Terra/Aqua MODIS Fire Panel

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NASA Terra, Aqua, and Aura Drifting Orbits Workshop
1 November 2022

Fire-Related RFI Responses

- Morton et al. *Terra and Aqua Orbital Drift Enables Novel Fire Science*
- Giglio et al. *Improving Long-Term Historical and Future NASA Fire Data Continuity by Exploiting Terra and Aqua Orbital Drift*
- McCarty et al. *Accurate quantification of fire timing with peak severity, burned area, fuels & emissions, plus pollution events dominated by rush-hour traffic*

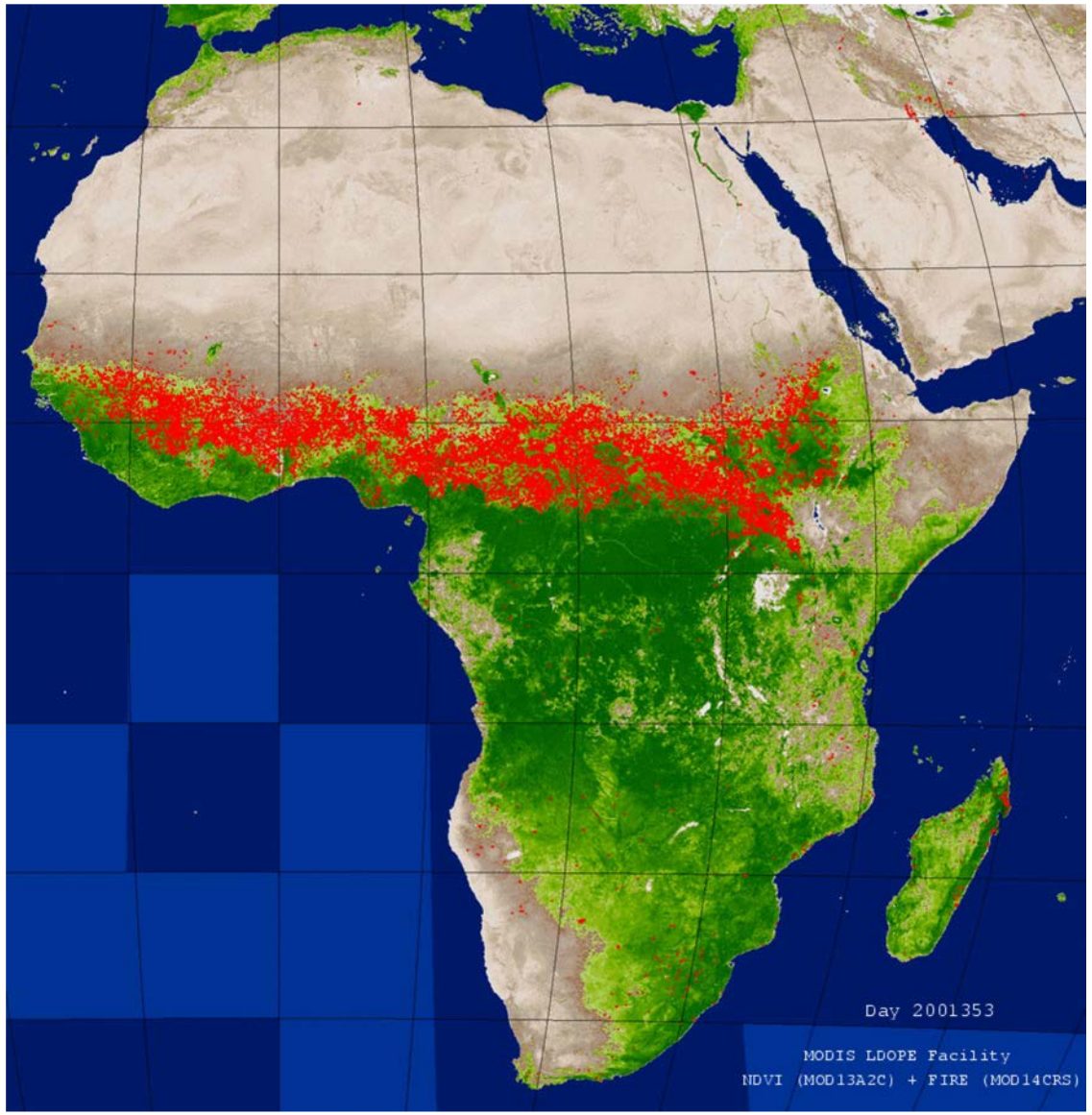
Background: Global, daily, monitoring of active fires from the MODIS Terra and Aqua satellites since 2000

ACTIVE FIRES

2001 animation

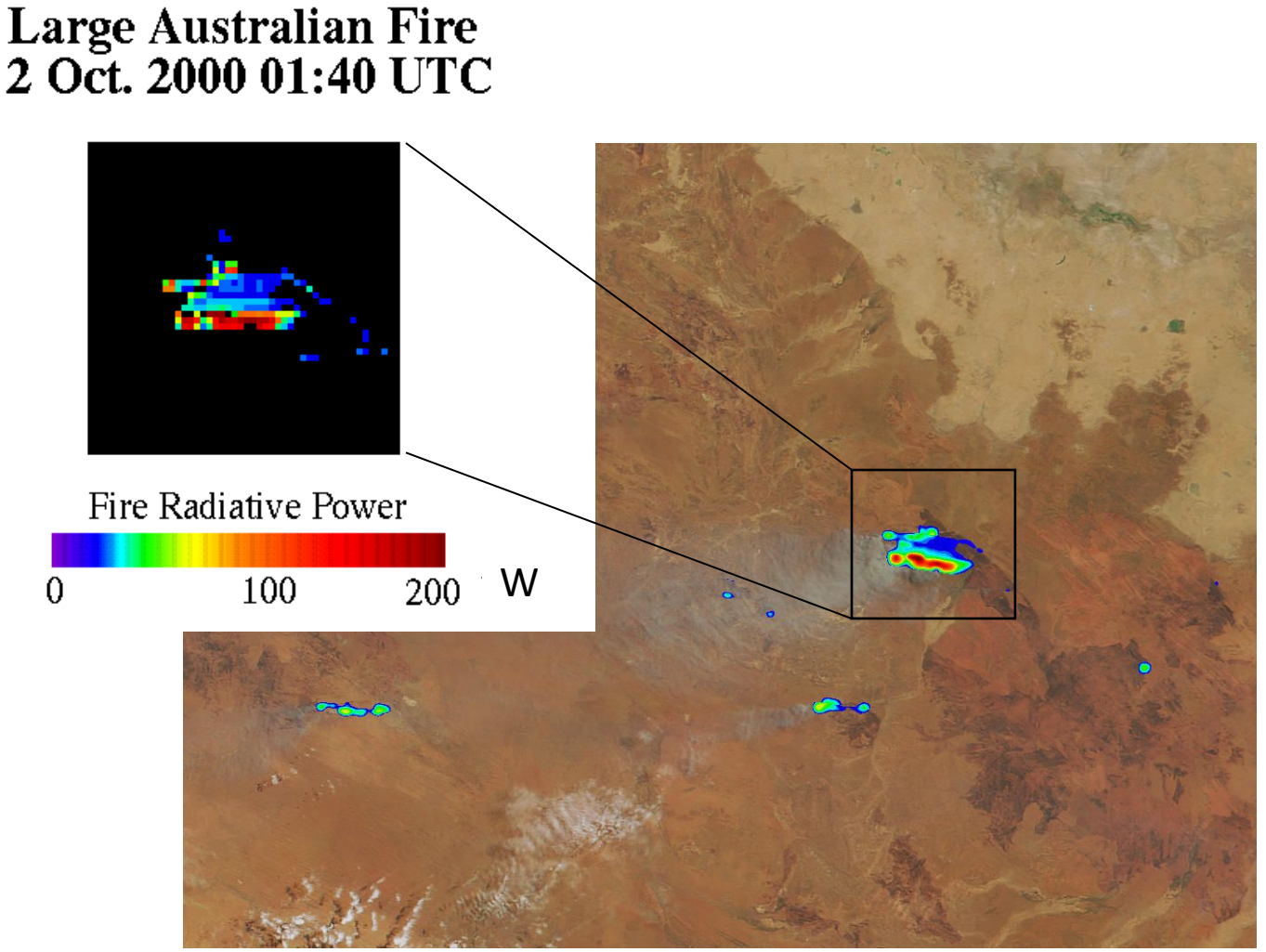
1km MODIS active fire detections (red)

superimposed on MODIS 16 day NDVI



David Roy/LDOPE

Background: Fire Radiative Power (W) retrieved at MODIS 1km Active Fire Detections



Kaufman et al. (1996)
FRP directly proportional to rate of biomass consumption.

