WRF-Chem simulations of the May 29, 2012 DC3 Oklahoma severe storm case and comparison with aircraft data

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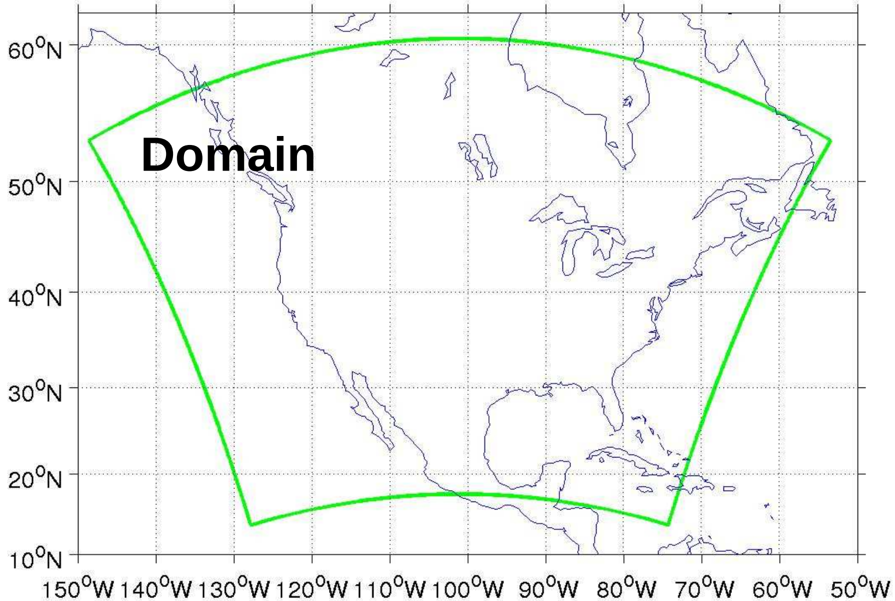
Abstract

Deep convective thunderstorms affect the vertical distribution of chemical species through vertical transport, wet scavenging of soluble species as well as aqueous and ice chemistry. This work focuses on the vertical distribution of chemical species in the May 29, 2012 DC3 Oklahoma thunderstorm. Simulations were conducted with the Weather Research and Forecasting with Chemistry (WRF Chem) model, with a 15km grid encompassing the continental US. WRF-Chem shows good agreement with observed precipitation rate and radar reflectivity, as well as CO and O3, indicating that emissions and model dynamics are reasonable. However, WRF-Chem underestimates NOx in the upper troposphere, suggesting the need for furtherwork on the lightning NOx parameterization, and soluble species such as SO2 and CH2O are overestimated, indicating the need to include wet scavenging processes in WRF-Chem.

WRF-Chem Setup



Grid spacing: dx = 15 km, 40 vertical levels to 50 hPa (~650 m in UT)

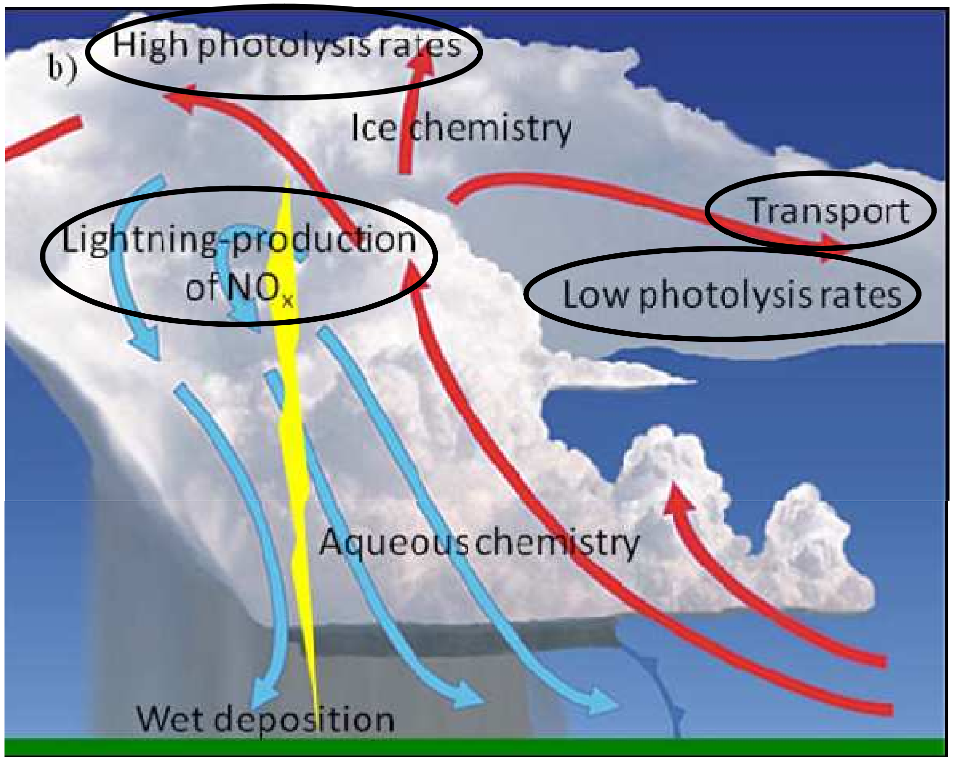
Initial/Boundary Conditions: DART (met), MOZART (chem)

Physics: Grell 3D convection, Morrison cloud microphysics, MYJ PBL

Chemistry: MOZART gas chemistry mechanism; GOCART aerosol scheme

Emissions: EPA NEI 2005 anthropogenic (2012 NO/NO2 based on OMI NO2), aircraft from Baughcum (1999), MEGAN v2.0.4 biogenic, FINN fire

Included processes:



