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DATA MANAGEMENT FOR SUPPORT OF THE OREGON TRANSECT ECOSYSTEM RESEARCH (OTTER) PROJECT

by

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Key words: database management, remote sensing, Oregon forestry project support

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SUMMARY

Management of data collected during projects that involve large numbers of scientists is an often overlooked aspect of the experimental plan. Ecosystem science projects like the Oregon Transect Ecosystem Research (OTTER) Project that involve many investigators from many institutions and that run for multiple years, collect and archive large amounts of data. These data range in size from a few kilobytes of information for such measurements as canopy chemistry and meteorological variables, to hundreds of megabytes of information for such items as views from multi-band spectrometers flown on aircraft and scenes from imaging radiometers aboard satellites. Organizing and storing data from the OTTER Project, certifying those data, correcting errors in data sets, validating the data, and distributing those data to other OTTER investigators is a major undertaking. Using the National Aeronautics and Space Administration's (NASA) Pilot Land Data System (PLDS), a support mechanism was established for the OTTER Project which accomplished all of the above. At the onset of the interaction between PLDS and OTTER, it was not certain that PLDS could accomplish these tasks in a manner that would aid researchers in the OTTER Project. This paper documents the data types that were collected under the auspices of the OTTER Project and the procedures implemented to store, catalog, validate, and certify those data. The issues of the compliance of investigators with data-management requirements, data use and certification, and the ease of retrieving data are discussed. We advance the hypothesis that formal data management is necessary in ecological investigations involving multiple investigators using many data gathering instruments and experimental procedures. The issues and experience gained in this exercise give an indication of the needs for data management systems that must be addressed in the coming decades when other large data-gathering endeavors are undertaken by the ecological science community.

INTRODUCTION

One feature that distinguishes contemporary ecology from natural history is the gathering and manipulation of data to make inferences and draw conclusions about the system under study (McIntosh 1985). Ecologists are accustomed to gathering data, making inferences and drawing conclusions. They are not, however, aware of the benefits of pooling their information in large databases, nor are they inclined to check a database to determine if a specific set of data is present. Ecologists typically share data by passing information between themselves on data sheets, spreadsheets, field notes, and floppy disks. In large multiple-investigator studies, however, such handling of data can lead to improper conclusions being drawn, conclusions being drawn based on erroneous data, or data that are out of date. Principal investigators also waste their time sending out many copies of each data set as errors are found and the data refined.

In the last two decades, numerous studies have been undertaken by multiple investigators who have gathered vast amounts of important ecological data. These studies include the International Biological Program (IBP) (which in the United States was made up of several biome studies), the First ISLSCP (for International Satellite Land Surface Climatology Project) Field Experiment (FIFE), Forest Ecosystem Dynamics Multisensor Airborne Campaign (FEDMAC), and others. Data gathered during the IBP, for example, have generally been unavailable to ecologists outside the study itself, being made available as analyses in published papers and synthesis volumes. Distribution of data among the many scientists within the study was limited to technical and progress reports. New technical reports were required to rectify any errors found in the data and, more bothersome, anyone not involved in the project had no access to the actual data. Data obtained during the IBP have been published in numerous scientific papers and in several synthesis volume series (see especially the series published by

Cambridge University Press), but this is not the same as access to the original experimental data.

More recent large-scale, ecological studies within the land-science community involving extensive amounts of collected data and many investigators have employed a data-management system. As an example, the FIFE Project developed a specific data system, the FIFE Information System (FIS) (Strebel et al. 1990) to accommodate the needs of the scientists in the project. The FIS structure was put in place as the science project developed and consequently was tailored to one specific study. The philosophy behind the FIS operation was that the information system would serve to capture, integrate, check, and archive the data gathered during FIFE. Distribution of FIFE data was a concern later in the project. For the OTTER Project, the question was one of how well an existing, general purpose data-management system could support an on-going research effort.

Pilot Land Data System (PLDS)

The Pilot Land Data System (PLDS) was a data and information system serving investigators from the U.S. National Aeronautics and Space Administration (NASA) and participating agencies and universities in the land science community who were supported by NASA. There were three main science support sites: one at the Ames Research Center (ARC) in California; one at the Goddard Space Flight Center (GSFC) in Maryland; one at the Jet Propulsion Laboratory (JPL) in California. The sites cooperated in providing information stored on several computers (the information is therefore termed "on-line") describing the various data holdings in the PLDS. The system was accessible to authorized scientists through several computer networks and through telecommunications via modem.

The information in the on-line database was primarily an inventory of the data holdings. These "metadata" described the wide range of land science data, from meteorological data to remote sensing imagery that was available from PLDS. The majority of the data types in PLDS were collected from instruments mounted on aircraft and satellites. Special software was developed by the PLDS staff that could track a request for data from the time the data were ordered until the order was filled and the data sent to the user.

Oregon Transect Ecosystem Research (OTTER) Project

One activity of the PLDS site at ARC was the collaboration with the NASA-sponsored Oregon Transect Ecosystem Research (OTTER) Project. OTTER was a study of a climatic and elevational gradient in Oregon, USA, extending from the Pacific coast approximately 300 kilometers to the east. [A detailed description of OTTER is given by Peterson and Waring (1992).] The collaboration between OTTER and PLDS involves the management of, access to, and the distribution of the large volume of widely-varying aircraft, satellite, and ground-truth data collected by investigators in the project. Meteorological, plant canopy chemistry data, and simulation results from a forest simulation model are also stored in the database.

The principal objective of the OTTER study was to estimate major fluxes of carbon, nitrogen, and water through temperate, coniferous forest ecosystems using remotely sensed data. More than 30 scientists from ten research institutions participated in the collection and analysis of data that describe these fluxes and the processes that contribute to them.

Data were collected at six separate sites along the elevational and climatic gradient in west central Oregon principally during the spring, summer and fall of 1990. Additional data were collected in 1988, 1989, and 1991 (Peterson and Waring, 1992).

The bulk of the inventory data in the OTTER database described data that were obtained from instruments flown on high-altitude, medium-altitude, light, and experimental (ultralight) aircraft. Inventory data from the NOAA-11 (U.S. National Oceanic and Atmospheric

Administration) satellite instrument called the AVHRR (Advanced Very High Resolution Radiometer) were also in the database.

NASA's ER-2, C-130, and DC-8 aircraft, as well as light aircraft from Canada and the U.S. and an ultralight aircraft from the U.S., participated in the acquisition of data over the Oregon transect. The months during which data were collected and the platforms on which the various instruments were flown for the OTTER Project are shown in Figure 1. Brief descriptions of some of the instruments flown on the NOAA-11 satellite and on NASA and Canadian aircraft are given in the Appendix.

The flights for the aircraft were coordinated by the OTTER MACs (Multisensor Airborne Campaign) which facilitated aircraft flight scheduling and data collection activities. (A list of instruments flown on aircraft and other types of data gathered during the OTTER MAC's is shown in Table 1.) Also, ground-truth measurements were timed to coincide with aircraft overflights; these included spectral reflectance measurements using a variety of spectroradiometers. Other ground data collected include base station meteorological data, field sunphotometer and ceptometer data as well as various biochemical, biophysical, physiological, and nutrient cycling measurements.