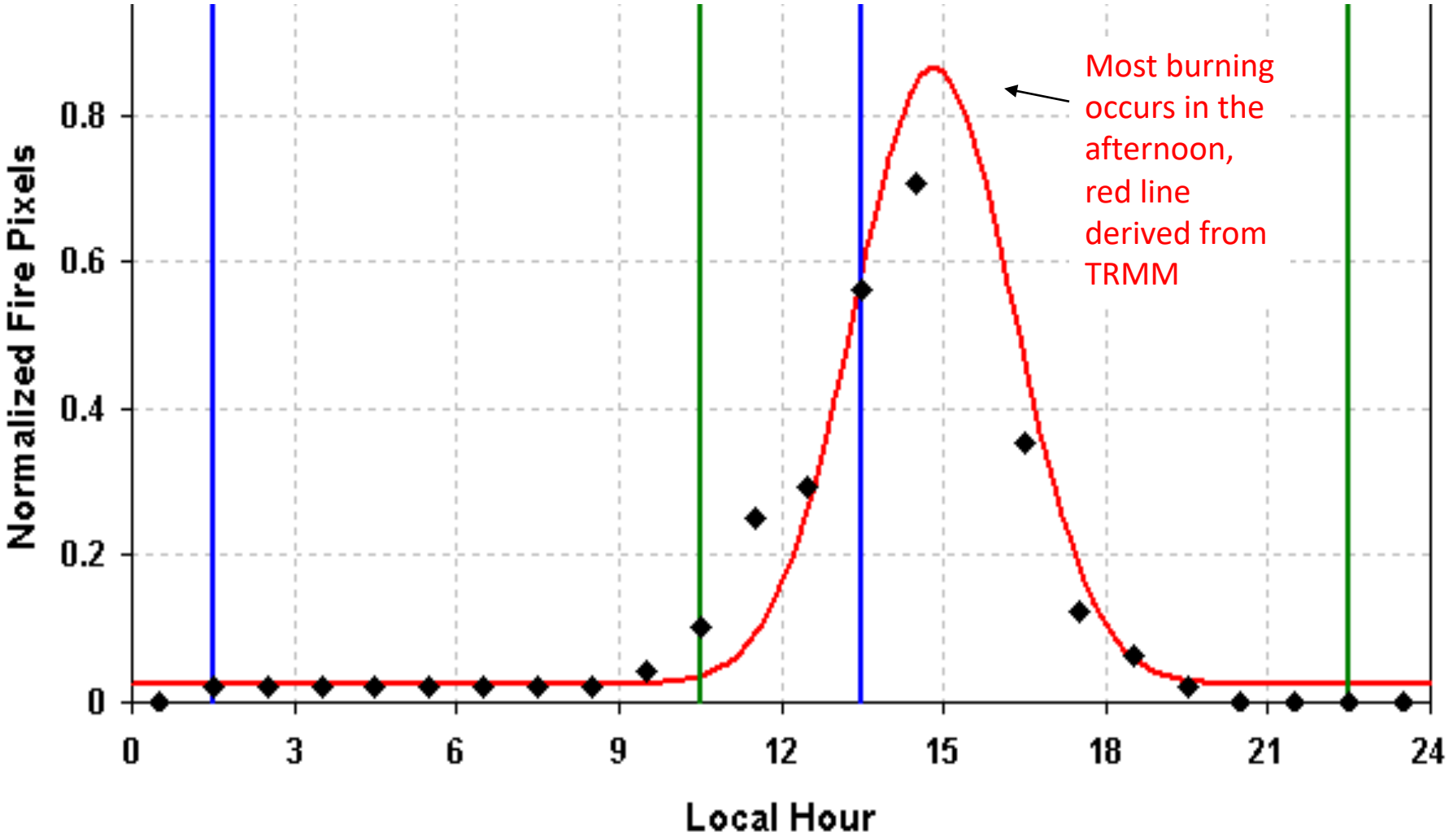
$C_6H_{10}O_5 + O_2 + \text{heat} \rightarrow C0_2 + H_20 + \mathbf{heat}$

FRP is the heat energy liberated by combustion per unit time

Background: Fire has a diurnal variability (# active fires and FRP magnitude)

Southern Africa diurnal fire probability distribution (red curve fit)

local overpass times of MODIS-Terra (green lines), MODIS-Aqua (blue lines)



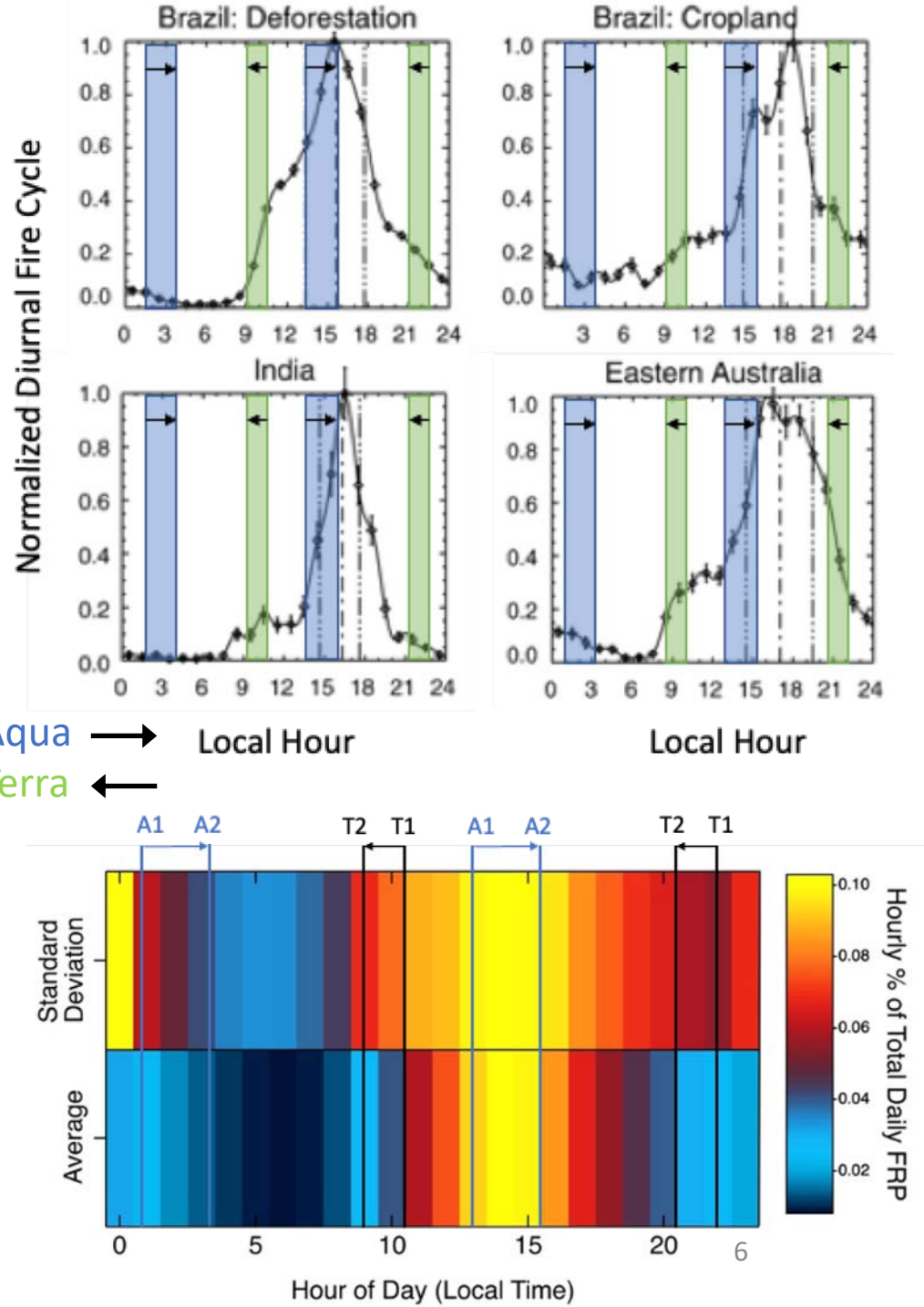
Terra and Aqua Orbital Drift Enables Novel Fire Science

