Committee on Earth Observation Satellites

WildFire Pilot

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CEOS WG Disasters Meeting #19
April 18-20th, 2023

WildFire Pilot Scope

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

Four specific Objectives:

1. Conduct a detailed inventory and gap analysis of existing and proposed EO systems suitable for global active-fire monitoring;
   - *Considering climate change driven fire regime changes and projected mission life spans*
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 the disaster mitigation applications;
4. Propose a way forward in coordinating global wildfire monitoring activities.

WildFire Pilot Scope

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. ***Map*** existing and future ***EO coverage & weather projections*** over 5-10 year intervals, develop metrics ***for intercomparison***

CEOS MIM Database

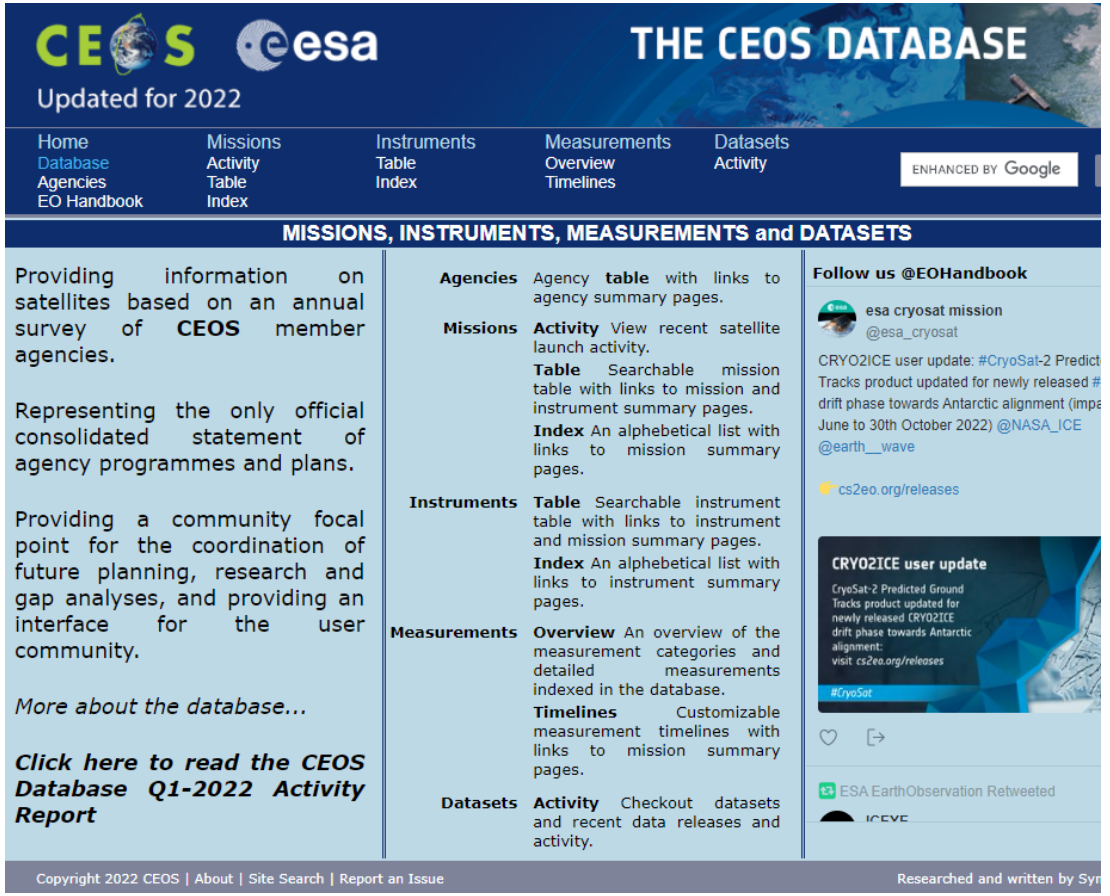
CEOS Missions, Instruments, Measurements (MIM) Database

- 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



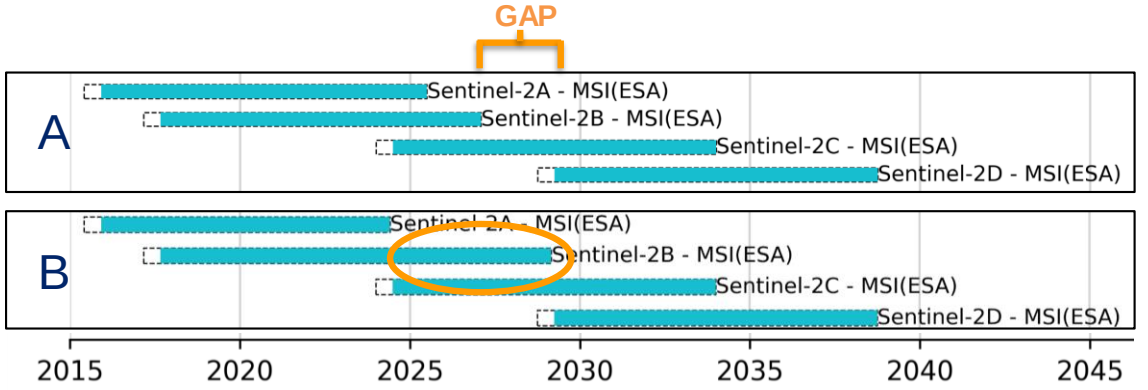
CEOS MIM database: http://database.eohandbook.com/

Data Collection & Assumptions

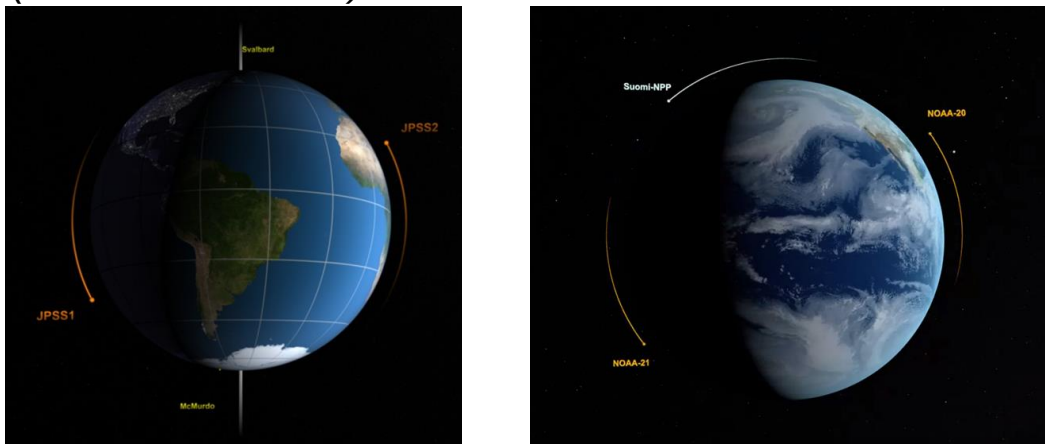
- ***Gathering*** and ***calculating parameters*** needed for ***STK modelling*** from CEOS MIM DB, WMO OSCAR, agency websites e.g.:
  Launch & end of life dates; LTAN; altitude; inclination; orbit separation; GSD; sensor half angles

(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



*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***
- Currently working on ***polar orbiting*** capabilities, other systems to follow

