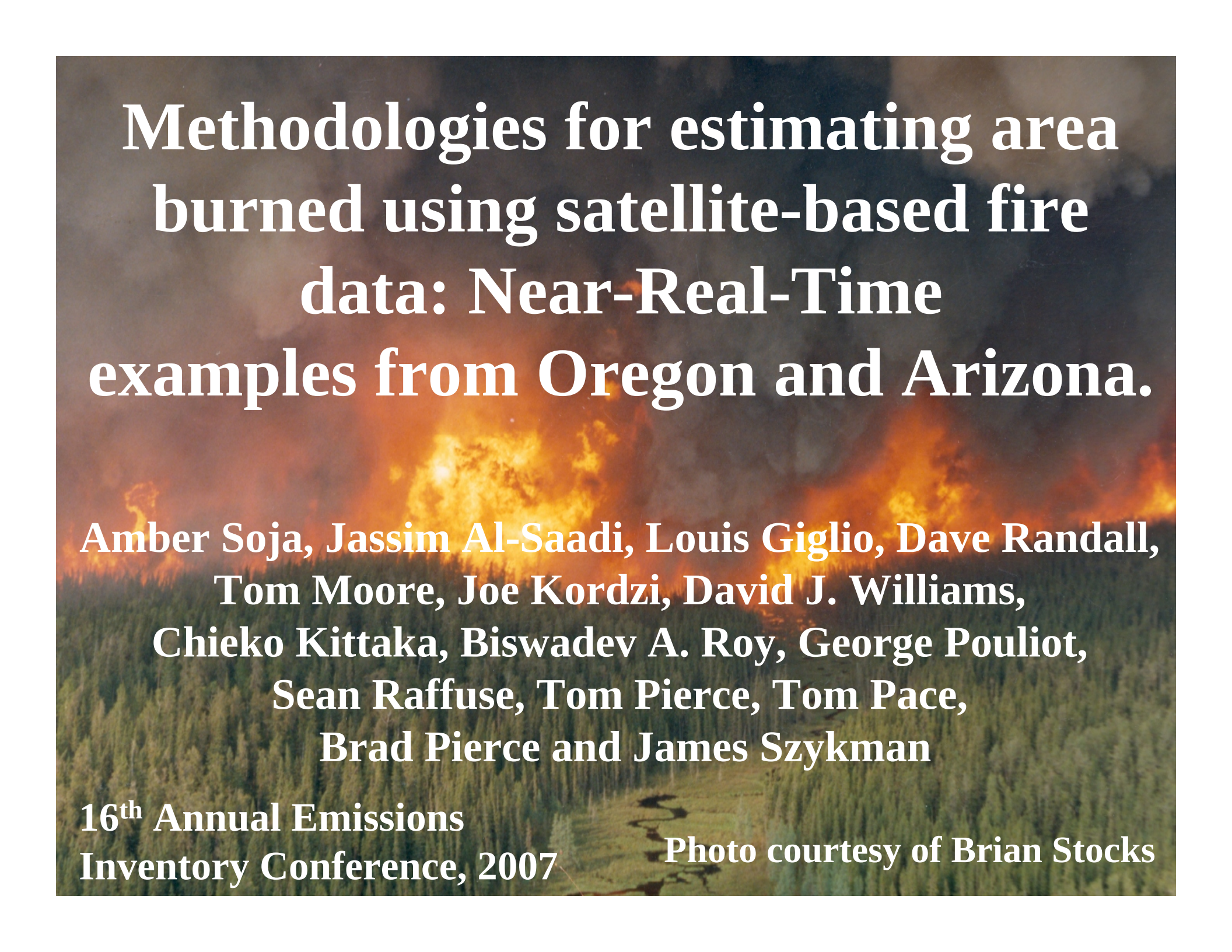




Methodologies for estimating area burned using satellite-based fire data: Near-Real-Time examples from Oregon and Arizona.

**Amber Soja, Jassim Al-Saadi, Louis Giglio, Dave Randall,
Tom Moore, Joe Kordzi, David J. Williams,
Chieko Kittaka, Biswadev A. Roy, George Pouliot,
Sean Raffuse, Tom Pierce, Tom Pace,
Brad Pierce and James Szykman**

**16th Annual Emissions
Inventory Conference, 2007**

Photo courtesy of Brian Stocks



1 year after fire

General Purpose

**Quantify the ability of satellite data
to define area burned**

**in an effort to enhance the spatial and
temporal estimates of biomass
burning and emissions**

**by comparing ground- to satellite-
based fire data.**

Specific Purpose

- * Compare coincident satellite-based
fire detections to ground data**
- * Compare all fire detections to
ground-based data**
- * Compare an area burned product**



**Fireweed
1 year after burn**

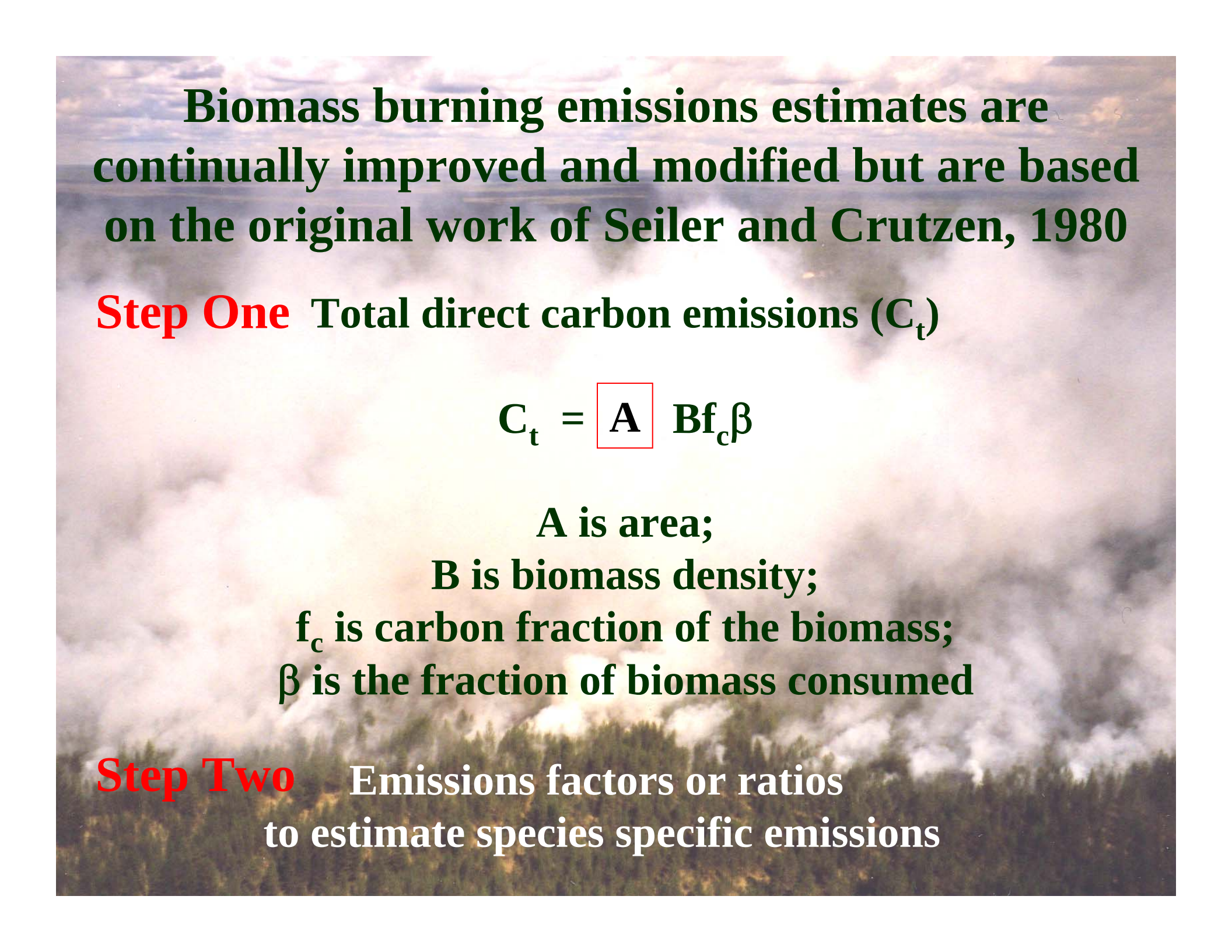
Motivation

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:

- (1) the opportunity to objectively remotely sense fire across governmental and private boundaries and
- (2) the data is available in Near-Real-Time.



Biomass burning emissions estimates are continually improved and modified but are based on the original work of Seiler and Crutzen, 1980

Step One Total direct carbon emissions (C_t)

$$C_t = \boxed{A} B f_c \beta$$

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

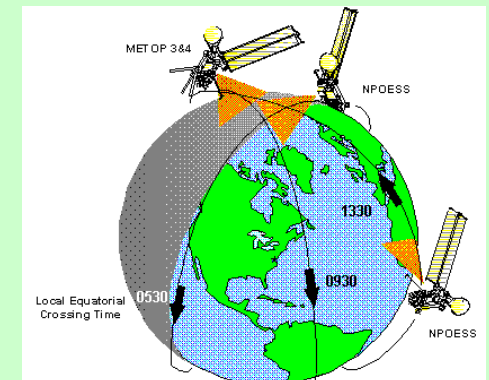
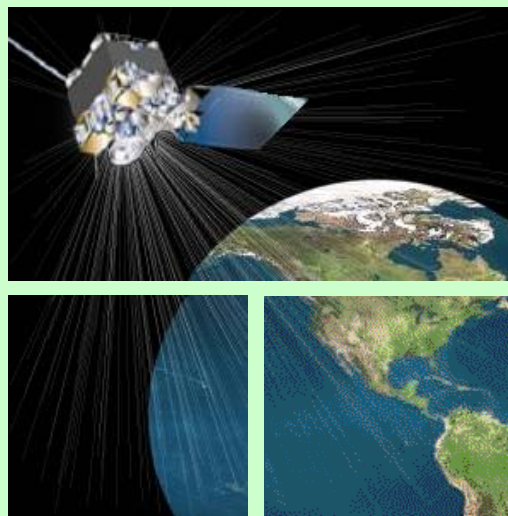
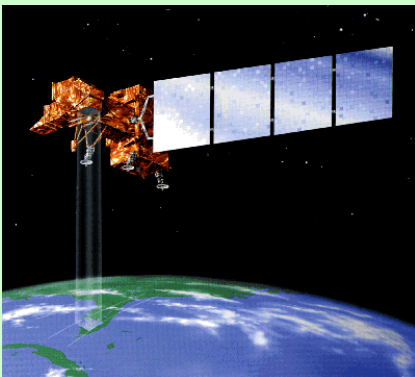
- (1) Moderate Resolution Imaging Spectroradiometer (MODIS)
and
- (2) Geostationary Operational Environmental Satellite (GOES)
Automated Biomass Burning Algorithm (ABBA)

