Building a global fire climate record: The challenge of meeting the Essential Climate Variable requirements

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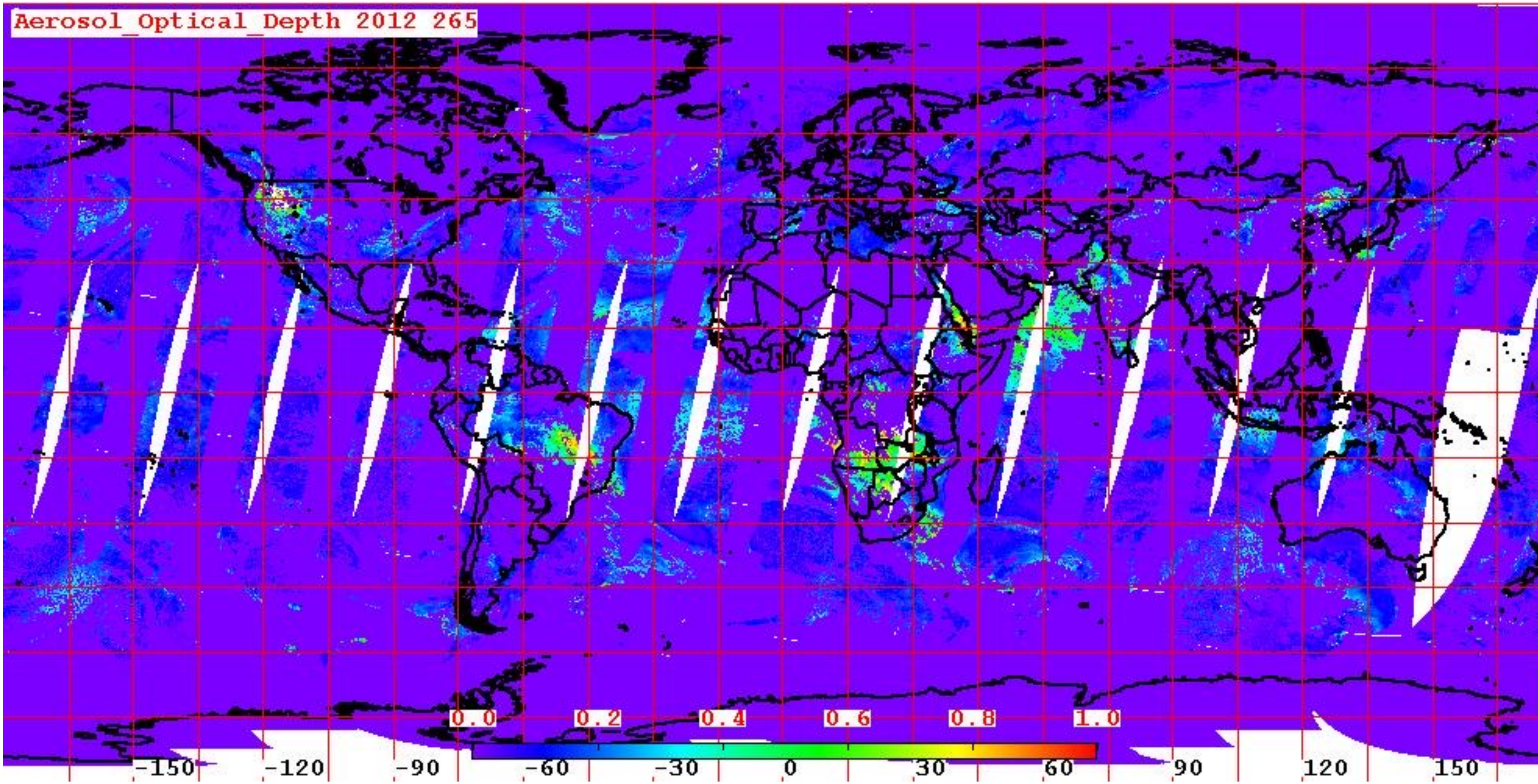
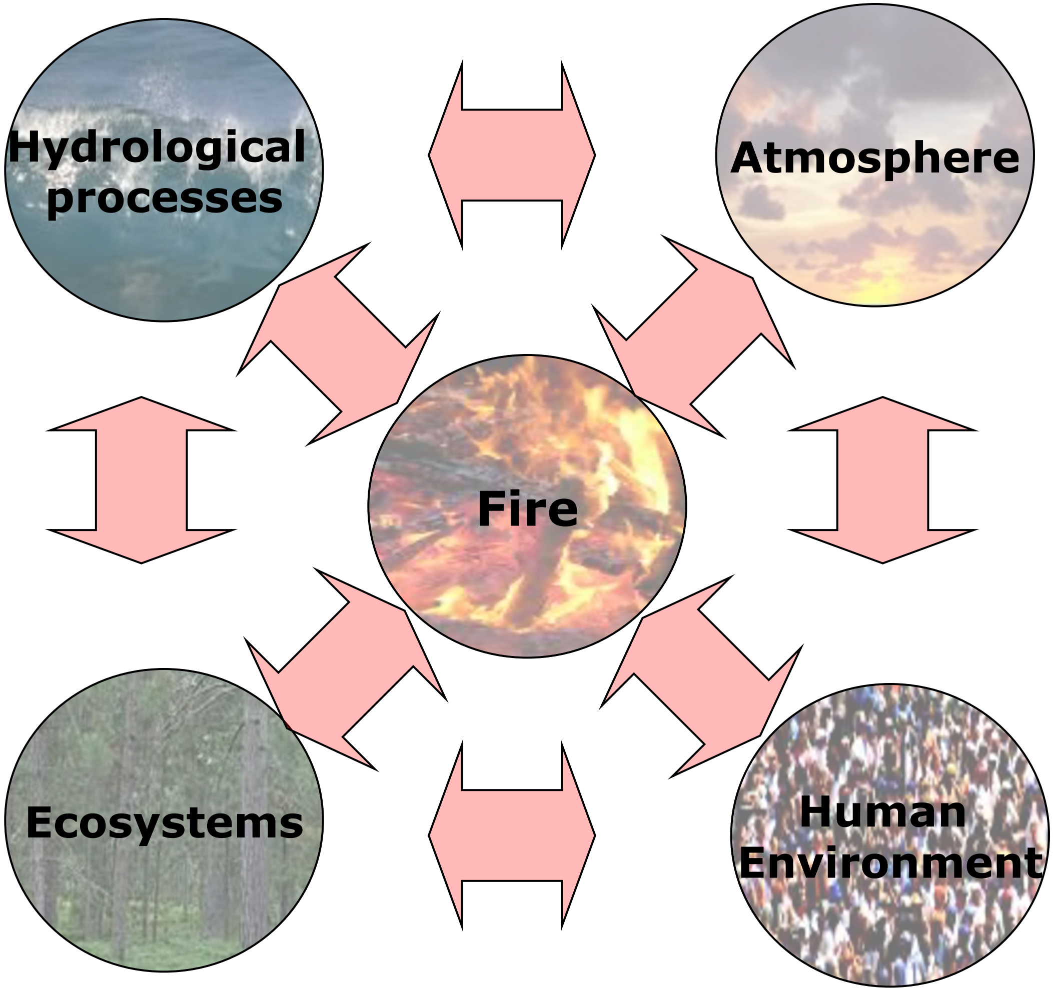
CEOS LPV CalVal
Frascati Jan 30 2014



Aerosol_Optical_Depth 2012 265
75
60
45
30
15
0
-15
-30
-45
-60
-75
0.0
0.2
0.4
0.6
0.8
1.0
-150
-120
-90
-60
-30
0
30
60
90
120
150

Why is a global View of Fire Important ?

- **Fire is a global phenomenon (biomass burning)**
- **Important and poorly understood Earth System process**
- **Multiple loops and feedbacks**



MAKING THE CASE FOR LONG TERM MEASUREMENTS

GLOBAL
CLIMATE
OBSERVING
SYSTEM

WMO · IOC of UNESCO · UNEP · ICSU

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

IMPLEMENTATION PLAN FOR THE GLOBAL OBSERVING SYSTEM FOR CLIMATE IN SUPPORT OF THE UNFCCC

October 2004

GCOS - 92

(WMO/TD No. 1219)

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL COUNCIL FOR SCIENCE

GCOS Implementation Plan

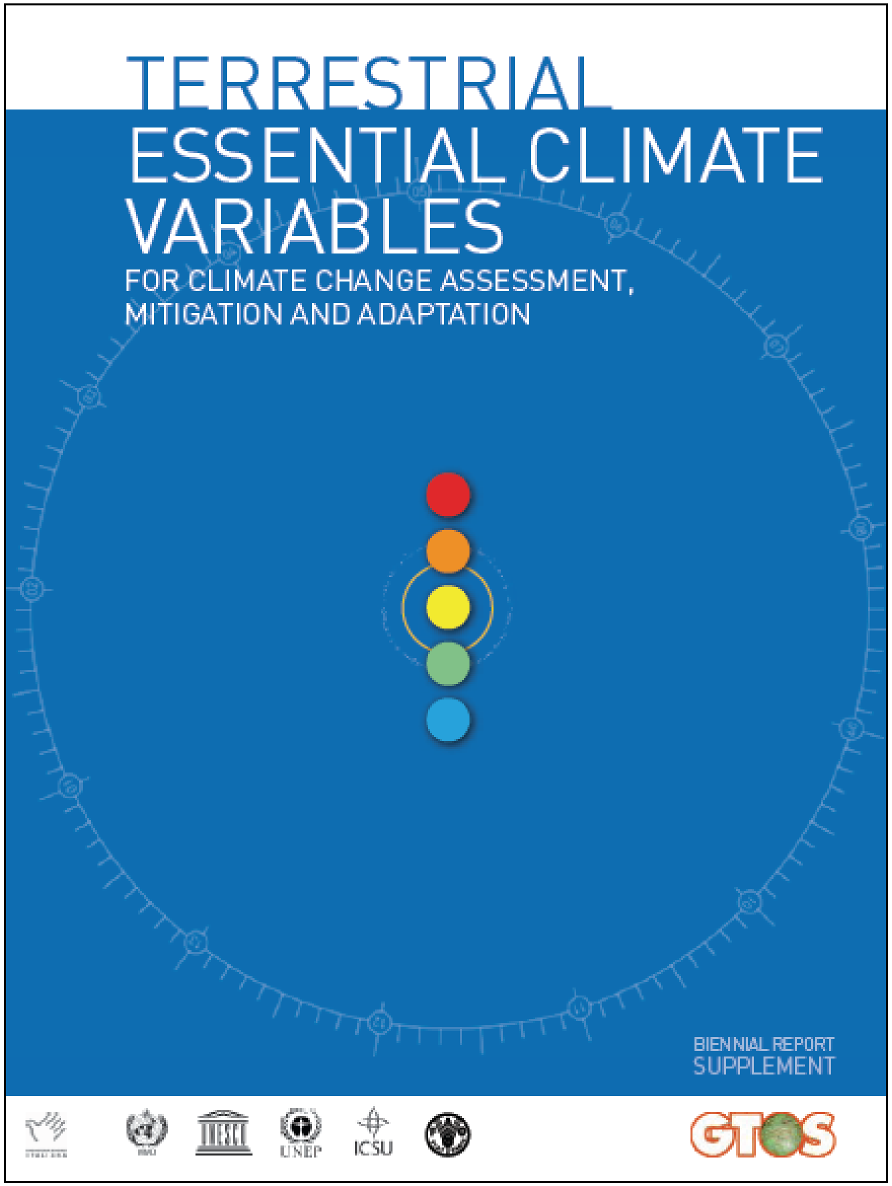
Essential Climate Variables (ECV)

Table 1. Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements.

