Long-term Inventory of Fire Burned Areas and Emissions of North America's Boreal and Temperate Forests

P.Gong, Z. Li, I. Csiszar, W. Hao, R. Fraser
J.Z. Jin, R. Pu

Objectives

1. Map burn scars in boreal and temperate forest between 1985-2000 using NOAA AVHRR data for the US and Canada
2. Estimate forest fire emissions during the corresponding period

Acquisition of historical 1-km AVHRR data (level 1b)

Acquisition of 1-km AVHRR data

- Source: NOAA Satellite Active Archive (SAA)
  - HRPT: direct-readout (50-60 MB/scene)
  - LHRR (LAC): recorded onboard satellite (20-30 MB/scene)
    - level-1b data files
  - all files acquired and archived for November 1988 - March 1994 and January 1995 - December 1999
    - data stored on 35GB DLT tapes (2 months/tape)
  - all May - October data have been transferred to Berkeley
  - all months transferred to Berkeley for 1996 and 1999

Acquisition of 1-km AVHRR data (cont.)

- Source: Canada Center for Remote Sensing
  - HRPT from Prince Albert receiving station
    - coverage over most of North America
    - NATAS CEOS format
  - all months from 1994 available
- Source: NOAA National Climatic Data Center (NCDC)
  - May 1985 - October 1988 period
  - 80% discount negotiated ($6/scene)
  - for May-October: ~3000 scenes; $18000
  - under consideration

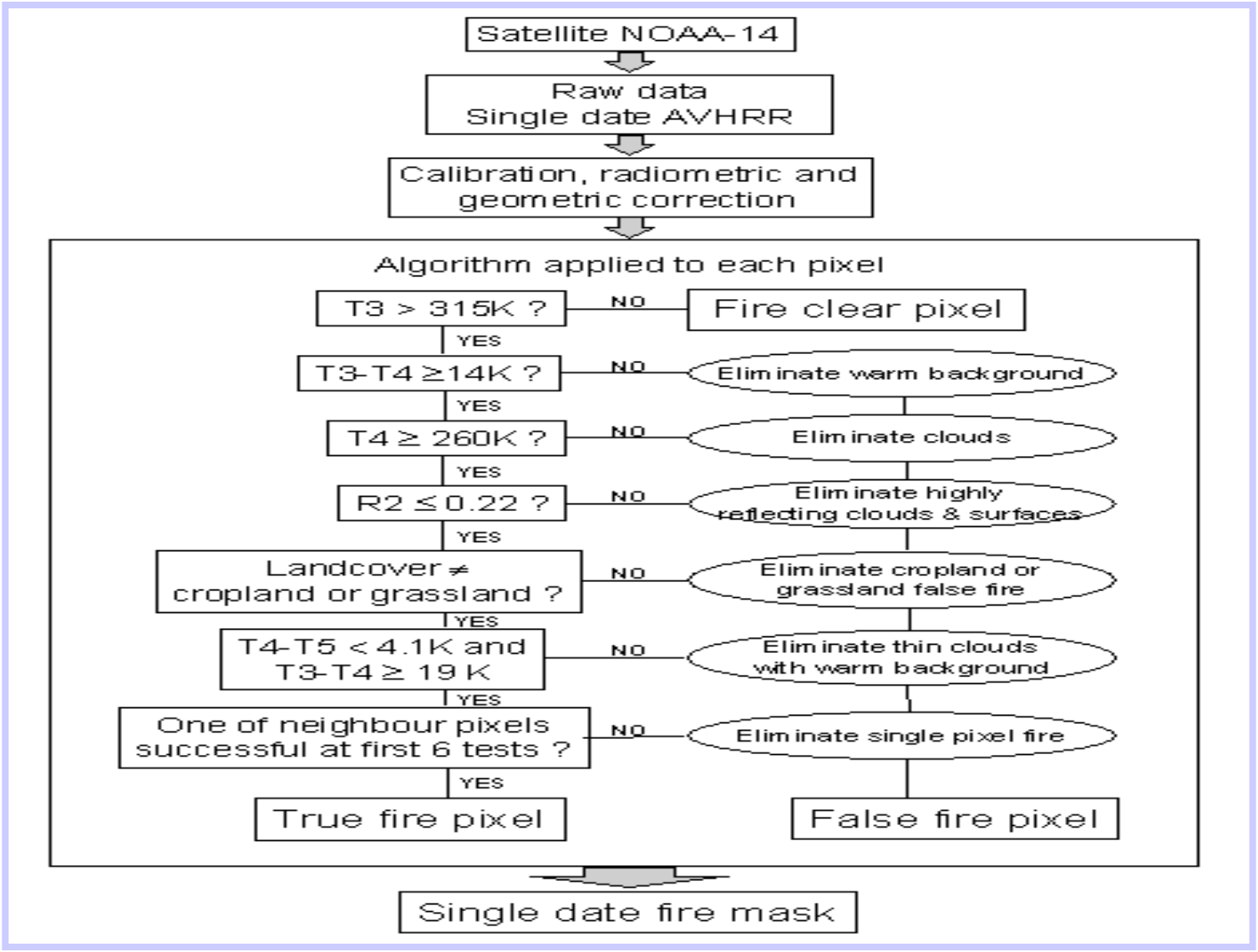
Processing of historical 1-km AVHRR data (level 1b)

Progress

- Over 1000 GCP chips added for the US to Geocomp-N
- Years of data processed
  - By October 17, 2001, we have processed the following daily AVHRR data for the entire US and Canada:
  - 2000, Apr-Oct;
  - 1999, Jun-Oct; 1998, May-Oct; 1997, May-Oct;
  - 1996, Jan-Dec; 1995, May-Oct; 1993, May-Oct;
  - 1992, May-Oct; 1991, May-Aug; 1989, May-Oct;
  - For data processing rate, one day AVHRR covering the entire NA needs ~3h (geocoding and composite) + .5h (hotspot detection
  - 1.2h (for HANDS running for burn scar mapping).

CCRS algorithm adaptation to the US and Canada

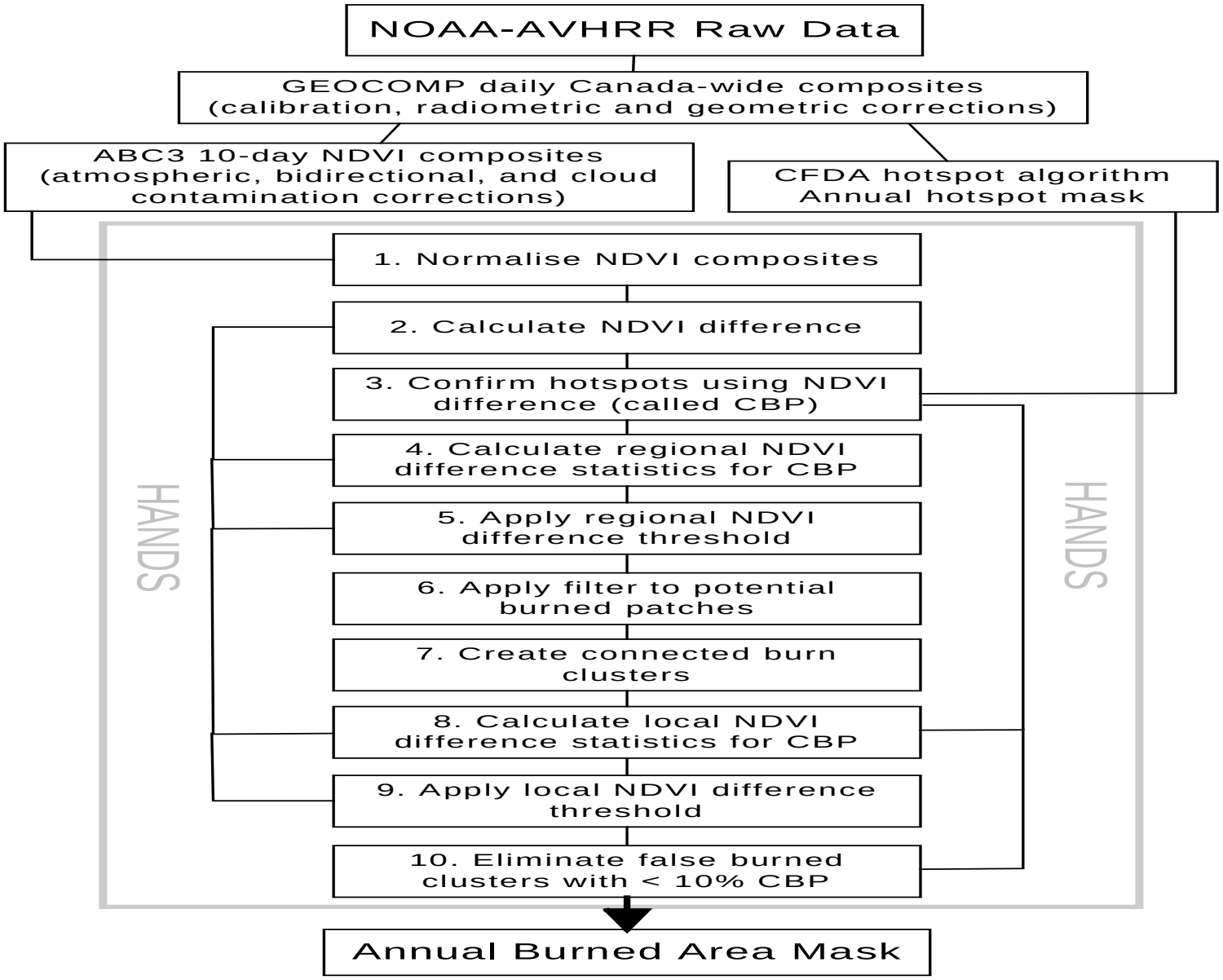
Fire Detection Algorithm



Li et al. (Int. J. Rem. Sen., 2000)

