Exploration of a Multi-Sensor Approach for the Detection and Mapping of Coal Mine Fires in the United States

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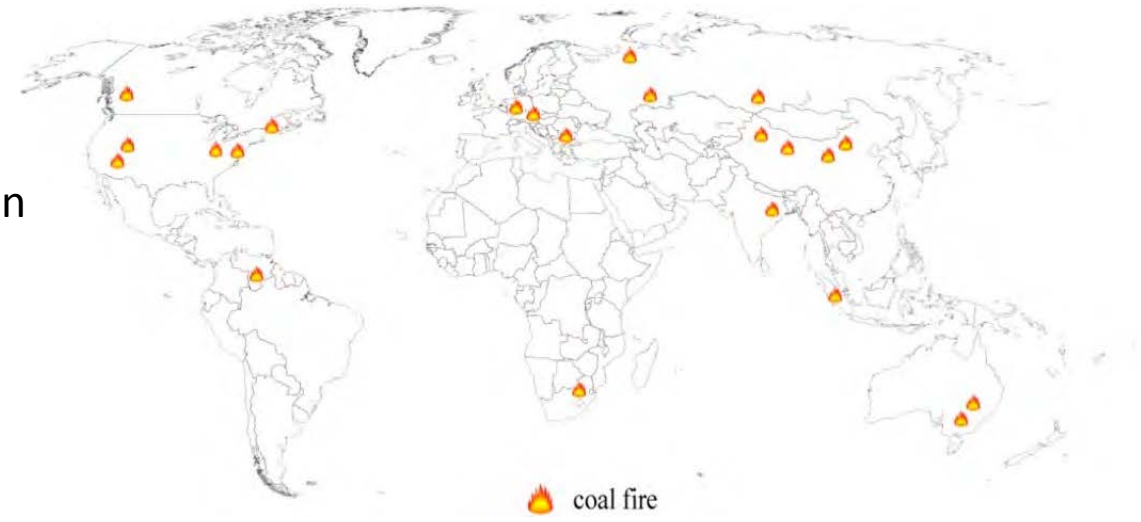
Coal Fires: A Global Occurrence

- Worldwide distribution
- Natural spontaneous combustion
- Influenced by mining activity



