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Interactive comment on "Greenhouse gas emissions from Indian rice fields: calibration and upscaling using the DNDC model" *by* H. Pathak et al.

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Anonymous Referee #1 This paper deals with greenhouse gas emissions from Indian rice fields. The authors modified the widely used DNDC-model and calibrated it with data from irrigated rice fields near New Delhi. The model was linked to a GIS and used to calculate the annual methane emission from all major rice ecologies of the Indian subcontinent.

The model: (i) As I understand from the ms, the model treats nitrification as an aerobic process that stops once a soil is becoming anoxic after flooding. This is not entirely true: nitrification can occur in the rhizosphere where oxygen is leaking from the roots into the soil. This nitrification is tightly coupled to denitrification in the surrounding anoxic bulk soil and may be a potential source for N2O.

Response: DNDC simulates CH4 or N2O production/consumption through a kinetic scheme “anaerobic balloon”. The size of an aerobic balloon sitting in a soil layer is defined to be the anaerobic volumetric fraction, which is quantified by the soil redox potential (i.e., Eh). In DNDC, nitrification and denitrification, or CH4 production and oxidation, occur in a soil simultaneously. The N2O produced through nitrification outside of the balloon can diffuse into the balloon to participate in denitrification, and can be further reduced to N2. The same is true for CH4. The CH4 produced within the balloon can diffuse into outside of the balloon to be oxidized. In general, nitrification and denitrification, or CH4 production and oxidation, are both modeled in DNDC. These details have been published in former papers as cited below and are discussed in brief in the revised manuscript.

Stange F, Butterbach-BahlK, Papen H, Zechmeister-Boltenstern S, Li C, Aber J (2000) A process-oriented model of N2O and NO emission from forest soils 2, Sensitivity analysis and validation, J. Geophys. Res. Vol. 105, No. 4, p. 4385-4398.

Li C (2000), Modeling trace gas emissions from agricultural ecosystems, Nutrient Cycling in Agroecosystems 58:259-276.

Li, C., A. Mosier, R. Wassmann, Z. Cai, X. Zheng, Y. Huang, H. Tsuruta, J. Boonjawat, and R. Lantin. 2004. Modeling Greenhouse Gas Emissions from Rice-Based Production Systems: Sensitivity and Upscaling. Global Biogeochemical Cycles 18: GB1043, doi:10.1019/2003 GB002045.

(ii) The model does not include methane oxidation. Methane oxidation is subject to other controls than methane production and may display different seasonal patterns in different rice ecologies.

Response: As above-stated, DNDC does simulate CH4 oxidation.

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(iii) The most severe deficit is the lack of an iron-reduction routine. The amount of iron may differ largely between different soils, and evidence is increasing that reducible iron is the major control of methanogenesis e.g. after an intermittent drainage.

Response: DNDC tracks soil Eh evolution by simulating reductions of nitrate, Mn, Fe, and sulfate. Initial concentrations of the substrates can be defined by users although DNDC provides default values of their geochemical background. The points have been included in the revised manuscript.

(iv) Calibration and validation: Maybe I missed it, but the modified DNDC model seems not to be validated. As a minimum requirement, the model should been validated against data from other irrigated rice fields that have not been used for calibration. However, it would be much better to use data from the other major rice ecologies as well.

Response: The DNDC model has been validated against a number of field data sets observed in China, the U.S., Japan, and Thailand. The results have been published in

Cai, Z., T. Sawamoto, C. Li, G. Kang, J. Boonjawat, A. Mosier, R. Wassmann, and H. Tsuruta, Field validation of the DNDC model for greenhouse gas emissions in East Asian cropping systems, Global Biogeochem. Cycles, 17(4), 1107, doi:10.1029/2003GB002046, 2003.

Li, C., 2000, Modeling trace gas emissions from agricultural ecosystems, Nutrient Cycling in Agroecosystems 58:259-276.

After modifications of DNDC for the Indian study, all of the field cases were re-run with the modified DNDC again. The results indicated that the modifications (e.g., improved crop yield, DOC leaching etc.) didn't alter the original results at all for the soils with low or moderate leaking rates, and improved the simulations for the high leaking soils. These points have been incorporated in the revised manuscript.

(v) Other models: A comparison to process-oriented models like that by Walter (Walter and Heimann, 2000; Bogner et al. 2000) or van Bodegom (van Bodegom et al. 2000; van Bodegom et al. 2001) would help to understand better the specific power as well as the limitations of the modified DNDC model. Similarly, the regional estimates in other major rice growing areas should be mentioned. Bachelet and Neue and Matthews et al. have made important contributions, but they are definitively not the only authors calculating regional estimates (p. 4).

