Modeling the Flux Processes over Sparse Vegetation
Influences of Dead Leaves on Energy Partition in Shuttleworth-Wallace Approach

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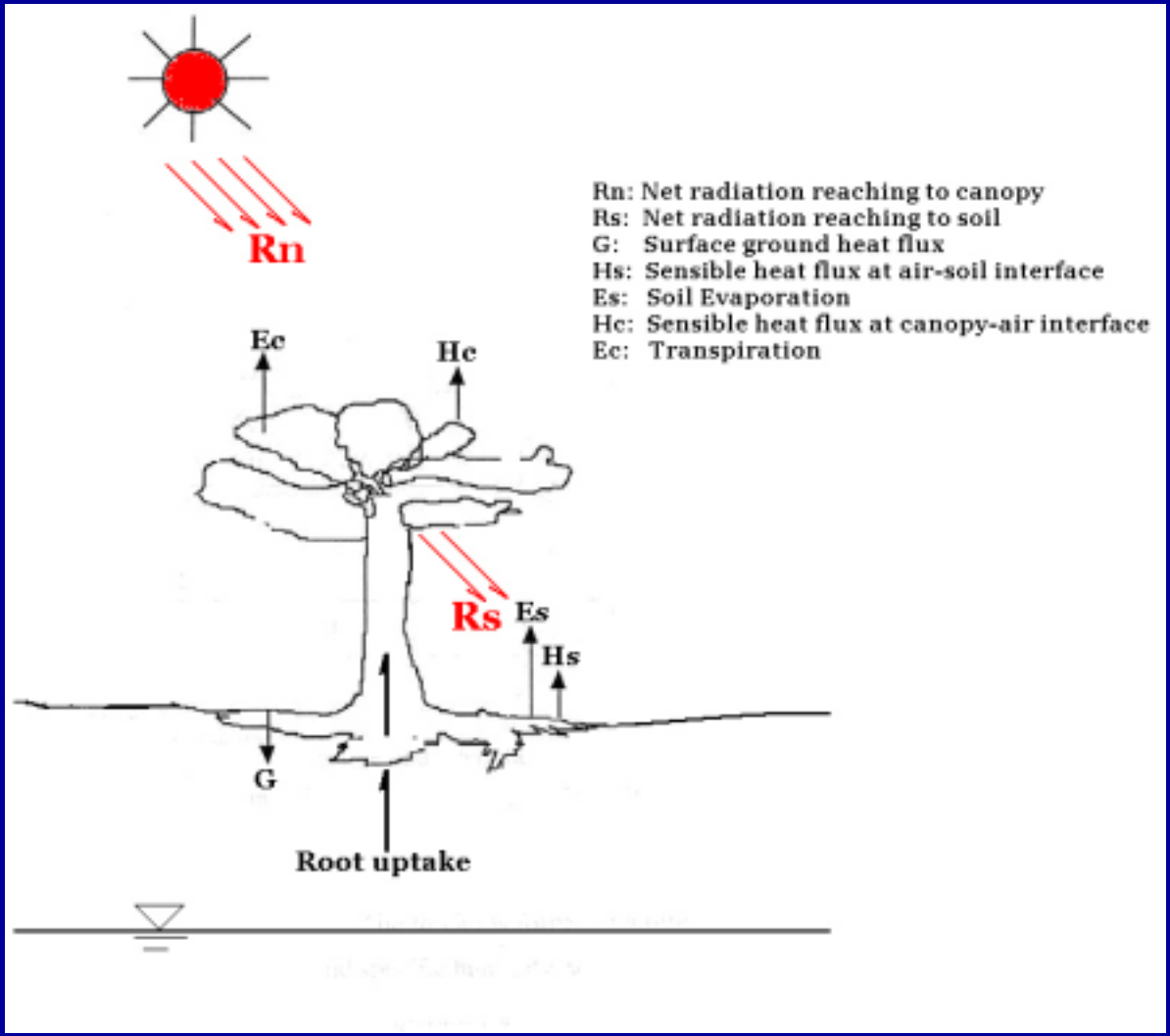
Problem Definition

Water vapor flux estimation is always an important issue in studies of hydrology, micrometeorology, and etc

Lots of approaches have been put forwarded and used. Penman-Monteith and Shuttle-Wallace (S-W) approaches are the most popular ones for their simplicity and good performance.

Problem Definition



Penman-Monteith:

Big leaf model, estimating the soil evaporation and canopy transpiration as a whole

Shuttleworth-Wallace:

Two-layer model, dealing with the soil evaporation and canopy transpiration seperately

Problem Definition

Shuttleworth-Wallace approach is a two-layers model that can distinguish the soil evaporation and vegetation transpiration from the total evapotranspiration.

However, in energy partition between the canopy and soil surface, the influence of dead leaves that remain on vegetation stand is not included in the current approach.

Problem Definition

Therefore, how to incorporate the impacts of the dead leaves in energy partition remains to be investigated.

