Climate Change and Wildfire Dynamics at the Wildland-Urban Interface

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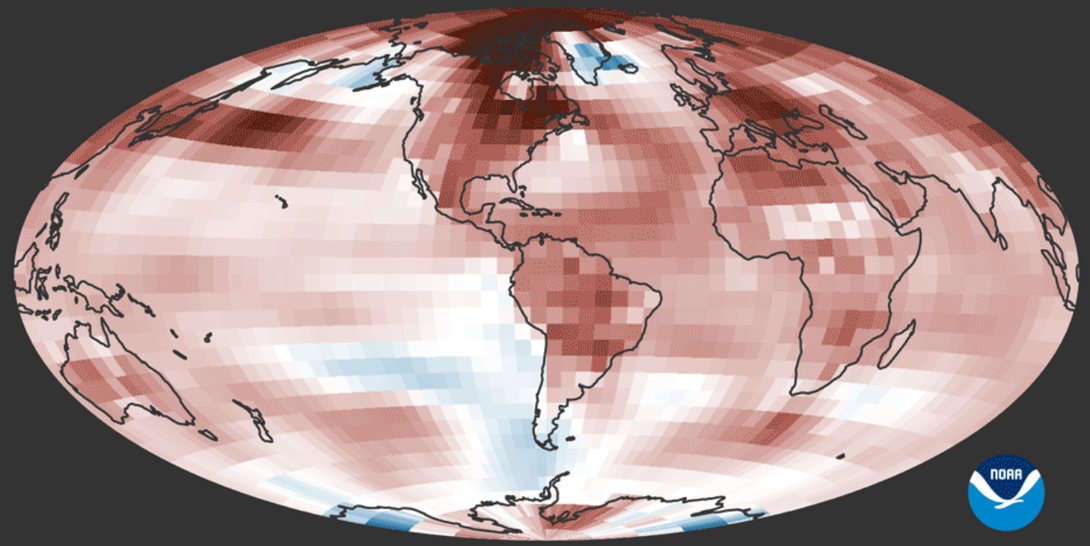
TEXAS TECH UNIVERSITY

National Oceanic and Atmospheric Administration

U.S. Department of Commerce

IT'S OFFICIAL:



Difference from 1991–2020 average

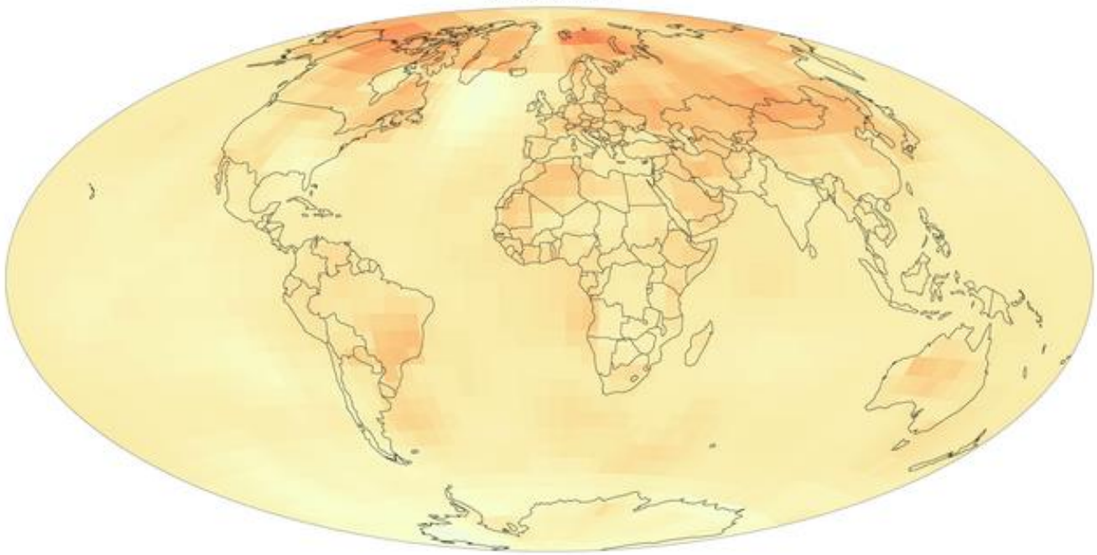
−5 0 5 (°F)

−2.7 0 2.7 (°C)

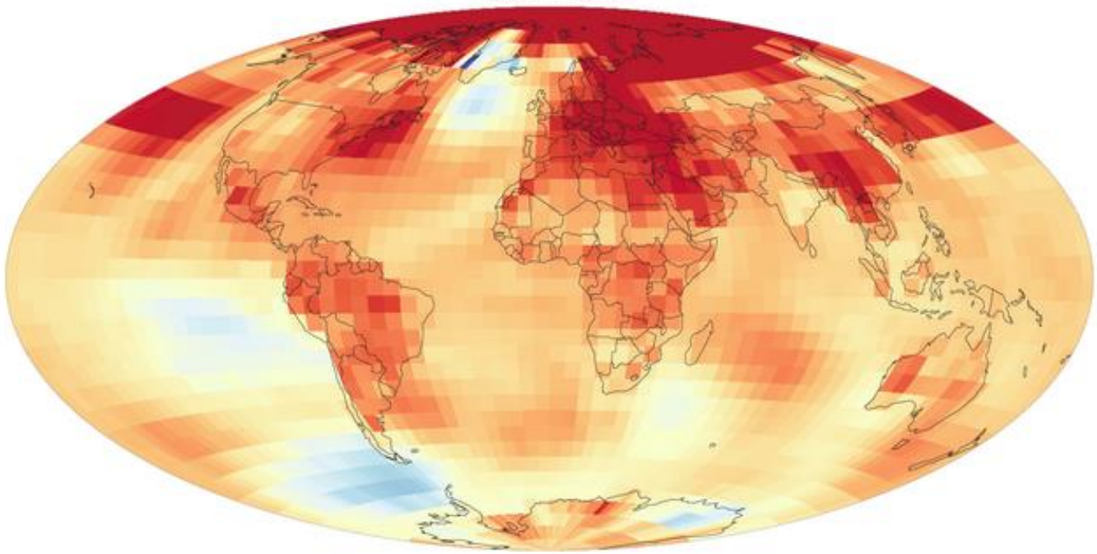
NOAA Climate.gov/NCEI

Warming over past 30 years is much faster than long-term trend

1901–2024



1994–2024



Change in temperature (°F/decade)

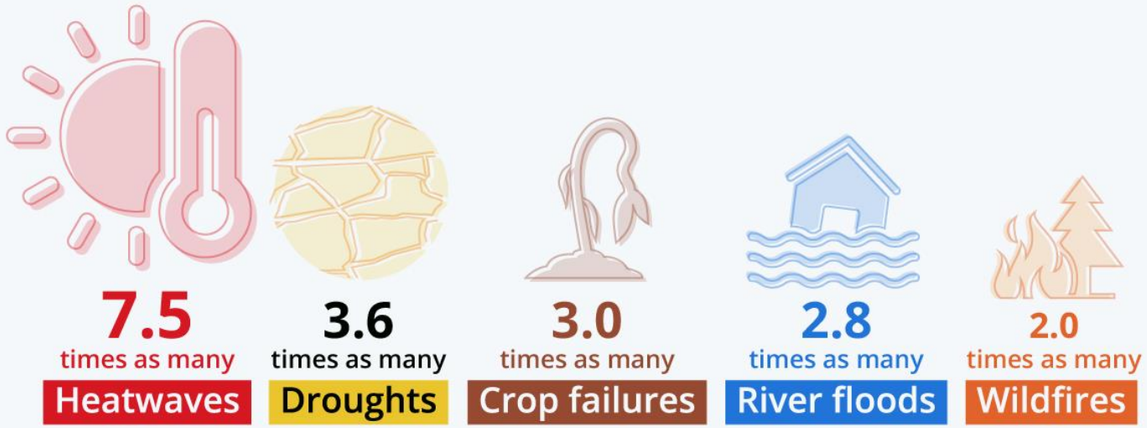
-1 0 1

NOAA Climate.gov
Data: NCEI

Motivations for Research

Number of Climate Disasters to Triple for New Generation

Frequency of climate disasters experienced in a lifetime for a person born in 2020 compared to one born in 1960



