GOFC-GOLD

Global Observations of Forest Cover and Land Use Dynamics

Fire Implementation Team priorities

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Michigan State University, USA

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Department of Geography, King's College London, UK

[c] Joint Research Center, European Commission, Italy

NASA LCLUC annual meeting, Gaithersburg, MD, April 2-4 2024

Quick overview: GOFC-GOLD Fire Implementation Team

Fire IT

- About
- Background
- Implementation Goals
- Objectives
- Participants
- Documents and Publications
- Structure
- Meetings

Focus

help refine and articulate the international observation requirements

&

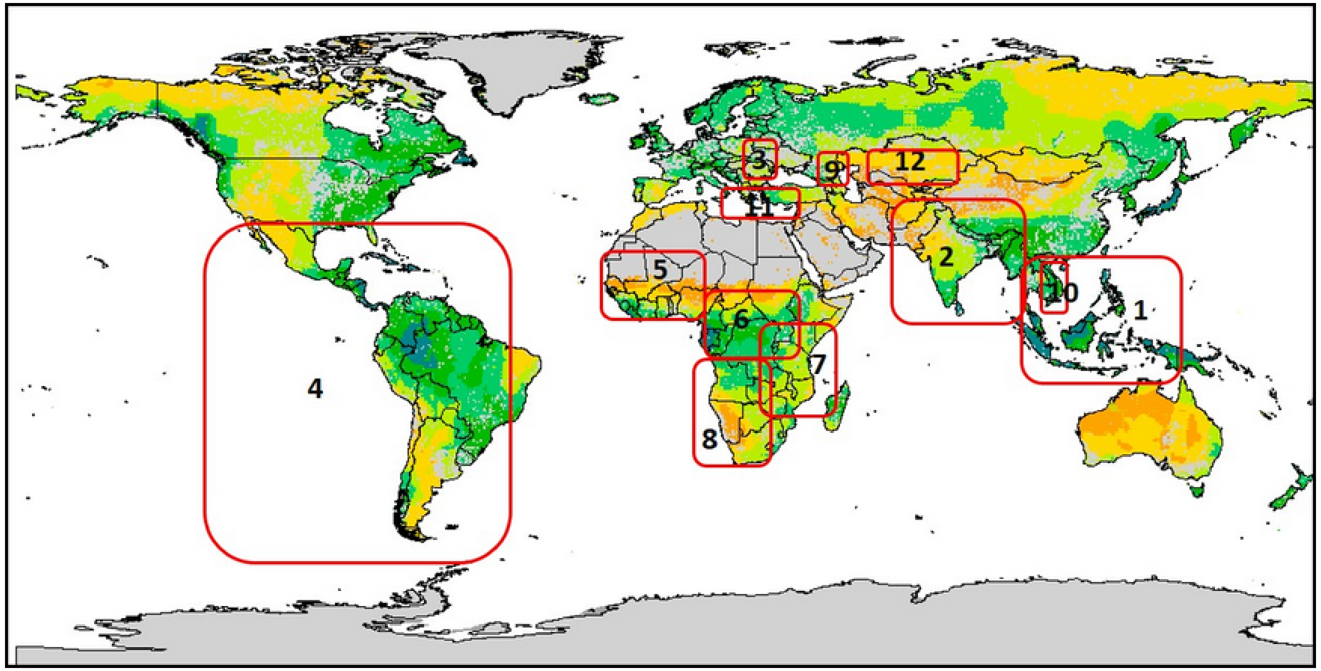
help make the best possible use of fire products from the existing and future satellite observing systems

for

fire management, policy decision-making, global change research

Quick overview: GOFC-GOLD Fire Membership

- International
- Voluntary
- Satellite fire product providers, users, stakeholders, fire practitioners, scientists, and GOFC/GOLD regional networks (fire prone & typically less developed regions)
- Annual meetings currently funded by the EU Global Wildfire Information System (GWIS) project



Previous GOFC-GOLD Fire IT / GWIS meeting

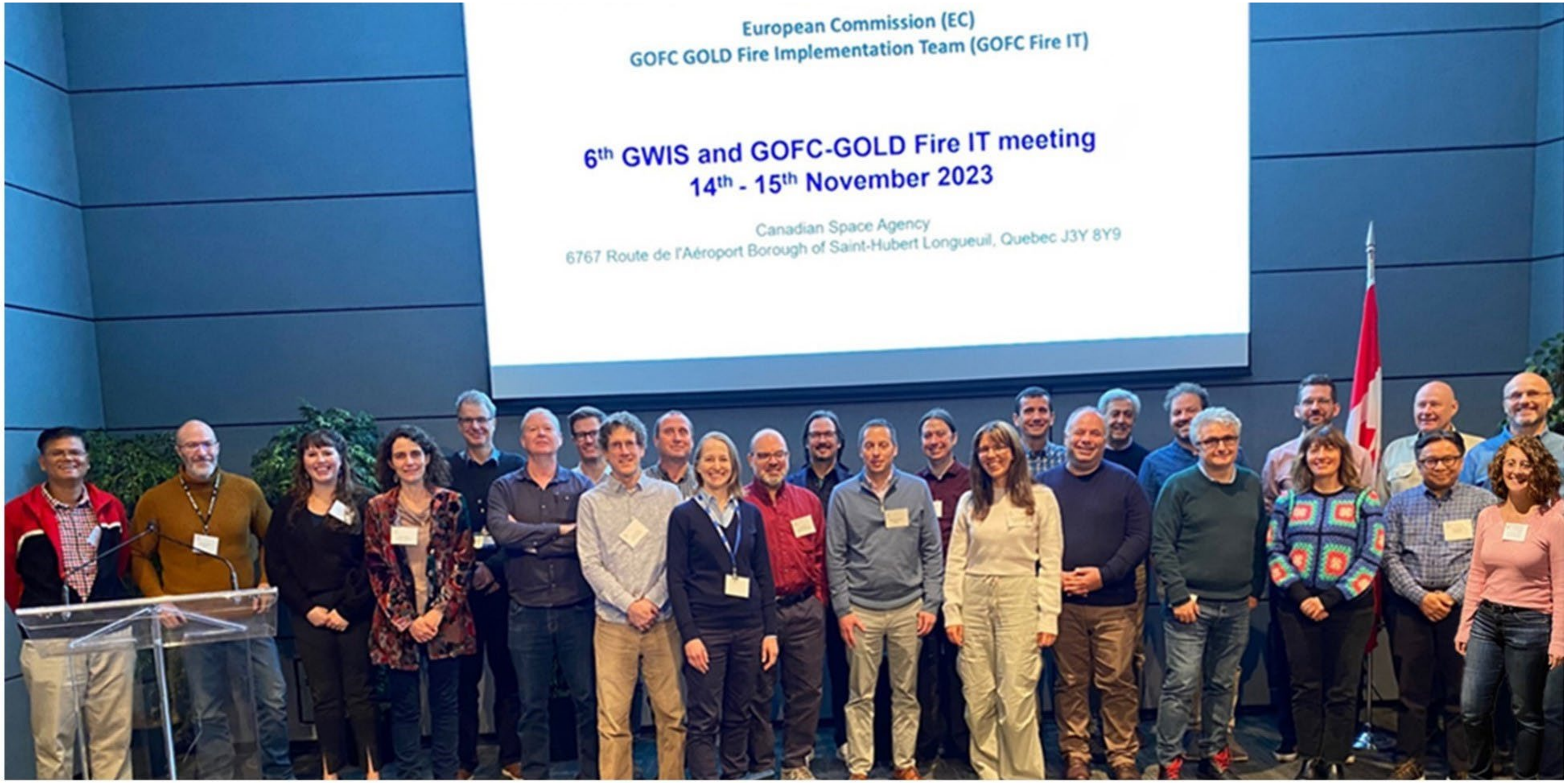
June 2022, Stresa, Italy

(the catch up, post-COVID meeting)

Presentations: https://gofcgold.org/meetings/5th-gofc-gold-fire-it-and-global-wildfire-information-system-gwis

Most recent GOFC-GOLD/GWIS meeting

November 2023, Canadian Space Agency, Quebec
joint with Canadian WildFireSat stakeholder meeting



Presentations:
https://gofcgold.org/meetings/6th-global-wildfire-information-system-gwis-and-gofc-gold-fire-implementation-team-meeting

GOFC/GOLD Fire Implementation Team priorities

(support R&D / advocate / share information / provide platform / do)

- small area & low Fire Radiative Power (FRP) fires
- continuity of global fire product record
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- fire product policy relevant information service in the post-MODIS era
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Ongoing research on relative importance of small area & low Fire Radiative Power (FRP) fires

JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
AN AGU JOURNAL

JGR

Explore this journal >

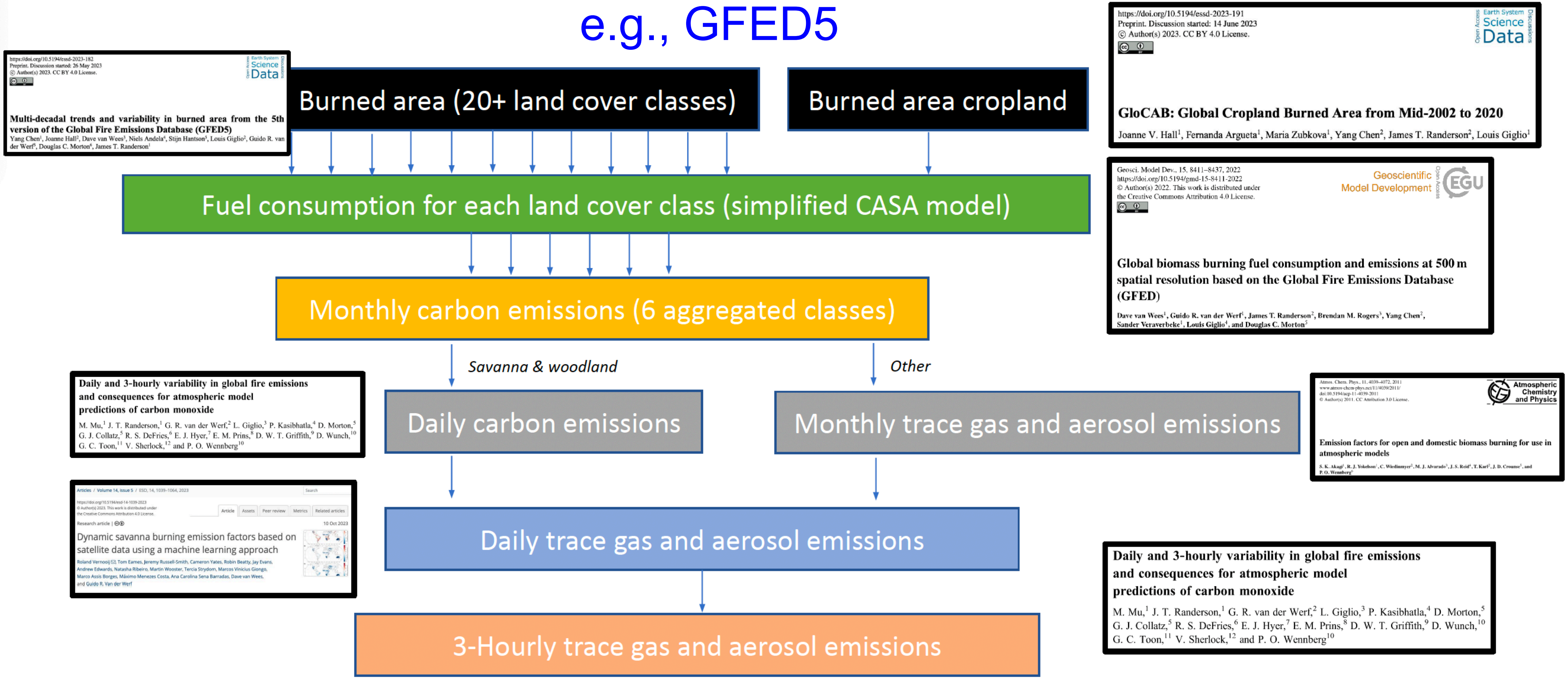
Global burned area and biomass burning emissions from small fires

J. T. Randerson, Y. Chen, G. R. van der Werf, B. M. Rogers, D. C. Morton

Accounting for small fires increased total global burned area by ~35%, from 345 Mha/yr to 464 Mha/yr

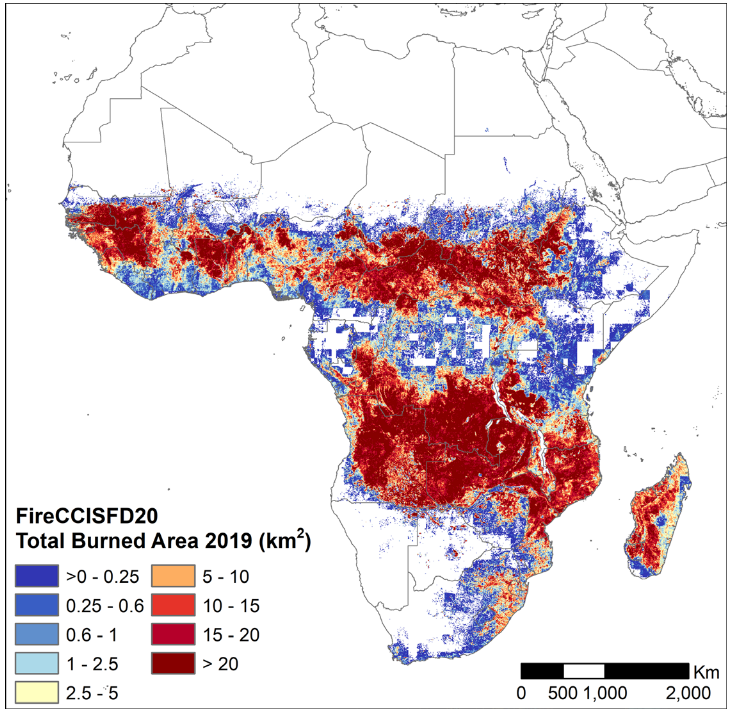
"A formal quantification of uncertainties was not possible …"

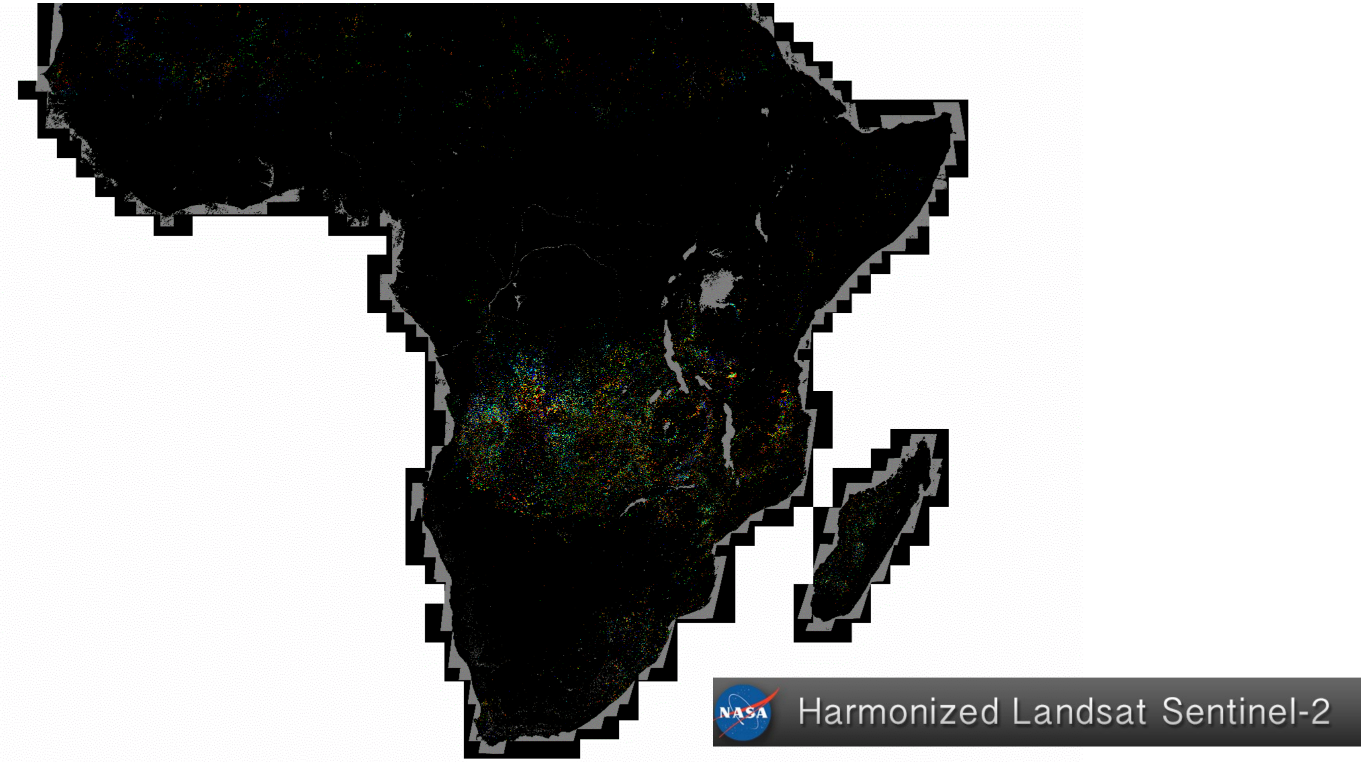
Small fires being integrated into Global Emissions Inventories e.g., GFED5



Guido van der Werf et al.