From Huo 2015

The Costs of Coal Fires

Environmental:
- Subsidence
- Scarred landscapes
- Pollution

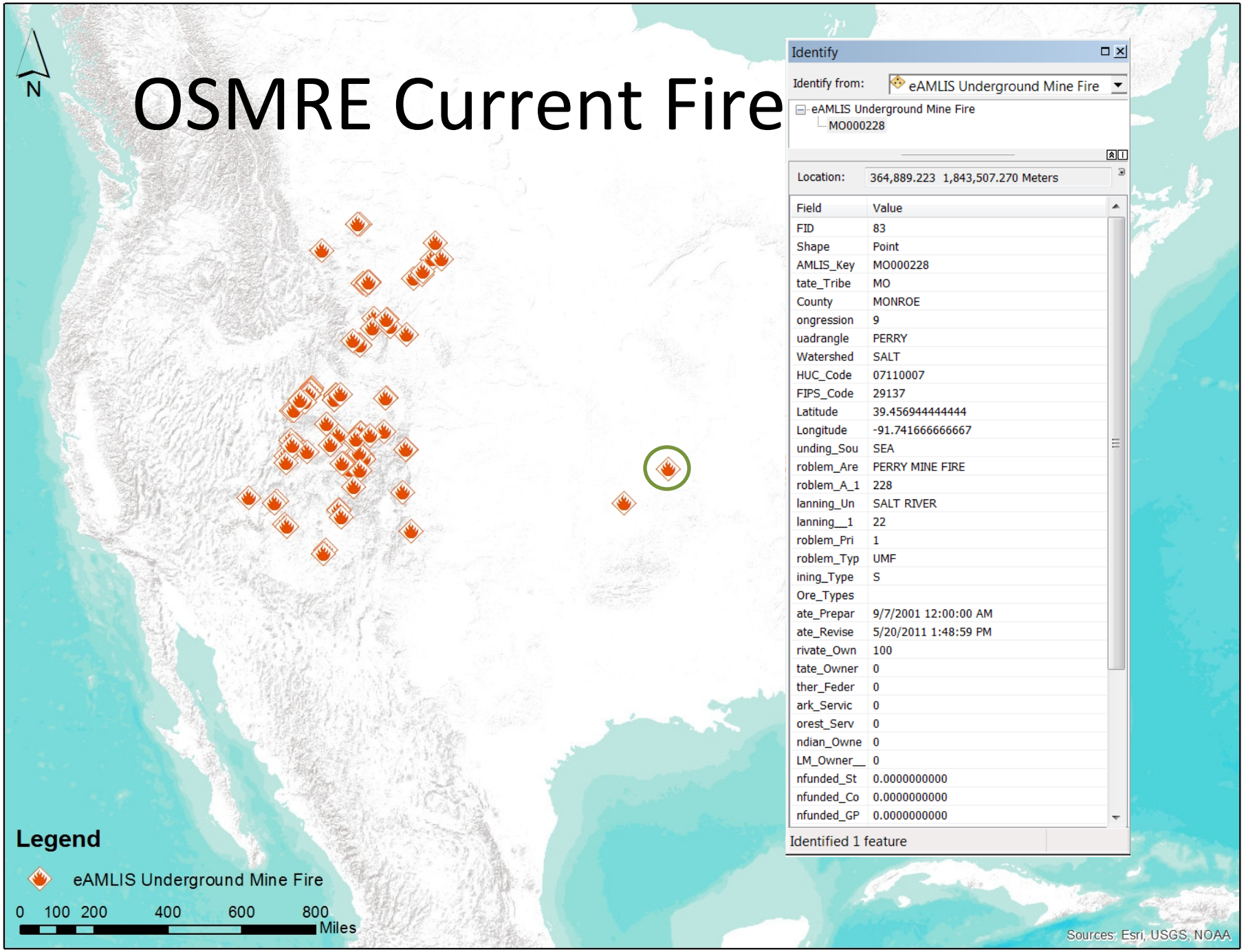
Public Health:
- Respiratory
- Dangerous temperatures

Economic:
- Loss of resources

Often **poorly reported**

Need citation

OSMRE Current Fire



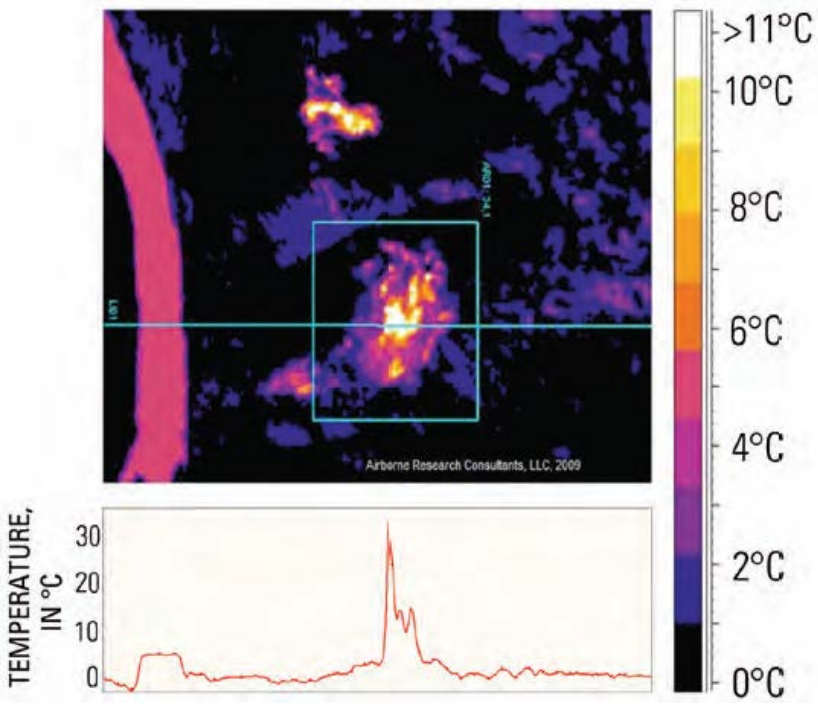
Investigation Proposal

- Problem
  - Incomplete records
  - Limited scope of spatial data

- Remote Sensing Solution
  - Improve spatial data
  - Enhance understanding of fire dynamics and history
  - Inform future reclamation efforts & decision making