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

Anticipated worst coverage

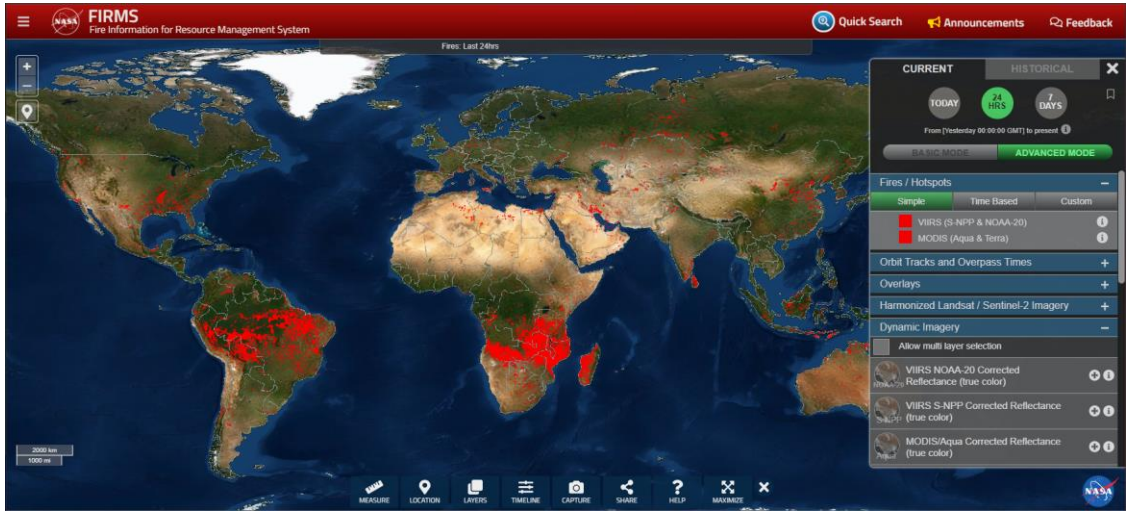
Anticipated best coverage

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]

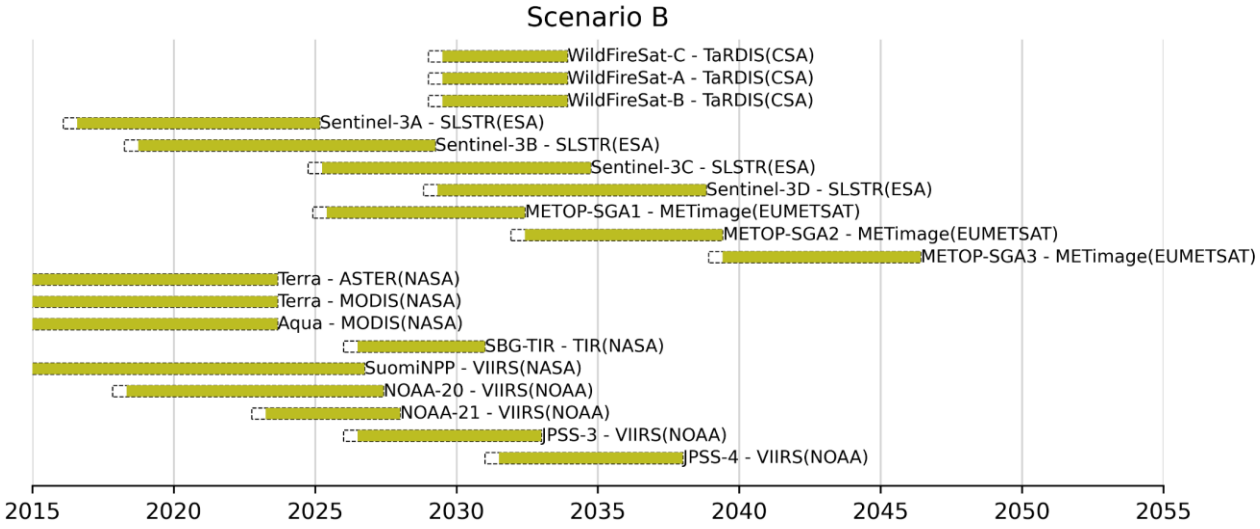
GWIS - a joint GEO/Copernicus initiative provides NRT and historic hotspot and fire environment data https://gwis.jrc.ec.europa.eu/

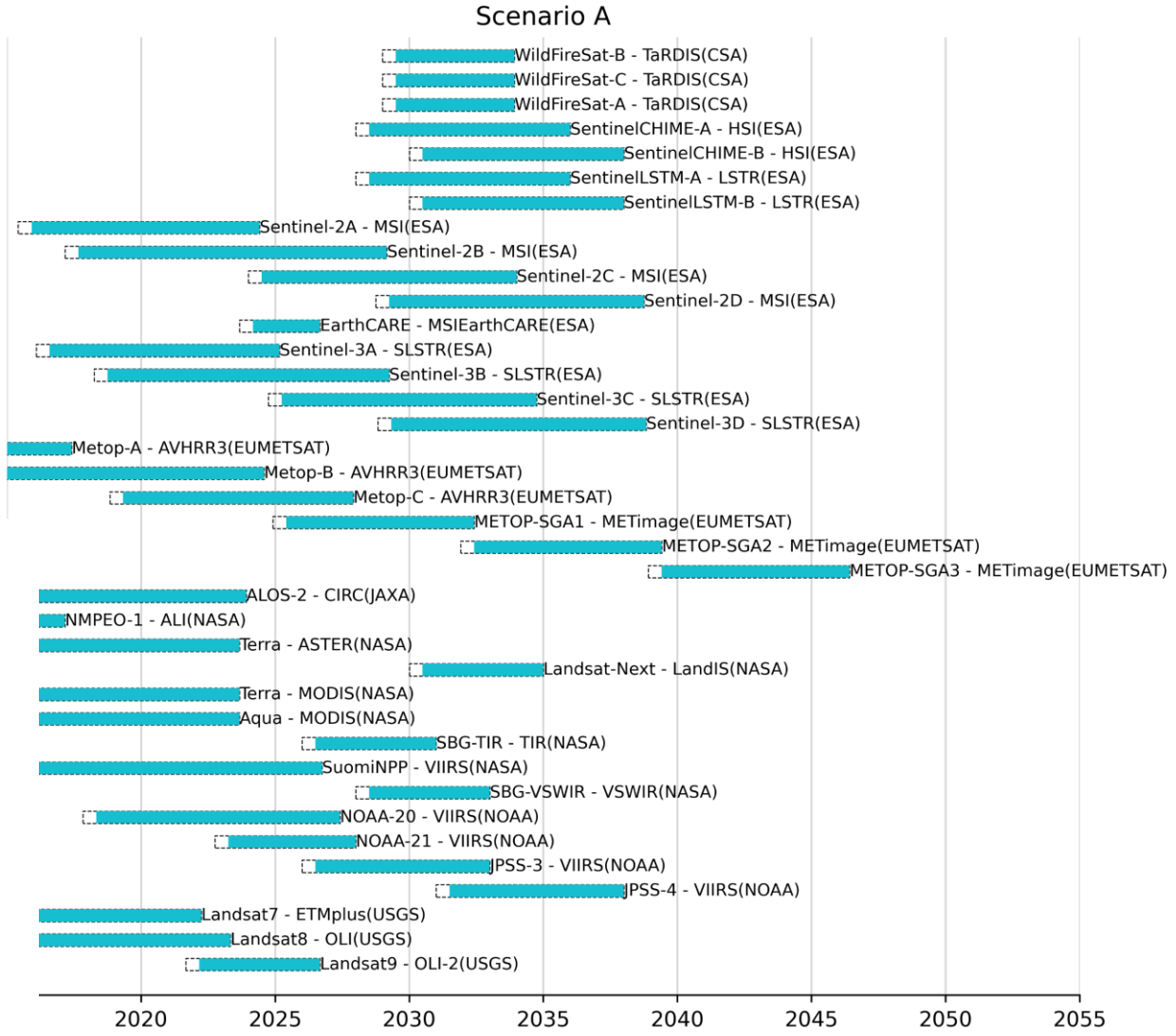
Scenario A & B

- **FIRM/GWIS affiliated** agencies

Scenario A
Fire hotspot detection
- I.e., **SWIR [≥2.2µm]** ***or*** **MWIR** ***or*** **LWIR**

Scenario B
Fire detection and **characterization**
- I.e., **MWIR** ***and*** **LWIR**



