Burned area mapping in Southern Africa: Case Study Synthesis and Regional Application of MODIS data

(funded by NASA's Land Cover Land Use Change & Applications programs)

Roy, D.P. Department of Geography, University of Maryland, College Park, Greenbelt MD
droy@kratmos.gsfc.nasa.gov

Outline

- *Project Rationale*
- *Significant Results to date*
  - *Facilitate Southern Africa Fire Network (SAFNet)*
  - *Algorithm to map southern African burned areas*
  - *Production of 2000-2003 southern Africa burned area products*
  - *Development of consensus SAFNet burned area validation protocol*
  - *Multi-year burned area product validation results*
- *Next Steps*

Project Rationale

- Systematic monitoring of burned areas is needed by the global change research community as an input to biogeochemical models and to understand and model how fire regimes are likely to change as a function of climate, population dynamics, and land use change.

- Southern Africa has the most extensive biomass burning globally and is undergoing rapid social and economic change. Majority of fires are lit by people primarily for land management.

- Development of regional multi-year burned area products using MODIS data.

- An applications component is included following a guiding GOFC-GOLD principle that the user community play an active role in undertaking product assessment and testing of pre-operational algorithms.

- The project collaborators are located at case study sites throughout southern Africa. Multitemporal Landsat ETM+ data acquired over the case study sites used to validate the MODIS burned area products.

- Evaluate LCLUC hypotheses that explore the interplay between physical and human variables on fire size and timing at the regional scale.

Collaborators listed geographically from west to east

Namibia
Etosha Ecological Institute - *Etosha National Park and surrounding land,* Johan Le Roux

Botswana
University of Botswana - *Hainaveld and Gumare,* Pauline Dube
Harry Oppenheimer Okavango Research Center - *Okavango delta,* Budzanani Tacheba

Zimbabwe
Forestry Commission - *North Western Matebeleland indigenous forests,* Kolethi Gumbo
WWF - *Save Valley Conservancy,* Fay Robertson, Kevin Dunham, Raoul du Toit

South Africa
Kruger National Park Scientific Services - *Kruger National Park,* Tobias Landmann, David Woods

Malawi
Forest Research Institute of Malawi - *Chimaliro Forest Reserve,* Steve Makungwa

Mozambique
FAO - *Mecuburi Forest Reserve,* Agostinho Zacarias
National Directorate of Forests and Wildlife, Carla Cuambe

Peter Frost (Co-Investigator), Institute of Environmental Studies, University of Zimbabwe

Significant Result : Facilitate Southern Africa Fire Network (SAFNet)

Site Index

- Home
- Overview
- Outputs
- Activities
- Products
- Meetings
- Links
- Contacts
- Site Map

*Low Bandwidth Site

The **Southern African Fire Network** is a regional network that fosters collaborative efforts in fire monitoring and management in southern Africa. SAFNet is a Global Observation for Forest and Land Cover Dynamics (GOFC/GOLD) regional fire network and contributes to meeting the goals of the GOFC/GOLD program. SAFNet was initiated using small seed funding grants from NASA, USAID (EMIS and GISD) and START. Future collaboration with partners and funding agents is being sought.

The SAFNet Mission

SAFNet's **goal** is to achieve more effective and appropriate fire management policies and practices in southern Africa through the use of remote sensing and other geospatial information technology.

SAFNet's **purpose** is to enhance the use of information from field observations and remote sensing of fires for natural resource management in southern Africa

SAFNet is a contributor to the GOFC/GOLD Initiative.

Maintained by Deirdre Smith at University of Maryland.

NOTE: Many documents on this site are available in Adobe Acrobat format.

http://safnet.umd.edu/index.asp

Statement by SAFNet on *The use and control of fire in Africa*, delivered at the International Wildland Fire Summit, Syndey, Australia, 8 October 2003

Introduction:

The Southern Africa Fire Network (SAFNet) is an open network of southern Africa fire scientists, managers and communicators that has functioned over the past four years. It currently comprises over 40 members drawn from 10 countries of the Southern African Development Community, together with international partners, principally from the United States of America.

The network was originally formed to contribute regionally to the development and validation of a burned-scar algorithm for use with remotely-sensed data from the MODIS sensor on the NASA Terra satellite.

SAFNet

Southern African Fire Network

2003 country contacts

Santos Virgilio

ANGOLA

Joseph Kanyanga

ZAMBIA

Steve Makungwa

MALAWI

Kolethi Gumbo

ZIMBABWE

Carla Cuambe

MOZAMBIQUE

Johan Le Roux

NAMIBIA

Felix Monggae

BOTSWANA

Philip Frost

SOUTH AFRICA

Pauline Dube
University of Botswana

SAFNet Regional Coordinator

Significant Result : Algorithm to map southern African burned areas

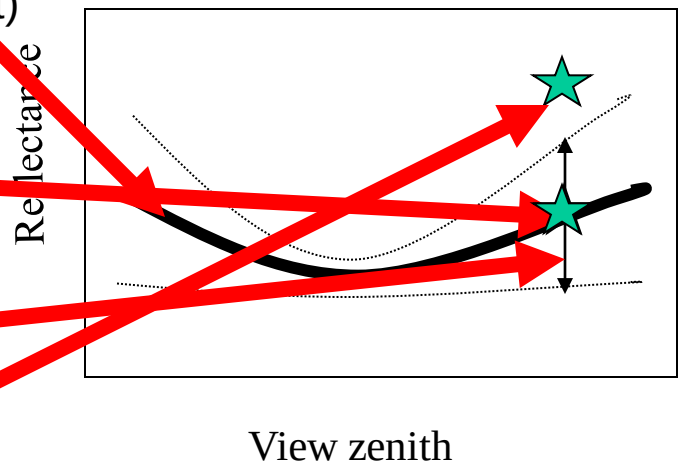
- Developed for systematic automated burned area product generation
  - not a classification approach requiring training data or human intervention
  - now a planned standard MODIS burned area product (*MODIS fire science team*) & attempting to articulate the case for a burned area climate data record (*NPP fire evaluation team*)

- Support
  - applications users (e.g., natural resource management, wildfire management)
  - LCLUC research (e.g., Fire – Climate – People)
  - regional-global trace gases & aerosol emissions estimation (SAFARI-2000 context)
  - fire policy development (e.g., early dry season burning policies in savanna fire prone ecosystems)

- Algorithm maps the approximate day of burning at 500m
  - new change detection approach applied independently per pixel to daily gridded MODIS 500m land surface reflectance time series
  - taking advantage of the temporal persistence of fire effects
  - complement the standard MODIS 1km active fire (hot spot) product

Algorithm: multitemporal BRDF-based change detection

- Model reflectance over moving window (t-N_W to t)
- Predict reflectance of next observation (t+1)
- Predict uncertainty in model result for (t+1)



- Compute Z-score
  Z-score = predicted - observed reflectance / (model + observation uncertainty)
- Threshold Z-score time series to detect change from previously observed state
- Consider cases where (predicted - observed reflectance) $< 3\sigma_{\text{band noise}}$
- Apply temporal and spectral consistency constraints to reject
  - noisy pixels
  - sub-pixel cloud & shadows
  - changes not due to burning

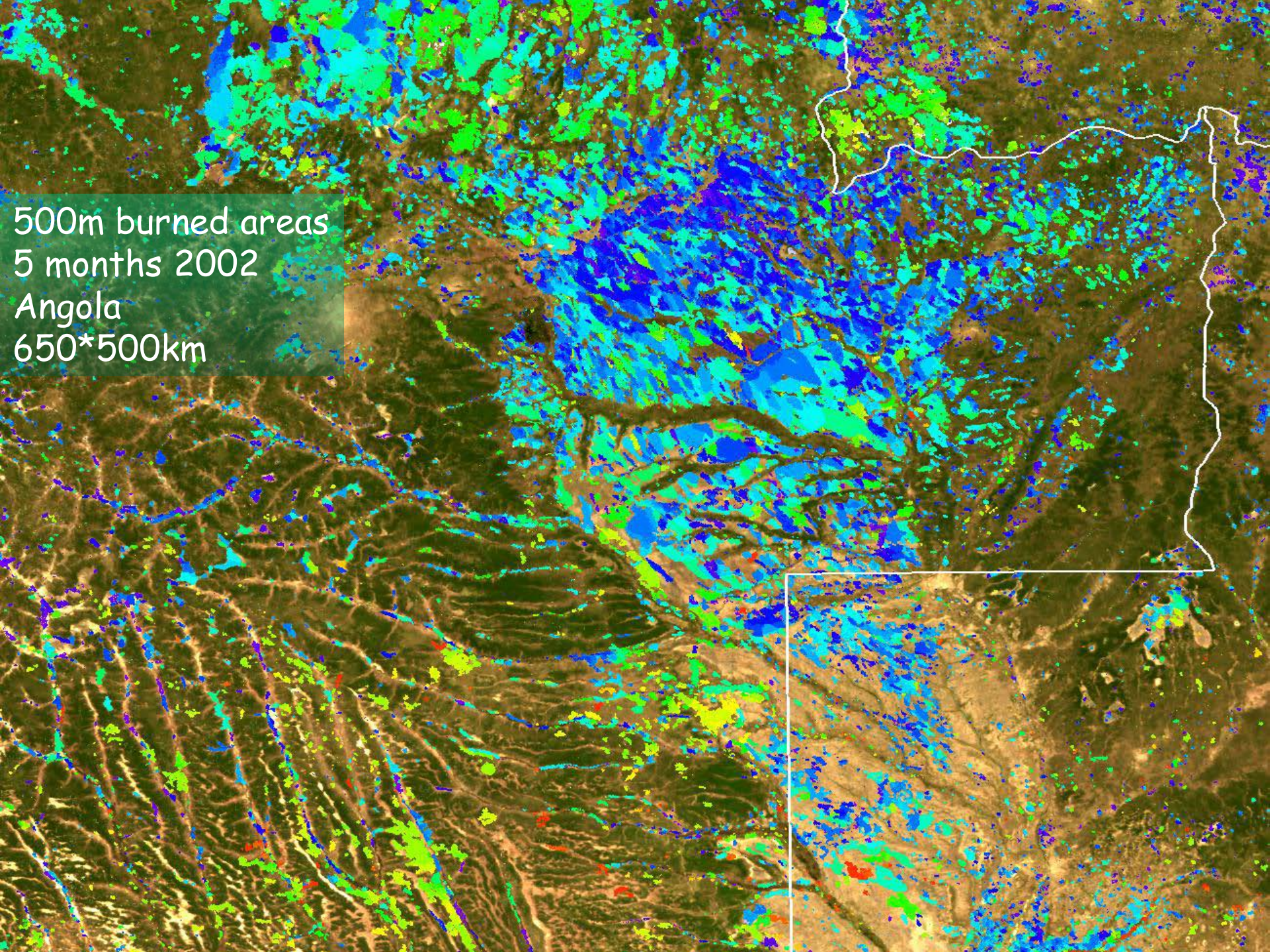
Significant Result : Production of 2000-2003 southern Africa burned area products

