FIRST ISLSCP FIELD EXPERIMENT : EXPERIMENT EXECUTION AND PRELIMINARY ANALYSES

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1. INTRODUCTION

This paper is an overview of the first year of FIFE : it covers the field phase of 1987 and some preliminary results and analyses arising from the first FIFE Results workshop.

FIFE was designed to determine the extent to which satellite data and modeling could yield information on the energy and mass balance of vegetated land surfaces. An explicit recognition of the role of vegetation in the land surface energy balance was central to the design and execution of the experiment as were the problems associated with translating our understanding of biophysical and radiative transfer processes at small scales up to the scales commensurate with satellite data. These problems and some practical considerations are discussed in Sellers et al. (1988) and in more detail in Sellers and Hall (1987). The principal issues currently under investigation by the FIFE scientists may be posed as a series of questions.

Are the FIFE data sufficient in quantity and adequate in quality to:

(i) Improve our understanding of the links between biophysical processes and surface radiance fields at the local scale?

(ii) Check the output of satellite algorithms; that is, to validate our models of radiation, mass and heat flux on larger scales?

(iii) See how the relationships between radiometric observations (remote sensing) and surface fluxes (heat, mass and radiation) change with spatial scale?

Prior to a discussion of these issues, a brief description of the design and execution of the experiment is appropriate.

2. EXPERIMENT EXECUTION

The field phase of FIFE was executed at and around the Konza Prairie Reserve near Manhattan, Kansas during 1987. The FIFE site itself is a 15 x 15 km area of grassland, most of which is under private management for grazing. About one-third of the area is managed as a Long Term Ecological Reserve (the Konza Prairie) for the study of grassland ecosystem dynamics.

Figure 1 shows the location of surface flux stations and automatic meteorological stations (AMS) within the FIFE site. The AMS were put in place in April-May 1987 and are still in operation and the flux stations were moved into the site for the four Intensive Field Campaigns; both kinds of instrumentation were distributed around the site by means of a stratified sampling scheme.

The data acquisition effort of FIFE can be divided into two broad categories; the monitoring effort and the Intensive Field Campaigns (IFCs).

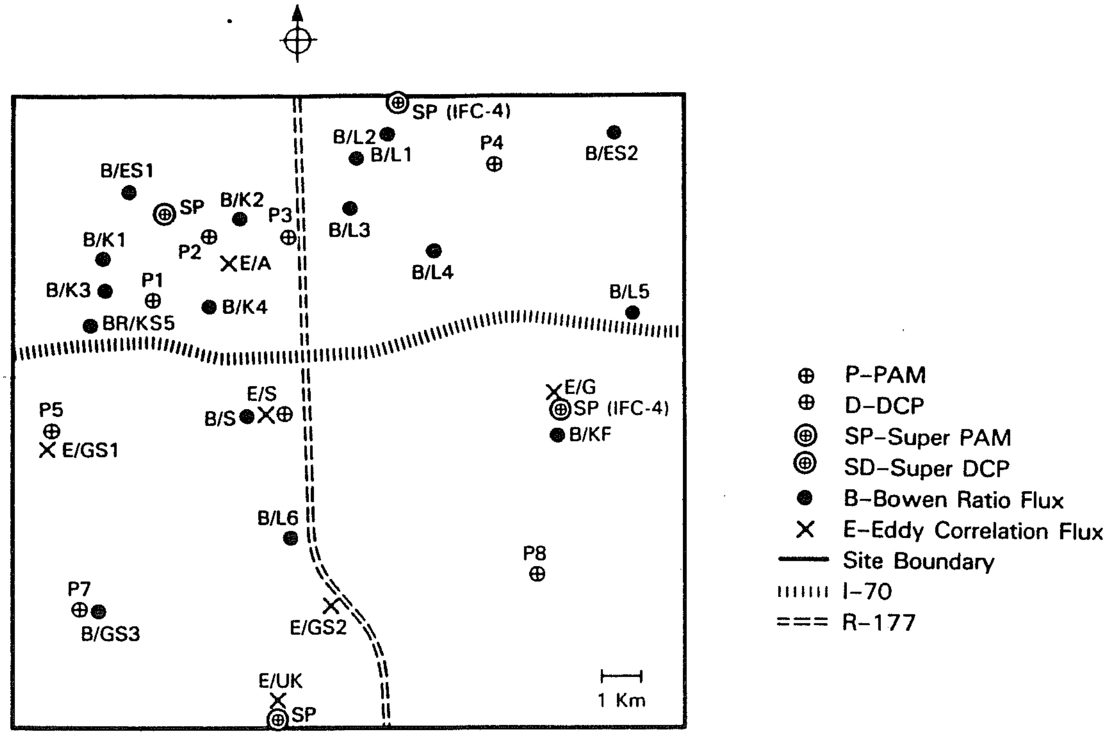

Fig. 1 Map of FIFE site showing locations of flux stations and AMS during the 1987 field phase.

