Comments about paper "An improved process-oriented hydro-biogeochemical model for simulating dynamic fluxes of methane and nitrous oxide in alpine ecosystems with seasonally frozen soils" Submitted by Zhang et al. to Biogeosciences

General remarks

This paper presents measurements and modelling of evolution of soil temperature, soil moisture, methane and nitrous oxide emissions in cold altitude wetlands, alpine meadows and forest. The used CNMM-DNDC model has been adapted by the authors to simulate the freeze-thaw cycles of the area. It is a matter for Biogeosciences but the authors have to improve seriously the paper before publication.

Primarily, they have to complete their bibliographic list and more discuss their results considering other published models. CNMM-DNDC incorporates the core biogeochemical processes of DNDC into the hydrological framework of CNMM (Catchment Nutrient Management Model). These coupling attempts, like present adaptation to freeze-thaw cycles are interesting efforts. My doubts concern the use without discussion of the DNDC corpus published near 30 years ago, when other models have showed more recently their interest in modelling the ecological functioning of microorganisms, using a smaller number of well-defined kinetic parameters and avoiding badly defined parameters of flow fractionation. Conversely, the decomposition part of DNDC uses a lot of these parameters and is for me largely over parameterized. Consequently, its prediction must be discussed, not only by the results of the usual statistic tests, comparing measurements and predictions (It is well known that any complex signal can be adjusted by any model using a great number of parameter e.g. in Fourrier transforms), but also in terms of microbial functioning.
Revised.
The descriptions about the DNDC and further discussions of the results with updated references have been added as the reviewer suggested. "*Biogeochemical models, such as DNDC, LandscapeDNDC, WNMM, MOMOS, CENTURY and DayCent, are effective tools for simulating the cycling of nitrogen and carbon and quantifying the effects of climate change and anthropogenic activities on ecosystems (e.g., Foereid et al., 2007; Hass et al., 2013; Li, 2007; Li et al., 2007; Pansu et al., 2010; Cheng et al., 2014; Pansu et al., 2014). In recent years, some new conceptual approaches are applied in the biogeochemical models, such as centering on the functional role of the soil microbial biomass (Pansu et al., 2010; Pansu et al., 2014) and detailing the lateral transport of water and nutrients (Hass et al., 2013; Zhang et al., 2018b).*" (**See lines 61-66 in the revised manuscript**). "*For the new generation of biogeochemical models, the microbial ecology was integrated into the biogeochemical models, which represents direct microbial control over decomposition, such as MOMOS (Pansu et al., 2010; Treseder et al., 2011; Todd-Brown et al., 2012; Pansu et al., 2014). The biogeochemical processes simulated by the DNDC were generally based on first-order kinetics for decomposition, Michaelis-Menten kinetics of two substrates for nitrification and denitrification, which only the parameterized growth and death of*

nitrifiers and denitrifiers were considered (Li, 2000). However, due to the global application and validation of DNDC (e.g., Chen et al., 2008; Giltrap et al., 2010; Cui et al., 2014), the biogeochemical processes of DNDC were selected in the CNMM-DNDC despite some deficiencies in simulating microbial biomass." (**See lines 132-139 in the revised manuscript**). "*Compared with the empirical model, one key advantage of the process-oriented models is that the models are independent of the local parameterization (Zhang et al., 2015). In this study, default internal parameter combinations of biogeochemical processes were used for the original and modified models, which have been applied in the catchment simulation in the subtropical region (Zhang et al., 2018b), due to the limit field observations (only one year) for both calibration and validation. The biogeochemical processes were predicted by the first-order and Michaelis-Menten kinetics in the CNMM-DNDC based on some defined parameters of flow fractionation. For instance, there are 17 parameters related with N_2O emission in the module of denitrification (Table S6), which would inevitably increase the uncertainty of simulation. Houska et al. (2017) found that hydro-biogeochemical models can be right for the wrong reasons, such as matching greenhouse gas emissions while failing to simulate soil moisture, which emphasized the importance for simultaneous validations of multi-variables. Thus, simultaneous validations of CH_4 and N_2O fluxes, as well as soil environment variables, were necessary for comprehensive evaluation of the model performance. In addition, the microbial ecology was recently recommended to be integrated into the biogeochemical model using a smaller number of well-defined kinetic parameters, such as MOMOS (Pansu et al., 2010; Treseder et al., 2011). Therefore, the direct control of microbial on biogeochemical processes, such as the stoichiometry of decomposer, is required to be included in the CNMM-DNDC in near future.*" (**See lines 417-430 in the revised manuscript**).

