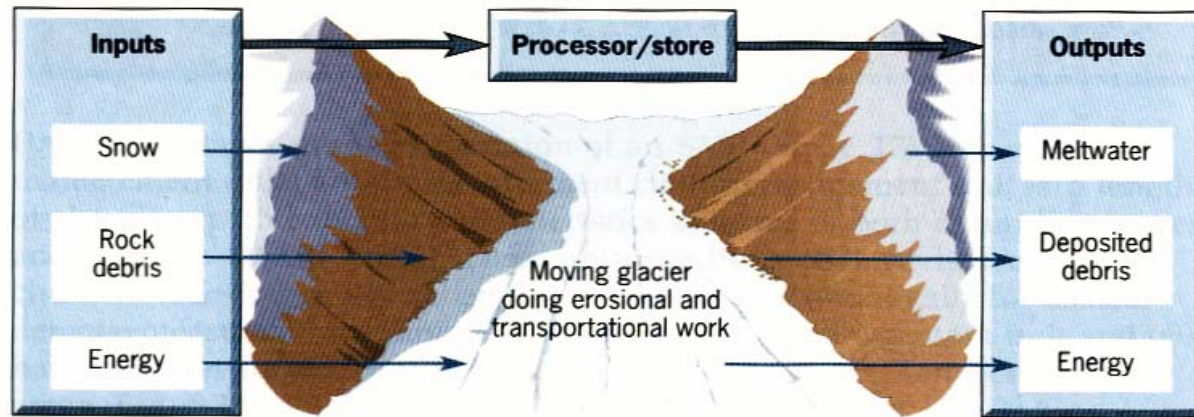


1. Glaciers as Dynamic Systems.

The Glacier System of Inputs, Outputs and Stores.**KEY TERMS:**

Glacier: An extensive body of land ice, consisting of ice crystals, trapped air, water and rock debris, which exhibits evidence of down slope movement under the influence of gravity. These include:

- **Cirque Glacier:** a small glacier occupying a glacially eroded “arm-chair” shaped hollow in a mountainous region.
- **Valley Glacier:** a glacier that occupies a pre-glacial valley, either resulting from the coalescence of several cirque glaciers (**Alpine type**) or flowing from the edge of an ice cap or ice-sheet (**outlet glacier**).
- **Icecap:** A dome shaped covering of ice, small than an ice-sheet and often in a mountainous area, such as on Iceland or **Baffin Island**.
- **Ice-Sheet:** A large, continuous layer of land ice of considerable thickness, such as in **Antarctica** or **Greenland**. It is larger than an ice cap.

Firn: German term for old granular snow which is in the process of being transformed into glacial ice. It has a density between 0.4 and 0.9 kg m^{-3}

Glacial ice: Ice, which forms from the recrystallisation of *firn* (firnification)

Inputs: a combination of the accumulation of the mass and energy of glacial ice plus the *rock debris* that it transports.

Outputs: a combination of loss of ice and energy through *ablation* plus the removal or deposition of rock debris, either directly as a glacial deposit or indirectly as part of the *meltwater's* load.

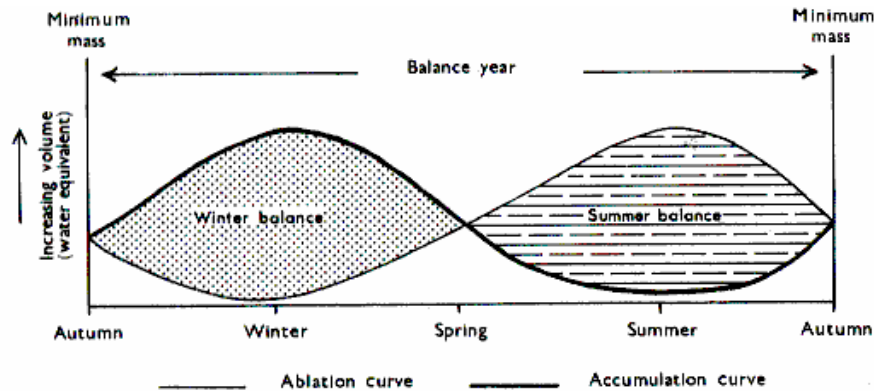
Glacial system stores: the rock, ice water and air of which a *glacier* is composed.