The monitoring effort, which operated more or less continuously through 1987, consisted of the following:

(i) Acquisition of NOAA-9, NOAA-10, Landsat, SPOT and GOES satellite data over and around the site.

(ii) Extraction and archiving of operational NOAA meteorological observations, radiosonde data and analyses for a 500 km area around the site.

(iii) Placement of 16 Automatic Meteorological Stations within the site; each of which reported temperature, humidity, wind speed (2 components), several components of radiation flux, soil temperature and precipitation at 15 minute intervals (see Figure 1).

(iv) A program of gravimetric soil moisture surveys, streamflow measurements and biometric measurements.

(v) A program of sun photometer measurements during satellite overpasses to allow subsequent atmospheric correction of the satellite imagery.

The Intensive Field Campaigns (IFC's) had the specific objective of acquiring surface, airborne and satellite radiometric and flux data together with biophysical and ancillary measurements to allow the comparison of satellite data with surface conditions and fluxes. Because of the large commitment of manpower and resources required for the IFCs, their combined duration during 1987 was only 57 days, see Figure 2. Each IFC was targeted at a separate phase of the vegetations development (IFC-1 'greenup'; IFC-2 'peak greeness'; IFC-3 'dry-down'; IFC-4 'senescence') but the unusual weather conditions produced very similar conditions; wet soils and green vegetation, during the first three IFC's, followed by a totally senescent vegetation cover and dry soil in IFC-4; see Figure 3.

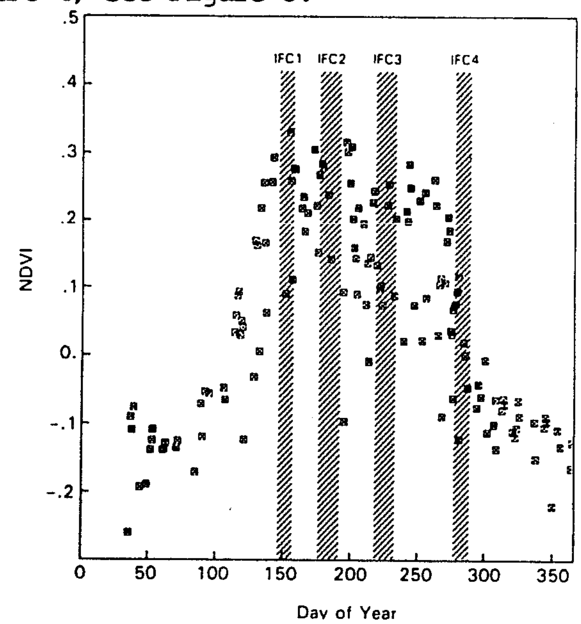

Fig. 2 Timing of Intensive Field Campaigns during 1987. Also shown are the NOAA-9 Normalized Difference Vegetation Index (NDVI) values for the year; high values indicate greener vegetation. Data from Staff/GSFC and Staff/KSU.

Roughly 100 science investigators and support staff were working at the FIFE site during IFC's. These were split into five groups.

(1) Atmospheric Boundary Layer (ABL) Group. The ABL group used three 'flux' aircraft (equipped with airborne eddy correlation equipment) radiosondes and lidars to measure turbulent fluxes of heat mass and momentum, profiles and motion fields, respectively, within the ABL above the FIFE site.