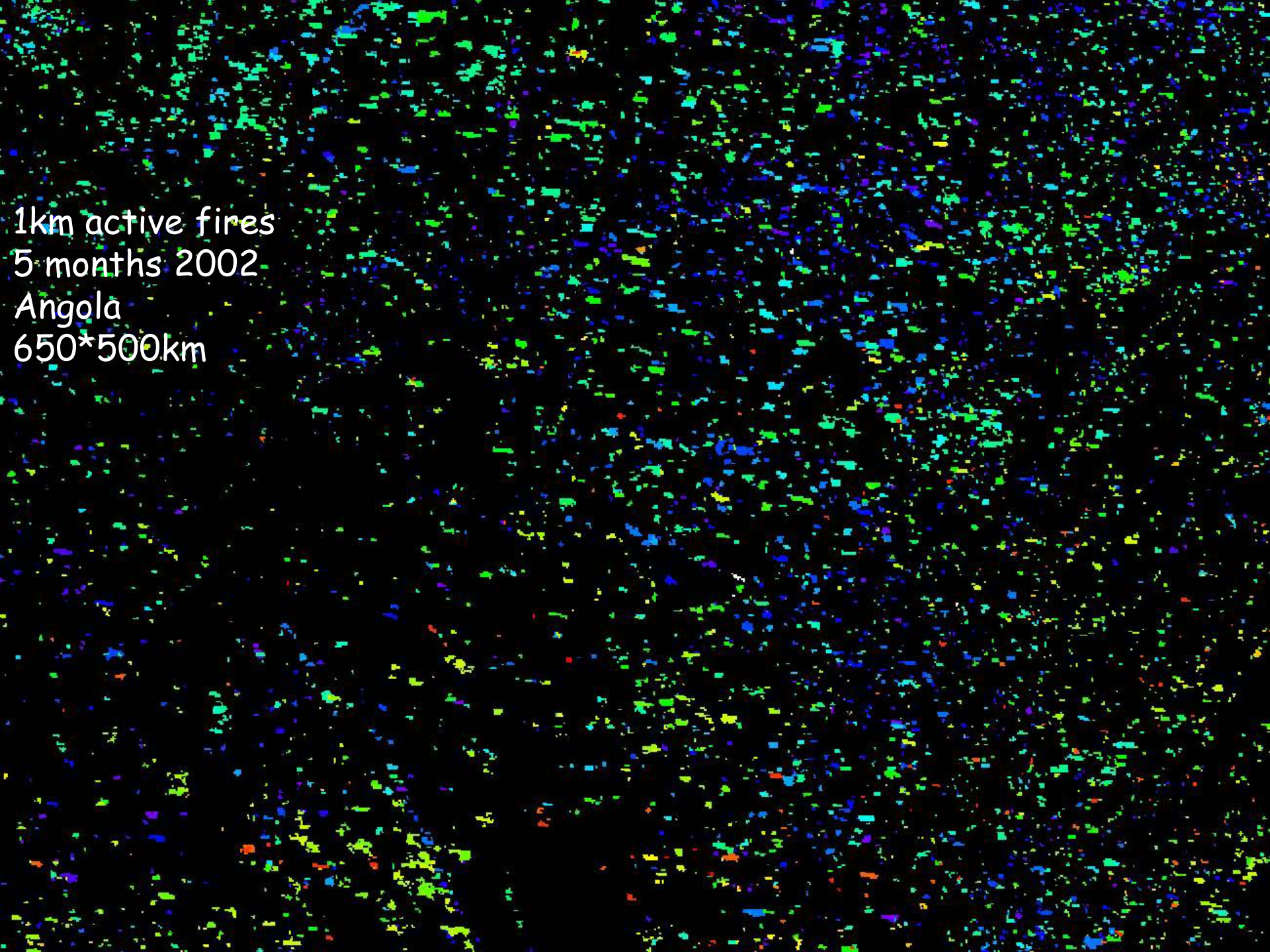
- Roy, D.P., (2003), SAFARI 2000 July and September MODIS 500m Burned Area Products for Southern Africa, *SAFARI 2000 CD-ROM Series. Volume 3*. J. Nickeson, *et al.* eds. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, USA.

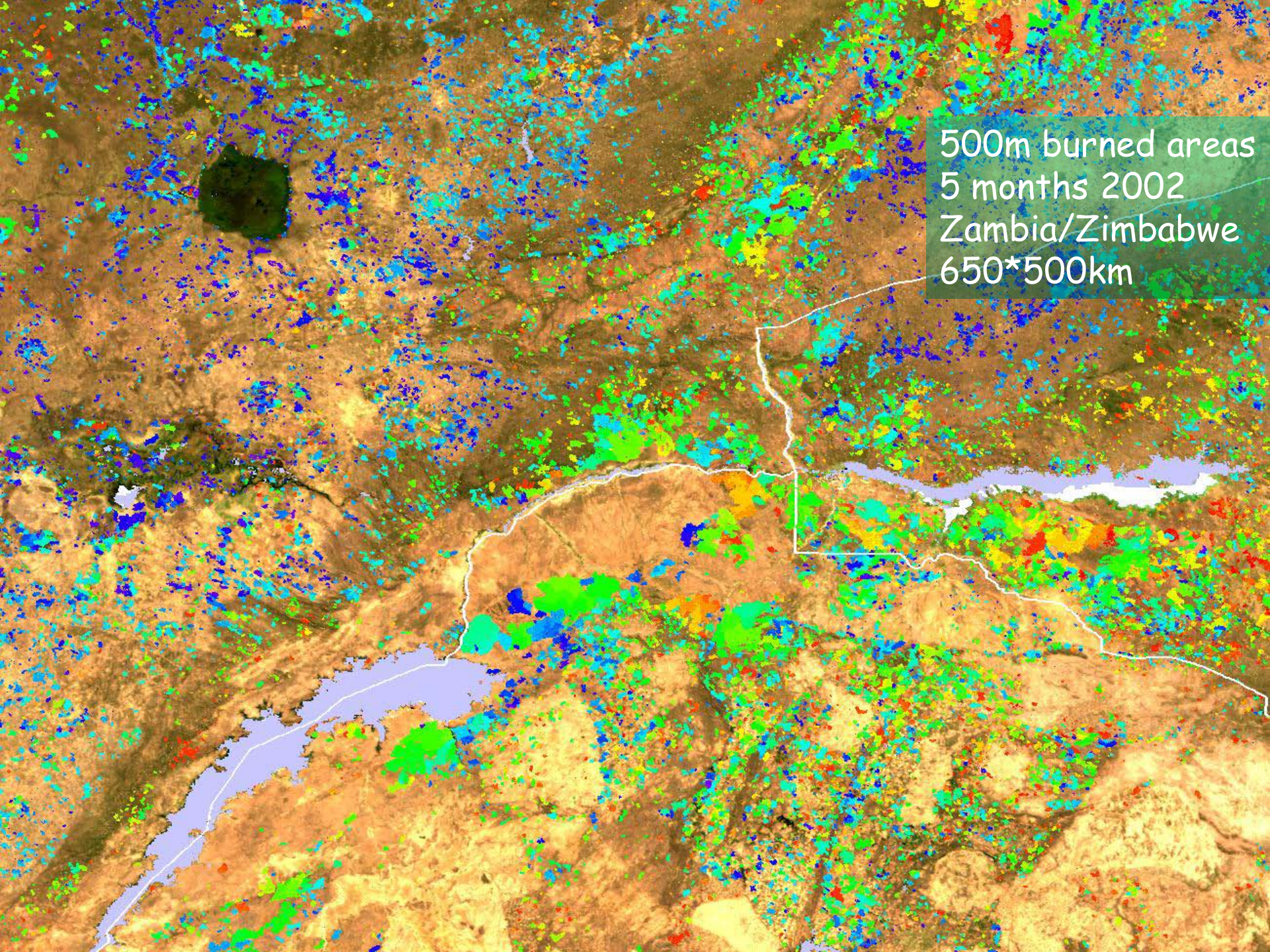
- Note, 2000 product less reliable than products for 2001+ due to noisy and poorly performing MODIS detectors in the post-launch period 25 February to 1 November 2000.

