Changing Landscapes: Glaciated Landscapes

How do glaciers form?

What you need to know

The glacial system including inputs, outputs, stores and transfers of energy and materials

Change in the inputs to and outputs from a glacier over short and long-time scales

The glacial budget including glacier mass balance and equilibrium

Positive and negative feedback in the glacier system

Seasonal changes and their impact on the glacier budget

GLACIER ICE FORMATION

Glacier ice is derived mainly through compacted snow

This can only happen if snow survives all year round – snow that survives summer melting is called firn or névé

A key factor is the number of **positive degree-days** – fewer leads to less melting so snow, then ice can accumulate

As snow is compacted trapped air is expelled, density increases and ice forms at the bottom (the process is called diagenesis)

Some summer melting creates meltwater and this fills the gaps between the grains of ice helping to increase the density still further

GLACIER ICE FORMATION

Density comparisons (pure water = 1gcm^{-3}):

- snow = 0.06gcm^{-3}
- firn/névé = 0.4gcm^{-3}
- glacier ice = 0.83 to 0.91gcm^{-3} (pure ice = 0.92gcm^{-3})

As ice is compacted it becomes granular

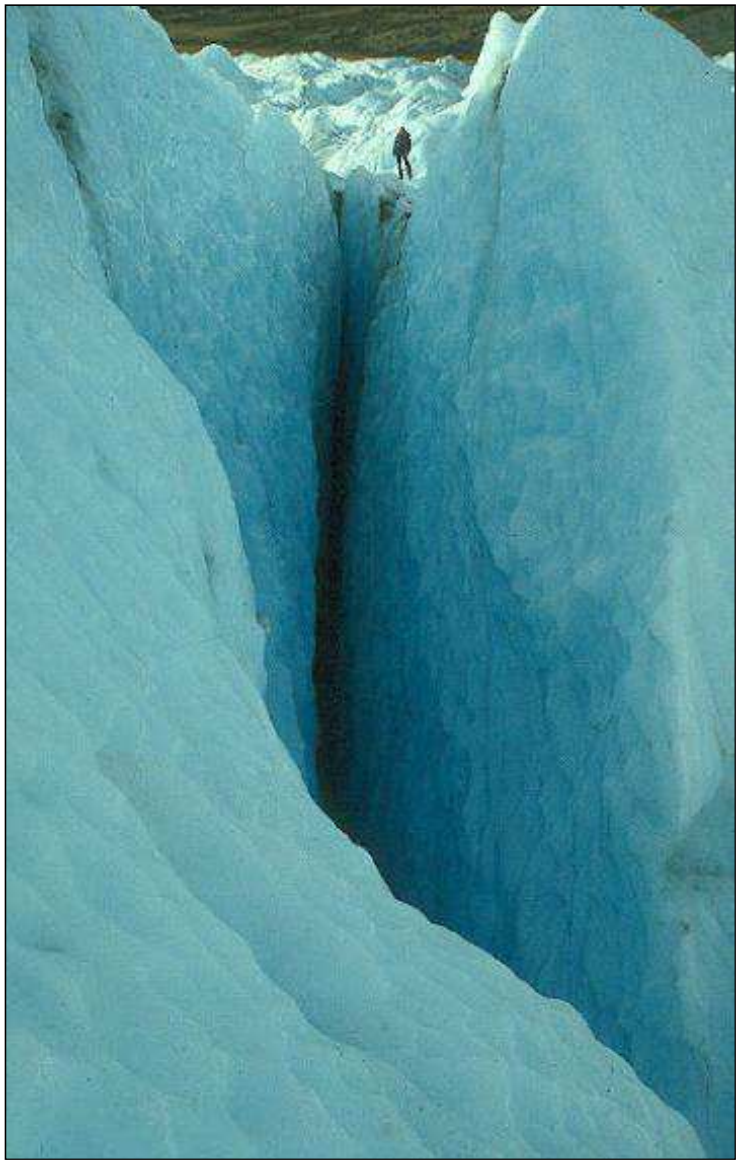
Despite the cold, there's usually a thin intergranular film around each grain of ice (caused by a solution of salts that lowers the freezing point of water)

This is a lubricant that aids ice movement

GLACIER ICE

Air pockets in névé give it a white-ish colour...

