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Advancing Wildfire Monitoring with TEMPO and ML tools: Hourly Smoke and Fire-Front Mapping and Near-Surface NO_2 Predictions

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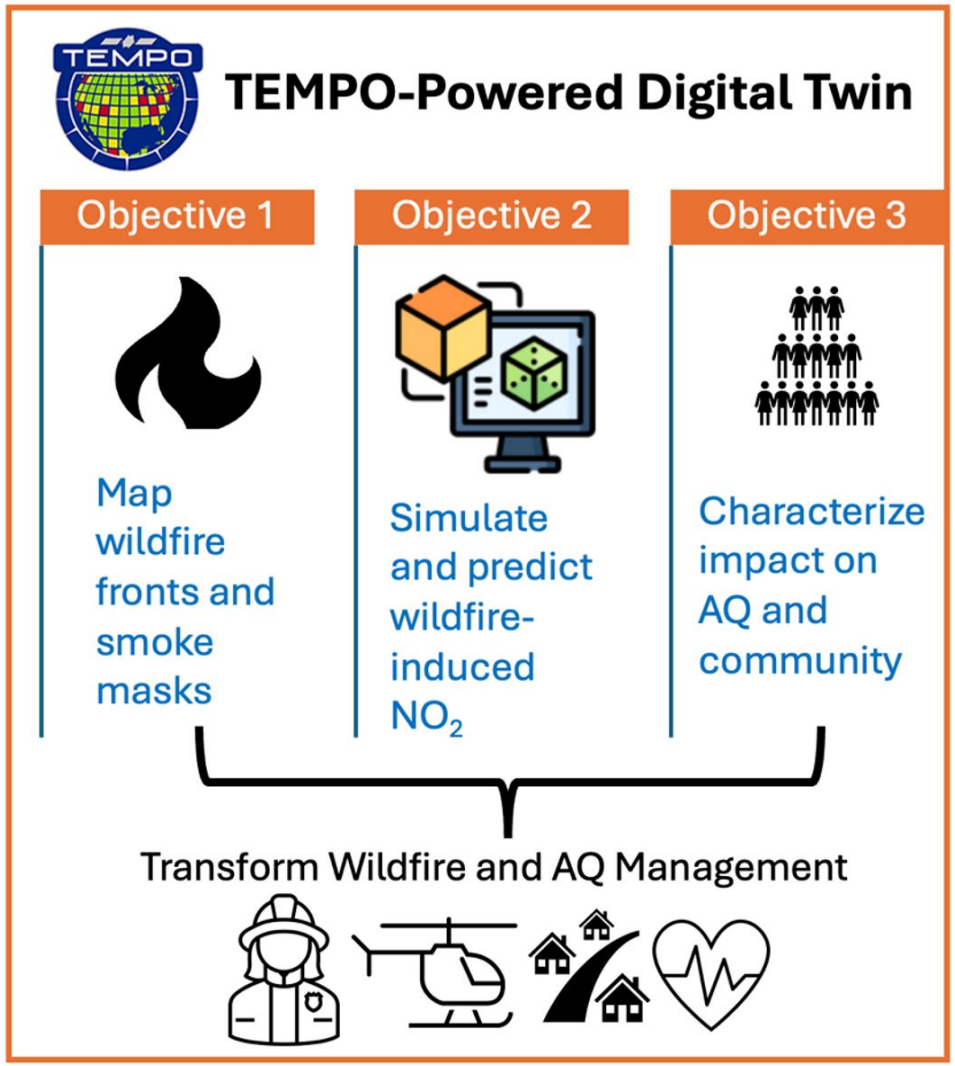
TEMPO DART meeting June 15-18, 2026

Objectives



Overall Objective:

- Leveraging TEMPO data's unprecedented advantages and advanced technologies (e.g., machine learning)
- Enabling TEMPO data to the action

Social Benefit:

- Transforming wildfire and AQ management by helping issuing timely and accurate wildfire watches and air quality warnings.
- Consequesnlty, helping protect lives and property in wildfire-prone areas of North America, focusing particularly on vulnerable communities.

Stakeholders:

- Wildfire and AQ management agencies, such as FEMA.

The concrete deliverables

1. Hourly level 3 **wildfire smoke plume mask** product, a value-added product for TEMPO.
2. Hourly level 3 **wildfire front maps product**, another value-added product for TEMPO.
3. Hourly **predicted wildfire-induced near-ground NO2 outputs** with a few hours of lead-time.
4. The TEMPO-powered Digital Twin (DT) platform that can integrate and **visualize the products** from 1), 2), and 3).
5. **Characterizations of wildfire's impacts** using the social vulnerability index (SVI).

