Assessing Convective Influence by Utilizing Cloud to Ground Lightning Data and High Resolution Kinematic Trajectories

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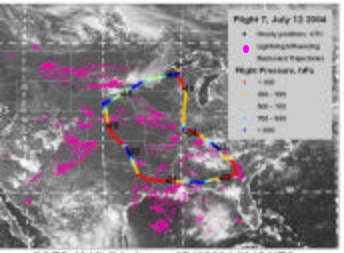
Goals

- Quantify the convective influence of parcels sampled during INTEX-A by using National Lightning Detection Network cloud to ground flash counts as a convection indicator
- Perform "lightning tracing" along backward air trajectories created by a mesoscale meteorological model, expanding upon the work of **Jeker et al., JGR, 2000**
- Construct a post-convective vertical profile of lightning NOx from INTEX-A observations



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Case Study 12 July 2004

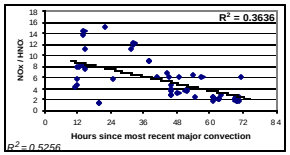
- Diurnal heating generated afternoon thunderstorms across the Midwest and Southeast for several days prior to the flight
- A large high pressure system covered the Southeast, producing stagnation and clockwise wraparound circulation
- Strong cold front with associated thunderstorms moved through the northern Great Plains

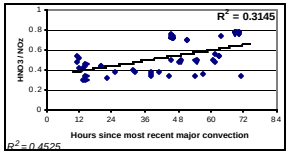
Methodology

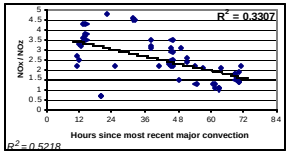
- This initial analysis was performed on Flight 7 (lower left) since it was influenced by widespread deep convection on several previous days
- Back trajectories from the flight were made using output from the Rapid Update Cycle (RUC) model which has spatial and temporal resolutions of 20 km and 3 hours, respectively
- For each hour back along a trajectory, a flash is said to have influenced that trajectory if it fell within a spatial threshold of the trajectory up to an hour before or half an hour after trajectory arrival
- The spatial threshold was increased 2 km every hour back from the flight to account for increasing trajectory uncertainty with time
- As a further precaution against trajectory uncertainties, only those initialized along level flight were considered for analysis
- To account for mixing processes, both the chemical data and the time since convection were converted into 3 min running averages
- The most recent major convection was defined as the first time a trajectory encountered a flash rate of 0.5 flashes/min
- Only points with measurements of all relevant NOy species (NO, NO_2, HNO_3, PAN) were analyzed
- Low NOy signals (< 1000 ppt) from 3 mid-level flight legs (300 - 700 hPa) complicated comparison between them and 4 higher altitude segments, so only the high level legs were examined
- Finally, 8 high altitude points with an NOy signal in the lowest quartile for that altitude range (1269 ppt) were deleted as false hits, leaving 48 points out of 541 to compare convective influence with the chemical data

Convective Age

- Convectively fresh parcels, ones that have recently encountered convection, have a higher ratio of reactive NOx to NOz (HNO_3 and PAN) than do older encounters
- The change in the ratio of NOx to HNO3 is more noticeable between fresh and stale parcels than is the change in the NOx to NOz ratio
- HNO_3 is a more significant component of a stale parcels NOz than a fresh parcel's NOz
- Some grouping of points is noticeable, but there is indication of multiple convective origins along the 4 flight legs







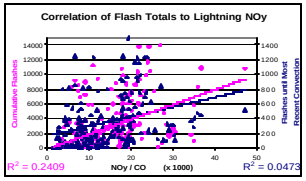
- The resulting correlations from the 48 points are shown in bold on the upper right of the above charts
- Removal of the 5 most significant outliers (not shown) generates the correlations in italics on the lower left of the above charts

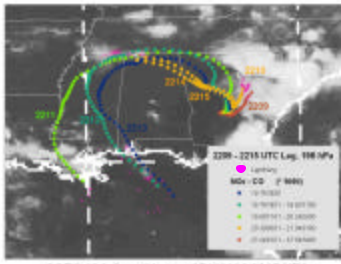
Detailed Structure

- Spatial analyses (right) were made to understand the observed high NOy variability
- Chemistry indicated similar NOy history for the beginning and end of the 2209–2215 UTC leg, but a different origin for the middle
- Results from lightning tracing corroborate different convective origins for this flight leg
- Flight minutes 2211-2213 were influenced by marine convection ~ 3 days earlier, while the preceding and following flight minutes were influenced by more intense continental convection only 24 hours before

NOx Sources

- CO was used as a correction factor (after **Pickering et al., JGR 1996**) to distinguish between convectively lofted boundary layer NOx and lightning generated species
- The number of flashes influencing a trajectory was plotted against the observed NOy to CO ratio (below)
- To determine the utility of cumulative lightning tracing along the entire trajectory versus ending the trajectory at the most recent convection, both analyses were performed
- For all tested subsets of the data, NOy : CO was more strongly correlated with the record of cumulative lightning influence than with the total flashes until the most recent lightning event





GOES 12 Infrared Image 07112004 2245 UTC
(valid for Northern and Eastern lightning)

Summary

- By using high resolution trajectories to perform lightning tracing, a procedure has been crafted to analyze the convective influences on INTEX-A observations
- Tested on the chemical data from flight 7, this method provided results which seem reasonable statistically and theoretically
- The calculated age since convection agrees with expected trends in the temporal evolution of NOx products
- It is important to note that assessing a parcels cumulative lightning influence is more advantageous in potential lightning NOx calculations
- When this model is applied to the full INTEX-A dataset, it will optimally allow the development of a post-convective vertical lightning NOx profile
- Potential offshoots of this research include addressing NO per flash production estimates, comparing the usefulness of lightning with other convection indicators, and quantifying trajectory uncertainties with chemical observations of NOy