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HARVARD & SMITHSONIAN

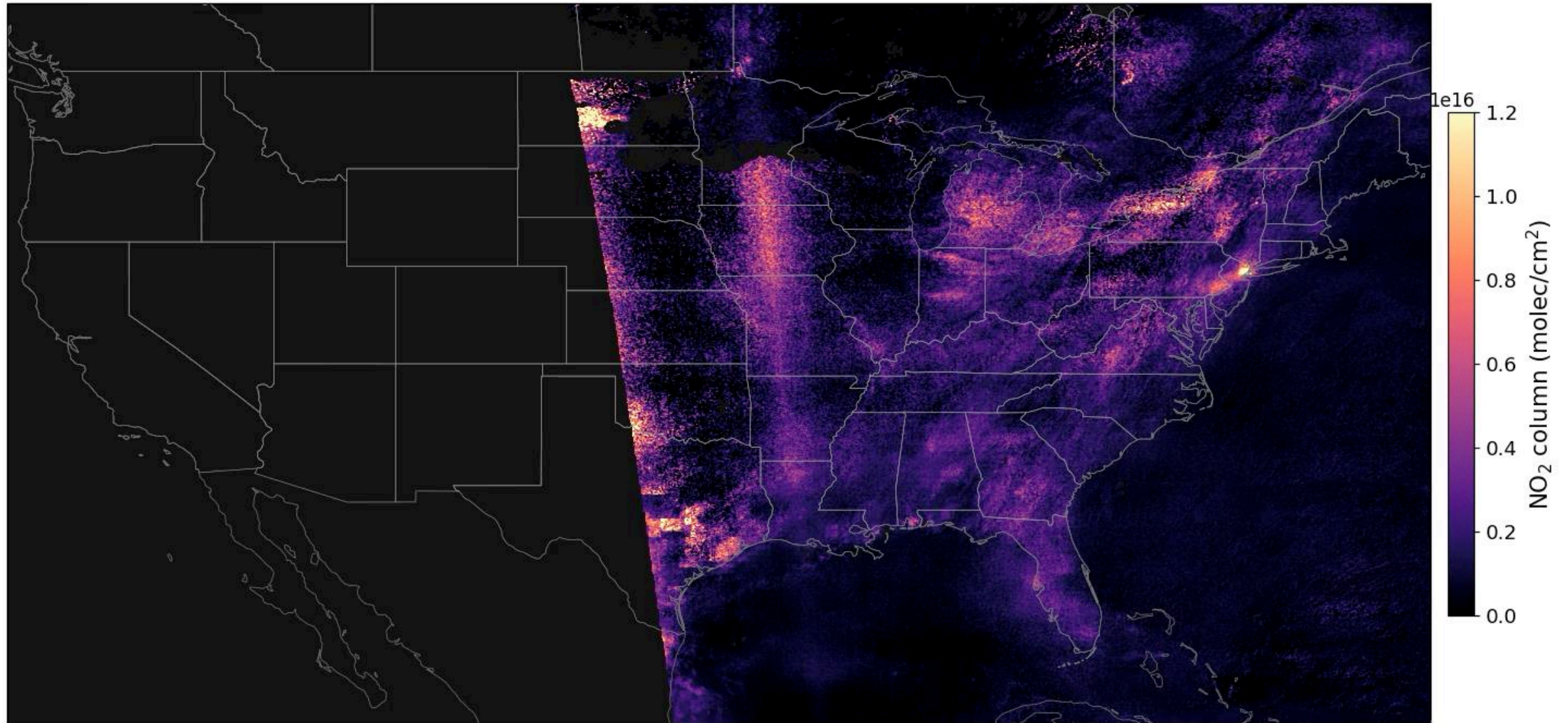
Automated NO₂ Plume Detection Using TEMPO

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Center for Astrophysics | Harvard & Smithsonian

