



POLICY BRIEF

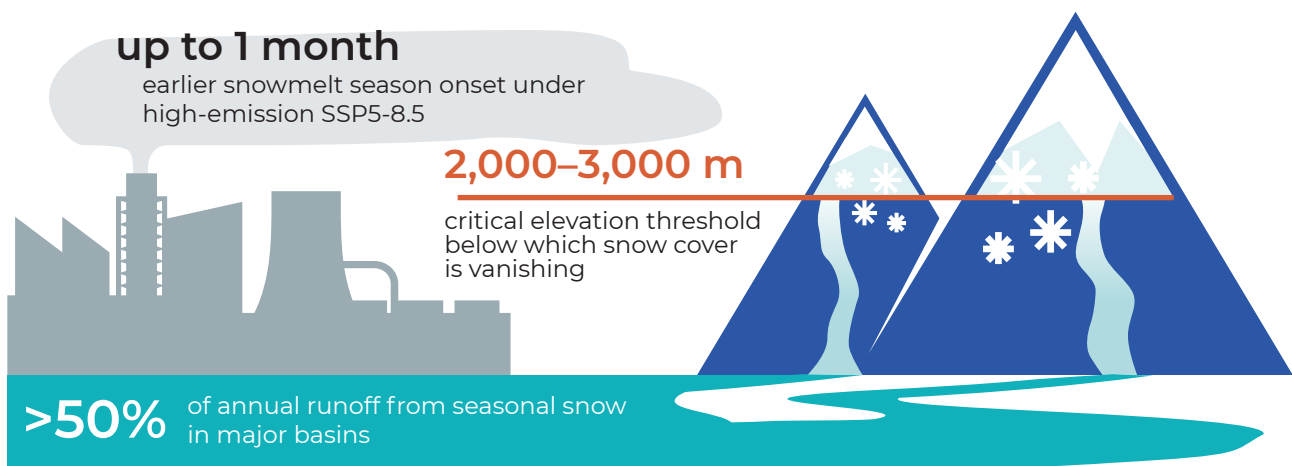
MELTING SNOW, RISING RISKS: SECURING CENTRAL ASIA'S WATER FUTURE

CLIMATE INSIGHTS FOR WATER RESILIENCE
IN CENTRAL ASIA



KEY MESSAGES

- **Seasonal snow is the dominant water source in Central Asia**, contributing over 50% of annual runoff in major basins and up to 65–72% in smaller headwater catchments – far exceeding rainfall (~23%) or glacier ice (~2–8%).
- **SWE is declining across all scenarios, all basins and all elevation bands**, with the most critical losses below ~2,000 m in the Syr Darya basin and below ~3,000 m in the Amu Darya basin. In exposed low-elevation basins such as the Afghan Murghab, losses are near-total under all but the lowest emission scenario.
- **The snowmelt season is compressing and shifting earlier** – peak SWE is arriving several weeks sooner, and peak runoff may shift by up to one month under high-emission scenarios (SSP5-8.5), creating a dangerous mismatch with irrigation demand in late spring and summer.
- **Runoff from snowpack is declining in the water-critical western catchments** (the Zarafshan, the Chatkal, the Talas rivers) while increasing in the northern and eastern high mountains above ~3,500 m, creating divergent adaptation needs across the region.
- **National Action Plans (NAPs) and a ministerial-level Strategic Action Programme (SAP)** are critical for translating snow science into actionable, transboundary water policies across Central Asia.



EXPLORE THE DATA: INTERACTIVE SNOW SCENARIO DASHBOARD [APPS.MOUNTAINFUTURES.CH/UNESCO-SNOW-SCENARIOS](https://apps.mountainfutures.ch/unesco-snow-scenarios)

The dashboard provides open access to all modelled snow scenarios in two interactive tools:

Seasonal Snow Cycle Explorer

Interactive seasonal curves of SWE, Snow Depth, Runoff, Albedo and Temperature – selectable by river basin, elevation band and SSP scenario.

Catchment Anomaly Map

Spatial map of projected anomalies for 295 catchments across High Mountain Central Asia, covering all five major river basins and three SSP scenarios.

