MODIS Fire Product: update

Contributors

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Update on Activities

- Fire Algorithm Refinements
  - Version 3 > Version 4 Code
  - Evaluation of mid-IR reflectance detection technique (w. E. Vermote)
- AQUA initial QA (4 observations per day – improved characterization of the diurnal cycle)
- Global Validation (Stage 2) of Terra Active Fire using ASTER
- Climate Modeling Grid (ready for Collection 4)
- Validated MODIS Burned Area product – regional approach
- Fire Emissions Estimation
- Experimental Fire Energy information (w. Y. Kaufman et al.)
- International outreach through GOFC/GOLD-Fire
  - Rapid Response
  - International Validation Collaborations
  - Fire Management Community (USFS, UN IATFDR Wg4)
  - IGAC BIBEX Global/Regional Emissions Agenda

MODIS Global Fire Products

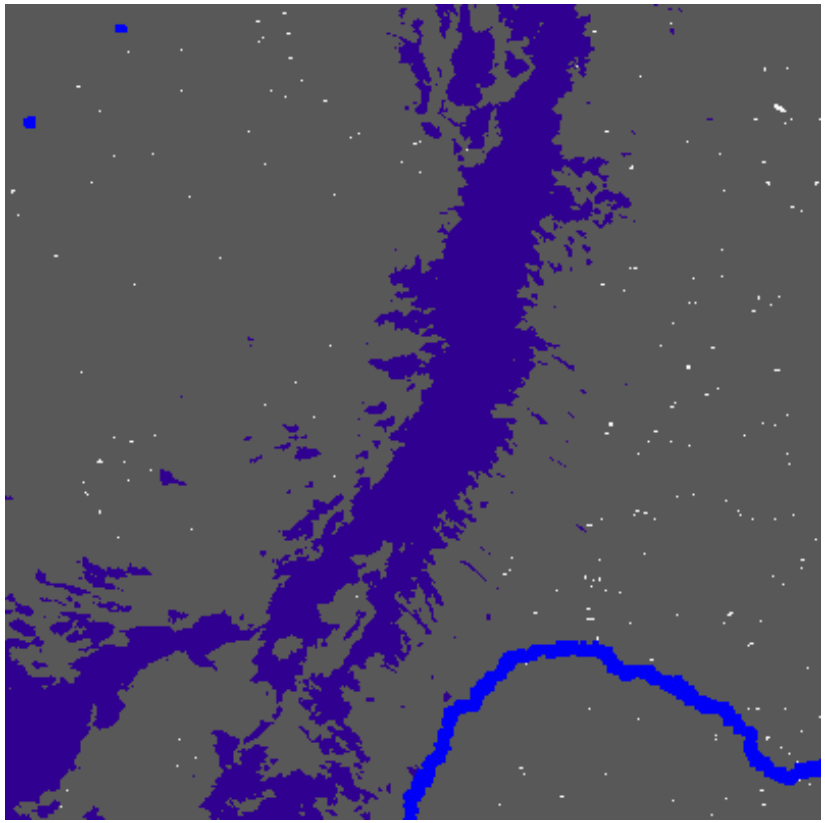
- **Current MODIS Fire Products**
  - Active Fire (Level 2)
    - Fire mask
    - QA layer
    - Detailed information about each fire pixel
  - Active Fire (Level 2G)
    - Used to produce L3 fire products
  - Active Fire (Level 3)
    - Cumulative fire mask
    - Daily and 8-day summaries
  - Active Fire Daily Global Browse
  - Rapid Response Products
    - JPGs > GEOTIFF Imagery
    - Active fire locations - text files (same algorithm as the Standard Product)
    - Web GIS Fire Mapping
  - ***Active Fire (CMG) – Oct 02***
  - ***Burned Area Product (Level 3) – regional test 02, global 03***
    - ***Initial emphasis 2002 on validated regional products (500 m) to support NASA Regional Science (Southern Africa)***
    - ***Global multiyear product (Starting 2003)***

Algorithm Status

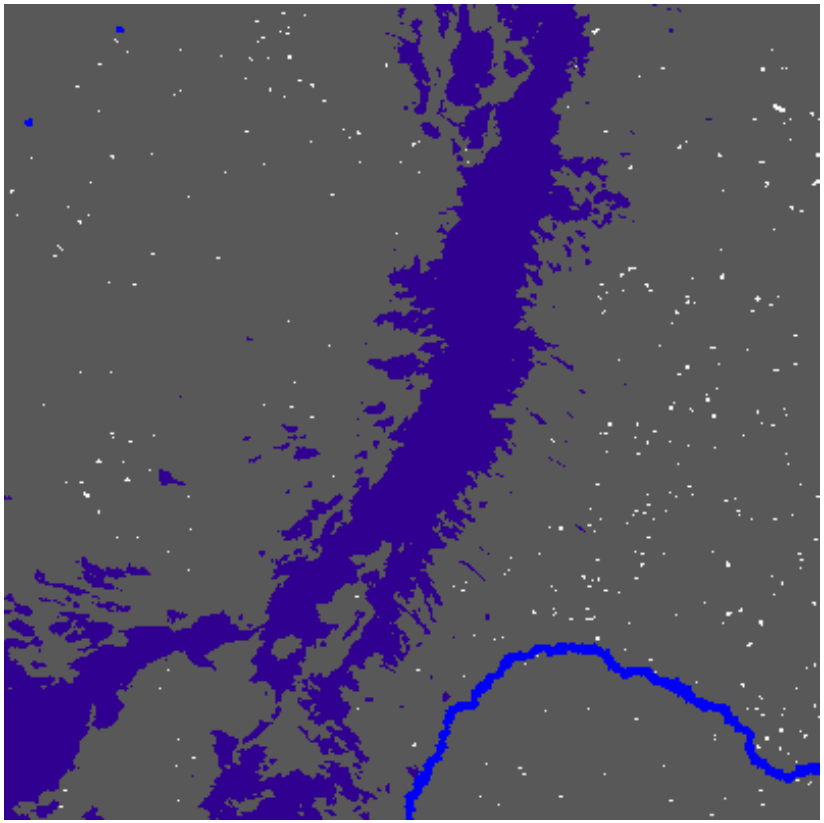
- Version 3
  - Currently used in MODAPS
  - Current version in archive
  - Generally good quality, but...
    - Small fires frequently undetected
    - Significant false alarms under certain conditions
- Version 4
  - Currently used in Rapid Response system
  - Improved detection algorithm
    - More robust
    - Detects many more small fires
    - Fewer false alarms overall
    - The “Unknown” output class arises much less frequently
  - Will be used in Collection 4 reprocessing

Algorithm Comparison (1/2)

V3 , $N_f = 267$



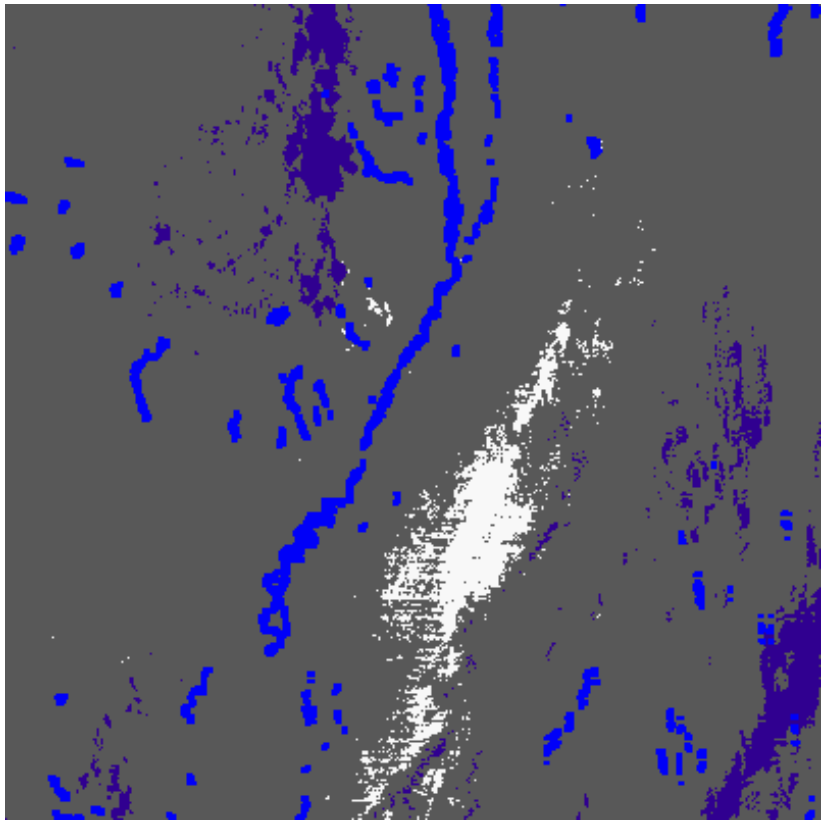
V4, $N_f = 568$



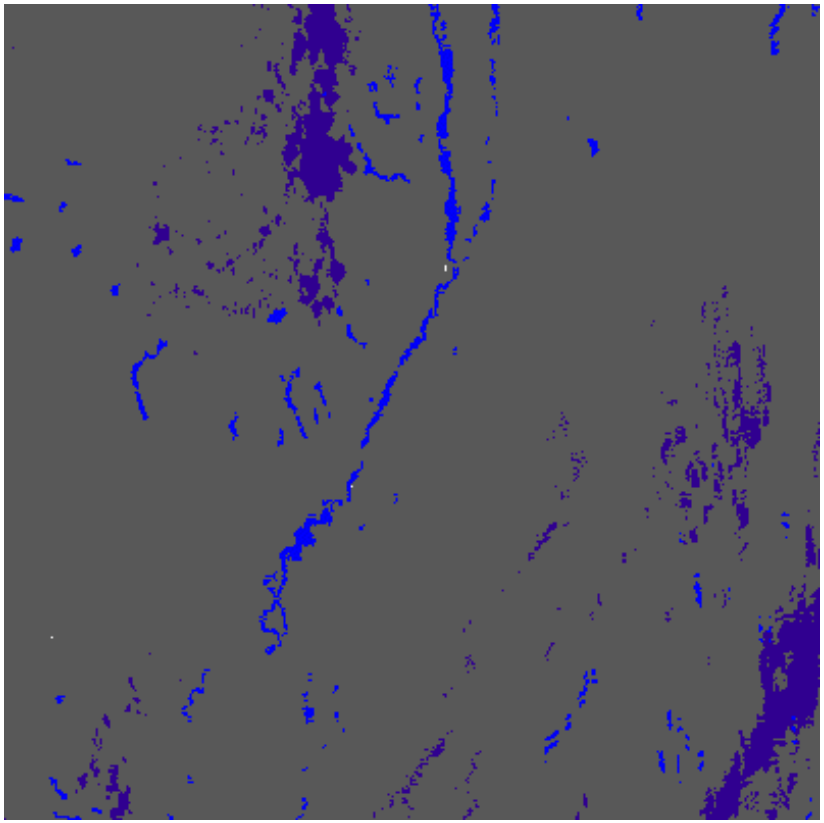
Northern Zaire, 16 December 2000 (2000351) 09:30

Algorithm Comparison (2/2)

V3 , $N_f = 4769$



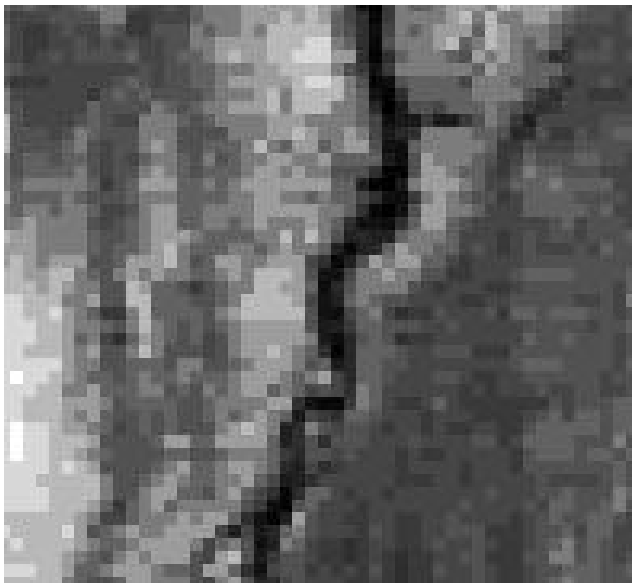
V4, $N_f = 5$



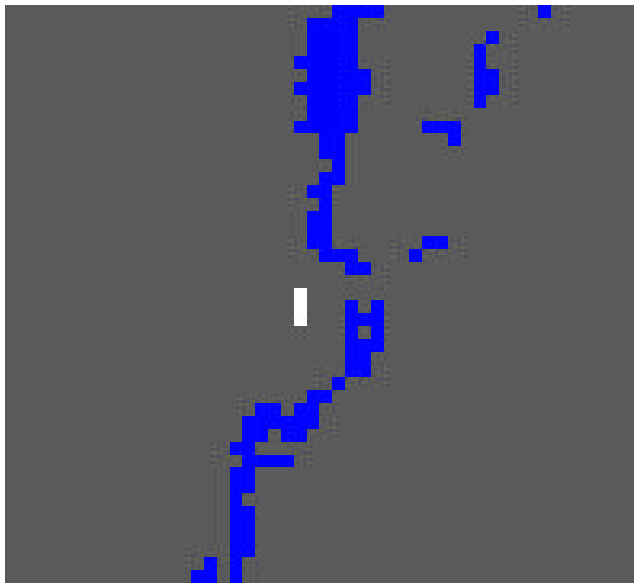
Pakistan, 13 June 2001 (2001164) 06:30

Example V4 False Detection

Errors in land-sea mask (here ~ 4 km) can cause false alarms in MODIS fire product.



Band 21



Fire Mask

Pakistan, 13 June 2001 (2001164) 06:30

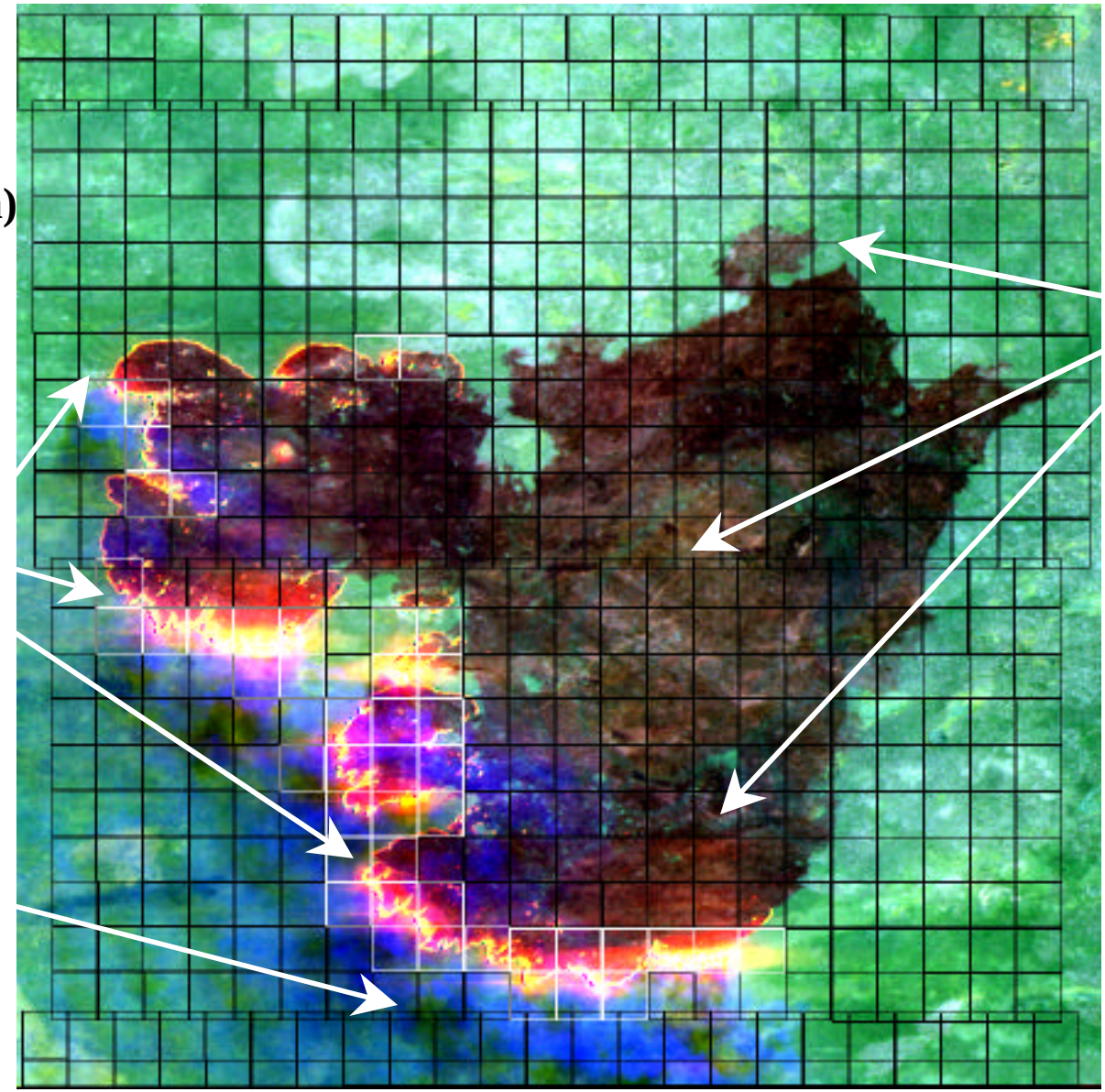
MODIS Active Fire Validation Strategy

Objective to determine product accuracy

- Initial product intercomparison with
  - GOES, TRMM VIRS, DMSP, AVHRR
- Compare fires identified with MODIS to fires identified simultaneously in high-resolution ASTER imagery – global sampling of fire regimes
- Field-based product validation by fire scientists and management agencies organized with international partners through GOFC/GOLD-Fire
  - Mexico
  - Russia
  - Brazil
  - Southern Africa (SAFNET)
  - Southeast Asia (SEARIN)
  - Australia

Active Fire Validation
Collocating ASTER and MODIS data

Aug 17 2001
09:08 UTC
18.8S 19.9 E
(NE Namibia)



White squares:
MODIS fire pixels

Burn scar

Fire fronts

Smoke

R: 2.16 µm
G: 1.65 µm
B: 0.56 µm

Statistical summaries within MODIS footprints

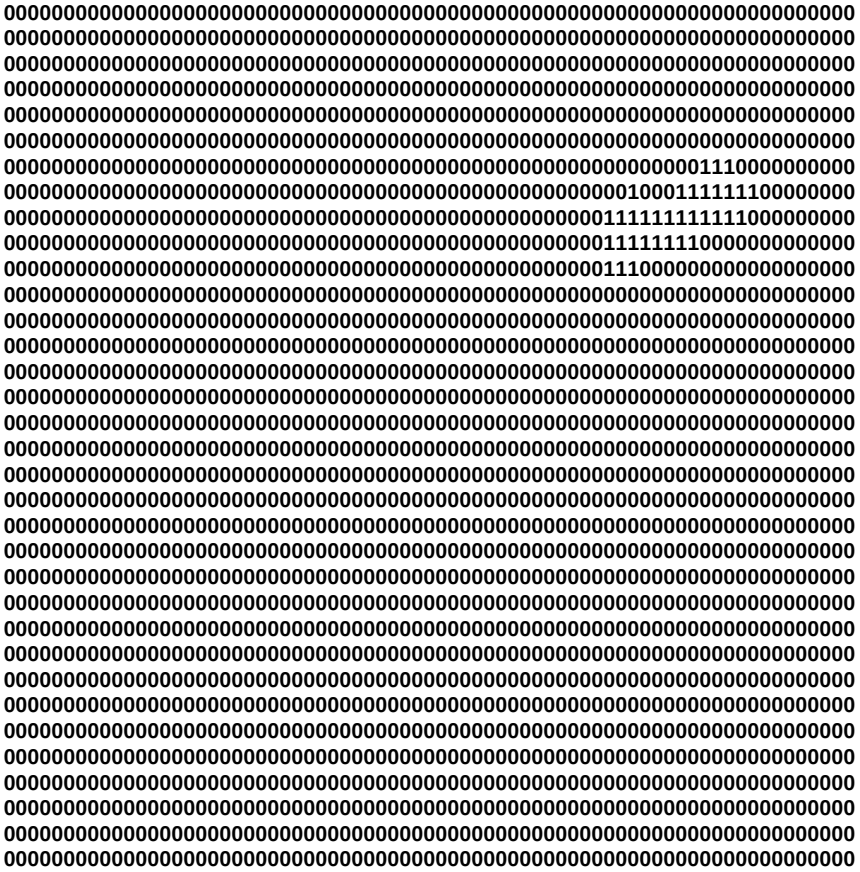
- Fractional area: number of ASTER fire pixels
- Fire heterogeneity: Moran's *I*

$$\text{Moran's I} = n \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}(y_i - \mu)(y_j - \mu)}{\left(\sum_{i=1}^{n}(y_i - \mu)^2\right)\left(\sum\sum_{i \neq j} w_{ij}\right)}$$

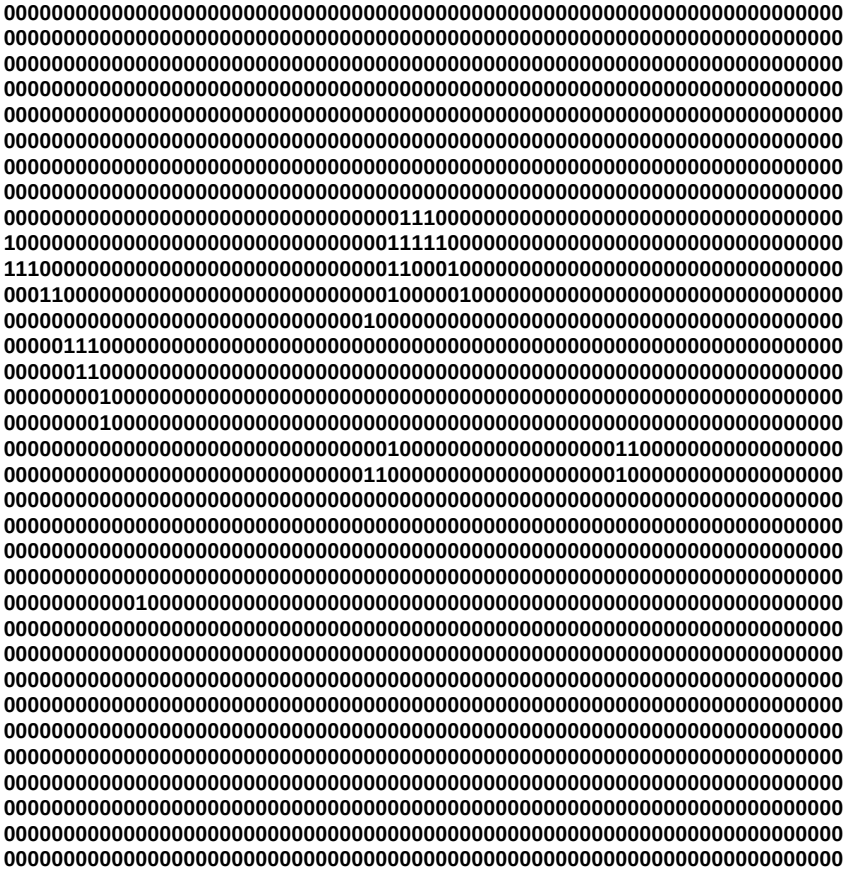
n: **number of ASTER pixels covered by a MODIS pixel**
w_{ij}**:1 for the eight adjacent pixels and 0 for all others**
y_i**: value of the ASTER fire pixel (either 0 or 1) for pixel *i***
μ**: mean of ASTER fire map for the area represented by the MODIS pixel**

