

Estimation of Soil Freezing Date Using Air Temperature Remotely Measured

K. Noborio¹, M. Mizoguchi², and H. Iwase³

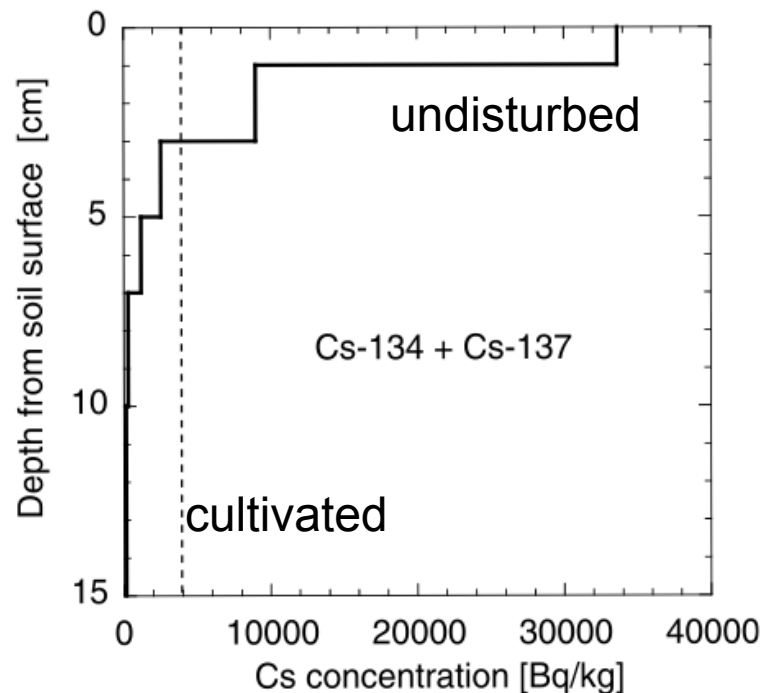
¹ Meiji University, Kawasaki, Japan

² University of Tokyo, Tokyo, Japan

³ High Energy Accelerator Research Organization,
KEK, Tsukuba, Japan

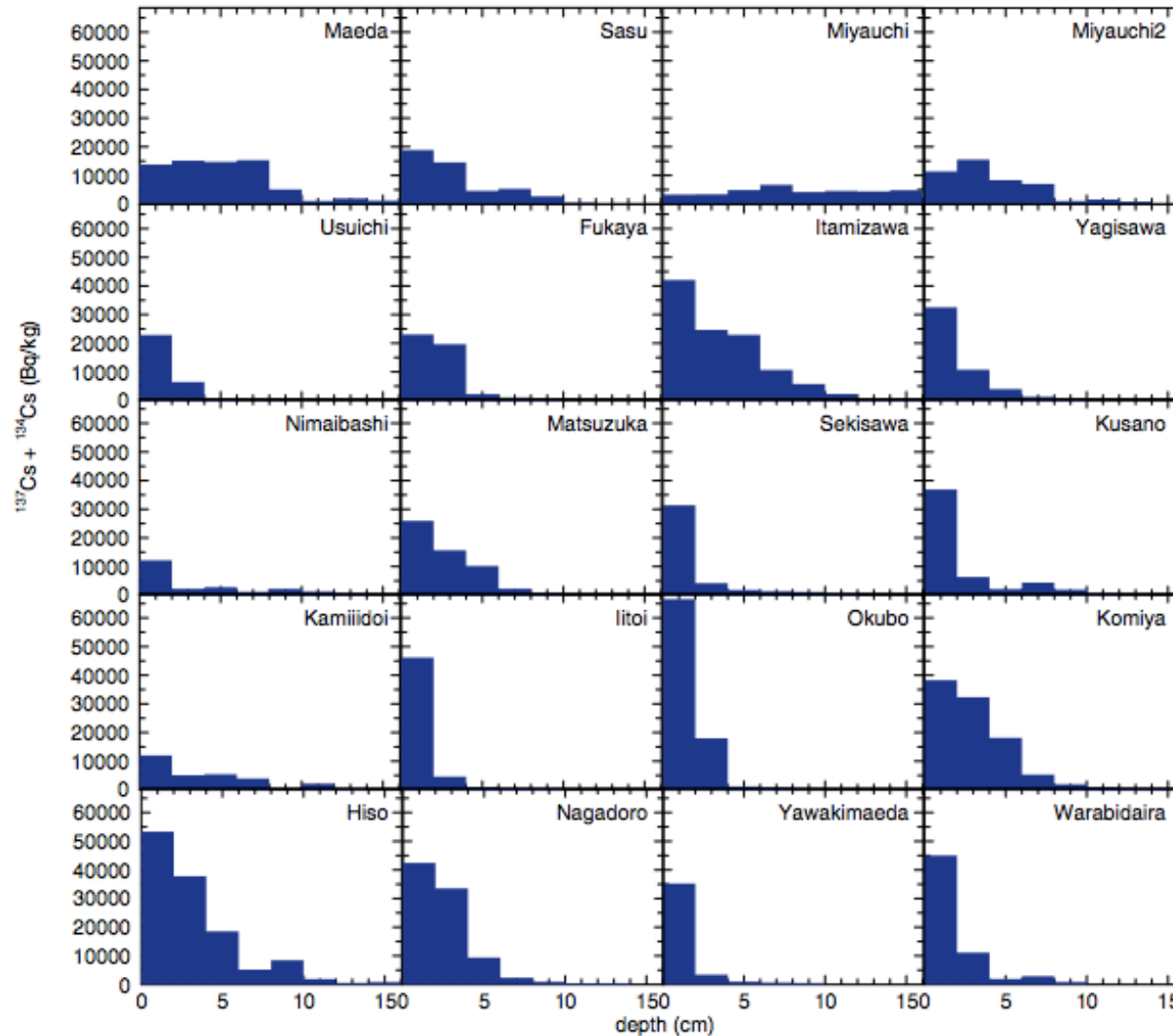
Background

- Removal of radiocesium contaminated soil in farmlands is mandatory.



The Cs profiles of rice paddy fields on May 24, 2011 (Shiozawa, 2011).

