Ozone Air Quality in Nigeria: a View from Space

Presented on behalf of:

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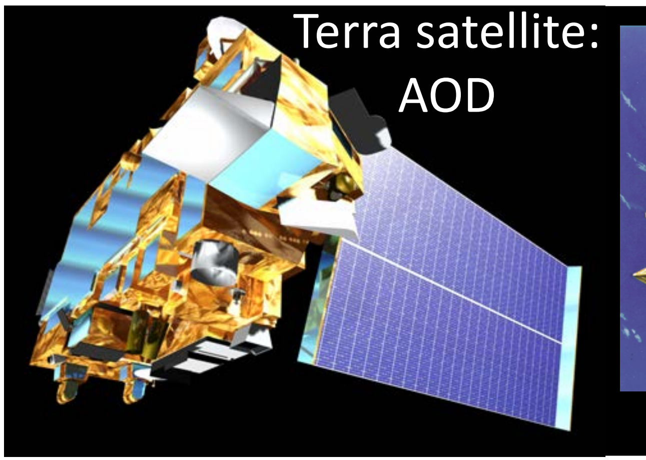

HCHO ≡ formaldehyde
CHOCHO ≡ glyoxal
AOD ≡ aerosol optical depth

Simone Tilmes (UCAR)

West Africa Air Quality Workshop
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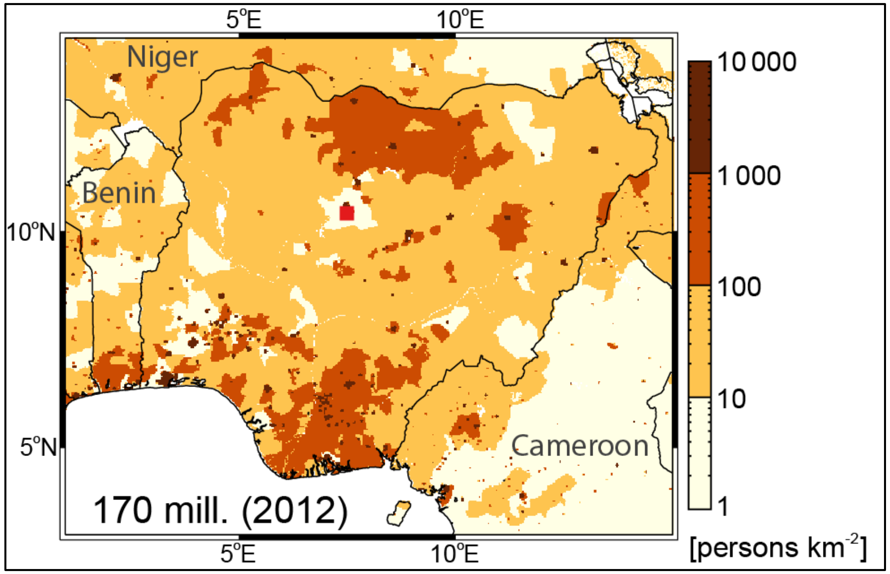
Sources of Pollution in Nigeria

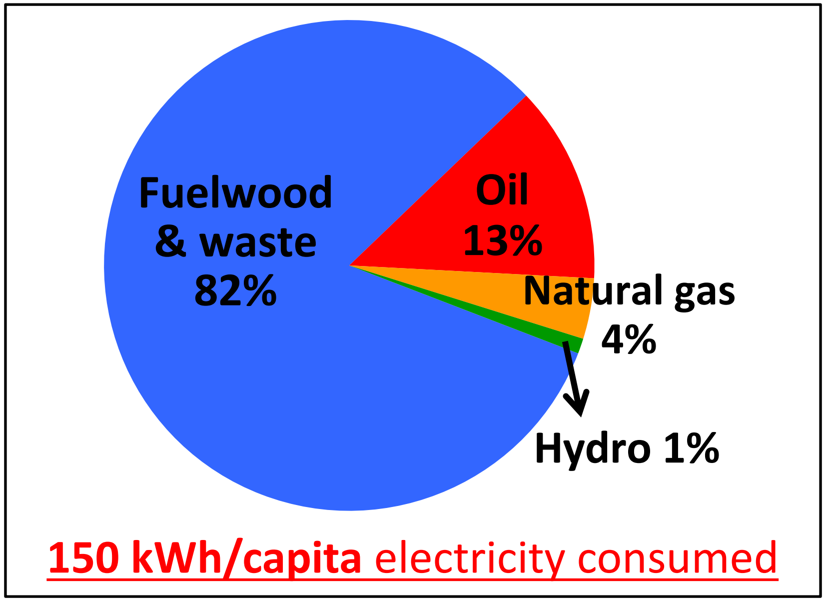
Large and growing **population** with inefficient **energy mix** and wasted natural gas

