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Intensified water-ecological risks in the arid regions of Central Asia under global warming

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Abstract: Primary industries in NSW face one of the most variable climates in the world, and many of the Global warming is profoundly altering the hydrological and ecological dynamics of Central Asia's arid regions. This study provides a comprehensive assessment of climate change impacts on hydrological and ecological processes, along with the associated risks. Research results indicate significant reductions in snowfall amount and duration during 1970-2020, while projections from the PyGEM–OGGM model suggest that the region is nearing the peak of glacier runoff. Notably, peak water in the Western Tianshan is projected to occur between 2027 and 2050, depending on emission scenarios, whereas the Eastern Tianshan has likely already passed its peak in the 2020s. Meanwhile, the accelerated expansion of glacial lakes has raised the risk of glacial lake outburst floods (GLOFs), which are currently 3–4 times higher in the western subregion compared to other areas.

At the same time, the intensification of heatwaves and compound drought-heatwave events (CDHWs) is posing escalating threats to both water security and ecosystem stability across Central Asia. Between 1981 and 2020, heatwaves have become more frequent, intense, and longer-lasting, particularly in northwestern Kazakhstan, driven by declining soil moisture and increased solar radiation. CDHWs have risen significantly in frequency and intensity, especially under high-emission scenarios (SSP370/585), with their duration exceeding 18 days in some areas. Heatwaves account for the dominant share of CDHW impacts, but coupled drought-heatwave interactions also exert strong influence, particularly in drylands. Additionally, snow droughts (SDs)—especially warm and compound types—are projected to become more frequent, with the share of warm SDs rising to 65% by 2050. These shifts reflect an ongoing transition from precipitation-dominated to temperature-dominated drought regimes, exacerbated by anthropogenic forcing.

Overall, this research highlights the escalating water-ecological risks in arid Central Asia driven by intensified melting and intensified heat extremes, and shifting drought regimes. The findings underscore the urgent need for adaptive water management and climate resilience strategies to support sustainable development goals in this highly vulnerable region.

Keywords: *Glacier Runoff; Heatwaves and Droughts; Glacial Lake Outburst Floods (GLOFs);Central Asia*

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