TEMPO datasets used in our project

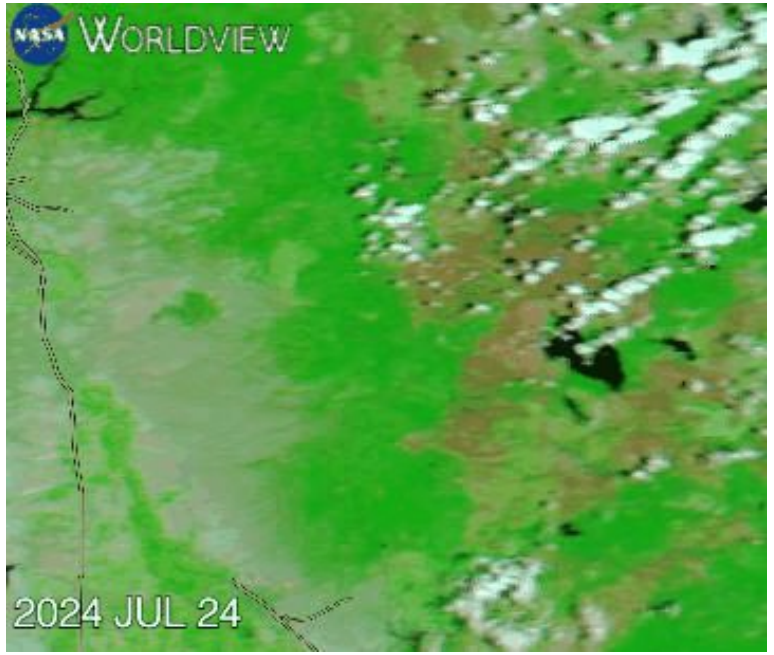
- **Spatial coverage:** Western U.S. and Park Fire in 2024 for this presentation
- **Collections:** TEMPO_NO2_L3 and TEMPO_RAD_L1
- **Version:** 3

Case Study: 2024 Park Fire, CA

- Burned from 2024/07/24 to 2024/09/26
- Burned about **429,603 acres** (≈1,739 km², about 2.2 times the size of New York City, Fourth-largest wildfire in California history)
- **Over 700 structures** destroyed or damaged
- Firefighting alone cost about **$351 million**

Date (2024)	Fire size	What happened
July 24	ignition	Fire started near Bidwell Park close to Chico.
July 25	~45,000 acres	Rapid spread through dry grass and brush.
July 26	~164,000 acres	Explosive growth; strong winds pushed fire northeast.
July 27	~307,000 acres	Became one of the fastest-growing fires in CA history.
July 28	~350,000 acres	Continued expansion into Tehama County forests.
July 29	~358,000 acres	Large pyrocumulus clouds visible from satellites.
July 31	~392,000 acres	Fire perimeter stabilized somewhat as crews increased containment.

Corrected Reflectance (Bands 7-2-1) Aqua/MODIS



Link: https://go.nasa.gov/4bjnolF

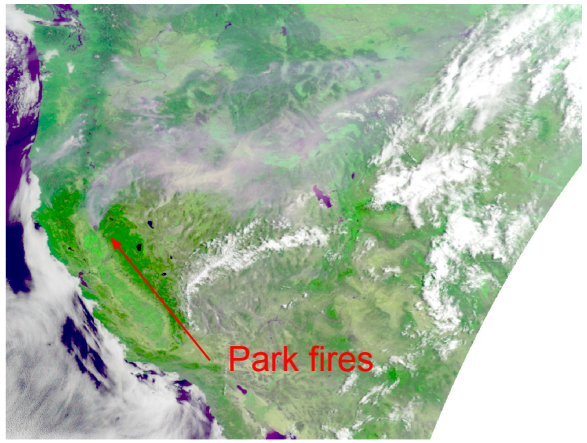
Obj 1: Map the hourly spread of the wildfire smoke plume masks and wildfire fronts in NRT

Led by Nicholas LaHaye

Hourly Wildfire Smoke Masks

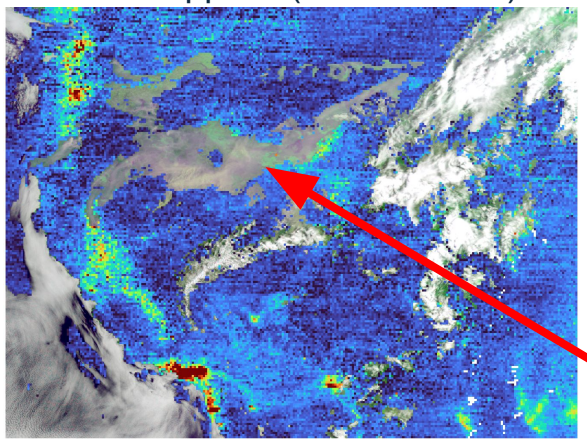
RGB

GOES-18 RGB on July 26, 2024
Time = 16:01 UTC



Before our work

TEMPO NO2 with Operational Cloud Mask Applied (0.2 threshold)

