Evapotranspiration partitioning in a semiarid shrubland and its relation to spring precipitation

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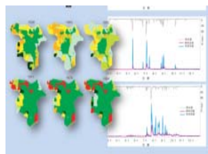


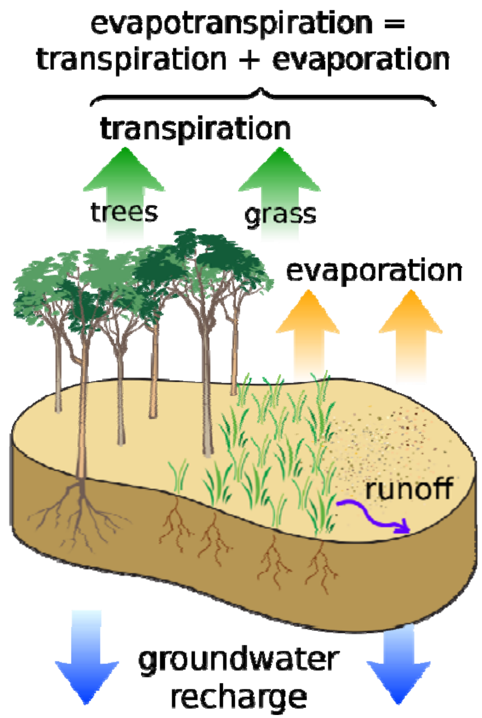
1 Background

ET partitioning and its relationship to climate

- Evapotranspiration (ET) partitioning is of great importance in understanding the interaction of water and carbon cycles.

- Climate, especially precipitation, exert profound impact on ET partitioning.

- More efforts need to paid to the effect of precipitation on ET partitioning with regard to different vegetation types and different climate (Scott et al., 2006).



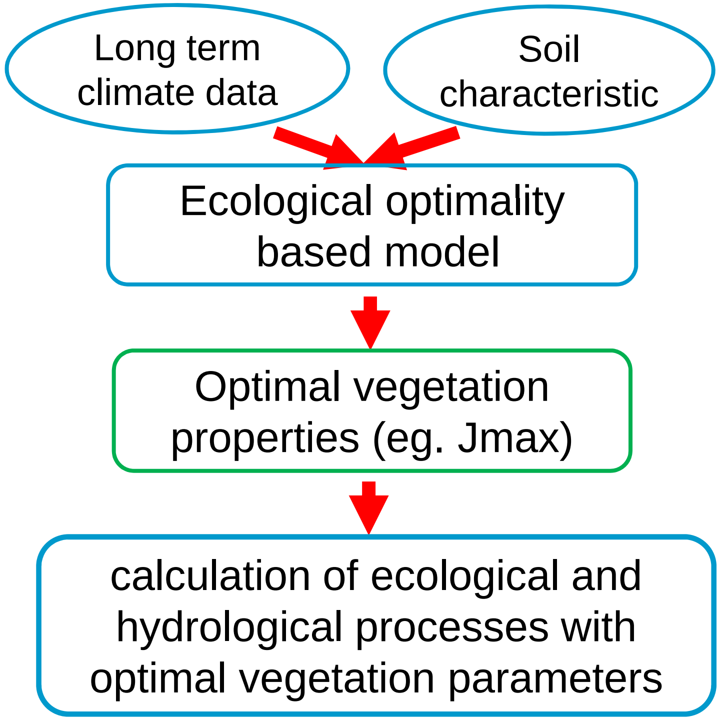
(https://en.wikipedia.org/wiki/Evapotranspiration)

1 Background

Method of ET partitioning

- **Traditional model**
  - Treat ET as if it is a physical process controlled by energy, vapor pressure, etc.
  - High parameterization requirement.

- **Models based on optimality**



Advantages

More realistic

Less parameter requirement

Problems

Still at the very outset, requires to examine in more conditions and more ecosystems