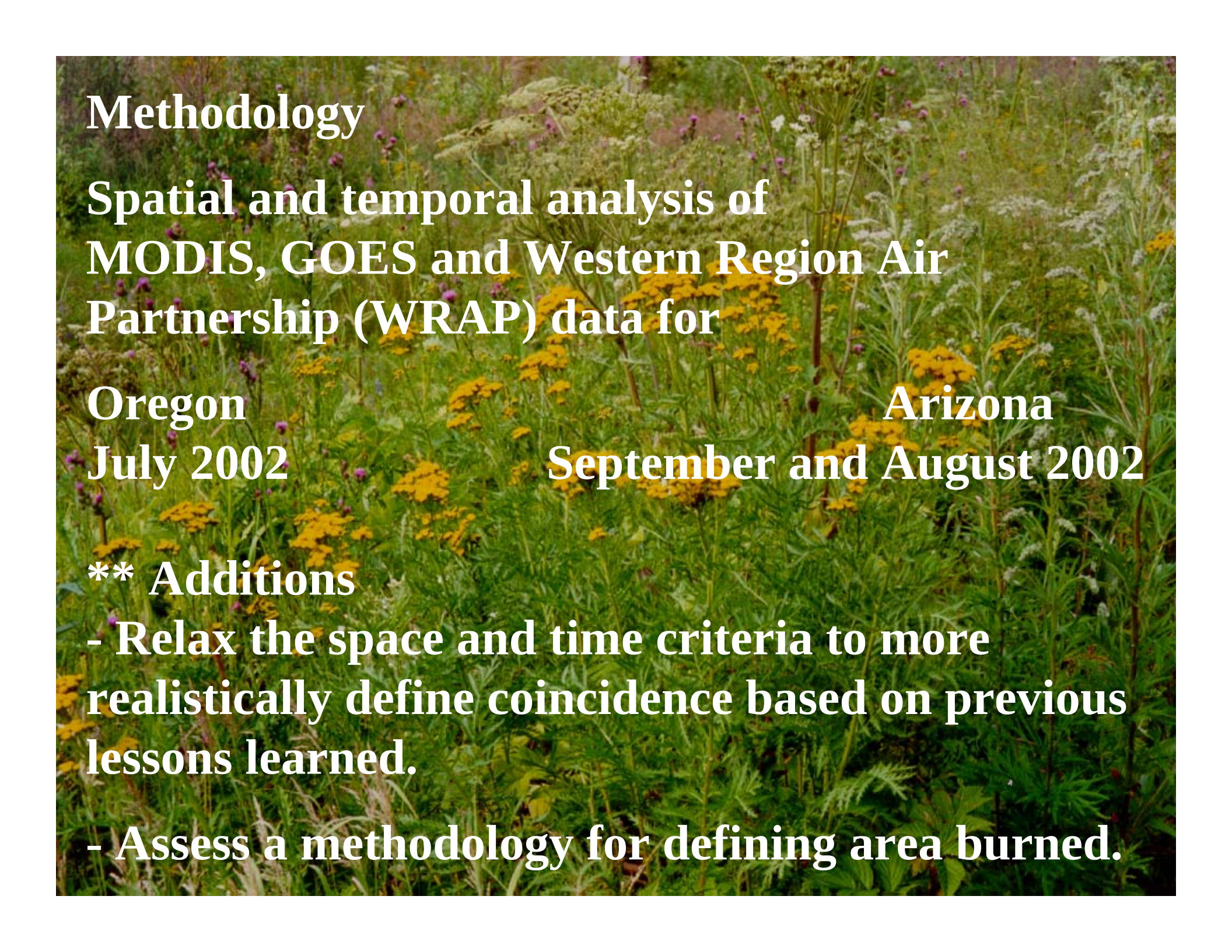
MODIS

sun-synchronous orbit
twice daily (terra & aqua)
spatial resolution 1 km²

GOES

geostationary orbit
15 minute (east & west)
spatial resolution 16 km²



The background of the slide is a photograph of a dense field of green plants with numerous small yellow and purple flowers. The text is overlaid on this image.

Methodology

**Spatial and temporal analysis of
MODIS, GOES and Western Region Air
Partnership (WRAP) data for**

Oregon

July 2002

Arizona

September and August 2002

**** Additions**

- Relax the space and time criteria to more realistically define coincidence based on previous lessons learned.**
- Assess a methodology for defining area burned.**

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

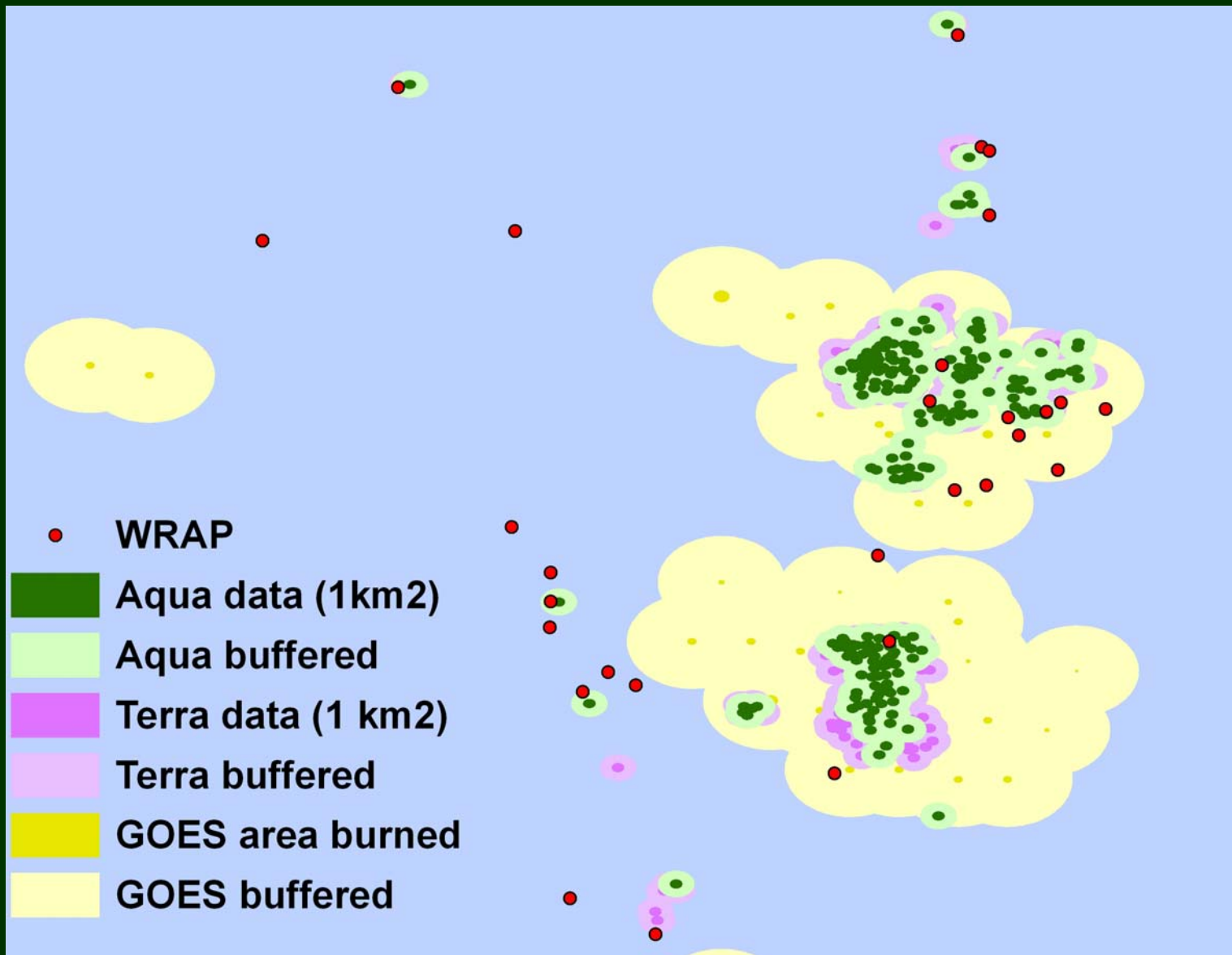
Inventories prepared for 2002 emissions inventories for wildfire, wildland fire use, prescribed burning in wildlands, **non-federal rangeland fires and agricultural** burning. (209 reports, NIFMD/USFS, SACS/1202, DEQ reports, state and local data, etc.)

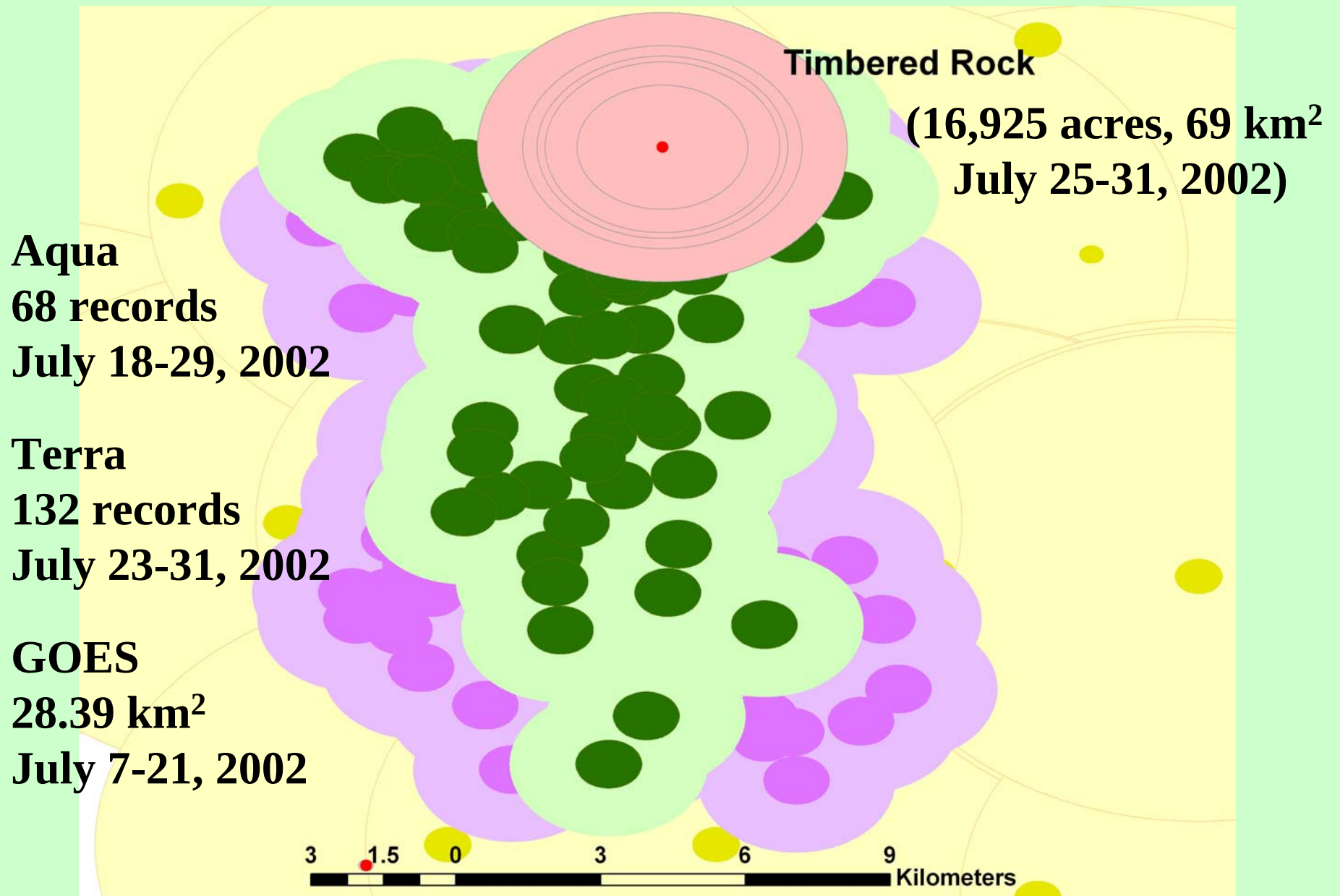
These data have been checked, geolocated and quality control reviewed by Air Sciences Inc.

