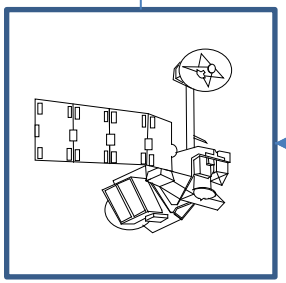
→ 6th ESA ADVANCED TRAINING COURSE
ON LAND REMOTE SENSING

# Advanced Thermal/Optical: Fire Applications

E. Chuvieco
(Univ. of Alcala, Spain)

14–18 September 2015 | University of Agronomic Science and Veterinary Medicine Bucharest | Bucharest, Romania

# RS is a basic tool to retrieve fire information



Fuel moisture

Soils

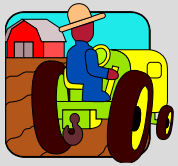
Elevation / DTM

Fuel Types

Meteorology / climate

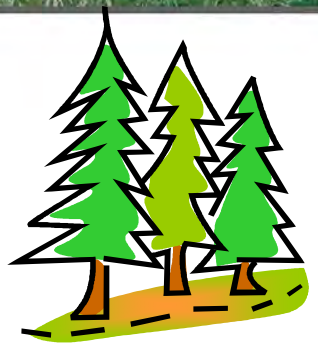
Density
Duration / size
Recurrence
Intensity

Socio-economic data



## Questions RS may answer

- When will a fire occur? How much potential negative impact?
- Is there an active fire? Where? When did it start? How is it growing? How much energy? How many gas emissions?
- How much area is burned? How often? When in the year? How much biomass is consumed? Are fire characteristics changing?



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- How much area is burned? How often? When in the year? How much biomass is consumed? Are fire characteristics changing?

# When – where?

Socio-economic conditions

Fuels

Heat source

Amount

Human

Dryness

Lightning

Weather - Climate Conditions

Oxigen

Fire ignition

Terrain

Fire Propagation

Wind

# When – where?

Socio-economic conditions

Fuels

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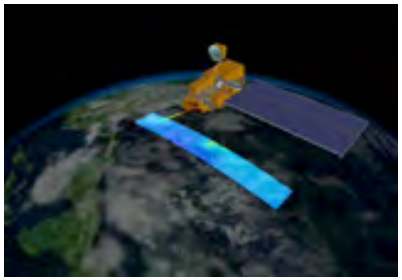
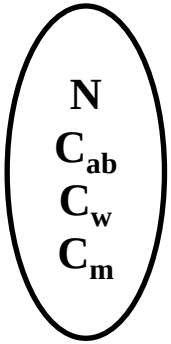
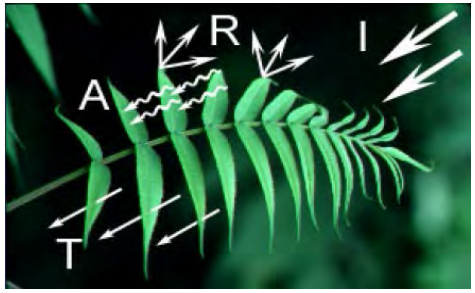
# Methods to estimate FMC from RS

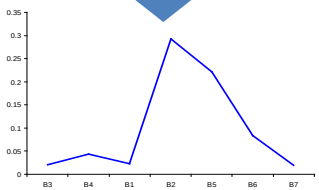


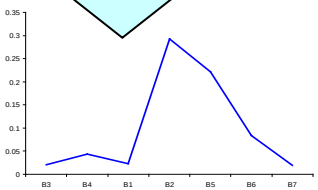


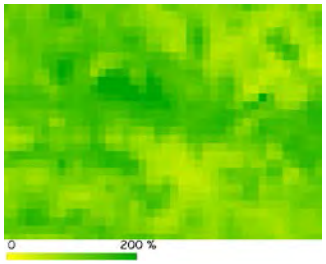



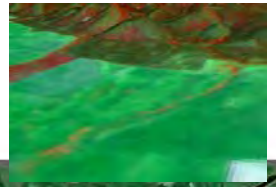

DIRECT

INVERSE



# Effects of FMC on leaf reflectance

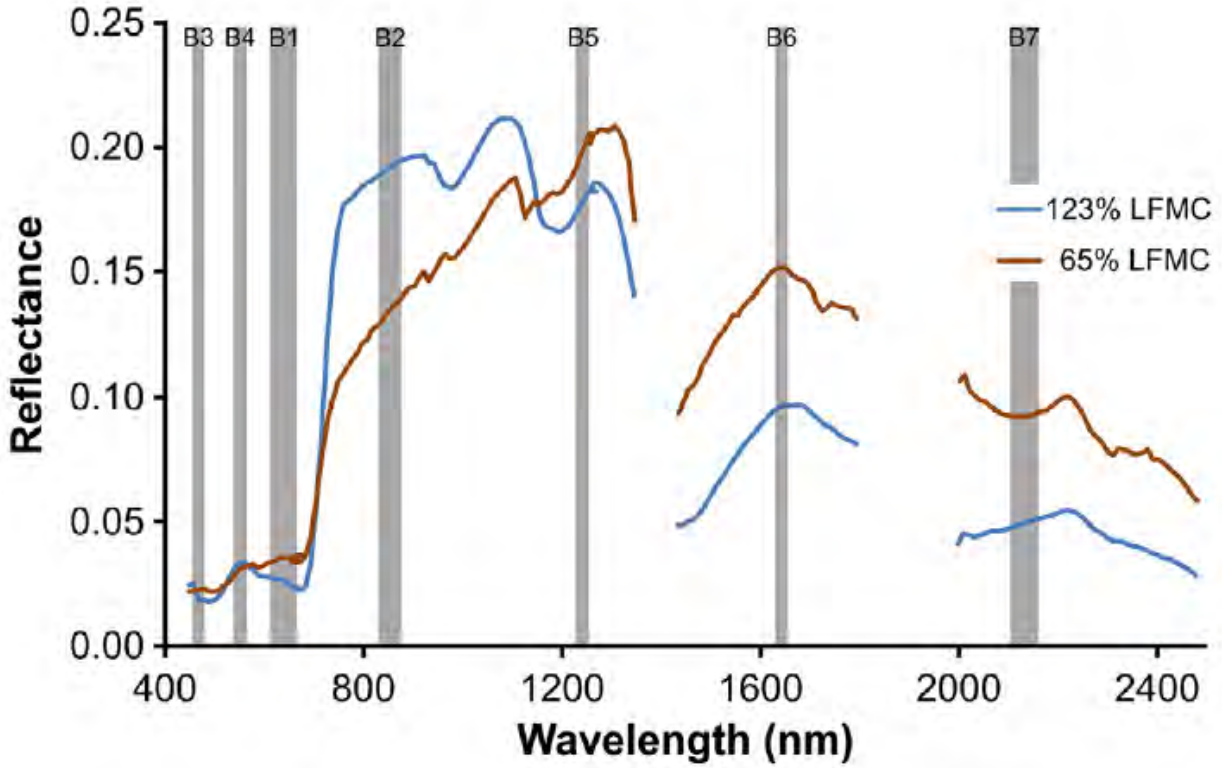
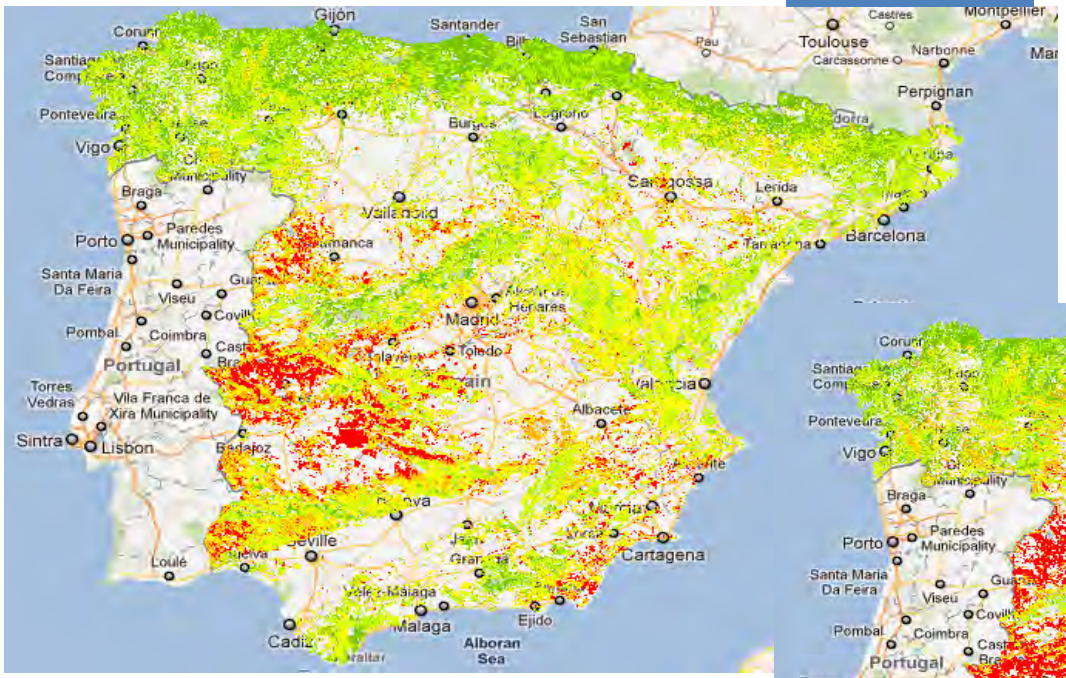


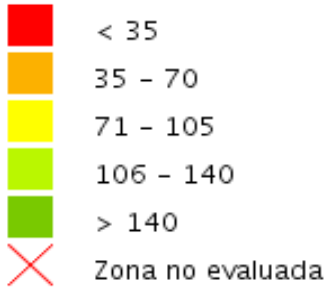

**Fig. 1.** Reflectance spectra for vegetation canopies with different LFMC values. Spectra were collected by the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) over a plot dominated by *Adenostoma fasciculatum* in southern California, U.S.A. The approximate spectral extent of the first seven MODIS bands is also shown in gray.

Yebra et al., 2013 RSE

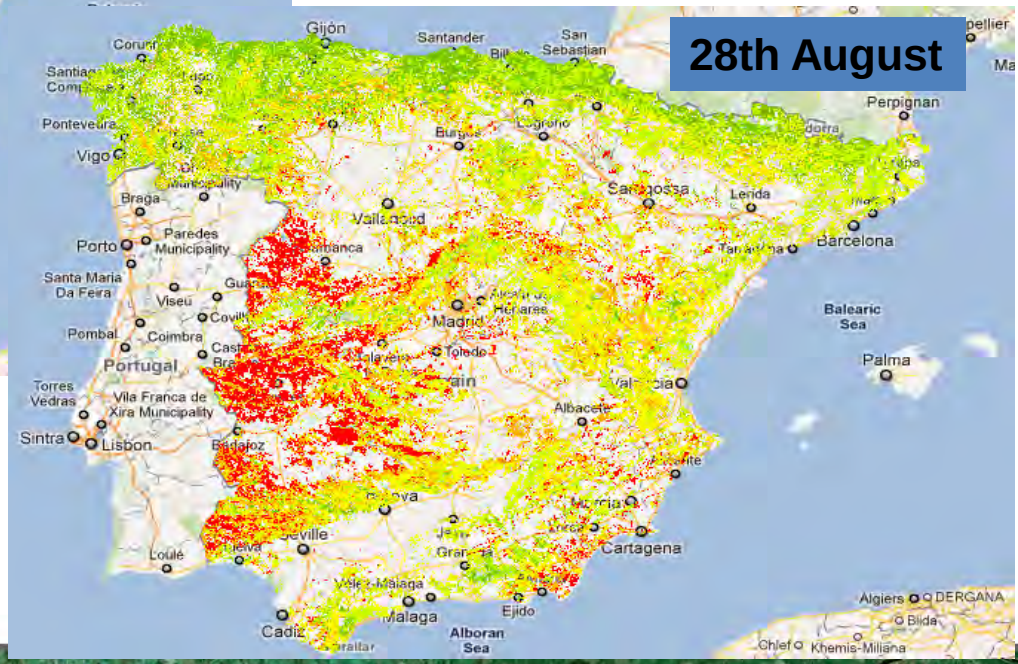
# Examples of FMC maps

**10th June**




**28th August**

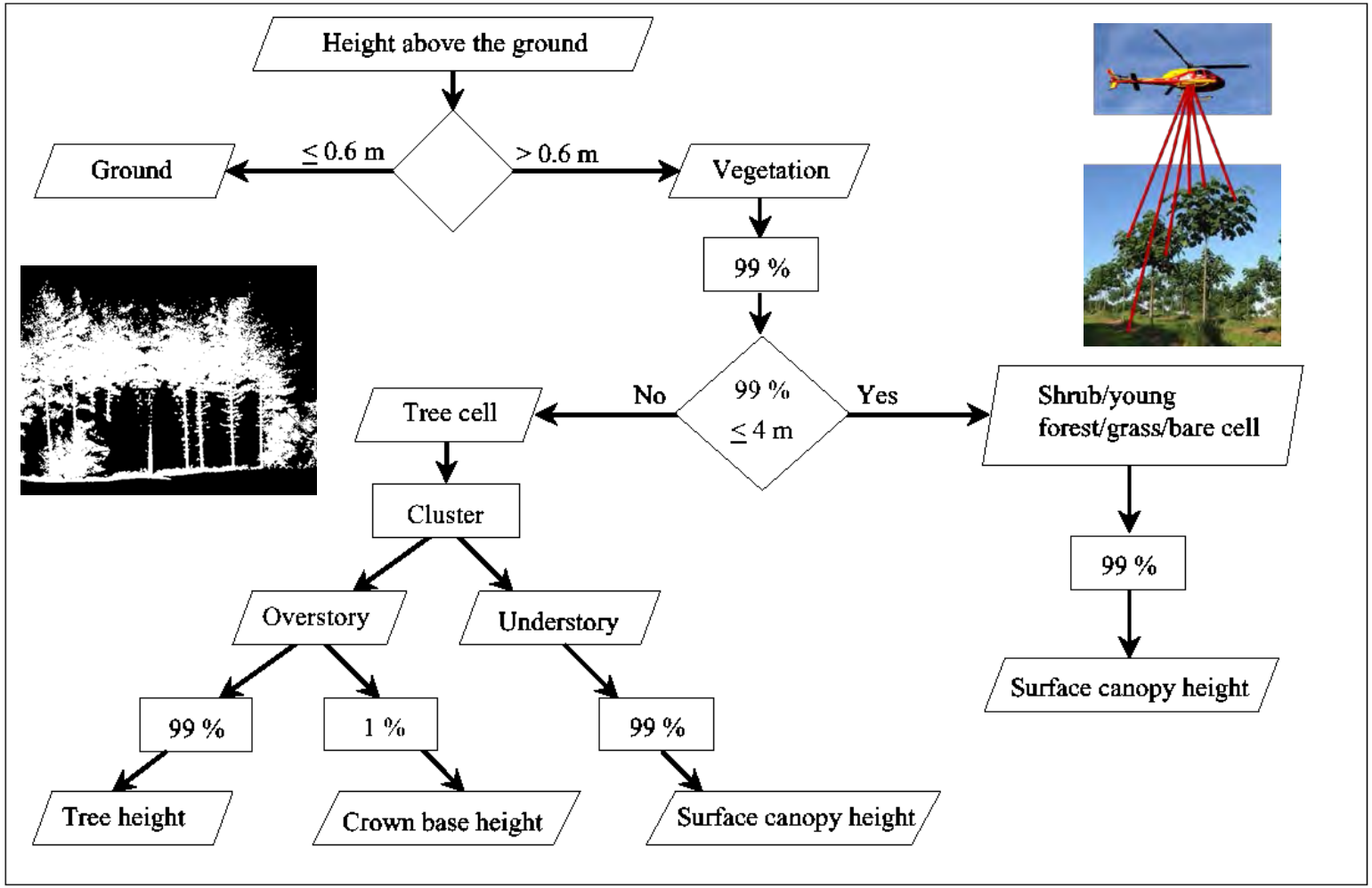



geogra.uah.es/fireglobe

# Fuel parameters

| | Passive optical | Lidar | Radar |
|---|---|---|---|
| **Horizontal continuity** | some | some | some |
| **Vertical distribution** | no | yes | some |
| **Biomass loads** | no | yes | some |
| **Surface conditions** | no | some | some |
| **Crown bulk density** | no | yes | no |

