"Comparison of GOME-2 and OMI Tropospheric NO2 with CMAQ Predictions for the 2008 Smog Season in the United States"

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Scientific Objective

- Use satellite data from multiple sensors (GOME-2 and OMI tropospheric NO2) to evaluate CMAQ model NO2
- This study focuses on understanding diurnal variation and weekday/weekend differences of NOx emissions in the CMAQ model. Specifically,
  - Can OMI and GOME-2 NO2 data with different observation time be used to study diurnal variation of NO2?
  - Are spatio-temporal patterns of NOx emissions in NWS operational CMAQ model consistent with GOME-2 and OMI observations?
- Data
  - » Processed summer 2008 of GOME-2 data. Converted L2 pixel data to 0.25^{o} X 0.25^{o} gridded fields.
  - » Obtained summer 2008 of L2 OMI data from NASA. Converted L2 pixel data to 0.25^{o} X 0.25^{o} grid gridded fields. OMI data with row anomaly were discarded.
  - » For both OMI and GOME-2, only data with cloud fraction less than 0.2 were used.

Recent Work

- Findings from recent work by Kim et al., JGR, 2009
  - » For regions dominated by power plants, model (WRF-Chem) NO2 and OMI/SCIAMACHY NO2 agree well;
  - » For regions dominated by mobile emissions, model overestimates NO2 by a factor of 2. WRF-Chem model used NEI99 inventory

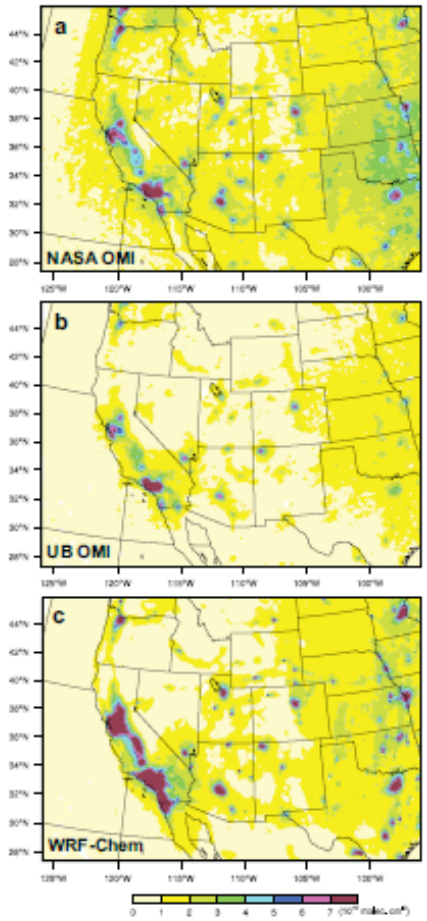


Figure 3. (a) NASA OMI, (b) UB OMI, and (c) WRF-Chem average NO_2 columns during the summer of 2005 for the same domain as Figure 2. Satellite datasets NASA-OMI 2 and UB-OMI 2 (Table 1) and model simulation case M2 (Table 3) were used to construct this figure.

http://www.agu.org/pubs/crossref/2009/2008JD011343.shtml

GOME-2 and OMI NO2 Retrieval Algorithms

- NO2 slant column
  - » OMI from KNMI
  - » GOME-2 code is from Harvard
  - » But, algorithm differences were minimized as much as possible (see slide 5)
- Vertical Column Density
  - » OMI algorithm was adapted for GOME-2 including NO2 profiles used to calculate air mass factors.
  - » NOAA operational GOME-2 NO2 algorithm uses surface reflectivity data based on OMI. However, for this study algorithm was run using surface reflectivity based on GOME-1 as 2008 OMI data were processed using GOME-1 surface reflectivity (see slide 7)
- Tropospheric NO2 Column
  - » OMI algorithm was adapted for GOME-2

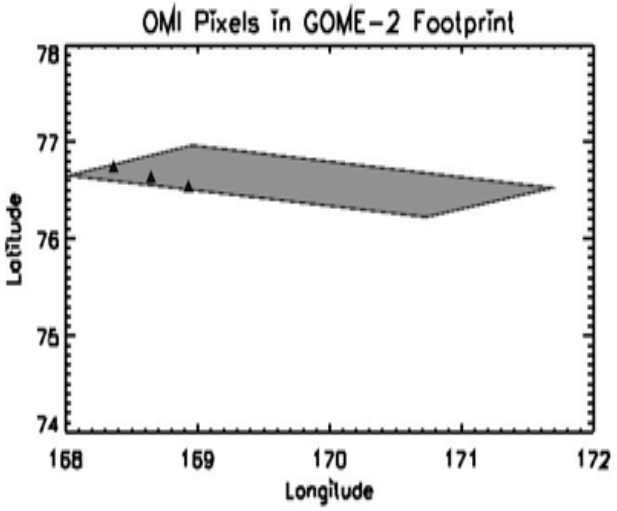
GOME-2 and OMI NO2 differences can be strictly interpreted as real diurnal differences other than the effects of viewing geometry if any

