Spatiotemporal Variations In Burned Areas And Biomass Burning Emissions Derived From Multiple Satellite-based Active Fires Across The USA

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Outline

1. Algorithm of biomass burning emissions
2. Burned area simulated from active fires observed from Hazard Mapping System (HMS)
3. Biomass burning emissions across the Contiguous USA
4. Summary
Model of Biomass Burning Emissions

\[ E = \sum_{k=1}^{K} \sum_{l=1}^{L} \sum_{j=1}^{J} \sum_{i=1}^{I} A_{ijkl} M_{ijk} C_{ijkl} F_{ijkl} \]

- \( E \)---biomass burning emissions (kg)
- \( A \)---burned area (km\(^2\))
- \( M \)---biomass density/fuel loading (kg.km\(^{-2}\))
- \( C \)---fraction of combustion
- \( F \)---fraction of emission
- \( i \) and \( j \) define the fire (pixel) locations
- \( l \) is the fuel type
- \( k \) is the time period

HMS fire products
MODIS vegetation properties
AVHRR moisture condition
AVHRR moisture condition
MODIS Vegetation Property-based Fuel System (MVPFS)

(A) forest foliage, (B) forest branch, (C) grass, (D) shrub, (E) litter, (F) coarse woody detritus.
## Simulation of Burned Area From HMS Fire Size

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Observation time</th>
<th>Spatial resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOES-E</td>
<td>15 and 45 minutes</td>
<td>4 km</td>
</tr>
<tr>
<td>GOES-W</td>
<td>0 and 30 minutes</td>
<td>4 km</td>
</tr>
<tr>
<td>Terra MODIS/NOAA-17</td>
<td>10:30 AM/PM</td>
<td>1 km</td>
</tr>
<tr>
<td>Aqua MODIS/NOAA-18</td>
<td>1:30 AM/PM</td>
<td>1 km</td>
</tr>
<tr>
<td>NOAA-15</td>
<td>6:00 AM/PM</td>
<td>1 km</td>
</tr>
</tbody>
</table>
Evaluation of Fire Detections from Multiple Satellite Instruments using ETM+-Based Burn Scars
Detection Rate of ETM+-Based Burn Scars from Multiple Satellite Instruments

<table>
<thead>
<tr>
<th>Size of burn scar (km²)</th>
<th>Detection rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>30</td>
</tr>
<tr>
<td>1~2</td>
<td>40</td>
</tr>
<tr>
<td>2~3</td>
<td>50</td>
</tr>
<tr>
<td>3~4</td>
<td>60</td>
</tr>
<tr>
<td>4~5</td>
<td>70</td>
</tr>
<tr>
<td>5~10</td>
<td>80</td>
</tr>
<tr>
<td>10~15</td>
<td>90</td>
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<tr>
<td>15~20</td>
<td>100</td>
</tr>
<tr>
<td>20~50</td>
<td>&gt;100</td>
</tr>
<tr>
<td>50~100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>&gt;100</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

ETM+ burn scar
MODIS+AVHRR+GOES detection
MODIS detection
GOES detection

Number of ETM+ burn scars
0 20 40 60 80 100 120 140 160
Conversion of Active Fire Size to Burned Area

\[ A = \alpha \int_{t_s}^{t_e} F_t \]

\( A \) -- area burned within a specified time period (km²)
\( F_t \) -- subpixel fire size (km²)
\( t_s \) and \( t_e \) -- starting and ending time of a fire event, where the time step is set to half hours to match the temporal resolution of GOES satellite fire detection
\( \alpha \) -- coefficient of conversion, which is defined as 1
Quality in GOES Fire Product

- Low probability fire
- No fire size
- With fire size
- High probability fire
- Medium probability fire
- Low probability fire
- Fire-size processed
- Fire-pixel saturated
- Fire-pixel cloudy
Diurnal Fire Size in An Individual Fire Pixel

![Graph showing diurnal fire size](image-url)
Fourier-Fitted Diurnal GOES Fire Sizes
---Representative diurnal curves
Fitting Diurnal Fire Size for Individual Fire Pixels
Fire Size for MODIS + AVHRR
Observation

![Graph showing the relationship between active fire counts from MODIS+AVHRR and burned area (km2). The x-axis represents active fire counts, and the y-axis represents burned area. The data points are scattered, with a trend line indicating a positive correlation. The text indicates that the burned area is less than 160 km2 for Low-High CONUS.]
Burned Area Simulated from GOES Fire Size (2006)
Validation of Burned Areas from Multiple Satellite Hotspots using National Fire Inventory Data in 2005

(a) Forests
- Estimated area (km²)
- National inventory data (km²)
- $n=203$
- $R^2=0.93$

(b) Savannas
- Estimated area (km²)
- National inventory data (km²)
- $n=80$
- $R^2=0.57$

(c) Shrublands
- Estimated area (km²)
- National inventory data (km²)
- $n=216$
- $R^2=0.95$

(d) Grasslands
- Estimated area (km²)
- National inventory data (km²)
- $n=249$
- $R^2=0.93$

(e) Croplands
- Estimated area (km²)
- National inventory data (km²)
- $n=70$
- $R^2=0.83$

(f) All samples
- Estimated area (km²)
- National inventory data (km²)
- $n=818$
- $R^2=0.93$
Burned Area in Individual States
Calculation of Biomass Burning Emissions

\[ E = \sum_{k=1}^{K} \sum_{l=1}^{L} \sum_{j=1}^{J} \sum_{i=1}^{I} A_{ijkl} M_{ijk} C_{ijkl} F_{ijkl} \]

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Annual PM2.5 Emissions Released from Fires
Biomass Burning Emissions (CH4, CO and NOX) in 2005
Biomass burning Emissions in Top 20 States

1. CO (10^7 kg)
2. CH4 (10^6 kg)
3. PM2.5 (10^6 kg)
4. TNMHC (10^6 kg)
5. NH3 (10^6 kg)
6. N2O (10^5 kg)
7. NOX (10^6 kg)
8. SO2 (10^5 kg)
Biomass Burning Emissions Varying with Ecosystems
Diurnal Variations in Biomass Burning Emissions for Different Years
San Diego Fire Emissions in October 2007
Florida Fire Emissions in May 2007
Summary

• MODIS Vegetation Property-based Fuel System (MVPFS) provides realistic fuel loading data

• Burned area can be reasonably estimated by blending active fire observations from MODIS, AVHRR, and GOES instruments

• Hourly biomass burning emissions (PM2.5, CH4, CO, N2O, NH3, NOX, SO2, and TNMHC) inventory can be created in near real time using multiple satellite data