The Effects of Deep Convection on Atmospheric Chemistry

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Effects of Deep Convection

Convection over “Polluted Regions”

- Venting of boundary layer pollution
- Transport of NO\textsubscript{x}, NMHCs, CO, and HO\textsubscript{x} precursors to the upper troposphere (UT) and sometimes to the lower stratosphere (LS), where chemical lifetimes are longer and wind speeds greater
- Downward transport of cleaner air to PBL
- Transported pollutants allow efficient ozone production in UT, resulting in enhanced UT ozone over broad regions

\[
\begin{align*}
\text{NO} + \text{HO}_2 & \rightarrow \text{NO}_2 + \text{OH} \\
\text{NO}_2 + \text{hv} & \rightarrow \text{NO} + \text{O}^* \\
\text{O}_2 + \text{O}^* + \text{M} & \rightarrow \text{O}_3 + \text{M}
\end{align*}
\]

- Increased potential for intercontinental transport
- Enhanced radiative forcing by ozone
Effects of Deep Convection

Convection over “Clean” Regions
- In remote regions low values of PBL $O_3$ and $NO_x$ are transported to the upper troposphere
- Potential for decreased ozone production in UT
- Larger values of these species transported downward to PBL where they can more readily be destroyed

Convection over all Regions
- Lightning production of NO (much more over land)
- Perturbation of photolysis rates
- Effective wet scavenging of soluble species
- Nucleation of particles in convective outflow
Observations and Models

- Combination of observations and model simulations is a powerful tool to better understand physical and chemical processes in thunderstorms.

- Convection/chemistry field experiments (the last 25 years):
  
  PRESTORM – OK, KS 1985  
  ABLE-2A – Brazil 1985  
  ABLE-2B – Brazil 1987  
  STEP – Australia 1987  
  NDTE – North Dakota 1989  
  TRACE-A – Brazil 1992  
  STERAO – Colorado 1996  
  EULINOX – Germany 1998  
  CRYSTAL-FACE – Florida 2002  
  TROCCINOX – Brazil 2005  
  SCOUT-O3/ACTIVE – Australia 2005  
  AMMA – West Africa 2006  
  TC4 – Costa Rica 2007
Observations and Models

• **Cloud-resolved chemistry models:**
  - Storm simulation with Goddard Cumulus Ensemble (GCE) Model or cloud-resolved MM5 drives offline transport and chemistry model with lightning NO production.
  - Cloud-resolved WRF-Chem (online transport/chemistry) now being used.

• **Regional chemistry models:**
  - Driven by WRF with parameterized convection (examples: offline CMAQ; on-line WRF-Chem). Lightning schemes being developed.

• **Global chemical transport models:**
  - Offline global chemistry and transport in UMD-CTM and NASA/GMI CTM driven by GEOS-DAS from Goddard GMAO. Lightning parameterized with model convective mass fluxes and constrained with satellite observations.

  - Online chemistry and transport in GEOS-5 Chemistry and Climate Model, allowing chemistry to feedback to meteorology through perturbations to radiative fluxes. Physically-based lightning scheme under development.
Midlatitude Convection

Examples from field experiments and models
Aircraft Measurements of Trace Gas Redistribution in Oklahoma PRESTORM June 15, 1985 MCC

CO

O₃

Dickerson et al., 1987, Science
Pickering et al., 1990
Mid – upper trop. ozone production enhanced by factor of 4  

Pickering et al., 1990
Kansas-Oklahoma Squall Line Cell

PRE-STORM June 10–11th
CO (110 ppbv) isosurface at 4 hours

z axis: each tick is 2.5km
x and y axis: grid number (each grid 1.5km)

Pickering et al., 1992
3-D GCE model simulation of one squall line cell
Central United States

Thompson et al., 1994

Uses cloud-resolved model transport statistics and ISCCP convective cloud climatology
North Dakota Thunderstorm Experiment
CO and O₃ Tracer Simulation for June 28, 1989 NDTP storm

CO – color scale; O₃ – isolines
(a) base simulation; (b) moist boundary condition simulation

Note downward ozone transport near rear anvil

Stenchikov et al. (1996)
CO and $O_3$ Tracers Along Anvil Passes for July 10, 1996 STERAO storm

Note enhanced ozone at southwest (upwind) edge of anvil

Figure 11. Citation CO and $O_3$ measurements for anvil passes close to the southeasternmost convective cell (leg 2, 10 km downwind, 11.6 km msl) and downwind (leg 5, 50 km downwind, 11.2 km msl), along with analogous tracks taken through the simulation. The plot tracks are from the southwest (left) to the northeast (right).