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.
	Upper-air:	Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.
	Composition:	Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases[2], Aerosol properties.
Oceanic	**Surface:**	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.
Terrestrial[3]	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance.	

Fire disturbance ECV: burned area, active fire (suppl.) and fire radiated power (suppl.)

GTOS and Terrestrial ECVs



ECV T13

FIRE DISTURBANCE

Ivan Csiszar and Guido van der Werf

OBSERVATIONAL IMPORTANCE

Fire is an important ecosystem disturbance with varying return frequencies, resulting in land cover alteration and change, and atmospheric emissions on multiple time scales. Fire is also an important land management practice and is an important natural abiotic agent in fire-dependent ecosystems. The Fire Disturbance Essential Climate Variable (ECV) consists of burnt-area maps, supplemented by active fires; High-Temperature Events (HTE); and Fire Radiated Power (FRP). Information on fire activity is used for global change research, estimating atmospheric emissions and developing periodic global and regional assessments, and also for planning and operational purposes (fire management, local to national) and development of informed policies (national and international, e.g. IPCC).

OBSERVATIONS

Due to the large spatial and temporal variability in fire activity, satellite data provides the most useful means to monitor fire. There exist polar and geostationary systems with full operational status and experimental systems providing systematic observations that have been used for the creation of long-term data fire mapping. Major long-term global records of active fires have been generated by ESA (ATSR World Fire Atlas) and NASA (TRMM and MODIS). Geostationary fire monitoring has been undertaken using GOES (WF-ABBA) and MSG SEVIRI (EUMETSAT Active Fire Monitoring). Future systems, such as NPP/NPOESS Visible Infrared Imagery Radiometer Suite (VIIRS) and sensors on Global Monitoring for Environment and Security (GMES) Sentinel satellites and the provision of baseline high resolution fire observations for product validation should ensure the continuity of fire mapping and detection capabilities.

The only long-term burnt area dataset available at the moment is also partly based on active fire detections GFED2, but true multi-year burnt area products are about to be released (MODIS, L3JRC, GLOBCARBON). Validation with *in situ* measurements is limited to only certain regions and is lacking, especially in developing countries. In other regions, calibration with high-resolution satellite data provides the best means for validation. Estimating emissions from these active fire detections or burnt areas has improved recently, with the use of biogeochemical models, but fails to capture fine-scale fire processes due to coarse resolutions. With the new burnt area products, this situation will probably be improved.

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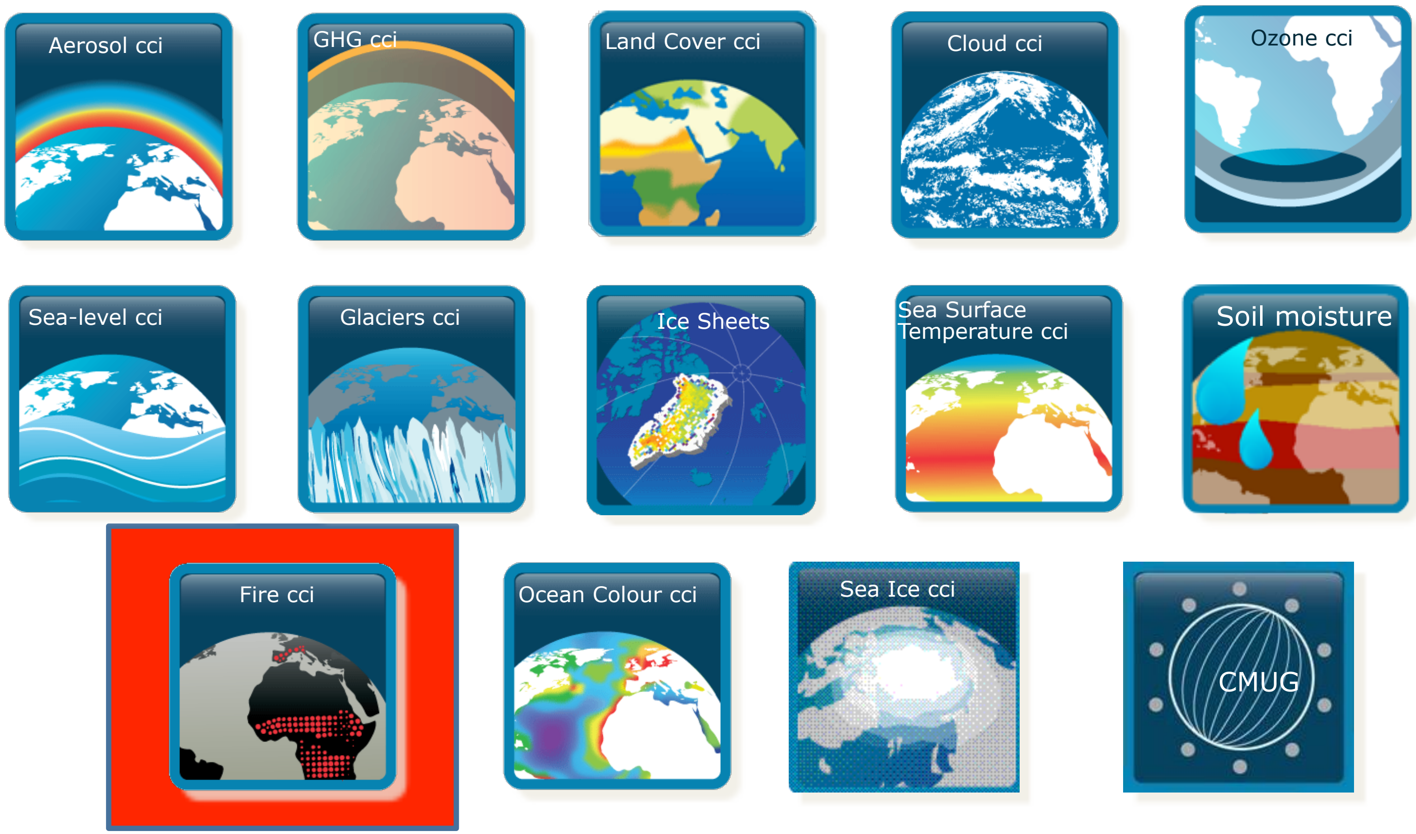
RELATED LINKS (BURNT AREA PRODUCTS UNDER DEVELOPMENT)

Part of GEO Task CL-06-03

ESA-CCI programme



ECV or supporting variable[19]	Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)	Product Numbers (IP-10 Reference Actions)
Lakes	Lake levels and areas of lakes in the Global Terrestrial Network for Lakes (GTN-L)	VIS/NIR imager radiances, and radar imager radiances Altimetry	T.1.1 T.1.2 (T8)
Snow Cover	Snow areal extent, supplemented by snow water equivalent	Moderate-resolution VIS/NIR/IR and passive microwave imager radiances	T.2 (T16)
Glaciers and Ice Caps	2D vector outlines of glaciers and ice caps (delineating glacier area), supplemented by digital elevation models for drainage divides and topographic parameters	High-resolution VIS/NIR/SWIR optical imager radiances, supplemented by microwave InSAR and along-track optical stereo imaging	T.3.1 T.3.2 (T17)
Ice Sheets	Ice-sheet elevation changes, supplemented by fields of ice velocity and ice-mass change	Radar and laser altimetry, supplemented by:SAR, gravity	T.4 (T20)
Albedo	Reflectance anisotropy (BRDF), black-sky and white-sky albedo	Multispectral and multiangular imager radiances	T.5 (T3, T24, T25)
Land Cover	Moderate-resolution maps of land-cover type High-resolution maps of land-cover type, for the detection of land-cover change	Moderate-resolution multispectral VIS/NIR imager radiances High-resolution multispectral VIS/NIR imager radiances, supplemented by radar	T.6.1 T.6.2 (T26, T27, T28)
FAPAR	Maps of the Fraction of Absorbed Photosynthetically Active Radiation	VIS/NIR multispectral imager radiances	T.7 (T3, T29, T31)
LAI	Maps of Leaf Area Index	VIS/NIR multispectral imager radiances	T.8 (T3, T30, T29,T31)
Biomass	Regional and global above-ground forest biomass	Long-wavelength radar and lidar	T.9 (T32)
Fire Disturbance	Maps of burnt area, supplemented by active-fire maps and fire-radiative power	VIS/NIR/SWIR/TIR moderate-resolution multispectral imager radiances	T.10 (T35, T36, T37, T38, T39)
Soil Moisture	Research towards global near-surface soil-moisture map (up to 10cm soil depth)	Active and passive microwave	T.11 (T13, T14)
Land-surface Temperature	Land-surface temperature records to support generation of land ECVs	High-resolution IR radiances from geostationary and polar-orbiting satellites; Microwave radiances from polar-orbiting satellites	T.12 (T5, T13, T23, T27, T28)

The Fire ECV

Essential climate variables provide long term monitoring in support of UNFCC.

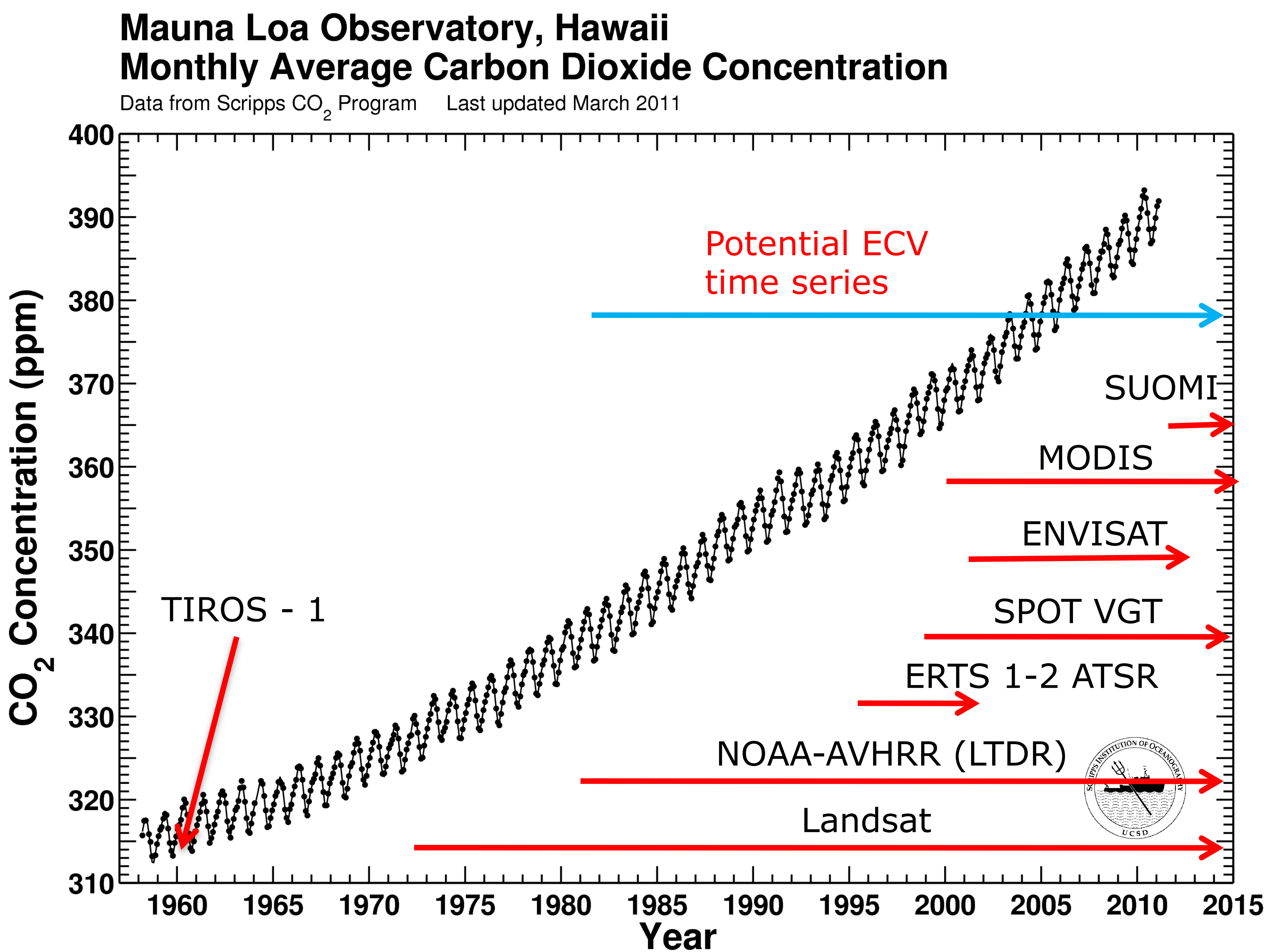
Application domains of the Fire ECV:

greenhouse gas estimations (primary application)

