Postprint of the Yulong Snow Mountain Cryosphere and Sustainable Development Field Scientific Observation and Research Station, Chinese Academy of Sciences

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Abstract

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Full Text

Preamble

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Yulong Snow Mountain Cryosphere and Sustainable Development Field Observation and Research Station, Chinese Academy of Sciences

Established in 2006, the Yulong Snow Mountain Station is China's first national-level field station dedicated to observing and researching maritime glaciers and their environment. Affiliated with the Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences (CAS), the station is located in Baisha Town, Yulong Naxi Autonomous County, Lijiang City, Yunnan Province, on the southeastern edge of the Tibetan Plateau (27°1$‘17.25’‘$ N, 100°14$’6.08’ ’$ E, elevation 2,600 m). It joined the CAS Alpine Surface Process and Environmental Observation and Research Network in 2013, was approved as a CAS-level station in 2019, and entered the National Field Observation and Research Station sequence of the Ministry of Science and Technology in 2021. The station represents a typical monitoring site for maritime glaciers in China and globally, serving as a crucial field support platform and research base for cryosphere science and collaborative research on cryosphere-sustainable development interactions.

Research Positioning. The Yulong Snow Mountain Station aims to become: (1) a scientific research base for cryosphere studies, (2) a transformation base for cryosphere services and disaster prevention and mitigation technologies, (3) a demonstration base integrating basic research with social application services, and (4) a talent cultivation base combining popular science, environmental education, teaching practice, and internships. It provides scientific and technological support for transforming the concept that "ice and snow are also invaluable assets" and for implementing the "life community" framework of mountains, rivers, forests, farmlands, lakes, grasslands, deserts, and ice, ultimately achieving international parity in long-term cryosphere and sustainable development research and addressing national strategic needs.

Main Research Directions. The station focuses on three core areas: (1) **Cryosphere change processes and mechanisms**, including long-term monitoring and comparative studies of cryosphere changes, and investigation of the laws and mechanisms governing these processes; (2) **Environmental effects and impacts of cryosphere change**, encompassing cryosphere hydrological processes and water resource effects, as well as climatic effects and ecosystem impacts; and (3) **Cryosphere and regional sustainable development**, covering cryosphere service functions and structural optimization, cryosphere disaster risk and prevention, and the intersection of cryosphere science with sustainable development.

2. Research Achievements and Scientific Contributions

Over its 20-year history, the station has established a major scientific research platform and achieved original fundamental research results. Key accomplishments include: (1) Development of a "One Station, Four Regions" spatial observation network (Yulong Snow Mountain Station, Meili Snow Mountain, Gangri Gabu, Gongga Snow Mountain, and Dagu Snow Mountain research areas), enhancing collaborative observation capabilities; (2) Creation of the longest time-series dataset on maritime glacier mass balance in continental Asia, based on long-term positioning observations of the Baishui River No. 1 glacier, enabling comparative studies with global reference glaciers; (3) Investigation of the hydrological, bacterial microbiological, and climatic-environmental effects of maritime glacier changes, clarifying the contribution of ice-snow meltwater to surface runoff and groundwater, analyzing bacterial community structure differences in glacier retreat areas and their influencing factors, and assessing the climate effects of light-absorbing impurities on glaciers; and (4) Service to major societal needs including regional water resource optimization, sustainable development of ice-snow tourism, and cryosphere disaster prevention and mitigation.

These research findings have had significant domestic and international impact, substantially advancing the formation and development of cryospheric chemistry, cryospheric microbiology, and cryospheric disaster science, while effectively serving regional sustainable development. Station researchers have published over 1,000 papers in major domestic and international journals, authored 15 monographs and contributed to 30+ additional volumes, obtained 10 authorized invention patents and 12 software copyrights, and submitted 20+ policy consultation reports or recommendations. The station has received numerous awards, including: the Special Prize of National Excellent Textbooks (Higher Education Category) for *Cryosphere Science* (edited by Qin Dahe, academic committee chair of the station); the CAS Outstanding Scientific and Technological Achievement Award for cryosphere science research (led by Qin Dahe with station participation); and first prizes of Gansu Provincial Natural Science Award and Gansu Provincial Science and Technology Progress Award for research on cryospheric chemistry and cryospheric microorganisms.