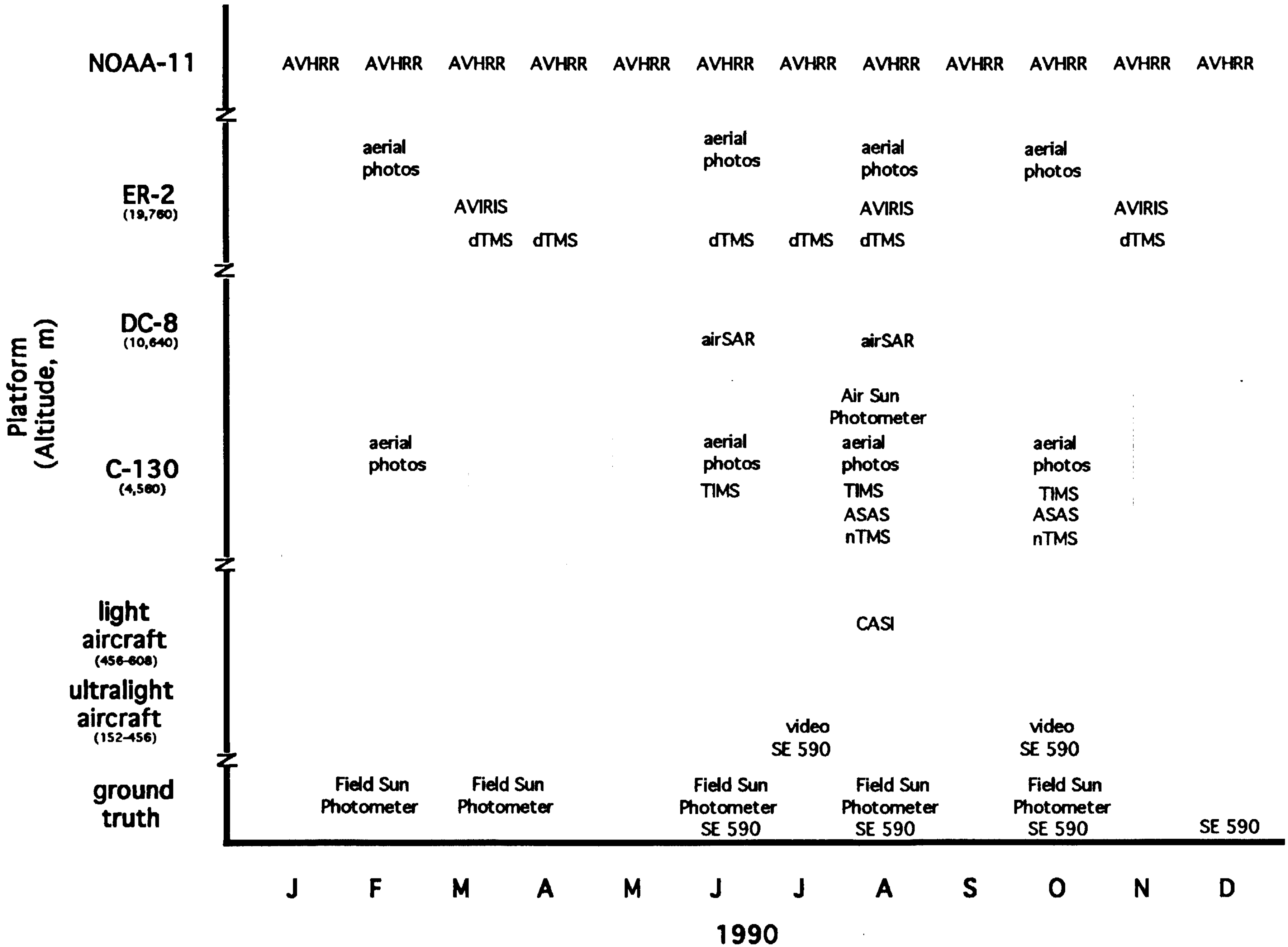
Platform (Altitude, m)
NOAA-11
ER-2 (19,760)
DC-8 (10,640)
C-130 (4,560)
light aircraft (456-608)
ultralight aircraft (152-456)
ground truth
AVHRR
aerial photos
AVIRIS
dTMS
airSAR
Air Sun Photometer
TIMS
ASAS
nTMS
CASI
video
SE 590
Field Sun Photometer
J F M A M J J A S O N D
1990

Figure 1.

Figure 1. Temporal sequence of data collection in the OTTER Project. Note that some flights did not sample all sites. (Additional data collected during the OTTER Project but that are not shown in the figure include AVIRIS in June of 1989 and March of 1991; Daedalus TMS in May of 1988 and June of 1989; airSAR in March of 1991; and aerial photos in February of 1988. Field sun photometer measurements were also taken in May and June of 1991.)

ACRONYMS:
AVHRR - Advanced Very High Resolution Radiometer
AVIRIS - Advanced Visible Infrared Imaging Spectrometer
airSAR - airborne Synthetic Aperture Radar
dTMS - Daedalus Thematic Mapper Simulator
nTMS - NS001 Thematic Mapper Simulator
SE 590 - Spectron Engineering 590 Spectrometer

Table 1. INSTRUMENTS FLOWN DURING THE OTTER MULTISENSOR AIRCRAFT CAMPAIGN.

Advanced Solid-state Array Spectrometer (ASAS)
Airborne tracking sunphotometer
Airborne Visible Infrared Imaging Spectrometer (AVIRIS)
Compact Airborne Spectrographic Imager (CASI)
Daedalus Thematic Mapper Simulator (TMS)
Fluorescence Line Imager (FLI)
Large format true color and color IR cameras (RC-10, Zeiss)
NS001 Thematic Mapper Simulator
Spectron Engineering (SE) 590
Surface temperature measurements and video tapes
Synthetic Aperture Radar (SAR)
Thermal Infrared Multispectral Scanner (TIMS)

Note: Forty AVHRR (Advanced Very High Resolution Radiometer) scenes which show all six OTTER sites at different times in 1990 were also in the OTTER database. The AVHRR instrument flies aboard the NOAA-11 satellite.

The Data Management Hypothesis

At the onset of the OTTER Project, the question arose as to how well PLDS could support an on-going ecosystem research project. Other questions asked of the data-management system included: Could the rigid structures of a formal database-management scheme change as the requirements of the ecosystem project evolved over time? Could the database software and hardware configurations support data access and inventory of data some of which were projected to be of a few kilobytes in size while others were expected to number in the hundreds of megabytes? Could a user interface consisting of appropriate menu-driven software and protocols be developed so that investigators had easy access to project data? Would the scientists involved in the project submit data to the database, write descriptions of how their data were gathered and submit them for inclusion in the database? Could the initialization files and the output files of an ecosystem model be stored in the database and made accessible to interested investigators? Would the use of a data management system enhance ecosystem research?

In essence, the hypothesis we tested was that an existing data management system, PLDS, could support an active ecosystem research project. The answers to these questions and our conclusion regarding the above hypothesis are described in the remainder of this report.

DATABASE SUPPORT FOR OTTER

In the context of the OTTER Project, the main task for the PLDS site at Ames was to effectively manage and store the extensive set of OTTER data collected during the course of the project for use by project scientists and their collaborators. (Manage in this context means to store, organize, certify, and distribute data.) Collaterally, the PLDS site at Ames was to acquaint the OTTER scientists with the use of the database and distribute requested data.

To accomplish these goals, the PLDS site at ARC worked closely with OTTER Project scientists from both the NASA centers and participating universities and agencies to place the data and information about the data collected under the auspices of the OTTER Project into the PLDS inventory at ARC. The OTTER scientists were to have access to the data and information via software and procedures specifically developed by the PLDS staff which would allow database query and data ordering. To facilitate scientist use of OTTER data, all image data stored off-line at ARC were duplicated and distributed to requesting users. For data stored on-line, a file transfer capability that existed on the PLDS computer at ARC was used for the retrieval of on-line data sets (Table 2). The OTTER/PLDS data-management staff provided coordination and format documentation services for data collected by investigators for data such as ground-based spectrometer data.