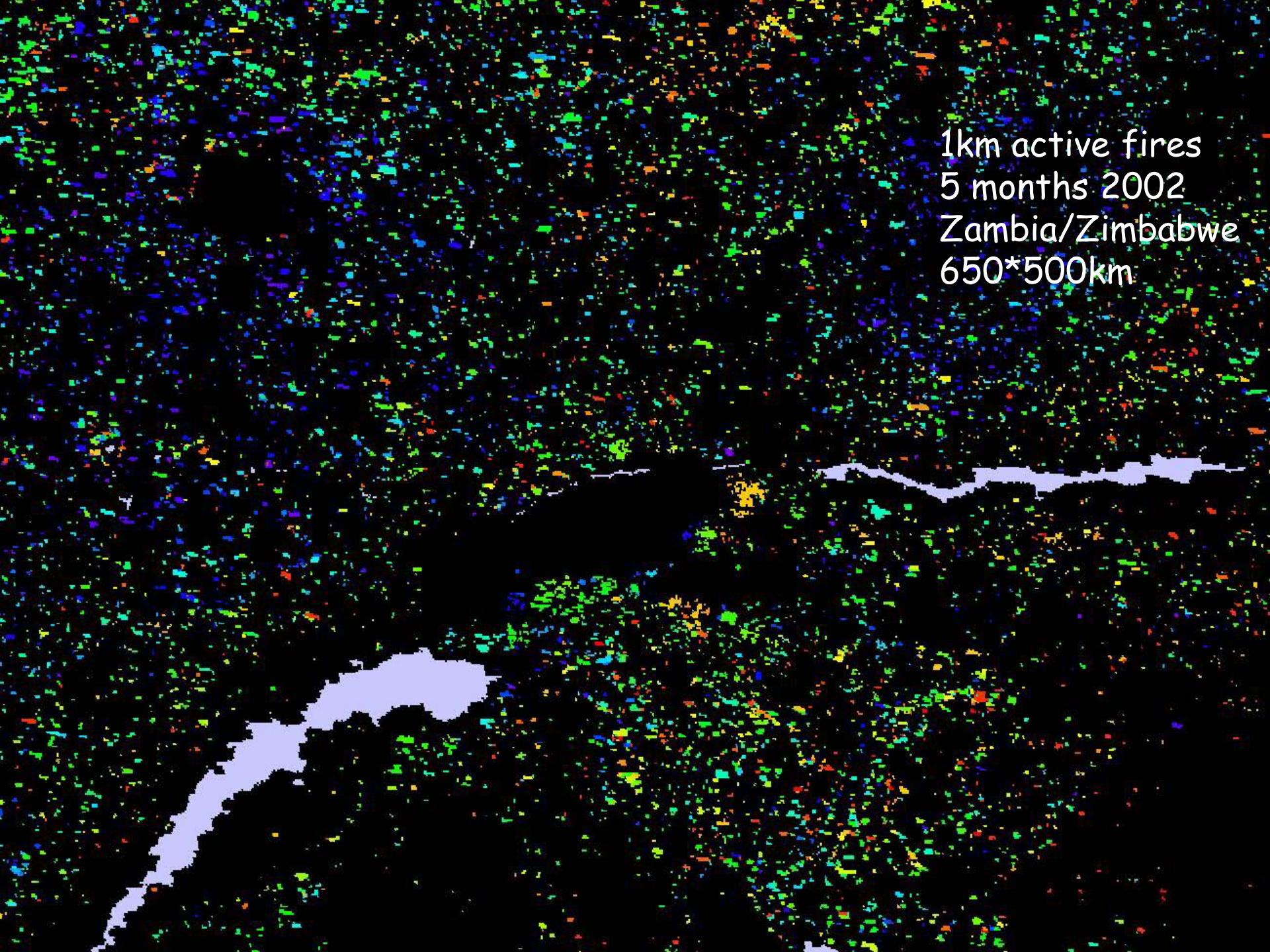
- 2001, 2002 and 2003 products to be available by the end of grant via the UMD GLCF, SAFnet web site and/or SAFNet CD

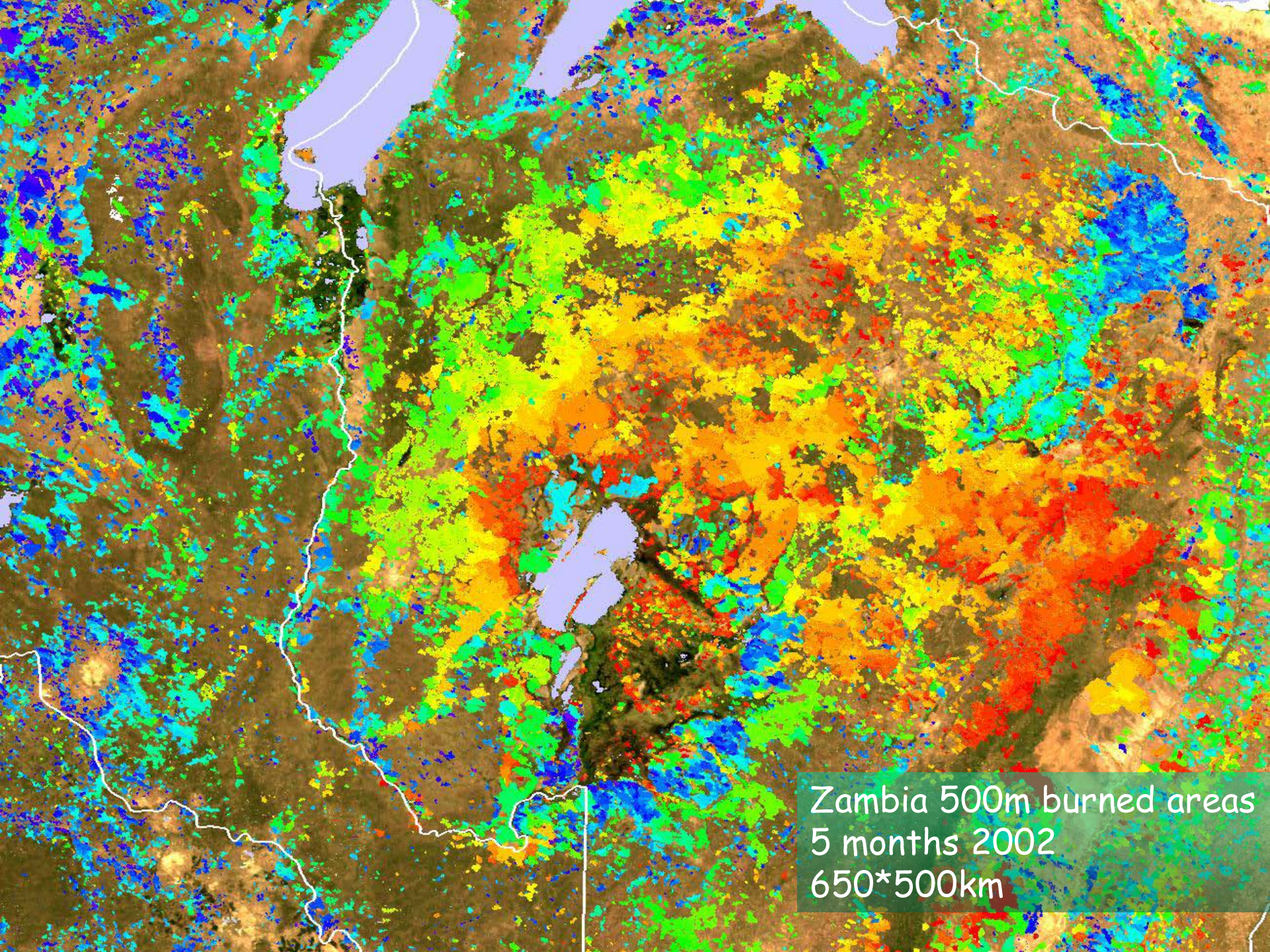
- Examples ….

