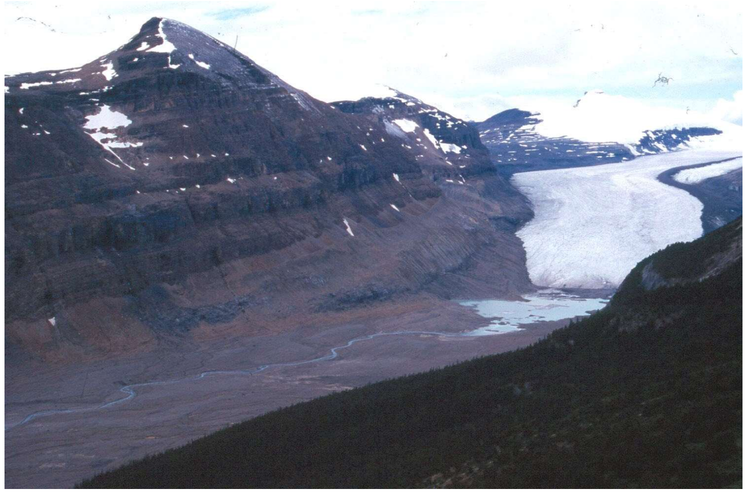
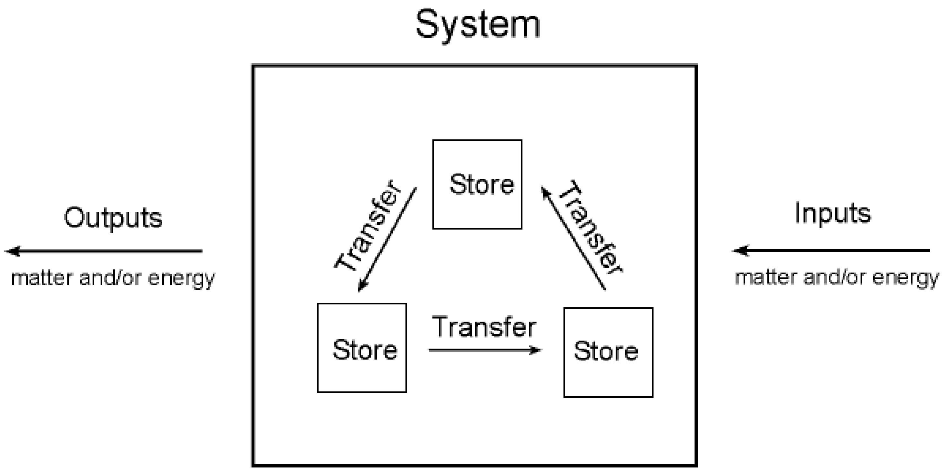
## Educational Resources—Glacial Environments

## Glacial Systems and Mass Balance

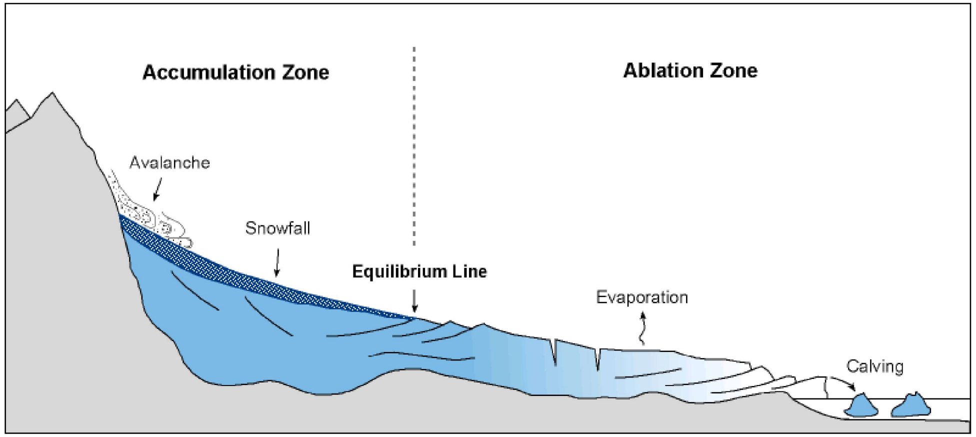
**The Glacial System:** Glaciers gain mass through the transformation of snow into ice and then flow downhill (in response to gravity) and eventually lose mass due to melting. Hence glaciers can be viewed as systems with inputs, stores, transfers and outputs.



