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Early Warning and Crop Condition Assessment

UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY FOR WORLD-WIDE ENVIRONMENTAL MONITORING THE LOWER MISSISSIPPI RIVER FLOOD OF 1979—CASE 1

Michael R. Helfert, Dee G. McCrary and Thomas I. Gray

(E82-10113) UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY FOR WORLD-WIDE ENVIRONMENTAL MONITORING THE LOWER MISSISSIPPI RIVER FLOOD OF 1979—CASE 1

U.S. Department of Commerce
1050 Bay Area Blvd.
Houston, Texas 77058

Lyndon B. Johnson Space Center
Houston, Texas 77058
UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY
FOR WORLD-WIDE ENVIRONMENTAL MONITORING
THE LOWER MISSISSIPPI RIVER FLOOD OF 1979 - CASE 1

PRINCIPAL INVESTIGATORS
Michael R. Helfert, Dee G. McCrary,
and Thomas I. Gray

APPROVED BY

[Signature]
G.O. Boatwright, Manager
Early Warning/Crop Condition Assessment Project
AgRISTARS Program

Earth Observations Division
Space and Life Sciences Directorate
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

May 1981
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A need by policy and decision-makers for real-time or near real-time monitoring of the evolution of major natural environmental disruptions exists. With the growing realization of the need for worldwide information, a data collection technique must be identified and refined that will permit timely, repetitive environmental monitoring while bypassing issues of access restriction.

Such environmental monitoring has been proposed previously as a mission of the Landsat family, the proposed Landsat-D family, and of future families of active sensors such as the Shuttle Imaging Radar and its potential evolutions.

Two of the current U.S. satellite families have the capabilities of multi-temporal, "good" spatial, and multi-band image acquisition to allow timely world-wide disaster monitoring. The older, better-known family is the experimental NASA Landsat series. This series has been proposed as a candidate for an operational system. The second satellite series is the MESS operational polar-orbiting environmental satellites (NOAA-n series). The characteristics of the two satellite series' orbital parameters, onboard sensors, ground processing and data distribution systems, and operational user requirements indicate that integrated utilization of imagery from both satellite series is feasible in a complementary mode.

As an interim and a supplement, we would like to propose utilization of imagery from the NOAA-n meteorological satellite series to monitor worldwide environmental disruptions. Previous applications of meteorological satellite families (ESSA, SMS/GOES, ITOS, TIRCS, and NOAA) have been focussed primarily in the realm of atmospheric monitoring.

As a test case of environmental disaster monitoring utilizing NOAA-n imagery, we have selected the 1979 Lower Mississippi River flood. An earlier, small-scale study of the St. Louis, Missouri, area comparing ENTS-1 (Landsat) and NOAA-2 imagery has been done. Similar flood studies have been done using only Landsat imagery for mapping the Red River of the North and Nimbus-5 imagery for East Australia.
I. CURRENT REMOTE SENSING PLATFORMS:
ADVANTAGES AND DISADVANTAGES FOR ENVIRONMENTAL MONITORING

Within the various operational and research satellite families, two systems exist with characteristics which nearly satisfy the previously mentioned criteria. These are the operational NOAA-n series (the follow-on to the TIROS-N research satellite) and the proposed operational system. Both are designed to remotely-sense the earth from near-polar sun-synchronous orbits, to have nearly equal orbital periods, to make blind broadcasts of their multi-channel imaged data, and to record data of distant scenes for later readouts. Each system is expected to relay its distant data acquisitions via geostationary repeater satellites later in this decade. However, each satellite has been designed for different objectives: the NOAA series for daily total global coverage of atmospheric states (both day and night); and the Landsat series for detailed coverage of cloud free areas. The sensor designs produce resolutions at nadir near 0.95 sq. km. for the NOAA series and about 0.09 sq. km. for the Landsat series.

The NOAA-n system provides the better temporal data acquisition by viewing any given target every clear day. On the other hand, Landsat imagery provides tenfold better linear resolution, but revisits a particular target area only at 18 day intervals. This long temporal interval in Landsat imagery permits consecutive acquisitions only if clear sky conditions are also in step – an irregular occurrence.

The NOAA-n series, an operational remote sensing system underutilized by the non-meteorological community, are designed to maintain two satellites in orbit during at least the period 1979-1982. Each satellite will have a life expectancy of two to four years.

