GOES-Early Fire Detection (EFD) Project Overview

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Active Fire Mapping (AFM) Program
(http://activefiremaps.fs.fed.us)

- Developed and implemented at RSAC in 2001
  - Coordination w/NASA, NOAA & space agency science teams

- Operational near real-time (NRT) satellite data/mapping/visualization products for wildfire management
  - “Value-added” data/products
  - All lands and ownerships in U.S. and Canada

- Facilitates wildfire decision support
  - Prioritize allocation of fire suppression assets
  - Focus tactical airborne reconnaissance assets
  - Key data input to several fire-related operational applications
GOES-Early Fire Detection (EFD) Project

What is it?
- An effort to develop a low-cost and reliable capacity for systematic rapid detection and initial confirmation of new ignitions at a regional level.

Project Goals
- 24/7 real-time surveillance for new fire ignition activity
  - Detect new incidents consistently within first 1-2 hours
  - Initially at a regional scale (Western U.S.)
- Low latency information for new ignition events to first responders
- Corroborating data/information for reports by conventional sources
GOES-EFD & Active Fire Mapping Program

Objective is to integrate GOES-EFD into AFM to:

• Complement existing related fire detection/monitoring products (MODIS, VIIRS, GOES, AVHRR)

• Provide standardized operational geospatial EFD products and web services to interagency fire community

• Facilitate integration EFD products/services into existing decision-making environment at dispatch centers and GACCs

• Support improvement of situational awareness and response planning/prioritization
**GOES-EFD Effort: Structure and Participants**

**Sponsors**
- USDA FS
- UC Davis
- DHS

**Developers**
- UC Davis
- FS RSAC
- NASA/CSUMB

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

**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 NASA Ames**

**Funding Sources:**
- Forest Service/UC Davis Interagency Cost Share Agreement (I0-CS-11130400-009)
- DHS Science and Technology (S&T) Directorate’s Long-Range Broad Agency Announcement (BAA): BAA 11-03-IDD.08-0011-I
Where are we today?

- **Alpha-version** (GOES-EFD v0.3) recently completed
  - Simulated real-time mode
  - Mainly Matlab implementation

- **Case studies in California indicate:**
  - Consistently and significantly more successful at early detection than the operational satellite algorithm
  - Commits 35% fewer false alarms than GOES-EFD v0.2
  - Potential to provide earliest alarm

- **Algorithm optimizations and tests are continuing (as resources permit)**
GOES-EFD: Intended Schedule

- **2013-15:** Major development-test iterations, implementation, and integration: complete the GOES-EFD $\beta$-version
- **2015:** Deployment of GOES-EFD-$\beta$ at USFS RSAC as a component of the FS Active Fire Mapping Program
- **2015-2016:** Near-real-time delivery to participating users;
  - Initial training and evaluation by participating users
  - User feedback and performance documentation
  - Follow-up optimizations
- **2017:** Post-Deployment system maintenance and enhancement
- **2016-2017:** Adaptation to GOES-R Advanced Baseline Imager
Geostationary Satellites (GOES East/West): Frequent, Low-Cost Imaging of Vast Territories

GOES Imager (NOAA):
- Viewing geometry – fixed 😊
- Visible + Thermal Infrared (TIR) images 😊
- @ ~15-30 min step (5-min during Rapid Scan) 😊
- Effective TIR pixel size ~ 6 x 4 km over CA 😊
# Active Fire Monitoring vs. Early Fire Detection

## Primary Objectives are Related but Rather Different:

<table>
<thead>
<tr>
<th>Active Fire Monitoring</th>
<th>Early Fire Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximize % of detected burning <strong>pixels</strong></td>
<td>Maximize % of detected <strong>new</strong> fire <em>incidents (ignitions)</em></td>
</tr>
<tr>
<td>Minimize % of false fire <strong>pixels</strong></td>
<td>Minimize the number of false <strong>new incidents</strong> (alarms)</td>
</tr>
<tr>
<td>Estimate <strong>flaming area, temperature, etc.</strong></td>
<td>Minimize <strong>time to initial detection</strong> of an incident</td>
</tr>
<tr>
<td>Perform <strong>consistently all year-round globally</strong> (e.g. for comparative studies)</td>
<td>Optimize for <strong>fire season</strong> and a chosen surveyed <strong>scene</strong></td>
</tr>
</tbody>
</table>

... and So Are the Optimal Algorithms

- GOES WF-ABBA, MODIS / VIIRS Active Fire, AVHRR FIMMA
- GOES-EFD
GOES-EFD is a tool specifically optimized for the objectives of early detection...
Physical Basis for Infrared Fire Detection

Planck’s Law: \[ \text{Radiance} (\lambda) = B(\lambda, T) \]

- Fire: \( R_{4\mu m} \gg R_{11\mu m} \)
- Soil: \( R_{4\mu m} \sim R_{11\mu m} \)

