# Evaluate NAQFC with Other Observations: A Study in Summer 2023

NOAA/ARL-George Mason University, NOAA/CSL, and NOAA/NCEP

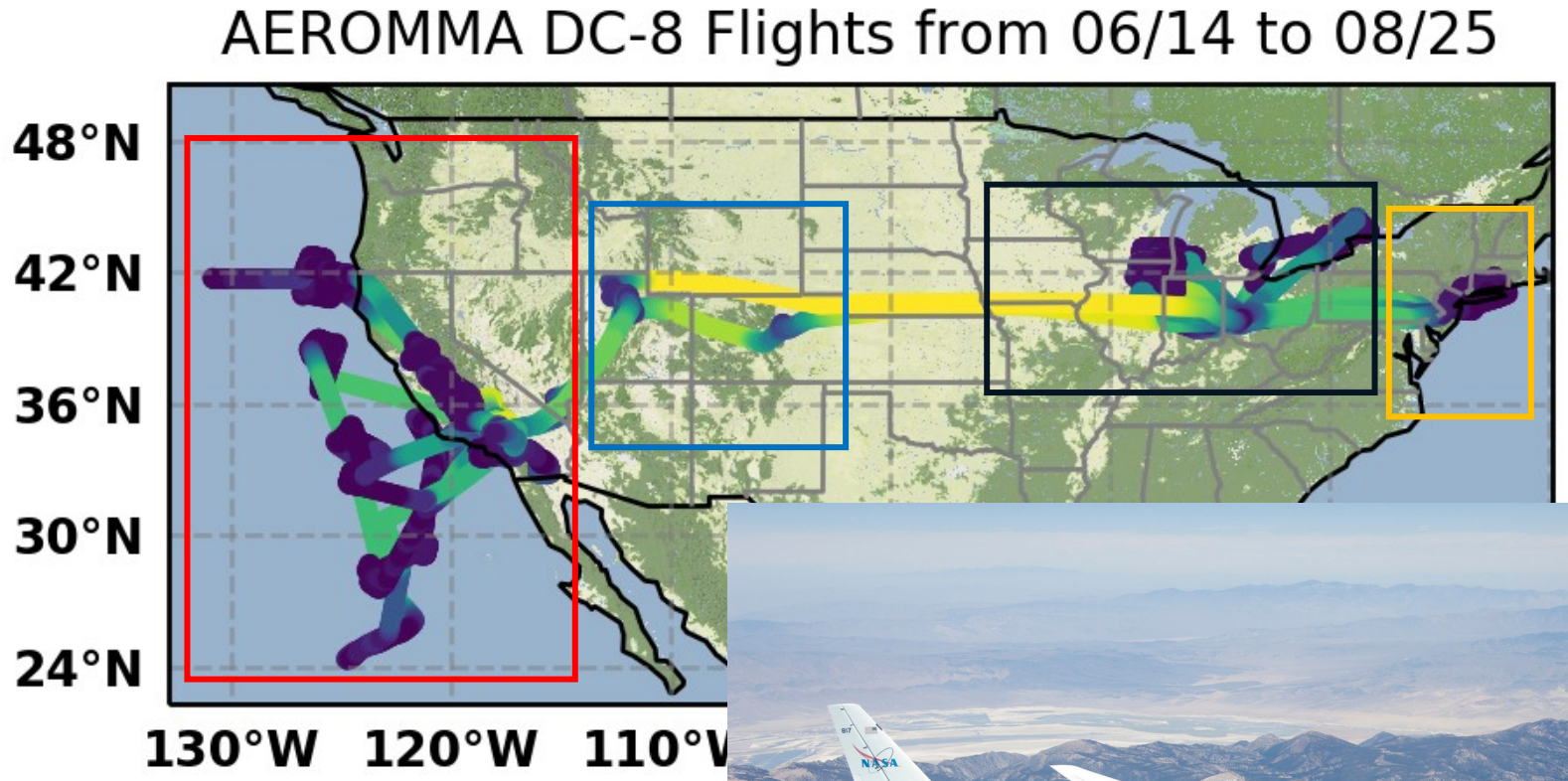
# Background

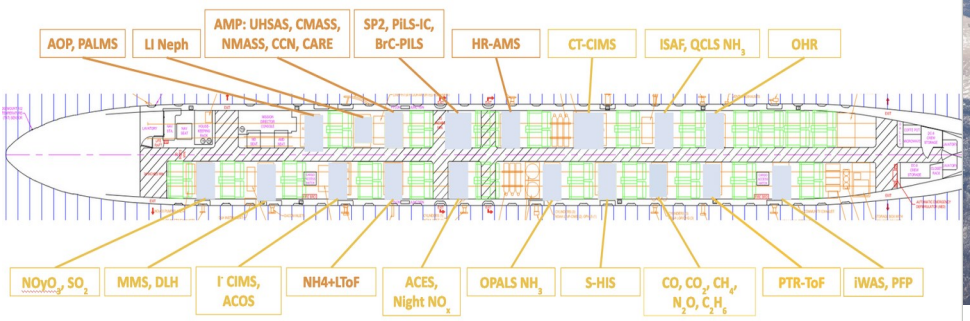
- **The existing NAQFC is mainly verified with AIRNow/AQS data for its surface ozone and PM2.5 prediction.  During summer 2023, the field experiment of  Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas (AEROMMA) took place, and provided comprehensive airborne measurements to evaluate the 3-D full-chemistry performance of NAQFC.**
- **Besides the in-situ measurements, some newly available satellite data could also be used to evaluate the NAQFC's emission etc.**

# NAQFC Configuration

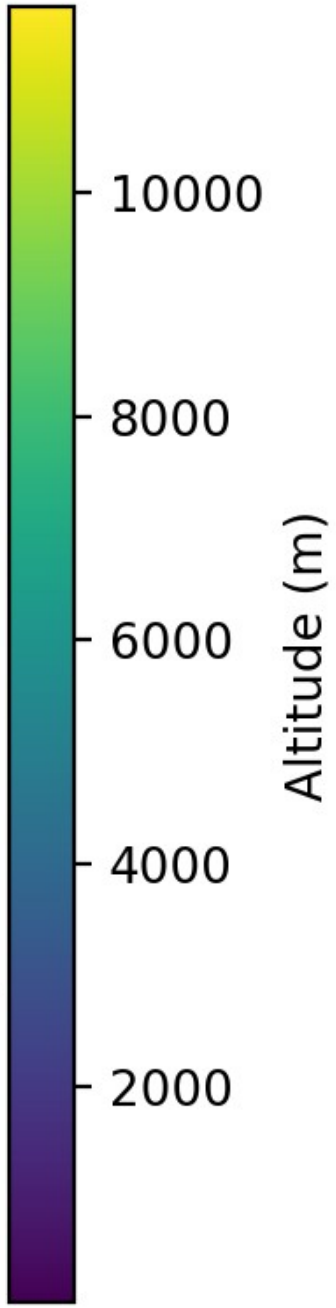
- Full-chemistry CMAQ mechanism: currently CMAQ 5.2 and will move to CMAQ 5.4
- Currently 13km horizontal resolution over North America.
- 4-cycles-per-day forecast up to 72 hours
- Aerosol Lateral Boundary conditions: GEFS-Aerosol
- Anthropogenic Emission: National Emission Inventory (NEI) for CONUS, CEDS etc for other regions.
- Biogenic Emission: MEGAN scheme
- Dust Emission: FENGSHA scheme
- Fire Emission: Regional ABI and VIIRS fire Emissions (RAVE) emission. Will be upgraded to RAVE2