Population distribution in 2000



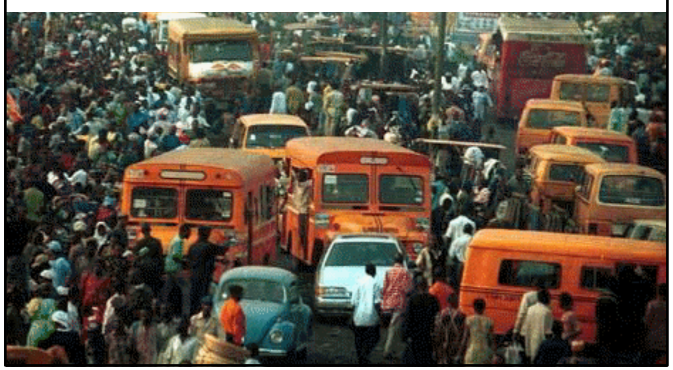
[CIESN, 2005]

Energy Mix in 2010



[EIA, 2012]

Vehicle Emissions



[Assamoi et al., 2010]

Ad Hoc Oil Refining

[EIA, 2012]

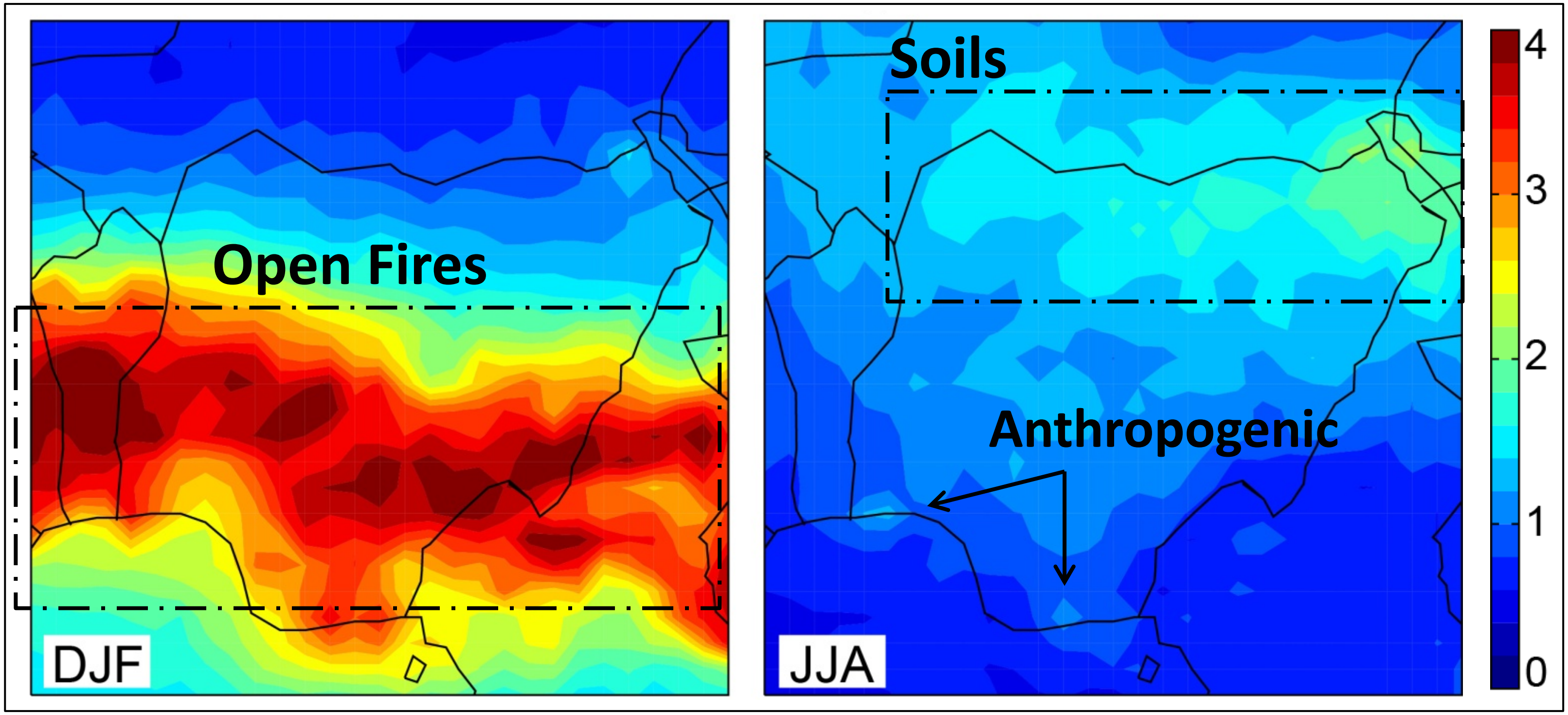
Flaring of natural gas

[Ologunorisa, 2001]

Sources of Pollution in Nigeria

Seasonal enhancements from **open fires** (Dec-Feb) and **soils** (Jun-Aug)

OMI tropospheric NO_2 in 2005-2007 [10^{15} molecules cm^{-2}]



