

Aerial Thermal Imaging of Rivers and Streams In the Pacific Northwest

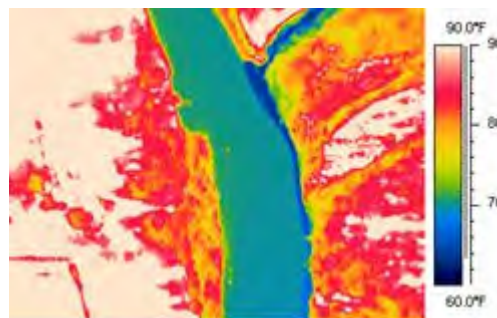
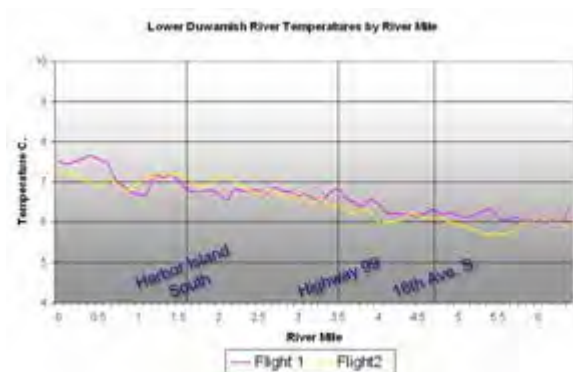
Thaddeus Fickel
Infrared Baron LLC

INTRODUCTION

Recent watershed concerns in the Pacific Northwest have necessitated studies by a range of agencies such as the Department of Environmental Quality, United States Forest Service, Department of Fish and Wildlife, numerous universities, and Native American Tribes to map river temperature and associated riparian habitat. Many natural and manmade variables can impact the health and well being of a given body of water. Water temperature is a critical factor in the survival of fish and aquatic plants that support a balanced eco-system. If the risk is correctly identified, action can be taken to repair or prevent damage.

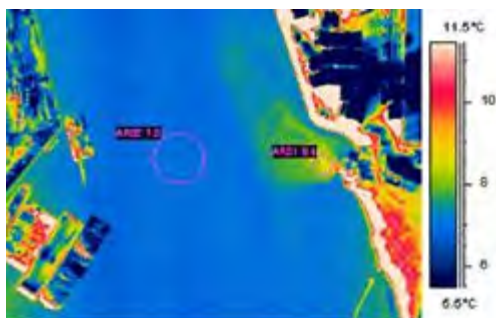
Since the early 1990's, thermal infrared technology has gained acceptance as the ideal tool for quickly and accurately measuring the temperature of rivers and streams. Prior to the employment of infrared, ground-based data loggers were widely used. While they are still the best device for recording temperature fluctuation over a long span of time, their use with the marriage of infrared permits a researcher to document changes during a short span; allowing for a complete picture.

While the goal of each river project is unique, thermal data are generally collected for the following reasons:



Document stream temperatures over a large area in a short period of time. The graph above illustrates the temperature of the Duwamish river in Seattle over two flights in the same 24-hour period

Identify areas of cool water inputs. In the above image a tributary entering from the right is contributing cooler water to the river.



Locate and identify heat sources.

HISTORY

Aerial application of thermal infrared imagery has been in use almost as long as the technology has existed. Initially many technological shortcomings existed which prohibited widespread use. The earliest cameras were large and cumbersome, not lending themselves to easy portability. Systems were cryogenically cooled with liquid nitrogen to a temperature of -320°F. This single factor made transportability a difficult obstacle to surmount. Additionally, each unit cost hundreds of thousands of dollars to produce, which made them cost prohibitive to all but the largest industrial or government consumers. In 1978, Texas Instruments offered the first viable infrared thermal imager. The TI machine was uncooled, alleviating the portability issue. The US Army was the first consumer, and as cost dropped, the technology spread to commercial and industrial users too.

Texas Instruments also introduced the RS-18A thermal line scanner in the early '70s. Cooled with liquid nitrogen, this camera could be mounted on an aircraft and generate quantitative thermal imagery where the horizontal dimension was produced by the scanner and the vertical dimension was produced by the aircraft motion. Electronic stabilization and computer processing allowed production of some of the first airborne imagery for environmental studies, such as analysis of electric power plant heated water discharges authored by Robert P. Madding and others in 1977.

By the early 1990's, thermal infrared cameras were much more straightforward to operate. Microbolometers allowed the infrared cameras to work without the hazard of liquid nitrogen and the units were compact enough to fit into general aviation aircraft.

While the cameras could fit into the planes, other obstacles existed which hindered convenience.

- Limitations in the hardware still hindered acquisition of data suitable for river temperature projects:
- Slow image acquisition rates for radiometric imagery (up to 20 seconds per image)
- Non-radiometric video output (NTSC only)
- Data storage limitations (floppy disks)

PRESENT

Modern cameras are compact and easily transportable. They work well when used in tandem with off the shelf computers. Current technology allows for the recording and storing data at a frame rate sufficient to capture full motion video that is fully radiometric. Additionally, Geographic Information Systems (GIS) presents a method of displaying and manipulating spatial data.