# Most AEROMMA flights flew around megacities

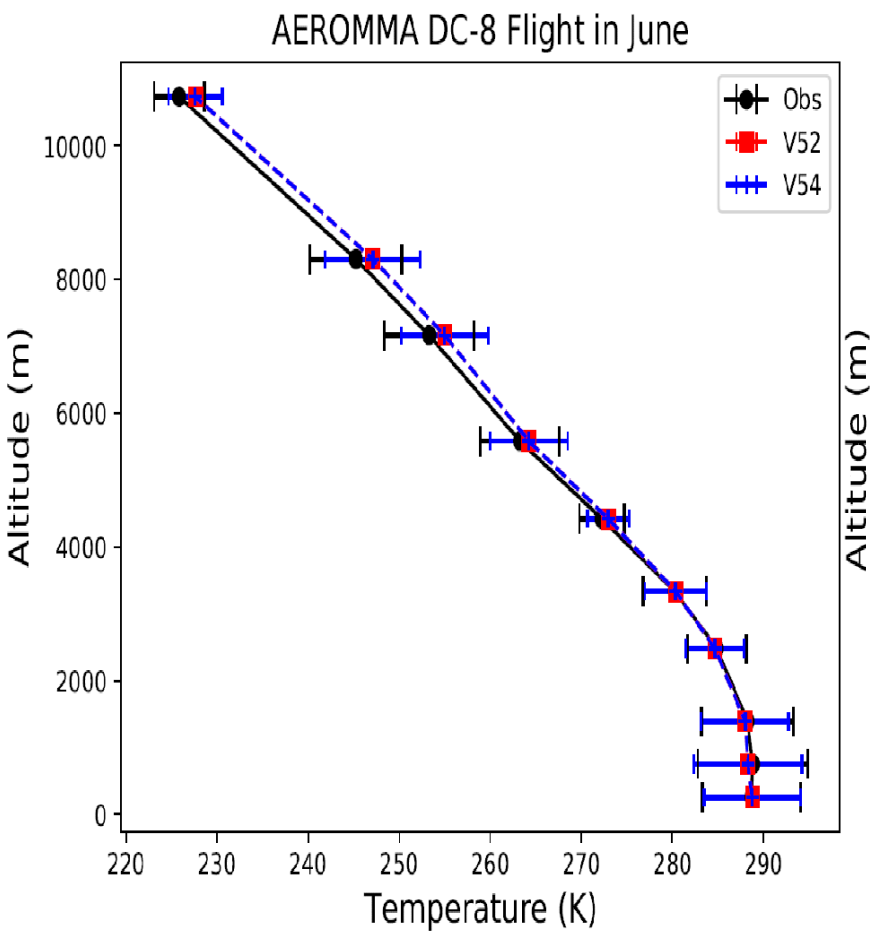


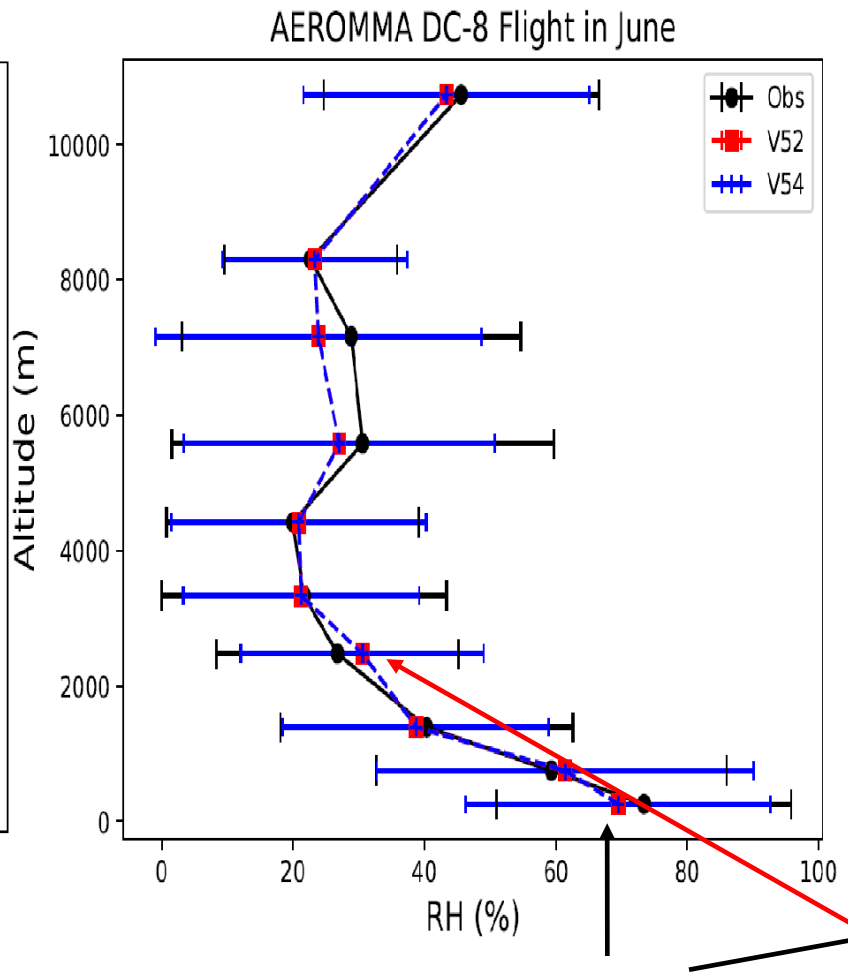



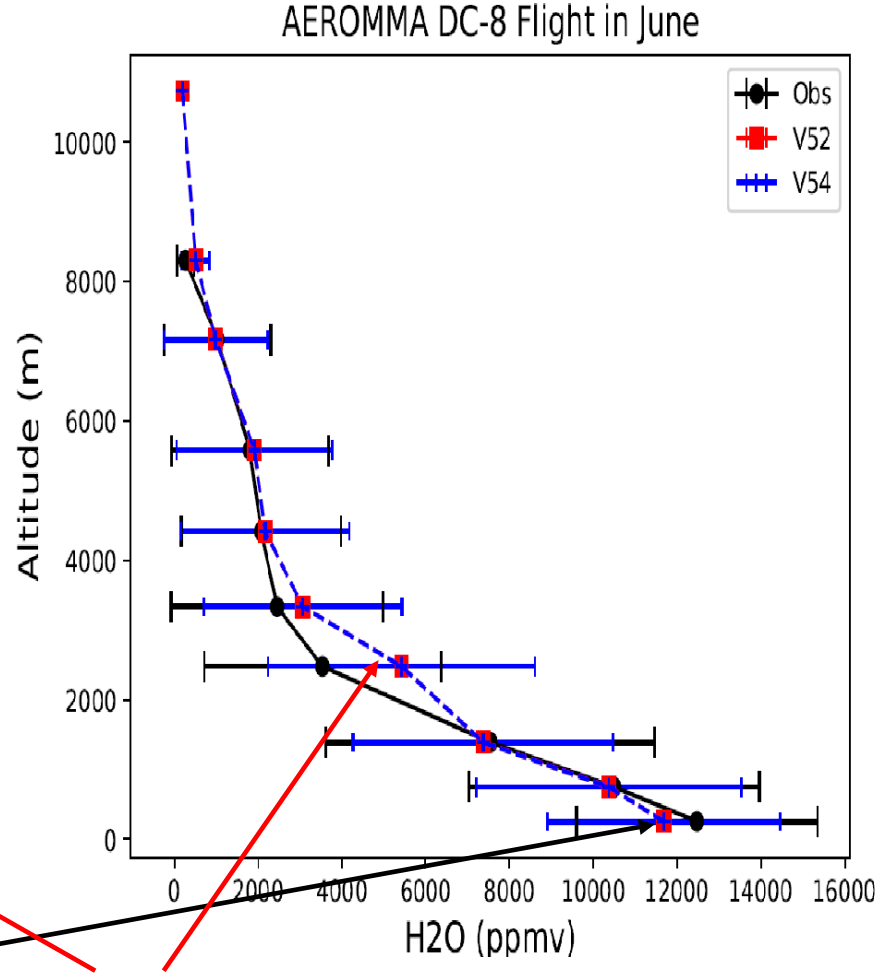




# Meteorology over the U.S. West

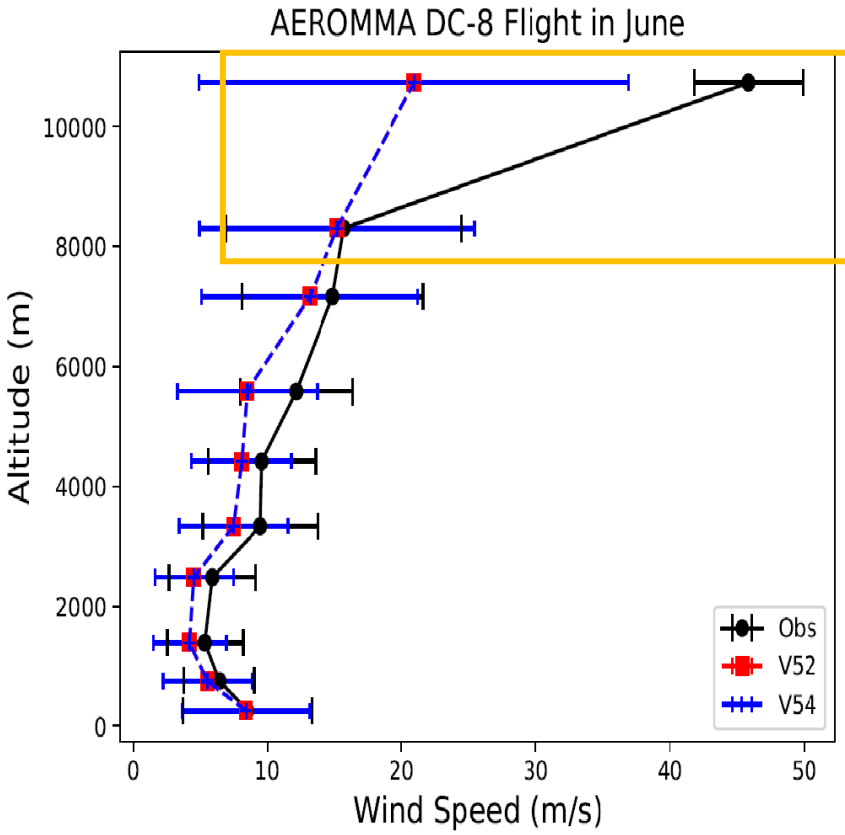


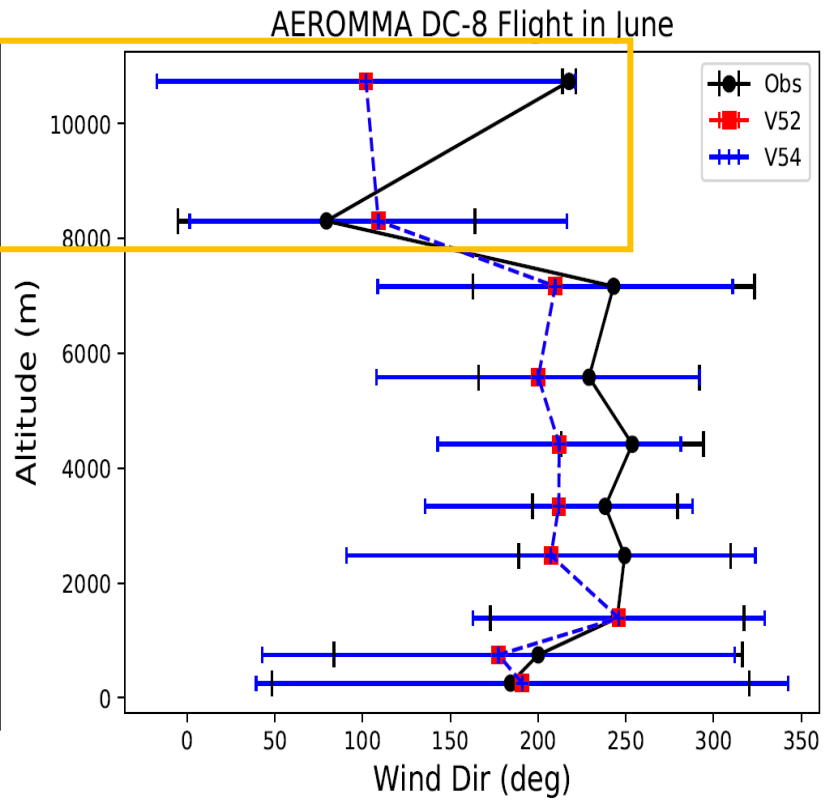



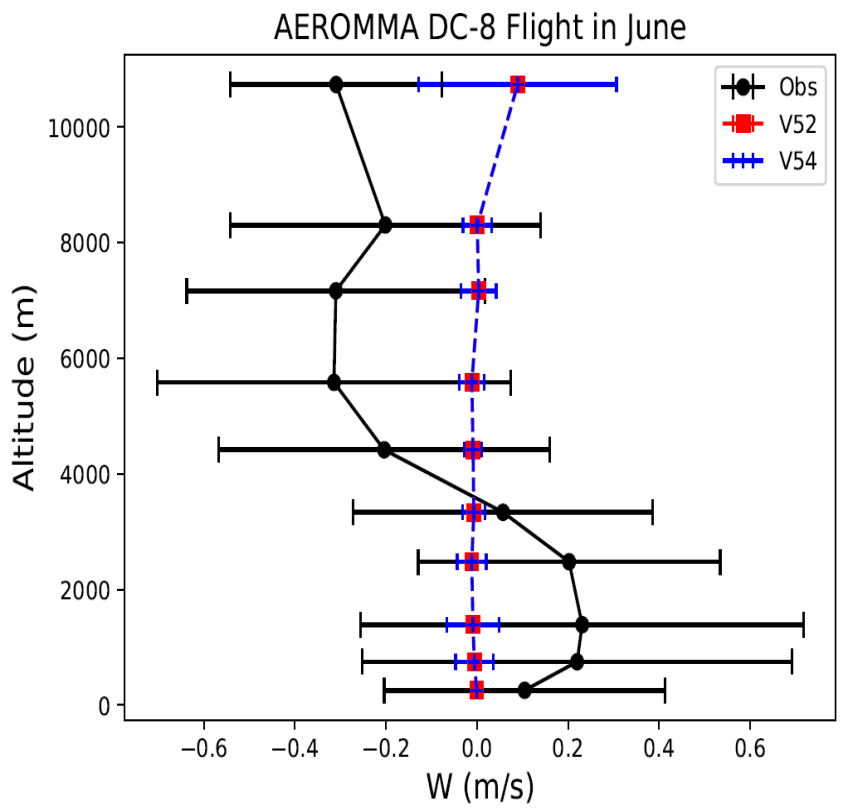




**Dry bias near surface , wet bias near the PBL top**

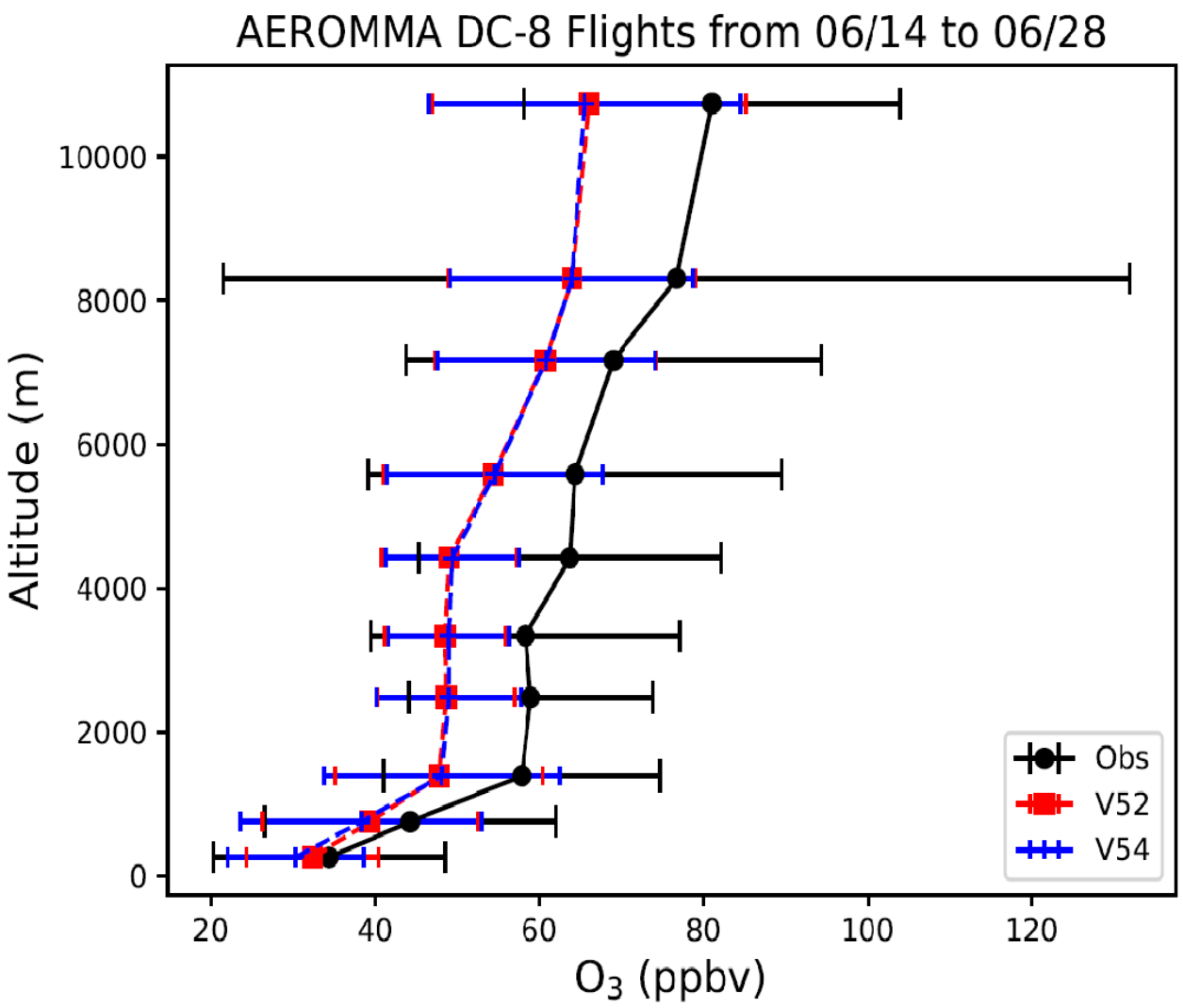
# The vertical gradient of modeled winds are too smooth near the tropopause. The model tends to underpredict W by one or two orders of magnitude.

