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Interactive Comment

Interactive comment on "Inverse modelling of national and European CH₄ emissions using the atmospheric zoom model TM5" *by* P. Bergamaschi et al.

P. Bergamaschi et al.

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Reply to review of Sander Houweling

GENERAL COMMENTS

(1) Finnish emissions

The CH4 wetland emissions [Walter and Heimann, 2000; Walter et al., 2001a; Walter et al., 2001b] used in our study as a priori estimate represent a multi-annual average over the years 1982-1993. Certainly inter-annual variations are important. However, the differences among different inventories are still much larger and considerable differences in their spatial distribution are apparent (e.g. compare Kaplan [2002] and



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Walter et al. [2001a]). The original number of 260 Tg/yr from Walter et al. [2001a] has been downscaled in our study to 175 Tg/yr, as Walter et al. [2001a] argue that their value is probably overestimated (as the six data sets used for their global extrapolation show relatively high emissions). Various other bottom-up and top-down studies range from 80 - 230 Tg / yr [Walter et al., 2001a]. Houweling et al. [2000] estimated a pre-industrial wetland source of 130-194 Tg/yr, and it seems likely that the reduction of CH4 emissions by cultivation and drainage since preindustrial times may have been approximately compensated by the increase of CH4 emissions induced by the rise of temperature [Walter et al., 2001a]. Summarizing, a value of 175+/-50 Tg/yr seems consistent with our current understanding of wetlands and the global CH4 cycle.

Certainly the main focus of the Walter et al. [2001a] process-based model / inventory is to provide reasonable estimates on the global scale, rather than on smaller regional scales. However, to our knowledge there are no better inventories available today (with global coverage).

Minkkinen et al. [2002] estimated the present-day CH4 emissions from Finnish peatlands to 0.6 Tg CH4/yr, based on detailed statistical data for 10 different peatland types. Their estimate is considered consistent with our inverse modelling derived values (total emissions for Finland -0.27... 1.30 Tg / yr) taking into account a contribution of 0.24 Tg CH4/yr form anthropogenic sources (UNFCCC value).

The main reason for the very high value for Finnish wetlands in the Walter et al. [2001a] inventory (3 Tg/yr) seems the underlying wetland distribution [Matthews and Fung, 1987]. However, recent vegetation maps, such as Corine land cover database [EEA, 2000] and the Global Land Cover 2000 database [Bartholomé and Belward, 2005] indicate much smaller wetland areas for Finland.

Further concerns have been expressed by the reviewer whether the transport model and inverse system are sensitive enough to detect the rather distant signal from Finland (as no measurements were available for 2001 for Pallas). Alternatively to the

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suggested synthetic experiments we further investigated the base functions used for our inversions. The summer months base functions from Finland (using the Walter et al. [2001a] inventory) for emissions of July and August exhibit signals e.g. at the sites Zingst (ZGT) or Baltic sea (BAL) (which are the stations closest to the Finnish wetlands) of up to 40-60 ppb for single days (daily average). Even at Schauinsland (SIL) daily average signals of up to 3.7 ppb are calculated. Obviously these strong signals are not consistent with the observations, leading the inversion to drastically reduce the contribution from the Finnish summer base functions (for comparison, the influence of winter base functions from Finland is typically below 1 ppb at BAL and ZGT). This is also reflected in the inversion based on single sites only (Table 6), where the sites ZGT, NGB, SIL, BAL lead to significant reductions of Finnish emissions.

As further evidence for the lower emissions from Finland we had presented forward simulations for year 2002 and compared them with observations at Pallas (Figure 9). Sander Houweling raised the question, whether these simulations at Pallas might be significantly influenced by emissions within the model grid cell of Pallas (which is located in the transition zoom region with $3^{\circ}x2^{\circ}$ resolution). In order to clarify this potential influence we performed a simulation where the emissions of the Pallas $3^{\circ}x2^{\circ}$ grid cell were switched off. This, however, has an only small effect on the simulated CH4 mixing ratio at Pallas, demonstrating that the signal mainly arises from the large scale influence of the Finnish wetlands (based on the Walter et al [2001a] inventory), rather than local emissions (which might be difficult to simulate). In addition, as requested, we performed forward simulations for 2002 with the a posteriori inventory of year 2001 (using scenario S1). This leads to simulated CH4 mixing ratios very close to observations. The figure will be presented in the revised version of the paper.