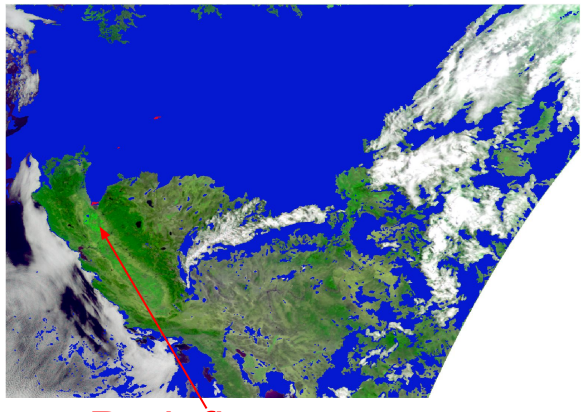


Method: SIT-FUSE Binary Smoke and Fire Mask

Thick smokes are misclassified as clouds

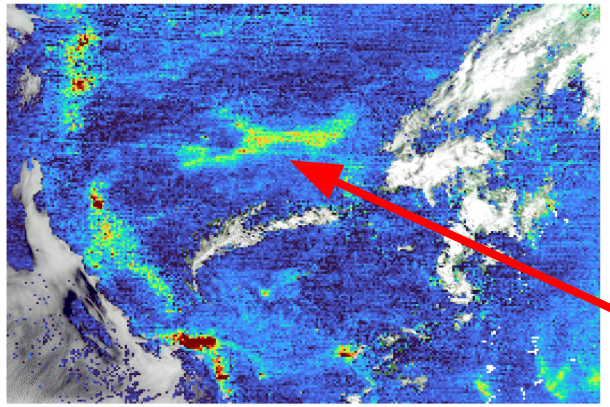
Smoke mask developed by our project

SIT-FUSE Binary Smoke and Fire Mask on GOES-18 Image

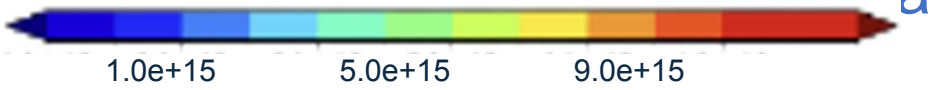


After our work

Smoke and Fire Masked TEMPO NO2 (From our Project)



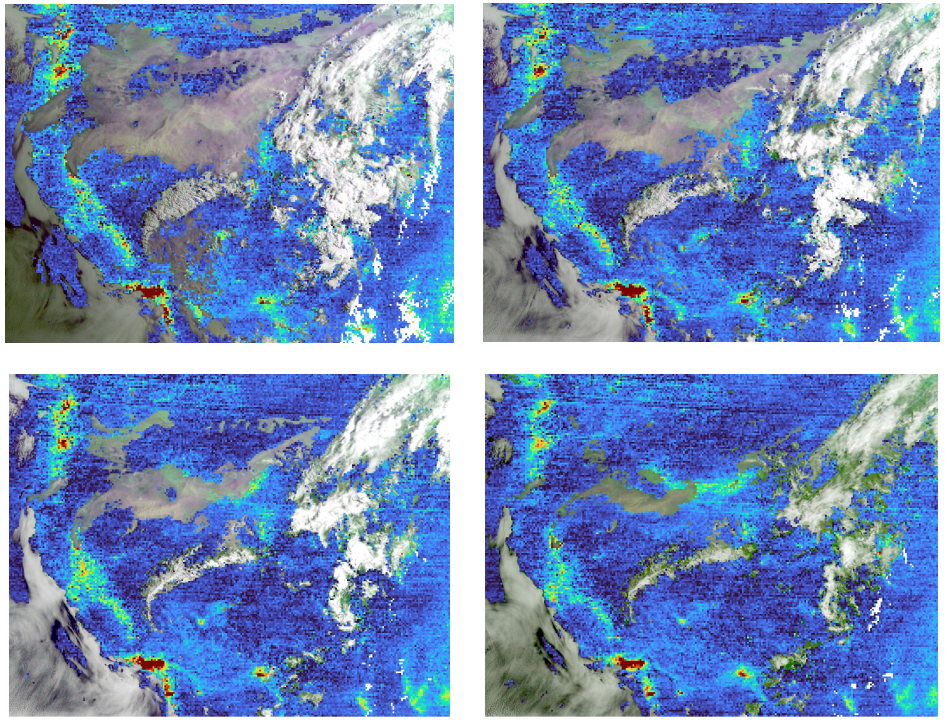
NO2 (Molecules cm^2)



