Serving Beijing 2022 Olympic Winter Games and Developing Ice and Snow Industry: Application and Extension of Cryospheric Science

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Abstract
Cryospheric Science, as an emerging interdisciplinary research field combining natural science and humanity, aims to understand nature's law, serve human society and promote sustainable development. In recent years, by deepening the understanding of the cryosphere elements and the whole sphere, and by expanding the application research of cryospheric science, the Chinese community of cryospheric science has developed by leaps and bounds and realized the crossover from the traditional basic research to serving the major national needs, which marks the increasing maturity of the discipline. The Beijing 2022 Olympic Winter Games is a major landmark event at an important historical time in China. The special need of using snow and ice as the sports interface has led China's cryosphere scientific team to focus on tackling key technical links of icy snow physics since 2016, and promoted the development of China's cryosphere scientific application research in the past five years. In view of the key technology of snow service for the Beijing 2022 Olympic Winter Games and the national needs of ice and snow economic development, a research team was formed by the State Key Laboratory of Cryospheric Science, in cooperation with scientific institutions (such as Beijing Normal University, Chinese Academy of Meteorological Sciences, and Harbin Sport University) and first-class enterprises in the domestic ice and snow industry (such as Yabuli Sports Training Base, National Alpine Skiing Centre, and Genting Snow Park). The team has solved many technical problems, including snow making, icy snow track making, snow quality prediction and snow storage. The team studied the impact of climate change on China's ski tourism and how ice and snow tourism can help with the sustainable development of mountainous regions economy. It also trained the first batch of graduate students and core technicians of ski resorts in China. This paper summarizes the key snow-making technology of the Beijing 2022 Olympic Winter Games, and projects the development path of China's ice and snow industry. It expounds the application and expansion of cryospheric science from the perspective of strategic thinking, knowledge building and practical innovation, and puts forward relevant thoughts and suggestions.

Keywords
cryospheric science; Beijing 2022 Olympic Winter Games; snow service and guarantee technology; ice and snow industry; cryospheric service

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Serving Beijing 2022 Olympic Winter Games and Developing Ice and Snow Industry: Application and Extension of Cryospheric Science

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Abstract: Cryospheric science, as an emerging interdisciplinary research field combining natural science and humanity, aims to understand nature’s law, serve human society, and promote sustainable development. In recent years, by deepening the understanding of the cryosphere elements and the whole sphere, and by expanding the application research of cryospheric science, the Chinese community of cryospheric science has developed by leaps and bounds and realized the crossover from the traditional basic research to serving the major national needs, which marks the increasing maturity of the discipline. The Beijing 2022 Olympic Winter Games is a major landmark at an important historical time in China. The special need of using snow and ice as the sports interface has led China’s cryospheric scientific team to focus on tackling key technical links of icy snow physics since 2016, and promoted the development of China’s cryosphere scientific application research in the past five years. In view of the key technology of snow service for the Beijing 2022 Olympic Winter Games and the national needs of ice and snow economic development, a research team was built by the State Key Laboratory of Cryospheric Science, in cooperation with scientific institutions (such as Beijing Normal University, Chinese Academy of Meteorological Sciences, and Harbin Sport University) and first-class enterprises in the domestic ice and snow industry (such as Yabuli Sports Training Base, National Alpine Skiing Centre, and Genting Snow Park). The team has solved many technical problems, including snow making, icy snow track making, snow quality prediction, and snow storage. The team studied the impact of climate change on China’s ski tourism and how ice and snow tourism can help with the sustainable development of economy in mountainous regions. It also trained the first batch of graduate students and core technicians of ski resorts in China. This paper summarizes the key snow-making technology of the Beijing 2022 Olympic Winter Games, and projects the development path of China’s ice and snow industry. It expounds the application and expansion of cryospheric science from the perspective of strategic thinking, knowledge building, and practical innovation, and puts forward relevant thoughts and suggestions. DOI: 10.16418/j.issn.1000-3045.20220303011-en

Keywords: cryospheric science; Beijing 2022 Olympic Winter Games; snow service and guarantee technology; ice and snow industry; cryospheric service