Douglas Morton[*♦], Joshua Johnston[*#], James Randerson[♦], Andrew Hudak, Mark de Jong[*], Elizabeth Wiggins[♦], Denis Dufour[*], David Peterson, David Saah[♦], Robert Field[♦], Benjamin Poulter, Louis Giglio[#], Melanie Follette-Cook[♦], Wilfrid Schroeder[#], Shane Coffield[♦], David Roy[#], Brendan Rogers, Nancy French, Martin Wooster[#]

[*] CEOS WG Disasters Wildfire Pilot, [♦] NASA EIS-Fire, [#] GOFC-GOLD Fire Implementation Team

Novel Science:

- **At novel times:** Terra and Aqua drift data will sample longstanding data gaps when fires are most common (**upper**, data from Giglio 2007) and often most intense (**lower**, data from GOES, Wiggins et al., in prep) to understand new extreme fires and small fires that worsen air quality where people live.
- **From repeat sampling:** Growing time offsets between MODIS & VIIRS will track sub-daily behavior of large fires needed to build and test the next generation of fire spread models.
- **With multi-sensor observations**: MODIS, MISR, MOPITT, and ASTER provide complementary data to advance fire science.
- **To optimize future missions:** Terra and Aqua orbital drift data will help optimize overpass times and algorithm development for future dedicated wildfire monitoring systems (e.g., WildFireSat) and permit cross-calibration with ESA's Sentinel-3 fire products (10:00/22:00) to extend the Terra data record.



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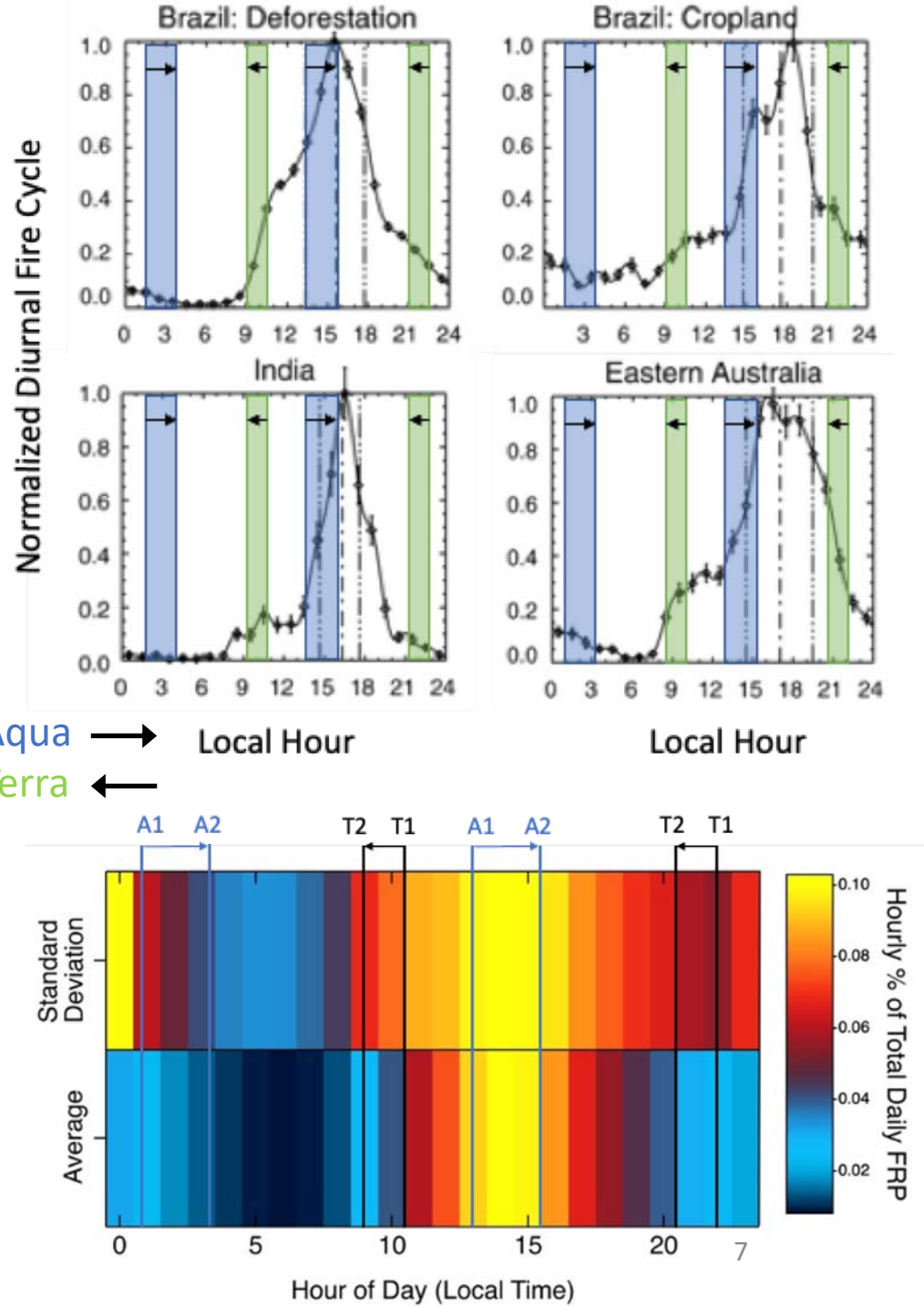


Improving Long-Term Historical and Future NASA Fire Data Continuity by Exploiting Terra and Aqua Orbital Drift

L. Giglio and W. Schroeder

- Future
  - Facilitate MODIS-to-VIIRS transition and continuity
- Historical
  - Aid in development of long-term, pre-MODIS AVHRR fire record

NASA Active Fire + Burned Area Products

MODIS

MOD14/MYD14 active fire	1-km swath (L2)
MxD14A1, MxD14A2 active fire	1-km gridded daily, 8-day (L3)
Derived GIS products (SCF)	monthly fire locations, 0.25° monthly
MCD64A1 burned area	500-m gridded monthly (L3)
Derived GIS products (SCF)	shapefile, 500-m GeoTIFF, 0.25° monthly

VIIRS

VNP14IMG/VJ114IMG active fire	375-m swath (L2)
VNP14/VJ114IMG active fire	750-m swath (L2)
VNP14A1, etc. active fire	500-m gridded daily (L3)
Derived GIS products (SCF)	monthly fire locations
VNP64A1 burned area	500-m gridded monthly (L3)
Derived GIS products (SCF)	shapefile, 500-m GeoTIFF, 0.25° monthly

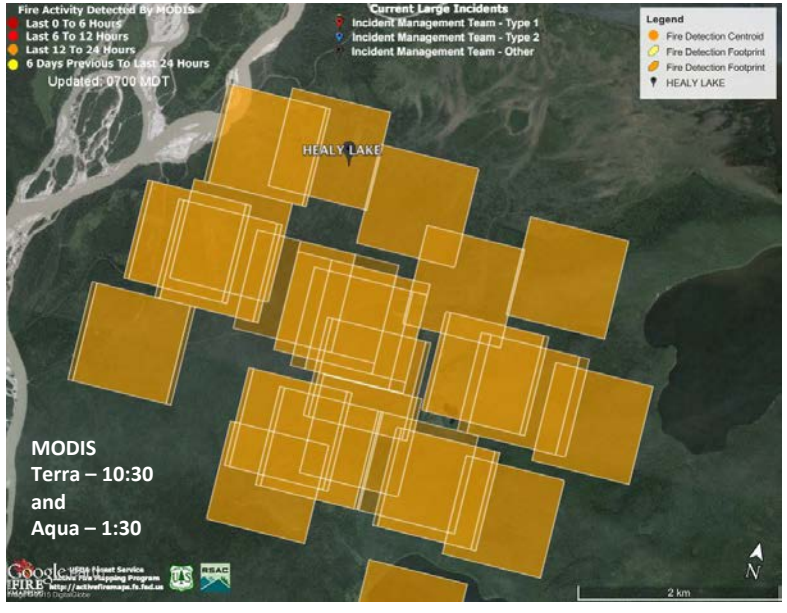
VIIRS Active Fire (VNP14/VNP14IMG)