Carbon budget assessments

Dynamic vegetation modeling

Natural Hazards Management


Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program
Last updated March 2011
CO2 Concentration (ppm)
Year
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Potential ECV
time series
SUOMI
MODIS
ENVISAT
SPOT VGT
ERTS 1-2 ATSR
NOAA-AVHRR (LTDR)
Landsat
TIROS - 1

MODIS launched on EOS Terra

Terra Launch: Dec. 18, 1999
First Image: Feb. 24, 2000

MODIS launched on EOS Terra & Aqua satellites

Terra Launch: Dec. 18, 1999
First Image: Feb. 24, 2000

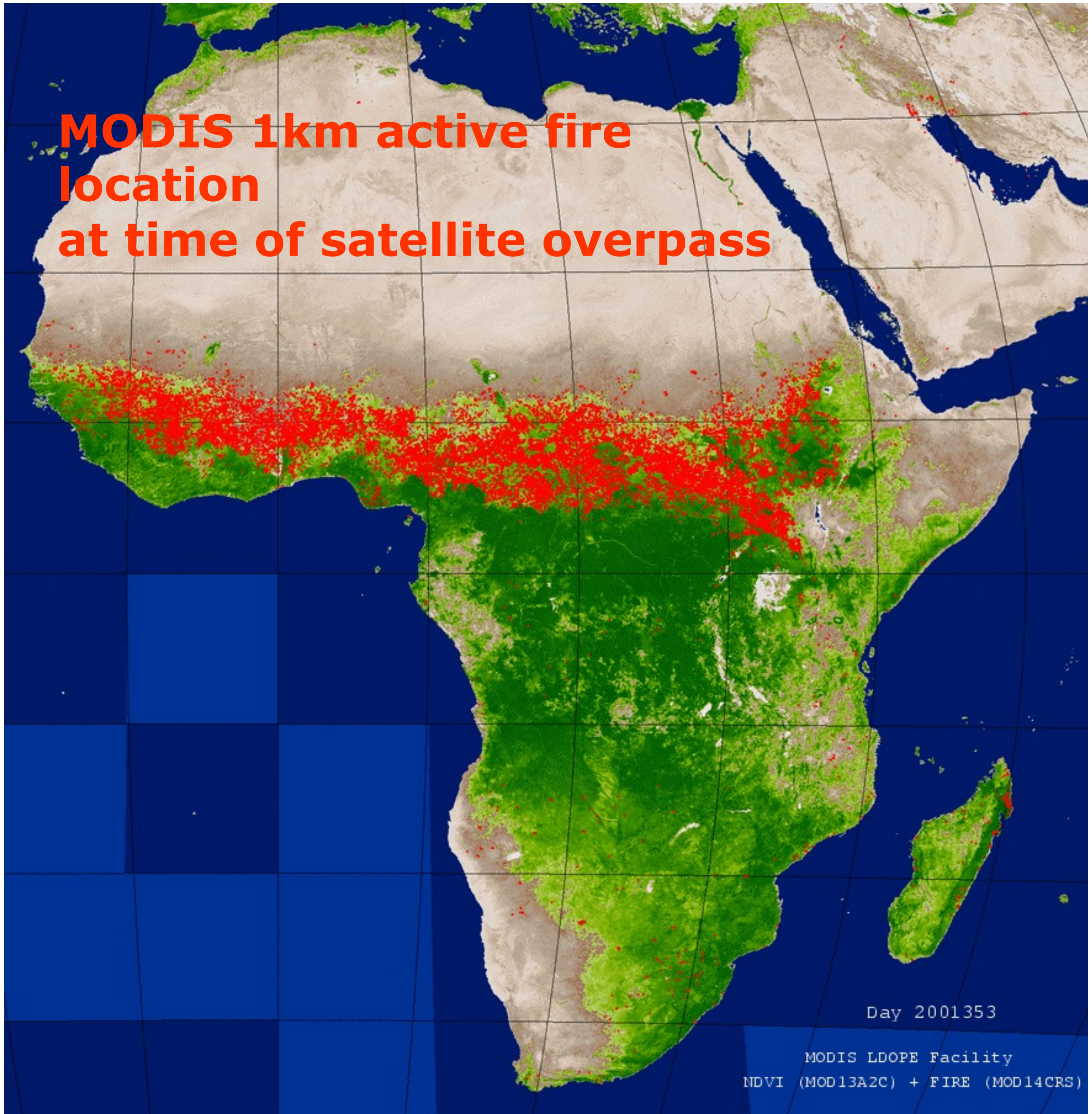
Aqua Launch: May 04, 2002
First Image: June 26, 2002

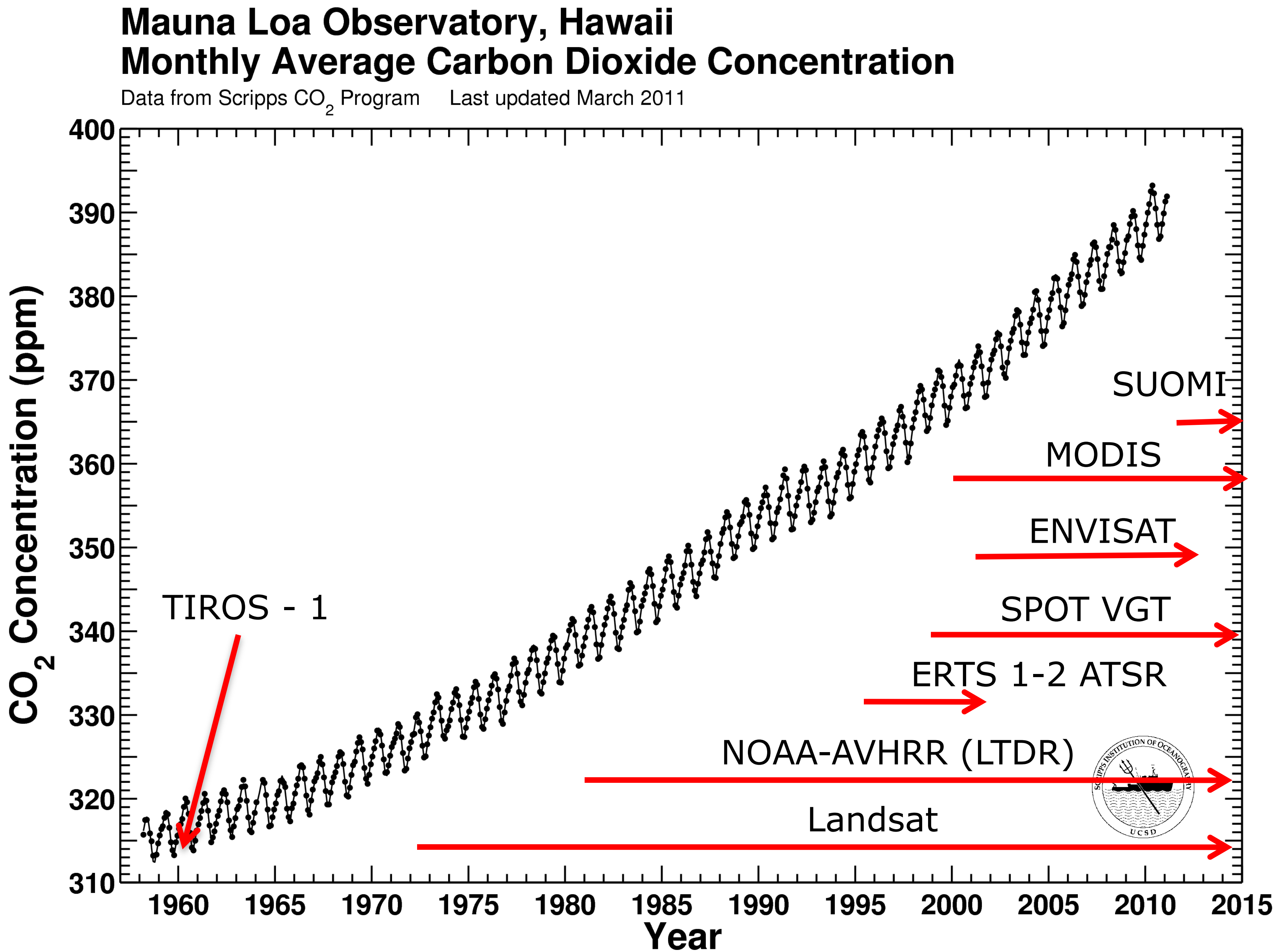
‘Ten Year’ Achievement: Daily, Global, monitoring of spatio-temporal fire dynamics, since 2000, for a sensor that is specifically designed to do this

2001 animation

1km MODIS active fire detections (red)

