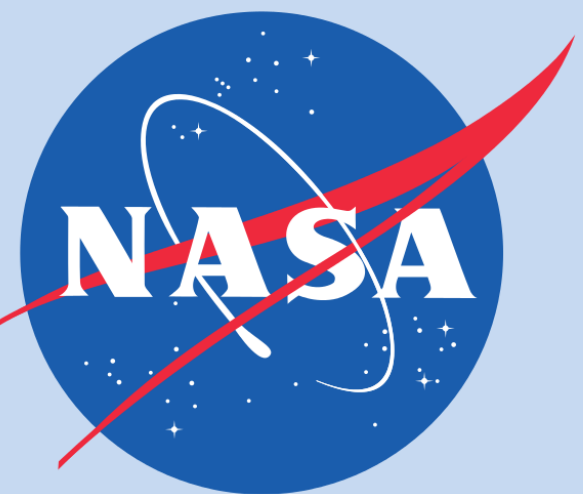


TEMPO-Powered Digital Twin: Real-Time Wildfire Mapping and Air-Quality Intelligence for the Western U.S.

(NASA 24-TEMPOACX24-0058, Transforming Wildfire and Air Quality Management with TEMPO-Powered Digital Twin)

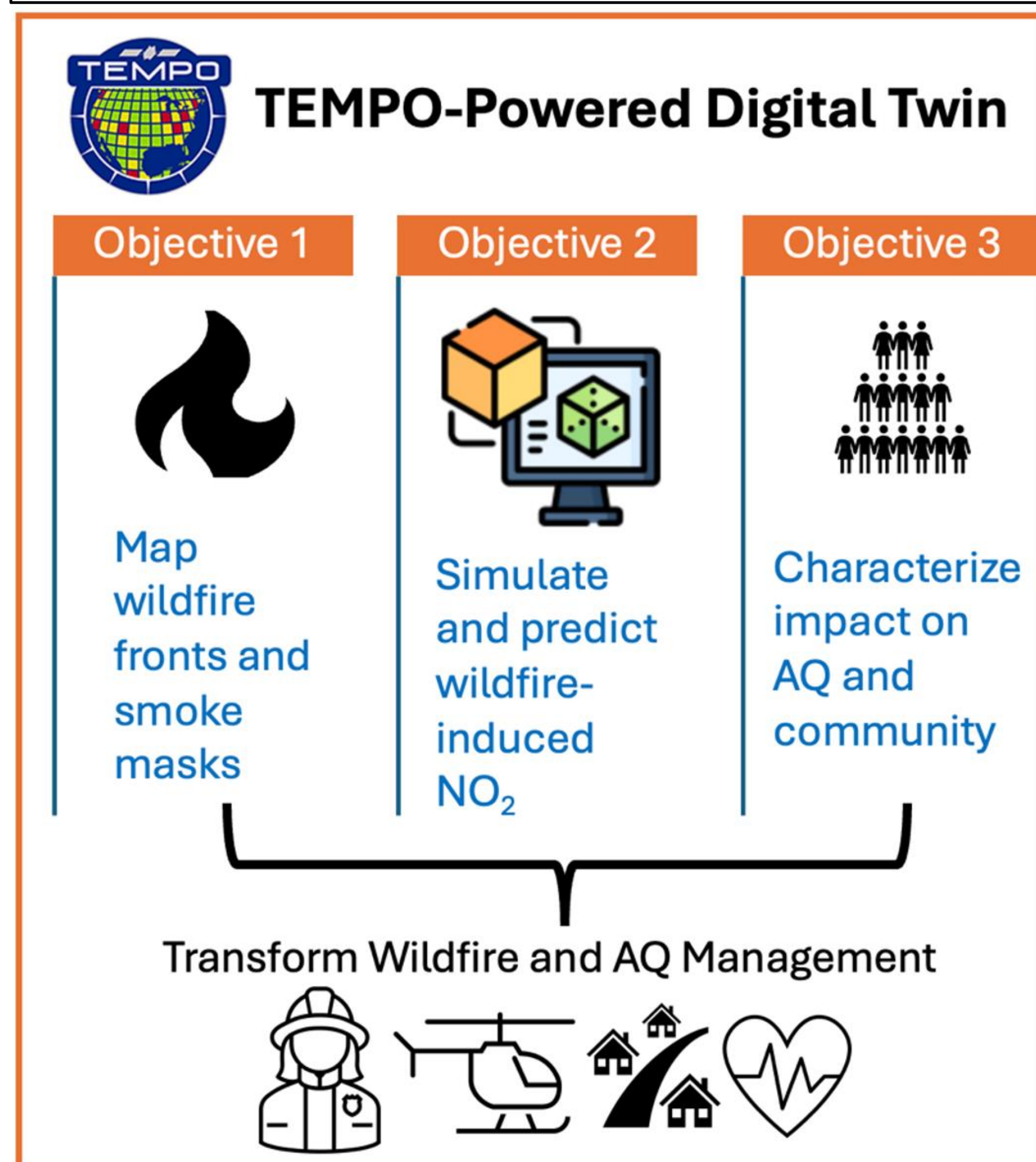
PI: Xiaohua Pan (ADNET SYS / NASA GSFC)