Cryospheric science is the study of the formation and evolution of land cryosphere elements [such as glaciers (ice caps), permafrost, snow cover, river ice, and lake ice], marine cryosphere elements (such as sea ice, ice shelves, and icebergs), and atmospheric cryosphere elements (such as snow, shale, and hail), and of the mechanisms of interaction with other earth spheres, to serve sustainable social and economic development[1]. It involves the research in three layers: cryospheric processes, mechanisms and changes; the impact of cryospheric changes; and adaptation to cryospheric changes. These three research layers correspond to the gradual advancement from basic research to applied basic research and further to applied research. The growing understanding of basic research will drive the application of cryospheric science. An important direction for the development of cryospheric applied science is integrating cryospheric research with social and economic development to meet national major demands and serve regional sustainable development[2]. China is rich in ice and snow resources, which lays a foundation for the development of the ice and snow sports and the ice and snow tourism industry. The success in hosting the Beijing 2022 Olympic Winter Games has stimulated the public enthusiasm for winter sports and invigorated China’s ice and snow industry. Dozens of new ski resorts spring up every year across China in recent years, which has promoted the rapid development of the snow and ice resources and the fast popularization of the ice and snow sports and the ice and snow tourism. However, China’s ice and snow industry starts late,
which is out of reach by the existing ice and snow research teams. Therefore, China’s ice and snow industry is facing both opportunities and challenges in the new era.

1 Ages of accumulation in glaciology has laid a foundation for applied research

“Missions leading discipline development” has been a common path of scientific research in the early years since the People’s Republic of China was founded, which is also suitable for China’s cryospheric science. Under the leadership of Shi Yafeng, the ice and snow utilization research team of the Chinese Academy of Sciences (CAS) took the lead in introducing glaciology and geocryology to China in the late 1950s. To meet the needs of national development, this team mainly solved the problems in the development and utilization of meltwater resources in Qilian Mountains and the permafrost problems in the construction of Qinghai-Tibet Highway. In 1965, Lanzhou Institute of Glaciology, Geocryology and Desert, Chinese Academy of Sciences was founded (The institute was divided into Lanzhou Institute of Glaciology and Cryopedology and Lanzhou Institute of Desert Research, Chinese Academy of Sciences in 1978. Now, both of them are incorporated into the Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences) [3]. Despite the stagnation of studies due to the social factors during 1966–1976, glaciological research advanced under the harsh circumstance and achieved certain growth in applied glaciology. During this period, the Lanzhou Institute of Glaciology and Cryopedology initiated the experimental research on avalanches and drifting snow in the western section of the Tianshan Highway, and proposed the engineering design for the prevention and control of such disasters [4]. At the same time, they started the observation and experimental research on the mechanical properties of the Yellow River ice. In the early 1980s, Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences established a laboratory for applied research of ice and snow physics, specializing in physics and applied basic research of snow cover, glaciers and other ice bodies. With their efforts, China’s snow and ice physics achieved some progress in ice structure, ice formation of snow, snow and ice thermodynamics, ice dynamics, glacier dynamics, etc. However, as the research developed toward the goal of publishing SCI papers, the traditional applied research team of snow and ice physics has been gradually separated, and the research entered a temporary stage of stagnation.

Since the 21st century, China’s cryospheric research has been advancing and the understanding of cryosphere has been deepening accordingly. Significant progress has been achieved in the research on the formation and evolution of cryosphere elements, the process and mechanism of cryospheric changes, as well as the single-point and basin-scale observation experiments and the theoretical research. The research of cryospheric science in China has gained international convergence and entered a stable and rapid development stage. Chinese researchers have achieved systematic results in the research on cryospheric changes [5,6], the impact of cryospheric changes, and the adaptation to cryospheric changes [7], basically completing the transition from basic research to applied research and developing cryospheric science to be systematic.

