Supplementary materials

Table S1 Information about the observed data for model validation

Item	Period	Ecosystem	Data provider
Soil temperature	2013.11−2014.11	Wetland	H Zhang
	2014.06−2015.10	Meadow	Z Yao, H Zhang
	2014.04−2015.04	Forest	Z Yao
Soil moisture	2013.11−2014.11	Wetland	H Zhang
	2014.06−2015.10	Meadow	Z Yao, H Zhang
	2014.04−2015.04	Forest	Z Yao
Methan flux	2013.11−2014.11	Wetland	H Zhang
	2013.11−2014.11	Meadow	Z Yao, H Zhang
	2014.04−2015.04	Forest	Z Yao
Nitrous oxide flux	2013.11−2014.11	Wetland	H Zhang
	2013.11−2014.11	Meadow	Z Yao, H Zhang
	2014.04−2015.04	Forest	Z Yao

References

Yao, Z., Ma, L., Zhang, H., Zheng, X., Wang, K., Zhu, B., Wang, R., Wang, Y., Zhang, W., Liu, C., Butterbach-Bahl, K., 2019. Characteristics of annual greenhouse gas flux and NO release from alpine meadow and forest on the eastern Tibetan Plateau. Agric. For. Meteorol. 272-273, 166-175.

Zhang, H., Yao, Z., Ma, L., Zheng, X., Wang, R., Wang, K., Liu, C., Zhang, W., Zhu, B., Tang, X., Hu, Z., Han, S., 2019. Annual methane emissions from degraded alpine wetlands in the eastern Tibetan Plateau. Sci. Total Environ. 657, 1323–1333.

Zhang, H., Yao, Z., Wang, K., Zheng, X., Ma, L., Wang, R., Liu, C., Zhang, W., Zhu, B., Tang, X., Hu, Z., Han, S., 2018. Annual N_2O emissions from conventionally grazed typically alpine grass meadows in the eastern QInghai-Tibetan Plateau. Sci. Total Environ. 625, 885–899.

Table S2 Equations for the statistical criteria for model valiation.

$$\mathrm{IA} = 1 - \frac{\sum_{k=1}^{n}(s_k - o_k)^2}{\sum_{k=1}^{n}(|s_k - \bar{o}|+|o_k - \bar{o}|)^2} \quad \text{(S1)}$$

$$\mathrm{NSI} = 1 - \frac{\sum_{k=1}^{n}(o_k - s_k)^2}{\sum_{k=1}^{n}(o_k - \bar{o})^2} \quad \text{(S2)}$$

$$R^2 = 1 - \frac{\sum_{k=1}^{n}(o_k - \hat{o}_k)^2}{\sum_{k=1}^{n}(o_k - \bar{o})^2} \quad \text{(S3)}$$

$$\mathrm{MRB} = \frac{\sum_{k=1}^{n} s_k / n}{\sum_{k=1}^{n} o_k / n} - 1 \quad \text{(S4)}$$

In Eqs. S1−4, IA, NSI, R^2 and MRB are abbreviations of the index of agreement, Nash–Sutcliffe index, determination coefficient of the zero-intercept univariate linear regression of the observations against the simulations and model relative bias respectively, k and n (k = 1, 2..., n) denote the kth pair and the total pair number of the values, respectively; s and o denote the simulation and observation, respectively; $\bar{o}$ represents the mean of the observations (o); and $\hat{o}$ is the prediction using the regression. These equations are given by referring to Nash and Sutcliffe (1970), Willmott and Matsuurra (2005), Moriasi et al. (2007), Jiang (2010), Congreves et al. (2016) and Dubache et al. (2019).

Reference

Congreves, K., Grant, B., Dutta, B., Smith, W., Chantigny, M., Rochette, Desjardins, R.L., 2016. Prediction ammonia volatilization after field application of swine slurry: DNDC model development, Agric. Ecosyst. Environ. 219, 179−189.

Dubache, G., Li, S., Zheng, X., Zhang, W., Deng, J., 2019. Modeling ammonia volatilization following urea application to winter cereal fields in the United Kingdom by improving a biogeochemical model, Sci. Total Environ. 660, 1403–1418.

Jiang, Z., 2010. Analysis on the establishment conditions of the square sum decomposition formular of regression model, J. Industr. Techn. Econ. 29(4), 116−119 (in Chinese).

Moriasi, D., Arnold, J., Van Liew, M., Bingner, R., Harmel, R., Veith, T., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulation, T. Am. Soc. Agr. Biol. Eng. 50, 885−900.