TEMPO observes NO₂ plumes from various sources

CONUS 2026-04-05 11:51 UTC

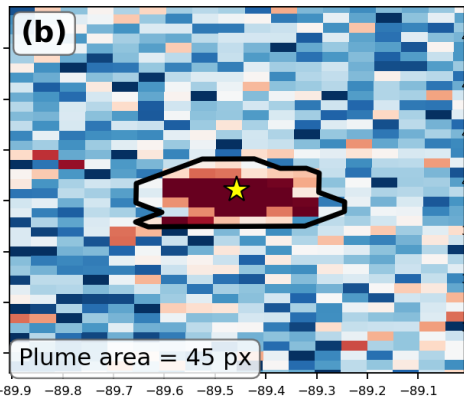
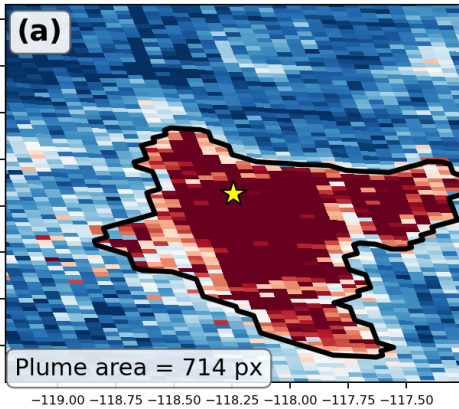


Build an AI model to detect and segment NO₂ plumes from episodic and emerging sources

Persistent sources

Los Angeles Basin
2024-01-16 19:08 UTC

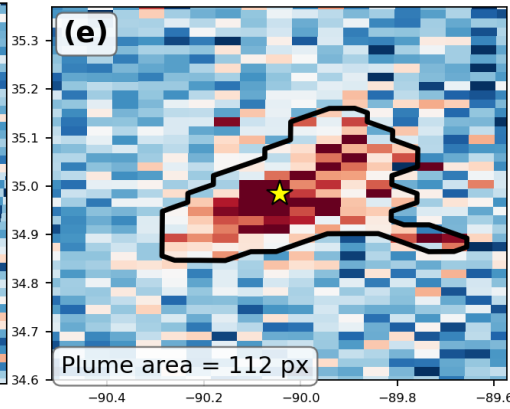
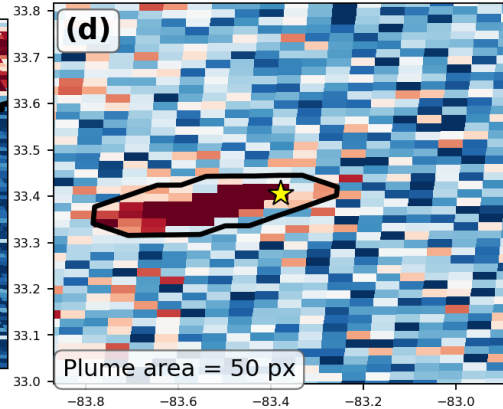
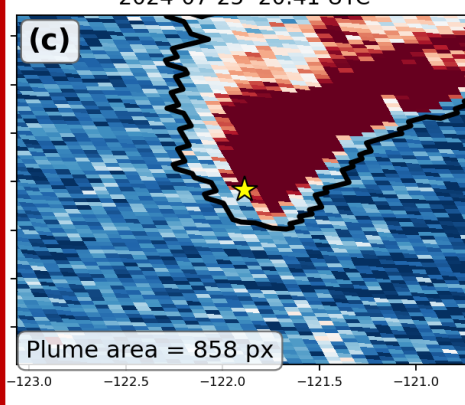
New Madrid Power Plant
2023-08-25 19:00 UTC



