Supplementary Information

Methods Summary:

SCIAMACHY XCH_4 retrievals [Frankenberg et al., 2011] have been gridded at 1/3 degree resolution for the long-term averages as shown in Figure 1. Small-scale elevation features can have an impact on XCH_4 as they affect the fractional contribution of the depleted stratosphere (hence generally lower XCH_4 over mountains). The anomaly maps were created by fitting a 3rd order polynomial through the surface elevation – XCH_4 dependence in the region of interest and subtracting this fit from the original XCH_4 dataset (detailed below "Surface topography impact on SCIAMACHY"). WRF-Chem output was converted into XCH_4 and gridded at 1/3 degree as well. Statistical comparisons made in Figure 2 are done after gridding at 1/2 degree for each season separately. Figure 1c depicts a smoothed Edgar emission map using a Gaussian 2D filter with 0.3 degrees as 1-sigma.

The WRF-Chem v3.5 simulation employed four interactive, telescoping nested grids. Horizontal grid spacing ranged from 16.2 km to 600 m and 59 vertical levels were stretched with height above the surface to a domain top of ~ 50 hPa. Initial and boundary conditions were derived from the NCEP (National Centers for Environmental Prediction) Eta model data set [NCEP 2013] and the model fields on the three largest grids were gently nudged to the Eta model six-hourly analyses. Six model simulations were run for six days, producing a total of 36 simulated days. Each simulation was initialized at 0000 UTC on the 27th of every other month in 2012, starting on 27 January. (In the simulation that began on 27 November 2012, some Eta model forecast fields were substituted for the analysis fields because of missing information in the archived analysis fields at three of the analysis times.)

The WRF-Chem tracer with emissions option was chosen with an initial concentration of 0.0001 ppm throughout the domain. Anthropogenic CH_4 emissions were mapped onto the model grids from the EDGAR v4.2 total global emissions for 2008 [EDGAR 2010] (recent years not available). Hourly emissions were derived assuming a constant release rate through the year and that all emissions were released into the model's lowest grid level. CH_4 emitted on the smallest grid was tracked in separate tracers than CH_4 emitted on the larger grids. Model CH_4 column enhancement was constructed by a pressure weighted integration of the simulated CH_4 profile.

Surface topography impact on SCIAMACHY

The Rocky Mountains exhibit high variability in surface elevation. As methane in the stratosphere is depleted, its fractional contribution to the total column impacts XCH_4, even if tropospheric abundances remain constant. This behavior typically results in lower XCH_4 over highly elevated sites, as can be seen in Fig. S1. In the raw SCIAMACHY data, considerably lower XCH_4 can be observed to the northeast of Four Corners (top-left panel), specifically in areas with highest surface elevations of more than 3km (top-right panel). Here, we correct for these altitude driven variations by fitting a 3rd order polynomial through the elevation-XCH_4 relationship in the area of interest. The corresponding polynomial fit, as shown in its spatial distribution in Fig. S1 is subsequently subtracted from the raw SCIAMACHY data to derive an elevation corrected XCH_4 distribution (Fig. S1). Two aspects are important to note. First, some spurious negative anomalies in the raw data are removed, meaning that they are related to elevation. Second, the overall enhancements in the corrected map are of similar magnitude as in the raw data (note the smaller range of the color-scale in the anomaly plot).

Representativeness of simulated days to the full calendar year:

We assess the representativeness of the simulations with two methods. First, we leverage the TCCON observations to query whether the simulated days produce a column methane anomaly comparable to a full year of observations. Figure 3 illustrates that indeed the subset of 30 days (black line) matches closely with the full year of observations (black circles). This figure indicates that, from a methane emissions/transport perspective, these 30 days accurately capture the full annual dynamic, making comparison of annual data with these simulated days appropriate. Second, we consider the impact of only comparing one set of 6 simulated days with the SCIAMACHY data. This test is summarized in Fig. S6, where the scaling factor for each individual simulation run is plotted. It can be seen there is greater scatter, as is expected when considering only on six-day simulation with annual observations. As a whole though, selecting one six-day simulated time frame produces a result within the statistical uncertainty of the annual estimate (excepting July, where some combination of transport and emissions lead to a much larger scaling factor).

Linear fitting of SCIAMACHY and WRF-Chem simulations:

We use the fitexy method to account for uncertainties in both the ordinate and abscissa, as described previously [Kort et al., 2008]. To approximate the uncertainty in both the observations and simulations, we calculate the standard error in each 1/2 degree grid (shown for each point in Fig. 2). Each data-point represents a 0.5x0.5 degree grid box average in one of the seasonal averages computed from both SCIAMACHY and WRF-Chem data. We eliminate data points from the fit where the simulation was indistinguishable from zero (simulated enhancement < 0.5 ppb)- these points are grayed out in Figure 2. This also serves to filter out regions not influenced by the Four Corners source. The robustness of this scaling factor is demonstrated in Fig. S6, where it is shown that the slopes for individual simulation time frames are within uncertainties of that found with the whole data set. Furthermore, application of this scaling factor matches the TCCON observations (Figure 3), and the observed spatial distribution (Figure 1). We report 2σ error bars on our slopes—these are derived statistically and do not account for additional uncertainties which derive from sources such as representation error.