Comparison of Satellite- to Ground-based Data: How Well Does Remotely Sensed Data Define Fire?

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Purpose

Quantify the capability of satellite data to define area burned

in an effort to enhance the spatial and temporal estimates of biomass burning, hence emissions from biomass burning,

by comparing ground- to satellite-based data.


Fireweed
1 year after burn

Motivation

Biomass burning:

- **Major contributor of particulate matter and other pollutants.**
- **Poorly defined.**
- **Impedes the ability of regions to achieve National Ambient Air Quality Standards for PM 2.5 and ozone.**
- **No standard biomass burning products exist for the United States.**

Satellite imagery offers the opportunity to remotely sense fire across governmental and private boundaries.

Biomass burning emissions estimates

Step One **Total direct carbon emissions (C_t)**

$$C_t = A \; B f_c \beta$$

(Seiler and Crutzen 1980)

A is area;

B is biomass density;

f_c is carbon fraction of the biomass;

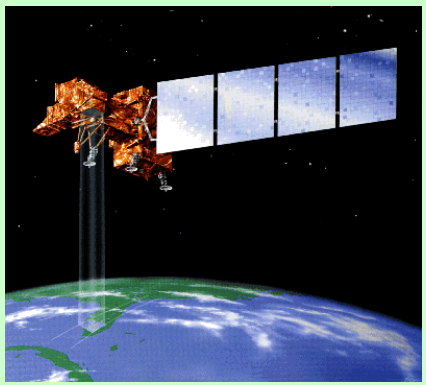
β is the fraction of biomass consumed

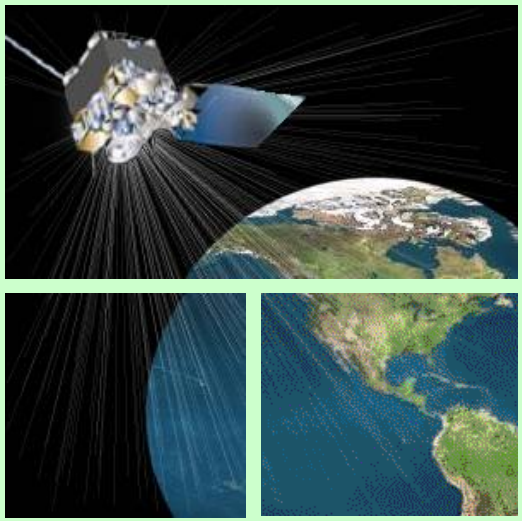
Step Two **Emissions factors or ratios to estimate species specific emissions**

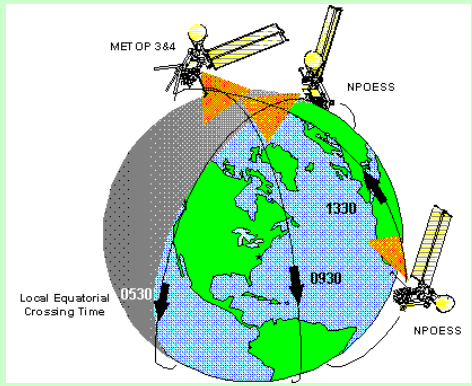
Two satellite products

(1) Moderate Resolution Imaging Spectroradiometer (MODIS) and (2) Geostationary Operational Environmental Satellite (GOES) Automated Biomass Burning Algorithm (ABBA)

MODIS	GOES
sun-synchronous orbit	geostationary orbit
twice daily (terra & aqua)	15 minute (east & west)
spatial resolution 1 km^2	spatial resolution 16 km^2





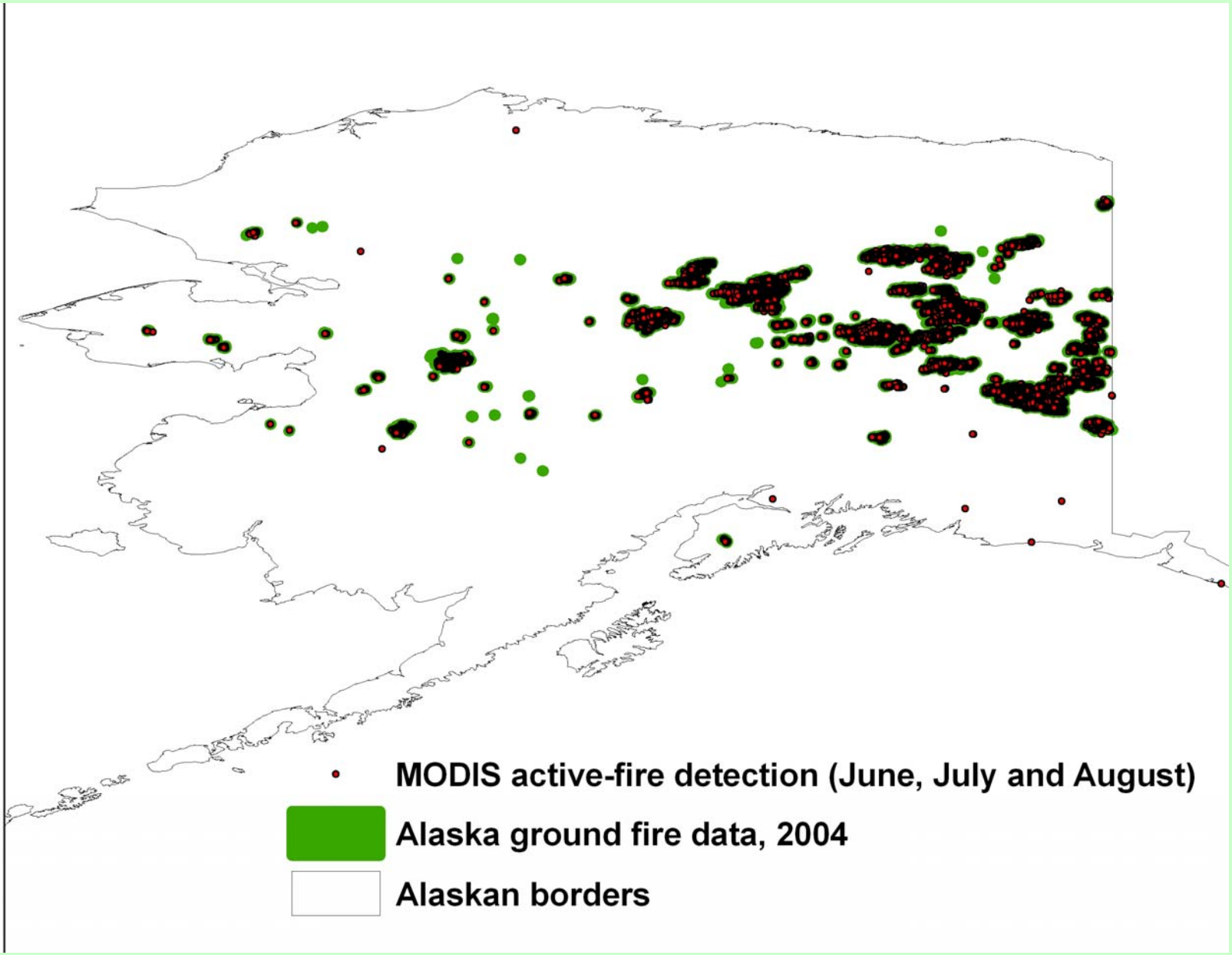


Methodology

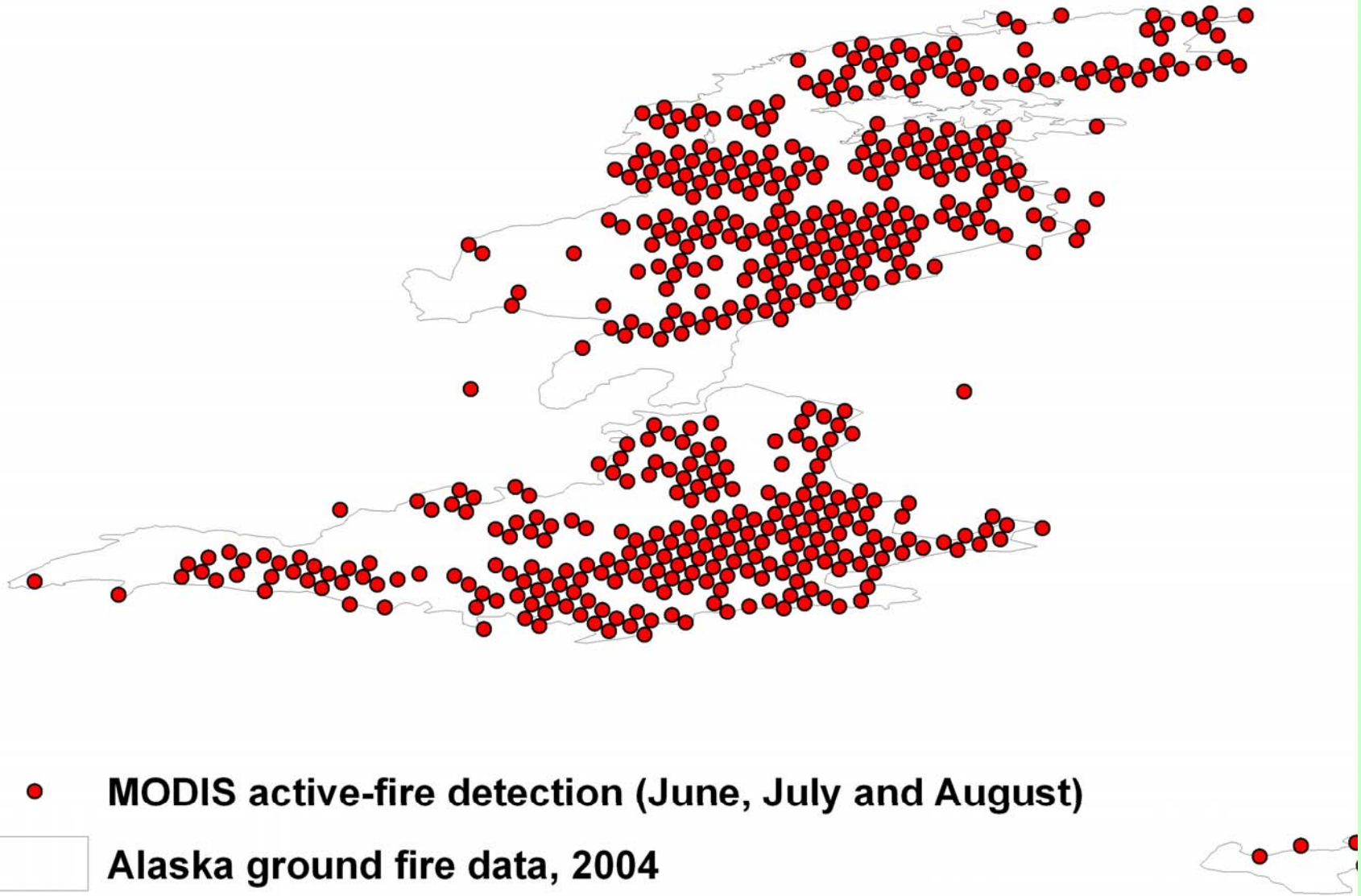
Compare Alaskan ground fire data from the 2004 fires to satellite data using

