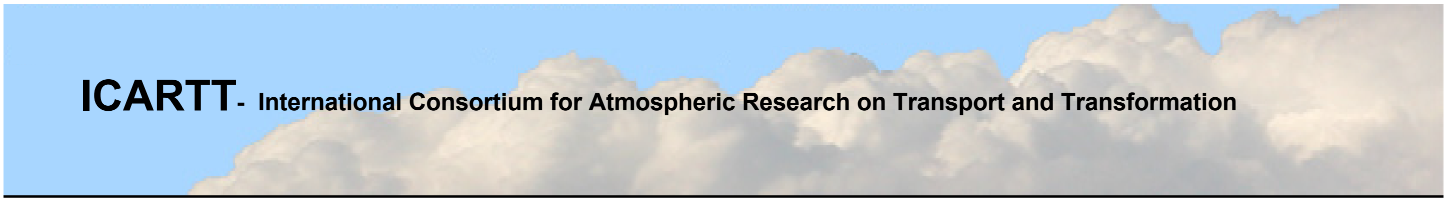
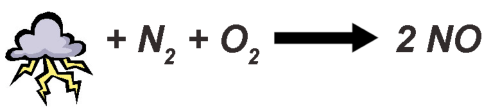
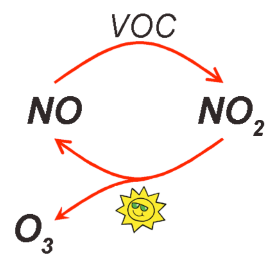


A Major Lightning Influence on the U.S. Atmosphere

The most commonly noted consequences of lightning include: widespread power outages, lightning initiated forest fires and direct damage to personal property. However, lightning also has a pronounced effect on the chemical composition of the atmosphere. Nitrogen oxides ($NO_x \equiv NO + NO_2$), a precursor to ozone (O_3), are produced in high temperature lightning channels (E1). Ozone production in the Upper Troposphere (UT) is directly coupled to lightning formed NO_x (E2) injected at the outflow of cloud towers. The resulting O_3 affects climate through its greenhouse warming potential. Lightning is widespread over the continental United States during the late spring and summer months adding significantly to the global NO_x burden. Research flights conducted during the ICARTT experiment, during the summer of 2004, provided a unique opportunity to test the extent to which lightning affects the magnitude and distribution of NO_x and its resulting effects on ozone.



(E1)



(E2)

Above Left (E1) NO is produced in high temperature lightning channels from molecular N_2 and O_2 in an analogous mechanism to that occurring during fossil fuel combustion. ***Above Right*** (E2) Ozone is a byproduct formed during the cycling of NO and NO_2 in the presence of Volatile Organic Compounds (VOC) and sunlight.

What did we do during ICARTT?

Above UC Berkeley LIF instrument aboard the NASA DC-8 during the INTEX-NA campaign (Summer 2004).

- Measured the concentration of NO_2, in parallel with a large suite of other trace gas and aerosols species, aboard the NASA DC-8 as part of the INTEX-NA program.

- NO_2 was measured directly by Laser Induced Fluorescence (LIF), a technique that has been proven to be specific, sensitive and accurate.

- Measurements of NO_2 were made at altitudes ranging from 0-12.5 km in: i.) remote marine environments, ii.) continental air masses that were heavily influenced by recent lightning activity, and iii.) regions that had been influenced by convection several days prior to sampling.

For more information contact:

Ronald C. Cohen [rccohen@berkeley.edu] or Timothy H. Bertram [tbertram@berkeley.edu]

What did we learn?

- Significant enhancements in NO_2 concentrations were observed at high altitude (>8 km) over the continental US during the summer as compared with similar measurements made over the remote pacific and over the continental US during the following winter.

- High altitude enhancements are strongly correlated with regions of heavy convection and lightning activity.

- The magnitude of lightning NO_x emissions in the current generation of global atmospheric models (e.g. GEOS-CHEM) needed to be increased by a factor of four in order to account for the observed enhancements in NO_2 at high altitude.

