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## International Mega-Science Program for Integrated Disaster Risk Research: A Ten-Year Review and Outlook (Postprint)

**Authors:** Guo Huadong, Chen Fang, Han Qunli, Liu Jie

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### Abstract

The Integrated Research on Disaster Risk (IRDR) program is a 10-year international mega-science initiative launched by the former International Council for Science (ICSU), the former International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UNISDR). In 2009, the IRDR International Program Office (IRDR IPO) was successfully bid for and established in China by the China Association for Science and Technology, becoming the first international mega-science program established by ICSU in Asia. Through its 10-year implementation, the IRDR program has become a flagship initiative for integrated global disaster risk research, established an extensive global network for integrated disaster risk research, formed an effective management mechanism for international scientific programs, and achieved four major outcomes: (1) China's first successful establishment of an ICSU international mega-science program; (2) Successful operation of the IRDR program for 10 years, ensuring its full implementation; (3) Enhanced the level of global scientific and technological governance for disasters and risks; (4) Facilitated the establishment of the "new decade" IRDR Phase II program. Simultaneously, leveraging the IRDR program as a project platform, China learned advanced international concepts, contributed Chinese wisdom and strength, provided experience for organizing international mega-science programs in China, and made important contributions to global integrated disaster reduction.

### Full Text

### Preamble

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**Authors:** Guo Huadong<sup>1, 2\*</sup>, Chen Fang<sup>1, 2</sup>, Han Qunli<sup>3</sup>, Liu Jie<sup>1, 2</sup>

<sup>1</sup> International Research Center of Big Data for Sustainable Development Goals, Beijing 100094, China

<sup>2</sup> Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100094, China

<sup>3</sup> International Programme Office, Integrated Research on Disaster Risk, Beijing 100094, China

## Abstract

The Integrated Research on Disaster Risk (IRDR) Program is a ten-year international scientific initiative launched by the International Council for Science (ICSU), the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UNISDR). In 2009, the IRDR International Programme Office (IRDR IPO) was successfully bid for and established in China by the China Association for Science and Technology, becoming the first ICSU interdisciplinary body hosted in Asia. Over its decade-long implementation, the IRDR Program has evolved into the flagship initiative for global integrated disaster risk research, built an extensive worldwide research network, and developed an effective management mechanism for international scientific programs. Four major achievements have been accomplished: (1) China successfully hosted its first ICSU international science program; (2) the IRDR Program operated successfully for ten years, ensuring its full implementation; (3) global scientific governance of disaster risk was enhanced; and (4) the establishment of the IRDR Phase II “New Decade” plan was facilitated. Through this platform, China has absorbed advanced international concepts, contributed Chinese wisdom and strength, gained experience in organizing international science programs, and made significant contributions to global integrated disaster risk reduction.

**Keywords:** Integrated Research on Disaster Risk (IRDR) Program, international science program, disaster risk reduction

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The devastating economic and social impacts of the 2004 Indian Ocean tsunami underscored the critical role of science and technology in comprehensive disaster reduction. In response, the 29th General Assembly of the International Council for Science (ICSU) announced in October 2008 the launch of a ten-year international science program—the Integrated Research on Disaster Risk (IRDR) Program—in partnership with the International Social Science Council (ISSC) [1]. In early 2009, the program was officially co-sponsored by ICSU, ISSC, and the United Nations International Strategy for Disaster Reduction (UNISDR),

which issued a global call for hosting the IRDR International Programme Office (IRDR IPO). With State Council approval and guidance from the Ministry of Foreign Affairs and other agencies, and with support from the Chinese Academy of Sciences, Chinese Academy of Social Sciences, and relevant departments, the China Association for Science and Technology and the Chinese Academy of Sciences submitted a joint application to ICSU to host the IRDR IPO in China. Following a competitive selection process, the sponsoring bodies unanimously approved China's bid. The IRDR IPO was subsequently established at the Center for Earth Observation and Digital Earth (now the Aerospace Information Research Institute), Chinese Academy of Sciences, marking the first ICSU international science program office established in Asia.

Over more than a decade of operation, scientists from various countries have advanced the IRDR Program, fostering global consensus, promoting scientific methodologies, and exploring strategies for addressing risks. The program has made outstanding contributions to integrated disaster risk research through its scientific objectives.