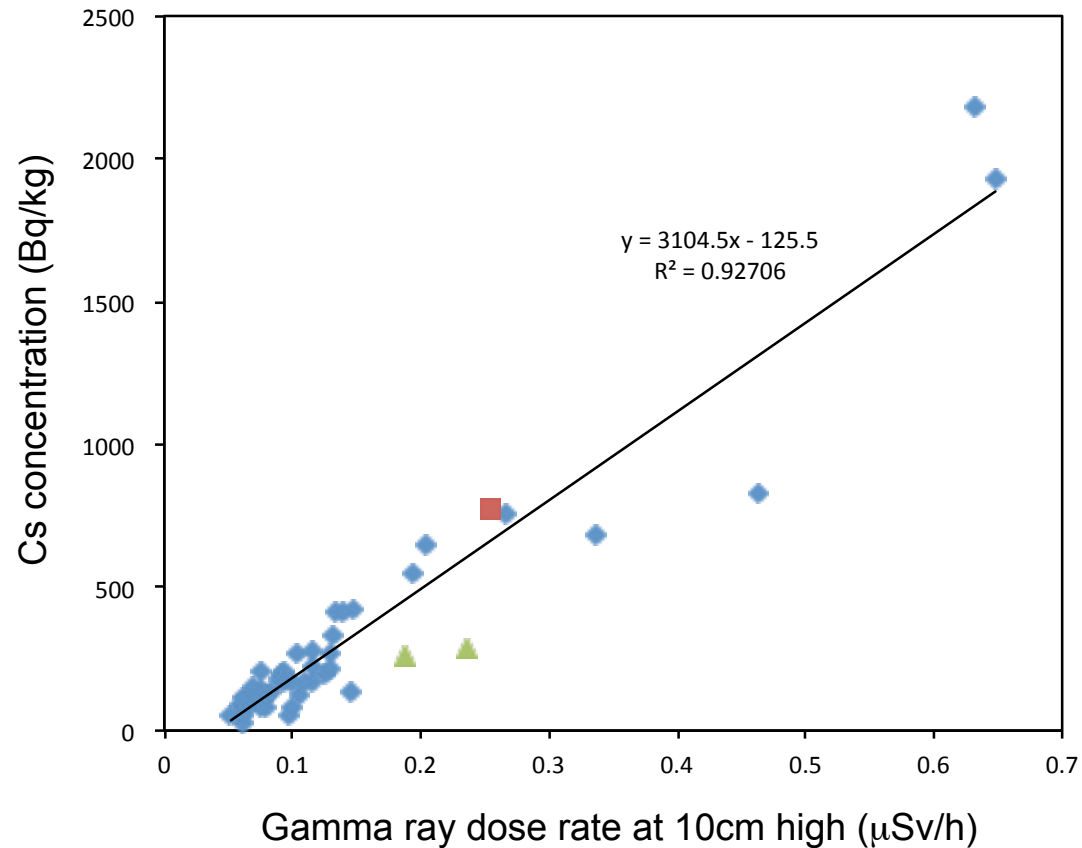
Cs profiles of litate soils



(Fukushima Saisei-no-kai, 2012 from Mizoguchi, 2013)

Cs concentration vs dose rate

$$\text{Bq/kg} \approx 3,000 \times \mu\text{Sv/h}$$



(Inao, 2012)

Rationale

- Striping off a frozen soil layer might be an alternative decontaminating method (Mizoguchi, 2013).