Table 2. ON-LINE OTTER DATA.
Airborne and Field Spectron SE393 and SE590 Spectrometers
Airborne Sunphotometer
Canopy Chemistry
Field Sunphotometer
Forest-BGC Model Data and Experiment Results
Meteorological Data
Other Field Spectrometers
Other Ground Truth Data

A decision was made at the beginning of the OTTER Project to archive selected meteorological and canopy chemistry data at Oregon State University on the Long Term Ecological Research (LTER) Forest Science Data Bank (FSDB) computer. The PLDS site at ARC provided a network file-transfer capability so that users on the Ames node could access the OSU data.

Other Service Activities

Close coordination between OTTER investigators and the data-management staff during the course of the project was extremely important. Prior to and during the field campaigns, the data dictionary for the data types to be collected in the OTTER project was implemented according to a schedule for expected data receipt. [A data dictionary consists of the information about the definition, structure, and use of the data (Vinden 1990).] Data entry procedures for the entry of information for data types to be kept both off-line and on-line were created and tested by the PLDS staff. Menus for use by OTTER investigators to access information about OTTER data were developed and placed in the PLDS.

At OTTER team meetings, data file formats for the wide variety of data types, more precise schedules for dates of data collection, the volume of data to be collected, and expected data needs of individual OTTER scientists were determined. Procedures to track the orders for data and the receipt of the data by scientists were implemented as were procedures for the receipt, logging, and tracking of data.

Many data management services were added during the course of the OTTER Project, some not envisioned at the project outset. A special addendum to the PLDS User's Guide dedicated to the data query, ordering and transfer needs of the OTTER Project was completed, distributed, and then revised to reflect an upgrade to the PLDS software. Procedures for the entry of information into the PLDS inventory for remaining data types were created. Software to automatically enter information about certain types of data, such as ASAS (Advanced Solid State Array Spectrometer) data, by reading tape header files was written. A new format for spectrometer data collected by OTTER investigators was agreed upon by OTTER scientists and the data-management staff. Documentation displaying the layout of the fields for the new format and a set of guidelines for documenting the spectrometer data were written and distributed.

Perhaps most importantly, the OTTER/PLDS data management staff offered personalized assistance and training in the use of the database software. Instruction and aid in the ordering of data was also given personally via electronic mail and over the telephone. This personal touch made the database system seem much more accessible and less foreboding than would have otherwise been the case.

These added services demonstrated that the PLDS structure and strictures, in place at the inception of the project, had sufficient flexibility to change and evolve as the ecosystem study progressed. The changes implemented in the data-management scheme reflect the need in large, data collection efforts for a flexible data archive and retrieval capability in order for the data to be made known to investigators, requested, and then used.

Data Certification

A protocol for the certification of OTTER data was produced by the PLDS staff and adopted by OTTER investigators with the result that database entries reflecting certification level, date for certification, and pertinent comments about the certification were inserted into the OTTER database. This scheme put into place a hierarchical protocol which explicitly defined the degree of accuracy for OTTER data sets by assigning each a certification category. These categories and their collateral definitions are shown in Table 3.

Table 3. DATA CERTIFICATION CATEGORIES USED IN THE OTTER PROJECT.

Category	Definition
TEST DATA	example or test data (not for release)
UNCHECKED	preliminary data (unchecked, use at your own risk)
PI CHECKED	checked by principal investigator
GROUP CHECK	checked by a group (data comparisons and cross-checks done)
DERIVED CHECK	checked by comparisons of derived variables and between groups
MODEL CHECK	checked by comparison to or used in comprehensive models

The first three categories, which apply to original data sets and were shown in the metadata, were used most extensively by OTTER scientists. The first was included so that investigators developing software and spreadsheets could set up the formats necessary for analysis of the data. The second category for data certification could be used in place of the first, but typically this designation denoted a more extensive data set, albeit one that had not been checked for errors by the investigator. The third category was assigned to data that had been checked by the principal investigator; it was assumed to be free of error or, if errors were present, the investigator had explained the error(s) in the metadata comments field or in the description of the experiment.

The category of GROUP CHECKED meant that data set had been checked by a group of OTTER scientists knowledgeable about the instrument or technique used to gather the data and knowledgeable about any problems associated with the data collection. This amounted to a peer review of the data set and the methods used to collect it.

The DERIVED CHECKED category was assigned a data set which had been checked against other groups of data or which had been processed so that derived information (e.g., leaf area index (LAI), acquired photosynthetically active radiation (APAR)) could be obtained. This derived information was itself checked against other derived information. (This latter might be protein content of a canopy derived from one data set compared to a different protein content derived from another data set.)

The final category, MODEL CHECK, pertains to checks between derived data sets that have been used in models and between model output generated by using those different data sets.

A set of data did not necessarily progress from the first certification category to the last, but may have had as a final designation PI CHECKED. Similarly, an UNCHECKED data set may have moved directly to DERIVED CHECK without any intermediate designations. However, a data set with any of the last three designations in Table 3 implies that it also has been PI checked.

The benefit from this hierarchy of certification was that any project investigator could know before using a data set how much faith could be placed in the data set and which information in the data set could be missing because of faulty instruments or cloudy days or other measurement errors.

Data-Use Protocol

A policy on the use of the OTTER data by OTTER investigators and potential collaborators was adopted early in the project. As with any scientific endeavor, the OTTER scientists and collaborators wanted to protect the data they gathered during the project until they could complete their analyses and write their papers. However, because the project involves many scientists, some of whom need data from other OTTER investigators in order to complete their studies, data had to be shared. This conflict was resolved by adopting a data-use protocol devised by the data-management staff and endorsed by the investigators.

Simply stated, the protocol was that every OTTER investigator could have access to any OTTER data providing that investigator had submitted his/her data gathered under the auspices of OTTER to the OTTER database. The result of imposing this rule was that collaboration between scientists was enhanced since a scientist who put data in the database was the authority on those data and he/she was consulted for any questions regarding those data. This policy helped the *esprit'* within the project because scientists who contributed their data to the database knew that others had made their contribution as well. Further, investigators who needed other OTTER data to complete their analyses knew these data sets were in the database with an assigned level of certification. They had only to look in the OTTER data inventory for specific data sets and then order (for off-line data) or transfer those data (for on-line data) for their use.

Instrument and Data Collection Descriptions

Descriptions of each instrument as well as descriptions of the data collected for the OTTER project were written by data management personnel and placed in the on-line system. These descriptions were intended to serve as references for scientists who wish to describe the instruments used to collect data when writing about their experiments and analyses. The descriptions included summaries of instrument design, instrument specifications, parameters for instrument use, selected references to published articles and papers wherein the instrument was used, dates of data acquisition for the OTTER Project, and names and telephone numbers of persons able to answer questions about the instrument and the data gathered. Portions of these descriptions are presented in the Appendix.

Descriptions of data collection procedures written by OTTER investigators of the methods used to collect data for ground truth, from the light aircraft, and from the ultralight aircraft were also in the database. These descriptions served as a resource for anyone who accessed these data. The descriptions detailed the characteristics of the instrument(s) used, the data collection methodology, any problems encountered with the instrument or the data collected, references to support the collection methodology, and finally, the names, addresses, and telephone numbers of the persons responsible for the data collection.