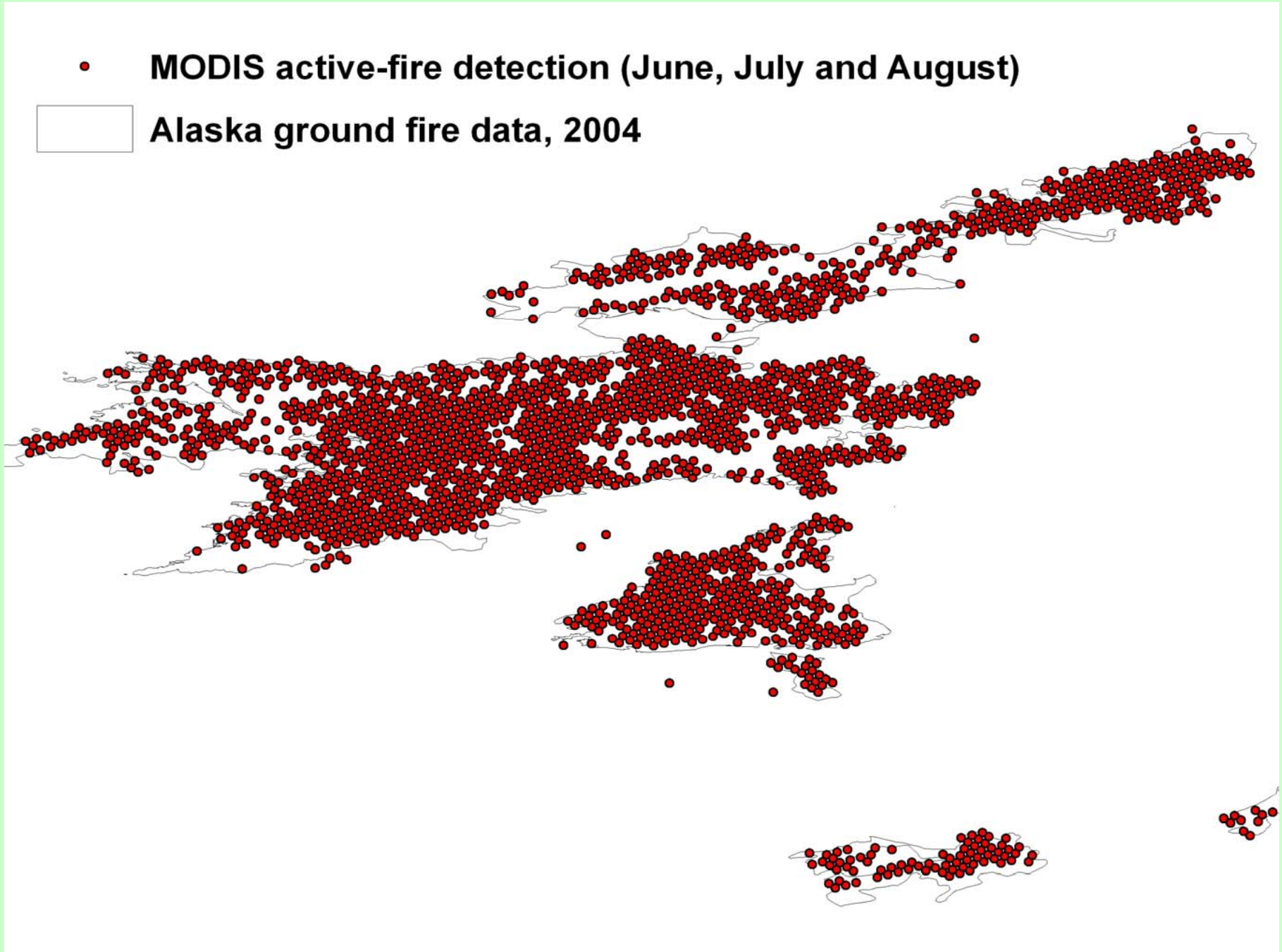
HMS-extracted MODIS (terra and aqua) fire detections.

Each fire detection is considered to equal 1 km^2.



Alaskan 2004 fire scars compared with HMS-MODIS fire data


MODIS active-fire detection (June, July and August)
Alaska ground fire data, 2004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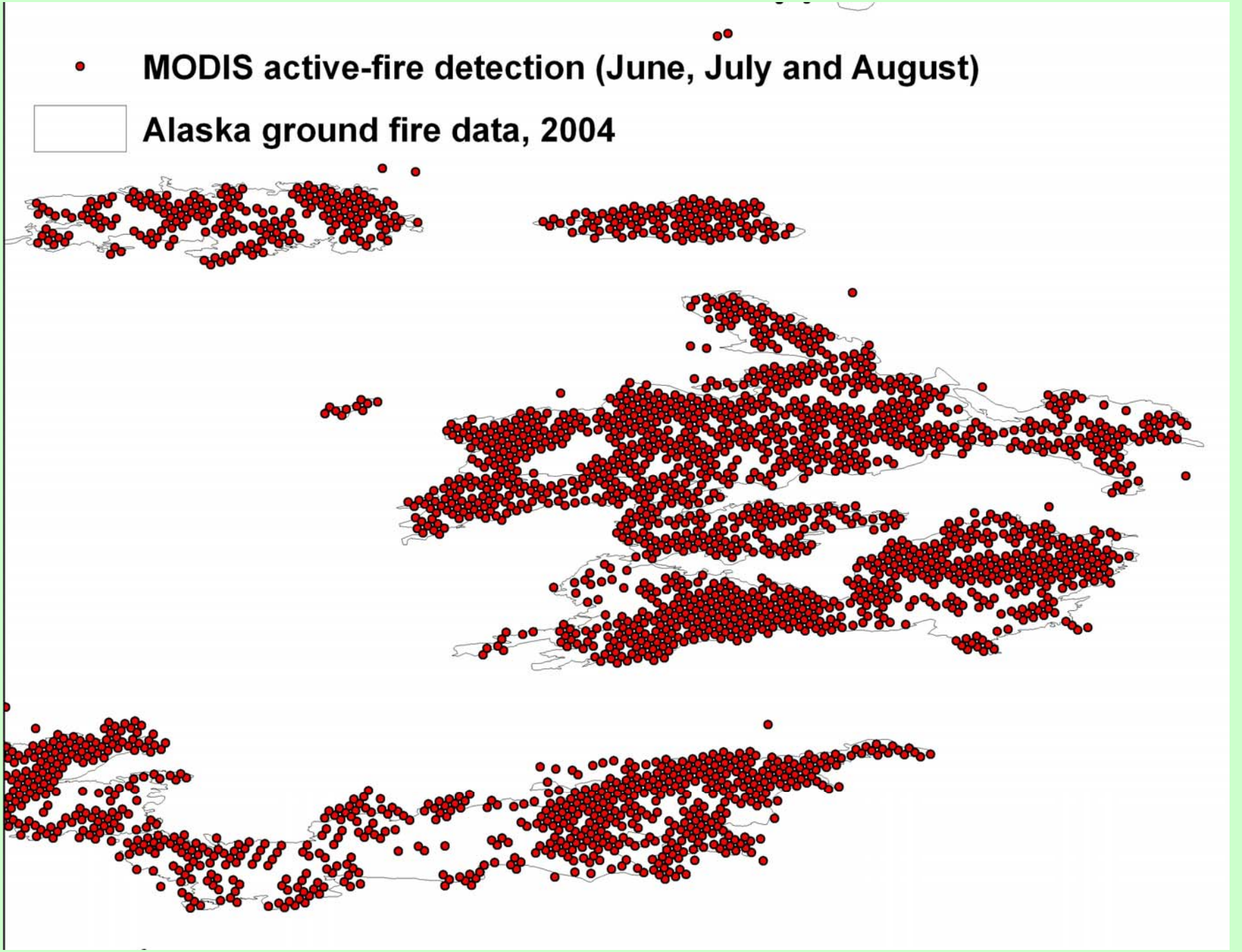
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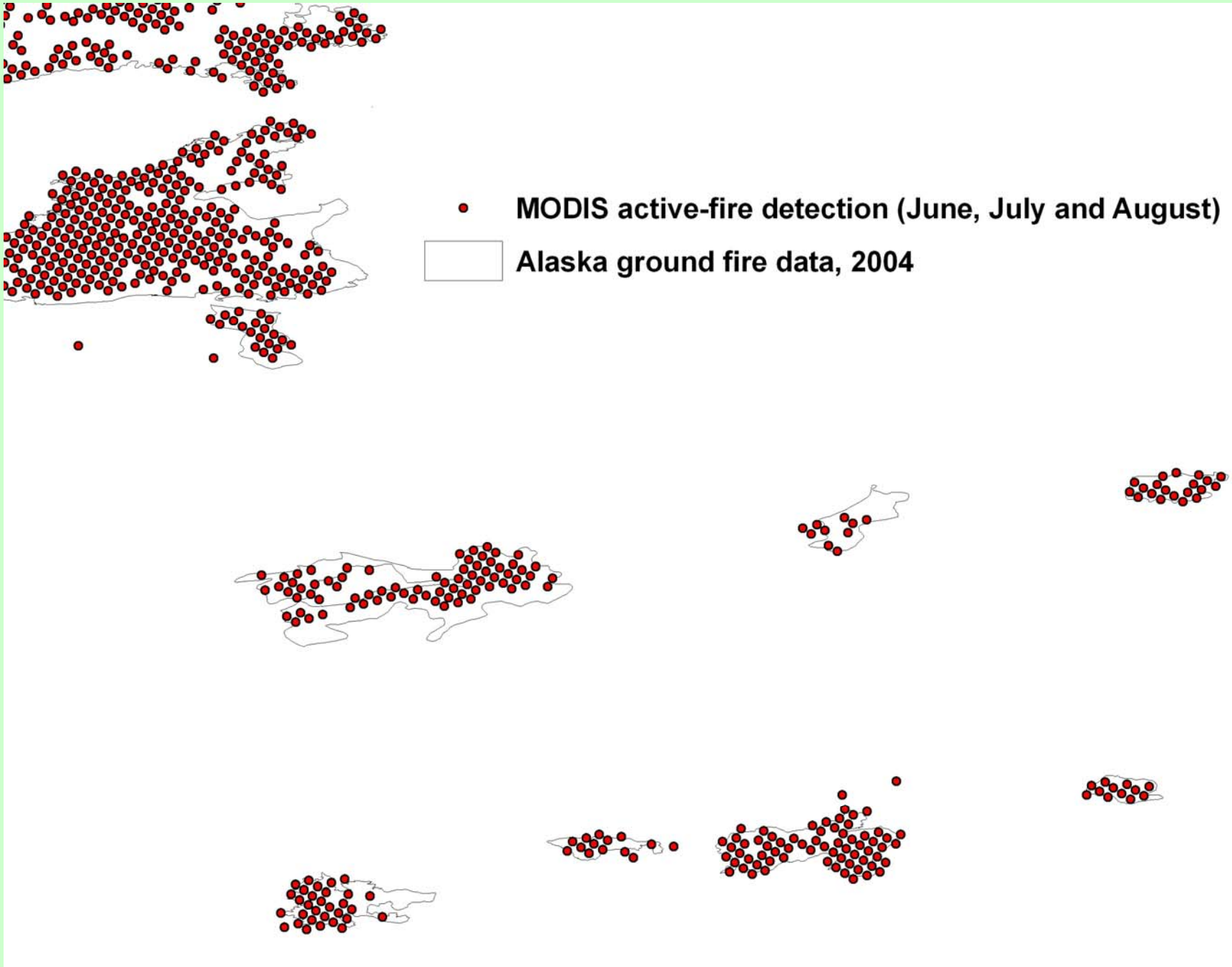
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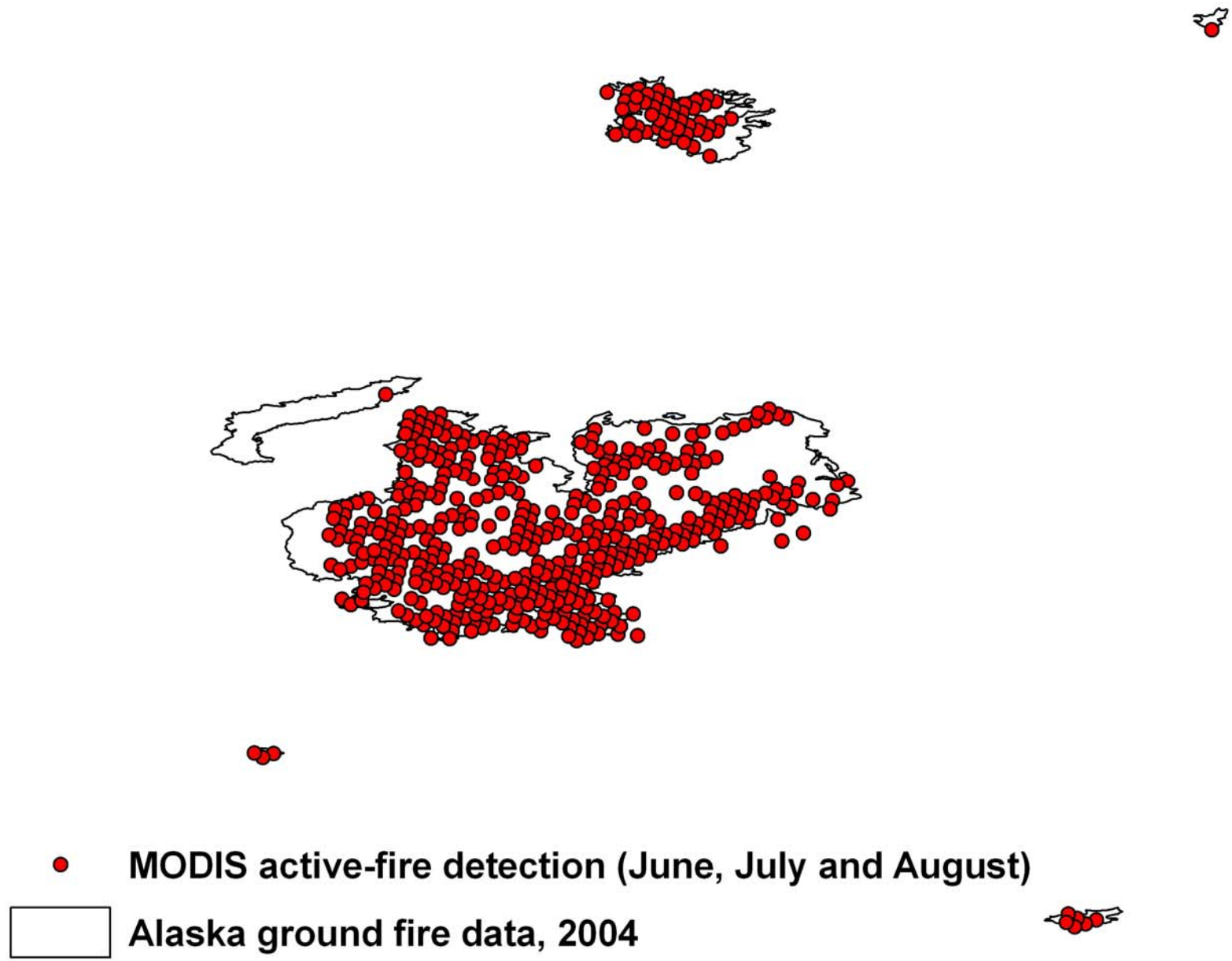
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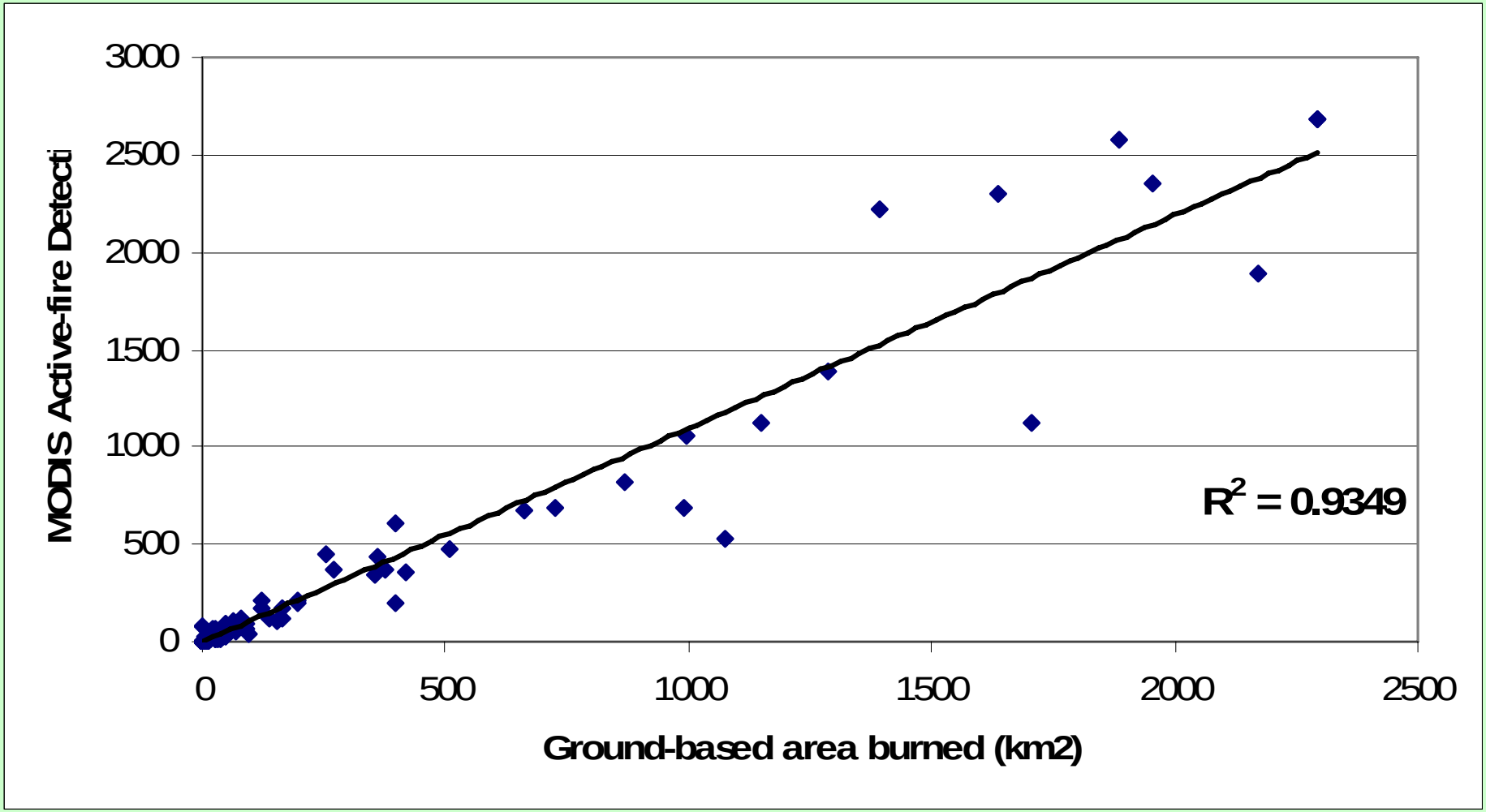


