Fire Spectral Characterization Experiment

Rocky Mountain Research Station
Rochester Institute of Technology

The Fires Team

RIT

BURN

TO LEARN

Don Latham

USFS RMRS

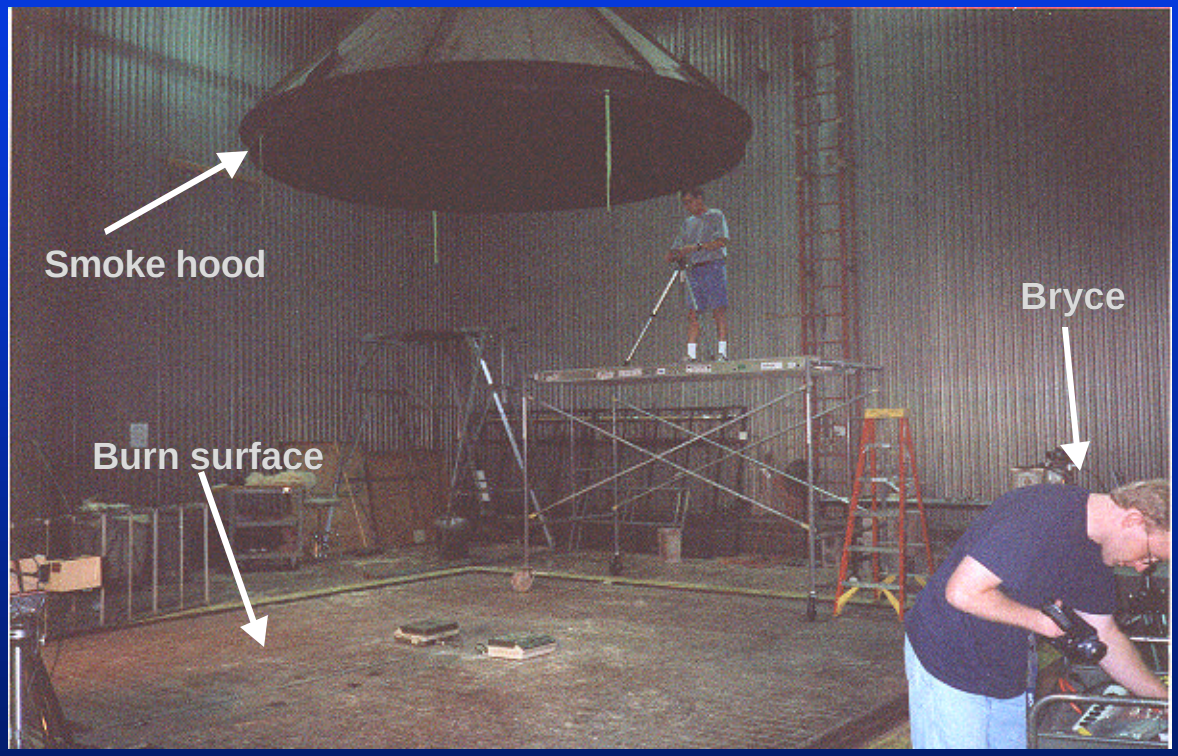
FireLab
MISSOULA, MONTANA

Who, what, where, when?

- Personnel:
  - RIT: Stef VanGorden, 'Burn' Nordgren, krem
  - RMRS: Don Latham, Bret Butler, cast of many characters essential to the operation
- 'Broad band spectral characterization of biomass fires'
  - Better spectra for Stef and Andy
  - Small scale spatial modeling for Stef and ??
- Many coordinated instruments to record basic physical processes during a burn
- Adjunct to field collects (which have only been moderately sucessful)
- Experiments took place at Rocky Mountain Research Station in Missoula MT, 16-17July 2001

The experiments were conducted in the combustion chamber at the RMSC in Missoula Montana

- The burn surface of the chamber is about 10 m square
- The smoke stack of the burn chamber is about 40 m high
- The 'draw' from the combustion chamber is assisted by a 25 hp fan



•In-situ instrumentation includes combustible material mass, CO_2, chamber temperature
•An aluminum fire bed (0.91m X 2.43m) was used. A gauge grid (0.3m) was present to judge the location of the fire.