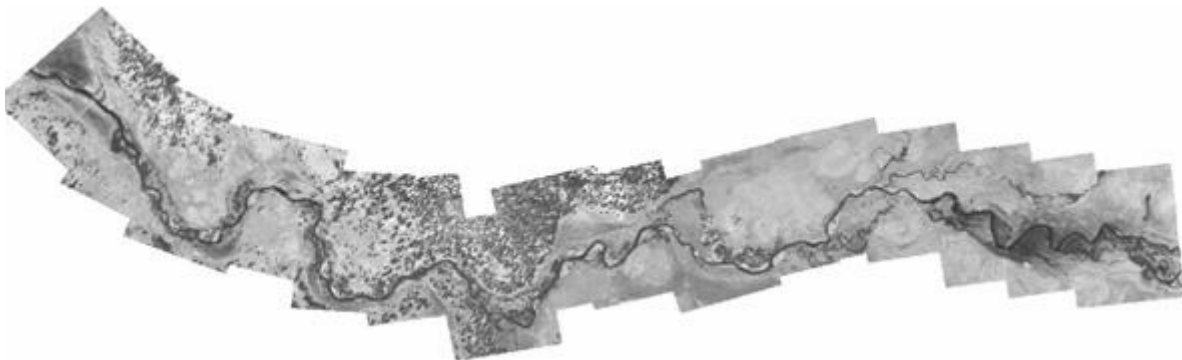


Figure 1 Red Clover Creek near Portola, CA. Geo-referenced FLIR image mosaic.

With any thermal imaging application the thermographer is required to also collect context information. For rivers, observation of the following data is compulsory to make an accurate determination.

- Date and time
- Location (latitude/longitude/altitude)
- Temperature conditions in stream
- Weather conditions for the previous few days, including presence or absence of cloud cover
- Humidity
- Visual reference video
- Color infrared imagery

Today, small, high-resolution cameras are suitable for mounting in a helicopter or small airplane. Cameras such as the FLIR S series will stream full motion video via firewire interface to software programs like ThermaCam Researcher. Moderately priced lap top computers are capable of storing the data. The FLIR S65 has a built-in video camera that makes collecting simultaneous thermal video and visual imagery much simpler.

Higher pixel densities also make it possible to resolve ground features of a given size from a higher altitude than what was previously allowed. Where before it might have been necessary to utilize a helicopter on a small stream, an airplane can fly twice as high to resolve the same size features.

Off the shelf video production software permit for simultaneous display of thermal and video imagery. By putting data in the proper context and giving the customer tools to disseminate the information, the data is now in a format that does not require expensive computer workstations or specialized training to interpret.

Finally, Geographic Information Systems (GIS) are becoming increasingly prevalent. Most state and federal agencies charged with stream restoration are GIS equipped. Products such as Google Earth are making spatial data available to more people than ever before (Figure 2).

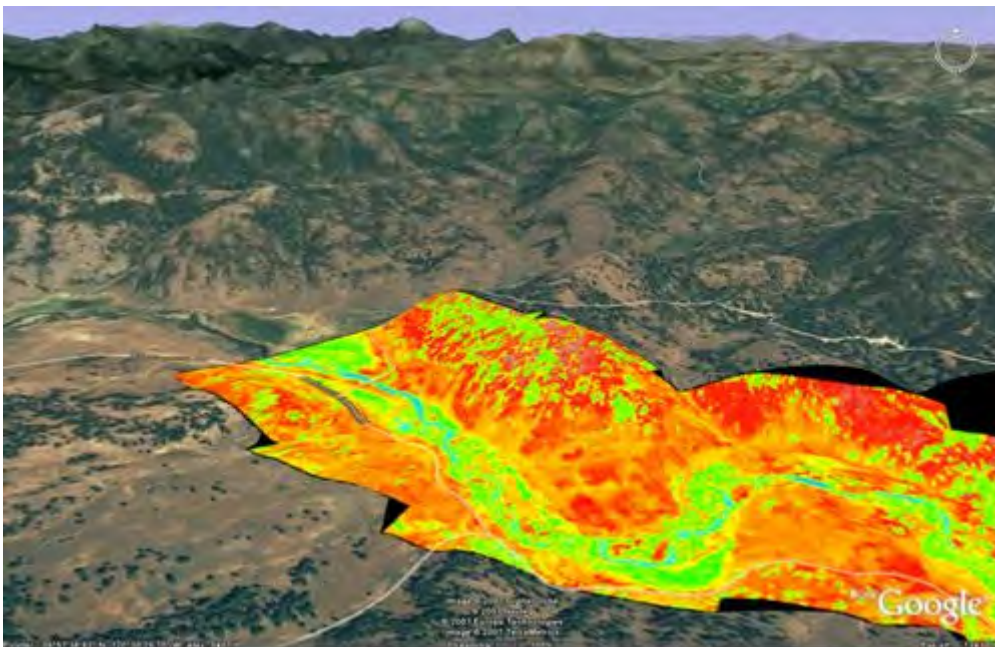


Figure 2: Geo-referenced FLIR image mosaic displayed in Google Earth.

