General requirements/recommendations of implementing transport/removal tracers for AeroCom Phase III experiments

(Document prepared by Mian Chin, <u>mian.chin@nasa.gov</u>, February 26, 2019)

In order to diagnose the inter-model differences and the inter-annual variability of characteristics in transport and removal processes for the current AeroCom Phase III model experiments, it is important to implement common tracers of transport and dry/wet removal across all models for all simulated years. These requirements are described below. One-year spin-up is recommended.

1. Transport tracer: CO

We will use CO with prescribed emission and a 50-day lifetime (exponential decay rate = $2.315 \times 10^{-7} \text{ s}^{-1}$) as a common transport tracer for all models and for all simulated years. Sources of CO are from (1) direct emissions from anthropogenic and biomass burning emissions, (2) production from non-methane volatile organic compounds (NMVOC) oxidation, and (3) from methane oxidation. To simplify the tracer implementation, we treat the atmospheric production of CO from all NMVOC oxidation in a manner of direct emission, as described below.

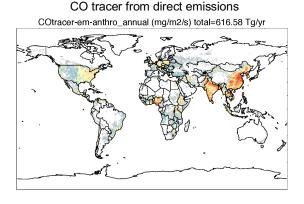
- Prescribed sources:
 - CO from anthropogenic (anthro) emissions: CMIP6, 2010, annual total=617.2 Tg/yr
 - CO from biomass burning (bb) emissions: CMIP6, 2010, annual total=336.8 Tg/yr
 - CO from anthro NMVOC oxidation: Assuming it is in the order of 0.20 of the direct anthropogenic emission of CO (Bian et al., 2007). Annual total = 123.4 Tg/yr
 - CO from bb NMVOC oxidation: Assuming it is in the order of 0.11 of the direct biomass burning (bb) emission of CO (Bian et al., 2007). Annual total = 37.1 Tg/yr
 - CO from biogenic (bio) NMVOC oxidation: Assuming a CO yield of 0.2 from the oxidation of isoprene, monoterpene, and other biogenic NMVOC species (Bian et al., 2007). The CO from biogenic NMVOC is calculated based on the 2010 NMVOC emissions in the GMI model with an annual total of 254.5 Tg/yr
 - CO from CH₄ oxidation: assuming a fixed uniform CH₄ concentration of 1760 ppbv and a CH₄ decay rate = 3.73×10^{-9} s⁻¹ (lifetime 8.5 years) to produce CO with a molar yield of 0.86
 - Reference: Bian, H., M. Chin, S.R. Kawa, B. Duncan, A. Arellano, and P. Kasibhatla, Sensitivity of global CO simulations to uncertainties in biomass burning sources, J. Geophys. Res., 112, D23308, doi:10.1029/2006JD008376, 2007

The monthly CO sources from direct anthropogenic and biomass burning emissions and from anthropogenic, biomass burning, and biogenic NMVOC oxidations (note the different spatial resolutions between anthropogenic and biomass burning sources that are kept as the same resolution as the corresponding CMIP6 emissions) can also be downloaded at https://tropo.gsfc.nasa.gov/gocart/products/xchange/aerocom/aerocom3/COtracer/:

- *COtracer-em-anthro_monthly_0.5x0.5.nc* (CO from direct anthro emission)
- COtracer-em-bb_monthly_0.25x0.25.nc (CO from direct bb emission)
- COtracer-em-anthronmvoc_monthly_0.5x0.5.nc (CO from anthro NMVOC oxidation)
- COtracer-em-bbnmvoc_monthly_0.25x0.25.nc (CO from bb NMVOC oxidation)
- COtracer-em-bionmvoc_monthly_0.5x0.5.nc (CO from bio NMVOC oxidation)

Total source of CO (excluding CO from CH_4 oxidation) as a transport tracer is 1368 Tg/yr, as listed in the table below. **Figure 1** plots the annual average of the five CO sources treated as "emission".

