### 22th AIM International workshop

## **Output of Project S14-5**

### Qian ZHOU

### **National Institute for Environmental Studies**







## What's Project S14?



Strategic R&D Area Project "S-14" of the Environment Research and Technology Development Fund Strategic Research on Global Mitigation and Local Adaptation to Climate Change [MiLAi]









## What's Project S14?



# What did we do in Project S14-5(2)?

Mission: Establishing theoretical and technical foundation for coupling Global Hydrology model H08 and CGE model

PI: Dr. Hanasaki Naota

Dr. Zhou Qian

Focus: Water constraints on global <u>hydropower</u> and <u>thermoelectric</u> supply capability under climate change







# Background: hydropower supply

• Currently, hydropower is a dominant renewable resource due to its <u>low cost</u> and <u>low greenhouse gas (GHG) emissions</u> (IEA, 2012).

• However, hydropower potential is effected by climate change





# **Background: thermal power supply**

### Climate change



### **Cooling water shortage**



# Thermal power plant shut down



# How climate change constraints hydropower and thermal power supply capability through water ?





![](_page_8_Picture_0.jpeg)

### Model-Based Analysis of Impact of Climate change and Mitigation on Hydropower

#### Qian ZHOU, Naota HANASAKI, Shinichiro FUJIMORI, Yoshimitsu MASAKI and Yasuaki HIJIOKA

National Institute for Environmental Studies

![](_page_8_Picture_4.jpeg)

![](_page_8_Picture_5.jpeg)

![](_page_8_Picture_6.jpeg)

This paper aims to address following research questions:

- What is the state-of-the-art knowledge on the impact of climate change on hydropower?
- What are the potential key interactions of combining physical models and economic models in terms of hydropower in global and regional scales?
- How significant such interactions are?

![](_page_9_Picture_5.jpeg)

### Method

- Global Hydrology model
- AIM/CGE model

![](_page_10_Figure_3.jpeg)

![](_page_10_Picture_4.jpeg)

![](_page_11_Figure_0.jpeg)

![](_page_12_Figure_0.jpeg)

Zhou et al. 2016 Union and c) North Africa

#### **Results**

### Climate change impact on hydropower potential Mitigation impact on hydropower generation

![](_page_13_Figure_2.jpeg)

Fig.5 Fix\_EEC: regional Fix\_EEC set in AIM/CGE model; Mitigation policy: average percentage changes in region '+'IG normalized by Fix\_EEC due to mitigation policy; Climate change: average percentage changes in EEC nominalized by regional Fix\_EEC due to climate change; With VS. without mitigation policy: HG in AIM/CGE\_RCP2.6 VS. AIM/CGE\_Ref; without Climate change: New EEC in H08 RCP2.6 VS. Fix EEC. Zhou et al. 2016

![](_page_14_Picture_0.jpeg)

- Is climate change impact on hydropower potential is negligible?
- How to quantify economy consequence of hydropower potential change?

![](_page_14_Picture_3.jpeg)

![](_page_15_Picture_0.jpeg)

![](_page_16_Picture_0.jpeg)

# Economic consequences of global climate change and mitigation on future hydropower

Qian ZHOU, Naota HANASAKI, Shinichiro FUJIMORI,

**Yoshimitsu MASAKI and Yasuaki HIJIOKA** 

![](_page_16_Picture_4.jpeg)

![](_page_16_Picture_5.jpeg)

![](_page_16_Picture_6.jpeg)

## Methodology

How to quantify economy consequence of hydropower potential change?

![](_page_17_Figure_2.jpeg)

Exogenous parameter for AIM/CGE: MAHG

Endogenous variable

![](_page_17_Picture_5.jpeg)

## Results Hydropower Generation change

![](_page_18_Figure_1.jpeg)

Figure 4. Magnitude of hydropower generation changes

## Results Why GDP changes is different in these regions?

![](_page_19_Figure_1.jpeg)

## **Results** *GCMs* uncertainty analysis for *GDP*

![](_page_20_Figure_1.jpeg)

Figure 9. Magnitude of GDP changes due to individual and ensemble GCM based MAHG shocks