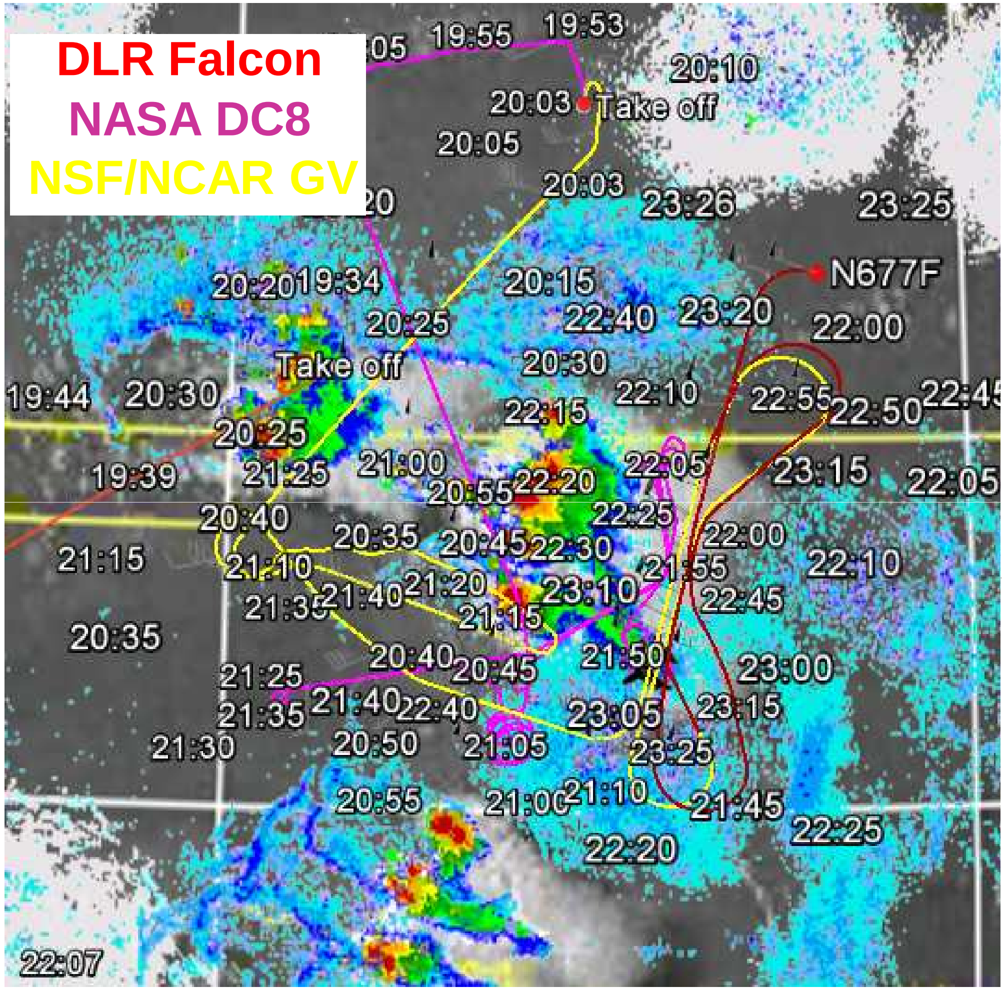
https://www2.acd.ucar.edu/sites/default/files/dc3/thunderstorm-airmass_squall-line.jpg

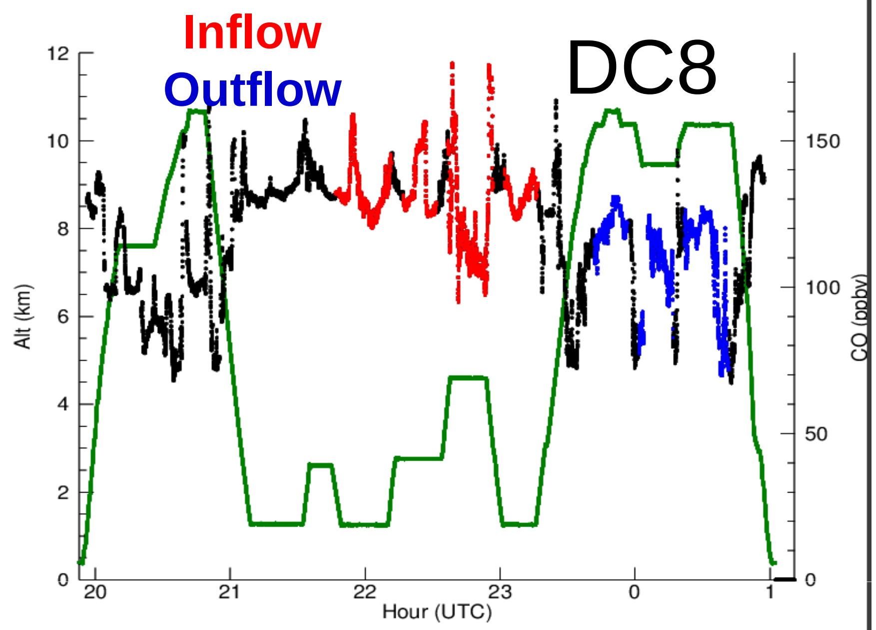
Lightning-NOx : FR = $3.44 \times 10^{-5} z_{top}^{4.9}$

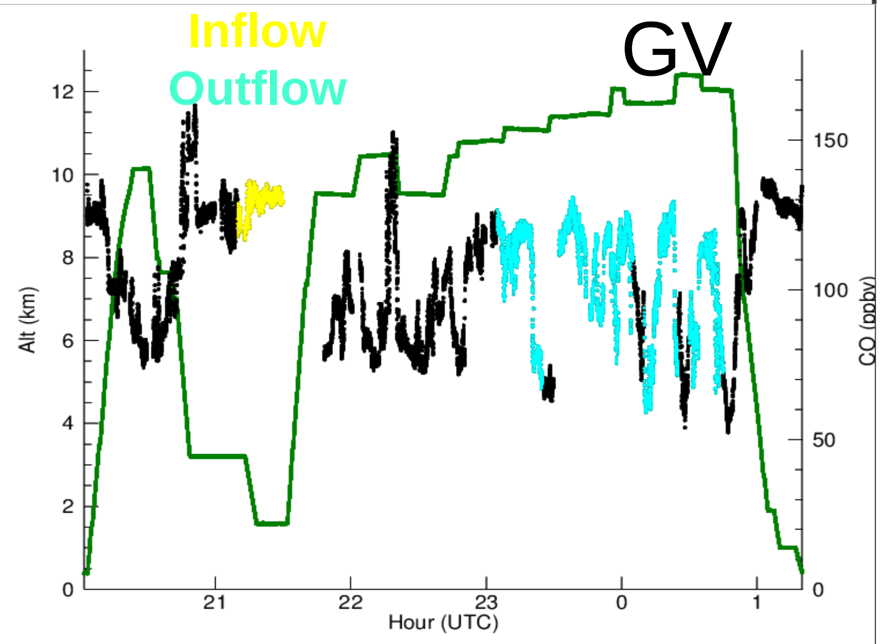
z_{top} = cloud top height = level neutral buoyancy – 2 km (Wong et al., 2012)