NO2 are restored after applying smoke masks

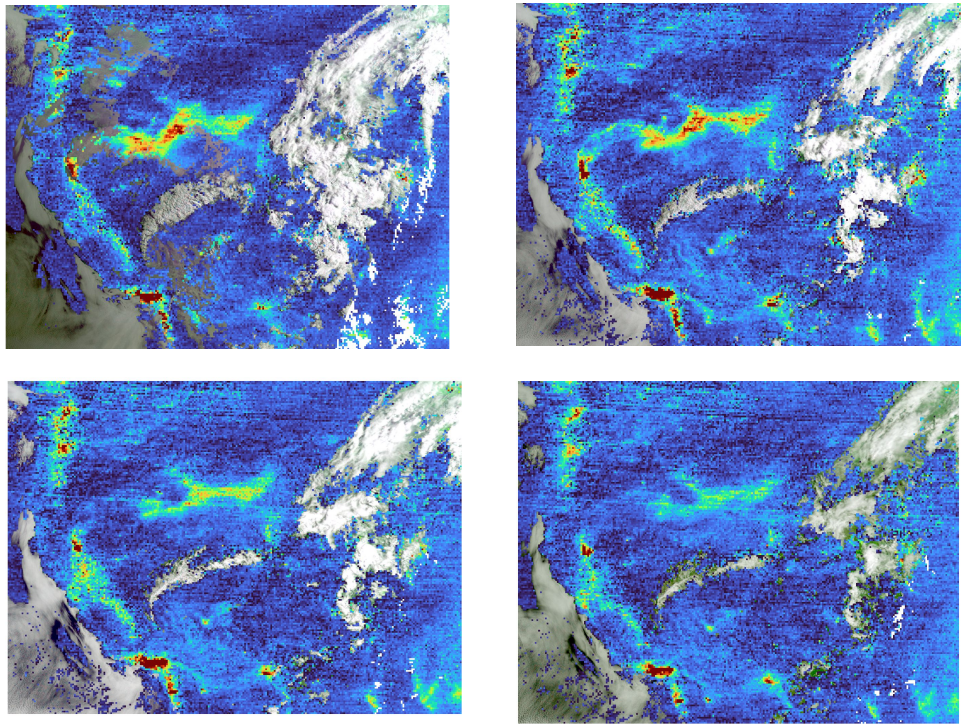
Hourly Evolution of TEMPO Trop. NO2

Before applying smoke masks



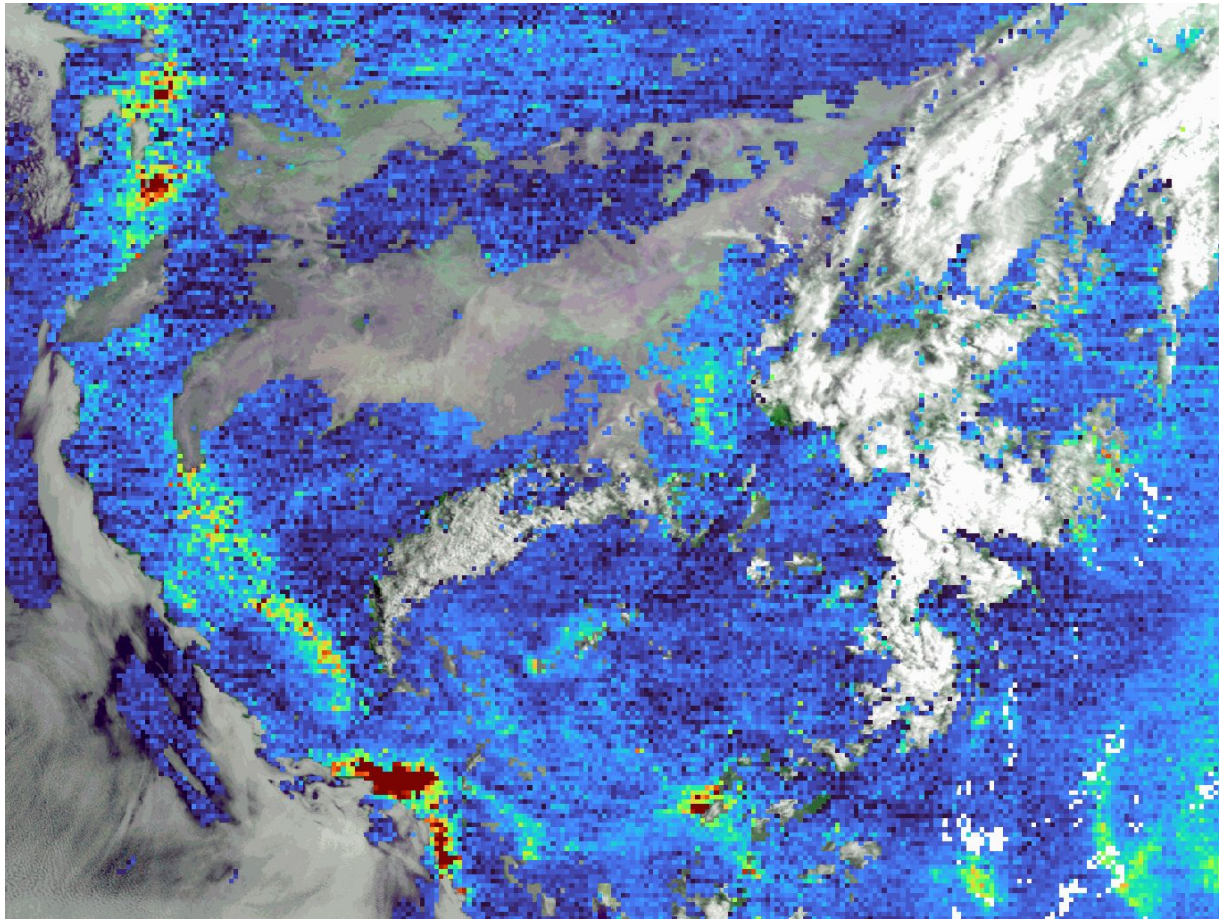
4 time sequences from 13:51 UTC to 16:51 UTC on July 26, 2026

