Band Selection & Algorithm Development for Remote Sensing of Wildland Fires

Andy Fordham

Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology
Rochester, New York 14623-5604

ajf8207@cis.rit.edu

Outline

Overall goal was to select *correct* bands and design *simple* algorithms for a fire sensor where the fire occupied only a small fraction of a pixel

If *correct* bands are selected, very simple algorithms will prevail

Band Selection based on modeling

- SW IR
- MW/LW IR
- Potassium atomic emission lines

Thermal Results

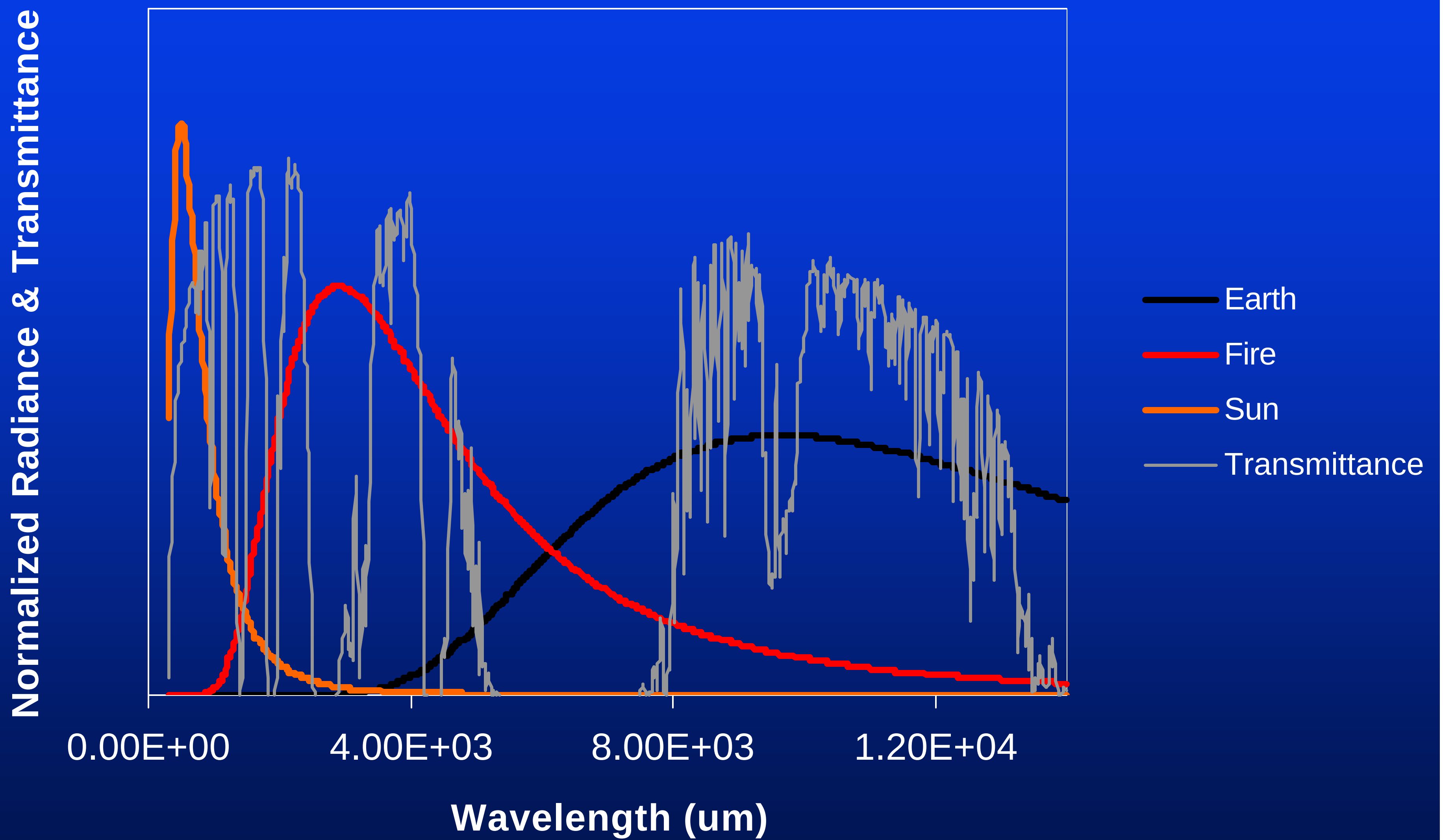
