Regional and global evapotranspiration trend under a changing environment

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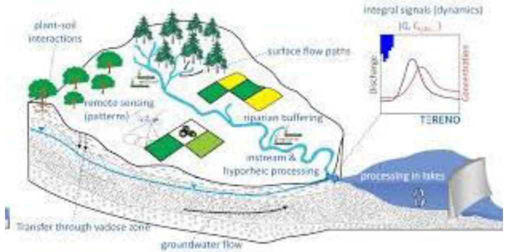
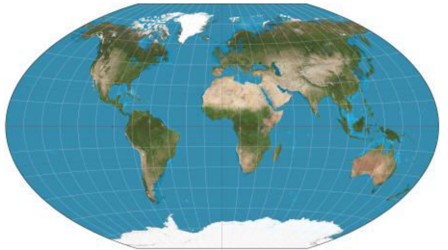




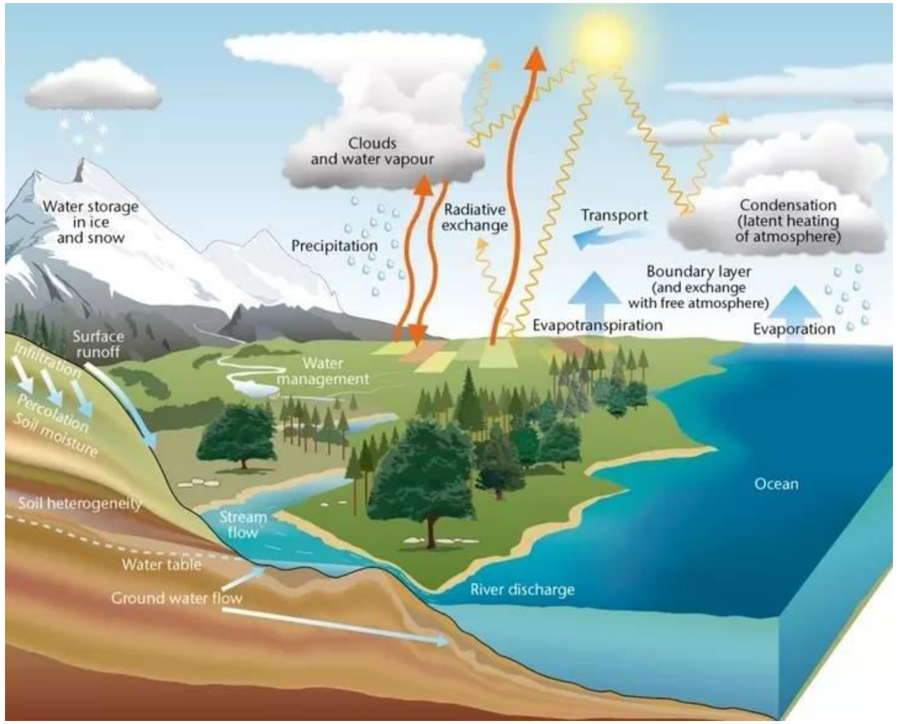
Outline

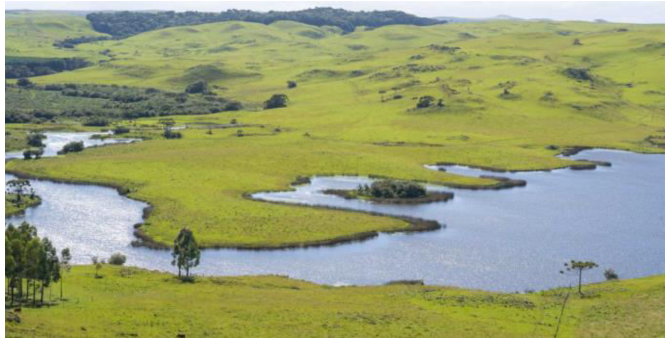
1. **Background**
2. **Process and pattern of global ET**
3. **Process and pattern of regional ET**
4. **Impact of vegetation change on evapotranspiration**
5. **Conclusions**

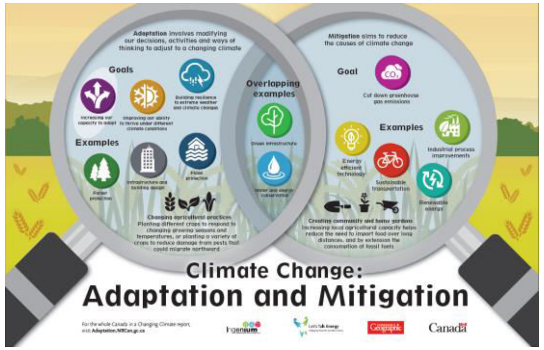
Background： why do we need ET study?

- **Science:** a key process for mass cycle and energy balances across different layers of the Earth, and a key indicator to understand climate change

- **Application:** agricultural water consumption; ecological, environment and climate effect of urbanization; coping with extreme climate risk







Background: vegetation change

- **Dramatic vegetation change in last 40 years**
- **Vegetation change becoming a hot pot for studying ET, its ecohydrological effects in global land cycle**
- **Spatial pattern and vegetation dynamics**

Tropical deforestation in Amazon

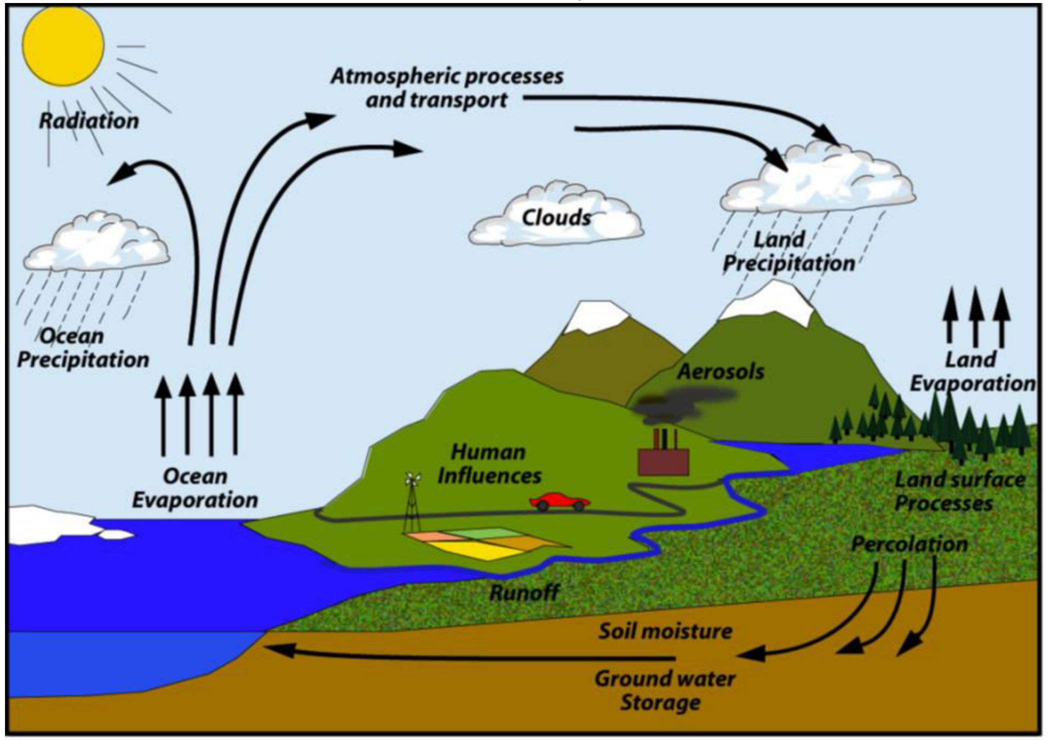
Plantation in the Loess Plateau

Fire in southeastern Australia

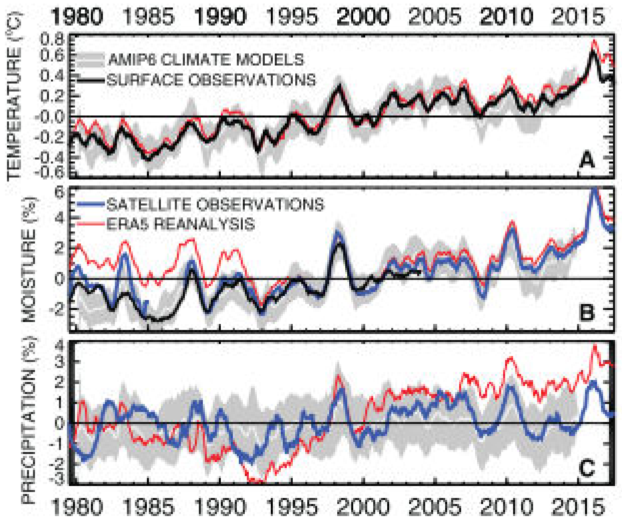
Background: global water cycle

- P = ET at a global scale
- Over the land, there are complex land covers and land types, influencing ET complexly
- 60-65% of precipitation used for ET, 35-40% for runoff
- Trend and attribution are the key for understanding hydrological cycle

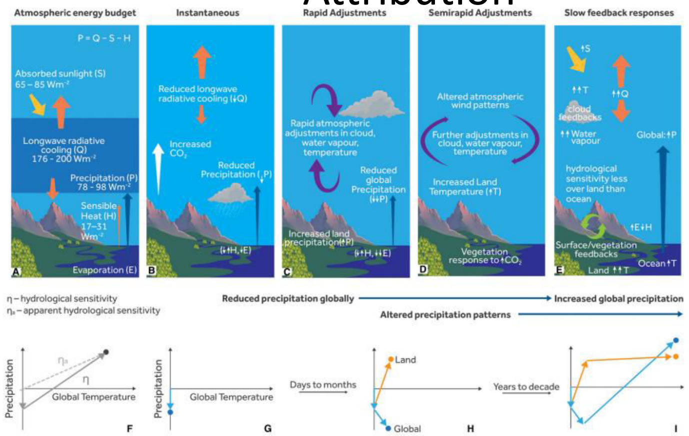
Global water cycle



Diagnostic



Attribution



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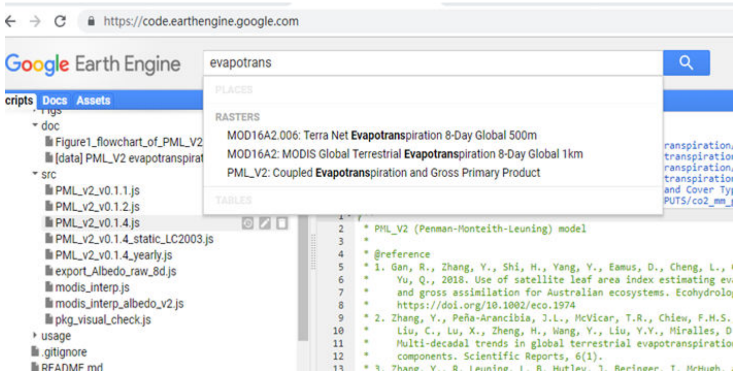
Major approach: PML evapotranspiration model

