CEOS LPV: Fire Disturbance

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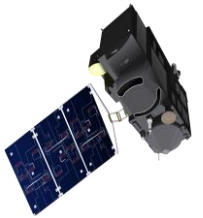
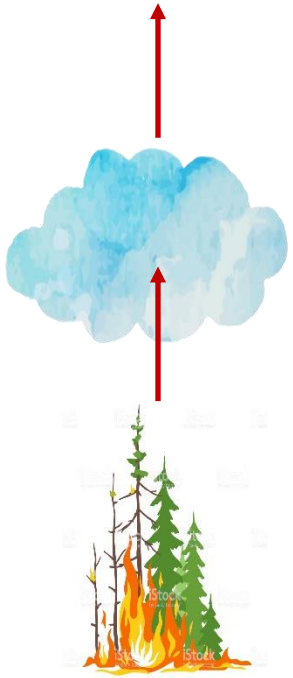
CEOS LPV Plenary: 15 June 2023

Fire Disturbance

Outline

- Fire disturbance products and validation framework
- Active fire and FRP validation approach and key issues
- Burned area validation approach and key issues
- Validation protocol
- Current status
- Recent publications & product developments





Fire Disturbance

Active fire detection, FRP, and burned area comprise three separate GCOS Essential Climate Variables (ECVs).

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**.*

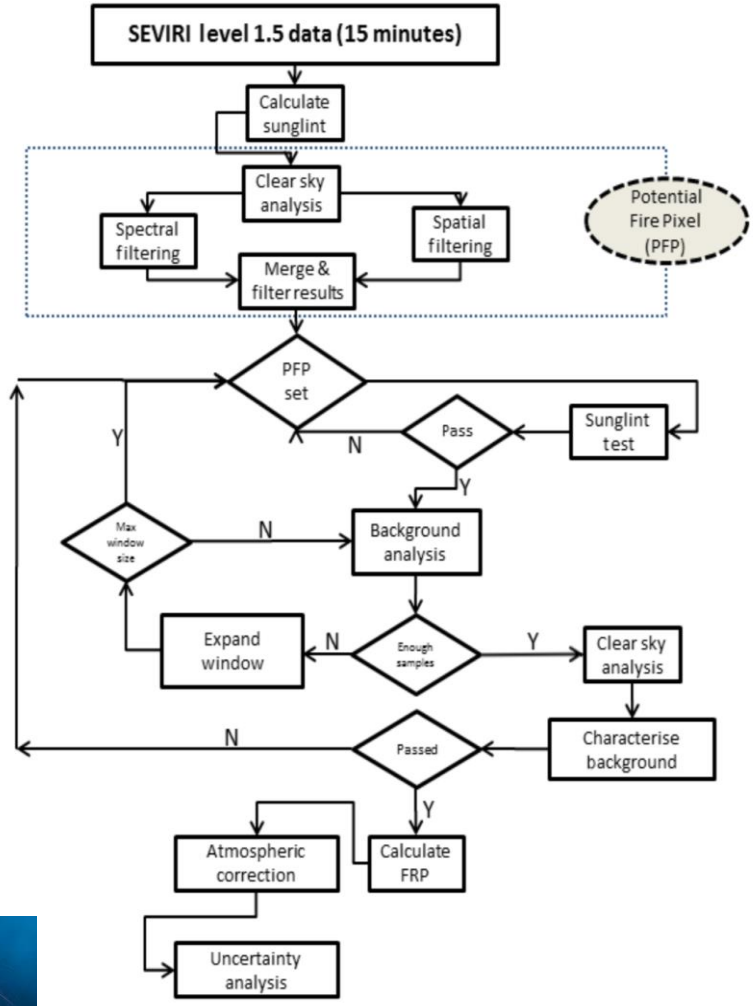
PRODUCT	DEFINITION	FREQ.	RES.	REQUIRED MEASUREMENT UNCERTAINTY	STAB.	REF.
Burnt Area	Burned area means the area affected by the fire, including natural vegetation and croplands. X_area means the horizontal area occupied by X within the grid cell. The extent of an individual grid cell is defined by the 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

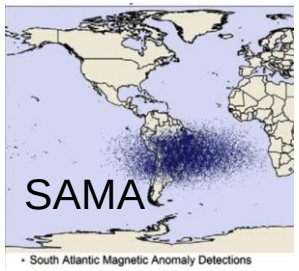
https://gcos.wmo.int/en/essential-climate-variables/fire

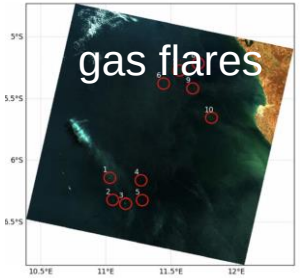
Fire Disturbance

Active Fire [#]

- *Capture fire presence/characteristics at time of satellite overpass*
- Relies on the detection of a thermal anomaly (MWIR and LWIR)
- Need to differentiate from other sources of anomalies.
- Challenge to produce L3/L4 products (spatial consistency)
- No validation protocol exist







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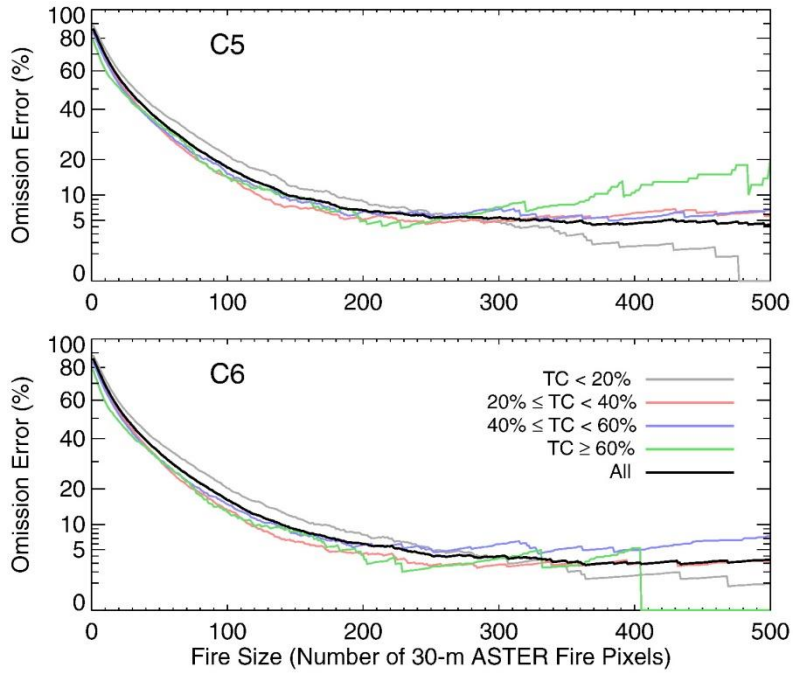
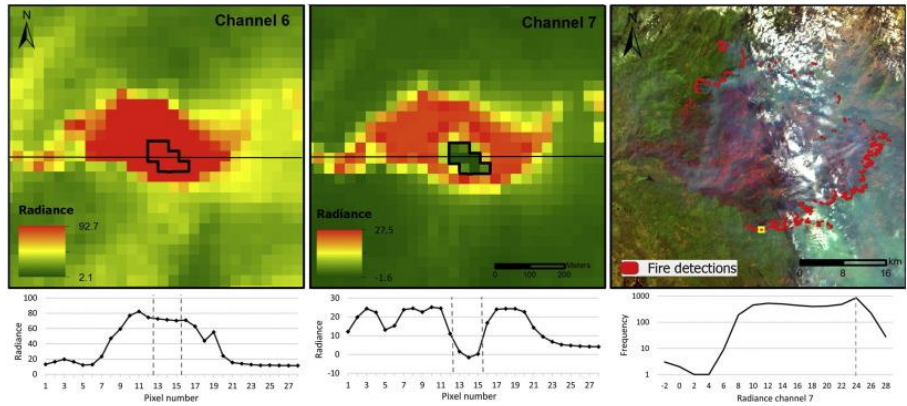
Active Fire Validation

- Contemporaneous product inter-comparison
  - *Moderate (m) resolution data*
    - Fire omission/commission as a function of fire size
      - ASTER, Landsat OLI & Sentinel-2 MSI active fire
  - *Coarse (km) resolution data*
    - Fire omission/commission
      - MODIS/VIIRS inter-comparison with geostationary products

- Prescribed fire programmes
  - Few global locations
  - Typically small fires



Giglio et al., 2016; RSE

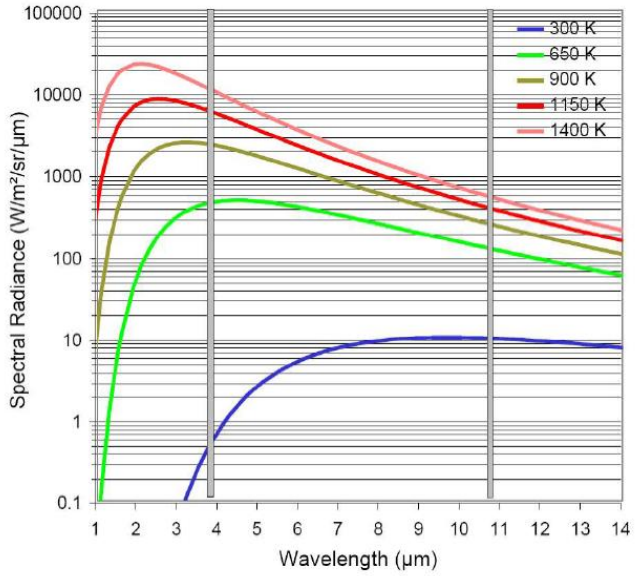


Schroeder, W., et al., 2016. RSE

Fire Disturbance

Fire Radiative Power [MW]

- *Based on Active Fire products*
- Measure the amount of energy that is being released by an ongoing fire.
- Mostly relies on the MWIR band difference between the fire pixel and its background (physical based function)
- Uncertainty characterization in its initial stages (some effects considered)
- Challenge to produce L3/L4 products spatially and temporally consistent
- No validation standard exist.



