IMPLICATIONS OF CO BIAS FOR OZONE AND METHANE LIFETIME IN A CCM

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CO bias: what does it tell us?

- Low bias in CO at high latitudes is a common CCM feature: consistent with CH$_4$ lifetime underestimate

- To what extent is low CO a symptom or cause of low OH?
  - Low CO emissions driving low CO, high OH? or
  - Other biases driving high OH driving low CO?

- What are the implications for ozone and methane?

Naik et al. (2013)
Models and Methods

- Use chemistry options of varying complexity in GEOS-5 to quantify impact of specific CO drivers:
  - **Full Chemistry:**
    - radiatively coupled stratospheric and tropospheric chemistry
    - >100 species
  - **Tagged CO:**
    - Computationally efficient
    - CO tracers tagged by source type
    - specified OH, CH$_4$, biogenic hydrocarbon oxidation
    - Isolate impact of specific source and OH adjustments
  - **CH$_4$-OH-CO parameterization**
    - Feedback between OH, CH$_4$, and CO
    - Specify methane, ozone, NOt, etc.
    - examine sensitivity of CO and OH to biases in these inputs
Latitudinal gradient of CO

March-Aug. model vs. GMD CO: Sensitivity to Asian anthro. emiss

- largest absolute bias in NH Spring/Summer
- increasing mid-high latitude emissions reduces NH bias w/ little impact on SH
Source Contributions

- increasing NH emissions reduces total and interhemispheric (IH) gradient biases

March-Aug Tracer Sensitivity

**March-Aug Tracer Sensitivity**

**Fullchem: high emis**

**Fullchem: ACCMIP**

- TotCO
- Asian anth
- N Am, Eu anth
- Trop BB
- Siberian BB

Higher Emiss
Source Contributions

- Global OH decrease reduces global bias
- Decreasing NH OH lowers IH & global bias

March-Aug Tracer Sensitivity

-5% OH
-10% OH
-20% NH OH

-20% NH OH

Fullchem: high emis
TagCO
Fullchem: ACCMIP
500mb CO Comparison to MOPITT

- Increasing Asian anthro & boreal BB emission, or decreasing NH OH both reduce negative NH bias
- Positive bias over Asian source regions for Asian and boreal emissions increase
Impacts of CO emission increase

- Ran GEOSCCM full chemistry with increased Asian anthropogenic & boreal biomass burning emissions
- reduces CO bias compared to surface obs
- ~3% increase in CH$_4$ lifetime against OH: OH decreases 5% in NH, 1% in SH
  - small compared to the 20% reduction in N. hemisphere OH needed to correct CO bias for base emission case

Next step: examine other model biases
- Can they drive CO bias via OH?
Impact of Water Vapor Bias

- high bias in water vapor
- Adjust H₂O in CH₄-OH-CO parameterization to better match AIRS
- Lower H₂O → lower OH → 12% increase in CH₄ lifetime

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<th>Annual, (Mar-Aug)</th>
<th>S. Hemisphere</th>
<th>N. Hemisphere</th>
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<tbody>
<tr>
<td>ΔOH (%)</td>
<td>-11 (-9)</td>
<td>-13 (-14)</td>
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<tr>
<td>ΔCO (%)</td>
<td>+9 (+9)</td>
<td>+6 (+6)</td>
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Impact of Tropospheric O$_3$ Bias

- Replace modeled O$_3$ w/ GMAO O$_3$ assimilation in the troposphere in CO-OH-CH$_4$ parameterization

- largest O$_3$ decrease in the upper troposphere; increase in tropical lower troposphere $\rightarrow$ net increase in OH

- 9% decrease in methane lifetime; small impact on CO
Conclusions & Future Work

• Effects of removing NH CO bias:
  • w/ increasing high latitude emissions has small impact on methane lifetime
  • w/ decreased OH requires shift in inter-hemispheric gradient of OH
  • H₂O bias increases global mean OH, while tropospheric O₃ bias decreases it
    • Neither bias alone explains CO gradient bias
  • Combination of H₂O bias reduction and emissions could explain CO bias

• Future work
  • CO sensitivity to overhead ozone, NOx, isoprene, convection
  • Quantify radiative forcing associated with each possible correction to CO bias
Impact of Tropospheric O$_3$ on OH & CO

- GEOSCCM tropospheric O$_3$ column compared to OMI/MLS climatology [Ziemke et al., 2011]: high bias in NH, low bias in SH
- Bias also seen in ACCMIP multi-model mean [Young et al., 2013]
- GMAO ozone assimilation incorporates OMI total O$_3$ column and MLS stratospheric O$_3$ profiles into GEOS-5
- Run CO-CH4-OH parameterization with GEOSCCM ozone, then rerun replacing tropospheric ozone with assimilated ozone
- 9% decrease in methane lifetime

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<tr>
<td>$\Delta$OH (%)</td>
<td>+10 (8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta$CO (%)</td>
<td>-3 (-3)</td>
<td></td>
<td>-1 (-1)</td>
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*Surf. CO & trop OH changes from $\Delta$O$_3$*