Modeling evapotranspiration over China's landmass from 1979 to 2012 using three land surface models

Shaobo Sun[1, 2], Baozhang Chen[1], Huifang Zhang[1], Xiaofeng Lin[1, 2]

[1] State Key Laboratory of Resources and Environment Information System, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, China;

[2] University of Chinese Academy of Sciences, Beijing, China

(Corresponding author email: Shaobo Sun, sunshaobo@lreis.ac.cn)

Summary & conclusion: Recent intercomparison studies suggested that land surface models (LSMs) showed a great potential for estimating land ET at long-term regional or global scales. In our study, we forced the Community Land Model, version 4.0 (CLM4.0); Dynamic Land Model (DLM); and Variable Infiltration Capacity model (VIC) with observation-based forcing datasets and developed a multiple-LSM ensemble-averaged China ET product (LSMs-ET), and further analyzed China ET spatial–temporal variations with the LSMs-ET data. The LSMs-ET produced a mean annual ET of 351.24±10.7 mm yr^{-1} over 1979–2012, and its spatial–temporal variation analyses showed that (i) there was an overall significant ET increasing trend, with a value of 0.72 mm yr^{-1} ($p < 0.01$); (ii) 36.01% of Chinese land had significant increasing trends, ranging from 1 to 9 mm yr^{-1}, while only 6.41% of the area showed significant decreasing trends, ranging from 26.28 to 20.08 mm yr^{-1} and (iii) the Tibetan Plateau areas were the main contributors to the overall increasing ET trends of China.

1. Data & models

Data used for verification and comparison

- Nine eddy covariance flux towers located in different climate regions of China (Fig. 1).

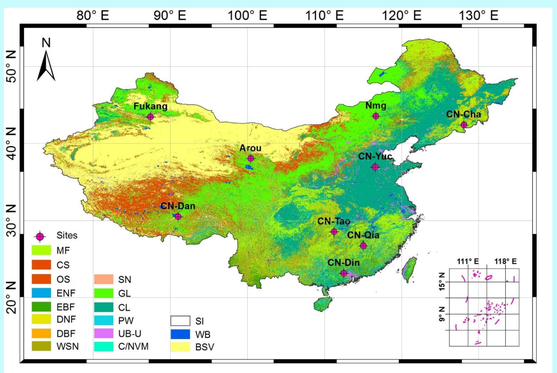
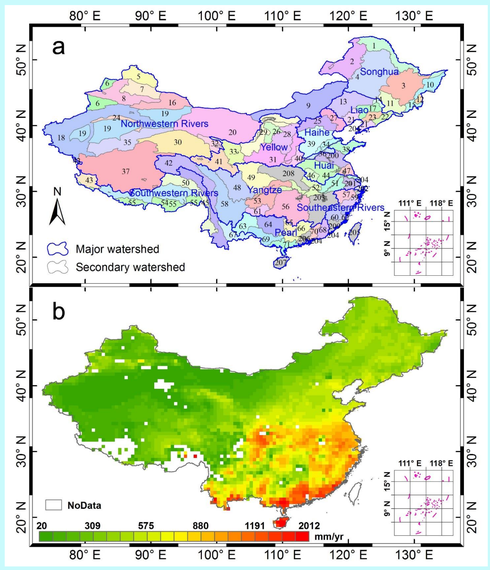


Fig. 1 Location of the flux towers

- Water budget-based climatologically averaged ET (Fig. 2).
- MODIS ET and FLUXNET-MTE ET (Jung et al., 2011).

Fig. 2 The main watersheds (a) and surface water budget-based ET (b)



The land surface models

a) CLM4.0

The ET algorithm was based on a mass transfer formulation and one-leaf strategy (Oleson et al., 2010);

b) DLM

The ET algorithm was Penman-Monteith equation and two-leaf strategy (Chen et al., 2013);

c) VIC

The ET algorithm was Penman-Monteith equation (Liang et al., 1994).

Model inputs

- The meteorological forcing data (0.1° x 0.1°) for CLM4.0 and DLM was the the China high resolution forcing datasets (Chen et al., 2012) and that of VIC was a China forcing data interpolating from 756 stations (0.25° x 0.25°);
- The soil texture of CLM4.0 and DLM was the China 30 arc-second resolution gridded soil texture data set;
- The other model land surface data sets were model defaults.