3. Talent Cultivation and Team Building

The station has formed a stable research team and monitoring force for cryosphere field observation and research. Currently, 23 staff members work at the station long-term, including 17 researchers and 6 technical and management personnel. The station boasts exceptional talent, with one recipient of the National Science Fund for Distinguished Young Scholars and three CAS Youth Innovation Promotion Association members. Additionally, 15 guest researchers have been appointed, including two foreign experts.

Since its establishment, the station has trained over 120 master's, doctoral, and postdoctoral researchers. Currently, 20 graduate students are based at the station, five of whom have received national scholarships. Each year, more than 100 graduate students conduct experimental research at the station.

4. Research Capabilities and Technical Platforms

The station area currently includes conference rooms, offices, instrument rooms, laboratories, expert apartments, and dormitories for students and researchers (20+ rooms total), with 60+ sets of instruments and equipment valued at approximately 12 million RMB. The station has established long-term field monitoring plots and experimental platforms across the "One Station, Four Regions" network, covering a total area of 30 km^2. This includes seven meteorological observation fields at different elevation gradients, three glacier observation sites, and four ice-snow runoff observation points. Indoor testing and analysis platforms span 300 m^2.

The station has developed China's first real-time glacier monitoring system (comprising GNSS, laser ranging, cameras, meteorological modules, ice temperature sensors, etc.), obtaining real-time data on glacier mass ablation, accumulation, and ice flow velocity, achieving continuous and precise data acquisition with online visualization of data transmission. A global cryosphere and sustainable development data visualization platform enables visualization of meteorological, glacial, and runoff monitoring site videos and data from the Yulong Snow Mountain Station, as well as offline data visualization.

5. Openness and Exchange

The Yulong Snow Mountain Station maintains high international standards with extensive international exchange and cooperation, serving as a renowned collaborative research base for cryosphere and sustainable development and a platform for domestic and international scientific cooperation and exchange. Each year, more than 10 research institutions and universities conduct cooperative research at the station, with over 1,000 visitors. The station has hosted three international conferences and more than 10 domestic conferences related to cryosphere research. Since its establishment, over 200 scientists from the United States, Canada, Germany, France, the United Kingdom, Switzerland, India, Japan, Russia, Norway, Sweden, and other countries have conducted collaborative research and scientific investigations at the station. The station has also established long-term, substantive research partnerships with multiple CAS institutes, the University of Hong Kong, Yunnan University, Wuhan University, the Chinese Antarctic Center of Surveying and Mapping (Wuhan University), the Chinese Polar Research Center, Tongji University, the Chinese Academy of Meteorological Sciences, the National Climate Center, Lanzhou University, Nanjing University, and other institutions.

Over the past decade, the station has hosted more than 500 university students for summer practice and camps, and provided popular science education services to approximately 20,000 scenic area managers, tourists, and primary and secondary school students. (See related images on inside back cover)

2023 Top Ten Scientific Advances in China

The "Top Ten Scientific Advances in China" selection aims to publicize major basic research achievements, inspire scientific enthusiasm among researchers, promote basic science popularization, and foster public understanding and support for basic research. It has become a flagship activity for reviewing annual major scientific accomplishments in China's basic research fields.

The 19th edition (2023) was organized by the National Natural Science Foundation of China (NSFC), hosted by the NSFC High-Tech Research and Development Center (Basic Research Management Center) and Science Communication and Achievement Transformation Center, and co-organized by five editorial departments. The selection process comprised four stages: recommendation, preliminary selection, final selection, and deliberation. Over 600 scientific research achievements published between December 1, 2022, and November 30, 2023, were recommended. Nearly 100 experts from relevant disciplines selected 30 achievements, which were then voted on by more than 2,100 high-level experts in basic research (including CAS and CAE academicians). The NSFC Consultative Committee finalized the list of ten major scientific advances.

