Use of VIS/NIR/SWIR/TIR Remote Sensing for U.S. Wildland Fire Characterization and Management: Potential for HyspIRI

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The Three Phases of Wildland Fire Mapping

• **Pre-fire**
  – Available fuels (type, size, arrangement, age)
  – Fuel Conditions (moisture, bug kill, blow down)

• **Active fire**
  – Detection of ignitions (primarily via ground report in the lower 48)
  – Movement of the fire front, breach of containment

• **Post-fire**
  – Fire effects on vegetation and soils
  – Mitigation of adverse impacts (mass wasting, water quality, invasive species)
Mature Heritage

- Airborne Missions
  - Phoenix (beginning in latter 1960s)
  - MASTER
  - AVIRIS
  - AMS
  - Military Assets
- Geostationary Satellite Missions
  - GOES
- Polar Orbit Satellite Survey Missions
  - AVHRR
  - MODIS (will continue with VIIRS)
- Satellite Mapping Missions
  - Landsat
  - ASTER
  - Spot
  - ALI/Hyperion
  - IKONOS, Quickbird
Principal Users

- National Interagency Fire Center
- USDA Forest Service
- Bureau of Land Management
- National Park Service
- Alaska Fire Service
- Bureau of Indian Affairs
- Fish and Wildlife Service
- DoD (i.e. NORTHCOM)
- Department of Homeland Security
- FEMA
- States (i.e. CAL FIRE)
Wildland Fire Assessment System

- Produced daily by USDA Forest Service Rocky Mountain Research Station.
- Dozens of variables and metrics reported
  - Fire Danger Rating
  - Lighting Ignition Efficiency
  - Haines Index (lower atmosphere stability)
  - Fire Weather
  - Fuel Moisture (10, 100 and 1,000 hour)
  - NDVI
  - Palmer Drought Index
  - And so on ...
Satellite Fuels and Fuel Condition Pre-Fire Characterization DSS all use the VIS / NIR / SWIR bands available on HyspIRI (in addition to a lot of wx data).

*Opportunity to develop new experimental methods using hyperspectral VIS/NIR/SWIR signal. TIR has potential for water balance.*
• What remote sensing provides for mapping of active wildland fires
  – Fire perimeter and active fire fronts
  – Problem areas – hot spots outside line
  – Where the fire has been
  – Lines of containment
  – Effectiveness of backfire operations
  – Hot-spots during the mop-up phase
  – Post-fire burn severity
Command Structure & Customers
Where the data goes

- National Interagency Fire Center (NIFC)
- Geographic Area Command Center (GACC)
- Incident Command Posts (ICPs)
- FEMA Joint Field Office (JFO)
- Emergency Operations Centers (EOC)

The ICP is the primary customer for TIR Data
National Infrared Operations

Citation jet at NIFC

Phoenix Sensor Workstation on Citation Jet

Output Product
PHOENIX Output Products

- GeoTiffs
  - Color
  - Grayscale
- JPEGS
- Mosaics
- Active Heat Areas shape file
today from AVHRR
today from MODIS

Produced via Direct Readout facility at USFS-RSAC, Salt Lake City.
## Sensor System: AMS Wildfire Instrument

### AMS Wildfire Sensor

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (μm)</th>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>0.42- 0.45</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.45- 0.52</td>
<td>(TM1)</td>
</tr>
<tr>
<td>3</td>
<td>0.52- 0.60</td>
<td>(TM2)</td>
</tr>
<tr>
<td>4</td>
<td>0.60- 0.62</td>
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</tr>
<tr>
<td>5</td>
<td>0.63- 0.69</td>
<td>(TM3)</td>
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<tr>
<td>6</td>
<td>0.69- 0.75</td>
<td></td>
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<tr>
<td>7</td>
<td>0.76- 0.90</td>
<td>(TM4)</td>
</tr>
<tr>
<td>8</td>
<td>0.91- 1.05</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1.55- 1.75</td>
<td>(TM5)</td>
</tr>
<tr>
<td>10</td>
<td>2.08- 2.35</td>
<td>(TM7)</td>
</tr>
<tr>
<td>11</td>
<td>3.60- 3.79</td>
<td>(VIIRS M12)</td>
</tr>
<tr>
<td>12</td>
<td>10.26-11.26</td>
<td>(VIIRS M15)</td>
</tr>
</tbody>
</table>

- Total Field of View: 85.9 degrees
-IFOV: 2.5mrad
- Altitude: 25000’
- Spatial Resolution: 20m (at sea level)
Wildfire - Collaborative Decision Environment

Google Earth
Weather
NWS, NRL, MIT
MODIS
USFS, NASA/UMD
Fire Incidents
NIFC, USFS, USGS
Airspace Restrictions
FAA, NASA

Ikhana UAS
Internet
Visualization
Satellite track prediction
Streaming Video
Group IM
Northern California Firestorm - 2008

Images From
8 & 19 July 2008
Airborne and Satellite Active Fire Detection Systems all use the 4 and 11 μm TIR bands available on HyspIRI.
The goal of BAER mapping ...

