

Geostationary Remote Sensing of Trace Gases for Air Quality Applications in North America

Part 2: Case Studies in Trace Gas Monitoring with North American Geostationary Sensors

Kristina Pistone (BAERI/NASA Ames), Aaron Naeger (NASA MSFC)

January 22, 2026



Training Outline

Part 1

North American Geostationary Trace Gas Data Products for Air Quality

January 20, 2026

Session A: 11:00 a.m. - 12:30 p.m. EST

Session B: 3.00 p.m. - 4.30 p.m. EST

Part 2

Case Studies in Trace Gas Monitoring with North American Geostationary Sensors

January 22, 2026

Session A: 11:00 a.m. - 12:30 p.m. EST

Session B: 3.00 p.m. - 4.30 p.m. EST

Homework

Opens January 22 – Due February 5 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Trainers

Kristina Pistone

Research Scientist
Bay Area Environmental
Research Institute & NASA ARC



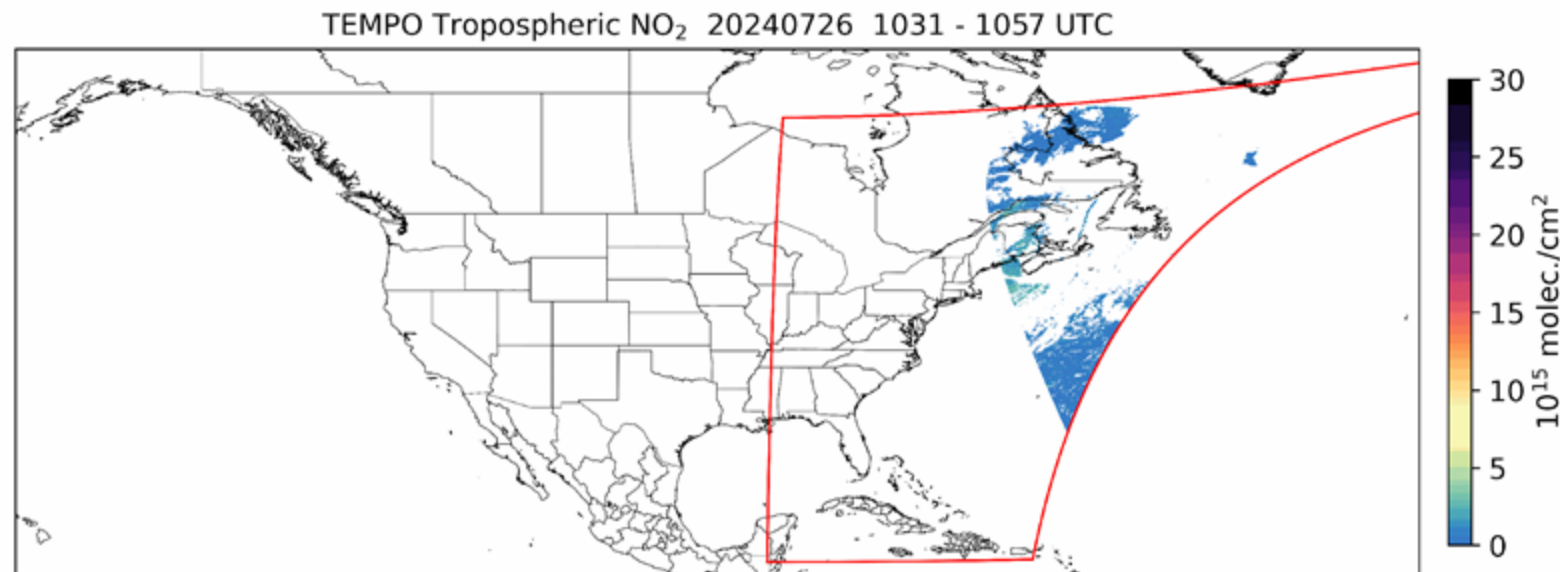
Aaron Naeger

TEMPO Mission Applications
Lead
NASA MSFC



Recap of Part 1

- TEMPO
 - Geostationary
 - Hyperspectral (UV/Vis.) covers North America
- TEMPO provides trace gases
 - Nitrogen Dioxide (NO_2)
 - Formaldehyde (HCHO)
 - Ozone (O_3) Total Column
 - Ozone Profile (beta)
- Worldview visualizes TEMPO Level 2 and 3 data
 - QA settings suitable for qualitative applications



Example of TEMPO Nominal Operation (Daytime)

- Hourly scans
- Optimized 30-40 minute scans during morning and afternoon
- Special operations ~10 minute scans for selected areas



Part 2 Objectives

By the end of Part 2, attendees will be able to:

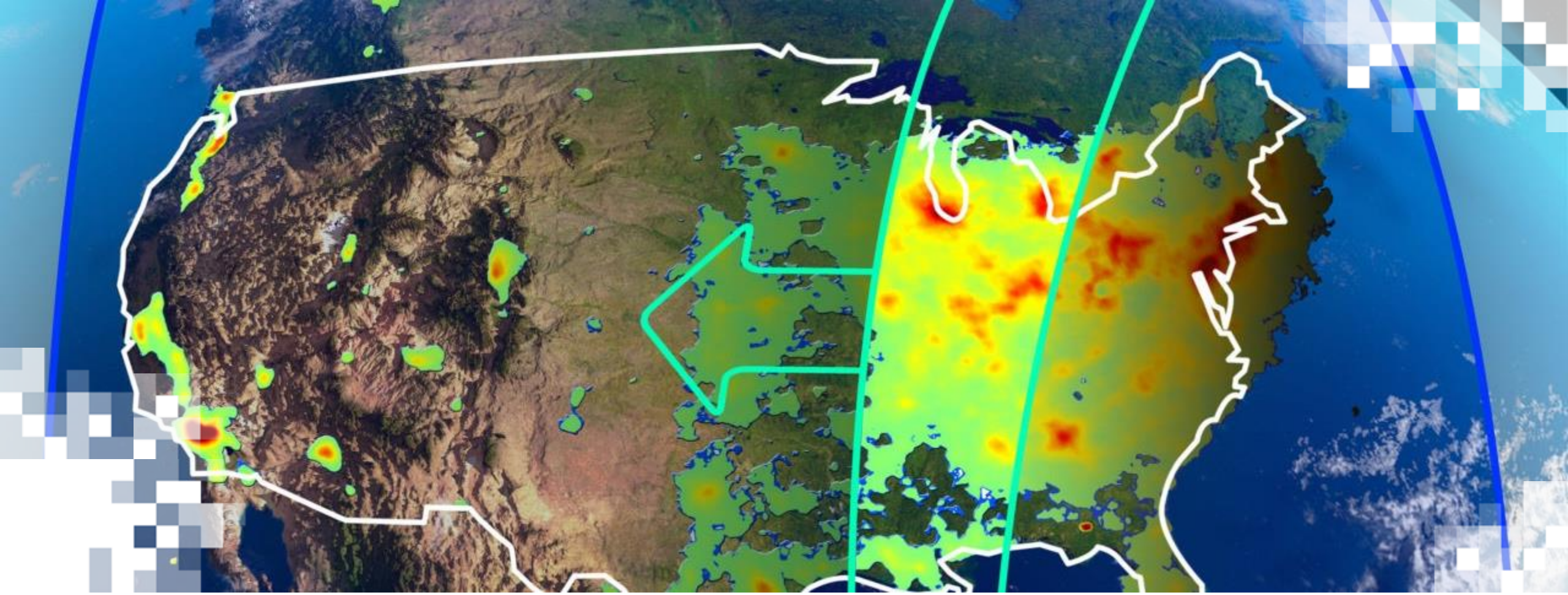
- Evaluate TEMPO trace gas products in Worldview to anticipate short-term air quality risks, such as high concentrations of ozone pre-cursors.
- Determine the spatial patterns, temporal trends, and likely sources of trace gases related to wildfire smoke and urban area air pollution events, using TEMPO data via Worldview.
 - Case 1: Colorado Front Range Fires and Ozone Exceedance - July 28-31, 2024
 - Case 2: Urban Air Quality Conditions and Major Pollution Sources in Eastern Texas



How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



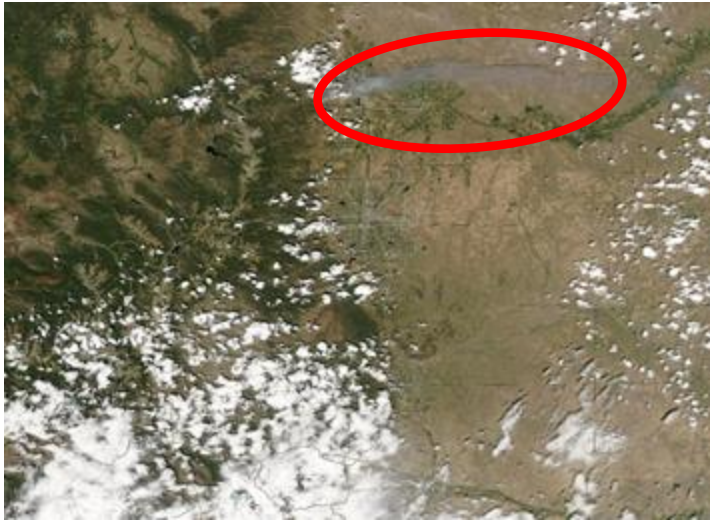


**Case 1: Ozone Exceedances along the Colorado Front Range
July 2024**

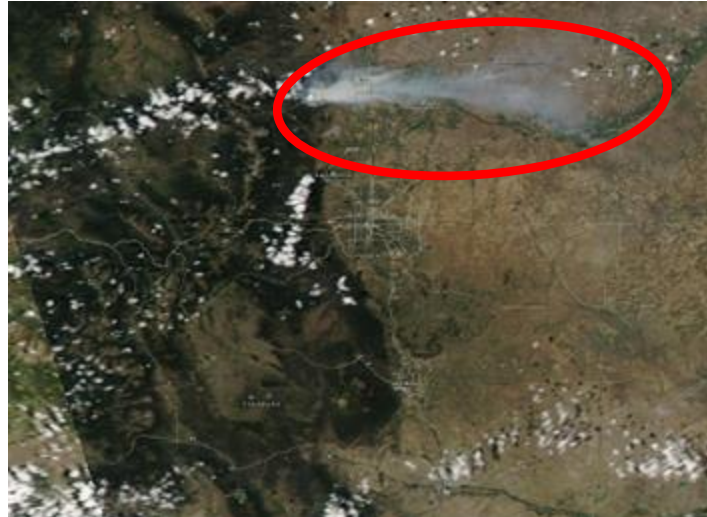
O₃ Exceedances along CO Front Range

July 28-31, 2024

- July 29, 2024
True Color MODIS Aqua via
Worldview
- Centered on Denver, CO



- July 30, 2024
True Color MODIS Aqua via
Worldview
- Centered on Denver, CO



- Photo by Dan Welsh (CDPHE)



- Numerous O₃ exceedances were observed across the CO Front Range during July 2024.
- Wildfire smoke from regional and local fires impacted the CO Front Range.

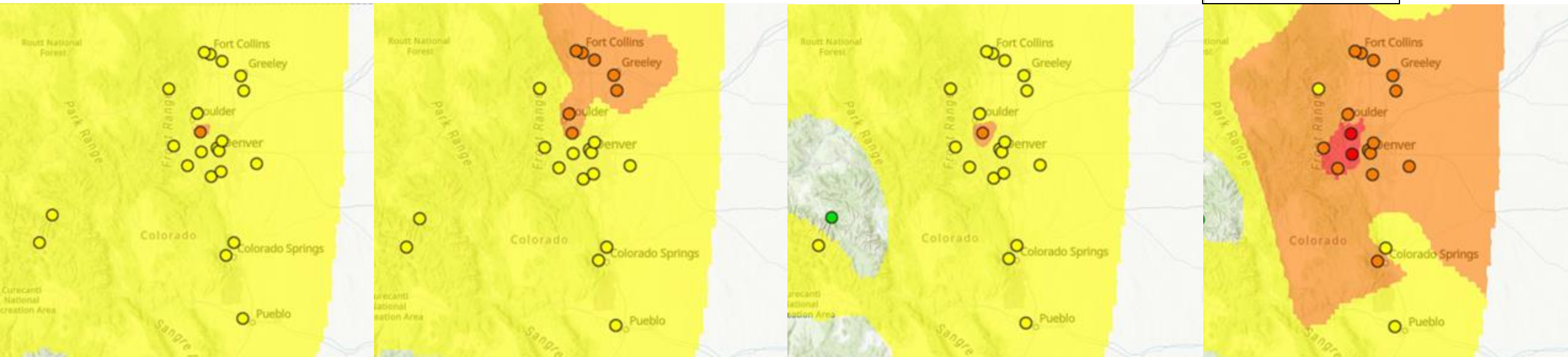


Surface Monitors Ozone Measurements

- Numerous monitors across the CO Front Range at unhealthy levels of O₃.
- By July 31, unhealthy O₃ levels for all groups was measured.

