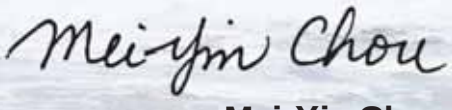
Center for Sustainability Science
Academia Sinica

2018
Annual Report of Center for Sustainability Science, Academia Sinica

Foreword

As we all know, sustainability science is unequivocally transdisciplinary and in great demand worldwide, especially for complicated and unsolved problems encountered in attempting to achieve the sustainable development of human society. As part of its mission of using scientific methods to tackle the above-mentioned issues, Academia Sinica established the Center for Sustainability Science (CSS) in 2012. This was done in hopes of facilitating knowledge-building for this transdisciplinary research field, and to provide solutions for problems we currently face at both the local and global levels. In brief, the CSS has two functions: 1) To organize our scientists to work on specific topics through research programs; 2) To encourage our scientists to engage in important international initiatives. During the past 7 years, the CSS has funded over 40 integrated programs in 6 designed research orientations. In the 2018 Annual Report, 6 recently completed projects have been selected to showcase their outcomes. These projects encompass subjects such as novel energy technologies, vaccine biological experiments for food security, societal risk recognition on food supply and the environment, impact simulations for future climate change, climate reconstruction by means of historical documents, and IT applications for disaster resilience building. I am pleased to see these promising results, which can play a major role in helping us find solutions for issues related to sustainable development mentioned above. In addition, the CSS has worked to fulfill its second function by operating two offices for international collaboration: IRDR ICoE Taipei and Future Earth Taipei. In 2018, the CSS continued its work of participating in global and regional events, as well as organizing a series of international workshops and training courses. Special efforts were devoted to launching the young scientist workshop in Taiwan, and to proactively collaborating with the CTCI Education Foundation and Taiwan Institute for Sustainable Energy in co-organizing conferences. These initiatives indicate that the CSS has strengthened its efforts for promoting interactions between generations and stakeholders. Such networking contributions constitute a key facet of comprehending transdisciplinary research and implementing future actions. I believe that the CSS has attained impressive growth as shown in the Annual Report and will maintain this momentum for many years to come.



Mei-Yin Chou
Chairman, Center for Sustainability Science
Academia Sinica

Center for Sustainability Science

Introduction

The Center for Sustainability Science (CSS), Academia Sinica was established in 2012 with one key purpose: to promote sustainability science research. These researches explore the dynamic interactions between human society activities and the Earth System, especially targeting several contemporary problems that affect the sustainability of natural ecological system and human society. These problems often transcend boundaries, affect generations, and involve several scientific fields and governmental agencies. Therefore, it is scientists' responsibility to provide sound scientific evidence and information to solve these complicated and difficult problems.

There are over 30 research institutes in Academia Sinica with three divisions: Physical Sciences, Life/Medical Sciences, and Humanity/Social Sciences. In addition to accumulate basic scientific research capacity in each research field, these top-notch researchers are keys to resolve sustainability problems. Thus, with three principles (i.e., problem-solving oriented, interdisciplinary cooperation and integration, solution-oriented), CSS aims to promote sustainability science researches in Academia Sinica.

Missions

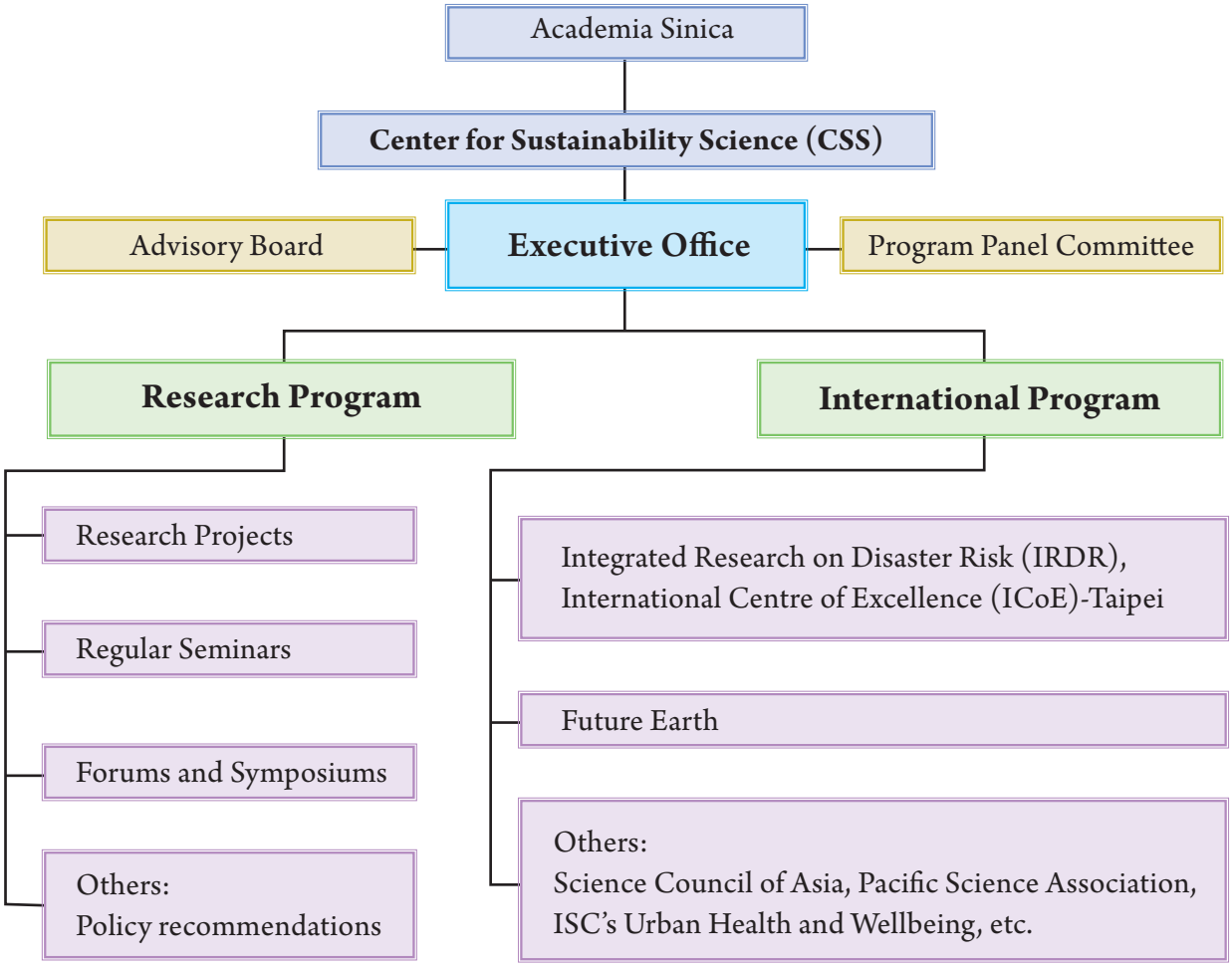
There are three primary missions of Center for Sustainability Science:

(1) To plan, organize, and promote transdisciplinary Sustainability Science Research Program.

(2) To promote sustainability science-related international cooperation programs and to bridge Taiwan's sustainability science researcher with international sustainability research network, namely IRDR-ICoE and Future Earth

(3) To provide objective policy recommendations on significant

Organization and Task



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Research Program and International Program

Research Program

The Sustainability Science Research Program emphasizes on transdisciplinary scientific research. It aims at synthesizing the research results of different dimensions and applying the results on solving problems of sustainable development for human society. The current focal themes include the following six research orientations.

Energy and Decarbonization Technologies

Food, Air, and Water Security and Safety

Transformation towards Sustainable Society

Earth System under Global Changes

Earth System under Global Changes

Disaster Prevention, Reduction and Recovery

Academia Sinica has initiated an interdisciplinary Sustainability Science Program in September 2012 with the establishment of the Center for Sustainability Science. Researchers from the three divisions of the Academy, the Physical Sciences, Life and Medical Sciences, and Humanity and Social Sciences are encouraged to engage in boundary crossing research projects organized and coordinated by the Center, aimed at solving relevant problems and serving as a think tank for the Government on issues related to sustainable development. Six research projects are included in this annual report.

- Efficient Transformation and Utilization of Solar Energy
- Research and development of bird flu vaccines against highly pathogenic avian influenza virus
- Facing " Risk Society" in Taiwan: Issues and Strategies
- Taiwan Drought Study: Change, Water Resource Impacts, and Risk Perception and Communication
- Reconstructing East Asian Historical Climate Series using China's Chronological Records in Past Two Millennia (REACHES)
- Disaster Resilience through Big open Data and Smart Things (DRBoaST)

International Program

The Integrated Research on Disaster Risk-International Centre of Excellence (IRDR-ICoE) established at Academia Sinica in 2011 with the support of International Council for Science (ICSU) was incorporated into the Center in 2012 to serve as an international platform for conducting integrated research, establishing a partnership network of interdisciplinary researchers and strengthening international collaborations.

Center for Sustainability Science (CSS) in Academia Sinica has organized a series of events for Future Earth, a major international scientific activity and research initiative on global environmental change and sustainability, to promote sustainability science. Currently, CSS is closely collaborating with Future Earth Global Hub, Future Earth in Asia, and Future Earth Knowledge Action Networks (KANs) in capacity building programs and actively engaging in these international activities.



Efficient Transformation and Utilization of Solar Energy



Project starting year: 2016
Hosting Institute: Institute of Chemistry, Academia Sinica

Research Objectives

The objectives of this project were to develop technologies for harnessing solar energy and efficiently converting it into chemical or electrical energy. The project has three subprojects: (1) to develop dye-sensitized solar cells (DSSCs) through design and synthesis of novel light-absorbing molecules, electrolytes, and photoelectrodes; (2) to study organic–inorganic hybrid solar cells through surface modification and nanostructure fabrication of silicon wafers for solar cells or through material development or device structure modulation of perovskite solar cells; and (3) to study solar energy-based hydrogen generation and storage systems through development of highly efficient photocatalytic and electrochemical systems for water splitting.

Main Results to Date

In terms of DSSCs, a number of dyes were developed, including (1) D-π-A type monoanchored dyes incorporating a rigid segment comprising fused electron-rich and electron-deficient aromatics in the conjugated spacer between the electron donor and acceptor; and (2) D-$(\pi\text{-A})_2$ type dianchored dyes with a 12-crown-4 substituent at the nitrogen atom of the phenothiazine donor. These dyes have intense and broad absorption in the visible region and exhibit excellent cell conversion efficiencies of >10% under 1 sun illumination. Another dye type, the D-A'-π-A type dye, exhibits favorable cell performance under dim light illumination, with its highest cell performance being 18.95%, 20.16%, and 27.17% under 300, 600, and 6000 lux irradiance, respectively. Submodule panels (10 × 10

Figure 1. Solar cell modules utilizing the dyes developed in this project: Humidity sensor, cell phone charger, and calculator respectively.

cm^2 and 5 × 10 cm^2 dimensions) with an efficiency of >10% were also fabricated from D-$(\pi\text{-A})_2$ dianchored dyes. A new dipolar organic dye functionalized with a diacetylene unit, which undergoes photoinduced cross-linking to generate a hydrophobic polydiacetylene layer, was also developed. The polydiacetylene layer serves as not only an electrolyte-blocking layer that blocks the approach of the oxidized redox mediator and suppresses the dark current, but it also plays a light-harvesting role by efficiently transferring energy to the dipolar dye. In addition, a new synthetic protocol for preparing NiO for use as the photocathode material in p-type DSSCs was designed. The p-type DSSCs containing this newly prepared NiO with dipolar organic dye achieved high performance of up to 0.207%. Counter electrodes (CEs) composed of different silicon compounds and transition metal selenides (TMSe)—including Si_3N_4, SiO_2, SiS_2, $SiSe_2$ CoSe, $CoSe_2$, $TiSe_2$, and $MoSe_2$—were synthesized to replace the rare and expensive Pt metal. TMSe-based CEs with hierarchical morphology offer low-dimensional charge transfer pathways because the main body is decorated with extended electrocatalytically active sites; thus, orientated charge transfer routes and a large surface area are achieved simultaneously. The newly synthesized TMSe-based and metal–organic framework–based CEs have (1) favorable electrocatalytic ability, (2) a large effective surface area, and (3) high conductivity.

Regarding hybrid organic–inorganic solar cells, efforts were made to obtain low-temperature, solution-processed hybrid poly polystyrene sulfonate (PEDOT:PSS)-silicon solar cells and modules. Hierarchically structured silicon wafers containing both microscale pyramidal structures and nanoscale wires were prepared. A 14% power conversion efficiency (PCE) with an active cell area of 1 × 1 cm^2on an industrial standard Si wafer was achieved. Efforts to use thinner and larger-area silicon wafers finally led to a hybrid device with 7% PCE for a 50-μm-thick cell with an area of 100 cm^2. The stability of the cell is improved by soft packaging. For hole selective contact, PEDOT-PSS was found to result in an excellent PCE of 18.6% for 180-μm-thick silicon on a 4 cm^2 area. When developing perovskite solar cells, various interlayer materials were explored for the cathode and anode in the configuration of a conventional or inverted polymer solar cell with the goal of cheaper and easier synthesis of materials compared with the benchmark materials PCBM and spiroOMeTAD. With a conventional cell structure, an efficiency of 18.1% was achieved. With an inverted structure, an efficiency of 17.1% was obtained.

Figure 2. The scheme of hybrid heterojunction solar cell.

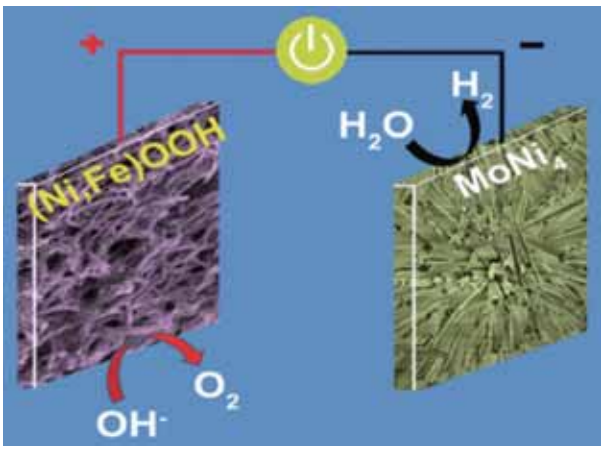

Figure 3. Alkaline water electrolysis at ambient temperature.

Progress has also been made in the development of efficient, robust, and economical electrocatalysts for use in both the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER). A pioneering study on the electrocatalytic properties of electrodeposited-film electrodes derived from irreversible electro-reduction and -oxidation of the molecular dinitrosyl iron complex revealed that the overpotential and Tafel slope for the HER are lower than those for an equivalent-weight Pt/C electrode in alkaline solution. The electrodeposited-film anode for OER is stable for 139 h. A single electrode-pair device containing an electrodeposited-film cathode and anode and used for electrocatalytic water splitting has an onset voltage of 1.77 V and geometrical current density of 10 mA/cm^2. In consideration of the OER activity of iron and cobalt oxides and the superior electroconductivity and propitious H atom binding energy of metallic iron and cobalt, a bifunctional electrodeposited-film electrode composed of CoFe and $CoFeP_xO_y(OH)_z$ was prepared from irreversible cathodic deposition of $FeSO_4$ and $CoSO_4$ on the surface of a graphite plate. The as-prepared CFeCoP electrode exhibited excellent HER activity (specific activity [j_s] = 0.169 mA/cm^2) with low charge transfer resistance (4.5 Ωcm^2), an overpotential of 57 mV, and a current density of 10 mA/cm^2; conversely, its OER activity j_s = 1.316 mA/cm^2 with low charge transfer resistance (7.8 Ωcm^2) and 282-mV overpotential, approaching a current density of 10 mA/cm2 in 1 M NaOH aqueous solution. In addition, the CFeCoP electrode has long-term stability (139 h) for both HER and OER activity with stable current density. In the cell, the CFeCoP–CFeCoP electrode pair achieved a current density of 10 mA/cm^2 at a voltage of 1.56 V (Tafel slope of 51 mV/dec), close to that of a Pt–IrO_2 electrode-pair device in 1 M NaOH aqueous solution (10 mA/cm^2 at a voltage of 1.58 V; Tafel slope of 68 mV/dec). X-ray photoelectron spectroscopy, scanning electron microscopy–energy-dispersive X-ray spectroscopy, and powder X-ray diffraction revealed that metallic iron and cobalt and iron and cobalt (oxy) hydroxides were embedded in a metal–oxide matrix and formed films on the graphite surface to form the CFeCoP electrode. The electrodeposited film majorly composed of FeCo and $CoFeP_xO_y(OH)_z$ may mediate the kinetics that occur at the catalyst–electrolyte interface and exhibit stable intrinsic catalytic activity for water splitting.

Future Research Plan

In the next phase, the results obtained in this project will be integrated to produce a highly efficient solar energy-driven hydrogen generation system. Sensitizers will be used to harvest light for initiating photocatalytic water splitting to generate hydrogen. Materials will be optimized toward total water splitting, light-harvesting antenna and solar cell units will be developed, electrode material and interface engineering will be performed, and a device will be assembled and optimized. Toward these goals, we will continue the development of sensitizers and hole transport materials to increase the efficiency of DSSCs and increase the stability of perovskite solar cells.