Binary ASTER fire masks

Moran's I = 0.681 Variance=0.0141



Moran's I = 0.347 Variance=0.0139



Total number of ASTER fire pixels = 34

Statistical method for comparison

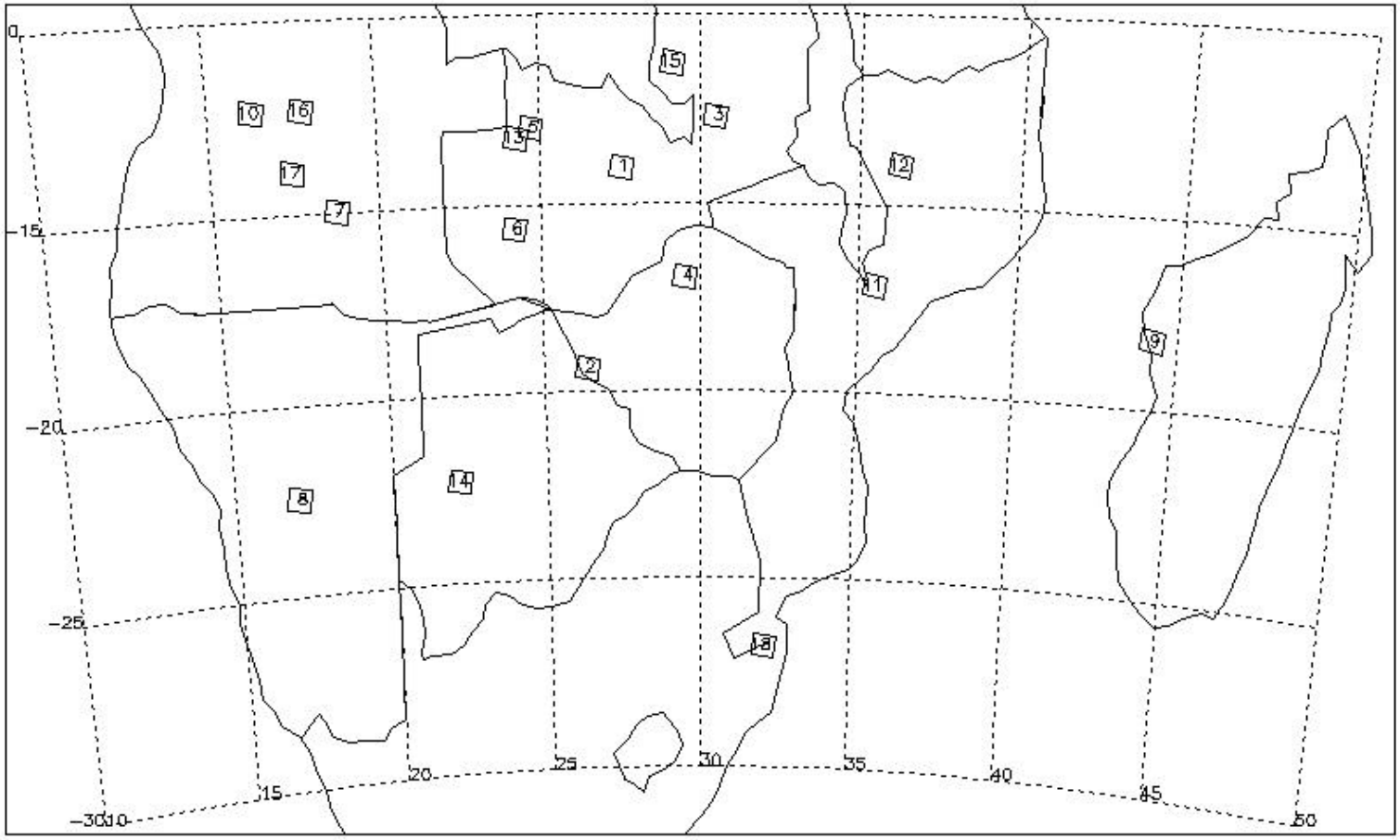
MODIS "fire/no fire" ⟷ **statistical summaries from binary ASTER fire mask**

	Fixed effect models (within-scene variability only)	**Random effect models (include between-scene variability also)**
Model 1	$\pi(x_i) = \frac{e^{\beta_0 + \beta_1 x_i}}{1 + e^{\beta_0 + \beta_1 x_i}}$	$\pi(x_{ij}) = \frac{e^{(\beta_0 + b_{0j}) + (\beta_1 + b_{1j}) x_{ij}}}{1 + e^{(\beta_0 + b_{0j}) + (\beta_1 + b_{1j}) x_{ij}}}$
Model 2	$\pi(x_i, m_i) = \frac{e^{\beta_0 + \beta_1 x_i + \beta_2 m_i}}{1 + e^{\beta_0 + \beta_1 x_i + \beta_2 m_i}}$	$\pi(x_{ij}, m_{ij}) = \frac{e^{(\beta_0 + b_{0j}) + (\beta_1 + b_{1j}) x_{ij} + (\beta_2 + b_{2j}) m_{ij}}}{1 + e^{(\beta_0 + b_{0j}) + (\beta_1 + b_{1j}) x_{ij} + (\beta_2 + b_{2j}) m_{ij}}}$

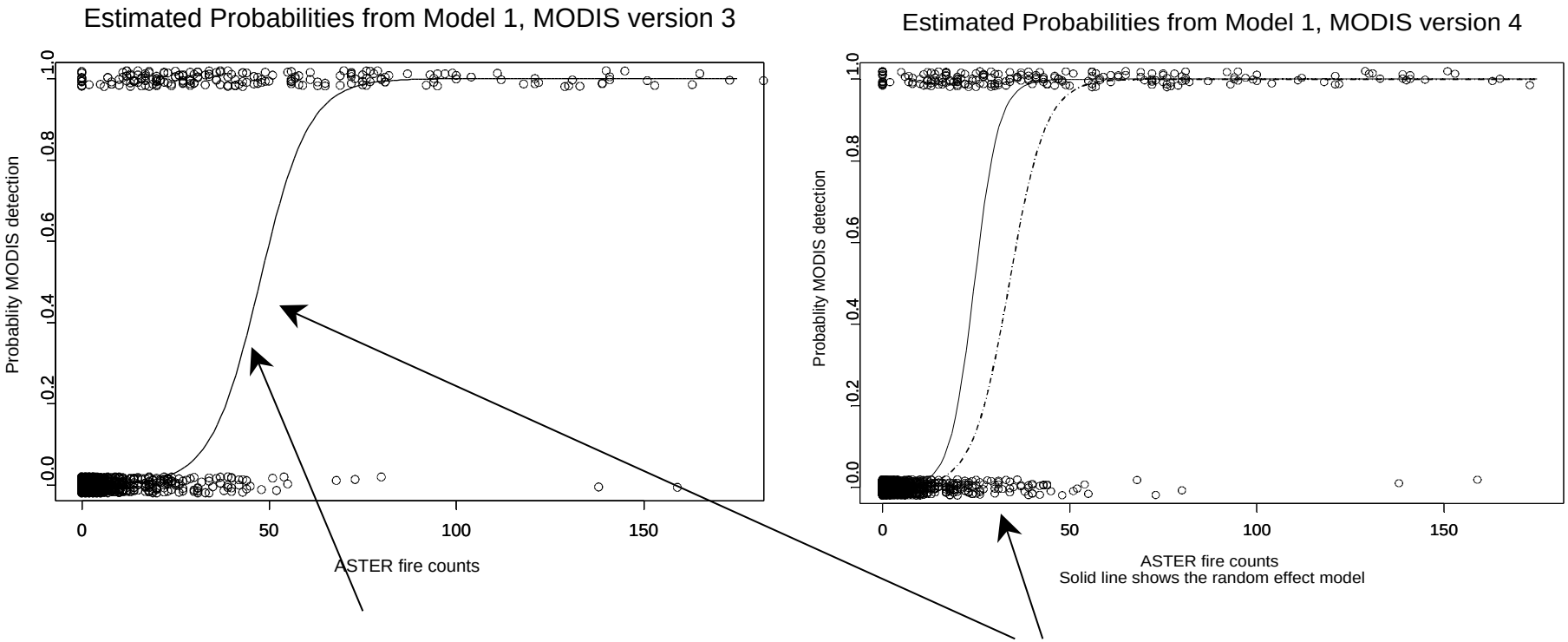
i denotes MODIS pixel; *j* denotes ASTER scene
x: count of ASTER fire pixels within MODIS pixel
m: Moran's *I* within MODIS pixel
π: probability that MODIS pixel is flagged as "fire"
β_0, β_1, β_2: fixed effects parameters estimated from the data population
b_0, b_1, b_2: random effects parameters associated with experimental units drawn at random

ASTER Validation in Southern Africa

Aug 5-Oct 5 2001



Model results: number of fires

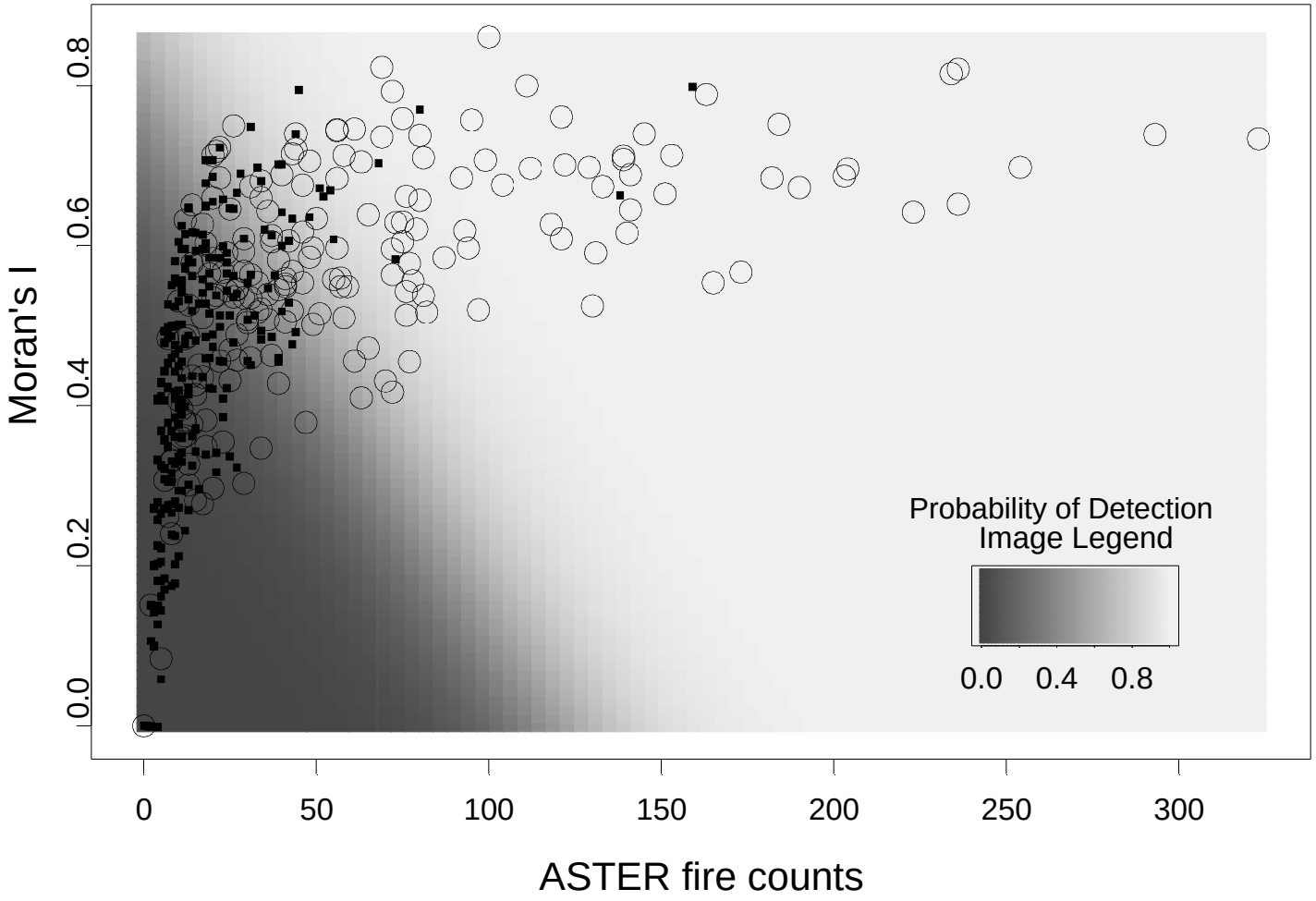


fixed and random effect model results are the same for Version 3

higher detection probabilities for Version 4

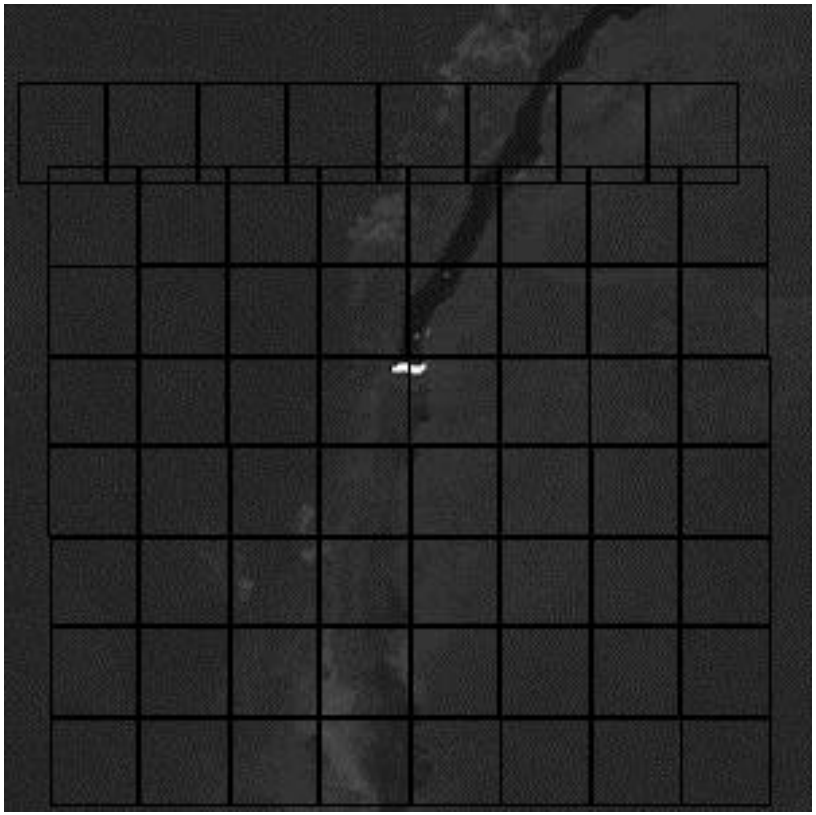
Model results: number of fires + Moran's *I*

Estimated Probabilities from Model 2, MODIS version 4

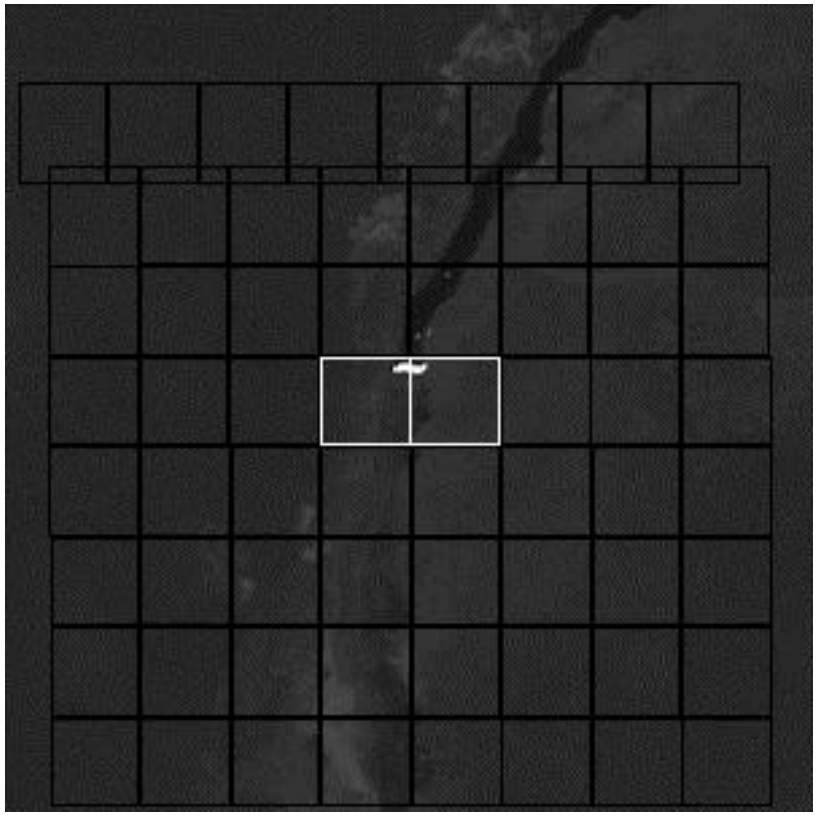


Effects of MODIS algorithm change

“Dambo” fire in Western Zambia, August 12 2001, 16.6S 24.4E.



Version 3

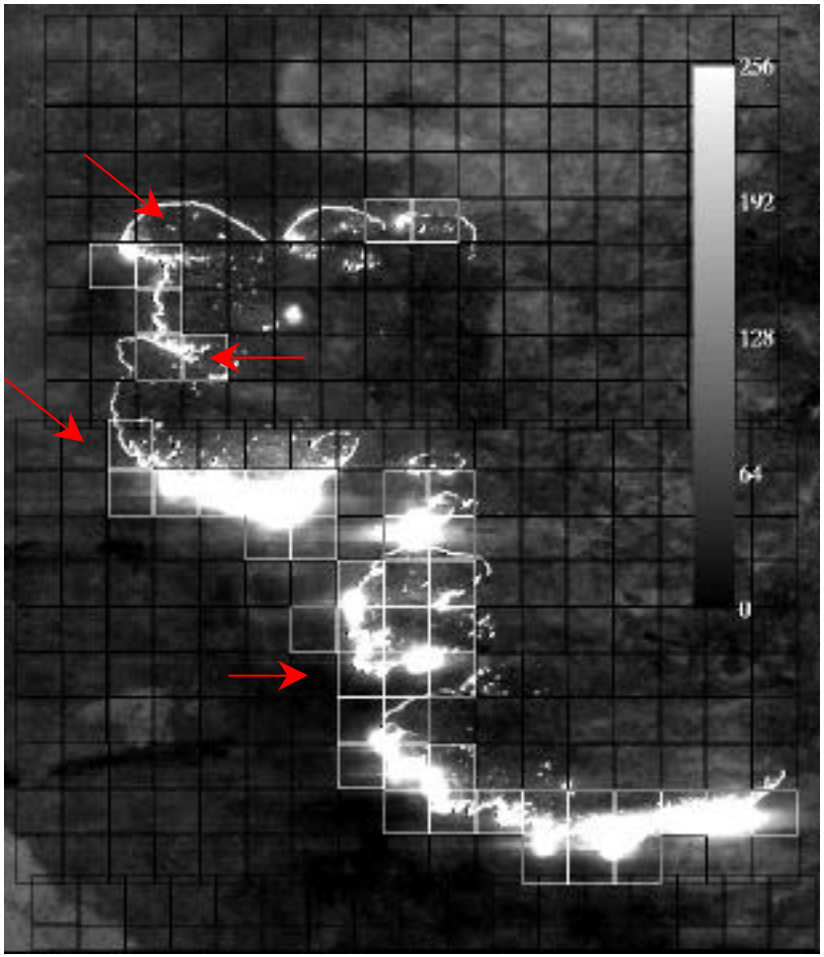


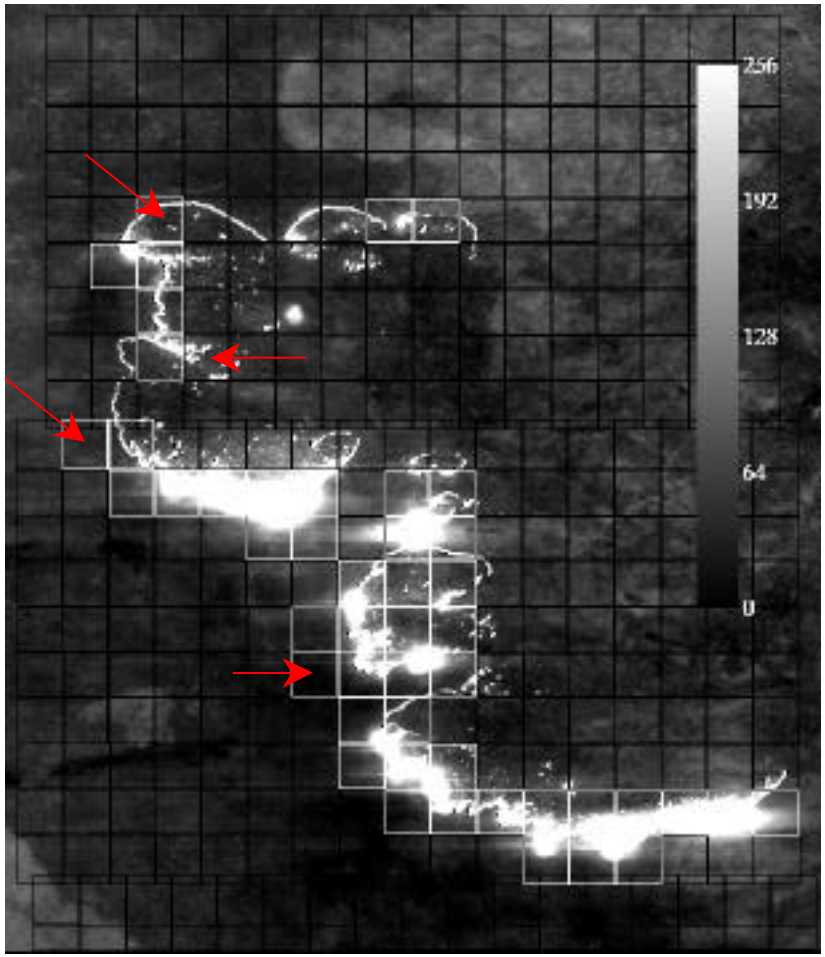
Version 4

ASTER channel 9 image. White squares show MODIS fire pixels.

Effects of MODIS algorithm change

Fire front in NE Namibia, August 17 2001, 18.8S 19.9E





Version 3 **Version 4**

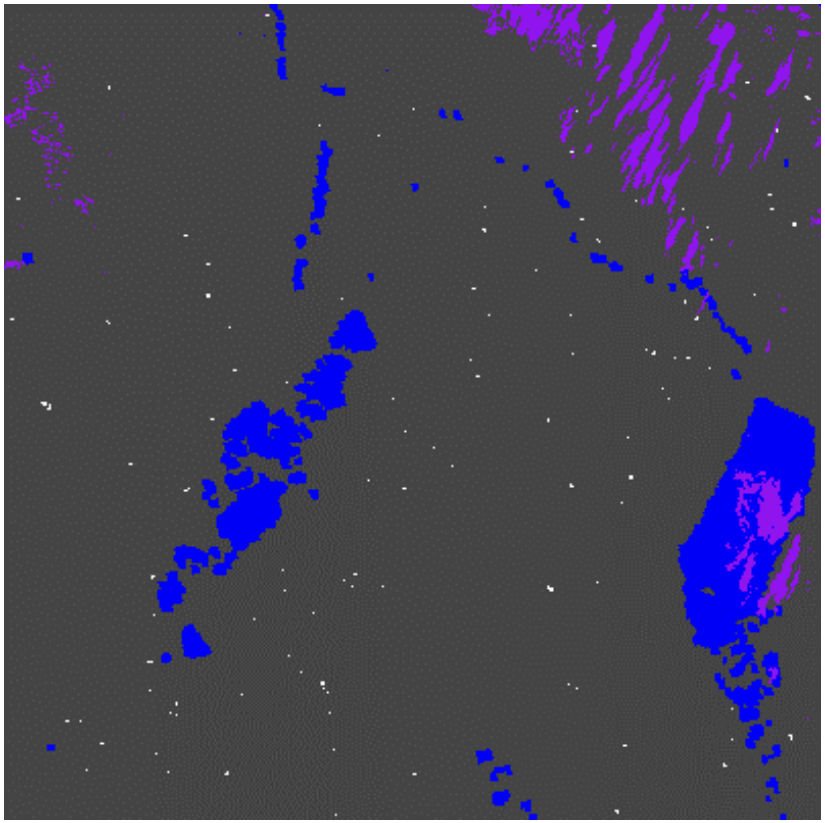
ASTER channel 9 image. White squares show MODIS fire pixels.

