



Office of Surface Mining Reclamation and Enforcement
Geospatial Information Services

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:

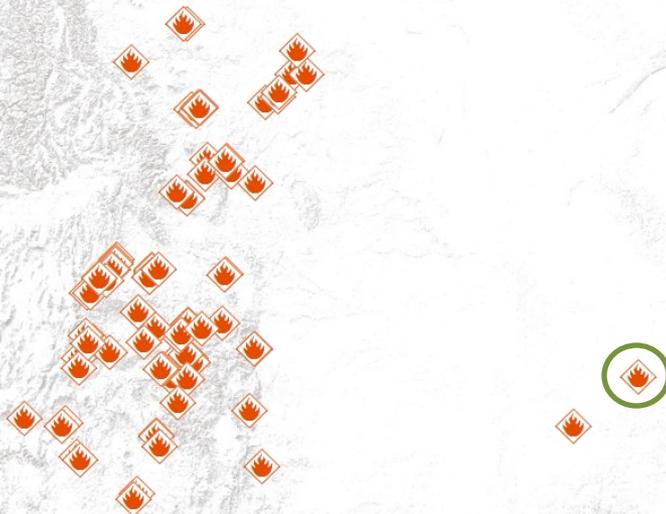
- Loss of resources

Often **poorly reported**



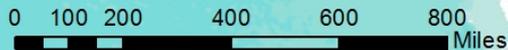
Need citation

OSMRE Current Fire



Legend

 eAMLIS Underground Mine Fire



Identify

Identify from: eAMLIS Underground Mine Fire

eAMLIS Underground Mine Fire
MO000228

Location: 364,889.223 1,843,507.270 Meters

Field	Value
FID	83
Shape	Point
AMLIS_Key	MO000228
tate_Tribe	MO
County	MONROE
ongression	9
uadrangle	PERRY
Watershed	SALT
HUC_Code	07110007
FIPS_Code	29137
Latitude	39.456944444444
Longitude	-91.741666666667
unding_Sou	SEA
roblem_Are	PERRY MINE FIRE
roblem_A_1	228
lanning_Un	SALT RIVER
lanning__1	22
roblem_Pri	1
roblem_Typ	UMF
ining_Type	S
Ore_Types	
ate_Prepar	9/7/2001 12:00:00 AM
ate_Revise	5/20/2011 1:48:59 PM
rivate_Own	100
tate_Owner	0
ther_Feder	0
ark_Servic	0
orest_Serv	0
ndian_Owne	0
LM_Owner__	0
nfunded_St	0.0000000000
nfunded_Co	0.0000000000
nfunded_GP	0.0000000000