Skamarock et al. (2000)
Enhanced UT HO$_x$ Production

- Jaeglé et al. (1997) and Prather and Jacob (1997) noted that deep convection is effective in transporting HO$_x$ precursors to the upper troposphere.
- Water vapor, acetone, methylhydroperoxide, and formaldehyde shown to be important as HO$_x$ precursors.
- Enhanced HO$_x$ leads to enhanced O$_3$ production
Fried et al. (2008) INTEX-A obs showed 46% of samples had HCHO enhanced above background, and 30% of these samples resulted from direct convective injection to the UT

Ott et al. (2006)
NO$_x$/HNO$_3$ ratio used as a chemical clock to determine time since air was influenced by convection

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>7.5-8.5 km,</td>
<td>$f_{&lt;2\text{ Days}} = 0.43$</td>
</tr>
<tr>
<td>8.5-9.5 km,</td>
<td>$f_{&lt;2\text{ Days}} = 0.56$</td>
</tr>
<tr>
<td>9.5-10.5 km,</td>
<td>$f_{&lt;2\text{ Days}} = 0.69$</td>
</tr>
<tr>
<td>10.5-11.5 km,</td>
<td>$f_{&lt;2\text{ Days}} = 0.43$</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>0.54</strong></td>
</tr>
</tbody>
</table>

Bertram et al., 2007
Ozone Export from North America – Early Summer

Martini et al., 2010
Net Downward LW Radiative Flux Perturbations at the Tropopause Due to Tropospheric Ozone

Martini et al., 2010
Relative Importance of Anthropogenic and Lightning Emissions on Radiative Forcing by Ozone

Early Summer 2004

$\frac{RF_{LNOx}}{RF_{ANTHRO}}$

Martini et al., 2010
Surface air quality effects of deep convection

On the third day of a high O₃ episode (June 24-26 1998), a line of thunderstorms passed just north of the Fair Hill, MD monitoring station.

The effect of thunderstorms on surface O₃ can be remarkable even at periphery of storm.
Tropical Convection
Tropical squall line over Amazon Basin

Dry Season

Pickering et al, 1991

Arrows indicate major transport paths

Columns of numbers indicate percentage of air at these locations that is cloud outflow based on trajectory analysis

CO redistribution from biomass burning plume
ABLE-2B April 26, 1987 Brazil Squall Line

Arrows indicate major transport pathways

Wet Season

Scala et al., 1990
More vigorous vertical transport of tracers with strong theta-e min.
PRESTORM
June 10-11

26% of BL tracer reaches 10-12 km

Weak vertical transport to upper troposphere due to midlevel overturning

ABLE 2B
April 26

7% of BL tracer reaches 12-16 km; 6% reaches 8-12 km

Fig. 6. Fractional redistribution of tracer mass initially in lowest kilometer to other indicated layers for (a) Kansas-Oklahoma PRESTORM event (June 10–11, 1985) and (b) April 26, 1987, Amazonian ABLE 2B event.

Pickering et al., 1992
Convective Transport of Biomass Burning Emissions over Brazil

Kain-Fritsch Convective Parameterization

MM5 Simulation of System Sampled on GTE/TRACE-A

Positive definite scheme, grid+subgrid transport

Comparison of model with DC-8 observations along sampling tracks (thin lines)

Pickering et al., 1996
Ozone Production Downstream of 26-27 Sept 92 Convection Box Model Calculations vs. Observations (9.5-12km)

NASA GTE/TRACE-A

Day 0
DC-8 Flt 7
11.3km
Day 1.1
+10 ppbv

Day 1
+5.6/+8.2

Day 2
+11.8/+16.0

Day 3
+18.0/+22.2

Day 3.3
+26 ppbv

Day 4
+24.0/+27.3

Natal 11-12km
Ozoneonde

Day 5
+29.8/+31.6

Day 6
+35.3/+35.4

Day 7
+40.5/+38.8

Day 8
+45.5/+41.8

Pickering et al., 1996
Convection over Remote Oceans

• Pickering et al. (1993) noted $O_3$ and NO$_y$ minima in UT convective outflow in STEP (near Darwin, Australia) and computed a decrease in $P(O_3)$ due to convection.