- First and second generation of PML model developed in last 15 years
- Features: easy parameterization, physical meaningful, three components partitioned (E_s, E_t and E_i)
- Stomatal conductance is estimated by coupling with photosynthesis, which can estimate the constraint effect of increased CO_2 concentration on stomatal conductance
- Used by 300+ research organizations, universities and industrial partners



Linkage： https://code.earthengine.google.com/ ：500m
https://data.tpdc.ac.cn/zh-hans/ ：0.05deg

Chinese and global users

Most valued dataset in Earth data in 2021
(国家对地观测数据中心)

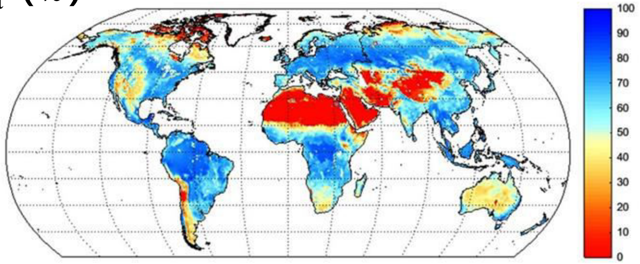
Advanced scientific and technological outcomes in 2022
（中国国际大数据产业博览会）

Over 3000 ISI citations with 40+ leading journal publications

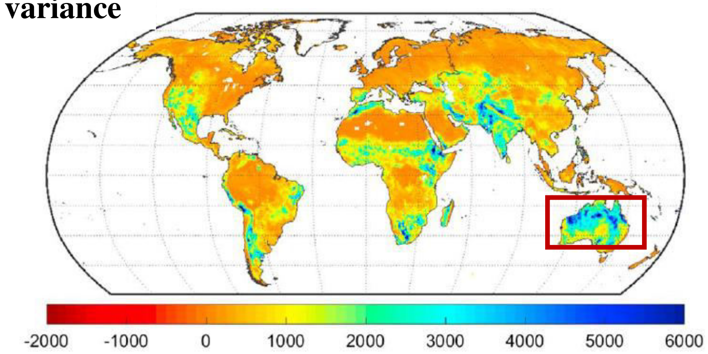
Process and pattern of global ET

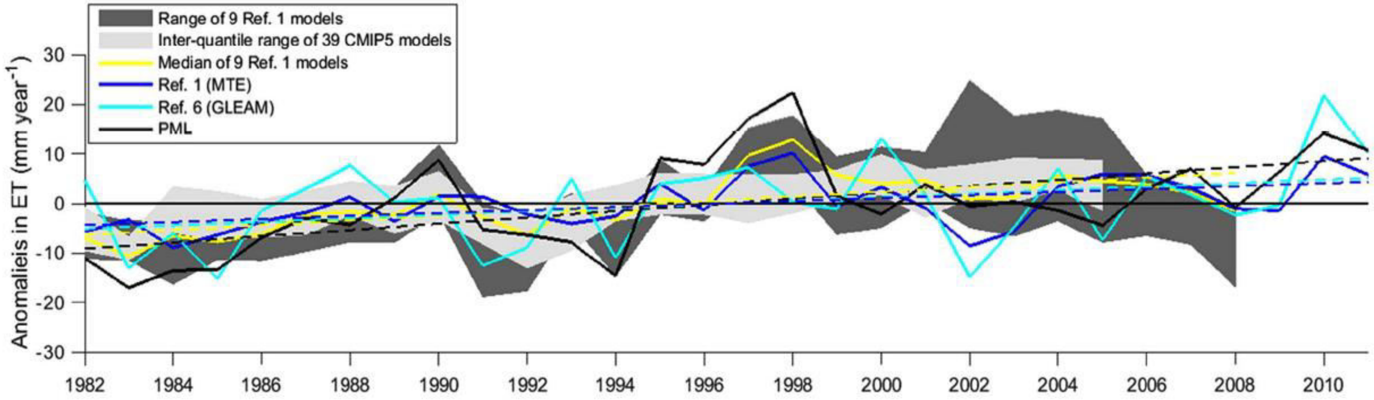
- E_t, E_s, and E_i account for **65%, 25% and 10% of ET, respectively**
- Land between 13°- 27°S accounts for 11% of global land, contributing to 21% of E_s globally
- Significant increase ($p < 0.05$) in evapotranspiration in the past 30-40 years

E_t (%)



E_s variance

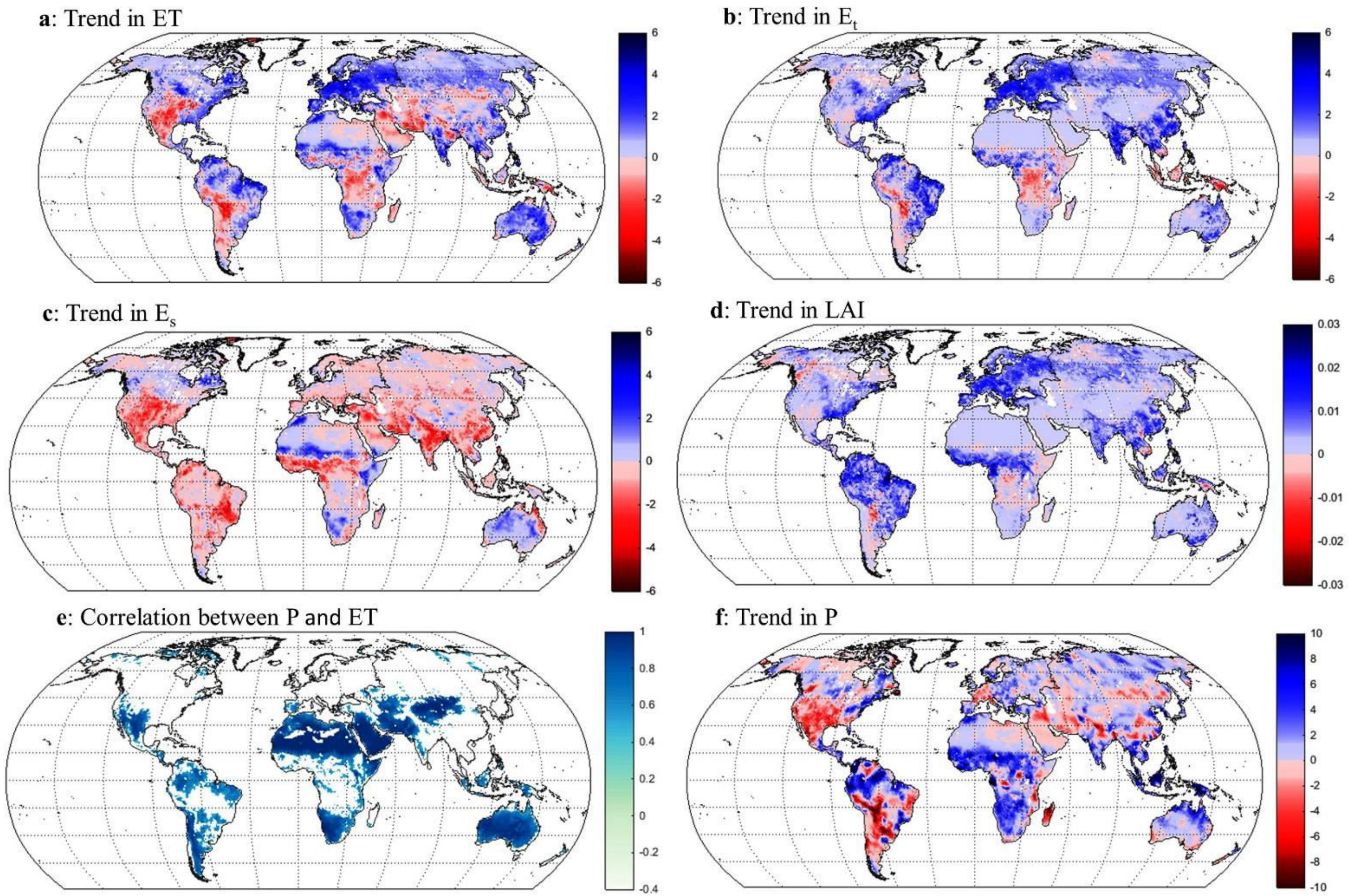




Zhang YQ, et al. (2016), SciRep; Zhang YQ, et al. (2017), JGR; Zhang et al. (2019), RSE