Remote Sensing of Coal Fires

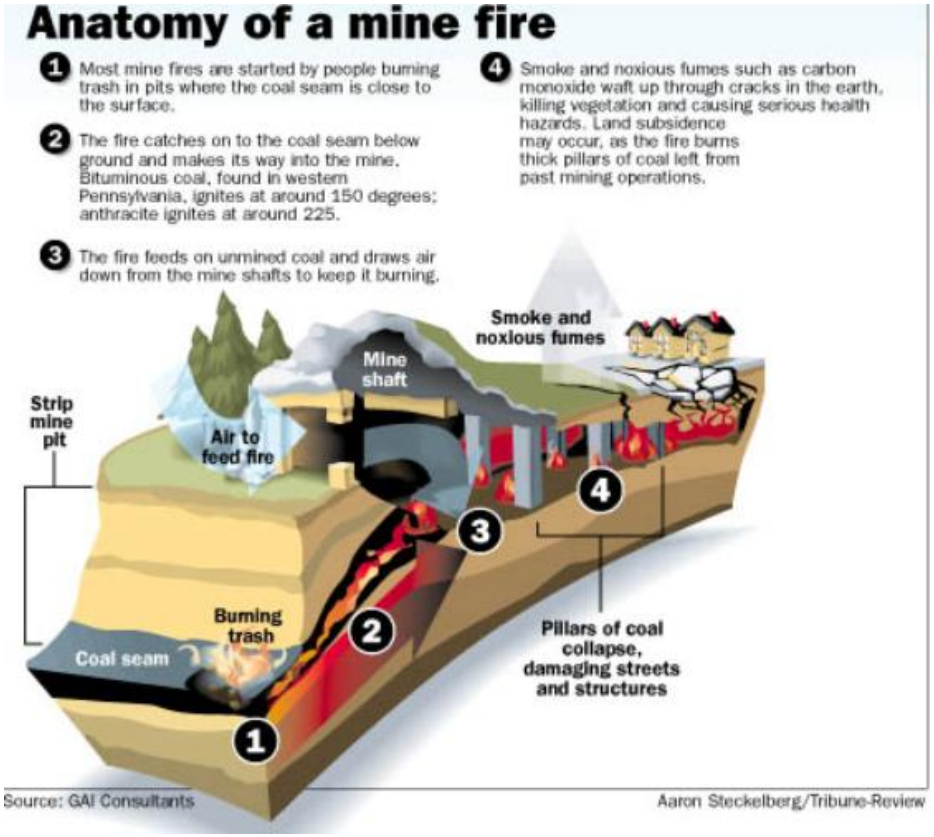
- Airborne Thermal Infrared
  - –In use since the 1960's
  - –High spatial resolution and control
  - –Individual tasking
- Spaceborne Thermal Infrared
  - –Coarser spatial resolution
  - –Constant collection
  - –Freely available data



From Kolker 2009

Generalized Workflow

- Acquire Data
  - –Process to temperature
- Find thermal anomaly
  - –Differentiate from background temperatures
    - •Geographic subsets
    - •Hotspot image stacking
- Delineate a fire boundary



