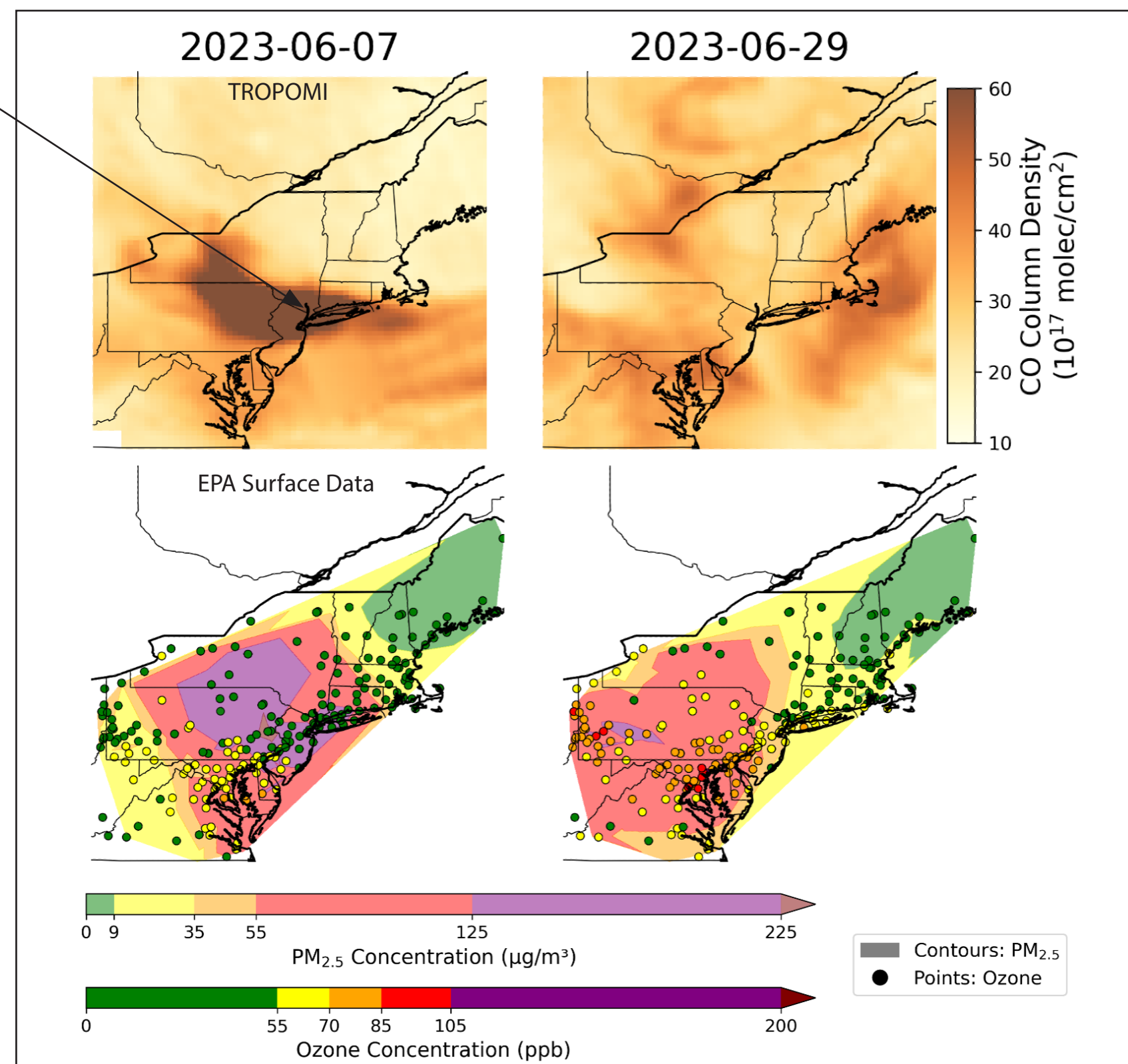


I. Introduction



New York City on 2023/6/7 (credit: NOAA)