Park Fire
2024-07-25 20:41 UTC

Chattahoochee-Oconee National Forest Prescribed Fire
2026-04-08 19:42 UTC

xAI Colossus 2 Power Plant
2026-04-25 22:33 UTC



Episodic / unrecognized sources

Train

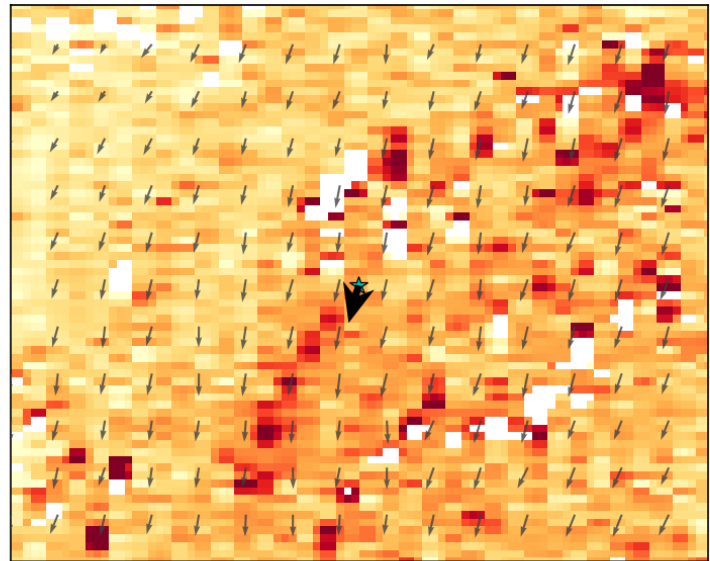
AI segmentation model

Segment

Normalized NO₂ VCD

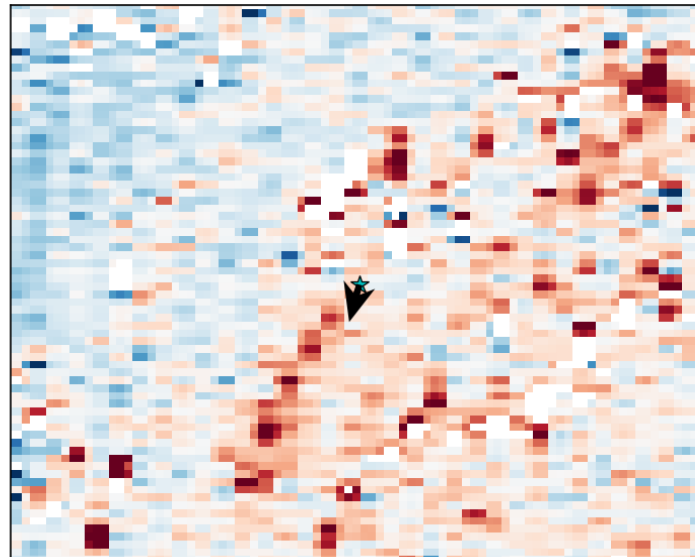
Build the training datasets using CEMS inventoried power plant + cities

TEMPO NO₂ + HRRR wind



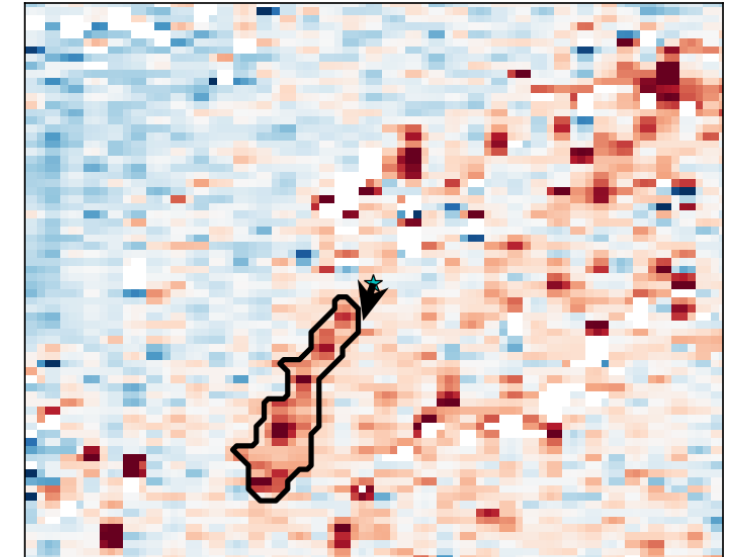
NO₂ VCD [10^{15} molec cm⁻²]