Common Sensors in Coal Fire Research

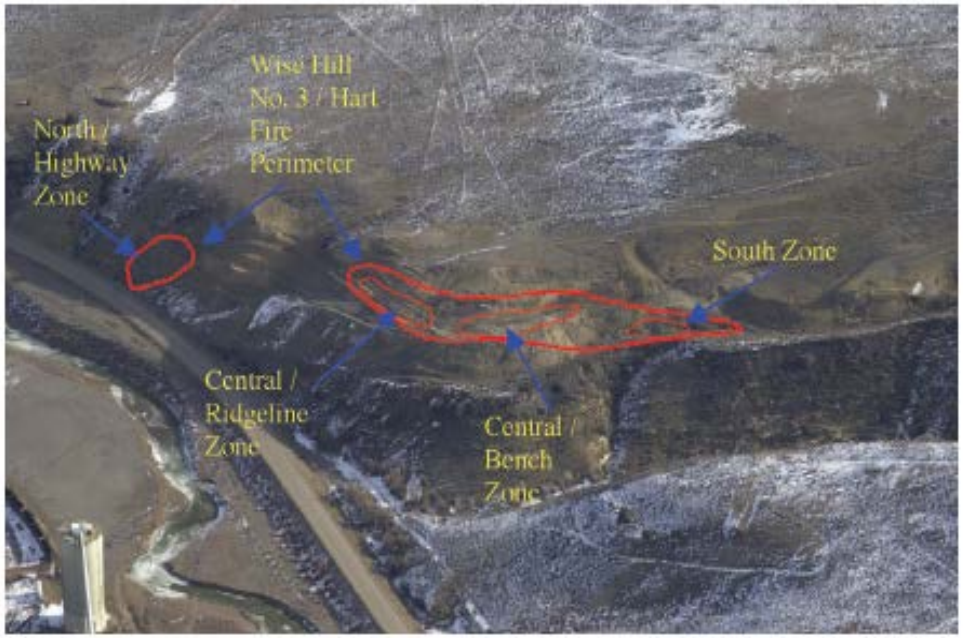
- ASTER
  - –Derived kinetic surface temperature (KST) products
  - –90m spatial res
  - –Success mapping surface fires

- Landsat 7 & 8
  - –Requires preprocessing for KST
  - –30m spatial resolution
  - –Success mapping of underground fires

ASTER

- Basics
  - –Advanced Spaceborne Thermal Emission and Reflection Radiometer
  - –Wide scale applications:
    - •Archaeology
    - •Geology
    - •Hydrology
    - •Natural Hazards
    - •Landuse
- Bands
  - –3 – 15 m bands in Visible & Near-infrared (VNIR)
  - –6 – 30 m Shortwave Infrared (SWIR)*
  - –5 – 90 m Thermal Infrared (TIR)

Wise Hill Fire (Craig CO)