- MW/LW IR
- SW IR

Potassium line emission analysis

Effects of smoke obscuration

Conclusions

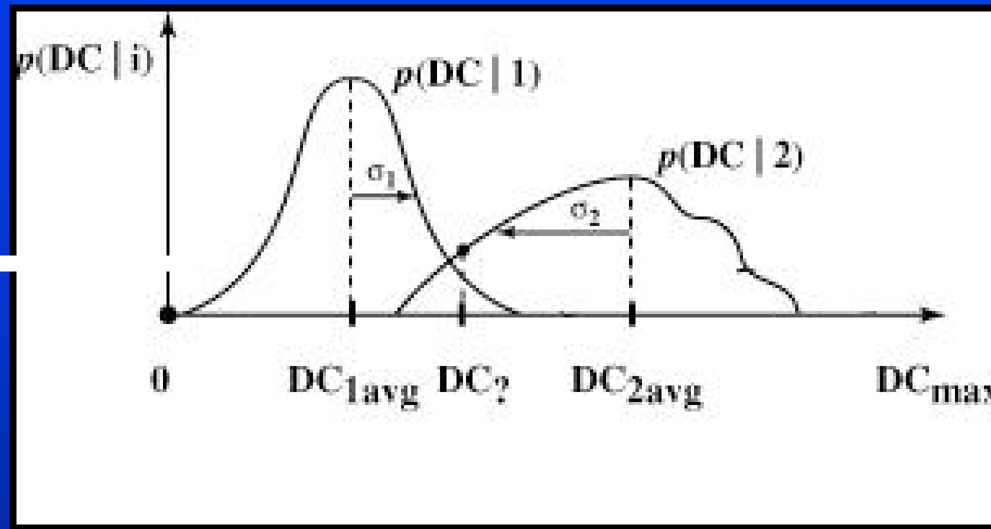
A wildland fire appears predominantly as a ~1000K blackbody



Band selection was performed by

Selection Metric

$$\frac{DC_2 - DC_1}{(s_2)^2 + (s_2)^2} = Q$$



Select Bands that Maximize “Q”

MW-LW is best

- Minimal clutter in emissive spectra
- Large difference between fire & background

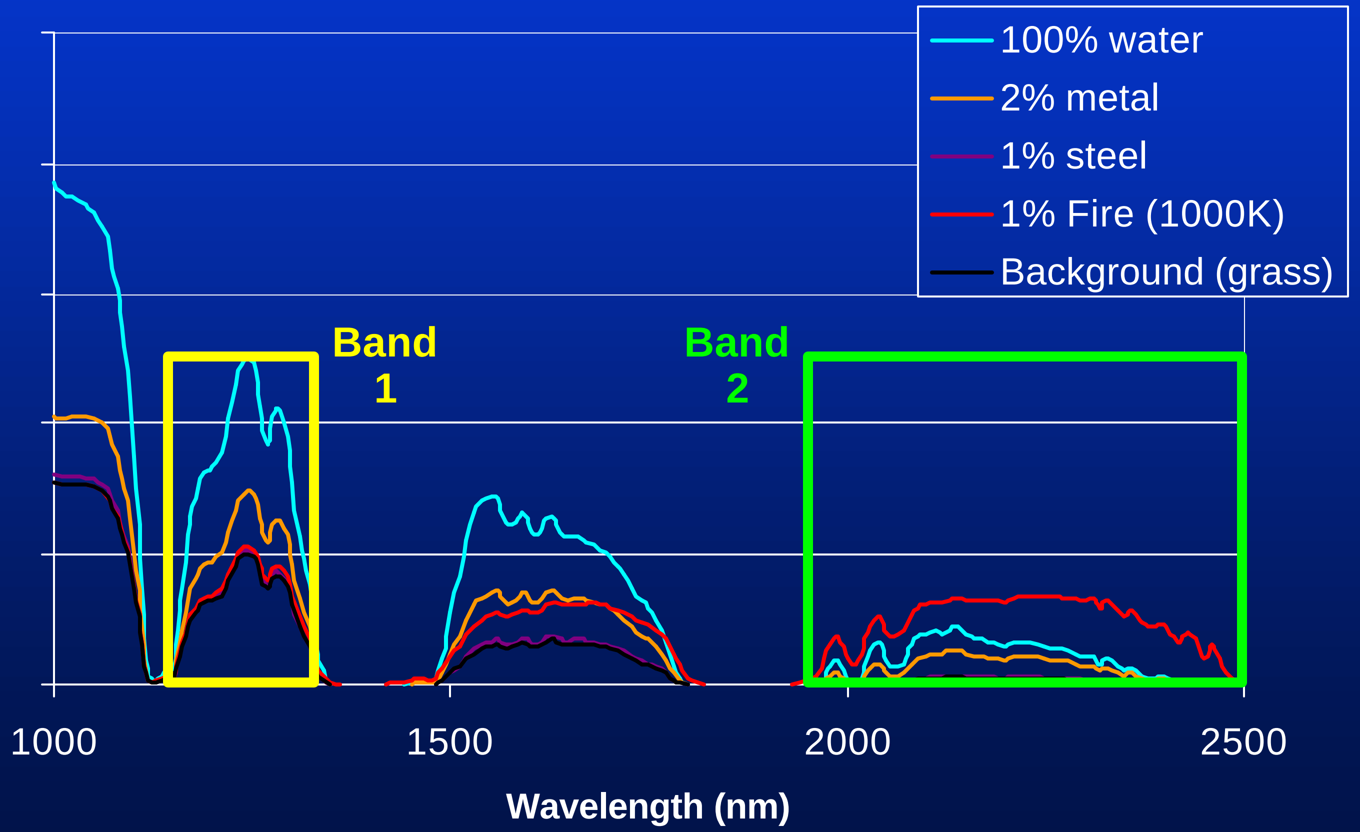
SWIR is very good

- More clutter between 1-2.5mm
- Easy to detect specular reflectors with 1 mm band