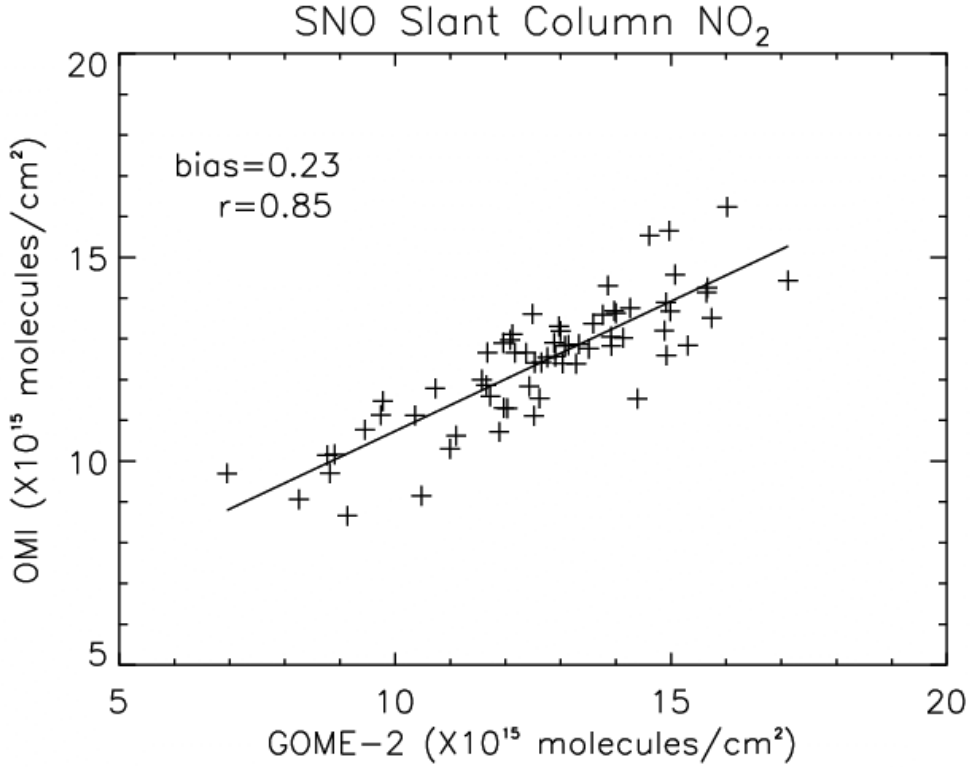
DOAS (NO2A) Algorithm

	GOME-2	OMI
Spectral Window	426 – 452 nm	405 – 465 nm
NO2 cross section	Vandaele et al. BIRA laboratory. Convolved with GOME-2 estimated slit function, temperature 220K	Vandaele et al. BIRA laboratory. Convolved with OMI estimated slit function, temperature 220K
Ozone cross section	Gur et al., ESA/ EUMETSATContractNo. 16007/02/NL/SF	Bass, Johnsten, 1975
H2O cross section	HITRAN database	?
O2-O2 cross section	Greenblatt et al.,	Not included in the DOAS fit
Ring Effect spectra	Chance, SAO	De Hann, 2006
Pixel Resolution	40 km X 80 km (all scan position)	13 km X 24 km at nadir

Simultaneous Nadir Overpass (SNO) Analysis of GOME-2 vs OMI Slant Column NO_2

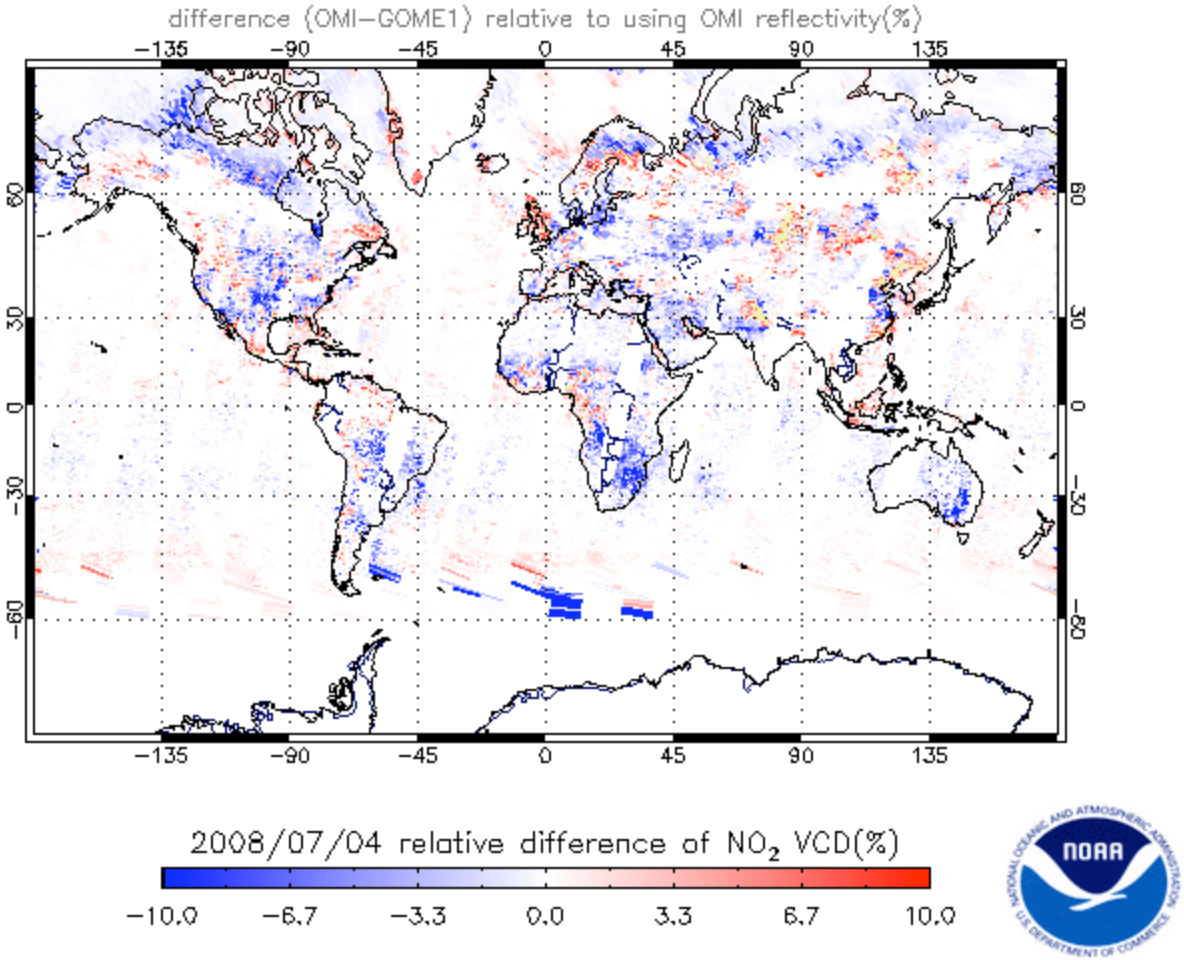
- 15 months of GOME-2 and OMI slant column NO2 data (2008-2009) were intercompared using SNO analysis. Number of matchups for this analysis were 77.
- SNO matchup criteria
  - » ± 2 minutes overpass
  - » Solar zenith angles less than 80º
  - » View zenith angles less than 4º (nadir)
  - » OMI row anomaly flag used
- Results
  - » Mean bias is 0.23 (~ 2%)
  - » Correlation coefficient is 0.85





