1. INTRODUCTION

The goals of FIRE are (1) to seek the basic understanding of the roles played by physical processes in determining life cycles of cirrus and marine stratocumulus systems and the radiative properties of these clouds during their life cycles and (2) to investigate the interrelationships between the ISCCP data, GCM parameterizations, and higher space and time resolution cloud data.

The FIRE Implementation Plan outlines a series of investigations and observations designed to meet the goals of basic understanding and parameterizations of cirrus and marine stratocumulus cloud fields and ISCCP data products. There are three components described in the Implementation Plan: a modeling component and two data gathering components.

The Modeling component includes radiative transfer models, cirrus and marine stratocumulus physical process models, general circulation and climate models, and retrieval algorithm models. All FIRE modeling strategies seek (1) to compare the best current understanding of a phenomenon with observations of that phenomenon and (2) to extend that understanding by utilizing the models to extrapolate to other conditions.

The Intensive Field Observations (IFO) data gathering component consists of separate field missions to study cirrus clouds over the mid-continent U.S. and marine stratocumulus clouds off the southwestern coast of California. The cirrus mission will be performed in the fall of 1986 in central Wisconsin; the marine stratocumulus mission will be performed in the summer of 1987 in the vicinity of San Nicolas Island, California. Each three-week mission will combine coordinated satellite, airborne, and surface observations with modeling studies to investigate the cloud properties and physical processes of the cloud systems. Both field missions will be repeated: the cirrus in spring of 1988 and marine stratocumulus in June 1989.

The Extended Time Observations (ETO) component will consist of coordinatea sate" lite data, meteorological analyses, and data from a limited number of surface observing sites throughout the year over a four year period. These data will provide a means of extendiny the results derived in the more detailed Intensive Field Observation intercomparison studies to larger time and space scales. The ETO program will directly support the ISCCP and GCM validation efforts.

The ETO is subdivided into two space scales: Extended Area (EA) and Limited Area (LA). The EA data set is meant to provide data over a large geographical area where occurrences of cirrus and stratocumulus cloud systems may be found in a variety of geographical locations; and to allow for multi-satellite, multiple-view observations of these systems. The LA data set is geographically specific to the location and surrounding area of surface observing sites being maintained throughout the FIRE experiment.

Though the results of the LA studies will be significant in and of themselves, it is their relationships to the other parts of FIRE cirrus and marine stratocumulus cloud studies that is most important. For example, preliminary cirrus cloud modeling results have shown that the linkage between fine-scale radiative and microphysical processes determines the overall character of a cirrus cloud in a given environment. However, the linkage between microphysical and radiative parameters in actual cirrus is speculative. The LA studies will very significantly increase our understanding of this radiative-microphysical coupling.

There is a close relationship between the Intensive Field Observations and the Limited Area climatological studies. Results of the climatological studies will be used to evaluate the representativeness of the specific intensively observed cases. Results from the IFO's will be used to interpret the climatological studies.

This Operation Plan will describe the detailed experiment and operations-plans for the ET/LA data gathering component.

2. SCIENTIFIC OBJECTIVES

2.1 General

The ET/LA observational program aims to assemble a data set which will permit empirical relationships to be developed between the finescale structure/variability and suitable averages of various cloud properties of cirrus and marine stratocumulus cloud systems. The observations will also serve as a "ground truth" cloud data set for comparison with coincident satellite observations and will support the evaluation of the representativeness of the intensive case studies. Key observational elements are: -

The use of very high spatial resolution satellite data (1 km and smaller field of view).

(2) Ground based lidar and surface radiometry.

(3) Collection of simultaneous multiple satellite (i.e., multiple viewing angle) data.

(4) Collection of simultaneous satellite and surface based lidar data. See section 4.2.

2.2 Specific

Cirrus - The Cirrus Limited Area studies involve the analysis of observations taken at a small number of special surface based observing sites over an extended time period. The specific objective of this effort is to relate average physical cirrus cloud properties to fine-scale (~10-100 m) structure/variability. These observations, which are based on surface lidar and radiometry measurements, and analyses will also serve as a "ground truth" validating data set for cirrus cloud retrieval algorithms (FIRE Implementation Plan). As such, this work is important to the success of the EA climatological studies. Cloud properties, to be considered, include:

(l) cloud base and top heights/temperatures

(2) areal cloud fraction

(3) cloud radiative properties in the solar and infrared spectral regions

(4) cloud particle phase and habit

(5) cloud water content

(6) cloud dynamic structure (limited).

The determination of properties (4) and (5) from the observations will most likely be in relative terms although improvements in this respect may result form the intensive case studies. Furthermore, it should be emphasized that the fine-scale structure of -these properties is our focus here.

Attendant environmental factors, which will be considered, include:

(1) ambient temperature and static stability;

(2) ambient horizontal winds and the vertical wind shear;

(3) ambient moisture content to the extent that it is observable; and

(4) local vertical motion (limited).

The downwelling radiative fluxes at the surface will also be considered. Complete data sets will be assembled for some sites while, at others, only limited subsets will be available.

Marine Stratocumulus - A specific objective of the marine cloudcapped boundary layer segment of FIRE is to develop physical models and parameterizations for fractional cloud cover. Observations of stratus and stratocumulus systems to support this modeling activity will involve satellite observations and surface-based observations from a limited number of stations. These observations should yield climatological properties of stratus and stratocumulus for the eastern Pacific off the southwest coast of California. The observations will follow a sampling strategy designed to produce stable, representative statistics of the properties and to produce a long-term statistics of surface radiation and cloud fields.

An outline of the climatological objectives are as follows:

I. Satellite Observations

A. Influence of marine stratus and stratocumulus on earth's energy budget.

B. Time and space scales of variability for these systems.

C. Structures within the systems that affect their influence on the earth's radiative energy budget.

D. Validation of interpretation derived from low-resolution data, through the use of very high resolution (e.g., LANDSAT or AVHRR HRPT) data, and through analysis of simultaneous multiple views.

II. Surface-Based Observations

A. Radiometry

1. Influence of stratus and stratocumulus systems on surface radiative energy budget.

B. Thermodynamic Structure

1. Radiosonde measurements of temperature and humidity profiles.

2. Surface measurements of temperature and humidity.

3. Sea surface temperature in the vicinity of San Nicolas Island.

A summary of the specific objectives for various studies relevant to the ET/LA observations are listed below. For each study, a section reference to the FIRE Implementation Plan is given. Each study is also numbered consecutively for easy reference in summary tables of data sampling requirements discussed in Section 4 of the Operations Plan. The studies are listed in the order given in the Implementation Plan, and not by priority.

No.	Study Objective	I
	Development of cloud description/classification schemes	
1.1	Cloud classification scheme development	3
	Improvement of cloud radiation models	
2.1	Cloud radiance directionality.	3
2.2	Intercalibrate satellite radiometers.	3
2.3	Unresolved cloud cell radiative effects	3
2.4	Spectral dependence of cloud reflected radiation.	3
2.5	Relate shortwave opt. depth and 11mm emissivity of cirrus	3
2.6	Validate lidar SW optical depth vs. sunphotometer.	3
2.7	Cirrus particle phase/orientation.	3
2.8	Cloud diurnal variations.	3
2.9	Relationship of cloud to downward radiative flux at the surface	3
2.10	Relationship of cloud to upward top of atmosphere (TOA) radiative flux	3
2.11	Space and time average cloud radiative properties	3
	Improvement of satellite cloud retrieval techniques	
3.1	Validate satellite derived cloud cover and cloud size.	3
3.2	Determine sensitivity to satellite to sensor resolution	3
3.3	Validate satellite derived cloud height.	3
3.4	Validate satellite derived cloud optical thickness	3
3.5	Diurnal dependence of satellite retrieval accuracy	3
	Description of cloud space/time statistical structure	
4.1	Mesoscale and synoptic scale cloud cover variations.	3
4.2	Diurnal and seasonal scale cloud variations.	3
	Improvement of Cloud Dynamics Models	
5.1	Cloud cell scale space/time structure	3
5.2	Coupling of cloud structure, dynamics, and radiation	3
	Improvement of GCM Cloud Parameterizations	
6.1	Improvemetn of GCM Cloud Parameterizations	3

3. PLATFORMS INSTRUMENTS AND MEASUREMENTS

3.1 Satellite

Data will be collected for a spatial area bounded by 30°N to 50°N latitude and 60°W to 140°W longitude. This area will encompass the four limited areas (see Figure 3.1). Data collection tentaviley begins on April 1, 1986. The satellite data to be included in the FIRE ET/LA archive is given below:

i. AVHRR GAC data, 5 spectral channels, 2 satellites, day and night, giving 4 samples per day.

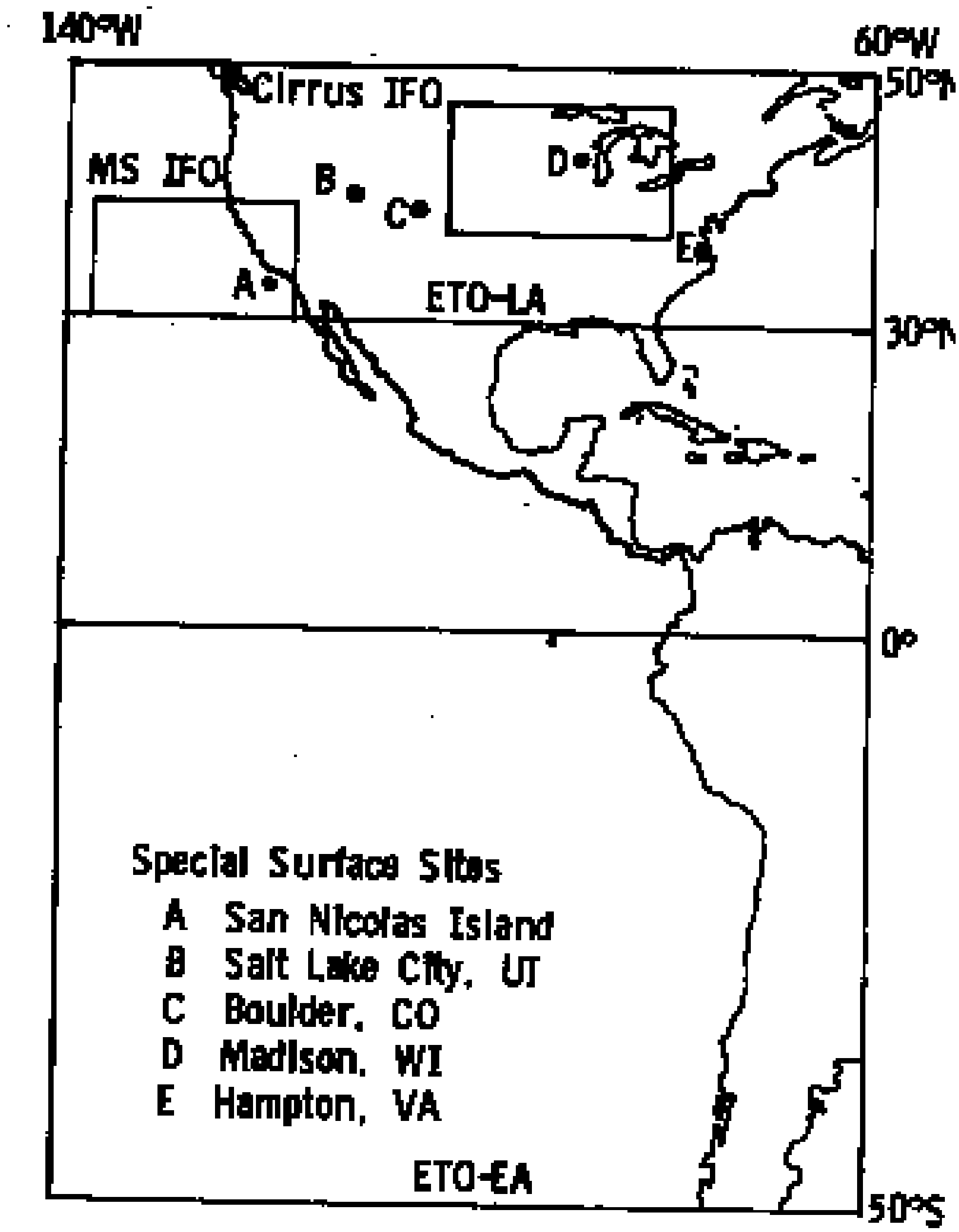

Figure 3.1 - FIRE ETO and IFO Regions and Special Surface Sites

ii. AVHRR HRPT data, 1 km resolution, 5 spectral channels, afternoon polar orbit only, day and nig

iii. TOVS radiance data, 20 spectral channels, 2 satellites, day and night, giving 4 samples per day.

iv. GOES VAS Imager data, 1 km spatial resolution (visible), 8 km spatial resolution (visible and infrared), GOES East and West, every hour.

v. GOES VAS Sounder data, 14 km spatial resolution, 2 to 4 spectral channels, GOES East and West, as available.

vi. ERBE broadband data, 2 channels, scanner and nonscanner, up to 3 satellites, day and night, 6 times per day.

vii. ISCCP B3 data and C data, 3 hourly, GOES East and West.

viii. SAGE II aerosol extinction and water vapor data, whenever satellite occultation point falls within LA areas,

LANDSAT 5/TM data as avaiIable (retrospective case studies).

DMSP, 1 km resolution, visible and infrared radiances, daytime and nighttime, digital swath data.

Within each month of the year, data will be collected for 6 days on, 9 days off, and 6 days on. This sampling will allow time dependent studies of cloud evolution, while obtaining two independent synoptic meteorological samples. The 6 days on and 9 days off cycle is dictated by the NOAA polar orbiter ground track repeat cycle of 9.5 days. By allowing 9 days off between the two data samples, the complete range of NOAA viewing angles will be sampled for any geographic area within 1 month. In order to simplify data collection planning, the two 6 day periods will be taken on the 5th to 10th days and the 20th to 25th days of each month.

During the FIRE IFO periods, ET-LA satellite data will be collected on its normal schedule. The IFO satellite data collection provides additional time coverage and time sampling over that provided in the ET-LA data, but the IFO improvements are provided over a more -limited region of the earth If anv satellite data collection conflicts arise between the ET-LA and IFO data requirements, the IFO requirements are given a higher priority.

The satellite data is to be archived for access by the FIRE science team. If funding sources are inadequate to archive all of the data, the AVHRR HRPT data has the highest priority for archive, since it is the only data not regularly archived. The remaining data is to be ordered retrospectively for selected cloud case studies if funding sources do not allow initial archival of the complete set.

3.2 Surface

Ground-based measurements from a limited number of locations offer a variety of advantages for the study of the radiative behavior of clouds. They can be made in a nearly continuous manner as the overhead atmosphere's properties change, and they can represent a time averaged measurement at a point in space as well. The measurements are usually inexpensive comparied to aircraft and balloon methods, although the ground-based measurements by no means replace in situ measurements. A list of the surface-based instrumentation is included in Table 3.2-1.

