Challenges in Biomass-Burning–Influenced TEMPO HCHO and NO_2 Retrievals

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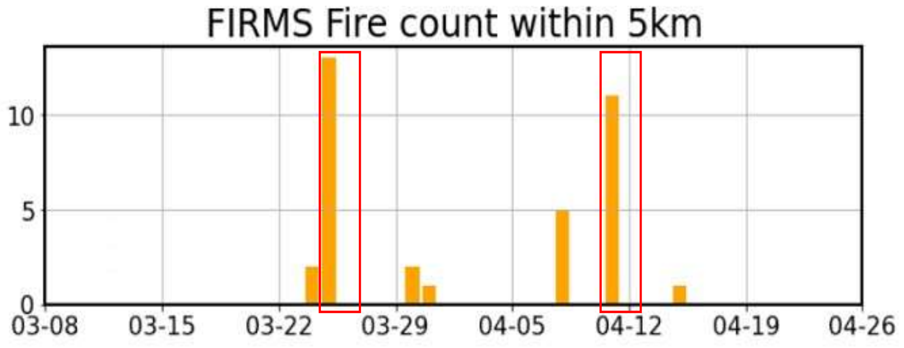
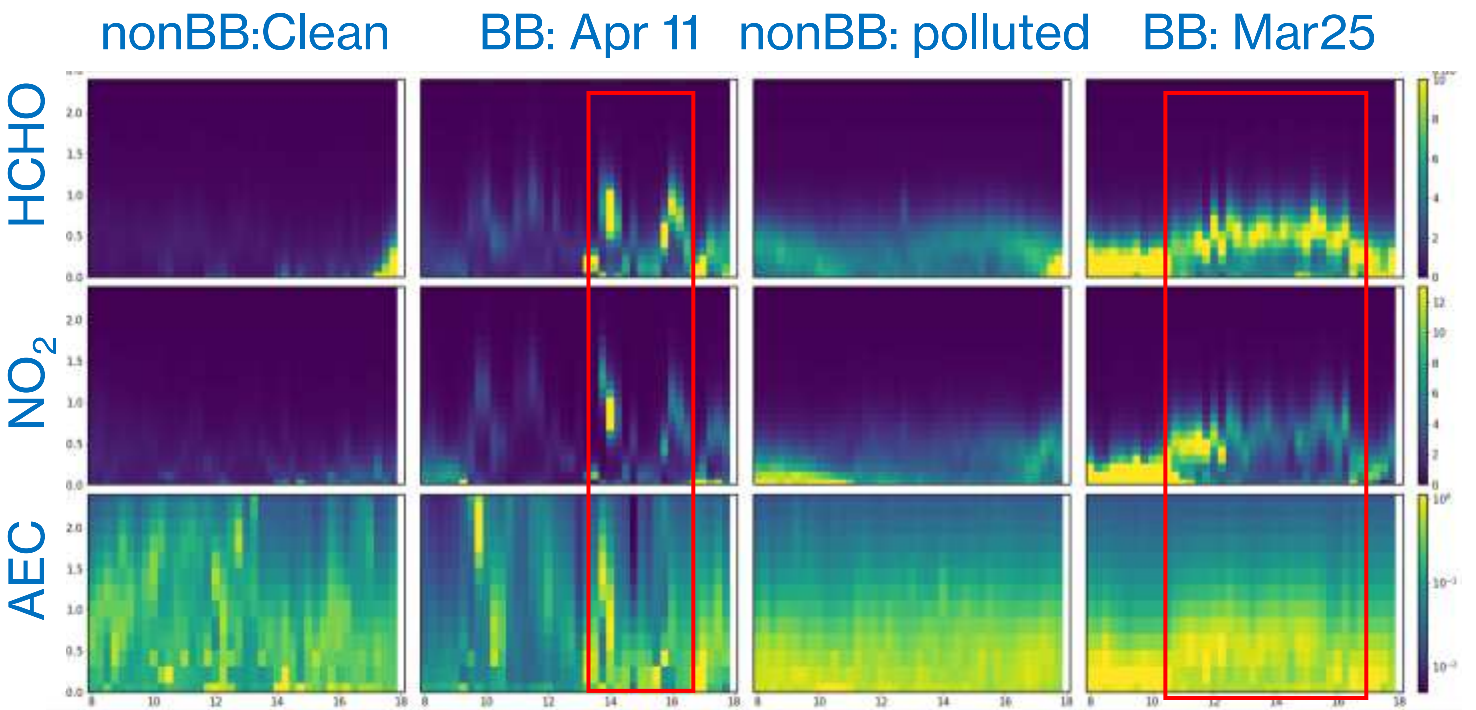
Varying Biomass-Burning Emissions of HCHO, NO_2 and Aerosols

- Max-DOAS observations of biomass-burning-induced enhancements under clean and polluted conditions reveal **variations in emission rates and emission ratios.**
- The HCHO signal is stronger than that of NO_2.