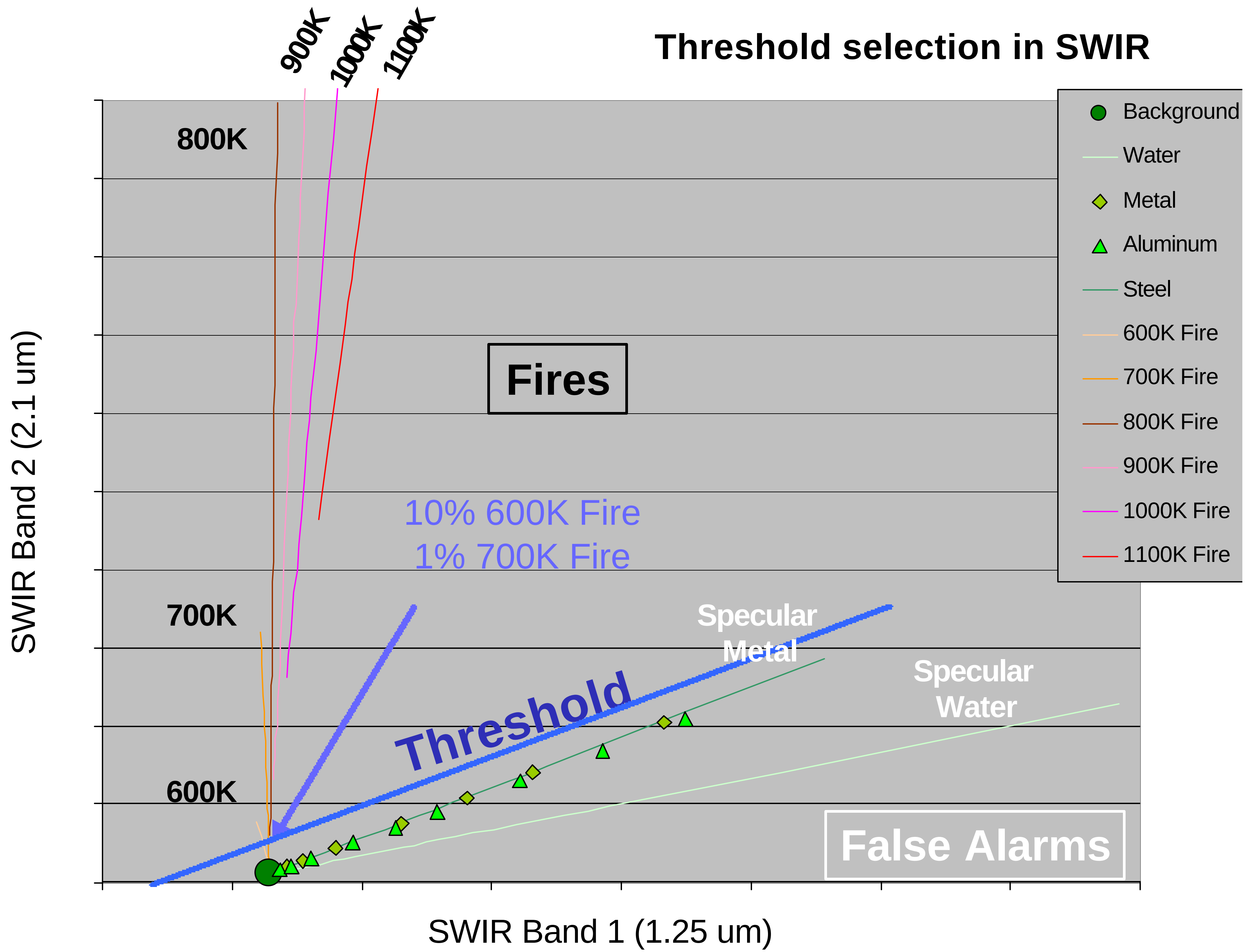
We devised a simple algorithm based on band ratios rather than thresholds or other complex calculations