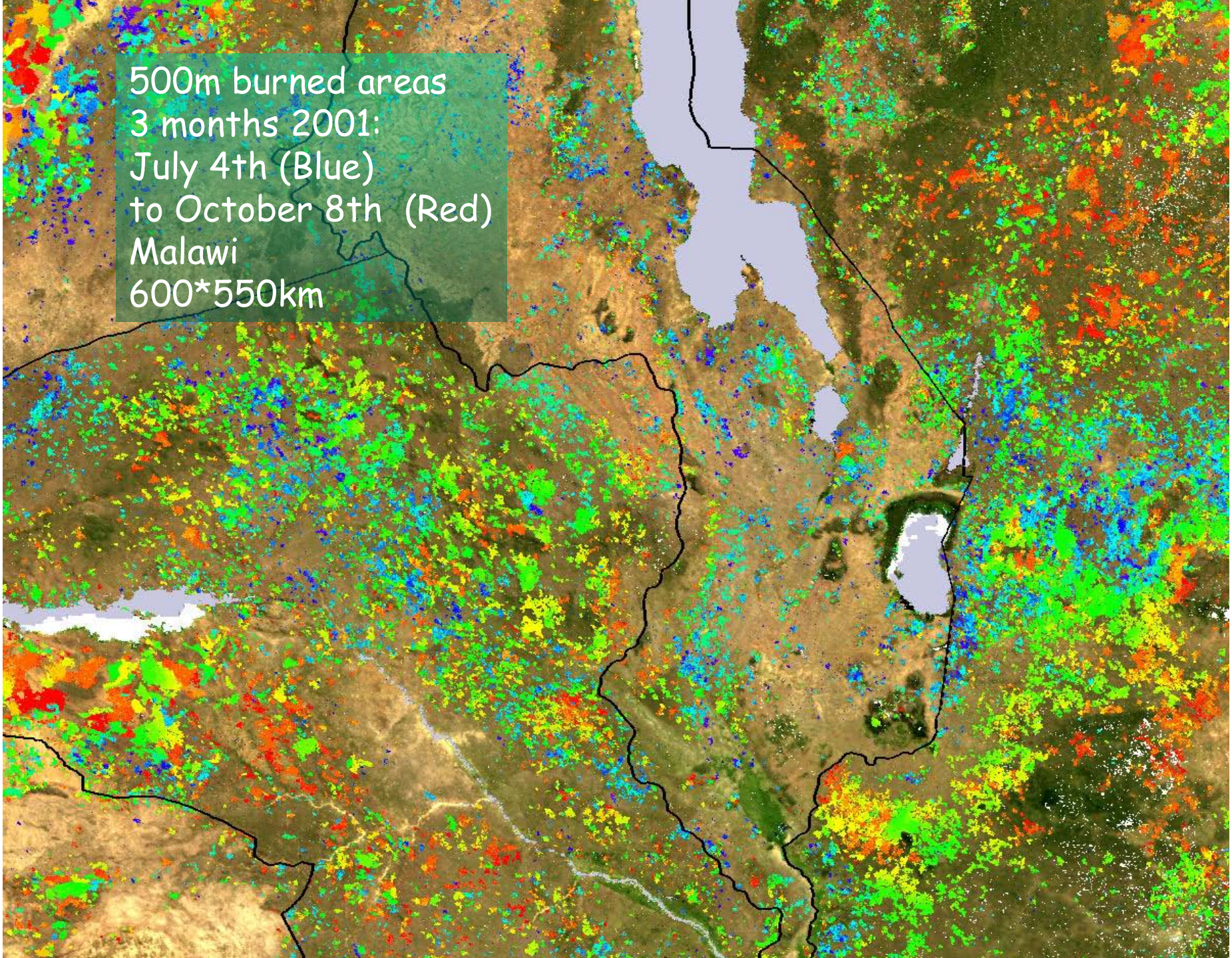

500m burned areas
5 months 2002
Angola
650*500km


1km active fires
5 months 2002
Angola
650*500km

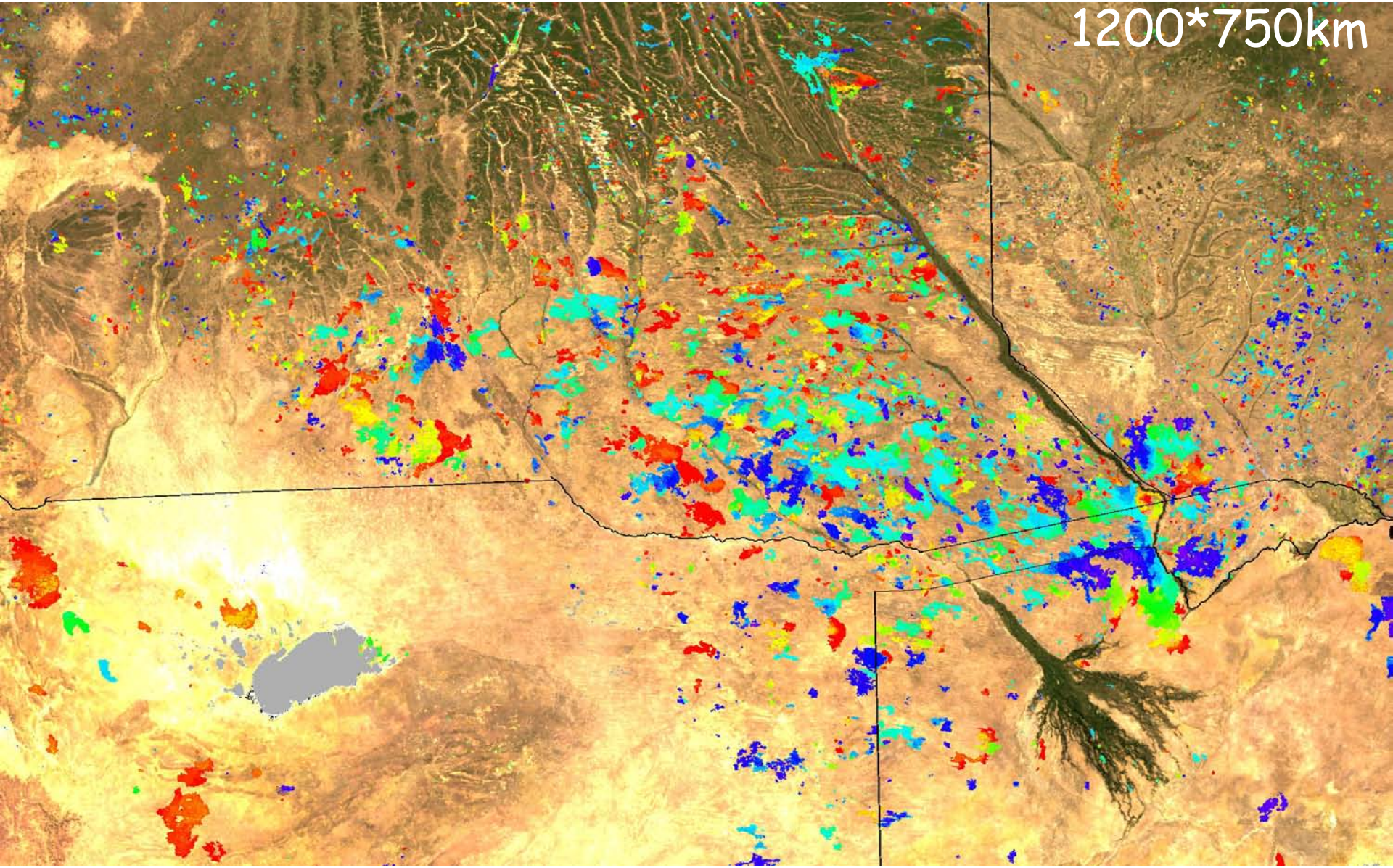

500m burned areas
5 months 2002
Zambia/Zimbabwe
650*500km


1km active fires
5 months 2002
Zambia/Zimbabwe
650*500km

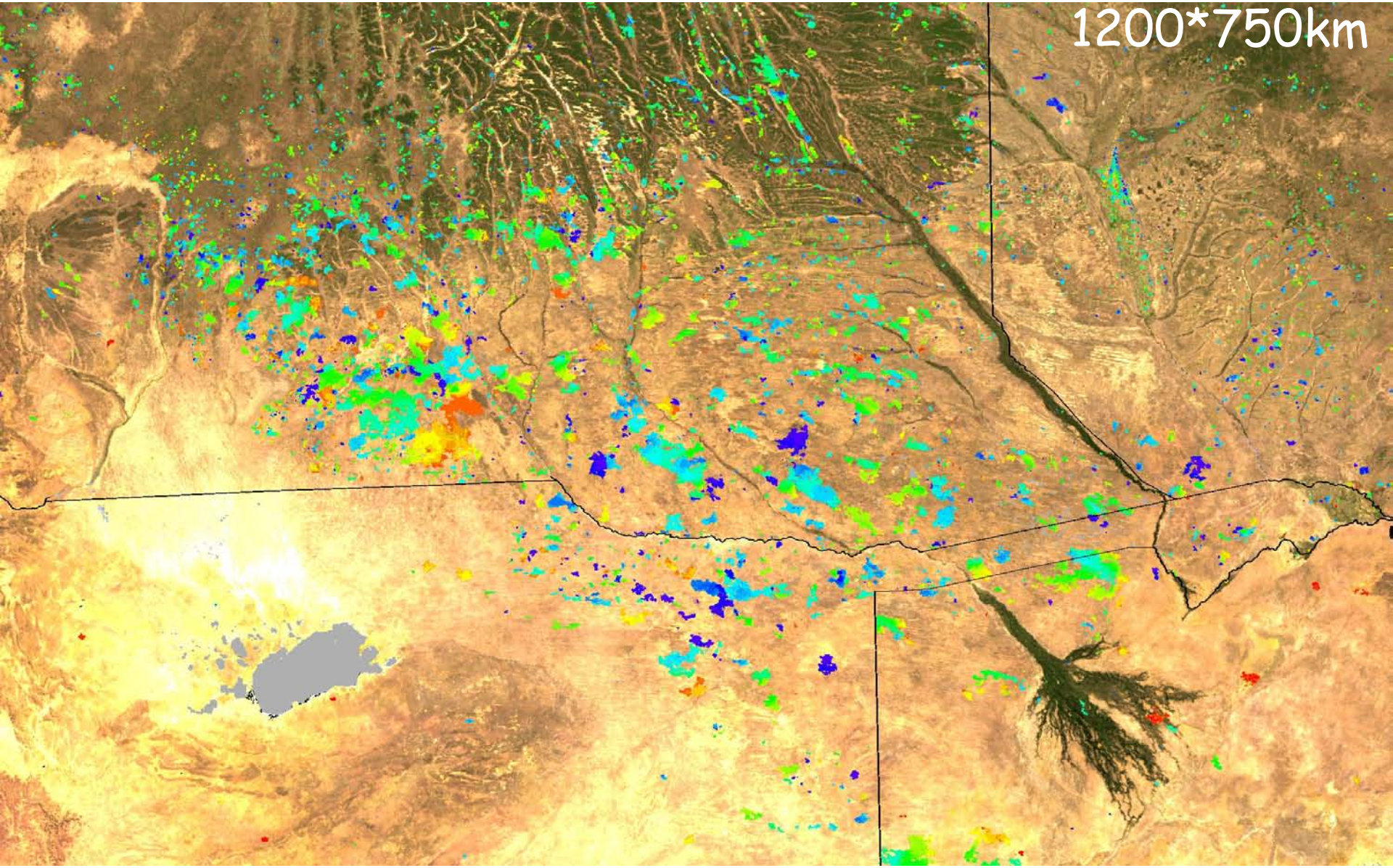

Zambia 500m burned areas
5 months 2002
650*500km


500m burned areas
3 months 2001:
July 4th (Blue)
to October 8th (Red)
Malawi
600*550km

