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Title: Implementing methane dynamics into the LPJmL6 model

Author(s): Sibyll Schaphoff et al.

MS No.: egusphere-2025-6210

MS type: Model description paper

Special issue: The Lund–Potsdam–Jena managed Land (LPJmL) dynamic global vegetation, hydrology and crop model - developments, evaluations and documentation

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Thank you very much in advance for your cooperation. In case any questions arise, please do not hesitate to contact me.

Kind regards,

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Biblio

Line 82 Within each grid cell we assume that CTli follows a gamma distribution (Sivapalan et al., 1987; Kleinen et al., 2012). Vérifier ref si bien ou mieux trouver

Line 90 Pourquoi cette discretisation, est ce que bien adapté au vitesse des processus d'infiltration, ... pour le pas journalier qui est considéré et est ce que le modèle est utilisé en horaire est si oui est il possible d'adapter la discrétisation.

Line 104 Psy inf pas expliqué

Line 106 at a time veut bien dire par jour si le pas de temps est journalier ?

The newly added Haggard est ce que plus nouveau ?

Line 119 D'où vient la valeur 2.0 m-1

L124 100mm day-1 for agriculture d'où vient la valeur

Paragraphe 2.2.3 lwt c'est la couche au dessus de la couche qui contient zdelta mais duc oup la couche qui a zdelta a une partie sature et une non sature donc psy lwt correspond au milieu de la couche au dessus où à son integrale ? mais après on dit que lwt correspond juste au dessus de la zone saturée et donc dans la même couche qu'appartient zdelta

Line 169 manque ref equation

This article presents the works to implement the main terrestrial mechanism of CH₄ fluxes anthropic as agriculture and natural with a well representative link with the carbon nitrogen and water cycle. A focus on water table depth modeled is done to estimated notably the wetland using the CTI-TOPMODEL framework. Then the new model is used to model the wetland in a first time and compared with observation and then to model the CH₄ fluxes compared with obs.

General comment

The paper is well constructed and well written. The papers describe the new model and a lot of mechanism is implemented which represent really an impressive work in once.

The article only just need some missing details clarifications

Specific comments :

On the part model

- The time step is not explicitly mentioned. The main timestep used with the climate data and so with the hydrologic part. At the 2.3, it does a mention of « An adaptive sub stepping scheme refines the time step when local CH₄-O₂ concentration gradients become steep, ensuring numerical stability and mass conservation. » It is important to be explicit of the numerical scheme by mentioned where to find the informations or to explain it in the article.

On the validation

- Line 82 hypothesis de la construction of the distribution. It could be nice to say a word coupled with the wetland fraction observation if the hypothesis is too raw
- Line 90 why this choice at least mentioned the previous work. Later line ..., it is mention than only the backward euler scheme is stable, this do not imply precision, it could be nice to give CFL number and numerical pecelet number for each equation to see why backward euler and not forward euler
- Line 104 Ψ_{inf} pas expliqué
- Line 106 at a time veut bien dire par jour si le pas de temps est journalier ?
- The newly added Haggard est ce que plus nouveau ?
- Line 119 D'où vient la valeur 2.0 m⁻¹
- L124 100mm day⁻¹ for agriculture d'où vient la valeur
- Line 496 add the time step of GSWP3-W5E5 time step
- 5.2 It is a pertinent comparaison. However I think than we can add in supplementary figures other comparason to check if the hypothesis on the CTI distribussion is well chosen. For exemple a map of anomaly with the different database on the fraction of wetland. It could be interesting in supplementary also if it is pertinent if there is a relation of error with the fraction, with the topology or other relevant variable.

L930 Add the « The model is well constructed, but it should be add in the conclusion, maybe a perspective of sensitivity analysys of all the parametrasation, the impact of it on the CH₄ result and wetland « after the sentence

General Comments

This article presents an implementation of the main terrestrial mechanisms governing CH_4 fluxes, covering both anthropogenic sources (agriculture) and natural sources, with well-represented links to the carbon, nitrogen, and water cycles. A particular focus is placed on water table depth modeling to estimate wetland extent using the CTI-TOPMODEL framework. The new model is first evaluated against wetland observations, then used to simulate CH_4 fluxes compared with observational data.

The paper is well constructed and clearly written. The description of the new model is thorough, and the number of mechanisms implemented represents an impressive and comprehensive effort. The article only requires a few minor clarifications on missing details, as outlined below.