heavy smoke, no ozone
medium smoke, lots of ozone

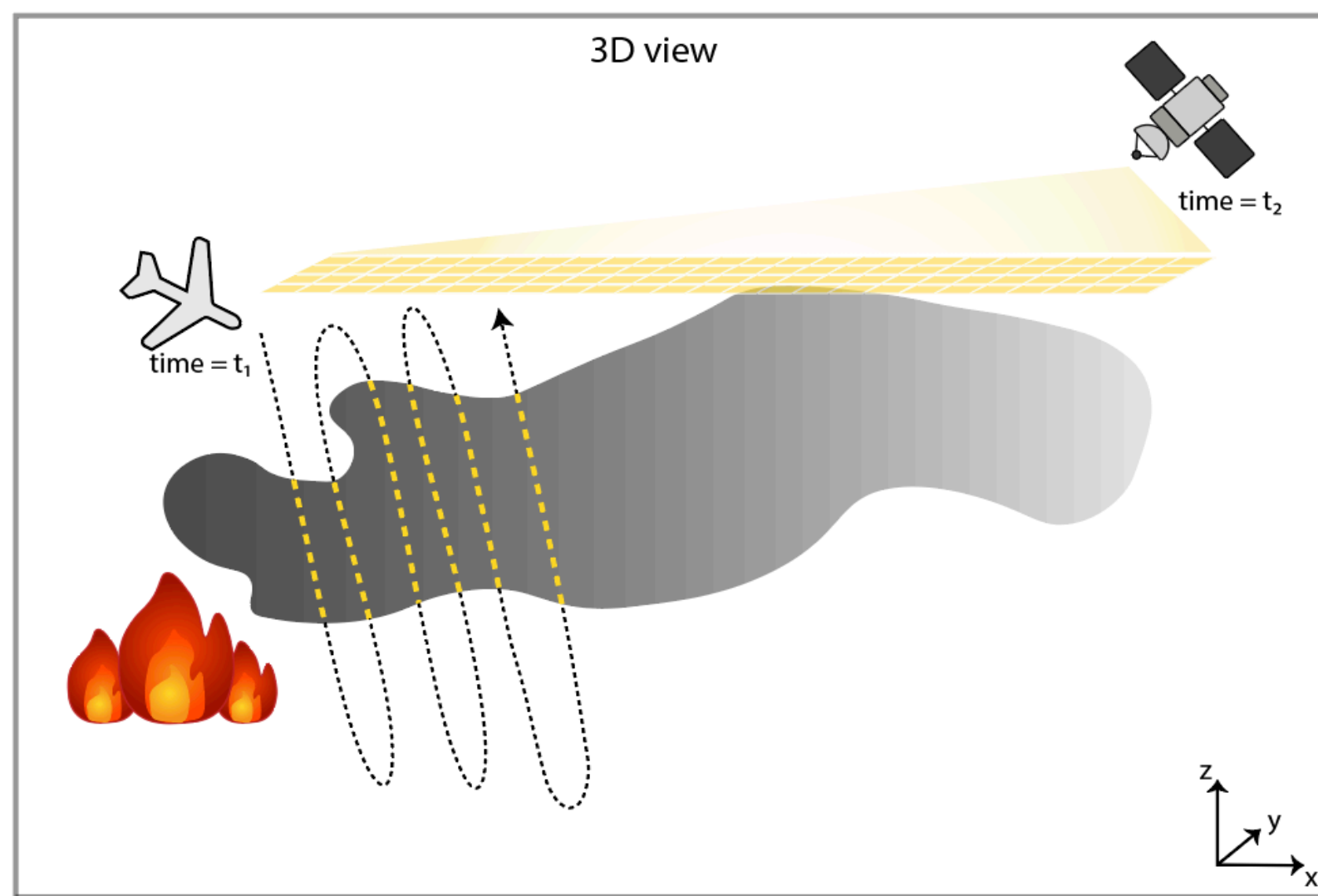


- Ozone is a harmful air pollutant that is photochemically produced
- Wildfires emit ozone precursors – but plume-to-plume variability remains unexplained [1,2]
- Whether ozone exceedances are impacted by transported wildfire smoke changes the appropriate emission control strategy (of interest to our stakeholders at NYSDEC and NESCAUM)

II. Can satellite column measurements be used to approximate smoke-ozone chemistry?

Satellite observations have the necessary spatiotemporal resolution to track smoke plume development

- Airborne observations are detailed and high resolution, but limited in coverage

