Using observations of Western U.S. wildfire smoke to improve fire emissions in air quality forecasting models

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Motivation

- Fire risk and property damage and loss of life due to fires are expected to continue to grow in the western U.S. along with population and longer, warmer, and drier fire seasons
- Air quality forecasts using regional chemical models provide key information for affected communities and smoke management efforts, yet models fail to accurately predict ozone and particulate matter levels during fire events
- Large source of model uncertainty is satellite-based emissions, which for the Oct. 2017 Northern California fires range among inventories by factor of 83 (**Fig. 1**)

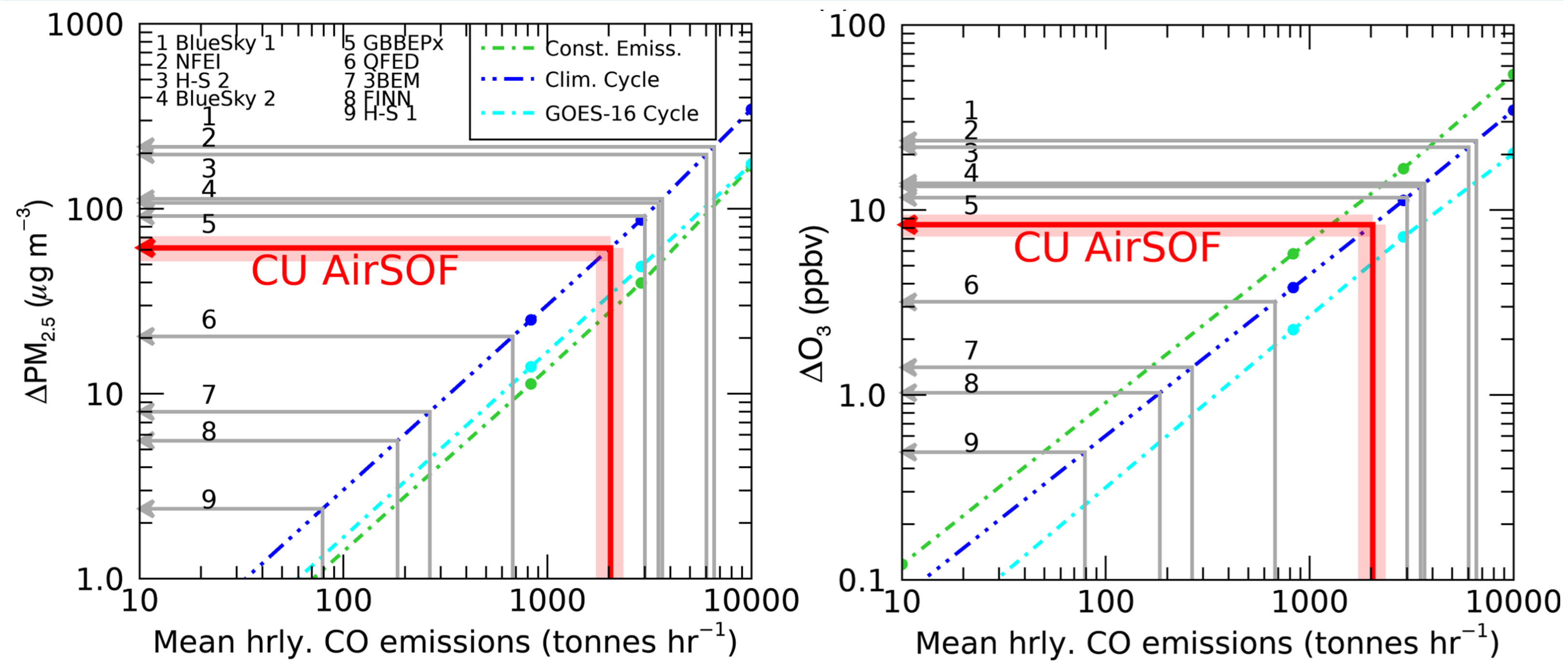

Fig. 1. Daily mean CO emissions on Oct. 10, 2017 for the N. CA fires estimated from CU SOF measurements (red) and by satellite-based methods (black) (Bela et al., 2022, GRL)