Comparison of 2004 Alaskan ground fire data to HMS-MODIS data from June, July and August.

All data, not just coincident data.

6.78% Commission errors by numbers of scars (false positives – fire detected by satellite when none are evident in 1km^2 imagery or by Alaskan fire database)

0.31% Commission errors total (in pixels or area)

14.41% Omission errors by number of scars (fire that was actually burning but omitted from satellite data)

0.08% Omission errors total (in pixels or area), most < 1km^2, largest 4.56 km^2 (1km^2 = 247 acres)

Methodology

Spatial and temporal analysis of WRAP, GOES and MODIS data for

Oregon
July 2002 and

Arizona
September and August 2002

MODIS data processing

MODIS Terra and Aqua data are downloaded from the Rapid Response Fire team

Exclude data that are < 20% confident

Convert the point data to ArcGIS shape files

These are point data, no area

Buffered the data to 0.5 km (size of pixel) to account for the instrument spatial resolution

Buffered data an additional 1 km to account for the Point Response Function

GOES data processing

- Downloaded data from the historic filtered ABBA data website: Fire Locating and Modeling of Burning Emissions (FLAMBE)
- Integrated ½ hour data from GOES east & west into daily files
- Combined data from GOES east and GOES west
- Delete low probability fire data (flag 5)
- Average the area of processed data (flag 0) and assign the average area to flags 1 – 4 (in each state).****
- Generate a cumulative ArcGIS shape file. Polygons are defined by area. ****
- Data are buffered to 5 km to account for the instrument spatial resolution and the Point Response Function

**** Area computed for the process data (flag 0) represents the instantaneous fire area burning ****

P. Siberica under a *P. Sylvestris* canopy

Western Region Air Partnership or WRAP Ground Fire Data

Inventories prepared for 2002 emissions inventories for wildfire, wildland fire use, prescribed burning in wildlands, non-federal rangeland fires and agricultural burning.

This data have been checked, geolocated and quality control reviewed by Air Sciences Inc.

Treatment

- **Data are converted to ArcGIS shape files, where area defines the polygon size.**
- **We concentrate on fires that burned in Oregon, July 2002 and in Arizona, August and September 2002.**

Criteria for Coincidence

(1) Time

- Satellite data must be within the timeframe reported in the WRAP data.