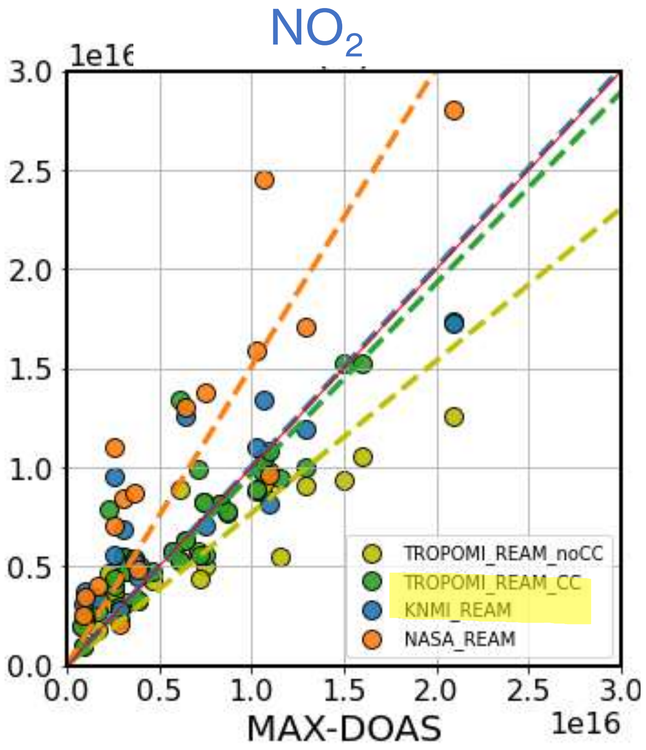


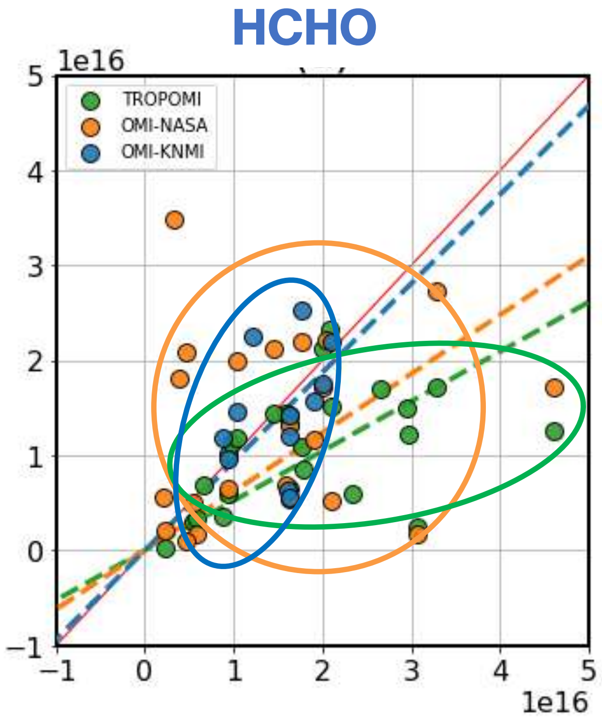


Measured species concentrations with and without biomass burning in clean and polluted days

(Chong et al, 2024)