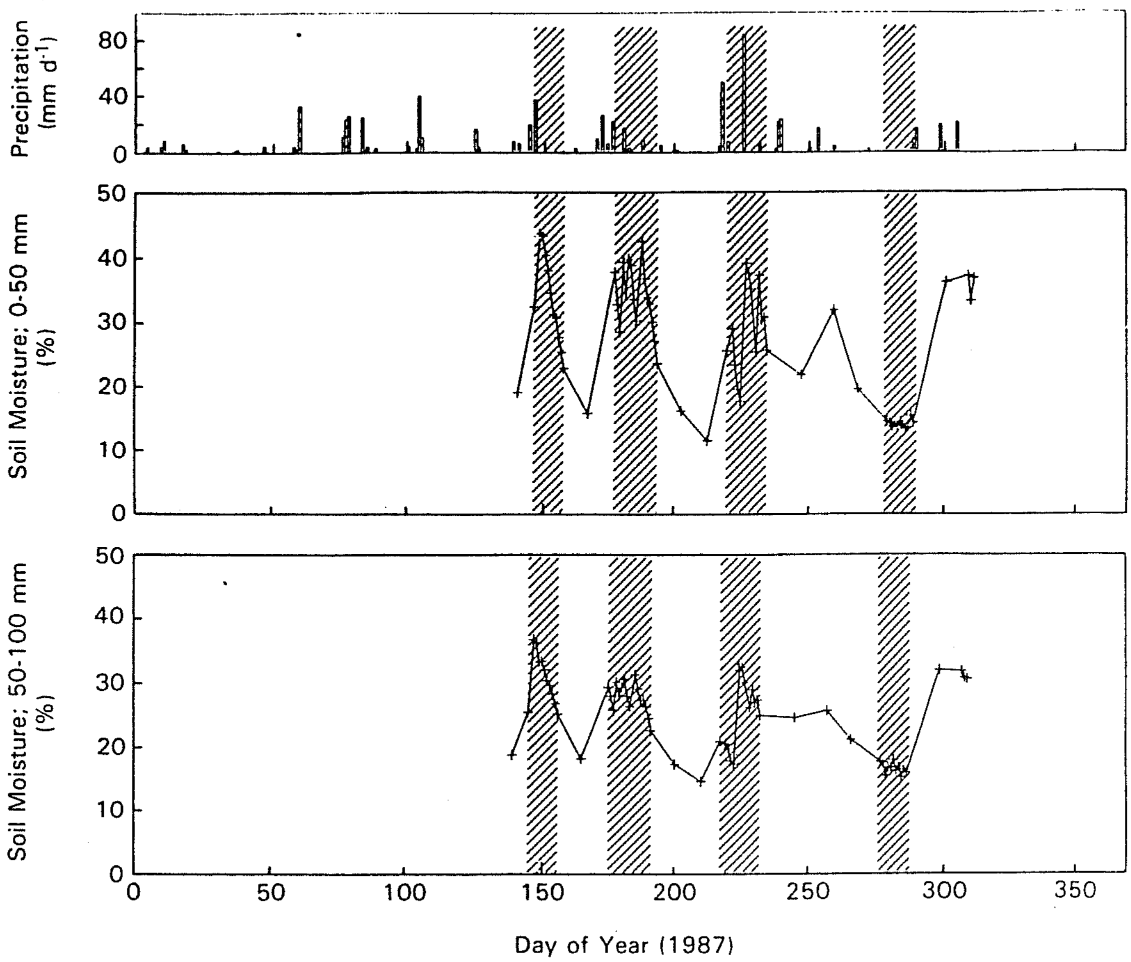

Fig. 3 Precipitation and soil moisture conditions as measured at the FIFE site at or near the AMS during 1987. Note wet soil moisture conditions during IFC-1, IFC-2, IFC-3. Data from Staff/KSU.

(2) Surface Flux (SF) Group: The SF group used 6 eddy correlation and 17 Bowen ratio rigs to measure the surface sensible and latent heat fluxes, and in some cases CO_2 fluxes, around the site, see Figure 1.

(3) Correction/Calibration (CC) Group: The CC group conducted a number of atmospheric optical and thermal measurements during satellite overpasses. This group also had the responsibility of calibrating all the field radiometers used in FIFE to a common standard.

(4) Surface Radiances and Biology (SRB) Group: The SRB group used a range of radiometers and spectrometers to measure radiances and emittances at selected points within the site. Additionally, some physiological and biophysical measurements were made by three teams in this group.

(5) Soil Moisture (SM) Group: The SM group used a range of direct (gravimetric samples, radio frequency probes, neutron probes) and indirect (airborne microwave and gamma-ray remote sensing, radar, scatterometry) techniques to map soil

In addition to the selected investigators working in FIFE, there were two large groups of scientists and support staff conducting measurements on site and designing and operating the FIFE Information System (FIS). One group based at Kansas State University (Staff/KSU) carried out a wide range of measurements for the monitoring program and during IFC's. The Goddard Space Flight Center group (Staff/GSFC) provided administrative support, satellite data processing and are responsible for FIS.