Our goal was to extensively characterize optical emissions from several wildland fire materials

- Make definitive spectral measurements of laboratory-condition controlled fires --> *Wideband measurements not available*
- Correlate narrowband spectral features with broadband (blackbody) features ---> *Little or no high resolution characterization in visible bands*
- Determine emissivity of flames and the fuel bed --->*Emissivity not known, some anecdotal information*
- Develop a shape library and/or methodology for local, detailed spatial rendering of flames --> *Even Hollywood can't do this modeling!*
- Make other discoveries (alkali number density in flame, temperature, etc.) based on quality of the data. ---> *????*

Using elemental spectral signatures as a probe, we may be able to extract fundamental fire physical parameters

- What we have measured in these experiments:
  - Spatial extent of the fire a a function of time (*Path length / volume vs. time*)
  - Spectra (*Narrow bandwidth features*)
    - » 0.18 - 10.600 mm (UV to IR)
    - » High resolution 0.18 - 2.5 mm
    - » Filter BW (50 - 250 nm FWHM) 2.44 - 10.6 mm centers (thermopile) + wideband channel (CaF window, UV to 30 mm)
  - Optical pyrometry (*Total energy in a given waveband*)
    - » IR videographic pyrometer (1/30 sec resolution, 1000 K span)
    - » 10-12 mm band pyrometer with datalogger

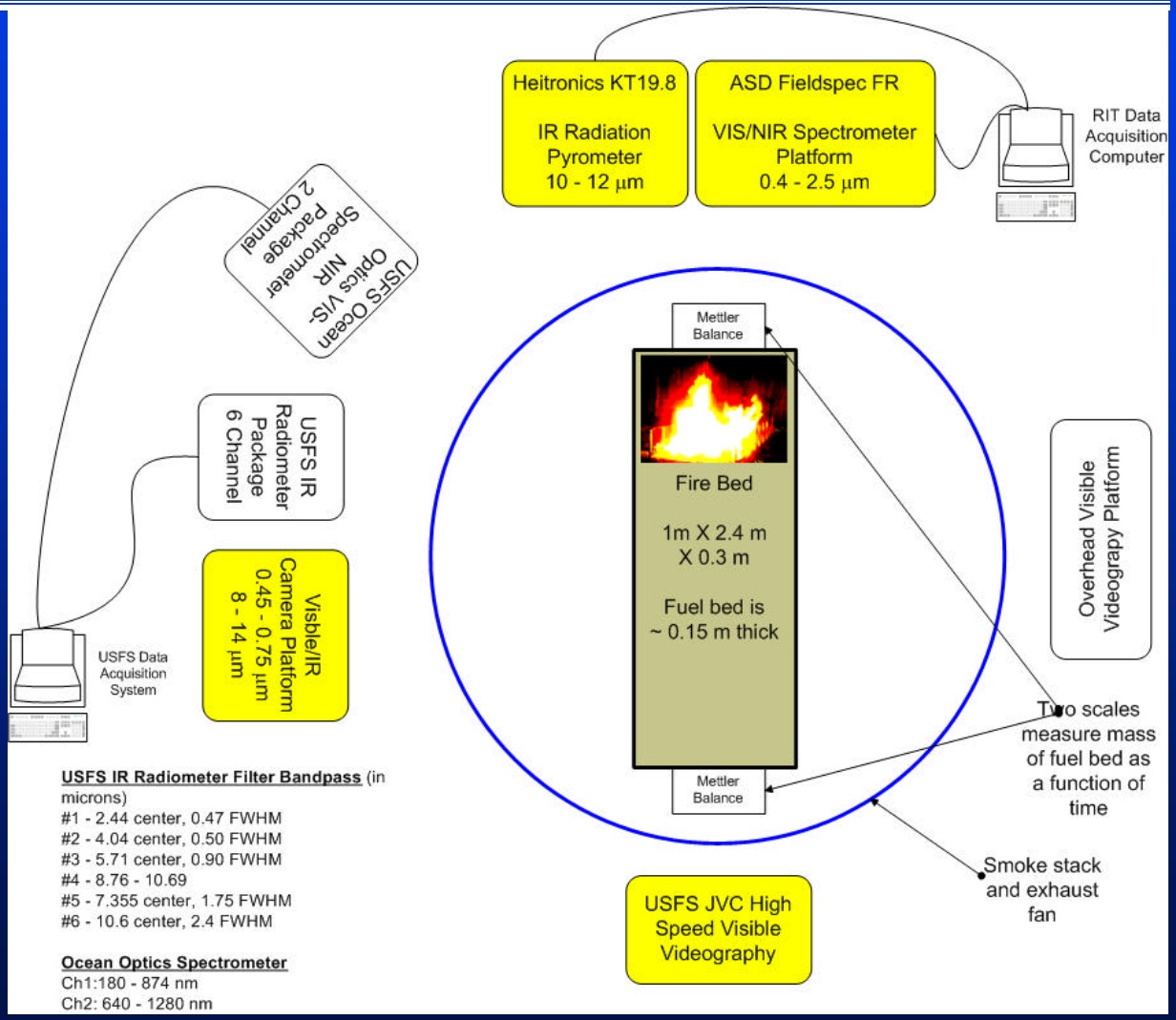
Using elemental spectral signatures as a probe, we may be able to extract fundamental fire physical parameters (2)

