LARS Technical Report 121278

Calibration of Landsat MSS Data

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by

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INTRODUCTION

The primary aim of an analyst of Landsat MSS data is to obtain as much useful and reliable information as possible about the different ground cover types present in an earth surface scene. In order to assist the analyst in accomplishing this objective, quantitative data analysis techniques have been developed and successfully applied in computer-aided mapping, inventoring, and monitoring the earht resources (Swain and Davis, 1978).

To further enhance the effectiveness of these techniques, the analyst should have a thorough understanding of 1) the spectral behavior of earth surface features, 2) the characteristics of the digital Landsat MSS data, and 3) the fundamental theory supporting each numerical analysis function used.

The purpose of this paper is to show that by performing a radiometric calibration of the Landsat MSS spectral responses, the analyst can then more effectively utilize his knowledge about the spectral characteristics of earth surface materials to make more intelligent decisions during the most critical phases of the analysis and interpretation of the Landsat MSS data.

SPECTRAL CHARACTERISTICS OF EARTH SURFACE FEATURES

Although the inherent spectral variability of earth surface features is such that it precludes the description of a particular ground cover type by means of a "unique spectral signature," it is possible nevertheless, to categorize the major

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ground cover types, i.e. vegetation, soil and water into distinct "families" of spectral response curves. Furthermore, linear combinations of the spectral responses of the major ground cover types also yield distinct families of spectral response curves (mixture classes) which could be very useful in interpreting spectral classes derived from clustered Landsat MSS data, particularly in situations for which adequate reference (ground-truth) data are not available.

Figure 1 shows the spectral response curves of green vegetation (corn), bare soil (silt loam), turbid and clear water. These *in situ* spectral measurements were obtained in the field using an EXOTECH model 20C spectroradiometer (Bartolucci et al., 1977). The location and width of the four reflective wavelength bands of the Landsat multispectral scanner system are also shown in this figure.

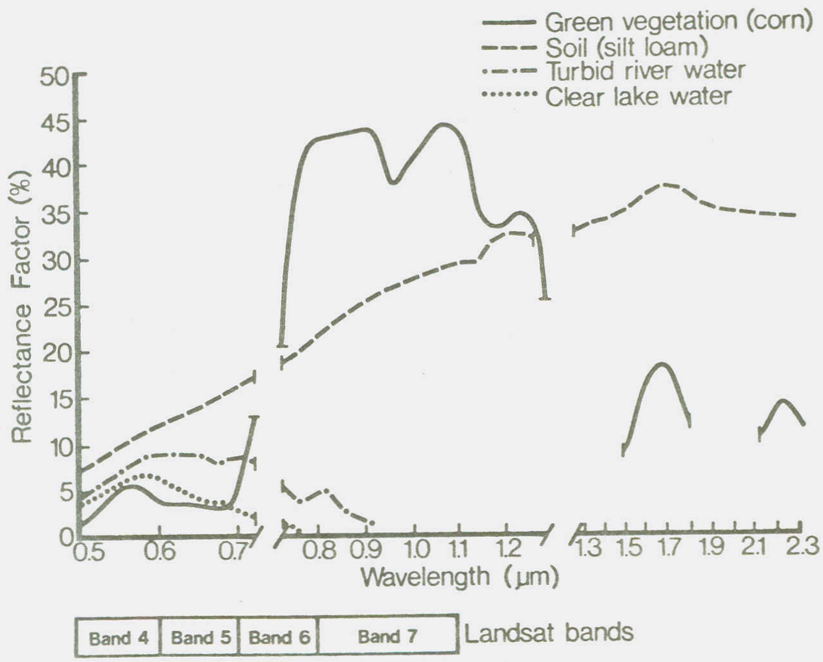

Figure 1. Spectral reflectance characteristics of major ground cover types [After Bartolucci et al., 1977].

RADIOMETRIC CALIBRATION OF THE LANDSAT MSS DATA

The oscillating scanner mirror of the Landsat MSS system collects ground scene radiation during the forward or active scan motion (from west to east) and then during alternate retrace scan cycles (from east to west) it measures the maximum radiation from an incandescent tungsten lamp (internal calibration standard; Hughes, 1977) and also records a minimum radiation signal as illustrated in Figure 2.

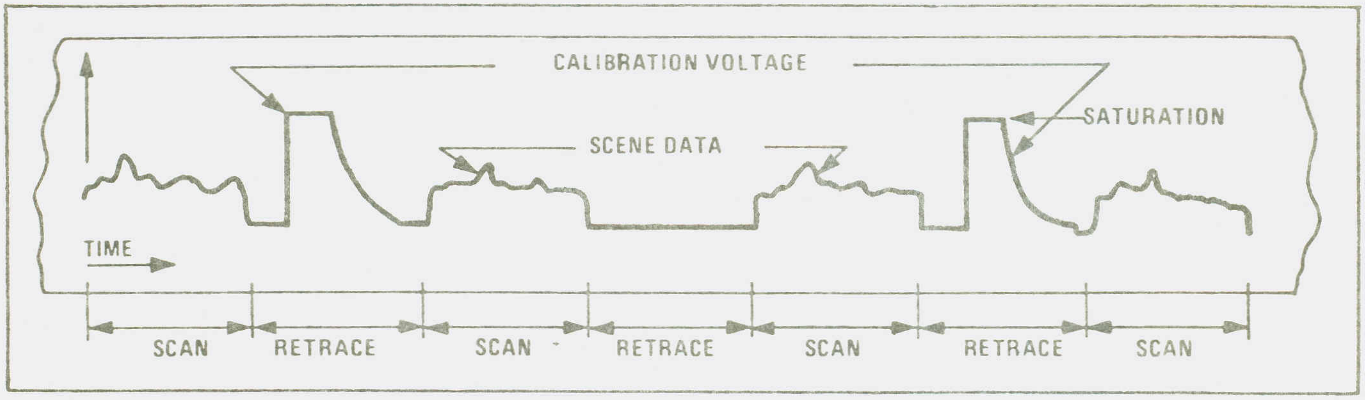

Figure 2. Typical output signal from the Landsat MSS system including the maximum (saturation) and minimum calibration signals.

Table 1 shows the minimum radiation values corresponding to the CCT´s zero digital counts, and the maximum radiation values (in $mW/cm^2 .sr$) from the maximum radiation emitted by the calibration lamp that correspond to the CCT´s full scale digital counts for the different periods of operation of the Landsat 1, 2, and 3 satellites (NASA, 1972A; NASA, 1972B; Otterman and Fraser, 1976). To correct for any long-term degradation of the internal calibration lamp the sun is used as a reference source (NASA, 1972A).

Table 1. Calibration Information for Different Periods of Operation of Landsat 1, 2 and 3 Systems

System and Performance Period	Wavelength Band (in μm)	Minimum CCT Digital Count	Maximum CCT Digital Count	Minimum Radiance (in mwatts/cm^2 sr)	Maximum Radiance (in mwatts/cm^2 sr)
Landsat 1	0.5 - 0.6	0	127	0	2.48
	0.6 - 0.7	0	127	0	2.00
	0.7 - 0.8	0	127	0	1.76
	0.8 - 1.1	0	63	0	4.60
Landsat 2 1/22/75 - 7/16/75	0.5 - 0.6	0	127	0.10	2.10
	0.6 - 0.7	0	127	0.07	1.56
	0.7 - 0.8	0	127	0.07	1.40
	0.8 - 1.1	0	63	0.14	4.15
Landsat 2 after 7/16/75	0.5 - 0.6	0	127	0.08	2.63
	0.6 - 0.7	0	127	0.06	1.76
	0.7 - 0.8	0	127	0.06	1.52
	0.8 - 1.1	0	63	0.11	3.91
Landsat 3 3/5/78 - 5/31/78	0.5 - 0.6	0	127	0.04	2.20
	0.6 - 0.7	0	127	0.03	1.75
	0.7 - 0.8	0	127	0.03	1.45
	0.8 - 1.1	0	63	0.03	4.41
Landsat 3 after 5/31/78	0.5 - 0.6	0	127	0.04	2.59
	0.6 - 0.7	0	127	0.03	1.79
	0.7 - 0.8	0	127	0.03	1.49
	0.8 - 1.1	0	63	0.03	3.83

During the process of reformatting the Landsat CCT´s to a LARSYS MIST (Multispectral Image Storage Tape) format, the radiometric calibration information is included in the ID record and at the end of every line of data. The maximum "in-band" radiance (in milliwatts/cm^2 .sr) for each spectral band can be obtained using the LARSYS *IDPRINT function as shown in Figure 3. The corresponding maximum digital count for every line of data and for each spectral band can be obtained by printing the last six records (columns) of every line of data using the *TRANSFERDATA function as illustrated in Figure 4.

