DC3 Science Team Meeting Summary

The goals of the DC3 STM were to 1) learn and discuss what DC3 analyses has thus far been accomplished, 2) develop a short list of preliminary findings from the DC3 observations and analysis, 3) compile a list of potential papers and the paper's lead investigator, 4) determine any gaps in the science analysis, and 5) decide on top case study days and develop collaborative teams to work on these cases.

The list of preliminary findings is organized by the 5 science topics:

- convective transport, scavenging, effect on UTLS transport, and stratospheric-tropospheric exchange (STE),
- lightning and its production of NO_x (= NO + NO_2),
- chemical transformations from anvil to downwind of the storm,
- source characterization including biomass burning, and
- other studies including properties of aerosols, and distribution of halogens.

These 5 topics can be used to propose special sessions at AGU or other conferences. They can also be used as special issues/sections in journals. A keyword will be used to identify the paper as part of the DC3 project.

Preliminary Findings

<u>Convective Transport, Scavenging, Effect on UTLS Transport and STE</u>

- Oil and gas hydrocarbons measurements in the upper troposphere are useful tracers of boundary layer air over the Colorado and Texas-Oklahoma regions
- The 22 June Colorado case provides a means of assessing entrainment into storm core from the free troposphere because the High Park fire biomass-burning (BB) plume was ingested by the storm at 7 km altitude. One finding is that some of the aerosol mass in the BB plume is removed (possibly by scavenging processes) as it is ingested and transported to the anvil when compared to formaldehyde. That is, the ratio of aerosol mass in the anvil outflow to BB plume ingested into the storm is smaller (by ~50%) than the ratio of formaldehyde in the anvil outflow to the BB plume inflow.
- Asymmetric mixing ratios were observed in the across-anvil measurements of the outflow of June 22nd case, indicating that the injection of different sources at different levels (low-level and mid-level) results in outflow that is not well-mixed
- The ingested smoke in the 22 June case may have had an effect on ice concentrations, which increased in the anvil after biomass-burning markers were sampled

- Preliminary estimates for formaldehyde are that 60% of the boundary layer CH_2O is scavenged
- Organosulfates in aerosols were more abundant in the Eastern U.S. compared to the West. The organosulfates were enhanced in convective outflow compared to background upper troposphere.
- Stratosphere signatures are often present abutting convective outflow for both anvil regions and downwind
- Evidence of transport from convective storms into stratosphere
- Both the GV and DC-8 aircraft sampled a biomass-burning plume, located in the lower stratosphere (spanning 500 km and 200 m thick) and estimated to originate in northern Nepal. Initial analysis suggests that chemical aging of this BB plume differs from most BB plumes found in the troposphere.

Lightning and Its Production of NO_x

- Evidence of enhancements in NO_x will yield better estimates of lightning-produced NO_x when analyzed and simulated in combination with radar and LMA data
- There appear to be fundamental differences in the characteristics of lightning in and near updrafts and those further away from the updrafts
- Alabama results suggest large uncertainties in relating absolute ice mass to absolute flash rate
- The internal charge structure of most storms in Colorado depart from the ordinary tripole configuration indicating these Colorado storms are anomalous charge structured storms, while in Alabama most storms are normal polarity, and Oklahoma storms have both normal and anomalous cases. Aircraft sampled both normal and anomalous polarity storms.
- Storms found near the Colorado wildfires had an anomalous charge structure while nearby storms not subject to the biomass-burning emissions contained normal polarity charge layers

Chemical Transformations of Convective Outflow from Anvil to Downwind of the Storm

- 1-2 ppbv/hr net ozone production rates in anvil of the 21 June dissipating MCS case based on HO_x chemistry
- June 21st dissipating MCS case is an outstanding case to look at the anvil and downwind chemistry of trace gases and aerosols. Preliminary O_3 mixing ratios increase by 20 ppbv during the day as the MCS dissipates. This is likely a combination of chemical production and mixing.