3.2.1 Cirrus - Class I

Instrumentation at Salt Lake City, Utah.-The following instrumentation will be operated by personnel from the University of Utah (see Appendix C for more details):

- i. Scanning ruby (694 nm) lidar with dual polarization receiver
- ii. Scanning narrow beam infrared (10-12 m) radiometer
- iii. All-sky, 35 mm fisheye camera
- iv. Ka-band (0.8 cm) radar (occasionally)
- v. Pyranometers
- vi. Pryheliometer (solar tracking)

The corresponding directly calculable cloud physical properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical depth at 694 nm; and (ii) cloud type and amount. The corresponding inferentially calculable cloud properties are (i) broadband visible cloud optical thickness and ice crystal habits; (ii) cloud emittance at 10-12 pm and broadband infrared cloud emittance; and (iii) cloud [ice] water content [occasionally].

Instrumentation at Hampton, Virginia.-The following instrumentation will be operated by personnel from the Langley Research Center, NASA (see Appendix C for more details):

- i. Scanning ruby, doubled ruby and doubled Nd YAG lidar (694, 347, 532 nm) with dual polarization receiver.

- ii. Scanning, narrow beam, visible (400-750 nm) radiometer

iii. Scanning, narrow beam, near infrared (1.04 - 2.2 pm) radiometer
iv. Precision spectral pyranometers

v. Cloud imaging cameras

The corresponding directly calculable cloud properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical thickness at 694, 347, and 523 nm; (ii) cloud optical thickness at multiple wavelengths from 0.4-2.2 pm; (iii) surface radiation budget; and (iv) cloud type and amount.

Instrumentation at Boulder, Colorado.-The following instrumenta~on will be operated by personnel from the Environmental Research Laboratory, NOAA (see Appendix C for more details):

i. Scanning ruby, doubled ruby and doubled Nd YAG lidar (694, 347, 532 nm) with dual polarization receiver.
ii. Scanning CO2 doppler lidar (9-11 pm)
iii. Vertically pointing, narrow beam, infrared (10-12 ~m) radiometer
iv. Narrow beam, visible, sun photometer (solar tracking)
v. PROFS mesoscale solar radiation network (23 stations with pyranometers)

The corresponding di ectly calculable cloud properties are (i) cloud base and top heights, areal cloud fraction, particle phase, ice crystal orientation, and cloud optical thickness at 694, 347, and 532 nm; (ii) ice particle fall speeds, turbulent intensity and vertical profiles of horizontal convergence/divergence; and (iii) broadband visible cloud optical thickness. The corresponding inferentially calculable cloud properties are (i) broadband visible cloud optical thickness and ice crystal habits; (ii) local vertical profile of vertical wind speeds and ice crystal habits; (iii) cloud emittance at 10-12 pm and broadband infrared cloud emittance; and (iv) areal cloud fraction.

In addition, the following support facilities will exist at each of the sites:

i. NWS rawinsonde site (close proximity)

ii. data logging and eel time data processing and display facilities.

iii. access to NWS analysis and forecast products

iv. access to satellite imagery in near real time.

These instrumentation facilities will provide measurements of the vertical profiles of environmental pressure, temperature, humidity, and horizontal winds. Occasional supplementary rawinsonde launches will be required in addition to the usual, twice daily, routine launches. On average, one supplementary launch per week per site is likely to be required. A minimum 12 hour advance notice for a special launch will be needed from the special observing sites. The last two items, which are support facilities, will assist a local 12-36 hour forecast to be made at the site.

This will be used in scheduling observing periods, requesting special rawinsonde launches, and coordinating with satellite observations.

3.2.2 Cirrus - Class II

Class II sites will be operated continuously during daylight hours throughout the duration of the FIRE (4 years). Five class II sites are planned. The class II sites are:

Location
Champaign, Illinois
Mauna Loa, Hawaii
Madison, Wisconsin
Palisades, New York
West Lafayette, Indiana

At each of the Class II special observing sites, most of the following instrumentation and support facilities will be in place:

i. multiple field-of-view, solar (visible) radiometer
ii. pyranometers
iii. NWS rawinsonde site (close proximity)
iv. data logging facilities,

These instruments will provide a direct measurement of (i) the broadband visible cloud optical depth; (ii) the direct and diffuse components of downwelling visible radiation; (iii) the total downwelling solar radiation at the surface; and (iv) the environmental profiles of pressure, temperature, humidity, and horizontal winds - no special launches required. Inferentially, an estimate of local cloud cover or cloud structure (variability of visible optical depth over sky) may be made based on observations (i).

3.2.3 Marine Stratocumulus

The site selected for the marine stratocumulus LA observations is San Nicolas Island (SNI) located approximately 100 km. west of Los Angeles, California (see Figure 3.1). San Nicolas Island was chosen for a number of reasons. The island is relatively small and minimally disrupts the marine boundary layer flow; climatological data show that the northwest tip of the island receives marine flow more than 60% of the time; marine stratocumulus clouds occur approximately 38% of the time during the month of June. As part of the Pacific Missile Test Center, the island has very good support facilities for scientists and their experiments; the restricted airspace around the island will eliminate any conflict with commercial air traffic. Collaboration with the Naval Post Graduate School and Naval Research Laboratory personnel will be optimized as a result fo their access and previous utilization of the SNI facilities.

4.0EXPERIMENT DESIGN

4.1 Sites

Data will be collected over four limited areas (recall Figure 3.1). The locations for the four major Class I observing LA sites are: Salt Lake City, Utah; Hampton, Virginia; Boulder, Colorado; and San Nicolas island, California (see Figure 3.1).

The location of the Class II sites are: Champaign, Illinois; Manua Loa, Hawaii; Madison, Wisconsin; Palisades, New York; and West Lafayette, Indiana.

4.2Simultaneous Satellite/Surface Site Observations

One of the key elements of the FIRE ET-LA plan is to obtain a set of surface observations (especially surface lidar) which are time and space coincident with satellite overpasses. The most critical coincidences are between surface lidar and either Landsat or NOAA AVHRR-HRPT observations. The Landsat and HRPT data provide the highest spatial resolutions (28.5 meter and 1.1 km respectively) allowing the most direct comparisons of lidar and satellite radiance data. For GOES and Landsat satellite data, these times are invariant from day to day (within less than a minute). For the NOAA polar orbiter data (HIRS, AVHRR, ERBE) and for the ERBS satellite (ERBE, SAGE-II), however, the exact time of overpass will vary by as much as an orbital period (approx. 100 minutes). A summary of the time coincidence for each satellite is given below.

4.2.1 GOES Satellite Data

The GOES satellites start an Earth scan at the North Pole, and scan the Earth's disk from north to south in approximately 18 minutes. GOES East scans start on the hour and the half hour, GOES West scans start at 15 minutes past the hour and 45 minutes past the hour. Currently one GOES satellite is operational, with scans starting on the hour and the half hour. The time of GOES observations for any surface station is simply a function of the latitude of the surface station and is given by

T = TStart + 9*(1-sinO)

where ~ is the latitude (positive north, negative south), T is in minutes, and TStart is the time at which the GOES scan starts. Two GOES satellites should be operational by summer, 1986.

4.2.2 Landsat Satellite Data

Currrently Landsat 5 is the primary Landsat satellite. Data is operationally acquired over the entire continental U.S. The Landsat orbit is adjusted as necessary to maintain the sampling time for each region constant to within 1 minute. Landsat data is collected in "scenes" which are 180 km by 170 km in size. The satellite views the scene area in approximately 170 km / (7 km/see) = 24 seconds. Since Landsat only acquires data immediately beneath the satellite (viewing zenith angles within 7 degrees of nadir), complete Earth coverage requires many days of sampling. The orbit has been designed so that each Landsat scene is viewed once each 16 days. Therefore for a given surface observation site, Landsat data will be taken over that site once every 16 days at the same GMT time each day. Appendix E lists the overpass times and dates for the ET-LA class I sites.

4.2.3 NOAA Polar Orbiter Satellite Data

NOAA overpass times for a given surface site will vary by up to 100 minutes from day to day. Predicted satellite orbital elements are used to predict the viewing conditions (time and viewing angle) for each day of the year for selected ET-LA surface sites. Because the NOAA satellite orbits are not continually adjusted like the Landsatsatellites, the orbits drift in time. It is estimated that predicted satellite overpass times are accurate to plus or minus 5 minutes. Overpass times have been calculated for each day of the year for selected FIRE ET-LA surface sites (Class I and Class II) from April, 1986 through December, 1986. Updates to these overpass times will be issued at every 6 months beginning in December, 1986. Experience with the accuracy of the orbitalpredictions will dictate i~f more frequent updates are required. Appendix F gives a sample of the overpass times for Boulder, Colorado.

4.2.4 Earth Radiation Budget Satellite (ERBS)

The primary surface/satellite coincidence target for this satellite is the SAGE II solar occultation measurement. This measurement is taken at sunrise/sunset and coincidence times will vary from surface site to surface site. Observation days will be scattered through the year for any given site. Coincidence times and dates predicted for the ERBS orbital elements are given in Appendix G.

4 3 Experiment Constraints

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TBD

4.4 Experiment Plans

The FIRE experiment is interdisciplinary in nature, causing significant difficulties in clarifying experiment design. A wide range of research objectives (approx. 21 were listed in the section 2.2 for the ETO-LA data) and of instrument types results in a multiplicity of data sampling strategies. This complexity can best be viewed as a three-dimensional matrix as shown in Fig. 4.4-1. Research objectives are listed along the z-axis, Instuments along the y-axis, and Data Sampling Requirements along the x-axis. In the simplest of scientific research, there is a single scientific goal, a single instrument or measuring device, and a single sampling strategy to best achieve the research objective. Such a study would be described by a single line along the x-axis in Fig. 4.4-1. The next level of complexity would utilize several instruments to achieve a single research objective. Such a study would be described by an x-y plane in Fig. 4.4-1. A study such as FIRE, however, seeks to combine multiple instruments and scientific objectives in a synergystic way to attack a research area. The most serious complication is that while scientific investigators have expertise with particular instruments (or models), the scientific objectives cross these boundaries of individual expertise. Therefore, data sampling and data analysis requirements must be coordinated with both the Instruments and the Scientific Objectives viewpoints in mind. The Y-2 plane (objective vs. instrument) is shown in Table 4.4-1.

Section 4.4.1 gives the time/space sampling strategy for the Cirrus Class I and Class II Observing sites. Section 4.4.2 gives the sampling strategy for the Stratocumulus San Nicholas Island Site. The satellite data sampling was described in section 3.1.

4.4.1 Cirrus

The sampling strategy adopted for the program of special surface based observations over extended time periods reflects the availability and operation of suitable instrumentation. Three major Class I (section 3.2.1) and five Class II (section 3.2.2) surface based observing sites will be used. In addition to the three Class I sites, surface lidar observations will be taken occasionally at Madison, WI.

Each site will be operated throughout the duration of FIRE (4 years). Observations will be taken when cirrus clouds are present and generally unobstructed by extensive underlying cloud layers. At each site observations will be taken at one second intervals during at least one continuous three hour time period on at least three days of most weeks subject to the occurrence of suitable conditions.

It should also be noted that the cirrus cloud observations taken at Class II sites will allow unambiguous discrimination of cirrus clouds and their structure only in situations when the clouds are unobstructed and optically thin ($T_{vis} < 10$). A similar constraint also exists at the Class I sites due to the physical limitations of lidar probing, i.e., attentuation limits the information return when the cirrus cloud is very dense/deep or obstructed by underlying cloud layers.

RESEARCH OBJECTIVES	********** SURFACE OBSERVATIONS ******************************											***** SATELLITE OBSERVATIONS ***					
	Ruby Lidar	Doppl Lidar	Pyranom	Sun phot	11µm rad	Cloud image	MFOV rad	Rwn snde	SNI Tower	Sodar	K_a Radar	AVHRR	HIRS2	GOES Imager	GOES Snder	Land sat	SA I
1.1 Cloud Classif.	X				X	X	X		X	X		X	X	X	X	X	
2.1 Rad. Direction.												X		X		X	
2.2 Sat. Intercal.												X		X		X	
2.3 Unresolved Cld	X					X						X	X	X	X	X	
2.4 Spectral Refl.												X				X	
2.5 Swave vs. 11µm	X				X			X				X		X		X	
2.6 Lidar vs. Sphot	X			X		X	X										
2.7 Cirrus particle	X	X						X									
2.8 Diurnal var..	X					X			X			X	X	X	X		
2.9 Surf Rad Fluxes	X		X					X	X			X	X	X	X	X	
2.10 TOA Rad Fluxes	X			X		X		X									
2.11 Avged Rad Prop												X		X		X	
3.1 Sat Cld Cover	X					X						X	X	X	X	X	
3.2 Sensor Resol												X		X		X	
3.3 Sat Cld Height	X								X			X	X	X	X	X	
3.4 Sat Opt Thick.	X				X	X						X		X		X	
3.5 Diurnal Accur.	X								X			X	X	X	X		
4.1 Meso,Synoptic												X	X	X	X	X	
4.2 Diurnal, Seas.	X		X	X	X	X	X	X	X	X		X	X	X	X	X	
5.1 Cld cell struc.	X	X				X			X	X		X		X		X	
5.2 Struc, Dyn, Rad	X	X						X	X	X							
6.1 GCM paramet.	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	

Table 4.4-1 - Research Objectives vs. Surface and Satellite Observations

4.4.1.1 Class I Sites

Ground Based Ruby Lidar (Dual Polarization)

The ground based lidar data will be used in several of the FIRE studies using the ETO-LA data. There are substantial differences in the scanning capability of the surface based Lidar systems at the three Class I sites. The Salt Lake City Lidar has very limited scanning capabilities, the Hampton Lidar has moderate scanning capability, and the Boulder Lidar has extensive scanning capability. There are seven Lidar scan modes appropriate to FIRE objectives. The Lidar systems capable of achieving each scan mode are listed at the end of each description.

Fast Zenith Mode - The lidar is pointed vertically and the lidar is pulsed once every two seconds. In this mode, a vertical/horizontal crossection of the cirrus cloud will be obtained. Vertical resolution of the lidar returns is 15 meters or less, and horizontal resolution is dependent on the advection velocity of the cirrus. For a typical upper level wind speed of 25 m/s, the lidar will sample the cloud every 50 meters along the wind direction. This mode will allow the determination of cirrus cloud microstucture. If cirrus clouds exhibit only small variations on these scales, the repetition rate will be decreased for future lidar data collection. The Hampton and Boulder ruby lidar systems are both capable of operating in this mode.

