RAPID TURN-AROUND MAPPING OF WILDFIRES AND DISASTERS WITH AIRBORNE INFRARED IMAGERY FROM THE NEW FIREMAPPER® 2.0 AND OILMAPPER SYSTEMS

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ABSTRACT

The new FireMapper® 2.0 and OilMapper airborne, infrared imaging systems operate in a "snapshot" mode. Both systems feature the real time display of single image frames, in any selected spectral band, on a daylight readable tablet PC. These single frames are displayed to the operator with full temperature calibration in color or grayscale renditions. A rapid "Tactical" imaging mode is also available for low level operation, such as lead plane use during wildfire operations. All of the images are tagged with GPS and are recorded on hard drives upon operator command.

To support fire and disaster management incident commanders in the field, rapid turn-around of fully mosaicked and orthorectified image maps is necessary. To accomplish this, the raw image frames are transmitted from the aircraft, via satellite, to a data processing facility which generates the digital map products and then transmits them electronically back to the incident commanders in the field. After the individual image frames are mosaicked and orthorectified, they are overlaid on digital map base layers such as USGS Digital Raster Graphics. FireMapper® 2.0 and OilMapper exhibit a wide dynamic range (up to 1200 °C) without saturating and the thermal infrared maps are color coded by temperature so that fire intensities and oil spill thicknesses can be readily interpreted. Fully annotated maps are then generated and transmitted to the fire and disaster management incident commanders for use in the field.

INTRODUCTION

The development of the infrared microbolometer detector array in the 1990s opened up the possibility of building small, uncooled thermal sensors for airborne and spaceborne applications. By eliminating the need for cryogenic cooling with liquid nitrogen or refrigerators, the cost and maintenance requirements of the sensor could be reduced and the operational lifetime increased. Because the microbolometer images an entire frame at one time, no mechanical scanning is required. This simplifies the design, reduces the size of the sensor, and improves the geometric fidelity of the images. With proper calibration techniques, microbolometer sensors can provide extremely high quality images with excellent linearity and negligible crosstalk and lag. This makes them the ideal sensors for accurate wildfire and disaster imaging from aircraft, helicopters, and even unmanned aerial vehicles (UAVs). With modern satellite communication links, raw data can be transmitted from the air to a remote processing facility. The final data products, consisting of orthorectified image mosaics covering the entire fire or area of interest, can then be rapidly transmitted to the operational units on the ground.

In 1993 Space Instruments, Inc. began development of a prototype microbolometer sensor for satellite use with funding from NASA and DARPA. The resulting ISIR (Infrared Spectral Imaging Radiometer) was built and successfully operated by NASA on the shuttle STS-85 mission in August, 1997 (Hoffman et al., 1998).

In 1998 Space Instruments, Inc. used this design to begin fabrication of a prototype FireMapper® system under a Research Joint Venture with the Pacific Southwest Research Station of the USDA Forest Service. Over two years of flight testing and improvements on this system provided the foundation for the design and fabrication of the new FireMapper® 2.0 sensor and operating software (Riggan et al., 1999; Riggan et al., 2000; Riggan et al., 2003). The first FireMapper® 2.0 system began flying in late 2003. During the spring and summer of 2004, a FireMapper® 2.0 system was deployed on a BLM lead aircraft for use in operational fire fighting missions in Arizona, New Mexico, and Alaska. Sample ortho-rectified image mosaics from some of these flight operations are shown in the following pages.

The OilMapper system uses the FireMapper® 2.0 sensor but combines it with a UV sensor. The FireMapper® 2.0 sensor is the primary sensor for the mapping of normal oil spills. The UV sensor is used when trying to detect and map very thin layers of oil on the surface.

