Quantify the Evapotranspiration and Evaporation Amounts over Different Landscapes On The Tibetan Plateau

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1 Introduction

Land evapotranspiration (ET) and lake evaporation are important water budget components, representing the main processes of energy and water exchange between the earth and the atmosphere, and thus can influence the regional-scale hydrological cycles. Under the global warming, the water cycle over the TP intensifies, with not only increase in net water vapor transport, precipitation, evapotranspiration, underground water storage and surface runoff, but also showing glacier retreat, snow melt, ice duration shortening, thus decrease in glacier and snow water storage (Figure 1a). For studying land-atmosphere interaction and boundary layer processes, the 3-D observation stations with measurements of AWS, PBL tower, EC, microwave radiometer, wind profiler have been established over the different landscapes on the TP (Figure 1b).

Based on several long-term and comprehensive land-atmosphere interaction measurements over the Tibetan Plateau, the land evapotranspiration have been estimated by application of satellite-based algorithms of Surface Energy Balance System (SEBS, Han et.al., 2021) and MOD16-STM (Yuan et.al., 2021). While presenting a plausible hypothesis of energy balance during the ice-free seasons, the multiyear (2003–2016) average ice phenology and evaporation amounts of 75 large dimictic lakes have also been estimated by using a combination of meteorological and satellite data (Wang et.al. 2020). The detailed method can be found in the above-mentioned three references.

The objectives of our study are to quantifying the exact land evapotransporation and lake evaporation amounts and their uncertainties over the Third Pole region. The three-dimensional comprehensive observation system of multi-layers interactions are shown in Figure 1. The spatial distribution of lake evaporation and relative variables are shown in Figure 2. The spatial disctirbution of land evapotranspiration by SEBS method is shown in Figure 3. The spatial distribution of evapotranspiration, soil evaporation, vegetation transpiration, canopy interception are shown in Figure 4. The average evapotranspiration by all kinds of different methods is plotted in Figure 5 and the trends of evapotranspiration globally and over the TP are shown in Figure 6.

2 Sites observation

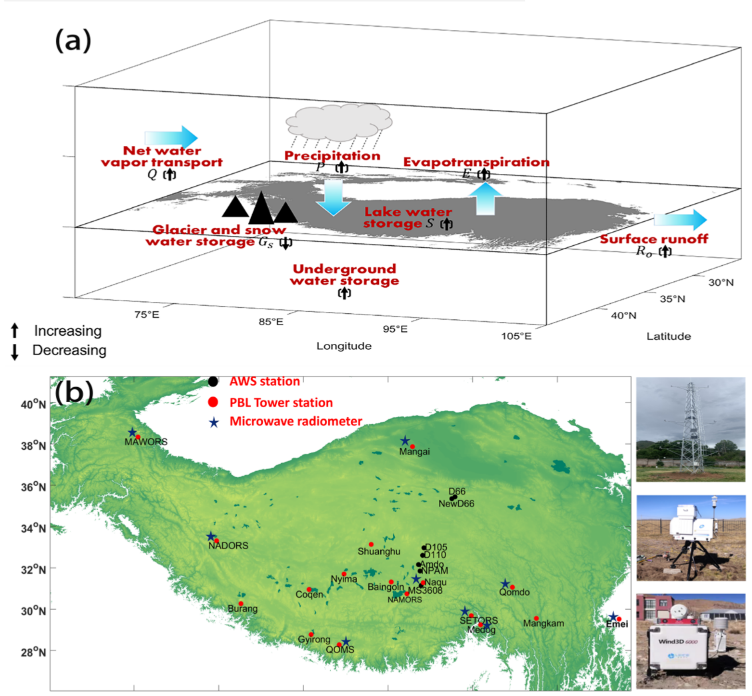

Figure 1 (a) changes in the water cycle components for the Asian Water Tower; (b) the spatial distributions of 3-D observation stations over the TP, with black dot representing automatic weather stations, red dot representing stations having PBL tower and EC system, black pentagram representing microwave radiometers. The three photos show the pictures of PBL tower, microwave radiometer, and wind profiler.