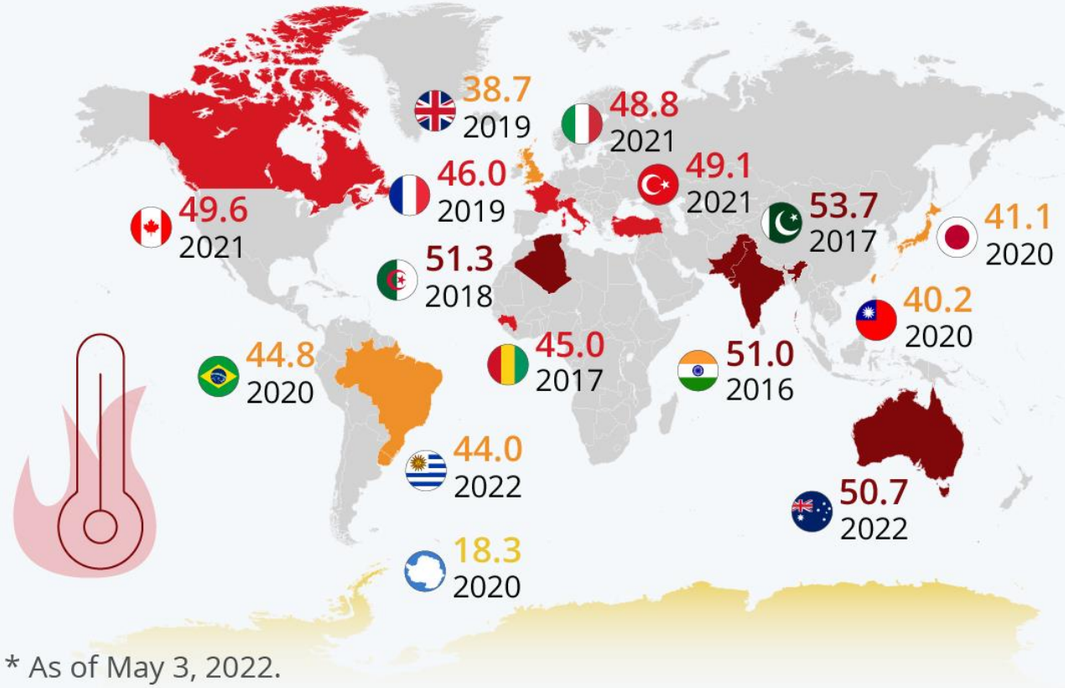
All climate disasters
~3 times as many

Based on NDC scenario (following Paris Agreement) of 2.7 °C/4.9 °F warming until 2100
Source: Thiery et al. Intergenerational Inequities in Exposure to Climate Change. Science (2021) via media reports

statista

World Sees Record Heat Waves

Selection of temperature records by country (or continent) recorded during the last five years, in °C

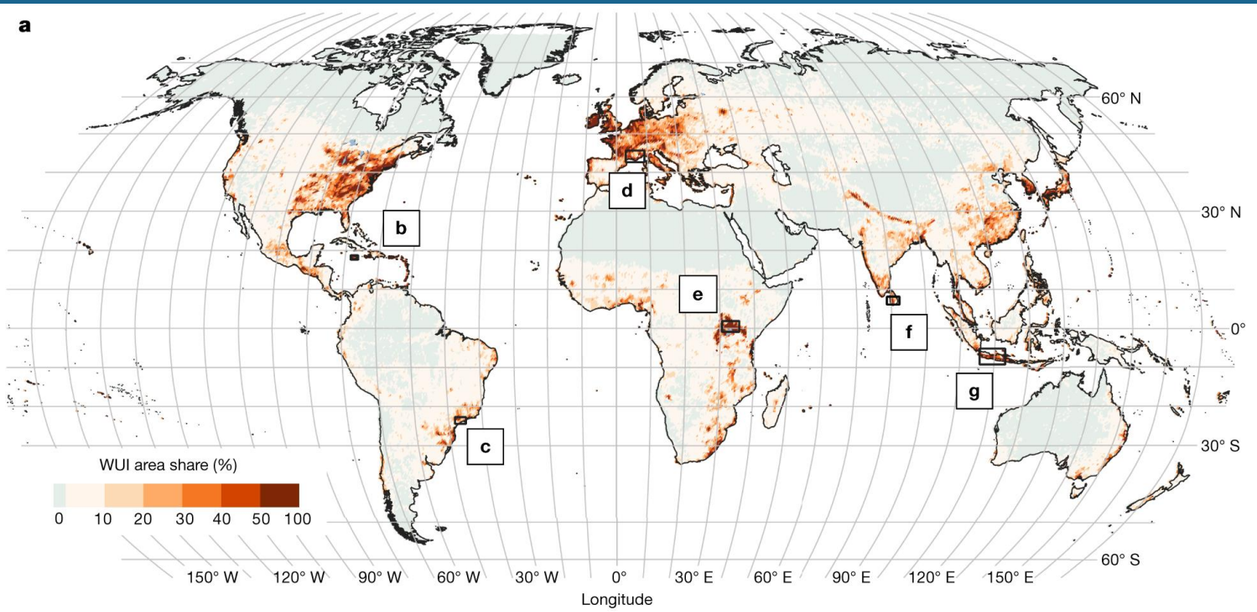


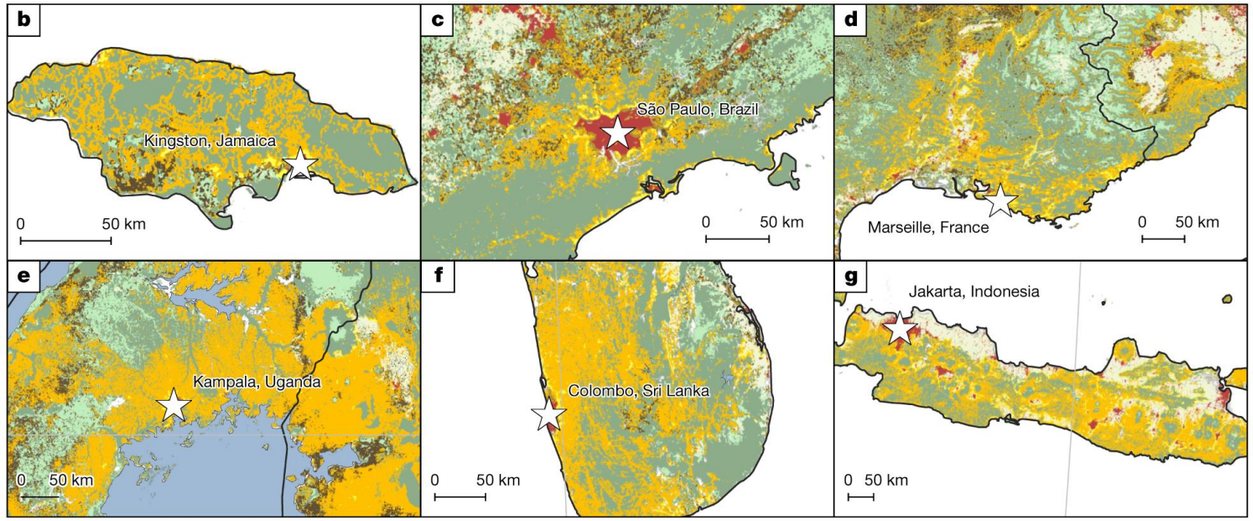
* As of May 3, 2022.
Sources: World Meteorological Organization, media reports, Statista research