Co-Is: Hugo Lee (JPL), Nicholas LaHaye (Spatial Informatics Group/JPL), Thilanka Munasinghe (RPI)



Project objectives

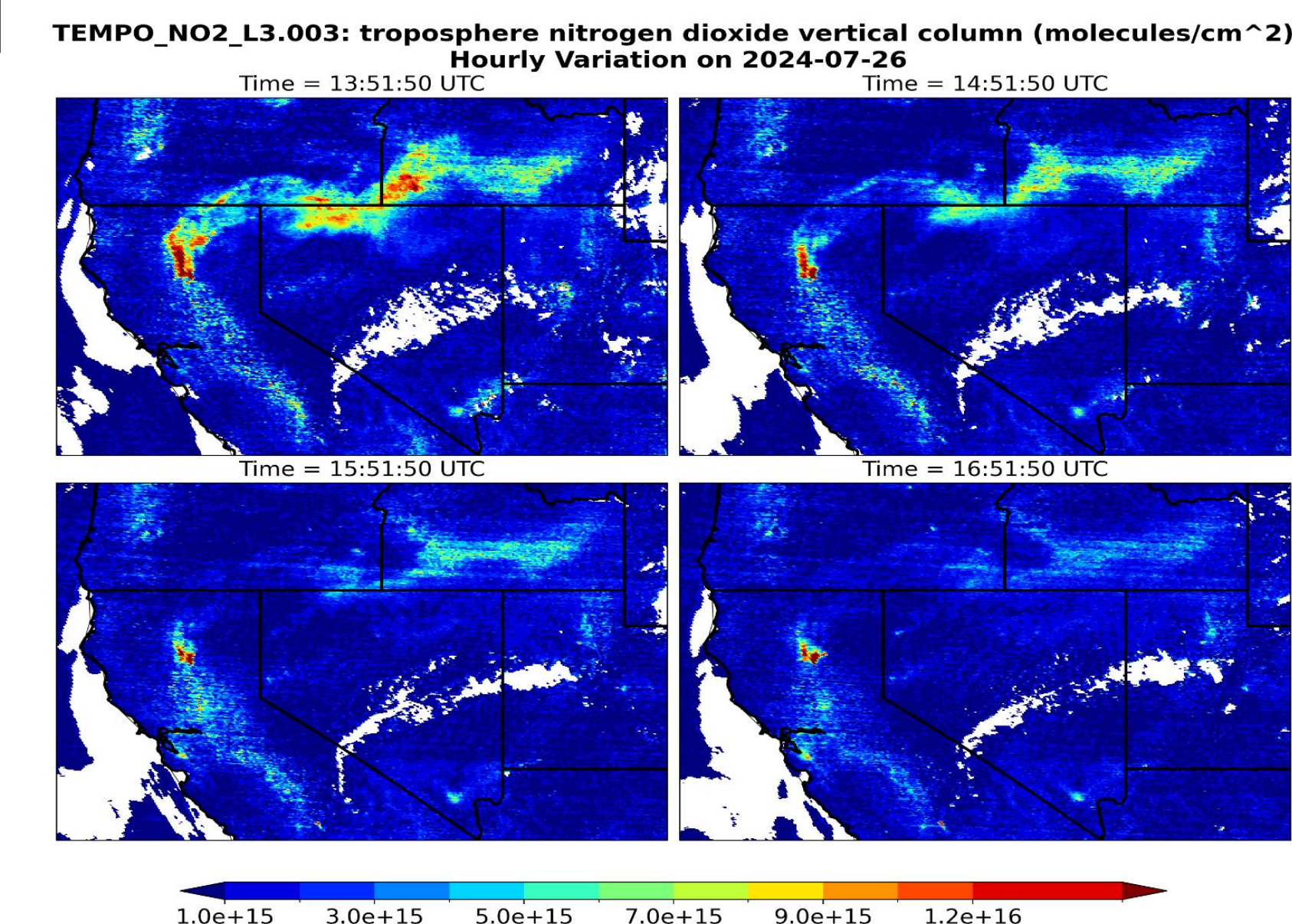
- To leverage the potential of TEMPO data, this project is structured around three integrated objectives. This multi-pronged approach is designed to convert TEMPO observations into actionable intelligence, directly addressing key scientific questions and societal needs related to wildfire management in the western U.S.