As part of the experiment, three aircraft (NASA C-130, NASA Helicopter, NOAA Aerocommander) took radiometric measurements using a variety of scanners, radiometers and scatterometers operating over the visible, near infrared, thermal and microwave wavelength intervals. Three other aircraft (Canadian Twin Otter, National Center for Atmospheric Research Kingair, University of Wyoming Kingair) took measurements of heat, moisture, momentum and carbon dioxide (Twin Otter only) fluxes over the site. These activities were closely coordinated with each other and with satellite overpasses. In total, some 180 missions and over 400 flight hours of aircraft flight time were dedicated to data acquisition during FIFE.

RESULTS AND PRELIMINARY ANALYSES

It would be difficult to give a comprehensive summary of all of the data that have so far been submitted to the FIFE Information System. Here we will review a few subsets of the data set in the context of the major issues addressed by FIFE.

I. Will the FIFE data set allow us to check our current understanding of the relationships between biophysical processes and spectral radiances on small space scales?

Figure 4 shows a plot of surface radiometric temperatures, T_{rad}, as measured by a helicopter-mounted radiometer from a height of 1000′ above ground level (agl), against surface aerodynamic temperatures, T_{aero}, as derived from measurements of air temperature, wind speed and sensible heat flux measured by surface flux stations in FIFE. Two features are immediately apparent; there is a bias, which is probably due to the different contributions made by the soil and vegetation canopy therodynamic temperatures to T_{rad} and T_{aero}; and there is a large scatter in the data which may be due to natural variability in the T_{rad} field and 'noise' in the flux data. Further analyses will determine whether the surface radiometric temperatures, as measured by airborne or satellite radiometers, can be used to calculate the surface sensible and latent heat fluxes using the methods of Abdellaoui et al. (1986), Carlson et al. (1984), Seguin and Itier (1983) and Hope (1987).

Figure 5 shows a comparison between the unstressed canopy conductance calculated for an insolation of 600 W m^{-2} (g_c*; SW = 600), derived from analyses of several flux station data sets for different IFC's, with corresponding simple ratio vegetation index (SR) data from the Helicopter-mounted Barnes Modular Multichannel Radiometer, (MMR). The SR values are calculated as the ratio of band MMR 4 (.75 - .88 μm) to band MMR 3 (.63 - .68 μm) with a simple adjustment to normalize all values to a solar zenith angle of 30^{o}; see Sellers et al. (1988b).

