Glacier flow
GES-441

Glacier Flow

Gravity ultimately responsible for flow; need 30-50 m of ice to get started

Surface Flow

Agassiz installed posts on the ice and measured rate at which they moved; this method can still be used, as well as GPS and satellite images

Internal Flow

Harder to measure

Extrusion Flow Hypothesis - Max Demorest 1943 – flow increases with depth

Blumke and Hess early 1900's - pipes in glacier, surface moved faster

With better drilling equipment, it was found that the surface does indeed move faster than the bed.

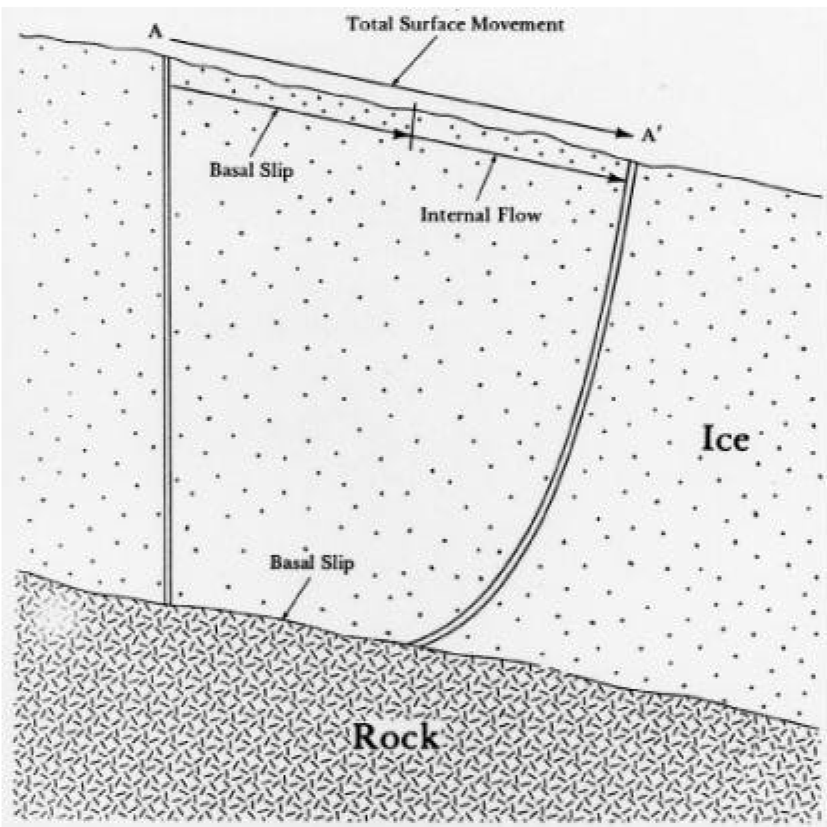

Figure 3.3. Vertical section through a glacier cut parallel to the flow direction, showing what a pipe, initially extending vertically from the surface to the base, would look like after a year or two. The total movement, A A', measured on the surface is the summation of flow within the ice and slip upon the base. Experiments of this type have been performed on a number of valley ice streams.

Ice velocity through a vertical section of the glacier parallel to ice flow (from Sharp, Living Ice: Understanding Glaciers and Glaciation, 1988.)

Velocity Measurements

Jakobshavn - 7 km/yr surface motion
Small Antarctic alpine glaciers 1-4 m/yr

How does ice flow?

Flows due to gravity, caused by imbalance between accumulation and ablation, need a surface slope.

Shear Stress - is the force per unit area that causes ice deformation and allows flow

$$J = Dgh\sin "$$

Shear stress varies with ice thickness (h) and surface slope (")

Shear stresses generally are fairly constant under glaciers. Thus, h and " tend to vary inversely. When h is large, the surface slope is low; when h is small, the slope is steep

Ice Flow by Internal Deformation

Creep - ice flow through deformation of ice crystals that causes a fabric of preferred orientation to develop; this fabric is favorable to continued movement along glide planes; rate is dependent upon shear stress

Glen's Flow Law-

$g = BJ^n$

where the creep rate is equal to a temperature and fabric-dependent ice-hardness constant multiplied by the shear stress raised to a power n (av. value = 3). Doubling shear stress increases creep 8X. Creep is more effective at higher temperatures as the ice is softer.

Folding - internal deformation that happens when the creep can't adjust fast enough to changes in stress

Fracture - brittle failure in upper part of glacier or when stresses change dramatically (i.e., icefalls)

Ice Flow by Basal Slip

Enhanced Creep - ice deforms around obstacles at bed. Ice pressure increases on upstream side, increases shear stress which increases creep; large obstacles favored

Regelation - ice at the **pressure melting point** on upstream side of obstacle melts due to increased pressure; water refreezes on lee side of obstacle in low pressure zone; small obstacles are favored

Sliding - sliding at bed is dependent on reduced friction; factors involved include:

1) size and number of obstacles
2) amount of debris in ice
3) adhesion
4) presence of water

Even a thin film of water will increase sliding

Deformable Beds

In unfrozen sediment, weight of glacier causes deformation and flow of sediments. The deformation of the sediments may cause the ice above it to move faster; controversial; high pore water pressure in the sediments likely also would cause faster ice flow

Spatial Variations

Vertical profiles - ice flow is faster at the surface than at the bed.
Plan view - ice flow is generally faster in the center of a glacier than at its edges; this can be affected by topographic irregularities or at the junction of two glaciers, particularly those of unequal strength

In areas of fast-moving, accelerating ice, there commonly is extending flow. Compressive flow tends to occur where ice is slowing down. Topography creates local zones of extending and compressive flow.

Temporal Variations

Some glaciers have daily cycles, some seasonal cycles. These changes in flow commonly relate to changes in water at the bed. Rainfall and melting events also can affect flow. **Surge** - anomalously fast glacier movement