1 Background

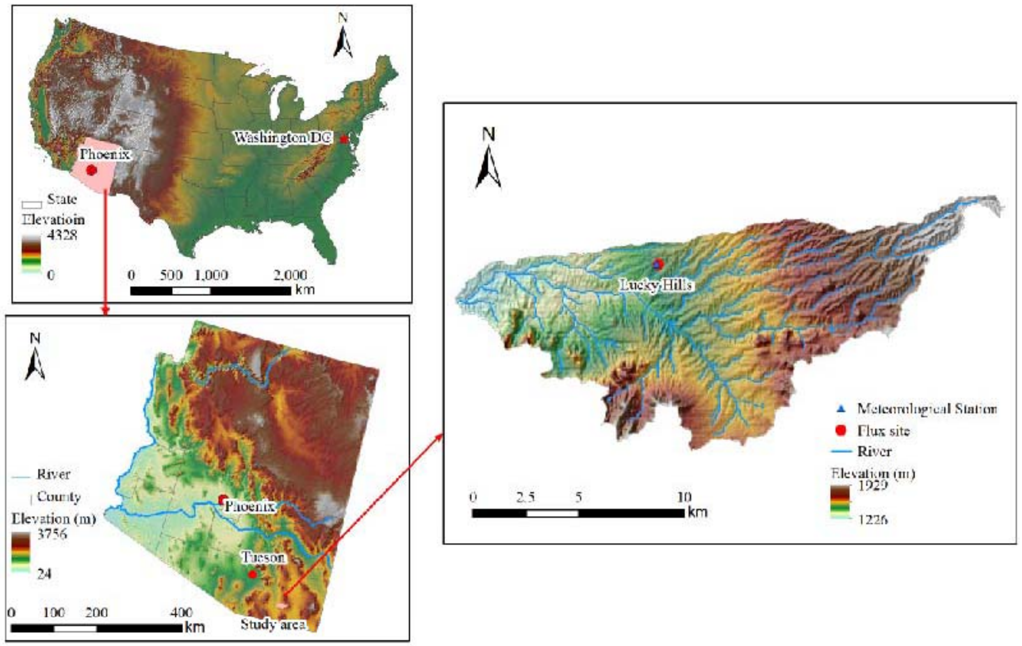
❖ Aim of this study

- To better understand the response of evaporation and transpiration to climate characteristics.

- To test ecological-optimality based models for ET partitioning.

❖ Study area

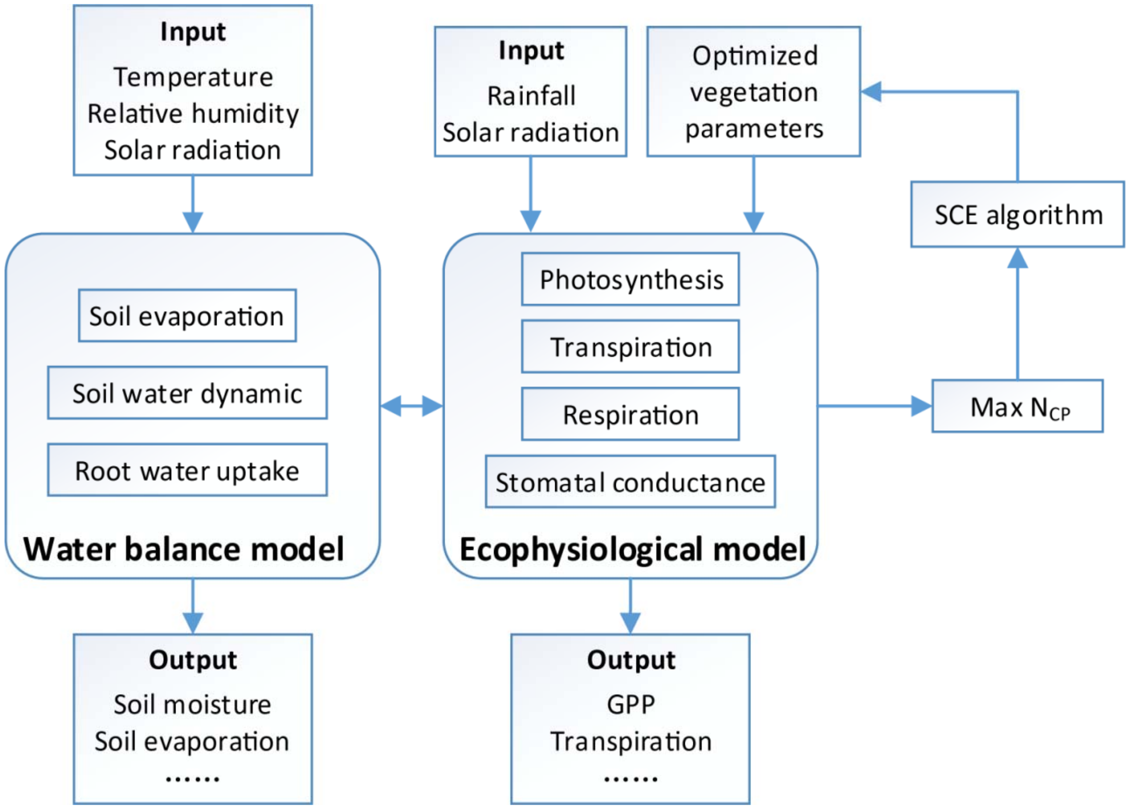
- **Lucky Hills site**
  - USDA-ARS WGEW in southeastern Arizona
  - Climate: Typical semiarid
    - ➢ Cool winters, warm summers with annual temperature: 17 ℃
    - ➢ Low precipitation with annual value of 356 mm.
  - Elevation:1372 m with slopes ranged from 3% to 8%
  - Vegetation: Shrub



2 | Methodology

❖ Optimality-based ecohydrological model (VOM)

- VOM (Schymanski et al, 2009) coupled a multilayered physically based water balance model and an ecophysiological gas exchange model



2 Methodology

VOM theory basis

Optimization strategy: Max Net Carbon Profit for long term

$$NCP = A_g - R_f - R_r - R_v$$

Where, A_g is the combined CO_2 uptake by trees and grasses , R_f is the foliage costs of grasses and trees combined, R_r is the root cost of grasses and trees combined, R_v is the cost associated with the vascular systems of grasses and trees combined.

Optimal stomata: the slope of CO_2 uptake and transpiration is maintained constant.

$$\lambda = \frac{\partial E_t}{\partial A_g}$$

Where, A_g is is the combined CO_2 uptake by trees and grasses, E_t is transpiration .

2 Methodology

VOM description-optimized vegetation parameters

Long term optimization

Vegetation properties adapted to long-term environment, optimized by SCE optimization for the whole simulation.

Daily optimization

Vegetation properties adapted in short-term environment, optimized each day based on the condition on previous day.