OTTER DATABASE HOLDINGS

Data (and information about the data) from 1988, 1989, and the major campaigns of 1990 and 1991 for the OTTER project were collected and made accessible through the OTTER/PLDS database software at Ames Research Center. Database entries existed for calibrated data from Daedalus TMS, NS001 TMS, and TIMS. Entries for data that were processed to some extent were present for ASAS, AVHRR, AVIRIS, SAR, Daedalus TMS, digitized air photographs, airborne and field sunphotometers (see Figure 1 for definition of acronyms). Entries for the registration of aerial photographs were in the database as well.

Data were processed by OTTER investigators for field sunphotometer and Spectron SE590 spectrometer. In addition, simulation runs of the Forest-BGC model (Running and Coughlan 1988) were done by OTTER investigators at the University of Montana. Information about the runs and simulation results were placed in the OTTER/PLDS database. Table 4 lists entries in the OTTER database by data type, size per entry of the data type, and the number of entries in the OTTER database.

In addition to the OTTER data sets managed by PLDS at Ames, derived data such as LAI and APAR were expected to be inventoried there as well. As the OTTER project investigators determined which variables were important in understanding the various fluxes occurring across the Oregon Transect, PLDS/ARC was involved in characterizing the derived data sets for inclusion in the OTTER/PLDS inventory. As with other data types, attributes were determined and procedures developed to enter the data into PLDS. (An attribute is defined here as a descriptor of the data set; these include site for collection, date and time of collection, etc.) Again, derived data sets are those that are not directly measurable remotely, but were calculated from remotely sensed information, examples being LAI and APAR.

CD-ROM Publication of OTTER Data

As is shown in Table 4, a large volume of OTTER data were collected. In order to characterize the ecosystems studied and to preserve useful data from this large volume, PLDS/Ames published OTTER data sets on five CD-ROMs (Compact Disk-Read Only Memory). With the assistance and guidance from OTTER investigators, OTTER/PLDS staff coordinated the

Table IV. DATA TYPES, ENTRIES PER DATA TYPE, AND SIZE PER ENTRY IN THE OTTER DATABASE AS OF FEBRUARY 1993.

Data Type	Entries	Size per Entry[a]
Aerial Photography Frames	300	na
Airborne Sunphotometer Days	2	1.85
Aircraft SAR Scenes	18	141
ASAS Tilt Angles	362	5560
AVHRR Scenes	40	131
AVIRIS Scenes	30	6600
Canopy Chemistry	70	0.032[b]
CASI Scenes	24	245
Daedalus TMS Flight Lines (Raw and Atmospherically Corrected)	95	499
Digitized Aerial Photography Frames	7	5
Field Sunphotometer Entries	414	0.1
Forest-BGC Model Files	4	0.18
Leaf Area Index	7	0.064[b]
Meteorology	10	4[b]
NS001 TMS Flight Runs	68	1224
Spectron SE590, Perkin-Elmer	536	2.5
Timber Measurements	5	0.009[b]
TIMS Scenes	71	596
Ultralight Video Images	15	3.9
Total	**2078**	**~15 gigabytes**

[a] Size per entry is in millions of bytes of information and is approximate.
[b] Average per entry

processing and documentation of OTTER data in preparation for the pre-mastering and mastering of the OTTER CD-ROMs, which were be distributed to interested terrestrial ecologists, scientists, and resource managers. In this way, raw data, imagery, spectra, and other important information were made available to scientists interested in forest ecosystems but who were not part of the science project itself. The publication of CD-ROMs insured that important data were not lost to investigators when the project concluded.

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OTTER DATABASE CONSTRUCTION AND USE

Scientists participating in the OTTER Project were required to follow specified formats for submission of data to the OTTER database to facilitate incorporation of the data into the database. While this seemed an imposition to the scientists, this assured that the persons most knowledgeable about the data put them into an understandable and usable format. This requirement was also necessary because of limited funds for OTTER/PLDS staff; there simply were not enough people to manipulate the data and put them all into a common format. The spectrometer data format, however, was revised during the course of the project to meet user concerns about spreadsheet compatibility and to reflect the interest of some scientists for more information in the metadata.

An important use of the database by OTTER scientists was as a browse facility. When a scientist logged into the system, an OTTER Project Inventory Menu was presented which showed the types of OTTER data available (Table 1 is an example of such a list). As an example, a scientist may have been interested in the off-line ASAS data. He could then perform a query through the OTTER ASAS data menu for specific data at a specific site, for example ASAS data taken at site 3 (Scio). He could then ask for the full metadata for that entry (Figure 2). This enabled him to determine if the data, stored off-line and described by this metadata, were appropriate for his requirements. If so, he could then place an order for the data to be written to tape and sent to him. If the data were not appropriate, he could then move on through the rest of the database for that particular instrument, stopping to examine the full metadata for each site. Multiple entries for the data type could be examined and ordered in this way. Further, he could query the database as to the date specific data were collected and examine the metadata or he could customize his query so that the database was searched for specific attributes in which he had interest.

Menu

Otter Asas

Entry Id	140076
Start Date	21-JUN-90 16:13:18
Lat Center	044 39 06.12
Radius	8.6700801849
Lon 1	-122 29 12.13
Lon 2	-122 42 12.24
Geographical Reg	OREGON TRANSECT
Site	SCIO
Flight Proj NO	90L314D
Full Flight NO	90-003-06
Run	3
Altitude Agl	4754.9000000000
Nadir Pixel Size	
Total Look Angl	7
Image Line	710

Platform	C-130
Stop Date	21-JUN-90 16:15:58
Lon Center	-122 35 42.17
Lat 1	044 38 24.00
Lat 2	044 39 48.24
Political Subdiv	OREGON
Site NO	3
Site Descriptor	
Flight NO	6
Line NO	3
Mission NO	90-003
Heading	275.0000000000
Look Angl	-45
Image Sample	512
Bands	29

Figure 2. An example of the ASAS metadata report from the OTTER/PLDS database. This report shows the pertinent information about the aircraft heading, height, and flight information including the OTTER site overflown. Note that the look angle reported is one of a total of seven and that the instrument was pointing in the maximum direction aft (-45°).

An additional use of the database was to examine and extract on-line data. On-line data sets were small enough that the user could transfer them to his/her own computer without going through the ordering procedures. This meant that the user could acquire selected data immediately without waiting for tapes to be sent in the mail. As an example, suppose the user was interested in field sunphotometer data for the OTTER Juniper site. He or she could query the database for those data, examine all the data immediately, and transfer the data over the network during the same session (Figure 3).

Otter Field Sunphoto

Entry	150291	Start Date	13-AUG-90 22:54:30
Stop Date	13-AUG-90 22:54:30	Local Date	13-AUG-90 15:54:30
Lat Cente	044 17 20.00	Lon Cente	-121 19 52.00
Radius	0.0000000000	Site NO	6
Site	JUNIPER	Political Subdiv	OREGON
Geographical Reg	OREGON TRANSECT	Lat	044 17 20.00
Lon	-121 19 52.00	Instrumer	Reagan1
Solar Ang	45.7835500000	Airmass Fact.	1.4312100000
Ray 370	0.4469700000	Ray 400	0.3230200000
Ray 440	0.2177500000	Ray 520	0.1096900000
Ray 610	0.0572400000	Ray 670	0.0391200000
Ray 780	0.0211600000	Ray 870	0.0136200000
Ray 940	0.0099700000	Ray 1030	0.0069000000
Net 370	0.4181000000	Net 400	0.3100700000
Net 440	0.2957200000	Net 520	0.2352300000
Net 610	0.1747700000	Net 670	0.1388700000
Net 800	0.0986400000	Net 870	0.0841700000
Net 940	0.7866900000	Net 1030	0.0636600000
Certification Le	PI CHECKED	Certification Date	24-OCT-90
Certification Comm		Investigator	SPANNER,MICHAEL
Comments		Entry Date	24-OCT-90 00:00:00
Online Data File	/d/otter/files/fieldsunp/field_sunp.aug90		

Figure 3. An example of on-line data stored in the OTTER/PLDS database. The entry shows the important information for the field sunphotometer at the Juniper site on 13 August 1990. The user may copy the optical densities by hand or he may access the on-line data file shown.