## 1. Global Progress of the IRDR Program

The IRDR Program comprises multiple platforms and branches, including the IRDR Scientific Committee representing the sponsors, IRDR Working Groups, IRDR National and Regional Committees, IRDR International Centres of Excellence, partnerships with international programs and organizations, the IRDR Young Scientists Programme, and collaborative projects [2].

**IRDR Scientific Committee.** This committee's primary responsibilities are to define, develop, and establish the program's priorities, guide its planning, budgeting, and execution, establish monitoring mechanisms for project activities, and disseminate research findings on behalf of the sponsors. Over the past decade, 41 renowned scientists from 21 countries have participated in this committee.

**IRDR Working Groups.** These groups serve the program's research objectives and interdisciplinary themes, generating innovative solutions to address current gaps in disaster risk research. Six working groups have been established: Assessment of Integrated Research on Disaster Risk (AIRDR), Disaster Loss Data (DATA), Forensic Investigations of Disasters (FORIN), Risk Interpretation and Action (RIA), Climate Change and Disaster (DRR-CCA-SDGs), and National Synthesis Report for the Sendai Framework (NSR). These groups and their partners have published over 40 thematic reports, including special issues on science and technology for disaster reduction and international policy briefs.

**IRDR National and Regional Committees.** These committees support the implementation of IRDR research and help establish critical linkages between national disaster reduction programs and international frameworks. Thirteen national committees have been established in Australia, Canada, China, Colom-

bia, France, Germany, Japan, New Zealand, Indonesia, South Korea, Nepal, Iran, and the United States, along with one Latin American regional committee. These committees, 依托本国和本地区的科研机构 and 政策决策机构, have developed interdisciplinary research methods to reduce disaster risk and facilitated connections among domestic scientific unions and associations.

**IRDR International Centres of Excellence.** These centers provide regional research platforms for the IRDR Program, conducting regionally-focused work and serving as research entities to encourage participation in IRDR and promote scientific activities within their regions. Eighteen International Centres of Excellence have been established, including ICoE-Taipei, ICoE-VaRM, ICoE-CR, ICoE-UR&S, ICoE-REaL, ICoE-DRHBPI, ICoE-RIA, ICoE-CI&SP, ICoE-CCOUC, ICoE-SEADPRI-UKM, ICoE-NSET, ICoE-SDS IDRR, ICoE-TDDR, ICoE-IRDRS, ICoE-RCS, ICoE-DCE, ICoE-RIG-WECEIPHE, and ICoE-Coherence.

**IRDR Young Scientists Programme.** This program aims to promote capacity building among young professionals and encourage needs-based innovative research, thereby strengthening the link between science policy and practice. Launched in 2016, the program has attracted 163 young researchers. Through the IRDR Scientific Committee, National Committees, and International Centres of Excellence, the program provides professional support and training opportunities, including various technical training workshops.

## 2. Scientific Objectives of the IRDR Program

The IRDR Program aims to unite experts in natural sciences, social sciences, economics, health, and engineering from around the world to conduct disaster reduction capacity building and integrated case studies from regional to global scales, perform disaster risk assessment and data management, and study decision-making mechanisms under disaster risk to jointly address challenges posed by natural and human-induced hazards [3]. The main research objectives include three components: scientific assessment of hazards, exposure, vulnerability, and disaster risk; understanding decision-making in the context of complex and changing risks; and reducing risk and controlling losses through science-based action.

### 2.1 Characterizing Disaster Risk

**Development of forensic research methodologies for disasters.** The FORIN working group employs research on the natural and social root causes of disasters, proposing four methodological approaches: Retrospective Longitudinal Analysis (RLA), Forward-looking Disaster Scenario Building (FDSB), comparative case analysis, and integration analysis. These approaches have advanced research on the natural and social root causes of disasters [4]. FORIN's perspectives and methods assume that disasters are linked by systemic causes and their widespread, continuously expanding consequences,

which can be viewed as an “epidemiological” approach to disaster research.