• Kley et al. (1996) reported very low ozone measurements near tropopause over the Central Pacific. Resulted from convective transport of very clean marine boundary layer air.
Note ozone minimum at 12 km resulting from convective outflow

Folkins et al., 2002
Low Ozone Events in UT Indicative of Convective Frequency

Increases in frequency of low ozone events in the UT in the mid to late 1990s suggest increased convection

Solomon et al., 2005
Convective Downdrafts Transport Ozone Downward into PBL

Betts et al., 2002
Rondonia, Brazil

Sahu and Lal, 2006
Bay of Bengal
NET EFFECT OF CONVECTION ON TROPOSPHERIC OZONE

• Lelieveld and Crutzen (1994) model calculations indicate that dominant effect of convection is to enhance ozone destruction.

• Lawrence et al. (2003) with better treatment of convection and hydrocarbons found that convection caused an overall net increase of tropospheric ozone.

• Doherty et al. (2005) found that convective overturning of ozone dominates over changes in ozone chemistry. Obtained a decrease in global tropospheric ozone burden with convection. Differences in convective and chemical schemes yield results in contrast to Lawrence et al. (2003).
Convective Mass Flux and Detrainment During AMMA as Computed by Four Models

Averaged over 0 -30 deg. E
Colors – detrainment
White contours – upward convective mass flux

Barret et al., 2010
Physics:

- Cu parameterization:
  Kain-Fritsch scheme (for the outer grid only)

- Cloud microphysics:
  Goddard microphysics 3ice-Graupel

- Radiation:
  New Goddard radiation scheme for both longwave and shortwave

- PBL parameterization:
  Mellor-Yamada-Janjic TKE scheme

- Surface Layer:
  Monin-Obukhov (Janjic)

- Land Surface Model:
  Noah land-surface

Resolutions: 18, 6 and 2 km
Grid size: 391x271, 424x412, 466x466, and 61 vertical layers
$\Delta t = 18$ seconds
Starting time: 00Z 08/06/2006
Initial and Boundary Conditions:
  NCEP/GFS, no data assimilation
WRF-Calculated Radar Reflectivity

COMDBZ (dBz) and 900mb Wind (m/s) at 9h
09206AUG2006

COMDBZ (dBz) and 900mb Wind (m/s) at 20h
20206AUG2006
Evaluation of Parameterized Convective Transport in the Offline NASA Global Modeling Initiative (GMI) Chemistry and Transport Model

GMI CTM driven by GEOS-4 DAS with Zhang and McFarlane convective parameterization

GMI CTM driven by GEOS-5 DAS with Relaxed Arakawa-Schubert convective parameterization

NASA DC-8 data from TC4 flight matched in time and with nearest grid cell in GMI model with deep convection

T. Lyons
Fig. 2. Zonal mean deposition fluxes of $^{210}$Pb in the model contributed by convective precipitation (solid line), large-scale precipitation (dashed line), and dry processes (dotted line). Values are yearly averages.

Balkanski et al. (1993)
July 10, 1996 STERAO storm

HNO3 (ppbv) $t = 6000$ s

Ott et al., 2006
South Pacific Convergence Zone Convection Near Fiji

Pickering et al. (2001)
DC-8 Aircraft Measurements in SPCZ System

PEM TROPICS-B Flight 10 [3.00000 - 3.60000] GMT

Graph showing HNO3 and NOx concentrations over time. The graph indicates a peak in NOx concentration at 11 km altitude in convective outflow.

Pickering et al., 2001
HNO$_3$ simulation for SPCZ convection without wet scavenging (~80 pptv at 11 km)

Comparison with observations (~5-10 pptv) at 11 km within storm suggest ~90-95% removal

Pickering et al., 2001
Lightning NO Production

- How much NO is produced per cloud-to-ground (CG) flash and per intracloud (IC) flash? Or per meter of flash length?
  
  *Varies over two orders of magnitude*

- How are lightning channels distributed throughout a storm?

  *Some indication of bimodal distribution in the vertical*

- How is the NO distributed in the vertical at the end of the storm?

