Recent results from the NASA MSFC Lightning Nitrogen Oxides Model (LNOM)

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1. INTRODUCTION

There has been considerable variability in the estimates of lightning NOx production per flash; see for example the summary table in Labrador et al. (2004), the review paper by Schumann and Huntrieser (2007), and the studies by DeCaria et al. (2000, 2005), Beirle et al. (2004, 2010), Langford et al. (2004), Rahman et al. (2007), Huntrieser et al. (2008), Jourdain et al. (2010), and Ott et al. (2010). The variability in these estimates is linked to the differences in the estimation methods employed, and the natural variability of lightning.

The NASA Marshall Space Flight Center introduced the Lightning Nitrogen Oxides Model (LNOM; Koshak et al., 2009, 2010) to combine useful, routine, and accurate measurements of lightning with laboratory empirical results of lightning NOx production derived from Wang et al. (1998). The LNOM has recently been updated to include several non-return stroke lightning NOx production mechanisms described in Cooray et al., (2009): (1) hot core stepped and dart leaders, (2) stepped leader corona sheath, K-changes, continuing currents, and M-components. The impact of including LNOM-estimates of lightning NOx for an August 2006 run of CMAQ is discussed. **It is desired to extend the LNOM analyses to the GEOS-Chem model.** The input data into the LNOM includes VHF lightning source data [such as from the North Alabama Lightning Mapping Array (LMA)], and ground flash location, peak current, and stroke multiplicity data from the National Lightning Detection Network (NLDN). Figure 1 summarizes LNOM data processing.

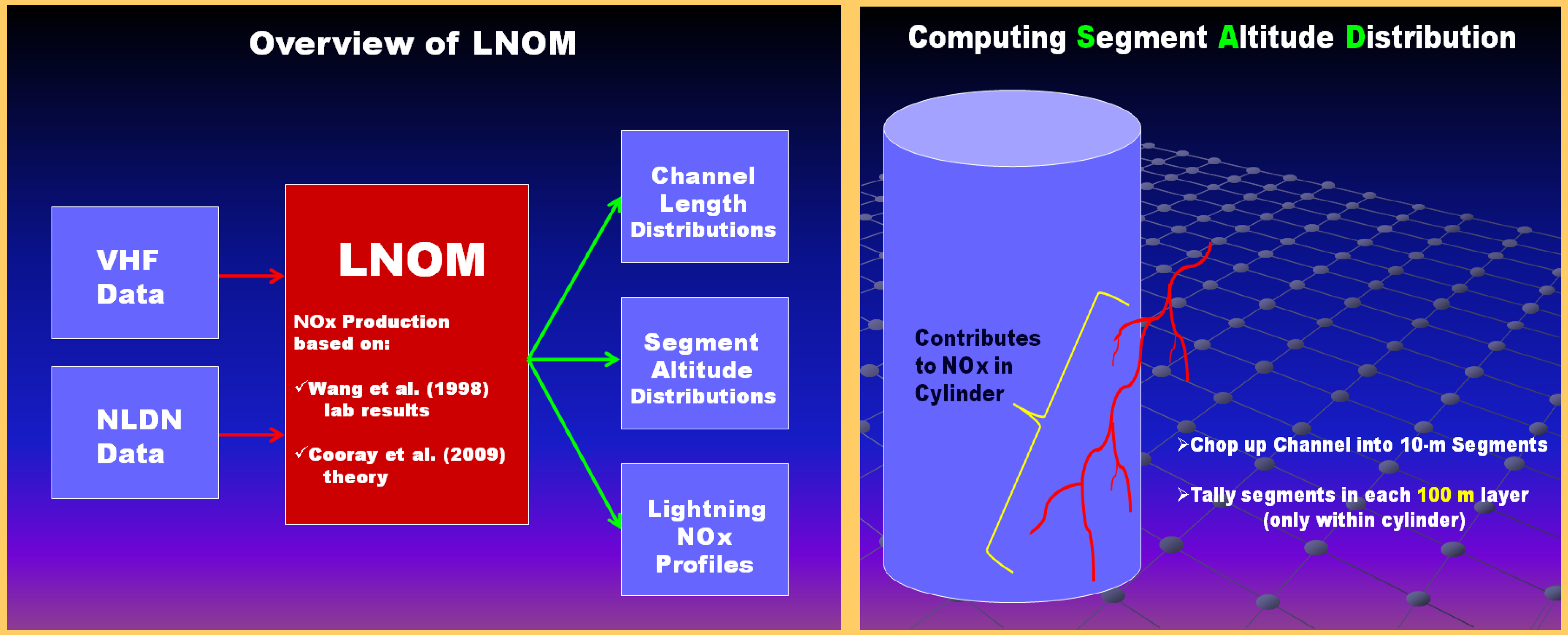

Figure 1. Functionality of the LNOM showing inputs, outputs, and details on channel segment altitude distribution computation.