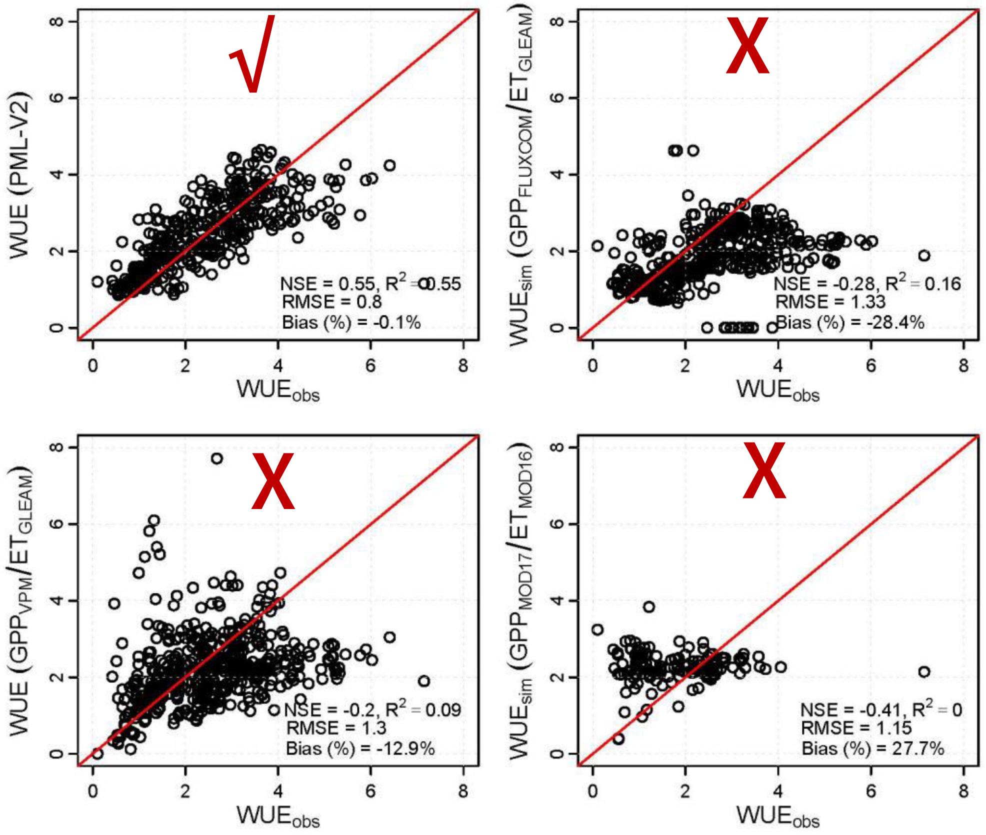
Process and pattern of global ET

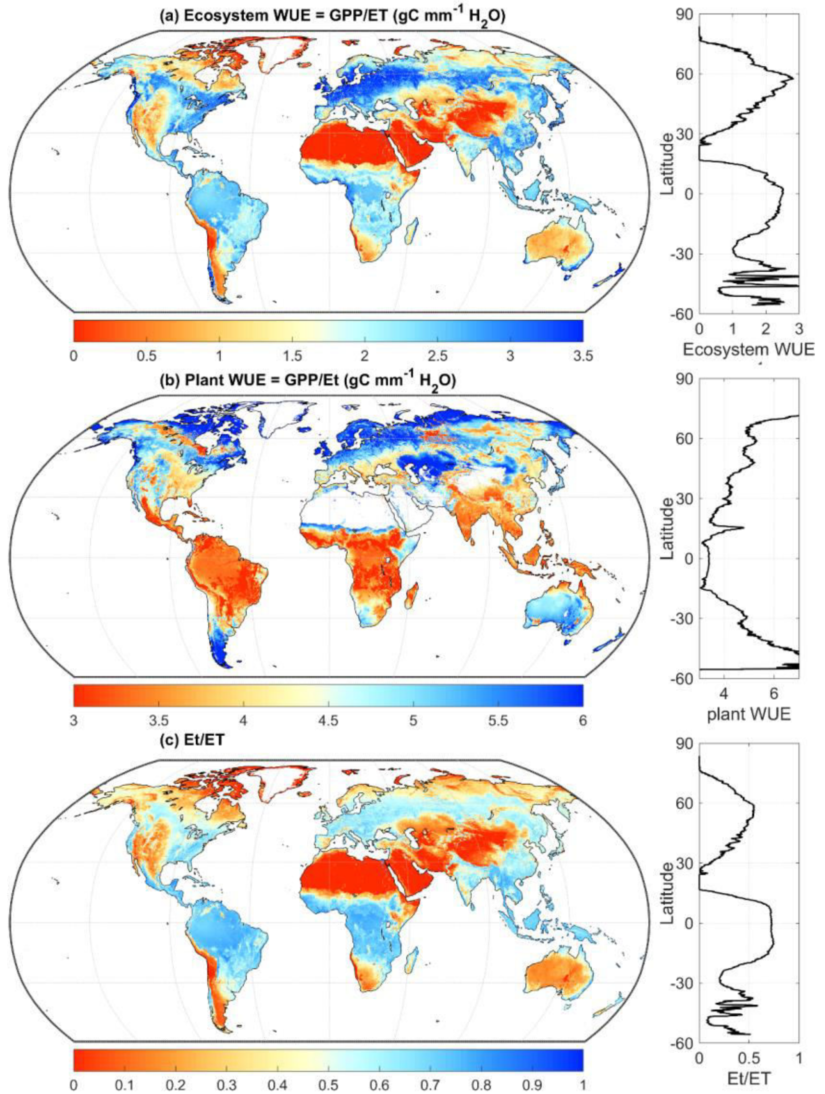
Greening has strongly contributed to increase in ET, especially in middle and high northern latitudes



Process and pattern of global WUE (GPP/ET)

- **PML-V2 doing a good job in simulating GPP and ET, and corresponding WUE**
- **Ecosystem WUE shows different pattern from plant WUE**





Zhang YQ, et al. (2019). RSE

Process and pattern of global ET

A 10 per cent increase in global land evapotranspiration from 2003 to 2019

Madeleine Pascolini-Campbell, John T. Reager, Hrishikesh A. Chandanpurkar & Matthew Rodell

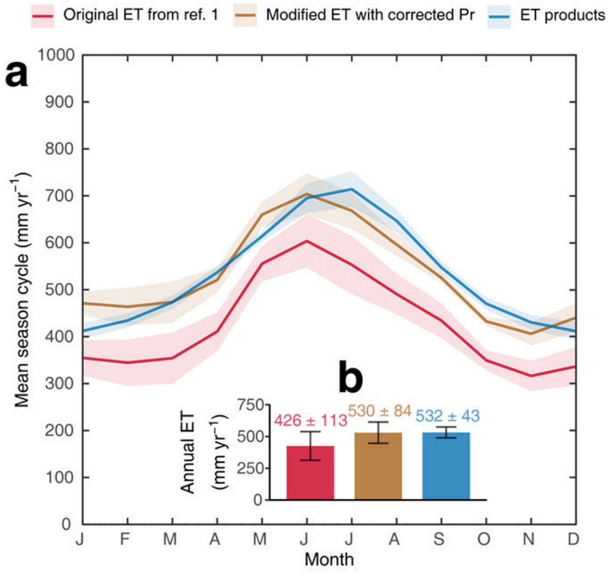
Nature **593**, 543–547 (2021) | Cite this article

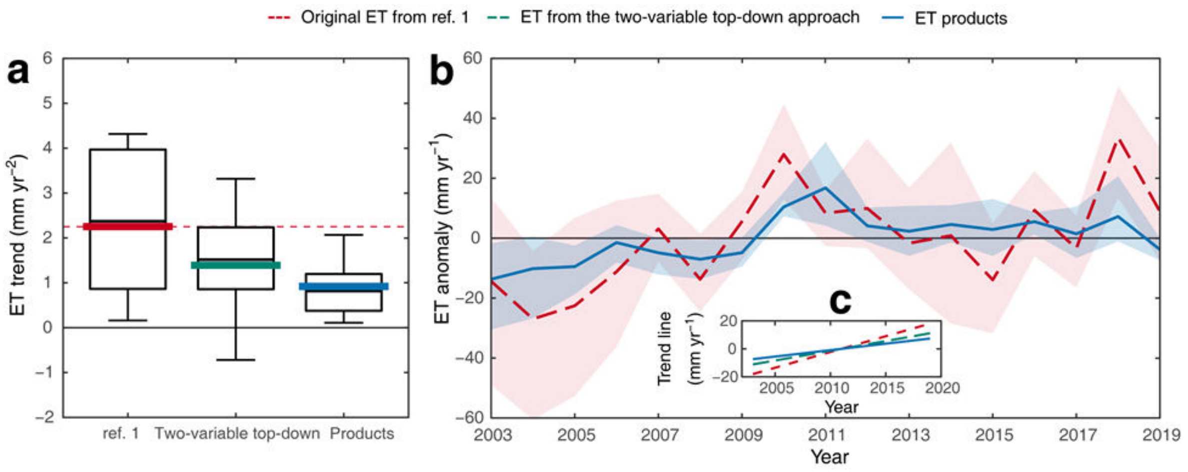
Original conclusions

- ET = 423 mm yr^{-1} over 2003-2019
- Trend of 2.30 ± 0.52mm yr^{-2}, ~10% increase in 2003-2019
- ENSO explains 17% change, T_a explaining 54%

Conclusions from our study

- ET = 530 mm yr^{-1} over 2003-2019
- 1.39 ± 0.4 mm yr^{-2} or 0.92 ± 0.52mm yr^{-2}
- 4.5 ± 1.3% or 3.0 ± 1.1% in 2003-2019