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NOVEMBER 5,1978
11 58 00 AM
LARSYS VERSION 3

TAPE NUMBER.............. 1576
CONTINUATION CODE........... 0
FLIGHT LINE.. 132115595 IN
PLATFORM ALTITUDE.3062000 FEET

FILE NUMBER............... 1
NUMBER OF DATA CHANNELS.... 4
DATE DATA TAKEN...... 6/ 9/73
GROUND HEADING.... 190 DEGREES
NUMBER OF LINES......... 2340

RUN NUMBER.......... 73033804
NUMBER OF DATA SAMPLES... 3232
TIME DATA TAKEN.... 0959 HOURS
REFORMATTING DATE.JUNE 24,1974

CHANNEL	SPECTRAL BAND LOWER	UPPER	CALIBRATION PULSE VALUES C0	C1	C2
1	0.50	0.60	.0	2.480	.0
2	0.60	0.70	.0	2.000	.0
3	0.70	0.80	.0	1.760	.0
4	0.80	1.10	.0	4.600	.0

(IN MILLIWATTS/CM^2.SR.)

Figure 3. Output from the LARSYS *IDPRINT function showing the calibration pulse values.

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NOVEMBER 5,1978
11 53 38 AM
LARSYS VERSION 3

RUN NUMBER... 73033804 LINES... (1, 5, 1) COLUMNS... (3226, 3232, 1)

CHANNEL 1 SPECTRAL BAND 0.50 TO 0.60 MICROMETERS CALIBRATION CODE = 1 C0 = .0
CHANNEL 2 SPECTRAL BAND 0.60 TO 0.70 MICROMETERS CALIBRATION CODE = 1 C0 = .0
CHANNEL 3 SPECTRAL BAND 0.70 TO 0.80 MICROMETERS CALIBRATION CODE = 1 C0 = .0
CHANNEL 4 SPECTRAL BAND 0.80 TO 1.10 MICROMETERS CALIBRATION CODE = 1 C0 = .0

CHANNELS

LINE	COL	1	2	3	4	DATA
1	3226	39.0	33.0	52.0	28.0	← scene data
1	3227	0.0	0.0	0.0	0.0	← CØ
1	3228	0.0	0.0	0.0	0.0	← SCØ
1	3229	128.0	128.0	128.0	64.0	← C1
1	3230	0.0	0.0	0.0	0.0	← SC1
1	3231	0.0	0.0	0.0	0.0	← C2
1	3232	0.0	0.0	0.0	0.0	← SC2
2	3226	33.0	23.0	46.0	25.0	
2	3227	0.0	0.0	0.0	0.0	
2	3228	0.0	0.0	0.0	0.0	
2	3229	128.0	128.0	128.0	64.0	
2	3230	0.0	0.0	0.0	0.0	
2	3231	0.0	0.0	0.0	0.0	
2	3232	0.0	0.0	0.0	0.0	

Figure 4. Output from the LARSYS *TRANSFERDATA function showing the minimum (CØ) and maximum (C1) digital counts in a Landsat scene.

The last six samples of every line of data in the MIST format are reserved for the calibration values CØ, SCØ, C1, SC1, C2, and SC2 respectively (Phillips, 1969). Usually for Landsat data the digital count "zero" which corresponds to the minimum radiation signal is stored as CØ and the full scale digital count corresponding to the maximum radiation level of the calibration lamp is stored as C1. Therefore, in order to perform the calibration of the Landsat MSS data using LARSYS, one has to use the calibration code 4 in the generalized form of the CHANNELS control card as shown in the following example:*

```
CHANNELS 4(3/Ø, 1.76/)
```

where, 4 is the calibration code
3 is the channel number (Landsat band 6)
0 is the minimum radiation level (for Landsat 1)
1.76 is the maximum radiation level (in mwatts/cm^2 .sr) of the calibration lamp for band 6.

Calibration of the Landsat MSS data can be performed by any of the LARSYS processors that include a CHANNELS control card. The standard calibration function in LARSYS is essentially a linear equation of the form:

$$y = mx + b$$

where, y = calibrated spectral response (in mwatts/cm^2 .sr)
m = maximum radiance from the calibration lamp divided by the maximum digital count
b = minimum radiation reading corresponding to the "zero" digital count. For Landsat 1, b = Ø; and for Landsat 2 and 3, b ≠ Ø.

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* See Phillips (1969) for a detailed description of the seven available LARSYS calibration codes.

For the example given above, the calibration of channel 3 (band 6) data from Landsat 1 is illustrated graphically in Figure 5. Basically, this calibration procedure converts the relative spectral response values x into "in-band" radiance measurements y.

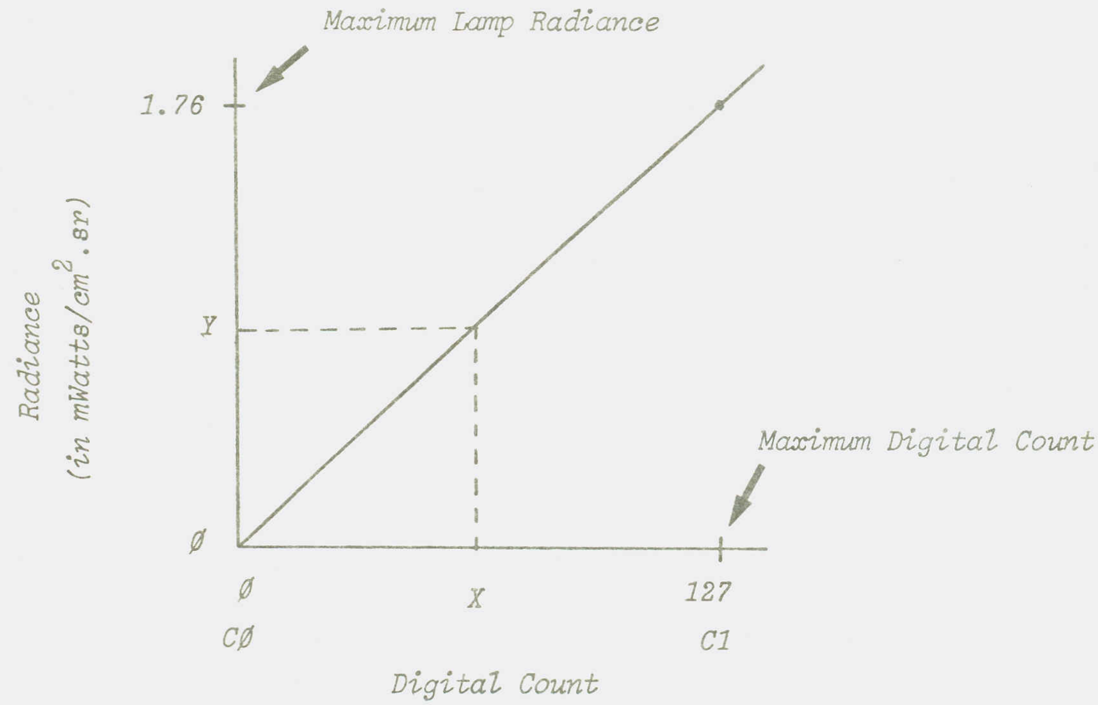

Figure 5. Graphic representation of the "linear calibration" of Landsat 1 data (for band 6).