Opportunity of Using TEMPO to detect Biomass-Burning Emissions

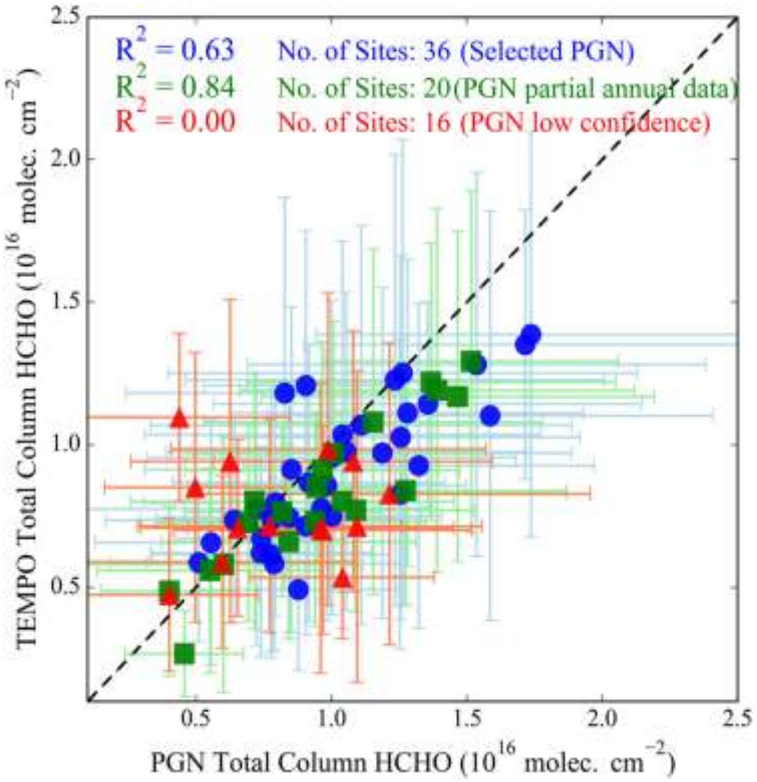




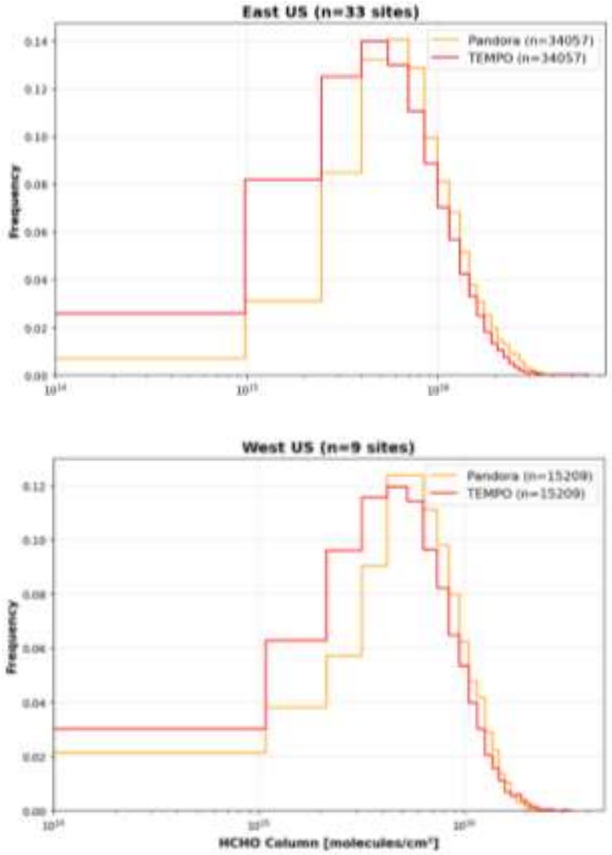
(Chong et al., 2024)

Compared with OMI and TROPOMI, the improved sensitivity and spatial–temporal resolution of TEMPO HCHO measurements enable more effective quantification of biomass-burning emissions.

Opportunity of Using TEMPO to detect Biomass-Burning Emissions



8/23-9/24
(Rawat et al, 2026)



Comparison for 2024

Compared with OMI and TROPOMI, the improved sensitivity and spatial–temporal resolution of TEMPO HCHO measurements enable more effective quantification of biomass-burning emissions.

Statistics of Biomass-Burning Influences Using TEMPO and Pandora Observations

- **TEMPO HCHO (L2 V03):** Hourly daytime vertical column densities (VCD) over North America

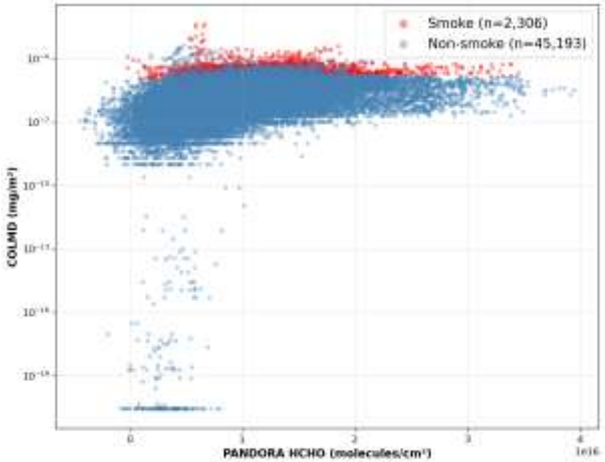
- **PANDORA MAX-DOAS:** “Clean” tropospheric HCHO columns sensitive to the lower troposphere

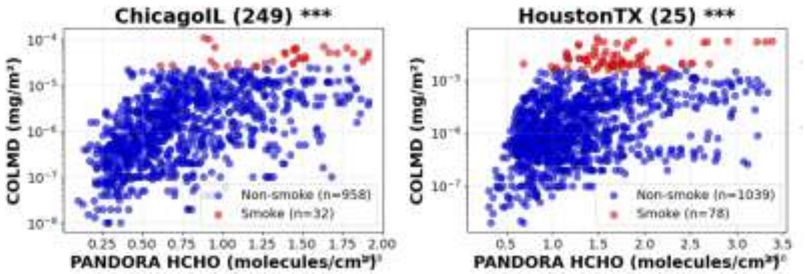
- **HRRR-Smoke (NOAA):** Column-integrated smoke mass density (COLMD) used to classify smoke-impacted data

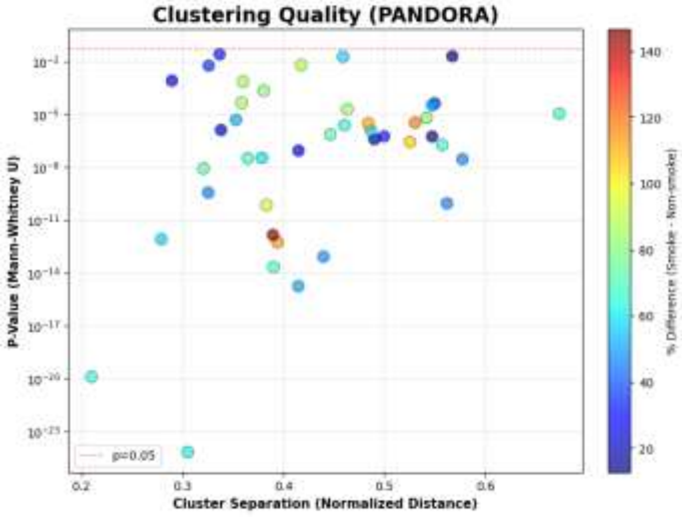
- **ERA5 Meteorological Reanalysis:** Matches hourly boundary layer dynamics, temperature, dewpoint, and UV radiation fields.