NO₂ enhancement



Δ NO₂ [10^{15} molec cm⁻²]

Plume contour



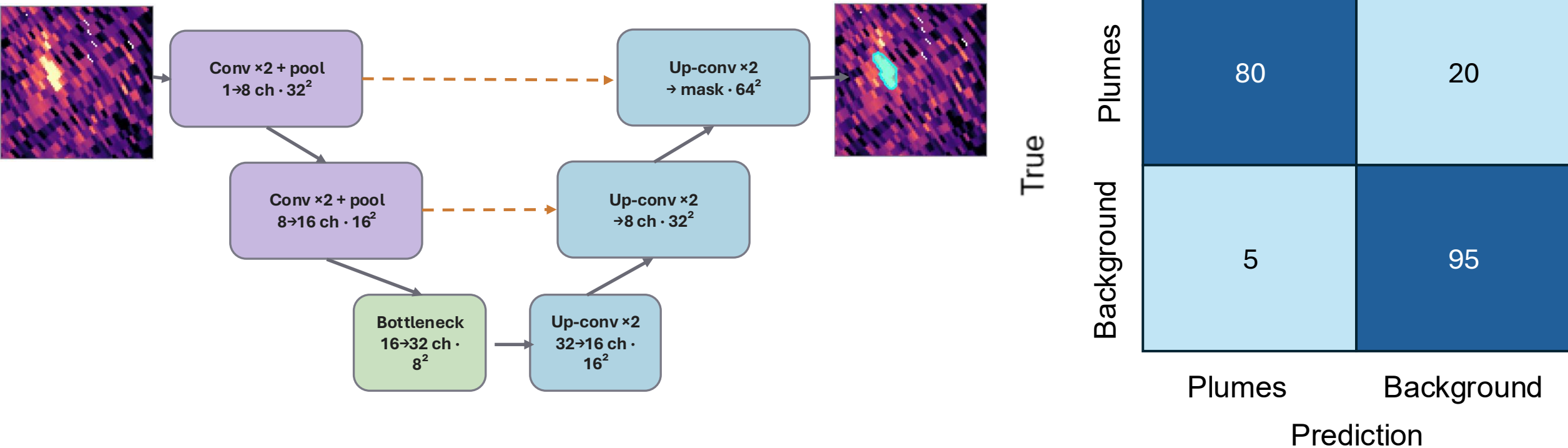
Δ NO₂ [10^{15} molec cm⁻²]

- Estimate background and calculate NO₂ enhancement
- Extract plume composite: pixels $>$ background + 4 \times median absolute deviation
- Post-hoc filtering: (1) $<$ 10 km of the plant location, (2) aligns with the wind direction.