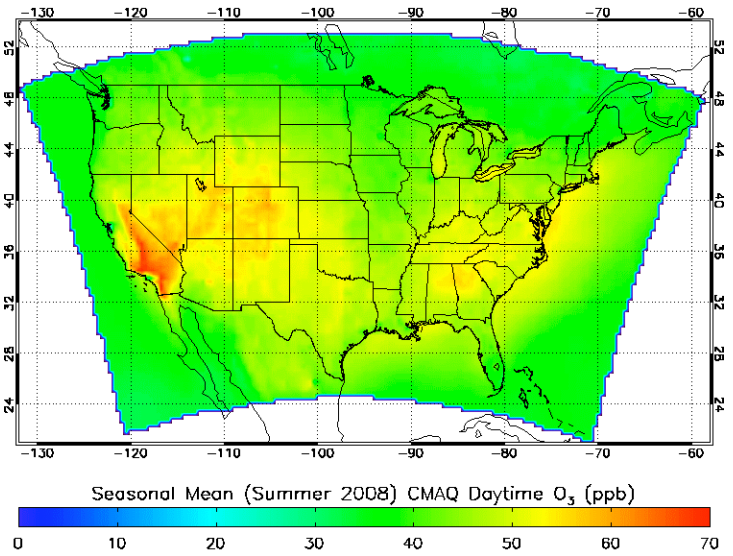
NO2BC Algorithm

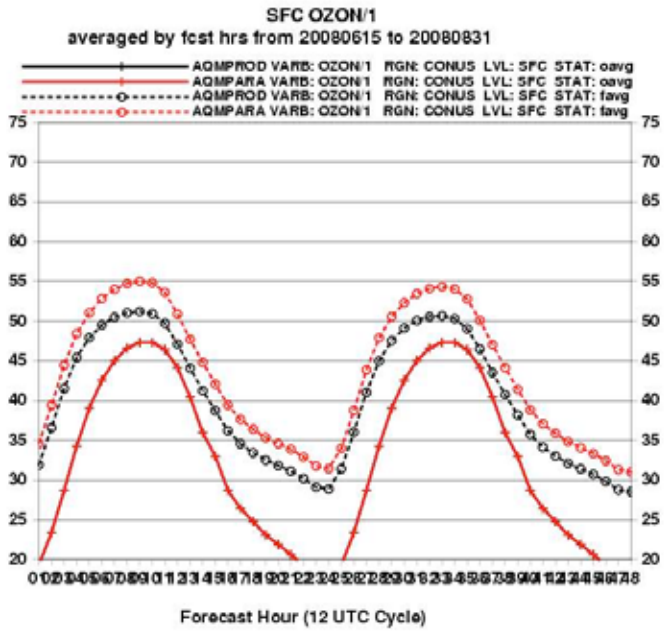
Impact of surface reflectivity substantial (up to 10%) on retrieved NO2 vertical column density. Adjacent map shows percent difference in NO2 vertical column density for July 4, 2008. Percent difference is for GOME-2 retrievals with OMI surface reflectivity and GOME-2 retrievals with GOME-1 surface reflectivity



Study Time Period

- Summer 2008 smog season
  - » June to September
  - » NWS operational CMAQ runs were archived by NESDIS for this study
  - » CMAQ layer NO2 mixing ratios were converted into number density and integrated vertically to compare with satellite data
- CMAQ performance
  - » Hourly averages of 48-hr forecasts for the summer 2008 are shown in bottom right panel. Operational run (carbon bond 4 mechanism) is shown in black dashed line, parallel run (carbon bond 5 mechanism) is shown in red dashed line, and observations are shown in solid red line
  - » Both operational and parallel runs overpredicted ozone