500 moles NO/flash placed vertically following Ott et al. (2010) curves

May 29, 2012 DC3 Oklahoma severe storm case



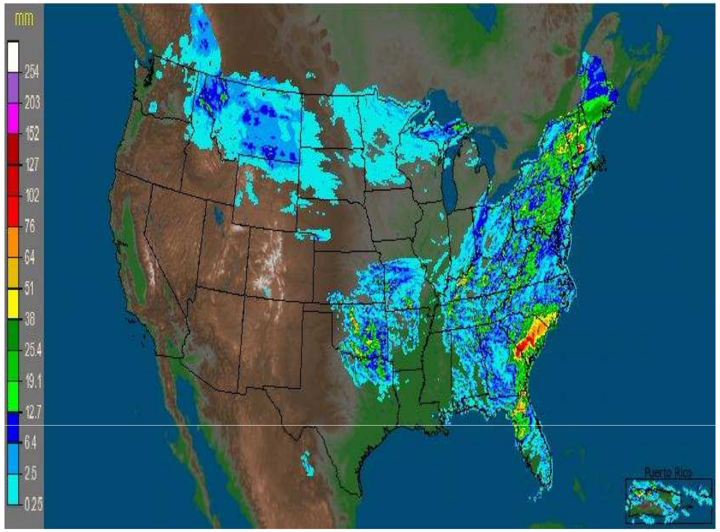




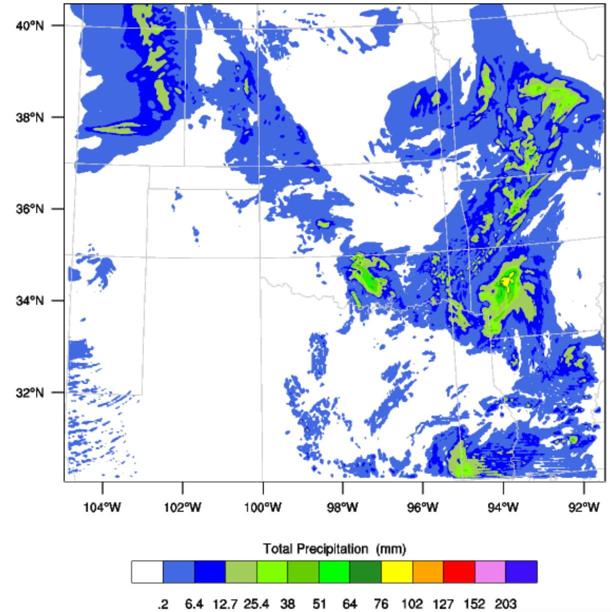
Simulated and observed storm location and intensity show good agreement

24-hr Accumulated Precipitation 2012-05-29 12Z – 2012-05-30 12Z

NWS Precip Analysis

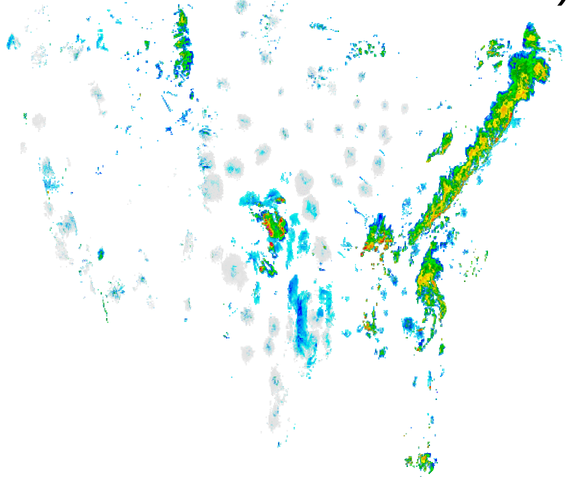


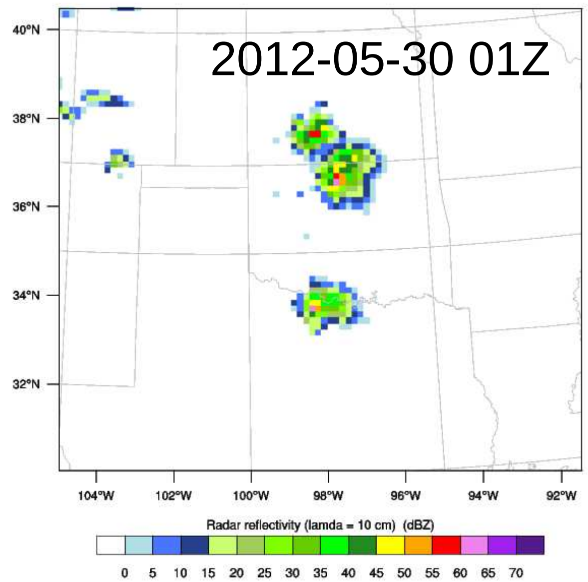
WRF



Maximum radar reflectivity (dBZ)

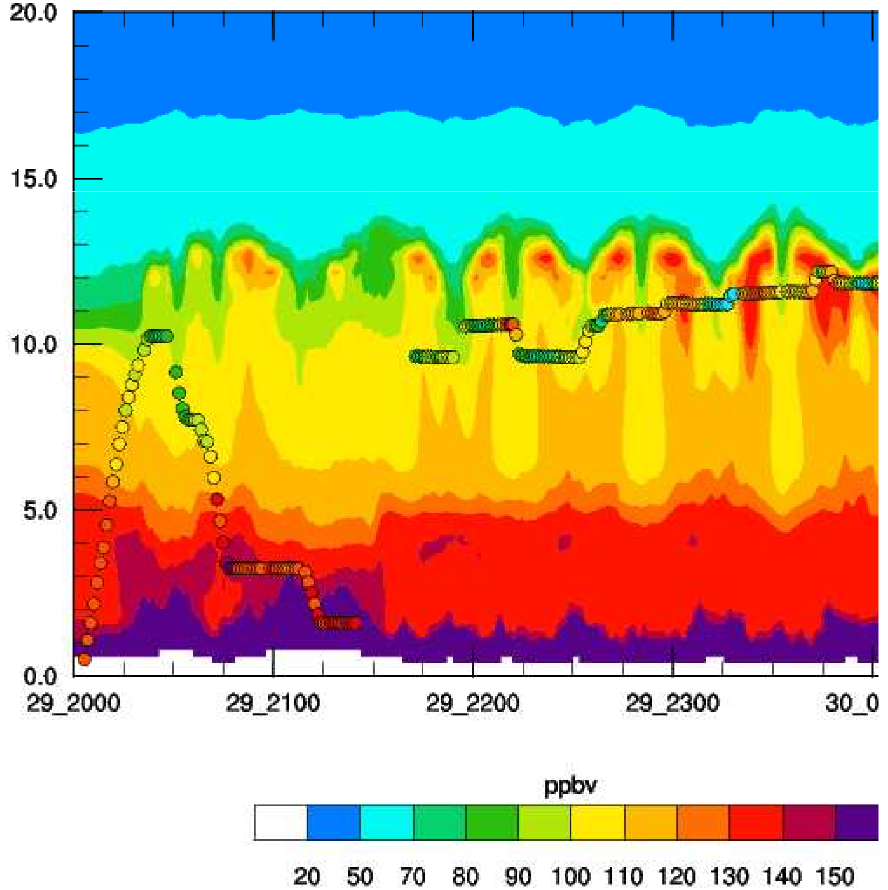
NEXRAD 2012-05-30 01Z)