After ages of academic accumulation, Chinese scientists have proposed the concept and theoretical framework of cryospheric science and established a preliminary system of cryospheric research. Ahead of the global counterparts, they took the lead in establishing the State Key Laboratory of Cryospheric Science. The laboratory has identified the processes and mechanisms of cryosphere, the interaction between cryosphere and other spheres, and the measures to adapt to the cryospheric changes as the primary research tasks, with the aim of serving sustainable social and economic development [8]. The cryospheric research group was awarded the Outstanding Science and Technology Achievement Prize of the Chinese Academy of Sciences in 2021. To cater to future needs, the State Key Laboratory of Cryospheric Science has strengthened the cultivation of young talents and compiled English-Chinese Dictionary of Cryospheric Sciences, Glossary of Cryospheric Science, and other reference books. The textbook system compiled by the laboratory with the Introduction to Cryospheric Science (in Chinese and English) as the mainstay and 15 volumes of cryospheric science theories as the support won the Grand Prize of 1st National Excellent Textbook (for higher education). The general courses and postgraduate courses on cryospheric science that are offered in 8 universities in China including the University of Chinese Academy of Sciences have fostered a large number of young and middle-aged talents. A nationwide talent layout has come out with the State Key Laboratory of Cryospheric Science as the source of the discipline development and the center of thought, and the research teams at the Institute of Tibetan Plateau Research (Chinese Academy of Sciences), Tsinghua University, Peking University, Beijing Normal University, Chinese Academy of Meteorological Sciences, Polar Research Institute of China and other research institutes/universities as the branches. This marks a new era of cryospheric science development.

2 Snow service for the Beijing 2022 Olympic Winter Games: Opportunities for applied research

At the time when Beijing won the bid for the 2022 Olympic Winter Games, none of the hundreds of ski resorts in China had a snow track in line with the alpine snow track standards of the International Ski Federation (FIS). To guarantee the key technologies for the Winter Olympic Games and meet the national demand for ice and snow
economic development, research institutions and government departments have initiated a variety of research projects. Specifically, the Chinese Academy of Sciences has launched the Academic Advising Program of the Academic Divisions of the Chinese Academy of Sciences and the Key Research Program; the National Natural Science Foundation of China has sponsored the Science Fund (Phase III) for Creative Research Groups and the Major Program; the Ministry of Science and Technology has supported the special project of Science and Technology for Olympic Winter Games of the State Key Research and Development Program. With the support of these projects, the State Key Laboratory of Cryospheric Science has formed a research team guided by academicians, led by middle-aged scientists, contributed by young researchers, and participated by graduate students and industrial personnel in cooperation with the scientific institutions (Beijing Normal University, Chinese Academy of Meteorological Sciences, Harbin Sport University, Shandong Normal University, Hebei Meteorological Service, and Nanjing Institute of Astronomical and Optics & Technology, Chinese Academy of Sciences) and the first-class enterprises in the domestic ice and snow industry (such as Xuebang Snow Industry, Yabuli Sports Training Base, National Alpine Skiing Centre, and Genting Snow Park). The team has solved many technical problems, including snow making, icy snow track making, snow quality prediction, and snow storage. The team studied the impact of climate change on China’s ski tourism and how ice and snow tourism can help with the sustainable development of economy in mountainous regions.

In the research process, a number of young talents have stood out by undertaking the key tasks. For example, Ding Minghu, Wang Feiteng, and Wang Shijin have become the key members of research teams. At the same time, China’s first batch of postgraduates in snow service and technical engineers in ski resorts have been fostered, stepping up the development of China’s ice and snow industry in the post-Beijing Winter Olympics era. Such research helps cryospheric science to serve the national demands and is a typical case of discipline extension.

The Beijing 2022 Olympic Winter Games has driven 300 million people to participate in ice and snow sports and turned the cold resources into a hot economy. On July 18, 2021, the State Council issued the National Fitness Program (2021–2025), which emphasized the popularization of winter sports. In the post-Beijing Winter Olympics era, efforts should be made to keep the dividends of ice and snow sports. The establishment of a research innovation team composed of the members from research institutes and enterprises provides the intellectual support for the successful hosting of the Beijing 2022 Olympic Winter Games and the sustainable development of China’s ice and snow industry.

The main achievements of the research on key technologies of snow service for the Beijing 2022 Olympic Winter Games and the sustainable development for the ice and snow industry in China are summarized as follows.