(2) Global constraints

In order to investigate the potential influence of the global OH levels we have generated an additional base function, in which the OH sink is simulated as negative CH4 source (similar to the approach used by Hein et al. [1997], and Houweling et al. [1999]). 5, S862–S869, 2005

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Note that in the regular source functions used in our study the OH sink is already included. The new additional OH sink base function is added to these regular base functions (according to equation (1)). In this way we investigate the influence of +/-5% deviations in the global OH field (assuming, however, exactly the same spatiotemporal OH distribution). The resulting inversions show a negligible influence only on the results for the European countries. The change of approximately +/-5% in the total global CH4 source strength (which is required in order to balance the +/-5% difference in the sink), is achieved mainly by those global regions, which cover the tropical areas (where the OH sink is largest). This confirms that the emissions derived for European countries are strongly determined by the signals related to synoptic variations (which carry information from recent emissions which have not been influenced significantly by the OH sink). A dipole behavior between Finland and Benelux-Germany-France, as speculated by the reviewer, is not apparent from these exercises. Summarizing, the OH sensitivity experiment demonstrates a remarkable stability of the results for Europe with a maximum deviation between +/-5% OH sink experiments of 0.14 Tq/yr for Finland, even smaller deviations for the other European countries and a deviation of 0.03 Tg CH4/yr for the EU-15 total. We will include a discussion of these experiments (as additional scenarios S8, S9) in the revised version of the paper.

Specific comments

Page 1012, "wetland emission total"

see our reply to the general comment (1)

Page 1018, 'alpha'

As discussed in the paper, the inversion is characterized by a very large number of observations (treated as daily averages) compared to the number of parameters (monthly emissions). We have chosen the higher temporal resolution in order to utilize the information content of individual synoptic events. On the other hand, most CH4 sources are likely to be relatively constant over one month. Combining such different time scales is likely to introduce some bias towards the observations, and in many cases subsequent 5, S862–S869, 2005

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observations are correlated. In the absence of a statistical framework for an exact treatment of such different time scales and temporal correlations we chose to introduce the weighting factors alpha. In fact, this is equivalent to scaling the covariances (see equation 10). Due to the application of equation 10, the factor alpha is implicitly included in the calculation of chi2. Indeed, we consider the data part of chi2 only in the compilation of Table 4 (intending to illustrate the mismatch between observed and simulated data). Note that we also tried one experiment with a more formal treatment of correlations between subsequent observations (as described in section 3.2.3).

Page 1016, '100% prior uncertainty '

In order to investigate a potential effect of the relatively small European/national regions on the uncertainty estimate for the EU-15 total we performed an additional inversion, where the uncertainties of all European base functions were doubled (except Finland, where we kept the original uncertainty in order to avoid negative a posteriori emissions), otherwise identical to scenario S1. The resulting a posteriori EU-15 total is 21.39 + 1.19 Tg CH4 / yr, i.e. very close to the value for scenario S1 (21.28 + 1.02 CH4 / yr). This demonstrates that the EU-15 total estimates remain very stable.

Page 1018, 'Sensitivity scenarios'

The different scenarios are already summarized in Table 4, listing all parameters which have been varied. This table will be extended including the new scenarios S8 and S9 (see reply to general comment (2))

Page 1020, 'iterative approach'

The 2-step iteration serves to exclude outliers of the data (e.g. due to measurement errors, but also due to deficiencies to simulate a certain synoptic situation (or local emissions)). The first iteration is performed using the full set of observations. The resulting model data / observations which differ more than a certain threshold (according to equation (11)) are then rejected. The second (and final) iteration is performed using this reduced set of observations. There is, however, no separation of the global and European domain, nor any double-counting of measurements.

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Page 1023, 'Figure 9'

vations and correlations for individual sites were calculated.

Page 1022, '...freedom for the parameters'

This sentence will be removed.

see reply to general comment (2)

Page 1034, 'Concerning potential implications... / Figure 10'

The sentence states that, even if inverse modelling indicates higher absolute emissions than UNFCCC values this does not mean a violation of the Kyoto targets, which are defined as relative targets compared to base year 1990.

(http://www.knmi.nl/evergreen/), where forward simulations are compared with obser-

hensive model intercomparison performed within the EVERGREEN

Instead we will refer to a compre-

project

Whether inverse modelling will be able to verify these relatively small reduction targets, certainly still needs to be demonstrated. This, and the need for further model intercomparison, will be more clearly emphasized in the revised version. Note however, that we have already mentioned the need for improvement of inversion techniques, use of different models ('ensemble inversions applying different models') and further expansion of the measurement network.

Regarding the previous studies shown in Figure 10 it should be emphasized that these were based on very limited sets of sites only (1-4 sites only, compared to >10 European sites plus >40 global sites in our study). In particular for those studies using one site only (Mace Head) it appears remarkable that already pretty reasonable estimates can be derived.

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