Legend	
U.S. Air Quality Index	
● Good (0-50)	
● Moderate (51-100)	
Unhealthy for Sensitive Groups (101-150)	
● Unhealthy (151-200)	
● Very Unhealthy (201-300)	
● Hazardous (301+)	
○ No Data	

AirNow Ozone Monitors



July 28

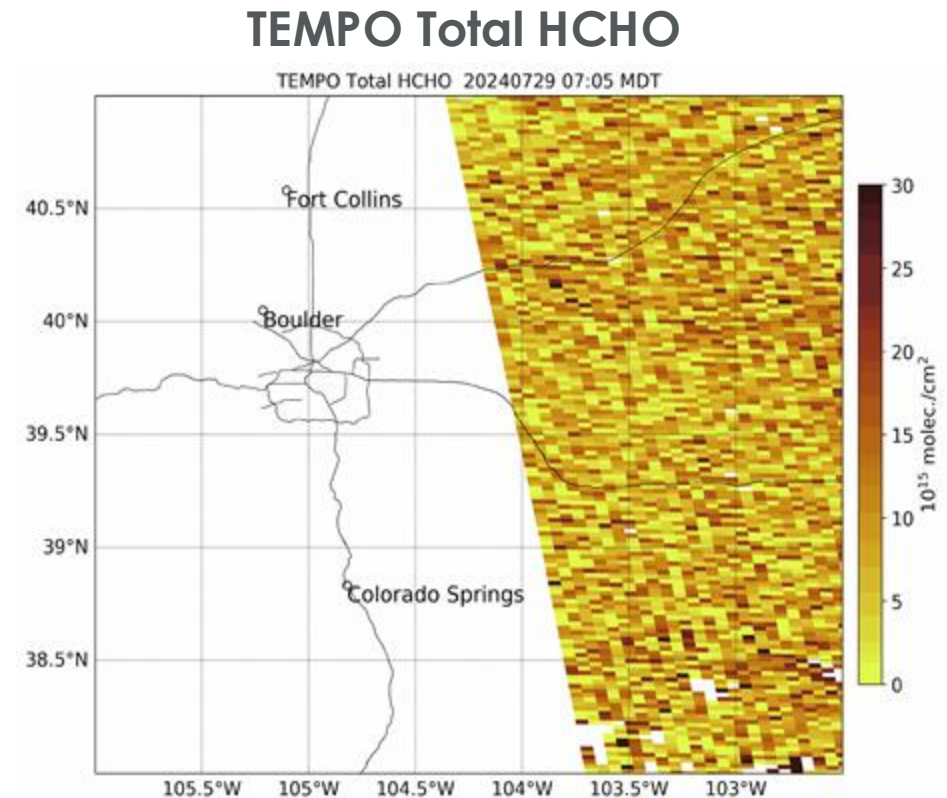
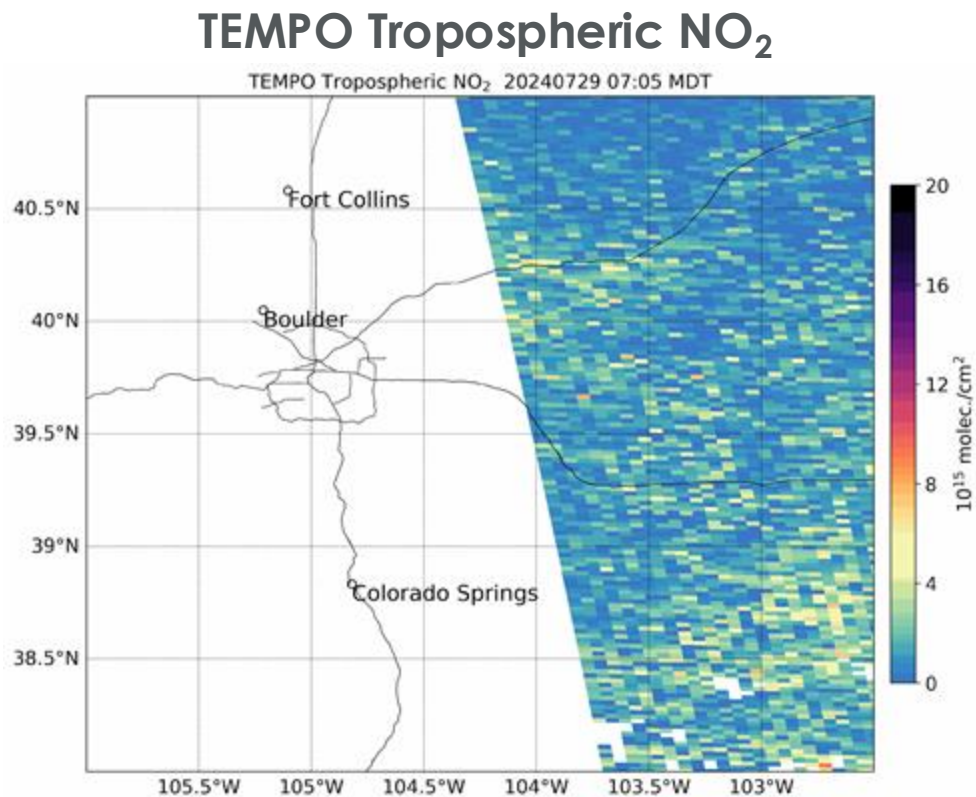
July 29

July 30

July 31

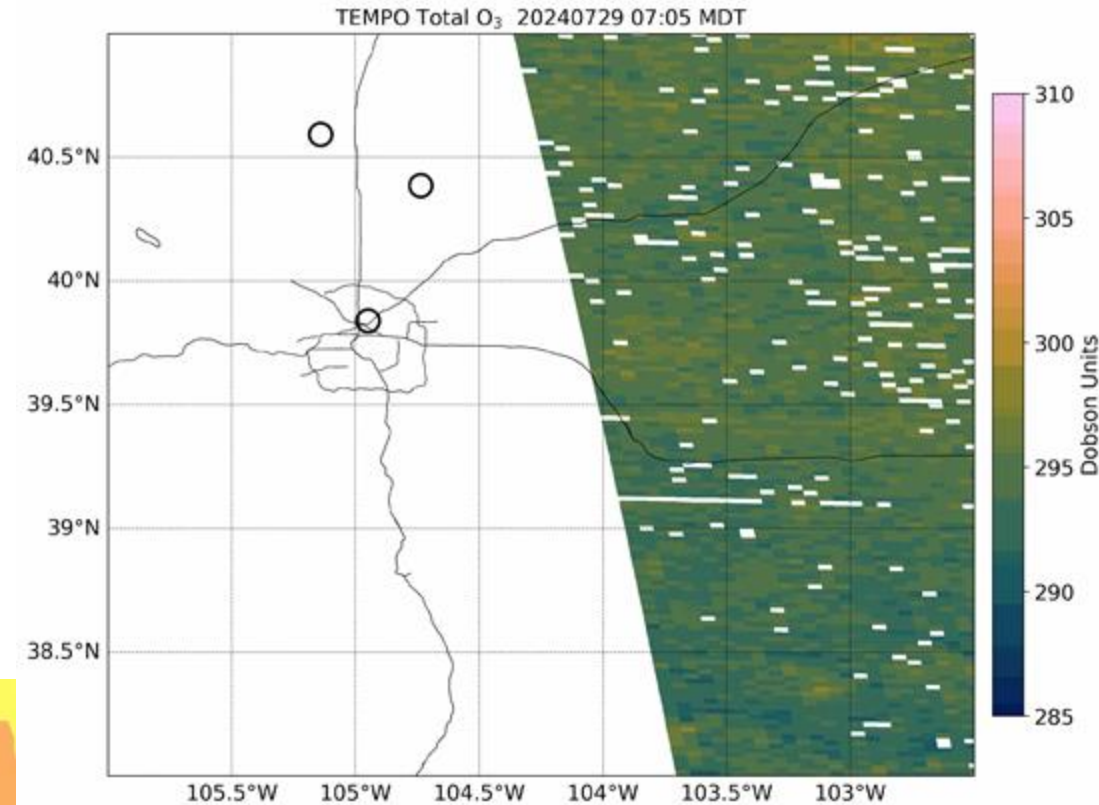
TEMPO NO₂ & HCHO from Front Range Wildfire

- TEMPO observes NO₂ and total HCHO associated with the wildfire smoke plume on July 29.



TEMPO Total Column O₃ from Wildfire on July 29

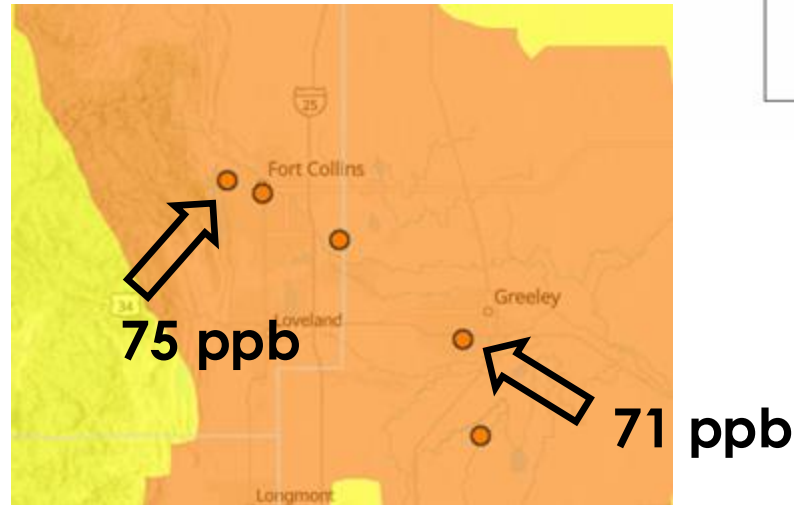
- TEMPO: Rapid ozone production within the wildfire smoke plume
 - Bright pink in upper portion of O₃ animation
- Surface Monitors: Ozone concentrations of 75 and 72 ppb
 - Increase of 8 and 6 ppb, respectively, from the previous day



MODIS Aqua

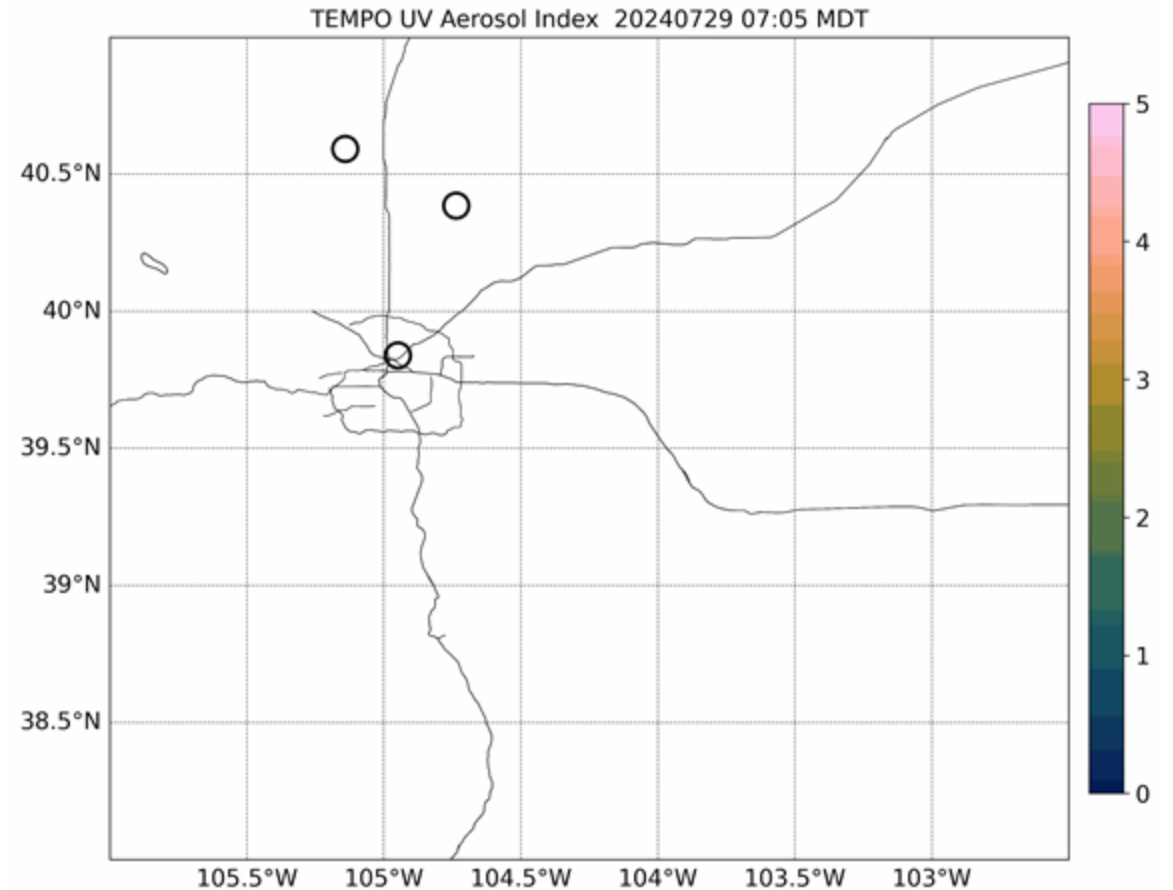


AirNow Ozone Monitors



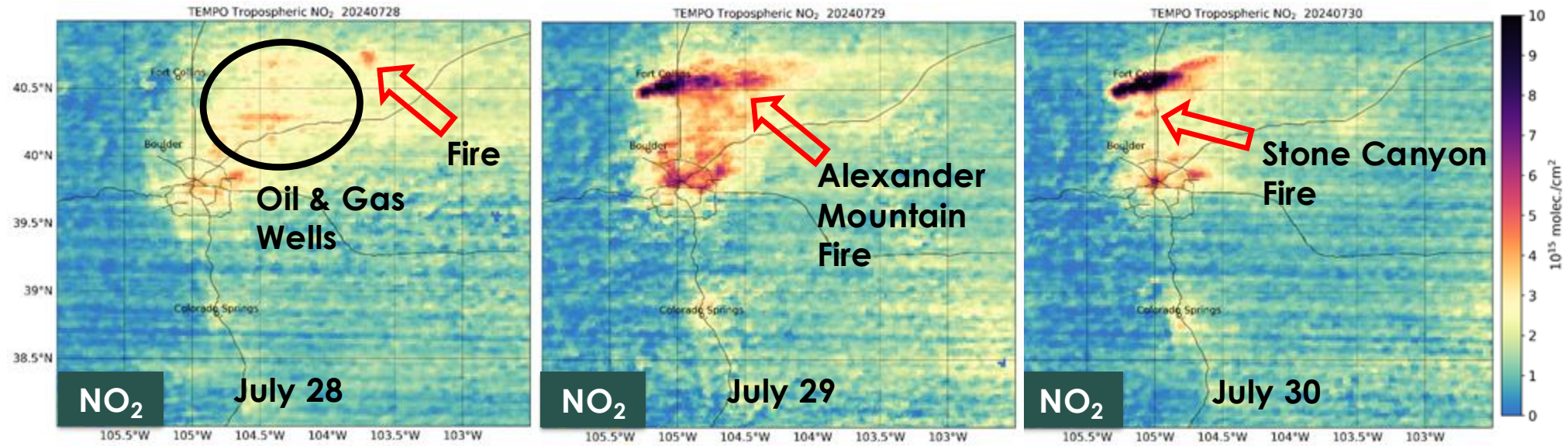
TEMPO Ultraviolet (UV) Aerosol Index

- TEMPO UV Aerosol Index distinguishes and tracks absorbing aerosol particles in the atmosphere.
- Absorbing aerosol particles, such as smoke and dust, are generally associated with positive UV Aerosol Index values.
- TEMPO tracked strong positive UV Aerosol Index values within the transported wildfire plume.