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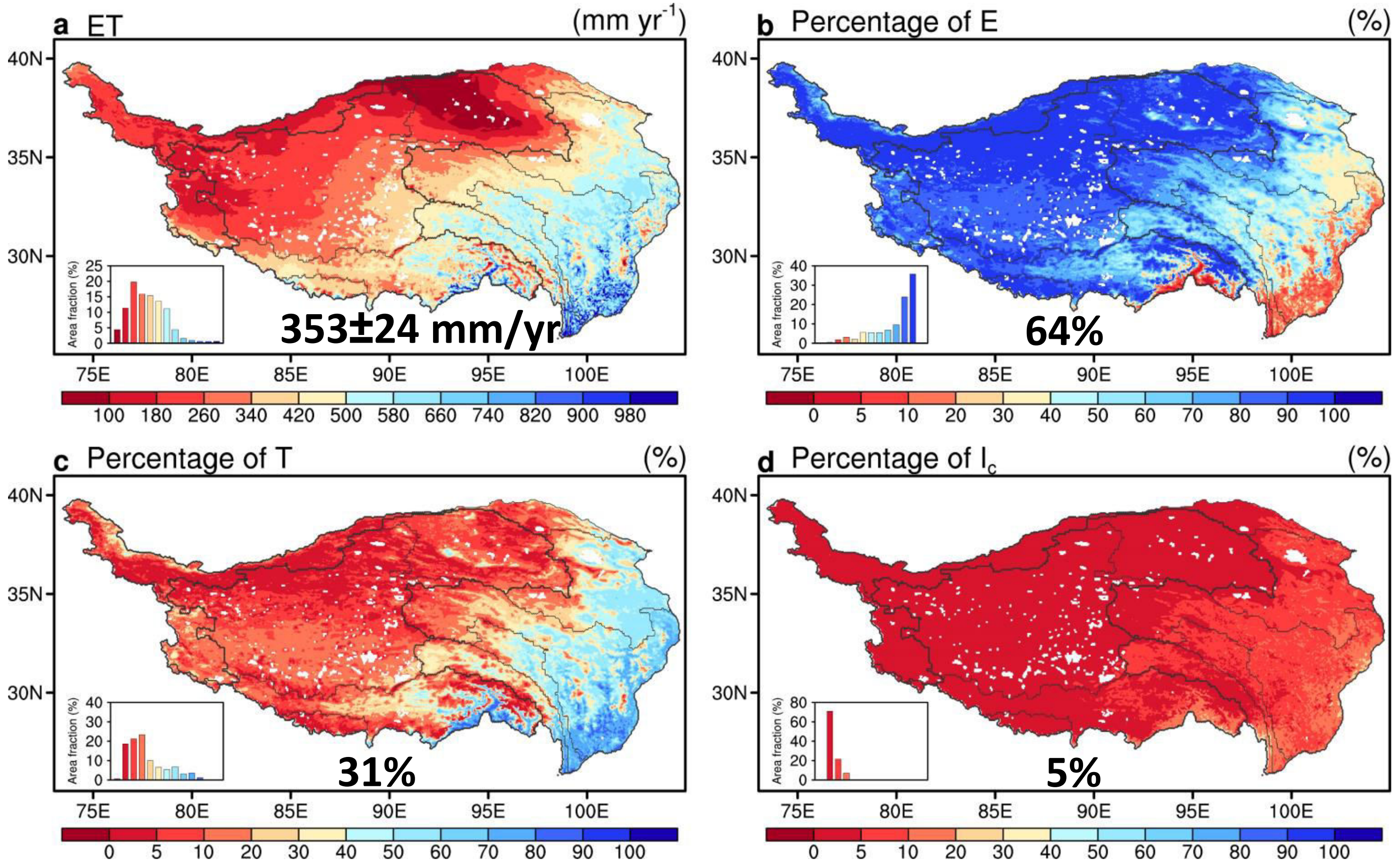
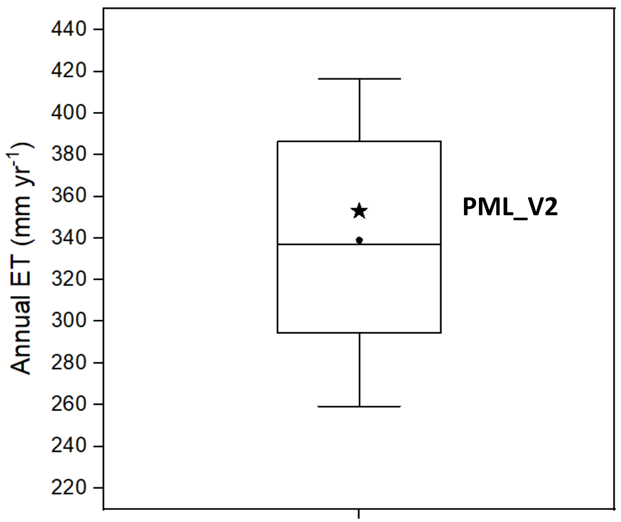
Trend and attribution of ET on the Tibetan Plateau

Q1: How much is ET on the TP？

PML-V2 estimates of mean annual ET: 353±24 mm/yr, 64% by soil evaporation, 31% by transpiration, and 5% by intercepted precipitation





ET estimates from ERA5, JRA55, MERRA2, FLUXCOM, CR, GLEAM, Noah_GL and CLSM_GL in 1982-2016

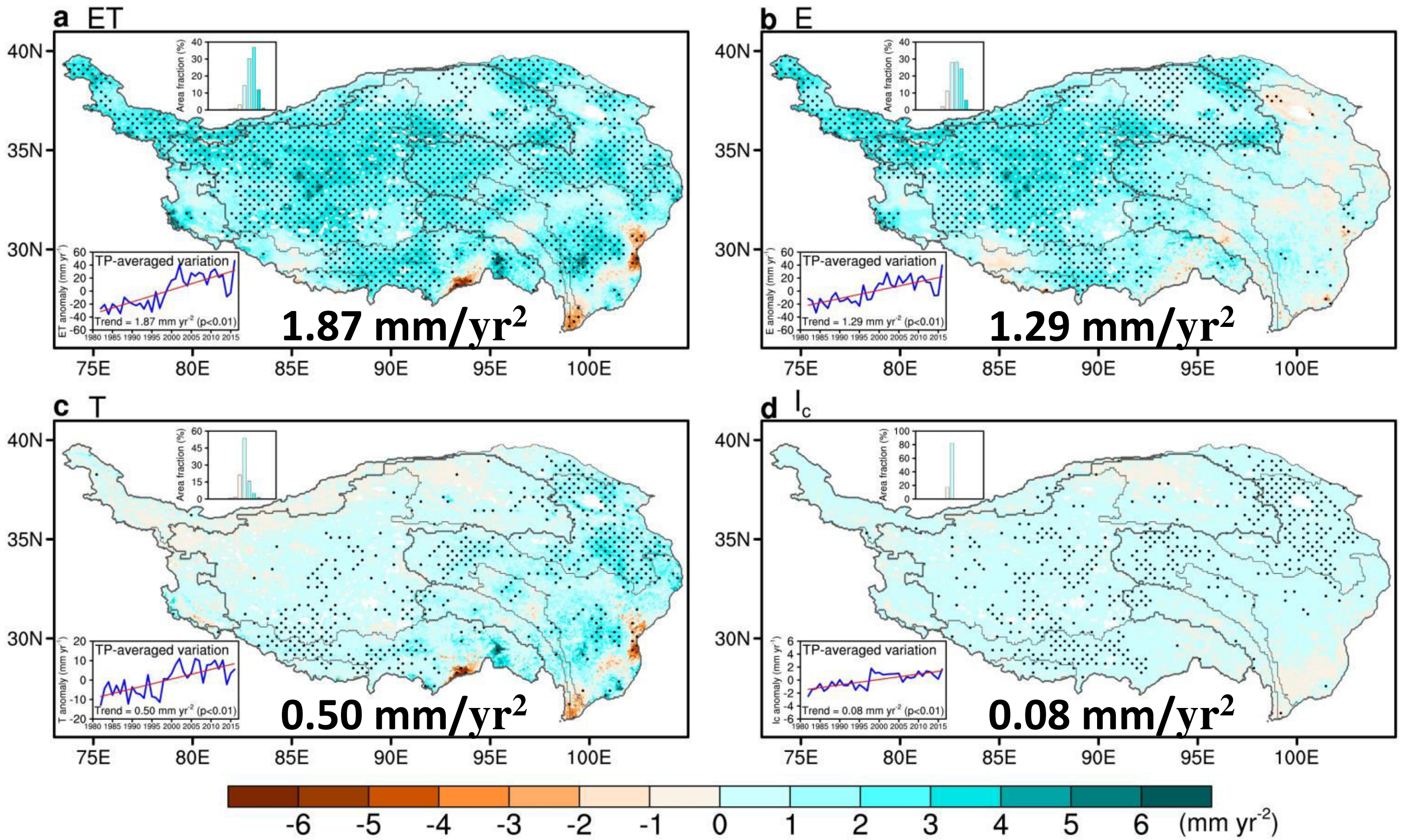
Spatial pattern of ET and its components (1982-2016)

Ma and Zhang (2022). Agricultural and Forest Meteorology

Trend and attribution of ET on the Tibetan Plateau

Q2: How did ET change?

- **Pattern**: majority increased (77%), excepted for southeastern TP
- **Components**: E increased in the western TP; T increased in eastern and southwestern TP
- **Total trends:** 1.87mm/yr^2 of ET, 64% contributed by E, 31% contributed by T
- **Temporal change**: quick increase in late 1990s, mean ET in 1998-2016 is 11.5% larger than that in 1982-1997



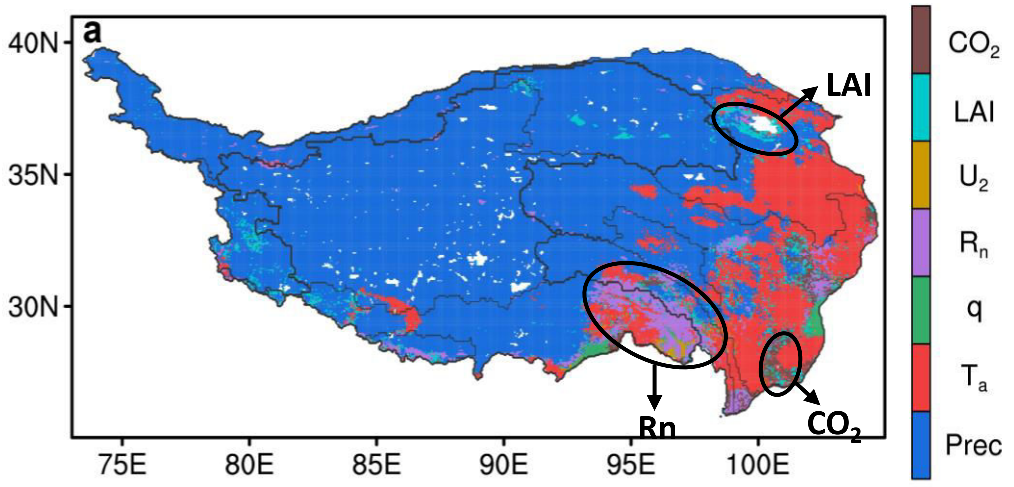
Spatial pattern of trends in ET and its components (1982-2016)