Vegetation parameters optimized (Schymanski et al., 2009)

	Vegetation Parameters	Time Scale
Long-term vegetation parameters	Fraction of area covered by perennial vegetation ($M_{A,p}$)	Constant over entire simulation period
	Thickness of root zone of perennial vegetation($y_{r,p}$)	
	Water use parameters of perennial vegetation ($c_{\lambda f,p}$ $c_{\lambda e,p}$)	
	Water use parameters of seasonal vegetation ($c_{\lambda f,s}$ $c_{\lambda e,s}$)	
Short-term vegetation parameters	Fraction of area covered by seasonal vegetation ($M_{A,s}$)	Varying on a daily scale
	Electron transport capacity of perennial vegetation ($J_{\max 25,p}$)	
	Electron transport capacity of seasonal vegetation ($J_{\max 25,s}$)	
	Root area depth distribution of perennial vegetation ($S_{adr,i,p}$)	
	Root area depth distribution of seasonal vegetation ($S_{adr,i,s}$)	

2 Methodology

❖ Data used in this study

Sites	Data type	Data items	Scale	Period
Inputs	Meteorological data	Solar radiation, temperature, precipitation, relative humidity, PAR	20 min, scaled up to 1 hour	1998–2006
Validation	Flux data	water vapor flux	20 min, scaled up to 1 hour	1998–2006
	Satellite data	NDVI	16-days	2000-2006

2 Methodology

Model parameterization

Parameters need to be specified.

Vegetation parameters setting

Parameters	Description	Value
$y_{r,s}$	Thickness of root zone of seasonal vegetation (m)	1
α	Initial slope of quantum yield of electron transport (mol/mol)	0.1
H_a	Rate of exponential increase of *Jmax* with temperature（J/ mol）	159500
H_d	Rate of exponential decrease of *Jmax* with temperature（J/ mol）	200000
T_{opt}	Optimum temperature for electron transport (K)	305
c_{rv}	Proportionality constant for water transport carbon costs (mol/m^3)	$2.2*10^{-6}$
tcf	Turnover cost factor for foliage (mol/m^2/s)	$2.2*10^{-7}$
c_{rl}	Leaf respiration coefficient	0.07
c_{Rr}	Root respiration rate per volume of fine roots	0.0017
rurfmin	Minimum root surface area (m^2/m^3)	0.08
rurfinit	Initial root surface area (m^2/m^3)	0.08
r_r	Mean radius of fine roots (m)	$0.3*10^{-3}$
growthmax	Parameter determining the maximum daily growth increment of root surface are	0.1
prootmg	Constant root balance pressure of 1.5 MPa in grasses	150

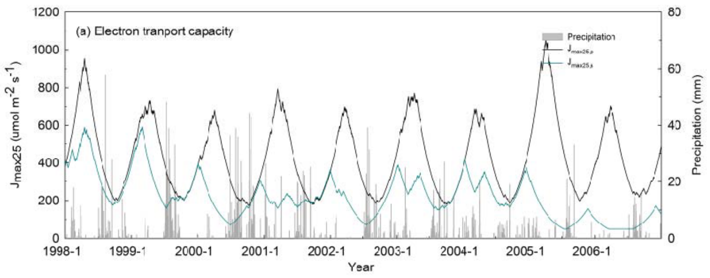
Soil parameters setting

Parameters	Description	Value
Z	Average depth of the pedosphere (m)	2.5
δ	Thickness of soil sublayers (m)	0.5
K_{sat}	Saturated hydraulic conductivity (mm/s^{-1})	$1.28*10^{-5}$
a_{vG}	Soil parameter of Van Genuchten water retention (m^{-1}) (-)	7.5
n_{vG}	Soil parameter of Van Genuchten water retention model (-)	1.89
θ_r	Residual soil water content (m^{-3} /m^{-3})	0.065
θ_s	Statured soil water content (m^{-3} /m^{-3})	0.36

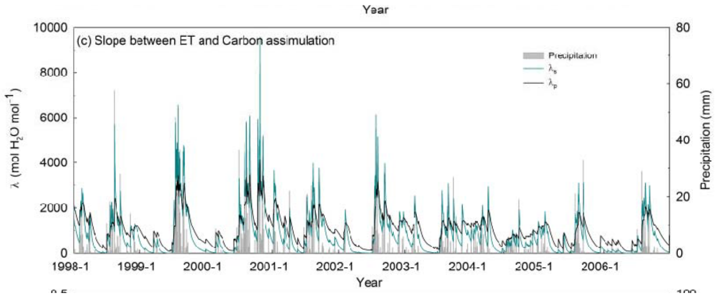
2 Methodology

Model parameterization

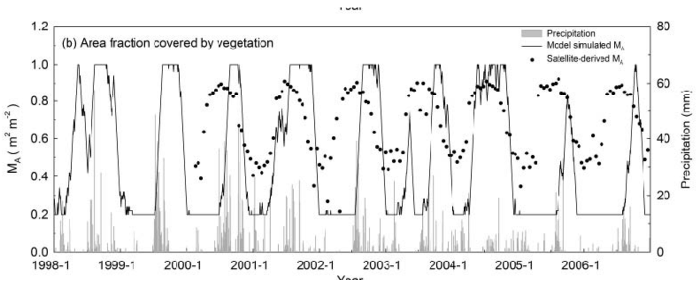
The model is firstly applied to achieve the optimal vegetation parameters.
The *NCP* is about 130.2 mol/m^2 for the 9 years.