- Recent Landsat & Sentinel-2 20m – 30 m regional burned area products providing insights into role of small burned areas
- more informative than provided by MODIS 500 m burned area product – but accuracy assessment challenging





- Current outstanding need to systematically generate validated global daily burned area products at medium resolution (Landsat & Saentinel-2)

- to support science & applications

ELSEVIER

Remote Sensing of Environment

Volume 300, 1 January 2024, 113918

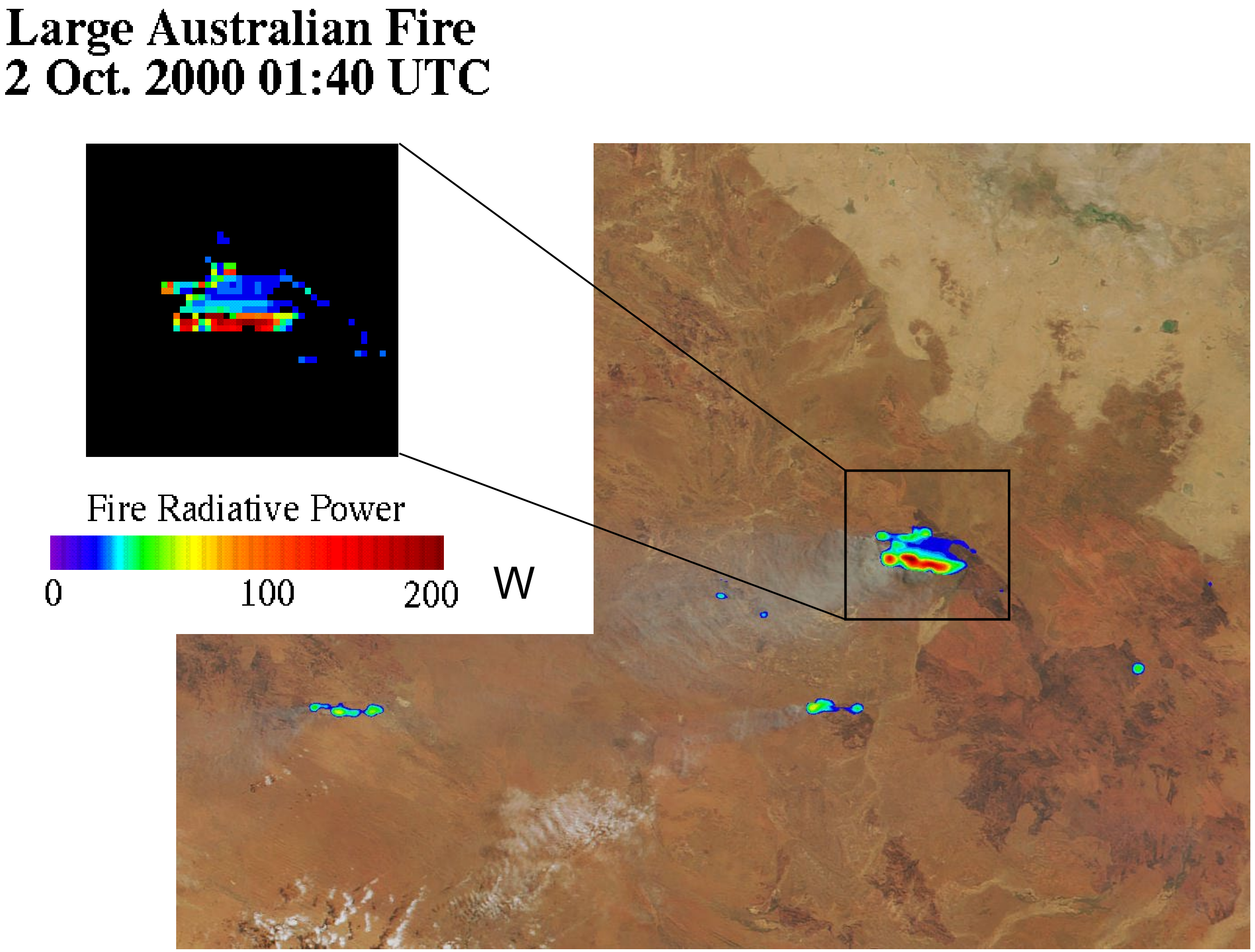
Review

Need and vision for global medium-resolution Landsat and Sentinel-2 data products

Volker C. Radeloff [a], David P. Roy [b], Michael A. Wulder [c], Martha Anderson [d], Bruce Cook [e], Christopher J. Crawford [f], Mark Friedl [g], Feng Gao [d], Noel Gorelick [h], Matthew Hansen [i], Sean Healey [j], Patrick Hostert [k l], Glynn Hulley [m], Justin L. Huntington [n], David M. Johnson [o], Chris Neigh [e], Alexei Lyapustin [e], Leo Lymburner [p], Nima Pahlevan [e], Jean-Francois Pekel [q]… Zhe Zhu [u]

- Federal funding of airborne fire campaigns is awesome (but not if the global products the applications and science community needs are not available)

Recap: Fire Radiative Power (FRP)



Retrieved at active fire detections from MIR

Directly proportional to rate of biomass consumption

Useful for emissions & fire characterization

$C_6H_{10}O_5 + O_2 + \text{heat} \rightarrow C0_2 + H_20 + \textbf{heat}$

FRP is the heat energy liberated by combustion per unit time

Low FRP fires are cool and/or small

- unclear what the emissions from low FRP fires are as they not being detected by current polar and geostationary systems

Photo from airplane window flying into Kinshasa, DRC during the unusually wet little dry season, March 2024

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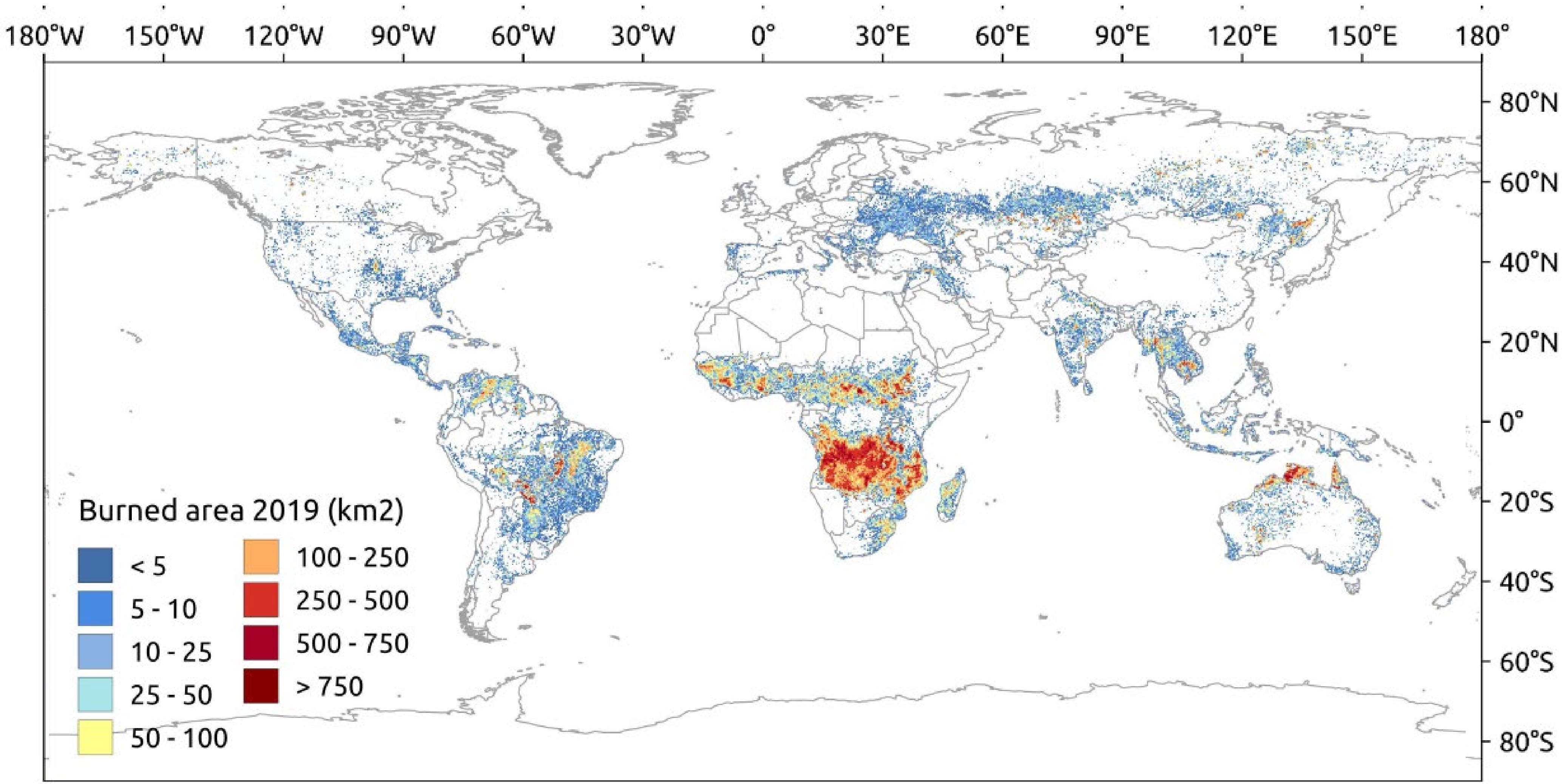
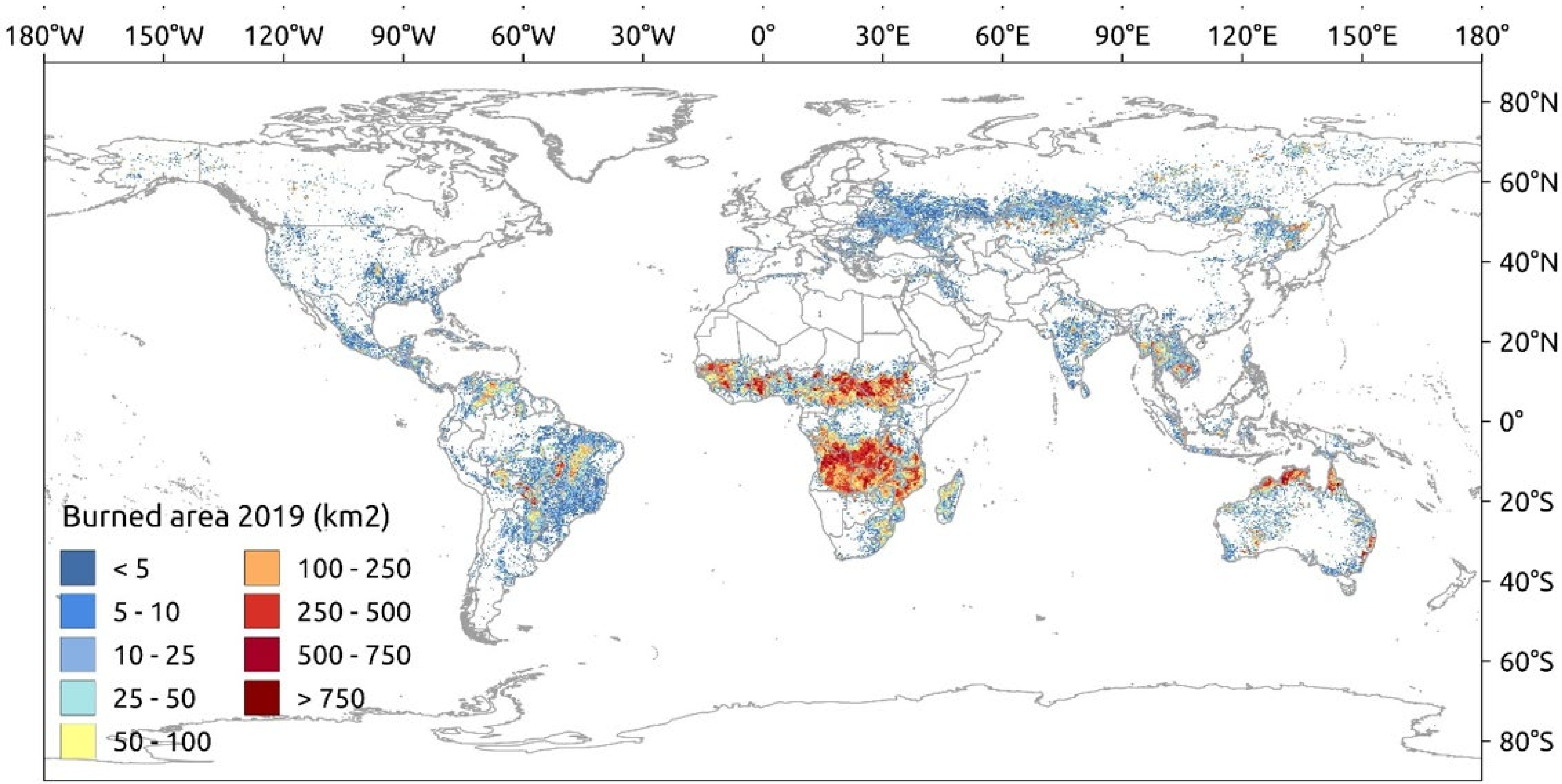
Recent ESA 250m BA product (FireCCI51) (MODIS 250 m reflectance + MODIS active fire detections)



Lizundia-Loiola et al., 2020, RSE

(E. Chuvieco)

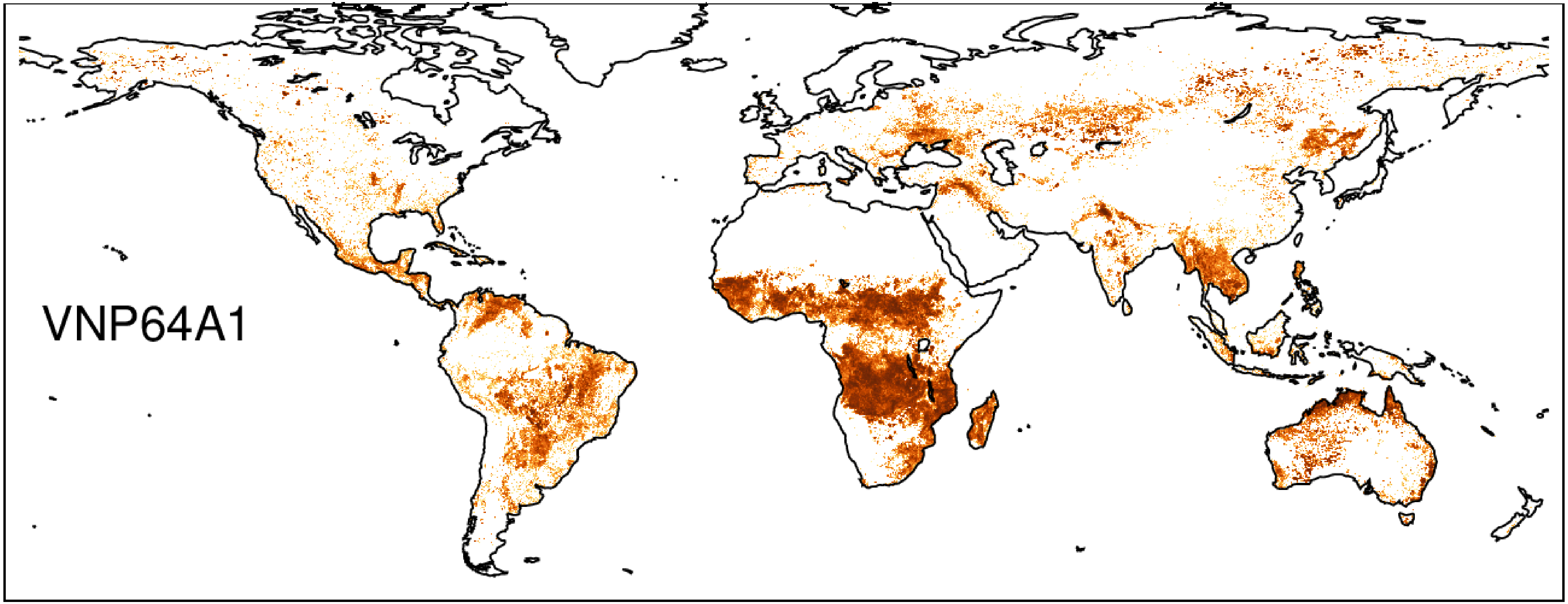
Recent ESA 300m BA product (C3SBA10 BA)
(OLCI 300m reflectance + MODIS active fire detections)



Lizundia-Loiola et al., 2021, *Remote Sensing*

(E. Chuvieco)

