Estimation of the hourly snowmelt based on the heat balance method using the Japan Meteorological Agency observation data alone and application for analyzing groundwater level fluctuation in a landslide site

Takamasa MATSUNAGA[1], Shin'ya KATSURA[2]
[1]Graduate School of Agriculture, Hokkaido University,[2]Resarch Faculty of Agriculture, Hokkaido University

Introduction

- In snow-covered area, a lot of landslides occur due to snowmelt from March to May in Japan (Aoyama et al, 1984)
- It is important to observe or estimate **MR (meltwater and/or rainwater)** and analyze the relationship between MR and the groundwater level fluctuation

From Niigata prefecture, the Kokugawa landslide

But there are some problems of observation or estimation of the snowmelt

Ex)
- Observation by lysimeters → High cost
- Degree-day method → Need to adjust the degree-day factor
- Heat balance method → Need **not-frequently observed meteorological** data (ex. atmospheric radiation)

In the field of meteorology, cryology, etc., methods for estimating **the not-frequently observed meteorological data** necessary for the heat balance method from **frequently observed one** have been developed

In Japan, **the Japan Meteorological Agency** provides hourly routine meteorological data observed at many locations (at intervals of about 17km in average), which is **the most easily available meteorological data**

Purpose:
Estimate the hourly **MR (meltwater and/or rainwater)** based on the heat balance method using **the Japan Meteorological Agency observation data alone** and apply for analyzing groundwater level fluctuation in a landslide site

Develop estimation of the MR(meltwater and/or rainwater) model

- **Estimation of the MR**

$$MR = M + P_r$$

M : **Meltwater** (mm/hour)

P_r : Rainwater(mm/hour)

※Regardless of the snow layer, surface meltwater and rainwater reach the soil without any delay

- **The Japan Meteorological Agency observation data**

→Temperature, Precipitation
Wind speed, Daylight hours
Atmospheric pressure,
Water vapor pressure

coincidence

※ the routine meteorological data observed in many place (at intervals of about 17km) hourly

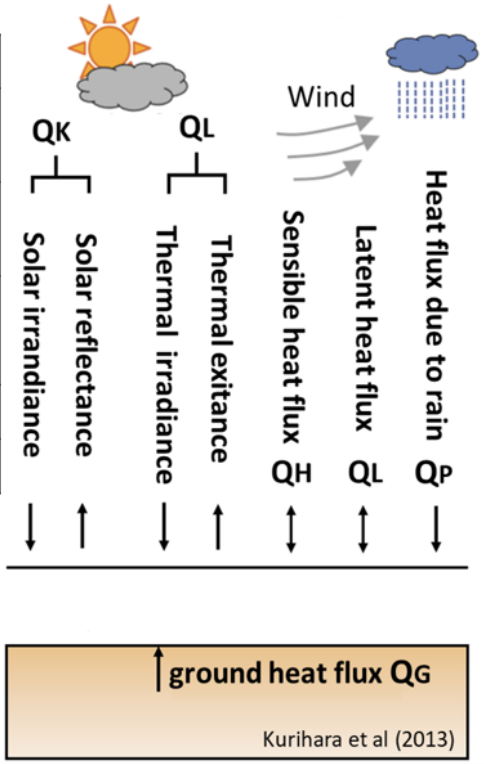
- **Estimation of the meltwater based on the heat balance method**

Q_M(snowmelt energy) $= Q_K + Q_L + Q_H + Q_E + Q_P + Q_G$

M(snowmelt) $= Q_M$/heat of melting ice

→Calculate the heat balance, and estimate the snowmelt from the difference

Energy fluxes	Necessary meteorological data	References
Q_K	Temperature, Precipitation, Daylight hours	Yang and Koike(2005), Yamazaki et al.(1994)
Q_L	Temperature,Daylight hours, Atmospheric pressure, Water vapor pressure, Wind speed	Huzieda(2018), Ninomiya(1996)
Q_H		Taguchi et al.(1994), Kondou(1994)
Q_L		
Q_P	Temperature,Precipitation	Kurihara(2013)
Q_G	0.02mm/hour	Japanese average value