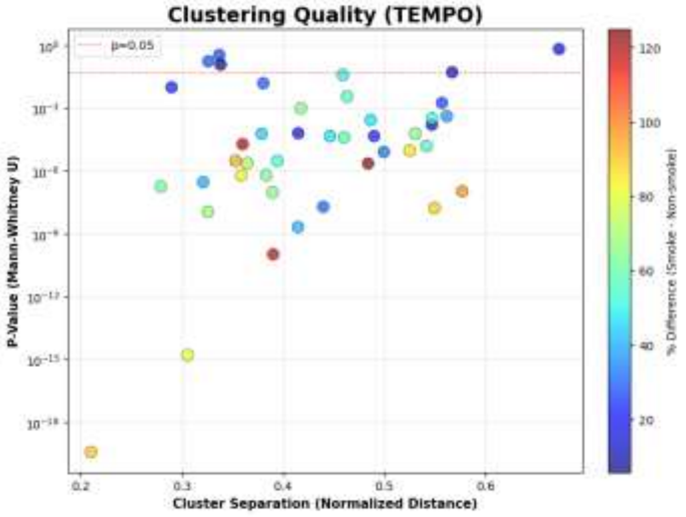
Site-Dependent Dynamic Separation of Detectable BB HCHO Enhancements

- Clustering of Pandora and TEMPO HCHO columns using HRRR COLMD
- Pandora HCHO exhibits clearer separation than TEMPO HCHO



