A High-resolution Estimation of Terrestrial Evapotranspiration from Landsat Images and its Applications in a Sparse Vegetation Region

Ting Liang, Hanbo Yang

Department of Hydraulic Engineering, Tsinghua University, Beijing, 100084, China. **E-mail: liangt20@mails.tsinghua.edu.cn**

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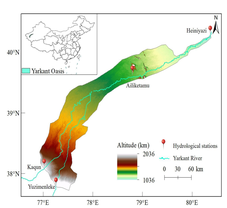
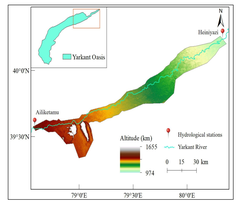
1. Introduction

Accurate estimation of high resolutions of evapotranspiration (ET) is essential to study the variation of water resources in highly heterogeneous regions, but there is a severe paucity of ET products with high spatial resolution for long time series.

- This research improves the PML_V2 model to estimate a 30 m resolution monthly ET, called the PML_30 model.
- It is validated and applied to estimate the monthly ET from 2000 to 2020 in the Yarkand Oasis.
- All research tasks, including Landsat data fusion, ET estimation, and output of results, are performed on the Google Earth Engine (GEE).

2. Study area and data use





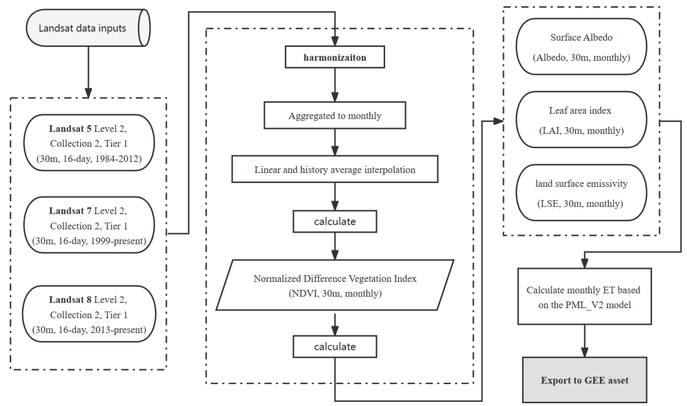
- Yarkand Oasis :
  - Area (km^2): 16,000
- The lower reach:
  - Area (km^2): 2600

- Typically dry climate characterized by scant precipitation and high evaporation.
- Since the 1950s, an increasingly precarious water resource situation and ecological deterioration in the basin.
- The riverbanks of the lower reach are dominated by sparse Populus euphratica.

	Available time	Spatial resolution
Landsat TM	2000-2012	30 m
Landsat ETM	2000-2020	30 m
Landsat OLI	2013-2020	30 m
GLDAS-2.1	2020 - 2020	0.25 deg
MCD12Q1.006	2020 – 2020	500 m

3. Methodology

■ Flowchart of the PML_30 model



- **Uses a linear transformation to harmonize remote sensing data from three Landsat TM, ETM+ and OLI data.**
- Resulting high quality long time series of surface parameters.
- Export ET result with 30 m resolution to the GEE asset

■ Landsat data processing

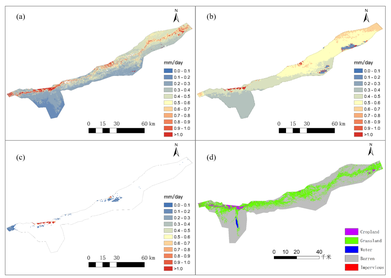
$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Red}} \qquad f_{NDVI} = (\frac{NDVI - NDVI_0}{NDVI_1 - NDVI_0}) \qquad LAI = -2In(1 - f_{NDVI})$$

$$\varepsilon_\lambda = \begin{cases} \varepsilon_{s\lambda}, & NDVI < NDVI_0 \\ \varepsilon_{s\lambda} + (\varepsilon_{v\lambda} - \varepsilon_{s\lambda}) f_{NDVI}, & NDVI_0 \le NDVI \le NDVI_1 \\ \varepsilon_{v\lambda}, & DVI > NDVI_1 \end{cases}$$

$$\text{Albedo} = \frac{0.356\rho_1 + 0.130\rho_3 + 0.373\rho_4 + 0.085\rho_5 + 0.072\rho_5 - 0.0018}{1.016}$$

5. Discussion

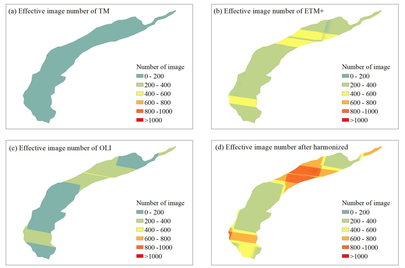
■ Compared with other ET product



The PML_30 model can simulate the ET distribution maps of the region more precisely, and their spatial distribution is more comparable with the actual land cover type and river seepage pattern of the lower Yarkand River.