Full Title:         Article Type:         Corresponding Author:         Corresponding Author Secondary Information:         Corresponding Author's Institution:         Corresponding Author's Institution:         Corresponding Author's Secondary Institution:         First Author:         First Author:         Order of Authors Secondary Information:         Order of Authors Secondary Information:         Funding Information:         Abstract:	Economic con generation Research Artic Qian Zhou, Ph National Institu Tsuluuba, Ibara Qian Zhou, Ph National Institu Qian Zhou, Ph National Institu Yashimitsi Ma Yasuaki Hijok Technology D the Ministry of Hydropower g power supply: be affected by models. In this under two phy Integrated Mox	B1 (Hydraulic Eng MODEL-BASED ANALYSIS OF I CLIMATE CHANGE AND MITIC HYDROPOWER Qian ZHOU <sup>1</sup> , Naota HANASAKI <sup>2</sup> , Shinichiro FUJIMORI and Yasuaki HUIOKA <sup>5</sup> <sup>1</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>5</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for Envire <sup>4</sup> Member of ISCE, Dr. of Env., National Institute for En	INPACT OF TATION ON AN ANALYSIS ON HYPOTHETICAL SHOCKS REPRESENTING COOLING WATER SHORTAGE USING A COMPUTABLE GENERAL EQUILIBRIUM MODEL Qian ZHOU <sup>1</sup> , Naota HANASAKI <sup>2</sup> , Jun'ya TAKAKURA <sup>3</sup> , Shinichiro FUJIMORI <sup>4</sup> , Kiyoshi TAKAHASHI <sup>3</sup> and Yasuaki HIJIOKA <sup>6</sup>	nermal power 1 Thermal pow	ver 2 and
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	the MAHG ave in RCP8.5). W	1 INTRODUCTION precipitation	*Member of JSCE, Senior Researcher, National Institute for Environmental Studies E-mail: hijioka@nies.go.jp		
	product (GDP) mitigation police	change and vari			
	implementation	generate electricity in the world today. Currently, sustainability an	Due to global warming, it is concerned that cooling water for thermoelectric generation would be n short more framently in many places of the world. We used a Computable General Equilibrium (CG		
	there would be	electricity power supply and 86% of the worldwide 10 begin to	model to quantify the socio-economic impact of a hypothetical shock of capital productivity, while	On the mon	
ou et al. 201?		renewable electricity energy source <sup>1)</sup> . This is due to Theoretical is its low cost low greenhouse gas (GHG) emission total potential e	represents shortage of cooling water on infermal power generation plants. The result showed that to magnitude of electricity generation change and subsequent economic indicators change due to 1% capit	Un the way	
		and relatively high reliability compared to other maximum hydr renewable source of energy	productivity reduction were varied by region. The mean electricity generation loss was largest in Southea Asia and smallest in North Africa when an identical shock was given to all regions throughout th		
		Climate change is a big concern of the society. To completely con	simulation period. Considerable regional differences in GDP and electricity price were attributed to n only the capital productivity, but also the amount of capital in thermoelectric sector and its contribution fi		
		emission is required accompanied by gradual shift Economical e	GDP. Additionally, thermoelectric sector shock propagates into the global economy. These findir demonstrate the significance in quantifying the economic consequence of cooling water shortage.		
		from fossil fuel to renewable energy. Stringent by World Energ climate mitigation policy would increase demand of the gross theore			
00.000.00		the hydropower because it emits no GHG. On the other hand, hydropower is dependent on streamflow and expected lo	Key Words : cooling water shortage, thermoelectric sectors, capital productivity, CGE model		
		which is influenced by hydrological change (e.g. Present situ			
			1. INTRODUCTION major source of cooling water is seawater plants located near seashore and fresh water t		
	7	hou et al $2016^{\circ\circ}$	Fresh water is indispensable to sustain humans' in inland. For example, in USA, 222 kr		
	L L	100 Et al. 2010	plant cooling is one of major water usages in the cooling water, which accounts for 45%		
			world. Globally 19.9 EJ/yr of electricity is national total withdrawal <sup>47</sup> . produced <sup>10</sup> . Among various technology, 16.5 EJ/yr Availability of cooling water is crucially in		
			(81%) was generated by thermal power in 2010 <sup>1</sup> ). in electricity generation. Indeed, shortage		
			includes gas, oil, coal, nuclear, and biomass. The influenced the operation of plants. In 2007,		
			$7hou \text{ ot al } 2017^{-17}$		

