Global Inventory of Natural Gas Geochemical Measurements for Improved Atmospheric Methane Modeling

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Introduction
Methane (CH₄) is a potent greenhouse gas (GHG) which accounts for ~20% of the GHG radiative forcing over the industrial era (Dlugokencky et al., 2011). The rise in atmospheric CH₄ has been non-linear, with a period of relative stability from 1997-2007, followed by a renewed increase since 2008 (Nisbet et al., 2014; Fig. 1). The reasons for these variations are not completely understood, partly because specific contributions from natural and anthropogenic sources remain unclear (Fig. 2).

Why δ¹³C end-members?
Measurements of δ¹³C can be used to constrain global methane sources (Fig. 1). However, the global-weighted end-member values are not well characterized. By knowing where the end-member values fall horizontally on the scale (Fig. 3), we can estimate how much each of the sources contribute to overall methane concentrations in the atmosphere.

Database
We compiled a global inventory of natural gas molecular and isotopic measurements from the peer-reviewed literature and government reports. The inventory contains data from 45 countries, 179 basins, 597 geological formations, and 1079 unique samples. On a country-level basis, the data represent 79% of world natural gas production.

Results
Data for different types of natural gas production (conventional, coal and shale gas) are presented in Figs. 5 and 6. Note how CH₄-δ¹³C values are skewed to more negative values, because of the importance of isotopically-depleted microbial gas. By weighting the data by continent-level gas production (BP, 2015) integrated over the years 2000-2014, we obtain a global, production-weighted average of -43.9 ± 0.3 ‰ (bootstrapped 95% confidence intervals) for the CH₄-δ¹³C of conventional gas. This value is considerably lower than the value (-40 ‰) typically used in global, top-down models of the global CH₄ budget. This could have a major consequence in methane emissions estimates (Fig. 7).

References
Nisbet et al. (2014); Science 343: 403-405.
Bousquet et al. et al. (2006); Global Biogeochemical Cycles 18(6): GB4004.
Source: Figure 3: Mass balance of three CH₄ source categories. “Microbial” includes wetlands, ruminants, rice, landfills, and termites.

Figure 1: Global time series plots of CH₄ and δ¹³C of CH₄ from 1999-2014. The recent rise in CH₄ is concurrent with a decrease in δ¹³C of CH₄.

Figure 2: Illustration of uncertainties in attribution of global CH₄ sources. L to R: fossil fuels, ruminants, rice production, landfills, wetlands, and biomass burning.

Figure 4: Global sample count of CH₄-δ¹³C for all types of natural gas and coal production.

Figure 5: Generic classification of natural gases in the database, according to Whiticar (1999).

Figure 6: Visual representations of three analyzed parameters (δ¹³C, δD, and C₂H₆) and three types of production (conventional, shale, coal) in the global database. Statistical weighting of the geochemical parameters by basin-level production is still in progress.

Figure 7: Time series plot of modeled CH₄ emissions from different sources. The recent increase in global CH₄ can be attributed primarily to microbial emissions. Model adapted from Schwietzke et al. (2014) assuming -45 ‰ as the value for integrated fossil fuel methane emissions.