2. Results

Modeled ET evaluation

Fig. 3 Comparison of seasonal variations among the six ET data sets for nine sites

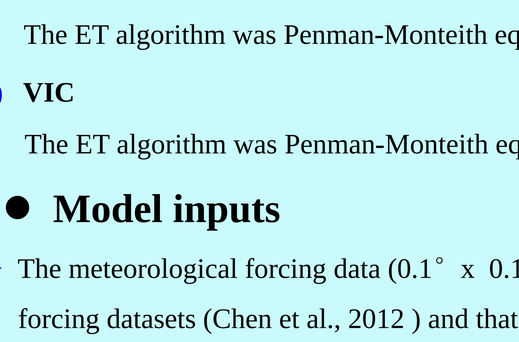


Fig. 4 Comparisons of watershed mean annual ET from the surface water budget approach and the land surface models

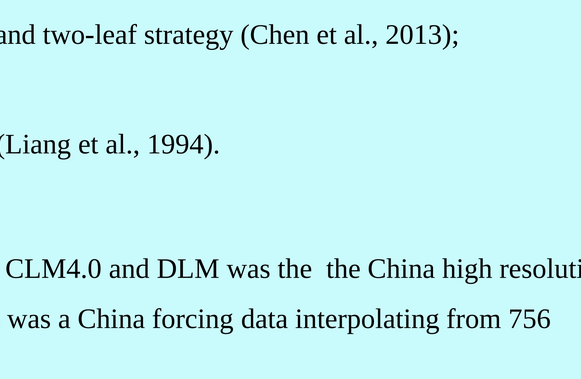
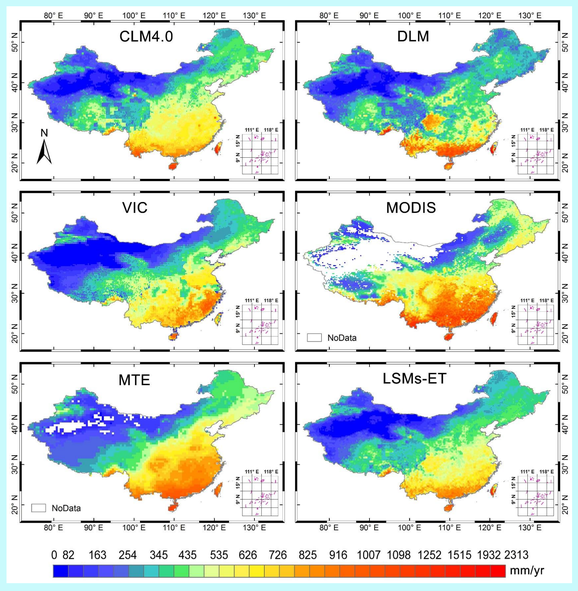


Table1 Statistics of the monthly ET estimates versus site measurements (units: mm mon^{-1})

Sites	CLM4.0		DLM		VIC		MTE-GPP		MOD17		LSMs-ET	
	BIAS	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*
CN-Cha	-8.24	14.62	-19.50	25.47	-2.77	10.62	-3.79	6.11	2.99	8.49	-10.16	13.87
CN-Yuc	-13.75	27.32	-18.61	27.91	-10.63	36.83	6.21	24.97	-12.24	32.27	-14.32	28.78
CN-Qia	1.38	19.12	-11.46	18.87	18.44	32.68	19.70	25.32	24.67	35.11	2.78	19.75
CN-Din	-5.36	20.96	6.38	25.33	-10.04	31.10	9.86	17.70	5.21	16.47	-3.00	22.60
CN-Dan	-8.91	20.30	-13.67	24.33	-18.91	24.02	-14.98	25.50	-16.74	37.25	-13.83	22.23
CN-Tao	11.69	20.52	-3.96	12.86	25.36	40.42	30.09	36.70	32.01	40.41	11.03	22.44
Arou	-0.66	8.25	-3.46	8.29	-7.82	10.19	-5.27	11.70	5.38	23.31	-3.98	7.99
Fukang	21.57	29.51	20.91	29.03	19.12	27.87	12.84	16.47	21.01	22.41	20.53	28.52
Nmg	-16.47	19.02	-12.79	15.66	-18.95	21.13	-6.80	11.99	-13.33	19.30	-16.07	18.18
Average	-2.08	19.96	-6.24	20.86	-0.69	26.10	5.32	19.61	5.44	26.11	-3.00	20.48

Comparison with the MODIS and MTE ET

Fig. 5 Spatial distributions of China mean annual ET from each data set (2000-2011)

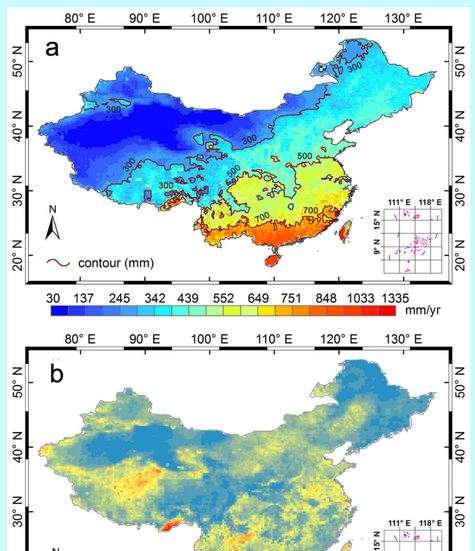


- The site level evaluations showed that the LSMs-ET was generally slightly better than signal LSM modeled ET;
- The regional-level evaluations suggested that overall our modeled ET agreed well with the water budget ET in most areas of China's landmass;
- The mean annual ET data sets demonstrated similar spatial patterns, but the differences between different ET data sets were large in south high ET areas;
- The LSMs-ET produced moderate annual mean ET with a value of 360.99±7 mm yr^{-1} and seemed to have the most reasonable spatial pattern.

