Water & Energy Fluxes & Budgets

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WATER BUDGET

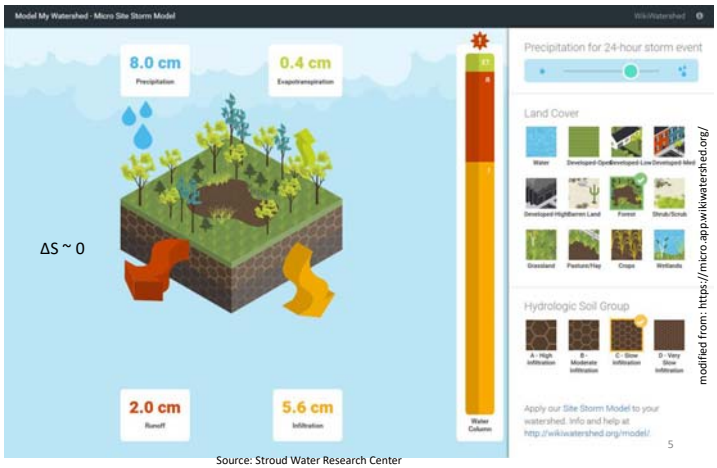
Watershed-scale Water Budget – Conservation of mass

- Ppt = ET + RO + Rchg + ΔS
- where:
  - Ppt, precipitation
  - ET, evapotranspiration
  - RO, runoff
  - Rchg, Recharge / Infiltration
  - ΔS, chg in storage (soil moisture)

How is precip. partitioned @ WS scale?

Watershed Schematic
© Jenny Parks, courtesy Southern Sierra Critical Zone Observatory

What factors affect this partitioning?

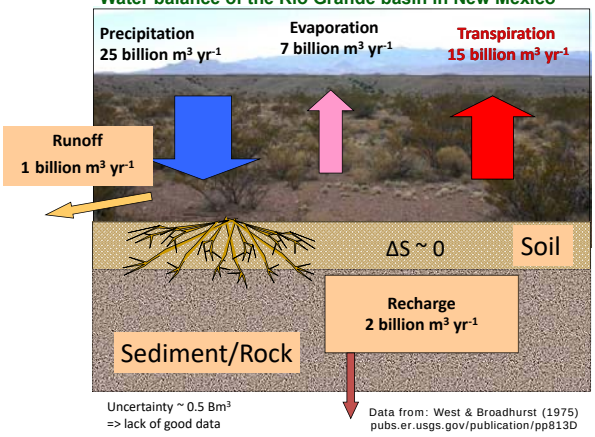


modified from: https://micro.app.wikiwatershed.org/

Source: Stroud Water Research Center

Surface Water Budget

Water balance of the Rio Grande basin in New Mexico

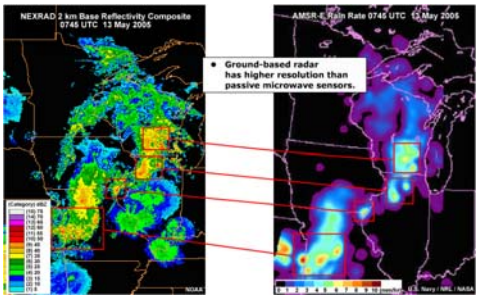


Uncertainty ~ 0.5 Bm³
=> lack of good data

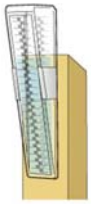
Data from: West & Broadhurst (1975)
pubs.er.usgs.gov/publication/pp813D

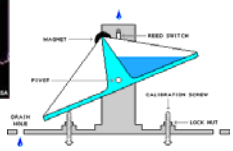
Precipitation

TruCheck Raingauge
rainlog.org/usprn/html/main/choosing-a-gauge.jsp
© 2014 Arizona Board of Reagents/SAHRA



radar vs. satellite





"Tipping bucket"

www.weathershack.com/
© 2002-2013

Runoff

P304 flume © USDA Forest Service / Pacific Southwest Research Station

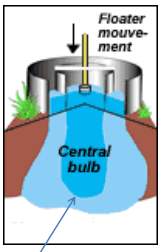
Marshall Gulch flume © CJ CZO

Valles flume © CJ CZO

"Source: http://criticalzone.org/catalina-jemez/infrastructure/field-areas-catalina-jemez/".

