Implementation of Lightning NOx Production in CMAQ over the Contiguous United States with Lightning Flash Data from WWLLN

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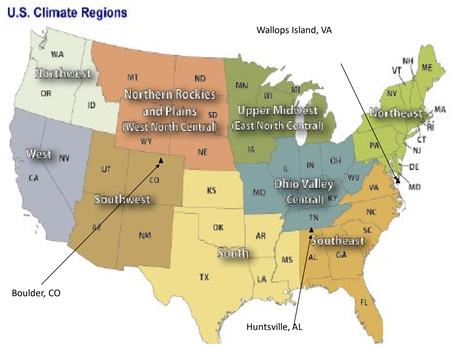
Introduction

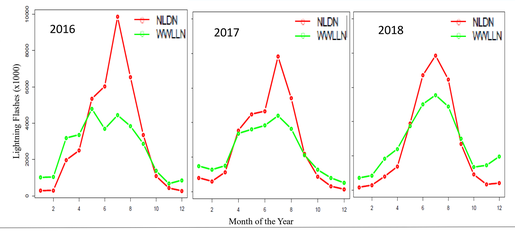
- Lightning Nitrogen Oxides (LNOx) emissions have been previously integrated into the Community Multiscale Air Quality (CMAQ) model using data from the National Lightning Detection Network (NLDN).
- NLDN has high detection efficiency, but only covers the United States.
- The World Wide Lightning Location Network (WWLLN) has global coverage but has lower detection efficiency.
- In this study, we compare NLDN and WWLLN over the CONUS domain and propose a simple empirical scaling for WWLLN flashes.
- The impact of scaling is evaluated through CMAQ simulations over the continental US (CONUS) for July 2016 with:
  - Hourly LNOx based on flashes from NLDN, raw WWLLN data, and scaled WWLLN (WWLLNs).
  - The model case without LNOx is designated as BASE.
  - Boundary and initial conditions, meteorology, and emissions are identical for all model cases.
- Refer to Madden et al. presentation in the same session for the assessment of hemispheric CMAQ simulations that would inform impact from outside the domain.



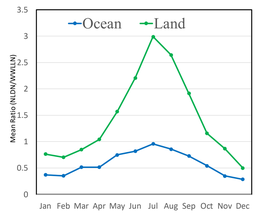
U.S. Climate Regions and ozonesonde locations. The regions: **NE** – Northeast, **SE** – Southeast, **UM** – Upper Midwest, **OVC** – Ohio Valley Central, **WNC** – West North Central, South, **SW** – Southwest, **NW** – Northwest, and West

Lightning Flashes

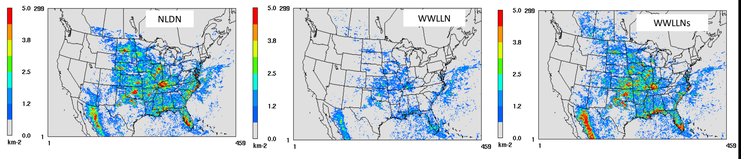
- NLDN has a stronger monthly mean seasonality than WWLLN in 2016, 2017, and 2018 over the Continental US (CONUS).



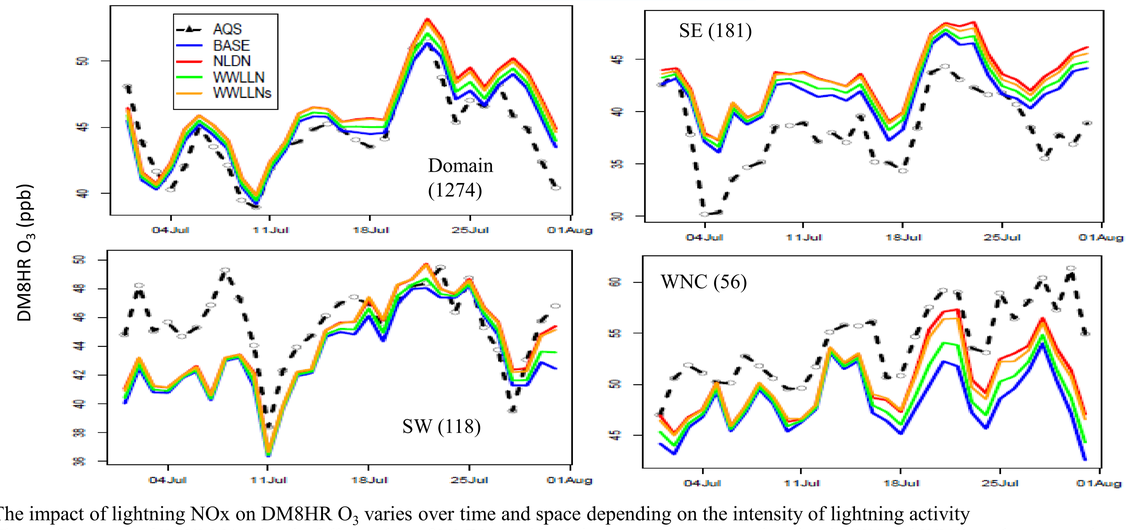
- NLDN generally has more flashes over land and fewer over the ocean.



- If we assume the land/ocean ratios are spatially constant, we can use the monthly mean ratios to scale WWLLN flashes in hemispheric and continental applications.
- Scaled WWLLN flash rates (WWLLNs) are spatially comparable to NLDN over the CONUS
- Only CONUS results are used in this poster.