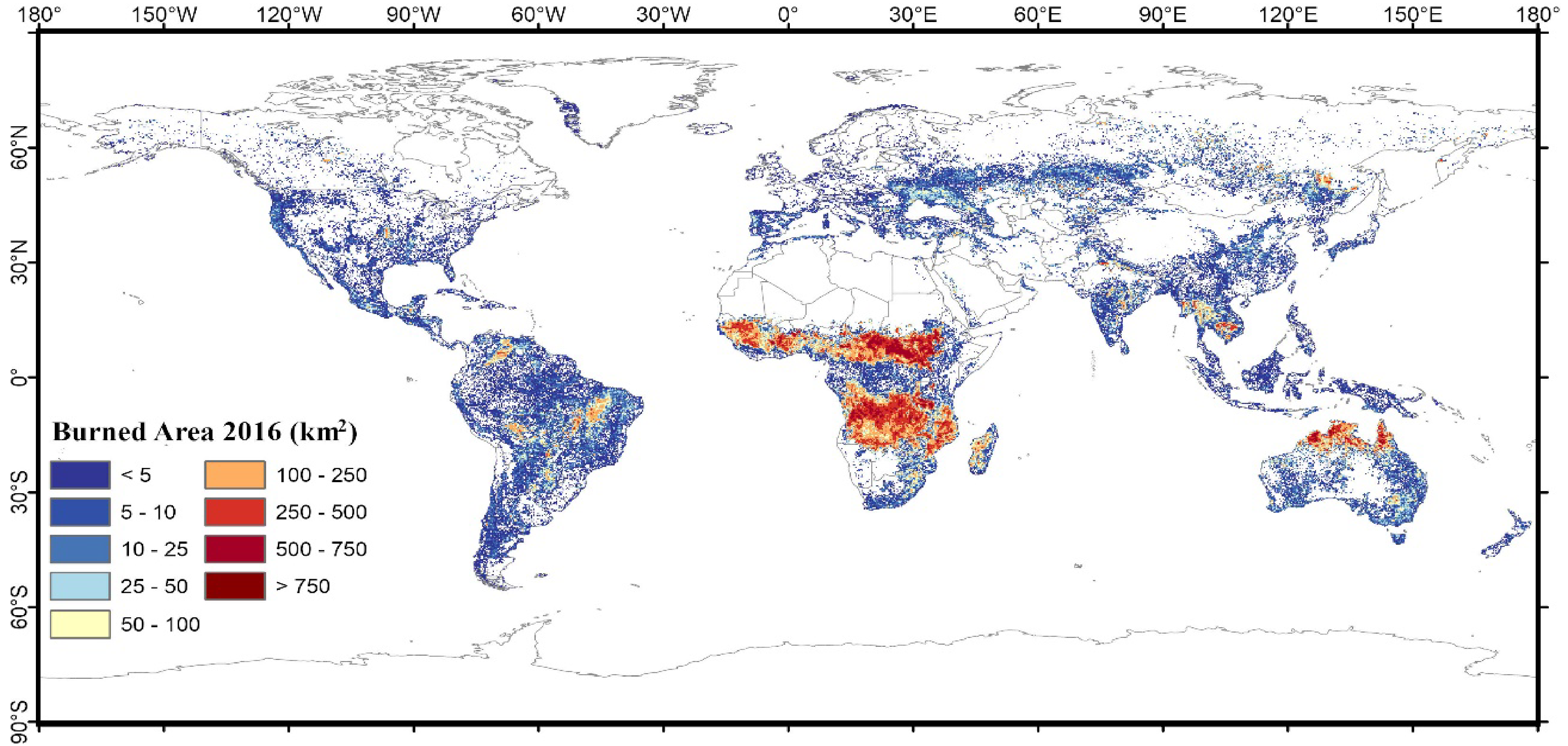
Very recent 500 m NASA VIIRS Burned Area product (VIIRS reflectance and active fire detections)



Giglio et al. 2024 In Prep.

+ need for a validated long-term pre-MODIS burned area record

Recent ESA AVHRR 0.05° BA product (FireCCILT11) 1982+

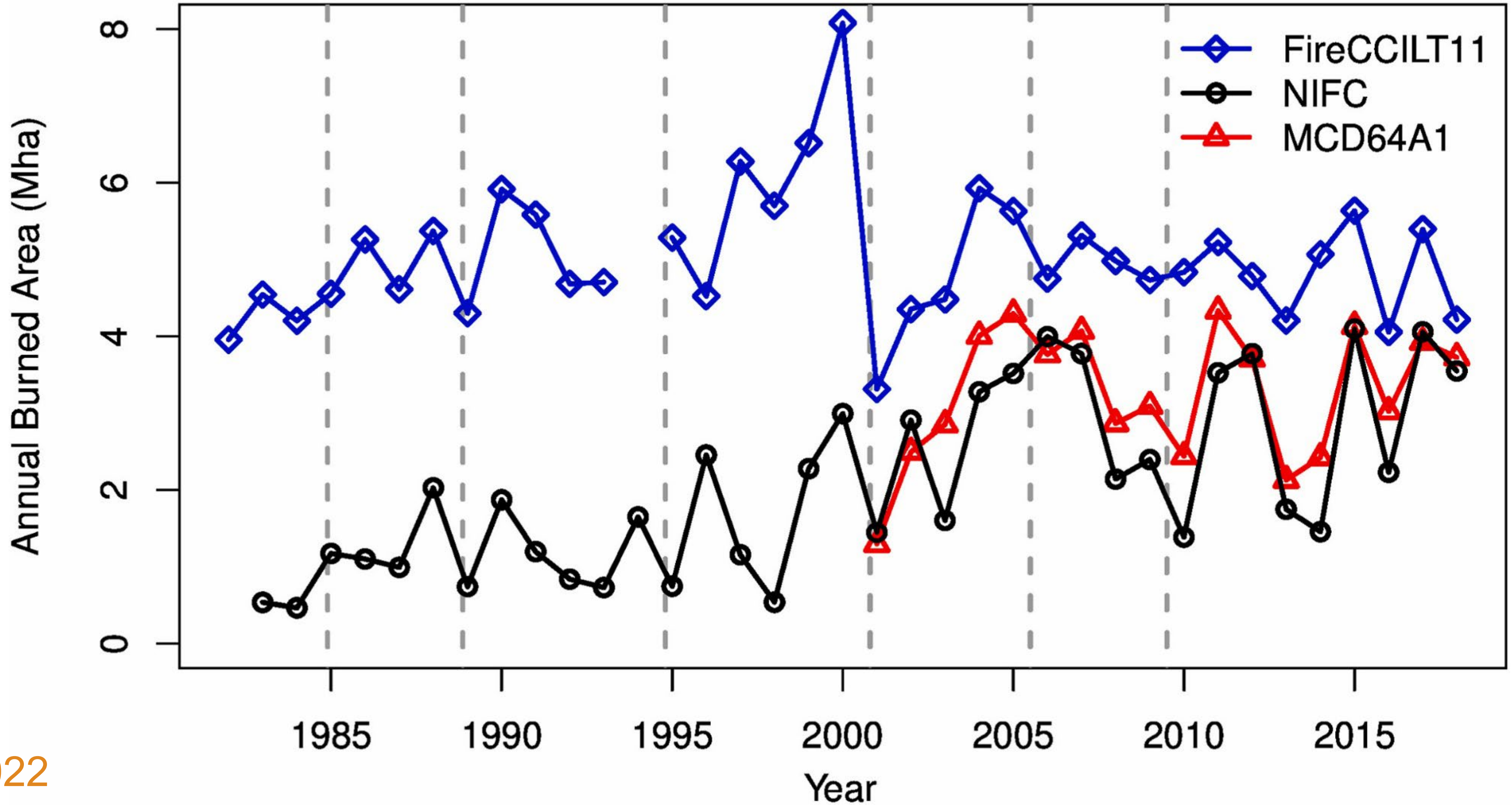


Oton et al., 2021, IJAG

not validated following CEOS protocol

Annual total BA for the conterminous United States, Alaska, Hawaii reported by FireCCILT11 (AVHRR), MCD64A1 (MODIS) and as compiled by U.S. National Interagency Fire Center (NIFC)

- significant orbit-drift artifacts in the FireCCILT11 product
- FireCCILT11 drastically overestimates U.S burned area before 2001



Gilgio & Roy, *Science of RS*, 2022

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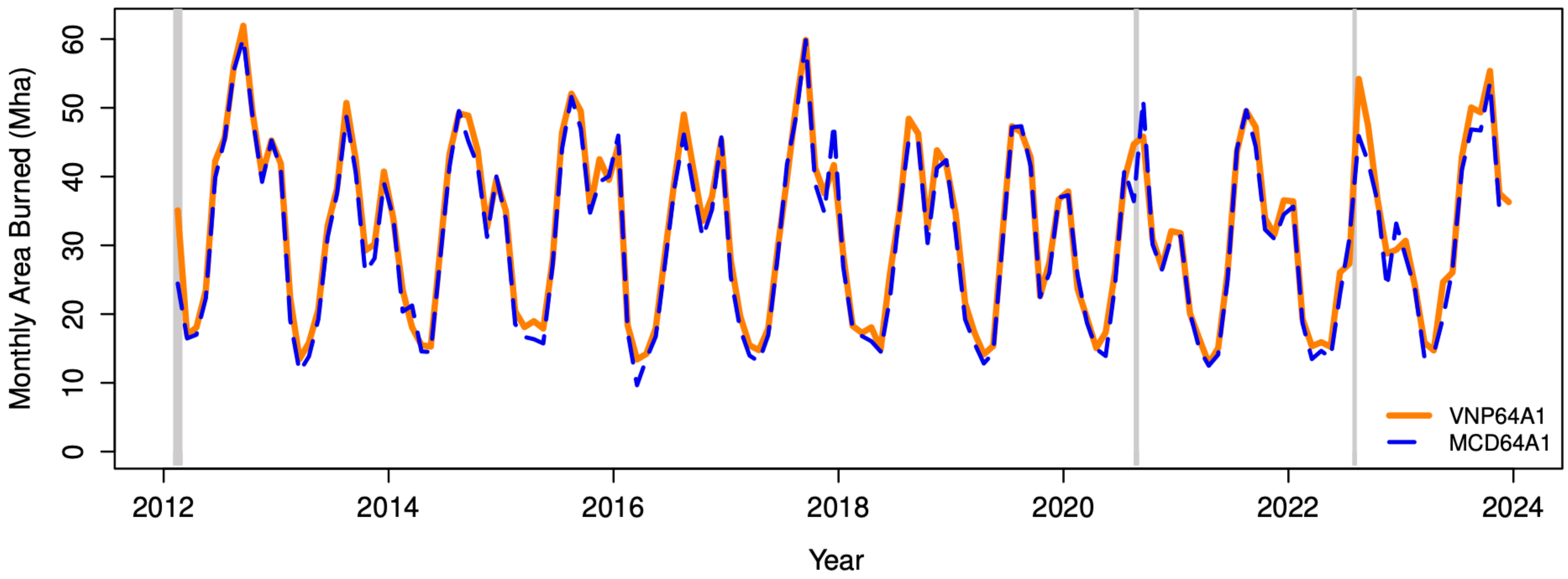
Global monthly NASA MODIS and VIIRS Burned Area



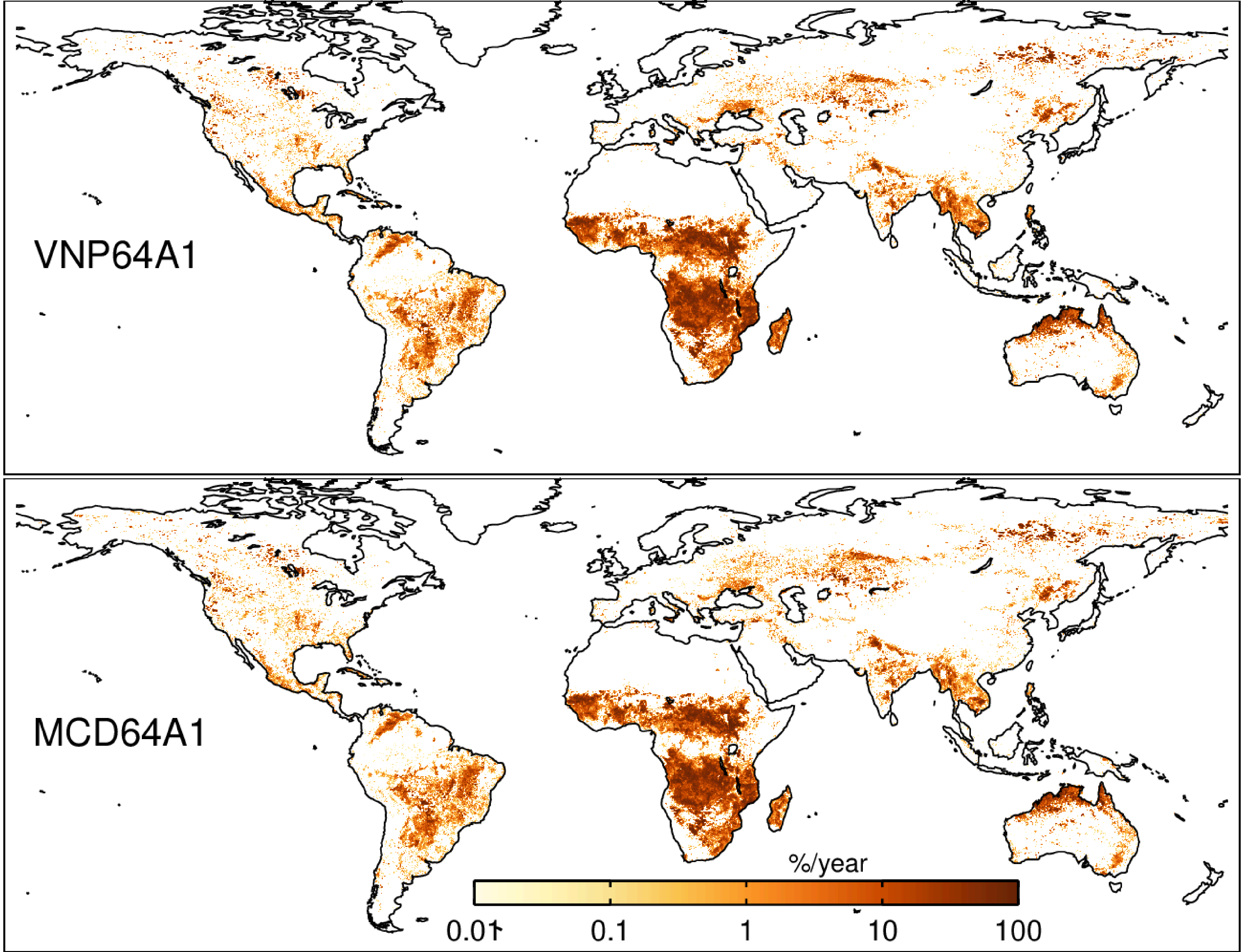
Grey bars indicate 2012 S-NPP VIIRS, 2020 Aqua MODIS, and 2022 S-NPP VIIRS data gaps

C6.1 MCD64A1 (MODIS) C2 VNP64A1 (VIIRS)

Annual 2021

VIIRS

MODIS



Likely factors impacting MODIS/VIIRS Burned Area product consistency …

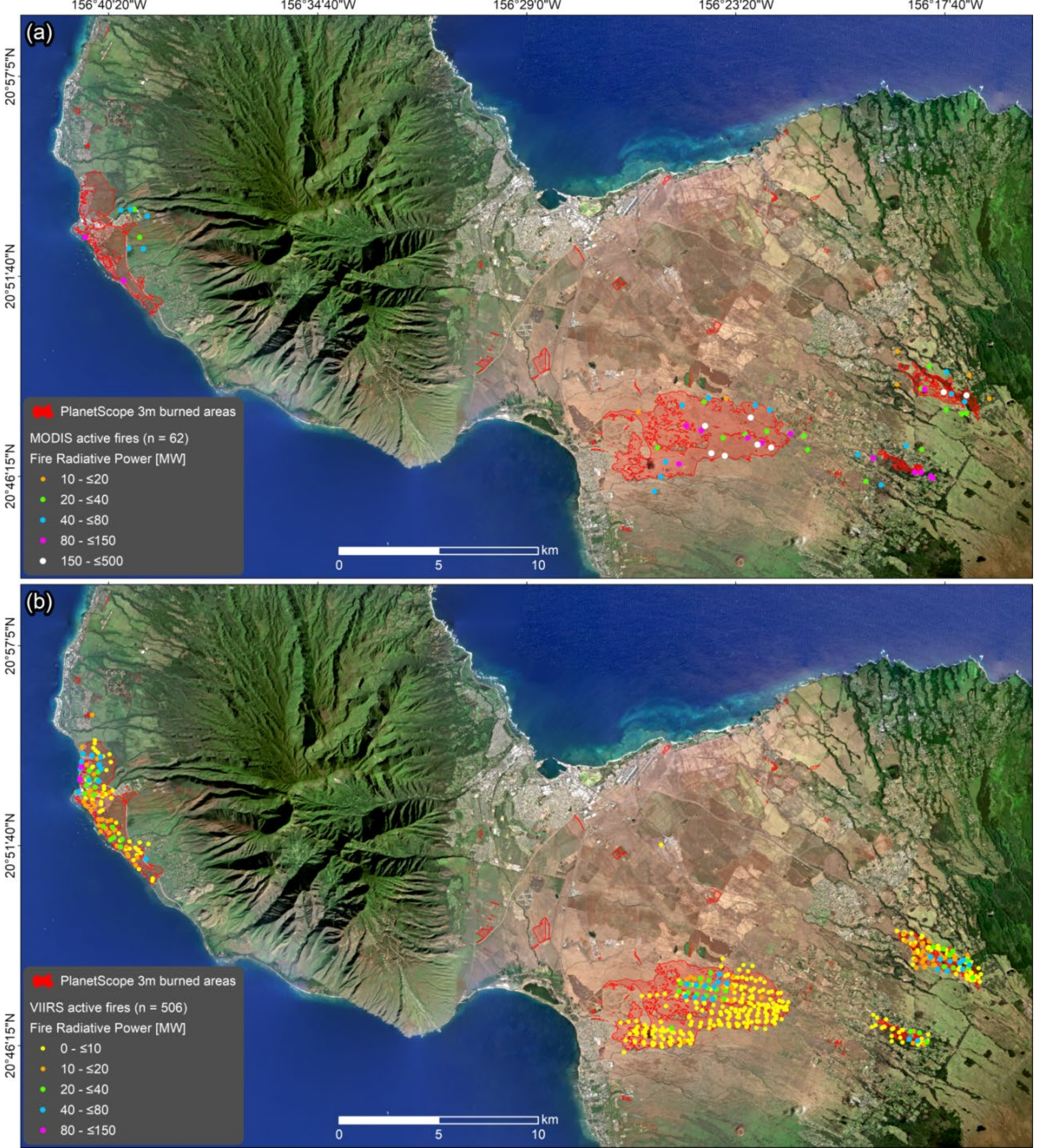
- Band placement (different spectral response)
- Sensor swath width ➞ coverage + view zenith angle sampling
- Native (swath pixel) resolution + VIIRS pixel aggregation
- “1-km” (926-m) and “500-m” (463-m) sinusoidal grid resampling effects
- No VIIRS morning overpass
- Upstream surface reflectance product differences
  - cloud mask, snow mask, QA bits
- Land/sea mask