The NOAA-n satellites, like their Defense Meteorological Satellite Program (DMSP) cousins, are in a near polar orbit at an altitude of approximately 520 miles. Each satellite makes about 14.2 orbits per day and provides coverage of the entire globe twice per day, once in daylight and once during night. The two operational satellite orbits are separated by about 90° of longitude. The resolution of the NOAA-n AVHRR is 1.1 kilometer at nadir with four or five channel sensor coverage. Channels 1 and 2 are sensitive to frequencies similar to those of the current Landsats. Sensor data are recorded on board the NOAA-n satellite in two formats - local-area coverage (LAC) and global-area coverage (GAC). The GAC data are readily available for each complete orbit, but the LAC data, being very voluminous, are restricted to a maximum of a 19-minute recording per orbit. The GAC data are a quasi-summary of the LAC data. GAC is the total of four contiguous pixels, skipping the next one, then the total of the next four, etc., for the entire scanline. The next two scanlines are skipped. GAC data are archived in a digital form and are available from National Climatic Center’s Satellite Data Services Division (NSDS). The LAC data must be prescheduled on a priority basis, and thus is available from NSDS only if it was initially acquired.
Multi-spectral scanner (MSS) data can be acquired from the Landsat within a near-real time frame. However, two factors exist which reduce the effectiveness of MSS data:

1. Excessive cloudiness over the desired target at time of acquisition; and

2. system design which limits acquisition of the target to once every 10 days per satellite.

The two satellite systems, Landsat and NOAA-n, have some common sensor frequencies which make it possible to compare sensor frequency combinations using the Gray-McCrary Index (GMI). Table 1 compares the frequencies of each satellite system:

<table>
<thead>
<tr>
<th>NOAA Channel No.</th>
<th>AVHRR Span of Wave Length</th>
<th>Landsat Channel No.</th>
<th>MSS Span of Wave Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>550-680 nm</td>
<td>4</td>
<td>580-660 nm</td>
</tr>
<tr>
<td>2</td>
<td>780-1100 nm</td>
<td>5</td>
<td>885-910 nm</td>
</tr>
</tbody>
</table>

A single receiving station on the globe is usually able to acquire two consecutive passes of the information from a NOAA-n satellite during the daytime hours and again for nighttime hours. The nighttime data is limited to the high number channels only. The number of daily acquisitions increases from one or two at the equator to 14 at the pole.
The Landsat data is available to a receiving station in geographic coverage similar to that of NOAA-n. However, the Landsat image areal coverage is much less than for the NOAA-n because of the more narrow instantaneous Field of View (IFOV). The chief advantage of the Landsat series has been high-resolution, multi-spectral imagery sufficient for fairly precise mapping of differentials of surface reflectance. Previous high-quality Landsat imagery mapping has included bathymetric studies, urban, and rural, land-use discrimination, geologic mapping, coastal zone, characteristic definition pollution, studies, hydrologic and ice-mapping, and agricultural studies. Problems with the current Landsat system vis-à-vis user requirements have begun to arise with the electronic degradation of both the space-borne sensors and the ground-processing system. This degradation with age is only to be expected when it is realized that Landsat-2 and 3 were launched in 1975 and 1978 with expected satellite lifetimes of one year. The present Landsat ground-processing system is a custom-designed, composite, experimental system that has borne up well although subjected to heavy operational use requirements.

For some user requirements, Landsat MSS target acquisition repeatability every 9 days (2 satellite system) or 12 days (1 satellite system) is now marginal. This repeatability becomes critical when cloud cover over a desired target prevents an acquisition. This now results in a minimum 18-day MSS image repeatability. These temporal gaps are particularly frustrating to time-dependent agricultural, vegetation, hydrologic, and ice-cover monitoring studies. Although cloudsiness affects target acquisitions for both Landsat and the NOAA-n systems, the wider IFOV of the NOAA-n designed for total global coverage usually provides useful agriculture target coverages as often as four to eight times in an eighteen day period.

The launch of the Landsat-D family (currently scheduled for the summer of 1982) will provide continuity for the Landsat MSS image archive. Such continuity assumes that the MSS aboard current Landsats remains operational until that time. As of this writing, Landsat-D will carry both a four-band MSS and seven-band MSS (Thematic Mapper). Workup of a new ground processing system rated for operational use also is underway at this time. The Landsat-D family satellites will be Shuttle-recoverable, allowing refurbishment of onboard expendables and maintenance/updating of onboard sensors and electronics. The Landsat-D system, as currently funded, will consist of two satellites in orbit. This will allow 8-day (15-day single satellite repeatability) image acquisition cycles. The potential problems of cloud cover interfering with this repeatability remain. The cloud cover problem must await the arrival of "smart" tiltable sensors and active microwave systems such as the proposed Landsat-H, GEOSAT, MARSAT, etc., systems.
II. SELECTION OF THE 1979 LOWER MISSISSIPPI VALLEY FLOODS

In an attempt to fill the temporal gaps of Landsat imagery cycles, we have investigated the possibility of using the NOAA-n environmental satellite family imagery for timely, repeatable acquisition of data for assessing vegetative health using the Cray-McCrae Index (GMI), and now, for disaster assessment.