- Flame temperature (if a temperature can be defined - non-equilibrium conditions)
- Ratio of Na to K line emission (and other lines)
  - If K And Na concentrations are known or can be estimated, ratio of energy in lines measures temperature.
- K number density
  - Observed K line strength depends on K number density, temperature, and path length of fire. Knowing any two, we can infer the other.
- Emissivity
  - Several methods: BB peak observed in spectrometers (defines temperature), simultaneous observation with optical pyrometer defines emissivity. Other methods possible using fits to leading edge of BB spectra and intensity of K emission line (+ knowledge of K concentration in material)

We measured a broad range of spectral and physical data during the experiments

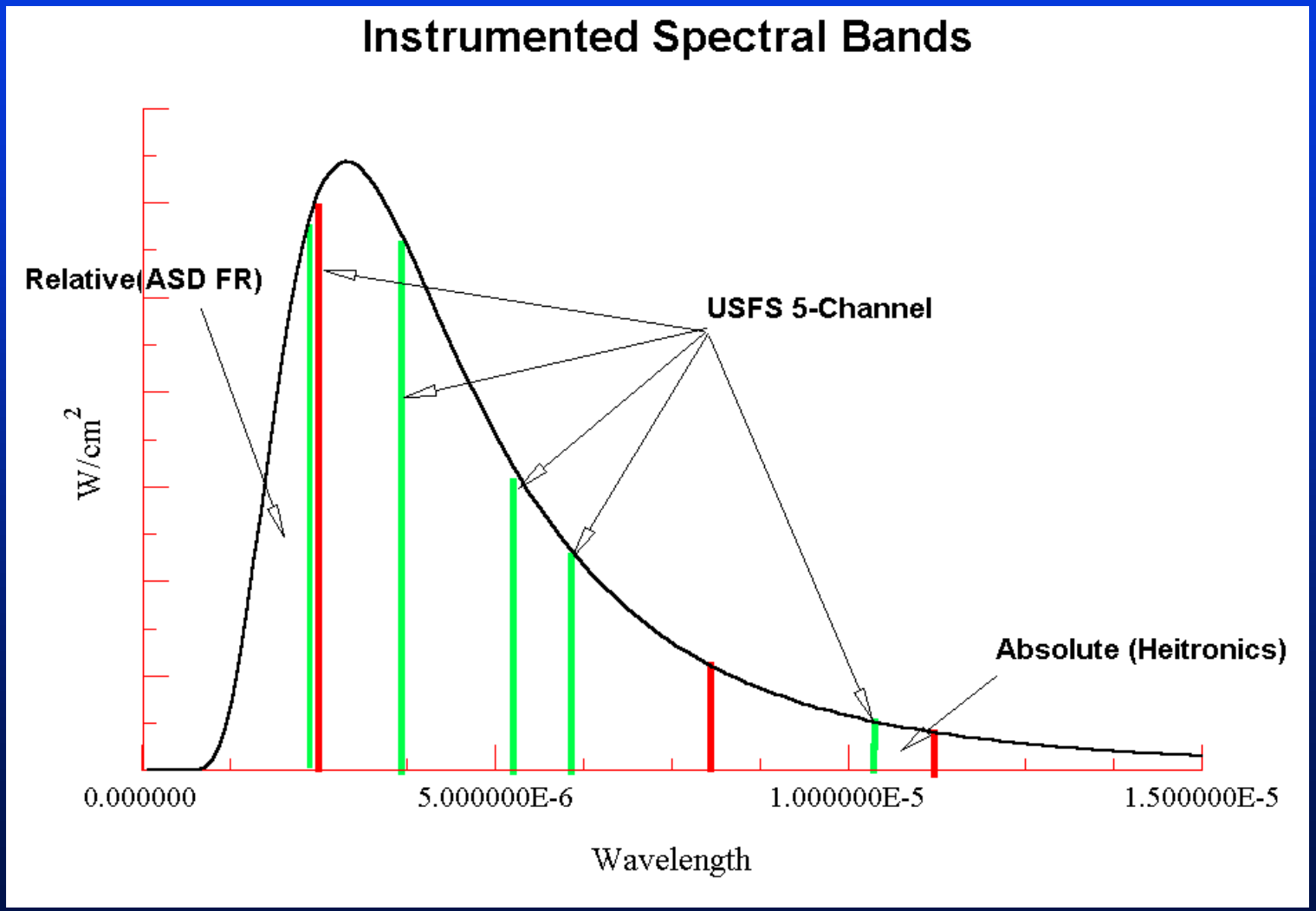
Yellow - RIT instrument

White - USFS instrument

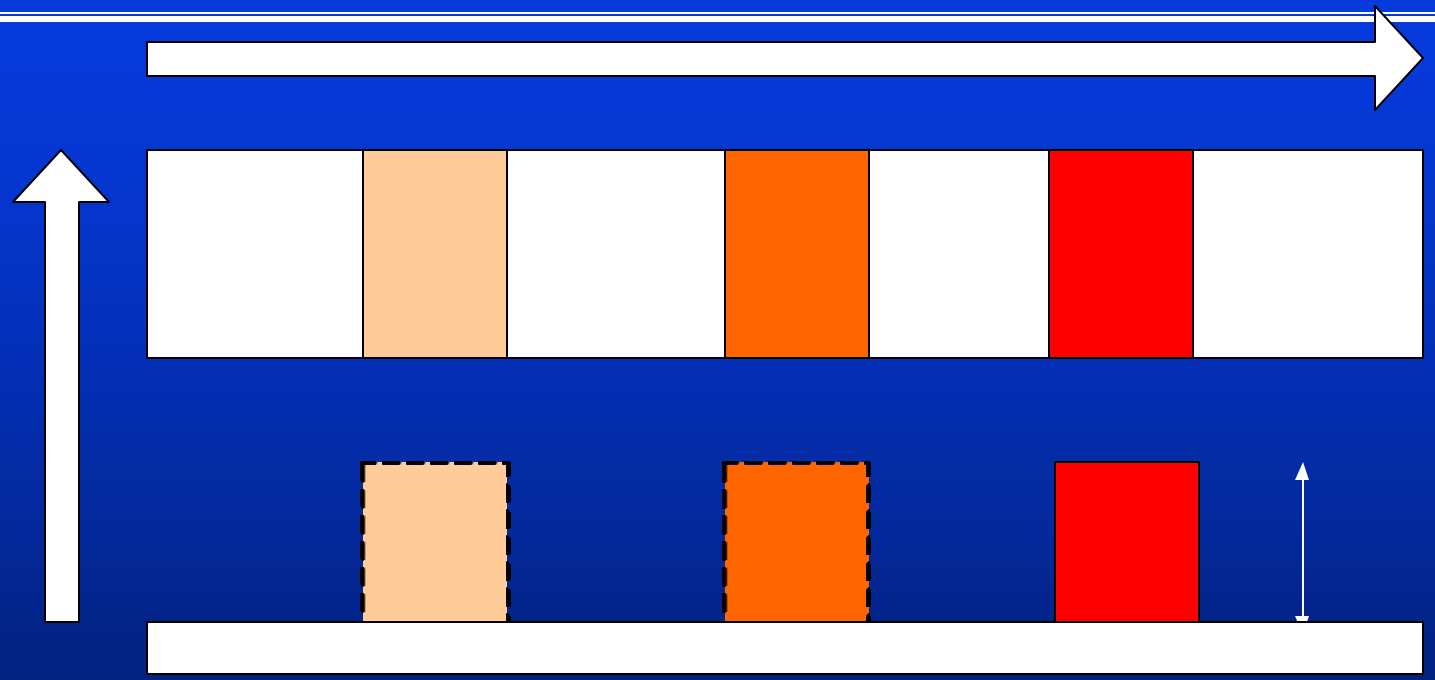


We have one absolute and several relative spectral measurements

We may be able to infer emissivity, temperature and other relevant flame physical parameters



Instruments viewed the fire along and across the fire track



- Along-track instruments observed temperature, spectra and vertical spatial extent
- Across track instruments observed IR emission, wide-band spectra and horizontal extent

Across track videography measures the (visible and IR) spatial extent of the fire and fire 'temperature'

- A Sony digital video camera are used to record the visible emissions form the fire (manual exposure + ND filter)
- An Inframetrics-600 records the IR emission in the 10-12 mm waveband
- A Sony digital video camera records the video stream from the Inframetrics IR video camera (set to 1000K span and 325K lower limit)

Across track videography

High-speed visible videography was acquired along-track

- A JVC digital video camera can capture ~120 frames per second in a sub-sampled mode.
- The camera viewed the fire along-track, opposite from the ASD Fieldspec spectrometer