...whilst glacier ice is a blue or glassy-green



GLACIER ICE FORMATION

In areas of high snowfall and temperatures that fluctuate about 0°C (e.g. Alaska's Coast Range) glacier ice can begin to form at depths of c. 10m below the snow surface, and in under 5yrs.

In colder, drier areas (e.g. Antarctica's interior) snow depths of 60m+ are needed and it can take hundreds-thousands of yrs

Under the weight of ice, the lower layers begin to deform and flow outwards and downwards…of which, more later!

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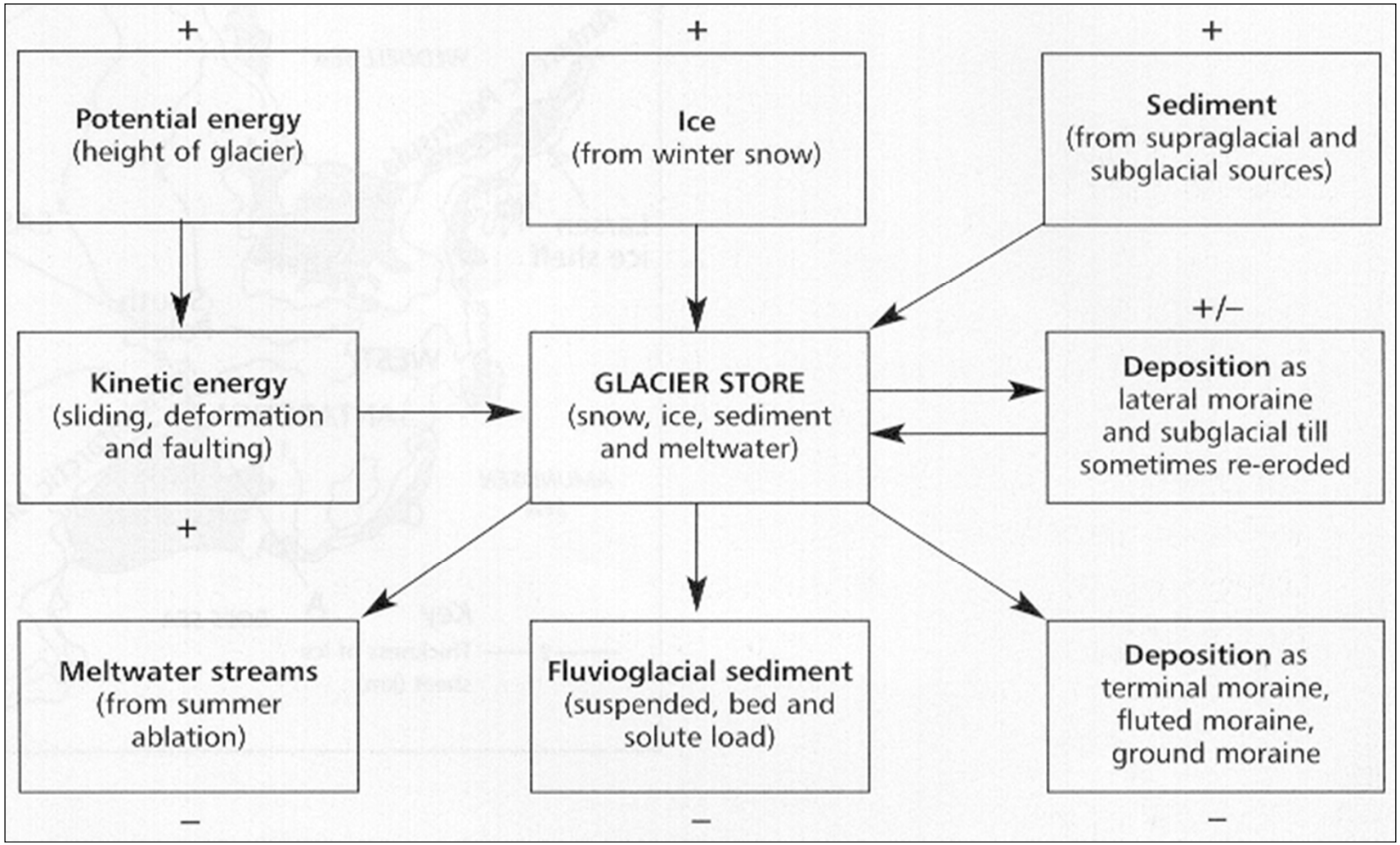
Glaciers as systems