SNOW AS CENTRAL ASIA'S PRIMARY WATER TOWER

Central Asia's major rivers, the Amu Darya and the Syr Darya, depend on seasonal snow as their principal water source. Snowmelt can contribute up to 80% of total runoff in some basins, with seasonal snow providing more than half of annual river flow in major basins and up to 65–72% in smaller headwater catchments. This contrasts with rainfall (~23%) and glacier ice (~2–8%), making snow the dominant natural water reservoir underpinning irrigated agriculture, hydropower, and domestic water supply for millions of people across the region.

This policy brief draws on high-resolution climate modelling using the SnowMapper-climate framework – forced by an ensemble of four CMIP6 global climate models under four Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5), covering 221 sub-catchments in the High Mountain Central Asia (HMCA) domain.

PROJECTED CHANGES IN SNOW COVER

Declining Snow Water Equivalent and Depth

Snow Water Equivalent (SWE), the volume of water stored in the snowpack available for spring and summer runoff, is projected to **decrease in all scenarios, all basins, and across all elevation bands**. The losses are most critical at lower elevations. In the Syr Darya basin, declines are most pronounced below approximately 2,000 m; in the more southerly Amu Darya basin, this threshold rises to around 3,000 m.

In the most exposed low-elevation basins, such as the **Afghan Murghab**, SWE losses are near-total under all but the most optimistic (SSP1-2.6) scenario, with potentially severe consequences for spring and summer water availability.

Earlier Snowmelt and a Compressed Snow Season

Peak SWE is arriving several weeks earlier under medium and high emission scenarios, and the melt-out date is also advancing. The snow season compresses at both ends: later onset in autumn and earlier melt-out in spring. Under SSP5-8.5, snowmelt peak runoff may shift by **up to one month** earlier in the season, creating a dangerous mismatch between peak water availability and peak agricultural demand.

Temperature Warming and Its Seasonal Pattern

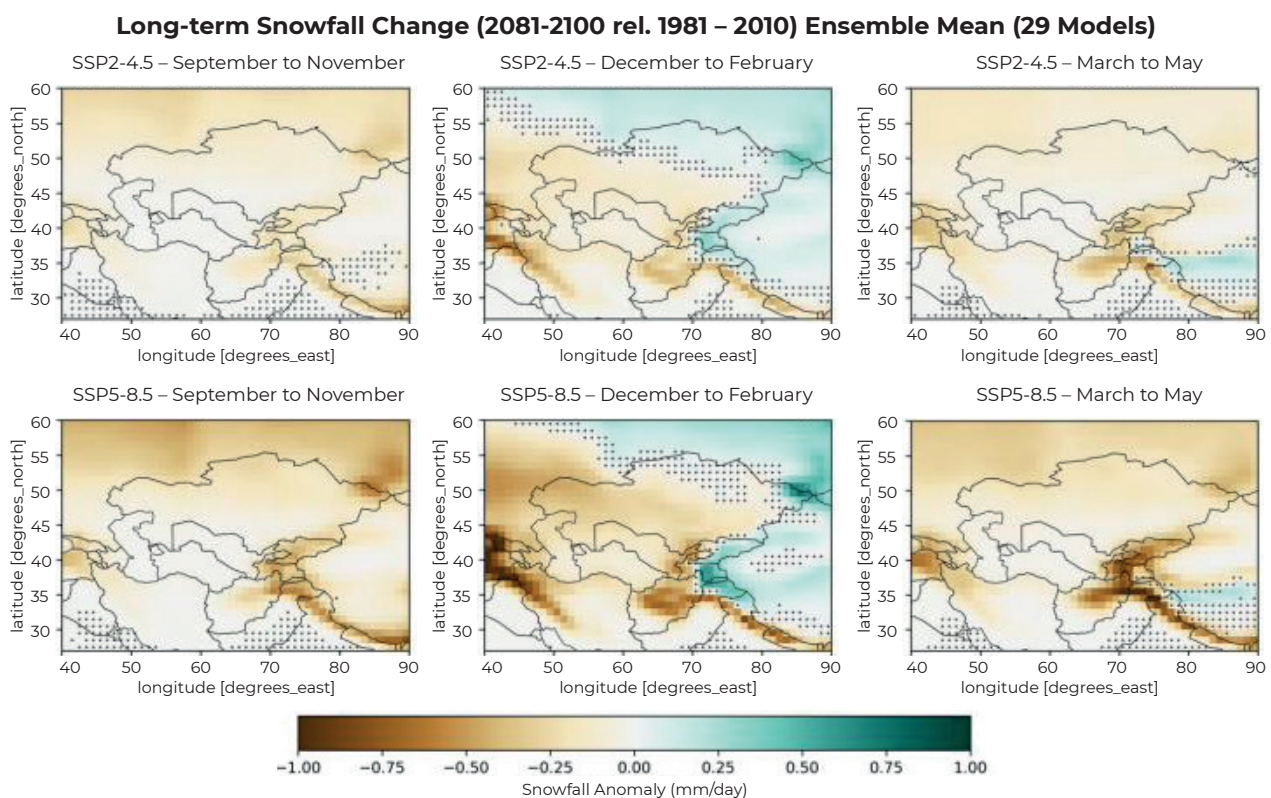
Surface temperature is projected to increase across all seasons, elevations, and scenarios, with **4°C of warming exceeded by the end of the century under SSP5-8.5**. Critically, **winter months (DJF) show the strongest warming**, particularly at high elevations and high latitudes, which drives more frequent snowmelt-refreeze cycles, thinner snowpacks, and reduced snow cover duration even in traditionally cold periods.