The future work on organic–inorganic solar cells will be focused on using various organic materials as a diffusion-free hole selective layer. We will also investigate the coupling of a high-density self-assembled monolayer to silicon surfaces to enhance the photovoltaic characteristics and stability of micropyramidal textured hybrid silicon solar cells. Perovskite tandem cells will be investigated to increase the PCE and design a practical solar energy-supplying module. A crucial challenge is to extend the lifetime of the materials used in the oxygen evolution anode. Currently, connection of the whole cell to a 3-V solar panel is sufficient to drive the water-splitting reaction. A scale-up device is being developed to increase the efficiency.

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Project Director: *Dr. Yu-Tai Tao*

Yu-Tai Tao is a Distinguished Research Fellow of IoC. His research centers around organic materials chemistry and surface chemistry, including electroluminescent materials and devices, organic field effect transistor materials and devices, organic memory devices, and solar cells.

Sub-Project PI, Co-PI:

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Shih-Sheng Sun, IoC, AS
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Dr. Kuang-Lieh Lu, IoC, AS



Research and development of bird flu vaccines against highly pathogenic avian influenza virus



Project starting year: 2017
Hosting Institute: ABRC, Academia Sinica

Research Objectives

Highly pathogenic avian influenza virus (HPAIV), which infects birds with high mortality, is considered a major threat to the poultry industry. The newly emerged AIV Gs/GD clade 2.3.4.4 H5N2 has severely affected the poultry industry in Taiwan and many countries since spring 2015. Infected poultry species include not only chicken and turkey but also water birds, especially duck and geese. An effective vaccine against AIVs is critical to inhibit the spread of epidemics among poultry and to mitigate the risk of avian-to-human transmission. Our project research team successfully created a bird flu vaccine against H5N2 AIVs by formulating a virus-like particle (VLP) antigen and a novel VP3 adjuvant. Targeting the currently circulating H5N2 strains, this project will advance bird flu vaccines against H5Nx HPAIV of clade 2.3.4, broaden cross-protective efficacy, optimize dose-sparing parameters, and curtail the manufacturing cost of VLP and VP3.

Main Results to Date

Production of H5N2-VLP as a vaccine antigen: The main goal of Subproject-1 is to establish site-specific insertion of viral genes to introduce concomitant expression of M1 and hemagglutinin/neuraminidase (HA/NA) genes in the insect Hi5 cell line (BTI-TN5B1-4, derived from Trichoplusia ni ovarian germ cells). Before the insect vector system and founder cell lines were created, we used the human 293F cell line to produce H5N2-VLP for HPAIV Gs/GD clade 2.3.4.4 to serve as the initial vaccine antigen. The H5N2-VLP produced by stable transfection of the 293F cell line has been characterized by a standard procedure and shows high activities of viral HA and NA. Each microgram of H5N2-VLP contains 64 HAU and 100 ng H5 protein, the main target of the neutralizing antibody, as quantified through a new assay using a monoclonal antibody recognizing the conserved HA stem and recombinant HA proteins. We have established and validated all essential insect cell vectors for inducible expression of M1, HA, and NA in Hi5 cells. Furthermore, founder cells harboring high-level transgenic expression have been enriched. High-expressing clones will be isolated and chosen to form stable clones and produce H5N2-VLP. Engineering of N-glycosylation in the insect Hi5 cell line is also in progress and part of planned future research.

Production of H5N2-VLP in silk worm. As an alternative approach for antigen production, we constructed bicistronic expression vectors of H5 and M1 genes in the most commonly used baculovirus, *Autographa californica* multiple nuclear polyhedrosis (AcMNPV). We have produced and purified H5-VLP by infecting the suspension culture of Sf21 and Hi5 cell lines. To expand the production scale and lower the cost, we design to use another baculovirus *Bombyx mori*

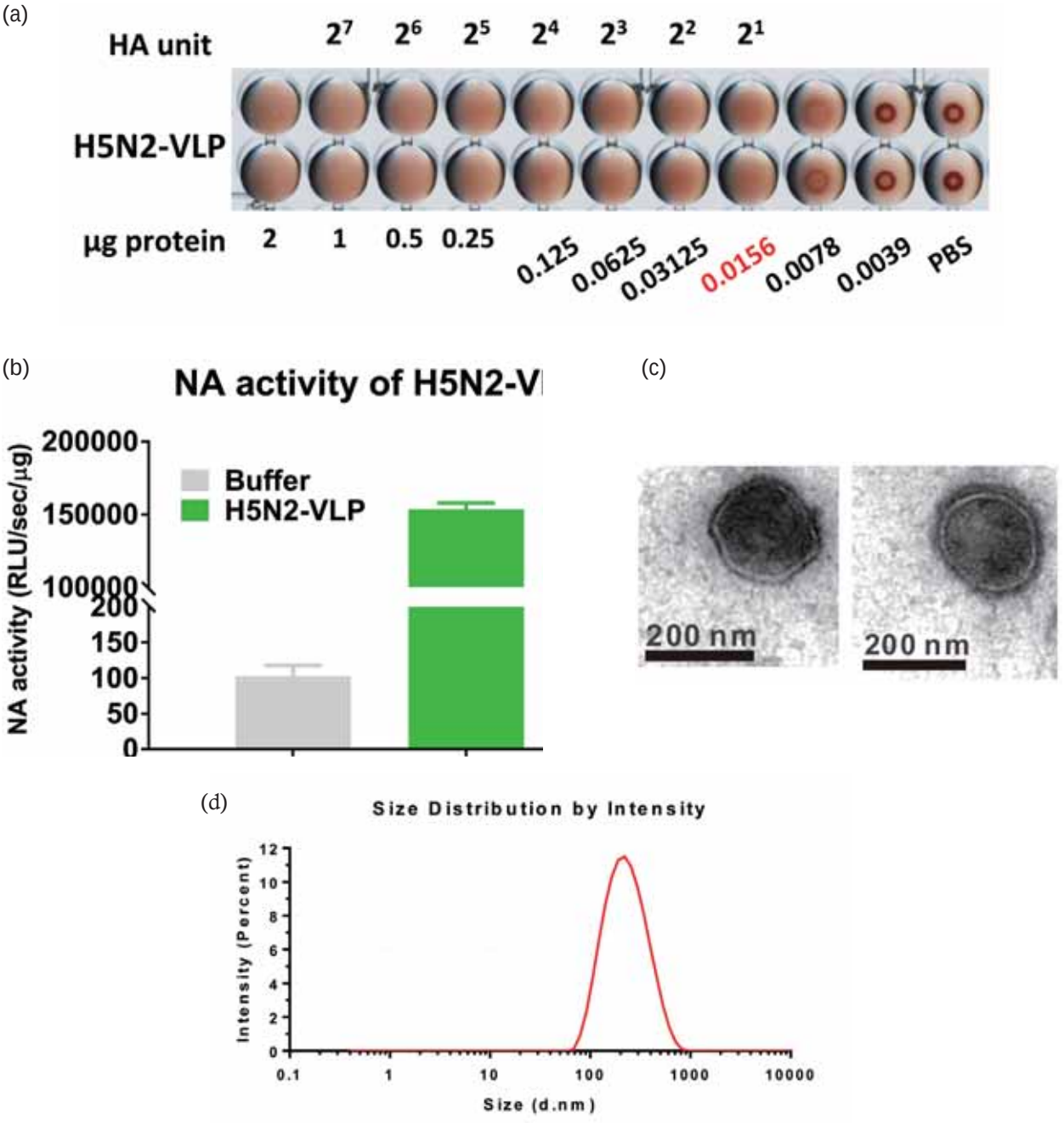

Figure 1. Characterization of H5N2-VLP produced by 293F cell line. Functional and physical characterizations of H5N2-VLP produced by a 293F cell clone. H5N2-VLPs were purified by sucrose density gradient ultracentrifugation and characterized by various different methods. (a) Hemagglutination assay. (b) NA activity were measured by NA-star Influenza Neuraminidase Inhibitor Resistance Detection Kit (Thermo Fisher). Per µg H5N2-VLPs provided 150,000 unit of NA activity. (c) H5N2-VLPs were negatively stained with 2% uranyl acetate, and observed by TEM at 100,000x magnification. (d) Dynamic light scattering (DLS) measurements of particle sizes and distributions of H5N2-VLPs produced by the 293F cell clone.

nuclear polyhedrosis virus (BmNPV) system, which infects silkworm pupae for the mass production of H5-VLP. We recreated the DH10Bac/BmNPV bacmid and inserted the coding sequences of clade 2.3.4.4 AIV H5 protein and M1 protein into the BmNPV bacmid vector. Viral packaging and replication of recombinant BmNPV through transfection of the BmN cell line have been conducted. Next, large-scale H5-VLP expression by infecting silkworm pupae is underway.

Production of rVP3 and H5N2-VLP as a better adjuvant and a cross-protective antigen, respectively. The goal of this subproject is to develop more effective and affordable vaccine adjuvants against HPAIV. We have developed rVP3 as a protein adjuvant, which effectively activates chicken TLR2-2 and TLR16 and thus downstream NF-κB activity. Ex vivo treatment of chicken splenocytes with rVP3 increased the expression of IFN-γ, IL-18, and IL-10. When chickens were vaccinated with the H5N2-VLP antigen, adding rVP3 in the adjuvant increased the survival rate after lethal

challenge and pronouncedly diminished postinfection viral shedding. Compared with the inactivated reverse genetic recombinant H5 (rRG6) virus, one dose of VLP induced high levels of hemagglutination inhibition antibody (HI Ab) and a greater Ab response after booster immunization (data not shown). Montanide ISV 71VG oil adjuvant is commercially available and effective in AIV vaccines. Therefore, we compared the adjuvant effect of rVP3+Alum and the Montanide incomplete Seppic adjuvant 71VG on the H5N2-VLP antigen in chicken immunization. Although both adjuvants are effective at high-dose (64 HAU) antigen (Fig. 2A), at low-dose (8 HAU) H5N2-VLP vaccination, HI titers in the VLP+Alum group were higher than those in the 71VG group (Fig. 2B). Although commercial 71VG had a superior enhancing effect on rRG6 vaccine-induced Ab response than alum (data not shown), our VP3 adjuvant considerably enhanced VLP-induced Ab responses against the homologous H5 antigen (Fig. 2). We further compared the vaccine effects of different antigens (H5N2-VLP) against the rRG6-inactivated virus (both were formulated with the 71VG adjuvant) in chicken immunization. Antisera taken on day 28 after prime-boost immunization with H5N2-VLP (Fig. 3A) or rRG6 (Fig. 3B) vaccines were examined for their neutralizing antibodies. Although both VLP and rRG6 induced high levels of homologous HI Ab in chickens, only VLP-induced Ab cross-reacted with the rRG6 H5 antigen, as determined through HI assays, suggesting a superiority of the VLP antigen over the conventional inactivated virus (Fig. 3). In the future, we will optimize all necessary parameters to make an effective formula of bird flu vaccine by minimizing the dosage of H5N2-VLP and the VP3 adjuvant, which can also provide cross-clade protection with considerations of cost-effective manufacturing. With the technology of cross-protective bird flu vaccine developed in this project, poultry and egg agriculture can be made more sustainable when confronting the potential outbreak of HPAIV.

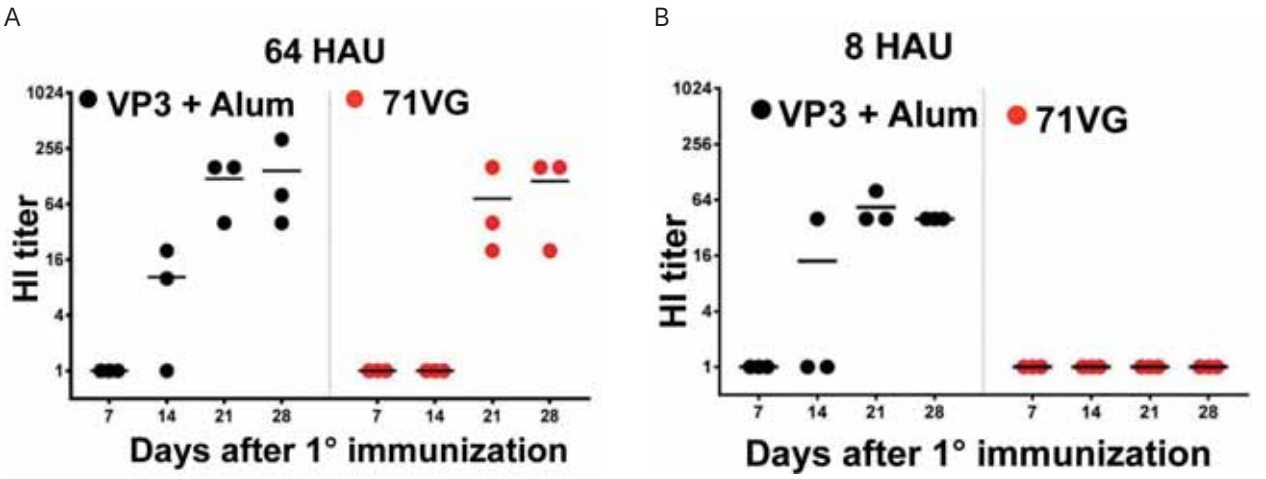

Figure 2. Immunization of H5N2-VLP with VP3+alum induced a better Ab response than that with 71VG in chickens. Group of 3 chickens were immunized with (A) 64 HAU or (B) 8 HAU of H5N2-VLP with VP3+Alum (black circles) or with 71VG adjuvant (red circles). Immunization schedule, collection of antiserum samples (up to day 28) and HI assays were as described in the legend of Figure 1.

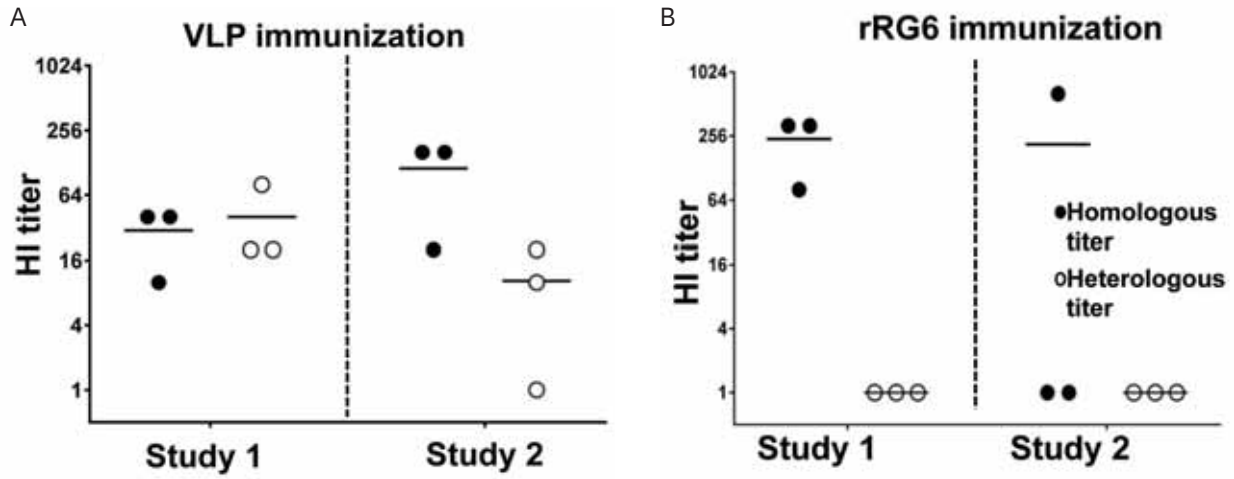

Figure 3. VLP vaccine induces both homologous and heterologous HI Ab responses in chickens. Group of 3 chickens were immunized with 64 HAU of H5N2-VLP or rRG6 inactivated virus in combination with 71VG adjuvant. Antiserum samples were obtained on day 28 after primary-boost immunization. HI titers were cross-examined with either antigen as homologous and heterologous titer. Two independent experiments were represented separately.

The research team has achieved production of H5N2-VLP from the human 293F cell line and H5-VLP from insect Sf21 and Hi5 cell lines. We also produced rVP3 and characterized its immunoadjuvant effects in chicken models. Immunization experiments in chickens have indicated that the H5N2-VLP vaccine effectively elicits neutralizing antibodies with cross-protective effects. Our research plan will optimize the minimal dose of the VLP antigen, as defined by the protein amount of H5 and HAU, to elicit effective and cross-protective antibodies in the formulation with the rVP3 adjuvant. Various forms of VLPs will be efficiently generated in the near future, including H5N2-VLP from the Hi5 cell line and H5-VLP from silkworm pupae. Both will be validated for their immunoprotective and cross-protective effects using the dose and adjuvant decided in the near future. We will optimize the vaccine formula according to chicken immune responses and validate it for its efficacy by using a lethal virus challenge.