### 2.1 Key technologies of snow service for the Beijing 2022 Olympic Winter Games

1. **Prediction of track snow quality in ski resorts.** The meteorological conditions of the ski resort and the snow quality on the track are key factors influencing the competition results and the critical factors for the FIS and athletes to judge the comfort and the possibility of competition. Local meteorological conditions significantly influence snow quality evolution, and thus the accuracy of local meteorological forecast determines the accuracy of snow quality prediction. The complex mountainous terrain of the ski field in Zhangjiakou for the Beijing 2022 Olympic Winter Games increased the difficulty of using downscaling techniques. The research team combined the dynamic and statistical downscaling methods to improve the forecasting accuracy of the local meteorological conditions. Meanwhile, the team developed physical models and artificial neural network models of snow quality evolution based on the mechanism of meteorological factor changes influencing snow quality evolution. In addition, the team systematically studied the spatial and temporal distribution of snow cover in the Beijing-Zhangjiakou region with the data of snow observation and revealed the characteristics and trend of snow cover in the region in the context of global warming, which provided a scientific reference for the Beijing 2022 Olympic Winter Games. The research achieved the following key breakthroughs in this field. 1. They established the quantitative criteria and a grading model for track snow quality with snow thickness, hardness, density, surface temperature, grain size, and water content as the primary indicators. 2. They developed a downscaling technique combining dynamics and statistics for the meteorological field in response to the complex mountainous terrain of the ski field in Chongli District, Zhangjiakou and created a high-precision meteorological-snow quality evolution model. 3. They established a snow quality monitoring-predicting-evaluation system for the risk assessment of weather changes and the warning of unqualified track snow in the ski field.

2. **The combined effect of climatic conditions and production processes on the snow quality of icy snow tracks.** Icy snow is a general name in the snow and ice sports community. In glaciology, the terminology is firn, with a density of 0.45–0.83 g/cm³. Before the Beijing 2022 Olympic Winter Games, the ski resorts in China barely had any experience in making the icy snow tracks. Foreign teams were hired to make and maintain the icy snow tracks for large events (including the Olympic Winter Games), and they kept their technology in secret. Through systematic research and field tests in the Yabuli Sports Training Base (Heilongjiang), the Genting Snow Park (Hebei), and the National Alpine Skiing Centre (Beijing), the research team broke through the technical blockade on key parameters in making icy snow tracks. They developed key technologies and standards for making alpine icy snow tracks that are suitable for different climatic
conditions in China and meet the technical standards of international sports events, which provided scientific support for China to host large snow projects and develop the ice and snow industry. The research team achieved the following key breakthroughs in this field. ① They determined the physical parameters for snow and ice on icy snow tracks, and formulated the criteria for assessing the snow quality of icy snow tracks based on the parameters. ② They determined the key factors affecting the quality of icy snow tracks, developed localized icy snow making techniques for different climate regions in China, and compiled the technical procedures and guidelines for making icy snow tracks. ③ They developed the special instruments for inspecting the quality for icy snow tracks, including those for measuring hardness and ice and snow particle size.

(3) Simulation and prediction of snowpack melting dynamics. During the Beijing 2022 Olympic Winter Games, specific snow storage technical plans were made according to the local terrain, meteorological conditions, and the snow quality requirements of competition. A total of 7 000 m³ snow was stored at the Big Air Shougang and the National Ski Jumping Centre during the grand competition. A snow storage plan was determined, which involved the monitoring of the snow volume and quality in real time, thus guaranteeing the snow for competition. The research team employed the numerical simulation method to analyze the thermal insulation performance of different covering materials and evaluated the possible snow covering plans to determine the best snow storage plan [10,11]. On this basis, the research team developed an intelligent system for designing snow storage according to local conditions, which overcame the disadvantages (e.g., poor generalization and unpredictable performance) of traditional plans. The research team achieved the following key breakthroughs in this technology. ① They developed the intelligent system for automatically designing snow storage under different climate and terrain conditions and with different thermal insulation materials. ② They established an internal snow quality monitoring system for the scientific evaluation and grading of possible risks in snow storage, based on which response plans can be proposed.

(4) Integrated technology for efficient snow making. Before the Beijing 2022 Olympic Winter Games, snow making in China mostly resorted to homemade inefficient manual control equipment or introduced high-power high-voltage direct supply and relay semi-automatic or automatic systems. Special design and construction were needed according to the local conditions and needs of different ski fields. Such snow making is characterized by inconvenient operation, low efficiency, high operating cost, excessive investment, and environmental damage arising from the system construction. Because of the complex ski fields for the Beijing 2022 Olympic Winter Games, the snow making is influenced by a variety of factors [12]. After studying the geographical conditions suitable for skiing in China, the research team designed a multi-mode networked system to meet the needs of snow making for competitions in different ski fields. This system includes multiple associated independent subsystems based on the division of the field to adapt to the changes in altitude, temperature, and humidity, which improves the operational capacity and efficiency of the snow making system. The research team achieved the following key breakthroughs in the development of this system. ① They developed efficient optimization and integration technology for the system modules. Specifically, it integrated the pumping station module, snowmaking water treatment module, snowmaking pipeline module and pumping station module in the ski resort to realize the intelligent module integration design. ② They developed intelligent networked control software. Specifically, a control system for pumping stations in the intelligent networked snow making system was built based on Android platform and local, hybrid, and mobile network (Web) architecture to adapt to the characteristics of efficient snow making system and fulfill the intelligent networked control demand.