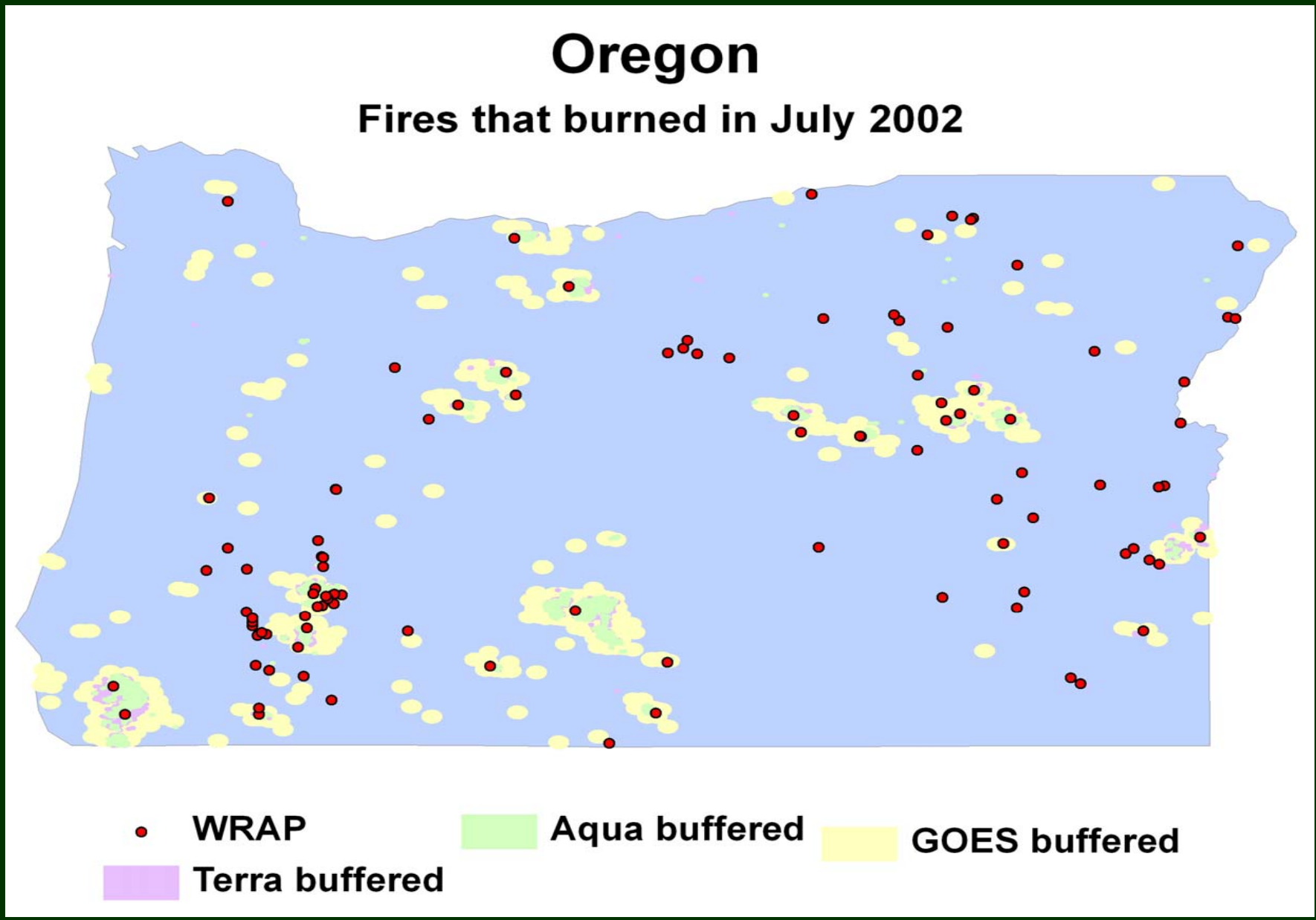
(2) Space

-WRAP data must overlap satellite buffered space.

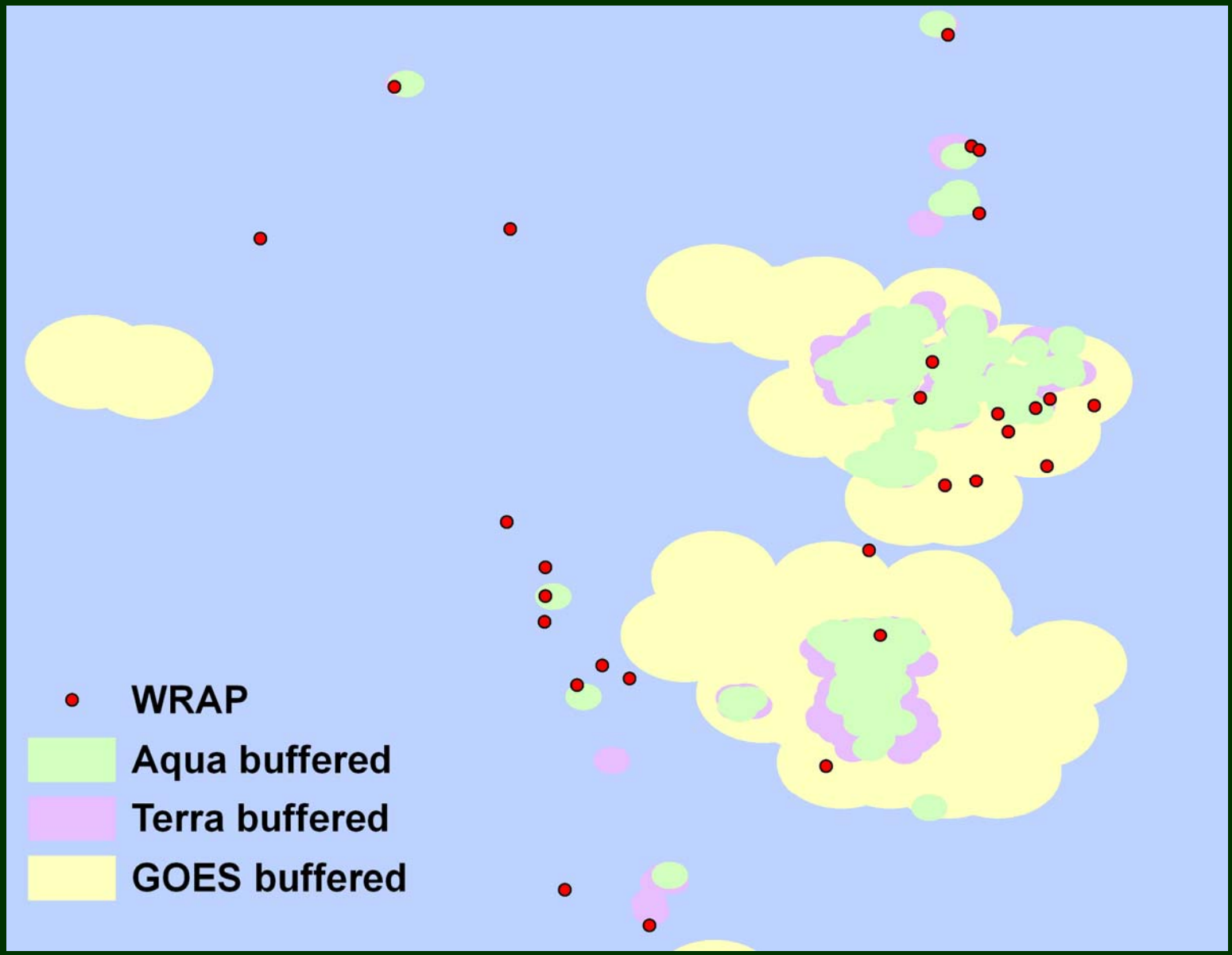
or

-When a buffered space overlaps another buffered space, even though it is not physically touching the WRAP data, it is still considered to potentially be coincident.

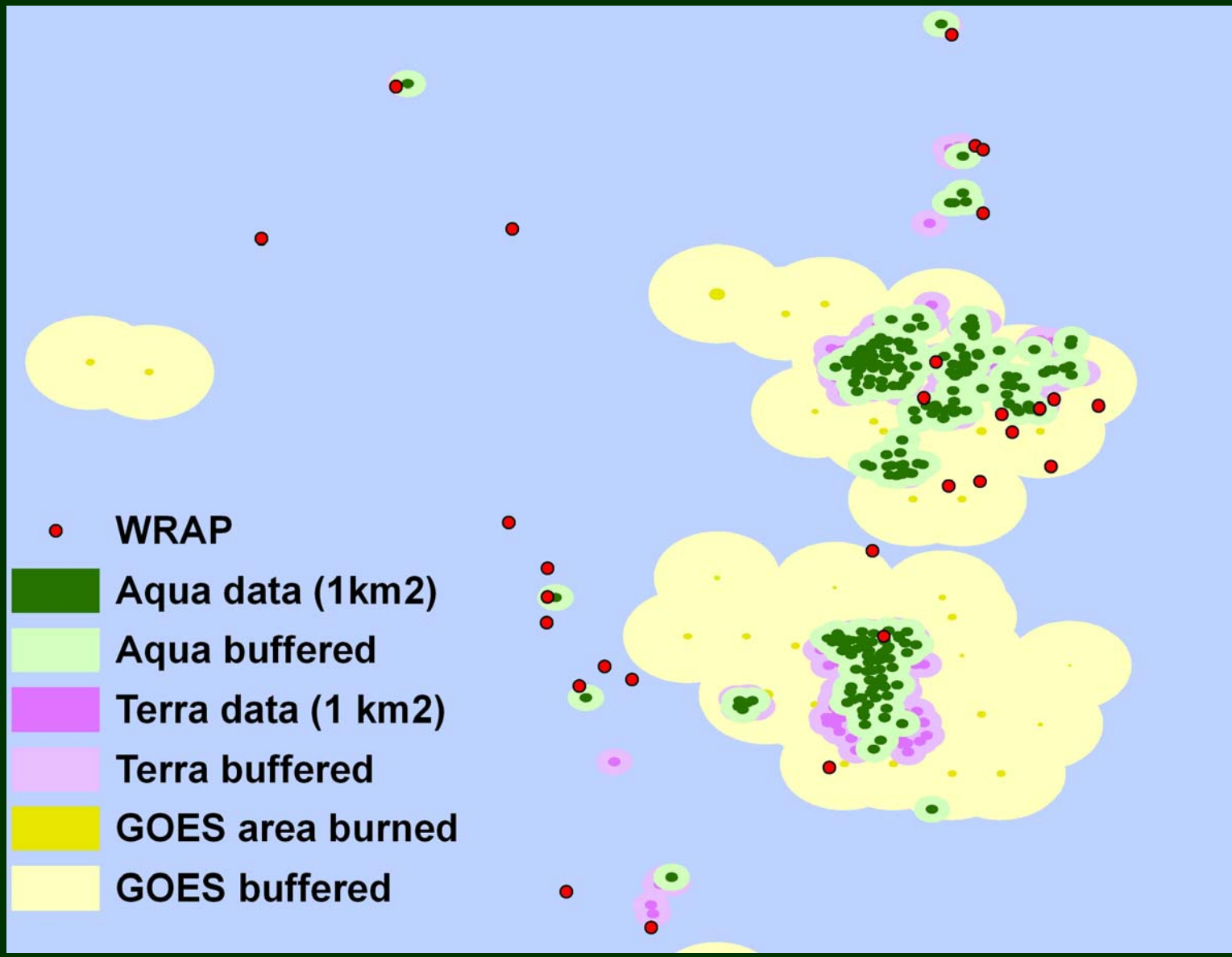
Spatial coincidence in satellite- and ground-based fire data.