Louis Giglio
April 2024

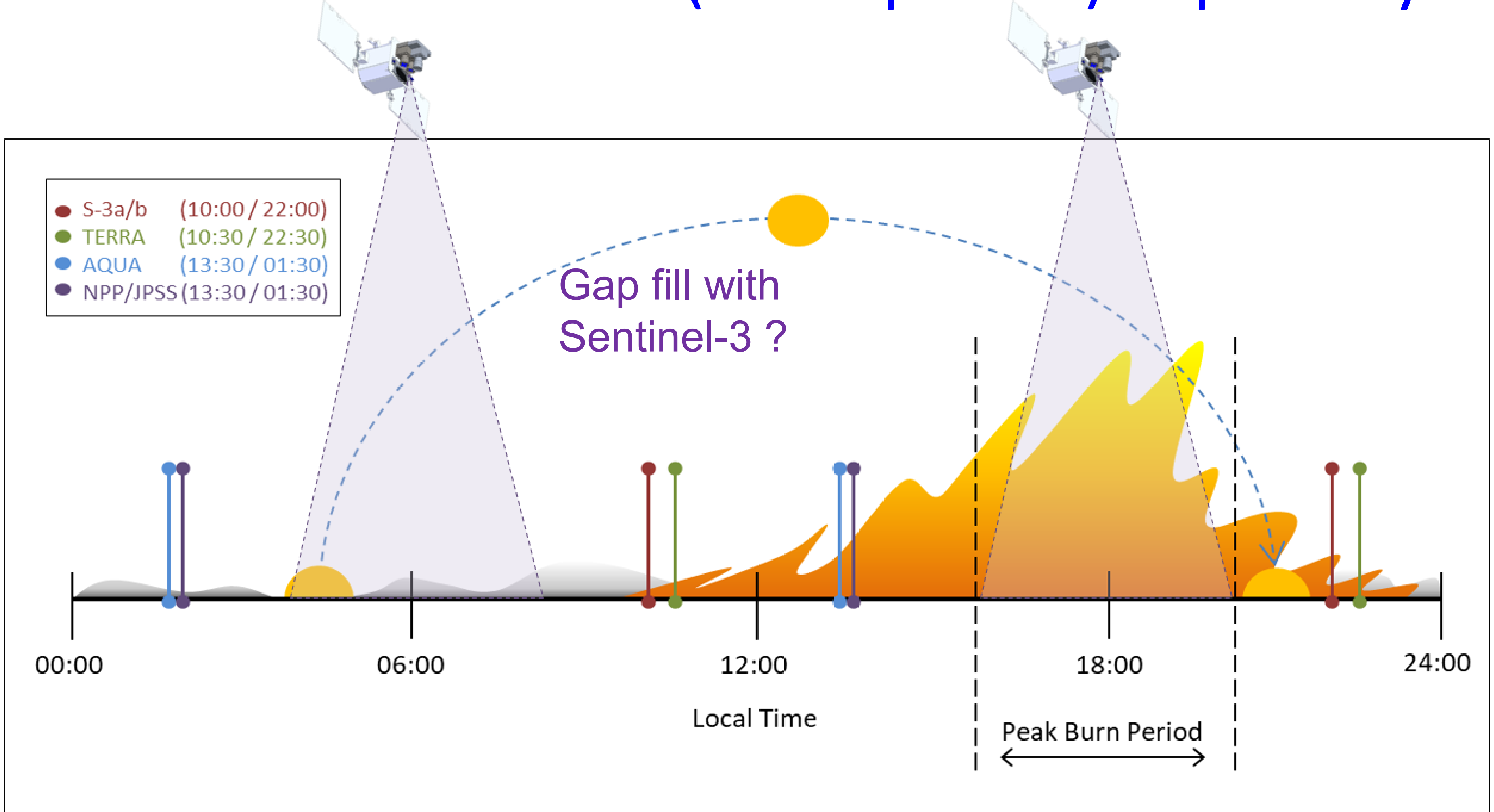
MODIS & VIIRS FRP significantly different also

Maui Fire Disaster
August 2023

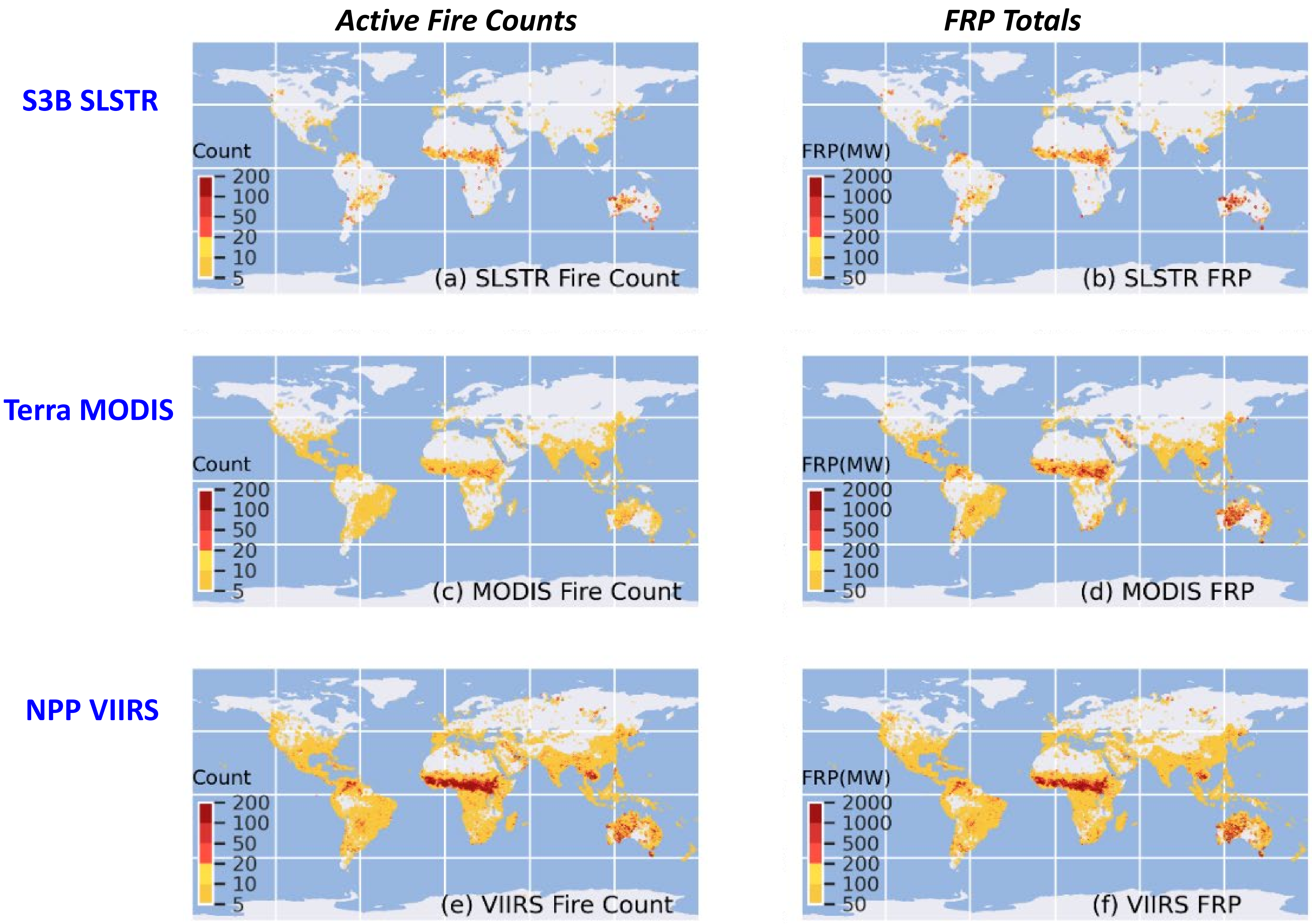
De Lemos et al. 2024



Upcoming gap in morning active fire & FRP observation capability due to MODIS decommissioning – huge concern for operational users - need to characterize Sentinel-3 active fire & FRP (sub-optimal) capability



Sentinel-3 detects fewer active fires than MODIS, & far fewer than VIIRS, & different FRP



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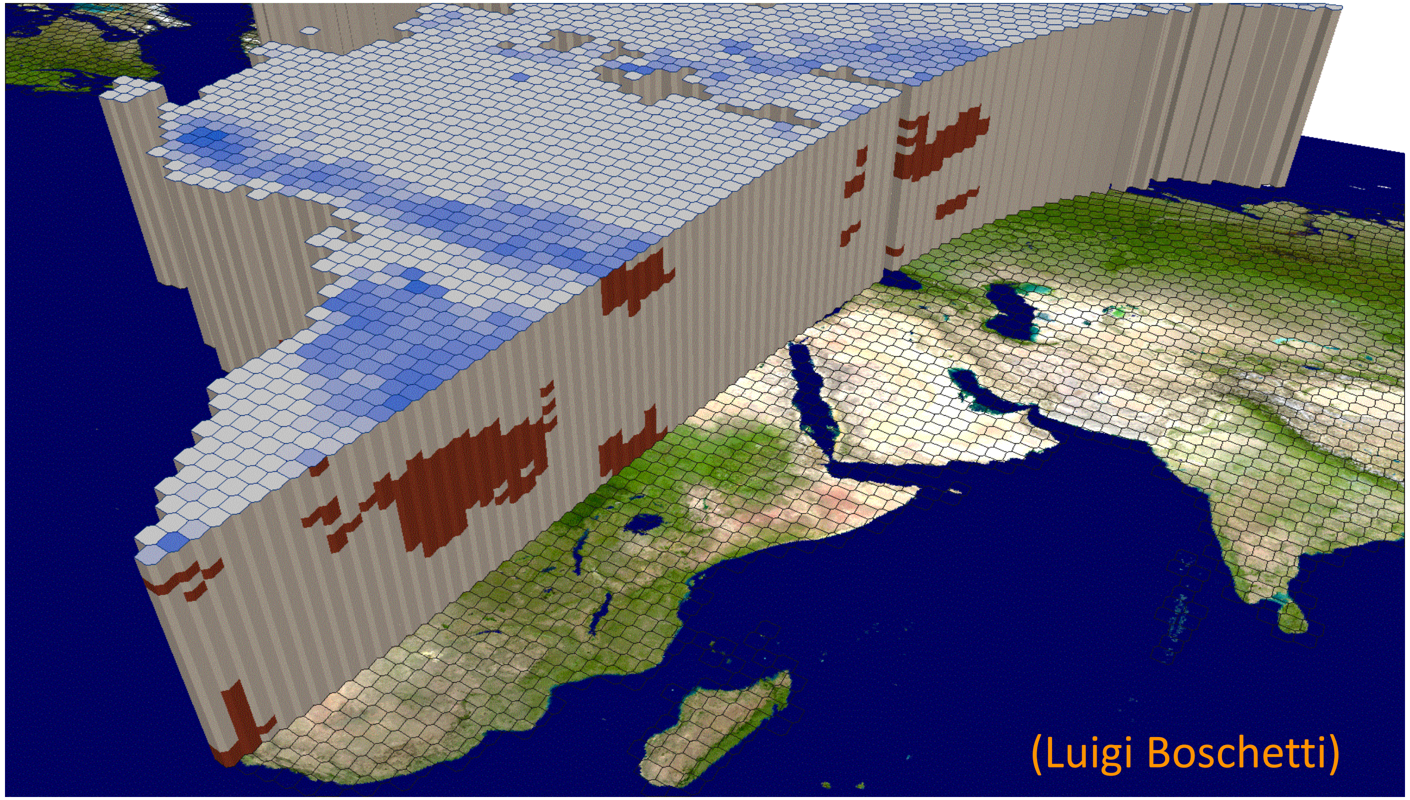
Burned Area Product Validation protocol adopted but some producer published approaches underwhelming …. as using

- insufficient number and distribution of independent reference data sampled in space and time to acquire CEOS Stage 3 validation

- same spatial resolution independent reference data as the product

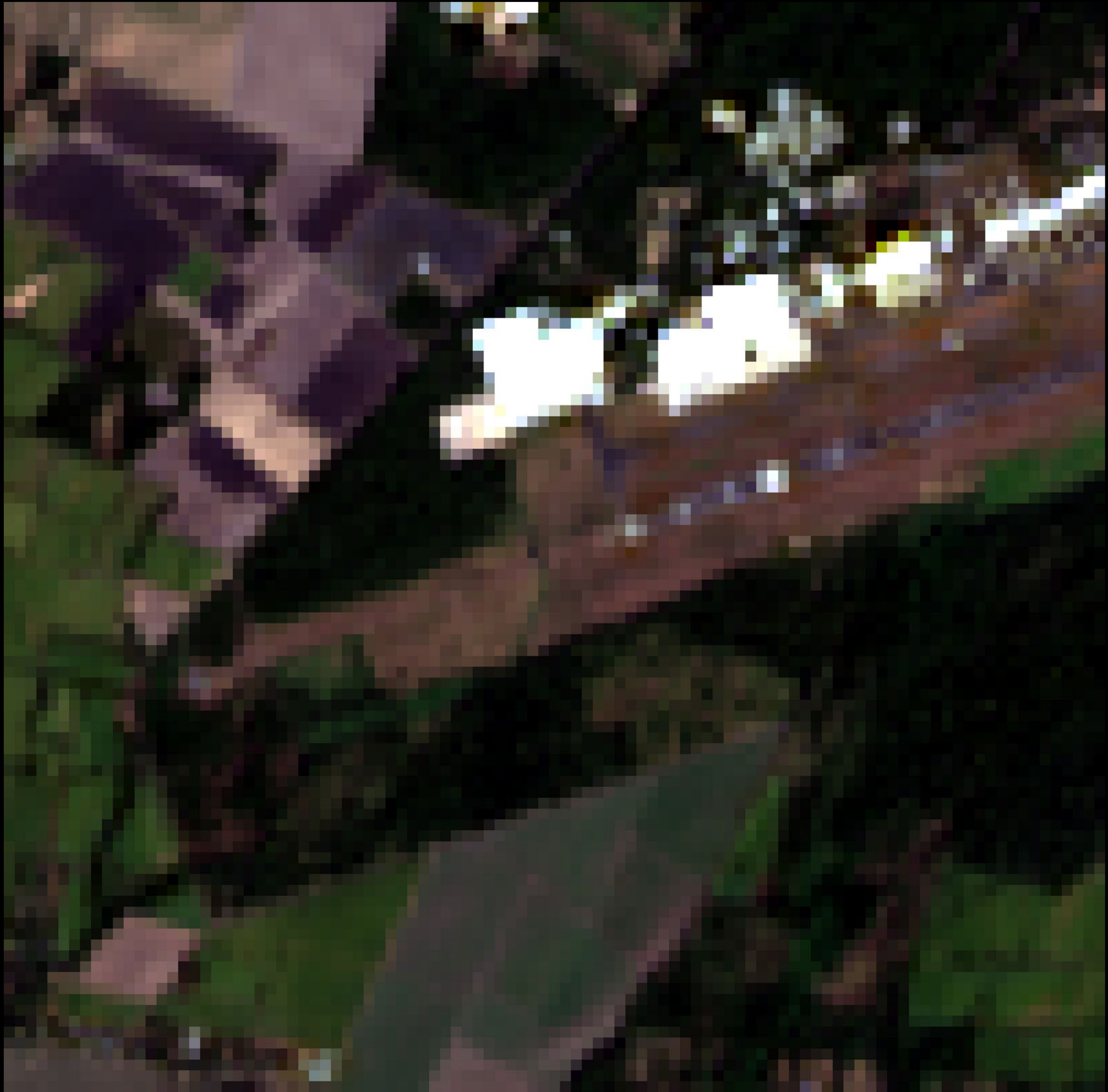
Commercial satellite data provide new opportunities for validation of medium resolution burned area products



Sensor: Landsat 9
Spatial Resolution: 30 m
Date: 2022/01/12
Time: 16:18:34 UTC
Solar Elevation: 46°

Location: SAL Airport, San Luis Talpa, La Paz, El Salvador

Dimension: 100 x 100



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2022/01/05
Time: 17:01:25 UTC
Solar Elevation: 51°

Location: SAL Airport, San Luis Talpa, La Paz, El Salvador

Dimension:
1000 x 1000

Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2022/01/05
Time: 16:03:37 UTC
Solar Elevation: 44°

Location: SAL Airport, San Luis Talpa, La Paz, El Salvador

Dimension: 3000 x 3000

International Journal of Applied Earth Observation and Geoinformation
Volume 102, October 2021, 102443

ELSEVIER

Validation of MCD64A1 and FireCCI51 cropland burned area mapping in Ukraine

Joanne V. Hall, Fernanda Argueta, Louis Giglio

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https://doi.org/10.1016/j.jag.2021.102443 Get rights and content

Highlights

- Large burned area omission and commission errors within Ukraine cropland.