THE FIREMAPPER® 2.0 SENSOR AND OPERATOR INTERFACE

The Firemapper® 2.0 sensor is shown in Figure 1. The sensor is approximately 7 by 7 by 8 inches tall and weighs less than 9 pounds with its protective infrared window. It is operated from a small, handheld tablet computer that is 9 by 12 inches across and weighs less than 4 pounds (Hoffman et al., 2003). The main screen from the operating application is shown in Figure 2. The application software resides in a computer that is connected to the sensor via an electronic interface unit and a fifteen foot system cable. The data can be recorded on the tablet internal drive or on external USB drives. A GPS receiver provides time and location that are included, with sensor housekeeping information, in the header of each image data file.

Figure 1. FireMapper® 2.0 sensor.

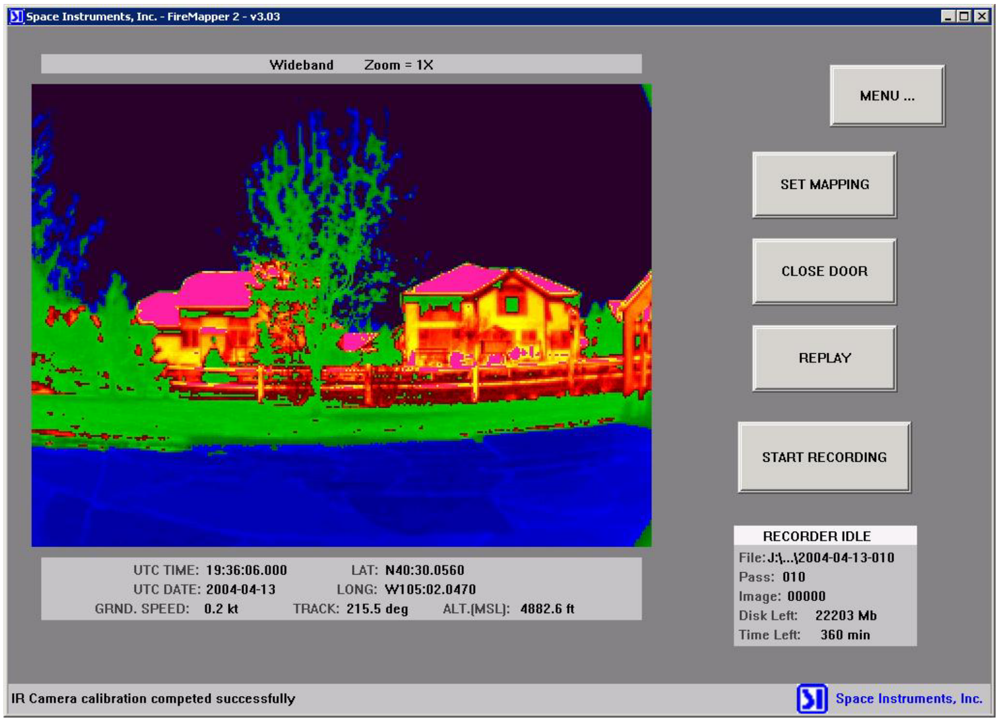

Figure 2. Operator Tablet with real-time image display and sensor control menus.

The images are displayed in real-time in either color or grayscale on the tablet computer. The GPS data for each image is displayed in the window beneath the image. The spectral band shown and level of zoom are noted above the image. The touch buttons to the right of the image allow the operator to control the sensor and the data recording functions. The buttons are used to select operating mode, spectral bands, image replay, image display settings, and data recording functions. The complete calibration of all three spectral bands is automatically accomplished every time the door is opened. The calibration of the images displayed to the operator is performed automatically. The operator can read the temperature of any pixel in the image merely by touching the stylus to the designated pixel.

The sensor can be operated in either a high altitude "Mapping" mode with all 3 spectral bands, or a low altitude, rapid imaging "Tactical" mode with a single band. In the rapid "Tactical" mode, 6 images per second are obtained and overlapping images can be recorded while flying as low as 50 feet above the ground at a speed of 120 knots. This is especially valuable for tactical work in leading aerial tankers in to perform low altitude retardant drops on wildfires.

