鉛直熱収支および植物生育指数を用いた田面水温予測モデルの研究

Paddy Water Temperature Forecasting Model using Vertical Heat-Balance and Vegetation Growth Status Parameter

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1. Introduction

The temperature of shallow water is an essential factor in various fields, such as wet lends, fish ponds and irrigation fields, since the water temperature directly relates to physical and biochemical processes in those ecosystems. Due to the global warming, the air temperature around the world has increased and the extreme weather has become frequent, especially the heat waves. In paddy conditions, the long-term high temperatures during the rice-growing season will increase the risk of rice suffering from high-temperature damage. Therefore, it is necessary to forecast the water temperature of paddy fields in order to mitigate the damage. However, accurate one-day-ahead forecasting of water temperature continues to be a challenging task due to the lack of relevant research and the uncertainty of the meteorological forecast.

We proposed simulation models of the paddy water temperature in two ways; one is the forecast model. This model is based on physical processes and can predict water temperature considered the effect of the vegetation layer using meteorological forecast data from the Meso-Spectral model provided by the Japan Meteorological Agency. According to the requirements of the forecast model, an estimating method of K_L is introduced to describe the vegetation growth status from the temporal evolution of water temperature. Another method is multiple regression analysis (MRA), based on statistical principles. MRA uses the correlation between current meteorological data and future water temperature to estimate water temperature.

2. Data collection

We performed field experiments in the rice-growing season from 2016 to 2018 at four different locations to verify the model. The measured items include the air temperature (°C), solar radiation (W/m^2), relative humidity (%), air pressure (kPa) and the horizontal wind speed (m/s). To predict the water temperature profile, the meteorological forecast data was obtained from Meso-Spectral Model (MSM). MSM provides Gird Point Value (GPV) of 1-day ahead meteorological factors and employs full-compressible elastic equations based on the non-hydrostatic equilibrium model. The horizontal resolution was set as 5km. The meteorological forecast data was published every three hours, and the forecast range was 33 hours. We used meteorological forecast data published at 15UTC to predict 24-hour water temperature profile.

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3. Forecast model

Vertical models, like the one developed in this study, based on energy storage to express heat transfer conditions and temperature dynamics of individual components of paddy fields. The heat transfer items include the long-wave radiation, short-wave radiation, sensible heat flux, latent heat flux, and soil heat flux. Individually, the principle of the present model is to use the meteorological data as variables, calculate the temperature of the surface water by solving the vertical heat exchange between the atmosphere, the vegetation community, the surface water, and the ground.

4. Estimating method of K_L

K_L is a plant growth status parameter related to radiation transmittance, describing the denseness of the vegetation layer, the range is [0.03, 10]. The relationship between water temperature gradient and radiation and heat flux parameters was used to deduce the value of K_L.

$$f_v = \frac{\frac{\partial T_w}{\partial t}\rho_w C_w h + H_w + lE_w + G - L_{dc} + L_{uw}}{(1-a_w)(1-a_c)S + L_{da} - L_{dc}} \quad (1)$$

$$f_v = \exp(-k \cdot K_L) \quad (2)$$

5. MRA

In this study, we use the meteorological and paddy condition data that have a large effect on 1-day ahead water temperature to construct the MRA model, as shown below

$$T_{w,t+1} = w_0 + w_1 T_{a,t} + w_2 T_{w,t} + w_3 humid_t + w_4 depth_t + w_5 solar_t \quad (3)$$

In addition, 80% of the data is used for regression analysis and 20% of the data is used for verification.

6. Results

From the calculation results of K_L shown in **Figure 1**, we note that the K_L calculation method can obtain similar K_L curves under different weather conditions and irrigation conditions but the same cultivars of rice. Therefore, K_L is universal when the heading date and rice cultivars are known.

In **Table 1**, from the prediction results of forecast model, the RMSE between the measured and predicted water temperature was approximately 2 ℃, and the water temperature was underestimated during the daytime. It is suggested that the error was significant, which may be caused by the low resolution of the forecast model. In MRA, the prediction result shows a good agreement between predicted and measured water temperature with yielding RMSE is 1.5℃, and the correlation coefficient is higher. However, we should note that MRA is not a method based on physical processes.

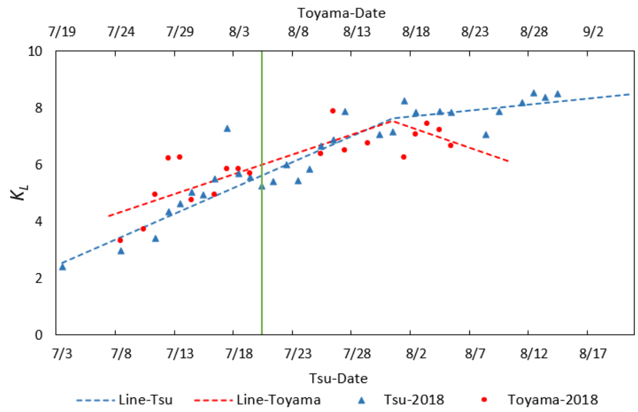

Figure 1 K_L calculation results of Tsu-2018 and Toyama-2018

Table 1 Comparison of Forecast model and MRA

Study case	Prediction method	R^2	RMSE (℃)
Tochigi-2016	Forecast model	0.5938	1.55
	MRA	0.5516	1.45
Toyama-2017	Forecast model	0.86	1.51
Tsukuba-2017	Forecast model	0.50	1.67
Tsu-2018	Forecast model	0.7995	2.24
	MRA	0.7619	1.44