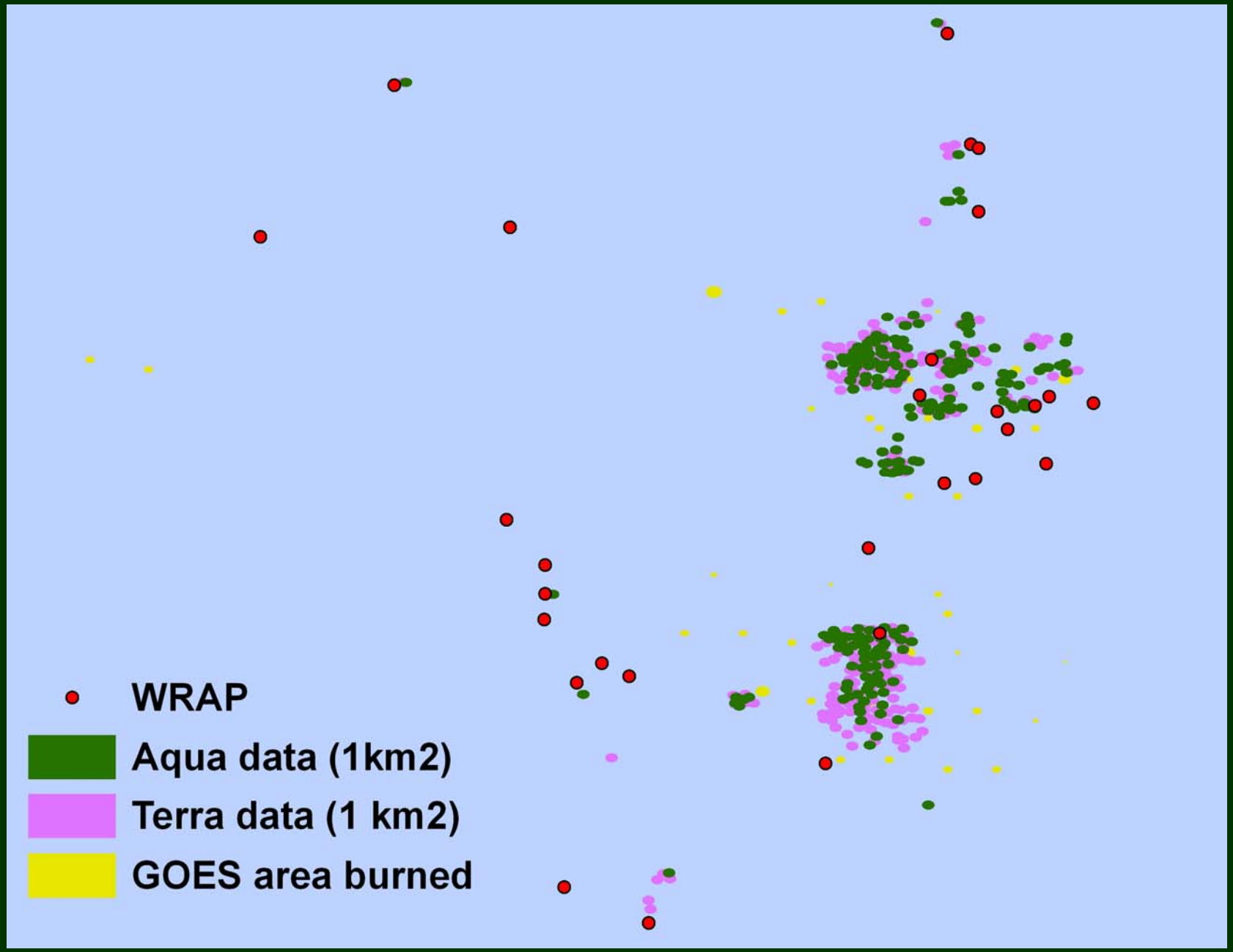
Zoom to data: MODIS and GOES data are buffered to 1.5 and 5 km, respectively.

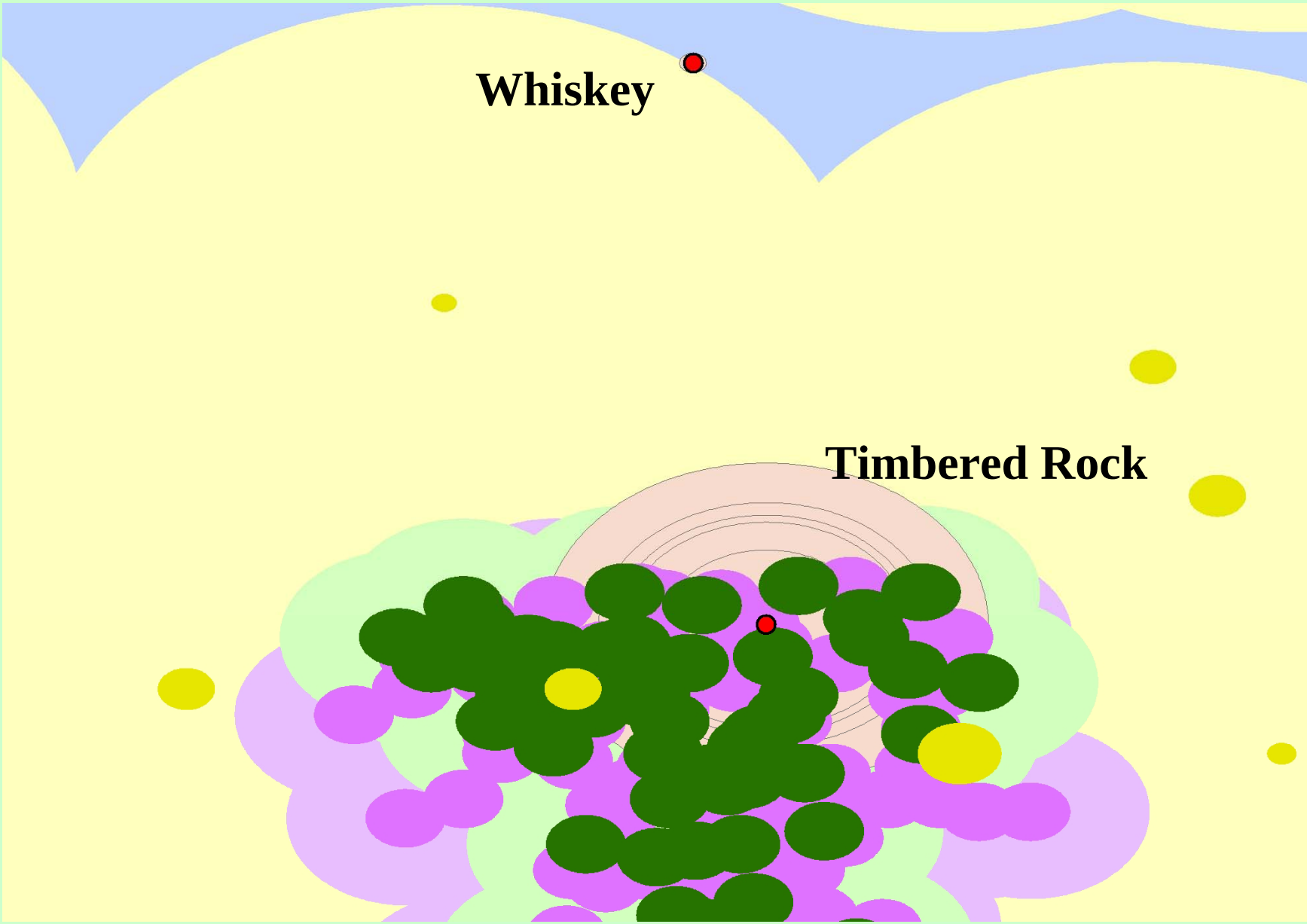


Zoom to data:
MODIS and GOES, area and buffered data



Zoom to data: MODIS and GOES; area data; no buffers



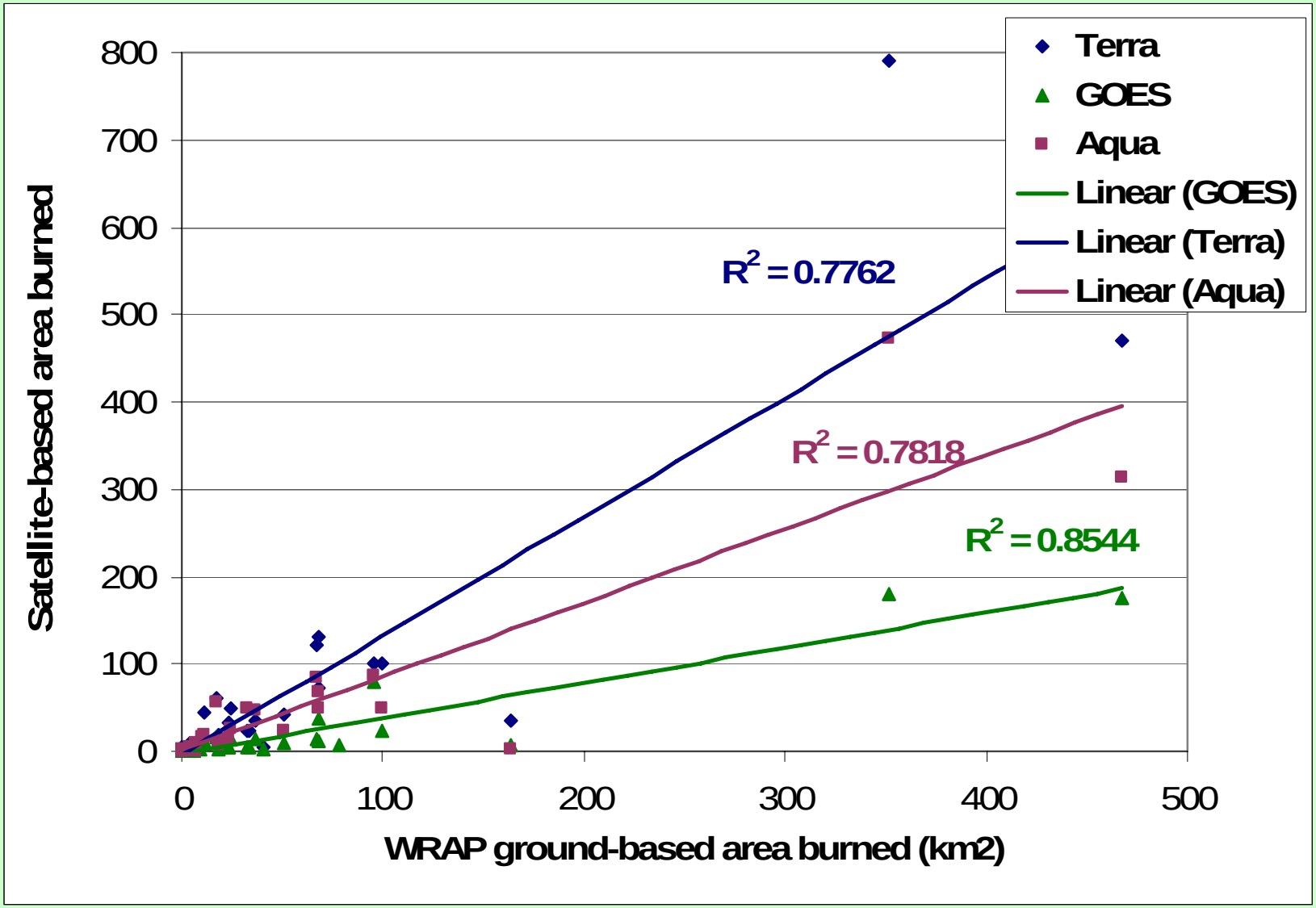


Zoom – Note the size and number of fire records surrounding the WRAP fire data (red buffered with reported area in rose).

