

Bing WANG, Ge HONG, Chao-Qun CUI, Hao YU, Tad MURTY

Comprehensive analysis on China's National Climate Change Assessment Reports: Action and emphasis

© Higher Education Press 2019

Abstract Climate change assessment is central for low-carbon management practice. This paper investigates China's National Climate Change Assessment Reports of 2007, 2011, and 2015. These three reports are compared with other climate change assessment reports by data mining. The necessity of national climate change assessment is analyzed with the requirements at home and abroad. The latest progress surrounding climate change impacts, adaptation, and mitigation is outlined with the

increasing temperature rise in China and the urgency of climate change commitments. The achievements in climate change assessment indicate the increasing climate change vulnerability on sectors and regions in China and the strategies and priorities for low-carbon actions. Distinct gaps and differences are identified in the coverage of industry, regions, and vulnerability assessment between our assessments and other evaluation reports. These gaps and differences demonstrate the importance and future improvements of China's national climate change assessment in international climate governance. The outlook for China's fourth assessment report is proposed.

Received April 23, 2018; accepted August 1, 2018

Bing WANG (✉)

Beijing Key Laboratory for Precise Mining of Intergrown Energy and Resources, China University of Mining and Technology (Beijing), Beijing 100083, China; College of Resources and Safety Engineering, China University of Mining and Technology (Beijing), Beijing 100083, China; Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China
E-mail: bingwang_bit@163.com

Ge HONG

College of Resources and Safety Engineering, China University of Mining and Technology (Beijing), Beijing 100083, China

Chao-Qun CUI

Beijing Key Laboratory for Precise Mining of Intergrown Energy and Resources, China University of Mining and Technology (Beijing), Beijing 100083, China; College of Resources and Safety Engineering, China University of Mining and Technology (Beijing), Beijing 100083, China

Hao YU

Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China; State Grid Energy Research Institute Company Limited, Beijing 102209, China

Tad MURTY

Department of Civil Engineering, University of Ottawa, Ottawa, Canada

This work was funded by National Natural Science Foundation of China (Grant No. 71704178), Beijing Excellent Talent Program (Grant No. 2017000020124G133), Major Consulting Project of Chinese Academy of Engineering (Grant Nos. 2016-ZD-07 and 2017-ZD-03), and Beijing Undergraduate Research Training Program (Grant No. C201801229).

Keywords climate change assessment, low-carbon management, impact, adaptation, mitigation

1 Introduction

1.1 Low-carbon research progress for foreign climate change assessment report

Assessments of climate change by Intergovernmental Panel on Climate Change (IPCC) are an important knowledge base of global climate change assessment, which provide scientific support for international climate governance. From the perspective of global climate change research, the United Nations IPCC has systematically reviewed and summarized the research results of scientific facts, impacts, adaptation, and mitigation of climate change (Drouet et al., 2015). IPCC has issued five assessment reports published roughly in 1990, 1995, 2001, 2007, and 2014. These reports mainly consisted of three working groups and an integrated group for the Synthesis Report. The first working group developed the physical science of climate change (IPCC, 2013); the second working group targeted the impacts, adaptation, and vulnerability of climate change; and the third one worked on climate change mitigation. The Synthesis

Report was responsible for integrating working groups I, II, and III. The IPCC climate change assessment reports provided important scientific support for the international conferences on climate change in the United Nations (Hughes and Paterson, 2017).

Developed countries, such as the US and UK, have summarized climate change impacts on social economy and climate change mitigation and adaptation at the national level. Their summaries could provide scientific basis for decision makers. To formulate scientifically and implement measures for coping with climate change, the major developed countries have compiled and issued relevant climate change assessment reports. For example, according to the US Global Change Research Act (1990), the interagency US Global Change Research Program (USGCRP) organizes, evaluates, and integrates research findings in the field of climate change every four years; and this program also submitted the National Climate Change Assessment Report to the national government in 2000, 2009, and 2014 (USGCRP, 2000, 2009, 2014). The third US national assessment report on climate change was officially released in May 2014. Its main contents included climate change facts in the US, the influence of climate change on the main sectors and 10 regions in the US, and the strategies for addressing climate change (USGCRP, 2014). According to the Climate Change Act of 2008, the UK government has planned to conduct climate change risk assessment report every five years, with its first and second reports released in 2012 and 2017. These reports could identify the risk of climate change in the UK and the breakthrough to mitigate and adapt to climate change (UK Department for Environment, Food and Rural Affairs, 2012, 2017). These national efforts on climate change assessment show that the climate change assessment in developed countries focuses on evaluating the impact of climate change, finding the key climate change risks and opportunities for each country, and taking the most effective actions to mitigate and adapt to climate change.