1. AI Large Models Bring New Breakthroughs to Precision Weather Forecasting

Weather forecasting is a major international scientific frontier with significant societal value. The current numerical weather prediction paradigm, originating in the 1950s, solves atmospheric motion partial differential equations through large-scale supercomputing. However, improving forecasts through this traditional method faces increasing challenges. Tian Qi, Bi Kaifeng, Xie Lingxi, and colleagues from Huawei Cloud Computing Technologies developed a three-dimensional neural network adapted to Earth's coordinate system [Figure 1: see original paper] that effectively processes complex processes in weather data and reduces iterative errors through hierarchical temporal aggregation strategies, successfully achieving accurate medium-range weather forecasting. Trained on global weather reanalysis data from 1979–2017, they constructed the Pangu-Weather large model. This model can forecast meteorological elements including temperature, pressure, humidity, and wind speed at the surface and 13 upper-air levels within 7 days, extending the forecast lead time of the world's most advanced ECMWF integrated forecasting system by approximately 0.6 days and reducing tropical cyclone track forecast errors by 25% compared to the ECMWF system. The model completes global 7-day forecasts of key meteorological elements in just 10 seconds, representing a computational speed improvement of over 10,000 times compared to numerical methods. This research demonstrates a breakthrough in applying artificial intelligence and big data to solve weather forecasting problems.

2. Discovery of "Tangible" Biological Clocks in the Brain and Their Rhythmic Mechanisms

Circadian rhythm disorders are associated with sleep disturbances and depression, and can lead to major diseases such as cancer and diabetes. However, effective therapeutic drugs for rhythm-related diseases have not been developed internationally due to limited understanding of biological rhythm regulation mechanisms. Li Huiyan and Zhang Xuemin from the Academy of Military Medical Sciences/Nanhu Laboratory discovered that primary cilia—antenna-like structures on neurons in the brain's suprachiasmatic nucleus (SCN)—extend and retract once every 24 hours, functioning like clock hands [Figure 3: see original paper]. These primary cilia regulate rhythms by controlling "synchronization" among SCN neurons through the Shh signaling pathway. Thus, SCN neuron primary cilia serve as the structural basis for the body's "central biological clock," participating in circadian homeostasis maintenance, while targeting the Shh signaling pathway in SCN primary cilia represents a potential therapeutic strategy for human diseases related to circadian rhythm disorders. This discovery of a "tangible" biological clock is significant for understanding clock architecture and the connection between molecular- and cellular-level biological clocks.

3. Paleovirus Reactivation Mediates Programmable and Contagious Aging Processes

The human genome controls organ regeneration, homeostasis, and age-related diseases. Approximately 98% of the genome consists of non-coding sequences, including endogenous retroviral elements (about 8%)—remnants of ancient viruses integrated into the human genome millions of years ago. The role of these paleovirus sequences in aging remains unexplored. Liu Guanghui, Qu Jing from the Institute of Zoology, CAS, and Zhang Weiqi from the Beijing Institute of Genomics, CAS, revealed that dormant paleovirus "fossils" in the human genome can be reactivated during cellular aging due to epigenetic dysregulation, forming virus-like particles that drive cellular and organ aging [Figure 2: see original paper]. They proposed a theory of paleovirus reactivation mediating programmable and contagious aging, and a multi-dimensional intervention strategy to delay aging by blocking paleovirus reactivation or spread. Systematic screening of "rejuvenating" genes in human protein-coding regions identified novel molecular targets that can restart stem cells, motor neurons, and cardiomyocyte vitality, and reverse aging in joint cartilage, spinal cord, and heart. These findings establish a new theoretical framework for aging biology and geriatric medicine, laying a foundation for scientific intervention in aging and age-related chronic diseases.