Daily Averaging for NO₂

TEMPO Tropospheric NO₂ on 0.02° Grid (Filter using Cloud Fraction < 50%, SZA < 80°)

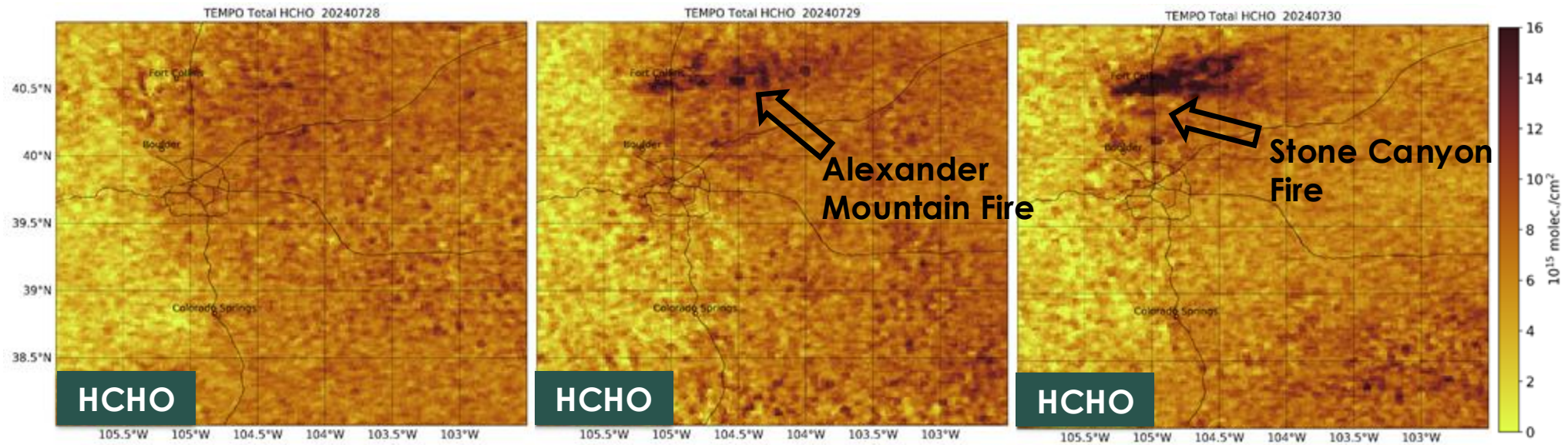


- Daily average of TEMPO L2 data onto a 0.02° grid before and after wildfire outbreak
- Large NO₂ signal from Alexander Mountain Fire
- NO₂ signal from Stone Canyon Fire apparent



Daily Averaging for HCHO

TEMPO Tropospheric HCHO on 0.02° Grid (Filter using Cloud Fraction < 50%, SZA < 80°)

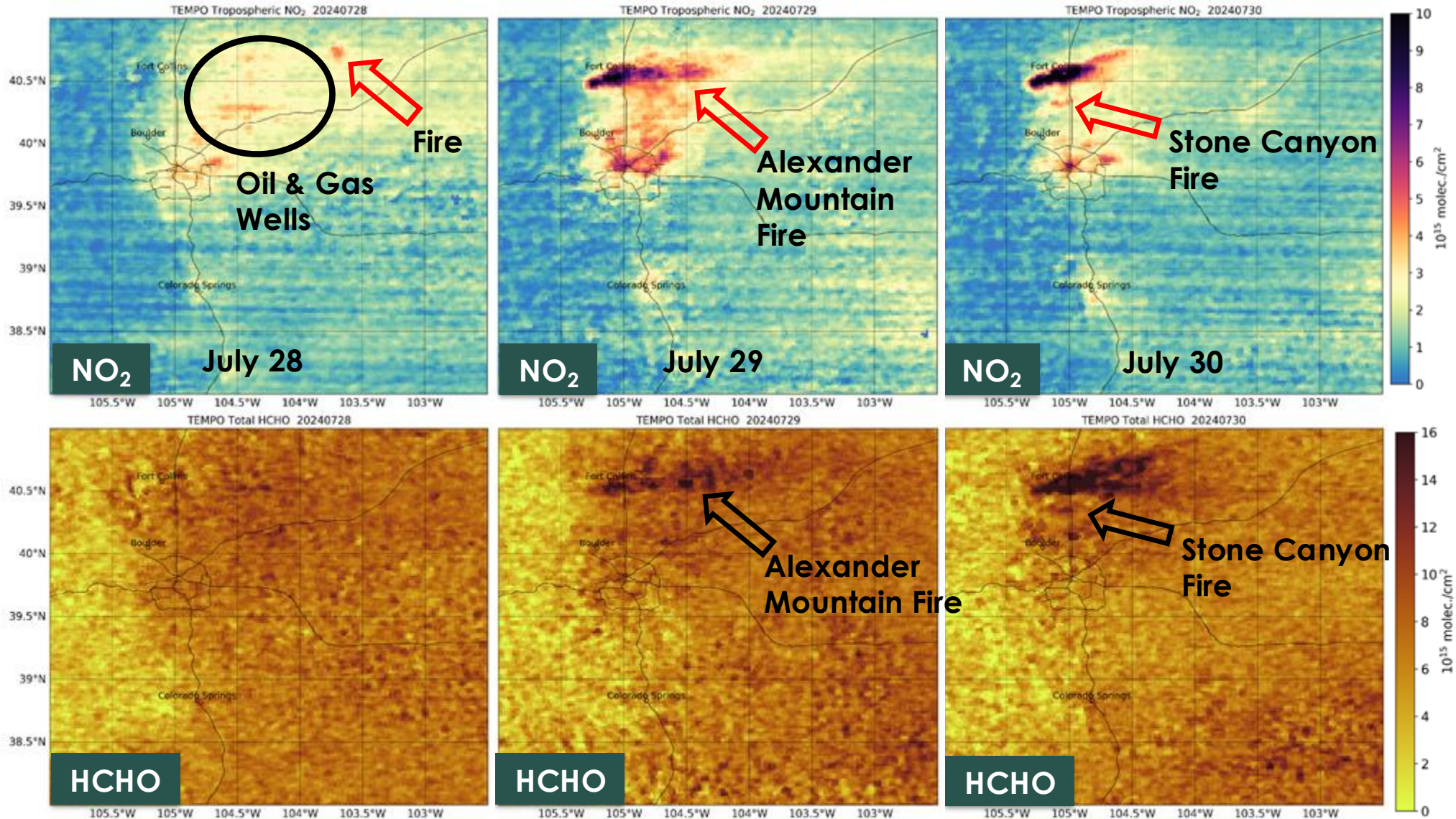


- Daily average of TEMPO L2 data onto a 0.02° grid before and after wildfire outbreak
- Largest HCHO signal from Alexander Mountain Fire on July 30



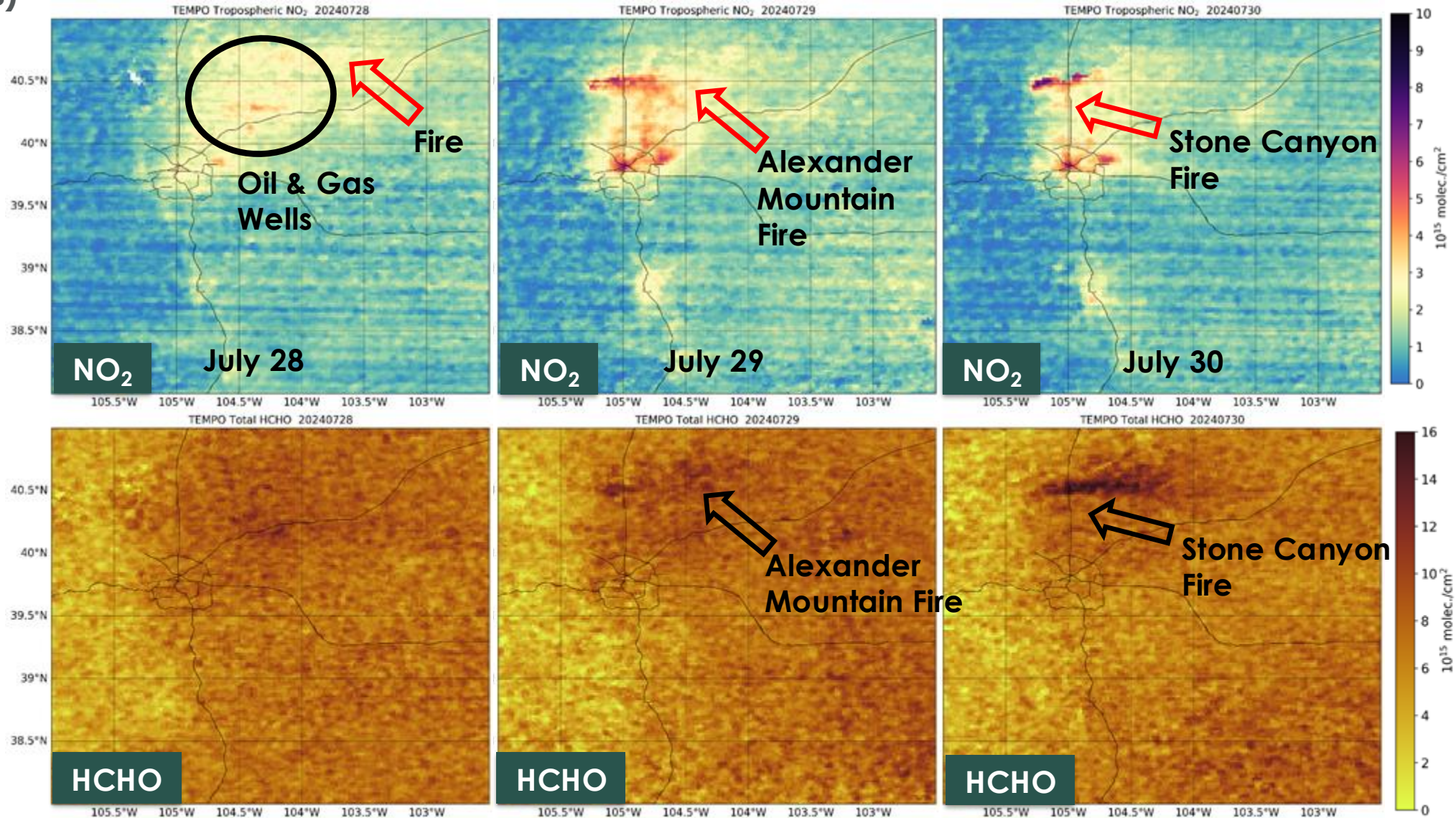
Daily Averaged NO₂ and HCHO Together

TEMPO NO₂ and HCHO on 0.02° Grid (Filter using Cloud Fraction < 50%, SZA < 80°)

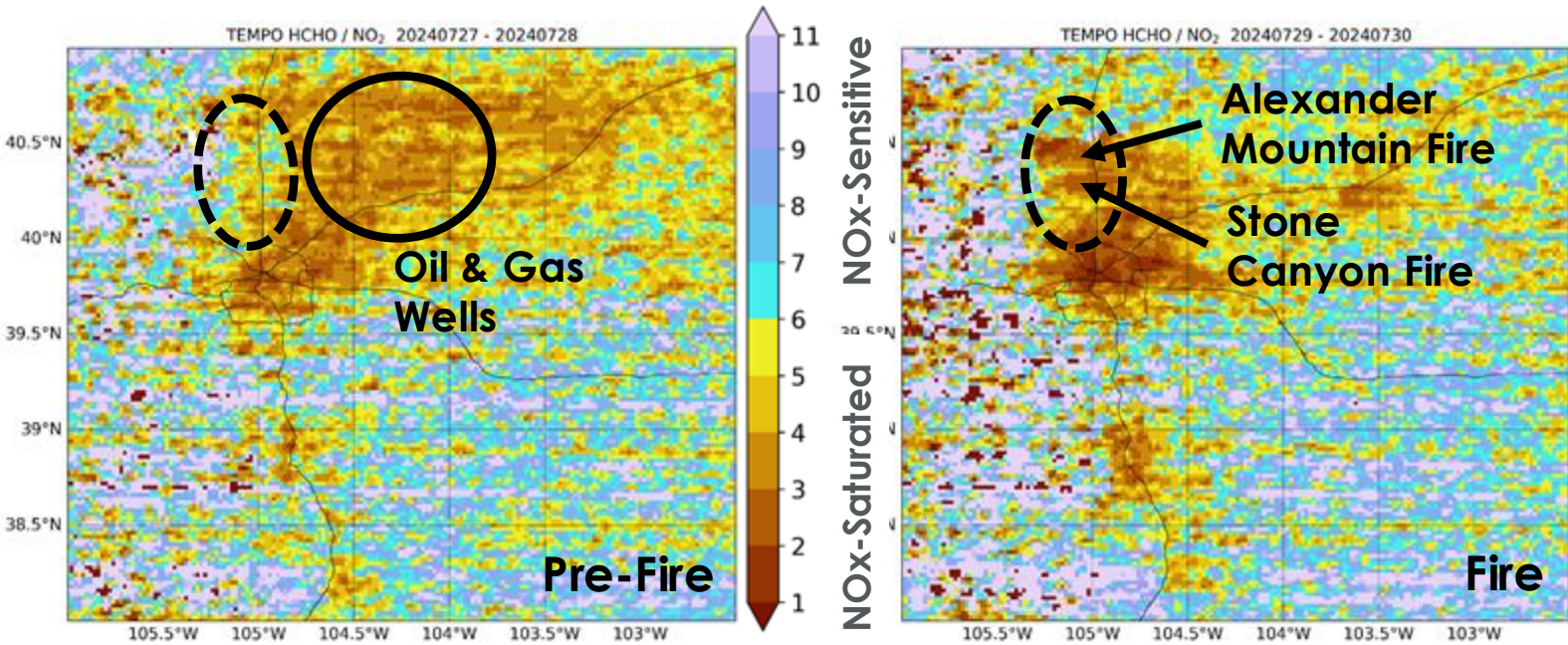


Change from <50% to <20% Cloud Cover Filtering of TEMPO Data

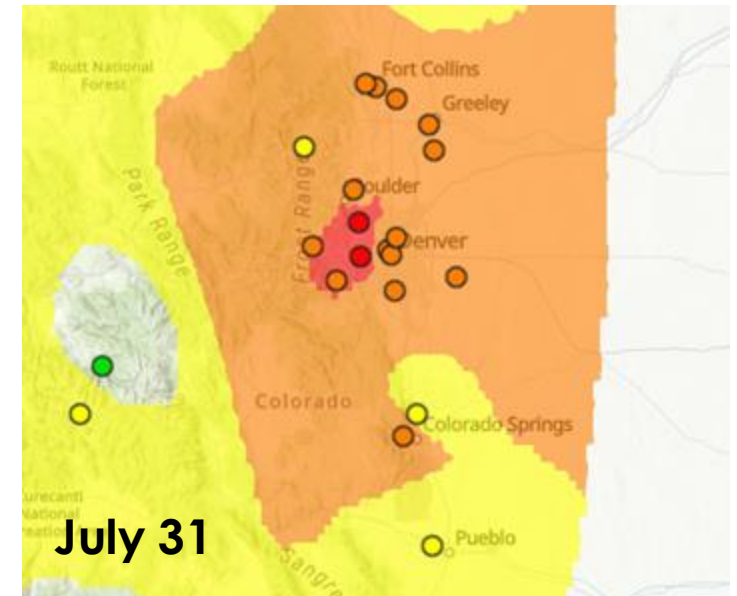
Stricter Cloud Fraction obscures fire impact (i.e., data considered only when cloud cover is 20% or less)