# Fuel characterization from Lidar



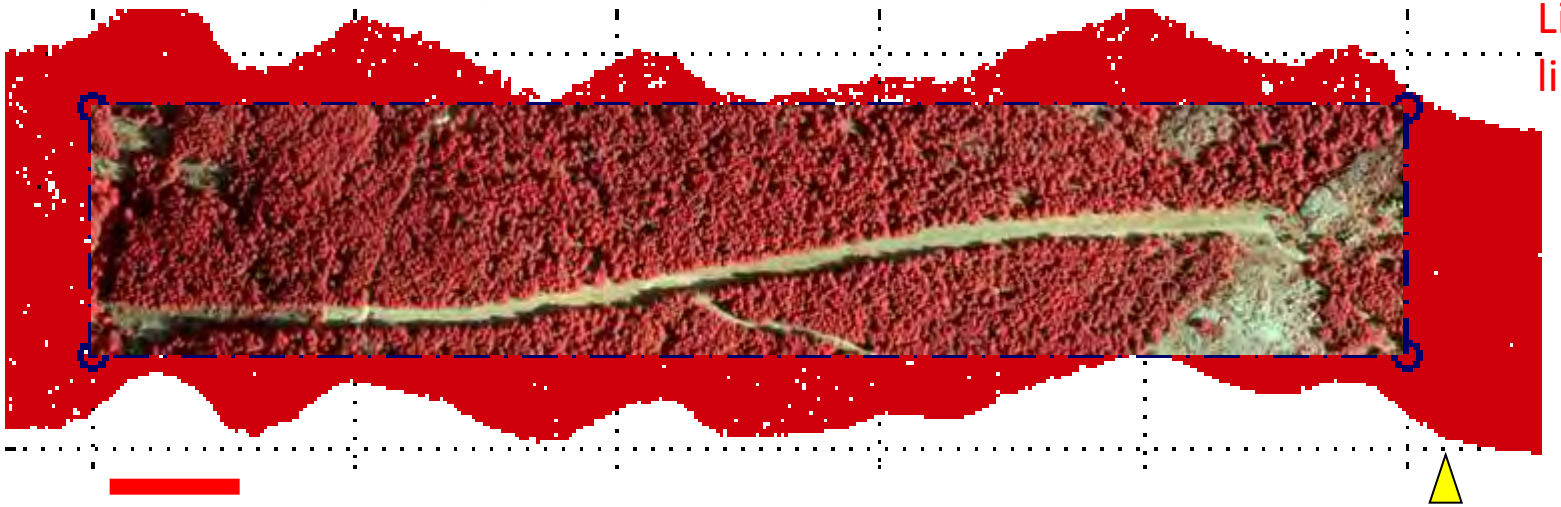

Riano et al., 2003, RSE

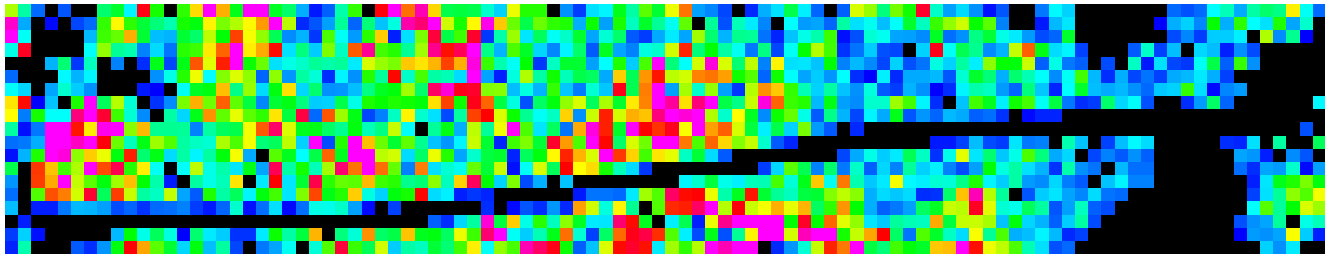
# Estimation of Fuel properties

| Variable | Lidar Parameter | $r^2$ (P<0.001) | Equations |
|---|---|---|---|
| Foliar Biomass FB | Tree height (CH) | 0.85 | $FB=0.39*e^{(MLH*0.15)}$ |
| Crown Volume (CV) | (P99-P1)*CH% | 0.92 | CV=1.11*(P99-P1)*CH%-1.71 |
| CBD | FB/CB | 0.81 | CBD=1.52*FB/CB-0.12 |

Riano et al., 2004, RSE

# Generation of CBD




Riaño et al., 2004 RSE

# Estimation of Biomass fractions

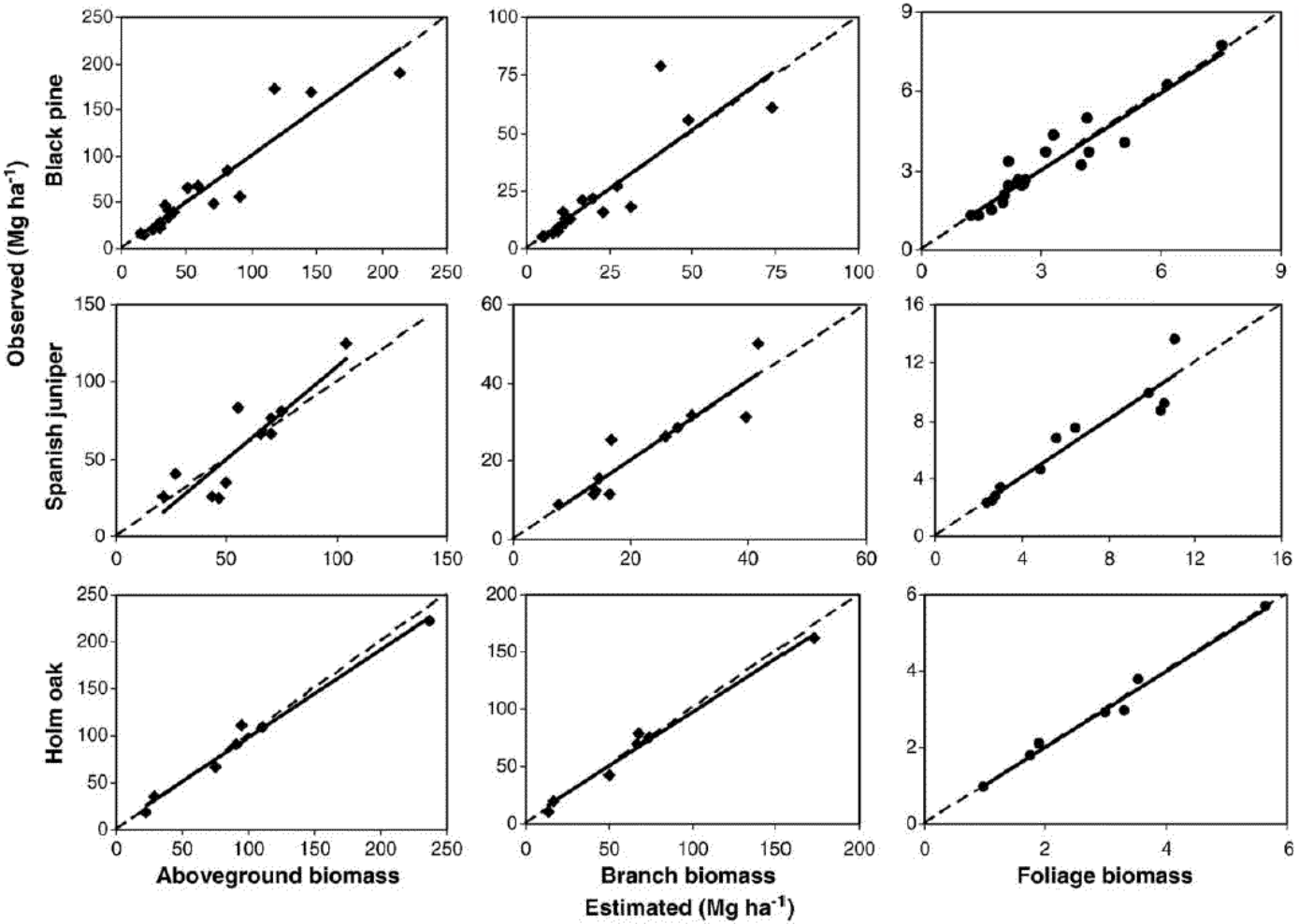



Fig. 4. Scatterplots of observed versus LiDAR-predicted biomass fractions.

Garcia et al., 2010, RSE

# Multi-sensor: Fuel classification

Remote Sensing of Environment 115 (2011) 1369–1379

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

## Multispectral and LiDAR data fusion for fuel type mapping using Support Vector Machine and decision rules

Mariano García [a,*], David Riaño [b,c], Emilio Chuvieco [a], Javier Salas [a], F. Mark Danson [d]

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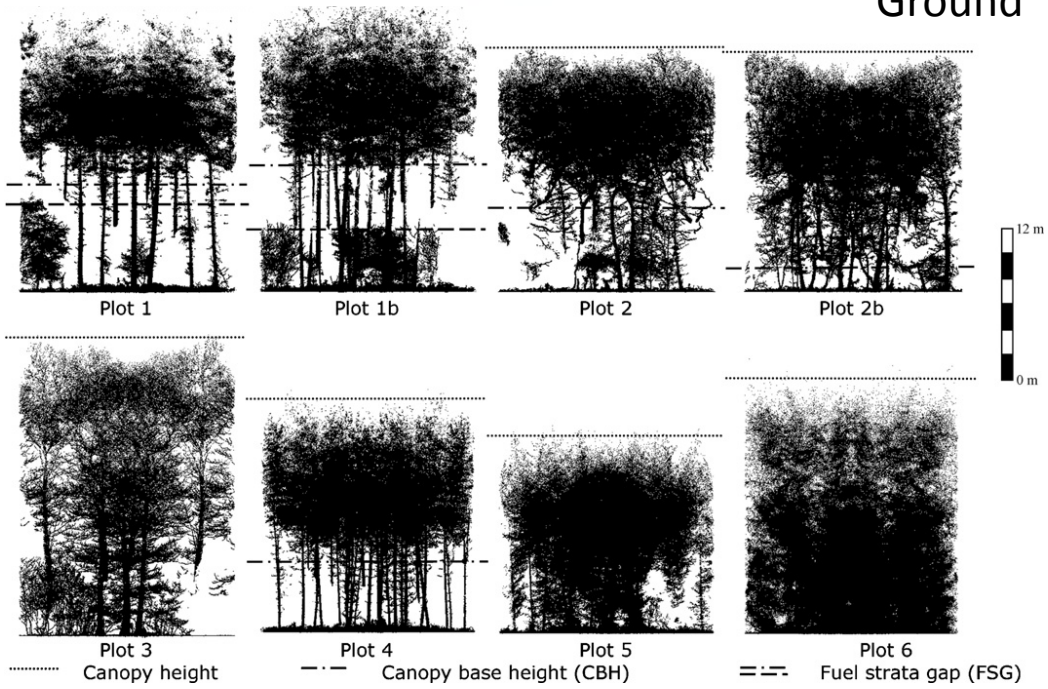
[b] Institute of Economics and Geography, Spanish National Research Council (CSIC), Albasanz 26-28 28037 Madrid, Spain
[c] Center for Spatial Technologies and Remote Sensing (CSTARS), University of California, 250-N, The Barn, One Shields Avenue, Davis, CA 95616-8617, USA

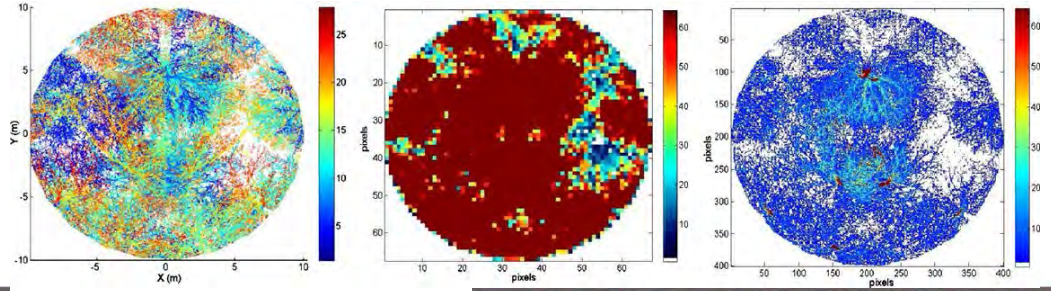
**Table 5**
confusion matrix of the fuel types classification after applying decision rules.

| | | Reference data | | | | | | | Total | User's accuracy (%) | Error of commission (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FT 0 | FT 1 | FT 3 | FT 4 | FT 5 | FT 6 | FT 7 | | | |
| Classified data | FT 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 100 | 0 |
| | FT 1 | 1 | 12 | 0 | 0 | 0 | 0 | 0 | 13 | 92.31 | 7.69 |
| | FT 3 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 9 | 100 | 0 |
| | FT 4 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 100 | 0 |
| | FT 5 | 2 | 0 | 0 | 0 | 15 | 1 | 4 | 22 | 66.67 | 33.33 |
| | FT 6 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 8 | 100 | 0 |
| | FT 7 | 0 | 1 | 1 | 1 | 0 | 1 | 27 | 31 | 87.1 | 12.9 |
| Total | | 13 | 13 | 10 | 11 | 15 | 10 | 31 | 103 | | |
| Producer's accuracy | | 76.92 | 92.31 | 90 | 90.91 | 100 | 80 | 87.1 | | | |
| Error of omission (%) | | 23.08 | 7.69 | 10 | 9.09 | 0 | 20 | 12.9 | | | |

