Impact of lightning NO emissions on tropospheric photochemistry

Kenneth E. Pickering¹, Dale J. Allen², and Megan Damon³

¹ Atmospheric Chem and Dynamics, NASA-GSFC
² Dept. of Atmospheric and Oceanic Science, UMCP
³ Northrup Grumman and NASA-GSFC

GMI Science Team Meeting
UC Irvine
March 18, 2008
Outline

- Comparison of convection-based and scaled flash rates with OTD/LIS climatology and ISCCP-based (default) flash rates
- Change in NOx, O3, and OH due to lightning NO emissions and due to change from default to updated lightning NO parameterization
- Comparison of tropospheric O3 and NO2 columns to satellite-based columns from Aura.
- Comparison of tropospheric O3 columns and profiles to SHADOZ measurements
- Contribution of lightning NO to O3 profiles at SHADOZ sites
How were lightning NO emissions determined?

1. Construct time series of 3-hr avg 434 hPa zmmu (updraft mass flux) using GEOS-4 AGCM (94-98) and DAS (01,04,05, 06) output
2. Set flash rate to nominal value at all locations where zmmu > a met-field dependent threshold.
3. Scale nominal flash rates so that total global monthly flash rates match v2.2 OTD/LIS climatological flash rates
4. Apply regional (tropical marine, African, S American, N American, Southeast Asian, N Asian, coastal, and rest-of-world) adjustments so that regional flash rates match OTD/LIS monthly climatology
5. Calculate N production rate (g s-1). (Assume IC and CG flashes produce same amount of NO per flash and scale to get desired global production rate)
Seasonal flash rate as a function of latitude.
Ott: Broader lower peak (outside of tropics) with much less in boundary layer at all latitudes.

Vertical profiles based on cloud-resolved modeling with lightning.
Additional NOx due to lightning NO emissions

Why does addition of lightning NO lead to decrease in NH PBL NOX?
Additional O3 resulting from lightning NO emissions

O3 GMI:geos4das

January 2005 c4_newLP–c4_noL

April 2005 c4_newLP–c4_noL

July 2005 c4_newLP–c4_noL

October 2005 c4_newLP–c4_noL

ppbv
Additional OH due to lightning NO emissions

OH GMI:geos4das
Change in NOx when updated lightning algorithm implemented

NOX GMI:geos4das

January 2005 c4_newLP-c4_dfL

April 2005 c4_newLP-c4_dfL

July 2005 c4_newLP-c4_dfL

October 2005 c4_newLP-c4_dfL

Latitude

Latitude

Pressure (hPa)

Pressure (hPa)

Height (km)

Height (km)

 pptv

-415
-382
-331
-280
-229
-178
-127
-76
-25
25
28
Change in O3 when updated lightning algorithm implemented
Change in OH when updated lightning NO algorithm implemented
Mean Trop (P>150 hPa) NO2 column 200507

No lightning NO

Default lightning NO

Updated lightning NO

---

<table>
<thead>
<tr>
<th>****</th>
<th>0.0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>8.0</th>
<th>10.0</th>
<th>15.0</th>
<th>50.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>p mol cm⁻²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Click on a site to access the data archive.
Tropospheric O3 column ascension

Mean(SHADOZ) = 39.15 stddev 9.42
Mean(DASc_noL) = 20.39 rms_b = -18.76 rms_c = 7.27 stddev 4.55 R = 0.66
Mean(DASc_dfl) = 36.87 rms_b = -2.28 rms_c = 7.72 stddev 4.08 R = 0.60
Mean(DASc_newLP) = 33.66 rms_b = -5.50 rms_c = 6.39 stddev 4.46 R = 0.81
Implementation of new scheme leads to a decrease in tropical tropospheric ozone
New scheme: Less tropospheric O3 in tropics → Low-bias in Atlantic but good agreement in Pacific
Implementation of new lightning algorithm leads to improvement in RMS after subtracting off mean bias at 10 of 12 sites.
Note: 2004 only
Note: 2004 only
Summary

• Updated lightning algorithm better captures Africa/South America flash rate contrast than default algorithm. Central African flash rates better but still too low. SE Brazil/Argentina flash rates remain too low during SH summer.

• Implementation of updated lightning NO algorithm leads to improved tropospheric O3 columns at 10 of 12 SHADOZ sites.

• Implementation of updated lightning NO algorithm reduces high-bias (wrt to OMI-MLS) of tropospheric O3 columns.

• Lightning NO emissions contribute 7-14 DU of O3 at SHADOZ sites on an annual mean basis over 2004-2005.
Extra Slides Follow
geos4das Lightning NO emissions DJF

- Default 1.1 Tg N
- Conv-based (Pickering) 1.0 Tg N
- Conv-based (Ott) 1.0 Tg N

Height (km) vs. Latitude
Pressure (hPa)

Color scale:
- 0.0 to 70.0 pptv per day
Mean Trop (P>150 hPa) NO2 column 200507

OMI column

c4_noL_column

c4_dFL_column

c4_newLP_column

**** 0.0 0.1 0.2 0.5 1.0 2.0 2.5 3.0 3.5 4.0 5.0 6.0 8.0 10.0 15.0 50.0
p mol cm$^{-2}$
Mean Tropospheric O3 column 200507

Column O3 OMI

Column O3 GMI:c4_noL

Column O3 GMI:c4_dfL

Column O3 GMI:c4_newLP

Dobson Units

0 10 15 20 25 30 35 40 45 50 55 60 70 80 100
irene Tropospheric O3 column  2004–2005

DASc_noL vs. SHADOZ

DASc_dfL vs. SHADOZ

DASc_newLP vs. SHADOZ
Tropospheric O3 column irene

Mean(SHADOZ) = 38.24 stddev 9.13
Mean(DASc_noL) = 26.38 rms_b = -11.86 rms_c = 6.00 stddev 8.37 R = 0.77
Mean(DASc_dL) = 38.51 rms_b = 0.27 rms_c = 5.07 stddev 7.45 R = 0.83
Mean(DASc_newLP) = 35.38 rms_b = -2.87 rms_c = 5.11 stddev 7.50 R = 0.83
New algorithm: Correlations increase (decrease) at 3 (1) site(s).
Huntsville, AL O3 profiles

IONS(solid)  CMI: DAS\textsubscript{c} noL(dash)  CMI: DAS\textsubscript{c} newLP(dash)
Wallops Island, VA O3 profiles

SION(solid)  CMi:DASe_noL(dot)  CMi:DASe_newLP(dash)