Ratio of HCHO to NO₂ Indicates Likelihood of Near-Surface Ozone Production



AirNow Ozone Monitors

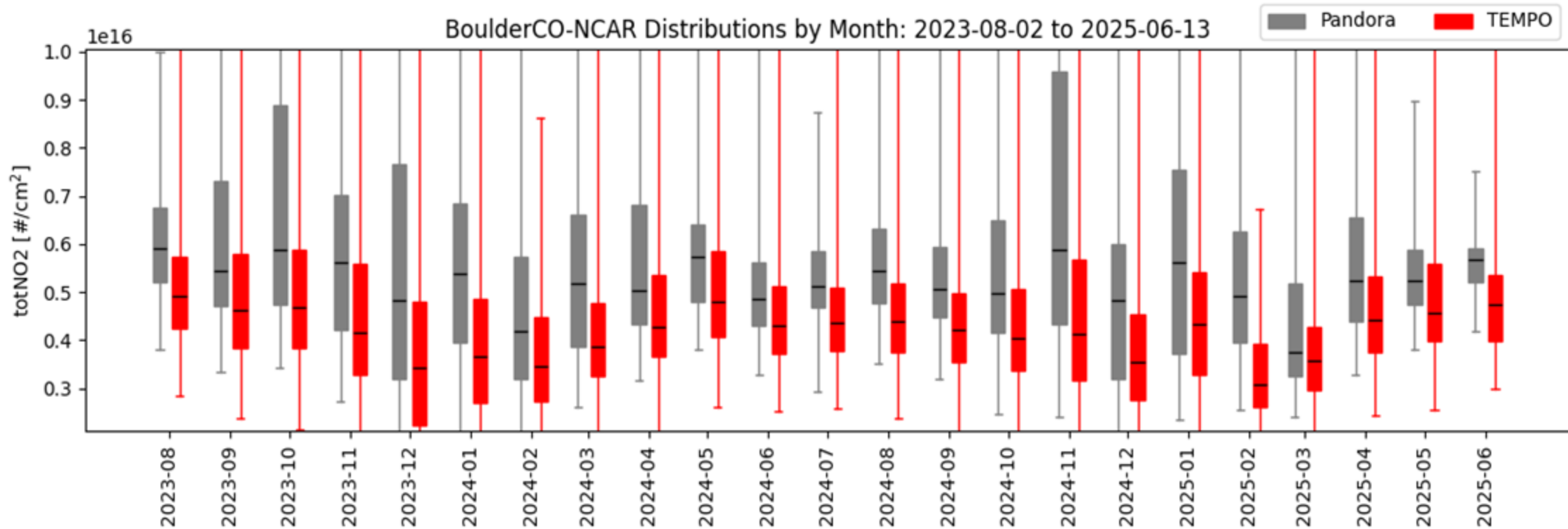


- Wildfire smoke promoted more efficient O₃ production in the area
 - Large NO₂ increases in NO_x-sensitive regime near fire sources
 - HCHO increases farther downwind in NO_x-saturated, oil & gas well area
- Transport of smoke likely led to additional increases in O₃ production in NO_x-saturated Denver urban area by July 31

- Unhealthy O₃ levels for all groups measured near the Denver area on July 31



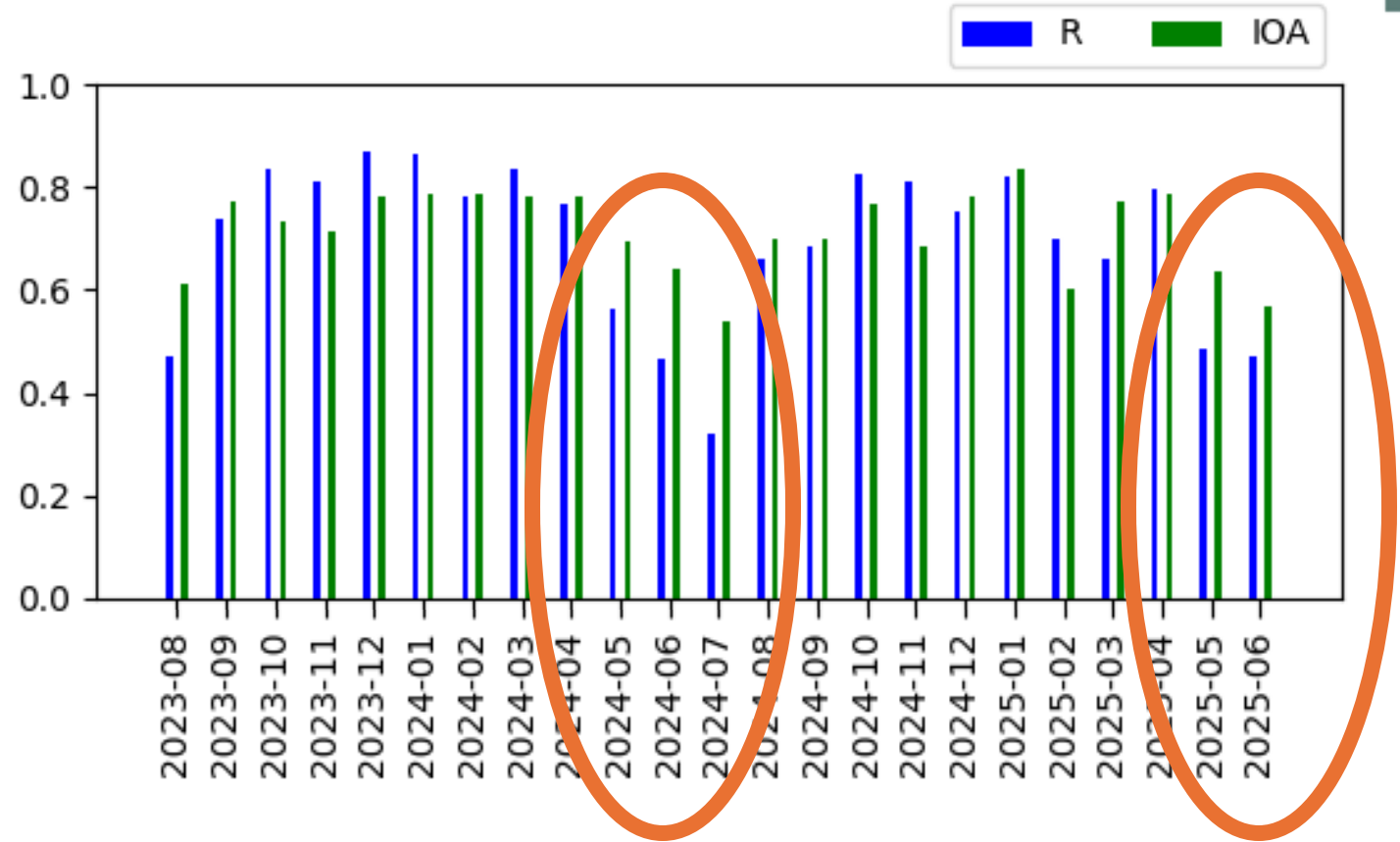
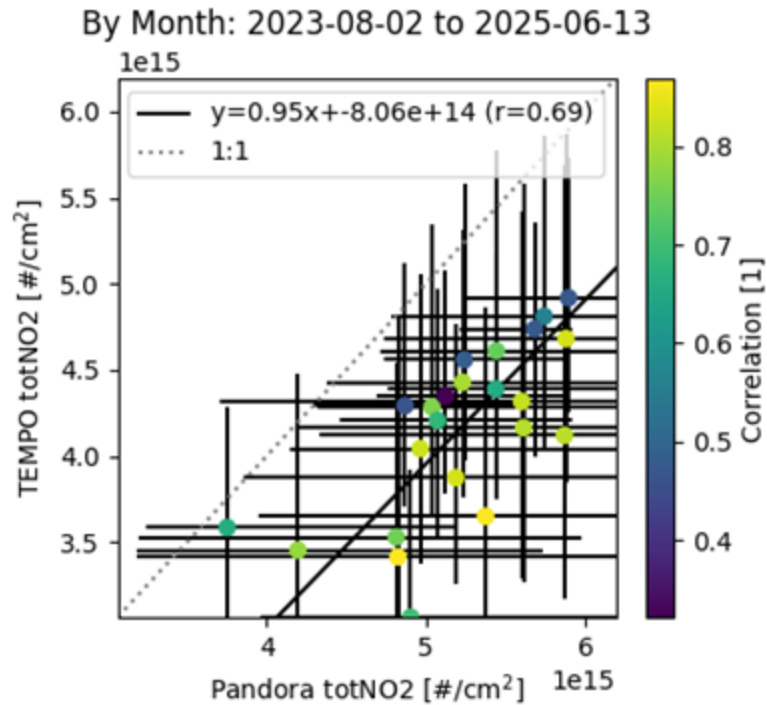
TEMPO vs. Pandora NO₂ – Boulder NCAR site



- Overall good agreement in terms of the monthly and seasonal pattern of NO₂ between Pandora and TEMPO
- General low bias in TEMPO NO₂ compared to Pandora Boulder NCAR site



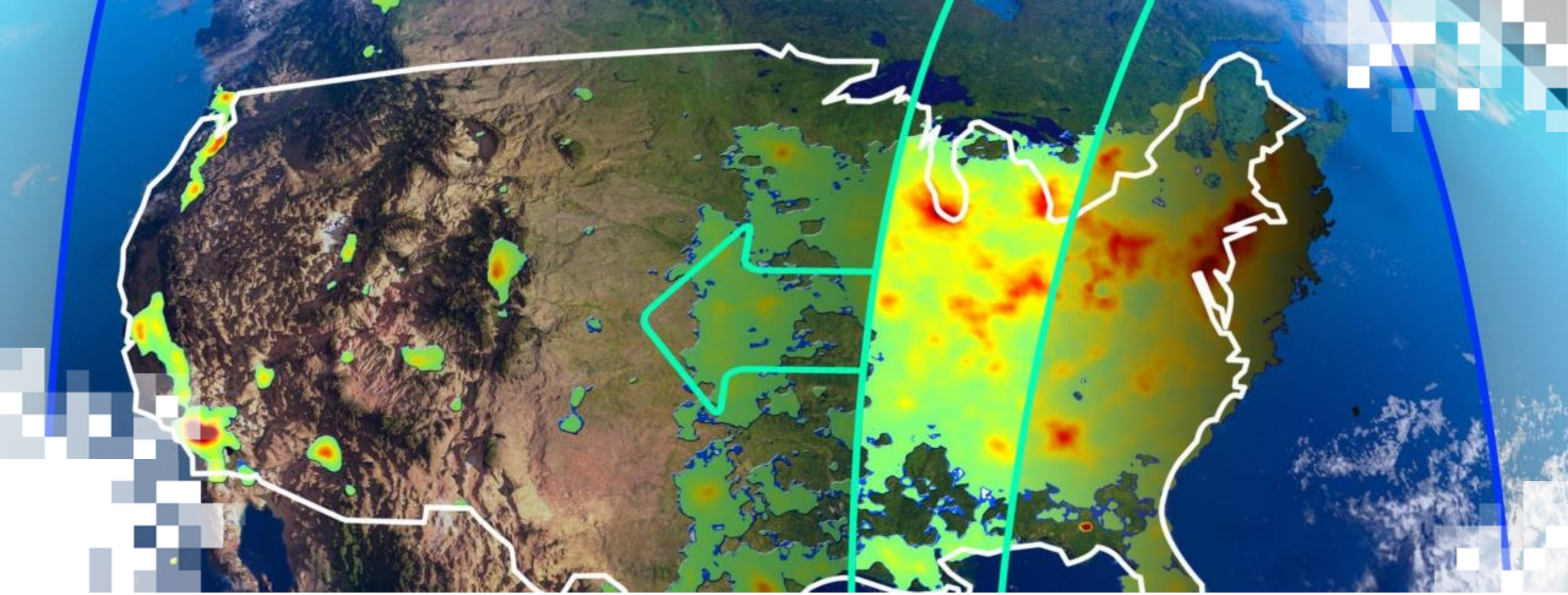
TEMPO vs. Pandora NO₂ – Boulder NCAR site



- Good correlations between TEMPO and Pandora total column NO₂ (monthly medians) at the Boulder NCAR site

- Strong correlations throughout much of the year except during the late spring to mid-summer period





Case Exercise 1

Case Exercise Instructions

CO Front Range Fire Event in Worldview: July 28-31, 2024

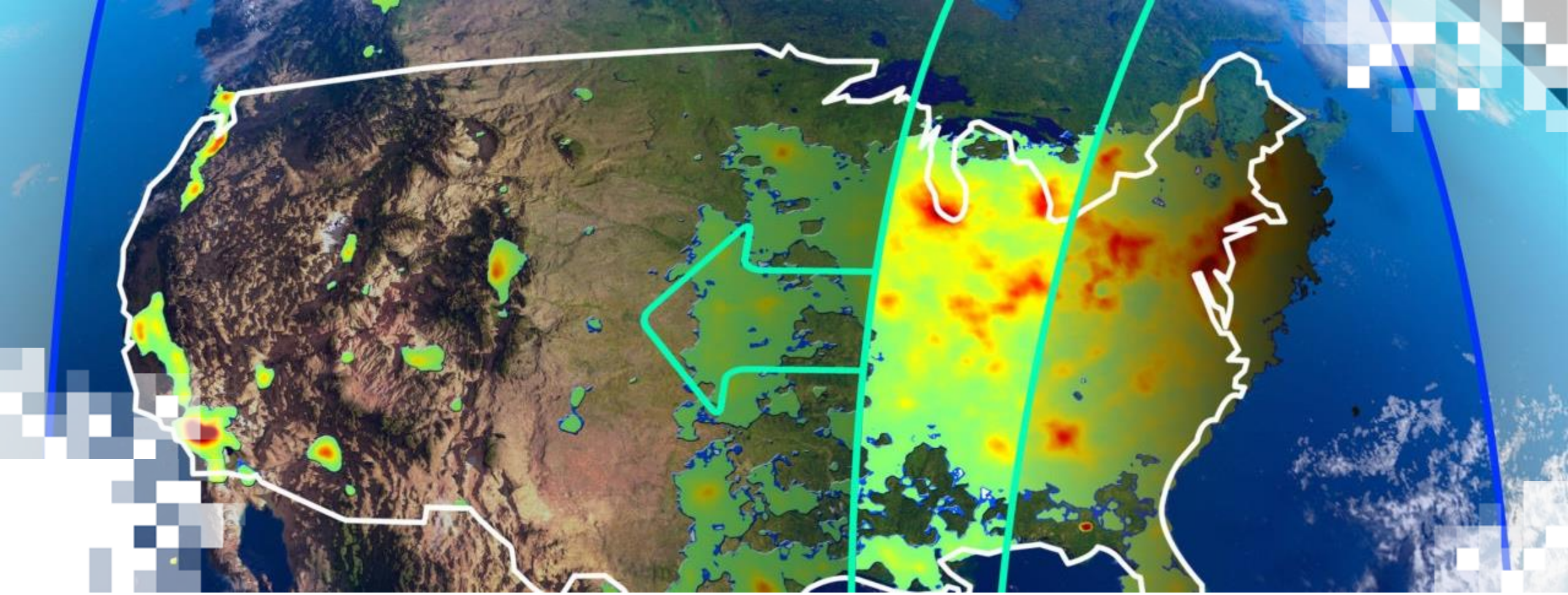
- worldview.earthdata.nasa.gov: case loaded here
- Explore the case evolution over time
- Create and save images and animations of the event
- Comparison with ground data from airnow.gov



Summary Case 1

- TEMPO helps track where ozone precursors from fires are going and their spatial extent far from ground monitors.
- More frequent observations support tracking precursors leading up to peak ozone formation times.
- Multiple measurements per day allow smoothing of noisy formaldehyde retrievals, although some noise remains.