Treatment

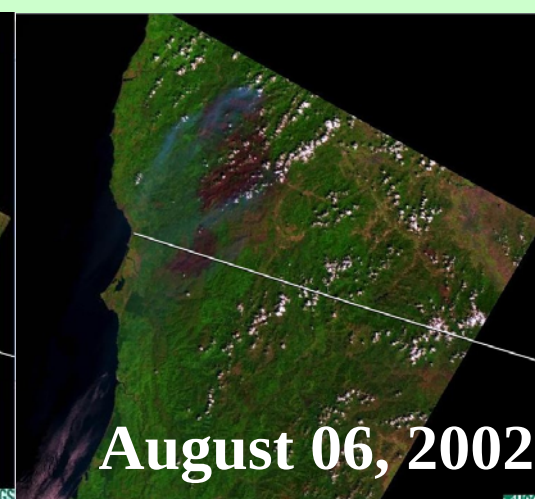
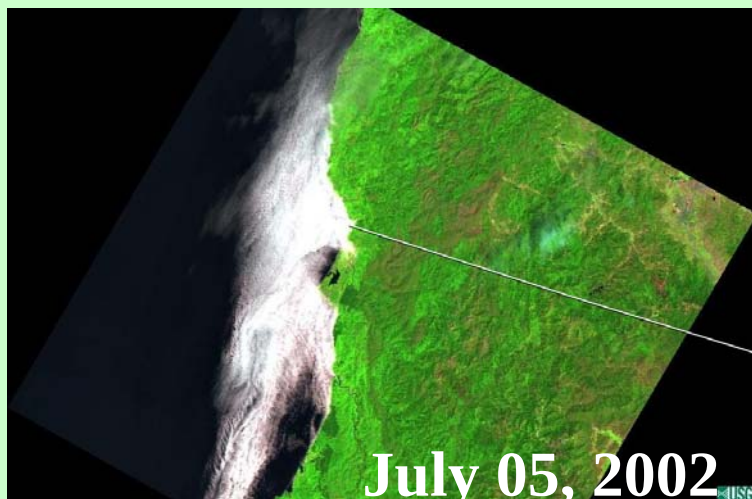
- ❖ Data are converted to ArcGIS shape files, where area defines the polygon size.
- ❖ We concentrate on fires that burned in Oregon, July 2002 and in Arizona, August and September 2002.

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

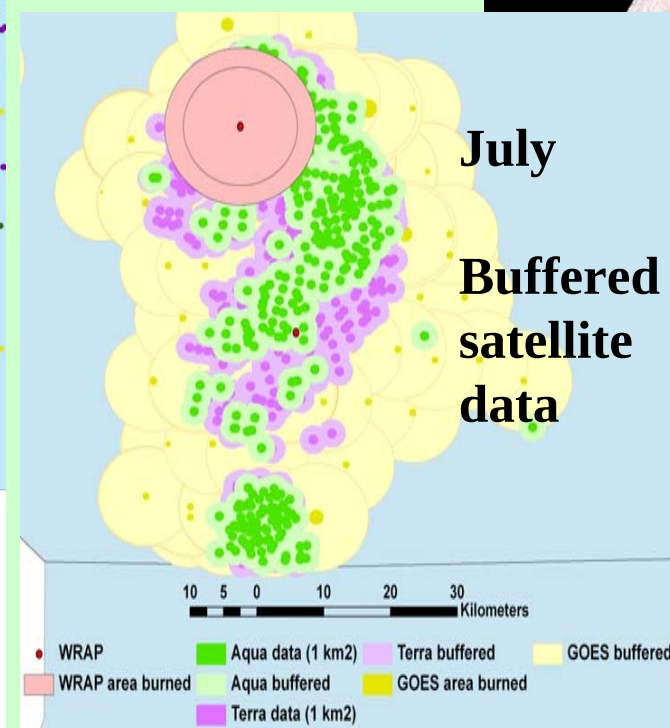
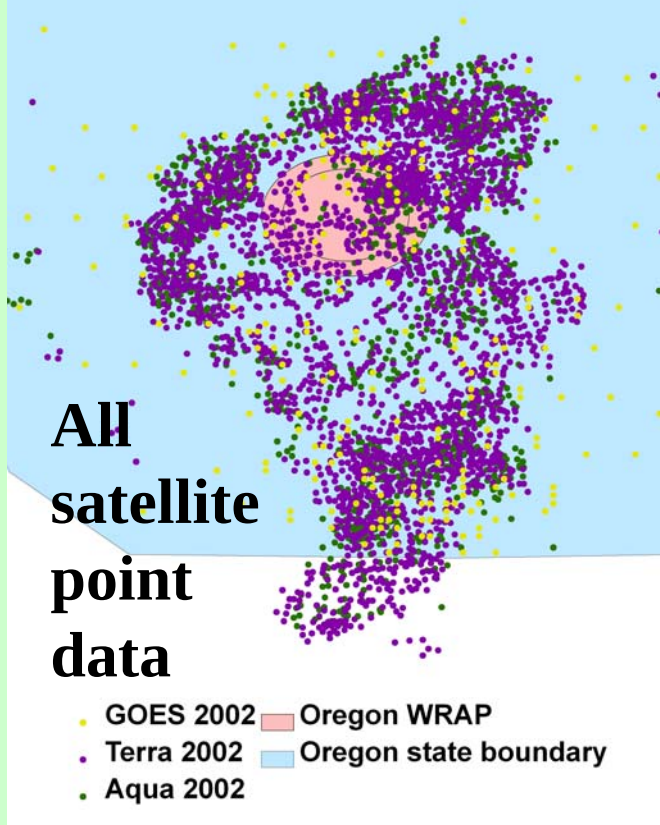




Zoom – Note the size and number of fire records surrounding the WRAP fire data (red buffered with reported area in rose).



Evolution of the Biscuit fire



Criteria for Coincidence

(1) Time

- Satellite data must be within days or contiguous days of the timeframe reported in the WRAP data, excluding agricultural and rangeland data.

(2) Space

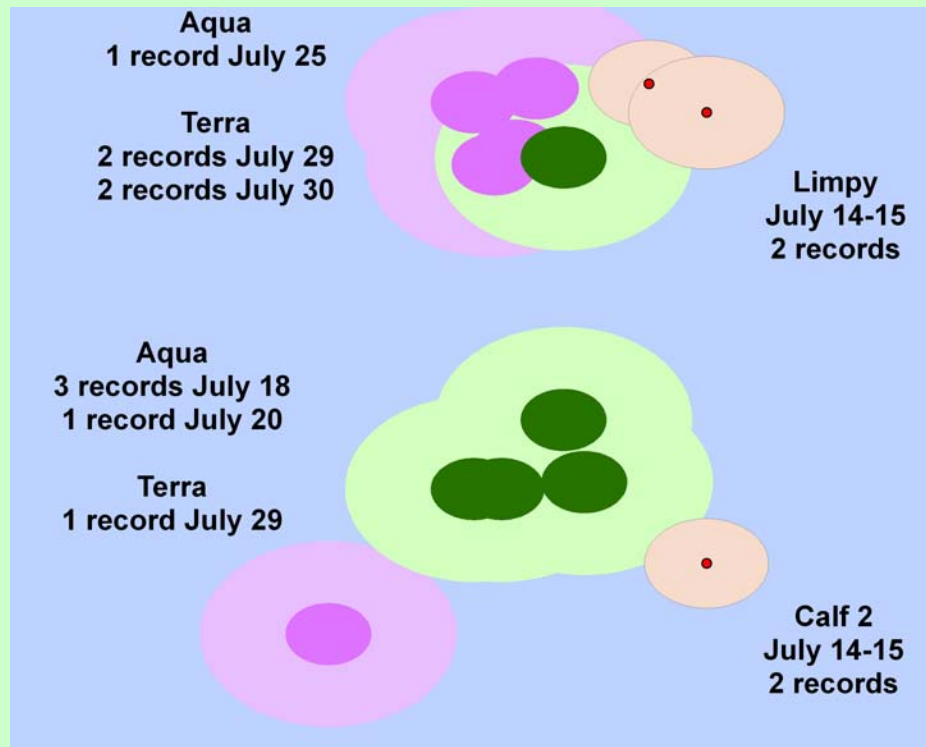
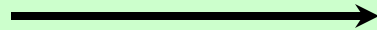
- Center of MODIS pixel must be within 3 km of reported fire (WRAP) and GOES within 10 km.
- or
- When a buffered space overlaps another buffered space, even though it is not physically touching the WRAP data, it is still considered to potentially be coincident.



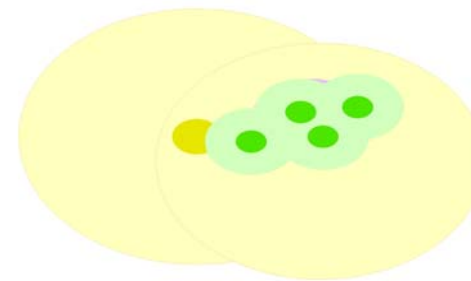
1 year after burn

**There is error in the ground-based data.
Several agencies do not report fires that burn < 100
acres (0.40 km²) in a day.**

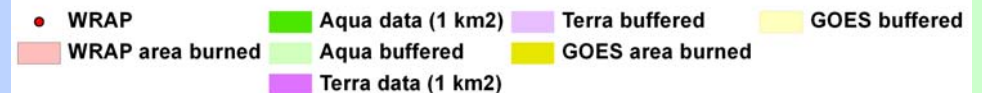
**All the satellites detect fire but
there is no coincident
ground data.**



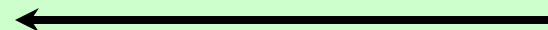
**GOES, Terra and Aqua
coincidence
in space and time,
no WRAP detection**