Use “Color” instead of Threshold

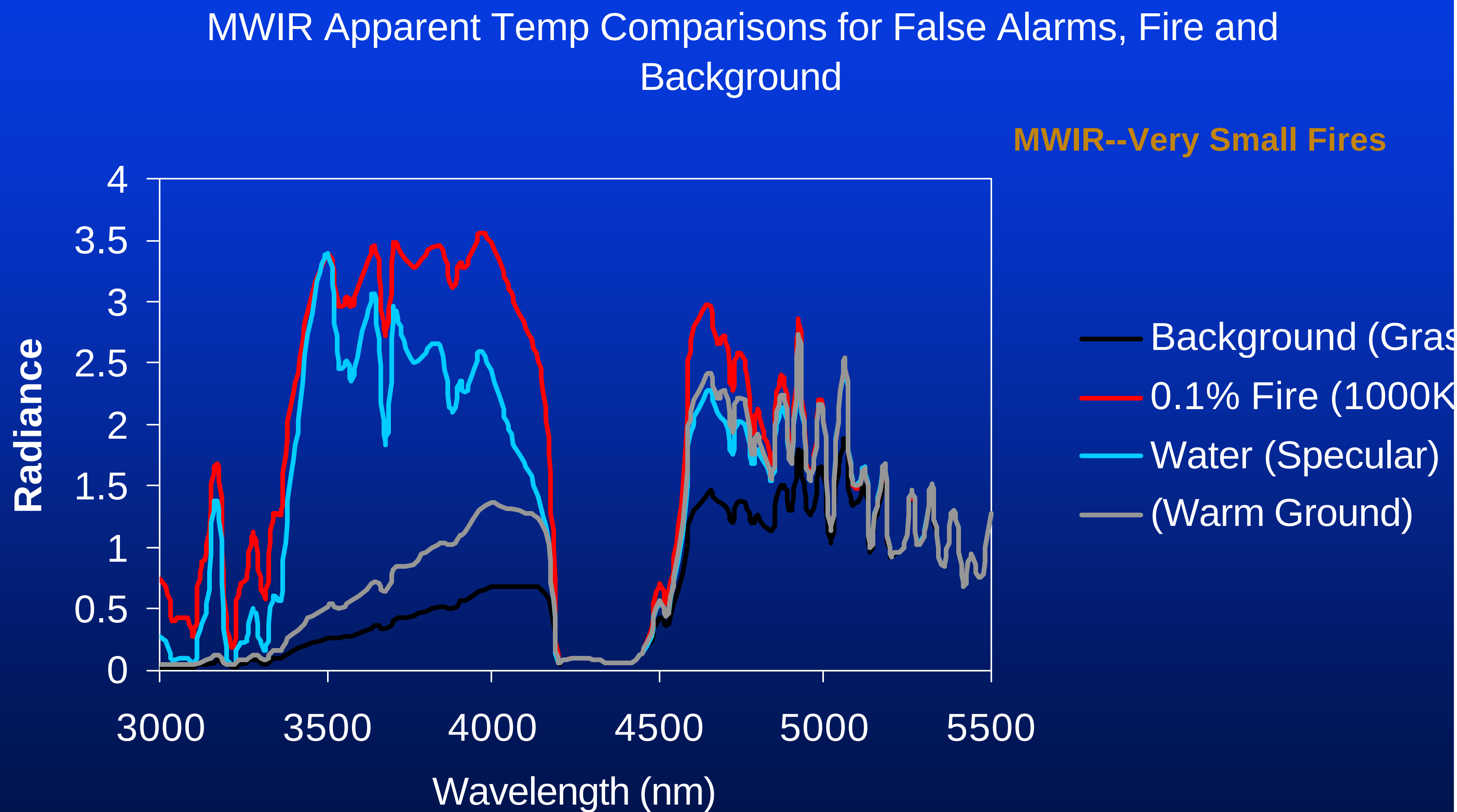
- do not consider individual band radiance values
- instead consider relationship between radiances
- can express this relationship with a ratio

