A23J-3370

The Deep Convective Clouds and Chemistry (DC3) Field Experiment

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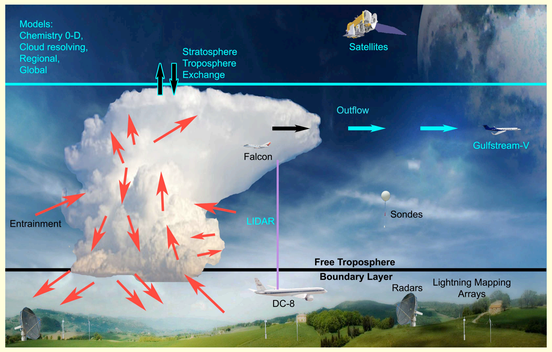
NCAR is sponsored by the National Science Foundation.

Motivation of the DC3 Field Campaign

What role do thunderstorms have in affecting the upper troposphere – lower stratosphere (UTLS) composition and chemistry?

Goals of the DC3 Field Campaign:

1. *To characterize thunderstorms and quantify how they process chemical compounds that are ingested into the storm*
2. *To quantify the changes in chemistry and composition after active convection*

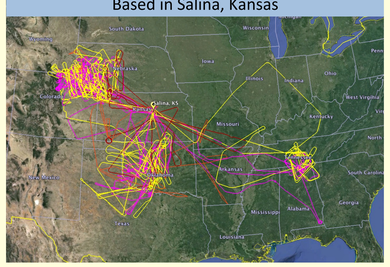


Facilities

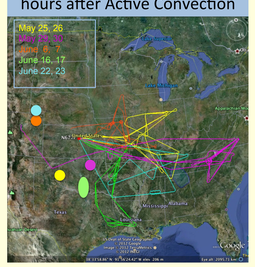
- Dual-Doppler and polarimetric radars to get storm structure and kinematics
- Lightning mapping arrays to get 3-d locations of lightning
- Weather balloon soundings before and during storms
- Aircraft to measure composition of inflow and outflow of storms and downwind of storms in UT

May – June 2012 over the Central U.S.

Sampled Storms in Colorado, Alabama, West Texas – Oklahoma Based in Salina, Kansas



Sampled Convective Outflow in Upper Troposphere 12-36 hours after Active Convection



NSF/NCAR Gulfstream V, NASA DC-8, and DLR Falcon aircraft flew 19 thunderstorm cases, > 6 photochemical aging cases

Data available from http://www.eol.ucar.edu/field_projects/dc3

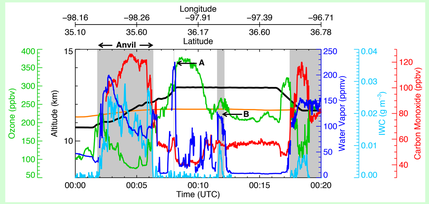
Overview paper: Barth et al., accepted by *Bull. Amer. Meteor. Soc.*

DC3 Data Analysis Activities

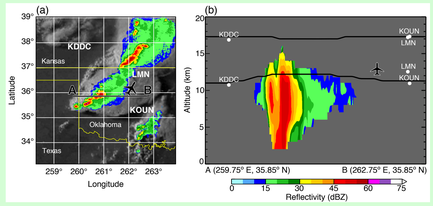
Research includes investigating the transport and dynamics of the storms, scavenging of soluble trace gases and aerosols, production of nitrogen oxides by lightning, relationships between lightning flash rates and storm parameters, and chemistry in the UT that is affected by the convection. Here, we show highlights of studies focused on the UTLS composition.

Convective transport of water vapor into the lower stratosphere observed during double-tropopause events

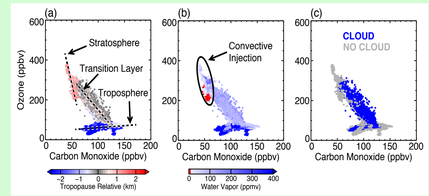
Homeyer et al., *J. Geophys. Res.*, 2014.



Time series of O_3, CO, water vapor, IWC, and altitude of GV aircraft as it sampled convective injection above the tropopause (marked in orange) for 19 May 2012 case.



Composite GOES satellite and NEXRAD radar data for the 19 May 2012 case. Vertical cross-section is located at A-B line. Black lines mark double tropopause.