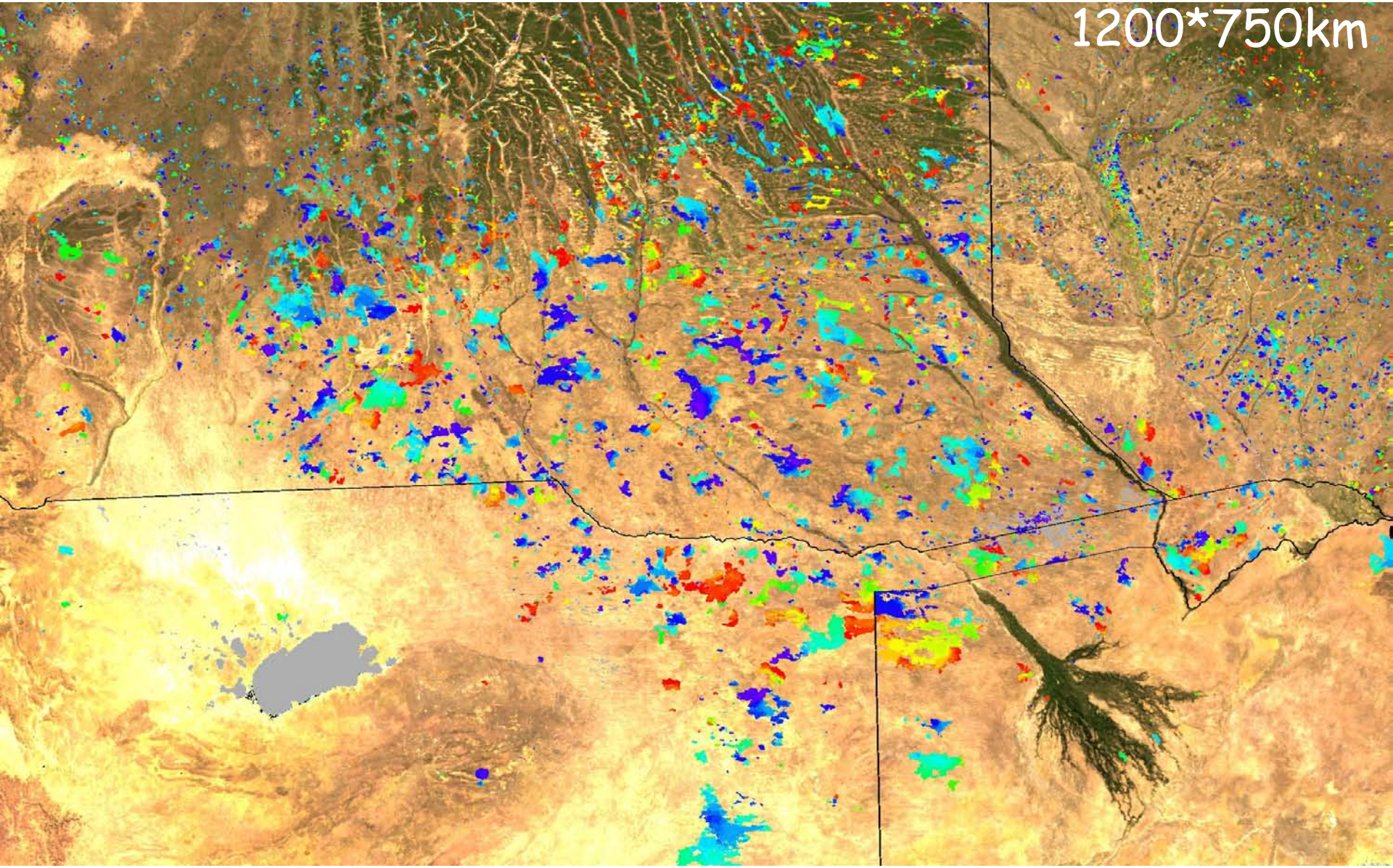
2001 September 1st (blue) to September 30th (red), Caprivi Strip



2002 September 1st (blue) to September 30th (red), Caprivi Strip



2003 September 1st (blue) to September 30th (red), Caprivi Strip



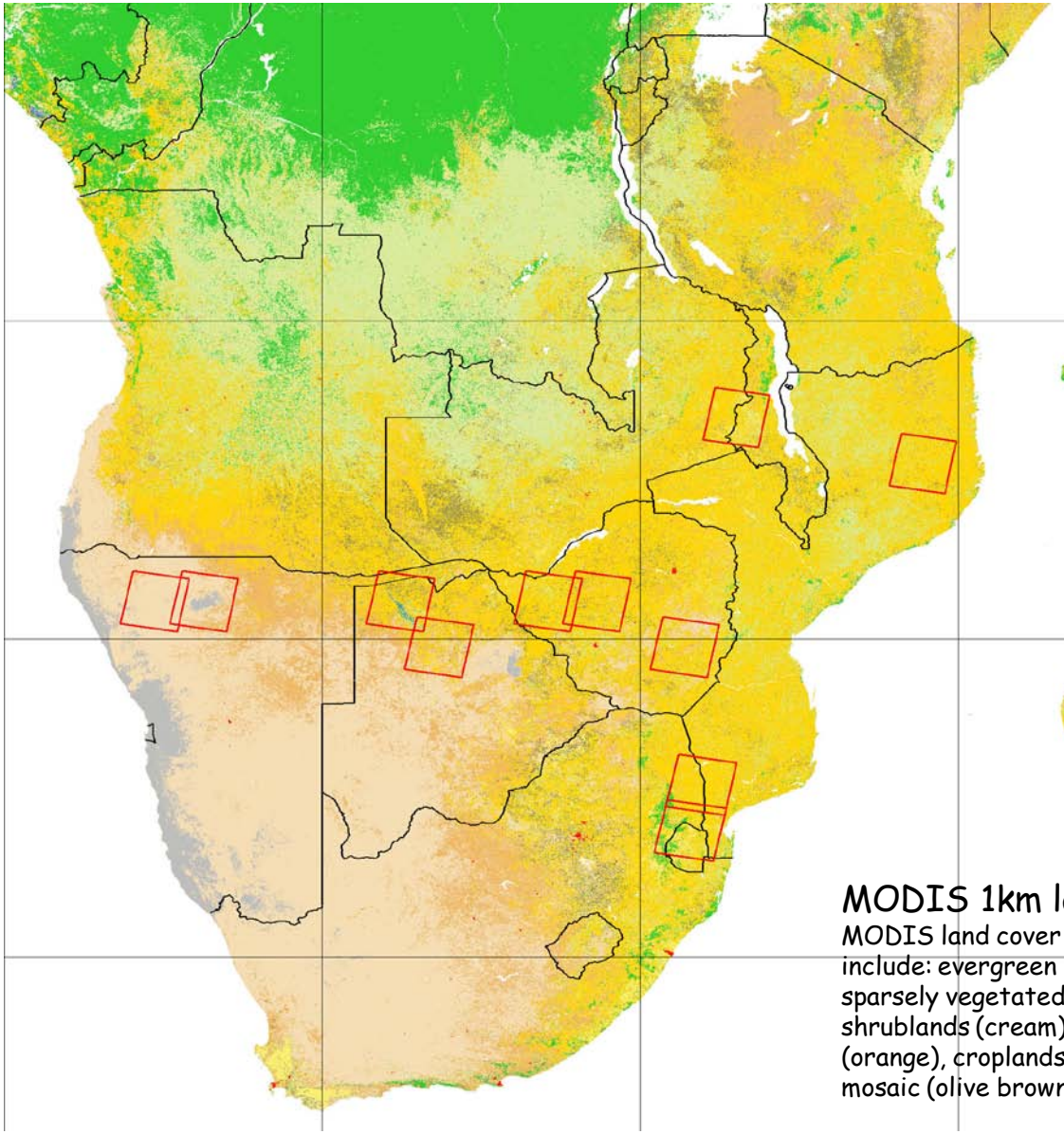
Significant Result : Develop and implement consensus SAFNet burned area validation protocol

- Compare MODIS burned area product with independent spatially explicit burned area data derived from multitemporal Landsat ETM+ data

- SAFNet field trip held to develop the mapping protocol and to discuss southern African fire information needs, Zimbabwe-Zambia, July 2000
- SAFNet members map the areas burned between 2+ Landsat acquisitions, augmented by limited fieldwork
- Consensus mapping protocol to ensure regionally consistent independent validation data

- protocol followed 2000-2002 at ~11 ETM+ scenes/year

Landsat ETM+ validation scenes distributed from dry savanna to wet miombo woodland to quantify product accuracy over range of representative biomass burning conditions



ETM+ scene
~185 * 185 km

Each ETM+ scene has a local SAFNet collaborator

11 scenes = ~3% of southern African surface

MODIS 1km land cover product: of the 17 MODIS land cover classes, predominant classes illustrated include: evergreen broadleaf forest (dark green), barren or sparsely vegetated (gray), woody savannas (light green), open shrublands (cream), grasslands (light brown), savannas (orange), croplands (yellow), cropland/natural vegetation mosaic (olive brown), urban (red).

