Reply to Hristov et al.: Linking methane emissions inventories with atmospheric observations

Hristov et al. (1) argue that our study "provides a comprehensive, quantitative analysis of anthropogenic methane sources," but that the conclusion "that US EPA [US Environmental Protection Agency] estimates for livestock methane emissions are grossly underestimated appears to be unsubstantiated by . . . [a] 'bottom-up' approach" outlined in their letter.

In this reply, we discuss the information provided by atmospheric methane data about methane emissions, and comment on the challenge of connecting "bottom-up" and "top-down" estimates, a conclusion shared Hristov et al. (1).

Our study (2) used both near-surface and airborne atmospheric measurements of CH_4 concentrations to characterize the total mass of methane added to the atmosphere by surface emissions, discretized in space and time. We conclude that total United States methane emissions in 2007–2008 were 33.4 ± 1.4 TgC/yr (44.5 $TgCH_4$/yr), 45–57% above the most recent US EPA baseline estimate for those years (3). Furthermore, we estimate "the magnitude of emissions with spatial patterns similar to animal husbandry and manure" (2) at 12.7 ± 5.0 TgC/yr (16.9 $TgCH_4$/yr), 11–156% above baseline EPA estimates for those sectors (best estimate 84% above EPA). Our conclusions are generally consistent with previous more limited top-down studies examining total United States (e.g., ref. 4) and regional livestock/manure methane emissions (e.g., ref. 5).

Hristov et al. (1) argue that "the validity of this 'top-down' approach can be verified by a relatively simple 'bottom-up' method using current livestock inventories and enteric or manure methane emission factors." The authors build this estimate for enteric fermentation by multiplying the US Department of Agriculture (USDA) livestock inventory estimates for 2013 (note that our study covers 2007–2008), by "assumed" feed dry matter intake and "assumed" methane production rates. "With the above assumptions," Hristov et al. estimate methane emissions from enteric fermentation comparable to the US EPA's inventory for 2011. Similarly, the authors use USDA livestock inventories and Intergovernmetal Panel on Climate Change (IPCC) (6) manure methane emissions factors to estimate United States manure emissions that are 35% lower than EPA inventory numbers.

The estimates of Hristov et al. (1) therefore require a series of assumptions, for which errors compound as several factors are multiplied and added. Feed matter intake and emission factors both have substantial uncertainties (6), as do the IPCC manure methane emission factors (6). Given these uncertainties, which are inherent in all bottom-up inventories, we strongly disagree that "the validity of [our] 'top-down' approach can be verified" using the Hristov et al. estimates (1).

The method we applied is especially suited to quantifying large-scale total emissions, and uncertainties increase for sector- and region-specific estimates [as outlined above and in our study (2)]. Even in light of these uncertainties, the total emissions with spatial patterns consistent with animal husbandry are still likely to be substantially above EPA estimates. Conversely, bottom-up inventories are strongest at detailing individual emission types, but uncertainties compound at larger scales, such as the national scale examined here. This difference is precisely why we argue that careful, detailed assessments are needed to reconcile the emissions clearly visible from atmospheric observations with bottom-up emissions inventories. Hristov et al. (1) also note a "need for a detailed inventory . . . to more accurately estimate . . . emissions." On this point we strongly agree.

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The authors declare no conflict of interest.

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