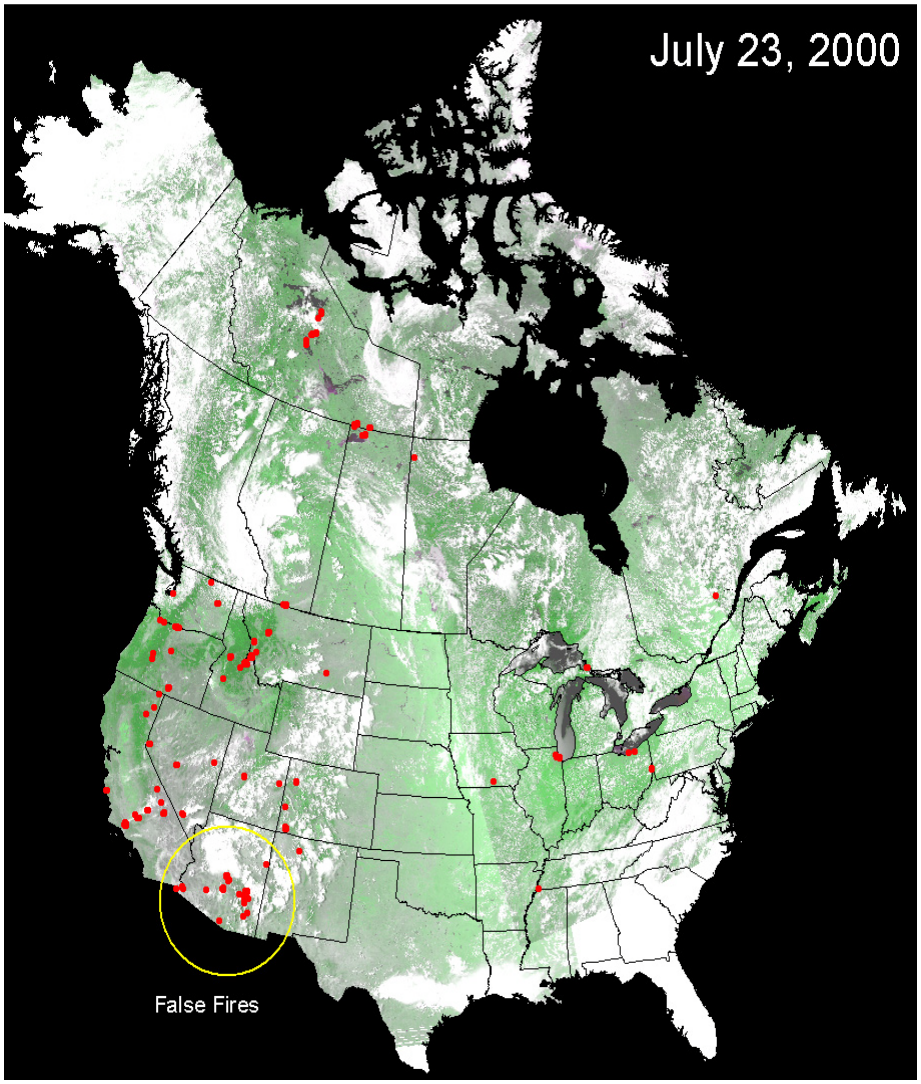
Burned-scar Mapping Algorithm

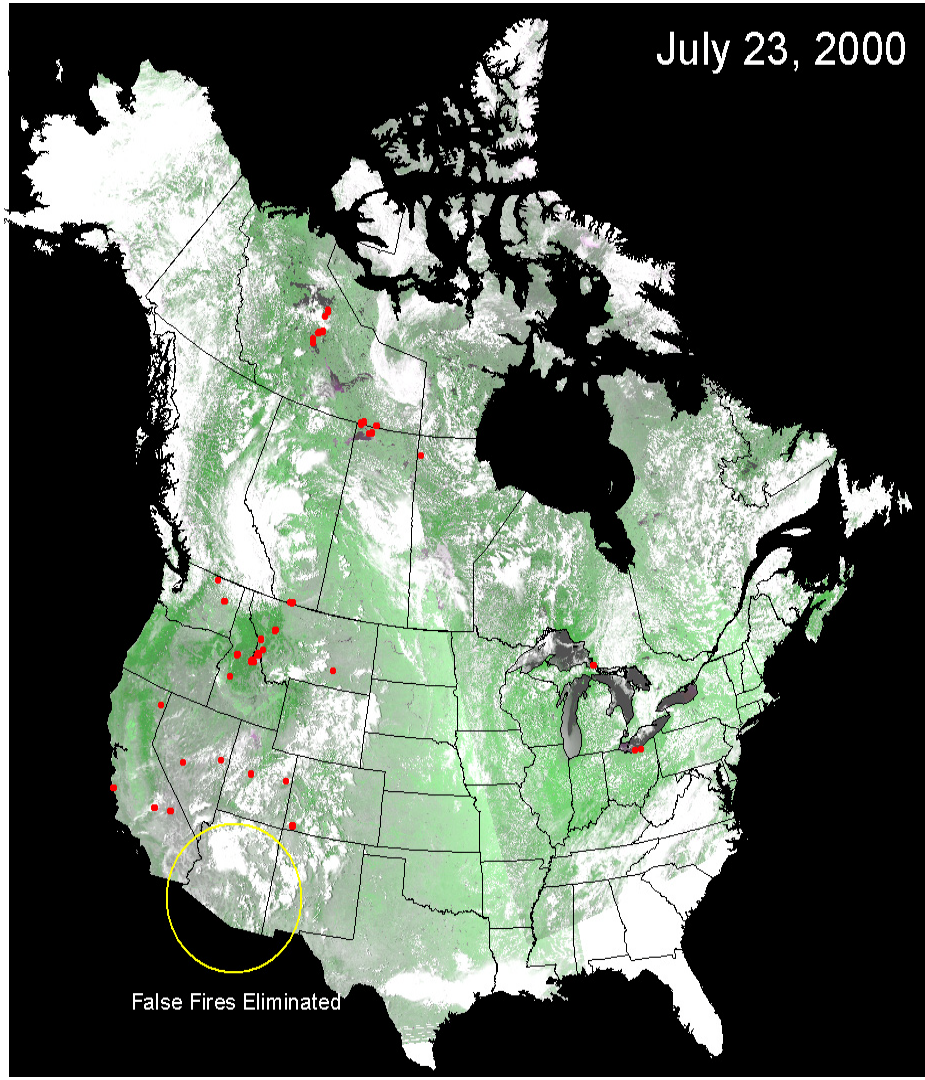
Figure 1



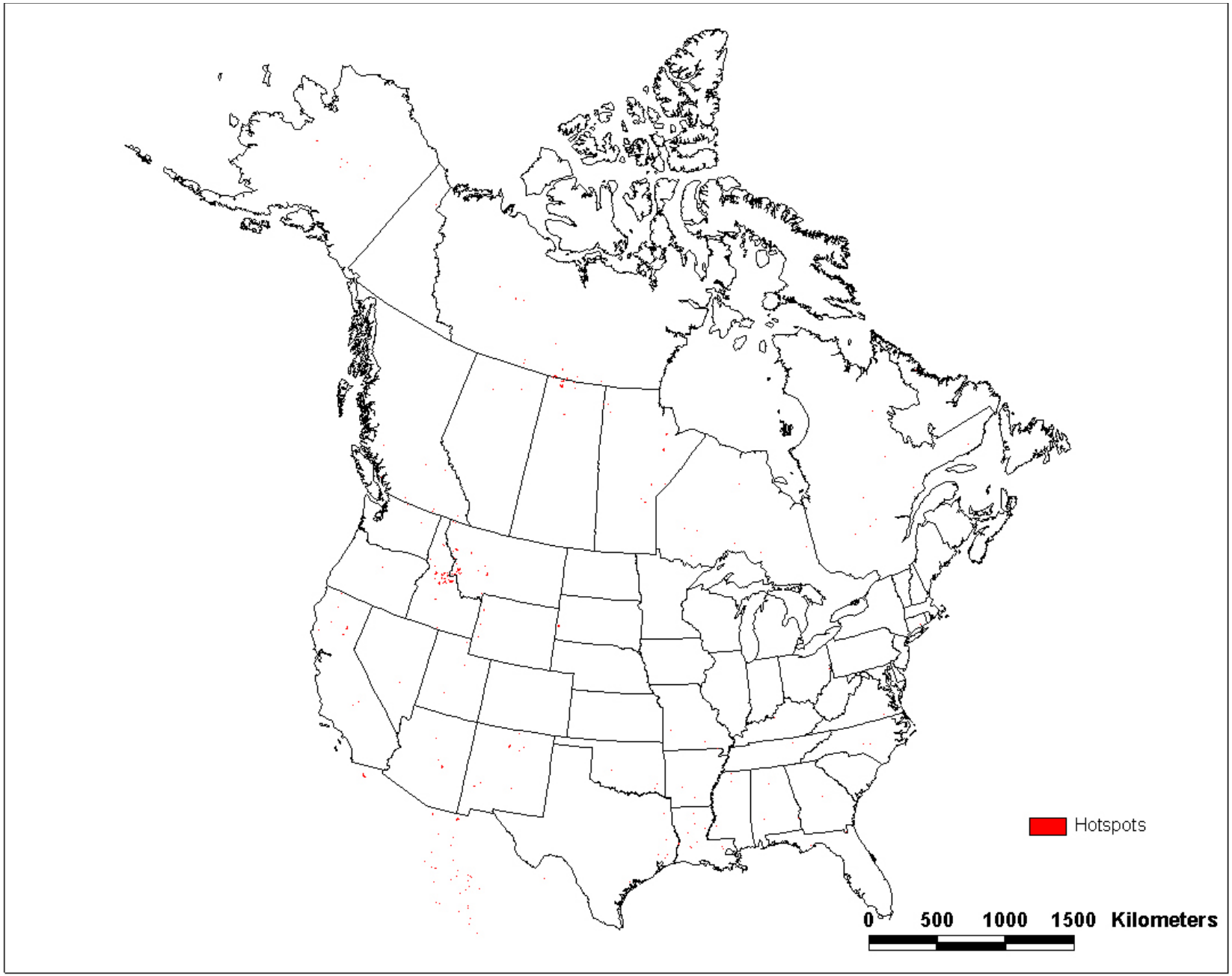
Fraser et al. (Rem. Sens. Env., 2000)

Comparison of the original and modified fire detection algorithms

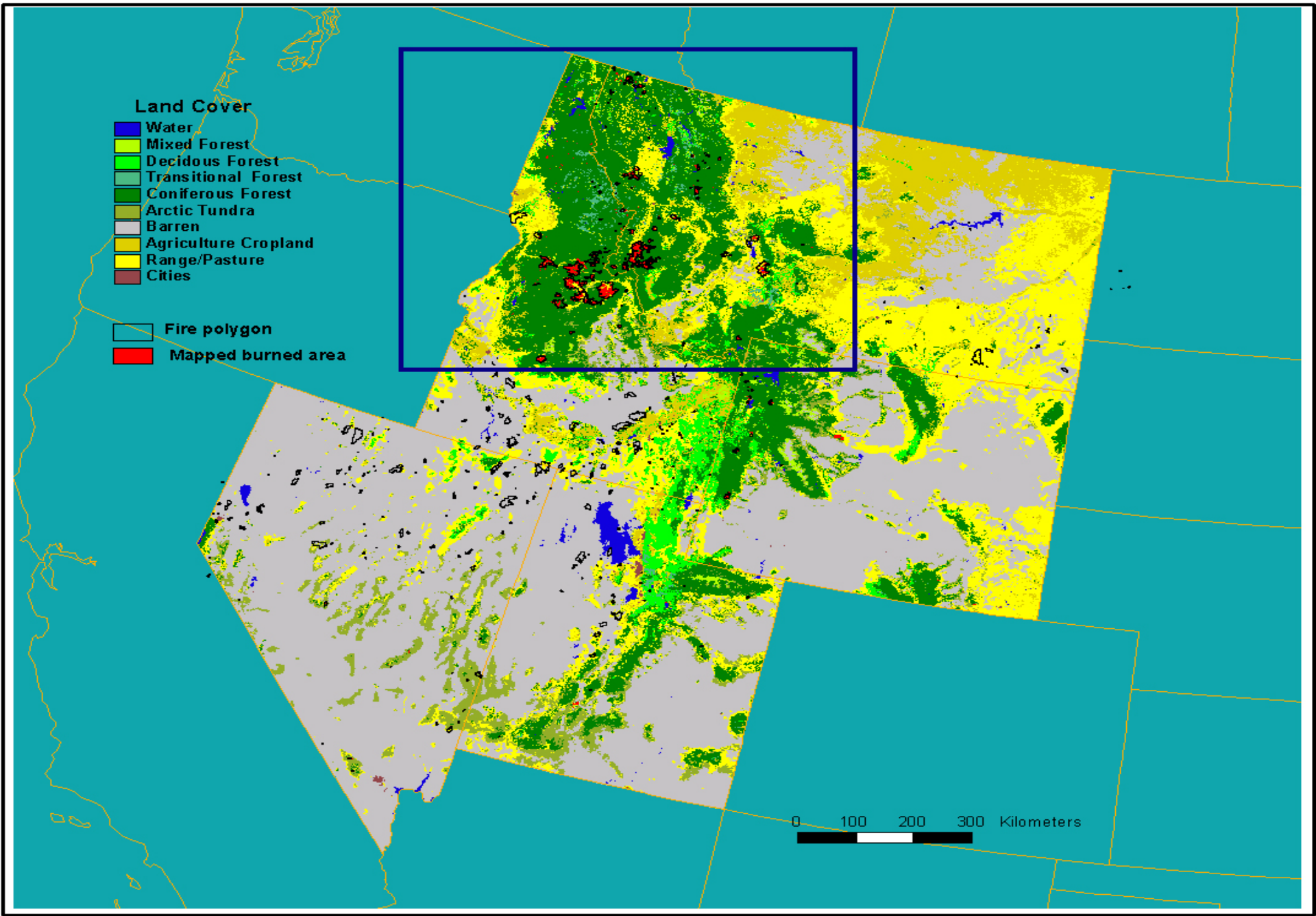




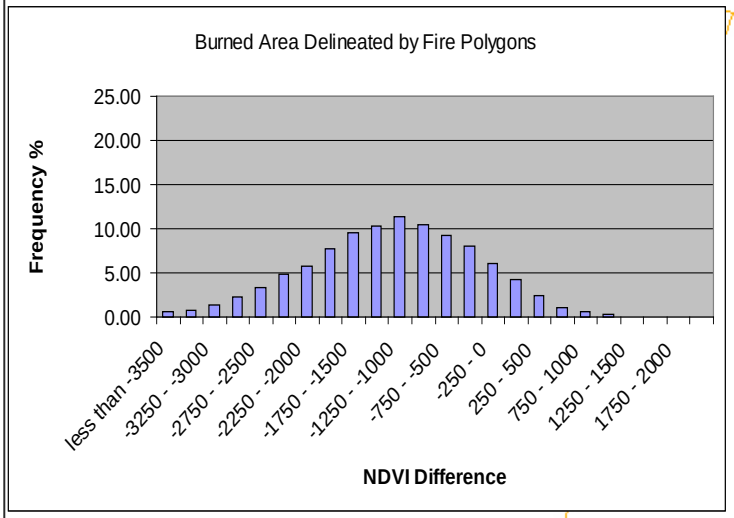
Fire Hot Spots Detected in 2000



Comparison between Satellite and Ground based Mapping of Burned Area in 5 States



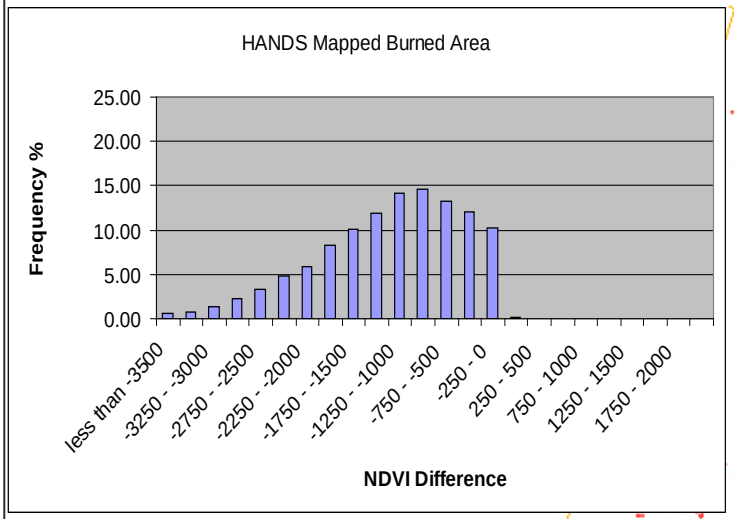
NDVI Statistics of Ground-based Mapping of Burned Area over Forests