After applying smoke masks

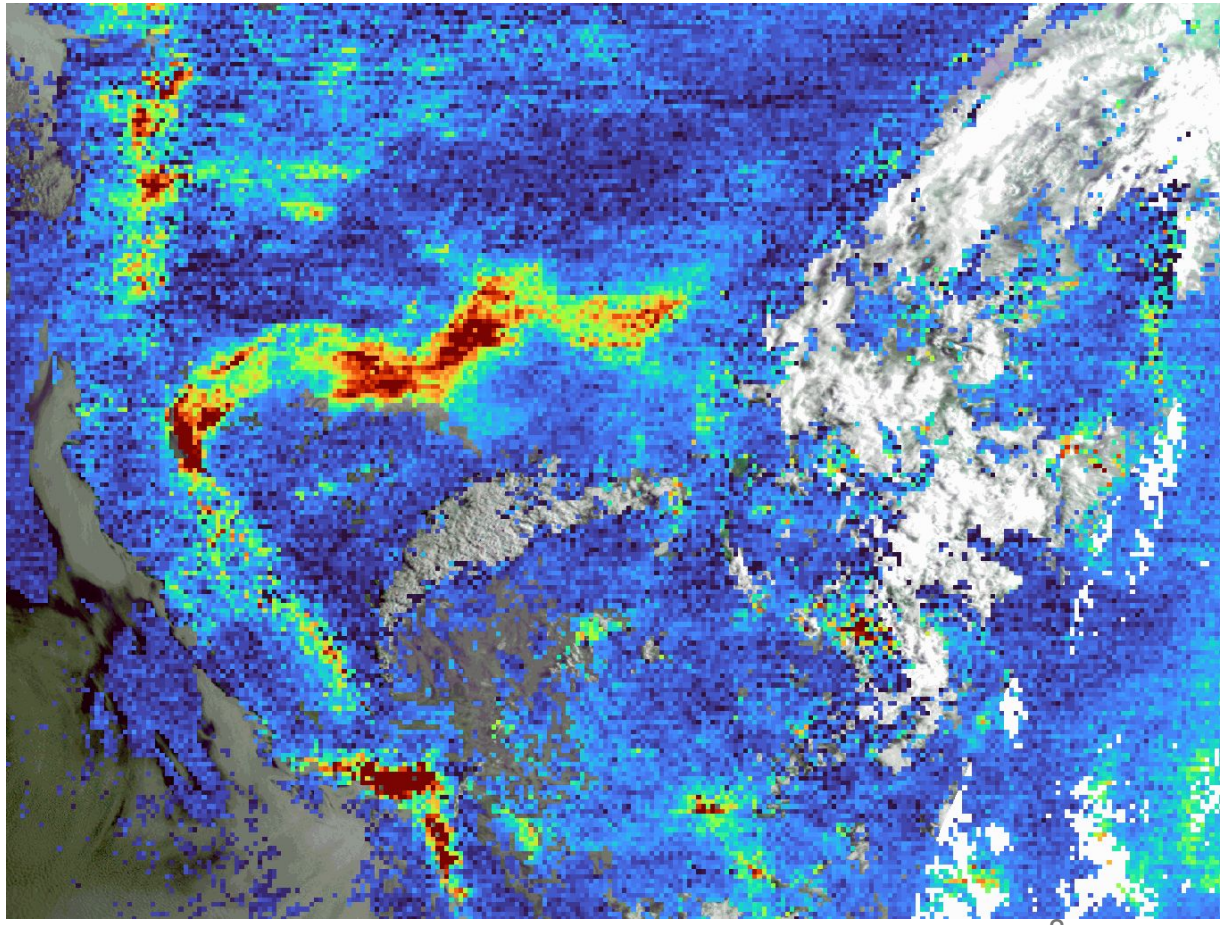


Hourly Evolution of TEMPO Trop. NO2

Before applying smoke masks

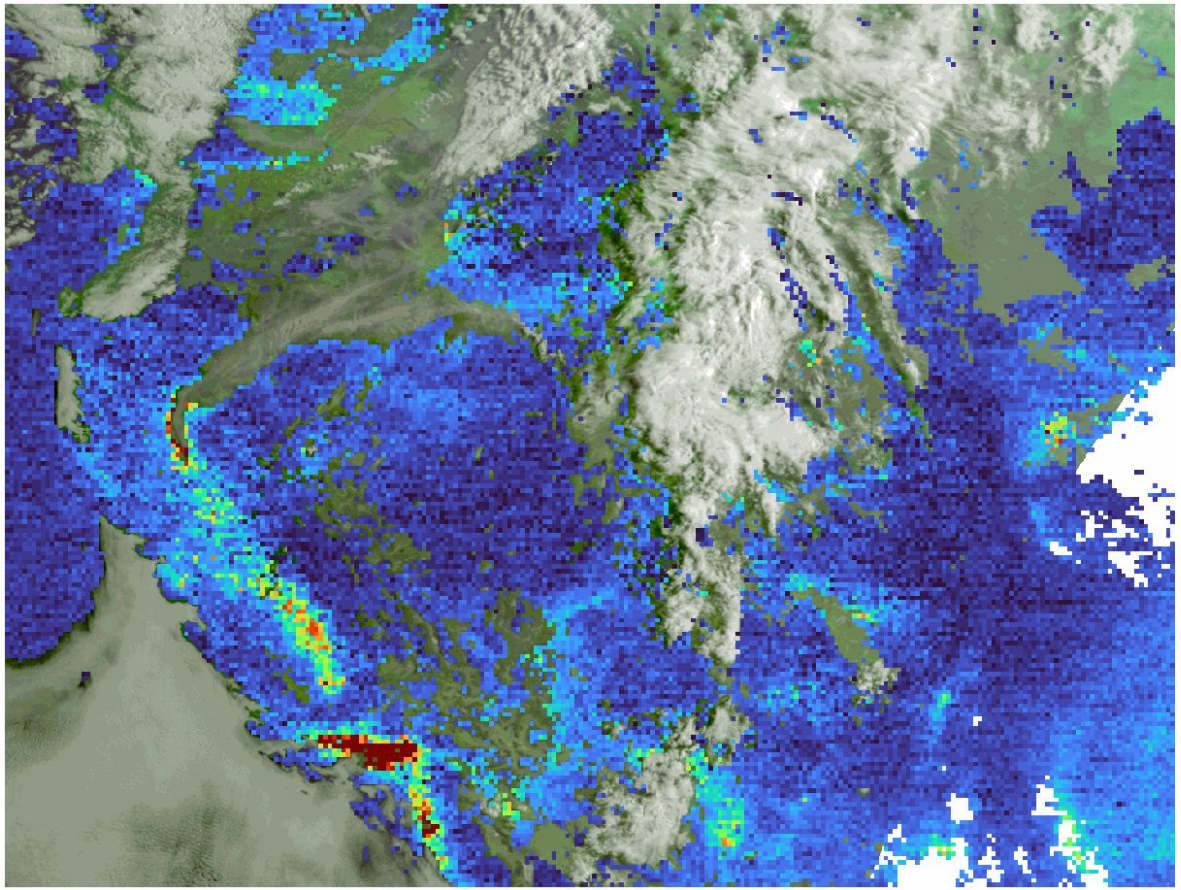


After applying smoke masks

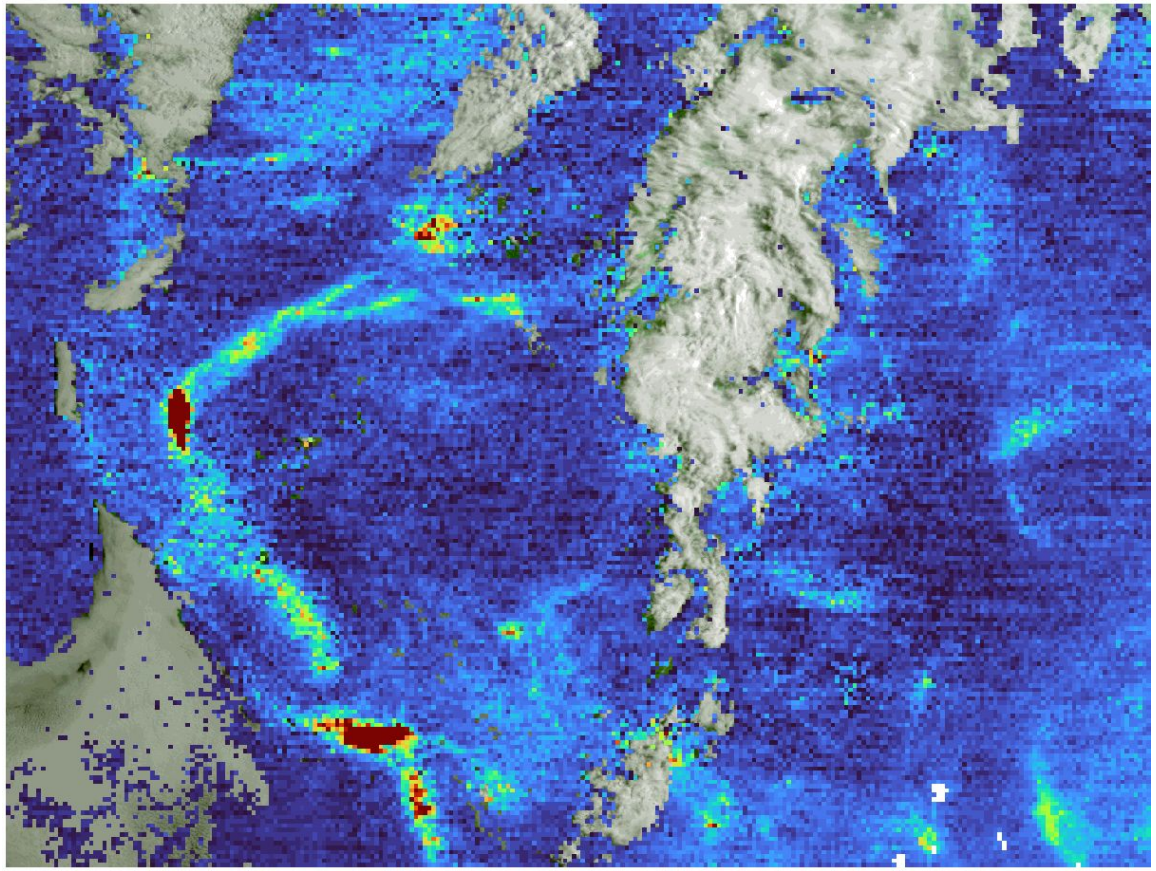