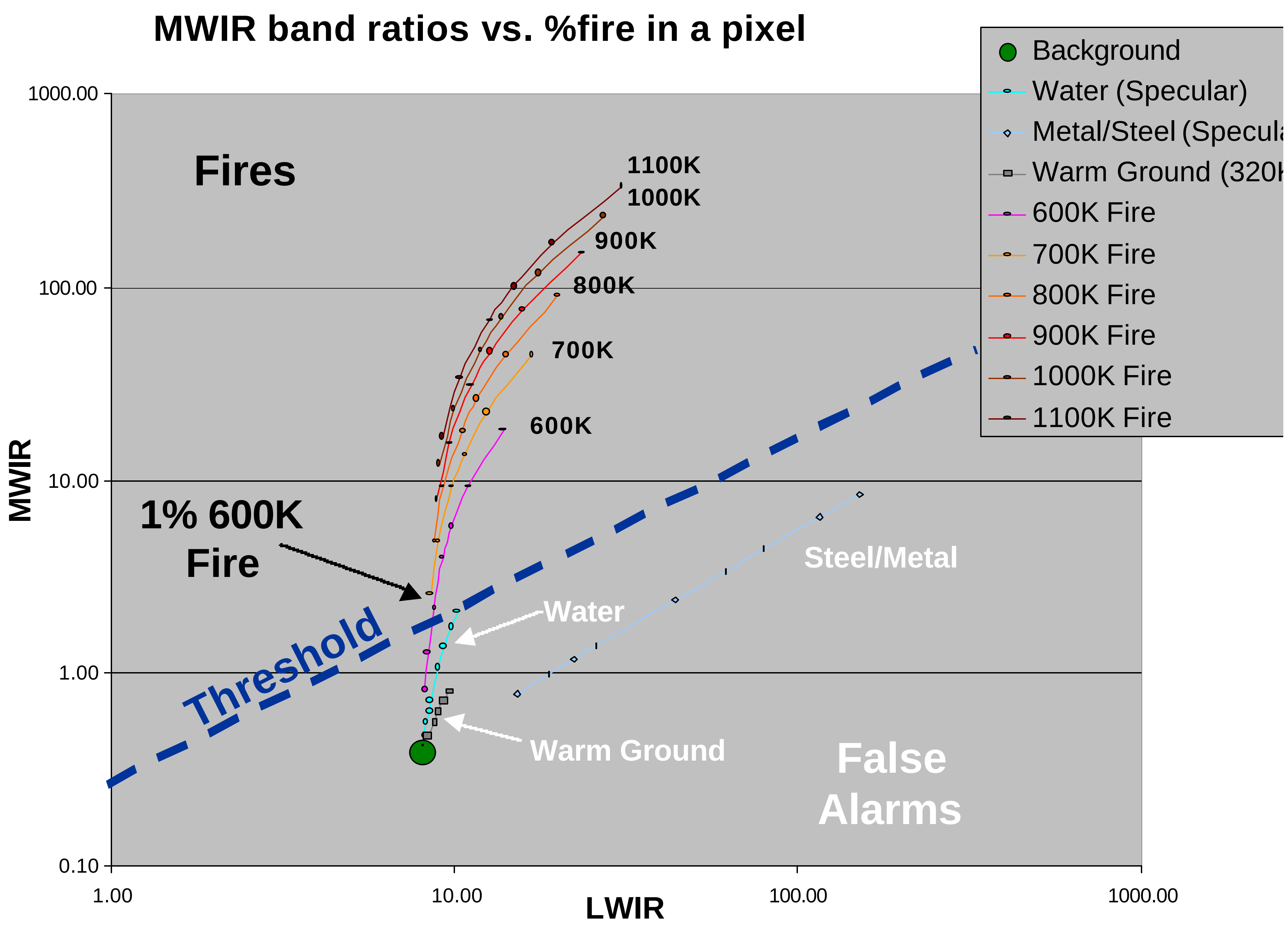


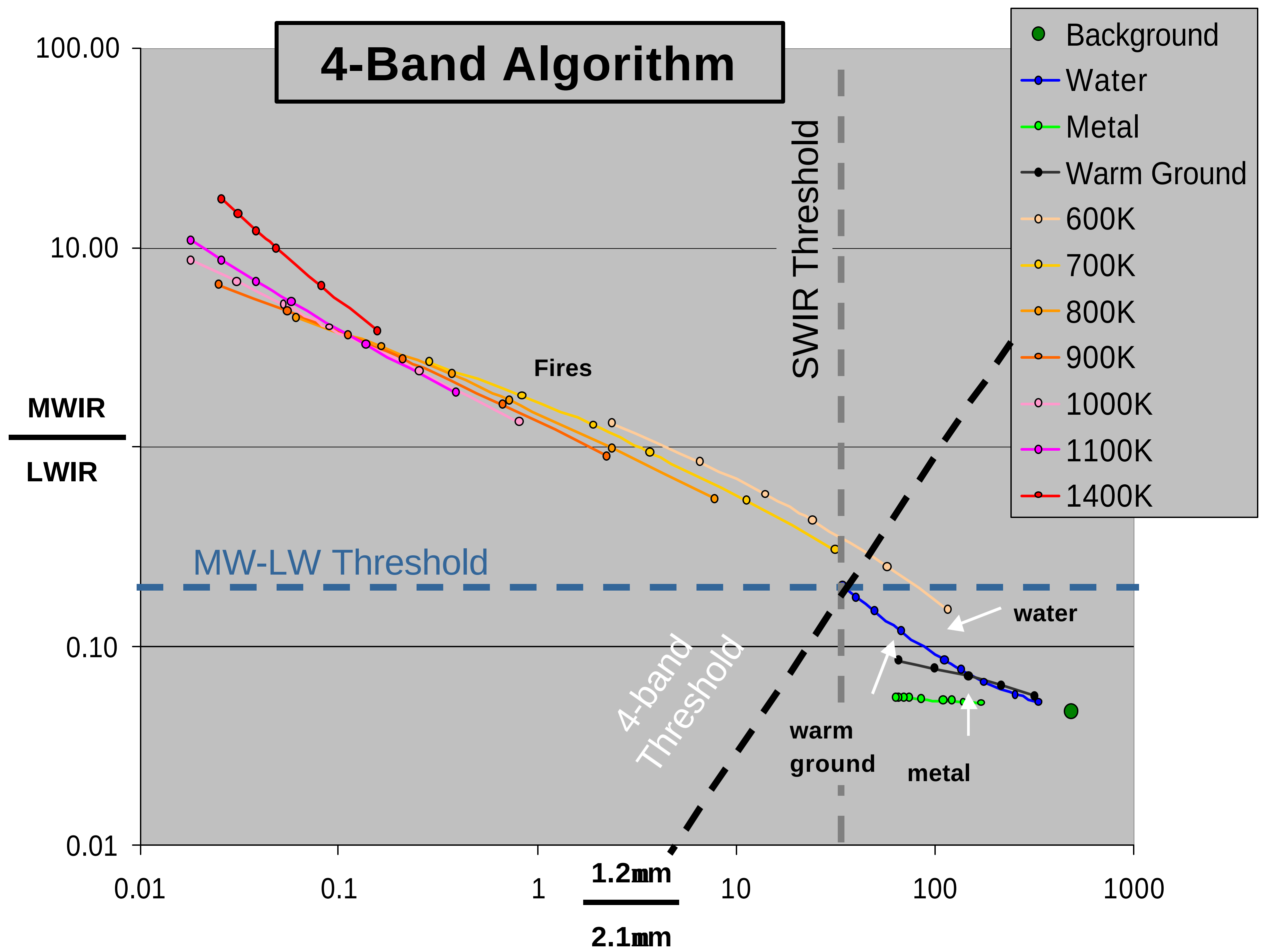
Threshold selection in SWIR



We modeled fire emissions using MODTRAN atmospheric transmittances and Planckian fire emission




MWIR band ratios vs. %fire in a pixel
Background
Water (Specular)
Metal/Steel (Specula
Warm Ground (320
600K Fire
700K Fire
800K Fire
900K Fire
1000K Fire
1100K Fire
Fires
1100K
1000K
900K
800K
700K
600K
1% 600K
Fire
Threshold
Water
Steel/Metal
Warm Ground
False
Alarms
MWIR
LWIR
1000.00
100.00
10.00
1.00
0.10
1.00
10.00
100.00
1000.00