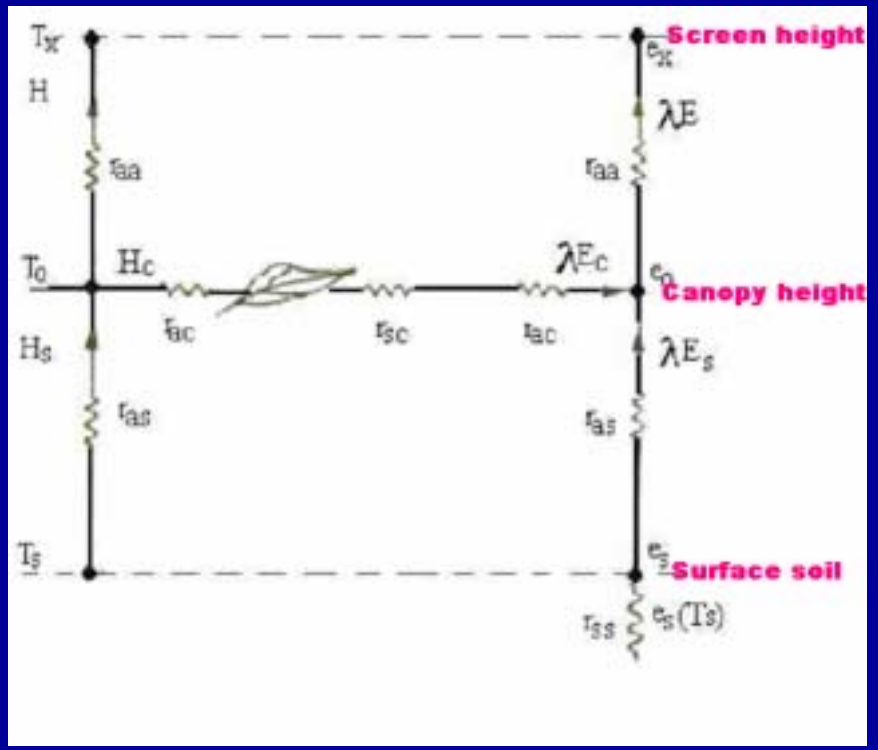
Theoretical Considerations

Radiation partition
in Shuttleworth-Wallace Approach

Theoretical Considerations

Shuttleworth-Wallace Approach

S-W approach partitions the net radiation between the canopy and soil, and and estimate the soil evaporation and canopy transpiration separately well in an integrated frame.



Theoretical Considerations

Net radiation partition among latent heat, sensible heat and ground heat flux:

Canopy energy balance

$$R_n - R_s = \lambda T_r + H_c \quad (2)$$

Soil surface energy balance

$$R_s = \lambda E_s + H_s - G \quad (3)$$

Radiation extinction in canopy

$$R_s = R_n \exp(-\kappa LAI) \quad (4)$$

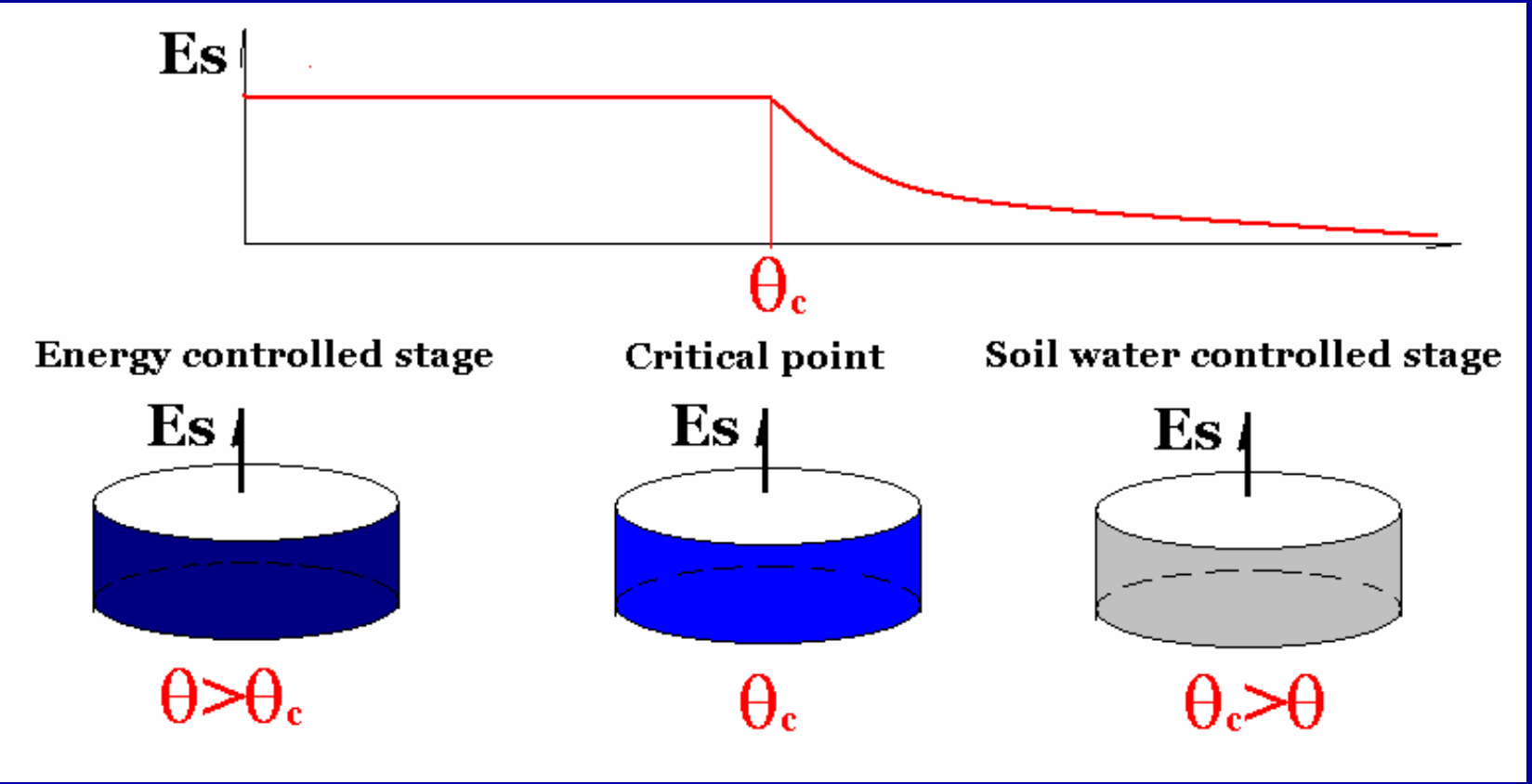
Theoretical Considerations

Es and Tr can be derived from:

$$PM_c = \frac{\Delta(R_n - G) + [\rho C_p D - \Delta r_{ac}(R_{ns} - G)] / (r_{aa} + r_{ac})}{\Delta + \gamma(1 + \frac{r_{sc}}{r_{aa} + r_{ac}})} \quad (5)$$

$$PM_s = \frac{\Delta(R_n - G) + [\rho C_p D - \Delta r_{as}(R_n - R_{ns})] / (r_{aa} + r_{as})}{\Delta + \gamma(1 + \frac{r_{ss}}{r_{aa} + r_{as}})} \quad (6)$$