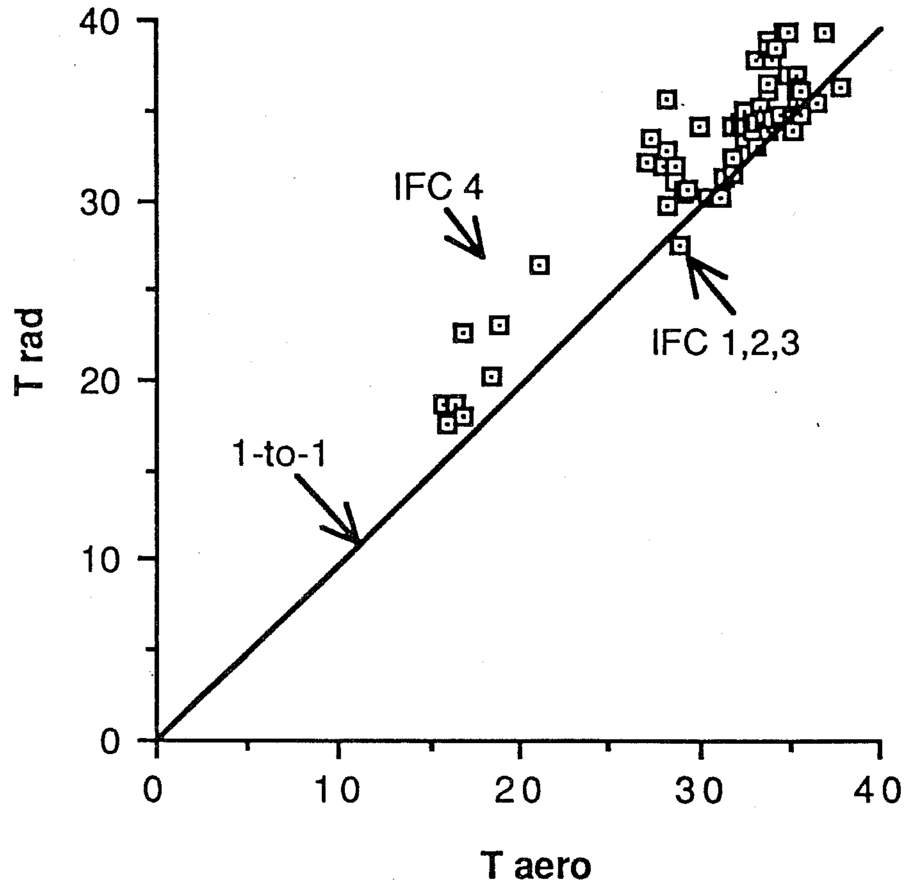

Fig. 4 Plot of surface radiometric temperature, T_{rad}, as measured by a helicopter mounted radiometer, and surface aerodynamic temperature, T_{aero}, as derived from surface flux data for different flux stations during different IFCs in FIFE-1987.

There appears to be a linear relationship between the two quantities, albeit with a large scatter; $r^2 = 0.5111$. We have yet to determine whether the scatter is due to data quality problems or other biophysical factors not considered in the analysis; see Sellers (1987). The derived values of g_c^* can be adjusted for environmental conditions (insolation, vapor pressure deficit, etc.) to yield an estimate of the surface resistance, r_c. This in turn may be used directly in the Penman-Monteith equation, see Monteith (1973), to calculate latent heat fluxes. Thus spectral radiances can be used to infer a biophysical quantity controlling the partitioning of energy at the surface.

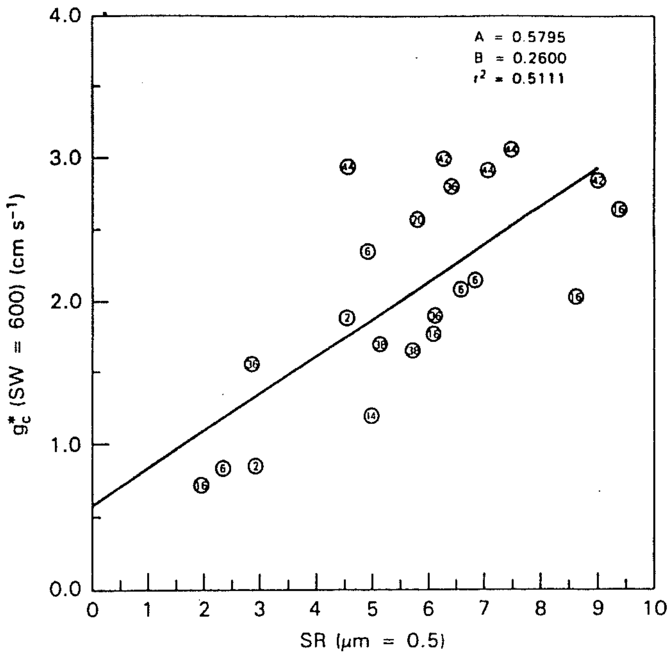

Fig. 5 Plot of unstressed canopy conductance calculated for an insolation of 600 W m^{-2}, (g_c*; sw = 600), plotted against (helicopter) simple ratio vegetation index data adjusted to a solar zenith angle of 30^{o}, (SR;μ = 0.5), for several flux station sites during different IFCs.

Figure 6 shows net CO_2 flux data plotted against Helicopter SR data for a single site over several IFCs. The data exhibit a near-linear relationship and surprisingly little scatter.

The above results indicate that our original hypotheses relating spectral radiances or emittances to biophysical properties appear to borne out by the data although much work needs to be done to refine the quality of the data set.

II. Will the FIFE data set allow us to evaluate the potential of satellite data for inferring radiation and energy budgets on larger spatial scales?