Some possible output products include:

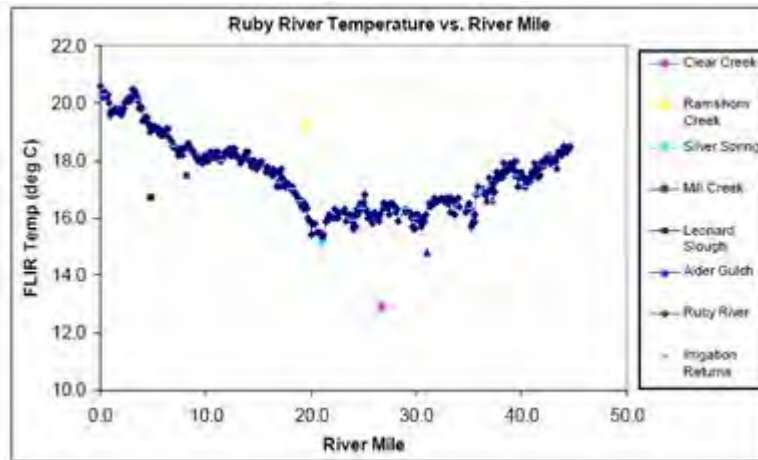


Figure 3. GIS Maps and GIS Ready Data Sets. This graph shows the temperature of 50 miles of the Ruby River in Montana. Also displayed is tributary temperature.

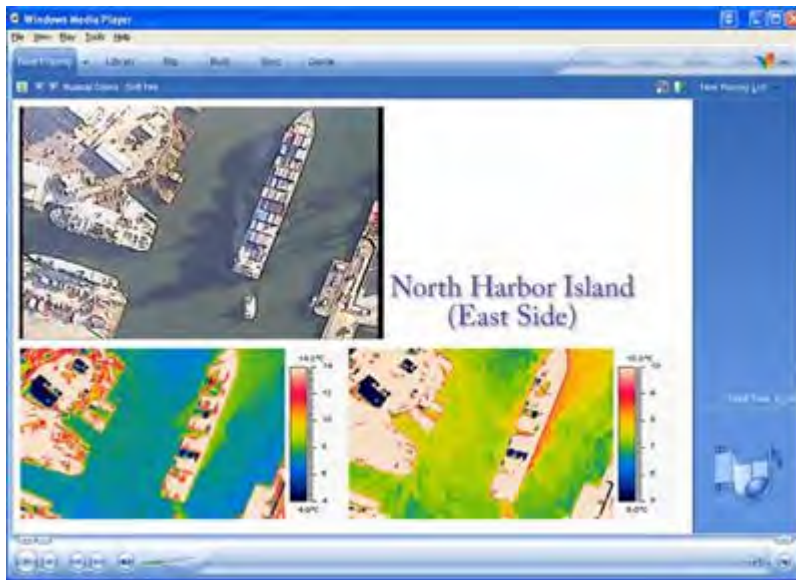


Figure 4. Synchronized video (thermal and visual video). This frame shows a change in temperature around a container ship in Puget Sound in Washington State.

FUTURE

Thermal imagers will continue to become more reasonably priced. Along with increased affordability, a corresponding enhancement of features and number of pixels can be expected. The Internet has created a generation of techno-savvy users who are growing more and more accustomed to having spatial data available to them. Online products such as Google Earth are allowing more people than ever to display and manipulate spatial data without specialized software or expertise.

ABOUT THE AUTHOR

Thaddeus Fickel has 15 years experience in remote sensing applications. He has conducted thermal infrared river surveys of over 15,000 miles of rivers and streams throughout Idaho, Oregon, Washington, Montana and

California. In addition to thermal infrared aerial imagery, he also uses near infrared cameras for agricultural applications. Thaddeus received his Bachelor's Degree from Walla Walla College and is a licensed commercial pilot.

REFERENCES

Madding Robert P., Scarpace F.L. and Green T.; "Thermal Plumes along the Wisconsin Shore of Lake Michigan"; Trans. Wisconsin Acad. Sci., Arts and Lett.; **1977**.

Coffin, Chris.

<http://www.ecy.wa.gov/pubs/0110045.pdf>

Publication Number 01-10-045

August 2001

Sujata Biswas, S. Sudhakar, and V. R. Desai

Remote Sensing and Geographic Information System Based Approach for Watershed Conservation

J. Surv. Engrg., Volume 128, Issue 3, pp. 108-124 (August 2002)

Torgersen, C.E.,

Airborn Thermal Remote Sensing for Water Temperature Assessment in Rivers and Streams

July 19, 2000

Watershed Consulting, LLC

Ruby River FLIR Temperature Analysis Interpretive Report

April 2, 2005

<http://www.infraredsolutions.com>

2006 Infrared Solutions Inc.

<http://www.thermal-eye.com>

2006 L-3 Communications