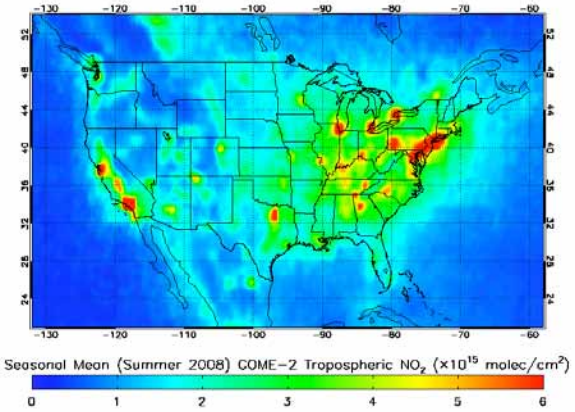




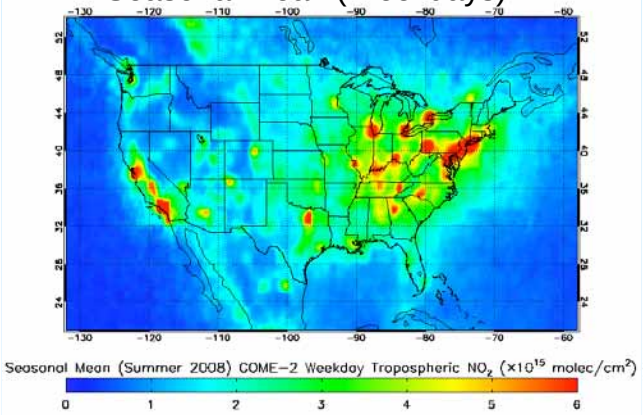
Summer Seasonal Mean Tropospheric NO2

GOME-2

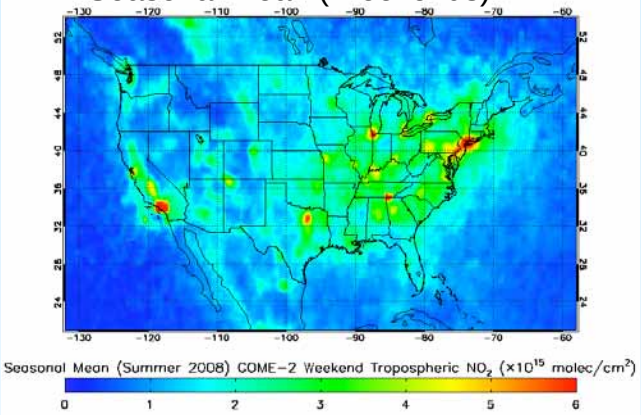
Seasonal Mean



Seasonal Mean (Weekdays)

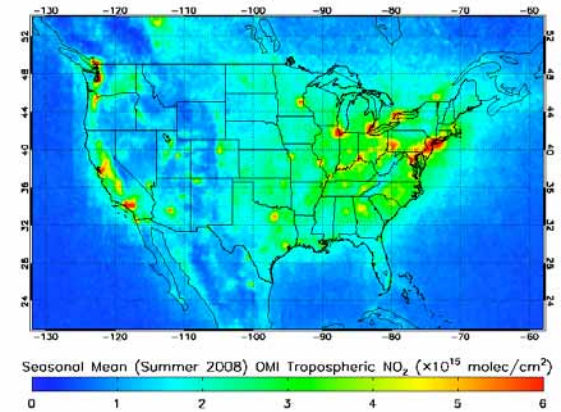


Seasonal Mean (Weekends)

