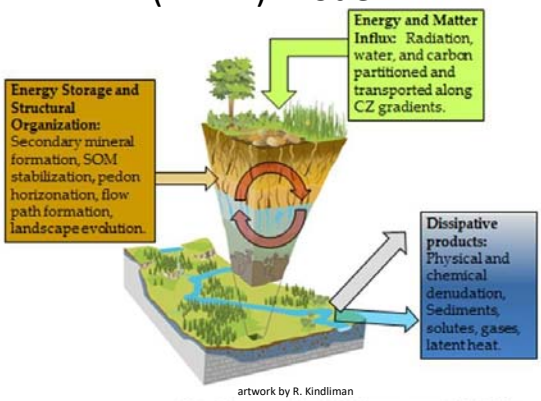
Water & Energy Fluxes – Integrative Concepts:
Effective Energy & Mass Transfer Eq.

Critical Zone Science
InTeGrate Teaching Team
(Washburne)

Effective Energy & Mass Transfer (EEMT) Model



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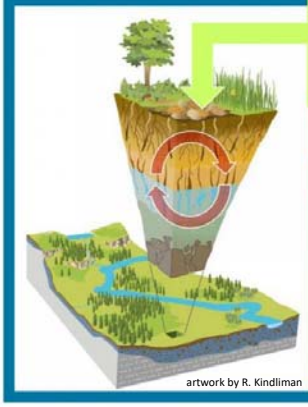
After Chorover et al., 2007; Rasmussen et al., 2010

Modified from: http://criticalzone.org/catalina-jemez/models/model details/environmental-energy-and-mass-transfer/

Energy inputs considered in the EEMT model derive from water and carbon influx to the CZ



$$EEMT = E_{PPT} + E_{BIO}$$
$$E_{PPT} = F_w \cdot \Delta T \cdot c_w$$
$$E_{BIO} = F_{OC} \cdot h_{bio}$$

Climatic and co-varying biotic forcings are incorporated into a single predictive energy flux parameter with units kJ m^{-2} s^{-1} (or kW m^{-2})

Rasmussen et al. 2011. **An open system framework for integrating critical zone structure and function.** *Biogeochemistry* **102**, 15-29.

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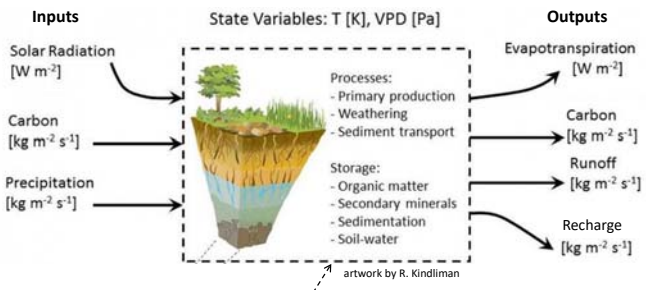

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Balance Equations	Energy Uses
$Rn \rightarrow \lambda E + H + G + \Delta S_H (\Delta T_s) + \lambda bio$	Latent heat changes
$Ppt \rightarrow ET + RO + Rchg + \Delta S_m (\Delta SM) + bio$	Warming rain
$CO_2 \rightarrow GPP \rightarrow Re + \Delta S_C (\Delta NEP)$	Driving photosynthesis

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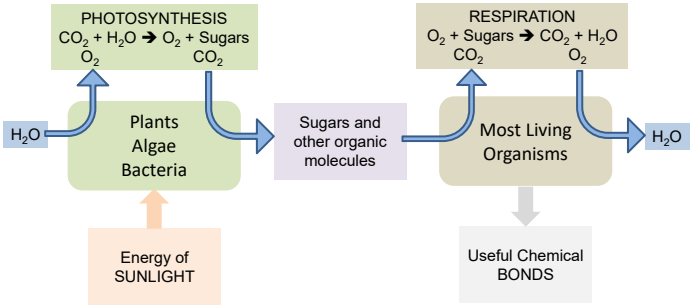
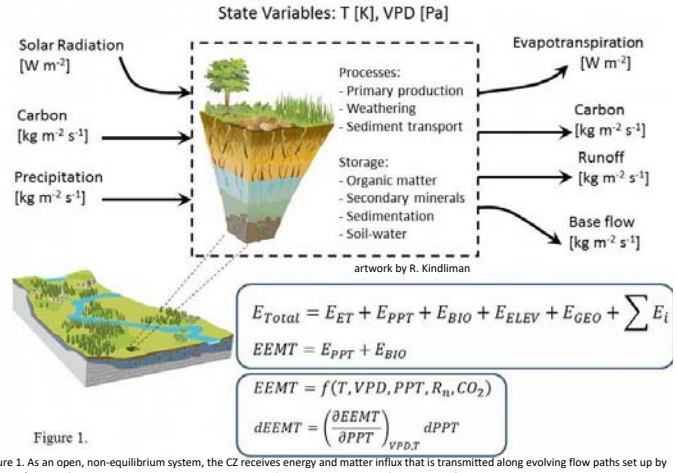
The Plant Carbon Cycle