Slow Zenith Mode - This mode is identical to the fast zenith mode but with a lidar pulse rate of 1 per minute. For a 25 m/s wind speed, lidar samples will be spaced 1.5 km in the cloud along the wind direction. All three lidar systems are capable of operation in this mode.

Line Scan Mode (LS) - This mode is similar in concept to the Range Height Indicator Mode (RHI) used by radar. This mode repeatedly scans the lidar from zenith to 45 degrees from zenith and back to zenith. Where possible, the scan plane is perpendicular to the advection vector of the cirrus. The lidar is pulsed every two seconds as in the Fast Zenith mode. For a cirrus cloud at 10 km altitude, this mode will sample a 10 km wide strip, with each lidar pulse separated in the cloud by 350m at zenith and 1 km at 45 degrees from zenith. As the cloud advects by the lidar scans at 25 m/s, the lidar will trace a zigzay pattern over a 10 by 10 km area in 6.7 minutes. Farthest spacing between any two lidar scans in the area will be .025 km/s times 90 seconds = 2.25 km. Average spacing would be approx. 1 km. Note that it would require a pulse rate of 10/see and a scan rate of 10 degrees/sec to obtain a horizontal spacing of 200 meters for both the alony wind and across wind directions in the 10 km by 10 km region described above. This mode will support both satellite/lidar coincidence studies, and observations of ice crystal orientation. The Hampton and Boulder Lidar can support this mode. In addition, the Boulder Lidar is capable of much higher scanning rates than 1 degree per second, allowing higher resolution spatial coverage for improved comparisons with satellite data.

The highest priority targets for the use of Line Scan Mode are the overpass times of the afternoon NOAA polar orbiter (i.e. AVHRR-HRPT data) and Landsat satellites.

Sun Photometer Mode (SP) - The lidar will be pointed 20 degrees in angle upwind of the solar position. Data will be taken every 2 seconds. Data should be taken only when the direction of cirrus advection can be clearly determined, and when cirrus will be advected from the lidar position to the solar position in the sky. Sun photometers will provide an independent observation of spectral cloud optical depth for comparison with lidar estimates. Because lidar can only point within 10 to 20 degrees of the sun, however, the lidar will ideally be observing upwind of the sun, so that the same portion of the cirrus cloud viewed by the lidar will later be viewed by the sunphotometer. For observations 20 degrees from the sun, a 10 km cloud altitude, and cloud advection speed of 25 m/s, the time and distance lag between the two observations are approximately 3 minutes and 5 km respectively. Sun photometer data may be available at the Hampton surface site, but will not be available at the other two sites.

Crystal Orientation Mode (CO) - Detection of preferential horizontal orientation of cirrus ice crystals relies on the change in backscatter intensity and depolarization measured at zenith to that measured a few degrees off zenith. This mode scans from zenith to 10 degrees off zenith, pulsing every two seconds. The lidar is scanned at 1 degree every 2 seconds resulting in a lidar profile sampled at one degree intervals in viewing zenith angle. Horizontal separation of successive lidar profiles within the cloud will be 2 seconds times 25 m/s = 50 meters. The sampling rate can be reduced to every 10 seconds if necessary, giving a separation of 250 meters between successive profiles. All three lidar systems can support this mode.

Plane Position Indicator Mode (PPI) - This is a common radar scan mode. A 360 degree azimuth scan is performed at a fixed elevation angle. Then step in elevation angle. Only the Boulder Lidar can achieve this scan mode. Each azimuth scan takes approximately 1 minute (approximately 500-1000 lidar shots per azimuth scan). This scan mode is most useful to determine Lidar doppler winds in the region of the surface Lidar.

Raster Scan Mode (RS) - This scan mode approximates the raster scanning pattern of a television or CRT and is used to map horizontal area. The Boulder Lidar has some limited capability to support this mode within 30 degrees of nadir. This mode is especially useful to satellite/lidar intercomparisons, but requires very rapid scanning and very fast lidar pulse rates.

Each lidar Class I site will determine its own observation schedule using the following general guidelines:

1. Observations will generally be taken when unobstructed cirrus are present.

2. 3 hours of observations on 3 days of each week with suitable conditions.

3. Normal lidar observation mode is the Slow Zenith Mode. This mode will establish the basic cirrus climatology. At least 25% of the observations should be at night to allow determination of systematic diurnal variations in cirrus cloud properties. Preferable observation times are during satellite overpasses (NOAA afternoon polar orbiter, and Landsat) and at 0 and 12 GMT to coincide with synoptic radiosonde launches. At least once per month a cirrus system should be observed for an extended time period of 12 continuous hours.

4. Fast Zenith Mode is used for at least one 30 minute period per week. This mode will document the small spatial scale fluctuations of cirrus (down to 50 meters horizontally) and should be used under a variety of cirrus cloud types.

5. Line Scan Mode is used for a 10 minute period centered on the afternoon NOAA polar orbiter overpasses (nominally 2:30 p.m. local, 12 overpasses per month on days 5-10 and 20-25) and for the Landsat 5 overpasses which occur every 16 days at approximately 9:45 a.m. local time. In addition, lidar data will be obtained for 3 nighttime NOAA polar orbiter overpasses (2:30 a.m.) per month. As opposed to the other lidar scan modes, the daytime satellite coincident Line Scan Mode data will be obtain ed under all cloud conditions, not only when cirrus is present. Since the nightime coincidences are limited in number, these should be taken when cirrus is present, to the extent possible. Total of 17 satellite coincid ences are expected per month.

6. Sun Photometer Mode should be used for one 10 minute period per week. Data should only be taken when cirrus is present at the lidar and solar positions and when the direction of cirrus advection can be clearly determined.

7. It is expected that experience in the first year of data collection will suggest substantial modifications

to the lidar scanning modes suggested above. In particular, the time sampling necessary to resolve cirrus horizontal spatial structure as it advects over the surface site must be established using the first year's observations. Initial expectations are that raw lidar data consisting of 1 to 2 second averages will adequately resolve spatial structure.

Pyranometers and Pyrheliometers

Radiative flux measurements at the surface will be taken continuously during daylight hours. These measurements are to be averaged over 1 minute periods.

11 Micron Radiometers Aligned With Lidar

Radiometers aligned with a lidar are to be sampled at times as near as possible to the lidar pulse times. In Slow Zenith Mode this would give 1 minute samples, while Fast Zenith Mode will use 2 second samples.

Sun Photometers

Sun photometer data should be taken at 2 second intervals whenever the lidar is operating in the SunPhotometer Mode. Data collection should begin when the lidar data begins and end no less than 5 minutes after the lidar data collection has stopped, or until the last section of cirrus observed by the lidar has moved under the sun. Typical data collection period should be 15 minutes.

Cloud Imaging Cameras

Cameras should have at least a 50 degree field of view, preferably 180 degree. Desired time intervals between images are dependent on the lidar scan mode:

Fast Zenith Mode,	image	every	2 minutes.	tTotal	=	60/month)
Slow Zenith Mode,	image	every	30 minutes.	(Total	=	60/month)
Line Scan Mode,	image	every	2 minutes.	(Total	=	85/month)
SunPhotometer Mode,	image	every	2 minutes.	(Total	=	20/month)

Giving a total of 225 images/month, or 2700 per year. The most critical times to have the cloud images is for the Line Scan Mode data to provide cloud cover estimates for satellite coincident measurements, and for the sunphotometer Mode to document cloud advection from the lidar to sunphotometer viewing angles. This data will also be used to document surface observed cloud type for comparison with objective cloud classification schemes based on surface or satellite measured cloud radiative properties.

CO2 Doppler Lidar
TBD

K_a - Band (0.8 cm) Radar

4.4.1.2 Class II Sites

Pyranometers and Pyrheliometers

Radiative flux measurements at the surface will be taken continuously throughout the duration of the FIRE (4 years). Measurements are to be averaged over l minute intervals.

Multiple Field of View Solar Radiometers

Multiple field of view radiometer data will be taken continuously during daylight hours throughout the duration of the FIRE (4 years). Measurements are to be averayed over l minute intervals.

4.4.1.3 Radiosonde and U.S. Solar Radiation Network

The standard NMC gridded analyses, solar network data, and full resolution rawindsonde observations for U.S. stations covering the FIRE ETO-LA regions will be contained in the FIRE ETO-EA data set.

Supplementary rawindsonde launches will be scheduled by the Cirrus Class I sites. Approximately l supplementary launch per week is expected. Times of satellite overpass (NOAA polar orbiter and Landsat) are high priority targets for supplemental launches.

4.4.2 Marine Stratocumulus

The Naval Postgraduate School and the Naval Research Laboratory are planning to use an existing network of radiosonde stations (two island, four coastal) to define horizontal variability and lower tropospheric thermodynamics in the vicinity of San Nicolas Island (SNI). In addition, routine observations will be obtained of surface temperature and humidity at SNI and sea surface temperature in the vicinity of SNI. Automated pyranometers, pyrheliometers, ad solar transmission instrumentation, supplied by Pennsylvania State University, will also make solar radiation observations.

The ET/LA program is closely tied to satellite measurements and their interpretation. Marine stratocumulus clouds present one of the most vexing aspects of satellite data interpretations: images taken at different resolutions almost invariably show different amounts of cloud cover in the same scene. Since satellites offer an economical climate monitoring technique, it is important to resolve such ambiguities. The ET/LA and Marine Stratocumulus IFO will identify the processes in the marine cloud top boundary layer that cause the ambiguities. Satellite observations will be used for extended time observations, with surface measurements to validate the satellite retrieval algorithms. A summary of the proposed satellite work is given in Table 4.4.2-1.

Satellite imayery can provide quantitative characterizations of stratocumulus cloudiness. The imagery can be used to determine the time and space scales for the variability of cloud amount, cloud height and visible reflectivity, and the cloud cover and radiative properties that can be linked to the thermodynamic structure of the lower atmosphere. Of course, as techniques for analyzing the imagery data are relatively new, their validation is an essential component of any major experiment such as FIRE.

4.5Experiment Plan Schedule

A schedule of the ET/LA milestone is yiven in Figure 4.5-1.

TBD

4.6 Communications

A telephone link (non-dedicated) will be required between each surface site and the nearest NWS radiosonde site to set up and coordinate special rawinsonde releases.

4.7Meteorological Support-Forecasting

A forecasting capability will be helpful for planning and observations. Forecasts of expected conditions will be made to 24, 48, and 72 hours. Forecast zones will include the area immediately surrounding the surface stations, as well as the LA region of interest. Forecasts will include assessment of significant weather, cloud conditions, upper tropospheric winds, and conditions favorable for the occurence of cirrus clouds. It is emphasized that cloud conditions include not only upper tropospheric levels but

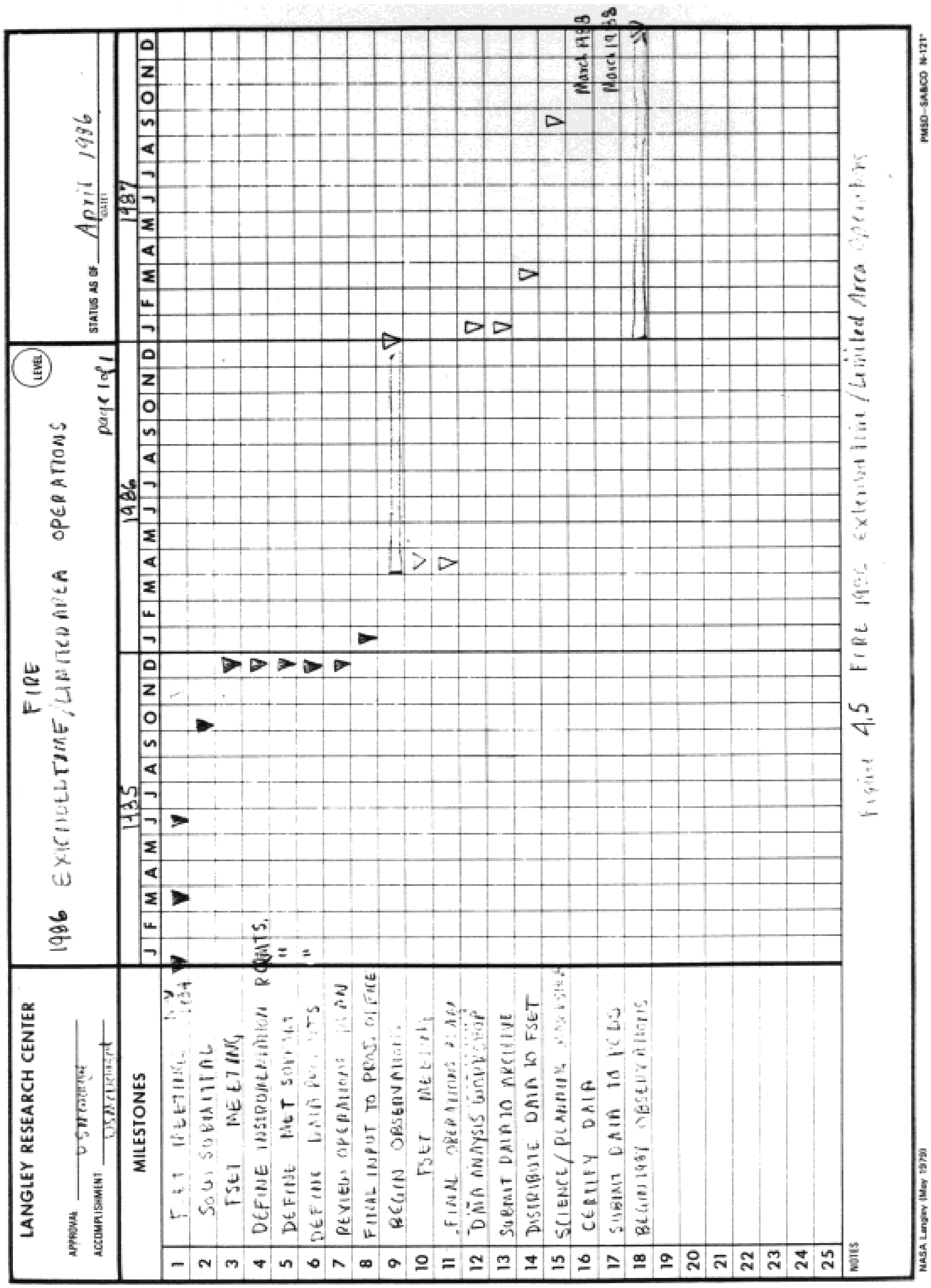

Figure 4.5-1 FIRE 1986 Extended Time/Limited Area Operators

Table 4.4.2-1 SUMMARY OF FIRE STRATOCUMULUS SATELLITE OBSERVATIONS

Satellite	Instrument	Application
.		
GOES	Visible and Infrared Spin Scanner Radiometer (VISSR)	Cloud fraction, cloud top, albedo diurnal variations.
ERBS	Broad-band IR and Shortwave	Mesoscale structure, realtime imagery .
NOAA	Advanced Very High Resolution Radiometer (AVHR/TOVS)	High resolution cloud structure comparison with in situ measurements and LANDSAT satellite data interpretation.
LANDSAT	Multispectral Scanner (MSS) Themetic mapper (TM) (Visible, 28.5 m resolution; IR, 120 m)	Size distribution of cloud elements, comparison with in situ measurements.

all levels. This will be important in planning due to the negative impact of intervening cloud layers on the surface based lidar and radiometric observations with respect to the overlying cirrus.