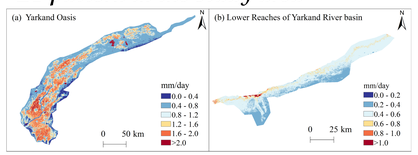
4. Results

■ *Effective image number*

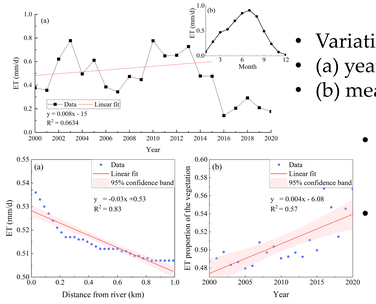


- Spatial distribution of effective images
- Few images are available for each satellite
- Increasing in quantity and quality after integration

■ *ET pattern in the study area*



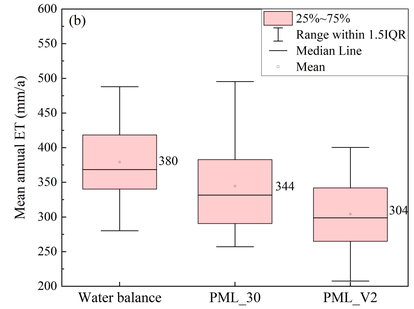
- Spatial distribution



- Variations in
- (a) yearly mean ET and
- (b) mean monthly ET

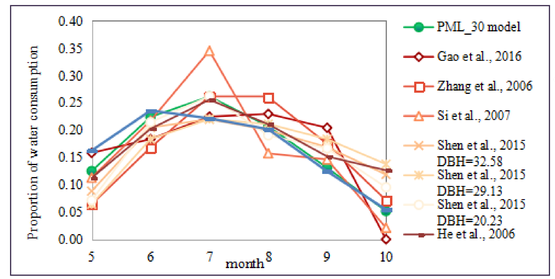
- (a) Variation of mean ET value of the section.
- (b) Changes in the proportion of vegetation ET to total ET.

■ *Validation at the Region scale*



- The average ET calculated by the water balance analysis for the basin region was 380 mm over the 21-year period, while the PML_30 modle calculated 344 mm with a relative error of 0.09.
- The PML_V2 model's multi-year ET average 304mm with a relative error of 0.2.

■ *Validation at the Point scale*



- Consistent with the growth rhythm and other researcher's findings.
- PML_30 model estimated the annual water consumption at this point would be 236 mm in 2020, with a relative error of only 1.67 percent.

Compares the total/average annual ET of cotton in Xinjiang according to existed researches.

researches	PML_30 model	Yang, 2016 (Yang, 2016)	Yang, 2016 (Yang, 2016)	Yang, 2016 (Yang, 2016)	Zhou et al., 2012 (Zhou et al., 2012)	researches	PML_30 model	researches	PML_30 model
ET(mm/y)	595	554	534	489	538	ET(mm/y)	595	ET(mm/y)	595
Year	2000-2020	2012	2013	2014	2008-2010	Year	2000-2020	Year	2000-2020

Conclusion

- Retrieved long-term monthly 30 m resolution Leaf Area Index (LAI), Land Surface Emissivity (LSE) and Albedo, by harmonizing data from three satellite products, namely TM, ETM+ and OLI, in the GEE platform
- Constructed a 30 m resolution monthly ET model based on PML-V2 model
- Applied this model to estimate monthly ET from 2000 to 2020 in the Yarkand River basin, a sparse vegetation region in Northwest China.
- The proposed PML_30 model is easily applicable to a larger scale with increased estimation accuracy and is well suited for areas with high heterogeneity such as areas with sparse vegetation cover.