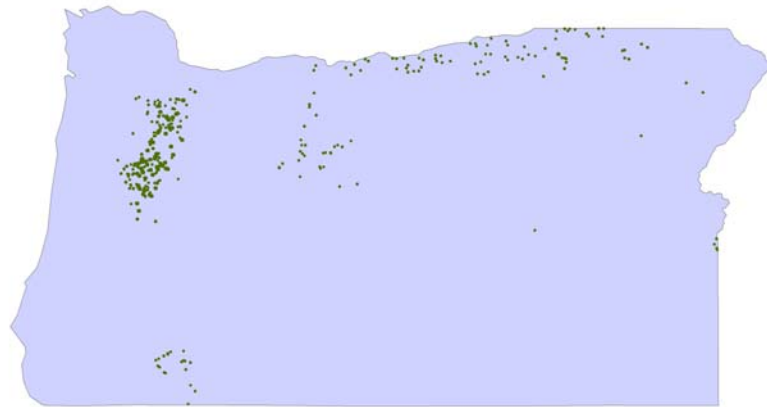


**5 GOES detections,
2 Terra detections and
4 Aqua detections.**

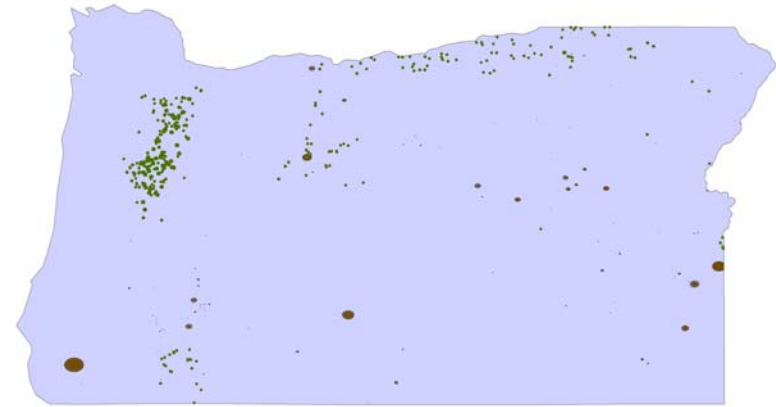


**One of these fires fits our
current temporal criteria and
the other does not.**



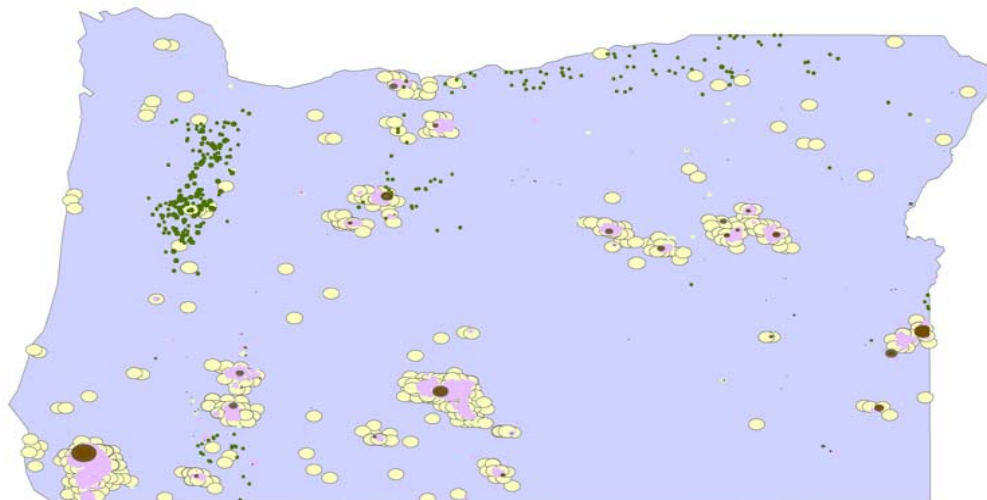


Agriculture Only



**Agricultural, State, Federal
and Private Ground-based Fire Data**

Satellite- and Ground-based Fire Data



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

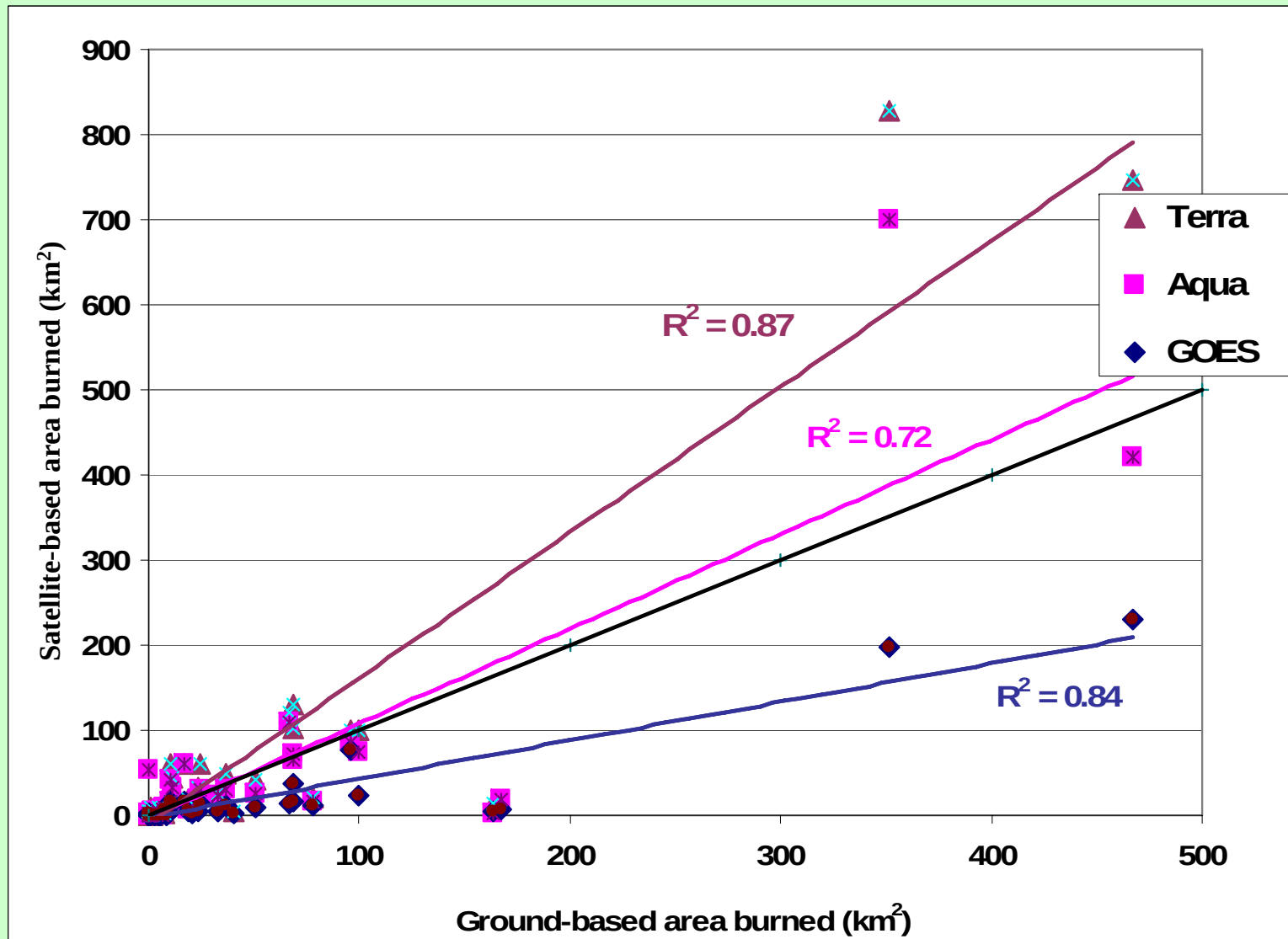
Oregon, July 2002

Data source	Number of records	Non – Ag acres burned (range)	% area burned all grnd. data, % area non-ag % area ag	% # all fires coincident % # non-ag % # ag
GOES ABBA [Agric. Fires]	1996	197,655 (1.16 – 806.66)	37%, 32% (Instantaneous) [20% Ag area]	34 % 34 % [34 %]
MODIS Terra [Agric. Fires]	2761	682,268 (from detections)	126%, 131% (detect = 1km ²) [10% Ag area]	10 % 37 % [< 2 %]
MODIS Aqua [Agric. Fires]	1984	350,643 (from detections)	94%, 98% (detect = 1km ²) [10% Ag area]	12 % 43 % [< 2 %]
Oregon ground, 101 fires, mean 1691 acres [Agric. Fires] mean 69 acres	296 [312]	500,555 (1.98 – 54400.5) [21,570 Agric. acres]	All satellites, all area 181% Combined representative satellite area 97%	Combined satellite, all fires 53 % [41 %]

Oregon July, 2002:

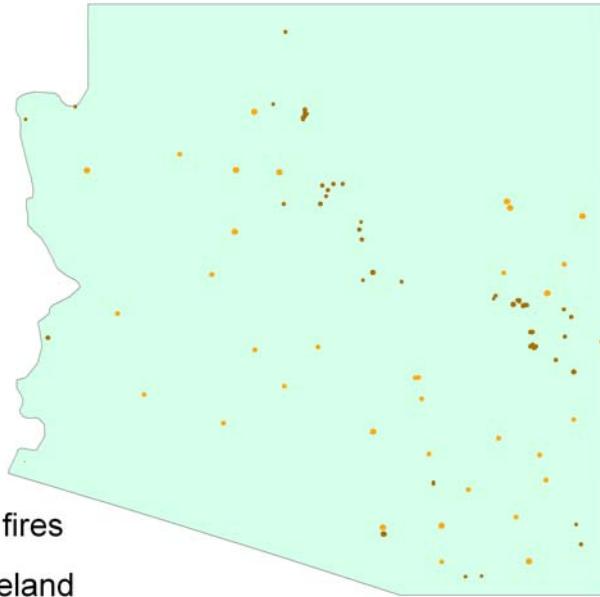
Coincident satellite- and ground-based fire data.