1.2 Low-carbon research progress for China's climate change assessment report

The international response to climate change suggests the urgent need for China to conduct national assessment of climate change. The international community has reached a political consensus on controlling the global temperature rise to 2°C compared with the pre-industrial era and further strengthening the global actions in response to climate change. The international community has arrived at the basic framework for global response to climate change before and after 2020 at the Paris Climate Change Conference in 2015. The international climate negotiation is a political framework, which directly affects the trend of every country's economic development and environmental protection around the world (Mahony and Beck, 2017). If China wants to take guidance from international climate

governance, the national assessment of climate change will present new understanding of the scientific basis of climate change, as well as the impacts, vulnerability, mitigation, and adaptation to climate change. This assessment can also provide cost-benefit and emission reduction path analyses for climate change actions, which are an important support for deciding China's Intended Nationally Determined Contributions (China INDCs) on climate change.

China's international commitments to combat climate change reflect the responsible attitude of positively fulfilling international joint obligations and promoting global joint development. Although some organizations withdrew from the Paris agreement and emission leaked among international trade (Mi et al., 2018), high requirements are proposed for scientifically combating climate change and promoting low-carbon development in the near future. On June 30, 2015, China submitted the National White Paper "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions (China INDCs)" to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat in response to climate change (State Council of China, 2015). China has nationally determined its actions by 2030, such as the peaking of carbon dioxide emissions around 2030 (Mi et al., 2017a, 2017b) and the reduction in carbon dioxide emissions per unit of GDP by 60%–65% from the 2005 level. Furthermore, the China INDCs and the Sino-US, Sino-Indian, and Sino-European Climate Change Joint Statements have embodied the responsible actions and determinations of Beijing in coping with climate change. This positive momentum of combating climate change is in dire need of a comprehensive climate change assessment in China.

Therefore, China's National Assessment Report on Climate Change is an important work under the mutual promotion of the international pressure and domestic development. It is a systematic summary that collects achievements on the science, technology, economy, and social aspects of climate change. Moreover, the comprehensive assessment of climate change will provide an important decision-making foundation for formulating the economic development plan for the 13th Five-Year Plan and the policies of climate change mitigation and adaptation. Finally, the directions for scientific climate change research will also be implied in the National Climate Change Assessment Report.

As such, the China's First and Second National Assessment Reports on Climate Change (China's National AR1 and AR2) were launched in December 2002 and December 2008, respectively. Under the guidance of the working group on national climate change assessment, more than 10 departments in China cooperated closely and organized a multidisciplinary research team. The first two reports were initially published in February 2007 and November 2011, respectively (China's National AR1 Editorial Committee, 2006; China's National AR2 Editor-

ial Committee, 2011).

Since 2010, the international climate change negotiations have had a profound change, and China's increasing energy consumption and carbon emissions have brought considerable pressure on China's energy conservation and emission reduction. Meanwhile, China's goal of implementing low-carbon development and building environmentally friendly and resource-saving society has prompted it to adopt a number of measures to combat climate change. Therefore, in accordance with the previous experiences on national assessment reports, the compiling group that included the Ministry of Science and Technology (MOST), China Meteorological Administration, Chinese Academy of Sciences, and other departments, were working on China's Third National Assessment Report on Climate Change (China's National AR3) since 2011 and completed the main report after four years (China's AR3 Editorial Committee, 2015). Furthermore, a series of special reports, such as China's Carbon Dioxide Utilization Technology Assessment Report (The Administrative Center for China's Agenda 21, 2014), the Impact of Climate Change on China's Major Projects and Countermeasures Research, and the National Assessment Report on Climate Change (Science dissemination Edition), was being released successively since April 2014.

1.3 Importance of comparative analysis

The three national assessment reports of China on climate change are the climate change research literature review of the Chinese scientific community. Systematic summary and comparative analysis on these climate change assessment reports at home and abroad are helpful to understand the latest research progress and key points in the field of climate change and widen the view of China's climate change research further. A comparative analysis on the three national assessment reports of China on climate change is conducive to present new ideas, judgments, and conclusions regarding climate change issues. Moreover, comparative analysis with foreign climate change assessment reports can reflect the differences among the focus fields of assessment reports and provide a reference for the subsequent assessment work of climate change.

Therefore, on the basis of introducing the background, the purpose, and the significance of assessment reports, this paper compares and analyzes China's three assessment reports with those of other countries and the international

assessment reports on climate change from the aspects of organization, methodology, and achievement. Section 3 presents an in-depth analysis of the main conclusions in China's three previous assessment reports and international assessment reports. The future focus and improvements of assessment reports are discussed in Section 4.

2 Process for national climate change assessment

2.1 Organization mode for climate change assessment

The number of scientists participating in preparing the national assessment report has continuously increased from 88 experts in China's National AR1 to over 500 experts in China's National AR3. The working group is composed of the leading group and its administrative office, the editorial committee group and its working office, the expert reviewer group. Table 1 summarizes the main content of the three national assessment reports on climate change. China's National AR3 is different from the previous two reports. It contains two parts, namely, the methods and data and the case studies of enterprises in coping with climate change. However, because the two additional parts have been published separately, Table 1 covers only the main content of China's National AR 3. Table 1 shows that the participation of experts in the three national assessment reports has been enhanced by the increasing number of experts. The number of authors in Chinese assessment reports is less than that in IPCC reports (Corbera et al., 2016). According to the catalog and word count of the reports, the main content of the report is constantly enriched and refined.