- The gamma ray dose rate reduced from 1.28 to 0.16 $\mu\text{Sv/h}$.



(Mizoguchi, 2013)

Freezing front depth

modified Stefan's formula (Mizoguchi, 2013)

$$z = \sqrt{\frac{2\lambda}{\rho_i \theta L} \int T dt}$$



$$z = \alpha \sqrt{F}$$

sub-zero air
temperature: T ($^{\circ}\text{C}$)

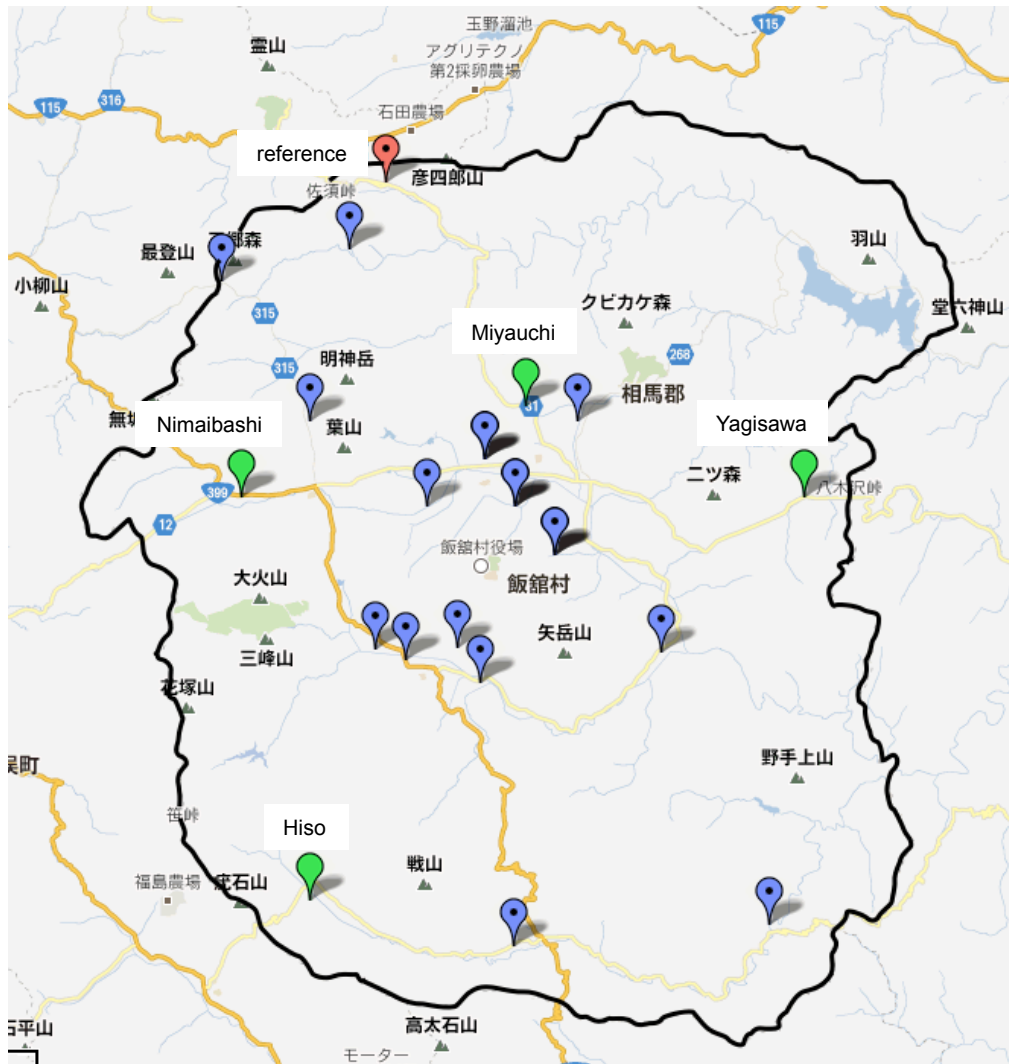
freezing index:

$$F = \int T dt$$

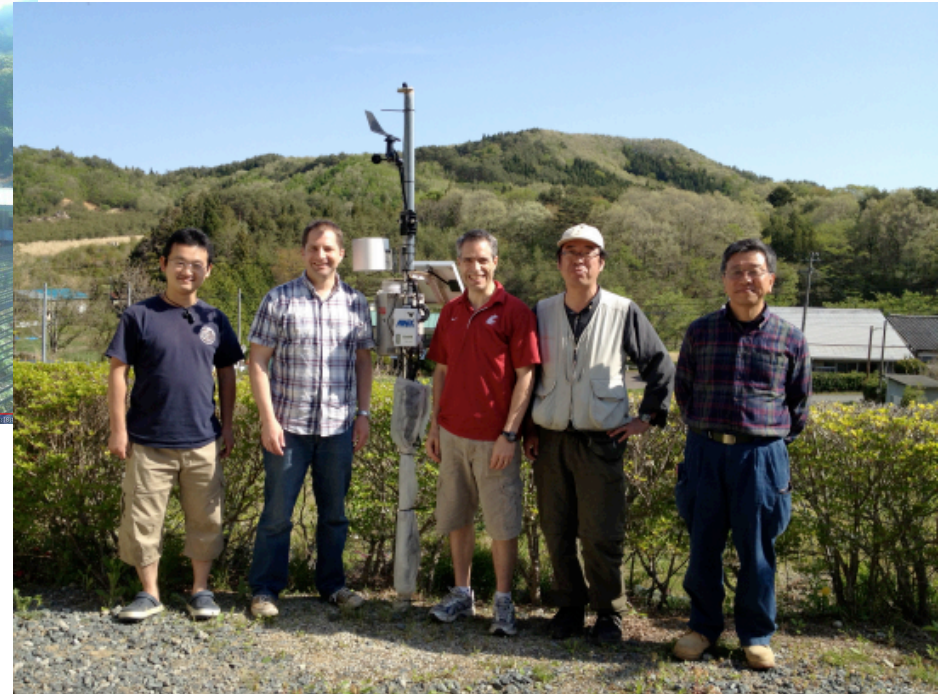
empirical constant:

$$\alpha = \sqrt{\frac{2\lambda}{\rho_i \theta L}}$$

Location of measuring sites



Reference weather station



Safari

Index of vbox0045

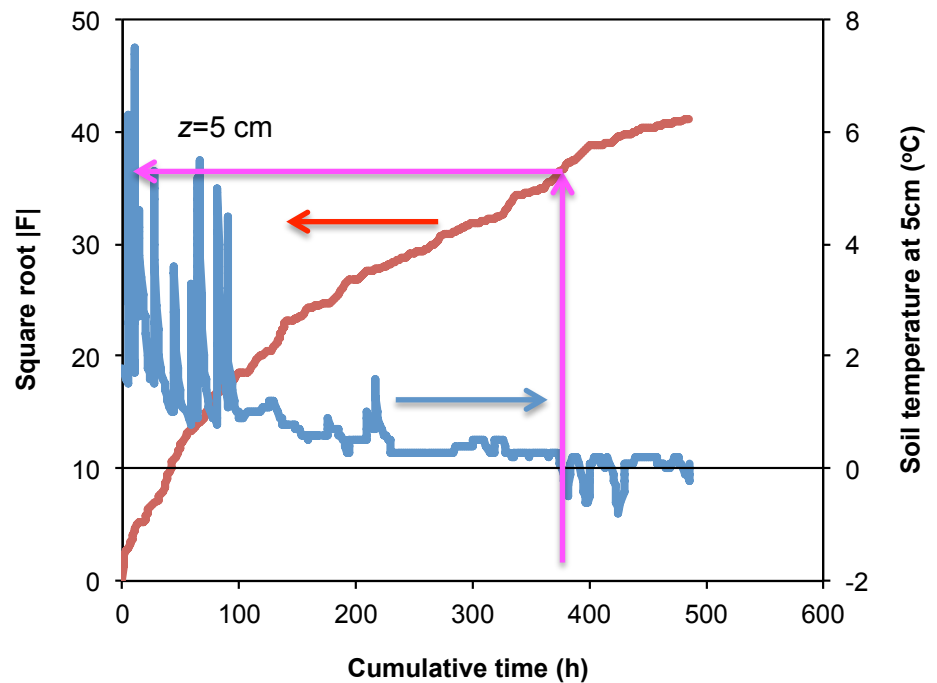
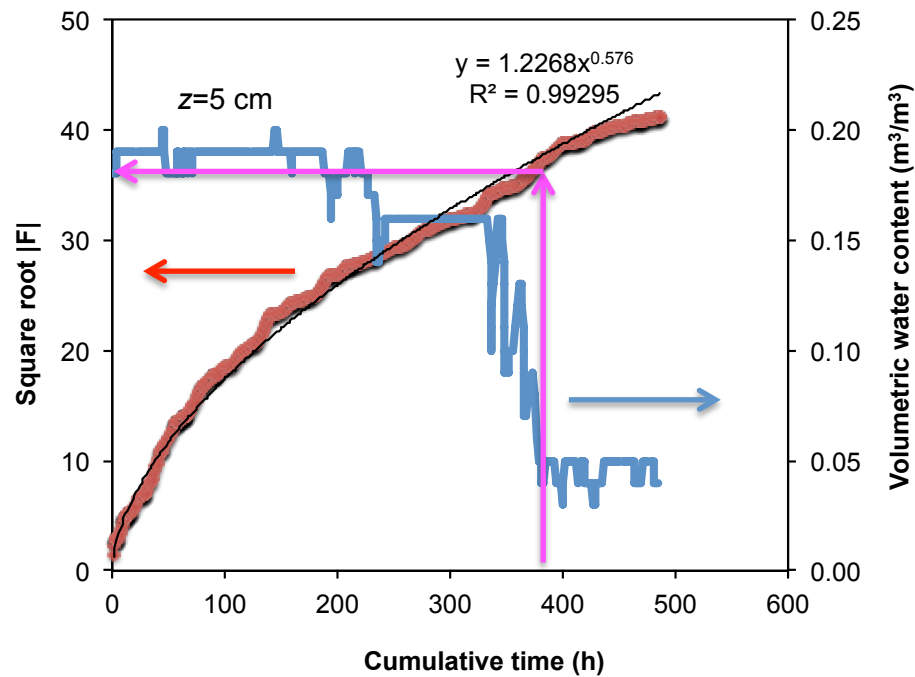
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Images

[image]2013/11/02 12:22 (207.0K) calendar memo

File Name	Size	Download	Thumbnail
EM14736	266.1K	CSV	2013.11.02
PriskCounter	0.4K	CSV	2013.11.02
SimpleCounter	0.2K	CSV	2012.09.17

Freezing index



$$\sqrt{F} = 36.7 \text{ for 5 cm deep freezing}$$

Empirical constant for freezing

$$\alpha = \frac{z}{\sqrt{F}}$$



$$\sqrt{F} = 36.7$$

$$z = 5\text{cm}$$

$$\alpha = 0.136$$

theoretical consideration

$$\alpha = \sqrt{\frac{2\lambda}{\rho_i\theta L}}$$

thermal conductivity $\lambda=0.6$ W/m/K
=21.6 J/h/cm/K (Tokumoto et al., 2010)