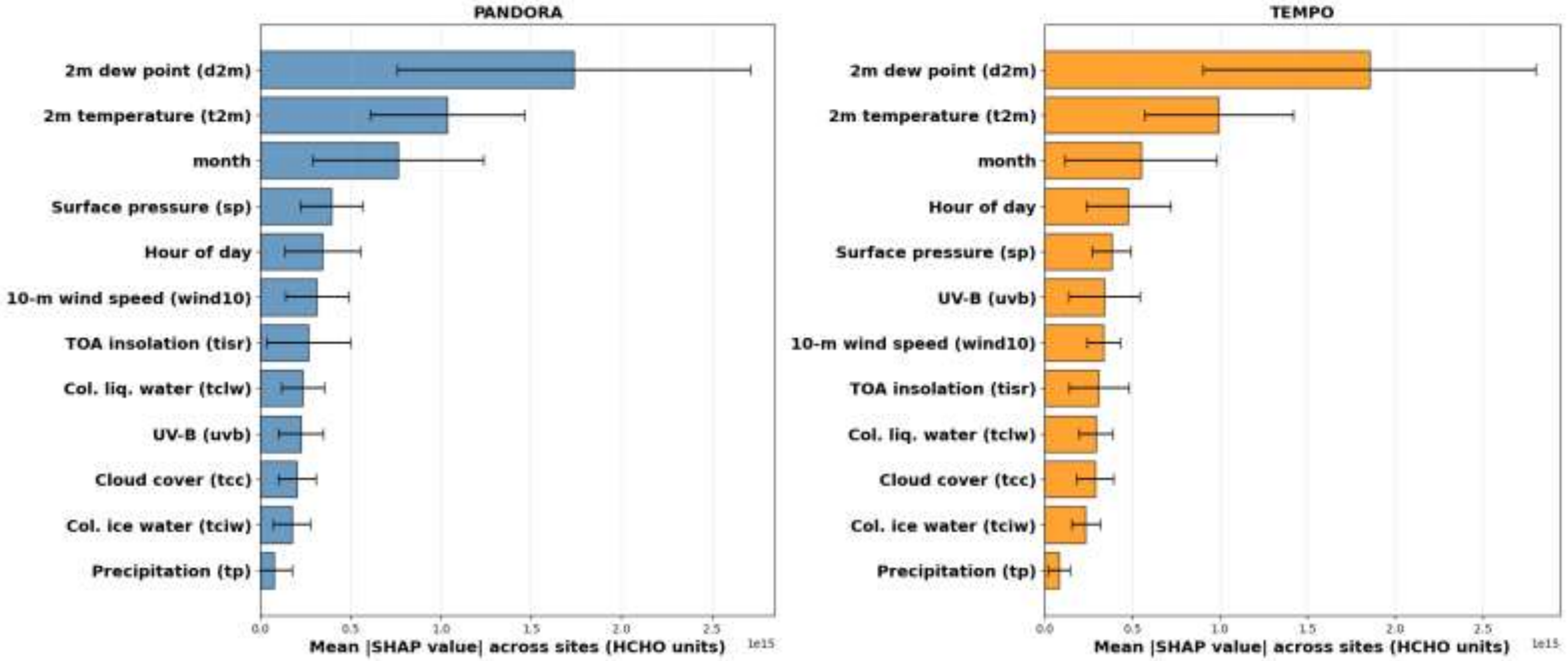




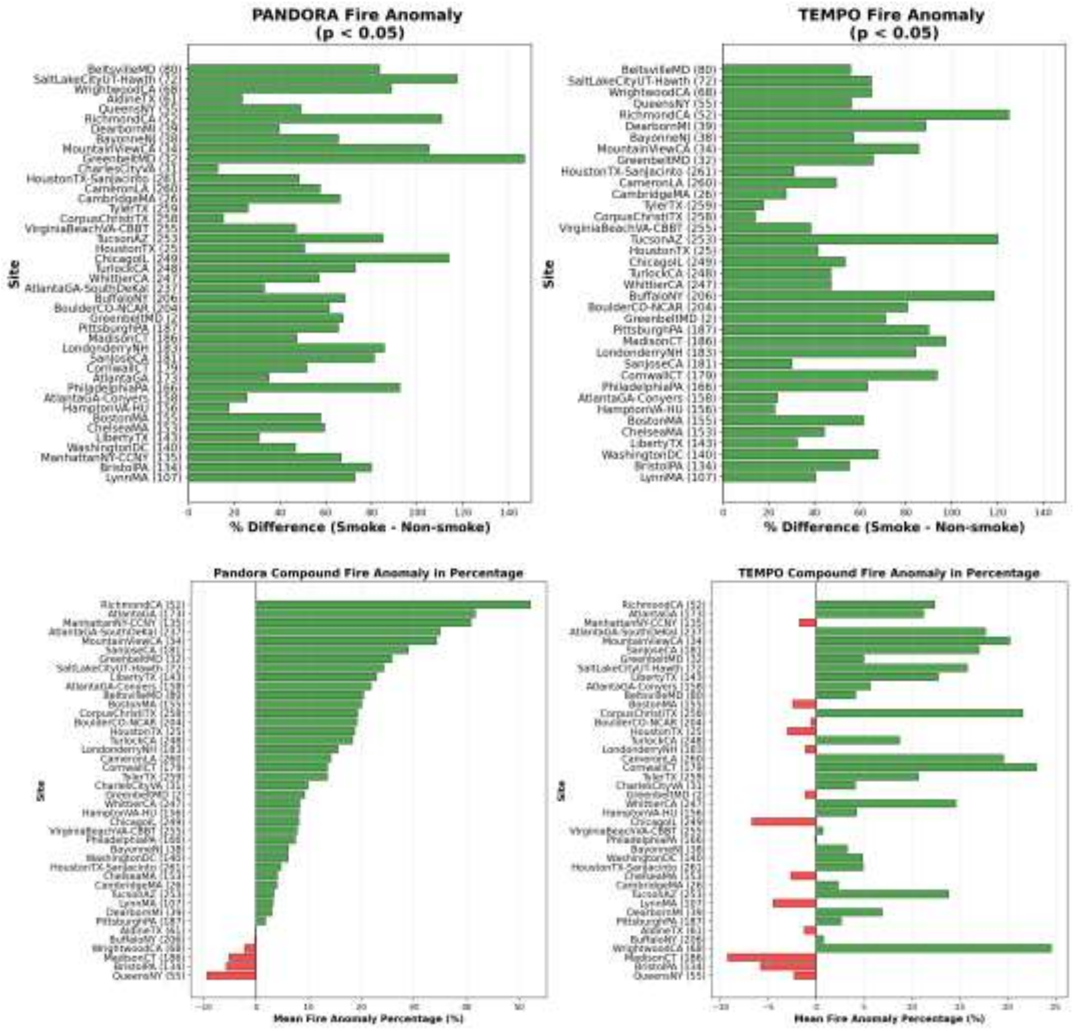


Machine-Learning Estimates of Baseline HCHO for BB-Affected Data

- ML regressor trained on non-smoke days to establish a robust meteorological baseline
- Surface dew point and temperature dependence reflects biogenic VOC emissions, boundary-layer depth, photochemical HCHO production, as well as fuel conditions

