales than accessible from the ground, or for data validation of model results.

Specific requests for the Loch Vale and Global Change research are listed below. These do not yet include

collaborative studies with Niwot Ridge scientists (since we don't have that proposal), but they include some work we will be conducting for both sites ourselves.

1. LANDSAT THEMATIC MAPPER July 1August 31 time period TM acquisition could be used immediately for calculating and mapping LAI for parameterization of the BGC component of the RHESSys model structure. For Landsat-TM data, these data may be the same as acquired for NWT. Data will be processed either at CSU, CU, or at NPS GIS and Remote Sensing Laboratory in Denver. Ground verification will occur with spectrometers and sapwood area equations for forests. We would like to use TM data for developing understanding of snowmelt processes at both Rocky Mountain and Niwot Ridge, butit is very difficult to get a spring data where is no cloud cover, much less a sequence of images depicting the melt period. We would like an image during the period April 1-May 15 in order to parameterize the snow redistribution model developed by Don Cline (and originally applied to Niwot Ridge). It will help us define relationships between snow water content, terrain characteristics, and landscape characteristics. TM-derived snow cover extents will provide the spatial boundary conditions for this statistical model, particularly in the Big Thompson and larger areas.

2. TIMS Thermal Infrared Multispectral Scanner to: a) derive surface temperature for validating RAMS simulations; b) exploring spatial patterns of water stress. We would like two flights an early season, nonstressed condition and a late season water stressed condition. Processing and interpretation of the data could take place at either the University of Montana or University of Toronto graduate student stipends are available. Ground verification of soil moisture and surface temperatures could be made with existing sensors (thermocouples and TDR sensors) at permanent vegetation plots established in Rocky Mountain National Park and on Niwot Ridge.

3. SUN PHOTOMETER DATA would be very useful for generating spatial radiation inputs. This would be compared with 5 groundbased radiation sensors currently operating in Rocky Mountain National Park. Support for interpretation of this research would come from the Department of Atmospheric Sciences at CSU. We would be interested in mounting groundbased photometers onto our met stations. We might be able to install one at the met station, operated as part of the NOAA PROFS network, at 2590 m in Rocky Mountain National Park.

4. We would use summerflown AVIRIS data for a number of questions in addition to those relating to plant physiology and nutrient cycling: geomorphologic processes and soil chronosequences, spatial distribution of water vapor over different landforms and vegetation types. Springflown AVIRIS could possibly be used to determine snow water content for Rocky Mountain and Niwot Ridge, a central theme of our global change research.

5. ADVANCED SOLID STATE ARRAY SENSOR (ASAS), could be used to validate RAMS model output of surface temperature and albedo. We have student stipends for processing and interpreting this work (CSU Department of Atmospheric Sciences) if the data become available.

Information for Loch Vale from Jill Baron

Site: MCM McMurdo Station, Antarctica

The operational NSF Antarctic station, planned as a second Antarctic LTER site has two major NSF/LTER projects already underway to expand the NSF/LTER NASA link. There are two programs jointly operated by both agencies in the McMurdo area. One is a joint research program between NSF/DPP and NASA's Exobiology program that supports research on the terrestrial and aquatic ecosystems of ice free areas in Antarctica. The second is ASAP or the Antarctic Planetary Analog Program which supports efforts to use the Antarctic as an analog for preparing for future missions to other planets. John Rummel (Jrummel@nasamail.nasa.gov) is the Exobiology program manager at NASA HQ.

Information for MCM provided by Robert Wharton

Site: PAL Palmer Station, Antarctic Peninsula

Path 219 , Row 105; Lat/Long: 64°40'S / 64°W

Preferred acquisition window November 1 -February 28

Very difficult acquisition due to extreme south latitude and short acquisition window

For Landsat-TM, any data that could be acquired would be useful since little to no data exist in the Landsat archives.

Ocean temperature, ocean color and ice edge imagery would be of immediate use. Such imagery could be used for real-time support and precruise sampling design. A space/time overview of the antarctic peninsula area would be combined with the seasonal sampling and would permit development of regional biooptical models. Ray Smith, a PAL/LTER PI has been funded by NASA to work with satellite imagery in the past and is currently a member of the NASA SeaWifs project team so has an ongoing interest in combining lter site data with imagery.

