RailAdapt Workshops

Beijing
19-20 June 2017
Building a resilient railway

STUDY ON THE TEMPERATURE FIELD UNDER RAILWAY EMBANKMENT RESPONDING TO GLOBAL WARMING IN COLD REGION

YUANBING CAO, CHINA RAILWAY DESIGN CORPORATION

ABSTRACT

This paper studies the change of the ground temperature field in the next 100 years under the effect of global warming. Numerical model is used. The three scenarios upper boundary temperature(RCP2.6、RCP6.0 and RCP8.5) data is from IPCC report AR5.The temperature of RCP2.6 is increasing linearly to 0.6 ℃ and stop rising after 2040,temperature of RCP6 is increasing linearly to 2.3 ℃ to the end, temperature of RCP8.5 is increasing linearly to 1.2 ℃ to 2045 and continue to 3.2 ℃ to the end. The results show that, the shallower, the greater the temperature increases, warming under the three scenarios (RCP2.6, RCP6.0 and RCP8.5) is increased in turn. Ground temperature field in which is -0.7℃ at the depth of 15m increased 0.23℃ largest 20 years later, and 0.34℃ largest 50 years later. The temperature increase varies greatly 100 years later in the three scenarios (RCP2.6、RCP6.0 and RCP8.5),and temperature at the depth of 5m increased 5℃ under RCP8.5.Ground temperature field in which is -0.2℃ at the depth of 15m increased more, and the shallower, the more different the temperature increases.100 years later, the ground temperature field rise between 1.6 ℃ and 7.2 ℃.This paper provides a reference for the design of the railway facilities related to the temperature field.

Key words: frozen ground, ground temperature field, global warming, response, IPCC

INTRODUCTION

Global warming has become the consensus. The latest report(AR5) from the Intergovernmental Panel on Climate Change(IPCC) says there is no doubt that the global climate system is warming, and almost every region of the world has experienced a warming process. Global warming is mainly embodied in the earth's surface temperature and ocean temperatures, rising sea levels, melting ice caps and glaciers retreat, increased frequency of extreme weather events, etc. Therefore, the railway that grows as a linear engineering will face huge challenges, especially in the cold region. This paper studies the change of the ground temperature field in the next 100 years under the effect of global warming.

NUMERICAL MODEL

- Based on the theory of heat conduction
- Ignoring seepage and convection inside of the ground soil
- Consider the ice-water phase change

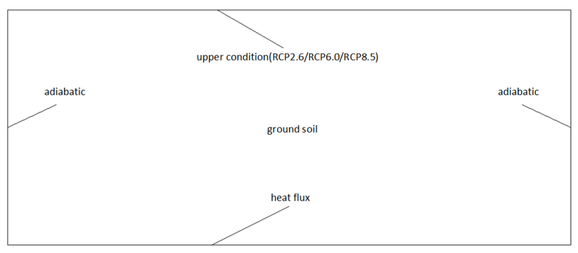
$$\rho C_f \frac{\partial T_1}{\partial t} = \frac{\partial}{\partial x}(\lambda_f \frac{\partial T_1}{\partial x}), \rho C_w \frac{\partial T_2}{\partial t} = \frac{\partial}{\partial x}(\lambda_w \frac{\partial T_2}{\partial x})$$

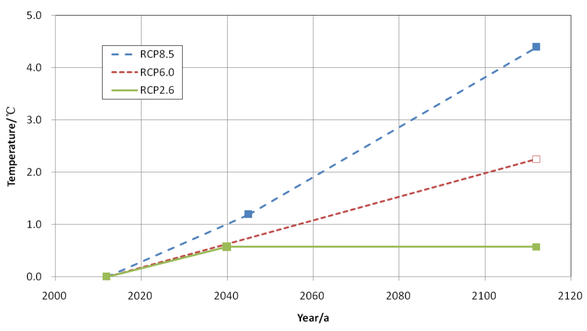
$$T(0,t) = f(t), T(x,0) = g(x), T_1(x,t)\big|_{x=\xi} = T_2(x,t)\big|_{x=\xi} = T_f$$

$$\lambda_f \frac{\partial T_1}{\partial x}\Big|_{x=\xi} - C_w \frac{\partial T_2}{\partial t}\Big|_{x=\xi} = L\gamma_d (W - W_u)\frac{d\xi}{dt}$$

$$T_1(x,t)\big|_{x=\xi_d} = T_2(x,t)\big|_{x=\xi_d} = T_f, \lambda_w \frac{\partial T_1}{\partial t}\big|_{x=H} = q$$

$$\lambda_f \frac{\partial T_1}{\partial x}\Big|_{x=\xi_d} - \lambda_w \frac{\partial T_2}{\partial t}\Big|_{x=\xi_d} = L\gamma_d (W - W_u)\frac{d\xi}{dt}$$





