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Aircraft Remote Sensing Of Soil Moisture and Hydrologic Parameters, Chickasha, Okla., 1980 Data Report

ABSTRACT

Jackson, T. J., P. E. O'Neill, G. C. Coleman, and T. J. Schmugge. 1982. Aircraft remote sensing of soil moisture and hydrologic parameters, Chickasha, Okla., 1980 data report. U.S. Department of Agriculture, Agricultural Research Results 14, 16 pp.

Experiments were conducted to evaluate aircraft remote sensing techniques for hydrology in a range of physiographic and climatic areas using several sensor systems. The data were collected in the summer of 1980 near Chickasha, Okla., to supplement previous data sets. This report includes soil moisture measurements, climatic observations, and the remote sensing data collected using thermal infrared, passive microwave, and active microwave systems.

KEYWORDS: Hydrology, microwave, remote sensing, soil moisture.

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AIRCRAFT REMOTE SENSING OF SOIL MOISTURE AND HYDROLOGIC PARAMETERS, CHICKASHA, OKLA., 1980 DATA REPORT

by T. J. Jackson, P. E. O'Neill, G. C. Coleman, and T. J. Schmuggel/

Cooperative investigations were conducted during 1980 by the National Aeronautics and Space Administration (NASA) and the U.S. Department of Agriculture (USDA) as part of a project to evaluate remote sensing in hydrologic studies with primary emphasis on field measurements. Participants in the study were from the NASA Goddard Space Flight Center and the USDA Hydrology Laboratory and the Southern Plains Watershed and Water Quality Laboratory, Agricultural Research Service (ARS).

Experiments were planned to evaluate aircraft remote sensing techniques in a range of physiographic and climatic areas using several sensor platforms. Previous reports 2/ 3/ presented the results obtained in experiments in semiarid and humid regions. The 1980 experiments were designed to complement the work conducted in 1978 at sites in Oklahoma.2/ Data collected in 1978 and 1979 were obtained only under relatively wet soil moisture conditions. The 1980 data included some very dry soil conditions. This report describes the experiment and presents the data collected at Chickasha, Okla., in 1980.

1/ T. J. Jackson, hydrologist, Hydrology Laboratory, Agricultural Research Service (ARS), Beltsville Agricultural Research Center, Beltsville, Md. 20705; G. C. Coleman, hydraulic engineer, Southern Plains Watershed and Water Quality Laboratory, ARS, Chickasha, Okla. 73018; and P. E. O'Neill and T. J. Schmugge, scientists, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, Md. 20771.

2/ Jackson, T. J., T. J. Schmugge, G. C. Coleman, and others. Aircraft remote sensing of soil moisture and hydrologic parameters, Chickasha, Okla., and Riesel, Tex., 1978 data report. U.S. Dept. Agr. ARR-NE-8, 52 pp. 1980.

3/ Jackson, T. J., T. J. Schmugge, L. H. Allen, Jr., and others. Aircraft remote sensing of soil moisture and hydrologic parameters, Taylor Creek, Fla., and Little River, Ga., 1979 data report. U.S. Dept. Agr. ARR-NE-13, 36 pp. 1981.

EXPERIMENTAL DESIGN

GROUND SAMPLING PROCEDURES

The study sites in Oklahoma were in the Washita River Experimental Watershed, Chickasha area, which is monitored by the Southern Plains Watershed and Water Quality Laboratory.

Background information on the area and the watersheds is included in the previous report on these sites by Jackson et al.3/ In this 1980 data report, only the changes are described.

The four flightlines in 1980 had also been used in 1978. Their general locations are shown in figure 1. Flightline 1 covered the cropland or C watershed area, flightline 2 the rangeland watersheds R5 and R6, and flightline 3 the watersheds R7 and R8. Flightline 4 was a high altitude pass of a watershed cross section.

Data flights were made and ground samples collected on June 24, August 14, and September 9, 1980. Land cover for each site on each of these dates is listed in table 1. Typical cropland watershed cover conditions are shown in figures 2 and 3 and the rangeland watersheds in figure 4.

Table 1.--Land cover at Chickasha, Okla., sites, 1980

Site	Land cover on- June 24	Aug. 14	Sept. 9
C4	Fallow	Cotton 1/	Cotton.2/
C5C6	Wheat stubble	Wheat stubble	Wheat stubble.
R5	Pasture	Pasture	Pasture.
R6	---do	---do	Do.
R7	---do	---do	Do.
R8	---do	---do	Do.
R5R6	---do	---do	Do.

1/ 75 percent cover.
2/ 100 percent cover.

3/ See footnotes 2, p. 1.