State Boundary
Fire polygon

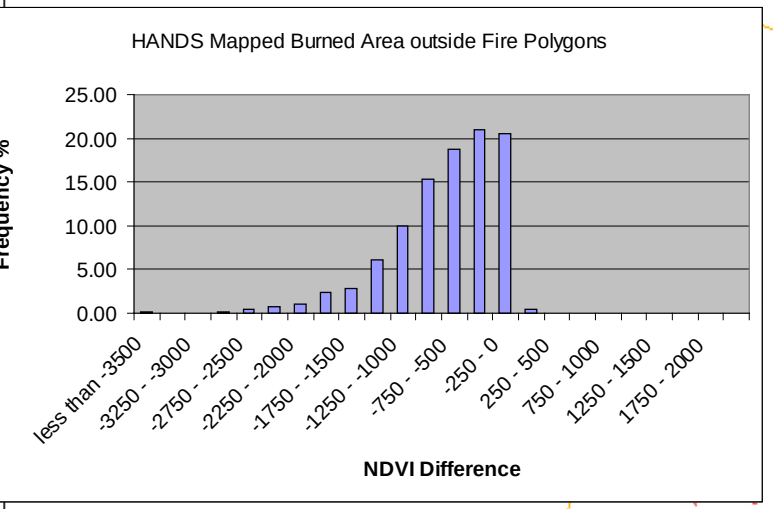
50 0 50 Kilometers

NDVI Statistics of Satellite-based Mapping of Burned Area over Forest Regions



State Boundary
Fire polygon

50 0 50 Kilometers

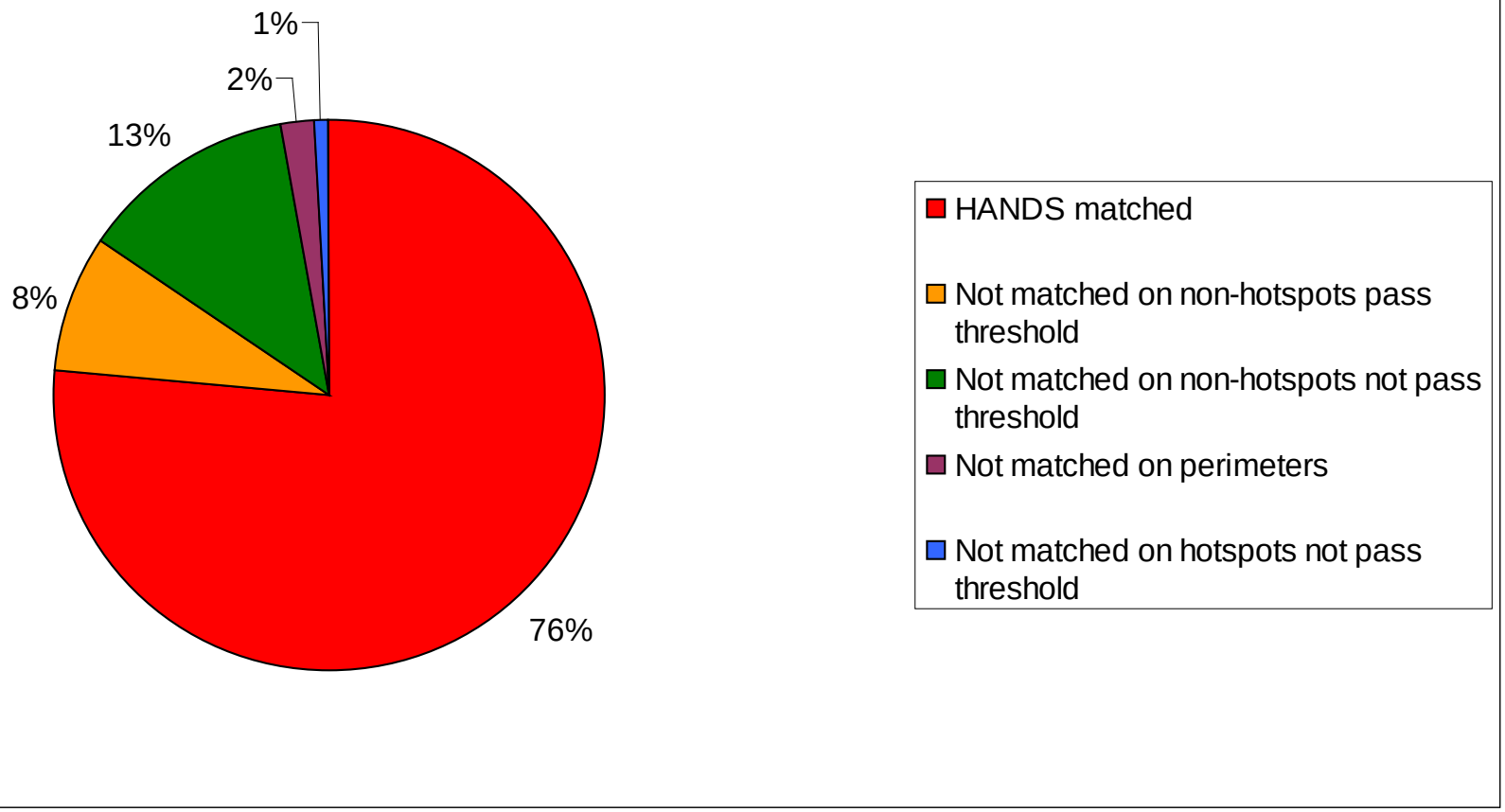


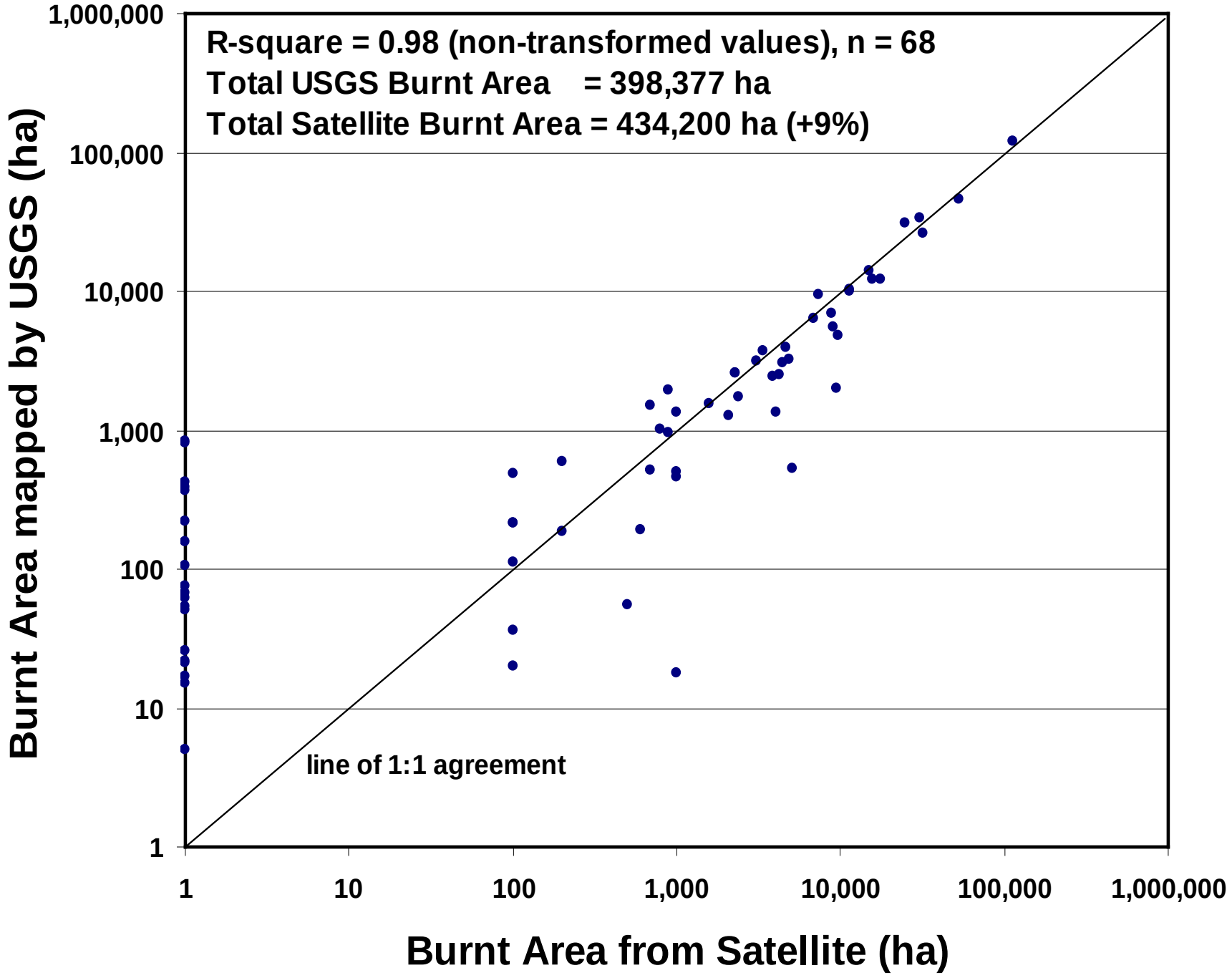
NDVI statistics of burned area mapped by satellite but not by ground.

State Boundary
Fire polygon

50 0 50 Kilometers

HANDS Burned Area Mapping within USDA FS Fire polygons



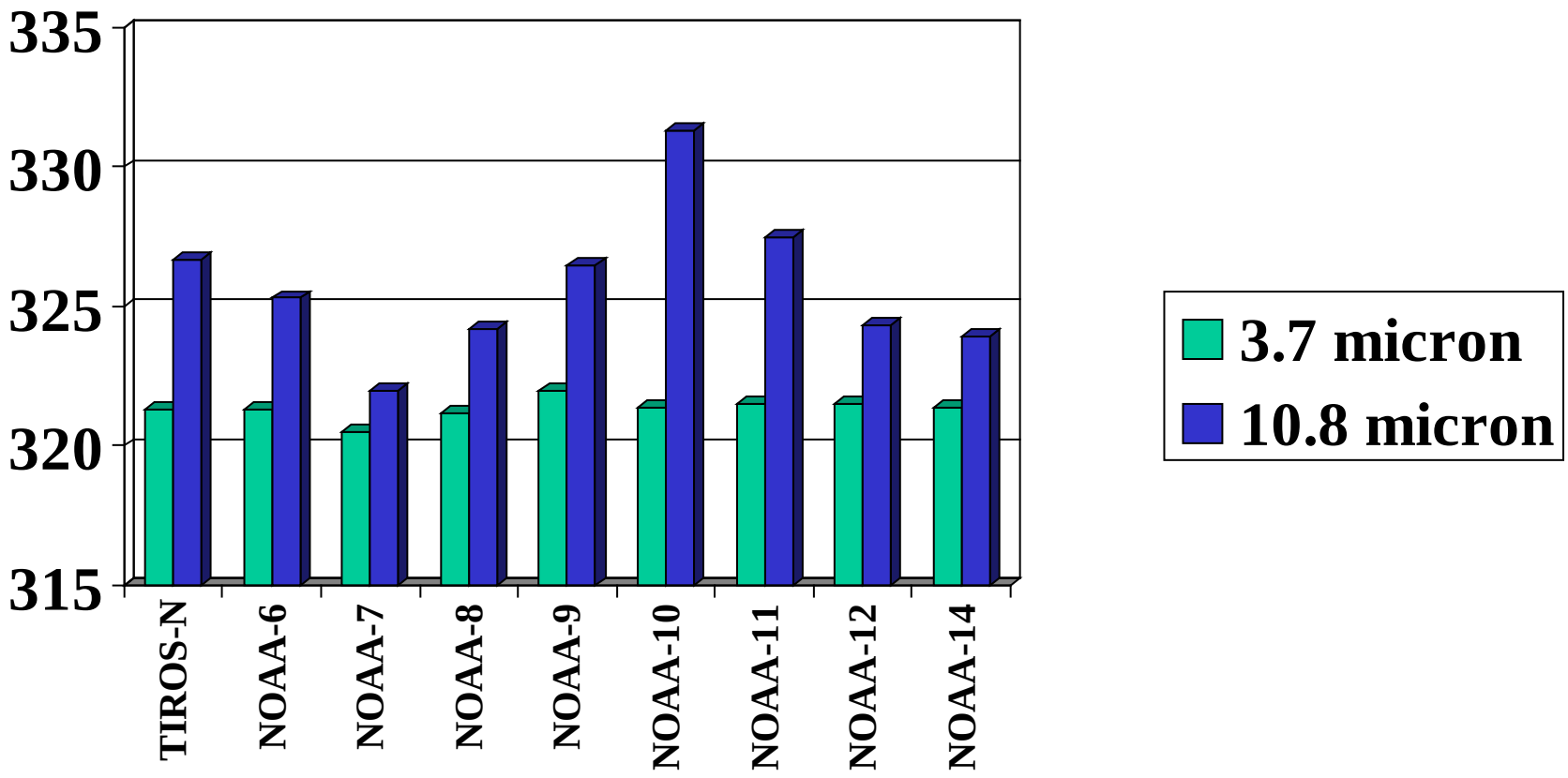

R-square = 0.98 (non-transformed values), n = 68
Total USGS Burnt Area = 398,377 ha
Total Satellite Burnt Area = 434,200 ha (+9%)
line of 1:1 agreement
Burnt Area mapped by USGS (ha)
Burnt Area from Satellite (ha)
1,000,000
100,000
10,000
1,000
100
10
1
1
10
100
1,000
10,000
100,000
1,000,000