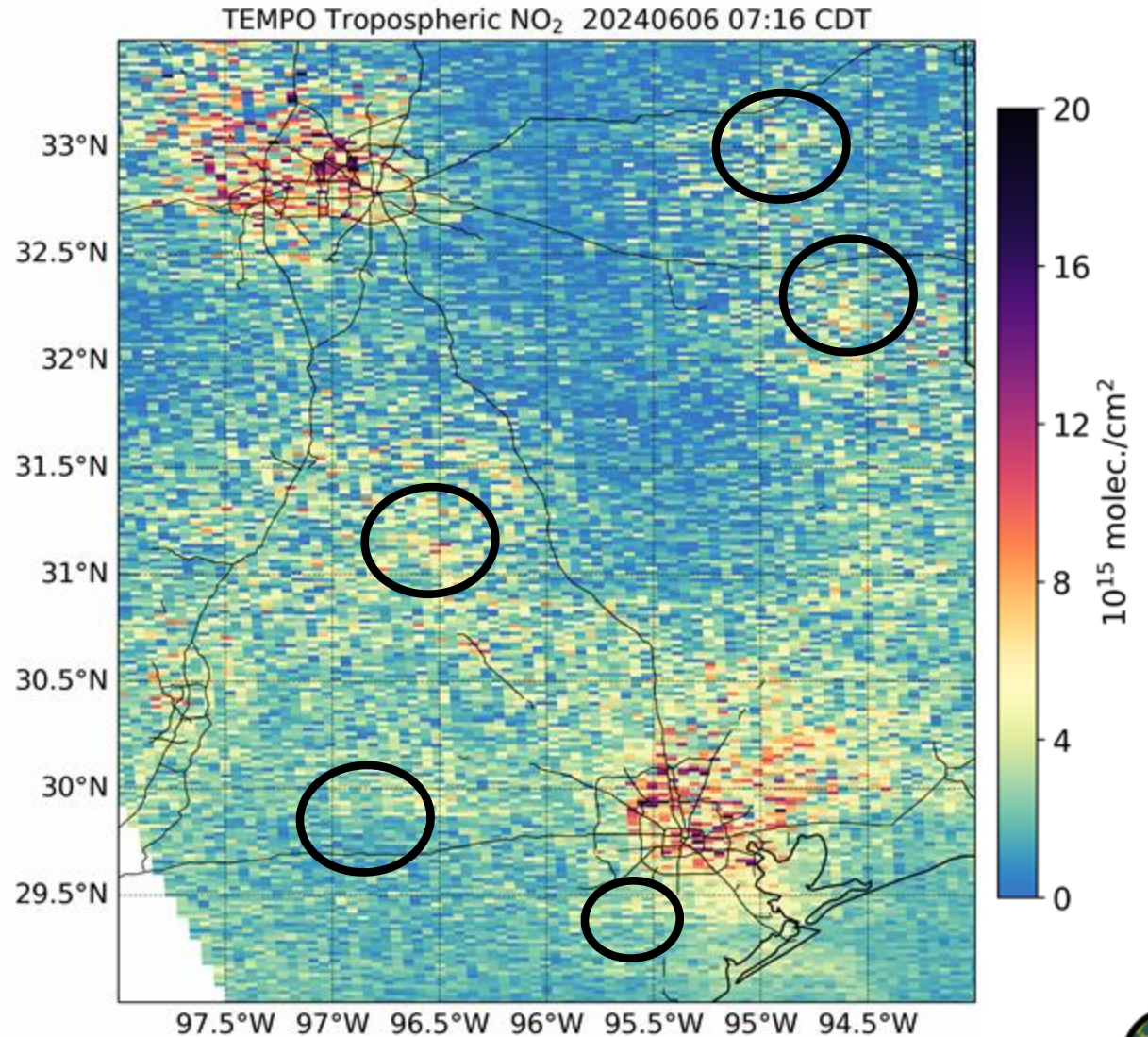
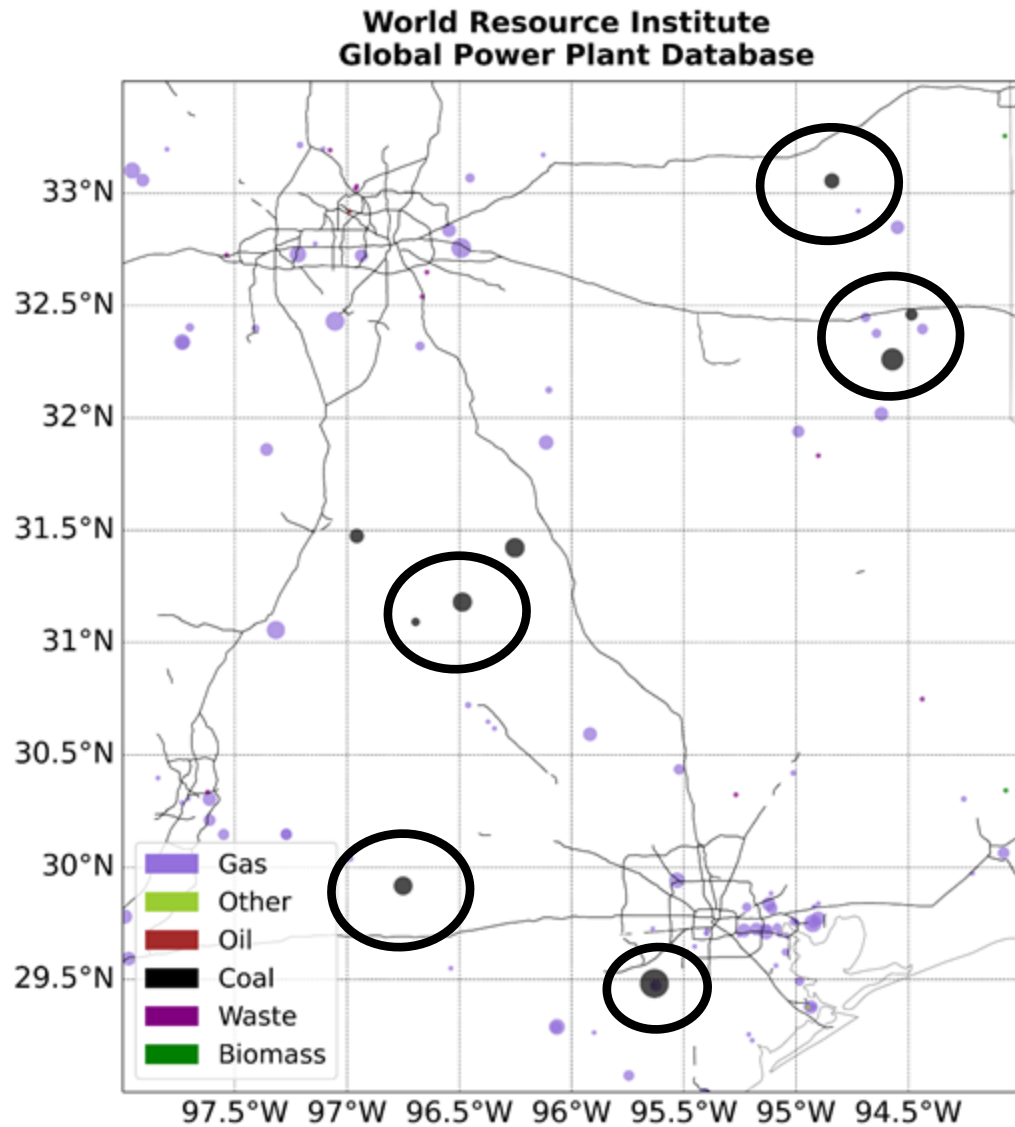




**Case 2: Urban Pollution and Sources in Eastern Texas
June 2024 & October 2025**

East Texas NO₂ Hot Spots June 6, 2024 (Version 3 Data)

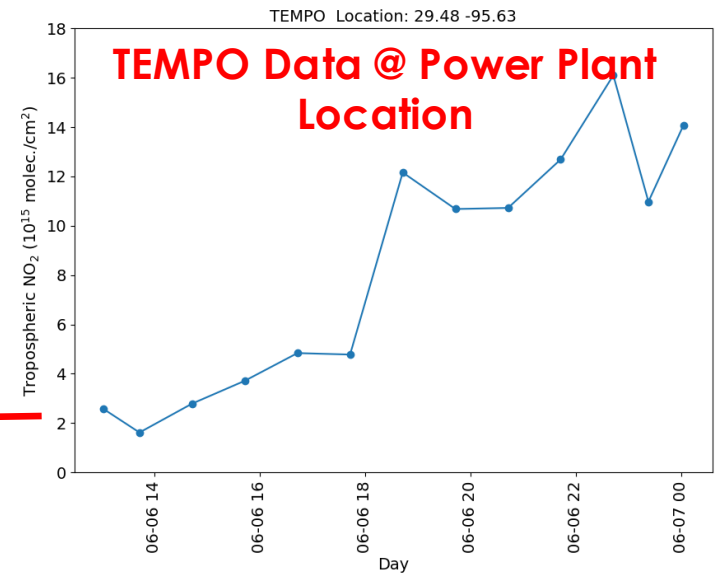
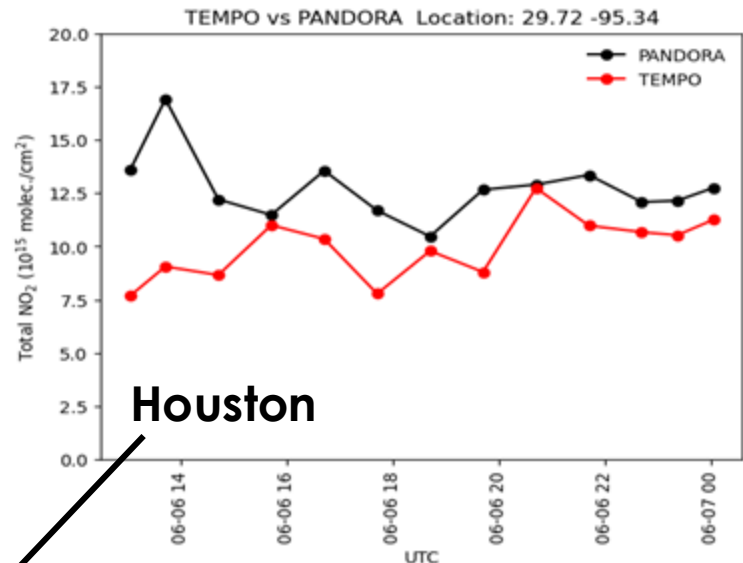
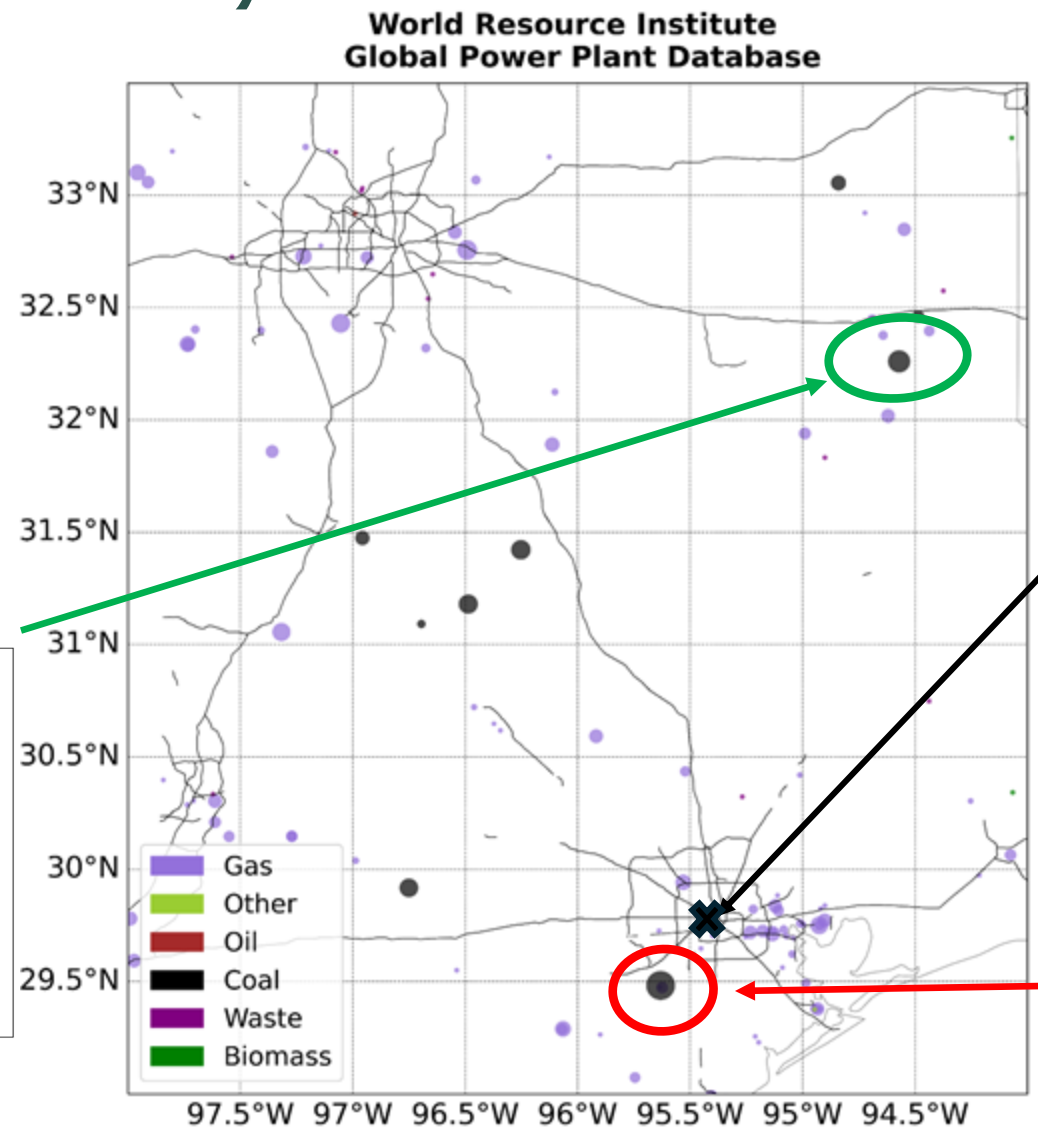
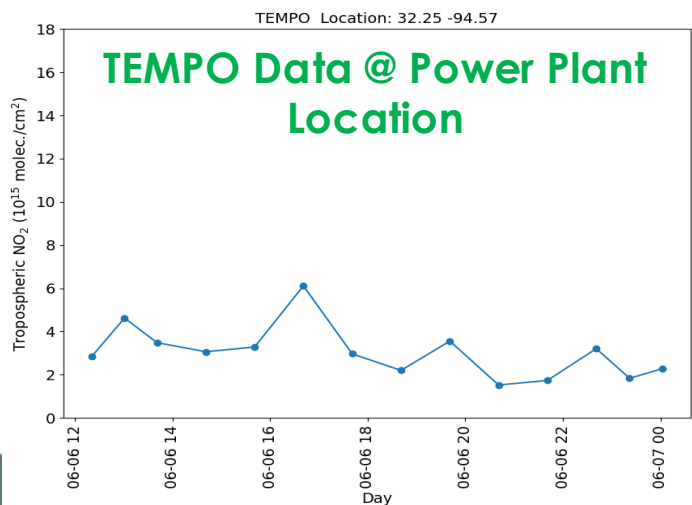
- TEMPO captures NO₂ hot spots in the vicinity of coal- and gas-fired power plants.