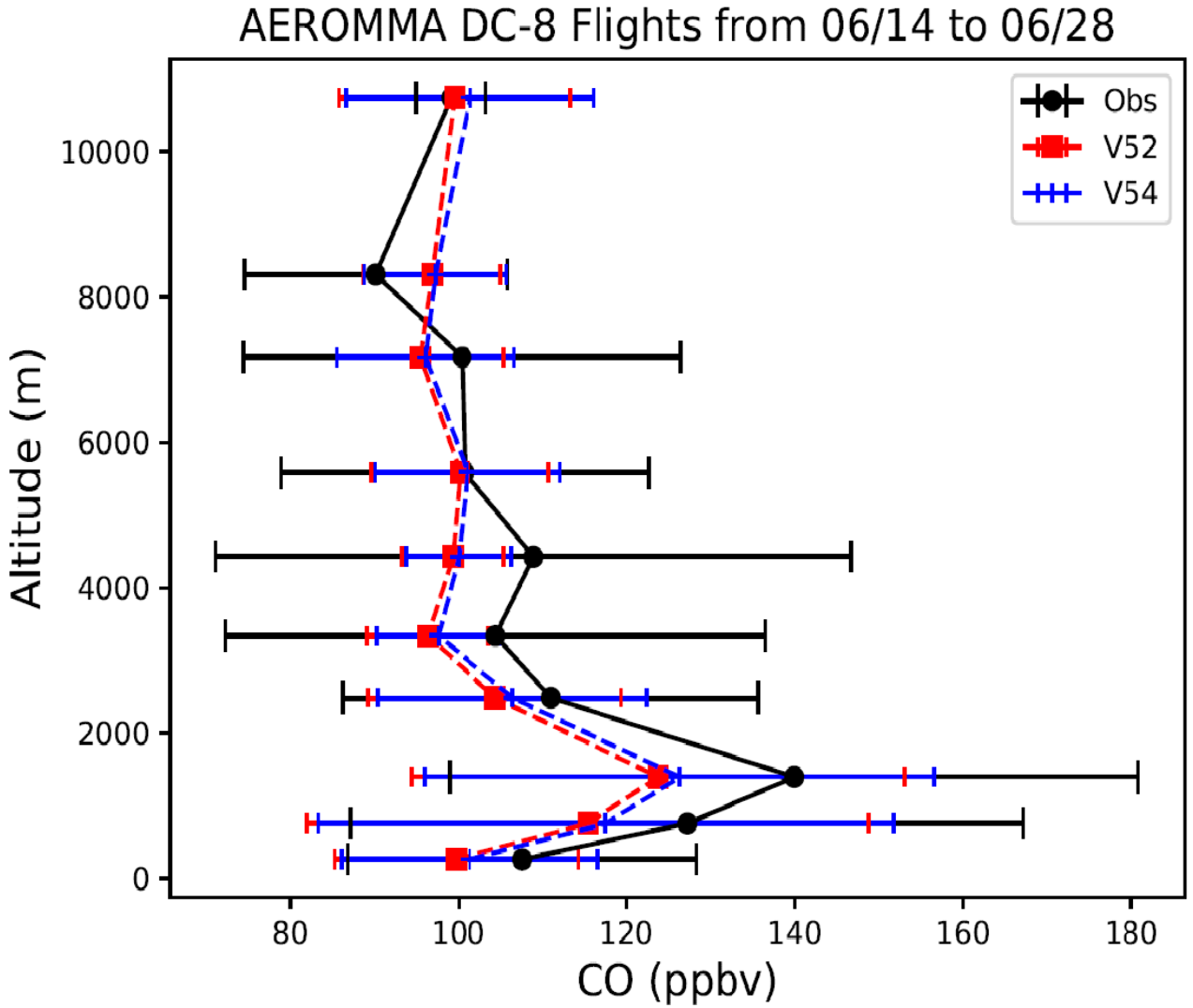


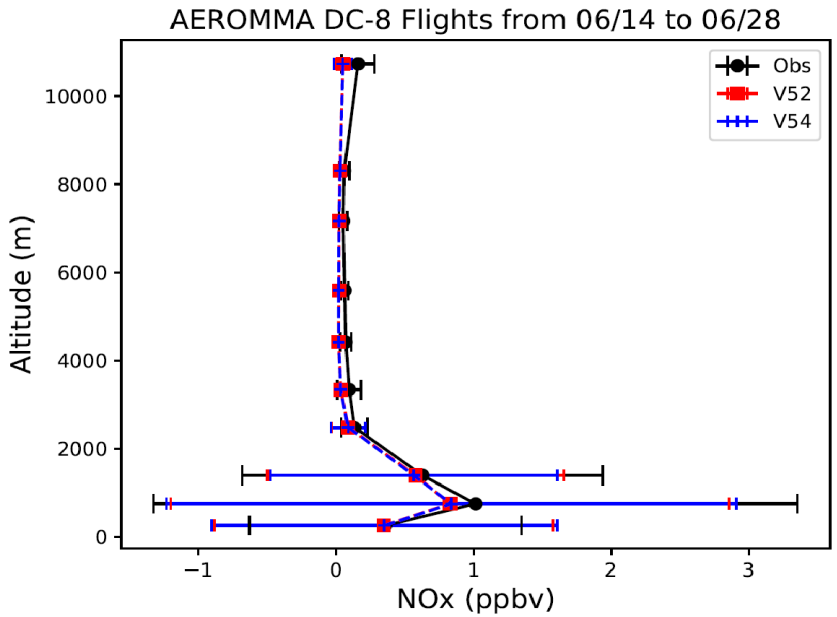



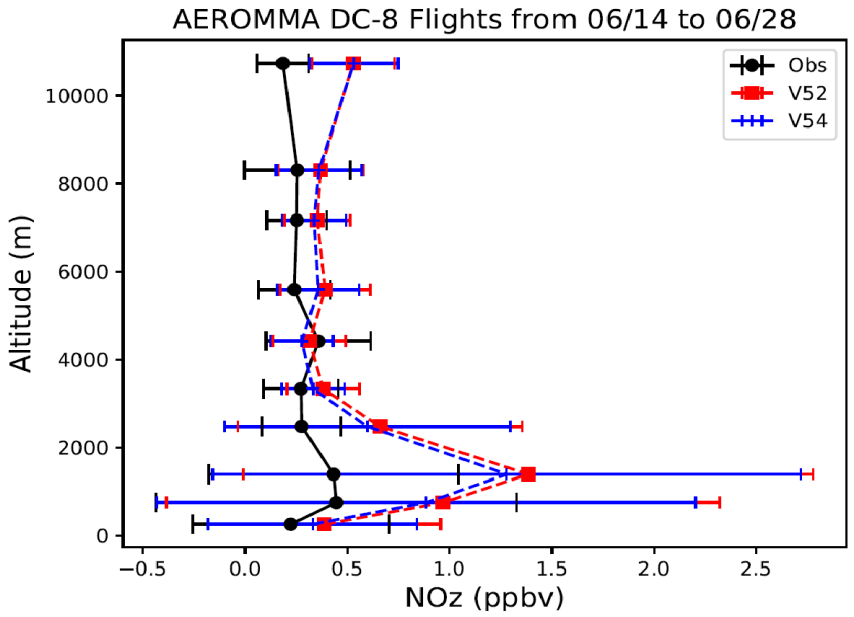
# The background ozone and tropospheric CO are underestimated over U.S. West Coast, which is related to the AM4 monthly lateral boundary condition.

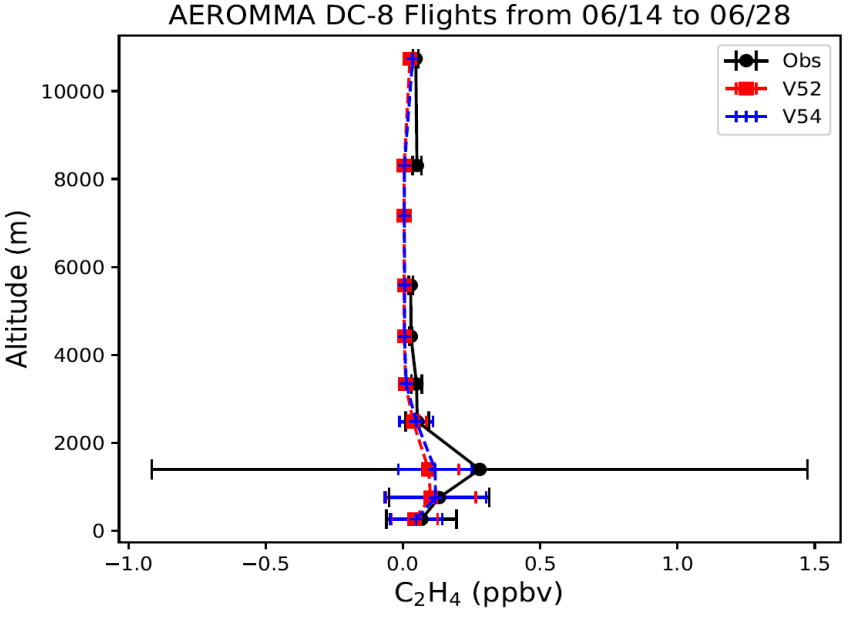


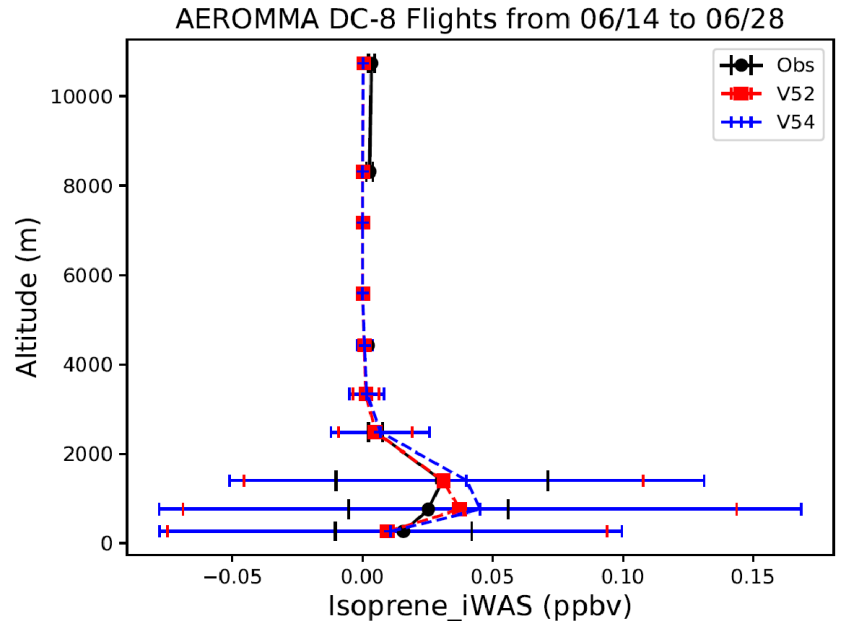



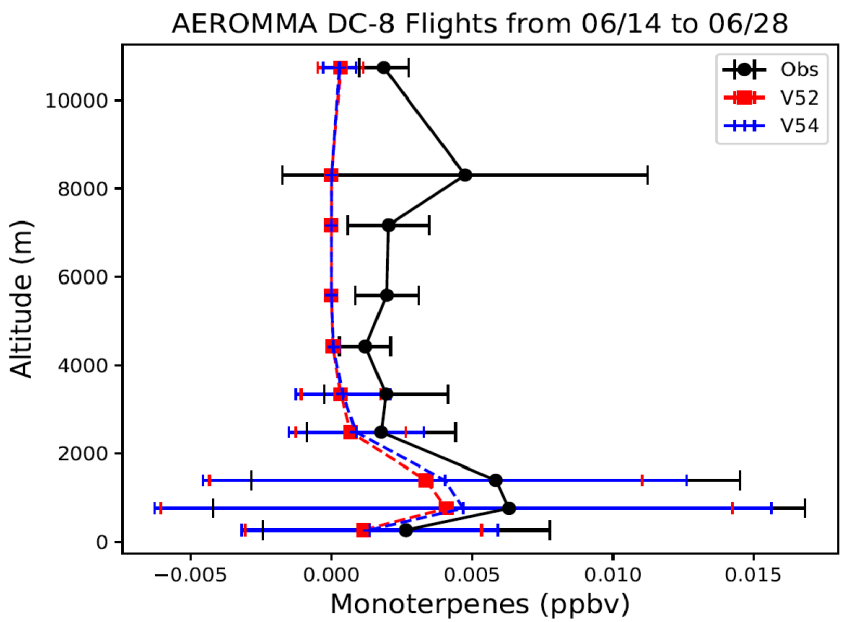
# Over the U.S. West Coast, NOz is overpredicted or modeled NOx-to-NOz conversion is too fast.