For our first disaster assessment study, we have selected the floods along the Lower Mississippi River and its tributaries during the late spring of 1979. Reasons for this selection were easy geographic access for ground truth, availability of high-quality surface meteorological and hydrologic data, availability of NOAA aircraft strip photography, and the assumption of Landsat imagery availability.

The last assumption proved unfounded. No acceptable Landsat MSS imagery for the target area exists for the flood crest period of 15 April-31 May 1979. This is due to intermittent cloud cover coinciding with Landsat passes over the region. As a result, Landsat imagery from the 1977 floods in the same region were used for imagery comparison purposes. Table 2 illustrated the problem of Landsat imagery continuity in this case.

As a comparison to the Landsat regional imagery acquisition history during the April-May 1979 period, an incomplete inventory of NOAA-n imagery available from 27 April through 15 May for regional flood assessment is presented in Table 3.

The TIROS-N (NOAA-n) image of the Lower Mississippi Valley on 7 May 1979 (orbit 2097) was selected for detailed analysis (see Figure 1). Mid-point on the image is a north-south line from approximately Brownsville, Texas, to Wichita, Kansas. Mid-point on the image is pixel 1724. The image is 2786 pixels wide (east-west). The target area of North Louisiana and South Arkansas runs from pixel 351 to pixel 987. Despite this bias of the study area towards the eastern edge of the image, few problems with geometric distortion were encountered.
### Table 2

<table>
<thead>
<tr>
<th>Acquisition Date</th>
<th>Path-Row</th>
<th>Acquisition Available</th>
<th>Cloud Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 5</td>
<td>25-37</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>April 5</td>
<td>25-38</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>April 6</td>
<td>25-37</td>
<td>L-2</td>
<td>10²</td>
</tr>
<tr>
<td>April 14</td>
<td>25-37</td>
<td>L-2</td>
<td>0³</td>
</tr>
<tr>
<td>April 14</td>
<td>25-38</td>
<td>L-2</td>
<td>0³</td>
</tr>
<tr>
<td>April 15</td>
<td>25-37</td>
<td>L-2</td>
<td>10²</td>
</tr>
<tr>
<td>April 23</td>
<td>25-37</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>April 23</td>
<td>25-38</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>April 23</td>
<td>26-37</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>May 2</td>
<td>25-37</td>
<td>NA</td>
<td>---</td>
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<tr>
<td>May 2</td>
<td>25-38</td>
<td>L-2</td>
<td>90</td>
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<tr>
<td>May 7</td>
<td>26-37</td>
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<td>---</td>
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<tr>
<td>May 11</td>
<td>25-37</td>
<td>L-3</td>
<td>90</td>
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<td>25-38</td>
<td>L-3</td>
<td>90</td>
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<tr>
<td>May 12</td>
<td>25-37</td>
<td>L-3</td>
<td>90</td>
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<td>25-37</td>
<td>L-2</td>
<td>90</td>
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<tr>
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<td>L-2</td>
<td>70</td>
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<td>May 21</td>
<td>25-37</td>
<td>L-2</td>
<td>90</td>
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<td>May 29</td>
<td>25-37</td>
<td>NA</td>
<td>---</td>
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<tr>
<td>May 29</td>
<td>25-38</td>
<td>NA</td>
<td>---</td>
</tr>
<tr>
<td>May 30</td>
<td>26-37</td>
<td>L-3</td>
<td>90</td>
</tr>
</tbody>
</table>

1. From U.S. Department of Interior Landsat archive at EROS Data Center, Sioux Falls, SD.
2. Neither satellite (Landsat-2 or -3) turned on due to cloud cover forecasts.
3. Flooding and flood crests had not arrived in area during this period.
<table>
<thead>
<tr>
<th>ACQUISITION DATE</th>
<th>CHANNELS</th>
<th>CLOUD COVER (%)</th>
<th>ORBIT</th>
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<td>April 27</td>
<td>1-4</td>
<td>0</td>
<td>2777</td>
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<tr>
<td>April 28</td>
<td>1-4</td>
<td>26</td>
<td>2777</td>
</tr>
<tr>
<td>April 29</td>
<td>1-4</td>
<td>0</td>
<td>2785</td>
</tr>
<tr>
<td>April 30</td>
<td>1-4</td>
<td>50</td>
<td>2809</td>
</tr>
<tr>
<td>April 31</td>
<td>1-4</td>
<td>0</td>
<td>2812</td>
</tr>
<tr>
<td>May 1</td>
<td>1-4</td>
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<td>2819</td>
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<td>May 1</td>
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<td>100</td>
<td>2825</td>
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<tr>
<td>May 5</td>
<td>1-4</td>
<td>40</td>
<td>2875</td>
</tr>
<tr>
<td>May 6</td>
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<td>0</td>
<td>2896</td>
</tr>
<tr>
<td>May 8</td>
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<td>10</td>
<td>2897</td>
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<td>2</td>
<td>2914</td>
</tr>
<tr>
<td>May 15</td>
<td>1-4</td>
<td>30</td>
<td>2925</td>
</tr>
<tr>
<td>May 15</td>
<td>1-4</td>
<td>0</td>
<td>3003</td>
</tr>
<tr>
<td>May 15</td>
<td>1-4</td>
<td>0</td>
<td>3017</td>
</tr>
<tr>
<td>May 24</td>
<td>1-4</td>
<td>0</td>
<td>3024</td>
</tr>
</tbody>
</table>