ANO / MOD14 Comparison

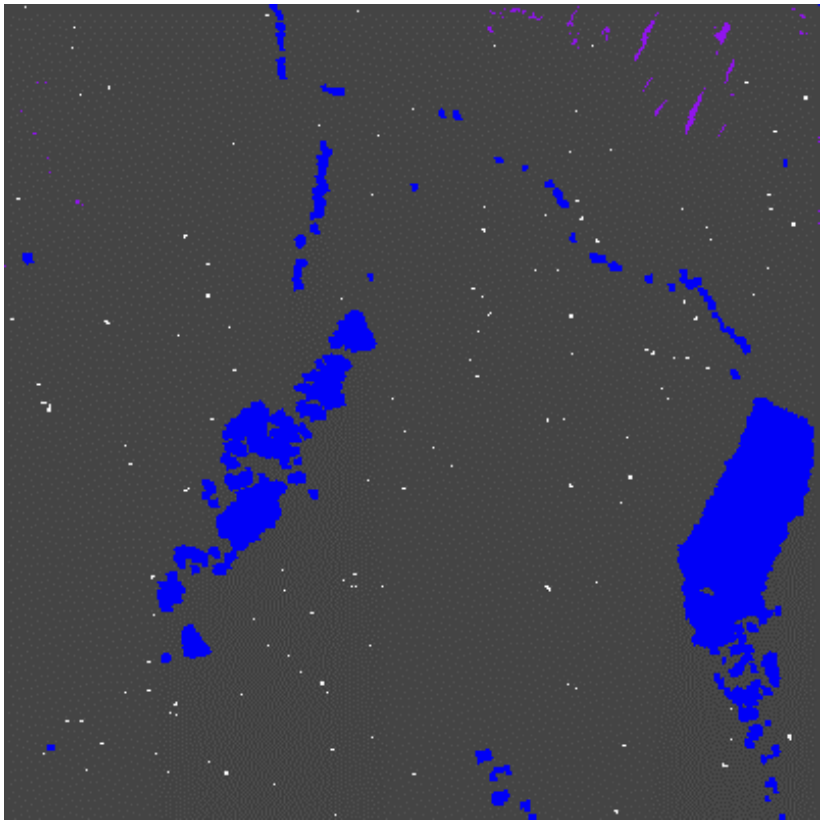
- Middle-infrared reflectance anomaly (“ANO”) approach developed by Vermote et al.
  - Threshold technique (vs. MOD14 contextual)
- Currently comparing daytime MOD14 V4 and ANO
  - Current configuration gives comparable rates of detection, but very different false alarm characteristics
- Refining ANO performance based on MOD14 intercomparisons and ASTER validation
- Goal of robust global detection algorithm

ANO / MOD14 Comparison

ANO/MOD09 V3.1.9, $N_f = 187$



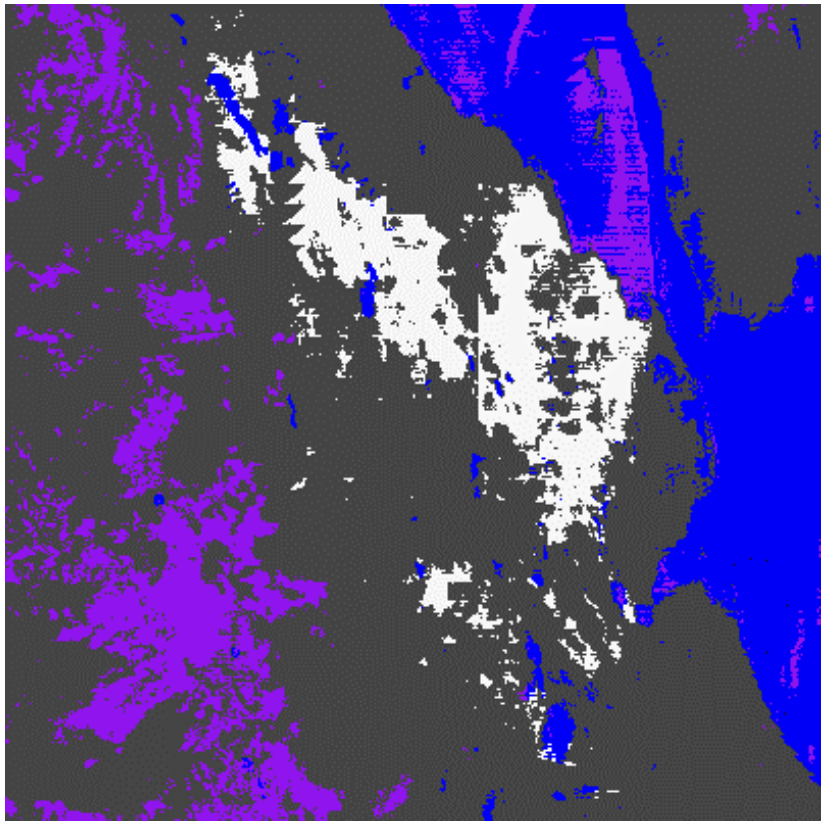
MOD14 V4.1.1, $N_f = 227$



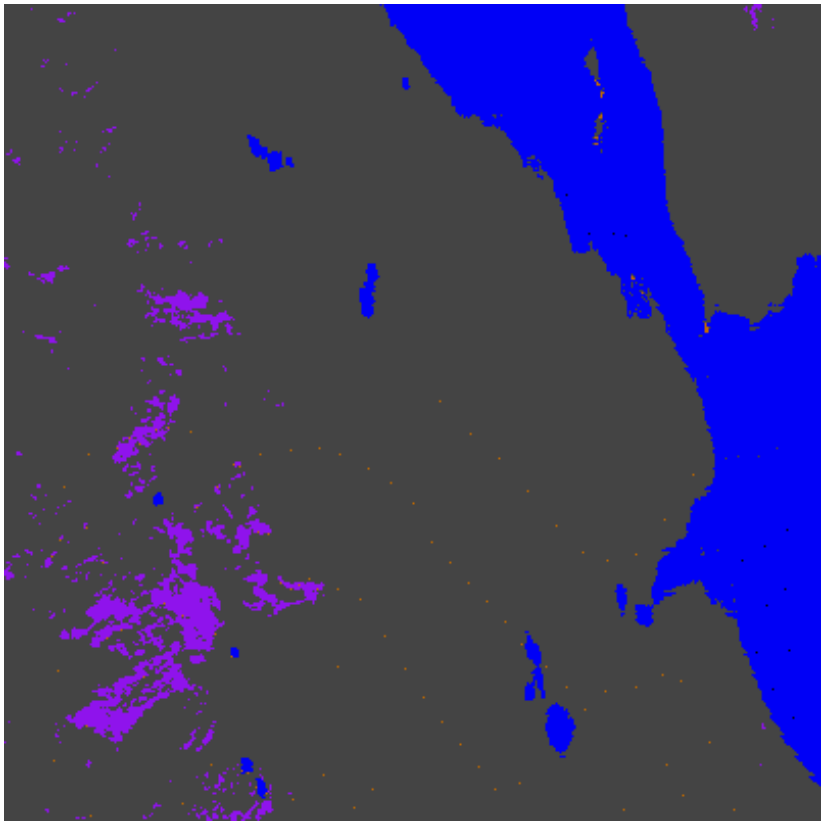
Zaire and Zambia, 18 July 2002 (2002199) 08:10