Currently a lot of time is involved in establishing the site-based aspects of the PAL research, but are very interested in potential intersite activities.

PAL would be glad to cooperate with AVIRIS funded investigators interested in the biology and optics of the Antarctic region.

PAL would like to participate in a 1995 MAC, although logistics for the antarctic are difficult.

Sun photometers would be a very important installation at the site. This capability could be used immediately with ongoing NASA SeaWiFS research as well as for the LTER.

Information for PAL/LTER from Karen Baker

Site: SEV Sevilleta National Wildlife Refuge, New Mexico

Path 33, Row 36; Lat/Long: 34°19' / 106°48'W

Preferred acquisition window: May 10 to June 14

Secondary preference for Sep 1 to Sep 30, and third for Feb 1-Feb28. These dates given by Bruce Milne nearly match acquisition for JRN. A second alternative provided by Brad Musick would be for primary acquisition Sept 1 to Sept 30, with a secondary window April 1 to May 15.The Longitude listed above (from Bruce Milne) provides a more accurate "scene center" from previously listed coordinates. Also, see notes on JRN acquisition

1. Site needs for remote sensing research.

SEV currently acquires two or three TM quarter scenes per year. We use the data to: (a) detect greenness responses of plants throughout the 100,000 ha site, (b) compare greenness responses across seasons (winter, spring, late growing season), and (c) detect differential spatial and temporal responses as functions of El N«no, La N«na, and medial ENSO years. We are engaged in the construction of a vegetation map of the site with emphasis on plant species cover, landform, soil conditions, and floristic affinities to surrounding biomes.

For Piggyback flights of AVIRIS, ASAS, etc., we would assess plant species phenology based on direct observations of plants and on hand held radiometric measurements. By measuring the temporal variation in spectral response for several representative plant communities, we intend to represent the short term variation in plant responses to better interpret the greenness measures obtained from relatively

infrequent TM images. AVIRIS may enable us to obtain synoptic measures of spectral variation in soils and canopies dominated by dead plant matter throughout most of our ungrazed grasslands (dead to live ratios vary between 5 and 10) and to differentiate various soil types.

Specific remote sensing data sets that are needed include:

Multiseasonal TM 3 scenes/yr

AVIRIS

Polarimetric SAR (JPL instrument on aircraft)

The data would be used to investigate distribution of plant communities and ecotones between them, i.e., vegetation mapping. A major theme of our research is identification of ecotones and characterization of their structure and dynamics. The data would also be used for soil moisture distribution to study the patterns of water redistribution over the landscape and how these patterns relate to distribution of plant communities and of primary production.

We would welcome the acquisition of any AVIRIS, POLSAR, or other aircraft data that NASA might "piggy-back" on other missions. The data would be most useful if we had some control over the acquisition date. Lacking that, it would at least be useful if we had some advance notice of the acquisition date.

2. Proposal for intersite research.

A major theme of Sevilleta research is that the site is at the junction of several major biomes (Great Basin, Chihuahuan, short grass prairie, Mogollon woodland) and thus is particularly sensitive to climate fluctuation. By fluctuation we mean both semidecadal fluctuation due to the influence of the El N«no Southern Oscillation and long term monotonic global climate change. LandsatTM images reveal differential responses of plant communities across seasons and years due to ENSO fluctuations. We are interested in the landscapelevel controls (e.g., hydrology, soils, elevation and aspect) that transduce precipitation inputs and result in ecological responses. An intersite comparison would enable us to: (a) determine whether the magnitude of temporal fluctuations observed in the Sevilleta plant responses is unusual and (b) determine how the proximity to recognized biomes affects the magnitude of plant responses within the site.

There is possibility of collaboration especially with Jornada LTER, who are also concerned with runoff/runon relations. JRN and SEV have many vegetation types in common, and several that are found only at one or the other of these sites. JRN also has good experience with remotely sensed data.