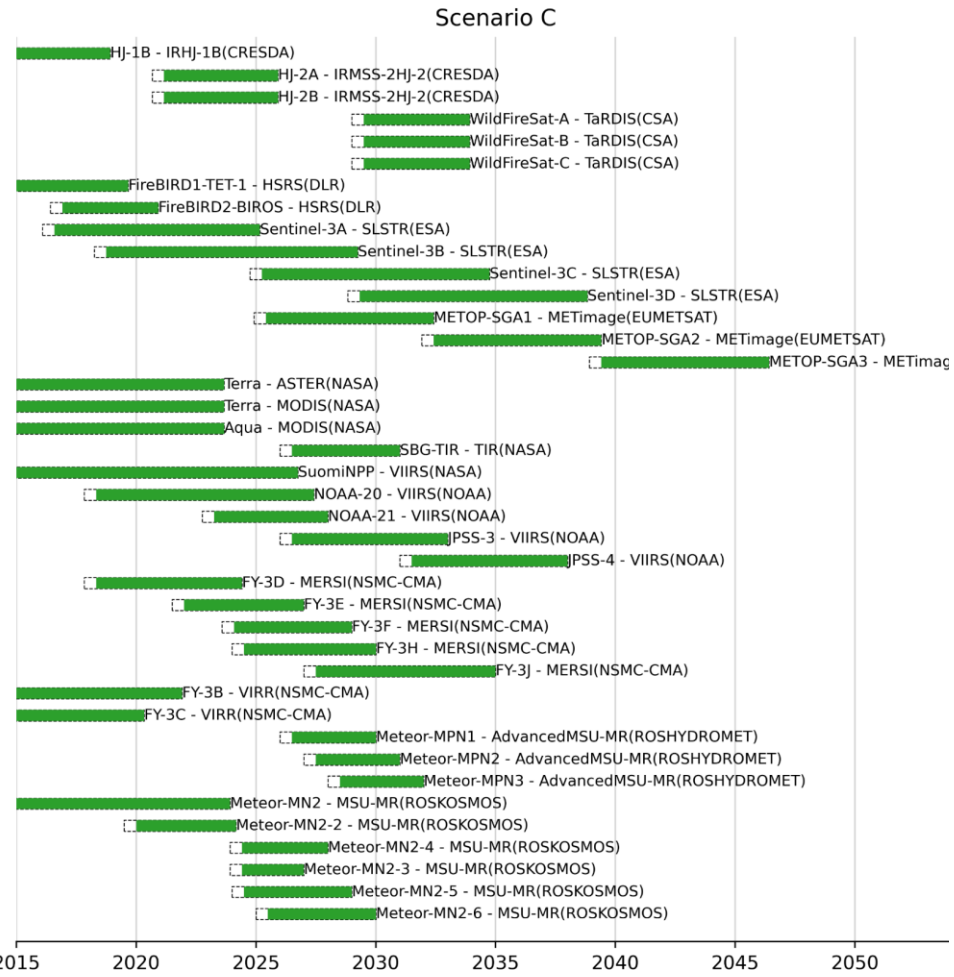


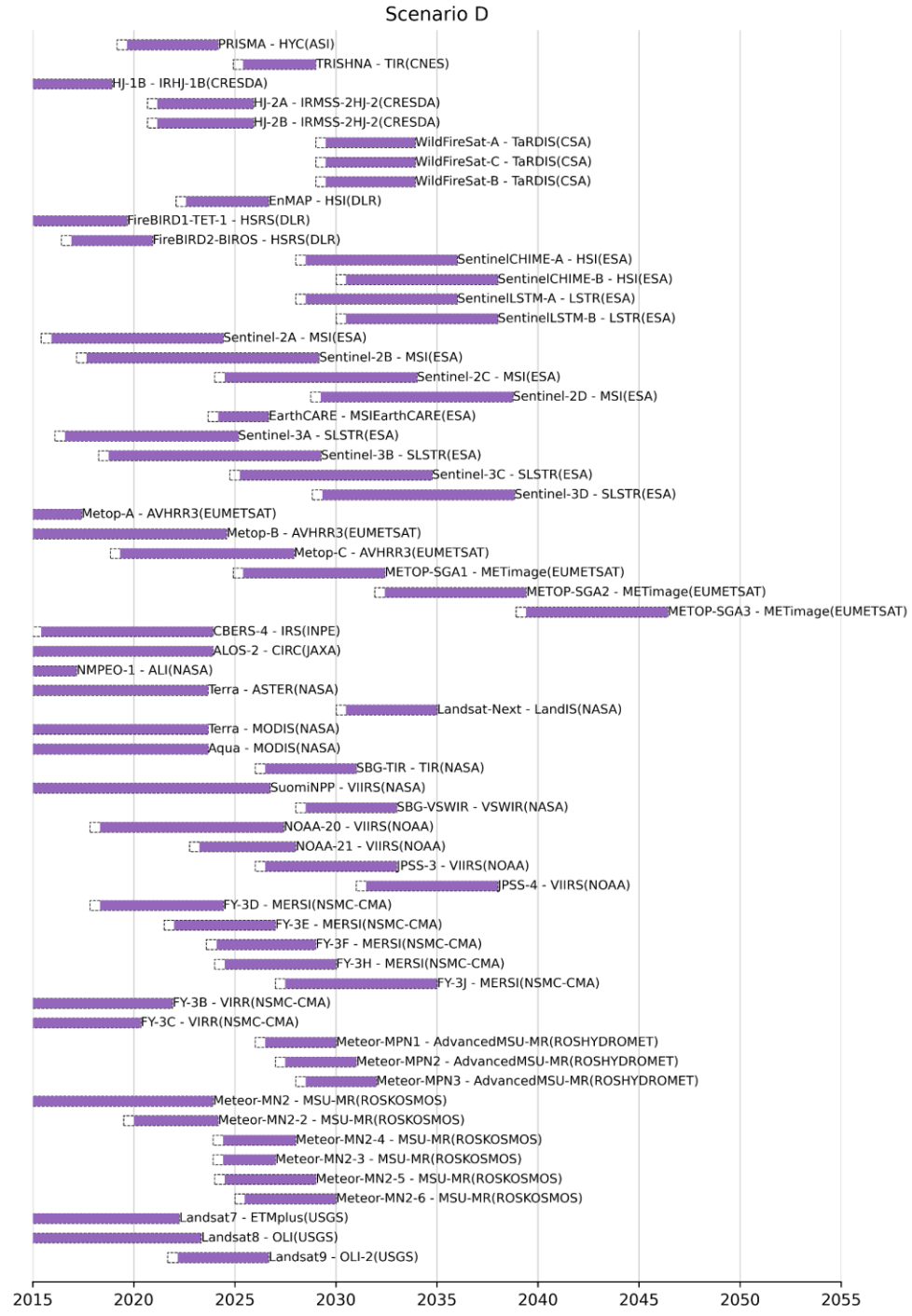
Scenario C & D

- **All agencies**

Scenario C
Fire detection and **characterization**
- I.e., **MWIR *and* LWIR**

Scenario D
Fire hotspot detection
- I.e., **SWIR [≥2.2µm] *or* MWIR *or* LWIR**





STK modelling

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

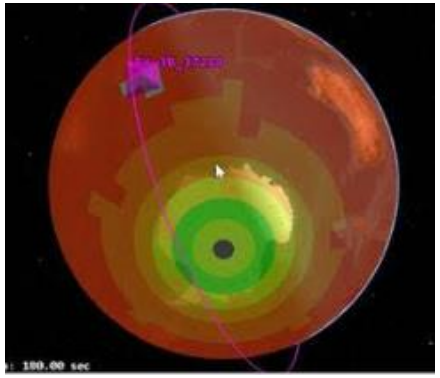
1) Revisit time analysis

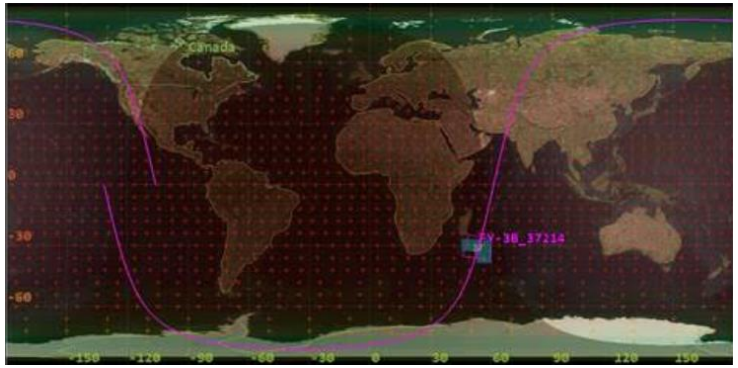
- **Aim**: what is the maximum revisit time for satellites capable of fire monitoring in different locations? How does it change over time?
  - i.e. how long do fire managers have to wait for satellite observations, in the worst case scenario?