Infiltration / Recharge

Soil Physics, Public



recharge

ENERGY BUDGET

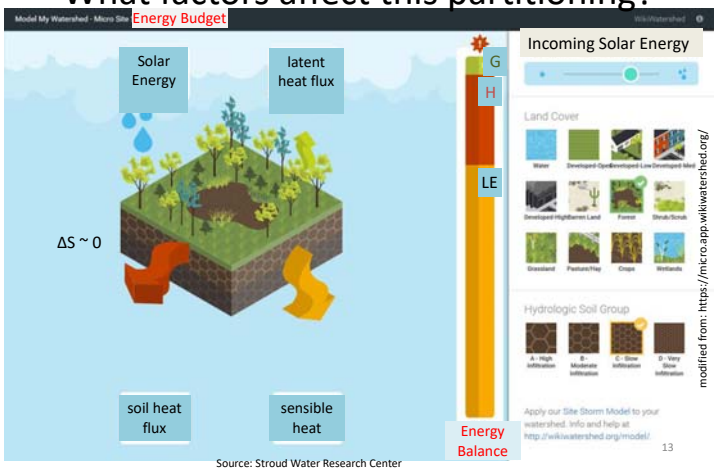
Energy Budget – Conservation of energy

- $R_n = \lambda E + H + G + \Delta S$
- where
  - R_n, Net Radiation
  - E, Evaporation
  - H, Sensible heat flux
  - G, Soil heat flux
  - ΔS, chg in heat storage (T_s, T_a)
  - λ, latent heat of evaporation, 2.45 MJ/kg

How is energy partitioned @ WS scale?

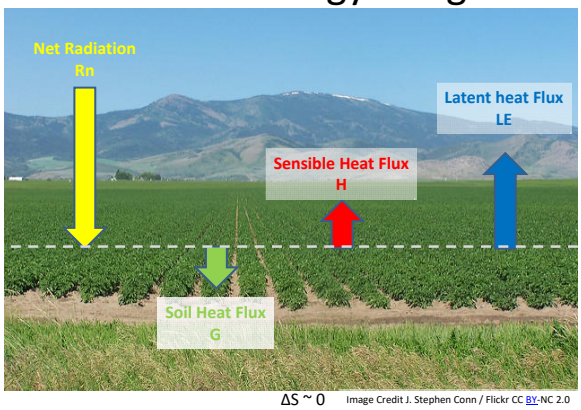
Watershed schematic – SSN CZO
© Jenny Parks, courtesy Southern Sierra Critical Zone Observatory

What factors affect this partitioning?



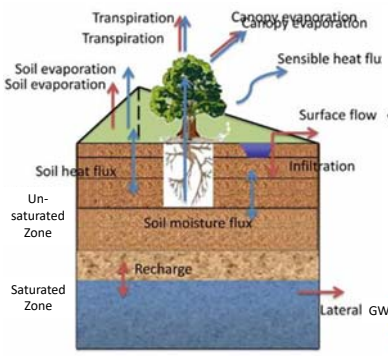
Source: Stroud Water Research Center

Surface Energy Budget

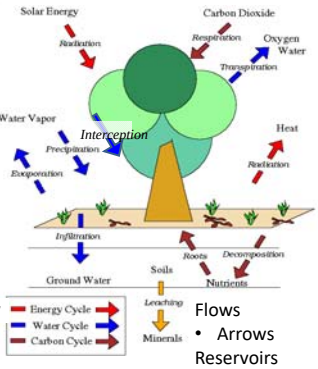


ΔS ~ 0 Image Credit J. Stephen Conn / Flickr CC BY-NC 2.0

Common Water & Energy Fluxes



Flux-PIHM model – SSH CZO
Source: http://criticalzone.org/shale-hills/models/conceptual-models-shale-hills/