The organization form of the three assessment reports is similar to the matrix organization design in project management. The organizational unit of the three assessment reports on climate change is the MOST of China. MOST is responsible for assigning missions and supervising, coordinating, and summarizing the final version of the reports. Furthermore, MOST, together with China Meteorological Administration, Chinese Academy of Sciences, Chinese Academy of Engineering, National Development and Reform Commission, Ministry of Foreign Affairs, Ministry of Education, and other partners (a total of 15 departments), organized experts to participate in the working editorial group of China's National AR3.

Table 1 General changes in the three national assessment reports on climate change

	Departments	Editorial experts	Chapters	Word count
China's National AR1	17	88	25	0.68 million
China's National AR2	16	158	40	1.12 million
China's National AR3	16	over 500	42	1.67 million

The participants include researchers from government, universities, scientific research institutes, enterprises, and public institutions.

2.2 Achievement exhibition

With the increasing attention from the international and domestic community on China's climate change actions, the presentation of climate change assessment report has been improved. The combination of main, special, and summary reports is the new form of China's National AR3. This exhibition provides corresponding reading versions for different levels of readers, which greatly enriches and expands the scope of the report's popularization. For example, the adoption of the National Assessment Report on Climate Change (Science Dissemination Edition) is a major progress. Special reports, such as the Impact of Climate Change on China's Major Projects and Countermeasures and China's Assessment Report on Carbon Dioxide Utilization Technology, are meaningful supplements to the main report, which aims to conduct in-depth research and assessment on the hotspots of climate change research.

2.3 Methodology and influence

The main methodology of China's national assessment report on climate change has a trend of continuous refinement and practical execution. In terms of mitigation and adaptation to climate change, China's National AR1 briefly discussed the traditional adaptive measures in natural ecological department and has a relatively less rigorous evaluation on the emission reduction potential in power, manufacturing industry, transportation, and building. Meanwhile, China's National AR3 includes four chapters to evaluate the emission reduction potentials from the aspects of the industrial structural adjustment, energy supply, energy consumption, and industrial production.

The national assessment report on climate change has become a window for China to advertise their efforts in coping with climate change. The main opportunities of international publicity have been obtained in international climate negotiations, such as UNFCCC and United Nations Climate Change conferences. This publicity in international occasions is beneficial in establishing the image of a responsible country in addressing the issues of climate change. It also shows the new understanding and research progress to climate change in the Chinese scientific community.

The assessment reports on climate change and its related research condense the core research results on climate change in China. These reports have also received increasing attention from the climate change research field. Statistics show that the climate change assessment reports were retrieved 10279 times in 2017. According to the retrieval results from the Wanfang database, the

introduction on China's National AR1 (Ding et al., 2006; Lin et al., 2006) has been cited 510 times in 2017.

3 Comparisons of national climate change assessment results

Given the background of new urbanization and the economic model of "new normal" in China, climate change assessment has a profound influence on long-term sustainable development. First, the assessment outlines the government's attitude toward climate change and the measures for coping with climate change. Second, the assessment results provide scientific and technological support for future international affairs of China's role in global climate change; these results also contribute to China's participation in global climate change governance. Third, the evaluation report provides important reference for China's economic transformation and energy transition. This section presents an intercomparison of the three national assessment reports and identify the differences between China's assessments and other foreign frameworks.

3.1 Coverage and emphasis of national assessment reports

China's national climate change assessment includes concerns from physical aspects of climate change to the impacts and mitigation of climate change. The process of national climate change assessment is a progress of enrichment on research outcomes of climate change. Table 2 shows that all the three national assessment reports of China contain the physical and social aspects of climate change. However, the latest two assessment reports include additions, such as assessment methodologies, actions for coping with climate change, and international cooperation. These additions represent the substantial efforts made by the Chinese government in the climate change field and the positive attitude toward Beijing's participation in climate change governance. The other outstanding point is found in researching the physical aspects of climate change. In comparison with China's National AR1, the new physical science basis not only has the history and the temporal state of climate change but also the further trend and the possible impact of climate change. Further details for Parts 1–5 in Table 2 are organized as follows. Parts 1–3 are mentioned in Sections 3.2–3.4, respectively. Parts 4 and 5 are included in Section 3.5. Section 3.6 targets the differences between China's reports and other reports abroad.