THE GLACIER SYSTEM

Regardless of size, all glaciers can be regarded as systems:



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Mass balance and
Glacial budgets

Some key terms

Accumulation

the increase in the mass of ice from precipitation, avalanches and ice falls, and wind blown snow

Ablation

the decrease in ice mass, mostly through melting but also through sublimation, wind blowing snow off the surface and iceberg calving

Net balance

the outcome of opposing forces/factors, in this case, accumulation-ablation

Equilibrium

a state of balance achieved when opposing forces/factors cancel each other out

MASS BALANCE

= the net result of accumulation-ablation over the whole glacier, i.e.

inputs (snowfall & avalanches) - **outputs** (melting, sublimation…)

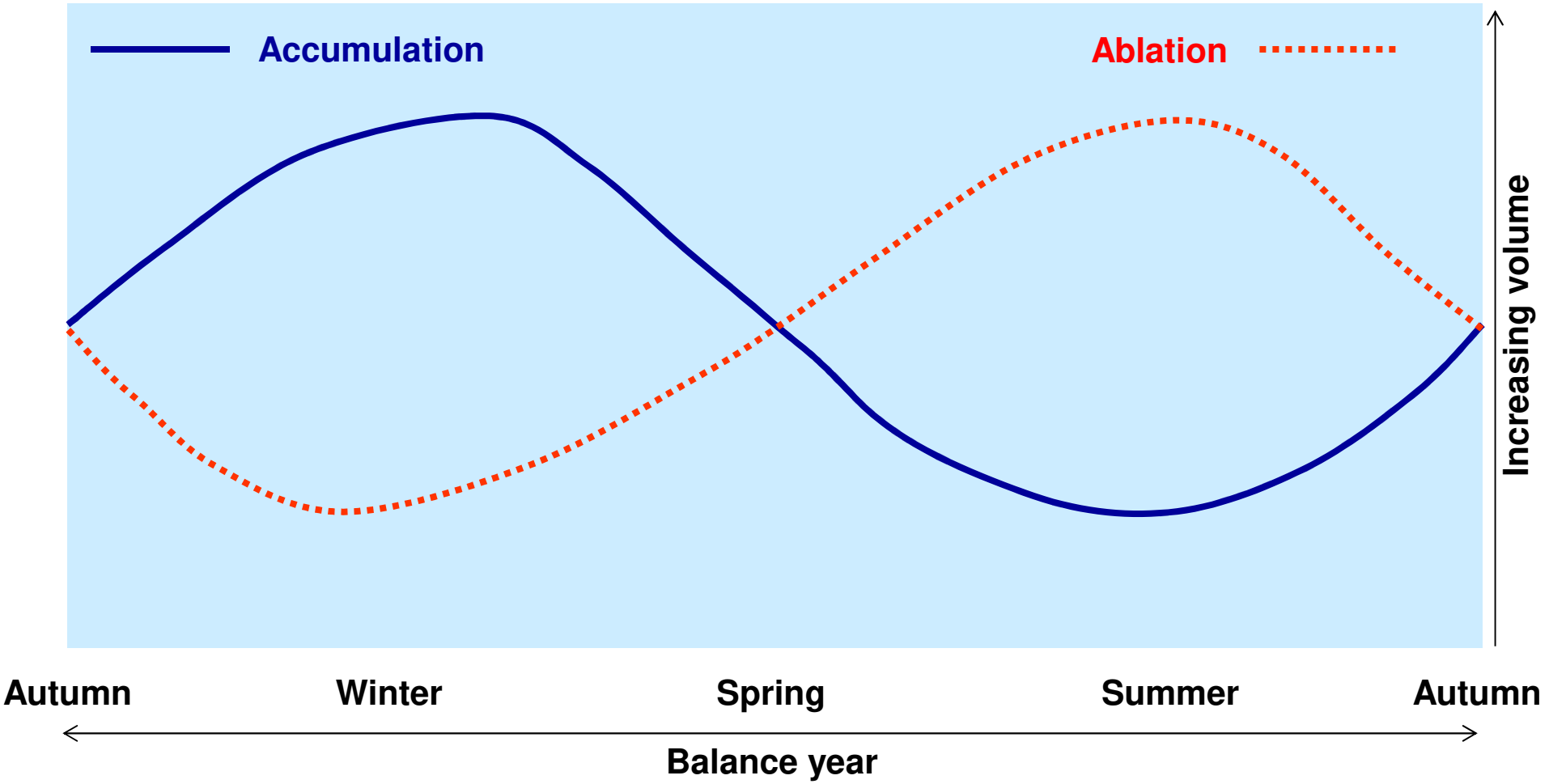
Accumulation & ablation vary all the time, but the average variation over a year = (**cumulative**) **net balance**.