ANO / MOD14 Comparison

ANO

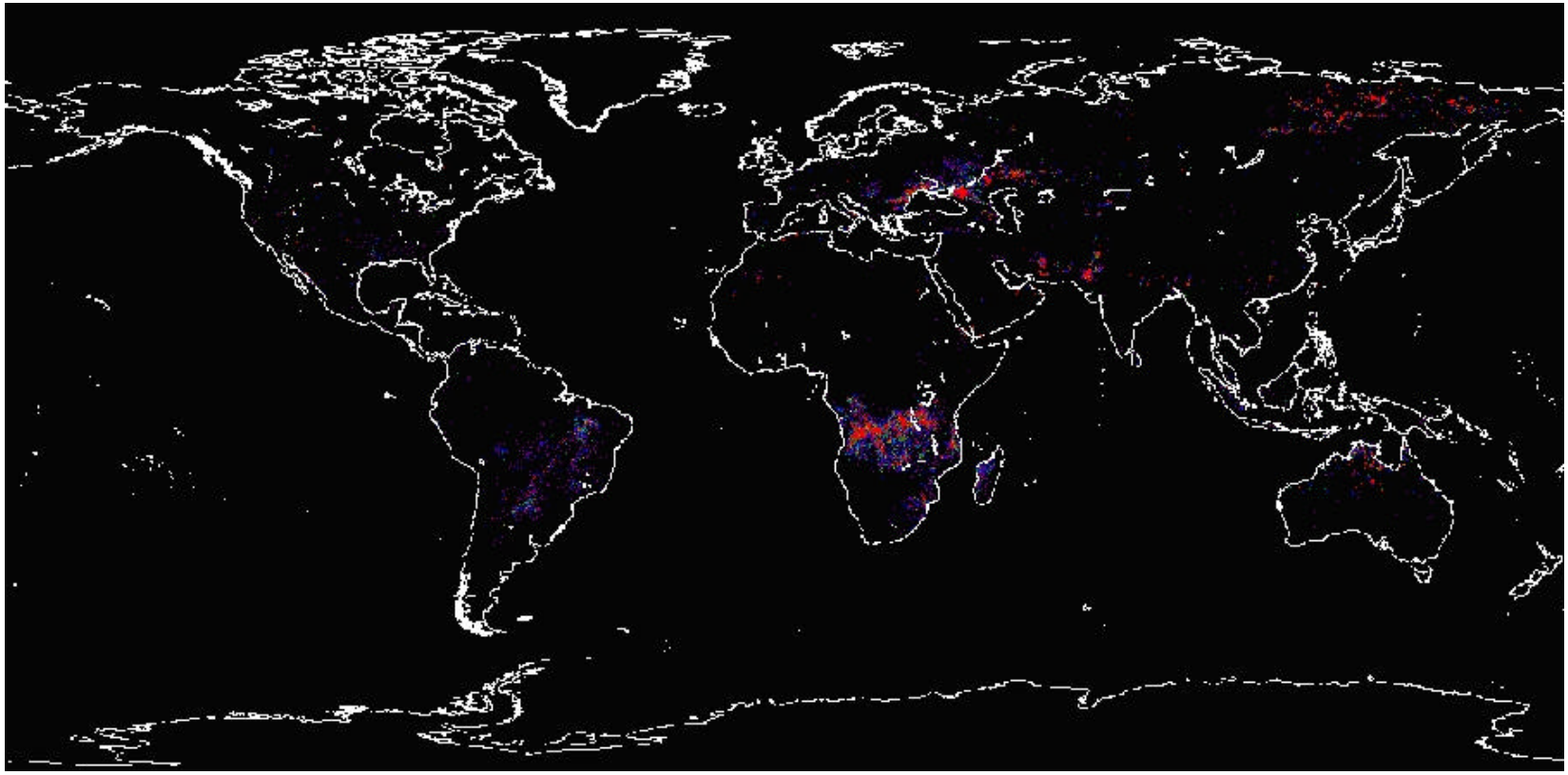


Mod 14

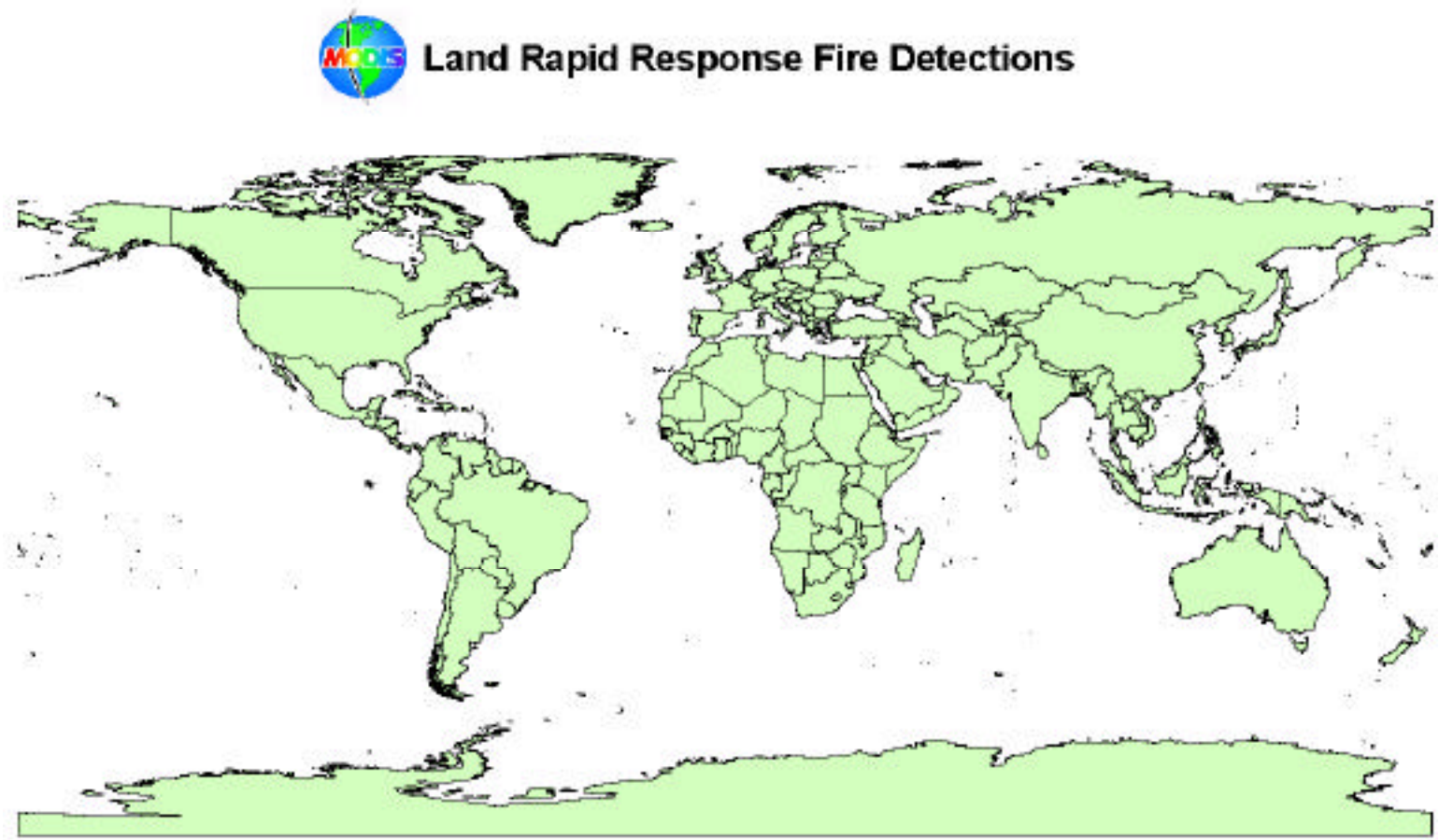


Ethiopia, 18 July 2002 (2002199) 08:10

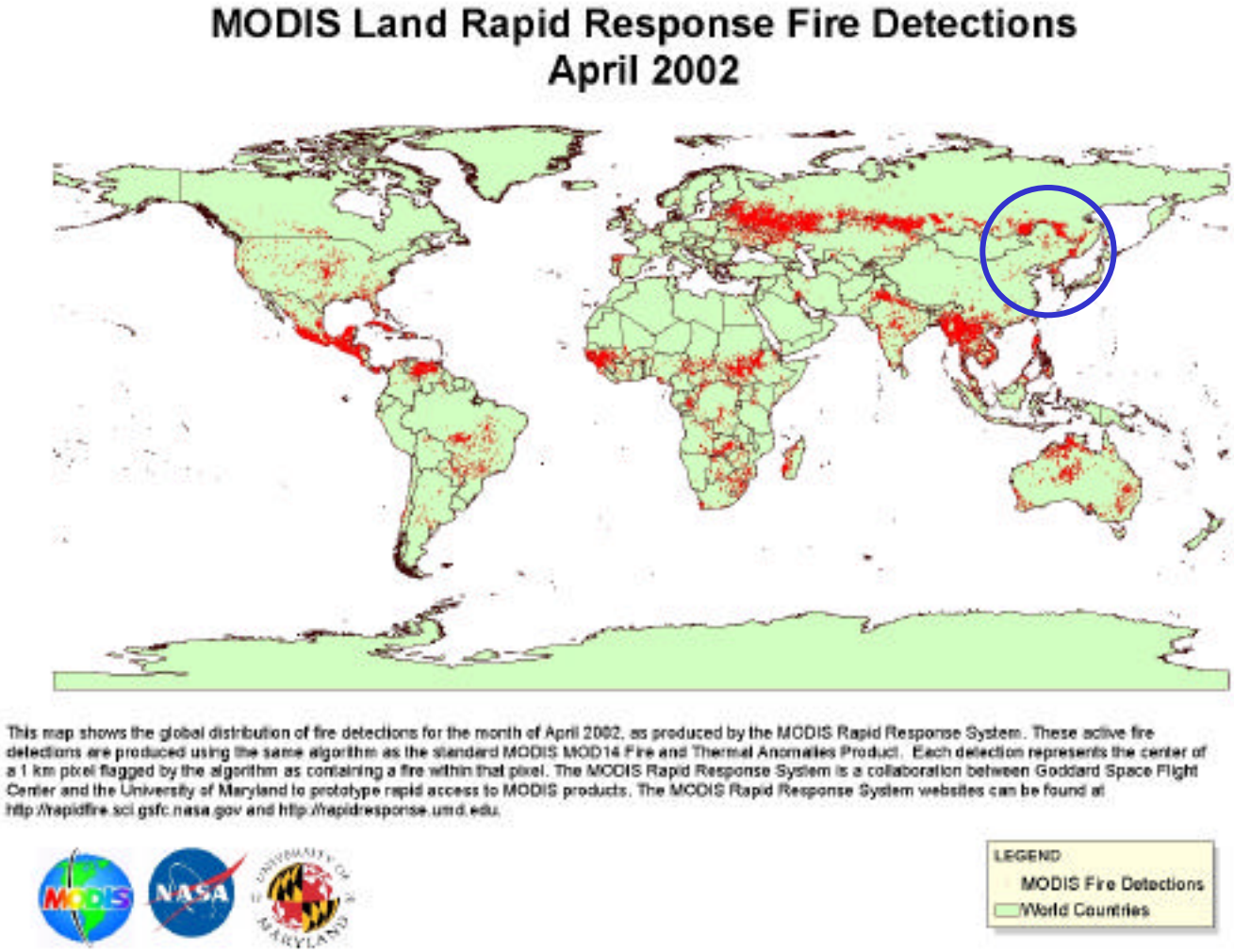
July 2001 CMG Layer



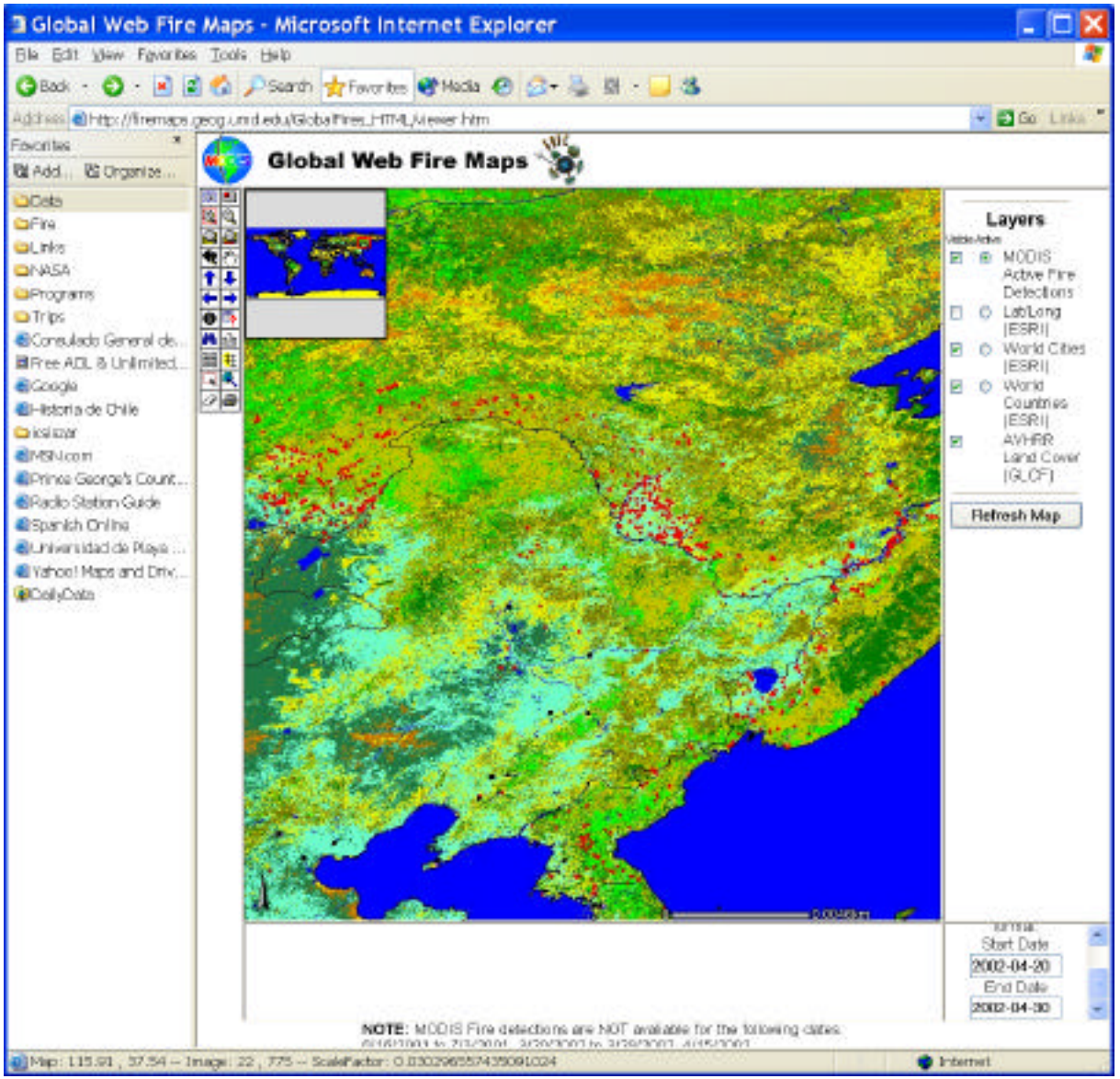
Fire Animation July 2001-2002



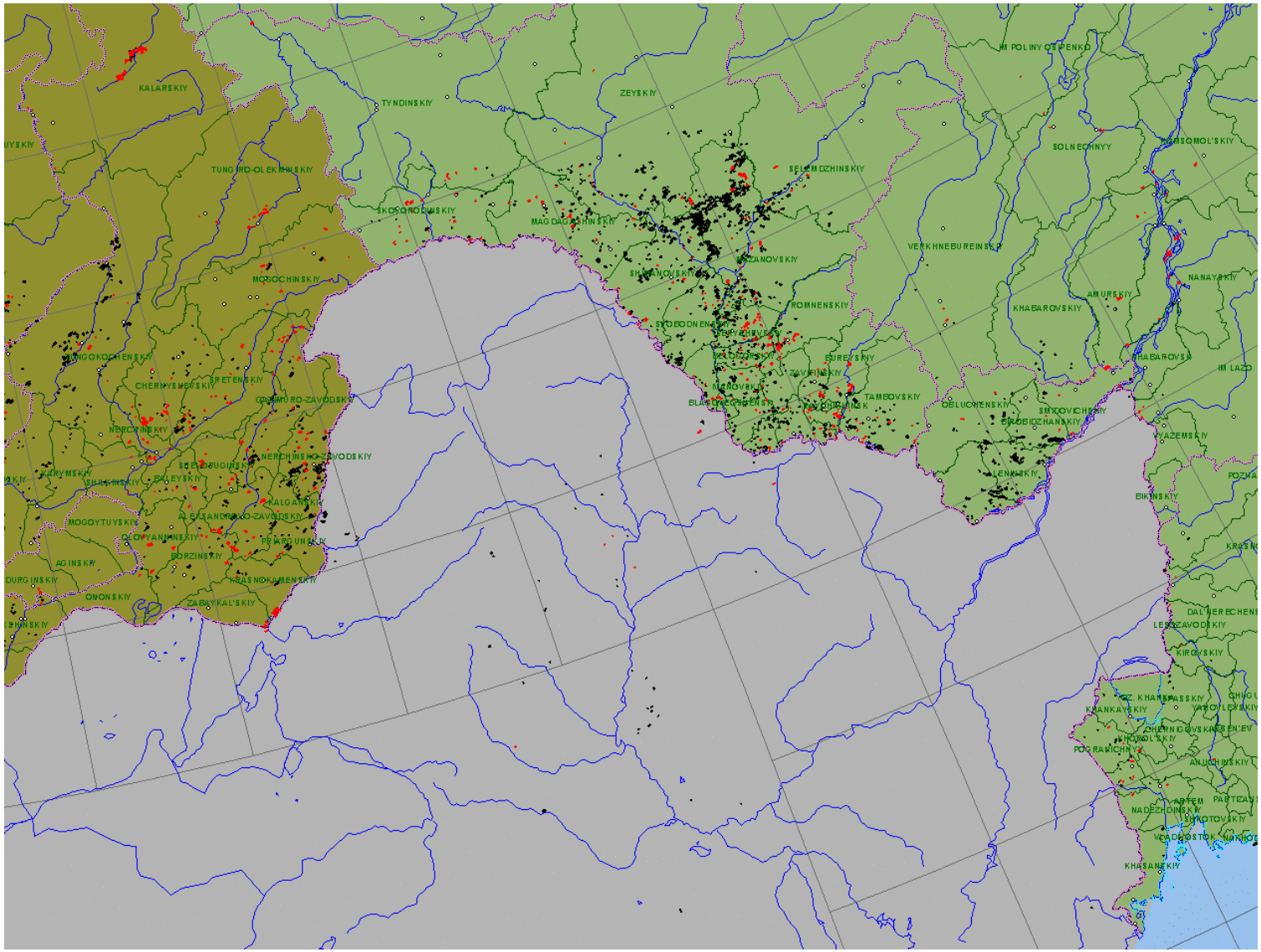
Investigating Global Fire Patterns



Siberian Fires – Russia/China Border



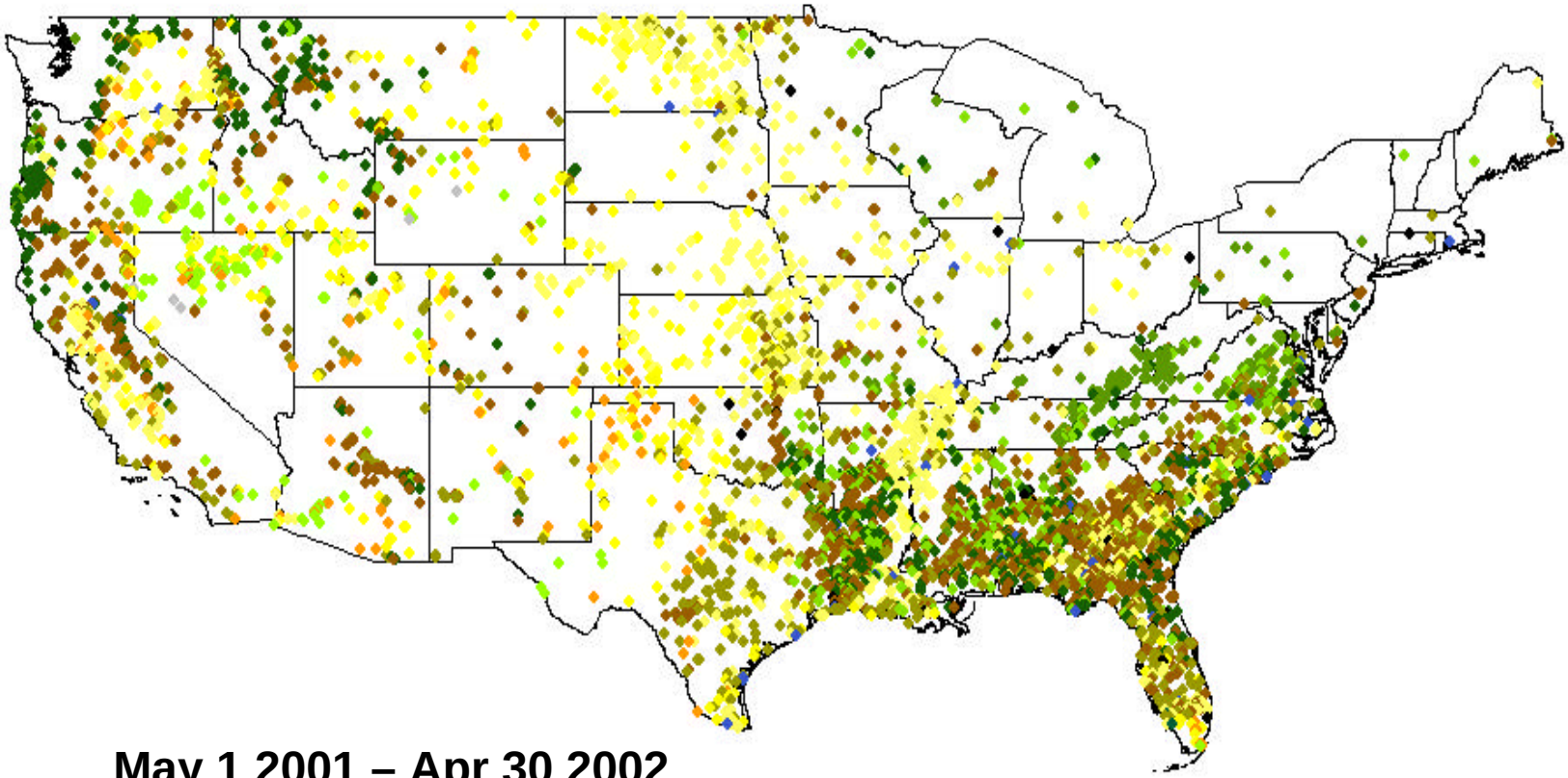
Siberian Fires



Credit: A. Sukhinin

Sukhachev Inst., Russia

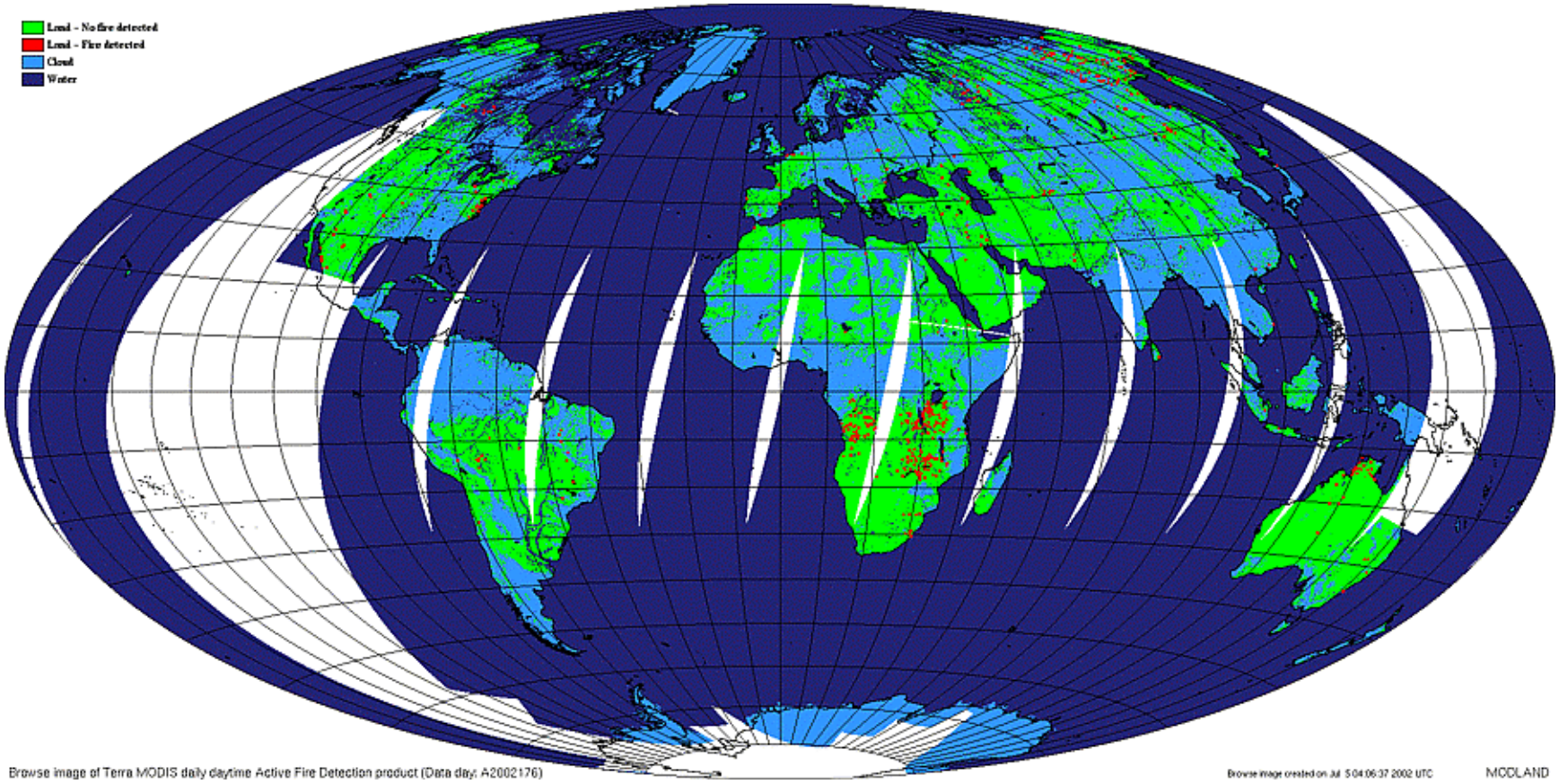
MODIS Land Rapid Response Fire Locations by Land Cover Type



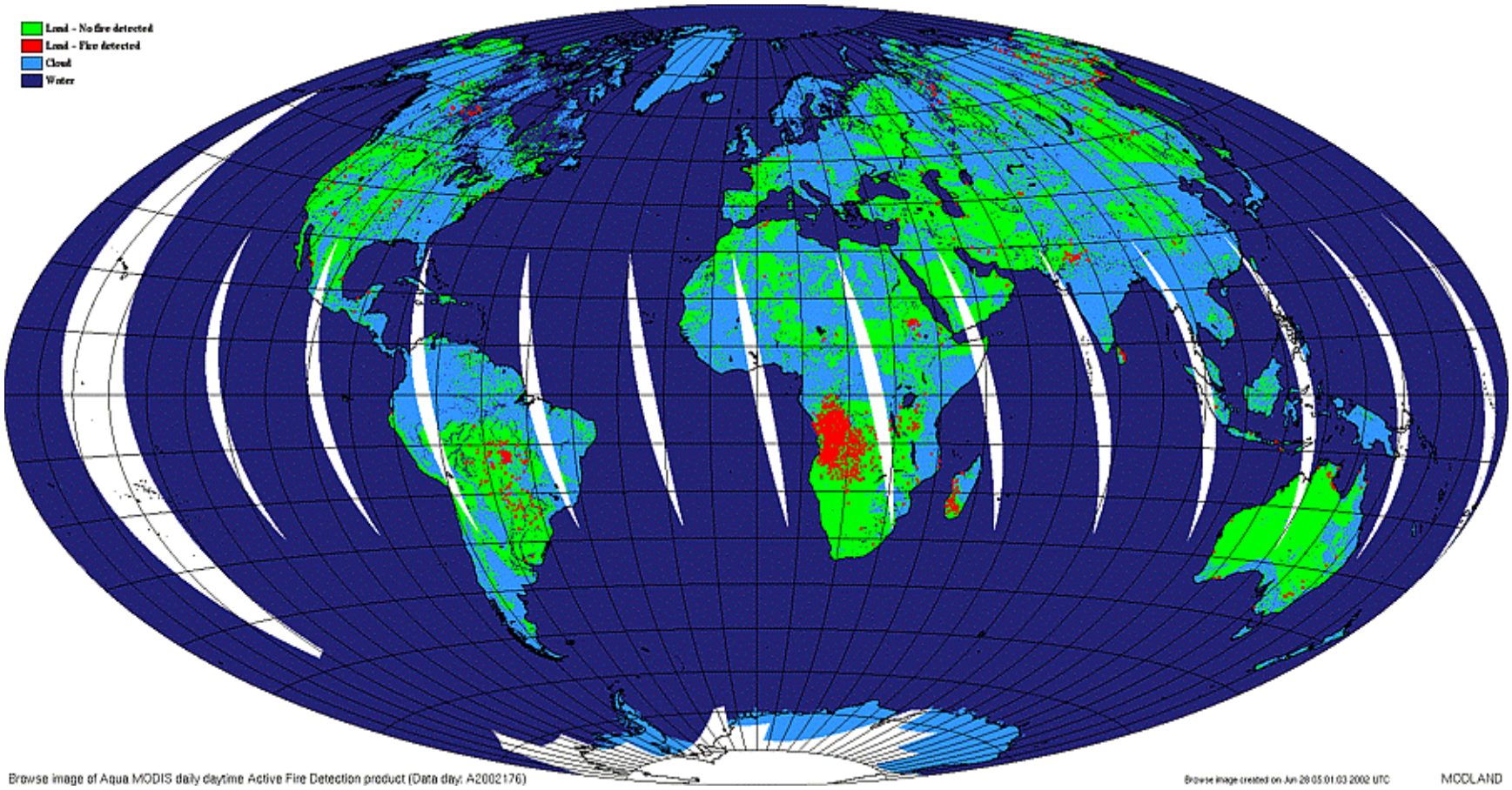
May 1 2001 – Apr 30 2002

Color Coding by UMd Land Cover
Greens – Forested
Yellows/Browns – Grassland /Ag

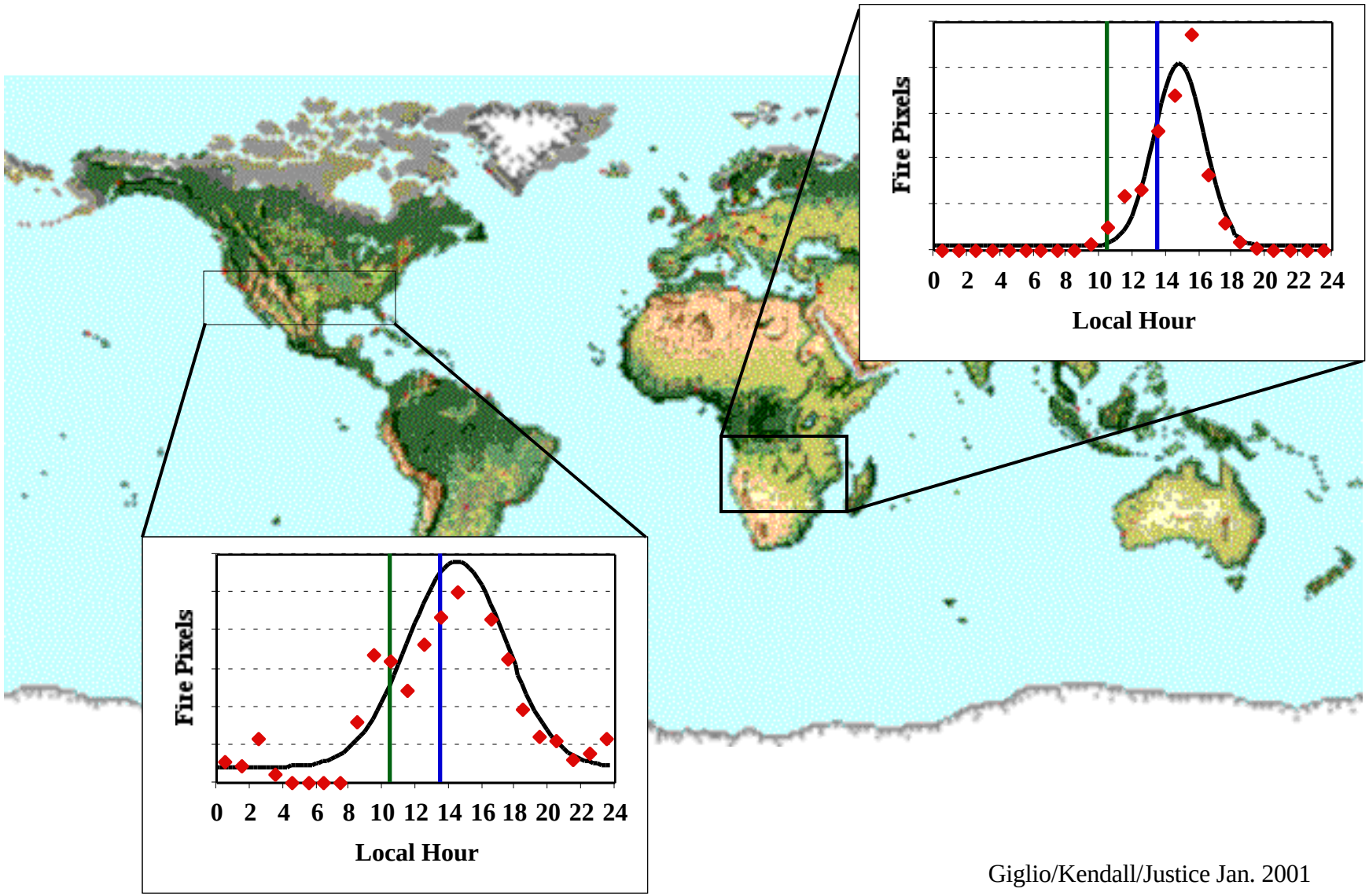
MODIS Terra Daily Global Browse
June 25th 2002



MODIS Aqua Daily Global Browse
June 25th 2002

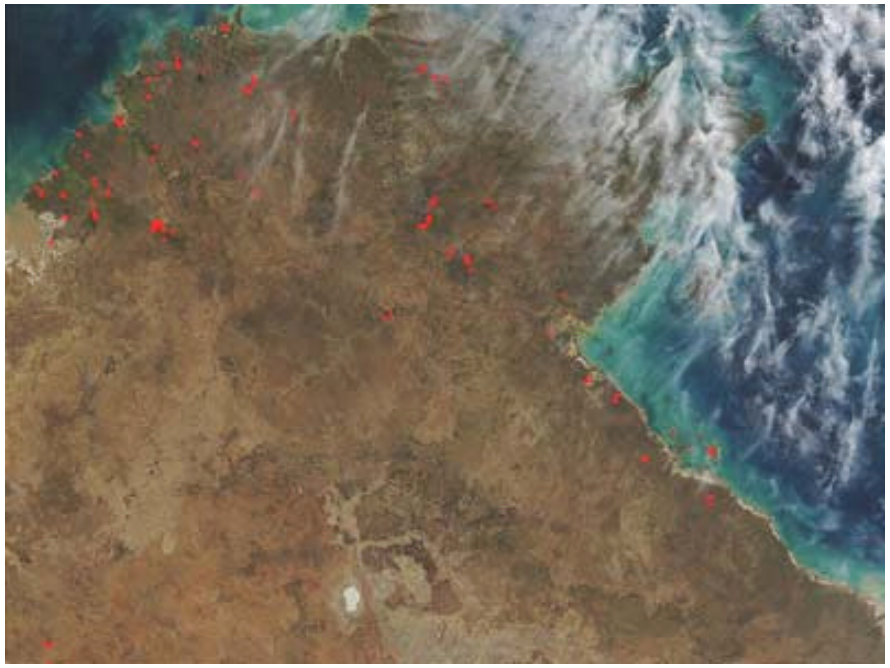


TRMM VIRS-Derived Diurnal Burning Cycle (July)



Giglio/Kendall/Justice Jan. 2001

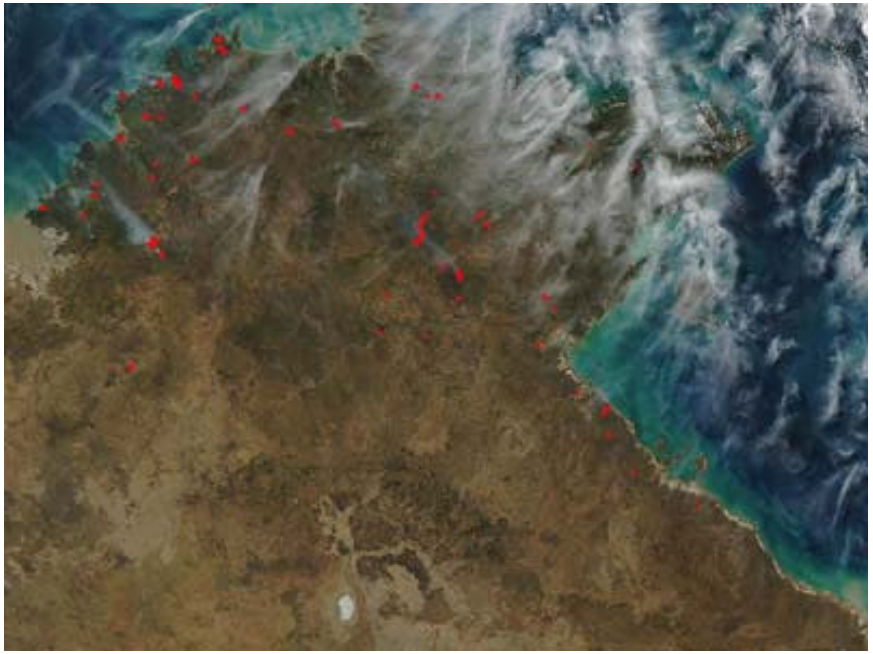
MODLAND/Giglio et al



MODIS Terra and Aqua

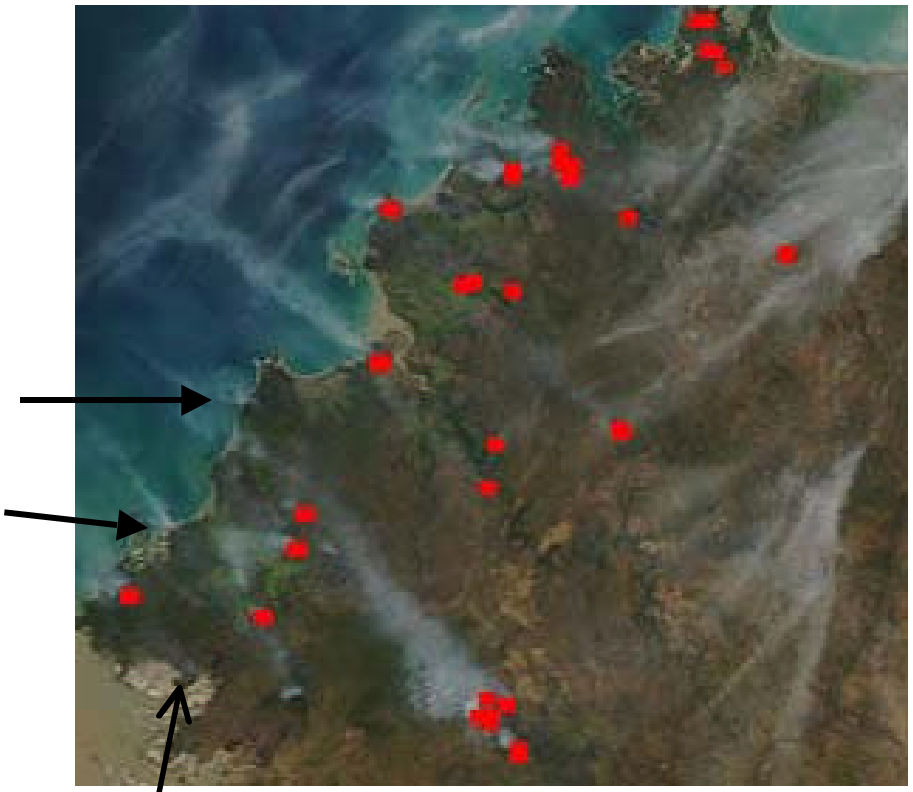
June 25th 2002

01.35 UTC

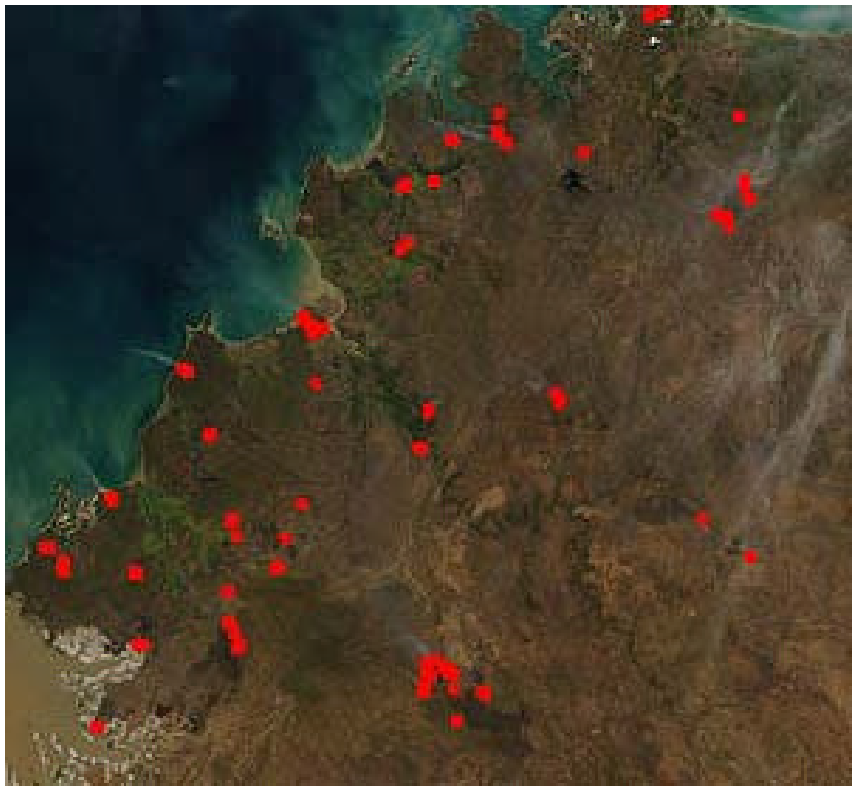


O4.20 UTC

MODIS Terra/Aqua
June 25th 2002



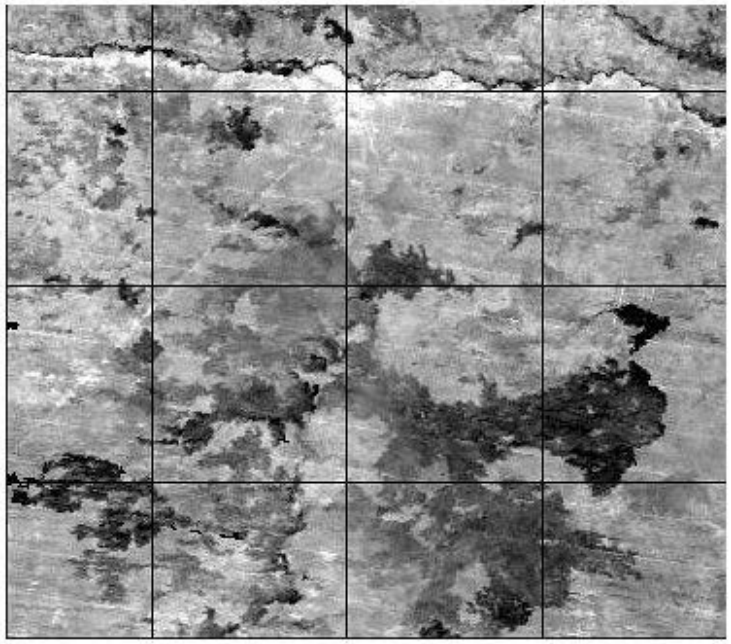
10.35am



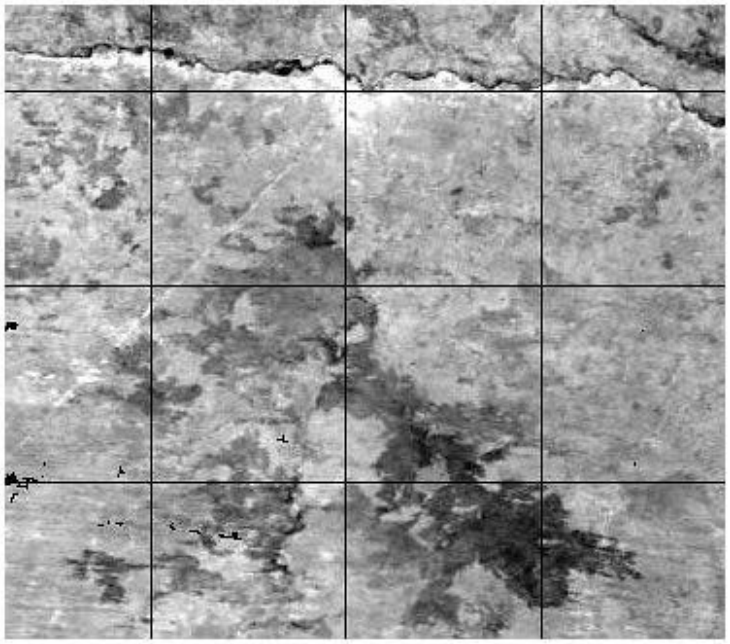
1.20pm

MODIS Burned Area Product

- Initial focus on generating regional validated products (Lisbon GOFC Workshop)
- Tied to NASA regional science initiatives and collaborations
  - SAFARI 2000
    - late August – late October 2000 (validated by SAFNet)
    - 2001 (validated by SAFNet)
  - LBA
  - Northern Eurasian Project
  - S.E Asia/Australia
- Global 500m production (2003)
- Local 250m production (2003 following emissions model sensitivity study)
  - in support of regional, natural resource management activities