Outstanding need find a solution for unambiguous validation of burned area products wrt harvesting

as cropland harvesting can be spectrally & temporally similar to burning

Active Fire and FRP product validation remains challenging

Active Fire

- well established comparison with QA'd contemporaneous active fire detections from ASTER, Landsat, Sentinel-2

- definition of "*contemporaneous*" observations TBD (ballooned from ± minutes to ± ~8 hours)

- small & low FRP fire validation uncertain

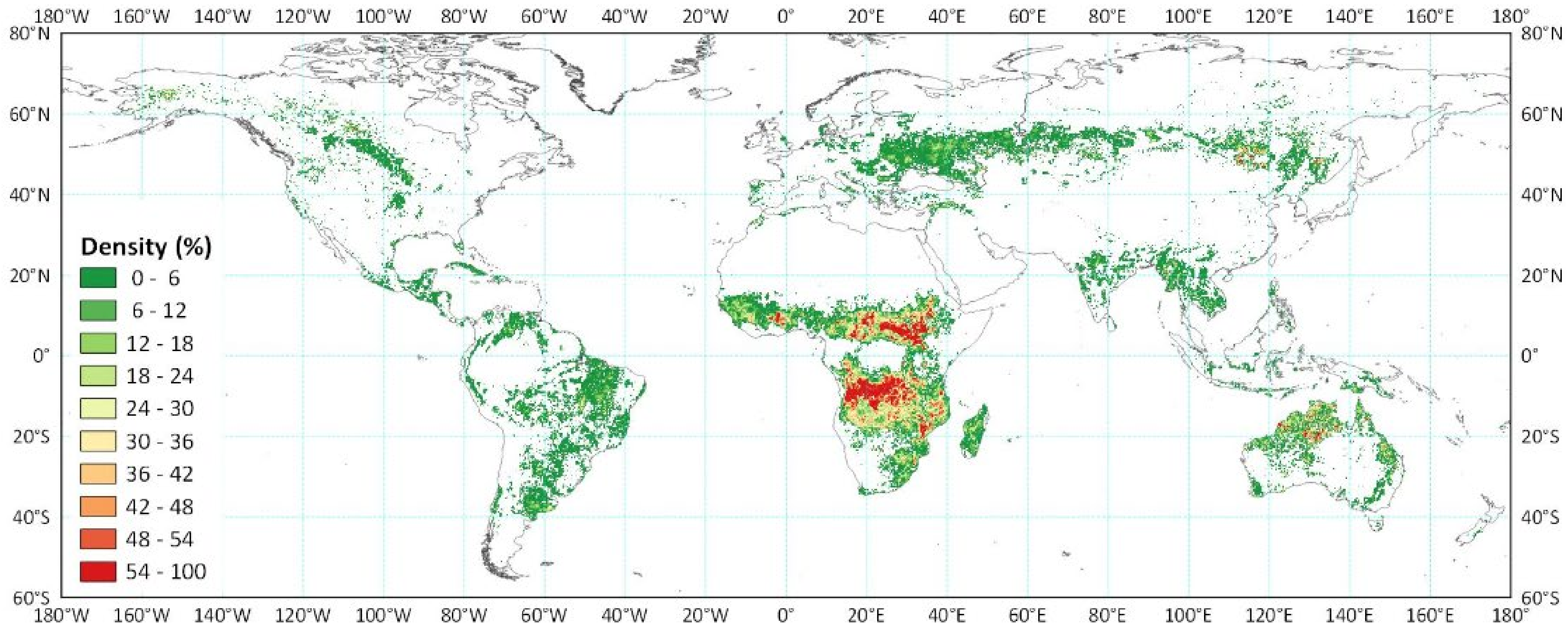
FRP

- challenging due to limited availability of reference data (airborne data and field campaigns) and need for "*contemporaneous*" obs. within ± minutes

(Roberts & Giglio, CEOS LPV Plenary: 28-29 September 2022)

Need to ensure QA undertaken *before* Validation (quality issues typically remain undetected by validation that necessarily relies on a sample of independent reference data)

Google Earth Engine Landsat-8 burned area prototype looks good at this scale



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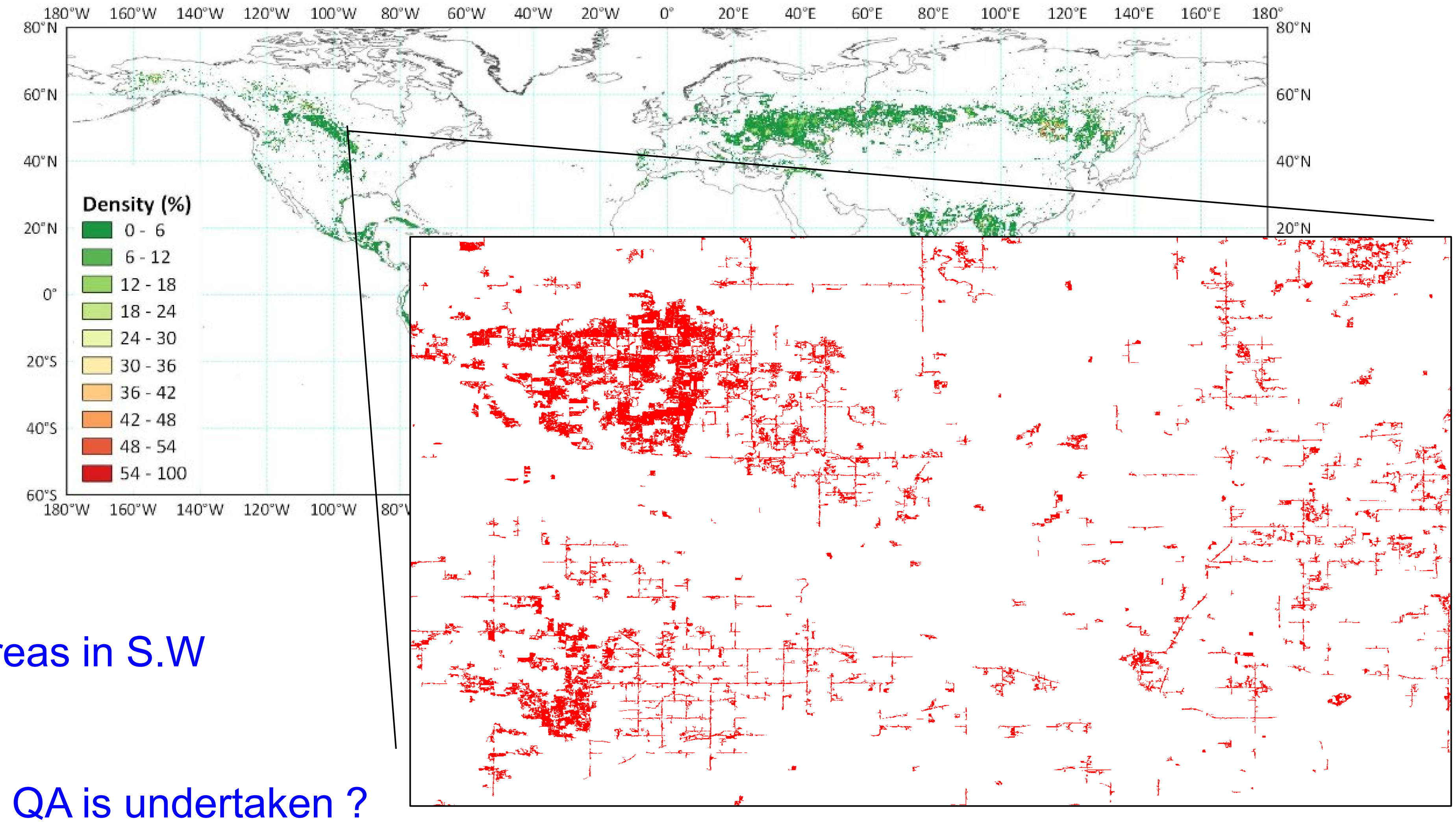

30m burned areas in S.W Minnesota ?

How to ensure QA is undertaken ?

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Independent fire product QA and Validation endorsement process being discussed

- “Foxes in hen house”

- Advocate for QA and Validation “clearing house”
  - use of fire products for policy analysis implies products may be possibly challenged
  - as more, and similar, global products are produced, product inter-use requires reliable characterization of each product’s accuracy
  - explicit statements of accuracy/uncertainty will foster an informed user community and improved/appropriate product use

- Need to develop community repository for
  - harmonized, accurate, endorsed, fire product validation data

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- Community briefing on current status of systems and global/large area products – CEOS gap analysis underway led by Canadian GOFC/GOLD members
- Define the optimal fire monitoring system of systems – initially science and applications user observation requirements
- Discussion of how to find an effective way to communicate findings (in addition to peer reviewed literature)

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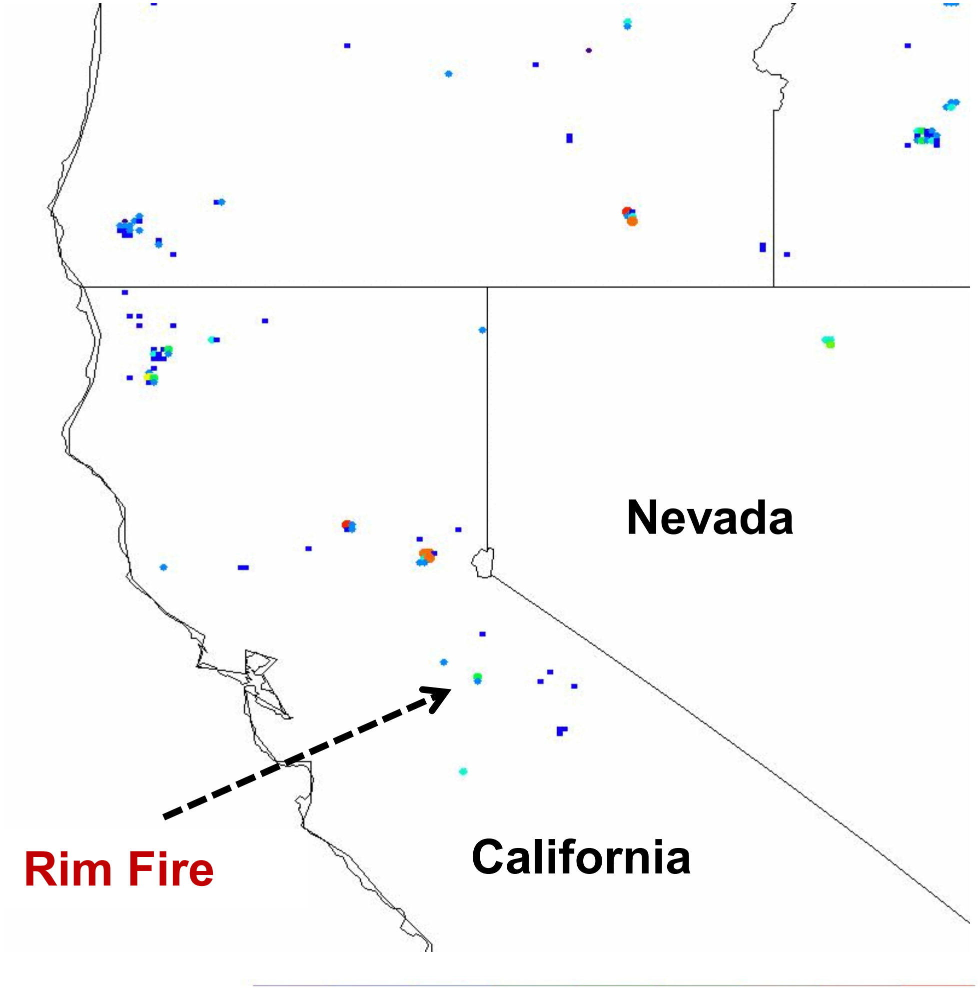
Users (e.g. international GOFC Fire network members) would appreciate a sensor agnostic harmonized satellite fire monitoring system of systems – active fires, FRP & burned areas



August 2013
Yosemite Rim Fire

- GOES Imager Instrument
- AVHRR on NOAA 18-19
- MODIS Terra and Aqua

(Xiaoyang Zhang)

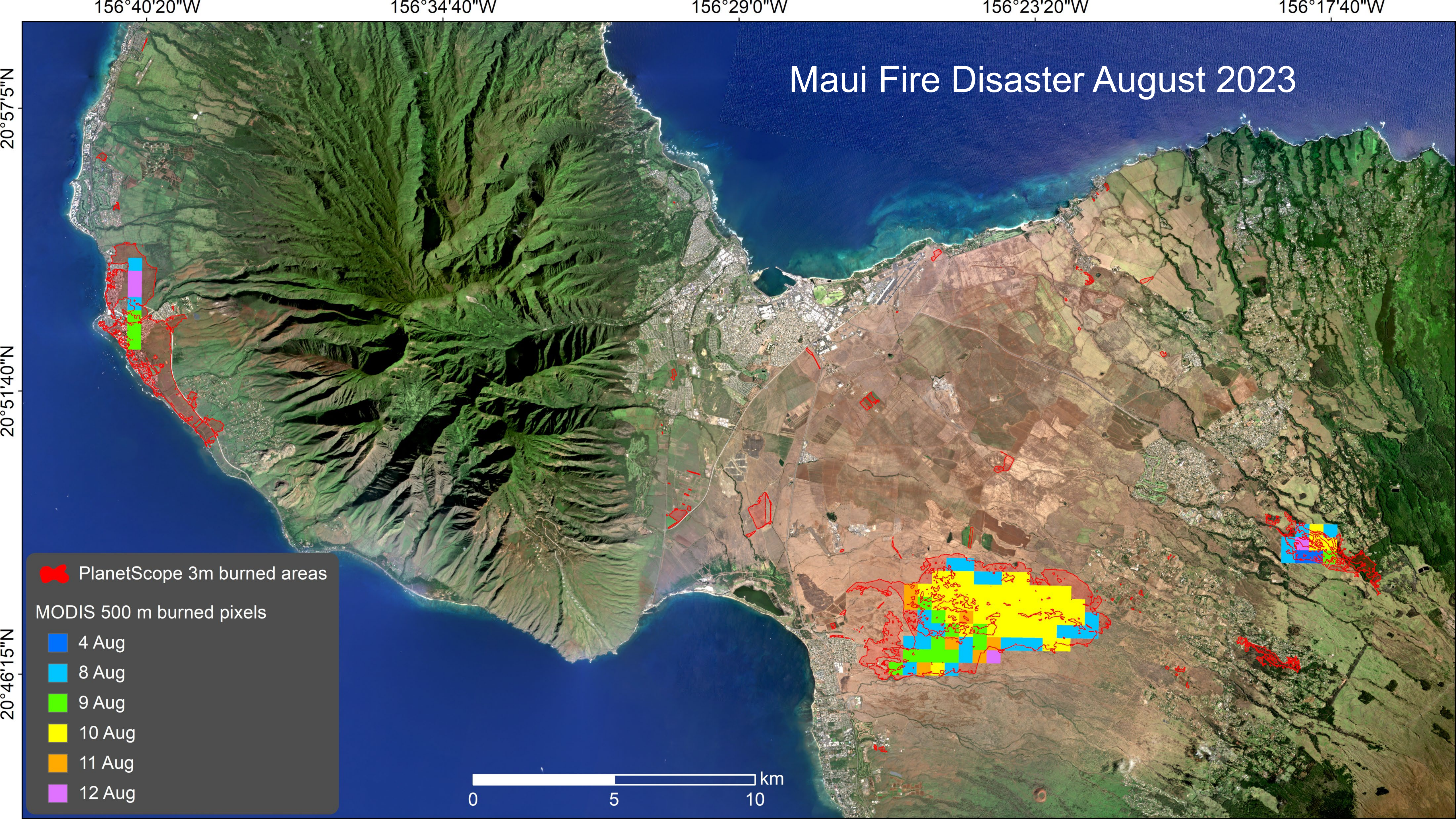
Fire disaster satellite monitoring system still needed …

The New York Times

Death Toll of Maui Wildfire Rises to 101

A new report released by the Maui Police Department this month revealed that a large number of victims had died along a single street.

one of the deadliest U.S. wildfire incidents on record with an estimated U.S. $5.5 billion cost



156°40'20"W
156°34'40"W
156°29'0"W
156°23'20"W
156°17'40"W
20°57'5"N
20°51'40"N
20°46'15"N
Maui Fire Disaster August 2023
PlanetScope 3m burned areas
MODIS 500 m burned pixels
4 Aug
8 Aug
9 Aug
10 Aug
11 Aug
12 Aug
km
0
5
10

Have focus groups etc. to help define needs beyond the relatively scant detail provided in GCOS Fire ECV definitions/requirements

ECV Products and Requirements for Fire

These products and requirements reflect the Implementation Plan 2016 (GCOS-200). GCOS is reviewing and will update the requirements until 2022. More information on: gcos.wmo.int.