superimposed on MODIS 16 day NDVI




Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO_2 Program   Last updated March 2011
CO_2 Concentration (ppm)
Year
400
390
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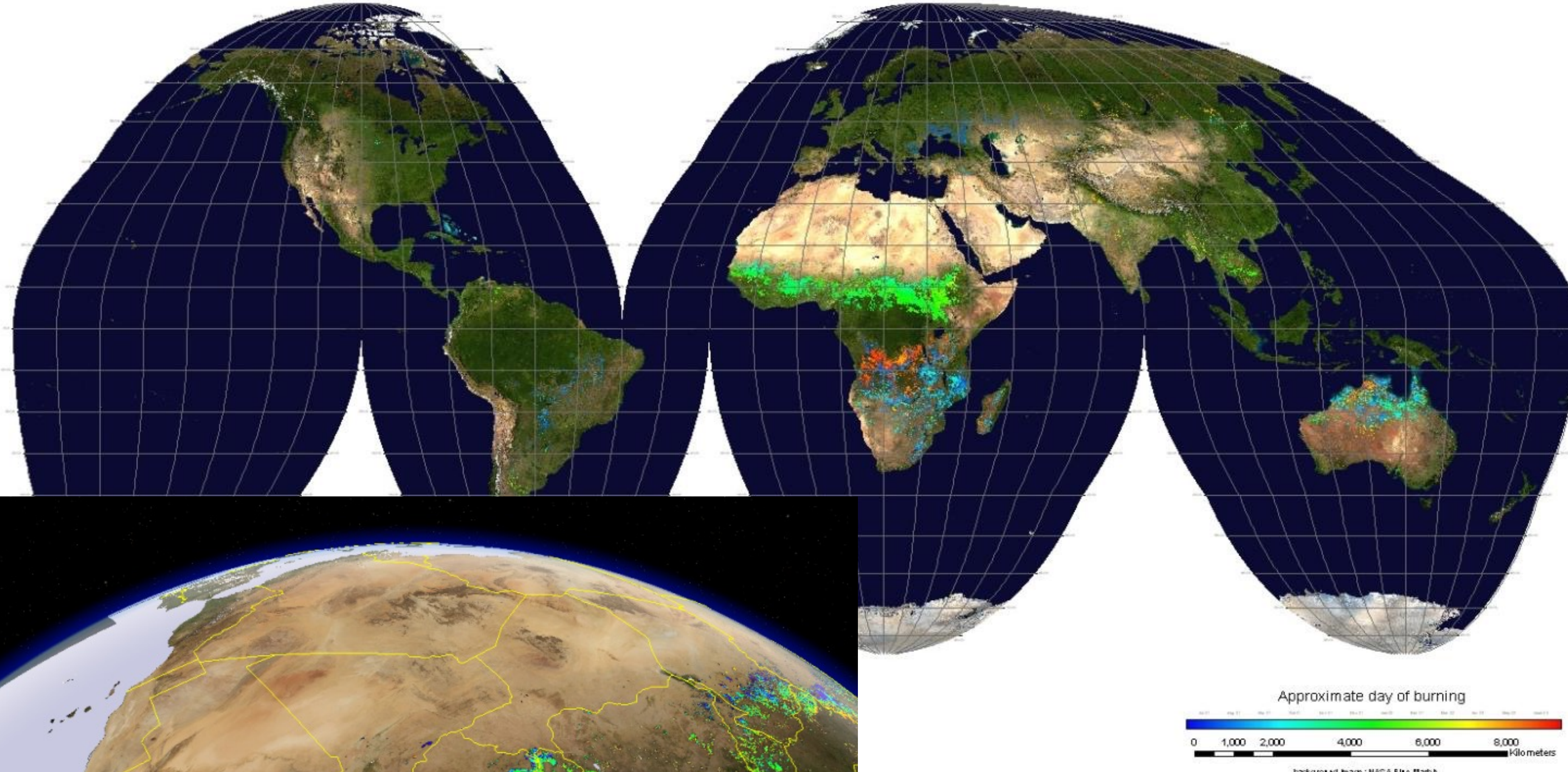
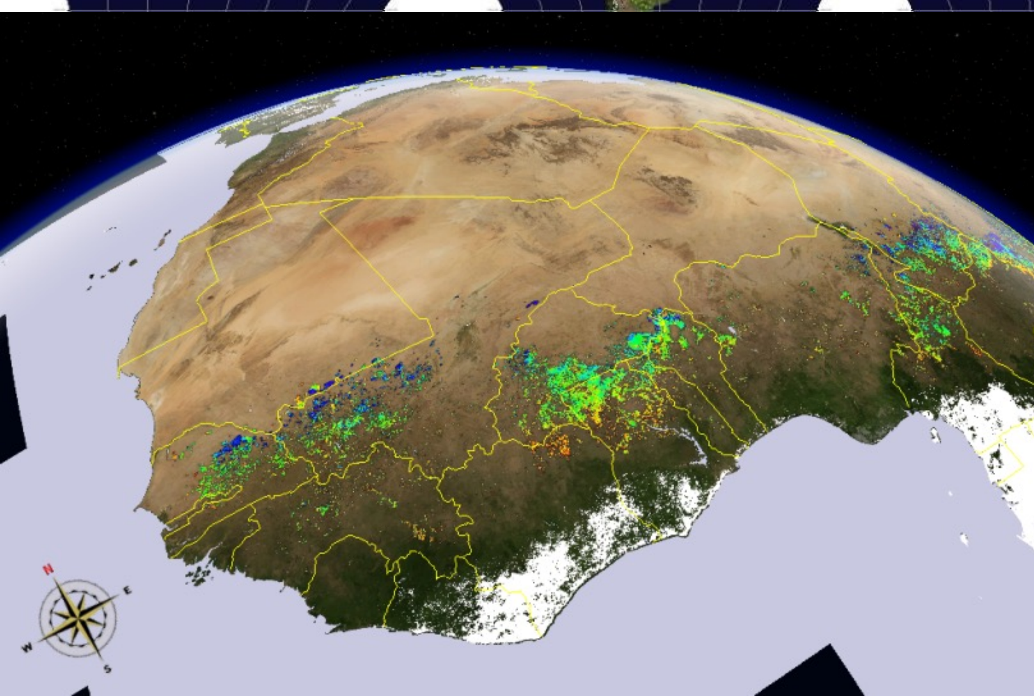
2015
TIROS - 1
SUOMI
MODIS
ENVISAT
SPOT VGT
ERTS 1-2 ATSR
NOAA-AVHRR (LTDR)
Landsat

Global Burned Area (MODIS)

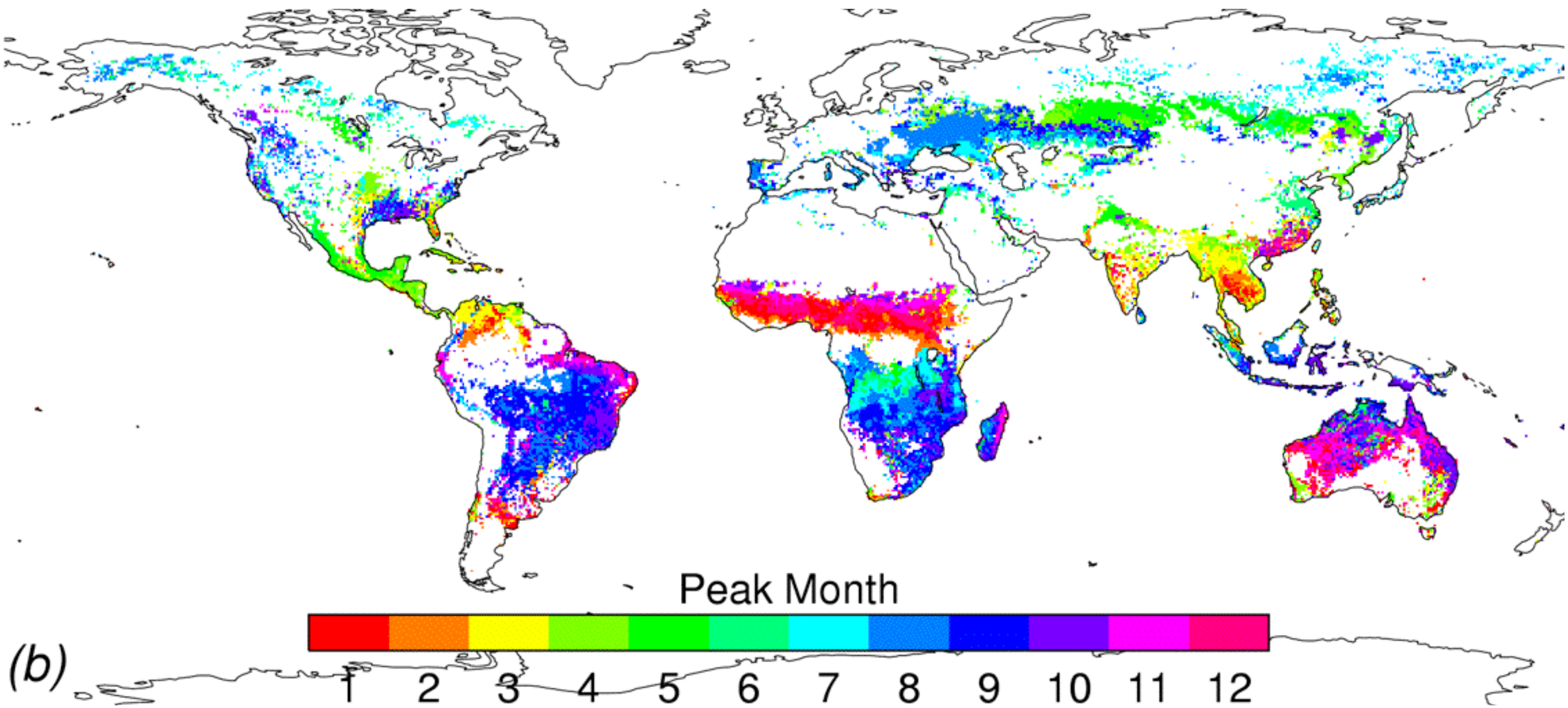




- Global Product 500m
- Monthly Composite – showing date of burning

(Roy and Boschetti

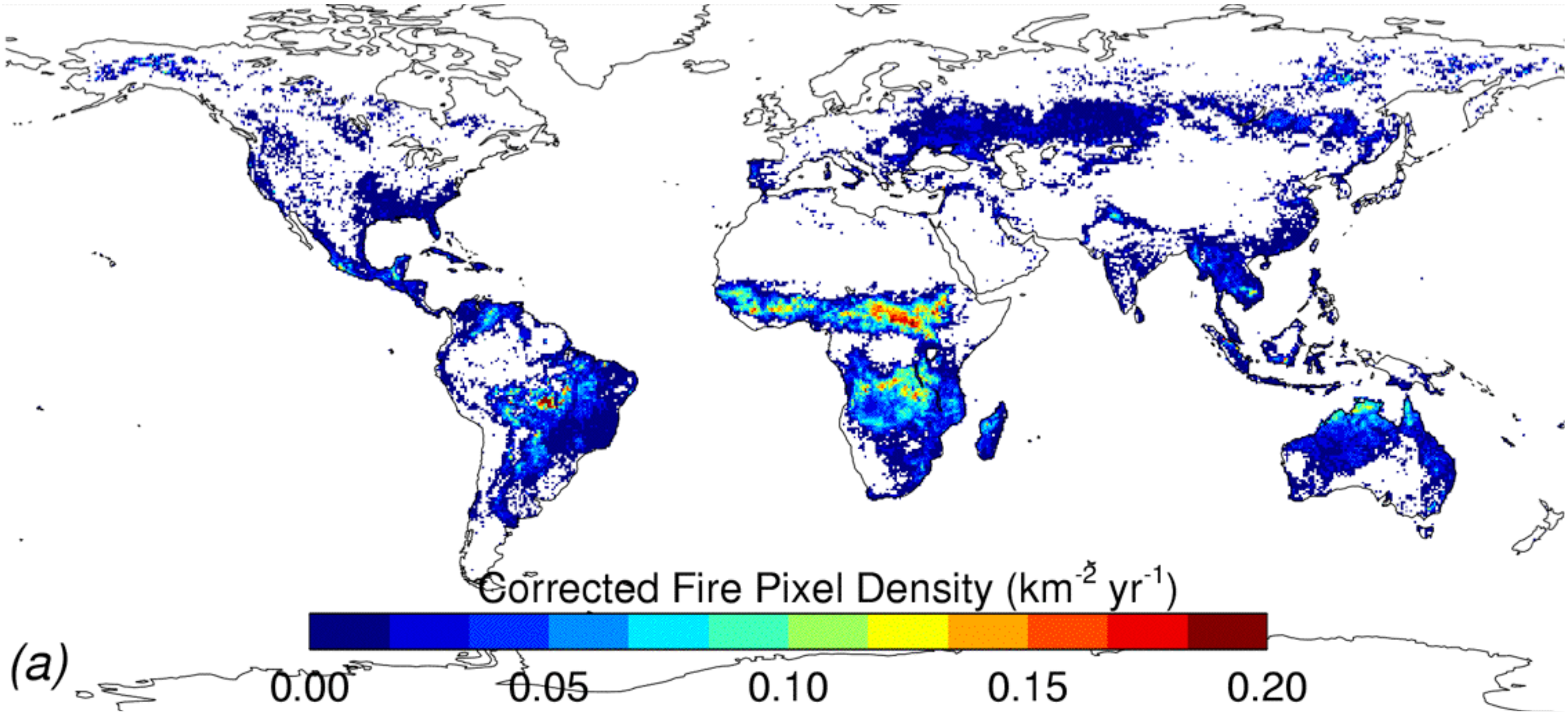
‘Ten Year’ Achievement:
Global Fire Regime Characterization