To date, all Landsat CCT's reformatted at LARS contain the incorrect full scale calibration values of 128 for bands 4, 5, and 6 and 64 for band 7. In the future, these values should be 127 and 63 respectively.* Similarly, the calibration information contained in the ID record of all Landsat scenes reformatted at LARS is only valid for data from the Landsat 1 scanner system.

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* The full scale digital count for Landsat MSS data received and processed by the Brazilian ground receiving station is 255 for all four bands.

It should be noted that calibration of the Landsat MSS data yields "in-band" radiance measurements, and since band 7 is almost three times wider than the other three bands, the in-band radiance values for band 7 frequently appear disproportionately larger than the calibrated values in the other three bands. Similarly, since the in-band radiance for band 4 of the Landsat calibration lamp is approximately 20% greater than its in-band radiance for band 5, and the in-band radiance for the 0.5-0.6 μm band of a 6000 K Blackbody is only 13% greater than the in-band radiance for the 0.6-0.7 μm band, usually the Landsat calibrated values for band 4 appear a great deal higher than those corresponding to band 5.

Plotting the four Landsat in-band radiances, that is, the calibrated spectral responses of ground cover types, such as those illustrated in Figure 6, can be extremely useful during the analysis of the Landsat MSS data. Although these plots cannot be compared in absolute terms with the spectral reflectance curves of the major ground cover types as those shown in Figure 1, the general shape of the plots provide an indication as to the identity of the spectral classes.

For example the "agricultural crop" and "forest" plots illustrated in Figure 6 have the same general shape of green vegetation; the water plot has a decreasing spectral response from the visible (band 4) towards the infrared (band 7); and the "reservoir edge" plot correspond to those pixels which cover partially water and forest along the edge of the reservoir. Note that the spectral response of this "edge" class is an average (linear combination) of the spectral responces of pure forest and pure water. In certain situations, it is possible to use these plots to determine the proportions of pure cover types that compose a "mixture" class. They are also extremely useful to make decisions regarding the validity of pooling or deleting spectral classes that are not separable.

Figures 7 through 17 show a series of examples of calibrated spectral responses for different ground cover types, different seasons, and different geographic locations.

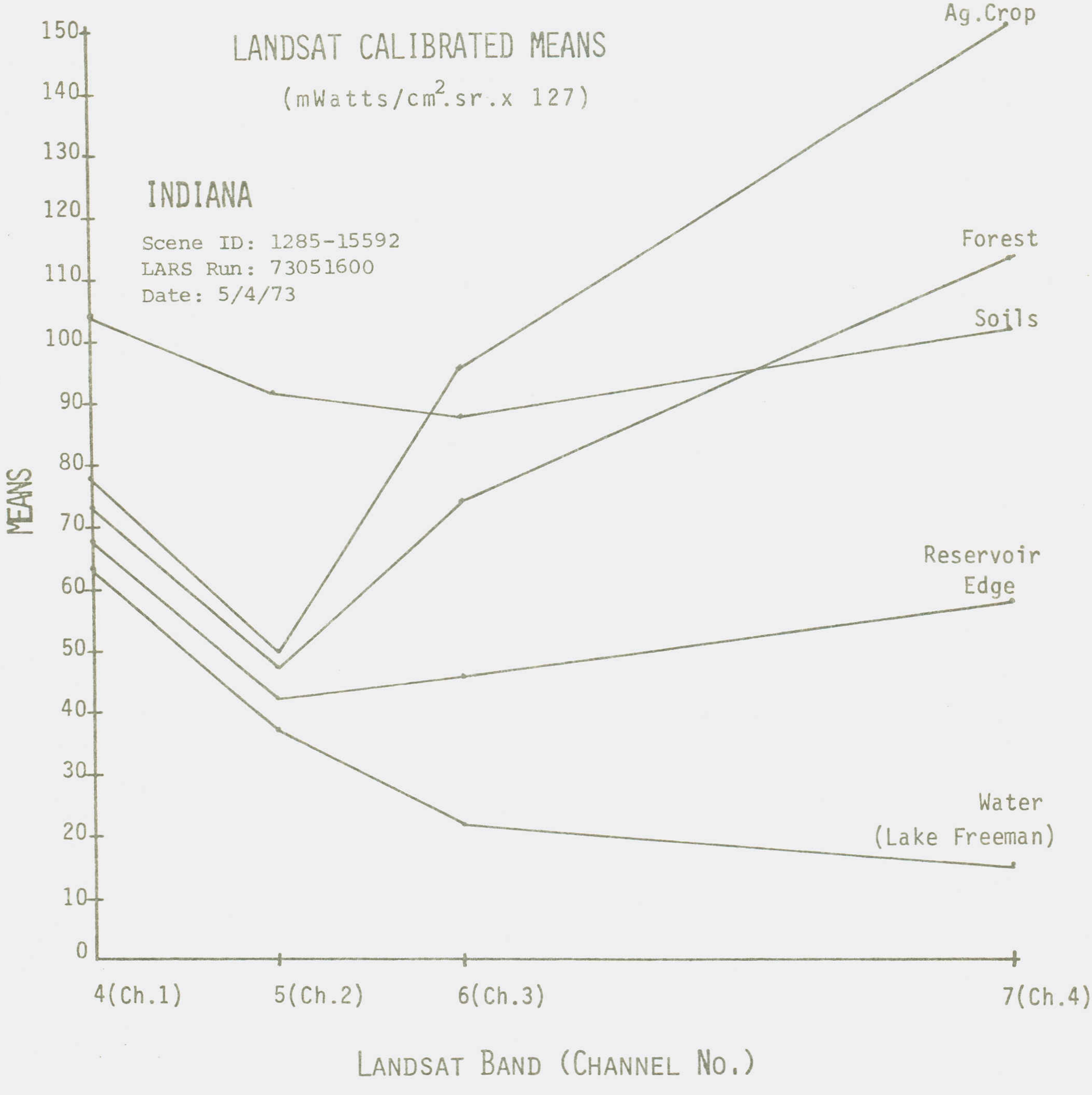


Figure 6. Plot of calibrated Landsat data corresponding to the mean spectral response of major classes.