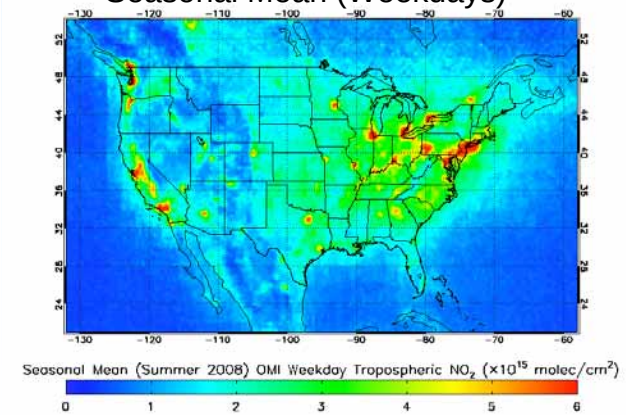


OMI

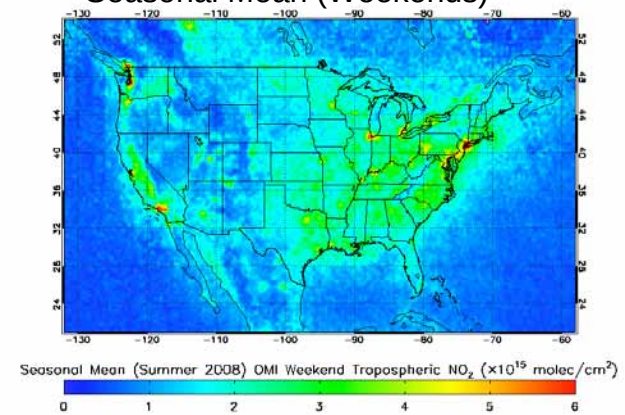
Seasonal Mean



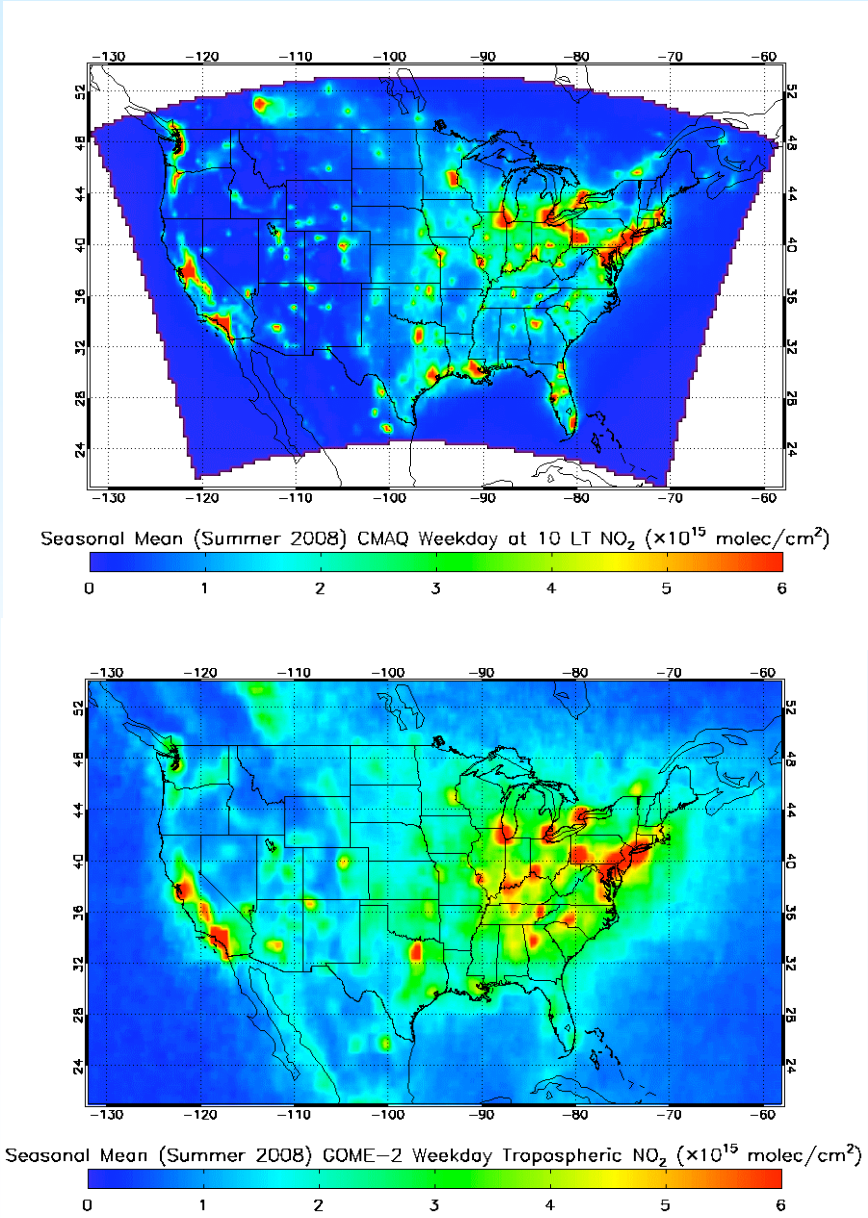
Seasonal Mean (Weekdays)



Seasonal Mean (Weekends)