Source	Direct emission	NMVOC oxidation	Total (Tg yr ⁻¹)
Anthropogenic	616.6	123.3	739.9
Biomass burning	336.8	37.0	373.8
Biogenic		254.5	254.5
Total	953.4	414.8	1368.2



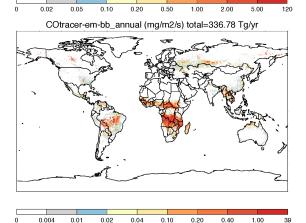
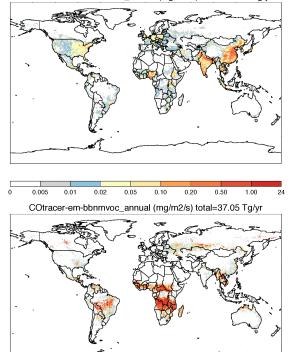


Figure 1. Prescribed sources of CO transport tracer to be implemented in the AeroCom Phase III model experiments. Left column: annual averaged direct emission rates of CO from (top) anthropogenic and (bottom) biomass burning sources. Right colum: annual averaged CO production rates from NMVOC oxidation from (top) anthropogenic, (middle)

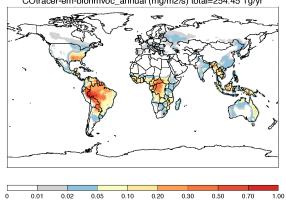
biomass burning, and (bottom) biogenic

emissions.

CO tracer from NMVOC oxidation COtracer-em-anthronmvoc_annual (mg/m2/s) total=123.32 Tg/yr



0.0004 0.001 0.002 0.004 0.01 0.02 0.04 0.10 4.31 COtracer-em-bionmvoc_annual (mg/m2/s) total=254.45 Tg/yr



2. Deposition tracer: ²¹⁰Pb (lead-210)

²¹⁰Pb is formed from ²²²Rn decay and attached to fine-mode aerosols that will experience the same removal processes as soluble aerosols. Prescribed emissions of ²²²Rn and removals of ²²²Rn and ²¹⁰Pb are listed below.

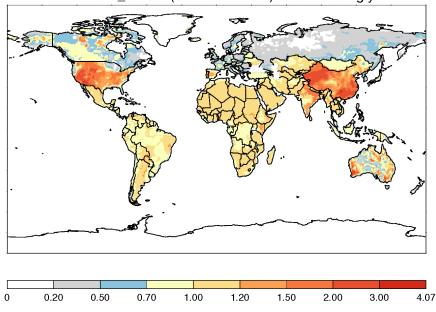
- ²²²Rn emission from land: The prescribed monthly varying ²²²Rn emission dataset from Zhang, B. et al., 2019 (modified from Zhang K. et al., 2011) will be used for all simulations. Total annual emission is 14.4 kg/yr.
- ²¹⁰Pb production from the ²²²Rn radio-active decay: A fixed first order decay rate of ²²²Rn at 2.11x10⁻⁶ s⁻¹ (equivalent to 5.5 days of lifetime or 3.8 days of half-life) is prescribed to produce ²¹⁰Pb. No other removal of ²²²Rn.
- ²¹⁰Pb removal: the dry and wet deposition should be implemented in the models in the way as if it were sulfate.
- Reference: (1) Zhang, B., et al., Simulation of Radon-222 with the GEOS-Chem global model: Emissions, Seasonality, and Convective Transport, to be submitted to Atmos. Chem. Phys., 2019; (2) Zhang, K., et al., Radon activity in the lower troposphere and its impact on ionization rate: A global estimate using different radon emissions, Atmos. Chem. Phys., 11(15), 7817–7838, doi:10.5194/acp-11-7817-2011, 2011.

The monthly ²²²Rn emission from Zhang B. et al. 2019 (modified from Zhang K. et al., 2011) can also be downloaded at

https://tropo.gsfc.nasa.gov/gocart/products/xchange/aerocom/aerocom3/Rn222/

Rn222-em_monthly_0.5x0.5.nc

Figure 2 shows the annual average ²²²Rn emission rate and its spatial distribution.



Rn222-em_annual (atoms cm-2 s-1) total=14.15 kg/yr

Figure 2. Annual averaged ²²²Rn emission rate. (Note: 1 mole ²²²Rn = 222 g = 6.023x10²³ atoms.)