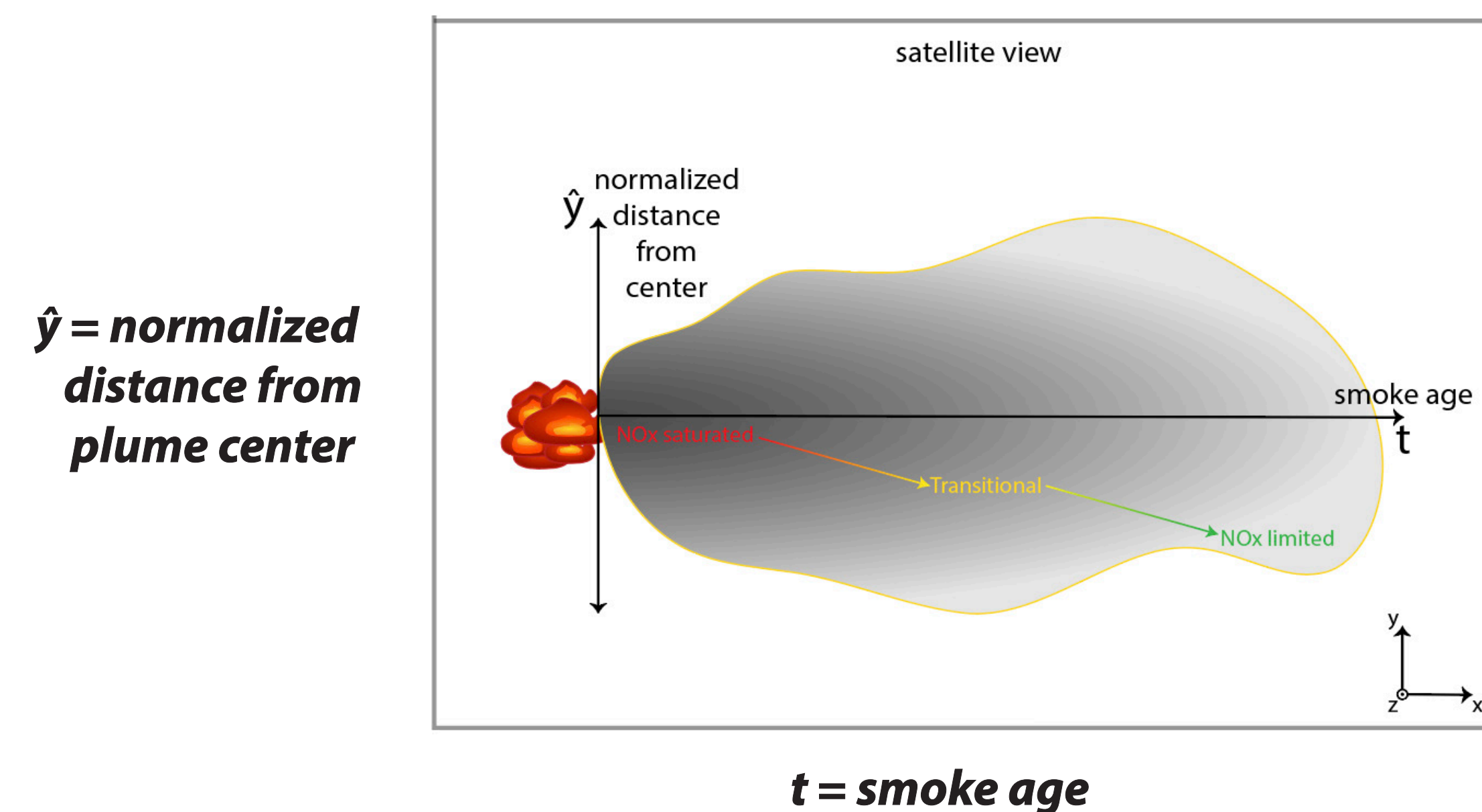


- Satellite observations provide comprehensive coverage, but limited vertical information



We link in-situ observations of smoke composition to satellite column measurements