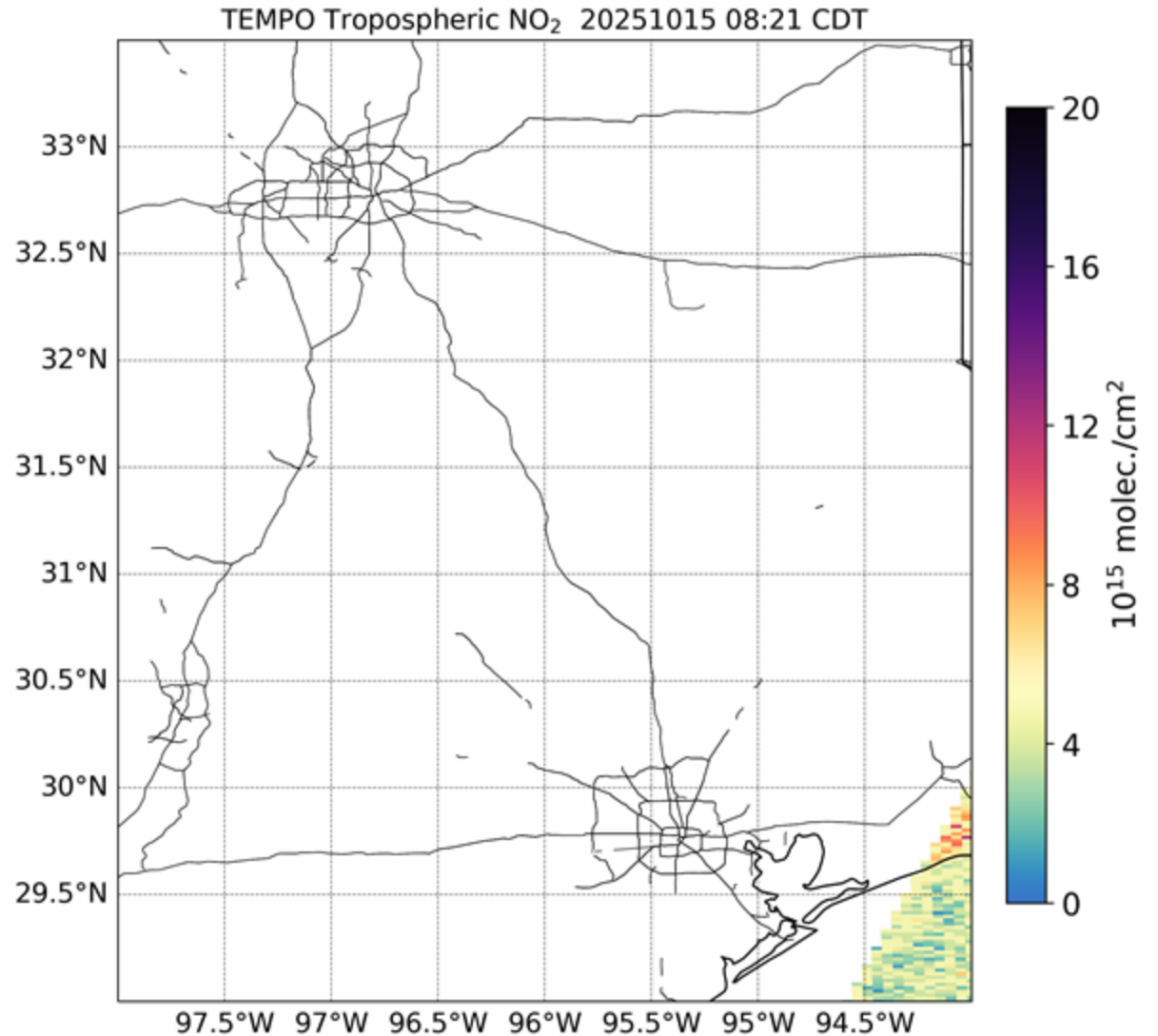
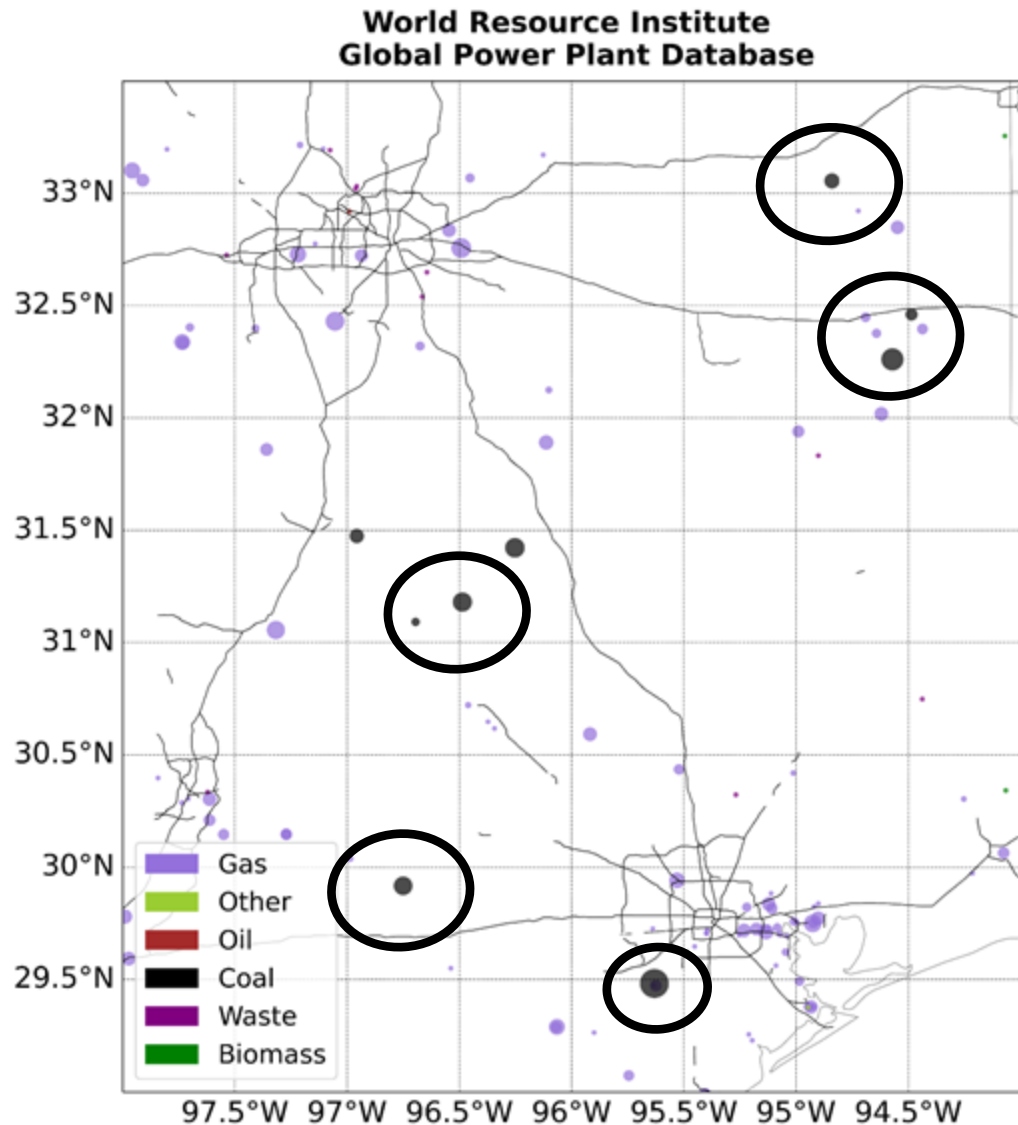
East Texas NO₂ Time Series at Power Plant and Urban Locations

June 6, 2024 (Version 3 Data)

- TEMPO observes diurnal variations in NO₂ columns around coal-fired power plants and urban areas
- Largest power plant near Houston shows strongest NO₂ variations and peaks