3.2 Physical scientific aspects of the climate system and climate change

This section mainly discusses the comparison for Part 1 in Table 2, that is, the history of climate change in AR1;

Table 2 Framework comparison of five climate change assessment reports

	China's National AR1	China's National AR2	China's National AR3	US National AR3	IPCC AR5
Part 1	History of climate change (7*)	Climate change in China (10*)	Facts, causes, and future of climate (10*)	Changing climate in the US	Physical science basis (14*)
Part 2	Impacts and adaptation (9*)	Impacts and adaptation (10*)	Impacts and adaptation (10*)	Climate change impacts on 13 sectors (13*)	Impacts, adaptation, and vulnerability (30*)
Part 3	Mitigation of socioeconomic impacts (9*)	Mitigation of socioeconomic impacts (8*)	Mitigation (10*)	Climate change impacts on 10 regions (10*)	Mitigation of climate change (16*)
Part 4	-	Global assessment methods (6*)	Socioeconomic impact of climate change (6*)	Response Strategies (5*)	Synthesis Report
Part 5	-	Policies, measures, actions, and outcomes (6*)	Policies, actions, and international cooperation (6*)	-	-

Note: The symbol * means the number of chapters in one part.

climate change in China in AR2; and facts, causes, and the future of climate in AR3. The averaged land surface temperature shows an obvious warming trend in China, and the warming rate over China has increased. As shown in Table 2, the figures in the three national reports reveal that the judgment on the temperature increase in the recent century has obviously changed into a grim situation. This revision is generated by the amendment on the data imperfection during the early 20th century. In comparison with other international assessment results, the increase rate of temperature in China is larger than that reported in IPCC and is equal to the American standard (Howarth et al., 2017).

The overall trend of precipitation in China is not evident; however, regional differences and interannual variations have increased. As shown in Table 2, the conclusions in China's three climate change assessment reports on the trend of precipitation change are consistent. Thus, the overall trend of change is not obvious. However, with the deepening understanding of climate change science, the assessment of regional precipitation suggests that a huge rainfall difference is observed among regions. For example, the annual precipitation has reduced in a swath from the north-east to south-west, especially the North-east, North, Central, and South-west China and Huanghuai Region. This spatiotemporal differences in precipitation lead to an uneven distribution of precipitation in China. In comparison with the precipitation figures from the reports in foreign countries, the conclusion from the IPCC report is consistent with the conclusion of China's National AR3; meanwhile, the US reported a significant increase in the average precipitation with different increase rates of precipitation in each region.

The frequency and the intensity of extreme precipitation events in China have increased in recent years. Furthermore, the frequency, intensity, and affected area of high-temperature events have also increased, thereby resulting in the shrinkage and vulnerability of glaciers to climate

change. The conclusions for glaciers are first presented in the China's National AR2. Since the 1990s, the extreme events associated with low temperature have decreased considerably, whereas the intensity and frequency of regional high temperature have increased significantly. Regional differences in extreme precipitation suggest that a decreasing tendency occurs in North-east and North China and the Sichuan Basin, whereas the western region, middle and lower reaches of the Yangtze River, and South China show an increasing trend. In addition, an increased frequency of drought occurred in China. For example, the "three north" area experienced an increasingly large area of drought. A rare but severe drought disaster occurred in Chongqing, Yunnan, and other south-west provinces.

The literature review of the physical aspects of climate change in the assessment report is detailed and in-depth. For example, in comparison with China's National AR1, China's National AR2 and AR3 contain many types of extreme weather events, such as tropical cyclones, typhoons, and heavy fog. They also added assessments on the changes in cryosphere, regional climate patterns, Asian monsoons, and water cycle. Particularly, China's national AR3 aims to investigate the influence of the Tibetan Plateau on the East Asian monsoon and the prediction for the arrival time of 2°C increase threshold.

3.3 Impacts on natural systems and adaption to climate change in China

In China's three assessment reports, the impact of climate change on the agricultural sector is negative in most regions but is slightly positive in North-east China. China's National AR2 and AR3 conclude that the impact of global warming on China's crop planting are obvious, and the appropriate bound for crop planting considerably moves northward. The latest results on food production indicate that climate change has posed a major challenge to

the stability of China's grain production and the sustainable development of the agriculture sector. In terms of the future impacts, if technological progress is ignored, then the production mode and layout of agriculture will be affected by climate change and the fluctuation of grain production will increase. For example, in 1980–2008, climate change caused yield decrease of 1.27% and 1.73% in wheat and maize, respectively.

Over the past 100 years, major river runoff has tended to decrease, and future water resources may be reduced by a total of 5%. The response to climate change is obviously region driven, and the sensitivity of runoff to precipitation is considerably greater than that to temperature. Attribution analysis on the change of river runoff suggests that the two main factors are human activities and climatic factors. China's National AR3 further indicates that the influences of human activities on the runoff reduction are most obvious in the middle reaches of the Yellow River, the Haihe River Basin, and the Liaohe Basin. Seven regions among China's top ten water resources areas show a decreasing trend.