Examples of single frame thermal images acquired from the Firemapper® 2.0 sensor are given in Figures 3-6. Figure 3 shows an image of the Oceanside, California small boat harbor acquired from 2600 feet. The field of view in the wide, cross flight direction is 63 degrees.

Figure 4 shows the warm water outflow from the Encinitas, California power plant. The image was taken from an altitude of approximately 1000 feet. The effect of power plant or other discharges into the ocean can be used to monitor the effects they have on coastal marine life. In a similar manner, the system can be used for environmental monitoring and protection by its ability to detect even small amounts of waste discharge or fertilizer runoff into streams and lakes. A typical pattern of oil slicks on the surface of the ocean off the Santa Barbara, California coastline is shown in Figure 5. The slicks were imaged from an altitude of approximately 1000 feet and were almost impossible to see visibly from the aircraft. The high sensitivity and exceptional uniformity calibration of the FireMapper 2.0 sensor allow it to accurately map even thin layers of oil and to separate the varying thicknesses as shown by the different colors. In other images taken from 1000 to 3000 feet ships, ship wakes, and oil drilling platforms can also easily be seen.

A single frame image of a small agricultural burn fire is shown in Figure 6. When the image was taken, from 4500 feet, the ground could not visibly be seen due to the thick, black smoke column that rose directly up from the fire. In addition to imaging the actively burning crop residue, the smoldering lines between the rows of crops can also clearly be seen.

Figure 3. Small boat harbor.

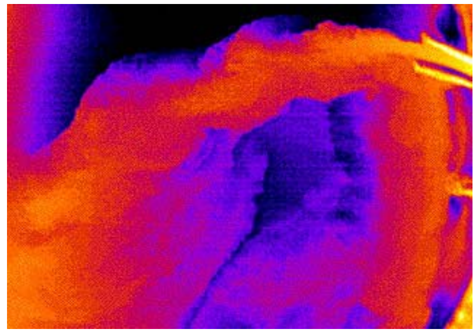

Figure 4. Thermal water plume from power plant.

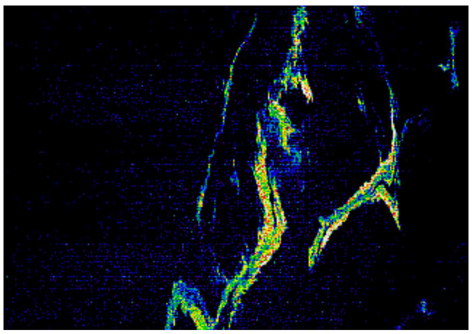

Figure 5. Oil slick on ocean.

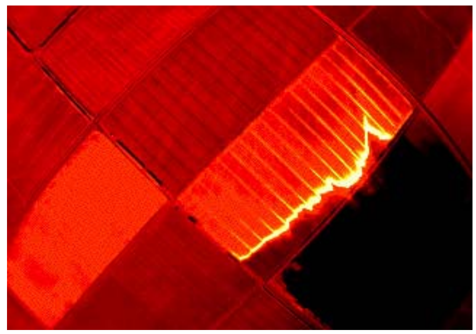

Figure. 6. Agriculture field burning.

IMAGE PROCESSING

Rapid response data processing services provided by Space Instruments, Inc. support emergency mapping of wildfires and oil spills. A few data transfer and processing steps turn single frame imagery into map information for critical decision making. Airborne imaging and subsequent processing of Firemapper® 2.0 and OilMapper imagery is performed 24 hours per day.

Imagery and corresponding GPS data acquired during imaging missions is written to a single digital file. At the completion of an imaging sequence, the digital file is transferred via a satellite phone and file transfer protocol (FTP) to an image processing center. Using this system, imagery acquired anywhere around the world may be immediately transferred to a central facility for processing and rapid turn-around.