[wildfire, wildland fire use, prescribed burning in wildlands]



* Note
difference
in axis

**All Ground-based Fire
Rangeland, Federal, State and Local**



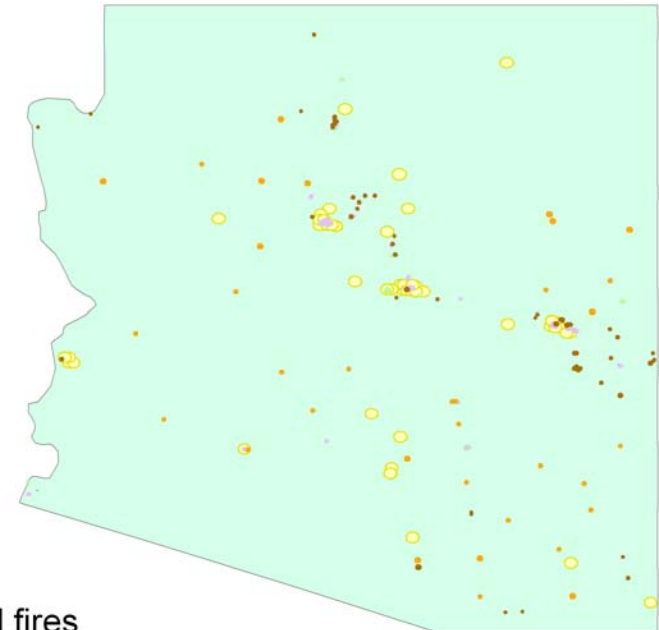
-  Fed/state/local fires
-  Non-Fed Rangeland
-  Agricultural

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

Arizona

**August and
September
2002**

Ground- and Satellite-based Fire

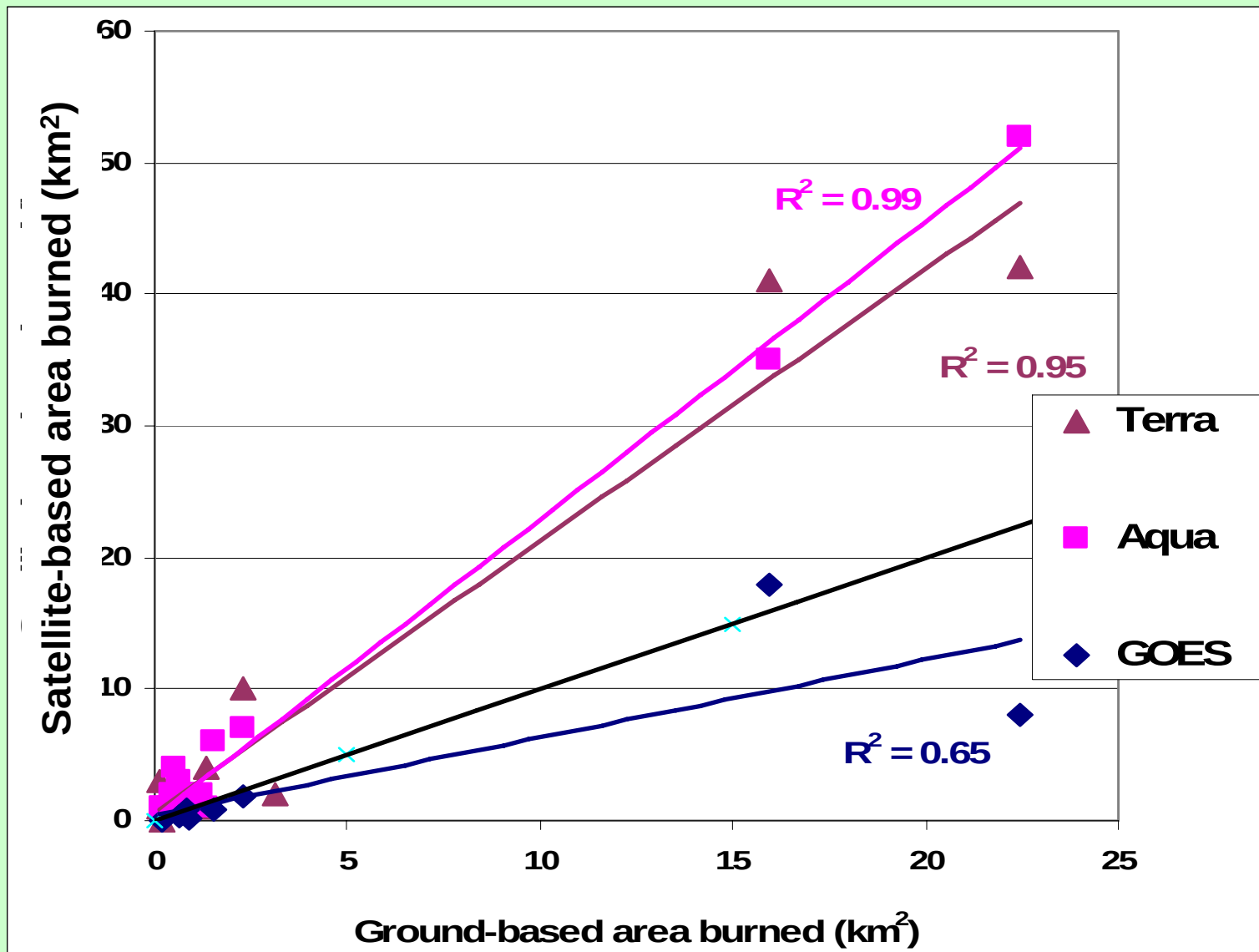


-  Terra
-  Aqua
-  GOES
-  Agricultural
-  Fed/state/local fires
-  Non-Fed Rangeland

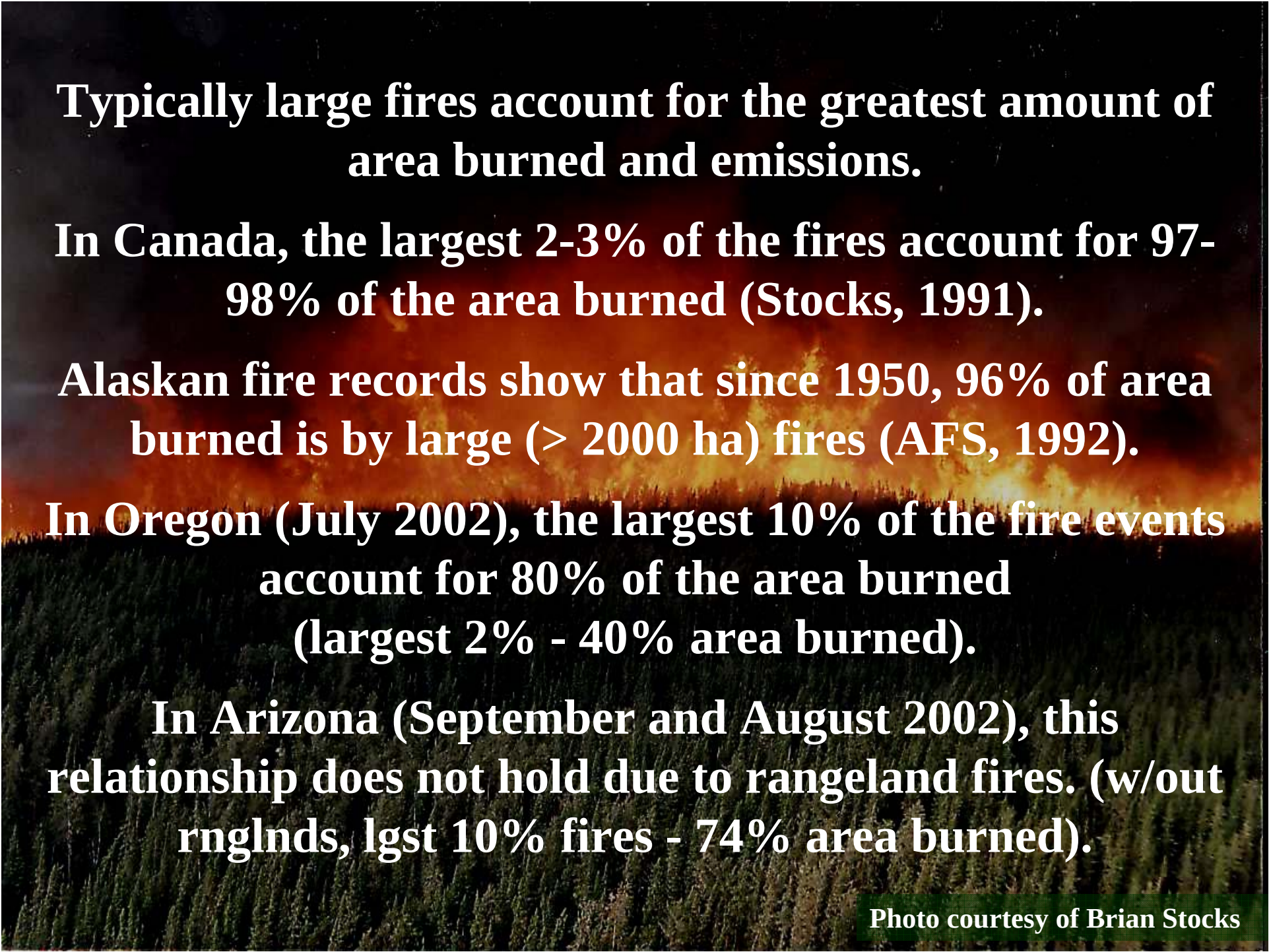
Data source	Number of records	Non-federal rangeland acres burned Non-federal Rangeland	Percent area burned, all data	% # fires coincident, % # without Rngeland,
GOES ABBA	169	7358 acres	18 % all (Instantaneous)	5%, 5%
MODIS Terra	168	31,877 acres (from detections)	77 % all (1km ² detection)	14%, 15%
MODIS Aqua	162	31,382 acres (from detections)	76 % all (1km ² detection)	12%, 12%
Arizona ground fire data, Non-federal rangeland	165 fires 201 records 34 non- fed range	22,613 acres mean 113 acres, range (0.5 - 1598) 18,750 acres	All sat. 171 %, Representative area 40%, w/out rangeland 69%	Combined satellite 20%

(1 km² = 247 acres or 100 ha)

Arizona: September and August, 2002
Coincident satellite- and ground-based fire data.
[wildfire, wildland fire use, prescribed burning in wildlands]



*** Note
difference
in axis**



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), this relationship does not hold due to rangeland fires. (w/out rnglnds, lgst 10% fires - 74% area burned).

Photo courtesy of Brian Stocks

Total area comparison using detections and instantaneous area, without coincidence consideration.

	MODIS Terra	MODIS Aqua	GOES instantaneous area	WRAP
Oregon	2761	1984	800	2113
Arizona	168	162	38	167

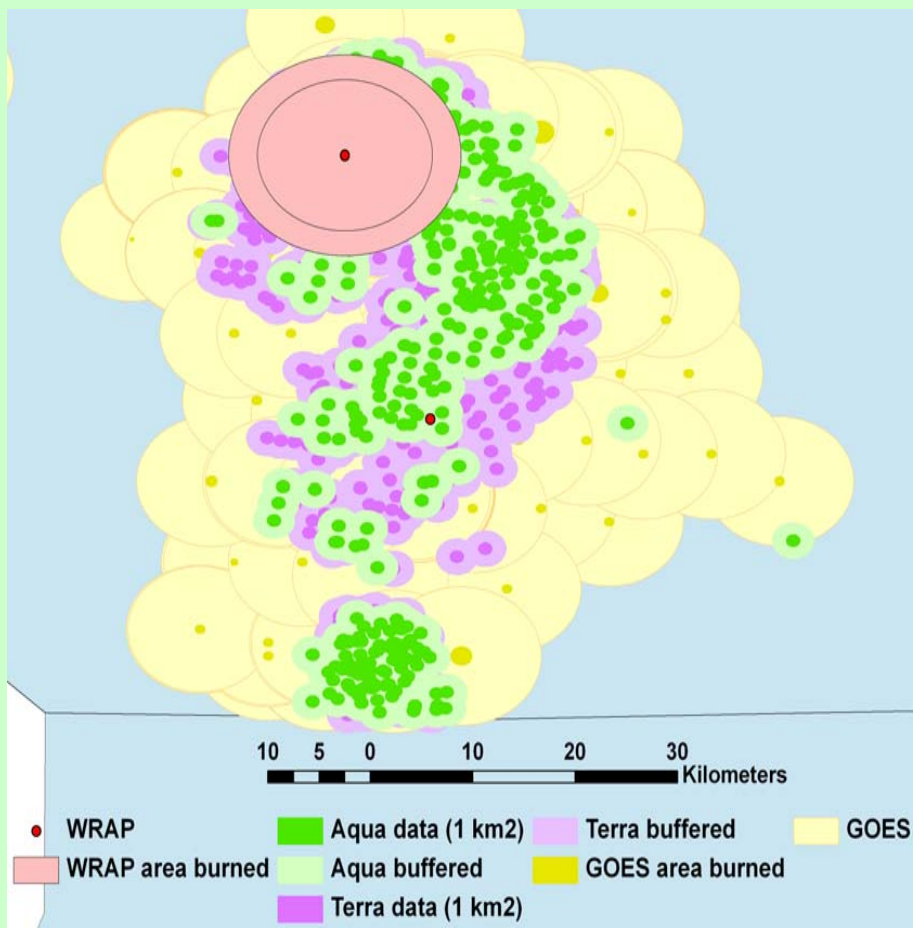
Total percent difference

Oregon	all MODIS 225% > WRAP	38% of WRAP
Arizona	all MODIS 197% > WRAP	23% of WRAP