Observed 1.24 micron reflectance (500m) day 275



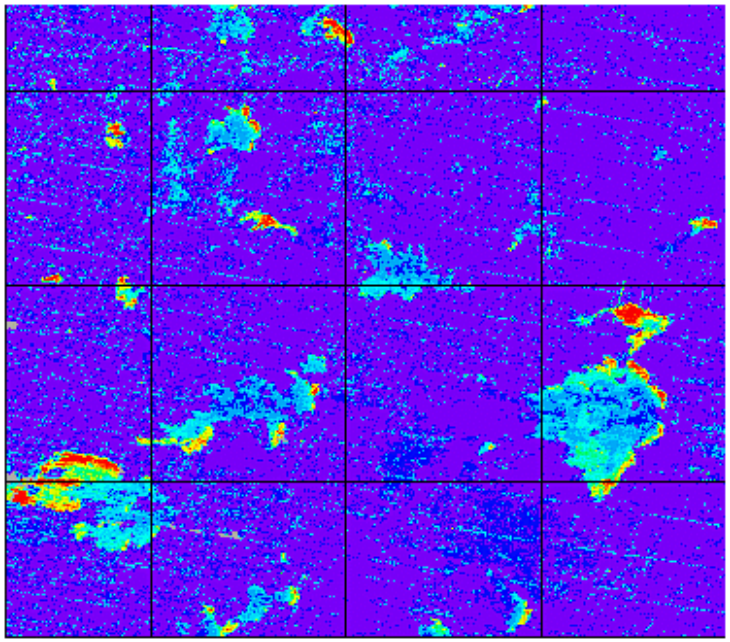
BRDF predicted 1.24 micron reflectance (500m) day 275

MODIS 500m Bi-Directional Reflectance Model-Based Expectation Approach

NW: MODIS reflectance day 275

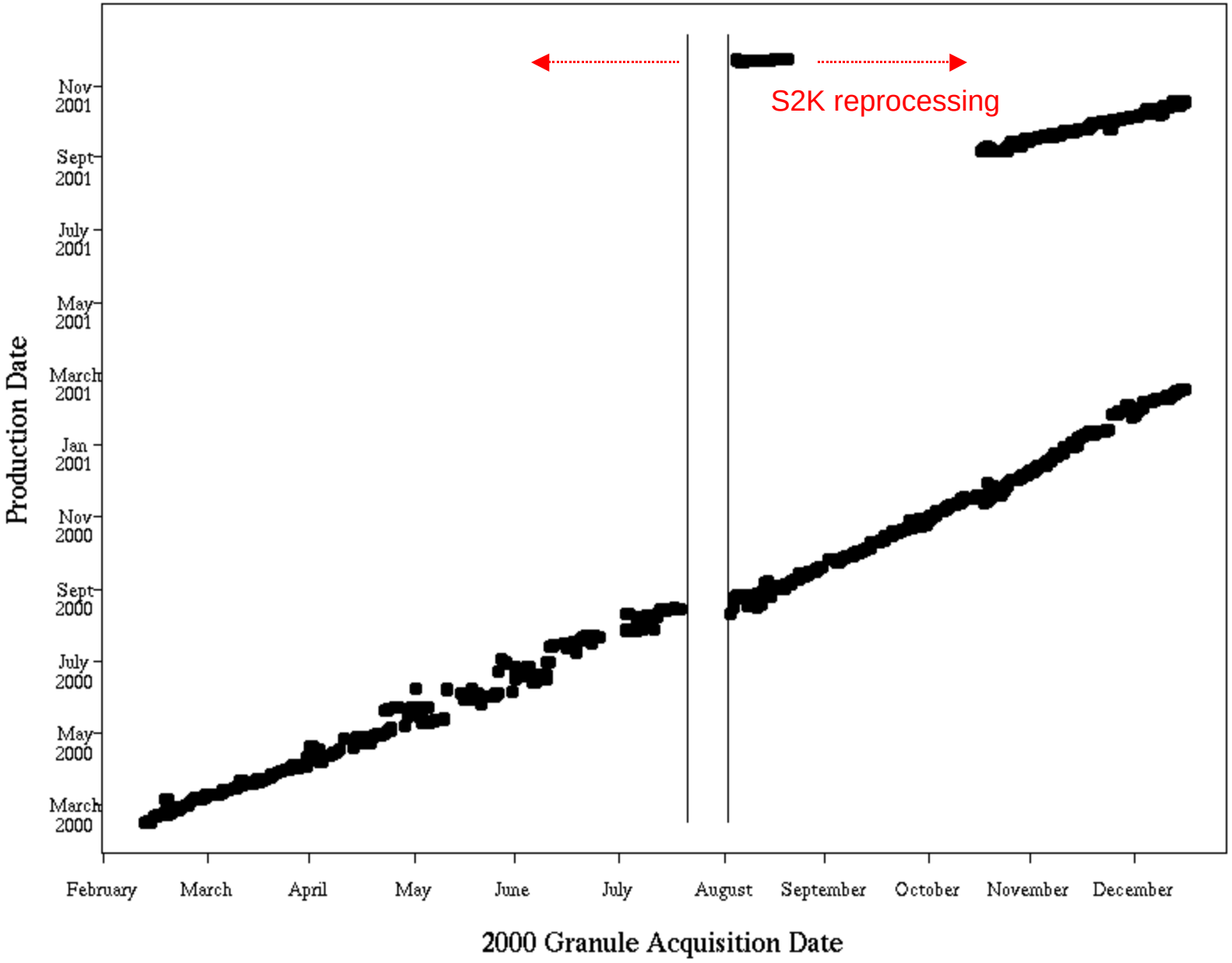
NE: Day 275 predicted reflectance modeled from previous 16 days observations

SE: Z-score = predicted-observed/error (probability of change)



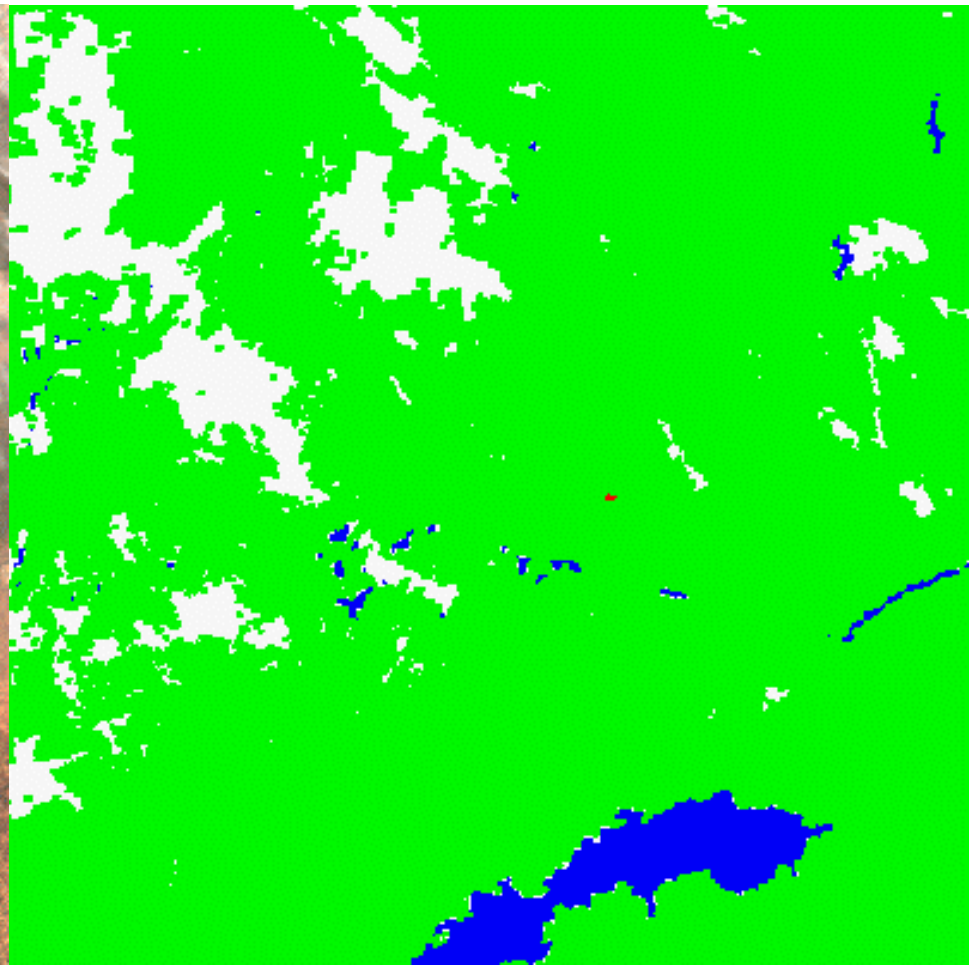
Z–score 1.24 micron reflectance (500m) day 275

MODIS 2000 Reprocessing Status, 12/10/01



Original

August 22nd 2000

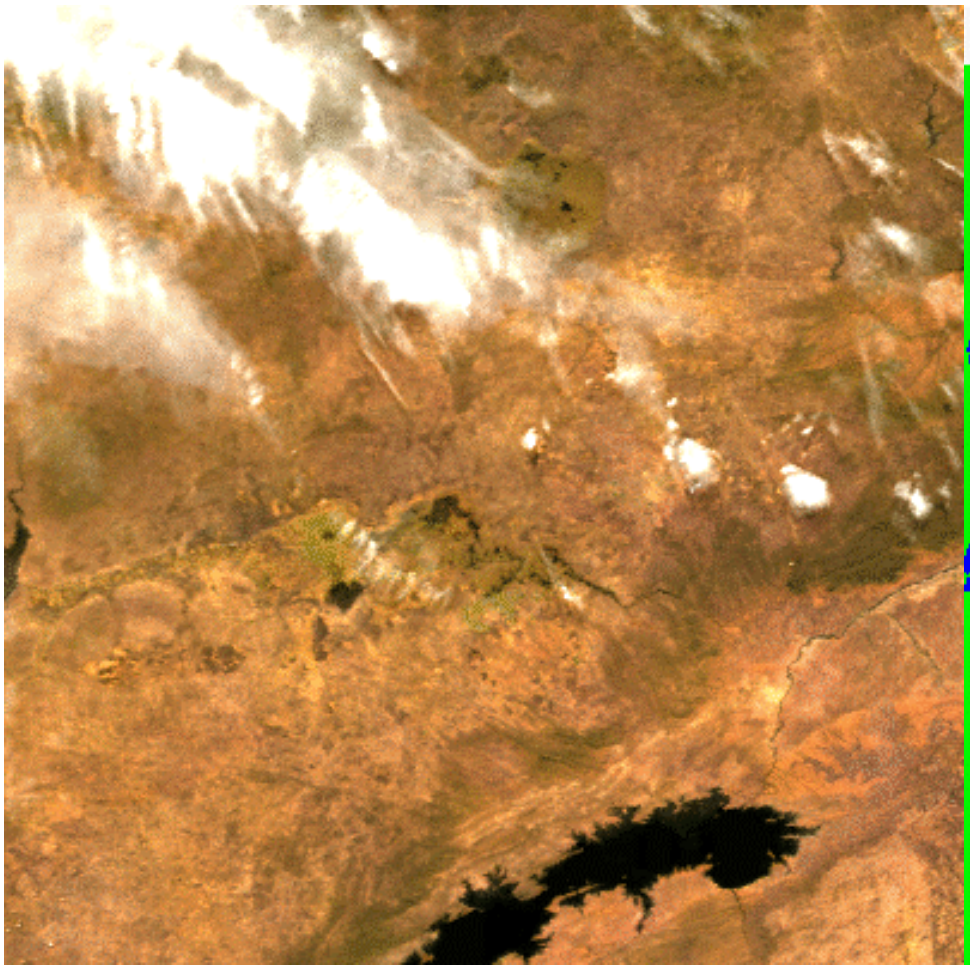


MODIS red, green, blue 500m land surface reflectance

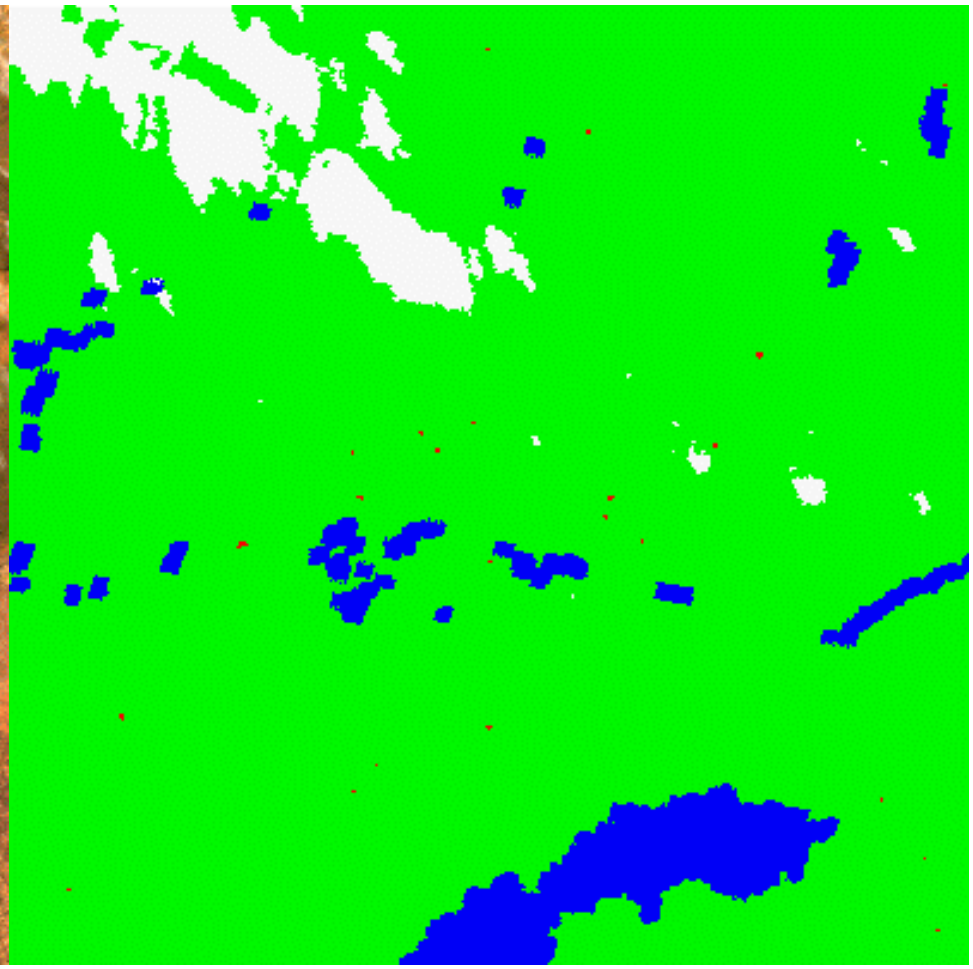
MODIS 1km active fire

Reprocessed

August 22nd 2000



MODIS red, green, blue 500m land surface reflectance



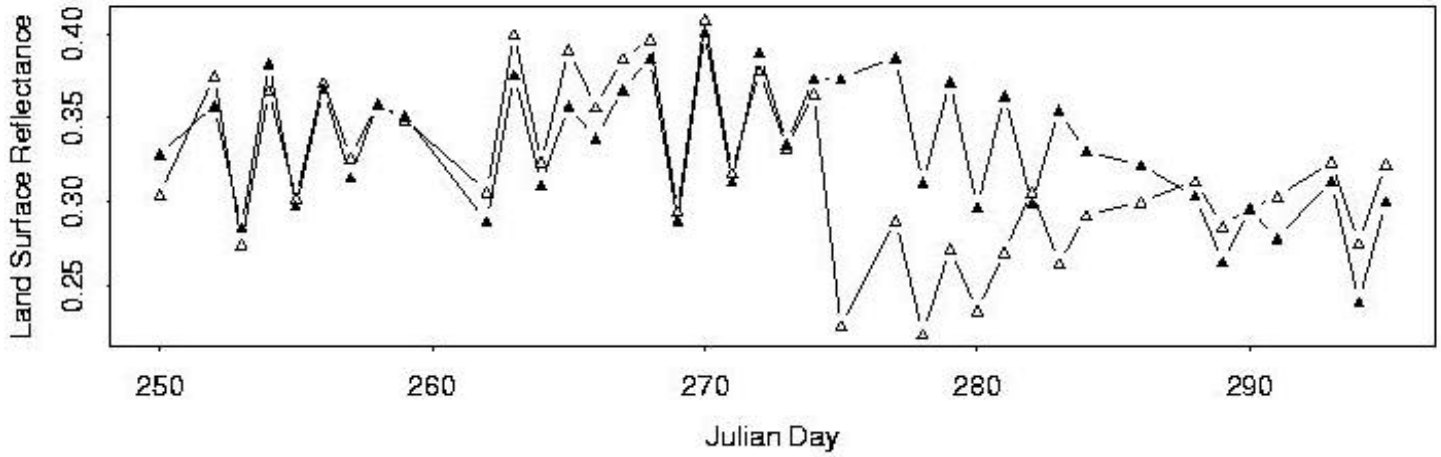
MODIS 1km active fire

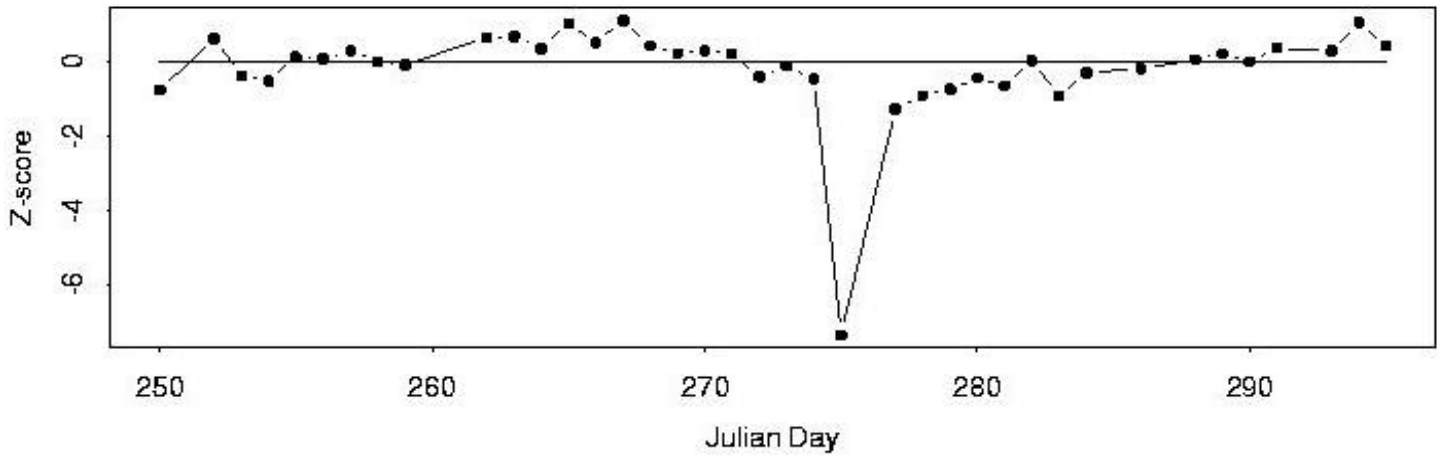
MODIS burned area product description

- Monthly geolocated product
- 500m pixel dimension
  - defined in the Level 3 MODIS land tile grid
  - 2400*2400 500m pixels, ~10*10º area
  - approximately 11Mb per tile
- Pixel values
  - n = approximate Julian day of burning
  - 0 = not burned
  - 999 = could not perform mapping due to missing data or persistent cloud
  - 991-998 = QA codes

Time series of observed (open triangles) and predicted (filled triangles) MODIS band 5 (1.240μm) land surface reflectance data and corresponding Z-score values

Single pixel located near the Angolan-Namibian border, fire on day 275

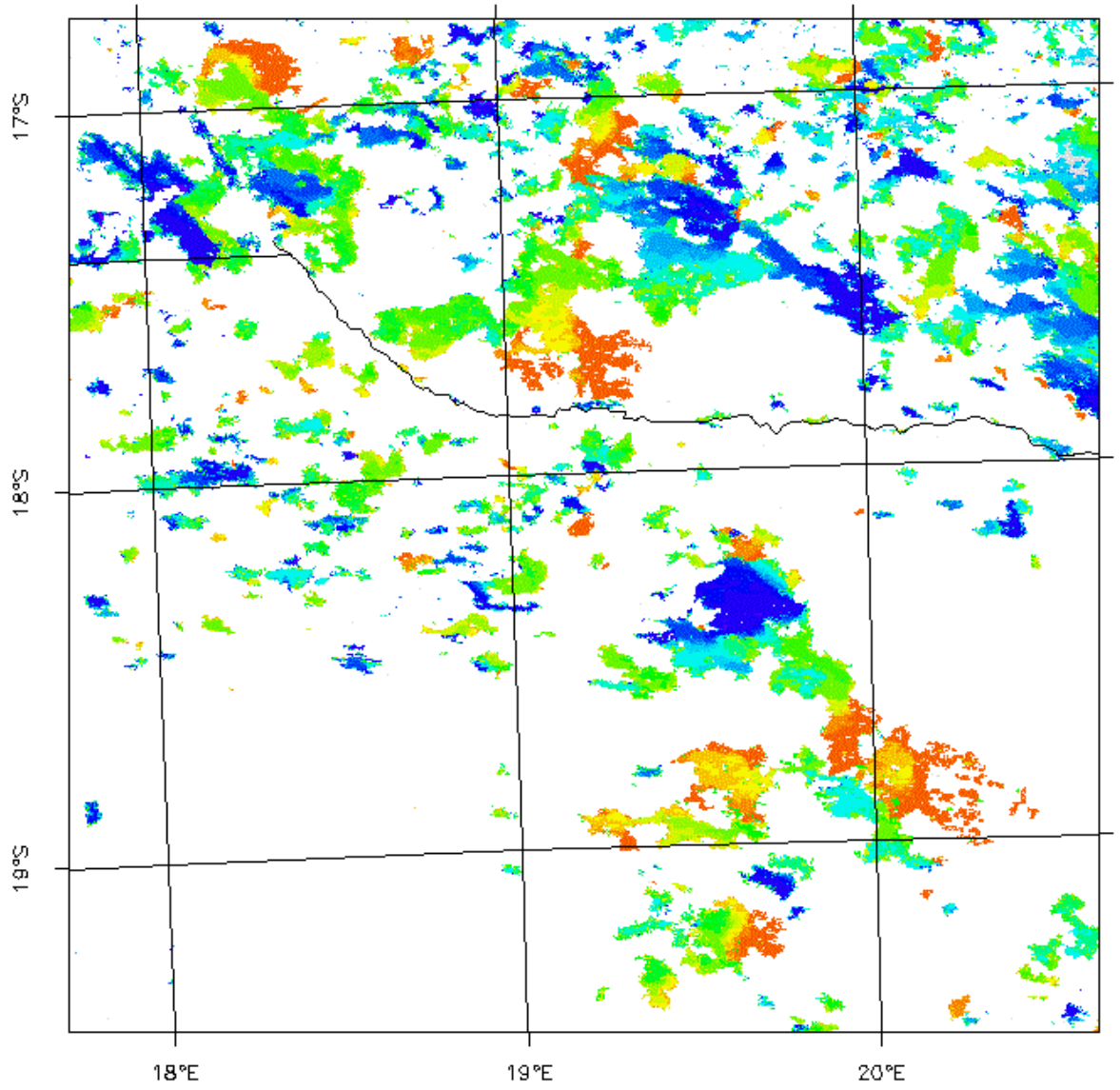




D. Roy

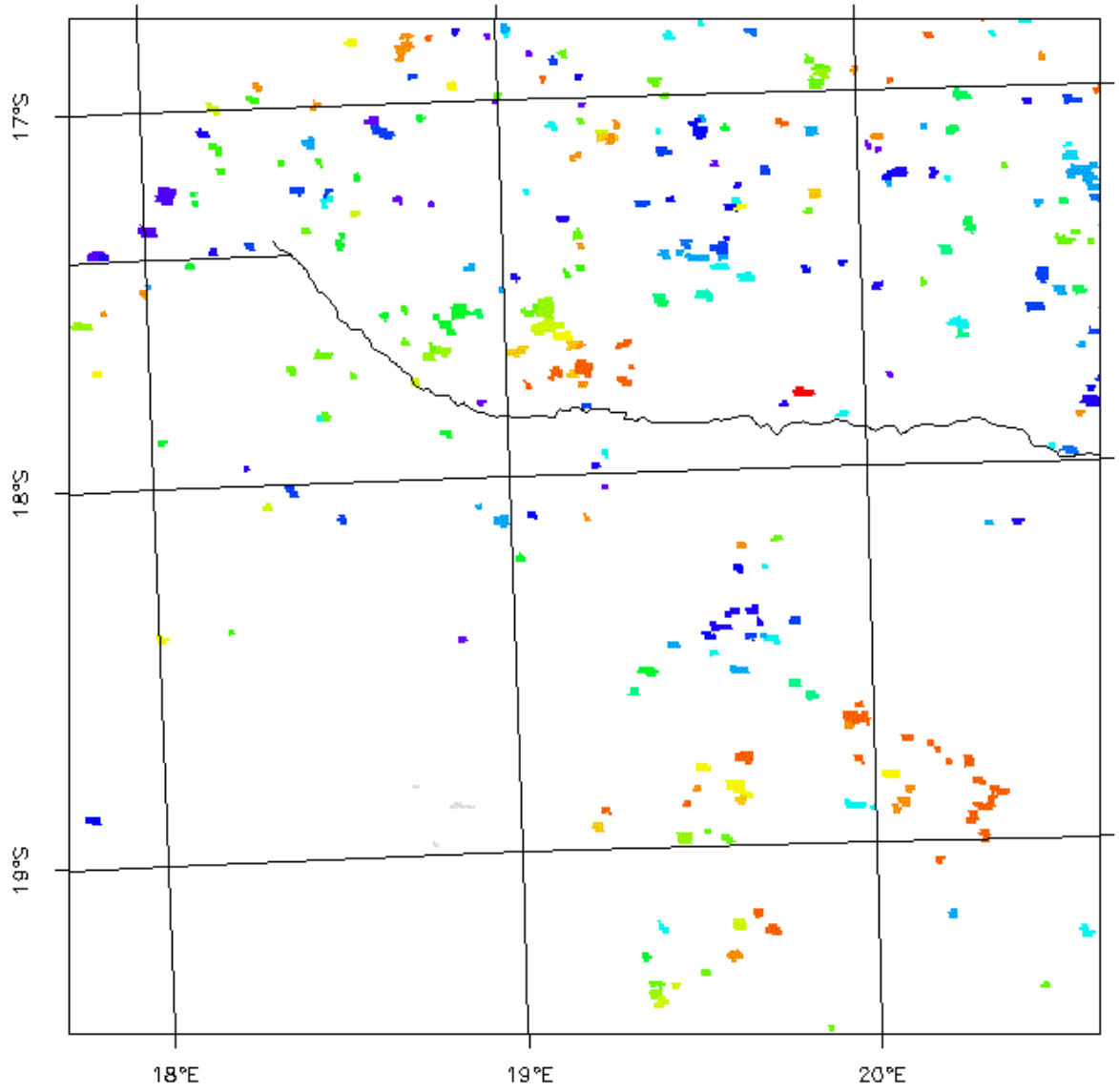
MODIS 500m burned area results, Angolan-Nambian border