Peak Fire Month
(Terra MODIS; Nov. 2001 - Oct. 2005)

Giglio et al., 2006

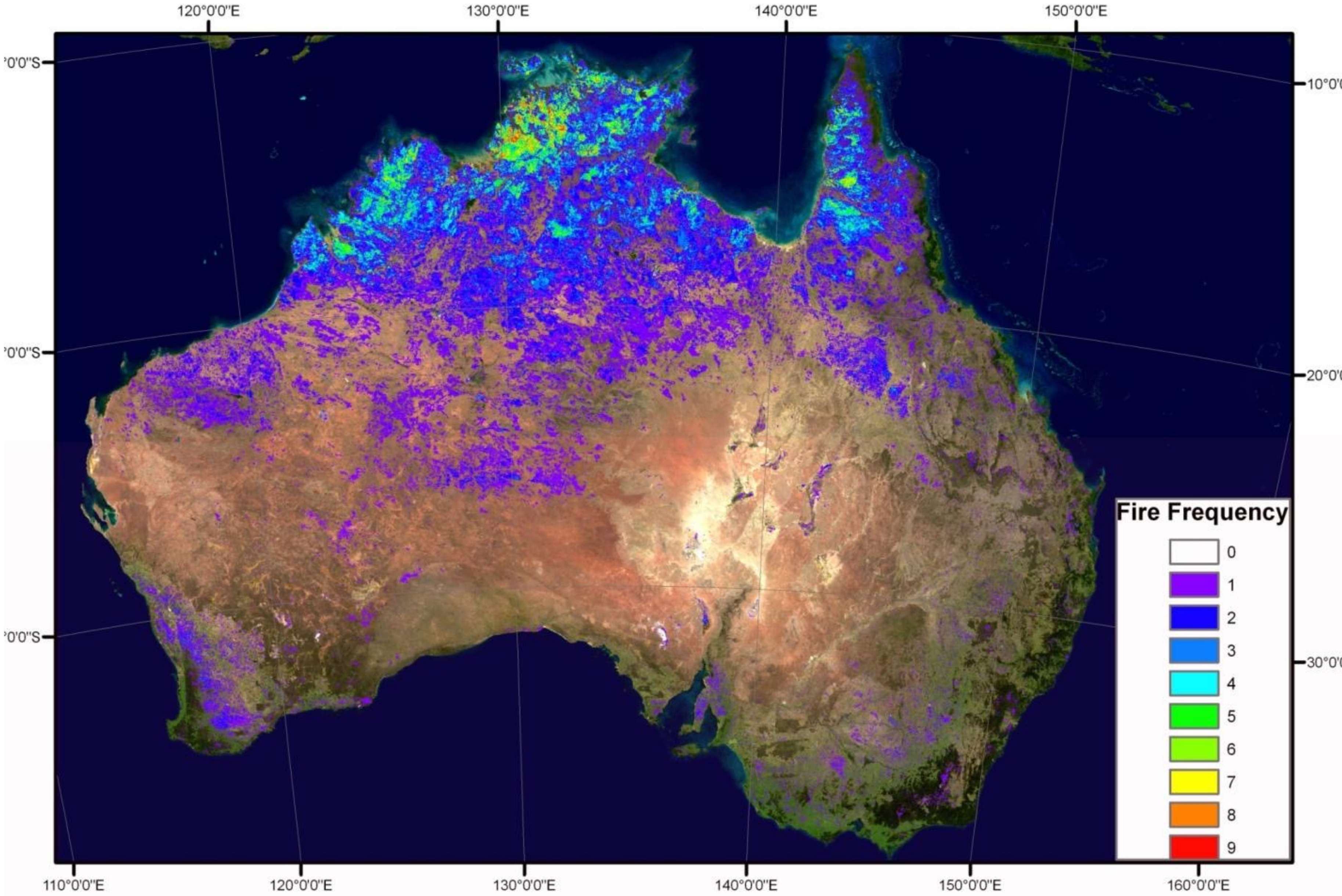
'Ten Year' Achievement:
Global Fire Regime Characterization



Peak Fire Month Mean Fire Pixel Density
(Terra MODIS mean ; Nov. 2001 - Oct. 2005)

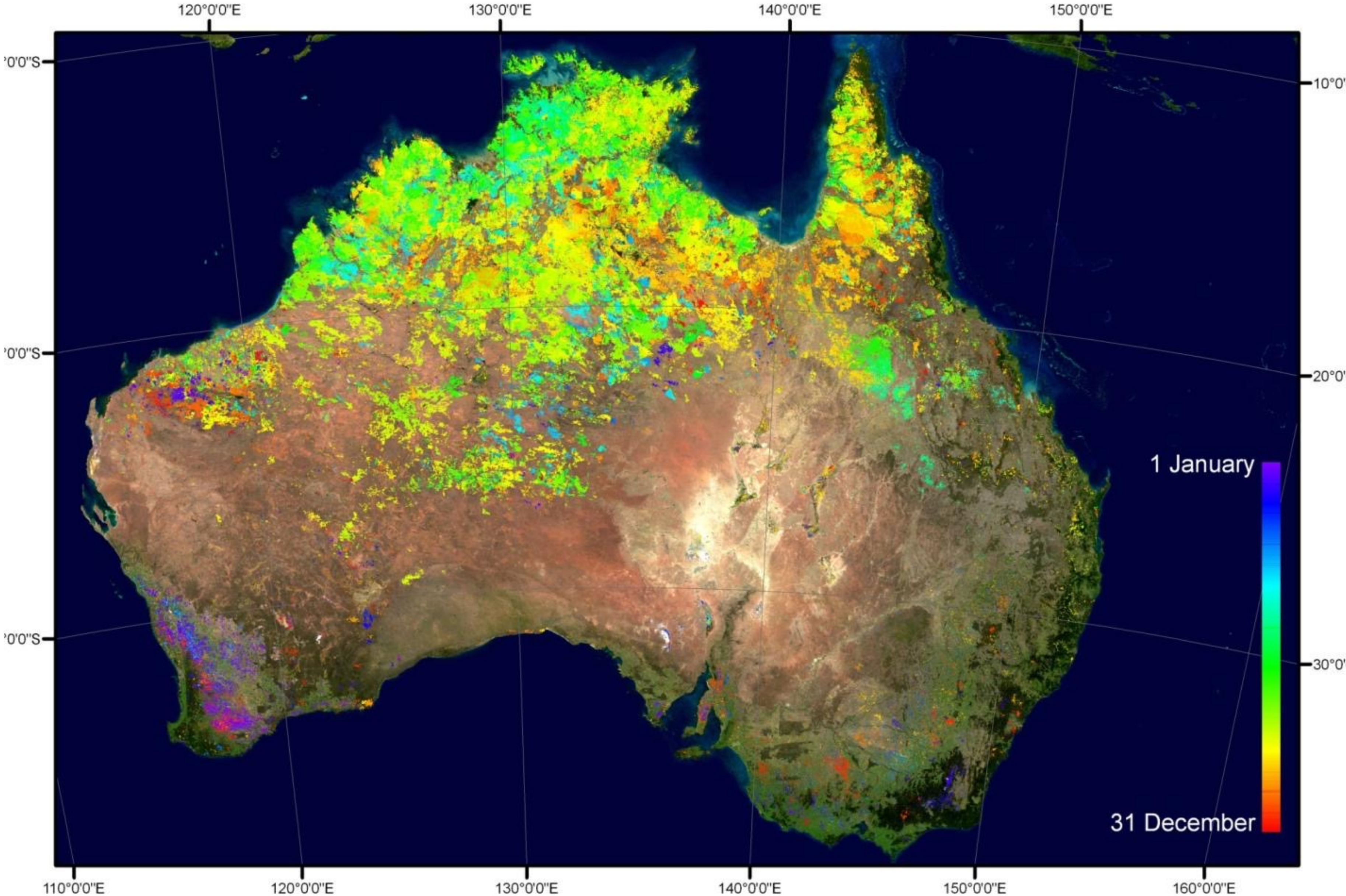
Giglio et al., 2007

MODIS Burned Area Frequency



Boschetti, Roy and Justice

MODIS Burned Area Median Date



2000 - 2008 Boschetti, Roy and Justice

The Fire ECV

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

Three key points

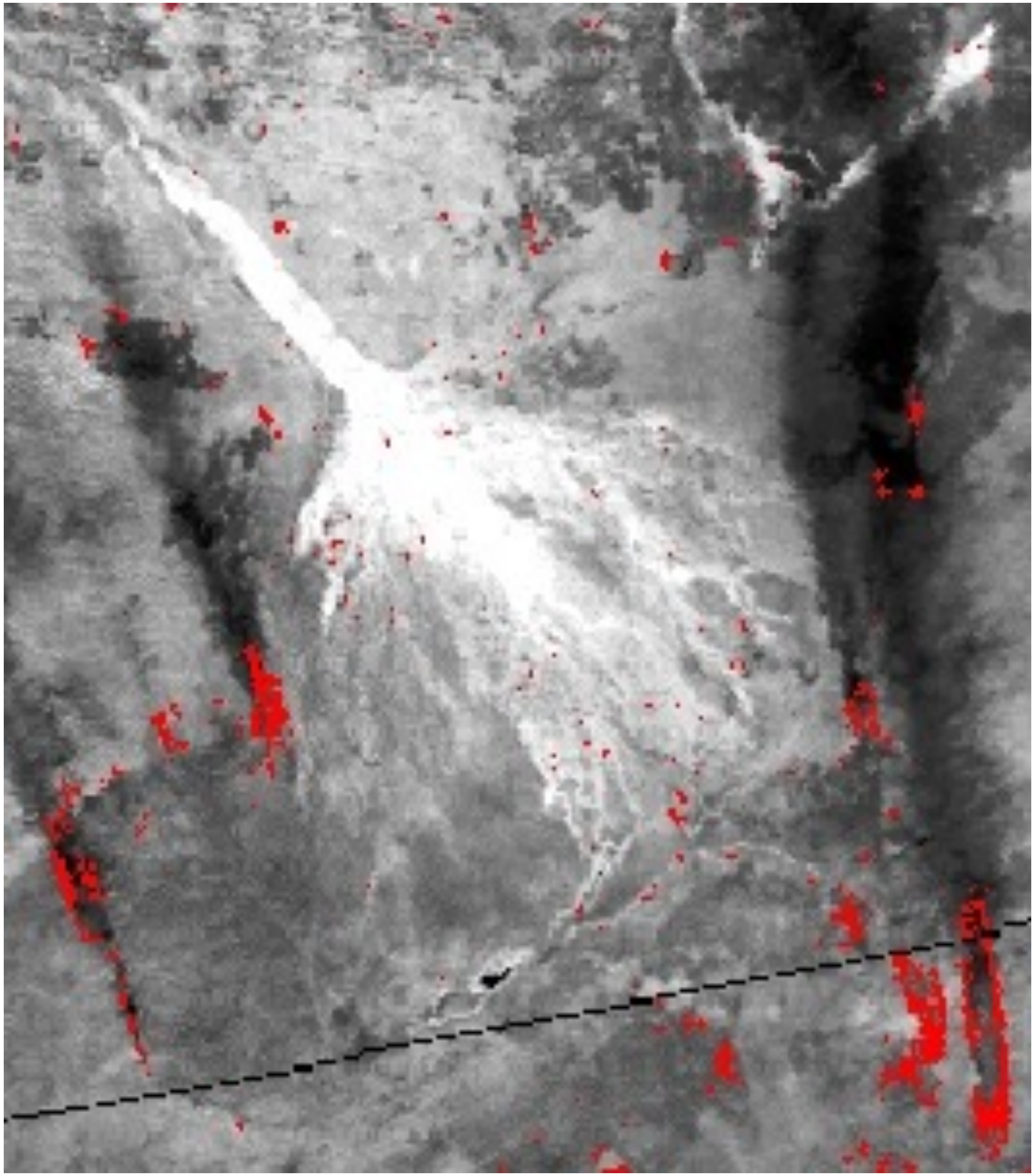
Expanding the data record to the past

Assessing if a product meets the ECV requirements (Validation techniques)