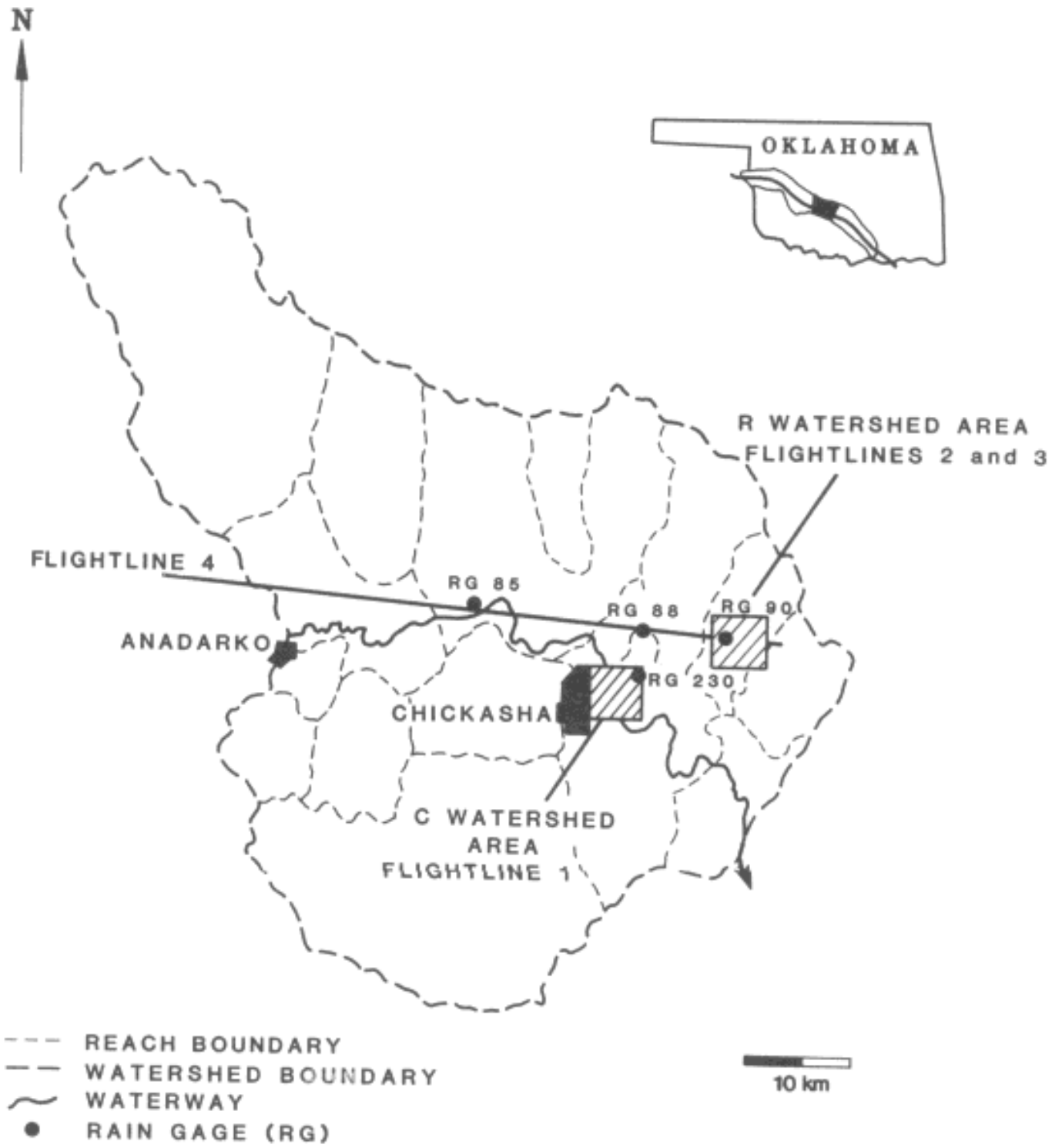

Figure 1.--Chickasha, Okla., watershed.