Meltwater: water resulting from the melting of glacial ice or snow.

Annual Glacier Budget (Accumulation and Ablation).

Accumulation: the process of **snow and ice nourishment** of a *glacier* form precipitation (snow and freezing rain), *rime* ice, from direct *sublimation*, *hoarfrost*, *avalanche* material and drifting snow.

Ablation: the **wastage or removal of surface snow or ice by melting, evaporation and sublimation**. The process involves the transfer of heat from the glaciers surroundings (sensible heat, latent heat and conducted heat) and direct insolation (radiation from the sun).



The curves of total accumulation and total ablation define an annual mass balance. The winter balance is positive and the summer balance is negative. If the two areas between the lines areas are equal, the annual balance is zero.

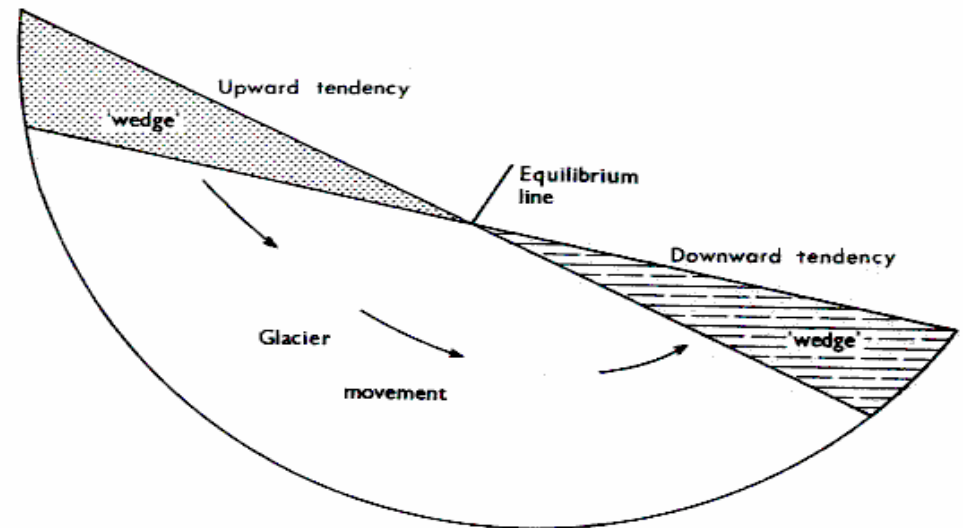
Mass balance: the **annual budget** of a glacier describes the input/output relationships of ice, *firm* and snow and is measured in water equivalent (i.e. the amount of water involved if melted). In other words, it is the balance between *accumulation*, *ablation* and the stored ice. The difference between *accumulation* and *ablation* for a whole glacier over a year is called the **net balance** (usually measured over a calendar year between periods of minimal loss). For most *warm glaciers* the winter balance is positive and the summer balance is negative. This can be presented both as a diagram or a graph.

The diagram (Below Right) shows an idealised glacier with the net accumulation “wedge” above, and the net ablation “wedge” below the equilibrium line. Glacial flow (movement) is necessary in order to maintain equilibrium.

Dynamic Equilibrium: In a system, dynamic equilibrium is a state of balance between the inputs and outputs, in spite of changes taking place. In a glacial system, dynamic equilibrium is achieved when, over a period of time, accumulation and ablation are in balance. Although ice and rock debris are flowing through the system, the appearance of the glacier does not change overall as fresh inputs of snow and rock are balanced by ablation and deposition of till and the removal of outwash sediments.