daily-optimized J_{max25}



Vegetation water use parameters

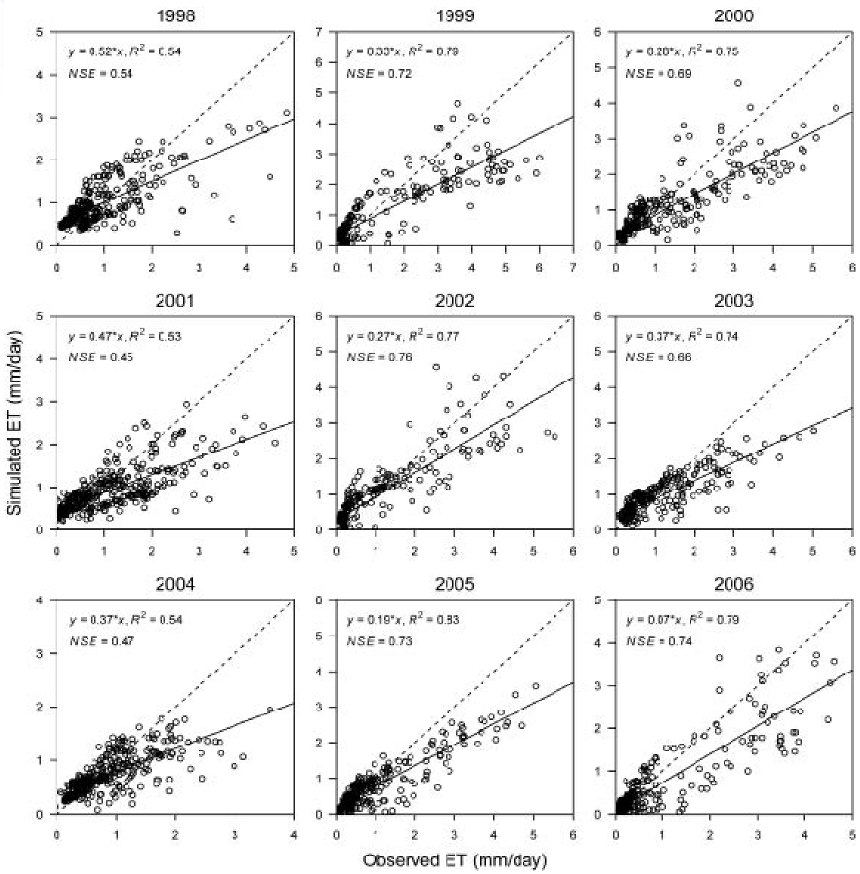


Area covered by seasonal vegetation
Simulated VS satellite-derived MA

Simulated values follow the seasonal dynamic of satellite-derived MA

3 Results and discussions

❖ Model validation with site observations

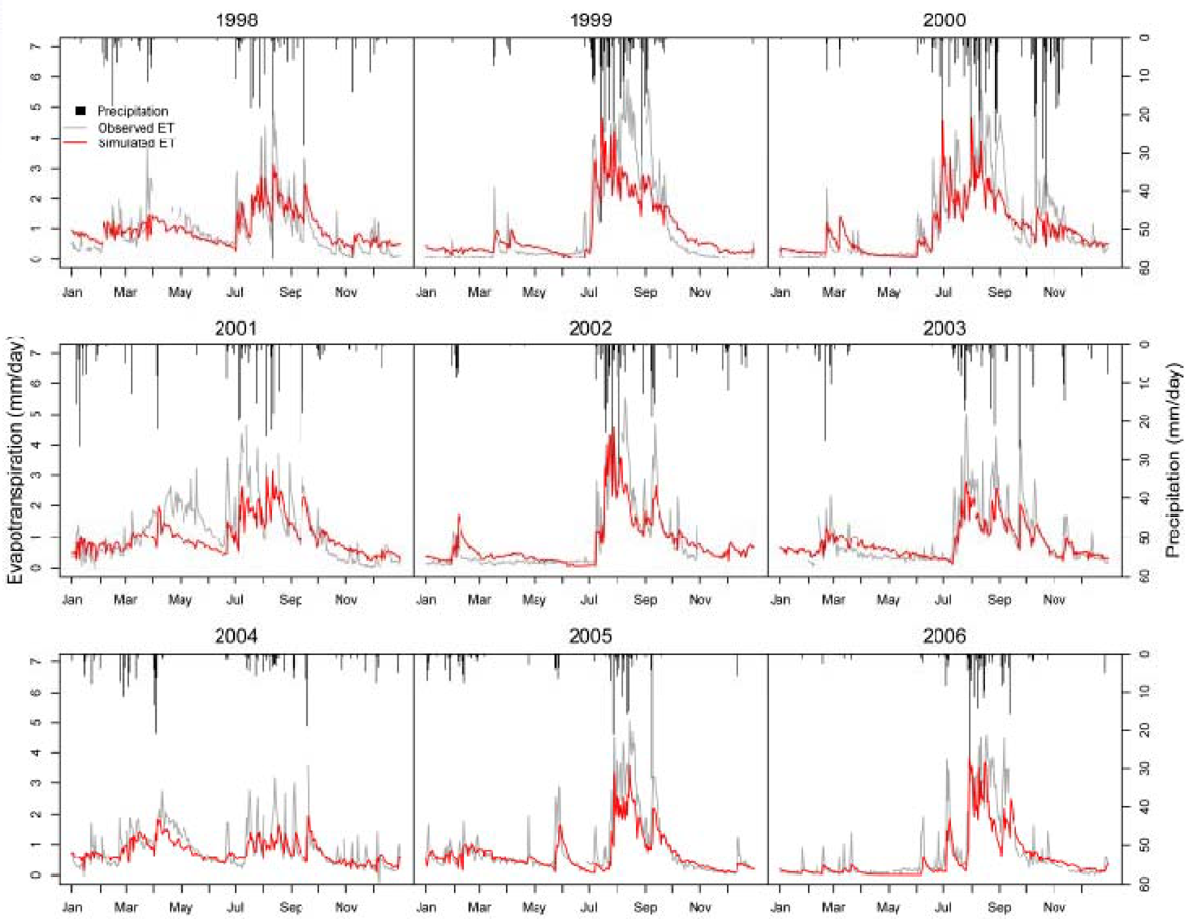


Observed and simulated daily ET
（1999-2007）

- Most of years are simulated well with the dots distributed along the 1:1 lines.
