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Atmospheric
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Interactive comment on “Stable isotopes provide revised global limits of aerobic methane emissions from plants” *by* D. F. Ferretti et al.

D. F. Ferretti et al.

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1. Abstract, line 4. Modified to read ∼10–40% as suggested.

2. Abstract, lines 10, 11. Included both pre-industrial and modern information in the abstract as suggested. Sentence now reads:

Our top-down approach determines that global plant emissions must be much lower than proposed by Keppler et al. (2006) during the last 2000 years and are likely to lie in the range 0–46 Tg yr^{-1} and 0–176 Tg yr^{-1} during the pre-industrial and modern eras, respectively.

Note: The ’Best Estimate’ of modern emissions is adjusted to accommodate a larger total source as discussed in point number 2 in response to S. Houweling comments.

3. Introduction. Have included a reference to the special report on the ’methane mys-

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tery' recently published in Nature as suggested.

4. Temperature dependency. This part of the discussion has been rewritten to avoid a conflict between our initial interpretation and Keppler's belief that there is a significant temperature dependence and Houweling's statement that just because there isn't yet evidence in that range we should not discount the possibility. The modified text now reads:

Large pre-industrial δ^{13}CH$_4$ variations have been partially explained by natural temperature and precipitation changes causing anaerobic and biomass burning emission variations (Ferretti et al., 2005). Even though there is no evidence yet for significant temperature dependency of methane emissions from plants over ambient ranges ($\sim$10–30°C) it is likely that during 1000–1700 AD a cooling climate with increasing moisture availability, together with changes in both anthropogenic deforestation and natural vegetation re-growth, may have combined to maintain near-constant plant emissions, thus explaining the relatively small change in “Best-Estimate" plant emissions during 1000–1700 AD (see Table 1).

5. Biomass burning and global methane budget uncertainties. Small changes in biomass burning do not actually significantly alter the isotope composition of the methane budget nor significantly affect plant emissions and our conclusions. For example, if biomass burning emissions vary by the uncertainty quoted in the Ferretti et al. (2005) Science paper ($\pm$ 1 Tg) then plant emissions change by only $\pm$ 8 Tg. To reflect these issues, and also against potential criticism that the Ferretti et al. (2005) biomass burning variations were constructed without considering the role of plants, we have inserted two new paragraphs into the Results and discussion as follows:

In our approach for constructing the “Best Estimate" of the methane budget, we use a comprehensive and very recent reconstruction of pre-industrial biomass burning emissions (Ferretti et al., 2005) that was constrained by the large atmospheric δ^{13}CH$_4$ depletion from -47 to -49 during 1000–1700 AD. While it is possible to construct a

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1000 AD budget with 85 Tg yr^{-1} of plants, as suggested by Houweling et al. (2006), and with only 15 Tg yr^{-1} of biomass burning, balancing the atmospheric variations during 1000–1700 AD requires a reduction in biomass burning to less than 10 Tg yr^{-1} by 1700 AD. However, lightning-induced wildfires alone are very likely to be more than 10 Tg yr^{-1} (Table 1, note b) so the Ferretti et al. (2005) estimate of pre-industrial biomass burning is still the most reasonable reconstruction, even with the inclusion of plant emissions into the methane budget.

The Ferretti et al. (2005) reconstruction of biomass burning is based on a top down approach in which atmospheric measurement uncertainties translate to a reconstructed biomass burning emission uncertainty of ± 1 Tg. If the biomass burning source varies by this uncertainty, then plant emissions only vary by ± 8 Tg yr^{-1}. Therefore small changes in biomass burning do not significantly affect plant emissions and our conclusions.

We also consider fossil emission uncertainties in the following text:

Considering fossil emission uncertainties (± 1 Tg yr^{-1}) in a similar way, plant emissions only change by ± 2 Tg yr^{-1}, so our conclusions are also not significantly affected by uncertainties in our postulated sources.

Other uncertainties associated with the source strength and stable carbon isotope values of each source, including the plant source isotope value, are also addressed in the following text that is inserted as a new paragraph, and by adding a new table (Table 2).

To account for the uncertainties associated with the stable carbon isotope values of each source, including that of the plant source isotope value, our approach is to consider two scenarios in which we vary the C_3:C_4 plant type ratio between 40:60 and 60:40. As well as being a plausible range of environmental change, this introduces an uncertainty in the isotopic composition of each source which is similar to that associated with bottom up estimates of the isotopic composition of each source type (Table 2a). Since the assigned isotope values of plant emissions are still not known with certainty, the range of C_3:C_4 mix allows us to gauge the effect of this uncertainty. We also consider sink uncertainties in the global methane budget so that the total aggregate sink encompasses a large range of errors (Table 2b) and is not significantly affected by estimated changes in OH between modern and pre-industrial times (Houweling et al., 2000). These source and sink uncertainties in the global methane budget cause our calculated results of revised global limits of aerobic methane emissions from plants to contain accumulated uncertainties that are reflected as a relatively large range of possible values (Table 1).

6. Completeness. The work published recently by Houweling et al. (2006) is referenced and discussed in the introduction.

7. Clarity of stable carbon isotope source signatures and uncertainty ranges. We include a new Table 2 as described above in comment 5, and rewrite part of Table 1 caption as follows:

Anaerobic and aerobic plant emissions cover a range because we allow for: (i) uncertainties in the weighted-mean value of the CH_4 sink fractionation factor between -7 and -5 (Lassey et al., 2005); and (ii) variations in the C_3:C_4 plant type ratio from 40:60 to 60:40. The resulting variation in the weighted-mean $\delta^{13}CH_4$ source signatures are: biomass burning (-19.8 to -17.2), plant (-49.8 to -48.7), and anaerobic sources (-60 to -58) (see Table 2). The fossil source signature is held constant at -40

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Table 1: Uncertainties in the global methane budget for sources (a) and sinks (b).

[a] C_3 and C_4 components from Ferretti et al. (2005), Keppler et al. (2006).
[b] Values from Lassey et al. (2005), Table II. ε_{sink} is the sink ‘kinetic isotope effect’ (KIE).
[c] Methane is largely removed from the stratosphere by various processes that discriminate against $^{13}CH_4$ leaving a minor return flux of ^{13}C-enriched methane that we ignore. Consequently, and consistently with IPCC assessments, the stratosphere is viewed as a transport-mediated tropospheric sink, a process which is isotopically neutral.
[d] If the recent Allan et al. (2006) estimate of the global chlorine sink strength is used (25 ± 12 Tg yr^{-1}) the upper limits of global CH_4 emissions from plants presented in Table 1 would decrease even further.

(a) Source $\delta^{13}CH_4$ () [a]	C_3	C_4	40:60	60:40
Biomass Burning	−25	−12	−17.2	−19.8
Aerobic Plant	−52	−46.5	−48.7	−49.8
Anaerobic	−64	−54	−58	−60

(b) Sinks[b]	(Tg yr^{-1})	ε_{sink} ()
OH	490 ± 85	−4.65 ± 0.75
Soil	30 ± 15	−20 ± 0.2
Stratosphere	40 ± 8	0 ± 0[c]
Chlorine	10 ± 9[d]	−60 ± 1
TOTAL	570 ± 87	−6 ± 1