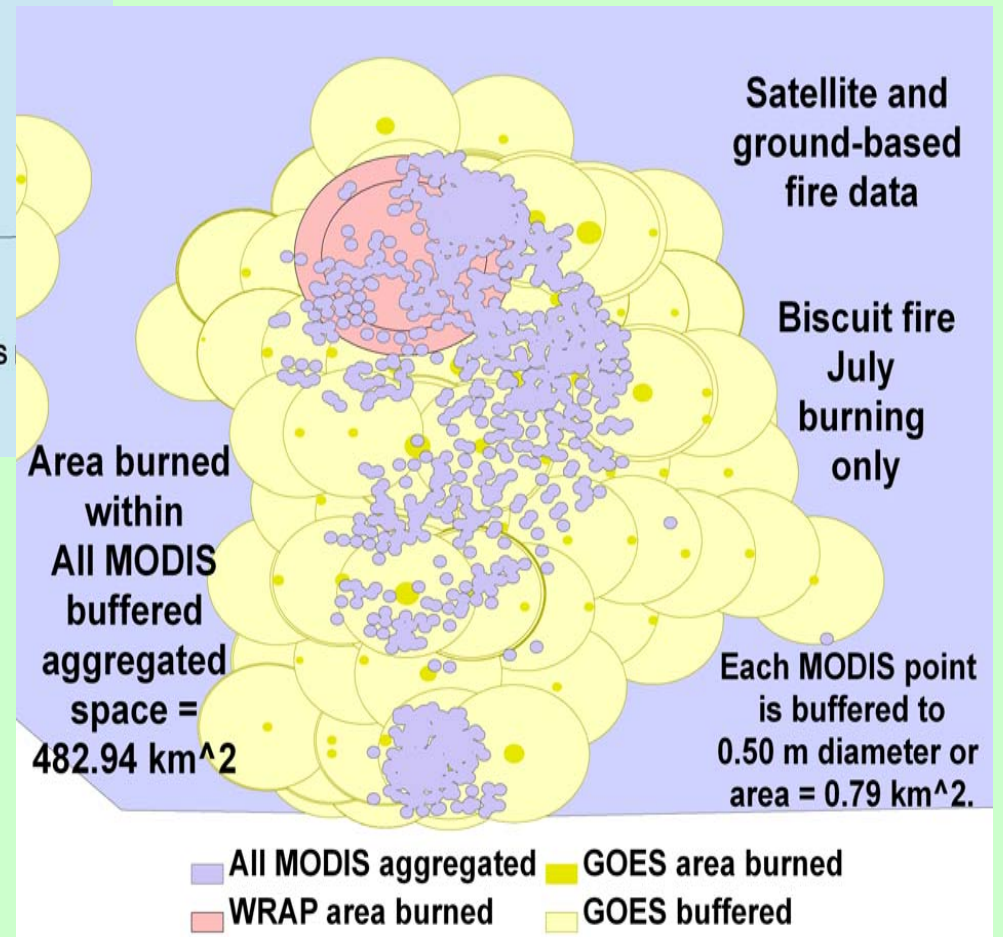
All values in Km²

Biscuit fire

July 2022 analysis



MODIS (Terra and Aqua) data Combined, buffered to 0.50 radius (1 pixel area = 0.79 km²) and aggregated (overlap removed).

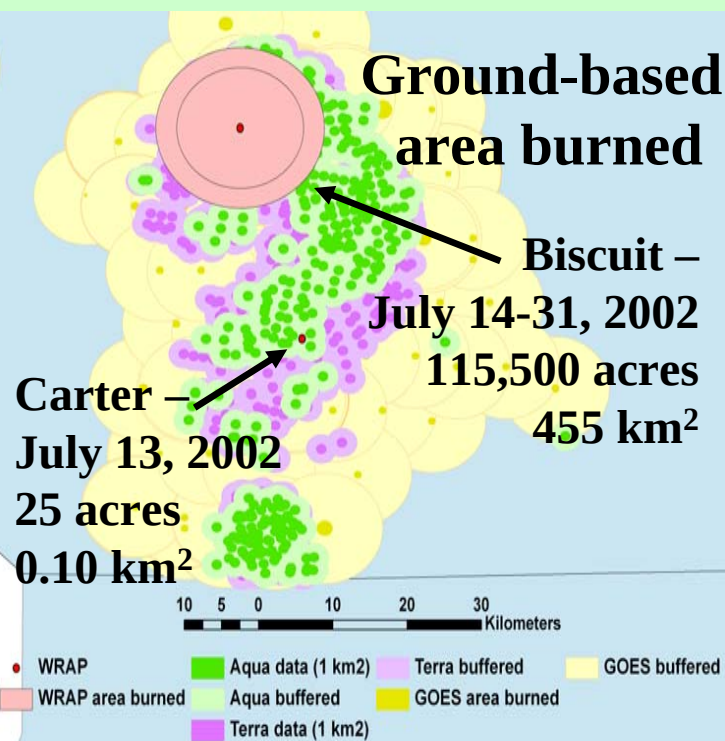


Evolution of the Biscuit fire

July 05, 2002

July 21, 2002

August 22, 2002

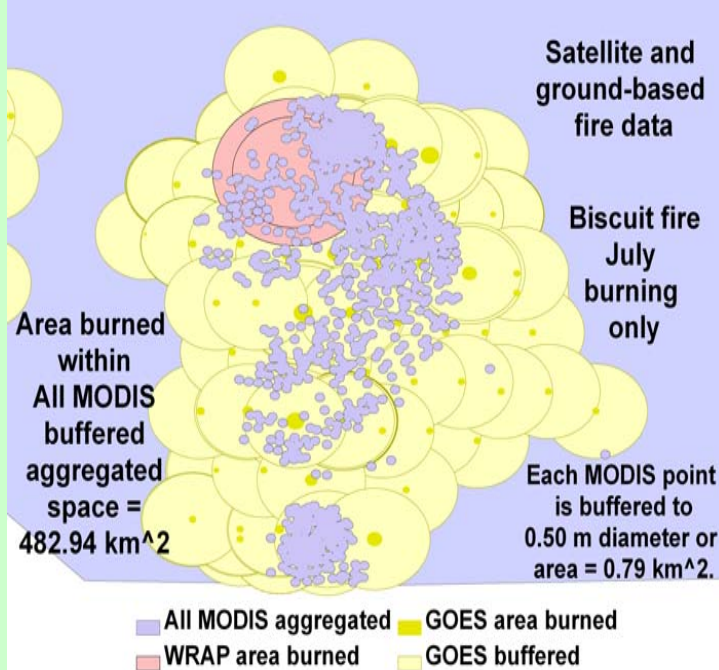


Fire detections
(1 detect = 1 km²)

Aqua
423 records
July 11-29, 2002

Terra
746 records
July 14-31, 2002
(MODIS 257% >)

GOES
231.79 km²
July 4-31, 2002 (51%)



Area burned product
482.94 km² (6% >)

July Analysis

Fire product generated from lessons learned:

**MODIS data combined, buffered and aggregated
plus
GOES data in agricultural lands x 5**

Total area captured:

**Arizona - 81% of all fires
(wildfire, prescribed and rangeland)**

**Oregon - 92% of all fires
(wildfire, prescribed and agricultural)**

Photo courtesy of Brian Stocks

MODIS area burned product

Total area captured:

Arizona - 81% of all fires (wildfire, prescribed and rangeland)

Oregon - 92% of all fires (wildfire, prescribed and agricultural)

Satellite and ground comparison

All data including non-coincident

**GOES
instantaneous**

	MODIS Terra	MODIS Aqua	area	WRAP
Oregon	2761	1984	800	2113
Arizona	168	162	38	167

Total percent difference

Oregon	all MODIS 225% > WRAP	38% of WRAP
Arizona	all MODIS 197% > WRAP	23% of WRAP

Photo courtesy of Brian Stocks

Conclusions

Oregon

53 % of the number of fires are identified by satellite

97 % of the combined area burned is identified by satellite

Total area comparison (coincident and non-coincident)

MODIS 225%; GOES 38 %

GOES identifies 34% of Agric. fires (Terra and Aqua < 2%)

Arizona

20 % of the number of fires are identified by satellite

69 % of the area burned is identified by satellite

Total area comparison (coincident and non-coincident)

MODIS 197 %; GOES 23 %

Total area captured with a combined product:

Arizona - 81% of all fires (wildfire, prescribed and rangeland)

Oregon - 92% of all fires (wildfire, prescribed and agricultural)

Ultimately, biomass 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.