2. EXAMPLES OF LNOM OUTPUT FOR AUGUST 2006

Figure 2 below provides examples of the LNOM output. LNOM output was also obtained for Aug 2005, Aug 2007, Aug 2008, and August 2009.

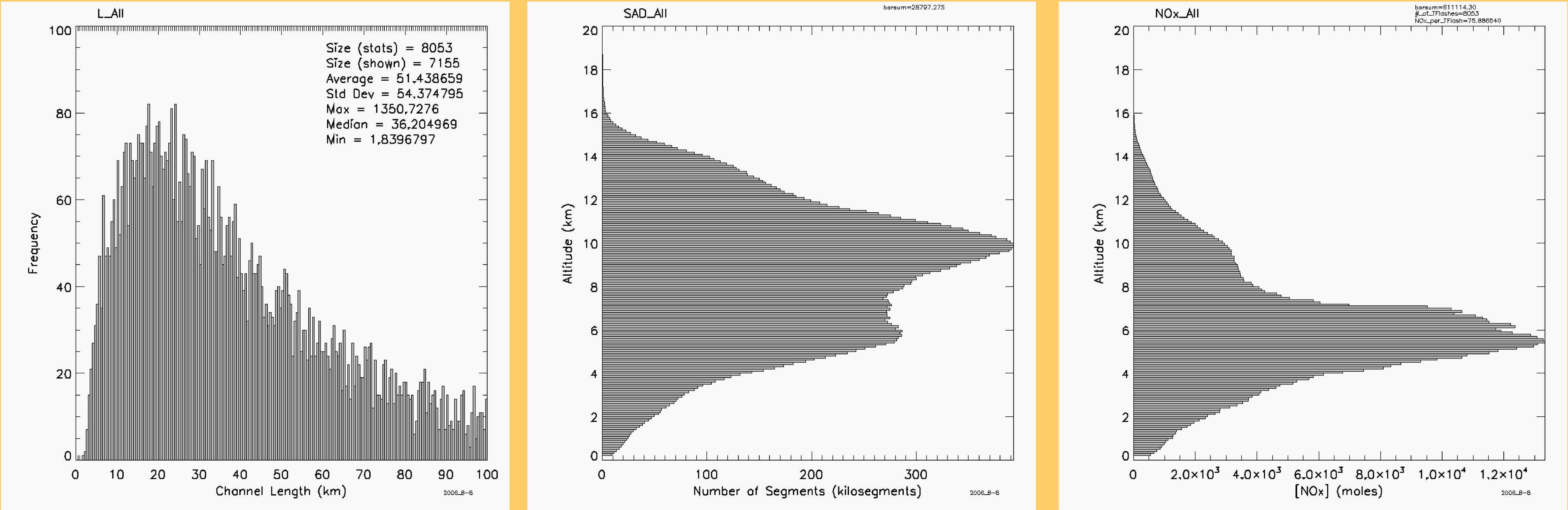

Figure 2. LNOM output (left to right): channel length distribution, segment altitude distribution, vertical NOx profile.

3. LIGHTNING NOx SUMMARY STATS

Table 1. Summary of lightning NOx production from LNOM analyses.

Period	# Ground Flashes	# Cloud Flashes	Total # of Flashes	NOx per Ground Flash	NOx per Cloud Flash	NOx per Flash
August 2005	1023	5306	6329	403.26	26.34	87.27
August 2006	1067	6986	8053	601.41	34.03	109.21
August 2007	1058	5766	6824	450.17	37.22	101.24
August 2008	1237	7563	8800	380.70	33.52	82.32
August 2009	447	2252	2699	756.08	54.97	171.09
Total Flashes & Weighted Mean NOx	4832	27,873	32,705	**484.15**	**34.78**	101.17

4. APPLICATION TO CMAQ

We summed the Aug 2005-2009 lightning NOx profiles and divided by the number of flashes (to obtain per flash NOx profiles; we also obtained the separate per ground flash and per cloud flash lightning NOx profiles). The August 2006 NLDN data was then used to find the # ground flashes in each Community Multiscale Air Quality (CMAQ) grid cell; climatological Z-ratio data was used to estimate the associated # of cloud flashes. The flash counts were then multiplied by the per flash lightning NOx profiles to estimate the lightning NOx profile within each CMAQ grid cell. The Aug 2006 CMAQ run was then completed. Figure 3 shows the impact of LNOM-derived lightning NOx on CMAQ ozone predictions.