Theoretical Considerations

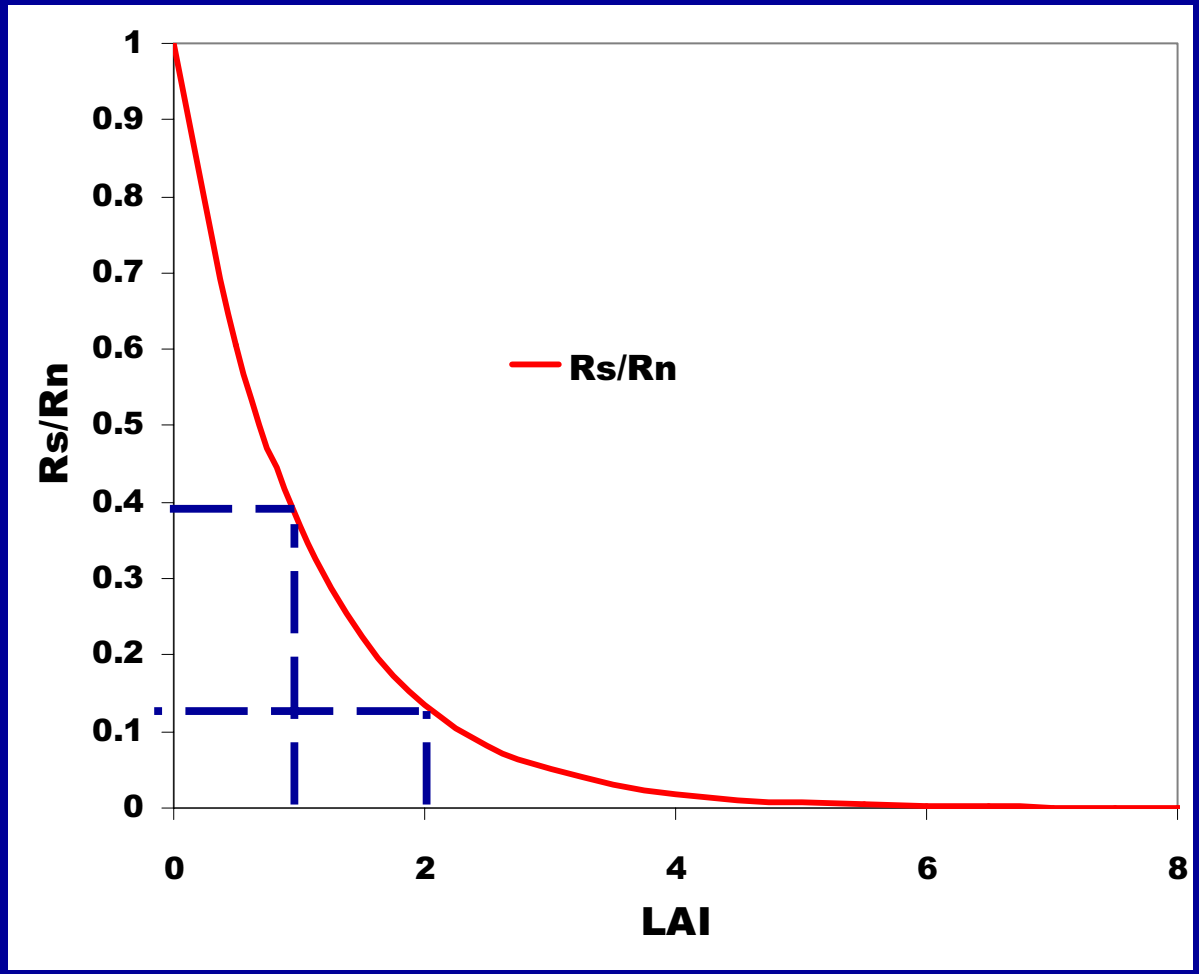


Evaporation density is controlled by the received radiation Rs and surface soil content θ. Es decreases with surface soil water content depletion