MWIR (3-5 µm): spectral window where fires radiant intensity is greatest in this even for very small fires compared to the sensor spatial resolution (10^{-3} to 10^{-4})

Fire Radiative Power [MW]

Ground pixel area [km^2]

Stefan-Boltzmann constant [$Wm^{-2}K^{-4}$]

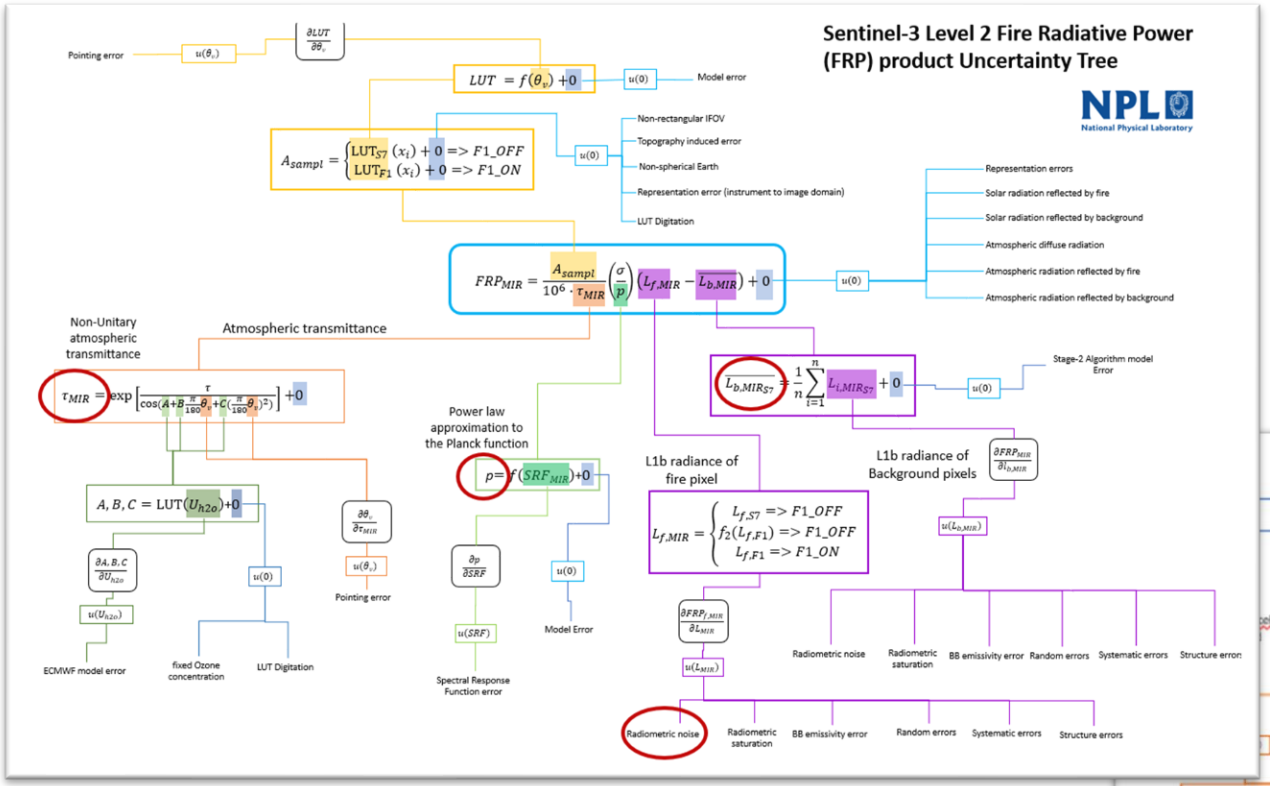
$$FRP_{MIR} = \frac{A_{sampl}}{10^6 \cdot \tau_{MIR}} \left(\frac{\sigma}{p}\right) \left(L_{f,MIR} - \overline{L_{b,MIR}}\right) + 0$$

Atmospheric **Transmittance** [unitless]

AF pixel spectral radiance [$Wm^{-2}sr^{-1}\mu^{-1}$]

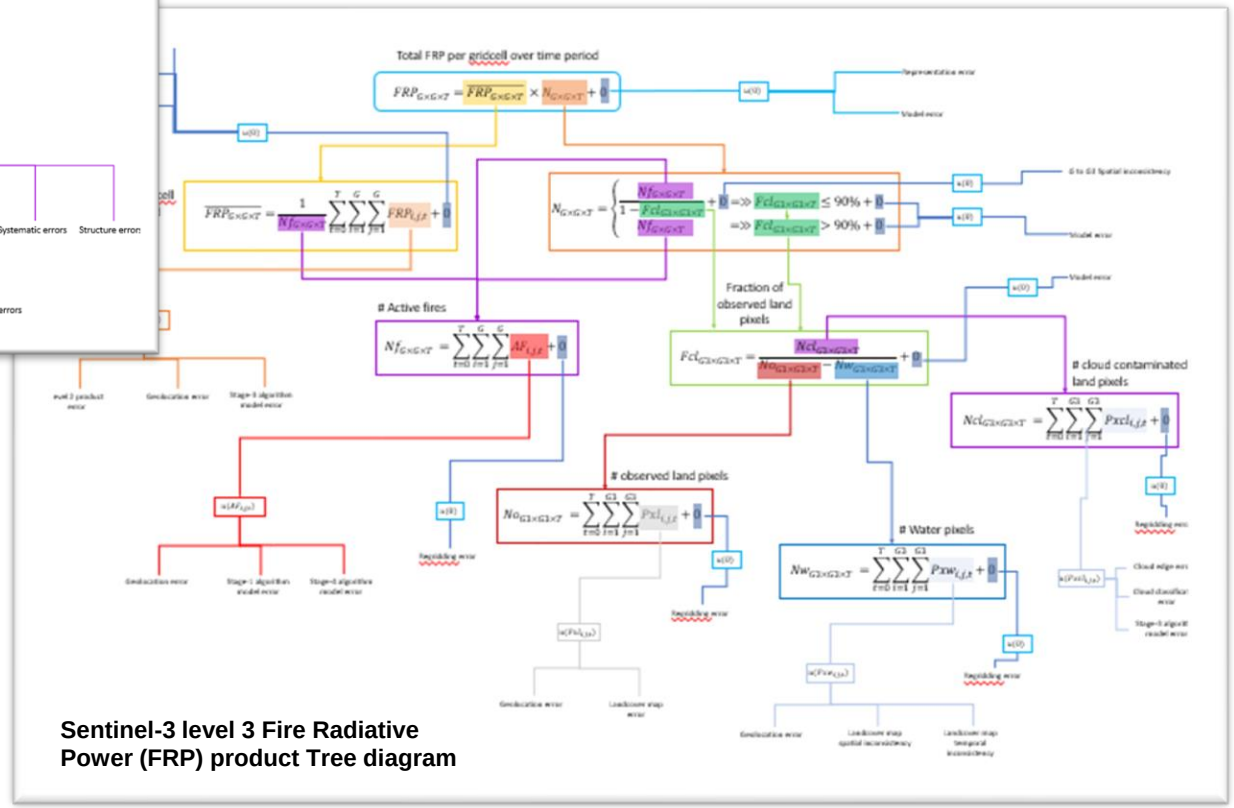
background mean spectral radiance [$Wm^{-2}sr^{-1}\mu^{-1}$]

Fire Disturbance



Recent advances in characterizing uncertainty

- Using tools developed under the FIDUCEO project



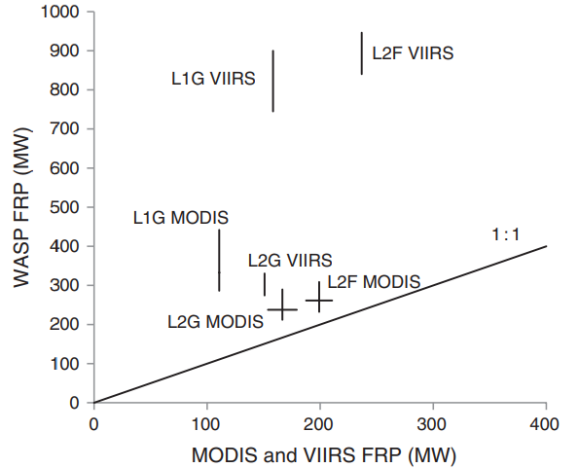
Sentinel-3 level 3 Fire Radiative Power (FRP) product Tree diagram

Gobron et al., 2022. Performance Analysis and Impact on Level 3 - D 3.5 of the Copernicus Cal/Val Solutions (CCVS) project

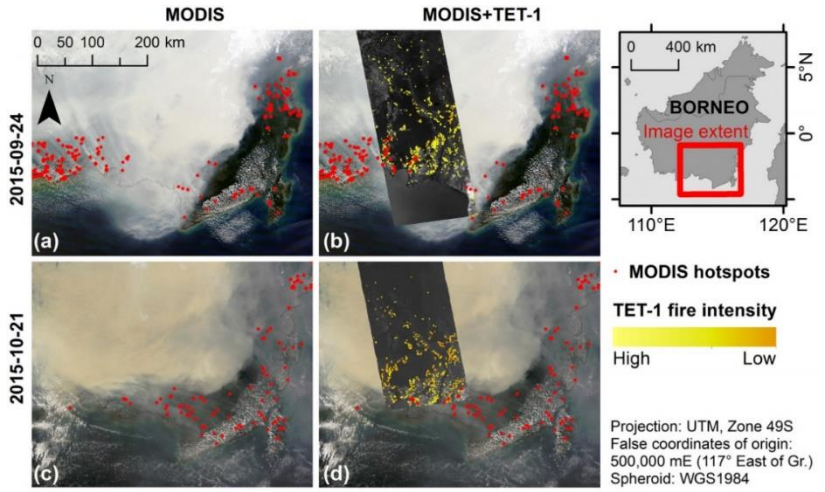
Fire Disturbance

FRP Validation

- Constrained by:
  - Limited availability of reference data
    - FireBIRD (DLR) or airborne data
  - Field campaigns (surface & airborne imagery)
    - Fire And Smoke Model Evaluation Experiment (FASMEE) (Ottmar et al., 2017)
    - RxCADRE project
    - FIDEX Campaign
    - Logistically challenging/limited sample size
- Satellite inter-comparison activities
  - Typically on the scale of 'fire cluster' or larger



Dickinson, M.B., Hudak, A.T., Zajkowski, T., Loudermilk, E.L., Schroeder, W., Ellison, L., Kremens, R.L., Holley, W., Martinez, O., Paxton, A. and Bright, B.C., 2015. Measuring radiant emissions from entire prescribed fires with ground, airborne and satellite sensors–RxCADRE 2012. *International Journal of Wildland Fire*, *25*(1), pp.48-61.