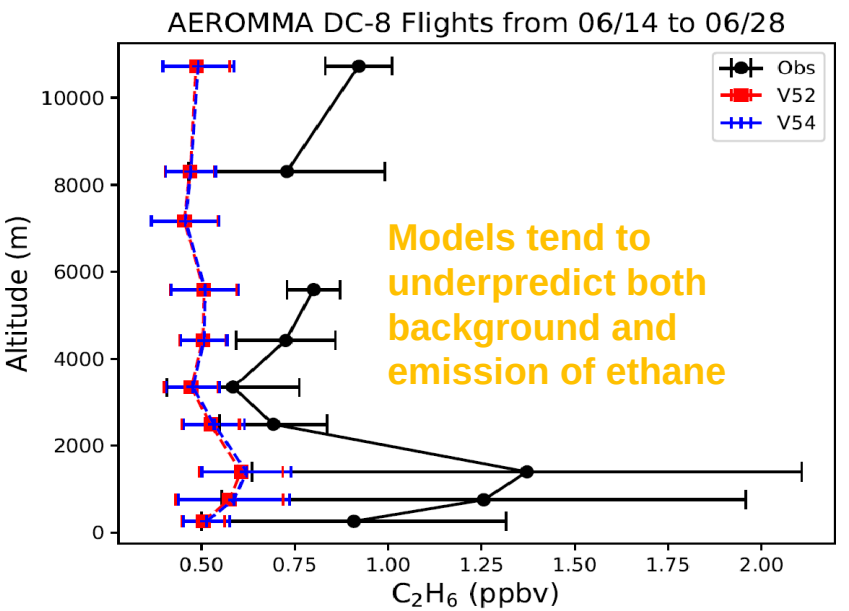


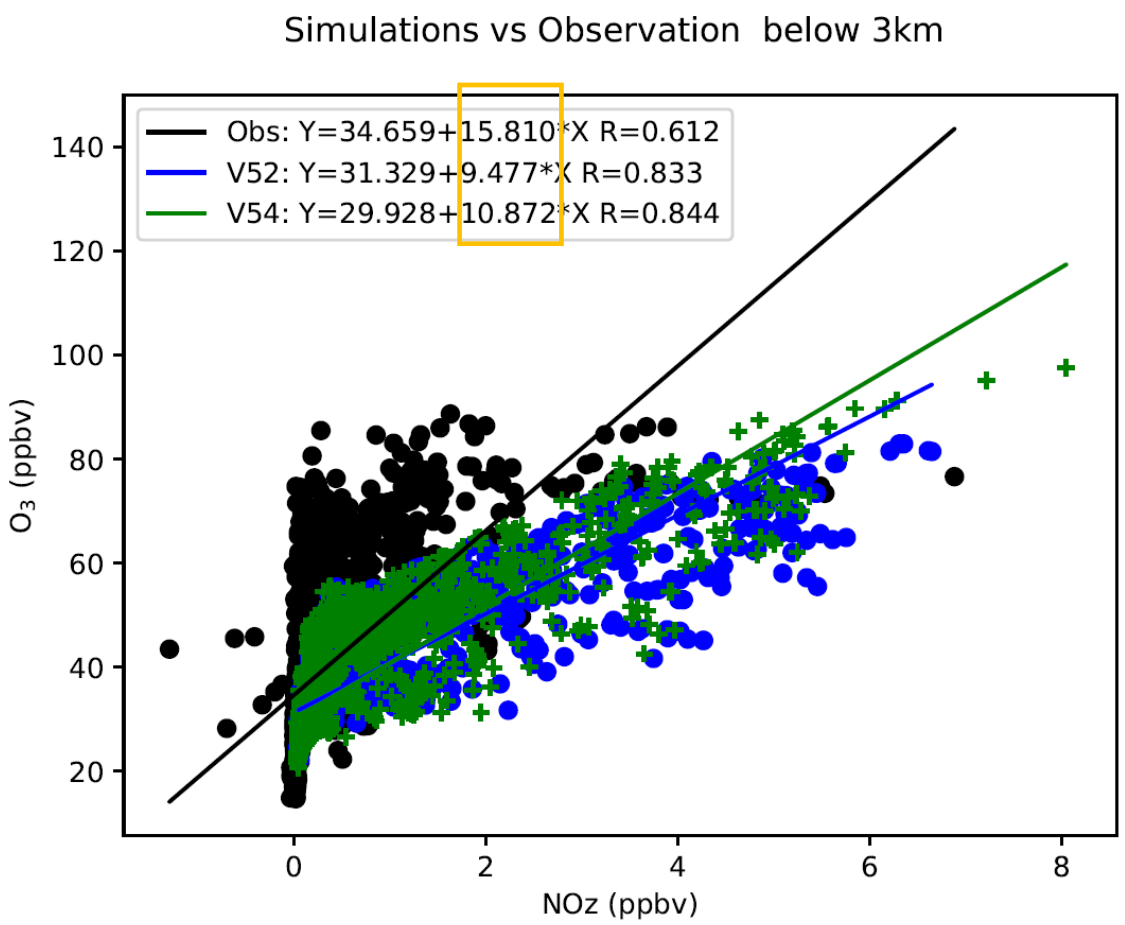



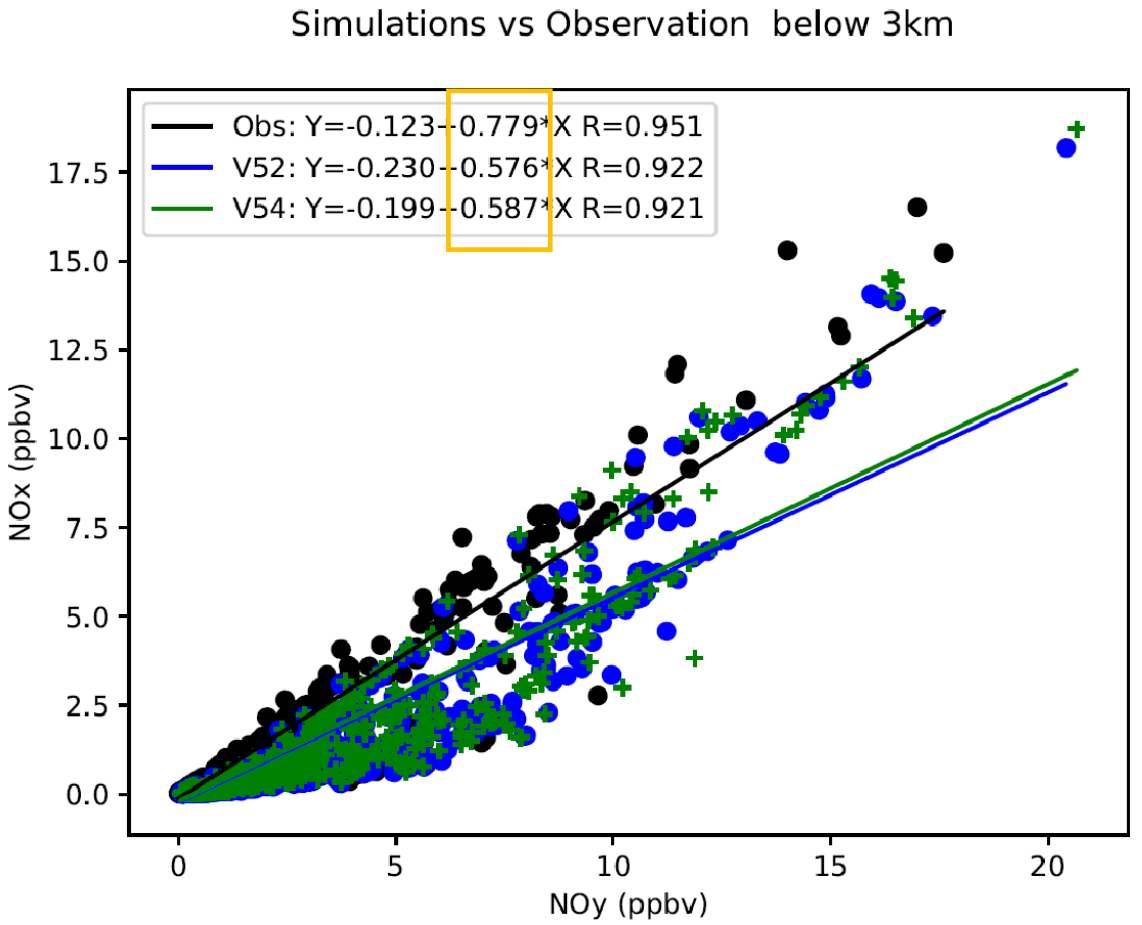



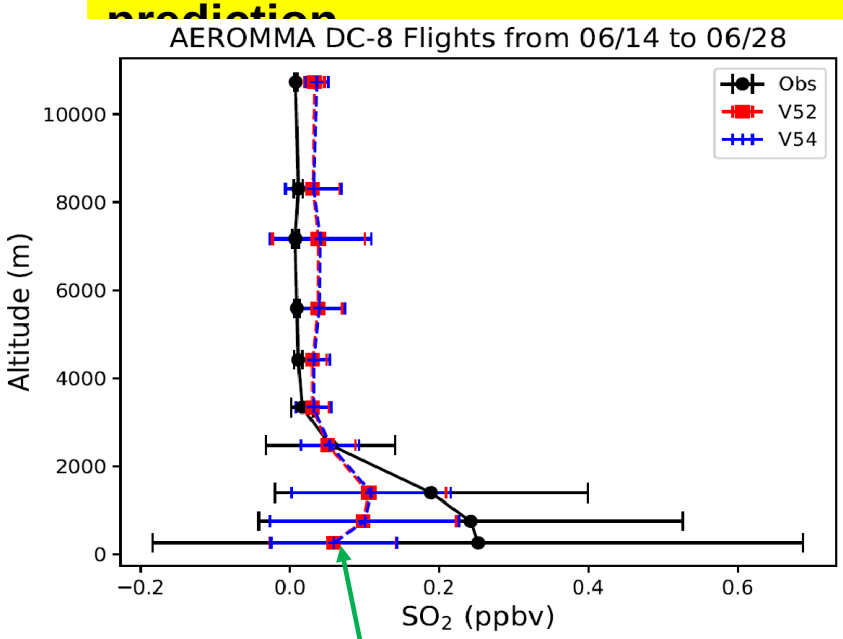



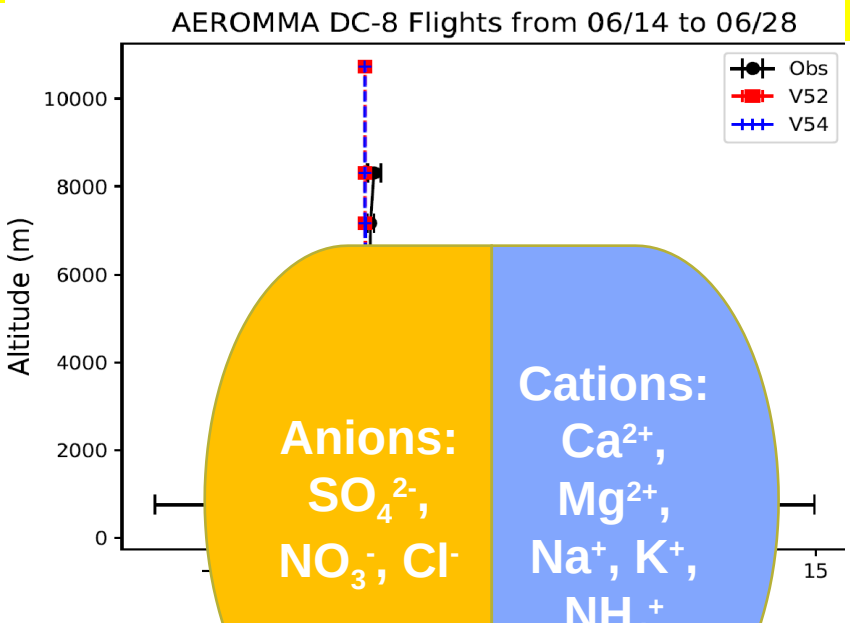
**The overpredicted NOx-to-NOz conversion leads to underpredictions of ozone production efficiency, represented by the O3-to-NOz ratio, and NOx age and NOx/NOy ratio. It is caused by the model's well-mixing assumption in each grid cell or insufficient spatial resolution.**