IMPLICATIONS FOR OTHER ECOLOGICAL STUDIES

The composition of the scientists involved in the OTTER Project were of two different kinds. The first type was the scientist whose primary tools were remote sensing instruments. This scientist used the voluminous image data sets gathered by instruments flown on satellites and aircraft and generated large amounts of data in the form of spectra and imagery. The other type of scientist used tools which tended to produce much smaller data sets; such data as leaf or canopy chemistry, diameters of tree boles, or tree density.

For the former scientist, the need for a data management scheme is apparent - there must be a mechanism in place for the collection, storage, and certification of a large number of these large data sets. These investigators do not have the time or the funding to maintain an orderly database.

The second set of investigators saw no real need for a large, and to them cumbersome, data management structure. Their data sets were relatively small and they could be passed to other scientists on floppy disks, over the telephone, and by facsimile transmission.

These two kinds of scientists had two different data management needs and this showed the distinction between ecological studies and remote sensing studies. However, in the OTTER Project there was the opportunity for collaboration between the two camps.

As ecologists become more and more aware of the kinds of information remote sensing provides them and as more and varied remote sensing data become available during the forthcoming EOS (Earth Observing System) era (see Wickland 1991), data management will become a more essential part of ecosystem research. Further, the capability of storing model initialization files and results from ecosystem simulations in the database will also require the use of a formal database structure. This data organization will become essential as more interdisciplinary research projects are carried out and provide usable data to drive ecosystem and other kinds of models (Ustin et al. 1991).

DISCUSSION AND CONCLUSIONS

Regarding our original hypothesis that PLDS could support an on-going ecosystem research project, we accept the hypothesis. The PLDS staff at ARC was able to archive remote sensing data for the OTTER database. The PLDS staff was able to modify spectrometer formats for those investigators collecting such data in the project so that they could more easily submit their data to the database. To emphasize database use, we produced and modified as needed an addendum to the Pilot Land Data System User's Guide which was especially written for the OTTER database and for the OTTER scientists. Data distribution was successful and large numbers of data sets have been sent to requesting OTTER investigators. (See Table 5.)

Table 5. OTTER PROJECT DATA DISTRIBUTION AS OF JUNE 1993.

Data Set	Database Entries Distributed	Tapes Copies & Distributed	Megabytes Distributed
Aircraft SAR Scenes	12	2	54
ASAS Tilt Angles	63	9	968
AVHRR Scenes	40	5	131
AVIRIS Scenes	32	32	7,040
Daedalus TMS Flight Lines	8	4	54
Digitized Aerial Photographs	7	1	5
NS001 TMS Flight Lines	3	3	54
TIMS Flight Lines	21	3	176
Total	**186**	**59**	**8,482**

As to the question of PLDS supporting a large number of data sets of very disparate sizes, the answer was yes, again with qualifications. Scientists who were used to gathering remotely sensed data and who produced data sets that number in the millions of bytes of information understand that some mechanism had to be in place for data storage, certification, and retrieval. Scientists who were used to having data on data sheets or on floppy disks or who, in the case of ecosystem simulation models, were used to deriving values for parameters from published papers, felt no need to use a large database. These latter contended that putting their data into the database is an extra and unnecessary step. They typically swapped data between themselves using photocopies and data sheets without going through formal data certification and data use protocols. The larger science community suffered from these activities.

A major failing of the OTTER/PLDS database on-line system was the lack of an attractive, easy-to-use software system. Most scientists today use microcomputers and most of these come with software that has been documented in useful manuals; some software even comes with tutorials that teach the user the operation and special features of the software. When logging into the PLDS database system, the user was confronted with terse black and white menus that was difficult to use. The fact that these menus presented the user with all the appropriate information needed to view and retrieve data sets of interest often unfortunately escaped the user. Although they would rather have been gathering data or writing papers than being forced to use another software package, investigators usually become converts once they learned to use the system.

Interaction between the OTTER/PLDS staff and the OTTER scientists was developed and maintained through face-to-face meetings, electronic mail and telephone contact. This interaction was especially important as it presented a supportive human face on what could have been forbidding database software. Once these contacts were established, the scientist felt he had a friend who was ready to help with any questions about the database and its usage.

Remote sensing scientists involved in the OTTER Project were generally willing to order and/or submit their data to the database. Especially helpful in getting this cooperation was the imposition of the data use protocol. Some scientists involved in collecting ground-truth data were generally unwilling to send data to the database due to the pressure of other commitments and because they had less experience with formal data processing and management and did not perceive any benefits from doing so.

Scientists who submitted data to the database also wrote descriptions of their experiments and the instruments they used and these appeared in the database. Usually these scientists were reluctant to write descriptions, but at the insistence of the data-management staff, they complied and found that in so doing they began the "methods" sections of their formal research papers. One investigator even went back and gathered more accurate data as a result of the high data and documentation standards imposed by the data-management staff.

The use of the database in OTTER facilitated cooperation and collaboration between scientists in the project. This served to enhanced ecosystem science by showing scientists the different kinds of data gathered during the project. Scientists were able to order and receive data which compliment their own research and thereby write more complete papers.

As ecosystem research makes more and more use of remote sensing technology (Roughgarden et al. 1991), consideration must be given to the storage, retrieval, and distribution of data. The use of formal data-management schemes should be a part of every request for funding such research.

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APPENDIX

The instruments described below were used in the collection of data during the OTTER Project. These descriptions are provided for those persons unfamiliar with remote sensing instrumentation.

[Author's Note: James Freemantle and John Miller assisted in writing the descriptions for the CASI and FLI instruments in this Appendix.]

Aerial Photographs

Two cameras which supply aerial photographs for the six OTTER sites were flown in the OTTER project. A Zeiss camera is flown on NASA's C-130 and a Wild-Heerbrug RC-10 is flown on NASA's ER-2. The Zeiss camera has a focal length of 153 mm and has an f stop of 4. It uses Aerochrome Infrared 2443 film type sensitive to the 510-900 nm spectral band and a Wratten 12+ 0.36AV filtration system. The shutter speed is typically 1/200 of a second. The Wild-Heerbrug RC-10 has a focal length of 305 mm and uses high definition Aerochrome IR SO-131 film using cc 0.20B filtration in the spectral band between 510-900 nm. The camera f stop is typically set at 4 with a shutter speed of 1/125 seconds.

Advanced Solid-State Array Spectroradiometer (ASAS)

ASAS employs a cooled 512 by 34 element silicon charge injection device (CID) detector array to generate multispectral digital image data in a "pushbroom" fashion. The first two rows or 512 elements are blacked out with the remaining 32 rows intended for image data acquisition. As radiance is received at the sensor aperture, a diffraction grating within the optical path disperses the wavelength spectrum of the radiance across the 32 rows of the detector array on the focal plane. Each row receives radiance from a spectral band which is 15 nm wide at full-width-half-maximum. Presently, the first row and the last two rows are inoperable and ASAS currently generates data for 29 contiguous spectral bands. The 29 band centers range from 465 nm to 871 nm at approximately 14 nm increments.