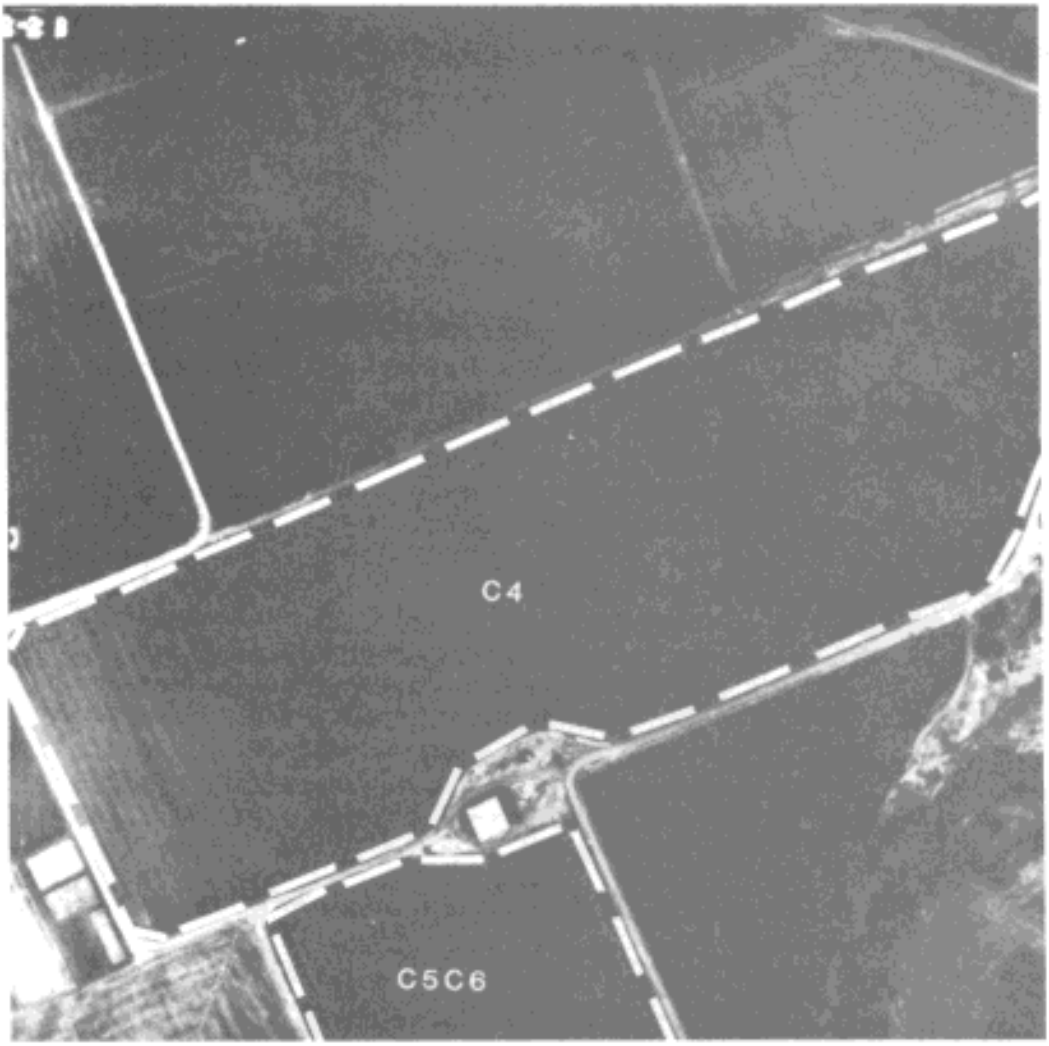

Figure 2.--Watershed C4. Black and white rendition of color infrared photo obtained on Aug. 14, 1980, at 1:5,700 scale.

Figure 3.--Watershed C5C6. Black and white rendition of color infrared photo obtained on Aug. 14, 1980, at 1:5,700 scale.