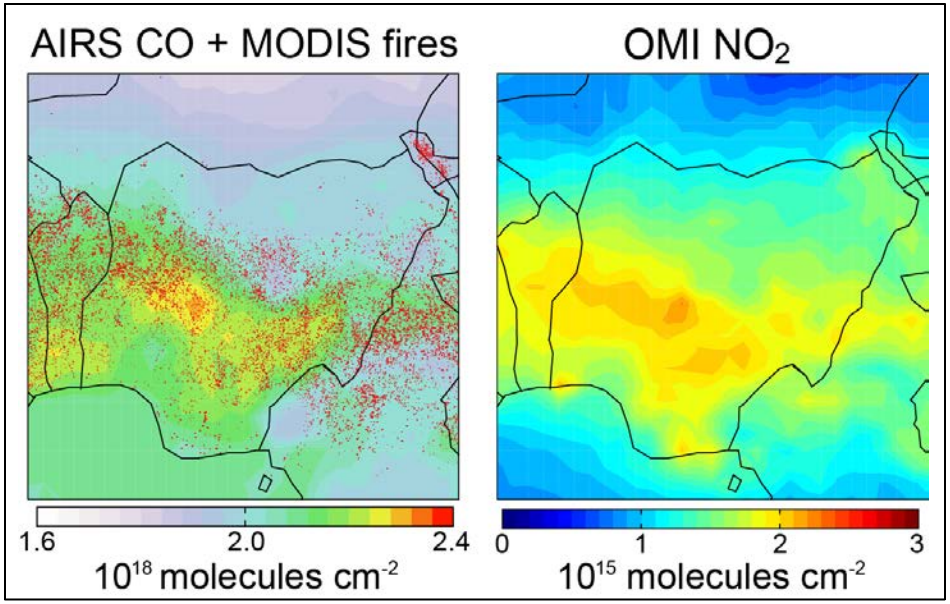
Meteorological features in each season

Temperature inversion (**Harmattan winds**)	**West African Monsoon**
Severely restricted ventilation	Efficient ventilation

Atmospheric Composition in Nigeria

Annual mean satellite data for 2005-2007 at 0.5×0.5° (GOME-2 is 2007 only)

CO and NO_2 are dominated by **open fires** (but AIRS boundary layer sensitivity is low)

