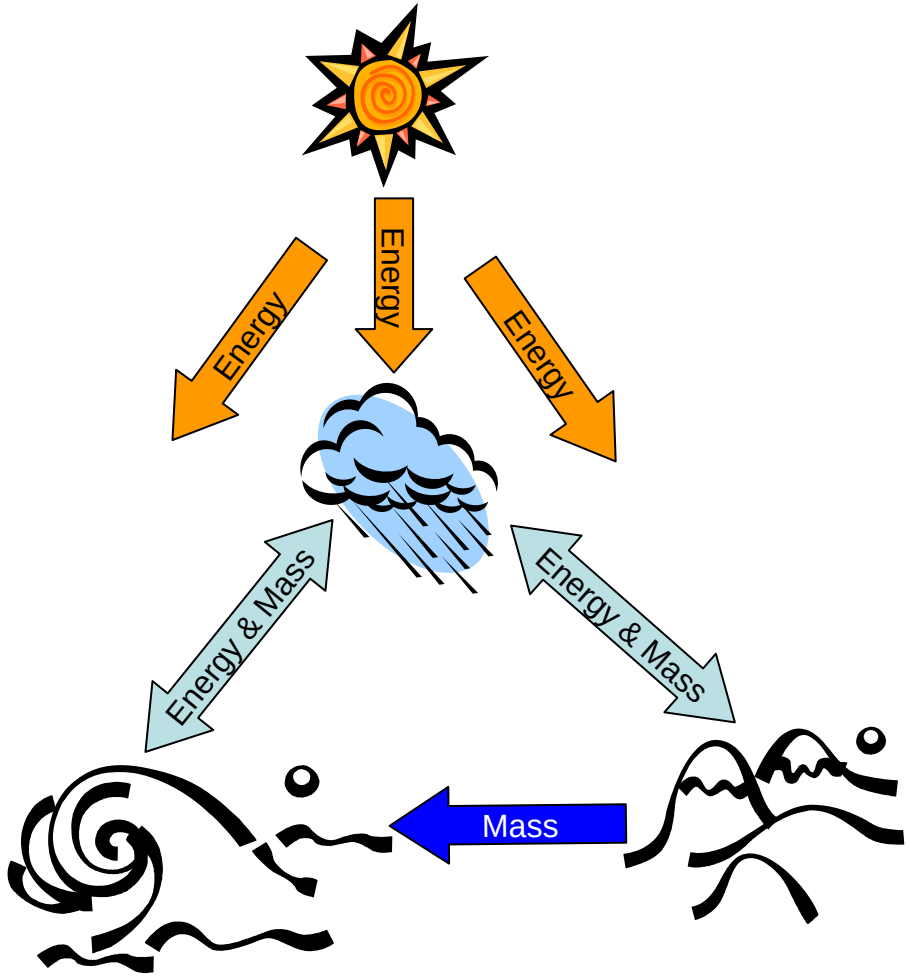
CE 374 K – Hydrology

Transport Processes

Daene C. McKinney

Transport In The Hydrologic Cycle

- Energy enters hydrologic cycle through solar radiation
- Energy, momentum and mass transport in the atmosphere and oceans
- Energy redistribution occurs by conduction and convection it the atmosphere and oceans



Transport Phenomena

	Mass	Momentum	Energy
Laminar Flux	$f_m = -D\frac{dC}{dz}$ Fick's Law	$\tau = \mu\frac{du}{dz}$ Newton's Law	$f_h = -k\frac{dT}{dz}$ Fourier's Law
Turbulent Flux	$f_m = -\rho K_w\frac{dC}{dz}$	$\tau = \rho K_m\frac{du}{dz}$	$f_h = -\rho C_p K_h\frac{dT}{dz}$

Flux = Flow Rate/Area

Shear stress = Momentum Flux = lateral movement of momentum between fluid elements with different velocities

Turbulent momentum flux – dominant mechanism in hydrology

Conduction and Convection

- **Conduction**
  - Molecular exchange between different layers due to *differences* in
    - temperature (transporting heat),
    - velocity (transporting momentum),
    - concentration (transporting mass)
- **Convection**
  - Turbulent exchange of mass, energy, and momentum
  - Much greater than molecular exchange (conduction)

In a wide stream:

$$\Re = \frac{VD\rho}{\mu} \geq 500 \quad (turbulent)$$

V = mean velocity

D = depth of flowing stream

Turbulence occurs:

$VD \geq 7x10^{-3}$ *(air)*

$VD \geq 6x10^{-6}$ *(water)*

Velocity Profile

- Determining momentum transfer requires knowing velocity profile
- Flow of air over land or water – log velocity profile

