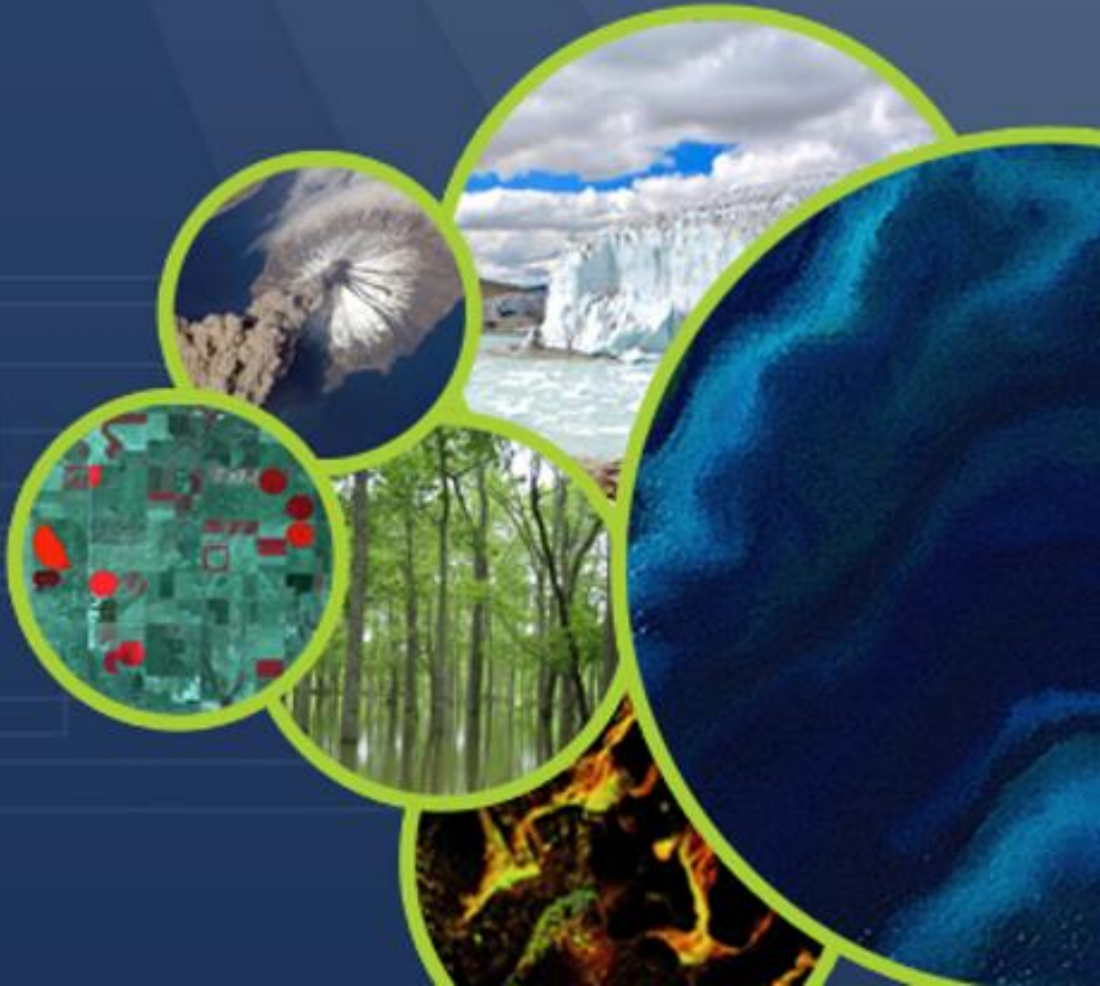
Committee on Earth Observation Satellites

WildFire Pilot

de Jong, M. (**Presenting**),
McFayden, C. (**Presenting**)
Johnston, J. (**Project PI**)

Dufour, D., Moore, P., Morton, D., Crowley, M., Dobbin, J., Flannigan, M., Hope, E. Jain, P., Lynham, T., MacPherson, L., Patel, M., Turbelin, A., van Mierlo, H., Wang, X., Woolford, D., Yebra, M., Zhu, J.

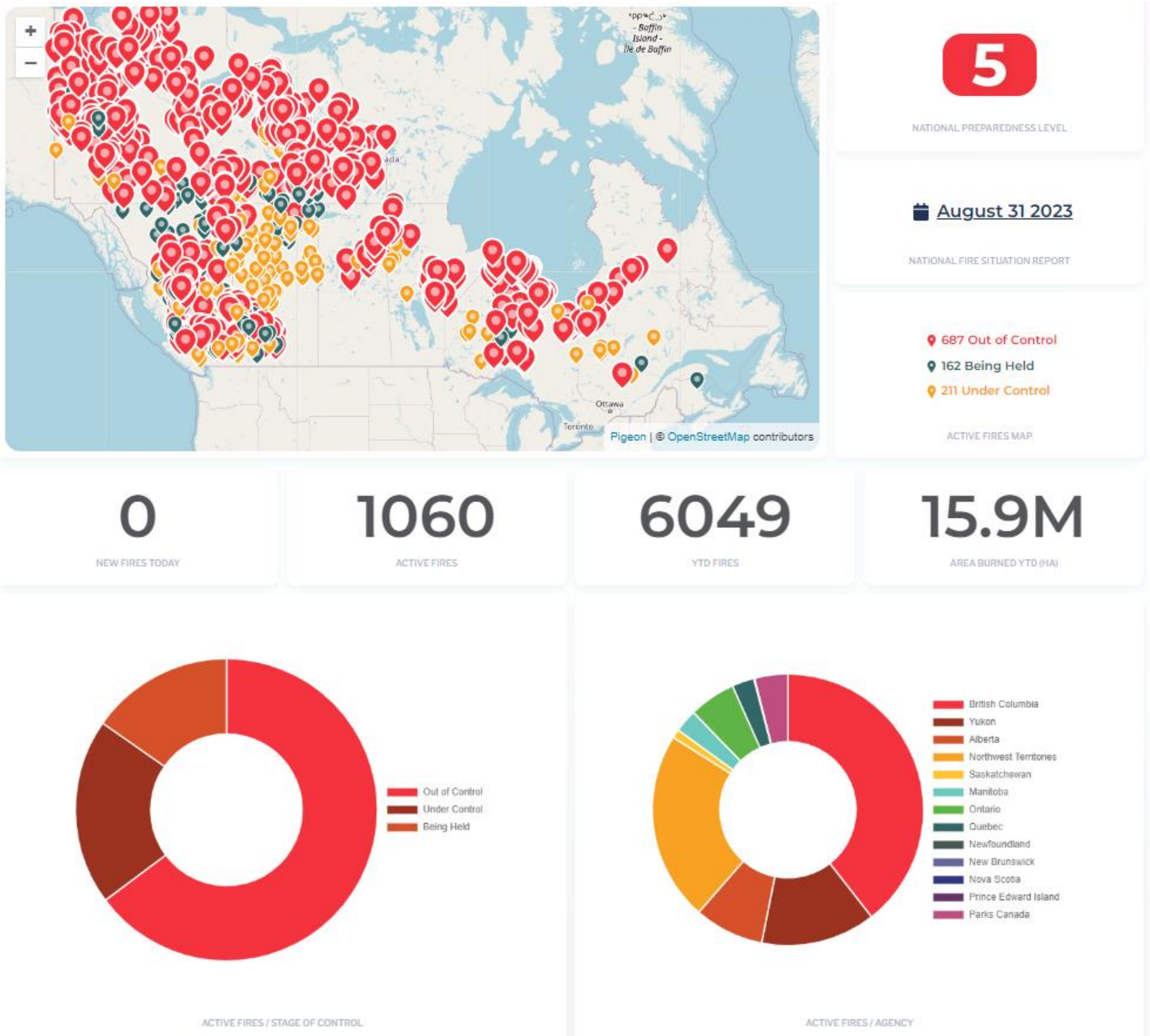


CEOS WG Disasters Meeting #20
April 5-7th, 2023

Overview

1) Canadian fire season 2023
2) Pilot background
3) Objective 1: recent developments
4) Objective 2: recent developments
5) Post Pilot planning

Canadian Fire Season 2023

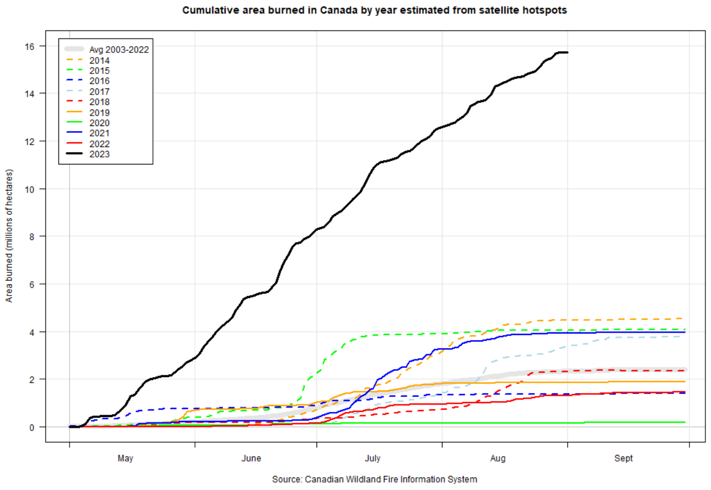


Canadian Interagency Forest Fire Centre, 31/08/2023

- 2023 is an exceptional year
- Annual average burned area: ~2.6M Ha
- YTD: 16M Ha
- Fire fighting philosophy in Canada is fairly unique
  - Fire is only fought where necessary (values at risk)
  - ecological value & expensive/impractical to fight everywhere
- Recent international impacts of smoke are problematic

	Area burned YTD Ha	
Agency	**2022**	**2023**
QC	29,570	5,311,100
NT	489,128	3,079,789
AB	141,273	2,204,726
BC	42,996	1,904,735
SK	252,145	1,444,004
PC	25,558	774,041
ON	2,581	407,444
YT	175,310	222,836
MB	168,381	186,995
NS	3,364	24,819
NL	24,258	21,883
NB	144	892
PE	-	8
Total	**1,354,708**	**15,583,272**

CIFFC Sit rep Aug 31, 2023

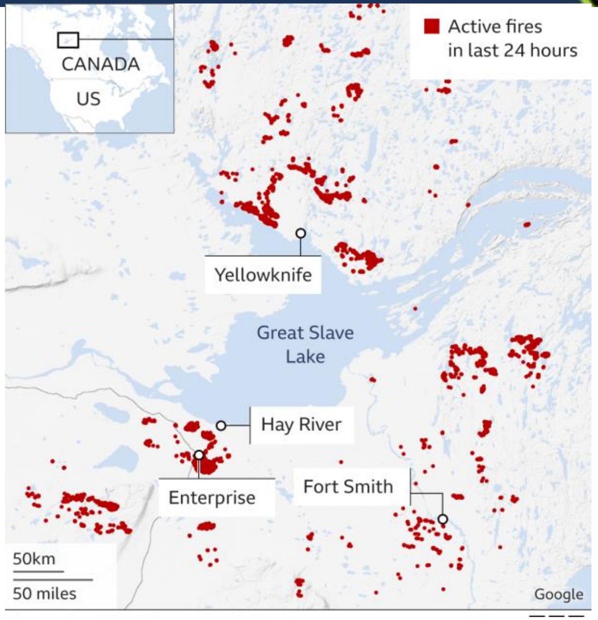


CWFIS
https://cwfis.cfs.nrcan.gc.ca/downloads/hotspots/burnarea_chart_10yr.png

Canadian Fire Season 2023

The human cost (YTD)

- 6 deaths (4 direct)
- 100s of properties destroyed (e.g. Kelowna, BC, Enterprise, NWT)
- >270 communities (>230,000 individuals) evacuated
- NWT: 70 % of population evacuated; huge societal disruption
- Just suppression costs alone are estimated (***very rough***) to be $2billion CAD



https://www.bbc.com/news/world-us-canada-66526554


lowna, BC. Landsat-8 17/08/2023


Kelowna, BC. Sentinel-2 20/08/2023


https://cabinradio.ca/141313/news/environment/wildfires/in-pictures-enterprise-after-a-wildfire-tore-through-the-hamlet/

Evacuation statistics provided by personal comm. with D. McVittie, CFS
Sentinel-2/Landsat satellite imagery provided by M. Crowley, CFS

Canadian Fire Season 2023

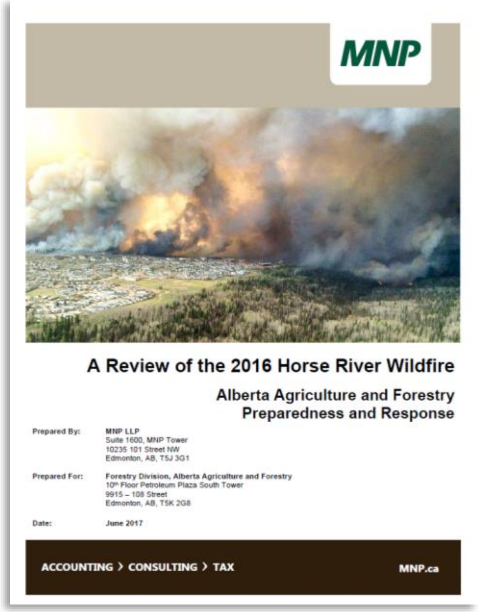
- Reconnaissance ***aircraft*** are ***frequently grounded*** by dense ***smoke***
- ***Infrared Earth observations*** can still be used to ***detect fire through smoke*** and inform ***operational decision making***

Quebec fires, Early Summer 2023. Credit: Dan Thompson, CFS.

Hay River Fire smoke from a NWT fire tower, August 2023.