Ma and Zhang (2022). Agricultural and Forest Meteorology

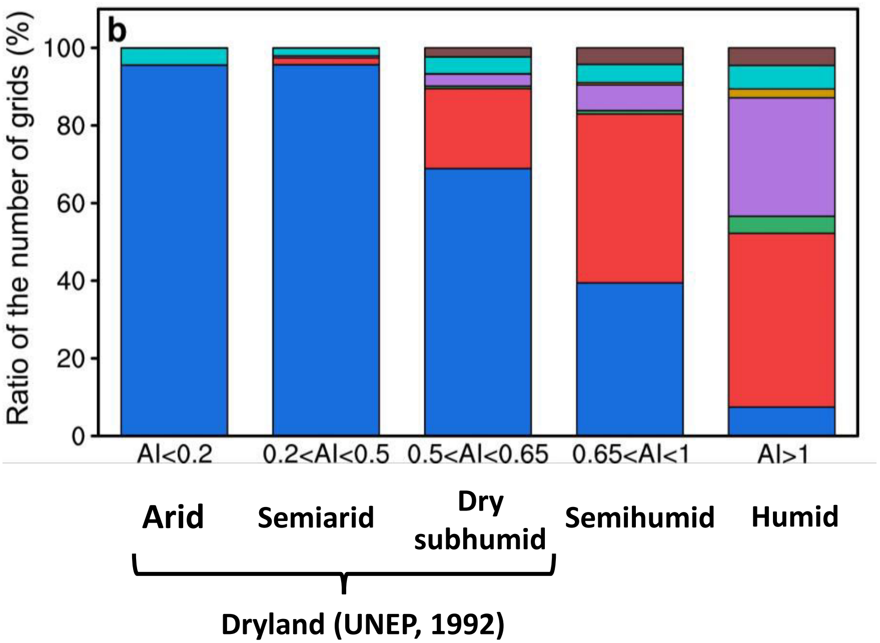
Trend and attribution of ET on the Tibetan Plateau

Q3: What are major drivers?

- **Precipitation is the major driver in west and middle; other drivers dominate ET trends in northeastern, eastern and southeastern TP;**
- **This pattern is consistent with that of climate regimes**



Spatial pattern of major drivers for ET trends



Ma and Zhang (2022). Agricultural and Forest Meteorology

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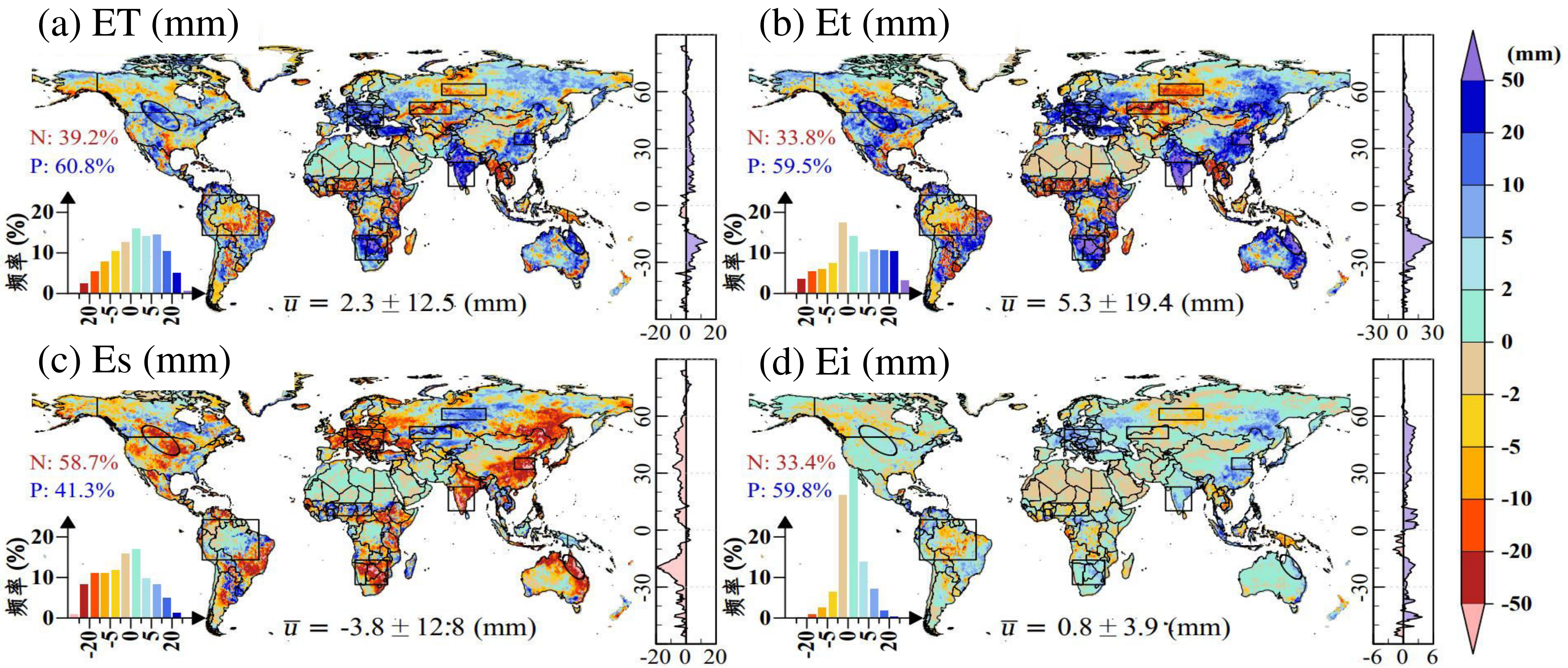
Vegetation change imact on ET

Global

- **ET increased because of vegetation change in 2003-2017**
- **Increased impacts appear in eastern China, majority India, southern Europe, southern Africa and central North America**
- **Decreased impacts appear in Amazons, tropical Africa and eastern Europe**



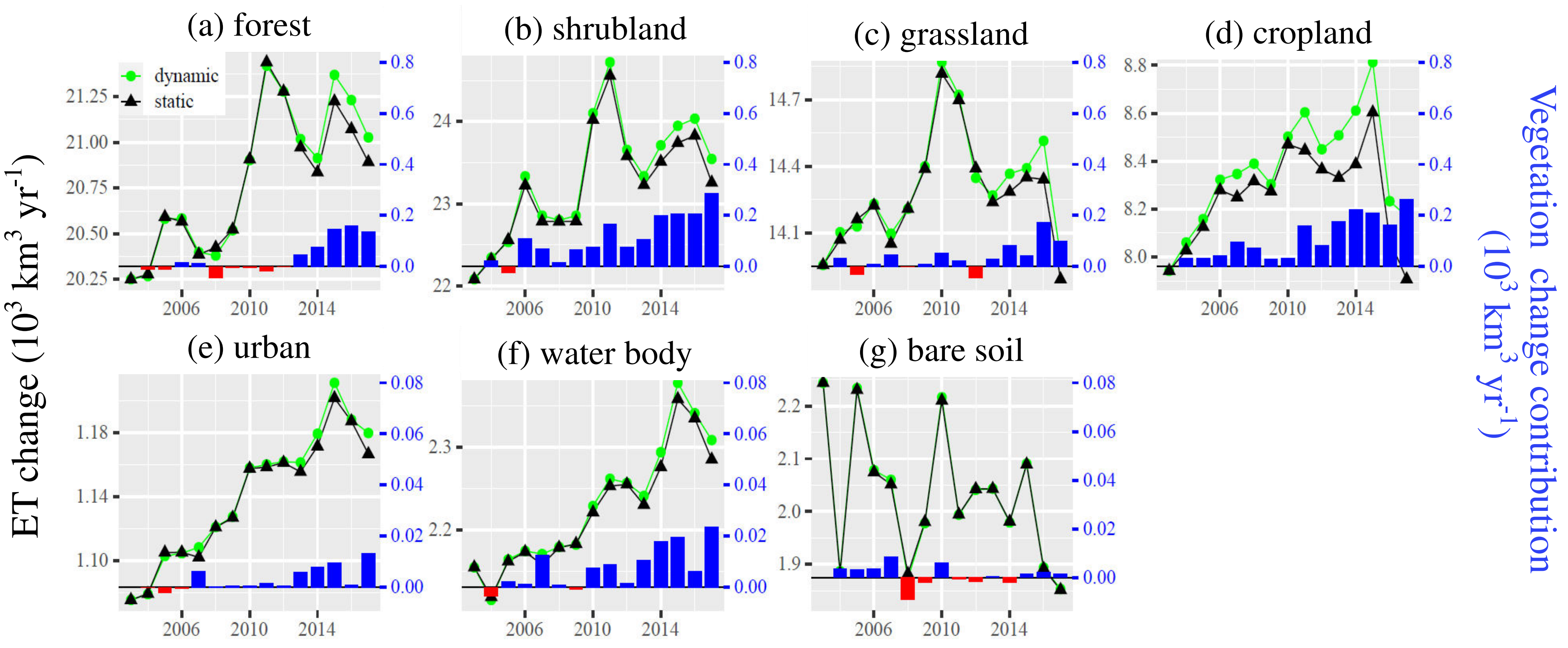
Changes in ET and its components driven by vegetation change in 2003-2017

Zhang, et al. 2021. Acta Geograpica Sinica

Vegetation change imact on ET

Global

- **Smaller impact in 2003-2012, larger impact for post-2012**
- **Increased impact reached 0.20×10^3 km^3 and 0.21×10^3 km^3 for cropland and shurbland**
- **Increased impact reached 0.11×10^3 km^3 and 0.09×10^3 km^3 for forest and grassland**



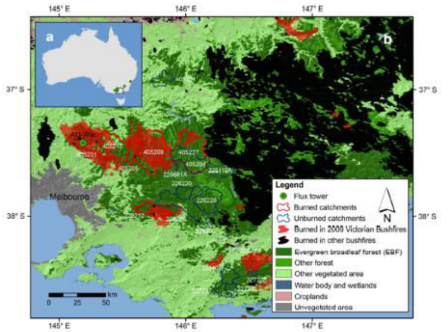
Impact of vegetation change on ET in 2003-2017, aggregated by plant functional types