- RAP-SMOKE represented transport of smoke from U.S. West Coast fires over Pacific Ocean in Sept. 2020 (**Fig. 2**)

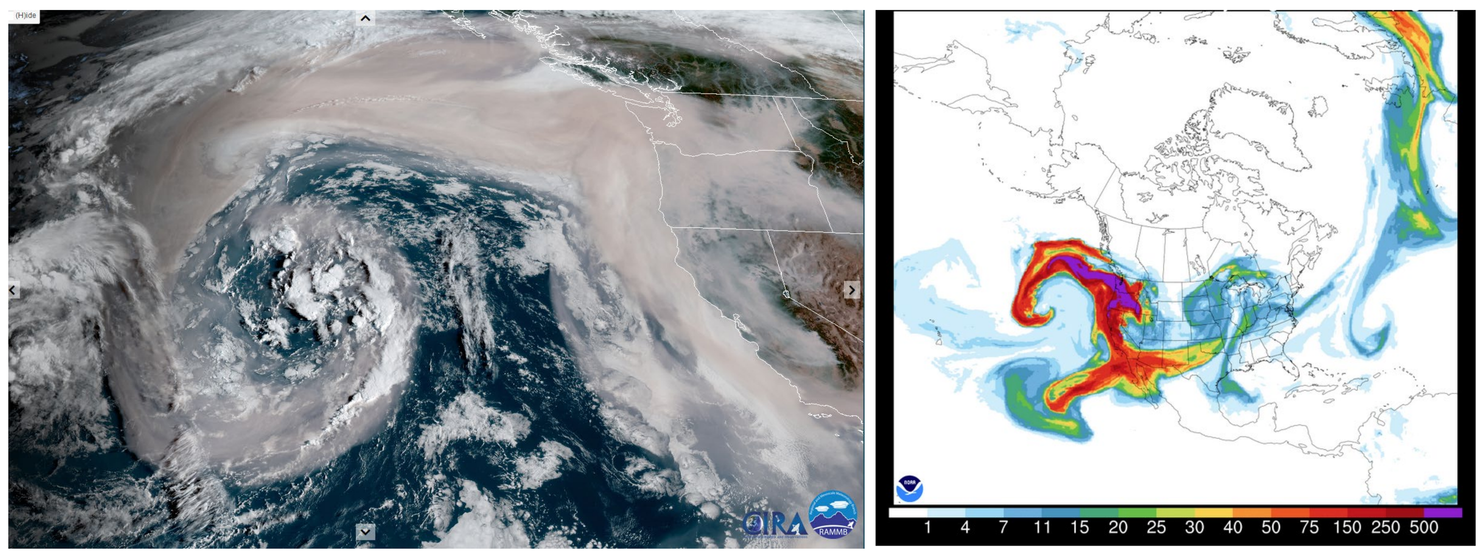

Fig. 2. (left) GOES West Visible Image, 2020-09-12;
(right) RAP-SMOKE vertically integrated smoke ($\mu g\ m^{-3}$) 2020-09-12 14 UTC

- RAP-Chem useful for studying air quality impacts of intense 2020 fire season, but had a high O_3 bias for fire impacted regions (**Fig. 3**)