PRODUCT	DEFINITION	FREQ.	RES.	REQUIRED MEASUREMENT UNCERTAINTY	STAB.	REF.
Burnt Area	Burned area means the area affected by the fire, including natural vegetation and croplands. X_area means the horizontal area occupied by X within the grid cell. The extent of an individual grid cell is defined by the horizontal coordinates and any associated coordinate bounds or by a string valued auxiliary coordinate variable with a standard name of region.	24 hours	30m	15% (error of omission and commission), compared to 30 m observations		None
Active Fire Maps	Presence of a temporal thermal anomaly within a grid cell. Those thermal anomalies that are permanent should be linked to other sources of thermal emission (volcanos, gas flaring, industrial or power plants). Generally, the active fire maps are defined by the date/hour when the thermal anomaly was detected	6 hours at all latitudes from Polar-Orbiting and 1 hour from Geostationary	0.25-1 km (Polar); 1-3 km (Geo)	5% error of commission; 10% error of omission; Based on per-fire comparisons for fires above target threshold of 5 MW/km² equivalent integrated FRP per pixel (i.e. for a 0.5 km² pixel the target threshold would be 2.5 MW, for a 9 km² pixel it would be 45 MW).		None
Fire Radiative Power	Amount of energy released by area unit. Commonly it is expressed in W/m2. This variable is a function of actual temperature of the active fire at the satellite overpass and the proportion of the grid cell being burned.	6 hours at all latitudes from Polar-Orbiting and 1 hour from Geostationary	0.25-1 km (Polar); 1-3 km (Geo)	10% integrated over pixel. Based on target detection threshold of 5 MW/km² equivalent integrated FRP per pixel (i.e. for a 0.5 km² pixel the target threshold would be 2.5 MW, for a 9 km² pixel it would be 45 MW).and with the same detection accuracy as the Active Fire Maps.		None

https://gcos.wmo.int/en/essential-climate-variables/fire/ecv-requirements

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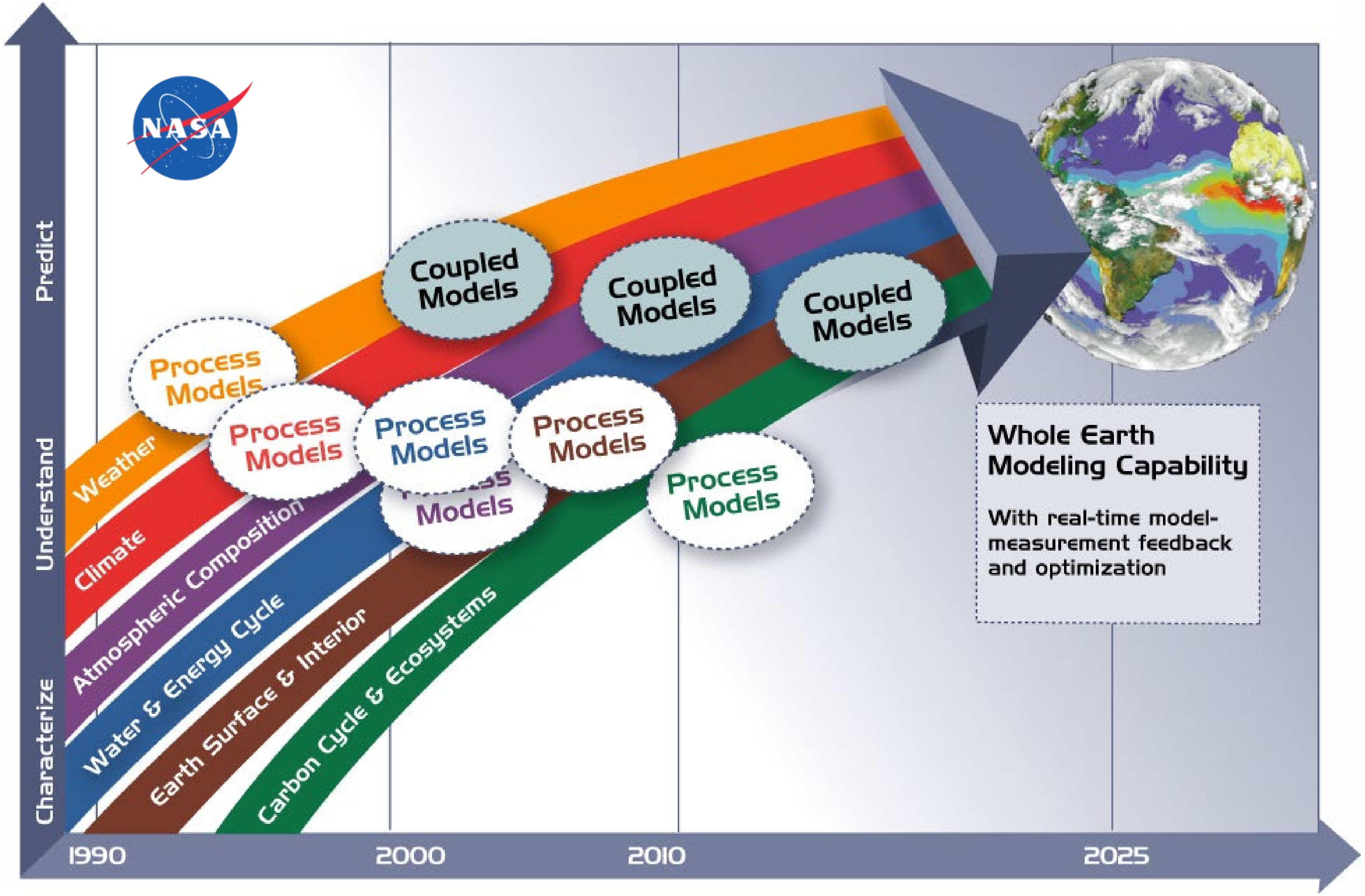
Future fire modelling and fire regime change research (forecasting, understanding, conjecturing)



Need to coordinate and perhaps fund research in a more coherent and so impactful manner.

Early statistical approaches

- satellite fire products
- gridded human and physical explanatory variables
- random forest

Global Change Biology (2009) **15**, 613–630, doi: 10.1111/j.1365-2486.2008.01754.x

What limits fire? An examination of drivers of burnt area in Southern Africa

SALLY ARCHIBALD*, DAVID P. ROY†, BRIAN W. VAN WILGEN‡ and ROBERT J. SCHOLES*

**Natural Resources and the Environment, CSIR, PO Box 395, Pretoria 0001, South Africa, †Geographic Information Science Centre of Excellence, South Dakota State University, Brookings, SD 57007, USA, ‡Centre for Invasion Biology, Natural Resources and the Environment, CSIR, PO Box 320, Stellenbosch, South Africa,*

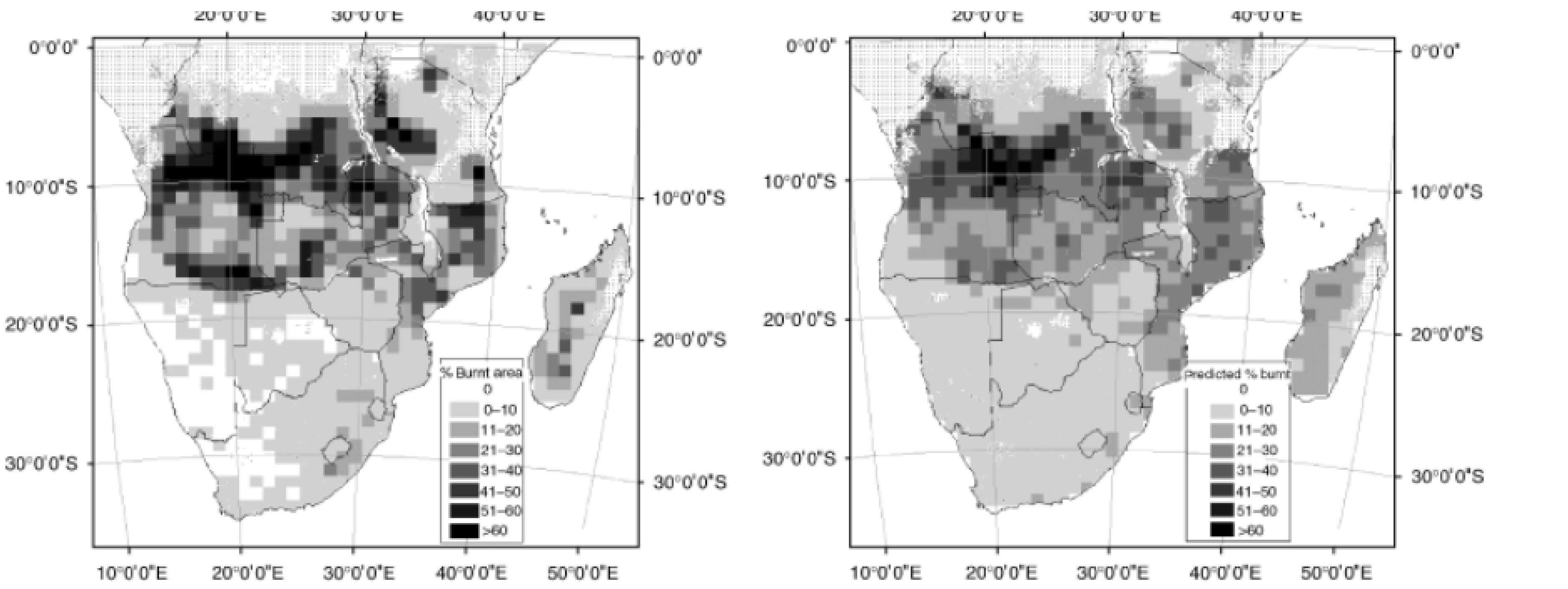


Fig. 5 Observed (left) and predicted (right) percent burnt areas for 100 km × 100 km windows across southern Africa. Predictions are mean values for the reserve samples in the random forest (see 'Data and methods'). Dark stipples represent areas where cloud or missing Moderate Spatial Resolution Spectroradiometer (MODIS) data preclude burned area mapping for more than 5 months of the year.

Evolving process-based approaches for both long- and short-term future fire modelling

AGU ADVANCING EARTH AND SPACE SCIENCE

Reviews of Geophysics

REVIEW ARTICLE
10.1029/2020RG000726

Special Section:
Fire in the Earth System

Key Points:

- The frequency and severity of fire weather has increased in recent decades and is projected to escalate with each added increment of warming
- Fire weather is one of the major controls on fire activity, and is the dominant control on variability in burned area (BA) in many mesic forest ecoregions
- Various human and bioclimatic factors also control fire, modulating the relationship between BA and fire weather in many regions

Global and Regional Trends and Drivers of Fire Under Climate Change

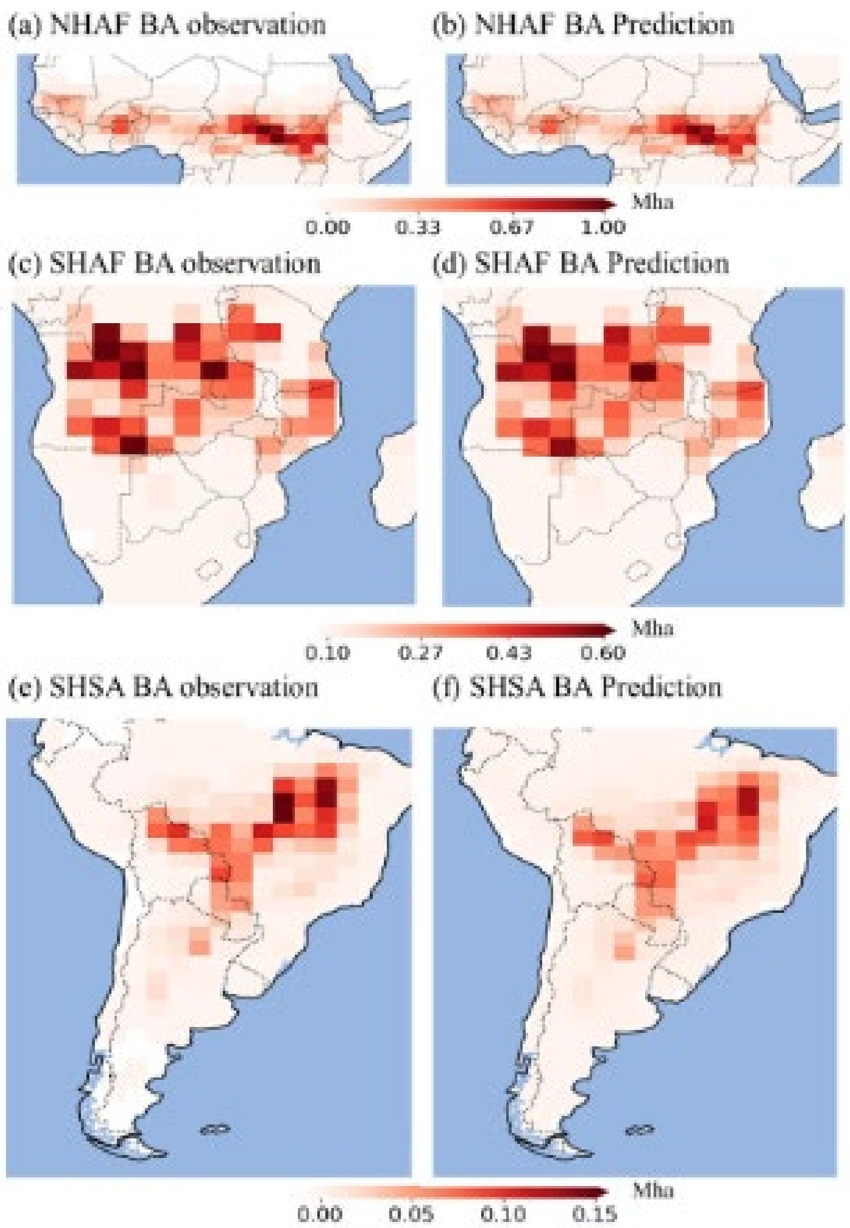
Matthew W. Jones[1], John T. Abatzoglou[2], Sander Veraverbeke[3], Niels Andela[4,5], Gitta Lasslop[6], Matthias Forkel[7], Adam J. P. Smith[1], Chantelle Burton[8], Richard A. Betts[8,9], Guido R. van der Werf[3], Stephen Sitch[9], Josep G. Canadell[10], Cristina Santín[11,12], Crystal Kolden[2], Stefan H. Doerr[12], and Corinne Le Quéré[1]

[1]Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK, [2]Department of Management of Complex Systems, University of California, Merced, Merced, CA, USA, [3]Faculty of Science, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands, [4]School of Earth and Ocean Sciences, Cardiff University, Cardiff, UK, [5]Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA, [6]Senckenberg Biodiversity and Climate Research Centre, Frankfurt am Main, Germany, [7]Institute of Photogrammetry and Remote Sensing, Technische Universität Dresden, Dresden, Germany, [8]Met Office, Exeter, UK, [9]Global Systems Institute, University of Exeter, Exeter, UK, [10]CSIRO Oceans and Atmosphere, Canberra, Australia, [11]Research Institute of Biodiversity (IMIB), CSIC-University of Oviedo, Mieres, Spain, [12]Centre for Wildfire Research, Swansea University, Swansea, UK

Abstract Recent wildfire outbreaks around the world have prompted concern that climate change is

New deep learning statisrtical opportunities

F. Li et al.: AttentionFire_v1.0 Geosci. Model Dev, 2023



R&D needed on how to

- develop for *understanding* of drivers and constraints on fire
- support *conjectures* about future fire occurrence and variability

Long-term fire products and explanatory variable data sets that are consistent and accurate needed for training

Earth System Digital Twins Components

ESDT 2022
OCTOBER 26–28, 2022

Digital Replica . . .