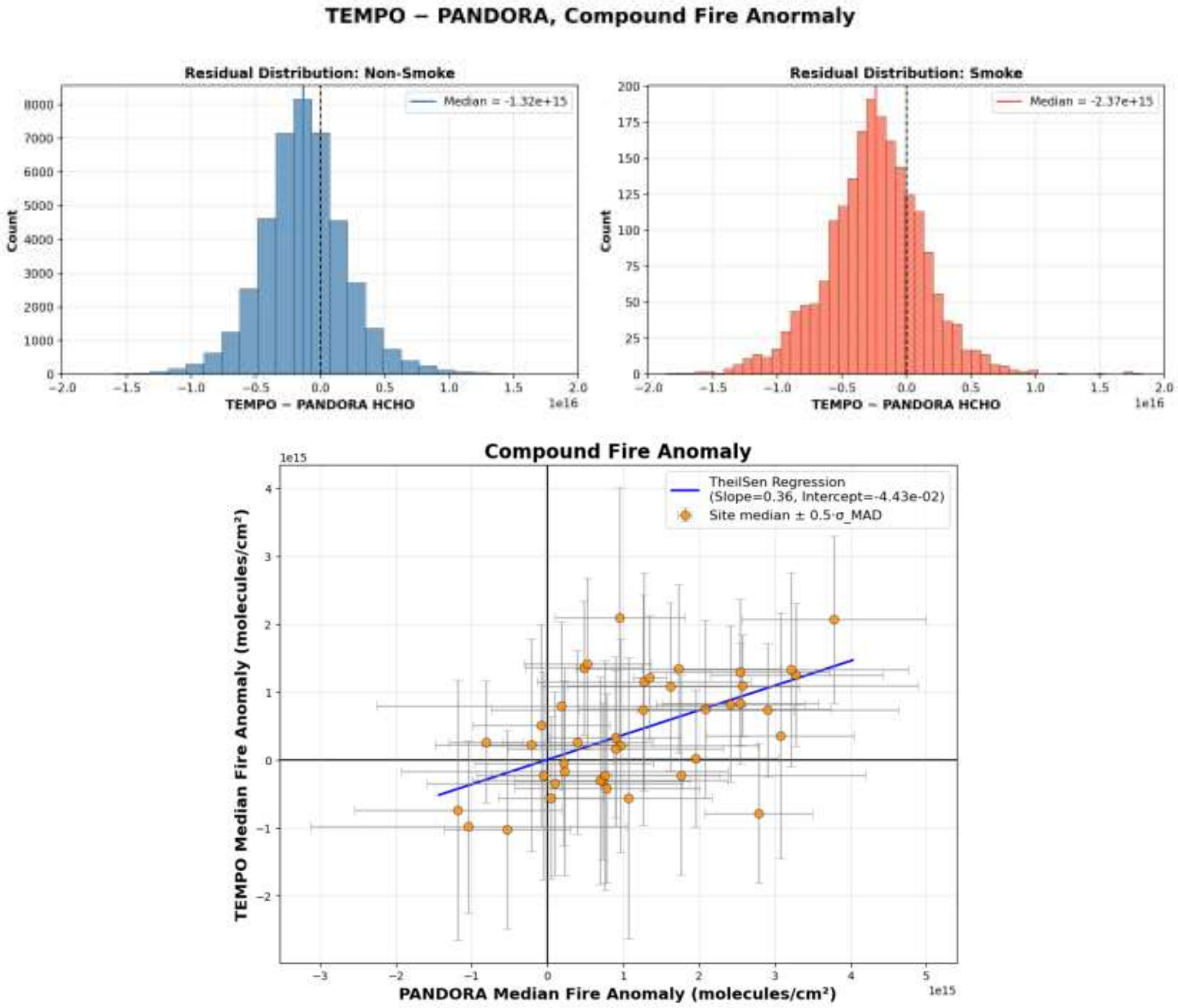


Biomass-Burning HCHO Enhancements: Raw vs. Compound



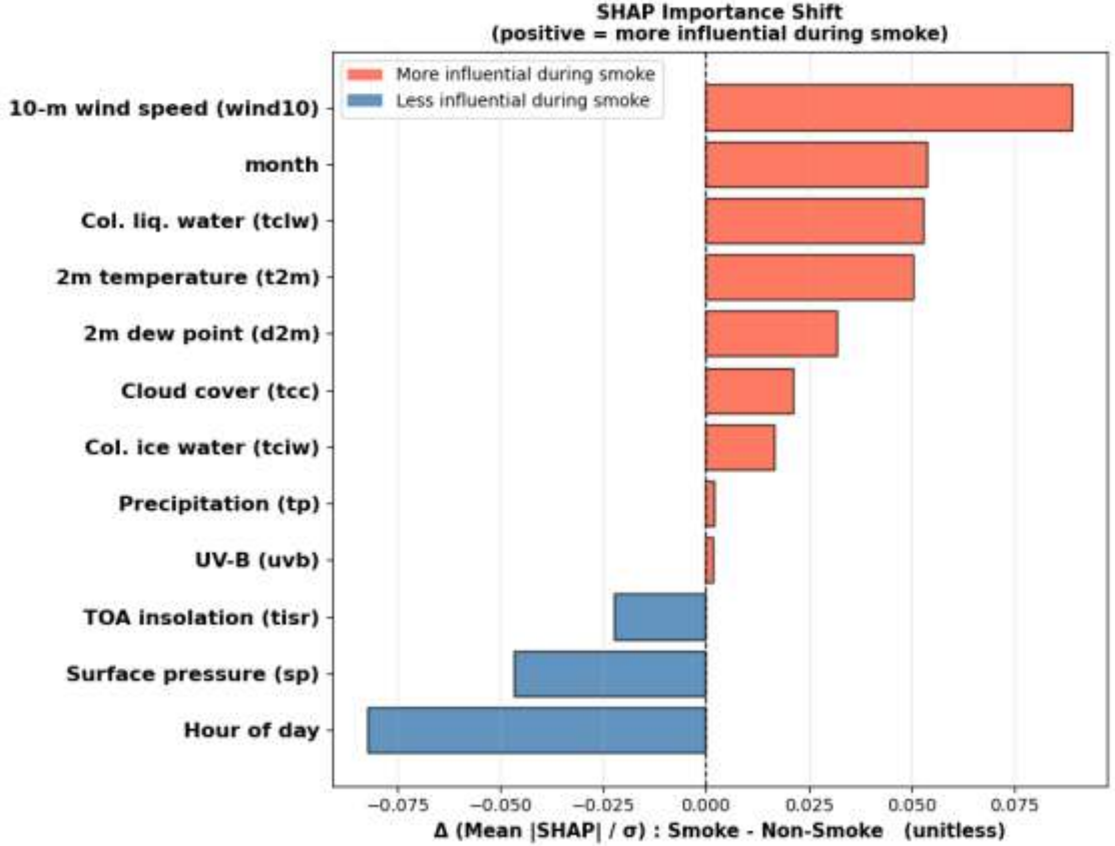
- The **raw difference** is defined as smoke minus non-smoke HCHO
- The corresponding relative raw difference is large (20–140%)
- The **compound difference** is computed as smoke HCHO relative to the corresponding ML-estimated baseline
- Relative compound differences are substantially smaller than raw differences
- Pandora relative compound differences are larger, on average, than those of TEMPO and variations between Pandora and TEMPO results are large

