

## The Comprehensive observations and numerical simulations of energy and water exchanges and their climatic effects over the Third Pole region

Presenter: **Binbin Wang**

Contributors: Yaoming Ma, Weiqiang Ma, Lijun Sun, LAIC group, et al.

2026-09-09

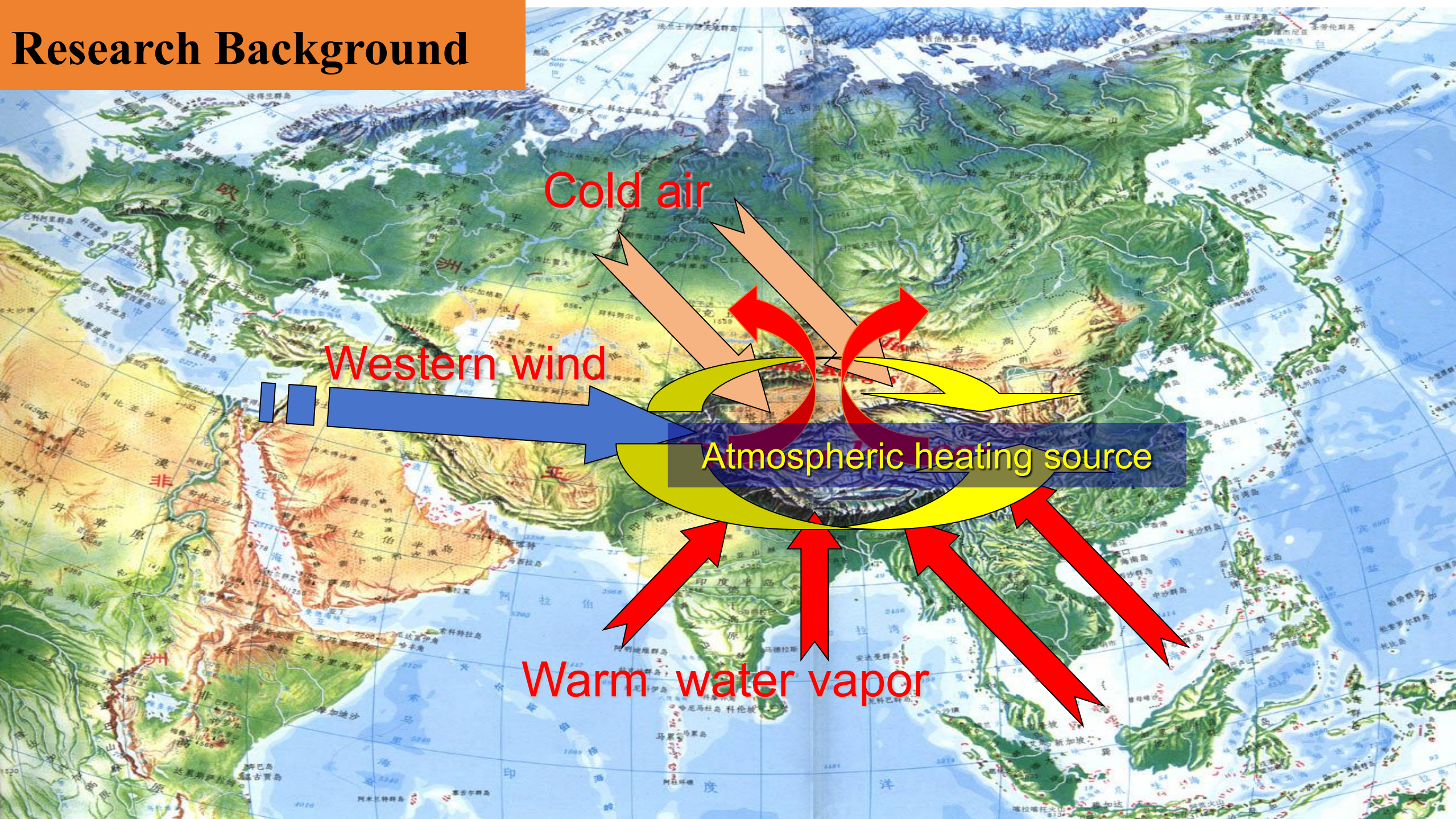


# Outline

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- **Research Background**
- **Observational Platform**
- **Key findings**
- **Concluding Remarks**

# Research Background



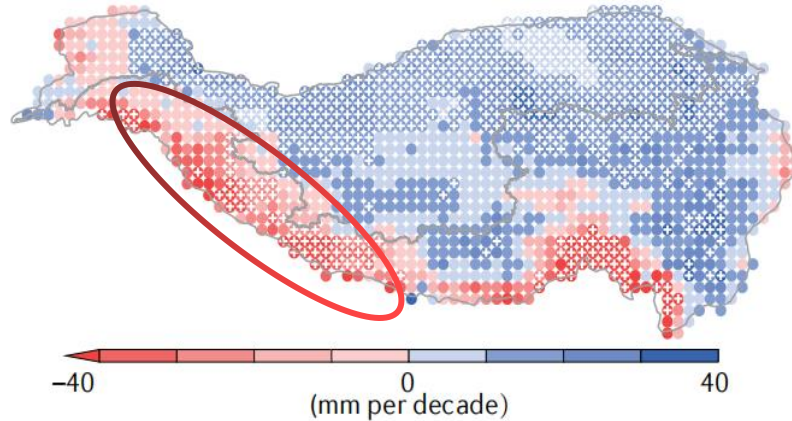
# Research Background



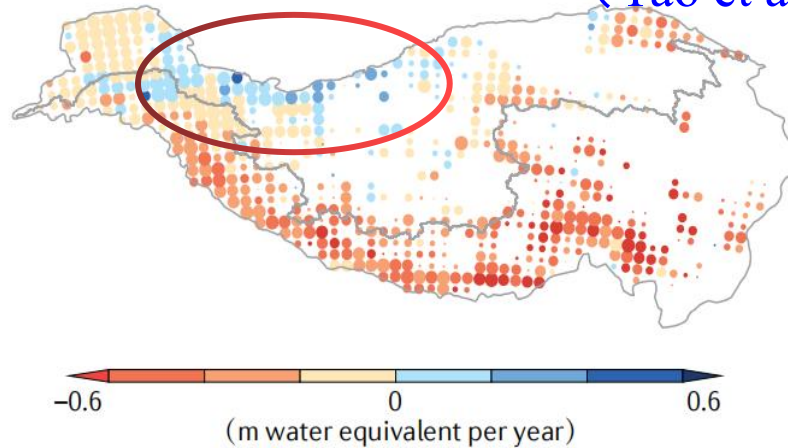
**How to properly understand the regional-scale water, heat and carbon exchange patterns over the complex land surface of the Tibetan Plateau?**

# Research Background

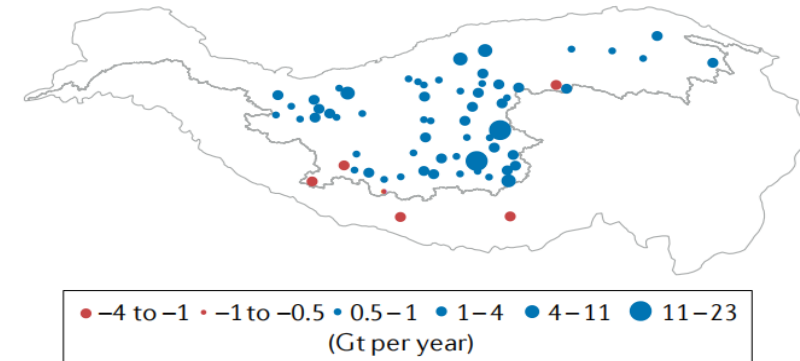
a Precipitation trends (1980–2018)



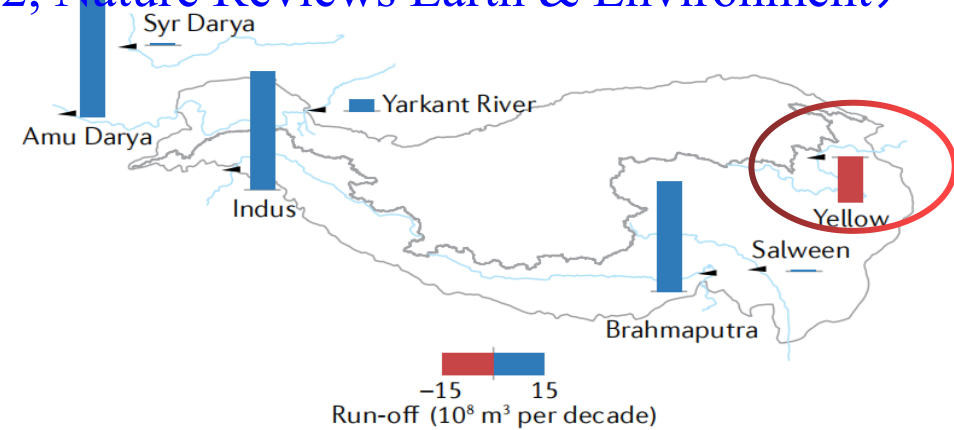
c Glacier mass balance (2000–2018)



e Lake volume change (1976–2019)



g River run-off trends (1980–2018)



(Yao et al, 2022, Nature Reviews Earth & Environment)

**To understand the water and energy exchanges over the Tibetan Plateau and their associated weather and climatic effects .**