Hourly Evolution of TEMPO Trop. NO2

Before applying smoke masks



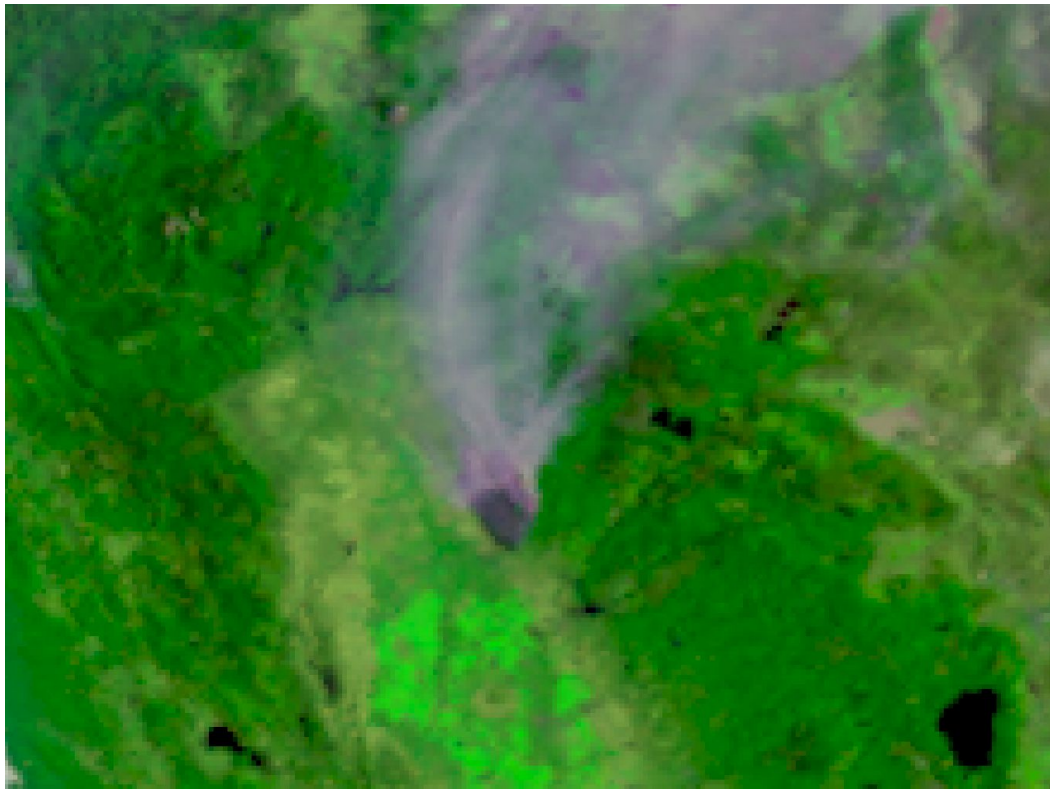
After applying smoke masks



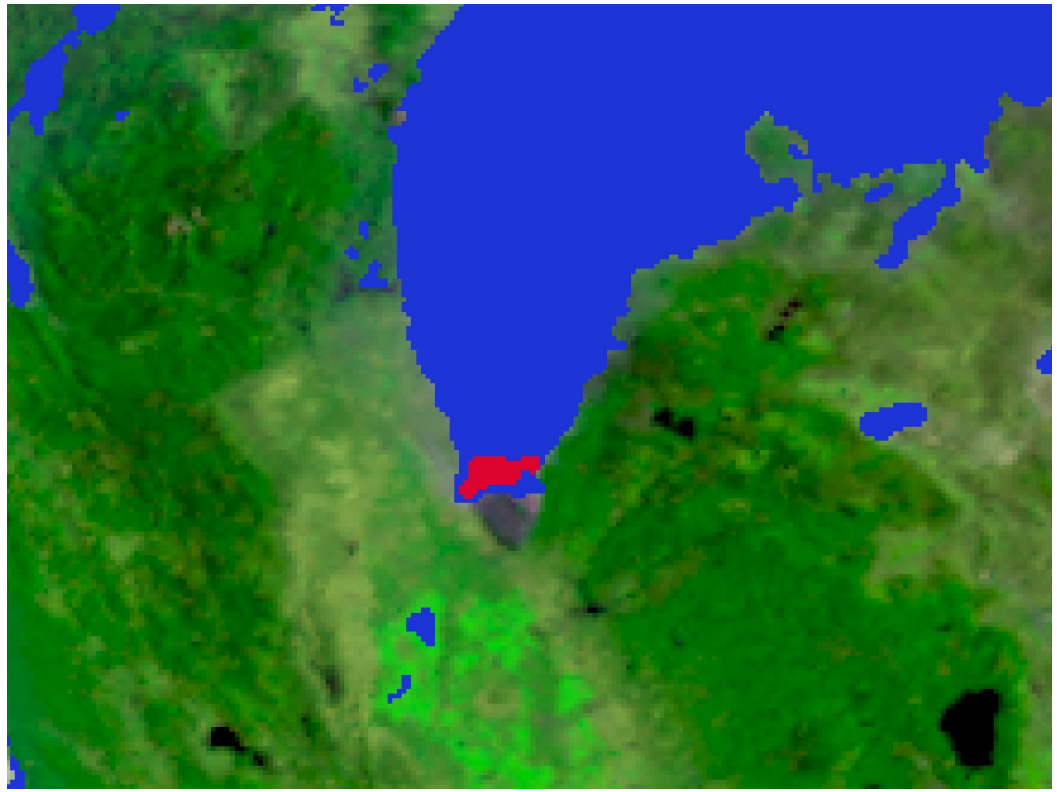
Hourly Evolution of Wildfire Fronts + Smoke Masks

2024/07/26 16:00 UTC - Fire front + Smoke

RGB



Wildire fronts + Smoke masks



Hourly Evolution of Wildfire Fronts + Smoke Masks

- Animation of July 25 to July 26

RGB

Wildire fronts + Smoke masks

Obj 2: Predict hourly wildfire-induced near-ground NO2 using foundation model Aurora