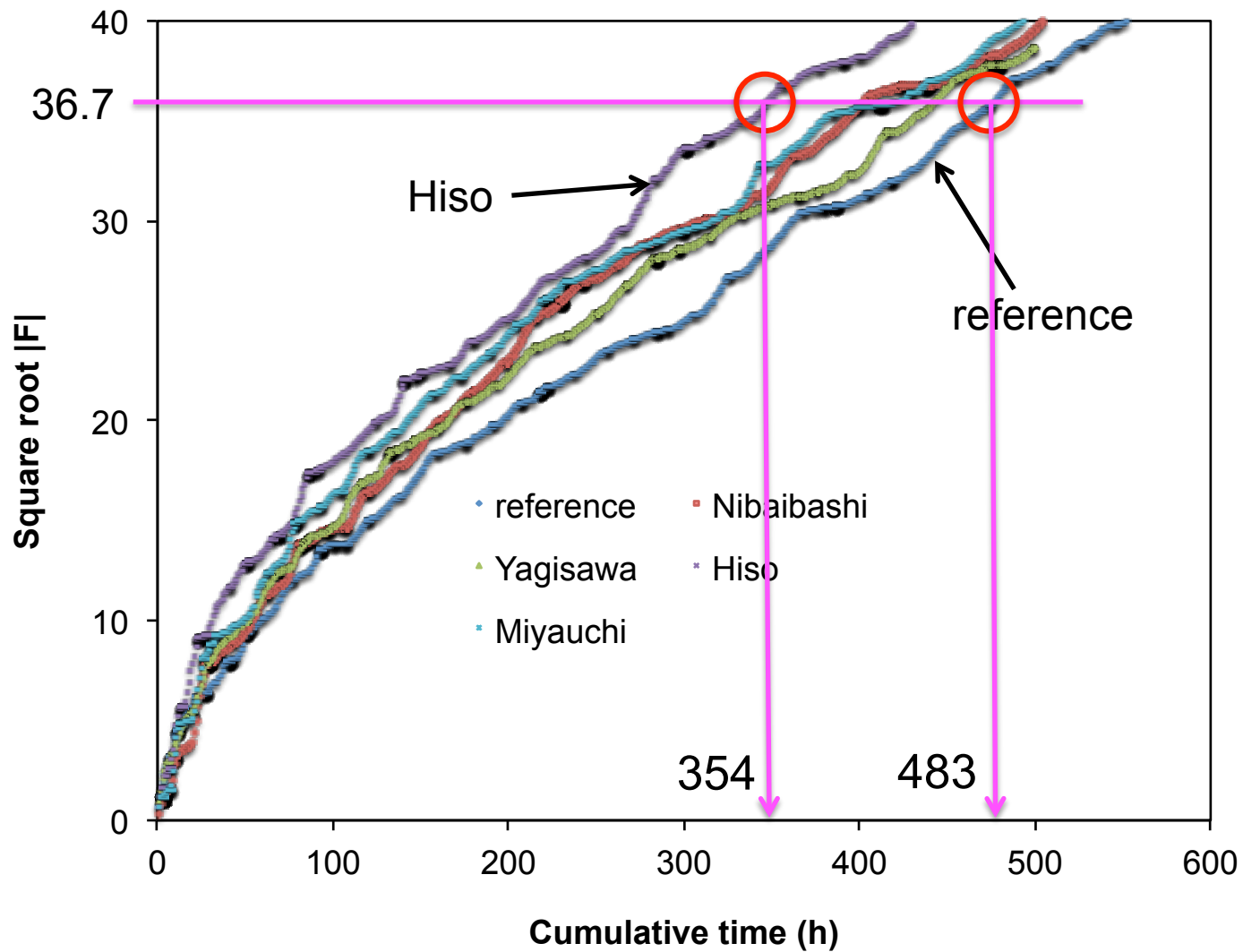
density of ice $\rho_i=0.918$ g/cm³
(Dall'Amico et al., 2011)

latent heat of fusion $L=334.0$ J/g
(Kojima et al., 2012)