Snowfall Trends by Season

For snowfall, the projected trends differ markedly by season:

- **Autumn (SON) and spring (MAM) snowfall declines across all regions** under all scenarios.
- **Winter (DJF) snowfall may increase** in the Northern Tien Shan, Eastern Pamir, and high latitudes, partly compensating for losses at very high elevations in those areas.
- **Spring snowfall (MAM) faces a particularly severe reduction under SSP5-8.5**, representing the most acute near-term threat to water supply at the critical onset of the irrigation season.

Figure 1. Snowfall is declining almost everywhere in the seasons that matter for water - spring and autumn - and under high emissions (SSP5-8.5) that spring loss becomes dramatically severe. Winter gains in the far north-east do not compensate.



TWO BASINS, DIVERGING FUTURES

The snow results reveal an important spatial asymmetry. Snow and runoff loss is most acute in the **western and lower-elevation catchments**,

while some northern and eastern high-altitude zones, particularly the Eastern Pamir, may see partially compensating winter snowfall increases.

THE SYR DARYA BASIN (LOWER ELEVATIONS)



CRITICAL SWE LOSS THRESHOLD:

Below ~2,000 m



SNOWMELT TIMING:

Peak SWE several weeks earlier; melt-out also advancing



RUNOFF TREND:

Decreasing in western catchments: the Zarafshan, the Chatkal, the Talas; increasing in the Northern Tien Shan above ~3,500 m



PRIMARY RISK:

Spring/summer water deficit; irrigation failures at critical growing season



POLICY PRIORITY:

Demand management, water storage, irrigation efficiency

THE AMU DARYA BASIN (THE PAMIR, HIGH ELEVATIONS)



CRITICAL SWE LOSS THRESHOLD:

Below ~3,000 m; near-total loss in the Afghan Murghab in all but SSP1-2.6; Eastern Pamir may see increased winter snowfall



SNOWMELT TIMING:

Earlier melt onset; runoff peak shifting from August toward June–July



RUNOFF TREND:

Increasing in the Eastern Pamir at elevations above ~3,500 m



PRIMARY RISK:

Potential flood risk from enhanced winter/spring melt; infrastructure stress



POLICY PRIORITY:

Flood preparedness, adaptive reservoir operations, hazard monitoring

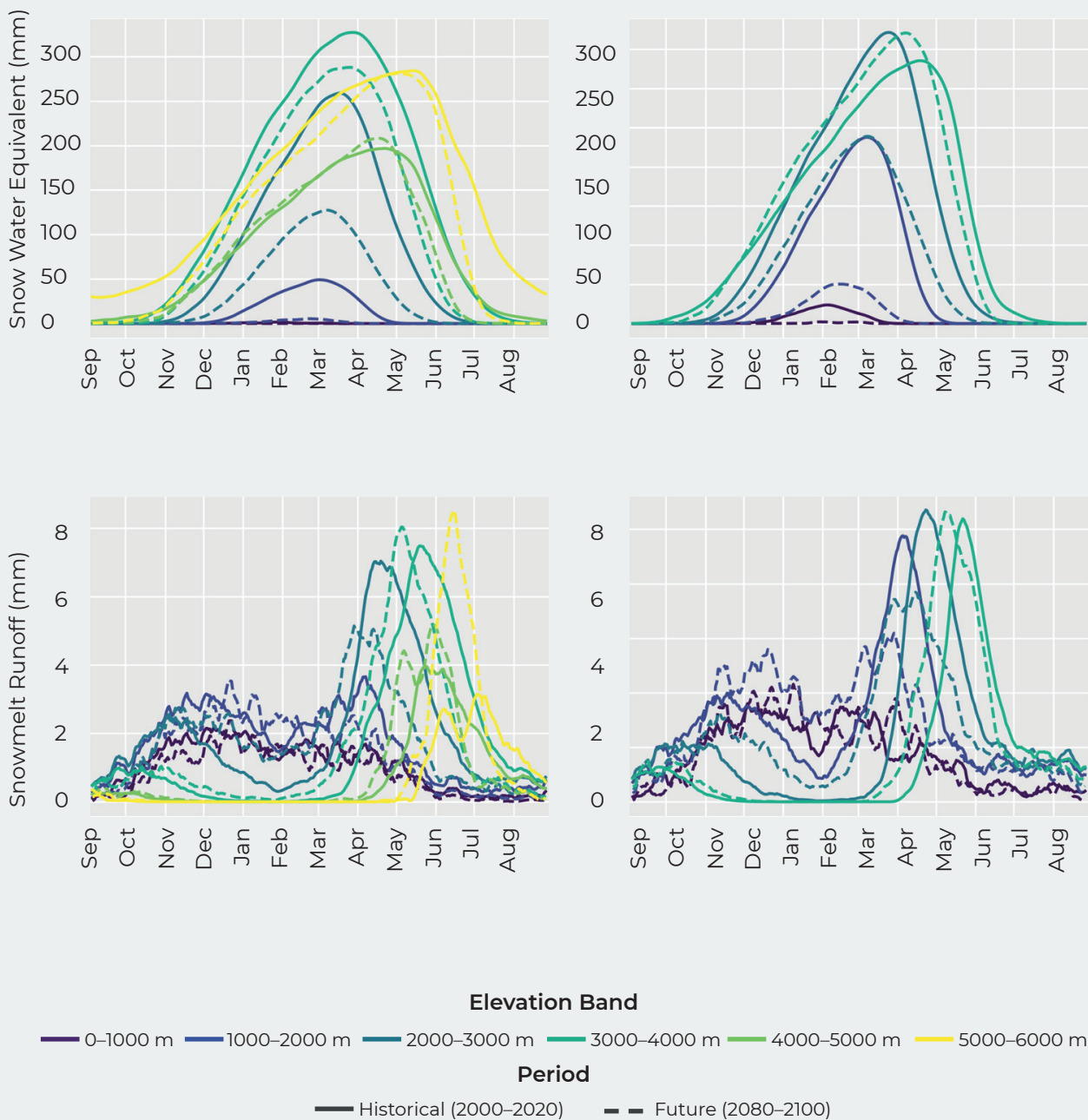
Divergent trajectories require differentiated policy responses: scarcity management in western catchments versus flood preparedness and adaptive reservoir management in the north and east.

Figure 2. Snow is disappearing and arriving earlier. Projected far-future (2080–2100, dashed) versus historical (2000–2020, solid) seasonal snow cycles for the Amu Darya and Syr Darya under SSP5-8.5. SWE collapses at lower elevations; snowmelt runoff peaks up to one month earlier – draining away before irrigation demand peaks. Colours = elevation bands (0–6,000 m). Source: Fiddes (2025), Figs 15–17.

Projected Seasonal Snow Changes Under High Emissions (SSP5-8.5)

THE AMU DARYA BASIN

THE SYR DARYA BASIN



EMERGING RISKS

Seasonal water scarcity

As SWE declines and the melt season shifts earlier, the natural snowmelt buffer that currently sustains late-spring and summer irrigation is eroding. Western catchments, already among the most water-stressed in the region, face the sharpest reductions in snowmelt-derived flows.

Hydrological extremes

Shorter, more intense melt seasons and more frequent melt-refreeze cycles increase variability of runoff flows. Combined with permafrost degradation and glacier retreat, this raises the risk of spring flood events and extended summer droughts within the same year.

Transboundary complexity

Shifting runoff seasonality and volumes complicate water-sharing arrangements in both basins. Accurate snow scenario data are essential for any future revision of transboundary agreements so that they reflect updated hydrological realities rather than historical baselines.