The spatial patterns and mean annual ET of China's landmass

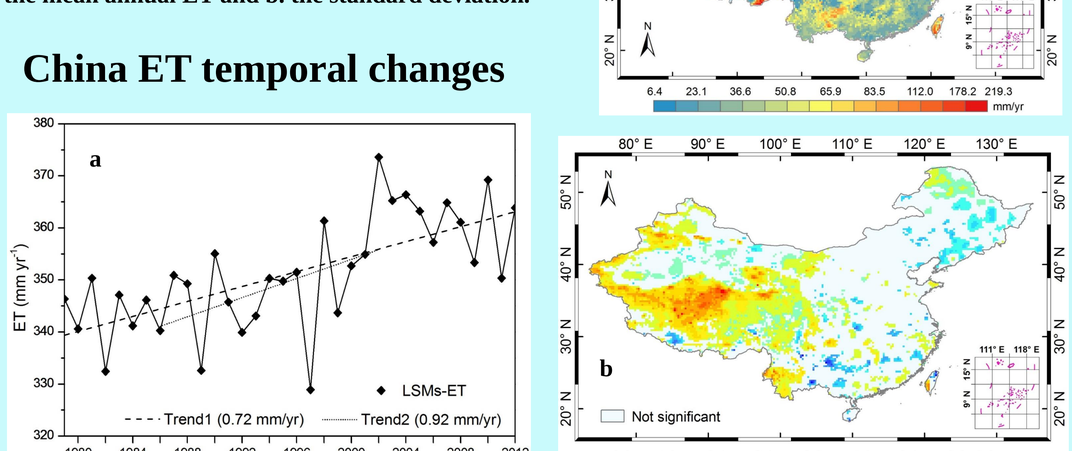
- The mean annual LSMs-ET value during 1979-2012 was 351.24±10.7 mm;
- The mean annual ET of China had a distinct four-stage declining characteristic: the high ET areas where ET values exceeded 700 mm yr^{-1}; the moderate ET areas with values above 500 mm yr^{-1}; the low ET areas where the ET values exceeded 300 mm yr^{-1}; and the lowest ET areas where the ET values were less than 300 mm yr^{-1}.

Fig. 6 The spatial distribution and standard deviation of mean annual LSMs-ET over China from). 1979-2012. a. the mean annual ET and b. the standard deviation.



China ET temporal changes

Fig. 7 The annual LSMs-ET trends in China from 1979 to 2012. a. The grid-average annual ET trends, b. The spatial distribution of annual ET trends.



- The ET trend analyses suggested that the ET over China increased significantly from 1979 to 2012, with value of 0.72 mm yr^{-1} ($p < 0.01$);
- 58% region of China's landmass showed insignificant changes. The increase in the significant area was 36.01%, mainly distributed in the Tibetan Plateau, western Xinjiang, Sichuan and Yunnan and far northern regions of Inner Mongolia and Heilongjiang.

ET variations across climate regions

Fig. 8 The climate regions of China (Koppen-Geiger classification, Kottek et al. 2006)

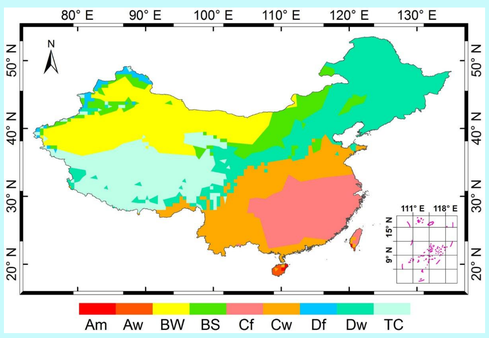
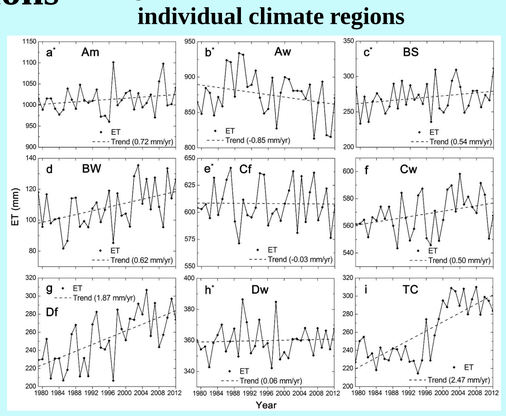


Fig. 9 The LSMs-ET trends for individual climate regions



- The increasing ET in Tibetan Plateau (TC) mostly contributed to the increased ET over China from 1979-2012

- Shaobo Sun, Baozhang Chen, et al. 2017. Modeling evapotranspiration over China's landmass from 1979-2012 using multi-land surface models: Evaluations and analyses. J. Hydrometeor., 18: 1185-1203.