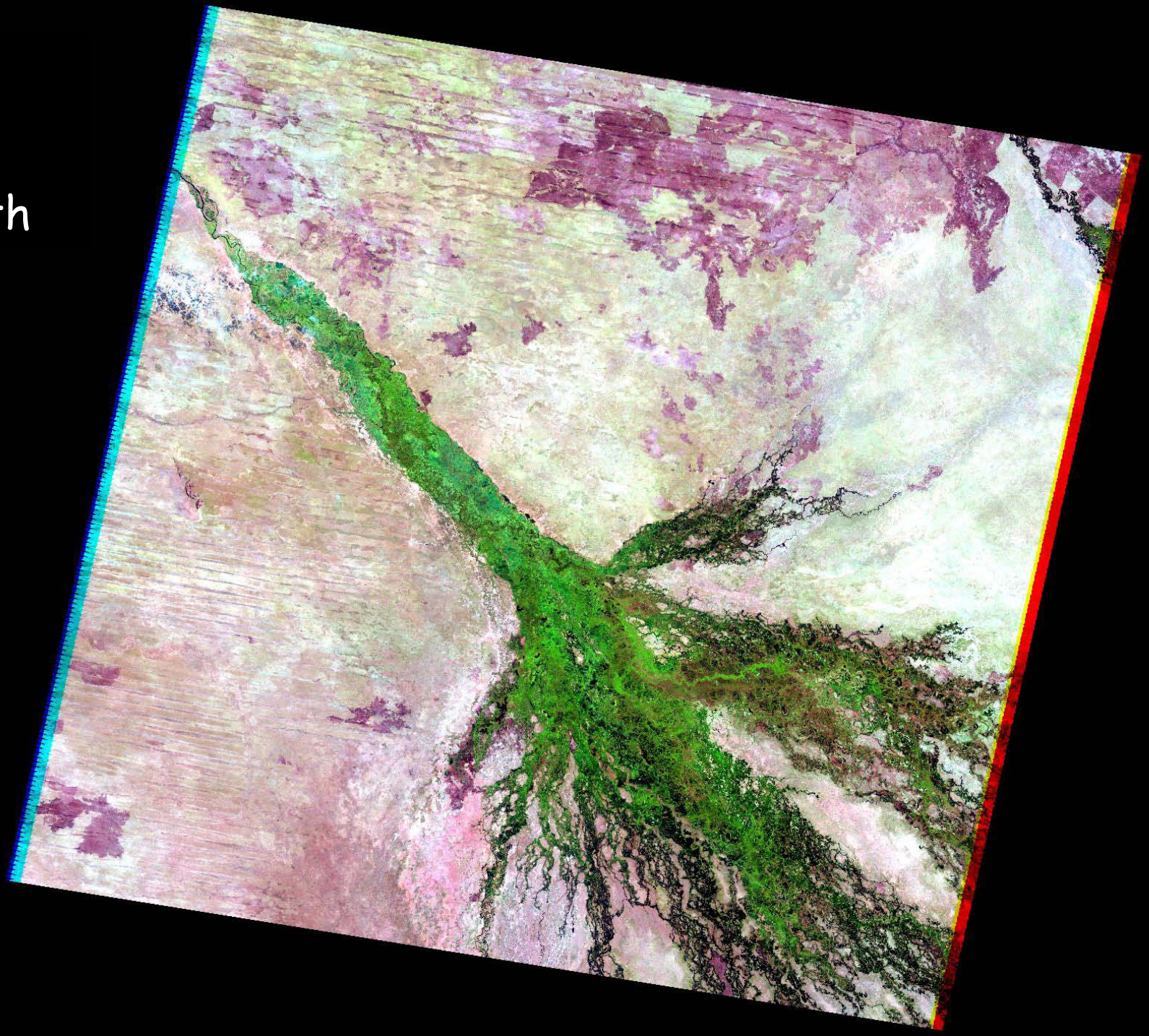
Detailed Validation Example

- Botswana, Okavango Delta, 2001
- Landsat ETM+ path 175 row 073

- Cloud-free scenes acquired 32 days apart:
  - September 4th
  - October 6th

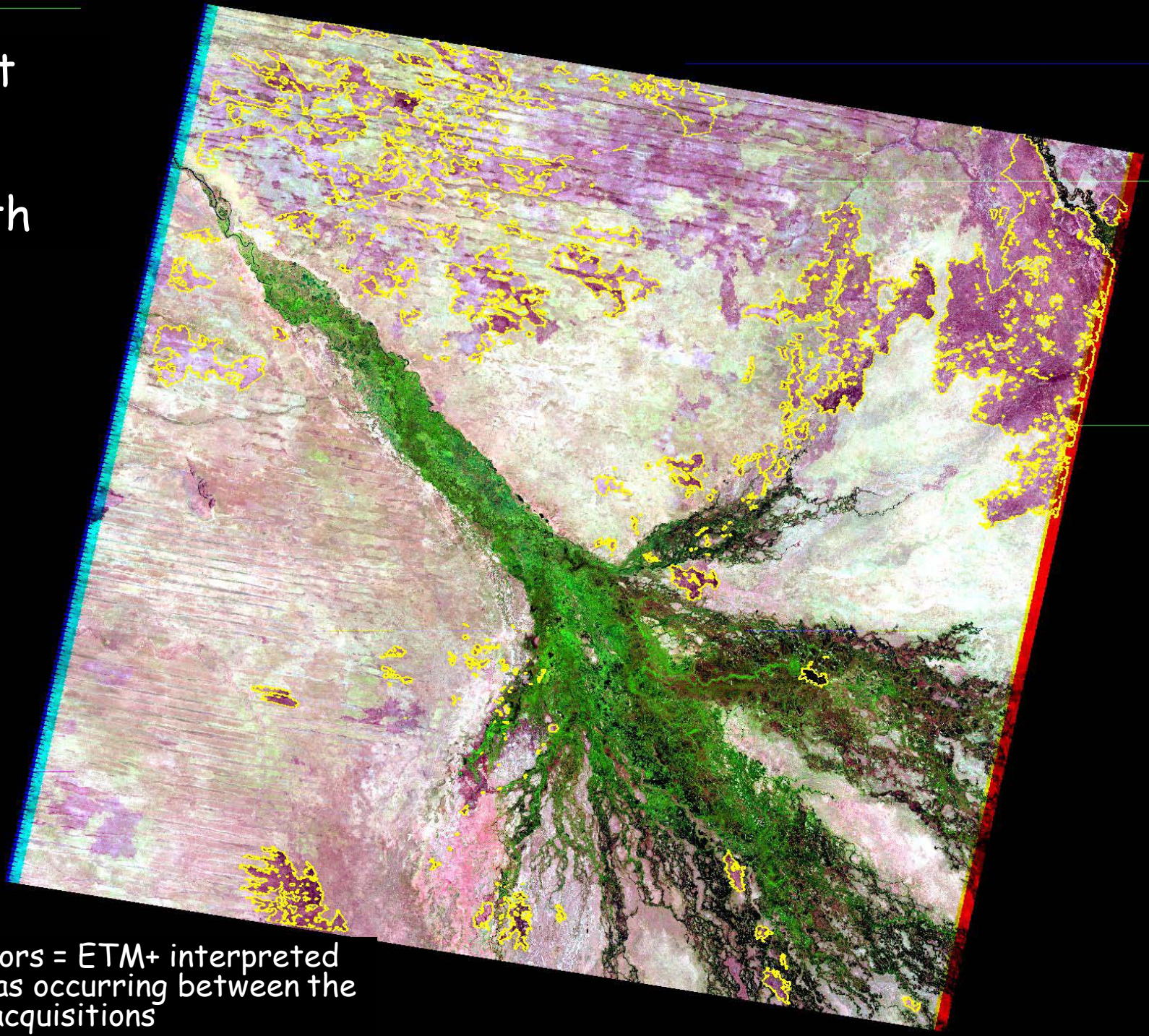
Landsat
ETM+

Sept. 4th



Landsat
ETM+

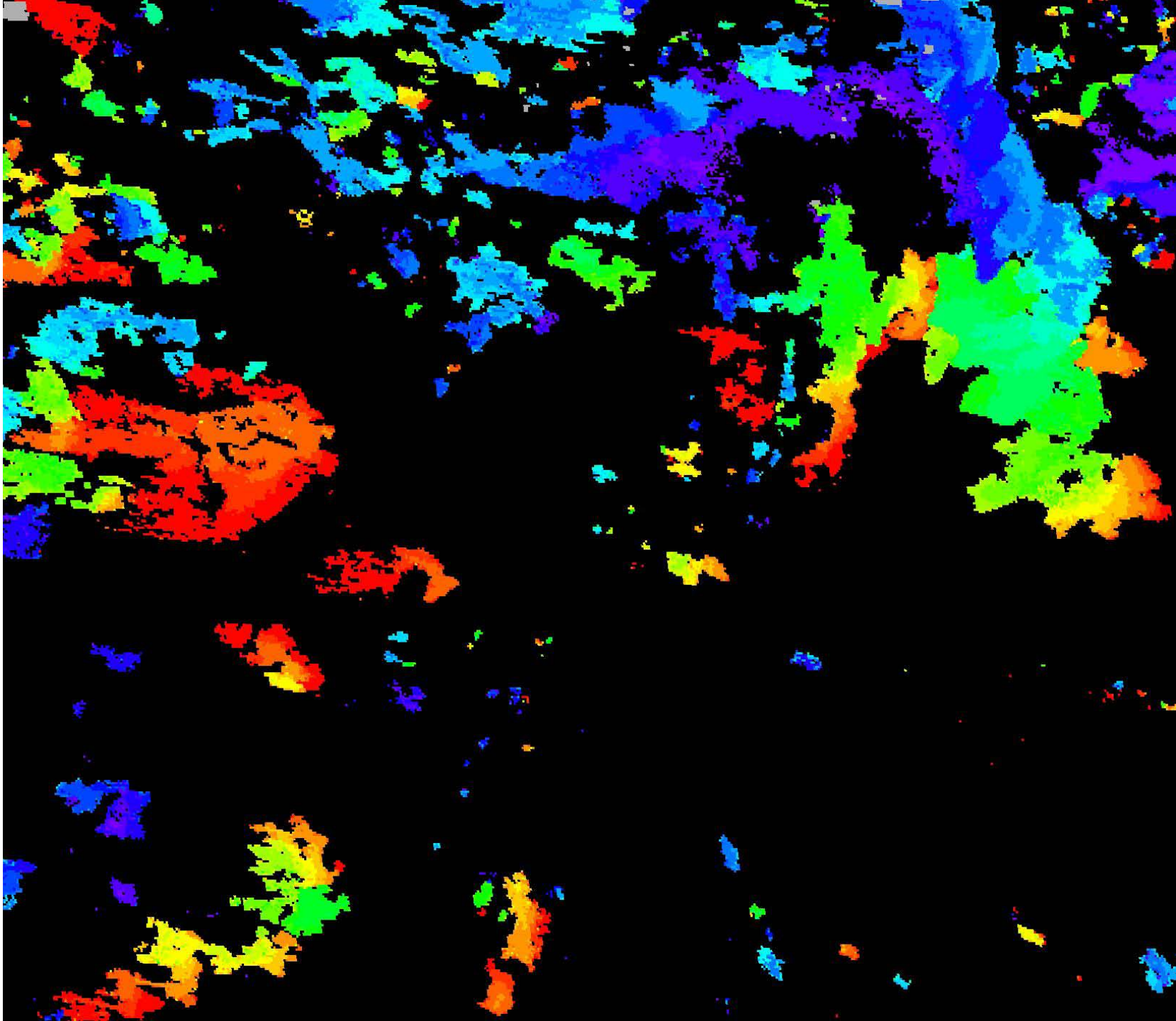
Oct. 6th