Runoff timing mismatch

Peak snowmelt runoff shifting by up to one month earlier than historical patterns will outpace the adaptation capacity of reservoir systems and irrigation schedules designed around the current seasonal regime. This is the highest-priority near-term water management challenge.

Loss of natural water storage

Snowpack functions as a distributed slow-release reservoir. As snow cover disappears below ~2,000 m in the north and ~3,000 m in the south, the buffering capacity of the mountain cryosphere permanently diminishes, increasing reliance on engineered storage.

Monitoring gaps

Significant uncertainties remain at sub-regional and catchment scales due to sparse in-situ snow observation networks across the HMCA domain. Filling these gaps is a prerequisite for reliable seasonal forecasting.

RECOMMENDATIONS

SIX PRIORITY ACTIONS ACROSS TWO TRACKS

TRACK 1.

Strengthen Monitoring and Snow Science

- 1. Expand snow observation networks.** Integrate in-situ monitoring with remote sensing and snow modelling tools to reduce uncertainty in sub-regional projections. Priority zones are low-elevation areas below the critical thresholds (~2,000 m in the Syr Darya; ~3,000 m in the Amu Darya) where change is fastest and data are most scarce.
- 2. Integrate snow scenarios into national planning.** Use differentiated catchment-scale projections for each basin in National Adaptation Plans (NAPs), water allocation strategies, and hydropower infrastructure design. The asymmetry between declining western runoff and potentially increasing eastern runoff demands basin-specific – not region-wide – planning assumptions.
- 3. Deploy seasonal forecasting and early warning services.** Link cryosphere monitoring to operational hydrological forecasting to enable proactive reservoir management, irrigation scheduling, and spring flood preparedness. The interactive **Snow Climate Scenario Explorer** and **Snow Anomaly Atlas** are freely accessible at apps.mountainfutures.ch/unesco-snow-scenarios – providing a ready foundation for basin-level seasonal scenario planning.

TRACK 2.

Adapt Water Governance and Infrastructure

- 4. Reform reservoir operations and irrigation scheduling.** Revise operational rules to capture earlier meltwater peaks and build dry-season buffers, reflecting the up-to-one-month shift in peak runoff timing projected under high-emission scenarios.
- 5. Embed snow scenarios in transboundary agreements.** Expand regional data sharing and joint hydrological planning within the Amu Darya and Syr Darya basin frameworks. Position this work within the **UN Decade of Action for Cryospheric Sciences (2025–2034)**, in which Tajikistan is a co-champion, as a concrete regional contribution to the Decade's Data-Sharing and Adaptation Objectives (UNGA resolution 78/321).
- 6. Develop National Action Plans and a Strategic Action Programme.** NAPs and a ministerial-level SAP are critical for ensuring science-policy coherence and transboundary alignment in Central Asia's cryosphere management. This coordinated framework should explicitly address snow – not only glaciers – as a primary driver of regional water security.

UPCOMING OPPORTUNITY FOR REGIONAL COORDINATION

The Regional Ecological Summit in Astana (April 2026) provides an opportunity for the Central Asian countries to commit to a Joint Statement on integrated cryosphere monitoring, covering both snow and glaciers. This could include establishing shared snow observation protocols, harmonizing snowmelt forecasting across the Syr Darya and the Amu Darya basins, and embedding snow scenario projections into National Adaptation Plans. Such coordination would advance SDG 6 targets and the Cryosphere Vision 2050.

ABOUT THIS POLICY BRIEF

This policy brief is based on the study Fiddes, J. (2025). High-Resolution Climate Change Impact Scenarios for Central Asian Snow Cover, conducted by the University of Fribourg within the framework of the GEF–UNDP–UNESCO Cryosphere Project “Strengthening the Resilience of Central Asian Countries by Enabling Regional Cooperation to Assess Glacio-nival Systems to Develop Integrated Methods for Sustainable Development and Adaptation to Climate Change.”

The GEF-UNDP-UNESCO Cryosphere project is implemented by the UNESCO Regional Office in Almaty.

Interactive scenario dashboard: apps.mountainfutures.ch/unesco-snow-scenarios

Full report: cryosphereca.org



GEF-UNDP-UNESCO project "Strengthening the Resilience of Central Asian Countries by Enabling Regional Cooperation to Assess Glacio-nival Systems to Develop Integrated Methods for Sustainable Development and Adaptation to Climate Change"

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