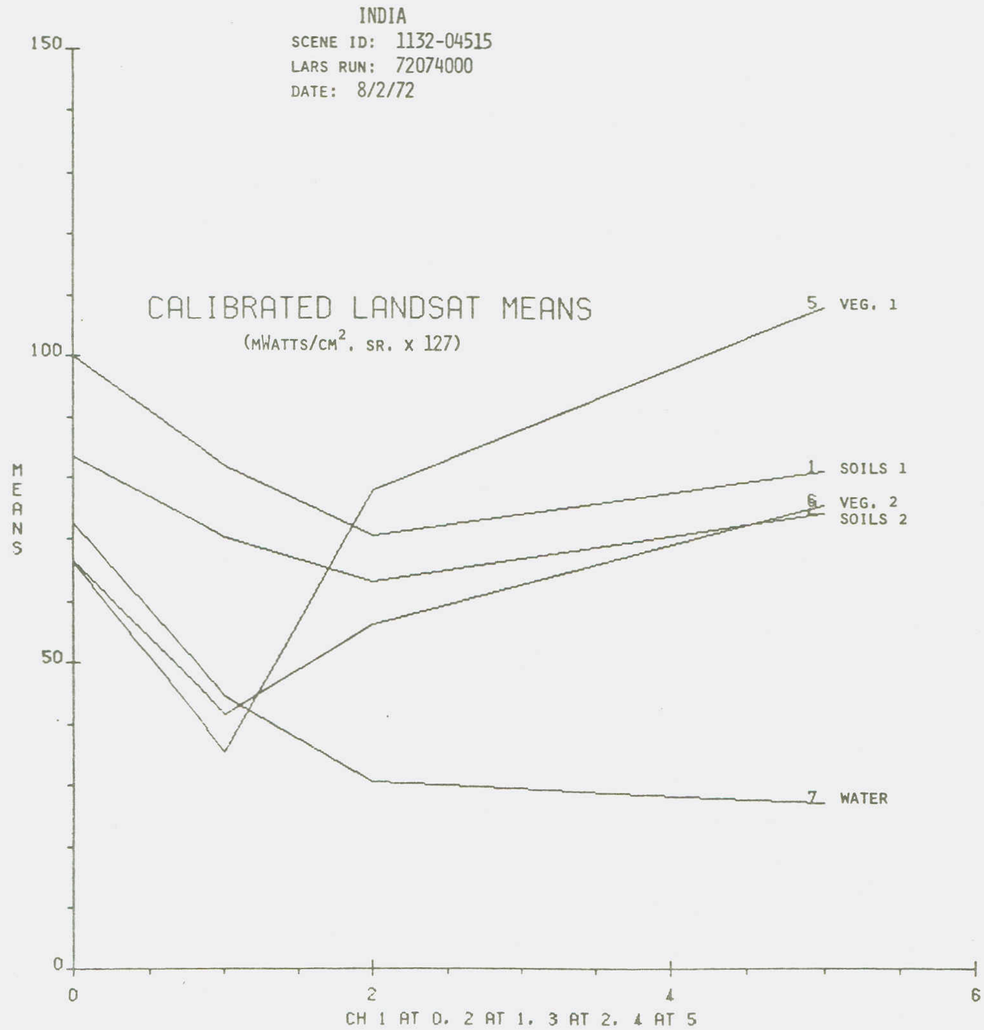

INDIA
SCENE ID: 1132-04515
LARS RUN: 72074000
DATE: 8/2/72
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. X 127)
150
100
50
0
MEANS
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5
5 VEG. 1
1 SOILS 1
6 VEG. 2
SOILS 2
7 WATER

Figure 7

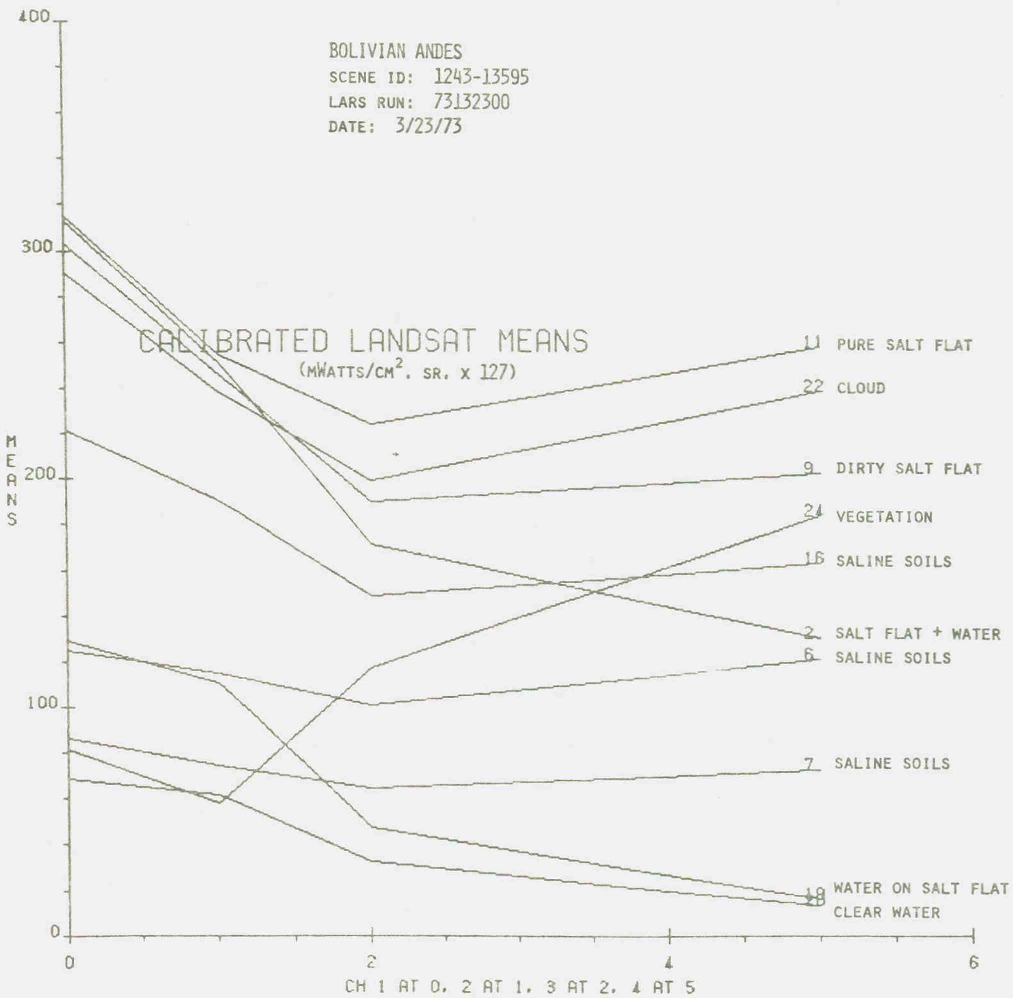

BOLIVIAN ANDES
SCENE ID: 1243-13595
LARS RUN: 73132300
DATE: 3/23/73
CALIBRATED LANDSAT MEANS
(mWATTS/CM². SR. X 127)
MEANS
400
300
200
100
0
2
4
6
CH 1 AT 0, 2 AT 1, 3 AT 2, 4 AT 5
11 PURE SALT FLAT
22 CLOUD
9 DIRTY SALT FLAT
24 VEGETATION
16 SALINE SOILS
2 SALT FLAT + WATER
6 SALINE SOILS
7 SALINE SOILS
19 WATER ON SALT FLAT
20 CLEAR WATER