Image pre-processing includes three primary steps: 1) orthorectify the individual image frames, 2) mosaic the image frames, 3) calibrate the thermal image mosaic to values of temperature (degrees Celsius). During the orthorectification procedure, individual image frames are georeferenced and terrain related distortions are corrected. Following orthorectification, accurate measurements of the aerial extent of fires and oil spills is possible. Image mosaicking procedures are then applied to turn hundreds of image frames into a single comprehensive image of the disaster scene. Thermal calibration enables temperature values to be directly extracted from the image mosaic.

Following image preprocessing, map information products are prepared. Key products include: 1) the thermally calibrated image mosaic, 2) vector map files representing the fire front or full fire extent, and 3) vector map files indicating the precise location of hot spots ahead of the fire front or behind the fire front. Hot spots ahead of the fire front indicate new areas of fire spread, while hot spots behind the fire front must be controlled by ground crews to ensure that the fire is extinguished. All of these products may be transferred digitally to incident command centers and used alone or with existing geographic information systems (GIS) data for planning purposes. The locations of hot spots may also be indicated by geographic coordinates and provided in a text file format directly to field crews equipped with global positioning systems (GPS).

In addition to GIS-ready data products, printer-ready map products are also available. Map products are enhanced and overlaid onto digital base map layers. Examples in Figures 7 to 10 illustrate Firemapper® 2.0 products overlaid onto Digital Raster Graphic (DRG) products from the United States Geological Survey (USGS). Custom base maps may also be used to indicate the location of the disaster and the relative locations of physical and cultural features. A wide range of information is contained in these graphic products, including date, time, location, scale and distance on the map, and fire temperatures. Color coding of fires by temperature allows clear discrimination of the hottest parts of a fire. Non-fire areas are transparent so that it is clear which areas were imaged, but background map information is not obscured. For oil spills, color coding makes oil slicks readily apparent (Figure 11). The high sensitivity and uniformity corrections automatically applied to the images within the sensor software allow the varying thicknesses of oil to be differentiated and color coded. This provides valuable information to the clean up crews in assigning priorities to the clean up operations. All printer-ready map products are provided in digital format and are delivered electronically to incident commanders and on-site GIS groups so that the critical information is available for immediate decision making.

CONCLUSIONS

The Firemapper® 2.0 and OilMapper sensors use state of the art technology to provide high quality and cost effective thermal imagery for mapping wildfires and oil spills. These advanced systems are lightweight and easy to operate. Image processing services provided by Space Instruments, Inc. turn single frame imagery into map information. Rapid turn-around of map products provides critical information to incident commanders for informed decision making. Further information is available at www.firemapper.com.