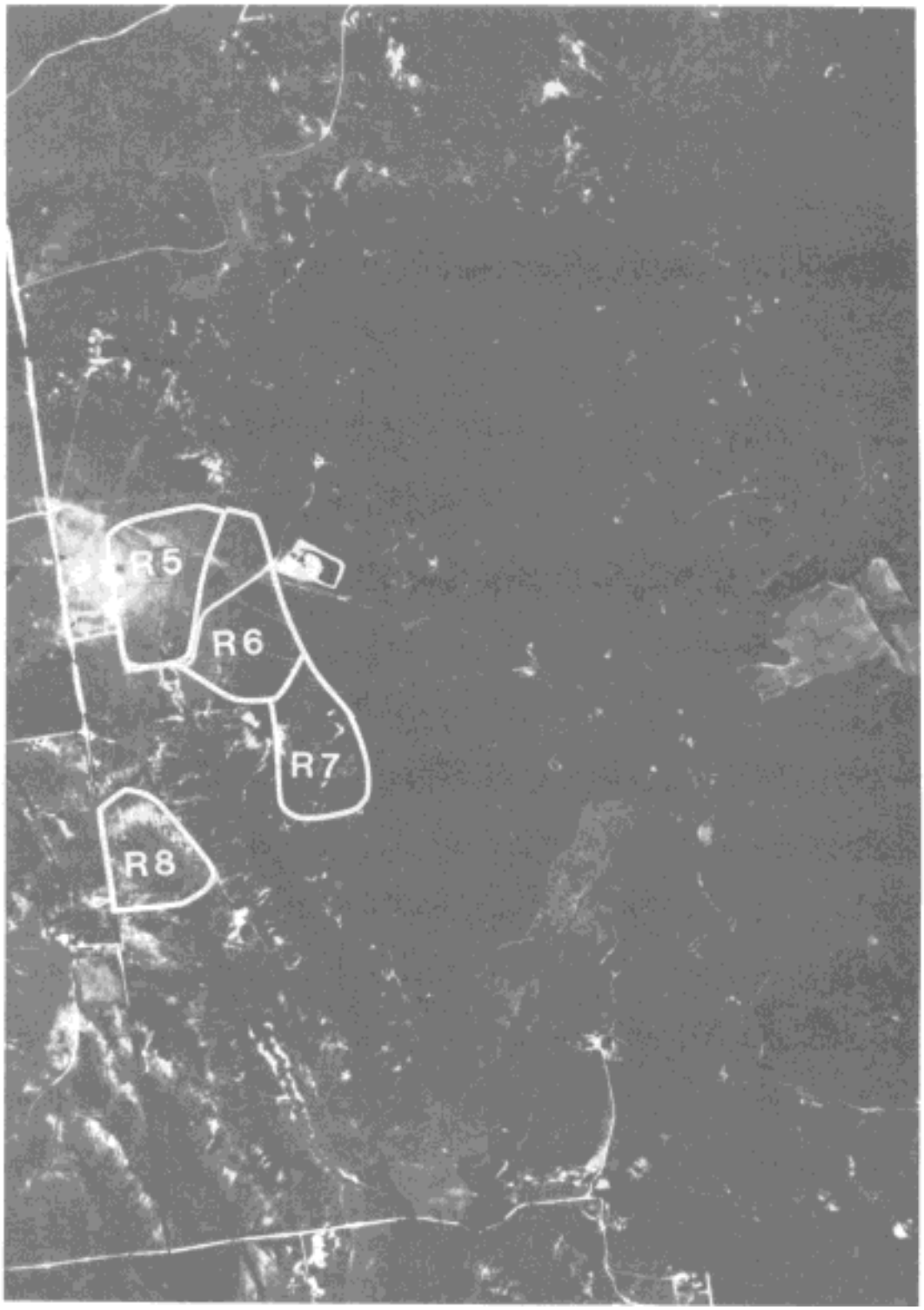

Figure 4.--Rangeland watersheds. Black and white rendition of color infrared photo obtained on June 24, 1980, at 1:12,500 scale.

Soil moisture samples were collected using a gravimetric technique for depth intervals of 0-2.5, 2.5-5, and 5-15 cm. Soil temperature samples were obtained at depths of 2.5 and 15 cm. Gravimetric samples were weighed as soon as possible. These samples were collected using a grid scheme similar to that in the 1978 experiments. Maps of the sampling locations are presented in Jackson et al.4/

Climatological observations for June through September 1980 are summarized in table 2. Rain gage locations are shown in figure 1.

REMOTE SENSING SYSTEMS

The NASA 929 (C-130B) aircraft was the sensor platform used in these experiments. A nominal altitude of 305 m (1,000 ft) and a ground speed of 278 km per hour (150 knots) were chosen. The sensor configuration included color infrared photography, a modular multispectral scanner, a thermal infrared radiometer, L (1.41 GHz) and C band (5.00 GHz) radiometers, a passive microwave scanner (10.69 GHz), and four active microwave sensors-K (13.2 GHz), C (4.75 GHz), L (1.6 GHz), and P (0.4 GHz) band scatterometers. L and C band radiometer observations were made at look angles of 0 and 40 degrees. L band data were collected for only a horizontal polarization (hor. polar.), and C band data were collected for both horizontal and vertical polarizations (vert. polar.).

These sensors were described by Jackson et al. 4/ Some changes have been made in the aircraft systems by NASA since the May 1978 flights described in that radiometers were removed, and the C band sensor was mounted on the rear platform of the plane.

4/ See footnote 2, p. 1.

Table 2.--Chickasha, Okla., climatological data, 1980

Date	Pan evaporation	daily temperature Min.	Max.	Rainfall at rain gage-- 85	88	90	230
	Cm	---Deg. K---			----------Cm----------		
June							
1----	0.58	294	300	0.00	0.00	0.00	0.00
2----	0.41	295	302	0	0	0	0
3----	0.71	294	301	0	0	0	0
4----	0.51	296	303	0	0	0	0
5----	1.02	295	304	0	0	0	0
6----	1.35	295	306	0	0	0	0
7----	1.12	297	309	0	0	0	0
8----	0.91	289	297	0.38	0.51	0.38	0.56
9----	0.71	289	299	0.15	0.15	0.15	0.13
10----	---	289	302	0	0	0	0
11----	0.74	292	302	0	0	0	0
12----	1.04	291	303	0	0	0	0
13----	1.19	294	304	0	0	0	0
14----	1.40	293	305	0	0	0	0
15----	0.64	294	307	0	0	0	0
16----	1.73	296	302	0	0	0	0
17----	0.99	293	303	0	0	0	0
18----	0.46	295	308	0	0	0	0
19----	1.04	294	306	0.30	1.04	0.53	---
20----	1.42	291	302	2.59	2.51	3.28	3.02
21----	0.41	293	302	0	0	0	0
22----	0.89	292	303	2.69	1.42	1.55	1.65
23----	0.96	294	308	0	0	0	0
24----	0.96	297	311	0	0	0	0
25----	1.24	296	312	0	0	0	0
26----	1.45	294	312	0	0	0	0
27----	1.12	294	313	0	0	0	0
28----	1.52	296	314	0	0	0	0
29----	1.22	294	308	0	0	0	0
30----	1.07	297	310	0	0	0	0
July							
1----	1.45	297	311	0	0	0	0
2----	1.42	300	313	0	0	0	0
3----	1.37	296	313	0	0	0	0
4----	---	297	310	0	0	0	0
5----	1.90	296	309	0	0	0	0
6----	0.99	296	309	0	0	0	0
7----	1.57	296	309	0	0	0	0
8----	1.37	298	310	0	0	0	0
9----	1.83	298	311	0	0	0	0
10----	---	297	310	0	0	0	0