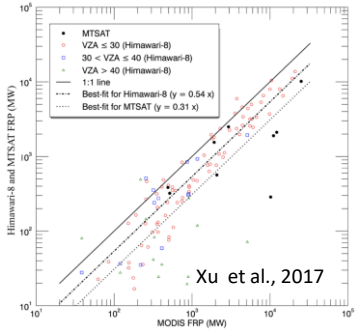


Atwood et al., 2016; PLoS One

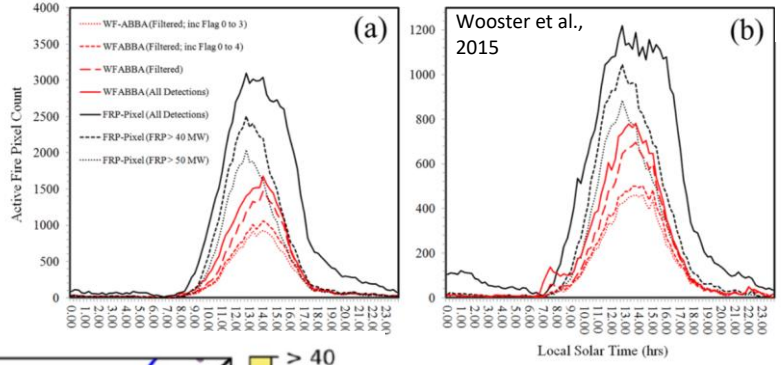
Fire Disturbance

Ex: Product inter-comparison exercises

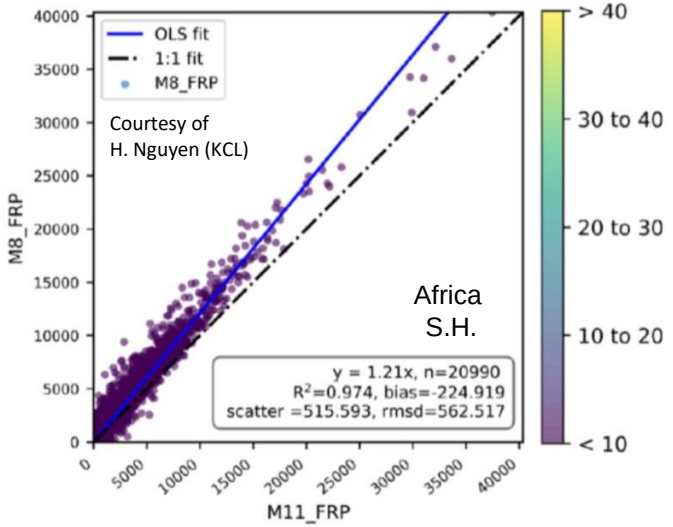
GEO vs GEO



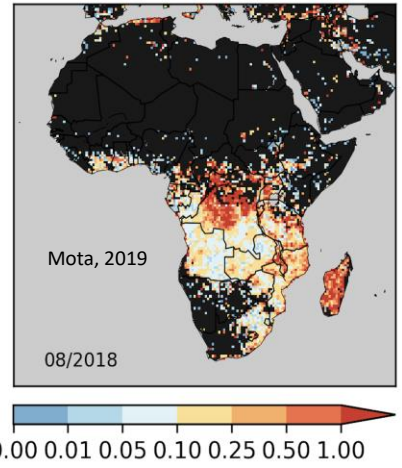
Xu et al., 2017



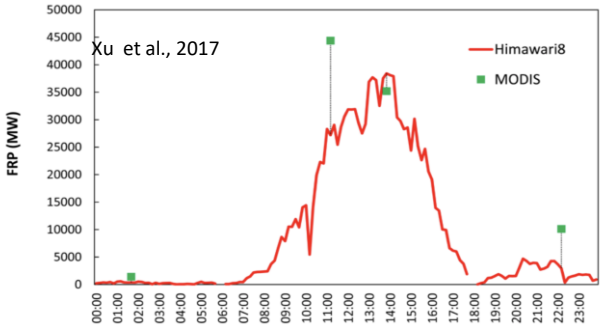
Wooster et al., 2015

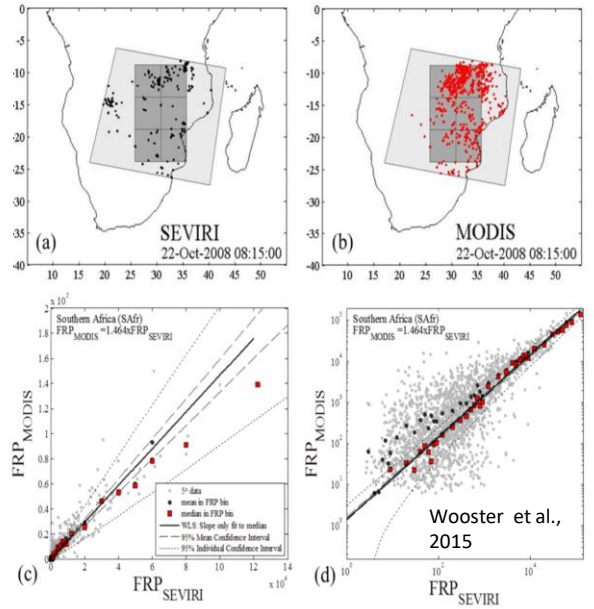


VIIRS_FRP/M11_FRP



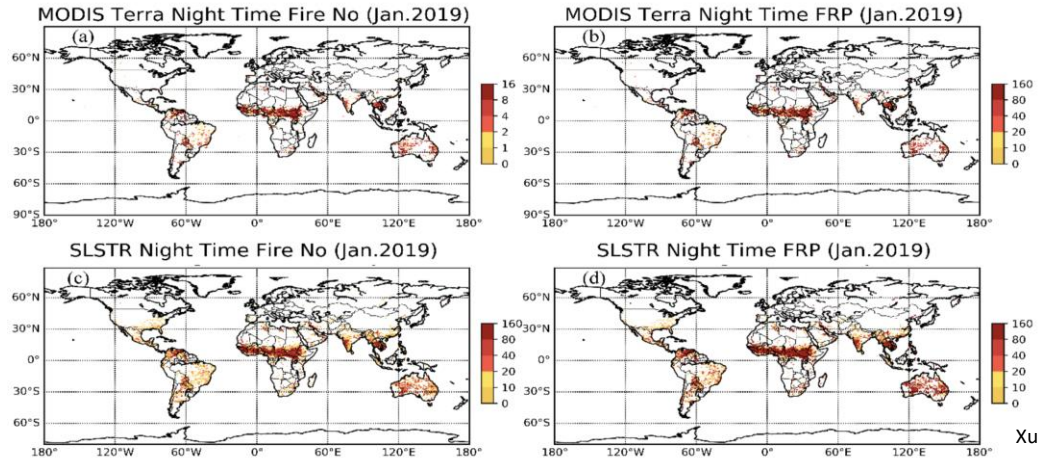
GEO vs LEO





Wooster et al., 2015

LEO vs LEO



Xu et al., 2017

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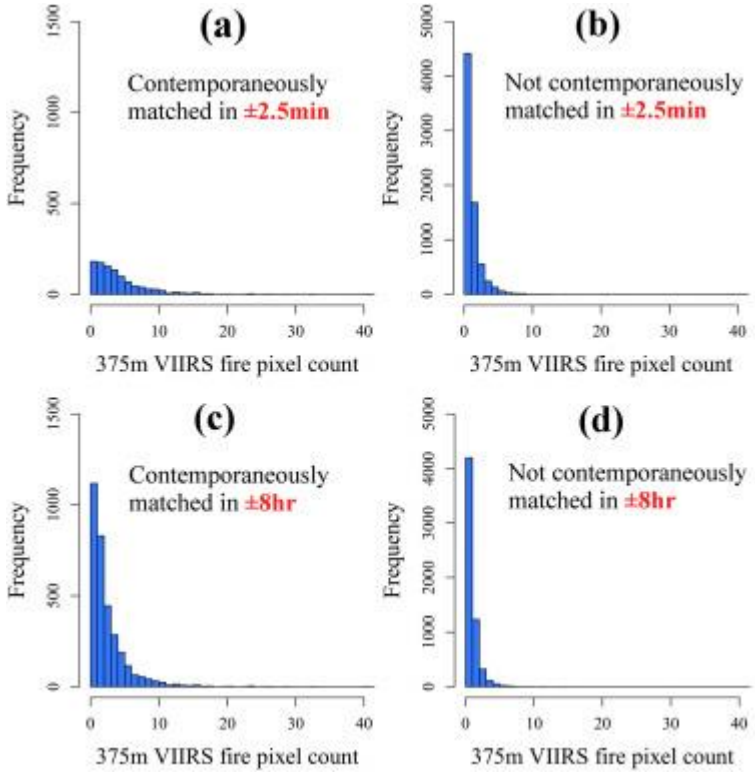
Fire Disturbance

Active Fire and FRP Validation: Challenges

- Active fire
  - Definition of "*contemporaneous*" observations
    - Without formal protocol, threshold used in literature has ballooned from ± minutes to ± ~8 hours
- FRP
  - "*contemporaneous*" observations typically ± minutes but can be up to ± 2 hours
- Small fires and agricultural fires highly uncertain



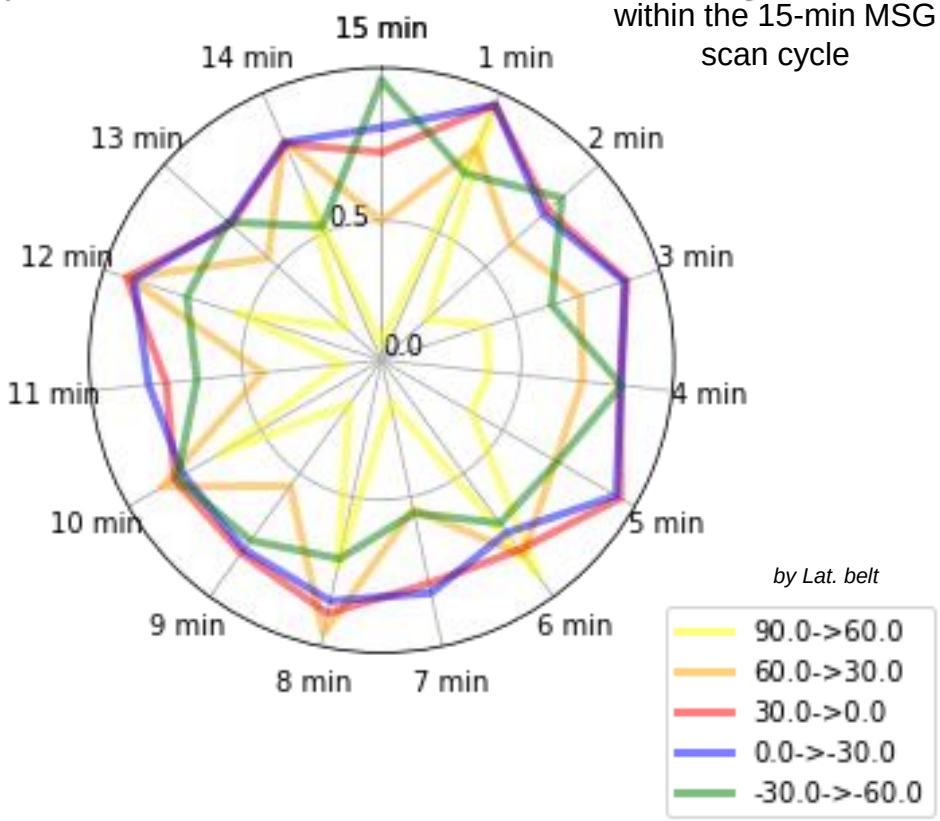
Li, F., Zhang, X., Kondragunta, S., Schmidt, C.C. and Holmes, C.D., 2020. A preliminary evaluation of GOES-16 active fire product using Landsat-8 and VIIRS active fire data, and ground-based prescribed fire records. *Remote Sensing of Environment*, *237*, p.111600.