As yet, we have only a few direct comparisons between satellite and surface observations available at the time of writing, (September 1988). Figure 7 shows a comparison between estimates of insolation and photosynthetically active radiation calculated from a simple atmospheric radiative transfer model driven by GOES satellite radiances, measured every 30 minutes, compared with surface

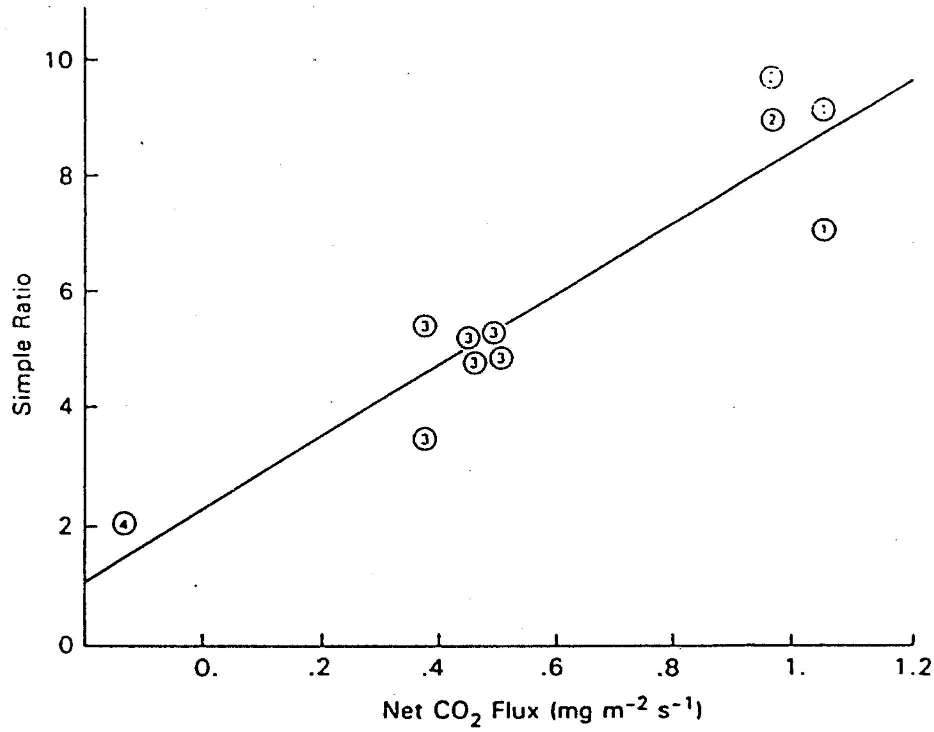

Fig. 6 Plot of midday net CO_2 flux, as measured at Site 16 (Verma) using an eddy correlation technique, against helicopter SR data. Numbered points denote IFC.

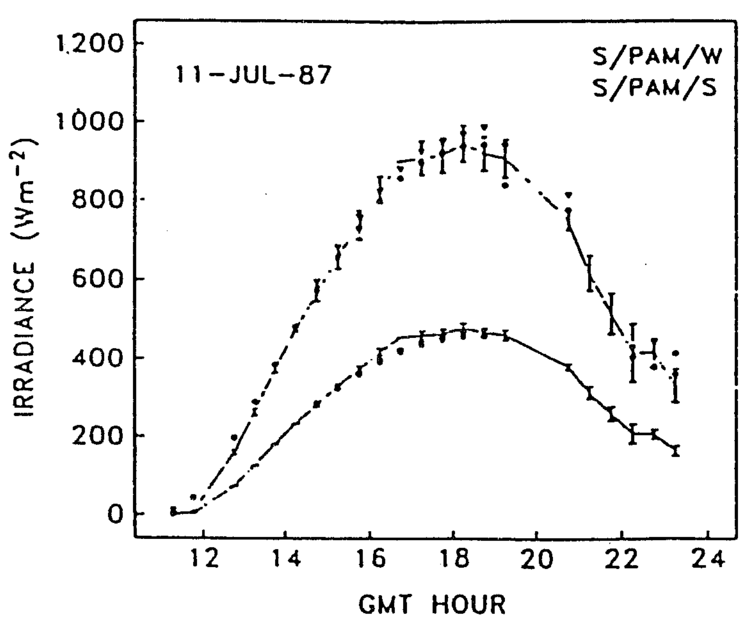

Fig. 7 Comparison between GOES satellite-derived estimates of the downwelling radiation fluxes, with surface measurements; (a) Insolation, (b) Photosynthetically active radiation.

observations made within the FIFE site; see Gautier et al. (1980), Gautier and Frouin (1984) and Frouin et al. (1988). The agreement appears to be very good.

There were a number of heat and moisture flux data sets collected at different scales but at the same time. Figure 8 shows the midday evaporation ratio (latent heat flux divided by the sum of sensible and latent heat flux) as measured by airborne and surface eddy correlation techniques and as calculated from radiosonde data for one day in each IFC. Also shown are the NOAA-9 maximum NDVI values for the corresponding IFCs. The flux measurement techniques appear to agree fairly well and all capture the large drop in the evaporation ratio between IFC-3 and IFC-4.