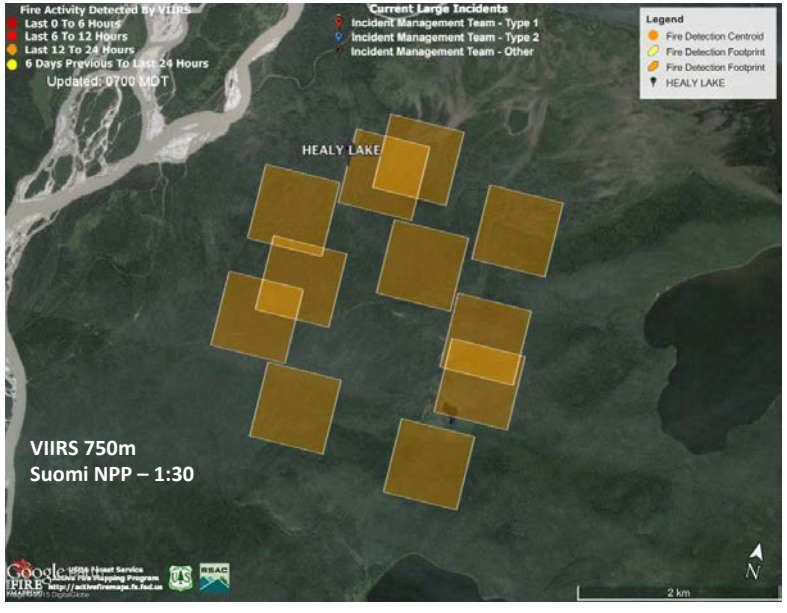
Product Overview

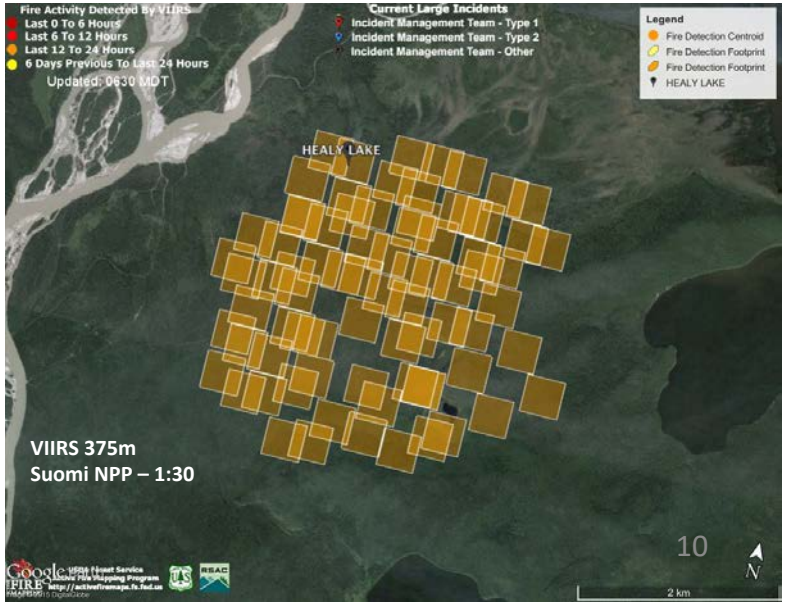
- 375-m product is a significant improvement over MODIS and is widely used
- 750-m product retained for continuity (more like MODIS)

Limitations and Strengths

- No morning VIIRS overpass
- Sub-optimal M13 location (tweaked for later VIIRS)
- Responsivity across swath is much more uniform
- Unprecedented sensitivity to small fires







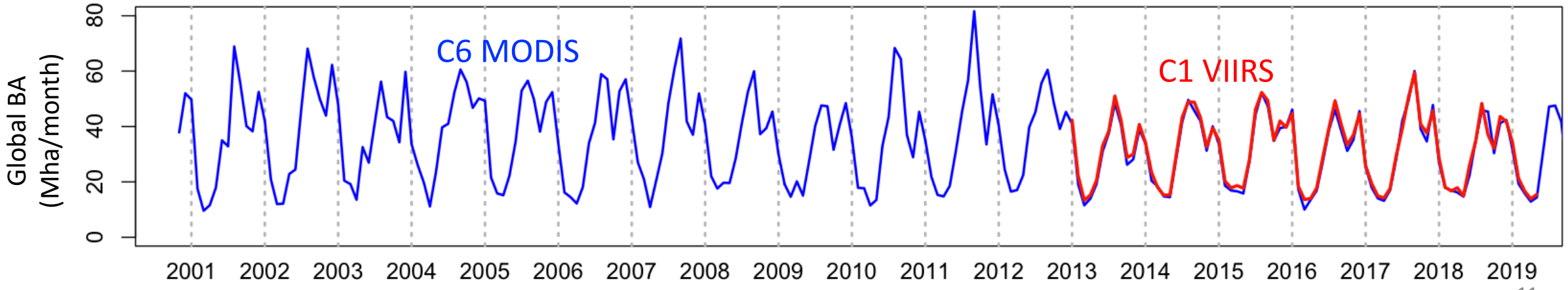
VIIRS Burned Area (VNP64A1)

Product Overview

- Monthly global burned area with date of burn mapped to nearest day
- Adapted MODIS MCD64A1 production code to use VIIRS data
- Retained 500-m MODIS grid for compatibility

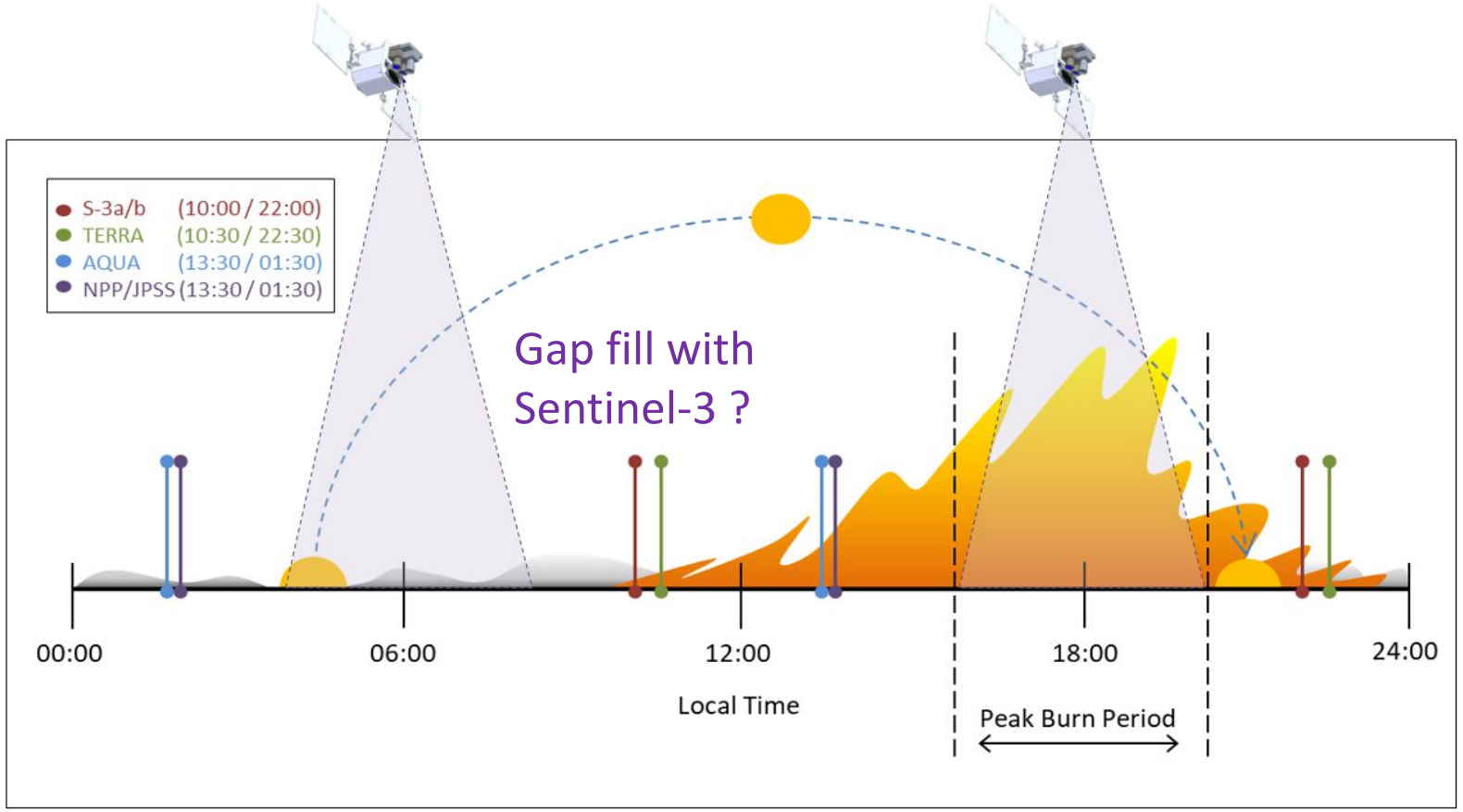
Limitations and Strengths

- No morning VIIRS overpass
- 750-m (vs. 500-m) imagery – I-bands not designed for BA mapping
- Nevertheless, highly consistent with MODIS MCD64A1 product at large scales