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

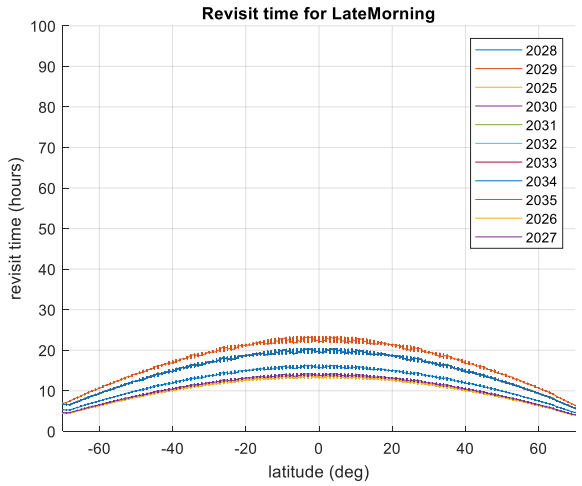
Initial STK modelling of FY-3B overpasses

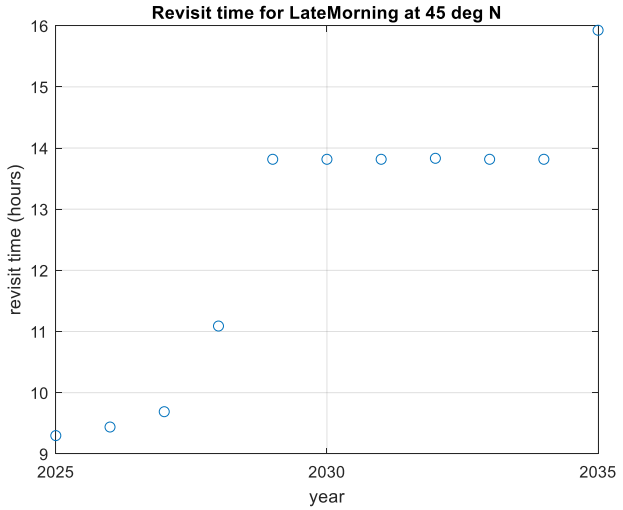




Revisit time analysis (prelim.)

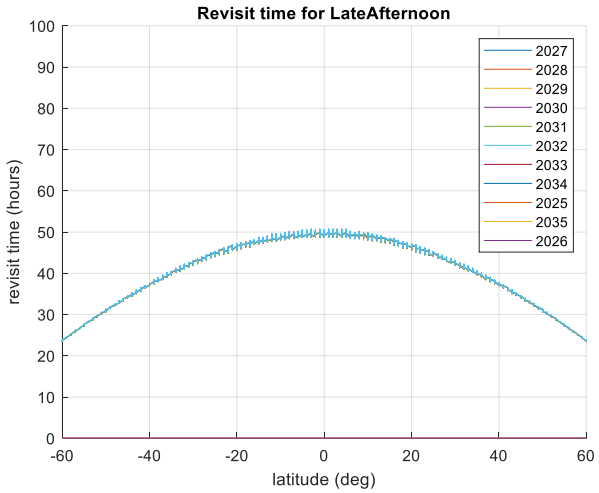
- **Evolution of average revisit time for Scenario B - Fire Characterisation *(preliminary)***

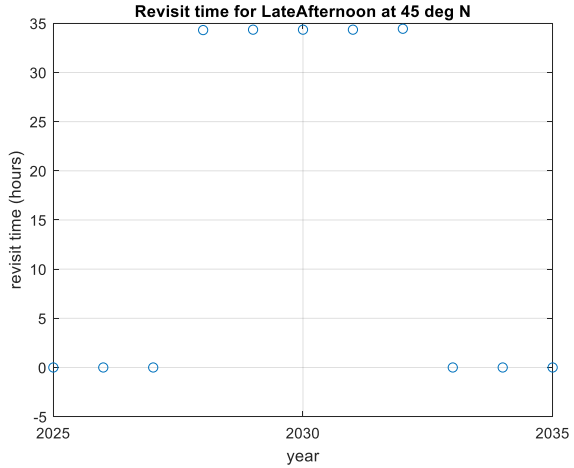




Late Morning

- *Less frequent revisits after 2029 in late morning orbit period*



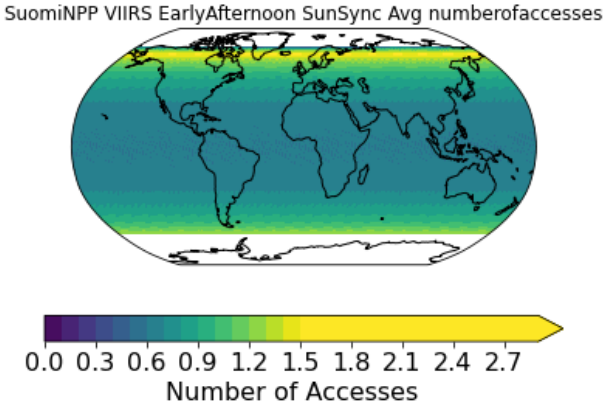


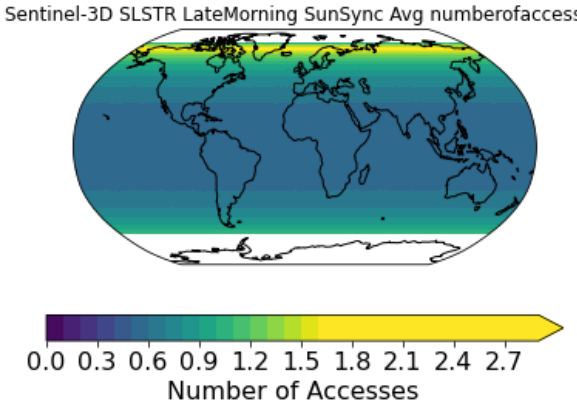
Late Afternoon

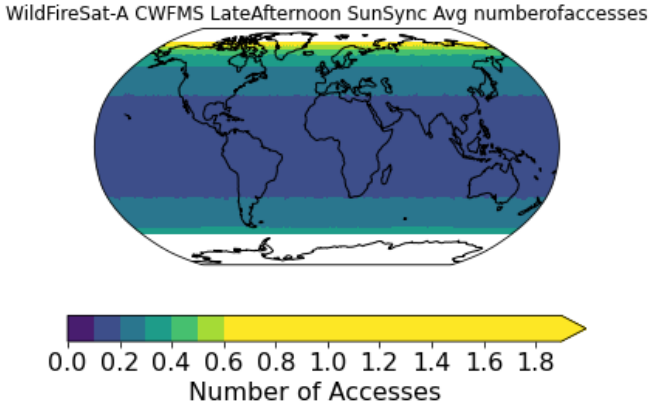
- *Wildfiresat will provide daily revisits in higher latitudes starting in 2029*
- *Currently no other Scenario B satellites in late afternoon orbit*

Coverage analysis (prelim.)