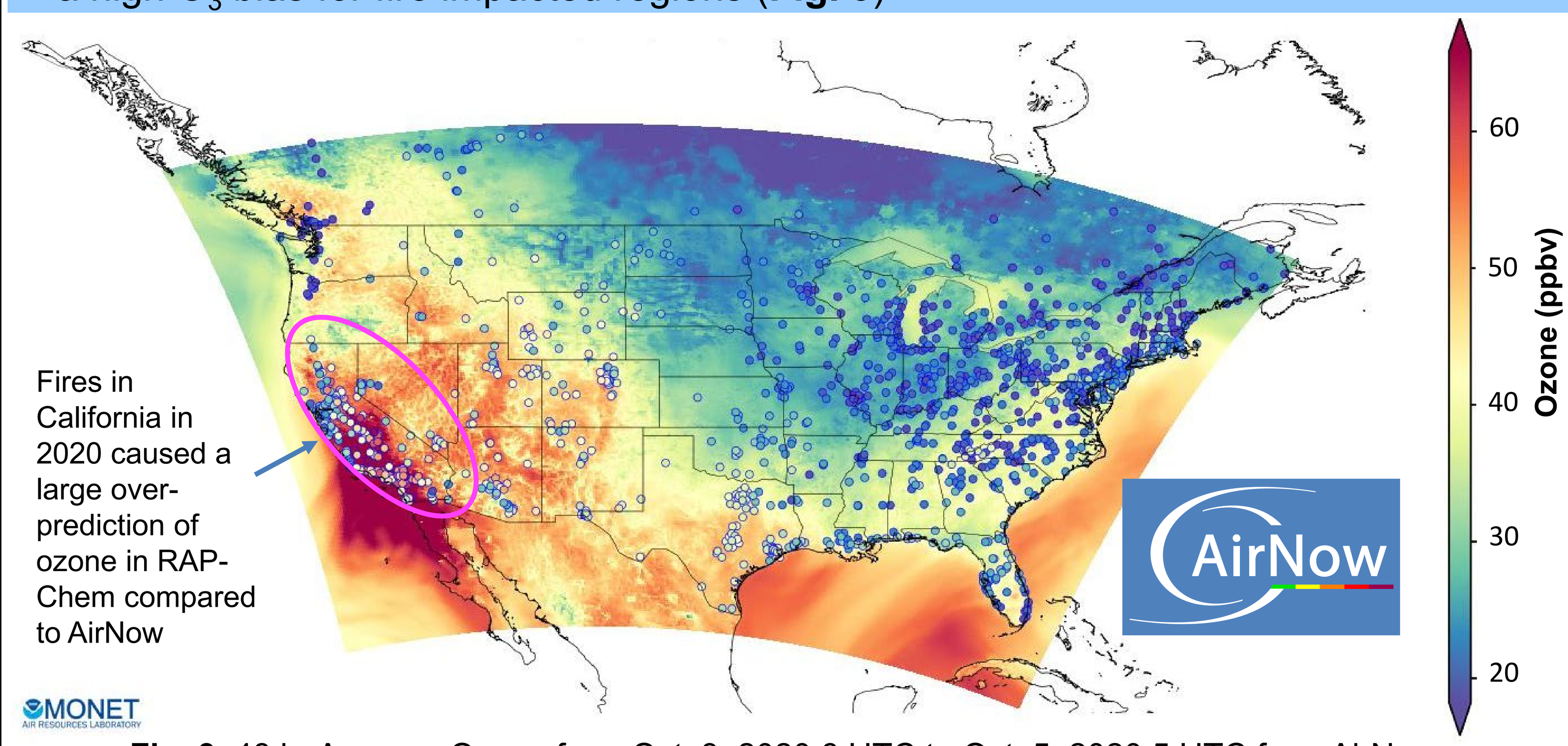

Fig. 3. 48 hr Average Ozone from Oct. 3, 2020 6 UTC to Oct. 5, 2020 5 UTC from AirNow (colored circles) and RAP-Chem (contours)

Questions

How does using reactive nitrogen, VOC, and aerosol EFs from 2019 NOAA/NASA Fire Influence on Regional and Global Environments Experiment – Air Quality (FIREX-AQ) campaign affect trace gases and aerosols in smoke plumes simulated by a regional chemical model?

How well does a burned-area-based plume injection scheme simulate injection heights observed during FIREX-AQ?

Aircraft and satellite observations and WRF-Chem simulations

WRF-Chem simulations:
Emission amounts from Brazilian Biomass Burning Emission Method (3BEM), based on MODIS/WF-ABBA satellite fire detections

Sensitivity tests:
(1) Gas and aerosol emission factors (EFs) from Andreae (2019)
(2) EFs from Andreae (2019) with updated reactive nitrogen, VOC, and aerosol EFs from FIREX-AQ aircraft observations

Results

Simulated trace gas mixing ratios and aerosol concentrations better correspond to observed values when FIREX-AQ EFs used (**Figs. 4 and 5**)