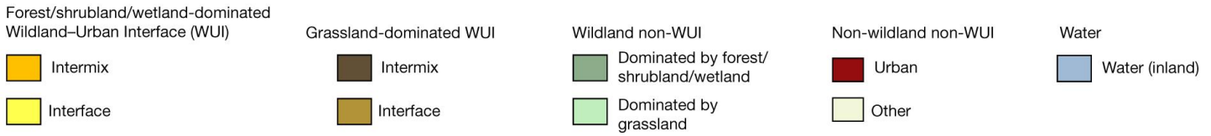
> The climate and inequality crises need to be addressed at the same time so that no one is left behind.
>
> WMO Secretary-General, Prof. Celeste Saulo

statista

Global WUI Fire Hotspots







Australia (2019–20)

46M acres burned, 5,900+ buildings destroyed, 33 lives lost in "Black Summer“

Canada (2023)

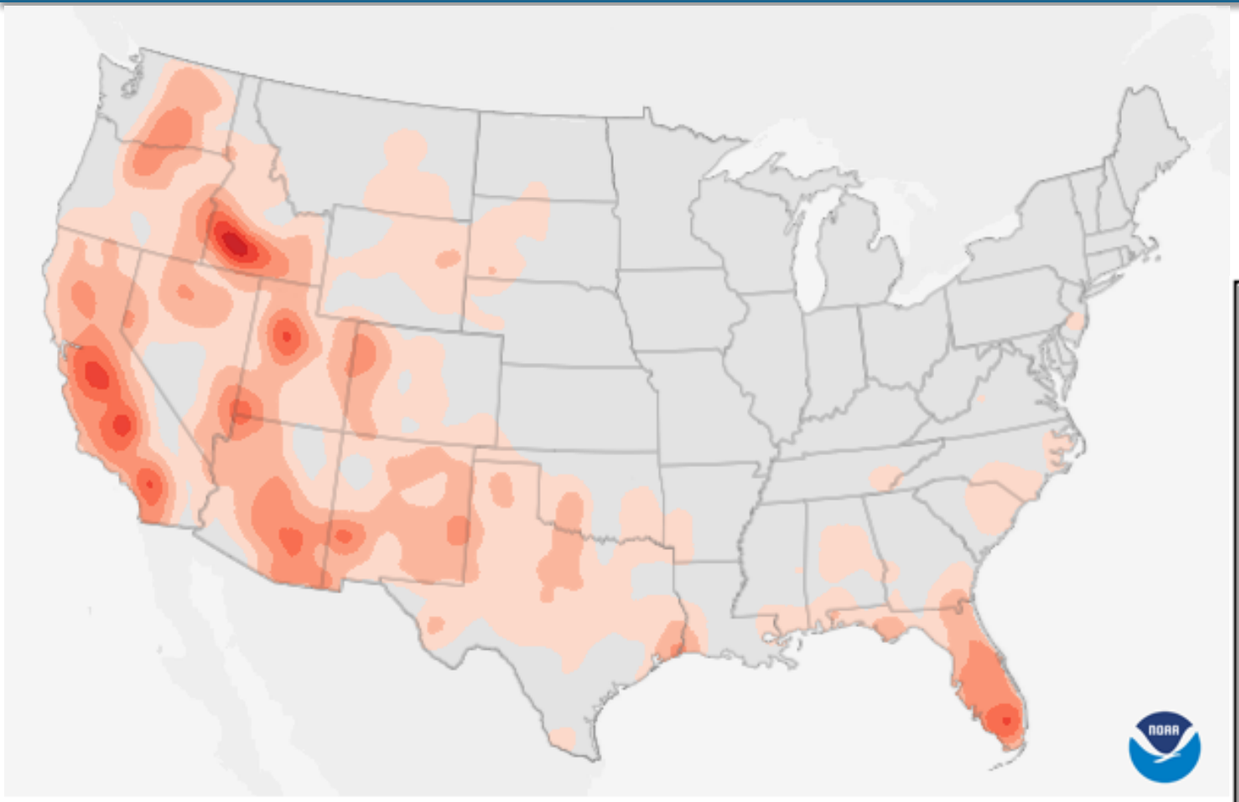
Record ~45M acres burned, smoke affected US air quality for weeks

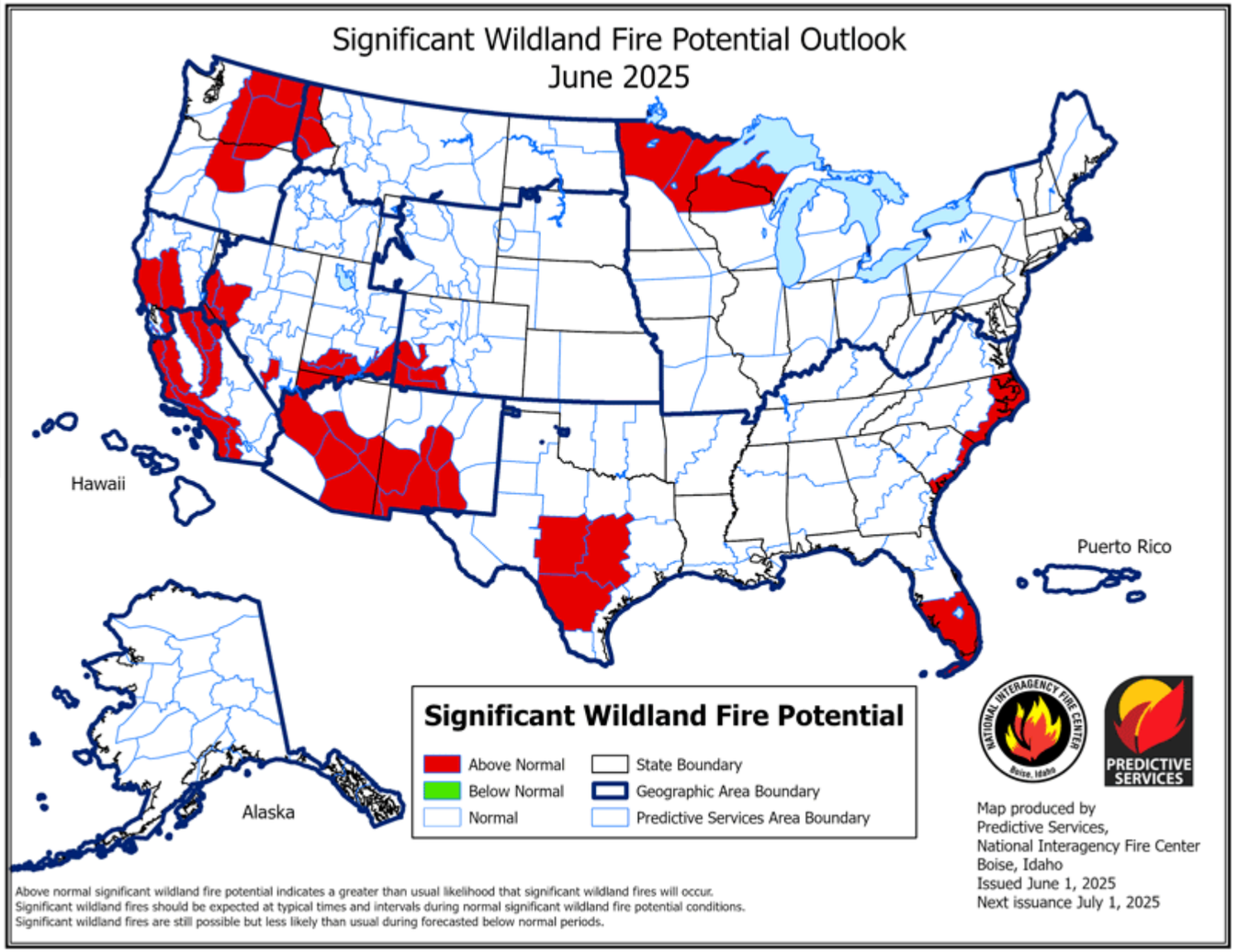
Europe (2022)