- Comparison of the May 30 downwind flight with the May 29 fresh convective outflow shows that NO_y repartitions from being composed mostly of NO_x to fairly equal contributions of peroxy nitrates, HNO_3, and NO_x. Preliminary modeling of hydrocarbons shows a limited effect of dilution during transport downwind of the storm.
- New particle formation was evident in both the June 21st dissipating MCS case and the downwind flights (20-24 hours after active convection). Growth of particles also occurred yielding sizes that are likely CCN active and contribute to AOD

Source Characterization Including Biomass Burning (BB) Studies

- Substantial regional background of BB and BC aerosol in FT (esp. 2-6 km) with mid-level injection of BB smoke
- BB mixed with dust (evident from in situ and lidar)
- Evidence of particulate mercury in BB plumes
- Entrainment and convective transport of smoke on June 22nd
- Observation of size dependent wet removal of BC in the UT
- Aging of BB particles showed a) evidence for restructuring of soot when humidified (growth factor < 1), b) rapid aging based on the O/C ratio, c) the SO_4^{2-}, NH_4^+ fraction increases with tracer oxidation, and d) the single-scatter albedo increase with age.
- DC3 saw significant and widespread influence of oil and gas activities that dominated VOC alkane distributions
- Ammonium nitrate was enhanced over feedlots

Other Studies Including Aerosol Properties and Halogen Distributions

- Brown Carbon is an increasing fraction of total light absorption at higher altitudes
- HCl over the continent is pretty much everywhere in the boundary layer at a few tens of pptv levels
- Continental short-lived bromine compounds may be a source of bromine to the lower stratosphere.
- Particulate mercury correlated with halogens

Primary Cases

From the over 20 research flights, 10 aircraft cases were highlighted because of their interesting situations and fairly complete complements of data. To work toward the goal of having the DC3 science team collaborate together on specific cases, 5 cases have been selected for primary analysis efforts. These cases are listed here.

Primary Cases

29-30 May	Oklahoma storm and downwind flights
06-07 June	Colorado storm and downwind flights
21 May	Alabama storm
22 June	Colorado storm with mid-level smoke plume
21 June	dissipating MCS chemical aging study

Other highlighted cases

19 May	Oklahoma storm
30 May	DC-8 track over and profile behind MCS
16 June	Oklahoma storm (has downwind flight next day)
02 June	Colorado storm (DC-8 only)
11 June	MCS inflow and outflow properties, biomass burning aerosol from High Park and New Mexico fires, DC-8 – Falcon intercomparison flight
28 June	Colorado storm

Science Issues Identified Not Yet Being Worked On

Identifying science issues that are not currently being addressed was one of the goals of the science team meeting. Specific science questions were suggested as good research topics that are not currently being addressed, although a couple of questions had people volunteer to take on that topic (their name appears after the question). These questions mostly focus on transport, scavenging, lightning, lightning production of NO_x, and aerosol-storm interactions.

- How does the DC3 time period (May-June 2012) compare with climatology? Lightning, storm characteristics, storm frequency, chemical and aerosol environment, biomass burning, Asian transport – M. Barth

Convective Transport, Scavenging, and STE

- Is photochemistry during convective transport important? – E. Apel
- Need to investigate wide array of Henry's Law coefficients – H. Arkinson

Lightning and Its Production of NO_x

- Characterize uncertainties associated with the lightning-NO_x (LNO_x) production calculation
- Conduct analyses of LMA (Lightning Mapping Array) versus radar data to evaluate likely horizontal region of the LNO_x source
- Evaluate the vertical distribution of LNO_x with different storm types

- Determine LNO_x production per flash length
- Does one LNO_x parameterization fit all storms globally or regionally?
- Identify characteristics of anomalous storms
- Estimate LNO_x production in "anomalous" storms versus "normal" storms
- Do aerosols influence lightning flash rates and its production of NO_x
- Using LMA and radar data, assess how representative the storm sampled by the aircraft is for that region

<u>Aerosol-Storm Interactions</u>

- Are cloud-aerosol interactions evident based on the observations?
- Do direct (radiative) effects of aerosols affect storm dynamics?

Analysis Methods Issues To Be Addressed

Discussion during the science team meeting included questions about methods used. While the aerosol group suggested that each instrument PI should determine if they have artifacts when in cloud, other questions need someone to ensure the questions are addressed. Here are some methods that need to be addressed in order for consistent analysis by the DC3 science team.

- Marker of when we intended the aircraft to be in the inflow region of the storm – J. Dibb and M. Barth
- What portion of the vertical distribution is ingested into storm?
- Trace gas sampling in clouds – are there artifacts in data?
- Aerosol sampling in clouds – are there artifacts in data?
- Nomenclature on lightning polarity and storm types. Instead of "normal" and "inverted" use "normal" and "anomalous"
- Currently the LNO_x analyses emphasize the Oklahoma storms. The Colorado and Alabama storms also need to be investigated.
- Conduct consistent methodology for assessing lightning – storm parameter relationships
- Backward and forward trajectories for aircraft flight levels are needed for inflow flight legs and downwind flights