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- **Observational Platform**
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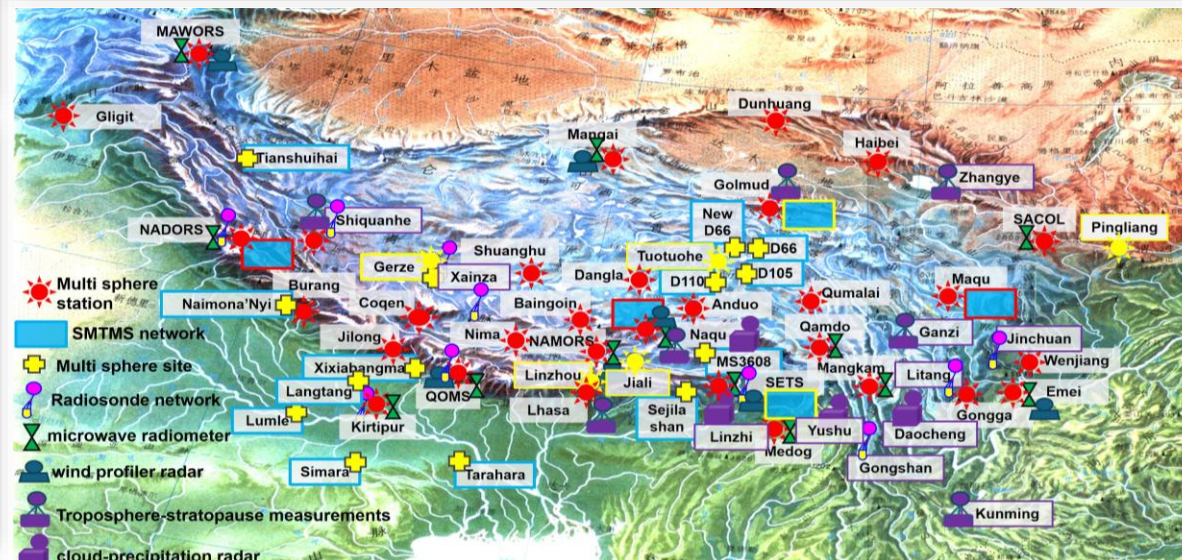
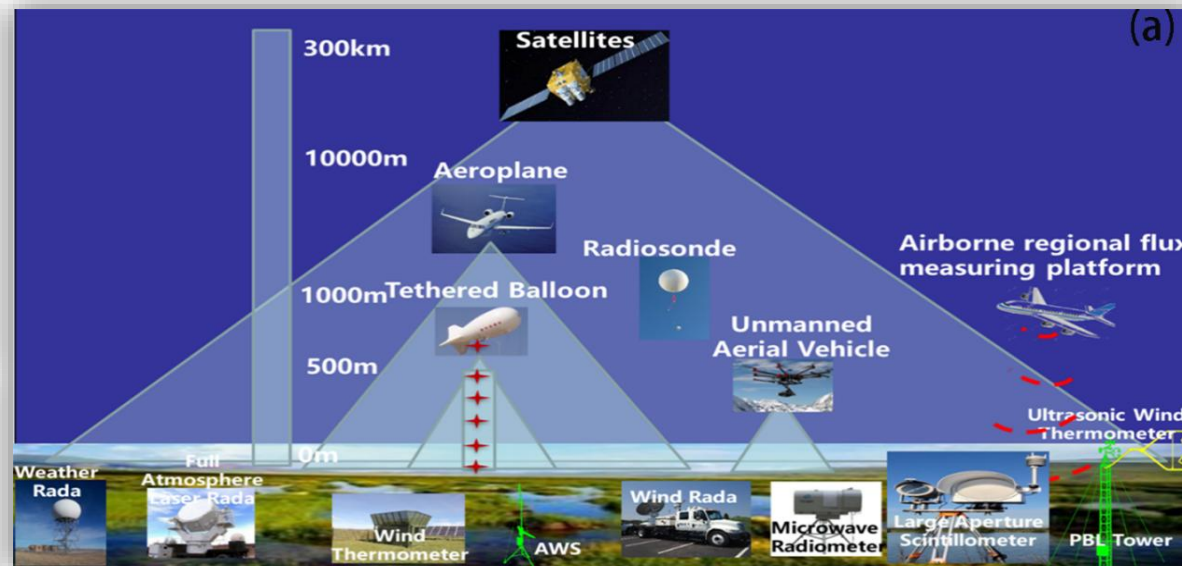
## (一)

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**We have established a three-dimensional observation network for land–atmosphere interactions across the Third Pole, and built a multi-sphere integrated database for the region.**

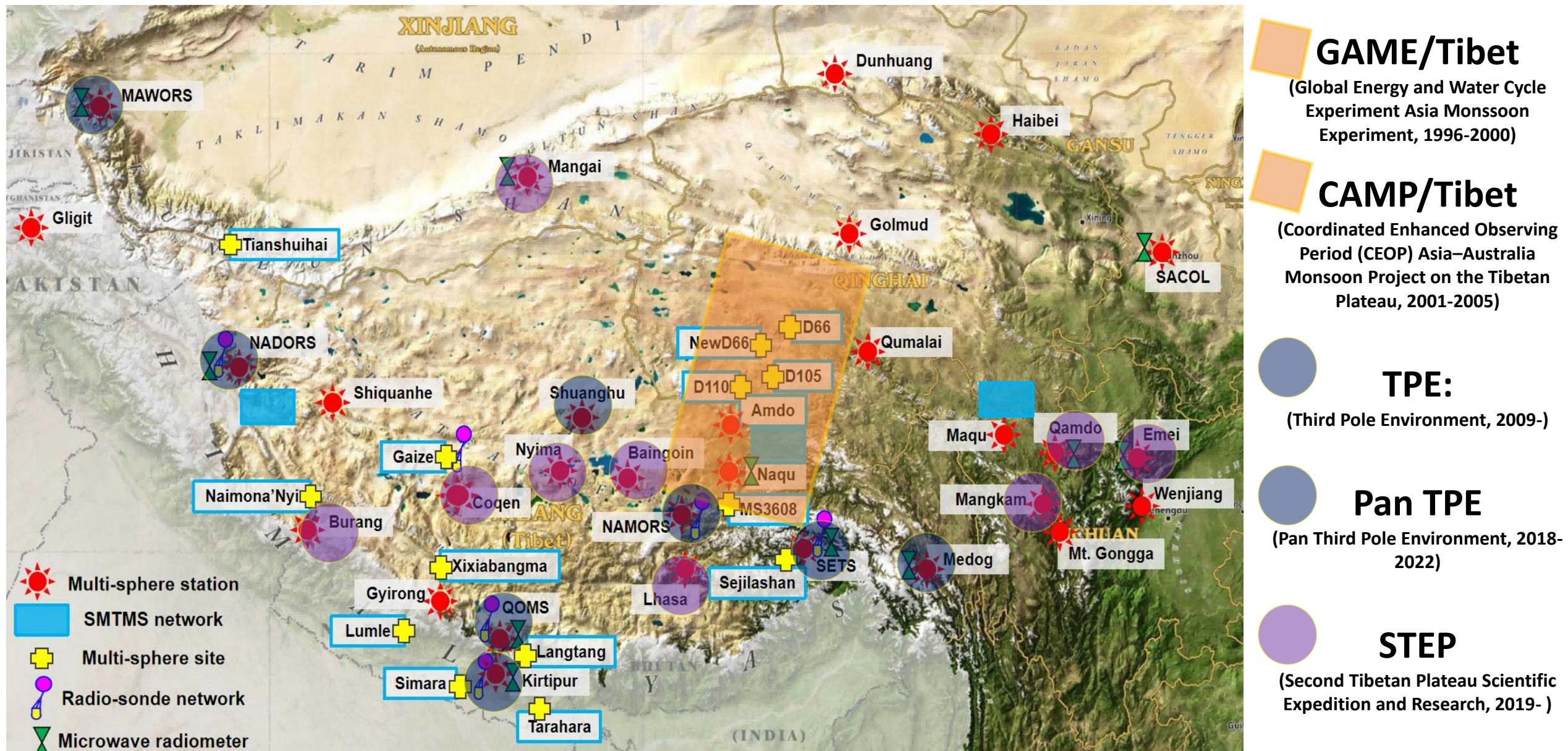
(**Ma, Y.** et al., 2008; **Ma, Y.** et al., 2017; **Ma, Y.** et al., 2020, ESSD ; Nieberding, **Ma\***, **Y.**, et al., 2020, ESSD ; 马耀明等, 2021, 高原气象; **Ma, Y.** et al., 2020, ESSD ; **Ma, Y.**, et al., 2023, AOSL; **Ma, Y.**, et al., 2023, ESR; Chen, **Ma, Y.\***, et al., 2024, AAS; Wang, **Ma, Y.\***, et al., 2026, ESSD)

# Three-dimensional Integrated Observation and Research Network for Multi-sphere Land–Atmosphere Interactions over the Tibetan Plateau



(Ma, Y., et al., 2023, ESR; Ma, Y., et al., 2023, BAMS; Chen\*, Xu, and Ma\*, Y. et al., 2024, BAMS; Chen, Liu\* and Ma\*, Y. et al., 2024, AAS; Ma, Y. et al., 2024, ESSD)

# A history of the construction of the comprehensive 3-D In-situ observation network



# Atmospheric boundary layer tower observation network for land-atmosphere interactions



阿里站



藏东南站



珠峰站



双湖站



纳木错站



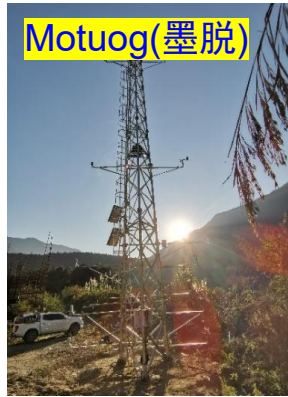
慕士塔格站



埃塞尔比亚



Kirtipur



Motuog(墨脱)



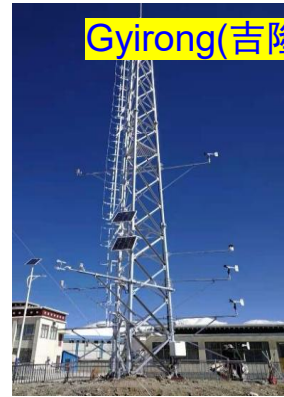
Mangkam(芒康)



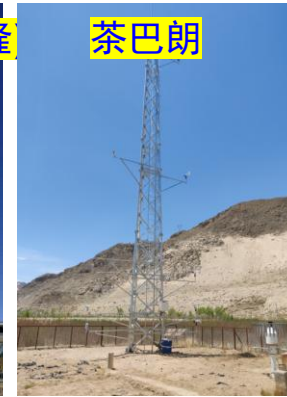
Qamdo(昌都)