Training datasets: 6K plumes + 6K background from 2024/07 TEMPO L3 V4

Model architecture: U-Net

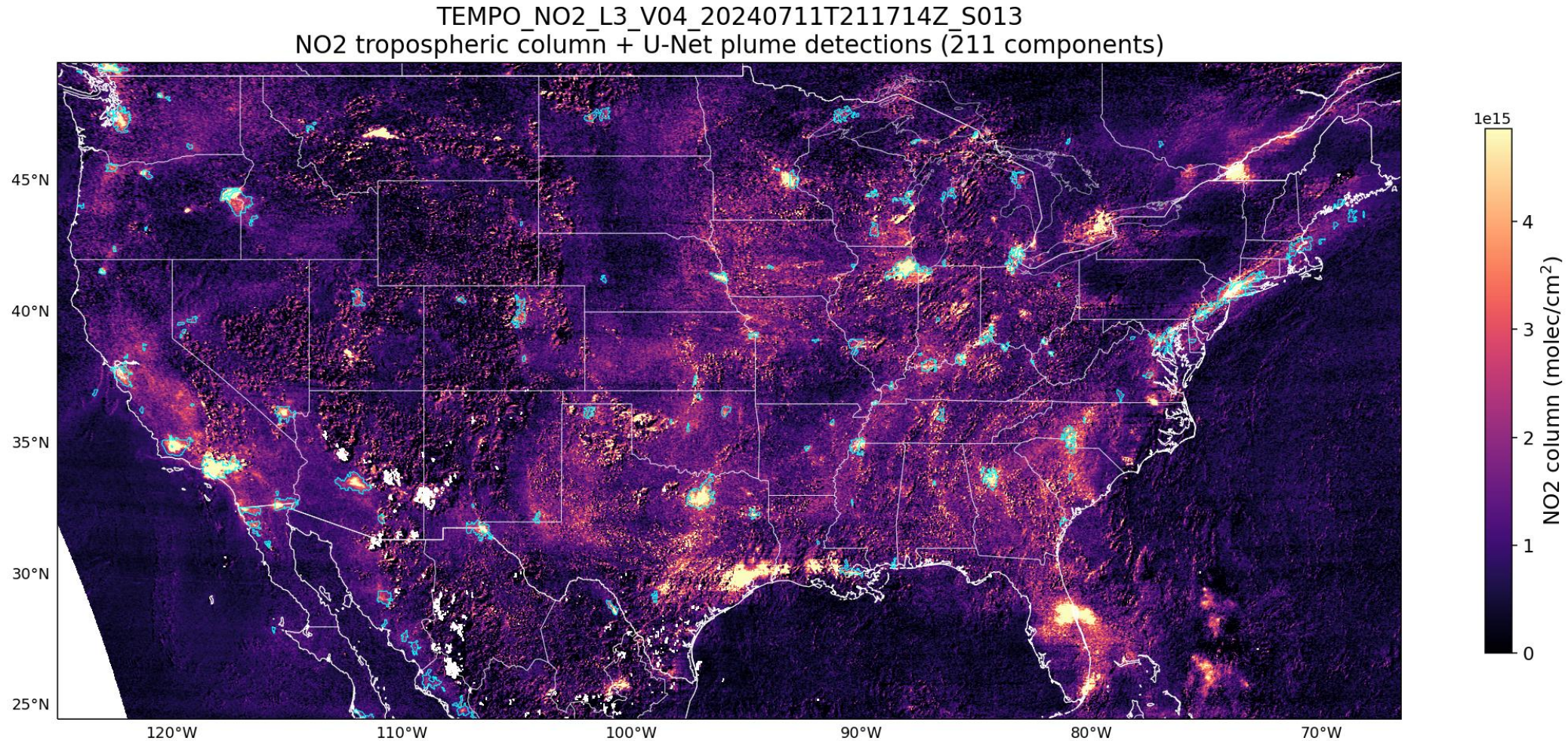
- Prior studies utilize CNN (TROPOMI, Finch et al., 2022), U-Net and MaskRCNN (MethaneSat, Pérez-Carrasco et al., submitted).



- **U-Net achieve ~80% plume precision using 20% held-out test.**

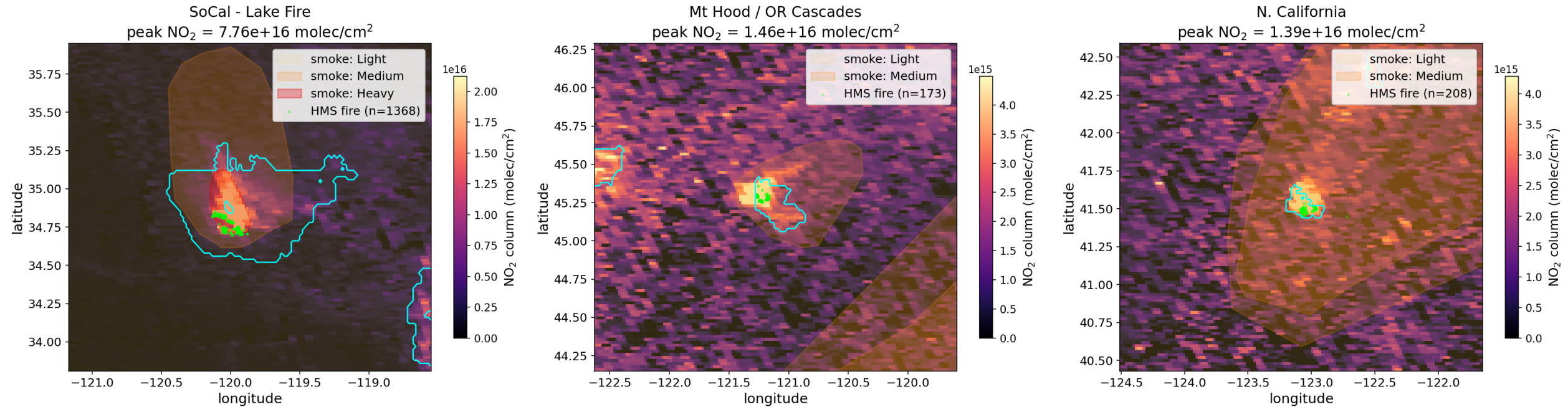
The lightweight U-Net segments plumes in near-real-time