An integrated picture of the past and current states of Earth systems.

Forecasting . . .

An integrated picture of how Earth systems will evolve in the future from the current state.

Impact Assessment . . .

An integrated picture of how Earth systems could evolve under different hypothetical what-if scenarios.

- **Continuous observations** of interacting Earth systems and human systems
- From many **disparate sources**
- Driving **inter-connected models**
- At many **physical and temporal scales**
- With fast, powerful and integrated **prediction, analysis** and **visualization** capabilities
- Using **Machine Learning, causality and uncertainty quantification**
- Running at **scale** in order to improve our **science** understanding of those systems, their **interactions and** their **applications**

GOFC/GOLD Fire Implementation Team priorities

(support R&D / advocate / share information / provide platform / do)

- small area & low Fire Radiative Power (FRP) fires
- continuity of global fire product record
- product continuity characterization (among mission/sensor continuity *ad hoc.*)
- meaningful validation of new and existing fire products, new opportunities provided by commercial satellite data, product QA then validation concern
- develop an independent fire product QA and Validation endorsement process
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- fire modelling and fire regime change research, deep learning revolution provides new opportunities
- fuel load and fire consumption
- fire product policy relevant information service in the post-MODIS era
- strengthen fire-related GOFC/GOLD regional networks

J. R. McNorton and F. Di Giuseppe: A global fuel characteristic model and dataset for wildfire prediction
Biogeosciences, 21, 279–300, 2024

Fuel load intercomparison exercise needed

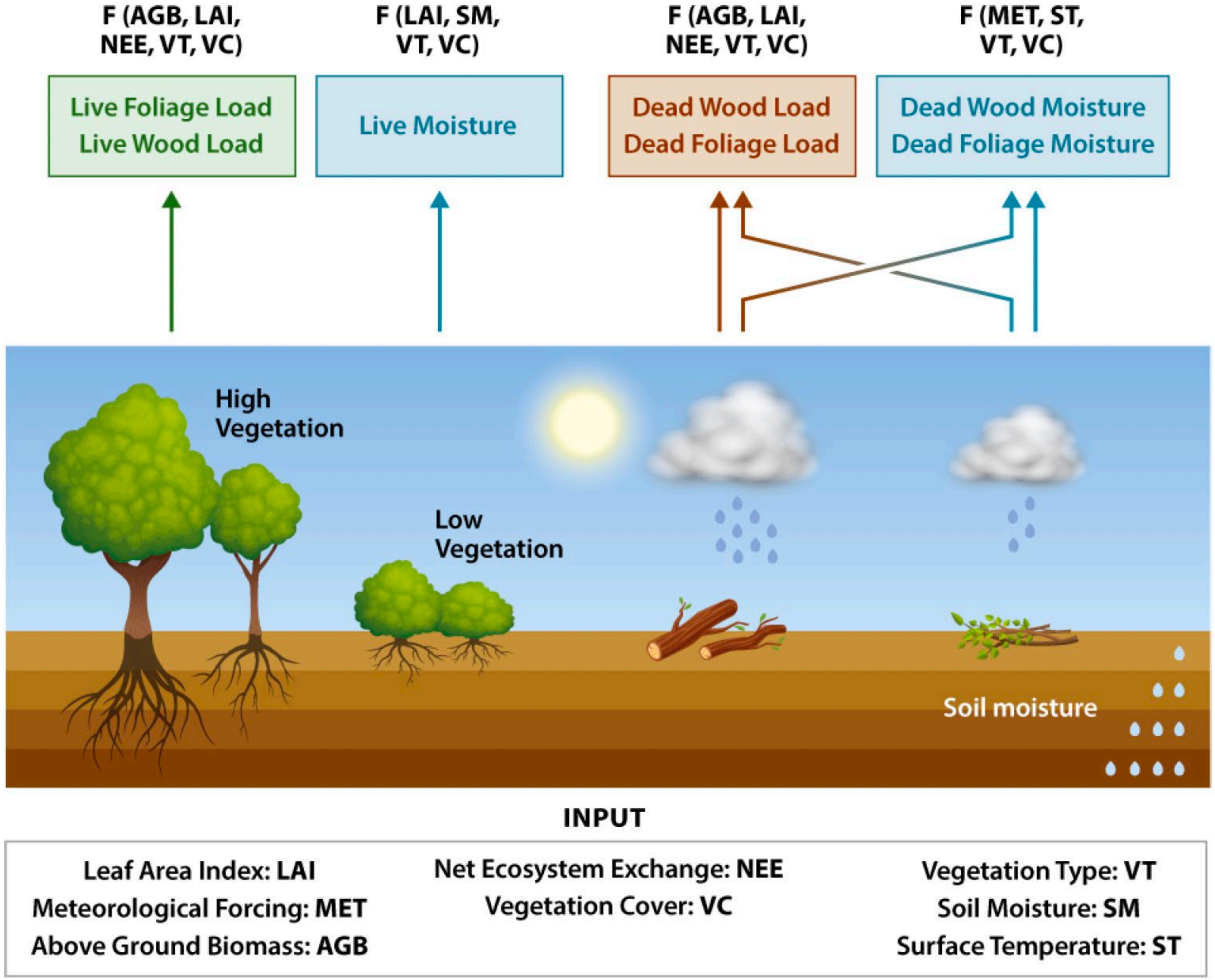
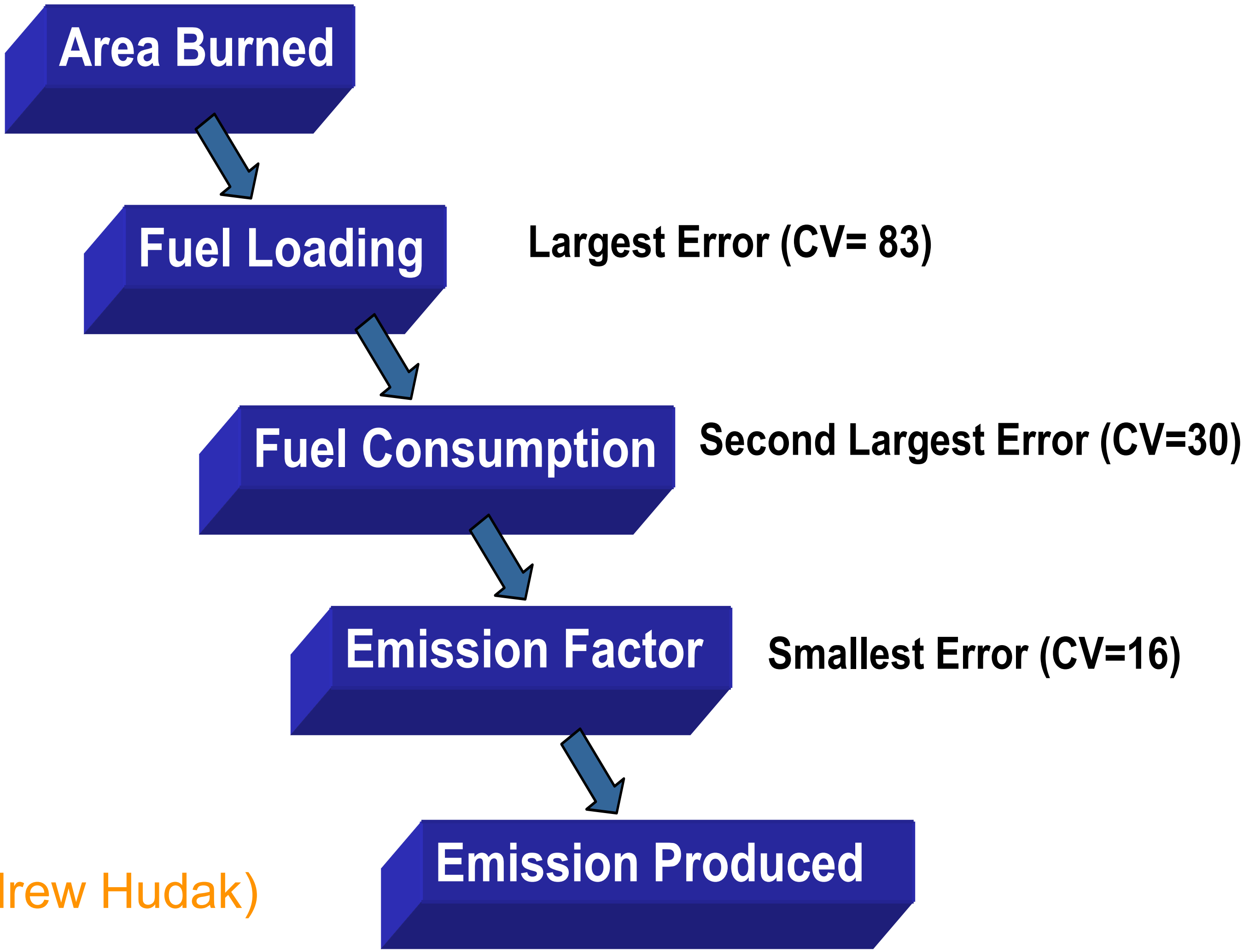


Figure 1. A schematic of the fuel characteristic model showing the required input data and the dependencies for the output variables

Different approaches to convert satellite fire products into estimates of fuel consumption (and then fire emissions)

Intercomparison exercise becoming needed



(Andrew Hudak)

Fuel loading & consumption (the proportion of the fuel that is combusted) have highest uncertainty

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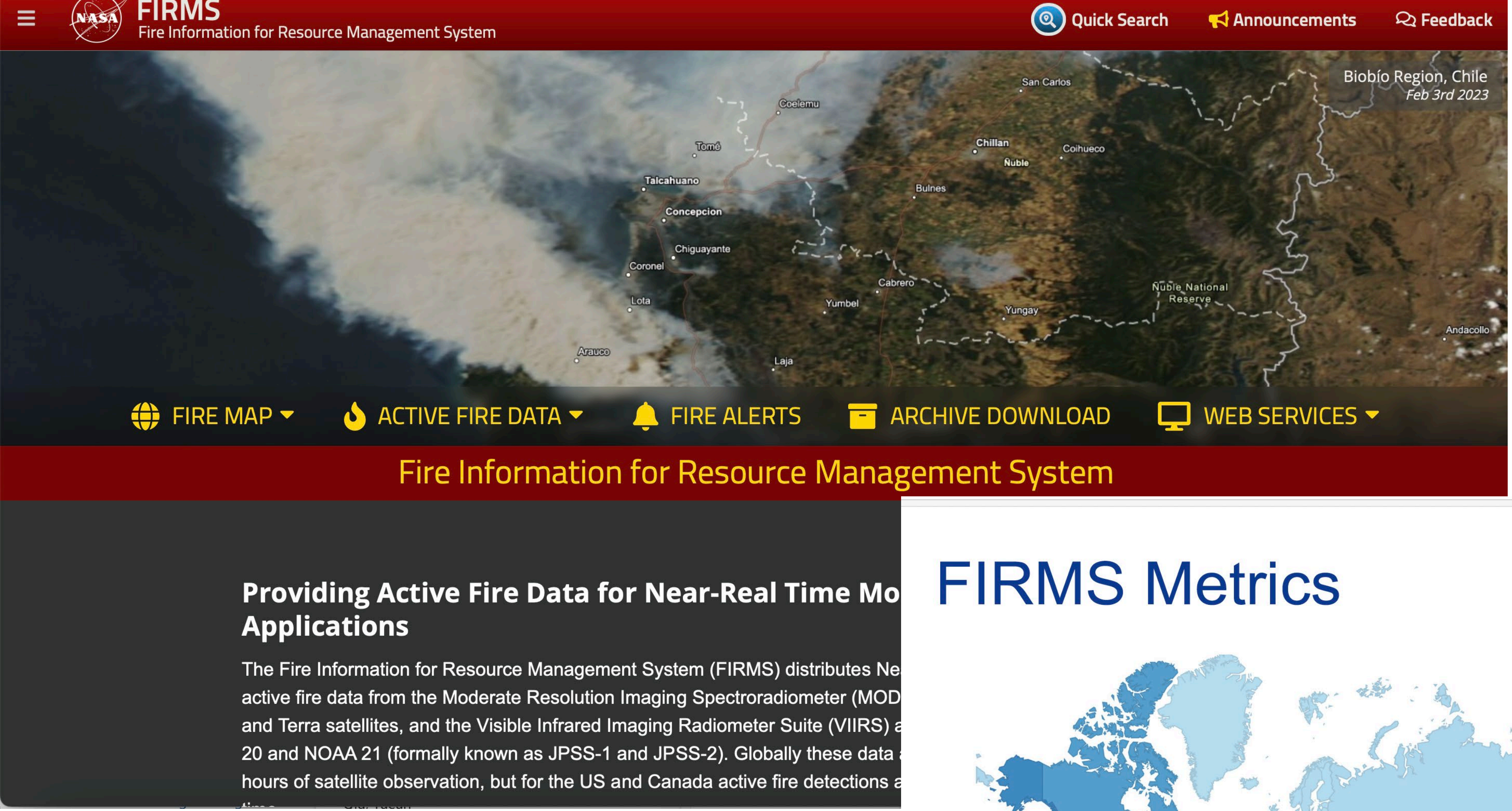
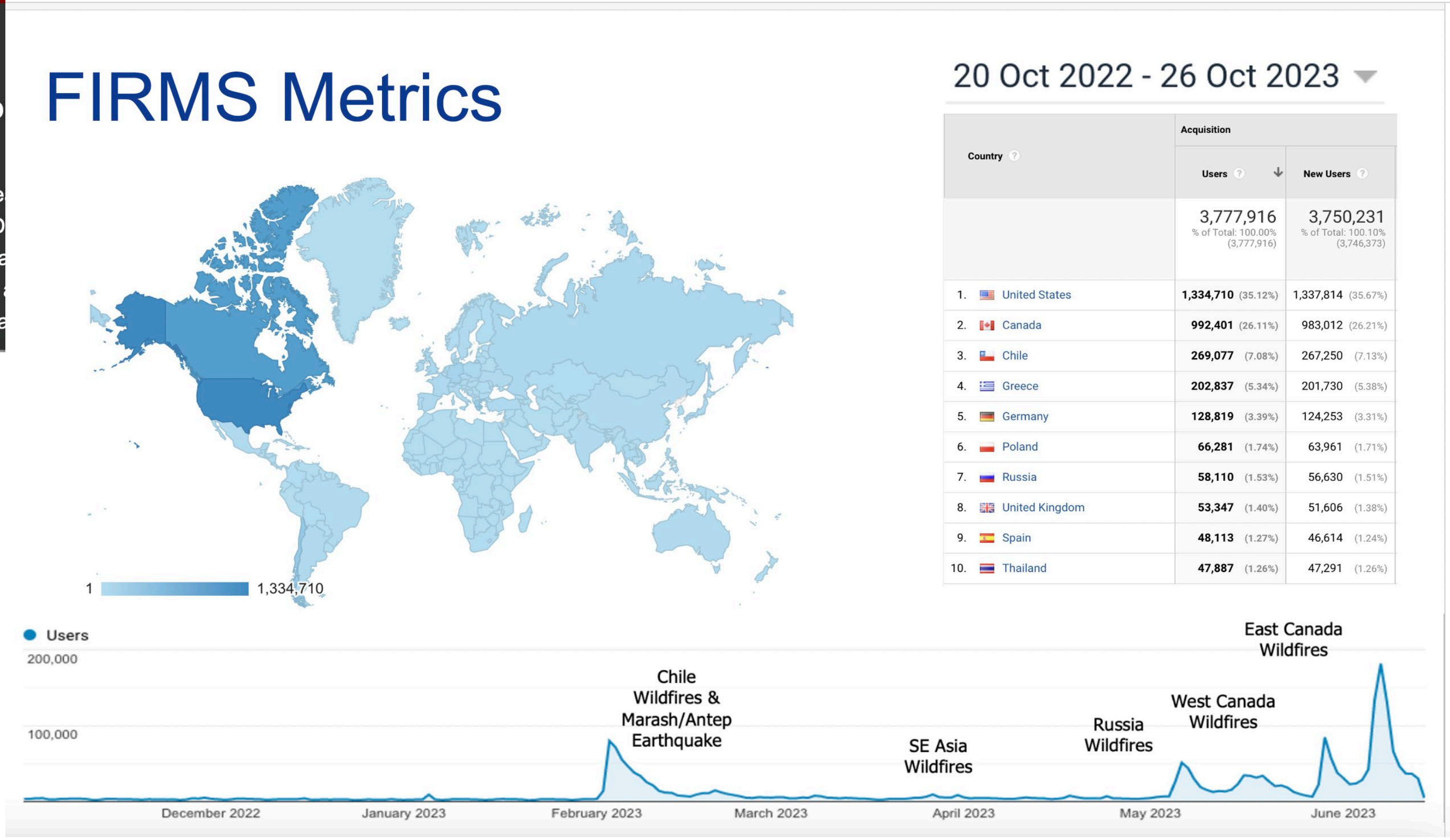
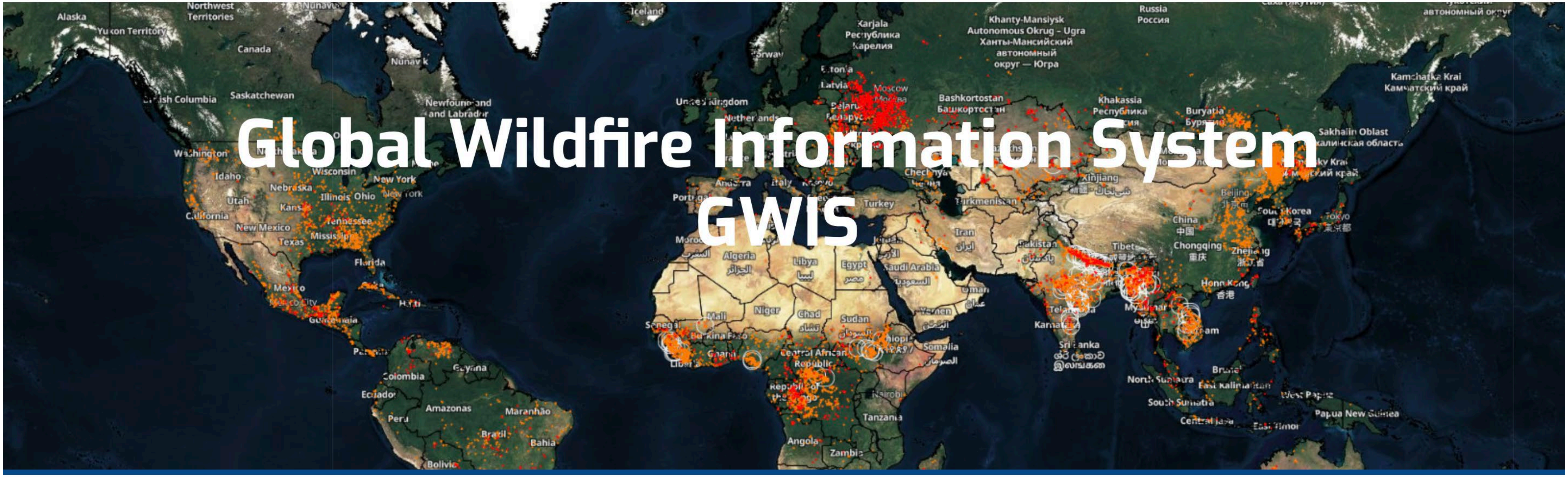