Lahasa(拉萨)



Gyirong(吉隆)



茶巴朗



Simara



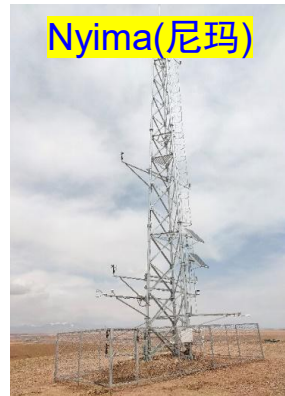
Tarahara



Namuco Lake  
(纳木错湖)



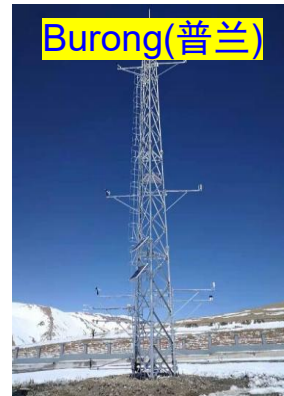
Mang Ai(茫崖)



Nyima(尼玛)



Baingoin(班戈)



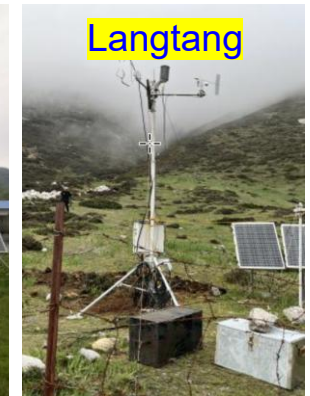
Burong(普兰)



Coqen(措勤)



Lumle



Langtang

# Microwave radiometer network

MAWORS



NADORS



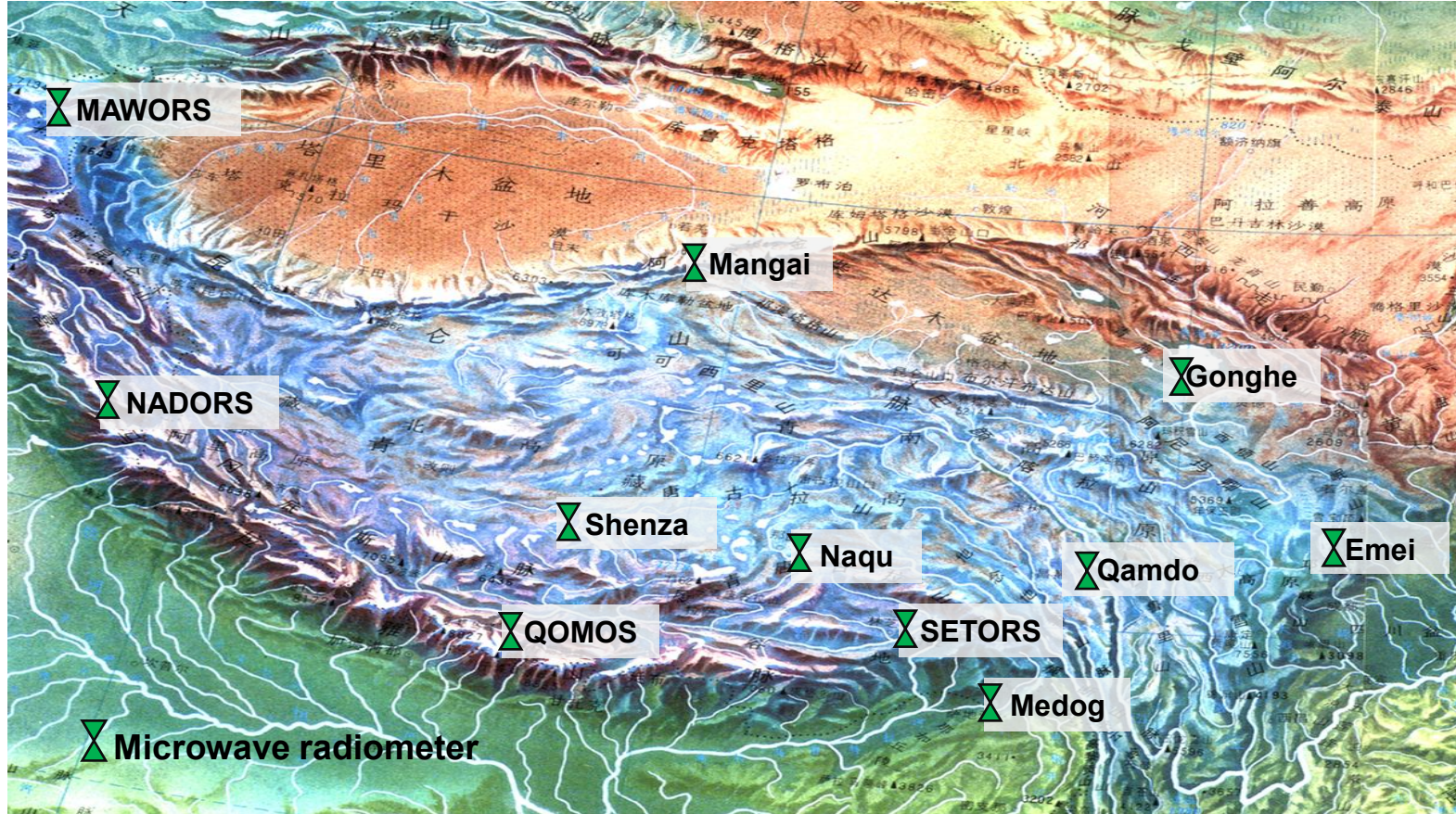
QOMOS



Naqu



MAWORS



Microwave radiometer

Mangai



Emei



Medog



Shenza



SETORS



Qamdo



Gonghe





# Laser disdrometer observation network

慕士塔格



阿里



尼玛



曲水



那曲



曲麻莱



墨脱



共和



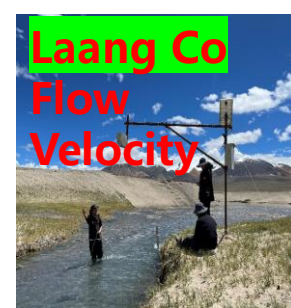
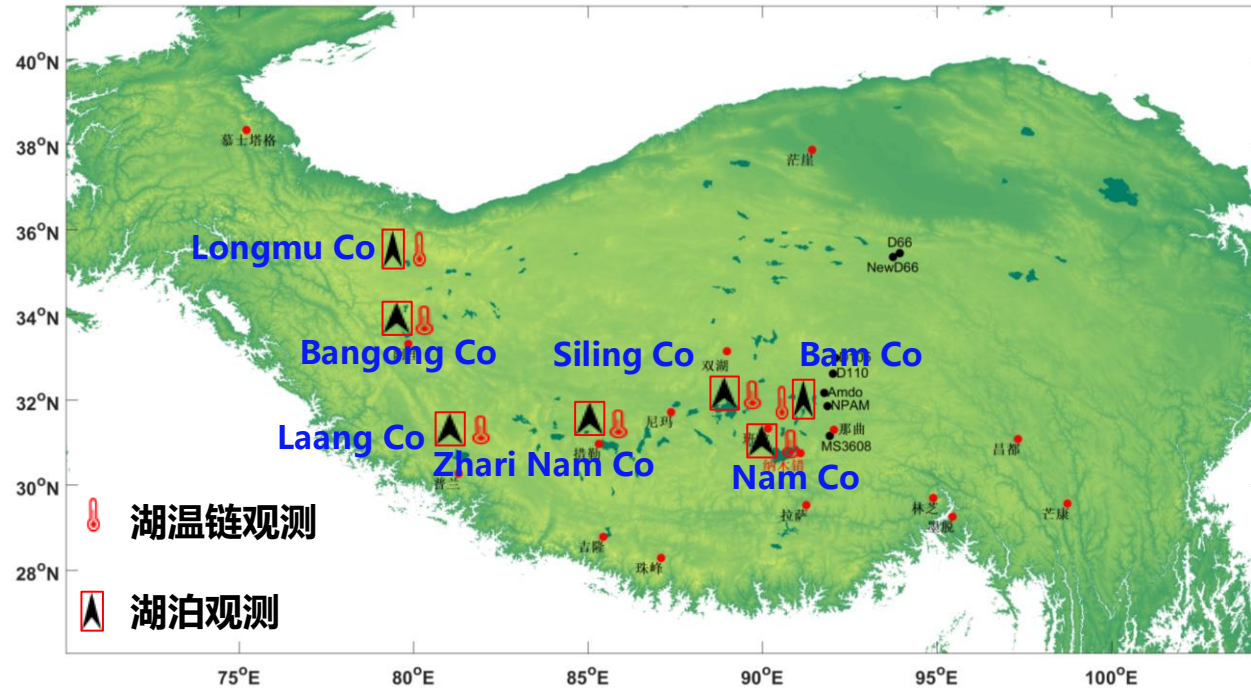
昌都



珠峰



# Comprehensive observation and research network for lake-atmosphere interaction



(Wang, Ma Y., et al., 2015, JGR; Wang, Ma Y.\*, et al., 2017, JGR; Wang, Ma Y.\*, et al., 2019, JoH; Wang, Ma Y.\*, et al., 2020, SA; Ma, W., ..., Ma Y., et al., 2025, BAMS; Shi, Wang\*, Ma Y.\*, et al., 2025, JGR)