Table 2.--Chickasha, Okla., climatological data, 1980

Date	Pan evaporation	Daily Temperature Min.	Max.	Rainfall at rain gage-- 85	88	90	230
	Cm	---Deg. K---			----------Cm----------		
July							
11----	1.73	297	311	0.00	0.00	0.00	0.00
12----	1.62	297	312	0	0	0	0
13----	1.52	298	312	0	0	0	0
14----	1.22	297	312	0	0	0	0
15----	1.35	297	311	0	0	0	0
16----	---	298	312	0	0	0	0
17----	1.37	295	312	0	0	0	0
18----	1.40	295	312	0	0	0	0
19----	1.45	296	311	0	0	0	0
20----	0.96	297	310	0	0	0	0
21----	0.89	296	307	---	0.1	---	---
22----	0.74	293	307	0	0	0	0
23----	1.27	291	306	0	0	0	0
24----	0.79	292	308	0	0	0	0
25----	1.14	294	309	0	0	0	0
26----	1.02	296	309	0	0	0	0
27----	1.55	295	307	0	0	0	0
28----	---	292	311	0	0	0	0
29----	---	292	312	0	0	0	0
30----	---	293	312	0	0	0	0
31----	1.4	297	312	0	0	0	0
Aug.							
1----	1.5	297	312	0	0	0	0
2----	1.47	296	312	0	0	0	0
3----	1.50	298	308	0	0	0	0
4----	1.17	299	308	0	0	0	0
5----	1.45	297	309	0	0	0	0
6----	1.45	298	309	0	0	0	0
7----	1.27	297	309	0	0	0	0
8----	1.17	296	309	0	0	0	0
9----	1.37	296	309	0	0	0	0
10----	1.24	296	308	0	0	0	0
11----	1.04	293	308	0	0	0	0
12----	0.99	292	308	0	0	0	0
13----	0.51	297	308	0	0	0	0
14----	0.94	298	309	0	0	0	0
15----	1.04	298	308	0	0	0	0
16----	1.14	297	310	0	0	0	0
17----	1.45	296	309	---	---	---	0.1
18----	1.02	296	308	0	0	0	0
19----	1.19	298	309	0	0	0	0
20----	1.27	297	311	0	0	0	0
21----	1.14	294	306	0.76	0.61	0.76	0.61

Table 2.--Chickasha, Okla., climatological data, 1980

Date	Pan evaporation	Daily Temperature Min.	Max.	Rainfall at rain gage-- 85	88	90	230
	Cm	---Deg. K---			----------Cm----------		
Aug.							
22----	0.56	295	309	0.00	0.00	0.00	0.00
23----	1.27	295	311	0	0	0	0
24----	0.94	296	312	0	0	0	0
25 ----	0.84	294	310	0	0	0	0
26 ----	1.09	294	310	0.30	1.04	0.53	---
27----	1.09	292	310	2.59	2.51	3.28	3.02
28 ----	0.79	293	304	0	0	0	0
29 ----	0.46	293	308	2.69	1.42	1.55	1.65
30 ----	0.71	296	309	0	0	0	0
31----	1.52	298	309	0	0	0	0
Sept.							
1----	0.99	298	309	0	0	0	0
2----	1.30	294	303	0.46	0.2	2.77	0.38
3 ----	0.28	294	307	---	---	0.05	---
4 ----	0.86	294	309	---	---	0.05	---
5 ----	0.86	294	309	0	0	0	0
6 ----	0.58	294	307	0	0	0	0
7 ----	0.68	293	306	---	---	0.08	---
8 ----	0.84	293	307	---	---	---	1.47
9 ----	---	293	307	0.56	0.33	1.52	0.25
10 ----	0.86	293	304	0	0	0	0
11----	0.61	294	307	0	0	0	0
12----	0.91	294	308	0	0	0	0
13----	1.24	296	309	0	0	0	0
14----	0.89	293	308	0	0	0	0
15---	0.68	294	308	0.38	0.51	0.38	0.56
16 ----	0.79	285	309	0.61	0.51	0.74	1.14
17 ----	1.47	282	299	0	0	0	0
18 ----	0.74	288	306	0	0	0	0
19 ----	0.53	294	308	0	0	0	0
20 ----	1.30	296	308	0	0	0	0
21 ----	1.24	296	308	0	0	0	0
22 ----	1.22	294	302	0	0	0	0
23 ----	0.68	287	296	0	0	0	0
24 ----	0.38	287	301	0	0	0	0
25 ----	0.38	290	297	0	0	0	0
26 ----	0.66	287	292	0.51	0.46	0.43	0.46
27 ----	---	284	287	2.21	2.08	2.56	1.96
28 ----	---	284	288	0.20	0.05	0.10	0.08
29 ----	0.18	287	290	0	0	0	0
30----	---	288	301	0	0	0	0

DATA AND PROCESSING

SOIL MOISTURE OBSERVATIONS

Gravimetric soil moisture data for each depth interval were combined with bulk density values by the method reported by Jackson et al.5/ to compute the volumetric soil moisture. Mean and standard deviation values for each site are listed in table 3.