The long dimension of the ASAS detector array furnishes 512 elements for cross-track imaging. The total cross track field of view of 25 degrees is provided by a f/1.4 objective lens with a 57.2-mm focal length. The lens focuses incoming energy through an entrance slit into a 1:1 relay with an effective focal length of 76.3 mm in each half. A 90 degree mirror prism in each half of the relay folds the optical path to create a compact optical head. A transmission grating ruled at 75 lines per mm and blazed at 530 nm is located between the two prisms to disperse the radiant energy into its wavelength spectrum. The second prism directs the dispersed energy onto the focal plane.

The sensor has typically been flown at 5000 meters of altitude for data acquisition. At this altitude, the total cross-track field of view is 2200 m and the cross-track field of view of each detector is 4.25 m.

Along-track imaging is achieved by periodic read out of the signal generated by each detector element along each array row as the platform aircraft flies forward. The read out rate, referred to as the frame rate, is adjustable and determines the detector element dwell time. The frame rate thus determines the radiometric response of the elements. Experience has shown that a rate of 48 frames per second (fps) is appropriate for flights over vegetated surfaces. The rate has been increased to 64 fps for flights over bright surfaces (the alkali flats of White Sands, New Mexico) in order to decrease the radiometric response. At a typical aircraft speed of 100 meters per second, a rate of 48 fps, translates to the generation of a 29-channel digital image scan line every 2 meters along the ground.

The ASAS optical head is mounted in an open port on the underside of the platform aircraft by a gimballed bracket. An electric motor rotates the optical head about the gimbal to permit off-nadir pointing of the field of view up to 45 degrees either fore or aft of the aircraft. The ASAS operator controls the pointing through a microcomputer aboard the aircraft. The mounting bracket also holds a video camera boresighted with ASAS to provide the operator with a video image of the ground for target location. The operator can fix the optical head in one position or can step the optical head through a sequence of fore-to-aft view directions as the aircraft flies over a target.

The ASAS instrument is flown on NASA's C-130b aircraft, based at the Ames Research Center, Moffett Field, California.

References consulted in writing this instrument description include Irons and Irish (1988), Irons et al. (1989a, b), Irons et al. (1990), and Irons et al. (1991).

Advanced Very High Resolution Radiometer (AVHRR)

The Advanced Very High Resolution Radiometer (AVHRR) is a cross-track scanning system with a resolution of 1.1 km, with a frequency of scan twice per day (0230 and 1430 local solar time). AVHRR data used in the OTTER Project come from the instrument aboard the NOAA-11 satellite. The AVHRR Global Area Coverage (GAC) is full resolution image data that is processed aboard the satellite taking only one line out of every three and averaging every four of five adjacent samples along the scan line. The AVHRR has two high resolution modes, HRPT (High Resolution Picture Transmission) and Lac (Local Area Coverage). A HRPT data set is a real-time downlink of data while a LAC data set is recorded aboard for later playback. The OTTER AVHRR scenes are of the LAC variety.

The AVHRR has five spectral channels. Applications for channel 1 (0.58 to 0.68 μm) include daytime cloud and surface mapping. For channel 2 (0.75 to 1.1 μm) surface water delineation can be determined. Formulation of a vegetation gradient model can be created when a normalized difference vegetation index (NDVI) is taken using both channels 1 and 2 (see Tarpley et al. 1984). This procedure is a useful tool for global vegetation stratification and monitoring. Applications for channels 3 (3.55 to 3.93 μm), 4 and 5 (10.5 to 12.5 μm) include sea surface temperature monitoring and day/nighttime cloud mapping, snow and ice extent, ice or snow melt inception, and temperatures of radiating surfaces.

References consulted in writing this instrument description include Choudhury and Fung (1989), Goward et al. (1985), Goward and Hope (1989), Nemani and Running (1989), Running and Nemani (1988), Running et al. (1989), Spanner et al. (1990), and Tarpley et al. (1984).

Advanced Visible/Infrared Imaging Spectrometer (AVIRIS)

The instrument is a group of four dispersive grating spectrometers that view the ground through a scanner while being carried over the test site in a high-altitude aircraft. At any given instant, the spectrometers are viewing a spot on the ground 20 meters square. This area or pixel is viewed simultaneously in 224 spectral bands. AVIRIS measures the surface reflected radiance in the visible and short wavelength infrared region of the electromagnetic spectrum (0.4 to 2.5 μm). The spectrum is sampled at 10 nanometer intervals and spatially the instrument samples at 20 meters across an 11 kilometer swath from 19,760 meters AGL.

A spatial image is built up through the scanner motion which defines an image line that is 614 pixels wide perpendicular to the aircraft direction and through the aircraft motion. The data are collected on a tape recorder for later analysis.

Spectral sampling requirements were determined by the desire to detect shifts in the chlorophyll spectrum on the order of 10 to 40 nm at 0.7 μm, and the desire to resolve spectral features as narrow as the kaolinite doublet at 2.2 μm. The longwave cutoff point of 2.45 μm was chosen to avoid viewing thermal emissions.

The recorded data set forms a data cube of which two axes represent spatial dimensions and the third represents a spectral dimension (see Ustin et al. (1991) for an example). The spectral data carry information corresponding to the composition of the ground being viewed and the intervening atmosphere. Computer processing of the data produces an image of the site in any of the 224 spectral bands, the spectrum corresponding to any of the pixels in the scene. Data may be processed in the spatial domain to create a continuous image of a given channel, or in the spectral domain to compile instrument response to a given target throughout multiple or all channels.

The electronics of AVIRIS are packaged by major function and include the signal chain, the digital control section, data buffers, the roll correction gyro, and the power supplies. In order to simplify operation for the ER-2 pilot, AVIRIS has only two basic control functions -- power and record.

The control subsystem also interfaces with the aircraft navigation computer to receive flight parameter data. These data are recorded along with the science and calibration data as are data pertaining to the operation of the instrument.

A reference consulted in writing this instrument description was Porter and Enmark (1987).

Airborne Sun Photometer Description

The instrument, which is mounted on NASA's C-130b aircraft, consists of a solar-tracking system, detector module, temperature-control system, nitrogen-purge system, mechanical drive chain, and data-collection system.

The two-axis solar-tracking system is designed to 1) be able to acquire the sun starting from a position several degrees away and 2) to track the sun with an accuracy of plus or minus one-tenth of a degree during aircraft movement. A large field of view (FOV) is required because the initial pointing is manually controlled until solar acquisition occurs. The large FOV simplifies the initial pointing and, in addition, enables the system to re-acquire the sun if tracking is lost because of abrupt movements of the aircraft.

The sensors used are Claires photoresistors that have been matched to track each other over the operational range of sun intensities. The sensing technique uses a shadow mask that bisects each detector when the system is in balance. This design allows for very accurate tracking, yet at the same time provides a FOV of plus or minus twenty-five degrees. The dome rotation is referred to as azimuth motion. The central section of the dome is free to rotate within the dome, perpendicular to the azimuth, and is referred to as elevation motion.

The detector module is a cylindrical unit that plugs into the main unit through a connector. It contains six separate silicon photodectors, each with its own optical filter; a sun sensor for sun-tracking purposes; and a temperature sensor and heater to control the temperature inside the module. The filters range for 380 to 1020 nm with a nominal bandwidth of 10 nm. The detectors used are silicon Detector Corp. devices that combine a detector and preamplifier inside a TO-5 style can. The FOV of each detector is set by the entrance aperture to two degrees, the inside surfaces of the aperture assembly are anodized a dull black to reduce internal reflections, and a baffle is included to further reduce reflections. The 2-degree FOV allows for plus or minus one degree of tracking error without affecting the solar-radiation signal. The entrance aperture is protected from the airstream with a fused quartz window; no lenses are used in the system.