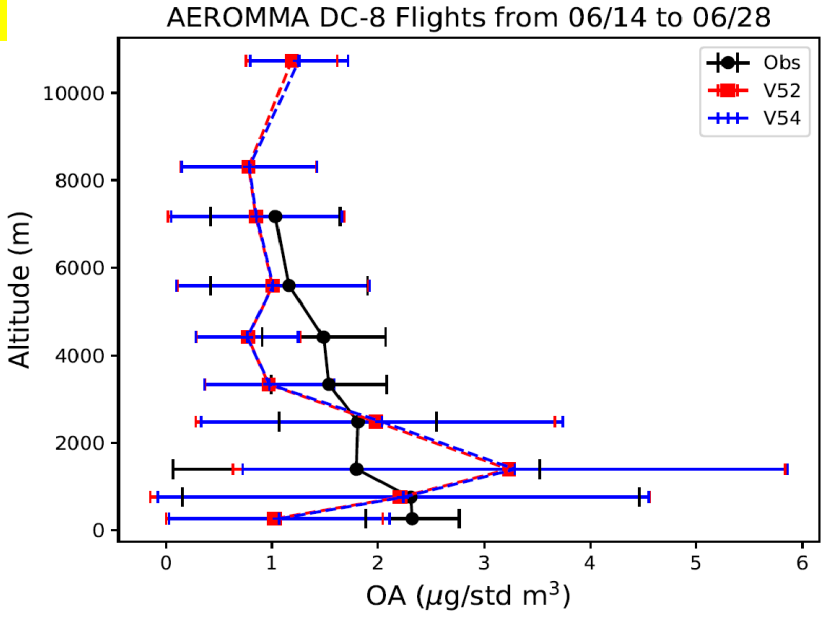


**$SO_2$ undeprediction over U.S. West leads to underprediction of sulfate and ammonium, and overprediction of nitrate. This bias on aerosol compositions could also affect the downstream PM2.5 prediction**

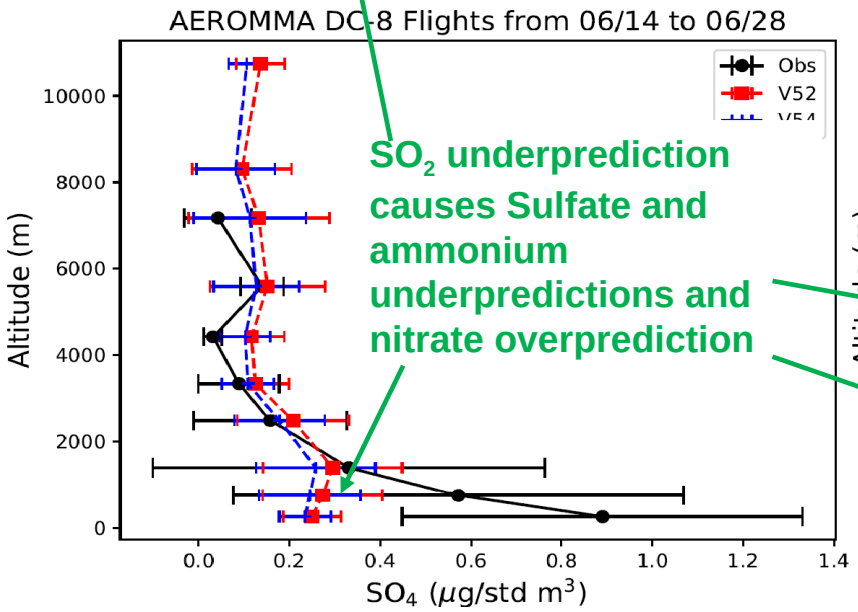


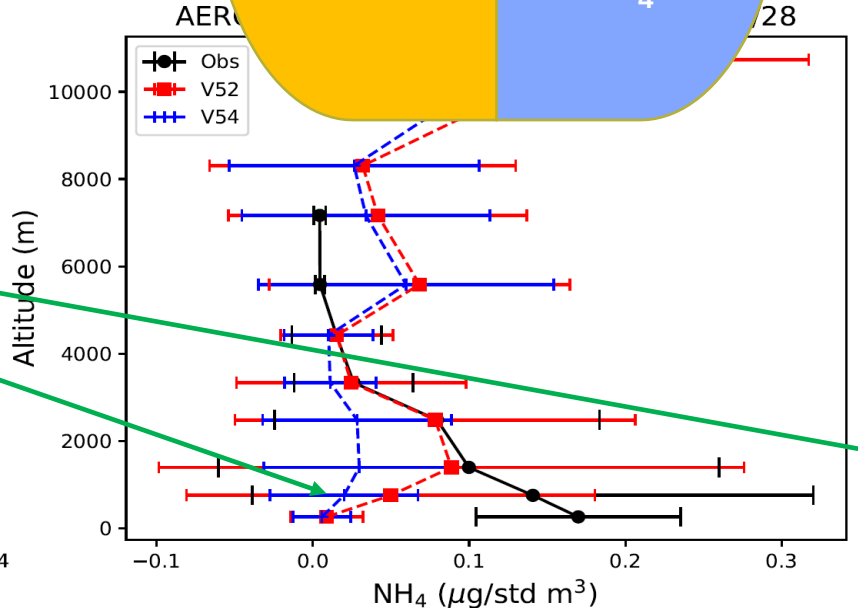



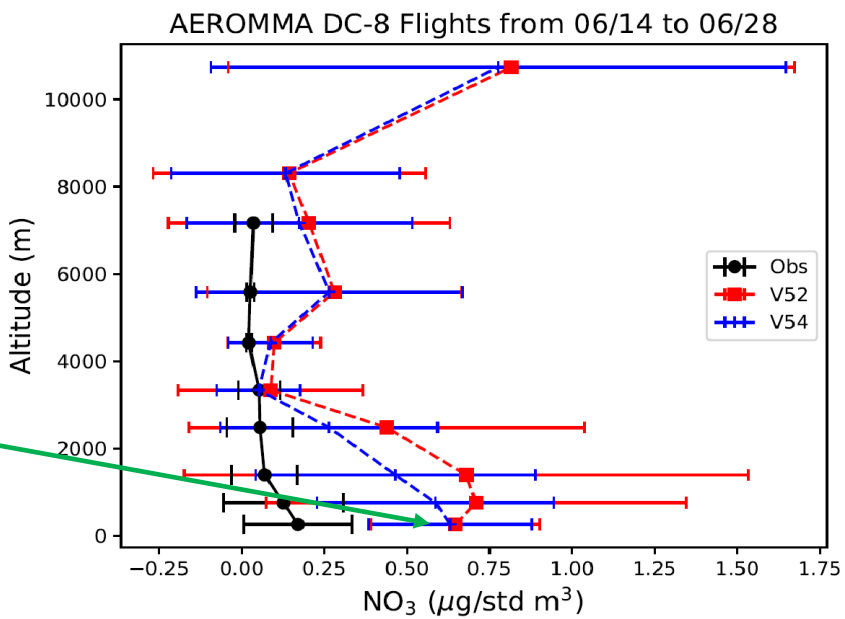

Anions: $SO_4^{2-}$, $NO_3^-$, $Cl^-$

Cations: $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $NH_4^+$

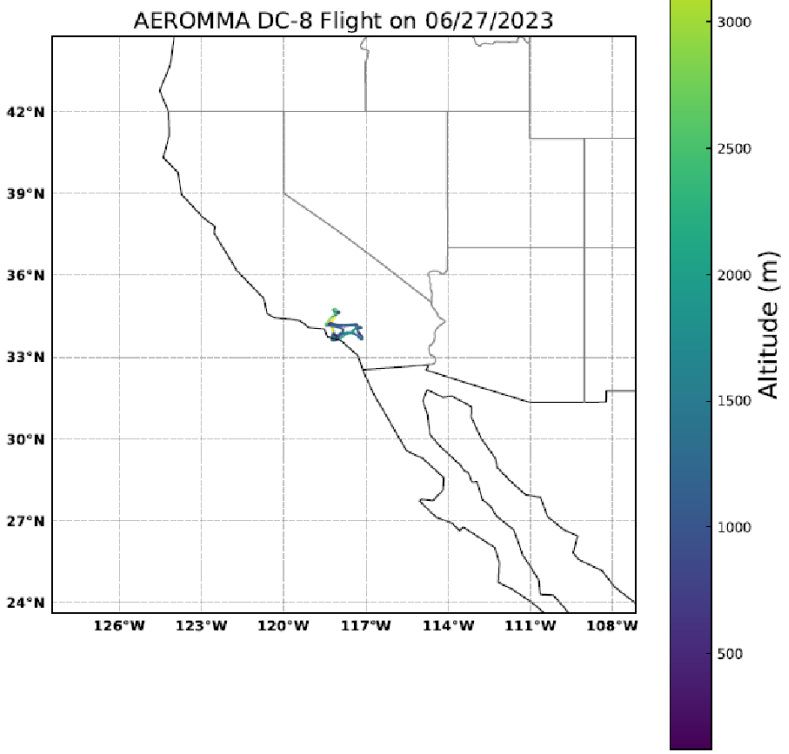


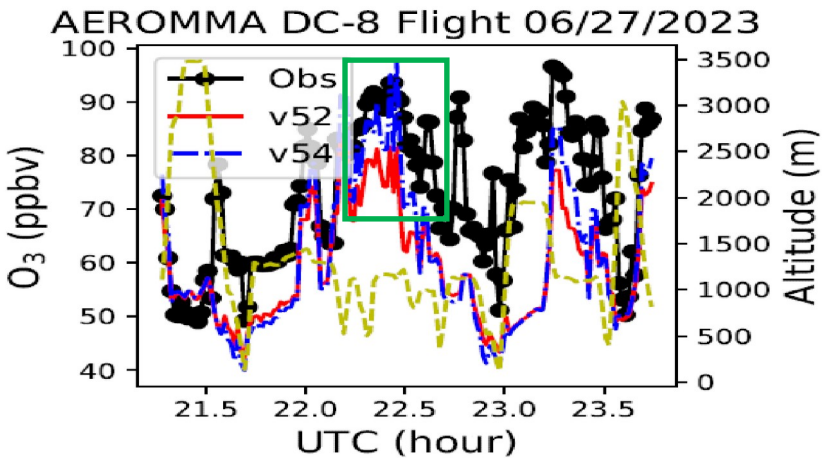

$SO_2$ underprediction causes Sulfate and ammonium underpredictions and nitrate overprediction