4-Band Algorithm
Background
Water
Metal
Warm Ground
600K
700K
800K
900K
1000K
1100K
1400K
100.00
10.00
0.10
0.01
MWIR
LWIR
0.01
0.1
1
10
100
1000
1.2mm
2.1mm
Fires
SWIR Threshold
MW-LW Threshold
4-band Threshold
water
warm ground
metal

Basics of thermally-excited atomic emission from potassium

•Extremely narrow lines at 766.5 and 769.9 nm

•Very high spectral power density compared to the thermal emission from fire or other hot backgrounds

•Relatively low excitation energy - 4.34 eV

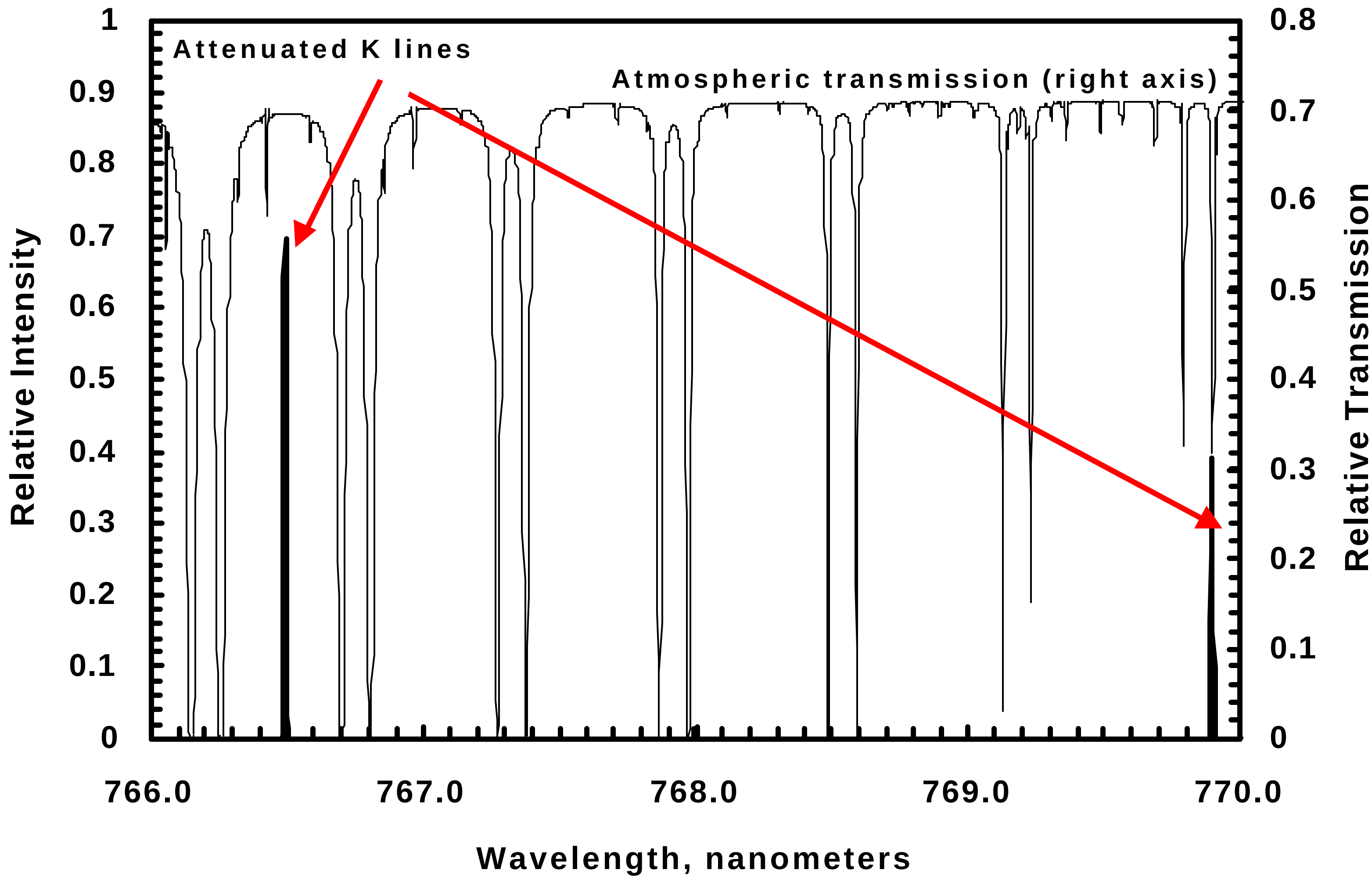
•Relatively high concentration in plant tissue