# Multi-scale: fuel parameters

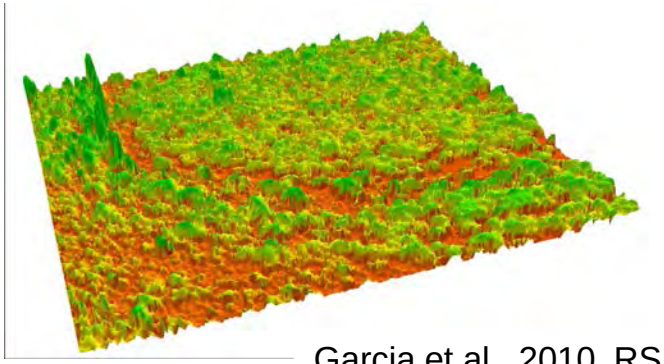
Ground



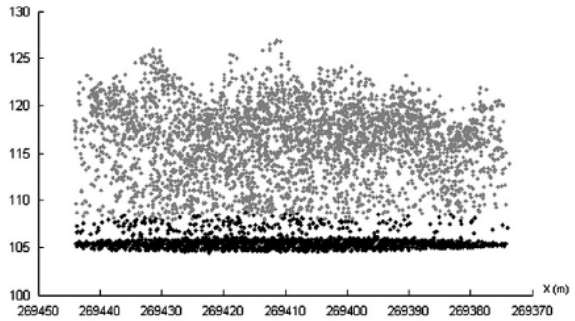



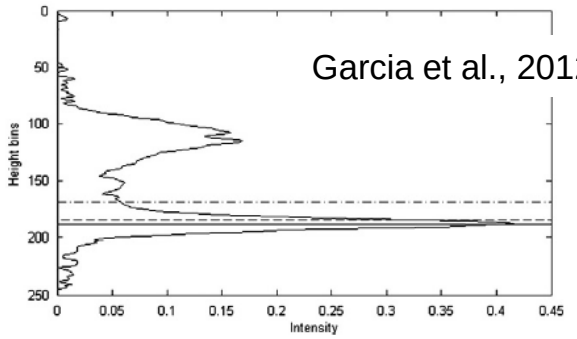

Garcia et al. 2011, IJAEO

Airborne



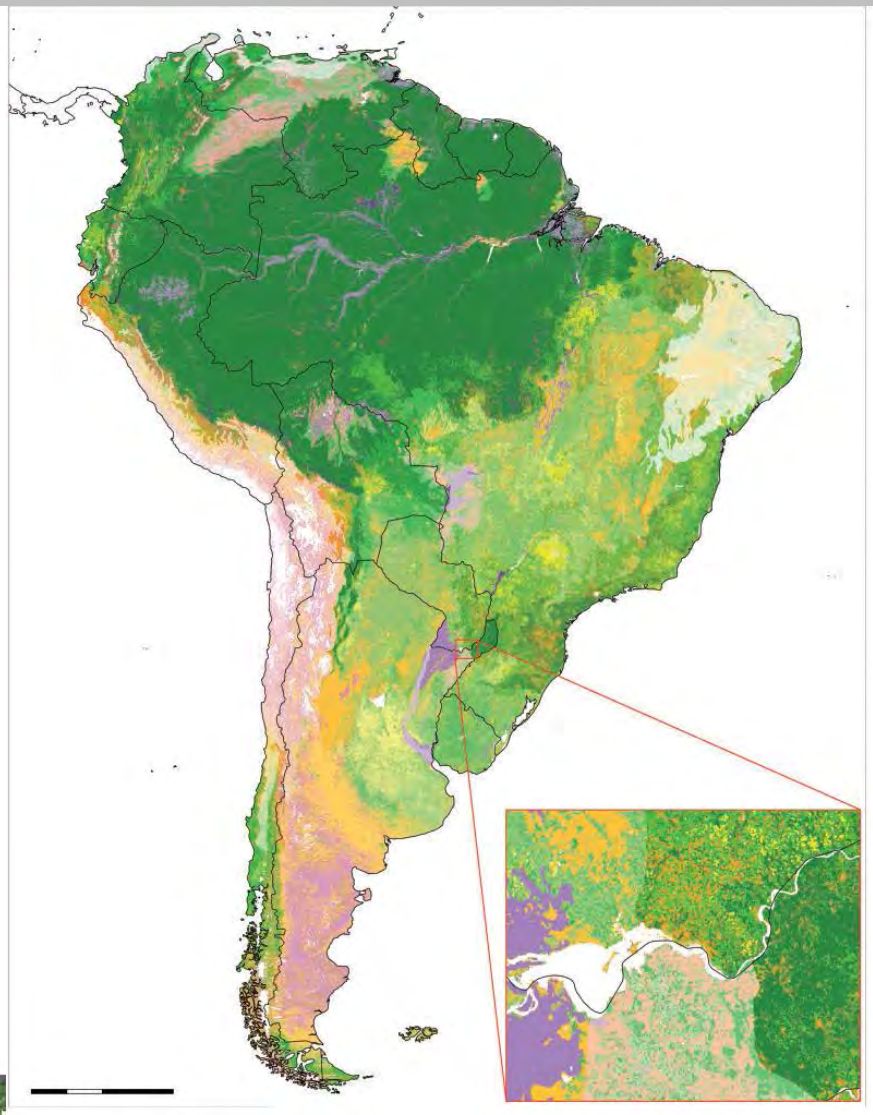
Garcia et al., 2010, RSE




Garcia et al., 2012, RSE

# Global fuel parameters

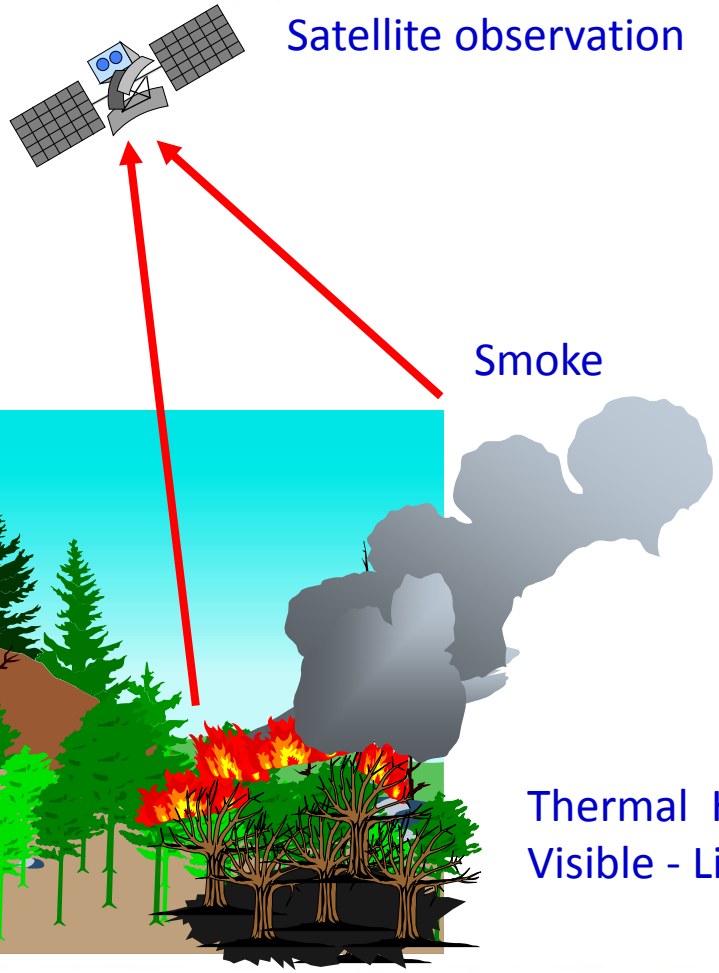


Pettinari et al., 2014, IJWF

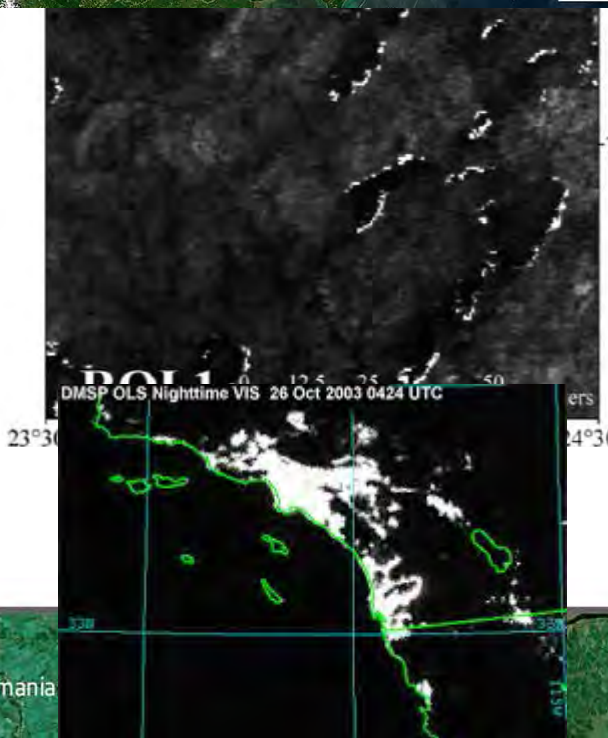
## Questions RS may answer

- When will a fire occur? How much potential negative impact?
- Is there an active fire? Where? When did it start? How is it growing? How much energy? How many gas emissions?
- How much area is burned? How often? When in the year? How much biomass is consumed? Are fire characteristics changing?

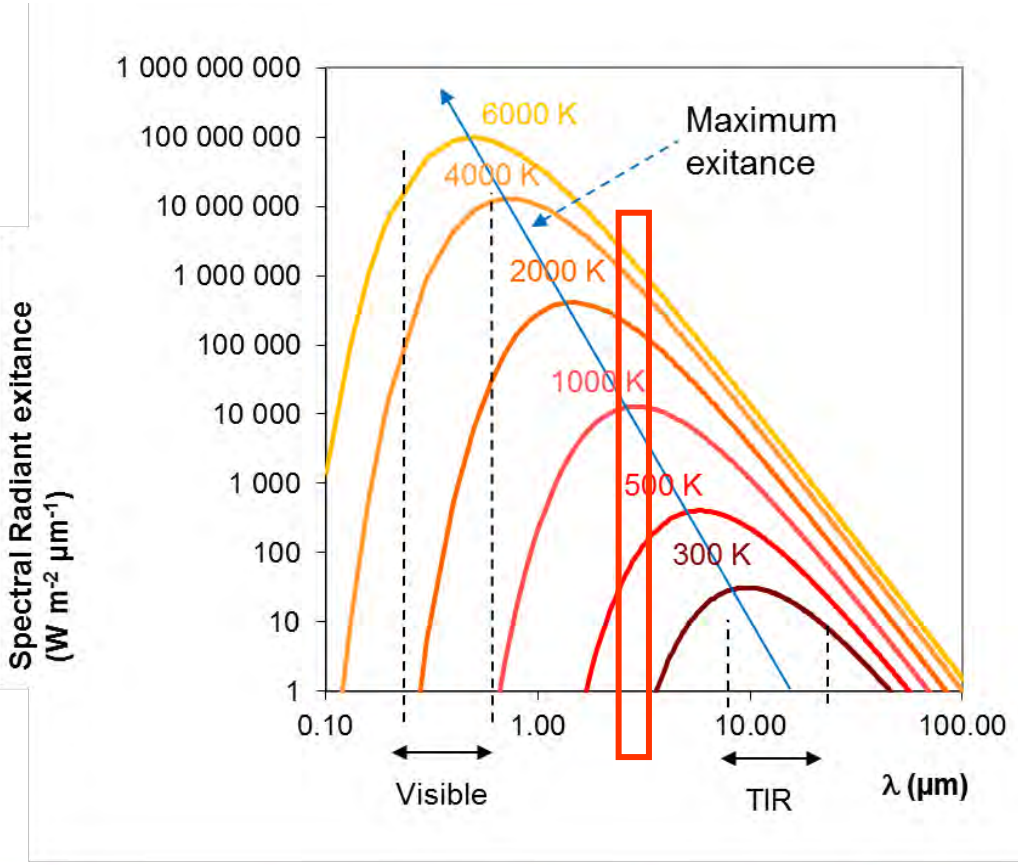
# Detection of active fires

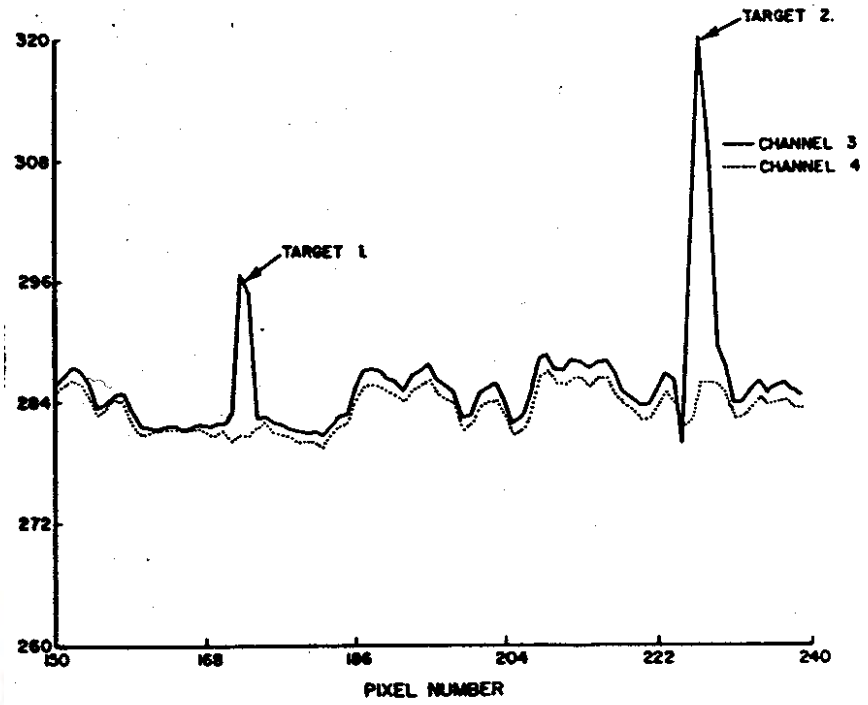






# MIR detection of fires

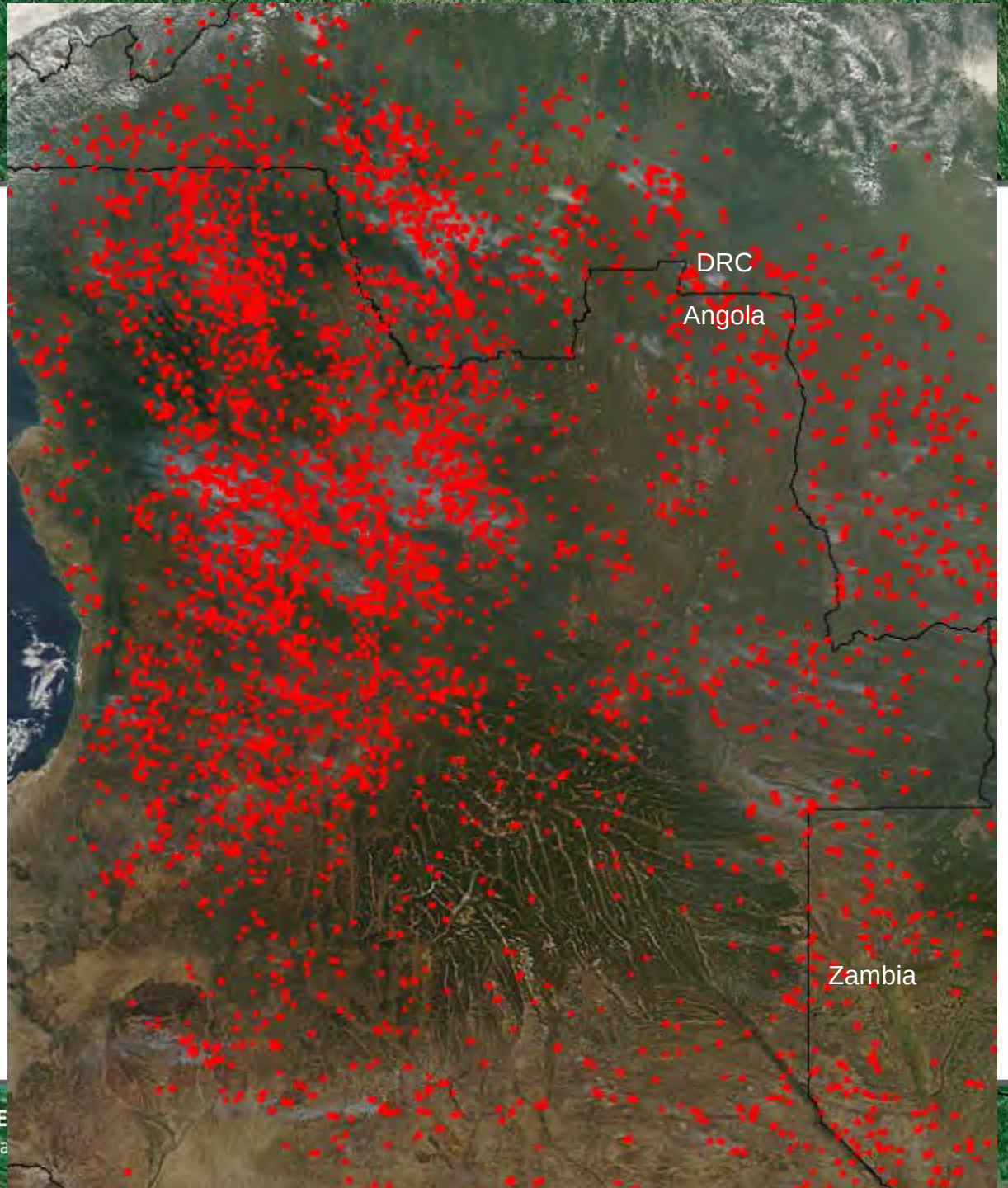


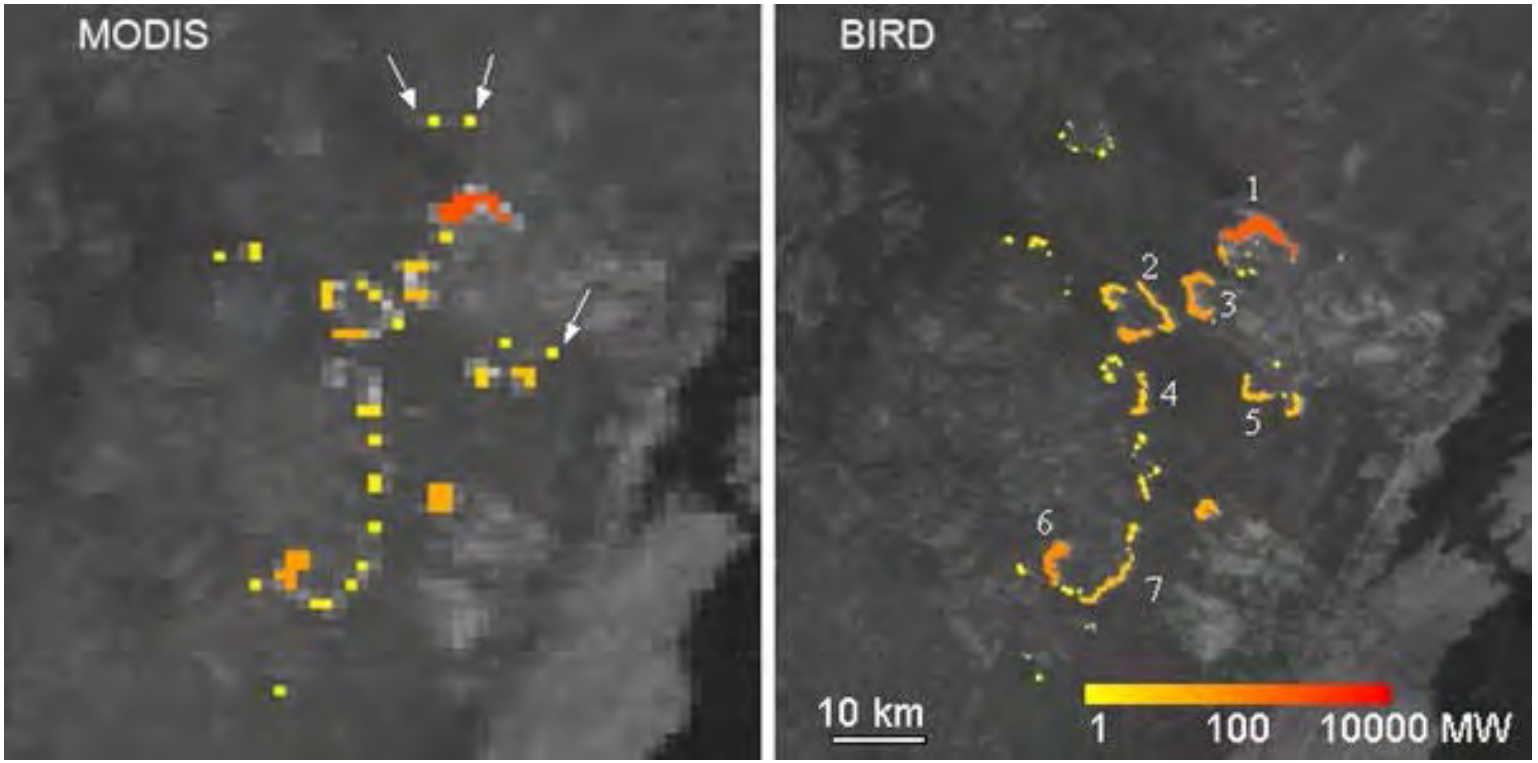

(Stephens y Matson, 1987)