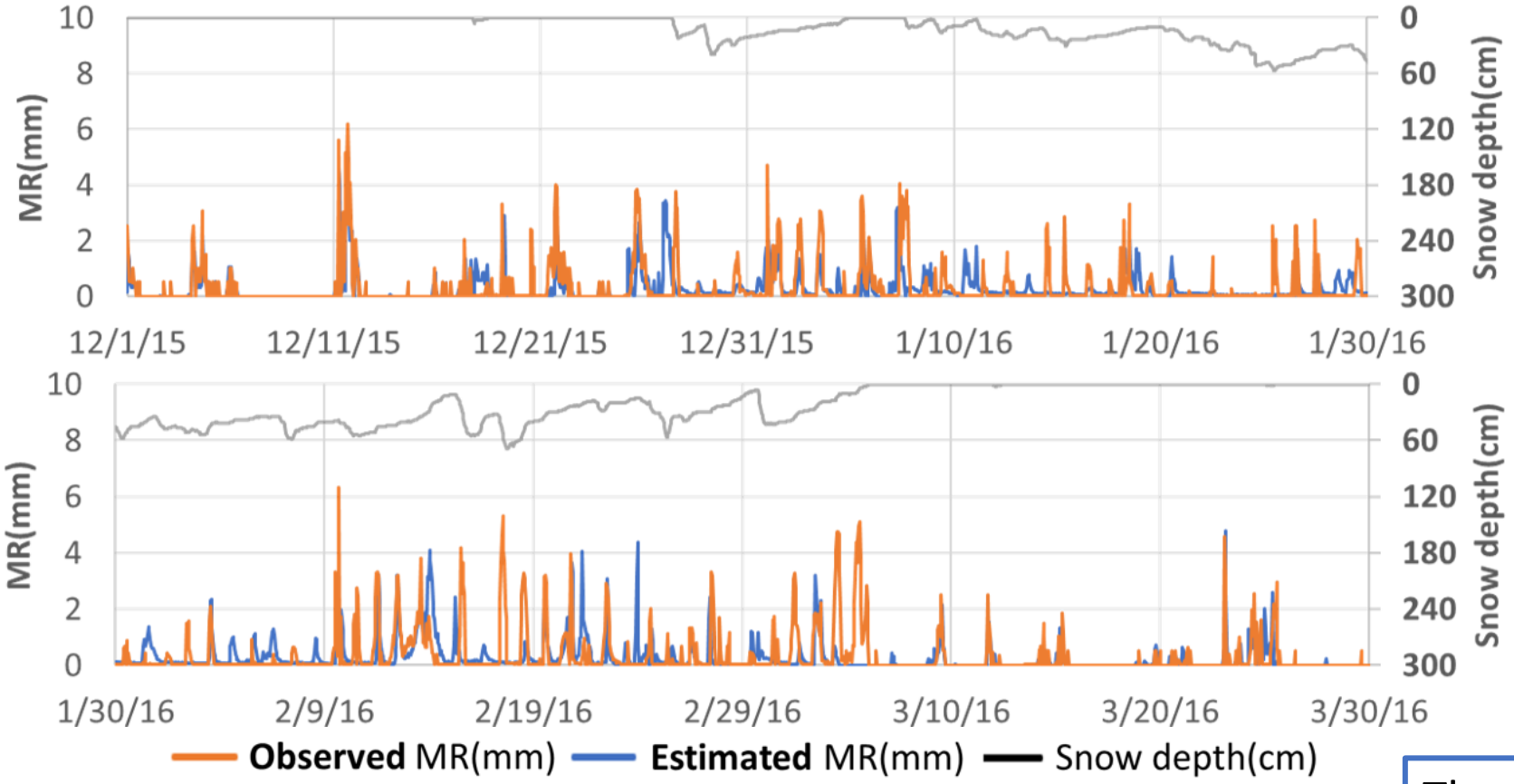
・Necessary meteorological data for estimation of the MR is the Japan Meteorological Agency Observation data