Algorithm issues related to long-term processing

Active fires: homogeneous data record

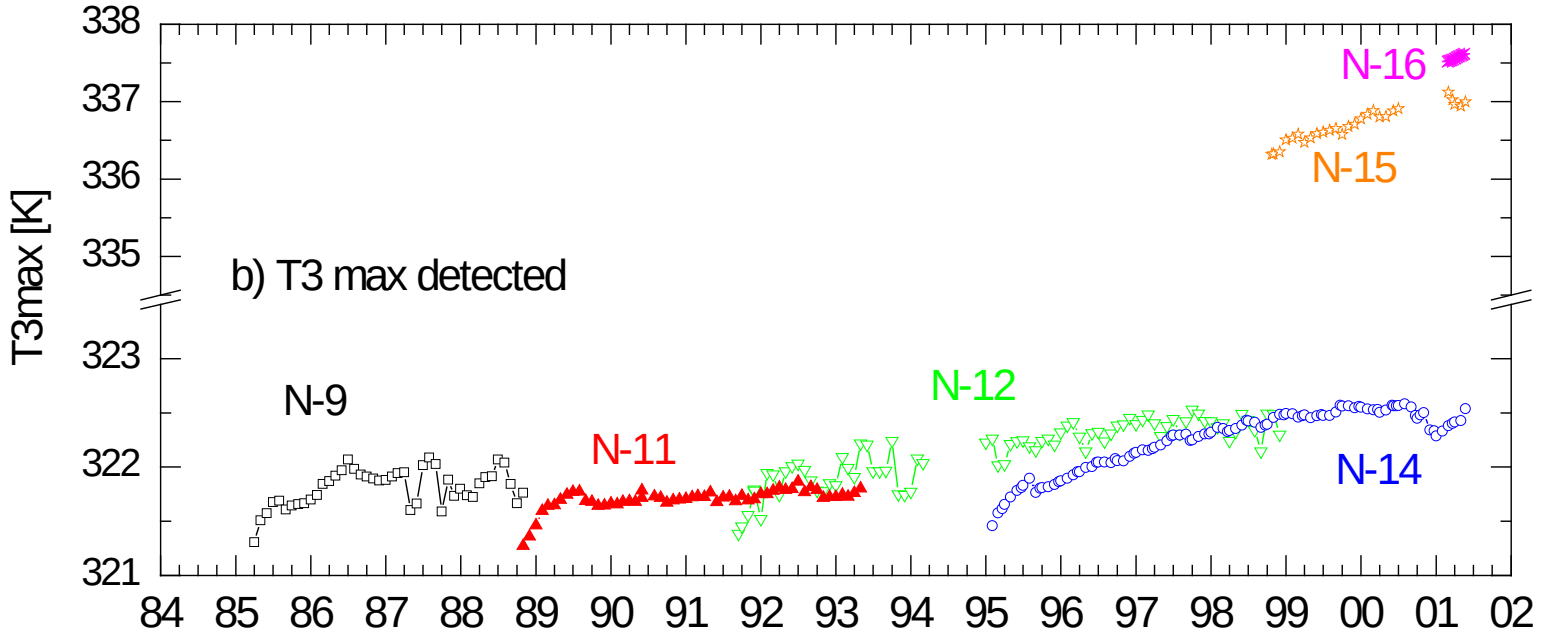
- Minimize and stabilize omission and commission errors over the entire period
- 1. Changes in instrument characteristics (inter-satellite and sensor degradation)
  - AVHRR channel 3 saturation temperature
- 2. Changes in background conditions from orbital drift and natural inter-annual variability
  - time series of background MIR and TIR brightness temperatures

AVHRR pre-launch saturation temperatures



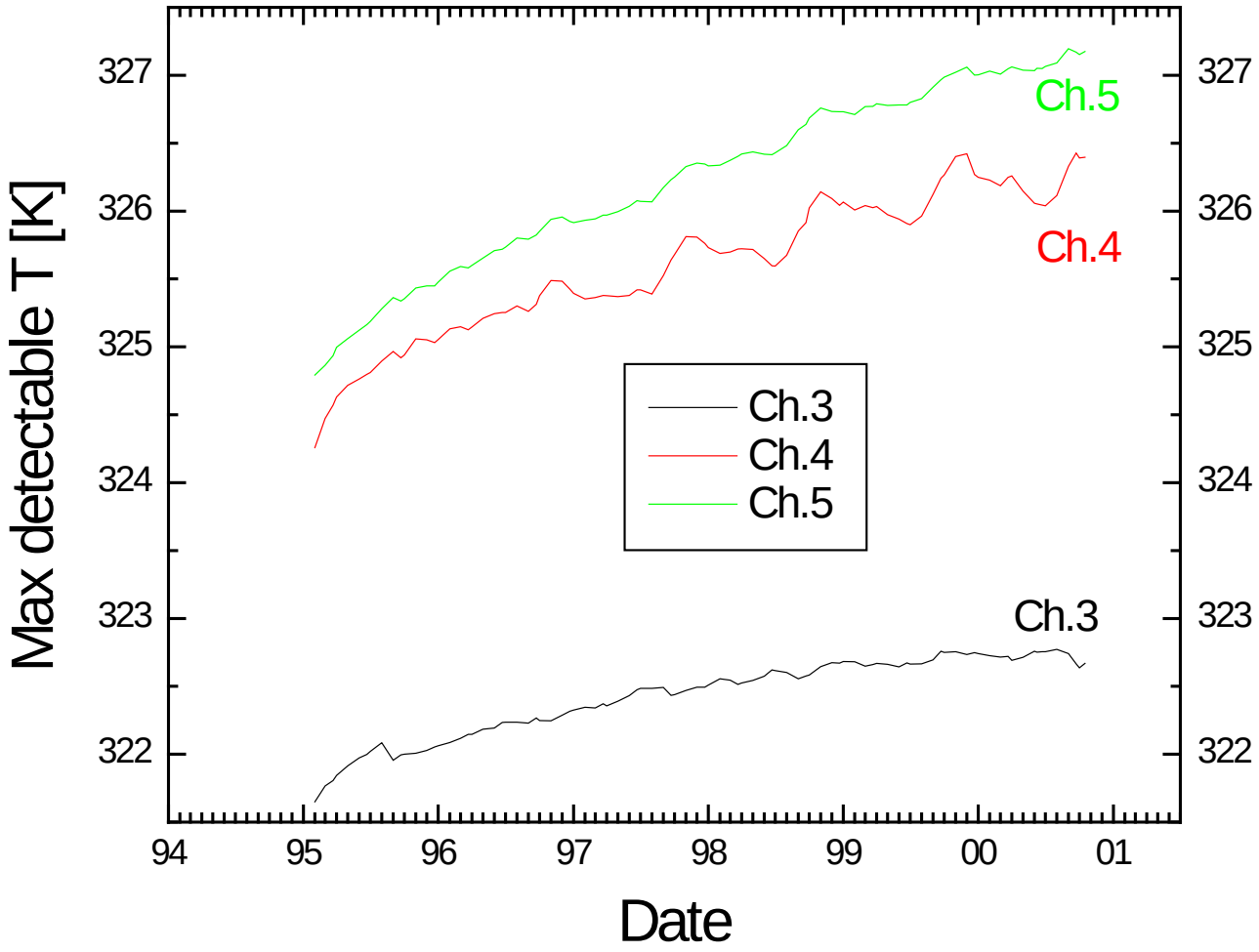
Csiszar, I. and J. Sullivan, On the saturation temperatures of the 3.7 μm sensors of the Advanced Very High Resolution Radiometer (AVHRR) on board the TIROS-N to NOAA–14 satellites. Submitted to Remote Sensing Letters.

Maximal detectable temperature in ch.3 (B)



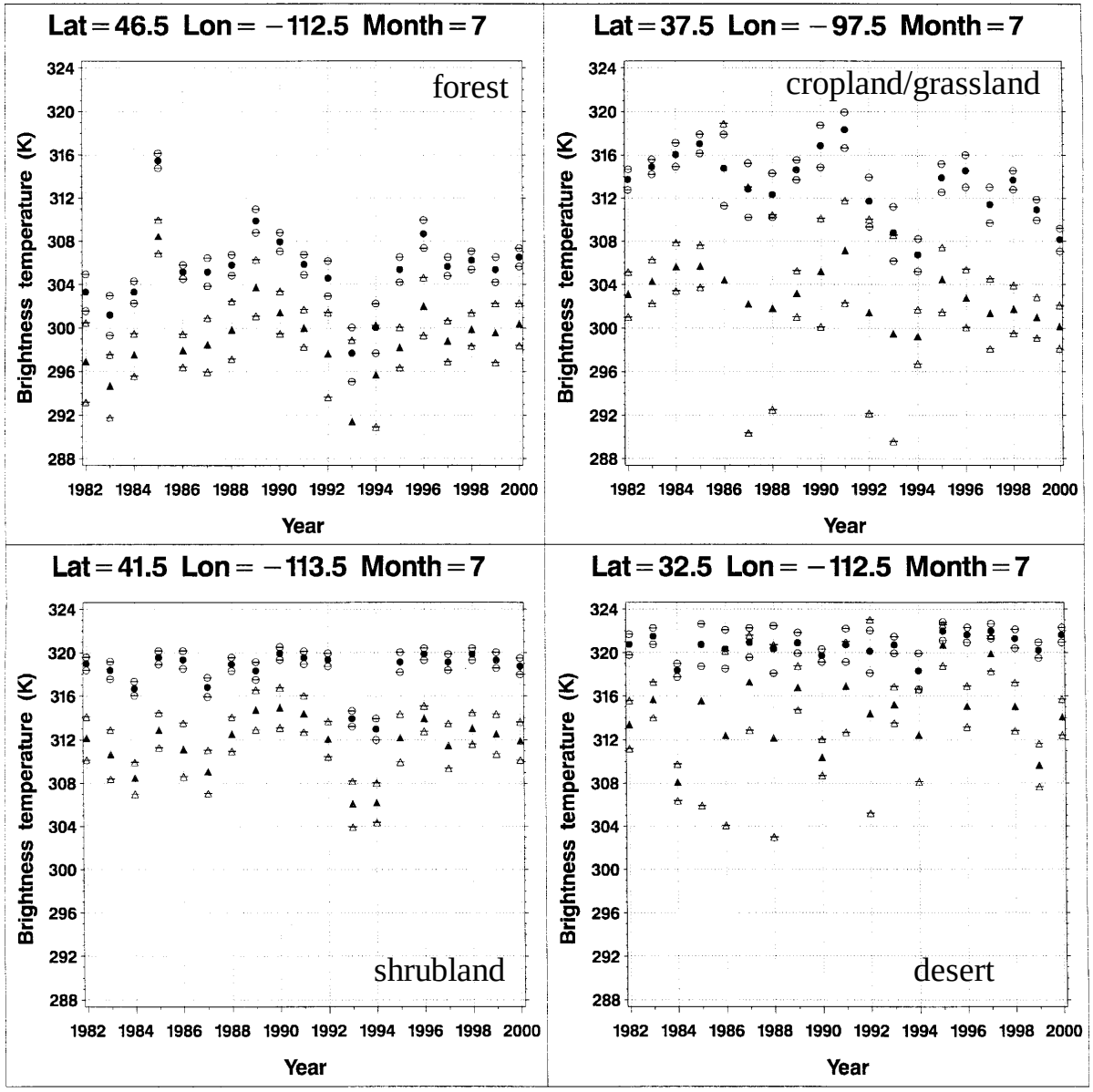
Trishchenko A.P., and Z.Li, 2001: Internal consistency, consequences of solar blackbody contamination and temporal trends in the calibration of AVHRR's thermal channels. Proc. of IAMAS 2001. Abstracts. Innsbruck. 2001. p. 59.

Maximal detectable temperatures for AVHRR/NOAA-14. HRPT Prince Albert scenes



Trishchenko A.P., and Z.Li, 2001: Internal consistency, consequences of solar blackbody contamination and temporal trends in the calibration of AVHRR's thermal channels. Proc. of IAMAS 2001. Abstracts. Innsbruck. 2001. p. 59.