- **Average Number of daily observation from various satellites -> *This data will be used to determine future coverage density trends***







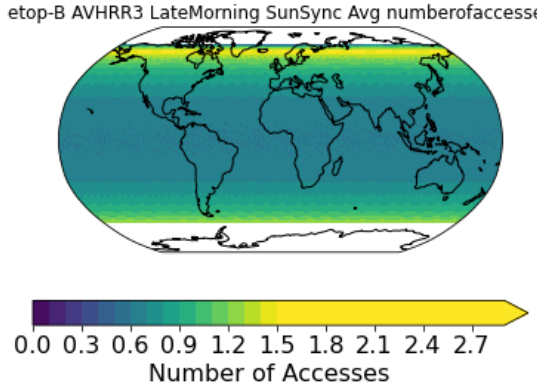
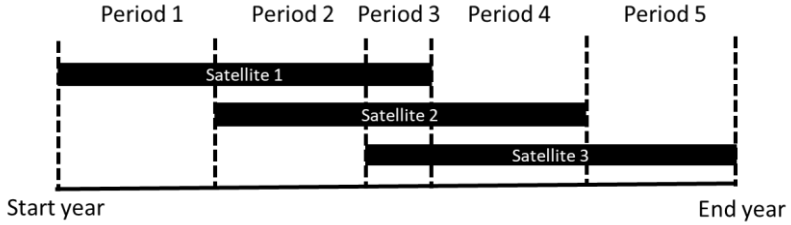
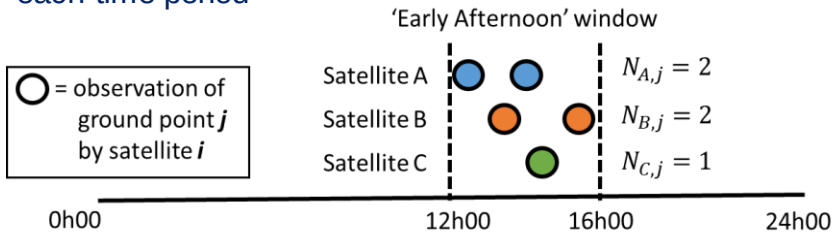


Illustration of stages of coverage density analysis

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

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?

- Canadian Fire Management Agency Readiness for WildFireSat: Assessment and Strategies for Enhanced Preparedness: **https://doi.org/10.3390/fire6020073**

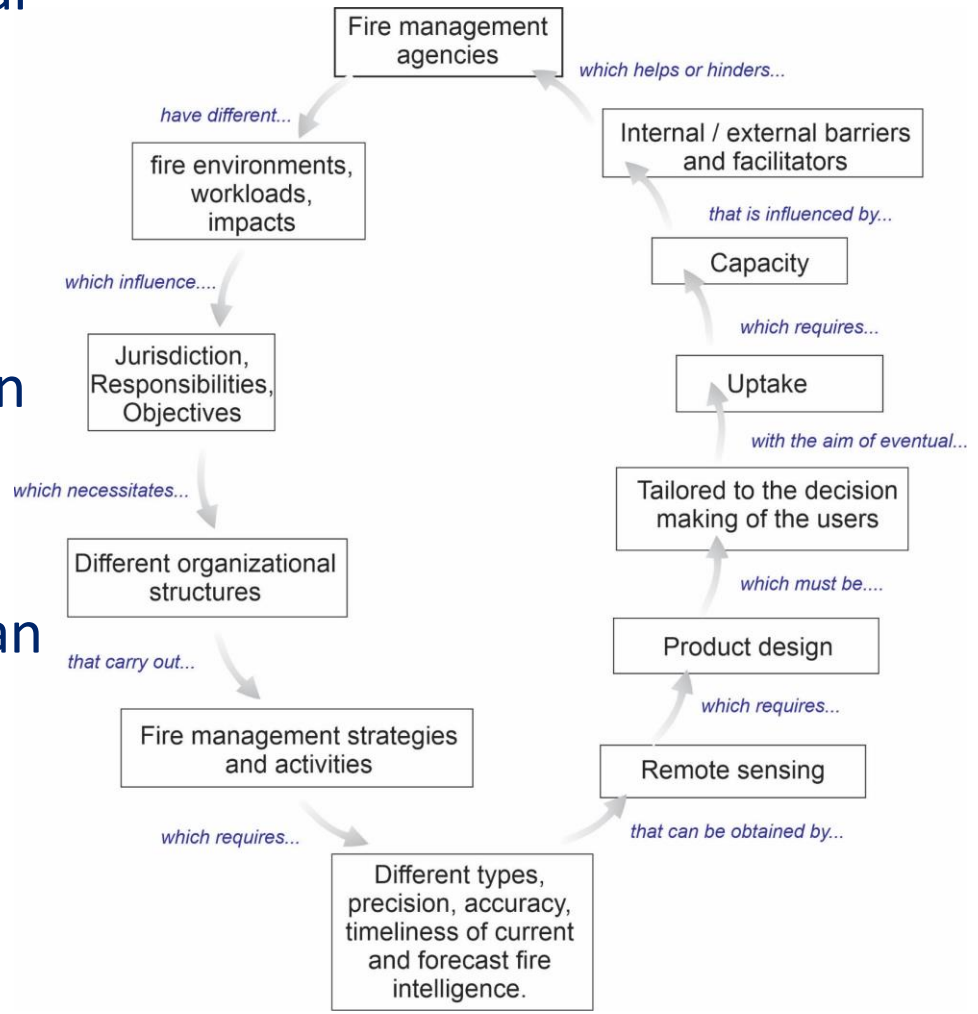
Scope (of this round)

- **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).

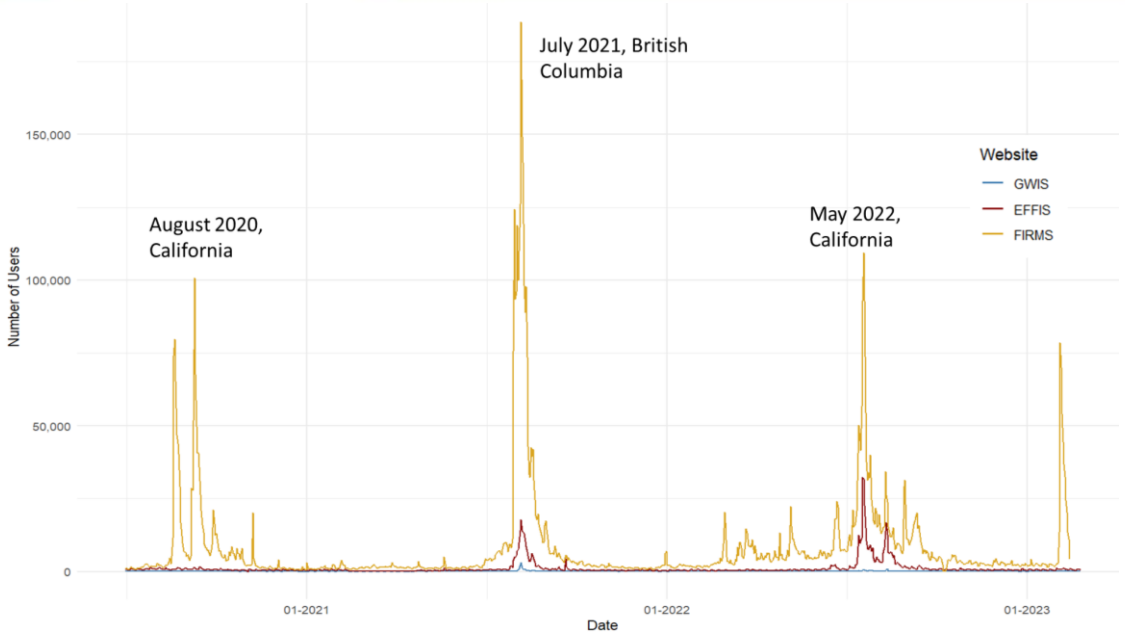
Courtesy of Yukon Wildland Fire Management