Fire Disturbance

Active Fire and FRP Validation: Challenges

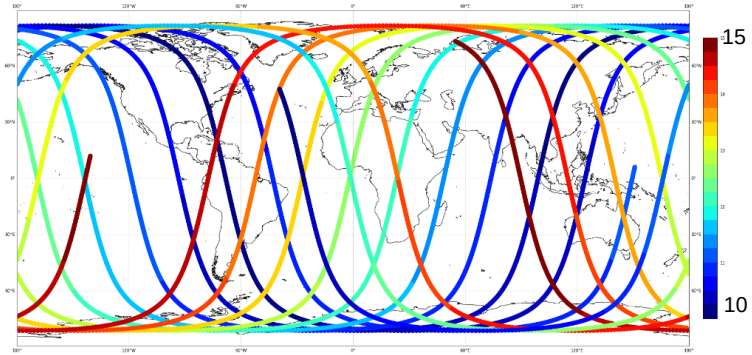
contemporaneous overpasses?

LOE vs GEO
S3A and S3B detections within the 15-min MSG scan cycle

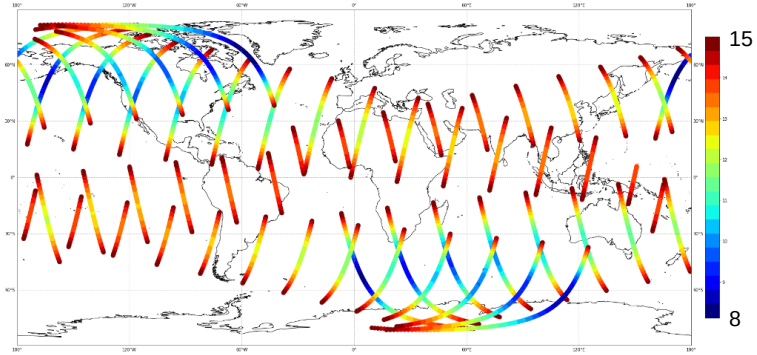


LEO vs LEO
S3A and S3B 1-day orbit simulations
(overlaps limited to 15 min)

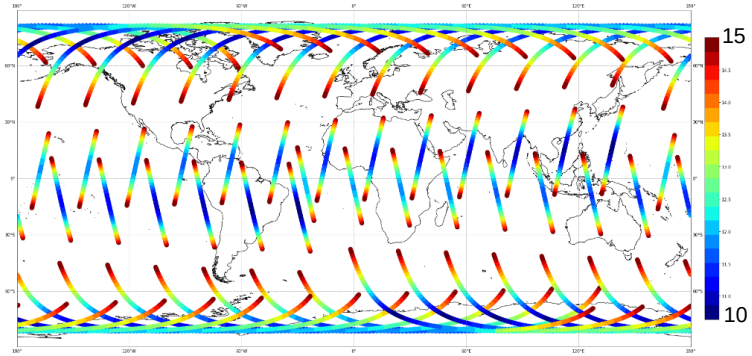
TERRA MODIS



AQUA MODIS



SUOMI VIIRS



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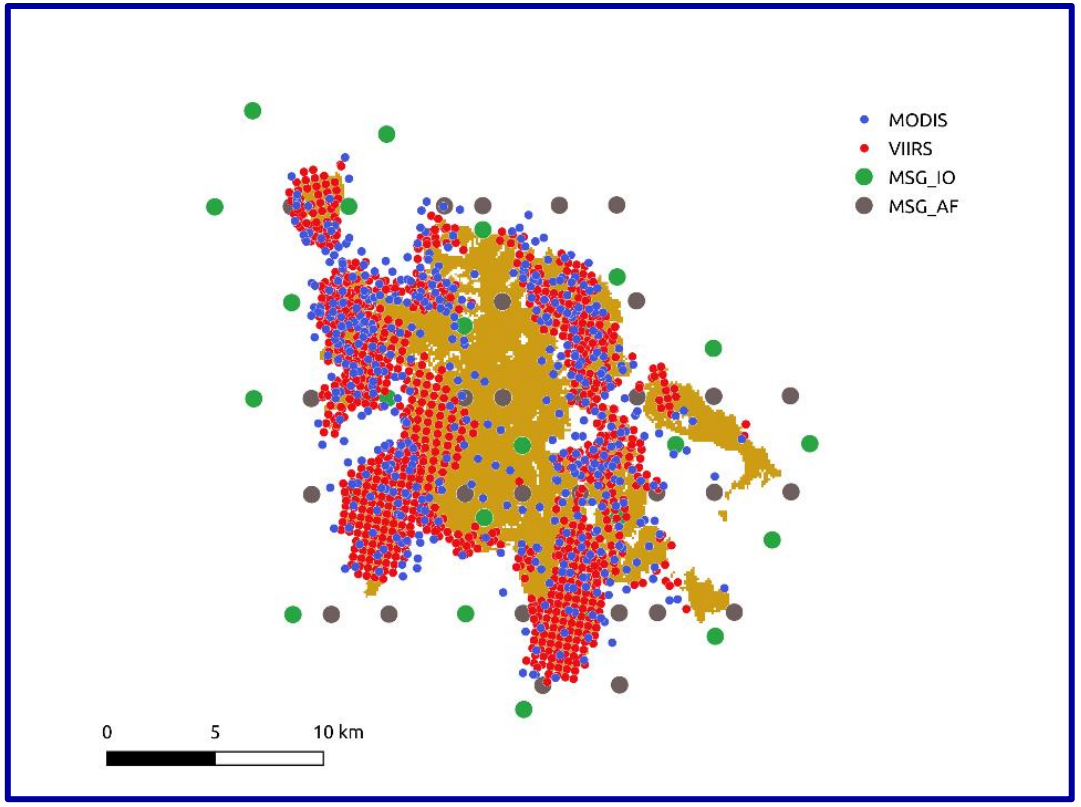
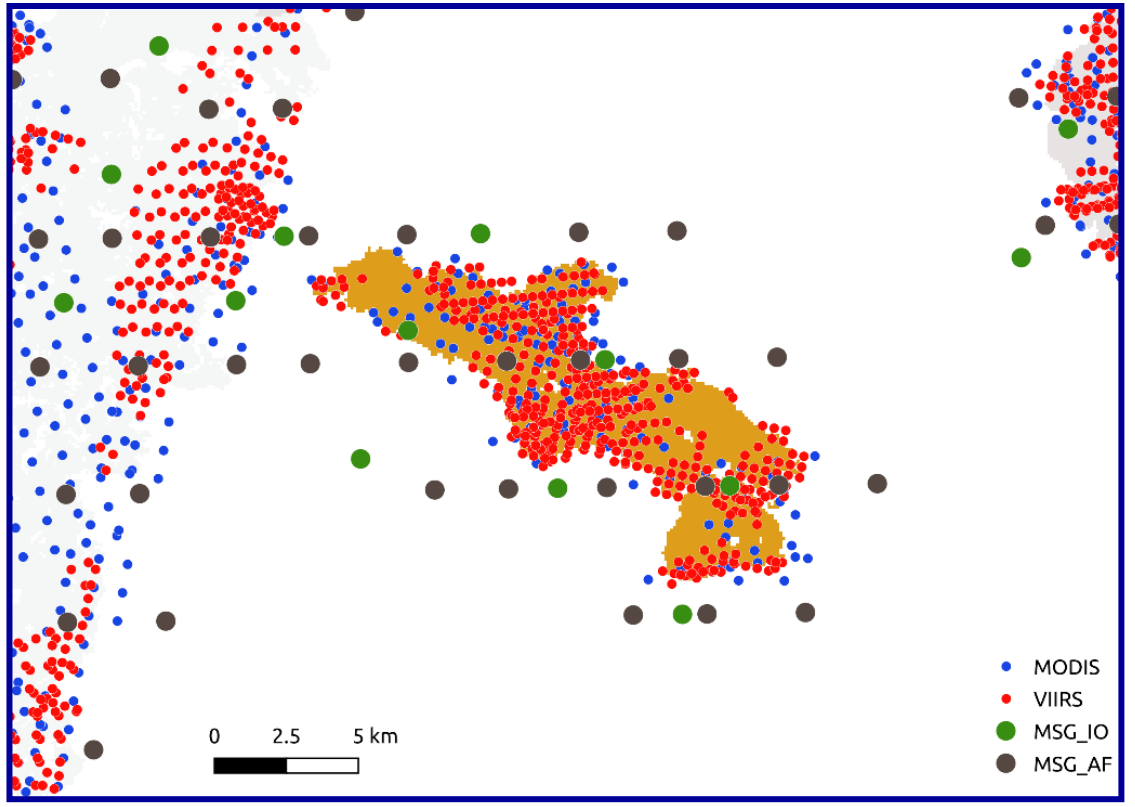
Active Fire and FRP Validation: Challenges

What is ‘fire cluster’ criterion? How to account for the different Spatial resolutions and associated geolocation errors?