- Good correlation with R^2 square higher than 0.8 for all of the years.
- Acceptable Nash-Sutcliffe coefficient.

3 Results and discussions

❖ Model validation with site observations

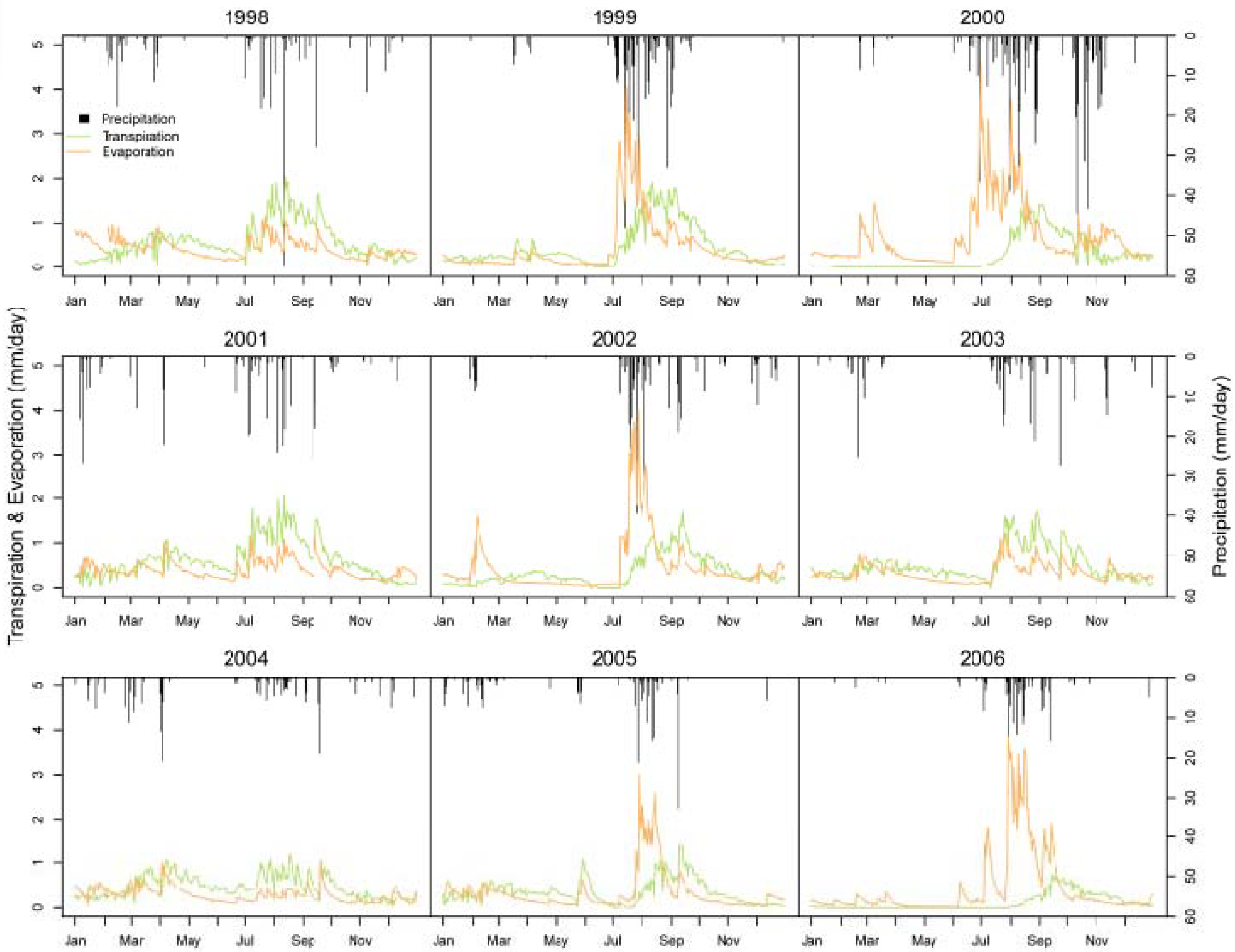


dynamics of Observed and simulated daily ET (1998-2006)

- Variation pattern of the simulated ET corresponds with the measured ET.
- Simulated ET is mainly concentrated in monsoon when rainfall concentrates.
- A tendency of underestimation of ET in some years.