MODIS thermal anomalies

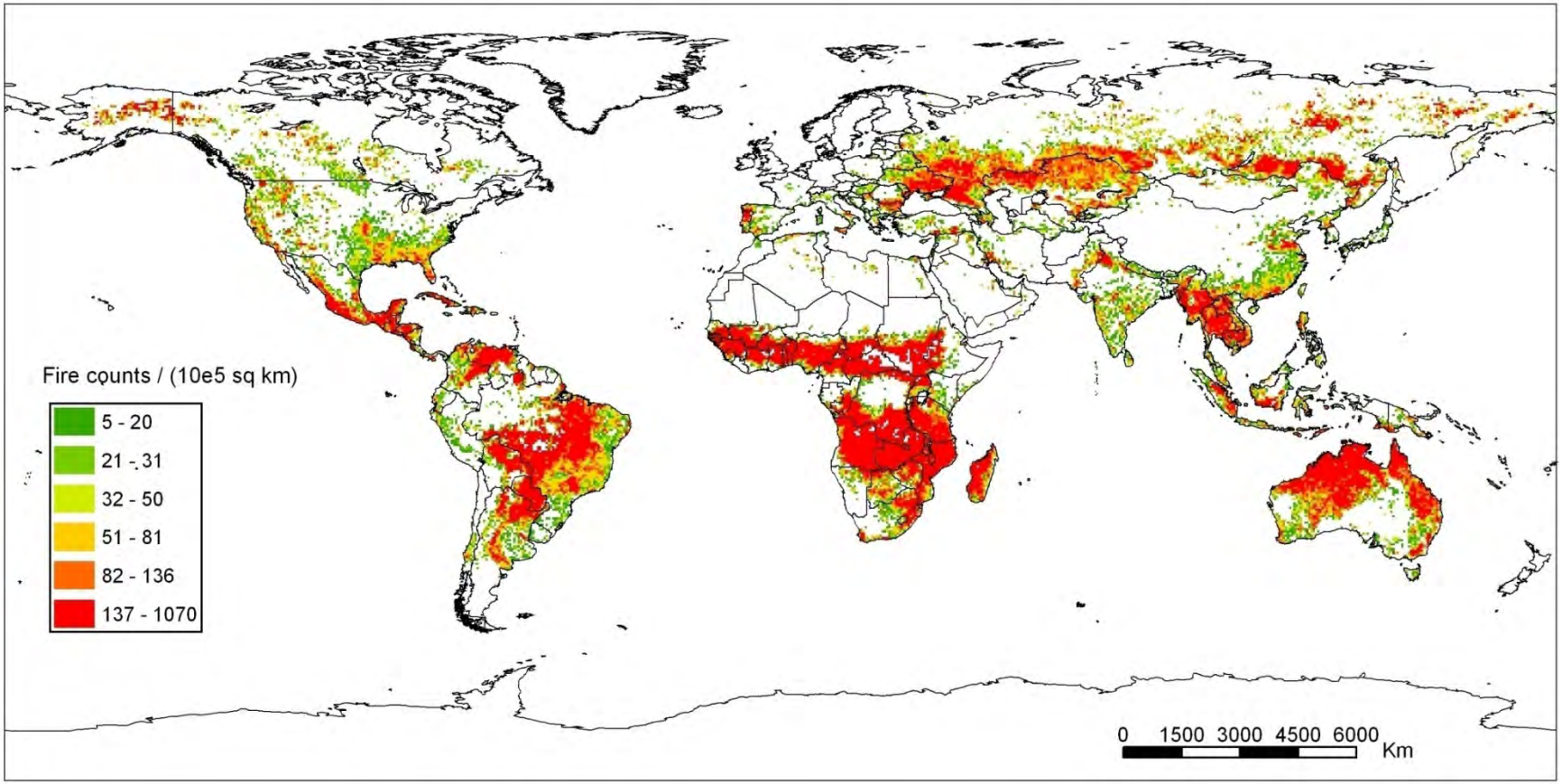
Aqua satellite of fires across Angola, Central Africa on June 16th 2007



