GOES Early Fire Detection System Development

Alexander Koltunov

(Principal Investigator)

akoltunov@ucdavis.edu

Center for Spatial Technologies and Remote Sensing (CSTARS), University of California, Davis

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GOES-EFD effort: Data/Work Flow and Participants

Co-Investigators: Susan Ustin (UC Davis), Brad Quayle, (USFS RSAC), Brian Schwind (USFS RSAC), Vince Ambrosia (NASA Ames)

Sponsors
USDA FS
UC Davis
DHS

Developers
UC Davis
FS RSAC
NASA Ames

Supporting End-User Partners
CAL FIRE
Los Angeles County Fire Department (LACoFD)
San-Bernardino National Forest
Federal Interagency Communications Center (FICC)

GOES Images @15 min
Landsat Images

GOES-EFD Algorithm, Software, and Utility Programs

R&D, Implementation, Validation, Integration
Feedback, Requirements, Evaluations, Integration
RSAC: Format, Merge, Distribute to First Responders

Output Products
- New ignition locations
- Detection confidence
- Metadata per incident
- Performance stats over previous fire seasons

Run @ RSAC, and UCD servers
GOES Early Fire Detection (GOES-EFD) System

**Objective:** A low-cost and reliable capacity for systematic *rapid* detection and initial confirmation of new ignitions at regional level (TBD)

Detect new wildfire incidents consistently within first 1-2 hours after start, preferably before they are reported by conventional sources
Geostationary Satellites: GOES

GOES Imager:
- Viewing geometry – fixed
- VIS and TIR images every 15-30 min
- TIR pixel size $\sim 6 \times 4 \text{ km}$ over CA

Radiance $\sim 4 \mu\text{m}$

Band 5 Fr. 480 Time = 213.375 (2006213.0900 8/02)

GOES-West  GOES-East

GOES-11 Scene
WF-ABBA* operational algorithm for active fire monitoring

Designed for applications interested in, for example:

- % eventually detected fires
- burned area accuracy
- number of false positive pixels

Optimized well for global scale performance

*Wildfire Automated Biomass Burning Algorithm

(Prins & Menzel, 1994)
In contrast,

Early Detection has different priorities:

- Minimize the time to *initial* detection of an incident
- Minimize the number of false *incidents* (alarms)
Planck’s Law: \[ \text{Radiance}(\lambda) = B(\lambda, T) \]

fire \( T_{4\mu m} \gg T_{12\mu m} \)

soil \( T_{4\mu m} \sim T_{12\mu m} \)

Primary regions used for detection:
- Short-wave TIR (3 - 5 \( \mu m \))
- Long-wave TIR (10 - 12 \( \mu m \))
WF-ABBA Principle: Contextual Detection
(find pixels that are much hotter than neighbors)

- Good for detecting large/hot fires (sooner or later)
- OK for thermally homogeneous areas (σ is small)
- Less effective on ecosystem boundaries
GOES-EFD principle: Temporal + Contextual (detect anomalous changes in surface properties)

Multitemporal background prediction by Dynamic Detection Model:

Training Stage

- Select Images
- Database of Optimal Basis Images

Detection Stage

- Pre-processing
- Compute Parameters
- Combine Past Images
- Inspection Image
- Reference Image
- Post-processing

Koltunov, Ben-Dor, & Ustin (2009) Int J of Rem Sens
Automatic Thermal Image Registration

Radiance $\sim 4 \, \mu m$

Band 5 Fr. 480 Time: 213.375 (2006/213.0900 8/02)

Band 5 Fr. 480 Time: 213.375 (2006/213.0900 8/02) Warped by $T=[0.142, -0.143]$

original

registered

Flow constraints under Brightness Constancy assumption

Registration Transform
GOES-EFD ver. 0.2: Detection Stage

Detection Stage

- Preliminary Pass
  - Anomalies, Missing Values
  - Apply DDM 1
  - Classify Anomalies

- Main Pass
  - Anomaly Classes, Missing Values
  - Apply DDM 1,2
  - Apply Contextual
  - Classify Anomalies

- Post-Detection
  - Anomaly Classes
  - Fire Confidence (unfiltered pixel-wise product)

- Output
  - Temporal Filter, Event Tracker
  - FIRE LOCATIONS
  - FIRE CONFIDENCE
Event Tracking: from pixels to events

1) Do pixels flagged “fire” in this frame form the same fire incident/complex?
2) A new incident?