3 Results and discussions

❖ Evaporation and transpiration

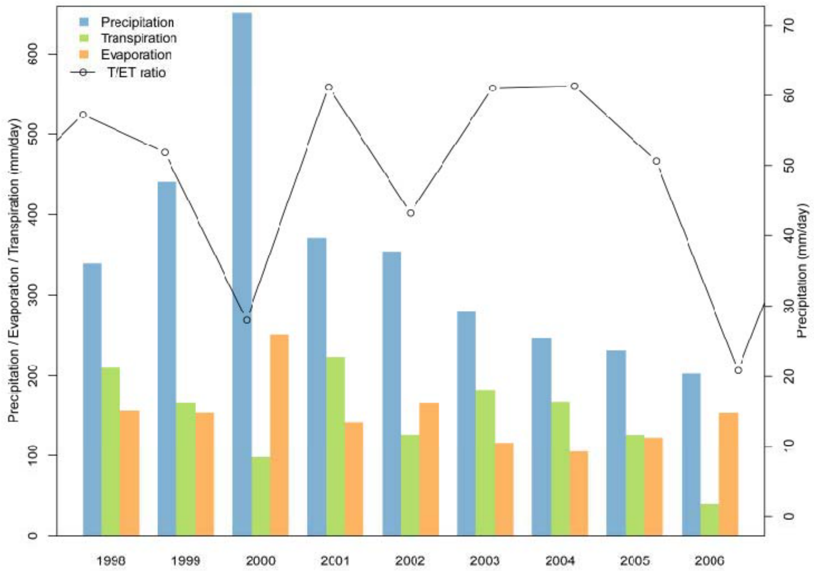


- Evaporation and transpiration mainly occur in monsoon.
- Evaporation responds immediately to precipitation events
- Transpiration shows a lagged response to precipitation events.

3 Results and discussions

❖ Evaporation and transpiration

Plant transpiration accounts for 49% of the total ET for the period from 1998 to 2006.

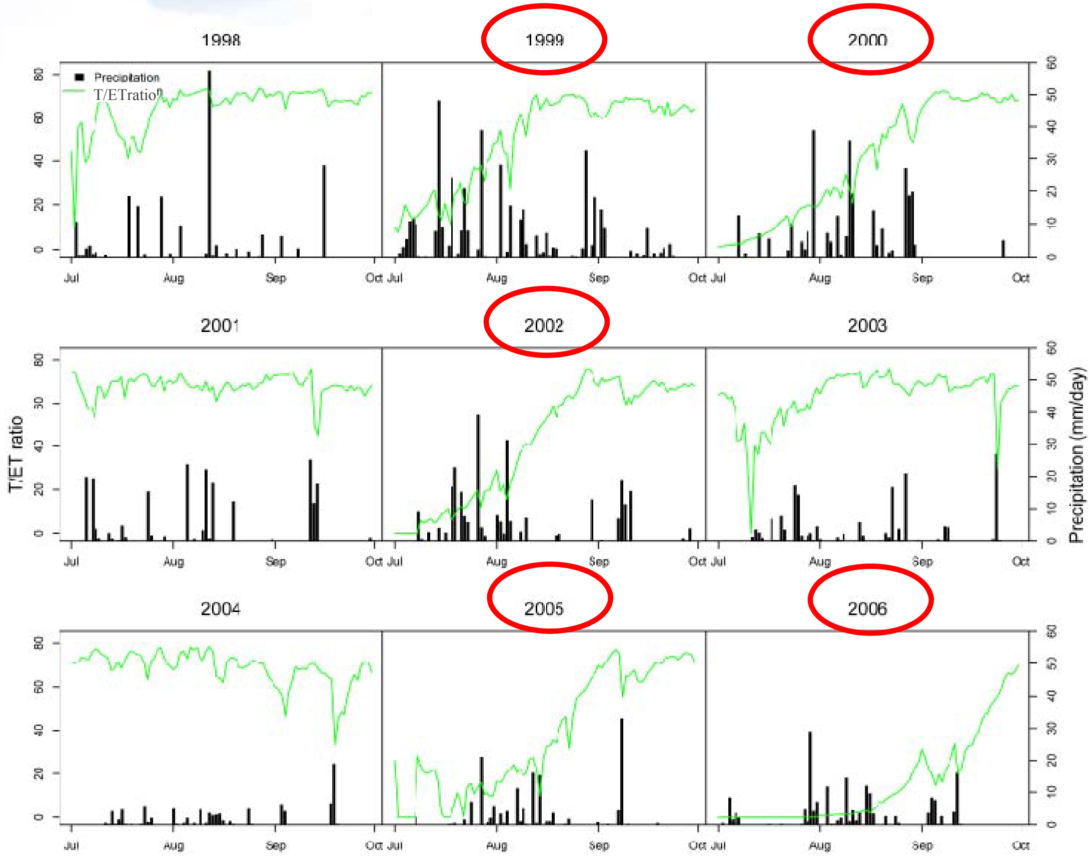


- *T/ET* ratio varies dramatically among different years, from 21% to 61%
- No evident relationship of *T/ET* ratio with the amount of precipitation

3 Results and discussions

❖ Dynamic of *T/ET* ratio in monsoon

T/ET ratio dynamic in monsoon demonstrates two different patterns.