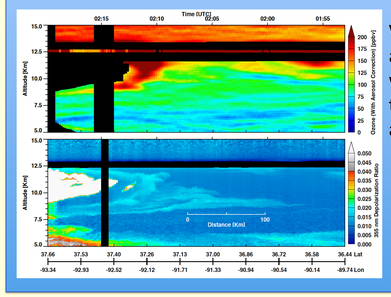
Scatterplots of O_3 and CO for the 19 May 2012 convective line case. Points are colored by (a) altitude relative to the GFS analysis tropopause, (b) water vapor mixing ratio, and (c) detection of cloud particles.

Key Points

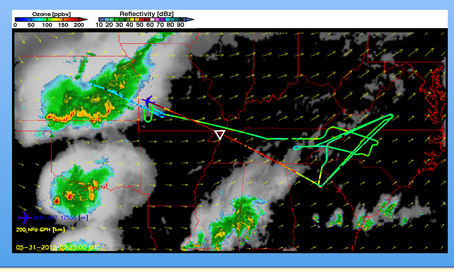
- Injected water vapor up to 200 ppm above background lower stratosphere
- Convective overshooting up to 4 km above tropopause
- Reduced stability from double tropopause may facilitate deep overshooting

Thunderstorms Enhance Tropospheric Ozone by Wrapping and Shedding Stratospheric Air

Pan et al., *Geophys. Res. Lett.*, 2014



Vertical distribution of (a) ozone and (b) depolarization ratio, which indicates the location of the cloud. In-situ ozone is shown along the flight track.



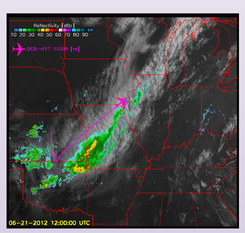
Composite GOES satellite and NEXRAD radar data showing the MCS in the upper left over Kansas. The DC-8 flight track is colored by the in situ ozone mixing ratio.

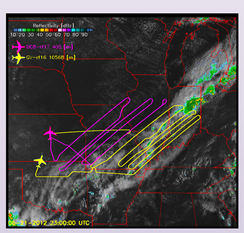
Key Points

- Tropopause-reaching MCSs entrain ozone-rich stratospheric air into troposphere
- Airborne lidar measurement is key to revealing this transport mechanism
- A missing transport pathway for ozone budget in major global models

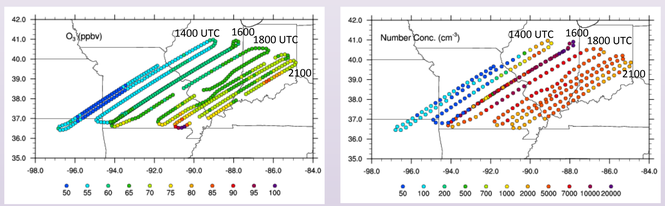
Photochemical Aging and New Particle Formation in the Convective Outflow of a Decaying Mesoscale Convective System (MCS)

Cantrell, Barth, Ziemba, Nault, Cohen and others



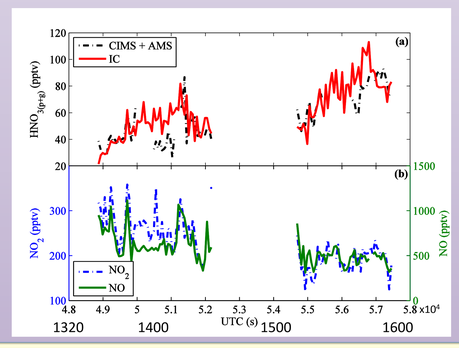


Composite GOES satellite and NEXRAD radar data at 1200 UTC (left) and 2300 UTC (right) on 21 June 2012. The DC8 (magenta) and GV (yellow) flight tracks are overlaid.



Ozone (left) and particle number concentration (right) for the 21 June 2012 DC3 case along the flight tracks. Both variables are quite low until late morning (1600 UTC) when values increase substantially.

In situ measurements of nitric acid plus particulate nitrate increase from early morning to mid day while NO and NO_2 decrease. These data are being analyzed to constrain rate constants for the production of HNO_3 in the UT, including NO_2 + OH → HNO_3 and HO_2 + NO → HNO_3. See poster by Ben Nault et al. **A23J-3379** for more details.



Key Points

- Probing the convective outflow region of a decaying MCS is a fruitful way of measuring changes in UTLS composition after active convection
- Ozone mixing ratios increase by ~20 ppbv during day
- Thousands of new particles are formed beginning in mid-morning
- Analysis of total nitric acid and NO_x species can constrain UT rate constants and NO_x-HO_x-O_3 chemistry