Record 785,000 hectares burned, displacing 2.6M people

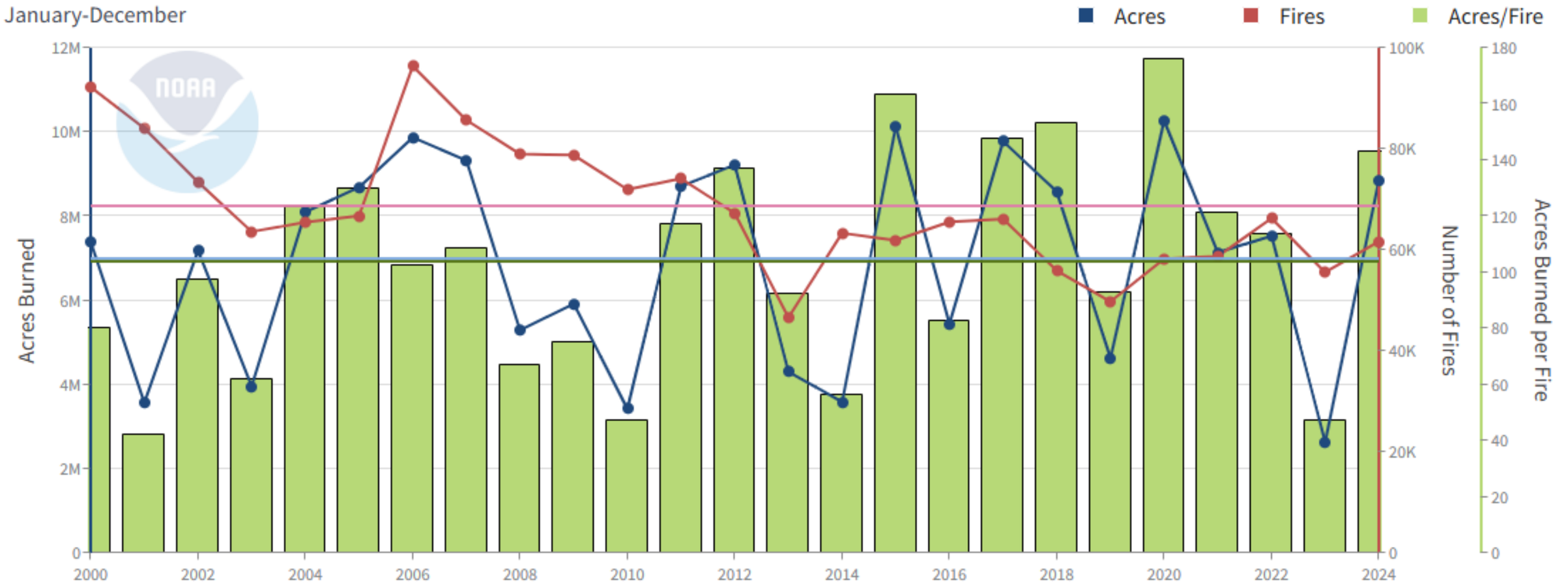
Schug, F., Bar-Massada, A., Carlson, A.R. *et al.* The global wildland–urban interface. *Nature* **621**, 94–99 (2023). https://doi.org/10.1038/s41586-023-06320-0

Historic Probability of Large Wildfire





U.S. Wildfires



2001-2020 Average: 7,000,513.55 Acres 68,707.25 Fires 103.92 Acres/Fire

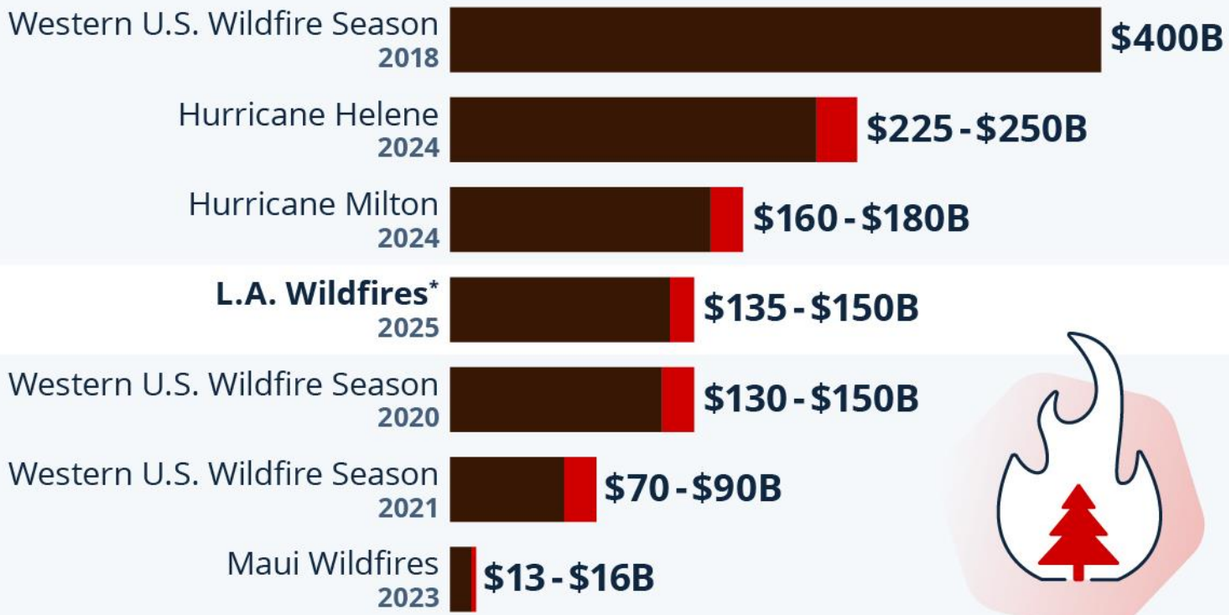
Source: National Interagency Fire Center (NIFC)

Powered by **ZingChart**

Escalating Human and Economic Impact

L.A. Wildfires Among the Costliest in Recent History

Estimated total damage and economic losses associated with recent natural disasters in the U.S.



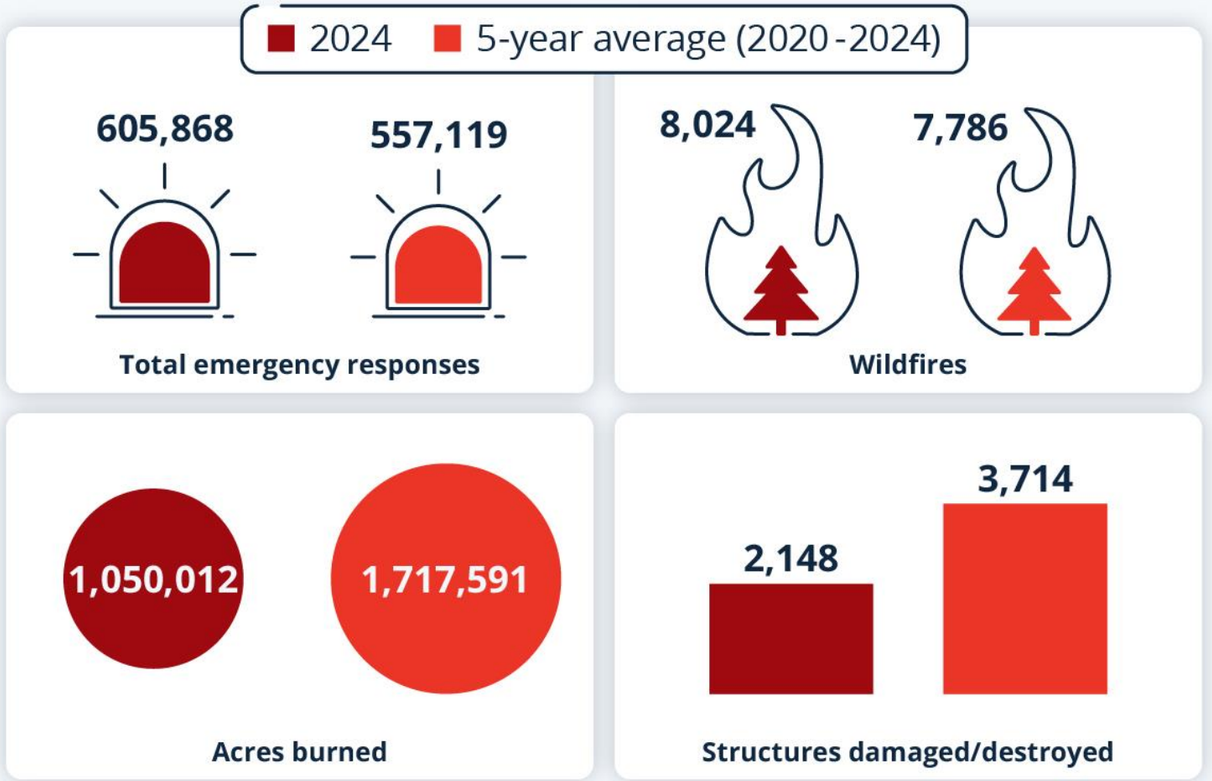
* Latest preliminary estimate as of Jan. 9, 2025. Estimates includes direct costs (e.g. property damage) and indirect costs (e.g. wage losses and supply chain disruptions)

Source: AccuWeather

statista

California's Wildfire Problem

Key statistics for emergency responses connected to wildfires in California



Source: CAL FIRE

statista

Beyond these numbers, wildfire smoke now impacts air quality for millions of people across continents, creating widespread public health concerns even for those far from actual flames.