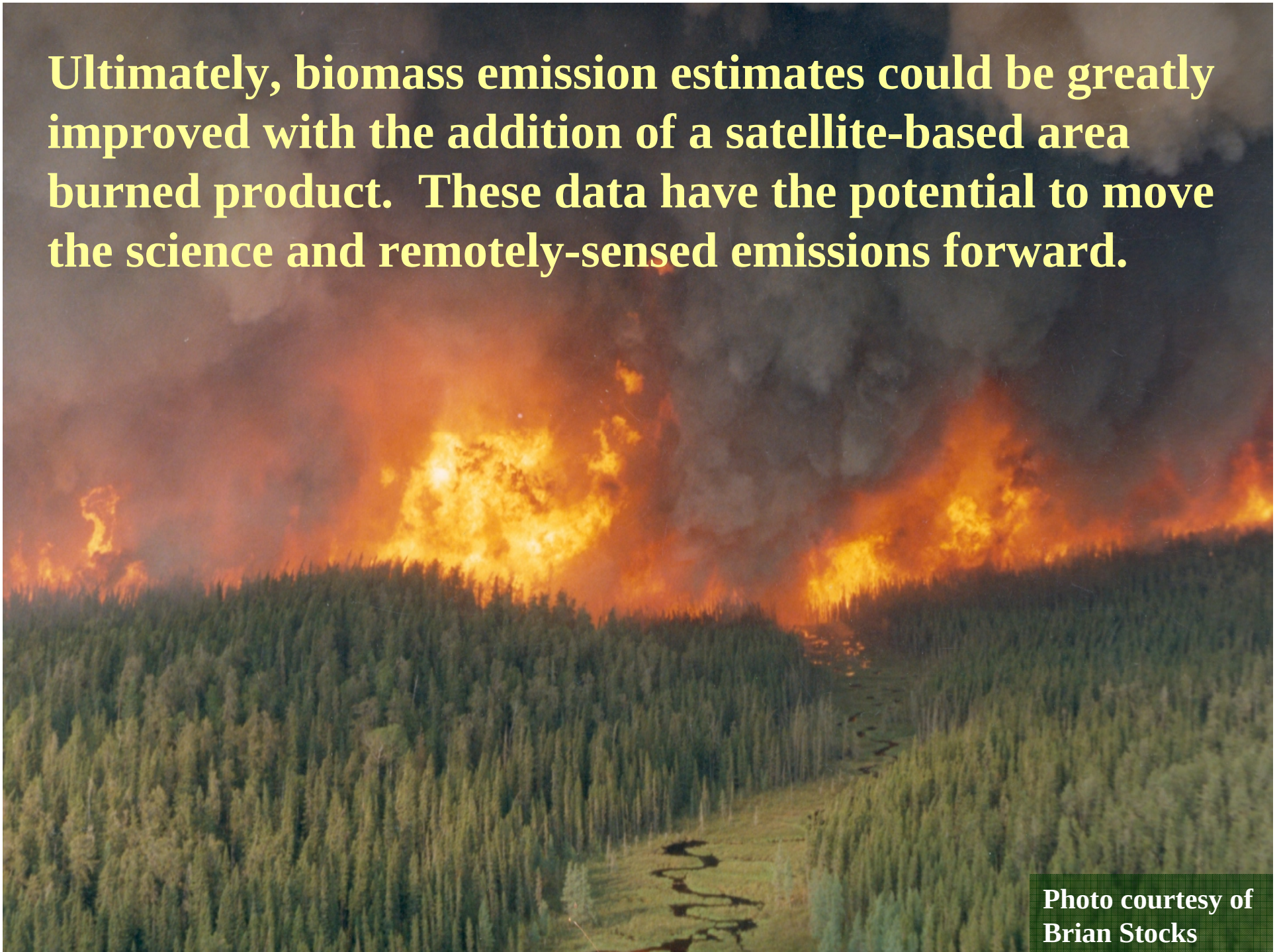


Photo courtesy of
Brian Stocks



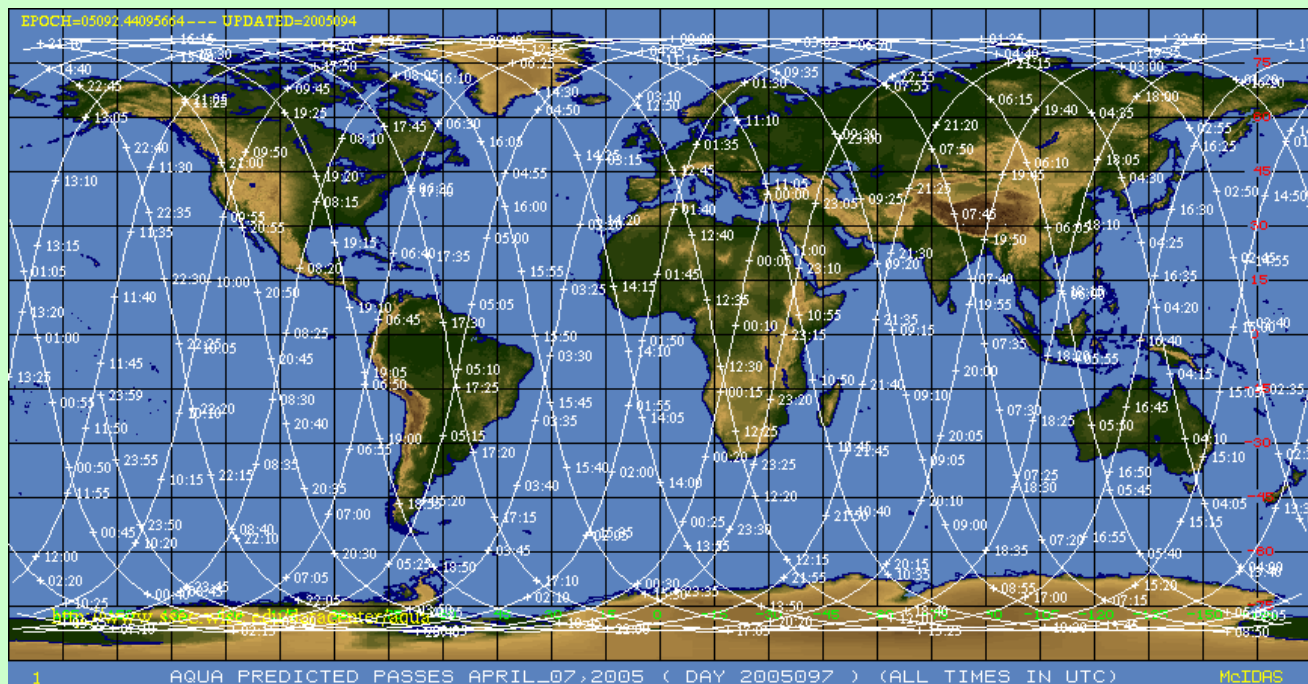
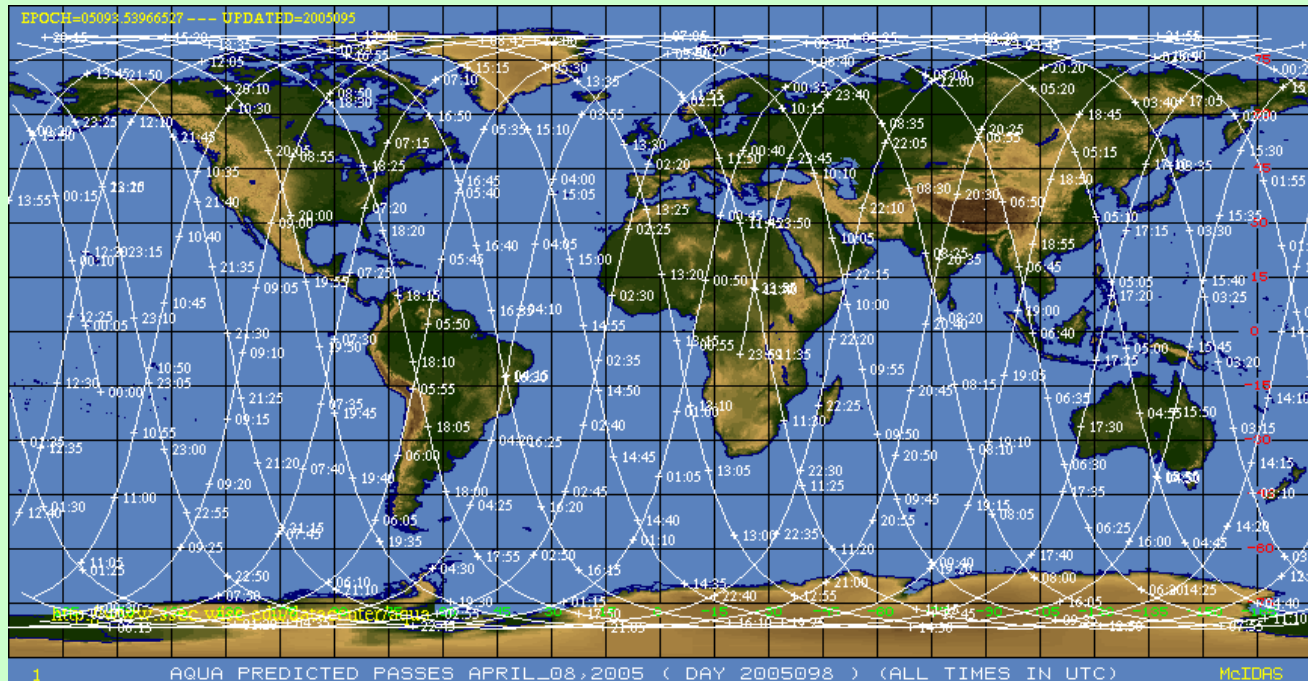
Acknowledgements

Elaine Prins and Chris Schmidt

**NASA Langley Research Center, Environmental
Protection Agency, Regional Planning
Organizations, NOAA, Air Sciences Inc.,
SSAI, Sonoma Technologies and
National Institute of Aerospace**