Glycoproteins produced in insects generally display less complex N-glycans than those produced in mammals. The insect N-glycans are pauci-mannose type with terminal mannose residues, whereas mammalian N-glycans often extend with N-acetyllactosamine repeats and terminal sialic acid residues. These differences in N-glycan processing may affect the immunogenicity of VLP antigens produced by the Hi5 cell line silkworm pupae. In case the VLPs produced by insect systems show higher doses of the antigen than H5N2-VLP produced by the 293F cell line, this would suggest that insect N-glycans may lead to an immunosuppressive effect in chickens. To address this concern, we are also engineering the N-glycosylation pathway in the Hi5 cell line. To facilitate this, we will produce VLP bearing a single terminal GlcNAc residue in the N-glycans by intracellular cleavage with Endo H at the endoplasmic reticulum lumen. Genetic engineering to install complex-type N-glycosylation in the Hi5 cell line in this project has begun. If the aforementioned attempt fails to enable a satisfied immunogenicity, we will inevitably produce H5-VLP using the Hi5 cell line expressing complex-type N-glycosylation for the vaccine antigen.

Publications

1. Yang JR, Cheng CY, Chen CY, Lin CH, Kuo CY, Huang HY, Wu FT, Yang YC, Wu CY, Liu MT*, and **Hsiao PW***. (2017) A virus-like particle vaccination strategy expands its tolerance to H3N2 antigenic drift by enhancing neutralizing antibodies against hemagglutinin stalk. Antiviral Research, 140: 62-75.
2. Yang JR, Chen CY, Kuo CY, Cheng CY, Lee MS, Cheng MC, Yang YC, Wu CY, Wu HS, Liu MT*, and **Hsiao PW***. (2016) A novel H6N1 virus-like particle vaccine induces long-lasting cross-clade antibody immunity against human and avian H6N1 viruses. Antiviral Research, 126:8-17.

Project Director: *Dr. Hsiao, Pei-Wen*

Dr. Hsiao has experiences in vaccine research for 15 years. He has worked at Academic Sinica since 2002 and start to work on SARS and influenza vaccine since 2004 and 2006. He has also had successful experiences in developing herbal medicine for prostate cancer and licensed the technology to Wyntek Corp., a domestic biotechnology company. His research focuses on cancer research, natural product medicine, and virus-like particle vaccines against animal and human viral diseases.

Sub-Project PI, Co-PI:

Dr. Hsiao, Pei-Wen, ABRC, AS
Dr. Ku, Chia-Chi, II, NTU
Dr. Jan, Jia-Tsrong, GRC. AS
Dr. Lee, Ming-Shyue, GIBMB, CMNTU
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Dr. Wang, Lih-Chiann, DVM, NTU
Dr. Ma, Che Alex, GRC, AS



Facing " Risk Society" in Taiwan: Issues and Strategies





Project starting year: 2016
Hosting Institute: Institute of Sociology, Academia Sinica

Research Objectives

The objectives of this integrated research project entitled, *Facing Risk Society in Taiwan: Issues and Strategies*, can be summarized as follows.

1. To elaborate the concept of "risk society" proposed and coined by Ulrich Beck in the context of Taiwan by examining three major emerging risk problems: depletion of farmland and food security risks, living security risks faced by ethnic minorities, and nuclear waste risks.
2. To analyze the general risk perception and confidence gap between the general public and the epistemic community and to compare the differences among the aforementioned three risk issues.
3. To propose feasible coping strategies and policy options regarding how Taiwan's civil society and the state can respond effectively to the rise of "risk society."

Main Results to Date

Our project has four research themes, including ''Deterioration of Farmland and the Risk of Food Security'', "The Risk of Living Security and the Ethnic Minority"," Technology Risk: Controversy over Nuclear Waste" and "Risk Perception and Risk Assessment: Implications for Risk Management".

To achieve the first objective, our research individually and empirically examined the causes and conditions of each risk domain (farmland and food risks, residential risks, and nuclear waste risks) by presenting the facts of severity of each risk, controversies over each risk, and the political-economic contexts under which each risk has been emerging and worsening. To achieve the second objective, we utilized the most recent survey data from both the general public and academics and professors on how they perceive different types of risks and disasters and how the scholars' knowledge and state solution are trusted or distrusted and why. To achieve the third objective, we formulated policy options for established institutions and mechanisms of more effective risk communication among the state, experts, and the public to overcome the growing severe risks in Taiwan.

Due to the extreme climate change and national security considerations, food security has become an urgent concern in Taiwan. The first subproject aimed to explore the deterioration and destruction of agricultural land resources in Taiwan and the risk of food security caused by the deterioration and destruction. To understand the current situation of farmland destruction, in the first subproject, fieldwork was conducted in all agricultural counties in Taiwan. For example, researchers visited Chishan and Meinong in Kaohsiung, Annan in Tainan, Lugang in Changhua, and Yilan, Taoyuan, Yunlin, and

Chiayi counties. The first subproject focused on the analysis of important agricultural open data released for the first time by the Council of Agriculture (COA).

According to the data, 16,589 hectares of farmland in Taiwan are actually occupied by factories. These land areas are almost equal to 20% of the total industrial land areas in Taiwan. The issue of the industrial plants located on farmlands, therefore, has become very serious in Taiwan. The next step of the project focused on investigating the deteriorative and destructive effects of factories on the farmlands. In this step, the research areas were narrowed down to the most severe counties, for example, Taichung and Changhua. The research team also interviewed key NGOs for their criticisms and solution suggestions.

The Risk of Living Security and the Ethnic Minority investigated the problem of how indigenous communities managed to continue their livelihood in postdisaster areas and how their sociocultural resilience helped them mitigate possible future disasters. The interview results reflected their vulnerability situations of indigenous people living in high security–risk areas and revealed their low perception when encountering risks.

In the past 3 years, in Technology Risk: Controversy over Nuclear Waste, 52 nuclear waste-related stakeholders have been interviewed, including antinuclear groups, experts, scholars, and public officials. Moreover, journal articles, newspapers, magazines, and government bulletins on nuclear waste-related issues have been collected.

Our research provided the following preliminary research conclusions. In the past, the government decisions mainly relied on scientific and technological rationality. However, citizens have always had concerns about environmental injustice related to nuclear waste disposal–related issues and about rural areas being ignored and cities being given emphasis in terms of development. It is advised that local rights must be protected, and that principles should be incorporated into nuclear waste disposal policies. If the government cannot include front-end trust, fairness, and justice in policy considerations, the progress of relevant policies in the future will be extremely difficult. The following challenges should be overcome by government policies on risk communications in the future: convincing the affected communities to pay for the "inevitable sacrifices" and urging the entire Taiwanese society to equally take up nuclear waste disposal responsibilities.

In this regard, Technology Risk: Controversy over Nuclear Waste proposes two criteria for rebuilding public trust. 1. The government should advocate legislation and policy planning for relocating the nuclear waste stored in Orchid Island. 2. The government should reflect on the negative social costs and impacts under the "established feedback methods" and reconsider more feasible "compensation" mechanisms. The "Orchid Island Waste Storage Disposal and Compensation Bill" is encouraged to be passed to promote the right way of using public funds.

In Risk Perception and Risk Assessment: Implications for Risk Management, a reanalysis of the environment-related questions from 2013 Taiwan Social Change Survey and 2016 Taiwan Social Image Survey was conducted. Furthermore, a website survey on risk perception and risk policy preference among scientists and researchers in Academia Sinica was designed to compare the similarities and differences between the general public and scholars.

Figure 1. The third subproject was invited by the National Nuclear Abolition Action Platform (NNAAP) to provide academic support on designing and holding "The Civil Society Forums on Nuclear Waste."

Figure 2. Professor Keng-Ming Hsu visited Panyapiwat Institute of Management to investigate flood risk in Thailand.

Future Research Plan

After completing this project, Professor Hsiao has started another related integrative research project on "Moving toward a deep carbonized Taiwanese society: action research on social behavioral and institutional transformations." He argues that lifestyle change and related institutional and policy transformations should be taken seriously to successfully transit to a truly deep decarbonized Taiwanese society (DD society).

Additionally, an edited book is being planned for publication, which will include 10 chapters written by all our project PIs. This book is expected to be published in the summer of 2019.

- Book title:
  Facing Taiwan's Risk Society: Analysis and Strategies
- Editors:
  Hsin-Huang Michael Hsiao, Shih-Jung Hsu, and Wen-Ling Tu
- Table of Contents:

Chapter 1: "Crisis of Farmlands: Taiwan's Food Security Risks" by Shih-Jung Hsu, Li-Min Liao and Yi-Cheng Tsai

Chapter 2: "Unregistered Factories Sprawling on Taiwan's Farmlands" by Yuan-Yu Wu, Yi-Cheng Tsai and Shih-Jung Hsu

Chapter 3: "Environmental Risks and the Agricultural Soil Quality Affected by Farmland Illegal Factories" by Yao-Tung Lin, Shih-Jung Hsu and Chen-fang Lin

Chapter 4: "Indigenous Peoples' Risk and Resilience : Cases of Three Villages in Pingtung and Taitung" by Chun-Chieh Chi and Pei-Chun Li

Chapter 5: "Lessons of Environmental Injustice from The Civil Society Forums on Nuclear Waste" by Wen-Ling Tu

Chapter 6: "Where can the Nuclear Waste Go: the Evil Spirit that cannot be Removed from Orchid Island" by Wen-Ling Tu

Chapter 7: "From Environmental Risks to Social Practice: Risk Perception and Citizen Participation for the Environment under Climate Change" by Hsin-Huang Michael Hsiao, Thung-Hong Lin and Keng-Ming Hsu

Chapter 8: "Social Capital, Risk Perception and Public Action" by Thung-Hong Lin, Keng-Ming Hsu and Hsin-Huang Michael Hsiao

Chapter 9: "The Foundation of Public Opinion for the Transformation toward a Low-Carbon Society" by Keng-Ming Hsu, Hsin-Huang Michael Hsiao, Thung-Hong Lin and Kuei-Tien Chou

Chapter 10: "Comparing Citizens and Scholars' Risk Perception and Policy Preference" by Hsin-Huang Michael Hsiao, Keng-Ming Hsu and Thung-Hong Lin

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Project Director: *Dr. Hsin-Huang Michael Hsiao*

Hsin-Huang Michael Hsiao is Distinguished Research Fellow and Director of the Institute of Sociology at the Academia Sinica and Professor of Sociology at National Taiwan University and National Sun Yat-sen University. In addition, he is also Chair Professor of Hakka studies at National Central University. He has served as a Senior Advisor to the President of Taiwan since 2016, and as Executive Director of the Centre for Asia-Pacific Area Studies in Academia Sinica. His areas of specialization include civil society, new democracies, middle class in Asia, local risk society and low-carbon social transformation and Hakka studies.

Sub-Project PI, Co-PI:

Dr. Hsu, Shih-Jung, LE, NCCU
Dr. Tu, Wen-Ling, PA, NCCU
Dr. Lin, Yao-Tung, SES, NCHU
Dr. Hsu, Keng-Ming, PAM, NUTN
Dr. Chi, Chun-Chieh, ERC, NDHU
Dr. Lin, Thung-hong, IOS, AS



Taiwan Drought Study: Change, Water Resource Impacts, and Risk Perception and Communication



Project starting year: 2016
Hosting Institute: RCEC, Academia Sinica

Research Objectives

This project involves cross-disciplinary research to explore the potential impacts of future climate change on water resources in Northern Taiwan. The project also proposes policy recommendation for adequate adaptation measures in the case of potentially increasing water shortage. The involved researchers include climate scientists, hydrologists, and social scientists. The following issues are explored in this project:

1. High temporal- and spatial-resolution projection of rainfall changes in Taiwan based on multiple climate change scenarios and the worst scenario.
2. Risk assessment of drought and water resources.
3. Establishment of investigation and policy communication tools for investigating stakeholders' risk perception on the issue of "climate-change-induced water shortage and necessary adaptation."

Main Results to Date

1. Drying tendency during spring in Taiwan and Southern China under RCP8.5 scenario-based global modeling: (I) Changes in circulation by 2040–2060 will enhance the anomalous circulation that has been leading to spring drought in Taiwan, thus suggesting an enhancement in the occurrence, duration, and strength of spring drought in Taiwan (Figure 1). (II) Frontal activity that brings rainfall to Taiwan in spring will be significantly weakened. The situation favorable for spring drought may worsen in 2075–2099. (III) The consecutive dry day is projected to lengthen and the extreme rainfall is likely to enhance in the area surrounding Taiwan. On dividing the rainfall into 10 categories, the occurrence of categories 1–9 will decrease by approximately 20%, whereas the occurrence of category 10 (the most intensive rainfall category) will increase by approximately 50%. (IV) This study found that under the RCP8.5 scenario, the spring rainfall in Taiwan is likely to change in two extremes: enhanced island-wide drought and regional heavy rainfall. The increase in heavy rainfall may not help in replenishing water resources; however, it might have adverse effect on rain-related natural disasters.
2. Reduced spring rainfall in Taiwan in the near future (2040–2059) projected by regional modeling: The aforementioned results obtained from global climate models were confirmed by regional climate modeling in a 5-km spatial resolution. A pseudo global warming experiment was conducted to estimate the potential changes in rainfall for the 2001–2004 severe spring drought event by considering the warming effect in 2040–2060. The results illustrated in Figure 2 reveal that on average, the rainfall deficit will reduce by more than 50% in February and March, which indicates that a known spring drought event is likely

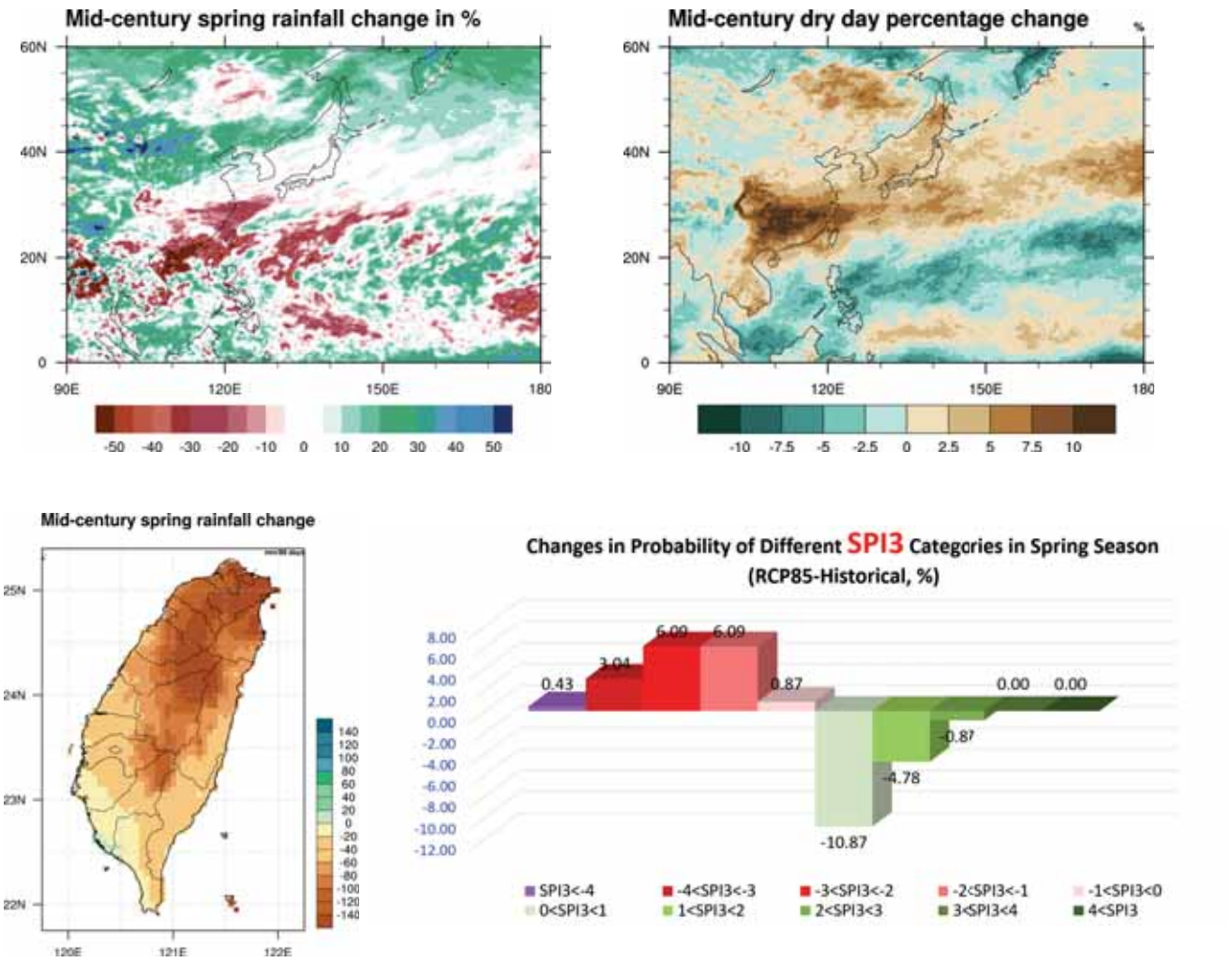

Figure 1. Changes (2040-2060 minus 1980-2008) in (top-left) rainfall and (top-right) number of dry day, derived from HiRAM), (lower-left) change in 3-month Standard Precipitation Index (negative means drier; from CMIP5 models) indicating more dry springs and less wet springs), (lower-right) changes in bias-corrected rainfall over Taiwan (from HiRAM). Similar but enlarged changes were identified for the 2075-2099 period.

to significantly worsen in the warming future. A long-term simulation for July in Northern Taiwan reveals that afternoon thunderstorms will occur more often over the northern basins and less often over mountain slopes. This potential change suggests that thunderstorms will contribute considerably less to the water storage in the reservoir in the future warming summer.

