Interannual Variability and Trends of $CH_4$, CO and OH using the Computational-Effectively CH$_4$-CO-OH (ECCOH) Module

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Introduction
- Methane (CH$_4$) is the second most important anthropogenic greenhouse gas (GHG). Its 100-year global warming potential (GWP) is 34 times larger than that for carbon dioxide. The 100-year integrated GWP of CH$_4$ is sensitive to changes in hydroxyl (OH) levels.
- Oxidation of CH$_4$ and carbon monoxide (CO) by OH is the main loss process, thus affecting the oxidizing capacity of the atmosphere and contributing to the global ozone background.
- Limitations of using archived, monthly OH fields for studies of methane’s and CO’s evolution are that the feedbacks of the CH$_4$-CO-OH system on methane, CO and OH are not captured.

In this study, we employ the computationally-Effectively CH$_4$-CO-OH (ECCOH) module (Elshorbany et al., 2015) to investigate the nonlinear feedbacks of the CH$_4$-CO-OH system on the interannual variability and trends of the CH$_4$-CO-OH system.

Modelling Approach
The ECOOH module (Elshorbany et al., 2015) is implemented within the NASA GEOS-5 Chemistry Climate Model (Rienecker et al., 2008; Pawson et al., 2008; Olt et al., 2010; and Molod et al. (2012)).

Model Scenarios:
  Resolution: 2.5° x 2.5° (longitude x latitude), 72 hybrid layers from the surface to 0.01 hPa.
- CH$_4$ emissions: Transcom (Pata et al., 2011) CTL scenario (only anthropogenic emissions vary)
- Chemistry: Fully interactive CH$_4$-CO-OH system, in which OH is accurately predicted by a set of high-order polynomials in meteorological variables (i.e., pressure, temperature, cloud albedo), solar irradiance variables (i.e., ozone column, surface albedo, declination angle, latitude) and chemical variables (e.g., CO, CH$_4$, NO, O$_3$, H$_2$O, and various VOCs). The computational cost of simulating tropospheric OH is reduced by about a factor of 500 when the full O, NO, VOC chemistry is replaced by the parametrization of OH (Sprykovsky et al., 1990; Duan et al., 2006). The losses of methane and CO in the ECOOH chemistry module are determined by their reaction with tropospheric OH. Additional losses of methane in the stratosphere occur by reactions with OH, Cl, and O$_3$. Hence, their distributions are simulated using archived, monthly fields. CH$_4$, CO, and OH tracers are radially inactive.
- $E_{CO}$ Vary: Similar to Base but CH$_4$ natural emissions vary annually (TransCom EXTRAs emissions scenario)
- $E_{CH4}$ Vary: Similar to Base but biomass burning (BB) CO emissions vary annually.
- $E_{NOx}$ Vary: Similar to Base but the excepted, archived chemical variables (e.g., VOCs, NO$_x$) used as input to the parametrization of OH are annually varying.
- AllVary: Annually varying methane and CO emissions from all sources and annually-varying OH constraints.

Results and Discussion
- Large Scale Interannual Variations in Methane, CO, and OH
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Spatial and Temporal Distributions of the Loss Rates of Methane and CO
- CO loss rate from the AllVary scenario is relatively higher than observed over Asia.

Interventional Impact on the variation of methane loss rates
- CO loss rate from the AllVary scenario shows much higher variability that reaches up to ~20% compared to ~5% in the Base scenario.

Conclusion
- The nonlinear effects of the CH$_4$-CO-OH system produce significant fluctuations in methane’s growth rate over our study period of ~4 ppbyr.
- CO loss rate from the AllVary scenario shows much higher variability that reaches up to ~20% compared to ~5% in the Base scenario.

Fig. 1: Deviations of tropospheric, mass-weighted OH, CO and methane (12 month running mean) from the Base (left) and AllVary (right) scenario. Note the different scales of the years.

Fig. 2: Atmospheric methane growth rate plotted by average of 2000 model results from several scenarios. The shaded area represents the difference between the $E_{CO}$Vary and AllVary scenarios and it illustrates the importance of non-linear components of the CH$_4$-CO-OH system on methane's growth rate.

Fig. 3: Annual mean measured and simulated surface methane levels by different scenarios. Vertical line represents the standard deviation of the measured annual mean.

Fig. 4: Annual mean CO (ppbv) from several scenarios and observations at six GMD stations. Vertical lines represent the standard deviation of the measured annual mean.

Fig. 5: Seasonal mean (1988-2007) mass-weighted tropospheric CO loss rates (ppbyr) from the Base scenario and different perturbation scenarios (JJA=July-August-September).

Fig. 6: Seasonal mean standard deviation of tropospheric methane loss rates (ppbyr) from the Base and AllVary scenarios.

Fig. 7: Seasonal mean (1988-2007) mass-weighted tropospheric CO loss rates (ppbyr) from the Base scenario and different perturbation scenarios (JJA=July-August-September).

References