Climate change has significant adverse effect on coastal environment, forest ecosystems, and major engineering projects. Sea level rise affects the coastal environment and protection facilities, which leads to continuous improvement of design standards for marine and coastal engineering. China's National AR3 indicates that the rise in sea levels caused by climate change is the major cause for the high frequency of storm surge and a substantial reduction in wetlands and coastal tidal flats. The current influence of climate change on forest and other natural ecosystems is positive but varies under regional environmental conditions, thereby suggesting future negative effects. The MOST has authorized China Academy of Engineering to study the influence of climate change on major engineering projects and publish a special report. This research is the first systematic research on the impact of climate change on major projects. Climate change has affected major projects, such as Three Gorges Project, Three North Shelter Belt Project, and Qinghai Tibet Railway. Its adverse impact will increase in the future.

The impact of climate change on China's regions is expanding. Seven regions are discussed in the assessment report in accordance with the administrative province, namely, north-east, north, east, central, south, south-west, and north-west. On the basis of China's National AR1 and AR2, AR3 summarizes the impact of climate change in the seven regions based on the latest research literature. For example, the topic of climate change impact assessment in North China changes from the first assessment of water resources, land desertification, and the agricultural sector to the third assessment report on farming and animal husbandry, water resources, urban environment, human health, and other fields. As sourced from China's National AR3, agriculture and animal husbandry in all regions are

affected by climate change, followed by water resources system. The impact of climate change is through fog, which worsens the Midwest urban environment, and the environment in cities in East China is affected by the urban heat island and the threat of extreme weather events.

3.4 Comprehensive evaluation of China's climate change mitigation actions

The structural adjustment between primary, secondary, and tertiary industries and the industrial restructuring, as well as the structural improvement of the export structure, are crucial to the future control of greenhouse gas (GHG) emissions. The assessments on climate change mitigation and its actions in China's three assessment reports mainly include the international situation, the global and China's GHG emissions, and emission reduction potential of the main departments in China. The main difference of China's National AR3 is that it reviews the contribution of industrial structural adjustment to carbon emission reduction and the potential impact of geo-engineering. For the contributions of industrial structure to emission reduction, China's National AR3 shows that China has adopted a series of policies and actions to promote the adjustment of industrial structure actively in response to climate change, and plenty of rooms are still available to enact enhanced policies and actions. These policies include reducing the proportion of industries with high consumption of water and energy, moderating heavy pollution, and promoting the use of new technologies, materials, and energy to cut down carbon emissions in key industries.

All sectors have their suitable potentials to reduce GHG emission. CCUS and coal cleaning utilization technologies possess deep emission reduction capacity, and a large number of emission reduction technologies with negative costs are worth promoting. China's National AR2 concludes that carbon dioxide emission reduction potential in energy supply sector and industrial production process can reach up to 1.8 billion tons and 239–543 million, respectively, in 2020 compared with that of 2005. Meanwhile, results from China's National AR3 show that carbon dioxide emission reduction potential in energy supply sector and industrial production process can reach 4.5 billion tons and 0.77 billion, respectively, in 2030 compared with that of 2011. Although the two assessments have a different base year for the prediction on emission reductions potential, China's National AR3 estimates that increasing potentials for reductions exist in the sectors.

3.5 Socioeconomic impact assessment of climate change and international cooperation

The sensitivity of GDP to the changes in climate meteorological conditions is approximately 12.36%, and the sensitivity of the agricultural sector is considerably

higher than that of other industries. China's National AR3 adds the economic and social impact assessment of climate change, which is listed as the fourth part of the main report. The climate change impacts on the social economy system of China are under the condition of the same factors of capital and labor. The susceptibility of China's GDP to the influence of meteorological conditions change from 1984 to 2006 is approximately 12.36%. Furthermore, the agricultural sensitivity to climate changes reaches 25.4%, which is considerably higher than that of other industries. The sensitivity of regional economic output to climate change in North and West China is higher than that of the South and East China.

In addition to reducing carbon emissions and improving the environment, climate change mitigation and adaptation actions are conducive to the long-term development of China's economy and increase employment opportunities. The results of China's National AR3 reveal that China's current development stage and resource endowment are negative factors for the cost reduction of climate change actions in China. Given the positive roles of climate change actions in China's economic and social development, low-carbon practice can provide fresh impetus to development mode transition, structural adjustment, employment, and innovation promotion. The future climate change measurements need to coordinate the relationship between economic development and climate change adaptation and mitigation. The uncertainty of existing research outcomes should be narrowed by quantitative methods rather than qualitative description.

3.6 Differences between China's national assessment report and other external ones

Unlike China's national assessment report, the US National Climate Change Assessment Report is a series of reports completed by the research institution under the Global Change Research Act 1990. The contents of the third assessment report from the US (US AR3) are constantly enriched, and the sectors and regions involved are constantly increasing. Specifically, the research fields of climate change assessment include energy, ecological system, urban and rural communities, land use on US AR1 inclusive agriculture, water resources, human health, and the forest system. In comparison with report US AR1, US AR3 has added the ocean and coastal zones for the extension of regional cover.