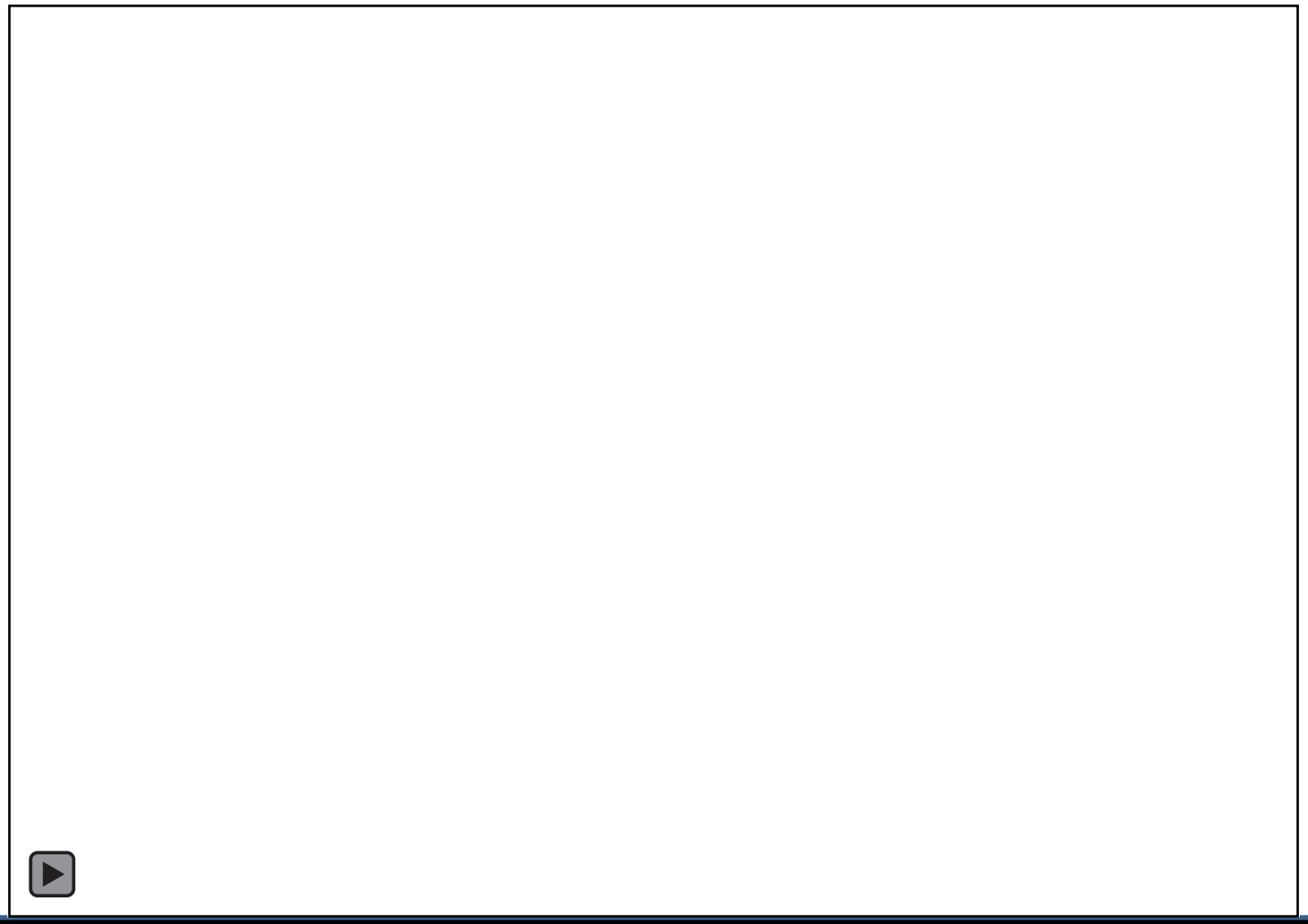
From Renner 2005

- Past fire suppression initiatives
- Four distinct fire zones
- Features including vents and fractures
- CO levels at ~200-300ppm
- Elevated surface temperatures from **125-600°F**

ASTER Detection

Scene Used: AST_08_00310232011050536_20161201080942_27454
Method: geographic subsets