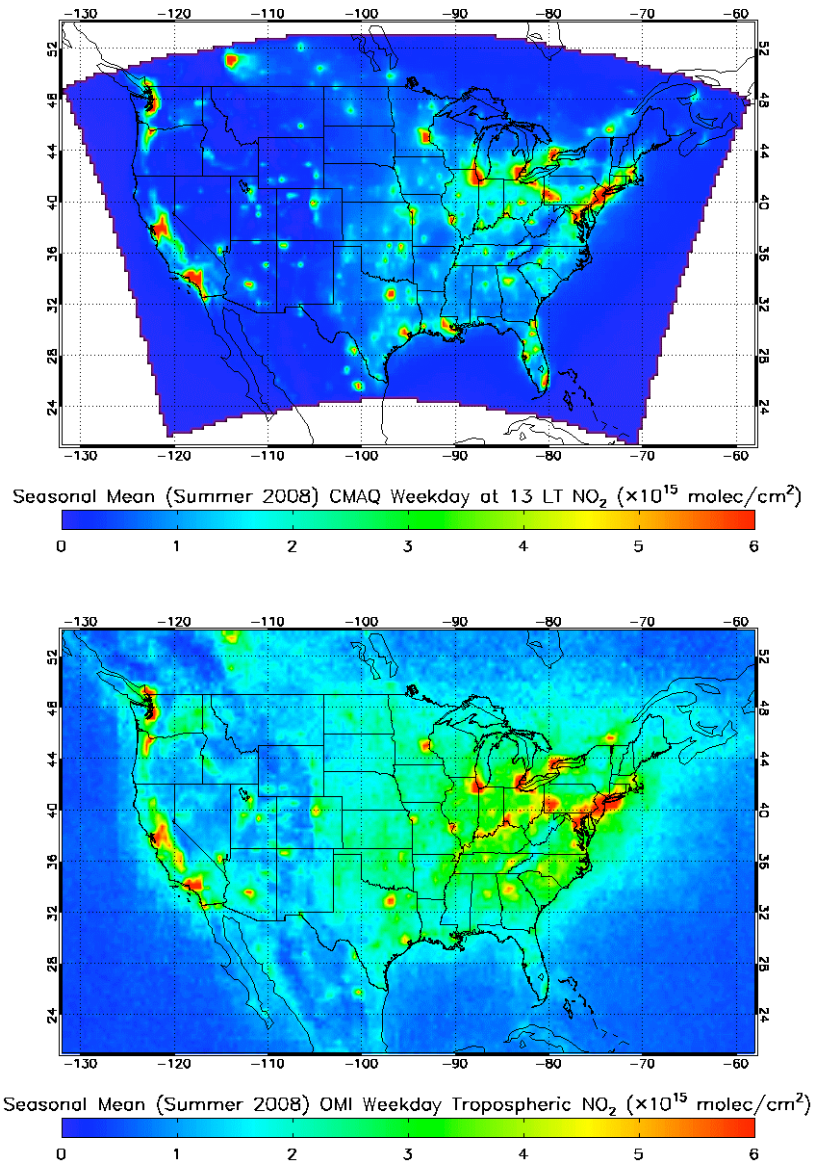


CMAQ Matched in Time with GOME-2



- NO2 source regions over major urban areas observed by GOME-2 are well represented in the model. *Note that CMAQ uses EPA 2005 NEI and adjusts the emissions based on DOE projections for the current time period*
- Similar to OMI observations, southeast Texas and Louisiana regions have elevated NO2 in CMAQ that GOME-2 did not observe. Similar differences in Florida and in Canada
- It is worth noting that GOME-2 observations show rural regions with NO2 concentrations higher than background values that CMAQ uses

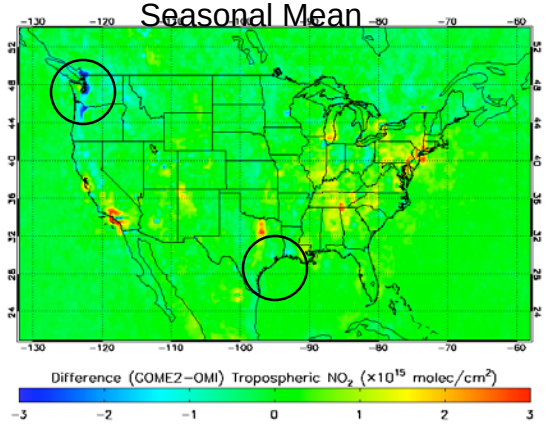
CMAQ Matched in Time with OMI



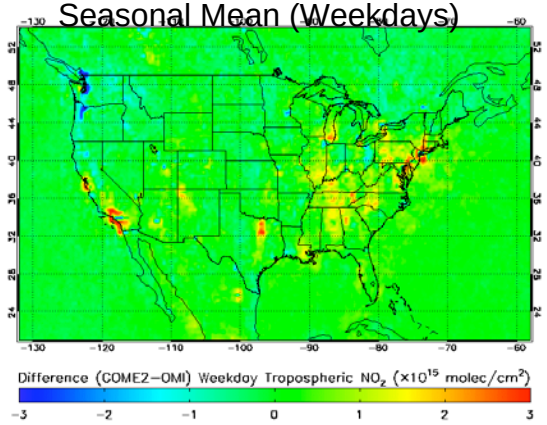
- NO2 source regions over major urban areas observed by OMI are well represented in the model. *Note that CMAQ uses EPA 2005 NEI and adjusts the emissions based on DOE projections for the current time period*
- Southeast Texas and Louisiana regions have elevated NO2 in CMAQ that OMI did not observe. Similar differences in Florida and in Canada
- It is worth noting that OMI observations show rural regions with NO2 concentrations higher than background values that CMAQ uses

Satellite Observed Diurnal Difference

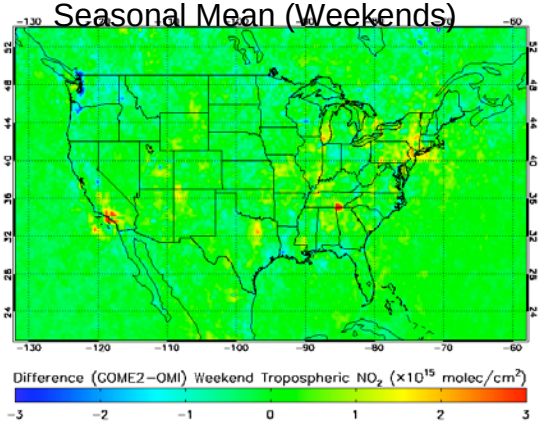
Seasonal Mean



Seasonal Mean (Weekdays)

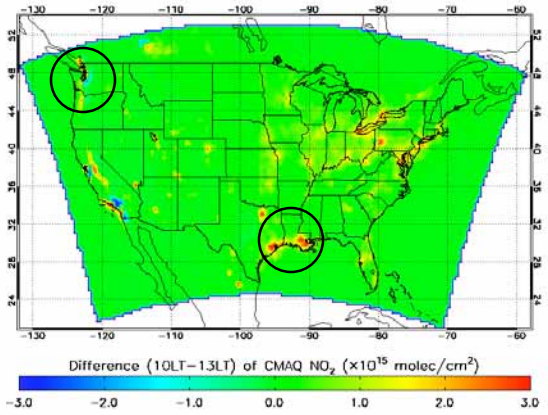


Seasonal Mean (Weekends)