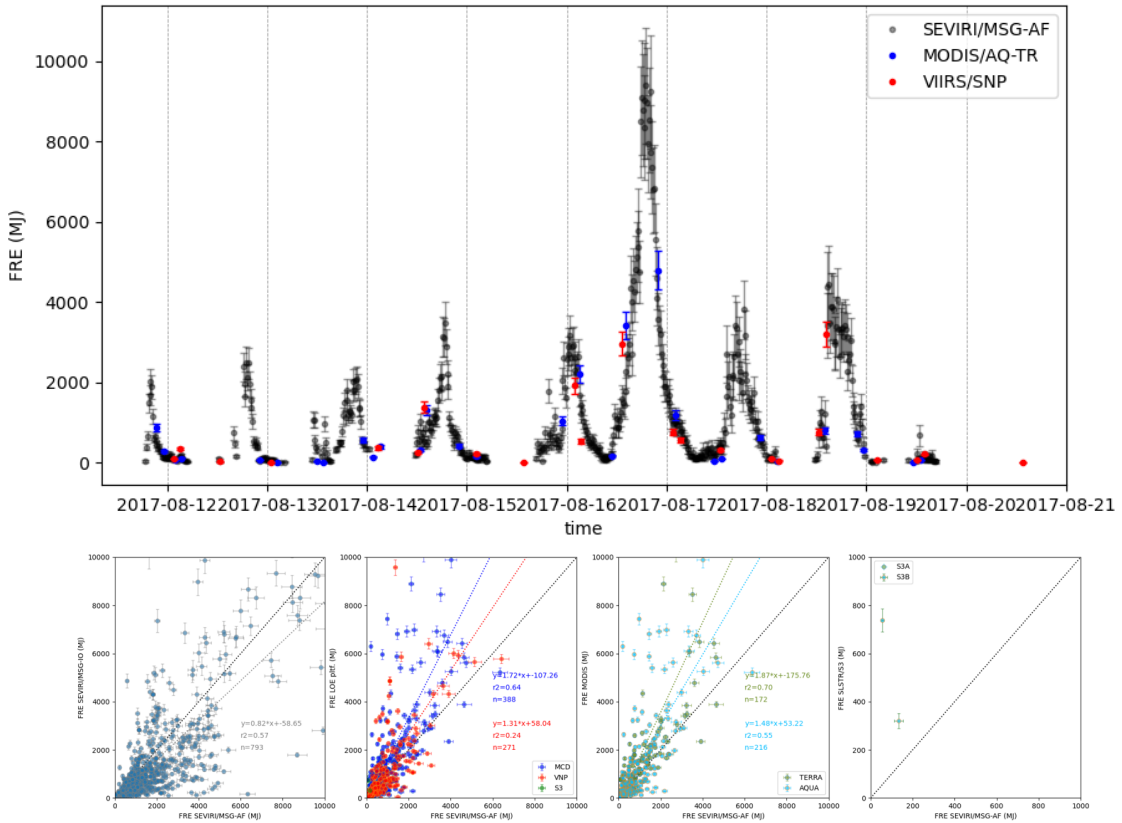


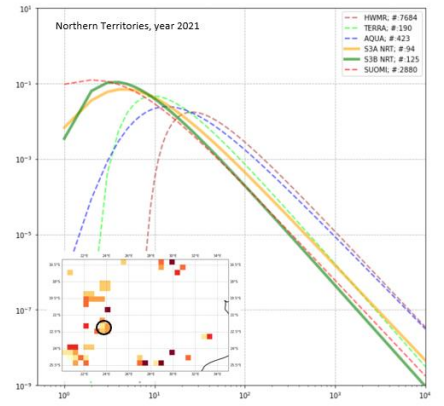


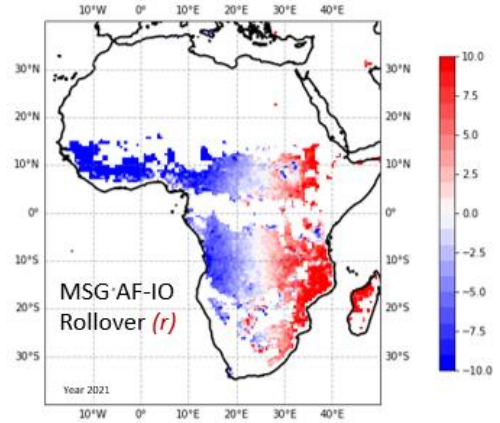
Fire Disturbance

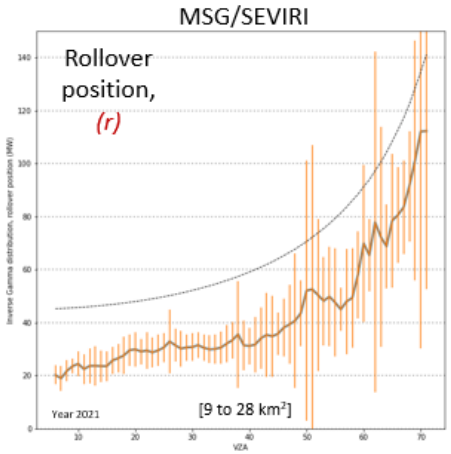
Recent advances in developing methodologies for the validation of FRP based on product inter-comparissons

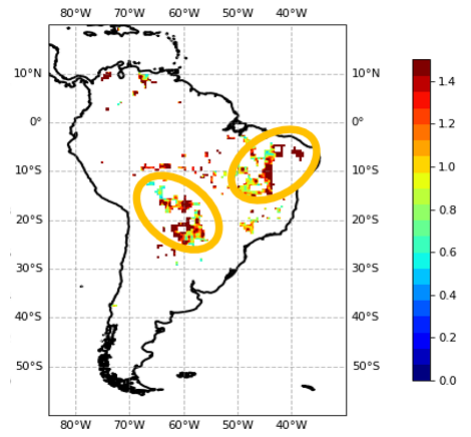
- Using wildfire progression maps to identify contemporaneous observations
- Robust statistical analysis based on products detection *pdf*







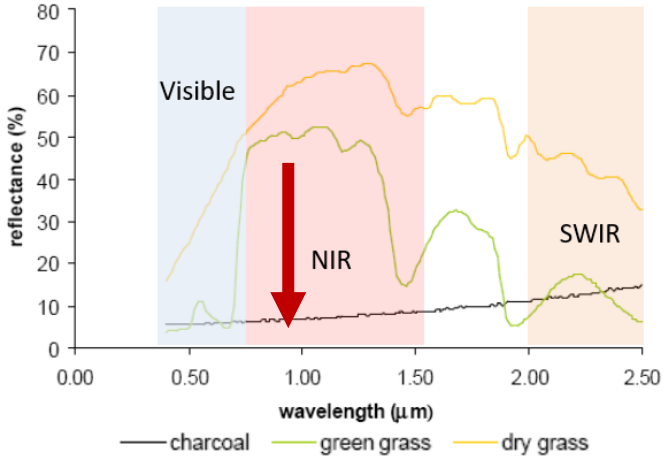


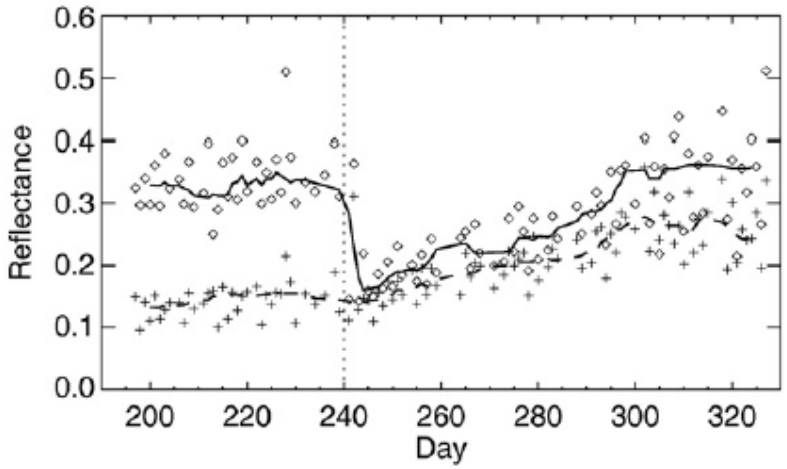


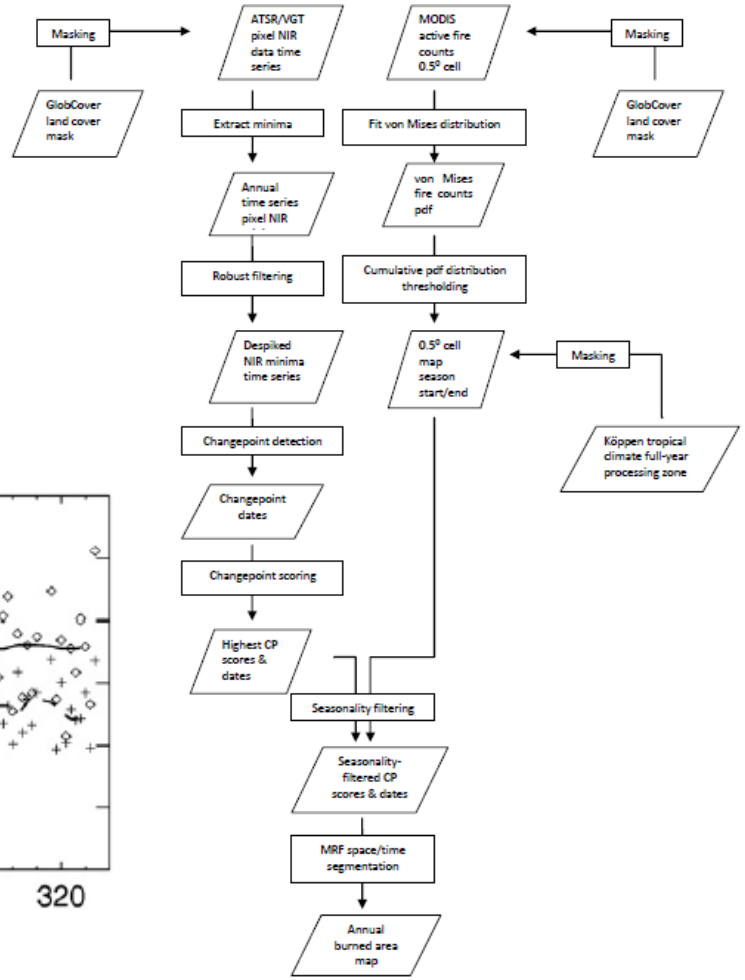
Fire Disturbance

Burned Area [km²]

- *Retrospective mapping of cumulative burned area extent*
- Typically includes date of burn
- Mostly relies on the NIR in spectral indixes
- Can incorporate AF information (seeds)
- No L2 products
- No physical based measuring function



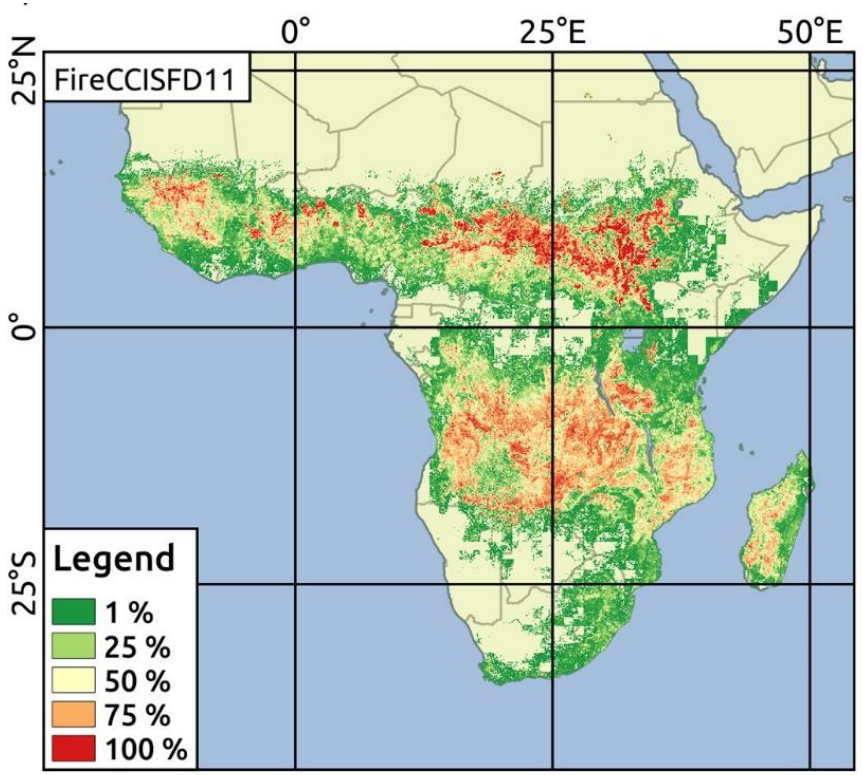




Fire Disturbance

Burned Area Validation

- Product inter-comparison
  - Coarse (250m – km) resolution BA products
    - Validated using moderate (20 - 30m) resolution imagery
      - Landsat OLI, Sentinel-2 MSI
  - Moderate (20 - 30m) resolution BA products
    - Product examples
      - Africa (Sentinel-2, Fire CCI)
      - CONUS (Landsat, USGS)
    - Need even higher resolution reference data
      - e.g., Planet Dove (3 - 5m)

