MODIS direct broadcast data for enhanced forecasting and real-time environmental decision making

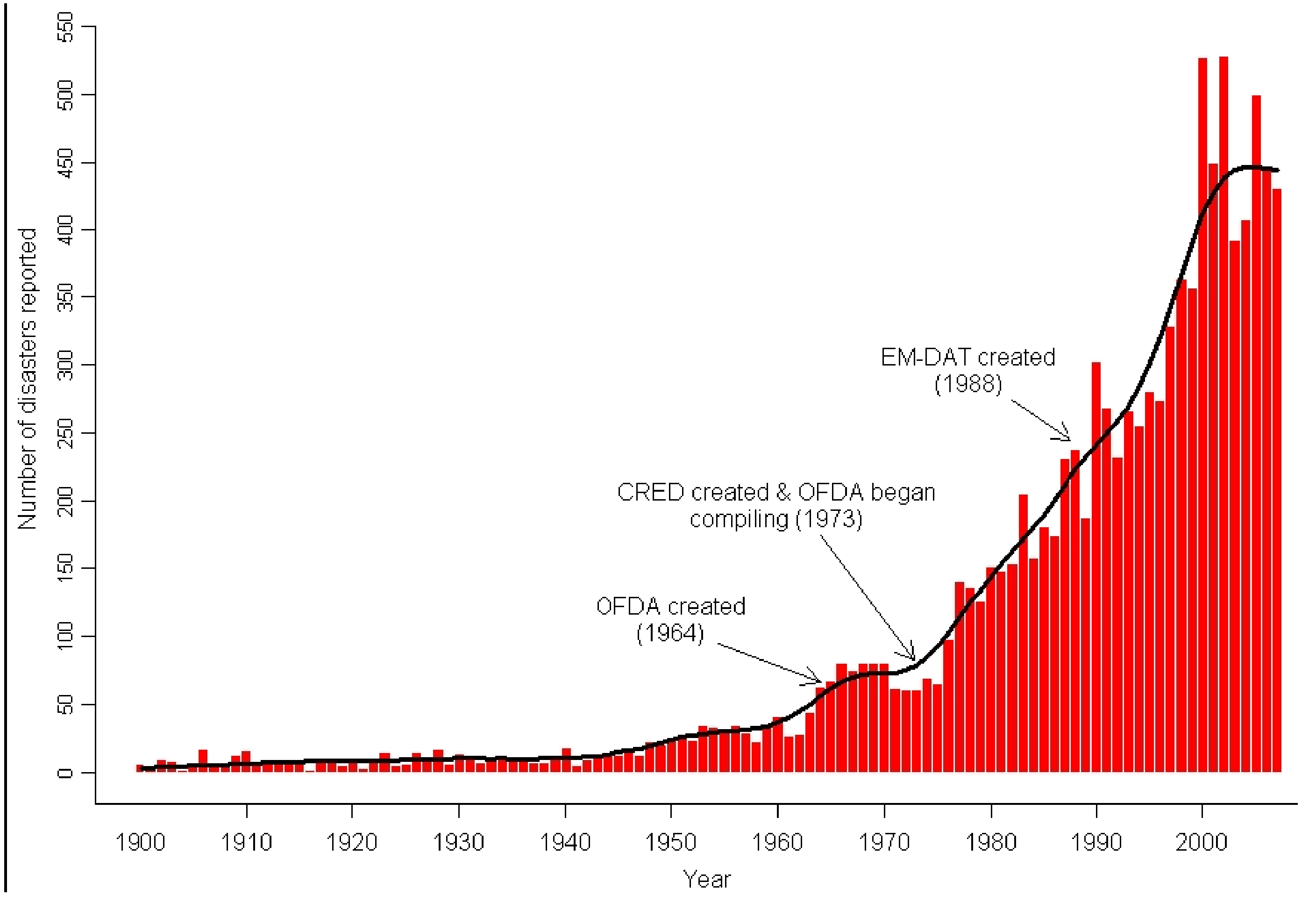
The role of Remote Sensing in Wildfire Management

Natural Disasters

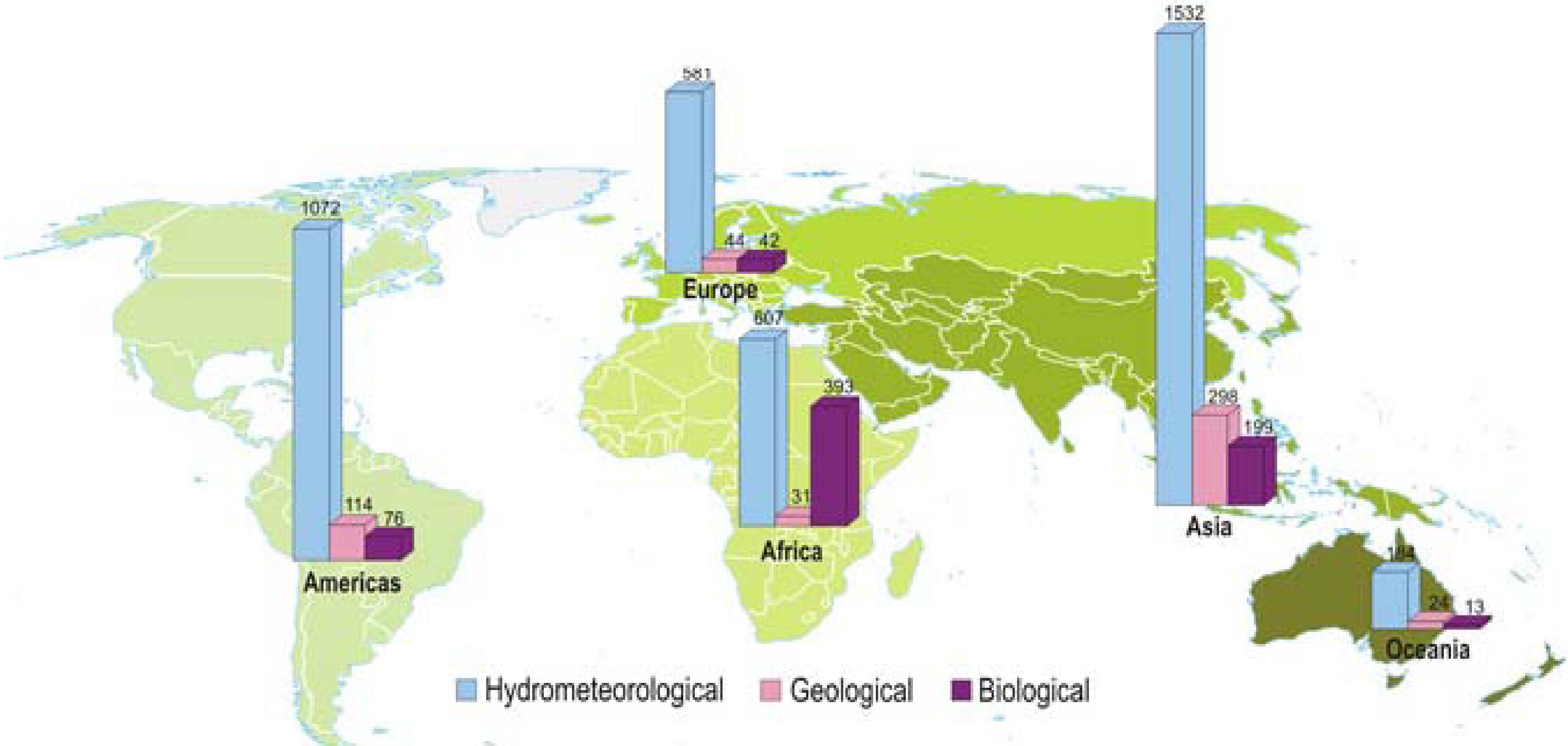
- Natural disasters are continuously increasing in number globally, and there is scientific agreement that:

(i) vulnerability is rising worldwide
(ii) economic damage and the number of affected people will increase
(iii) disasters constitute a severe impediment to economic growth.

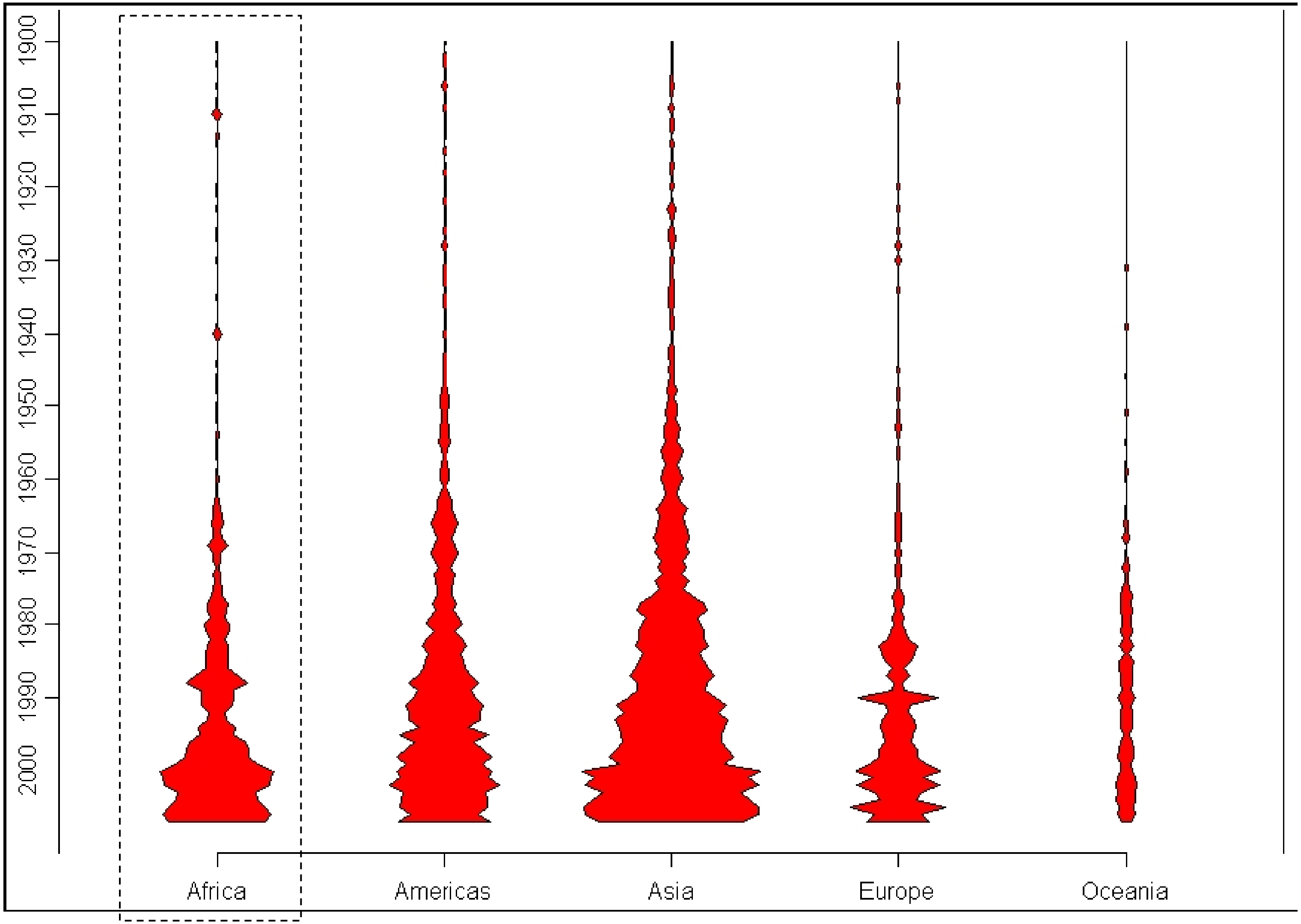
- This is especially true for developing countries, which have suffered more than 90% of all fatalities, and have been disproportionally burdened by the economic losses as well, due to, amongst other reasons, their lower GDP, limited reserves, and an underdeveloped insurance industry. While Asia has been confronted with the largest absolute number of annual natural disasters, Africa has seen the most rapid increase in recent years.



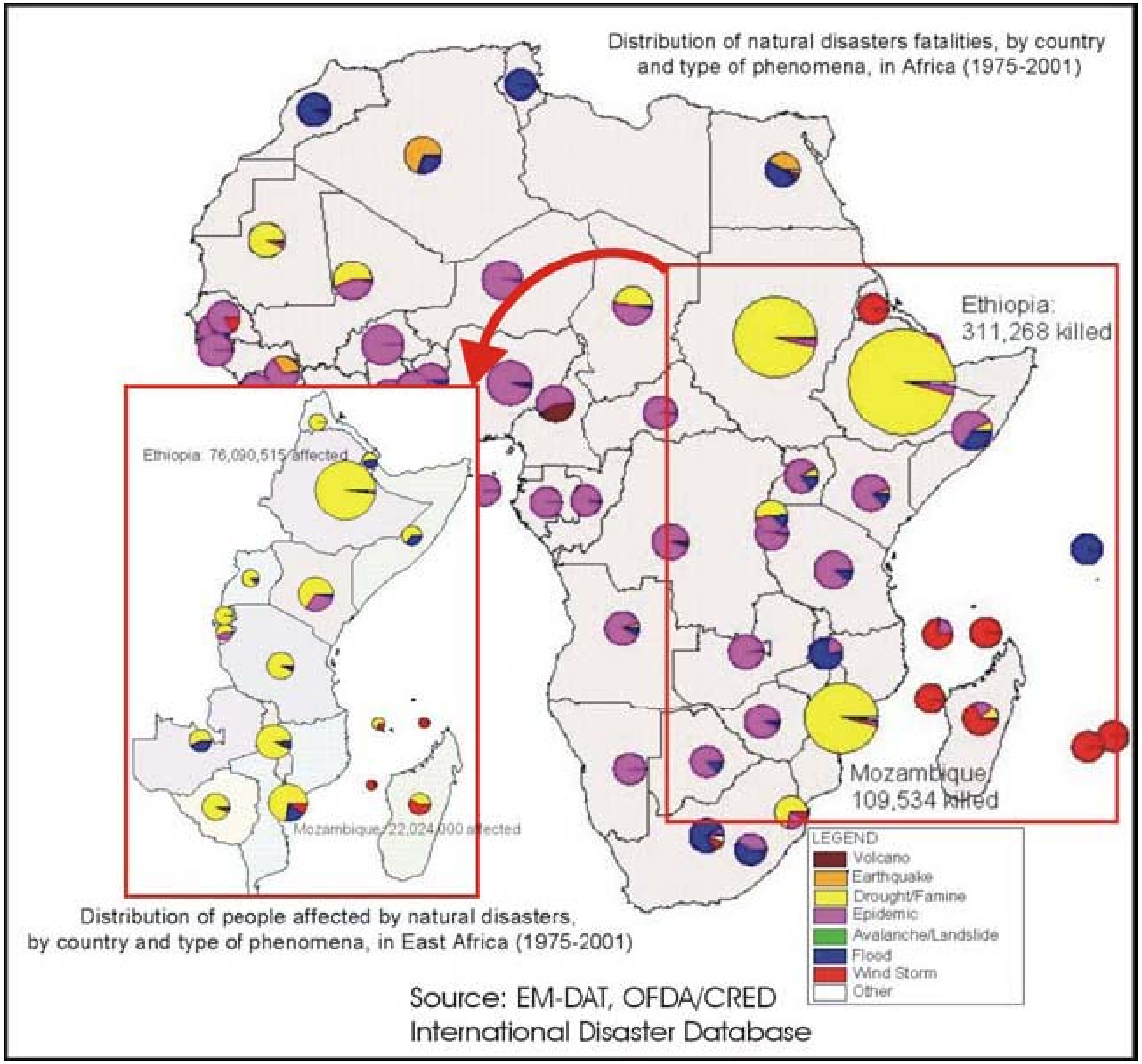
Number of natural disaster reported between 1900-2007. (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain)



Regional distribution of natural disaster by origin between 1991-2005 (Source: ISDR/ EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).



Number of reported natural disasters between 1900-2007 per continent. Africa has seen the strongest increase. (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain)



Number of affected people per hazard type in Africa, with inset showing the number of fatalities for the Eastern part of the continent (1975-2001).