Wildfire Climate Connection: The Core Catalyst

Rising Temperatures

Global average temperature up ~1.1°C since pre-industrial era, with Western US temperatures rising 2.5-4.5°F since the 1970s

Increased Drought

Western US experiencing its worst mega-drought in 1,200 years (2021), creating critically dry conditions

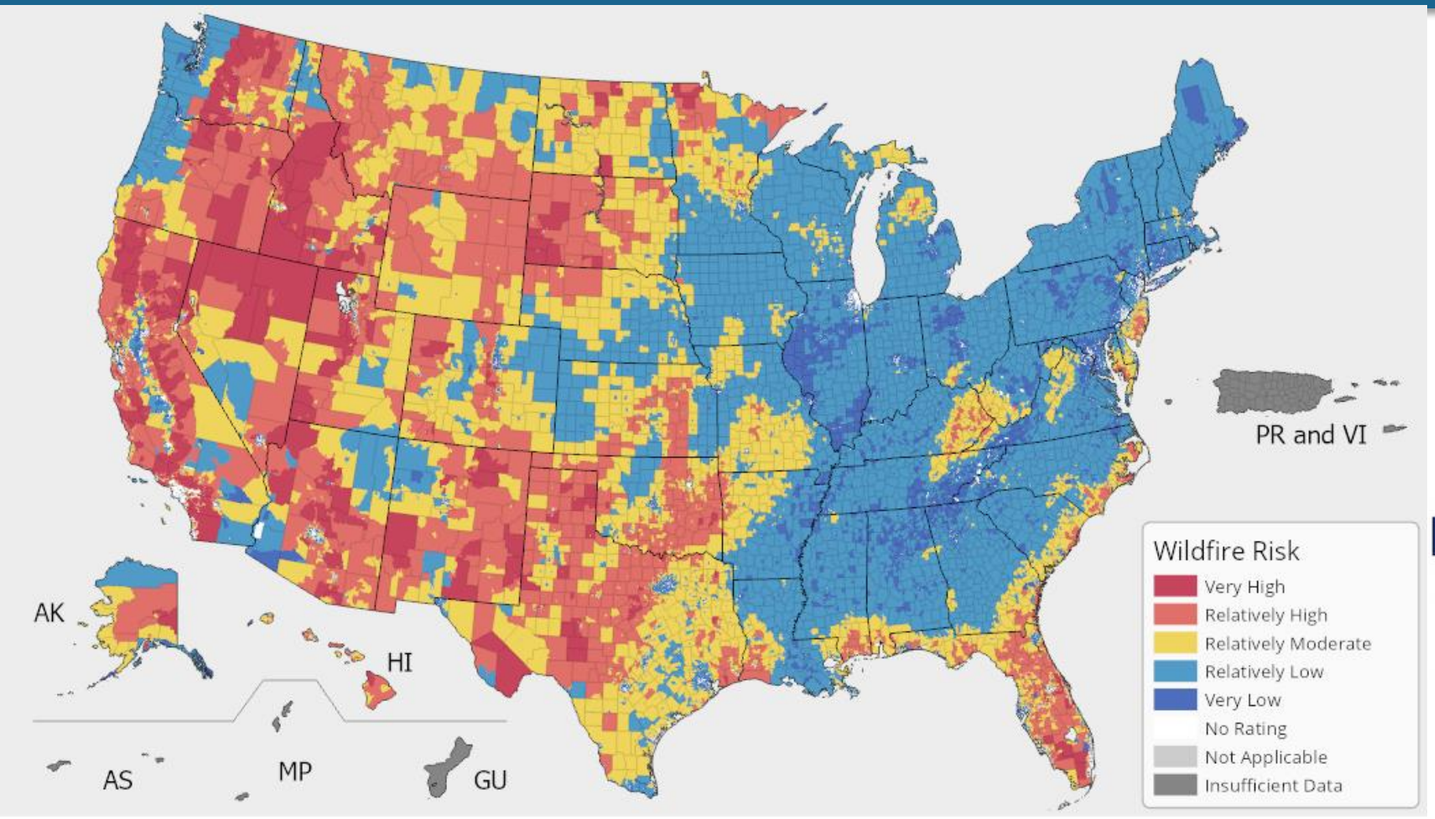
Extended Fire Seasons

US fire season now 78 days longer than in 1970, allowing more time for destructive events

Fuel Aridity

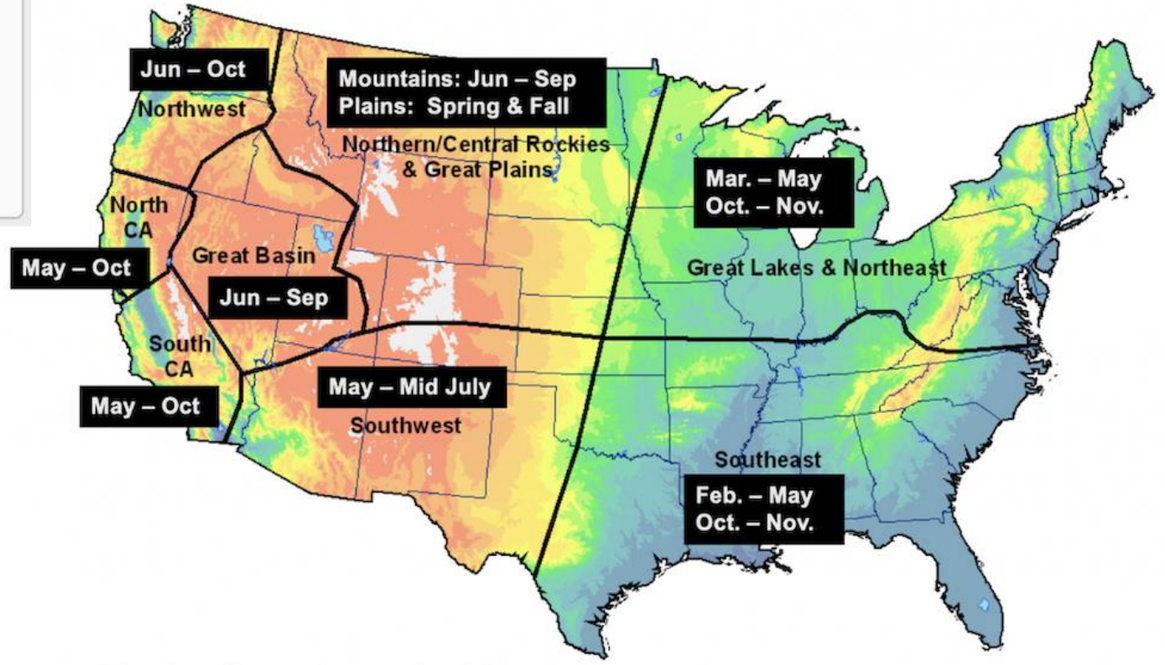
Drier vegetation with lower moisture content dramatically increases ignitability and fire intensity