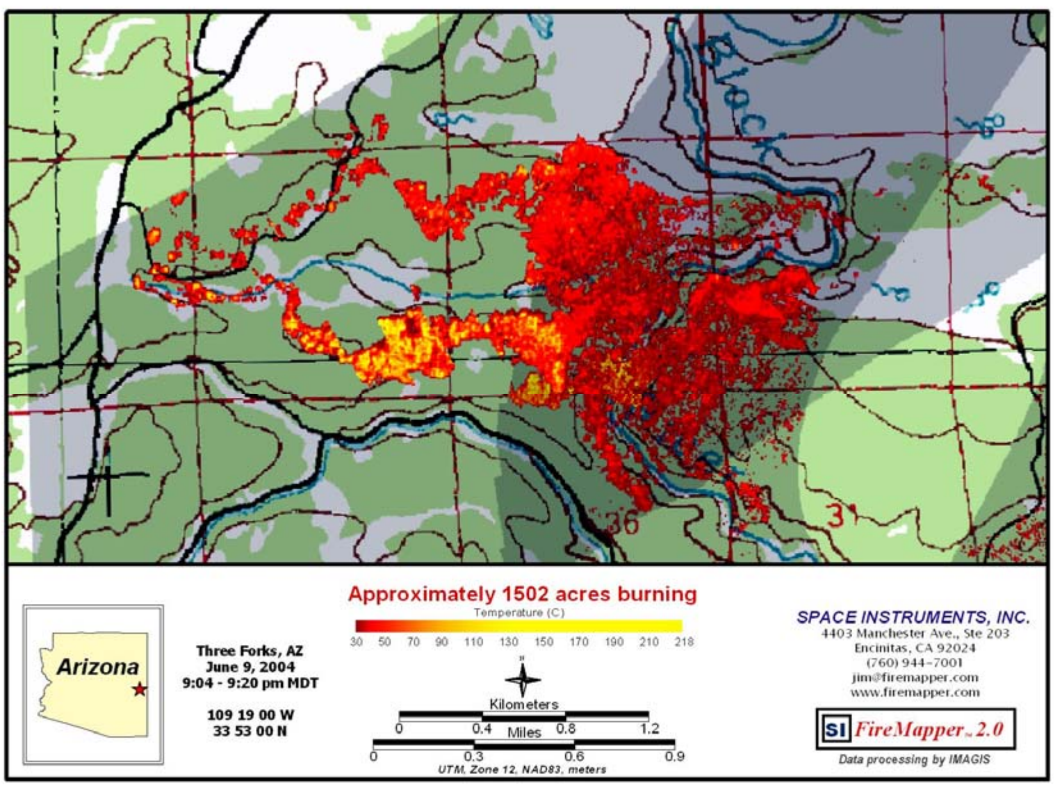

Figure 7. Three Forks fire map product.

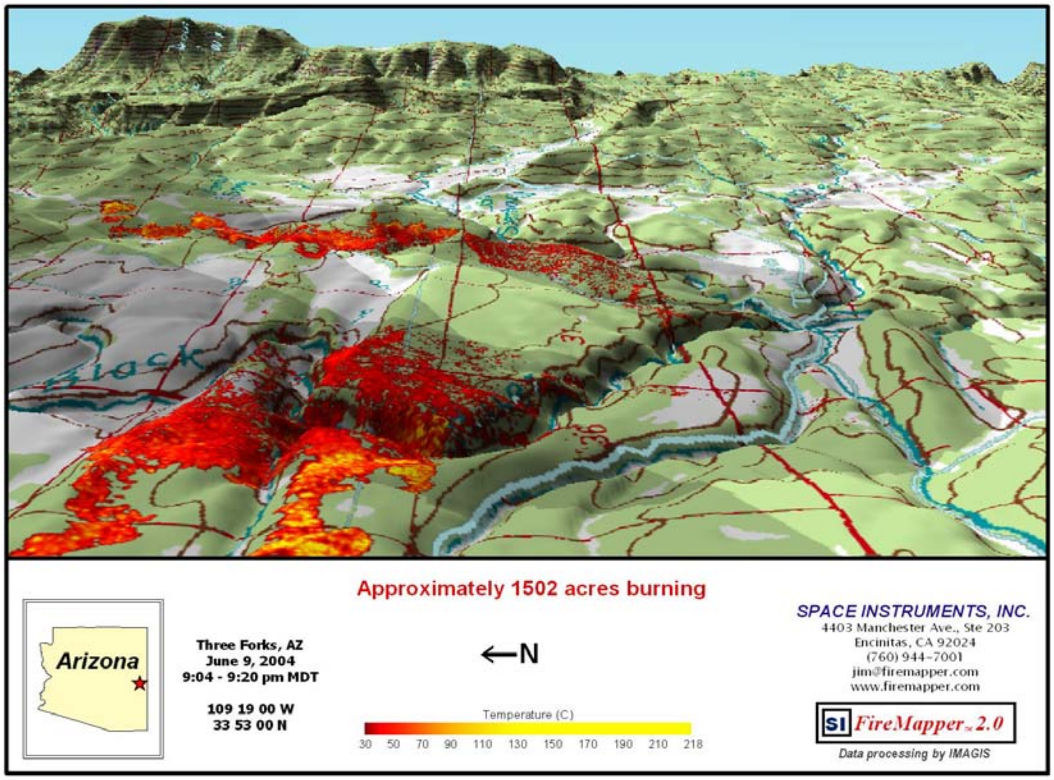

Figure 8. Three Forks fire 3-D view.

