Simulation of Carbonyl Sulfide (COS) to better understand the urban biosphere signal

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Background
Currently, anthropogenic CO2 emissions over urban regions can be calculated in several ways: 1) bottom-up approaches (or inventories) based on energy consumption within city limits and emission factors that depend on type of fuel and processes, 2) using 13CO2 as tracer for fossil CO2, and 3) subtracting the biosphere signal from observation (measured CO2 data). All of these approaches have their limitations. Given the immense amount of time and resources needed to develop inventories (1), generic emission factors and data assumptions are often used which result in a high degree of uncertainty. Additionally, temporal extrapolation and spatial redistribution lead to further uncertainties. Albeit 13CO2 is an ideal tracer for fossil CO2 because 13C is entirely lost to radioactive decay in fossil fuels, the high costs and technological requirements of radio isotope measurements make method (2) hardly reproducible in the long term and high frequency required to monitor urban emissions. There are many biosphere models that can be used to determine the biosphere signal to apply method (3), but it is not always clear which one has the best approximation of net ecosystem exchange (NEE) and the differences are significant.

Abstract
We suggest that COS can be used to determine which ecosystem model best represents the biosphere signal. Just like CO2, COS is taken up by photosynthesis but is not given off in respiration and can thus be used as a trace gas to estimate GPP. We begin with COS surface fluxes provided by Sill and CASA, regressed to lower resolution using NDVI values, for a 9, 3, and 1 km-resolution domain over the Bay Area of San Francisco and part of the San Joaquin Valley. Simulations using the atmospheric model WRF provide the meteorological data, which along with the COS fluxes, are used to run the transport model STEM over a 28-day period in March 2015. Simulations of COS mixing ratios based on the various surface flux models are compared to observed by Vulcan inventories from several locations. The model that best represents COS uptake consequently also provides the most accurate simulation of CO2 biosphere signal, and can be used to estimate fossil fuel CO2 emissions.

Methods

Domain

Calculating COS surface fluxes based on NDVI

Model
WRF
Model version: 3.7.1 (August 13, 2015)
Simulation period: March 2-25 2015
PBL scheme: Mellor-Yamada-Janjić (tke) TKE
Land surface model: NOAH
Climic: Grell-Davies scheme
STEM Sulfur Transport. di/sposition Model

Calculations:
Where:
1.84: LRU
(Simler et al 2012)
1.1: average ambient [COS]/[CO2] ratio from INTEX/NA experiment
(Blake et al 2004)

Using STEM to determine COS mixing ratios
Surface flux and drawdown (difference between 450 ppt and simulated COS surface concentrations) is shown below on left for a typical day reflecting mixed flow conditions, north-westerly winds, significant drawdown over the continent and less drawdown over the ocean. The model also showed some synoptic events in which continental air is brought to the land, and is brought back to the ocean again, showing atypical drawdowns such as is shown below on the right.

Results

Observed concentrations at Sutro Tower

\[ \text{COS flux} = \text{COS flux} \times \text{NDVI value} \]

\[ \text{COS mixing ratio} \]

Noted location.
505 ppt background included.
Amplitude: approx 20 ppt.
Wave: 24-hour variation, min 450, 461 ppt and max 503, 500 ppt, for Silli and CASA respectively.
Synoptic event happening on 3/21 after which COS concentrations rise by 20 ppt.
Potential continental influence until 21, after which marine air (less plant influence) seems more prominent.

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