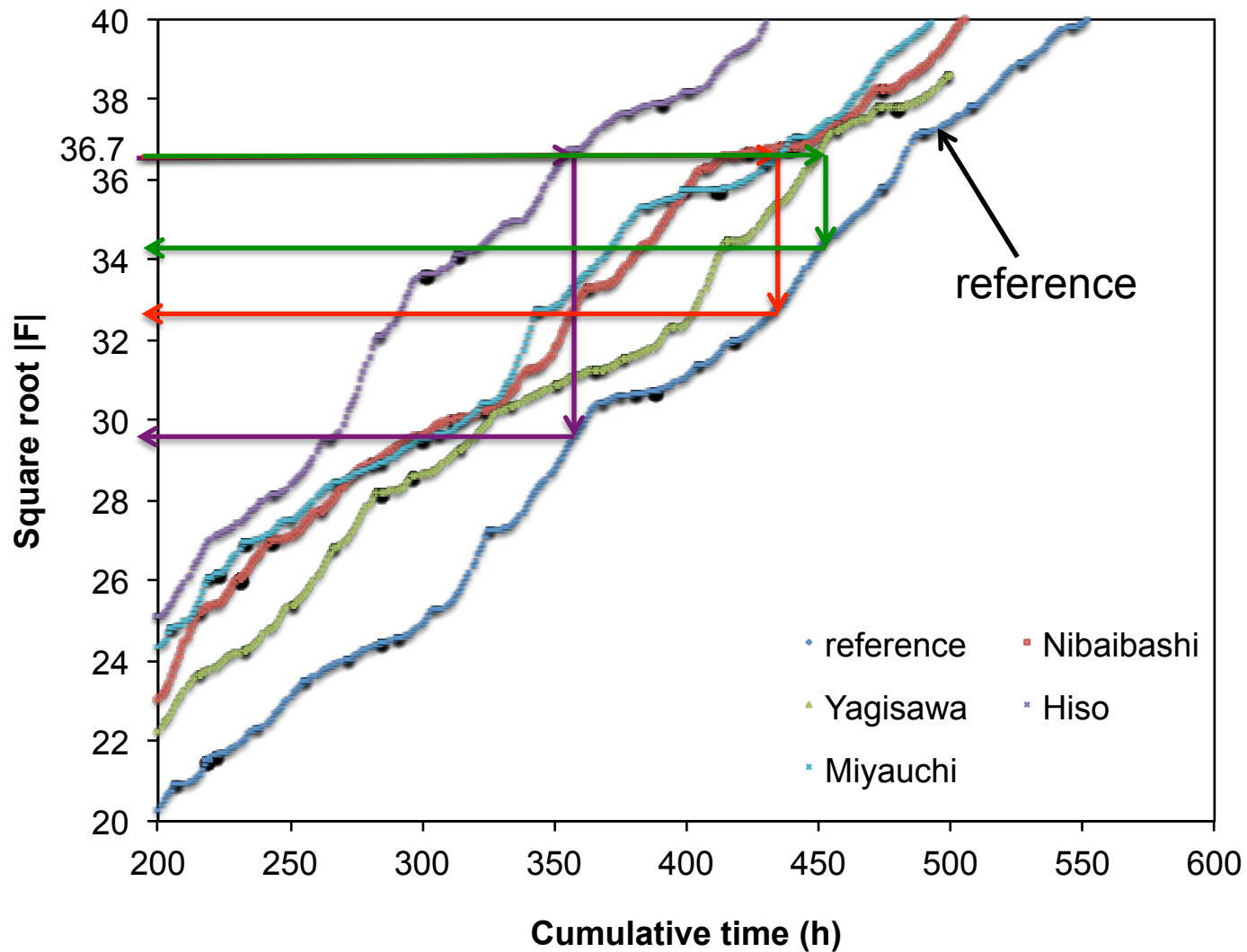
icing water content $\theta=0.15$ cm³/cm³