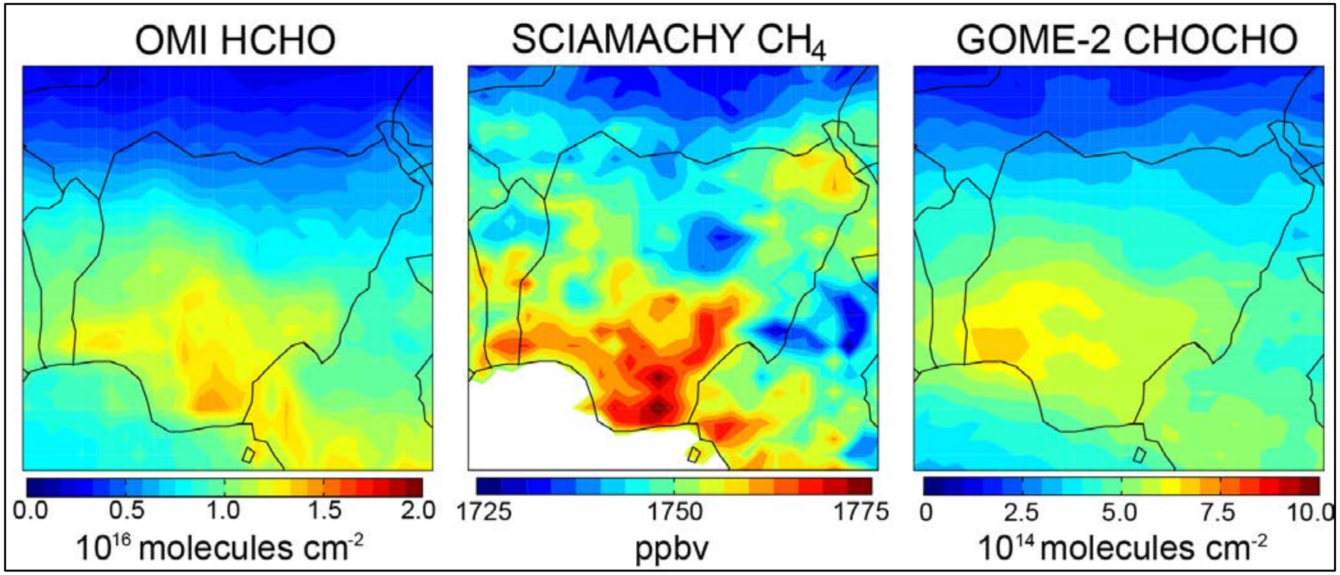


Evaluate **NMVOC emissions** with HCHO and CHOCHO:

NMVOC oxidation	→ **HCHO**
Aromatic oxidation	→ **CHOCHO**

Niger Delta CH_4 and HCHO hotpots indicate extensive **gas leakage**, **venting** and **flaring**.