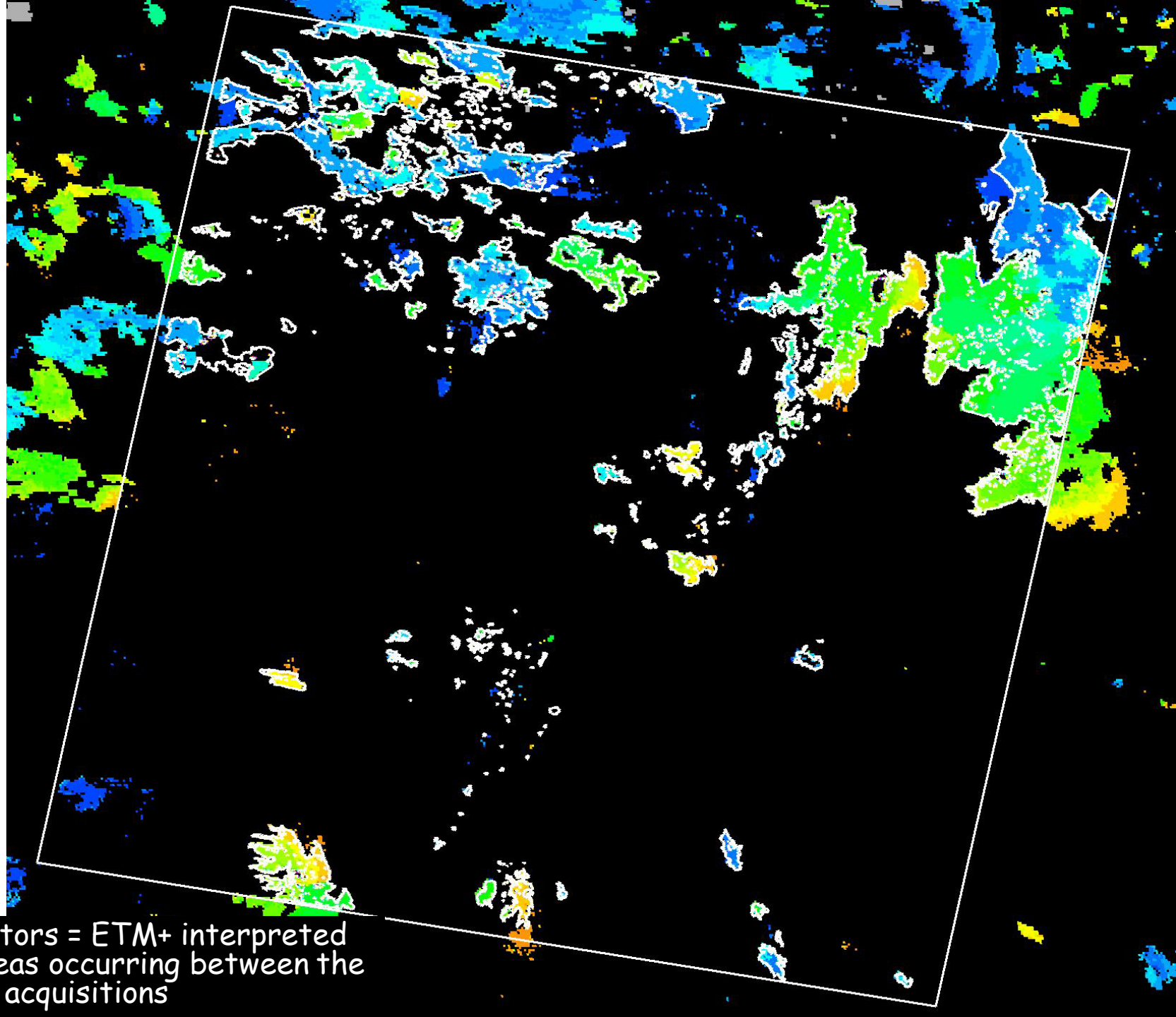


Yellow vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions

MODIS 500m Burned Areas

August 8 (blue) to Oct. 15 (red)

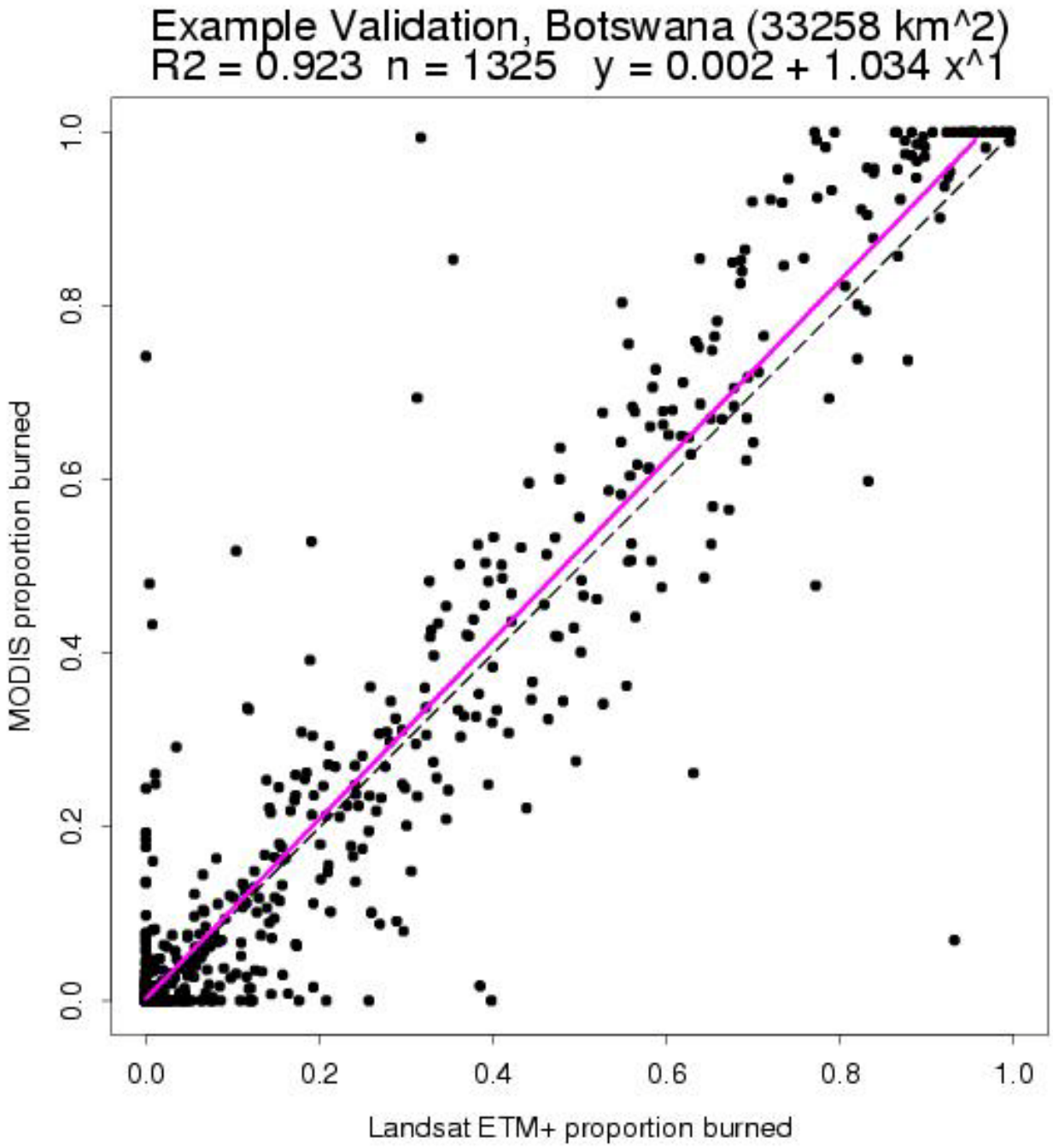



MODIS
500m
Burned
Areas
Sept. 4
to
Oct. 6
White vectors = ETM+ interpreted
burned areas occurring between the
two ETM+ acquisitions