3. Reduced water resources: Water supply shortage will occur for both daily living and agriculture irrigation, particularly in Northern Taiwan, in the near future because of the reduced rainfall

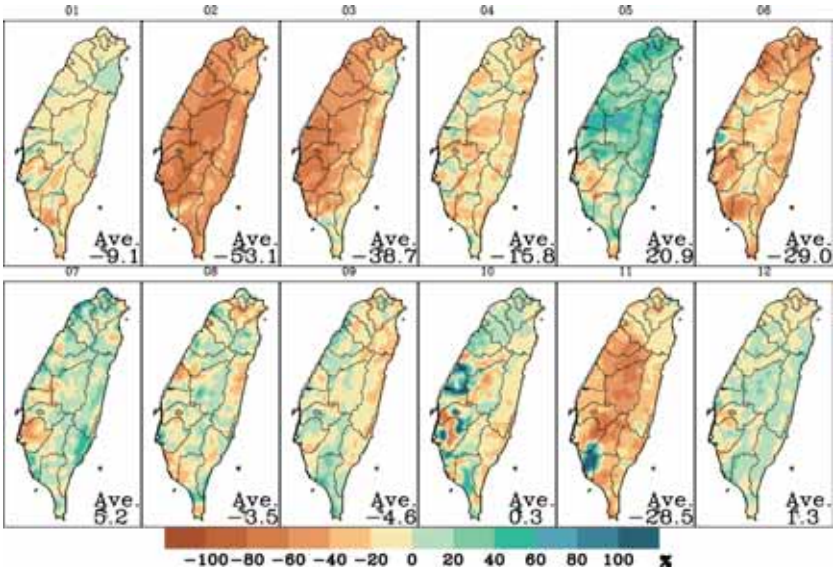

Figure 2. The change rates of monthly rainfall for the 2001-2004 period if the same drought event were to reoccur in the warmer 2040-2060. Number 1–12 on top of each figure represent January–December.

and increased evaporation. The impact on the water supply for daily living will be minimized through water management. However, the irrigation water shortage will significantly increase in the near future. Figure 3 indicates the water shortage rate for the Taipei and Taoyuan areas if the 2001–2004 drought event reoccurs in 2040–2060. Without considering the impact of global warming, the water shortage in Taipei may be minimal; however, the shortage in Taoyuan may be approximately 10% in spring. The impact of global warming may increase the shortage rate in Taipei to 7% and double the shortage rate in Taoyuan. The most affected season may be spring and summer.

4. Climate change risk perception: In total, 21 expert in-depth interviews were conducted. Four stakeholder risk perception surveys were administered (i.e., general public, farmers, corporate water managers, and public servants; n > 1500). The survey covered three key dimensions: general concern, scientific knowledge, and responses

   ◊ General Concern: Various stakeholders had similar perceptions. Most stakeholders considered Taiwan to have a high climate change risk and were concerned regarding this risk. In addition, they agreed that human activities induce contemporary climate change and that this climate change may worsen the drought problem in Taiwan.

   ◊ Scientific Knowledge: Although most stakeholders demonstrated low agreement in climate assessment efficacy to facilitate policymaking, they were in high agreement regarding the precautionary principle that the government should not wait for sound evidence to act. In addition, although most stakeholders had a basic understanding regarding the causes and consequences of drought, they had relatively poor understanding of water prices and the temporal dimensions of climate change. This may be the reason that adjusting the water price receives a low level of policy support.

   ◊ Response: Most stakeholders believed Taiwan should respond to global climate change on the basis of ethical and climate change impact motivations. In addition, most stakeholders demonstrated a medium to high level of support for some drought policies; however, they reported a low level of support for relocating agricultural water to other targets when droughts occur.

5. Climate change drought risk communication: In total, 11 climate change drought risk communication activities were conducted with approximately 170 participants across four different stakeholder groups (i.e., government, industrial, agricultural, and public sectors). These activities can not only enhance stakeholders' understanding of climate change drought risk in Northern Taiwan but also initiate the process of having in-depth discussion regarding the issue of climate change drought risk and potential adaptation.

6. Climate change drought risk communication materials: Four knowledge products were developed for climate change drought risk and adaptation (i.e., two PowerPoint presentations, an animation video, and a strategy recommendation report). The development of knowledge products was an attempt at innovation to demonstrate how scientific research can translate its scientific findings into different methods of presentation that various stakeholders can accept.

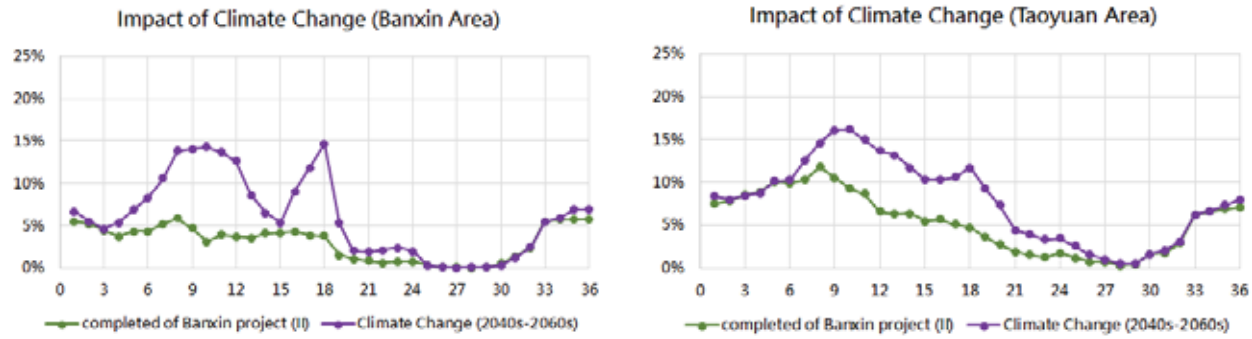

Figure 3. Changes in water shortage rate in (left) Taipei and (right) Taoyuan if the 2001-2004 drought event were to reoccur in the warmer 2040-2060. Green curve did not consider the global warming effect but consider the impact of Banxin project that is designed to supply water from Taipei to Banxin and Taoyuan area. Purple curve considers both factors.

Figure 4. Climate change drought risk communication activities (n=11)

Figure 5. Four climate change drought risk communication materials

Future Research Plan

1. Release of a 1-minute animation demonstrating the water resources in Taiwan and impact of climate change.
2. Discussion forum on the draft of "Policy Recommendation for Water Shortage Adaptation in Response to the Impact of Climate Change." Stakeholders, such as researchers and water resource and agricultural department members, will be invited.
3. Release of "Policy Recommendation for Water Shortage Adaptation in Response to the Impact of Climate Change" after revision.
4. Delivering presentations in various workshops for publicizing our findings and for advocating the need for cross-disciplinary research such as our project to pool specialists of different disciplines and form a tightly integrated research effort, which is particularly efficient and highly warranted in sustainability studies.

Website

1.PowerPoint " 臺灣氣候變遷乾旱風險評估與調適 " (Taiwan's Climate Change Drought Risk Assessment and Adaptation) link: https://dra.ncdr.nat.gov.tw/Frontend/Education/PublicationDetail?NowMenu=Publication&DetailPart=8

2.PowerPoint " 臺灣未來的乾旱問題與因應 " (Taiwan's Drought Problem and Response in the Future) link: https://dra.ncdr.nat.gov.tw/Frontend/Education/PublicationDetail?NowMenu=Publication&DetailPart=9

3.Animation " 氣候變遷，旱動臺灣 ?!" (Will Climate Change Make Drought Worse in Taiwan?) link: https://www.youtube.com/watch?v=wHN9ed6zYoI

Publications

1." 臺灣氣候變遷乾旱及水資源風險調適策略建議 "(Adaptation Strategies to the Risks of Climate Change Drought and Water Resource in Taiwan), to be released.

Project Director: *Dr. Hsu, Huang-Hsiung*

Huang-Hsiung Hsu is a distinguished research fellow and a Deputy Director of Research Center for Environmental Changes, Academia Sinica. His research interest includes climate variation and change, monsoon, and atmosphere-ocean teleconnection. He is now leading the implementation a climate model suite for climate change and impact study in Taiwan. He was the chief editor of three national science reports on Typhoon Morakot and Taiwan's climate change and was an editor of three international journals. He had served in national committees of IUGG, IGBP, and IHDP.

Sub-Project PI, Co-PI:

Dr. Lin, Chuan-Yao, RCEC, AS
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Dr. Chen, Yung-Ming, NCDR
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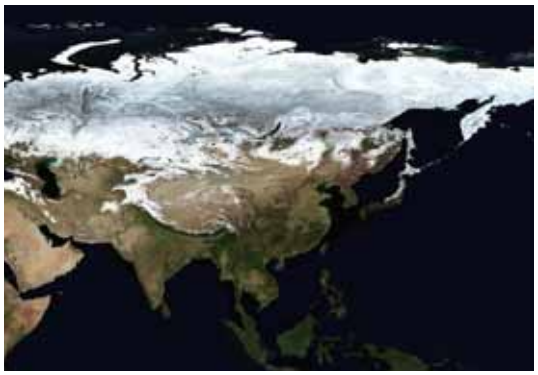
Reconstructing East Asian Historical Climate Series using China's Chronological Records in Past Two Millennia (REACHES)



Project starting year: 2016
Hosting Institute: RCEC, Academia Sinica

Research Objectives

The Earth's climate system may undergo changes in response to various external forcing, such as solar variability, volcanic eruption, Earth's orbital perturbation, and changes in atmospheric composition. Numerous such changes have been recorded thus far, with many glacial and interglacial periods being identified. However, no conclusive theory exists for explaining the reason for these changes. Moreover, accurately predicting future global climate changes is very difficult. To understand such changes and predict possible future changes, efficient physics-based climate models are required so that the root of the changes can be traced to model physics. However, the method for determining the validity and robustness of a climate model remains unclear. An applicable method involves using the climate model for reproducing past climate conditions. If the model-produced conditions match those observed in the past, then the validity of the model can be trusted. However, accurate past climate data remain a prerequisite for such a comparison. Thus, there exists a requirement for climate data reconstruction.

The spatial and temporal resolution of reconstructed climate data varies. For some purposes, coarse-resolution climate data may be adequate. However, understanding climate variations in a decadal or finer scale may require high-resolution past climate data at the annual level collected over several hundred years, which is the main motivation of the present project.

One of the most useful climate data sources is the climate information in human historical documents. Unlike many environmental proxy data, which often suffer from interpretation ambiguity, climate data derived from historical documents have fewer such problems because the climate conditions, such as cold, warm, humid, dry, rainy, or clear, were recorded directly. When available, a climate database based on information in historical documents can be extremely useful for climate studies. A notable example is the climate information in Chinese historical documents, such as the official chronicles and local records from the last 3000 years.

The main objective of the REACHES project is to build a sophisticated historical climate database for East Asia on the basis of the aforementioned sources. In line with this objective, we examined all the written climate records in these documents and subjected them to standardized digitizing and coding procedures to ensure the precision of the time (e.g., hour, date, week, month, season, or year), event categories (e.g., precipitation, temperature, wind, cloud, gas, air, drought, flood, crops, or famine), and space (e.g. city, county, or province) information. We aim to create digitized records and

derived climate data series that international researchers can use for conducting not only historical climate studies but also a wide spectrum of human–climate–environment interaction studies. Studies based on the REACHES can also be applied to compare with the climate models to justify or improve climate theories and model simulations.

The reconstructed climate series are of considerable significance because they can be cross-compared with climate models and other data from various paleoclimate archives, such as 2K (two millennia), Network of the Past Global Changes (PAGES), and Global Historical Climatology Network (GHCN). The current project is currently also participating in the activities of GHCN and in the 2K Network of PAGES.

Main Results to Date

The REACHES project involves a high degree of interdisciplinary collaboration that integrates climatology, environmental history, geography, philology, and meteorology knowledge. Our initial data source is The Compendium of Chinese Meteorological Records for the Last 3,000 Years (Volumes I–IV, edited by Prof. De'er Zhang and colleagues at the Academy of Meteorological Science, Beijing, China). It compiles meteorological, phenological, extreme events, and other climate-associated socioeconomic records from more than 8,000 government documents from the Shang to the Qing dynasties (1600 BCE–1911 CE). All records are digitized and structured on the basis of the Relational Database Management System, which contains five independent yet closely linked subsystems for data management (Figure 1). We began digitizing the records from the Ming and Qing dynasties (Volumes II–IV), and by the end of 2018, we had completed the digitization of all these records in the database. All the encoded records were doubly and carefully examined to maintain high accuracy. Our REACHES database is currently deposited at the National Oceanic and Atmospheric Administration World Data Center and the REACHES project website. The database is periodically updated when new data are ready for release.

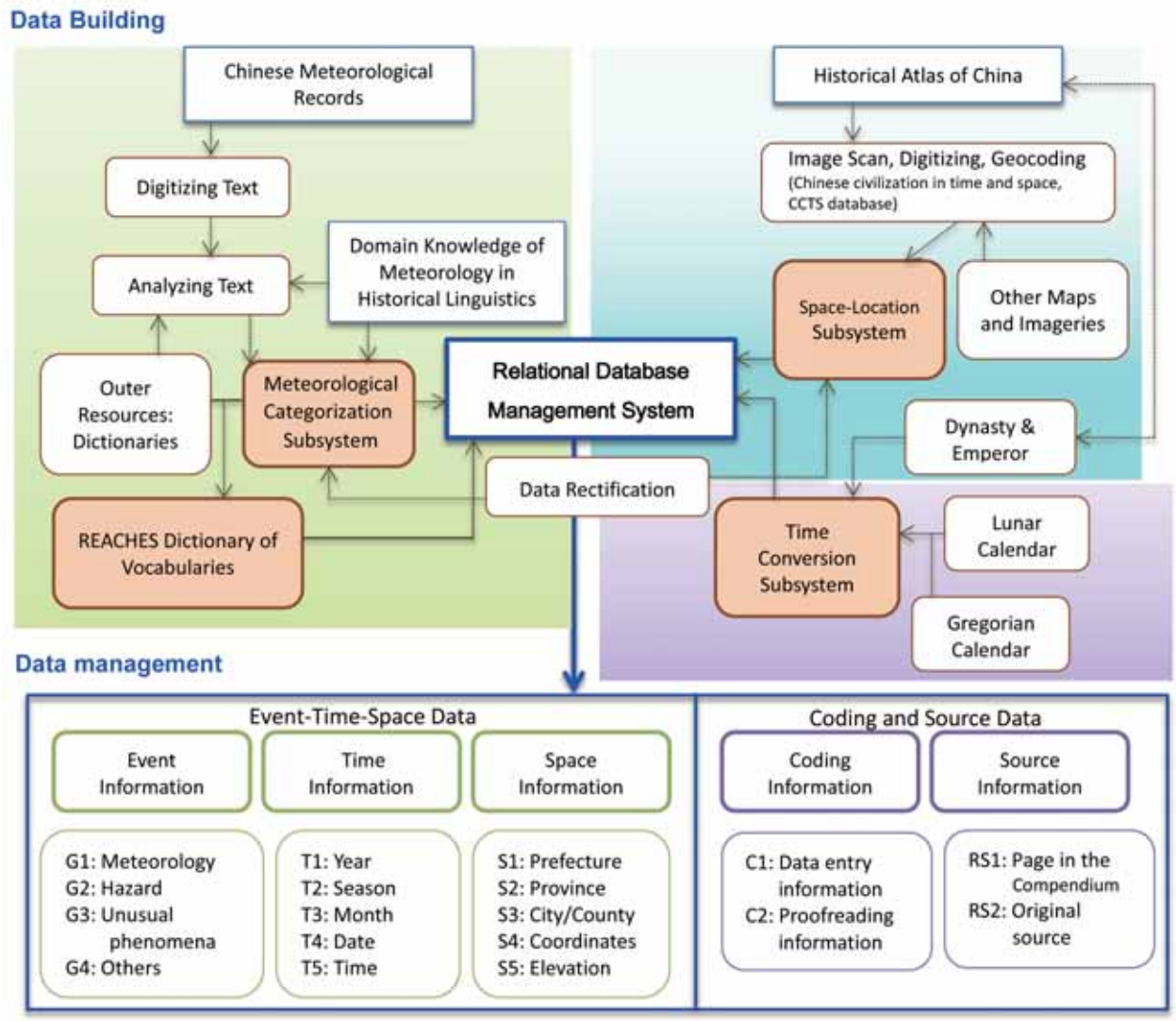


Figure 1. REACHES research methodology

The total number of records collected during the Ming and Qing dynasties was 59,283 and 99,259, respectively (Figure 2). The records cover 1,600 geographical sites in 32 Chinese provinces. The spatial distribution of the sites is uneven, with high densities in the Yellow and Yangtze River plains, which have traditionally been the political and economic centers of China. Thus, to prevent biased interpretation, caution should be exercised during data analysis. By using the database, we can visualize and estimate the spatial and temporal variations in the climate-relevant variables, such as drought, flood, locust outbreaks, tropical cyclone, and snowstorm. Figure 3 illustrates an example of summer and winter temperature anomalies during the mid-17th to 19th centuries over Eastern China. As displayed in the figure, clear cooler periods occurred in the 17th and 19th century, whereas warmer climate occurred in the 18th century. The multidecadal to centennial scale variability was consistent with the frequency of extreme hydroclimate events (Figure 4).