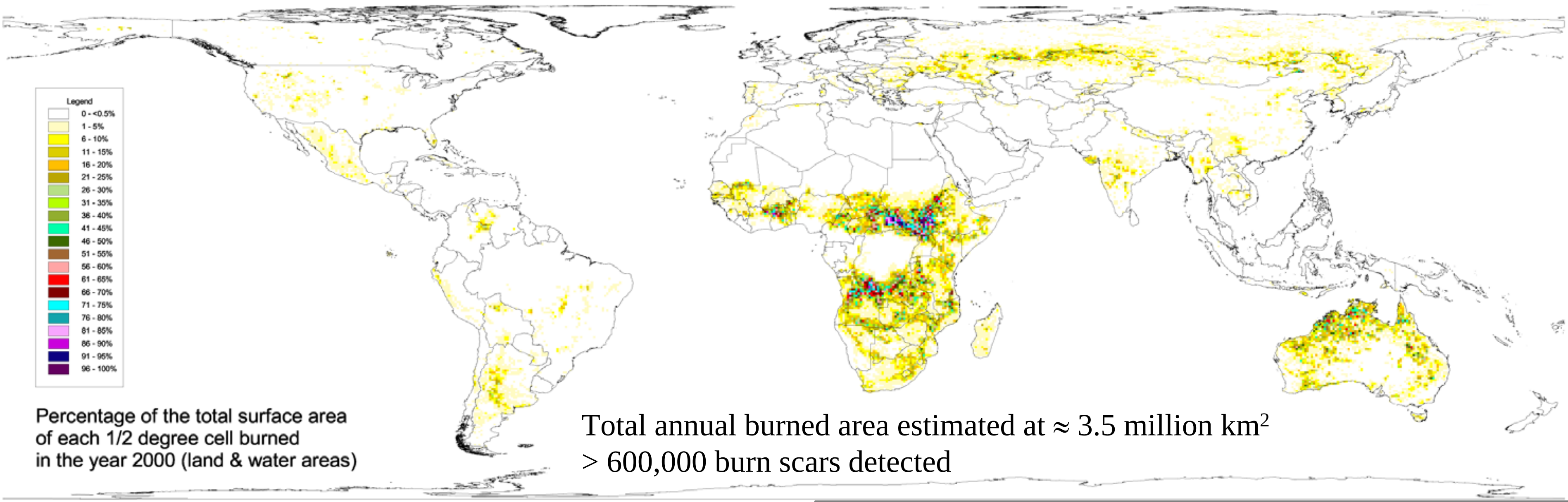
Background

- Wildfires are one of the major and chronic disasters affecting many countries in Africa
- Relative to other disasters in the region, wildfires do not necessarily cause many fatalities. However it causes serious impact on property and human health by smoke pollution
- Suppression of wildfires, demands large amounts of federal resources, costing up to $1.6 billion per year in the USA
- Historically, as many as 1,500 civilian lives have been lost in a single wildfire incident
- Indications are that this will get worse with global warming and climate change

	Number of fatalities	Number of affected people
Algeria	30	0
Benin	2	4,000
Central African Rep	1	85
Ghana	4	1,500
Guinea Bissau	3	1,200
South Africa	94	1,000
Sudan	47	0
Swaziland	2	1,500
Total	**183**	**9,285**

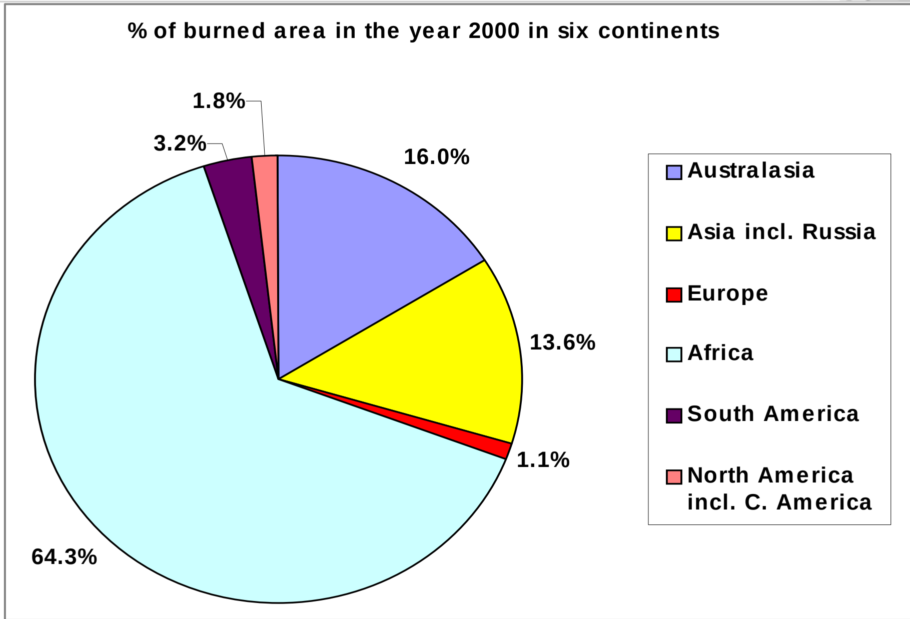
Number of fatalities and affected people per country in Africa due to wildfires (both forest and bushfires) between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

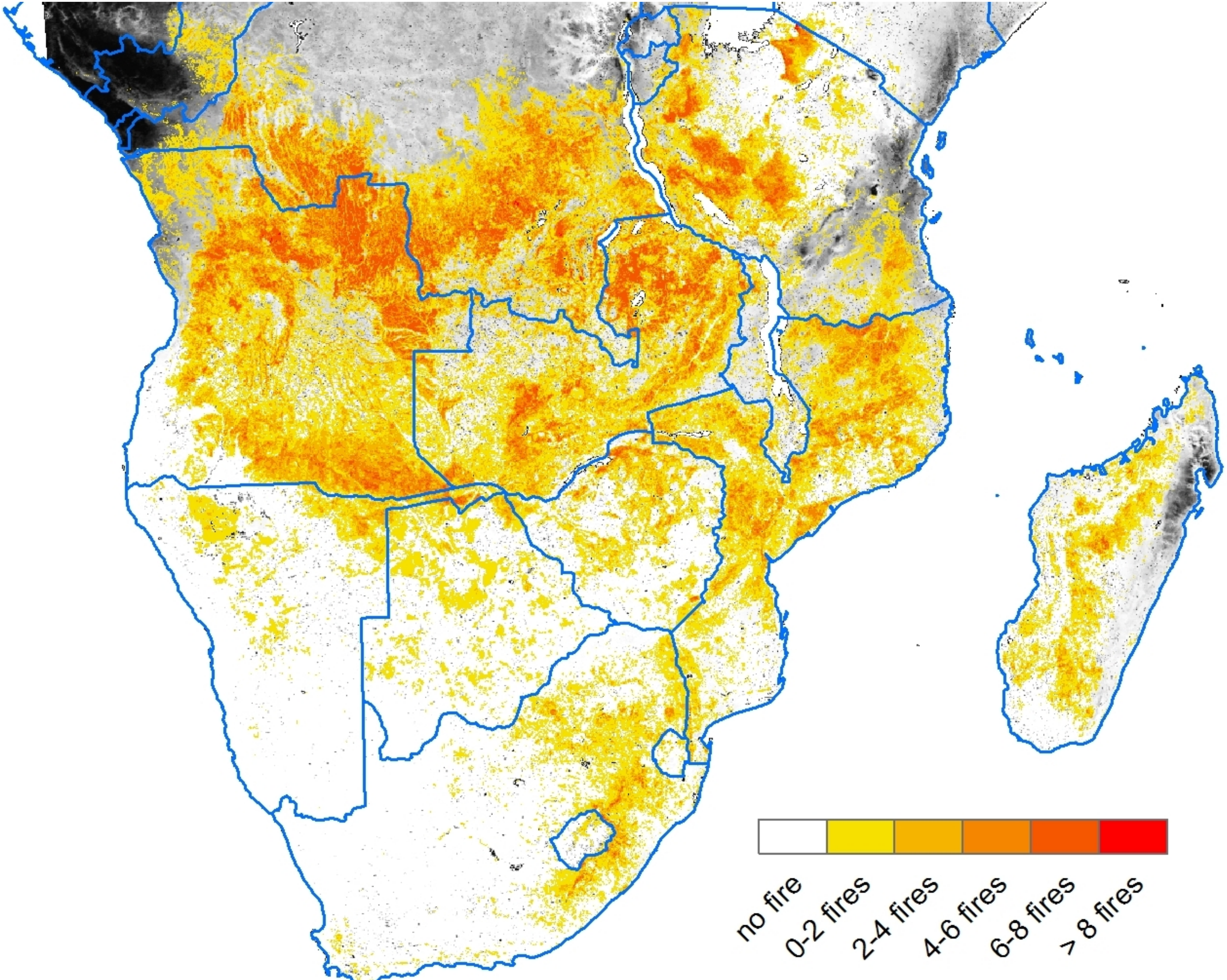
Global fire activity (GBA2000)



Total annual burned area estimated at ≈ 3.5 10^6 km2
> 600,000 burn scars

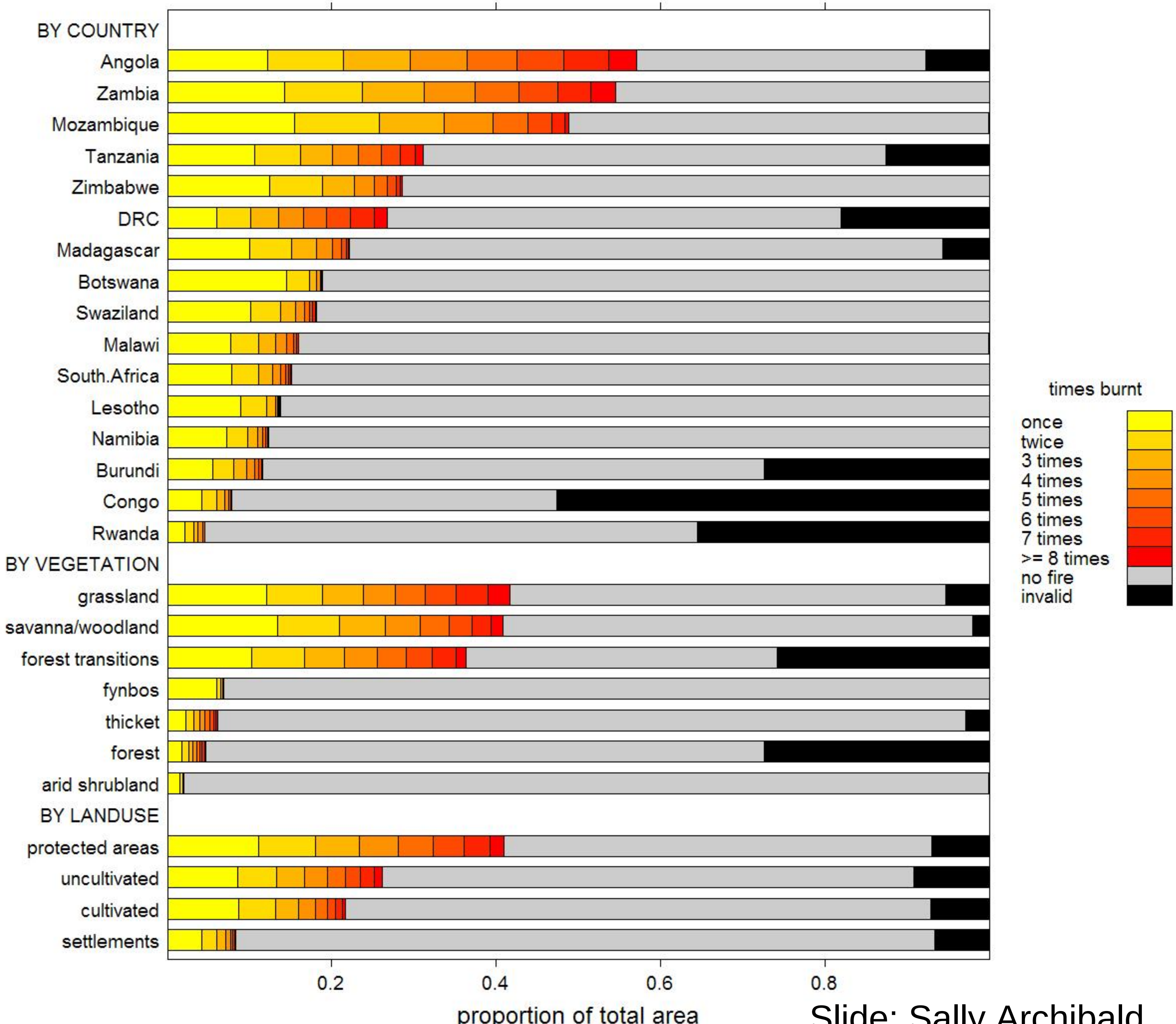
[Tansey et al., Climatic Change 2004]





MODIS BA 2000 - 2008

Slide: Sally Archibald

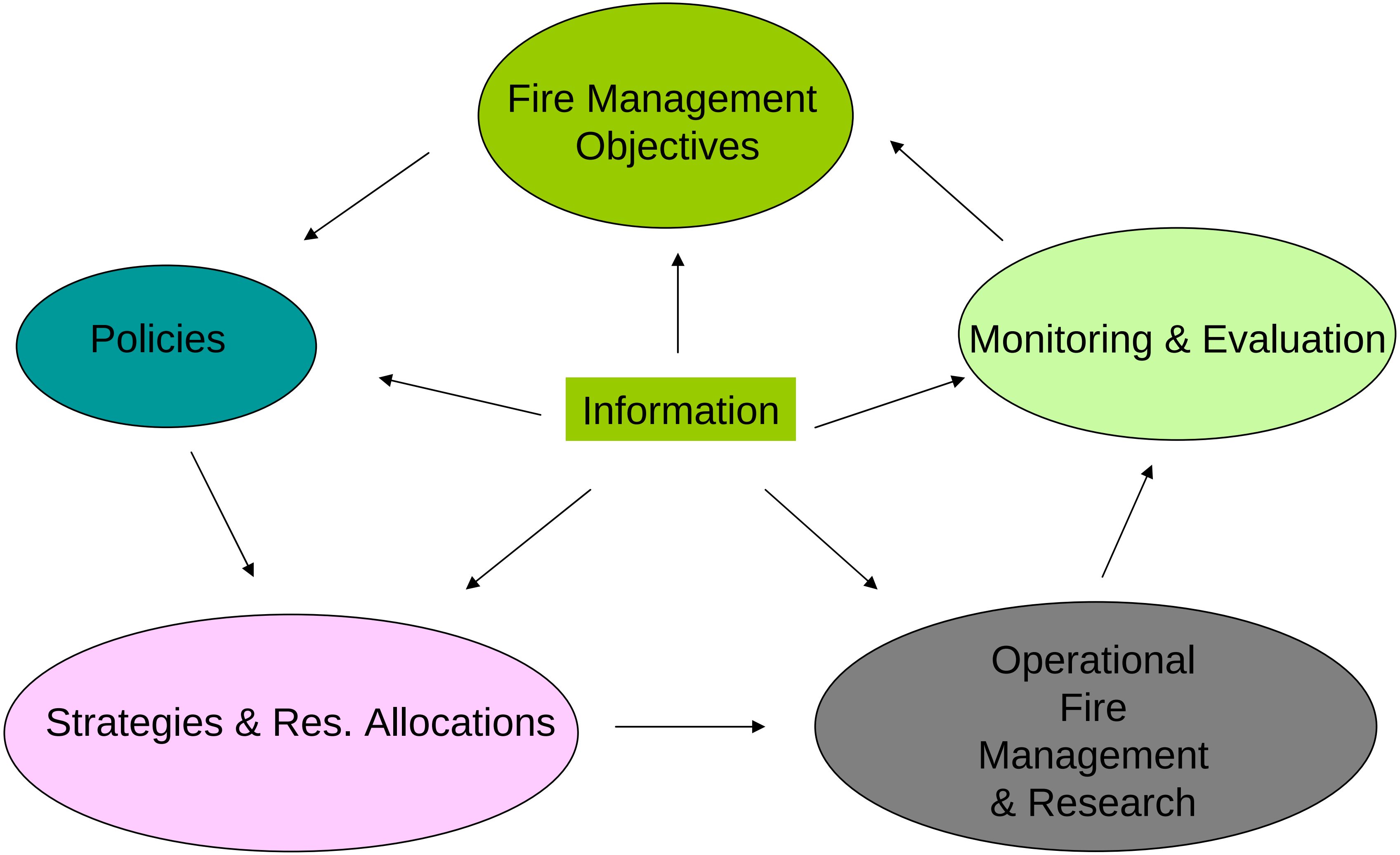


Slide: Sally Archibald

Fire Management and Information Needs

- Fire Management comprises activities designed to control the frequency, area, intensity or impact of fire
- These activities ranges from national to local scale and can be undertaken in different institutional, economic and geographic contexts.
- Effective management is reliant on reliable information on which to base appropriate decisions and actions
- Information will be required at many different stages of fire management - “Fire Management Loop”

Fire Management Loop



Fire Management Objectives

- This results from fire related objectives
- Appropriate objectives require scientific knowledge and up to date monitoring information
- Examples such as vegetation status, fire locations, land use and social economic context

Policies

- At national/governmental level provide legal long term framework to undertake actions.
- Policy creation is however dependent on a good knowledge of the fire issues and their evolution.