# Dedicated fire detection systems

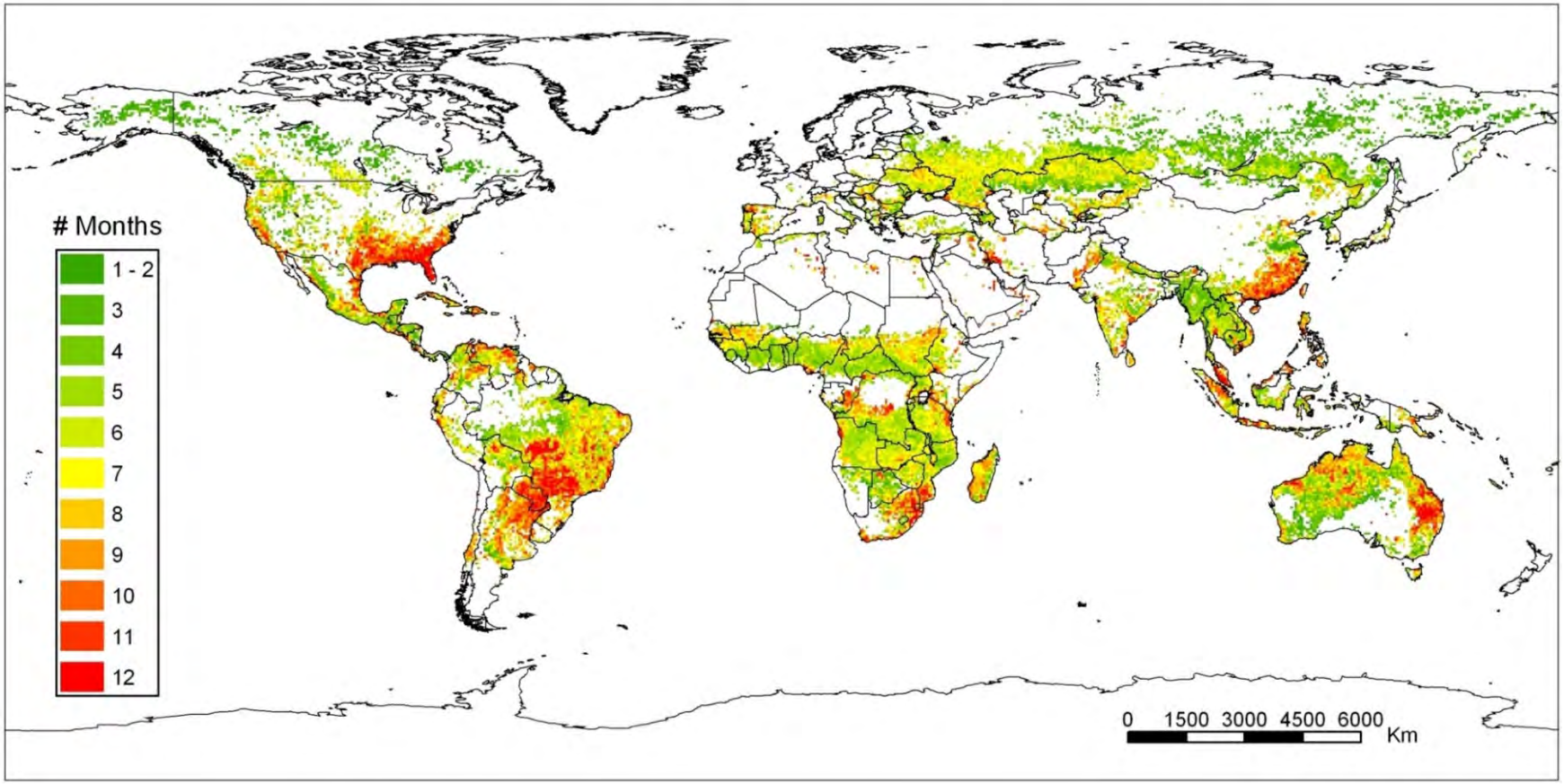


# Average fire density (2000-2006)



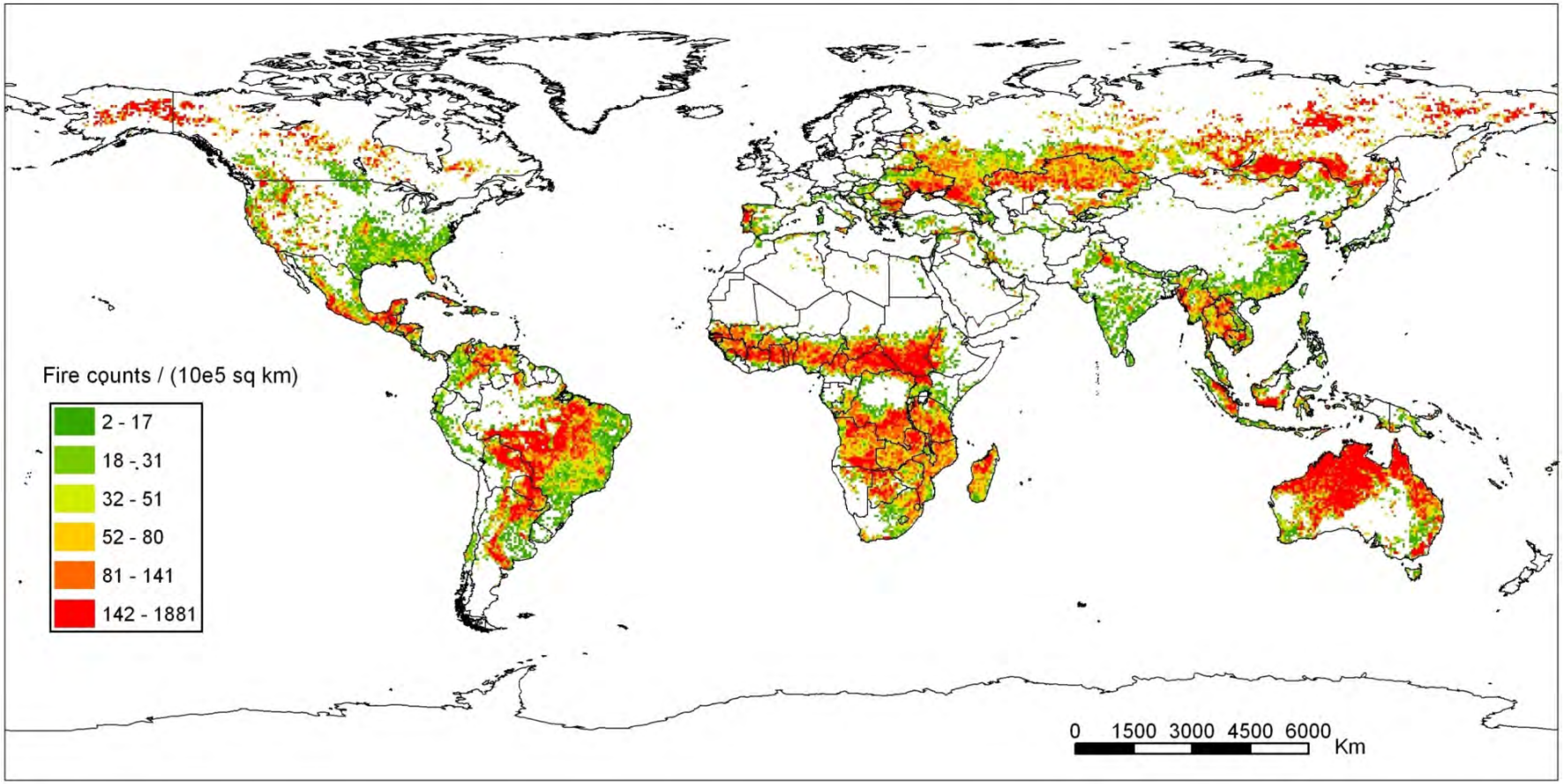

Chuvieco et al., 2008, GCB

# Length of fire season (2000-2006)



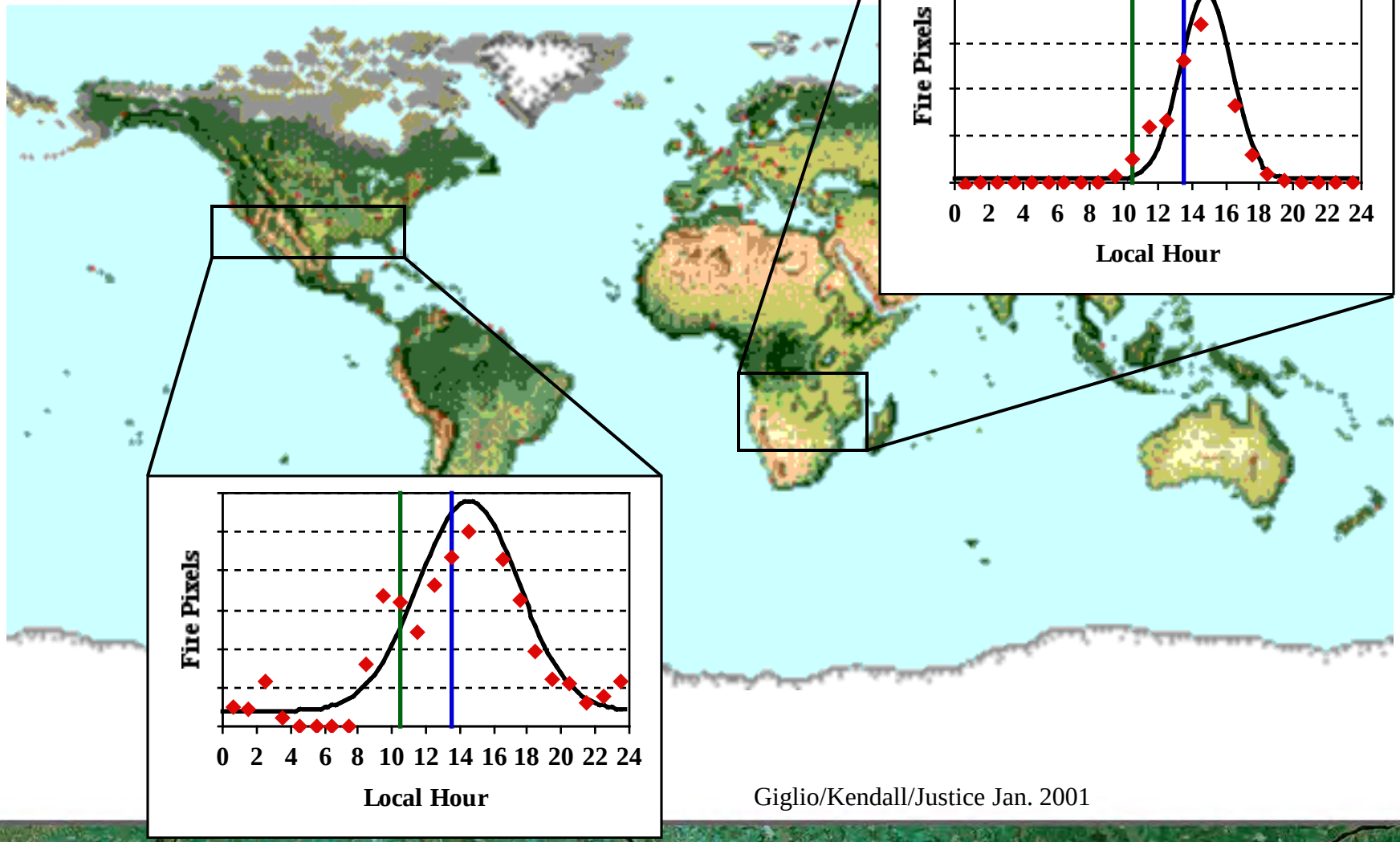

Chuvieco et al., 2008b

# Interanual variability (2000-2006)



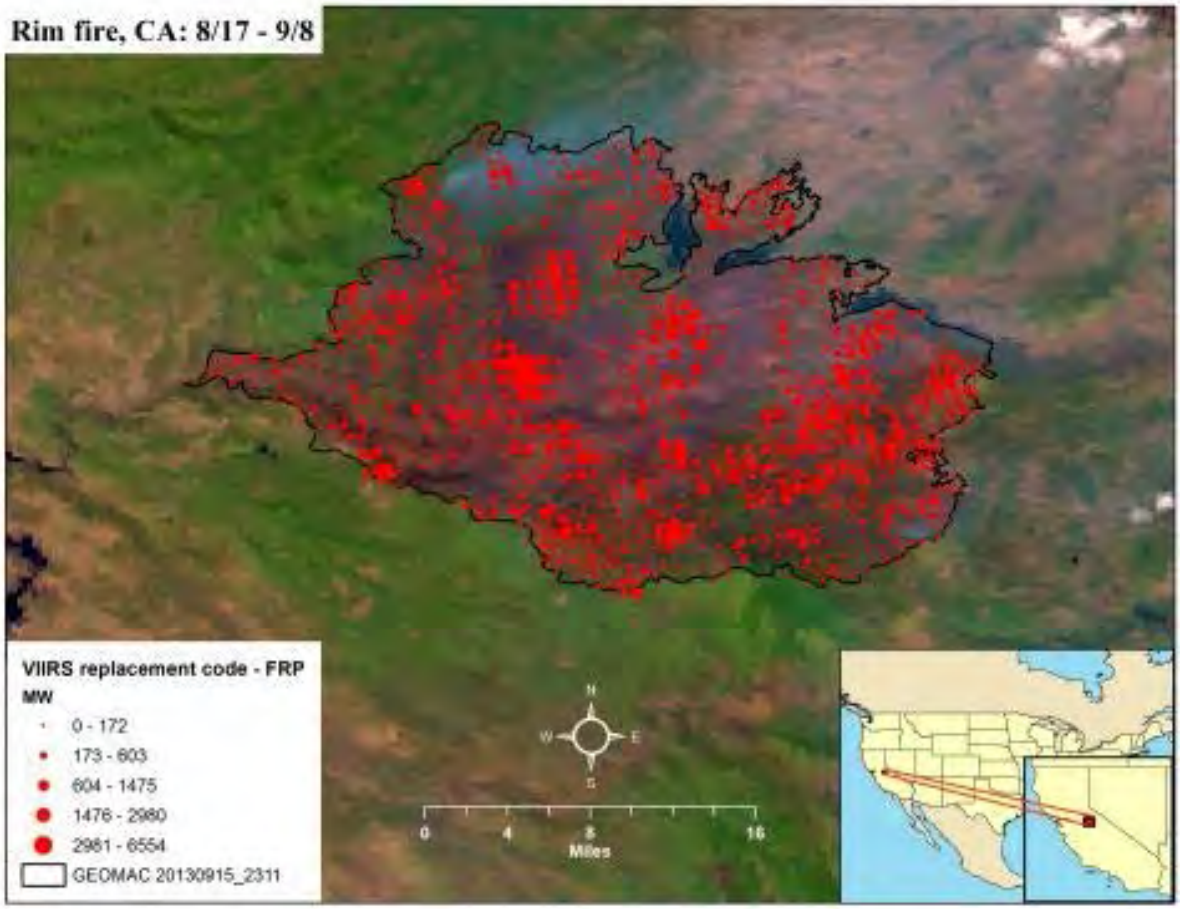

Chuvieco et al., 2008b

# Diurnal cycle



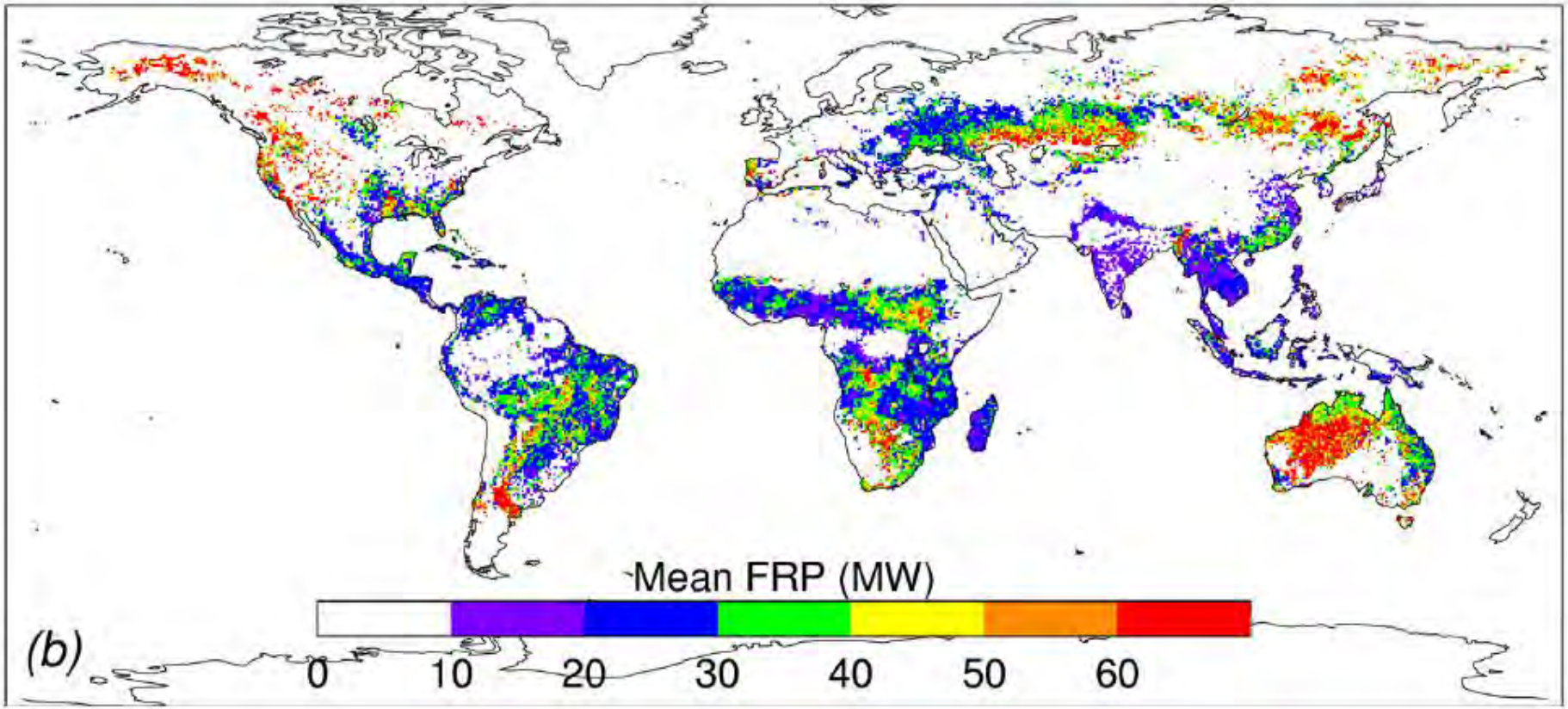

Giglio/Kendall/Justice Jan. 2001

# Estimation of Fire Radiative Power




http://viirsfire.geog.umd.edu/pages/AFPE.php

# Fire radiative power from MODIS active fires (2000-2005)




Giglio et al., 2006, JGR

## Questions RS may answer

- When will a fire occur? How much potential negative impact?
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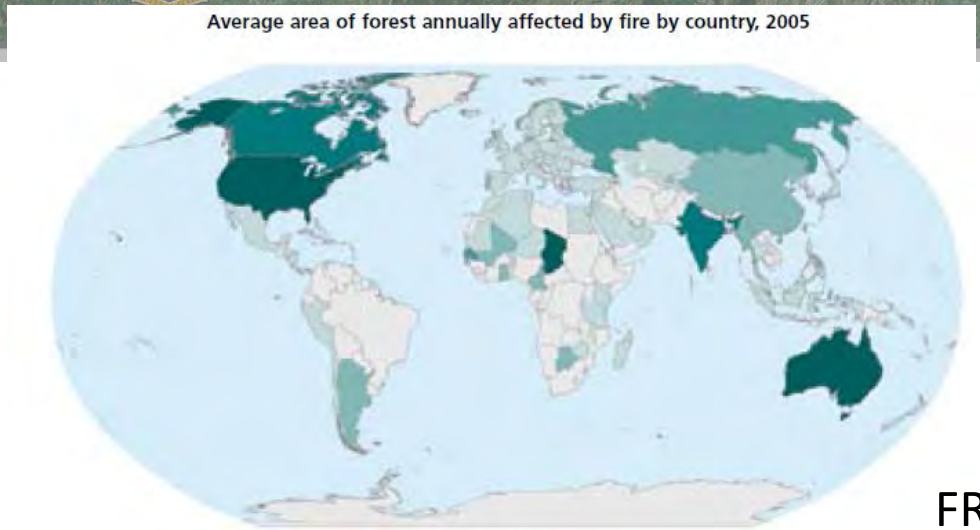
- How much area is burned? How often? When in the year? How much biomass is consumed? Are fire characteristics changing?

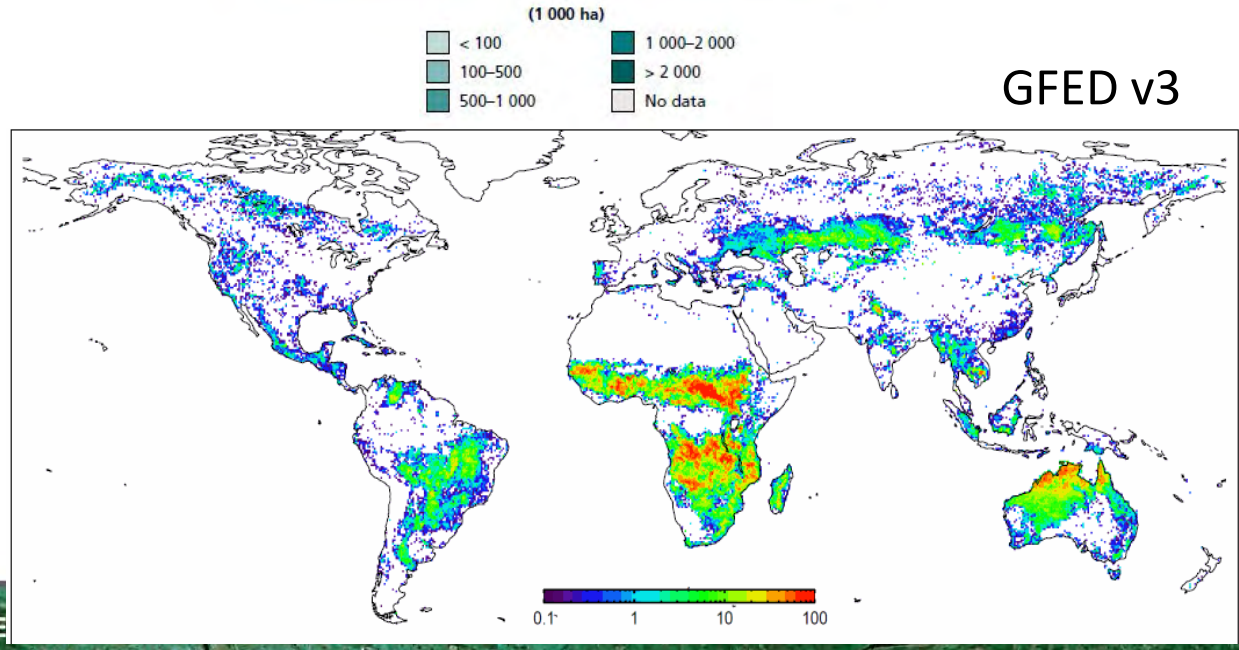
# How much area is burned?

From official FAO statistics (FRA2010): 0.6 Mkm².
Based on information from 78 countries



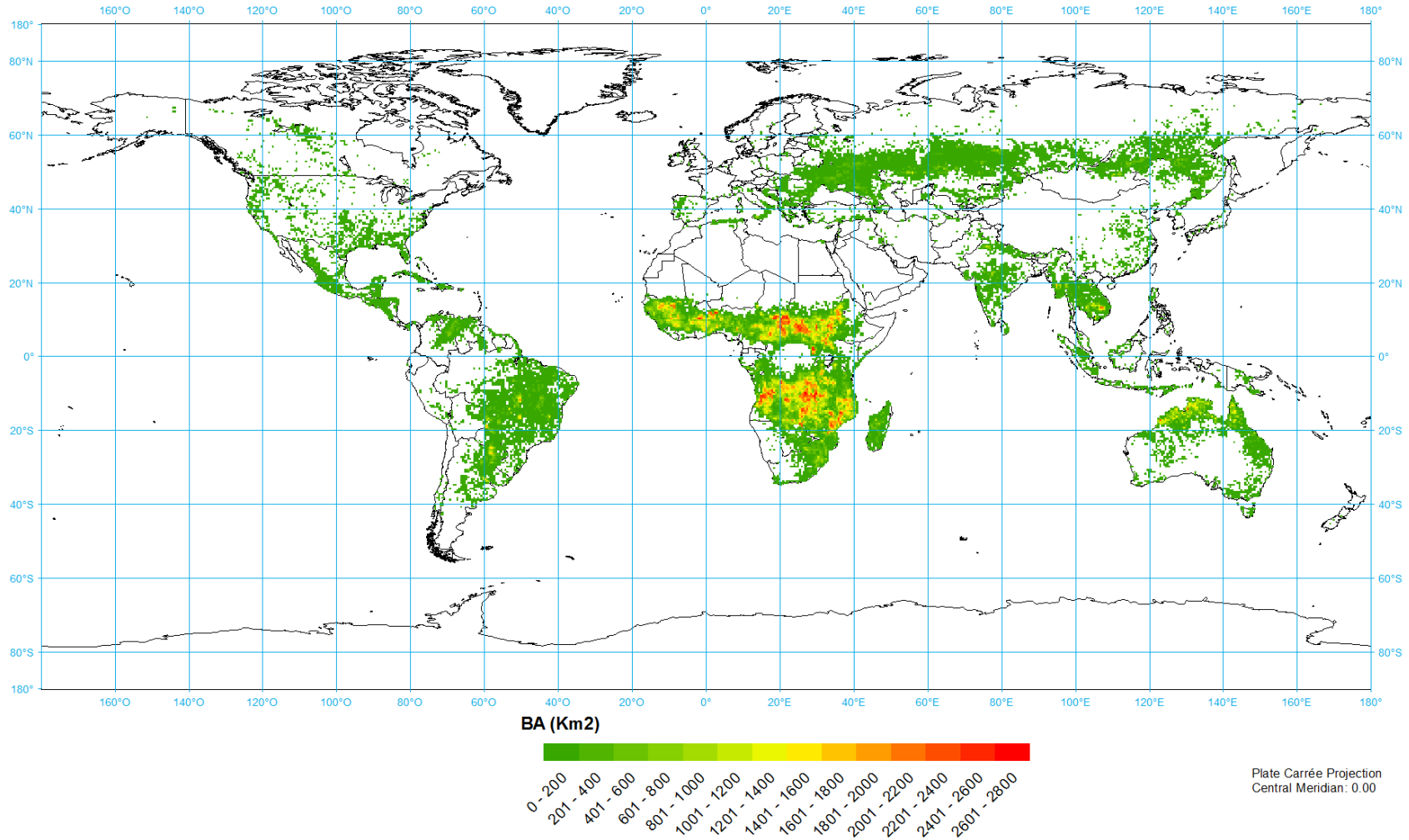

FRA2010

From satellite images
- L3JRC: 3.5 - 4.5 Mkm² (2000-07)
- MCD45 c5: 3.3 - 3.6 Mkm² (2000–2006)
- GFED v2: 2.97 – 3.74 Mkm² (2001–2004)
- GFED v3: 3.39 - 4.31 Mkm² (1997-2009).
- Fire_CCI: 3.5-3.7 MKm²

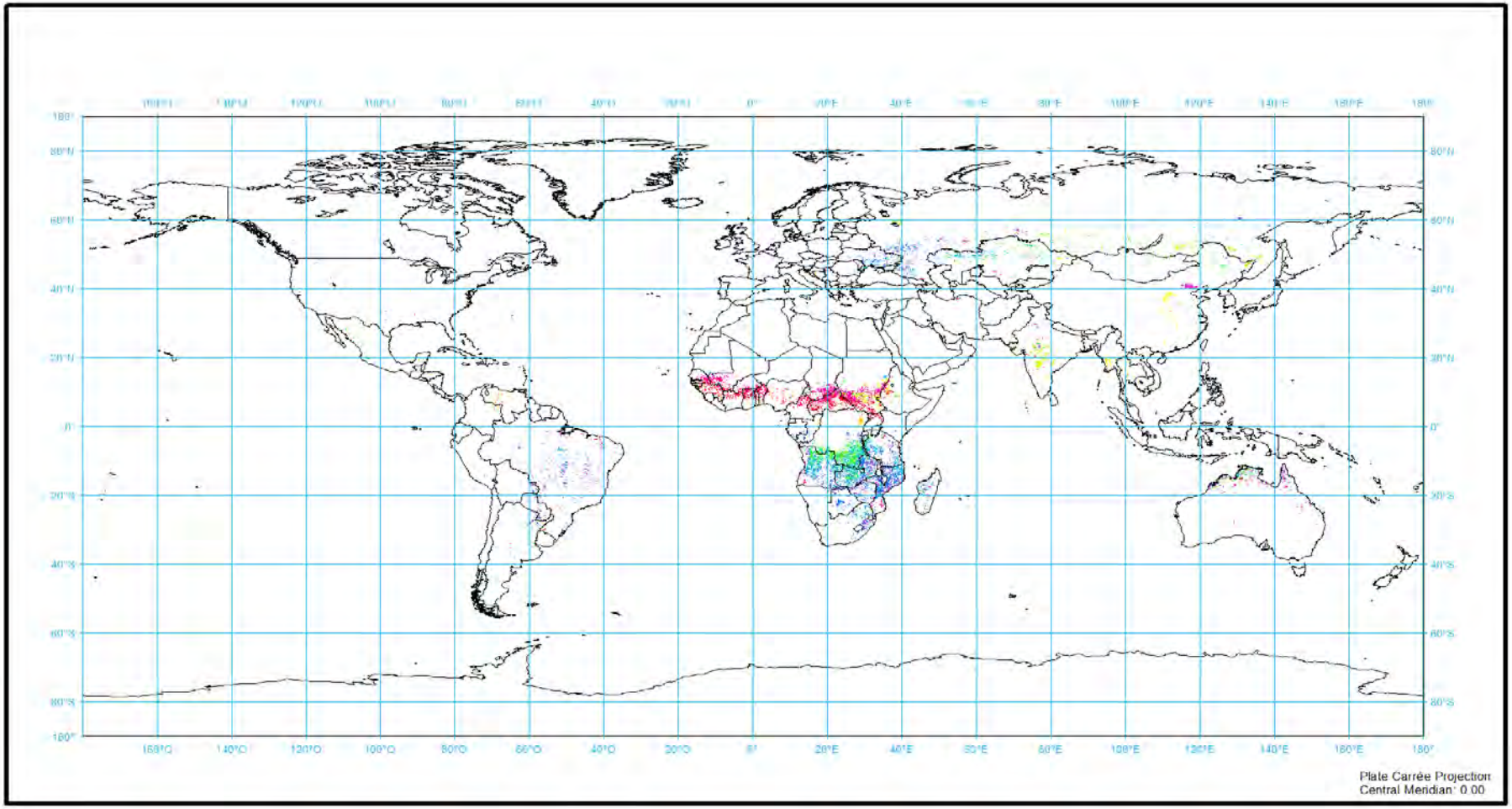



GFED v3

# Total Burned Area (2008) from Fire_CCI

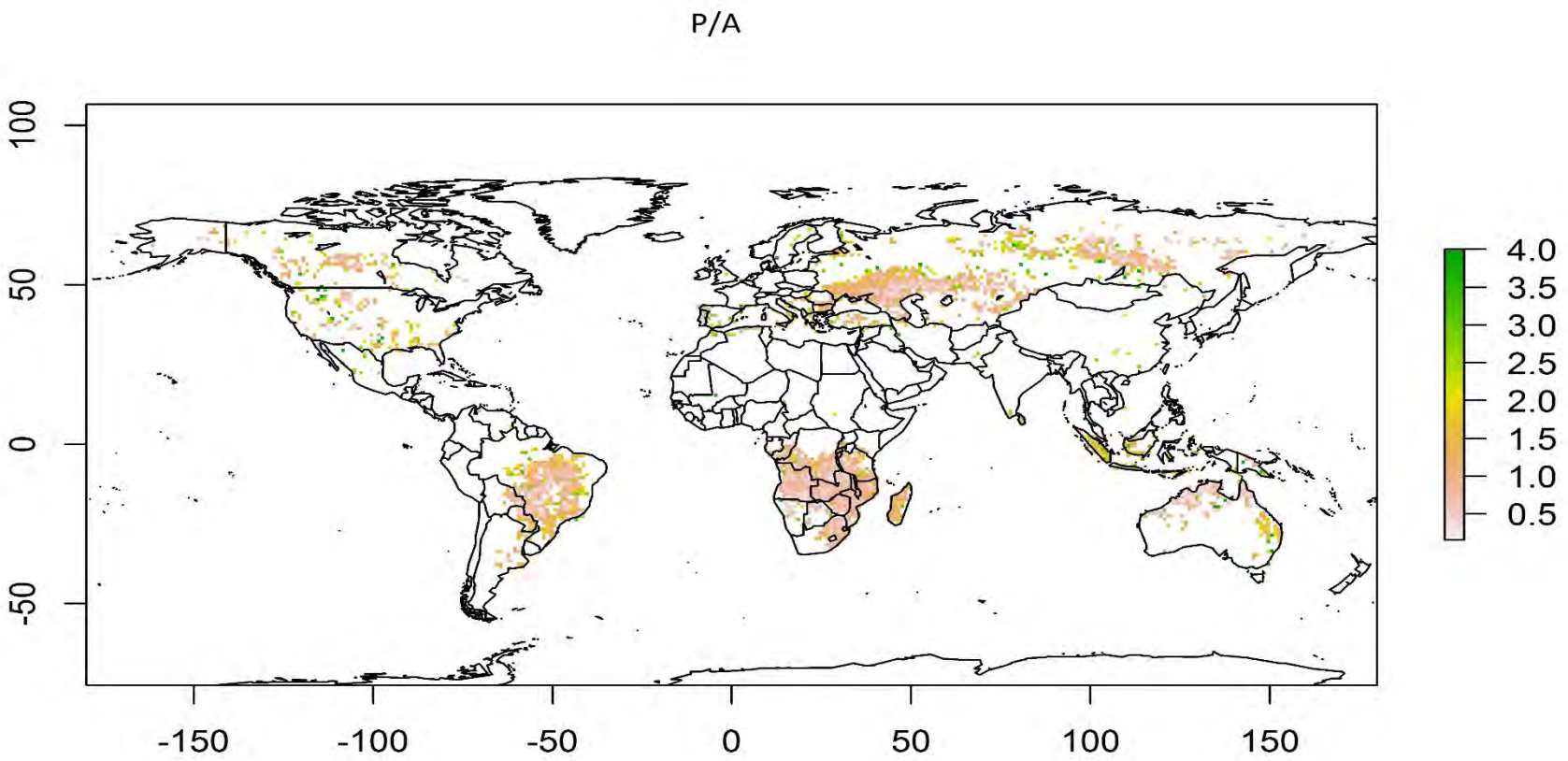


# Date of Detection (2008) from Fire_CCI




1 180 365 DoY

# Burned patch analysis




Mouillot et al., 2015

# Validation aspects / metrics

- Global accuracy.
- Error balance.
- Temporal stability.