We are interested in a small intersite multisensor airborne campaign, because it could help put our site within the broader context of surrounding biomes. Possibilities include the use of thermal sensors to map temperature minima and maxima that could control the invasion of species into the Sevilleta. We would require more information about this opportunity to form a complete proposal and wish to be included when this is discussed further, e.g., at the 1993 LTER AllScientists Meeting.

3. Sun Photometer data.

Our site is interested in a sun photometer. We currently operate seven class 1 automated, telemetered, weather stations that provide data directly to our computer network. A photometer on the Sevilleta could provide real time data to researchers at Sevilleta as well as the community. Sun photometer data would perhaps help us with atmospheric corrections for our TM data.

4. Some additional comments re LTER/NASA collaboration for SEV:

We have recently acquired an Analytical Spectral Devices spectroradiometer capable of obtaining reflectance in the visible and near-IR at moderately high spectral resolution. This instrument could be used to obtain signatures of scene components (veget., soil, etc.), which was indicated as an interest of NASA in the workshop.

Another need is support for groundtruth data acquisition. Most of our field data acquisition for purely ecological studies is concentrated in a few intensive study sites. These data are poorly suited for many remotesensing studies, which require numerous ground truth sites well distributed among a variety of surface conditions or landscape elements.

A lot of resources have already been used by the SEV/LTER in the acquisition of satellite data, purchase of a spectroradiometer etc. , but one of the greatest needs is for software (and perhaps hardware) that will enable processing of data SEV already has plus any additional data such as AVIRIS or POLSAR that might be provided by NASA .

Information for SEV/LTER from Bruce Milne and Brad Musick

Site: VCR Virginia Coast Reserve, Virginia

Path 14, Row 34; Lat/Long: 37^{o}30'N 75^{o}40'W

Preferred acquisition window: August 1 to September 30

The VCR/LTER is very interested in using remote sensing to follow the changes in our (very!) dynamic site. We would like to put together a longterm chronosequence of satellite and/or photographic images that could be used for change analysis. We would like to utilize Landsat-TM data to construct these chronosequences. Additionally, with appropriate groundreference data it may be possible to not only examine abrupt transitions (such as water to beach, or grassland to shrubland) but also relatively subtle shifts in the vigor of vegetation. The occurrence of a single shrub species (Myrica) in different aged stands, spanning approximately 80 years, has some interesting potential for both TM and AVIRISbased examinations of age and physiologically based changes in condition. Products that would result would be in the form of publications and data compilations.

In addition, VCR has a history of excellent collaboration with the Wallops Island NASA facility (Note that the primary VCR site is just south of Wallops Island) and we look forward to a larger relationship.

With the exception of some preliminary work with North Inlet, which involved landscape comparisons using TM and SPOT data, we have not approached other sites about any specific intersite research proposal. There are potential comparisons between the more xeric grasslands (KNZ and CPR) and our salt marshes, in terms of remote sensing of biomass and production that would be interesting. Additionally there may be other sites that share our interest in change detection which might be interested in a collaborative proposal. It would also be good for the network as a whole to make preparations for a rapid response to disturbance. Between fire, storms, landslides, and floods there are few LTER sites that are not prone to some catastrophic disturbance. The facilities of the LTER sites such as active GIS labs, good ground studies and catalogs of historical images make them an ideal place to begin assessments of largescale disturbance events. Rapid access to NASA resources would greatly help LTER sites respond to disturbances.

VCR would be interested in potential "piggyback" flights over the site. Some AVIRIS data was collected for our site as part of a joint NASA/Nat. Park Service campaign, but the factor limiting its use has been the cost of the data and processing, not the willingness to process it.

VCR is very interested in participating in any MAC that might be arranged.

VCR is very interested in the installation of a sun photometer. We currently monitor total and photosynthetically active radiation, but this would be a useful addition.