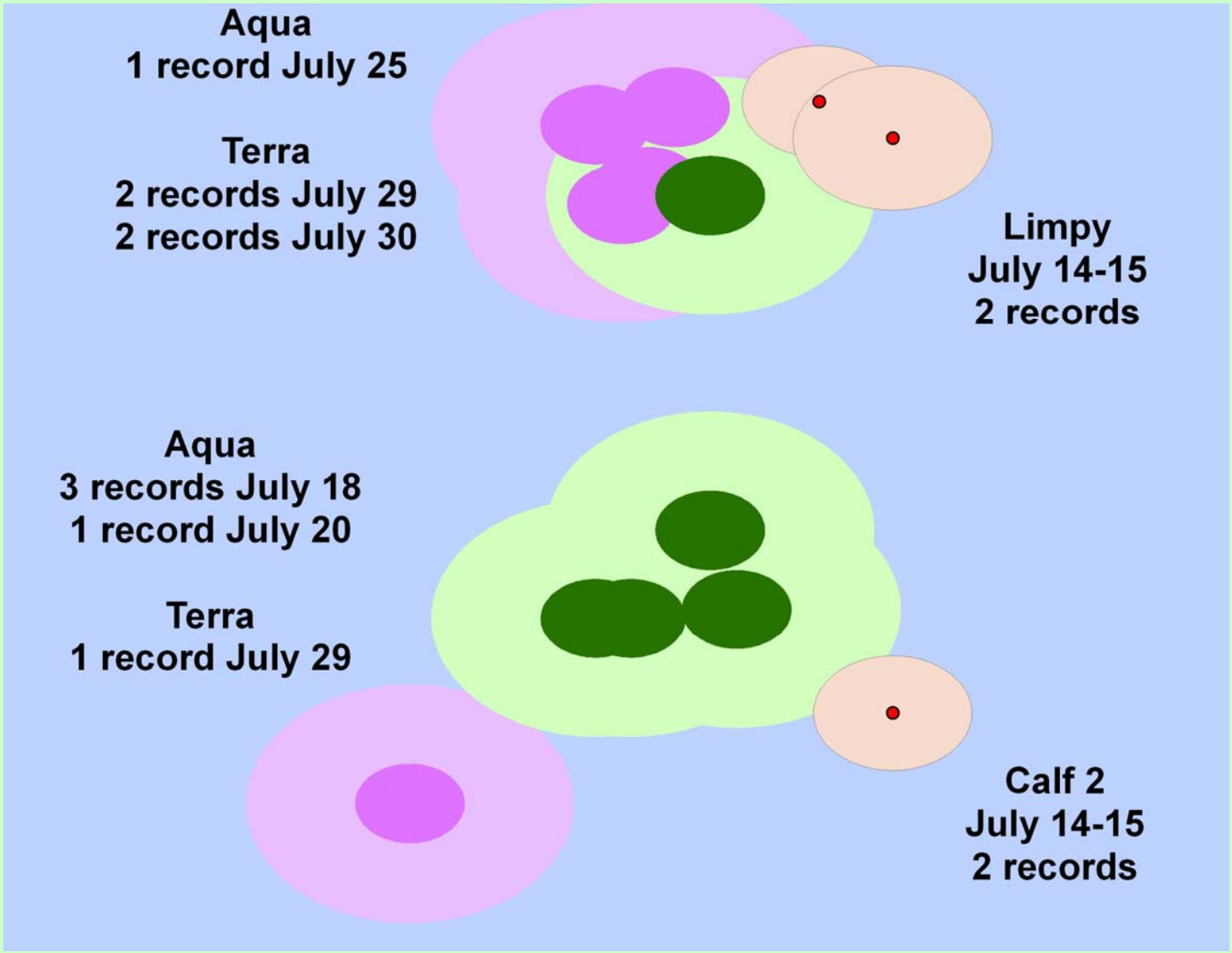
Data source	Number of records	Acres burned (range)	Percent area burned of ground data	Percent number of fires coincident	Percent representative area coincident
GOES ABBA	1996	197,655 (1.16 – 806.66)	40% (Instantaneous)	31%	89.5%
MODIS Terra	2761	682,268 (from detections)	136% (detect = 1km^2)	33%	85.7%
MODIS Aqua	1419	350,643 (from detections)	70% (detect = 1km^2)	27%	80.7%
Oregon ground data, 101 fires	296	500,555 (1.98 – 54400.5) **mean 1691 acres**		Combined satellite 39%	Combined satellite 90.1%

Comparison of Oregon ground fire data

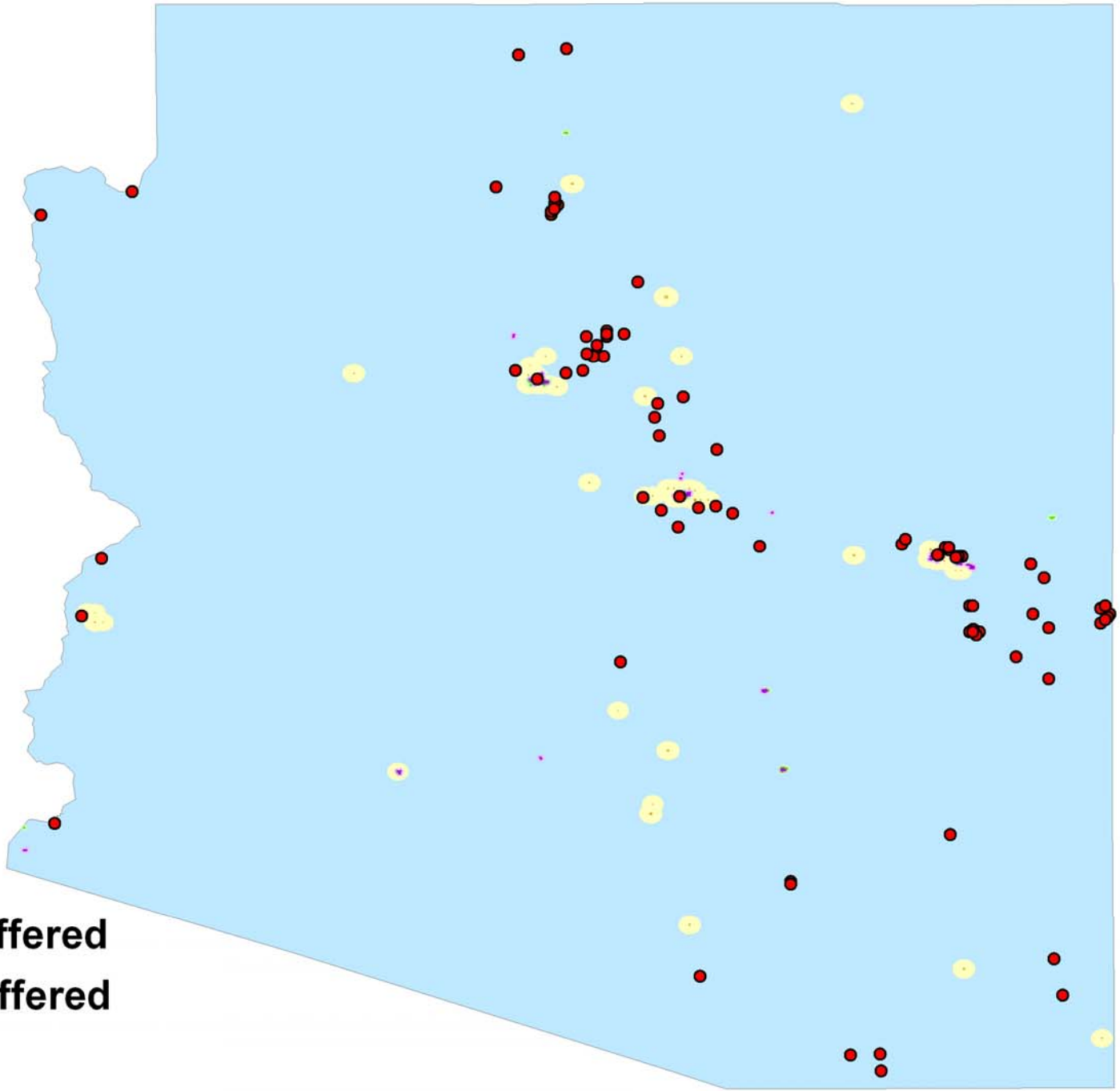
[wildfire, wildland fire use, prescribed burning in wildlands] and satellite data, July, 2002



Many fires that are close in space and time but are not counted towards coincidence.



Arizona



Fires that burned in August and September 2002.

Legend

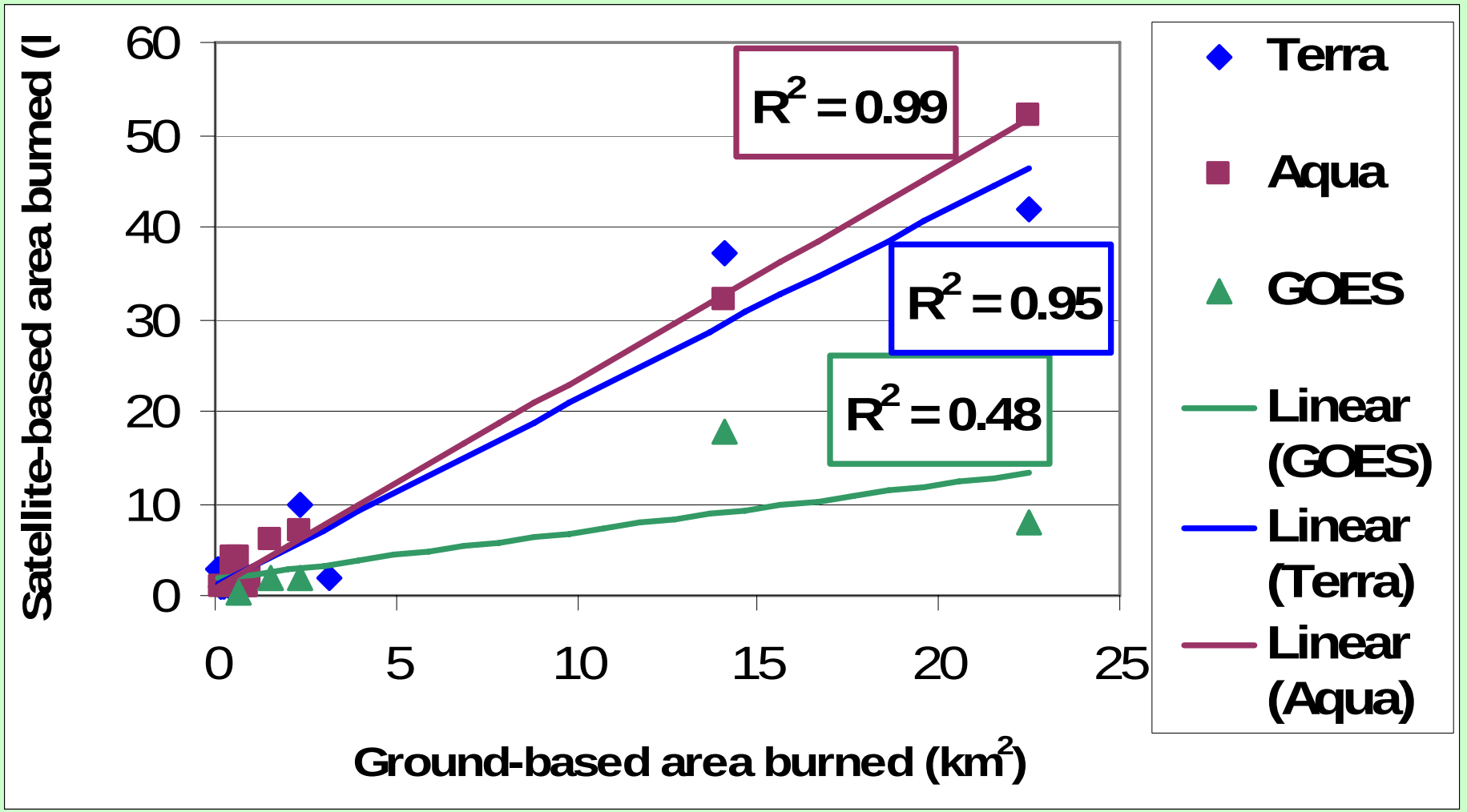
- WRAP
- Terra buffered
- Aqua buffered
- GOES

Data source	Number of records	Acres burned (range)	Percent area burned of ground data (all satellite data)	Percent number of ground fires coincident	Percent representative ground area coincident
GOES ABBA	169	9,491 (1.23 - 442)	42% (Instantaneous)	3%	44.8%
MODIS Terra	168	41,514 (from detections)	184% ($1km^2$ detection)	10%	51.4%
MODIS Aqua	162	40,031 (from detections)	177% ($1km^2$ detection)	9%	51.1%
Arizona ground fire data, 165 fires	201	22,612 (0.50 – 1,598) **mean 113 acres**		Combined satellite 15%	Combined satellite 58%

Comparison of Arizona ground fire data

[wildfire, wildland fire use, prescribed burning in wildlands] and satellite data

September and August, 2002



Typically large fires account for the greatest amount of area burned and emissions.