The forecaster should have access to standard NWS analysis and forecast products, to GOES satellite imagery, and relevant NWS observations (surface observations and rawinsonde data) in near real time.

5.0DATA MANAGEMENT

Data management is an ongoing activity, beginning immediately in the pre-experiment phase and continuing through the end of FIRE. Most of the data management tasks will be performed by the FIRE Investigators acting individually or as members of the Cirrus Working Groups (see section 5.2). The FIRE working groups will be the foci for identifying and coordinating items relating to the acquisition and use of data as a communal resource, working closely with other groups dealing with scheduling of platforms, identification of calibration and intercomparison needs, colocation requirements, and selection of case studies and integrated analyses.

Data management activities in FIRE will insure the exchange of data among FIRE investigators that is required to produce the integrated analyses of multi-platform, multi-scale and multi-spectral data sets; these integrated analyses are central to the accomplishment of the FIRE science objectives. In addition the data management activities will insure the availability of FIRE data and analysis products to the entire science community. These activities will be carried out by four organizational components within FIRE; (1) the individual FIRE investigators, (2) the FIRE Working Groups, (3) the FIRE Central Archive, and (4) the FIRE Project Office. The strategy embodied in this organization is to disperse most of the data reduction and processing functions to the FIRE investigators engaged in collecting and analyzing the data, but to hold the resultant data sets and analysis products centrally for ready access by all FIRE investigators. The FIRE Central Archive and the FIRE Project Office will provide a centralized source of information and copies of data which are centrally archived, whereas the FIRE Working Groups, composed of the investigators, will coordinate the decentralized data reduction and analysis activities. In addition, the FIRE Central Archive will transfer from time to time, certified FIRE data to PCDS for permanent archive and for open access by the scientific community.

5.1Data Products

Data products are listed below for each instrument in the FIRE ETO-LA data set. Data products are listed for three types of data: raw, reduced, and value-added.

Raw Data is instrument level data and is investigator archived. Raw data is not placed in the FIRE Central archive.

Reduced Data is data which has received the preliminary processing necessary to convert the measurement into physical units. Reduced data typically is calibrated, navigated, and may be time or space averaged. Reduced data is that version of the data closest to the raw data but which could be used by other FIRE investigators without a detailed background in the instrument technology used to obtain the measurement. Reduced data is placed in the FIRE central archive.

Value-Added Data is data which has been analyzed beyond the reduced data to obtain physical quantities other than the direct measurement. For example, lidar backscatter can be used to infer cloud optical depth. Value-added data is placed in the FIRE central archive.

Data volumes are given based on the sampling strategies outlined in section 3.1 for satellite data and section 4.4 for ground-based data.

5.1.1 Raw Data Products

5.1.1.1 Cirrus Class I Sites

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Lidar Backscatter (694 nm) vs altitude (every 100 m or less) Depolarization Ratio vs. altitude (every 100 m or less) Time of observation (Day/Month/Year, Hr/Min/Sec GMT) Viewing zenith angle (Degrees, accurate to 0.5 degree) Viewing azimuth angle (Clockwise relative to North, to 0.5 degree) Minimum altitude range of 1-20 km

Data Volume : ??? 6250 BPI tapes per year.

Pyranometers and Pyrheliometers

Measurements: Downward solar radiative flux at 1 minute intervals (W/m) Time of Observation (Day/Month/Yr, Hr/Min GMT)

Data Volume: 0.026 6250 BPI tapes per year.
(lobs/min)*(60min/hr)*(12hr/day)*(365days/yr)
*(lObytes/observation) = 2.6 million bytes (MB)
per year, or approximately 0.026 tapes

11 Micron Radiometer Aligned With Lidar

Measurements: Spectral radiance (watts/meter-squared/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.02 6250 BPI tapes/yr
Slow Zenith Mode:
(lobs/min)*(60min/hr)*(8hrs/week)*
(52wks/yr)*(15 bytes/observation) = 0.4 MB/yr
Fast Zenith Mode:
(30obs/min)*(30min/wk)*(52wks/yr)*
(15bytes/observation) = 0.7MB/yr
Line Scan Mode:
(30obs/min)*(lOmin/event)*(17 events/

month)*
(12mo/yr)*(15 bytes/observation) = 0.9 MB/yr.
Total = 2.0 MB/yr or 0.02 tapes.

Sun Photometers

Measurements: Spectral radiance (watts/meter-squared/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.003 6250BPI tapes/yr
(30obs/min)*(15min/event)*(4events/month)*
(12mo/yr)*(15 bytes/observation) = 0.3 MB/yr.

Cloud Imaging Cameras

Measurements: 35mm film slides of camera field of view and/or
Videotape of camera field of view.

Data Volume: 2700 slides per year, or for continuous videotape during lidar observations, approx. (8hrs/wk)*(52wks/ yr)/(4hrs/tape) = 104 tapes

CO2 Doppler Lidar

Measurements: T.B.D.

Data Volume: T.B.D.

K -Band (0.8 cm) Radar
Measurements: T.B.D
Data Volume: T.B.D

Supplementary Rawindsonde Launches
Measurements: T.B.D
Data Volume: T.B.D

5.1.1.2 Cirrus Class II Sites

Pyranometers

Measurements: Same as Class I sites
Data Volume: Same as Class I sites

- Multiple Field of View Solar Radiometers

Measurements: Spectral Radiance (watts/meter-squared/steradian)
for 5 angular fields of view.
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.13 6250 BPI tapes per year.
(5 channels)*(lobs/min)*(60min/hr)*(12hr/day)*(365
days/yr)

*(10bytes/observation) = 13.0 million bytes (MB) per year, or approximately 0.13 tapes

5.1.1.3 San Nicholas Island Site - Tower System

Measurements: T.B.D

Data Volume: T.B.D

5.1.1.4 Satellite Data

Raw satellite data will not be archived by the FIRE. Reduced (calibrated and geographically located) data and value-added data are described in sections 5.1.2.4 and 5.1.3.4.

5.1.2 Reduced Data Products

5.1.2.1 Cirrus Class I Sites

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Cloud Base Altitude (km)
Cloud Top Altitude (km) or Lidar Attenuation altitude Depolarization Ratio (unitless) profile every 100 meters from cloud base to cloud top. Backscatter Ratio (unitless) profile every 100 meters from cloud base to cloud top. Altitude (km) for each level in the profile. Time of observation (Day/Month/Year, Hr/Min/Sec GMT) Viewing zenith angle (Degrees, accurate to 0.5 degree) Viewing azimuth angle (Clockwise relative to North, to 0.5 degree) Minimum altitude range of 1-20 km

Data Volume : 0.55 6250 BPI tapes per year.
Slow Zenith Mode: (lprofile/min)*(60min/hr)*(8hrs/week)* (52wks/yr)*(20 levels/profile)*(20bytes/level) = 10 MB/yr Fast Zenith Mode: (30profiles/min) *(30min/wk)*(52wks/yr)* (20 levels/profile)*(20bytes/level) = 20 MB/yr
Line Scan Mode: (3Oprofiles/min)*(lOmin/event)* (17events/month)*(12mo/yr)* (20 levels/profile)*(20bytes/level) = 25 MB/yr. Total = 55 MB/yr or 0.55 tapes.

Pyranometers and Pyrheliometers

Measurements: Downward solar radiative flux at 1 minute intervals
(W/m) Time of Observation (Day/Month/Yr, Hr/Min
GMT)

Data Volume: 0.026 6250 BPI tapes per year.
(lobs/min)*(60min/hr)*(12hr/day)*(365days/yr)
*(lObytes/observation) = 2.6 million bytes (MB)
per year, or approximately 0.026 tapes

11 Micron Radiometers Aligned With Lidar

Measurements: Spectral radiance (equivalent blackbody temperature in degrees K) Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.02 6250 BPI tapes/yr
Slow Zenith Mode:
(lobs/min)*(60min/hr)*(8hrs/week)*
(52wks/yr)*(15 bytes/observation) = 0.4 MB/yr
Fast Zenith Mode:
(300bs/min)*(30min/wk)*(52wks/yr)*
(15bytes/observation) = 0.7MB/yr
Line Scan Mode: (3Oobs/min)*(lOmin/event)*(17
events/month)* (12mo/yr)*(15 bytes/observation) =
0.9 MB/yr. Total = 2.0 MB/yr or 0.02 tapes.

Sun Photometers

Measurements: Spectral radiance (watts/meter-squared/steradian)
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.003 6250BPI tapes/yr
(300bs/min)*(15min/event)*(4events/month)*
(12mo/yr)*(15 bytes/observation) = 0.3 MB/yr.

Cloud Imaging Cameras

Measurements: 35mm film slides of camera field of view and/or
Videotape of camera field of view.

Data Volume: 2700 slides per year, or for continuous videotape during lidar observations, approx. (8hrs/wk)*(52wks/ yr)/(4hrs/tape) = 104 tapes

CO2 Doppler Lidar

Measurements:

Data Volume:

T.B.D.

T.B.D.

Ka - Band (0.8 cm) Radar

Measurements: T.B.D

Data Volume: T.B.D

Supplementary Rawindsonde Launches

Measurements: T.B.D

Data Volume: T.B.D

5.1.2.2 Cirrus Class II Sites

Pyranometers

Measurements: Same as Class I sites

Data Volume: Same as Class I sites

Multiple Field of View Solar Radiometers

Measurements: Spectral Radiance (watts/meter-squared/steradian) for 5 angular fields of view.
Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.13 6250 BPI tapes per year.
(5 channels)*(lobs/min)*(60min/hr)*(12hr/day) *(365days/yr) *(lObytes/observation) = 13.0 million bytes (MB) per year, or approximately 0.13 tapes

5.1.2.3 San Nicholas Island Site

Tower System

Measurements: T.B.D

Data Volume: T.B.D

5.1.2.4 Satellite Data

Satellite data for the AVHRR-GAC, TOYS-2, GOES-VAS Imager, and GOES-VAS Sounder and ERBE are covered in the ETO-EA plan. These data are available for the ETO-LA studies on the same o-day on 9-day off schedule discussed in section 3.1. Satellite data which is particular to the ETO-LA are the AVHRR-HRPT, GOES-VAS Imager (1 km visible channel resolution), Landsat/5 Thematic Mapper, and SAGE II solar occultation data. Data characteristics for these last four satellites are discussed below.

AVHRR-HRPT

All 5 spectral channels have a 1.1 km spatial resolution at nadir. The current afternoon NOAA polar orbiter satellite is NOAA-9, which will observe the FIRE ETO-LA regions at approximately 2:30 p.m. local time at the satellite's ground track (track around the earth of the sub-satellite point). Since the satellite views up to 15 degrees longitude on either side of the ground track, any given satellite coincidence for the FIRE Class I and Class II sites will vary within plus or minus 1 hour of the nominal 2:30 p.m. crossing time.

Measurments: 0.58 - 0.68 micron lambertian reflectance

0.725 - 1.10 micron lambertian reflectance
3.55 - 3.93 micron brightness temperature
10.3 - 11.3 micron brightness temperature
11.5 - 12.5 micron brightness temperature

Data Volume: 108 6250BPI tapes/yr
(0.75tapes/day)*(12days/month)*(12months/yr) = 108 tapes (Volume for all 4 ETO-LA areas)

GOES VAS Imager

Visible channel data has 0.9 km spatial resolution, infrared channel has 7.2 km spatial resolution (at nadir view). Hourly data from GOES-East and GOES-West, 12 days per month.

Measurements: 0.55 - 0.75 micron radiance (squared instrument counts)

10.4 - 12.1 micron brightness temperature (K)

Data Volume: 72 6250BPI tapes/yr

(0.5 tapes/day)*(12days/mo)*(12months/yr) = 72 tapes/yr
(Volume for all 4 ETO-LA areas)

Landsat/5 Thematic Mapper

The Landsat satellite orbits in a 9:45 a.m. sun-synchronous orbit. Data is collected for 185 km by 170 km scenes. Spatial resolution in the 6 shortwave and near-infrared window channels is 28.5 meters. Spatial resolution in the 11 micron window channel is 114 meters. A given Landsat scene is viewed once every 16 days. The data is taken every 16 days over the continental U.S., but is only processed (radiometric calibration and geometric location) upon request. For especially interesting cirrus conditions over the FIRE class I sites, several Landsat TM scenes may be ordered. These scenes would be ordered only after preliminary examination of surface lidar and cloud image data to ve ify cirrus conditions. The same approach may be possible for San Nicolas Island.

Measurements: 0.45 - 0.52 micron reflected radiance (digital

counts which can be linearly converted to radiance
using supplied calibration coefficients.)
0.52 - 0.60 micron reflected radiance
0.63 - 0.69 micron reflected radiance
0.76 - 0.90 micron reflected radiance
1.55 - 1.75 micron reflected radiance
2.08 - 2.35 micron reflected radiance
10.4 - 12.5 micron brightness temperature (K)

Data Volume: 3 6250BPI tapes per scene

5.1.3 Value-Added Data Products

5.1.3.1 Cirrus Class I Sites

Ground Based Ruby Lidar (Dual Polarization)

Measurements: Cloud Optical Depth at 694 nm Cloud Particle Phase (ice, water) vs. altitude for each 100 meter height interval within the cloud. Cloud ice particle orientation vs. altitude If the above parameters are not included with reduced lidar data, include time of profile, viewing zenith angle, and viewing azimuth angle.

Data Volume : 0.27 6250 BPI
tapes per year.
Slow Zenith Mode: (lprofile/min)*(60min/hr)*(8hrs/
week)* (52wks/yr)*(20
levels/profile)*(10bytes/level)
s 5 MB/yr Fast Zenith Mode: (30profiles/min)*
(30min/wk)*(52wks/yr)* (20
levels/profile)*(10bytes/
level) = 10 MB/yr Line Scan Mode:
(30profiles/min)*
(10min/event)* (17events/month)*(12mo/yr)* (20
levels/profile)*(10bytes/level) = 12 MB/yr.
Total = 27 MB/yr or 0.27 tapes.
11 Micron Radiometer Aligned With Lidar

Measurements: Cirrus emissivity at 11 micron.
Time of observation

Data Volume: 0.02 6250 BPI tapes/yr

Slow Zenith Mode:

(lobs/min)*(60min/hr)*(8hrs/week)*

(52wks/yr)*(15 bytes/observation) = 0.4 MB/yr

Fast Zenith Mode:

(30obs/min)*(30min/wk)*(52wks/yr)*

(15bytes/observation) = 0.7 MB/yr

Line Scan Mode: (30obs/min)*(10min/event)*

(17events/month)*

(12mo/yr)*(15 bytes/observation) = 0.9 MB/yr.