  *Mostly in middle and upper troposphere*
How many flashes occur globally?

Satellite observations indicate ~44 flashes/s

How are the flashes distributed geographically?

At least 75% occur over continents

What is the IC/CG flash number ratio, and how does it vary from storm to storm?

Over continental U.S. annual mean varies from ~1.5 to ~10, with mean ~3

What is the global annual production?

Literature estimates range from 2-20 Tg/yr in the most recent decade, but 2-8 Tg/yr appears most likely
Motivation for Lightning NO Studies

• Production of NO by lightning is an important part of the tropospheric NO$_x$ budget (tropical UT: >50-60%), but it is also the most uncertain component.

• In most of the free troposphere O$_3$ production rates are highly sensitive to NO$_x$ mixing ratios.

• The maximum effectiveness of ozone as a greenhouse gas is in the UT/LS. Ozone is the third most important greenhouse gas.

• Global annual lightning NO production has been estimated to be 2-20 Tg N/yr, but recent observations and modeling have reduced the range to 2-8 Tg N/yr (Schumann and Huntrieser, 2007)

• Lightning observations from surface networks and satellites are being used in conjunction with cloud-resolving and global models in attempts to further reduce this uncertainty.
Requirements for Specifying Lightning NO Production in Global/Regional Chemical Transport and Climate Models

1) NO production per flash (DeCaria et al., 2000; 2005; Ott et al. (2006; 2007; 2010)

2) A method of specifying the effective vertical distribution of lightning NO\textsubscript{x} at the end of a storm (e.g., Pickering et al., 1998; Ott et al., 2010).

3) Flash rates need to be estimated for the times and locations for which parameterized convection is active in the model (e.g., Allen and Pickering, 2002).
Methods of Estimating NO Production Per Flash

• Theoretical estimates (e.g., Price et al., 1997)
  \[6.7 \times 10^{26} \text{ molecules/CG flash} \approx 1100 \text{ moles/flash}\]
  \[6.7 \times 10^{25} \text{ molecules/IC flash} \approx 110 \text{ moles/flash}\]

• Laboratory experiments (e.g., Wang et al., 1998)
  \[6.2 \times 10^{25} \text{ molecules/flash} \approx 103 \text{ moles/flash}\]

• Field experiments – anvil measurements by aircraft of NO from individual flashes and integrated effects (e.g., STERAO-A, EULINOX, CRYSTAL-FACE)

• Cloud-resolved models, lightning parameterizations, anvil measurements (e.g., Pickering et al., 1998; DeCaria et al., 2000; 2005; Ott et al., 2006; 2007; 2010)

• Cloud-resolved models with explicit electrophysics

• Satellite-based NO\textsubscript{2} observations and flash counts (Bucsela et al., 2010)
Cloud-Resolved Model Lightning Placement Parameterization

NO production by lightning injected into the model based on either observed flash rates or flash lengths.

Flash Rate Scheme

• Lightning NO production is calculated using observed CG and IC flash rates over 3-minute periods and specified production of NO per CG and per IC flash.

• NO production is assumed to be proportional to pressure and to the vertical distribution of lightning channel segments which is assumed to be bimodal.

• In each model layer, lightning NO production is distributed uniformly within the 20 dBZ contour.
Similar shape factors used in cloud/chemistry model along with assumption of NO production being proportional to pressure.
Make initial estimate of $P_{CG}$ using Price et al. (1997) equation: 

$$P_{CG} = E_{CG} \cdot P$$

where $E_{CG} = 1.823 \times 10^5 \text{ I}_o \text{ Joules}$

$P = 1 \times 10^{17} \text{ molecules \ NO/Joule}$

$I_o = \text{ peak current from observations}$

Let $P_{IC} = \alpha \cdot P_{CG}$ and test production scenarios with various values of $\alpha$. Compare simulation results with anvil NO$_x$ observations in terms of:

1) mean anvil profile (peak value, shape)
2) probability distributions at specific altitudes
3) anvil column mass
# Simulated Storms