Changes in background conditions



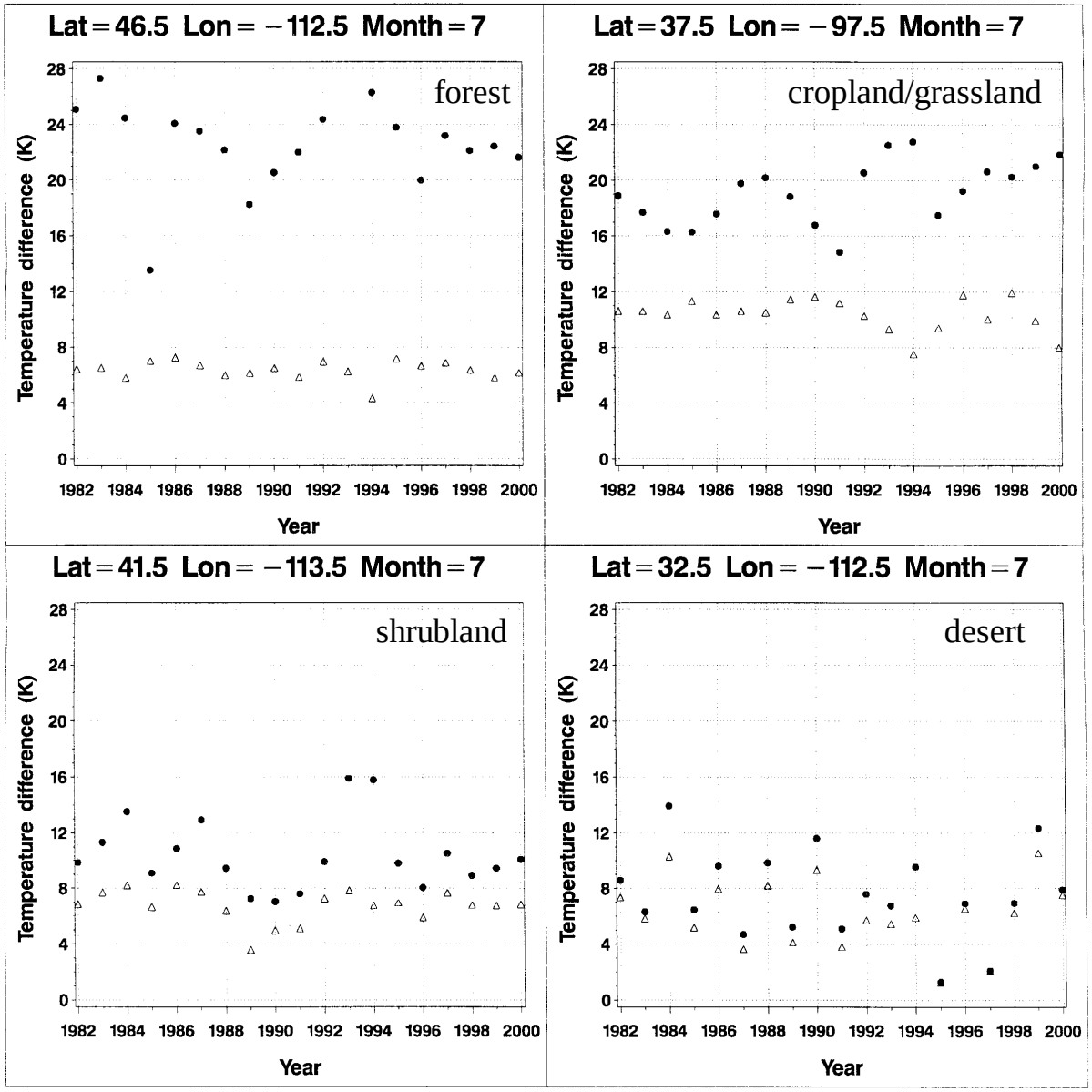
From Pathfinder Atmosphere 1°x 1° clear-sky radiances (AVHRR/GAC)

●: T3 ✂ std.

⬧: T4 ✂ std.

Csiszar, I. et al., Interannual changes of active fire detectability from long-term records of the Advanced Very High Resolution Radiometer. Submitted to JGR

Changes in background conditions (cont.)



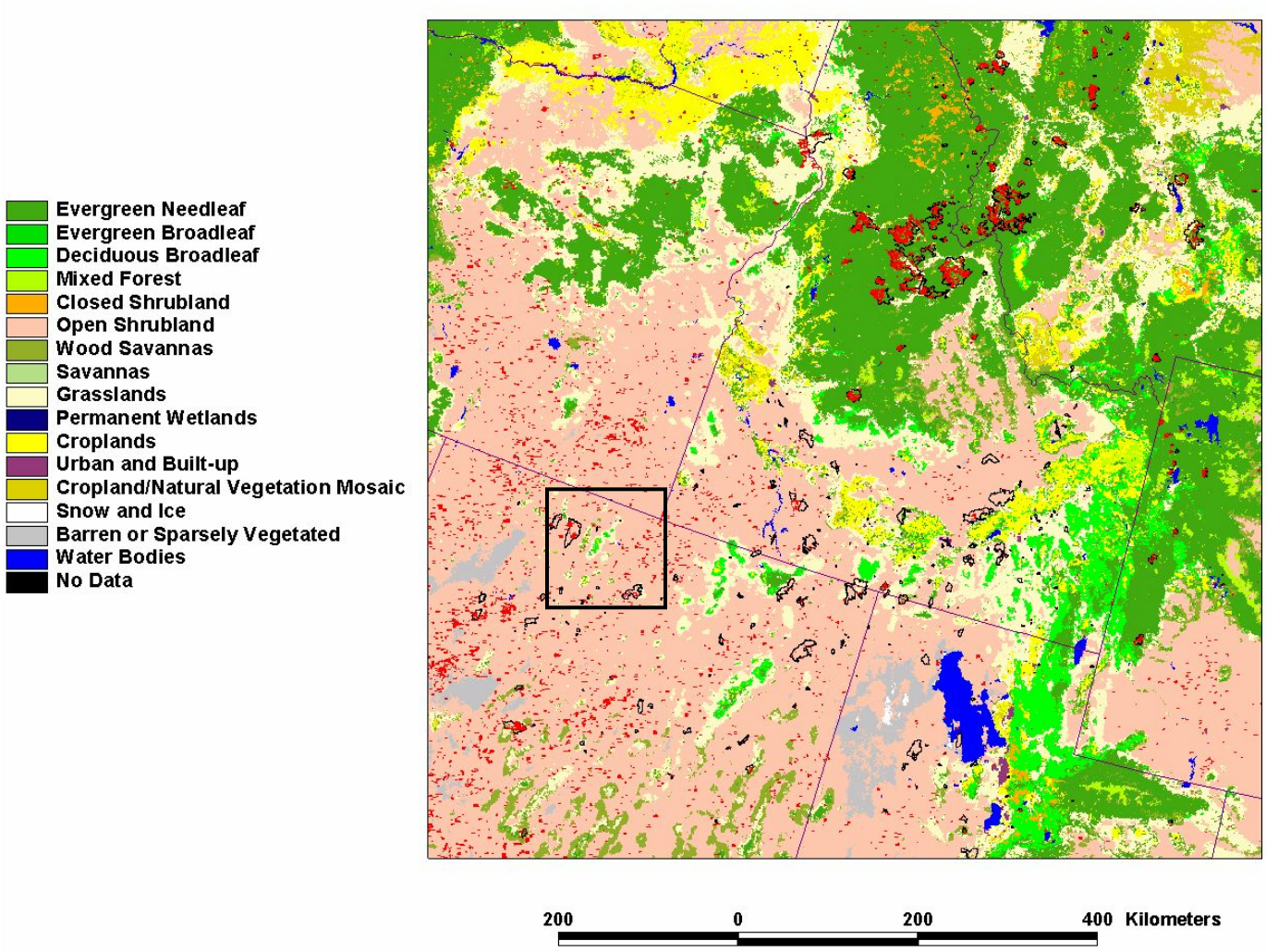
From Pathfinder Atmosphere 1°x 1° clear-sky radiances (AVHRR/GAC)

●: 322- T4

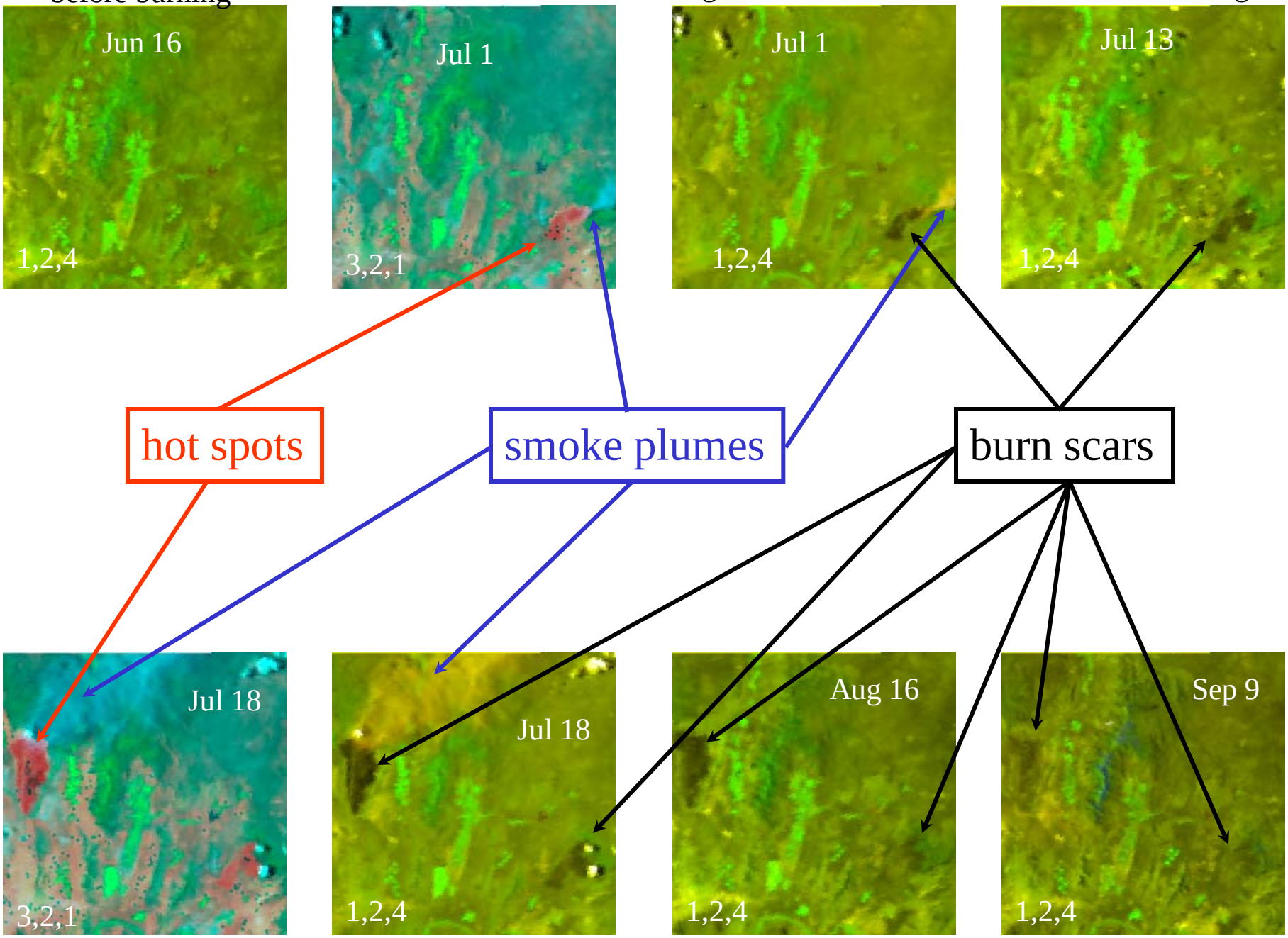
⬧: T3-T4

The wider the gap between ● and ⬧ the easier to separate the fire signal from the background.

Burning in non-forested areas



Yearly cumulative burned areas in NW US. The polygons are results of the US Forest Service survey. Red color indicates fire detection by the latest CCRS algorithm.


before burning
first burning
after first burning
Jun 16
1,2,4
Jul 1
3,2,1
Jul 1
1,2,4
Jul 13
1,2,4
hot spots
smoke plumes
burn scars
Jul 18
3,2,1
Jul 18
1,2,4
Aug 16
1,2,4
Sep 9
1,2,4
second burning
after burning; burned scar signal is fading

Summary

Fire detection and mapping is fairly reliable over forest cover

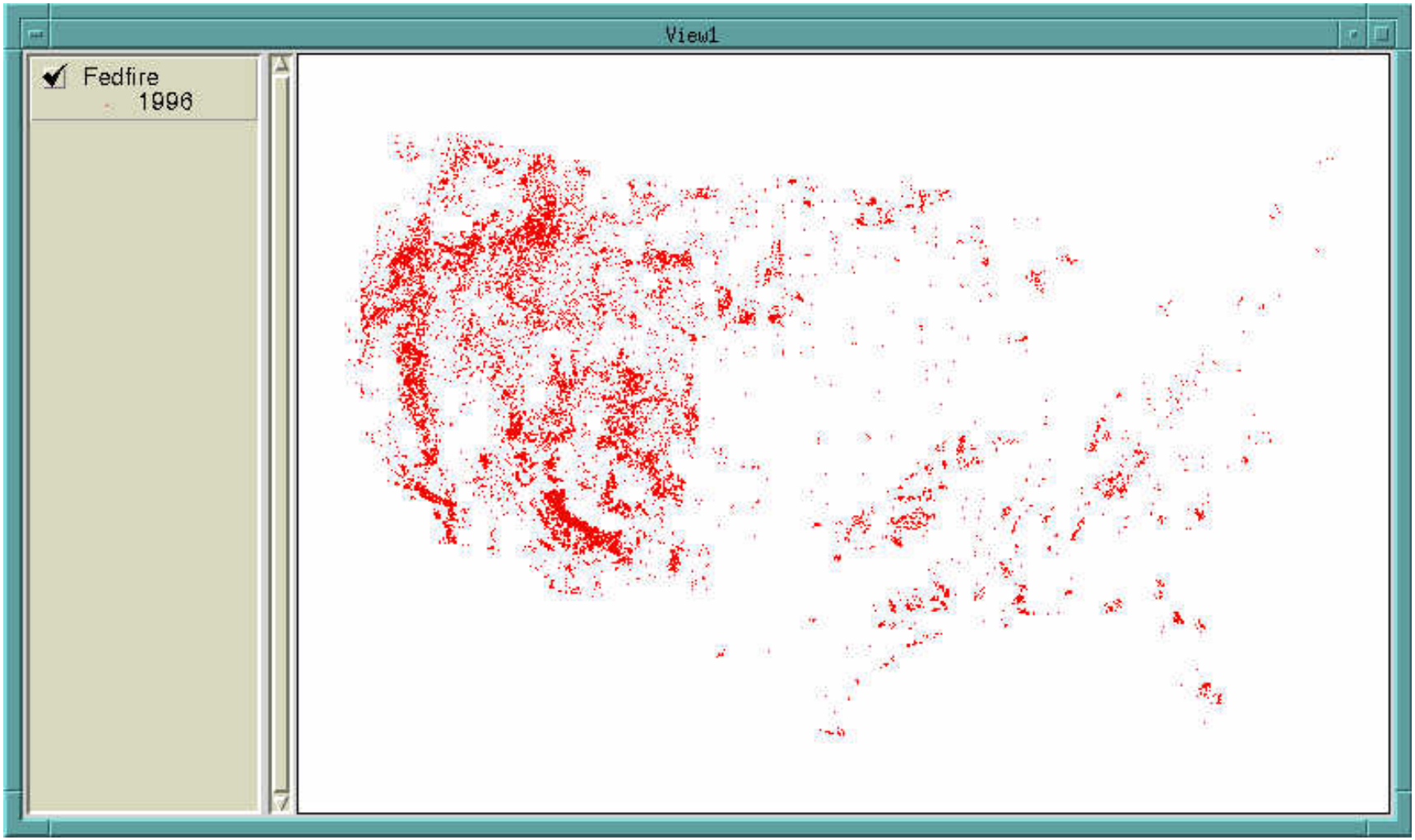
There is sufficient temperature contrast between fire pixels and non-burning background to detect fire hot spots