Total = 2.0 MB/yr or 0.02 tapes.

Cloud Imaging Cameras

Measurements: Cloud fraction (%) for the entire camera field of view Cloud fraction (%) for a 8 km by 8 km area of the cirrus, centered at zenith, for comparison to satellite derived cloud cover. Cloud type Cloud Height (km) Time of observation (Day/Mo/Yr, Hr/Min/ Sec GMT)

Data Volume: .001 6250BPI tapes per year

(2700 images/yr)*(40bytes/image) = 0.1 MB/yr

CO2 Doppler Lidar

Measurements: Ice particle fall speeds

Turbulent intensity

Vertical profiles of horizontal divergence/converg
ence

Data Volume: T.B.D.

K -Band (0.8 cm) Radar

Measurements: Cloud water (ice) content

Data Volume: T.B.D

5.1.3.2 Cirrus Class II Sites

Multiple Field of View Solar Radiometers

Measurements: Broadband visible cloud optical depth.

Variability of visible cloud optical depth.

Time (Day/Mo/Yr, Hr/Min/Sec GMT)

Data Volume: 0.05 6250 BPI tapes per year.

(lobs/min)*(60min/hr)*(12hr/day)*(365days/yr)

*(20bytes/observation) = 5.0 million bytes (MB)

per year, or

approximately 0.05 tapes

5.1.3.3 San Nicholas Island Site

Tower System

Measurements: T.B.D

Data Volume: T.B.D

5.1.3.4 Satellite Data

GOES-VAS Imager/AVHRR/Landsat Intercalibration

Comparison of shortwave reflected radiances for the GOES-VAS 0.55 - 0.75 micron channel, the AVHRR 0.58 - 0.68 micron channel, and the Landsat 0.63 - 0.69 micron channel will require intercalibration of the three radiometers. This intercalibration is expecially

critical for determination of the directional reflectance of cirrus and stratocumulus for testing radiative models. Intercalibration will be achieved by obtaining time and viewing angle coincident data as the AVHRR and Landsat TM instruments underfly the GOES sensor.

5.2 Data Management Responsibilities

5.2.1 Principal Investigators

All data reduction and analysis functions in FIRE reside with the scientists carrying out their research as part of FIRE. To encourage the interaction of these researchers needed to integrate the various observations and models into a more comprehensive understanding of clouds, FIRE investigators will have free access to all data sets collected during FIRE, either by individual principal investigators or collected from satellites. Coordination of data analysis and modeling activities requires all FIRE principal investigators to perform certain other tasks as part of the FIRE data management. These functions are:

(1) To provide to the FIRE Central Archive information concerning data holdings, including all data collected as part of FIRE and other data deemed relevant to FIRE research.

(2) To save all data collected during FIRE in un-reduced form for five years so that reduction of data can be repeated if necessary.

(3) To provide to the FIRE Central Archive copies of all reduced FIRE observations in a mutually agreed upon format, accompanied by complete instrument, reduction algorithm and data format documentation.

(4) To provide, within nine months after acquisition, to the FIRE Central Archive copies of any data analysis products deemed relevant to the accomplishment of FIRE objectives, accompanied by appropriate documentation.

(5) To provide to other FIRE investigators or the FIRE Central Archive, upon request, copies of other data sets acquired for FIRE research, that are relevant to other FIRE studies.

(6) To p.ovide to other FIRE investigators reasonable access to un-reduced observations to facilitate particularly crucial multi-data analyses.

5.2.2 Cirrus Working Group

There are two FIRE Working Groups - a Cirrus Working Group and a Marine Stratocumulus Working Group. These working groups will be composed of FIRE principal investigators pursuing research relevant to that working group. The data management responsibilities of the individual principal investigators, as dispersed elements of the FIRE data processing system, could become onerous if not coordinated properly, so the FIRE Working Groups must govern these individual activities to insure progress toward the FIRE science objectives. The data management functions of the two FIRE Working Groups are:

(1) To determine the content and format of all principal investigator data sets to be submitted to the FIRE Central Archive.

(2) To set standards for data quality control, documentation of all data sets, and certification criteria for data products that will be transferred to the permanent FIRE Data Archive.

t3) To select case study data sets for special intensive processing (including re-formatting) by all relevant principal investigators and to identify other additional processing of data to accomplish FIRE objectives.

(4) To coordinate data management decisions, through a standing sub-working group on data management, to insure uniform FIRE data characteristics.

(5) To certify, within 18 months after acquisition, those data products from the Central Archive that will be transferred to the permanent FIRE Data Archive.

5.2.3 FIRE Central Archive

The Pilot Climate Data Service (PCDS) at Goddard Space Flight Center will serve as the FIRE Central Archive. The PCDS is designed to be an interactive, easy-to-use, on-line, generalized scientific information system. It efficiently provides uniform data catalogs, inventories, and access methods, as well as manipulation and display tools for a large assortment of Earth, ocean, and atmospheric data for the climate-related research community. Programs conducted by NASA-sponsored investigators, such asclimate, weather, and severe storm research (e.g., cloud and land-surface climatology), can be supported by the system.

Researchers can employ the PCDS to scan, manipulate, compare, display, and study climate parameters from diverse data sets. Data producers can use the system for validating and archiving data, or for maintaining account records and data inventory. Information on data demands can be used by managers for planning data processing and analysis activities. In addition, academic researchers, who may be working with limited budgets, can obtain quick access to selected portions of larger data sets.

For further information on PCDS, contact Mr. Joseph Drewry, FIRE Data Manager, or Ms. Mary Reth, PCDS.

The FIRE Central Archive provides a centralized data holding and data cataloging service in order to facilitate easy access to all FIRE data by all FIRE investigators. Since most of the satellite data are not collected directly by FIRE principal investigators, the Central Archive will also be responsible for the collection of the satellite data sets required for FIRE research from the relevant satellite operating agencies. The specific data management functions of the Central Archive are:

(1) To collect all reduced observations and data analysis products submitted by individual principal investigators or groups of principal investigators upon the request of the FIRE Working Groups.

(2) To collect all satellite data sets required for FIRE as specified by the FIRE Working Groups.

(3) To provide for archival of all submitted data sets by producing back-up copies of all data and taking other necessary precautions to insure the preservation of the FIRE data throughout the duration of FIRE.

(4) To provide, upon request, copies of any data sets to FIRE investigators (at affordable cost to investigators).

(5) To produce a catalog of the complete FIRE data hold ings of the archive and the individual principal in vestigators indicating the current analysis status of these data. The catalog entries should provide information about the location of the data holding, the instrument(s) performing the observations, the resolution and areal coverage of the data, the date, time and location of the observations, and the format of the data. -

(6) To update the catalog (item 5) every six months and to disseminate it to FIRE investigators in both hard copy and electronic (on-line dial-up data set) form.

(7) To transfer, on an annual basis, certified FIRE data from the Central Archive to PCDS for permanent archive, called the FIRE Data Archive, and for access by the at-large scientific community.

(8) To publish a FIRE Data Archive Users Manual that describes the contents of the FIRE Data Archive, data formats, data request information, and other pertinent descriptive material.

5.2.4 Project Office

The FIRE data management structure vests the primary data processing function with the individual scientific investigators, the information and arhival functions with the Central Archive, and the decision-making with the FIRE Working Groups. The Project Office must provide for liaison among these different groups. The specific data management functions are:

(1) To provide liaison between the FIRE Working Groups (and individual principal investigators) and the data collecting agencies and agencies operating observing platforms required by FIRE.

(2) To provide liaison between the FIRE Central Archive and the satellite and other data collecting agencies to facilitate the acquisition of the data sets needed for FIRE.

(3) To provide for a close working relationship among the FIRE Working Groups and the Central Archive by including a representative of the Central Archive on the Project Office staff who can attend FIRE Science Team meetings.

5.3Standard Data Format

There are three types of data acquisition activities in FIRE involving different combinations of observing platforms. There are four Intensive Field Programs (IFP) scheduled, two concentrating on cirrus and two concentrating on marine stratocumulus. These include collection of data from the surface, aircraft and satellites. FIRE observations are extended in space and time by the Extended Time Observations - Limited Area (ETO-LA), which include observations from the surface and satellites for the duration of FIRE. Finally, the larger scale is covered by Extended Time Observations - Extended Area tETO-LA) from satellites. The FIRE data archive will contain the following types of information obtained from these different activities.

(1) Reduced data -- observations converted to the physical quantity directly sensed by the instrument with quality control inspection and removal of bad data.

(2) Calibration, quality and navigation information -describes the conversion to physical units, the conditions of observation and the location of the observation.

(3) Instrument documentation and data tape format description.

(4) Analysis products -- physical quantities derived

from the observations, including documentation on -

the analysis algorithm and any auxiliary data sets used in the analysis.

(5) Data for special case studies which have been asrranged for intercomparison of multi-platform observations.

(6) Data selected for special processing to facilitate model studies.

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(7) Bibliography of FIRE publications.

If funding sources are inadequate to archive all of the data, the AVHRR HRPT data has the highest priority for archive, since it is the only data not regularily archived. The remaining data is to be ordered retrospectively for selected cloud case studies if funding sources do not allow archival of the complete set.

The data acquired by the individual experimenters will be reduced to final numbers and forwarded to the Cirrus and Marine Stratocumulus Working Groups and Central Archive. The format for the archive is the FIRE Standard Data Format given in Appendix D. This format is a flexible, self-contained data encoding format that allows for access to the data without previous knowledge of the contents or data format. It is best suited for time sequential data. In addition, it allows for a brief written description of pertinent remarks to be included in the data file. Most experimenters, with a modest amount of software modification, should be able to accommodate into this format structures. If this format structure is not compatible, the data format that is to be used should be completely documented and submitted to the Working Groups and Central Archive before submittal of the final data.

Transfer of the final data between the investigators and the Central Archive may be accomplished in several ways. First, the final data may be transferred physically. The preferred method is the mailing of appropriately prepared 9 track tapes. Floppy diskettes of selected personal computers may also be mailed. For short data files of less than 3 pages, hard copies of tables, graphs etc. may be mailed di~ectly. Second, the electronic transfer of data files over "data grade" telephone lines using acoustic-coupled computers is another method of data transfer.

Transfer of the data from the data archive to the investigatiors will be done either physically (using 9 track tapes) or electronically, depending on the investigator/data archive requirements.

5.4Data Exchange

The following sequence and procedure for the exchange of data is envisioned as follows:

1. Data from the ET/LA studies will be placed in the FIRE Central Archive by each of the responsible PIs.

2. FSET PIs may acquire selected portions of the data from the Central Archive.

3. At the conclusion of the research effort, the FSET PI will submit the data products and documented outcome of the research to the Central Archive. This will be especially true if the data has undergone a "value-added" improvement.

5.5Data Schedule

Milestones in the reduction, analysis, distribution, archiving, and analysis of the data are as follows:

5.5.1 Preliminary Data Analysis Workshop

A data analysis workshop will be held on an annual basis within the first quarter of each year. The participating experimenters will describe the performance of their sensors, a sample of the final reduced data, an estimate of the sensor accuracy and precision, and report on key measurement results. At the time of the Data Analysis Workshop, the final reduced data obtained within the last year of the instruments will be submitted to the data archive in the appropriate format documented in Appendix D. The Cirrus and Marine Stratocumulus Working Groups will review each of the major scientific objectives in light of the measurements and analyses obtained to date, identify those areas requiring additional investigations, and determine the specific details of each investigation that is to be pursued. The Working Groups will integrate the individual measurements into several comprehensive case study data sets and where appropriate will compare the measurements with preliminary theory or model predictions. Results from the previous year will be used to provide new insight into the planning for upcoming year objectives and operation plans.

5.5.2 Distribution of Data Archive

Within two months after the final measurements have been received, the reduced data will be consolidated into a comprehensive ET/LA data archive and will be distributed to the experimenters and interested FSET researchers in appropriate media, such as printouts, graphs, 9 track tapes, etc.

5.5.3 Open Access to Data Archive

Twelve months after the Data Archive Distribution, the data archive will be certified by the Working Groups and transferred to PCDS for release to the scientific community. Any proprietary rights to the data and data interpretation will be voided at this time.

5.5.4 Annual Review of Results/Science

Planning Workshop

On an annual basis, at a time to be determined, a Science Workshop will be held to review the key research results. Some of the individual investigations may possibly be integrated into a broader cloud-radiation context. Results from the previous year will be used to provide new insight into the planning for the upcoming year objectives and operation plans.

A schedule pertinent to the data management activities is included in Table 5.1.

5.6Data Protocol

The FIRE Working Groups are responsible for the certification of data submitted to a permanent FIRE Data Archive. The certification process will normally take 18 months after acquisition. During the certification process period, a set of data protocol and publication ground rules will be agreed upon and abided to by all FSET members as a condition of their participation in the FIRE working groups.

6.0 OPERATIONS

6.1Functional Organization

The functional organization for implementing the ET/LA is shown in Figure 6.1-1. Names, addresses, and phone numbers of the incumbents are provided in Appendix C. A brief description of incumbent responsibilities follows:

Pro ram Manaqer - Responsible for overall program guidance,

g, review and selection of projects and project elements, and NASA funding and support.

Agency Representatives - Responsible for the assisting the Program Manager in selection of projects, project elements, and agency funding and support.

Project Manager - Responsible for the overall management, coordination, and reporting of the project activities.

FSET - Responsible for the goals, objectives, and stratgies for the FIRE Project.

Cirrus and Marine Stratocumulus Working Groups - Responsible for defining the goals of the ET/LA and monitoring the progress of individual and collective research. The membership of the Working Groups will come from the FSET.

ET/LA Subgroup - Responsible for the detailed planning of the ET/L: operations. Solicit and represent ideas of other FSET scientists in planning, execution, and analysis of operations.

O erations Mana er - The Operations Manager will have overP ~ all responsibi: ity for organizing, scheduling, and conducting operations, preparation of operations plans, establishing objectives with the Working Groups, determining special support requirements, conducting planning and data analysis workshops, and operational procedures.

Data Manager - The Data Manager will be responsible for coordinating the types, scope, and quantity of data collected during the ET/LA operations and its archiving and dissemination.

Satellite Coordinator - The Satellite Coordinator will be responsible for providing information on the periods and locations of satellite observation within each LA area. He is responsible for determining that the appropriate satellite observations are being collected, archived, and made available to the Working Groups and Central Archive.

Field Site Coordinators - The Field Site Coordinators will have primary responsibility for coordinating complementary ground measurement activities and overall integration, testing, operation of experiments, data reduction, "valueadded" data analysis, and data submitted of the instrumentation at their respective sites.