Balance year runs from minimum mass to minimum mass, i.e. autumn to autumn (*why?*)

Useful ref: http://www.antarcticglaciers.org/modern-glaciers/introduction-glacier-mass-balance/

THE GLACIER MASS BALANCE

Glaciers will typically have cycles of changing accumulation and ablation over a year:



IMPACTS of GLACIER MASS BALANCE

The annual growth and retreat of the glacier = **glacial budget**

1. If a glacier was increasing in mass (i.e. if it had a positive mass balance) what would the graph look like? Sketch the graph.
2. What would it be like if the glacier was shrinking (i.e. if it had a negative mass balance)? Sketch the graph.

IMPACTS of GLACIER MASS BALANCE

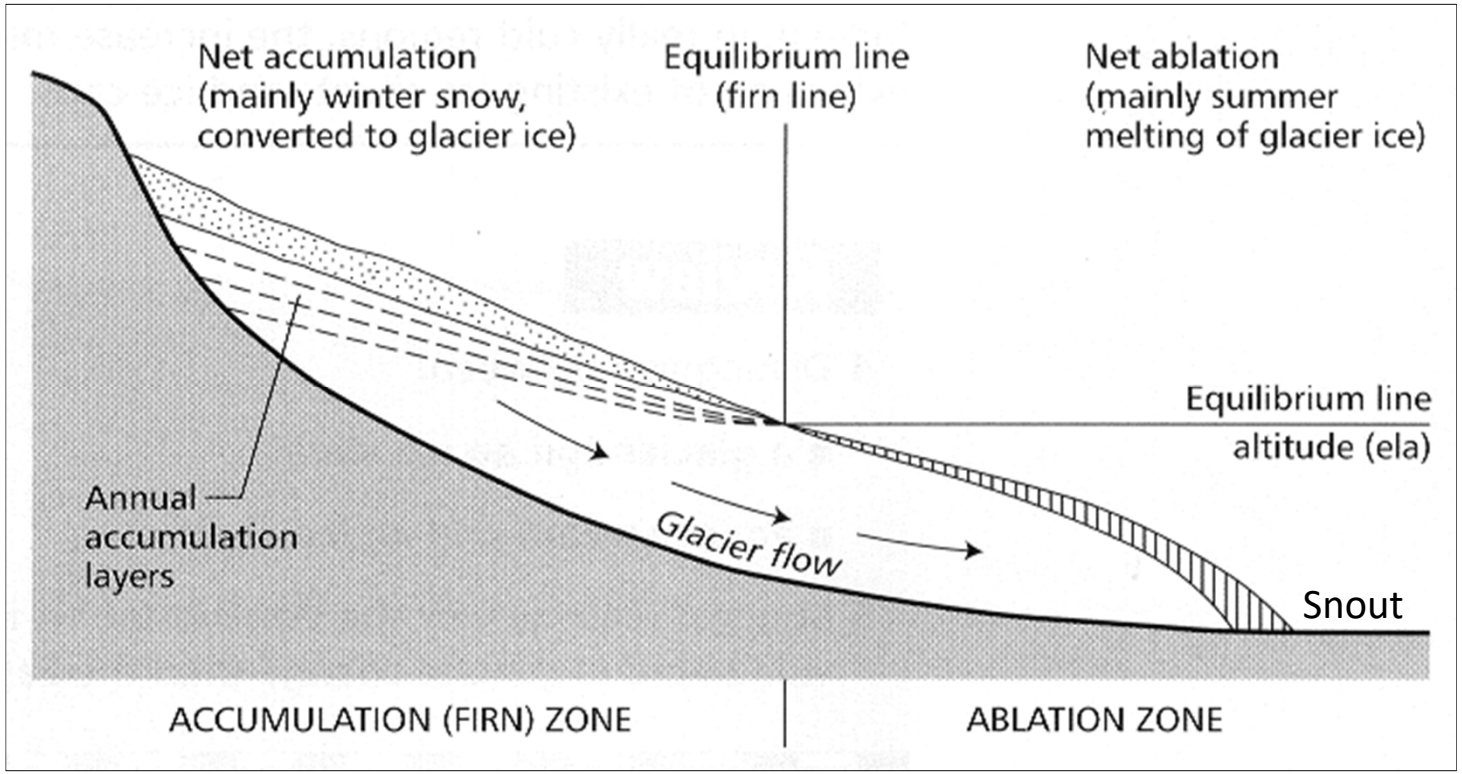
1. What would the climatic conditions be like to produce:
   - a positive mass balance?
   - a negative mass balance?
   - one that's in equilibrium?
2. What would you expect to happen at the glacier's snout (front end of the glacier) if the mass balance is:
   - positive?
   - negative?
   - zero?

GLACIER MASS BALANCE SUMMARY

State of glacier	Mass balance/ Glacial budget	Change in mass over year
No change		
Growing/advancing		
Shrinking/retreating		

THE GLACIER SYSTEM + MASS BALANCE

The two concepts can be combined if we look at variations in accumulation and ablation across the glacier:



If conditions get colder, what happens to the relative size of the accumulation zone?
What happens to the equilibrium line?
What do you think is the situation when the glacier is in equilibrium?

FEEDBACK IN THE GLACIAL SYSTEM

Feedback is an output that becomes an input – used to varying effect by rock guitarists the world over.

Negative feedback is where feedback reduces output allowing equilibrium to be re-established. This is the more usual response in natural systems to a change in inputs.

Positive feedback is where the feedback causes more output (see above) producing an unstable system – which is more rare in nature.

FEEDBACK IN THE GLACIAL SYSTEM

Which of these is negative feedback, and which is positive feedback?

a. Global warming melts snow and ice cover. This reduces the 'reflectivity' (albedo) of the land surface so more solar energy is absorbed than is reflected. Thus more infrared is radiated into the atmosphere leading to more warming. (This also happens if temperatures cool producing more snowfall.)

b. Global warming increases evaporation leading to more precipitation. At higher altitudes and latitudes this falls as snow, increasing the albedo of the land surface. More incoming solar radiation is reflected back into space reducing global warming.