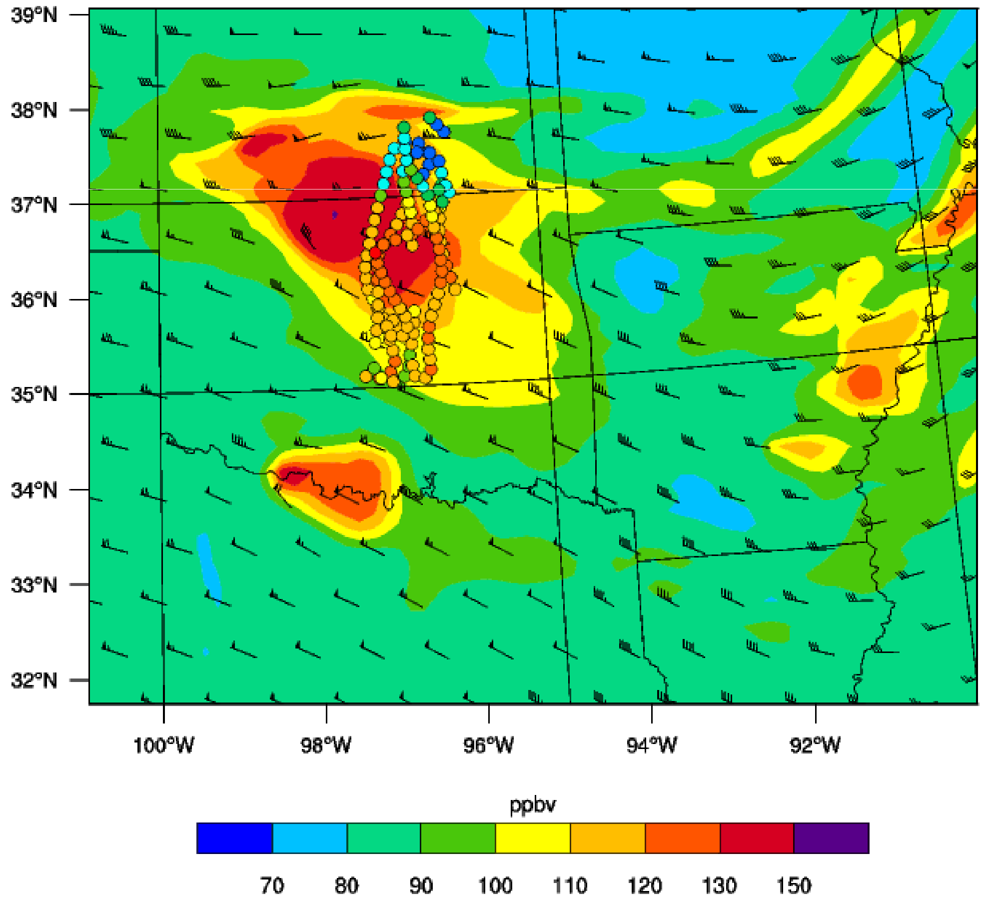


Simulated CO values match DC8 and GV observations of elevated CO in center of storm

Curtain plot of **CO (ppbv)** following GV flight track

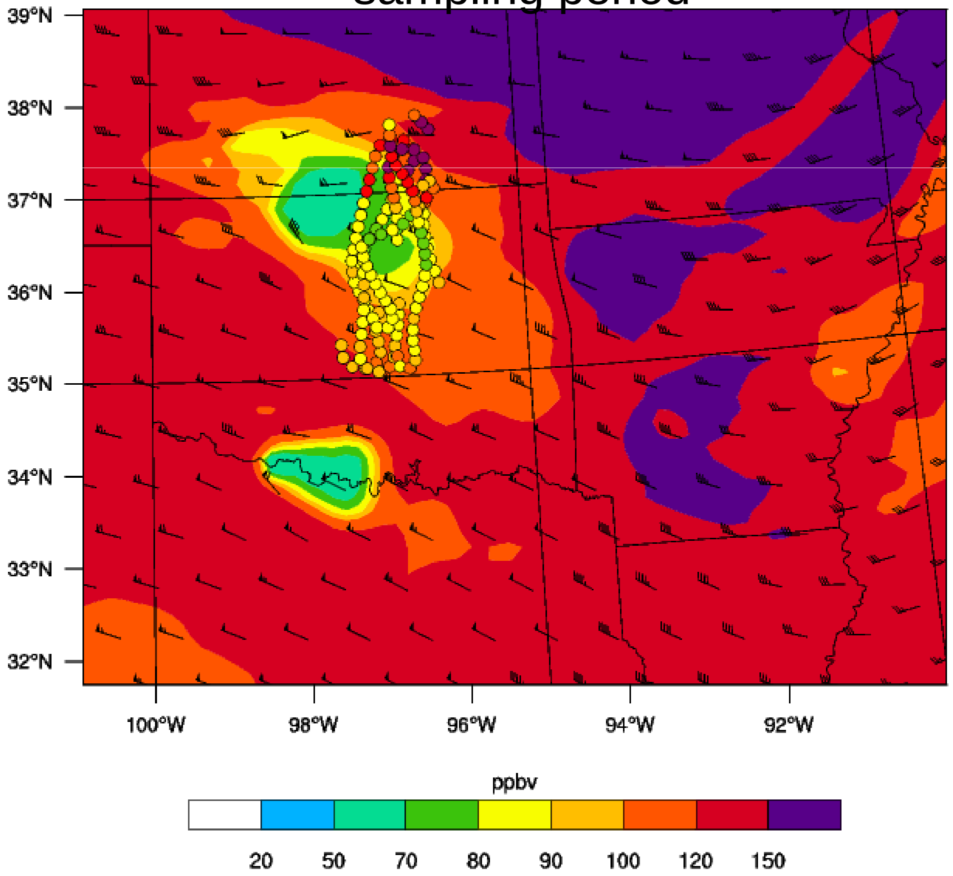


CO (ppbv) simulated by WRF-Chem at 11km at 2012-05-30 0Z and observed by DC8 and GV for 10<z<12km for storm sampling period

