Along the Silk Road

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Prof. Tandong Yao and **Prof. Fahu Chen** describe our growing understanding of climate change impacts in the "Pan-Third Pole" region, discussing both coping strategies and research initiatives focusing on the region.

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The Pan-Third Pole region, which stretches from the Tibet-centered "Third Pole" westwards to the Carpathians and includes Pamir, Hindu Kush, the Iranian Plateau, and the Caucasus (see map), covers more than 20 million square kilometers and contains more than 20 countries. The region has a population of more than 3 billion people. Historically, as a key corridor connecting western and eastern cultures and economies, this region has propelled the development of human civilization, and nowadays has become the core area of the Silk Road Economic Belt. Research into environmental changes in the Pan-Third Pole region is essential to overcome some of the challenges faced by countries along the Silk Road, and thereby safeguard the implementation of the Belt and Road Initiative, which aims to realize sustainable growth for common development and shared prosperity across the continents of Asia, Europe and Africa.

The Pan-Third Pole region is generally characterized by a dry and relatively cool climate, and has becomes a hotspot in terms of the rate of recent climate change. A comparison with historical climate recon-

structions reveals that the observed twentieth century warming in the Pan-Third Pole has exceeded any natural temperature variations in the past 2000 years. Furthermore, the warming rate in the region in the last few decades has been twice as fast as the global average, which means it may face a temperature increase of 4°C if the Earth gets 2°C warmer in the future. In contrast, precipitation in the region displays a large spatial heterogeneity. This drastic climate change, characterized by extraordinary warming, has already triggered a series of environmental issues, and poses significant threats to local resources and ecosystems in the Pan-Third Pole region. To achieve a green and healthy Pan-Third Pole, it is a scientific imperative to understand climate change and its impacts on human and natural systems.

Past climate change and human civilization

The Pan-Third Pole region is currently the largest mid-latitude arid area in the Northern Hemisphere. Some 6000 calendar years before the present (cal yr BP), the climate over the Pan-Third Pole region became relatively warm and wet, favoring the expansion of grass and mountain forests, and facilitating the development of human civilizations. The humid climate, and the introduction of new agriculture and animal husbandry techniques, promoted the rapid development of civilization and the emergence of trans-Eurasia exchange in the Central Asian Steppes during the subsequent two millennia. The millet and wheat-barley crops that were first domesticated in both the east and west of Eurasia spread out and encountered one another in central Asia in ~4500 cal yr BP. The agro-pastoral innovations made under the warm-wet conditions in the central Eurasian Steppes may have contributed to the extensive expansion of the Yamnaya culture (~5600–4200 BP), which profoundly influenced cultural and genetic patterns in Eurasia during the late Neolithic and early Bronze Age.

The trans-Eurasia culture exchange intensified after the fourth millennium BP, and further reshaped the evolution of civilization in the old world. For example, barley and wheat were introduced into northwest China around 4000 BP. The adoption of these cold-tolerant western crops facilitated permanent human settlement on the Tibetan Plateau since ~3600 BP. Although the influence of climate change in the Pan-Third Pole region on the formation of the proto-Silk Road has not been examined in detail, the major highway for trans-Eurasia exchange shifted from the Eurasian Steppes to the beaded oasis route in the third millennium BP, when the climate in the Xinjiang area was much wetter than before 4000 BP. That transformation in the spatiotemporal pattern for west-east culture exchange across Eurasia laid the foundation for the formation of the Ancient Silk Road, which has been named as one of the major centers of world civilization in the past 2000 years. The rise and fall of the ancient civilizations along the Silk Road was also influenced by climate change. It has been suggested that favorable climate conditions were an important factor for facilitating unprecedented communications of ancient civilization and technology along the Silk Road across the Pan-Third Pole region, while the collapse of the well-developed agriculture oasis such as in the region of the famous Luolan Kingdom (176 BC-630 AD) may resulted from strongly human-impacted environmental changes.

Recent impacts on water resources

The Tibetan Plateau, described as the Asian Water Tower, forms the core of the Pan-Third Pole region, and comprises numerous glaciers, lakes and rivers. It hosts the largest glacier area (>100,000 km^2) outside the North and South Pole regions. Warming-induced glacier retreat, floods and lake expansion or shrinkage are destabilizing the water tower, affecting human welfare all along the Belt and Road. The impacts of dramatic climate change have been witnessed in glaciers on the Tibetan plateau. The extraordinary warming has led to the severe decline of most of glaciers over the last several decades. For example, the mass of the Tien Shan glacier, which is a vital water resource for Kazakhstan, Kyrgyzstan, Uzbekistan and the Xinjiang Uyghur Autonomous Region, has declined by 27±15% from 1960 to 2012. Even worse, the glaciers in this region are retreating so fast that 64 percent of glacier mass is projected to disappear by 2100 under the worst-case emission scenario. Such rapid glacier melting could have devastating impacts. In arid and semi-arid regions, water from glacier melt could create a buffer for water stress in dry seasons or drought years, but the buffering capacity is projected to be severely reduced in a future warming world. Furthermore, the rapid glacier melting could also lead to catastrophic ice avalanches. To adapt to more commonly occurring climate extremes in the future, early warning systems must be designed to support decision-makers and local authorities in their response to these unprecedented types of natural hazards.