Remote Sensing of Environment 144 (2014) 187–196

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## Validation of the 2008 MODIS-MCD45 global burned area product using stratified random sampling

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[b] Department of Forest and Natural Resources Management, College of Environmental Science and Forestry, State University of New York, Syracuse, NY 13210, USA

ABSTRACT

The 2008 global burned area product MODIS-MCD45 was validated and accuracy measures were estimated globally and for several terrestrial biomes. Stratified random sampling was used to select 102 non-overlapping Thiessen scene areas (TSA) and reference fire perimeters were determined from two multi-temporal Landsat TM/ETM + images for each sampled TSA. Error matrices and six accuracy measures were chosen to satisfy criteria specified by end-users of burned area products. Globally, MODIS-MCD45 had estimated commission and omission error rates of 46% and 72% respectively, and a Dice coefficient of 0.37. Burned area extent tended to be underestimated as the MODIS product detected an estimated 48% of the burned area as determined from the reference data. The two biomes with highest accuracy were Boreal Forest and Tropical & Subtropical savanna, two of the most fire-prone biomes. In general, accuracy slightly improved in those areas where burned area was more prevalent.



*Remote Sens.* **2014**, *6*, 2050-2068; doi:10.3390/rs6032050

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*Article*

## Assessing the Temporal Stability of the Accuracy of a Time Series of Burned Area Products

**Marc Padilla [1,*], Stephen V. Stehman [2], Javier Litago [3] and Emilio Chuvieco [1]**

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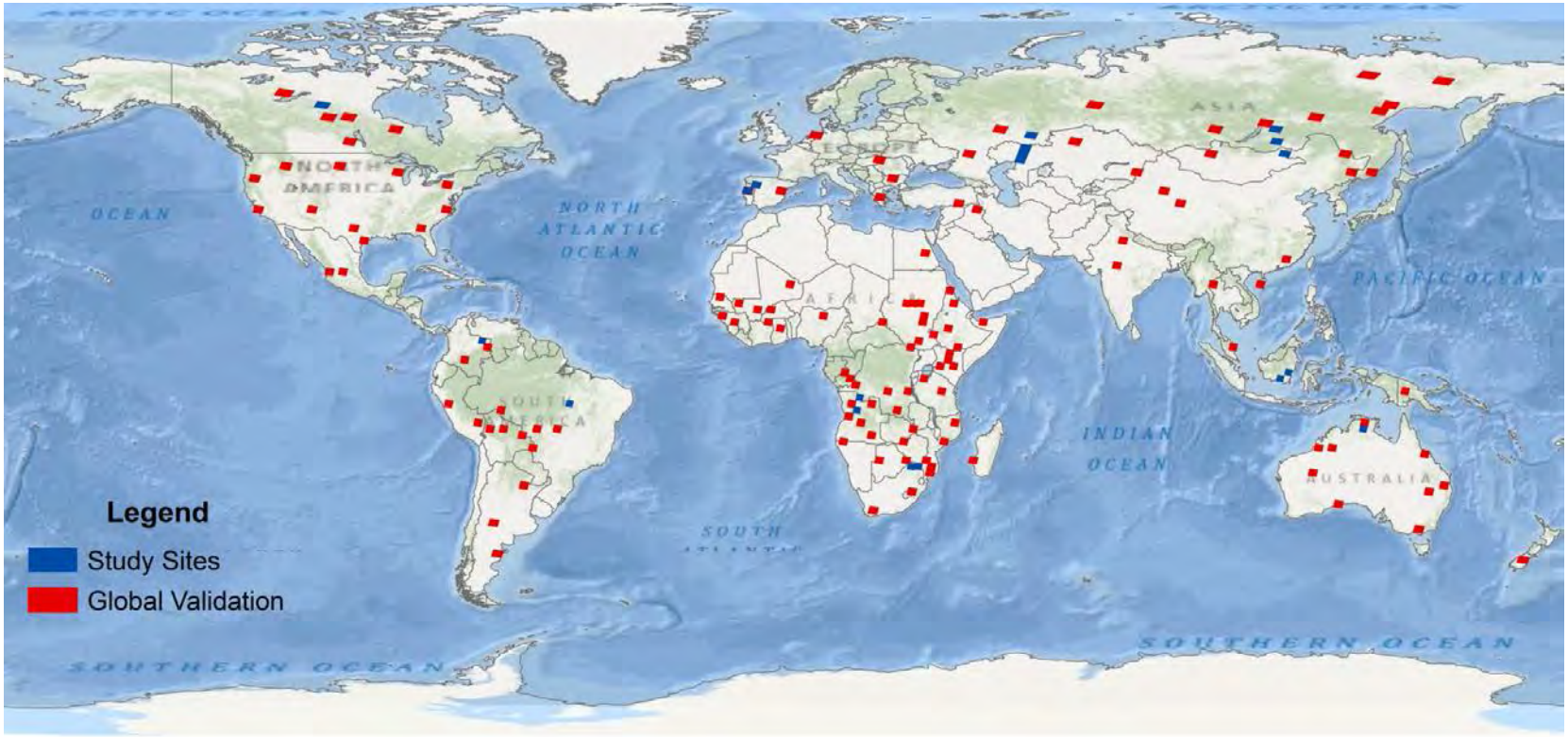
Romania

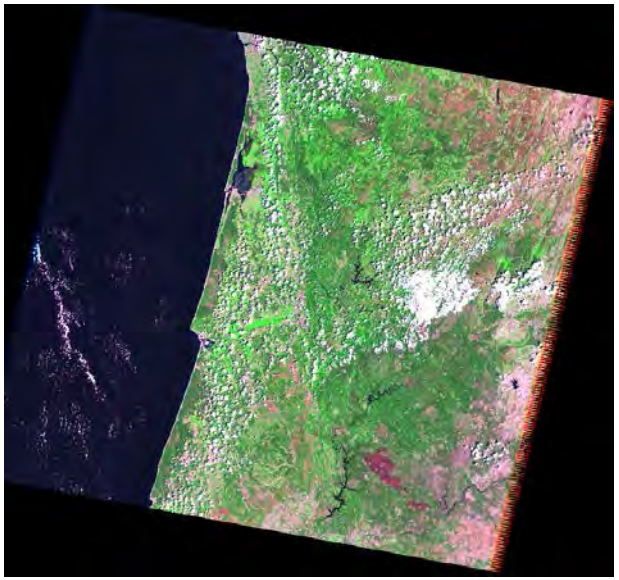
# Sites for validation

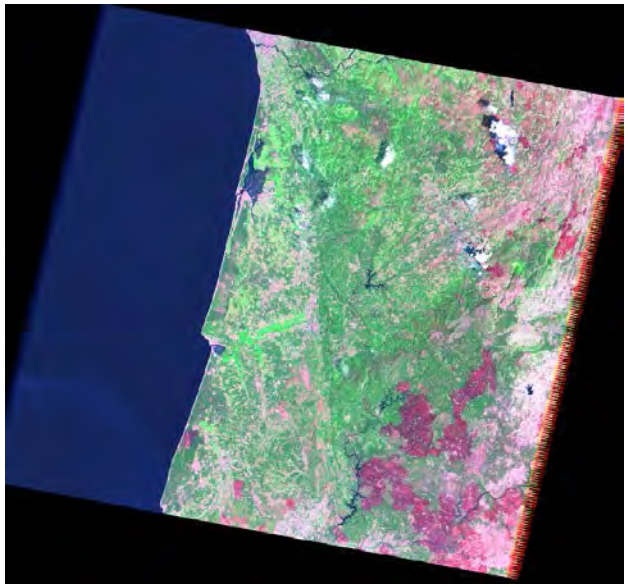


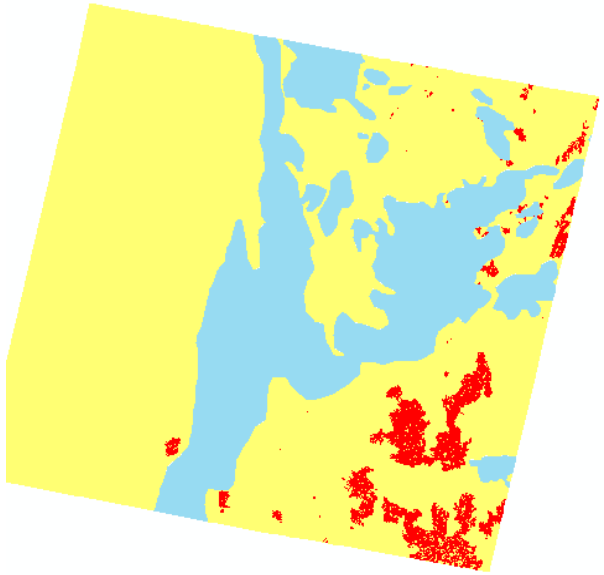

- A new full dataset of fire perimeters was derived from multitemporal pairs of Landsat TM/ETM+ data.
- All files are documented following standard CEOS Cal-Val guidelines.

# Landsat images used for validation

- Pre fire post fire BA_result

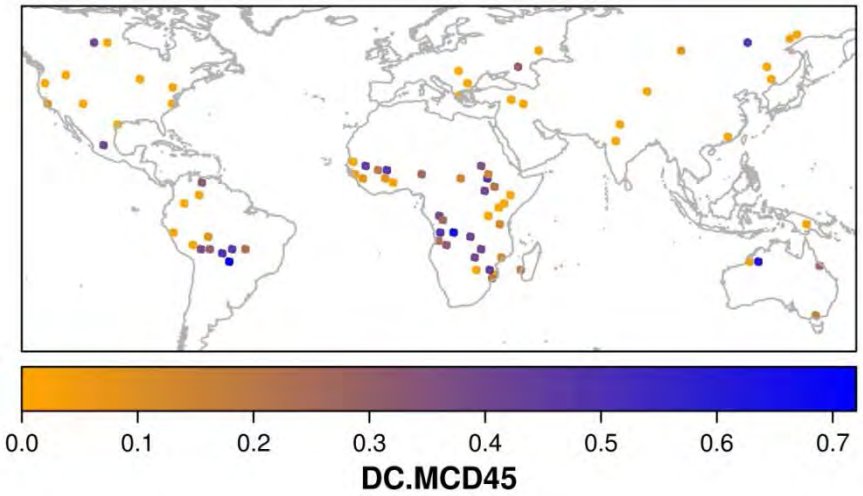


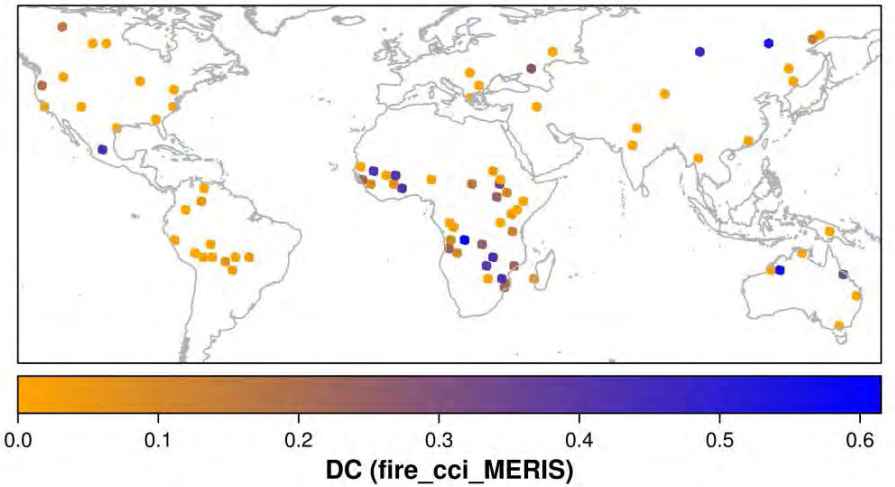


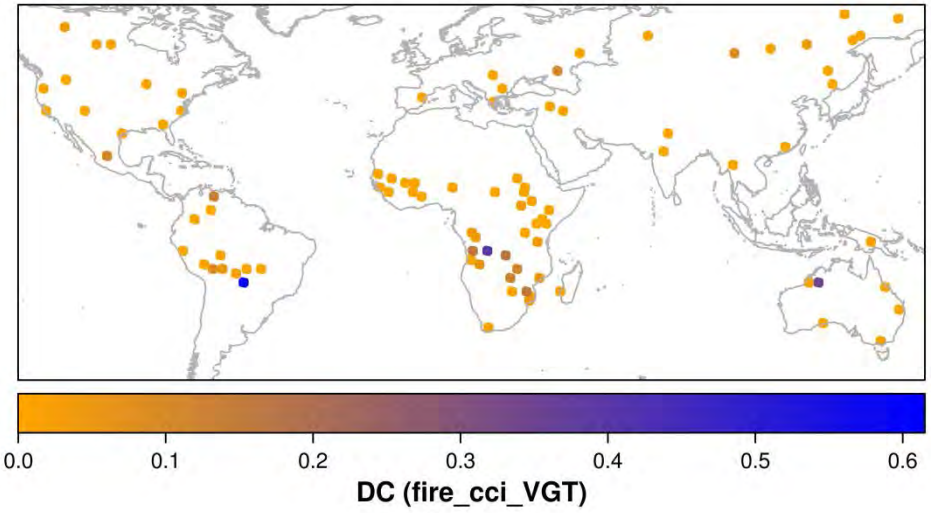


- Blue=no data (clouds,...)
- Red=Burned

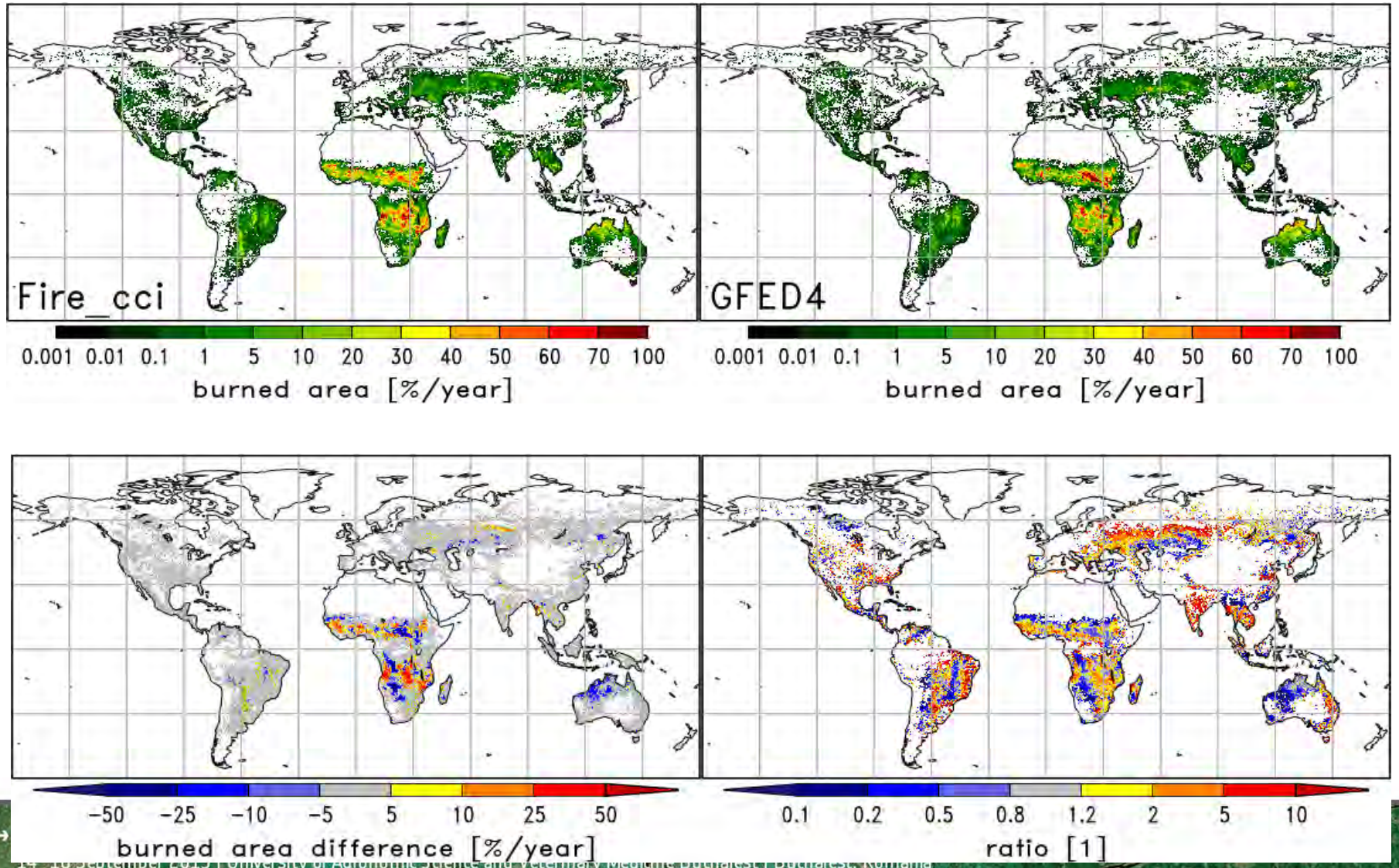
# Spatial variation of accuracy (2008)