The six detectors located inside the detector module require absolute temperature control and are temperature controlled to 45 °C plus or minus one degree by an analog temperature control system located inside the aircraft. To reduce heat loss the dome shell and the detector module are constructed of fiberglass.

The wavelength bands of the six detectors are centered at 380, 450, 526, 600, 940, and 1020 nm. Their full-width, half-maximum bands are 12.1, 5.5, 12.1, 10.3, 14.4, and 12.1 nm, respectively. Aside from the Rayleigh scattering, the 380- and 450-nm bands are affected by aerosol extinction and nitrogen dioxide absorption, the 526- and 600-nm bands are affected by aerosols and ozone, the 940-nm band is situated at a water vapor absorption feature but is also affected by aerosols; only the 1020-nm band is affected by aerosols alone.

The six detector signals, detector temperature, altitude, latitude, longitude, tracking error, suntracker azimuth and elevation position, and Greenwich mean and local times are recorded on floppy disks and (optionally) printed on hardcopy for backup. A microcomputer is used to process the data and to graphically display channel voltages and optical depth plots in real time. To prevent condensation from forming on the window, a dry-nitrogen purge system is included. The nitrogen is on during decent.

For further description of this instrument and of its use see Matsumoto et al. (1987), Pueschel et al. (1988), Pueschel and Livingston (1990), and Spanner et al. (1990).

Aircraft Synthetic Aperture Radar (airSAR)

NASA's aircraft synthetic aperture radar (SAR) system, which flies on NASA's DC-8 aircraft, is an advanced sensor for microwave remote sensing operating at three frequencies: C-band (5.66 cm), L-band (23.98 cm), and P-band (68.13 cm) and four polarizations. These latter are HH, HV, VH, and VV where the first character means the polarization on transmit and the and the second character is the polarization on receive; H stands for horizontal and V stands for vertical.

The radar system generates a pulse at the L-band which is frequency shifted using a common reference oscillator to generate the P- and C-band pulses. After amplification at each frequency, the transmitted chirp is alternately polarized by the operation of a switch to either the H or V antennas. Calibration is provided by on-board systems and by use of corner reflectors in specified scenes. Signals are derived from a stable local oscillator source operating at the L-band center frequency (1250 MHz). The P-band center frequency is derived from this source by converting the signal down, while the C-band center frequency is derived by converting the L-band up.

A basic set of parameters for this instrument system is given in Table A1.

References consulted in writing this instrument description include Freeman et al. (1990), Zebker and Lou (1989), and Zebker et al. (1987).

Table A1. PARAMETERS FOR THE AIRBORNE SYNTHETIC APERTURE RADAR (SAR) INSTRUMENT.

Parameter	L-band	C-band	P-band
Frequency (Mhz)	1260-1240	5310-5290	450-430
Wavelength (m)	0.2398	0.05656	0.6813
Pulse Length (μs)	11.25	11.25	11.25
Pulse Bandwidth (Mhz)	19	19	19
Peak Power (W)	6000	1000	1000
Az. 3 db Beamwidth (deg)	8	2.5	19
El. 3 db Beamwidth (deg)	44	50	38
Nominal Aircraft Altitude (m)	4572 to 12,192		
Nominal Aircraft Ground Speed (m/sec)	258		
PRF/Polarization (Hz)	250 to 750 (=1.36 or 0.68 x ground speed)		
Look Angle Range (deg)	20 to 70		
Caltone Frequency (MHz)	21.766875		
Receiver Gain (dB)	30 to 56		
No. of Bits/Real Sample	8		(no I and Q)
Azimuth Presum Factor	PRF8		
Azimuth Pixel Spacing (m)	3.03 or 12.01		(1-look or 4-look)
Slant Range Pixel Spacing (m)	6.67		
Number of Looks	1 or 4		
Image Sizes (1-look Complex)(pixels)	4096 x 750 (Az x Ra)		

Compact Airborne Spectrographic Imager (CASI)

The CASI instrument weighs 55 kg and run on 110 volts at 2.4 amps. It may be flown on light aircraft or helicopters or it may be mounted on a lift. It is a pushbroom imaging spectrograph with a reflection grating and a two-dimensional CCD (charge coupled device) solid-state array detector. "Pushbroom" as used here means the instrument operates by looking down in a fixed direction and imaging successive lines of the scene under the platform, thereby building up a two-dimensional image as the platform moves forward (Anger et al. 1990). This is done without any scanning or other mechanical motion except for the forward motion of the platform.

CASI has a spectral range of 430 nm to 870 nm with a spatial resolution of 512 pixels across the swath or field of view (FOV), giving a 1 to 10 meter ground resolution depending on altitude. The spectral resolution is 2.5 nm FWHM (full width, half maximum), with 288 pixels sampled at 1.8 nm intervals.

The CCD sensor is read out and digitized to 12 bits by a programmable electronics system which is controlled by an internal single-board computer. Data are recorded on a built-in digital recorder (Exabyte) which uses 8mm video cassettes as the recording medium. This gives up to two gigabytes of data per tape or up to two hours recording time depending on the frame rate. The frame rate is 100 lines/sec for a single spectral band and is reduced to 20 frames/sec for 8 bands.

The device operates in three modes. The first, the imaging mode (IM), has 512 spatial pixels across a 35 degree swath; programmable wavelengths and bandwidths (up to 15 bands) are available. In the multispectrometer mode (MSM), CASI has 288 spectral pixels for up to 39 look directions across a 35 degree swath. There is a programmable scene recovery channel in this mode. In the full-frame mode (FFM), the device uses 288 spectral pixels for all 512 spatial pixels. In the IM mode, the real time display may be black and white or color of selected bands. In the MSM and FFM modes, color or black and white displays of the scene recovery channel are available and display of the spectrum from any look direction may be done.

References used in writing this description include Anger et al. (1990), Babey and Anger (1989), Borstad et al. (1989), and Ryoer et al. (1989).

Fluorescence Line Imager (FLI)

[Author's Note: The FLI was flown on a light aircraft during one data-collection campaign in 1990. The data obtained by the instrument were disappointing and not included in the OTTER database. The description for the instrument is included here, however, for completeness.]

The Fluorescence Line Imager (also known as the Programmable Multispectral Imager) is an imaging spectrometer that provides 2.6nm spectral resolution in the visible/near infrared region (430 to 800nm) of the electromagnetic spectrum. The FLI instrument was designed to image the signal changes due to naturally stimulated chlorophyll fluorescence, the stimulation coming from solar radiation (Gower and Borstad 1981).

The FLI, made up of a detection head, a data acquisition unit, and a thermal regulation unit, weighs approximately 137 kg, meaning the instrument platform is a two-engined (or larger) aircraft. The FLI has five two-dimensional arrays, 288 x 385 in size, of charge coupled devices (CCD), giving more than 500,000 detectors. The image field is passed through a transmission grating and imaged on the CCD's providing the spectral separation of the image. The instrument is a pushbroom imager in that the field is imaged on a line of 1925 elements and only aircraft motion builds an image as successive lines are recorded.

The instrument has two modes. In the spectral mode, FLI yields 288 pixels with each pixel being 1.4 nm in size. In the spatial mode, the coverage is approximately 70 degrees with the five cameras in the instrument each giving an image 1925 pixels wide.