4. Mechanism Analysis and Application of Crop Saline-Alkali Tolerance

Soil salinization affects nearly 1.5 billion mu of land in China, with soda saline-alkali soils (high pH) accounting for about 60%. Approximately 500 million mu have development potential. However, limited understanding of plant saline-alkali tolerance mechanisms has hindered crop breeding and land utilization. Xie Qi from the Institute of Genetics and Developmental Biology, CAS, Yu Feifei from China Agricultural University, and Ouyang Yidan from Huazhong Agricultural University identified a major gene, *AT1*, associated with alkali tolerance using sorghum natural populations from high-salinity regions in Africa's Sahel. They revealed that *AT1* promotes H_2O_2 efflux in plant cells under alkali stress by regulating aquaporin phosphorylation, conferring high saline-alkali tolerance. Field experiments in saline-alkali soils showed that crops improved with the *AT1* tolerance allele achieved significant yield increases of 20–30% in rice, sorghum, and millet [Figure 4: see original paper]. This research provides new approaches for comprehensive saline-alkali land utilization and food security.

5. Novel Methods Enable Precision Manipulation from Single Base to Ultra-Large DNA Fragments

Genome editing holds broad prospects in biology and medicine, but current technologies face limitations in editing precision, DNA manipulation scale, and flexibility. Gao Caixia's team from the Institute of Genetics and Developmental Biology, CAS, and Zhao Tianmeng from Beijing Qihe Shengke Biotechnology used AI-assisted large-scale protein structure prediction to discover novel genome editing enzymes. They developed a new structure-based protein clustering method, identified multiple novel deaminase families, and created new base editors for diverse applications, solving the challenges of single AAV delivery and efficient soybean base editing. To overcome bottlenecks in large-scale DNA manipulation in plants, they integrated and optimized prime editing with site-specific recombinases to develop PrimeRoot technology for precise large-fragment DNA insertion, enabling efficient targeted integration of DNA fragments over 10 kb. Additionally, by de novo design and rational modification of upstream open reading frames, they developed a novel system for fine-tuning target protein expression and created a series of new rice germplasms with gradient changes in yield-related traits, providing new methods for precise crop improvement [Figure 5: see original paper]. These innovations in genome editing element mining and technical systems enable precise genome manipulation for crop improvement and gene therapy.

6. Revealing Novel Mechanisms of Human DNA Replication Initiation

Precise regulation of DNA replication initiation is crucial for maintaining genome stability and preventing genetic diseases and cancer. Assembly of MCM2-7 protein double hexamers (DH) at thousands of replication origins is essential for unwinding double-stranded DNA and initiating replication, but the specific assembly and mechanism of MCM-DH on chromosomes remain unclear. Zhai Yuanliang from the University of Hong Kong, and Dang Shangyu and Dai Bikun from the Hong Kong University of Science and Technology resolved the 2.59-Å high-resolution cryo-EM structure of human MCM-DH complex (hMCM-DH). In this structure, hMCM-DH directly destabilizes DNA double strands, unwinds the DNA at the junction of the two hexamers, and stretches it to create an initial opening structure (IOS). IOS clusters are widely distributed in transcriptionally inactive intergenic regions and highly overlap with sporadic DNA replication initiation regions. Interfering with IOS inhibits hMCM-DH formation and subsequent DNA replication initiation. This study reveals novel mechanisms of hMCM-DH assembly and initial DNA unwinding for replication initiation, providing an important basis for developing anticancer drugs targeting DNA replication [Figure 6: see original paper].

7. LHAASO Discovery of Extremely Narrow Jet in Brightest-Ever Gamma-Ray Burst

Gamma-ray bursts (GRBs) are the most violent explosions since the Big Bang. TeV-scale observations are crucial for revealing explosion processes, radiation mechanisms, and new physics frontiers. On October 9, 2022, the brightest GRB ever observed (GRB 221009A) released signals that traveled 2.4 billion light-years to Earth. The LHAASO (Large High Altitude Air Shower Observatory) collaboration, led by Cao Zhen from the Institute of High Energy Physics, CAS, leveraged LHAASO's unprecedented sensitivity and wide field of view to record for the first time the complete process of high-energy photon eruption above one trillion electronvolts, including rapid early-stage brightness enhancement and subsequent sudden dimming. This determined that the GRB's extreme relativistic jet has the smallest opening angle known to date, revealing the secret of its record-breaking brightness. LHAASO also precisely measured the GRB's brightness variation with photon energy, finding stable brightness-energy relationships with the spectrum extending beyond 10 TeV—exceeding theoretical predictions and challenging the standard GRB afterglow radiation model [Figure 7: see original paper].