3 Results

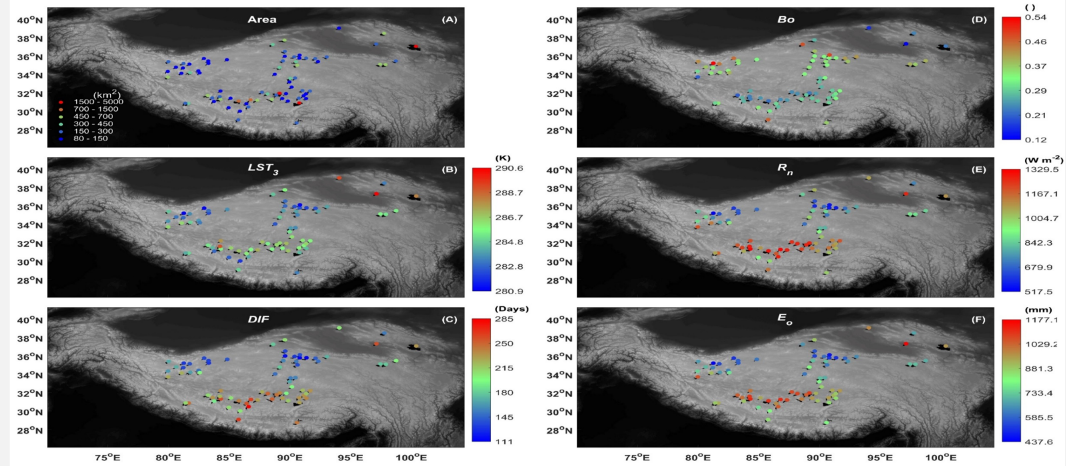

Fig. 2. The spatial distributions of lake area (A); lake surface temperature at the warmest three months (B); duration of ice-free season (C); Bowen ratio (D); net radiation (E); and evaporation during the ice-free season (F) of the 75 studied lakes.

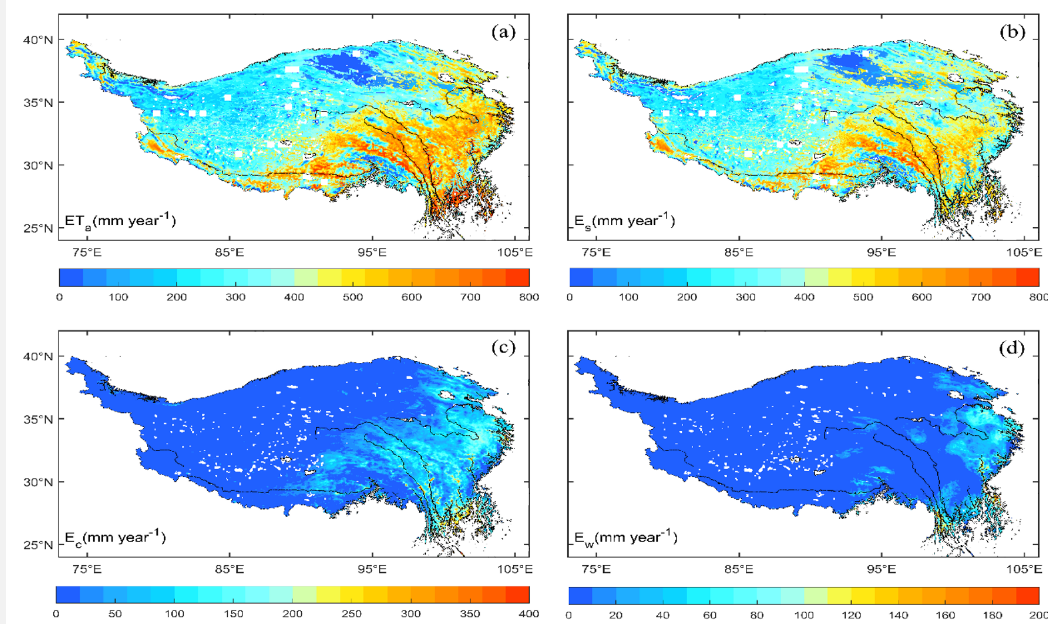

Fig. 4. The spatial distributions of land evapotranspiration (a); soil evaporation (b); canopy transpiration(c); canopy interception(d).