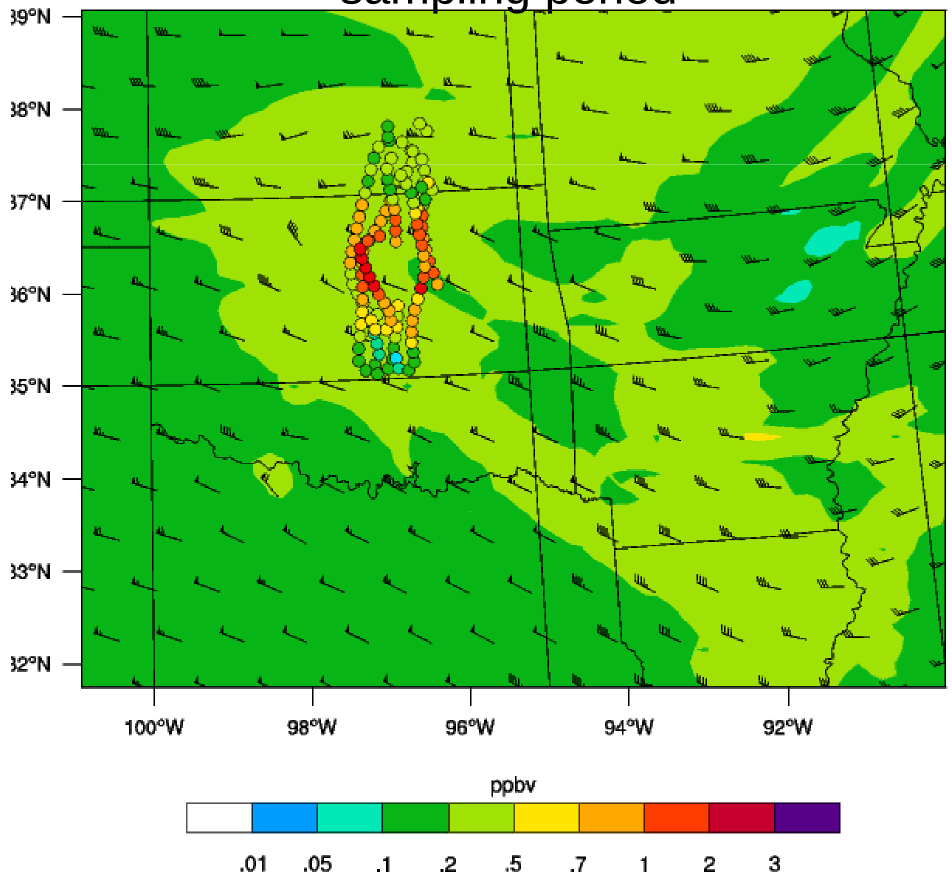


Simulated O_3 values at 11km compared well with DC8 and GV storm observations but NO_x is too low by a factor of ten

O_3 (ppbv) simulated by WRF-Chem at 11km at 2012-05-30 0Z and observed by DC8 and GV for 10<z<12km for storm sampling period



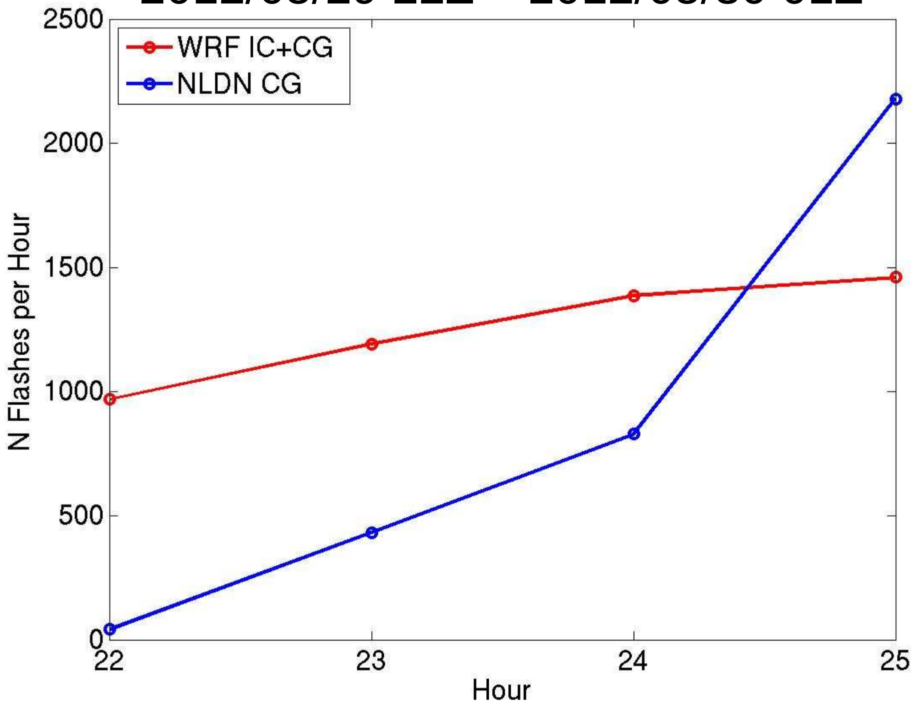
NOx (ppbv) simulated by WRF-Chem at 11km at 2012-05-30 0Z and observed by DC8 and GV for 10<z<12km for storm sampling period