Identified 1 feature



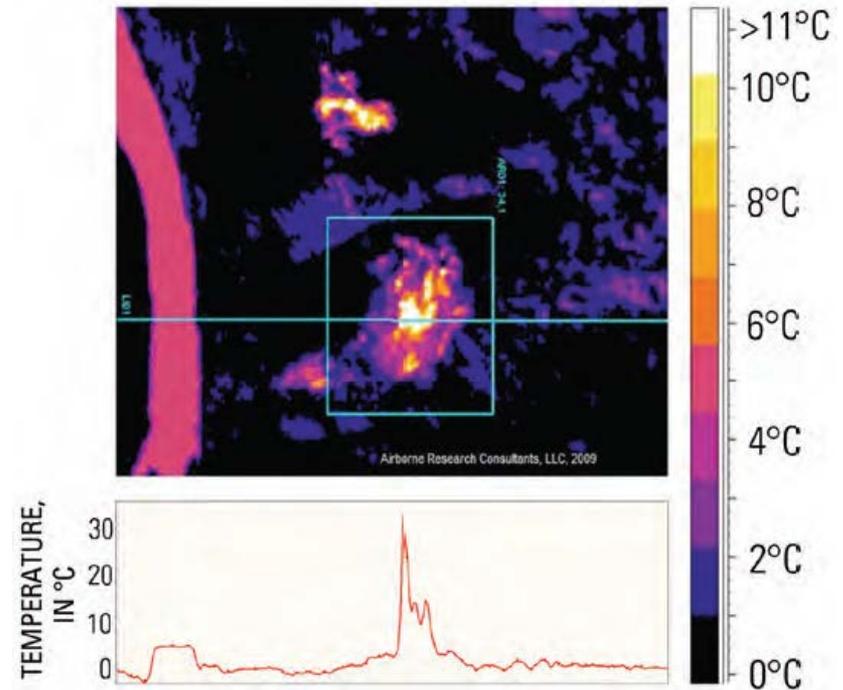
Investigation Proposal

- 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



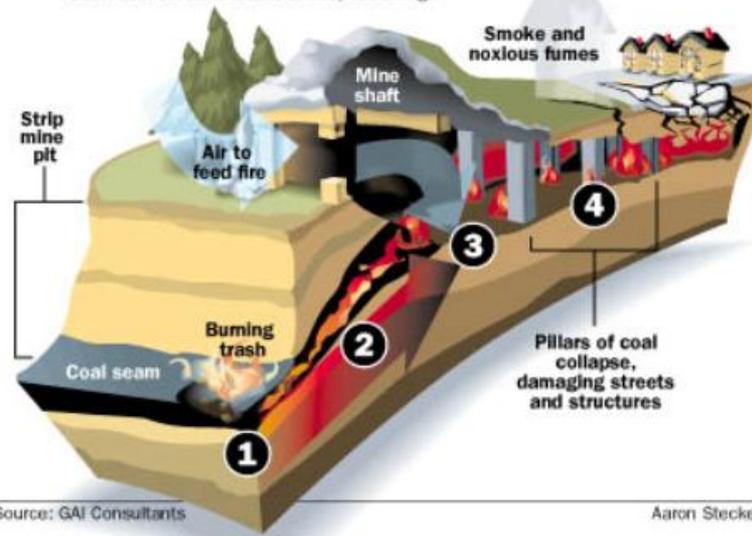


Generalized Workflow

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

Anatomy of a mine fire

- 1 Most mine fires are started by people burning trash in pits where the coal seam is close to the surface.
- 2 The fire catches on to the coal seam below ground and makes its way into the mine. Bituminous coal, found in western Pennsylvania, ignites at around 150 degrees; anthracite ignites at around 225.
- 3 The fire feeds on unmined coal and draws air down from the mine shafts to keep it burning.
- 4 Smoke and noxious fumes such as carbon monoxide waft up through cracks in the earth, killing vegetation and causing serious health hazards. Land subsidence may occur, as the fire burns thick pillars of coal left from past mining operations.



Source: GAI Consultants

Aaron Steckelberg/Tribune-Review



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

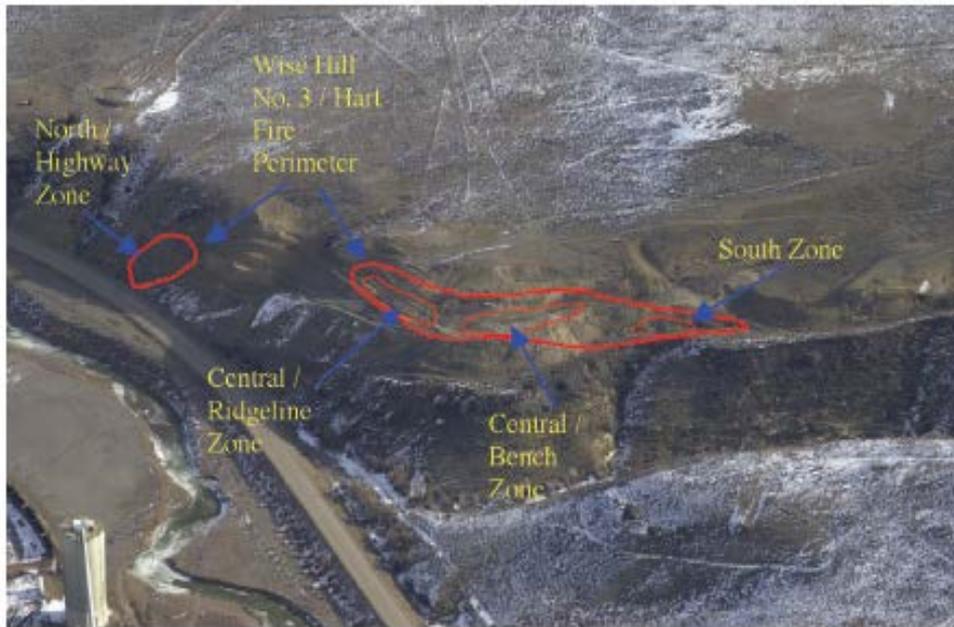
- 3 – 15 m bands in Visible & Near-infrared (VNIR)

