# A41B-0034. Evolution of Upper Tropospheric Composition Perturbed by a Mesoscale Convective System during the Deep Convective Clouds and Chemistry (DC3) Campaign


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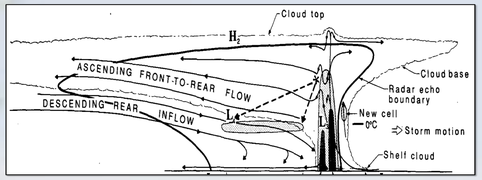
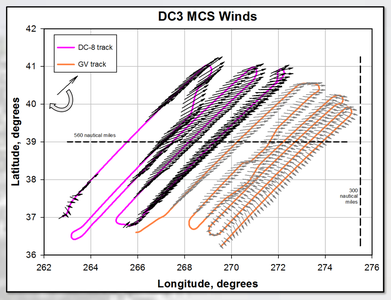
**Abstract**

The role of deep convection in altering the chemical composition of the upper troposphere (UT) is well known, having been observed in many airborne campaigns, including dedicated studies that were part of the Deep Convective Clouds and Chemistry (DC3) experiment in May and June, 2012. Because of the importance of Mesoscale Convective Systems (MCSs) in convective transport, their impact was assessed on two occasions as observations of opportunity during flights focused on other goals, and during one dedicated mission. The latter focused on a decaying nocturnal MCS that formed over the north central Great Plains and moved to the east over Illinois, Indiana, and Missouri during the day on June 21, 2012. The aircraft platforms were staged such that the DC-8 observed the aging from early morning to midday, and the GV observed from midday to early evening to determine the concentrations of a variety of gas-phase species as well as the composition and size distributions of aerosols in the outflow. Using various approaches, the observations are placed on a photochemical age scale. This allows calculations of ozone production, production and growth of aerosols, net production of nitric acid, and budgets of $HO_x$ and its reservoirs in the MCS outflow, which can lead to improved understanding of the role of MCSs in UT chemical composition and evolution.

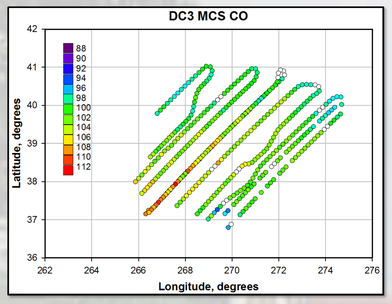

**MCS Schematic Diagram**

From Houze et al. (1989), this diagram shows characteristics of MCSs. he outflow trails the storm, which is depicted as moving right in the figure.



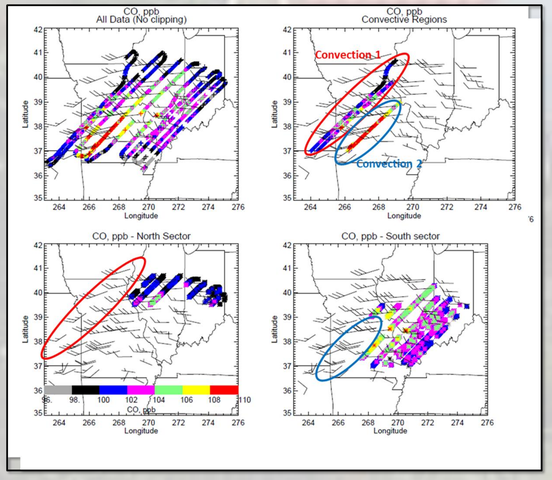

**Aircraft Observed Winds**

The DC-8 and GV flight tracks in the vicinity of the MCS outflow are shown in magenta and orange. Superimposed are wind vectors as observed on the aircraft. Wind directions less than 240 degrees (shown below legend) are removed since the trajectories are unlikely to be observed on later legs. Also removed trajectories with fewer than measurements on 4 legs.