Response: The following Table and paragraph comparing the existing research results related to regional estimation of CH_4 emissions from rice paddies in India have been included in the revised manuscript.

Table 5. Comparison of annual CH_4 emission estimates from rice fields in India. Reference Estimate (Tg yr-1) Methodology used Ahuja (1990) 37.5 Extrapolated from studies in USA and Europe to the rice growing regions in India Neue et al. (1990) 14.5 Assuming a CH_4-NPP (net primary productivity) ratio of 4.5% Mitra (1991) 3.0 Extrapolated from a limited No. of field measurements in India Matthews et al. (1991) 21.7 Based on area under rice, crop calendar and daily CH_4 emission rate Taylor et al. (1991) 18.4 Assuming a CH_4-NPP (net primary productivity) ratio of 5% Khalil and Shearer (1993) 15.3 Extrapolated from a few direct flux measurements Sinha (1995) 1.2 Based on relationship between biomass production and CH_4 emission in rice Parashar et al. (1996) 4.0 Extrapolated from several measurements all over India Cao et al. (1996) 14.4 Using the Methane Emission Model (MEM) Sass and Fischer (1997) 4.2 Extrapolated from measured data from selected rice-growing areas in India ALGAS (1998) 3.6 Extrapolated from large No. of measurements all over India Matthews et al. (2000) 2.1 Using the Methane Emission from Rice EcoSystems (MERES) simulation model Gupta et al. (2002) 5.0 Using CH_4 emission coefficients based on water regime and soil organic C Yan et al. (2003) 5.9 Using the region specific emission factors IINC (2004) 4.1 Using the IPCC methodology and IPCC default CH_4 emission coefficients Bhatia et al. (2004) 2.9 Using the IPCC methodology and measured CH_4 emission coefficients This study 1.5 Using the validated DNDC model

and newly compiled soil and weather data base

"Earlier several attempts have been made to estimate CH4 emission from Indian rice fields (Mitra, 1991; Parashar et al., 1991; 1996; Matthews et al., 2000; Yan et al., 2003; Bhatia et al., 2004). However, only a few studies (Cao et al., 1996; Matthews et al., 2000) have attempted to calculate detailed regional CH4 emissions using simulation modelling. The estimates vary greatly with the methodology adopted and assumptions made on the importance of different factors affecting CH4 emission (Table 5). Ahuja (1990) gave an estimate of 37.8 Tg yr-1 CH4 emission from Indian paddies, which was based on emission data of European and American paddy fields and extrapolated to the Indian region. Later on a value of 3 Tg yr-1 was estimated on the basis of measurements done up to 1990 at various rice growing regions in the country (Mitra, 1991; Parashar et al., 1991). Parashar et al. (1996) further revised the budget to be 4.0 Tg yr-1 with a range between 2.7 to 5.4 Tg yr-1. Gupta et al. (2002) using average emission factors for all paddy water regimes, which included harvested areas having soils with high organic carbon and organic amendments, estimated a budget of 5 Tg yr-1 for India. Recently, Yan et al. (2003) using region specific emission factors estimated India's CH4 emission to be 5.9 Tg yr-1. Matthews et al. (2000) used MERES model to simulate CH4 emission from rice paddies in India and estimated 2.1 Tg CH4 yr-1. The present estimate of 1.5 Tg is lower than the previous estimates, but is comparable with that of Sinha (1995) and Matthews et al. (2000). However, Matthews et al. (2000) assumed the percolation rate in soil to be zero due to the lack of spatial information on this parameter, and thus obtained higher emission estimate compared to the present study. In DNDC the percolation rate is calculated by the model using the soil parameters."

The model developed by Walter and Heimann (2000) describes natural wetlands and does exclude vital drivers of emissions in rice fields, e.g. land management. Comparison of different models could be useful but is beyond the scope of this paper. Moreover, most of these models are not available in the public domain, and even if available, require different data sets, which make them difficult to use.

(vi) On p12, the authors attribute the relatively low methane emissions from Indian rice fields to the high percolation rate in sandy loam soils that allows to leach dissolved organic carbon (DOC) to deeper soil profiles. Is this process really neutral with respect to GWP? Or is this DOC mineralized in the aquifer and emitted later to the atmosphere? If true, it would be a spatial separation between primary production in the rice field and the resulting GHG emission, but the overall balance might become more similar to other rice ecologies.

Response: The capacity of DNDC's predictions is limited to the plant-soil system within the field scale of cropland. DNDC does not track the fate of DOC in underground water or streams. The leached DOC could play a certain role in CO2, CH4 or N2O production in the aquatic systems, but the current version of DNDC is not able to simulate aquatic biogeochemistry. These points have been clarified in the revised text.

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