Validation of Hotspot Monitoring from MODIS, GOES, AVHRR and ATSR Sensors Over Canadian Wildfires in 2002-2003

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Canadian Forest Service

Robert Fraser
Robert Landry
Earth Sciences Sector
Hotspots Aid Emissions Modeling

Canadian Direct Carbon Emissions

Year

Megatonnes Carbon
0 20 40 60 80 100 120 140 160

Fire
Fossil Fuel

Sources:
Fossil fuels: www.nrcan.gc.ca/es_ceo/update.htm
Why Is Hotspot Monitoring Important?

- shows the location of current fires
- confirms that a disturbance or landuse change is a fire
- places a date stamp on pixels that indicate fire (may be necessary for completing emissions calculations)
- can be used to determine or confirm the rate of spread of a fire
- can be used to display the active parts of a fire
Objectives

1. to investigate the agreement between sensors and the fire polygons from fire management agencies,

2. to compare the detection sensitivity of the sensors, relative to each other,

3. to investigate the error of commission for each sensor,

4. “Do we need multiple sensors for detecting hotspots and mapping burned area?”

5. “Do the errors vary by land cover type?”
Fire polygons provided by each province
MODIS detected hotspots (except BC and Atlantic provinces)
AVHRR detected hotspots (except BC and Atlantic provinces)
Hotspots total and within fire polygons

- **MODIS**
  - 2002 within polygons: [chart data]
  - 2002 total: [chart data]
  - 2003 within polygons: [chart data]
  - 2003 total: [chart data]

- **AVHRR**
  - 2002 within polygons: [chart data]
  - 2002 total: [chart data]
  - 2003 within polygons: [chart data]
  - 2003 total: [chart data]

- **ATSR A1**
  - 2002 within polygons: [chart data]
  - 2002 total: [chart data]
  - 2003 within polygons: [chart data]
  - 2003 total: [chart data]

- **ATSR A2**
  - 2002 within polygons: [chart data]
  - 2002 total: [chart data]
  - 2003 within polygons: [chart data]
  - 2003 total: [chart data]

- **GOES**
  - 2002 within polygons: [chart data]
  - 2002 total: [chart data]
  - 2003 within polygons: [chart data]
  - 2003 total: [chart data]
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Percent of Hotspot within Fire Polygon in years

<table>
<thead>
<tr>
<th>Satellite</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>AVHRR</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>ATSR1</td>
<td>70</td>
<td>50</td>
</tr>
<tr>
<td>ATSR2</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>GOES</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>
Fire polygon and hotspot buffer in 2002 (Zoom in Quebec)
Percent of Hotspot within Buffered Fire Polygon vs. Satellite in 2002
Canadian Wildland Fire Information System (CWFIS)

Percent of Hotspot within Buffered Fire Polygon vs. Satellite in 2003

- MODIS
- AVHRR
- ATSR1
- ATSR2
- GOES

Satellite

Percent

0.0 20.0 40.0 60.0 80.0 100.0

0 km
1 km
2 km
3 km
4 km
5 km
6 km
Land Cover by Spot VGT 2000 (modified)
Land Cover: Needleleafed evergreen forest
Hotspot Distribution in Land Covers in 2002 and 2003

- **Deciduous**
- **Coniferous - closed**
- **Coniferous - open**
- **Mixedwood**
- **Shrubland**
- **Grassland**
- **Polar grassland**
- **Cropland**
- **Open forest**
- **Sparse vegetation**
- **Urban**
- **Water**
- **Burnt area**

Legend:
- MODIS
- AVHRR
- ATSR1
- ATSR2
- GOES
Hotspot within fire polygons Distribution in Land Covers in 2002 and 2003

- Deciduous
- Coniferous - closed
- Coniferous - open
- Mixedwood
- Shrubland
- Grassland
- Polar grassland
- Cropland
- Open forest
- Sparse vegetation
- Urban
- Water
- Burnt area

Land cover

- MODIS
- AVHRR
- ATSR1
- ATSR2
- GOES
Canadian Wildland Fire Information System (CWFIS)

Percent of Hotspot within land cover vs. Satellite for 2002 and 2003

- Percent
- Land cover: Deciduous, Coniferous - closed, Coniferous - open, Mixedwood, Shrubland, Grassland, Polar grassland, Cropland, Open forest, Sparse vegetation, Urban, Water, Burnt area