1 From Satellite Data Services Division (National Climatic Center), World Weather Building, Washington, DC
Full NOAA (TIROS-N) image used in this study. The coast of Texas is well-defined until the cloud area intercepts the coast over Galveston. The study area transects the color/shade difference across the Mississippi River.
III. REGIONAL GROUND DATA CONCERNING THE FLOOD

The 1979 floods in the Lower Mississippi Valley watersheds rank with the 1973 and 1927 floods as the greatest floods of the 20th century in Louisiana. Comparisons with the 1927 flood are not genuine for remote sensing comparison. Direct comparison is quite difficult because of the lack of early imagery and because of man-modifications to the entire river system during the intervening half-century. On the other hand, surface data on flooding patterns in 1973 and 1979 were quite similar. Thus, we felt the regional flood patterns imaged by Landsat in 1973 should be similar to those imaged by NOAA-n in 1979.

Meteorological and hydrologic patterns during all three flood years were similar—a wet autumn, heavy Midwest winter snowpack averaging 18-32", quick spring thaw, and heavy rain in the lower reaches of the Mississippi watershed.

In January 1979, a record snowpack was laid down in the Western and Southern Great Lakes states and watersheds. During February, the Great Plains averaged 300% of normal precipitation totals. A rapid snowmelt throughout the Midwest began 11-12 March. Flooding along upper Mississippi River watersheds began during mid and late March. These waterway crests coalesced along the mainstream of the Mississippi River in late March and early-mid April.

The mainline Mississippi crests were increased and compounded by continuous heavy rains throughout Louisiana, Arkansas, and Mississippi from December 1978 until mid-May 1979. The runoff from these six-month regional rains (see Table 4) averaging 45 inches resulted in flooding along the courses of local waterways, and backwater flooding at their confluence with the Mississippi River.

The result of the heavy rain, saturated ground, rapid snowmelt of a deep snowpack, and the natural reservoir of backwater flooding behind mainline levees were long, flat compound crests on area waterways. River stages during the period for representative regional Lower Mississippi River and the Ouachita River stations are summarized in Table 5.

Other waterways in flood between the Ouachita and Mississippi Rivers included the Bocuf and Tensas Rivers, Bayou Bartholomew, Bayou DeSiard, Bayou Macon, and Bayou LaFourche. Backwater flooding was extensive in area swamps and land normally under cultivation. Most of this standing water behind levees and bankful waterways had run out by the end of the first week of June.
TABLE 4

REPRESENTATIVE 6-MONTH PRECIPITATION TOTALS,
ARKANSAS AND LOUISIANA.

Precipitation (Inches)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>City/State</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camden, AR</td>
<td>5.62</td>
<td>7.55</td>
<td>5.57</td>
<td>4.25</td>
<td>10.51</td>
<td>7.57</td>
<td>42.27</td>
<td>23.87</td>
</tr>
<tr>
<td>Crossett, AR</td>
<td>5.32</td>
<td>11.47</td>
<td>5.14</td>
<td>6.39</td>
<td>15.68</td>
<td>8.16</td>
<td>52.17</td>
<td>30.76</td>
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<tr>
<td>El Dorado, AR</td>
<td>9.31</td>
<td>3.52</td>
<td>5.42</td>
<td>5.49</td>
<td>7.79</td>
<td>5.97</td>
<td>43.56</td>
<td>29.31</td>
</tr>
<tr>
<td>Helena, AR</td>
<td>17.91</td>
<td>6.79</td>
<td>4.65</td>
<td>5.84</td>
<td>16.80</td>
<td>12.96</td>
<td>52.04</td>
<td>29.29</td>
</tr>
<tr>
<td>Little Rock, AR</td>
<td>11.54</td>
<td>4.25</td>
<td>5.47</td>
<td>3.10</td>
<td>9.66</td>
<td>22.35</td>
<td>45.56</td>
<td>27.85</td>
</tr>
<tr>
<td>Monroe, LA</td>
<td>16.29</td>
<td>12.72</td>
<td>8.31</td>
<td>5.34</td>
<td>9.12</td>
<td>8.36</td>
<td>52.44</td>
<td>25.12</td>
</tr>
<tr>
<td>Sheridan, AR</td>
<td>17.16</td>
<td>4.48</td>
<td>5.03</td>
<td>3.28</td>
<td>9.75</td>
<td>14.26</td>
<td>47.74</td>
<td>22.64</td>
</tr>
</tbody>
</table>