- U-Net segments plumes using 0.66 s/GPU time for one TEMPO L3 file.



U-Net segments plumes from multi-scale fire-events

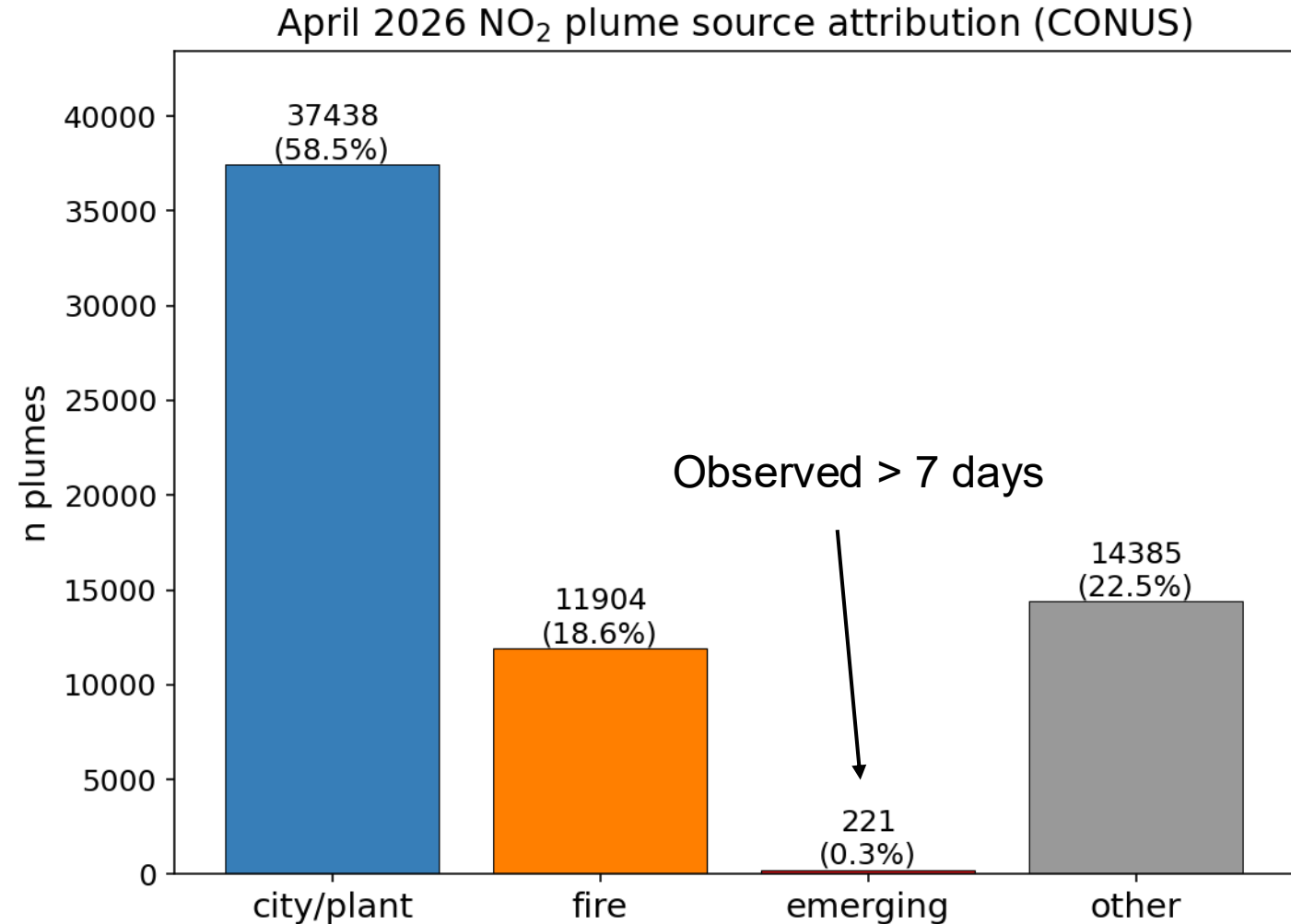
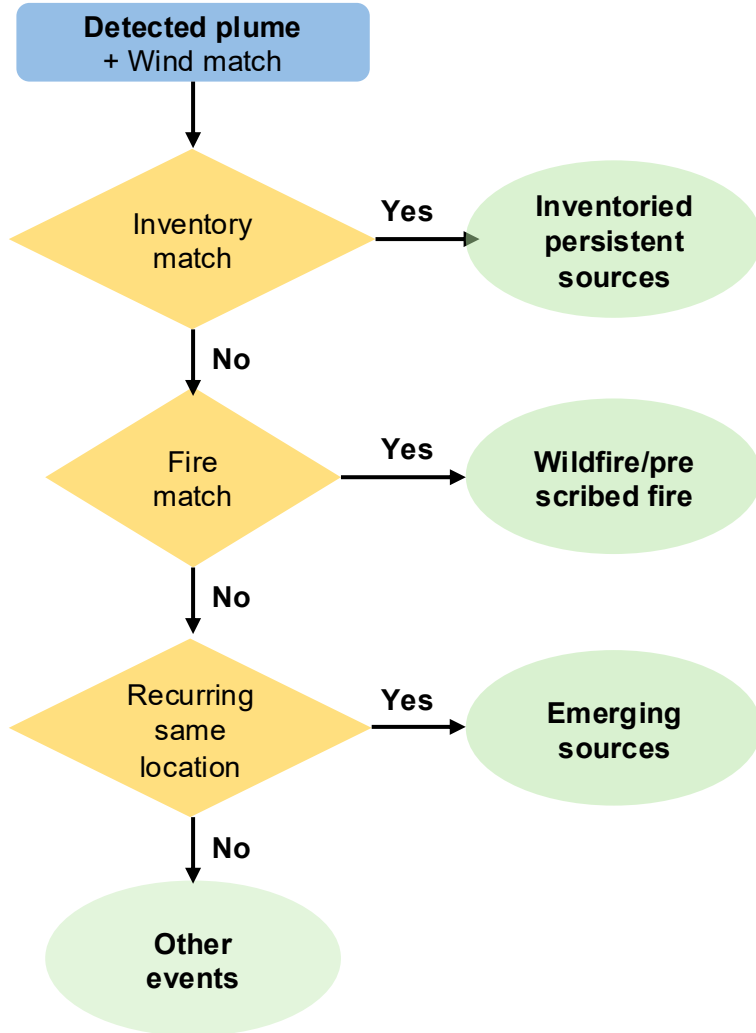
- Overlay with HMS fire plume polygons.



- **U-Net trained using persistent source plumes can segment plumes from fire events.**

Segment plumes at April 2026 attributes to fire/emerging sources

➤ We collapse the 74k plume detections into sources.



Ongoing work

- Develop an instance segmentation model (Mask-RCNN) to replace the semantic segmentation model (U-Net).
- Estimate emissions for segmented plumes.

