

final outline of topics

1. journal articles; *Global Outlook*
2. ice on earth
 - (a) H₂O crystals: growth from liquid & vapor, shape
 - (b) precipitation of ice from the atmosphere
 - (c) snow diagenesis: densification & near-surface processes
3. components of the cryosphere
 - (a) broad themes
 - formation
 - connections among components
 - issues of scale
 - (b) sea ice
 - formation; ice types
 - Arctic v. Antarctic: general characteristics
 - (c) snow
 - (d) lake & river ice
 - (e) frozen ground
 - thermal regime; seasonal cycles
 - distribution
 - (f) glaciers and ice sheets
 - classification: thermal, surface facies, flow
 - conservation equations
 - Conservation of ϕ within a volume V is

$$\frac{d}{dt} \int_V \phi dV = - \int_S \mathbf{F} \cdot \hat{n} dS - \int_S \phi \mathbf{V} \cdot \hat{n} dS + \int_V H dV \quad (1)$$

where \mathbf{F} represents the flux due to diffusion, $\phi \mathbf{V}$ represents advection of ϕ in a fluid flow with velocity \mathbf{V} , H represents a source (or sink) of ϕ within V and boldface indicates a vector-valued quantity. The unit vector \hat{n} normal to the surface S enclosing V .

- momentum balance
- * boundary conditions

- * constitutive relationship between stress and strain
 - energy balance
 - * processes affecting ice temperature (terms in the conservation equation)
 - * temperature profiles
4. global climatology
- (a) energy balance
 - (b) general circulation of atmosphere
 - (c) general circulation of ocean
 - shallow
 - thermohaline circulation
 - North Atlantic Deep Water formation processes
 - (d) seasonal cycles
 - (e) modes of variability (especially NAM/SAM)
5. the arctic cryosphere
- (a) Arctic ocean basics: stratification, circulation
 - (b) glacier and ice cap mass balance trends
 - (c) sea ice
 - growth, seasonal cycle
 - trends, variability
 - causes for change
 - (d) Greenland ice sheet
 - ice sheet change: specific mass balance, ice dynamics
 - processes
 - glacier mechanics
 - surface melting; melt ponds
 - tidewater calving and front position
 - stress perturbations
 - ocean warming
6. changes in northern hemisphere snow

7. Antarctic cryosphere

(a) relationship between geologic history and ice sheet characteristics

- east, west, peninsula

(b) variability and trends

- global warming, ozone depletion, SAM
- air temperature; ocean temperature; sea ice

(c) Antarctic Peninsula

- west v east
- ice shelves and glaciers

(d) West Antarctica

- mass balance
- Amundsen Sea: Pine Island Glacier, etc.
- Ross ice streams; thermomechanics, evidence for variability