There is sufficient and lasting reflectance contrast between burned and non-burned areas to allow for mapping burned scar

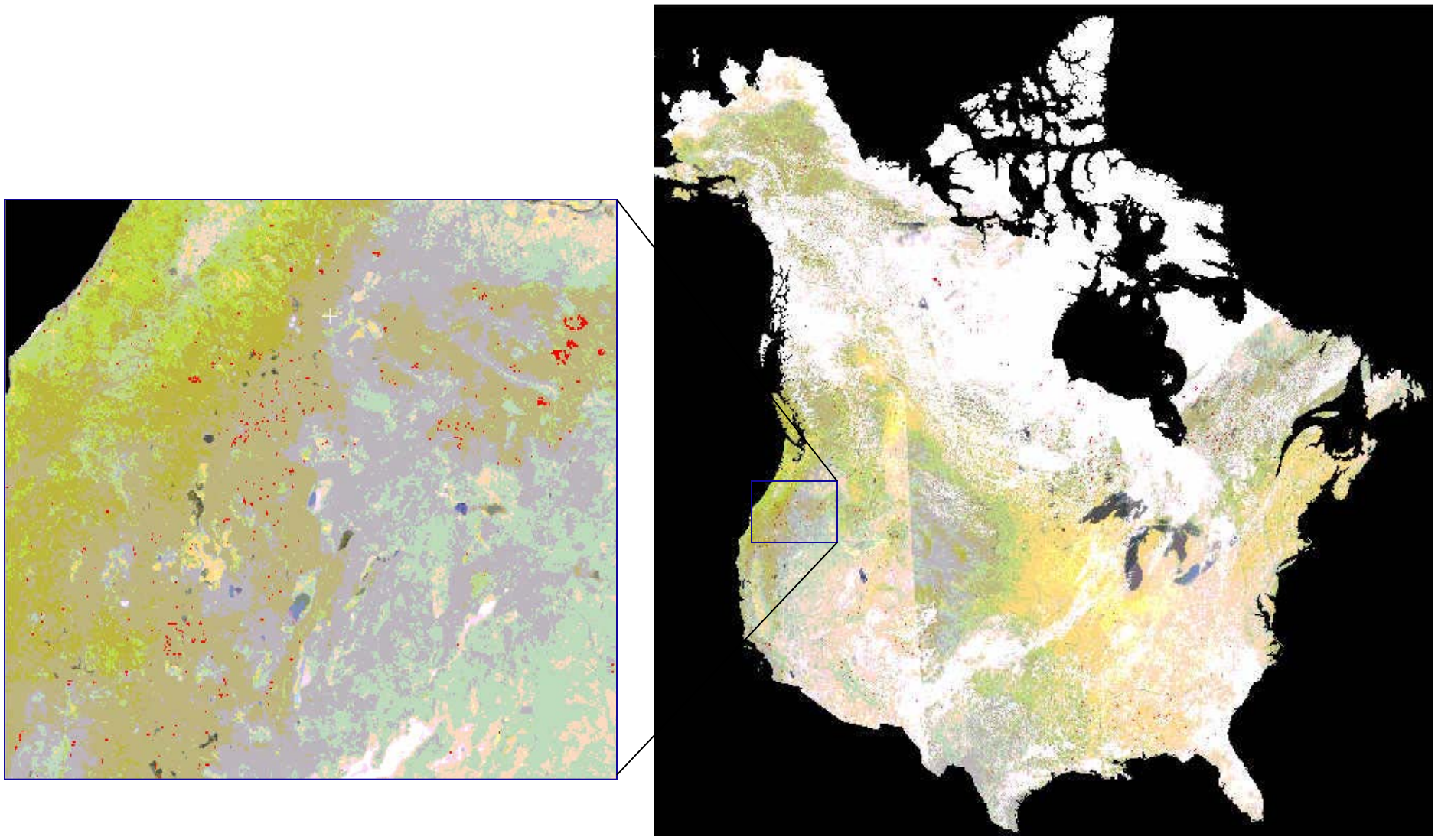
Persistent cloud cover is a major factor preventing both fire and scar being detected and mapped. The HANDS method may be modified to address the problem.

Overall, the rates of commission and omission errors for the algorithms selected are rather low and suitable for operation in NA.

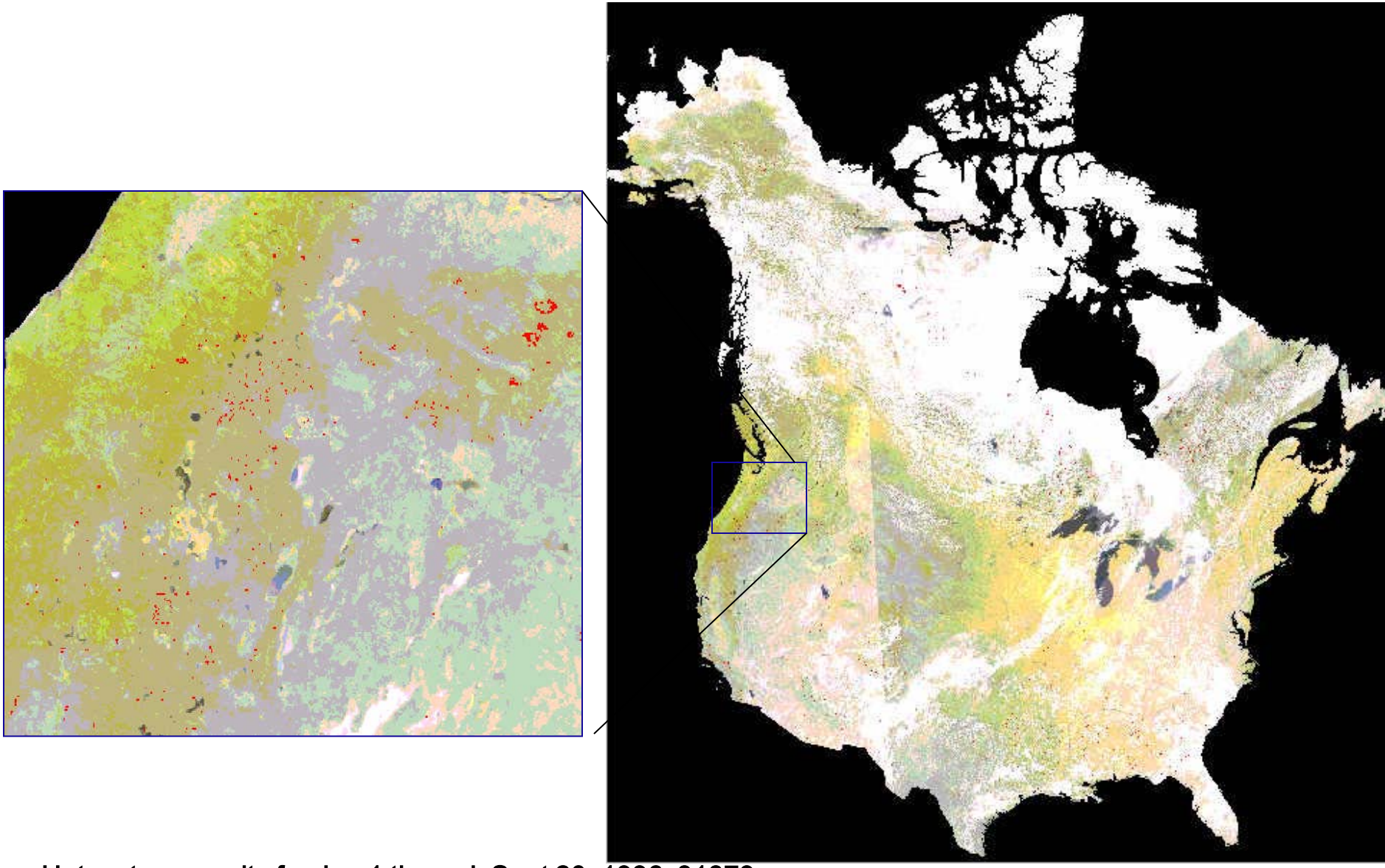
Hotspot and burn scar mapping in operation



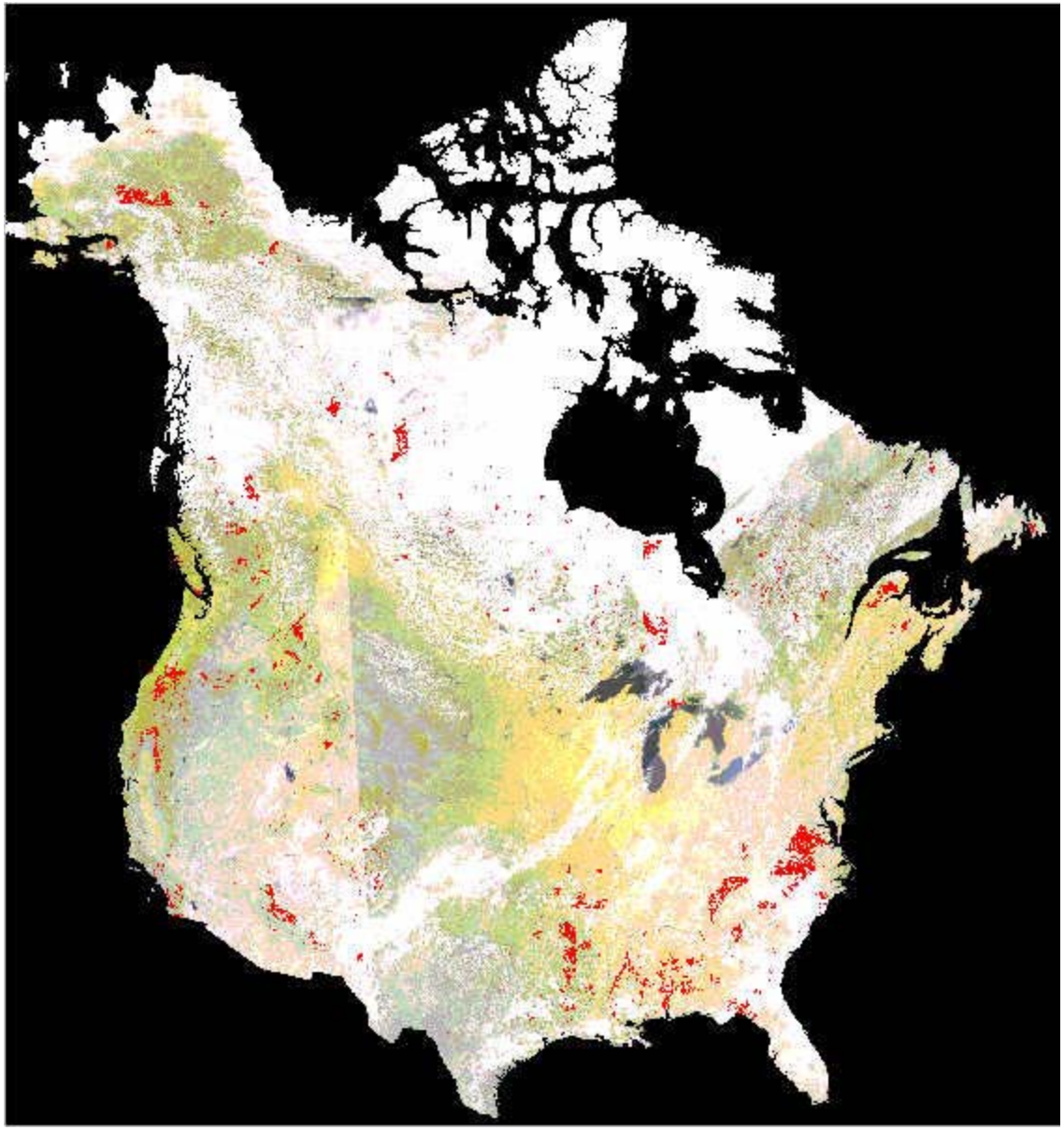
Point shape file from the USFS fire database covering 1996 data, 13,885 km2, not complete for entire US. Exaggerated by point patterns.