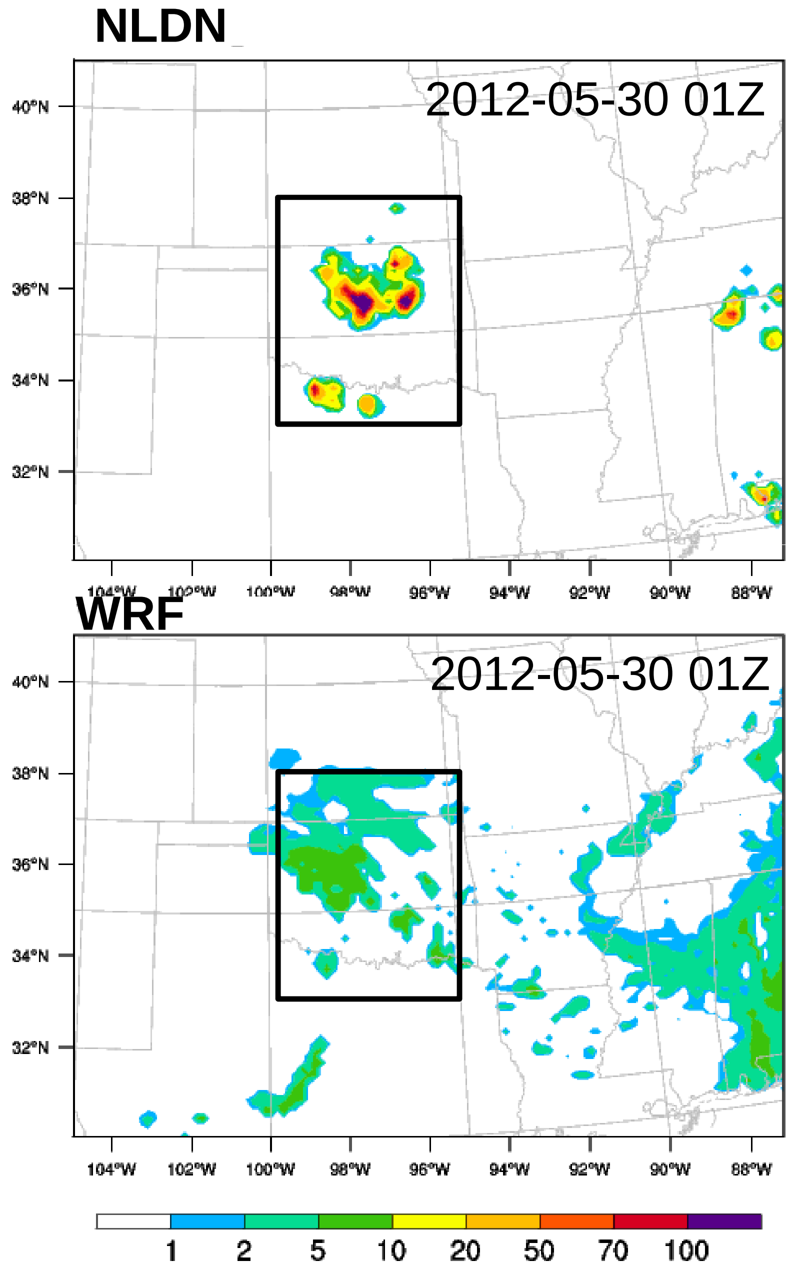
WRF-Chem overpredicts total hourly flash rate in storm region compared to NLDN, but underestimates intensity

Hourly Flash Rate

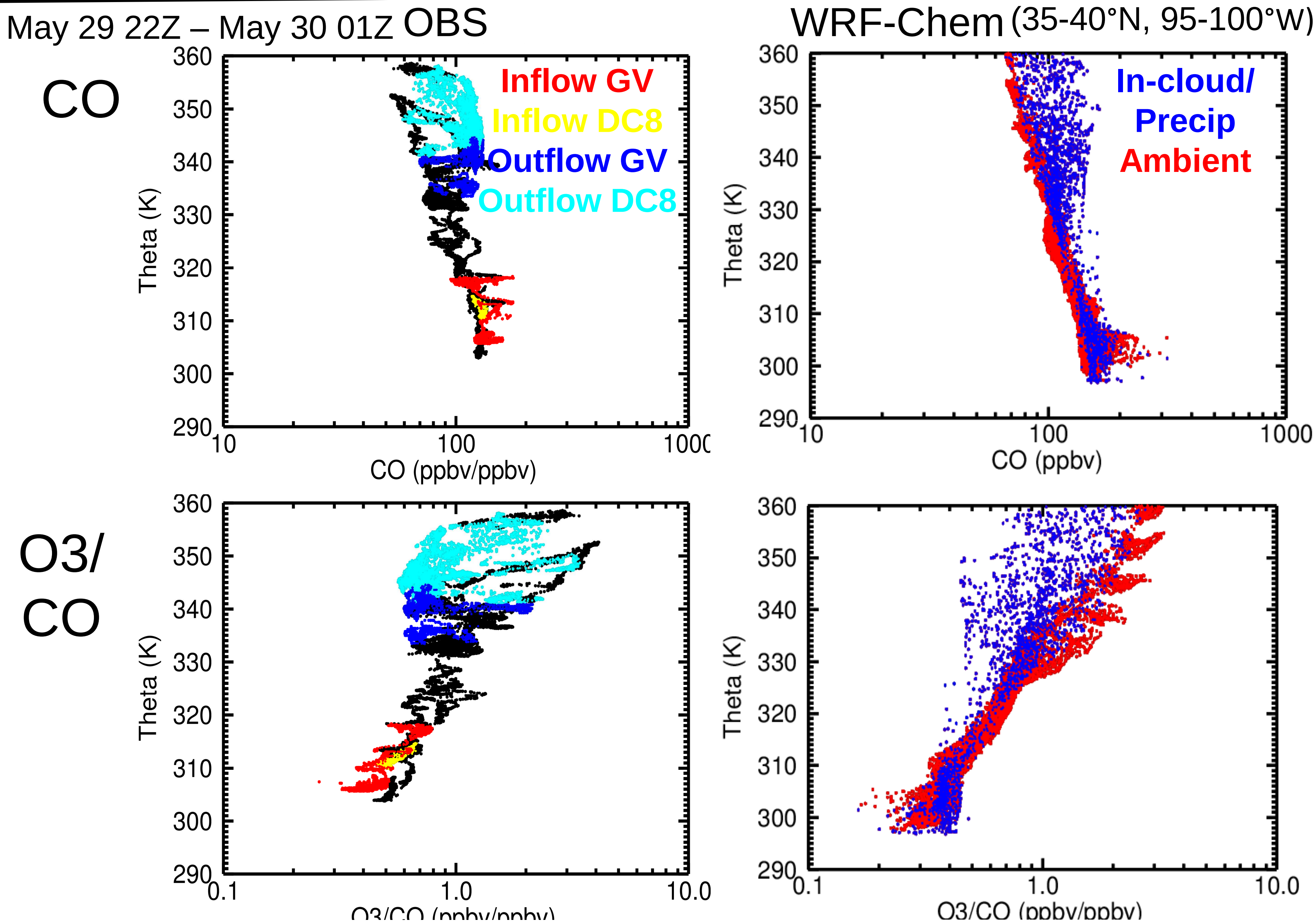
Total within 35-40°N, 95-100°W
2012/05/29 22Z – 2012/05/30 01Z