Information for VCR/LTER from John Porter

Associated NSF Programs: LMER

We are currently discussing projects with NASA scientists. The first of these is Curt Davis, with the Jet Propulsion Laboratory.We are discussing the possibility of using overflights with a multispectral scanner, in order to evaluate various aspects of vegetation types on land, as well as marine chlorophyll. The second is Michael Fitzgerald, a remote sensing analyst at NASA/AMES. John Largier has been talking with him about possibly getting involved in various terrestrial aspects of remote sensing in the Tomales area, perhaps as a thesis project.

In general terms, we would be interested in using remote sensing data to get at chlorophyll (primarily terrestrial), vegetation type, and water vapor data. We would be delighted with the opportunity for intersite comparison, and we believe that our site brings in some variation in biome/physiography which is distinctive from either LTER or other LMER sites. Without further development of the sorts of contacts I have mentioned above, I don't think we can comment in much detail about how rapidly we could process data or specifically what we need. We would be happy to see sun photometers added to LMER meteorological observations. We presently are operating two Sierra Misco ALERT stations with data telemetered back to our base station.

In addition, the Plum Island Sound LMER is also interested in cooperating with NASA on watershed characterization in the coastal zone. Jack Finn is the contact there for details of the information needed and data that is available.

Information from Steve Smith (BRIE/LMER)

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Workshop Summary

A number of results and recommendations concerning LTER/NASA collaborations were covered during this workshop and subsequent communication from the LTER sites. Of key interest were the following items:

1. Landsat Thematic Mapper data should be acquired for each LTER site at least once per year.

2. Other forms of data such as Pathfinder Datasets should be made available to LTER sites.

3. Sun photometers are needed for satellite data corrections and other atmospheric measurements. This would be most useful if acquired on a Network wide basis for every LTER site. The design of the instruments permits relaying the data by satellite to a central site for processing, which could also be a point of access and long-term archive for LTER, NASA and other ecological and atmospheric scientists.

4. Field spectroradiometers are needed by most sites for detailed remote sensing data validation.

5. There is an opportunity to organize a small multi-site, multi-sensor airborne campaign during 1995.

6. There is an opportunity to "piggy-back" overflights from NASA projects to acquire data for some LTER sites. Specific requests need to be communicated to NASA.

7. NASA could facilitate acquisition of data such as AVIRIS, ASAS, TIMS, and other sources.

8. Planning for specific collaborations should begin during the September 1993 LTER "All Scientists Meeting" at Estes Park CO.

9. Most LTER sites have a very active remote sensing program (as well as work with Geographic Information System databases), in addition to their more conventional site-based and intersite research including a large number of projects currently funded by NASA

8. LTER site location and Landsat-TM data information for each site have been compiled and are included below:

Landsat Overpass Information for LTER Sites

In general, scenes for the LTER sites are requested as geocorrected/geocoded map oriented to UTM coordinates, using nearest neighbor resampling to 25m The data could be scene-shifted to center image on site latitude-except where noted - Note that current path/row includes LTER sites. Row may need to be 1 less if downshifted to the center of the scene.

Acquisition of Landsat satellite data for ARC,BNZ,LUQ and PAL is difficult because data for these sites is recorded on board the satellite for later down-link, unlike sites in the conterminous United States where direct satellite data down-links are more often archived. Primarily because of this, there are very little data in the long-term archive for the above sites.

Site: AND Path 46, Row 29; Lat/Long: $44^{o}14'N$ / $122^{o}11'W$

Preferred acquisition window: July 1-August 31

This site requests that the scene NOT be shifted (acquire p/r 46/29) for comparison with historical TM

data already acquired by the site.

Site: ARC Path 73, Row 12; Lat/Long: 68°38'N / 149°34'W

Preferred acquisition window: July 1-August 31

Very Difficult acquisition - very little data in archive

Site: BNZ Path 69, Row 15; Lat/Long: 64°45'N / 148°00'W

Preferred acquisition window: July 1-August 31

Difficult acquisition - very little data in archive

John Yarie suggests that TM data centered at site latitude would be more useful than unadjusted path/row.