Boundary condition

- Upper temperature (RCP2.6/RCP6.0/RCP8.5) from IPCC AR5
- Lower boundary: constant heat flux
- Both sides: adiabatic

Ice-water phase change

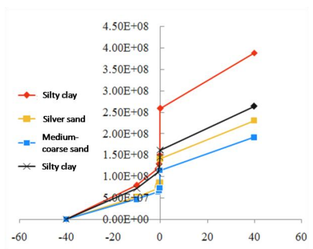
- Equation of enthalpy

$$\Delta H = \int \rho C(T) dT = \Delta H_1 + \Delta H_2$$

$$\Delta H_1 = \rho \cdot C \cdot (T_2 - T_1)$$

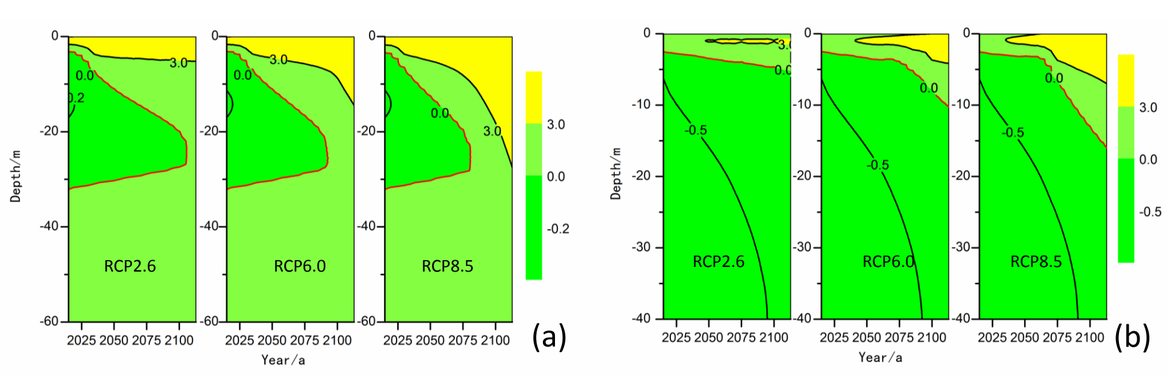
$$\Delta H_2 = L\rho \Delta W_u$$

$$W_u = aT^{-b}$$



RESULTS

Temperature field of ground soil which is -0.2 ℃(a) and -0.7 ℃(b) at the depth of 15m changing in the next 100 years under different RCP



(a)Temperature field change

- Permafrost disappeared at 2105/2092/2080
- Frozen soil upper limit move down quickly
- Move down rate: 0.19m/a,0.25m/a,0.29m/a

(b) Temperature field change

- Permafrost exist persistently
- Frozen soil upper limit move down quickly begin at non/2073/2062
- Move down rate: non,0.17m/a,0.26m/a

Temperature rise range(*ΔT*)

	Depth/m	Temperature of 2015	20 years			50 years		
			RCP2.6	RCP6	RCP8.5	RCP2.6	RCP6	RCP8.5
(a)	5	-0.13	1.53	1.45	1.99	2.77	3.39	4.34
	10	-0.20	0.02	0.02	0.04	1.02	1.32	2.05
	15	-0.20	0.01	0.01	0.01	0.08	0.12	0.61
(b)	5	-0.43	0.23	0.23	0.23	0.34	0.34	0.33
	10	-0.61	0.18	0.18	0.18	0.31	0.31	0.31
	15	-0.69	0.13	0.13	0.14	0.26	0.26	0.27

Temperature rise range(*ΔT*)

- Ground temperature (-0.7℃ depth of 15m) increased 0.23℃ largest 20 years later, and 0.34℃ largest 50 years later.
- Ground temperature (-0.2℃ depth of 15m) increased very small(green area) except depth<5m 20 years later, while change a lot 50 years later
- Change is different between RCPs in the yellow area.

CONCLUSIONS

1. Permafrost of -0.2 ℃ will disappear while -0.7 ℃ permafrost won't in the next 100 year.
2. Ground soil temperature field of -0.2 ℃ &-0.7 ℃ will heat up under any RCPs 50 years later as the global warming.
3. The faster the air temperature rises, the greater the ground temperature increases.

REFERENCES (selective)

Stocker T F, Qin D, Platter G K, et al. IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[C]// of the Intergovernmental Panel on Climate Change. 2013:1031-1044.

Cao Yuanbing, Sheng Yu, Wu Jichun, et al. Influence of upper boundary conditions on simulated ground temperature field in permafrost regions[J].*Journal of Glaciology and Geocryology*, 2014, 36 (4):802-810

Cao Yuanbing. Evolution and Engineering Geology Evaluation of Permafrost along Gonghe-Yushu Highway[D].Beijing: University of Chinese Academy of Sciences,2015