In Canada, the largest 2-3% of the fires account for 97-98% of the area burned (Stocks, 1991).

Alaskan fire records show that since 1950, 96% of area burned is by large (> 2000 ha) fires (AFS, 1992).

In Oregon (July 2002), the largest 10% of the fire events account for 80% of the area burned (largest 2% - 40% area burned).

In Arizona (September and August 2002), the largest 10% of the fire events account for 74% of the area burned. (largest 2% - 46% area burned).

Photo courtesy of Brian Stocks

Conclusions (1 of 2)

HMS-derived MODIS fire detections describe large fires in boreal Alaska well in terms of:

- **Spatial extent of the fires**

- **The amount of area burned**
  (r2 = 0.94 for all fires)

- **Low commission error (false detection)**
  (#'s 6.78%; area 0.31%)

- **Low omission error (#'s 14.41%; area 0.08%)**

Conclusions (2 of 2)

Oregon — **mean fire record 1691 acres**

- **39 % of the number of fires are identified by satellite**
- **90 % of the representative area burned is identified by satellite**

area to area comparison

MODIS (aqua and terra) $r^2 = 0.78$; GOES $r^2 = 0.85$

total area comparison

Aqua 70 %; Terra 136 %; GOES 40 %

Arizona — **mean fire record 113 acres**

- **15 % of the number of fires are identified by satellite**
- **58 % of the representative area burned is identified by satellite**

area to area comparison

Aqua $r^2 = 0.99$; Terra $r^2 = 0.95$; GOES $r^2 = 0.42$

total area comparison

Aqua 177 %; Terra 184 %; GOES 42 %

Future Research

Through the NASA Applications program, we intend to work with the EPA, the RPOs, the National Institute of Aerospace, Air Sciences Inc., MACTEC Engineering and Consulting Inc. and Sonoma Technologies to complete this analysis for CONUS.

Ultimately, satellite-based emission estimates could be greatly improved with the addition of a satellite-based area burned product. These data have the potential to move the science and remotely-sensed emissions forward.

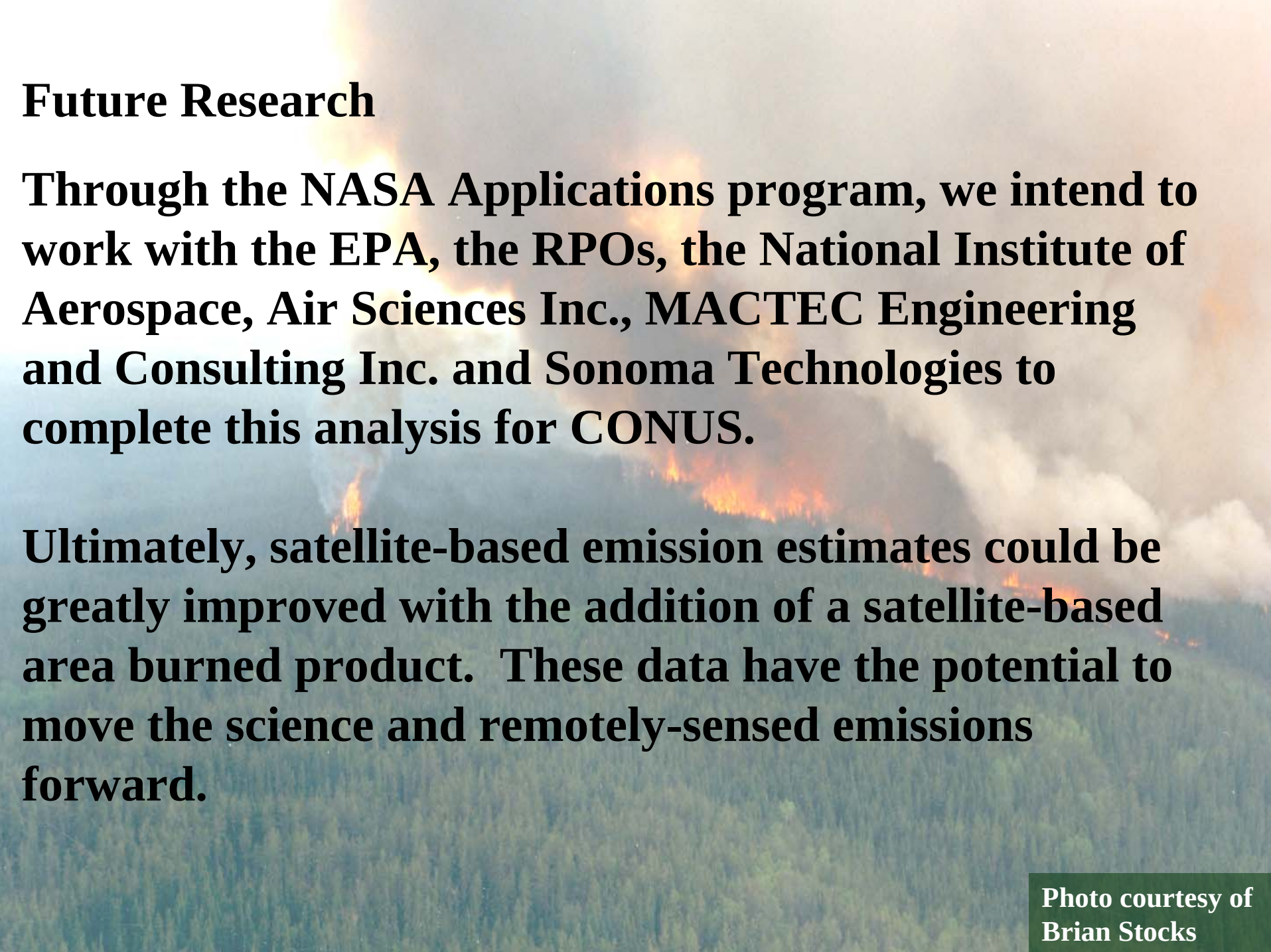


Photo courtesy of Brian Stocks

Acknowledgements

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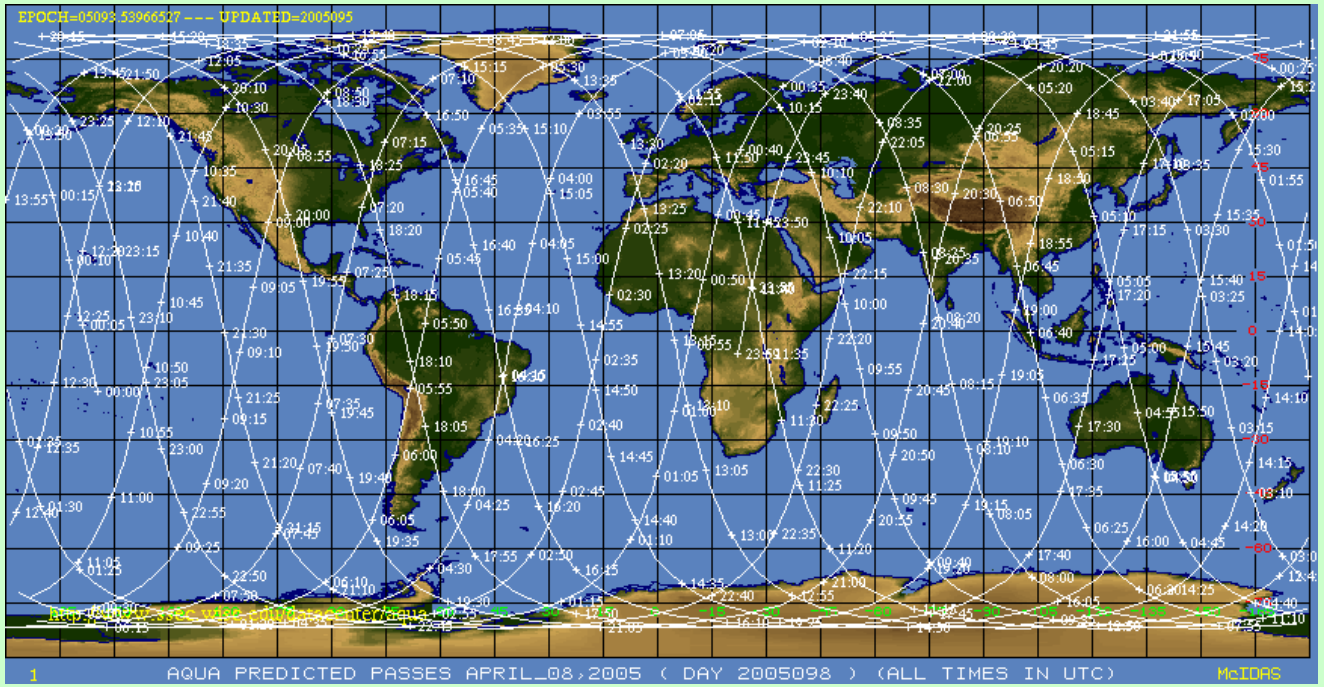
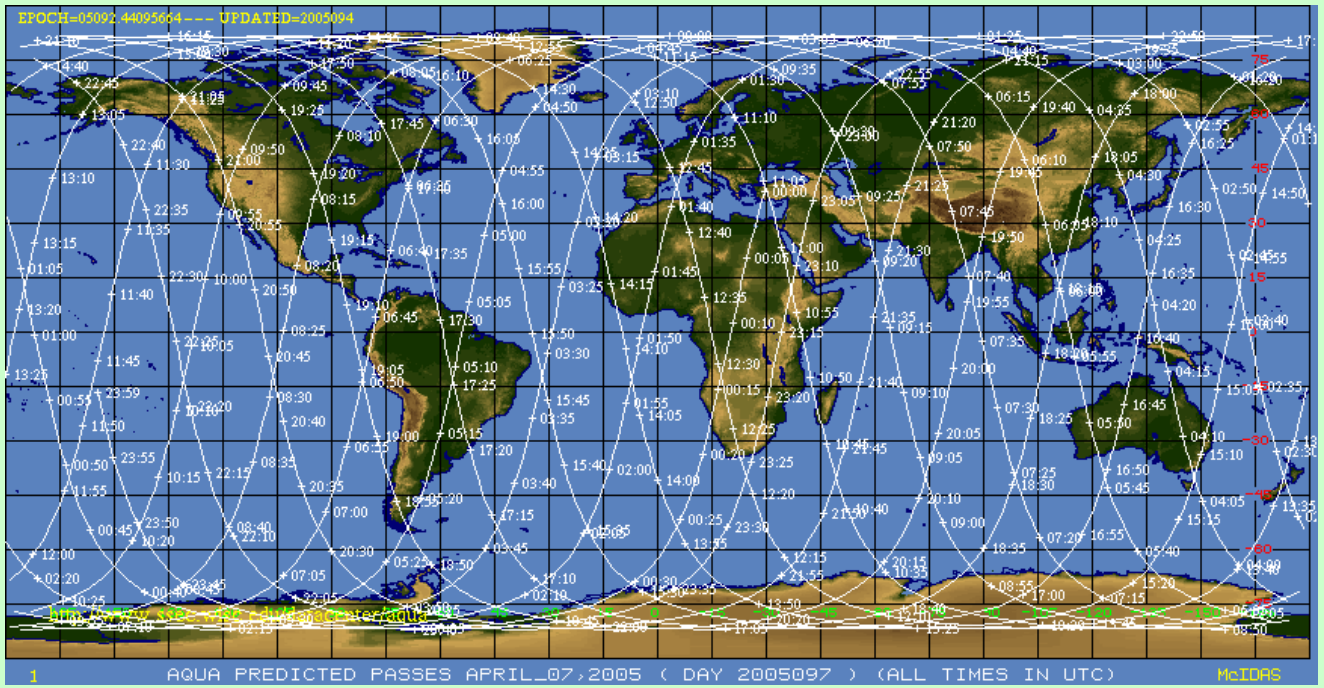