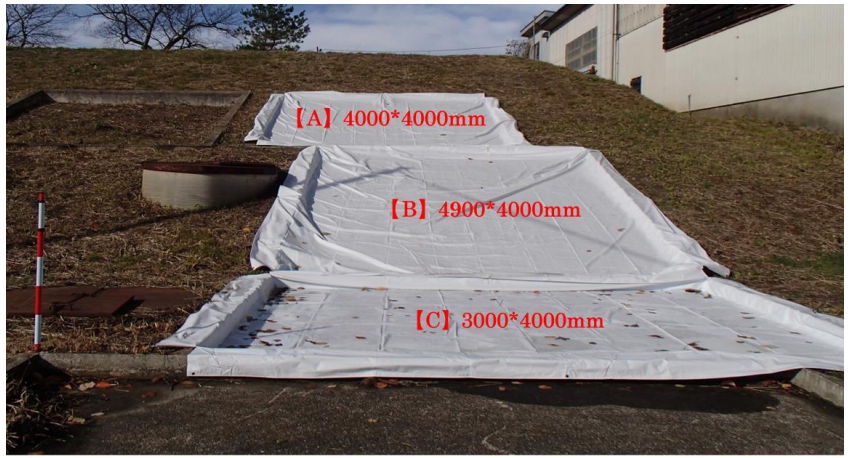
・This model can apply everywhere if the Japan Meteorological Agency Observation data is corrected and interpolated

Verification of the MR estimation model

- Apply the MR estimation model to the Snow Avalanche and Landslide Research Center, where the hourly MR is observed using a lysimeter, to test the validity of the model

Result





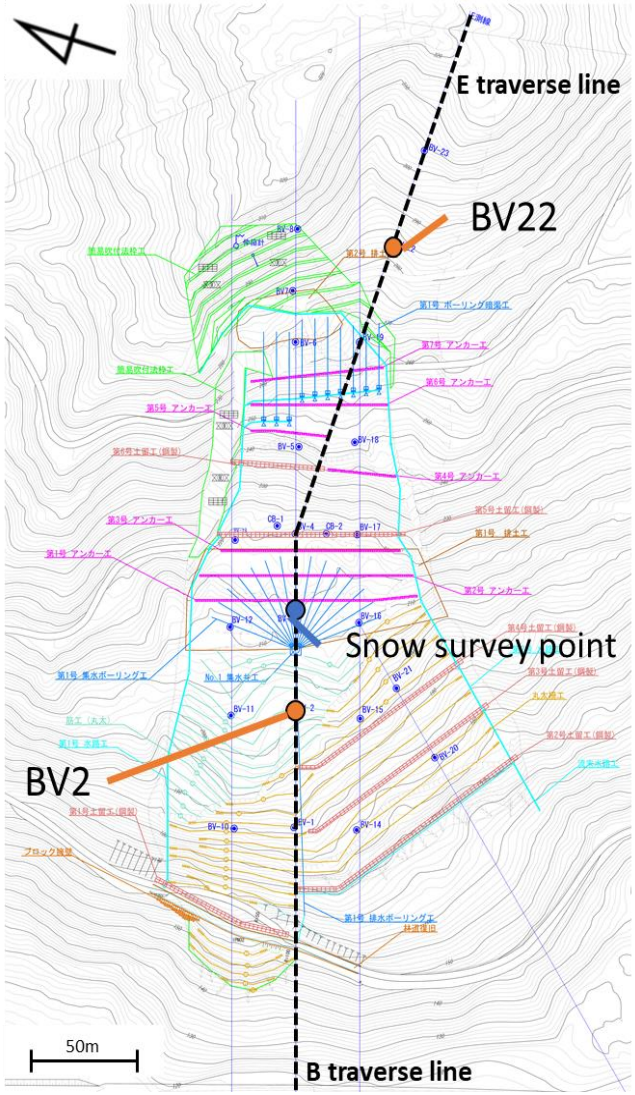
Average error is 0.35mm/hour
Estimated timing of the snow cover disappearance (2016/3/6 1:00) completely matched the observed one