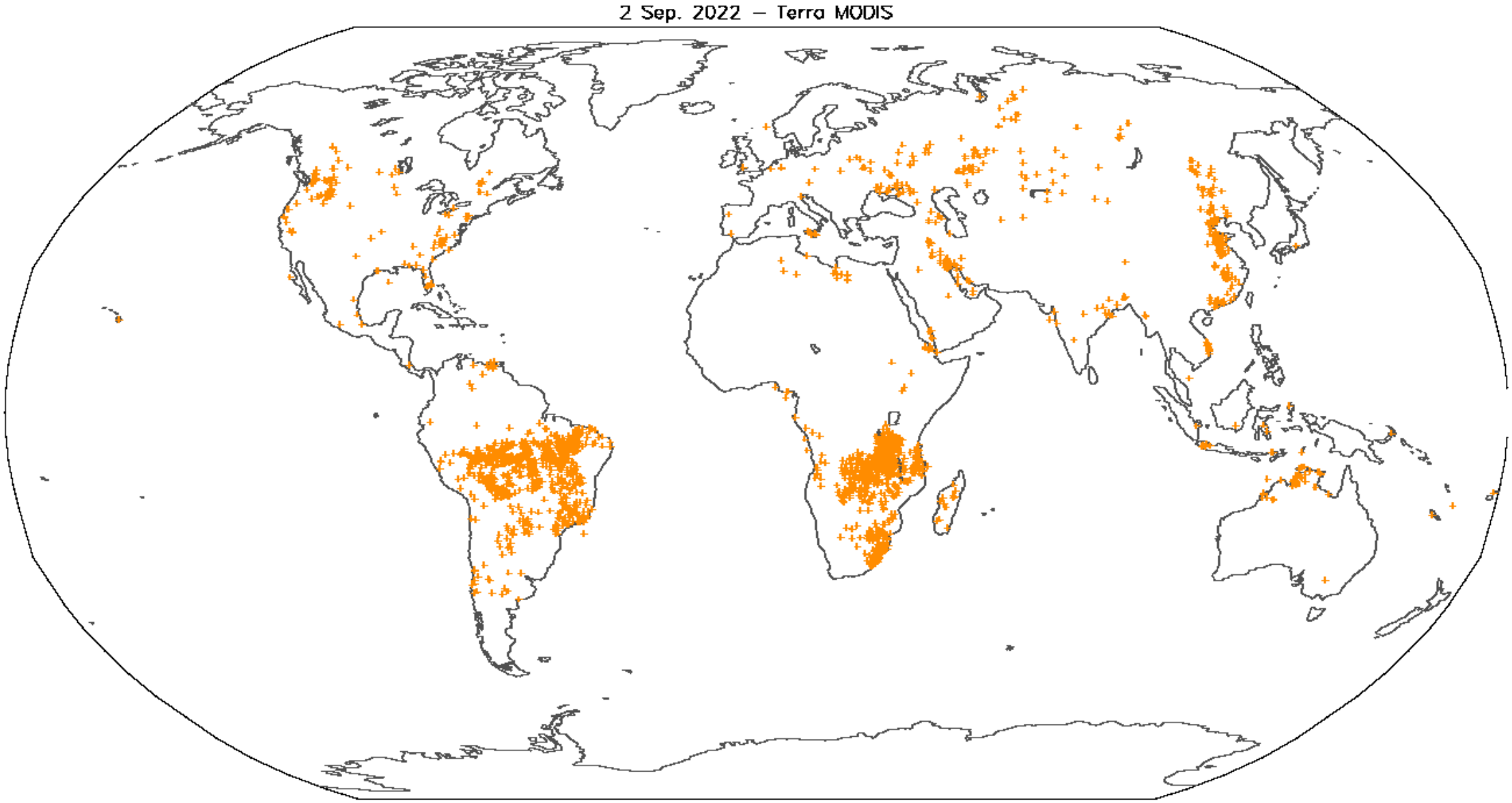
MODIS to VIIRS Fire-Product Transition

- Lack of morning VIIRS overpass can have major impact on product transition and continuity
- NASA pilot study: Evaluate Sentinel-3 SLSTR/OLCI as possible Terra MODIS replacement and source of morning observations for VIIRS land-product suite