# QOMS: A comprehensive observation station for climate change research on the top of Earth

8300 m



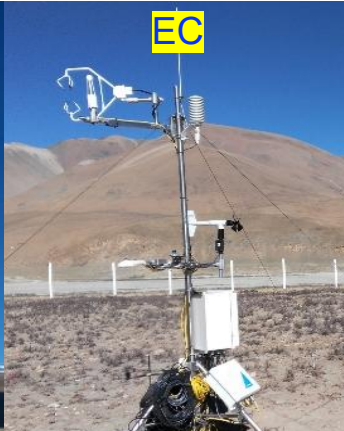
8021 m



7028 m



PBL Tower



EC



Microwave radiometer



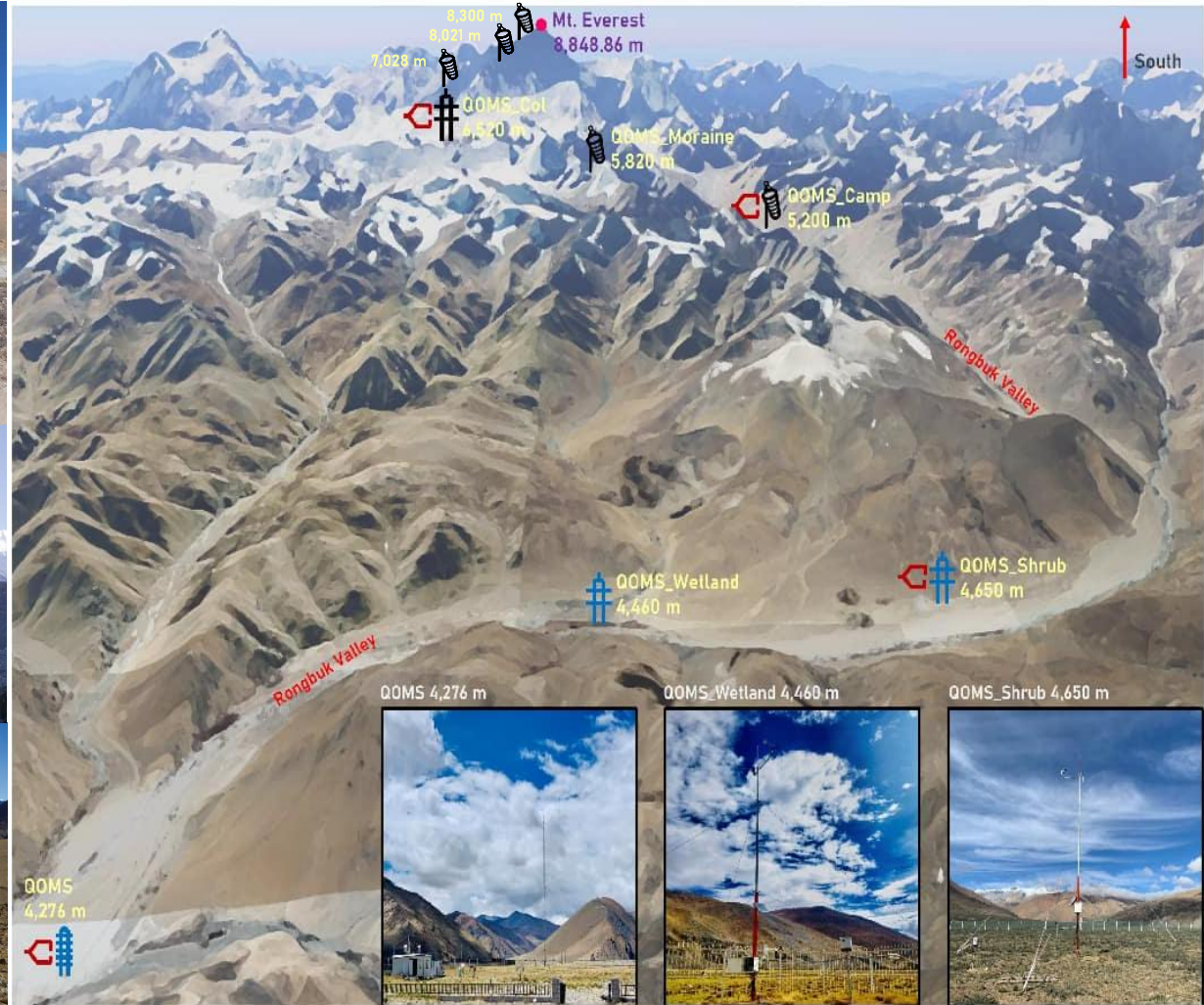
Radio sonde



Wind lidar



GPS



QOMS\_Col 6,520 m



QOMS\_Moraine 5,820 m

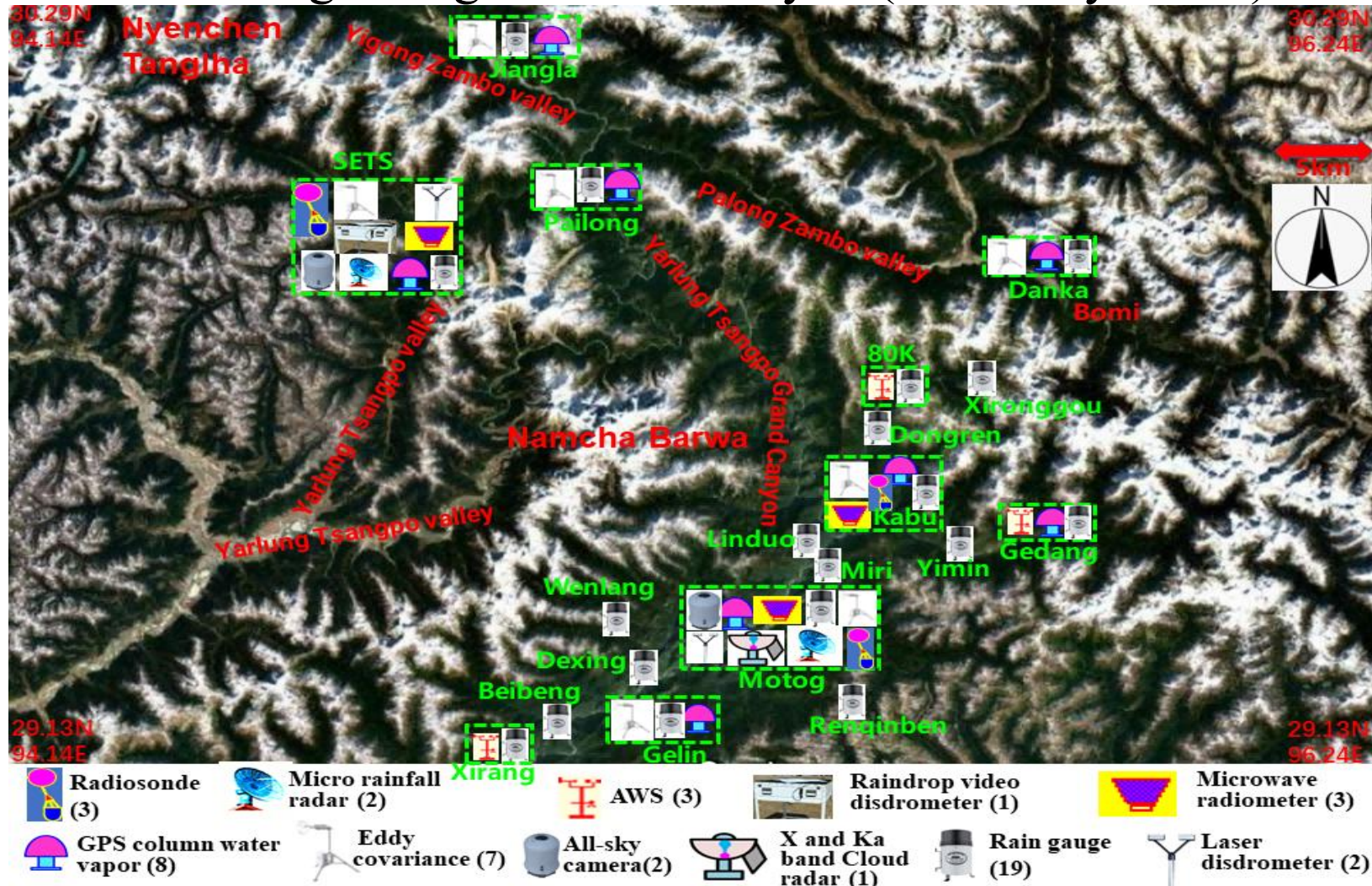


QOMS\_Camp 5,200 m

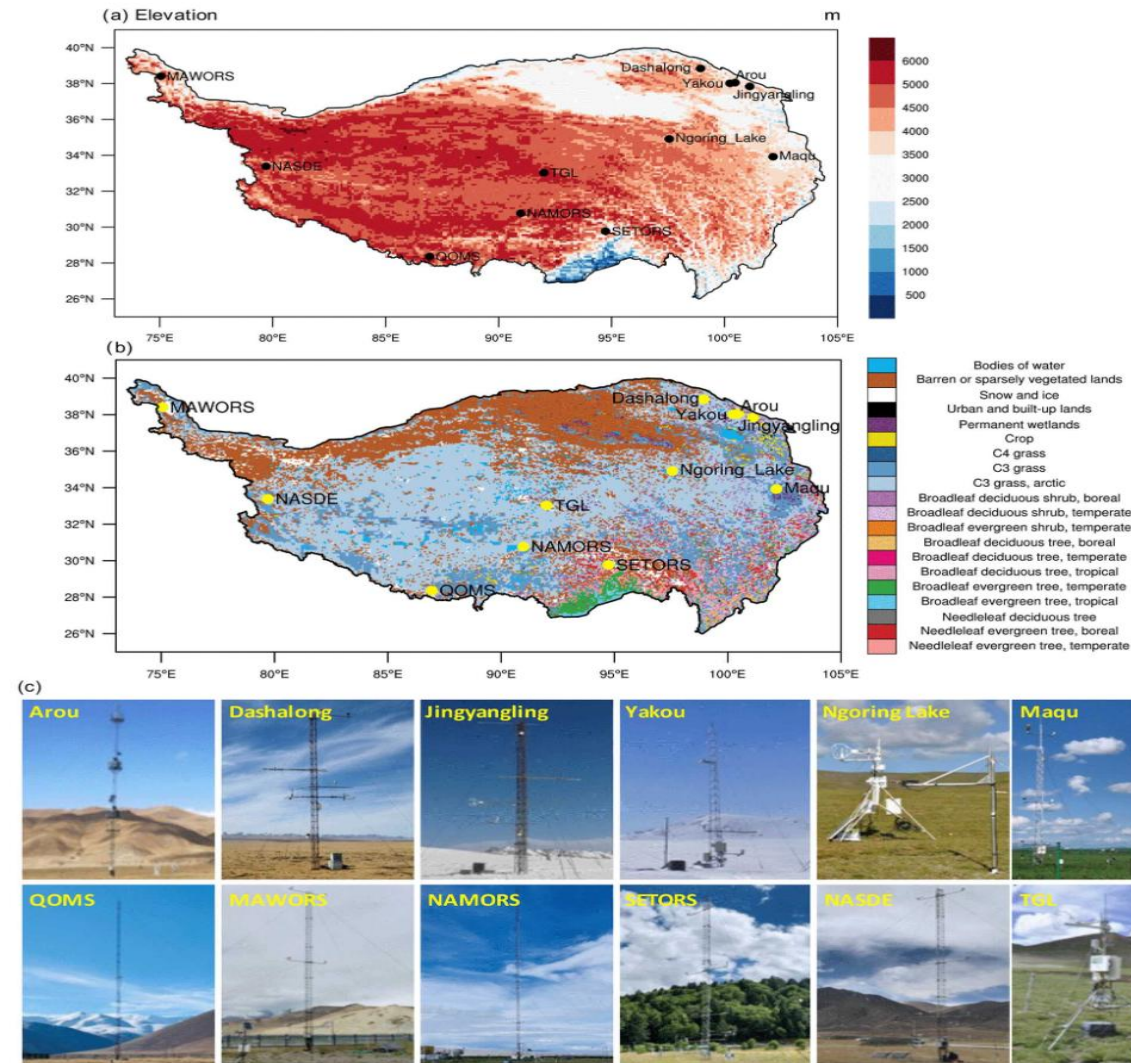


# The observation systems at the Yarlung Tsangbo Grand Canyon

Investigation of the extreme rainfall around the water vapor channel of the Yarlung Zsangbo Grand Canyon (funded by STEP)

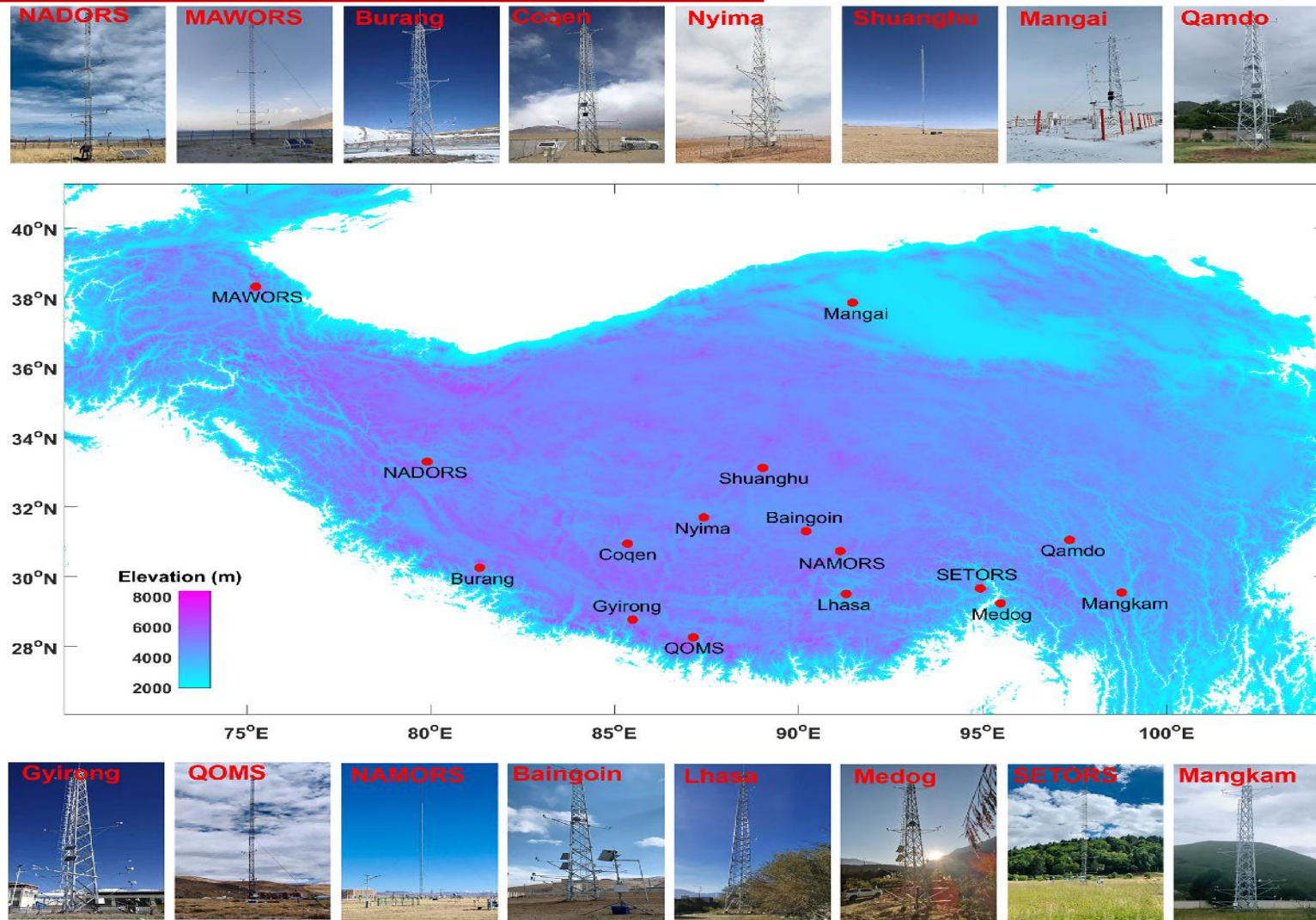


# The long-term land-atmosphere interaction measurements at 12 stations



Ma, Y., et al. (2024), Dataset of spatially extensive long-term quality-assured land-atmosphere interactions over the Tibetan Plateau, Earth Syst. Sci. Data, 16(6), 3017-3043, doi:10.5194/essd-16-3017-2024.

# Dataset for land-atmosphere interaction stations (2021-2023)



Wang, B., Ma, Y., Hu, Z., Li, X., Ma, W., Chen, X., Han, C., Xie, Z., Wang, Y., Li, M., Ma, B., Shi, X., Li, W., and Cai, Z.: Quantifying the spatial-seasonal patterns of land-atmosphere water, heat and CO<sub>2</sub> flux exchange over the Tibetan Plateau from an observational perspective, *Earth Syst. Sci. Data*, 18, 1147–1164, <https://doi.org/10.5194/essd-18-1147-2026>, 2026.