Strategies

- Short term framework to prioritise fire management activities
- Development of clear objectives
- Include research and capacity building in fire management

Operational Fire Management

- Concerns the implementation of fire strategy

- Daily activities dependant on up to date information such as fire frequencies, fuel loads and weather conditions in the management area.

Monitoring and evaluation

- Assessment of the effectiveness of different strategies, to document current situations and to learn from the past in order to adapt and improve knowledge management activities

A Fire Management Information System

- An important tool to support integrated fire management.
- Allows the incorporation of various sources of information such as static maps, historical fire locations and vegetation indices
- Could include modelling tools, such as fire spread models

Benefits of Remote Sensing data to Fire Management

- Often less expensive and faster to obtain data than acquiring data from the ground
- It permits the capturing of data across a wider EM spectrum than can be seen by the human eye
- Observations can cover large areas at a times, including remote and inaccessible areas
- It provides frequent updates
- Observations are consistent and objective

Remote Sensing: Introduction

“Remote sensing is the science and art of obtaining information about an object, area or phenomena through the analysis of data acquired by a device that is not in contact with the object , area or phenomena under investigation”

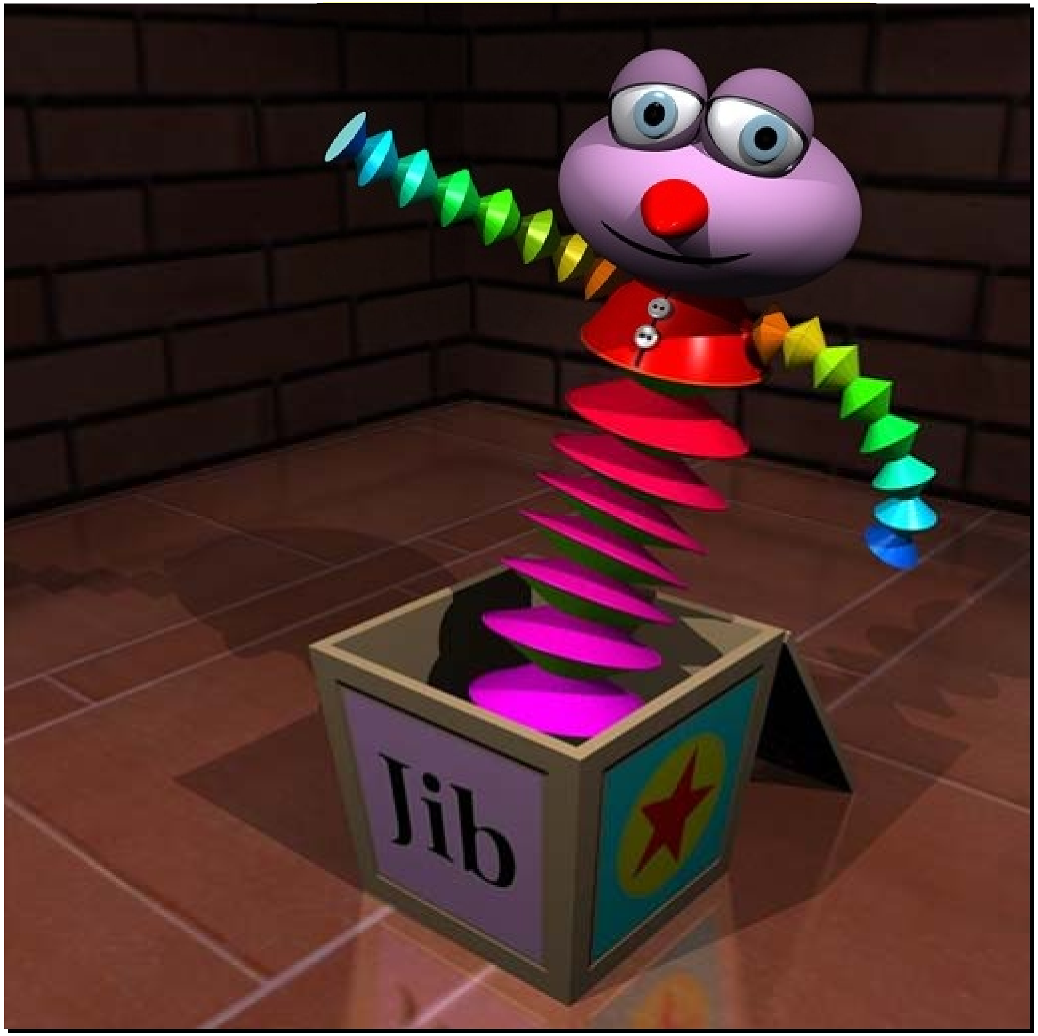
Lillesand and Kiefer (2000)

Remote Sensing: Introduction

Key points:

- Spatial resolution
- Swath Width
- Temporal Resolution
- Spectral Resolution
- Cost
- Operational vs. Research satellites
- Data Access

Spatial Resolution: Concept

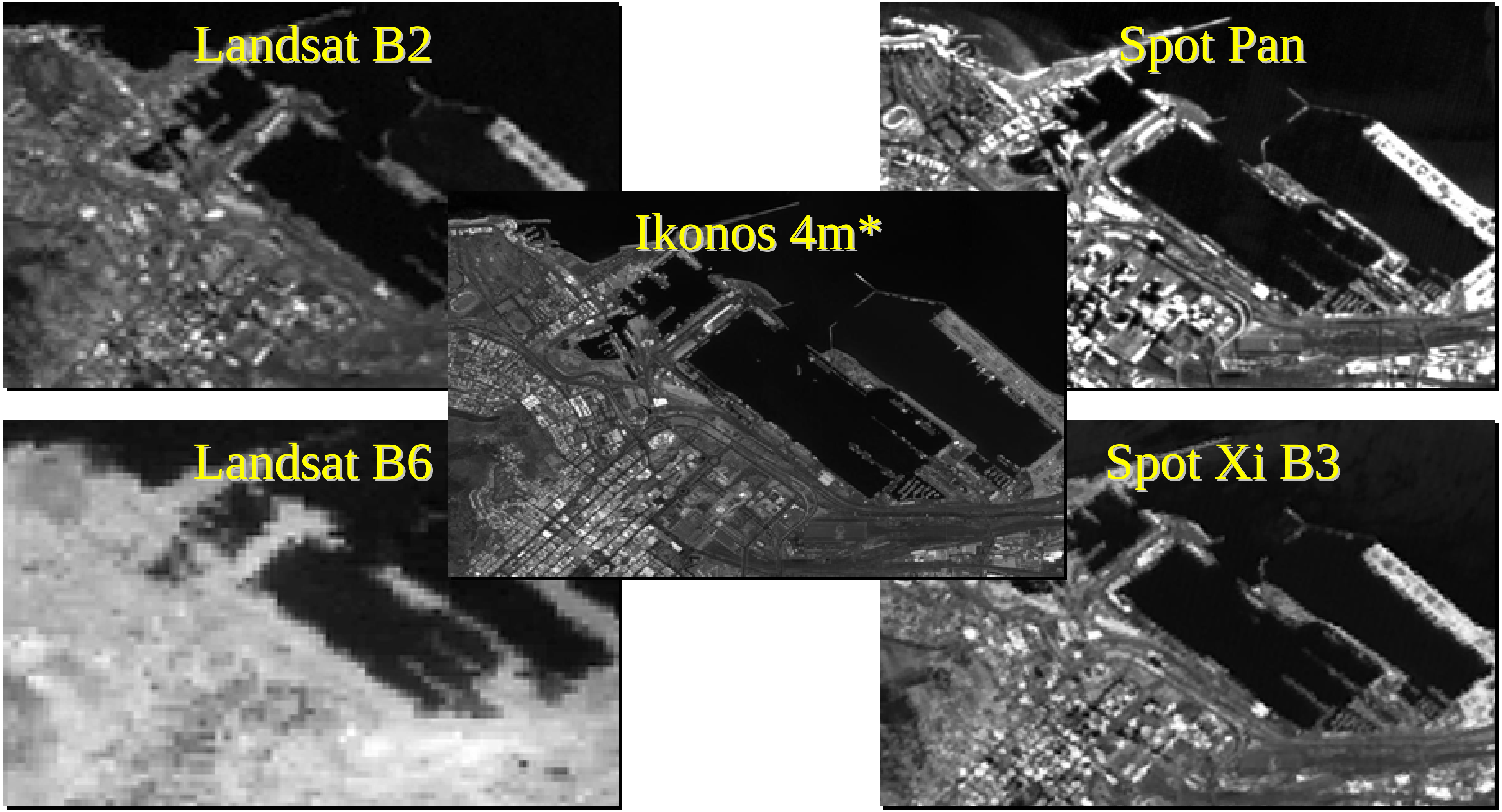


Half

Quarter

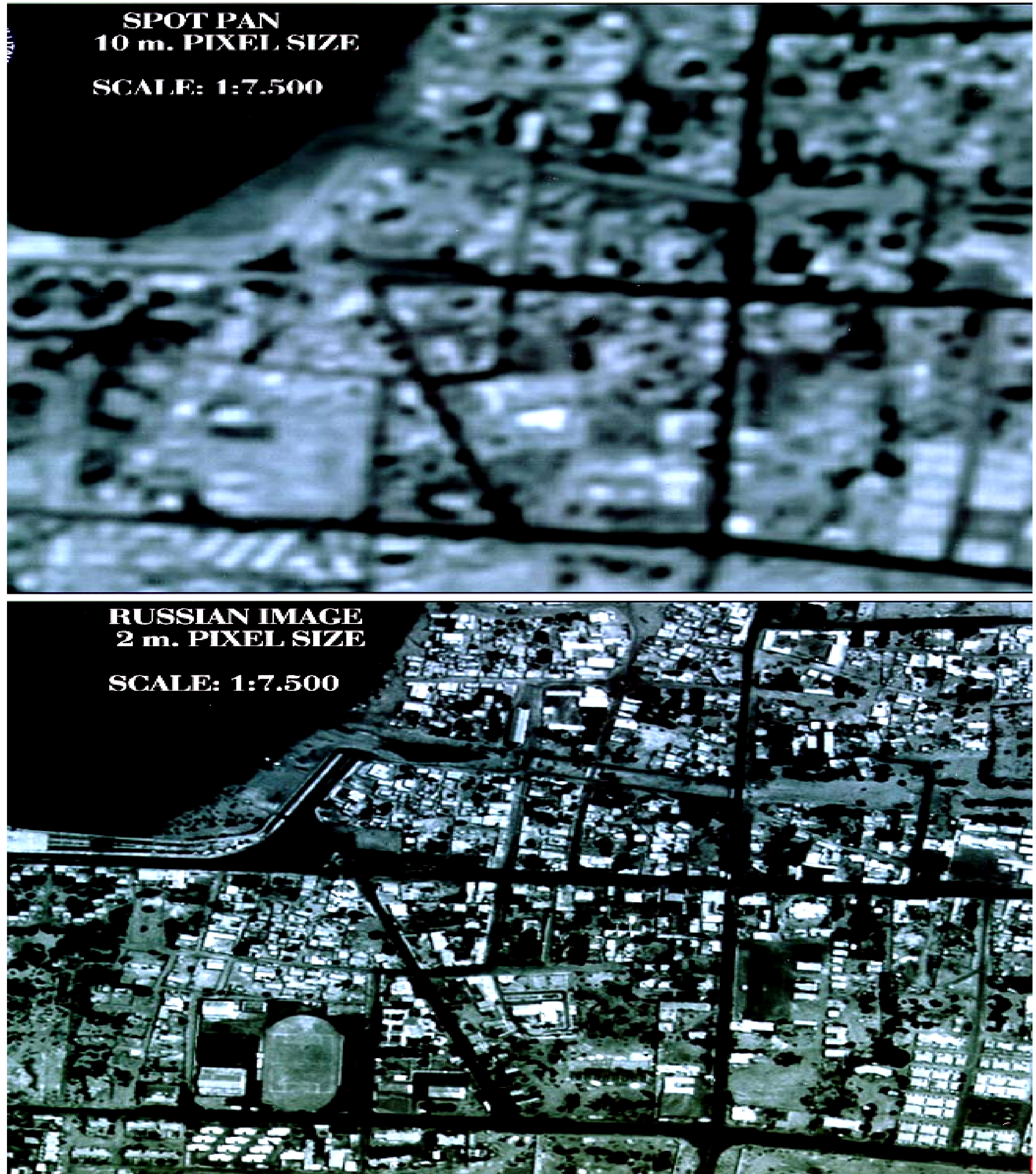
Eighth

Spatial Resolution (Various sensors)

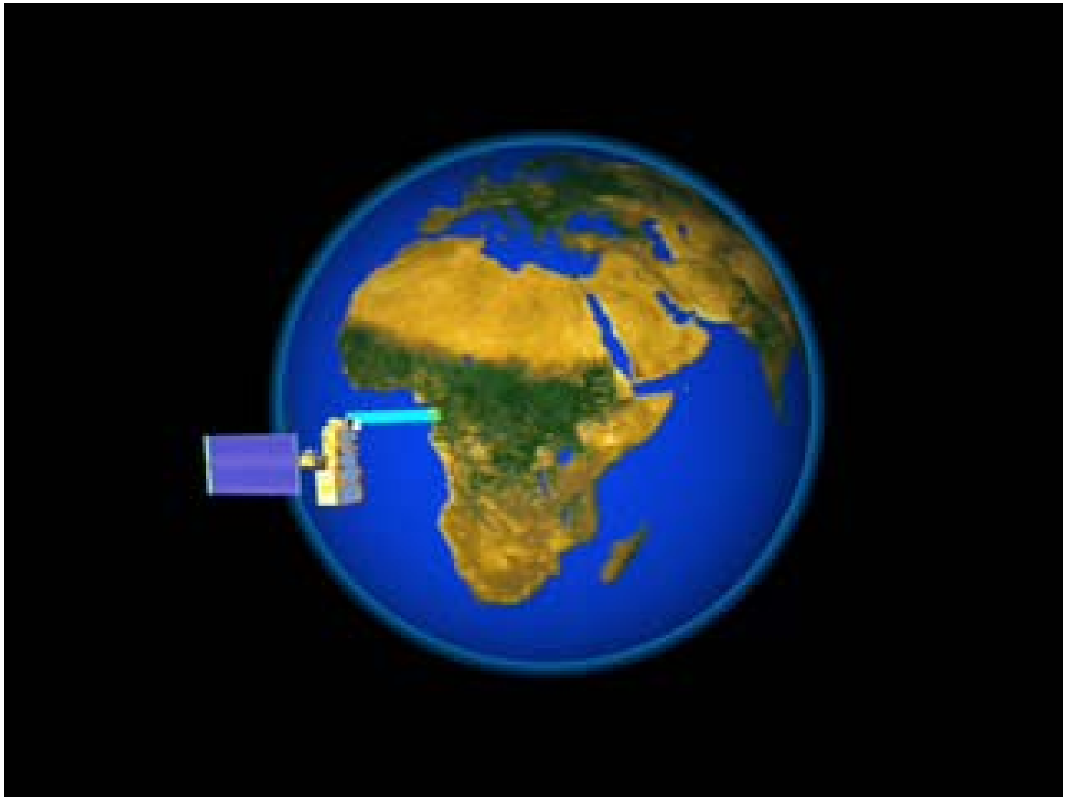


*1m not available for comparison

Comparison of resolution between SPOT Pan (10m GSD) at top and Russian KVR (2m GSD) at bottom