1 Data taken from National Weather Service Climatological Data series for Arkansas and Louisiana and Monthly Weather Summary series of the Climatic Research Center, Northeast Louisiana University, Monroe, Louisiana.
**TABLE 5**

REGIONAL MISSISSIPPI AND QUACHITA RIVER STAGES, APRIL-MAY 1979

<table>
<thead>
<tr>
<th>Date</th>
<th>Miss R. at Greenville</th>
<th>Miss R. at Vicksburg</th>
<th>Miss R. at Natchez</th>
<th>Quachita at Camden</th>
<th>Quachita at Monroe</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2</td>
<td>47.2 42.6</td>
<td>49.7</td>
<td>25.4</td>
<td>36.5</td>
<td></td>
</tr>
<tr>
<td>April 9</td>
<td>49.5 43.4</td>
<td>49.8</td>
<td>31.9</td>
<td>37.6</td>
<td></td>
</tr>
<tr>
<td>April 16</td>
<td>52.8 45.6</td>
<td>51.9</td>
<td>33.6</td>
<td>40.6</td>
<td></td>
</tr>
<tr>
<td>April 23</td>
<td>53.2 47.3</td>
<td>54.5</td>
<td>25.4</td>
<td>42.1</td>
<td></td>
</tr>
<tr>
<td>April 30</td>
<td>53.5 47.7</td>
<td>54.5</td>
<td>31.4</td>
<td>44.2</td>
<td></td>
</tr>
<tr>
<td>May 5</td>
<td>51.1 46.0</td>
<td>53.4</td>
<td>31.2</td>
<td>44.5</td>
<td></td>
</tr>
</tbody>
</table>

1 Flood stage 42.6 ft; crest 54.1-57.2 ft, 25-29 April.
2 Flood stage 43.0 ft; crest 47.9 ft, 26-29 April.
3 Flood stage 48.0 ft; crest 54.6 ft, 27-29 April.
4 Flood stage 25.6 ft; major crest 33.2-34.5, 26-29 April.
5 Flood stage 46.6 ft; crest 44.9 ft, 10-17 May.
IV. DISCUSSION OF NOAA IMAGERY

No acceptable Landsat imagery is available for the regional peak flooding period of mid-April through mid-May 1979. However, a Landsat image color composite (Figure 2c) for the 1979 flooding along the Mississippi, Ouachita, and Red Rivers was acquired. The pattern of the 1973 flooding as imaged by Landsat is similar to that known from 1979 surface data.

In the 1979 circumstance the major difference from the 1973 flood is that flooding along the course of the Red River was not of great duration or extent. Therefore, it was decided to compare areal patterns of water cover returns primarily for the Ouachita and Mississippi drainage basins in North Louisiana and South Arkansas. The narrow purpose of the comparison was to establish whether flood mapping could be done effectively using NOAA-n imagery with ground data as a control.

The NOAA-n image selected for detailed analysis is that of May 1979, orbit 2897. (Regional expansion of the entire acquisition (Figure 1) is Figure 2b.). Thirteen scanlines on the image from Western Mississippi to Eastern Texas were selected for detailed analysis using the Gray-McCrary Index (GMI). The GMI was developed originally for analysis of vegetation vigor as expressed by greenness (channel 2 minus channel 1). The GMI also classes cloud and water returns.

The GMI analyses of the NOAA-n image scanlines are presented as a composite graph (Figure 3). One of us (M.R.B.) ran the eastern half of the thirteen scanlines on the ground during the flood periods of 1975, 1977, and 1979, to evaluate flooding extent and duration. In addition, the southernmost scanline and the Gran Mal area (confluences of Ouachita and Saline Rivers) were ground-photographed in February and March 1971. These last trips were to determine the cause of mixed and anomalous pixel returns in areas that are topographically low. A regional map is presented in Figure 4. The mid-scale NOAA-n image for map comparison is Figure 5.

Comparison of ground data with the thirteen May 6, 1979 NOAA-n scanline GMI's, the 1973 Landsat image, and regional topographic maps show:

a. ready identification and crude classification by GMI value of land, water, and cloud-covered regions;
b. the potential for mapping and acreage estimates of each GMI class;
c. and surprising geometric constancy across the NOAA-n image.