# Dataset for microwave radiometer network



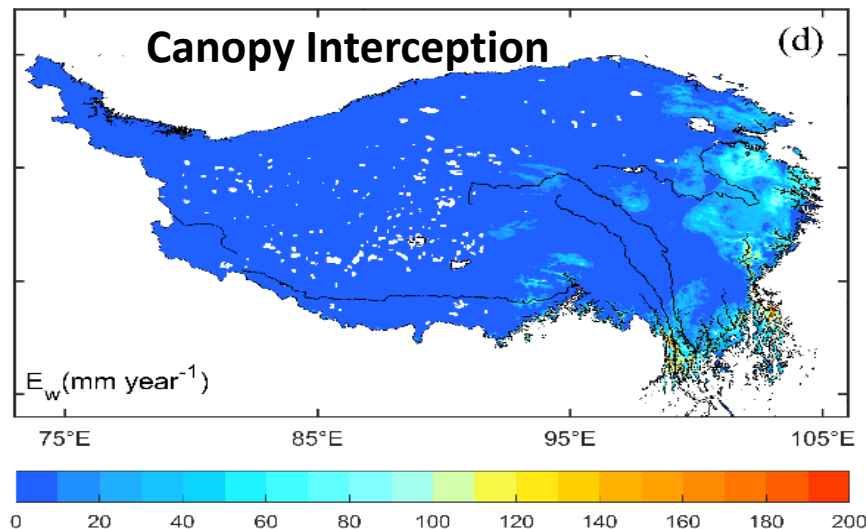
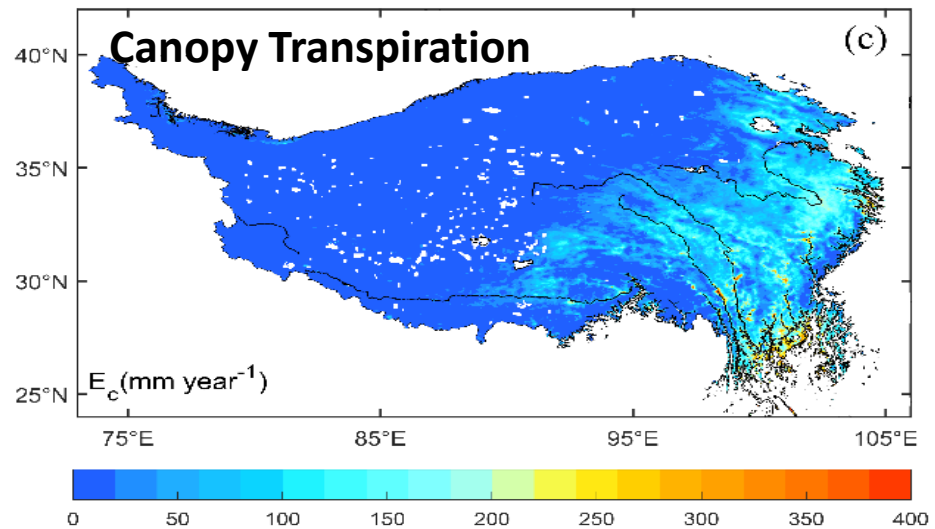
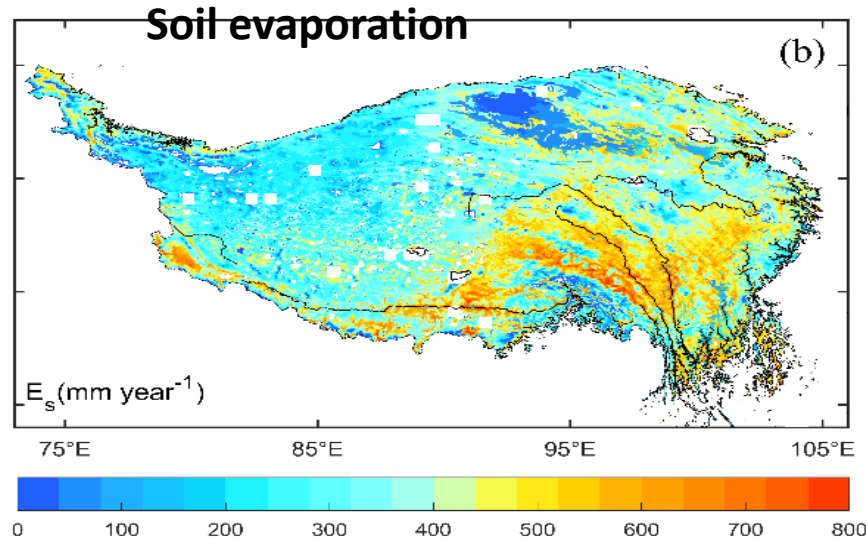
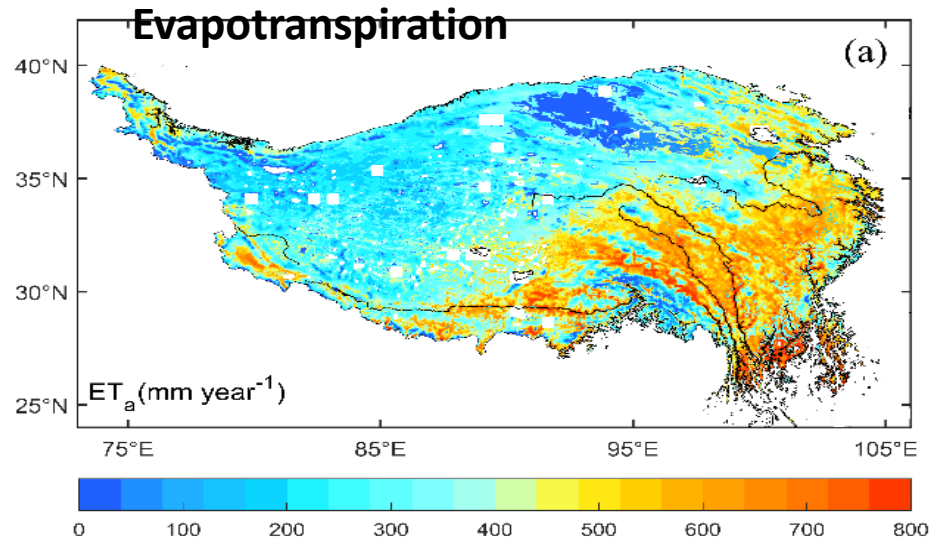
Chen X., Liu Y., Ma Y., Ma W., Xu X., Cheng X., Wang B., 2024, TP-PROFILE monitoring the thermodynamical structure of the troposphere over the Third Pole, Advances in Atmospheric Sciences, doi:10.1007/s00376-023-3199-y

## (二)

**We have revealed the spatiotemporal patterns of land–atmosphere water, heat, and carbon exchanges, including the lake-atmosphere interaction processes over the Tibetan Plateau.**

( **Ma\*,Y.** et al., 2026, AAS; Yao, and **Ma\*,Y.** et al., 2024, AOSL; Han, **Ma\*, Y.** et al., 2021, AR; Lai, Y., Chen\*,X. and **Ma\*,Y.** et al., 2021; Wang, C. and **Ma\*,Y.** et al., 2021, Water; ; Wang, B\*. and **Ma,Y.\*** et al., 2020,SA; Zhong and **Ma\*, Y.** et al., 2019 , JGR-A; Subba and **Ma\*,Y.** et al., 2019 , JGR-A; Wang,B. and **Ma\*,Y.** et.al, 2019, JH; Wang, B. and **Ma,Y.** et al., 2017,JGR-A; Wang and **Ma \***,Y. et al., 2011,JHM)

# Spatial distribution of land surface ET and its components

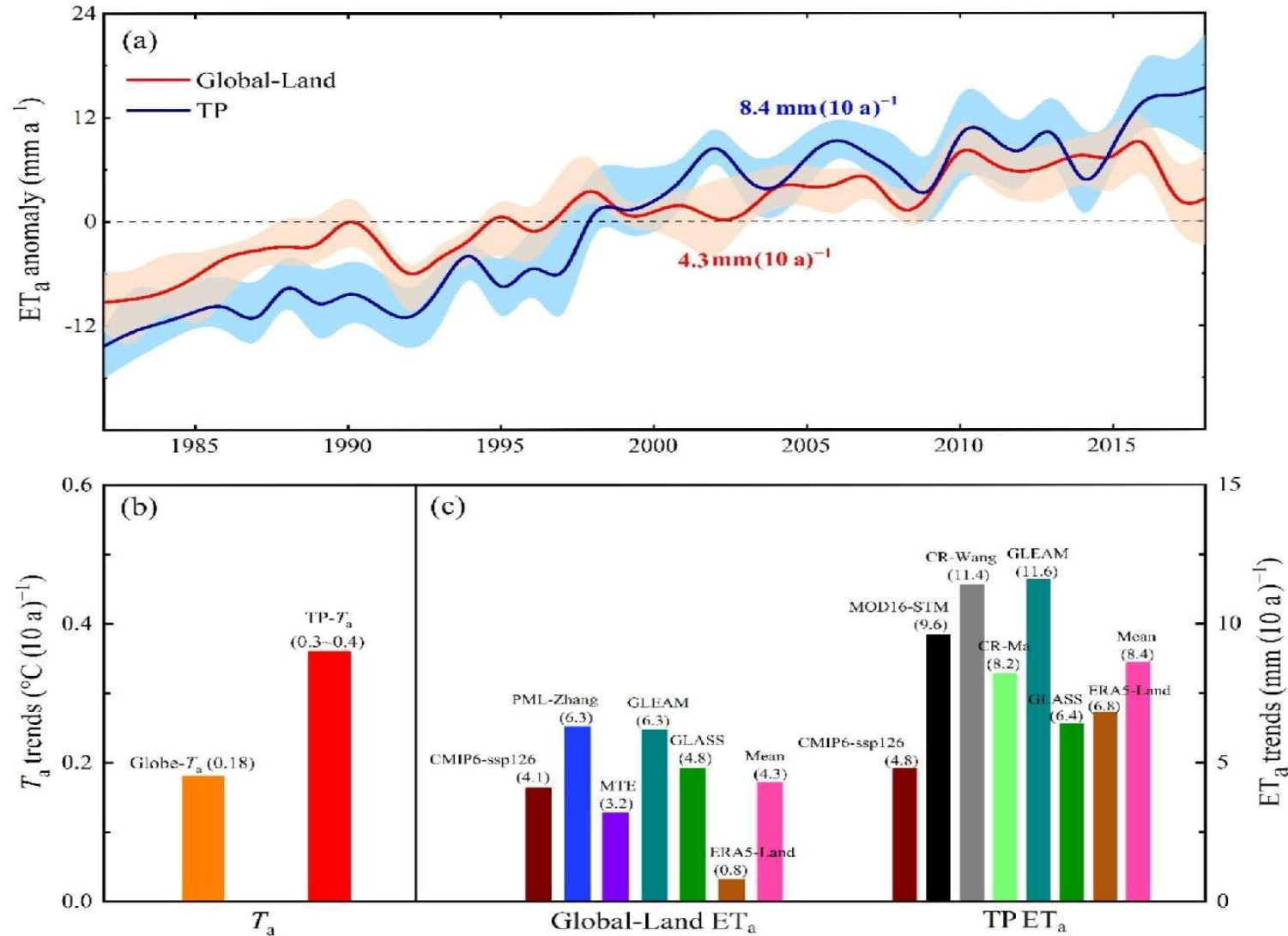


**Annual ET value of  
~360 mm per year**

**Total ET value of  
 $0.93 \pm 0.037 \times 10^3$  Gt**

(Yuan, Ma Y., et.al, 2022)