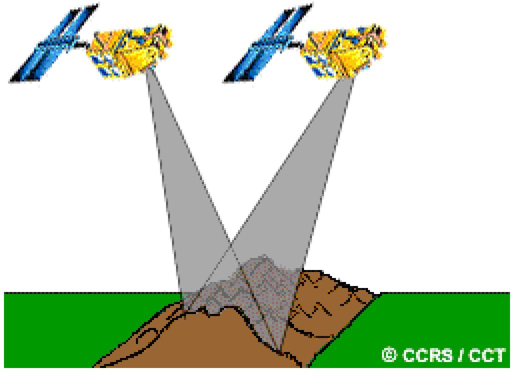


Swath Width

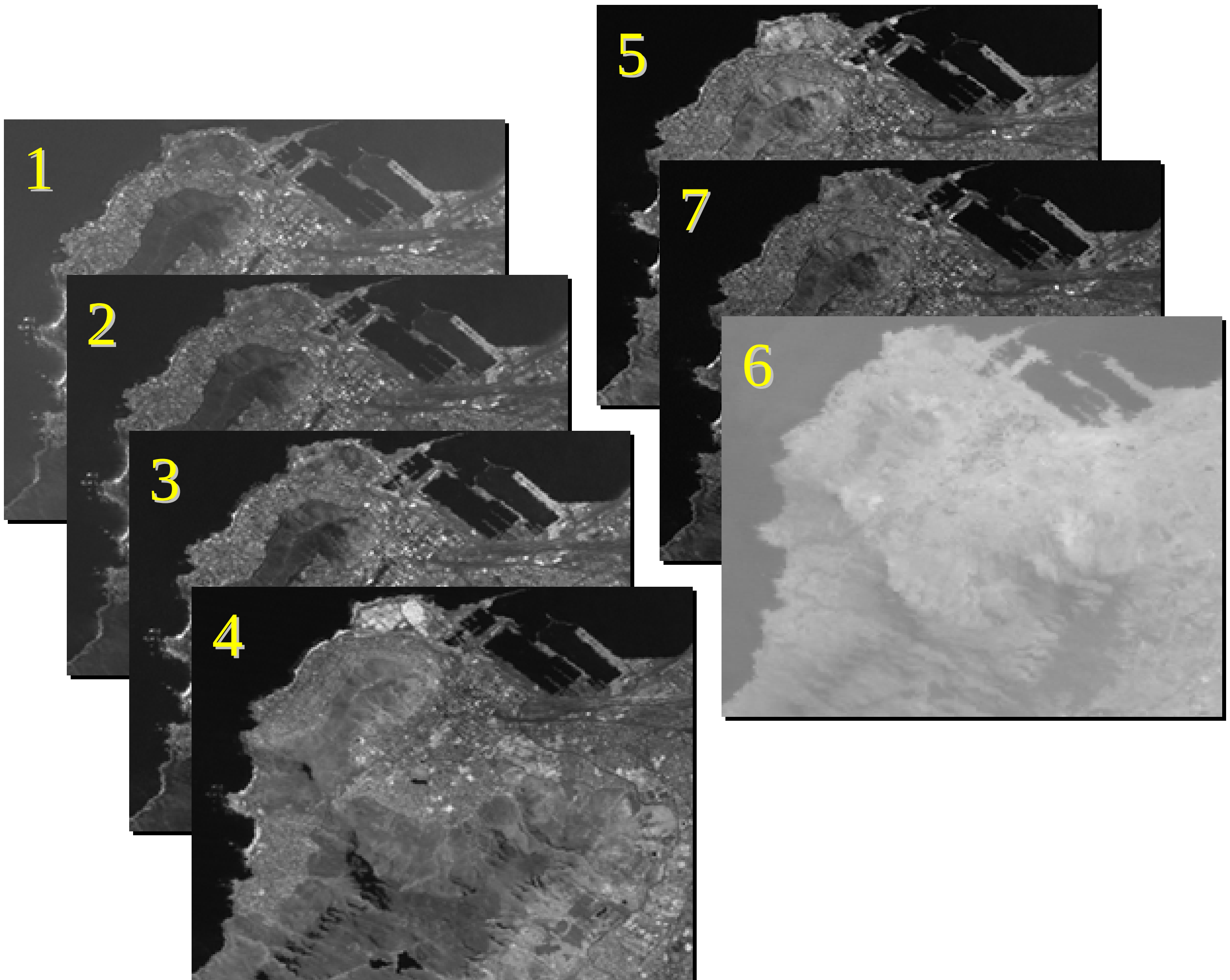


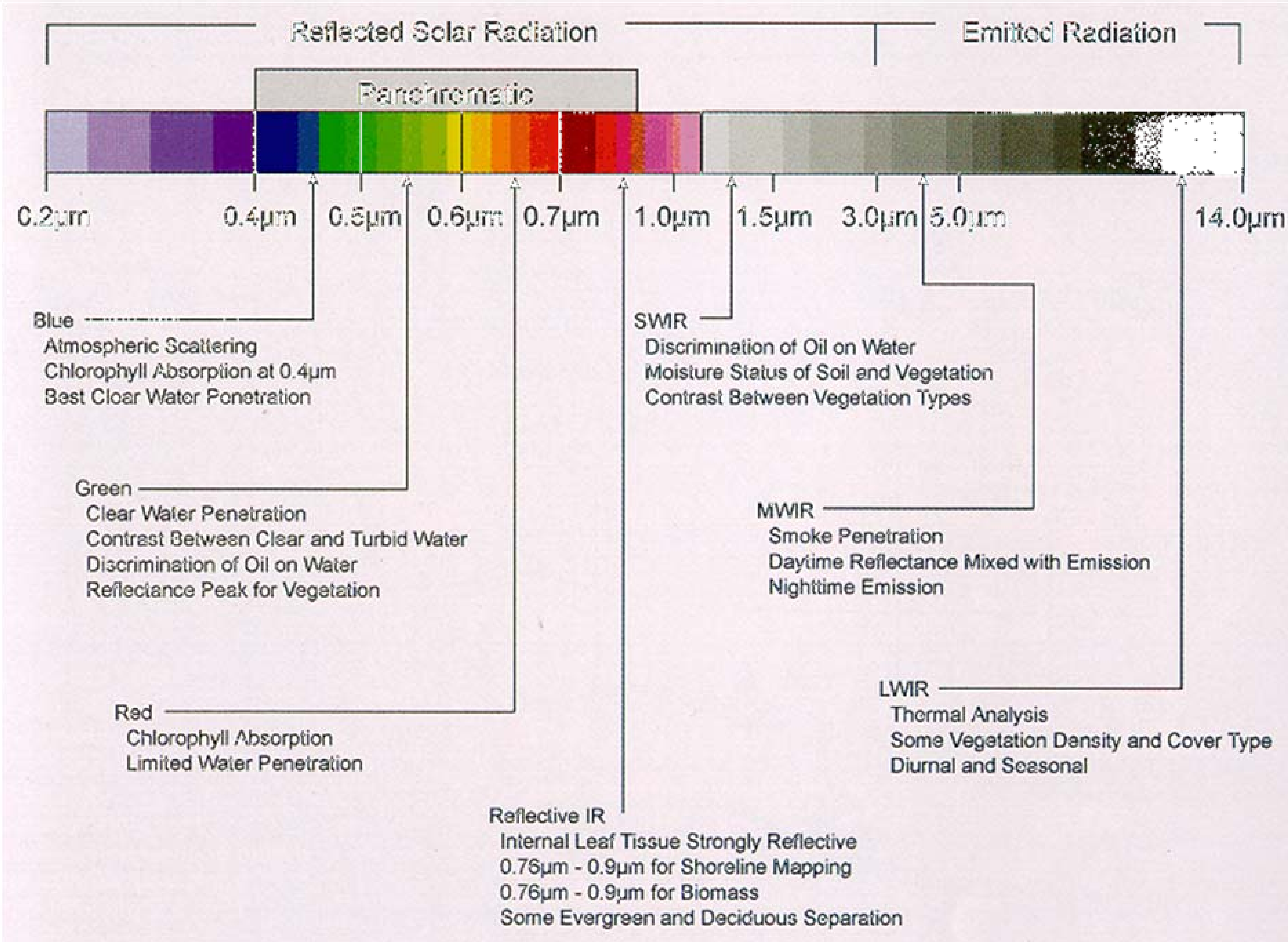
Temporal Resolution

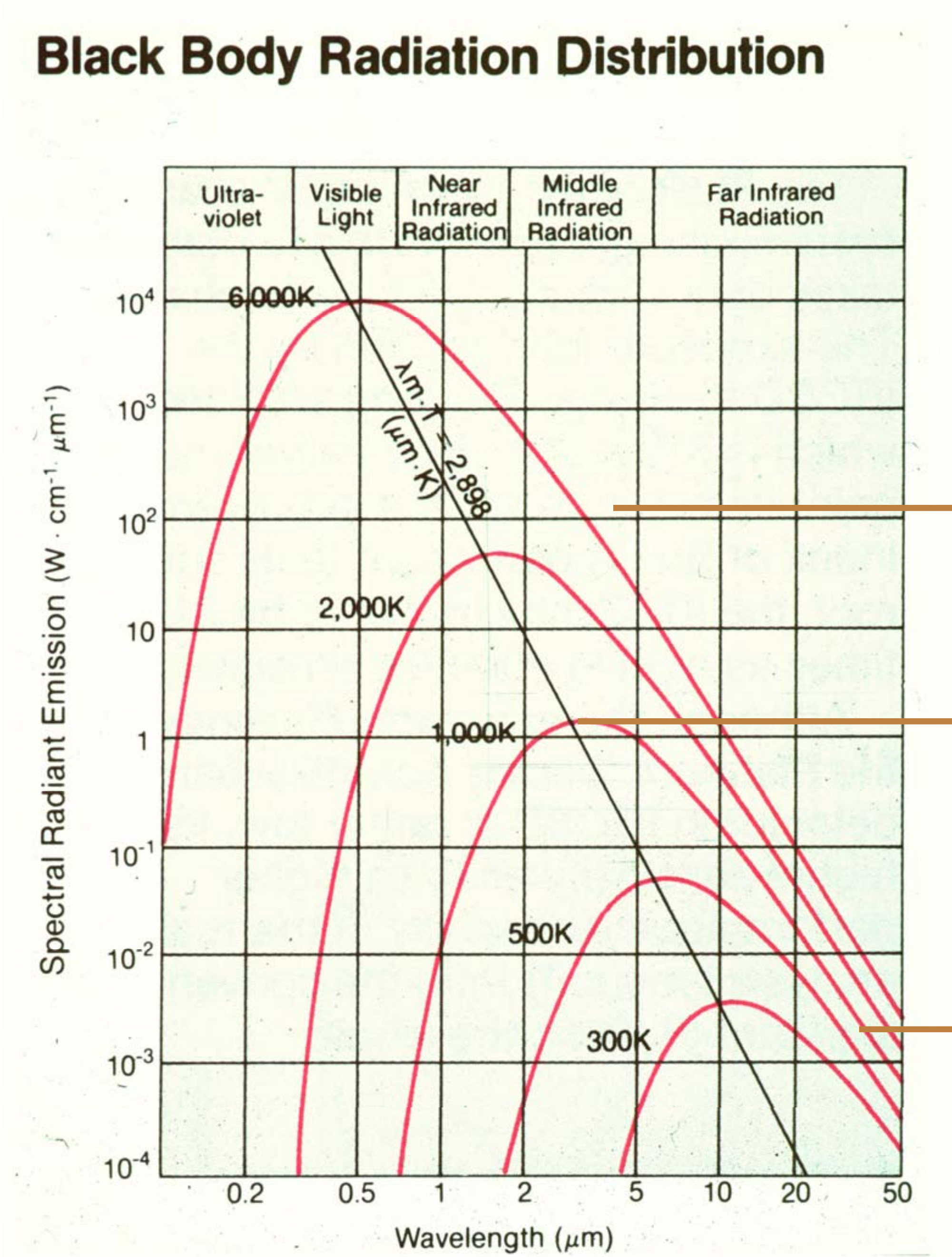
The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data. Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing **multi-temporal** imagery.



Spectral Resolution
(Landsat 7)




Reflected Solar Radiation
Emitted Radiation
Panchromatic
0.2µm
0.4µm
0.5µm
0.6µm
0.7µm
1.0µm
1.5µm
3.0µm
5.0µm
14.0µm
Blue
Atmospheric Scattering
Chlorophyll Absorption at 0.4µm
Best Clear Water Penetration
Green
Clear Water Penetration
Contrast Between Clear and Turbid Water
Discrimination of Oil on Water
Reflectance Peak for Vegetation
Red
Chlorophyll Absorption
Limited Water Penetration
Reflective IR
Internal Leaf Tissue Strongly Reflective
0.76µm - 0.9µm for Shoreline Mapping
0.76µm - 0.9µm for Biomass
Some Evergreen and Deciduous Separation
SWIR
Discrimination of Oil on Water
Moisture Status of Soil and Vegetation
Contrast Between Vegetation Types
MWIR
Smoke Penetration
Daytime Reflectance Mixed with Emission
Nighttime Emission
LWIR
Thermal Analysis
Some Vegetation Density and Cover Type
Diurnal and Seasonal



Sun's temperature

Wildfire's temperature

Earth's surface temperature

Data Cost

- Satellite data costs vary from free, unlimited access to satellite sensors like AVHRR and MODIS to high costs for high resolution data such as QuickBird.
- American low and medium resolution satellites normally free, while European satellites in most cases still have license requirements

- Free Landsat 7 data available from USGS

Operational vs. Research Satellites

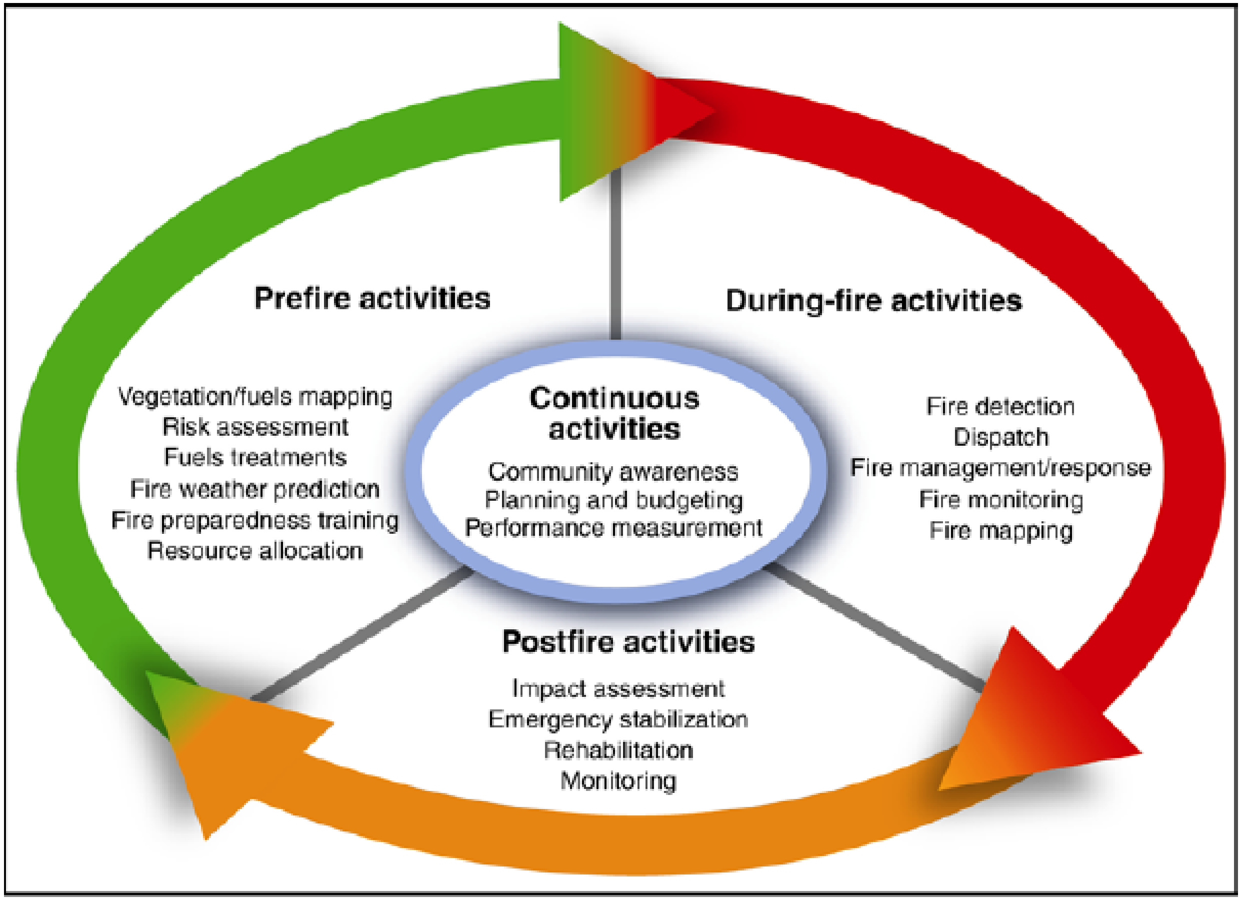
- Operational satellite programmes are organised to guarantee the routine availability of data over a specific period of time to ensure consistent products – Example AVHRR (1981 – 2008)
- Research satellites are aimed to demonstrate new technologies and can not guarantee data availability.