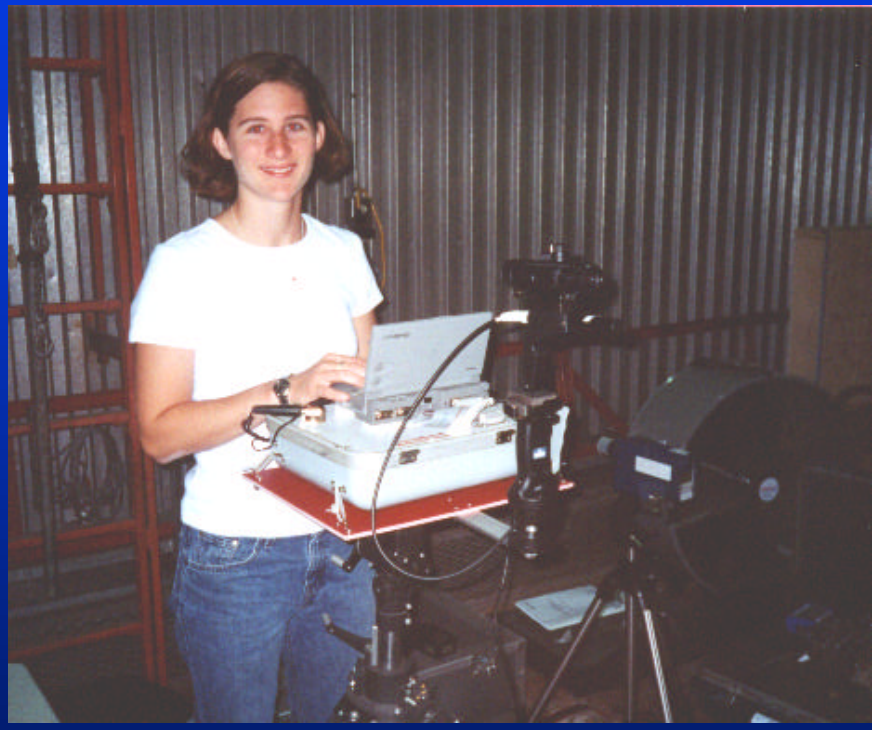
JVC High Speed Video

Across-track IR Videography will be analyzed to measure cooling rates of fire 'blobs'

- With some assumptions about the incandescent particulate smoke components, we can measure the cooling rate of particulate clumps that are evolved
- The volume of the fire at any time can be measured
- The size distribution of the particulates is known (C. Hardy, D. Ward, RMRS)
- The cooling rate can be modeled: Do we understand the emissivity and composition of the particles?

Spectrometers span the 0.35 - 10.6 mm wavelength regime

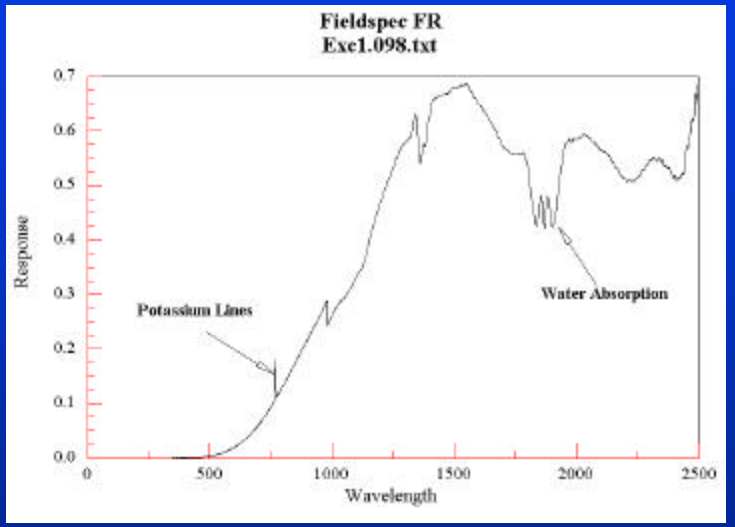
- ASD Fieldspec FR spectrometer:
  - 3 nm FWHM spectral resolution
  - 3° field of view
  - 0.35 - 2.5 mm spectral range
- Ocean Optics
  - 0.365 nm FWHM spectral resolution
  - Spec1: 0.64 - 1.28 mm
  - Spec2: 0.18 - 0.875 mm
  - 10° field of view
- RMRS Filter Spectrometer
  - 6 channel: 2.44, 4.04, 5.29,7.35,10.6 mm + wideband (0.2 - 30 mm)
  - 10° field of view