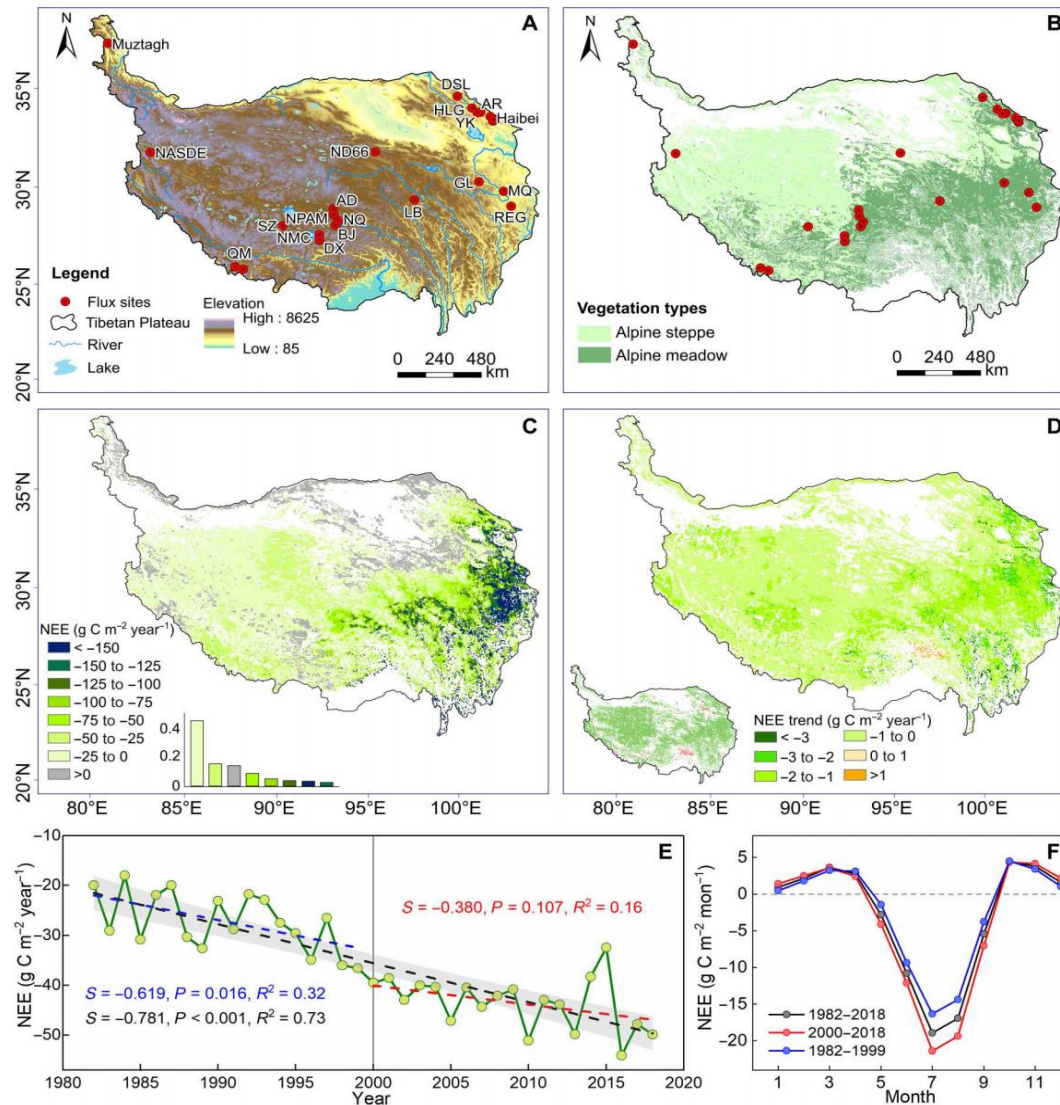
# The trends of land surface ET



The evapotranspiration increase rate over the Tibetan Plateau is about twice the global land surface average.

(Chen, Ma Y., et al., 2024)

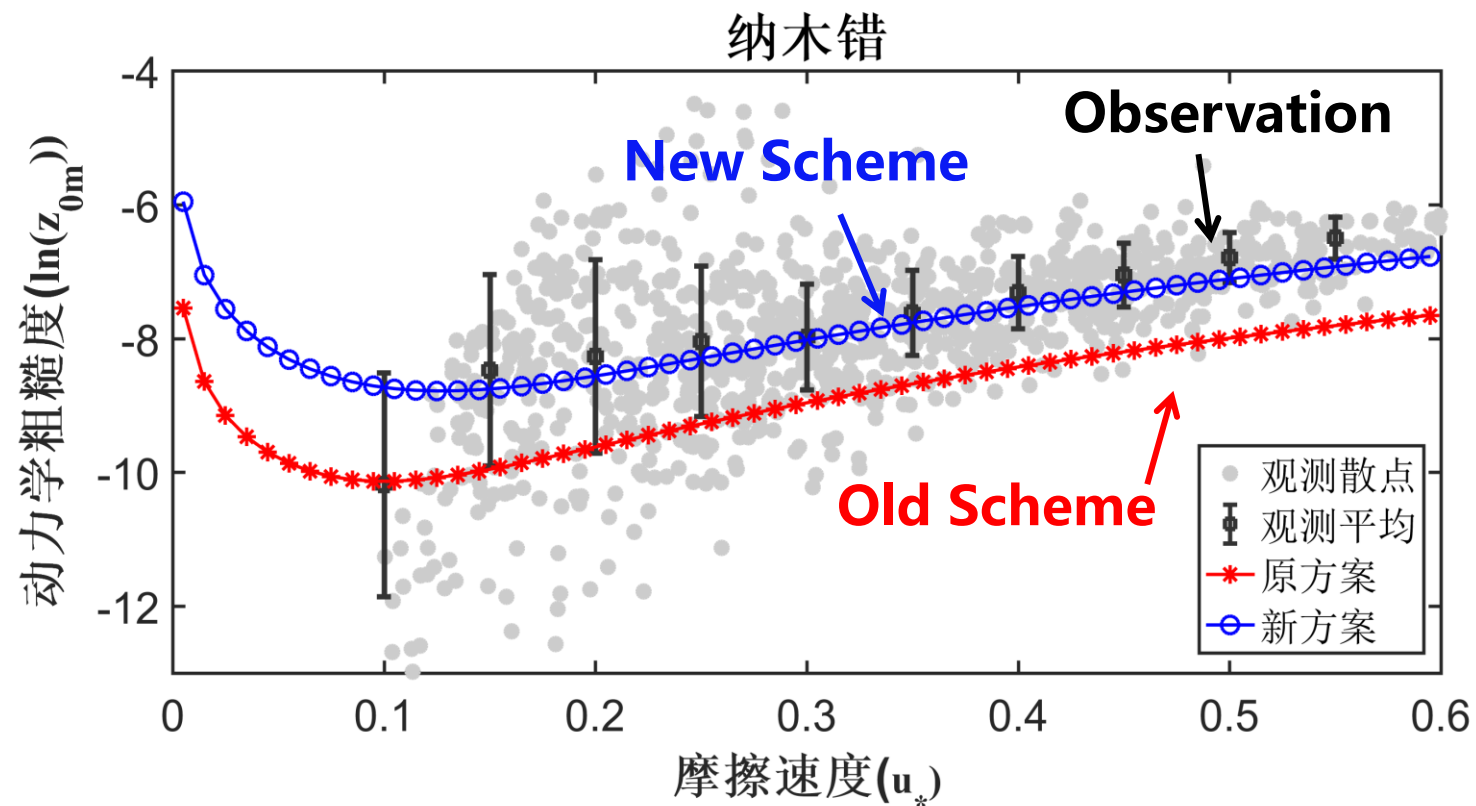
# Persistent and enhanced carbon sequestration capacity of alpine grasslands



(Wang, Xiao and Ma\*, et al., 2023, SA)

- The carbon sequestration of the alpine grasslands ranged from 26.39 to 79.19 Tg C year<sup>-1</sup> and had an increasing rate of 1.14 Tg C year<sup>-1</sup> between 1982 and 2018.
- Alpine meadows were relatively strong carbon sinks, the semiarid and arid alpine steppes were nearly carbon neutral. Alpine meadow areas experienced strong increases in carbon sequestration mainly because of increasing temperatures, while alpine steppe areas had weak increases mainly due to increasing precipitation.

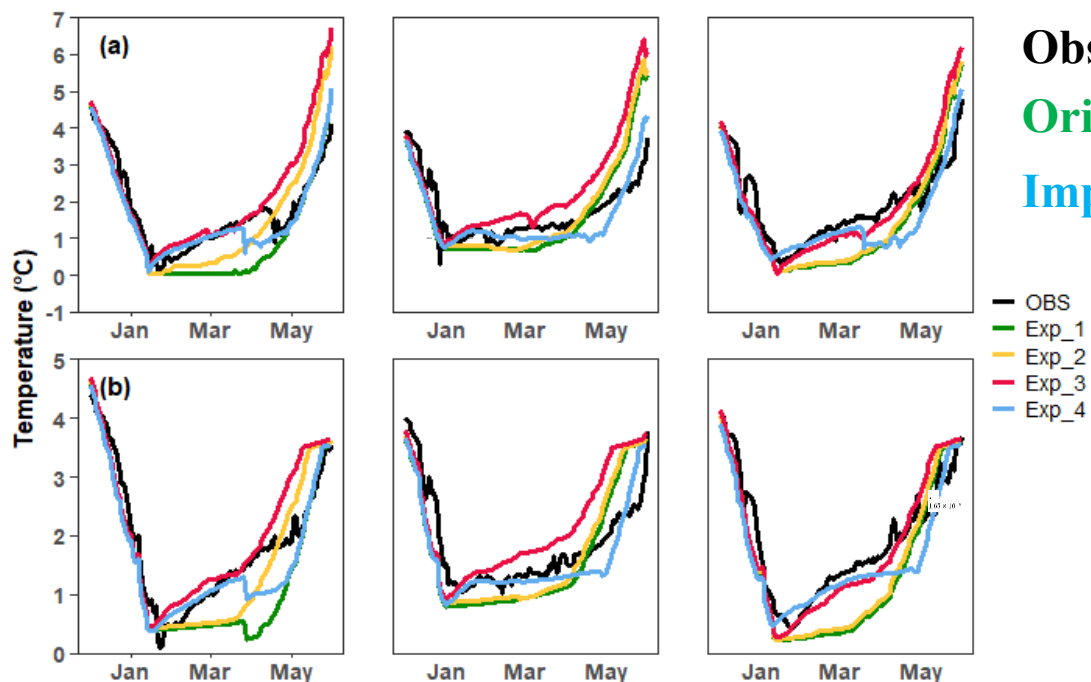
# Improve on lake's aerodynamic roughness length



(Wang\* et.al, 2015, JGR-atmosphere; Wang\* et al, 2019, JH)

We developed a parameterization scheme for aerodynamic roughness length to lakes on the Tibetan Plateau, and improved the modeling of water, heat, and momentum exchanges between the lake surface and the overlying atmosphere.