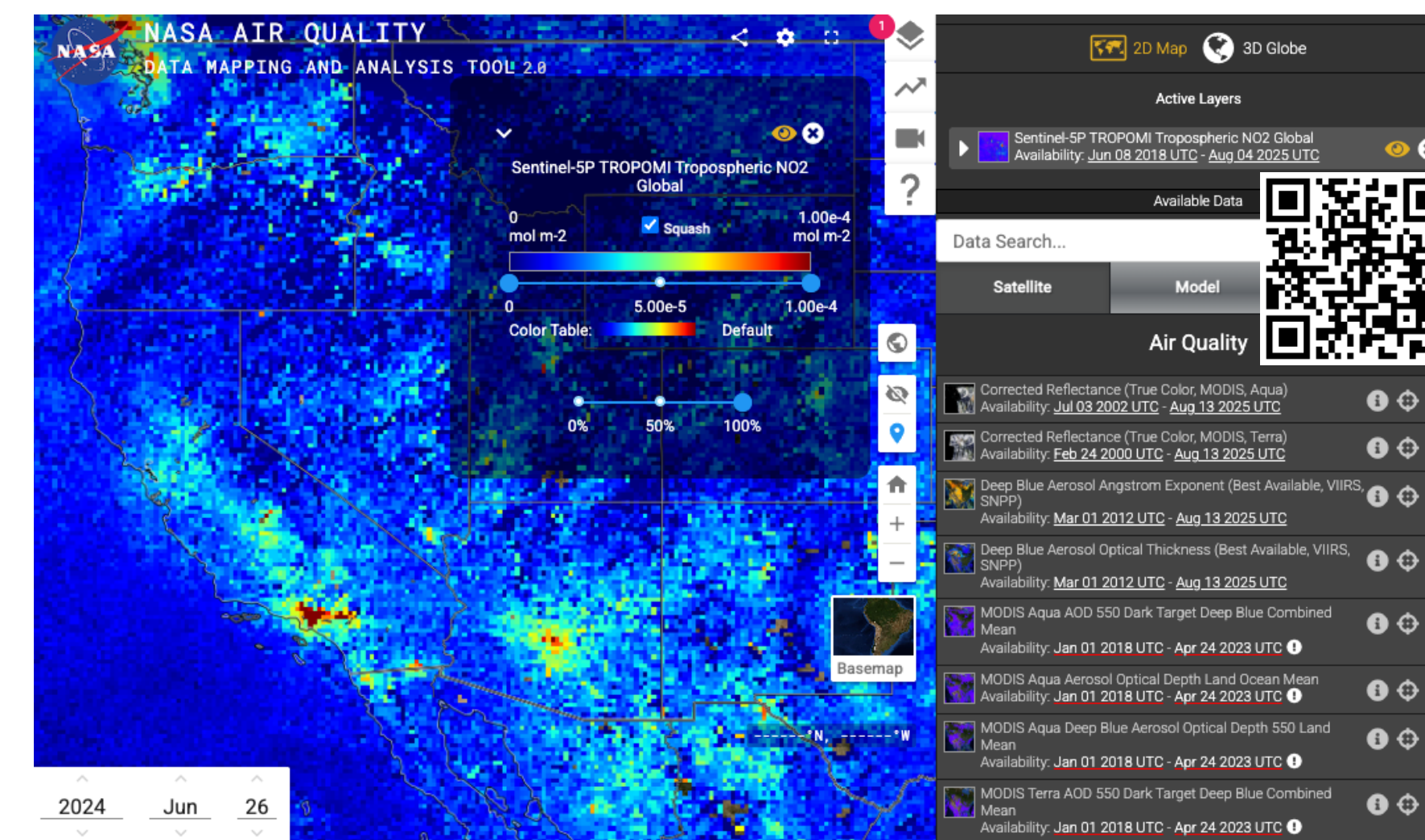
- Objective 1. (Map)** Develop value-added TEMPO data products that map the hourly spread of wildfire fronts and associated smoke plume masks in near-real time. This objective focuses on enhancing the core data and providing immediate situational awareness.
- Objective 2. (Predict)** Create and implement a novel predictive modeling framework to forecast hourly, wildfire-induced near-ground NO₂ concentrations with a lead time of several hours. This objective moves from observation to predictive intelligence.
- Objective 3. (Characterize & Impact)** Utilize the products from the first two objectives to conduct detailed data analysis, characterizing wildfire events, their impact on regional air quality, and the specific risks posed to vulnerable communities.