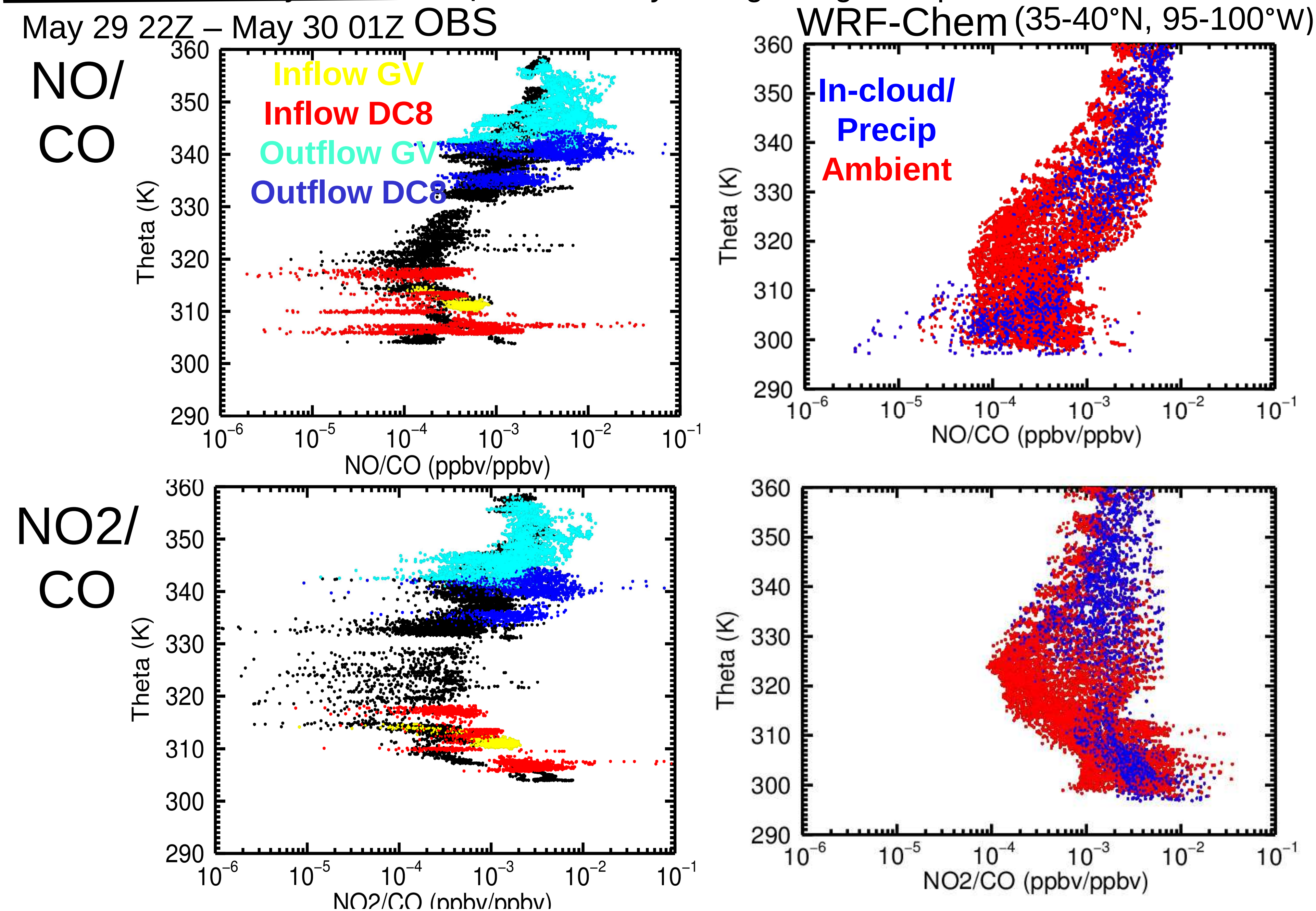
Note: NLDN data includes Cloud-to-Ground (CG) flashes only, while WRF data is CG plus Intracloud (IC)



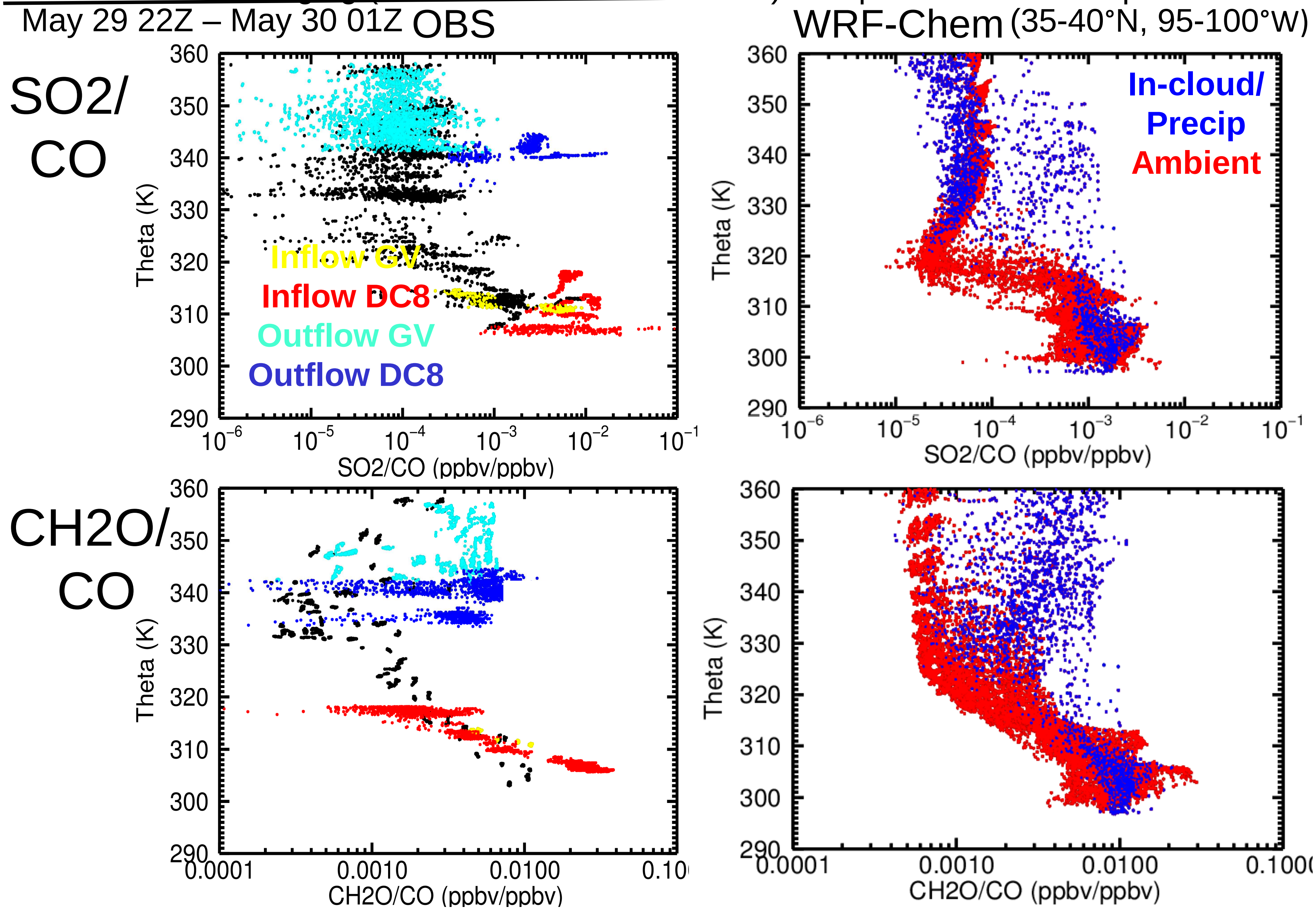
CO and O3 show good agreement between model and observations, indicating reasonable source emissions and model dynamics