Theoretical Considerations

Consideration of the dead leaves influence on radiation partition

Theoretical Considerations

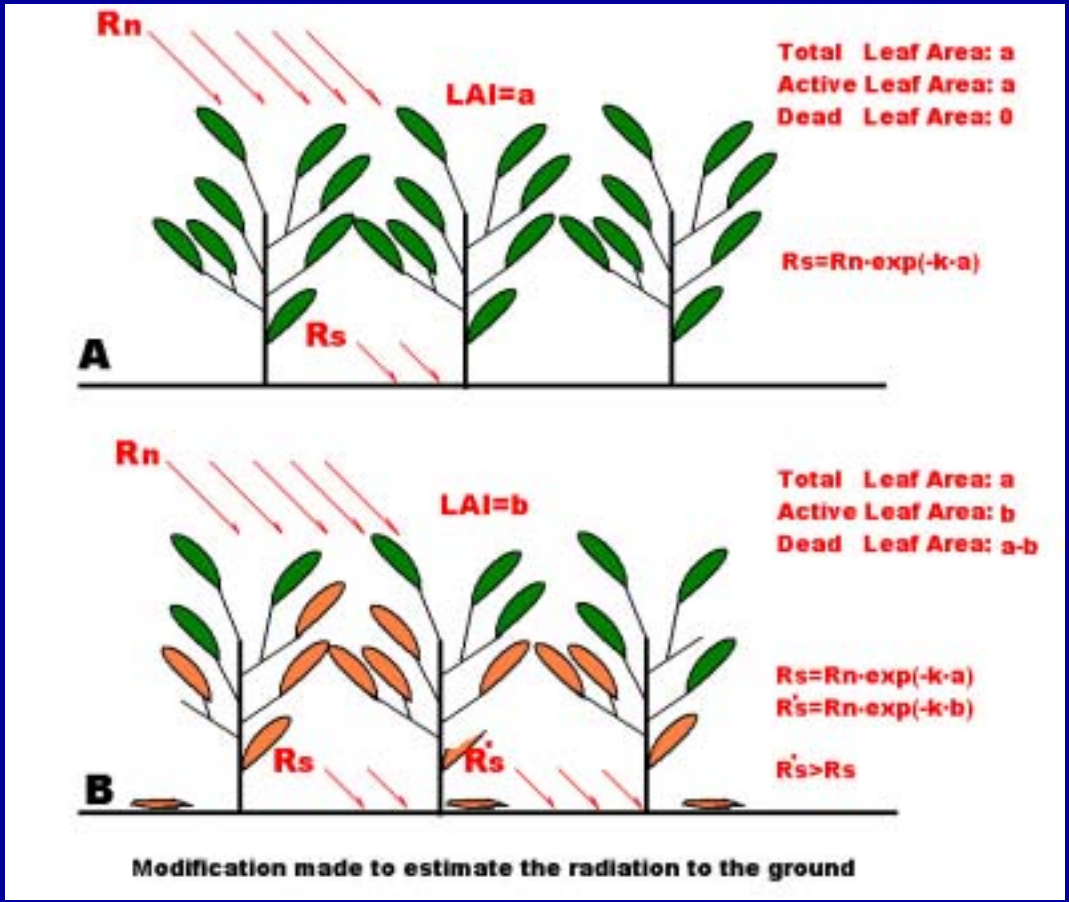


Beer's Law

$$R_s = R_n \exp(-\kappa LAI)$$

Less radiation goes through the denser canopy

Theoretical Considerations



Modification made to estimate the radiation to the ground

$$R_s = R_n \exp(-\kappa a)$$

$$R_s' = R_n \exp(-\kappa b)$$

$$a > b \Rightarrow R_s' > R_s$$

Radiation to soil can be overestimated in the Shuttleworth-Wallace approach in the LAI falling stage

Theoretical Considerations

Assume the peak value of LAI is a; the active LAI is b and the dead leaves LAI is c sometime during the LAI falling stage. Then radiation reaching to soil can be estimated as:

$$R_s = R_n \exp[-\kappa(b + c)] \qquad (7)$$

Theoretical Considerations

If the dead leaves LAI c is unknown, then the radiation reaching to soil can be approximately estimated as:

$$R_s = R_n \exp[-\kappa a] \qquad (8)$$

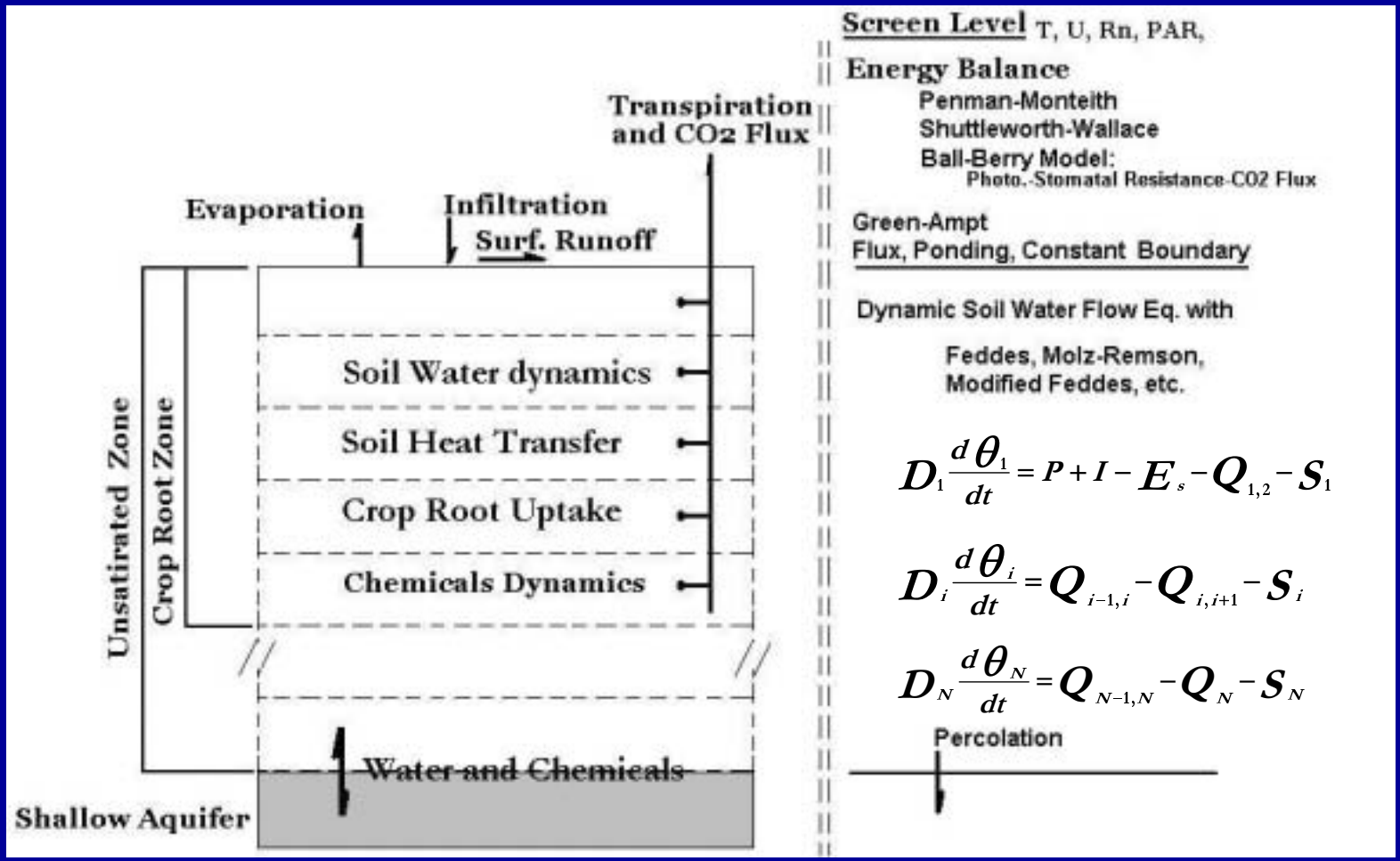
Since part of the dead leaves may leave the stand and fall down to the ground, equation (8) may underestimate the Rs.