- 0.4 – 3.4 % by dry weight

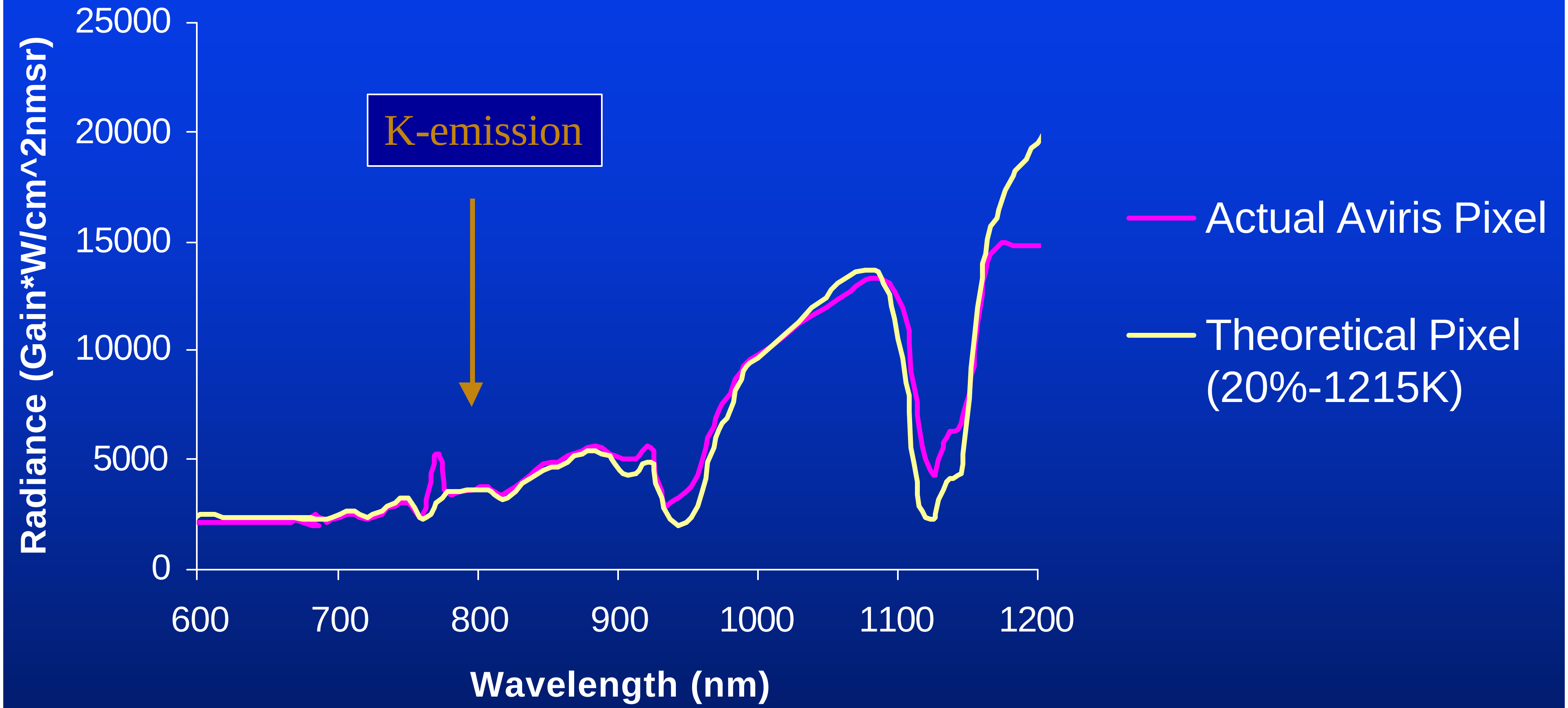
•>10-20% of potassium may be excited at fire temperatures

•The total emission will be determined by a complex combination of factors in the local environment of a flame

The potassium line emission (fortuitously) passes through the atmosphere



Example



- Planckian Curve-fitting allows measurement of fire temperature/size
- We can evaluate K-emission detection using Planckian data.

Initial results from potassium line emission are promising

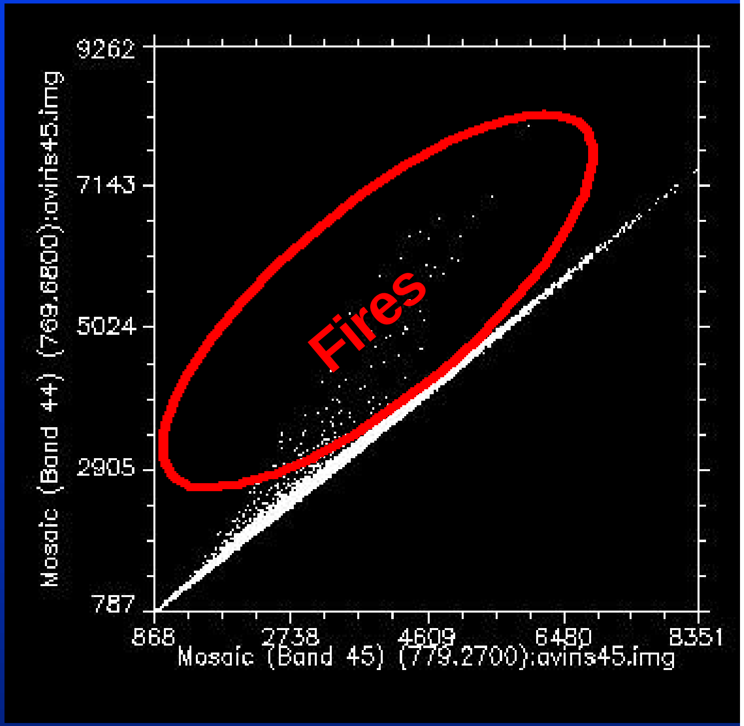
K detection works 50-70%

- 100m GSD is feasible
- Requires
  --High (1-2 nm) spectral resolution
  --High SNR
- Can only detect high temp fires (>1000°K)