Active Fire Earth Observation

- Long history (>30 years) of EO for **active fire monitoring** using MWIR (and SWIR)
- Historically, missions **not designed for oper. fire monitoring**; community developed around 'opportunistic use'
  - e.g. AVHRR, MODIS, GOES
- **Operational tools** are built on the back of these missions, but **no guaranteed long term mission continuation** leads to **vulnerabilities** (e.g. MODIS)
- Existing products are **not optimal** for **tactical operational use** by fire agencies


MNP
A Review of the 2016 Horse River Wildfire
Alberta Agriculture and Forestry
Preparedness and Response
Prepared By: MNP LLP
Suite 1600, MNP Tower
10235 101 Street NW
Edmonton, AB, T5J 3G1
Prepared For: Forestry Division, Alberta Agriculture and Forestry
10th Floor Petroleum Plaza South Tower
9915 – 108 Street
Edmonton, AB, T5K 2G8
Date: June 2017
ACCOUNTING › CONSULTING › TAX
MNP.ca

*"Satellite images are **not available in real time** and are **not generally used to support ongoing suppression activities**; rather they are available for single points in time and are **useful for strategy and planning**"*

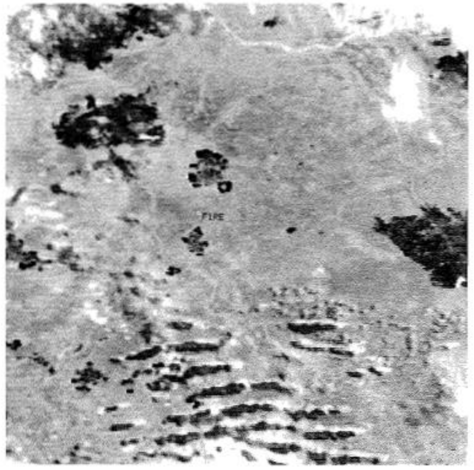
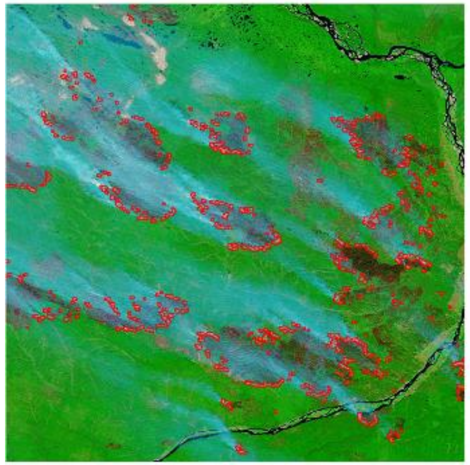
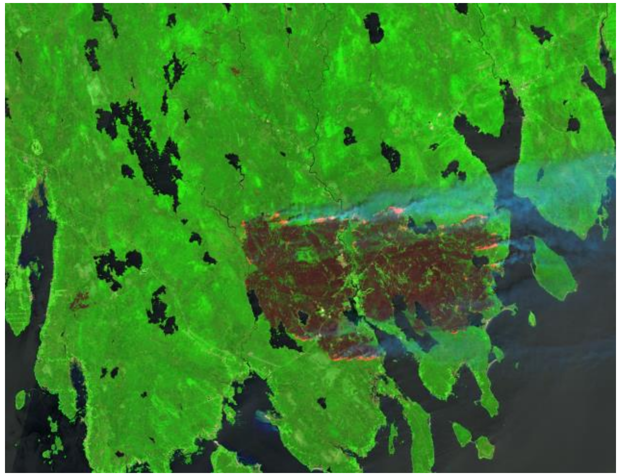


FIG. 10. NOAA-7 pass 5102, AVHRR channel 3, June 19, 1982, 1510 MDT. This is a two-times enlargement of the upper right portion of Fig. 6 showing active fire areas in two major fires near the centre of the image.

AVHRR, Flannigan & Vonder Haar, 1986



Fire burn scars (black) overlain with hotspot data (red) in MODIS imagery, Russia 2002 (Giglio et al 2006)



Sentinel-2 imagery of the Barringtom Lake Fire, NS, Canada May 2023. Processed by M. Crowley

WildFire Pilot Scope

Aim: to provide a comprehensive gap analysis for active-fire earth observation

Objectives:

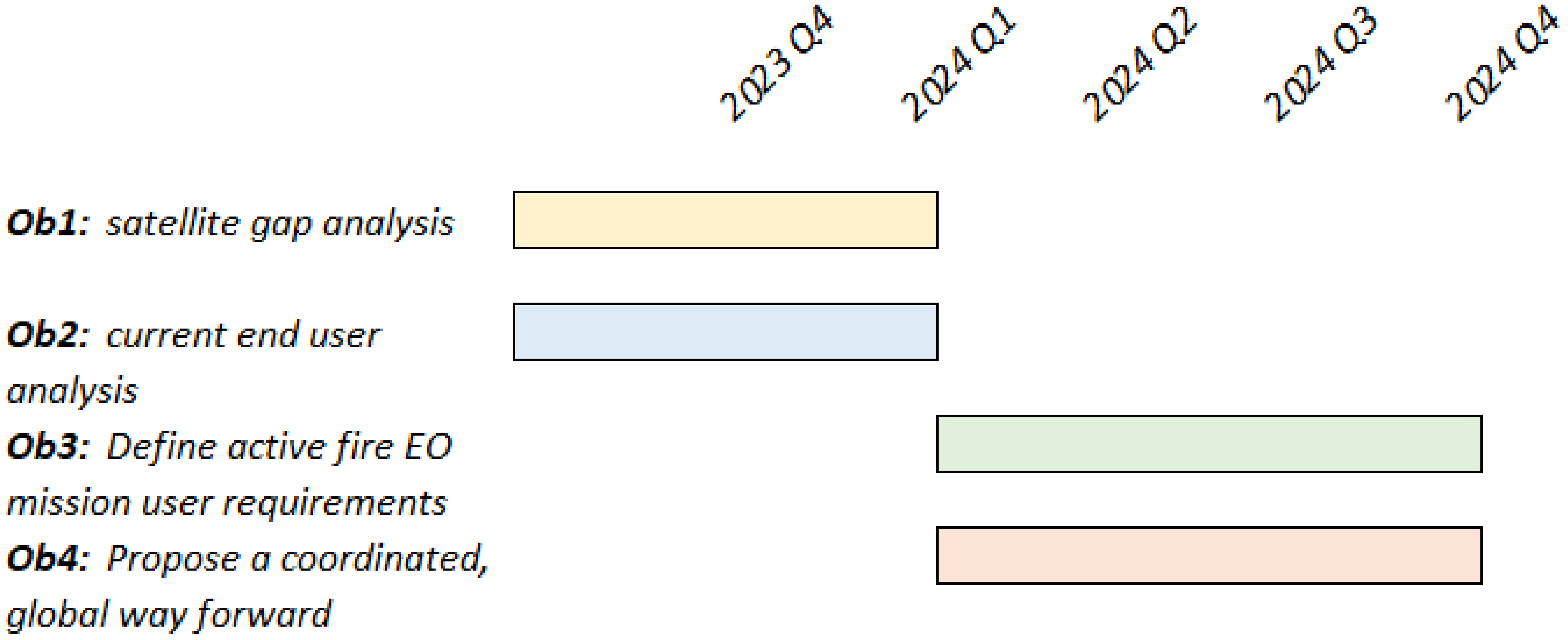
1. Conduct a ***detailed inventory and gap analysis*** of ***existing and proposed EO systems*** suitable for ***global active-fire monitoring***;

2. Conduct a ***detailed analysis of global stakeholders*** and ***end-users*** of near-real-time active-fire EO data;

3. ***Define*** targeted ***user requirements*** for active-fire remote sensing systems ***for disaster mitigation applications;***

4. ***Propose a way forward*** in coordinating global wildfire monitoring activities.

WildFire Pilot Timeline



WildFire Pilot Objective 1

Objective 1: Conduct a ***detailed inventory and gap analysis*** of ***existing and proposed EO systems*** suitable for ***global active-fire (AF) monitoring***, considering ***climate*** driven changes in fire

1. How does global future EO ***active fire*** monitoring ***capacity change***?

2. How will ***fire regimes*** (fire weather) ***change*** under future ***climate change***?

3. ***Intercomparison*** *of* existing and future ***EO coverage & weather projections***

CEOS MIM Database

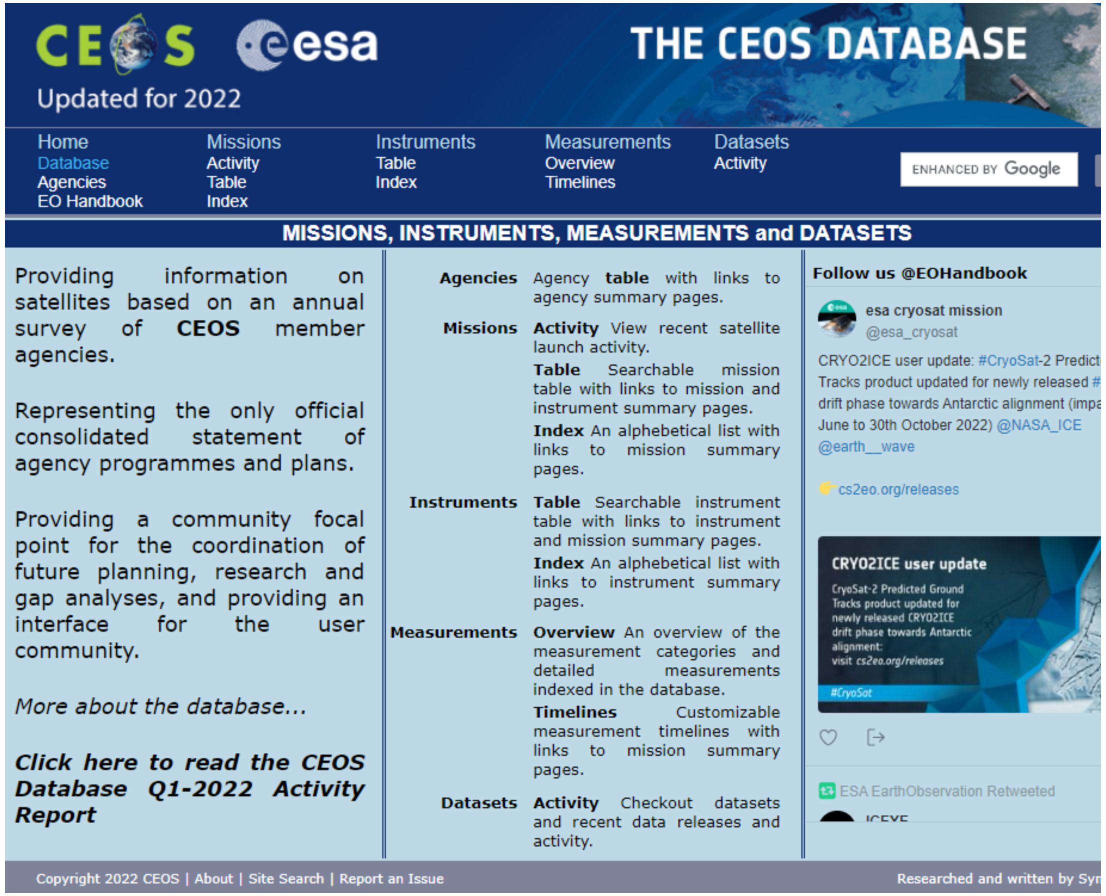
CEOS Missions, Instruments, Measurements (MIM) Database

- all historic, current & planned missions for CEOS member space agencies, annual updates
  - **1970s-2040s** period
  - **>650 missions, ~950 instruments** (~450 distinct)

- ***First pass, liberal*** screening of all systems on orbit 2015-2045 that are ***potentially useful*** for fire detection or characterisation [***N=~190 unique systems***]
  - Detection ('hotspot' mapping): **LWIR *or* MWIR *or* SWIR [≥2.2µm]**
  - Characterisation (FRP, bispectral etc): **MWIR *and* LWIR**

- ***Second pass:*** manual checking with e.g. space agency websites, EOPortal, WMO OSCAR
  - **119 unique systems** (instrument/satellite combinations)
  - Types: **SS-LEO=63, GEO=49, Other=7**

- Updated to reflect CEOS MIM Database as of late March 2023



CEOS MIM database:
http://database.eohandbook.com/

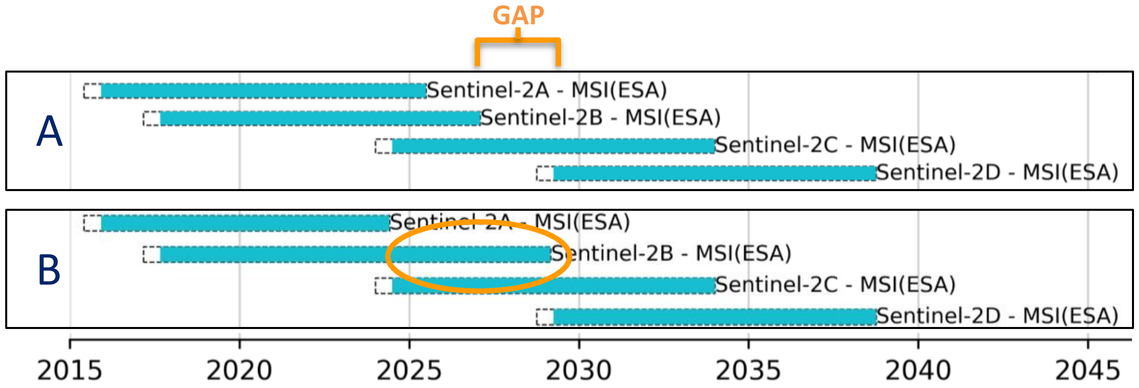
Data Collection & Assumptions

- ***Gathering*** and ***calculating parameters*** needed for ***STK modelling*** from CEOS MIM DB, WMO OSCAR, agency websites e.g.:

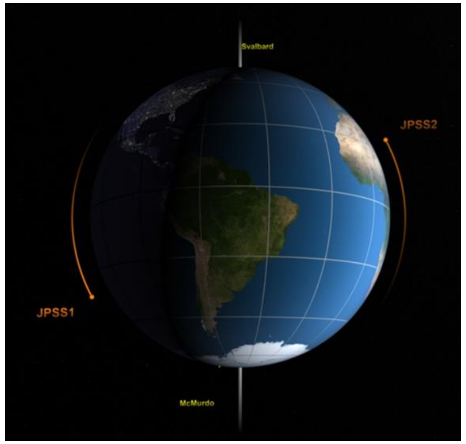
  Launch & end of life dates; LTAN; altitude; inclination; orbit separation; GSD; sensor half angles

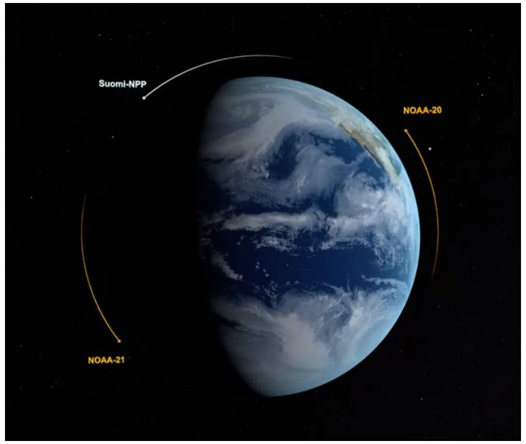
(Some!) assumptions:

- **Commissioning*: Assumed 6 months*** post-launch for ***SS-LEO***. ***Assumed 1 year*** for ***GEO***
- **End of Life (EoL):** stated ***nominal mission life only***
  extended operating capability is hard to estimate
- **Multi-satellite series gaps: *avoid short gaps*** by extending earlier system EoL (e.g. Sentinel-2B; FY-3D)
- **Orbit separation:** unless known, multi-satellite missions (e.g. JPSS; Sentinel; FY-3; METEOR-MN2) with same LTAN ***assigned maximum separation*** (i.e. 2 sats=180°, 3 sats=120°
- **Tasking:** all instruments (e.g. Terra – ASTER*)* ***assumed nadir pointing.*** No schedule information, so this represents a reasonable worst case scenario where fire is rarely an imaging priority



Sentinel-2 lifetimes: ***(A)*** *unmodified timeline* ***(B)*** *timeline modified to avoid gap in two satellite tandem coverage (extended S-2B EoL)*





Example of different multi-satellite orbit separation configurations (e.g. JPSS): 180° vs 90°
https://svs.gsfc.nasa.gov/4430

Modelling Scenarios

- ***Four scenarios*** representing different combinations of:
  (1) ***Type*** of fire information (***detection vs. characterisation***)
  (2) fire product ***data availability***

- Separate modelling of **LEO** and **GEO**

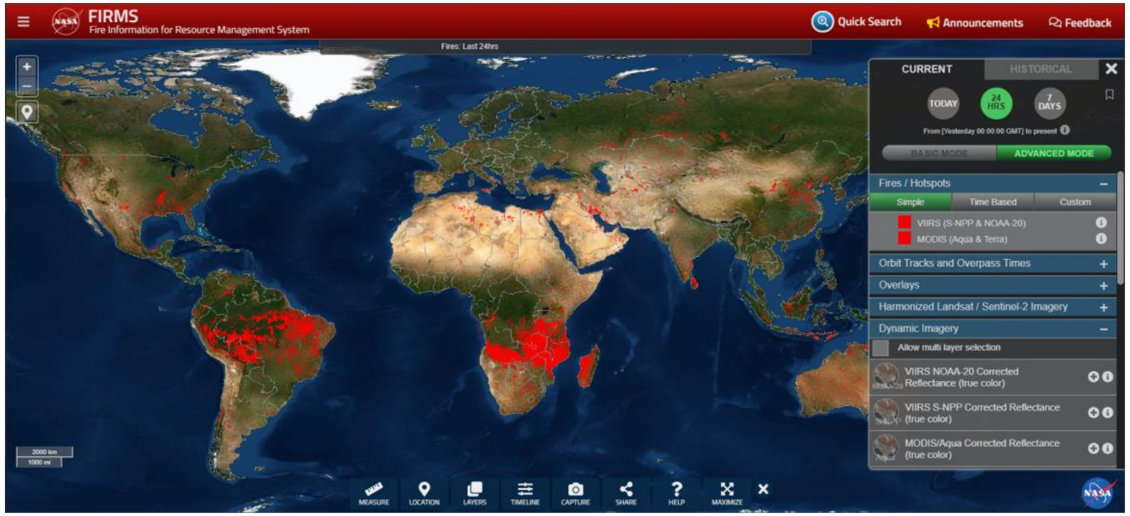
Scenario	Satellite systems 'All' or 'characterization'?	Space agencies 'All' or 'FIRMS/GWIS' agencies?	Description	
A – 'BaU'	All	FIRMS/GWIS	• Basic fire applications (detection/hotspots) • current international cooperation levels	
B	Characterization Capable only	FIRMS/GWIS	• Advanced fire applications (FRP, size, etc) • current international cooperation levels	Anticipated worst coverage
C	Characterization Capable only	All	• Advanced fire applications (FRP, size, etc) • broad international cooperation levels	
D	All	All	• Basic fire applications (detection/hotspots), • broad international cooperation levels	Anticipated best coverage

FIRMS & GWIS Agencies

- **FIRMS/GWIS** are **open data initiatives** providing NRT and historic **EO fire data**

- **Current** integrated satellite **fire products**:
  - MODIS
  - VIIRS
  - Landsat
  - Meteosat-SEVIRI
  - GOES
  - Himawari

- **All agencies** involved in the **development** of these satellites, according to **CEOS MIM Database**:
  - CSA
  - ESA
  - EUMETSAT
  - JAXA
  - NASA
  - NOAA
  - USGS



MODIS, VIIRS, Landsat, GOES, Meteosat-SEVIRI, Himawari NRT (<24h) and historic 'Fire & Thermal Anomalies Data' available from NASA FIRMS

GWIS - a joint GEO/Copernicus initiative provides NRT and historic hotspot and fire environment data https://gwis.jrc.ec.europa.eu/

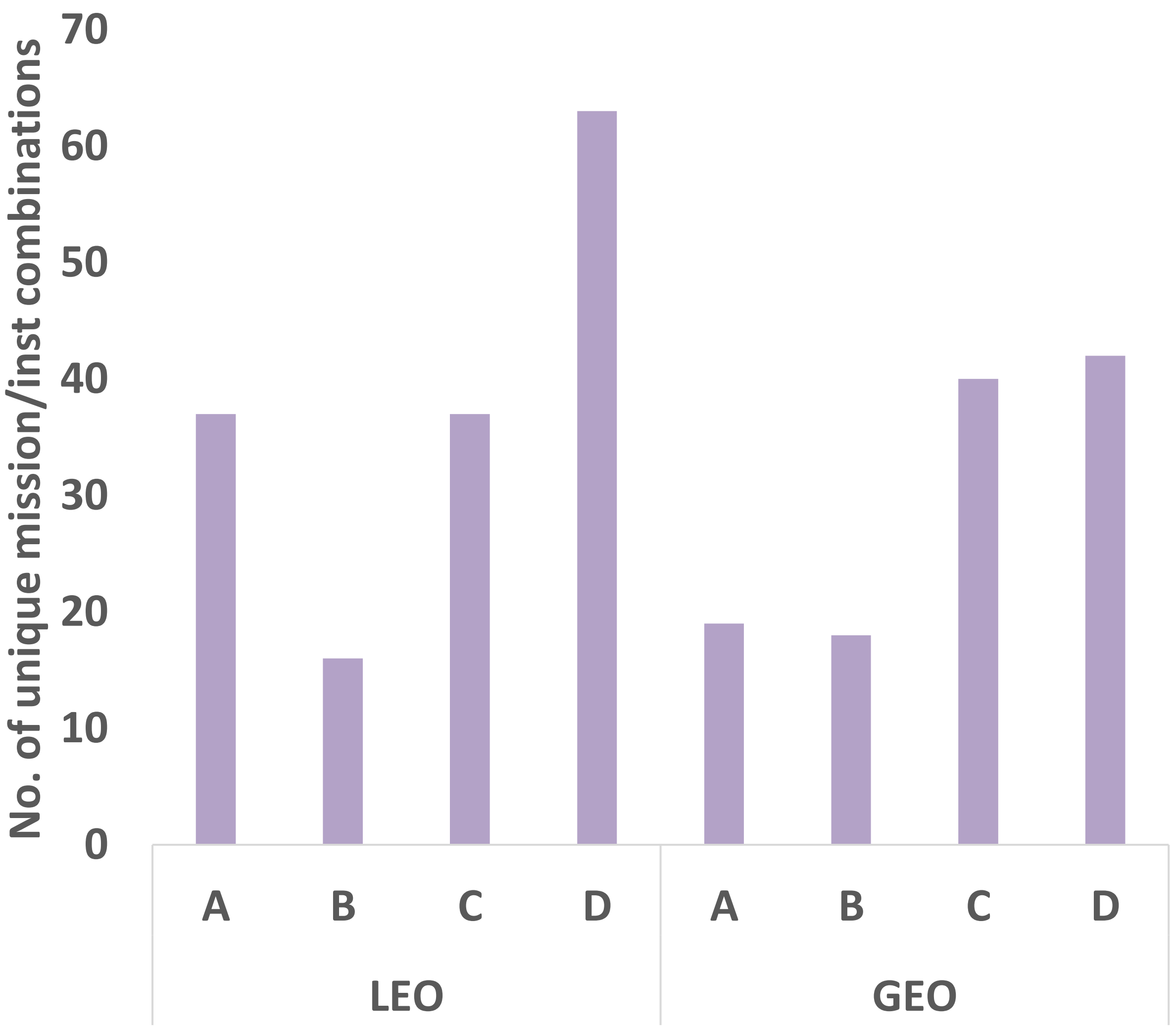
Scenario summary

In terms of **raw numbers** of AF capable EO missions:

- FIRMS/GWIS capability **only represents approx. half of global capability**, both for LEO and GEO
  (cf. Scenarios A and D)

- For LEO, few missions are capable of fire characterization. making all agency missions easily available would more than double this
  - *(cf. Scenarios LEO B and C*)

- **Conclusion: better global cooperation** would **vastly improve** active fire monitoring, **without committing to any new missions** beyond already on orbit/planned



STK modelling

Research Question 1: How does global future EO ***active fire*** monitoring ***capacity change***?

1) Revisit time analysis

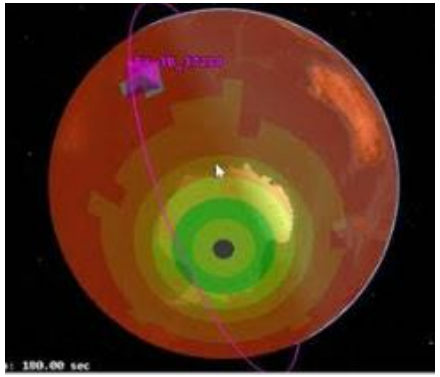
- **Aim**: what is the maximum revisit time for satellites capable of fire monitoring in different locations? How does it change over time?
  - i.e. how long do fire managers have to wait for satellite observations, in the worst case scenario?

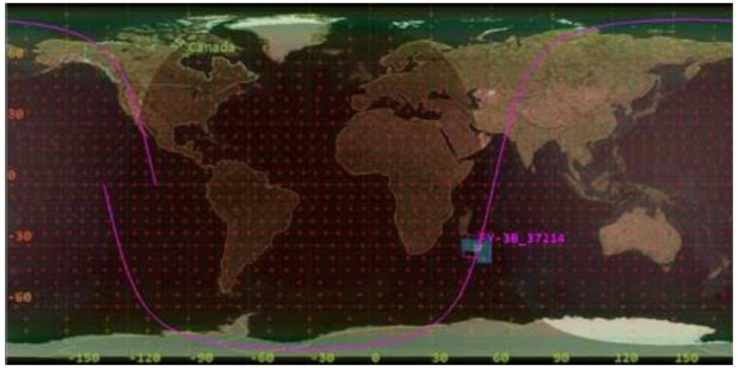
2) Coverage density analysis

- **Aim**: How does the average daily number of observations (weighted by GSD^2) change spatially, and over time?
  - sensors with higher spatial resolution (lower GSD) are weighted higher due to providing more observations per unit area

- *LEO modelling **complete,** data analysis **underway***

- ***GEO** modelling **ongoing***

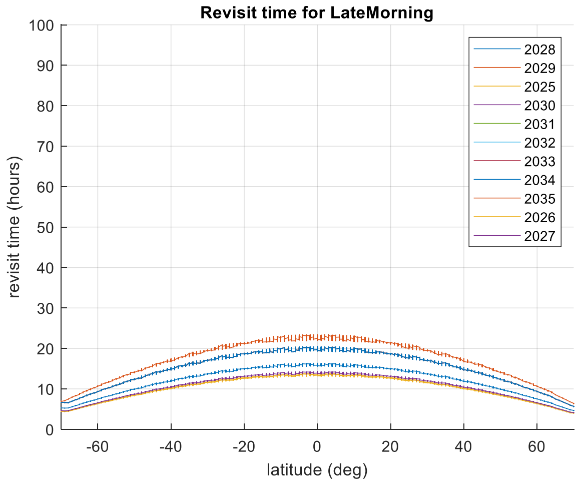


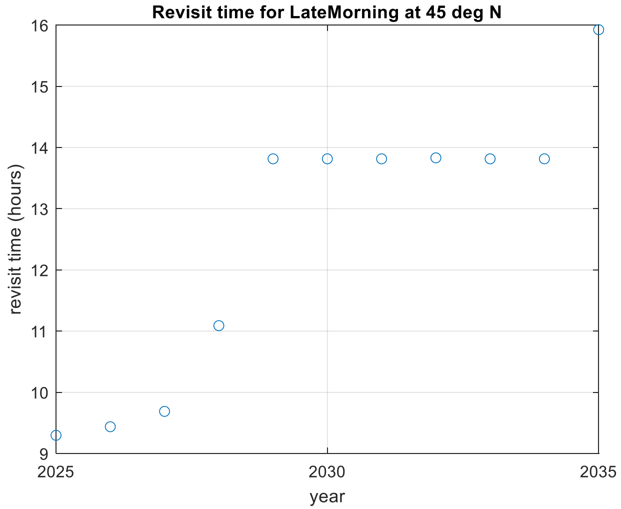


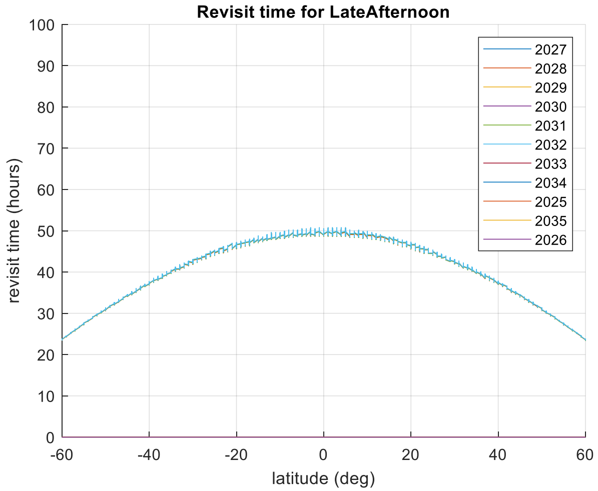
Initial STK modelling of FY-3B overpasses