Zhang, et al. 2021. Acta Geograpica Sinica

Forest fire imact on ET and water balance

SE Australia

- After 2009 forest fire, ET dramatically decreased and streamflow increased, but these two have asynchronous response to fires
- Increase in catchment water storage change is smaller than expected



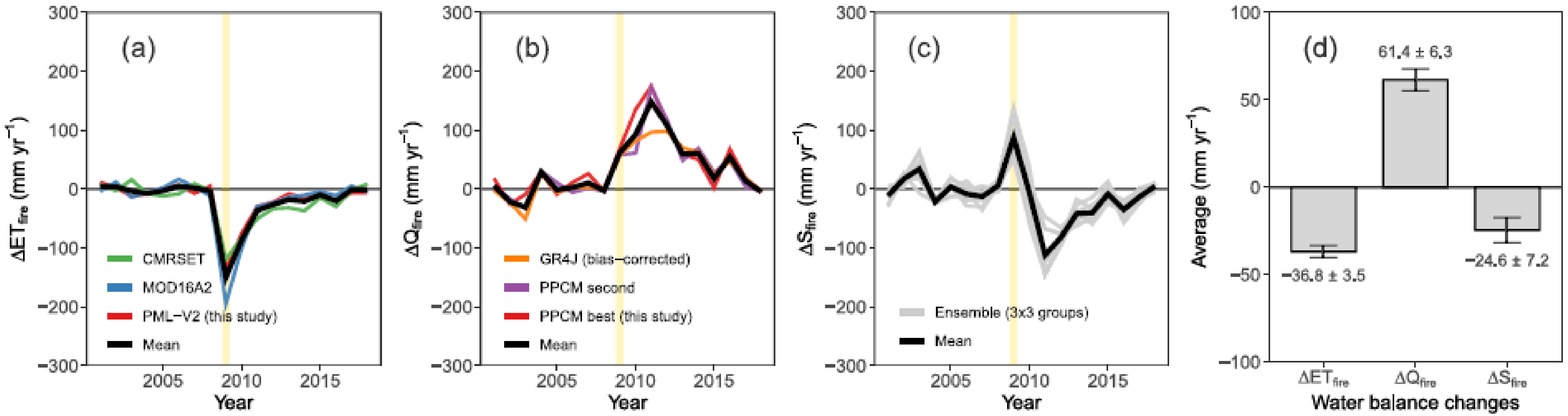


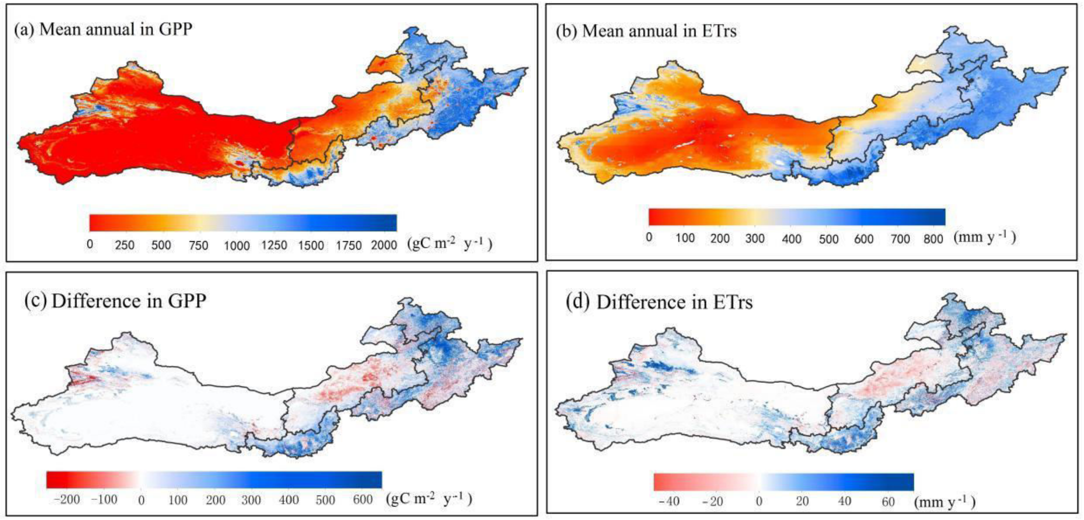
Figure 9. Estimated fire-induced water balance changes averaged for all burned catchments using independent data/methods. (a–c) Time series and (d) the average results for the postfire decade. The yellow vertical lines indicate the timing of the 2009 Victorian Bushfires. The ensemble in panel (c) is from the nine combinations of the evapotranspiration (ET) estimates from the three ET products in panel (a) and the three kinds of *Q* estimates in panel (b). The error bars shown in panel (d) are computed by the results of panels (a–c), respectively.

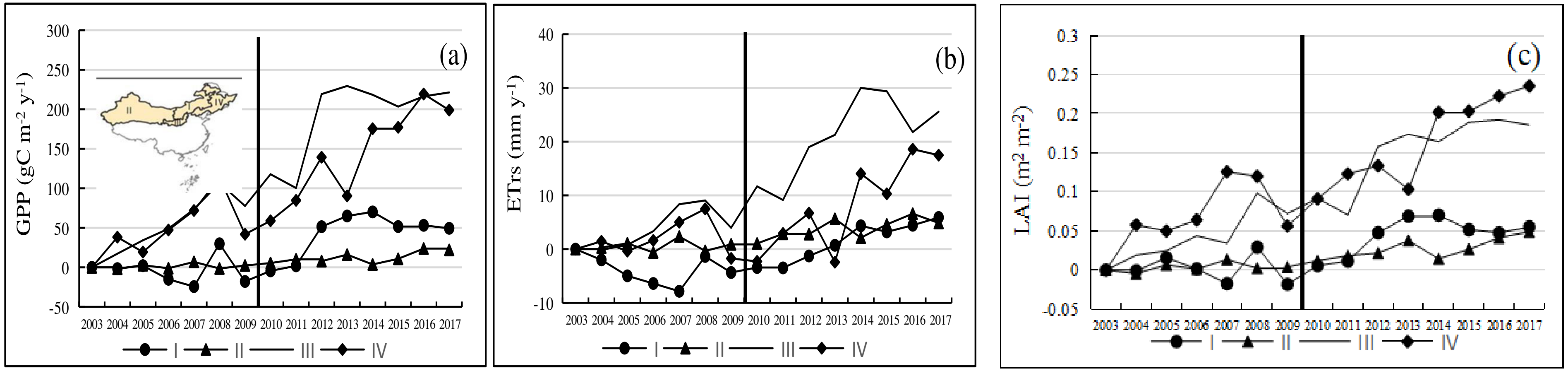
Xu, **Zhang***, et al. (2022). Water Resources Research

Impact of the ecological restoration project on ET and GPP

Northern China

- **ET and GPP increased strongly on the Loess Plateau and northeastern China plain**
- **Stronger for the post-2010 period**



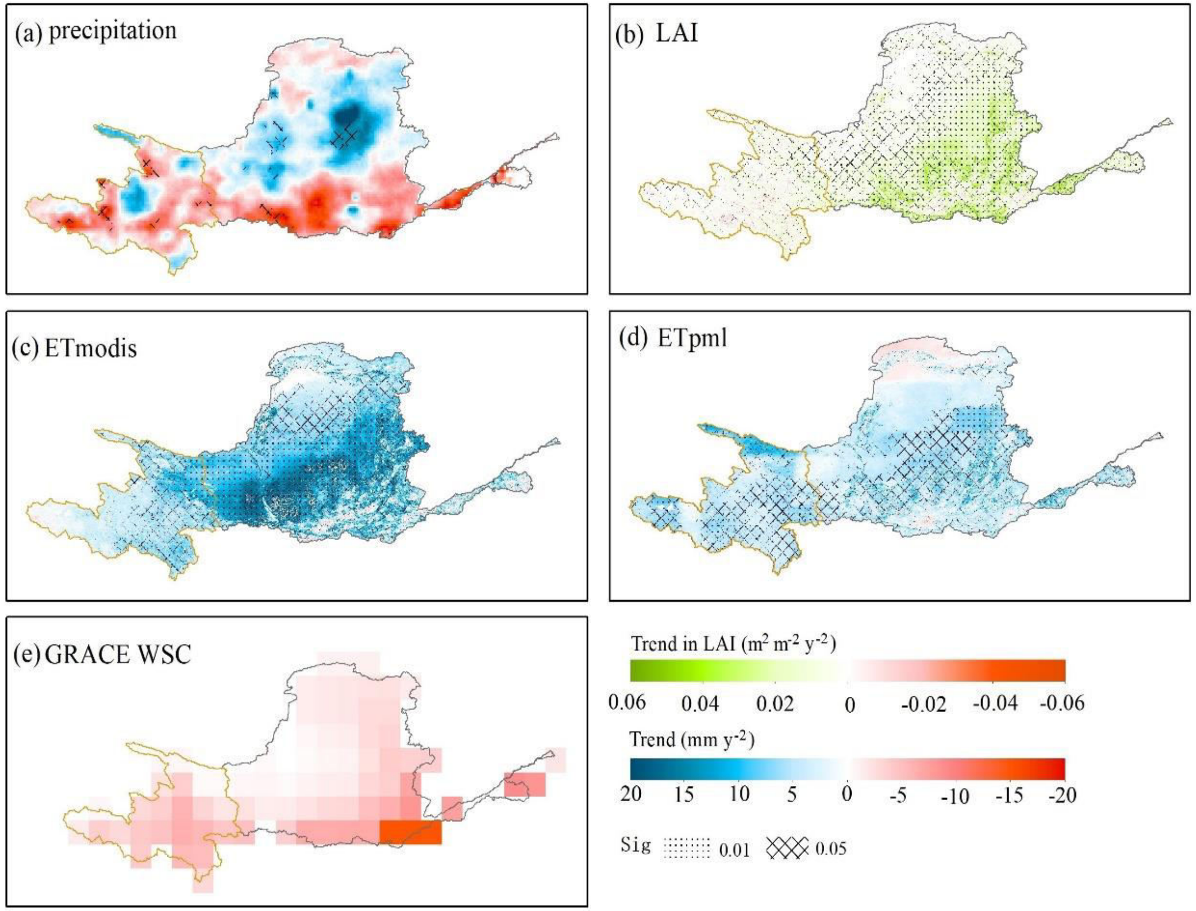


Li, **Zhang***, et al. (2020). JGR-Atmospheres

Impact of the ecological restoration project on ET and GPP

Yellow River Basin

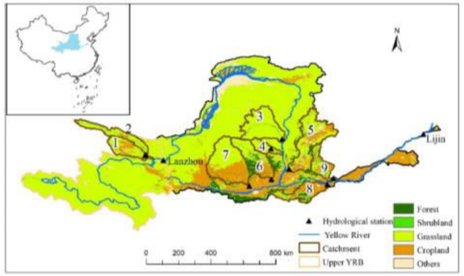
- P increased in central YRB in 2003-2016
- ET and LAI increased in central and lower reaches of YRB, consistent with decline in WSC