Better Data needed for validation

- Accurate ground-truth is required
- currently comparing K-data & thermal (e.g. flame detection vice heat detection)
- errors result since hot ground is not necessarily fire

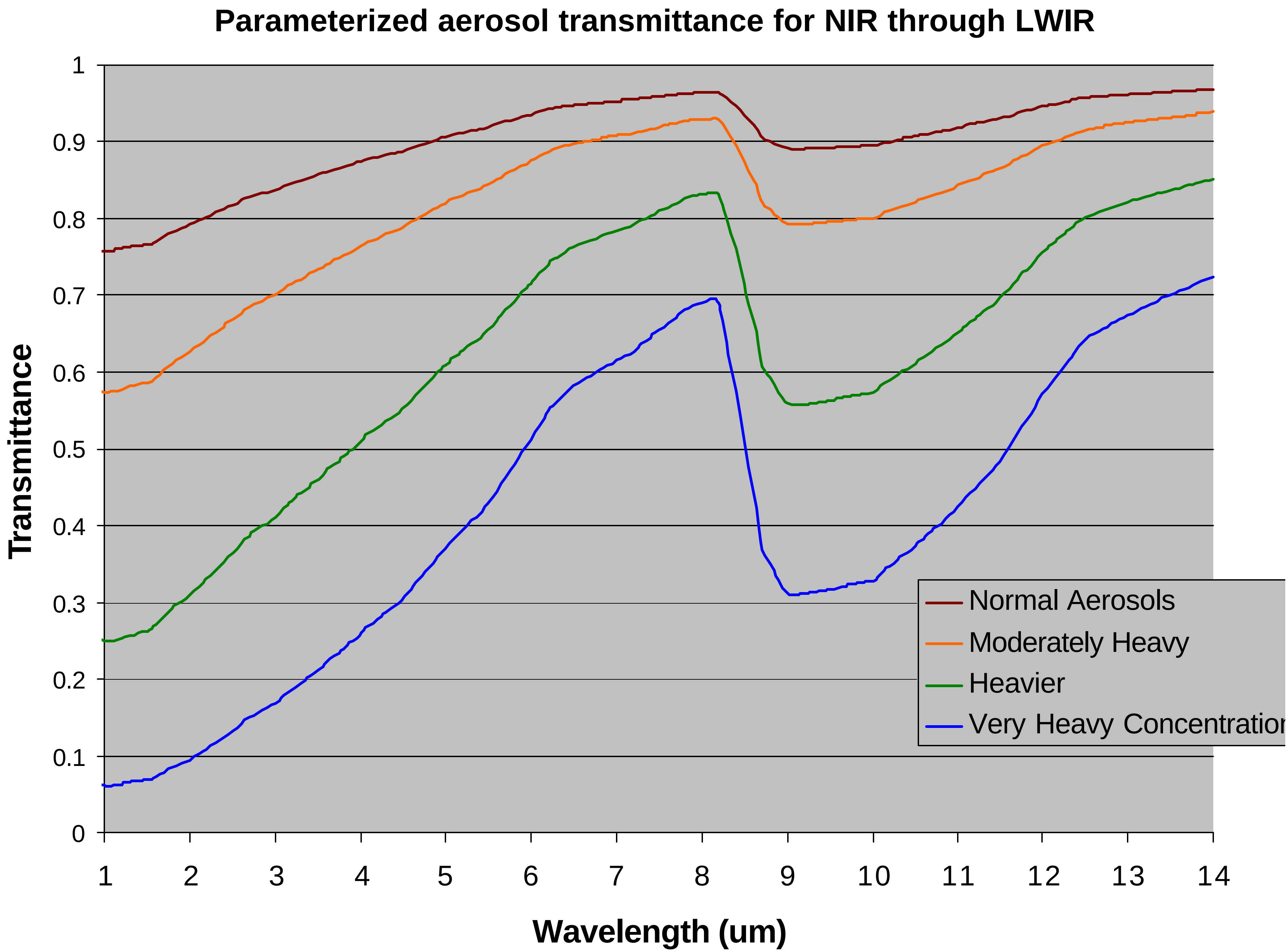
Potassium line emission is more susceptible to smoke than the infrared bands because of particle size distribution of smoke



The effects of heavy smoke must be considered as 'fire follows smoke follows fire'

- Heavy Smoke obscures all frequencies
- Effects of Moderate Smoke Vary
  - MWIR/LWIR has best propagation
  - SWIR is adequate
  - NIR (e.g. Potassium) is attenuated strongly
- Light Smoke is inconsequential in all bands

Detailed smoke model is still being constructed



Parameterized aerosol transmittance for NIR through LWIR
Transmittance
Wavelength (um)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Normal Aerosols
Moderately Heavy
Heavier
Very Heavy Concentration

Conclusions

Color has good potential for detection

- Need average 2-4°K NEDT
- Need relatively high saturation temps
- Avoids contextual algorithm

MWIR/LWIR is best band strategy

- SWIR is also very feasible (may be better if simpler or cheaper)
- Potassium detection is inconclusive

Need better test data for Potassium

- Current detection rates are 50-70%
- These rates compare flame information to heat information (Since heat ^{1} flame. Results may be better)