AN ASSESSMENT OF FLOOD DAMAGE IN NORTH CAROLINA USING A HIGH-RESOLUTION DIGITAL AIRBORNE IMAGING SYSTEM

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ABSTRACT

In September 1999, Hurricane Floyd caused extensive damage to the eastern seaboard of the United States. In North Carolina, the Tar and Neuse Rivers overflowed their banks displacing thousands of people from their homes. Potentially more devastating and long term than the human tragedy however, was the impact the floodwaters had on agriculture in the region, in particular the interaction of the flood with the large number of hog farms situated alongside the rivers. GER and Flight International, in a collaborative effort with the state Division of Emergency Management and the Federal Emergency Management Agency (FEMA), deployed a high-resolution airborne imaging system to the region to help assess the impact of the flood and to investigate whether pig waste contamination could be detected spectrally from the air. The system was deployed in a Piper Navajo aircraft and a large area (approximately 200 square km.) of multispectral imagery was collected in the region. The imagery was processed to spectrally differentiate the contaminated areas over the land and in the water. Ground truth data, including both soil and water samples, were collected to verify that the processed imagery was correctly identifying coliform (fecal bacteria) contamination.

1. INTRODUCTION

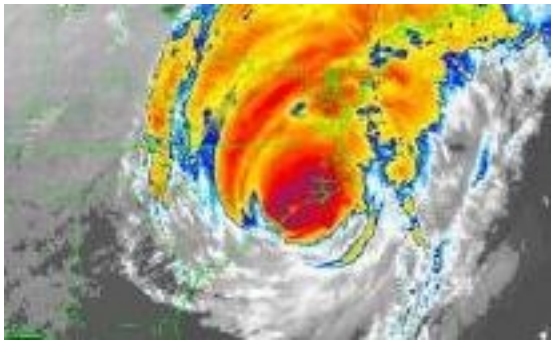

Figure 1 Hurricane Floyd

Hurricane Floyd (Figure 1) was one of the largest and most devastating storms in US history. It came ashore on September 14, 1999 and for the next four days traveled up the eastern seaboard of the United States. Flooding caused major problems across the region and at least 77 deaths were reported. The storm led to the evacuation of 2.6 million people from their homes, the largest peacetime evacuation in US history. Ten states were declared disaster areas with total damages estimated in excess of $6 billion. North Carolina was the hardest hit state.

Fifty-one people died in North Carolina, 7000 homes were lost and 73,000 homes damaged. The Tar and Neuse rivers crested far above

their flood stages and brought widespread flooding to the coastal plain. The impact to agriculture in the state was extensive with crop damage, building losses and livestock losses in excess of $1 billion.

After the hurricane had passed the Federal Emergency Management Agency and the North Carolina Division Of Emergency Management asked GER Corporation and Flight International to conduct an aerial survey of the region using one of GER's airborne hyperspectral scanners. The broad objective was to assess the damage to the environment caused by the storm, with the particular objective of determining whether pig-waste contamination of the water and land could be detected from the air.

2. THE FLIGHT PROGRAM

A GER scanner was deployed in a Piper Navajo aircraft and multiple flight lines flown over an approximately one-week period. Data tapes containing raw image data were returned to GER for post-flight processing. In all about 200 square kilometers of image data were acquired.

2.1 The Airborne Imaging Equipment

The components of the hyperspectral imager used during the flight campaign are shown in Figure 2. The sensor unit (to the left of the picture) contains the scanner and the spectrometer. The scanner defines the spatial characteristics of the acquired image while the spectrometer divides the energy from a pixel on the ground into its spectral components and transforms that energy into an electronic signal. The scanner module is a "whisk broom" strip mapper. The optical scanner is based on the Kennedy Scanner, which consists of a multi-faceted rotating mirror. As the mirror rotates, the field of view changes and data are acquired across the aircraft flight track to form a scan line. Scan lines are accumulated along the flight track and a strip map image is produced. The spectrometer module is composed of different optical paths and provides many channels of spectral information depending on the specific design. The scanner deployed in North Carolina recorded 31 channels, in the visible, short wave infrared and thermal infrared, at resolutions up to 1-meter, or 11 bands at up to 0.5-meter resolution. All channels of the GER spectrometer are fully co-registered assuring accurate measurement of spectra within each individual pixel. The user operates the system via a simple graphical interface. System status may be monitored, real-time image data displayed, and system parameters set from a simple menu driven user interface. The software can also be used for mission playback.

Figure 2 GER Optical Scanner

3. RESULTS

Many types of images were produced ranging from general-purpose true-color images useful for showing the extent of the flooding, to false color images developed to highlight the extent of contamination due to pig waste.

Figure 3, an image of flooded Greenville airport, shows a number of light aircraft either totally or partially submerged. The high resolution of the GER scanner is evident by the clearly defined runway markings visible through the floodwater.

The impact of hurricane Floyd on pig farming in the region was particularly severe. In North Carolina, pig farmers are allowed to store pig waste in open lagoons. After anaerobic breakdown of the waste in the lagoons, the waste is used as fertilizer for crops. During Floyd, a number of these lagoons were flooded or breached and waste was spread over a significant area of the river floodplains in the Coastal Plain region of the state.