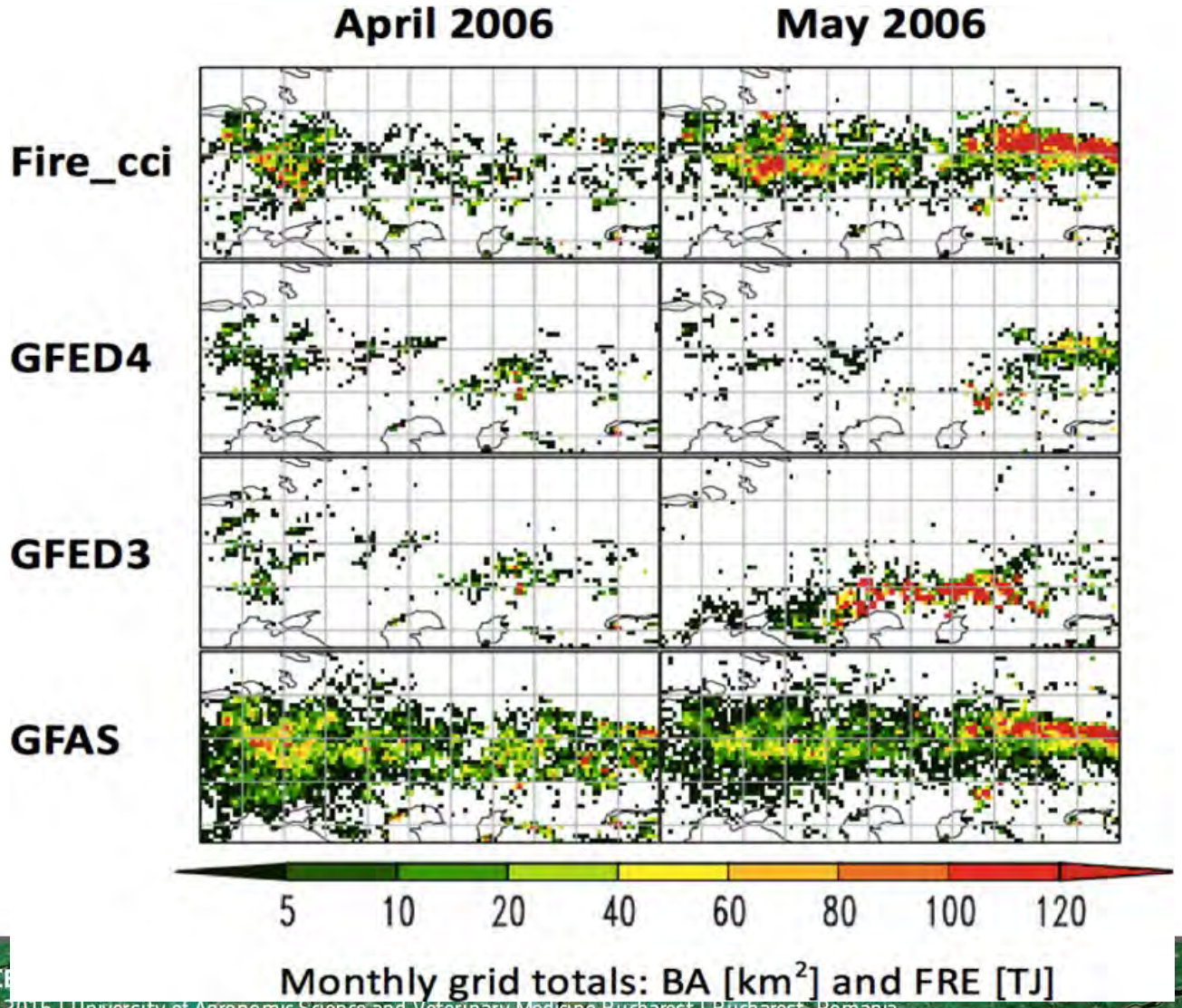



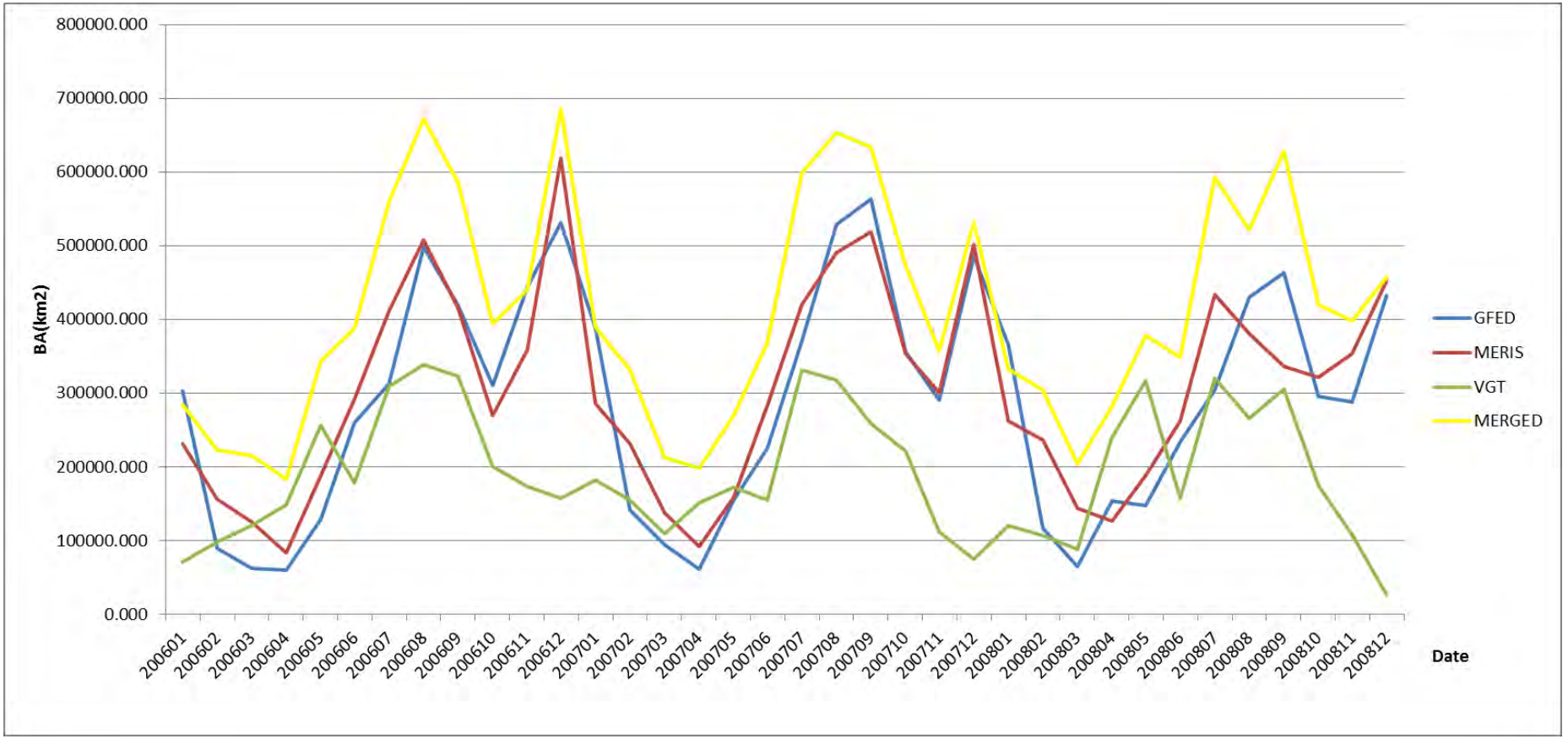
# Intercomparision



# Intercomparision

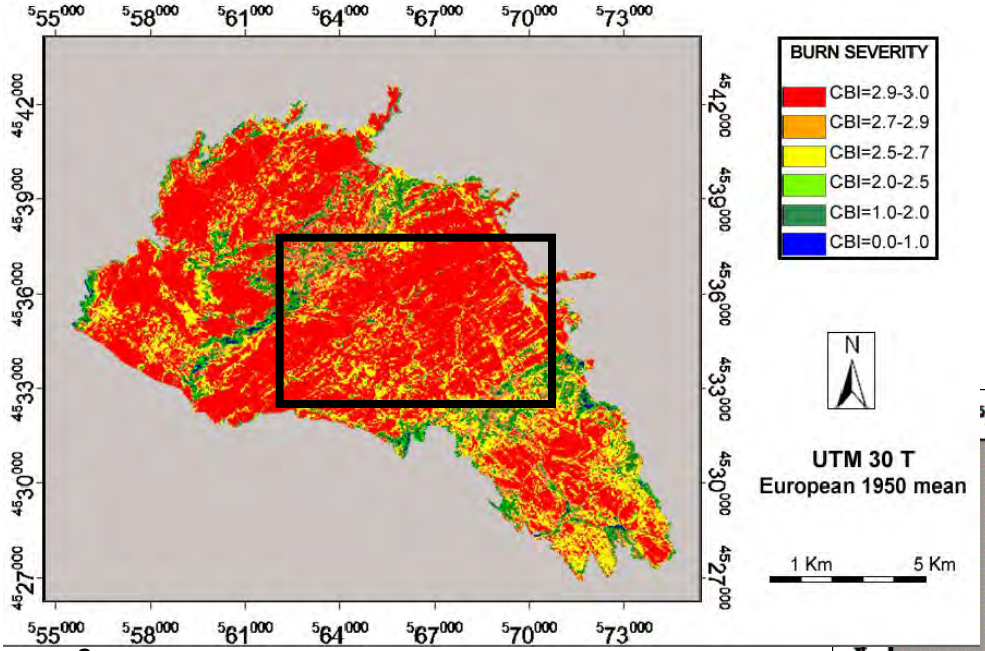


# BA trends of different products

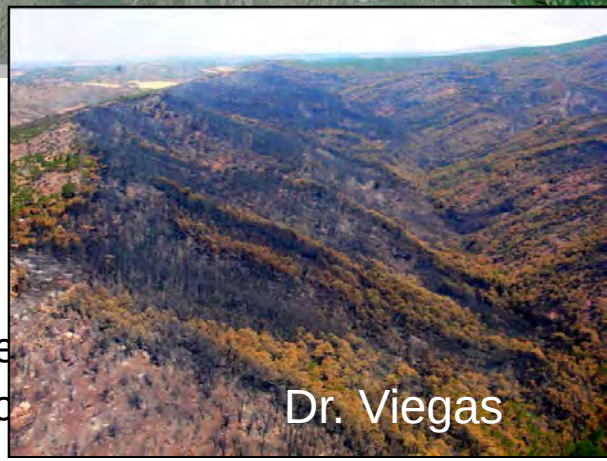


# Burn severity

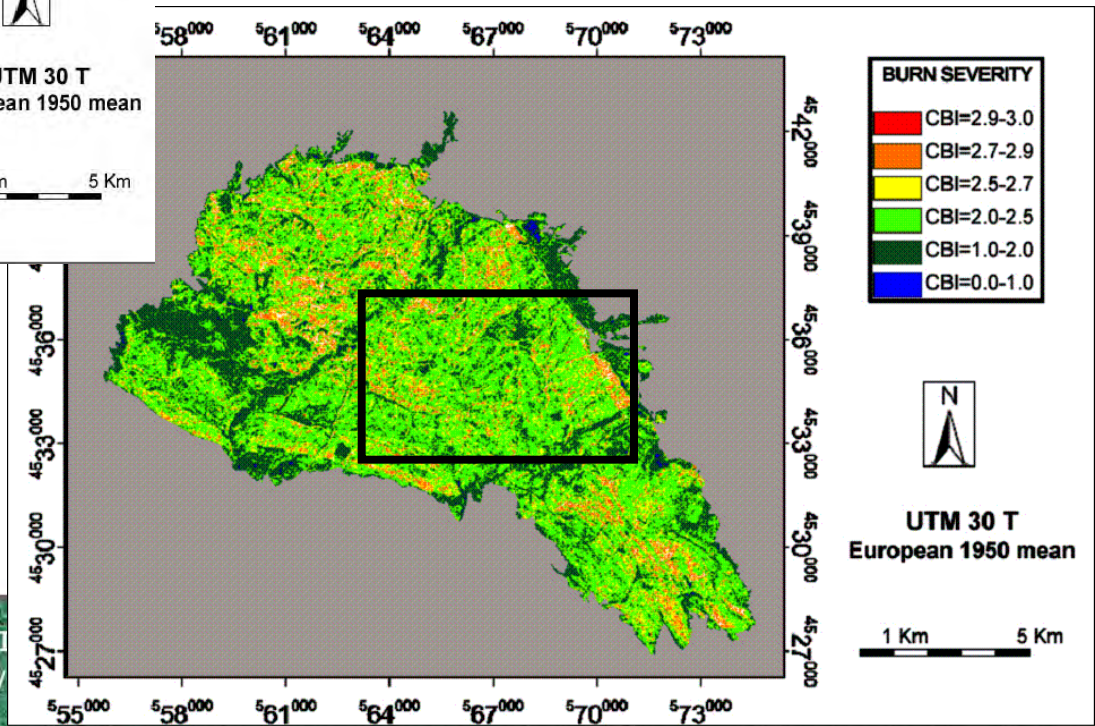
# Comparison with empirical model results




$R^2$= 0.66
Variables include
Tendency to smo

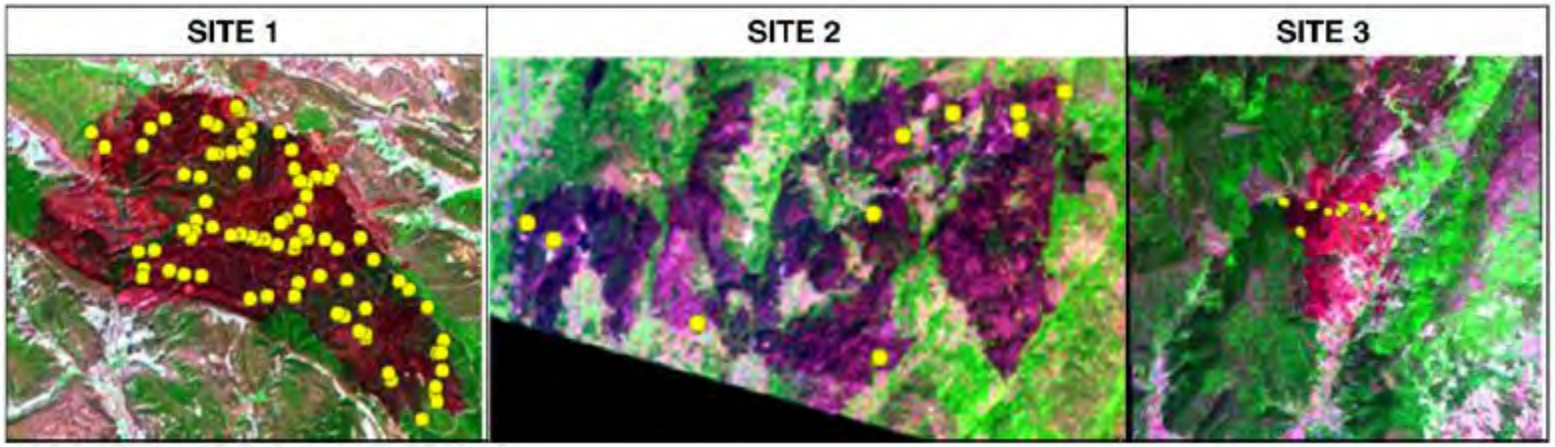



$R^2$= 0.63
Supervised simulation



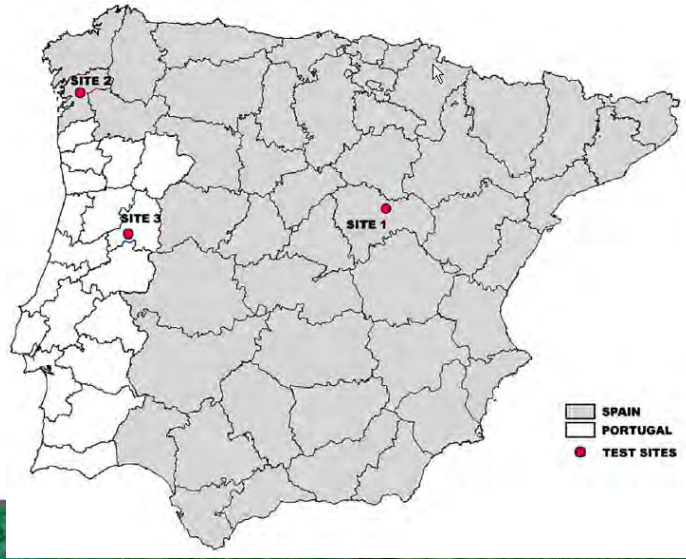

(De Santis and Chuvieco, 2007)