<table>
<thead>
<tr>
<th>Storm</th>
<th>Location</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>STERAO - 7/12/96</td>
<td>NE Colorado</td>
<td>DeCaria et al. (2000, JGR; 2005, JGR)</td>
</tr>
<tr>
<td>STERAO – 7/10/96</td>
<td>NE Colorado</td>
<td>Ott et al. (2010, JGR)</td>
</tr>
<tr>
<td>EULINOX – 7/21/98</td>
<td>Bavaria</td>
<td>Ott et al. (2007, JGR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fehr et al. (2004, JGR)</td>
</tr>
<tr>
<td>CRYSTAL-FACE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/29/02*</td>
<td>S. Florida</td>
<td>Ott et al. (2006; 2010, JGR)</td>
</tr>
<tr>
<td>7/16/02**</td>
<td>S. Florida</td>
<td></td>
</tr>
</tbody>
</table>

* Run using MM5
** Run using ARPS
Model-simulated vs. Measured NOx Profiles For Four Lightning NO Production Scenarios
DeCaria et al. (2005)
From MM5 simulation run at 2-km horiz. res.

Radar Reflectivity (dbz) 1430 - 7/29/02 $Z = 1$ km

Total of 5651 CG flashes over life of storm

Output from UMD CSCTM driven by cloud-resolved MM5 simulation

CRystal-FACE
South Florida
July 29, 2002
CRYSTAL-FACE

Mean NOx 7/29

Model

Ridley NO obs. + PSS NO₂
Ridley NO obs. + PSS NO₂ & j(NO₂) x 2

IC/CG = 5
P_{CG} = 590 moles/fl
P_{IC} = 354 moles/fl
Lightning NO Production Scenarios

Summary of Five Midlatitude and Subtropical Storms

Means: 500 moles/flash
0.94 ratio
For global rate of 44 flashes/sec, this implies ~9 Tg N/yr

Ott et al., 2010, JGR
Vertical Distribution of Lightning NO$_x$

- Analysis performed by Pickering et al. (1998, JGR) using 2-D cloud/transport model with simple lightning parameterization. These profiles have been used in many regional/global CTMs.

- New calculations of vertical profiles using output from 3-D CSCTM containing a more realistic lightning parameterization have been performed for five midlatitude and subtropical events (Ott et al., 2010). Now used in NASA GMI CTM.
NO Production in Midlatitude, Subtropical, and Tropical Flashes

• Cloud-resolved modeling of observed midlatitude and subtropical storms yields an average of ~500 moles NO per flash (both CG and IC).

• This result is supported for North America by GEOS-Chem model simulations by Hudman et al. (2007, *JGR*) for the ICARTT period of 2004 evaluated with NASA DC-8 data and by Jourdain et al. (2008, *ACP D*) evaluated with TES O₃ data.

• Huntrieser et al. (2008, *ACP*) has hypothesized that on average a tropical flash may produce less NO than a flash in a midlatitude or subtropical storm. This may be due to lesser vertical wind shear in the tropics, leading to shorter flash channel lengths.

• Recent tropical experiments will aid in obtaining improved estimates of LNOₓ production per flash

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Location</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>TROCCINOX</td>
<td>São Paulo State, Brazil</td>
<td>Feb. 2005</td>
</tr>
<tr>
<td>AMMA</td>
<td>West Africa</td>
<td>Aug. 2006</td>
</tr>
<tr>
<td>TC⁴</td>
<td>Costa Rica, Panama</td>
<td>July – Aug. 2007</td>
</tr>
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</table>

TC⁴ = Tropical Composition, Cloud and Climate Coupling
Hector Simulations

- Cloud-resolved chemistry simulation of “Hector” storm observed over Tiwi Islands near Darwin, Australia during the SCOUT-O3 and ACTIVE field experiments. Goal: Estimate LNOx production per flash.

- “Hector” thunderstorm is simulated with the WRF-AqChem cloud-resolving model (Barth et al., 2007) at 1-km horizontal resolution, and cloud simulation is evaluated with radar, satellite, and aircraft data.

- Trace gases are transported and chemical reactions are computed on-line in the cloud simulation. Same lightning scheme as in GCE/CSCTM.

- How does NO prod. per flash in Hector storm compare with that in higher latitude storms? Run simulation with assumption of 500 moles/flash.