The organization model for low-carbon assessment in China is that the government takes the lead while the working groups are responsible for the specific implementation of the national climate change assessment report. From the perspective of coordination mechanism, China's assessment report, which is led by the government departments, is enacted by the National Assessment Report on Climate Change Editorial Committee. For the US, the assessment report is guided by government legislation, and

the specific assessment work is performed under global change research program and includes 13 federal departments or agencies. The UK's climate change risk assessment report is being assessed every five years under the UK Climate Change Act 2008. It is supervised by the UK Department of Environment, Food, and Rural Affairs.

Developed countries, such as the US and the UK, pay close attention to the impact of climate change on various sectors and regions of society and how to reduce the risk of climate change. In comparison with the climate change assessment report in China, approximately 65% of the main report of US AR3 is about the influence of climate change at industrial and regional levels and the review of climate change facts has been given relatively less attention. UK's assessment report mainly focuses on the risk analysis of climate change, and the report is based on the premise that the inertia of climate system is and will continue to influence our society; hence, UK's report has inspired us to assess the risks of climate change and adopt the measures for coping with climate change.

The IPCC assessment report is an evaluation for global climate change. It mainly states the current development trends, impacts, risks, and vulnerability of climate change to reflect the urgency of climate change actions in the international level (O'Neill et al., 2017). The framework of IPCC reports is similar with China's assessment reports, and the nuance lies in the latter outlining the main action on coping with climate change in China, the achievement, and the future determination to address climate change. IPCC reports include the assessment results of climate change facts and a clear assessment of the uncertainty and GHG emission balances (Cellura et al., 2018). These parts in China's assessment report needs further clarification.

4 Outlooks for the China's National AR4

4.1 Conclusion remarks on the achievements of China's efforts in coping with climate change

The three previous national assessment reports on climate change contain systematic and comprehensive evaluation on five topics: (1) Observed changes in the climate system, including their attribution and future trend; (2) Impact of climate change and its adaptation; (3) Climate change mitigation in China; (4) Socioeconomic impact assessment on climate change; and (5) Policies, actions, and international cooperation. These assessment topics can provide scientific basis and data support for policy decisions and international climate negotiation. In comparison with the former two national reports and foreign assessment reports, China's National AR3 has opened three Chinese Corner meeting in the United Nations Climate Change Conference, which enhances its influence at home and abroad. Given the increasing strength of scientific research in the

climate change field, the contents of China's National A3 have been refined and its quality has been improved. Some suggestions for the further improvement on the report framework are as follows.

(1) Although the report adopts a combined quantitative and qualitative method to polish the conclusion, the report needs to quantify further additional explicit results. The mechanism research for climate change is important for Chinese scientists to share their efforts on the IPCC assessment report. Many studies by Chinese scholars have been cited in the IPCC assessment report (Working Group I). Thus, quantitative and precise results on climate change mechanism should be further improved.

(2) The latest assessment report is considerably more comprehensive than the first two reports, and some parts should be elaborated. The contents of the three reports reveal that the research topics of China's National AR3 are enlarged, especially for the impact of climate change on numerous sectors. Hence, the discussion on the impact of climate change and its adaptation must be improved.

(3) The literature review of climate change research may have conflicting conclusions. How to assess climate change based on these conflicting findings and finding solutions to these conflicts are the next step in the assessment report. For example, in the evaluation of land surface temperature rise in China, different scholars have obtained different conclusions on the basis of various historical data and observation periods. These conclusions must be analyzed in detail, and the results with high confidence should be screened for scientific rationality. The cost-benefit analysis of different emission reduction technologies directly influences the future development in the technology innovation for climate change in China. Thus, a comprehensive evaluation on the economic viability of different technologies is urgent.

4.2 Future emphasis for low-carbon framework of national assessment report

National climate change assessment reports cover many aspects in the field of climate change, which can help in understanding, evaluating, and responding to climate change. The key points that may require attention in future comprehensive assessment reports of climate change in China are as follows.

(1) Further research on the mechanism and impact of climate change on social and economic system should coincide with the physical facts of climate change in China. The economic analysis on the impact of climate change should target the challenge in the following aspects. First, the impact of climate change is complex and must represent on several sectors and regions with long periods of time. The various sectors of the socio-economic system are interconnected. Assessing the impact of climate change on one sector often requires a comprehensive consideration of the indirect effects of

other sectors. Second, the uncertainties of climate change render distinguishing between natural variability and human-caused climate change difficult. Certain climate extremes are often the result of the interaction between natural variability and climate change. Finally, when climate change has an impact on social systems, measuring this impact is often difficult.

(2) Study on the impact of climate change should consider a deep risk assessment of climate change. Risk assessment of climate change needs to involve different sectors, such that the government and social agencies can take reasonable allocation of resources to construct adaptive capacity buildings for climate change. Furthermore, this risk assessment must cover different regions to aid in finding the most affected areas that will cope with climate change. The research on climate change vulnerability is the main method to analyze the possibility of the negative impact of climate change in China (Wang et al., 2014a, 2014b). However, the current vulnerability research is mainly concentrated in few fields, such as ecology and health. Other aspects of the socioeconomic system should be included. Energy sector is not only the key sector in addressing climate change, energy conservation, and emissions reduction but is also the most vulnerable segment in climate change. Particularly, drawing attention to renewable energy as the pillar energy of the world is necessary (Wang et al., 2018b); moreover, the vulnerability of the energy sector to climate change and sustainable development deserves further systematic research (Wang et al., 2018a).