Also the article needs to be improved by more explanations about the CNMM part.

Revised.

The description about the CNMM has been added as the reviewer suggested. "*The soil moisture was calculated based on the mass balance of precipitation, irrigation, evapotranspiration, vertical flow, lateral flow and water from a rising water table. The total water that can be infiltrated during each time step was determined by a defined maximum infiltration rate. Darcy's law was applied for predicting the vertical water flow in the soil profile. A cell-by-cell approach using a kinematic approximation was applied to route the saturated overland and subsurface flow based on DEM. The stream flow was estimated using a cascade of linear channel reservoirs (Wigmosta et al., 1994). For plant growth, gross primary production was simulated using Farquhar et al. (1980) for C_3 and Collatz et al. (1992) for C_4, with annual primary productivity calculated as the residue of gross primary production and autotrophic respiration.*" (**See lines 141-148 in the revised manuscript**).

Some surprising choices must be better justified in the text, like why to predict temperature in all the profile for two systems when moisture is described in the 3 systems but only in the surface layer. The particular remarks below must be taken into account.

Revised.

The data used for model validation is determined by the field observations. Due to the limitation of field observations, only the simulated topsoil temperature for the alpine forest and topsoil moisture for the three alpine ecosystems were able to be validated by observations. "*The profile soil temperatures were observed for alpine wetland and meadow, but only topsoil temperature was observed for the alpine forest, which could be used for model validation.*" (**See lines 258-259 in the revised manuscript**). "*For the soil moisture, only topsoil moisture was observed in the three alpine ecosystems, which could be applied for model validation.*" (**See lines 268-269 in the revised manuscript**).

Particular remarks

L37 Is this 1st sentence a little banal?

Revised.

The sentence has been revised. "*During the last 50 years, the extraordinary changes in the nitrogen and carbon cycles have occurred globally, which are essential components of ecosystems (e.g., Galloway et al., 2008; Canfield et al., 2010).*" (**See lines 37-38 in the revised manuscript**).

L 60-62 the listed biogeochemical models is not exhaustive and limited to relatively old models sometimes subjected to critics (over parameterization, functional role of microorganisms…), e.g. the model MOMOS is ignored, please complete the list in such a way to better situate your work in the literature data.

Revised.

The sentences have been revised. "*Biogeochemical models, such as DNDC, LandscapeDNDC, WNMM, MOMOS, CENTURY and DayCent, are effective tools for simulating the cycling of nitrogen and carbon and quantifying the effects of climate change and anthropogenic activities on ecosystems (e.g., Foereid et al., 2007; Hass et al., 2013; Li, 2007; Li et al., 2007; Pansu et al., 2010; Cheng et al., 2014; Pansu et al., 2014). In recent years, some new conceptual approaches are applied in the biogeochemical models, such as centering on the functional role of the soil microbial biomass (Pansu et al., 2010; Pansu et al., 2014) and detailing the lateral transport of water and nutrients (Hass et al., 2013; Zhang et al., 2018b).*" (**See lines 61-66 in the revised manuscript**).

2.1 paragraphs: the original paper on DNDC includes a sub model for denitrification but not for methane emission; please clarify this part.

Revised.

In DNDC, the sub module of fermentation is closely related with methane emission, which includes the process of methane production, oxidation and transportation. Thus, the reference of Li (2000, 2007, 2016) has been added. "*The predicted CH_4 flux was influenced by CH_4 production, oxidation and transportation derived from the module of fermentation module in the DNDC (Li, 2007).*" (**See lines 155-156 in the revised manuscript**).

Li, C., 2000. Modeling trace gas emissions from agricutural ecosystems. Nutr. Cycl. Agroecosyst. 58, 259–276.

Li, C., 2007. Quantifying greenhouse gas emissions from soils: scientific basis and modeling approach. Soil Sci. Plant Nutr. 53, 344–352.

Li, C., 2016. Biogeochemistry: Scientific Fundamentals and Modelling Approach. Tsinghua University Press, Beijing. Pp. 530. (In Chinese)

The only denitrification submodel includes 17 parameters which must be combined to the numerous parameters regulating various splitting's in the DNDC core! By two points you can adjust a right line, but also a parabola, then more and more sophisticated functions by increasing the number of parameters, and the fittings will be already OK when evaluated by the statistic laws. All the models will predict the two points. You must discuss about the number of parameters in the paper (Ockham razor)

Revised.