Generally the soil moisture conditions were relatively wet on the date of the first flight and very dry on the last two flights. These results were ideal because the wet condition data provided verification of the sensor performance in 1978 and the dry condition data allowed the extension of the 1978 data set. The C watersheds had been furrow irrigated prior to the last flight and, therefore, the soil moisture was high.

REMOTE SENSING DATA

All data were processed as described by Jackson et al.5/ Separate time corrections had to be applied to the L and C band systems at 40 degrees because the L band looked backward and the C band looked forward. Passive Microwave Imaging System data were not processed since they have not been useful in previous studies because the short wavelength could not penetrate vegetation.

Data collected on the high altitude flightline depended on the cloud ceiling on the date. Altitudes on June 24, August 14, and September 9 were 3,050, 1,400, and 1,100 m, respectively. Measurements obtained over watersheds R5 and R6 from this altitude were isolated and are referred to as R5R6 for June 24 and September 9.

Soil temperature means for the 2.5 cm layer and Precision Radiation Thermometer data (PRT5) are listed in table 4. L and C band passive microwave radiometer data are given in table 5 and the scatterometer data in table 6.

5/ See footnote 2, p. 1.

Table 3.--Soil moisture observations at Chickasha, Okla., 1980

Date	Site	Volumetric soil moisture (percent) at indicated depths					
		0-2.5 cm		2.5-5 cm		5-15 cm	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
June 24---	C4	17.6	8.2	29.3	3.7	31.3	3.7
	C5C6	37.4	9.8	34.6	7.8	34.2	10.2
	R5	25.6	5.3	22.2	3.9	19.9	3.4
	R6	30.1	7.9	26.3	4.7	23.6	5.2
	R7	22.3	5.7	26.1	4.5	27.0	3.9
	R8	23.5	3.9	23.2	3.1	22.4	2.8
Aug. 14---	C4	5.1	1.8	9.6	4.5	18.3	6.1
	C5C6	2.1	1.2	2.7	1.4	10.3	5.5
	R5	4.2	2.3	4.7	2.1	6.3	1.6
	R6	2.7	0.9	3.1	1.4	4.5	1.7
	R7	2.0	1.0	3.5	1.9	4.3	2.0
	R8	3.2	1.2	4.4	1.9	6.5	1.8
Sept. 9 ---	C4	32.6	6.1	29.3	8.2	26.2	9.7
	C5C6	27.1	4.8	21.8	5.0	10.8	4.8
	R5	11.5	4.4	12.4	2.7	12.4	2.7
	R6	8.1	2.4	10.1	2.3	11.2	2.4
	R7	6.4	2.1	9.4	3.1	12.3	2.6
	R8	11.4	3.6	14.6	3.9	17.3	4.7

Table 4.--Temperature data at Chickasha, Okla., 1980

Date	Site	Temperature	
		Soil	PRT5
		-------Deg. K-------	
June 24 -------	C4	305.0	310.0
	C5C6	301.6	309.9
	R5	305.2	307.4
	R6	299.4	307.4
	R7	307.2	309.4
	R8	304.4	307.4
	R5R6	303.3	302.6
Aug. 14 -------	C4	302.7	300.8
	C5C6	308.8	309.8
	R5	306.6	310.2
	R6	306.6	311.0
	R7	308.8	310.2
	R8	306.1	308.9
Sept. 9 --------	C4	301.1	302.7
	C5C6	301.1	308.5
	R5	304.4	315.0
	R6	304.4	314.8
	R7	304.4	319.2
	R8	302.7	314.0
	R5R6	304.4	307.4

Table 5.--Microwave radiometer data at Chickasha, Okla., 1980

Date	Site	Brightness temperature					
		L Band		C Band			
		0 deg look angle	40 deg. look angle	0 deg. look angle		40 deg. Look angle	
		hor. polar.	hor. polar	Hor. Polar.	Vert. Polar.	Hor. Polar.	Vert. Polar.
		---------- Deg. K ----------					
June 24---	C4	249.4	264.5	264.5	278.0	243.7	243.7
	C5C6	198.7	160.1	222.1	231.3	180.4	222.8
	R5	236.5	227.0	271.0	282.8	250.0	264.5
	R6	229.4	225.4	262.1	273.4	239.9	260.3
	R7	241.1	217.7	267.9	279.2	245.8	263.7
	R8	243.8	229.5	263.0	273.9	238.3	262.0
	R5R6	235.7	---	260.6	270.6	---	---
Aug. 14---	C4	274.3	271.5	278.9	288.2	273.9	272.1
	C5C6	294.7	291.0	286.4	295.7	276.9	274.4
	R5	290.5	275.3	291.8	302.3	274.6	279.3
	R6	288.0	274.9	293.9	302.6	275.5	282.1
	R7	288.3	274.6	290.6	302.1	272.5	279.1
	R8	291.1	278.4	288.1	302.2	271.6	279.4
Sept. 9 ---	C4	258.9	255.8	273.2	281.9	258.1	263.8
	C5C6	275.0	260.3	278.7	287.5	260.7	267.5
	R5	274.6	256.5	289.8	302.1	275.5	278.9
	R6	275.0	261.5	288.5	299.6	273.2	278.8
	R7	284.9	266.5	290.8	302.5	271.3	279.8
	R8	280.1	265.7	287.7	300.3	270.1	277.5
	R5R6	276.4	---	288.4	300.3	---	---