- 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

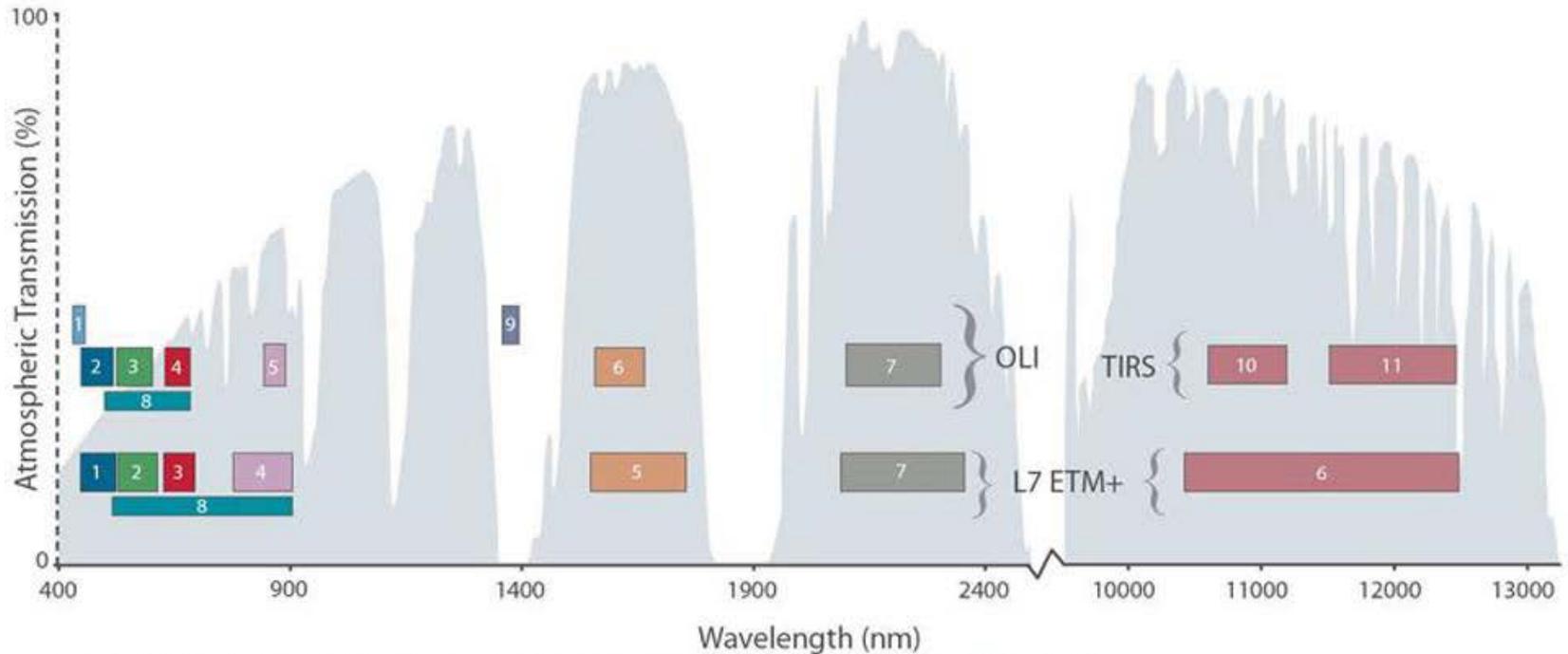
2005 field derived Fire Area



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