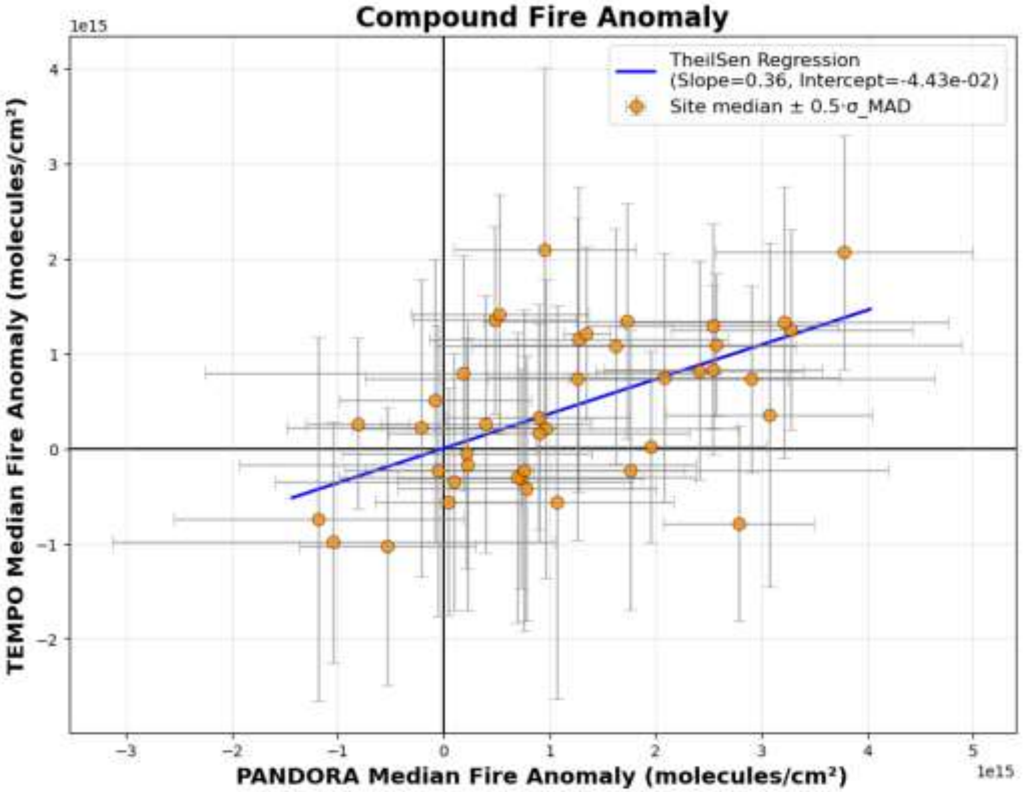
Low Biases in TEMPO HCHO Retrievals Relative to Pandora Measurements



- The TEMPO–Pandora HCHO difference is approximately twice as large during smoke-affected periods as during non-smoke conditions
- Theil–Sen regression indicates that TEMPO captures about 40% of the biomass-burning-induced anomaly observed by Pandora

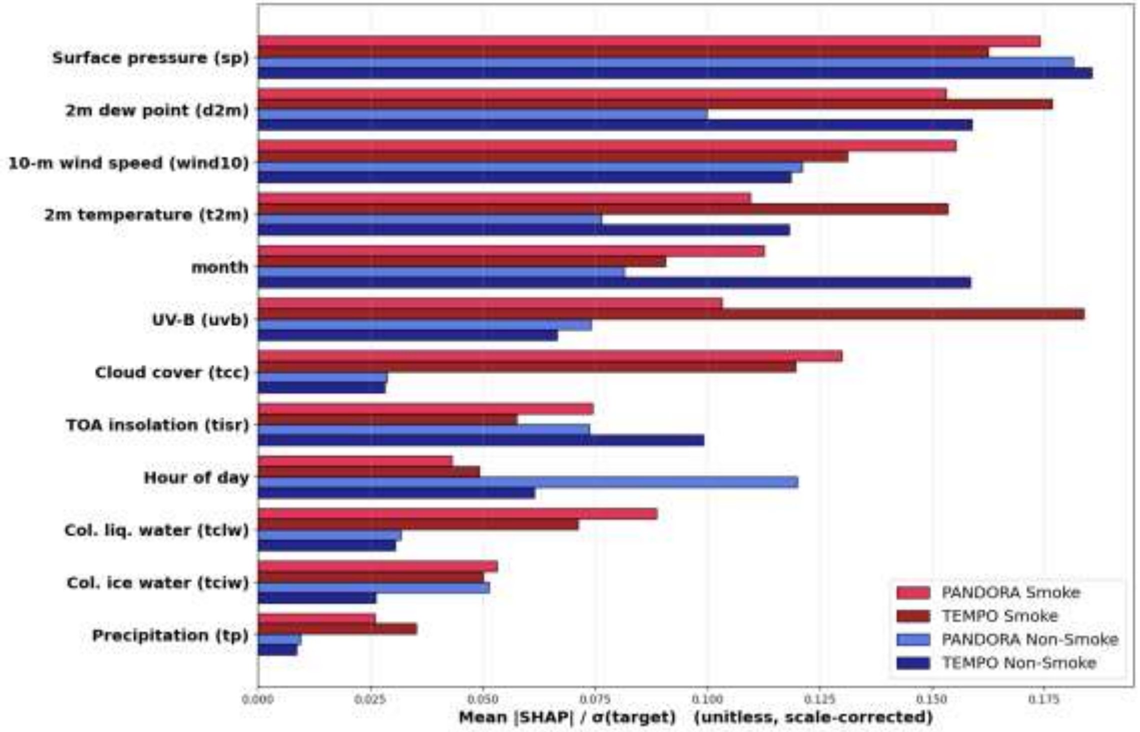
ML-Based Attribution of TEMPO-Pandora HCHO Differences