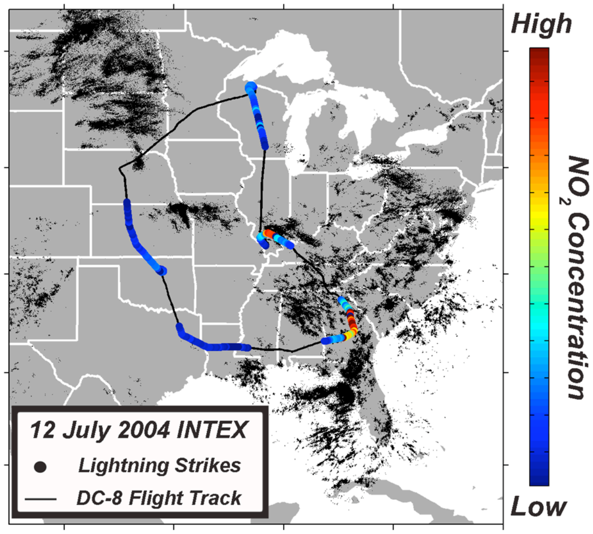


Figure 1 (above right) INTEX-NA research flight on 12 July 2004. Air masses influenced by heavy lightning were sampled frequently during this flight. The DC-8 flight track is shown with a solid black line and the daily lightning strikes are indicated with black dots. NO_2 concentrations (above 8 km) are shown in color, where red indicates high NO_2 and blue indicates low NO_2. High NO_2 concentrations were strongly correlated with regions of heavy lightning influence (e.g. south-east U.S.).

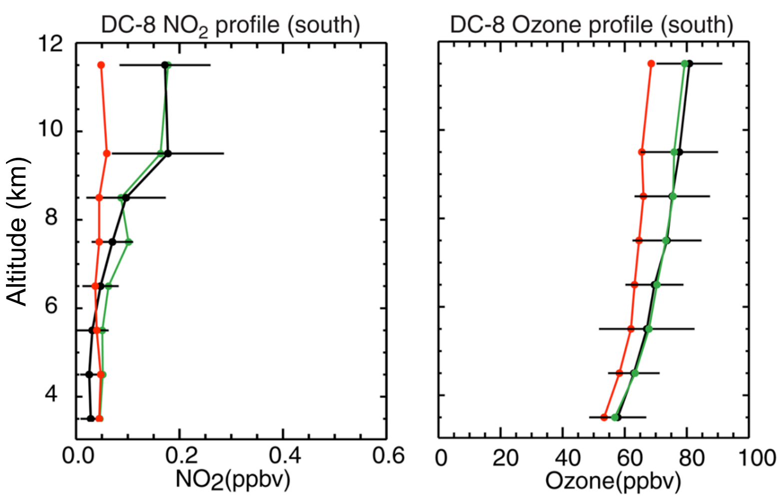


Figure 2 (left) A **standard simulation (red)** and an **improved simulation (green)** of NO_2 and O_3 in a global model of the atmosphere (GEOS-CHEM) and the **observed INTEX-NA (black)** mean vertical profiles of NO_2 (left panel) and O_3 (right panel) for INTEX-NA over the southern United States. The improved simulation, which accounts for increased lightning NO_x, brings the modeled and observed NO_x and O_3 into better agreement. [GEOS-CHEM figures provided by R.C. Hudman and D.J. Jacob]

What does it mean?

- Lightning NO_x often drives ozone production in the upper troposphere, over continental regions during the summer, where NO_x emissions from combustion sources are small.

- High altitude transport of ozone and its precursors on inter-continental scales is enhanced by the magnitude and broad distribution of lightning generated NO_x.

- The frequency of lightning is likely to be increased by climate change, suggesting an important positive climatic feedback loop through enhanced UT ozone, which has a greenhouse warming potential 1/3 as large as CO_2.

The multi-agency ICARTT <http://www.al.noaa.gov/ICARTT/> was formed to study the sources, sinks, chemical transformations and transport of ozone, aerosols and their precursors to and over the North Atlantic Ocean. ICARTT Fact Sheets are designed to present important new science results and findings of high societal relevance to technical non-experts in the community and have been reviewed by an internal committee of peers.