Key concepts

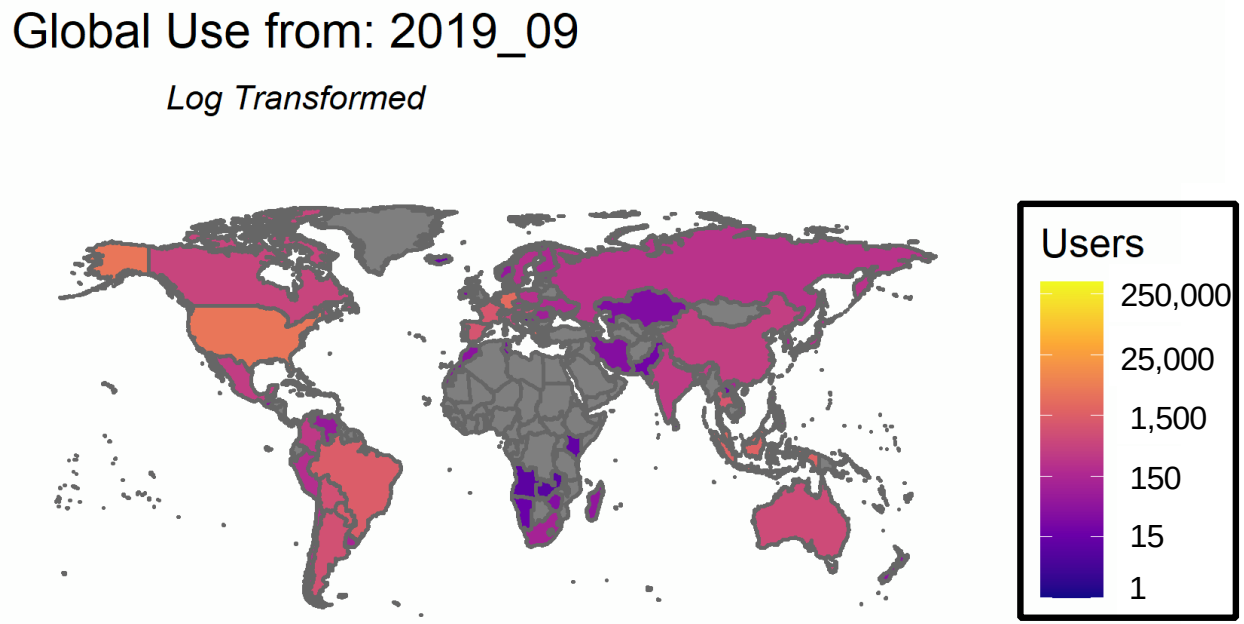
- **Capacity:** is the fire management organizations potential to use, create, develop and integrate EO active fire products. Requires resources (e.g., people, training, technology) and abilities (e.g., adaptability, skills).
- **Uptake:** is the understanding, comprehension and consequent use of EO active fire products which result in change and outcomes. Uptake requires capacity and attributes such as trust, commitment.
- **Agency characterises and perspectives:** the aspects of an "operational fire management" agency/group who interact, use, could use EO-active fire products. May include organizational structure/objectives, degree of integration, specialization, training, awareness, barriers etc. The *context* needed to infer *capacity* and *uptake*.

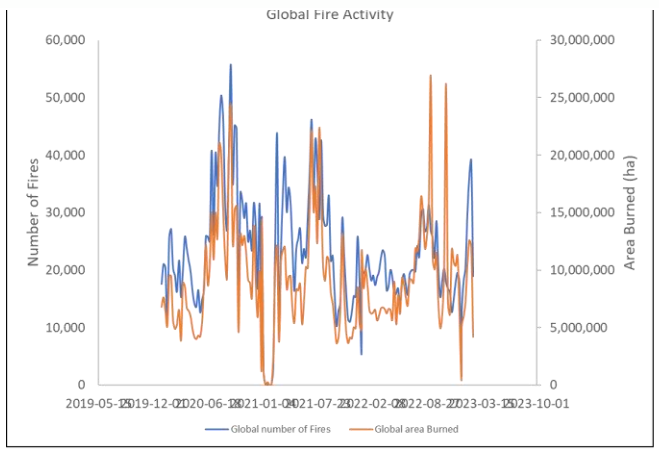


Generally – degree of use, when (why) – getting to “uptake”



- 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.





Global fire activity data taken from GWIS statistics portal

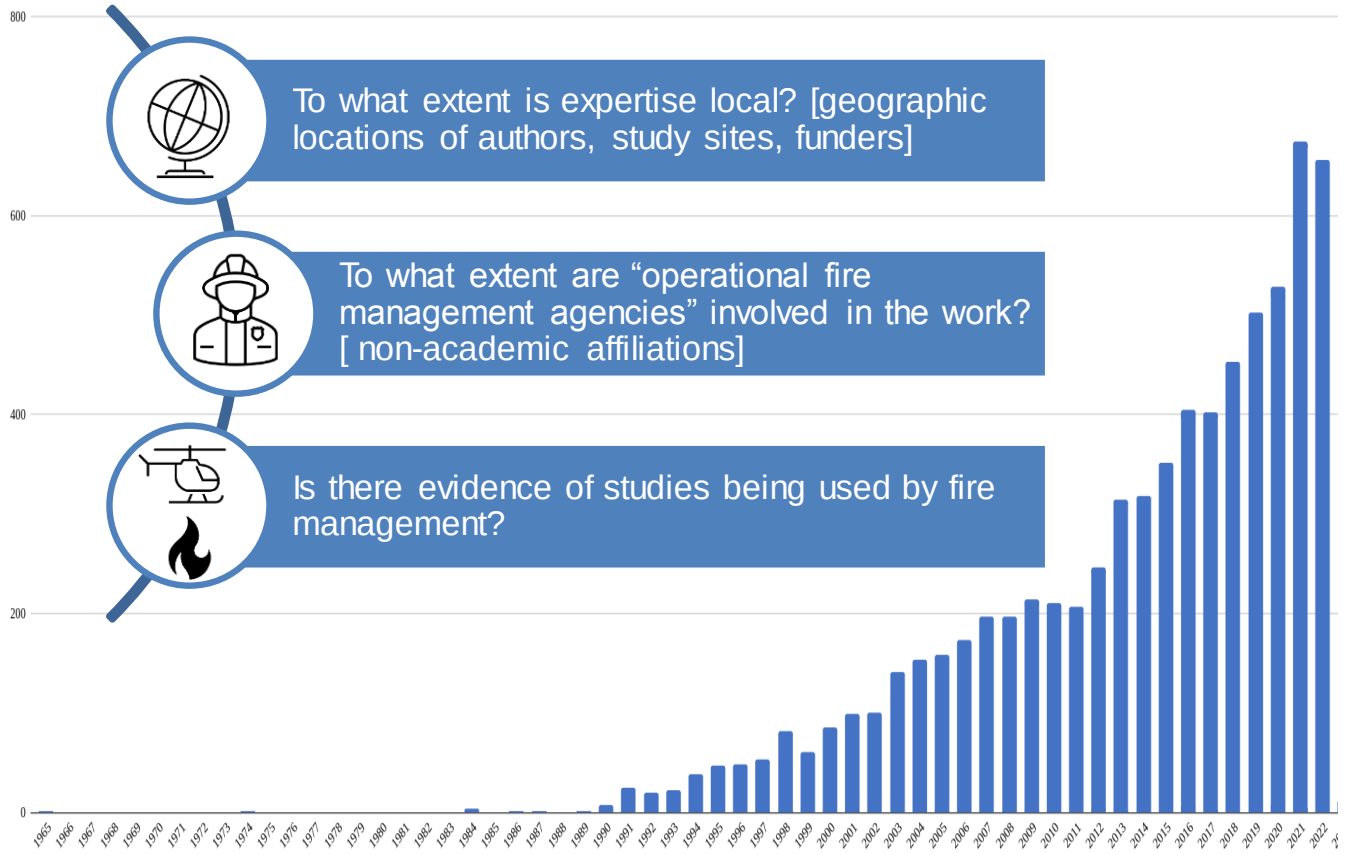
We will attempt to model what usage “should” be given some predictors like…

- Fire activity likely correlated with increase in users
- Media coverage level and timing
- Seasonality may influence users
- Internet availability

Generally – how much and where is there available and relevant “active fire” research. Getting to “capacity”

- 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 cut:** >7000 publications meet our filter criteria (figure).
- **Second cut**: ~1500 publications using EO for “active fire”.
- **Next steps**, classify/characterize author locations, study locations, operational affiliations