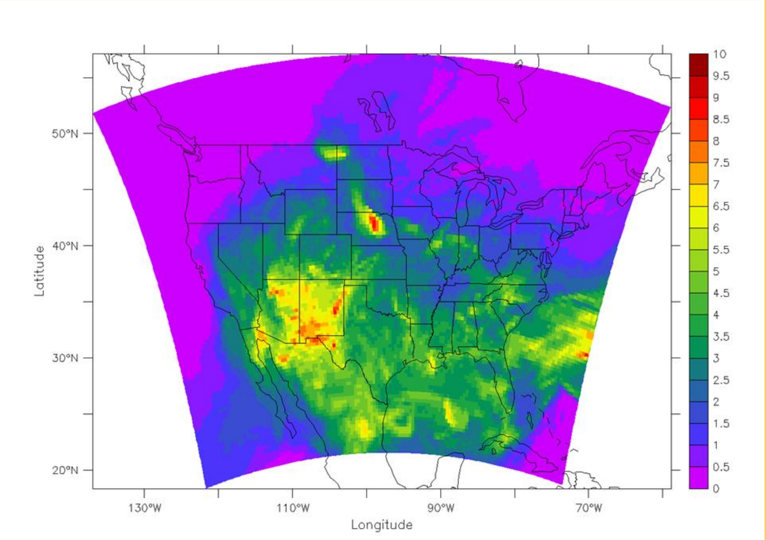

Figure 3a. Maximum increase in surface O_3 due to lightning NOx (ppb).

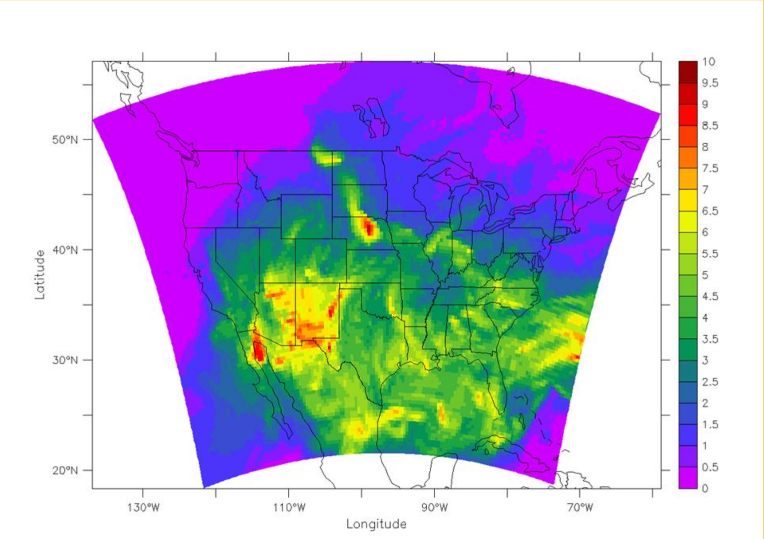

Figure 3b. Maximum increase in boundary layer O_3 due to lightning NOx (ppb).

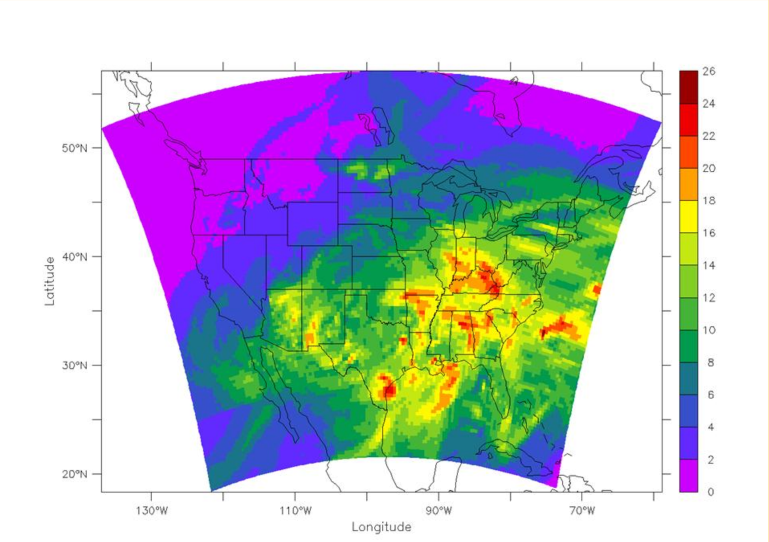

Figure 3c. Maximum domain-wide increase in O_3 due to lightning NOx (ppb).

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