August 21 – September 18, 2000



MODIS 1km day & night active fire results, Angolan-Nambian border

August 21 – September 18, 2000



Emissions Model Outline

Area burned (ha) x Fuel Loading (kg/ha) x Combustion Completeness (%) x Emission Factors ($g/kg_{dry\ fuel}$) = Emissions (g)

Data Inputs/Source

- MODIS Burned Area (1km, 500m), D.Roy
- JRC-GBA 2000 (1km)

- UVA fuel load(1km)
- S. Prince's NPP?? (8km)

Combustion Completeness

UMD Tree Cover< 10%: $C_g = f(PGREEN)$ —*ZIBBEE*

UMD Tree Cover≥ 10%: $C_w = f(PGREEN)$ *ZIBBEE*

Emission Factors

UMD Tree Cover< 10%: $E_g = f(MCE_g) = f(PGREEN)$ *Unpub.* *ZIBBEE*

UMD Tree Cover≥ 10%: $E_w = f(MCE_w) = f(PLITTER)$

Definition of terms:

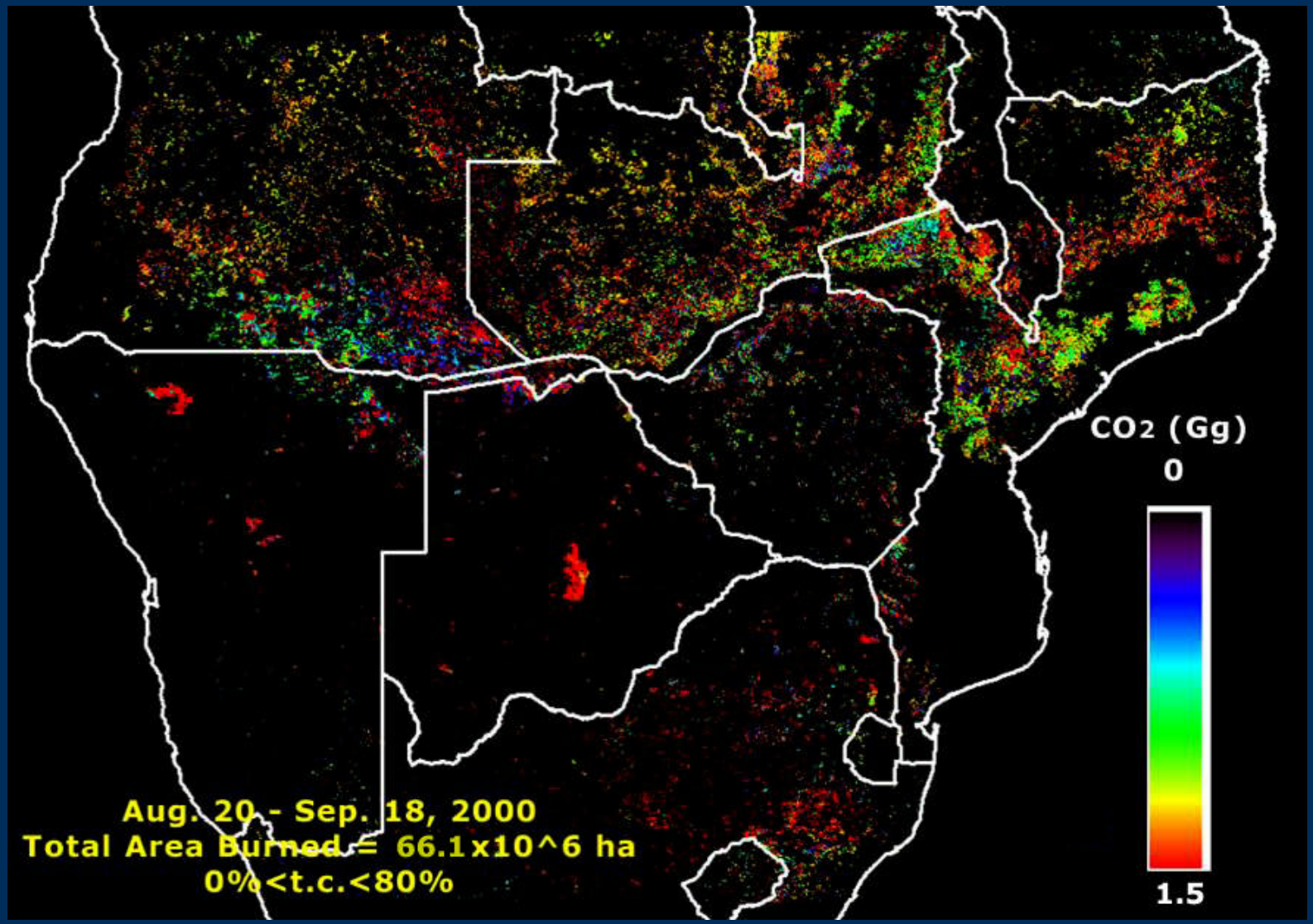
PLITTER = (litter/total fuel)

PGREEN = (green grass/total grass)

MCE = $CO_2/(CO+CO_2)$

Total Fuel = Litter+Grass (live,dead)+twigs

Preliminary Results:
MODIS-derived regional emissions



Preliminary Comparison of Emissions Estimates

Emissions	Preliminary results from this study	Scholes *et al.* (1996)
CO_2 (Tg)	305	81
CO (Tg)	15.6	3.7
CH_4 (Tg)	0.5	0.1
NMHC (Tg)	0.4	-
$PM_{2.5}$ (Tg)	0.6	0.2

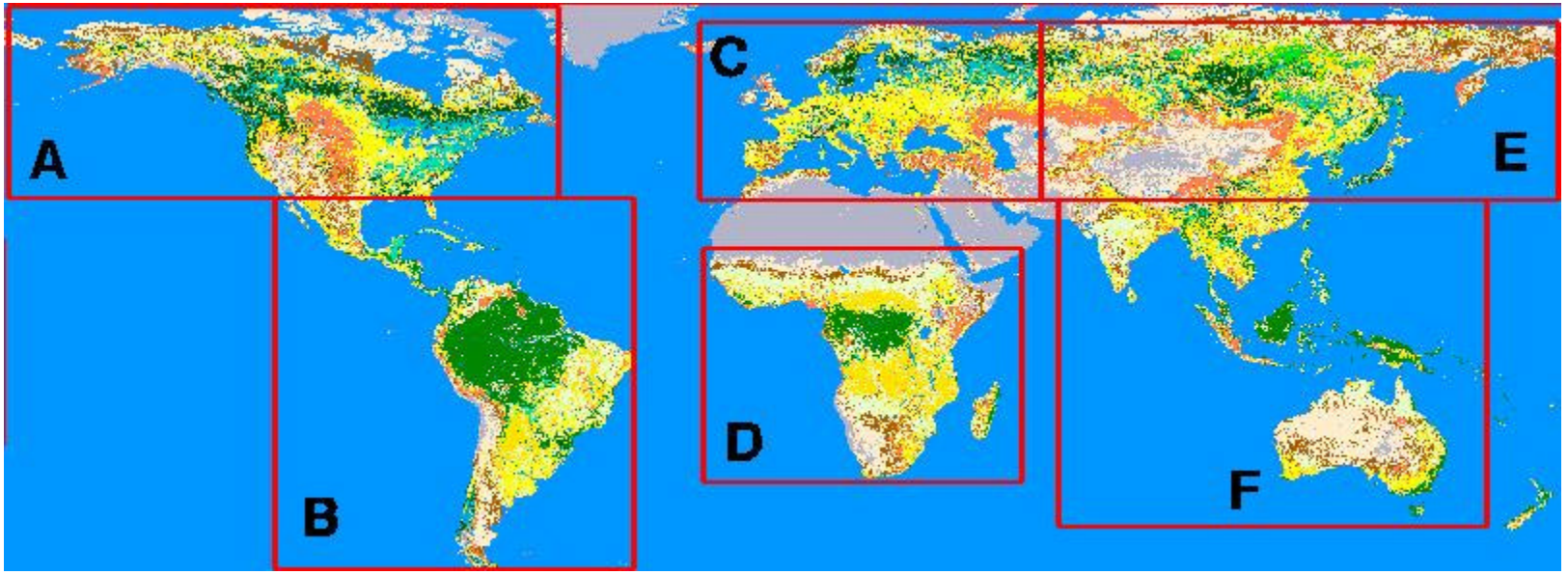
EU GBA 2000: SPOT VGT

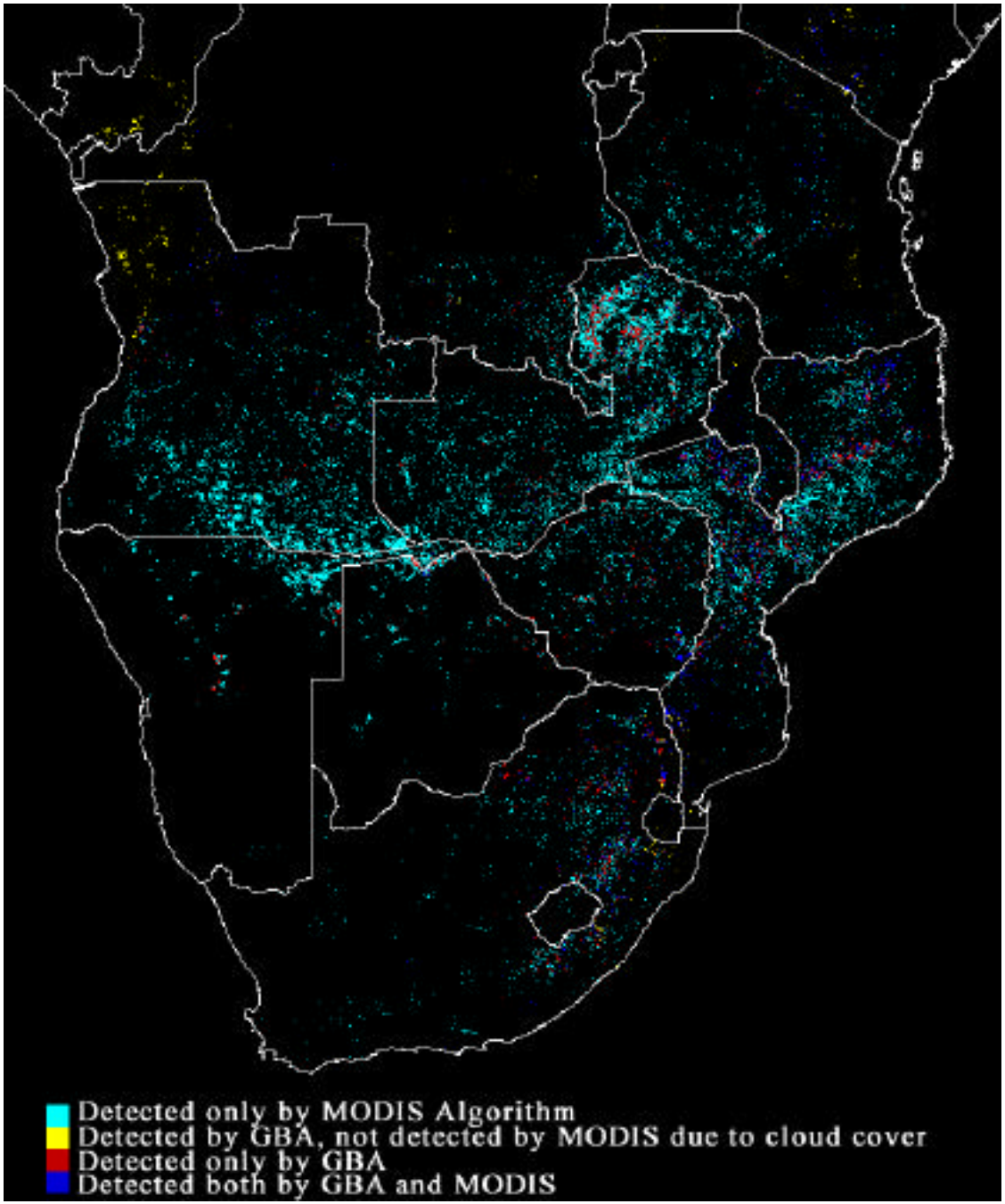
Monthly and Annual Beta products currently available for selected Regions

Region specific algorithm development

Feedback concerning Australia, Russia, S. Europe and C. Africa products
Some modifications to algorithms have been made

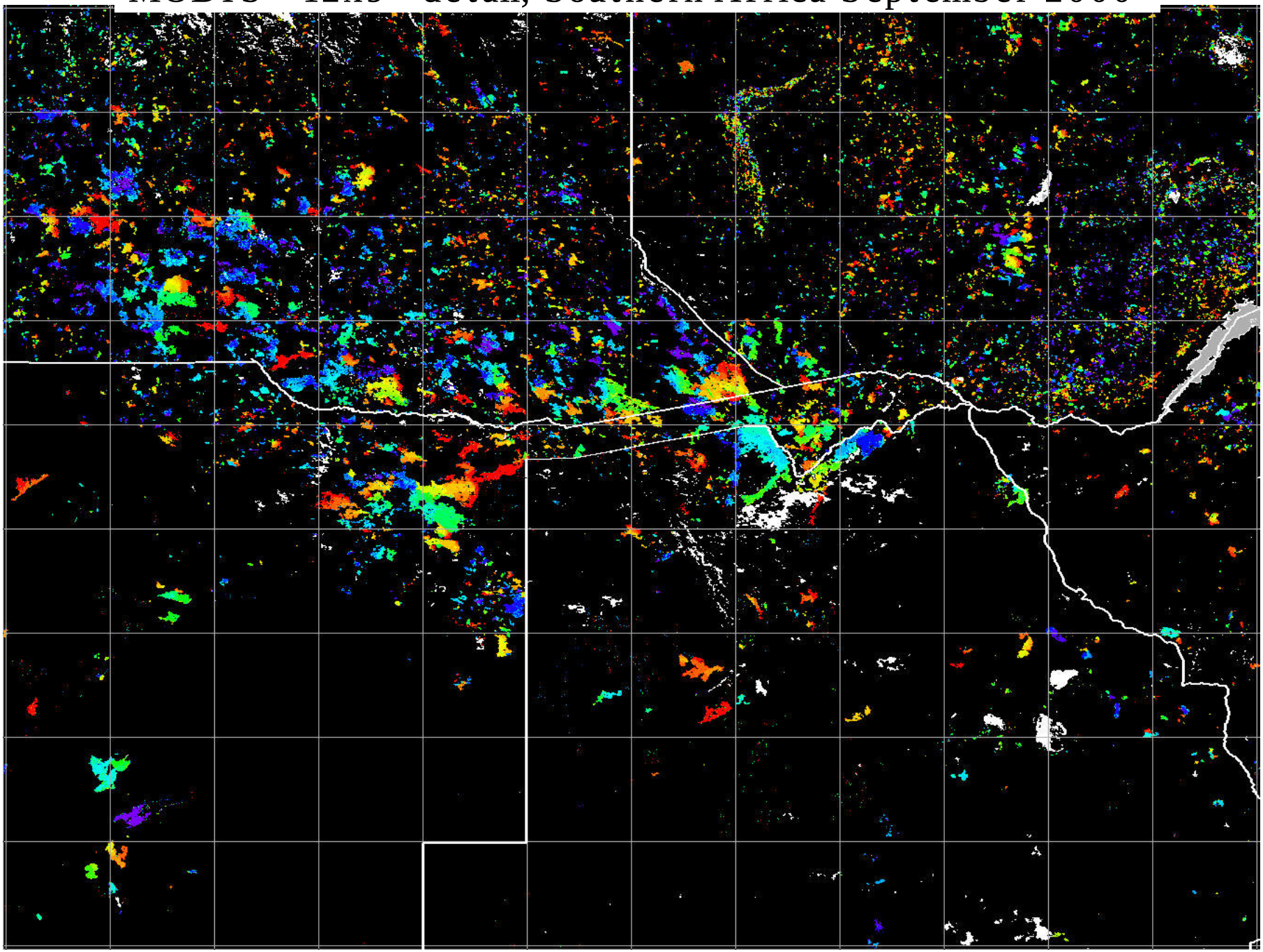
No plans for multi-year products – Product Validation TBD



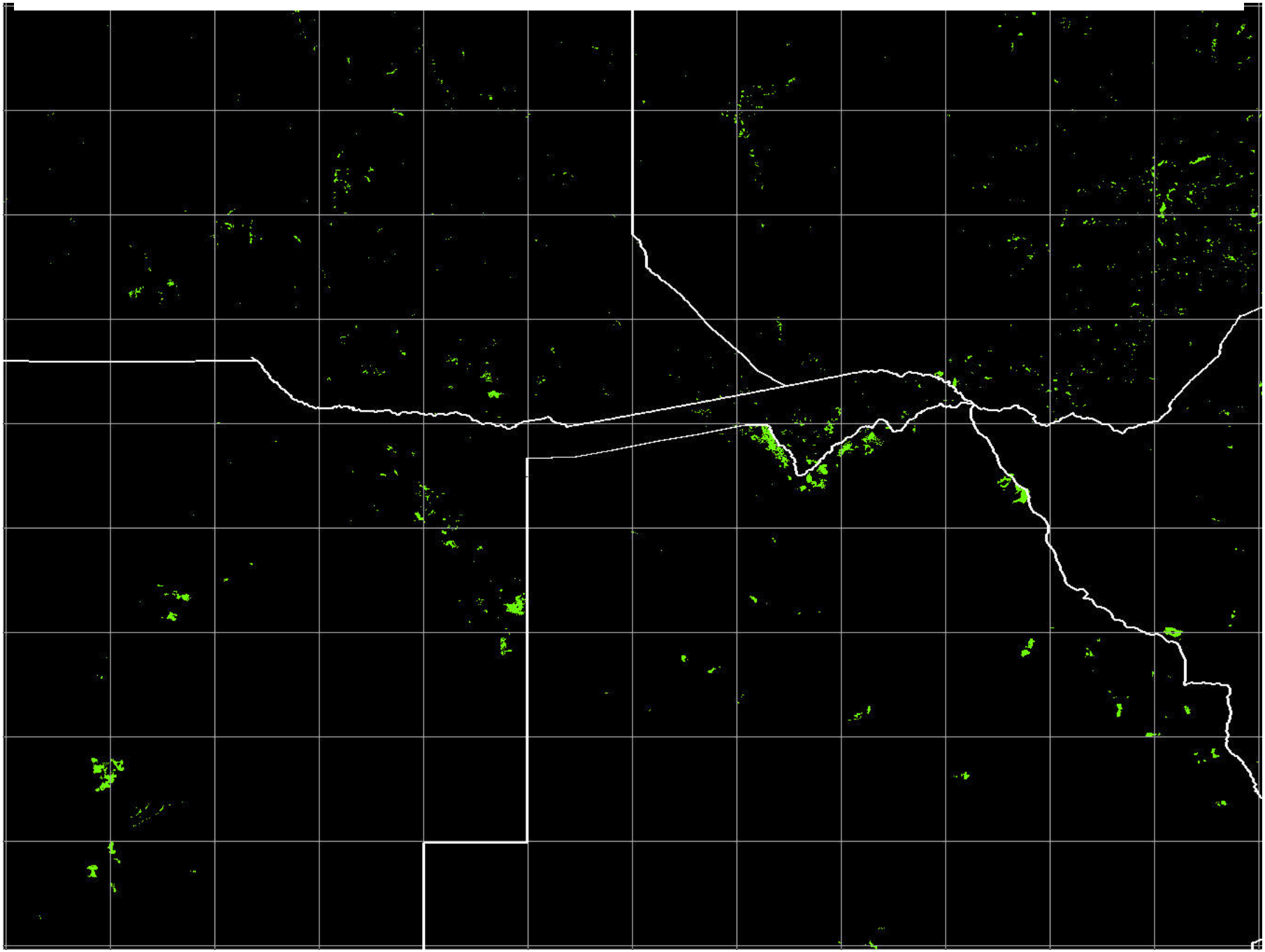


MODIS/VGT Burned Area Comparison September 2000

MODIS – 12x9° detail, Southern Africa September 2000



GBA – 12x9° detail, Southern Africa September 2000



Burned Area Impact on Emissions Estimation
(September 2000)

- MODIS Burned Area - 33.7 Million Ha > 163 Tg CO^2
- VEGT GBA - 7.8 Million Ha > 36.8 Tg CO^2

Need for Accurate Burned Area Products

Emphasis on Distribution of Validated Products

(GOFC/GOLDFire - IGAC/BIBEX Workshop)