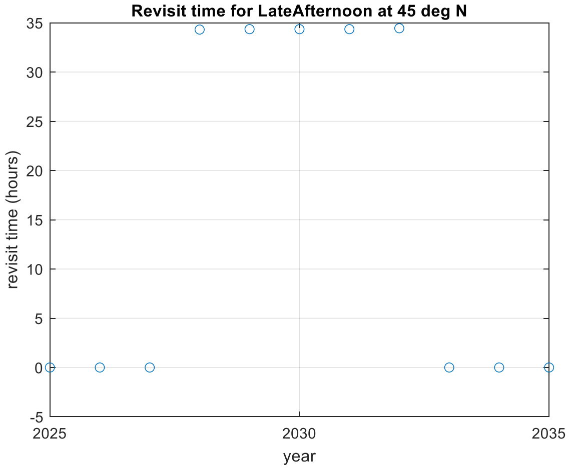
Revisit time analysis (prelim.)

- **Evolution of average revisit time for Scenario B - Fire Characterisation *(preliminary)***









Late Morning

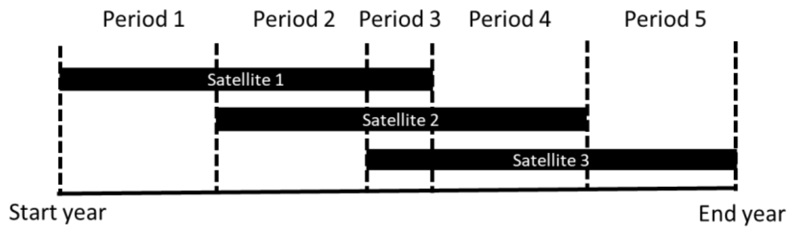
- Less frequent revisits after 2029 in late morning orbit period

Late Afternoon

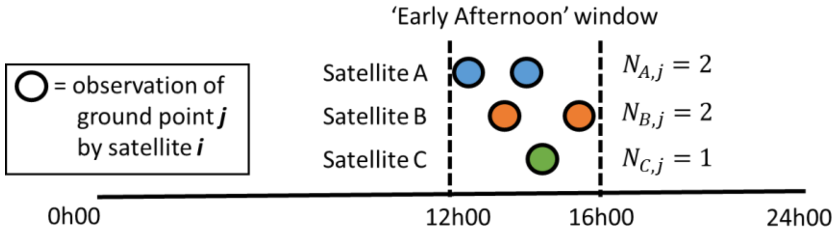
- Wildfiresat will provide daily revisits in higher latitudes starting in 2029
- Currently no other Scenario B satellites in late afternoon orbit

Coverage density analysis (prelim.)

1. Determine time periods with equal number of satellites

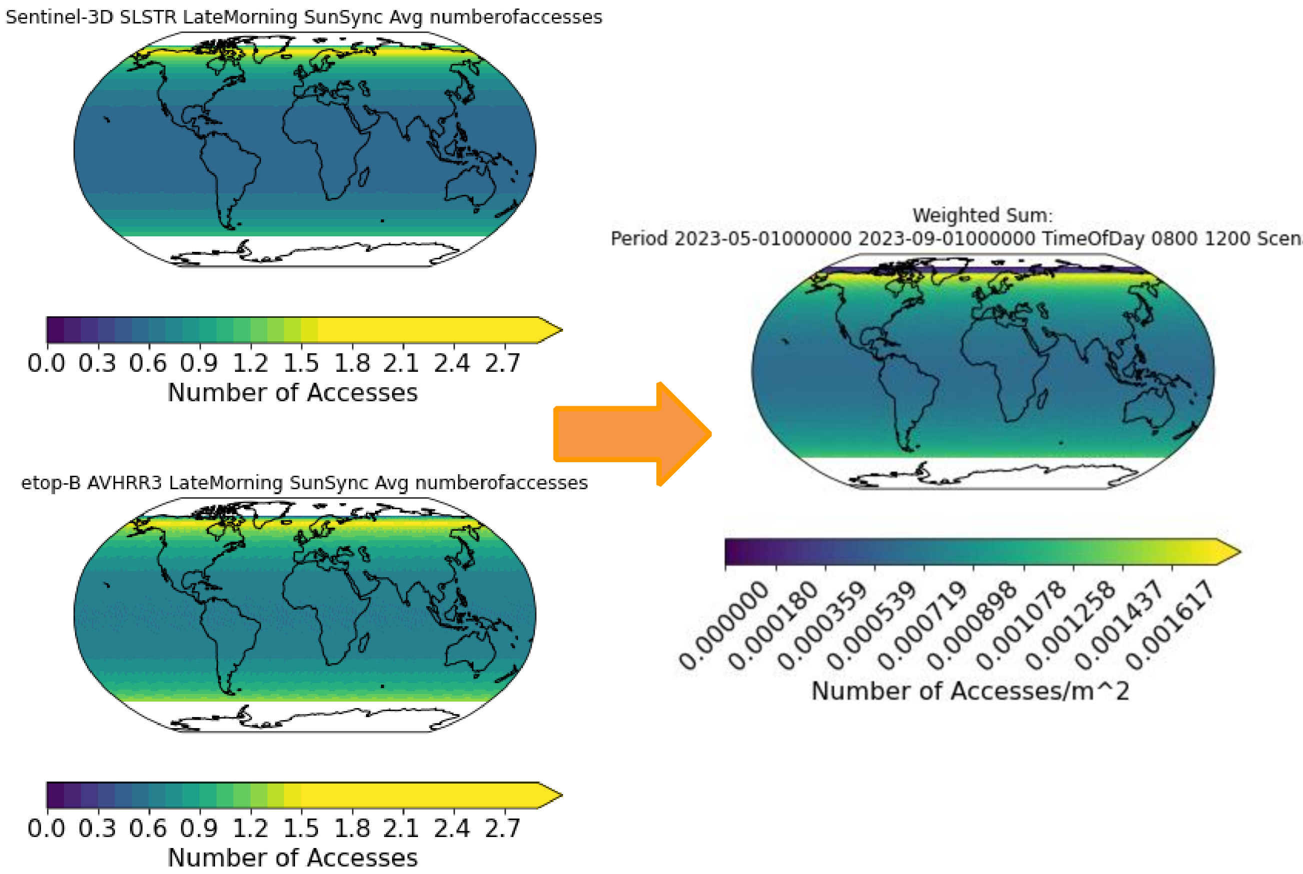


2. Model average number of overpasses for the satellites in each time period



3. Evaluate coverage density for each time period

$$Coverage\ density = \sum_{i=0}^{n} N_{i,j} \cdot \frac{1}{{GSD_i}^2}$$



Objective 2 – Key Elements

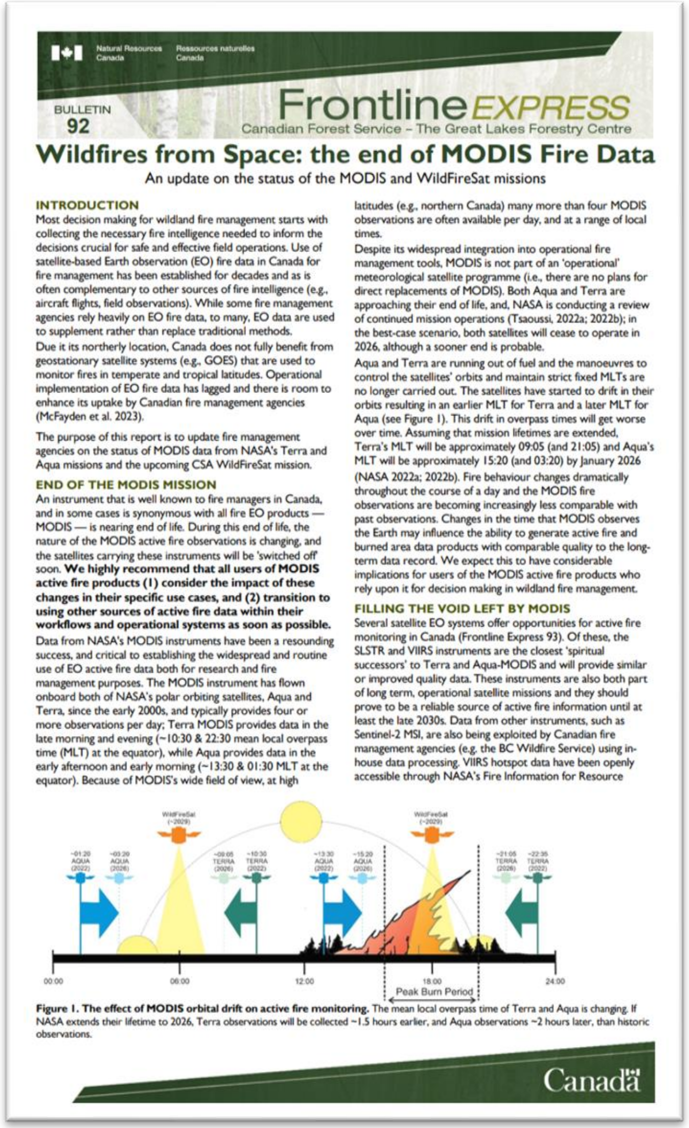
(Objective 2) "Conduct a detailed analysis of global stakeholders and end-users of near-real-time active-fire EO data"

- Seeking meaningful input on use of EO data and products; setting out needs from the wildfire management perspective.
- Understanding the user community in operational fire management, what they are using now and what they need in the future.
- Getting a handle on "the state of play".

Obj 2 - team

(alphabetical) M. Crowley, M. De Jong, J. Dobbin, E. Hope, J. Johnston, T. Lynham, L. MacPherson, C. McFayden, P. Moore, A. Turbelin, D. Woolford

Update: Two CEOS affiliated Canadian Forest Service Publications



Natural Resources Canada | Ressources naturelles Canada

BULLETIN 92

Frontline EXPRESS

Canadian Forest Service – The Great Lakes Forestry Centre

Wildfires from Space: the end of MODIS Fire Data

An update on the status of the MODIS and WildFireSat missions

INTRODUCTION

Most decision making for wildland fire management starts with collecting the necessary fire intelligence needed to inform the decisions crucial for safe and effective field operations. Use of satellite-based Earth observation (EO) fire data in Canada for fire management has been established for decades and as is often complementary to other sources of fire intelligence (e.g., aircraft flights, field observations). While some fire management agencies rely heavily on EO fire data, to many, EO data are used to supplement rather than replace traditional methods.

Due it its northerly location, Canada does not fully benefit from geostationary satellite systems (e.g., GOES) that are used to monitor fires in temperate and tropical latitudes. Operational implementation of EO fire data has lagged and there is room to enhance its uptake by Canadian fire management agencies (McFayden et al. 2023).

The purpose of this report is to update fire management agencies on the status of MODIS data from NASA's Terra and Aqua missions and the upcoming CSA WildFireSat mission.

END OF THE MODIS MISSION

An instrument that is well known to fire managers in Canada, and in some cases is synonymous with all fire EO products — MODIS — is nearing end of life. During this end of life, the nature of the MODIS active fire observations is changing, and the satellites carrying these instruments will be 'switched off' soon. **We highly recommend that all users of MODIS active fire products (1) consider the impact of these changes in their specific use cases, and (2) transition to using other sources of active fire data within their workflows and operational systems as soon as possible.**

Data from NASA's MODIS instruments have been a resounding success, and critical to establishing the widespread and routine use of EO active fire data both for research and fire management purposes. The MODIS instrument has flown onboard both of NASA's polar orbiting satellites, Aqua and Terra, since the early 2000s, and typically provides four or more observations per day; Terra MODIS provides data in the late morning and evening (~10:30 & 22:30 mean local overpass time (MLT) at the equator), while Aqua provides data in the early afternoon and early morning (~13:30 & 01:30 MLT at the equator). Because of MODIS's wide field of view, at high latitudes (e.g., northern Canada) many more than four MODIS observations are often available per day, and at a range of local times.

Despite its widespread integration into operational fire management tools, MODIS is not part of an 'operational' meteorological satellite programme (i.e., there are no plans for direct replacements of MODIS). Both Aqua and Terra are approaching their end of life, and, NASA is conducting a review of continued mission operations (Tsaoussi, 2022a; 2022b); in the best-case scenario, both satellites will cease to operate in 2026, although a sooner end is probable.