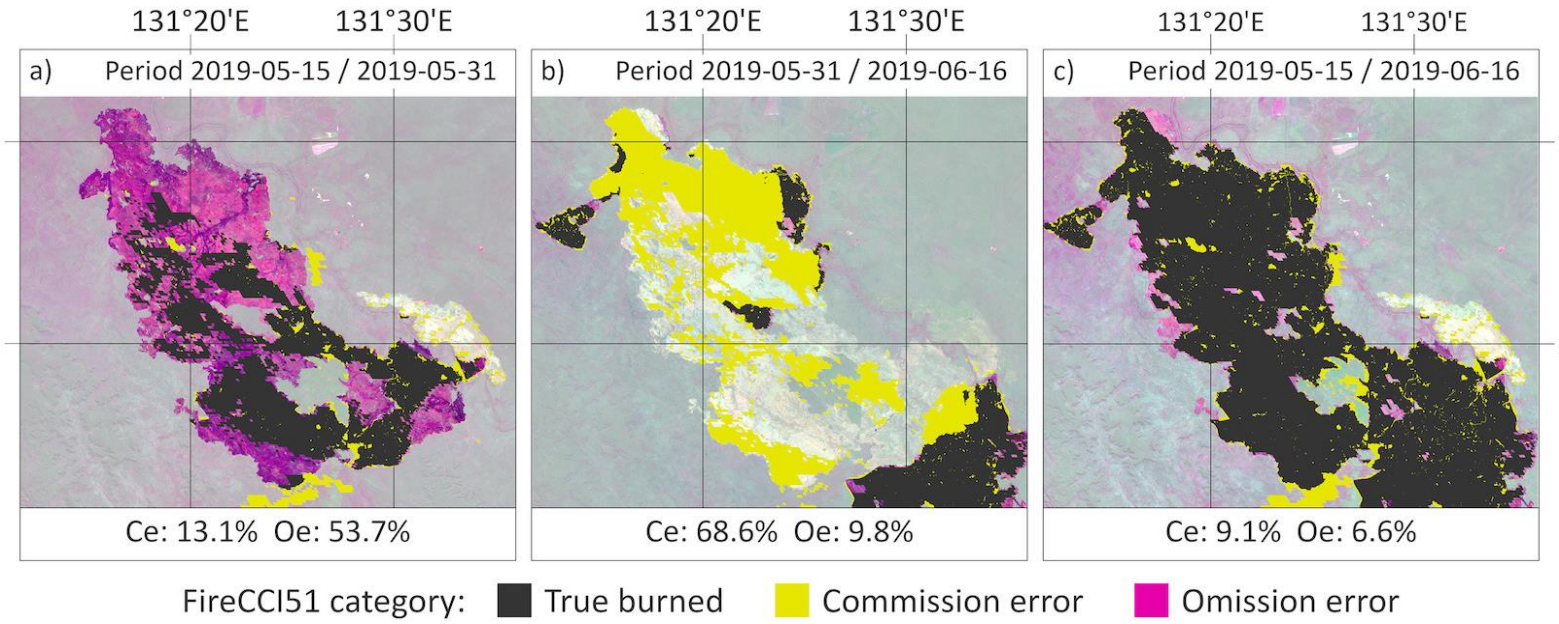


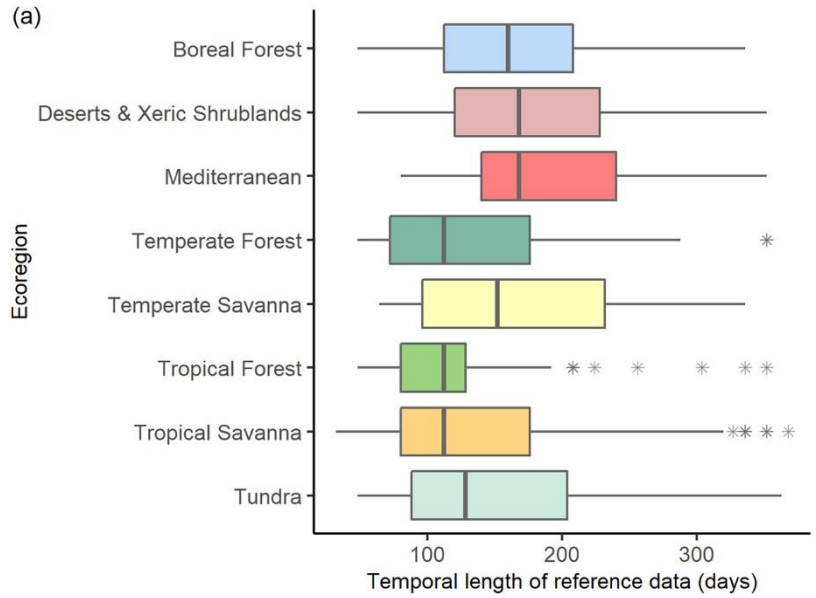
Roteta, E., Bastarrika, A., Padilla, M., Storm, T. and Chuvieco, E., 2019. Development of a Sentinel-2 burned area algorithm: Generation of a small fire database for sub-Saharan Africa. *Remote sensing of environment*, *222*, 1-17.

Fire Disturbance

Burned Area Validation: Challenges

- FireCCI "*long*" validation units
  - Need consensus re. time between 1st and last images used to derive reference maps





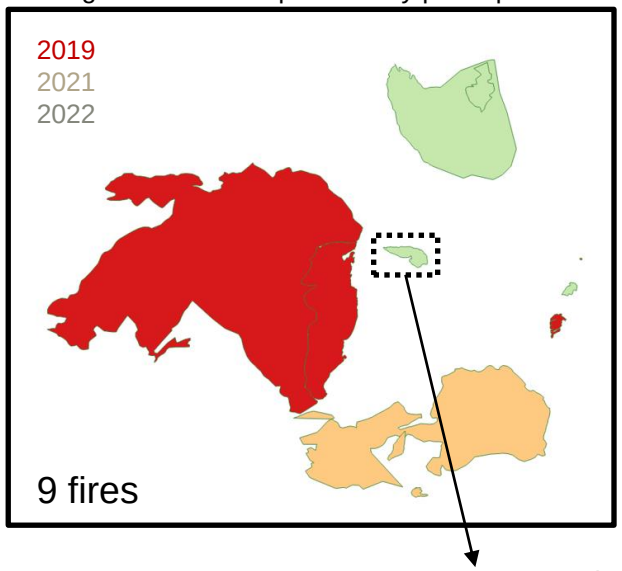
Franquesa et al., 2022, Using long temporal reference units to assess the spatial accuracy of global satellite-derived burned area products. *Remote Sensing of Environment*, 269, 112823.

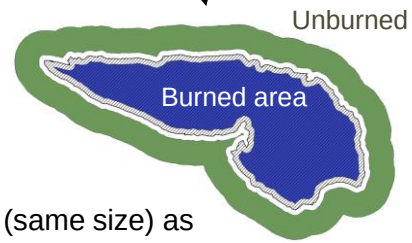
Long-unit periods will ideally not exceed vegetation regrowth + other post-burn disturbance time frames.