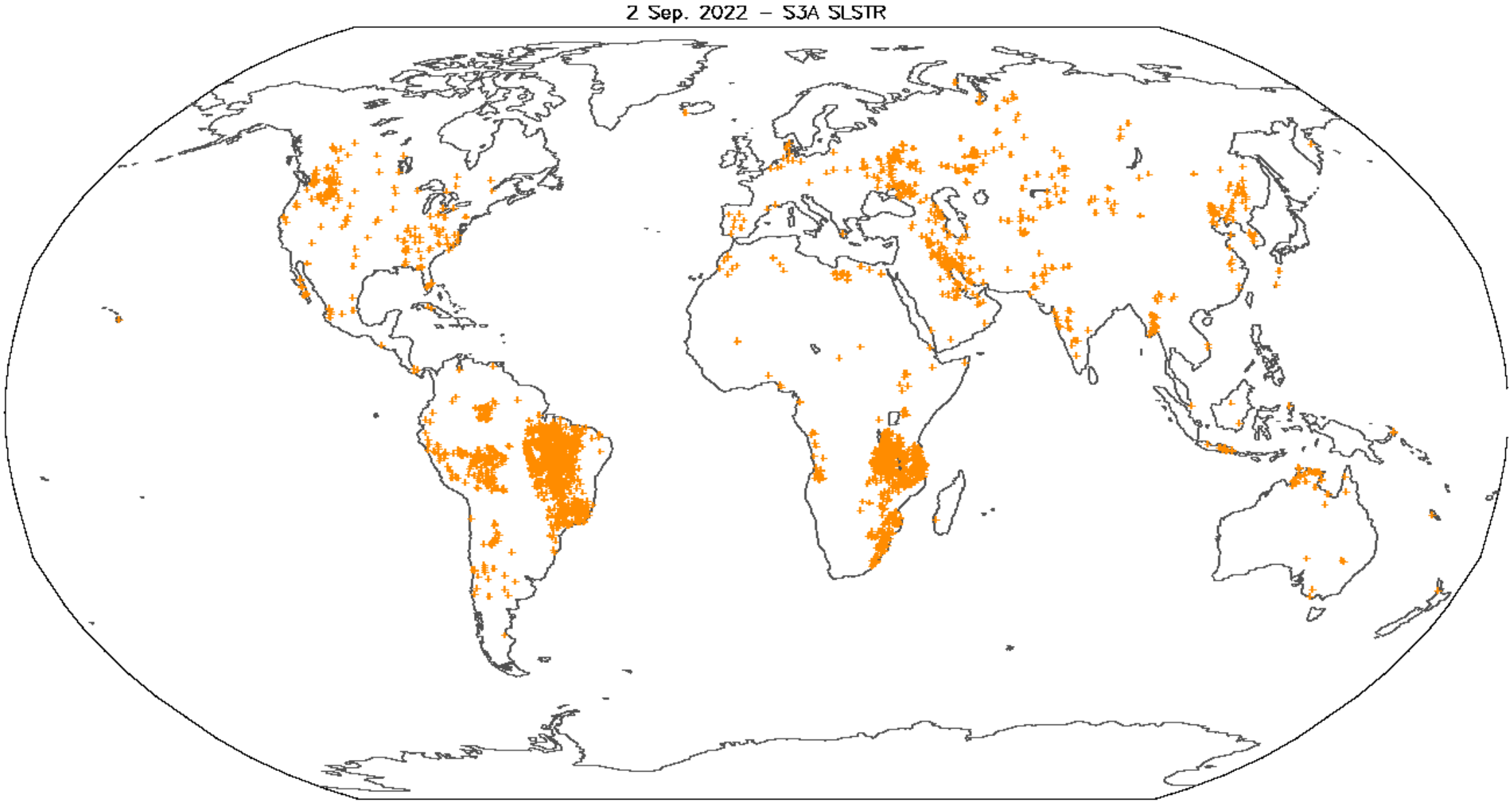


Joshua Johnston

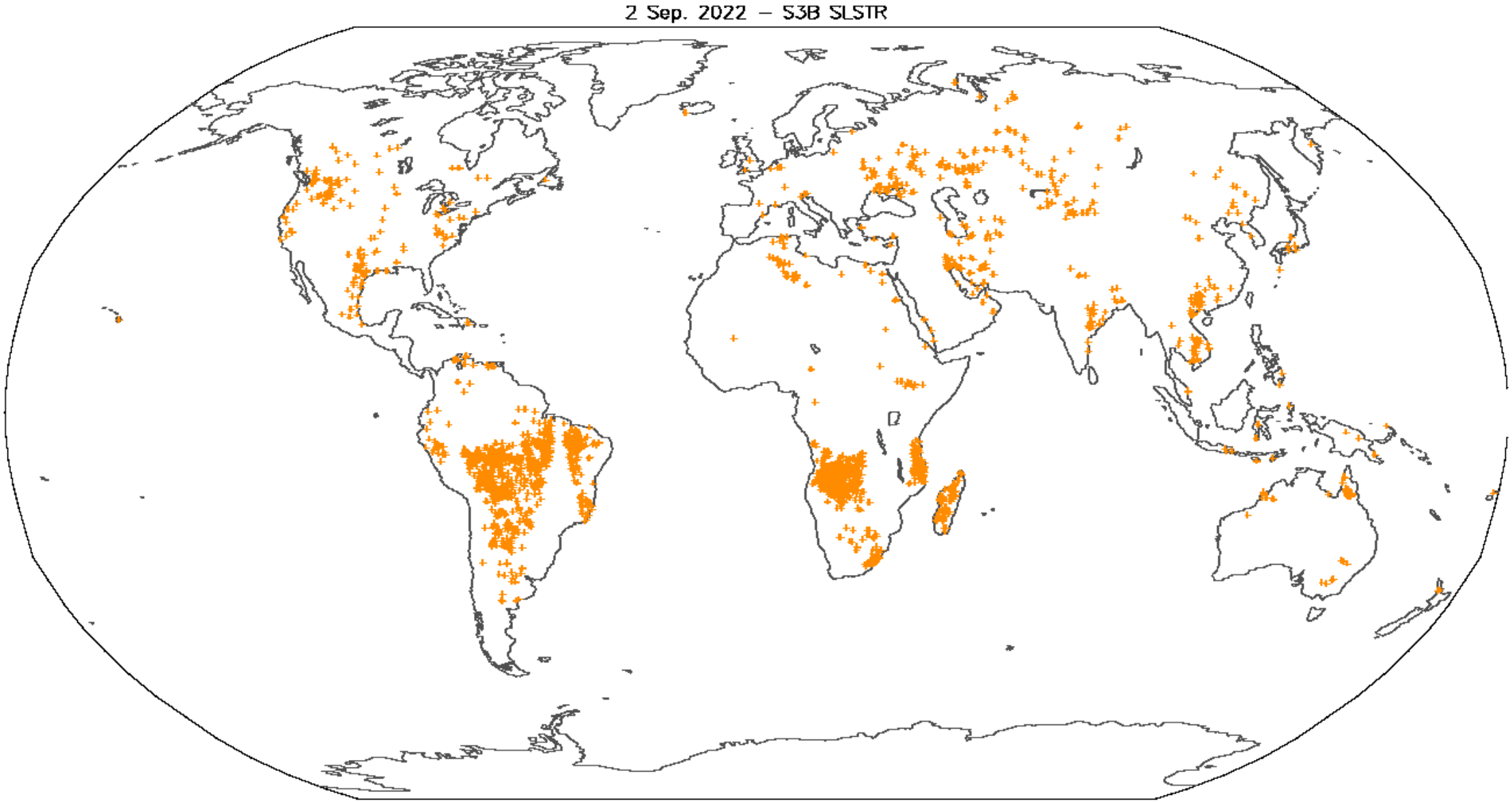
2 Sep. 2022 **Terra MODIS** 5,195 active fire pixels



2 Sep. 2022 **S3A SLSTR** 16,066 active fire pixels



2 Sep. 2022 **S3B SLSTR** 17,593 active fire pixels



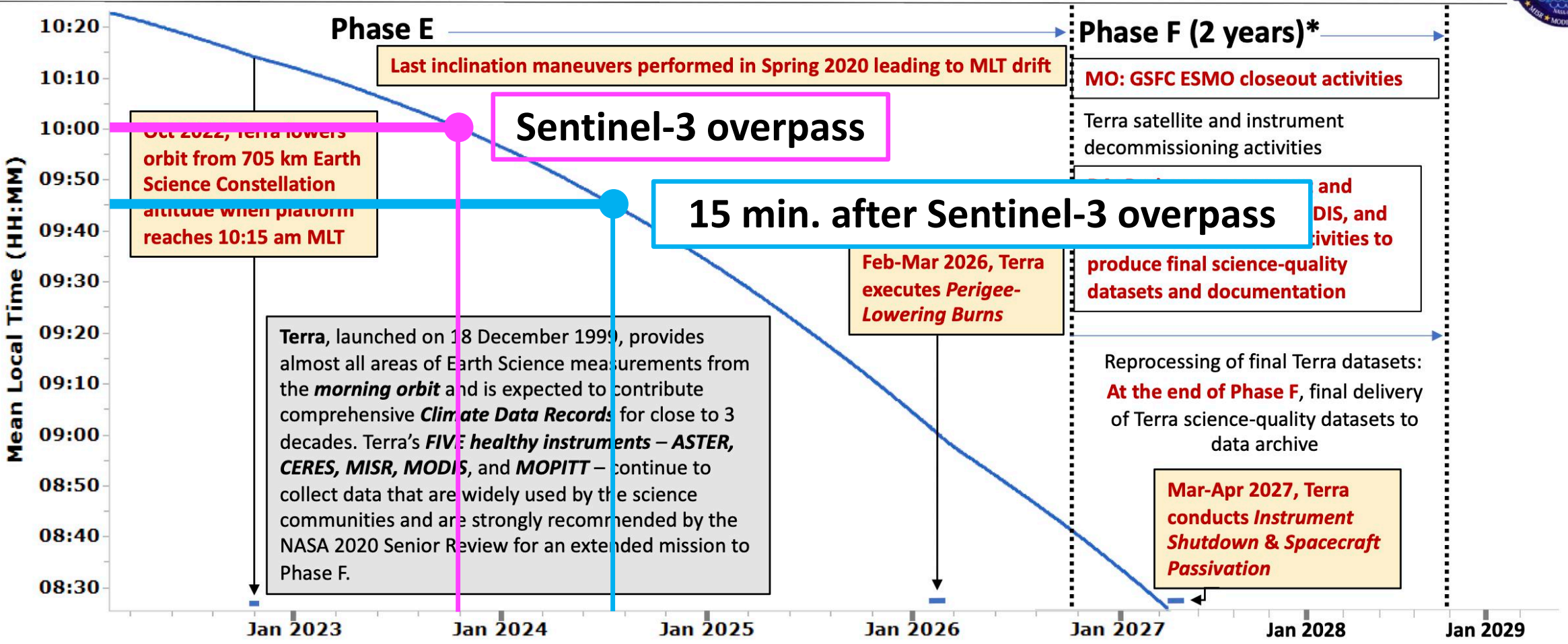
Sentinel-3A/3B SLSTR

- ESA Sentinel-3A (Feb. 2016 launch) + Sentinel-3B (Apr. 2018 launch)
- 10:00 local crossing time (sun-synchronous orbit)
- Sea and Land Surface Temperature Radiometer (SLSTR)
  - Somewhat less coverage than MODIS
    - 1420-km swath versus 2300-km swath
  - Oblique + nadir conical scans
  - Asymmetric swath avoids sun glint
  - 1-km fire bands
  - Quirks w/ respect to saturation and band-to-band co-registration
- NRT and science-quality SLSTR active fire products available from EUMETSAT and ESA