Figure 8

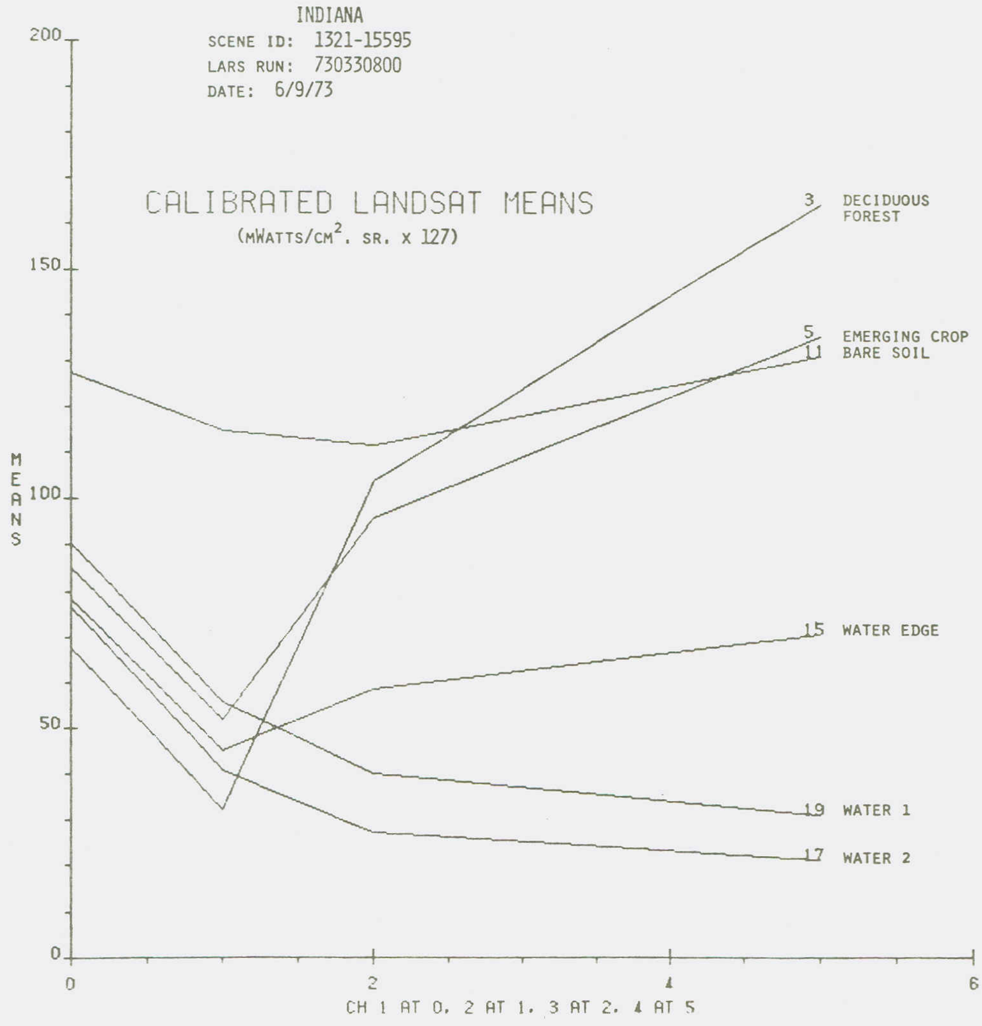

INDIANA
SCENE ID: 1321-15595
LARS RUN: 730330800
DATE: 6/9/73
CALIBRATED LANDSAT MEANS
(mWATTS/CM². SR. X 127)
MEANS
200
150
100
50
0
0
2
4
6
CH 1 AT 0, 2 AT 1, 3 AT 2, 4 AT 5
3 DECIDUOUS FOREST
5 EMERGING CROP
11 BARE SOIL
15 WATER EDGE
19 WATER 1
17 WATER 2

Figure 9

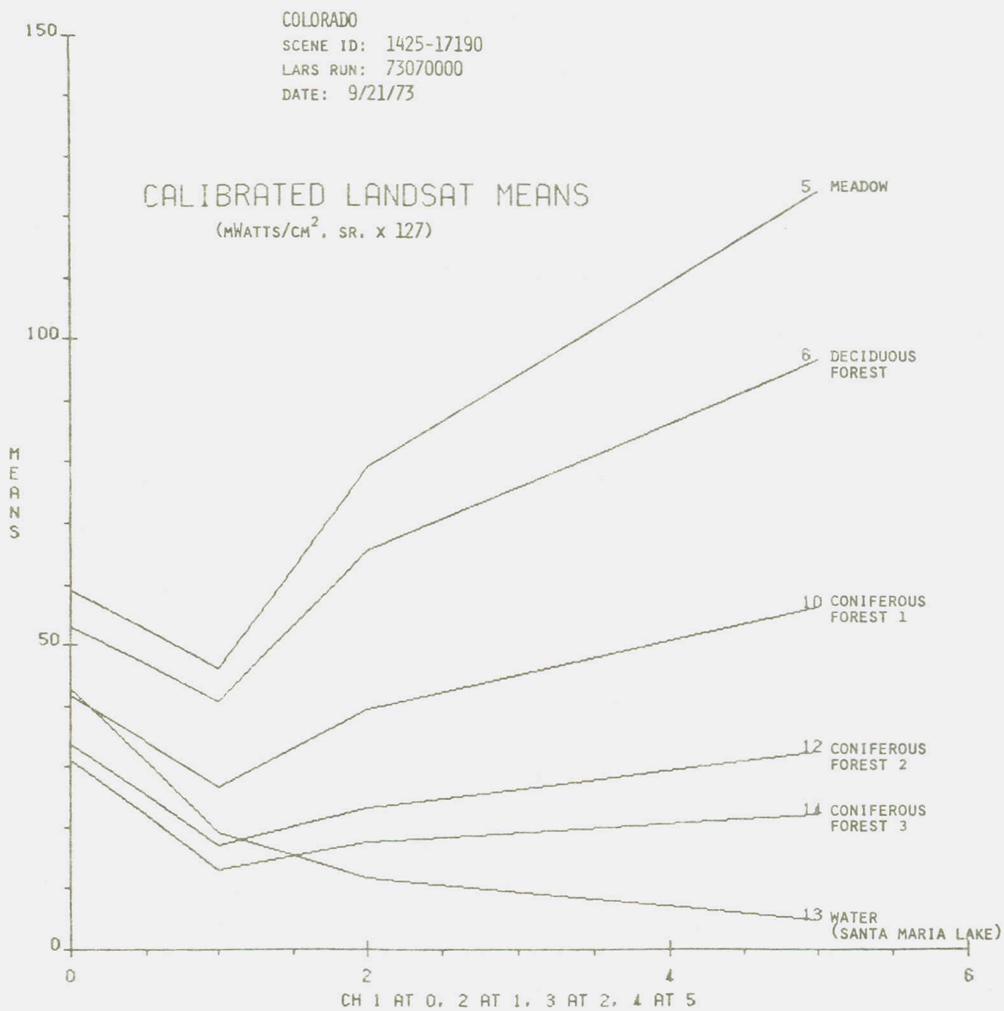

COLORADO
SCENE ID: 1425-17190
LARS RUN: 73070000
DATE: 9/21/73
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. x 127)
MEANS
150
100
50
0
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5
5 MEADOW
6 DECIDUOUS FOREST
10 CONIFEROUS FOREST 1
12 CONIFEROUS FOREST 2
14 CONIFEROUS FOREST 3
13 WATER (SANTA MARIA LAKE)