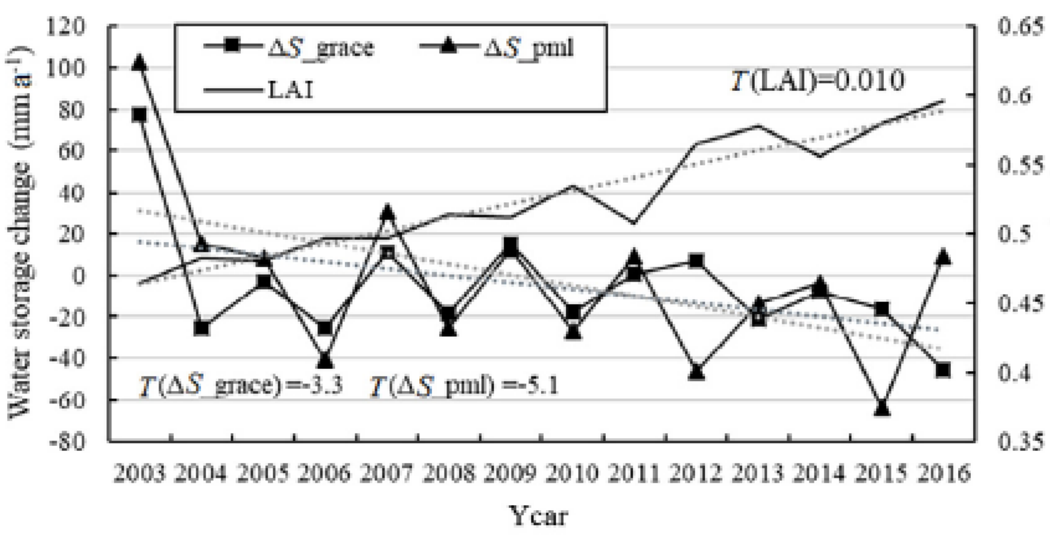
Spatial pattern of trends in P, LAI, ET and TWS (2003-2016)

Li, **Zhang***, et al. (2020). Science Bulletin

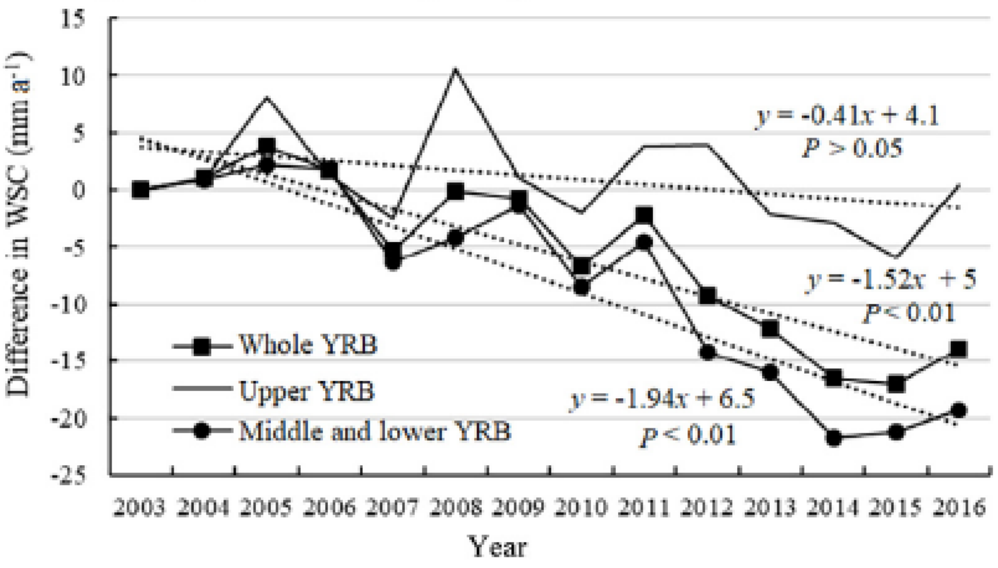
- **TWS slightly decreased in the upper reach**
- **It decreased strongly in the middle and lower reaches, causing the declined rate of 5.1 mm yr^{-1} for the entire YRB**



(e) The whole YRB



(f) Vegetation change impact



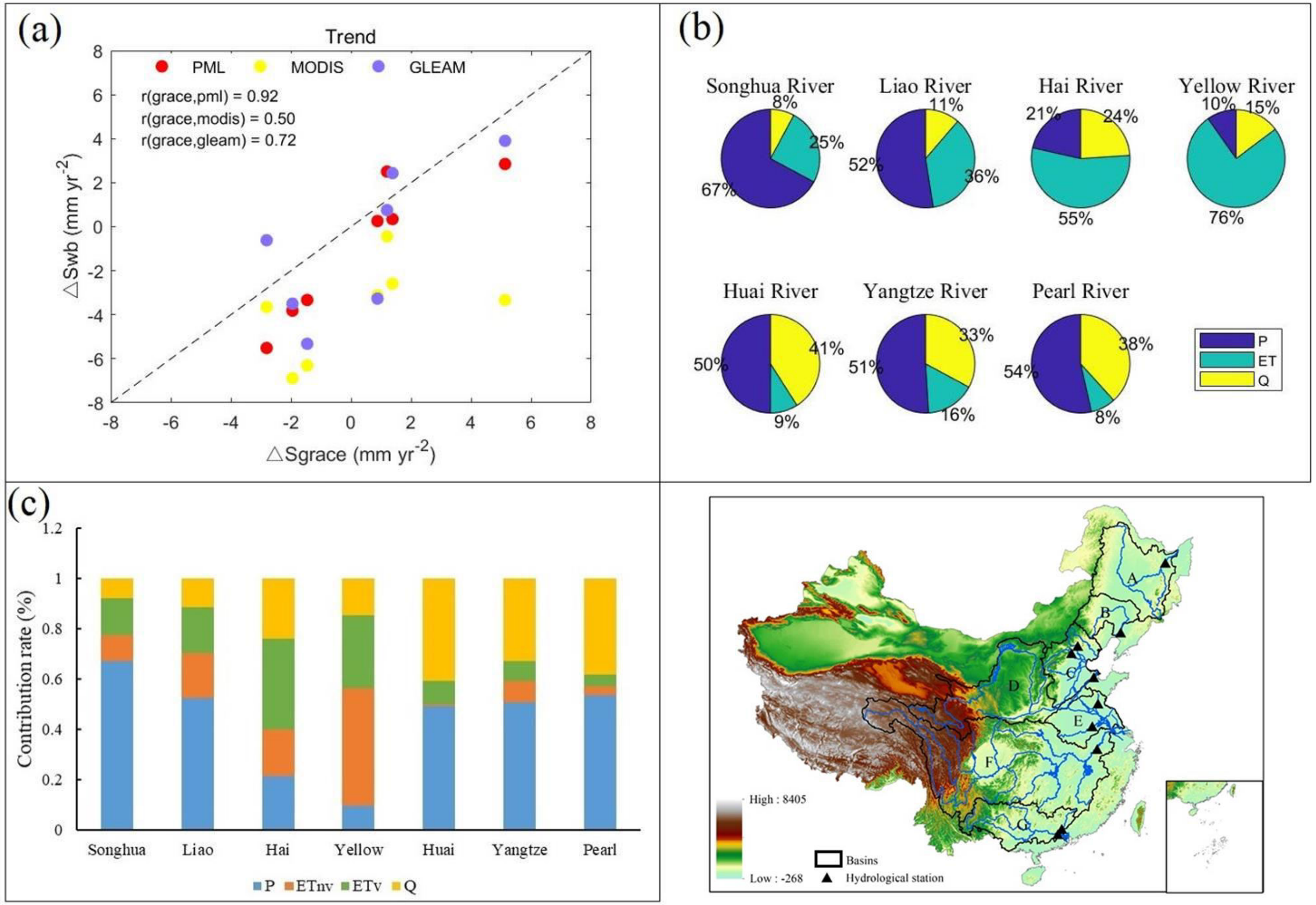
Li, **Zhang***, et al. (2020). Science Bulletin

Vegetation change impact on TWS

Seven large basins

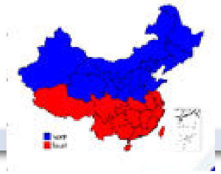
- **TWS change mainly contributed by ET in Hai River and Yellow River basins, but by P in other basins;**
- **ET contributions partitioned into vegetation and non-vegetation; vegetation change contributed a lot to the total in the Hai River and Yellow River basins.**