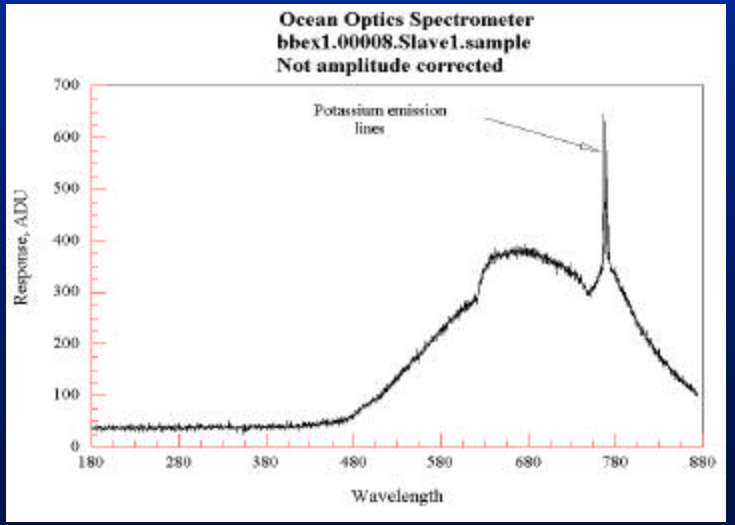


Stef beating the ASD into submission

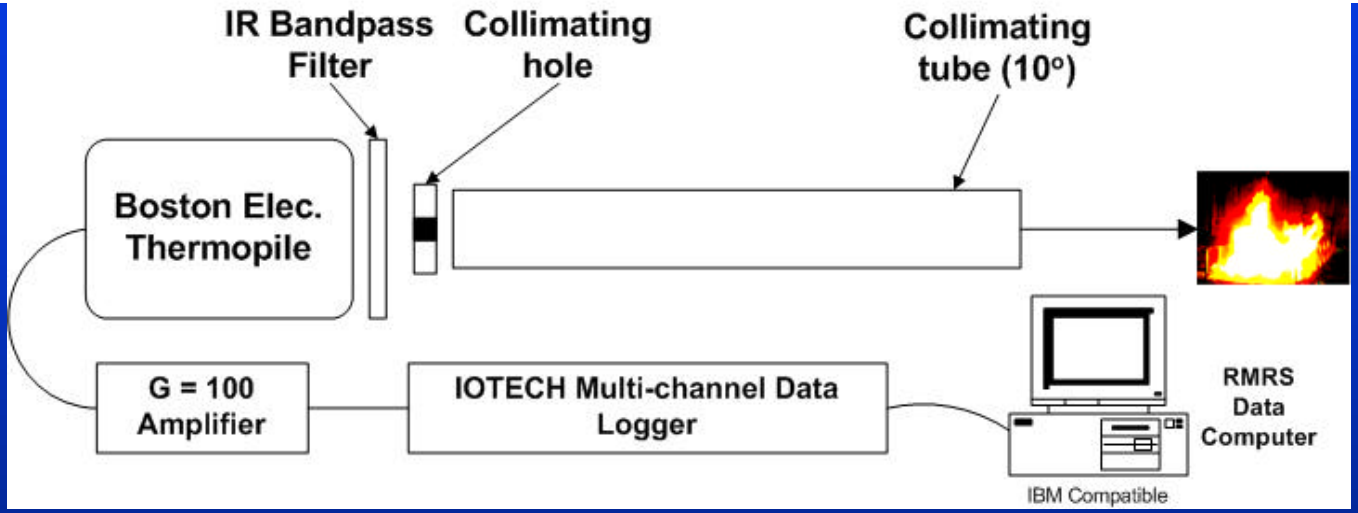
An ASD Fieldspec FR provided and an Ocean Optics D2J provided high resolution VIS-NIR spectra

- We have very good high resolution spectra in the visible.
- The Ocean Optics spectrometer is not calibrated for detector response. We await the calibration from RMRS.
- The NIR - MWIR is currently not as well understood. Are we having ASD problems? Is the ASD capable of making radiance measurements?

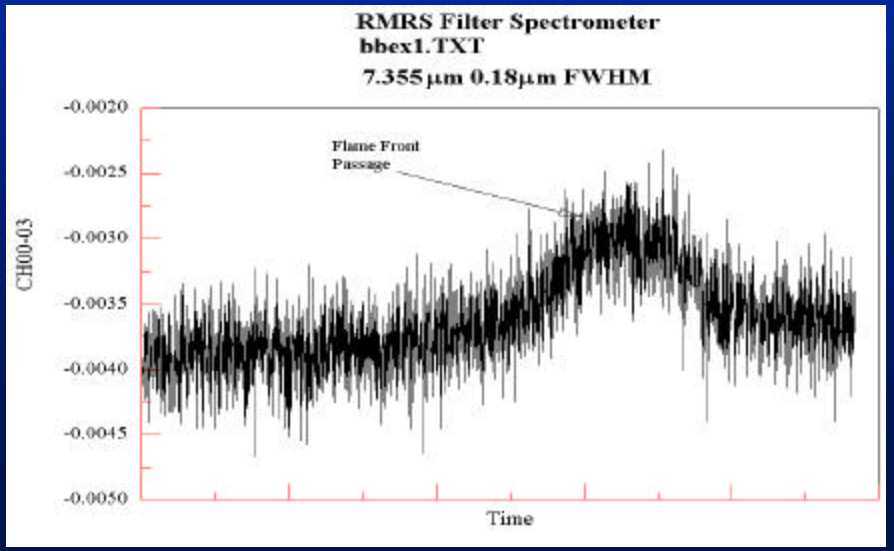




A USFS constructed 5-channel filter spectrometer measured the 2.4 - 10.6㎛m emission