Wise Hill Fire Detection: *Geographic Subsets*



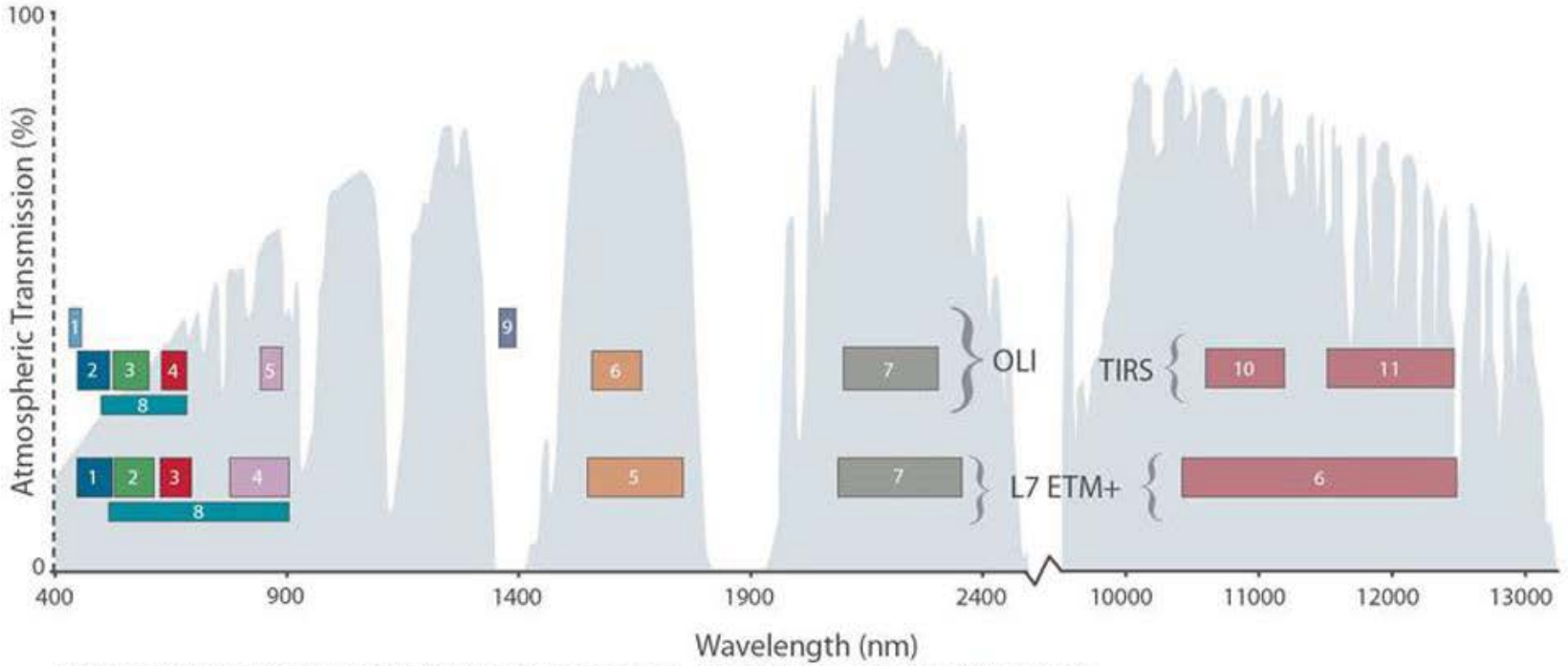
Wise Hill Detection Results

From Renner 2005

2005 field derived Fire Area

ASTER TIR Detection

Landsat



Bandpass wavelengths for Landsat 8 OLI and TIRS sensor, compared to Landsat 7 ETM+ sensor

Note: atmospheric transmission values for this graphic were calculated using MODTRAN for a summertime mid-latitude hazy atmosphere (circa 5 km visibility).

Landsat 7 Data Methodology

- Image Processing
  - –Convert DN to at sensor radiance (ASR) (Irish 2000)
  - –Convert ASR to at sensor brightness temperature (ASBT) (Irish 2000)
  - –Calculate Emissivity (Choudhury et al. 1994)
    - •Proportion of Vegetation from NDVI
  - –Convert to surface kinetic temperature (Prakash 2011)

- Fire Detection
  - –Multi –temporal approach
    - •Ten scenes collected 2002-2003
  - –Set threshold & identify hotspots
    - •Experimentally set at 10% (Prakash 2011)
  - –**Image Stacking** (Prakash 2011)
  - –Delineate fire area boundary


1 frame


4 frame stack


16 frame stack

IHI #3 Fire (Rifle CO)