(3) The cost-benefit analysis of climate change efforts should emphasize on future assessment reports. As one representative aspect of non-traditional security, the importance and impact of climate change on China's national security deserves urgent attention in the future. Climate security and energy and environmental security are the new elements of national security. In the context of energy revolution, energy security and environmental protection is an important strategic issue that is closely related to the field of climate change (Du, 2014). Furthermore, energy development is closely linked to coping with climate change (He, 2011). Energy security generally includes two parts, namely, energy supply security and energy consumption security (Wei et al., 2012). Ensuring energy security is also a process of deepening and coordinating the development of climate change. Research on the synergies between energy security measures and climate change actions will be a key to the cost-benefit analysis of climate change efforts.

(4) For the structural design of reports, the interrelationship between climate change adaptation and mitigation should be added in future reports. Adaptation to climate change and mitigation measures may lead to synergies or negative effects. The society should enlarge the synergies and reduce negative aspects. As shown in the white paper of policy and action to combat climate change in China,

climate change mitigation and adaptation are the integral part of coping with climate change. The former is a relatively long-term and difficult task; whereas the latter is realistic and pressing, which are particularly important for developing countries. Coordinating the relationship between development and climate change mitigation and adaptation is necessary. The research on this topic should

target a specific field for exploring how to select actions to address climate change (Drouet et al., 2015).

Acknowledgements The authors graciously acknowledge the support from Professor Ioan Nistor for the Visiting Researcher Internship and Dr. Xian Zhang from the Administrative Center for China's Agenda 21.

Appendix

Table A1 Observed changes in the climate system

	Temperature	Rainfall	Extreme weather	Sea level	Glacier
China's National AR1	An increase of 0.22°C /10 a in the recent 50 years and a total of 0.5°C–0.8°C/100 a	Unclear time trends and large regional difference	Obvious changes and regional differences	Average increase rate of 2.5 mm/a (recent 50 years)	-
China's National AR2	An increase of 0.23°C /10 a in 1951–2009 and a total of 0.5°C–0.8°C/100 a	Unclear time trends	Different trends and regional differences for different types of weather	Average increase rate of 2.6 mm/a (1977–2009)	Approximately 82% of glaciers are vulnerable, with more than 10% of areas decreased (1960–2005)
China's National AR3	An increase of 0.25°C /10 a in 1956–2012 and a total of 0.9°C–1.5°C/100 a	Unclear time trends and regional difference in distribution and time series	Different types of extreme weather events have their own trends	Average increase rate of 2.9 mm/a (1980–2012)	Approximately 92% of glaciers are vulnerable, with 10.1% of areas decreased (1960/1970 to early 21st century)
US National AR3	An increase of 1.3°C–1.9°C since 1895	An increase in average level since 1900 but different regional increase rates	Frequent heavy rain and hurricane events; regional variations in flooding and drought; and increased frequency and intensity in the heat wave	Sea-level rise of approximately 0.2 m since 1880; average increase rate of 1.69 mm/a (1880–2000)	The Arctic Sea ice area shrank by 40% in the most critical hours (from the late 1970s to the early 2000s)
IPCC AR5	An increase of 0.85°C in 1880–2012 and 0.12°C /10 a in 1951–2012	Unclear time trends but an increase in the mid and high latitudes of the Northern Hemisphere (1900–2010)	Numerous heavy precipitation events; drought at global level has no obvious trend	Mean rate of global sea level rise of 1.3 mm/a–2.3 mm/a since 1961	Global glaciers are generally in a state of constant withdrawal