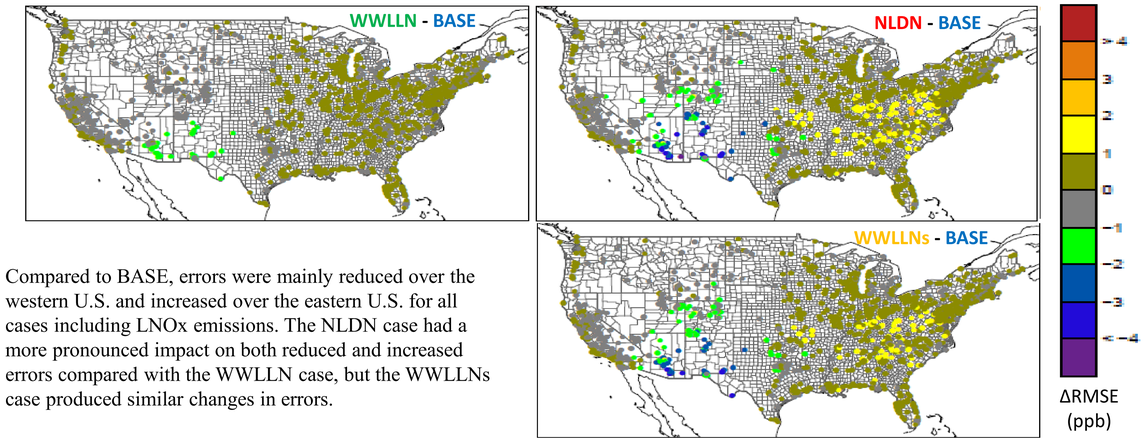


Time Series



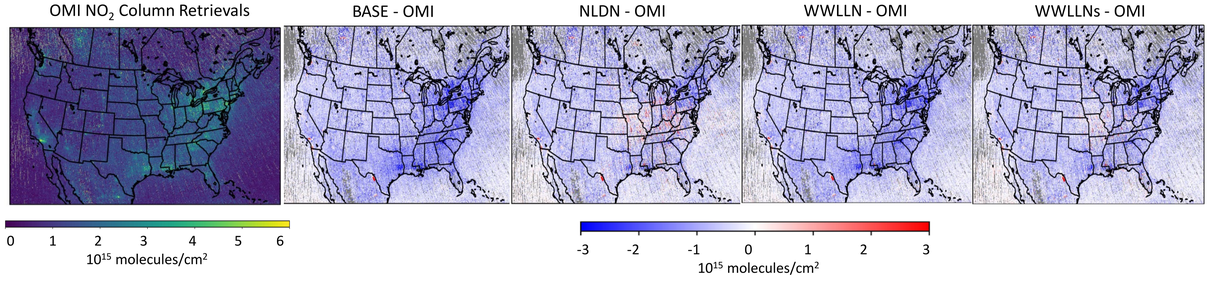
- The impact of lightning NOx on DM8HR O_3 varies over time and space depending on the intensity of lightning activity
- The performance of WWLLNs closely follows that of NLDN, and both improves the underestimation in SW and WNC, and worsens the overestimation in SE relative to the BASE simulations without LNOx emssions

Spatial Error Difference

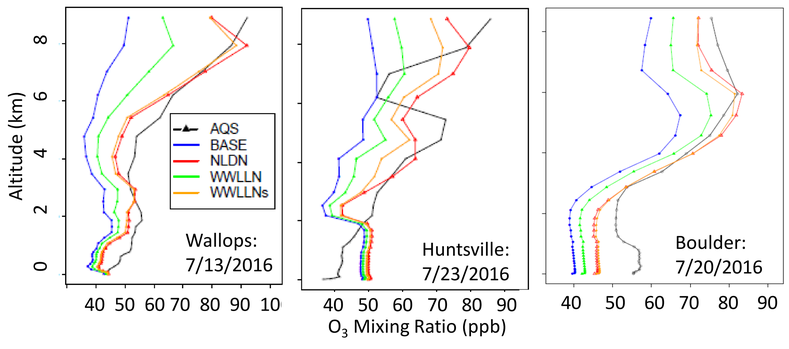


Compared to BASE, errors were mainly reduced over the western U.S. and increased over the eastern U.S. for all cases including LNOx emissions. The NLDN case had a more pronounced impact on both reduced and increased errors compared with the WWLLN case, but the WWLLNs case produced similar changes in errors.

NO_2 Columns and O_3 Vertical Profile



- The mean spatial pattern of OMI NO_2 Vertical Column Density (VCD) was reproduced by the CMAQ simulations during July 2016
- The BASE case underestimated NO_2 VCD across the CONUS domain, especially in the eastern U.S.
- The underestimation was much reduced by the NLDN case with localized small overestimation in the central-eastern U.S.
- The WWLLN case indicated moderate improvement in NO_2 VCD compared to the BASE case, but the effect was much smaller compared to the NLDN case due to lower lightning detection efficiency in WWLLN than in NLDN
- The WWLLNs case produced a comparable effect in reducing the underestimation of NO_2 VCD as the NLDN case across the CONUS



On days when lightning was present, significant LNOx impact on vertical O_3 profiles was observed at several ozonesonde sites located in the domain. Compared to the NLDN case, the WWLLN case produced less O_3 throughout the vertical layers due to fewer lightning flashes reported by WWLLN, but the WWLLNs case produced similar and at most times identical vertical profiles at all three locations.

Summary

- More lightning flashes were observed from NLDN than from WWLLN during summer months over land with similar month-to-month variations over the years in the contiguous United States
- Model simulations with the scaled lightning flash rates from WWLLN by the monthly NLDN/WWLLN ratios over land and over ocean produced results comparable to the NLDN simulations in terms of NO_2 columns and surface and vertical O_3 mixing ratios
- The original and scaled lightning flash rates are applied to Hemispheric CMAQ simulations (*See Mike Madden's presentation for the detailed Hemispheric CMAQ applications)*

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