From Renner 2005

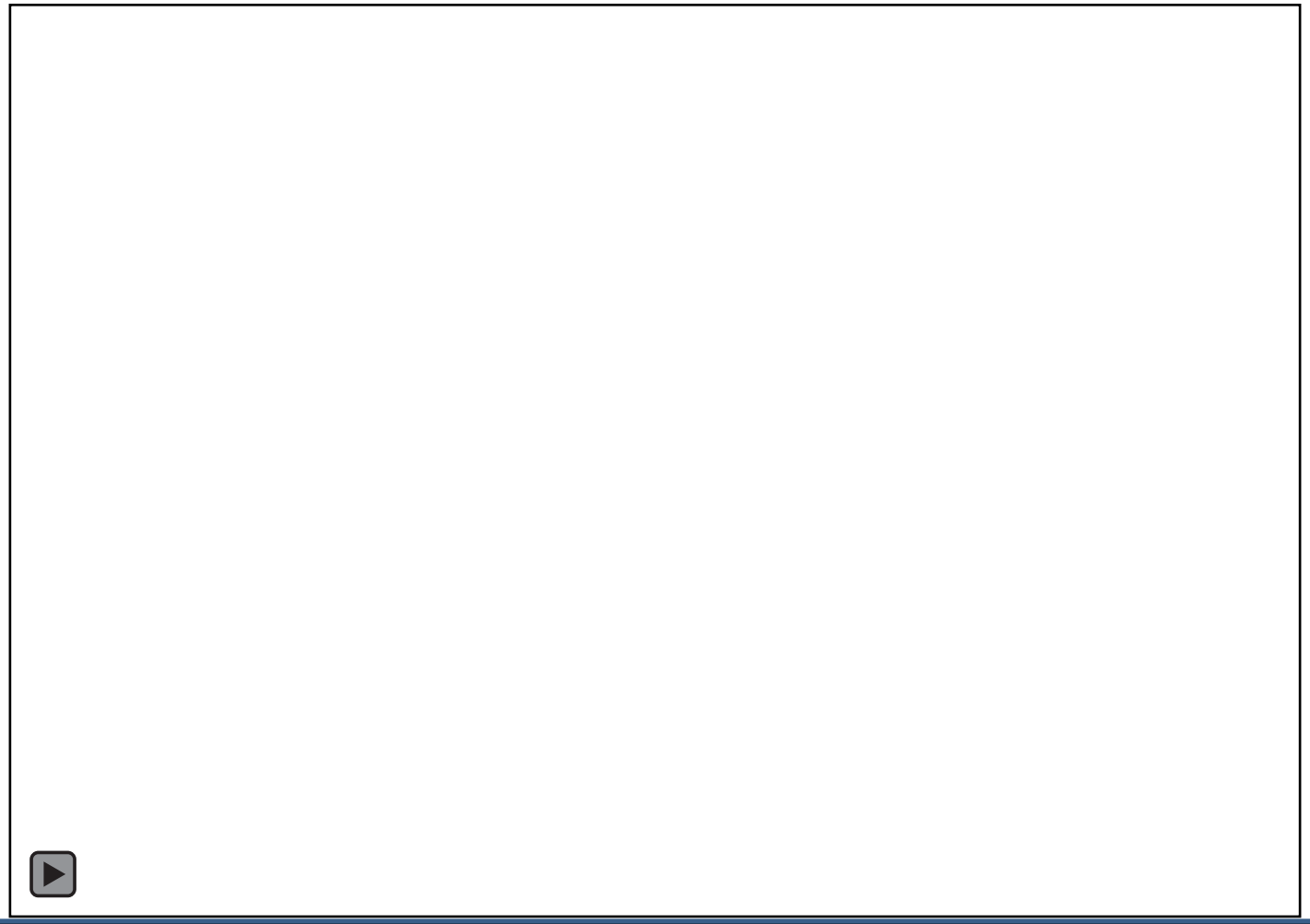
- Numerous abatement activities
- East and West fire zone
- Features including vents, fractures, subsidence
- Elevated surface temperatures from **125-500°F**