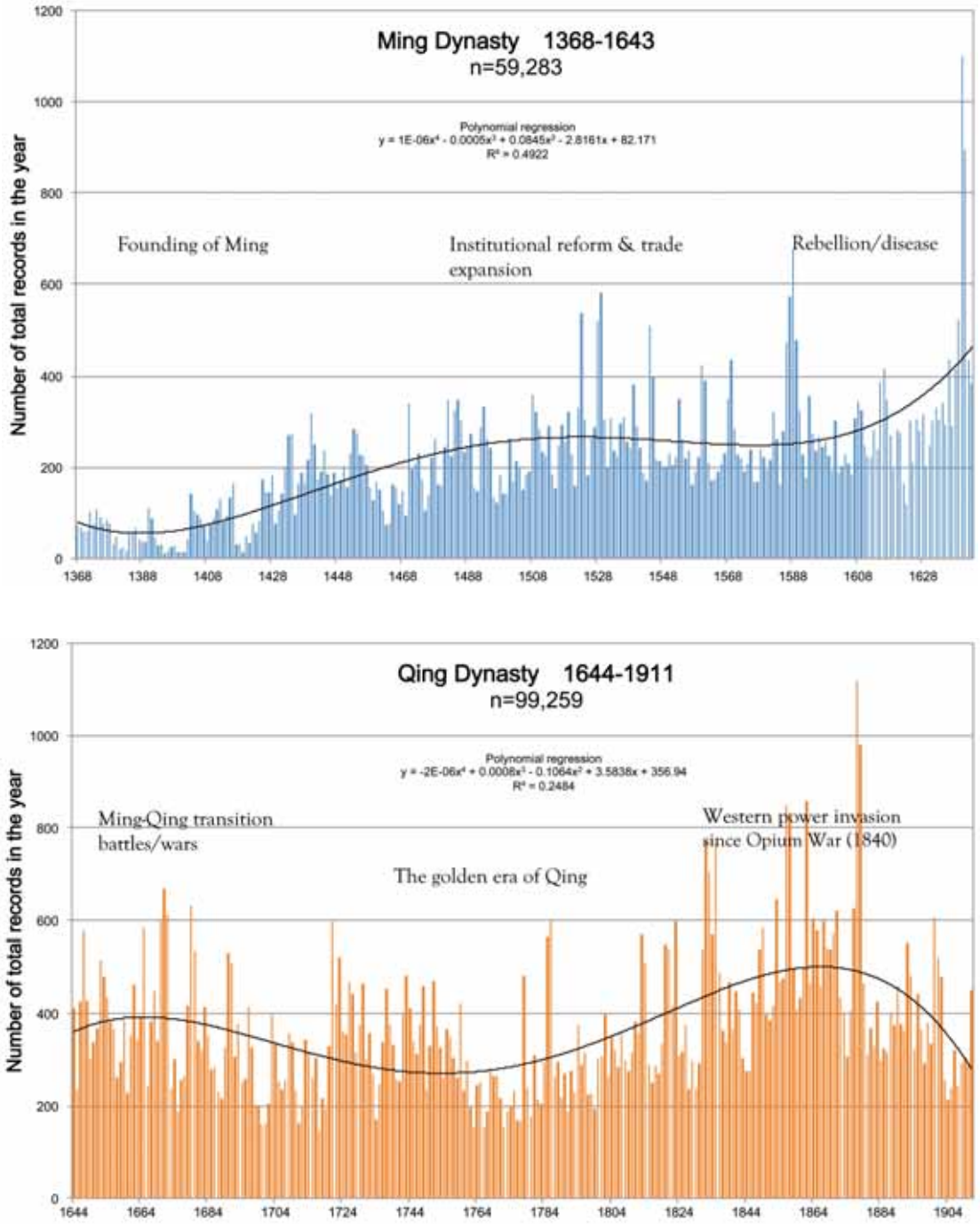


Figure 2. The number of Records as a function of time in Ming and Qing dynasties.

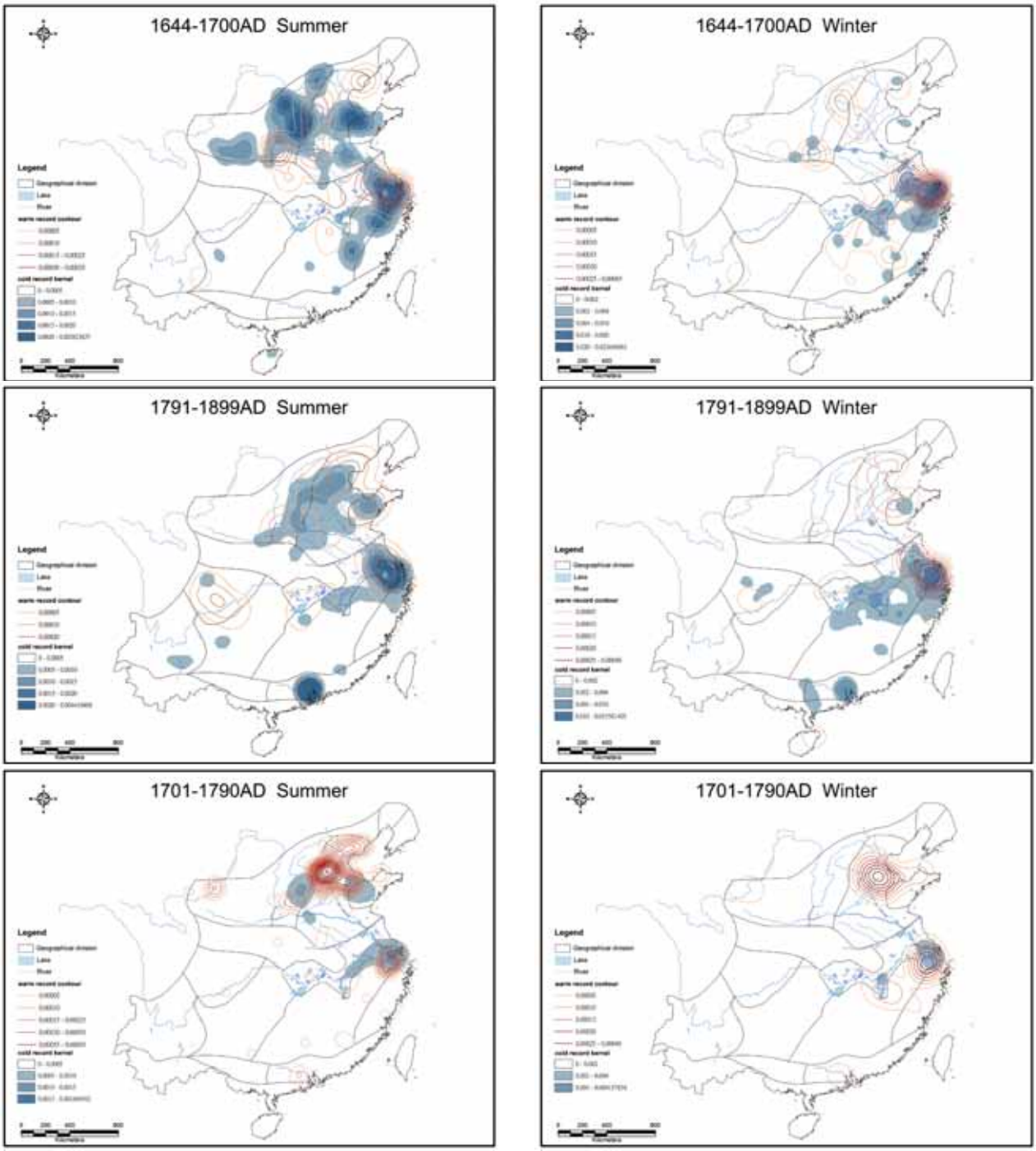


Figure 3. Multi-decadal or centennial summer and winter temperature anomalies. Intensity of warm records shown in red contours and that of cold records shown in blue kernel density. Darker colors present higher density.

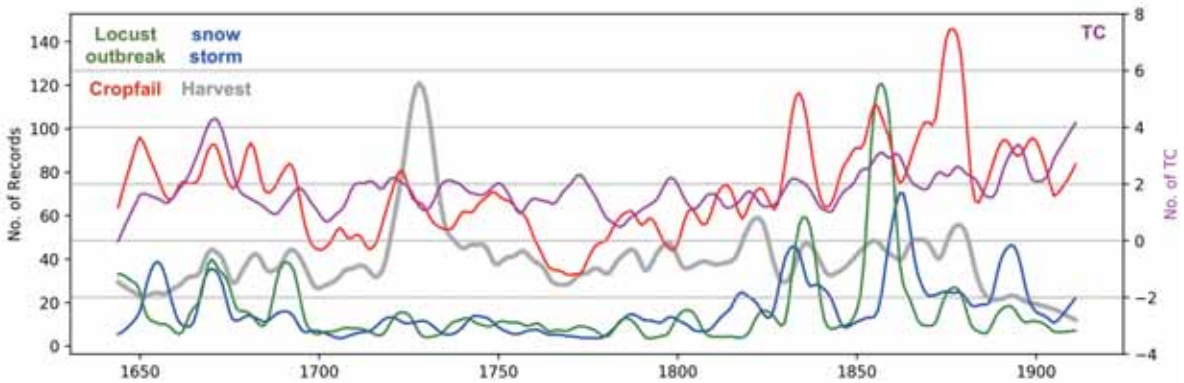


Figure 4. The number of records (smoothed) for locust outbreak, snowstorm, crop failure, harvest, and tropical cyclone.

In addition, several sets of climate intensity indices were established in this study. We developed several intensity indices (particularly for precipitation and temperature) according to multivariate analysis of climate-related variables to determine climate characteristics in space and time. We conducted analyses on series based on the cold–warm index (CWI) and drought–flood index (DFI) and performed several experiments to test the sensitivity of the index methods, including varying the criteria of intensity judgment and adjusting statistical methods for computing regional means to compare their advantages and limitations. The experiments were designed to understand the benefits and caveats of the reconstruction methods when instrumental time data are unavailable. We used the GHCN data series to calibrate the reconstructed temperature series of Beijing, Tianjin, Shanghai, and Hong Kong. Instrumental data were available for these locations dating to the 19th century. The instrumental data have partial overlaps with the reconstructed index series. Our preliminary result indicated moderate to high correlation coefficients in Shanghai (r = 0.41), Beijing (r = 0.64), and Tianjin (r = 0.68; Figure 6). The series and other locations will be further analyzed in the future.

The model results, particularly those of the Last Millennium Ensemble (LME), which was developed by the Community Earth System Model paleoclimate working group at National Center for Atmospheric Research, also demonstrated some similar centennial patterns in China as those exhibited in the reconstructed temperature and precipitation series. The LME presents a drying trend from 1660 to 1710, followed by a wet period in the later century. Single forcing ensemble was suggestive of the drying trend in East Asia being associated primarily with volcanic activity and orbital changes. However, as many studies have suggested, the degree of volcanic cooling in LME is generally stronger than that in the reconstructions, possibly because of model sensitivity to the aerosol indirect effect.

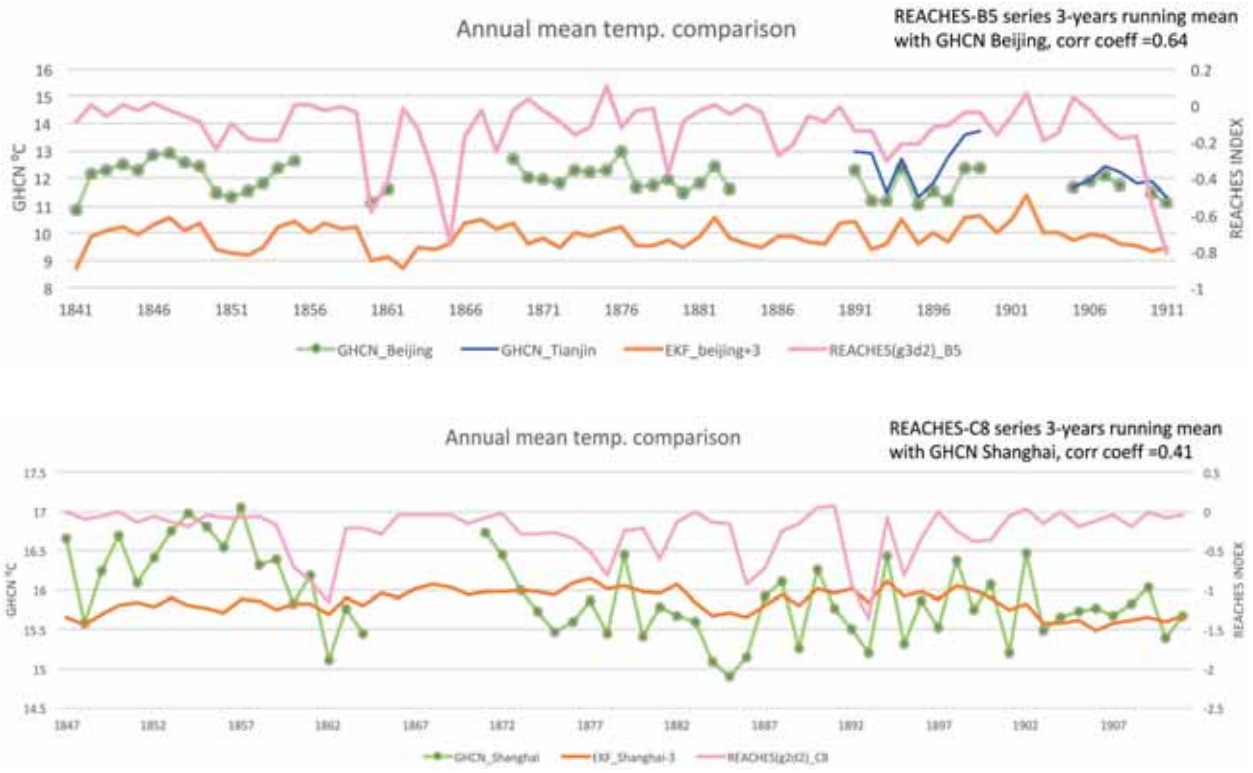


Figure 5. Comparison of temperature anomalies with GHCN and EKF data in Beijing, Tianjin (upper), and Shanghai (lower panel). GHCN represents early instrumental temperature measurements dating back to the 19th century. EKF is the Ensemble Kalman Fitting for climate data assimilation (Franke et al. 2017). REACHES-B5 and REACHES-C8 regions are our geographical divisions used to compute areal means for the comparison. REACHES-B5 represents domain approximately in Hebei Province, and C8 in the middle and lower reaches of the Yangtze River.

Future Research Plan

Over the past 3 years (January 2016 to December 2018), we established the East Asian historical climate database. Currently, the REACHES database has grown to become a globally standard database. Researchers can use the data for studies in both natural and social sciences irrespective of the researchers' backgrounds and languages. We emphasize the transparency of the database construction procedure and use different experiments to test the robustness and reliability of the database and the reconstructed series. In addition to historical climate reconstruction, another application of the database is in understanding human–climate relationships. The Earth currently is undergoing global warming at an unprecedented speed. Constructing high-resolution data is therefore critical for enhancing the understanding of climate change in time and space and the human responses to the changes.

Our future research plan has three parts. First, we aim to continue developing and expanding the REACHES database by collecting historical and early instrumental data through collaborations with scholars in different East Asian countries. New data will be carefully processed and integrated into the database. Second, to continue the REACHES project, we are collaborating with a new international research team funded by Belmont Forum from May 2019. The aim is to link global paleoclimate data sets for investigating abrupt changes and tipping points in Earth's climate and ecosystems. With this new partnership, we will be able to broaden our research scope to include intercontinental model data comparisons. Third, a main goal of the REACHES project is to investigate the relationships between human society and climate in depth. On the basis of the present results, we will seek additional opportunities for enhancing interdisciplinary archival exchange and collaboration to better understand how human civilizations evolved in the changing climates and their responses to such changes.

Website

NOAA-WDC Reaches database: https://www.ncdc.noaa.gov/paleo/study/23410
Reaches project website: http://reaches.rcec.sinica.edu.tw

Publications

1. Wang, P. K., Lin, K-H E., Liao, Y. C., et al. (2018) "Construction of the REACHES climate database based on historical documents of China ", *Scientific Data*, DOI: 10.1038/sdata.2018.288. (SCI, 2017-2018 IF=5.311, 8/64 in multidisciplinary sciences)
2. Brönnimann, S., Martius, O., Rohr, C., Bresch, D., and Lin, K-H E (2018) "Historical weather data for climate risk assessment" *Annals of the New York Academy of Sciences*. DOI: 10.1111/nyas.13966 (SCI, 2017-2018 IF=4.277, 10/64 in multidisciplinary sciences)
3. Lin, K-H E., Hsu, C.T, Wang, P. K., et al. (2019) "Reconstructing historical typhoon series and spatiotemporal characteristics from REACHES documentary records", *Journal of Geographical Sciences* (TSSCI), under review.