Project's schedule and key deliverables

Objectives	Year 1	Year 2	Year 3
O1: Mapping	Map 2023-2024 wildfire fronts & smoke masks.	Extend mapping to 2025 fires; develop NRT system.	Finalize and archive L3 hourly products.
O2: Prediction	Construct Wildfire KGs; build initial GDL model.	Tune KGs; enable GDL predictive capability.	Finalize Digital Twin integration and visualization.
O3: Characterization	Characterize 2023-2024 fires & community impacts.	Extend characterization to 2025 fires.	Finalize analysis and publish findings.



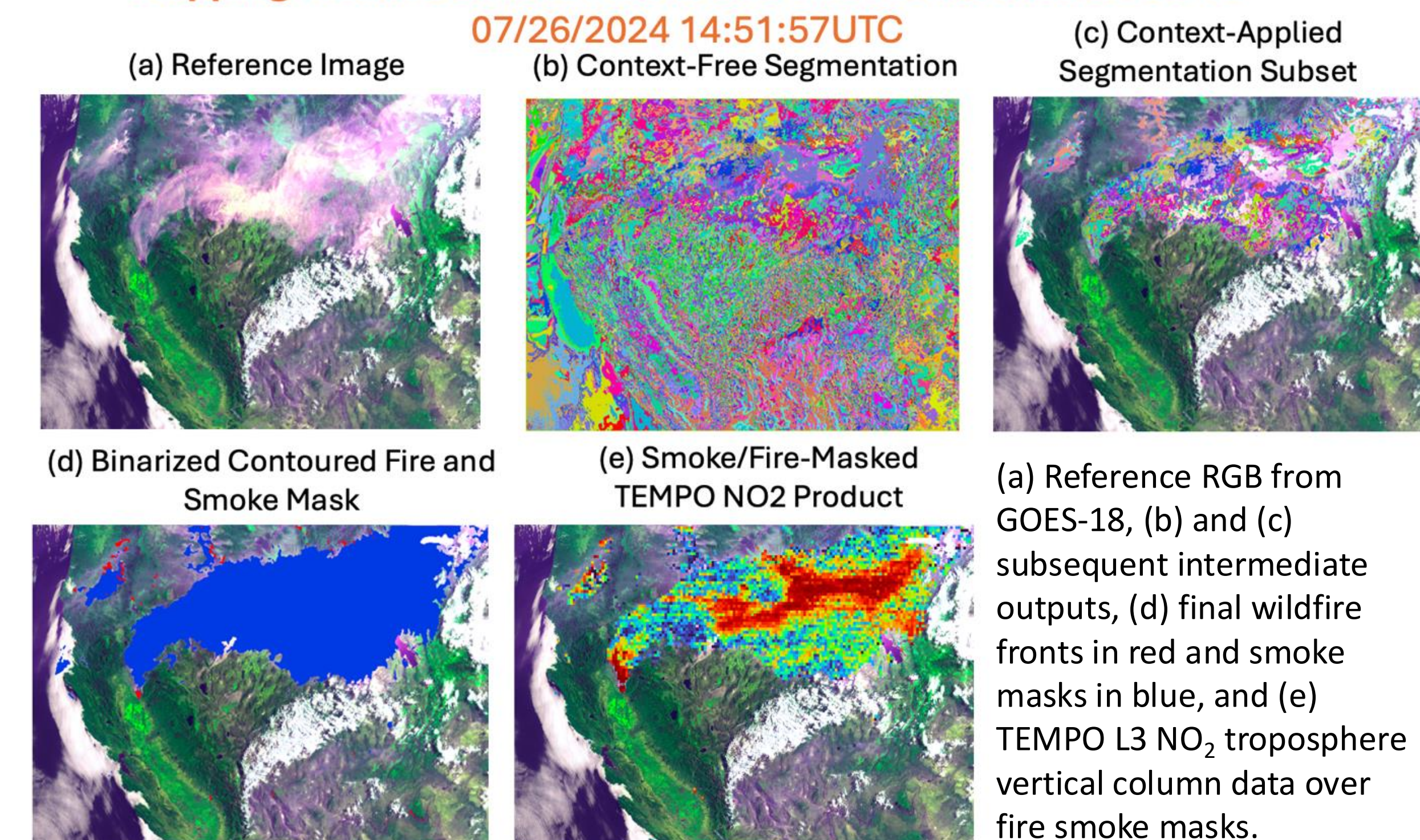
Fire Alarm Digital Twin (<https://ideas-digitaltwin.jpl.nasa.gov/airquality/>)