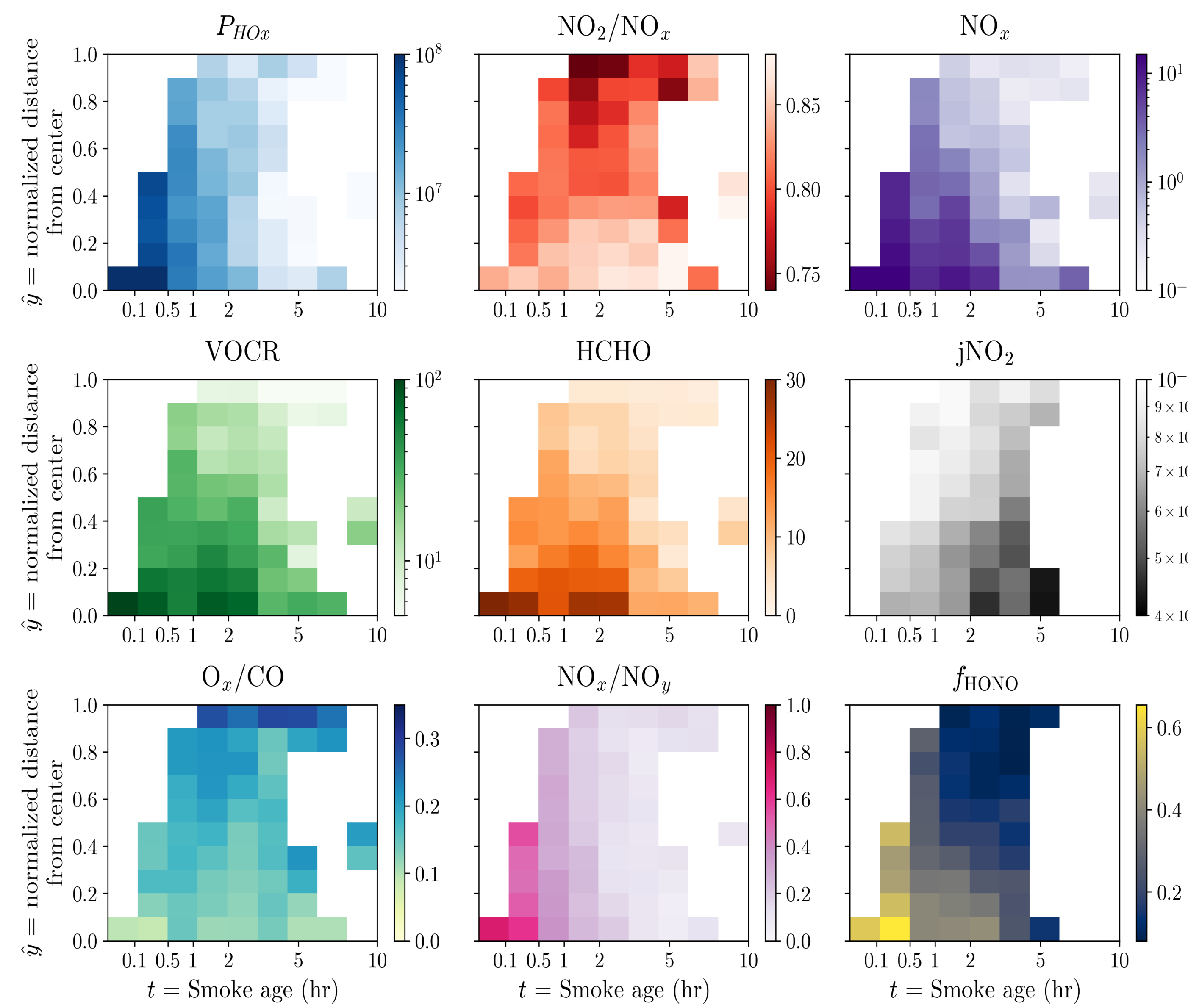
We propose a generalizable two-dimensional coordinate system (t, \hat{y})



- Extensive airborne data has been used to understand smoke plume structure and evolution [3-7]
- Space-based measurements must be interpreted in 2-D