The discussion has been added as the reviewer suggested. "*Compared with the empirical model, one key advantage of the process-oriented models is that the models are independent of the local parameterization (Zhang et al., 2015). In this study, default internal parameter combinations of biogeochemical processes were used for the original and modified models, which have been applied in the catchment simulation in the subtropical region (Zhang et al., 2018b), due to the limit field observations (only one year) for both calibration and validation. The biogeochemical processes were predicted by the first-order and Michaelis-Menten kinetics in the CNMM-DNDC based on some defined parameters of flow fractionation. For instance, there are 17 parameters related with N_2O emission in the module of denitrification (Table S6), which would inevitably increase the uncertainty of simulation. Houska et al. (2017) found that hydro-biogeochemical models can be right for the wrong reasons, such as matching greenhouse gas emissions while failing to simulate soil moisture, which emphasized the importance for simultaneous validations of multi-variables. Thus, simultaneous validations of CH_4 and N_2O fluxes, as well as soil environment variables, were necessary for comprehensive evaluation of the model performance. In addition, the microbial ecology was recently recommended to be integrated into the biogeochemical model using a smaller number of well-defined kinetic parameters, such as MOMOS (Pansu et al., 2010; Treseder et al., 2011). Therefore, the direct control of microbial on biogeochemical processes, such as the stoichiometry of decomposer, is required to be included in the CNMM-DNDC in near future.*" (**See lines 417-430 in the revised manuscript**).

L111-112 OK for hydro-geochemical but there is a doubt for biogeochemical, please discuss more deeply your choices considering all the literature data. The same for biogeochemistry in line 112; in contrast, paragraph 2 of 2.1.1 explain a particular interest of CNMM-DNDC

Revised.

More detailed descriptions have been added with updated references. "*For the new generation of biogeochemical models, the microbial ecology was integrated into the biogeochemical models, which represents direct microbial control over decomposition, such as MOMOS (Pansu et al., 2010; Treseder et al., 2011; Todd-Brown et al., 2012; Pansu et al., 2014). The biogeochemical processes simulated by the DNDC were generally based on first-order kinetics for decomposition, Michaelis-Menten kinetics of two substrates for nitrification and denitrification, which only the parameterized growth and death of nitrifiers and denitrifiers were considered (Li, 2000). However, due to the global application and validation of DNDC (e.g., Chen et al., 2008; Giltrap et al., 2010; Cui et al., 2014), the biogeochemical processes of DNDC were selected in the CNMM-DNDC despite some deficiencies in simulating microbial biomass.*" (**See lines 132-139 in the revised manuscript**).

Eq5: It looks like a sum, not a weighted average? Should j be defined in L148?

Revised.

The sentence and Eq. 5 have been revised to make it clear. "*The dynamic soil heat capacity (C, J m^{-3} ℃$^{-1}$) is the weighted average of the heat capacity for five constituents, including organic matter ($C_{l, OM}$), minerals ($C_{l,Min}$), water ($C_{l, Water}$), ice ($C_{l, Ice}$) and air ($C_{l, Air}$) (Eq. 5). The values of heat capacity for organic matter, minerals, water, ice and air were 2.5×10^6, 2.0×10^6, 4.2×10^6, 2.1×10^6 and 1.2×10^3 J m^{-3} ℃$^{-1}$, respectively (Huang, 2000).*" (**See lines 181-184 and Eq. 5 in the revised manuscript**).

Eq.6: product or geometric mean?

Revised.

The detailed the calculation steps of thermal conductivity (k_l) have been added as the reviewer suggested. (**See Eq. 6–13 in the revised manuscript**).

L148-151: is there references data for the values of C and k for each constituent j?

Revised.

The references have been added as the reviewer suggested. "*The values of heat capacity for organic matter, minerals, water, ice and air were 2.5×10^6, 2.0×10^6, 4.2×10^6, 2.1×10^6 and 1.2×10^3 J m^{-3} ℃$^{-1}$, respectively (Huang, 2000).*" (**See lines 183-184 in the revised manuscript**). "*...with values of 0.25 ($k_{l, OM}$), 2.9 ($k_{l, Min}$), 0.57 ($k_{l, Water}$), 2.2 ($k_{l, Ice}$) and 0.025 ($k_{l, Air}$) W m^{-1} ℃$^{-1}$ for organic matter, minerals, water, ice and air, respectively (Johansen, 1975).*" (**See lines 187-188 in the revised manuscript**).