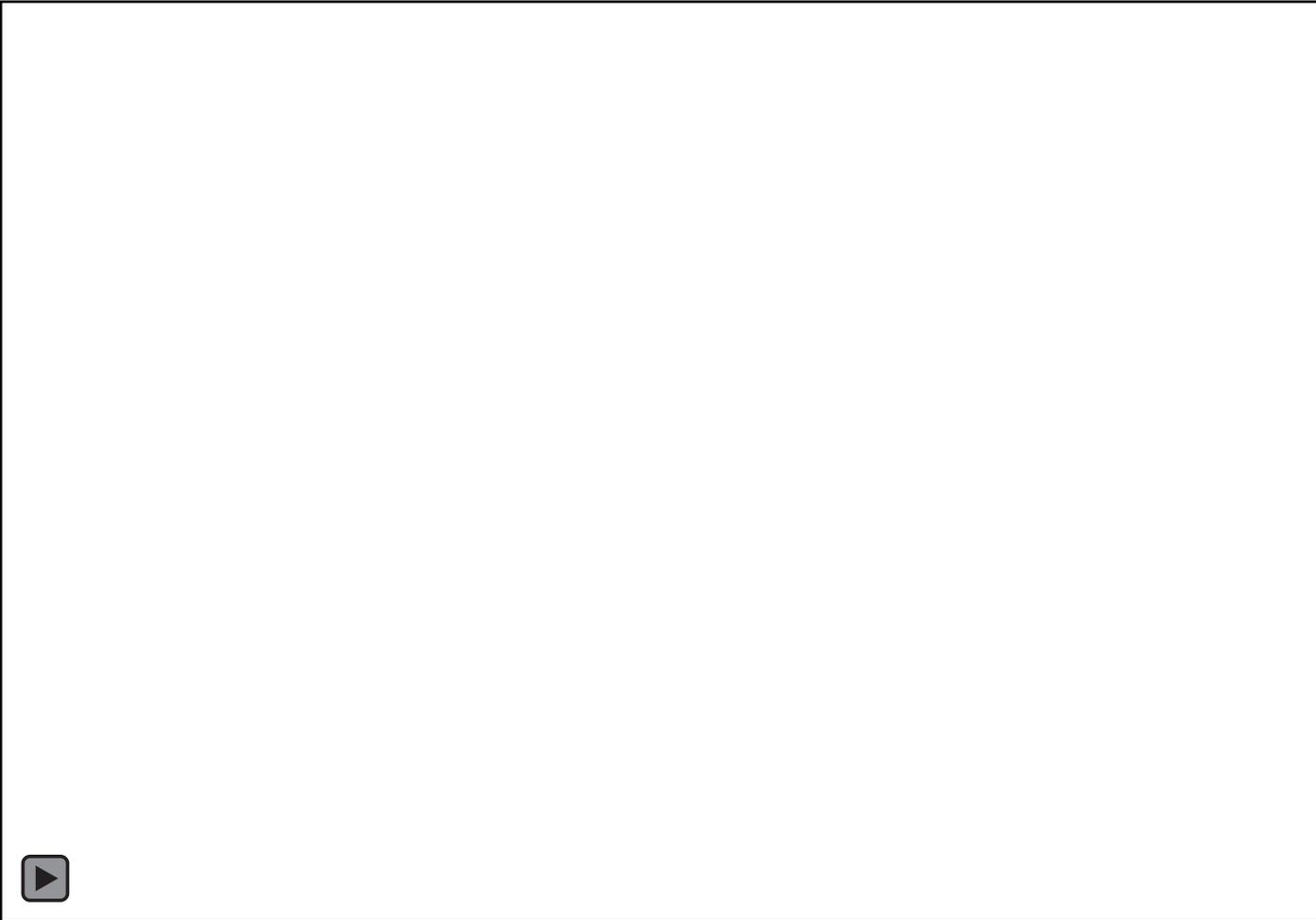


Conclusions

- 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





Works Referenced & Additional Reading

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