Mapping Risk with Earth Observation Systems



https://hazards.fema.gov/nri/wildfire

Peak Regional Fire Seasons

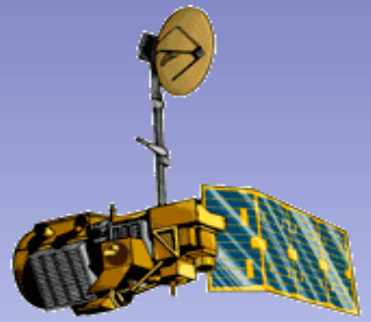


Alaska (not shown): May - August

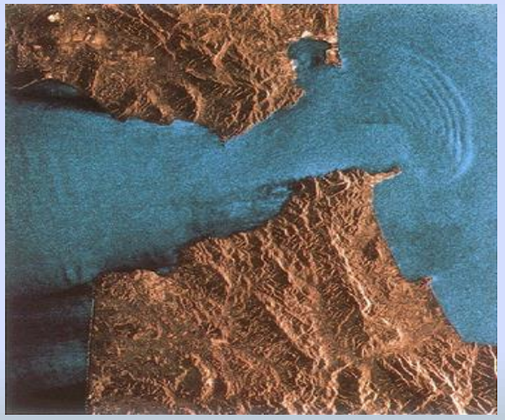
https://www.clarity.io/

Earth Observation Data Options

Aerial Camera

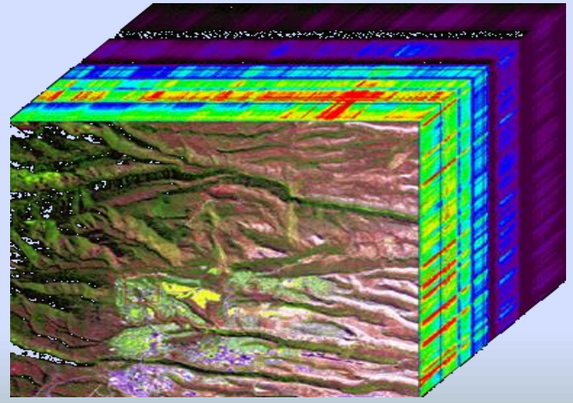


Multispectral Satellite



Radar Satellite

Landsat/Ikonos/ Quickbird



Hyperspectral Sensor

Hyperion

Why Urban Remote Sensing?

- Most of the world's population are living in cities.
- Urban environments shows high temporal dynamics and so requires monitoring.
- Analyses usually focus on Urban Composition, Extent And Growth

Scale Factor In Urban Remote Sensing

Aerial photograph 0.2 m 21.07.2015

HyMap 3.6 m 20.08.2009

Sentinel-2 10 m 23.08.2015

Landsat 8 30 m 03.10.2015

Step from approx. <1 m to 30 m leads to massive spatial aggregation.

Source: Small et al., 2018

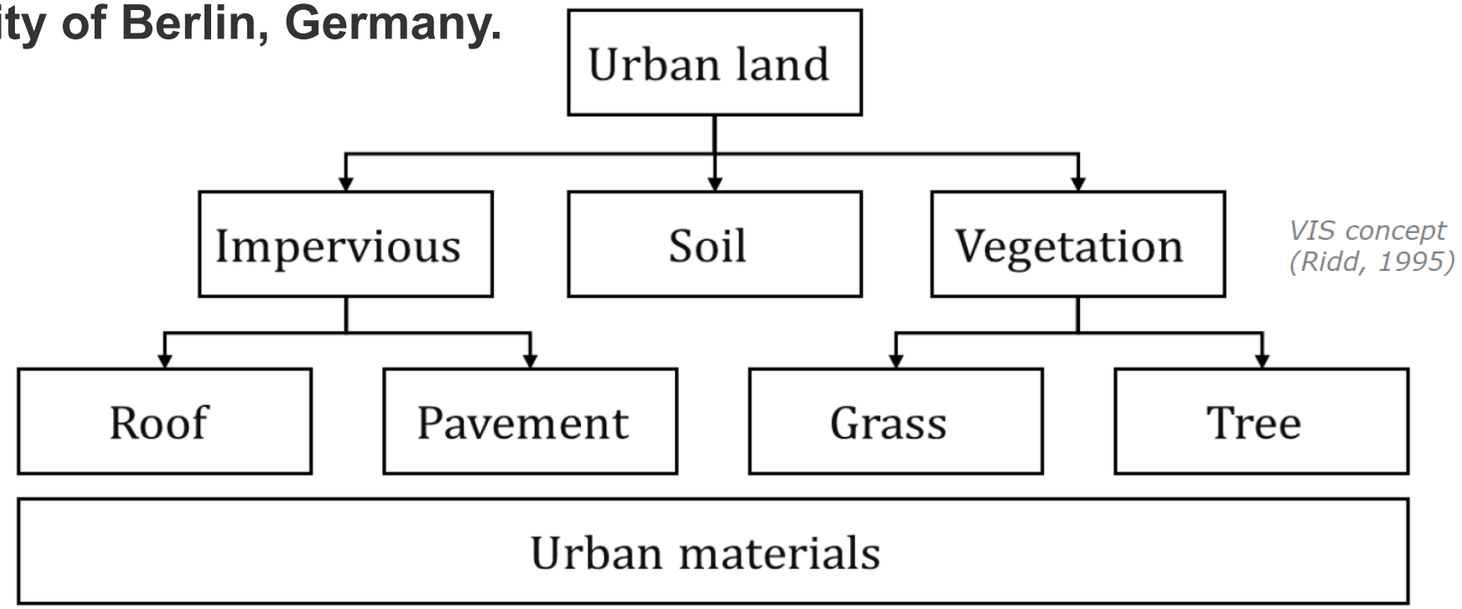
HyMap is an airborne hyperspectral imaging sensor

Mapping Urban Composition/ Land Cover

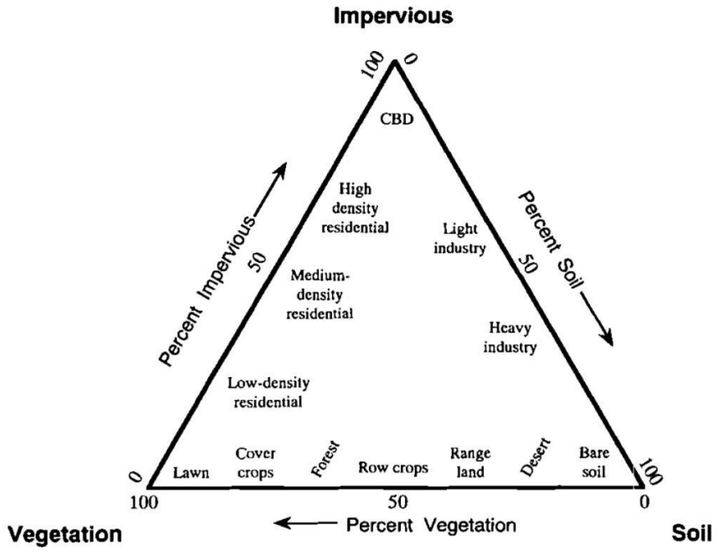
- Urban land cover classes can be hierarchically organized down to the material level.
- Urban land cover is characterized by great diversity of materials.

The city of Berlin, Germany.