Project Director: *Dr. Pao K. Wang*

Dr. Pao K. Wang received his BS in Meteorology from National Taiwan University and MS and PhD in Atmospheric Science from University of California-Los Angeles. He was a professor of Atmospheric and Oceanic Sciences in University of Wisconsin-Madison for 36 years and has served as the Director of Research Center for Environmental Changes since 2013. His research interests include cloud physics, aerosol physics, thunderstorm dynamics, satellite remote sensing and historical climate studies.

Sub-Project PI, Co-PI:

Dr. Fan, I-Chun, RCHSS, AS Dr. Tan, Pei-Hua, Dept. of Applied History, NCYU Dr. Lee, Shih-Yu, RCEC, AS



Disaster Resilience through Big open Data and Smart Things (DRBoaST)



Project starting year: 2016
Hosting Institute: Institute of Information Science, Academia Sinica

Research Objectives

An objective of the three-year multidisciplinary applied research project DRBoaST is to develop methods and tools for the generation, capture, and collection of critically needed but missing data for disaster preparedness and response. In particular, the project focuses on two types of data:

- Up-to-date, fine-scale data and information needed to support community-specific disaster risk-reduction strategies and operations in disaster-prone communities, and
- Data on geo-hazards caused by significant earthquakes in Taiwan needed for assessing new risks and predicting earthquake-triggered compound disasters.

The other objective of the DRBoaST project is to develop devices, applications, and services that can exploit buildings and environmental data and smart things to considerably advance the state of the art and practice of disaster preparedness and emergency response. Recent technological and infrastructure advances have enabled authorities in developed regions to generate accurate early alerts for common types of natural disasters, encode the alerts in an international standard, machine-readable format, authenticate the senders and compliance with the alerts, and then disseminate the alerts via available communication pathways to all receivers in affected areas. The project aims to provide the technologies for building and using pervasively active emergency response systems containing smart active devices and applications that can process the alerts and initiate location-, environment-, and situation-specific risk-reduction actions faster than humanly possible to help us minimize personal dangers and reduce property damage when disasters strike.

Main Results to Date

The results of the DRBoaST project include the creation of a volunteer GIS (VGIS) platform for crowdsourcing fine-scale, community-specific geo-information and indigenous knowledge for disaster-prone communities in Taiwan, a real-time earthquake information cloud for disaster preparedness and response, and a building/environmental data and information cloud (BeDIS), which provides an infrastructure component needed to support active emergency response. The remainder of this section will describe these elements. Other results of the project include the design of prototype tools for crowdsourcing disaster surveillance data to enhance physical sensor coverage and methods and tools for capturing machine-readable disaster records to ensure the quality of the data they present. Information concerning these results can be found on the project's website.

VGIS Platform and Community-Specific Disaster-Reduction Strategies

The devastating events in southern Taiwan during Typhoon Morakot revealed the limitations of geo-information infrastructures of a country and region. Built without sufficient input from individual communities, existing infrastructure typically cannot provide sufficiently up-to-date, community-level scale, accurate geo-data and information needed to support disaster-mitigation strategies and disaster-response operations of individual communities. One way to bridge the gap between available and needed disaster geo-data and information is to integrate public participation in the generation and maintenance of community-specific disaster geo-information and hazard-mitigation strategies.

The VGIS platform was built by the project to support public participation. Its targeted users include community residents as well as professionals and researchers who will help to verify the validity of the data collected via the platform and minimize uncertainties, duplications, inaccuracy, and incompleteness that may affect the data. The platform supports contributions from users' location-specific observational data and related information in text, pictures, or video forms. In addition, the VGIS platform enables users to narrate their experiences of past disasters and the lessons they learned from the disasters.

The VGIS graphical user interface (GUI) appears to the targeted users as a combination of Facebook and Google maps, both of which are familiar to most of them. Moreover, the platform provides links to disaster information residing in numerous sites, integrates the information through its GUI, and thus presents its users with a coherent and comprehensive view of available disaster information.

The VGIS platform has been open to the general public since 2017. It is being used to support pilot studies in Lunhshou Village in Taoyuan, Shenmu Village in Nantou, and Yilin Village in Pingtung, Taiwan. These are debris-flow, flooding, and landslide disaster–prone villages. During the studies, the platform supports collaboration among local residents, providing them with the means to incorporate observations of their community environment into the disaster-management infrastructure. One envisions the result of this effort to be a virtual community-specific disaster information cloud that is populated with databases containing observational data and geo-information for disaster-prone communities in Taiwan.

Real-Time Earthquake Information Cloud

Figure 1 shows the major components of the real-time earthquake information cloud developed by the DRBoaST project: They are the Taiwan Earthquake Science Information System (TESIS), Did You Feel It (DYFI), and the Taiwan Scientific Earthquake Reporting (TSER) system.

Figure 1. Components of real-time earthquake information cloud.
Upper row from the left: screenshots of TSER platform and TSER/VMS and screenshots of DYFI ; Bottom row: architecture and screenshots of TESIS

Taiwan is rich with data on earth crustal deformation and seismic activities that have been collected for decades through GPS and seismic networks and strong motion sensors deployed in the Taiwan region. Such data are vital to studies on earthquake behavior and geosciences in general and disaster management specifically. Their location in independent databases maintained by multiple data centers motivated the development of TESIS. In addition to relieving users from the task of accessing distributed data, TESIS also integrates the rapid earthquake report issued by Central Weather Bureaus with all available real-time scientific results, including near real-time data on earthquake source inversion derived by our automated earthquake source inversion system and co-seismic GPS displacements and faulting behavior of the latest earthquake. The system now enables users to access all available near-real-time scientific information on the latest felt earthquake in Taiwan.

DYFI is a platform for crowdsourcing "Internet seismic intensity" from the general public. The platform was tested during several earthquakes in Taiwan. On the basis of feedback, the project continues to improve the questionnaires used to collect data to raise the quantity and quality of intensity reports.

The TSER system is an online report and mapping platform. It incorporates open-source mapping tools from Ushahidi (http://www.ushahidi.com). The upper-left corner of Figure 1 shows the sample screenshots of the system. As its name indicates, the system is used to support the rapid collection of field observations of earthquake-triggered surface damage, such as surface rupture, landslides, rock falls, liquefaction, and landslide-triggered dam lakes after significant earthquakes. Such damage may not be identified easily by seismic instruments right after an earthquake. Some of the damages may be hazardous to the public. Data on all such geo-hazards are needed to assess new risks and predict earthquake-triggered compound disasters.

To ensure the quality and reliability of the reports collected by the TSER system, in 2016 the project started to offer training courses to volunteers and adopted the volunteer management system (TSER/VMS) to maintain their profiles. TSER/VMS can also be used to monitor participants' activities during crowdsourcing. To attract volunteers, an additional function was added to enable trained volunteers to post landscape pictures and geological explanations. A large portion of our trained volunteers are natural science teachers. This function not only helps them to become acquainted with the reporting system but also enables them to share materials on the TSER platform that can be used by their classes.

Today, when a potentially damaging earthquake occurs in the Taiwan area, trained volunteers are notified within one or two days. Email notifications then guide them to the epicenter to carry out field surveys. Reports submitted by the participants through the TSER system include descriptions of surface damage and on-site photos. The collected information is shared with the general public after a quick verification by on-duty scientists. This experimental crowdsourcing approach was tested during the 2018 Mw 6.4 Hualien earthquake. In the first three days following the earthquake, 19 field reports were received from volunteers at different locations along the Milun fault, which was triggered by the event. The data collected by the TSER platform provided not only the distribution of the surface ruptures but also the rupture orientation, type of faulting, and offset dimension. As validated by similar observations provided by other scientists in the following days and weeks, the volunteers evidently provided reliable rapid reports and surfaces evidence in a scientific way.

Active Emergency Response Support Infrastructure and Its Applications

A major effort of the DRBoaST project was directed towards developing the technological foundation and ICT infrastructure components that will enable the pervasive use of active smart devices and applications and active emergency response systems to improve significantly the disaster preparedness of our homes, workplaces, and living environment. Figure 2 presents an overview of the main results of this effort: The big dashed box in Figure 2 encircles the building/environmental data and information (BeDI) system, called BeDIS for short. The top part of the figure shows its relationship with information sources containing building/environmental data and interfaces with early disaster-warning systems and building safety systems. BeDIS is a keystone of fine-scale, location-specific services and applications, including active emergency response support (AERS), indoor positioning and indoor navigation, and object tracking in smart buildings. Examples of such services and applications are shown in the bottom part of Figure 2.

Functionally, one can view the system as being a BeDI-based indoor positioning system (BeDIPS) and a BeDI fog. During normal times, BeDIPS is configured to help hundreds and thousands of people to locate themselves and navigate amidst dense crowds and moving objects in the building through the use of their mobile phones. It also serves as a platform for other indoor location-specific services (e.g., identifying objects and friends). Structured as a fog/mist, BeDIPS is unique among modern indoor positioning systems (IPSs) in that the

system is scalable and responsive under overload; it can function without Internet, WiFi, and cell connections and degrades gracefully when parts of it are damaged. These are required features of an IPS for large public buildings. BeDIPS is unique in that it can meet these requirements.

When triggered by a disaster/emergency alert from responsible government agencies or the building safety system, BeDIS functions as a system of micro data servers. They deliver location- and situation-specific emergency response instructions to people and attributes of the building, interior layout, and objects in their immediate vicinities to support the choices of response actions of active smart devices and applications within the building. The required response time can be as short as fractions of a second to a few seconds in the case of earthquake and fire alerts. BeDI mist is also unique in its ability to meet these demanding requirements.

An AERS, as shown in the lower-right corner of Figure

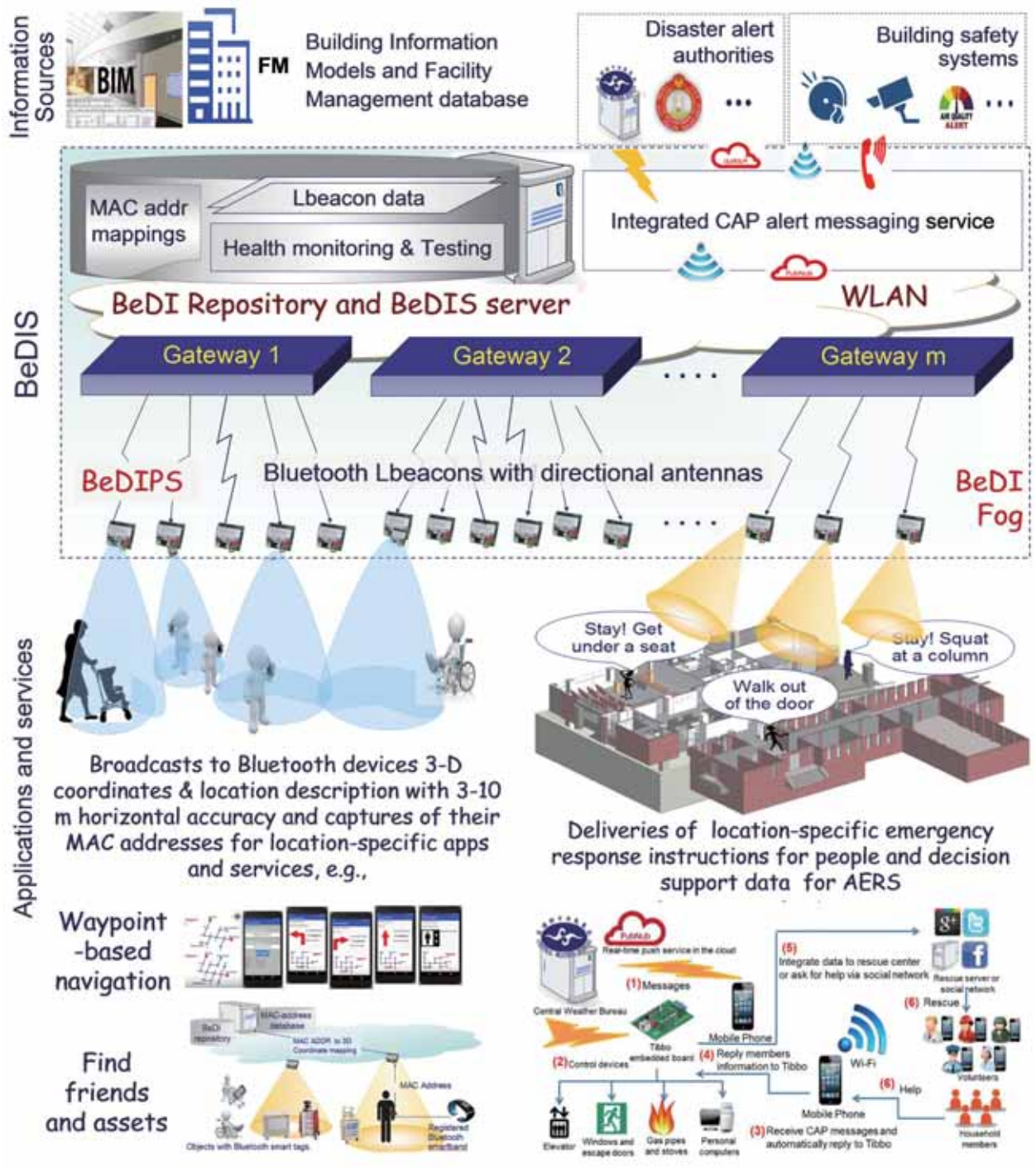


Figure 2. Overview of results on technologies for active disaster prepared living environment.

2, was prototyped to demonstrate the feasibility and effectiveness of using active smart devices in future smart homes and buildings. Upon receiving an alert of an imminent disaster, the individual devices in the system process the alert and perform appropriate emergency preparedness and response actions to help people stay safe and reduce property damage. Immediately after a disaster, the AERS collects and sends information to speed up rescue operations. An image-based damage-assessment system is a part of AERS. It can provide emergency managers and responders with damage assessment and enhanced situational awareness. In a field trial carried out to evaluate the effectiveness of AERS in a three-story office building, AERS shut off natural gas valves, opened escape doors, brought elevators to the nearest floor, and turned off electrical appliances in response to a simulated strong earthquake alert. Measured data revealed that the time for people to carry out these operations can be as long as 15 seconds. By having AERS perform them, people were given sufficient time to take shelter under sturdy furniture, to evacuate from the third floor to the first floor, or to run more than 100 meters.

Future Research Plan

In the near future, the project will complete the pilot study in Lunhshou Village, Shenmu Village, and Yilin Village and, as much as possible, expand the study to include other small disaster-prone communities in Taiwan. The project has developed tutorial materials, organized workshops for training volunteers, and worked with multidisciplinary experts and government sectors. Future work in this direction will leverage these results with the goal of building, with the participation of local residents, a virtual disaster information cloud containing community-scale observation data and geo-information for additional disaster-prone communities in Taiwan.

The project has initiated a citizen seismology program incorporating training courses and a volunteer management system with the webGIS-based TSER platform and plans to crowdsource scientific eyewitness reports for surface natural damage triggered by every earthquake in the future. The observations thus collected will complement real-time instrumental data and results. The intent of the project is to use the data to better understand damages and geohazards induced and triggered by large earthquakes with the goals of improving rescue operations and the assessment of social effects of the earthquakes.

Thus far, the project has only proved the concept of AERS. Much work remains to be done to transform the concept of active emergency response into widely deployable technologies for considerably enhanced disaster preparedness and response. The project has successfully transformed the concept of BeDIPS into a mature and easy-to-maintain platform. The system uses Bluetooth location beacons (Lbeacons) to deliver information to users. The current version of Lbeacons and an indoor navigator that uses Lbeacons for indoor positioning are ready for deployment. The project is now pursuing pilot studies/field trials to assess the usability and effectiveness of indoor positioning and navigation systems built under real-life operating conditions in several large public buildings.

Website

http://www.openisdm.com

Publications

1. W.-T. Liang, J.-C. Lee and N.-C. Hsiao (2019) Crowdsourcing Platform toward Seismic Disaster Reduction: the Taiwan Scientific Earthquake Reporting (TSER) System, Frontiers (in revision).
2. K.-L. Pan and H.-L. Lin (July 2018) A Spatio-Temporal flood analyze to urban flooding resilient assessment. AESOP Annual Congress, Gothenburg, Sweden.
3. H.-L. Pan and K.-L. Pan (July 2018) VGI Cooperative Platform for Geoinformation Crowdsourcing in Indigenous Knowledge of Community Disaster Resilience. IEEE and ICKII 2018 International Conference on Knowledge (Best paper award).
4. C. C. Li, P. Wu, H.. Wang, E. T.H. Chu, and J. W. S. Liu (May 2018) Building/environment Data/information System of Fine-Scale Indoor Location Specific Services. The 2nd IEEE Conference on Fog and Edge Computing, Washington, DC.