Figure 3 High-Resolution, True-Color Image Of Flooded Airport

The image data collected during the overflights of the stricken pig farms was processed to spectrally differentiate the areas contaminated with hog waste over the land and in the water. The spectral signature of hog waste was isolated by identifying an unbreached hog lagoon in the image and then using the spectral signature of those pixels as a matched filter through the rest of the collected imagery. Figure 4 shows an image of the coastal plain containing the unbreached lagoon on the left. The pink color (shown also in the aerial photograph) is typical of water containing hog waste and is very distinctive. The false color image on the right shows the analysis of this particular region with the land parts of the image colored red and yellow where hog contamination has been identified (by spectrally matching the pixels with the signature from the unbreached lagoon).

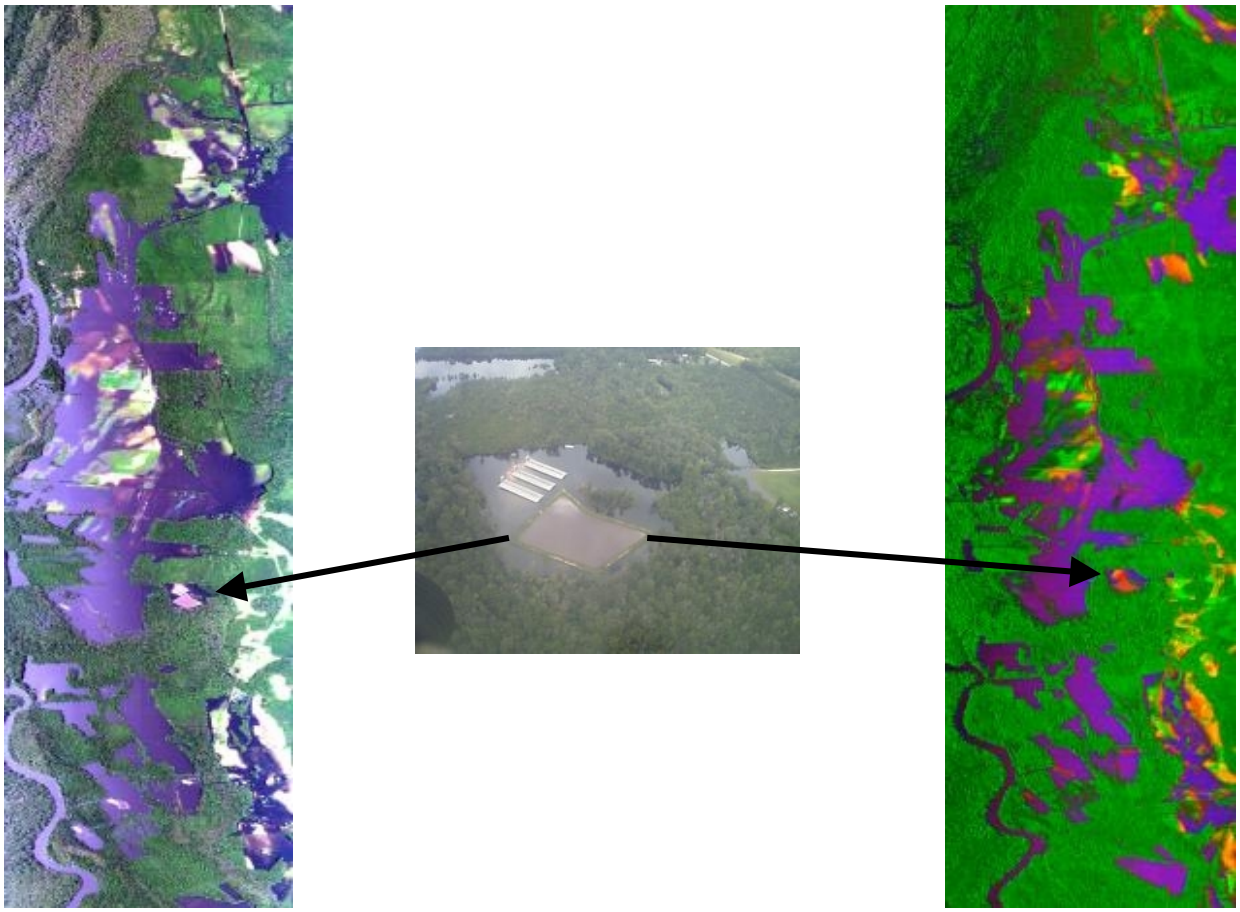

Figure 4 True-Color (Left) and False-Color (Right) Images Of Neuse River In North Carolina Showing Areas Contaminated By Hog Waste (Aerial Photograph In Center Shows Unbreached Lagoon)

Collecting ground truth data; including both soil and water samples, verified the elevated levels of coliform in the water. Levels of approximately 15,000 counts per milliliter of coliform were measured in two regions of the river that appeared contaminated in the image.

Aerial remote sensing proved extremely useful in assessing the damage done by Hurricane Floyd in North Carolina. Large areas could be rapidly surveyed, the extent of the flooding could be observed and the rate at which the waters receded could be determined. Moreover with the added ability to spectrally process the information contained in the image data a specific contaminant was identified and cleanup efforts directed.