6.2 Observation Sites

6.2.1 Cirrus - Class I

Salt Lake City, UT - K. Sassen
Hampton, VA - M. P. McCormick
Boulder, CO - F. Hall

6.2.2 Cirrus - Class II

Champaign, IL - TBD

Mauna Loa, HA - J. Deluisi
Madison, WI - D. Wylie
Palisades, NY - G. Kukla
West Lafayette, IN - R. Davies

6.2.3 Marine Stratocumulus

San Nicolas Island, CA - C. Fairall

6.3 Experiment Responsibilities

6.3.1 Cirrus - Class I

Salt Lake City, UT - K. Sassen Hampton, VA - M. P. McCormick Boulder, CO - F. Hall

6.3.2 Cirrus - Class II

Champaign, IL - TBD Mauna Loa, HA - J. Deluisi Madison, WI - D. Wylie Palisades, NY - G. Kukla West Lafayette, IN - R. Davies

6.3.3 Marine Stratocumulus

San Nicolas Island, CA - C. Fairall

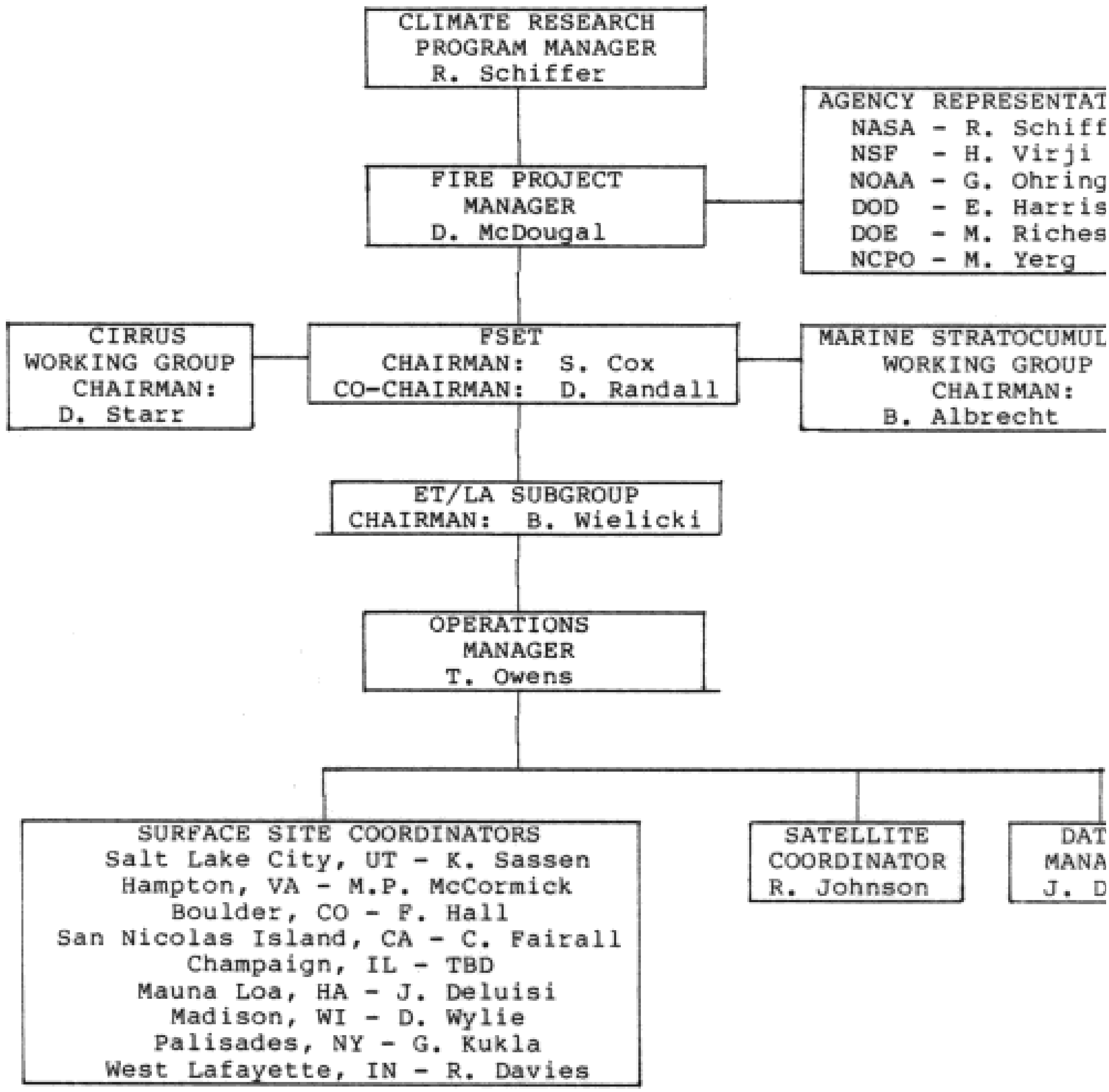

Figure 6.1-1 - Extended Time/Limited Area Functional Organization

APPENDIX A
SCIENTIFIC ELEMENTS

A.1 Satellite Observation Applications for Marine Stratocumulus Studies

As a part of ISCCP, FIRE is closely tied to satellite measurements and their interpretation. Marine stratocumulus clouds present one of the most vexing aspects of satellite data interpretations: images taken at different resolutions almost invariable show different amounts of cloud cover in the same scene. Since satellites offer an economical climate monitoring technique it is important to resolve such ambiguities. The FIRE stratocumulus studies will identify the processes in the CTBL that cause the ambiguities. Satellite observations will be used for extended time observations, with surface measurements to validate the satellite retrieval algorithms. A summary of the proposed satellite work is given in Table A.1-1.

Satellite imagery can provide quantitative characterizations of stratocumulus cloudiness. The imagery can be used to determine the time and space scales for the variability of cloud amount, cloud height, and visible reflectivity, and the cloud cover and radiative properties that can be linked to the thermodynamic structure of the lower atmosphere. Of course, as techniques for analyzing the imagery data are relatively new, their validation is an essential component of any major experiment such as FIRE.

The FIRE monitoring and intensive work is intended to provide a complete picture of the dynamics and thermodynamics will be obtained and related to satellite-observed parameters. A crucial role of satellite data is to provide a multi-year climatological setting for the intensive process studies.

A first aim of satellite observations for the CTBL is to determine the time scales (minutes-days) and space scales t1-3000 km) associated with variability within stratocumulus systems. The cellular structures and linear cloud bands evident in many images suggest that typical systems contain variations on a wide range of spatial scales. Temporally variability is also spectrally rich. An important observed aspect of stratocumulus systems is their diurnal evolution within a given geographical reyion. Diurnal variations of cloud-top height have been predicted in a number of model studies. Geostationary satellites will document this evolution.

Satellite imagery also provides an immediate opportunity to cha~acterize the radiative properties of stratocumulus systems. The systems do not always reflect solar radiation as plane parallel cloud models would predict; instead, they exhibit reflectivities with a large degree of horizontal variability. Unlike their infrared counterparts, radiances at visible wavelengths show nothing which typifies a stratocumulus cloud deck. In some cases, clouds which emit locally uniform radiation at 11 pm for mesoscale regions and larger do not show similarly uniform local radiances. The variability in reflectivity is due to the smallscale structure of cloud liquid water. Through multiwavelength observations it will be possible to analyze the dependence of the reflectivity on the liquid water content. A dual-channel microwave radiometer will also help to make this link. In addition, analysis of simultaneous views from different angles, obtainable from two geostationary satellites or from a combination of geostationary and polar orbiters, will characterize significant finitecloud effects on the observed radiances.

To validate the reflectivities determined with the satellites, they will be compared with radiances measured by ERBE sensors and/or calibrated aircraft-borne radiometers during the Intensive Field Observations. The aircraft-borne radiometers will test the validity of the spatial structure interred from satellite-derived reflectivities.

Table A.1-1

SUMMARY OF FIRE STRATOCUMULUS SATELLITE OBSERVATIONS

GOES	Visible and Infrared Spin Scanner Radiometer (VISSR)	Cloud fraction, cloud top, albedo, diurnal variations.
ERBS	Broad-band IR and Shortwave	Mesoscale structure, real time imagery.
NOAA	Advanced Very High Resolution Radiometer (AVHHR/HIRS)	High resolution cloud structure, comparison with *in situ* measurements and LANDSAT satellite data interpretation.
LANDSAT	Multispectral Scanner (MSS) Thematic mapper (TM) (Visible 28.5 m resolution; IR 120 m)	Size distribution of cloud elements, comparison with *in situ* measurements.

APPENDIX B

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DESCRIPTION OF INSTRUMENTATION

B.1 Satellite

TBD

B.2 Surface

B.2.1 Cirrus - Class I

TBD

B.2.2 Cirrus - Class II

TBD

B.2.3 Marine Stratocumulus

TBD

B.2.4 Radiosonde

TBD

APPENDIX C
FIRE Program, Project, and LA Personnel

Program Manager:	Dr. Robert A. Schiffer Code EET National Aeronautics and Space Administration Washington, D.C. 20546 (202) 453-1438 FTS453-1438
Project Manager:	Mr. David S. McDougal Mail Stop 483 NASA Langley Research Center Hampton, VA 23665 (804) 865-4342 FTS928-4342
Operations Manager:	Mr. Thomas L. Owens Mail Stop 483 NASA Langley Research Center Hampton, VA 23665 (804) 865-4343 FTS928-4343
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FSET Chairman:	Dr. Stephen K. Cox Dept. of Atmospheric Science Colorado State University Ft. Collins, CO 80523 (303) 491-8594
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Boulder, CO Coordinator:	Dr. Freeman F. Hall NOAA/WPL R/E/WP2 325 Broadway Boulder, CO 80303 (303) 497-6312 FTS 320-6312
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Satellite Coordinator:

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(804) 865-437 5
FTS 928-4375

APPENDIX D

PROPOSED STANDARD DATA FORMATS FOR FIRE

The following are proposed data format guidelines for all FIRE data sets submitted to the FIRE Central Archive. The detailed data tape format specifications discussed below are meant to serve as a guide to the FIRE Science Experiment Team (FSET) which - will approve the actual data format specifications.

1. Types of data

FIRE will produce several distinct types of data exhibiting very different characteristics: (a) digital satellite image data which are usually large in volume with varied formats and appended information, (b) digital ground and aircraft instrument data which can be either small or large in volume with formats that are nearly unique to the instruments, and (c) photographs (analog data) produced by ground and aircraft observers to document the clouds present. The film data are completely distinct from the digital data. The scientific objectives of FIRE call for the analysis of all these data types together for many cases in order to elucidate cloud and radiation processes and to obtain statistical descriptions of the cloud properties. Some standasrdization of data formats is required to facilitate this analysis.

2. Data archived

The data collected during FIRE will be held in a distributed archive, including the individual investigator holdings and the FIRE Central Archive; however, certain subsets of the total data set will be selected by the FSET for special study or identified by the FSET as especially important. All of these data will be submitted to the FIRE Central Archive to facilitate team-interaction and later to a permanent FIRE data archive. Only these data must be reformatted into the standard formats outlined here; however, investigators are encouraged to adopt the format described below for their own use or to take advantage of the formatting software developed for this purpose to reformat any data requested by another investigator.

3. Submission of data to archive

Since the format standards described here allow some variations of the format, investigators or other providers of data to FIRE must seek approval of their format by the FSET by submitting a document describing the format along with a sample data tape. The FIRE Central Archive will check the sample data tape to verify that it corresponds to the documentation for the approved format. In addition to the revised data format document, each investigator submitting data to the archive must provide the following: copies
(iii) Tape files may be composed of more than one data type (e.g., character, integer), but each record must be composed entirely of a single data type.

(iv) All tapes should be in unlabeled format; i.e., there should be no extra computer-specific records or files that identify a data file to that particular computer systems.

4.2 Data characteristics ~

(i) Only two data types shall be used: CHARACTER type (ASCII) for labelling and other textual information and 16-bit INTEGER for all numerical values.

(ii) All numerical values shall be reported as scaled integers with the scale factors given as numerical values in the same file; in other words, no floating point values should be used.

(iii) Bad data, missing data or filling of numerical records should be represented by the integer value corresponding to all 16-bits set to 1. Missing information or filling of character records should be represented by blanks.

4.3 Tape file structure

(i) Each data tape shall be constructed of a Volume ID file, a Volume Table of Contents file, a fixed number of Ancillary Data files, and a variable number of Observation Data files.

(ii) The last file on the tape shall be followed by an extra end-of-file mark.

(iii) The Volume ID and Table of Contents files are to be written entirely in CHARACTER type data.

(iv) All Data files begin with a fixed number of records containing only CHARACTER type data (the header) followed by a variable number of records containing INTEGER type data (the data),

(v) A fixed number of the first data records in a file shall contain the "global" numerical values (such as scale factors) described in the header for ease of processing.

4.4 File contents and structure

4.4.1 Volume ID file

This file is always the first file on a data tape and is composed entirely of ASCII CHARACTER type data, arranged in 80-byte units (card images), representing text describing the tape contents. The text information is arranged into five segments, each terminated by three 80-byte sequences of character blanks. This file should contain at least the following information.

CARD IMAGE #	CONTENTS
	SEGMENT 1

1 FIRE.CCCC.DDDD.BBBB.NNNNNN.V.YYDDD.YYDDD

CCCC = FIRE data collection element
(ETEA, ETLA, CIFO, STFO)
DDDD = source institution or investigator
BBBB = type of data (variable or
instrument name)
NNNNNN = tape sequence number for that
data type which is unique and
. starts with 000001
V = tape version number starting with 0
YYDDD = year and Julian day of first data
YYDDD = year and Julian day of last data

2 Investigator name(s) or contact person
3 - 7 Investigator institution address
8 Tape creation date (YYDDD)
9 - 10 Internal input tape numbers used to create tape
11 Tape creation software version number as date of last change (YYDDD)
12 Total number of files on tape
13 - II Contents of ancillary data files: variables, units, coverage and resolution
II+1 - JJ Contents of observation data files: variables, units, coverage and resolution

SEGMENT 2

JJ+2 - JJ+4 Instrument name and numerical code number
JJ+5 - KK Instrument description, including manufacturer, platform, spectral channels, sensitivity, noise level, spectral, time and space resolution

SEGMENT 3

KK+2 - LL Description of distribution of observations in time period
LL+1 - MM Description of observation site or location, navigation information, coordinate system used
MM+1 - NN Calibration information including source, uncertainties, and calibration factors

SEGMENT 4

NN+2 - III Bibliography of instrument

specifications, calibration, analysis
methods, and algorithms

SEGMENT 5

III+2 - JJJ Software for data manipulation, such as tape reading, navigation, remapping

4.4.2 Volume Table of Contents file

This file is always the second file on a data tape and is composed entirely of ASCII CHARACTER type data, arranged in 80-byte units (card images), representing text describing the tape contents. The textual information is arranged in the form of a table showing a file by file listing of contents. Information listed for each file should include the following.