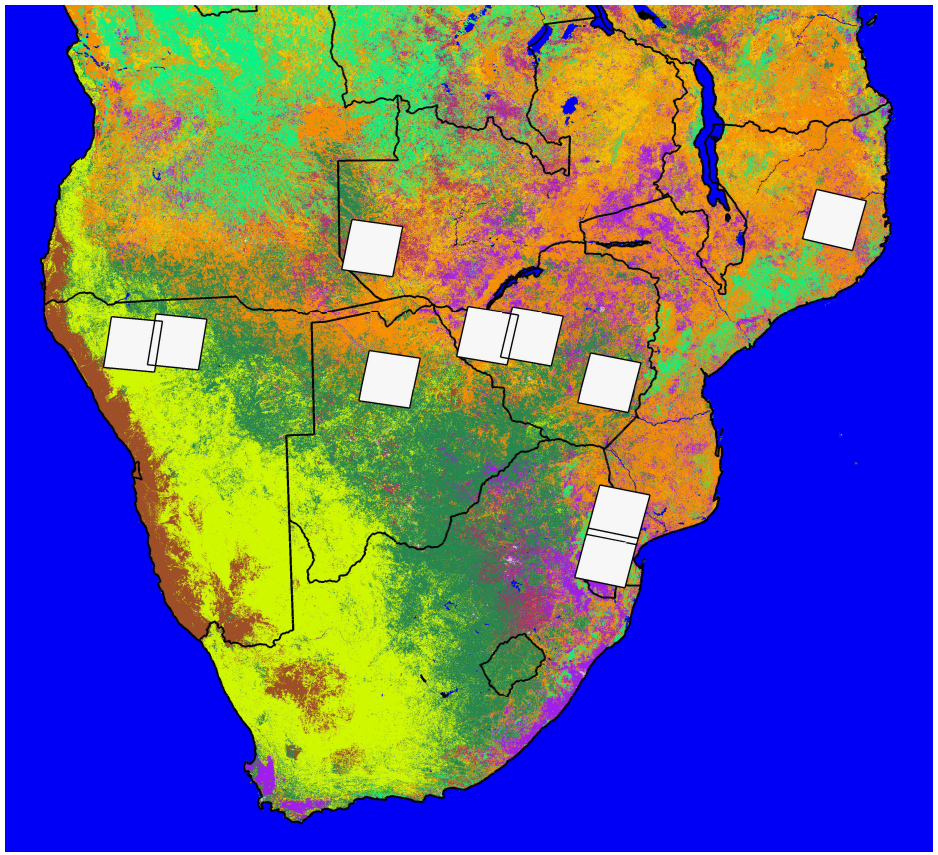
Korontzi and Roy

MODIS burned area product validation

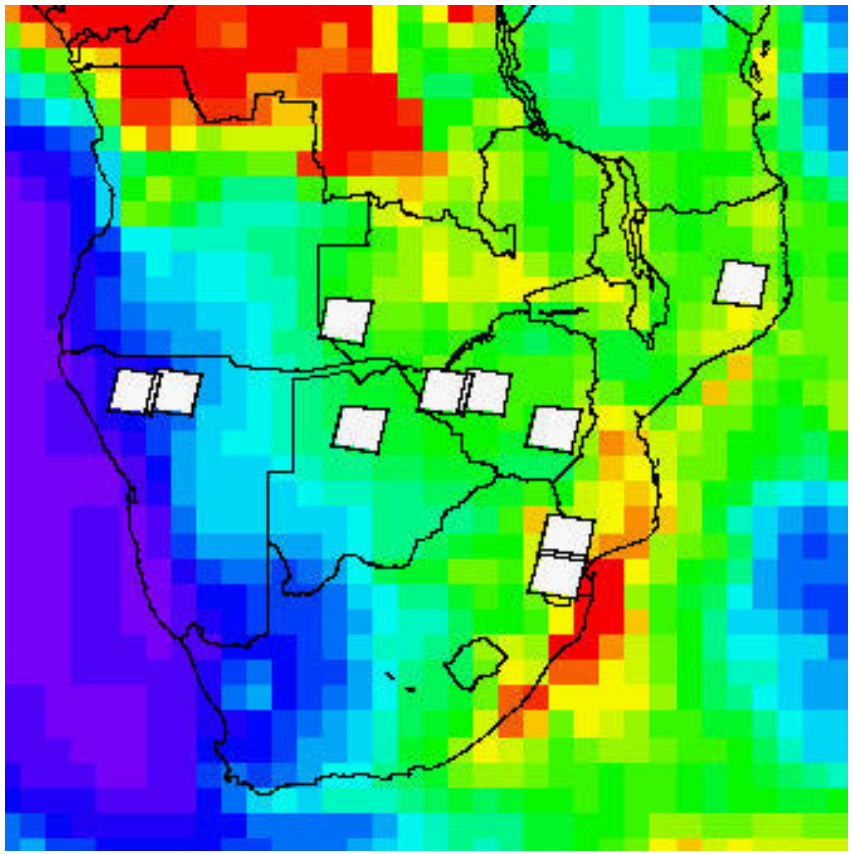
Zimbabwe-Zambia Traveling Meeting, 11-19th July 2000, to develop **consensus** valdiation protocol -> GOFC-Fire network SAFNet

2000 SAFNet sites, Landsat ETM+ path/rows distributed from dry savanna to wet miombo woodland

(quantify product accuracy over range of representative biomass burning conditions)



MODIS 1km land cover product



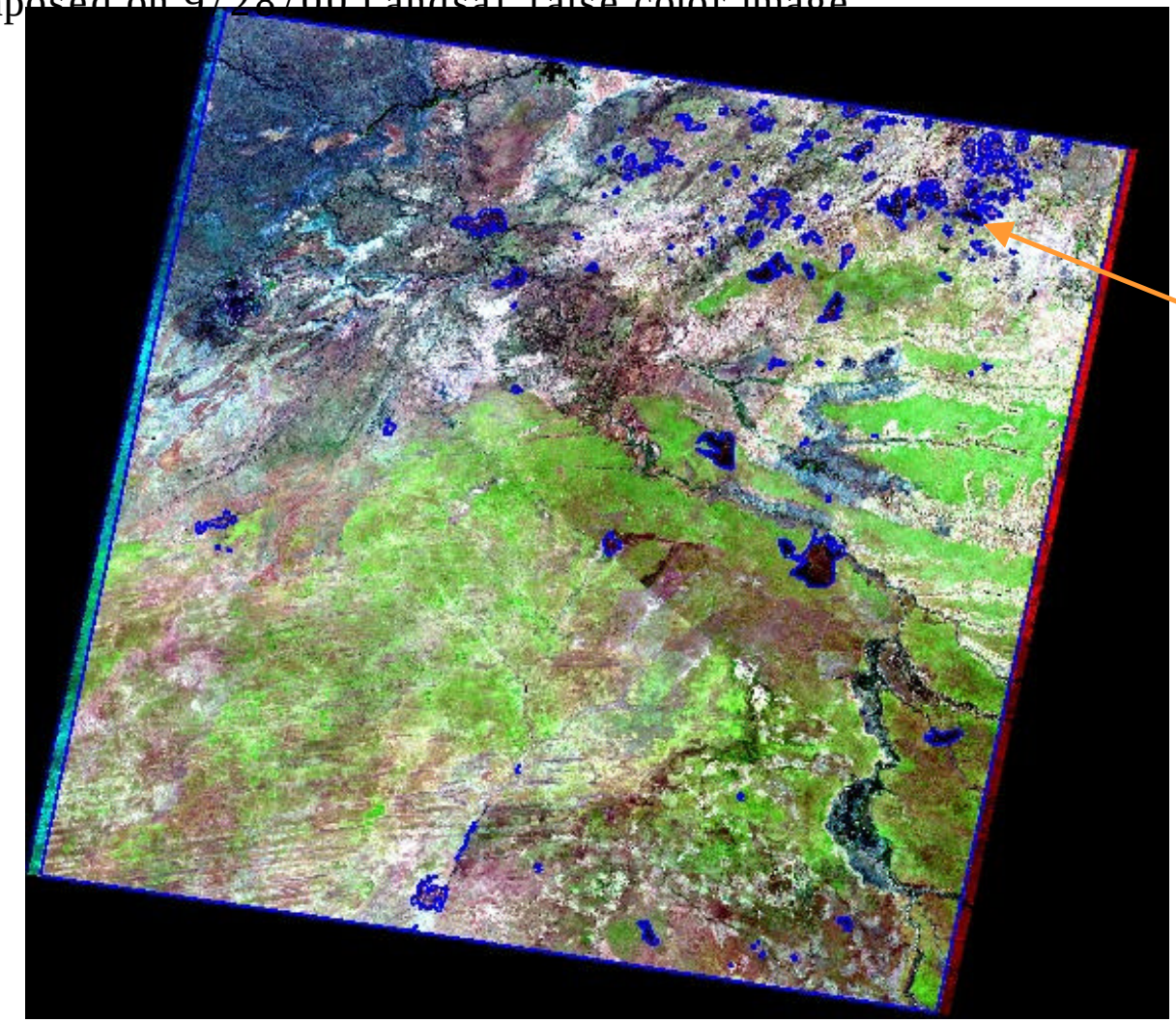
2000 annual precipitation
derived from TRMM 1º data
(blue < 300mm, red > 1500mm)

Consensus Validation Protocol

- Landsat 7 ETM data provision
  - two or more dates
  - 36” false color map prints & digital data, CD-ROM (all bands)
  - Level 1G, GeoTiff, UTM projection
- Limited field work by SAFNet members
  - focused on ambiguous burns
  - spectral analogues and contextual knowledge used to minimize time in field
  - where possible performed as part of collaborators existing activities
  - hand-held GPS for navigation
- Minimum mapping unit
  - 240m
  - delineate burn boundaries & areas that could not be mapped
  - issues of combustion completeness and sub-pixel area burned not addressed robustly

Example Landsat burned area interpretation: *Matabeleland Central Forest District, Zimbabwe*

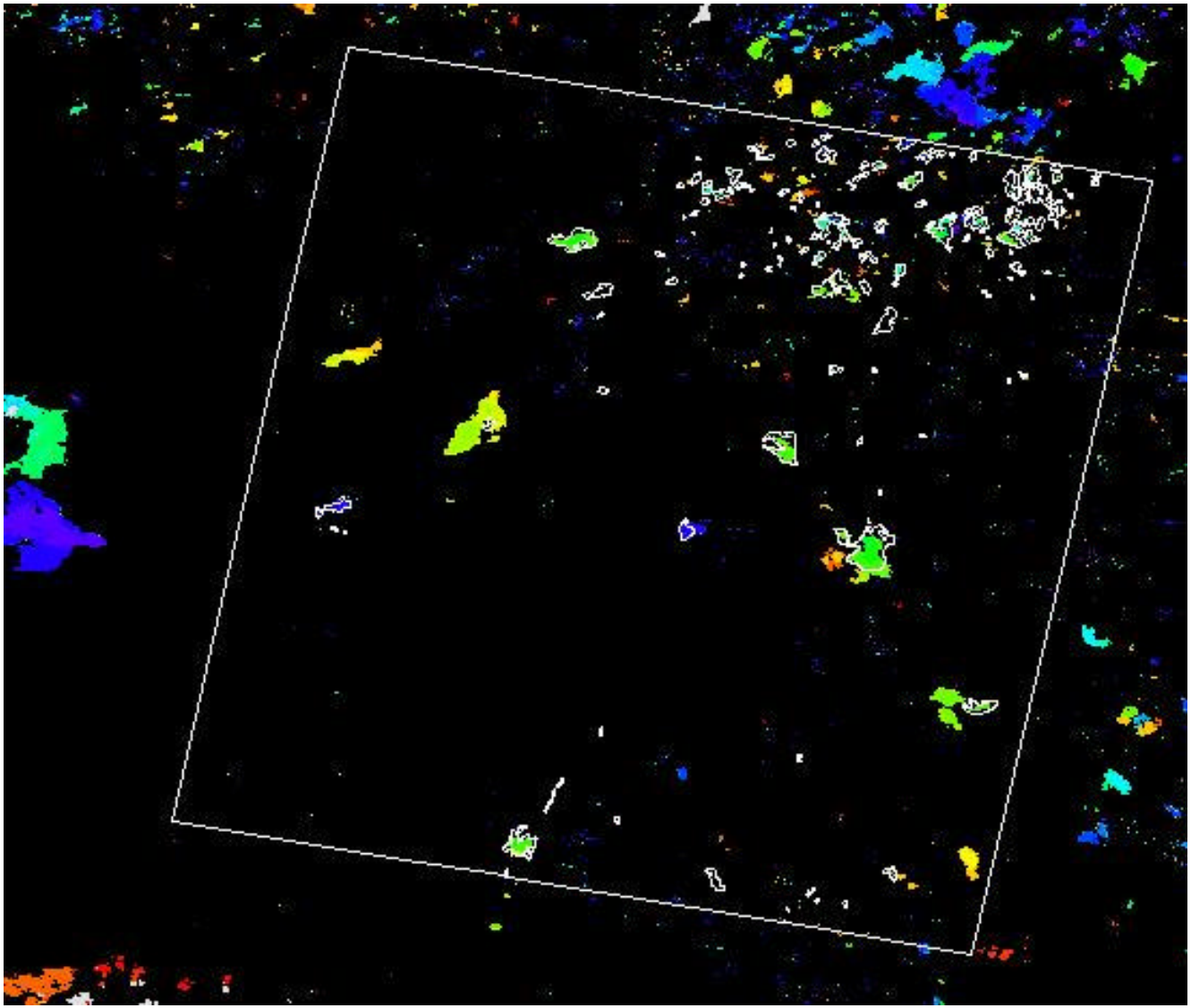
Landsat burned areas (blue vectors) mapped between Landsat acquisitions 8/27/00 and 9/28/00 superimposed on 9/28/00 Landsat false color image



Fragmented and small burned areas on communal land

Landsat burned areas mapped by SAFNet member Kolethi Gumbo, Zimbabwe Forestry Commission

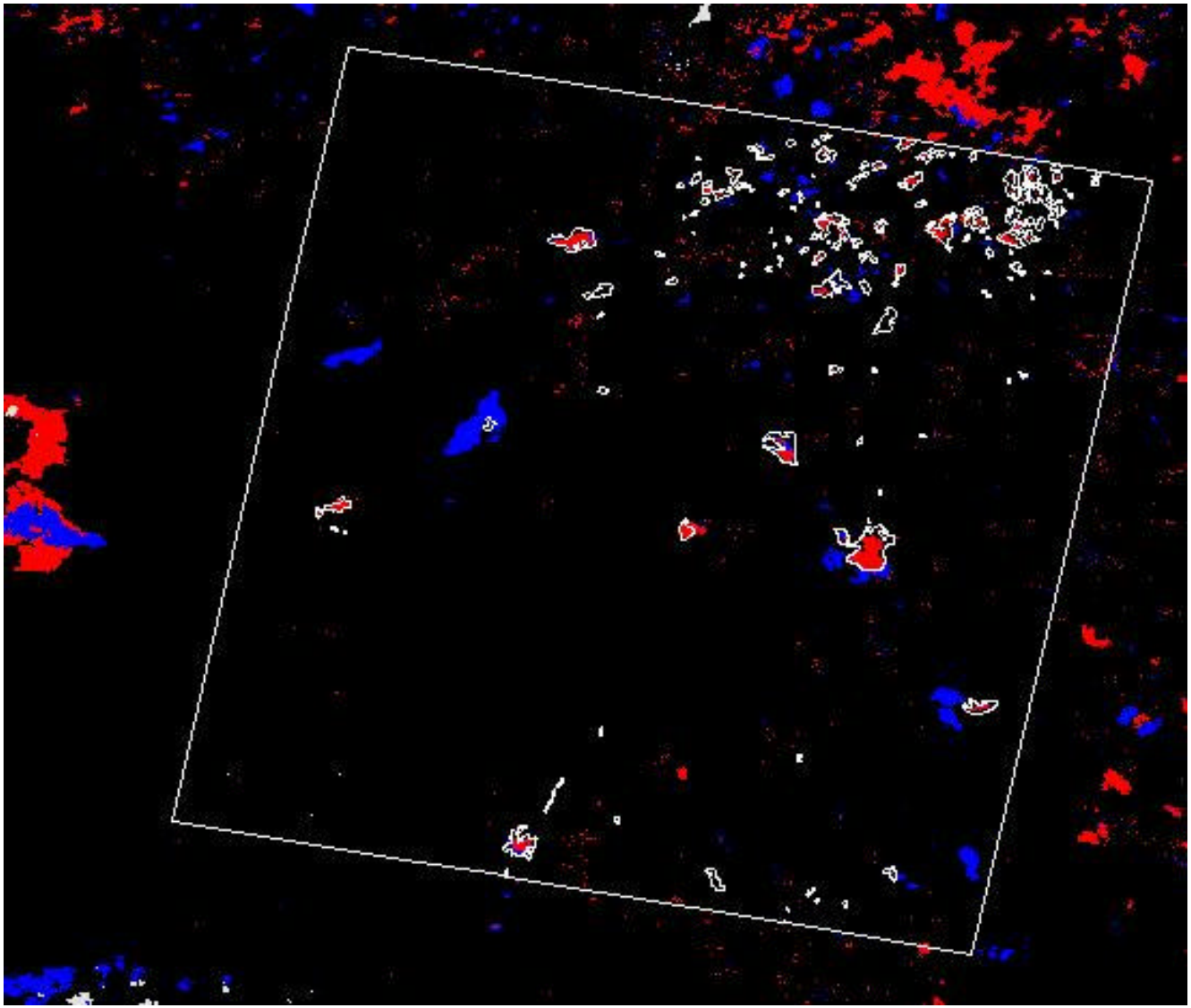
Landsat burned areas (**white vectors**) mapped between two Landsat acquisitions, 8/27/00 and 9/28/00, superimposed on **500m MODIS** burned area product (**colors**)



White vectors = Landsat interpretation, burns occurring 8/27/00 - 9/28/00

Red = MODIS burned areas detected during 8/27/00 - 9/28/00

Blue = MODIS burned areas detected before or after 8/27/00 - 9/28/00



Bi-spectral Infrared Detection (BIRD): a technology demonstration

Small satellite test of new infrared push broom sensor
Sampling of fire events

Payload

- a two-channel infrared Hot Spot Recognition Sensor system (HSRS)
  - MIR:3.4-4.2µm, TIR: 8.5-9.3µm
  - 370m IFOV, 190km
- a Wide-Angle Optoelectronic Stereo Scanner (WAOSS-B)
  - VIS: 600-670nm, NIR: 840-900nm
  - 185m IFOV, Swath 533km

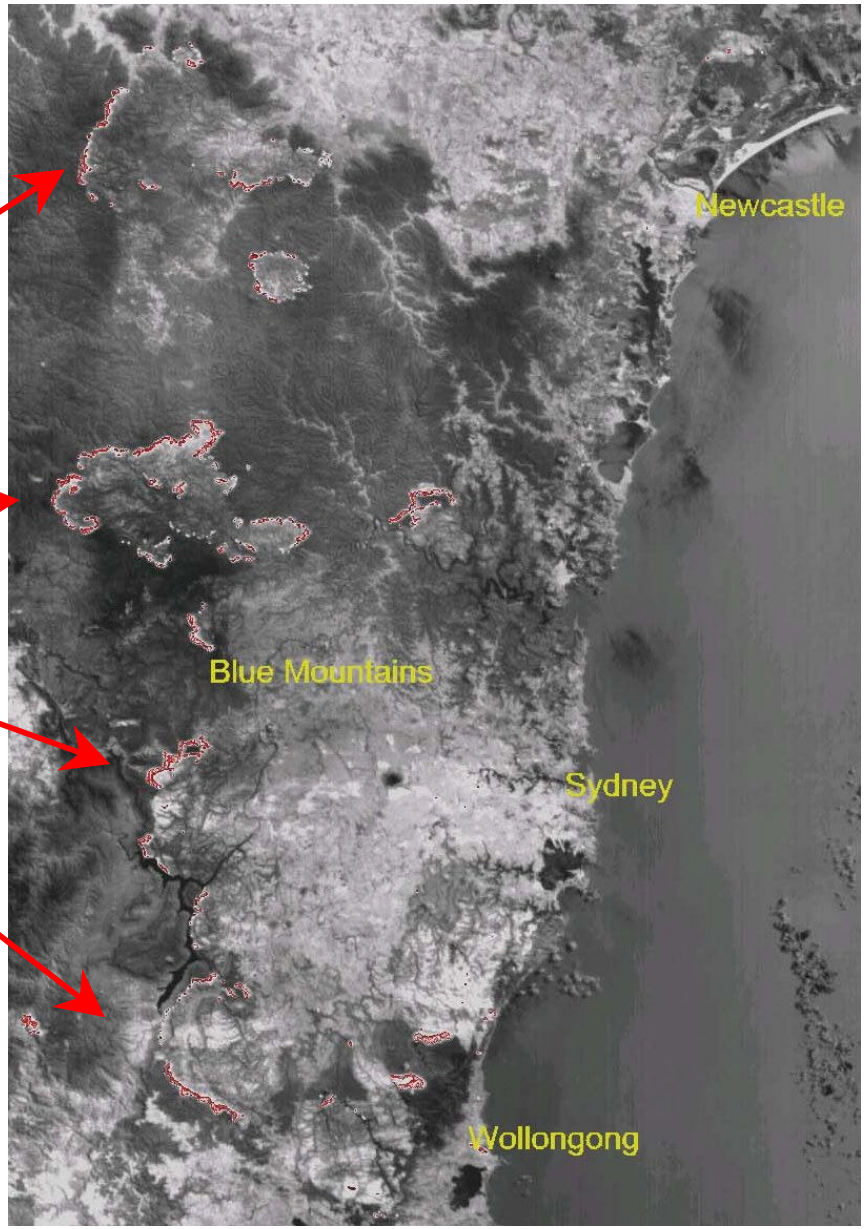
. Oertel, DLR, Germany - www.dlr.de/bird