The MR estimation model can accurately estimate MR

Apply the MR estimation model for analyzing the groundwater level fluctuation

- Apply the MR estimation model for analyzing the groundwater level fluctuation to Nokanan, where the groundwater level is observed, to test the validity of the model

- **Study site: Nokanan**



✓ Landslide occurred in 2010

✓ Observe hourly groundwater level from November, 2016 to April, 2017 (BoreholeBV2,BV22)

✓ Observe snow water equivalent 6 times

- **Groundwater level(GL) fluctuation model**
- $Hcal$ (Estimated GL) : Calculated using Kosugi et al. (2013)

$$Hcal = b_0 + b_1 {X_1}^{p_1} + b_2 {X_2}^{p_2}$$

$$X(t) = X(t-1)e^{\alpha} + MR(t)e^{\frac{\alpha}{2}}$$

$$\alpha = \ln(0.5)/M$$

$X(t), X(t-1)$: Effective MR at time t and t-1, respectively
$MR(t)$: MR at time t
α : Reduction factor
b_0, b_1, p_1, p_2, M : Parameters

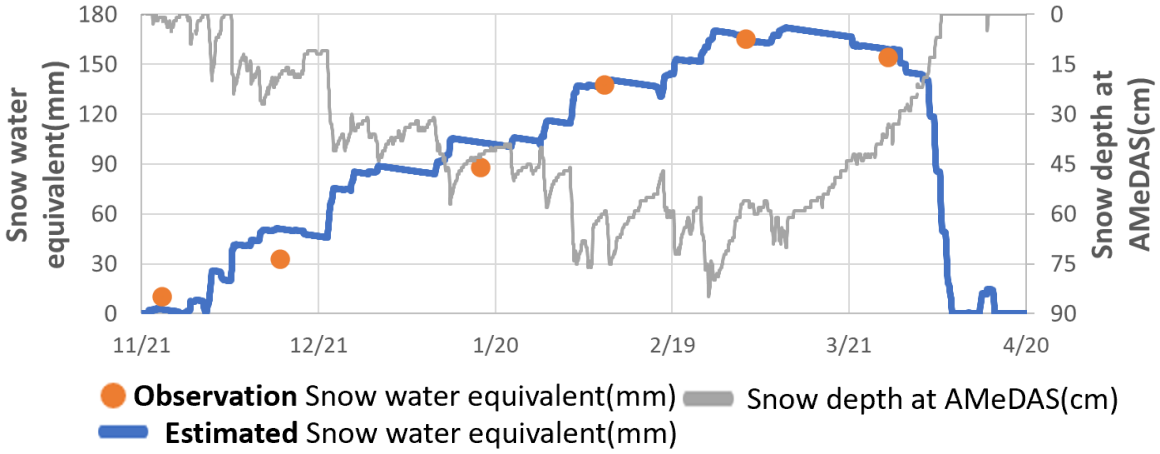
Parameters were determined to maximize Nash-Sutcliffe(*NSEF*)