Data file sequence number on tape

Data sequence number within data set
Date of first and last observations in file
Time of first and last observations in file
Variables actually present in file
Geographical region covered by data in file
Spatial resolution of data in file
Time resolution of data in file

The data sequence number refers to an internal numbering of observations within an observation set (e.g., image number, orbit number, flight number) that is used to relate the observations on this data tape to other observations on other data tapes. In order to keep the table of contents compact enough to be useful as a guide to data on the tape, the information about geographic coverage and time/space resolution should be highly coded and need only provide an approximate indication of these features of the data.

4.4.3 Data file

The first 10 records in a data file (ancillary or observation) contain descriptive information about the data in that file and are composed entirely ASCII CHARACTER type data. These records are called the file header. The next 2 records repeat all nume~ical factors in the file header, but entirely in 16-bit INTEGER form for computational convenience. These records are called the numerical file header. These parts of a data file must remain fixed even if the records are mostly fill. The information provided in both these parts of a data file should include the following.
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ASCII HEADER NUMERICAL HEADER

File number on tape *
Data sequence number within
data set on tape *
Number of records in header *

Number of records in numerical header *
Number of records for navigation *
Number of records for calibration *
Beginning date *
Beginning time *
Geographic location of first data *
Ending date *
Ending time *
Geographic location of last data *
Time resolution
Spatial resolution
Spectral resolution
Each variable, name
code number *
units
source instrument
instrument code *
order within file
observation sequence
obs. seq. numbers *
scale factors *
variable range *
Analysis method (brief) description
Code for data source (from Volume ID) *

The header information concerning the variables reported in the data file should provide a guide to the actual arrangement of the data within that file; i.e., the specific variables should be identified in the data records by code numbers given in the header and their order of appearance in the file described.

All data records within a data file should begin with a series of sequence numbers to prevent loss of synchronization by I/O errors. These sequence numbers are as follows.

Record sequence number within the file File number on tape observation sequence number on tape Data type code number Beginning data sequence number within file Ending data sequence number within file

The data sequence numbers within a file are simply reference numbers indicating the position of the data in that record within the file.

5. Standard format for satellite data

Satellite data will be submitted to the FIRE Central Archive in nearly original format to avoid reprocessing of this large volume of data. Certain modifications of the formats may be necessary, however, to insure the presence of all of the proper ancillary information or to change features which produce special handling difficulties. (No changes for the latter purpose are anticipated.) The FIRE Central Archive will attempt to supply satellite data to FIRE investigators which have been modified slightly to provide some uniform structure or to prepare complete format documentation, including sample tape-read software. However, certain satellite data sets identified by the FSET, especially for the key case studies, will be reprocessed into the standard format described above to facilitate intensive data comparisons. Investigators supplying satellite data to other investigators or analyzing certain subsets of the satellite data at the request of the FSET are also encouraged to reformat these data as well.

The key modification of the standard format for large volume satellite data sets is the use of 8-bit INTEGER to represent the radiances rather than 16-bit INTEGER. In this case bad or missing data will be represented by the integer value that corresponds to all bits set to 1. Interleaving of 8-bit and 16-bit INTEGERs may also be necessary. All such data should be arranged so that the numerical values are aligned on 16-bit word boundaries. (For example, an odd number of 8-bit values should not occur between two 16-bit values.)

6. Guidelines for organization of data

Because of the diversity of the FIRE data sets and planned analyses, specification of a single "best" way to organize these data is impractical. However, certain basic principles can be followed.

(i) Use of file divisions. The arrangement of the data on a single data tape should follow a "natural" sequence, usually time sequences of spatially correlated observations. The division of the sequence into files on the tape should produce a moderate number (10 -100) of files: too few files are vulnerable to I/O errors while too many files waste tape in end-of-file marks. (This guideline refers primarily to data sets which fill one or more data tapes.) Time records should be broken into at least daily files.

(ii) Geographical location information. Satellite data form an image of a region at one time; location information may be supplied as a function of pixel coordinate or interleaved with the data values. The latter is more convenient if the relation between pixel coordinate and location is variable; the former is more convenient if the relation is fixed, at least within the file. Ai~craft data should be presented as time records to which location tags asre appended.

(iii) Multi-component data. Many FIRE data sets are composed of measurements from multi-channel instruments or from groups of instruments making coincident measurements. Although many investigators may wish to examine particular components of such data sets and would, therefore, prefer the components in separate files, the heart of the FIRE concept is the analysis of many simultaneous or coincident observations of the same cloud. Since most multicomponent data are naturally collected with the different variables interleaved,these data should be organized by time period into files containing multiple variables that are interleaved to give all observations at each location.

(iv) Data and analysis products. Data (raw or reduced through straightforward processing) should be compiled separately from analysis products and placed on separate data tapes. However, subsequent studies of the initial analysis products can be enhanced by interleaving the original data on the data product tapes. Therefore, multiple forms of the same data may be required.

(v) The FSET shall decide the data types, analysis product types, and other desired combinations of these that will be produced by all data suppliers.
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APPENDIX E

LANDSAT 5 OVERPASS DATES FOR HAMPTON, VIRGINIA
TIME PERIOD: 1986 THROUGH 1988
TIME OF OVERPASS: 1510 GMT

1986	1987	1988
MONTH/DAY	MONTH/DAY	MONTH/DAY
1/14	1/1	1/4
1/ 30	1 / 17	1 / 20
2/15	2/2	2/5
3/3	2/18	2/21
3/19	3/6	3/8
4/4	3/22	3/24
4/20	4/7	4/9
5/6	4/23	4/25
5/22	5/9	5/11
6/7	5/25	5/Z7
6/23	6/10	6/12
7 /9	6/26	6/28
7/25	7/12	7/14
8/l0	7/28	7/30
8/26	8/13	8/15
9/11	8/29	8/31
9 /27	9 /14	9/16
10/13	9/30	10/2'
10/29	10/16	10/18
11/14	11/1	11/3
11/30	11/17	11/19
12/16		

LANDSAT 5 OVERPASS DATES FOR BOULDER, COLORADO

TIME PERIOD: 1986 THROUGH 1988

TIME OF OVERPASS: 1713 GMT

1986 MONTH/DAY	1987 MONTH/DAY	1988 MONTH/DAY
1/10	1/13	1/16
1/26	1/29	2/1
2/11	2/14	2/17
2/27	3/2	3/4
3/15	3/18	3/20
3/31	4/3	4/5
4/16	4/19	4/21
5/2	5/5	5/7
5/18	5/21	5/23
6/3	6/6	6/8
6/19	6/22	6/24
7/5	7/8	7/10
7/21	7/24	7/26
8/6	8/9	8/11
8/22	8/25	8/27
9/7	9/10	9/12
9/23	9/26	9/28
10/9	10/12	10/14
10/25	10/28	10/30
11/10	11/13	11/15
11/26	11/29	12/1
12/12	12/15	12/17
12/28	12/31	

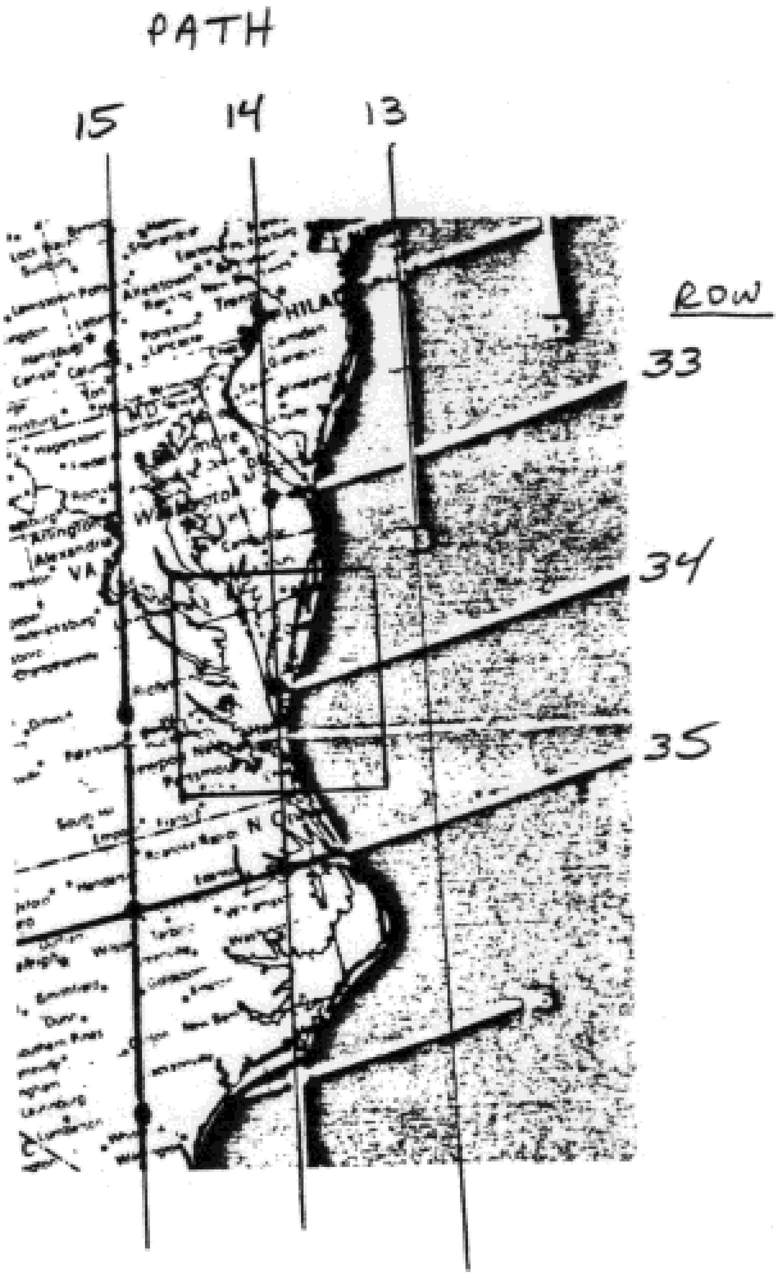
LANDSAT 5 OVERPASS DATES FOR SALT LAKE CITY, UTAH

TIME PERIOD: 1986 THROUGH 1988

TIME OF OVERPASS: 1738 GMT

1986 MONTH/DAY	1987 MONTH/DAY	1988 MONTH/DAY
1/6	1/9	1/12
1/22	1/25	1/28
2/7	2/10	2/13
2/23	2/26	2/29
3/11	3/14	3/16
3/27	3/30	4/1
4/12	4/15	4/17
4/28	5/1	5/3
5/14	5/17	5/19
5/30	6/2	6/4
6/15	6/18	6/20
7/1	7/4	7/6
7/17	7/20	7/22
8/2	8/5	8/7
8/18	8/21	8/23
9/3	9/6	9/8
9/19	9/22	9/24
10/5	10/8	10/10
10/21	10/24	10/26
11/6	11/9	11/11
11/22	11/25	11/27
12/8	12/11	12/13
12/24	12/27	12/29

LANDSAT AREA COVERED FOR VIEWS OF HAMPTON, VA PATH=14, ROW=34



LANDSAT

AREA COVERED FOR VIEWS OF SALT LAKE CITY, UT. (PATH = 41, ROW = 32) AND BOULDER, CO. (PATH=37, ROW=32). LANDSAT SCENE AREAS ARE 170KM BY 180 KM IN EXTENT.

TIME OF OVERPASS IS

LANDSAT OVERPASS TIMES FOR CLASS I SURFACE SITES
TBD

Appendix F

NOAA 9 Polar Orbiter Overpass Times

for Boulder, CO

The Langley Orbital Sampling Analysis Program has been used to calculate the overpass times and viewing angles of the NOAA 9 spacecraft for Boulder, CO(Table F.1). The time in GMT and the viewing zenith angle and azimuth angle measured from North are listed which coincide with the satellite AVHRR scanner observations of the ground site. These data are for the closest passage of the satellite to the site. The maximum viewing angle considered is 70 degrees. The printout includes the relative azimuth angle measured from the solar plane and the solar zenith angle at the site. In addition, the latitude and longitude of the satellite nadir position and the solar time at the subsatellite point are provided for your information. Both ascending (daytime) and descending(nighttime) coincident measurment opportunities are listed. The primary days(days 5 through 10 and 20 through 25) for each month are identified by an asterisk.
Table F.2 lists the latitudes and longitudes for each of the Class I and II surface sites for which the overpass predictions have been calculated. Table F.3 lists the FIRE Surface Observation distribution list for which the predictions have been provided.