Dedicated fire portals working well but not focused on needs of non-scientific & policy users



Country	Acquisition: Users	Acquisition: New Users
	3,777,916 % of Total: 100.00% (3,777,916)	3,750,231 % of Total: 100.10% (3,746,373)
1. United States	1,334,710 (35.12%)	1,337,814 (35.67%)
2. Canada	992,401 (26.11%)	983,012 (26.21%)
3. Chile	269,077 (7.08%)	267,250 (7.13%)
4. Greece	202,837 (5.34%)	201,730 (5.38%)
5. Germany	128,819 (3.39%)	124,253 (3.31%)
6. Poland	66,281 (1.74%)	63,961 (1.71%)
7. Russia	58,110 (1.53%)	56,630 (1.51%)
8. United Kingdom	53,347 (1.40%)	51,606 (1.38%)
9. Spain	48,113 (1.27%)	46,614 (1.24%)
10. Thailand	47,887 (1.26%)	47,291 (1.26%)

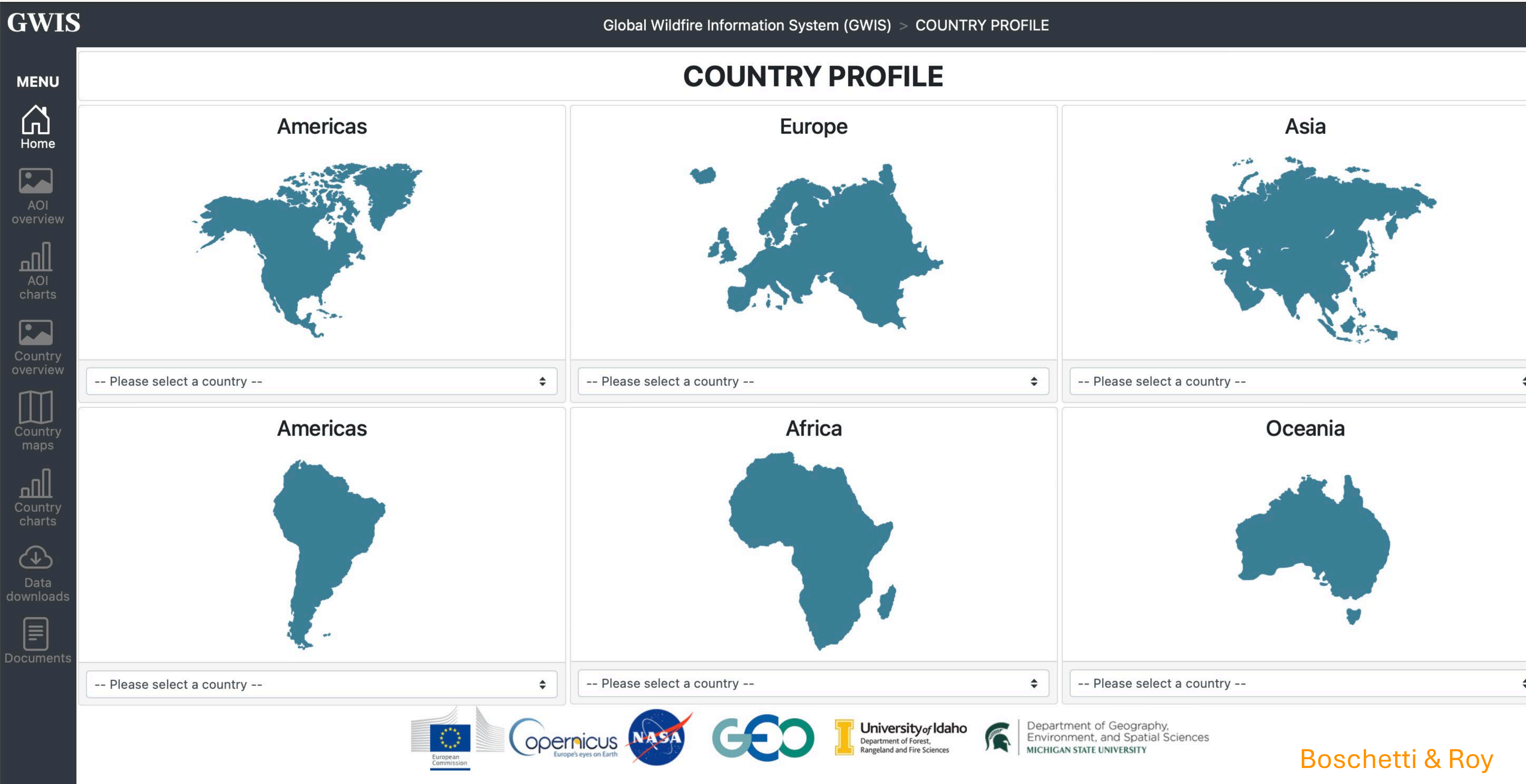


Global Wildfire Information System GWIS

Welcome to GWIS

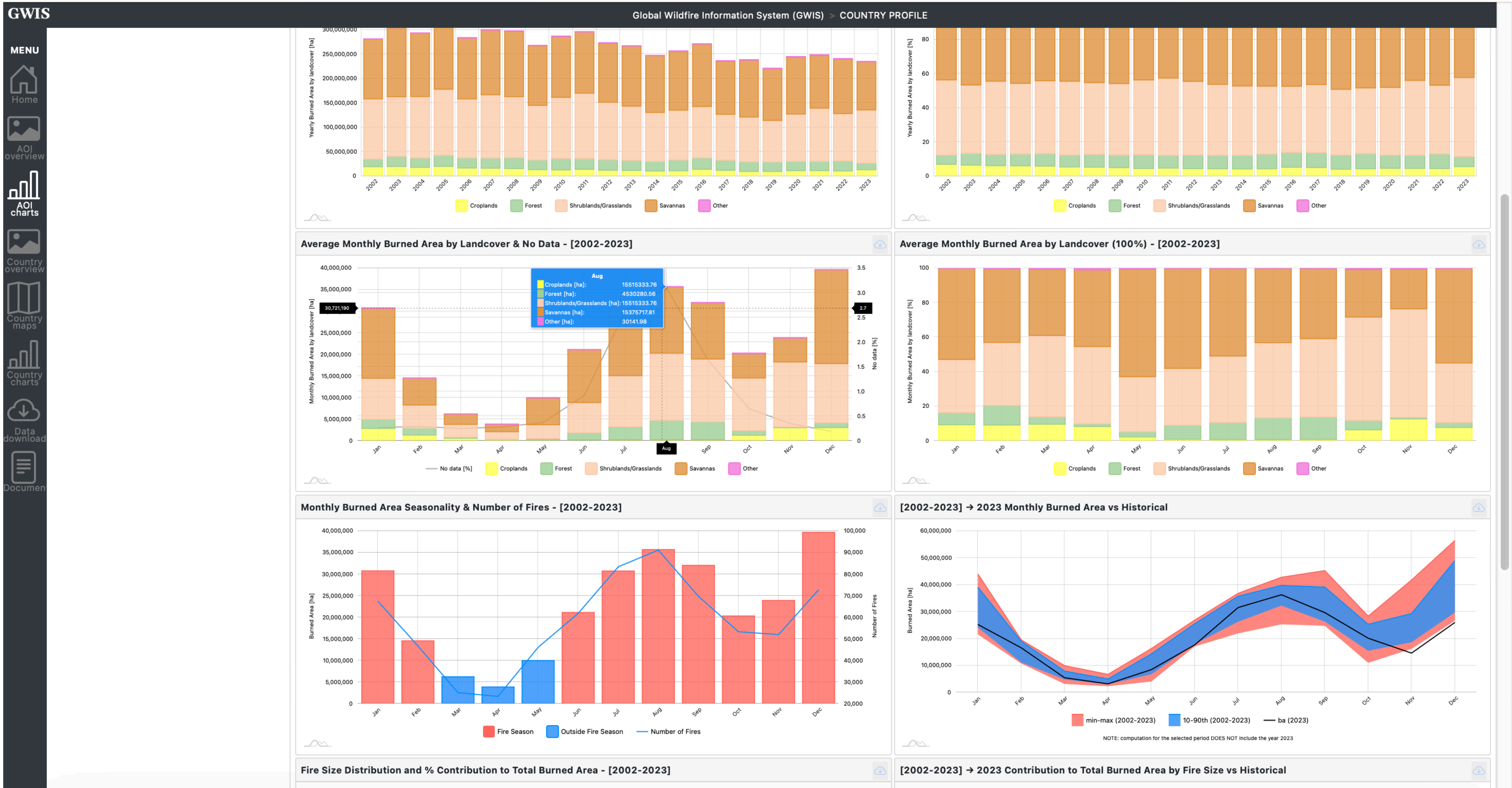
The Global Wildfire Information System (GWIS) is a joint initiative of the GEO and the Copernicus Work Programs. In the GEO GWIS work program for the years 2023-2025, GWIS aims at bringing together existing information sources at regional and national levels in order to provide a comprehensive view and evaluation of fire regimes and fire effects at global level; the fires mapped in GWIS may include fires set intentionally for the purpose of vegetation

Fire policy relevant information service in GWIS via a NASA GEO funded project



Boschetti & Roy

Fire policy relevant information service in GWIS via a NASA GEO funded project need to ensure continuity into the post-MODIS era



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GOFC-GOLD 20th Anniversary of Regional Networks (RN)
Sep 13-16th 2018, Tbilisi, Georgia

The Earth Observer January - February 2018 Volume 30, Issue 1

Summary of the GOFC–GOLD Twentieth-Anniversary Regional Networks Summit

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Introduction

Global Observation for Forest and Land Cover Dynamics (GOFC–GOLD) is a coordinated international program working to provide ongoing space-based and *in situ* observations of the land surface to support sustainable management of terrestrial resources at different scales. The GOFC–GOLD program acts as an international forum to exchange information, coordinate satellite observations, and provide a framework for and advocacy to establish long-term monitoring systems. It was established as a part of a Committee on Earth Observation Satellites (CEOS) pilot project in 1997, with a focus on global observations of forest cover. Since then, the program has expanded to include two Implementation Teams: Land Cover Characteristics and Change, and Fire Mapping and Monitoring. In addition, two working groups—Reducing Emissions from Deforestation and Forest Degradation (REDD), and Biomass Monitoring—were also formed. GOFC–

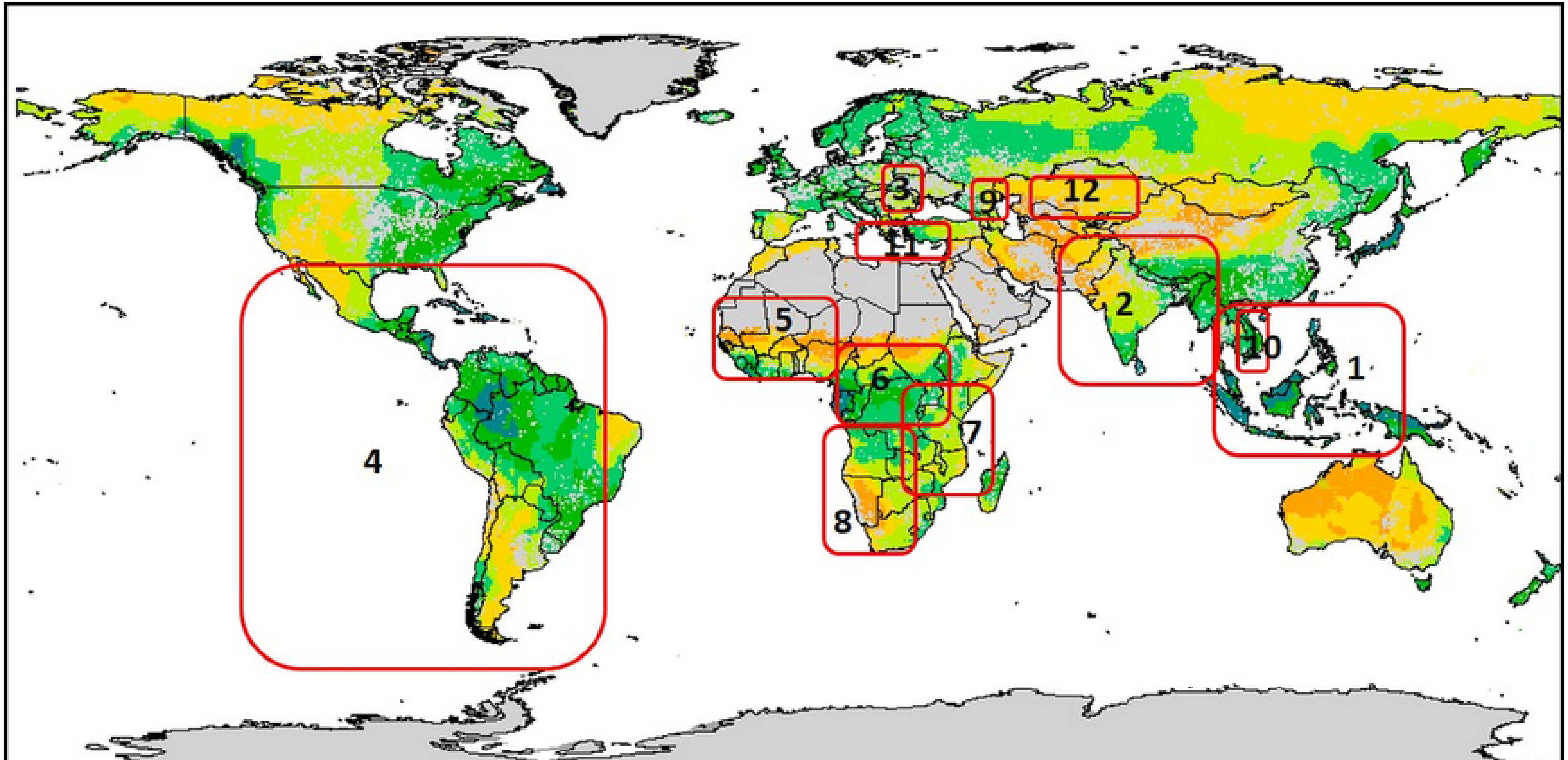
GOFC–GOLD Twentieth Anniversary meeting participants. **Photo credit:** Agricultural University of Georgia team

September 13-16, 2017. There were 45 people from 20 countries in attendance—including participants from Africa, Asia, South America, Eastern and Southern Europe, and the U.S. The Summit was jointly hosted

Keeping GOFC-GOLD RNs healthy can be challenging

Strengthen fire-related GOFC/GOLD regional networks

African regional networks #5/6/8 poor shape post-COVID (and Africa is the most fire prone continent)



How to prioritize these ?

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Discuss at Next GOFC Fire IT / GWIS meeting

September 17-18 2024, Milan, Italy

(immediately before Earsel meeting)

EARSEL abstract deadline 15 April 2024