**Characterization of hazards, vulnerability, and disaster risk across different countries and regions.** In 2010, the China Association for Science and Technology established the IRDR China National Committee, which conducted continuous tracking studies of geological hazards in earthquake-affected areas for over a decade. For the first time, geological hazard research was integrated with sociological studies to deeply analyze the impacts of geological hazards on social, economic, and community recovery resilience at different stages (emergency response, post-disaster reconstruction, and recovery). This work established fundamental principles for identifying potential geological hazards and risk prevention in strong earthquake zones [5]. The IRDR New Zealand National Committee contributed to the development of post-disaster reconstruction evaluation indicators, proposing the Canterbury Wellbeing Index [6] and survey results that made important contributions to the international post-disaster reconstruction knowledge base. ICoE-VaRM developed the Social Vulnerability Index (SoVI®) and Baseline Resilience Index for Communities (BRIC), providing empirical measurement methods for comparing different disaster impacts and studying capacity differences in community and individual preparedness, response, recovery, and resilience enhancement [7].

**Application of multi-hazard early warning systems for risk interpretation and action.** One of RIA’s flagship priority projects provides impact-based early warning systems for countries vulnerable to multiple hazards. In collaboration with the World Meteorological Organization (WMO), the International Science Council (ISC), and Tonkin and Taylor International of New Zealand, the IRDR Program developed a disaster reduction guideline based on end-to-end multi-hazard early warning systems [8]. This guideline consists of ten essential elements that together form a single, tightly connected, and robust warning system. The multi-hazard early warning system development project has been successfully applied in 25 countries from the Caribbean, Africa, Southeast Asia, and Pacific regions, establishing or improving their early warning systems.

## 2.2 Understanding Decision-Making in Complex and Changing Risk Contexts

**Linking scientific research, practice, and decision-making analysis.** The IRDR France National Committee has been implementing risk-based land resource management solutions that are typically “hazard-centric,” analyzing exposed areas and determining their vulnerability based on phenomena such as earthquakes, floods, crustal movement, and explosions. ICoE-Taipei has focused on enhancing disaster reduction capacity in the Asia-Pacific region, promoting collaborative research and building an efficient, open platform that connects scientists, engineers, government officials, practitioners, and stakeholders to jointly implement priorities under the Sendai Framework for Disaster Risk Reduction 2015–2030.

**Supporting the Sendai Framework’s science and technology roadmap.**

The IRDR Program has deliberated on the implementation of the Sendai Framework roadmap, proposing mechanisms for roadmap implementation and monitoring, linkages with national platforms, and dissemination. In July 2018, the original ICSU and ISSC officially merged to form the new International Science Council (ISC). In 2019, IRDR, together with the United Nations Office for Disaster Risk Reduction (UNDRR) and ISC, organized the “Science and Policy Forum for Implementing the Sendai Framework,” releasing the revised global science and technology roadmap for implementation by the science and technology community and other closely collaborating stakeholders.

**Disaster definition and classification.** In 2014, the DATA working group compiled a disaster classification and glossary that provides guidelines for disaster event classification and unified terminology applicable to the establishment and operation of disaster loss databases [9]. Although not intended as a complete disaster inventory or standard definition, the document details classification schemes and disaster definitions used in loss databases. In 2019, IRDR conducted a five-key-question review of the current disaster inventory version, clarifying its purpose, inclusion criteria, systematic construction, and national variations. In 2020, the *Technical Report on the Review of the Sendai Disaster Definition and Classification* was publicly released.

### 2.3 Reducing Risk and Controlling Losses Through Science-Based Action

**Policy recommendations at regional and national levels.** The IRDR Program provides scientific evidence and recommendations for decision-makers and policymakers to strengthen the role of science in policy formulation. For example, following the Third UN World Conference on Disaster Risk Reduction in 2015, IRDR released key issue briefs on implementing and monitoring the Sendai Framework. At the 2017 Global Platform for Disaster Risk Reduction, IRDR published five science-policy briefs, adding two more in 2019. Additionally, IRDR has published working report series that articulate the program’s contributions to international agendas such as the Sendai Framework, the UN 2030 Agenda for Sustainable Development, and the Paris Agreement, offering detailed recommendations for disaster reduction policies. In 2016 and 2018, IRDR collaborated with the UNDRR Asia-Pacific Science and Technology Advisory Group (AP-STAG) to review disaster reduction science and technology development, recommending 14 priority improvement actions and producing the report *Status of Science and Technology for Disaster Reduction in Asia: Perspectives from the Asian Disaster Risk Reduction Community*. In 2017, IRDR and the Digital Belt and Road (DBAR) Program’s disaster reduction working group jointly compiled and released the report *Enhancing Scientific Capacity for Sustainable Development and Disaster Risk Reduction: A Regional Research Strategy* [10,11].