Compared to glaciers, the response of lakes in the Pan-Third Pole region to climate change displays large spatial variations. The lakes in the Tibetan Plateau show expansion, but those in the Central Asia are shrinking rapidly. For example, the area of lakes in the Tibetan Plateau has expanded from 29,278 to 37,867 km^2 over the last 40 years, and the mean water

level has increased by 0.20 m per year. In contrast, the Aral Sea in Central Asia, once the fourth-largest inland sea in the world (66,000 km^2 in 1960s), lost more than 90% of its area before 2010. The Aral Sea shrinkage has been described as "probably the biggest ecological catastrophe of our time" by António Guterres, Secretary-General of the United Nations. An in-depth understanding of the patterns of water resource changes under rapid climate change and the underlying mechanisms is required. More research efforts need be made to enable scientifically sound projections and to support science-based policy making for the Pan-Third Pole region.

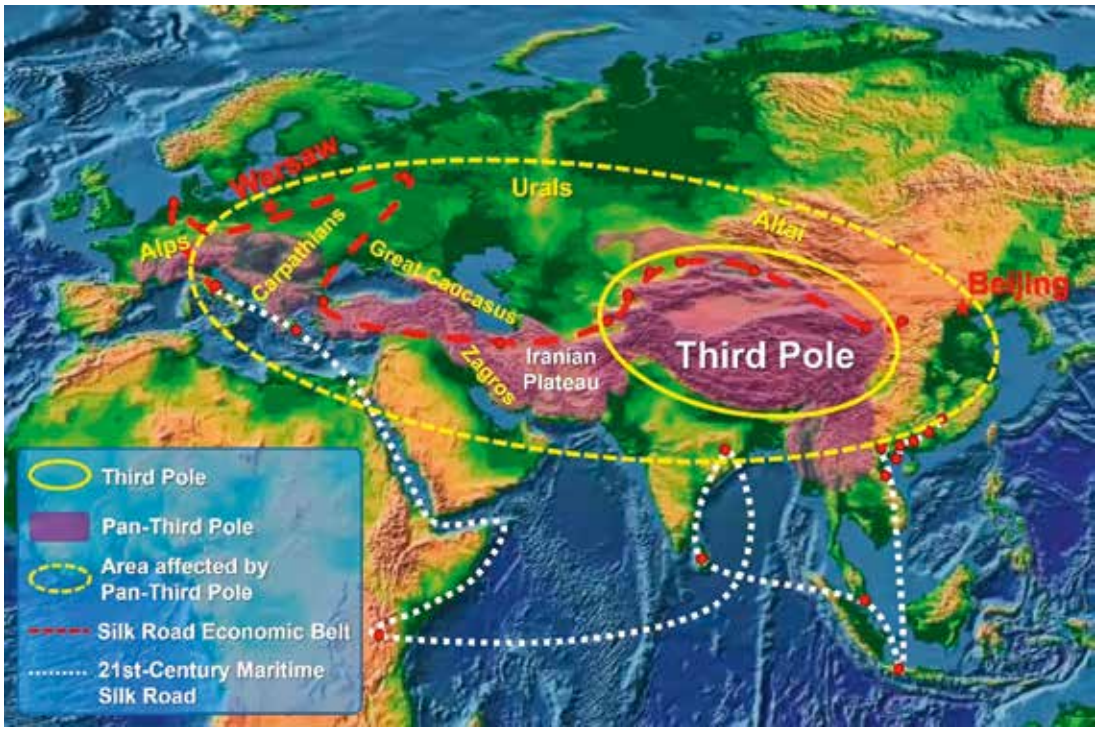
Impacts on ecosystems and biodiversity

Warming, together with elevated atmospheric CO_2 concentration and increasing nitrogen deposition, generally stimulates vegetation growth and enhances carbon uptake in the high mountain ranges in the Pan-Third Pole region. For example, net primary productivity in the Tibetan Plateau increased by 13.3% in the last 30 years. This warming-induced increase in production could enhance ecosystem services that are essential to livelihood and social development. However, the Tibetan plateau hosts the largest area of permafrost outside the Polar Regions. Continued warming will accelerate permafrost thawing and release "old carbon" buried beneath the permafrost, which will potentially overturn the warming-induced increase in carbon uptake. Moreover, grasslands in some key areas, being an important ecosystem type over the Pan-Third Pole region, are plagued by human-induced degradation. It is essential to understand how ecosystem services will respond to future climate change, to be able to guide the population to keep their activities within the ecosystem carrying capacity.