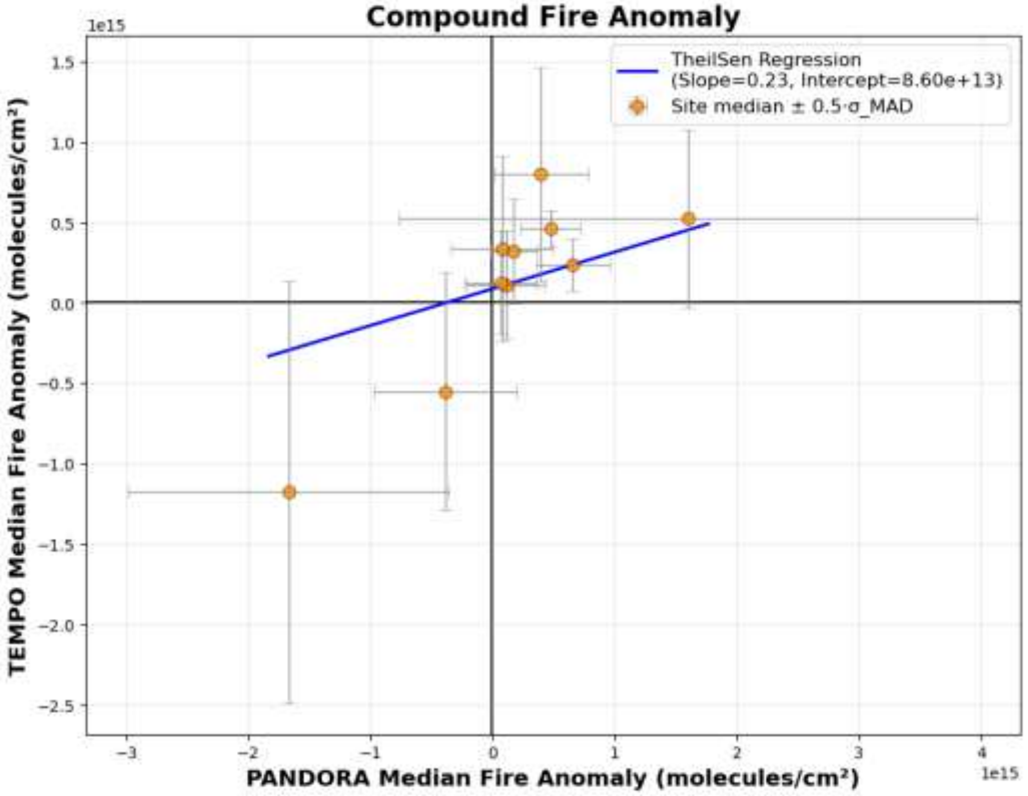




- SHAP importance metrics shifts non-smoke to smoke conditions
- Surface wind emerges as the dominant driver of the differences between TEMPO and Pandora results

Preliminary Analysis of BB-Influenced NO_2 retrievals in TEMPO and Pandora



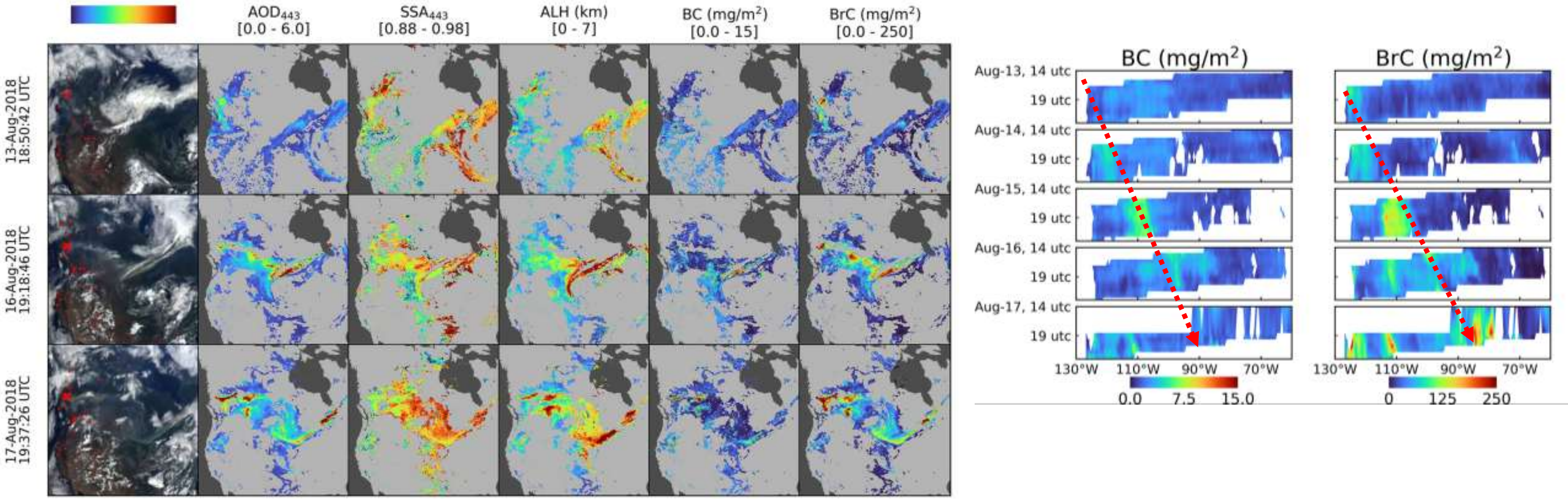


- ML attribution indicates a stronger role of surface pressure and wind in driving NO_2 VCD variations

- Biomass-burning (BB) enhancements in NO_2 are also underestimated by TEMPO relative to Pandora
- The number of sites showing statistically significant differences need to be increased

Next Step: Reducing Negative Biases in TEMPO Biomass-Burning Estimates

- **Absorbing Aerosols:** UV-absorbing aerosols shield HCHO columns below the plume
- **Elevated Fire Plume Profiles**



MAIAC EPIC retrievals of British Columbia wildfire plumes (Choi et al., 2024)