Legend:
- MODIS
- AVHRR
- ATSR1
- ATSR2
- GOES
Commission error
Hotspots (with 1-km buffer)
falling outside Agency polygons (with 5-km buffer)

MODIS 2003

<table>
<thead>
<tr>
<th>Area category</th>
<th>Frequency</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;5000</td>
<td>12</td>
<td>121,355</td>
</tr>
<tr>
<td>3000-5000</td>
<td>7</td>
<td>25,977</td>
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<tr>
<td>1000-3000</td>
<td>19</td>
<td>29,072</td>
</tr>
<tr>
<td>750-1000</td>
<td>7</td>
<td>5,773</td>
</tr>
<tr>
<td>500-750</td>
<td>13</td>
<td>7,364</td>
</tr>
<tr>
<td>200-500</td>
<td>59</td>
<td>17,594</td>
</tr>
<tr>
<td>&lt;200</td>
<td>261</td>
<td>17,815</td>
</tr>
</tbody>
</table>
Commission error
Hotspots (with 1-km buffer) falling outside Agency polygons (with 5-km buffer)

AVHRR 2003

<table>
<thead>
<tr>
<th>Area category</th>
<th>Frequency</th>
<th>Total area (ha)</th>
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<tbody>
<tr>
<td>&gt;5000</td>
<td>10</td>
<td>104,852</td>
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<tr>
<td>3000-5000</td>
<td>4</td>
<td>15,922</td>
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<tr>
<td>1000-3000</td>
<td>23</td>
<td>34,494</td>
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<td>5,966</td>
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<tr>
<td>500-750</td>
<td>14</td>
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<td>200-500</td>
<td>51</td>
<td>15,396</td>
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<tr>
<td>&lt;200</td>
<td>204</td>
<td>13,987</td>
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</table>
Commission error

Hotspots (with 1-km buffer) falling outside Agency polygons (with 5-km buffer)

<table>
<thead>
<tr>
<th>Area category</th>
<th>Frequency</th>
<th>Total area (ha)</th>
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<tbody>
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<td>5,772</td>
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<td>3000-5000</td>
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<td>750-1000</td>
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<td>1,631</td>
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<tr>
<td>500-750</td>
<td>12</td>
<td>7,271</td>
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<tr>
<td>200-500</td>
<td>28</td>
<td>9,319</td>
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<tr>
<td>&lt;200</td>
<td>30</td>
<td>2,540</td>
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Commission error
Hotspots (with 1-km buffer)
falling outside Agency polygons (with 5-km buffer)

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>&gt;5000</th>
<th>3000-5000</th>
<th>1000-3000</th>
<th>750-1000</th>
<th>500-750</th>
<th>200-500</th>
<th>&lt;200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Total area (ha)</td>
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<td></td>
<td></td>
<td></td>
<td>4,698</td>
<td>1,199</td>
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</tbody>
</table>
### Top 10 clusters of fire polygons, based on MODIS hotspots

<table>
<thead>
<tr>
<th>No.</th>
<th>MODIS</th>
<th>AVHRR</th>
<th>ATSR1</th>
<th>ATSR2</th>
<th>GOES</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>19,277</td>
<td>10,748</td>
<td>567</td>
<td>676</td>
<td>313</td>
</tr>
<tr>
<td>No.2</td>
<td>18,960</td>
<td>22,424</td>
<td>4,272</td>
<td>5,551</td>
<td>313</td>
</tr>
<tr>
<td>No.3</td>
<td>15,380</td>
<td>14,173</td>
<td>5,511</td>
<td>7,608</td>
<td>313</td>
</tr>
<tr>
<td>No.4</td>
<td>9,713</td>
<td>5,646</td>
<td>2,599</td>
<td>3,578</td>
<td>313</td>
</tr>
<tr>
<td>No.5</td>
<td>9,411</td>
<td>8,116</td>
<td>1,005</td>
<td>1,212</td>
<td>313</td>
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<tr>
<td>No.6</td>
<td>9,329</td>
<td>5,403</td>
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<tr>
<td>No.7</td>
<td>8,680</td>
<td>15,267</td>
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<tr>
<td>No.8</td>
<td>8,395</td>
<td>6,693</td>
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<tr>
<td>No.9</td>
<td>6,234</td>
<td>5,043</td>
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<tr>
<td>No.10</td>
<td>5,645</td>
<td>5,611</td>
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</tr>
</tbody>
</table>