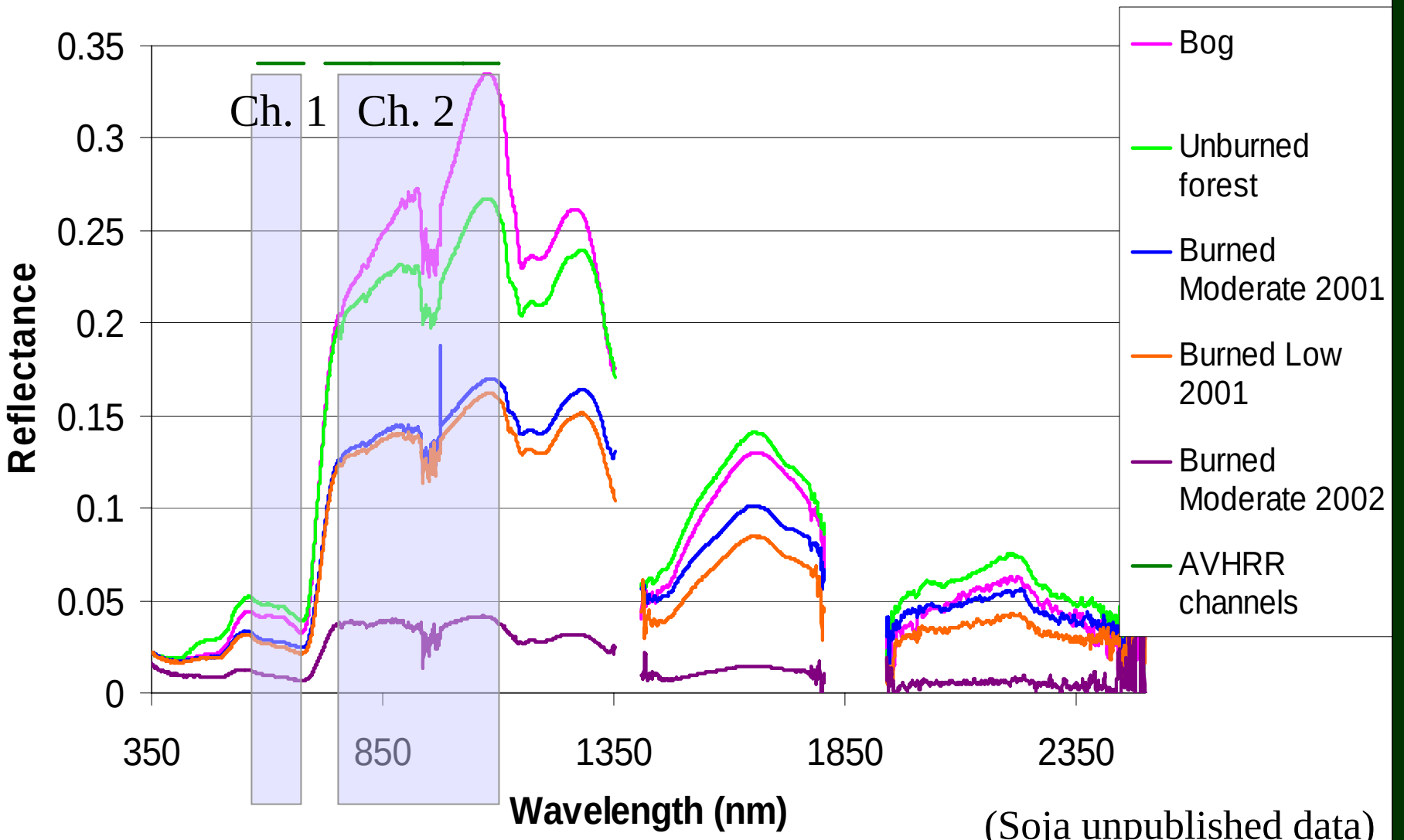


MODIS Aqua

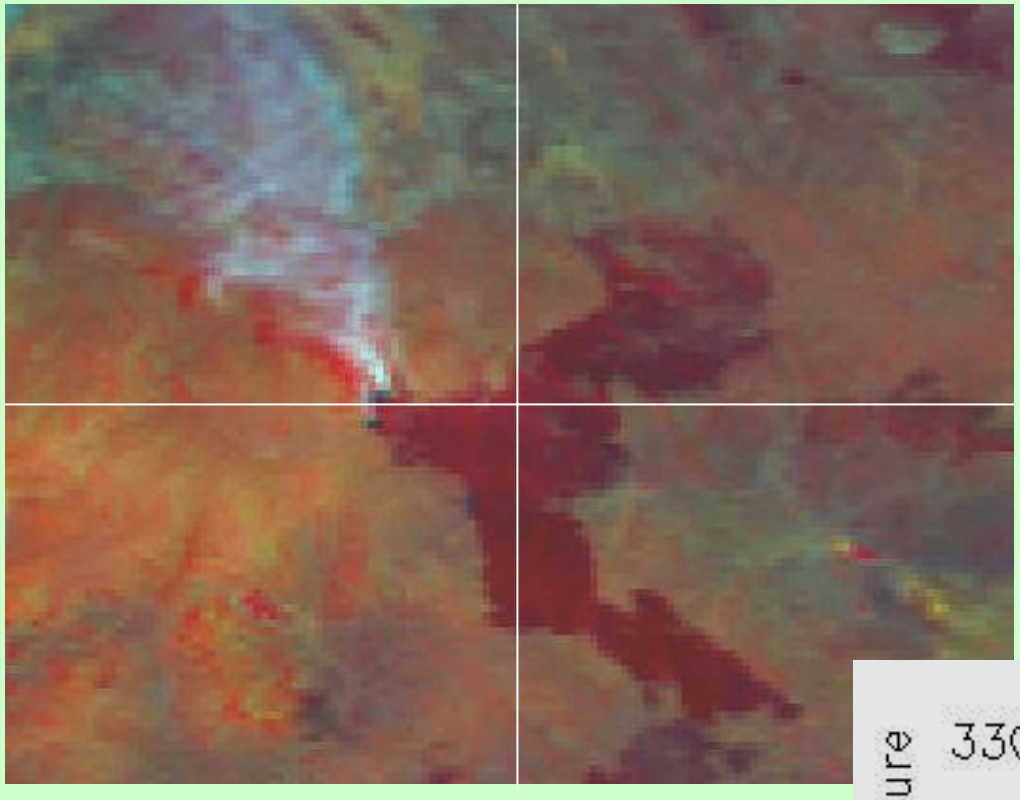
Predicted Sequential Orbit

Average Spectra from Helicopter: Yartsevo 2002

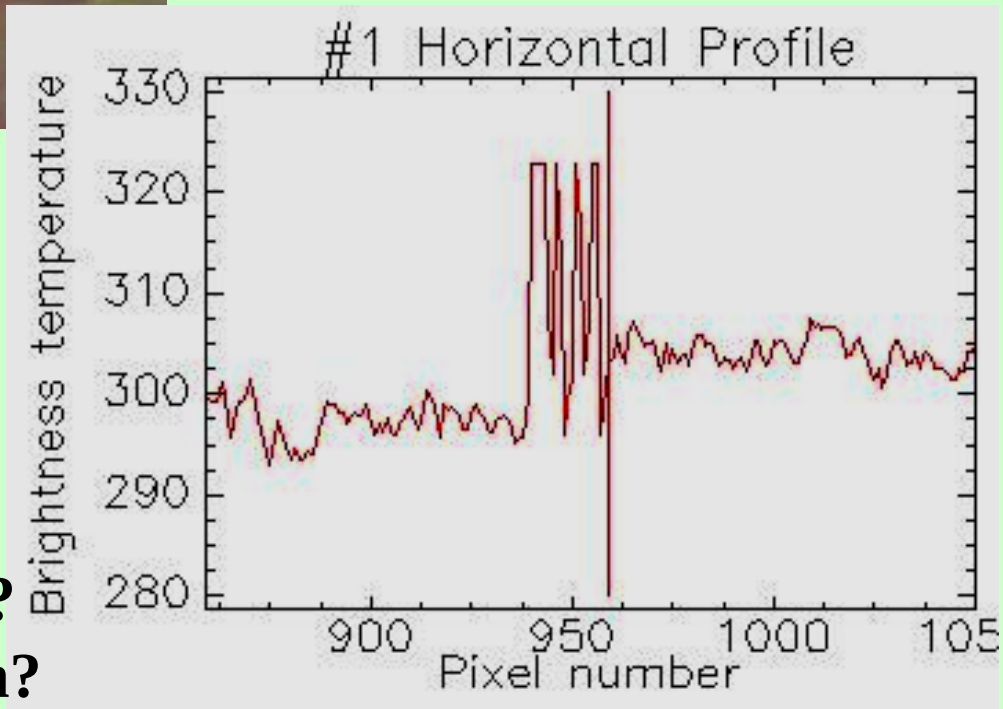
local time ~ 16:00 - 18:00, Field Of View 42m



(Soja unpublished data)



Active Fire Detected by AVHRR channel 3 (3.7 *u*m)



<u>Considerations</u>

Clouds prohibit detection.

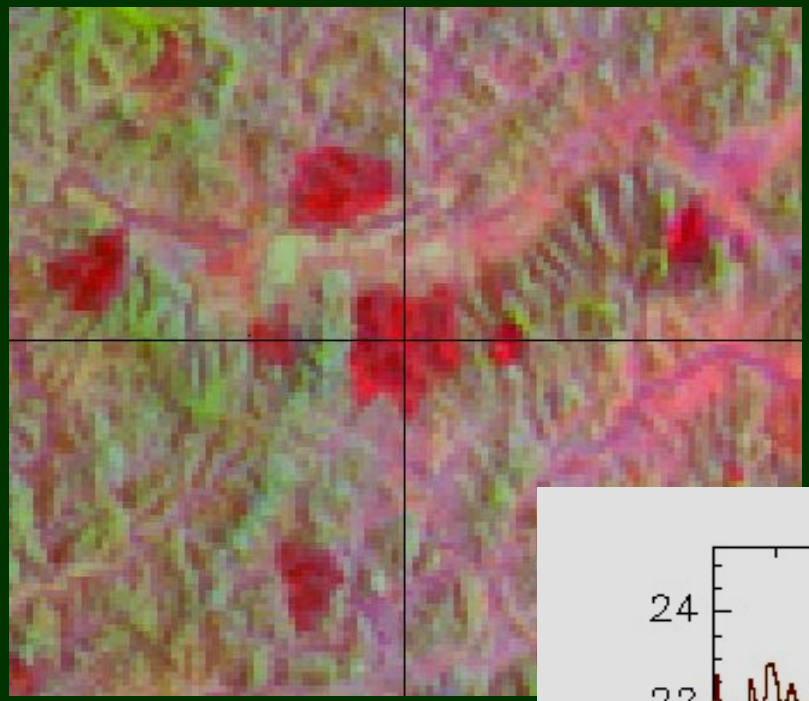
Fire size?

Fire intensity?

Viewing angle of satellite?

Instrument spatial resolution?

Instrument temporal resolution?



Identifying burn scars in AVHRR imagery