Aqua and Terra are running out of fuel and the manoeuvres to control the satellites' orbits and maintain strict fixed MLTs are no longer carried out. The satellites have started to drift in their orbits resulting in an earlier MLT for Terra and a later MLT for Aqua (see Figure 1). This drift in overpass times will get worse over time. Assuming that mission lifetimes are extended, Terra's MLT will be approximately 09:05 (and 21:05) and Aqua's MLT will be approximately 15:20 (and 03:20) by January 2026 (NASA 2022a; 2022b). Fire behaviour changes dramatically throughout the course of a day and the MODIS fire observations are becoming increasingly less comparable with past observations. Changes in the time that MODIS observes the Earth may influence the ability to generate active fire and burned area data products with comparable quality to the long-term data record. We expect this to have considerable implications for users of the MODIS active fire products who rely upon it for decision making in wildland fire management.

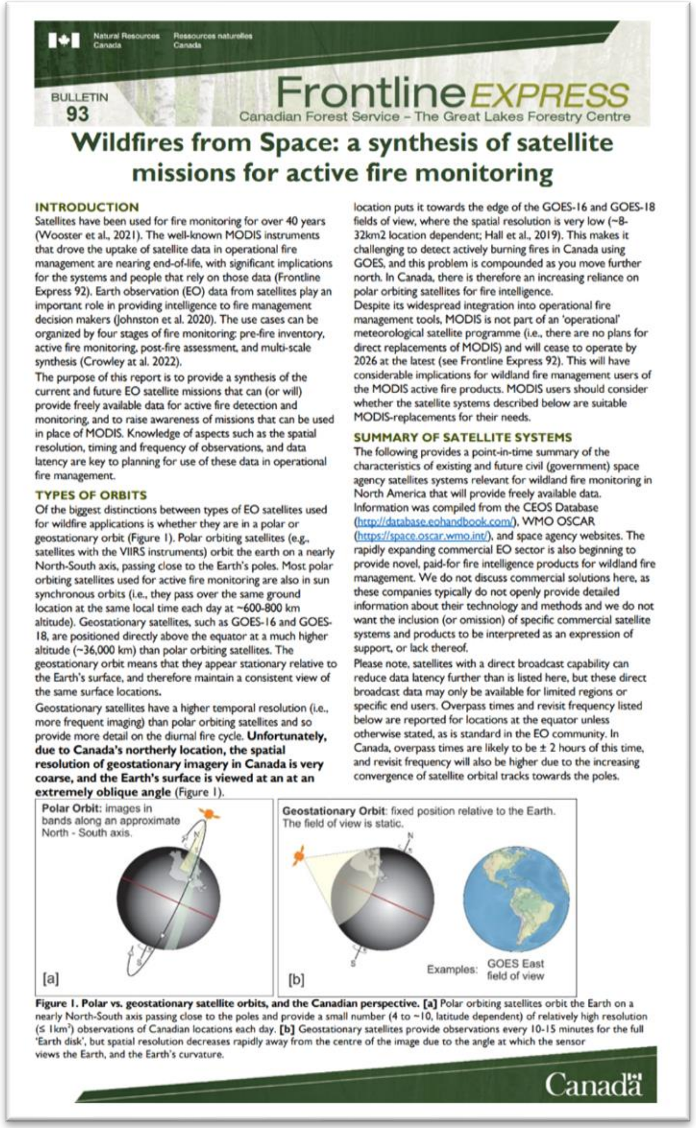
FILLING THE VOID LEFT BY MODIS

Several satellite EO systems offer opportunities for active fire monitoring in Canada (Frontline Express 93). Of these, the SLSTR and VIIRS instruments are the closest 'spiritual successors' to Terra and Aqua-MODIS and will provide similar or improved quality data. These instruments are also both part of long term, operational satellite missions and they should prove to be a reliable source of active fire information until at least the late 2030s. Data from other instruments, such as Sentinel-2 MSI, are also being exploited by Canadian fire management agencies (e.g. the BC Wildfire Service) using in-house data processing. VIIRS hotspot data have been openly accessible through NASA's Fire Information for Resource

WildFireSat (~2029) | ~01:20 AQUA (2022) | ~03:20 AQUA (2026) | ~09:05 TERRA (2026) | ~10:30 TERRA (2022) | ~13:30 AQUA (2022) | ~15:20 AQUA (2026) | ~21:05 TERRA (2026) | ~22:35 TERRA (2022) | 00:00 | 06:00 | 12:00 | 18:00 | 24:00 | Peak Burn Period

Figure 1. The effect of MODIS orbital drift on active fire monitoring. The mean local overpass time of Terra and Aqua is changing. If NASA extends their lifetime to 2026, Terra observations will be collected ~1.5 hours earlier, and Aqua observations ~2 hours later, than historic observations.

Canada



Natural Resources Canada | Ressources naturelles Canada

BULLETIN 93

Frontline EXPRESS

Canadian Forest Service – The Great Lakes Forestry Centre

Wildfires from Space: a synthesis of satellite missions for active fire monitoring

INTRODUCTION

Satellites have been used for fire monitoring for over 40 years (Wooster et al., 2021). The well-known MODIS instruments that drove the uptake of satellite data in operational fire management are nearing end-of-life, with significant implications for the systems and people that rely on those data (Frontline Express 92). Earth observation (EO) data from satellites play an important role in providing intelligence to fire management decision makers (Johnston et al. 2020). The use cases can be organized by four stages of fire monitoring: pre-fire inventory, active fire monitoring, post-fire assessment, and multi-scale synthesis (Crowley at al. 2022).

The purpose of this report is to provide a synthesis of the current and future EO satellite missions that can (or will) provide freely available data for active fire detection and monitoring, and to raise awareness of missions that can be used in place of MODIS. Knowledge of aspects such as the spatial resolution, timing and frequency of observations, and data latency are key to planning for use of these data in operational fire management.

TYPES OF ORBITS

Of the biggest distinctions between types of EO satellites used for wildfire applications is whether they are in a polar or geostationary orbit (Figure 1). Polar orbiting satellites (e.g., satellites with the VIIRS instruments) orbit the earth on a nearly North-South axis, passing close to the Earth's poles. Most polar orbiting satellites used for active fire monitoring are also in sun synchronous orbits (i.e., they pass over the same ground location at the same local time each day at ~600-800 km altitude). Geostationary satellites, such as GOES-16 and GOES-18, are positioned directly above the equator at a much higher altitude (~36,000 km) than polar orbiting satellites. The geostationary orbit means that they appear stationary relative to the Earth's surface, and therefore maintain a consistent view of the same surface locations.

Geostationary satellites have a higher temporal resolution (i.e., more frequent imaging) than polar orbiting satellites and so provide more detail on the diurnal fire cycle. **Unfortunately, due to Canada's northerly location, the spatial resolution of geostationary imagery in Canada is very coarse, and the Earth's surface is viewed at an at an extremely oblique angle** (Figure 1). location puts it towards the edge of the GOES-16 and GOES-18 fields of view, where the spatial resolution is very low (~8-32km2 location dependent; Hall et al., 2019). This makes it challenging to detect actively burning fires in Canada using GOES, and this problem is compounded as you move further north. In Canada, there is therefore an increasing reliance on polar orbiting satellites for fire intelligence.

Despite its widespread integration into operational fire management tools, MODIS is not part of an 'operational' meteorological satellite programme (i.e., there are no plans for direct replacements of MODIS) and will cease to operate by 2026 at the latest (see Frontline Express 92). This will have considerable implications for wildland fire management users of the MODIS active fire products. MODIS users should consider whether the satellite systems described below are suitable MODIS-replacements for their needs.

SUMMARY OF SATELLITE SYSTEMS

The following provides a point-in-time summary of the characteristics of existing and future civil (government) space agency satellites systems relevant for wildland fire monitoring in North America that will provide freely available data. Information was compiled from the CEOS Database (http://database.eohandbook.com/), WMO OSCAR (https://space.oscar.wmo.int/), and space agency websites. The rapidly expanding commercial EO sector is also beginning to provide novel, paid-for fire intelligence products for wildland fire management. We do not discuss commercial solutions here, as these companies typically do not openly provide detailed information about their technology and methods and we do not want the inclusion (or omission) of specific commercial satellite systems and products to be interpreted as an expression of support, or lack thereof.

Please note, satellites with a direct broadcast capability can reduce data latency further than is listed here, but these direct broadcast data may only be available for limited regions or specific end users. Overpass times and revisit frequency listed below are reported for locations at the equator unless otherwise stated, as is standard in the EO community. In Canada, overpass times are likely to be ± 2 hours of this time, and revisit frequency will also be higher due to the increasing convergence of satellite orbital tracks towards the poles.

Polar Orbit: images in bands along an approximate North - South axis. [a]

Geostationary Orbit: fixed position relative to the Earth. The field of view is static. [b] Examples: GOES East field of view

Figure 1. Polar vs. geostationary satellite orbits, and the Canadian perspective. [a] Polar orbiting satellites orbit the Earth on a nearly North-South axis passing close to the poles and provide a small number (4 to ~10, latitude dependent) of relatively high resolution (≤ 1km²) observations of Canadian locations each day. **[b]** Geostationary satellites provide observations every 10-15 minutes for the full 'Earth disk', but spatial resolution decreases rapidly away from the centre of the image due to the angle at which the sensor views the Earth, and the Earth's curvature.

Canada

- Update fire management agencies on the status of MODIS data from NASA's Terra and Aqua missions and showcase the CSA WildFireSat mission.
- Short synthesis of the current and future earth observation satellites that can (or will) provide freely available data for active fire detection and monitoring. Includes a description important criteria about different instruments to consider in fire management.

Important terms and scope

What are end users? What is a "state of play"? How do we organize this in a model where we can measure a baseline and/or make informed inference about the needs of users?

Scope

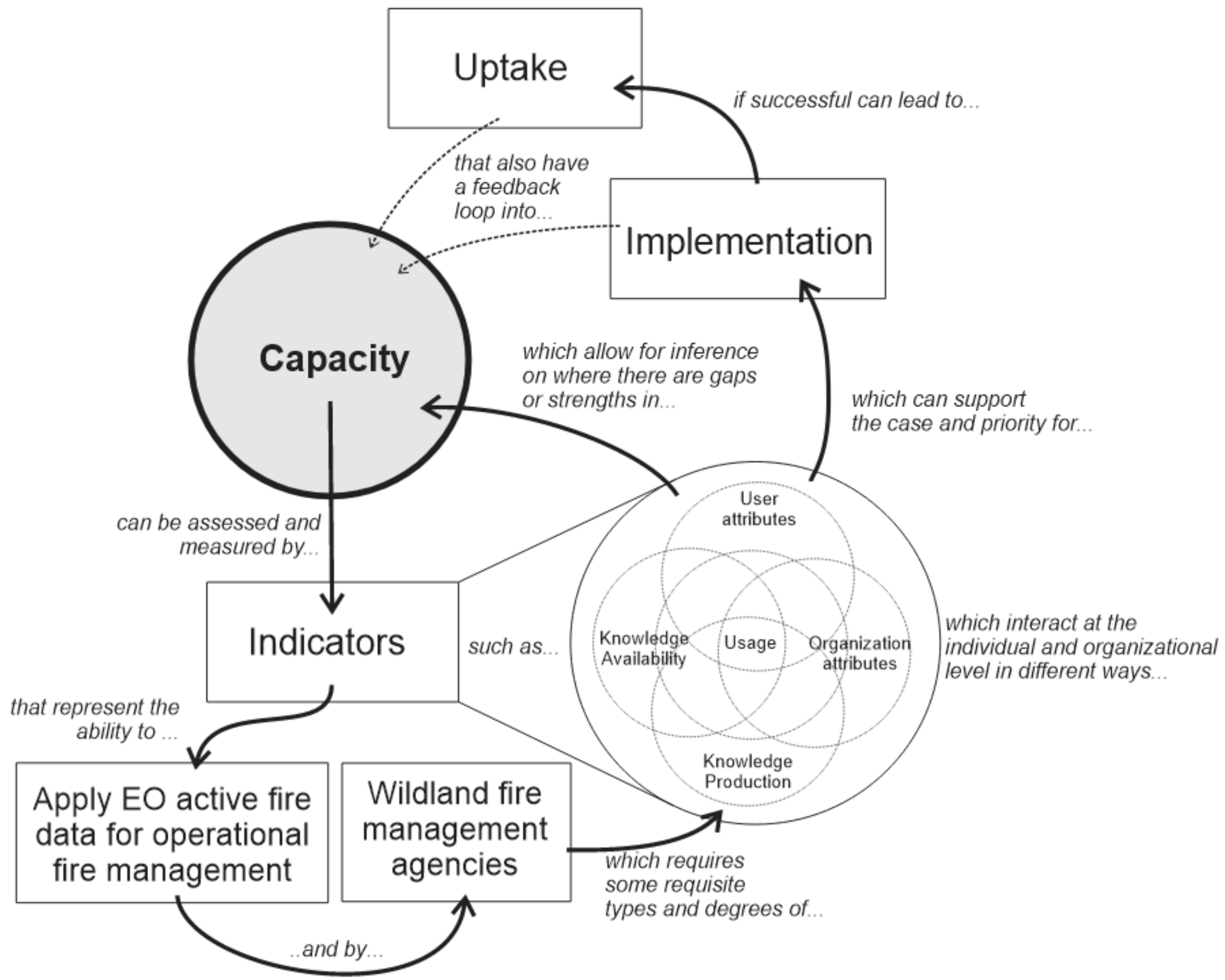
Wildland Fire Management: The activities concerned with the protection of people, property, and wildland areas from fire, which may include the use of fire for the attainment of wildland management and other land use objectives (e.g., forest management). Aspects include strategies for the prevention, mitigation, and response to wildland fire.

- **Operational Wildland Fire Management:** planning for and carrying out the operational activities of wildland fire management.
    - **End-user:** those who are responsible for operational wildland fire management on their land base.
- **Earth Observation (EO) data and active fire products:** includes information on the location, timing, and characteristics of a wildfire (pre and post fire not included).