References

- Cellura M, Cusenza M A, Longo S (2018). Energy-related GHG emissions balances: IPCC versus LCA. *Science of the Total Environment*, 628–629: 1328–1339
- Corbera E, Calvet-Mir L, Hughes H, Paterson M (2016). Patterns of authorship in the IPCC Working Group III report. *Nature Climate Change*, 6(1): 94–99
- Ding Y H, Ren G Y, Shi G Y, Gong P, Zhen X H, Zhai P M, Zhang D E, Zhao Z C, Wang S W, Wang H J, Luo Y, Chen D L, Gao X J, Dai X S (2006). National assessment report of climate change (I): Climate change in China and its future trend. *Advances in Climate Change Research*, 2(1): 3–8
- Drouet L, Bosetti V, Tavoni M (2015). Selection of climate policies under the uncertainties in the Fifth Assessment Report of the IPCC. *Nature Climate Change*, 5(10): 937–940
- Du X W (2014). Energy revolution for sustainable future. *Journal of Beijing Institute of Technology (Social Science)*, 24: 1–4
- He J K (2011). Energy development and addressing climate change in China. *China Population Resources and Environment*, 21(10): 40–48
- Howarth C, Viner D, Dessai S, Rapley C, Jones A (2017). Enhancing the contribution and role of practitioner knowledge in the Intergovernmental Panel on Climate Change (IPCC) Working Group (WG) II process: Insights from UK workshops. *Climate Services*, 5: 3–10
- Hughes H R, Paterson M (2017). Narrowing the climate field: The symbolic power of authors in the IPCC's assessment of mitigation. *Review of Policy Research*, 34(6): 744–766
- IPCC (2013). *Climate Change 2013—The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In: Stocker T F, Qin D, Plattner G K, Tignor M, Allen S K, Boschung J, Nauels A, Xia Y, Bex and Midgley P M, eds. Cambridge and New York: Cambridge University Press
- Lin E D, Xu Y L, Jiang J H, Li Y E, Yang X, Zhang J Y, Li C X, Wu S H, Zhao Z Q, Wu J G, Ju H, Yan C R, Wang S R, Liu Y F, Du B L, Zhao C Y, Qin B F, Liu C Z, Huang C Y, Zhang X Q, Ma S M (2006). National assessment report of climate change (II): Climate change impacts and adaptation. *Advances in Climate Change Research*, 2(2): 51–56
- Mahony M, Beck S (2017). The IPCC and the politics of anticipation. *Nature Climate Change*, 7(5): 311–313

- Mi Z, Meng J, Green F, Coffman D M, Guan D (2018). China's "exported carbon" peak: Patterns, drivers, and implications. *Geophysical Research Letters*, 45(9): 4309–4318
- Mi Z F, Wei Y M, Wang B, Meng J, Liu Z, Shan Y, Liu J, Guan D (2017a). Socioeconomic impact assessment of China's CO₂ emissions peak prior to 2030. *Journal of Cleaner Production*, 142: 2227–2236
- Mi Z, Meng J, Guan D, Shan Y, Song M, Wei Y M, Liu Z, Hubacek K (2017b). Chinese CO₂ emission flows have reversed since the global financial crisis. *Nature Communications*, 8(1): 1712
- O'Neill B C, Oppenheimer M, Warren R, Hallegatte S, Kopp R E, Pörtner H O, Scholes R, Birkmann J, Foden W, Licker R, Mach K J, Marbaix P, Mastrandrea M D, Price J, Takahashi K, van Ypersele J P, Yohe G (2017). IPCC reasons for concern regarding climate change risks. *Nature Climate Change*, 7(1): 28–37
- State Council of China (2015). Enhanced actions on climate change: China's intended nationally determined contributions. http://news.xinhuanet.com/2015-06/30/c_1115774759.htm, 2015–09–18
- The Administrative Center for China's Agenda 21 (2014). Assessment Report on CCS Technology in China. Beijing: Science Press
- The First National Assessment Report on Climate Change Editorial Committee (2006). First National Assessment Report on Climate Change. Beijing: Science Press
- The Second National Assessment Report on Climate Change Editorial Committee (2011). Second National Assessment Report on Climate Change. Beijing: Science Press
- The Third National Assessment Report on Climate Change Editorial Committee (2015). Third National Assessment Report on Climate Change. Beijing: Science Press
- UK Department for Environment Food and Rural Affairs (2012). UK Climate Change Risk Assessment: Government Report 2012. <https://www.gov.uk/government/publications>, 2015–09–18
- UK Department for Environment Food and Rural Affairs (2017). UK climate change risk assessment 2017. <https://www.gov.uk/government/publications>, 2018–04–18
- US Global Change Research Program (2000). Climate change impacts on the United States: The potential consequences of climate variability and change. <http://www.globalchange.gov/>, 2015–09–20
- US Global Change Research Program (2009). Global climate change impacts in the United States: The second national climate assessment. <http://nca2009.globalchange.gov/>, 2015–09–20
- US Global Change Research Program (2014). Climate change impacts in the United States: The third national climate assessment. <http://nca2014.globalchange.gov/>, 2015–09–20
- Wang B, Ke R Y, Yuan X C, Wei Y M (2014a). China's regional assessment of renewable energy vulnerability to climate change. *Renewable & Sustainable Energy Reviews*, 40: 185–195
- Wang B, Liang X J, Zhang H, Wang L, Wei Y M (2014b). Vulnerability of hydropower generation to climate change in China: Results based on Grey forecasting model. *Energy Policy*, 65: 701–707
- Wang B, Mi Z F, Nistor I, Yuan X C (2018a). How does hydrogen-based renewable energy change with economic development? Empirical evidence from 32 countries. *International Journal of Hydrogen Energy*, 43(25): 11629–11638
- Wang B, Wang Q, Wei Y M, Li Z (2018b). Role of renewable energy in China's energy security and climate change mitigation: An index decomposition analysis. *Renewable & Sustainable Energy Reviews*, 90: 187–194
- Wei Y M, Wu G, Liang Q M, Liao H (2012). China Energy Report: Energy Security Research. Beijing: Science Press (in Chinese)