Dynamic of T/ET ratio in monsoon

Pattern 1：1999, 2000, 2002, 2005, and 2006

– Low *T/ET* ratios at the beginning and an increased trend in the monsoon

Pattern 2：1999, 2000, 2002, 2005, and 2006

– Relatively high *T/ET* ratio during the monsoon

3 Results and discussions

❖ Averaged monthly *T/ET* ratio

Two different patterns is also obvious from the averaged monthly *T/ET* ratio.

No evident relationship of *T/ET* ratio with the amount of monthly precipitation.

3 Results and discussions

❖ Impact of spring precipitation on ET partitioning

Days and amount of spring precipitation by size class.

Year	Size class (mm) 0 – 5 Days / amount (mm)	5 – 10 Days / amount (mm)	> 10 Days / amount (mm)	Total days / total amount (mm)
1998	**28 / 28.4**	**5 / 34.3**	**3 / 40.4**	**36 / 103.1**
1999	8 / 15.6	1 / 7.4	0 / 0	9 / 23.0
2000	8 / 7.2	2 / 16.3	0 / 0	10 / 23.5
2001	**23 / 22.9**	**3 / 23.1**	**4 / 76.6**	**30 / 122.6**
2002	13 / 5	4 / 26.9	0 / 0	17 / 31.9
2003	**20 / 23.5**	**1 / 5.3**	**2 / 35.3**	**23 / 64.3**
2004	**19 / 26.9**	**7 / 47.8**	**3 / 45.7**	**29 / 120.4**
2005	32 / 46	5 / 34	0 / 0	37 / 80
2006	7 / 8.1	0 / 0	0 / 0	7 / 8.1

Pattern1：1999, 2000, 2002, 2005, and 2006

– **Dry spring** with extremely low spring precipitation

– **No precipitation with size >10 mm**

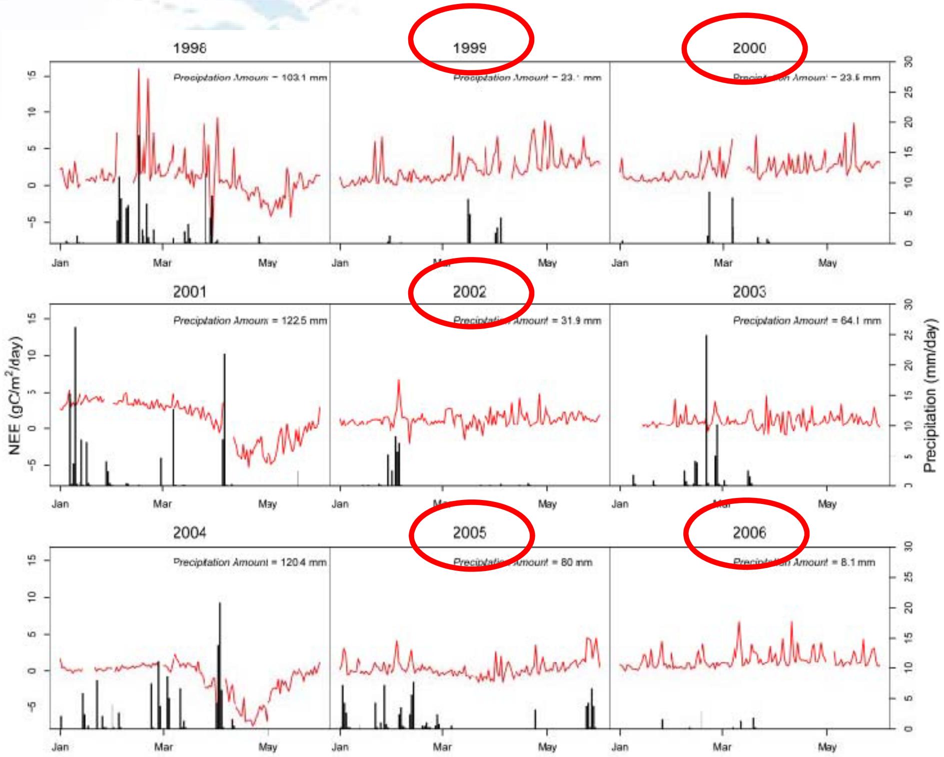
Pattern 2：1998, 2001, 2003, and 2004

– **Spring precipitation with size >10 mm**

High spring precipitation, but small size (0-5 mm)

3 Results and discussions

❖ Impact of spring precipitation on ET partitioning



Carbon uptake in spring

Pattern1：1999, 2000, 2002, 2005, and 2006

– No evident CO_2 uptake during the spring (**No precipitation with size >10 mm**)

Pattern 2：1998, 2001, 2003, and 2004

– Evident CO_2 uptake except for 2003 (**Spring precipitation with size >10 mm**)

10 mm class size might be the efficient precipitation for shrub growth in this area.