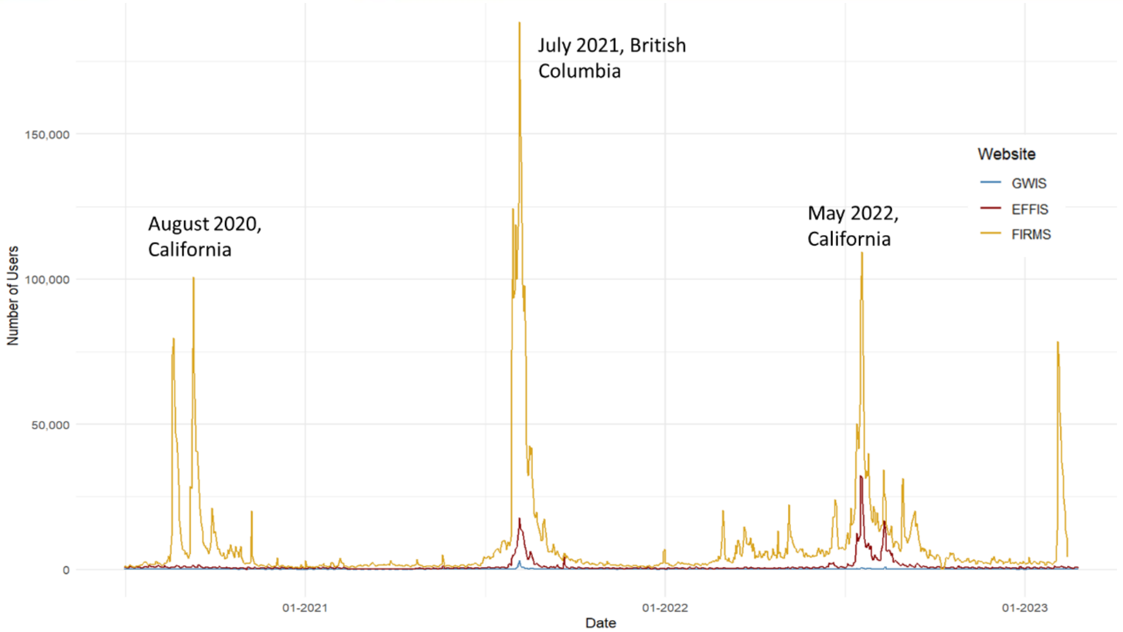

Courtesy of Yukon Wildland Fire Management

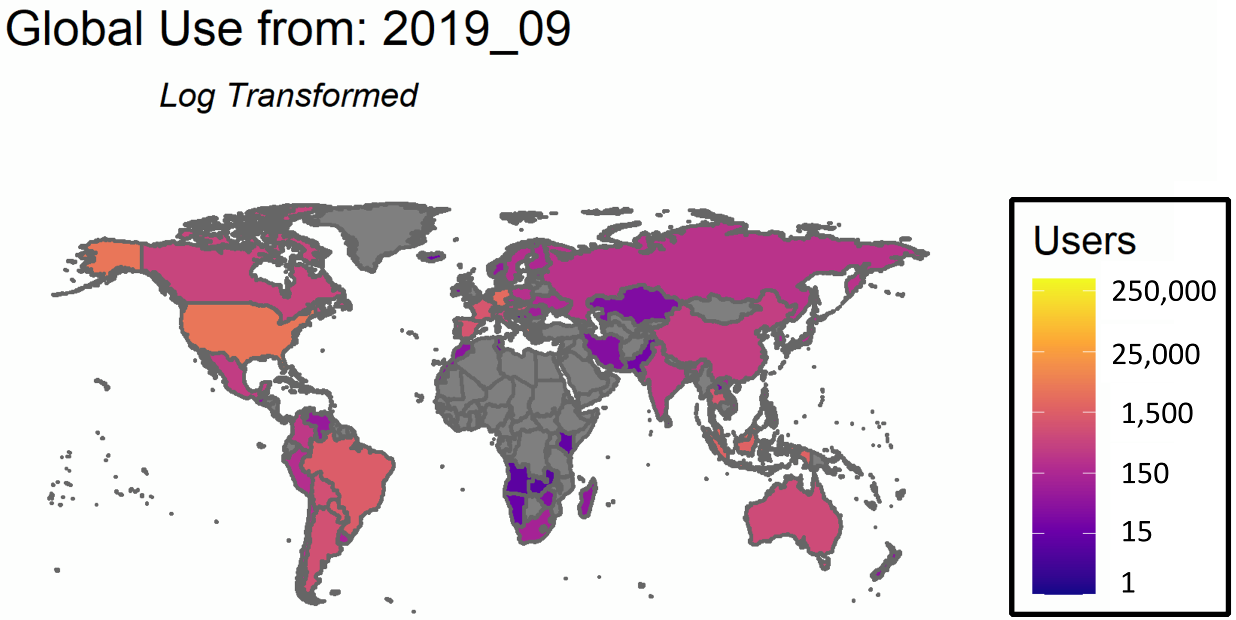
Key concepts (refined)

- **Capacity:** the actual or potential abilities and capabilities that enable a wildland fire management agency to adapt for and implement EO active fire products into operational fire management.
- **Implementation:** a systematic approach taken to assess the suitability of EO active fire products, adopt and integrate them into common practice, and sustained adoption through time.
- **Uptake:** is to adopt in processes as well as in the culture of an organization and the people within it, which enables creative application in novel ways and results in real-world impacts.
- **User/agency characterises and perspectives:** the aspects of an agency/group who interact, use, could use EO-active fire products. The *context* needed to infer *capacity* and *uptake*.



Usage, where, when (why)





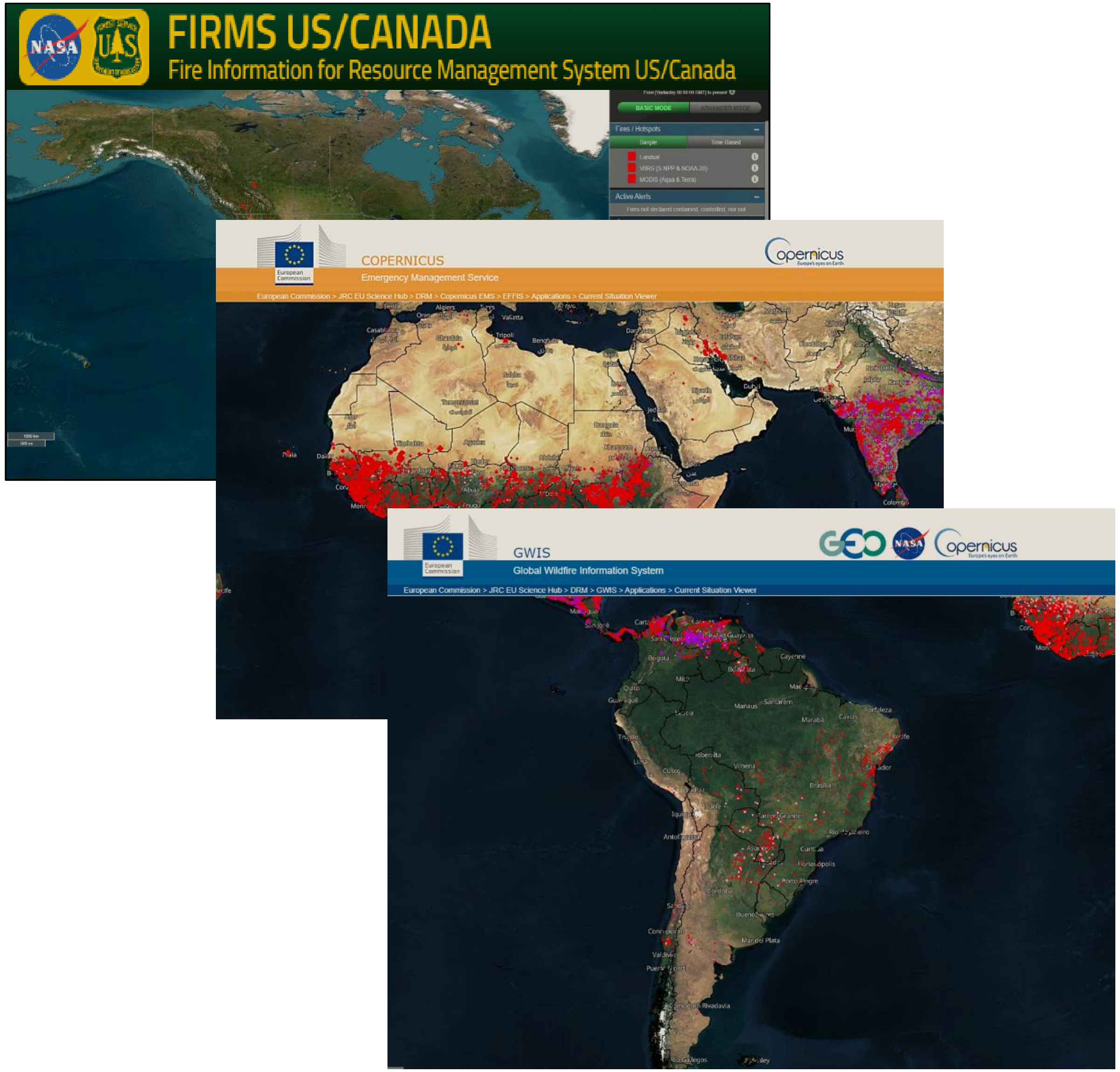
- EO data distributed to end users through popular online platforms
  - NASA FIRMS, EFFIS, GWIS
- Focus, “Active fire” map pages
  - Not looking at data pulls/webservice use yet
- Can’t differential between public and fire management.

Goals:

1) Characterize visitors to FIRMS, EFFIS and GWIS
2) Examine patterns of use
3) Uncover barriers that could restrict use and impact

Users…

- Users are likely divided into three primary groups:
  - **Fixed need users** – those users that must check EO hotspot data on a regular basis for business/safety/operational reasons.
  - **Variable need users** – those users that check EO hotspot data based on fire activity for business/safety/operational reasons (e.g., fire crews that are seeking additional insights)
  - **Variable non-need users** – those that check EO hotspot data, likely based on fire activity for interest reasons



Predictive Variables – What drives use?

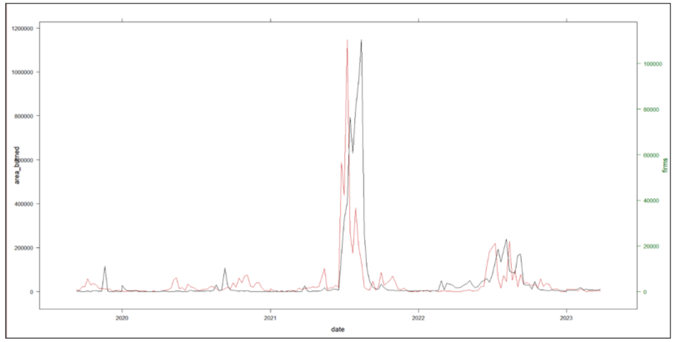
- Assuming more fire management personnel check with EO platforms for data during active periods.
- Correlations between fire activity (area burned and number of fires), seasonality and number of users visible at a continental and country scale.
- Specific platforms more popular in some regions (e.g., FIRMS appears more popular in the Americas, while GWIS/EFFIS is more commonly used in Europe).

Currently: Using models, forecast expected number of users based on area burned, fire season, global events, etc.

- Identify countries/regions where the model forecast is significantly different from actual use
- Examine countries with low levels of use for possible barriers (e.g., lack of internet connectivity)

When compared with user perspectives we can think about factors that may be barriers and consider where/how to encourage regional capacity.

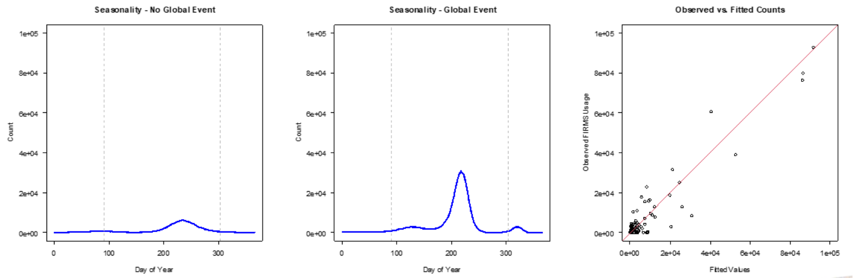
Example: Canadian Users



Canadian users from FIRMS, FIRMS2, FIRMS USFS, and FIRMS2 USFS, with weekly area burned in Canada