### An Analysis on Hypothetical Shocks Representing Cooling Water Shortage Using a Computable General Equilibrium Model

Qian ZHOU, Naota Hanasaki, Jun'ya TAKAKURA, Shinichiro FUJIMORI, Kiyoshi TAKAHASHI and Yasuaki HIJIOKA

National Institute for Environmental Studies

![](_page_22_Picture_4.jpeg)

![](_page_22_Picture_5.jpeg)

# Background

- In 2007, nuclear and coal-fired plants in the Tennessee Valley Authority system were forced to shut down or curtail operations because intake water exceeded 90 F (32.2° C) for 24 hours
- In 2003, France lost the electricity production of 7% to 15% of nuclear capacity for 5 weeks (DOE, 2012)

![](_page_23_Picture_3.jpeg)

# **Research Question**

 What is the socio-economic consequence of giving a certain intensity of shock representing the shortage of cooling water in thermal power sectors under the framework of a computable general equilibrium model?

• How the shock in thermal power sectors propagates into the global economy.

![](_page_24_Picture_3.jpeg)

# Method: Framework

- How to numerate cooling water shortage for CGE input data?
- How to connect cooling water shortage with CGE model?

![](_page_25_Figure_3.jpeg)

# Result: How were electricity and GDP changed?

![](_page_26_Figure_1.jpeg)

#### Fig. 3

- (a) Thermal power change compared with baseline in 2050 in ARAY scenario.
- (b) Mean difference in electricity generation (EG) from the baseline (between 2005 and 2100).
- (c) The rate of thermal electricity production to total electricity production in 2005.
- AMGDP change compared with baseline in 2050 in ARAY scenario