- **MODIS**: MODerate-resolution Imaging Spectroradiometer
- **AVHRR**: Advanced Very High Resolution Radiometer
- **ATSR1** and **ATSR2**: Advanced Terrain and Spectral Radiometer
- **GOES**: Geostationary Operational Environmental Satellites

The chart shows the area (ha) of the top 10 clusters of fire polygons, categorized by satellite sensors. The area values are listed from highest to lowest for each cluster.
Top 10 clusters of fire polygons, based on AVHRR hotspots

<table>
<thead>
<tr>
<th>No.1</th>
<th>Area (ha)</th>
<th>No.2</th>
<th>Area (ha)</th>
<th>No.3</th>
<th>Area (ha)</th>
<th>No.4</th>
<th>Area (ha)</th>
<th>No.5</th>
<th>Area (ha)</th>
<th>No.6</th>
<th>Area (ha)</th>
<th>No.7</th>
<th>Area (ha)</th>
<th>No.8</th>
<th>Area (ha)</th>
<th>No.9</th>
<th>Area (ha)</th>
<th>No.10</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVHRR</td>
<td>22,424</td>
<td>MODIS</td>
<td>18,960</td>
<td>ATSR1</td>
<td>5,551</td>
<td>ATSR2</td>
<td>7,608</td>
<td>GOES</td>
<td>313</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15,267</td>
<td>14,173</td>
<td>19,277</td>
<td>10,748</td>
<td>10,021</td>
<td>10,201</td>
<td>5,127</td>
<td>676</td>
<td>313</td>
<td>313</td>
<td>313</td>
<td>624</td>
<td>313</td>
<td>313</td>
<td>313</td>
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<td>313</td>
<td>313</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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MODIS Top 10 Clusters off Fire Polygons
Near boundary of Manitoba and Ontario

AVHRR top 10 Clusters off Fire Polygons
Near boundary of Manitoba and Ontario

Legend:
- Top 10 clusters
- Fire polygons
- VGT mapped burns
Canadian Wildland Fire Information System (CWFIS)

Hotspots (%) within fire polygons or VGT burns for MODIS and AVHRR in 2003

<table>
<thead>
<tr>
<th></th>
<th>MODIS</th>
<th>AVHRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire polygons</td>
<td>64.5</td>
<td>50.7</td>
</tr>
<tr>
<td>Fire polygons &amp; top 12 clusters</td>
<td>72.2</td>
<td>70.6</td>
</tr>
<tr>
<td>Buffered 2 km fire polygons &amp; top 12 clusters</td>
<td>83.6</td>
<td>76.4</td>
</tr>
<tr>
<td>Buffered 5 km fire polygon &amp; top 12 clusters</td>
<td>86.8</td>
<td>83.3</td>
</tr>
<tr>
<td>VGT_burns</td>
<td>74.4</td>
<td>69.4</td>
</tr>
<tr>
<td>Buffered 2 km VGT_burns</td>
<td>96.2</td>
<td>94.7</td>
</tr>
<tr>
<td>Buffered 5 km VGT_burns</td>
<td>97.2</td>
<td>96.6</td>
</tr>
</tbody>
</table>
Canadian Wildland Fire Information System (CWFIS)

Fire polygons area vs. Hotspots for MODIS and AVHRR in 2003

Number of hotspots

Fire polygons area (ha)

MODIS
AVHRR
Conclusions

1. Commission errors in the large size classes is an indication that large fire polygons are missing (we found 650,000 ha of missing fire polygons in 2003).

2. GOES agreement is the lowest of all satellites and may be due to:
   - the coarse pixel res. (4 km or larger),
   - oblique viewing angle of fires above 55°N,
   - a requirement for algorithm tuning for boreal fires.

3. MODIS has the highest agreement among the satellite sensors.
Conclusions (cont’d)

4. AVHRR has a greater commission error than MODIS that might be due to geoprocessing of the raw data.
Alberta's Jasper Park Fire in 2003

- Jasper fire polygon
- AVHRR hotspots
- AVHRR hotspot with 1-km buffer
- Provincial boundary
Alberta's Jasper Park Fire in 2003
Conclusions (cont'd)

5. ATSR has a low commission error, similar to MODIS, but its lower revisit time delivers higher omission errors than MODIS or AVHRR.

6. For Canada, the minimum strategy for hotspot monitoring should include MODIS, AVHRR, and ATSR.

7. Due to attractive repeat coverage offered by GOES, we are continuing to look at its utility.

8. The errors do not appear to vary between the major land cover types.