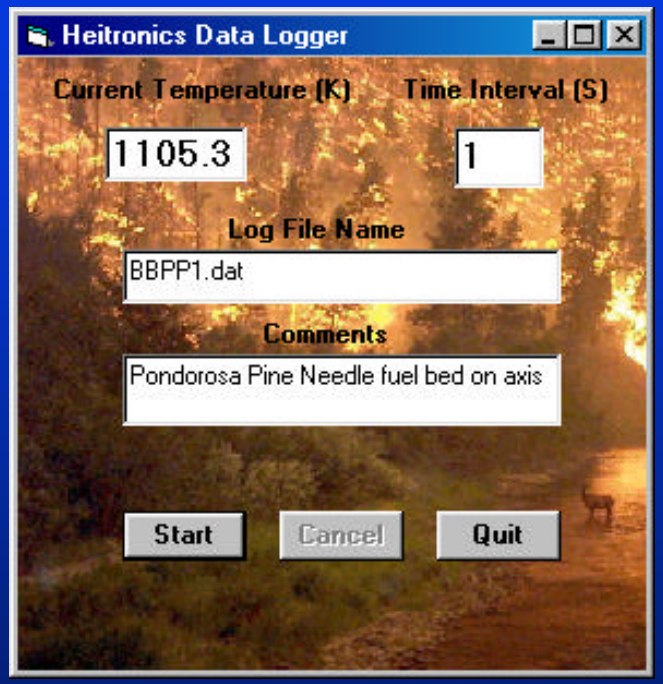


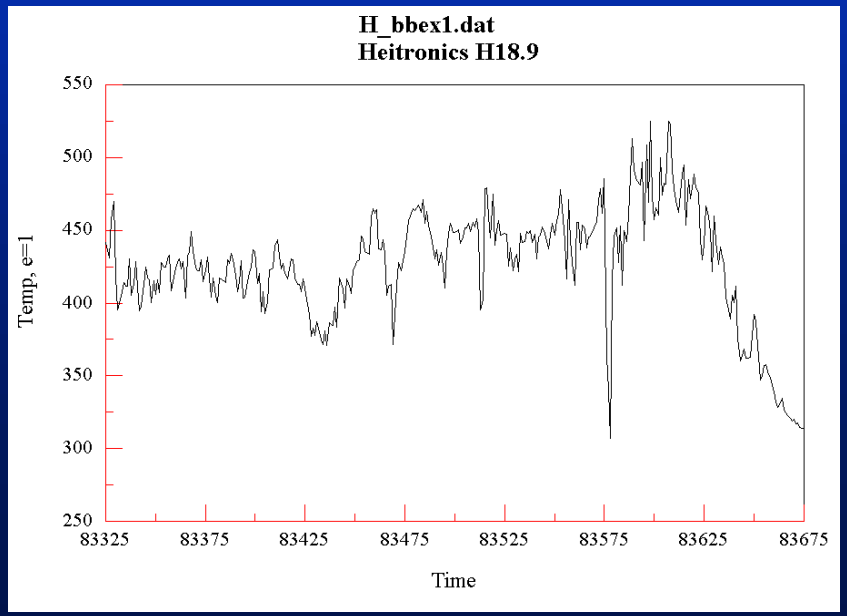
- Data reduction and re-calibration in progress
- Overlaps with ASD (2.44 ㎛m)
- Attempt to observe spectrum in the LWIR to measure departures from Planckian shape



A Heitronics KT19.8 logged 'temperatures' from the fire in the 10 - 12 mm waveband