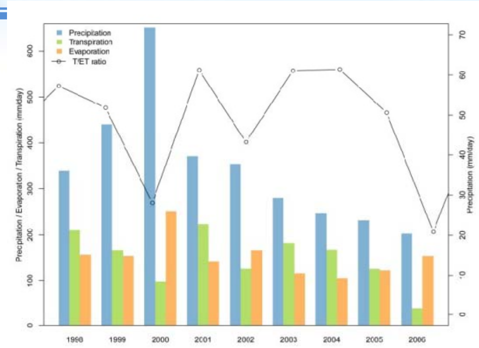
4 Conclusion

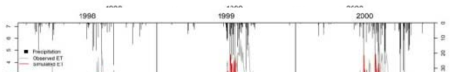
- In this study, we conduct a study of ET partitioning in a semiarid shrubland with an optimality-based ecohydrological model VOM.
- VOM model can reasonably predict ET and ET components in semiarid shrubland ecosystem.
- Overall, T/ET ratio is 49% for the study period with a peak of 61%.
- Different years demonstrate different patterns of T/ET ratio dynamic in monsoon.
- Spring precipitation especially the size of the precipitation have a significant influence on the T/ET ratio in monsoon.

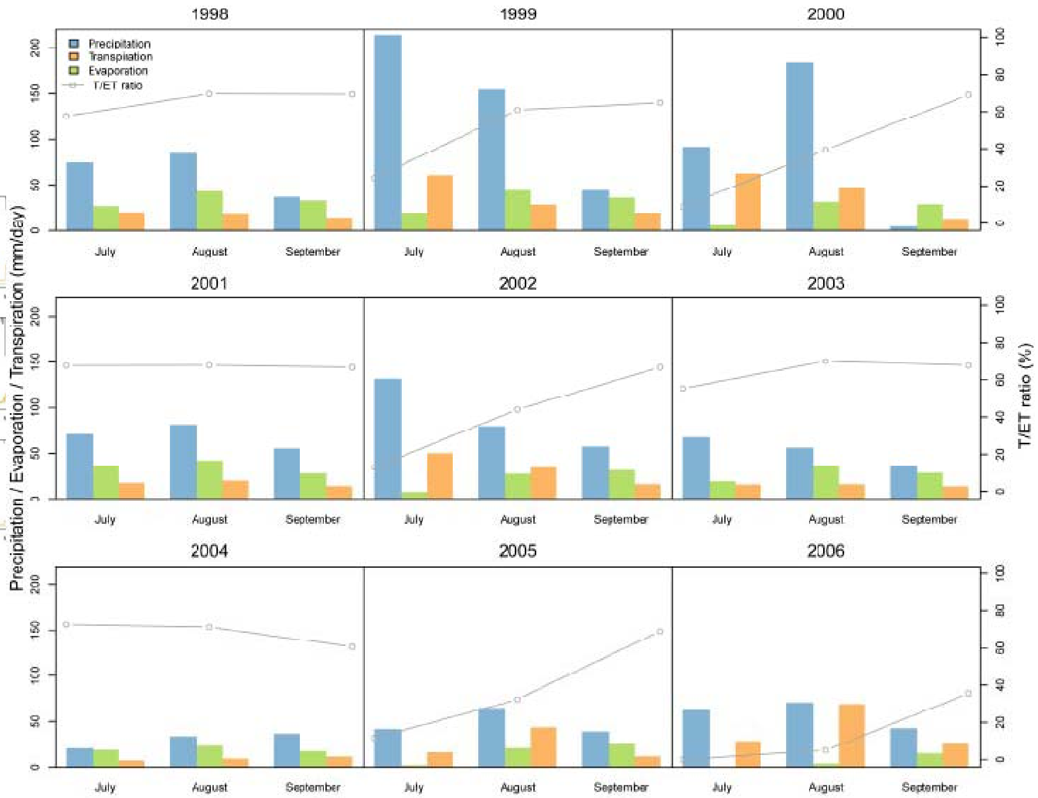
Thank you for your attention!

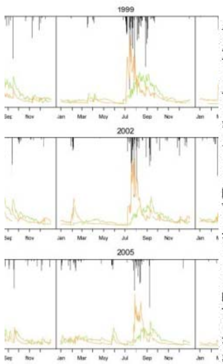
3

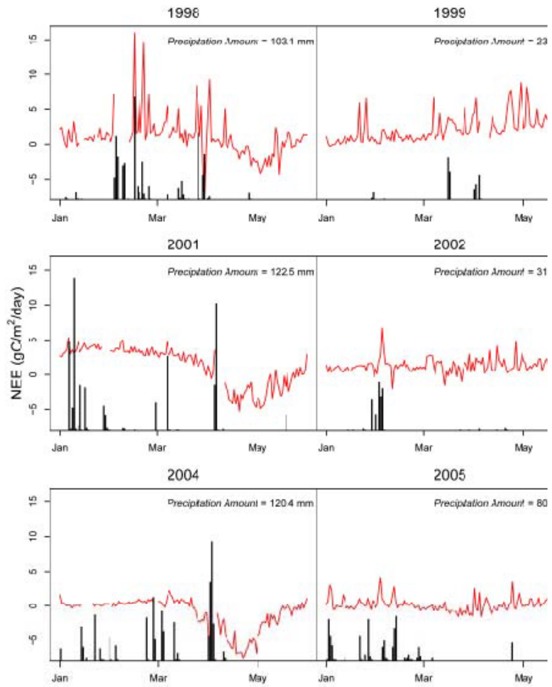
Results






1998
1999
2000
2001
2002
2003
2004
2005
2006
Precipitation
Transpiration
Evaporation
T/ET ratio
July
August
September
Precipitation / Evaporation / Transpiration (mm/day)
T/ET ratio (%)




1998
1999
2001
2002
2004
2005
NEE (gC/m²/day)
Jan
Mar
May