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Using an Inverse Model to Reconcile Differences in Simulated and Observed Global Ethane Concentrations and Trends Between 2008 and 2014

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Ethane (C_2H_6) is the most abundant nonmethane hydrocarbon (NMHC) in the troposphere and plays an important role in atmospheric chemistry. In the presence of nitrogen oxides (NO_x), emissions of C_2H_6 can result in the production of ozone (O_3), which is detrimental to human health, can decrease crop yields, and has a positive (warming) radiative effect on the climate. We use a global model, TOMCAT, and an inverse model, INVICAT, to estimate emissions of C_2H_6 between 2008 and 2014 by assimilating surface flask observations. We find that baseline global emissions in 2008 need to increase by a factor of 2.04–2.11 in order for the model to capture C_2H_6 observations, indicating large biases in current emission inventories. Most of this increase occurs over North America and Eurasia, with temperate North American emissions accounting for 23–26% of the total global emission increase and temperate Eurasian emissions accounting for 35–37%. Further to this, recent peer-reviewed analysis of long-term observational records shows an increase in C_2H_6 in the Northern Hemisphere since ∼2009. Our results indicate that annual global emissions of C_2H_6 have increased at a rate of 0.27 ± 0.54–0.33 ± 0.44 Tg/yr^2 between 2008 and 2014. A statistically significant positive trend of 0.20 ± 0.11–0.24 ± 0.13 Tg/yr^2 ($p \leq 0.01$) is found in temperate North America, resulting in emissions that are 31–32% larger in 2014 than in 2008. We also evaluated the effect of the improved C_2H_6 emissions on other chemical species using the TOMCAT full chemistry model. The near doubling of the C_2H_6 emissions led to increases in acetaldehyde (CH_3CHO), peroxyacetyl nitrate (PAN), and O_3. Several models have shown negative biases in CH_3CHO and improving C_2H_6 emissions may offer some improvements in the simulation of this species. We used methane-to-ethane emission ratios (MERs) calculated from observations made near oil and natural gas production facilities to find that that methane emissions in the United States could have increased simultaneously at a rate of 2.18 ± 1.09 Tg/yr^2 between 2008 and 2014. Our results corroborate previous studies' conclusions that a rapid increase in oil and natural gas production in United States over this time period is likely a large driver of the change in emissions.