Figure 3 is a composite graph along scanlines of the GMI's. They are plotted for about one-fourth of a complete scan and are for the area from 89°W to 94.5°W as indicated along the abscissa of the graph. The ordinate is the GMI value in deltas of four.
Landsat color composite of study area (31 March 1973). Mississippi River in flood is on the right (east) bounded by the red finger of the Moon Ridge on the western edge of the floodplain. The large lake in the western third is the ephemeral flood impoundment of the Ouachita River upstream from Monroe, Louisiana.
NOM-n image (6 May 1979) of approximately same area as in Landsat image. False colors assigned by pixel CR-value. Blacks and dark blues represent negative values grading to tans for higher CR-values. A few scattered clouds are seen as white pixels.
Figure 3
## MAJOR GEOGRAPHIC FEATURES

* (SCANLINES 795-735)

<table>
<thead>
<tr>
<th>LTR</th>
<th>FEATURE(S)</th>
<th>SCANLINES</th>
<th>WEST LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Caddo Lake, Louisiana and Fast Texas</td>
<td>770-750</td>
<td>94.1-93.9</td>
</tr>
<tr>
<td></td>
<td>Cross Lake, Louisiana</td>
<td>740</td>
<td>93.9-93.3</td>
</tr>
<tr>
<td>C</td>
<td>Red River, Arkansas and Louisiana</td>
<td>795-735</td>
<td>93.9-93.5</td>
</tr>
<tr>
<td></td>
<td>Note western levees with standing backwater especially prominent at scanlines 795-775</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Lake Erling, Arkansas and Murray Lake, Louisiana</td>
<td>795-790</td>
<td>93.5-93.4</td>
</tr>
<tr>
<td></td>
<td>Bayou Bodou Reservoir and Floodplain</td>
<td>780</td>
<td></td>
</tr>
<tr>
<td></td>
<td>These three water storage areas comprise a unified water shed.</td>
<td>770-750</td>
<td>93.5-93.6</td>
</tr>
<tr>
<td>E</td>
<td>Upper Lake Eustineau, Louisiana</td>
<td>740-725</td>
<td>93.5</td>
</tr>
<tr>
<td>F</td>
<td>Lake Claiborne, Louisiana</td>
<td>755-750</td>
<td>92.8-92.6</td>
</tr>
<tr>
<td>G</td>
<td>Corney Lake, Louisiana</td>
<td>765</td>
<td>92.7</td>
</tr>
<tr>
<td>H</td>
<td>Bayou D’Arbonne and Lake</td>
<td>795-755</td>
<td>92.6-92.8</td>
</tr>
<tr>
<td>I</td>
<td>Bayou D’Arbonne Floodway</td>
<td>750</td>
<td>92.6-92.2</td>
</tr>
<tr>
<td>J</td>
<td>Grand Marais (known locally as the Gran Mal Swamp) - Junction of Quachita and Saline Rivers. This Quachita River floodway forms a large lake for 2-6 months during major flood years.</td>
<td>795-745</td>
<td>92.3-91.9</td>
</tr>
<tr>
<td>J</td>
<td>Quachita River main course below Sterlington, Louisiana.</td>
<td>745-735</td>
<td>92.1-91.9</td>
</tr>
<tr>
<td>J</td>
<td>Backwater flooding and levees prominent on both scanlines.</td>
<td>745-735</td>
<td>92.31-92.32</td>
</tr>
<tr>
<td>K</td>
<td>Saline River prior to junction with Quachita River</td>
<td>795-796</td>
<td>92.6-91.9</td>
</tr>
<tr>
<td>L</td>
<td>Bastrop Ridge and east bank levees of Quachita River</td>
<td>795-735</td>
<td>92.9-91.5</td>
</tr>
<tr>
<td>M</td>
<td>Bayou DeSiard</td>
<td>795-746</td>
<td>91.0-91.5</td>
</tr>
<tr>
<td>N</td>
<td>Bayou Bartholomew, Little Bayou Roebuf, and Bayou LaFourche</td>
<td>795-735</td>
<td>91.5-91.4</td>
</tr>
<tr>
<td>O</td>
<td>Deoef River</td>
<td>795-735</td>
<td>91.5-91.1</td>
</tr>
<tr>
<td>P</td>
<td>Macon Ridge</td>
<td>775-725</td>
<td>91.5-91.1</td>
</tr>
<tr>
<td>Q</td>
<td>Bayou Macon</td>
<td>795-735</td>
<td>91.1-90.3</td>
</tr>
<tr>
<td>R</td>
<td>West bank levees of Mississippi River</td>
<td>795-735</td>
<td>90.9-90.5</td>
</tr>
<tr>
<td>S</td>
<td>Main channel of Mississippi</td>
<td>795-735</td>
<td>90.3-90.5</td>
</tr>
<tr>
<td>T</td>
<td>East bank levees of Mississippi River</td>
<td>795-735</td>
<td>90.5-90.4</td>
</tr>
<tr>
<td>U</td>
<td>High loess bluffs delimiting eastern edge of Mississippi River floodplain</td>
<td>795-735</td>
<td>86.4-90.6</td>
</tr>
</tbody>
</table>
Orientation map of study region. Areas depicted in Figures 2a and 2b are bounded by hatched box.
Mid-scale blowup of Figure 1 showing major geographic features detectable in NOAA imagery. Mississippi Floodplain, averaging 40-100 miles in width is the broad north-south blue strip to the east. The courses of the Arkansas, Red, and Ouachita Rivers and the Gran Hal Swamp are clearly defined. The dark wavy stripes south of the Arkansas River are the north-facing slopes of the various mountain groups of the Ouachita Geosyncline in Central Arkansas and Eastern Oklahoma. All NOAA images pictured in this study were taken with a 35-mm camera in front of a CRT.
CMI's of water and clouds are characteristically negative when the entire pixel is in water or cloud. In cases where the pixel area is mixed water and vegetation, the CMI has a depressed value. A table of preliminary CMI classifications based upon limited data is presented in Table 6.