$$u(z) = \frac{u^*}{k} \ln\left(\frac{z}{z_0}\right)$$

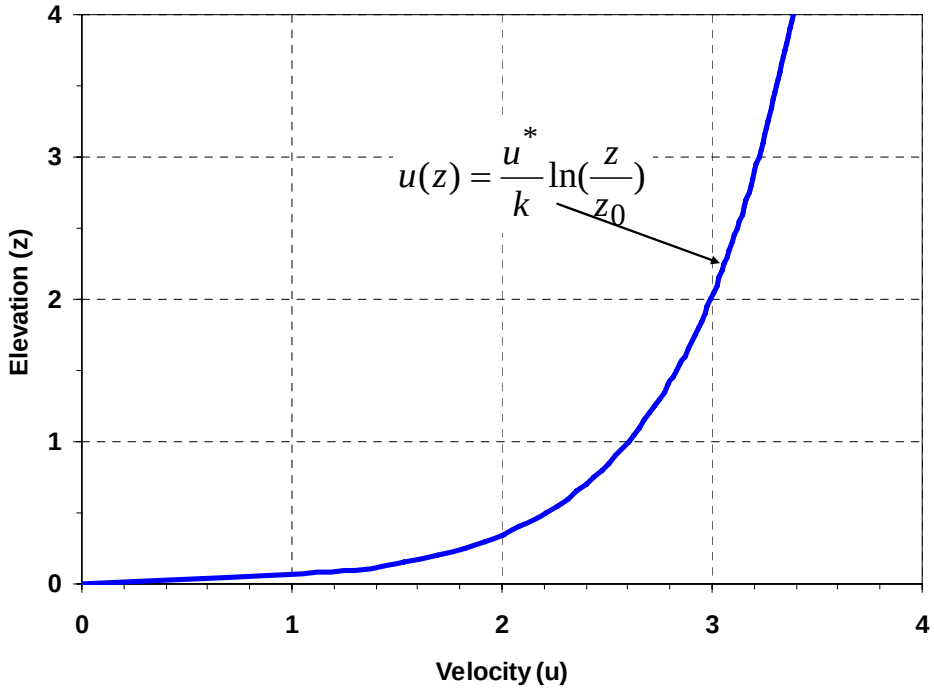
k **Von Karman constant**

z_0 **Roughness height**

$u^* = \sqrt{\tau_0 / \rho}$ **Shear velocity**

τ_0 **Wall shear stress**

$\frac{du}{dz} = \frac{u^*}{k}\frac{1}{z}$ **Velocity profile**



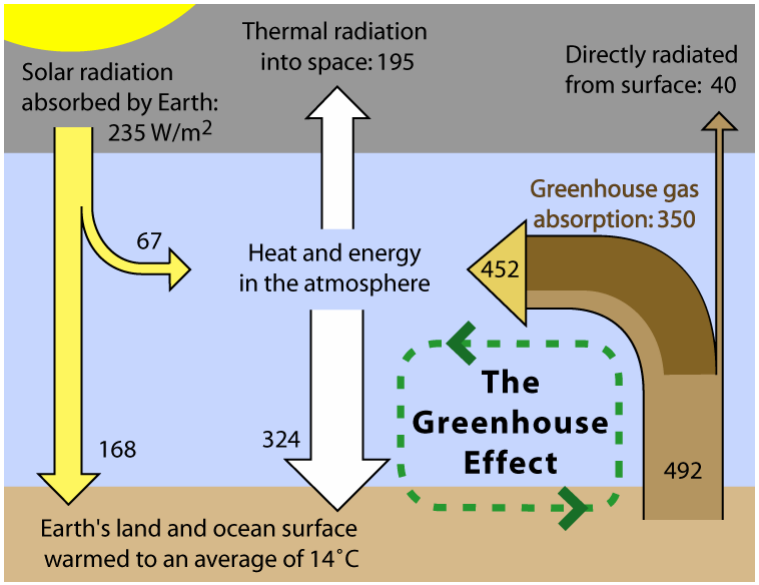
Radiation

- **Low** temperatures
  - Conduction and convection dominate
- **High** temperatures
  - Radiation dominates
- **Earth's** temperature (185 K to 311 K)
  - Balance between them
- **Solar constant** – radiation received on a plane at outer limit of atmosphere (1366 W/m^2)

Radiation

- Radiation loss in the atmosphere
  - **Reflection** (clouds, snow, ice, water, surfaces)
    - Albedo, makes clouds appear white
  - **Scattering** (molecules, particles), and
  - **Absorption** (molecules) – Atmosphere is transparent to shortwave, but H2O and CO2 absorb longwave reradiation
  - **Greehouse effect**, warms earth and provides energy for circulation of oceans and atmosphere

$$0 \leq \alpha = \frac{\text{Reflected}}{\text{Incident}} \leq 1$$

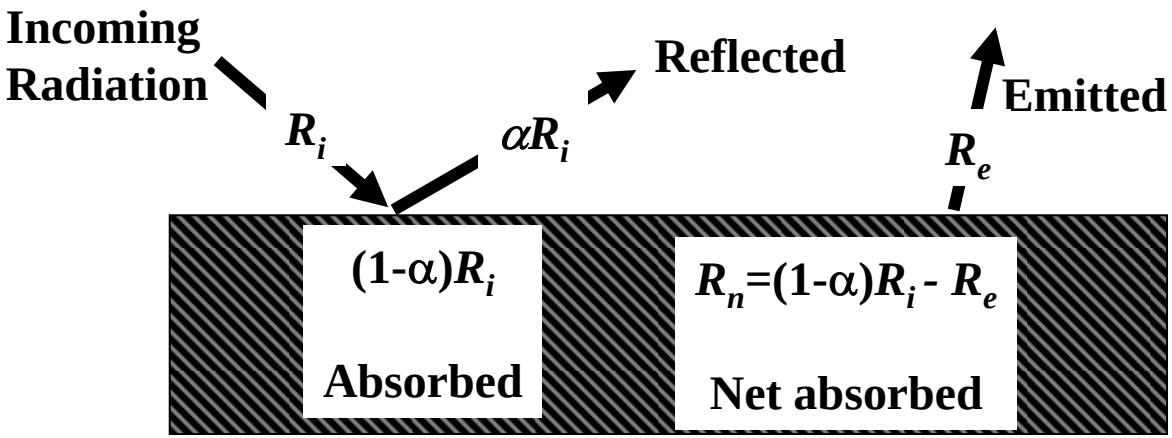


Radiation

- **Albedo**

Surface	Albedo
Water	0.03 – 0.4
White sand	0.34 – 0.4
Snow	0.4 – 0.85
Green grass	0.26
Top of Pine	0.14

- **Net radiation at surface (main source of energy for evaporation)**



Atmospheric Heat Balance