Site: CDR Path 27, Row Row28; Lat/Long: 45°24'N / 93°12'W

Preferred acquisition window: July 1-August 31

(Note that CDR is not included in Row 29-previously requested by site)

Site: CPR Path 33, Row 32; Lat/Long: 40°49'N / 104°46'W

Preferred acquisition window: July 1-August 31

Site: CWT Path 18, Row 36; Lat/Long: 35°00'N / 83°30'W

Although the "summer" acquisition window of July1-August 31 is generally preferred, the site currently would like a "winter" acquisition of December 1-March 1 to differentiate between conifer and deciduous vegetation..

Site: HFR Path 13, Row 30; Lat/Long: 42°32'N / 72°10'W

Preferred acquisition window: July 1-August 31

Can be acquired with HBR if scene shifted

Site: HBR Path 13, Row 29; Lat/Long: 43°56'N / 71°45'W

Preferred acquisition window: June 15-August 15

Path/Row 13/29 is the best for HBR acquisition although both HBR and HFR are covered if Row 29 is downshifted mid-way between the sites (placing HBR and HFR in the scene top 1/8 and bottom 1/8 respectively). There is also need for consideration of site-specific details(in more than just the HBR scene) such as the small HBR watershed and larger PemiMerrimack drainage under investigation by HBR researchers.

Site: JRN Path 33, Row 37; Lat/Long: 32°30'N / 106°45'W

Preferred acquisition window: April 21 - June 1

Second Preference Sept 21-Oct 21

Third preference Feb 1 - March 7

The above windows correspond with net primary productivity harvest.

Note that acquisition on same path as SEV is preferred. SEV acquisition date preference is similar (less restricted) to JRN for all 3 acquisition windows. JRN scene includes White Sands and is 1 row south of SEV.

Site: KBS Path 21, Row 31; Lat/Long: 85°24'W / 42°24'N

Preferred acquisition window: July 1-August 31

Site: KNZ Path 28, Row 33; Lat/Long: 39°05'N / 96°35'W

Preferred acquisition window: July 1-August 31

Secondary acquisition window: May 21-June 14

Site: LUQ Path 4, Row 47(48); Lat/Long: 18°18'N / 65°47'W

Preferred acquisition window: ALL

Very difficult acquisition due to cloud cover at time of overpass, although tropical location allows for year-around acquisition. Path location permits 100x100 km subscene with slight downshift centered at Latitude 18°18'N in path 47

Site: NWT Path 34, Row 32; Lat/Long: 40°03'N / 105°37'W

Preferred acquisition window: July 1-August 31

Difficult acquisition due to cloud cover at overpass time

Site: NIN Path 16, Row 37; Lat/Long: 33°30'N / 79°13'W

Preferred acquisition window: July 1-August 31

Site: NTL Path 25, Row 28; Lat/Long: 46°00'N / 89°40'W

Preferred acquisition window: July1-August 31

Site: PAL Path 219 , Row 105; Lat/Long: 64°40'S / 64°W

Preferred acquisition window November 1 -February 28

Very difficult acquisition due to south latitude

Site: SEV Path 33, Row 36; Lat/Long: 34°19' / 106°48'W

Preferred acquisition window: May 10 to June 14

Secondary preference for Sep 1 to Sep 30, and third for Feb 1-Feb 28. These dates given by Bruce Milne nearly match acquisition for JRN. A second alternative provided by Brad Musick would be for primary acquisition Sept 1 to Sept 30, with a secondary window April 1 to May 15.The Longitude listed above (from Bruce Milne) provides a more accurate "scene" center from previously listed coordinates. Also, see notes on JRN acquisition

Site: VCR Path 14, Row 34; Lat/Long: 37°30'N 75°40'W

Preferred acquisition window: August 1 to September 30

Acknowledgments

This workshop, to enhance collaboration between LTER and NASA, resulted from the continuing efforts of many of people. Support from officials of NASA and NSF, as well as principal investigators at each of the LTER sites was a crucial element. The workshop participants had added responsibilities to summarize presentations and represent their colleagues. Many LTER scientists responded to requests for information following inquiries initiated during this workshop. Finally, members of the Sevilleta LTER site served as admirable hosts, providing an ideal setting for the workshop.