III. Observed chemical gradients in (t, \hat{y}) space

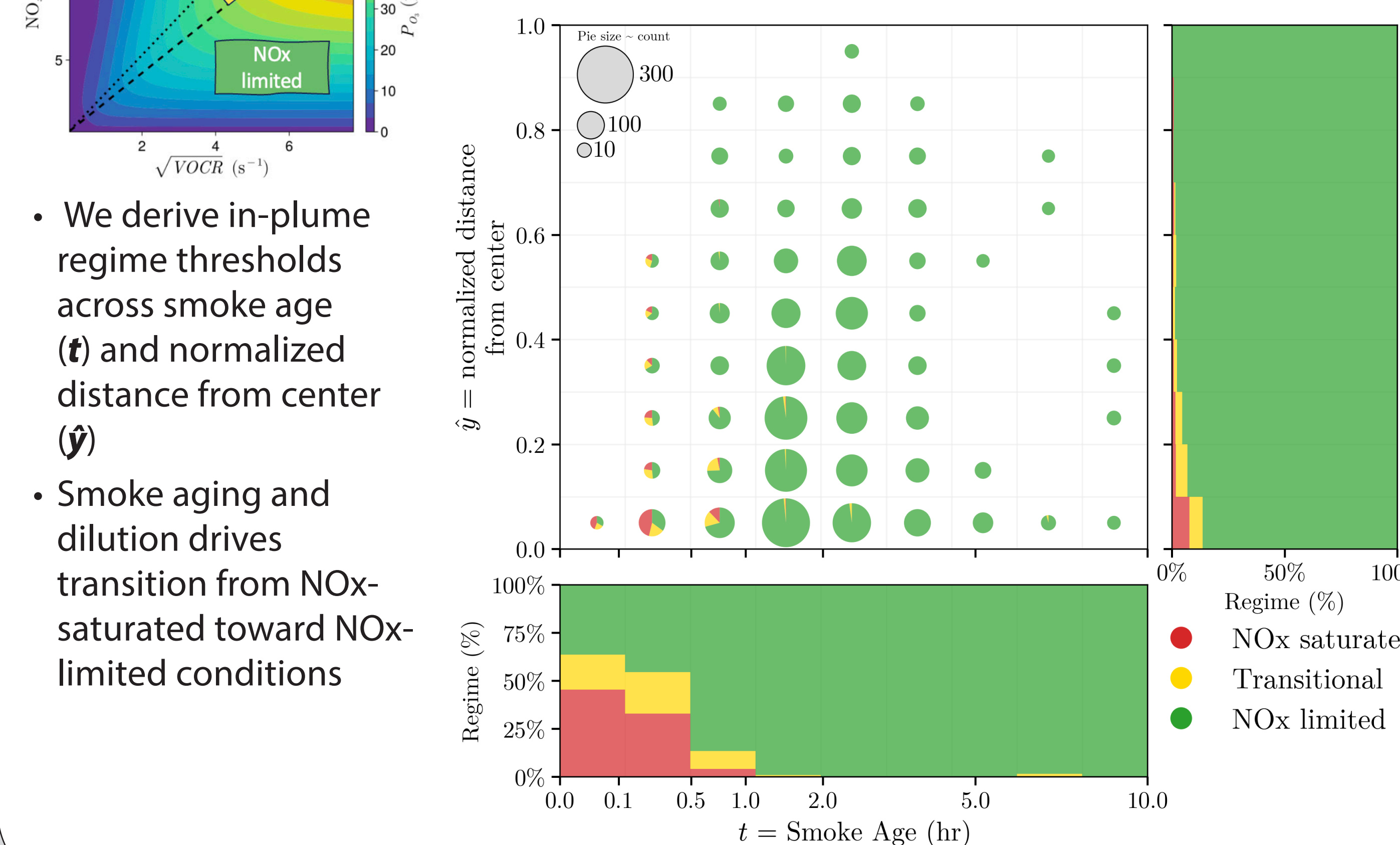
- We quantify changes in photolysis, oxidation, and concentrations across smoke age (t) and normalized distance from center (\hat{y})
- The transformed coordinate system reveals systematic chemical evolution



We show that evolving ozone-forming chemistry within wildfire smoke plumes can be derived from satellite observations

IV. Ozone formation regime analysis

- Using a steady-state model [8] coupled with FIREX-AQ airborne measurements, we predict how ozone chemical conditions evolve within smoke plumes