2.2 Cryospheric service leading the sustainable development of ice and snow industry

Ice and snow are also invaluable assets. Cryospheric service refers to all the benefits that human society can gain from the cryosphere system. Cryospheric service brings welfare to people in the ice and snow zone with supply, regulation, culture and support services. The working team has conducted extensive research in this regard.

(1) The team assessed natural endowments and future risks of the ski industry. ① The development of the ski industry depends highly on climatic resources and geographical conditions. Based on historical meteorological observations and topographic data, the team reveals the natural snow resources in China and finds that the snow abundance in stable snow-covered areas (northeast China, northern Xinjiang, and Tibet Plateau) is inferior to that in Western Europe and North America. The current development of ski industry mainly relies on snow making. The areas with considerable snow making potential in China are mainly distributed in the northwest of the Hengduan Mountains-Qinling Mountains-Taihang Mountains-Yanshan Mountains line, showing a spatial distribution pattern of more in the northwest and less in the southeast. Considering the terrain, snow, climate and other factors, the naturally suitable areas for ski tourism development in China are in Changbai Mountains and the Greater and Lesser Khingan Mountains in northeast China, Tianshan Mountains, Altay Mountains, and Qilian Mountains in northwest China, as well as Yanshan Mountains, Taihang Mountains, and Lviang Mountains in north China. Therefore, these areas should be regarded as the key for development [13–15]. ② Climate changes have become the greatest challenge for the ski industry. In the context of global warming, the development of ski resorts in China faces lowering natural suitability due to the decreasing natural...
snowfall and shortening snow making period. By the middle of
the 21st century, the natural suitability for ski resort de-
velopment shows a downturn and then a rising trend only in
the RCP2.6\(^{1}\) scenario but a continuous decline in RCP4.5
and RCP8.5 scenarios. The naturally suitable areas for ski
tourism development gradually shift to high-latitude and
high-altitude areas\(^{(19)}\). For this reason, we should fully con-
sider climate changes and construct a new development pat-
tern adaptive to climate changes for the sustainable
development of ski tourism in China.

(2) The team focused on the rural revitalization strategy
and ecological civilization construction in impoverished
mountainous areas and gave suggestions for the develop-
montains and high-altitude mountainous areas, where there is high inci-
dence of poverty. Among the former 832 impoverished
counties (all of them have overcome poverty) in China, those
located in glacier resource-rich areas and stable
snow-covered areas accounted for 15.0% and 26.4%, re-
spectively. As China achieved complete victory in the fight
against poverty, the transportation, communication, and in-
frastructure in the mountainous areas have been improved.
The abundant ice and snow resources in the mountainous areas
there have provided a basis for consolidating the achievements of poverty alleviation and developing ice and
snow economy. The team has carried out systematic research
in this regard. \(^{1}\) Given the natural, social, and economic
factors of ice and snow tourism development, they studied the
suitability of the former 14 contiguous poor areas to de-
velop the ice and snow industry. The results show that the key
areas suitable for developing glacier tourism for rural revi-
talization are mainly located in high-altitude areas such as
Tibet except the Qiangtang Plateau, the Tibetan area of Si-
chuan Province, along with Kashgar Prefecture, Hotan Pre-
fecture, and Kizilsu Kirghiz Autonomous Prefecture in
southern Xinjiang. The key areas suitable for developing ski
tourism for rural revitalization are mainly located in the
low-altitude mountainous areas such as the Yanshan Moun-
tains-Taihang Mountains, the northeastern part of Lvliang
Mountains, the western part of Liupan Mountains, the
southern foothills of the Greater Khingan Mountains, and the
northern part of Dabie Mountains. Ice and snow tourism will
become an important activator for economic development of
these mountainous areas where the achievements of poverty
alleviation are not yet solid, which has great development
potential for preventing poverty return and promoting overall
rural revitalization\(^{(13)}\). \(^{2}\) Since the ecology in the ice and
snow resource-rich areas is fragile, it is suggested that while
developing ice and snow tourism, we should pay attention to
environmental protection and adhere to the principle of
ecological priority and green and low-carbon development.
Additionally, we should integrate the development with sci-
ence, education, and traditional culture and promote both
high-quality development and environmental protection. On
the one hand, the government departments should strengthen
their leading role to integrate superior resources and generate
relevant policies to promote the rational development and
utilization of mountain and snow resources, thereby trans-
forming resource advantages into industrial advantages. At
the same time, they should boost the sustainable development
of mountainous areas by drawing upon the experience gained
from key points and aspects. On the other hand, ski industry
stakeholders should comprehensively consider the potential
of natural resources, the possibility of disasters, and the risk
of climate changes, and make short-term and long-term
planning according to the actual situations to avoid wasting
resources. In addition, relevant departments should provide
training for the tourism practitioners who are just relieved
from poverty, improve the quality of tourism service, and
ensure high-quality development of mountainous areas,
thereby achieving poverty alleviation in both materials and
knowledge.