Fire Disturbance

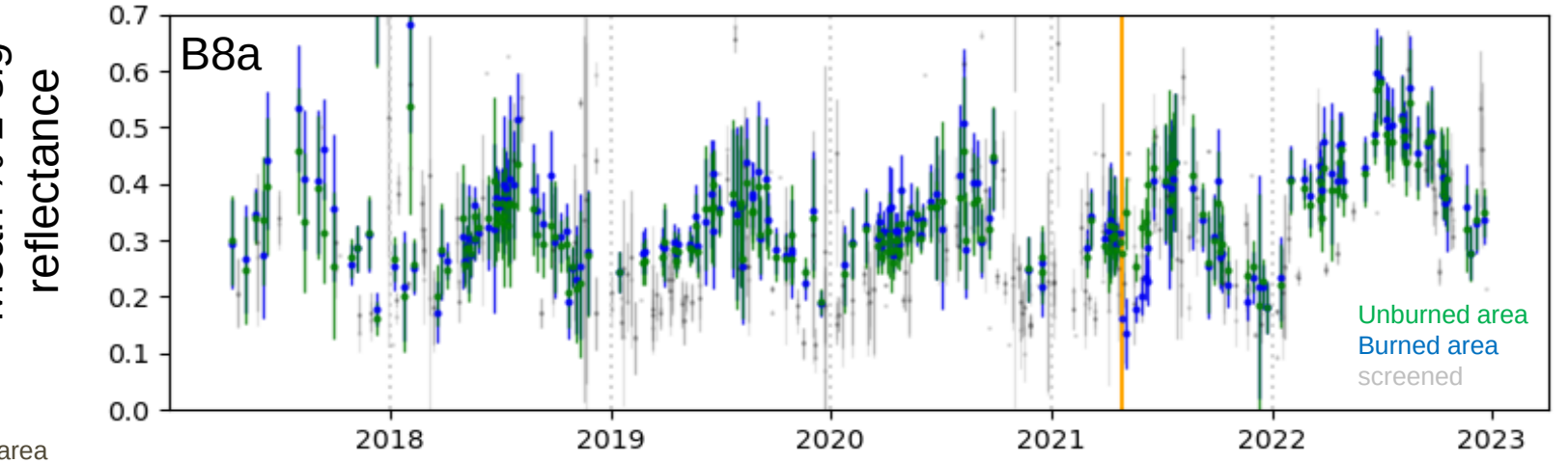
Burned Area Validation: Challenges

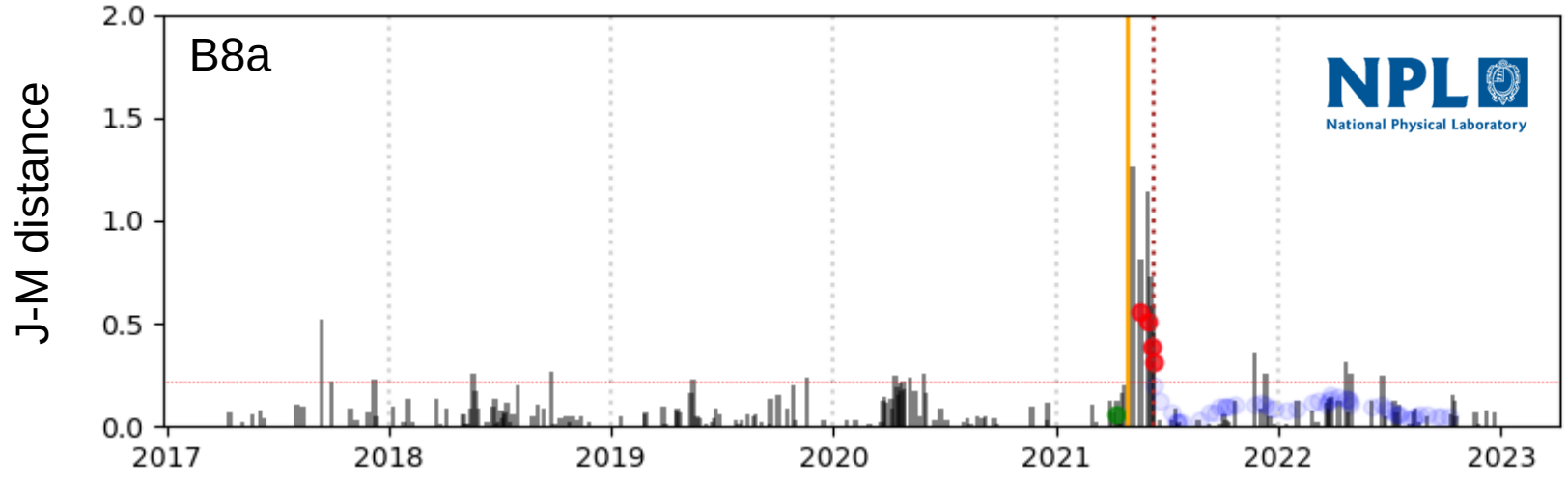
High resolution maps made by park operatives





- Define outer area (same size) as unburned comparison
- Assumed same vegetation
- Avoid mixed pixels: use buffer size
- Spectral descrimination evaluated using the Jeffries–Matusita distance
- Detectability criteria: J-M greater than mean+*2-sig* of pre-fire period





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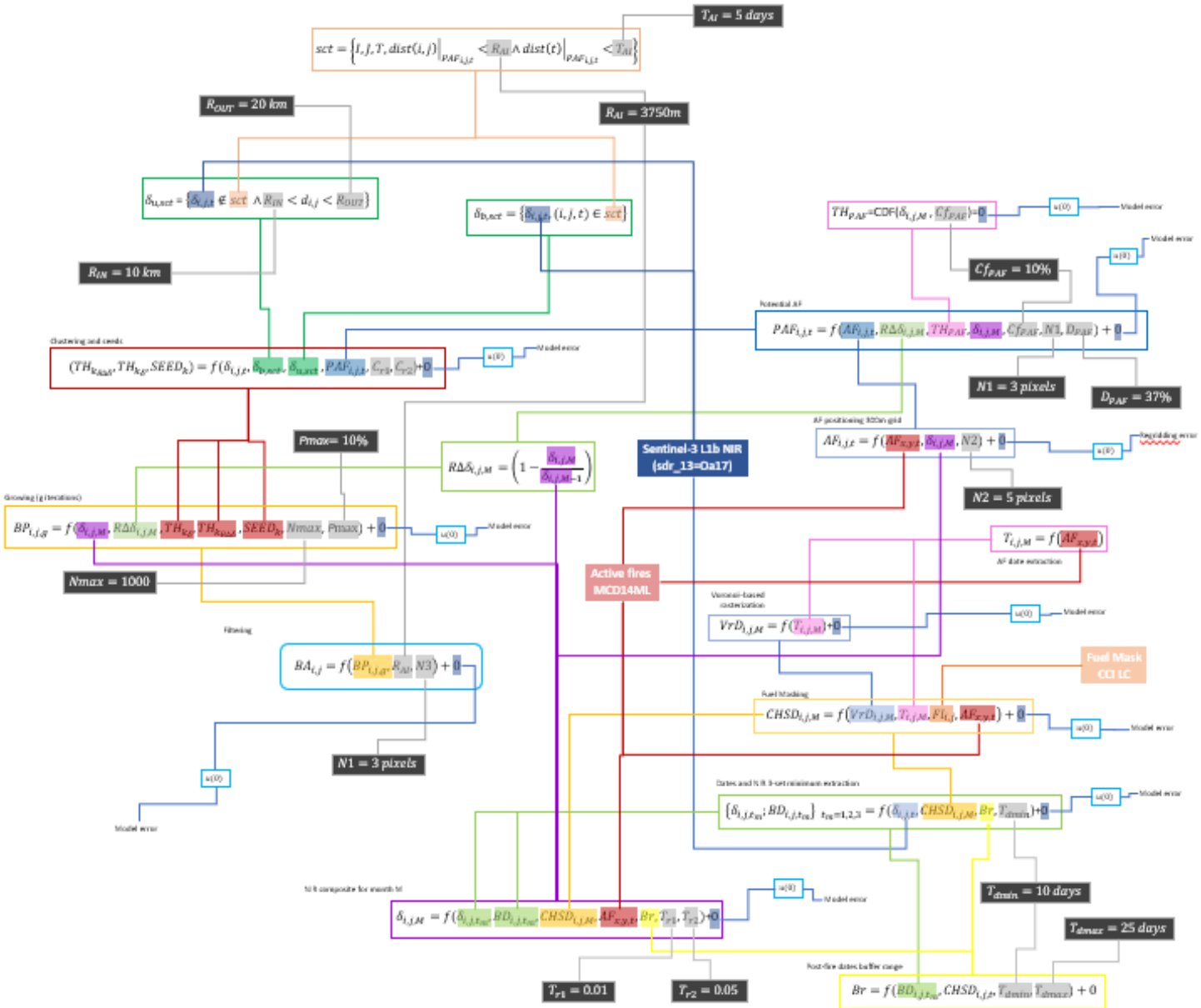

Burned Area Validation: Challenges

- Standard method of defining and estimating BA classification confidence level/probability of detection
- A clear understanding between classification confidence and uncertainty

C3S BA Level 3 product 'Uncertainty Tree diagram' part of the CCVS impact assessment of uncertainty propagation to L3/L4 products D3.5 CCVS project

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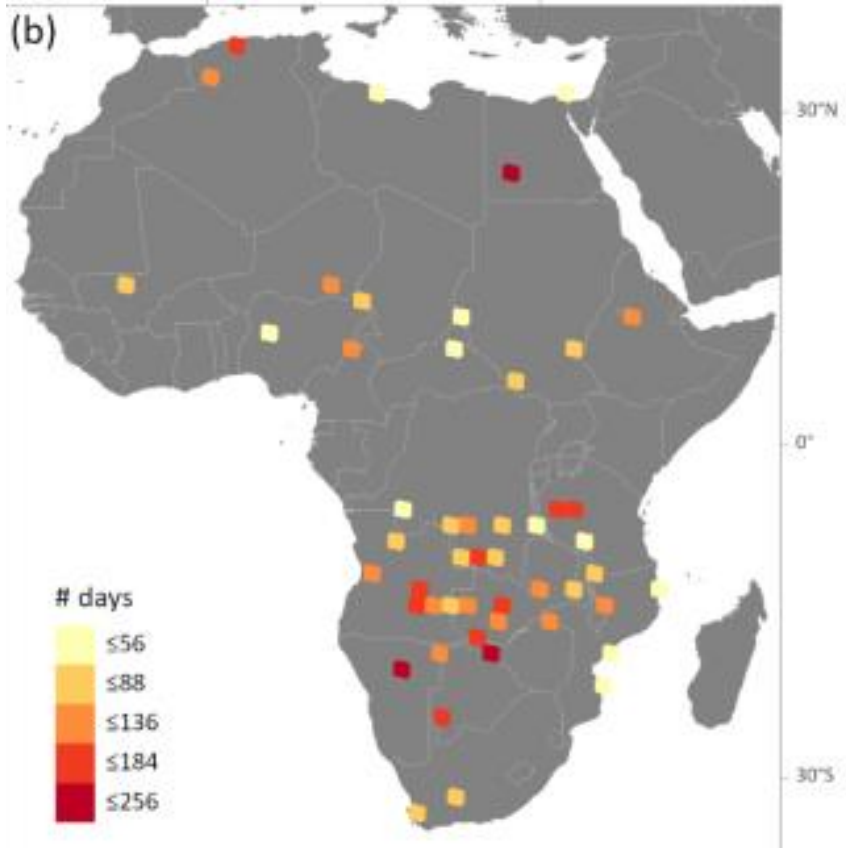
Burned Area Validation: Issue to Address

- Burned Area Reference Database (BARD) usage recommendations
  - Validation data versus training data
  - Validation of the reference data?

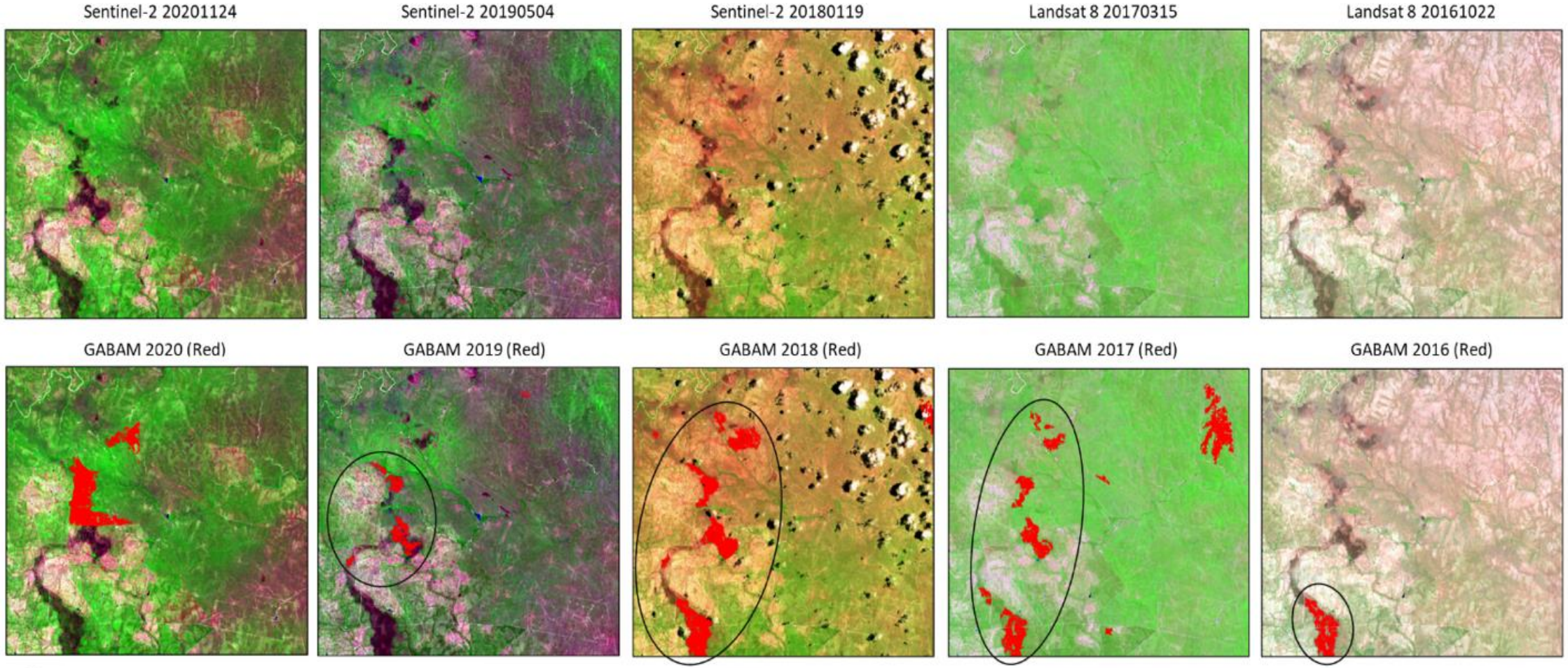


Franquesa, M., Vanderhoof, M.K., Stavrakoudis, D., Gitas, I.Z., Roteta, E., Padilla, M. and Chuvieco, E., 2020, Development of a standard database of reference sites for validating global burned area products. *Earth System Science Data*, *12*, 3229-3246.