5. W-T. Liang, J.-C. Lee, K.H. Chen, N.-C. Hsiao (December 2017) Citizen Earthquake Science in Taiwan: From Science to Hazard Mitigation, J. Disaster Res., 12, 1174-118

6. C. C. Li, J. Su, E. T. H. Chu and J. W. S. Liu (September 2017) Building/environment Data/information Enabled Location Specificity and Indoor Positioning. IEEE Internet of Things Journal, volume 4, no. 6, pp. 2116-2128.

7. C. Y. Lin, K. L. Yeh, E. T.-H. Chu, and J.W. S. Liu (January 2017) Participant Selection Problem - Relative Performance of Five Optimization Solvers. The 8th International Conference on Computer Modeling and Simulation (ICCMS 2017), Melbourne, Australia, pp. 24-37

Project Director: ***Dr. Jan-Ming Ho***

Dr. Jan-Ming Ho received his Ph.D. from Northwestern University in 1989 and is currently a research fellow in the Institute of Information Science. His research integrates theory and applications and has made significant contributions in many important areas, including VLSI physical design, web information mining, information retrieval and extraction, multimedia network protocols, continuous video streaming, content networks, bioinformatics, open source software, digital library and archive technologies, and financial computing. He held numerous patents and software licenses in these areas.

Sub-Project PI, Co-PI:

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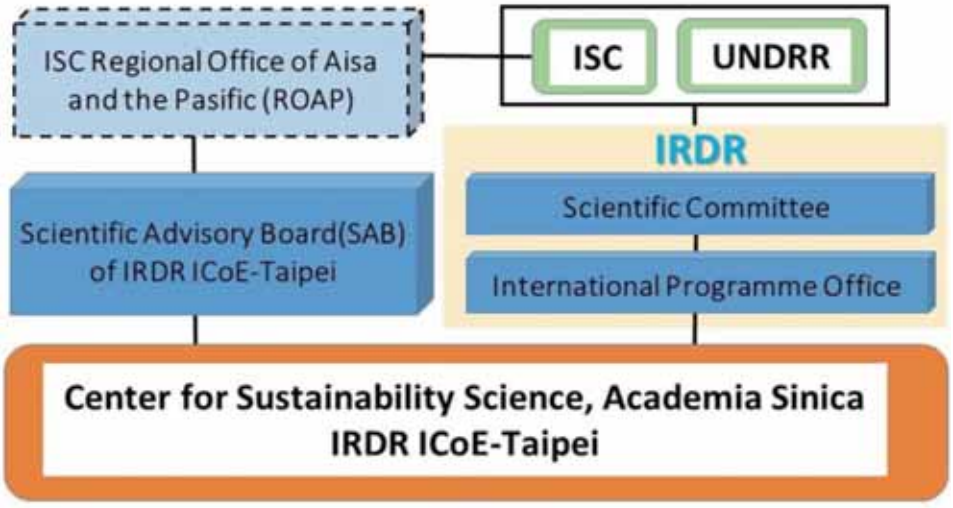
Dr. Jian-Cheng Lee, IES, AS	Dr. Wen-Tzong Liang, IES, AS	Dr. Nai-Chi Hsiao, SC, CWB
Dr. Wen-Lian Hsu, IIS, AS	Dr. Fu-Shih Lin, IHP, AS	Dr. Hsiang-Chieh Lee, SES, NCDR
Dr. Tei-Wei Kuo, CSIE, NTU	Dr. Edward T.-H. Chu, CSIE, YunTech	Dr. John Kar-Kin Zao CS, NCTU

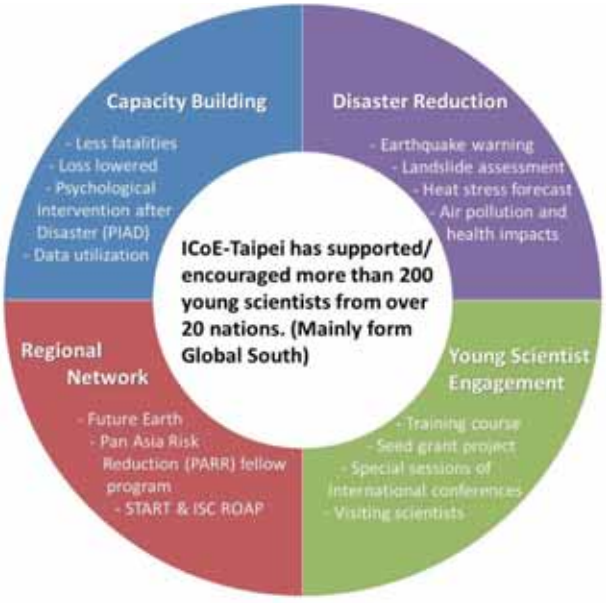
IRDR (Integrated Research in Disaster Risk) :
the challenge of natural and human-induced environmental hazards

Introduction

For more comprehensive engagement in disaster risk reduction and adaptation, ICoE-Taipei not only focused on research and technological applications in natural disaster–mitigation but also emphasized issues of "Knowledge Based Actions" and "Public Health Concerns" associated with sustainable development goals and the main goals of Future Earth in 2018.

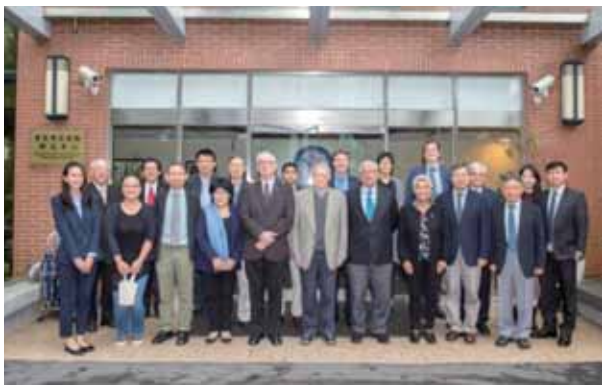
The Integrated Research on Disaster Risk (IRDR) is a decade-long, international interdisciplinary research program initiated and sponsored by the International Science Council (ISC) in partnership with the United Nations Office for Disaster Risk Reduction (formerly known as the UNISDR). It is a global initiative seeking to address the challenges from natural disasters, mitigate their impact, and improve policymaking mechanisms. The first Integrated Research on Disaster Risk, International Center of Excellence (IRDR ICoE) was established in Taipei in November, 2010 at Academia Sinica (AS) and was incorporated into the Center for Sustainability Science (CSS) in 2012.





For over 5 years, ICoE-Taipei has promoted regional collaboration in the integrated research of disaster risk as well as the sharing of practical experience in disaster early warning, response, and preparation. Since 2017, it has initiated "Seed Grant Projects" that follow up from the training courses of Advanced Institutes; 14 regional projects and 86 young researchers from 18 countries are involved.

The Scientific Advisory Board (SAB) Meeting of ICoE-Taipei was set to be held annually to gather suggestions on ICoE-Taipei's plans and strategic direction. SAB members are from academia and reputed international organizations, with a vast experience in international collaboration. ICoE-Taipei has actively participated in IRDR events and the annual Scientific Committee Meeting.



Previous ICoE-Taipei SAB Meeting held on 23 November, 2018, in Taipei, Taiwan

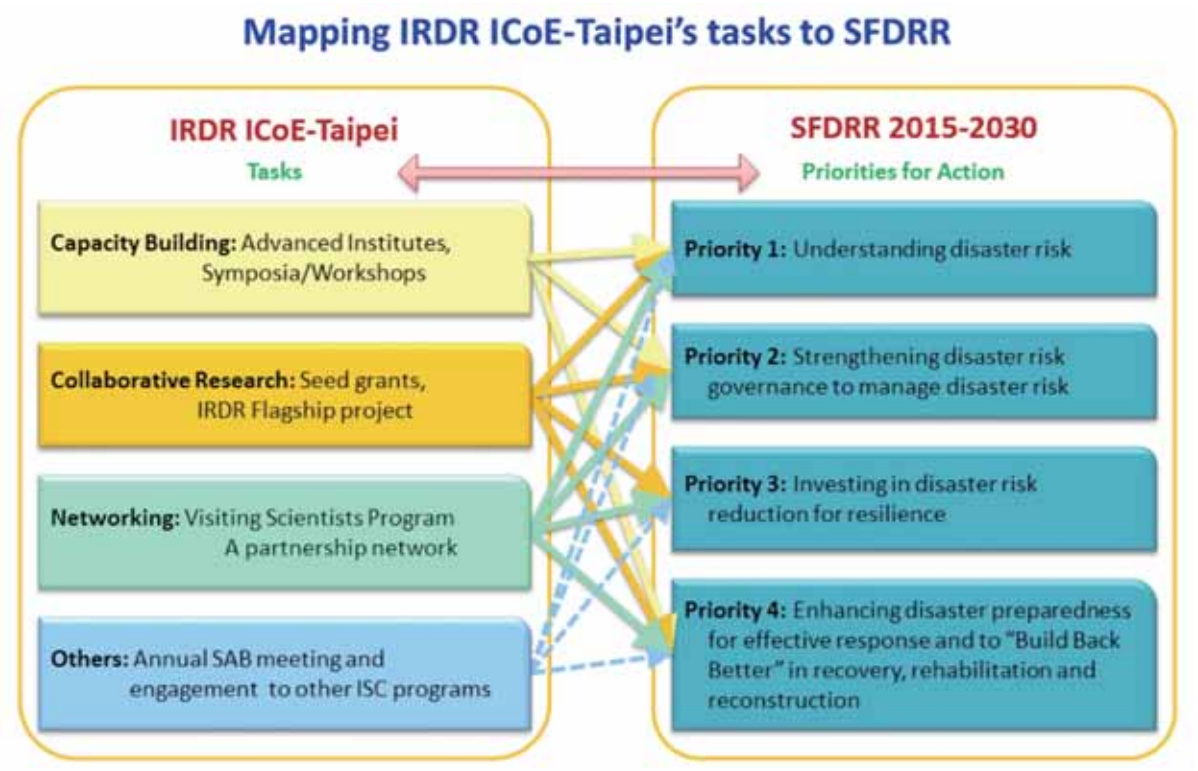
We have invited SAB members to join the meeting for early engagement. We also invited Mr. Charles Erkelens (Operations Director of the ISC Main Secretariat), Dr. Mazlan Othman (Director of ISC Regional Office for Asia and the Pacific, ISC ROAP), and Mrs. Lucy Lu (Science Officer of the IRDR International Program Office, IRDR IPO) as VIPs.

The 19th IRDR Science Committee Meeting held on 16 April, 2018, in Beijing, China

The 20th IRDR Science Committee Meeting held on 15 October, 2018, in Chengdu, China

International Activity Involvement and Advanced Institute/ Training Workshops

The Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) has been endorsed by the UN General Assembly and adopted globally. The SFDRR emphasizes managing the risk of small-scale and large-scale, frequent and infrequent, rapid and slow-onset disasters caused by natural or anthropogenic global hazards. With its global vision, in 2018, ICoE-Taipei strengthened its involvement in events and promoted regional networks that are aimed at realizing the SFDRR Priorities for Action.



The 2018 Asian Science and Technology Conference on Disaster Risk Reduction on 17-18 April, 2018, in Beijing, China

ICoE-Taipei joined the discussions on disaster prevention and adaptation plans and shared Taiwan's experience in policymaking and the application of technology.

The International Conference on Integrated Science & Technology Contributions for Informed National Policymaking and Action for the Implementation of the Sendai Framework on 16–17 October, 2018, in Chengdu, China

ICoE-Taipei presented Taiwan's experience in policy implementation and input from national and regional initiatives.

The Research Summit on Health-Related Emergency and Disaster Risk Management (H-EDRM) held on 9–10 July, 2018 in Hong Kong, China

ICoE-Taipei shared their experience regarding the health policy implementation in disaster risk management

ICoE-Taipei emphasizes capacity building for Southeast Asian countries. It organized various training workshops (Advanced Institutes), particularly for younger and early-career scientists. It also provides them with seed grants for initiating regional disaster risk reduction theme projects, especially those pertaining to the developing countries.

Since 2012, ICoE-Taipei has held eight Advanced Institutes, with three of the following held in 2018.

1) Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters—Heat Stress Sensors, Early Warning, and Information Technology, **AI-SOCD at Heat Stress** (June, 2018)
2) Advanced Institute on Landslide Risk Reduction Training School–Landslide hazards: From Site Specific to Regional Assessment, **AI-LRRTS** (August, 2018)
3) Training Course on Earthquake Hazard and Risk Assessment in East Asia (October, 2018)

ICOE-Taipei has supported more than 200 young and early-career scientists/researchers from over 20 nations worldwide to join these eight AIs and training courses since 2012.

Next, we detail the three Advanced Institutes that were held in 2018.

2.1 "Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters—Heat Stress Sensors, Early Warning, and Information Technology (AI-SOCD at Heat Stress), 4–8 June, 2018

The Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) emphasizes the management of the risk of small-scale and large-scale, frequent and infrequent, and sudden and slow-onset disasters caused by natural or human-induced hazards. It aims to guide the multi-hazard management of disaster risk within and across all sectors. Both heat stress and the resulting increase in air pollutants are detrimental to human health. To stress the importance of applying systems thinking and a systems approach to link environmental monitoring, information technology, and public health issues, the intensive training workshop, "Advanced Institute on Disaster Risk Reduction with Systems

Approach for Slow-Onset Climate Disasters—Heat Stress Sensors, Early Warning, and Information Technology (AI-SOCD at Heat Stress)," was held at AS, Taipei, Taiwan, on June 4–8, 2018.

It was sponsored by ICoE-Taipei in partnership with ISC ROAP and the Central Weather Bureaus of Taiwan. The primary objective of the workshop was to provide the participants with the best practices, understanding, skills, and practical know-how to apply systems approaches on hearing stress and other relevant health concerns.

"Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters—Heat Stress Sensors, Early Warning, and Information Technology (AI-SOCD at Heat Stress)" held on 4–8 June, 2018, at Taipei, Taiwan. There were approximately 20 participants from six East and Southeast Asian countries.

2.2 Advanced Institute on Landslide Risk Reduction Training School–Landslide hazards: From Site Specific to Regional Assessment (AI-LRRTS), 27 August–1 September, 2018

Landslides, as one of the common natural disasters globally, have exerted a grave human and economic toll. A fundamental understanding of slope stability analysis and critical mechanical parameters is essential, especially for the site-specific landslides. As one of the most tectonically active regions, Southeast Asian countries have suffered from landslide hazards for a long time. Thus, a platform for participants to share their experiences on landslide hazard evaluation is necessary. To advance the skills, understanding, and practical know-how in the analysis, laboratory testing, monitoring, modeling, and hazard evaluation of landslides, the "Advanced Institute on Landslide Risk Reduction Training School–Landslide hazards: From Site Specific to Regional Assessment (AI-LRRTS), was successfully held at the National Central University, Chungli, Taiwan on August 27 to September 1, 2018.

It was sponsored by ICoE-Taipei in partnership with ISC ROAP, and the National Central University in Taiwan. During the training course, the participants were asked to present their experience in their countries, and group discussions facilitated communication among the participants.

Advanced Institute on Landslide Risk Reduction Training School–Landslide hazards: From Site Specific to Regional Assessment (AI-LRRTS)" held on 27 August–1 September, 2018, at Chungli, Taiwan. There were around 30 participants from eight Southeast Asian countries who were selected to participate in the AI.

2.3 "Training Course on Earthquake Hazard and Risk Assessment in East Asia," 1–5 October, 2018

East Asia is located at the western Pacific, where large and moderate size earthquakes frequently occur and the locations of the active convergent plate boundary are defined. Many large cities of East Asia (such as Tokyo, Taipei, Manila, and Jakarta) are located either on or near active seism genic zones and are exposed to high-to-severe seismic hazard and risk. It is thus extremely important for the people of these countries to understand the seismic hazards and risks that they face. Taiwan is located in the middle of the western Pacific and had its share of large-to-moderate size earthquakes in recent years. Participants shared and discussed their experiences in earthquake hazard and risk assessment in"Training Course on Earthquake Hazard and Risk Assessment in East Asia," which was successfully held at AS, Taipei, Taiwan, on 1–5 October, 2018.

It was sponsored by ICoE-Taipei in partnership with ISC ROAP, and the Taiwan Earthquake Model. This training course focused on all aspects of earthquake hazard and risk assessment, including seismic hazard and risk modeling, active fault source model, geodetic deformation model, ground motion prediction and scenarios, as well as hazard and risk products.

"Training Course on Earthquake Hazard and Risk Assessment in East Asia" held on 1–5 October, 2018, at Taipei, Taiwan. There were around 40 participants from nine countries in the Southeast Asia region were selected to participate in the training course.

Seed Grant Projects

For each Advanced Institute, ICoE-Taipei also initiated "Seed Grant Projects" to encourage participants of the training workshops to start their research and establish the foundation for regional collaboration in the near future.