3 Future demand and prospect

As China successfully hosted the Beijing 2022 Olympic
Winter Games and athletes like Wu Dajing, Su Yiming, and
Gu Ailing won their medals, ice and snow sports have be-
come a hot topic for discussion on major social media, and
ski fields of all sizes have become incredibly popular. The
grand event has popularized ice and snow sports and tourism
to the country and greatly stimulated people’s enthusiasm to
be involved. The ice and snow industry is no longer exclusive
to the northeast China. A new pattern characterized by pro-
spority of three centers (northeast China, the Beijing-Tianjin-
Hebei region, and Xinjiang), the rise of two tourism belts, and
full prosperity has emerged. The ice and snow sightseeing
tourism belt in Tibetan Plateau represented by Tibet and
Qinghai and the ice and snow leisure tourism belt in central
and western China represented by Sichuan, Guizhou, and
Hubei are rising in addition to the three centers. Meanwhile,
the warm southern regions with green hills and clear waters
are also breaking the time and space restrictions to develop
ice and snow economy\(^{(13,16)}\). However, China’s ice and snow
industry is still in its infancy. Although we have achieved
some progress, it still needs some time to fully mature the
core technologies. At present, China’s ski industry has prob-
such as severe regional homogenization, unsound in-
dustrial chain, low integration between industries, and flawed
infrastructure\(^{(13,14)}\). In addition, we have not efficiently

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\(^{1}\) RCPs (Representative Concentration Pathways) are climate scenarios adopted by the Intergovernmental Panel on Climate Change (IPCC) of the
United Nations to indicate the effects of population, economic growth, energy mix, and technological innovation on greenhouse gas emissions. The
scenarios with stable greenhouse gas concentrations in the coming century are represented by the radiative forcing per unit area. Four scenarios are
commonly adopted, namely RCP2.6, RCP4.5, RCP6.0, and RCP8.5, with radiative forcing intensity increasing in this order.
formed the whole chain system connecting the ice and snow physics research, ski resorts/skating arenas, athletes, and other links of competitive sports. Therefore, the team will continue to carry out the research for ice and snow industry development, including application-oriented cryosphere basic science and ice and snow tourism, and tailor it according to local circumstances to realize the sustainable development of the ice and snow industry in a green, low-carbon path [17]. The research team will further basic research on ice and snow physics for different snow sports, especially the formation of snow particles under different combinations of temperature, humidity, and pressure (including wind speed), changes in particle size, density, moisture, and hardness, the internal cohesion of snow layers and the surface friction characteristics, as well as the impact of snowdrift and snow fog. They will commence with the independent technology research and development of applied ice science, and strengthen the research on ice physical parameters and ice-forming technologies involved in the construction and maintenance of ice rinks. Further, they will study the influence of the physical characteristics of ice and air exchange on the mechanical properties of ice/snow surfaces under different weather/environmental conditions, and the mechanical feedback between the ice surface state and ice skate blade, and between the viscous properties of snow surface and snowboard. Ultimately, we can provide “one-to-one” scientific and technological service for venues and athletes of ice and snow sports, reach the scientific and technological level of the ice and snow industry in Norway, Germany, and Switzerland as soon as possible, and help Chinese athletes gain breakthroughs in alpine skiing, ice hockey, and curling.

References


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