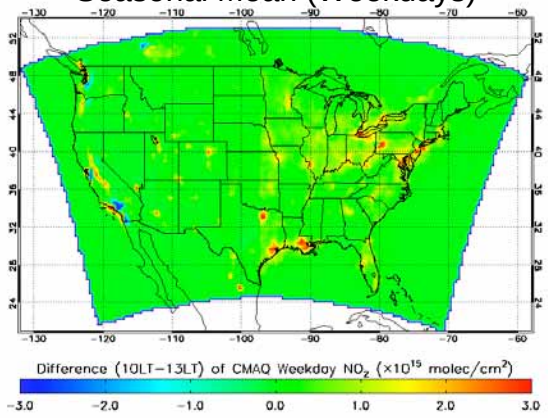


CMAQ Model Diurnal Difference

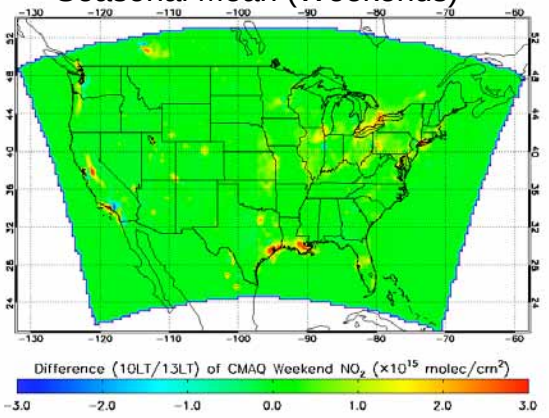
Seasonal Mean



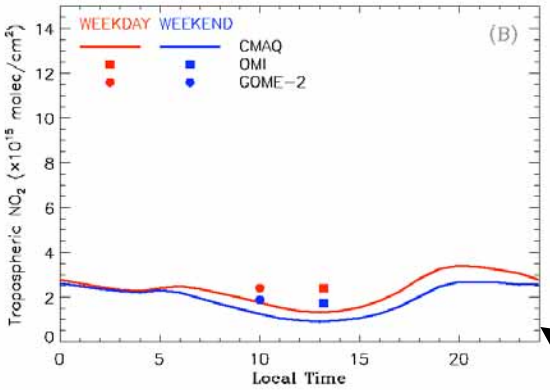
Seasonal Mean (Weekdays)

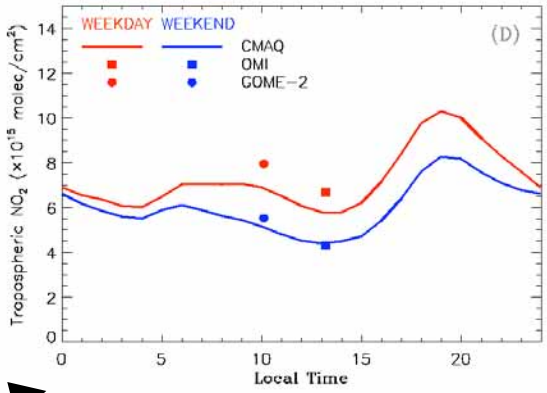


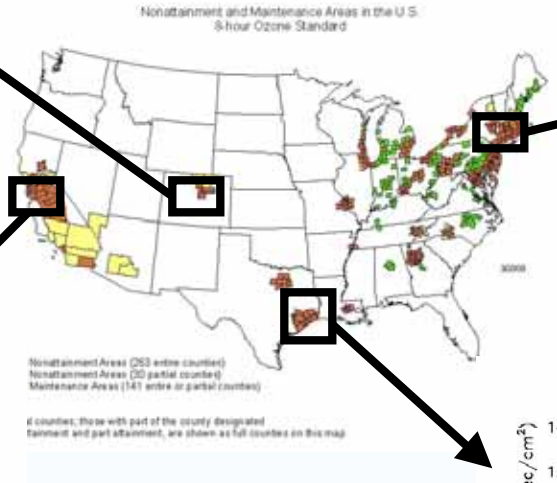
Seasonal Mean (Weekends)

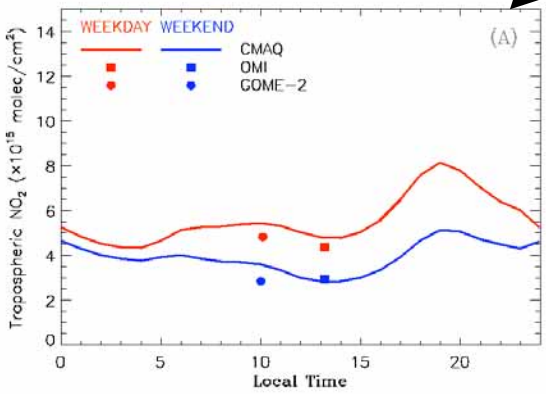


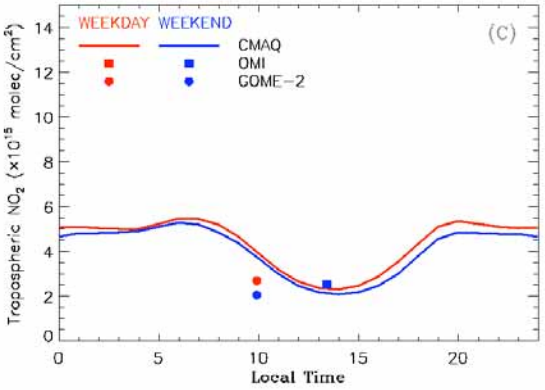
Modeled and Measured Diurnal Variation of NO2 in the U.S. Ozone Non-Attainment Areas