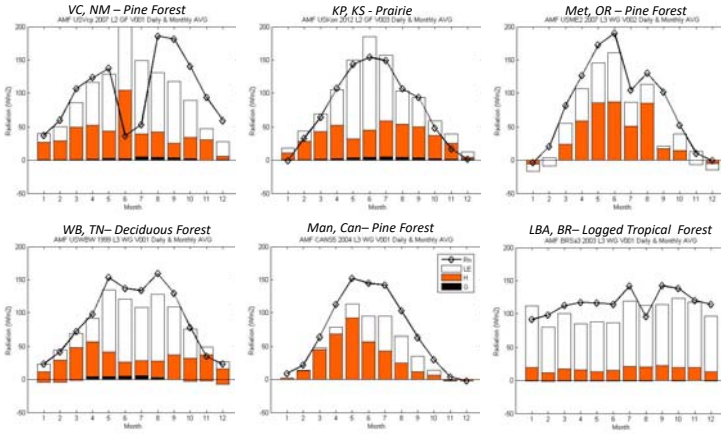


Washburne

Flows
- Arrows

Reservoirs
- Boxes

Activity-Monthly Ameriflux Energy Fluxes



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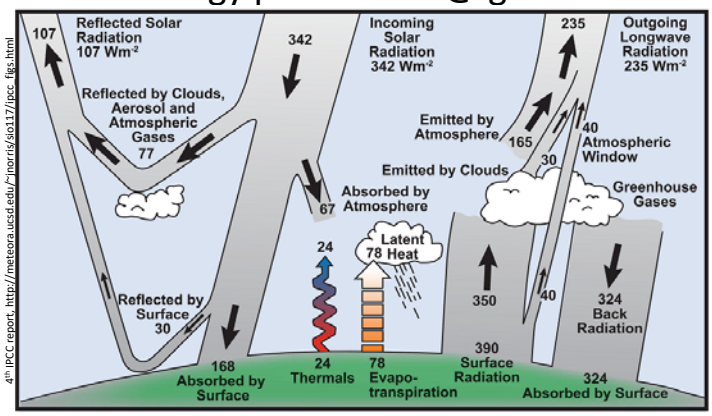
How is energy partitioned @ global scale?



4th IPCC report, http://meteora.ucsd.edu/~jnorris/sio117/ipcc_figs.html

FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

ENERGY BUDGET COMPONENTS & MEASUREMENTS

Net Radiation

- R_n = Net shortwave – Net longwave
- typically @ 0.3-3 um (visible) and 4.5-40 um (thermal)
- $R_n = (R_{s\downarrow} - R_{s\uparrow}) - (R_{L\downarrow} - R_{L\uparrow})$
- $R_n = R_{s\downarrow}(1-\alpha) - (R_{L\downarrow} - \varepsilon\, \sigma T_s^4)$
- where
  - α, surface albedo or reflectance: ratio of $R_{s\uparrow}$ over $R_{s\downarrow}$
  - ε, surface emissivity

Soil Heat Flux

- $G = -k\,\frac{T_{s1}-T_{s2}}{z_1-z_2}\,[\frac{W}{m^2}]$
- thermal conductivity (k) $[\frac{W}{m^oC}]$
- often assumed negligible at daily and longer times

Evaporation & Sensible Heat

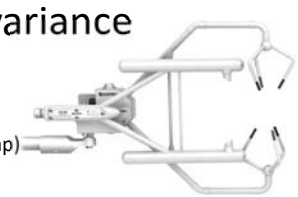
- Depends on Vapor pressure deficit,
- $\lambda E = \frac{\rho C_p}{\gamma}\,(e_s - e_a)/r_a\,[\frac{W}{m^2}]$
- Depends on Surface-Air temperature gradient
- $H = \rho C_p (T_s - T_a)/r_a\,[\frac{W}{m^2}]$
- where:
  - surface aerodynamic resistance, r_a [s/m] ~ $\frac{208}{u_2}$ (short crop)

Bowen Ratio

- manipulate these expressions to get:
- $R_n - G = \lambda E + H$
- divide by λE
- $\frac{R_n - G}{\lambda E} = 1 + \frac{H}{\lambda E}$
- Define the Bowen Ratio, $B = \frac{H}{\lambda E} = \gamma\,\frac{(T_s - T_a)}{(e_s - e_a)}$
- $\lambda E = \frac{R_n - G}{1+B}$

Image source: Hanson B, May D. 2006. New crop coefficients developed for high-yield processing tomatoes. Calif Agr 60(2):95-99. DOI: 10.3733/ca.v060n02p95. Figure 1

Eddy Covariance



Premise:
- w(t) = <w> + w' (wind)
- s(t) = <s> + s' (carbon, Temp)

Main eddy covariance assumption:
- Mean vertical velocity = 0

But, instantaneous vertical velocity ≠ 0:
- w(t) = w'

Measure:
- Vertical Velocity Fluctuation (w')
- CO_2 and Temp Fluctuation (s')

Correlate Fluctuations:
- <w's'>

Li-Cor, 2013