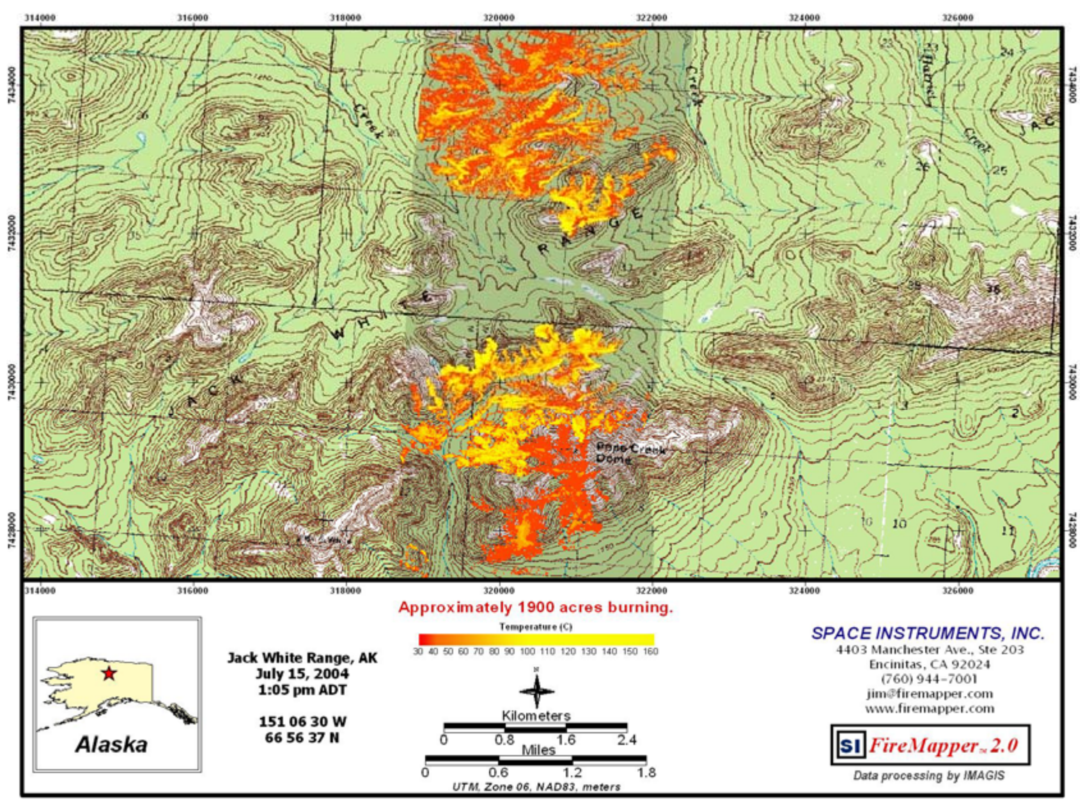

Figure 9. Jack White Range, Alaska map product.