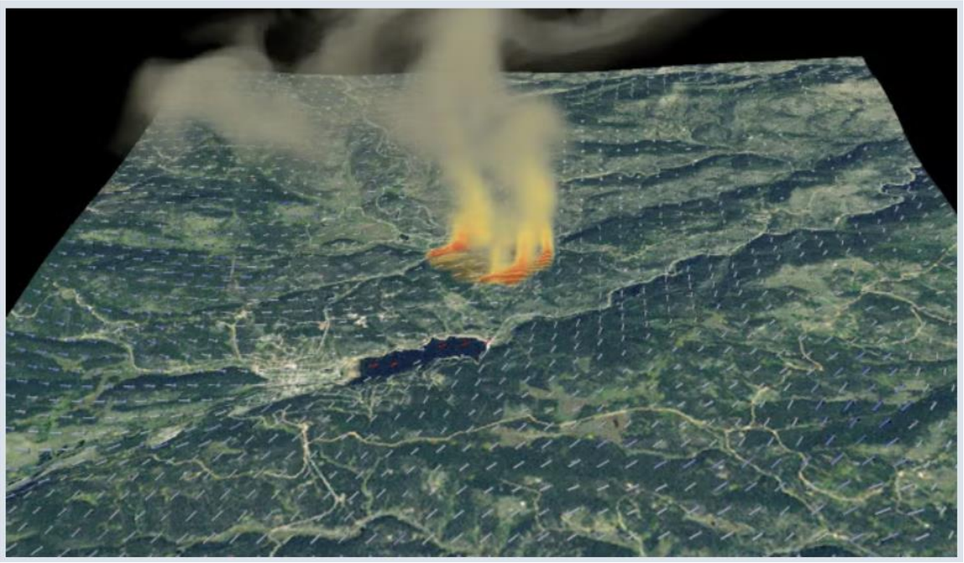
Source: Google Earth



VIS concept (Ridd, 1995)



WRF-Fire: Wildland Fire Modeling and Visualizing Megafires



The Weather Research and Forecasting (WRF) model is a state-of-the-art, open-source, mesoscale numerical weather prediction system used for both atmospheric research and operational forecasting

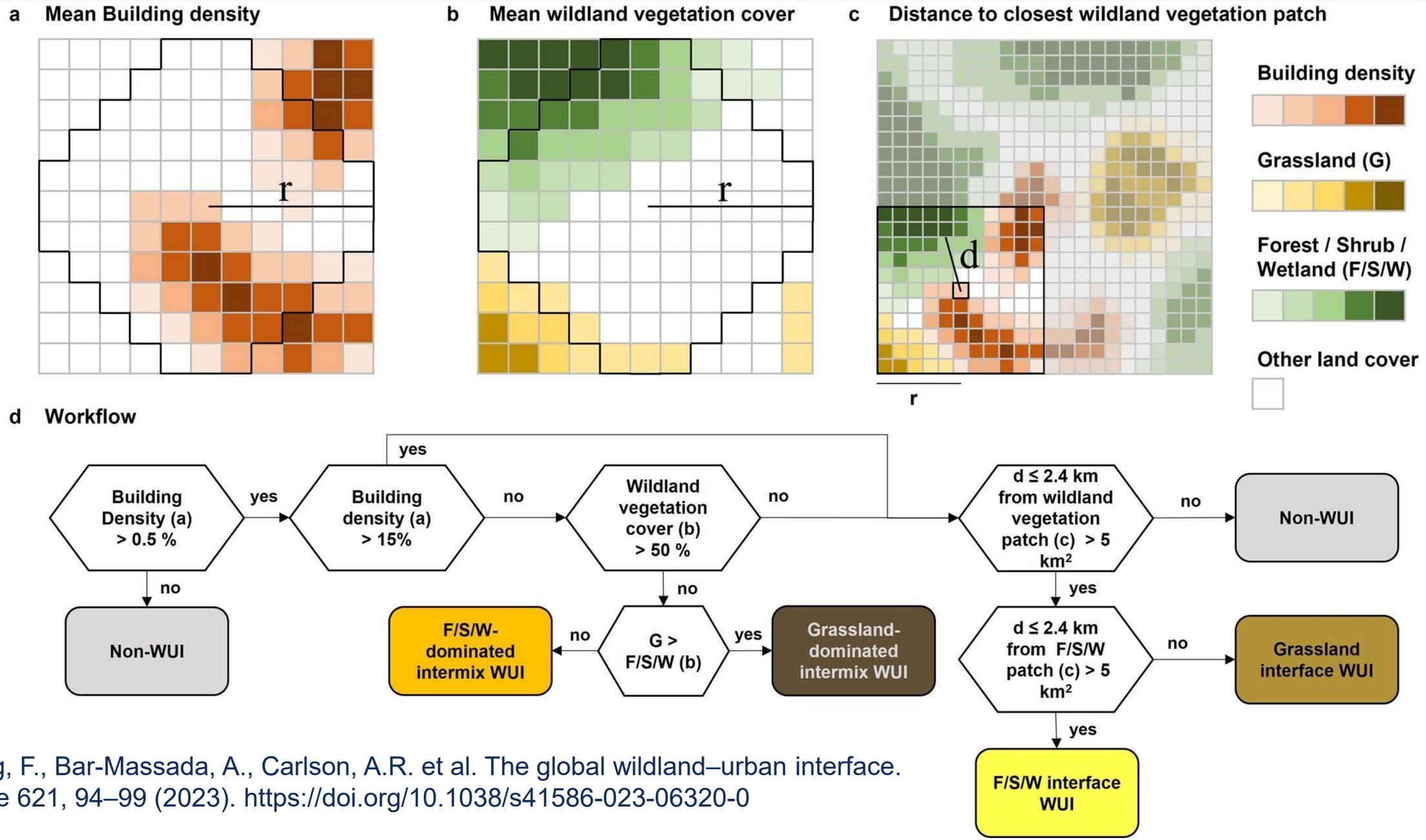
https://ral.ucar.edu/model/wrf-fire-wildland-fire-modeling

What is the Wildland-Urban Interface (WUI)?

The WUI is the transition zone between unoccupied wildland and human development. It's a hotspot for wildfire risk due to:

- Proximity to flammable vegetation
- Human ignition sources (power lines, construction, etc.)
- Difficult evacuation and fire suppression