Figure 10

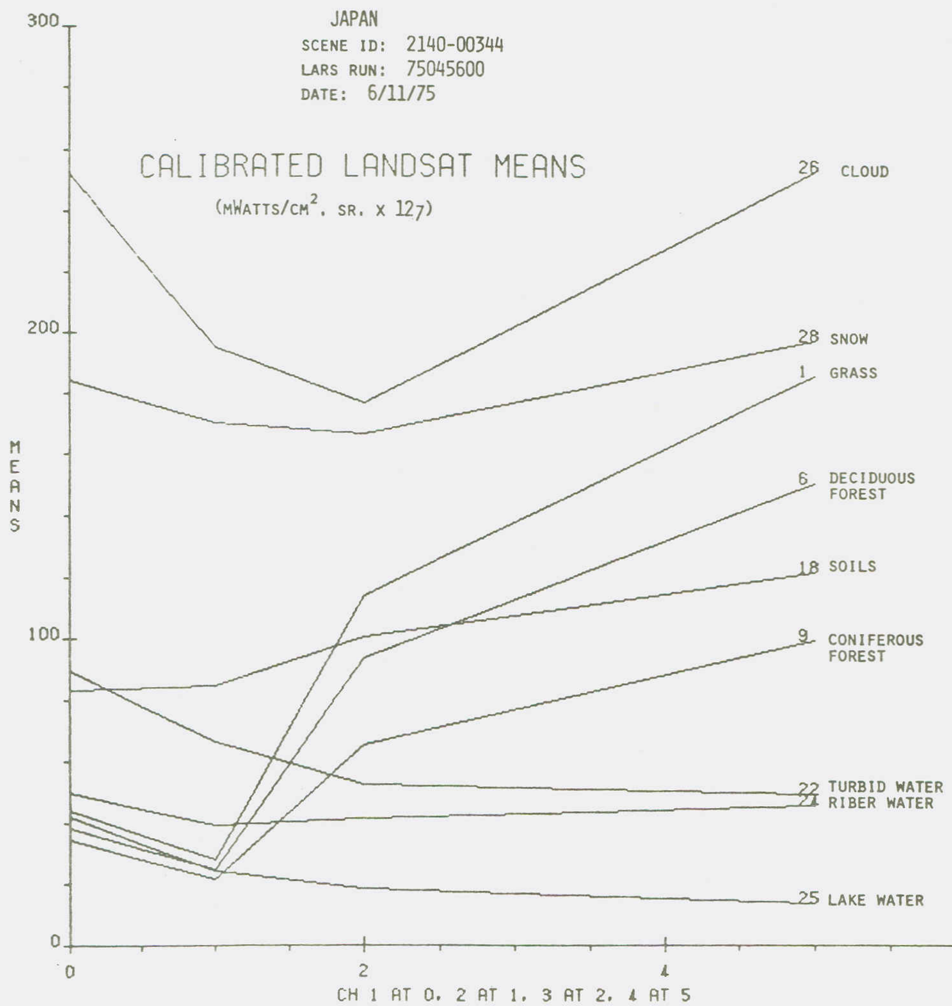
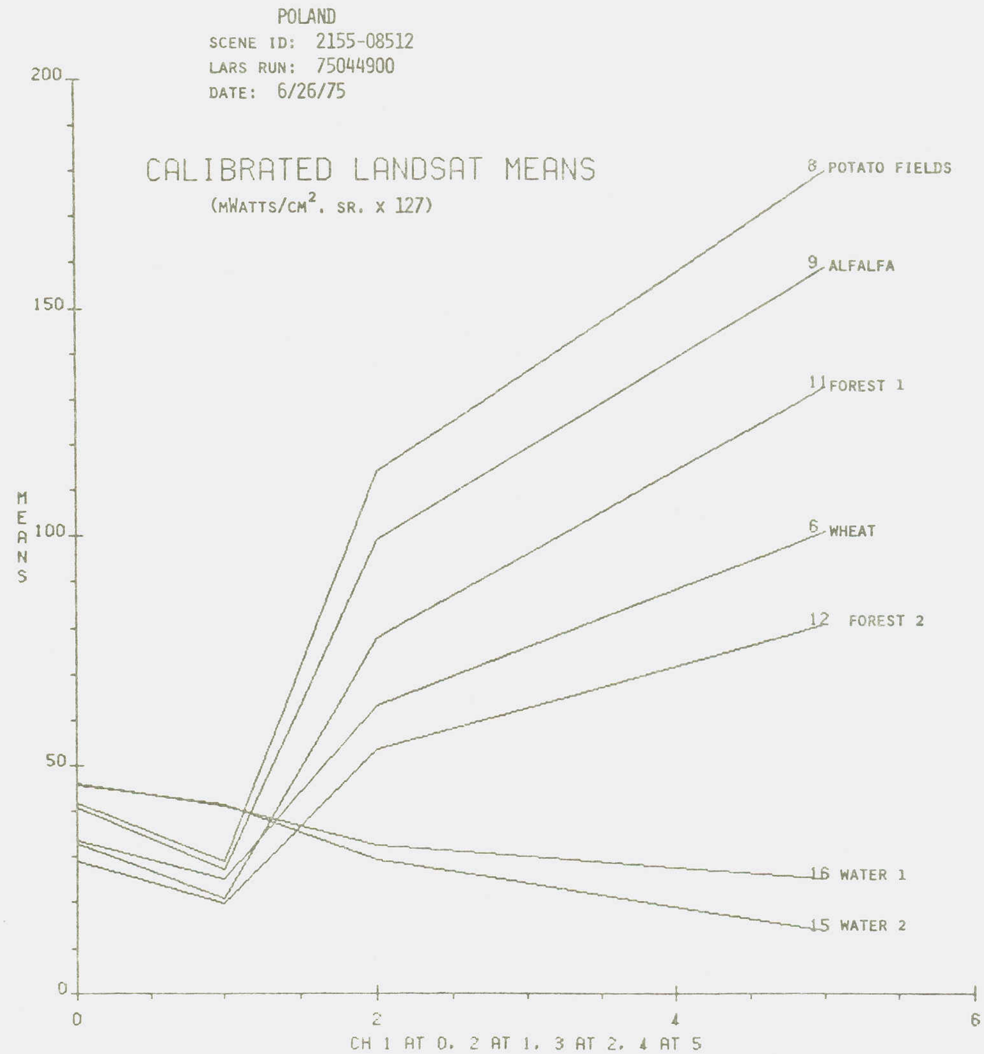

JAPAN
SCENE ID: 2140-00344
LARS RUN: 75045600
DATE: 6/11/75
CALIBRATED LANDSAT MEANS
(mWATTS/CM². SR. X 127)
300
200
100
0
MEANS
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5
26 CLOUD
28 SNOW
1 GRASS
6 DECIDUOUS FOREST
18 SOILS
9 CONIFEROUS FOREST
22 TURBID WATER
21 RIBER WATER
25 LAKE WATER

Figure 11



POLAND
SCENE ID: 2155-08512
LARS RUN: 75044900
DATE: 6/26/75
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. X 127)
MEANS
200
150
100
50
0
0
2
4
6
CH 1 AT 0, 2 AT 1, 3 AT 2, 4 AT 5
8 POTATO FIELDS
9 ALFALFA
11 FOREST 1
6 WHEAT
12 FOREST 2
16 WATER 1
15 WATER 2

Figure 12

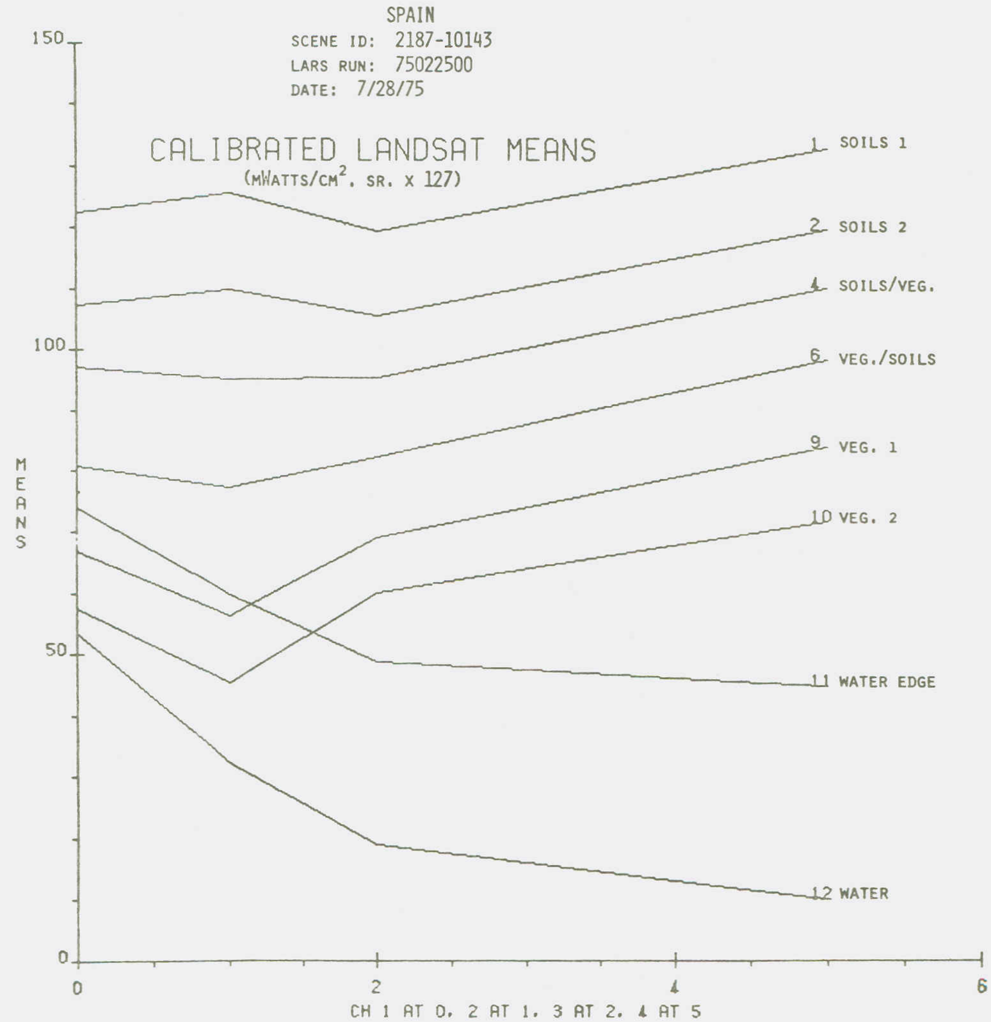

SPAIN
SCENE ID: 2187-10143
LARS RUN: 75022500
DATE: 7/28/75
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. X 127)
150
100
50
0
MEANS
1 SOILS 1
2 SOILS 2
4 SOILS/VEG.
6 VEG./SOILS
9 VEG. 1
10 VEG. 2
11 WATER EDGE
12 WATER
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5