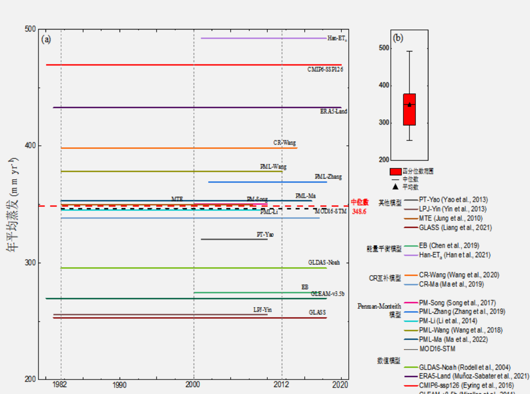

Figure 5 The average evapotransporation estimated by all kinds of different methods, where Han ET shows the highest value and the median value by all the results has a value of around 348.6 mm and amounts to 0.93±0.037×10³ Gt.

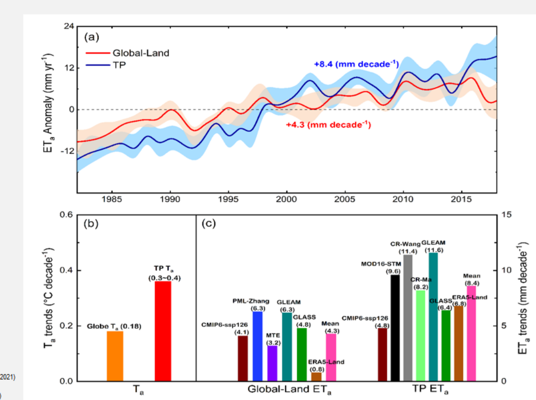

Figure 6 (a) the averaged ET globally and on the TP have averaged trends of 4.3 mm decade^{-1} and 8.4 mm decade^{-1}; (b) the air temperature over the TP is almost double than that globally; (c) the estimated trends by all kinds of ET estimations globally and over the TP.

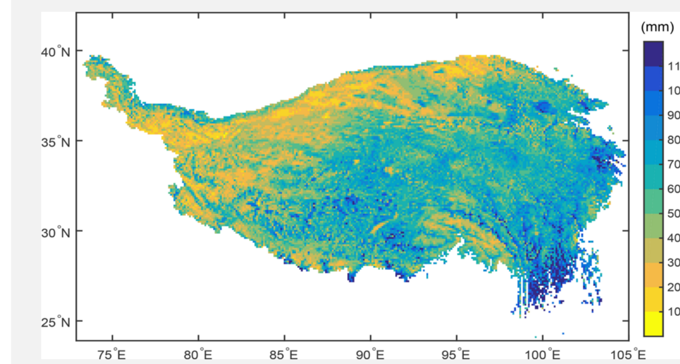

Figure3. Spatial distribution of the SEBS-estimated multiyear (2001–2018) average annual ET_a.

4 Conclusions

By a combination of in-situ measurements, reanalysis data and satellite products, the total amounts of land ET and lake evaporation are estimated and the results show that:

(1) the total ET amounts show very large variability amongst all kinds of different products, where Han-ET (Han, et.al., 2021) is the highest with an average annual value of approximately 490 mm (1.238±0.058×10³ km³). However, the median of all the different products has a value of only 348.6 mm, which is much close to the estimation by MOD16-STM (Yuan et.al., 2021), which amounts to 0.94×10³ km³. The trends of annual ET amount show an increasing trend with a value of 8.4 mm decade^{-1}, which is almost twice the value over the whole global (4.3 mm decade^{-1}).

(2) As for the lake surface, lake ice phenology are clearly presented by MODIS 8-day snow cover products, and they show large spatial variability in the duration of ice-free season. The estimated Bowen ratio and evaporation amounts show acceptable accuracies, and display opposite spatial distributions, with the latter being higher in the southern part than in the northern part. On the TP, a lake with a higher elevation, a smaller area and a larger latitude mostly corresponds to a shorter ice-free season (a lower total net radiation), a larger Bowen ratio and finally a lower evaporation amount. The multi-year average evaporation amounts are listed, with the total water evaporated from lake surface being approximately 29.4±1.2 km3 year-1 for the studied 75 lakes and 51.7±2.1 km3 year-1 for all Plateau lakes included.

(3) To further explore the land/lake-atmosphere interaction processes in detail over data-limited regions of the TP and supported by the "Third Pole Environment (TPE) program, 16 comprehensive observation and research stations have been constructed over all kinds of landscapes and in different regions of the TP in 2021.

References

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