MDPI World Water Day 2025: Glacier and Ice Cap Disequilibrium

In 2025 World Water Day (WWD), established in 1993, is dedicated as the “World Day for Glaciers”. This is part of the United Nations International year for Glaciers’ Preservation.”

The rapid and accelerating loss of glacier area and volume this century has led to the necessity of this declaration. The World Glacier Monitoring Service has ~60 reference and benchmark glaciers, each has a consistent long term mass balance observation record (WGMS, 2024). In 2023 for the first time all 59 reporting glaciers had a negative mass balance. In 2024, all 58-reporting reference and benchmark glacier again have negative mass balances. It does not matter whether the glacier is in an Arctic Ice Cap, on the highest mountains of the world, or a small mid-latitude mountain glacier, the story of loss is the same.(WGMS, 2025) The number of glaciers that have disappeared has also accelerated, leading to the creation of a new data layer, for extinct glaciers, in the GLIMS global glacier inventory. The response of increased mass loss after a prolonged period of loss indicates glaciers that are in disequilibrium.

Glaciers provide critical water resources to the watersheds they inhabit. Depending on the watershed this can be critical for aquatic life, hydropower, irrigation and village/city supply.

Salmon Pacific Northwest: The Fraser River is fed by 2600 glaciers covering 2500 km^2, and the watershed supports Chinook, Chum, Coho, Pink, Sockeye and Steelhead salmon. Glacier area is declining rapidly in the basin. Chum abundance during last five years has been 625,000 vs long term of 1.5 million. Sockeye abundance during last five years has been 1.8 million vs long term of 4.7 million. Pink salmon abundance during last five years has been 10 million vs long term of 9.5 million. Chinook have remained at historically low values but have been declining in the last few years (Pacific Salmon Foundation). The health of glaciers and salmon population are interconnected.

The Nooksack River in Washington is host to the same six species of salmon and glaciers are a primary source of streamflow during the summer low-flow season in two of the three tributaries. Glacier runoff mitigates low flow and warm water temperatures. The impact of glacier runoff on discharge and water temperature was examined during 24 late summer heat wave events from 2010–2021 (Pelto et al 2022). The primary response to heat waves is increased discharge in the heavily glaciated North Fork, which is helpful to salmon, and increased stream temperature in the unglaciated South Fork, which is stressful to salmon. During heat events discharge increased an average of +24% (±17%) in the North Fork and decreased an average of 20% (±8%) in the South Fork. For water temperature the mean increase was 0.7 °C (±0.4 °C) in the North Fork and 2.1 °C (±1.2 °C) in the South Fork. This

led to numerous periods in the glacier free South Fork where water temperature exceeded tolerance levels of several Pacific salmonid species.

Hydropower Alps: The Grand Dixence Dam the world's largest gravity dam collects water through a 100 km long system of water supply tunnels fed in part by 35 Valais, Switzerland glaciers. Much of the water comes from glaciers providing meltwater during the summer. The lake is usually full of water by late September when the melt season ends, and is emptied during the winter, reaching its lowest point by April.

Austria generates 70% of its electricity from hydropower, with many of the larger projects being glacier fed such as Kaprun. The Kaprun power station produces 700 MW, 60% of its water supply is from Pasterze Glacier, which is transferred through a 12 km long tunnel to Mooserboden Reservoir. Pasterze Glacier retreat accelerated to 175 m/year for 2021-2023, which will reduce melt season runoff.

The Rhone River has 19 hydropower plants supplying 25% of France's hydropower and 4% of the total energy supply. The Rhone River begins at the Rhone Glacier, Switzerland and is fed by the largest glacier in the Alps, Gross Aletsch.

Irrigation: High Mountain Asia glaciers are summer accumulation type glaciers releasing the highest volume of runoff during the summer coinciding with the highest period of precipitation. The result is that glacier runoff is critical particularly in the pre-monsoon period. In the Indus basin during the pre-monsoon season up to 60% of total irrigation withdrawals originate from mountain snow and glacier melt, contributing 11% to total crop production (Biemans et al 2019). In total, 129 million farmers in the Indus and Ganges substantially depend on snow and glacier melt to grow food crops sufficient to sustain a balanced diet for 38 million people (Biemans et al 2019). In the Indus Basin earlier glacier melt increases glacier meltwater withdrawal at the onset of the cropping season in May and June. This contrasts with increasing peak irrigation water demand during July and August aggravating non-renewable groundwater pumping (Lutz et al, 2022).

In 2009 there were 2061 glaciers in the Koshi River Basin, Nepal, with a total area of 3225 ±90 km^2. From 1976 to 2009, glacier area in the basin decreased by about 19±5.6% (Shangguan et al, 2014). The Sunsari Morang irrigation scheme is the largest in Nepal providing irrigation to 68,00 hectares. Water is diverted from the Koshi River near Chatara, withc anal inflow dependent only on hydraulic head differences. River water level is sufficiently high in the wet season, it is lower than desired in the dry period (November to May), limiting irrigation canal discharge and hence the irrigatable crop area. The main crops grown in this period are wheat, pulses, oilseed, maize, sugarcane, potato and

vegetables in the winter and early spring (November/December to March/April).

Irrigation and Municipal Supply-Andes:

The Maipo River, Chile is the main source of water to the Santiago Metropolitan area in central Chile The river provides approximately 70% of the region's drinking water and 90% of the water that is needed for irrigation. Mean annual contribution of glacier runoff to discharge to the Maipo River increased, from 11 ± 5% during the 2000-09 period to 16 ± 6% during the 2010-2018 period, primarily due to a large decrease in discharge from the basin during a period of drought, from 830 ± 120 mm yr^{-1} to 520 ± 80 mm yr^{-1} (McCarthy et al 2022).

Discharge peaked from glaciers peaked at 20 mm $month^{-1}$ during both periods, with March having the highest glacier contribution at 29 ± 14% from 2000-09 and 43 ± 16% from 2010-18 (McCarthy et al 2022). Glaciers provide 34% of the total summer runoff to the basin (Caro et al, 2024).

La Paz, Bolivia, drainage basins are fed by 70 glaciers that contribute 15% of the water resources annually, 27% during the dry season during the 1997-2006 period (Soruco et al, 2015). Focusing on the 2000-19 period the contribution of glaciers has increased to 22% annually of total runoff despite glacier runoff not increasing, because of declining overall runoff. Water demand in the region continues to grow putting further pressure on the system what will see ongoing glacier runoff declines.

Summary:

Each of these examples identifies the specific value that glaciers provide in various regions. Preservation of glaciers protects this resource that ecosystems and economies are dependent upon. Today glaciers in several mountain regions are vanishing too quickly to be preserved, but in other areas many large glaciers can be preserved if we accelerate our mitigation of greenhouse gas emissions.