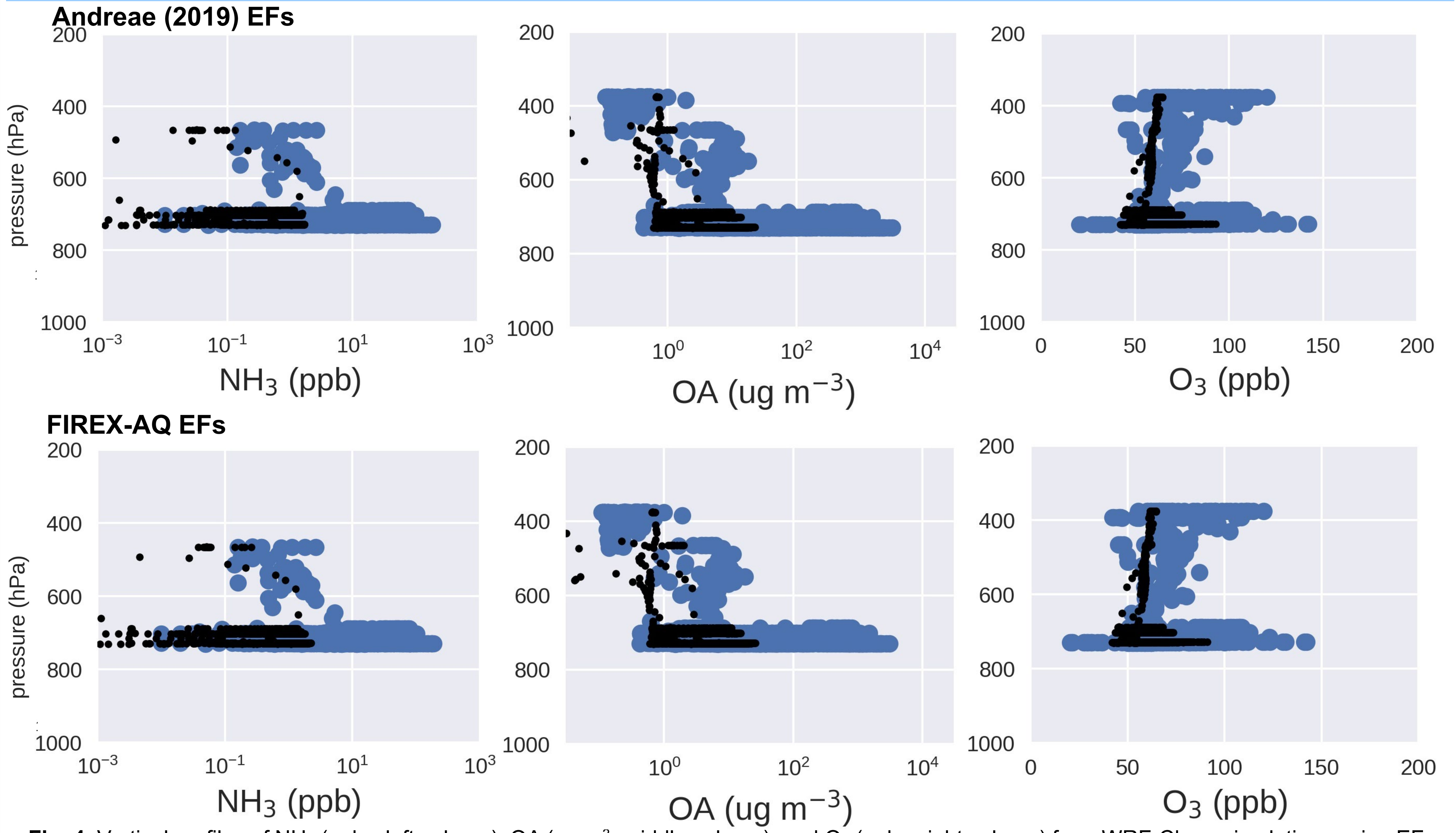

Fig. 4. Vertical profiles of NH_3 (ppbv, left column), OA ($\mu g\ m^{3}$, middle column), and O_3 (ppbv, right column) from WRF-Chem simulations using EFs from Andreae (2019) (top row) and FIREX-AQ (bottom row); DC-8 aircraft observations indicated by black dots and simulated values along the flight track by blue dots

