Detecting Trends in Fossil Fuel CO_2 Emissions from Atmospheric Measurements of CO_2 and $^{14}CO_2$

S. Basu[1,2], J.B. Miller[2] and S. Lehman[3]

[1]Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309; 303-497-6650, E-mail: sourish.basu@noaa.gov
[2]NOAA Earth System Research Laboratory, Global Monitoring Division (GMD), Boulder, CO 80305
[3]Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO 80309

Carbon in fossil fuels is devoid of carbon-14 (^{14}C), so burning them injects ^{14}C-devoid carbon dioxide (CO_2) into the atmosphere, in contrast to the other surface fluxes of CO_2 such as wildfires and ecosystem exchange. Therefore, the depletion in atmospheric carbon-14 dioxide ($^{14}CO_2$) relative to total CO_2 can serve as a proxy for recently emitted fossil fuel CO_2. Over the past several years, we have developed the capability to estimate fossil fuel emissions by assimilating atmospheric measurements of CO_2 and $^{14}CO_2$ simultaneously in a source-sink inversion. We have presented this capability previously, using Observing System Simulation Experiments (OSSEs) to demonstrate our ability to estimate monthly and annual fluxes from the continental U.S. (ConUS) as well as smaller regions therein. We have shown that with the current network of $^{14}CO_2$ measurements, we can estimate the U.S. national total emission to within a few percent, while with a proposed enhanced network of 5,000 observations per year we can estimate monthly totals from highly emissive regions to within 5% for most months. In this work, we present our ability to estimate decadal trends in emissions from those geographical areas, with quantified uncertainties, in the presence of realistic errors in the atmospheric transport model. We evaluate our trend detection capability with the existing observation network as well as the enhanced network of 5,000 observations per year. We show that with the enhanced network, we can robustly detect a national trend consistent with Nationally Determined Contributions (NDCs) of the COP21 Paris agreement, even when our system starts from prior emissions with zero trend. This ability to estimate and verify trends using independent data will become important in the future as more and more regions implement policies to reduce their own fossil fuel emissions. Finally, we will present some preliminary fossil fuel flux estimates over ConUS using real $^{14}CO_2$ data from our existing observation network.

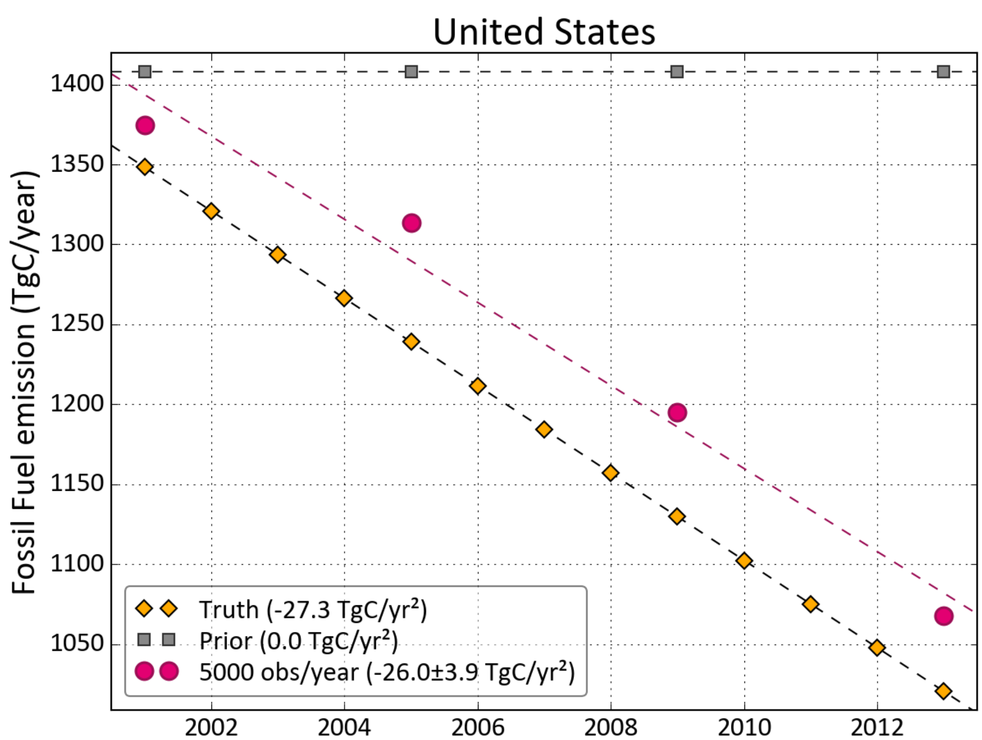

Figure 1. The performance of our inversion system in estimating fossil fuel trends over the U.S. yellow diamonds represent the "true" trend used to produce pseudo-observations, while gray squares represent the prior assumed in our inversions. Finally, pink circles are estimates from our inversion. The trend estimated by the circles is within 1 sigma of the true trend and statistically distinct from the prior trend. This performance is despite the prior being 40% off from the truth towards the end of the time period. In reality, we expect our system to perform even better, since fossil fuel inventories are typically within 10% of the true emissions for developed countries such as the U.S.