Identify those areas at greatest risk for adverse impacts on water quality and re-generation due to factors such as the formation of hydrophobic soils which can result in severe erosion.

This must be done quickly and over large areas. Remote sensing is of great value to help rapidly focus on those areas with the most critical need.
Creation of the BARC

Black Pine 2 Fire
Sawtooth NF
73,000 Acres

Normalized Burn Ratio (NBR)

\[ \text{NBR} = \left( \text{NIR} - \text{Mid IR} \right) / \left( \text{NIR} + \text{Mid IR} \right) \]

Differenced Normalized Burn Ratio (dNBR)

\[ \text{dNBR} = \text{Pre NBR} - \text{Post NBR} \]

Burned Area Reflectance Classification (BARC) is a simplified dNBR

- Dark Green = Unchanged
- Cyan = Low
- Yellow = Moderate
- Red = High
Operational Fire Support at RSAC

- Post-fire Assessment – Emergency, Rapid, and Extended Timing
  - BAER Image Support
    - BARC (Burned Area Reflectance Classification) creation
      - Emergency Assessment
  - Rapid Assessment of Vegetation Condition after Wildfire (RAVG)
    - For Forest Silviculturist
      - Rapid Assessment
  - Monitoring Trends in Burn Severity (MTBS)
    - National Fire Plan (NFP) and Healthy Forest Restoration Act (HFRA)
      - Extended Assessment
Burned Area Emergency Response (BAER)

Emergency Stabilization and Rehabilitation

- **Fast-Track** emergency assessment
- Assess effects of the fire on the soil and watershed hydrologic function (erosion and flood potential) for risks to:
  - life
  - property
  - long-term soil productivity
  - water quality
  - resources
## BAER Fire Support Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>USGS-EROS</th>
<th>USFS-RSAC</th>
<th>Sum</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Fires</td>
<td>Acres</td>
<td>Fires</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>N/A</td>
<td>15</td>
</tr>
<tr>
<td>2002</td>
<td>10</td>
<td>500,000</td>
<td>73</td>
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<tr>
<td>2003</td>
<td>17</td>
<td>307,034</td>
<td>54</td>
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<tr>
<td>2004</td>
<td>24</td>
<td>5,000,000</td>
<td>25</td>
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<tr>
<td>2005</td>
<td>23</td>
<td>800,000</td>
<td>46</td>
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<tr>
<td>2006</td>
<td>61</td>
<td>2,532,907</td>
<td>115</td>
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<tr>
<td>2007</td>
<td>48</td>
<td>2,422,130</td>
<td>106</td>
</tr>
<tr>
<td>2008</td>
<td>16</td>
<td>544,639</td>
<td>98</td>
</tr>
<tr>
<td>Sum</td>
<td>204</td>
<td>12,106,710</td>
<td>532</td>
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</tbody>
</table>

Collaborative effort between USFS-RSAC and USGS-EROS
RAVG (Rapid Assessment of Vegetation Condition after Wildfire)

- **RAVG Objectives**
  - Rapid post-fire damage assessment due to wildfire
  - Calculate acres of land suitable for reforestation
  - Spatially represent forested vs. deforested areas following wildfire
  - Delivered 30 calendar days after fire containment
  - **Data helps determine reforestation needs**

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<table>
<thead>
<tr>
<th>Vegetation Group (LANDFIRE)*</th>
<th>Vegetation Condition</th>
<th>Slope</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland / Shrubland / Non-Veg Total</td>
<td></td>
<td></td>
<td>664.2</td>
</tr>
<tr>
<td>Pinyon - Juniper Woodland</td>
<td>Forsted</td>
<td>Flat</td>
<td>56.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheep (&gt; 30%)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Deforested</td>
<td>Flat</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheep (&gt; 30%)</td>
<td>9</td>
</tr>
<tr>
<td>Pinyon - Juniper Woodland Total</td>
<td></td>
<td></td>
<td>311.4</td>
</tr>
<tr>
<td>Deciduous Open Tree Canopy Total</td>
<td>Forsted</td>
<td>Flat</td>
<td>92.7</td>
</tr>
<tr>
<td>Evergreen Closed Tree Canopy Total</td>
<td>Forsted</td>
<td>Flat</td>
<td>973.9</td>
</tr>
<tr>
<td>Mixed Evergreen - Deciduous Open Tree Canopy Total</td>
<td>Forsted</td>
<td>Flat</td>
<td>938.3</td>
</tr>
</tbody>
</table>

* See RAVG - LANDFIRE Crosswalk worksheet below for Vegetation Group definitions
MTBS (Monitoring Trends in Burn Severity)

• MTBS Objectives
  – Map *all* fires > 1,000 acres (in West) and > 500 acres (in East) between 1984 - present
    •Aligned with Landsat data record
  – Mapped using extended assessment protocol
    • Postfire imagery acquired during next growing season
  – Severity classifications focused on vegetation effects
  – *Used to answer National Fire Plan (NFP) and Healthy Forest Restoration Act (HFRA) questions*
Airborne and Satellite Post-Fire Characterization Systems all use the VIS / NIR / SWIR bands available on HyspIRI.
Questions ???