# Large-scale Impact of Lightning NOx on the Upper Tropospheric Composition Over the U.S.

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## HYPOTHESIS

Thunderstorms developing over the Rockies and High Plains and moving east should increase upper tropospheric NOx over the eastern United States compared to upper tropospheric NOx over the western United States.

## METHOD

Use summer 2008 data from the Stratosphere-Troposphere Analyses of Regional Transport 2008 (START-08), parse out western US data and compare it with data collected during the Deep Convetion, Clouds and Chemistry ($DC^3$) Experiment.
Limit sampling bias by removing all direct storm outflow measurements.

Analyze for NO only since no $NO_2$ data (or J-values) were measured during START-08.

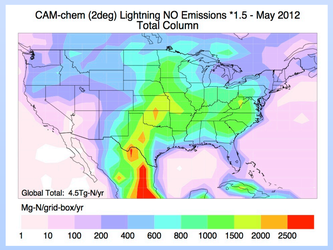
## MODEL DESCRIPTION

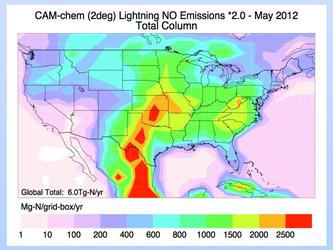
CAM-chem – Community Atmosphere Model with Chemistry, component of NCAR CESM, MOZART-4 troposphericchemistry mechanism.

Lightning NO emissions: Parameterization based on cloud height, Cloud-to-Ground and Inter-cloud flash rates equal. Arbitrary scale factor to get desired global annual total.

Specified dynamics from GEOS-5, horizontal resolution 1.9°x2.5°.

Two simulations with different global scale factors




## Campaigns:

Deep Convection, Clouds and Chemistry *(2012)*
Base: Salina, KS
22 flights between 5/18 and 6/30/2012
Western High Plains to Eastern US

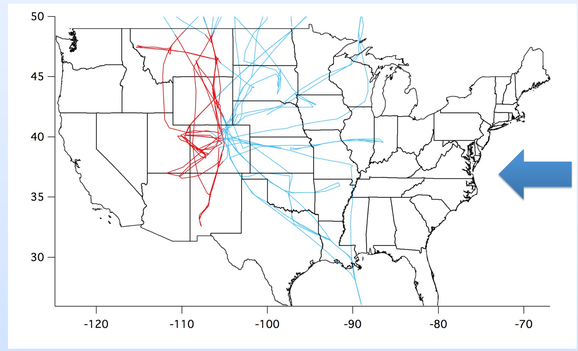
Stratosphere-Troposphere Analyses of Regional Transport *(2008)*
Base: Broomfield, CO
18 flights between 4/18 and 6/27/2008
Central Rockies and West of Rockies flights selected

NO data* selected from a a total of 26 NCAR/NSF GV flights
Altitude range 30-40 kft (main T-storm outflow and aircraft traffic)
West of 110W (START-08) and East of 100W (DC3)
Targeted outflow flight segments excluded
(*$NO_2$ was not measured during START-08)

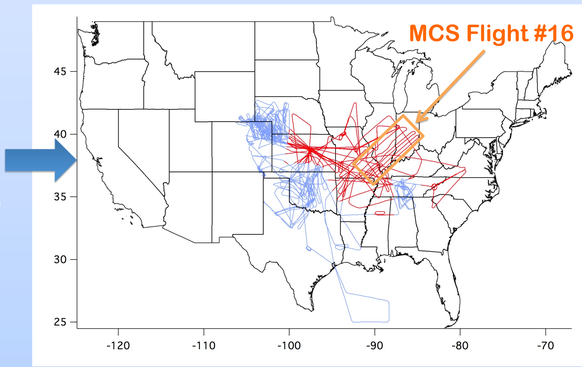
Photo by Steven Buczkowski

## FINDINGS

- The measurements show a factor of ~4 (or more than 300 pptv) enhancement of NO over the eastern US.
- Inclusion of the MCS flight made no significant difference (as expected).
- The model calculated NO values for the western US are close to the observations.
- The model under-predicts NO enhancement by more than a factor of two but there may still be some sampling bias (for example we did not fly on calm weather days with no storms).
- Since global models cannot reproduce single storms and the fine structure observed in aircraft measurements, average comparisons such as this are needed for evaluating lightning emissions in models.
- Future work will include evaluation of the vertical distribution of lightning emissions in the model.




START-08 (June 2008)
Red tracks mark flight data used here.
Further restrictions:
30-40 kft, $O_3$ < 100 ppb




$DC^3$ (May/June 2012)
Red tracks mark flight data used here.
Further restrictions:
30-40 kft, $O_3$ < 100 ppb,
Statistics for 2 sets of data (with and without the MCS flight #16)

## COMPARISON OF MODEL RESULTS WITH OBSERVATIONS

**CAM-chem:**
**Averaged over 30-40 kft altitude, 18-21Z, 35-48N, filtered for O3 < 100 ppb**
**Western US: 245-255E, June 1-15, 2012**
**Eastern US: 260-280E, May 16-31, 2012**

| | Observations Mean (Median) | CAM-chem – 4.5Tg Mean (Median) | CAM-chem – 6.0Tg Mean (Median) |
|---|---|---|---|
| West - NO | 76 (62) ppt | 61 (57) ppt | 67 (62) ppt |
| - NOx | | 83 (78) ppt | 90 (83) ppt |
| - O3 | 67.7 (68.4) ppb | 86 (87) ppb | 87 (88) ppb |
| East - NO | 404 (341) ppt<br>w/o MCS: 376 (270) ppt | 109 (104) ppt | 119 (115) ppt |
| - NOx | | 146 (139) ppt | 158 (151) ppt |
| - O3 | 77.9 (76.3) ppb<br>w/o MCS: 81.3 (81.9) ppb | 89 (91) ppb | 90 (92) ppb |



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