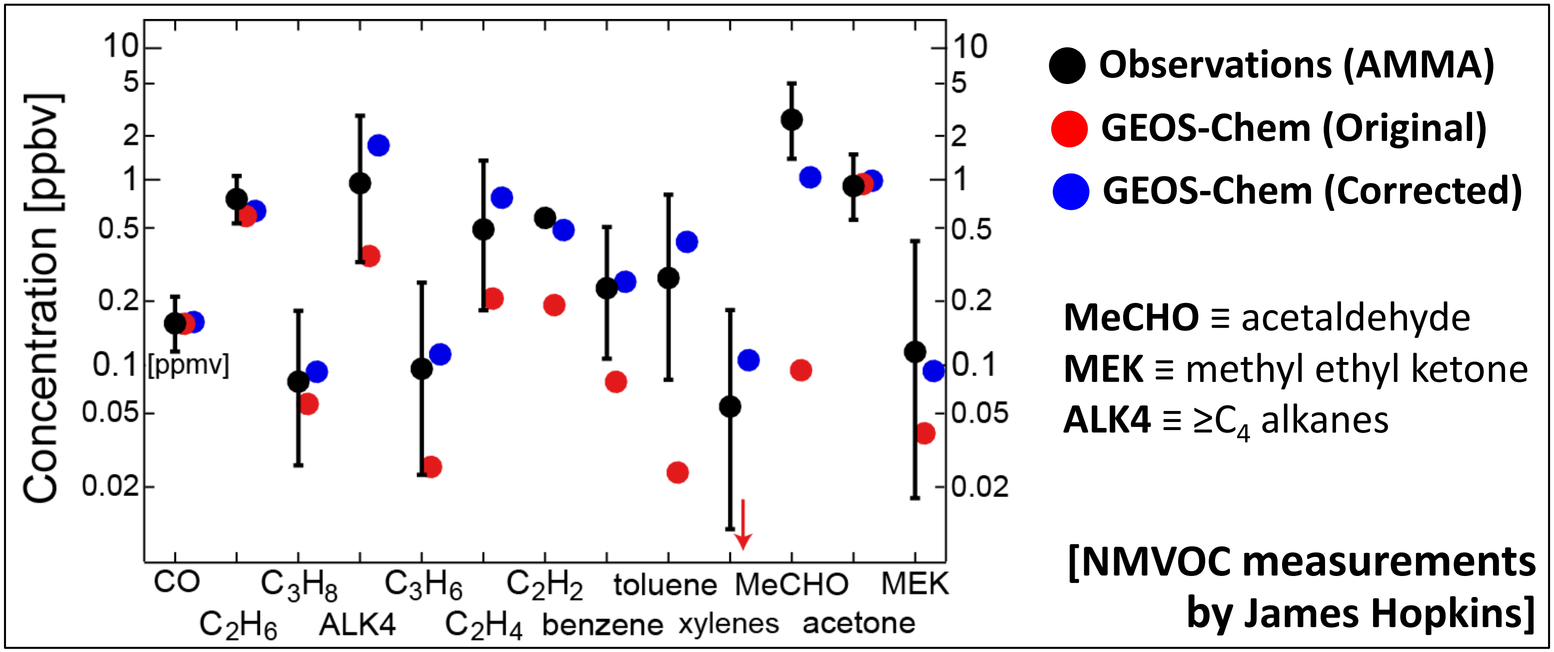
Lagos CHOCHO and HCHO hotspots from reactive aromatics (**vehicle and generator emissions**)



Constraints on Nigerian Emissions

Satellite observations and AMMA aircraft observations provide **constraints on emissions** in Nigeria

NMVOC and CO concentrations over Lagos below 1 km on 8 August 2006



Model (2×2.5° simulation) underestimates aromatic, acetaldehyde and higher alkanes.

Model bias is **due to emissions**, rather than dilution or transport (good agreement with CO, acetone and shorter alkanes)

The corrected **Nigerian NMVOC emissions are 5.7 Tg C a^{-1}** (*a priori* emissions =1.6 Tg C a^{-1})

EDGAR v4.2 **CH_4 oil & gas emissions** are also increased from 1.7 Tg CH_4 a^{-1} to **5.5 Tg CH_4 a^{-1}**.

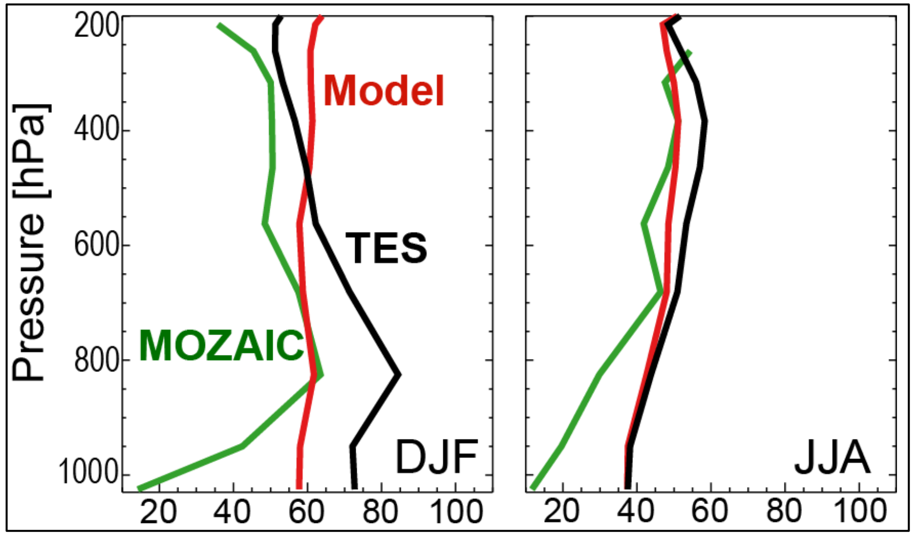
Ozone Air Quality Implications

Space-based observations of ozone indicate **severe ozone air pollution** in Nigeria