NOx is understimated in the upper troposphere by WRF-Chem by up to a factor of 10, likely due to low production by the lightning NOx parameterization



WRF-Chem values of SO2 and CH2O are higher than observed, indicating that wet scavenging (not included in WRF-Chem) is important for these species



Summary

A WRF-Chem simulation was conducted of the May 29, 2012 Oklahoma severe thunderstorm on a 15km grid encompassing the continental US, and results were compared with observations from the GV and DC8 aircraft. The model shows good agreement with observations for both CO and O_3/CO, indicating that model dynamics and boundary conditions are reasonable. NO_x is under predicted by the model in upper levels, due to underestimated lightning NO_x production. High mixing ratios of SO_2/CO and CH_2O/CO were found in the boundary layer and in convective outflow, indicating that material is convectively lofted from the boundary layer in the storm inflow region. WRF-Chem over predicts these soluble species, suggesting that some SO_2 and CH_2O are removed or transported downward by aqueous chemistry and/or wet deposition, which were not included in this simulation.

This work was funded by an NSF ATM grant.

DC3 Preliminary Data Provided by the following Instrument Teams:

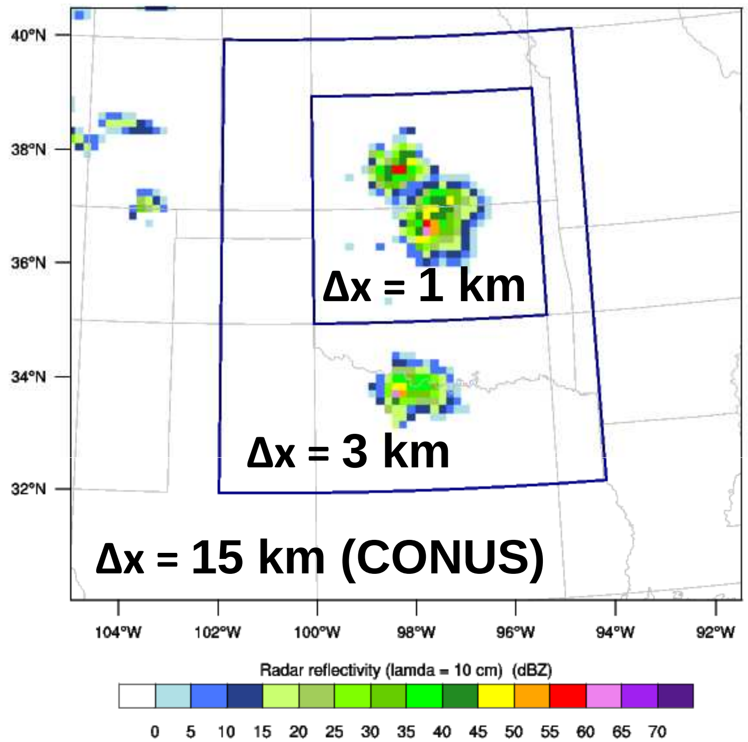
DC-8 CO: DACOM - Differential Absorption Mid-IR Diode Laser Spectrometer for CO, CH4, and N2O: G. Diskin, G. Sachse, J. Podolske (NASA/LaRC)

DC-8 O3, NOx: **CSD CL** – NOAA Chemical Luminescence NOyO3: T. Ryerson, I. Pollack, J. Peischl (NOAA/ESRL/CSD)

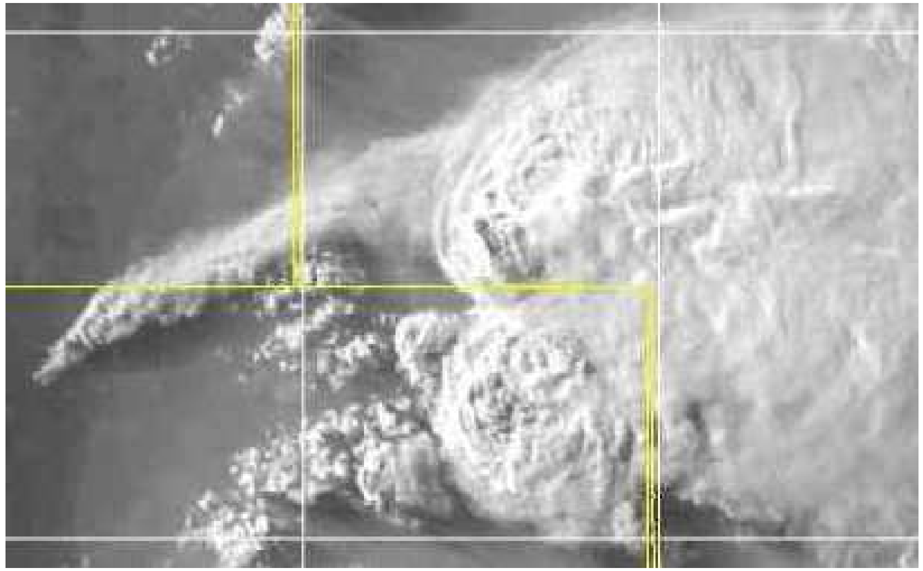
GV CO, O3, NOx: **CARI** – NCAR Community Airborne Research Instrumentation: A. Weinheimer, F. Flocke, T. Campos, D. Knapp, D. Montzka (NCAR)

Future Plans

Increase horizontal (3/1 km) and vertical resolution



Simulate June 22 NE CO storm (interaction with High Park Fire)



Couple wet scavenging to Morrison microphysics and G3 convection, explore ice adsorption, ice and aqueous chemistry

Simulate the rest of the DC3 case studies with CONUS 15 km domain