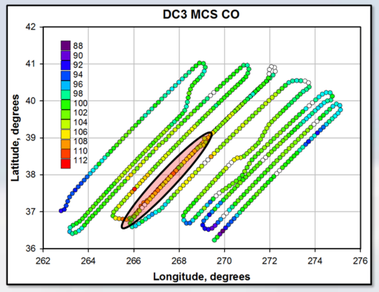

**Carbon Monoxide**

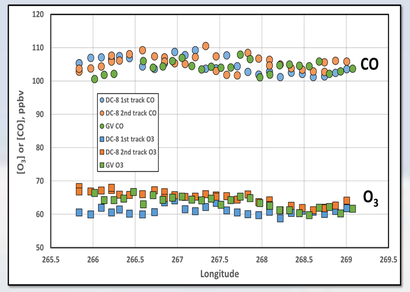
Aircraft flight tracks colored by carbon monoxide (CO) mixing ratios filtered by wind direction and trajectory in proximity of the MCS outflow. Some higher mixing ratios near the lower left remain likely due to fresh convection to the southwest of the study area. *Data from Glenn Diskin and Glen Sachse on the DC-8, and Teresa Campos and Frank Flocke on the GV.*




**Leg Segment Parsing**

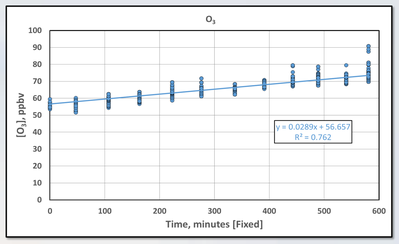
Flight tracks colored by CO and parsed for fresh convection (upper right) and aged outflow from those two convective regions in the north part of the study region (lower left) and in the south part (lower right). *Analysis by Jennifer Olson of NASA Langley.*

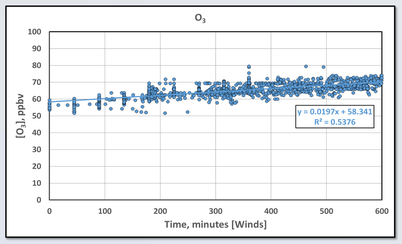


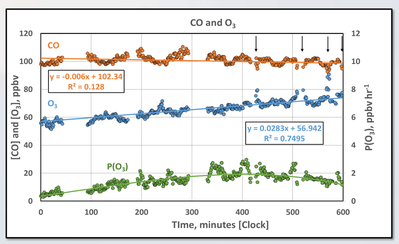



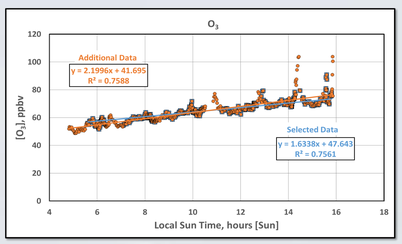

**Rough Measurement Comparison**

The region circled on the left plot shows a leg that was measured twice by the DC-8 and once by the GV. Measurements for CO and $O_3$ mixing ratios in this region versus longitude for the first DC-8 track (SW to NE), the second DC-8 track (NE to SW) and the GV track are shown in the right plot. Note that the time difference in the DC-8 observations near longitude 266 degrees from the two legs is about 110 minutes. The GV measurements are about 20 minutes after the 2nd DC-8 observation. *DC-8 $O_3$ data from Tom Ryerson and Ilana Pollack, and GV data from Andy Weinheimer, David Knapp, Denise Montzka, Frank Flocke, & Teresa Campos.*




**Processing Times for Trend Analysis**

In order to use the observations to determine trends, assignment of proper times to each point is critical. Four approaches were examined:

[Clock] Time of Measurement (UTC) – set 1st point of first leg to 0.

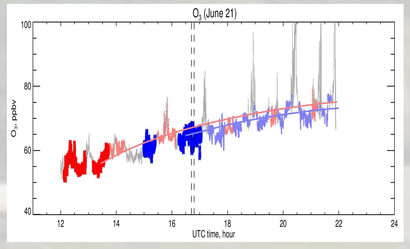
[Wind]Transport time from wind speed, wind direction and distance. Can use to filter out trajectories that cannot be sampled later in the day.

[Sun] Local sun time (solar time of day).

[Fixed] Same time for entire leg = time to sample previous leg (0 for first leg).

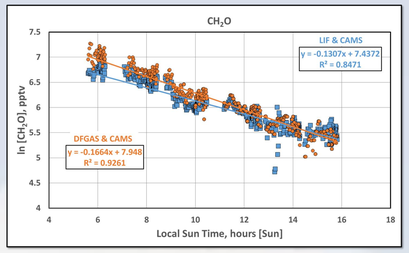
These are compared for ozone in the plots above and the Table below.