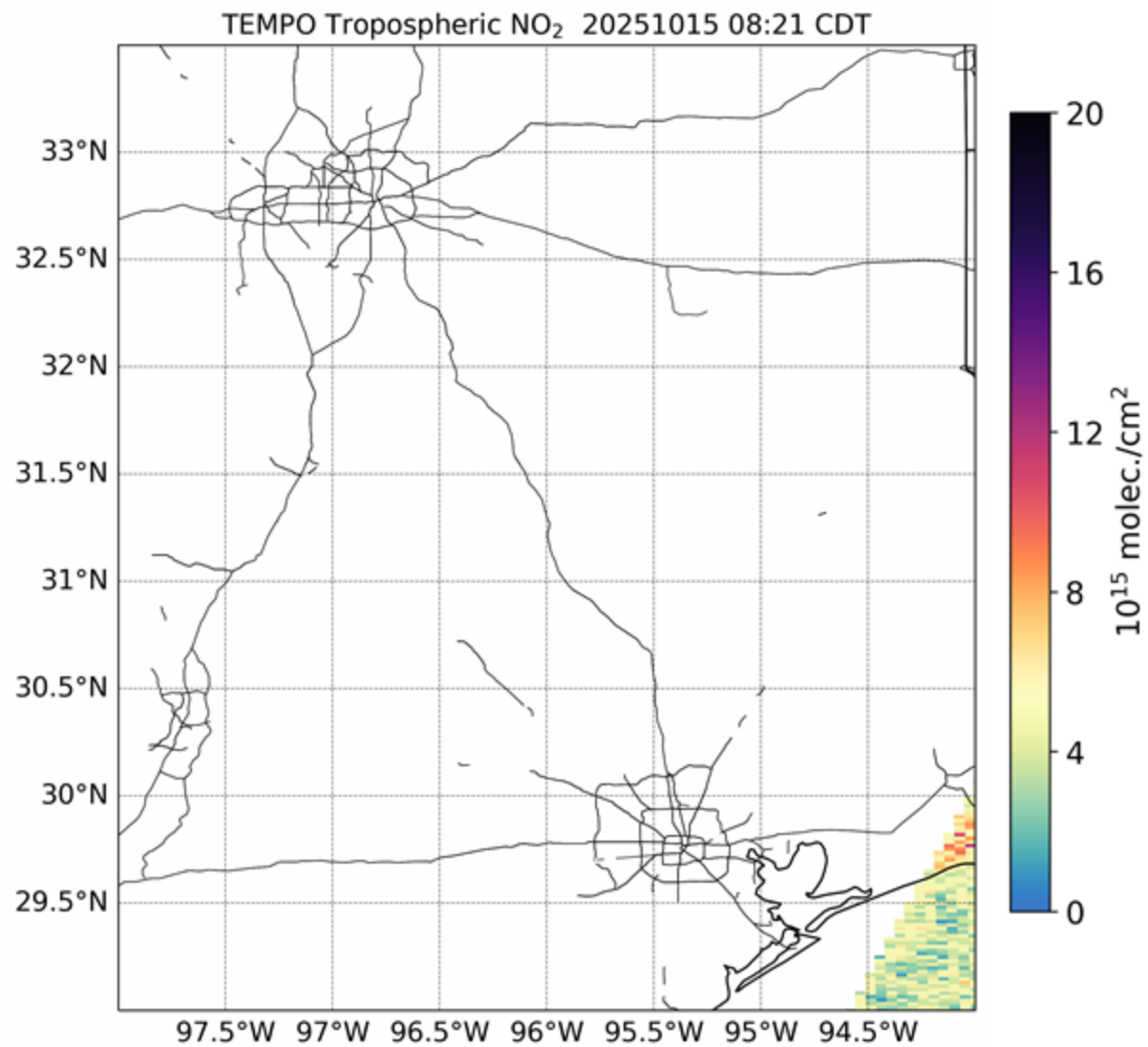
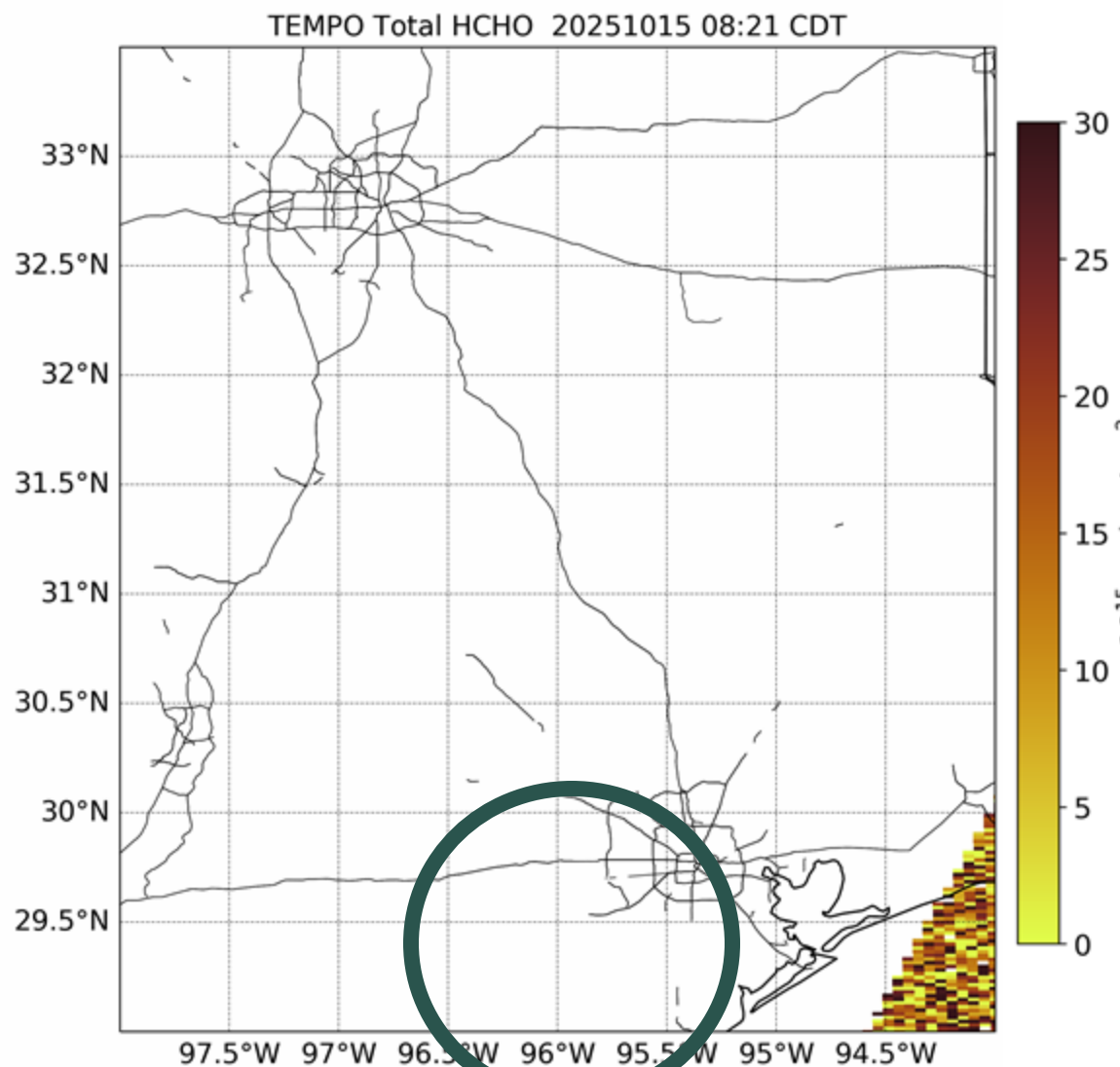
East Texas NO₂ Hot Spots – Oct 15, 2025 (Version 4 Data)



- Version 4 data captures similar NO₂ hot spots and patterns as the previous case



East Texas NO₂ and HCHO – Oct 15, 2025 (Version 4 Data)

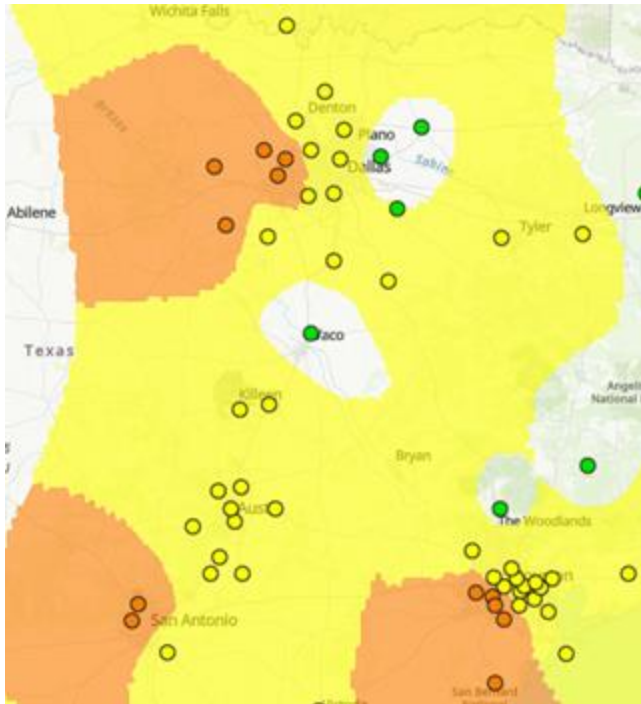


- Distinct increases in HCHO are observed over Houston and nearby power plant

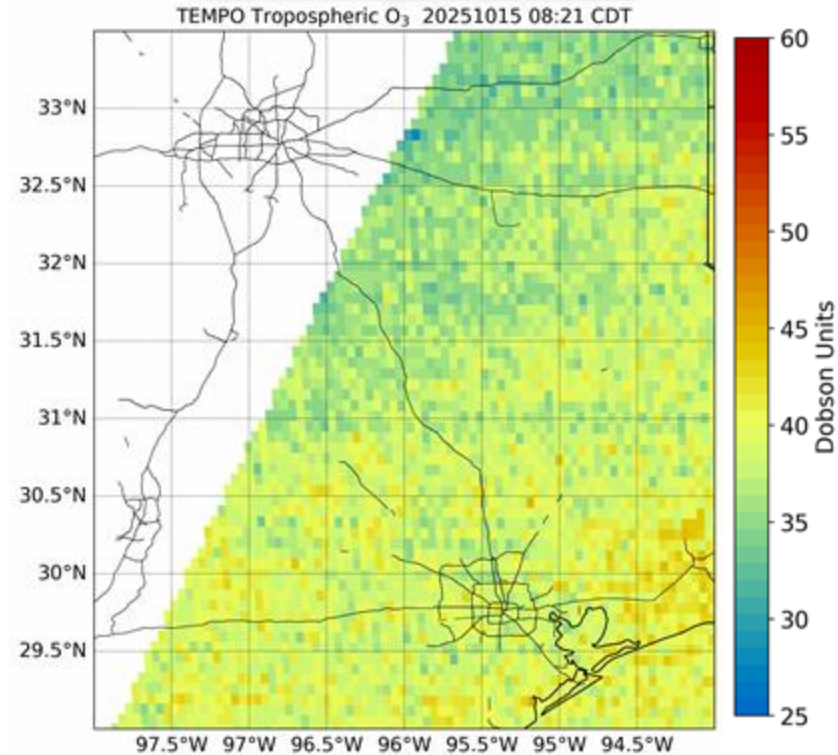


Oct 15, 2025 – East Texas Ozone (Version 4 Data)

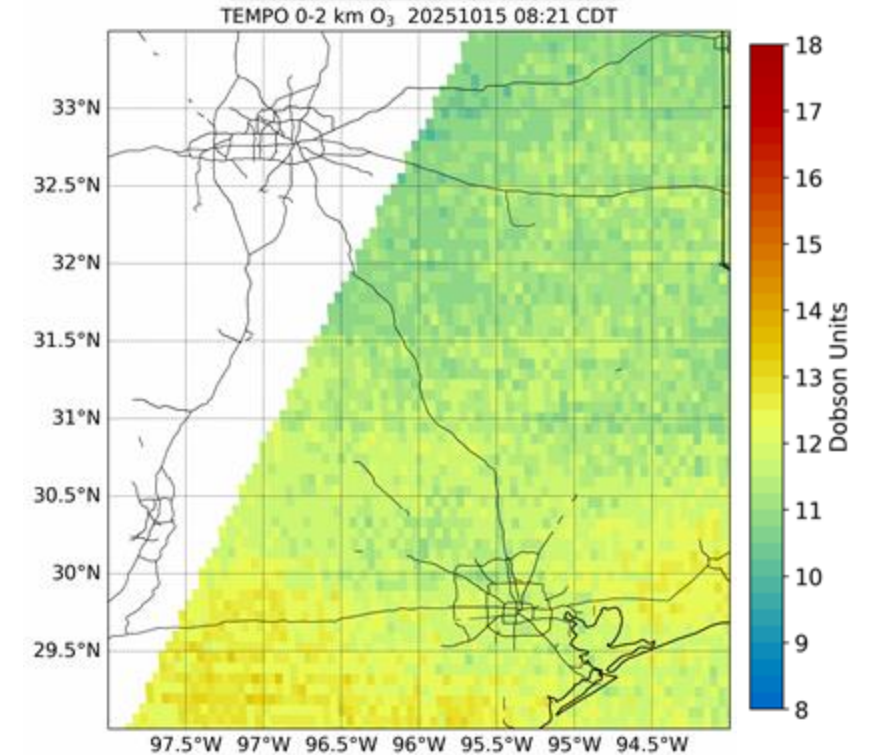
AirNow Ozone Monitors



Tropospheric O₃

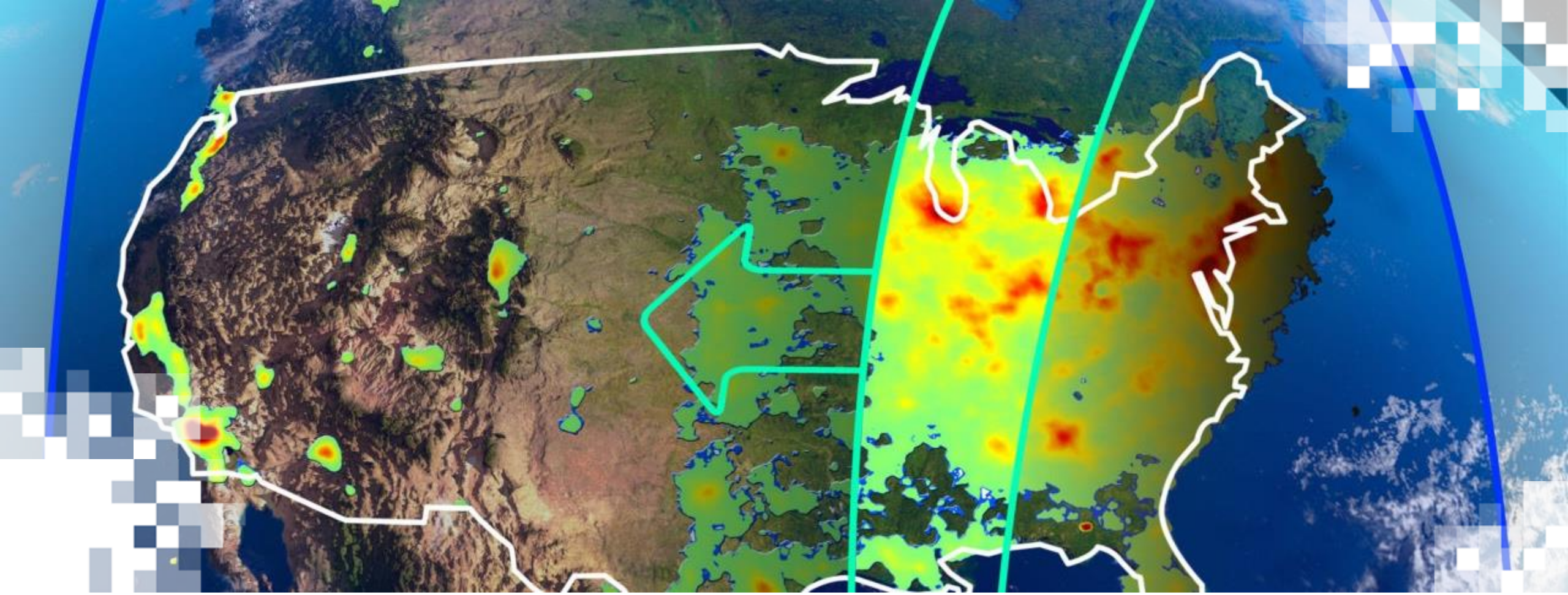


0-2 km O₃



- TEMPO observes elevated O₃ in the same regions as ground measurements.
- TEMPO's spatial and temporal information can supplement ground-based monitors.