Vertical seasonal mean O_3 [ppbv] over Lagos

MOZAIC O_3 data are invaluable for interpreting the vertical distribution of O_3.

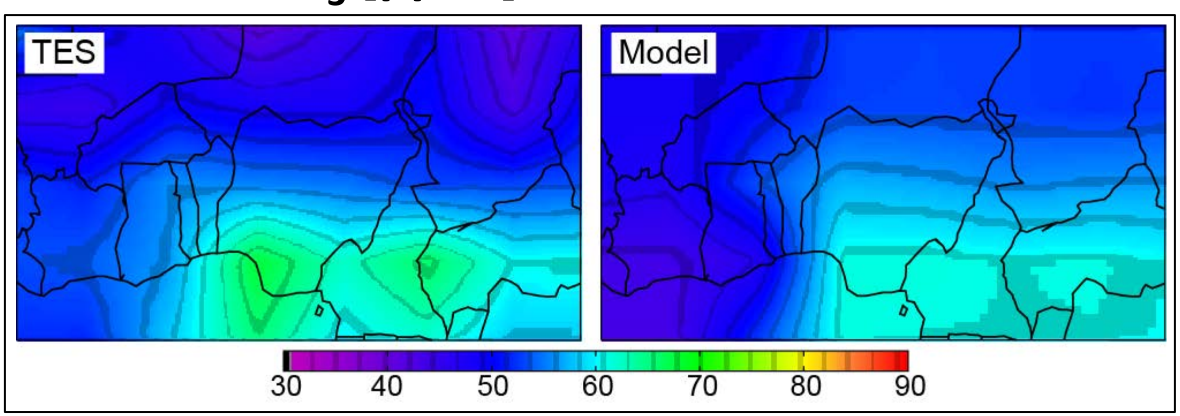
But, surface observations in W. African coastal cities sample clean oceanic air.



2005-2007 (4×5°)
2005-2007 (4×5°)
2000-2004

High seasonal mean surface **O_3** from TES (**70 ppbv**) and GEOS-Chem (60 ppbv).