Melting ice front or snout of a valley glacier. Note the meltwater draining across the proglacial area in front of the glacier. The glacier has flowed down from a ice cap situated over the mountains in the distance.




Glaciers accumulate mass from snow falling onto its surface, snow avalanching from the valley sides and by the accretion of rime ice by the direct freezing of atmospheric moisture onto the glacier.



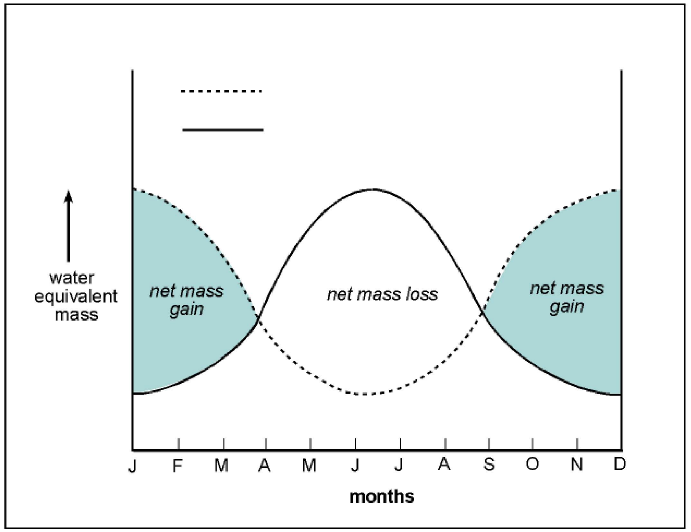

Glaciers lose or ablate mass by melting as a result of warm air temperatures or applied pressure, evaporation, wind erosion or by calving into icebergs along a floating ice front. (Photo) In extremely cold and arid areas, such as the interior of Antarctica ice, mass can also be lost by sublimation, i.e. the process thereby a solid (ice) changes directly into a gas (water vapour).

The collapse of ice (calving) at the front of the San Rasael Glacier, Chile

**Systems Analysis:** Systems analysis is widely used in many academic subjects. It involves viewing any part of the physical or human world as a entity that consists of stores and transfers of energy and matter, and operates because it receives a constant supply of energy and matter, which in turn are lost from the system as outputs. Changes in the level of inputs may cause instability within the system, and in response to the new amounts of energy, the system initiates feedback processes. Usually, feedbacks act to minimise the effect of the new inputs in order to re-establish stability (negative feedback). Thus, a system has the ability of self-regulation and can maintain a state of equilibrium. More rarely, the system may react to instability by initiating a response (positive feedback) that reinforces the effect of the original input. This snowballing effect may ultimately cause a shift in the system to a new state of equilibrium.

## Glacier Mass Balance

Glaciers gain mass in the accumulation zone, i.e. the upper part of the glacier where input (winter snowfall etc) exceeds output (summer melting etc). In contrast, mass is lost in the lower ablation zone where outputs exceed inputs. At the transition between the two zones accumulation equals ablation. (Fig) Hence, this boundary is called the equilibrium line, which in turn approximately coincides with the position of the snowline.



Full length of a glacier. The ice cap in the distance represents the accumulation zone of the glacier. The ablation zone probably includes all of the valley glacier.

The gains and loses of ice experienced by a glacier constitute its mass balance or glacial budget. (Fig) Overtime if a glacier gains more mass than it loses (i.e. accumulation > ablation) then the mass balance of a glacier is positive and this causes the snout of the glacier to advance. Alternatively, if the mass balance is negative (accumulation < ablation) the reverse will occur and the position of the snout will retreat. Finally, if the glacier neither gains nor loses mass (accumulation = ablation) the balance is zero and the snout will remain stationary.

Glaciers are extremely sensitive to climate change, which is currently being demonstrated by the gradual and sustained retreat of nearly all the world's glaciers over the last 150 years in response to global warming