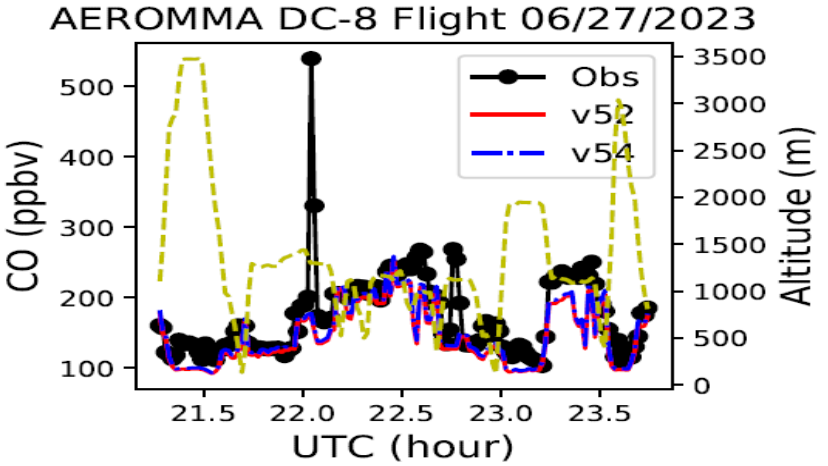


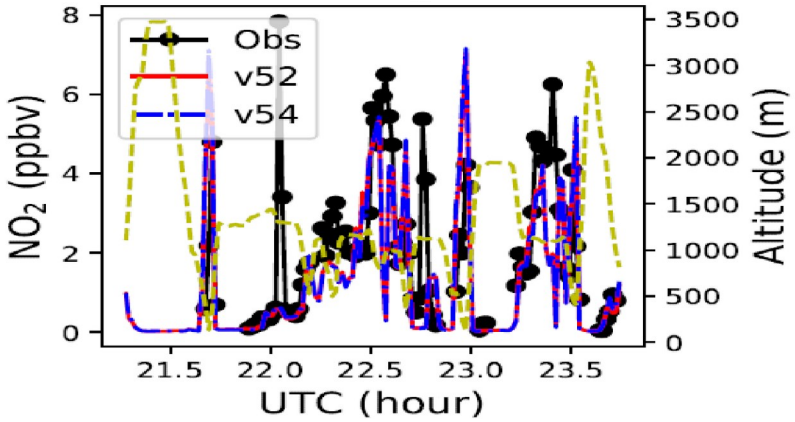



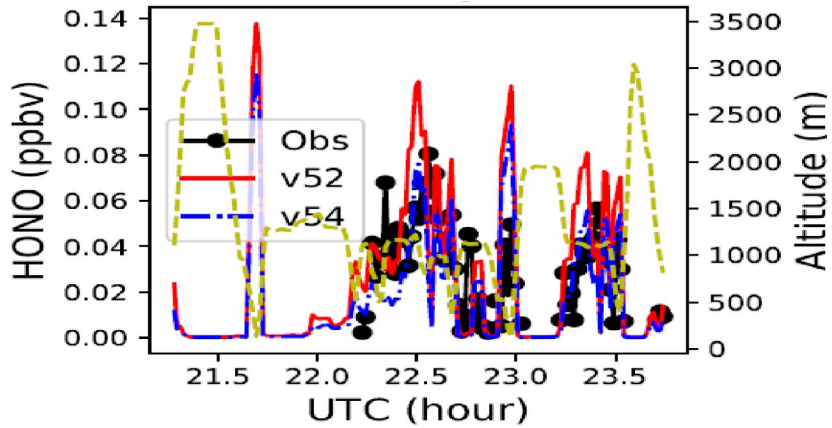
**V54 showed better chemical behavior over the LA flight**