Case Exercise 2

Case Exercise Instructions

Urban Pollution and Sources in Eastern Texas: June 6, 2024 and October 15, 2025

June 6, 2024

- Link to [Worldview](#)

October 15, 2025

- Link to [Worldview](#)



Summary Case 2

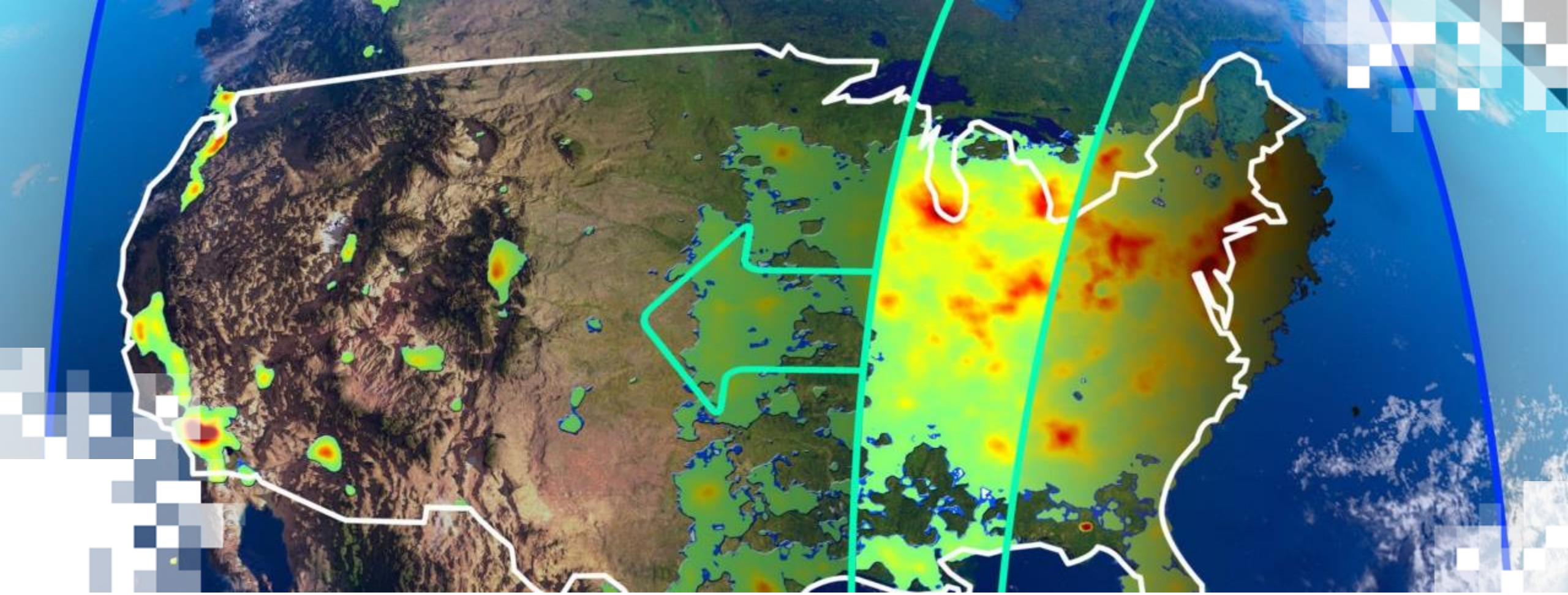
- TEMPO captures NO_2 and HCHO hot spots from major emission sources like power plants.
- Hourly data provides information about emission patterns and the varying importance of different sources at different times of day.
- TEMPO's ozone profile observations align with surface air quality conditions, detecting elevated O_3 where ground monitors show unhealthy O_3 levels.



Summary

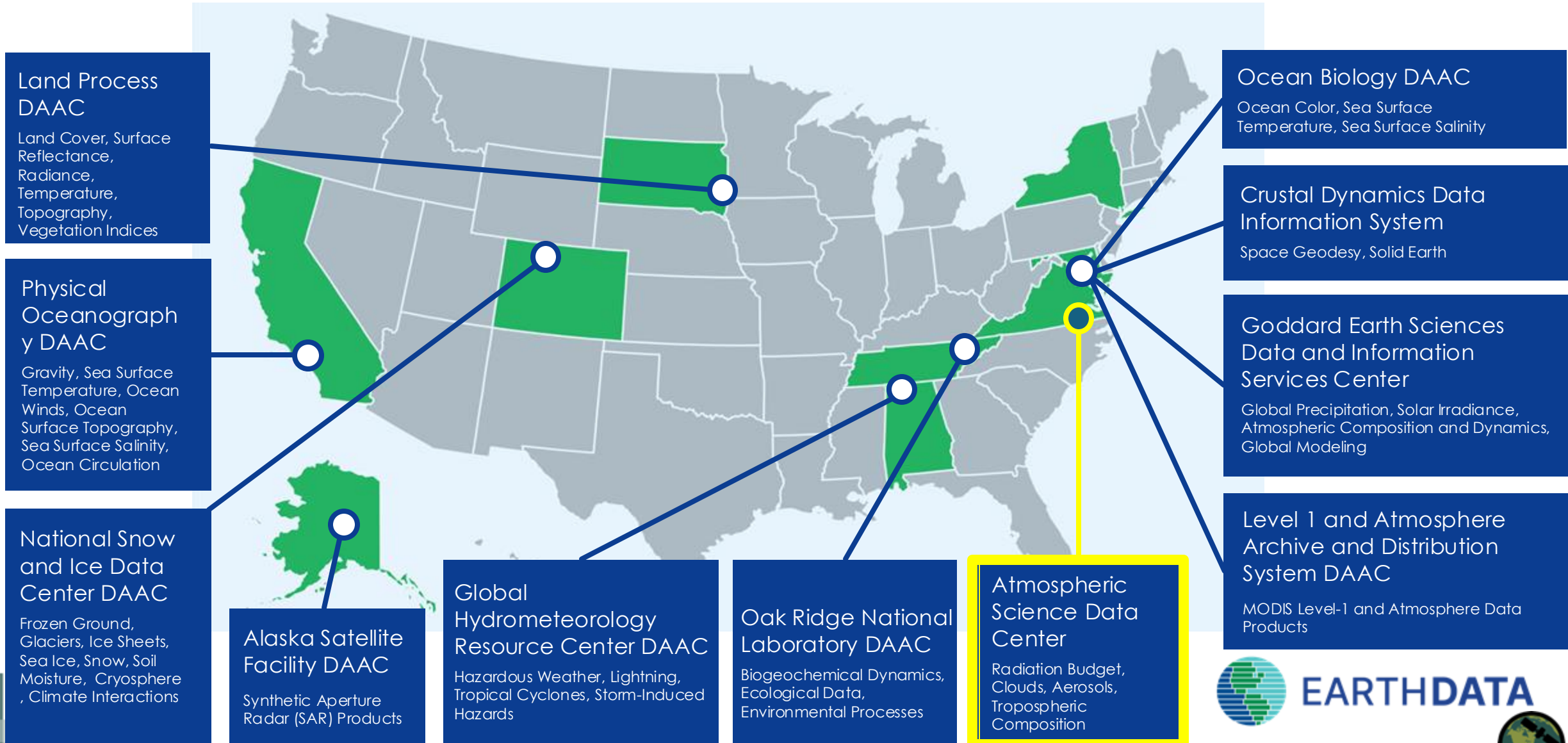
- In two case studies, we determined the spatial patterns, temporal evolution, and likely sources of trace gases related to wildfire smoke and urban area air pollution events using TEMPO data visualization via Worldview.
- TEMPO trace gas products in Worldview can be used to anticipate short-term air quality risks, such as high concentrations of ozone precursors.
- Hourly TEMPO data allows for tracking diurnal cycles of pollutants and identifying time-varying emission sources.
- The TEMPO products exhibit good correlation with ground-based column measurements, indicating that they may be useful to complement ground-based air quality monitoring to improve situational awareness of air quality risks.
- New TEMPO ozone profile products will add more insight to the air quality impacts of near-surface ozone.





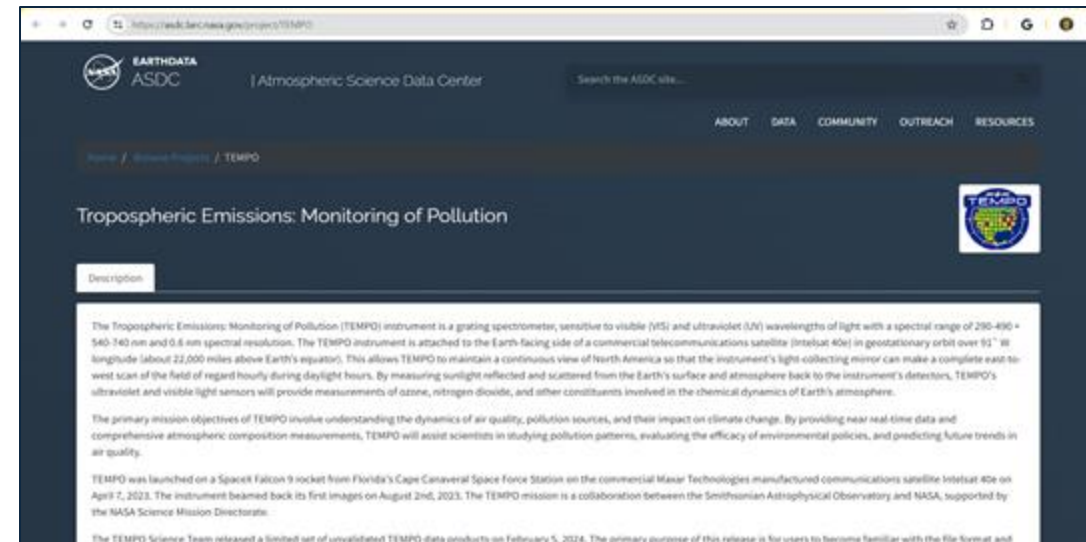
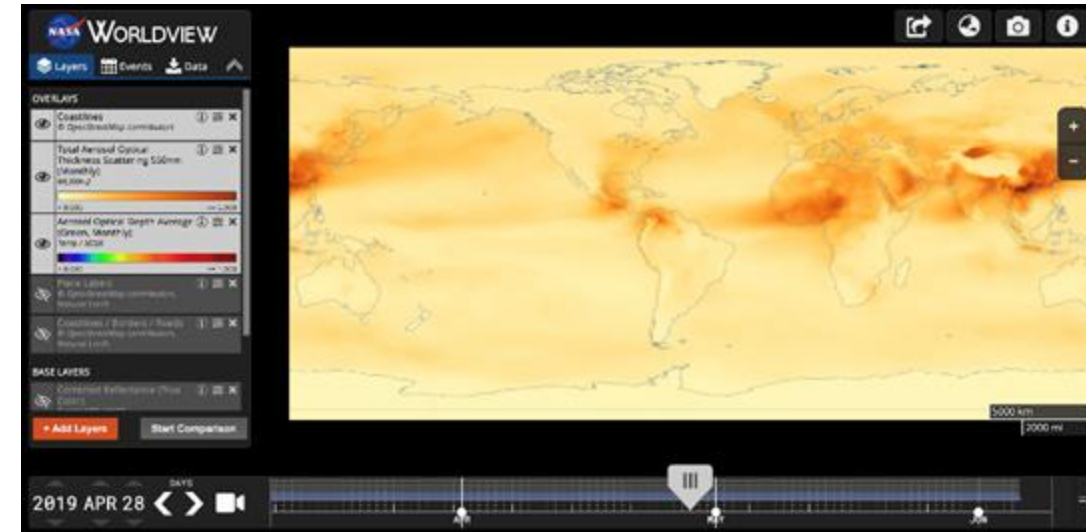
Options for Accessing TEMPO Data

NASA's Distributed Active Archive Centers (DAACs)



TEMPO Data Distribution: Tools and Services

- [ASDC TEMPO Page](#)
- [Earthdata Search](#)
- [Worldview](#)
- [Harmony](#)
- [Earthdata GIS](#)
- [OPeNDAP](#)
- [Google Earth Engine](#)
- [Jupyter Notebooks](#)
- [Earthdata Forum](#)



TEMPO Operations Mode

- Nominal Operations
- Twilight Scans
- Research Requests (e.g., Wildfires)
- Regularly Scheduled Maintenance (Usually Tuesdays & Saturdays)
- Unplanned Outages



[Check the TEMPO Operations Log Here](#)



Earthdata Forum

- **Science Data Users** can seamlessly search for information even if they do not know which DAAC the data belongs to.
- **Scientists & Data Providers** can effectively assist their user community in more accurately using their products.
- **DAACs & Subject Matter Experts (SMEs)** can quickly link users to existing resources.
- **DAAC User Services** can swiftly provide inquirers with an authoritative source related to DAAC data products & services.
- **Tag** posts with “ASDC” or “TEMPO”

The screenshot shows the Earthdata Forum website. At the top, there is a navigation bar with the Earthdata logo, a search bar for DAACs, and a feedback icon. Below the navigation bar is a header section with the NASA logo and the text "EARTHDATA Forum BETA". A welcome message follows, stating: "Welcome to the Earthdata User Forum! Here, subject matter experts from several NASA Distributed Active Archive Centers (DAAC) can discuss general questions, research needs and data applications. Users can query how to access, view and interpret the data." Below the header is a blue navigation bar with links for "Quick links", "FAQ", "Data Recipes", and a "Login" button. A "Home" button is also present. The main content area shows the current date and time: "It is currently Fri Feb 21, 2020 1:51 pm America/New_York". There is a "Post a New Question" button. Below this is a "SEARCH" section with a search input field containing the placeholder text "Search for keywords, tags..." and a "Submit" button. To the right of the search field is a link for "Advanced Search". Below the search section is a "SEARCH BY TAGS" section with four dropdown menus labeled "Discipline", "DAAC", "Major Projects", and "Services/Usage", each with a "Select" option. A "Submit" button is located below the dropdown menus. To the right of the "Submit" button is a link for "What do these tags mean?". Below the "SEARCH BY TAGS" section is a "FORUM" section with a table of forum posts. The table has columns for "FORUM", "QUESTIONS", "POSTS", and "LAST POST". The first row shows "All Questions/Comments" with 215 questions and 452 posts. The last post is titled "Where can I find more FAQs fr..." by "GES DISC - zliu" on "Fri Feb 21, 2020 10:18 am America/New_York".



Training Summary

- TEMPO's hyperspectral capability across ultraviolet to visible wavelengths enables retrieval of criteria trace gas pollutants in the troposphere at unprecedented spatial and temporal resolution across greater North America.
- TEMPO observes small-scale emission sources and fine-scale pollutant gradients that have not been adequately resolved by previous satellite missions.
- Its geostationary, hourly, daylight observations and special observation modes allow for monitoring rapidly evolving pollutants, supporting air quality analysis & forecasting.
- The newly-available O₃ profile product offers enhanced capabilities to monitor and characterize ozone concentrations in the tropospheric layer.
- NASA Worldview provides visualization capabilities of hourly Level 2 and Level 3 trace gas data products with basic quality assurance screening. This can be used to determine the spatial patterns, temporal trends, and likely sources of trace gases (criteria pollutants and precursors) related to wildfire smoke and urban area air pollution events.
- For more quantitative analysis, users need to apply quality assurance variables for removing TEMPO data associated with larger errors or uncertainties from their analysis.



Homework and Certificates

- Homework:
 - One homework assignment
 - Opens on 01/22/2026
 - Access from the [training webpage](#)
 - Answers must be submitted via Google Forms
 - Due by 02/05/2026
- Certificate of Completion:
 - Attend both live webinars (attendance is recorded automatically)
 - Complete the homework assignment by the deadline
 - You will receive a certificate via email approximately two months after completion of the course.





Thank You!