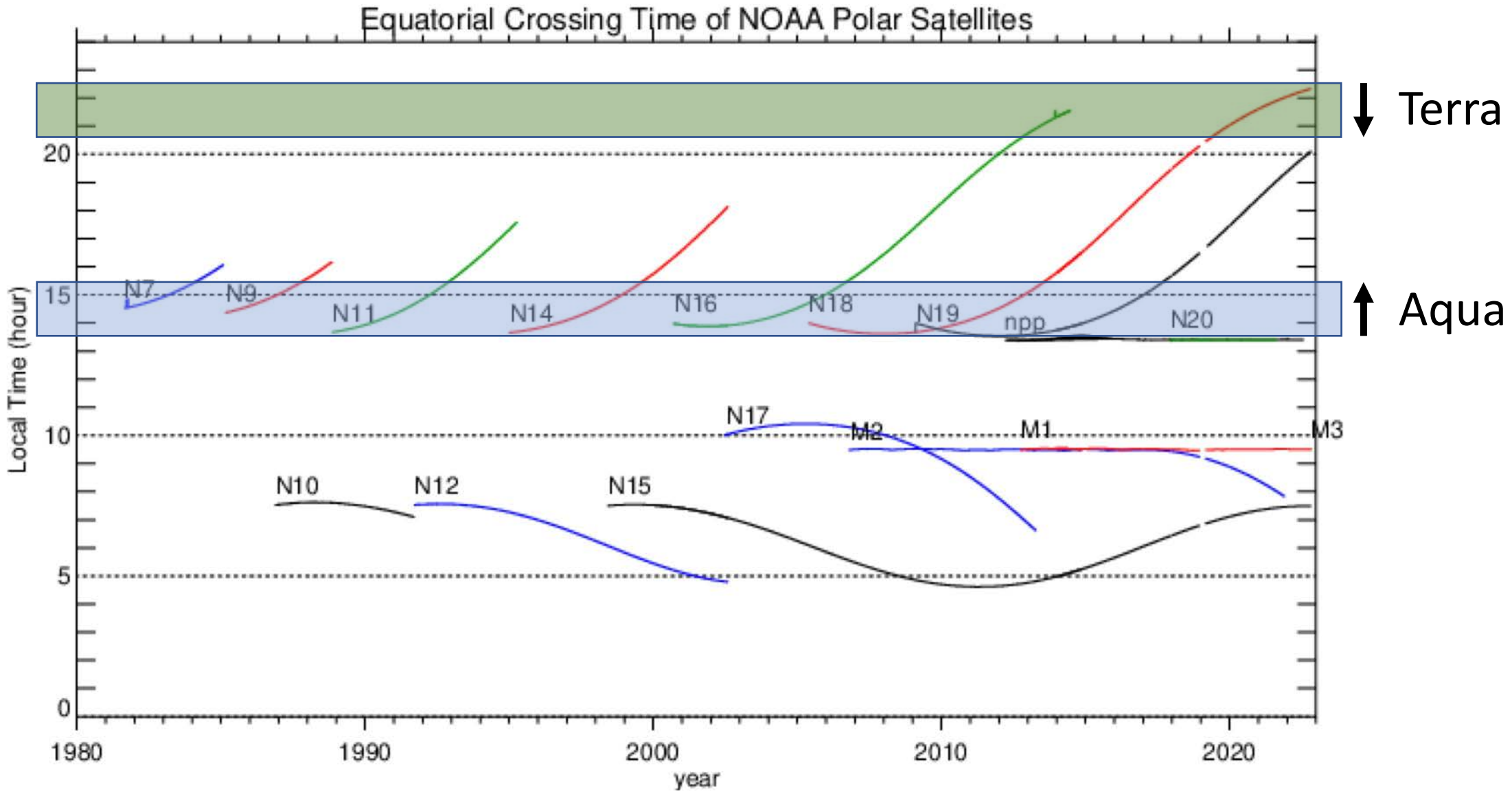
Initial Evaluation of SLSTR Active Fire Data

- Each SLSTR reports ~3× as many fire pixels as Terra MODIS
  - Higher sensitivity, especially at night
    - Constrained pixel growth (conical scan)
    - Wavelength: 3.74 µm MWIR channel vs. 3.96 µm for MODIS
  - High false alarm rate, especially along cloud edges
    - MWIR/LWIR misregistration + wavelength
- Fire radiative power (FRP) evaluation TBD
- Additional assorted practical (but manageable) product discrepancies
- Key step is to disentangle sensor/platform differences from overpass-related differences
  - Tolerance for validation reference data is generally **± 5 minutes**