Specific Comments

- **The Time stepping scheme (Section 2.3) is not explicitly mentioned for each model component.** The main time step used with climate forcing data, and consequently with the hydrological component, is not explicitly stated. Section 2.3 mentions *"an adaptive sub-stepping scheme that refines the time step when local CH_4 - O_2 concentration gradients become steep"*, but the baseline time step remains unclear and how the chemical time step is adapted. It would be beneficial to either explicitly state it or provide a reference where this information can be found.

Furthermore, regarding the numerical scheme selection (Line 355): the authors mention that only the backward Euler scheme provided sufficient stability. However, stability alone does not guarantee accuracy. It would strengthen the methodological justification to provide the CFL number for each governing equation. This would allow the reader to assess why the backward Euler scheme was preferred over Crank-Nicolson, and whether the spatial discretization, particularly the coarser vertical layers at depth, is consistent with the balance between diffusive and reactive processes. This is especially relevant for permafrost layers where coarse vertical resolution may dampen carbon release dynamics.

- The assumptions underlying the construction of the CTI distribution are not discussed in relation to observational constraints. It would be valuable to briefly assess whether these assumptions hold when compared with wetland fraction observations, particularly where the hypothesis may be too crude. In the paper, the comparison presented is pertinent. However, it would be valuable to add

supplementary figures showing anomaly maps of wetland fraction against multiple observational databases, in order to better evaluate the sensitivity of results to the chosen CTI distribution. If relevant, it could also be informative to explore whether the spatial pattern of errors correlates with wetland fraction, topographic characteristics, or other physically meaningful variables.

- The conclusion would benefit from an additional perspective on sensitivity analysis. Given the large number of parameterizations introduced, a discussion of their relative influence on wetland extent and CH₄ flux estimates would be a valuable addition — even as a stated future direction.

Technical comments

- **Line 104:** The variable Ψ_{inf} is used but not defined. Please provide its definition and units.
- **Line 106:** The expression "*at a time*" should be clarified — does this refer to a daily time step if the model operates at daily resolution?
- **Line 119:** The value of 2.0 m⁻¹ is used without justification. Please provide the source or rationale for this parameter.
- **Line 124:** The threshold of 100 mm day⁻¹ for agricultural water input requires a reference or justification.
- **Line 496:** Please add the time step of the GSWP3-W5E5 forcing dataset for completeness

Review 2

TODLIST to check

he introduction should present the state of the art of the soil methane processes in Earth System Modeling

It is important to validate the model on local fluxes. A comparison against site measurements of carbon and methane fluxes is required to show the model performances and give error metrics.

Line 75: grid cell mean water table depth: is it the annual mean? Precise please.

Table 1, 2 and 3 should be moved to an annex or supplementary document

Liner 169: equation number is missing

Line 181: Remove the article “the” at the beginning of the line

We therefore revised the introduction to list the main implemented components, including dynamic water-table depth, CTI-TOPMODEL-based wetland extent, soil-layer O_2 and CH_4 concentrations, methanogenesis, CH_4 oxidation, and CH_4 transport to the atmosphere through diffusion, ebullition, and plant-mediated transport. We also clarified that these processes were coupled to the simulated carbon, nitrogen, and water cycles and were applied to natural wetlands and rice systems.

We thank the reviewer for pointing out that the time-stepping procedure and numerical scheme required further clarificatio

Slope distribution and wetland fraction validation:

Sensitivity analysis and conclusion

Line 104: The variable Ψ_{inf}

Line 106: The expression "at a time" should be clarified — does this refer to a daily time step if the model operates at daily resolution « je n'ai pas vu »

Line 119: The value of 2.0 m^{-1} is used without justification. Please provide the source for this τ parameter value.

Line 124: The threshold of 100 mm day^{-1} for agricultural water input requires a reference or τ justification.

General comment

The paper is well constructed and clearly written as we remark at the first review. And we underline, as the first review, the modelling impressive and comprehensive effort with number of mechanisms implemented represents an within a single framework.

Specific comments

Introduction : the introduction benefits a lot with the two next paragraphes, the first add with the bibliography of the existing models and the second one with resume of the whole mechanism present in the model with the novelty.

Numerical scheme : the added paragraph helps to well understand the numerical scheme and the additional simulation was welcoming.

CTI : The global comparison in supplementary helps to know which region with higher anomaly compare to observations. It is useful for to know where brings effort for next development

Technical comments

All the technical comments was taken in account, only one is missing in the article but it was correctly answered :

Line 106: The expression "at a time" should be clarified — does this refer to a daily time step if the model operates at daily resolution?

We clarified this as follows: "To improve numerical stability during vertical soil-water routing, precipitation was internally partitioned into increments of at most 4 mm, which were sequentially routed through the soil column within the daily time step."

I do not see at the concerned line the correction.