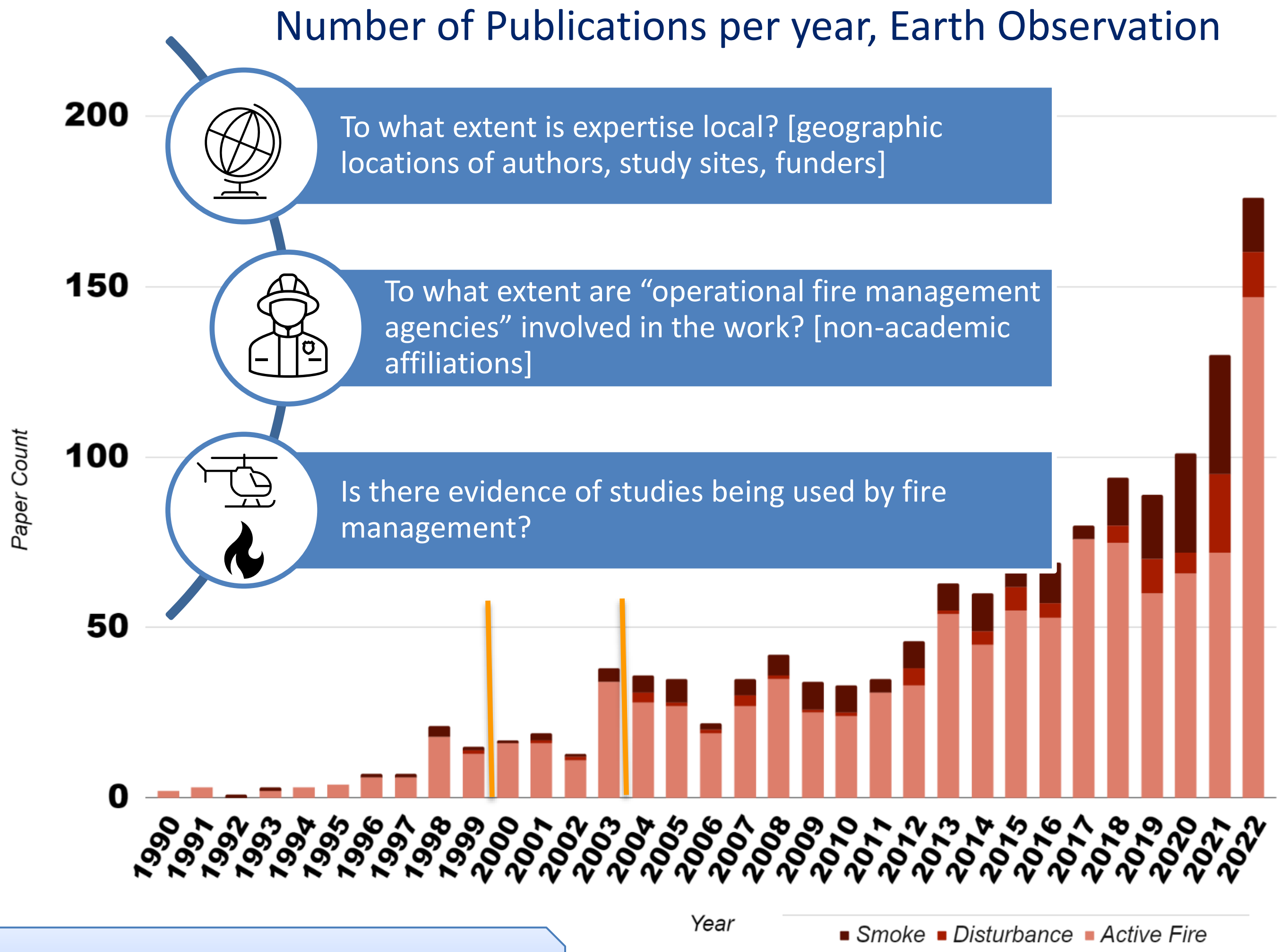
Example: Canadian Users

Preliminary modelling of the Canadian data suggests using a framework with a seasonal effect that changes depending on whether there is a global event along with current and recent area burned as predictors.



Knowledge availability – how much and where is there available and relevant "active fire" research.

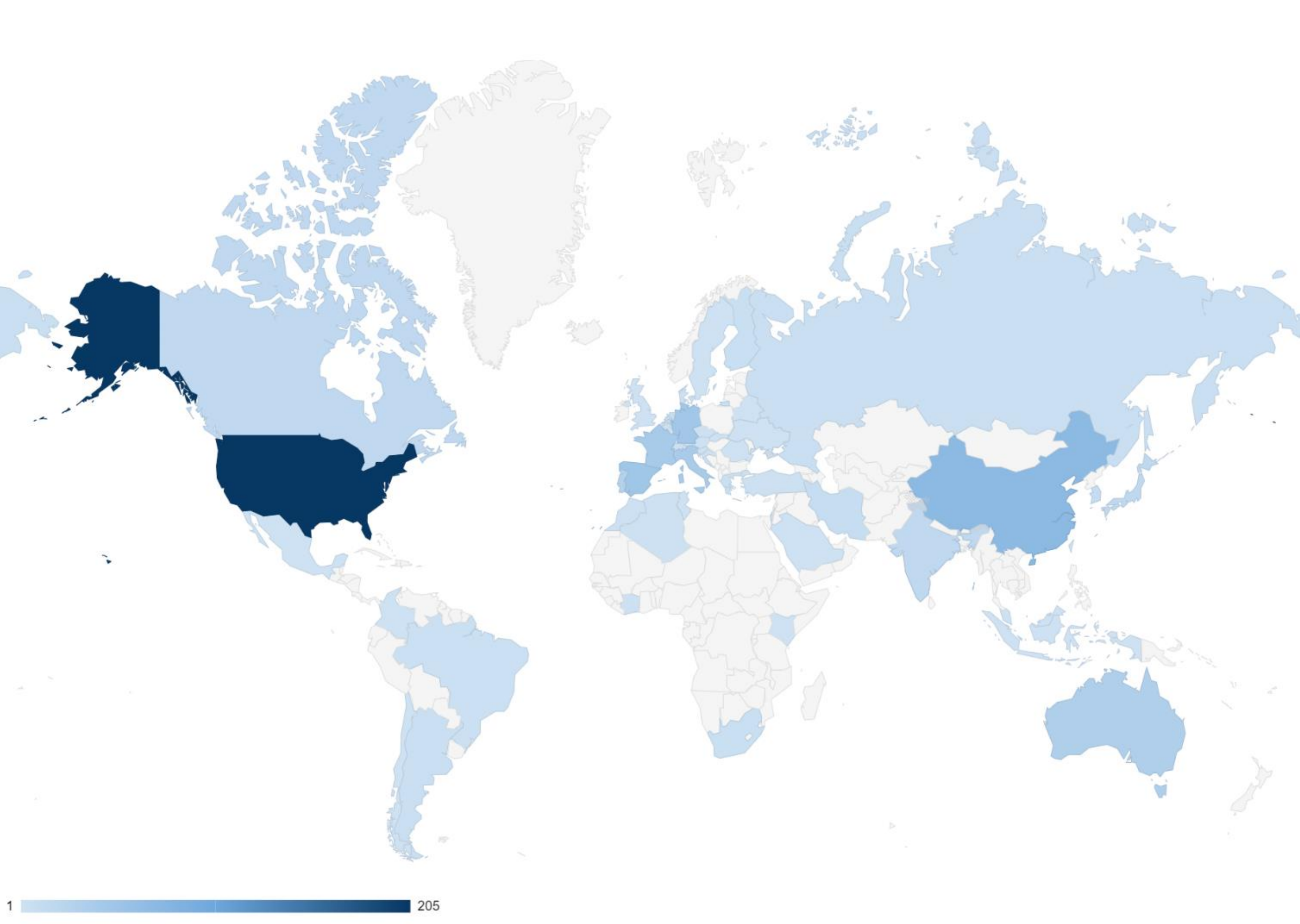
- **Bibliometric analysis** of academic studies to geographically assess levels of 'scientific expertise' – active fire.
- Similar to other trends in wildland fire science research – exponential growth (e.g., Neger & Rosas-Paz, 2022; Haghani et al. 2022)
- **First pass:** >7250 publications meet our filter criteria (figure).
- **Second pass**: 1425 publications using EO for "active fire"; focuses categorized as active fire; disturbance; or smoke
- **Third pass:** Classify/characterize papers
- **Next steps:** Normalizing results to country level to support further analyses



When compared with usage and user perspectives we can think about the influence of research and where/how to encourage regional capacity.

Approach and early observations

Study location(s) for articles that had both operational & local connections



"Operational": True if article had an author affiliation, funding source, or acknowledgement associated with an operational agency or organization.

"Local Connection": True if article had an author affiliation, funding source, or acknowledgement in the study location (where applicable).

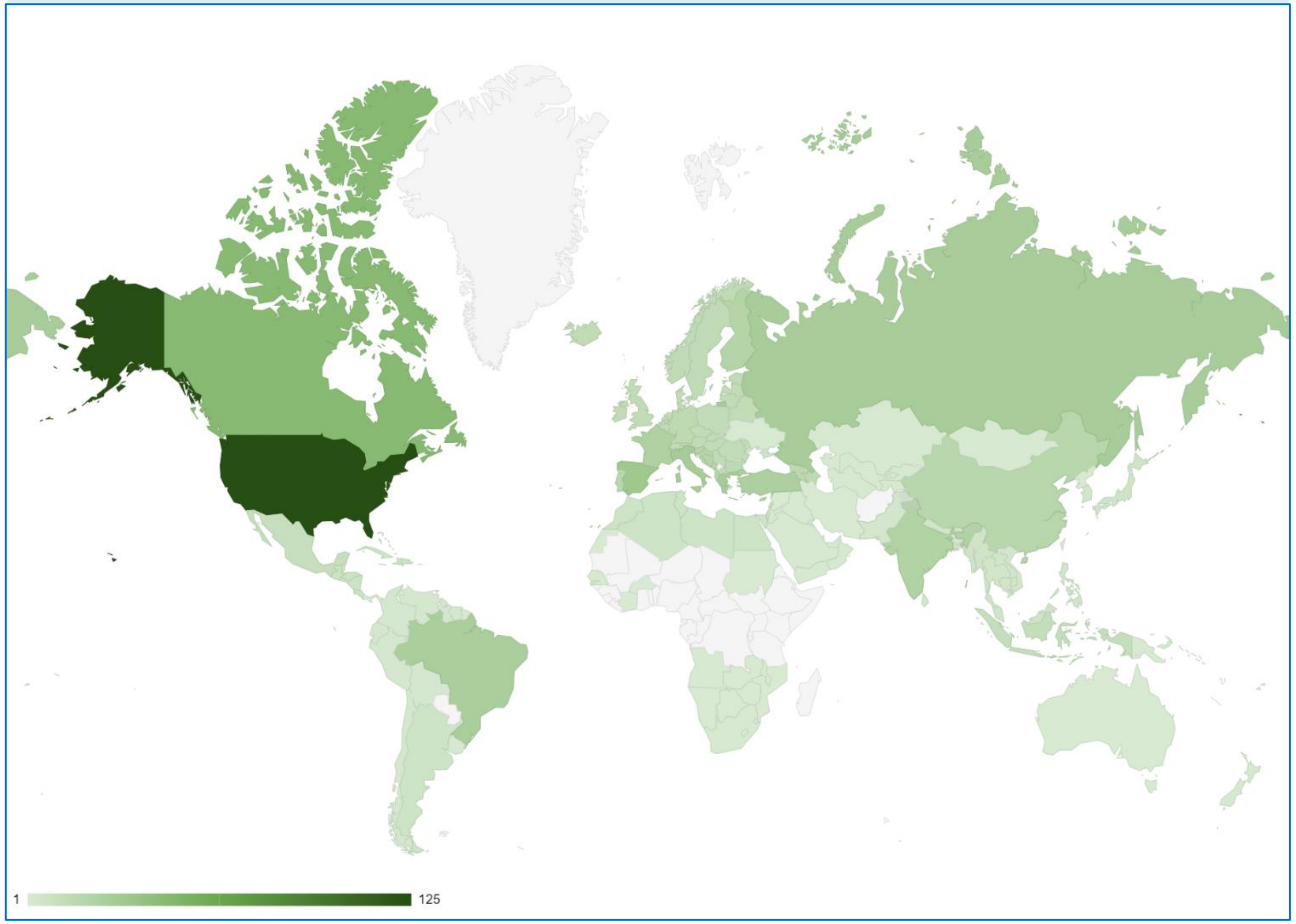
Study regions were parsed out to country level when necessary

Notable observations:

- **402 articles fit this criteria** (i.e., about a third of total articles examined)
- The **most frequent study location** for articles that fit this criteria included: the USA (125), Canada (46), Australia (40), Spain (33), Italy (29), Russia (28), Greece (28), Brazil (27), and Turkey (25).

Approach and early observations

First author location for satellite-based active fire articles that did not have any "local connection"



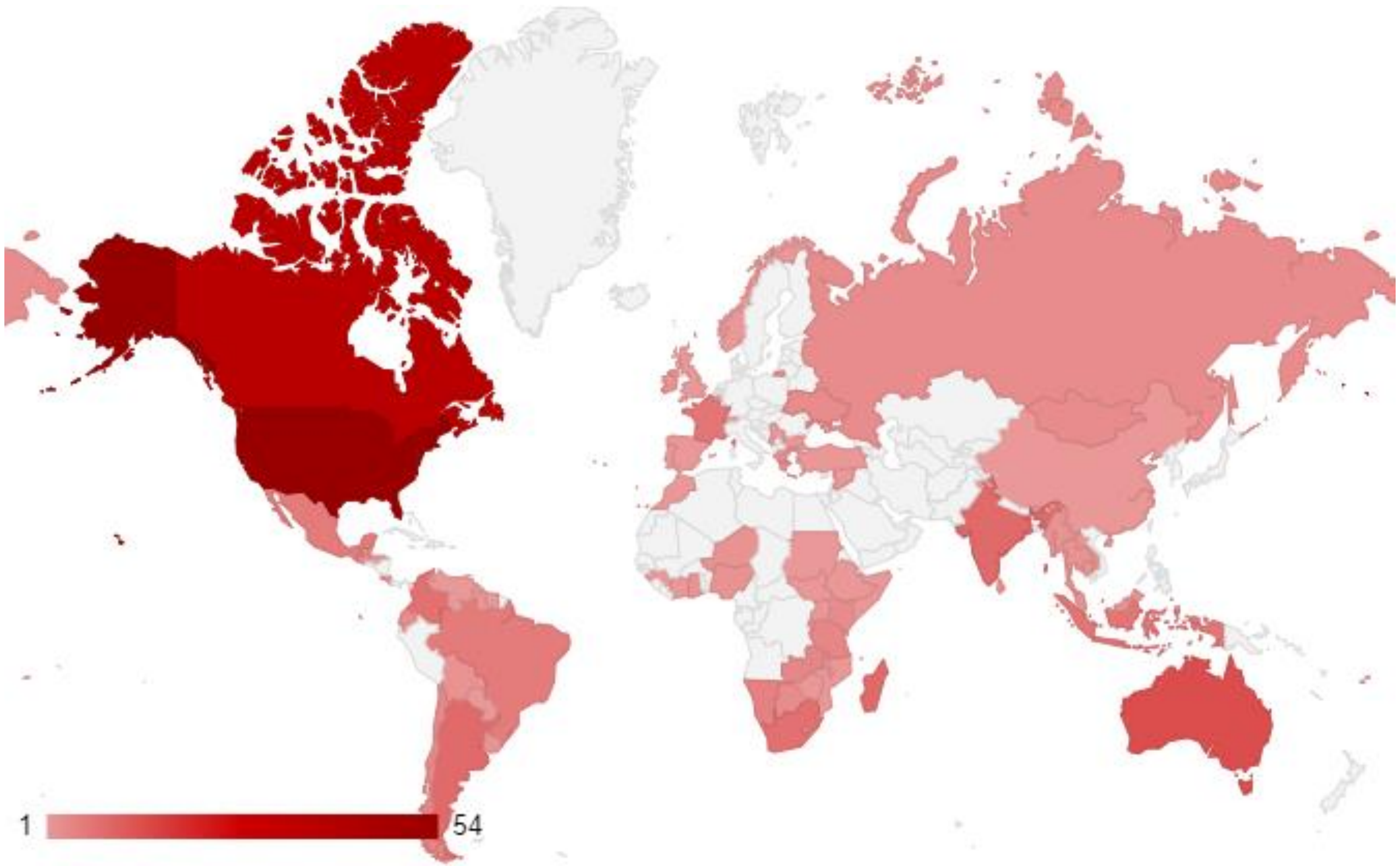
"Local Connection": Articles were categorized as having a local connection if they had an author affiliation, funding source, or acknowledgement in the study location (where applicable).