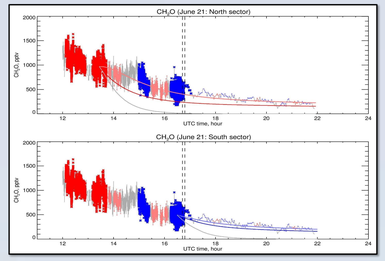
| Time Method | Linear Fit Slope, ppbv/hour | $\Delta[O_3]$ in 12 hrs | $r^2$ |
|---|---|---|---|
| Fixed | 1.73 | 20.8 | 0.76 |
| Winds | 1.18 | 14.2 | 0.54 |
| Clock | 1.70 | 20.4 | 0.75 |
| Sun | 1.64 | 19.7 | 0.76 |
| Calculated $P(O_3)$* | 1.62# | 19.4 | -- |




**Lagrangian Model**

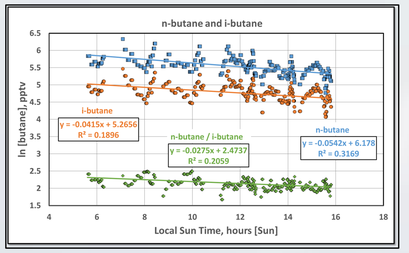
Modeled ozone versus time compared to observations. Red and blue lines are runs initialized at the two convective regions.

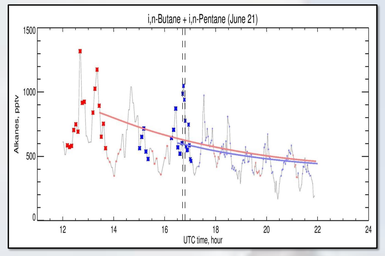



- Observed decay corresponds to lifetimes of about 6 to 7.5 hours
- Lifetime to loss to OH reaction and photolysis is 0.9 hours near midday
- Implies observed decay is the rate of decay of $CH_2O$ precursors
- Models show significant contributions from VOC oxidation (lower line: L($CH_2O$, middle line: $CH_4$ chemistry only, upper line: full run)

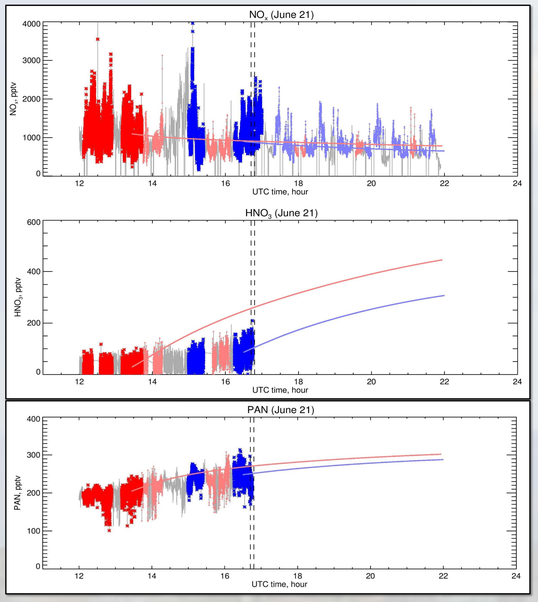
*Data from Tom Hanisco, Heather Arkinson, Alan Fried, Jim Walega, Dirk Richter & Petter Weibring. Model runs and figures from Jennifer Olson*




- Observed decay corresponds to lifetimes of about 18 & 24 hours
- Lifetime to loss to OH reaction is 13 & 25 hours near midday
- n-but / i-but ratio tends toward about 2; k(n-but) / k(-i-but) = 1.95
- Modeled decay consistent with observations

*Data from Eric Apel, Becky Hornbrook, Dan Riemer, Alan Hills, Don Blake, Nicola Blake, Simone Meinardi, and Barbara Barletta.*




**$NO_x$ Trends**

$NO_x$ observations, although spikey, decay at a rate consistent with gas-phase loss processes. $HNO_3$ and PAN are formed, although $HNO_3$ amounts are significant less than modeled. This could be due to uptake by aerosols.

**Summary**

Framework developed to assess transport of MCS outflow

Calculations of $O_3$ and $CH_2O$ tendencies are made and compared with known chemistry via numerical models and other approaches

- $O_3$ growth averages about 1.6 ppbv/hour
- $CH_2O$ decay with lifetime of 6 to 7.5 hours
- Butane decays consistent with known kinetics

Variety of extensions to $NO_x$ lifetimes, $HO_x$ radical budgets, $SO_2$ oxidation, aerosol nucleation and growth, etc. are planned