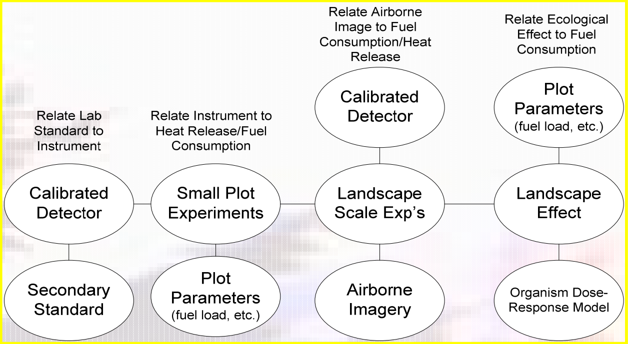
Landscape estimates of heat release from prescribed fires: analysis and calibration of infrared imagery from aircraft

ABSTRACT

We used infrared images acquired from aircraft and ground-based calibration to produce sequential maps of fire radiative power (FRP, kW m^2) over the period of active flaming during prescribed fires. Ground sensors were calibrated for total radiant heat flux. Because the residence time of flaming combustion is short relative to the aircraft return time (4-5 min), integrating FRP over time to estimate fire radiative energy (FRE, kJ m-2) is not straightforward. Integration can be done for pixels where active flaming fronts can be identified and if the typical time course of FRP can be estimated independently. Heat flux data from ground sensors within the fires and from experimental fires were used to describe the time course of heat release. Experimental data and the literature were used to estimate the proportionality between energy release and total and rate of fuel consumption. Image analysis showed considerable variability among prescribed fires in spatial pattern and magnitude of heat release owing to fire weather and ignition method.

WHAT IS OUR APPROACH TO THE 'FIRE PROBLEM'?



Our model for the 'fire problem': we look for a physical and organismic response to the fire. We calibrate a detector against a secondary standard, and use this calibrated detector to measure both small plot fires and landscape scale fires. The calibrated detector is used to remove the effects of atmospheric propagation and detector drift to calibrate overhead imagery. The fundamental measures, heat flux and total energy release (FRP and FRE) can then be used to determine landscape response based on organismal response.

WE HAVE DEVELOPED A NEW SUITE OF INSTRUMENTS TO MONITOR FIRE BEHAVIOR AND EFFECTS

Fire resistant, long duration video recorders

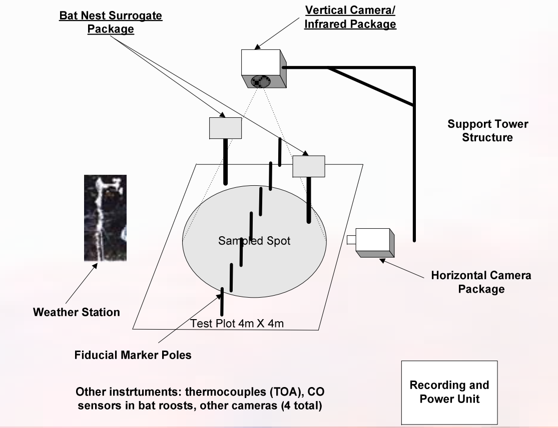
Absolutely calibrated dual-band IR radiometers (MWIR/LWIR)

Gas detectors (CO/CO_2)

Versatile fire resistant data loggers

Man-portable 'flux towers with midflame and 20' weather, IR radiometry and gas detection.

SMALL PLOT EXPERIMENTS LINK FUEL BURNUP TO RADIANT ENERGY RELEASE AND REMOTELY SENSED DATA



We measure heat release using two color radiometry. Using two infrared sensors (MWIR, LWIR) eliminates the need to measure the subtended fire area and emissivity

$$W_{i,j} := \left[\frac{((2\cdot\pi))\cdot h\cdot c^2}{(\lambda_i)^5 \cdot \left(e^{\frac{h\cdot c}{\lambda_i \cdot k \cdot \theta_j}} - 1 \right)} \right]$$

Use the discrete form of Stefan-Boltzman equation to predict sensor output

$$S_j := \sum_{i=98}^{13} (W_{i,j}\cdot step)$$

Integrate over MWIR passband (2-8 um)

$$L_j := \sum_{i=198}^{53} (W_{i,j}\cdot step)$$

Integrate over LWIR passband (8-12 um)

Fit these using the form:

$M = cT^n$, where $n < 4$

$$R_j := \frac{S_j}{L_j}$$

Calculate the ratio of MWIR/LWIR (analytically) as a function of *temperature*. We later use this to determine the '*equivalent blackbody temperature*' from the ground sensors.

From the table of the ratio of the sensor outputs R, find the equivalent blackbody temperature, T.

$$\varepsilon A := \frac{S_{LWIR}}{C(T^n + Ts^n)}$$

From the measured 'equivalent blackbody' temperature and a signal from one detector we calculate the emissivity-area product.(C is the detector calibration and Ts is the temperature of the sensor)

$$P := \varepsilon A \sigma T^4$$

Knowing the equivalent temperature T and the εA product we can calculate the ground-leaving flux

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