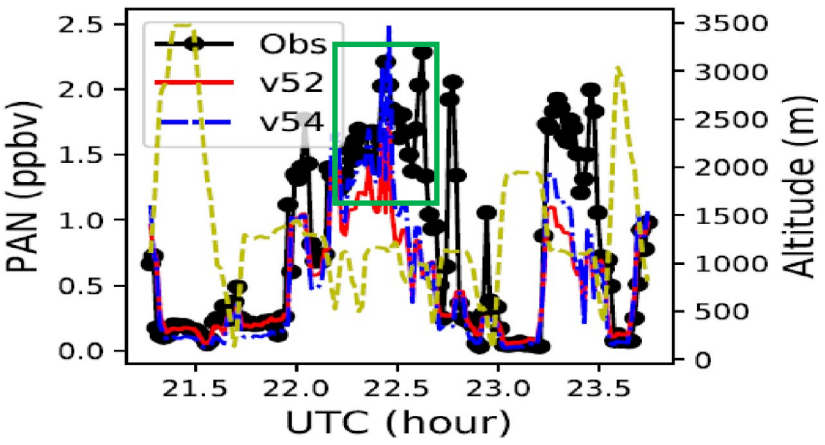


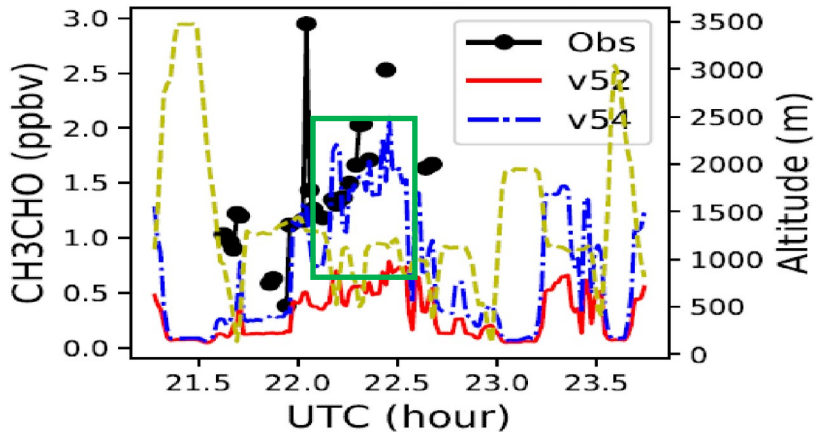



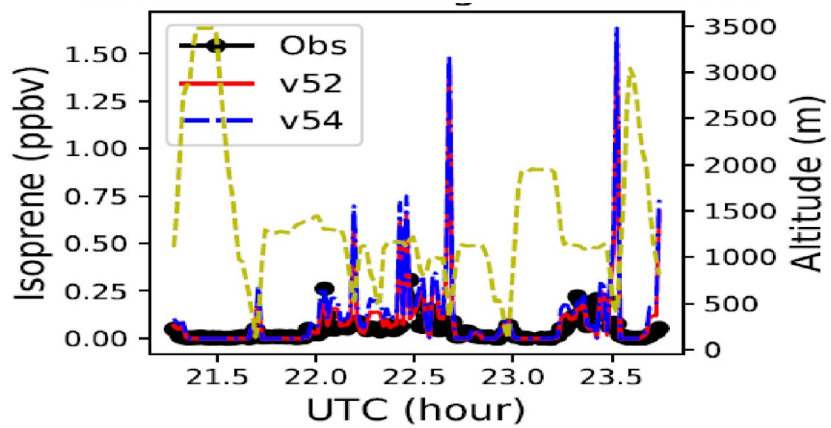



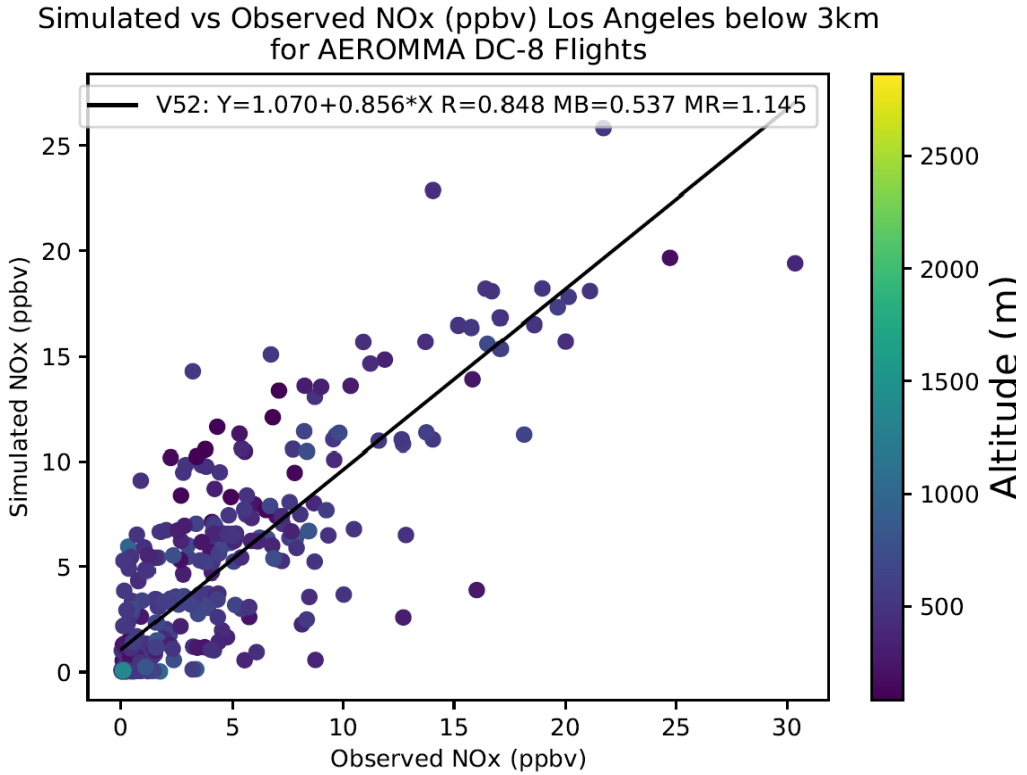



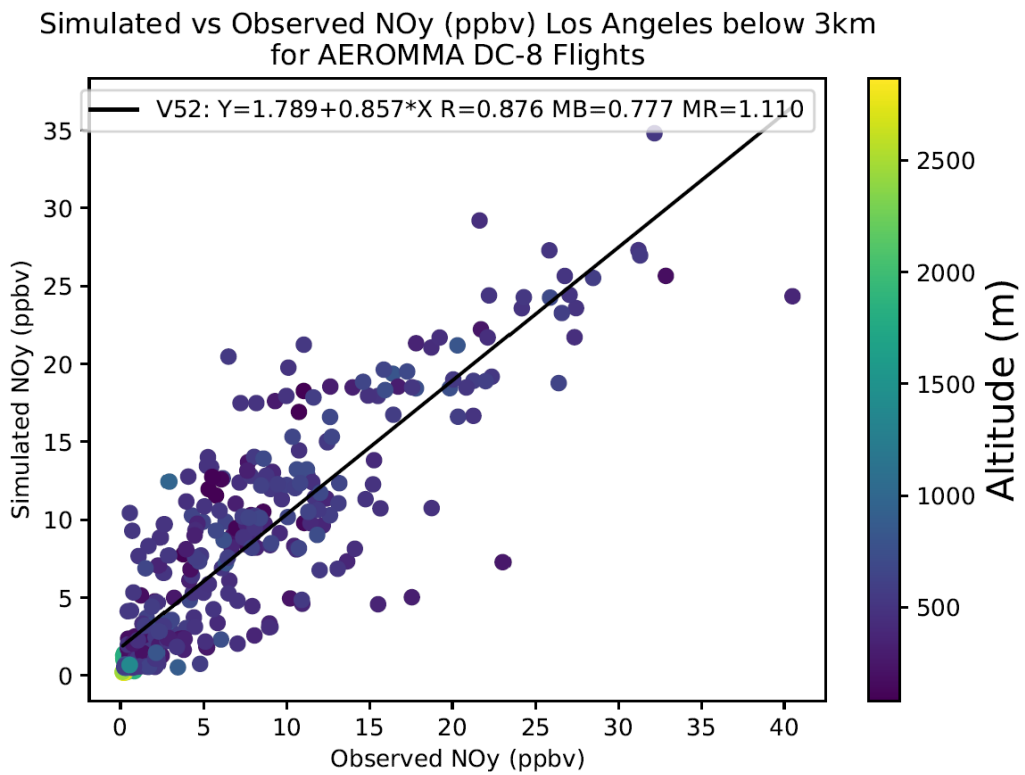



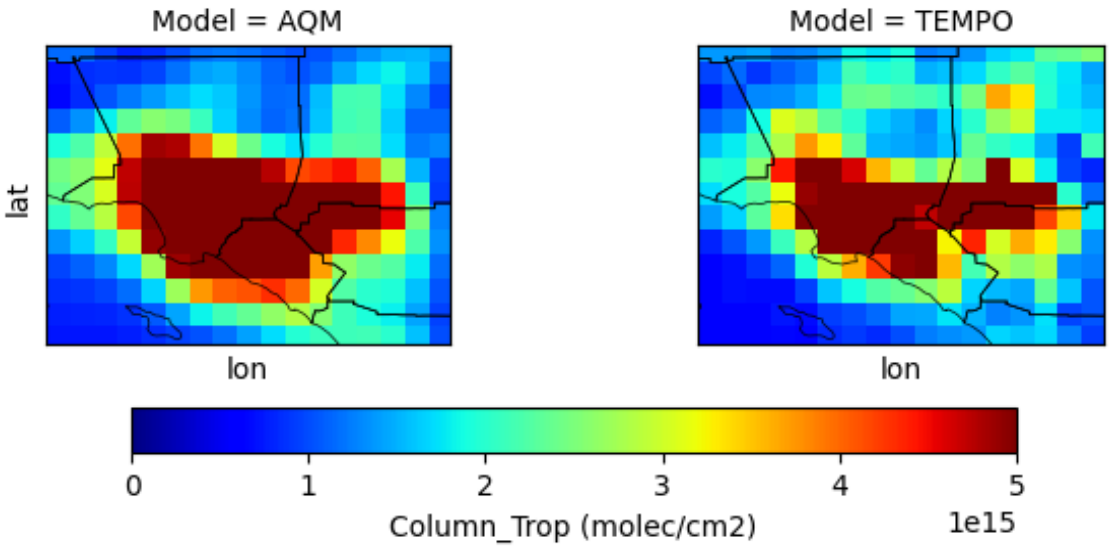



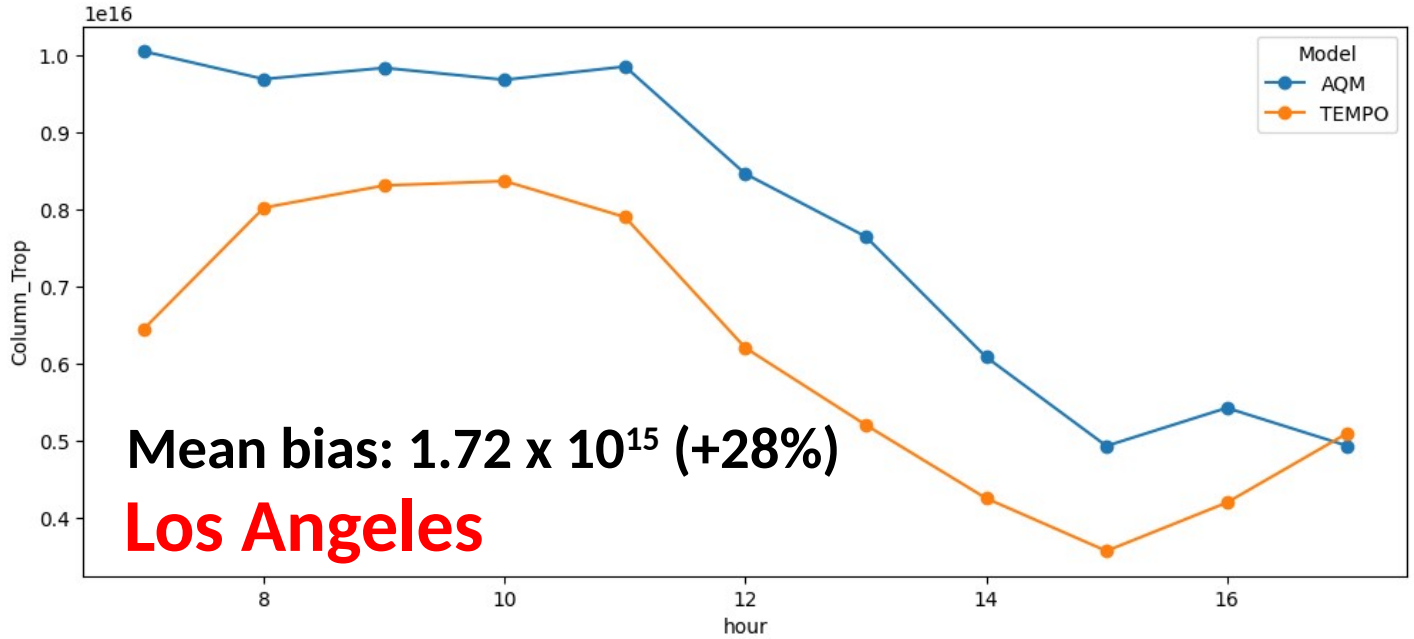





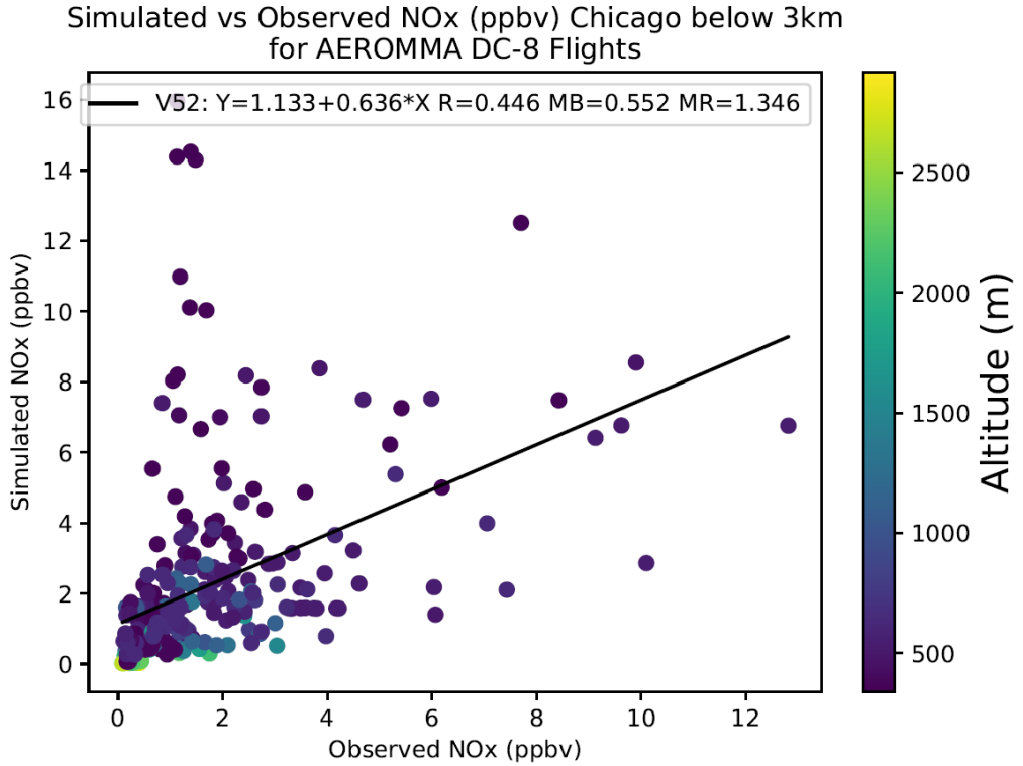



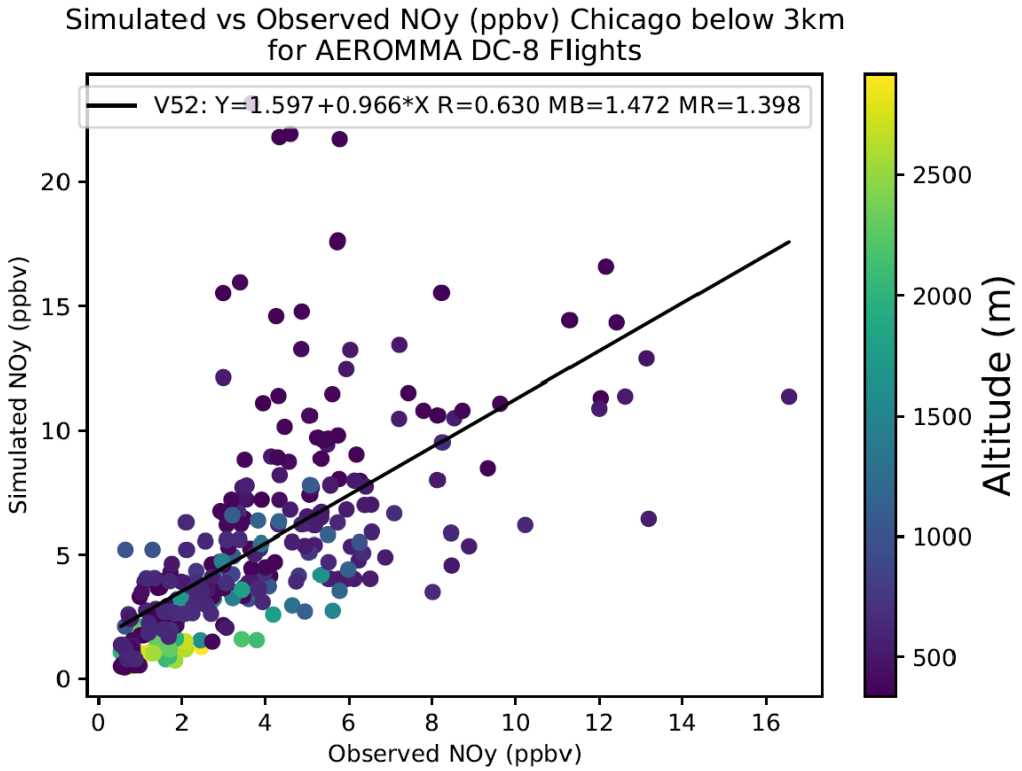

**This Cross-Comparison try to address the bias of the NOx emissions over Megacities, reflected by in-situ comparison (slope, mean bias, mean ratio) and TEMPO tropospheric vertical column**