Considering the mulching effect of the pitfall, the underestimation may be balanced by the mulching effect to some extent

Theoretical Considerations

Incorporating the modified S-W approach into the Crop and Soil system model-CropS

Theoretical Considerations



$$D_1 \frac{d\theta_1}{dt} = P + I - E_s - Q_{1,2} - S_1$$

$$D_i \frac{d\theta_i}{dt} = Q_{i-1,i} - Q_{i,i+1} - S_i$$

$$D_N \frac{d\theta_N}{dt} = Q_{N-1,N} - Q_N - S_N$$

CropS model

Results and Discussion

Data prepared for the CropS model

Results and Discussion

Data from APEIS site

Soil

water content, potential parameters, temp. ground heat flux

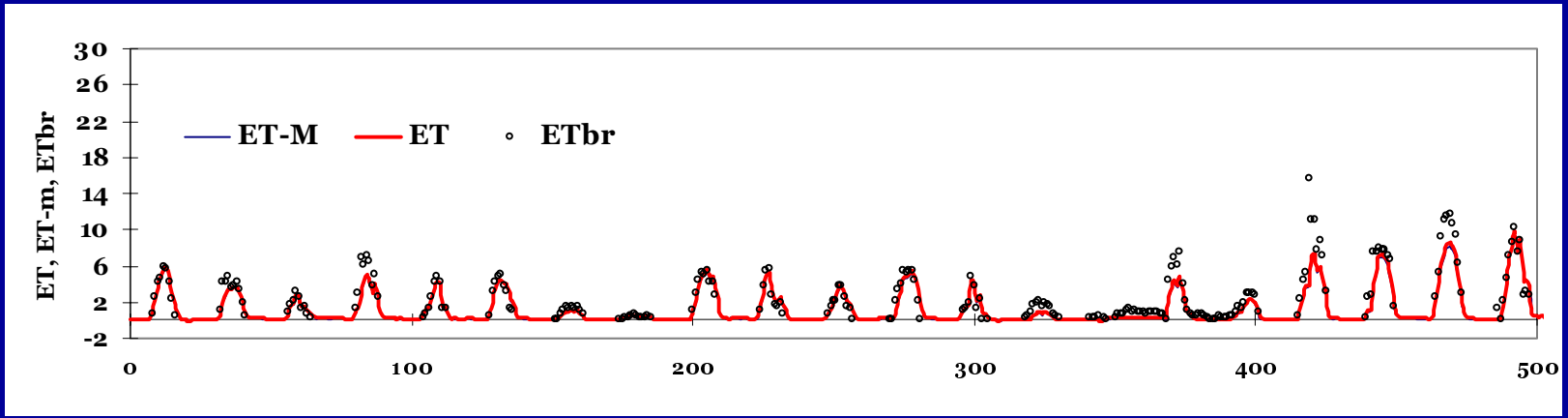
Crop

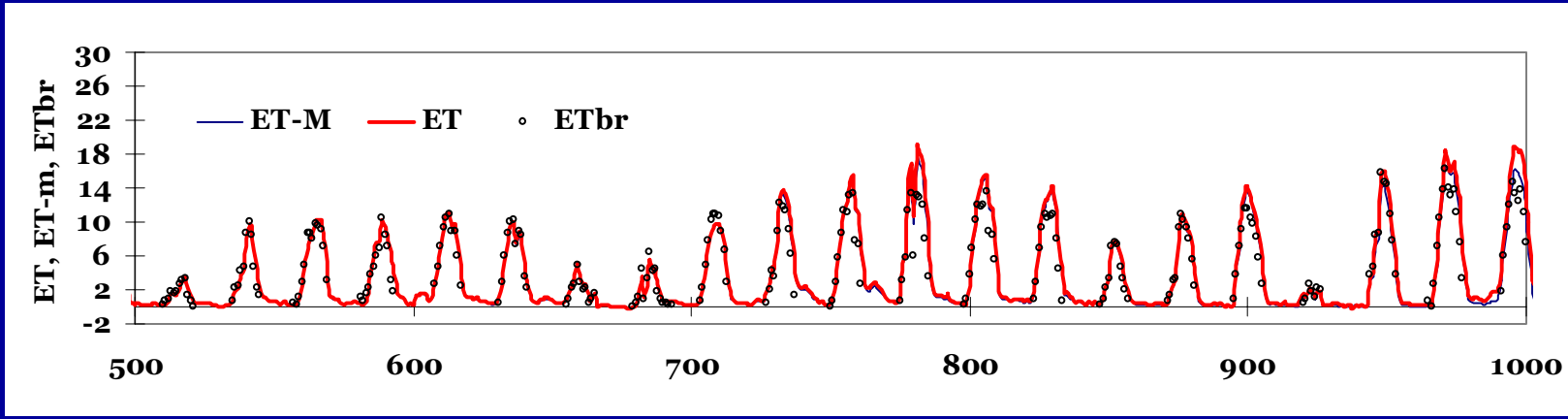
height, lai, leaf stomata resistance and photosynthesis