Table 6.--Scatterometer data at Chickasha, Okla., 1980

Date	Site	Backscattering coefficient at indicated degree of look angle									
		5	10	15	20	25	30	35	40	45	50
		----------DB----------									
		K band									
June 24---	C4	---	---	---	---	---	---	---	---	---	---
	C5C6	---	---	---	---	---	---	---	---	---	---
	R5	-0.8	-3.6	-6.6	-8.4	-10.4	-10.7	-11.2	-12.0	-12.6	-12.2
	R6	1.7	-1.4	-4.9	-7.4	-9.6	-10.9	-12.0	-12.0	-12.3	-13.6
	R7	3.9	-1.7	-5.3	-8.3	-10.1	-10.9	-11.7	-12.6	-12.4	-13.9
	R8	4.9	1.3	-2.5	-6.3	-8.2	-9.0	-10.4	-11.7	-11.5	-12.1
Aug. 14---	C4	0.1	-4.4	-5.9	-8.7	-8.8	-9.4	-9.9	-10.1	-11.2	-12.1
	C5C6	-3.6	-3.9	-6.0	-7.0	-7.5	-8.4	-9.0	-10.4	-11.1	-13.5
	R5	-1.0	-6.3	-9.3	-11.3	-12.4	-12.9	-13.4	-14.1	-14.5	-14.9
	R6	-2.0	-5.1	-8.2	-11.2	-12.4	-12.5	-13.2	-13.7	-14.3	-14.4
	R7	-0.7	-4.2	-7.5	-10.2	-11.4	-12.4	-13.1	-14.2	-14.1	-16.4
	R8	0.3	-3.0	-7.1	-9.3	-11.5	-12.1	-13.9	-14.5	-14.8	-16.2
Sept. 9---	C4	2.2	-1.3	-3.5	-1.3	-4.1	-8.0	-9.4	-9.4	8.2	-11.8
	C5C6	-3.5	-4.6	-6.9	-8.5	-9.7	-10.5	-11.5	-11.7	-12.4	-14.2
	R5	-4.2	-7.1	-10.4	-11.4	-13.3	-13.9	-14.0	-13.4	-13.1	-13.8
	R6	-2.2	-6.1	-10.1	-12.3	-13.3	-13.1	-13.5	-15.0	-14.0	-13.6
	R7	-1.4	-4.8	-9.0	-11.4	-13.3	-14.0	-15.1	-15.5	-15.3	-16.2
	R8	0.9	-3.0	-6.8	-10.3	-11.5	-11.7	-13.3	-14.5	-14.6	-15.4
		C band									
June 24---	C4	---	---	---	---	---	---	---	---	---	---
	C5C6	---	---	---	---	---	---	---	---	---	---
	R5	4.0	-3.3	-7.4	-9.7	-12.0	-13.9	-15.3	-15.7	-17.0	-15.0
	R6	4.5	-1	-6.6	-9.0	-11.2	-13.9	-16.0	-16.2	-18.1	-16.4
	R7	5.5	-0.3	-6.2	-9.1	-11.6	-13.1	-16.3	-16.2	-18.7	-17.0
	R8	7.3	1.4	-3.8	-7.9	-10.4	-12.1	-13.6	-14.8	-15.6	-16.6
Aug. 14---	C4	0.7	-7.4	-9.6	-10.0	-11.4	-11.8	-13.9	-14.0	-14.4	-13.8
	C5C6	-3.2	-7.3	-9.1	-9.9	-11.3	-12.1	-14.6	-15.9	-15.9	-15.8
	R5	-2.2	-11	-14.6	-16.0	-18.2	-18.5	-21.5	-21.2	-21.2	-22.2
	R6	-0.8	-7.8	-13.1	-15.6	-17.8	-18.8	-21.5	-20.4	-20.4	-23.5
	R7	-0.6	-7.5	-12.7	-14.5	-17.3	-17.6	-20.4	-20.5	-20.5	-23.3
	R8	1.6	-5.6	-9.9	-12.9	-14.9	-17.1	-17.7	-18.8	-22.5	-20.4
Sept. 9---	C4	4.4	-3.2	-6.6	-8.1	-10.9	-12.1	-15.2	-14.2	-15.9	-14.7
	C5C6	-2.4	-6.1	-8.4	-10.4	-11.4	-12.6	-14.5	-15.8	-16.9	-16.1
	R5	-1.9	-10.0	-13.5	-15.6	-17.7	-19.6	-20.8	-20.7	-22.5	-19.5
	R6	-2.4	-9.7	-14.0	-16.5	-18.8	-20.3	-21.7	-21.8	-21.4	-19.0
	R7	-2.3	-8.7	-12.4	-15.3	-17.8	-20.1	-21.7	-22.2	-23.5	-21.9
	R8	2.2	-3.5	-9.5	-12.9	-15.8	-17.4	-19.8	-20.1	-22.1	-22.4