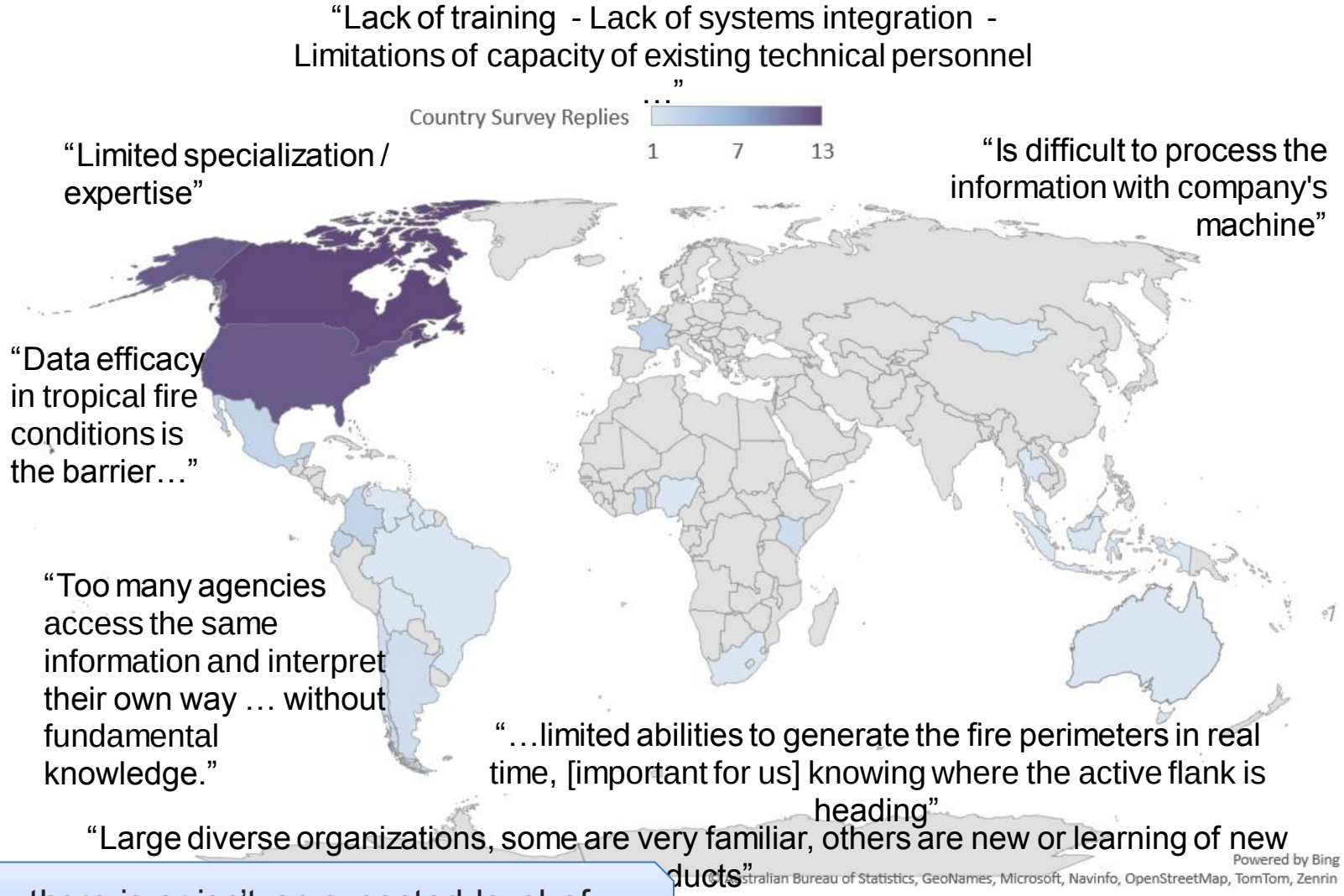
Number of Publications per year, Earth Observation



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

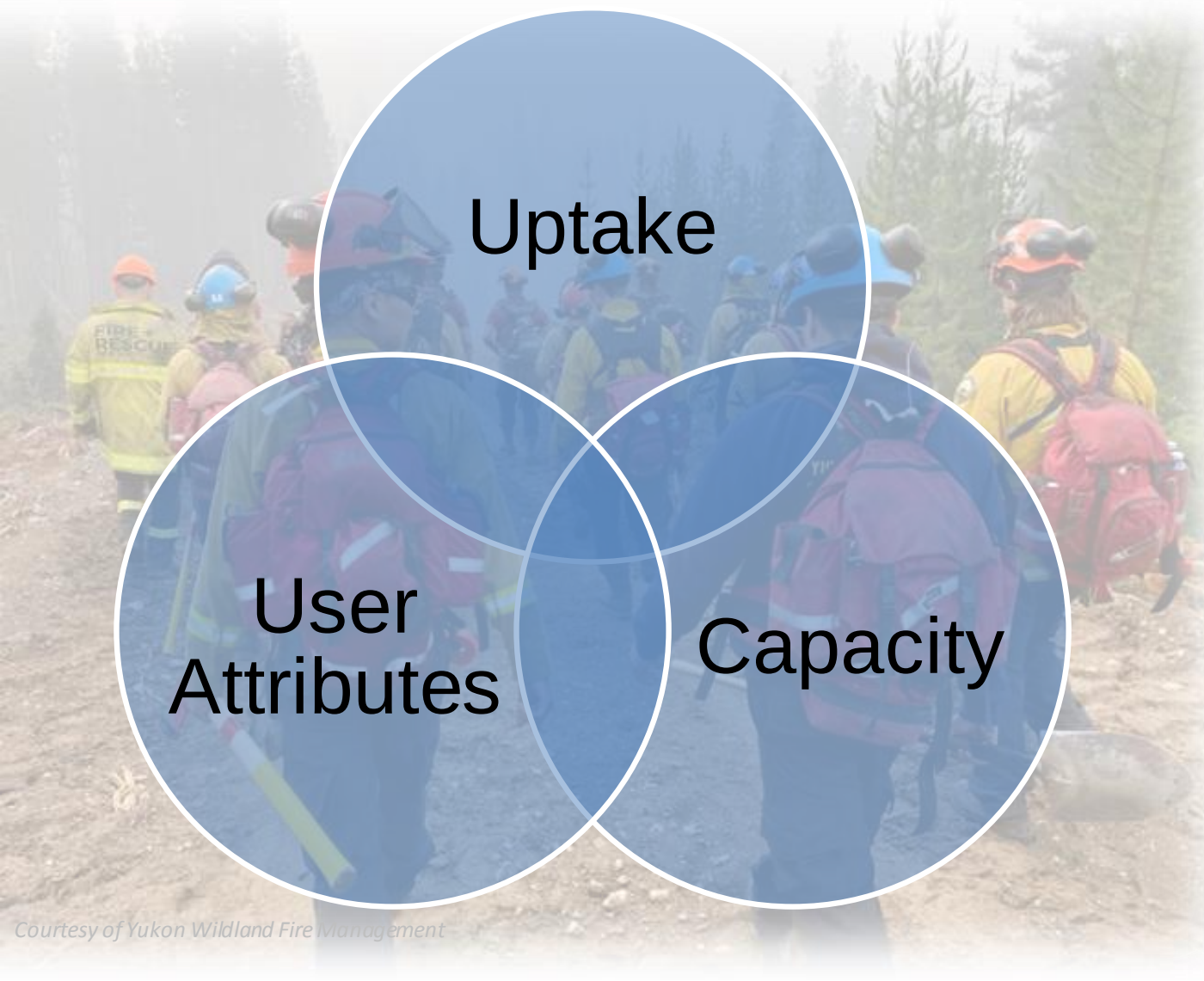
Generally – gives us perspectives on actual use and capacity from the local experts/knowledge holders

- Outreach to identify stakeholders and end-user communities.
  - First order - survey
- Characterizing agencies (responsibilities; priorities; challenges) aspects of:
  - Familiarity with EO
  - Degree of capacity
  - Degree of use
  - Trust in EO
  - Barriers to uptake
- 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 uptake or capacity. There may be barriers or facilitators that are not obvious.

Relationships and next steps



Courtesy of Yukon Wildland Fire Management

- Explore relationships between uptake, capacity and attributes of the user groups.
- Interactions between aspects of all three components.
- 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.

Please take a photo and share this slide with operational fire management colleagues.