Meteorology

air temp., radiation, wind velocity and vapor fluxes

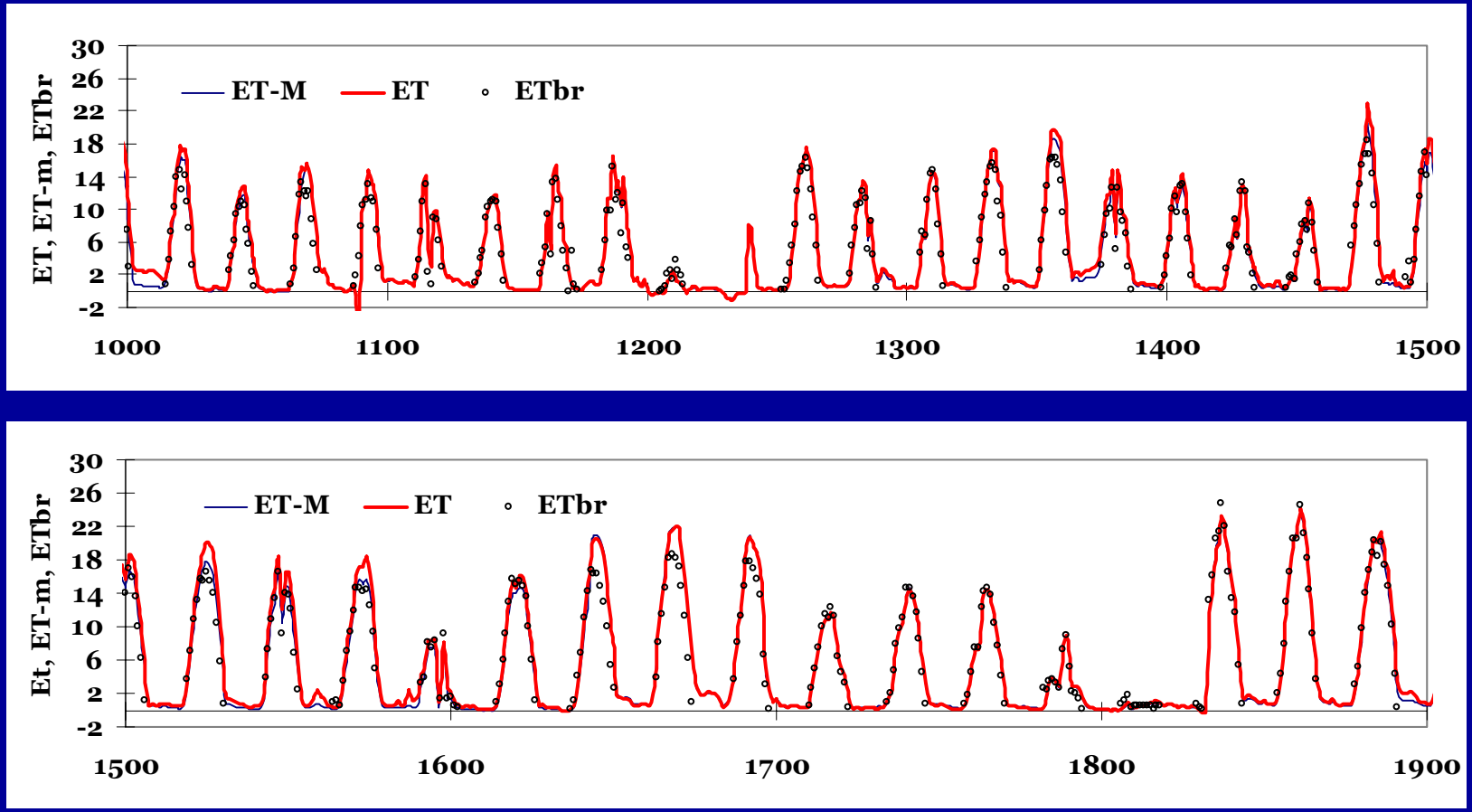
Results and Discussion





Diurnal process of ET given by S-W and its modified form, and that measured with Bowen Ratio System