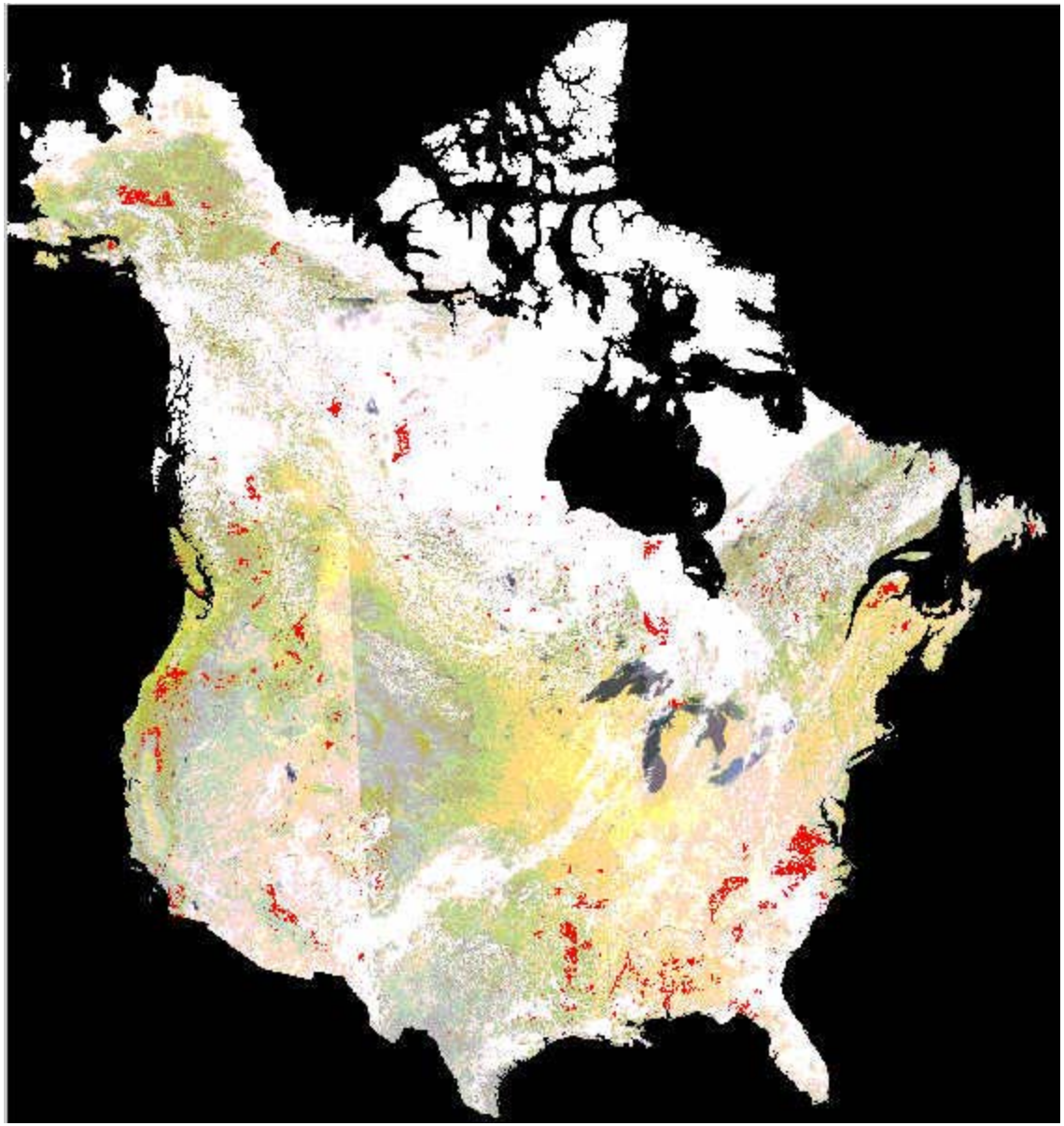
Hotspot composite for May to October, 1996, 29765 hotspots in red with background data on 08/07/1996,



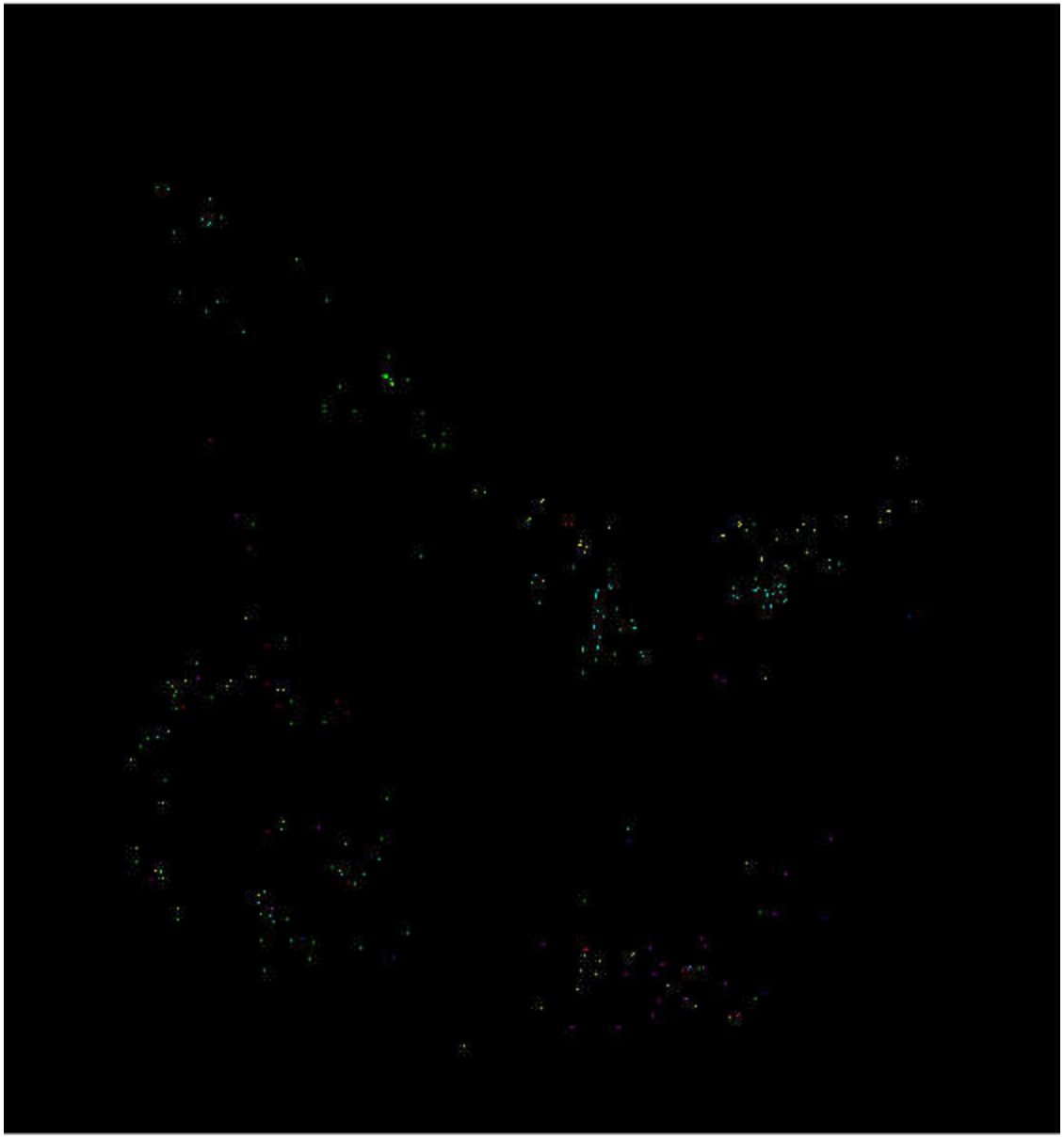
Hotspot composite for Jan 1 through Sept 20, 1996, 31879 hotspots in red with background data on 08/07/1996,



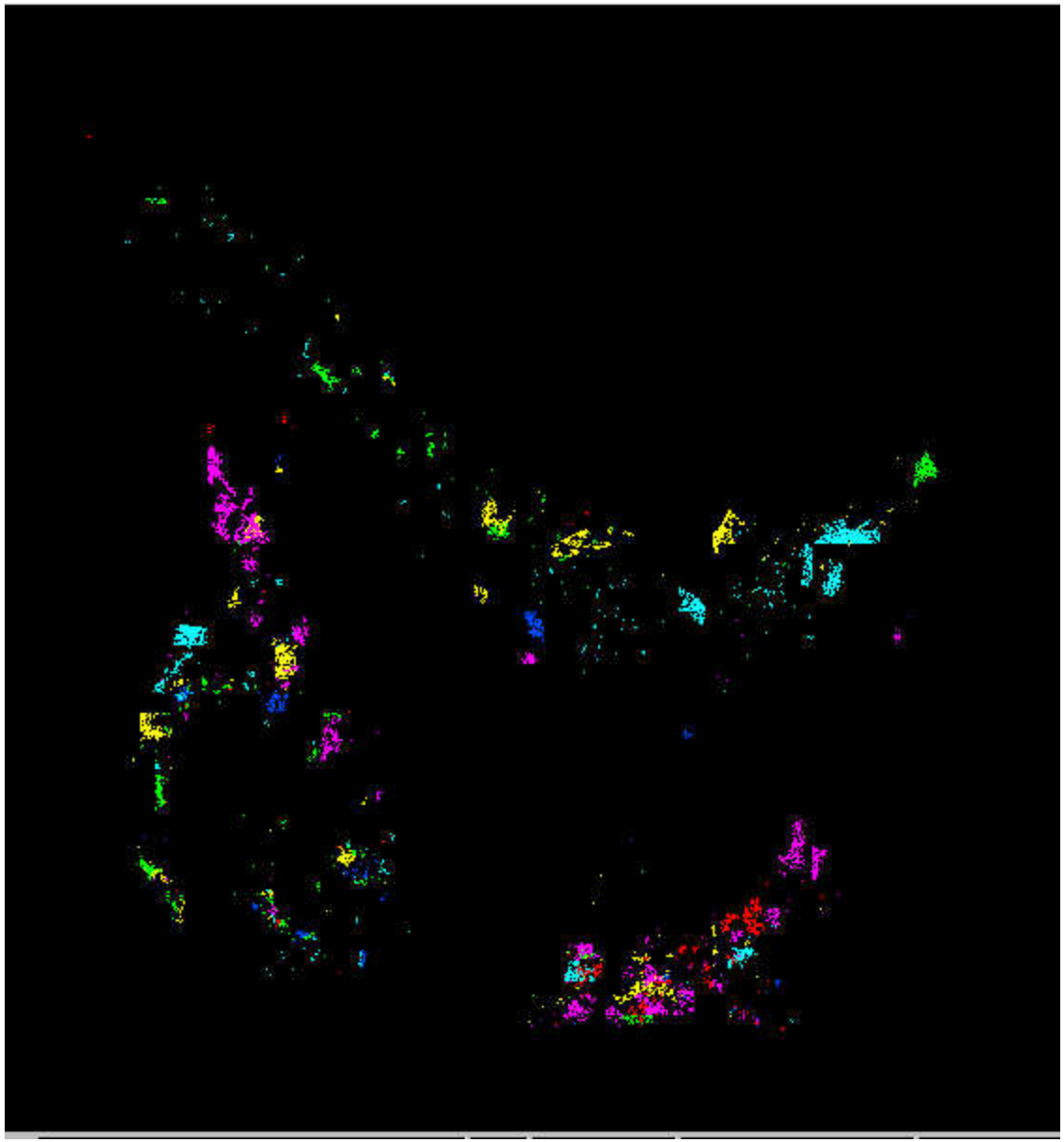
Burn scar map for May-Oct, 1996. Burn scars in red with background data from 08/07/1996.



Burn scar map for Jan. 1 – Sept. 20, 1996. Burn scars in red with background data from 08/07/1996.