English

Française

Analysis of global end-users of near-real-time active-fire Earth Observation Data

The Committee on Earth Observation Satellites (CEOS) Working Group Disasters Wildfire Pilot aims to provide a fundamental basis for defining global priorities for active-wildland fire monitoring and characterization from space. Learn more here: Wildfire Pilot | CEOS | Committee on Earth Observation Satellites.

The four objectives of the Wildfire Pilot are:

1. Conduct a detailed inventory and gap analysis of existing and proposed Earth Observation systems suitable for global active-wildland fire monitoring.
2. Conduct a detailed analysis of global end-users of active-wildland fire Earth Observation data and products.
3. Define targeted user requirements for active-wildland fire remote sensing systems for the disaster mitigation applications.
4. Propose a way forward in coordinating global wildland fire monitoring activities.

To support these objectives, we are conducting several initiatives. Using end-user engagement, we will identify the global community of Earth Observational active wildland fire data end-users and establish a framework for ongoing interaction and collaboration. Data collected will be used by the CEOS Wildfire Pilot Team in support of publications. Please do not include any personal identifying information in your response, such as people's names. No personal identifying information will be collected. Participation is voluntary.

- **Step One**: Survey wildland fire management organizations through the Global Observations of Forest Cover and Land-use Dynamics (GOFC–GOLD) Fire Implementation team and affiliated regional networks representatives for a high-level characterization of users and needs.
- **Step Two**: where necessary adopt a regionally specialized approach to ensure wildland fire management agencies and regional user groups are represented.

Step One - Survey One

To help provide scope in survey responses, please consider the following descriptions:

Extra slides

Future Fire Weather

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

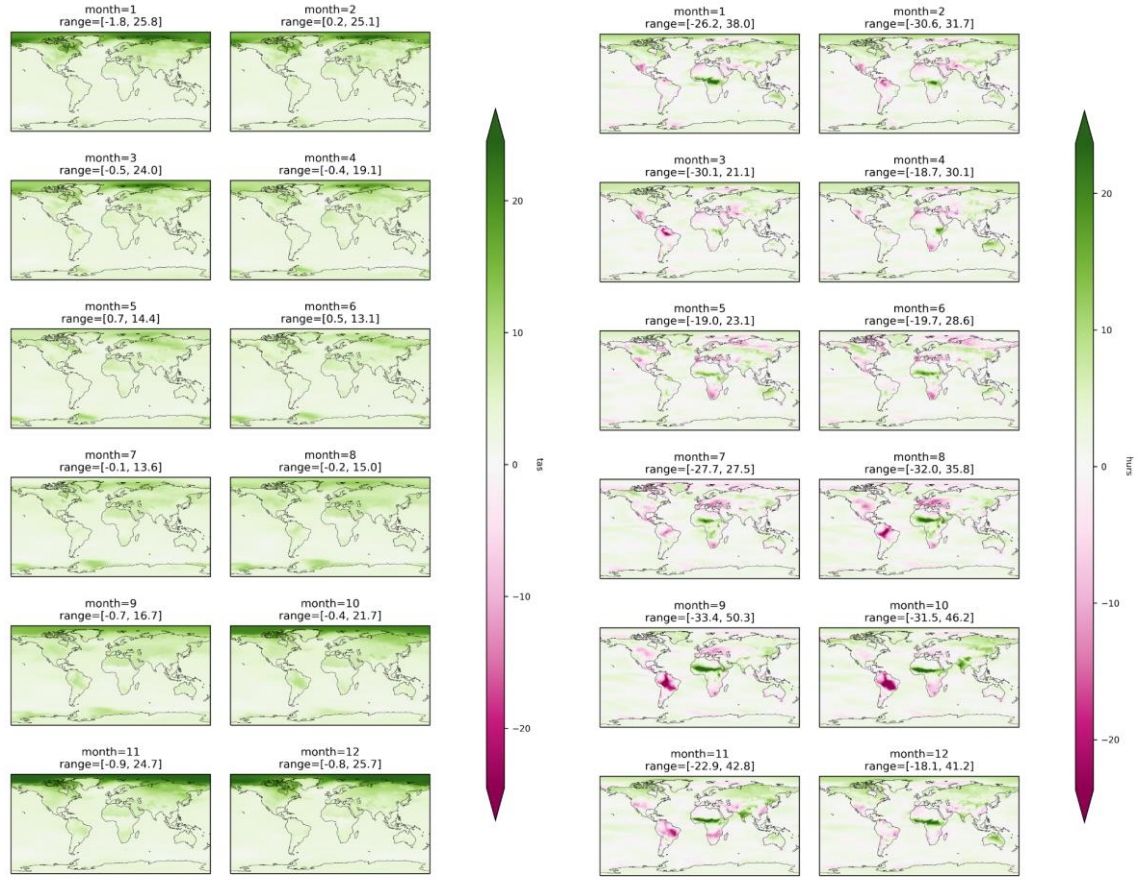
Additional contributors: Mike Flannigan, Xianli Wang, Piyush Jain

- Ensemble of future fire weather will be used as the indicator of future fire regime changes;

Method:

- delta-change approach with modified precipitation frequency
  - Where *pr* ±>X %, adjust *pr* freq. in addition / instead of magnitude

- Meteorological params -> FWI using McElhinney et al. (2020) method



Monthly deltas for GCM EC-Earth3-Veg, for SSP5-8.5, 2070-2099 period. Left panel = temperature, right panel = RH

Future Fire Weather

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

Additional contributors: Mike Flannigan, Xianli Wang, Piyush Jain

Datasets:

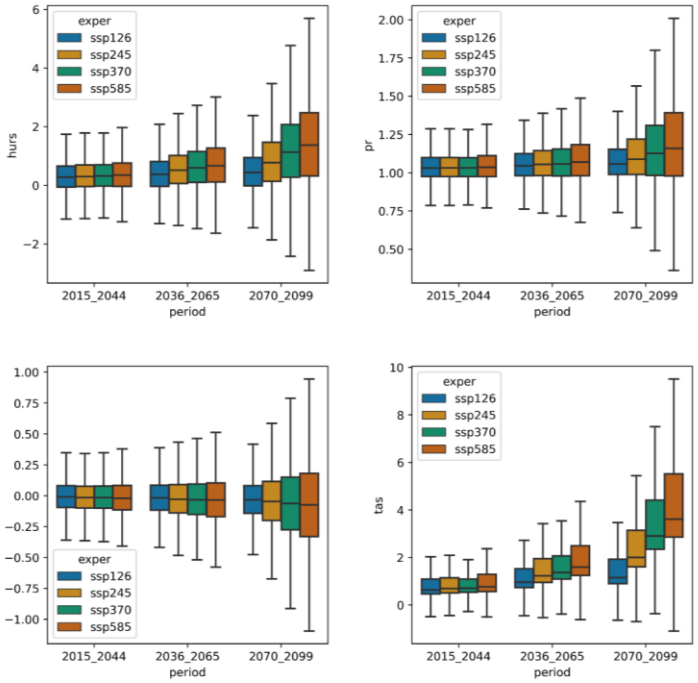
- ERA5 daily reanalysis (1985-2014)
- CMIP6 monthly data for 9 GCMs:
  - historical (1985-2014) & 4 scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5

- ***Alternative dataset to test:*** NASA NEX-GDDP-CMIP6 dataset (0.25° , bias corrected)

Contrast ***shifts in FWI outputs*** in regional fire season over 2015-2045 period to ***EO active fire coverage***

CMIP6 GCMs and their mean grid cell resolution

model	group	mean grid res (°)
ACCESS-ESM1-5	CSIRO	1.56
CESM2	NCAR	1.09
CNRM-ESM2-1	CNRM	1.41
EC-Earth3-Veg	EC-Earth	0.70
KACE-1-0-G	NIMS-KMA	1.56
MIROC6	MIROC	1.41
MPI-ESM1-2-LR	MPI-M	1.88
MRI-ESM2-0	MRI	1.13
UKESM1-0-LL	MOHC	1.56



Distributions of all monthly grid cell deltas for GCM EC-Earth3-Veg, by scenario and period.