$$NSEF = 1 - \frac{\sum_i (Hobs,i - Hcal,i)^2}{\sum_i (Hobs,i - \bar{H}obs)^2}$$

$Hobs$: Observed GL, $\bar{H}obs$: Average observed GL

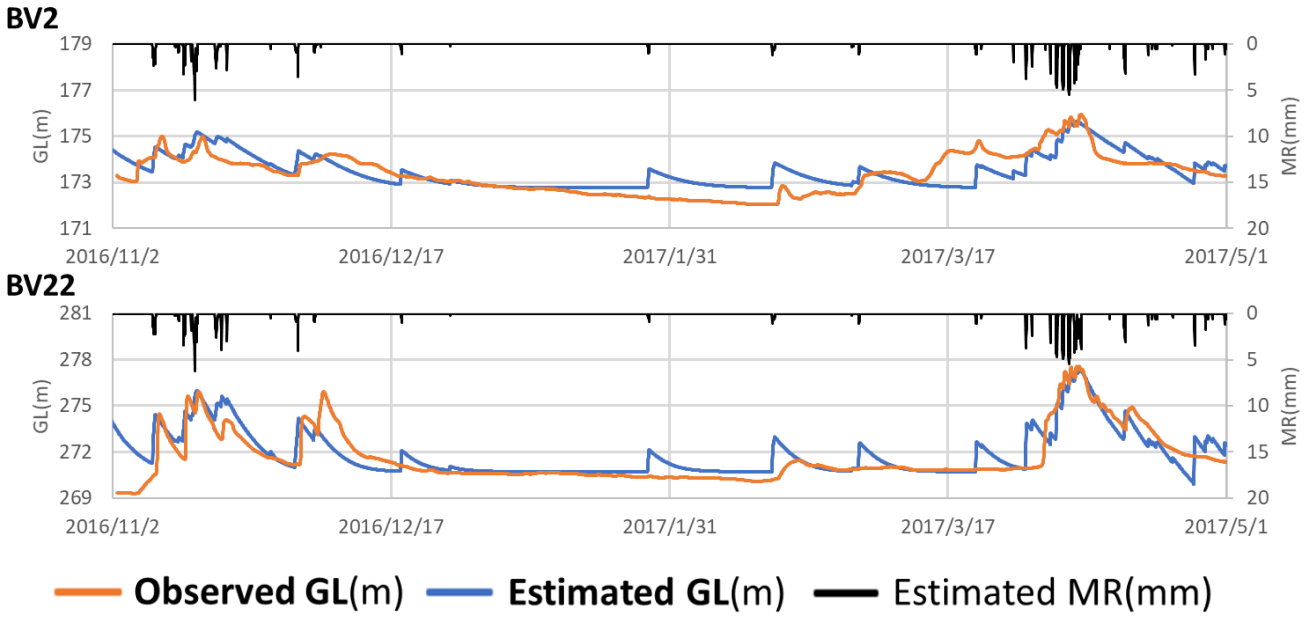
- *NSEF* is the evaluation index (the maximum *NSEF* is 1)
- *NSEF* > 0.5 means that the model is accurate (Kan,2001)

Result: Apply the estimation of the MR model for analyzing model of the groundwater level fluctuation



- Average error is 8.11mm
- Estimated timing of snow cover disappearance (2017/4/6 15:00) almost matched the observed (2017/4/5 16:00)

→The MR estimation model successfully estimated MR also at Nokanan



Summary of the results of the groundwater level fluctua -tion analyses in this study

	b_0	b_1	b_2	p_1	p_2	M_1	M_2	NSEF
BV2	40.56	122.1	9.343	0.004	0.034	165.1	21.94	**0.760**
BV22	261.6	0.100	8.643	0.721	0.094	194.0	28.62	**0.775**

※IF NSEF is over **0.5**, the model is accurate (Kan,2001)

We successfully reproduced the observed GL using MR estimated by the MR estimation model

Summary

- This study developed the MR (meltwater and/or rainwater) estimation model
- The snowmelt is estimated based on the heat balance method using the Japan Meteorological Agency observation data, the most easily available routine meteorological data in Japan, alone

- We successfully reproduced the groundwater level (GL) fluctuation in a snow-cover area using MR estimated by the MR estimation model

- The model and method allow to estimate MR and reproduce GL fluctuation anywhere in Japan
- In future work, applicability should further be tested in other sites