Nash, J., Sutcliffe, J., 1970. River flow forecasting through conceptual models: part I- a discussion of principles, J. Hydrol. 10, 282–290.

Willmott, C., Matsuurra, K., 2005. Advantages of the mean aboslute error (MAE) over the root mean square error (RMSE) in assessing average model performance, Clim. Res. 30, 79−82.

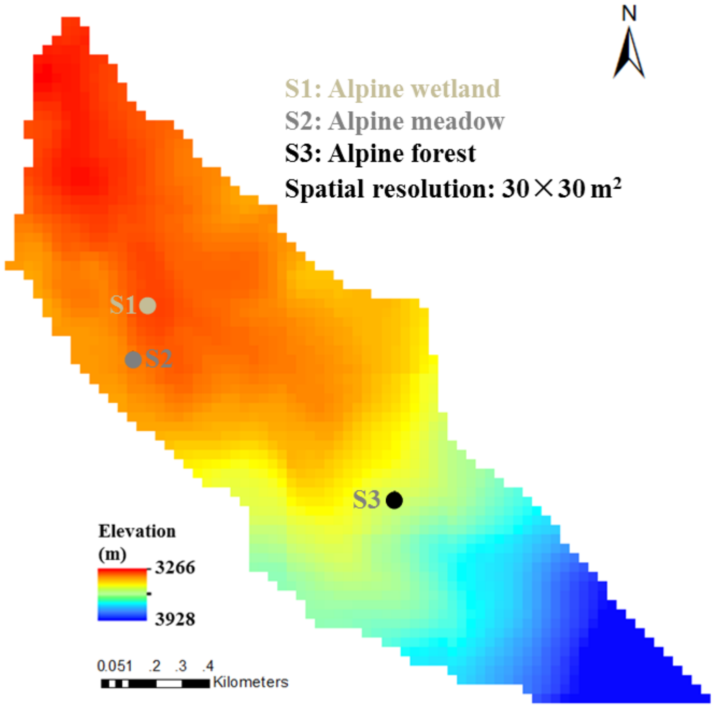

Figure: S1 The digital elevation model (DEM) of the Rierlangshan catchment (data from Geospatial Data Cloud; http://www.gscloud.cn/) with the sites of field observations.

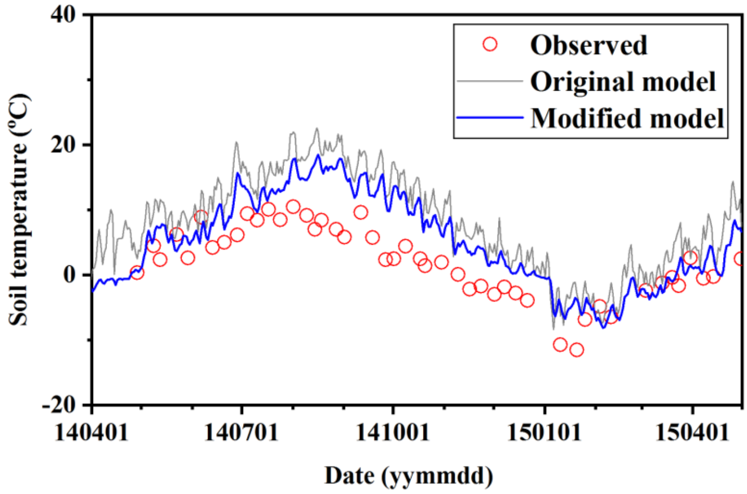

Figure: S2 Observed and simulated daily topsoil (5 cm) temperature from alpine forest by both the original and modified models.

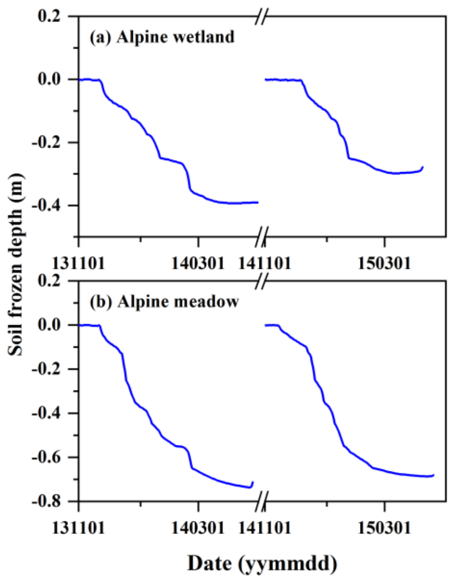

Figure: S3 The simulated dynamics of soil frozen depth dynamics from alpine wetland and alpine meadow.