See Banniger (1990), Borstad et al. (1985), Gower and Borstad (1981, 1990), and Rock et al. (1990) for further description and use of this instrument.

Spectron Spectroradiometer (Spectron)

The Spectron instrument is a portable, battery-powered spectroradiometer, weighing about 1 kg, with interchangeable detector heads. The three measurement heads have the following spectral ranges: 350-1100 nm, 400-800 nm, and a short-wave infrared (SWIR) head with a 1100-2500 nm range.

Each of the detector heads uses a diffraction grating to disperse the incoming light onto a linear photodiode array. The signal is conducted to the controller electronics via a cable. The controller is microprocessor based and processes the signal from the detector head. Integration times are from 1/60 sec to 1.0 sec. The integration time can be automatically selected by the instrument or manually chosen by input from a key pad. The SWIR head always collects data with a 1.0 sec integration time.

The SE590 can use an AC/DC converter instead of battery power. The instrument stores data in 16-bit words. The visible-to-near infrared heads record data in 256 channels and the SWIR head in 66 channels. Scans can be internally averaged.

Data can be output to a laptop computer through an RS 232 port, an oscilloscope, or to a built-in tape recorder. Data processing by the laptop computer results in an output file normalized to counts/sec.

This instrument has been used to take spectra of foliage, ground, and asphalt samples in the field and dried plant specimens in the laboratory. See the description of data collection by each investigator in the database.

References consulted in writing this description included Hall et al. (1981), Miller et al. (1990), and Schott et al. (1988).

Thermal Infrared Multispectral Scanner (TIMS)

The TIMS system consists of a scan head with thermal reference sources, a motor controller, a six channel spectrometer, a system control console inside the aircraft, and a digitizer. TIMS is mounted on NASA's C-130b.

The instrument provides six-channel spectral data in the thermal infrared region of the electromagnetic spectrum from 8.2 μm to 12.2 μm using the six-element mercury cadmium telluride array detector. TIMS has a channel sensitivity of approximately 0.1 °C and is used whenever an accurate measure of spectral radiance or brightness temperature of the earth's surface is needed.

Research applications include characterization of rocks, minerals, soils, vegetation, and surface coatings. Rock units can be identified for their free silica, carbonate, clay, and sulfate contents. Information about alteration and weathering can be obtained from TIMS data as well as an understanding of surface emissivity, porosity, grain size, and roughness. TIMS data is valuable in determining water surface and forest canopy temperatures. Relationships between canopy temperature and levels of green leaf biomass in newly planted clear-cut areas can be determined. Perturbed ecosystems can be monitored by observing surface temperature of vegetated areas which are cooler than surrounding non-vegetated areas. The instrument characteristics are shown in Table A2.

See Kahle (1987), Kahle and Abbott (1985), Kahle and Goetz (1983), and Palluconi and Meeks (1985) for more information on this instrument.

Table A2. PARAMETERS FOR THE THERMAL INFRARED IMAGING SPECTROMETER (TIMS).

TIMS Channel	Wavelengths (μm)
1	8.2 - 8.6
2	8.6 - 9.0
3	9.0 - 9.4
4	9.4 - 10.2
5	10.2 - 11.2
6	11.2 - 12.2
scan rates (selectable)	7.3, 8.7, 12, 25 scans per second
aperture	19.0 cm
IFOV[a]	2.5 mrad
roll correction	plus or minus 15 degrees
reference sources	2 controlled thermal blackbodies

[a] instantaneous field of view

Thematic Mapper Simulators (TMS)

The Thematic Mapper Simulator (TMS) instruments are designed to simulate spectral, spatial, and radiometric characteristics of the Thematic Mapper sensor on the Landsat-4 and 5 spacecraft. The two instruments used in OTTER are similar, but they are flown at different altitudes thereby yielding data with different resolutions. The NS001 TMS is generally flown at medium altitudes and provides 12.2 meter resolution at nadir at an altitude of 4,864 meters. The Daedalus TMS is flown at higher altitudes and provides a ground resolution of 25 meters at an altitude of 19,760 meters. The NS001 TMS is flown aboard NASA's C-130 aircraft. The Daedalus TMS is flown aboard the NASA ER-2 aircraft.

Although the TMS sensors are very similar, they differ slightly from each other and from the Landsat TM instruments. Both TMS instruments have 7 spectral channels that are very similar to those of the TM sensor. However, they both have additional channels; the NS001 TMS has one additional IR channel (see Table A3) and the Daedalus TMS has five additional channels (see Table A4).

Table A3. PARAMETERS FOR THE NS001 THEMATIC MAPPER SIMULATOR (TMS).

NS001 Channel	Wavelength, µm
1	0.45-0.52
2	0.52-0.60
3	0.63-0.69
4	0.76-0.90
5	1.00-1.30
6	1.55-1.75
7	2.08-2.35
8	10.4-12.5
IFOV[a]	2.5 mrad
Total Scan Angle	100 degrees
Pixels/Scan Line	699

[a] instantaneous field of view

Table A4. PARAMETERS FOR THE DAEDALUS THEMATIC MAPPER SIMULATOR (TMS).

Daedalus Channel	TM Band	Wavelength, μm
1	A	0.42-0.45
2	1	0.45-0.52
3	2	0.52-0.60
4	B	0.60-0.62
5	3	0.63-0.69
6	C	0.69-0.75
7	4	0.76-0.90
8	D	0.91-1.05
9	5	1.55-1.75
10	7	2.08-2.35
11	6	8.5-14.0 low gain
12	6	8.5-14.0 high gain

IFOV[a]	1.25 mrad
Ground Resolution	25 meters at 19,650 m
Total Scan Angle	43 degrees
Swath Width	15.6 km at 19,650 m
Pixel/Scan Line	716
Scan Rate	12.5 scans/second
Ground Speed	206 m/sec

[a] instantaneous field of view

Further information on the TMS instruments may be found in Peterson et al. (1986), Peterson et al. (1987), and Spanner (1984).

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13. ABSTRACT *(Maximum 200 words)*

Management of data collected during projects that involve large numbers of scientists is an often overlooked aspect of the experimental plan. Ecosystem science projects like the Oregon Transect Ecosystem Research (OTTER) Project that involve many investigators from many institutions and that run for multiple years, collect and archive large amounts of data. These data range in size from a few kilobytes of information for such measurements as canopy chemistry and meteorological variables, to hundreds of megabytes of information for such items as views from multi-band spectrometers flown on aircraft and scenes from imaging radiometers aboard satellites. Organizing and storing data from the OTTER Project, certifying those data, correcting errors in data sets, validating the data, and distributing those data to other OTTER investigators is a major undertaking. Using the National Aeronautics and Space Administration's (NASA) Pilot Land Data System (PLDS), a support mechanism was established for the OTTER Project which accomplished all of the above. At the onset of the interaction between PLDS and OTTER, it was not certain that PLDS could accomplish these tasks in a manner that would aid researchers in the OTTER Project. This paper documents the data types that were collected under the auspices of the OTTER Project and the procedures implemented to store, catalog, validate, and certify those data. The issues of the compliance of investigators with data-management requirements, data use and certification, and the ease of retrieving data are discussed. We advance the hypothesis that formal data management is necessary in ecological investigations involving multiple investigators using many data gathering instruments and experimental procedures. The issues and experience gained in this exercise give an indication of the needs for data management systems that must be addressed in the coming decades when other large data-gathering endeavors are undertaken by the ecological science community.

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