# Other sites



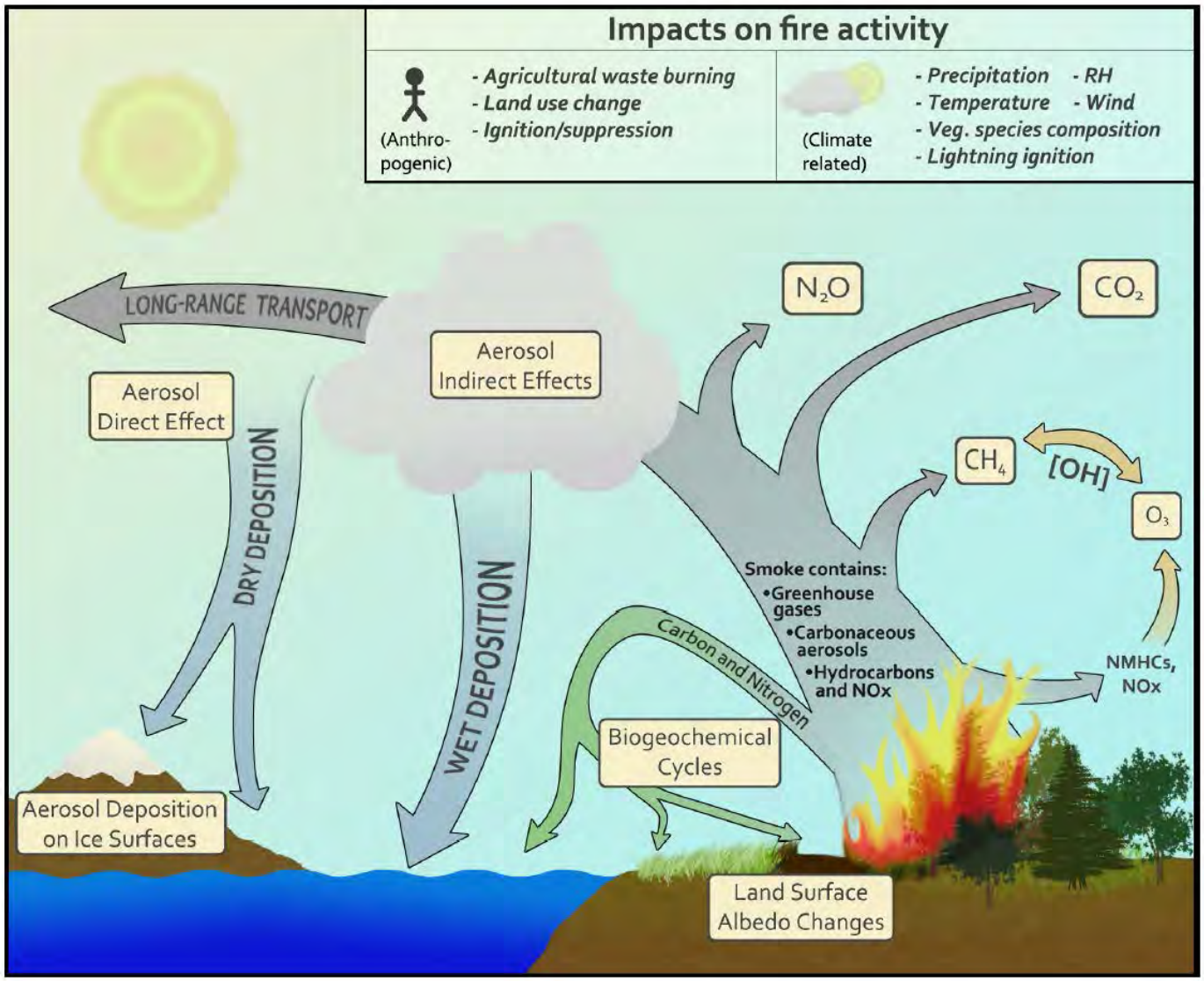

Validation results for the three study areas

| | Site 1 | Site 2 | Site 3 |
|---|---|---|---|
| Linear regression | $y=0.963x+0.032$ | $y=0.495x+1.443$ | $y=1.046x-0.062$ |
| $R^2$ | 0.43 | 0.69 | 0.96 |
| RMSE | 0.19 | 0.18 | 0.21 |




De Santis and Chuvieco, 2009, RSE

# Don miss the global approach!




Source: Ward et al., 2012


WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

# “Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)”

# Essential Climate Variables (ECV)



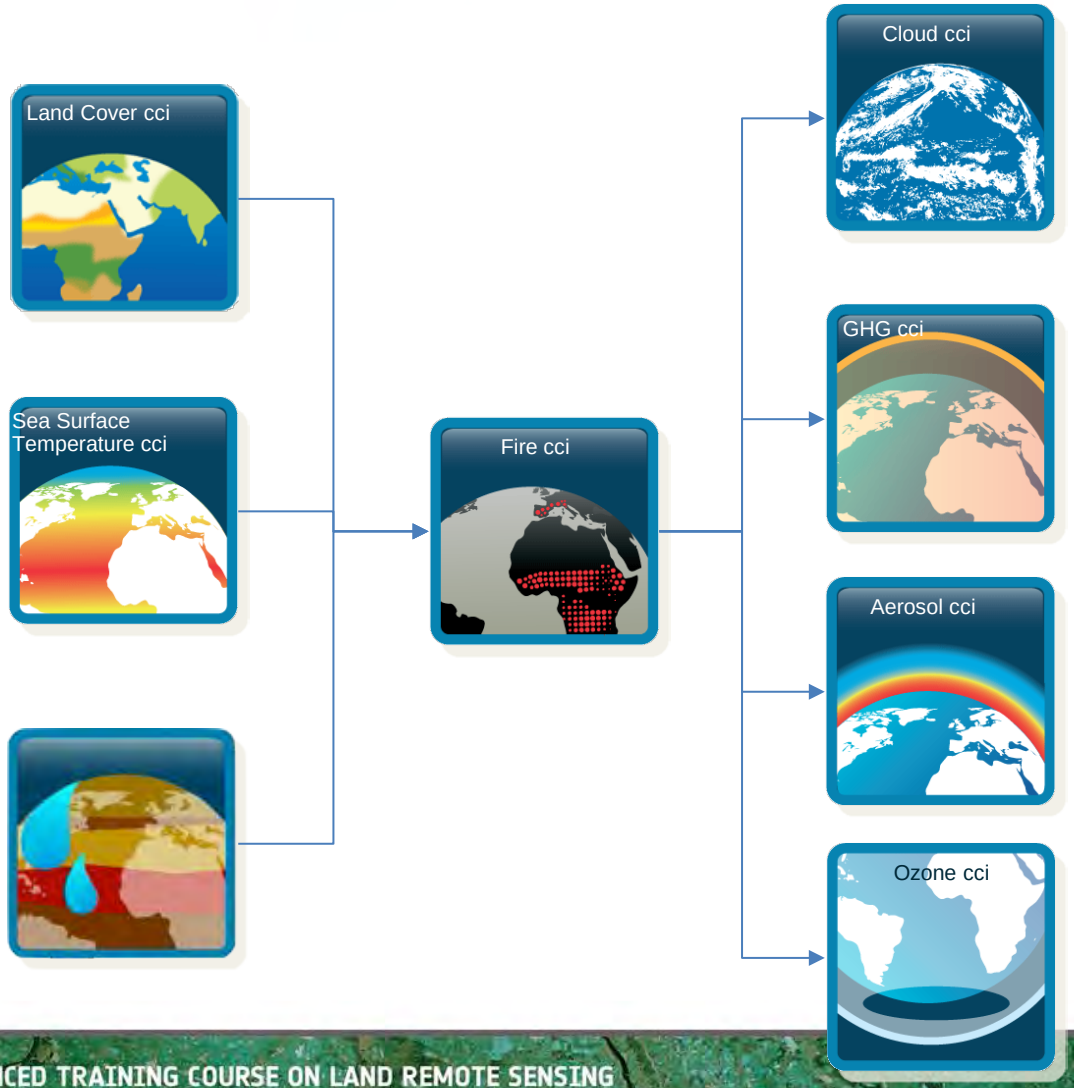
ECV Fire Disturbance

The following is required for this ECV:

- Burnt area (T.10)
- Active-fire maps (supplemental to T.10)
- Fire radiative power (FRP) (supplemental to T.10)

# ESA-CCI programme (ECV)

# Connections of Fire and other ECVs

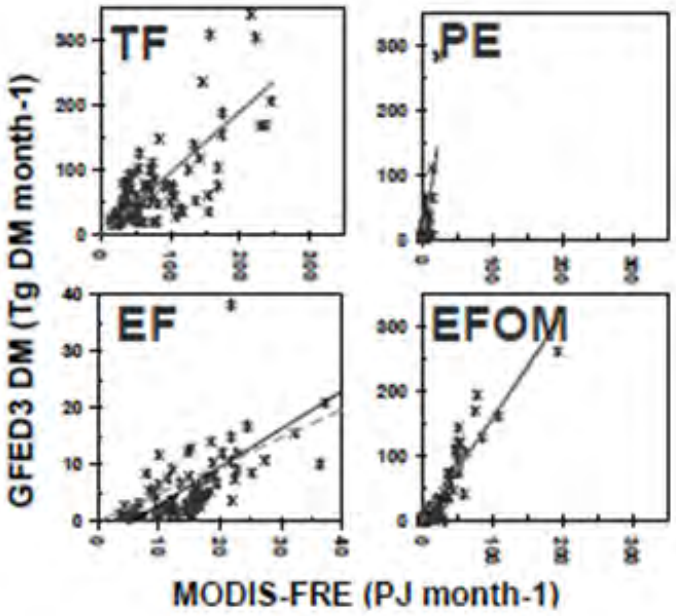


# Biomass emissions

- Bottom-up model: Seiler and Crutzen [1980] model:

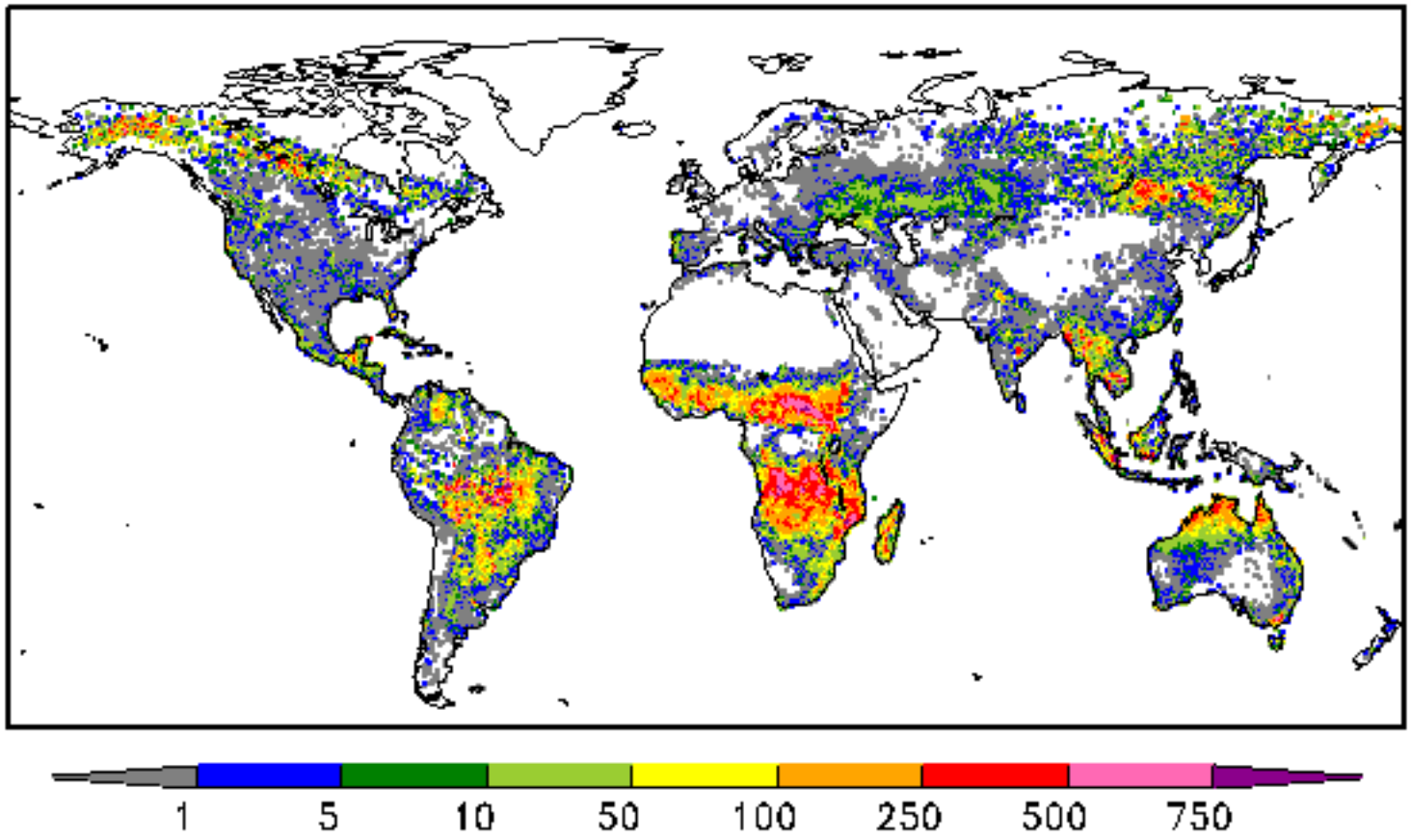
**E** (Emissions of Gas N) = **BA** (Burned Area) × **FL** (Fuel Loads) × **CC** (Combustion Completeness) × **EF** (Emission Factor)

- FRP related




Wooster et al., 2014

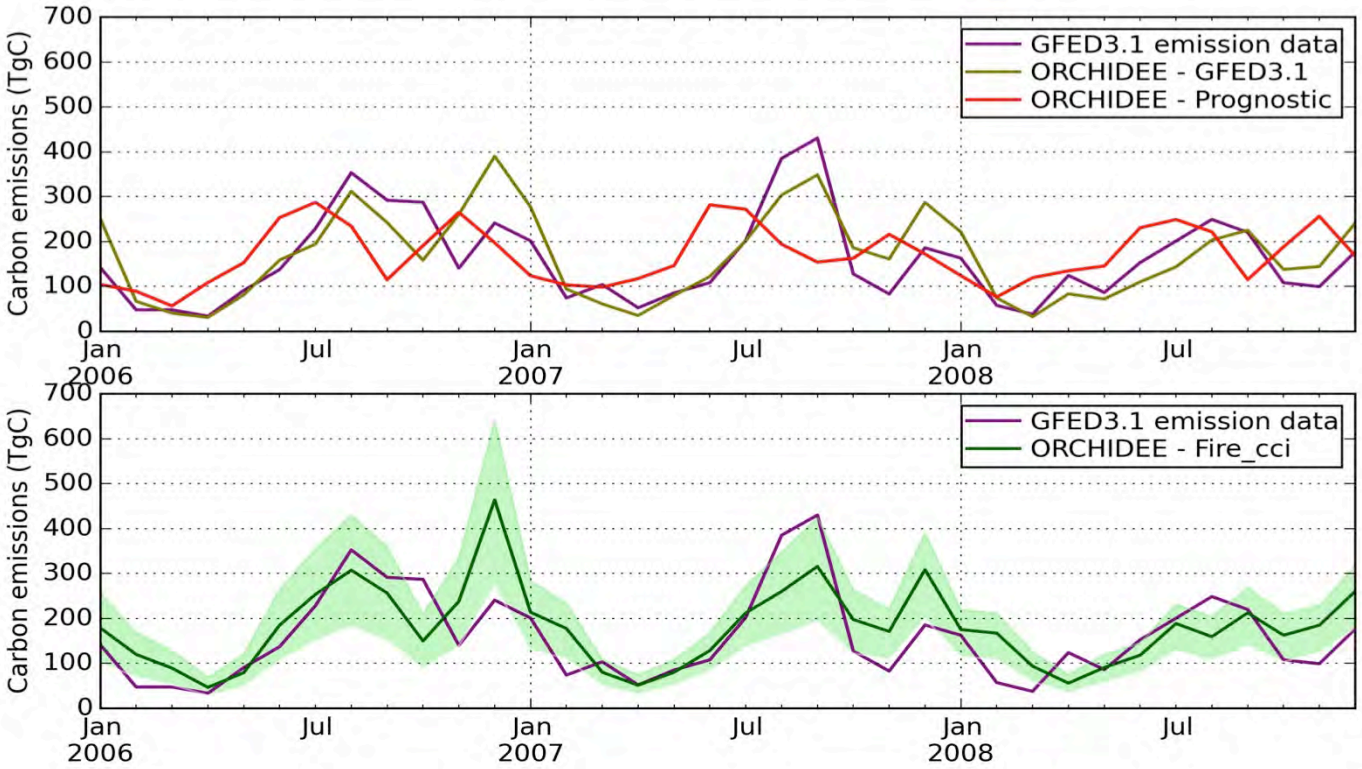
# Annual mean fire emissions 1997-2009a




DM burned [g DM m-2 year-1]

van der Werf et al., 2013 GFED3.1 Global Total: 4.0 Pg year-1

# Seasonal trends in carbon emissions




Yue et al., 2015

# Final remarks

- Fire is a very relevant global and regional issue.
- RS can contribute to the three phases of fire management:
  - Pre-fire: Fuel conditions and amount.
  - Active fires: detecion and fire properties.
  - Post-fire: burned area, severity and emissions.

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