  Example MODIS (2000 – 2008)

Data Access

- Example: MODIS data
- Internet (http://edcimswww.cr.usgs.gov/pub/imswelcome/)
- Direct Readout reception stations

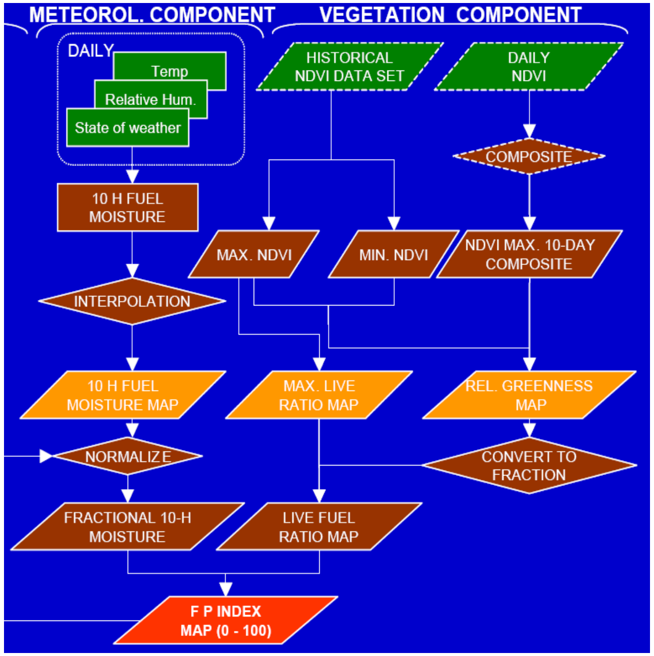
Remote Sensing products for Fire Management

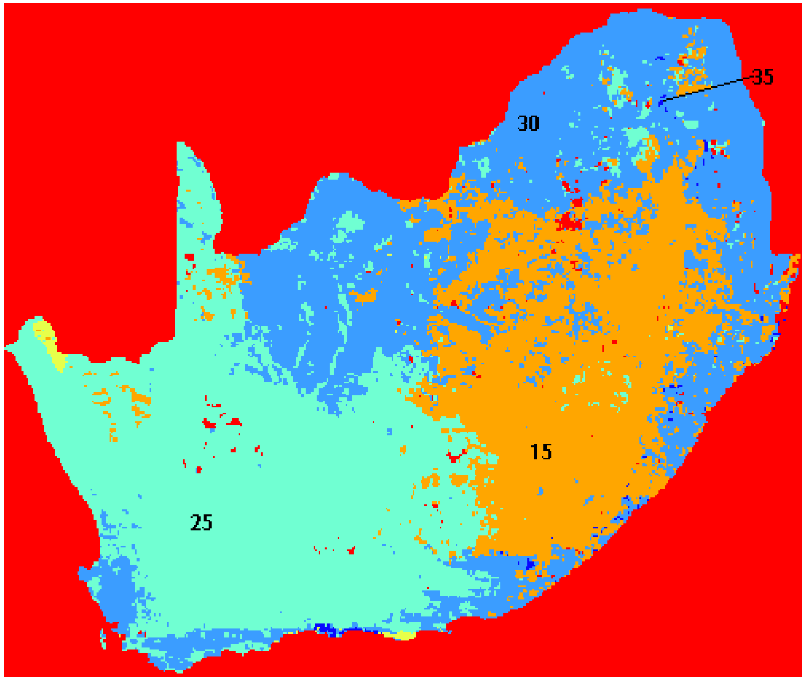


Source: GAO.

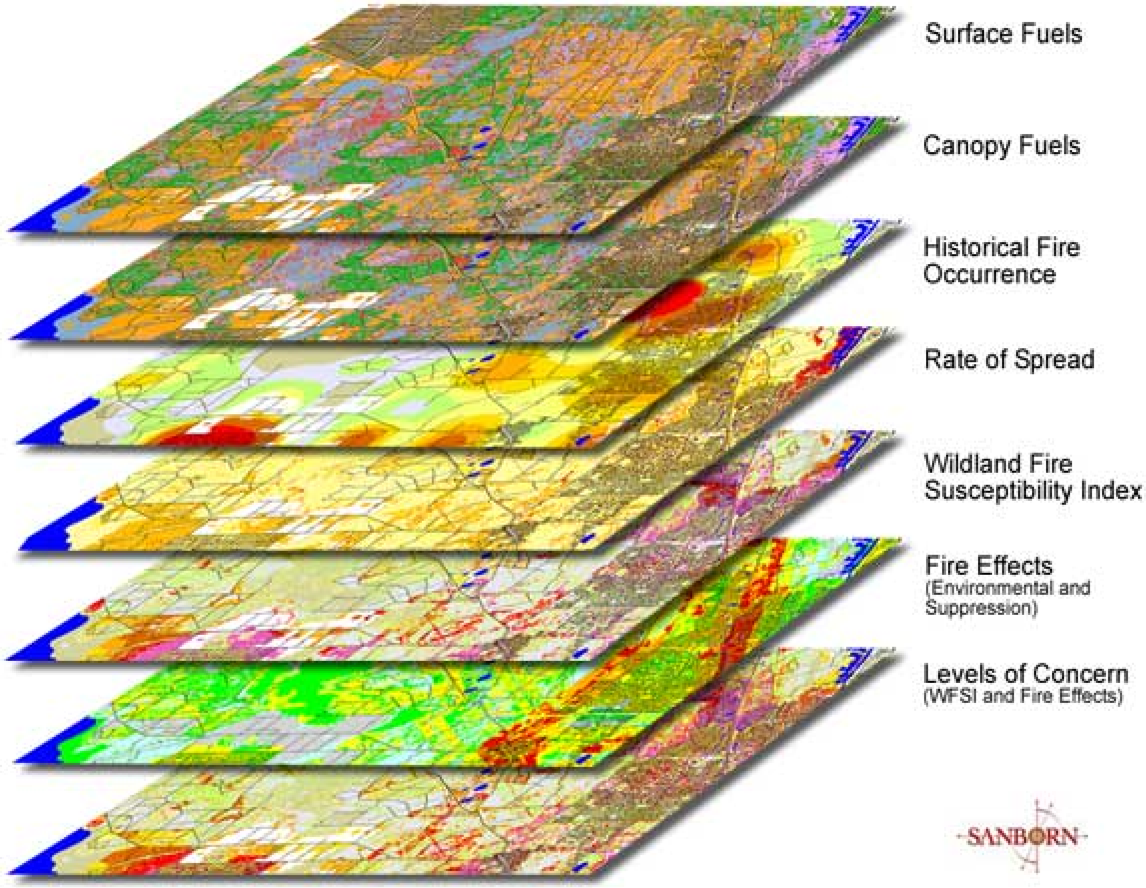
Pre-fire activities

- Vegetation/Fuel mapping
- Fire Weather prediction
- Risk assessment



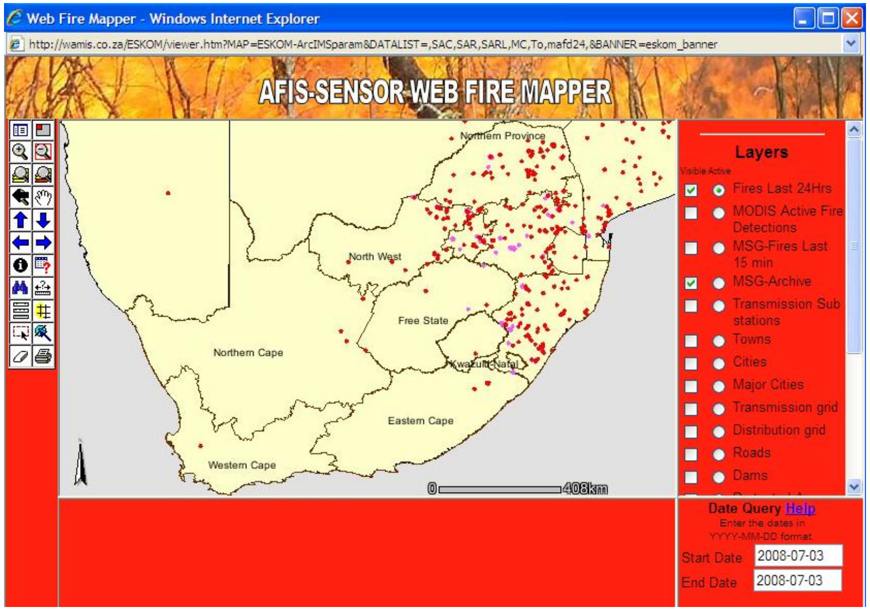


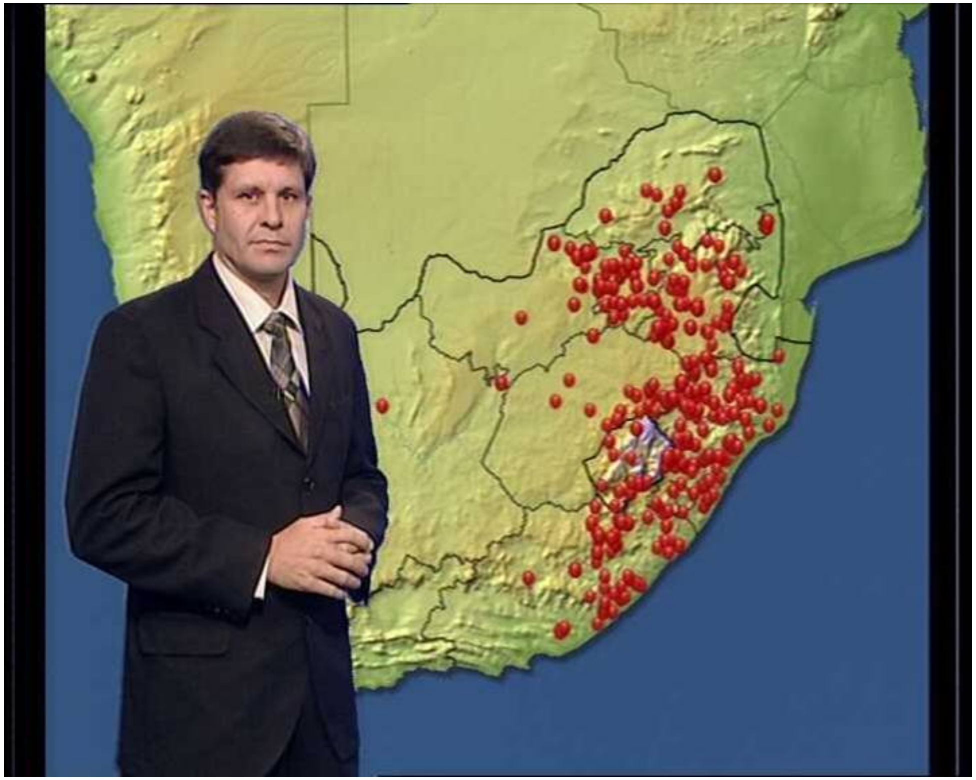
Fire Risk Assessment



During-fire activities

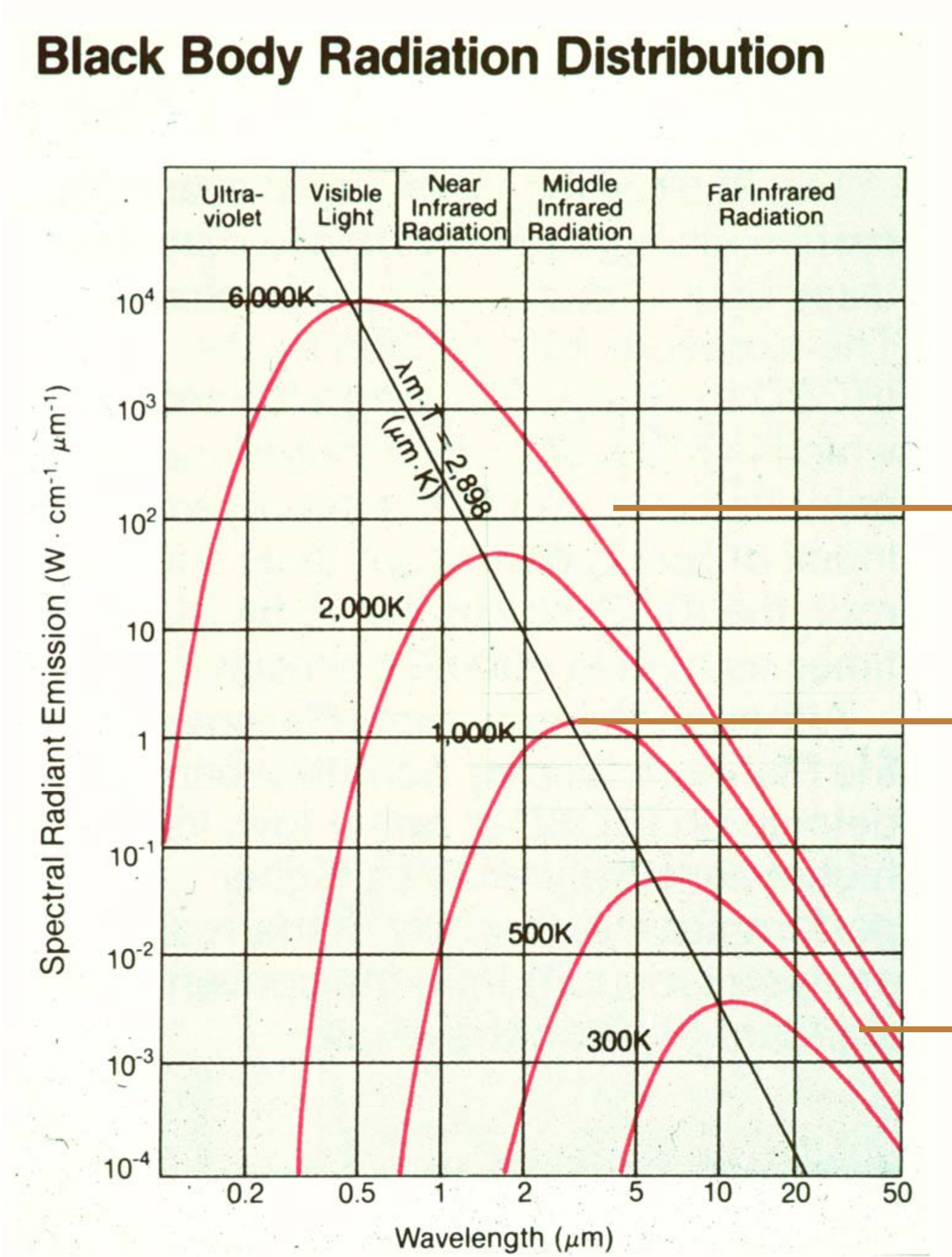
- Active fire detection
- Active fire monitoring
- Fire mapping





Active Fire Product

- Mid-infrared (3 – 4 µm) and thermal bands (10 – 12 µm) onboard satellite sensors permits the detection of active fires on the Earth's surface
- The essence of fire detection lies in significantly enhanced radiance emitted in the mid-infrared region for typical fire temperatures, as governed by the Planck function.
- The mid-infrared channel is thus highly sensitive to the presence of fires and most useful for fire detection.