redrawn from Figure 3-10 Essential Cell Biology 2/e, Garland Science, 2004



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$$E_{Total} = E_{ET} + E_{PPT} + E_{BIO} + E_{ELEV} + E_{GEO} + \sum E_i$$
$$EEMT = E_{PPT} + E_{BIO}$$
$$EEMT = f(T, VPD, PPT, R_n, CO_2)$$
$$dEEMT = \left(\frac{\partial EEMT}{\partial PPT}\right)_{VPD,T} dPPT$$

Figure 1. As an open, non-equilibrium system, the CZ receives energy and matter influx that is transmitted along evolving flow paths set up by tectonic/climatic forcing and subjected to internal gradients (Rasmussen et al., 2010). Evolution of internal structure is driven by system entropy dissipation in the form of water, heat and biogeochemical products of CZ erosion and weathering (sediments, solutes, and trace gases).

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Example Calculation

- Let ΔT=20 ^oK, F_{ppt}=500 mm, c_w=0.00418 MJ/kg/^oK

$$E_{ppt} = \Delta T * F_{ppt} * c_w$$

$$= 20^oK * 500\ \frac{mm}{yr} * \frac{m}{1000\ mm} * 1000\frac{kg}{m^3} * 0.00418\frac{MJ}{Kg-^oK}$$

$$= 41.8\frac{MJ}{m^2 - yr}$$

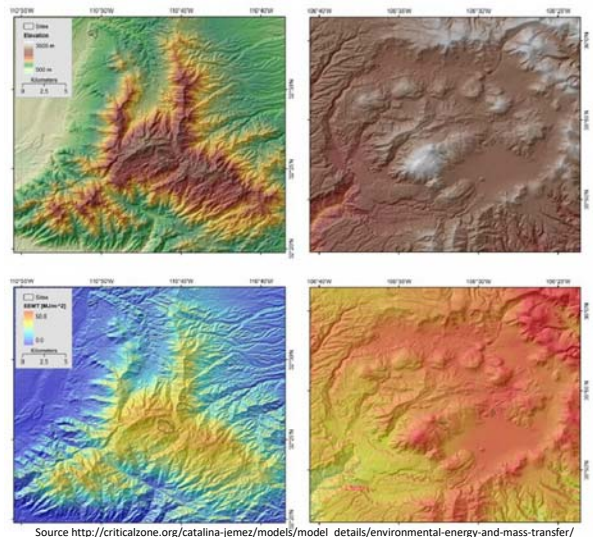
- Let F_{oc}=500 g/m^2/yr, h_{bio}=22 MJ/kg

$$E_{bio} = F_{oc} * h_{bio}$$

$$500\ \frac{g}{m^2 - yr} * \frac{kg}{1000\ g} * 22\frac{MJ}{Kg} = 11\frac{MJ}{m^2 - yr}$$

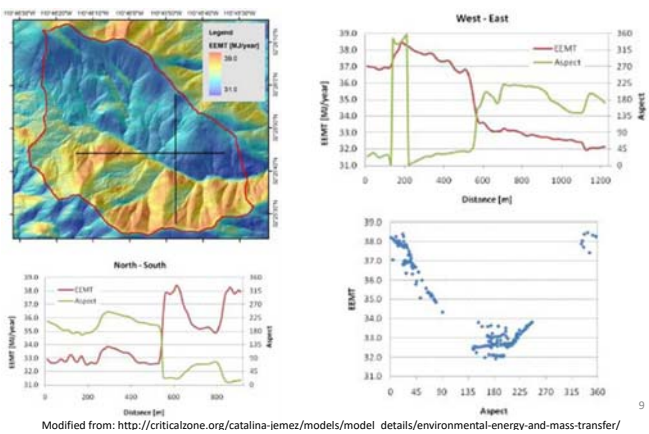
- EEMT = E_{ppt} + E_{bio} = 42 + 11

$$53\ \frac{MJ}{m^2 - yr} * \frac{yr}{31.54\ Ms} = 1.68\ \frac{W}{m^2}$$



Source http://criticalzone.org/catalina-jemez/models/model details/environmental-energy-and-mass-transfer/

EEMT – CJCZO site



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