Example 2001 Validation: Confusion Matrix comparison of MODIS and ETM+ data (30m pixels, MODIS data resampled to 30m)

	# MODIS burned pixels	# MODIS unburned pixels	total
# ETM+ burned pixels	**3617530**	**701992**	4319522
# ETM+ unburned pixels	**996970**	**33218960**	34215930
total	4614500	33920952	38535452

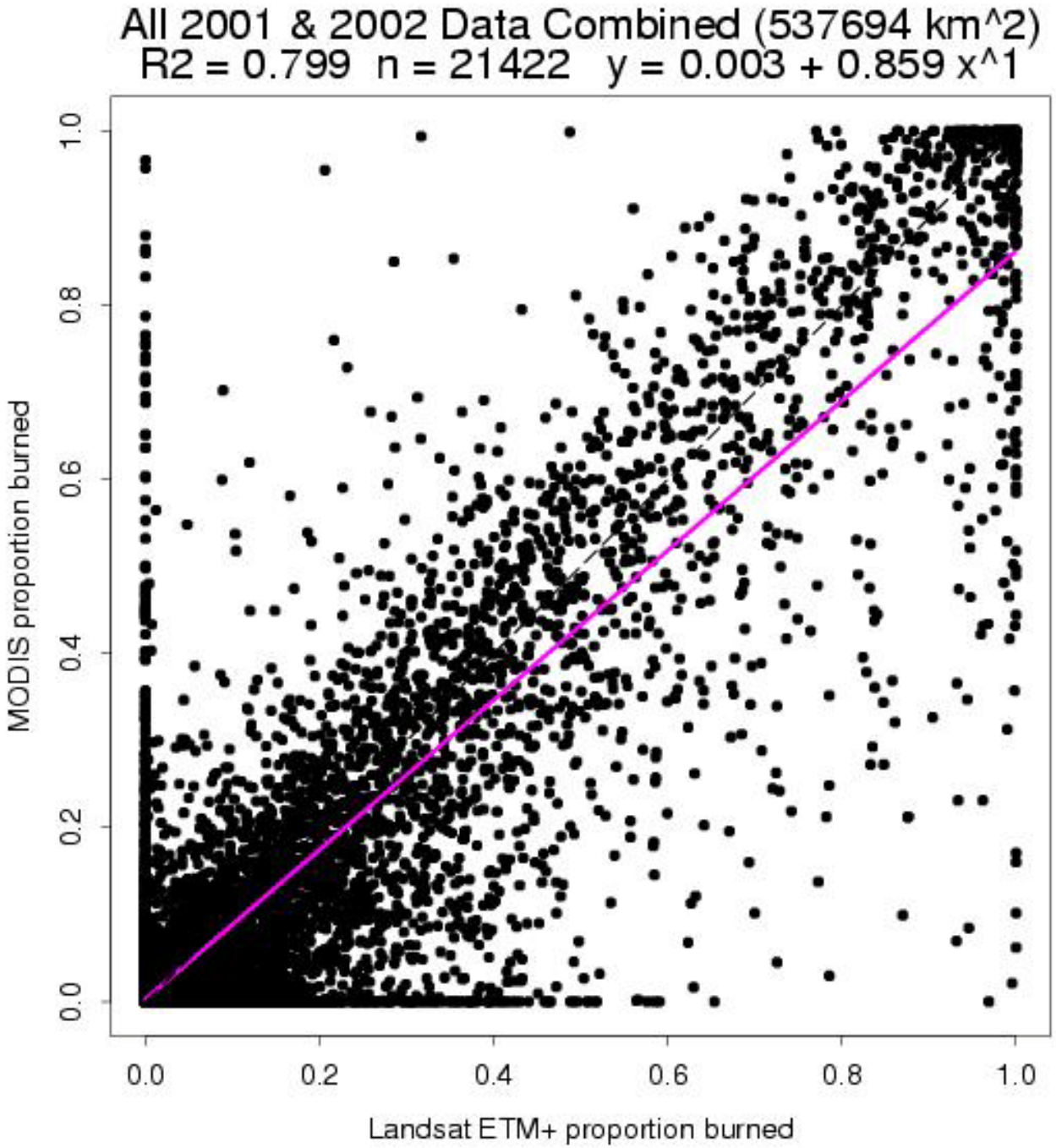
Percent correct {0-100%} = 95.6%
Kappa {0-1} = 0.785



Each point illustrates the proportion of a 5.0*5.0 km cell mapped as burned

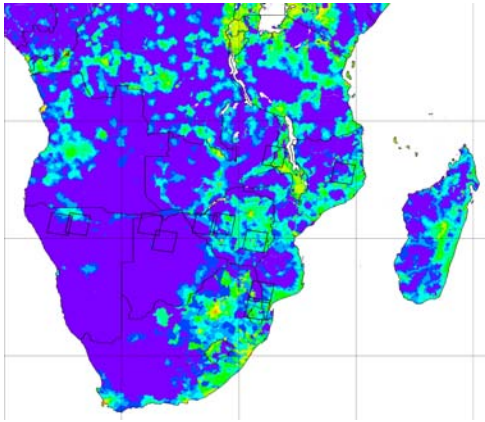
Significant Result : Validated 2000,2001,2002 burned area products

- Validation results indicate high product accuracy
  - MODIS Burned area = 0.85 “true” burned area (R2 = 0.8) [2001 & 2002]
  - burned area detection limits more complicated to define than initially thought
  - further investigation ongoing
  - Fundamental limitation: how to validate low combustion completeness fires & surface fires concealed by unburned overstorey vegetation not apparent in Landsat ETM+ ?
- Future work:
  - development of validation reporting metrics specific to the information needs of different SAFNet users
  - “calibrated” country level burned area statistics for national reporting

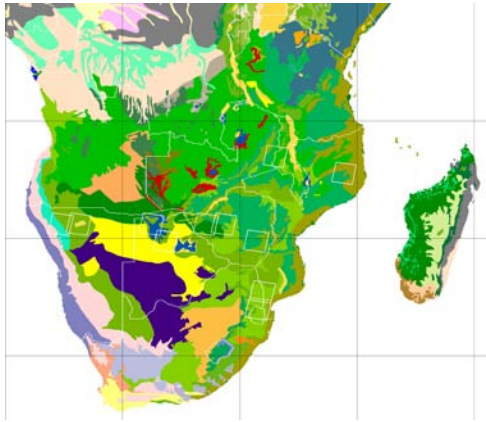

All 2001 & 2002 Data Combined (537694 km^2)
R2 = 0.799 n = 21422 y = 0.003 + 0.859 x^1
MODIS proportion burned
Landsat ETM+ proportion burned
0.0
0.2
0.4
0.6
0.8
1.0

Next Steps

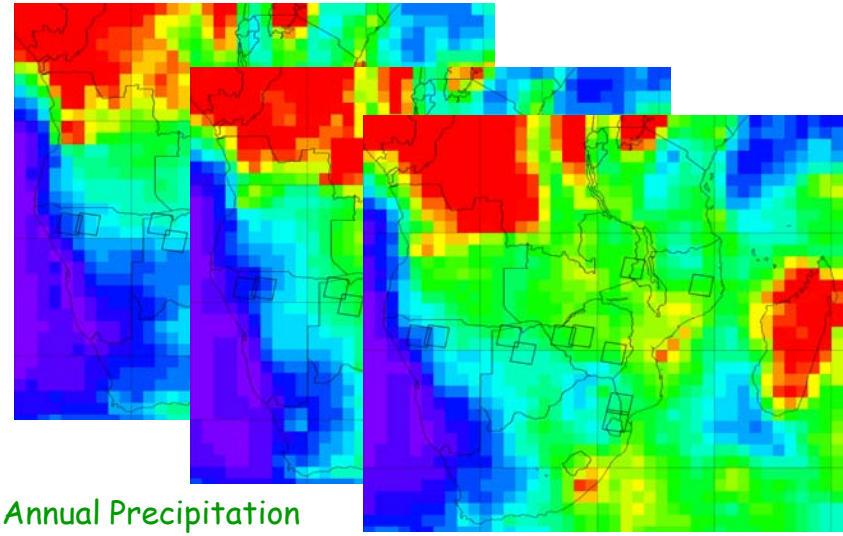
- SAFNet assessment of 2001-2003 MODIS burned area products in the context of their decision-making processes for fire management and reporting.
- Investigate LCLUC hypotheses that explore the interplay between physical and human variables on fire size and timing:



Population density



Vegetation



Annual Precipitation

- Research associate/GRA position open
- MODIS burned area algorithm in MODIS Land production system; tentative direct broadcast proposal (including Db site in southern Africa)