The impact of rapid climate change is not only seen in ecosystem changes, but also in biodiversity changes. The Pan-Third Pole region carries a huge number of endemic species, harbors 7 of the total 36 biodiversity hotspot regions in the world, and forms a unique natural gene bank in the high mountain ranges. But in the past decades, about 10.6% of western Asia's endemic species have come under threat because of drastic climate change and increasing human intervention. Besides the shrinkage of the number of endemic species, the abundance of invasive alien species is steadily increasing. For example, the tree line position in the eastern Himalayas has risen 110 m over the past century. This expansion of lowland tree species will create a further favorable niche for species invasion under rapid climate change. However, current knowledge on biodiversity and its response to climate change is still fragmented, and more thorough studies are needed.

Coping with climate challenges

As climate change has become more severe in recent years, climate-induced drastic ecosystem changes and



The geographic range of the Pan-Third Pole region.

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natural disasters such as drought, flood, sand storms and ice avalanches have started to pose great threats to countries along the Belt and Road routes. To gain a better understanding of climate and environment changes and their impacts on ecosystem and human activities in the Third Pole, the Chinese Academy of Sciences (CAS) initiated the Third Pole Environment (TPE) program in 2009. This program is designed to encourage world-known scientists and institutions to investigate the processes and mechanisms of the interactions among atmosphere-water-ice-vegetation-human activities in the Third Pole region. In 2011, TPE received funding of 0.12 billion RMB from the CAS, in the name of the Strategic Priority B Research Program "Multi-sphere interaction of the earth system in the Tibetan Plateau and its effects on resources and the environment."

As TPE research grows further, there is an increasing recognition that Third Pole environmental changes could have far-reaching impacts on regions that are not limited to the Third Pole. In 2016, the TPE proposed "Pan Third Pole" research that should also cover the regions affected by the Third Pole including East Asia, South Asia, Central Asia, East Europe etc. The proposed Pan-Third Pole region covers the Silk Road Economic Belt, and includes all the countries of the Belt and Road region. Soon after it was proposed, Pan-Third Pole research received large amounts of funding from both the Ministry of Science and Technology and CAS. In 2017, CAS instigated the Second Comprehensive Scientific Expedition to the Third Pole, followed by the Chinese Ministry of Science and Technology announcement in 2018 that 4.4 billion of research funding will be invested in the next five to ten years, with the aim of achieving a comprehensive understanding of changes in climate, water resources, ecosystem, biodiversity and human activities in the Third Pole and surrounding areas. Recently, CAS initiated the Strategic Priority A Research Program "Pan-Third Pole Environment Change Study for Green Silk Road Development," with financial support of 1.68 billion RMB. The overall objective of this program is to serve green growth in the Pan-Third Pole region, by clarifying the conditions of natural resources and environmental carrying capacity, revealing the mechanisms of environmental change and proposing a scientific strategy for green Silk Road development. Avoiding the worst impacts of climate change will also require deep international cooperation among scientific institutions and countries in the Pan-Third Pole. To ensure green growth, the CAS established the Alliance of International Science Organizations (ANSO) in the Belt and Road region in November 2018. The establishment of ANSO will bring together the international scientific community and mobilize efforts in jointly addressing the climate change challenges.

In the symposium "Safeguarding Our Climate, Advancing Our Society" held in Katowice on 10 December 2018, scientists suggested that we still have a window of opportunity to take full responsibility and avoid the climate crisis, but that this window is rapidly closing. The Third Pole together with the North and South Poles are the most vulnerable and sensitive regions to rapid climate change. There is compelling scientific evidence that the three poles (north, south, and third) are rapidly warming, and many of the climate change impacts are already negative for ecosystems and human beings e.g. irreversible ecosystem transformation, species extinction and sea-level rises. It is thus imperative to have a solid scientific base so that the climate actions can be understood and shared. Excitingly, the Chinese government is now promoting the Tri-Polar Environment and Climate Change (TPEC) program that will focus on the climate changes of the Three Poles, their impacts on the regional/global environment and the linkages among the Three Poles through establishing multi-dimension observation systems. The implementation of this project will help us to provide scientific and technological support for addressing climate-induced disaster, safeguarding polar security and eventually building "A community with a shared future for mankind."

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Further reading:

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