$$\alpha = 0.969$$

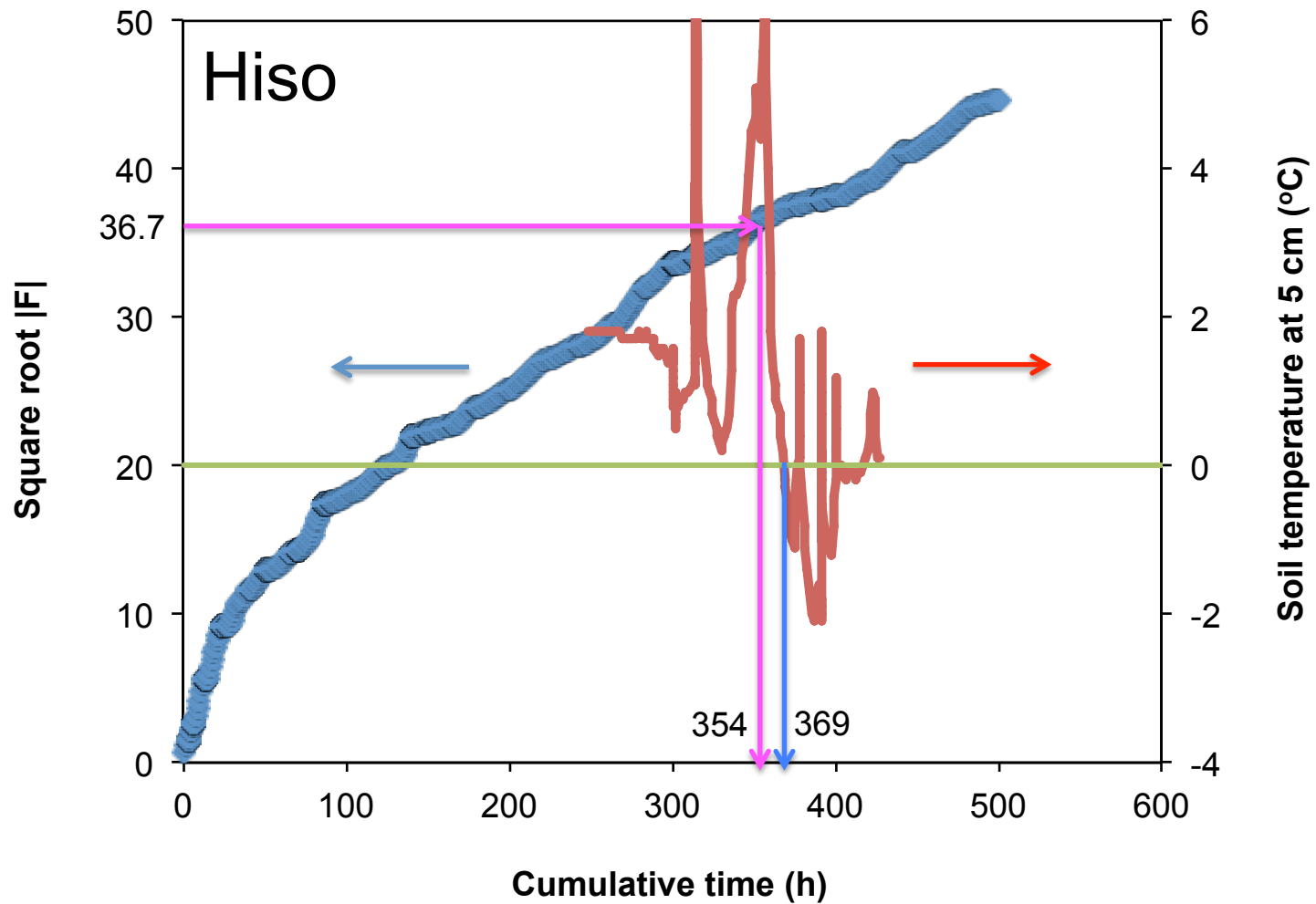
Freezing timing



Estimating freezing date



Comparing with soil temp. measured



Conclusions

- A simple modified Stephan equation proposed by Mizoguchi (2013) may predict freezing date at remote location with a reasonable accuracy.
- A numerical simulation model would be a useful tool for fine tuning the method.
- Further work is a definite need.

Acknowledgments

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Thank you.