Economic consequences of Manuscript Number: Full Title: Article Type: Corresponding Author: Corresponding Author Secondary Information: Corresponding Author's Institution:	Climati f global climate gen Manus CLIM-D-16-00501 Economic con generation Research Artic Qian Zhou, Ph National Instith Tsukuba, Ibara	Lic Change e change and mitigation on future hydropower script Draft B B (Hydraulic Eag B B (Hydraulic Eag B (Hydraulic Ea	wer 2 Hydropower 1 MPACT OF TATION ON Lange of Long management of Lange of Long management of Lange of Lang	nermal power 1	
First Author: First Author Secondary Information: Order of Authors: Order of Authors Secondary Information: Funding Information: Abstract:	Qian Zhou, Ph Qian Zhou, Ph Qian Zhou, Ph Nada Hanasa Shinichiro Fuji Yoshimitsu Ma Yasuaki Hijok c The Environm Technology D the Ministry of Hydropower g defacted by models. In this under two phy integrated Mox quantify the sc on hydropower of climate chan hydropower ag there would be prostive effect regions.	Qian ZHOU <sup>1</sup> , Naota HANASAKI <sup>2</sup> , Shinichiro FUJIMORI and Yasuki HIJIOKA <sup>5</sup> <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>2</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>3</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Member of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender of DSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender of JSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender of DSCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender of SCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender Of SCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender Of SCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender Of SCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender Of SCE, Dr. of Env., National Institute for Envire <sup>1</sup> Stender Of Scenari Equilibrium (ADV CGE) model <sup>1</sup> Charge variations of Increase the global total THP and accioecon <sup>1</sup> Instender Charge scenarios and periods. The quantified influence demonst <sup>1</sup> HO <sup>3</sup> and ADV CGE. <sup>1</sup> LINTRODUCTION <sup>1</sup> Hydropower is a dominant renevable source to <sup>1</sup> Instender accounts for 16% of the varidivida <sup>1</sup> Intervitative power supply and 86% of the total <sup>1</sup> Intervitative power supply and 86% of the total potential for	AN ANALYSIS ON HYPOTHETICAL SHOCKS REPRESENTING COOLING WATER SHORTAGE USING A COMPUTABLE GENERAL EQUILIBRIUM MODEL Qian ZHOU <sup>1</sup> , Naota HANASAKI <sup>2</sup> , Jun'ya TAKAKURA <sup>3</sup> , Shinichiro FUJIMORI <sup>4</sup> , Kiyoshi TAKAHASHI <sup>3</sup> and Yasuaki HJIOKA <sup>6</sup> <sup>1</sup> Member of ISCF, Resurch Associate, National Institute for Environmental Studies (16-2, Onogawa, Taukha, Ibrania 305-8506, Japan) <sup>2</sup> Member of ISCF, Senior Researcher, National Institute for Environmental Studies (16-2, Onogawa, Taukha, Ibrania 305-8506, Japan) <sup>2</sup> Member of ISCF, Senior Researcher, National Institute for Environmental Studies (16-2, Onogawa, Taukha, Ibrania 305-8506, Japan) <sup>3</sup> Resurch Associate, National Institute for Environmental Studies (16-2) Environmental Institute for Environmental Studies (16-2), Senior Researcher, National Institute for Environmental Studies (17), Senior Researcher, National Institute for Environmental Studies (17), Senior Researcher, National Institute for Environmental Studies (18), Bennber of ISCE, Senior Researcher, National Institute for Environmental Studies (18), Senior Researcher, National Institute for Environmental Studies (18), Senior Researcher, National Institute for Environmental Studies (18), Senior Senior (18), Senior Researcher, National Institute for Environmental Studies (18), Senior Benzio (18), Senior Researcher, National Institute for Environmental Studies (18), Senior (18), Senior Researcher, National Institute for Environmental Studies (18), Senior (18), Senior Researcher, National Institute for Environmental Studies (18),	On the way	wer 2 and 3
hou et al. 2	01?	renewable source of energy. Climate change is a big concern of the society. To stabilize the climate, considerable reacy. Stringent from fossil hel to renewable energy. Stringent the hydropower because it emits no GHG. On the other hand, hydropower is dependent on streamflow which is influenced by hydrological change (e.g. Thousand the limit and expected lo Present situ Thousand the limit of the society of the society of the society of the construction of the society of the so	Asia and smallest in North Africa when an identical shock was given to all regions throughout it simulation period. Considerable regional differences in GDP and deterricity prior were attributed to noty the capital productivity, but also the amount of capital in thermostectric sector and its contribution of GDP. Additionally, thermostectric sector hock propagates into the global economy. These finding demonstrate the significance in quantifying the economic consequence of cooling water shortage. <i>Low Words</i> : cooling water shortage, thermoelectric sectors, capital productivity. <i>CGE</i> model and the significance in quantifying the contomic consequence of cooling water shortage. THRODUCTION The final power is cooling water shortage thermoelectric sectors, capital productivity. <i>CGE</i> model plants located near seashore and fresh water is produced <sup>10</sup> . Among various tee of water, power in sources of cooling water was withdrawn in clobally 19.9 EL/yr of electricity is produced <sup>10</sup> . Among various technology, 16.5 El/yr (81%) was generated by thermal power in 2010 <sup>10</sup> . Here the primary energy sources of thermal power in cludes gas, oil, coal, nuclear, and biomass. The <b>Choou et al. 20017</b> <sup>1/29</sup>		
IM <sup>2017/12/1</sup>		-		Under preparation	27

**Topic 1**: Global thermal power usable capacity reduction from cooling water consumption shortage attributable to climate change

**Topic 2**: Economic consequences of cooling water shortage impact on thermoelectric supply capability under climate change

![](_page_28_Picture_3.jpeg)

![](_page_28_Picture_4.jpeg)

![](_page_28_Picture_5.jpeg)

Results

• How climate change impact the global thermoelectric usable capacity?

- 5 GCMs
- RCP2.6 and RCP8.5

![](_page_29_Figure_4.jpeg)

![](_page_29_Picture_5.jpeg)

![](_page_30_Figure_0.jpeg)

![](_page_31_Picture_0.jpeg)

 Climate change impact on hydropower and thermoelectric potential should not be negligible in IAM

![](_page_31_Picture_2.jpeg)

• The Environment Research and Technology Development Fund (S-14) of the Ministry of the Environment, Japan, supported this work.

![](_page_32_Picture_2.jpeg)

![](_page_32_Picture_3.jpeg)

### 22th AIM International workshop

### Thank you very much for your attention!

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![](_page_33_Picture_3.jpeg)

Strategic Research on Global Mitigation and Local Adaptation to Climate Change [S-14]

![](_page_33_Picture_5.jpeg)

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