The 1 kilometer resolution of the NOAA-n limits the size of the target that can be identified. Small lakes of about one mile in diameter can be detected by a negative spike on the graph caused by a mixed pixel. An example of this is found on the graph of scan line 755. A low CMI (6.43) is found at 23° 42.5'W, 32°57'N. This pixel is found to be that of Lake Conneely in Northern Louisiana. At 23° 59'W on scan line 755 we find very low CMI is on an area that has CMI values of 4-7. This position coincides with that of Lake Claiborne. In both of these cases, the spikes on the graphs were very pronounced, but did not have a negative value. This is because the lakes were not of sufficient size to generate a pure water return.

The graphs of CMI in the area of the Mississippi River indicates many mixed, depressed values, and pure water returns with negative values. It was initially expected that the flooded area would be all negative. In previous NOAA-n scanline runs, CMI's over large, uninterrupted bodies of water such as the Gulf of Mexico will give all negative values.

The mixed pixels from the flooded areas were determined to be in an area where the vegetation was above the surface water height, such as mixed cypress-oak bottoms. In addition, this area is populated by a dense concentration of Paleo-Indian mounds and old natural levees.

Thirteen scanlines spaced 5 km apart were plotted from the 6 May 1979 NOAA-n image and then analyzed for CMI determination (Table 7). These lines include an area from Mississippi to Texas (Figure 3). We concentrated our investigation on the areas in northeastern Louisiana and southeast Arkansas.

The main geographic features from east to west are the Mississippi River; Nacoochee Ridge; a low area of crop land between the Eoouf River and Bayou Bartholomew; the Ouachita River valley including the Gran Evil swamp; and two flooded bayous - Bayou de Loutre and Bayou d'Arbonne - dissecting the hills of North-Central Louisiana.

The contoured analysis of the CMI's clearly depicts these features when compared to the 1972 Landsat pictures and regional topographic maps. Several CMI anomalies are apparent and require explanation. First is the low crop land between the Eoouf River and Bayou Bartholomew. This area has low negative values of the CMI. However, the flood area just west of the Eoouf River is well defined. Bayou Bartholomew does not stand out on the CMI's as it does in the 1972 Landsat image. Even on the Landsat image it does not appear to cover a very wide area. This bayou is narrow and very winding. This results in only mixed returns on the CMI graph, and shows up only as lower values of the CMI.
The major difference noted between the 1972 Landsat image and 1976 NOAA-n GMI graphs is the size of the Gran Vel Swamp at the confluence of the Turchitz and Saline Rivers. In the 1972 GMI contours the swamp area is apparently much reduced as indicated by the limited distribution of negative values. However, the basic feature shape is well defined by the lower GMI values that would be expected for a body of water mixed with trees and duckweed. A ground survey of this area in the spring of 1971 and during the 19701 flood confirmed that this area is characterized by cypress-oak bottoms and thick duckweed concentrations in the backwater. Duckweed is fairly common in slow-moving and standing waters in the mid-South (see Figures 5a and 5b).

The overall graph of the NOAA-n GMI contours when compared to the Landsat image is very similar. An estimate of the area within each GMI class can be generated by a digital plotter. Such equipment support has not been available to us either directly or indirectly.