Wildfire & Smoke Mapping using SIT-FUSE

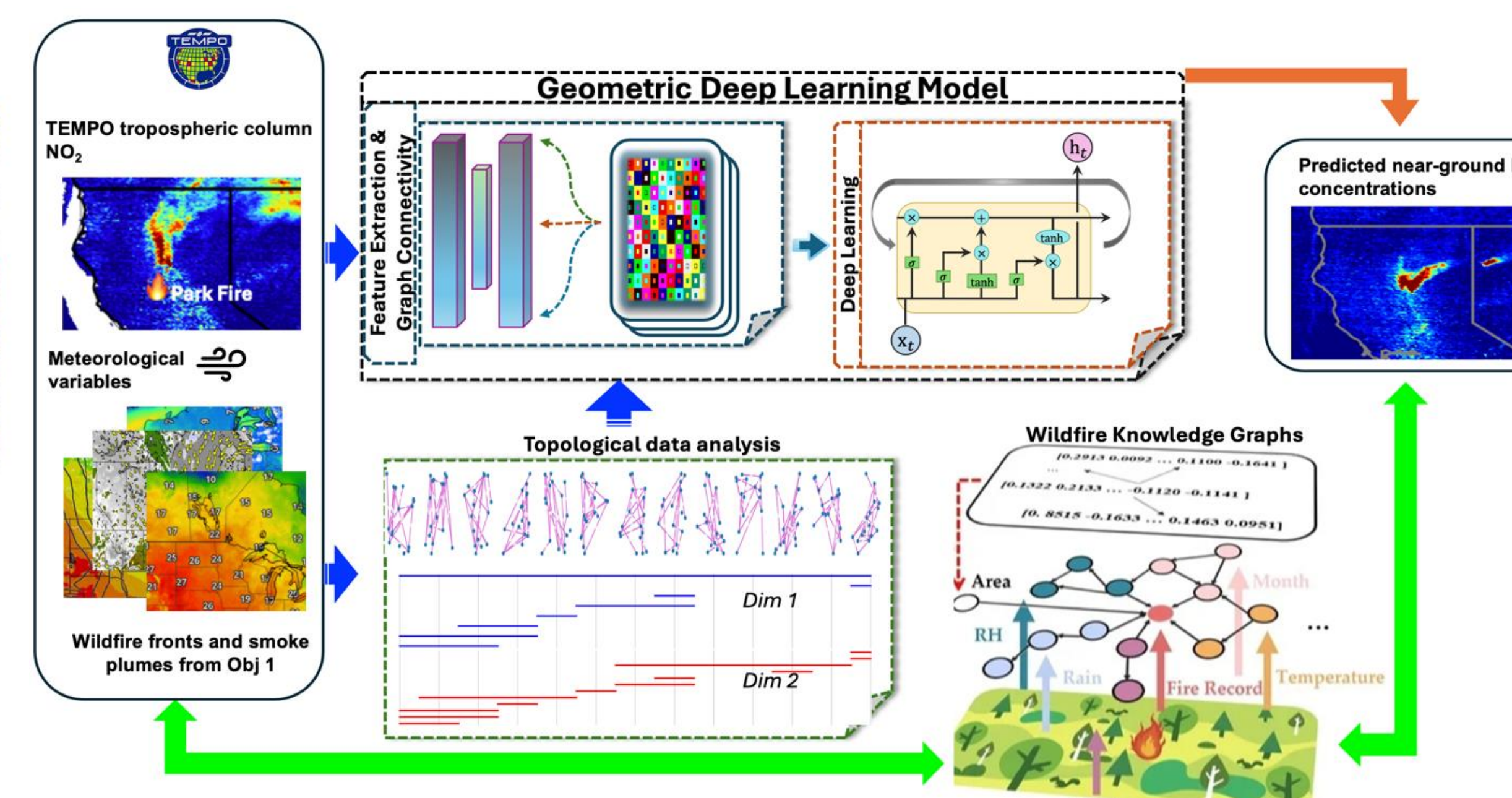
- Segmentation, Instance Tracking, and data Fusion Using multi-Sensor imagery (SIT-FUSE; <https://software.nasa.gov/software/NPO-52538-1>; LaHaye et al., 2025) is an open-source self-supervised Deep Learning (DL) framework to generate hourly products that map wildfire fronts and smoke plumes.
- The system is designed to ingest and fuse radiance data from multiple satellite sensors—including TEMPO, GOES-18 ABI, and JPSS-2 VIIRS—and its self-supervised nature allows for highly accurate detection and segmentation even when limited or no pre-existing labeled data is available.