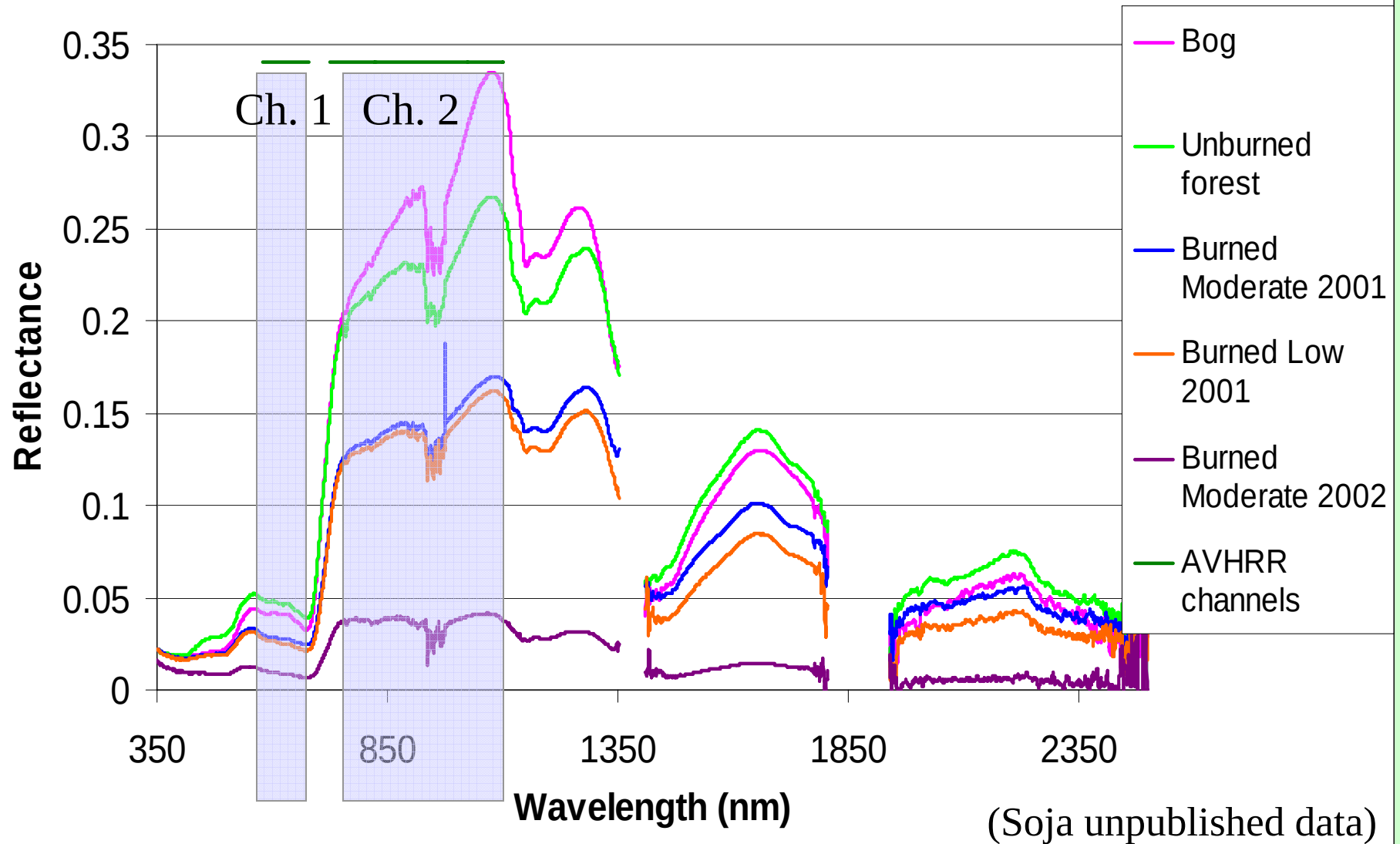
MODIS Aqua

Predicted Sequential Orbit

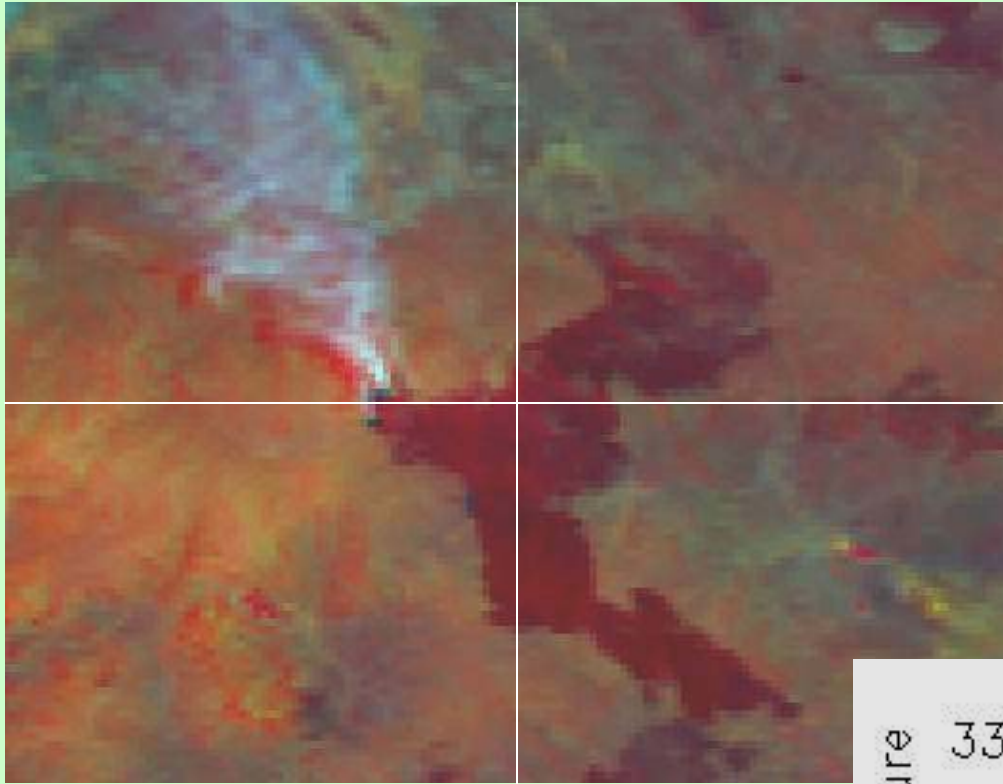


Average Spectra from Helicopter: Yartsevo 2002

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



Active Fire Detected by AVHRR channel 3 (3.7 μm)



Considerations

Clouds prohibit detection.

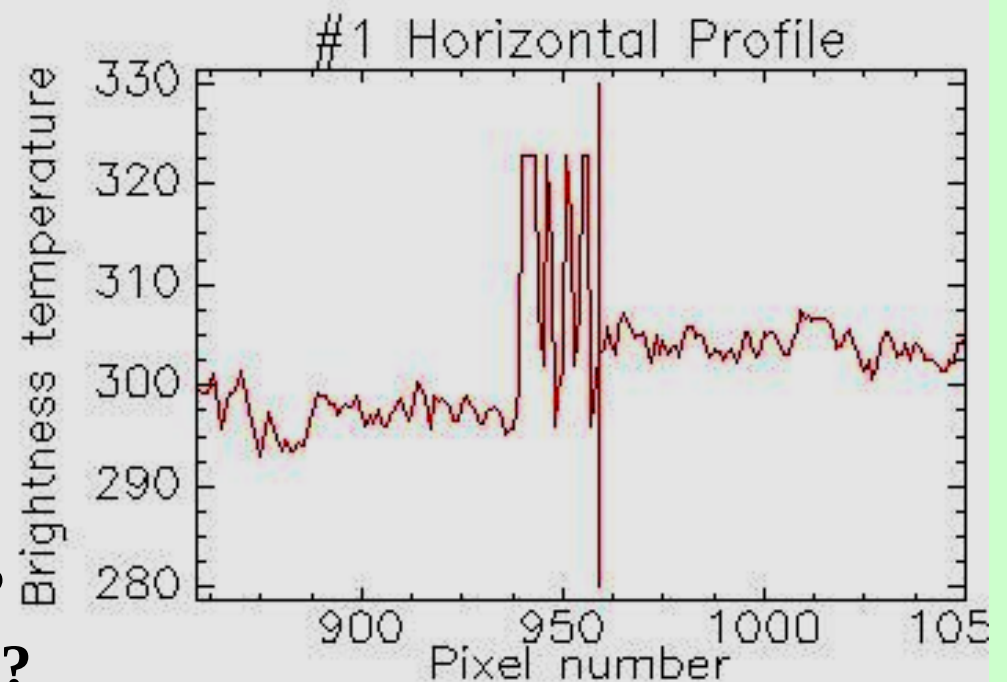
Fire size?

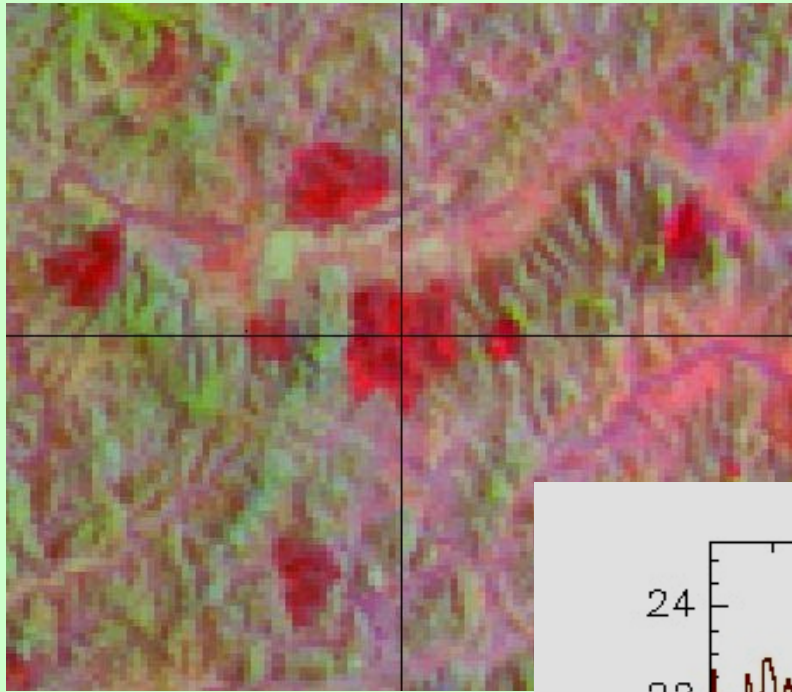
Fire intensity?

Viewing angle of satellite?

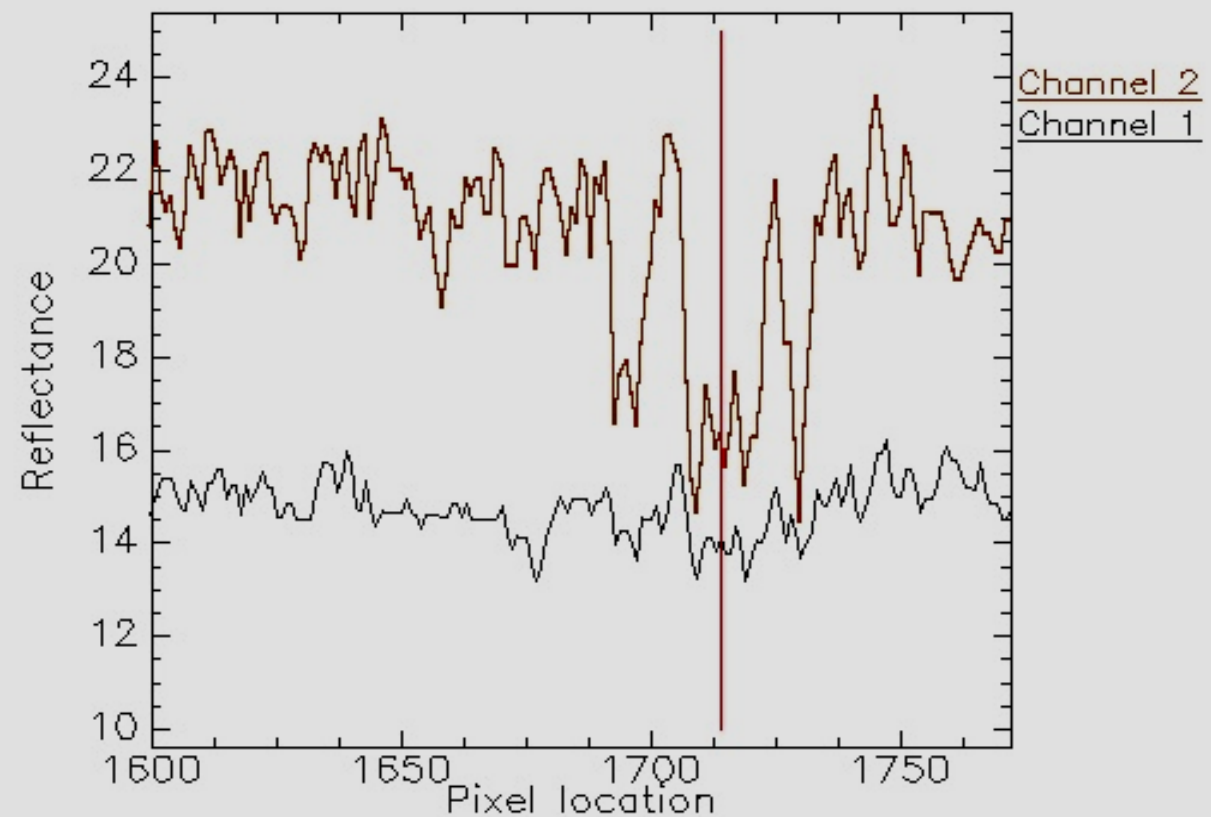
Instrument spatial resolution?

Instrument temporal resolution?





Identifying burn scars in AVHRR imagery



Total Biscuit fire

3077 km² or 769,338 acres

Terra 2672 Aqua 1475

26% greater, keeping in mind Aqua 1st started recoding in July