Results and Discussion



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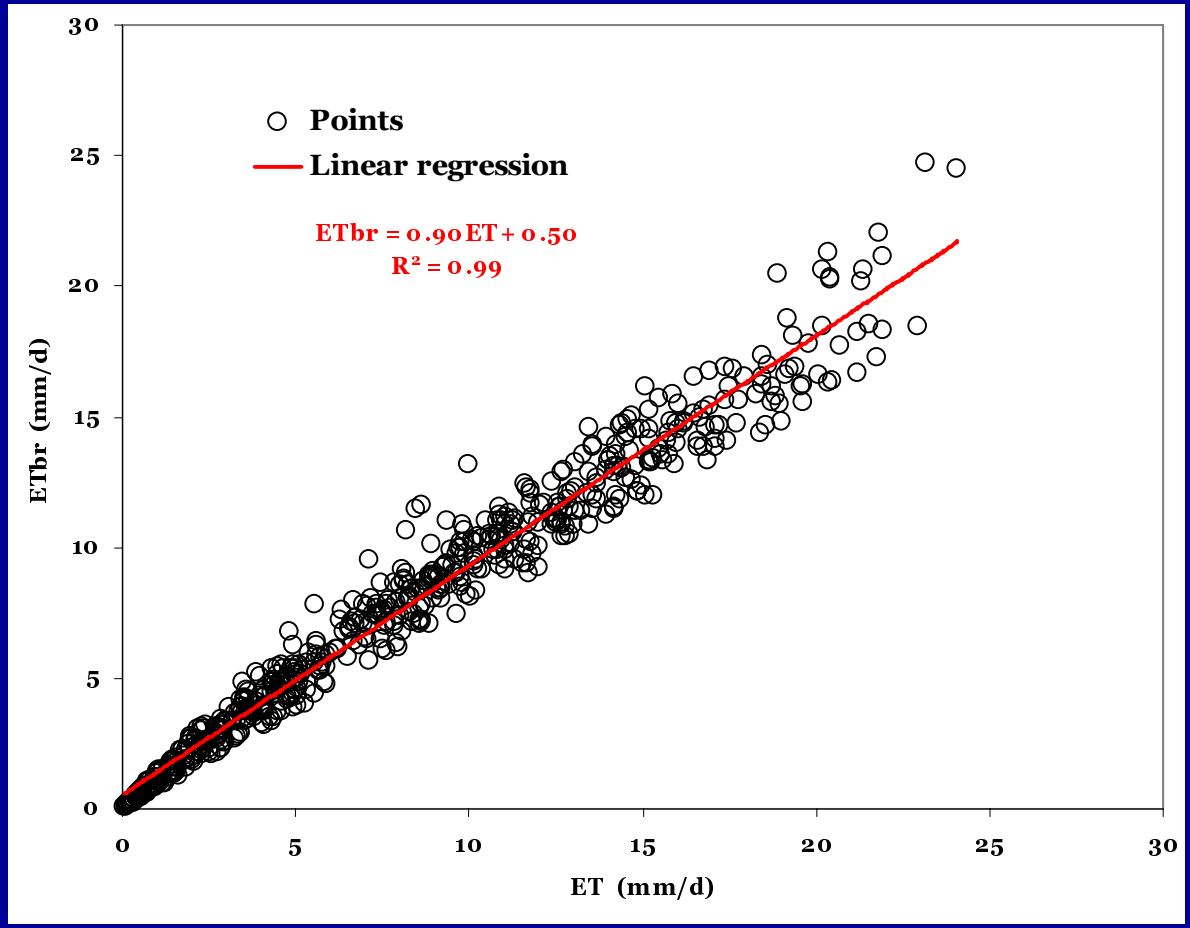
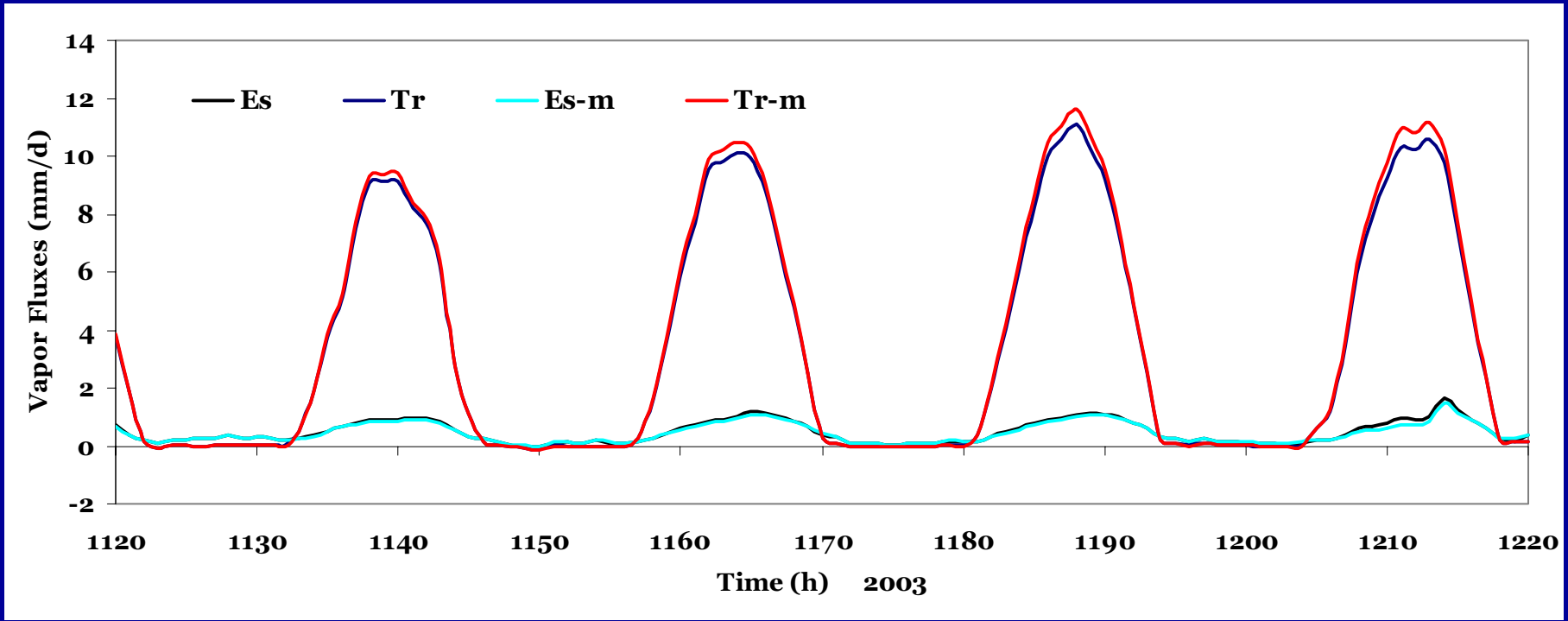


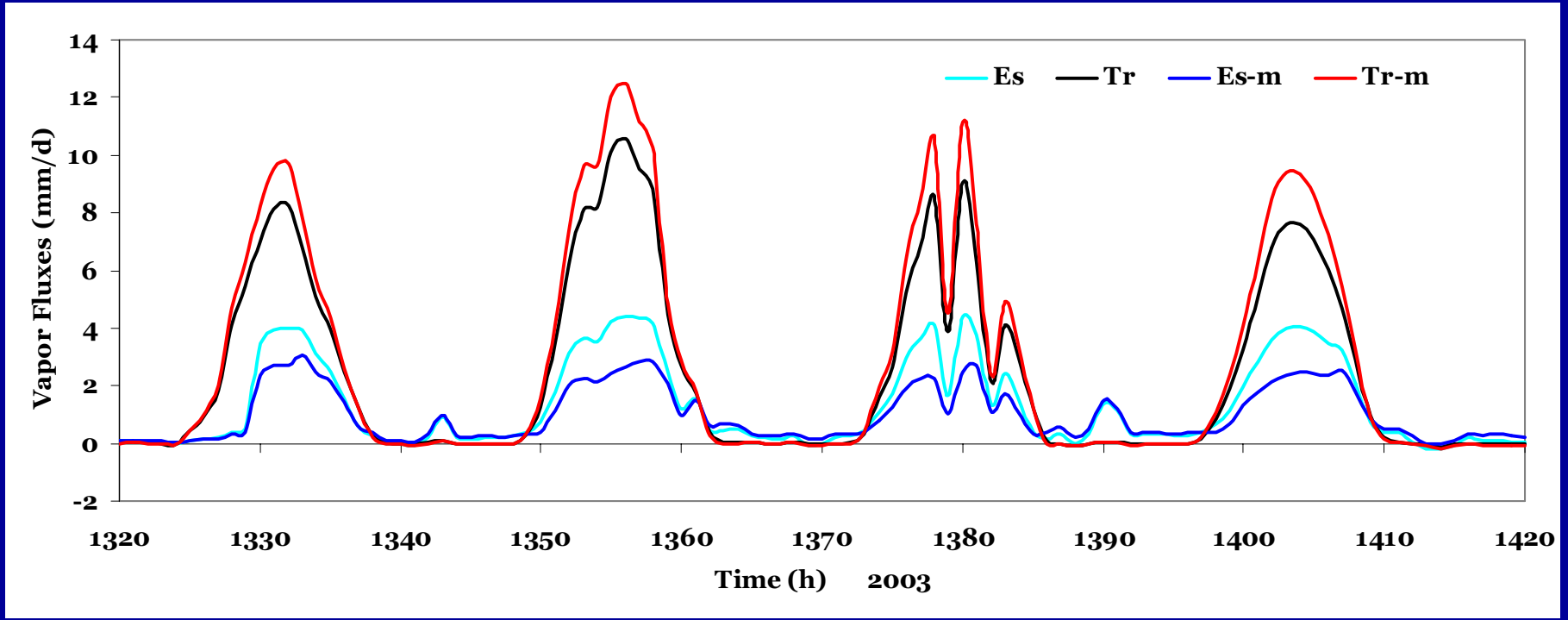
Regression analysis of ET estimated with S-W approach and that measured with Bowen Ratio System