FIGURE 4b. Duckweed being carried by current in Black Bayou. We suspect the preponderance of this plant in waters of at least Southern Arkansas and North Louisiana may be the explanation of unexpectedly high CMI values over water areas in the May 1979 NOAA image.
Based upon regional observations and albedo characteristics of various surfaces, the following preliminary table of GMI class identifications is proposed:

**TABLE 5**

**PROPOSED GMI CLASS IDENTIFICATIONS**

<table>
<thead>
<tr>
<th>GMI Values</th>
<th>Type Surface Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2 to -8</td>
<td>Large uninterrupted cloud masses.</td>
</tr>
<tr>
<td>-8 to -2</td>
<td>Coastal waters, large lakes, large areas flooded by deeper water, large rivers.</td>
</tr>
<tr>
<td>+1 to -1</td>
<td>Shallow and turbid water bodies with no floating vegetation; large highways and railroads; very light bare or plowed soils.</td>
</tr>
<tr>
<td>1 to 4</td>
<td>Large areas of standing water; water with aquatic vegetation (cypress, duckweed, etc.); dormant and emergent sparse vegetation; swampy areas thick with Spanish moss.</td>
</tr>
<tr>
<td>4 to 8</td>
<td>Early emergent agricultural fields vegetation.</td>
</tr>
<tr>
<td>8 to 12</td>
<td>Coniferous forest.</td>
</tr>
<tr>
<td>12 to 20</td>
<td>Mature agricultural areas; dense healthy crops standing; thick healthy deciduous forests in full leaf.</td>
</tr>
</tbody>
</table>

It should be emphasized that our data sample is small and biased on data from U.S. Southwest, mid-South, and Southeast. A time bias of observations during the March-October period is also present. Nevertheless, we feel that this unrefined classification will assist users in discriminating surface returns and may lead to a more confident systematization of GMI's in the future.
CONCLUSIONS ON STUDY PURPOSE

Our team view is that the non-meteorological applications of the NOAA satellite families have been underemphasized and little investigated by the remote sensing community. This negative bias is understandable in the desire to obtain the maximum image linear resolution, narrow sensor viewing spectra, and precision image registration that has become the habit of Landsat users. In the reality of ziling Landsats in orbit, the possibility of an inter-regnum in future Landsat MSS continuity, increasing user pressures for tighter temporal target imaging, and uncertain future Landsat funding levels and timing, this luxury of high-quality Landsat imagery may no longer be available as in the past.

Therefore, as an alternative—a complement—to Landsat, we invite further comparative studies of Landsat to NOAA imagery, and digital manipulation of NOAA imagery as a stand-alone for detecting fast-occurring and swiftly-changing environmental phenomena.

This study shows that NOAA-n imagery provides detailed non-meteorological scene information. Certainly the level of NOAA-n imagery detail is not that of a Landsat image. Nevertheless, for operational environmental monitoring users, the NOAA-n imagery may provide acceptable linear resolution and spectral isolation.

The possible criticism that this study contrasts two satellites’ images from two different years is a two-edged sword—prime facie valid, but ignoring our purpose of stretching NOAA-n image information.

Special future attention should be given to denial or refinement of the proposed GMI class information definitions; to geometric understanding of image edges; to the effects of atmospheric attenuation; to attaining the maximum timeliness in product delivery using smooth software processing techniques; to interactive digital image manipulation; and to similar applications of GOES imagery.

We find no philosophical or technical conflicts in users utilizing both satellites’ images: the NOAA-n for temporal continuity and "quick and dirty" reconnaissance; and, the Landsats for detailed, precision mapping of control and special interest areas.

Did we succeed in its narrow study purpose? We invite you—the potential user and professional critic—to review again for your discerning eye the Landsat and NOAA images (figures 2a and 2b—approximately same scale, 1:250,000) and the GMI values of the NOAA-5 scanlines (Figure 3).
References and Notes


3. Sivetson, W.E. 1980. Monitoring disaster areas via satellites. NASA-LRC Rpt. 12345. The weakness of this proposed application of active microwave (1-10 GHz) sensors is the requirements for emplacement of positional ground reflectors. Such a task might be difficult or impossible in areas of restricted access.

4. Perhaps the best current review of atmospheric applications of meteorological satellites are the three volumes below. Although written primarily for DMSP users, the applications and techniques should be familiar to NOAA-n users. The DMSP and NOAA-n sensors and buses are similar.


   National Environmental Prediction Research Facility, Monterey, California.


9. Details of the NOAA-5 and 7 (May 5, 1981, launch) satellites, orbital parameters, sensor characteristics, data formats and flows may be found in the respective users' guides:


b. NOAA-7: To be issued by NESS.

10. The evolution of the Gray-McCrery Index (GMI) applicable to both the GAC and LAC imagery of the NOAA-n series can be traced to their remote monitoring of the development of the 1980 drought in southern Texas.


The GMI has been adopted for daily operational use by the Crop Condition Assessment Division of the Foreign Agricultural Service of the USDA.