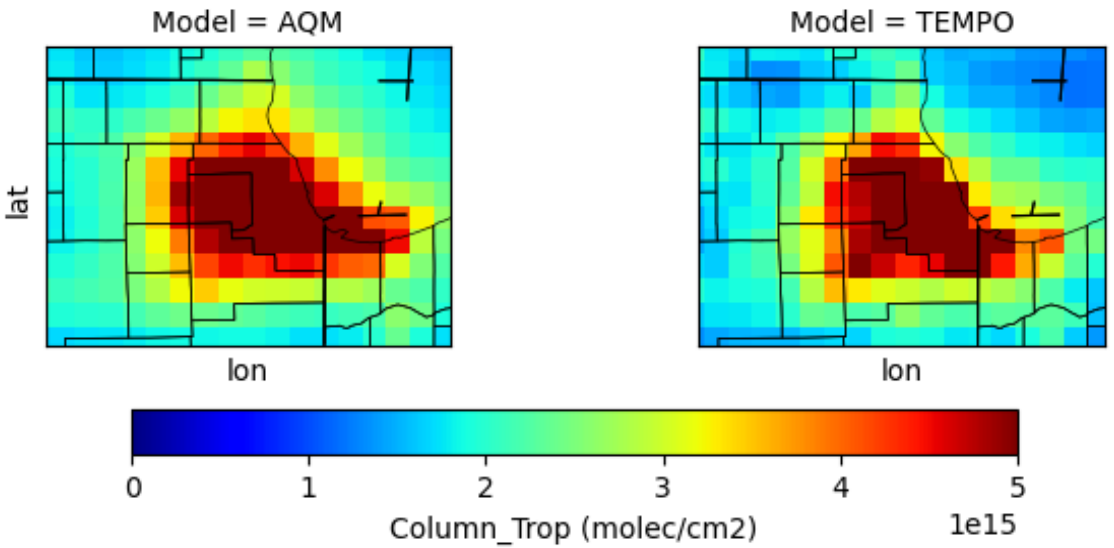



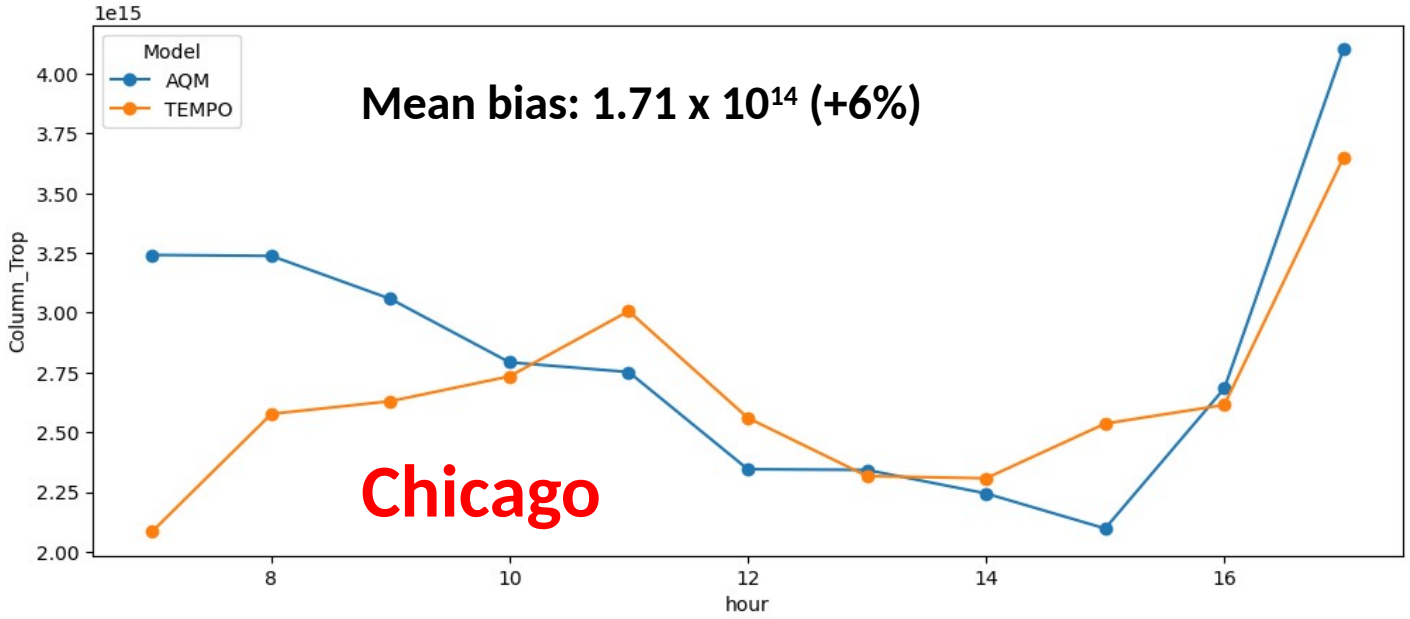

**Courtesy of**



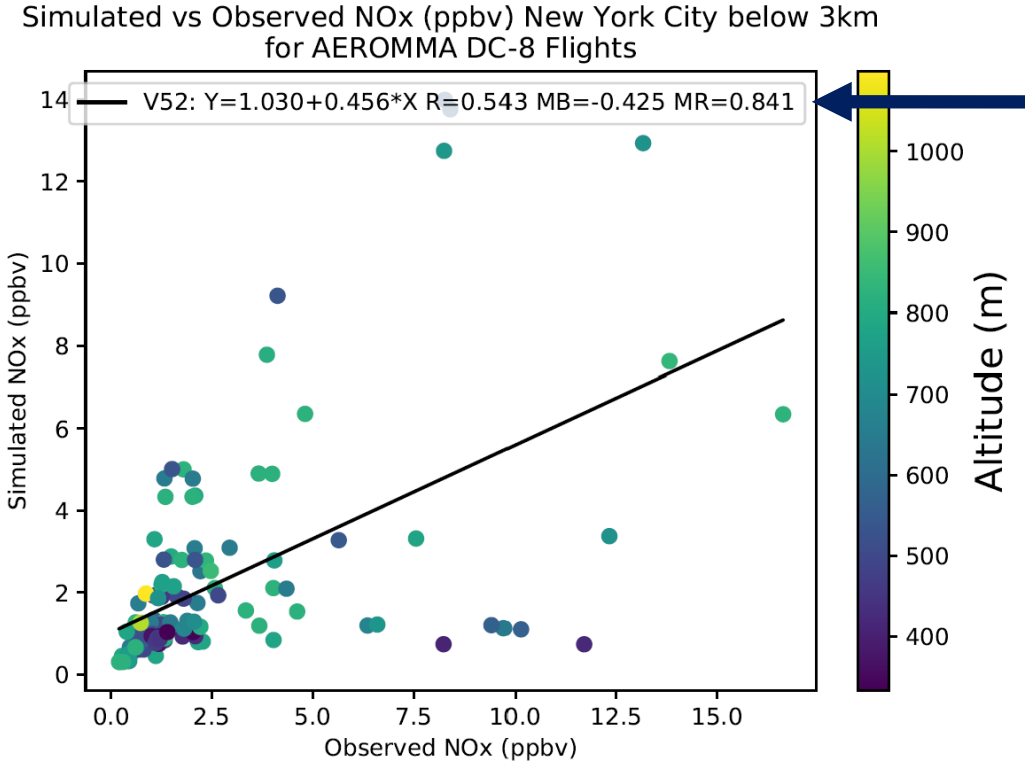



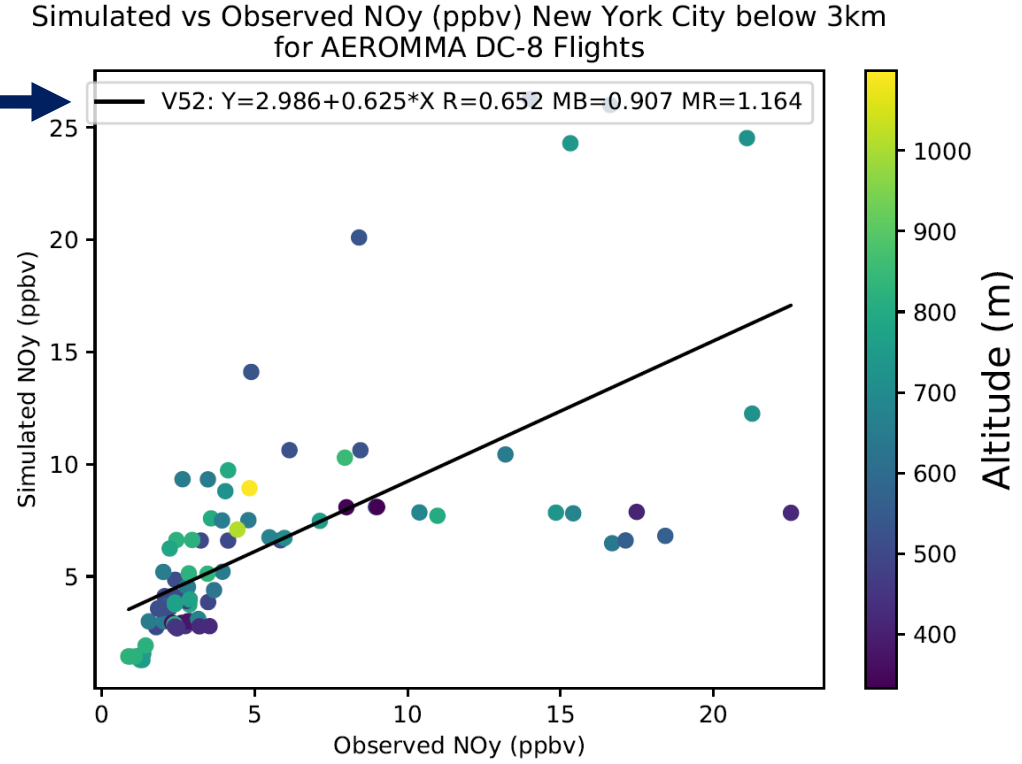

**Same but for Chicago**



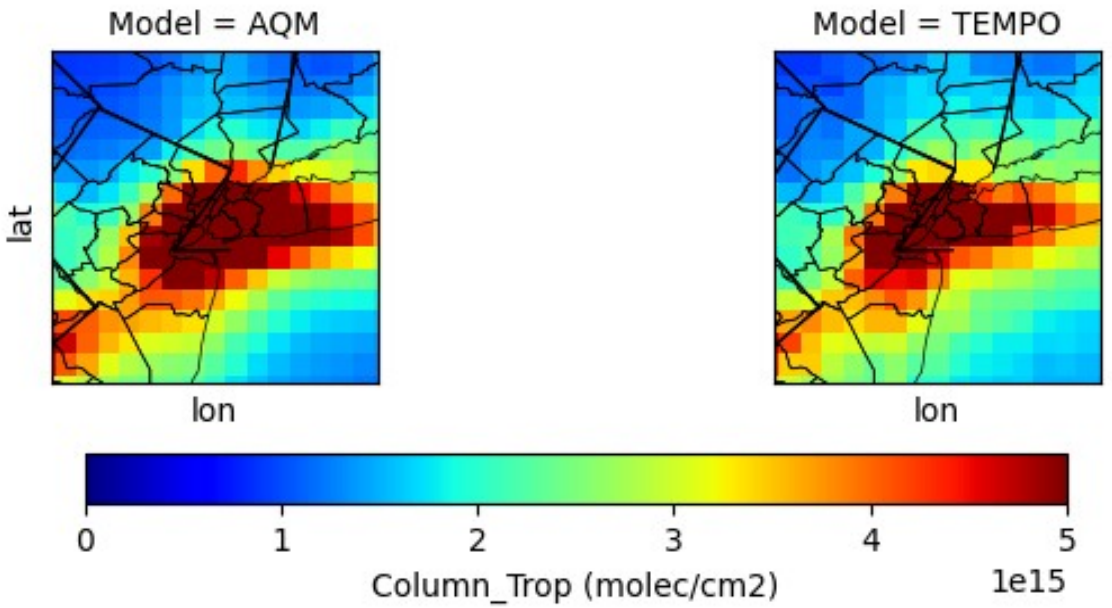



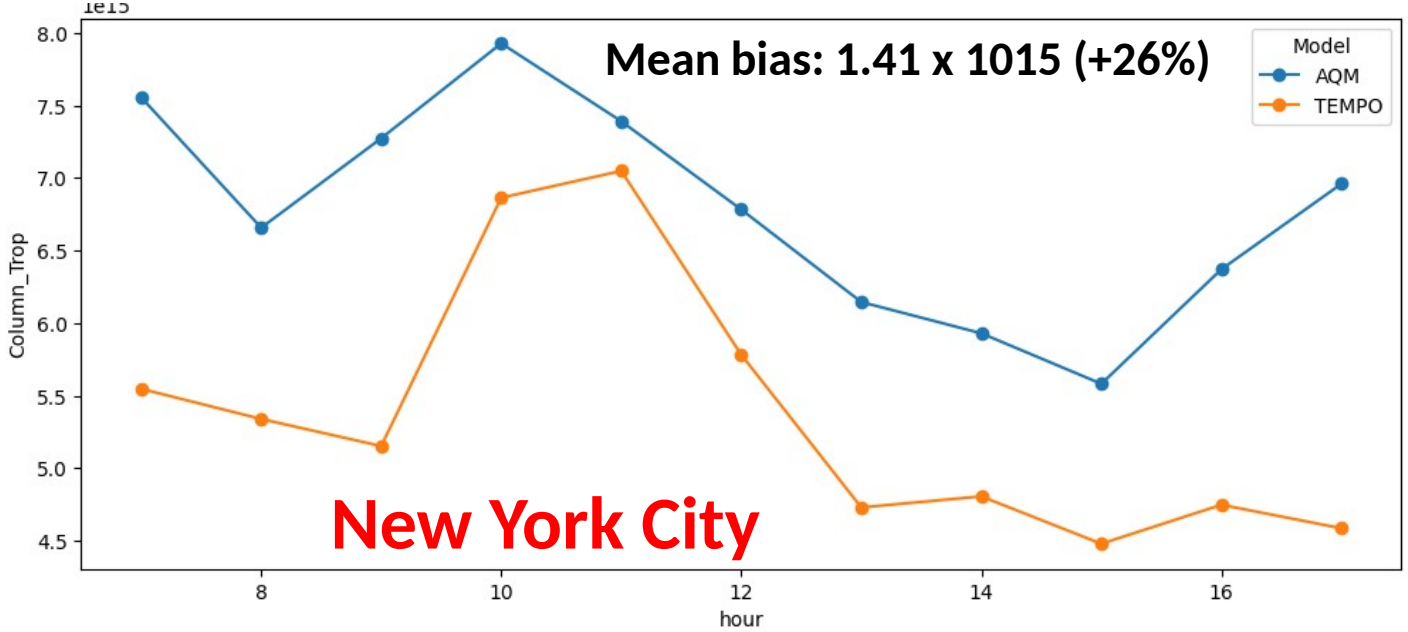

**Courtesy of**




**Same but for New York. The discrepancies exist among different species (NOx vs NOy) , as well as in-situ vs TEMPO comparison**




**Courtesy of**

# Summary

**The CMAQ5.4 chemistry has stronger photochemical variation than CMAQ 5.2, reflected by its higher ozone product efficiency and lower nighttime ozone.**

**The model's well-mixing assumption and insufficient spatial resolution lead to overpredicted NOx consumption and NOz production, and shorter NOx age. CMAQ 5.4 shows slightly better chemical behavior over some areas.**

**The lateral or top boundary conditions for some species need adjustments.**

**SO2 is underpredicted over U.S. West and lead to aerosol speciation shift.**

**The consistency between Satellite and in-situ data could be an issue, and we need to be caution for making emission adjustment based on them.**