Terra Timeline if Maximally Extended



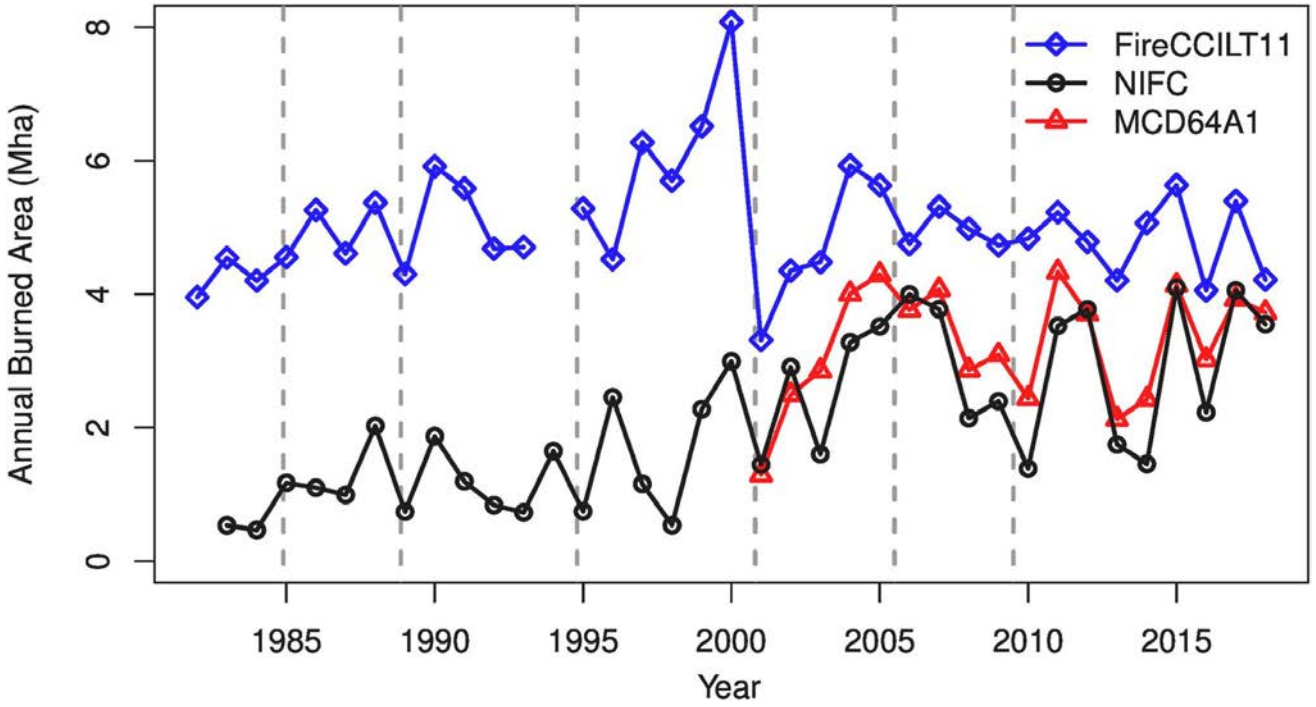
Historical Fire Data Record



https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_avhrr_ect.php

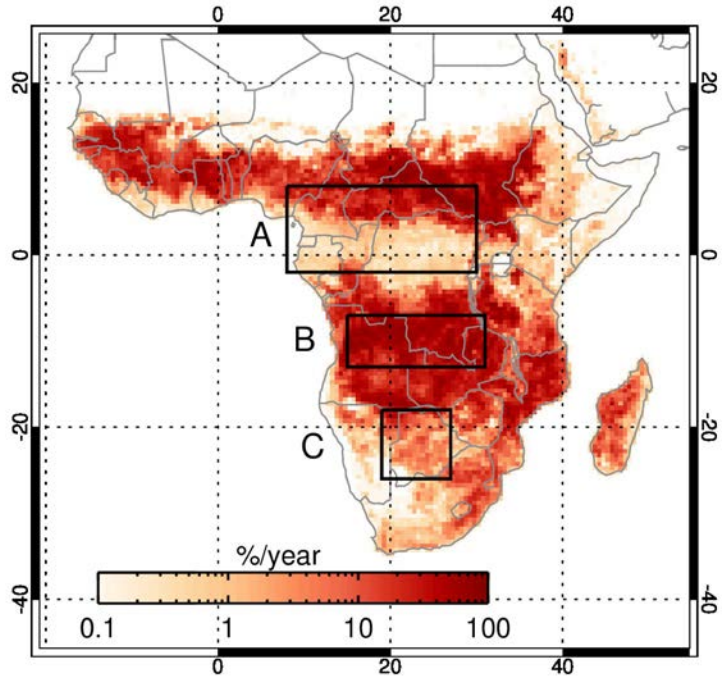
FireCCILT11 (AVHRR) Long-Term Fire Record

Annual total burned area (BA) for the **United States** reported by FireCCILT11, MCD64A1 (MODIS) and the U.S. National Interagency Fire Center (NIFC)

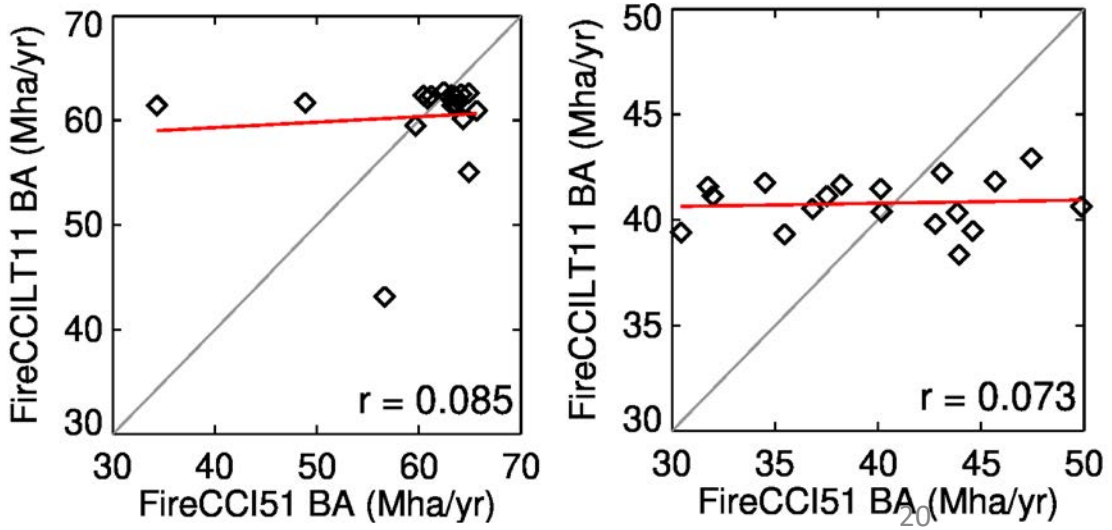


- Significant orbit-drift artifacts in the FireCCILT11 product
- FireCCILT11 drastically overestimates US burned area before 2001
- Poor agreement between FireCCILT11 and training data in vast areas of Africa, where majority of global BA occurs

Giglio & Roy, *Science of RS*, 2022



Annual FireCCILT11 BA versus *training data* set for large regions in **Africa**



Giglio, Zubkova, & Roy, *Fire*, 2022

Accurate quantification of fire timing with peak severity, burned area, fuels & emissions, plus pollution events dominated by rush-hour traffic

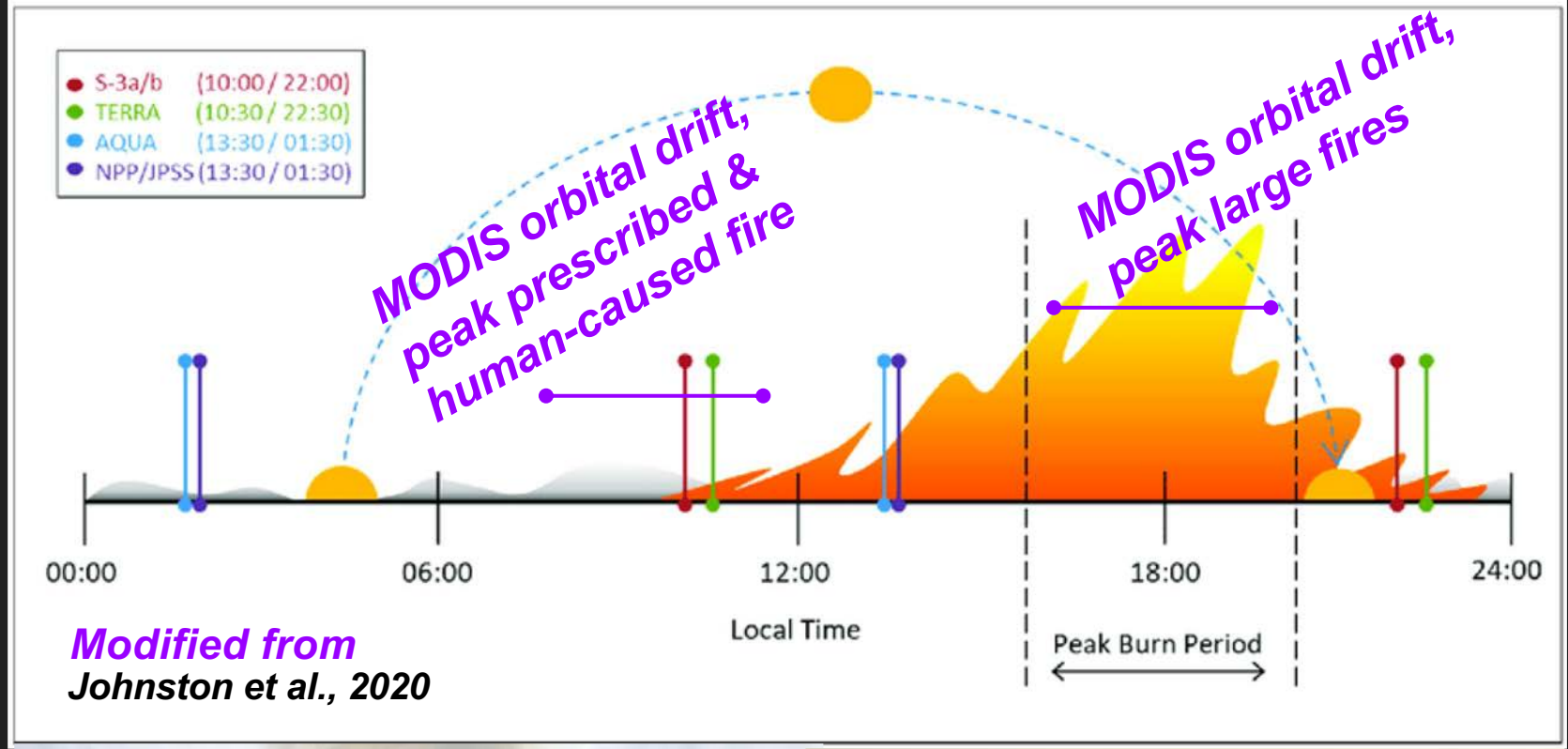
Jessica McCarty, Amber Soja, Joanne Hall, Ana Prados, David Green (NASA Wildland Fire Management program)

Fill Gaps in Knowledge

- Persistent vs episodic fire
- Calibrate extreme pollution
- Improve U.S. EPA National Emissions & GHG Inventories

Enable accurate Health Impact Assessments & epidemiological studies

- Per ecosystems, regions
- In underrepresented communities



Modified from
Johnston et al., 2020

Criteria pollutants: Unique view of morning & afternoon fires

Harvested wheat field burning in western Kansas, near Oklahoma. Image: J.L. McCarty.

Criteria pollutants: Unique view of morning & afternoon traffic

Getty Image Stock / Patrick Herrera