Sun's temperature

Wildfire's temperature

Earth's surface temperature

Value of active fire data

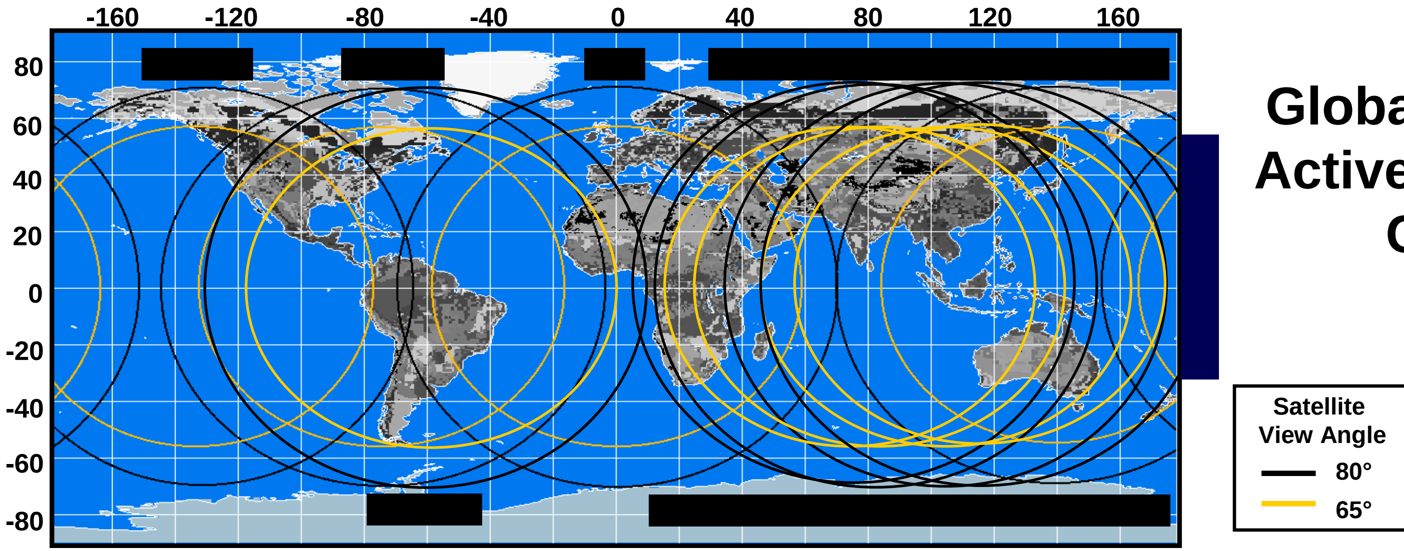
- Documenting the extent of individual fire fronts and the size of fires
- Document the trends over years
- Document the type of fires according to the vegetation in which they occur
- Identify areas of particular human pressure on natural forest
- Monitoring and evaluating fire strategies (prescribed burning, …)

Main sensors supporting active fire detection

- NOAA-AVHRR
- TERRA/AQUA MODIS
- FY-1/3

Channel	Center Wavelength (µm)	Maximum T (K)
MODIS Ch. 21	3.959	500
MODIS Ch. 22	3.959	328
MODIS Ch. 31	11.03	400 (Terra MODIS)
		340 (Aqua MODIS)
AVHRR Ch. 3	~3.75	~325
AVHRR Ch. 4	~10.8	~325

Goal: Establish a geostationary global fire network

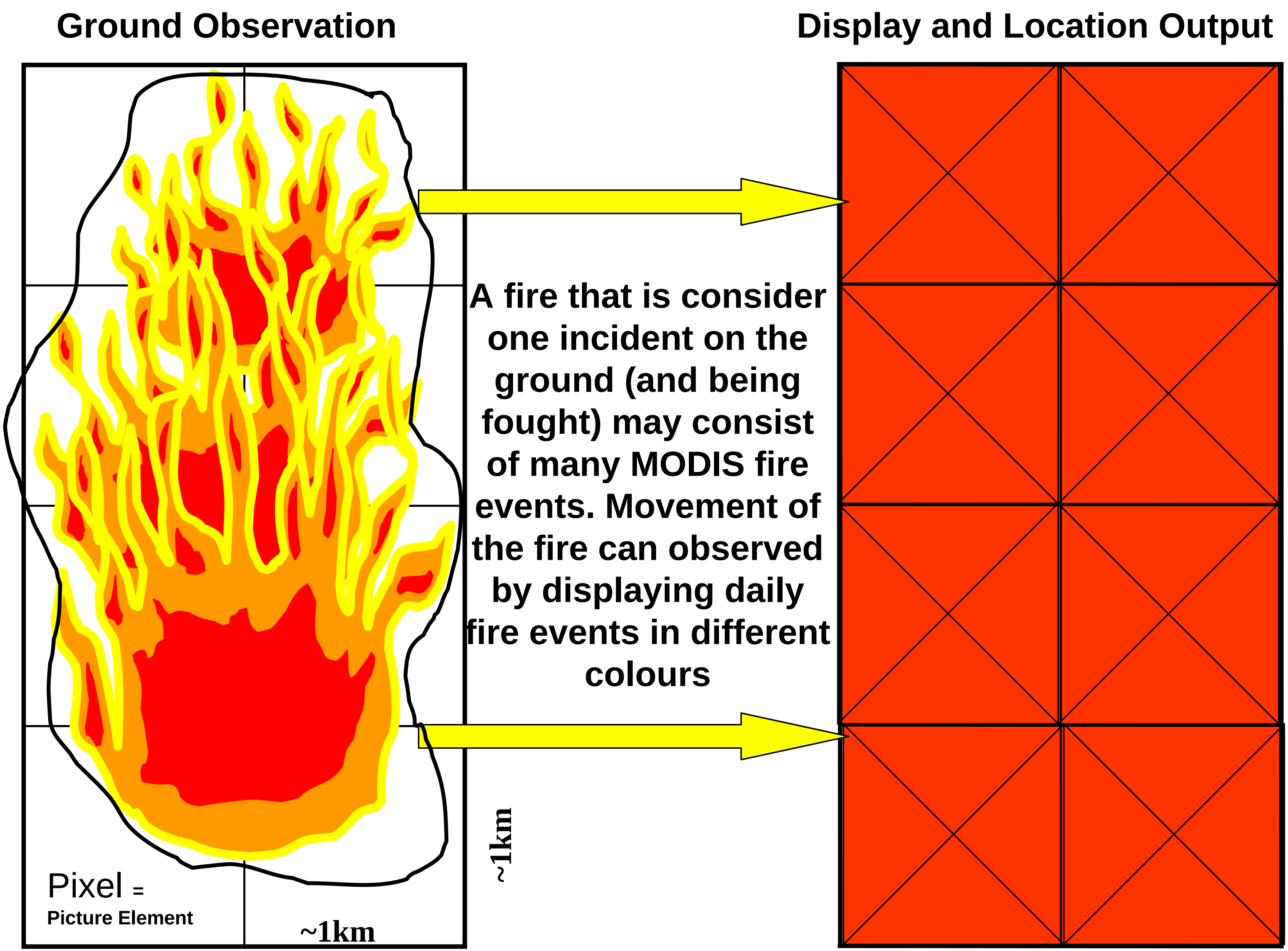


Global Geostationary Active Fire Monitoring Capabilities

Satellite	Active Fire Spectral Bands	Resolution IGFOV (km)	SSR (km)	Full Disk Coverage	3.9 µm Saturation Temperature (K)	Minimum Fire Size at Equator (at 750 K) (hectares)
GOES-E/-W Imager	1 visible 3.9 and 10.7 µm	1.0 4.0 (8.0)	0.57 2.3	3 hours	>335 K (G-11) >335 K (G-12)	0.15
GOES-10 Imager (South America, 2006)	1 visible 3.9 and 10.7 µm	1.0 4.0 (8.0)	0.57 2.3	3 hours (Full Disk) 15-min (SA)	~322 K (G-10)	0.15
MSG SEVIRI	1 HRV 2 visible 1.6, 3.9 and 10.8 µm	1.6 4.8 4.8	1.0 3.0 3.0	15 minutes	~335 K	0.22
FY-2C SVISSR (FY-2D, 2006)	1 visible, 3.75 and 10.8 µm	1.25 5.0		30 minutes	~330 K (?)	
MTSAT-1R JAMI (HRIT)	1 visible 3.7 and 10.8 µm	1.0 4.0		1 hour	~320 K	0.15
INSAT-3D (4th Qtr, 2007)	1 vis, 1.6 µm 3.9 and 10.7 µm	1.0 4.0	0.57 ? 2.3 ?	30 minutes		
GOMS Elektro N2 MSU-G (2010)	3 visible 1.6, 3.75 and 10.7 µm	1.0 km 4.0 km		30 minutes		
COMS (2008)	1 visible 3.9 and 10.7 µm	1.0 km 4.0 km		30 minutes		

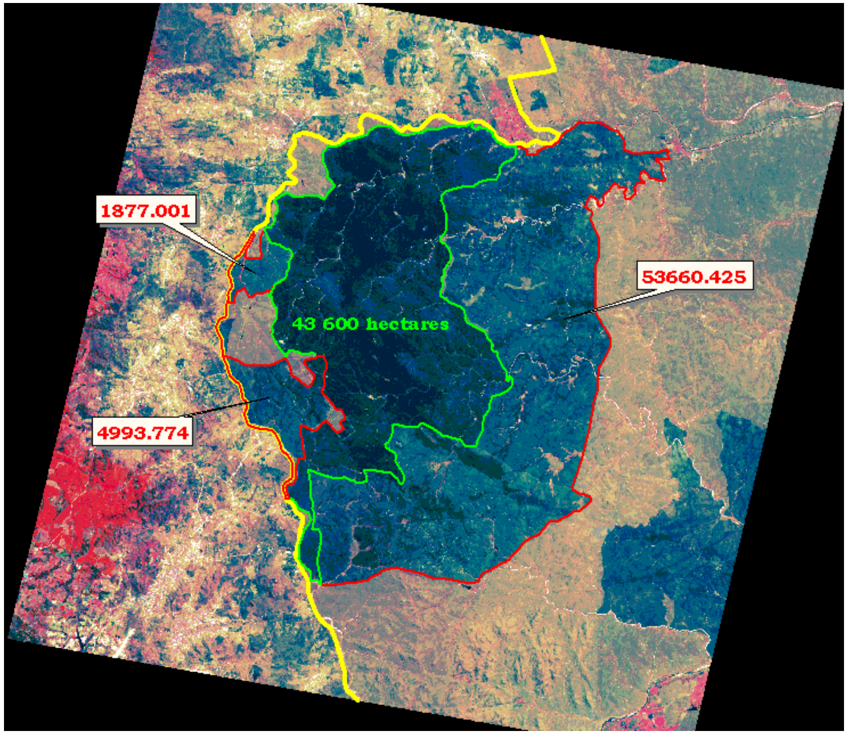
Active fire interpretation

- Fire and pixel size can vary due to saturation and fire size
- Fire location accuracy dependant on satellite geometric accuracy
- Only fires actively burning at time of overpass will be detected
- Fires obscured by clouds could be missed


Ground Observation
Display and Location Output
A fire that is consider one incident on the ground (and being fought) may consist of many MODIS fire events. Movement of the fire can observed by displaying daily fire events in different colours
Pixel =
Picture Element
~1km
~1km

Post-fire activities

- Calculation of area affected
- Impact assessment



Burned area principles

The detection of burned area by remote sensing satellites are dependant on:

1. The removal of vegetation
2. Combustion residue deposited on the ground
3. Increased surface temperature between burned surface and surrounding vegetation

Burned area as baseline data

Burned area can provide important information on fire regimes:

- Fire frequency - combining multiple years of burned area maps
- Fire intensity and severity – inferred from date and pattern of burns. Early season less intense while end of season more intense fires normally.

Main sensors supporting burned area mapping

- Landsat and Spot
  - manual image interpretation
  - 10 – 30 m resolution
  - Single scene

- MODIS
  - Existing operational product (MCD45)
  - 500 m resolution
  - Monthly composite

Burned area products

Choose format of burned area product:
Annual maps
Multi-temporal inter annual maps
Fire intensity
Fire severity

↓

Decide on appropriate scale of mapping:
Area to be covered
Level of detail

↓

Select suitable sources of data:
Spot, Landsat, MODIS, AVHRR

↓

Apply appropriate mapping method on data

↓

Assess map accuracy using reference data

Factors influencing burned area products

- Based on lower resolution data (MODIS – 500m and AVHRR – 1km)
- BRDF effects causing differences in surface reflectance
- Clouds and cloud shadows
- Vegetation type and re-growth rates

MODIS burned area product

- MODIS Level 3 Monthly tiled 500m Burned Area Product (MCD45A1)
- The algorithm developed for the MCD45 product uses a bi-directional reflectance (BRDF) model-based change detection approach
- It detects the approximate date of burning by locating the occurrence of rapid changes in daily MODIS reflectance time series
- Because of the BRDF model incorporated in the algorithm, the production of one month of MCD45 requires the availability of 90 days of daily MODIS data
- Time series available for download

Implementing Remote Sensing in a Fire Management Context

- Skilled personnel

  Combination of remote sensing skills and field experience essential
- Access to relevant information

  Staff should have access to publications and literature
- Infrastructure

  Computers hardware and software including GIS tools
- Adequate budgets to maintain information systems

Future Satellites

- NPP

National Polar-Orbiting Operational Environmental Satellite System (***NPOESS***) Preparatory Project (***NPP***) - 2011

- NPOESS

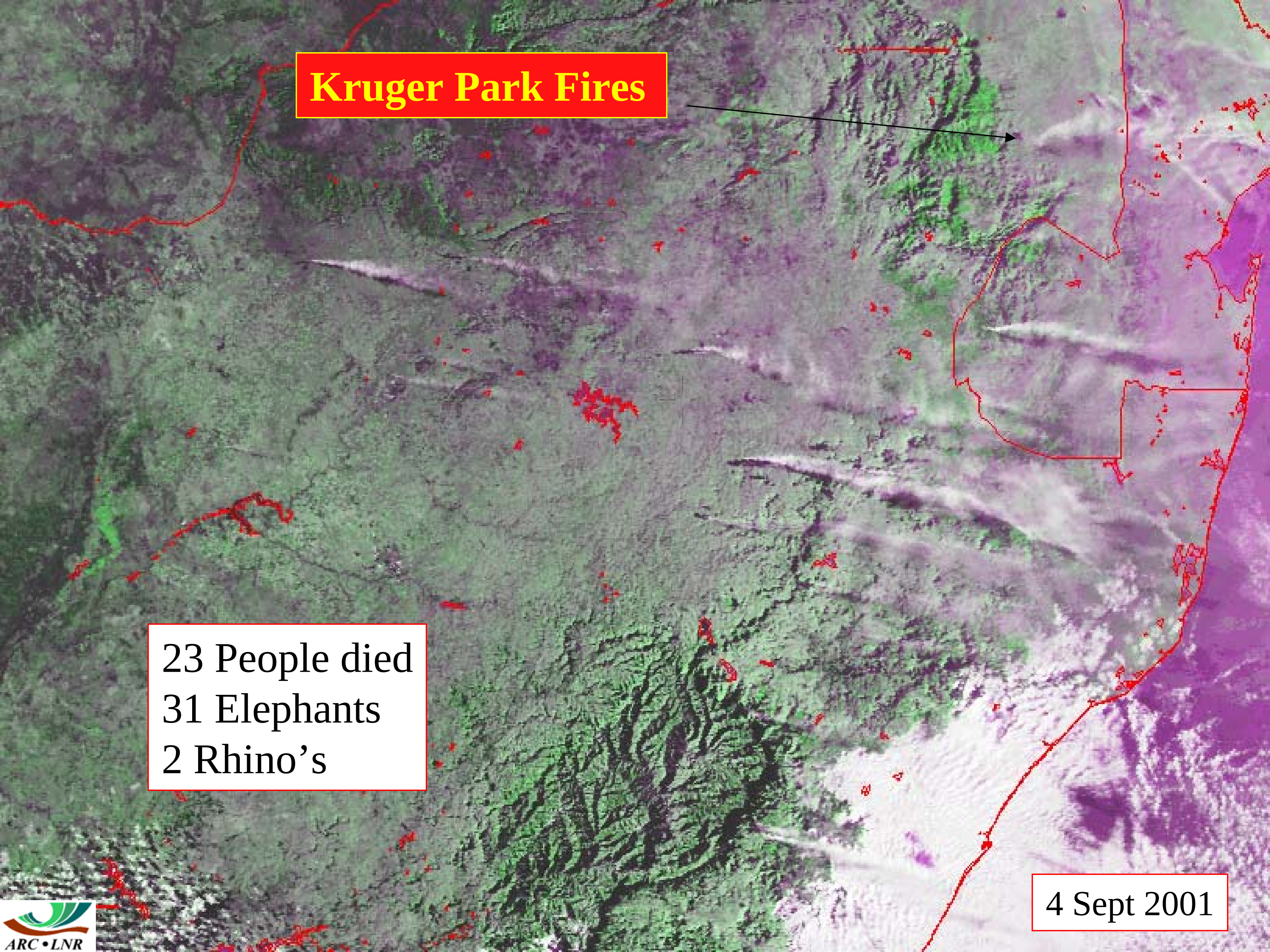
The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is the next generation of low earth orbiting environmental satellites to be launch in 2013