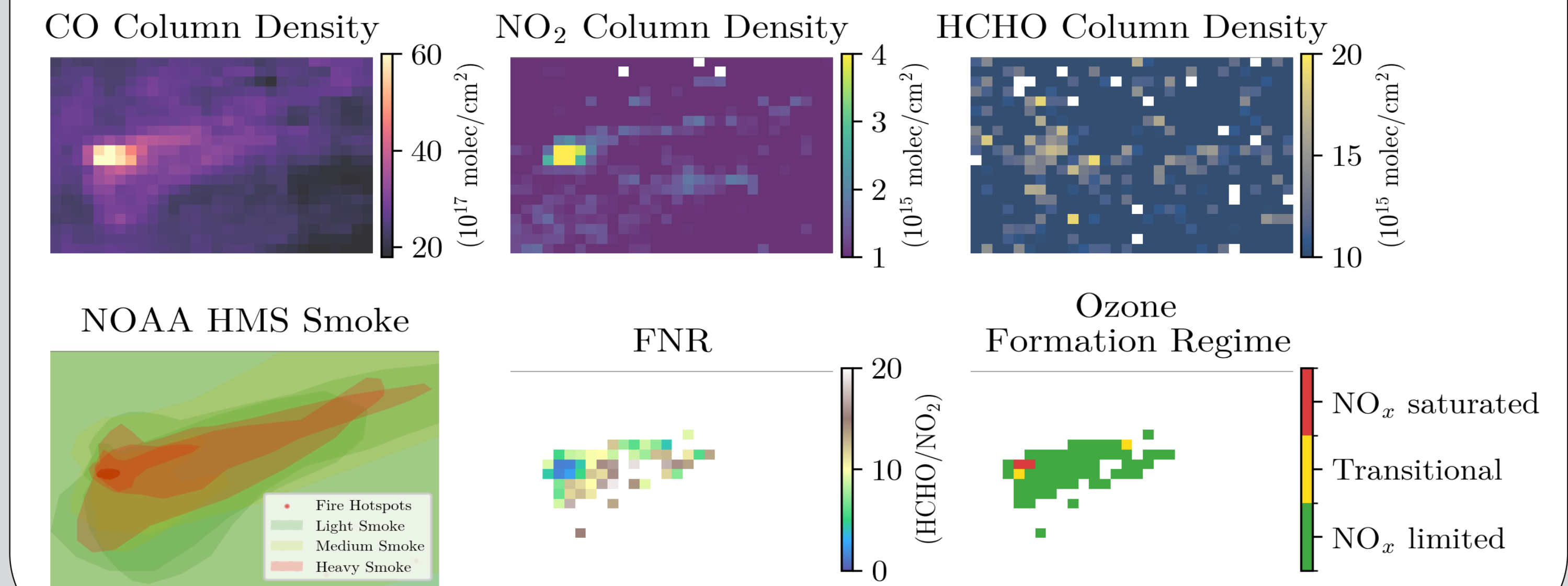
- We derive in-plume regime thresholds across smoke age (t) and normalized distance from center (\hat{y})
- Smoke aging and dilution drives transition from NOx-saturated toward NOx-limited conditions

V. Satellite application - Williams Flats Fire

We infer ozone formation regime evolution within smoke plume from space

- The following equation (Following Jin et al. [9]) translates in-plume regime thresholds to satellite-derived formaldehyde to nitrogen dioxide ratios (FNR) in (t, \hat{y}) space:

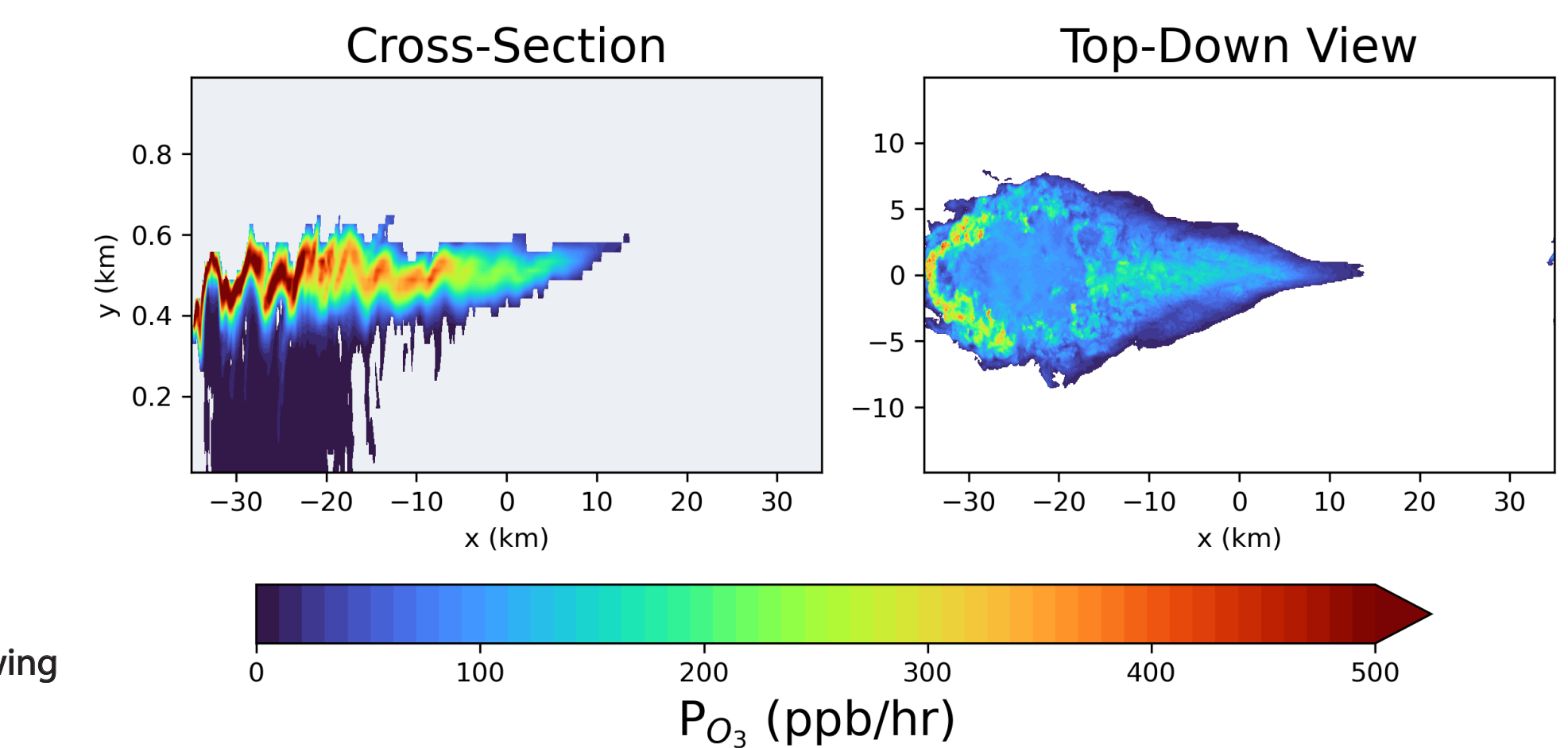
$$T_{\Omega_{\text{HCHO}}/\Omega_{\text{NO}_2}}(t, \hat{y}) = T_{\text{VOCR}/\text{NO}_x}(P_{\text{HO}_x}, f_{\text{NO}_2/\text{NO}_x}) \times \beta_{\text{HCHO}/\text{VOCR}}(t, \hat{y}) \times \frac{1}{f_{\text{NO}_2/\text{NO}_x}(t, \hat{y})} \times \frac{z_{p,\text{HCHO}}(t, \hat{y})}{z_{p,\text{NO}_2}(t, \hat{y})}$$



VI. High-resolution smoke modeling: WRF-LES-Chem

- High resolution (100m) model output for the Williams Flats Fire [7] allows us to:

- Estimate column density to plume concentration relationship
- Test neural network proxy approach (Following Sourì et al. [10,11])



VII. Neural network proxy

- We combine machine learning with satellite data to predict smoke ozone production rates
- Neural network with limited inputs ($t, \hat{y}, \text{HCHO}, \text{NO}_2$) struggles to reproduce fine-scale trends, such as aerosol induced photolysis suppression

VIII. Conclusions & Future Work

- We use satellite-observable smoke plume structure to infer ozone formation chemistry and regime evolution
- This approach can be used to disentangle plume variability in ozone production
- For accurate application of this framework, we need to reduce satellite retrieval uncertainties - which we are actively working on!