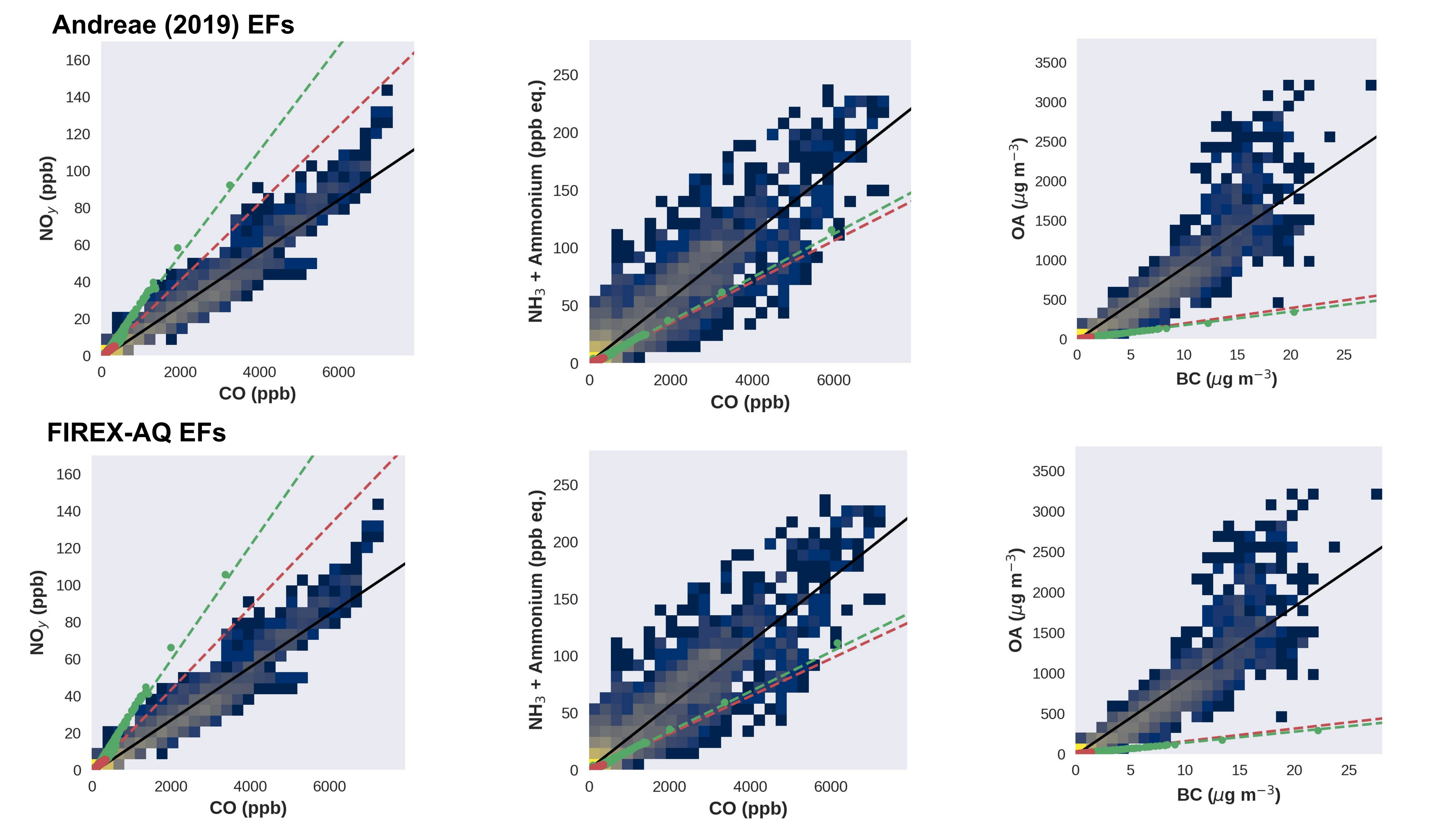

Fig. 5. NO_y vs CO (ppbv, left column), total ammonia versus CO (ppbv, middle column), and OA versus BC ($\mu g\ m^{-3}$, right column) from WRF-Chem simulations using EFs from Andreae (2019) (top row) and FIREX-AQ (bottom row); DC-8 aircraft observations depicted by colored squares, WRF-Chem sampled along the flight tracks by red dots, and WRF-Chem sampled in the broader fire/smoke region by green dots