Results and Discussion



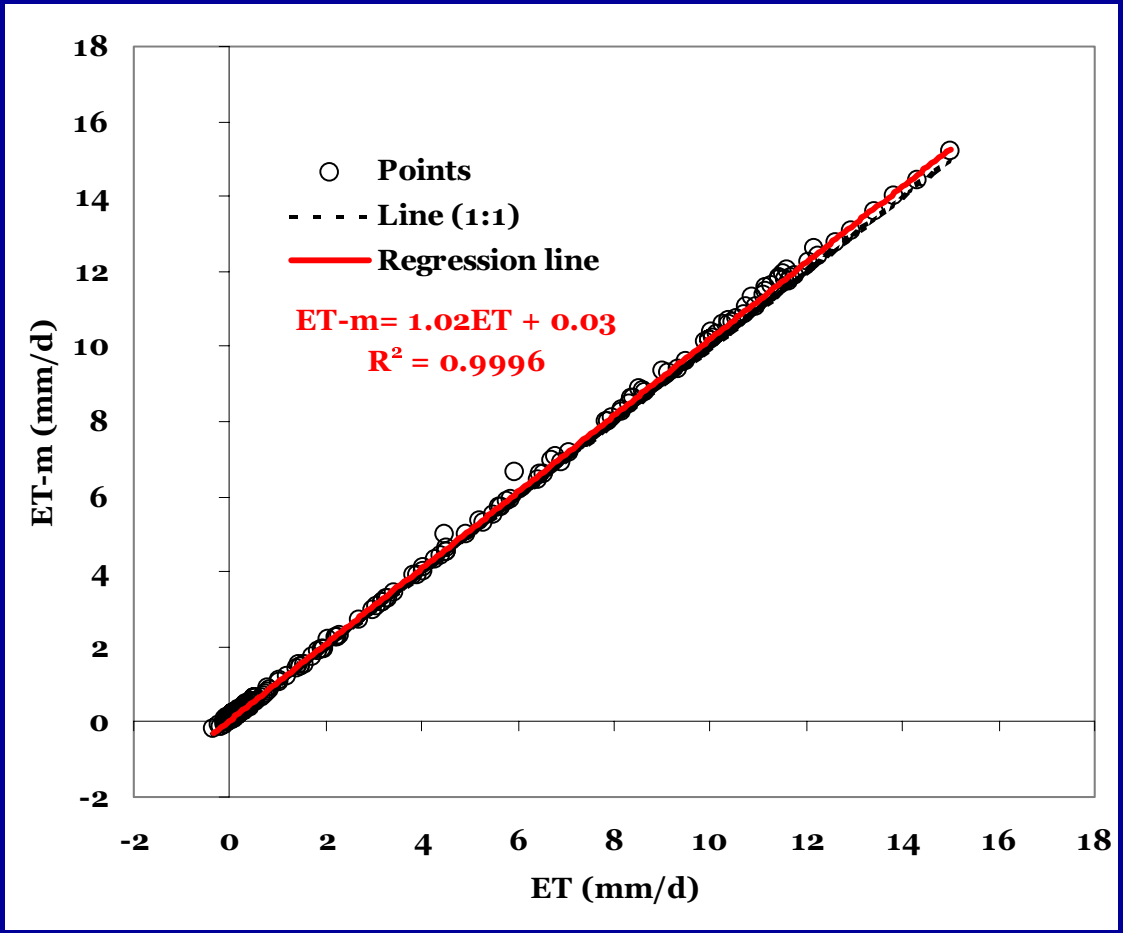
Soil water controlled evaporation process

Results and Discussion



Radiation energy controlled evaporation process

Results and Discussion



Regression analysis of the ET given by S-W approach and the modified one

Concluding Remarks

1. S-W approach performs very well in modeling total vapor flux for both the sparse and dense vegetation.

2. The dead leaves remaining on stand pose impacts to the energy partition between the canopy and soil surface. The original S-W partition scheme may overestimate the radiation reaching to soil.

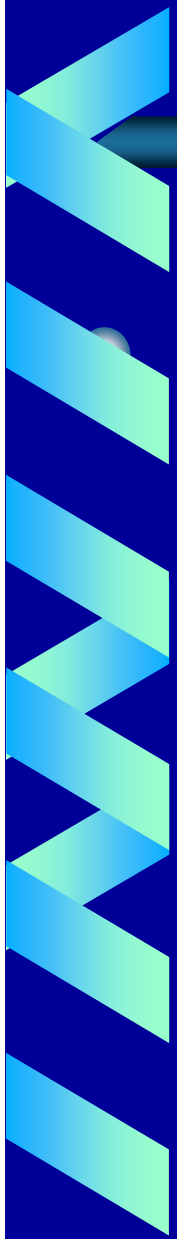
3. The overestimated radiation reaching to soil may cause overestimation of soil evaporation in case the evaporation is energy-controlled. In case of the soil water controlled evaporation, the overestimation may not be obvious.

4. No obvious difference was found between the ET given by S-W and the modified form in the case study .

Concluding Remarks

5. It is needed to obtain the field data of soil evaporation, canopy transpiration, and dead leave LAI to validate the modified scheme

6. How to partition the radiation between the active and dead leaf canopy remains to be investigated further



Thanks!