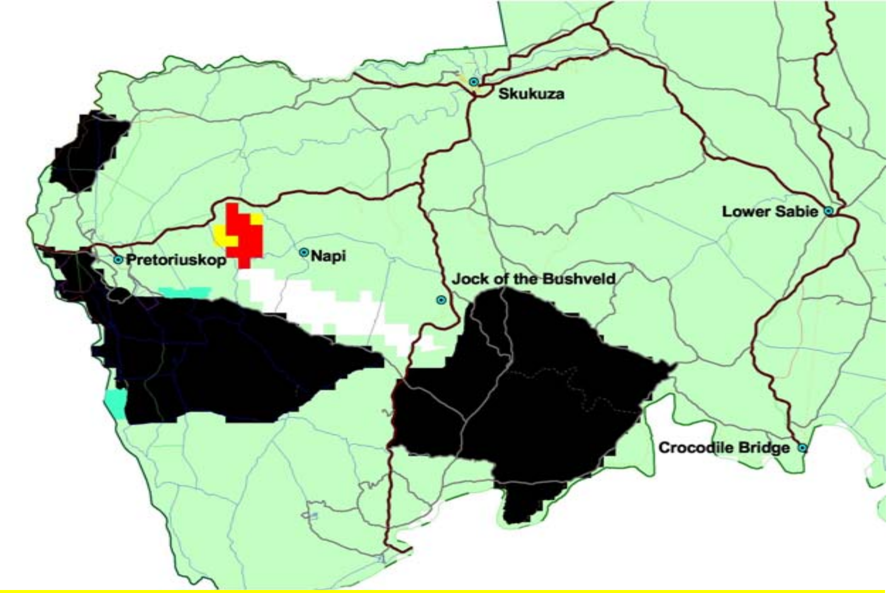
- MTG

Meteosat Third Generation to be launch 2015

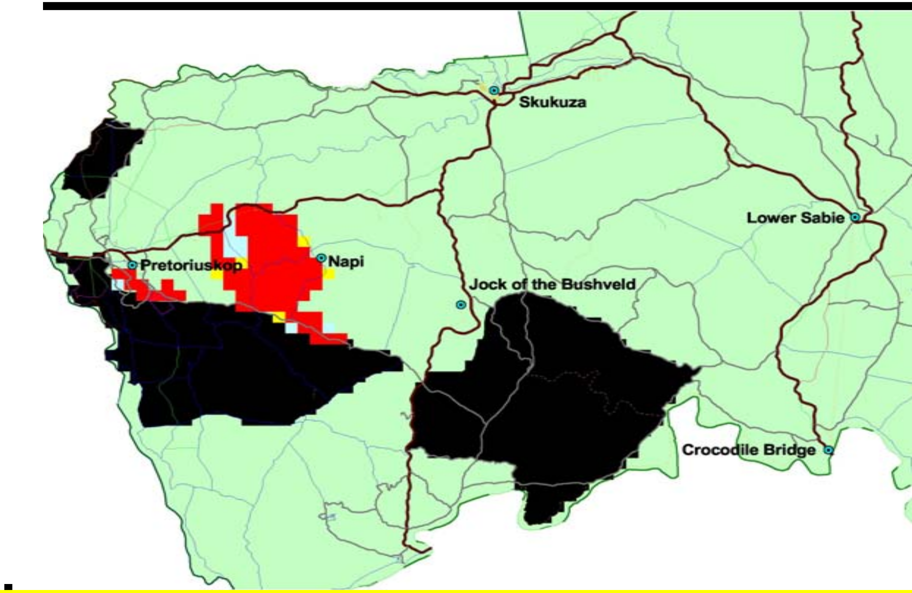
Examples of applications of Remote Sensing products in Fire Management in Africa

- Kruger National Park fire disaster (2001)
- Botswana fire management

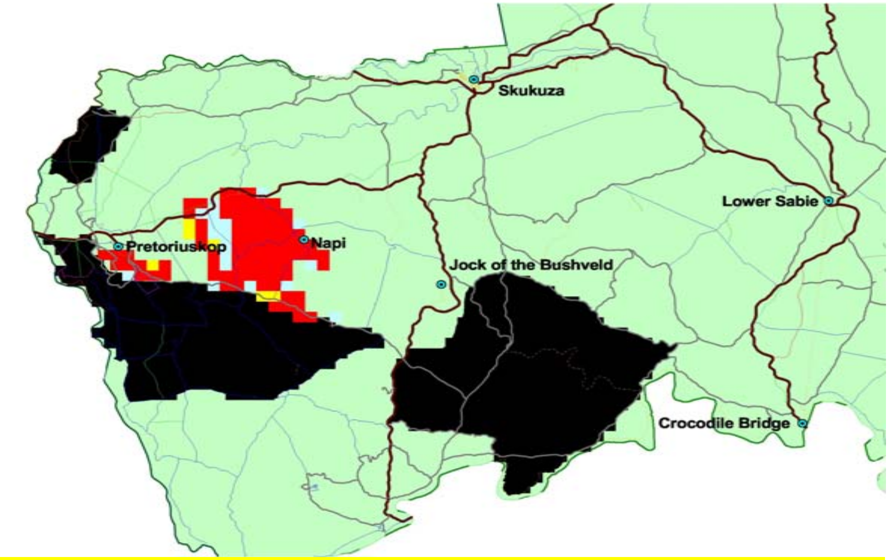

Kruger Park Fires
23 People died
31 Elephants
2 Rhino's
4 Sept 2001
ARC • LNR



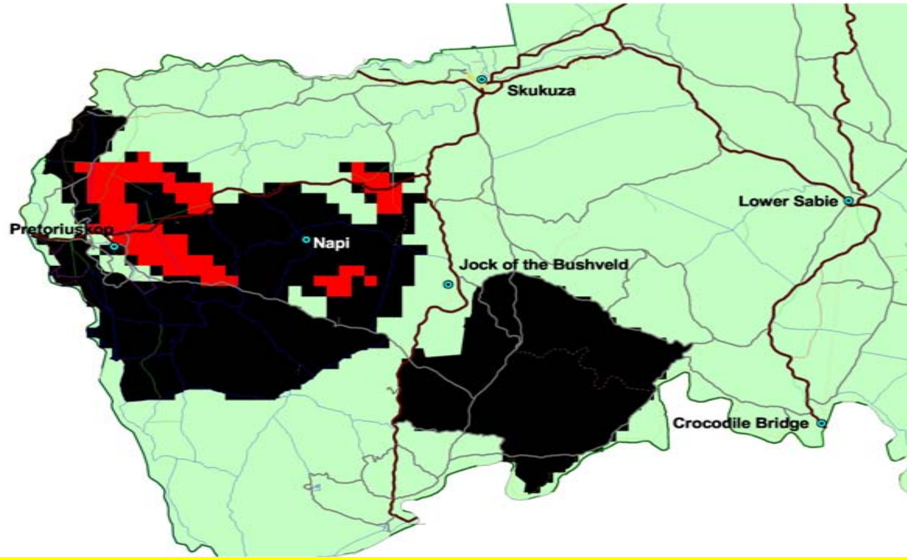
NOAA 16 – 13:53



NOAA 12 – 16:57



NOAA 14 – 17:23



NOAA 16 – 00:51

Example of Department of Forestry & Range Resources, Botswana

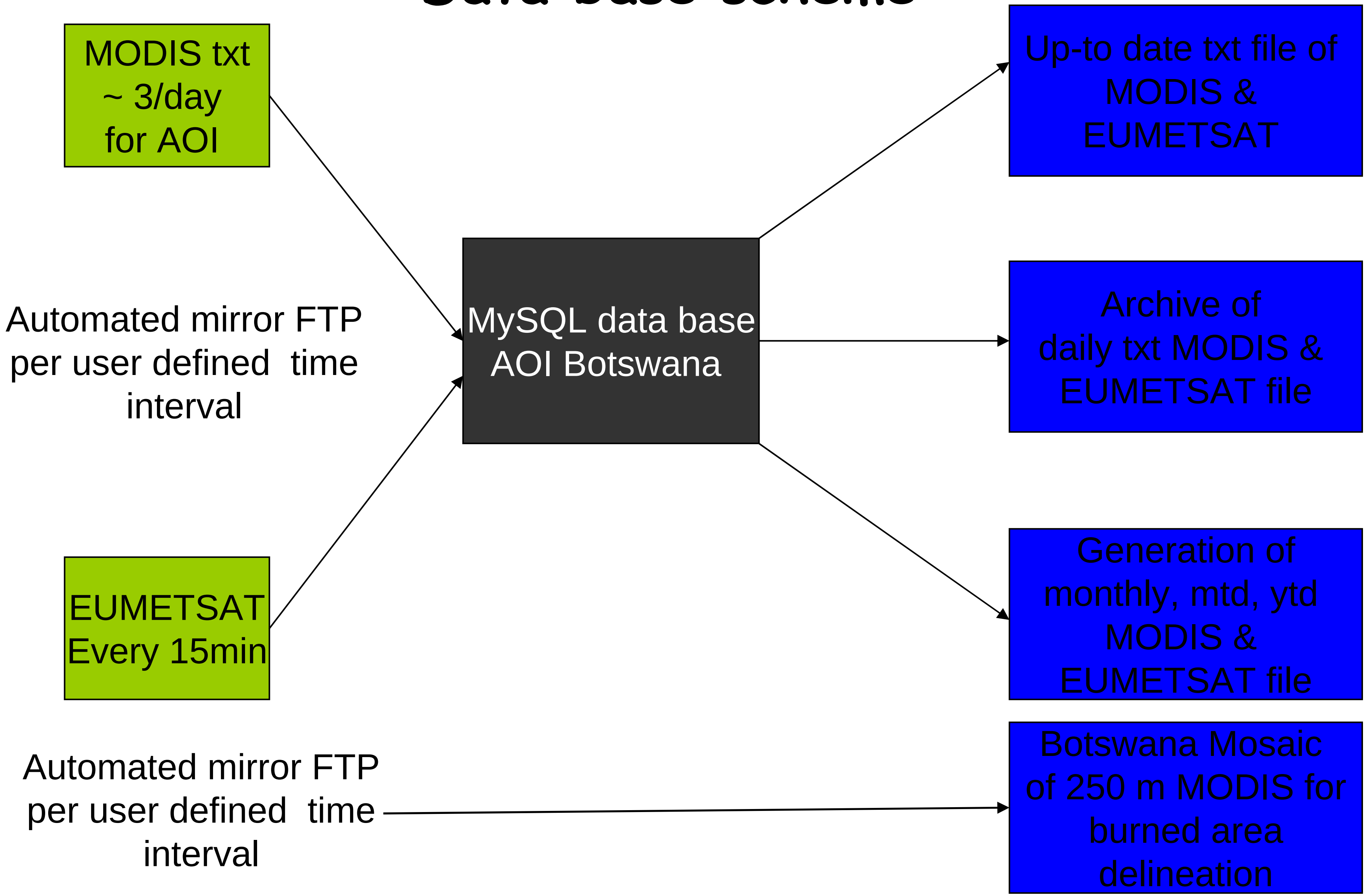
•Daily active fire data in txt from CSIR (MODIS and EUMETSAT) via automated mirror FTP

•Near real time satellite image (250m) ground from MODIS Rapid Response Center for burned area measurements

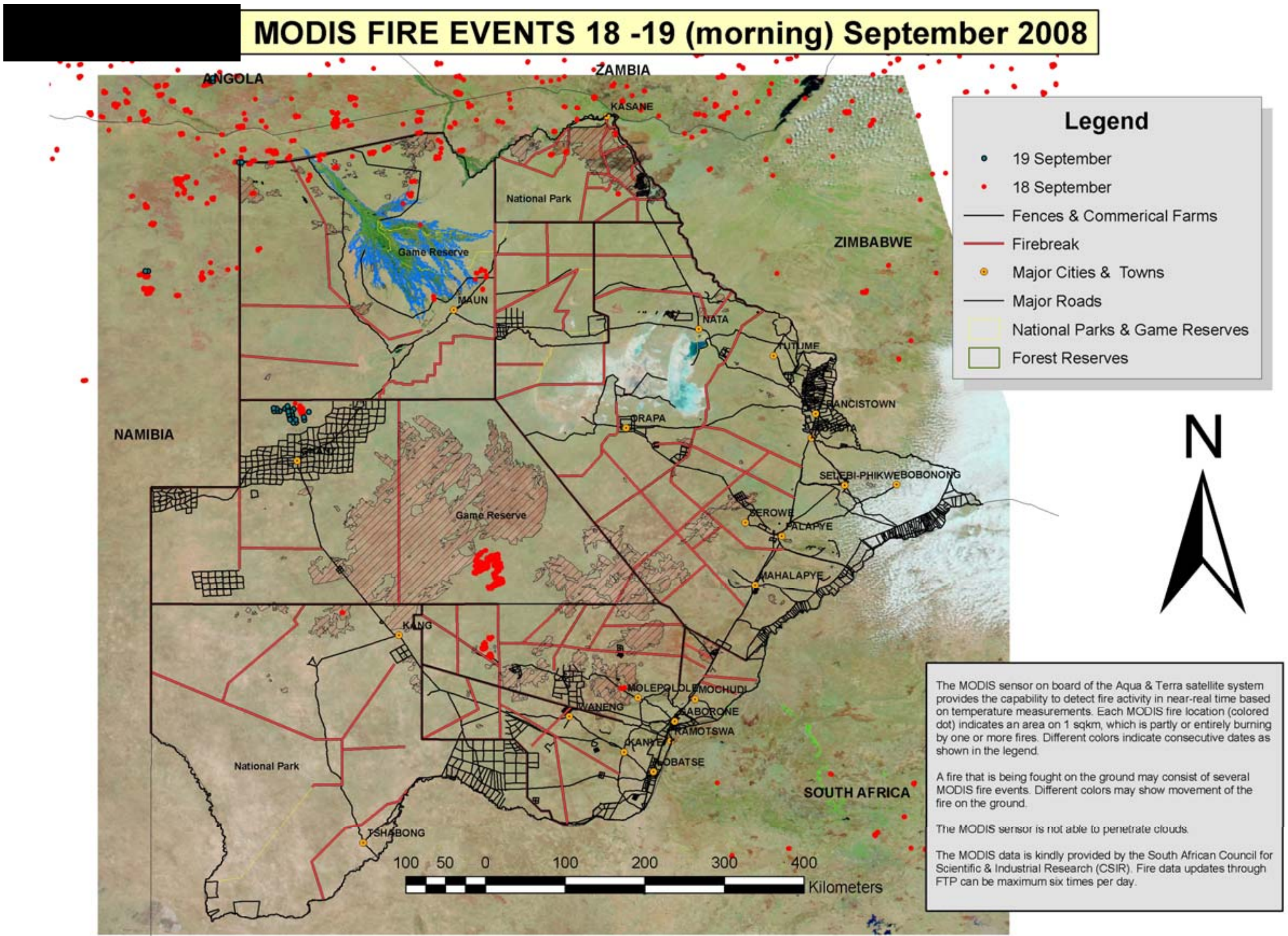
•Historical MODIS active fire data from University of Maryland

•Decoded GTS based weather data via EUMETSAT data stream to calculate Fire Danger