Improving the spatial resolution

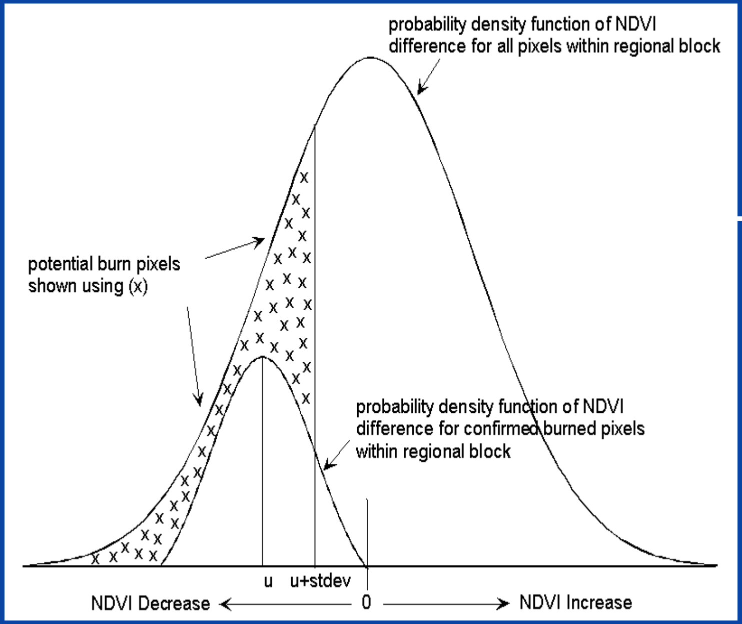
AVHRR Heritage:

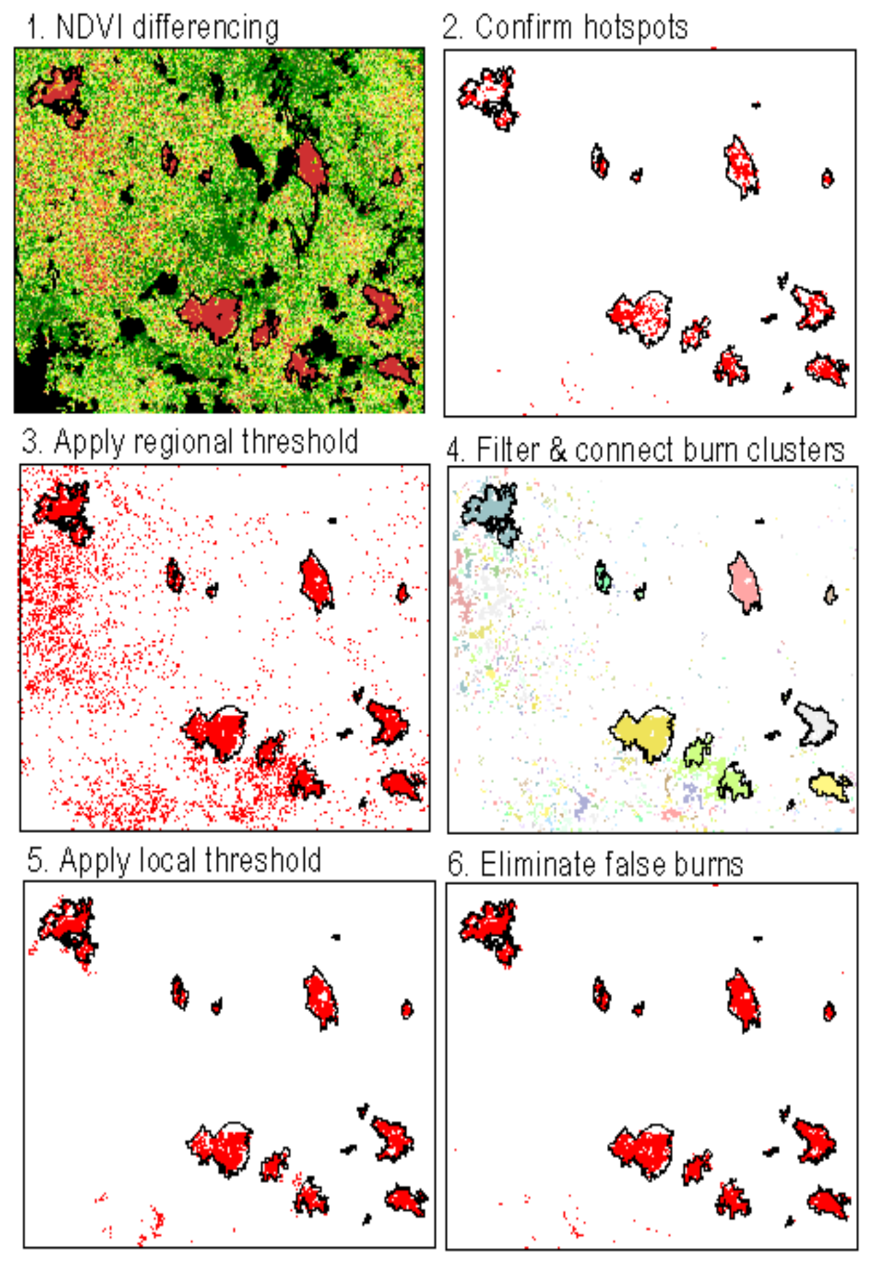
burned area statistics estimated from Active Fire Detections



AVHRR active fires (red) on NDVI
Okavango Delta, Botswana,
September 6th 1989

Burned area mapping by combining AVHRR hotspots and change detection (HANDS)

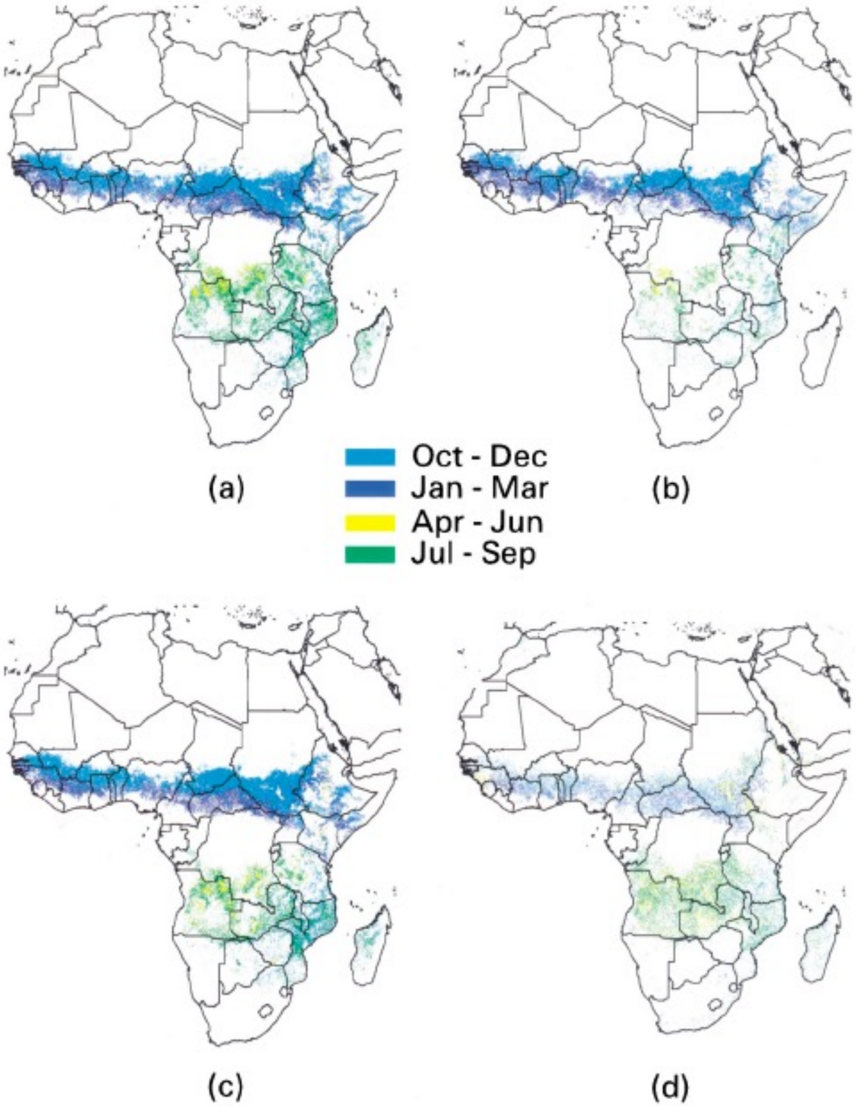




Potential burned pixel if:

$NDVI_{diff} < NDVI_{diff(mean)} + NDVI_{diff(stdev)}$

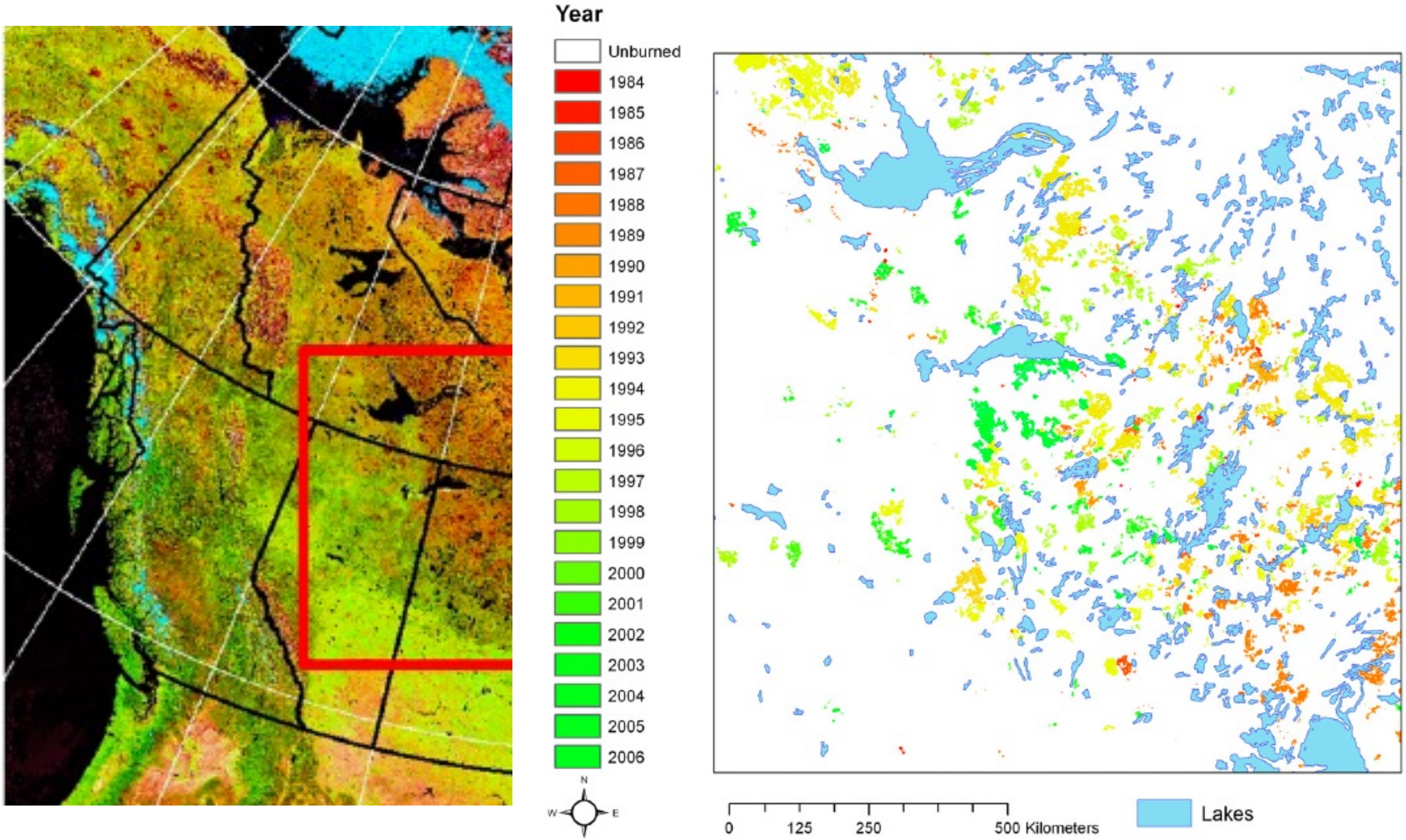
AVHRR burned areas



Barbosa et al,2007

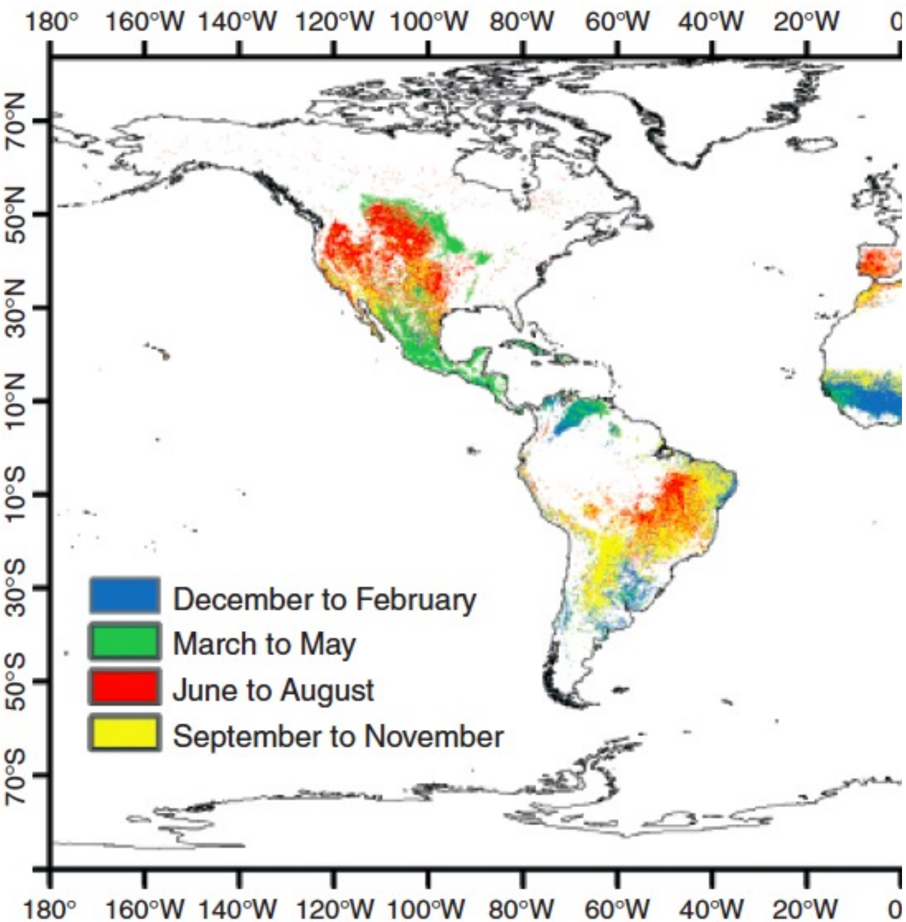
Figure 3. Comparison of the Burned Area Algorithm maps with the SAI/IGBP-DIS GFP active fire map: a) BAA 1985/86, b) BAA 1986/87, c) BAA 1990/91, d) GFP 1992/93.

AVHRR burned areas



(Chuvieco et al, 2008)

Sensitivity issues



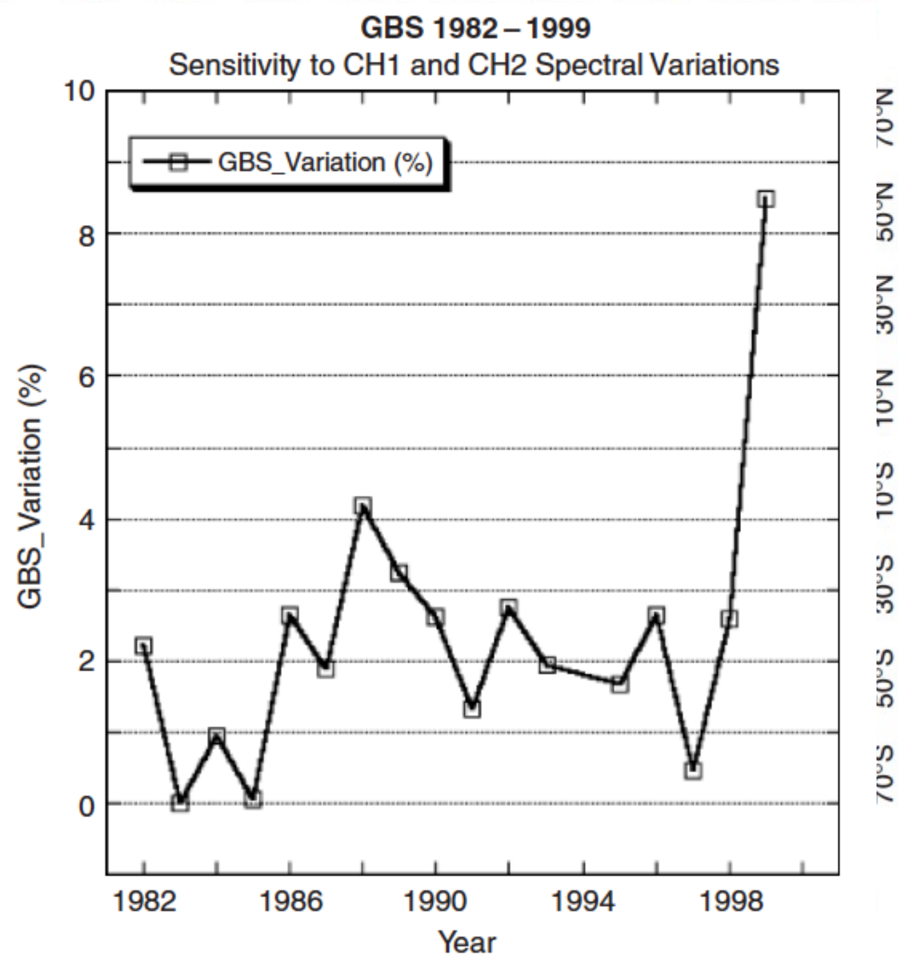


Fig. 3 Sensitivity of global burnt surface (GBS) 1982–1999 to CH1 and CH2 spectral variations.

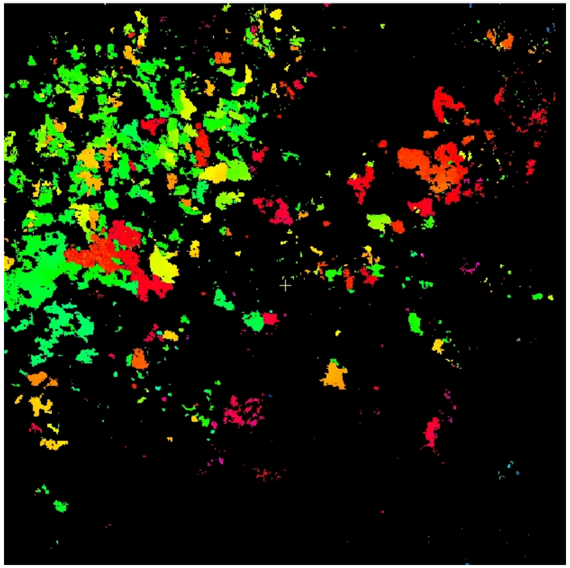
Carmona Moreno et al., 2005

AVHRR burned areas

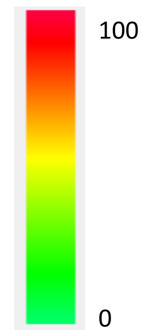
- Potentially expanding the fire record back to 1981
- Calibration issues have limited the potential to use the data for fire interannual variability
- Intercalibration with other products is possible only in overlap periods
- Lack of Landsat data to validate extensively pre Landsat 7
- A combination of intercalibration with overlapping products and Landsat validation is the only option

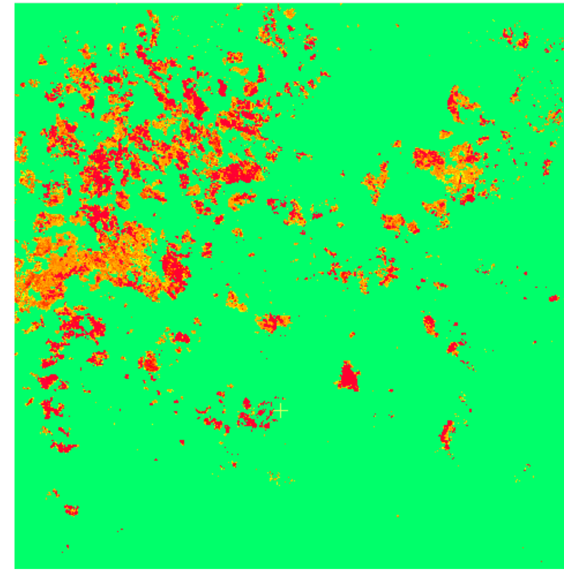
Pixel output: Merged product v1 (Australia)

Day of detection

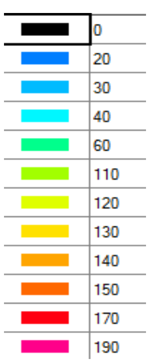


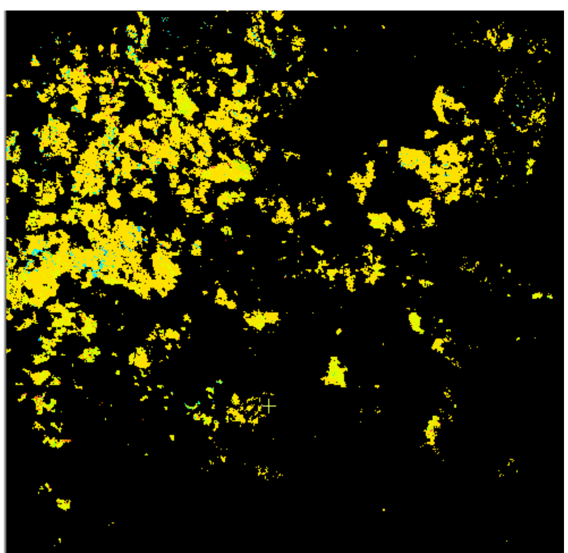
Confidence Level





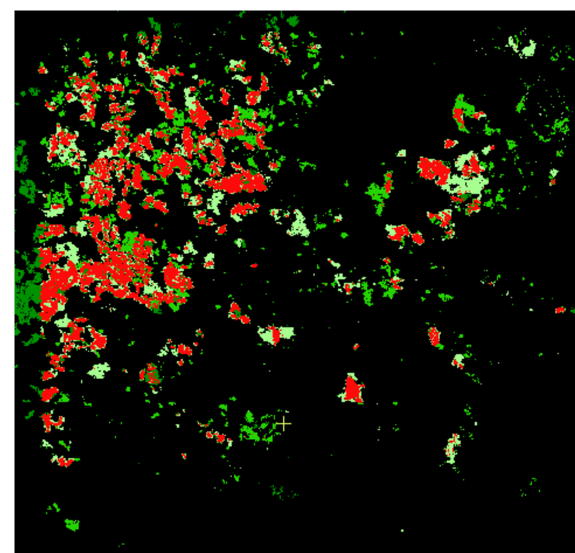
Land Cover Type





Sensor detecting

None
VGT + ATSR
ATSR + MERIS
VGT + MERIS
VGT + ATSR + MERIS



Stage 3 and Stage 4 validation:
(status tomorrow)

First order issues: the fire ECV

- Detecting *'Active fires'* and *'burned areas'* is an ill-posed problem
- Historically, the community has gone with the 'I know when I see it' approach
- We need an unambiguous definition of the quantity estimated in the ECV, and measured in the validation dataset

A fire on the ground…

Burned Area Requirements

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Burnt area	250m	N/A	Daily detection	15% (error of omission and commission), compared to 30m observations	15% (error of omission and commission), compared to 30m observations

Rationale: Product requirements are driven by the need to estimate emissions from burnt area and for dynamic vegetation modelling. The requirements are close to original instrument resolution and, with high resolution in space (250 m) and time (daily), provide a basis for weekly and monthly (gridded) products for the various user communities. Error traceability in the provision of aggregated, gridded products is essential.