**Development and sharing of disaster reduction data.** The IRDR China

National Committee has leveraged various Earth observation datasets from meteorological, resource, ocean, environment, and high-resolution satellites to develop effective disaster rapid response methods, models, and technologies, creating a series of disaster data products. Combined with the Chinese Academy of Sciences' Earth Big Data Science Engineering Program (CASEarth) [12], the committee has focused on disaster reduction research for Belt and Road countries, providing and sharing disaster data products with nations lacking disaster statistics.

**Hosting and actively participating in major international disaster reduction science and policy conferences.** The IRDR Program has organized three high-level international scientific conferences in 2011, 2014, and 2021 [13], discussing challenges in implementing integrated disaster risk research, inter-organizational cooperation, policy interactions, and global sustainable development issues. As a key convener of the UNDRR Global Platform for Disaster Risk Reduction (GPDRR) in 2017, 2019, and 2022, IRDR has provided scientific advice for regional intergovernmental disaster reduction cooperation, formulated the Global Science and Technology Roadmap for Sendai Framework Implementation (2016), and promoted synergy between the Sendai Framework and the UN 2030 Agenda for Sustainable Development, particularly aligning Sustainable Development Goals (SDGs) with the Paris Agreement. IRDR has led the development of global disaster reduction science systems and methodologies.

### 3. China's Progress in the IRDR Program

The IRDR China National Committee has four primary tasks: fully coordinating and utilizing China's resources in disaster reduction science and technology to provide strong support for IRDR implementation; formulating China's policies, strategies, and plans for participating in IRDR; organizing and coordinating domestic institutions and Chinese scientists in IRDR-related research activities; and leveraging IRDR to substantially improve China's disaster reduction research capabilities, focusing on Belt and Road disaster risk integrated research and building a scientific think tank.

Comprising 40 experts from multidisciplinary backgrounds in natural and social sciences, the IRDR China National Committee has established six working groups: earthquake and geological disaster risk, flood and drought disaster risk, storm surge disaster risk, climate change disaster risk response, urban disaster risk, and comprehensive disaster risk assessment in China. In 2020, IRDR established the International Centre of Excellence on Risk Interconnectivity and Governance of Weather/Climate Extremes and Public Health (ICoE-RIG-WECEIPHE) at Fudan University, focusing on integrated disaster reduction research, particularly risks related to climate change (especially extreme weather/climate), air pollution, and public health.

The IRDR China National Committee has studied new disaster reduction methods to address current research gaps, organized representative international con-

ferences and expert seminars, and produced influential outcomes, including the *2011 Beijing Declaration on Integrated Research on Disaster Risk* and joint promotion of the UN’s “Science and Technology Roadmap for Implementing the Sendai Framework for Disaster Risk Reduction 2015–2030.” As a contributor, China participated in the UN’s *Global Assessment Report on Disaster Risk Reduction* in 2015, 2017, and 2019.

### 3.1 Advancing China’s Disaster Risk Research

The work of the IRDR China National Committee has progressed through three stages: forming a platform and network for integrated disaster risk research in China; extending China’s disaster risk research results to Belt and Road countries; and supporting the Sendai Framework and UN 2030 Agenda for Sustainable Development with China’s integrated disaster risk research.

Through IRDR’s international network, the China National Committee organized Chinese experts to jointly author UN reports such as the *Global Spatial Disaster Reduction Strategy White Paper*, *Overview and Development Recommendations for Spatial Disaster Reduction Research in Developing Countries*, *Belt and Road Disaster Reduction Research Strategy Report*, and *Disaster Risks and Response Strategies in China’s Urbanization Process*, providing scientific recommendations on disaster reduction issues. For instance, the report on China’s urbanization analyzed disaster risks in the new context of China’s new-type urbanization, examining impacts from earthquakes, geological hazards, floods, droughts, storms, and climate change-related disasters, and proposed corresponding countermeasures.