Primary regions used for detection:
- Mid-wave TIR (3 - 5 \( \mu m \))
- Long-wave TIR (10 - 12 \( \mu m \))
Heritage Fire Detection Algorithms

Based on contextual detection... find pixels that are much hotter than neighbors

- Good for detecting large/hot fires relative to sensor spatial resolution
- Performs well in thermally homogenous areas
GOES-EFD Algorithmic Principle: Merge Temporal + Contextual Information

Multitemporal background prediction by Dynamic Detection Model:

Training Stage

- Select Images
- Database of Optimal Basis Images

Detection Stage

- Pre-processing
- Compute Parameters
- Compare
- Post-processing
- Reference Image
- Combine Past Images
- Inspection Image
Pixel-wise “Unfiltered” Fire Mask

GOES-EFD analyzes basis images and inspection image in the detection stage.

Anomaly Classifier: Excludes pixels affected by cloud, glint, etc. and classifies remaining pixels into one of 12 anomaly classes (7 for fire confidence classes).
From Pixels to Events (potential incidents)

GOES-EFD target objects are New Incidents (multi-pixel, multi-frame objects)

Event Tracker: Analyze the temporal evolution of spatially connected groups of fire pixels

An “old” event: do not report/report as “re-detected”

A “new” event: report this event
Retrospective Assessment of Incident Detection Timeliness and Accuracy

• Very different from validating an Active Fire Product
  – Not a trivial problem:
    • Official wildfire records -> Frequently are incomplete
    • High resolution imagery -> Infrequent acquisition schedule

• Truth Data Sources:
  – Official wildfire incident records
  – Landsat-based burn detection

• While any kind of error in the database is possible, not all kinds of errors are equally probable

• Challenge is to derive useful and reliable performance measures despite uncertainties and biases in truth data

GOES-EFD Experiment With 2006 Fire Season

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; Central California 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 (CALFIRE)
- Geospatial Multi-Agency Coordination (GeoMAC) group
Performance Statistics: GOES-EFD v03

<table>
<thead>
<tr>
<th>Detected incidents</th>
<th>GOES-EFD regular</th>
<th>WF--ABBA @30min</th>
</tr>
</thead>
<tbody>
<tr>
<td>for 13 test fires with recorded report hour:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detected in &lt; 1 hour</td>
<td>10/13</td>
<td>7/13</td>
</tr>
<tr>
<td>Detected before reported</td>
<td>4/13</td>
<td>2/13</td>
</tr>
<tr>
<td>Total latency reduction</td>
<td>142 min</td>
<td>45 min</td>
</tr>
<tr>
<td>for 25 test fires with recorded report date:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detected in &lt; 12 hours</td>
<td>15/25</td>
<td>11/25</td>
</tr>
<tr>
<td>False (non-wildfire) or unconfirmed incidents</td>
<td>51</td>
<td>55</td>
</tr>
</tbody>
</table>

- GOES-EFD tends to detect fires earlier than WF-ABBA
- Reduction of ~35% of false new incidents vs. v0.2
- GOES-EFD can provide the earliest detection alarm
GOES-R Advanced Baseline Imager (2016)

- Full disk coverage: every 15 minutes
- Continental US coverage: every 5 minutes.
- Spatial resolution: 2 km in TIR
- A new channel at: 10.3 µm.
- Fewer saturated pixels

When GOES-R is available:

- Mature, well tested GOES-EFD system
- EFD-prepared, EFD-friendly user community
- Acceptance by scientific community
Ongoing GOES EFD Activities

- Advance to a beta version level through continued algorithm/system optimization via test/development iterations
  - GOES image registration
  - Anomaly detection/classification
  - Improved filters for false alarms
  - Improved temporal filtering
  - Event tracking
  - Etc., etc.

- Retrospective validation
  - Preparing a large-area test for year 2012

- Increase involvement with end users to ensure sustained and informed use of data/products
  - Determine their decision-making bottlenecks
  - How to best use fire-candidates from GOES-EFD?
  - How to best combine GOES-EFD product with conventional wildfire identification means?
Ongoing GOES EFD Activities

• Continue to increase project visibility/acceptance
  – Scientific publications/presentations
  – Workshops
  – Project website

• Exploring mechanisms to implement a complete baseline system for deployment
  – NRT GOES imagery collection and ingest
  – IT infrastructure for data processing and repository/archiving
  – GOES EFD software
  – Output data products
  – Forest Service interface with GOES EFD
Conclusions/Potential Benefits

- GOES EFD shows significant promise while still in the alpha development phase
  - System enhancements are continuing based on resource availability

- GOES EFD is more successful than at early fire detection than GOES WF-ABBA algorithm

- GOES EFD offers substantially more accurate geolocation of detected fire candidates

- Anticipated results:
  - 20%-50% of wildfires detected before the documented report; 50%-80% within the first hour

- Significant technical advancements of GOES R will improve timeliness and reliability of GOES EFD