This research grant program aims to foster and enhance transdisciplinary disaster-risk-reduction projects in the Asia Pacific region. The focus is to develop a stronger interface between science, policy and practice by promoting effective collaboration between scientists and local governments to identify information and knowledge gaps in disaster-risk reduction and emergency preparedness as well as to introduce science and technology to fill gaps through knowledge-based action. To support collaborative interdisciplinary research that fall within the areas of interest, ICoE-Taipei called for proposals for the one-year research grant program comprising financial aid that was limited to USD 15,000.

IRDR ICoE-Taipei Scientific Advisory Board (2018)

Chair of the Board: Hayashi, Haruo
Chen, Hongyi
Chen, Liang-Chun
Liu, Chao-Han
Liu, Tony C
Lo, Ching-Hua
Loyazaga, Antonia Yulo
Snidvongs, Anond
Terry, James

(Arranged in alphabetical order.)

Future Earth

What's New in 2018

2018 is an important year for the Center for Sustainability Science (CSS) in Academia Sinica because the connection and collaboration strategies between the CSS and Future Earth were strengthened. Future Earth is a major international scientific enterprise and research initiative on global environmental change and sustainability, aimed at promoting sustainability science. In this year, the CSS co-organized and participated in more Future Earth–related events than it had before. The CSS also devoted more resources to the Future Earth programme to facilitate international collaboration and domestic promotions.

The CSS organized and co-organized three international and six domestic events in 2018 and participated in six international and three domestic events to facilitate cooperation between the networks of sustainability science. In total, 450 researchers and stakeholders from more than 25 (mostly Asia-Pacific) countries. Consulting key personnel, the CSS planned to organize a series of events for Future Earth in collaboration with Future Earth Global Hub, Future Earth in Asia, and Future Earth Knowledge-Action Networks (KANs) for capacity-building programs and other international activities in 2019.

The tasks of the CSS pertaining to Future Earth include the following:

International Networking

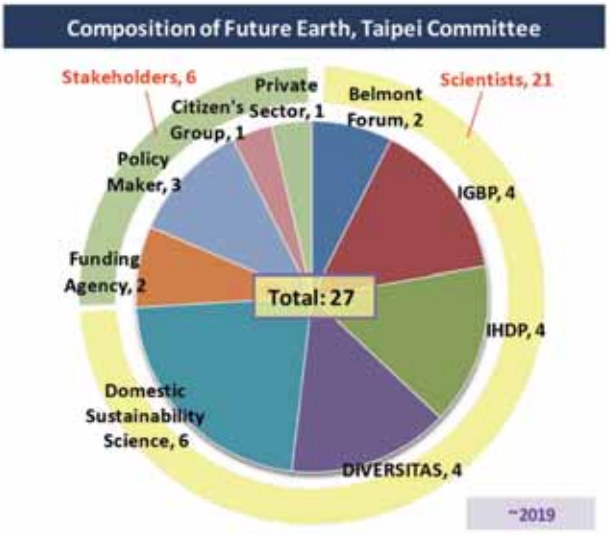
1. To participate in global and regional events involving Future Earth
2. To participate in and co-organize KAN activities
3. To participate in and co-organize GRP activities

Domestic Promotion

1. To collaborate with the Ministry of Science and Technology, Taiwan
2. To organize Future Earth Workshops for Taiwan Young Scientists
3. To organize regular meetings of Future Earth, Taipei
4. To participate in and co-organize local activities about sustainability

Support to Future Earth, Taipei

The National Committee of Future Earth, Academia Sinica, Taipei (Future Earth, Taipei) was established in October 2015. The CSS assists in the operation of the Secretariat of Future Earth, Taipei. The regular meetings of Future Earth, Taipei include the annual Committee Meetings of Future Earth, Taipei, and the biannual Standing Committee Meetings. The planned activities of Future Earth, Taipei are discussed and approved in these meetings. The 2nd Future Earth, Taipei, committee members were appointed in the 2017 Committee Meeting held on September 25, 2017. The committee includes 27 stakeholders and members from various disciplines.



2018 Activities

1. International Networking

1.1 Future Earth Global and Regional Activities

1.1.1 4th Future Earth in Asia Regional Advisory Committee Meeting

Prof. Shih-Chun Candice Lung, the Director of International Programs of the CSS and Executive Secretary of Future Earth, Taipei, is also one of the members of Regional Advisory Committee (RAC) for Future Earth in Asia. The 4th RAC

Meeting was held in Kyoto, Japan, on January 17, 2018. The mission of the RAC is to coordinate and support sustainability research in Asia and the Pacific, thus advancing the knowledge necessary to solve the challenges facing the region. The strategic plan of Future Earth in Asia was discussed and the planned activities were endorsed in the meeting. In this meeting, committee members had fruitful discussions on "Circular Economy" and "Air Pollution and Health." Prof. Lung also evoked the ideas of the international researchers on the two headlining topics.

4th Future Earth in Asia Regional Advisory Committee Meeting on January 17, 2018

1.1.2 2018 Future Earth Summit

The 2018 Future Earth Summit held in Bonn, Germany, on August 27–30, 2018 was the first global event of Future Earth, which included discussions on the future development strategies of Future Earth. The participants were from the Advisory Committee, Future Earth Secretariat, Global Research Projects, Knowledge-Action Networks (KANs), and Regional Centres. Taiwan and Korea were also invited as the only two national entities in the summit. As representative to Future Earth, Taipei, Prof. Shih-Chun Candice Lung participated in this summit. From this meeting, Future Earth decided to (1) issue the new initiative called Earth Systems Targets as part of the Global Systemic Challenges, (2) seek other sources of funding from MNCs or NGOs, (3) publish a Scientific Annual Report: State of Our Planet, (4) prioritize support in favor of several KANs, (5) organize the Annual Future Earth Summit, (6) organize the 1st Future Earth Assembly with support by Belmont Forum in 2020, (6) establish the Future Earth Society which will be further discussed in the 1st Future Earth Assembly, and (7) keep supporting the Anthropocene magazine.

2018 Future Earth Summit on August 27–30, 2018

1.1.3 18th Science Council of Asia (SCA) Conference

As one of the members of SCA, Academia Sinica was invited to participate in the SCA Conference held in Tokyo, Japan, on December 5–7, 2018. In this conference, Future Earth also organized the "Future Earth in Asia" session and invited Future Earth, Taipei, to make a brief report. The Vice President of Academia Sinica, Dr. Mei-Yin Chou; the Executive Secretary of Future Earth, Taipei Prof. Shih-Chun Candice Lung; and the Science Officer of the CSS, Dr. Chia-Hsing Jeffery Lee, participated in the SCA Conference. The major theme of this conference was "Role of Science for Society: Strategies toward SDGs (Sustainable Development Goals) in Asia" The importance of interdisciplinary issues for sustainability studies was stressed in the discussions. After Prof. Lung's report on the topic in the session of Future Earth in Asia, Future Earth's secretariat and committee members highly appreciated Future Earth, Taipei's contributions and expressed their strong interest in future collaboration.

Science Council of Asia (SCA) Management Board Meeting in the 18th SCA Conference on December 5–7, 2018

1.2 Activities regarding KANs

1.2.1 Workshop on Sustainable Consumption in Asia

Prof. Shih-Chun Candice Lung was invited to participate in the Workshop on Sustainable Consumption held in Kyoto, Japan, on January 15–16, 2018. This workshop was relevant to the Future Earth Systems of Sustainable Consumption and Production (SSCP) KAN. The research themes of the consumption section of the SSCP were thoroughly discussed. Linking the international network on SSCP and bringing the message and research focuses of SSCP KAN back to Taiwan, Prof. Lung established a channel for collaboration between international and Taiwanese researchers.

Workshop on Sustainable Consumption in Asia on January 15–16, 2018

1.2.2 Workshop on the Application of Micro-sensors and Exposure Modeling in Personal/Population Exposure Assessment and Epidemiology

As a preconference workshop of the 2018 International Society of Environmental Epidemiology/Exposure Science Asia Chapter (ISEE/ES AC 2018) Conference, CSS co-organized the Workshop on the Application of Micro-sensors and Exposure Modeling in Personal/Population Exposure Assessment and Epidemiology in Taipei on Jun 21, 2018. With 22 participants from seven countries, the workshop provided a platform for researchers, technicians and graduate students to learn how to operate these sensors and share their knowledge and expertise on sensor application and data interpretation. The microsensors developed in Academia Sinica and Hong Kong were displayed and introduced.

Workshop on the Application of Micro-sensors and Exposure Modeling in Personal/Population Exposure Assessment and Epidemiology on June 21, 2018

1.2.3 2018 International Conference on Integrated and Innovative Solutions for a Circular Economy

Collaborating with the CSS and Future Earth, Taipei, the CTCI Education Foundation in Taiwan held the 2018 International Conference on Integrated and Innovative Solutions for a Circular Economy in Taipei, Taiwan, on October 17, 2018. Among the distinguished guests were 26 renowned scholars and academics from 12 countries, there to jointly discuss key issues of global concern for the Circular Economy. An audience of 180 participants from government, industry, academia, and think tanks also joined the discussions. CSS also invited one of the co-chairs of SSCP KAN, Dr. Patrick Schroeder, to give a talk at this conference. Dr. Schroeder participated in the postconference roundtable discussion on October 18 and visited Academia Sinica on October 19 to further the discussion with researchers on related topics.

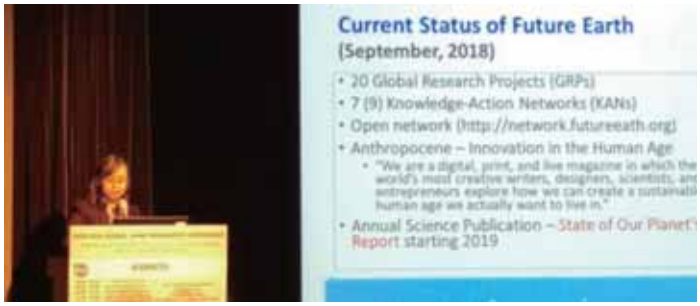
2018 International Conference on Integrated and Innovative Solutions for a Circular Economy on October 17, 2018

Roundtable Discussion on Circular Economy on October 18, 2018

1.3 Activities regarding Global Research Projects

1.3.1 Global Land Programme 2018 Asia Conference

Collaborating with the CSS, the Taipei Nodal Office of the Global Land Programme (GLP) in Taiwan organized the GLP 2018 Asia Conference held in Taipei, Taiwan, on September 3–5, 2018. Prof. Shih-Chun Candice Lung was invited to introduce Future Earth, Taipei, and the international development of Future Earth in the conference to promote sustainability science in Taiwan.



Global Land Programme (GLP) 2018 Asia Conference on September 3–5, 2018

1.3.2 2nd KLASICA Taipei Symposium on Social Dynamics to Sustainable Futures from Narratives of Vision and Identity

The series of KLASICA Taipei Symposiums traces back to the International Human Dimension Programme on Global Environmental Change (IHDP). The 2nd symposium was held in Taipei, Taiwan, on September 29–October 2, 2018 with

the major theme of "core affective narratives of vision and identity that guide and motivate societal change toward sustainable futures and their applicability for modeling social dynamics." Dr. Chia-Hsing Jeffery Lee participated in this symposium with the other 43 participants from 12 countries. Throughout the 3-day intensive discussions, participants learned how to narrate the positive effect of collective change from each other to inspire a social transformation toward sustainability. The models and elements of successful narratives were also discussed for future modeling studies.

2nd KLASICA Taipei Symposium on Social Dynamics to Sustainable Futures from Narratives of Vision and Identity on September 29–October 2, 2018

1.3.3 15th International Global Atmospheric Chemistry Conference

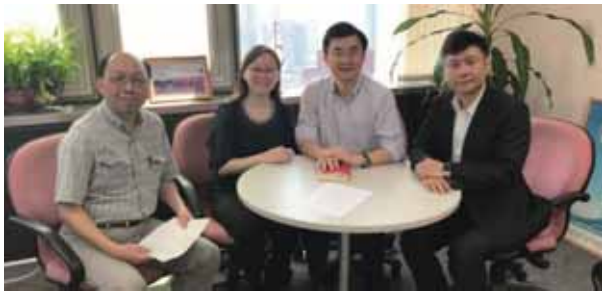
Prof. Shih-Chun Candice Lung was invited to participate in the 15th International Global Atmospheric Chemistry (IGAC) Conference in Takamatsu, Japan, on September 25–29, 2018. In the meeting of IGAC Monsoon Asia and Oceania Networking Group (MANGO), Prof. Lung proposed the "Air Pollution Sensing and Health in Asia" research initiative, which received the support of 12 Asian countries and the interest of scientists from those countries to participate.

15th IGAC Conference held in Takamatsu, Japan, on September 25–29, 2018.

2. Domestic Promotion

2.1 Discussion Meeting on Collaboration between CSS and Department of Natural Sciences and Sustainable Development, MOST

To facitate transformation toward sustainability in Taiwan, CSS is collaborating with Taiwanese scholars, government agencies—primarily the Ministry of Science and Technology (MOST)—and other stakeholders to the integrate capacities of different sectors to find a more effective way of promoting sustainability science and linking Taiwanese and international networks. In 2018, CSS held the Discussion Meeting of Future Earth, Taipei, and MOST Belmont Forum Program Office on March 28. CSS also organized the Discussion Meeting between Future Earth, Taipei and the Department of Natural Sciences and Sustainable Development of MOST on April 11. Invited personnel were senior Taiwanese scholars who were involved in the Belmont Forum—the main partner of Future Earth for generating research funding policy—as well as government officers of funding agencies; the possible pathways for Taiwan researchers to participate in Future Earth–Belmont Forum codesigned research programs were discussed.



Discussion Meeting between Future Earth, Taipei and the Department of Natural Sciences and Sustainable Development of MOST on April 11

2.2 Future Earth Workshops for Taiwan Young Scientists

Kindling the interest of early-career scientists and the younger generation toward sustainability science is critical to realizing a well-transformed sustainable future. Therefore, Future Earth, Taipei, and the CSS organized a series called "Future Earth Workshops for Taiwan Young Scientists" to promote a career in sustainability science and encourage them to participate in Future Earth.

2.2.1 Future Earth Workshops for Taiwan Young Scientists – Overall Introduction

The first workshop of the series was held in Academia Sinica on January 5, 2018, which broadly introduced Future Earth to the 20 young participants. The CSS also invited a young scientist from Germany, Ph.D. Candidate Jo-Ting Huang-Lachmann, to share her fruitful

experience in participating in Future Earth and other big international programmes.

Future Earth Workshops for Taiwan Young Scientists—Overall Introduction on January 5, 2018

2.2.2 Future Earth Workshops for Taiwan Young Scientists—SSCP

Together with the Taiwan Institute for Sustainable Energy (TAISE), the CSS organized the Future Earth Workshop for Taiwan Young Scientists–SSCP in Taipei on June 13, 2018, as the second workshop of the series. The participants included NGO and industry stakeholders, four international graduate students, and 25 young Taiwanese scientists from several disciplines. The director of Future Earth in Asia, Dr. Hein Mallee, was invited to give a speech via video conference to introduce Future Earth SSCP KAN and address the research focus of related issues.

Future Earth Workshops for Taiwan Young Scientists—Systems of Sustainable Consumption and Production (SSCP) on June 13, 2018

2.3 Future Earth, Taipei Regular Meeting

The CSS hosts and assists in the operation of the regular meetings of Future Earth, Taipei in Academia Sinica. Strategies for promoting sustainability science in Taiwan and activity plans are discussed and endorsed by the committee in the regular meetings, including annual plenary committee meetings and semiannual standing committee meetings. In 2018, the plenary committee meeting was held on January 5 and the standing committee meetings were held on March 30 and November 8. Participants discussed responses to the global development of Future Earth and the establishment of working groups of Future Earth, Taipei, relevant to the KANs. Research capacity in Taiwan would be integrated, and stakeholders, especially MOST (the major research funding agency of Taiwan government), was expected to be involved.

1st Plenary Committee Meeting of the 2nd Future Earth, Taipei, on January 5, 2018

2.4. Local Events on Sustainability Science

The CSS also actively participates and is highly interested in sustainability-related events organized by the public and private sector in Taiwan. In 2018, Dr. Chia-Hsing Jeffery Lee was assigned to participate in the following activities.

(1) International Workshop on Citizens' Capacity: Multi-Faceted Transformation of Citizen-Energy Interactions held in Taipei on August 15, 2018

(2) 2018 Learning and Exchange Workshop on University Sustainable Development Goals and Industrial Development held in Taipei on August 29–30

(3) 2018 Presentation of International Evaluation Wang Dao Sustainability Index (WDSI) held in Taipei on December 16

The National Committee of Future Earth, Academia Sinica, Taipei (Future Earth, Taipei)

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Chao-Han Liu
Chen-Tung Arthur Chen
Chia-Wei Li
Ching-Cheng Chang
Chun-Chieh Wu
Daigee Shaw
Eugene Chien
Fei-yu Kuo
Gin-Rong Liu
Hsing-juh Lin
Hsin-Huang Michael Hsiao
Huei-min Tsai
Huey-Jen Jenny Su
Hui-Chen Chien
Jiun-Chuan Lin
Jough-Tai Wang
Ling-Ling Lee
Pao-Kuan Wang
Sheng-Wei Chen
Shih-Chun Candice Lung
Shu-Li Huang
Tsair-Fuh Lin
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