Mapping Wildfire Smoke Masks and Fire Fronts with GOES-18



Wildfire Knowledge Graph (KG)

- A KG is a network that models real-world entities and their relationships (e.g., hot & dry weather – (is a condition for) -> LA Fire)
- The KG fuses highly diverse, multi-modal data (satellite observations, weather, topographical data, and ground-based observations) into a single, queryable structure.
- KG-powered RAG is a technique that enhances RAG by incorporating knowledge graphs.
- While RAG provides facts, the Knowledge Graph (KG) provides structured understanding.
- The Goal**
 - To capture the complex relationships that drive fire risk and impacts
 - To build a geometric deep learning (DL) model to predict near-ground NO₂ concentrations



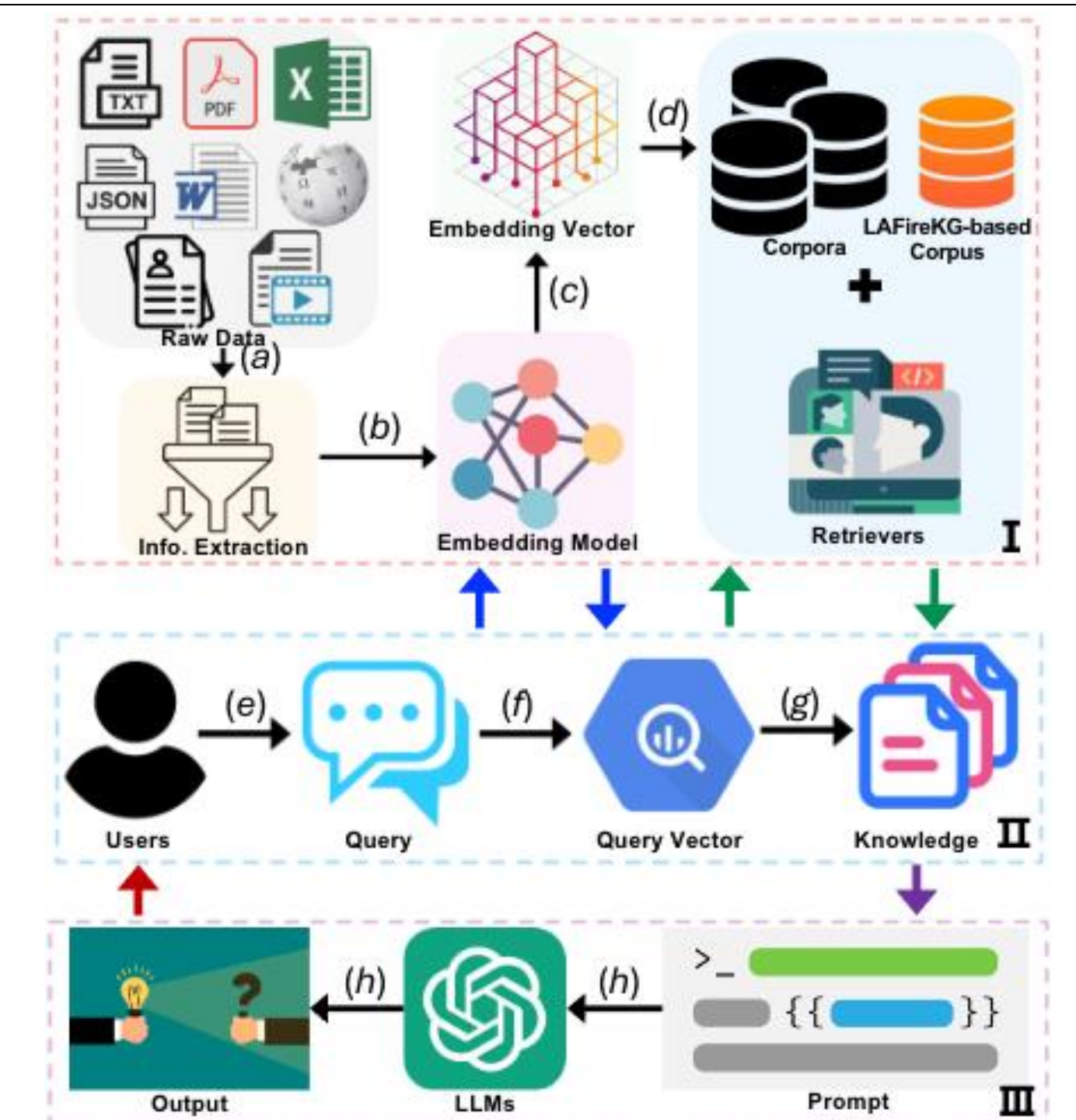
The blue arrows represent inputs, the orange arrows represent the outputs of the GDL model, and the green arrows represent interactions between the geometric deep learning model and Wildfire KGs.