Active Fire and FRP

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
ActiveFire Maps	1km	N/A	6h (all latitudes)	5% error of commission 30% error of omission compared to 30m spatial resolution detections (based on per-fire comparisons)	N/A

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
FRP (polar-orbiting platform)	1km	N/A	Sub-daily (e.g. 6h at all latitudes)	25% down to FRP of 10 MW	10%
FRP (Geostationary platform)	0.1km	N/A	1h	25% down to FRP of 50 MW	10%

Rationale: The product requirements are set to link with those set for burnt area so that the reasons for the occurrence of new burnt areas may be more effectively recognized

Terrestrial vegetation burning alters the land surface properties and releases large quantities of aerosols and trace gases, which in turn affect the atmosphere's chemical composition and Earth's climate. Quantifying biomass burning emissions, and therefore characterizing the lower boundary condition in atmospheric transport models, typically involves the use of burned area observations (along with fuel load and combustion completeness measures). There are many benefits of the burned-area based approach, although a key limitation is that it can only be applied in retrospective/reanalysis climate simulations. Active fire detections can supplement burnt-area estimates by describing the biomass burning source term in atmospheric transport models. Two further features of active fire observations are that they are available in near real time (NRT) and are able to characterize the diurnal fire cycle.

Second order issues: metrics used in the ECV requirements

- Some metrics are ill-defined (i.e. ‘stability’)
- Other metrics are not justifiable
  - Error characterized in terms of omission and commission. A subtle statistical point is that ‘omission error = commission error” does not mean that the estimate is unbiased!
  - Why not precision and accuracy?

Third order issues: target accuracies

- The target values are arbitrary and don't seem to have any justification in terms of user requirements
- Physical limitations are ignored
  - Egregious example: Omission and Commission = 15% compared to 30 m observations is physically impossible to achieve on highly fragmented burned areas.
- Geographic extent is ignored (15% omission and commission globally? Per continent? Per 5 degree cell?)

Where to go from here?

- What is the linkages between GCOS and LPV
- How can we ensure that the science community is involved in writing the requirements
- ‘Community reviews’ are hardly a good model – no incentive for the people we want to be involved.

Also some exciting news…

Moderate resolution:

- Successful launch of Landsat 8
- Sentinel 2

Low resolution

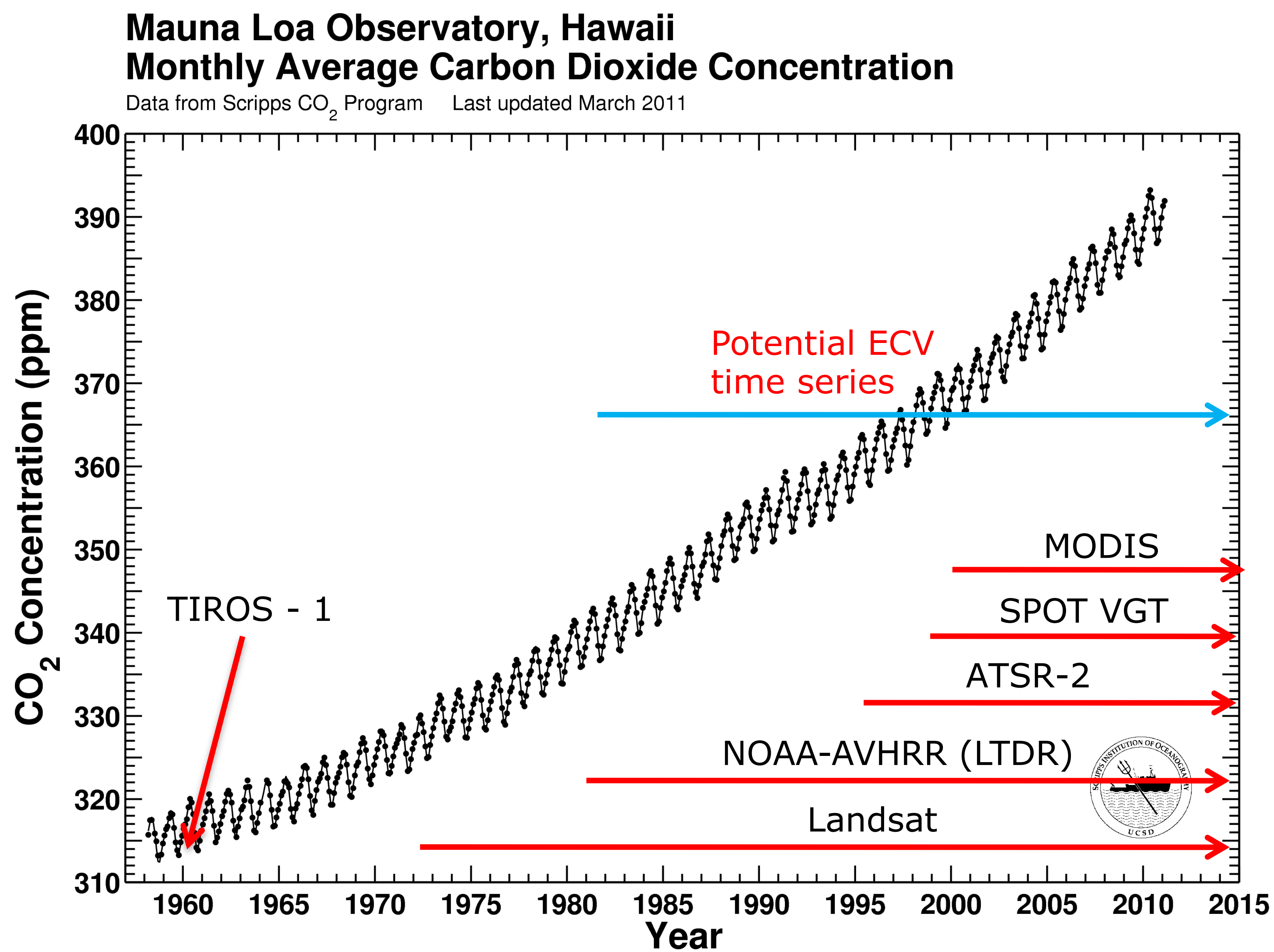
- Successful launch of VIIRS
- Sentinel 3

Unprecedented data availability for validation

Potential for data fusion

Beyond the ECV

Policy applications for the new generation of burned area products



Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO_2 Program
Last updated March 2011
CO_2 Concentration (ppm)
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
Potential ECV
time series
MODIS
SPOT VGT
ATSR-2
NOAA-AVHRR (LTDR)
Landsat
TIROS - 1

Integrated monitoring systems

- International pressure for free data access started with low resolution data, and now extending to moderate resolution datsets (i.e. 10-30m).
- Landsat data: free from 2006
- European Sentinel 2 and Sentinel 3 (~2013): commitment from ESA for free data
- Need to set up the framework for integrated system: VIIRS-Sentinel3 plus Landsat 8 – Sentinel 3

Global datasets in the context of international carbon conventions

- Thematic products are extremely relevant for national and international policy
  - Remote sensing role for Monitoring, Reporting and Verification in the REDD+ program under UNFCCC
- Fundamental science questions on our changing planet
- Scientific support for cooperation and environmental actions

"we must educate our masters"
(Robert Lowe, Chancellor of the Exchequer, after the 1867 Reform Act)

Remote sensing and REDD+

The role of remote sensing in national monitoring systems is recognised in decision 4 of COP15

- **Article 1 (d):**

  To establish, according to national circumstances and capabilities, robust and transparent national forest monitoring systems and, if appropriate, sub-national systems as part of national monitoring systems that:

(i) **Use a combination of remote sensing and ground-based forest carbon inventory approaches** for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes;

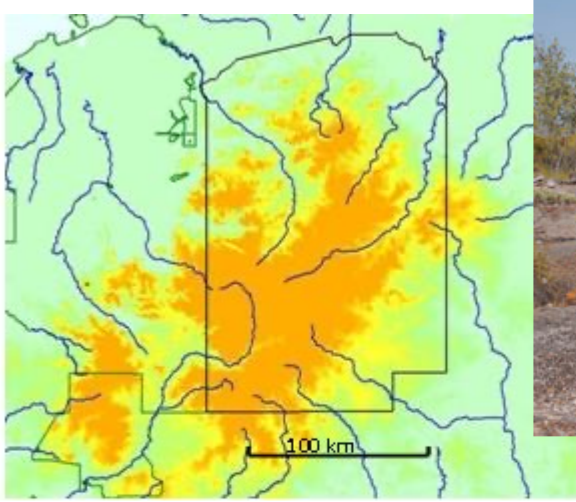
(ii) Provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities;

(iii) Are transparent and their results are available and suitable for review as agreed by the Conference of the Parties;

Early examples of fire management and carbon market

WALFA project in Northern Australia:

- Change in total annual emissions by managing fire and changing the seasonality (early versus late fires)
- Funded in the internal carbon market
- Science component to evaluate the effects on total biomass burned and on emission coefficients



SOURCEBOOK

COP 16 version 1

A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation

GOFC-GOLD

Global Observation of Forest and Land Cover Dynamics

Sourcebook Fire section

2.5 METHODS FOR ESTIMATING GHG'S EMISSIONS FROM BIOMASS BURNING

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Ivan Csiszar, NOAA, USA
Emilio Chiuvieco, University of Alcala, Spain
Allan Spessa, University of Reading, UK
Anja A. Hoffman, L.M. University of Munich, Germany
Jeremy Russell-Smith, Charles Darwin University, Australia
Marc Paganini, European Space Agency
Olivier Arino, European Space Agency

2.5.1 Scope of chapter

Chapter 2.5 is focused on fires in forest environments and how to calculate greenhouse gas emissions due to vegetation fires, using available satellite-based fire monitoring products, biomass estimates and coefficients.

Section 2.5.2 introduces emissions due to fire in forest environments and approaches to estimates emissions from fires.

Section 2.5.3 focuses on the IPCC guidelines for estimating fire-related emission.

Section 2.5.4 focuses on Systems for observing and mapping fire.

Section 2.5.5 describes the potential use of existing fire and burned area products.

2.5.2 Introduction

2.5.2.1 REDD and emissions due to fire in forest environments

Fire is a complex biophysical process with multiple direct and indirect effects on the atmosphere, the biosphere and the hydrosphere. Moreover, it is now widely recognized


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