Figure 13

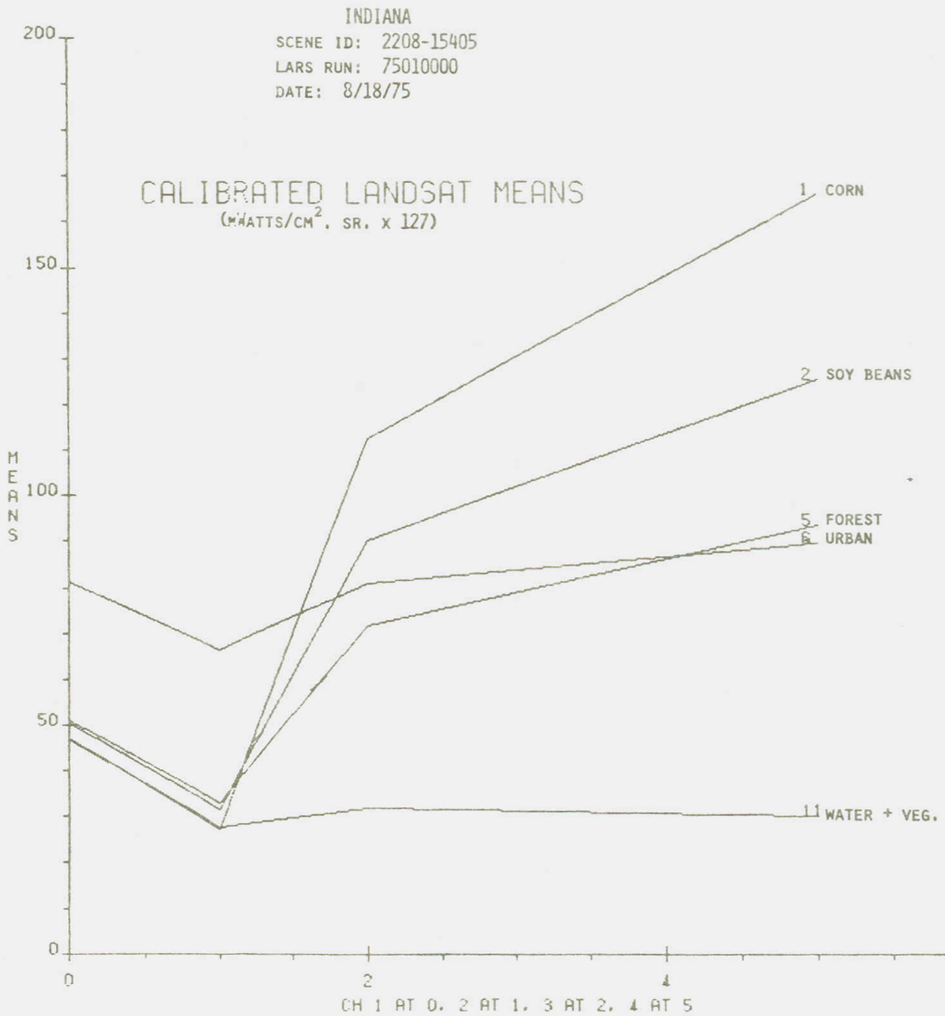
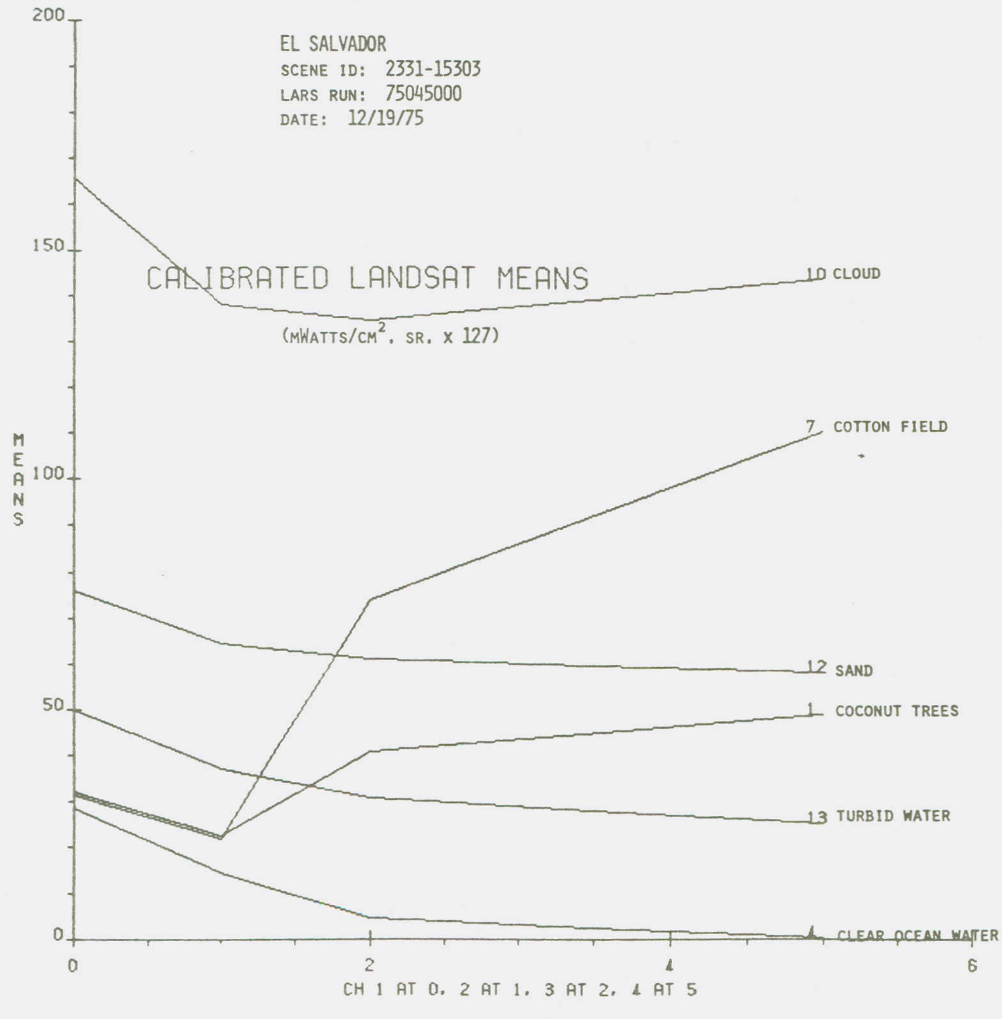

INDIANA
SCENE ID: 2208-15405
LARS RUN: 75010000
DATE: 8/18/75
CALIBRATED LANDSAT MEANS
(mWATTS/CM². SR. x 127)
200
150
100
50
0
MEANS
1 CORN
2 SOY BEANS
5 FOREST
6 URBAN
11 WATER + VEG.
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5

Figure 14



EL SALVADOR
SCENE ID: 2331-15303
LARS RUN: 75045000
DATE: 12/19/75
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. x 127)
200
150
100
50
0
MEANS
10 CLOUD
7 COTTON FIELD
12 SAND
1 COCONUT TREES
13 TURBID WATER
4 CLEAR OCEAN WATER
0
2
4
6
CH 1 AT 0. 2 AT 1. 3 AT 2. 4 AT 5