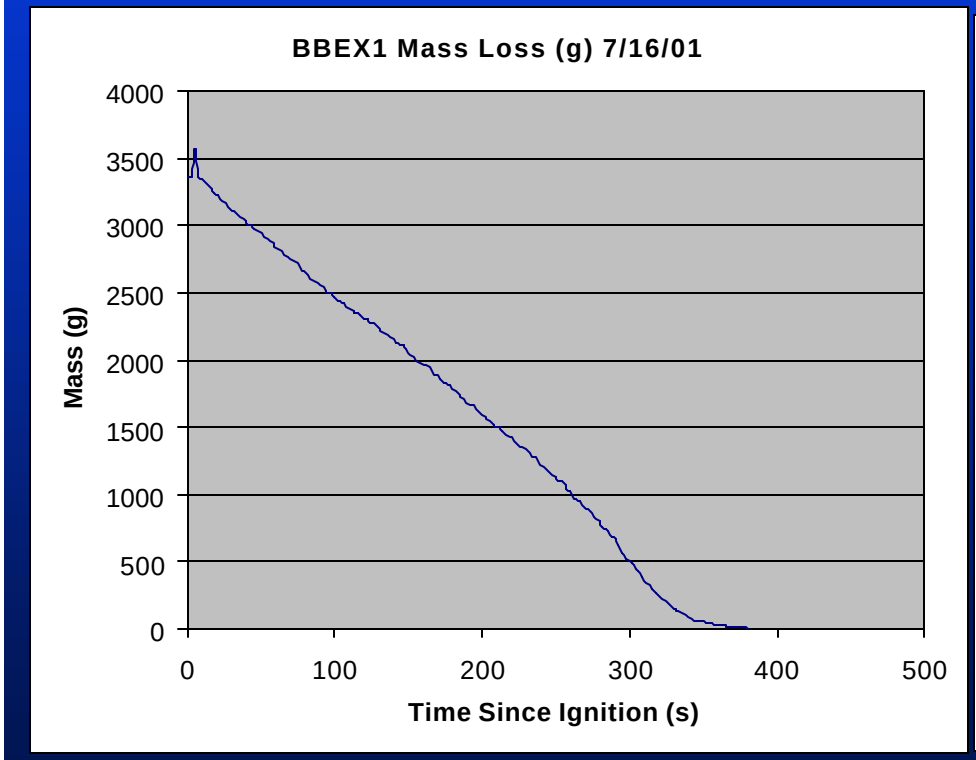
- Optical pyrometer with rapid readout provided a time history of the total energy output in the 10-12 mm band.
- Field of view of ° provided coverage of the entire fire event

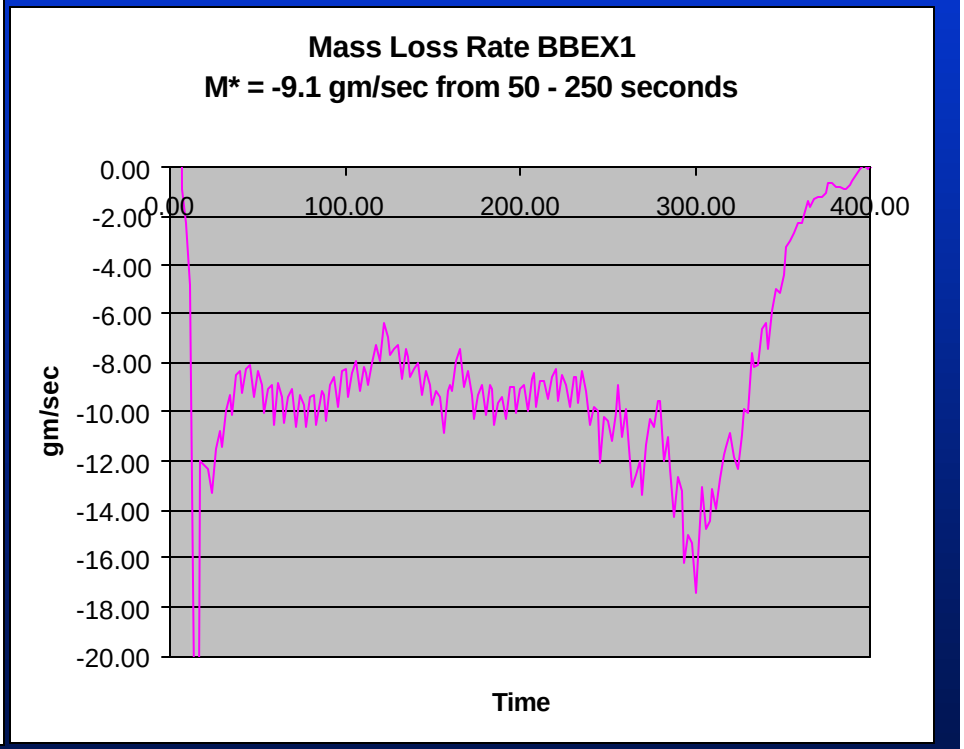




The mass loss is uniform during the burn

- The burn rate is constant for the aspen excelsior. The front thickness and velocity are also constant. Other materials have more variable burn rates.





Detailed analysis is now underway to correlate the data

- Take a first look at the spectra (Stef, Bryce). Concentrate on BBEX1, BBEX2 (aspen excelsior burns)
- Determining cooling rates/clump velocities for fire/particulate clumps. Compare these parameters for the different fuels. (Bryce)
- Measure the along-track extent of the fire (krem)
- Determine what points in time we want to analyze for which burns (Team)
- Calibration/re-calibration of Ocean Optics and LWIR Spectrometers (Don Latham)
- Other duties as assigned….