Event == group of fire pixels to be considered a single wildfire incident

• An “existing” event: No action is necessary
  – a re-detected wildfire
  – a re-detected false

• A “new” event: An action may be required
  – a true new ignition, or
  – a false positive
Initial Experiment with fire season 2006
Central California

Detection Period: 40 days; 2852 images: Aug 3 – Oct 1 at ~20-min time step on average.

-- Substantial Cloud Cover

Wildfire Incidents* Used: Large (>2 ha final size) wildfires; CA only

Sample #1: 13 fires with known initial report HOUR
Sample #2: 25 fires with known initial report DATE

* Used wildfire incident databases from:
  - California Department of Forestry and Fire Protection (CAL FIRE)
  - Geospatial Multi-Agency Coordination (GeoMAC) group
Include wildfire incident reports from: USFS, BLM, NPS, CAL FIRE, et al.
Validation methodology: use official incident reports and Landsat imagery

Koltunov, Ustin, & Prins (2012)

1. Match events in space and time to official wildfire incident records (including fire initial report/start time and estimated end time)
2. Matched incidents == true positives
3. Unmatched incidents == a false positive OR unreported actual fire

Check unmatched events against new burns in Landsat imagery

New burn detection in Landsat pairs

<table>
<thead>
<tr>
<th>Path-Row: 43-34</th>
<th>Zoom 1</th>
<th>Zoom 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB = bands (7,4,3)</td>
<td>June 25</td>
<td>June 25</td>
</tr>
<tr>
<td></td>
<td>July 27</td>
<td>July 27</td>
</tr>
<tr>
<td>dNBR</td>
<td>no true burns</td>
<td>dNBR</td>
</tr>
<tr>
<td>dNBRA</td>
<td></td>
<td>dNBRA</td>
</tr>
<tr>
<td>dNBR</td>
<td></td>
<td>one true burn</td>
</tr>
<tr>
<td>dNBRA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What if, there is a new burn near suspected false positive?

What if, no new burns found near suspected false positive?
Detection timeliness: cumulative distribution function (c.d.f.)

Detection latency relative to initial report from conventional sources

- EFDregular
- EFDrapid
- EFD@30min
- WF-ABBA

"ideal" c.d.f.

initial report time
## Performance statistics

<table>
<thead>
<tr>
<th>Detected incidents</th>
<th>GOES-EFD rapid</th>
<th>GOES-EFD regular</th>
<th>GOES-EFD @30min</th>
<th>WFABBA @30min</th>
</tr>
</thead>
<tbody>
<tr>
<td>for 13 fires with recorded report hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detected in &lt; 1 hour</td>
<td>11/13</td>
<td>10/13</td>
<td>10/13</td>
<td>7/13</td>
</tr>
<tr>
<td>Detected before reported</td>
<td>4/13</td>
<td>4/13</td>
<td>3/13</td>
<td>2/13</td>
</tr>
<tr>
<td>Total latency reduction</td>
<td>216 Min</td>
<td>142 min</td>
<td>105 min</td>
<td>45 min</td>
</tr>
<tr>
<td>for 25 fires with recorded report date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detected in &lt; 12 hours</td>
<td>16/25</td>
<td>15/25</td>
<td>15/25</td>
<td>11/25</td>
</tr>
<tr>
<td>False / non-wildfire incidents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>up to 784</td>
<td>up to 79</td>
<td>38 to 53</td>
<td>39 to 55</td>
<td></td>
</tr>
</tbody>
</table>

GOES-EFD detects fires earlier than WF-ABBA
Summary

- Initial, proof-of-concept version ready (optimizations under way)
- GOES-EFD will complement WF-ABBA global monitoring capabilities at regional level:

<table>
<thead>
<tr>
<th>GOES Early Fire Detection algorithm</th>
<th>WF-ABBA algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized for Regional Scale Surveillance</td>
<td>Optimized for Global Scale Surveillance</td>
</tr>
<tr>
<td>Best for Detecting New Ignitions ASAP</td>
<td>Best for Consistently Monitoring Active Fires</td>
</tr>
</tbody>
</table>

Next steps:

- Development-test iterations
- Work with end-users partners to ensure sustained and informed use
- Validate extensively
- Deploy
We gratefully acknowledge

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http://wwwcimis.water.ca.gov/cimis

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UC Davis
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