- Work in progress!
Hector WRF-AqChem simulation with Lightning NOx

K. Cummings
Aura/OMI

Ozone Monitoring Instrument

Wavelength range: 270 – 500 nm

Sun-synchronous polar orbit; Equator crossing at 1:30 PM LT

2600-km wide swath; horiz. res. 13 x 24 km at nadir

Global coverage every day

O$_3$, NO$_2$, SO$_2$, HCHO, aerosol, BrO, OClO
The vertical column of NO\textsubscript{x} due to lightning is:

\[
V_{\text{LNO}_x} = \left[ \frac{S - (V_S - V_{tCorr}) \cdot A_S - V_{tBG} \cdot A_{tBG}}{A_{tL}} \right]
\]

**Analysis of LNO\textsubscript{x} from OMI**

**VS** = OMI-derived stratospheric NO\textsubscript{2} vertical column ("clean" region data with wave-2 pattern imposed)

**V\textsubscript{tCorr}** = GMI model correction (about ~10%) of V\textsubscript{S} for tropospheric contamination

**V\textsubscript{tBG}** = GMI model tropospheric background in region of lightning measurement
Analysis of Results from TC4 cases

<table>
<thead>
<tr>
<th>Day</th>
<th>LNO$_x$ (moles/flash)</th>
<th>300 hPa NCEP wind (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/31</td>
<td>246 ± 287</td>
<td>8</td>
</tr>
<tr>
<td>8/5</td>
<td>227 ± 223</td>
<td>14</td>
</tr>
<tr>
<td>7/17</td>
<td>87 ± 252</td>
<td>4</td>
</tr>
<tr>
<td>7/21</td>
<td>135 ± 114</td>
<td>2</td>
</tr>
</tbody>
</table>

Smaller LNO$_x$ production per flash is associated with weaker upper tropospheric wind speeds in these example cases.

Perhaps lesser flash length associated with weaker anvil-level winds?
Case 1: Production Per Flash

Summing LNOx over the box and adjusting for 2 – 4 day chemical lifetime (7.2% decay in this case) we obtain:

\[ 8452 \pm 4858 \text{ kmoles} \]

Dividing by vertically mass-weighted flash count of 15,829 flashes yields:

\[ 534 \pm 351 \text{ moles LNOx per flash} \]
Vertical Distribution of Lightning NO$_x$

- Analysis performed by Pickering et al. (1998, JGR) using 2-D cloud/transport model with simple lightning parameterization. These profiles have been used in many regional/global CTMs.

- New calculations of vertical profiles using output from 3-D CSCTM containing a more realistic lightning parameterization have been performed for five midlatitude and subtropical events (Ott et al., 2010). Now used in NASA GMI CTM.

- Direct use of vertical profiles derived from 3-D Lightning Mapping Array data being used in CMAQ and WRF-Chem regional models.
Summary

• Convection is an effective mechanism for transporting pollution from the boundary layer to the upper troposphere where it can more readily contribute to intercontinental transport.

• As a result, ozone production is enhanced, contributing to enhanced radiative forcing.

• Ozone destroyed as a result of remote marine convection.

• Net effect of convection on tropospheric O$_3$ remains uncertain.

• Lightning is a major contributor to the upper tropospheric NO$_x$ budget and to ozone production.

• On a per flash basis, IC flashes are nearly as productive of NO as CG flashes. For five simulated storms, estimates of mean NO production per flash vary by a factor of two.

• Approximately 500 moles NO produced per flash on average over the five midlatitude and subtropical storms $\Rightarrow$ $\sim$9 Tg N/yr. Simulations of tropical events in progress.
Future Research

- Lightning NO - need more field projects with comprehensive data collection (radar, 3-D lightning flash mapping, chemistry)
- Ozone measurements downstream of convection to evaluate model estimates of ozone production
- Wet scavenging - better 3-D precipitation fields needed for use in CTMs; measurements of soluble species in cloud-scale field experiments
- Aerosol effects on convective strength and lightning
- Studies of new particle production in convective outflows
- Evaluation and improvement of convective parameterizations in regional and global models
Deep Convective Clouds and Chemistry – DC3

May/June 2012
Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS)

Measurement Objectives:

1) Characterize the chemical gradients associated with the dynamical background of the Asian Monsoon Anticyclone.
2) Characterize the chemical composition of convective outflow and microphysical properties of anvil cirrus.
3) Characterize the chemical and meteorological impact of biomass burning plumes.

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Acknowledgements

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