TABLE F.1

NOAA-9 OVERPASS TIMES FOR BOULDER, COLORADO

BOULDER, COLORADO
LAT= 40.00   LONG= 255.00

GMT YR	MO	DA	HR	MN	VIEWING ZENITH	AZIMUTH FR. NORTH	RELATIVE AZIMUTH	SOLAR ZENITH	SATELLITE DIRECTION	SATELLITE POSITION LAT	SATELLITE POSITION LONG	SATELLITE SOL. TIME	PRIMARY DAYS
85	4	1	10	11	2.08	113.24	57.72	118.12	DEC	39.97	255.34	3.13	
85	4	1	19	57	68.97	62.90	139.40	37.41	ASCENDING	45.04	272.15	14.00	
85	4	1	21	37	36.80	259.03	24.39	49.47	ASCENDING	38.98	248.82	14.12	
85	4	2	10	0	19.34	103.07	50.16	119.45	DEC	39.52	257.92	3.13	
85	4	2	21	26	23.05	256.62	24.42	47.56	ASCENDING	39.37	251.42	14.12	
85	4	3	9	49	33.55	100.88	50.59	120.66	DEC	39.13	260.52	3.11	
85	4	3	21	16	6.96	258.78	29.15	45.69	ASCENDING	39.92	253.97	14.13	
85	4	4	9	39	45.04	99.06	51.52	121.88	DEC	38.78	263.13	3.12	
85	4	4	11	19	65.02	295.65	132.69	105.59	DEC	44.36	239.61	3.23	
85	4	4	21	5	11.01	74.15	152.75	43.88	ASCENDING	40.40	256.53	14.13	
85	4	5	9	28	54.06	97.35	52.63	123.02	DEC	38.49	265.77	3.12	*
85	4	5	11	9	60.23	294.23	131.96	107.13	DEC	43.59	242.05	3.21	*
85	4	5	20	54	25.76	73.25	150.84	42.17	ASCENDING	40.93	259.07	14.11	*
85	4	6	9	17	61.15	95.67	53.85	124.08	DEC	38.25	268.42	3.12	*
85	4	6	10	58	53.55	292.15	131.85	108.64	DEC	42.76	244.47	3.20	*
85	4	6	20	44	38.59	70.50	150.51	40.49	ASCENDING	41.63	261.56	14.11	*
85	4	6	22	25	69.76	266.50	18.91	56.25	ASCENDING	37.87	237.33	14.17	*
85	4	7	9	6	66.83	94.02	55.18	125.05	DEC	38.06	271.09	3.12	*
85	4	7	10	47	44.89	289.90	131.62	110.15	DEC	41.98	246.92	3.20	*
85	4	7	20	33	48.56	69.26	148.57	38.92	ASCENDING	42.27	264.06	14.10	*
85	4	7	22	14	64.73	264.81	19.15	54.14	ASCENDING	38.03	240.00	14.18	*
85	4	8	10	37	33.98	288.66	130.77	111.58	DEC	41.36	249.43	3.18	*
85	4	8	20	22	56.37	67.08	147.26	37.41	ASCENDING	43.07	266.49	14.10	*
85	4	8	22	3	58.55	263.08	19.43	52.05	ASCENDING	38.24	242.66	14.18	*
85	4	9	10	26	19.69	288.15	128.89	113.02	DEC	40.80	251.96	3.18	*
85	4	9	20	12	62.49	65.03	145.70	36.02	ASCENDING	43.92	268.90	14.08	*
85	4	9	21	52	50.77	261.27	19.74	50.00	ASCENDING	38.51	245.31	14.18	*
85	4	10	10	15	4.55	282.47	132.13	114.40	DEC	40.17	254.47	3.19	*
85	4	10	20	1	67.46	63.59	143.31	34.73	ASCENDING	44.71	271.33	14.06	*
85	4	10	21	41	40.60	254.31	20.01	47.97	ASCENDING	38.82	247.93	14.18	*
85	4	11	10	5	13.77	102.80	50.65	115.68	DEC	39.71	257.04	3.17	
85	4	11	21	31	28.11	258.96	22.03	45.99	ASCENDING	39.31	250.50	14.18	
85	4	12	9	54	28.60	100.95	51.37	116.96	DEC	39.29	259.63	3.17	
85	4	12	21	20	13.02	257.06	22.65	44.04	ASCENDING	39.73	253.09	14.19	
85	4	13	9	43	41.35	100.59	53.64	118.17	DEC	38.81	262.20	3.18	
85	4	13	11	23	67.24	296.34	130.74	102.05	DEC	44.67	238.79	3.29	
85	4	13	21	9	5.13	77.20	154.64	42.19	ASCENDING	40.19	255.66	14.17	
85	4	14	9	37	51.20	98.64	54.39	119.31	DEC	38.49	264.82	3.18	

Table F.2 GROUND SITES FOR PROJECT FIRE

SITE	LATITUDE (°N)	LONGITUDE (°W)
BOULDER, CO[1,2]	40.08	105.00
CHAMPAIGN, IL[2]	40.17	88.25
HAMPTON, VA[1]	37.08	76.35
MADISON, WI[2]	43.22	89.35
MAUNA LOA, HI[2]	19.50	155.58
PALISADES, NY[2]	41.00	73.92
SALT LAKE CITY, UT[1,2]	40.77	111.85
SAN NICOLAS ISLAND, CA[3]	33.23	119.47
WEST LAFAYETTE, IN[2]	40.33	86.92

[1]Cirrus Class I site (instruments include lidar systems).

[2]Cirrus Class II site.

[3]Marine Stratocumulus Class I site.

TABLE F-3 FIRE SURFACE OBSERVATION DISTRIBUTION LIST

Dr. Bruce Albrecht, Penn State
Dr. Stephen K. Cox, CSU
Dr. Ken Davidson, Naval P.S.
Dr. Roger Davies, Purdue Univ.
Dr. John DeLuisi, NOAA/ERL
Dr. Yerner E. Derr, NOAA/ERL
Dr. Walter Egan, Grumman
Dr. Christopher W. Fairall, Penn State
Dr. Herman Gerber, NRL
Dr. Freeman F. Hall, NOAA/NPL
Dr. Andrew J. Heymsfield, NCAR

Dr. Robert Kropfli, NOAA/WPL
Dr. George S. Kukla, Columbia Univ.
Dr. M. Patrick McCormick, NASA/LaRC
Dr. David A. Randall, NASA/GSFC
Dr. Lothar Ruhoke, NRL
Dr. Ken Sassen, Univ. of Utah
Dr. David O'. C. Starr, SUNY
Dr. Verner E. Suomi, Univ. of Wisc.
Dr. Bruce A. Wielicki, NASA/LaRC
Dr. James Wienman, Univ. of Wisc.
Dr. Donald P. Wylie, Univ. of Wisc.

Mr. Joseph Drewry, NASA/LaRC
Dr. Robert Johnson, NASA/LaRC
Mr. David S. McDougal, NASA/LaRC
Mr. Thomas Owens, NASA/LaRC

NOAA POLAR ORBITER (AFTERNOON) OVERPASS TIMES
FOR CLASS I AND CLASS II SURFACE SITES

TBD

APPENDIX G

SAGE II (ERBS SATELLITE) OVERPASS TIMES FOR

CLASS I AND CLASS II SITES

Opportunities for near coincidental SAGE II satellite observations with other remote sensing measurement techniques can be determined from a knowledge of the predicted position of the Earth Radiation Budget Satellite (ERBS). A computer program was developed at NASA Langley Research Center to update the spacecraft position every minute from an initial set of measured orbital parameters. From this information, the geographical tangent location of the satellite-solar line of sight is calculated as it transverses through the atmosphere during local satellite sunrises and sunsets. The SAGE II sampling locations determined at the Earth's surface are compared with the specified location of potential correlative observations to provide a convenient list of possible near satellite overpasses. A list of these opportunities is presented for each of the specified experimental sites. All SAGE II sampling opportunities contained within a radius of 500 km from a given site are included in this list between April 1, 1986 and April 1, 1987.

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

PALISIDE, NY
STD LATITUDE 41.0
STD LONGITUDE -73.9
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
42.20	290.68	5/19/1986	9:18:13.26	404.35	SUNRISE
41.98	283.93	7/ 5/1986	0:37: 8.51	211.78	SUNSET
44.43	287.42	7/31/1986	9:41:33.08	396.77	SUNRISE
39.39	286.14	11/ 9/1986	21:41:40.11	179.73	SUNSET
41.91	281.48	11/10/1986	21:53:42.87	398.53	SUNSET
43.57	290.93	12/24/1986	12:12:27.30	490.02	SUNRISE
39.87	289.84	1/ 9/1987	12: 6:33.51	340.53	SUNRISE
37.61	285.22	1/10/1987	12:18:31.42	385.32	SUNRISE
37.31	288.38	1/20/1987	21:53:16.92	455.87	SUNSET
40.24	283.81	1/21/1987	22: 5:23.80	211.18	SUNSET
44.78	284.78	2/ 7/1987	22:12:41.68	434.22	SUNSET
42.33	283.40	2/ 8/1987	22:24:45.94	268.47	SUNSET
39.32	282.08	2/ 9/1987	22:36:57.61	389.84	SUNSET
41.97	285.51	3/31/1987	10:47:49.95	118.43	SUNRISE

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

NASA LANGELY RESEARCH CENTER, VA
STD LATITUDE 37.1
STD LONGITUDE -76.3
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
35.71	286.74	4/ 1/1986	10:44: 4.30	310.86	SUNRISE
36.06	281.36	10/10/1986	11:20:53.54	236.60	SUNRISE
39.92	279.27	10/11/1986	11:33:10.44	500.78	SUNRISE
39.39	286.14	11/ 9/1986	21:41:40.11	336.09	SUNSET
37.61	285.22	1/10/1987	12:18:31.42	148.20	SUNRISE
34.97	280.48	1/11/1987	12:30:33.87	371.50	SUNRISE
37.31	288.38	1/20/1987	21:53:16.92	415.94	SUNSET
40.24	283.81	1/21/1987	22: 5:23.80	354.90	SUNSET
39.32	282.08	2/ 9/1987	22:36:57.61	289.21	SUNSET
35.60	280.81	2/10/1987	22:49:19.23	305.36	SUNSET
33.61	281.68	3/ 3/1987	11:43:45.90	425.06	SUNRISE
37.77	279.03	3/ 4/1987	11:55:58.75	420.52	SUNRISE

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

MADISON, WI
STD LATITUDE 43.2
STD LONGITUDE -84.2
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
44.95	279.10	4/23/1986	0:12:13.56	327.85	SUNSET
41.46	274.92	4/24/1986	0:24: 9.96	206.59	SUNSET
42.55	278.30	9/16/1986	23:30:32.65	216.57	SUNSET
38.95	274.64	9/17/1986	23:42:29.63	483.11	SUNSET
39.92	279.27	10/11/1986	11:33:10.44	465.86	SUNRISE
43.21	277.25	10/12/1986	11:45:19.33	117.85	SUNRISE
46.01	275.30	10/13/1986	11:57:21.90	315.32	SUNRISE
44.14	275.75	10/31/1986	12:16:41.83	104.49	SUNRISE
40.69	271.35	11/ 1/1986	12:28:57.56	462.24	SUNRISE
41.91	281.48	11/10/1986	21:53:42.87	487.20	SUNSET
44.00	276.95	11/11/1986	22: 5:39.93	129.16	SUNSET
45.71	272.58	11/12/1986	22:17:31.82	378.74	SUNSET
46.24	276.55	11/26/1986	21:47:16.14	343.12	SUNSET
44.75	274.70	11/27/1986	21:59: 5.05	193.42	SUNSET
42.90	273.08	11/28/1986	22:10:59.40	223.57	SUNSET
40.60	271.70	11/29/1986	22:23: .69	446.34	SUNSET
44.64	278.47	1/ 6/1987	13: 7:50.37	267.22	SUNRISE
43.30	274.33	1/ 7/1987	13:19:37.09	120.00	SUNRISE
42.76	279.42	1/22/1987	22:17:25.86	298.86	SUNSET
44.90	275.22	1/23/1987	22:29:23.48	194.99	SUNSET
41.37	276.31	3/ 5/1987	12: 8: 2.18	207.90	SUNRISE
44.51	273.51	3/ 6/1987	12:19:58.12	234.52	SUNRISE

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

BOULDER, COLORADO
STD LATITUDE 40.1
STD LONGITUDE -105.0
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
41.21	250.64	4/24/1986	2: 0:58.32	390.47	SUNSET
41.76	259.54	7/ 5/1986	2:13:55.96	426.70	SUNSET
38.29	253.89	7/ 6/1986	2:25:44.81	218.19	SUNSET
42.33	254.06	9/17/1986	1: 7:19.95	265.92	SUNSET
38.70	250.40	9/18/1986	1:19:17.46	423.09	SUNSET
36.31	257.22	10/10/1986	12:57:42.46	459.13	SUNRISE
40.15	255.13	10/11/1986	13: 9:59.11	15.56	SUNRISE
43.41	253.12	10/12/1986	13:22: 7.73	405.11	SUNRISE
42.05	257.19	11/10/1986	23:30:30.39	288.43	SUNSET
44.11	252.67	11/11/1986	23:42:27.04	491.47	SUNSET
40.41	259.52	1/21/1987	23:42:11.96	385.94	SUNSET
42.91	255.14	1/22/1987	23:54:13.66	318.39	SUNSET
42.15	259.31	2/ 9/1987	0: 1:34.31	430.56	SUNSET
39.08	258.00	2/10/1987	0:13:47.06	279.33	SUNSET
38.01	254.85	3/ 4/1987	13:32:46.82	227.00	SUNRISE
41.58	252.12	3/ 5/1987	13:44:49.74	296.15	SUNRISE

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

SALT LAKE CITY, UTAH
STD LATITUDE 40.8
STD LONGITUDE -111.0
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
41.21	250.64	4/24/1986	2: 0:58.32	146.83	SUNSET
37.42	246.41	4/25/1986	2:12:59.49	432.70	SUNSET
39.17	247.40	5/18/1986	12:19:58.65	223.15	SUNRISE
37.82	248.60	7/29/1986	12:31:21.12	327.80	SUNRISE
41.47	243.69	7/30/1986	12:43:16.71	452.27	SUNRISE
42.33	254.06	9/17/1986	1: 7:19.95	456.73	SUNSET
38.70	250.40	9/18/1986	1:19:17.46	257.77	SUNSET
43.41	253.12	10/12/1986	13:22: 7.73	450.97	SUNRISE
43.91	251.45	10/31/1986	13:53:31.04	405.46	SUNRISE
40.45	247.06	11/ 1/1986	14: 5:46.48	166.93	SUNRISE
44.11	252.67	11/11/1986	23:42:27.04	480.60	SUNSET
44.63	250.59	11/27/1986	23:35:52.79	450.84	SUNSET
42.75	248.99	11/28/1986	23:47:47.61	222.18	SUNSET
40.41	247.63	11/29/1986	23:59:49.37	122.07	SUNSET
37.48	246.53	12/ 1/1986	0:12: .63	422.02	SUNSET
39.67	245.08	12/22/1986	15: 1:57.87	354.67	SUNRISE
41.99	244.05	12/23/1986	15:14: 4.43	435.76	SUNRISE
43.19	250.03	1/ 7/1987	14:56:24.83	284.39	SUNRISE
41.54	245.70	1/ 8/1987	15: 8:15.32	290.03	SUNRISE
41.58	252.12	3/ 5/1987	13:44:49.74	277.56	SUNRISE
44.69	249.32	3/ 6/1987	13:56:45.07	439.27	SUNRISE
39.25	244.55	3/29/1987	1:56:59.04	414.32	SUNSET

SAGE II PREDICTED MEASUREMENT TIME AND LOCATIONS

SAN NICOLAS ISLAND, CA
STD LATITUDE 33.2
STD LONGITUDE -119.5
RADIUS 500.0

LAT(DEG)	LONG(DEG)	DATE	GMT TIME	DIST(KM)	EVENT
34.29	238.39	4/ 1/1986	13:57:57.24	229.71	SUNRISE
33.34	242.14	4/26/1986	2:25: 5.30	153.34	SUNSET
30.65	242.96	7/ 8/1986	2:49:34.52	367.17	SUNSET
35.54	243.51	8/26/1986	13:17:53.20	379.75	SUNRISE
30.09	243.25	9/20/1986	1:43:35.57	433.41	SUNSET
36.42	242.50	11/ 2/1986	14:18: 9.17	402.39	SUNRISE
31.88	237.83	11/ 3/1986	14:30:37.38	290.39	SUNRISE
36.78	242.27	11/ 9/1986	0:43: 8.15	430.41	SUNSET
33.71	245.75	12/ 2/1986	0:24:25.45	490.53	SUNSET
34.45	244.44	1/20/1987	0:54:43.65	390.12	SUNSET