DJF mean O_3 [ppbv] in West Africa at 825 hPa



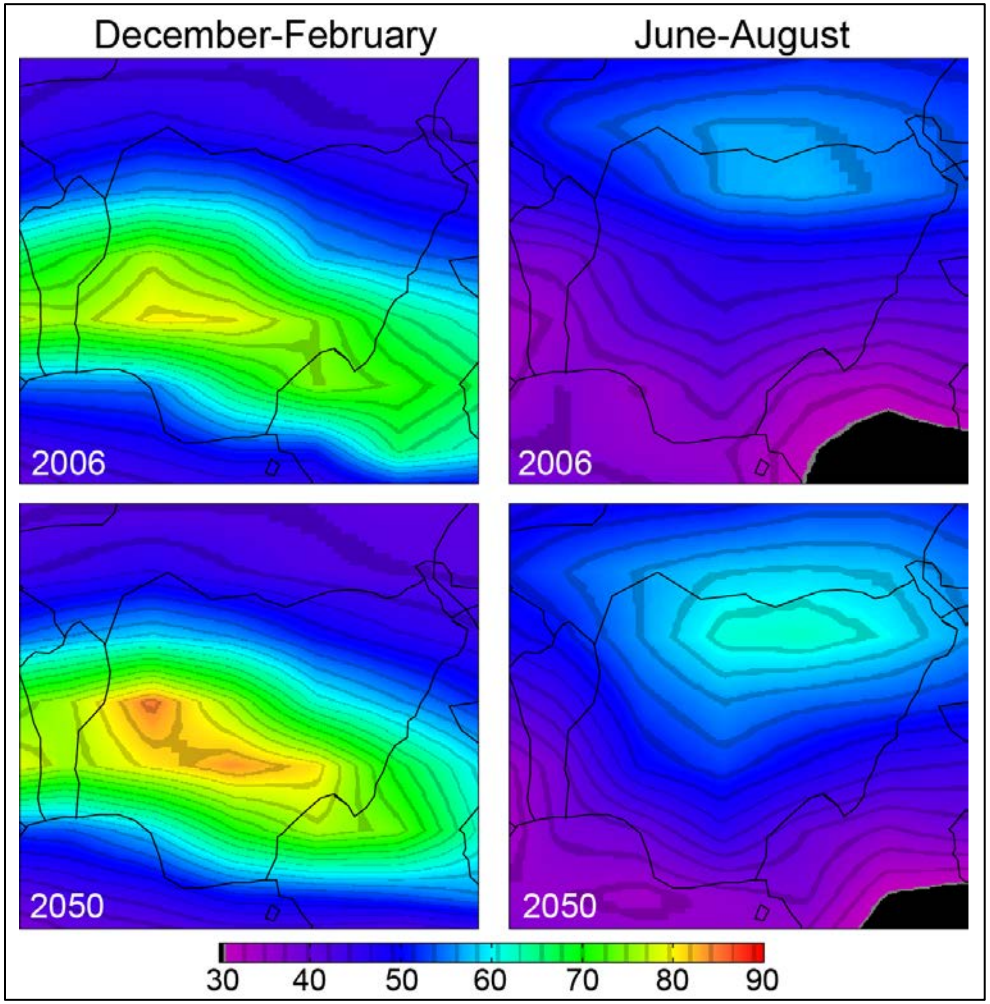
Model reproduces the spatial variability of seasonal mean near-surface O_3 in W. Africa

Use GEOS-Chem to link **O_3** air quality with **human health**

Ozone Air Quality Implications

Values of **MDA8 O_3 exceed 80 ppbv** in south-central Nigeria in DJF

GEOS-Chem surface mean MDA8 O_3 [ppbv]



Current (2006) MDA8 ozone

Anthropogenic emission contribution to MDA8 O_3 is low (7 ppbv)

Ozone production efficiency (OPE) is < 5 mol/mol in DJF compared with 9 mol/mol for the US in July

Future (2050) MDA8 ozone

1) **RCP Scenario:**
   Modest economic growth and strict emission controls
   4- fold increase in **NO_x** emissions
   5-6 ppbv increase in **MDA8 O_3**

2) **Alternate Scenario:**
   Rapid economic growth and no emission controls
   15-fold increase in **NO_x** emissions
   14-16 ppbv increase in **MDA8 O_3**

Concluding Remarks

Space-based observations show **high** concentrations of **formaldehyde, glyoxal, and methane** associated with vehicle and back-up generators in **Lagos** and oil and gas extraction in the **Niger Delta**.

GEOS-Chem **NMVOC and methane *a posteriori* emissions** constrained with satellite and aircraft observations are at least a **factor of 3 higher** than *a priori* emissions.

Severe ozone air pollution in winter is seen with the space-based Tropospheric Emission Spectrometer and reproduced in GEOS-Chem.

According to GEOS-Chem **anthropogenic emissions** in Nigeria are only responsible for **7 ppbv MDA8 O_3**.

GEOS-Chem **MDA8 O_3 exceeds 80 ppbv in winter** and future economic development that includes a transition to more efficient energy sources would add to it.

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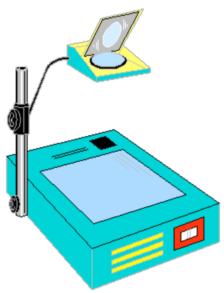
Atmospheric Chemistry Modeling Group
(acmg.seas.harvard.edu)



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Supplementary Slide

GEOS-Chem atmospheric composition after applying emissions corrections