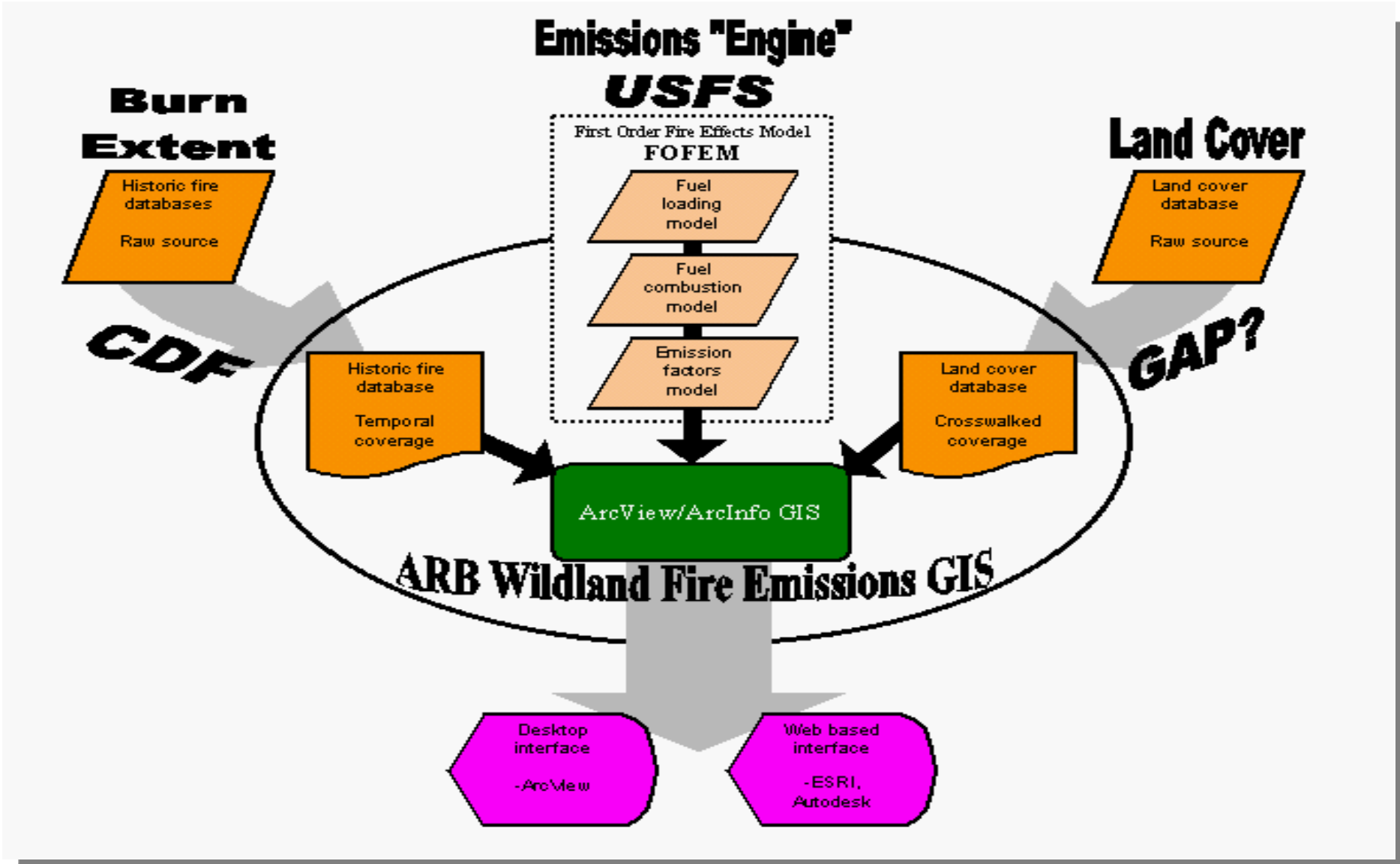
Hotspot monthly composite, May in dark blue, Jun in light blue, Jul in green, Aug in yellow, Sep in red, and Oct in Magenta, 1996



Burn scars monthly composite, May in dark blue, Jun in light blue, Jul in green, Aug in yellow, Sep in red, and Oct in Magenta, 1996

Fire Emissions Estimation

Software Flow Chart



Wildland Fire Emissions Estimation Web-GIS (UC Berkeley) - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Netsite: http://himalaya.cnr.berkeley.edu:1080/~jscar/ims.html

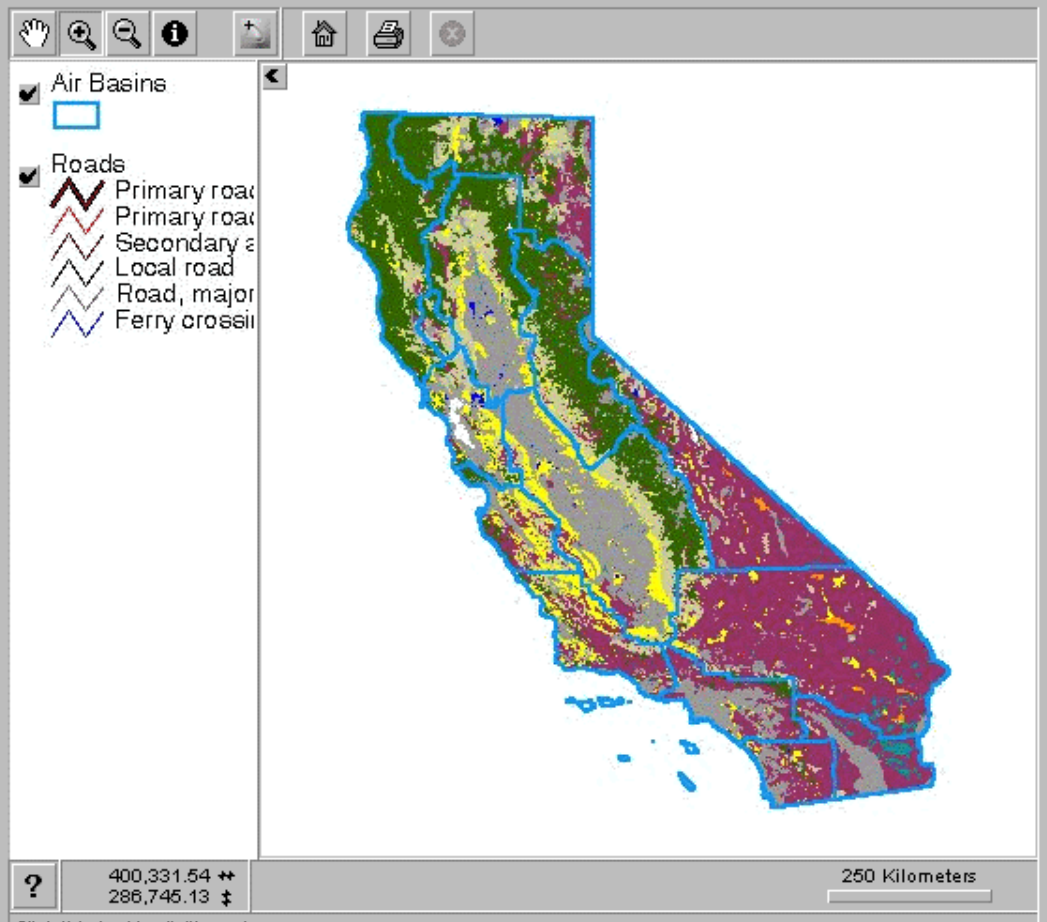
emissions pr phc James Scarborou Index of the HT Character entit Guardian Unlimi

project Homepage

Wildland Fire Emissions Estimation Web-GIS

UC Berkeley research funded by the California Air Resources Board

show Instructions



Instructions:

1. Zoom in and **locate** your area of interest.
2. **Digitize** a burn area with the polygon tool.

Emissions Parameters Input

(using FOFEM 4.0 as emissions engine)

Fuel Category:	Natural
Dead fuel adjustment factor:	Typical
Moisture conditions:	Dry
Fire intensity:	Very High
Will this fire burn tree crowns:	No
Tree crown biomass burning:	Typical
Herbaceous density:	Typical
Shrub density:	Typical
Tree regeneration density:	Typical
Season of burn:	Spring

Document: Done

Wildland Fire Emissions Estimation Web-GIS (UC Berkeley) - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Netsite: http://himalaya.cnr.berkeley.edu:1080/~jscar/ims.html

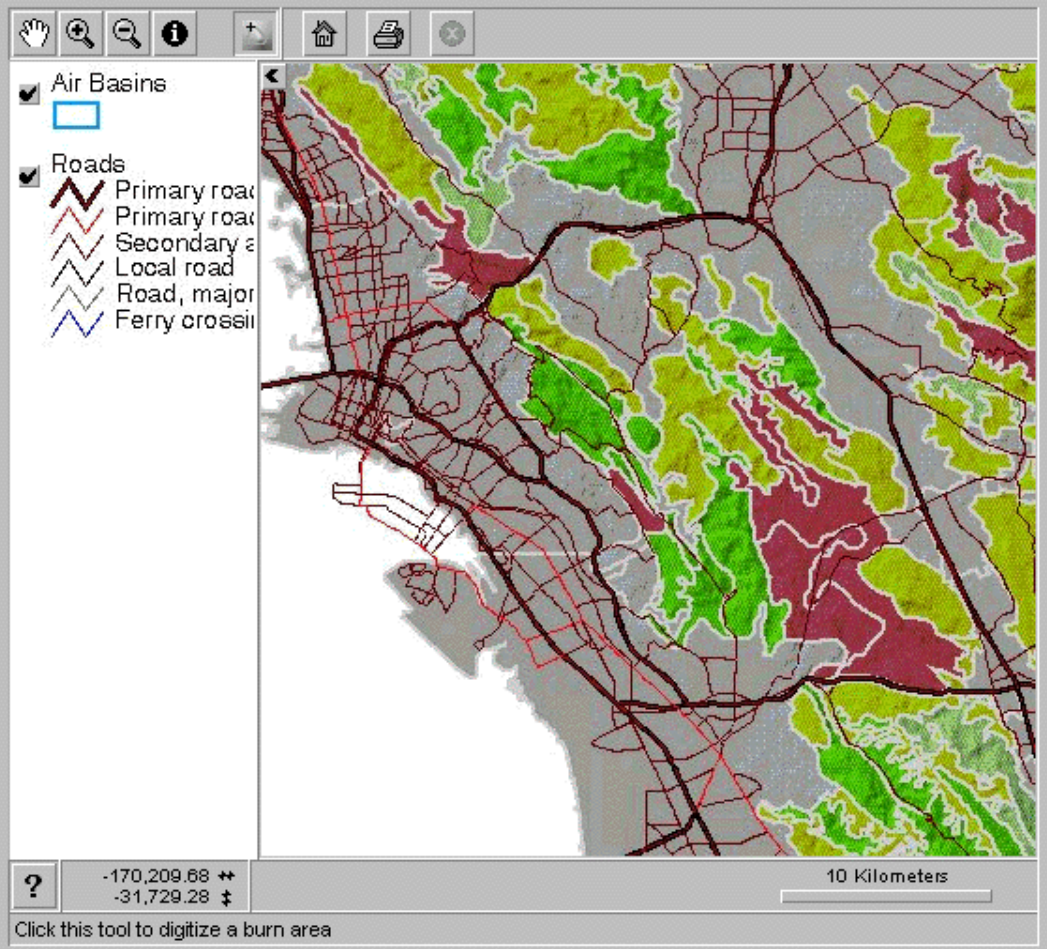
emissions pr phc James Scarborou Index of the HT Character entit Guardian Unlimi

project Homepage

Wildland Fire Emissions Estimation Web-GIS

UC Berkeley research funded by the California Air Resources Board

show Instructions



Instructions:

1. Zoom in and **locate** your area of interest.
2. **Digitize** a burn area with the polygon tool.

Fire intensity:	Very High
Will this fire burn tree crowns:	No
Tree crown biomass burning:	Typical
Herbaceous density:	Typical
Shrub density:	Typical
Tree regeneration density:	Typical
Season of burn:	Spring
1000hr moisture percentage (NFDTH):	20 %

Output format:

- (•) Summarized HTML Table
- ( ) Plain HTML Table

Estimate Clear Choices

Document: Done

Wildland Fire Emissions Estimation Web-GIS: Output table

UC Berkeley research funded by the California Air Resources Board. Please visit http://camfer.cnr.berkeley.edu/fire
These results serve as example only. This is a research work in progress and does not reflect California ARB policy.

Cover Code	Component	Fuel Load (tons/ac)	PM 10 (pounds/ac)	PM 2.5 (pounds/ac)	CO (pounds/ac)	Area (acres)	PM 10 Total (tons)	PM 2.5 Total (tons)	CO Total (tons)	Cover Type (Holland)
32100	Litter	0.11	1.00	0.90	5.80	1024.64	0.51	0.46	2.97	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Wood 0-1 inch	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Wood 1-3 inch	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Wood 3+ inches	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Herbs	0.40	10.00	8.50	99.70	1024.64	5.12	4.35	51.08	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Shrubs	2.28	28.60	24.30	284.10	1024.64	14.65	12.45	145.55	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Regen	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Duff	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB
32100	Canopy foliage	0	0	0	0	1024.64	0	0	0	NORTHERN(FRANCISCAN) COASTAL SCRUB

For Each Pixel:

$$T = M * EF\ X = A * B * \alpha * (EF\ X_f * P_f + EF\ X_s * P_s)$$

T	Amount of X produced by fire per unit time
M	Amount of biomass burned per unit time
EF X	Weighted-average emission factor of X
A	Area burned per unit time
B	Above-ground biomass density
α	Fraction of aboveground biomass burned
EF X_f	Emission factor of X during flaming phase
EF X_s	Emission factor of X during smoldering phase
P_f	% of biomass burned during flaming
P_s	% of biomass burned during smoldering

$EF\ X_f = f(CE_f)$, $EF\ X_s = f(CE_s)$, CE: Combustion efficiency

CE_f or $CE_s = f$ (temperature, humidity, wind velocity, topography; moisture and elemental composition of fuel)

National Fire Occurrence Database

- Lands: federal and 48 states
- Period: 1986-1996, 1997-2000
- GIS database fields:
  - Latitude and longitude
  - Time fire discovered and controlled
  - Size of burned areas
  - Cause: lightning, campfires, smoking, etc.

Publications submitted

- Gong, P., R. Pu, Z.Q. Li, An integrated approach to burned area mapping in California with NOAA AVHRR data, submitted to *International Journal of Remote Sensing*.
- Pu, R., P. Gong, Z.Q. Li, J. Scarborough, A dynamic algorithm for wild land burned scar detection using NOAA AVHRR data, submitted to *International Journal of Wildland Fire*.
- Li Z., R. Fraser, J. Jin, A.A. Abuelgasim, I. Csiszar, P. Gong, W. Hao. Evaluation of the Algorithms Used for Developing a Long-term Fire Inventory across North America and a Close-look at 2000 US Western Fires. Submitted to JGR
- Csiszar I., A. Abdelgadir, Z. Li, J. Jin, Inter-annual changes of active fire detectability from historical records of the Advanced Very High Resolution Radiometer. Submitted to JGR