8. Bosonic Code Error Correction Extends Qubit Lifetime

Current superconducting qubit error rates are more than ten orders of magnitude from practical application, requiring quantum error correction to build logical quantum circuits with lower error rates. Quantum error correction aims to protect logical qubits from noise using redundancy in infinite-dimensional Hilbert space. However, traditional error correction inevitably introduces new errors, creating a "more correction, more errors" dilemma. Surpassing the break-even point—where the logical qubit lifetime exceeds that of the best physical qubit—is the key criterion for effective error correction. Yu Dapeng and Xu Yuan from Southern University of Science and Technology, Zheng Shibiao from Fuzhou University, and Sun Luyan from Tsinghua University demonstrated a quantum error correction method based on superconducting circuit quantum electrodynamics. The core technology encodes logical qubits in discrete photon number states of a microwave cavity dispersively coupled to an auxiliary superconducting qubit, with orthogonal code and error subspaces. By applying truncated frequency comb pulses to the auxiliary qubit, they achieved high-fidelity repeated error syndrome detection and real-time feedback control, effectively extending logical qubit coherence lifetime beyond the break-even point by 16% and achieving positive quantum error correction gain. This research demonstrates the superiority of quantum error correction and the potential of hardware-efficient discrete-variable encoding for fault-tolerant quantum computing [Figure 8: see original paper].

9. Revealing Light Sensing Mechanisms in Blood Glucose Metabolism Regulation

Light is a crucial environmental factor regulating numerous physiological and pathological processes. Public health studies show artificial light is a risk factor for metabolic disorders—for example, nighttime light pollution significantly increases diabetes risk. However, the biological mechanisms remain unclear. Xue Tian from the University of Science and Technology of China revealed the neural mechanism by which light regulates blood glucose metabolism in mice and humans. In animal models, light signals received by intrinsically photosensitive retinal ganglion cells (ipRGCs) travel through hypothalamic supraoptic nucleus AVP neurons and brainstem nucleus tractus solitarius GABAergic inhibitory neurons, ultimately reaching brown adipose tissue via sympathetic nerves. This multi-level neural circuit suppresses sympathetic activity in brown fat, reducing thermogenic glucose consumption and impairing blood glucose metabolism. Critically, a similar mechanism exists in humans, where blue light pollution significantly reduces glucose consumption capacity. This discovery of a novel "eye-brain-brown fat axis" mediating light's regulation of glucose metabolism provides theoretical basis and potential intervention targets for preventing and treating light pollution-induced metabolic disorders [Figure 9: see original paper].

10. Discovery of Charge Storage Aggregation Reaction Mechanism at Lithium-Sulfur Battery Interfaces

Lithium-sulfur batteries offer extremely high theoretical energy density (2,600 Wh/kg) and low cost, but atomic/nanoscale understanding of their interface reactions remains limited due to constraints in spatiotemporal resolution of in-situ characterization tools and system instability. Liao Honggang and Sun Shigang from Xiamen University, and Chen Jianfeng from Beijing University of Chemical Technology developed high spatiotemporal resolution in-situ liquid-phase transmission electron microscopy coupled with realistic electrolyte environments and applied electric fields to observe lithium-sulfur battery interface reactions dynamically at atomic scale. They discovered that molecules on active material surfaces aggregate into clusters where charge transfer can first be stored; the clusters accumulate electrons until reaching a threshold for instantaneous crystallization conversion. Inactive surfaces follow classical single-molecule reaction pathways where lithium polysulfides gradually convert to Li_2S. Simulations confirm that electrostatic interactions between active centers and polysulfides promote Li^+ and polysulfide aggregation, enabling free charge transfer within clusters. For nearly a century, electrochemical interface reactions were thought to involve only "inner-sphere" and "outer-sphere" single-molecule pathways. This study reveals a third "charge storage aggregation reaction" mechanism, deepening understanding of polysulfide evolution and its impact on battery interface reaction kinetics, and providing guidance for next-generation lithium-sulfur battery design [Figure 10: see original paper].

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