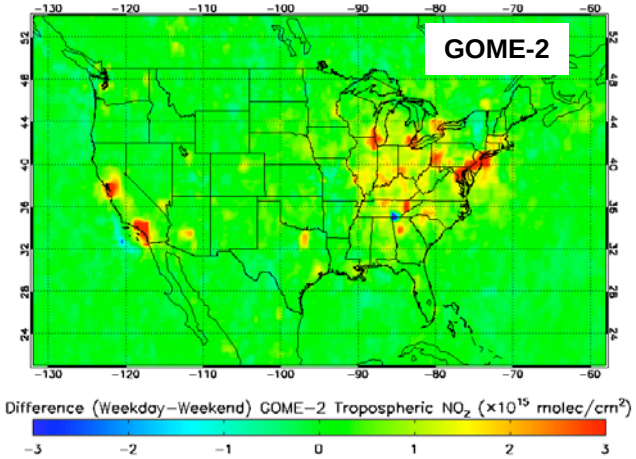


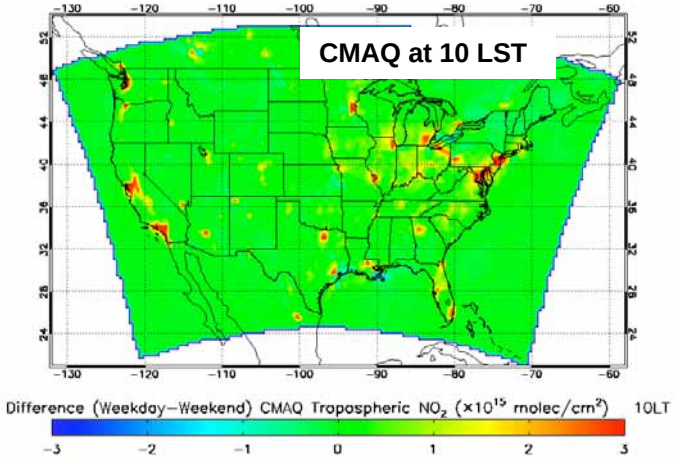


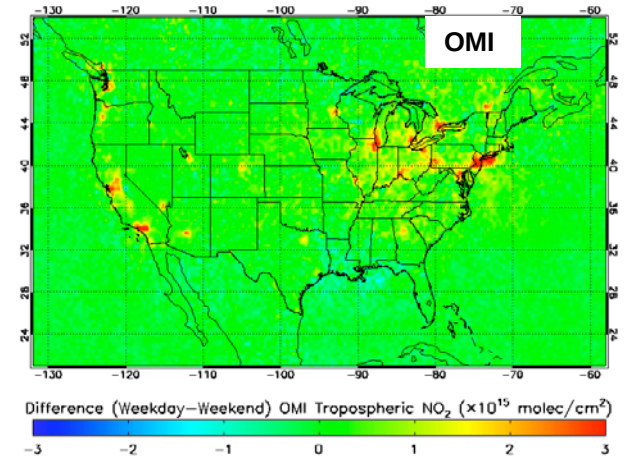


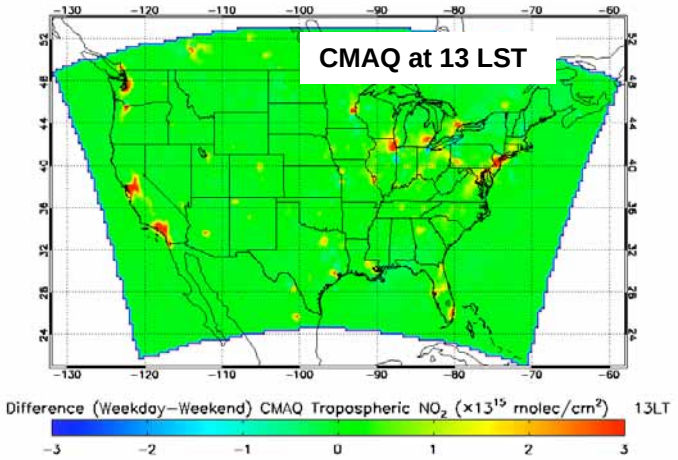


Observed and Modeled Weekday/Weekend Difference in Tropospheric NO2









Conclusions

- Demonstrated that NO2 data from two polar-orbiting (GOME-2 and OMI) satellites can be used to evaluate diurnal variation in an air quality model
- Spatial and temporal patterns observed in GOME-2 and OMI are consistent with our understanding of NO2 chemistry
  - » Diurnal variation in observed NO2 consistent with CMAQ model including the non-attainment areas except:
    - Texas region and northwest
- Weekday/weekend differences stronger in observations (both GOME-2 and OMI) compared to CMAQ model. CMAQ model emissions for weekends might need some tuning.
- Influence of these differences between weekday and weekend on ozone predictions will be investigated in the future

Acknowledgements

- Thanks to:
  - Harvard SAO (Kelly Chance and Thomas Kuruso) for NO2 slant column code
  - NASA for NO2B and NO2C code
  - EUMETSAT for provision of 1Bs through Initial Joint Polar Satellite System agreement with NOAA