L168: reference for this opaque chamber method? Is not a risk of perturbation by elimination of solar radiation?

Revised.

The reference has been added with the explanation for effects of the solar radiation. "*...using the gas chromatograph-based static opaque chamber method (Zhang et al., 2018a) at three sites ... Each chamber was wrapped with a layer of styrofoam and aluminium foil to mitigate temperature increases inside the enclosures due to the heating of solar radiation.*" (**See lines 207-208 and 210-212 in the revised manuscript**).

L189-190: could the layer description be clarified?

Revised.

The sentence has been revised to make it clear. "*The layer thicknesses of the soil (0−1.5 m) were 1, 5 10 and 50 cm for the depth of 0–10, 10–20, 20–100 and 100–150 cm, respectively. The layer thicknesses of the bedrock (1.5−35 m) were 3.5 and 31m for the depth of 1.5−4.0 and 4.0−35 m, respectively.*" (**See lines 234-235 in the revised manuscript**).

Table1: Could the legend remember the meaning of IA, NSI and R2? I suppose P is the probability of rejection, but for what test? Are the P columns necessary since P is always <0.001?

Revised.

The detailed information about the statistics has been added in Table 1 (**See Table 1 in the revised manuscript**).

Fig.1: legend in 1a is not very clear, perhaps write "observed" in red color; the same for other Figs

Revised.

The legends of all figures have been revised as the reviewer suggested (**See Figs. 1−6 in the revised manuscript**).

L210: ZIR does not appear in table 1

Revised.

The title line of Table 1 has been revised to detail the slope, R^2 and P of ZIR. The equation applied for the zero-intercept univariate linear regression (ZIR) of the observations against the simulations has been added in Table S5. (**See Table 1 in the revised manuscript**).

L216: The range values does not correspond to that of Table 1, please clarify

Revised.

The inconsistent range values has been checked and revised. "*...with IA and NSE values of 0.49−0.83 and -0.80−0.32 for the three alpine ecosystems...*" (**See lines 269-270 in the revised manuscript**).

L218: where is Fig S2? (the same for all S figures, I suppose supplementary not visible for me)

Revised.

The supplementary materials have been uploaded with the revised manuscript (**See the supplementary materials after the revised manuscript**).

Improve coherencies in Figs or more explain your choices: Fig 1 shows soil temperature for two systems at all soil layers; in contrast, Fig.2 shows moisture in the 3 systems but only in the 0-6 cm layer

Revised.

The data used for model validation is determined by the field observation. Due to the limitation of field observations, only the simulated topsoil temperature for the alpine forest and topsoil moisture for the three alpine ecosystems were able to be validated by observations. "*The profile soil temperatures were observed for alpine wetland and meadow, but only topsoil temperature was observed for the alpine forest, which could be used for model validation.*" (**See lines 258-259 in the revised manuscript**). "*For the soil moisture, only topsoil moisture was observed in the three alpine ecosystems, which could be applied for model validation.*" (**See lines 268-269 in the revised manuscript**).

Fig3: format date of x axis not very clear

Revised.

The formats of date for all figures have been revised to make them clear (**See Figs. 1−6 in the revised manuscript**).

L223: is the term "Water movement" exaggerated when you speak only of the surface water?

Revised.

The sentence has been revised as the reviewer suggested. "*... can generally predict the soil thermal and topsoil moisture dynamics in the three alpine ecosystems...*" (**See lines 276-277 in the revised manuscript**).

Fig.6:y axis legend not clear

Revised.

The y axis of Fig. 4 has been revised to make them clear (**See Fig. 4 in the revised manuscript**).

L293-294: should you present succinctly this concept of the CH4 balloon in material and methods?

Revised.

The contents have been added as the reviewer suggested. "*Methane production and oxidation occurred simultaneously and were determined by the sizes of the aerobic (production) and anaerobic (oxidation) microsites, which were defined by an Eh calculator in terms of an "anaerobic balloon" ("CH_4 balloon") (Li, 2007).*" (**See lines 156-158 in the revised manuscript**).

L351: define TP

Revised.

The sentence has been revised to make it clear. "*... annually inundated wetlands on the Tibetan Plateau...*" (**See lines 436-437 in the revised manuscript**).