Table 6.--Scatterometer data at Chickasha, Okla., 1980

Date	Site	Backscattering coefficient at indicated degree of look angle									
		5	10	15	20	25	30	35	40	45	50
		----------Db----------									
		L band									
June 24---	C4	---	---	---	---	---	---	---	---	---	---
	C5C6	---	---	---	---	---	---	---	---	---	---
	R5	-6.1	-12.2	-15.3	-18.5	-20.3	-24.0	-24.9	-26.4	-28.2	-29.2
	R6	0.7	-7.3	-11.5	-17	-20.5	-24.1	-24.3	-27.0	-29.0	-29.4
	R7	4.7	-6.2	-9.5	-14.4	-16.8	-22.0	-22.2	-25.3	-27.0	-29.8
	R8	7.8	4.1	-6.8	-13.1	-15.6	-19.1	-21.6	-23.4	-28.0	-27.0
Aug. 14---	C4	-2.6	-14.5	-12.1	-20.7	-16.3	-20.8	-20.4	-22.0	-23.6	-26.1
	C5C6	-12.6	-18.2	-18.2	-20.7	-20.0	-25.4	-23.2	-25.0	-28.3	-26.9
	R5	-12.7	-19.1	-21.8	-26.3	-26.9	-32.6	-32.6	-33.7	-37.1	-36.6
	R6	-4.4	-14.3	-18.2	-25.4	-26.7	-31.4	-31.0	-33.8	-36.2	-35.3
	R7	-10.3	-13.6	-17.0	-23.1	-23.1	-28.9	-28.9	-31.4	-31.5	-33.9
	R8	-8.3	-12.9	-16.9	-19.2	-22.5	-25.7	-24.8	-28.1	30.3	-29.7
Sept. 9---	C4	-8.9	-16.3	-16.0	-21.2	-18.5	-24.1	-23.6	-24.5	-24.4	-23.7
	C5C6	-13.3	-14.7	-17.2	-19.5	-21.0	-24.4	-23.2	-26.2	-27.8	-29.1
	R5	-16.0	-16.5	-23.5	-25.2	-28.0	-29.3	-31.0	-32.5	-32.3	-35.3
	R6	-9.7	-19.4	-22.1	-27.1	-28.6	-32.8	-33.1	-35.1	-36.3	-35.6
	R7	-15.7	-16.7	-21.5	-24.7	-26.9	-30.1	-31.9	-35.1	-35.8	-35.3
	R8	-6.4	-12.3	-15.7	-22.4	-24.2	-28.6	-28.9	-31.6	-34.8	-34.5
		P band									
June 24---	C4	---	---	---	---	---	---	---	---	---	---
	C5C6	---	---	---	---	---	---	---	---	---	---
	R5	-12.1	-28.3	-33.1	-36.4	-36.1	-36.2	-36.8	-36.2	-37.8	-39.9
	R6	-11.0	-21.1	-28.9	-30.4	-28.3	-28.5	-32.2	-29.9	-28.2	-36.9
	R7	-11.6	-20.3	-26.7	-31.2	-30.1	-28.6	-30.0	-28.1	-28.8	-32.7
	R8	-11.7	-16.4	-22.6	-28.7	-31.8	-26.8	-28.1	-31.3	-34.3	-31.4
Aug. 14---	C4	---	---	---	---	---	---	---	---	---	---
	C5C6	-3.9	-14.4	-19.2	-18.5	-22.5	-23.5	-20.5	-25.5	-30.6	-32.7
	R5	-4.6	-20.1	-23.3	-25.1	-28.9	-28.9	-30.8	-34.9	-35.8	-39.0
	R6	-1.8	-10.2	-15.5	-22.5	-26.1	-29.0	-25.7	-31.4	-33.8	-34.7
	R7	-4.4	-17.2	-21.3	-23.8	-25.0	-52.2	-27.3	-30.3	-31.1	-32.8
	R8	-1.3	-10.1	-16.1	-16.7	-21.0	-22.9	-25.4	-26.8	-27.8	-26.2
Sept. 9---	C4	-10.8	-20.5	-22.7	-24.3	-21.2	-19.2	-21.9	-25.1	-24.7	-27.3
	C5C6	-17.7	-20.3	-25.0	-25.8	-25.3	-27.3	-29.9	-31.7	-34.0	-36.5
	R5	-11.8	-27.5	-30.5	-30.3	-31.2	-28.9	-29.7	-30.9	-28.8	-29.3
	R6	10.1	-20.2	-32.6	-35.4	-34.9	-35.1	-35.3	-37.4	-36.1	-37.6
	R7	-17.0	-24.6	-28.3	-28.0	-30.3	-29.1	-31.5	-32.8	-31.6	-31.0
	R8	-9.9	-15.7	-20.3	-23.7	-23.2	-23.7	-28.8	-30.7	-29.2	-35.9