Trend analysis **Contribution analysis**

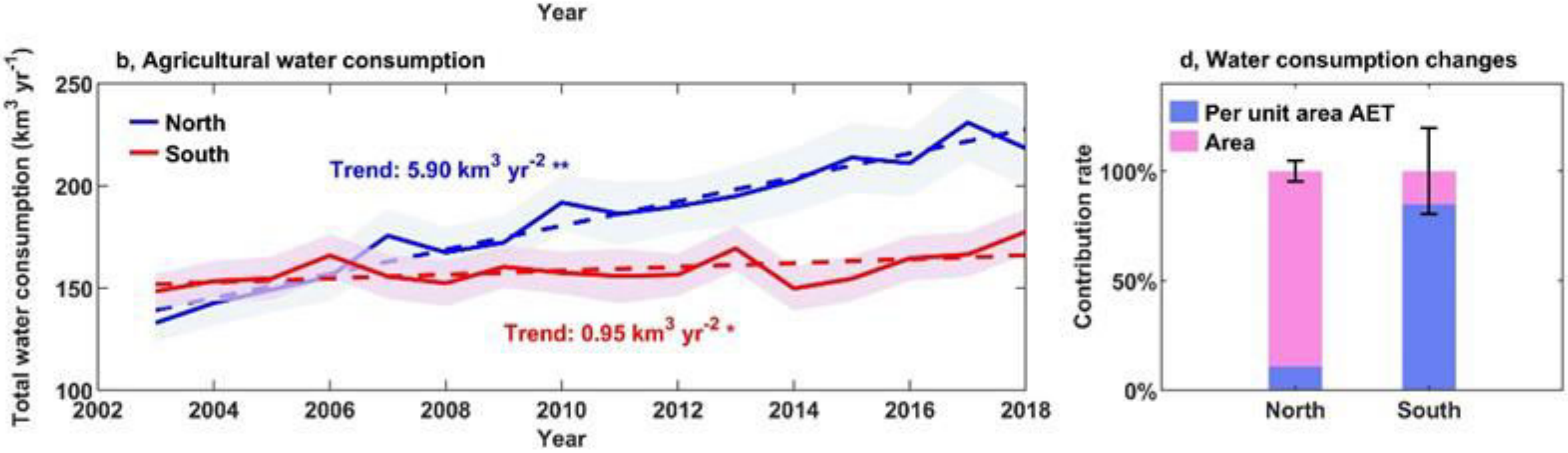


Li, **Zhang***, et al. (2023). Under review

Cropland expansion impacts on agricultural water use



- Agricultural water consumption increased dramatically in northern china, slightly increased in southern China
- Expansion of cropland area is the major cause in the north; increase in per unit area actual evapotranspiration is the major cause in the south.



Temporal variations in agricultural water consumption (wheat, maize and rice) and attribution analysis

Li, **Zhang***, et al. (2023). Earth's Future

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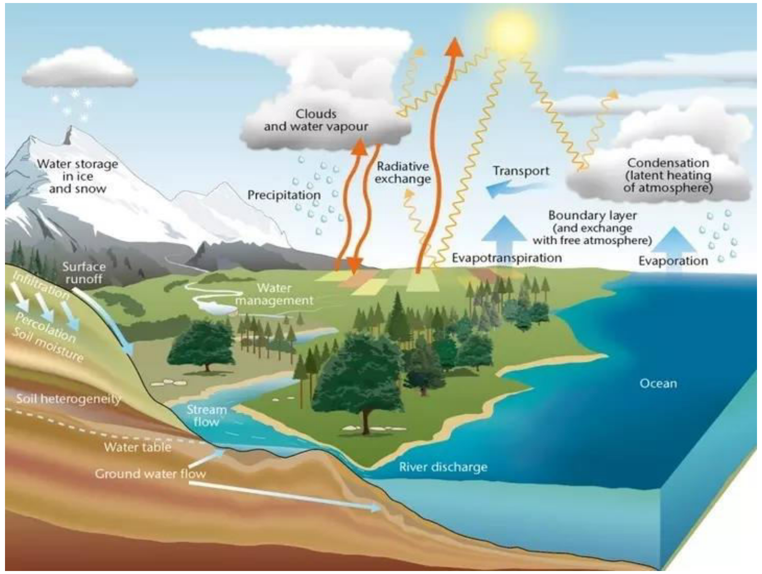
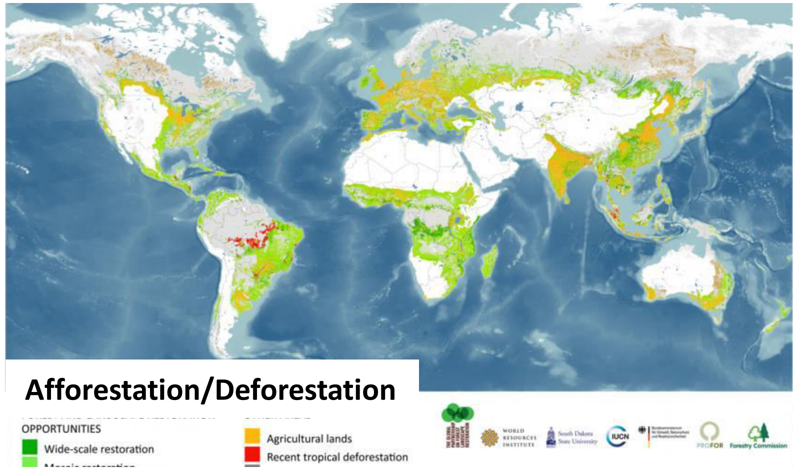
Conclusions: global and regional ET

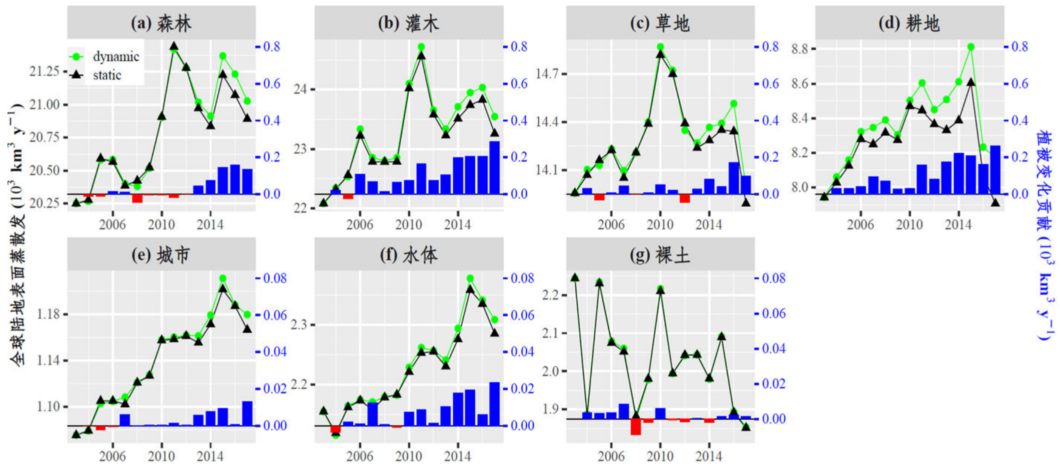
- **Land surface has experienced dramatic changes in last 40 years, which noticeably influence ET processes across global land surface**
- **ET has noticeably increased across the globe in last 40 years, and further intensified in some regions, such as the Tibetan Plateau**

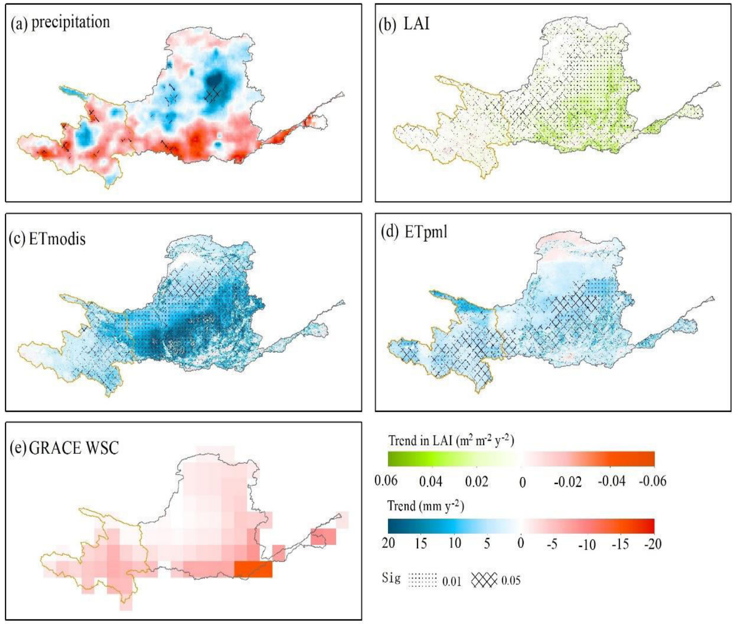


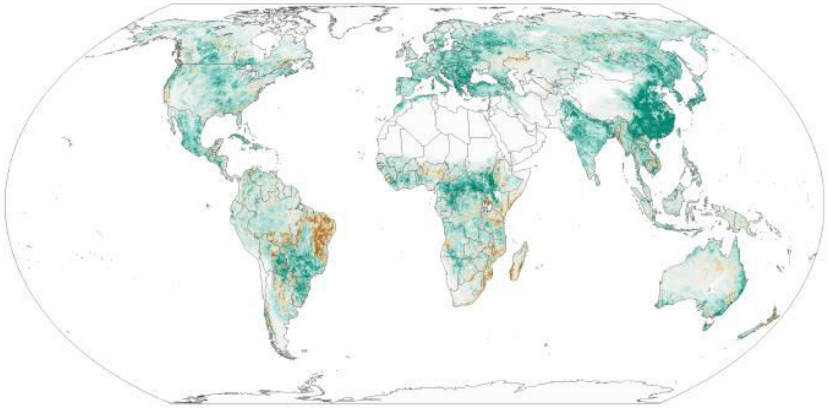


Conclusions: vegetation change impact on ET and water cycle

- **Vegetation change impact on global water cycle is a hot but hard topic nationally and globally**
- **Vegetation change indeed changed ET noticeably, especially in cropland and shrubland. The impact is more prominent for the post-2010 period**
- **Vegetation change resulted in strong ecohydrological consequences, worsening water crisis in northern China, especially in YRB**







Trend in Growing Season Mean Leaf Area Index (2000-2018, 10^{-3} m²/m²/year)

≤-18 -9 0 9 ≥18

Thank you!

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