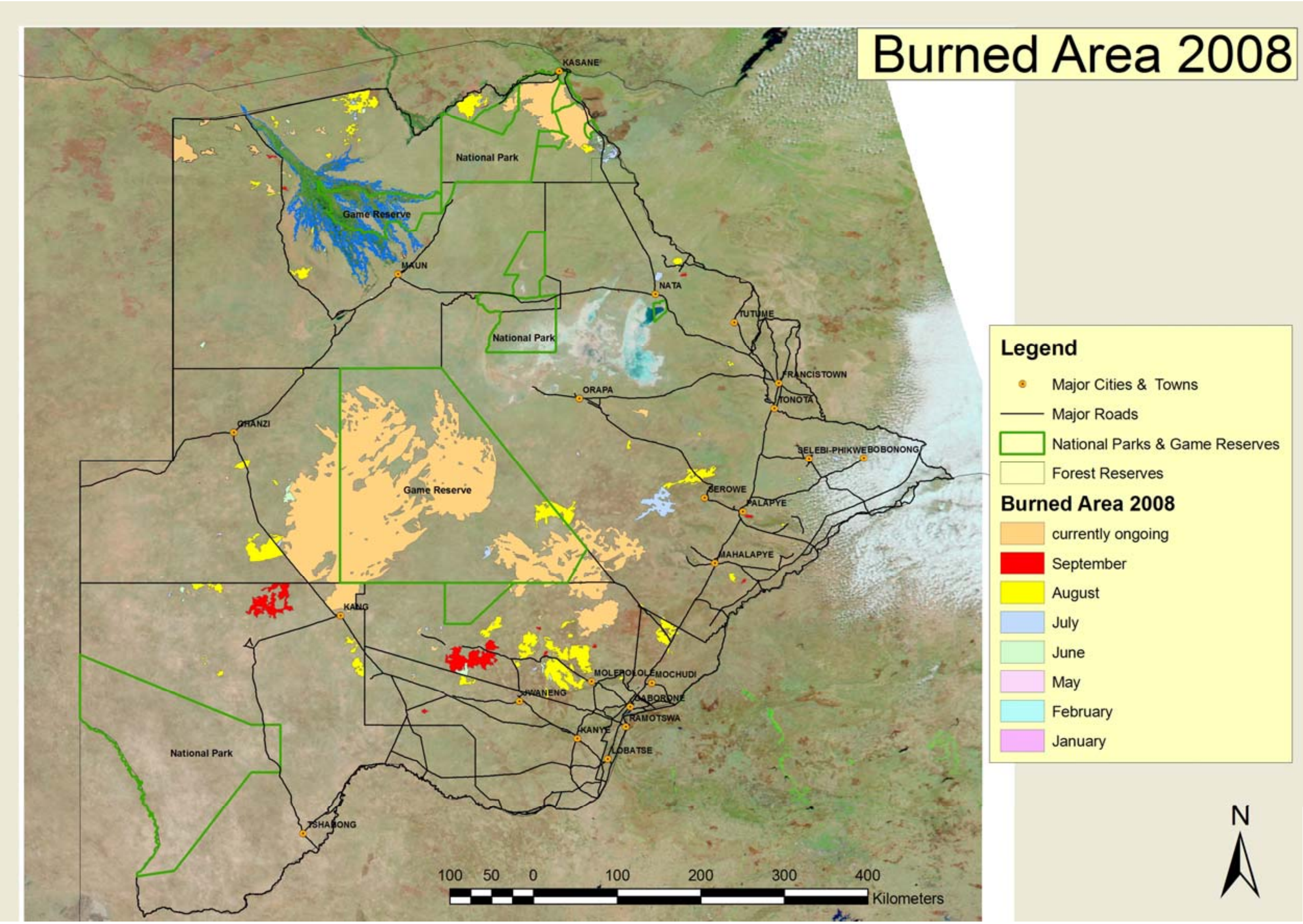
Data base scheme

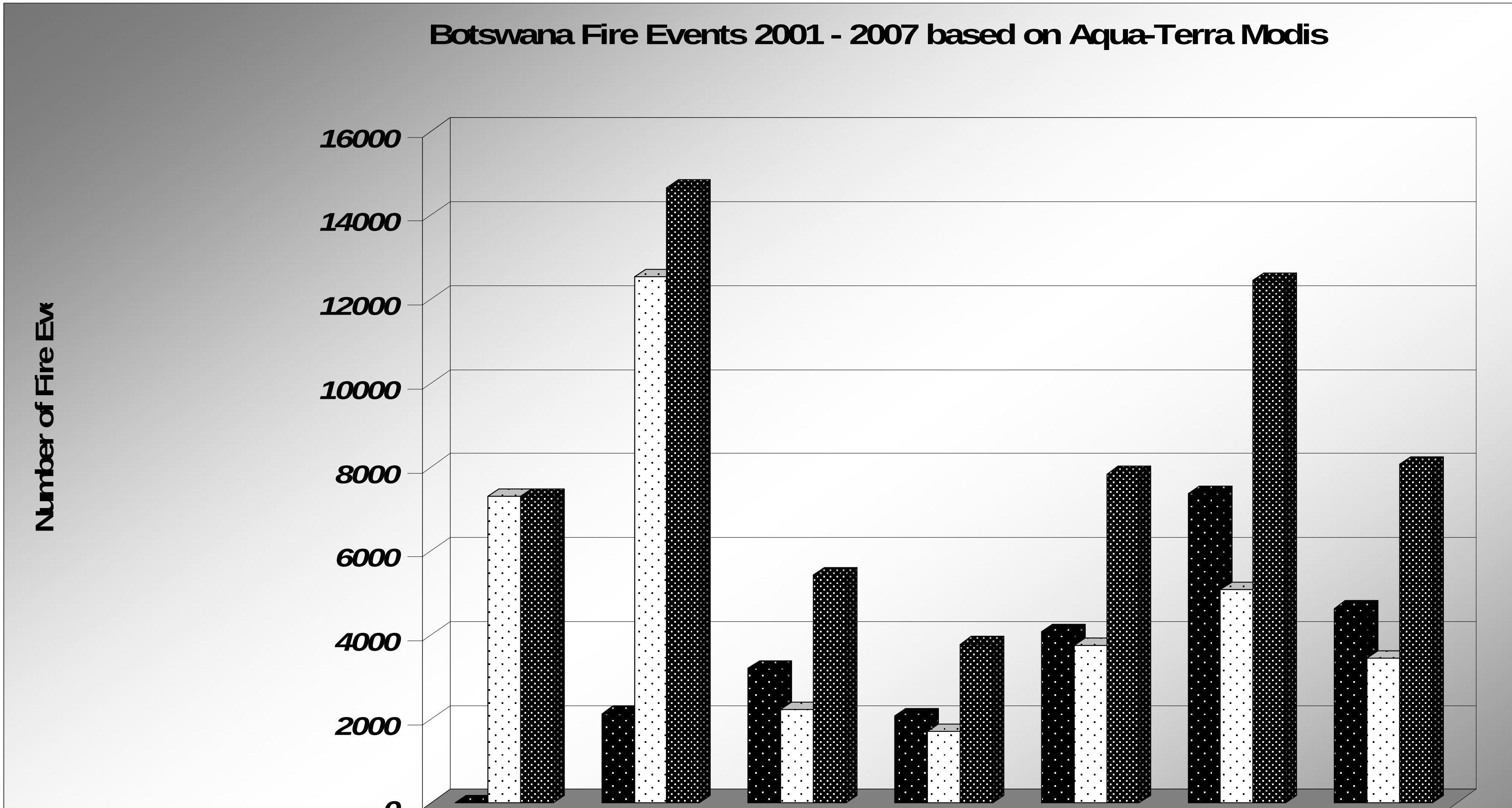


Daily Use of AFIS data



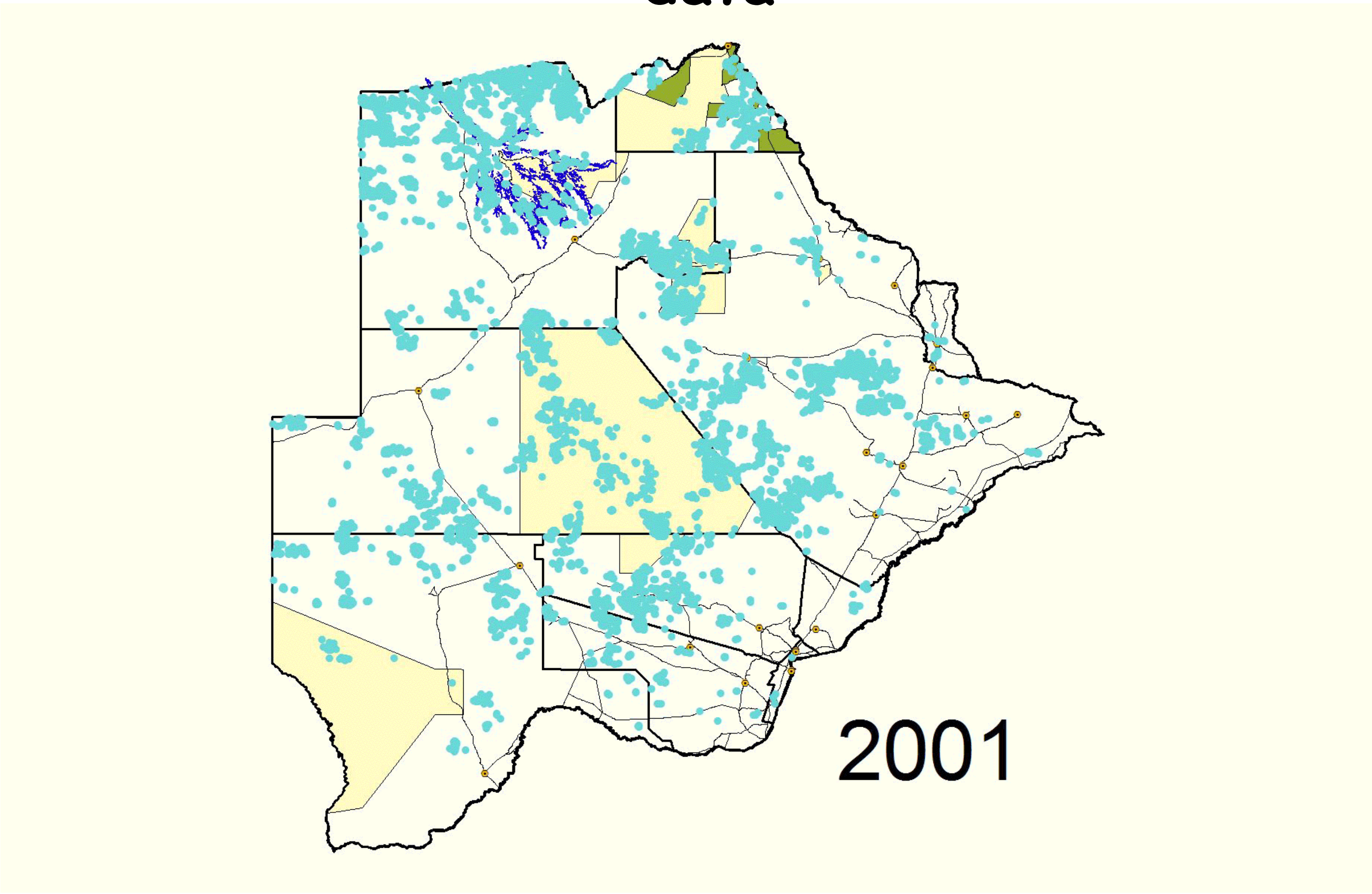
Burned Area measurements



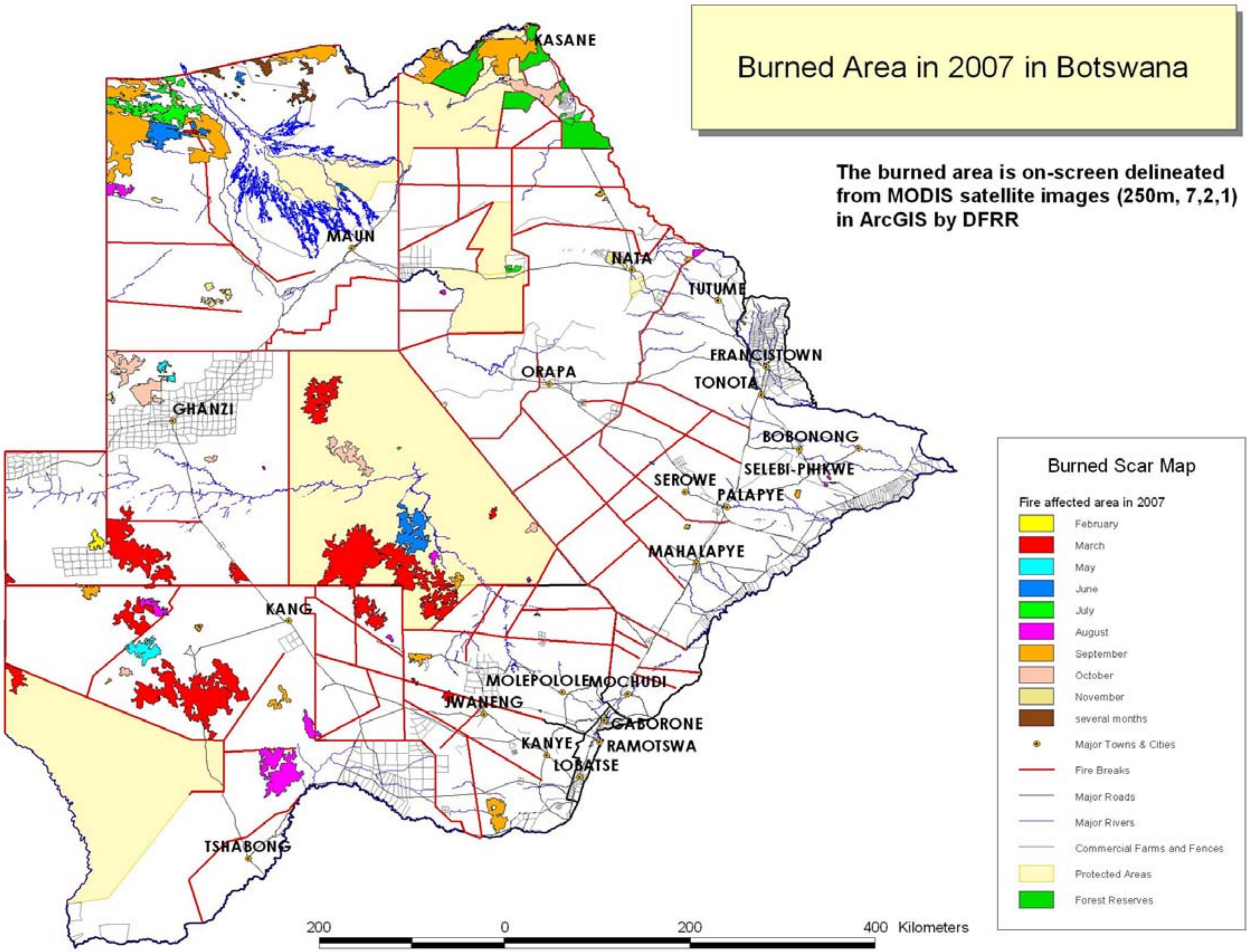


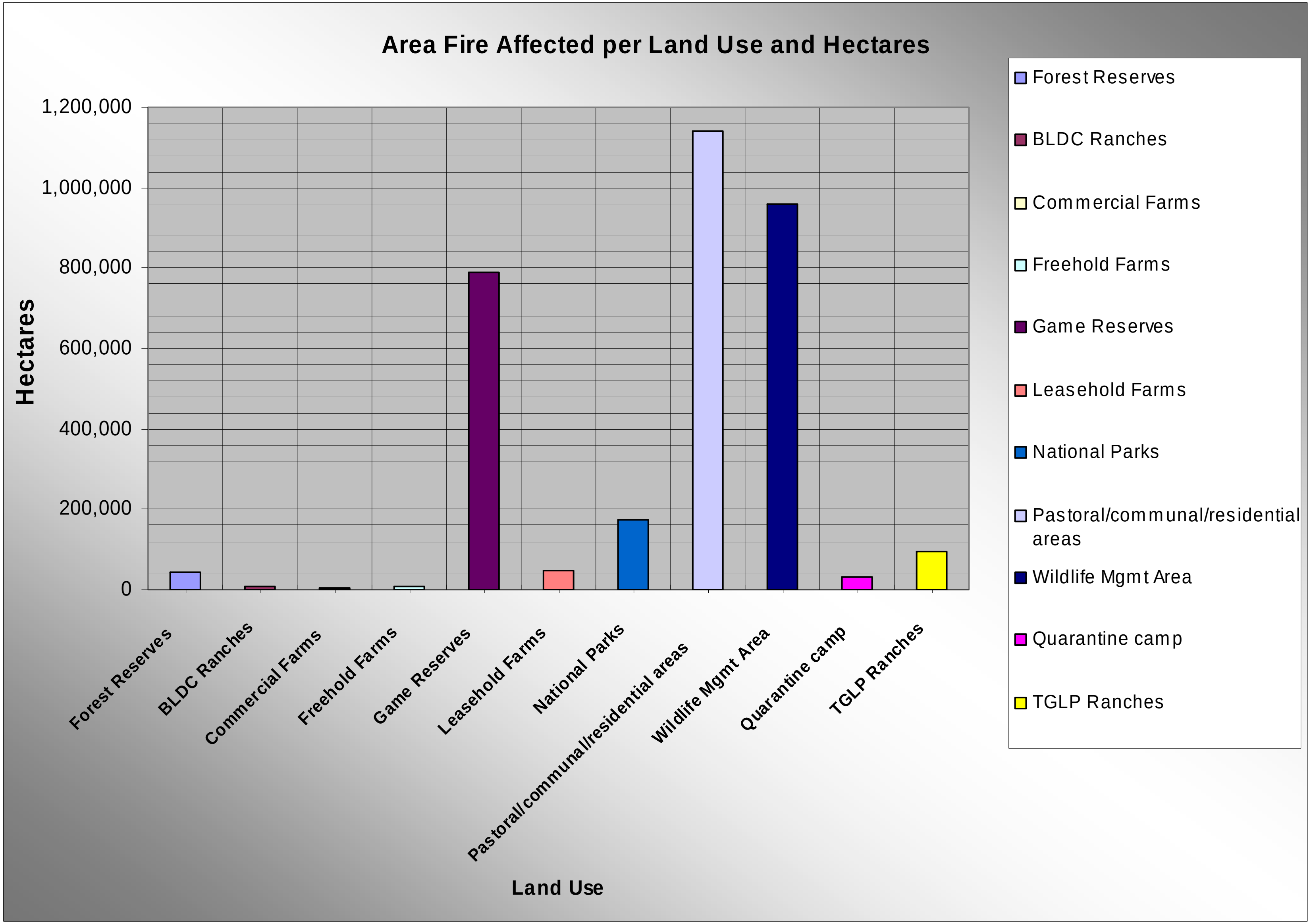
	2001	2002	2003	2004	2005	2006	2007
Aqua	0	2126	3203	2076	4078	7363	4630
Terra	7302	12529	2227	1705	3755	5079	3440
Total number of Fire Events	7302	14655	5430	3781	7833	12442	8070

Historical Analysis of the MODIS data



Burned Area in 2007




Area Fire Affected per Land Use and Hectares
Hectares
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Forest Reserves
BLDC Ranches
Commercial Farms
Freehold Farms
Game Reserves
Leasehold Farms
National Parks
Pastoral/communal/residential areas
Wildlife Mgmt Area
Quarantine camp
TGLP Ranches
Land Use
Forest Reserves
BLDC Ranches
Commercial Farms
Freehold Farms
Game Reserves
Leasehold Farms
National Parks
Pastoral/communal/residential areas
Wildlife Mgmt Area
Quarantine camp
TGLP Ranches

Determination of Readiness Levels following Fire Danger based on weather data