Notable observations:

- **731 articles fit this criteria** (i.e., nearly half of the total articles examined)
- **A majority of the articles** that fell into this category were led by authors located in USA (205), China (71), Spain (51), Germany (49), England (44), France (42), Italy (40), and Australia (35).

User and organizational attributes - perspectives on capacity from the local experts/knowledge holders

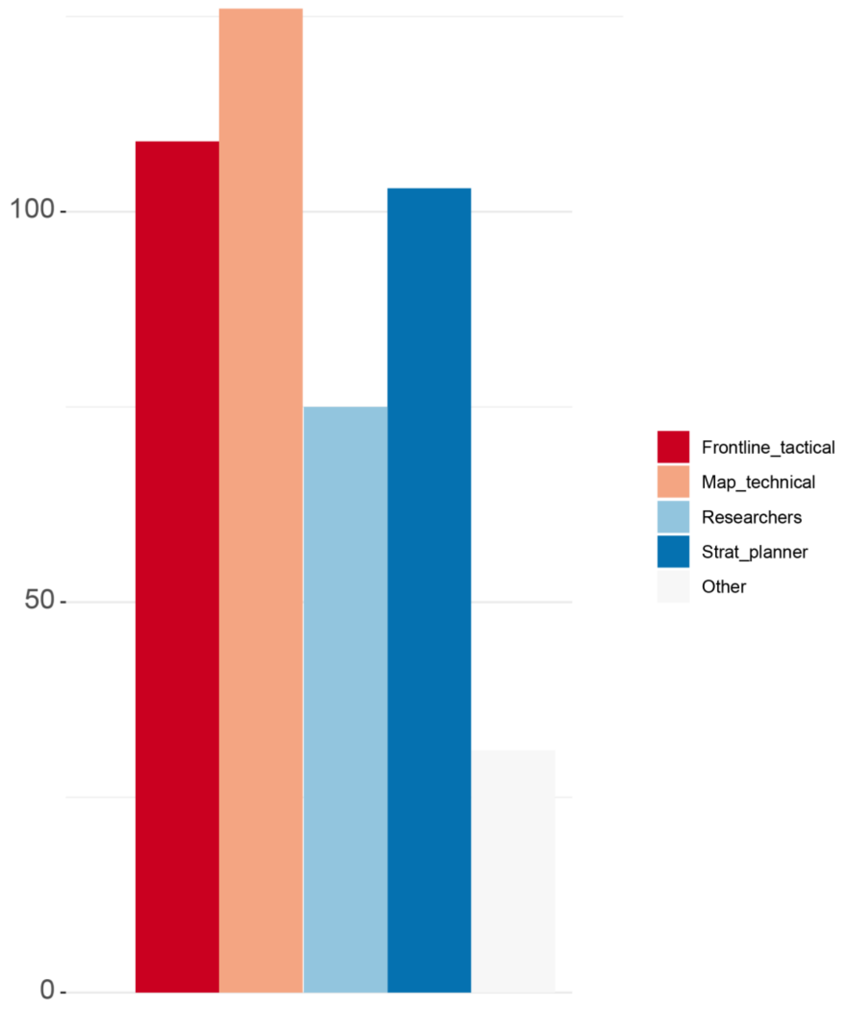
- **Outreach Survey** to identify stakeholders and end-user communities.
  - **>16,000 people/groups directly received survey. Indirectly many more.**
  - **Survey - 247 responses (76 countries)**
- Characterizing agencies/ users (responsibilities; priorities; challenges) aspects of:
  - Familiarity, Use, Trust, Barriers
- May be necessary to adopt a regionally specialized approach to ensure representation.

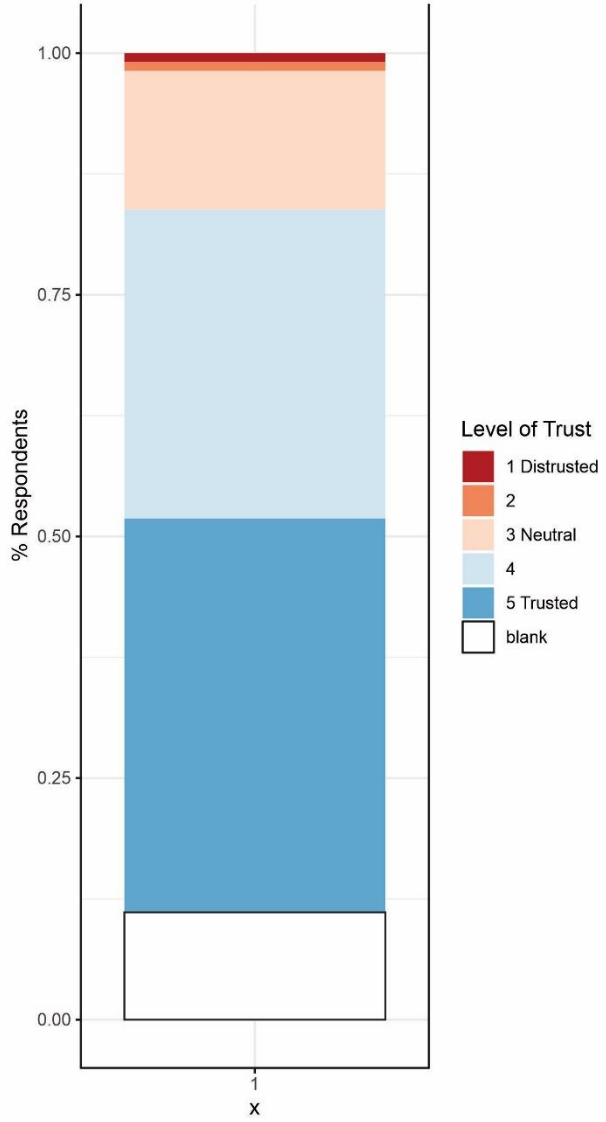


User perspectives and attributes can indicate why there is or isn't an expected level of capacity or uptake. There may be barriers or facilitators that are not obvious.

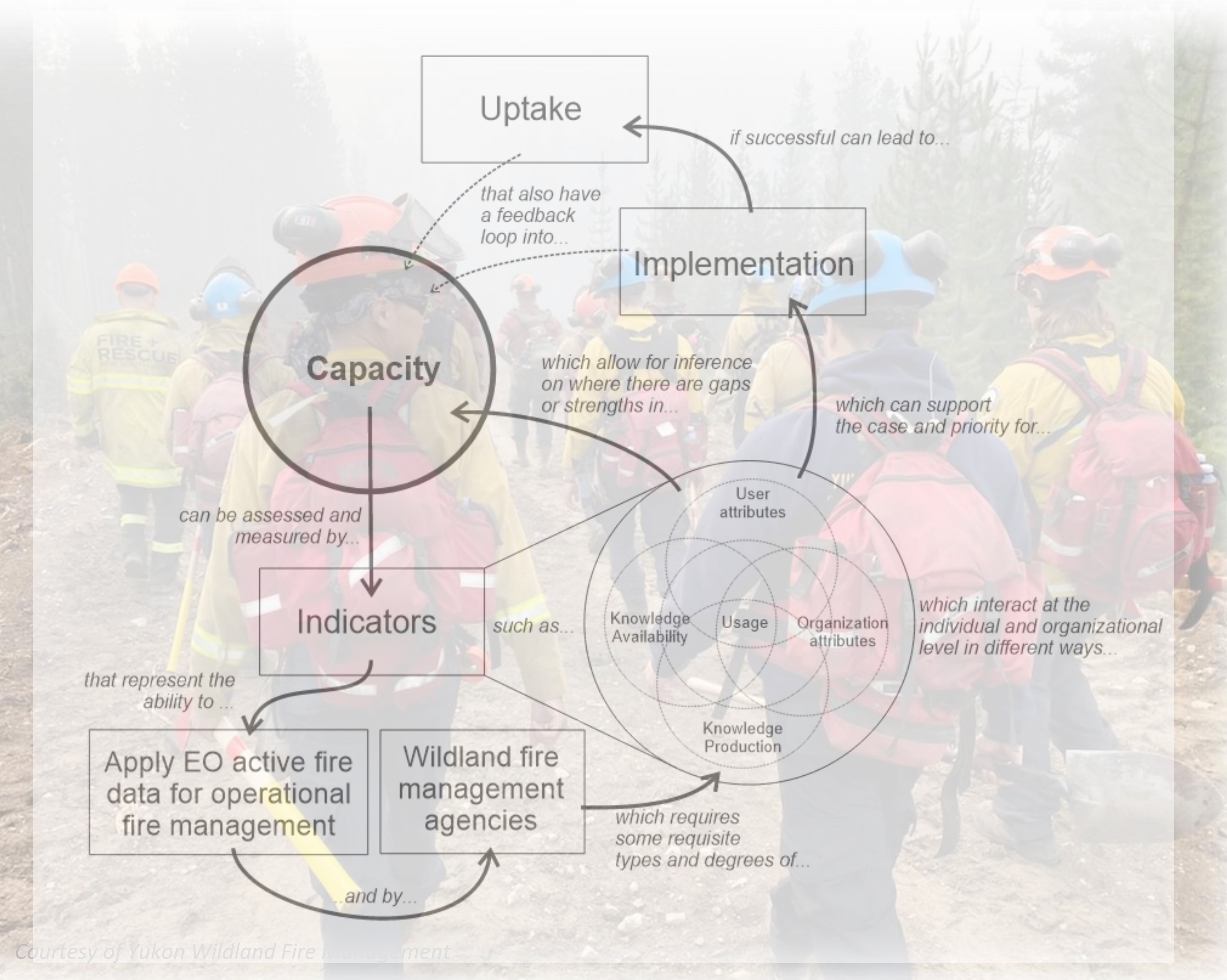
Approach and early observations

- We have an incredible amount of data… will take time to unpack
- 216 (out of 247) of respondents said they were EO active fire users.
  - Of the EO users, breakdown of the type of users within their organizations
  - Of note, 33 respondents stated their organization had all types of users. Good regional representation, mostly government (67%).
- Of EO active fire users, mostly a higher level of trust.





Relationships and next steps



- Explore relationships between usage, knowledge production/availability, organization and user attributes.
- Model the baselines for given criteria.
  - Identify relatively lower areas of uptake and capacity.
  - Forecast future demand and value of EO-active fire data
- Recommend strategies to address gaps and encourage EO-active fire products for fire management.
- Framework for evaluation approach for pre-post fire products.
- Concepts to extend to uptake by end users of other hazards.

Planned Publications and Next Steps

Publications:

1. (Usage) The use of publicly available satellite hotspot data in an operational wildland fire management context
2. (Knowledge) A synthesis of EO active fire knowledge production and co-production for operational fire management.
3. (Users/Organizations) Archetypes in wildland fire management end-users of EO active fire management products
4. (Capacity) An approach to determine capacity for implementation and uptake of EO active fire management products considering usage, knowledge and user attributes.

Next Steps:

- Implementation and uptake across the hazards, best practices to build operational capacity (a joint flood and fire project)

Future activities

- Current Wildfire Pilot **ends Q4 2024** – **where do we go from here?** Some early thoughts for further discussion…

- **Leverage gap analysis results to encourage increased data availability via FIRMS/GWIS?**
  - What would be an appropriate pathway to do this?

- **Use findings of Pilot Ob2 to try improve uptake / do targeted capacity development?**
  - WGD / WGCapD collaboration? UN agencies? EW4A? Global Wildfire Management Hub?

- Current Pilot is based on active fire observation (**response**) - new pilot focused on pre-fire conditions (**preparedness**)

Future activities

Pre-fire (‘preparedness/mitigation’) Wildfire Pilot

- Many EO methods can be used to assess ***fuel dryness*** (and ‘fire danger’)
- Studies show ***SAR (and passive microwave)*** relate to fuel dryness. **BUT** questions around:
  - how these relate to **different fuel moisture components** (veg canopies, surface fuels, soil moisture)
  - how **multi-sensor observations**, and **different moisture component** observations, can be **integrated**
  - how can this be used for **timely operational intelligence products**? E.g seasonal outlooks; predicting fire behaviour changes; identifying conditions suitable for prescribed burns
- **Potential data needs**: wide spatial and high temporal coverage, for ***multi-week*** periods. **Is this unrealistic**?
  - e.g. as much data as possible for Eastern Australia, daily, for ~30 days at onset of the fire season
  - Possibly just archive/opportunistic access, rather than tasking?

Future activities

Pre-fire ('preparedness/prevention') Wildfire Pilot – Next steps?

1. **Today**: **Potential interest** from agencies? What **scale of commitment** is viable? **Issues** to be aware of?

2. **'Science' users** (existing WF Pilot + others in fire community) and **WGD leadership team rep** meeting:
   - **Define & constrain** project scope
   - **Identify case study areas** e.g. countries with strong existing links (USA/Canada/Australia/Europe)? EW4A target countries?

3. Circulate rough pilot proposal to **CEOS agencies**, and simultaneously **operational users** in case study areas for partnership commitments