Wildland–Urban Interface mapping workflow



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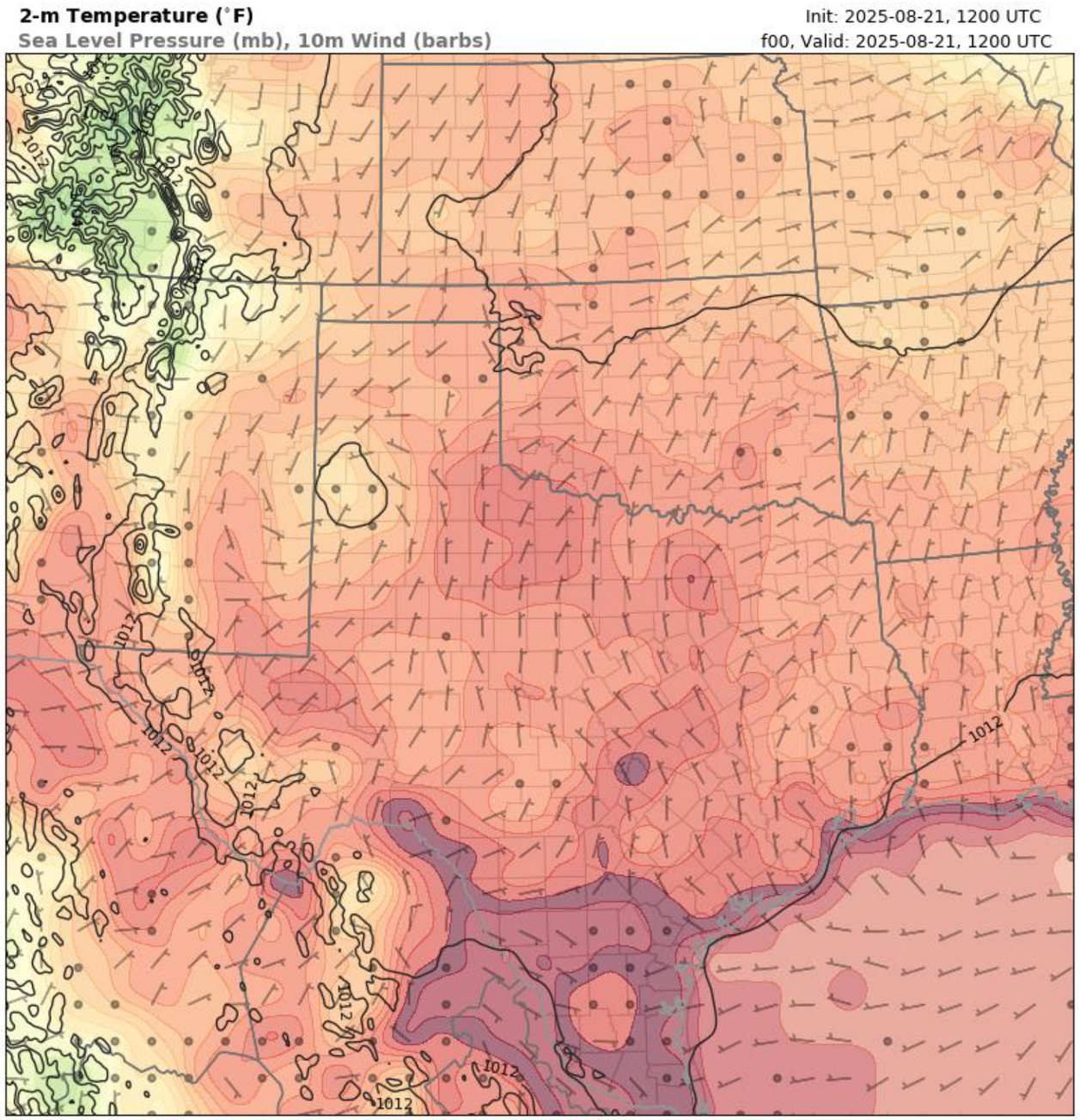
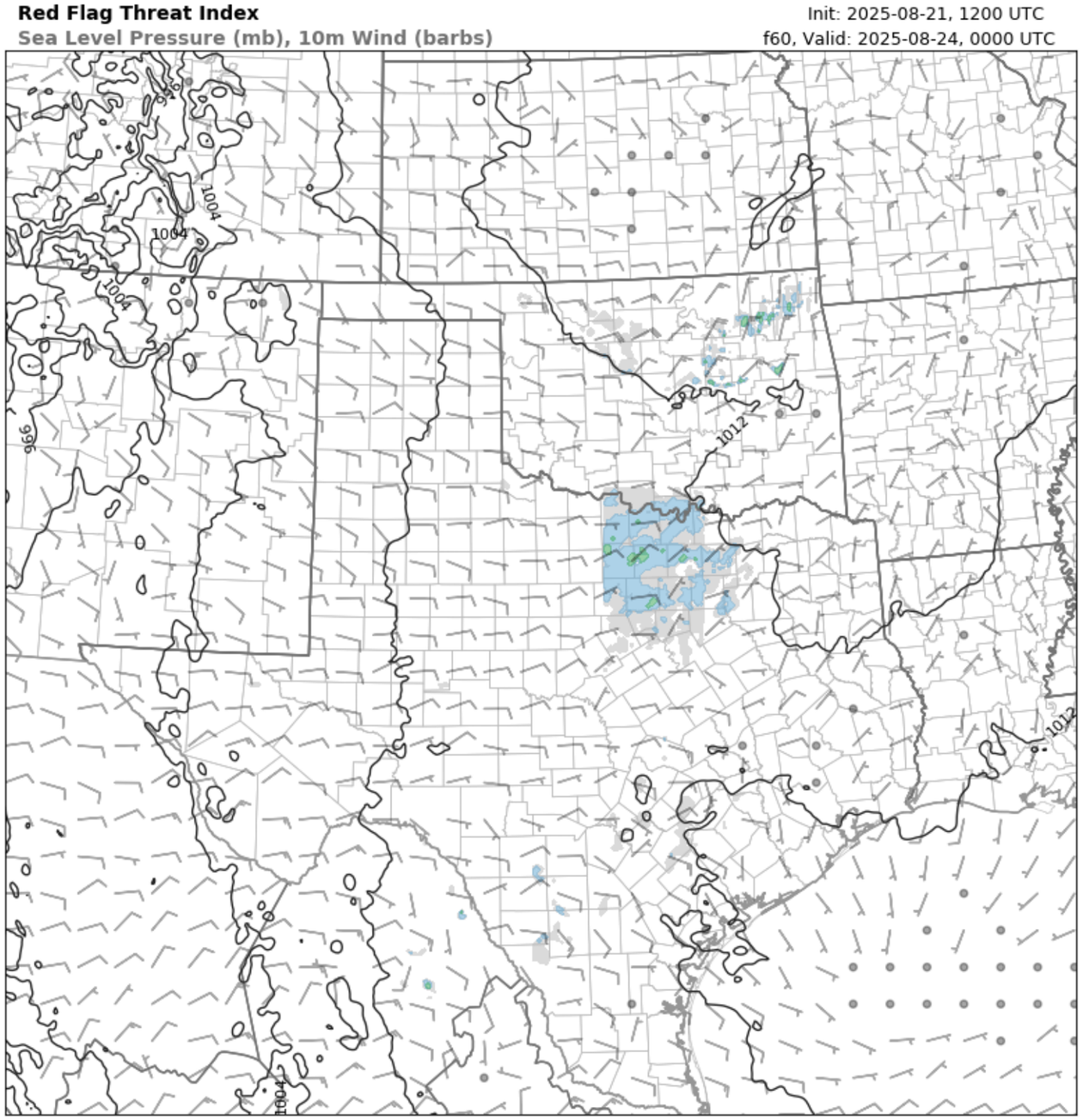
3km Real-Time WRF Modeling System





TEMPO Data Potential for WUI

Measures hourly air pollutants at high resolution data

- Nitrogen Dioxide (NO_2)
- Ozone (O_3)
- Aerosols and other trace gases

TEMPO Data for Wildfire Dynamics

Use Case	TEMPO Data Potential
Early Detection of Fires	Fires emit NO_2, HCHO, and VOCs. Spikes in these pollutants can signal active or smoldering fires even before visible flames are reported.
Smoke Plume Tracking	TEMPO can monitor air quality changes as smoke moves, helping with real-time modeling of plume transport, which affects visibility, health, and fire spread.
Assessing Fire Severity	High concentrations of NO_2 and HCHO can indicate intense biomass burning, aiding post-fire assessments.
Fire-Atmosphere Feedbacks	Fires emit pollutants that modify radiation and local weather, which TEMPO helps track in near real-time.

TEMPO Data For Climate Change Research

Use Case	TEMPO Potential
Short-Lived Climate Forcers	TEMPO tracks Gases like ozone and aerosols have strong but short-lived warming effects.
Long-Term Emissions Trends	With hourly and daily observations, It supports studies of how emissions change over time especially during heatwaves or droughts.
Urban Vs Wildland Air Quality	Comparing pollutant levels across urban, rural, and WUI regions can assess the interplay of anthropogenic and natural emissions.
Public Health Impacts	Supports health risk mapping and emergency response. Air pollution from wildfires worsens respiratory and cardiovascular health at the WUI.

TEMPO for Wildland-Urban Interface

Benefit Area	TEMPO Contribution
Fire Detection	NO_2 and HCHO spikes
Fire Behavior	Hourly air quality evolution
Climate Impact	Pollutants affecting radiation and temperature
WUI Risk	Mapping of pollution exposure near human development
Health Planning	Real-time exposure data for smoke and pollutants

Data Integration with Other Sources

TEMPO data can be combined to maximize impact:

- MODIS / VIIRS (FIRMS) fire detection
- HRRR Smoke models (from NOAA)
- Land cover and WUI maps
- Population and Infrastructure data
- Ground air quality stations (e.g., EPA AirNow)

Proactive Mitigation Strategies for Resilience

Fire Management

Defensible Space
Clear vegetation 100-200 feet around structures to create buffer zones

Infrastructure

Ignition-Resistant Materials

Class A roofing, tempered glass, non-combustible siding for new construction

Community Resilience

Firewise USA and similar initiatives promote local risk reduction

Policies

Wildfire burns near homes. Credit: ready.gov

Fires Along the Wildland-Urban Interface On the Rise

Suggestions ?

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