A convergence of three fields

Observations and Simulations	Digital Twins	Generative AI (LLM)
<ul style="list-style-type: none">NO₂ and HCHO observations from TEMPO, TROPOMI, and EPAMeteorological fields from MERRA-2 and GEOS-FPSocial Vulnerability Index	Creates a living, dynamic replica of the environment and generates test conditions to simulate various adverse event and interactions between environment	Delivers the intelligence to reason, interact, and translate data into actionable information for decision makers.

Generative AI User Interface for Fire Alarm Digital Twin

- Large Language Models (LLMs):
 - Excellent at summarizing, translating, and generating human-like texts.
 - Prone to hallucination, static knowledge, lack of domain-specific expertise, and biases from training data
- Retrieval-Augmented Generation (RAG):
 - Retrieves data from a trusted, up-to-date knowledge base before generating a constrained answer
 - Early applications (e.g., [ChatClimate.ai](https://www.openai.com/chatgpt)) demonstrate the capability of LLMs to summarize and interpret IPCC reports.



The LAFire KG schema from "Cyberinfrastructure Platform LAFireKG: Learning from Los Angeles Fires with Knowledge Graphs, Remote Sensing, and Large Language Models"

Multiple AI agents

<https://kg-kdd-bot.onrender.com/>

Your Chat Assistant

What kind of questions can you answer?

I can answer questions specifically about the content, methods, findings, and implications presented in the paper "A Lesson from LA Fires: Can Knowledge Graphs Help to Mitigate the Risks?" by Chen et al. (2025). This includes, but is not limited to:

- Summarizing sections, figures, and tables from the paper
 - Explaining the construction and structure of the wildfire knowledge graph (WKG)
 - Detailing the methods used, such as topological data analysis or machine learning approaches
 - Interpreting experimental results and metrics
 - Listing and explaining subject-relation-object triples extracted from wildfire-related literature
 - Discussing the roles of entities and relations in the WKG (e.g., how "wildfire risk" relates to "california" or "climate change")
 - Describing the implications for wildfire risk assessment, insurance, and policy
 - Providing concise explanations or more detailed breakdowns of any part of the paper as requested
- If your question pertains to these topics or any specific content from the paper, I can provide a detailed, cited answer. If your question is outside the scope of this paper, I will let you know accordingly (Section 1; Figure 1, p. 2).

Explore Climate Intelligence

Dashboard for NEX-GDDP-CMIP6

What kind of questions can you answer?