Led by Kyo Hugo Lee

Aurora zero-shot: 2-Day Global Forecast without Fine-Tuning

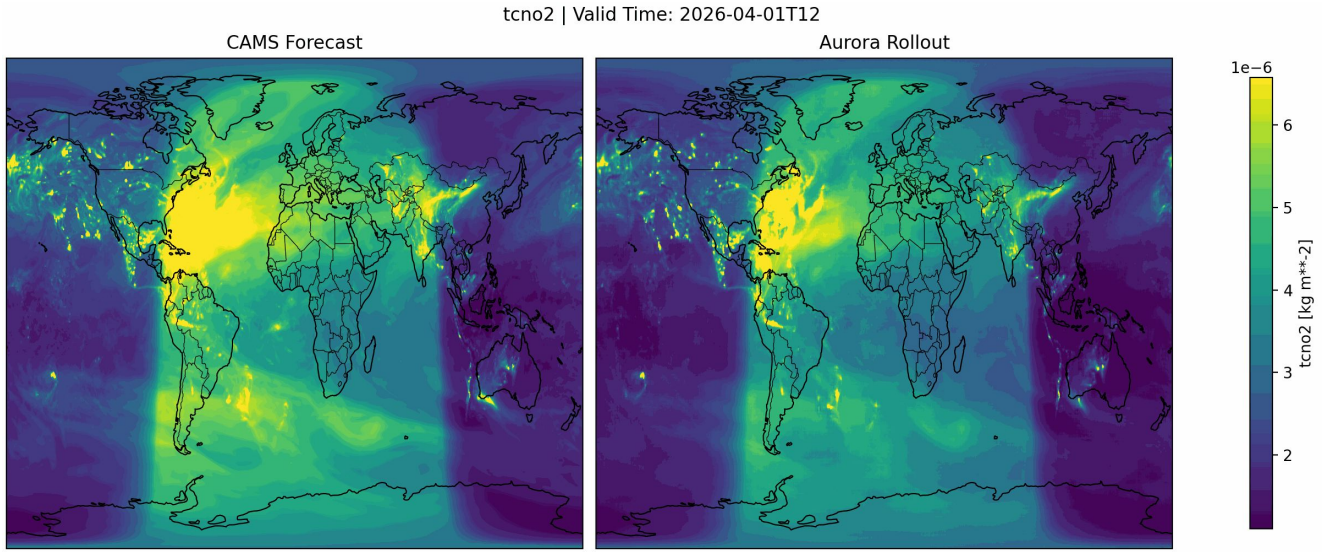
1 **Initial data:** Copernicus Atmosphere Monitoring Service (CAMS) 2026-04-01 00Z

- U10, V10, T2M, SLP
- PM1, PM2.5, PM10, CO, NO, NO2, O3, SO2 column
- U, V, T, Z, qv, CO, NO, NO2, O3, and SO2 at 13 levels (1000–50 hPa)

2 **Steps:** 4 × 12 hours (=2 days)

3 **Model:** pretrained Aurora Air Pollution (0.4°)

4 **Output:** CO, O3, NO, NO2, PM, SO2, U, V, T, Z



Zero-shot rollout workflow

01 **Download CAMS data**
(2026-04-01 initialization & 5-day prediction for validation)

→

02 **Aurora checkpoint**

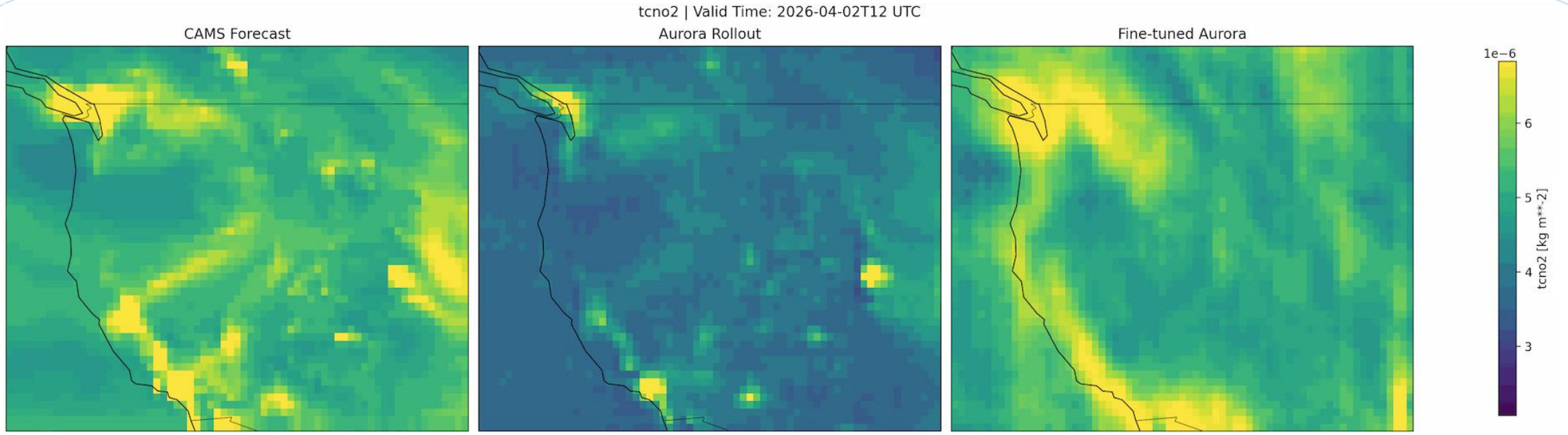
→

03 **Rollout**
(4 steps; 2 days)

→

04 **Save prediction output**
in NetCDF format

Fine-Tuning Results: Improvement with longer training data



- After training the Flow Matching model using 9-month CAMS data, the fine-tuned Aurora output shows better agreement with the CAMS forecast than the Aurora rollout. However, it still does not fully represent fine-scale spatial structures in column NO2.
- Bias correction for both total column NO2 and vertical NO2 profiles at 12 levels remains a significant challenge.

Take-home messages

- **Smoke masks:** By applying the smoke masks developed in our project, we successfully restored TEMPO NO_2 observations over thick smoke plumes.
- **Wildfire fronts:** Our wildfire-front products enable monitoring of the hourly progression of wildfire-burned areas.
- **Predicted wildfire-induced NO_2**: The Aurora foundational model shows promising skill in predicting wildfire-induced NO_2.