### 3.2 Establishing a Belt and Road Disaster Risk Research International Network

For Belt and Road disaster reduction research, the IRDR China National Committee, together with the IRDR IPO, led the establishment of a Belt and Road Disaster Reduction International Working Group comprising experts from 13 countries. The China National Committee has conducted cooperative research and application demonstrations with 13 Belt and Road developing countries, including Mongolia, Pakistan, Thailand, Indonesia, Cambodia, Bangladesh, Malaysia, Kyrgyzstan, Nepal, and Sri Lanka. Through spatial disaster reduction database development for droughts, floods, and earthquakes, and joint research and development of core systems such as the China-Mongolia drought monitoring system and China-Thailand flood system, the committee has achieved “actionable” disaster reduction cooperation, promoting integrated disaster risk research for the Belt and Road Initiative.

For example, the China National Committee jointly established the DBAR-Peshawar International Centre of Excellence with the University of Peshawar in Pakistan, gradually forming a new cooperation model of “collaborative data acquisition—joint research design—co-construction of platforms.” In collabora-

tion with the Indonesian Remote Sensing Association, the committee conducted joint research on disaster risks from land subsidence in Jakarta, establishing a foundational database on topography, geomorphology, environment, and flood control infrastructure for Jakarta's coastal areas, and developing an Asia-Pacific coastal flood risk climate change response system. Supported by the Chinese Academy of Sciences, the "Belt and Road" Natural Disaster Risk and Integrated Disaster Reduction International Research Program (SiDRR) was launched as IRDR's flagship project, building a new international collaborative disaster reduction platform through a series of Belt and Road disaster prevention and sustainable development conferences.

### **3.3 Promoting Capacity Building for Science-Based Disaster Reduction**

Leveraging China's scientific methods and technologies for disaster reduction, the IRDR China National Committee has provided series of information support for major global natural disaster responses. For instance, following the magnitude 8.1 earthquake in Nepal on April 25, 2015, the China National Committee rapidly organized experts to assess the earthquake's impacts, accurately detecting 32 high-level concealed landslides and providing disaster reduction analysis information to institutions in Nepal such as the International Centre for Integrated Mountain Development (ICIMOD). The significant practical results were highly praised by Nepalese government agencies including the Ministry of Foreign Affairs.

The China National Committee has conducted international application training on disaster reduction practices, focusing on technical methods and models for using Earth big data in disaster risk reduction research for Belt and Road countries. Jointly with the IRDR IPO, DBAR, and the Committee on Data of the International Science Council (CODATA), the committee organized nine training sessions on spatial disaster reduction for developing countries, with over 200 young talents from more than 40 countries participating. These trainings have promoted key technologies and methods developed by China in disaster reduction and increased the application rate of China's disaster reduction sustainable development indicator monitoring and assessment methodology systems in developing countries.

To enhance Chinese disaster reduction practitioners' knowledge and understanding of integrated disaster reduction and risk prevention, the IRDR China National Committee has relied on domestic research institutions to conduct technical training and seminars on major earthquake risk assessment and loss pre-assessment for hazard zones. Combined with activities such as National Disaster Prevention and Reduction Day, the committee has conducted public outreach on integrated disaster risk research to enhance social awareness, popularize disaster prevention and reduction knowledge, and improve comprehensive disaster reduction capabilities.

#### 4. IRDR Phase II Program

Over the past decade, global integrated disaster risk research has yielded substantial achievements. However, due to insufficient effective collaboration among information holders, policymakers, and practitioners, many results remain underutilized. Isolation and serious disconnects persist within and between disciplines, as well as between knowledge producers and potential users, reducing the influence of integrated disaster risk research and its capacity to help address macro-social challenges such as poverty alleviation, vulnerability reduction, and disaster risk reduction.

Based on multi-round consultations with disaster reduction experts, IRDR has led the development of *A Framework for Global Science in Support of Risk-informed Sustainable Development and Planetary Health* (hereinafter “the New Framework”) [13]. Chinese scientists have participated as core group members, expert advisory group members, and special consultants, making important contributions to the framework’s conception and content. The New Framework aims to promote linkages among disaster reduction knowledge, policy, and practice; foster innovative thinking; and encourage increased research investment in consensus priority areas for disaster reduction. It also helps connect all knowledge holders, including scientists, funders, the private sector, policymakers, and interdisciplinary, cross-sector practitioners, encouraging new partnerships that transcend traditional independent research to find new methods for addressing today’s global disaster challenges. To openly advance disaster reduction concepts, the New Framework advocates combining networks and communities of practice to promote knowledge sharing through “open science” approaches.