Figure 15

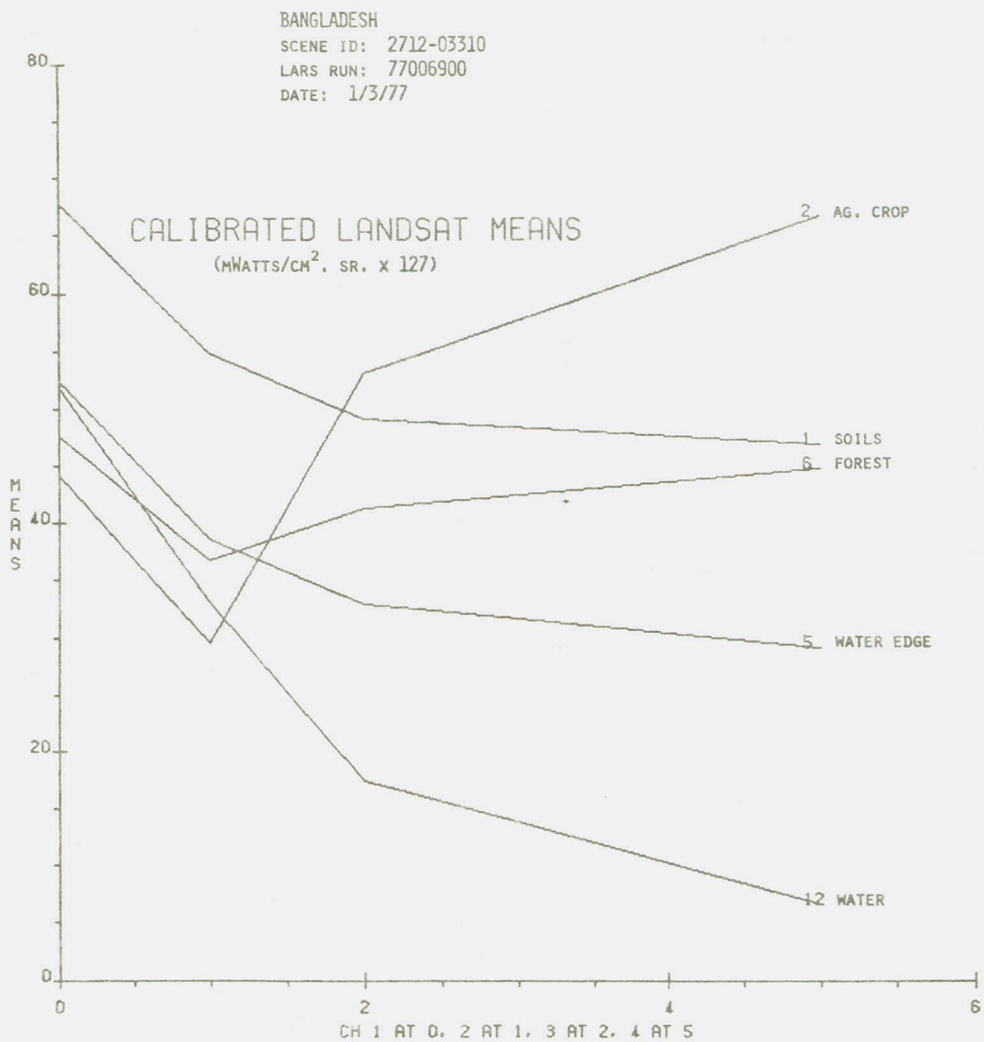

BANGLADESH
SCENE ID: 2712-03310
LARS RUN: 77006900
DATE: 1/3/77
CALIBRATED LANDSAT MEANS
(mWATTS/CM^2. SR. x 127)
80
60
40
20
0
MEANS
0
2
4
6
CH 1 AT 0, 2 AT 1, 3 AT 2, 4 AT 5
2 AG. CROP
1 SOILS
6 FOREST
5 WATER EDGE
12 WATER

Figure 16

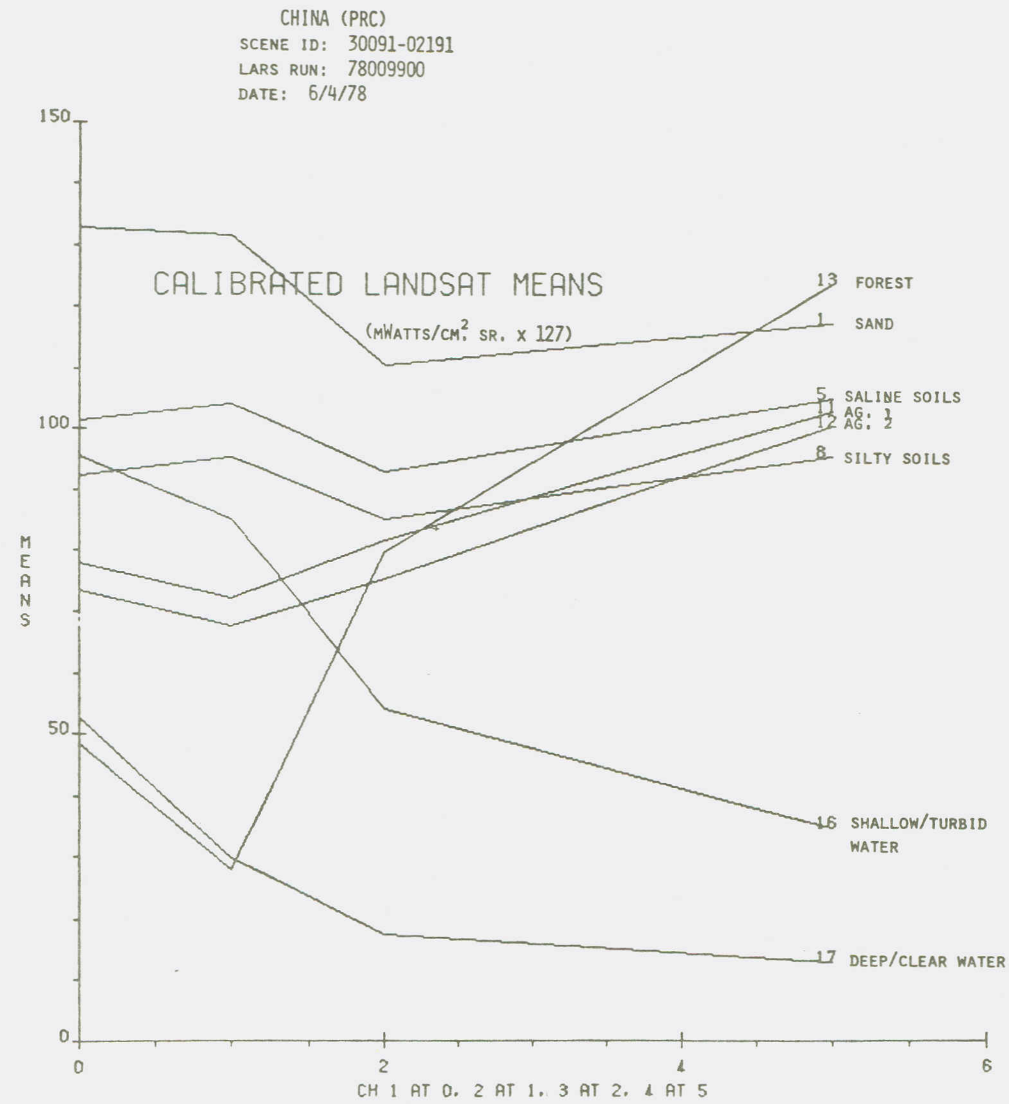

CHINA (PRC)
SCENE ID: 30091-02191
LARS RUN: 78009900
DATE: 6/4/78
CALIBRATED LANDSAT MEANS
(mWATTS/CM.² SR. X 127)
150
100
50
0
MEANS
13 FOREST
1 SAND
5 SALINE SOILS
11 AG. 1
12 AG. 2
8 SILTY SOILS
16 SHALLOW/TURBID WATER
17 DEEP/CLEAR WATER
0
2
4
6
CH 1 AT 0, 2 AT 1, 3 AT 2, 4 AT 5

Figure 17

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