Landsat 7 ETM+ Detection

Scene: ten “cloud-free” scenes from 2002-2003

Method: hotspot image stacking

IHI#3 Fire Detection: *Hotspot Image Stacking*



IHI#3 Detection Results

From Renner 2005

2005 field derived Fire Area

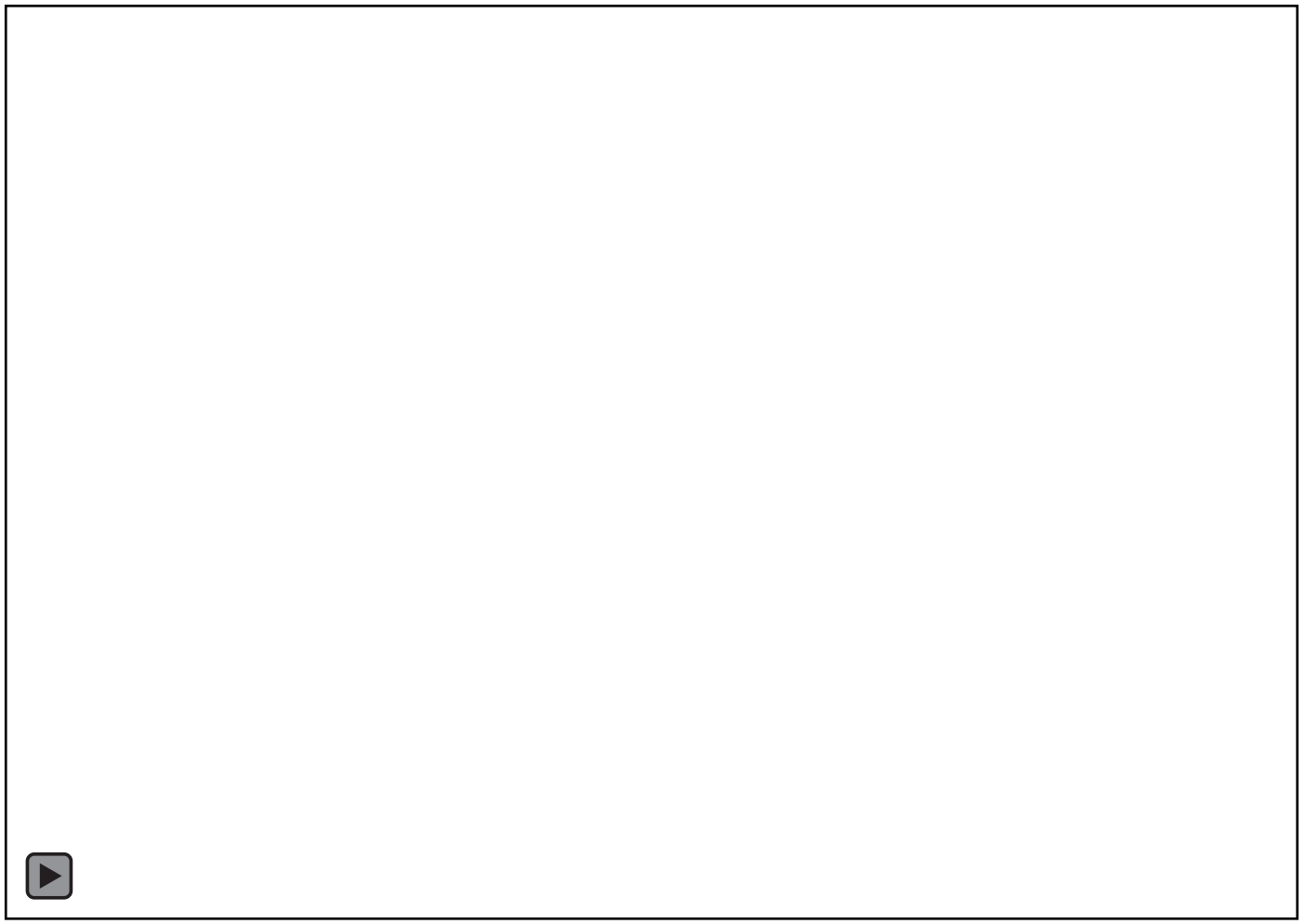
Landsat 7 ETM+ TIR Detection

Conclusions

- Need for improvement in mine fire spatial data

- TIR Spaceborne Remote sensing can:
  - Delineate fire boundaries
  - Enhance multi-temporal studies
  - Future: be streamlined for time & cost efficiency

Future Steps: Automation via Google Earth Engine



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