The mission of IRDR Phase II is to mobilize scientific power to reduce all types of disaster risk while building resilience and reducing vulnerability by integrating risk science with climate change adaptation and mitigation and the SDGs. IRDR Phase II aims to build an inclusive, safe, and sustainable world by promoting better understanding of disaster risk and effective use of risk science in decision-making. Centered on nine global disaster reduction research priorities proposed in the New Framework, Phase II will focus on different disaster risk causes, scenarios, risk interconnections, and scales, addressing disaster risks from regional to global levels and from rural to densely urban areas (Figure 1 [Figure 1: see original paper]).

The nine priorities are: (1) Understanding the emergence and persistence of risk to address systemic, cascading, and complex risks; (2) Addressing inequality, injustice, marginalization, and vulnerability; (3) Enabling transformative governance and action for risk reduction; (4) Understanding the implications of new thinking about disasters; (5) Leveraging technology, innovation, data, and knowledge for risk reduction; (6) Supporting regional and national science and knowledge for policy and action; (7) Enabling a “just transition” to sustainable development; (8) Optimizing measurement to drive progress; and (9) Fostering multi-stakeholder collaboration to address risk challenges.

The New Framework aligns closely with the priorities and targets of the Sendai Framework adopted by the UN in 2015, demonstrating the strategic foresight of the scientific community and international recognition. It transcends IRDR's initial 2008 scientific plan while remaining consistent in its scientific essence: understanding the nature and characteristics of disaster risk and how science can promote necessary policy changes remains the fundamental challenge. Global changes, particularly climate change and regional conflicts, have created unprecedented complexity in the global risk landscape. IRDR's progress since its launch represents only the beginning of the long journey of science and technology for disaster reduction; its mission must continue to respond to humanity's fundamental needs and vision for inclusive, safe, and sustainable development.

ISC has designated IRDR to lead the implementation of the New Framework in its *Action Plan 2022–2024* on systemic risk and global emergency response. The original sponsoring parties have agreed that China will continue hosting the IRDR IPO, providing institutional, policy, and resource support for IRDR Phase II.

## 5. Reflections on Future Development

The experience of IRDR over the past decade demonstrates that through its implementation, ISC and UNDRR have stimulated participation from national disaster reduction research communities, generated universally influential scientific outcomes in disaster reduction, and advanced the development of risk science as an integrated discipline. The program has strengthened science-policy linkages and promoted exchanges and interactions among science, policy, and civil society in disaster risk reduction. Through mechanisms such as IRDR National Committees, International Centres of Excellence, and the Young Scientists Network, IRDR has driven capacity building and development of disaster reduction institutions in different countries and translated scientific outcomes into practical actions at regional, national, and community levels. Notably, in terms of scientific service to international governance, the scientific mission and major research objectives represented by IRDR in 2008 aligned strategically with the priorities and targets of the UN's Sendai Framework adopted in 2015, reflecting the scientific community's strategic foresight and international recognition.

IRDR Phase II represents a human development imperative and a major concern for governments and scientific communities worldwide. The program's fundamental mission and scientific value remain theoretically and practically significant under current domestic and international development conditions, serving as an important vehicle for China's active participation in global governance. IRDR's continued implementation will play a positive role in demonstrating China's responsibility and capabilities as a major country and supporting new forms of international cooperation led by China, particularly the Belt and Road Initiative and the Global Development Initiative.

The cooperation agreement on the "New Decade" IRDR Phase II between ISC,

UNDRR, and China, effective May 11, 2023, indicates the willingness of influential international organizations to jointly advance important international cooperation agendas with China. This represents recognition of the level of China's integrated disaster risk research and affirmation of China's comprehensive capacity to host large-scale international science programs.

Looking forward, under the leadership of the China Association for Science and Technology and with support from the Chinese Academy of Sciences, Chinese Academy of Social Sciences, relevant government departments, and the scientific community, we anticipate jointly implementing the "New Decade" IRDR Phase II. By consolidating and further integrating and expanding IRDR's strategic resources, we can establish it as an international platform for China to promote disaster risk reduction and development security, making important contributions to achieving the SDGs, implementing the Global Development Initiative, and building a global community of shared future.

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*Note: Figure translations are in progress. See original paper for figures.*

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