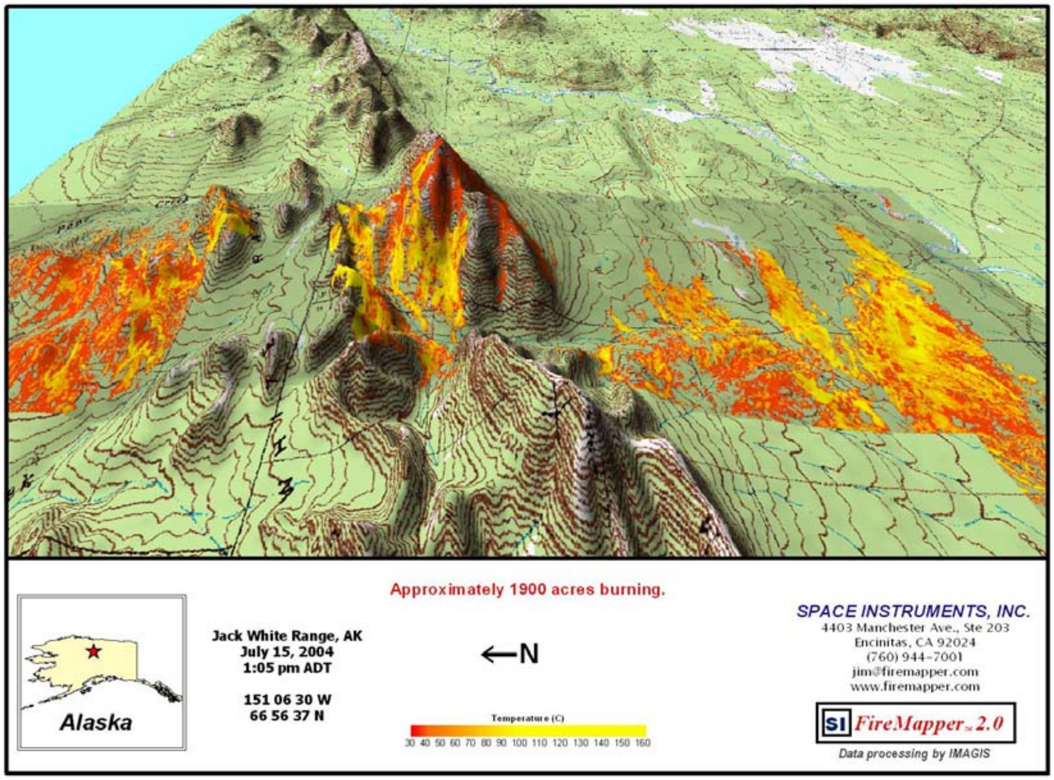

Figure 10. Jack White Range, Alaska 3-D view.

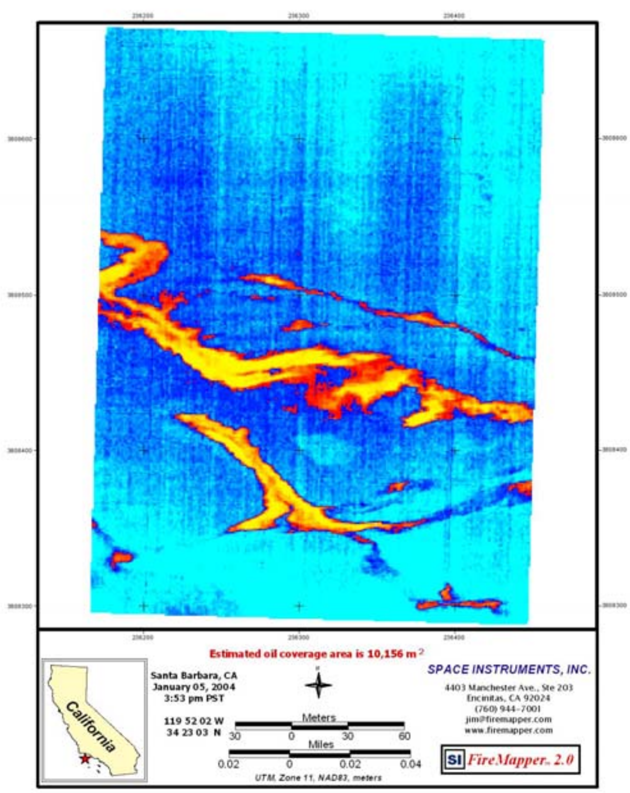

Figure 11. ***Oil spill map product.***

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FireMapper® is a registered trademark of Space Instruments, Inc.

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