Burned-area-based plume injection scheme underestimates injection heights observed during FIREX-AQ (**Fig. 6**)

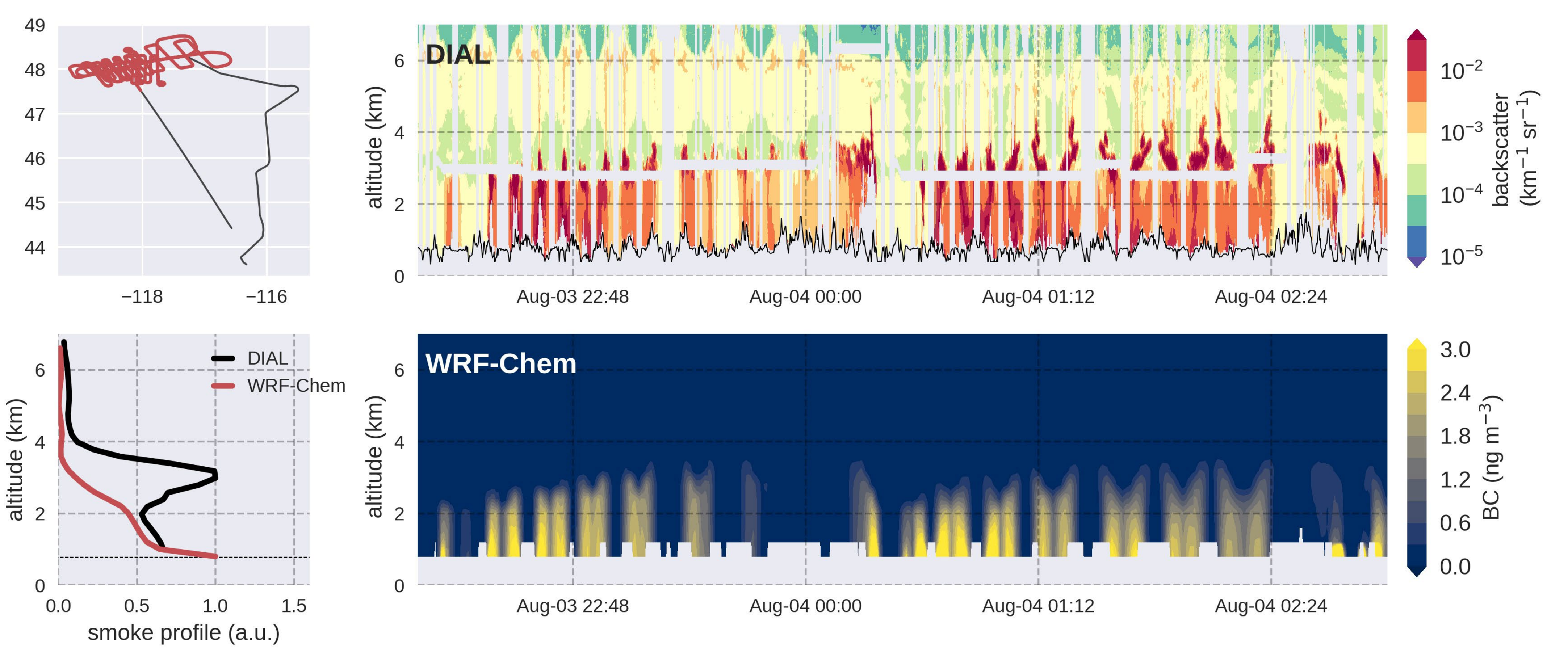

Fig. 6. DC-8 flight track (upper left); DIAL and WRF-Chem smoke profiles (lower left); aerosol backscatter from DIAL aboard the DC (upper right); black carbon simulated by WRF-Chem along the flight track (lower right)

Conclusions

- Simulated trace gas mixing ratios and aerosol amounts better reproduce observations when EFs from FIREX-AQ used
- Burned-area plume injection scheme underestimates FIREX-AQ injection heights

Outlook

FIREX-AQ observations being explored to improve model representations of fire emissions and plume rise (including FRP-based approaches used in RRFS-CMAQ and HRRR-Smoke/RAP-Chem), and chemistry

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