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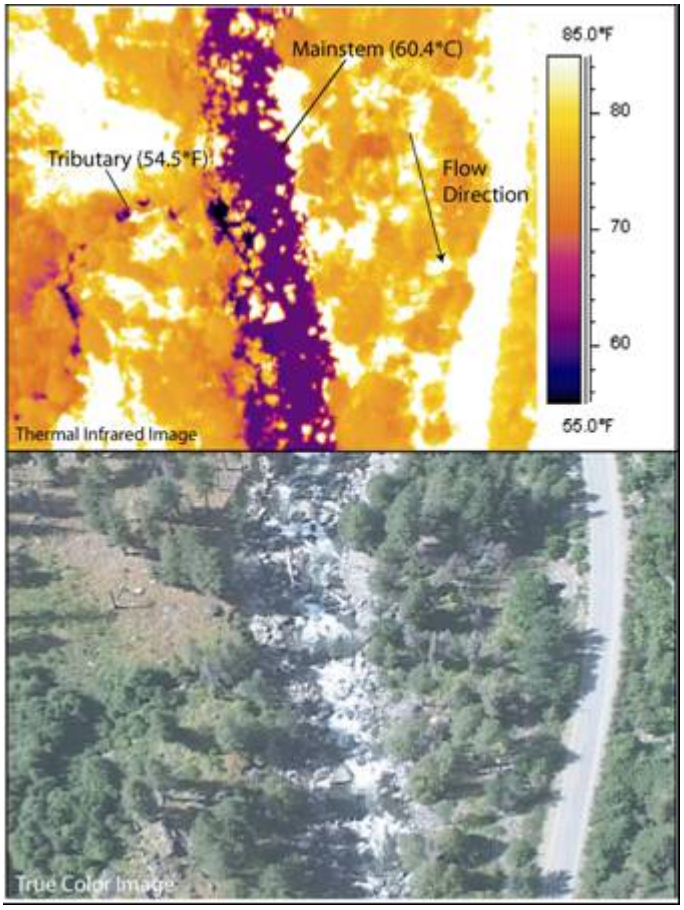
TIR Technology and Methods

Thermal infrared images are collected using a imaging radiometer (8-12µm) and a color video camera mounted to the underside of a helicopter. The helicopter is flown along the stream corridor and images are saved as a series of overlapping digital snapshots. As they are acquired, individual frames are tagged with coordinate information provided by an onboard geographic information system (GPS). Image spatial resolution and ground footprint vary depending on the character of the river and the objects of the survey. However, typical spatial resolutions range from 0.5 to 2 meters with image ground footprints of 130 to 650 meters.

Each element of a TIR image contains a measured energy level (radiance) within the operating waveband of the sensor. By knowing the emissive characteristics of water and the conditions under which the images was taken, the measured energy levels can be converted directly to temperatures. The result is a spatially continuous map of stream temperatures. Measured radiant temperatures are checked against a network of in-stream temperature recorders to fine tune the calculation and to verify accuracy. This process is known as ground truthing. Typical accuracies for TIR surveys conducted in the Pacific Northwest over the past five years are $\pm 0.5^{o}C$.

TIR images allow direct detection and measurement of inflows (cooling and warming) such as tributaries, surface springs, and in-channel seeps. TIR data also provide the ability to map spatial temperature patterns at the basin scale. Basin scale temperature patterns are derived by extracting temperature samples from individual TIR and graphing the sample medians versus river mile. The samples are taken longitudinally along the center of the stream channel. The resulting temperature profile illustrates patterns of warming and cooling longitudinally over the survey extent as well as the influence of tributaries and other surface inflows on mainstream temperatures.



Streams within the same basin sometimes show radically different thermal regimes. The temperature profiles provide a means to identify areas along the stream where maximum

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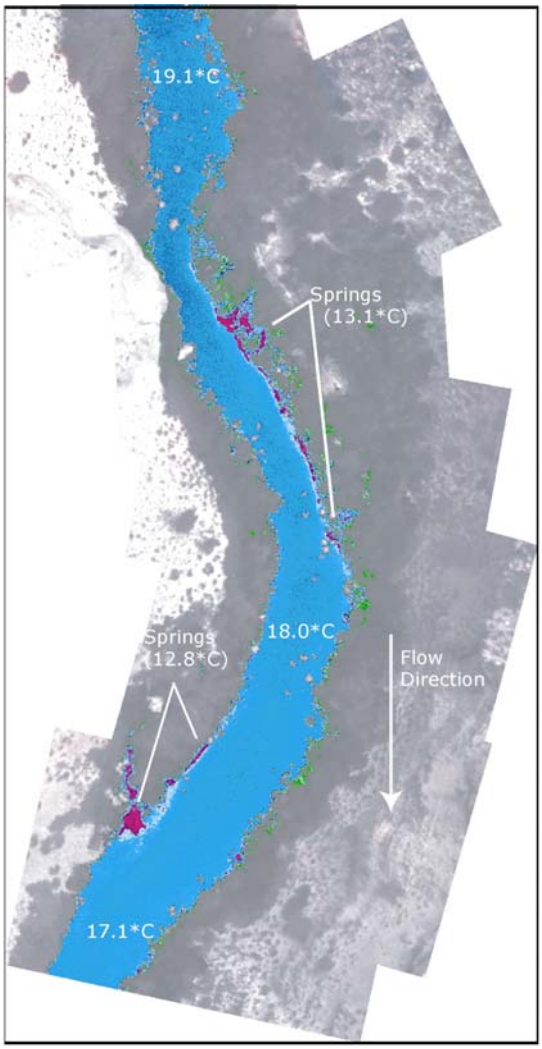
heating occurs as well as cool areas where fish can get away from warmer water (cold water refugia). The interpretation of temperature patterns across different scales is often an iterative process. Individual TIR images are processed to develop basin scale temperature profiles and to detect surface inflows. While the basin scale profile provides a context for reviewing the imagery to identify the factors potentially contributing the observed temperature patterns within a given reach.

TIR images represent temperatures at the water's surface. This fact is a consideration in how images are interpreted, but not a limitation for their use in stream temperature analysis. In most free flowing streams, the water column is well mixed due to turbulent flow. In-stream temperature data recorders placed near the bottom of the stream consistently match surface temperatures (radiant) in well mixed locations. In addition, mixing areas are often observed directly in the color video as rapids and riffles. The detection of a thermally stratified section of stream provides information about flow conditions and the existence of cooler water below the surface. Modern TIR radiometers are sensitive to temperature differences of 0.2-0.02^{o}C depending on make and model.

The overriding strength of TIR data is the ability to accurately map stream temperature patterns over multiple spatial scales. The images provide a snapshot of stream temperatures at the time of the survey. While absolute temperatures change, the sources of warming and cooling remain generally fixed from year-to-year (in the absence of major management changes). Consequently, spatial temperature patterns provide a good template for understanding how a stream is structured thermally. These spatial patterns illustrate changes in the interacting processes that determine stream temperature. In most cases, these processes are extremely difficult to detect and quantify using traditional ground based monitoring techniques.



Psuedo color TIR image showing a complex of surface springs serving as thermal refugia