Fire Disturbance

Long, T., et al., 2019, 30 m Resolution Global Annual Burned Area Mapping Based on Landsat Images and Google Earth Engine. *Remote Sensing*, 11.

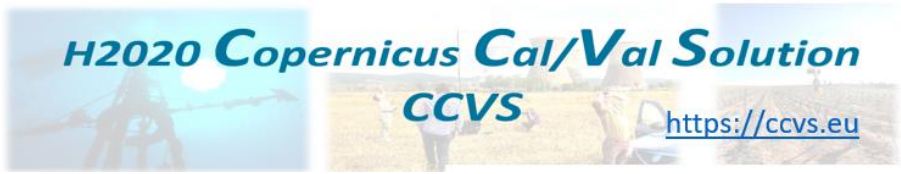
Changes in vegetation/soil moisture repeatedly misclassified as burned (GABAM tile S02E030):



Commission errors

M. Zubkova (University of Maryland)

Fire Disturbance



Resulted in a total of 74 **recommendations**:

- Generic
- Cross-domain
- Optical Observation
- Altimetry
- SAR imaging
- Atmospheric composition missions

4.3 Optical observation

Ref	Activity	Criticality	Objective
R-OPT_19	On-board calibration improvement	medium	R&D to improve on-board calibration
R-OPT_22	Instrument in-flight characterization	high	In flight characterization activities: yaw manœuvres, Moon acquisitions
R-OPT_23	Hyperspectral SDR network - phase 1	high	Development of an hyperspectral measurement network; (SI traceable, well representative, uncertainties)
R-OPT_24	Hyperspectral SDR network - phase 2	high	Operational support to hyperspectral measurement network
R-OPT_25	Field Campaigns	high	Regular field campaigns + community processors
R-OPT_26	FRM4FIRE : consolidation of validation methodology	medium	R&D activities to consolidate validation methodologies
R-OPT_27	Improve geometric calibration of TIR channels	high	R&D on geometric calibration approach for TIR bands

D4.2 - Reference Scenario for Implementation

2.2.2 Advancing validation methods for Fire Products

This recommendation calls for an "FRM" type of activity to advance validation methods for Fire Products and in particular Fire Radiative Power. It should ideally combine theoretical work (uncertainty analysis, development of an observation simulator, elaboration of protocols and guidelines) and a field campaign to acquire test data. The output could also include a community processor. The activity should be implemented in the 2023-2025 timeframe and could be linked to a reprocessing of the Sentinel-3 FRP product archive.

Reference in the table: R-OPT_26; Criticality: Medium, Effort: medium

4.2.10 Field campaigns for optical missions

Regular field campaigns are essential for the validation of some Sentinel core products (e.g. Fire products, Sentinel 3 OTCI, surface reflectance measurements, ocean colour products). Such campaigns are currently performed under funding from ESA or national agencies. The Copernicus programme should ensure that these campaigns are continued and expanded to cover current validation gaps. Financial support should ensure that data are timely and openly accessible to Sentinel Cal/Val teams. The context of the Brexit is an additional risk for the provision of these essential reference data. With the provision of so-called community processors, the validation results are comparable with each other.

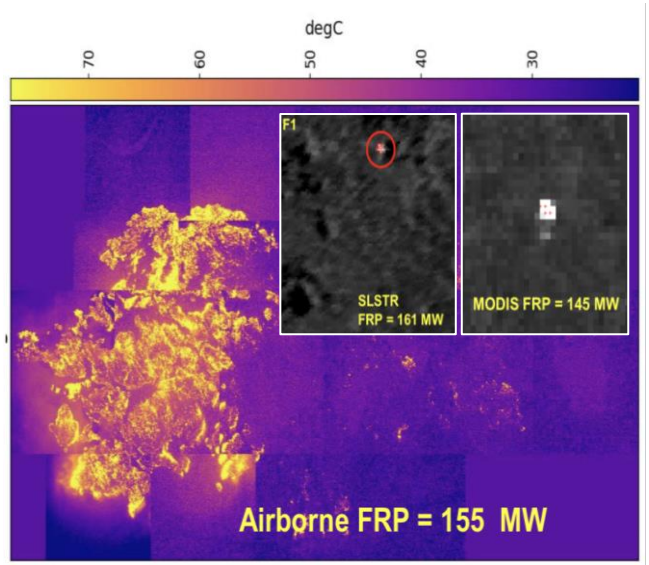
Reference in the table: R-OPT_25; Criticality: high, Effort: high

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

Fire Disturbance

Upcoming relevant projects: FRM4fire

- ESA funded (NPL + KCL + Soton) starting 3Q of 2023
- Phase one would focus on FRP
- Generate reference data for validation of SLSTR based measurements
- Capitalize on the FIDEX II campaign (Canada, August 2023)
- Additional airborne time to assess measurements under different conditions (sensor and environment)
- Full uncertainty budget and E2E propagation to pixel level
- Recommendations for measurement protocols and SLSTR-NG sensor

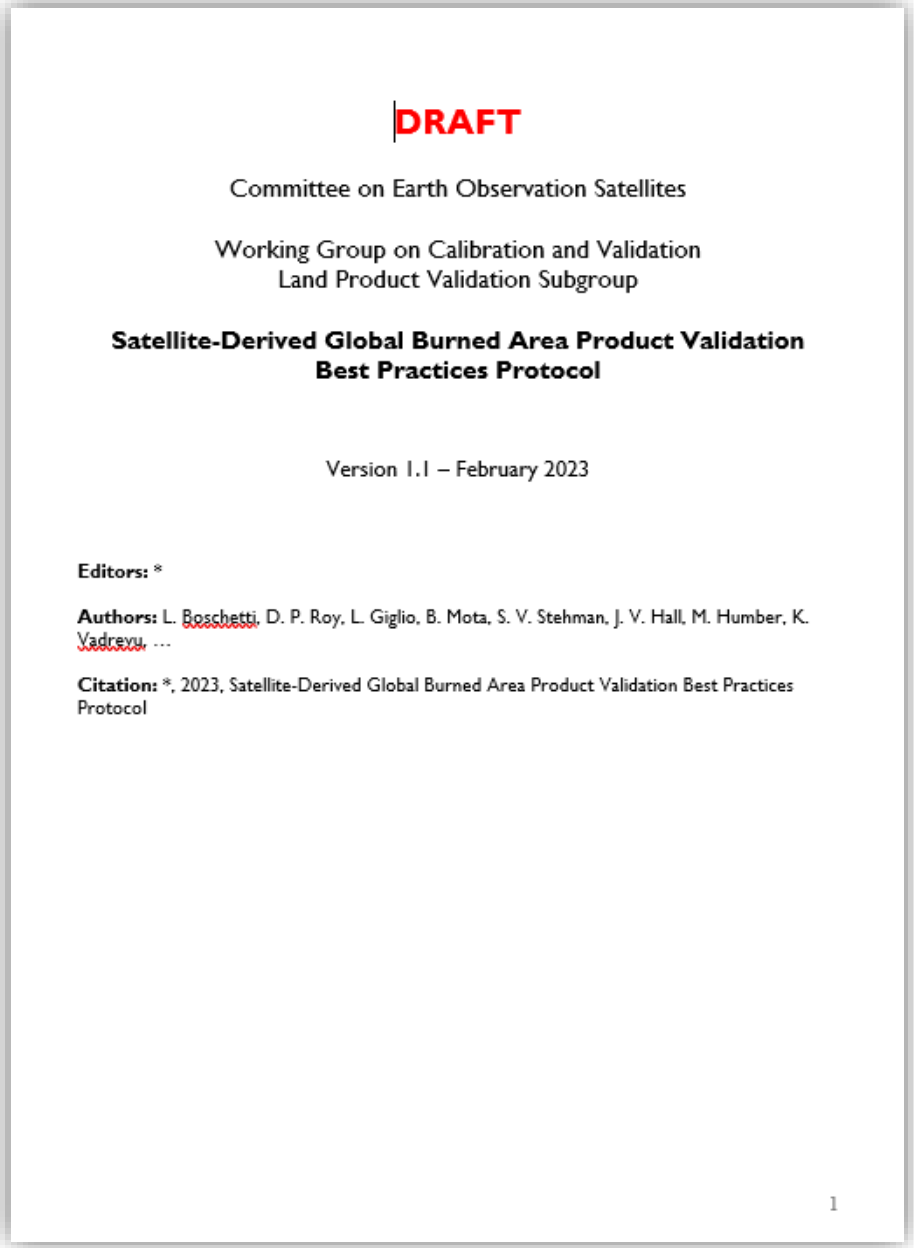


FIDEX Campaign Northern Ontario August 2018 courtesy of M. Wooster (KCL)

Fire Disturbance

Validation Protocol Status

- Update of 2010 draft burned area validation protocol is ongoing
- Goal: have discussion-ready draft for GOFC Fire Implementation Team meeting in Montreal (13-17 Nov. 2023)
- Active Fire / FRP protocol to follow (1st Draft during 2024)



DRAFT

Committee on Earth Observation Satellites

Working Group on Calibration and Validation
Land Product Validation Subgroup

Satellite-Derived Global Burned Area Product Validation Best Practices Protocol

Version 1.1 – February 2023

Editors: *

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Citation: *, 2023, Satellite-Derived Global Burned Area Product Validation Best Practices Protocol

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