These and other results indicate that the FIFE data set should be adequate for testing satellite data algorithms; that is, surface fluxes on large spatial scale can be computed from the field measurements and then compared with the output of surface energy balance models driven by satellite data.

SUMMARY

The field phase of the First ISLSCP Field Experiment (FIFE) was executed without mishap in 1987. Currently, the FIFE scientists and Staff are analyzing their data to determine the extent to which satellite data can be used to calculate surface-atmosphere, energy, heat and mass exchange rates. Preliminary analyses indicate that our hypotheses relating surface spectral radiances to biophysical properties are supported by the data. Also, it should be possible to derive estimates of surface heat and mass (moisture and CO_2) fluxes on scales comparable to the satellite data using the airborne and surface measurements collected during FIFE-1987.

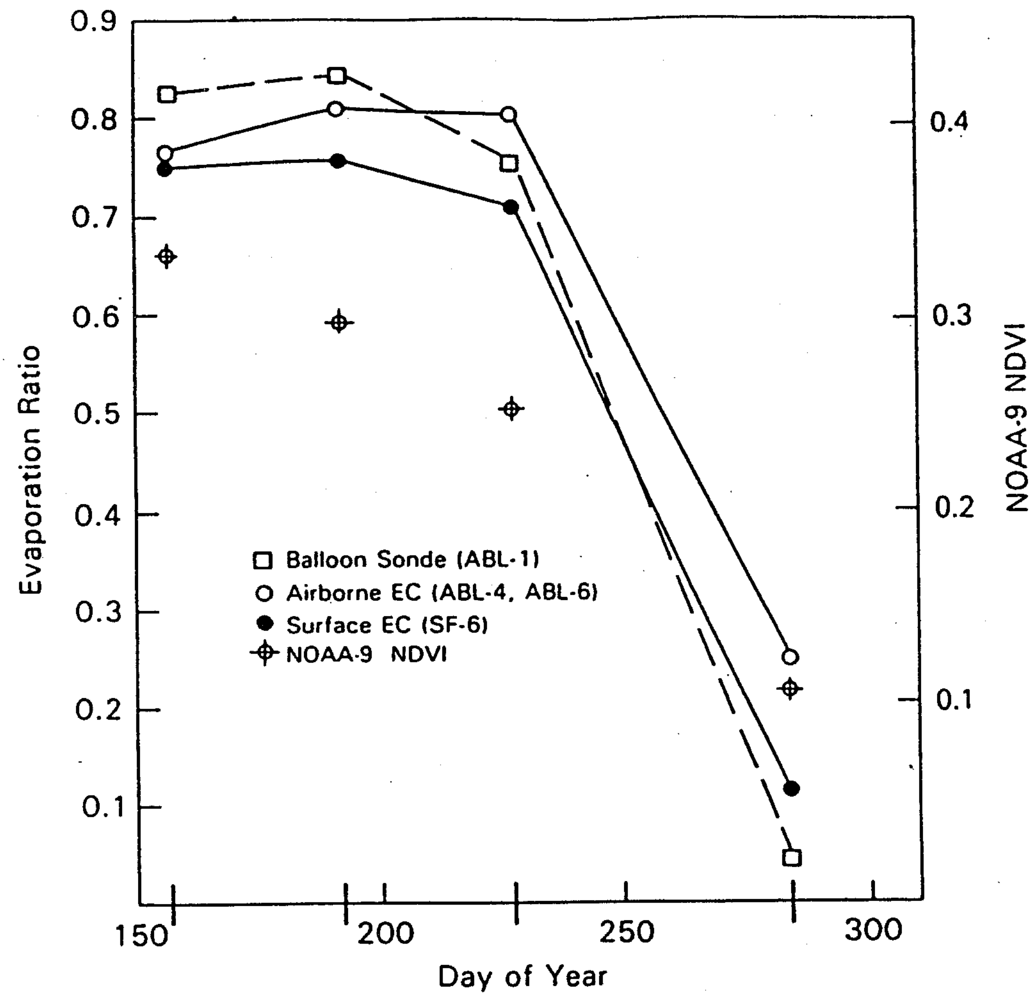

Fig. 8 Midday Evaporation Ratio as estimated from airborne and surface eddy correlation, flux measurements and radiosonde data.

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