What is the difference between the **firm line** and the **equilibrium line**?

The **firm-line** is the **snow-line** or the uppermost line on a glacier, below which the previous winter snowfall melts during the ablation season of the summer. The **equilibrium line** is the boundary between the **ablation zone** and the **accumulation zone** of a glacier. It is similar to the firm-line, but not synonymous with it because the surface of the glacier immediately below the elevation of the firm-line is regularly built up by layers of freezing meltwater.



The Impact of the Annual Budget on Advance and Retreat.

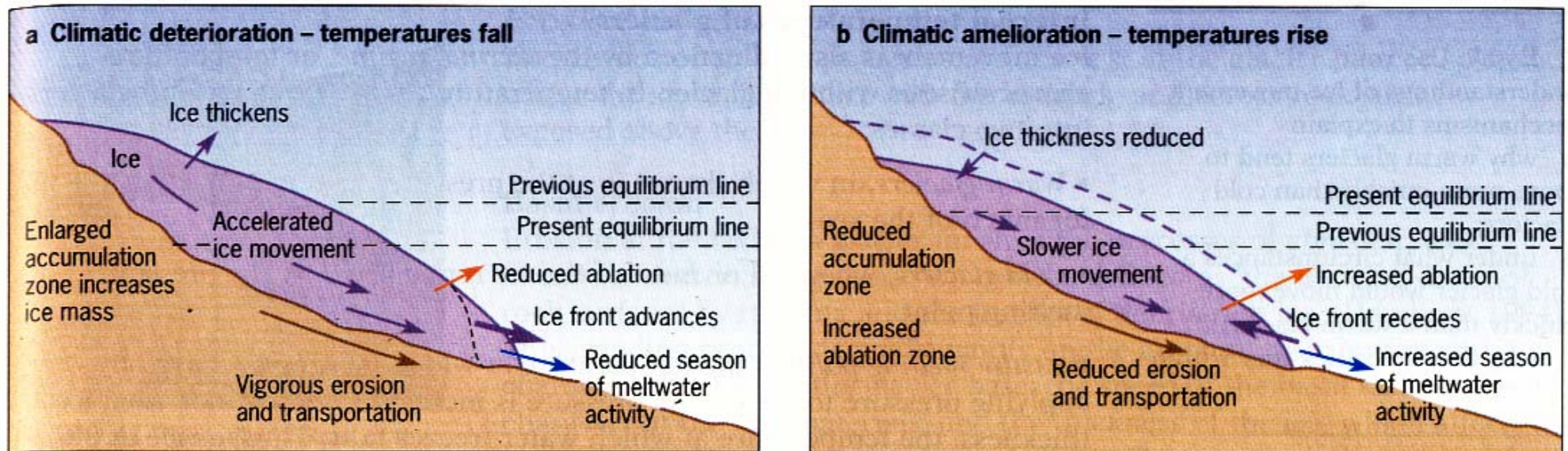
Glacial advance: the state of a glacier when its front or *snout* is advancing. This state is reached when **accumulation exceeds ablation** leading to a positive *mass balance*.

Glacial retreat: the state of a glacier when its front or *snout* is receding, although the body of the ice itself is still moving forward. This state is reached when **ablation exceeds accumulation** leading to a negative *mass balance*. **Note that the ice itself is still flowing forward, even when a glacier is in retreat.**

Glacial surge: A sudden advance of a glacier. A *kinematic wave* moves down the glacier as a type of accelerated flow, resulting from a change in its *mass balance*.

Glacier regime: the overall state of a glacier in relation to its *mass balance*. A *glacier* is said to have a positive regime when *accumulation* exceeds *ablation* leading to a thickening of the ice and a *glacial advance*. It has a negative regime when *ablation* exceeds *accumulation* leading to a *glacial retreat*.

Variations in the mass balance of a glacier can lead to advance or retreat.



The impacts of climatic fluctuations on glacier budgets