BIRD image

Sydney, Australia

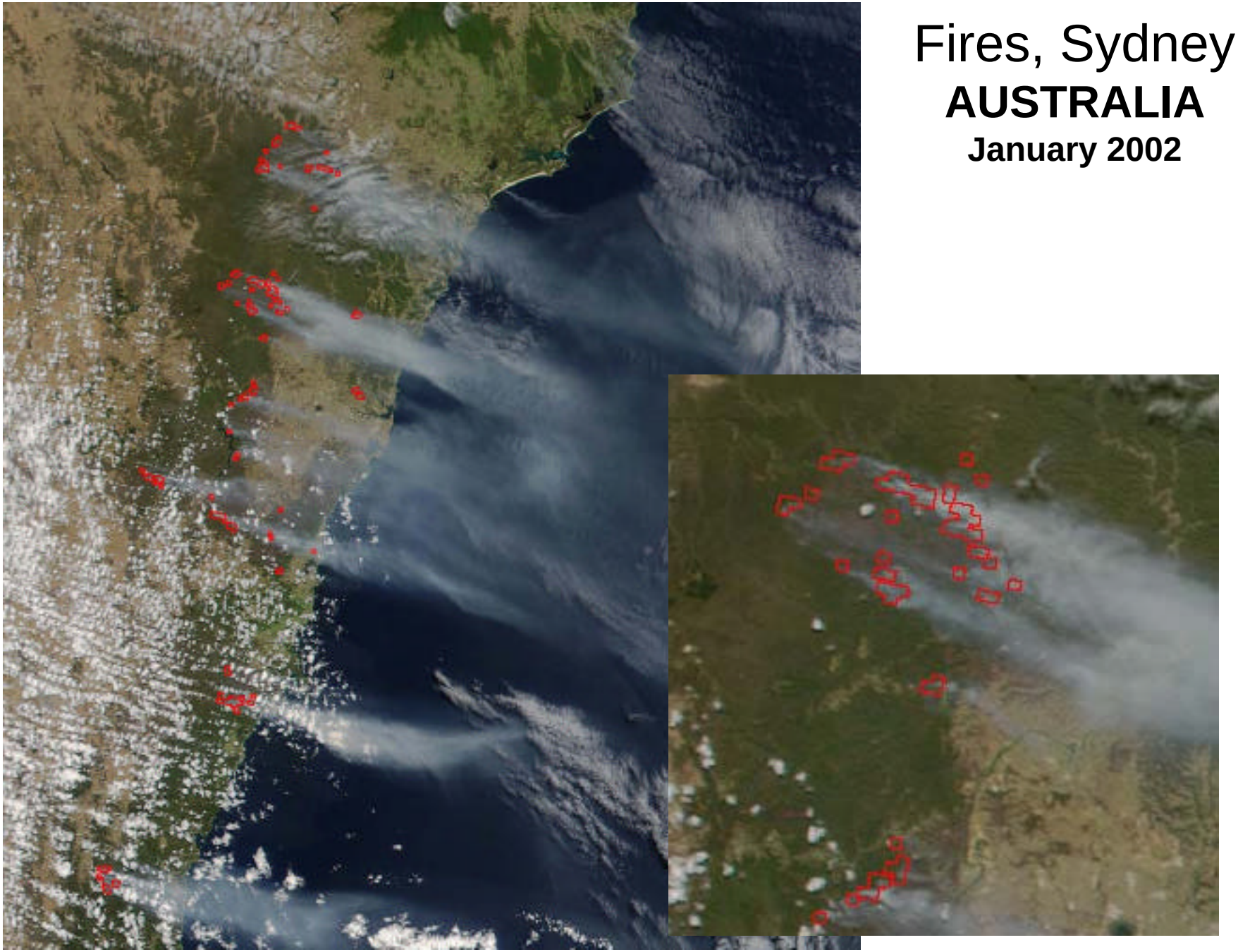
Jan 4, 2002

fires



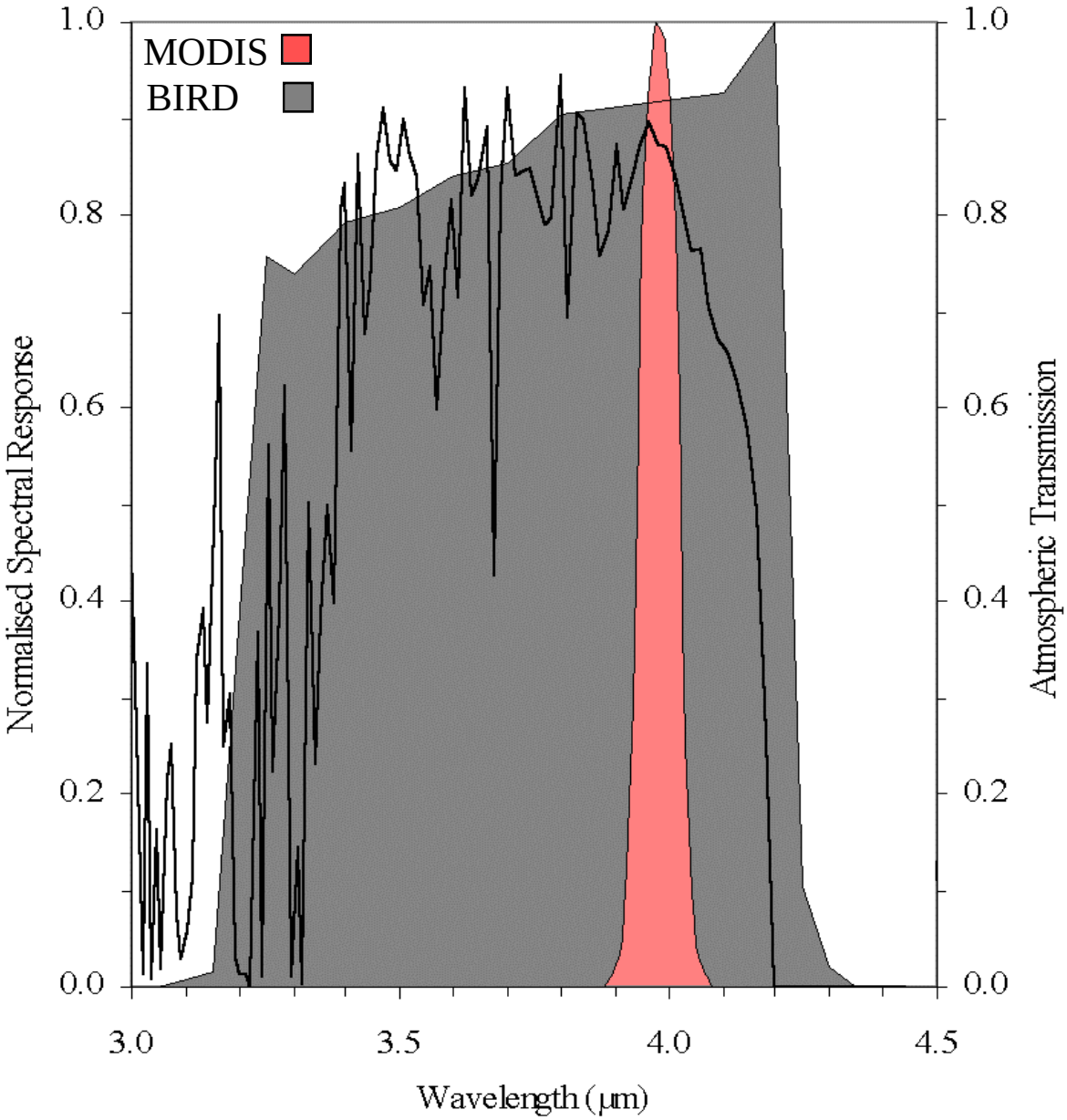
Credit: D. Oertel, DLR, Germany

www.dlr.de/bird



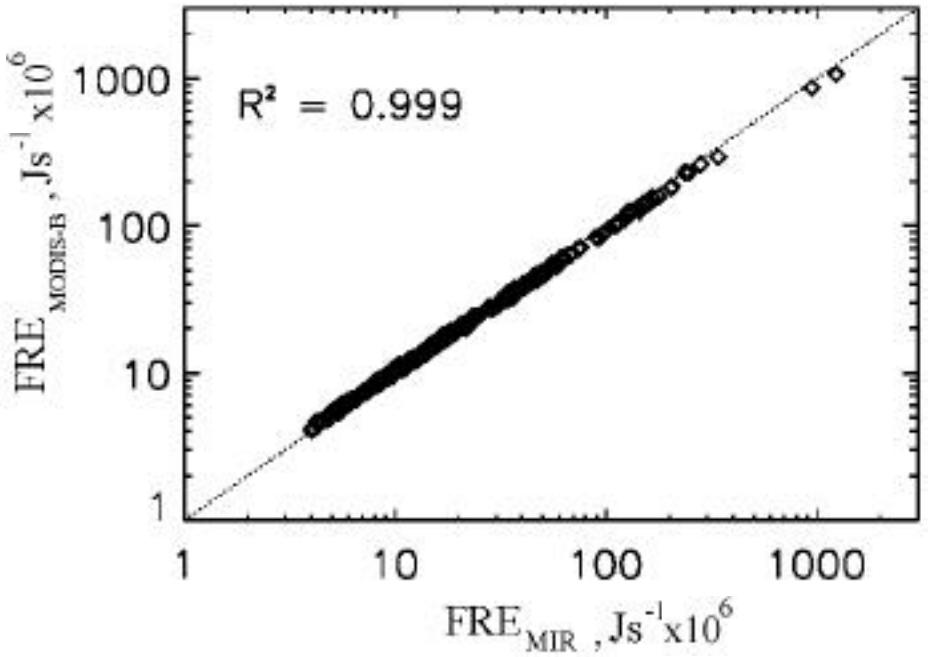
Fires, Sydney
AUSTRALIA
January 2002

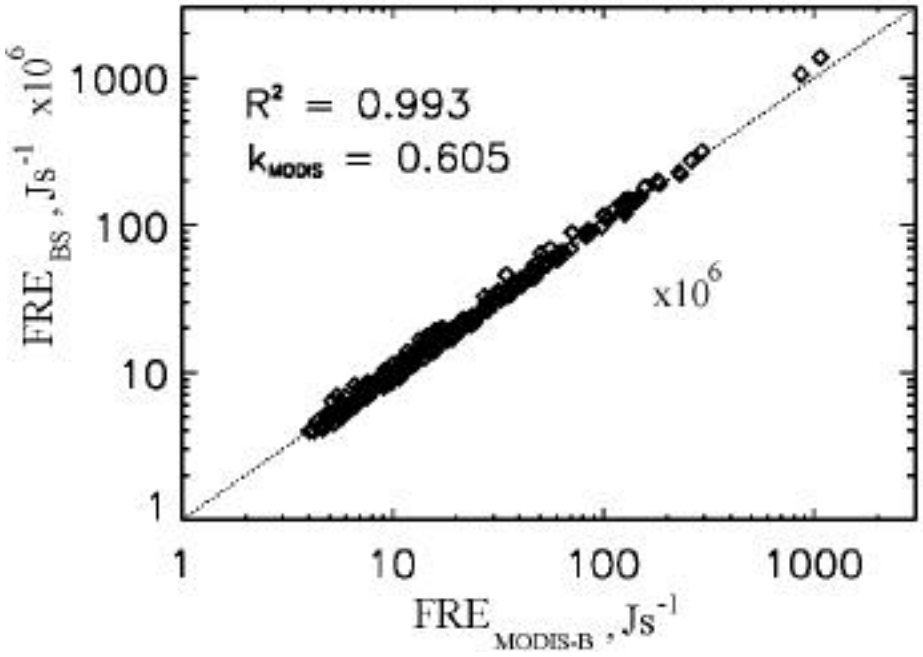
BIRD / MODIS MIR Band Comparison

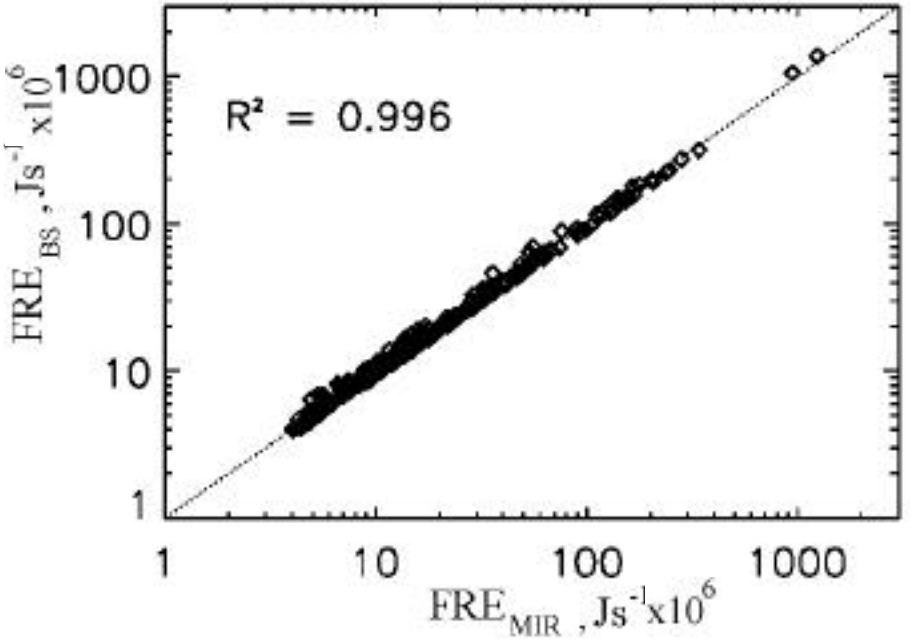


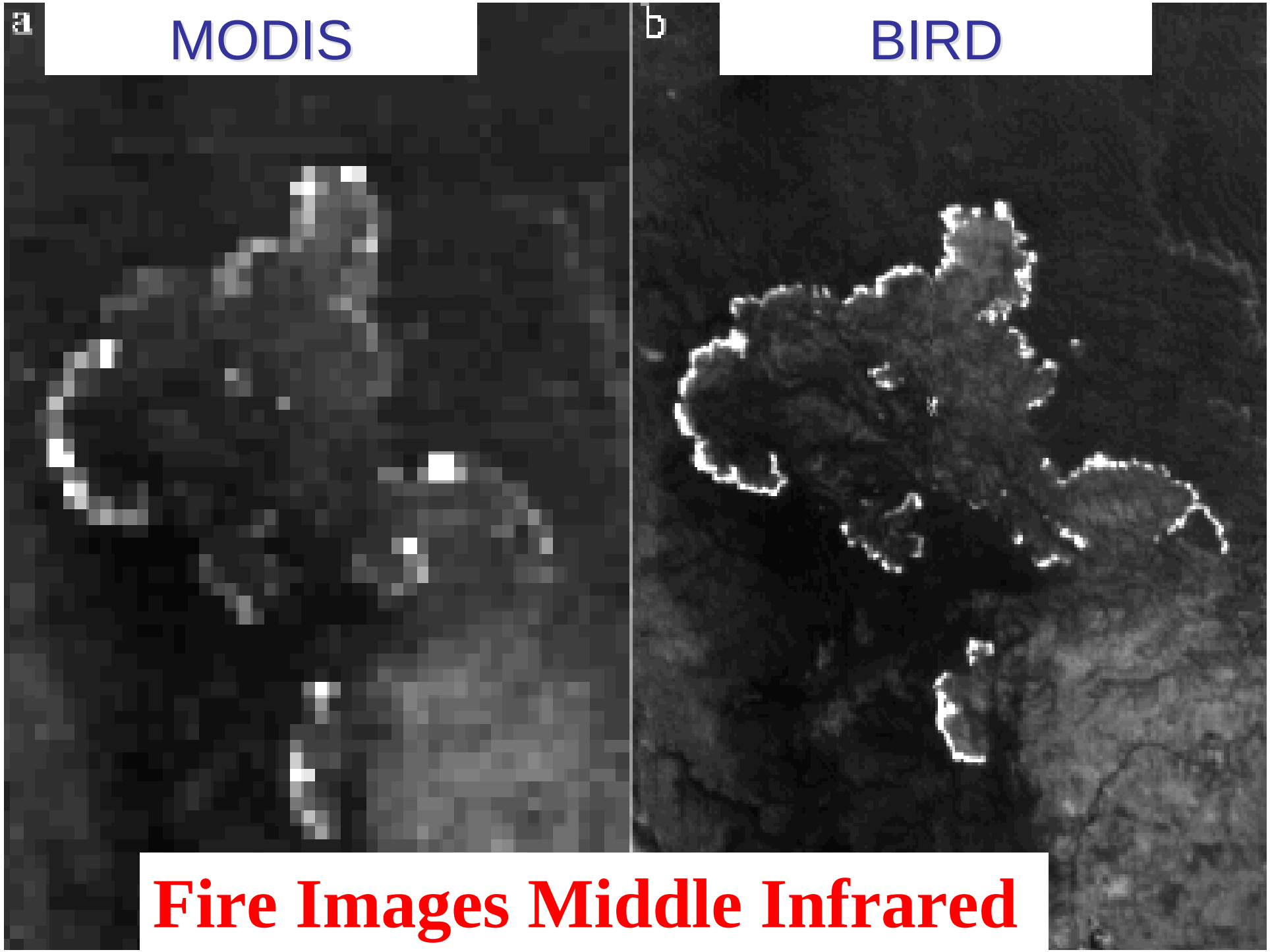
FIRE RADIATIVE ENERGY

Comparisons of derivation method developed for BIRD and for MODIS. Applied to BIRD-Sydney Fires Jan 2002
M. Wooster,
(Dept. Geography,
Kings College, London)

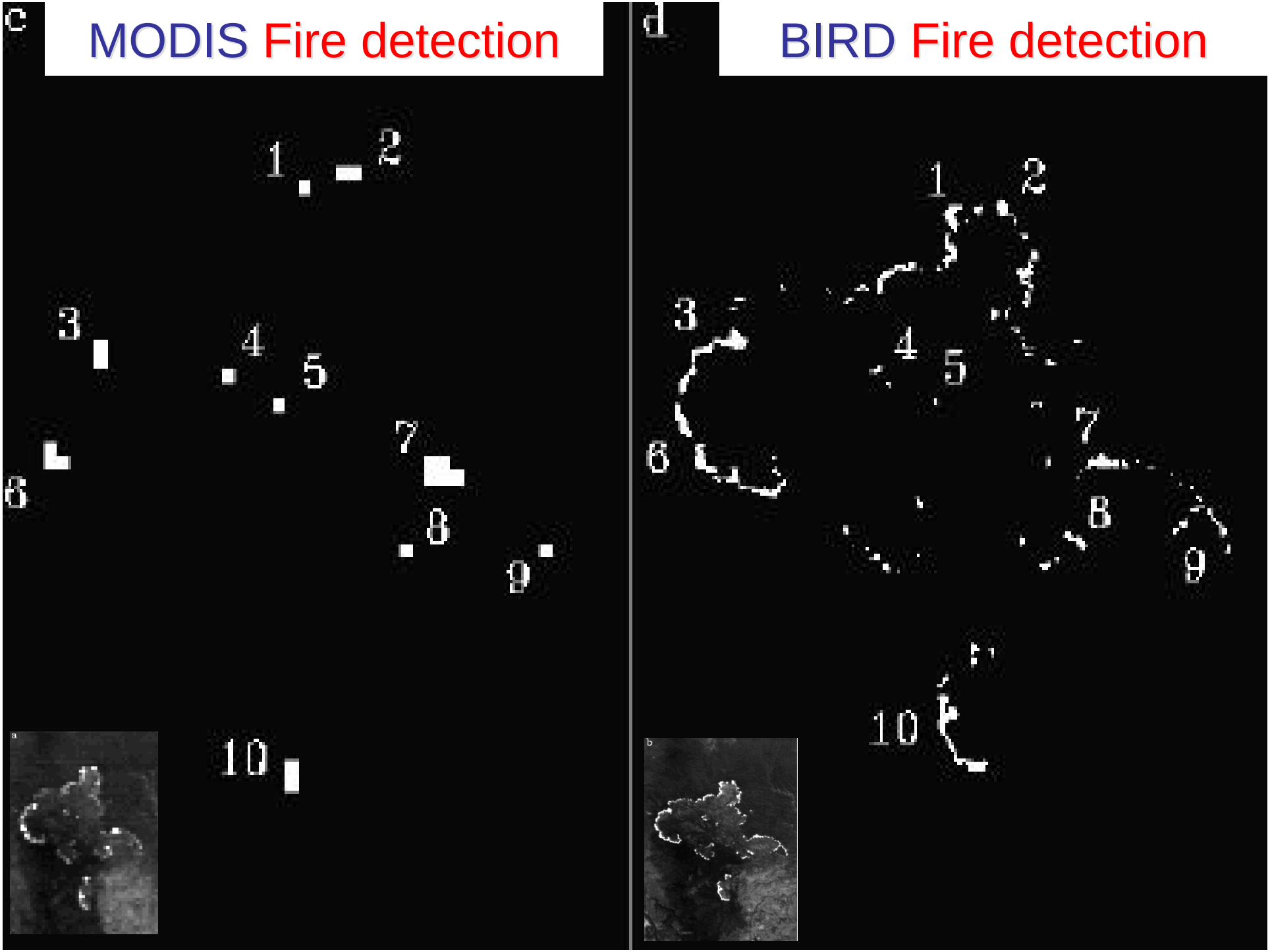




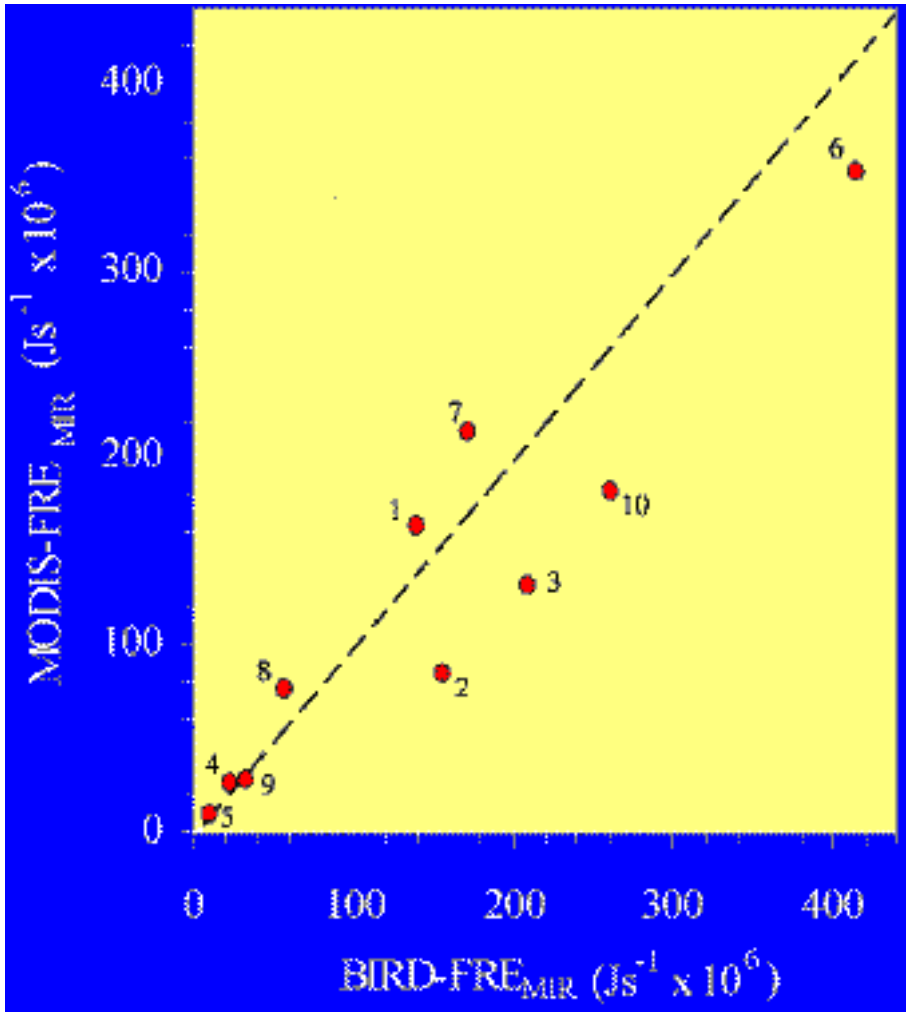


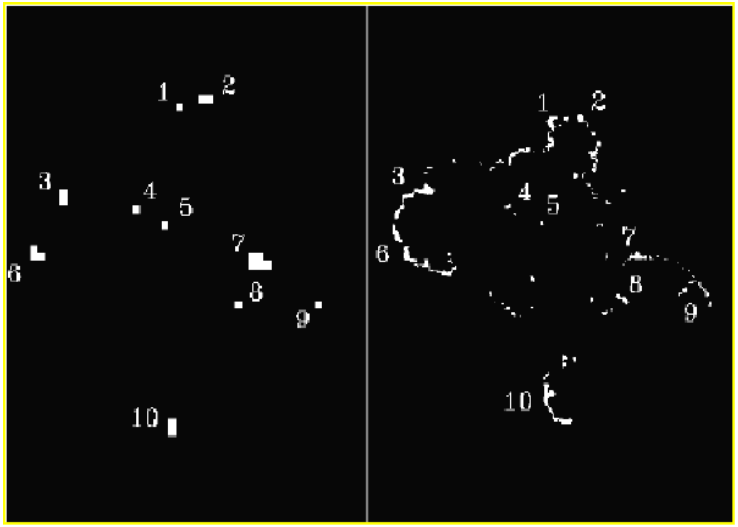


Fire Images Middle Infrared


c
MODIS Fire detection
1
2
3
4
5
6
7
8
9
10
a
d
BIRD Fire detection
1
2
3
4
5
6
7
8
9
10
b

MODIS ~ BIRD Fire Radiative Energy Comparison



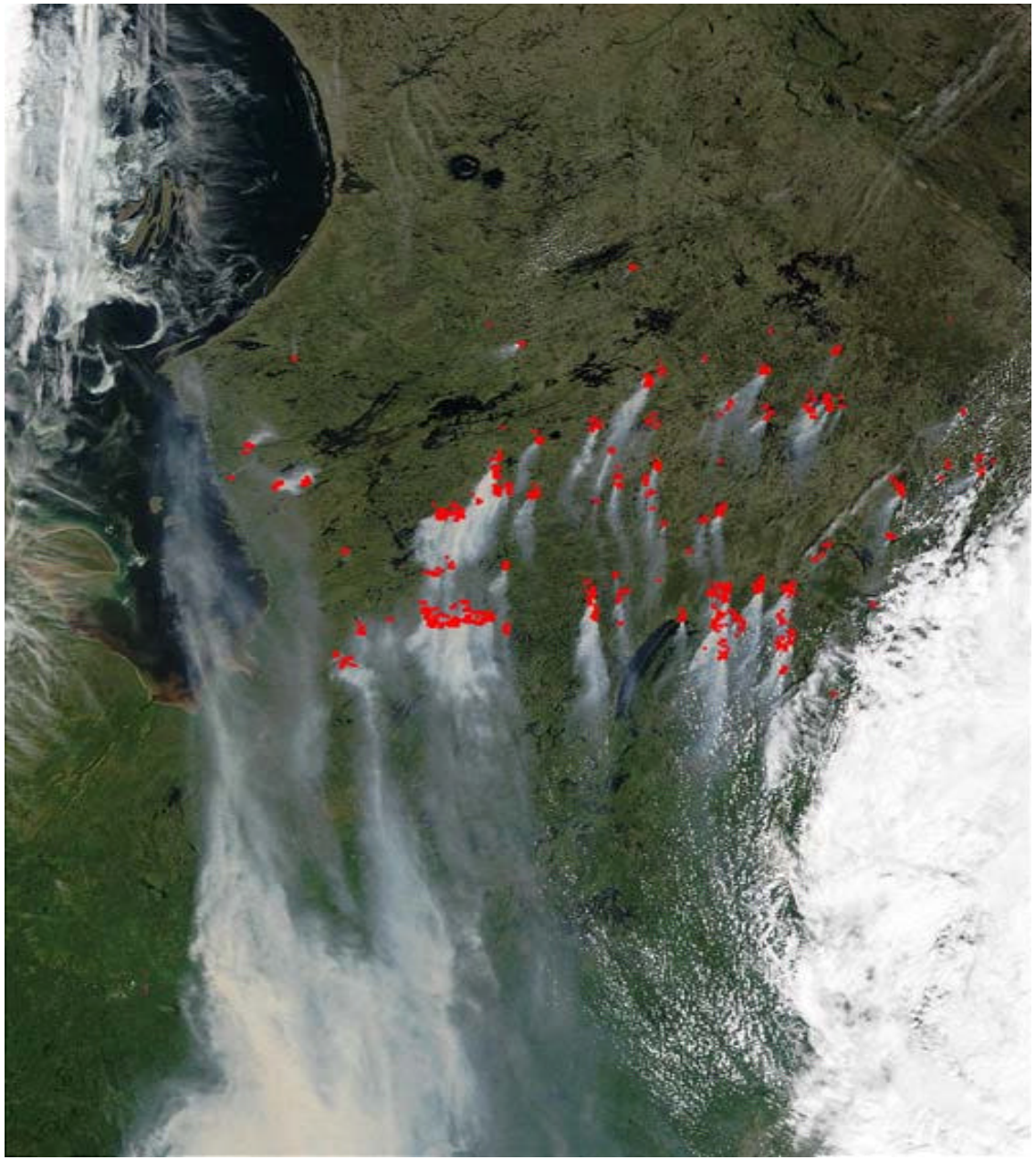


MODIS **BIRD**

M. Wooster,
(Dept. Geography, Kings College, London)

MODIS GLOBAL NEAR REAL TIME FIRE MONITORING

http://rapidfire.sci.gsfc.nasa.gov



MODIS Fire

Detections
Quebec,
Canada
07/06/02

MODIS Fire Next Steps

- **Algorithm Refinement**
  - **Complete evaluation of Mid IR Reflectance (ANO) – (prior to Collection 4)**
- **ASTER/MODIS Fire Validation**
  - **Improve ASTER detection algorithm**
  - **Globally representative sample of ASTER data (Level 2 Validation)**
  - **Investigate use of BIRD data for validation**
- **Burned Area**
  - **Test Algorithm in new regions - develop/distribute validated products**
  - **Undertake intercomparison with emerging European products**
  - **Initiate Global Multiyear Burned Area product (2003)**
- **Demonstrate how MODIS Burned Area contributes to National/Regional Emissions Estimates**
- **Fire Energy Development (Experimentation - Kaufman, Vermote, Petitecolin, Wooster et al)**
  - **Use of MODIS, ASTER and BIRD**
- **Operational Transition of MODIS RR to NOAA (the right idea but will NOAA support this)**
  - **NPP Fire – instrument performance/ algorithms / prototyping of operational delivery systems**
- **Community Outreach**
  - **Rapid Response – improve fire user oriented products and GUI**
  - **Direct Broadcast Fire Code Distribution (improved advertising) _**
  - **Improve and promote validation standards and protocols (GOFC-GOLD/CEOS –LPV)**
  - **Involving users in regional fire product validation activities (active fire/burned area)**
    - **Brazil (LBA), Australia, Mexico, Russia/Siberia, Southern Africa**
  - **User Outreach Workshop (next 9 months)**