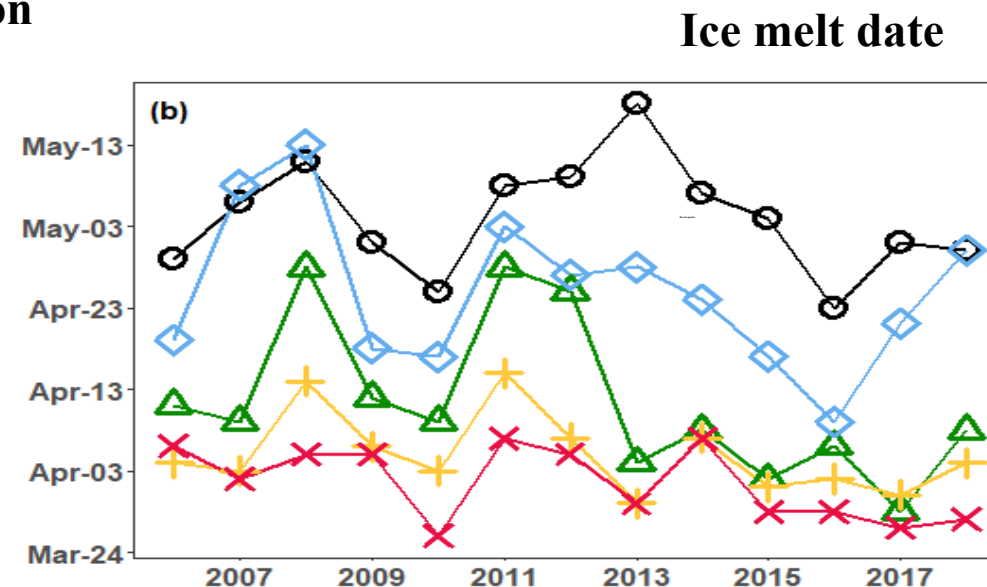
# Improvement of ice frozen-melt process over TP lakes



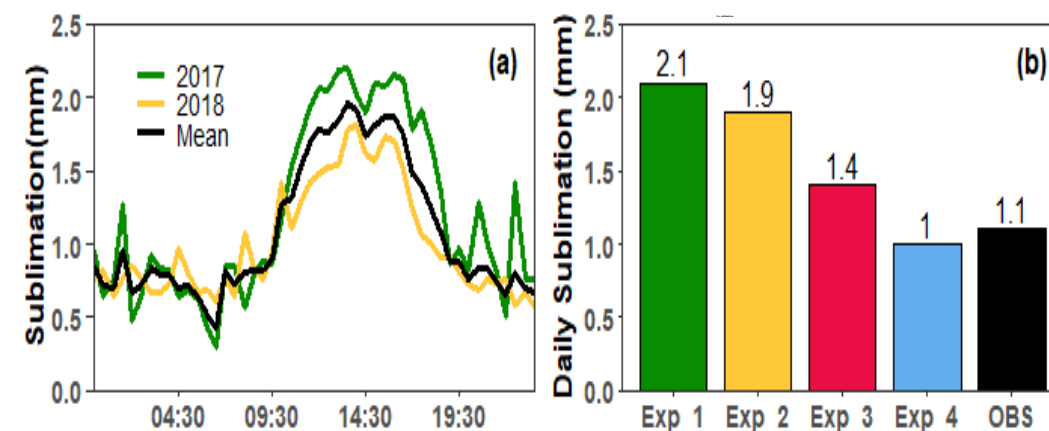
Observation

Original

Improved

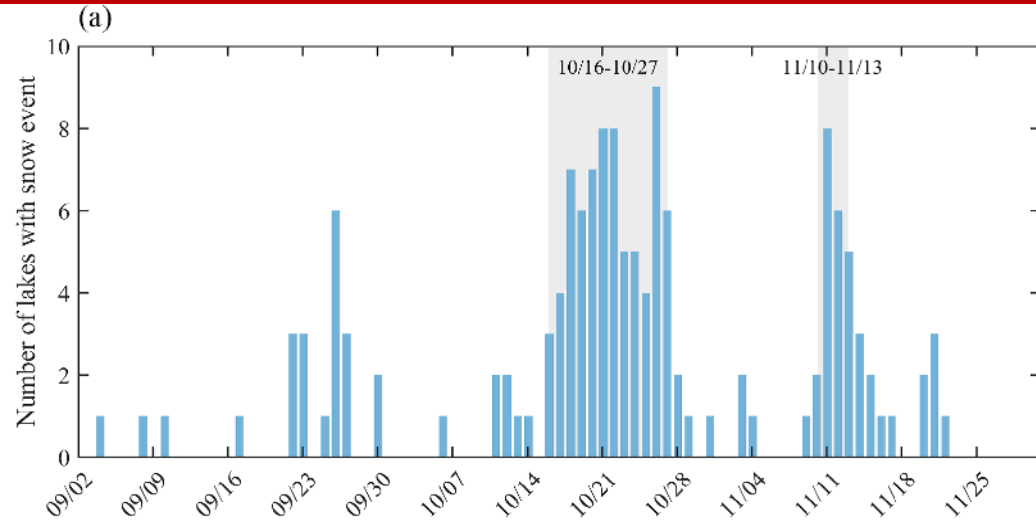


|           | Ice-covered |       |       |       | Entire period |       |       |       |
|-----------|-------------|-------|-------|-------|---------------|-------|-------|-------|
|           | Exp_1       | Exp_2 | Exp_3 | Exp_4 | Exp_1         | Exp_2 | Exp_3 | Exp_4 |
| RMSE(6m)  | 0.79        | 0.80  | 0.93  | 0.50  | 0.93          | 1.00  | 1.14  | 0.71  |
| RMSE(36m) | 0.62        | 0.55  | 0.52  | 0.42  | 0.84          | 0.77  | 0.72  | 0.77  |

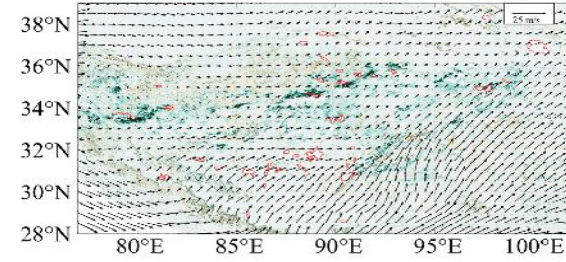


Shi, X., Wang, B., Ma, Y., et al. (2025).

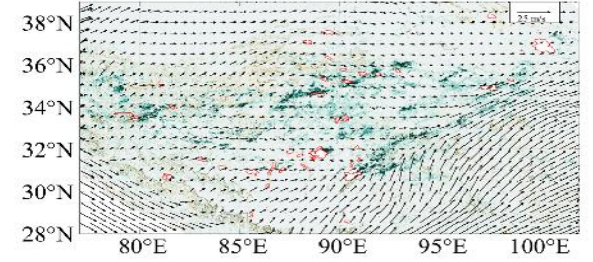
# Lake effect snow events over TP



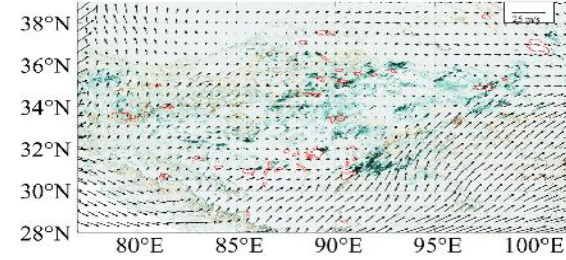
(a) 2022.10.18



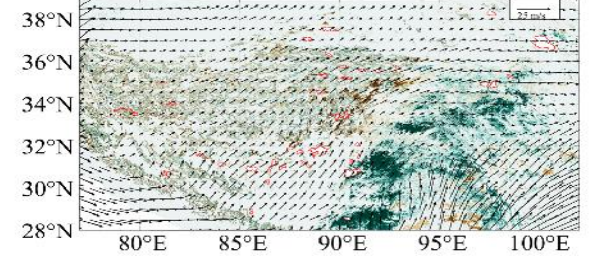
(b) 2022.10.19



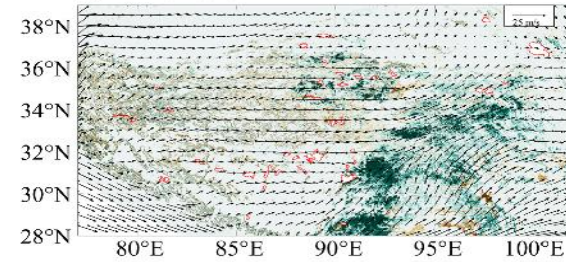
(c) 2022.10.20



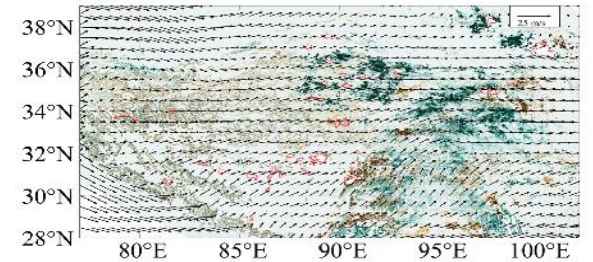
(d) 2022.10.25



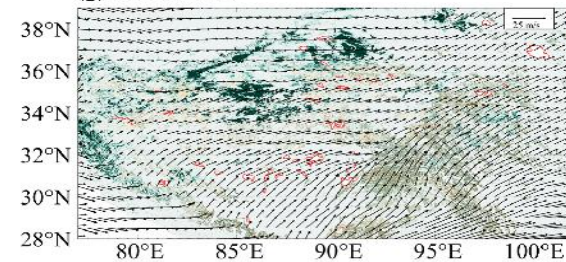
(e) 2022.10.26



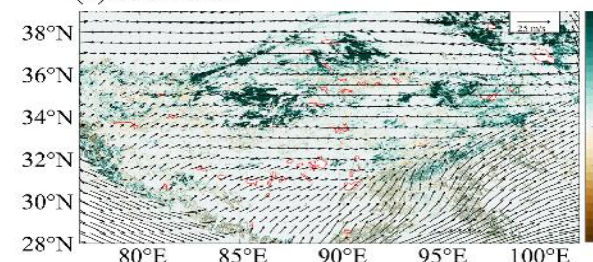
(f) 2022.10.27



(g) 2022.11.10

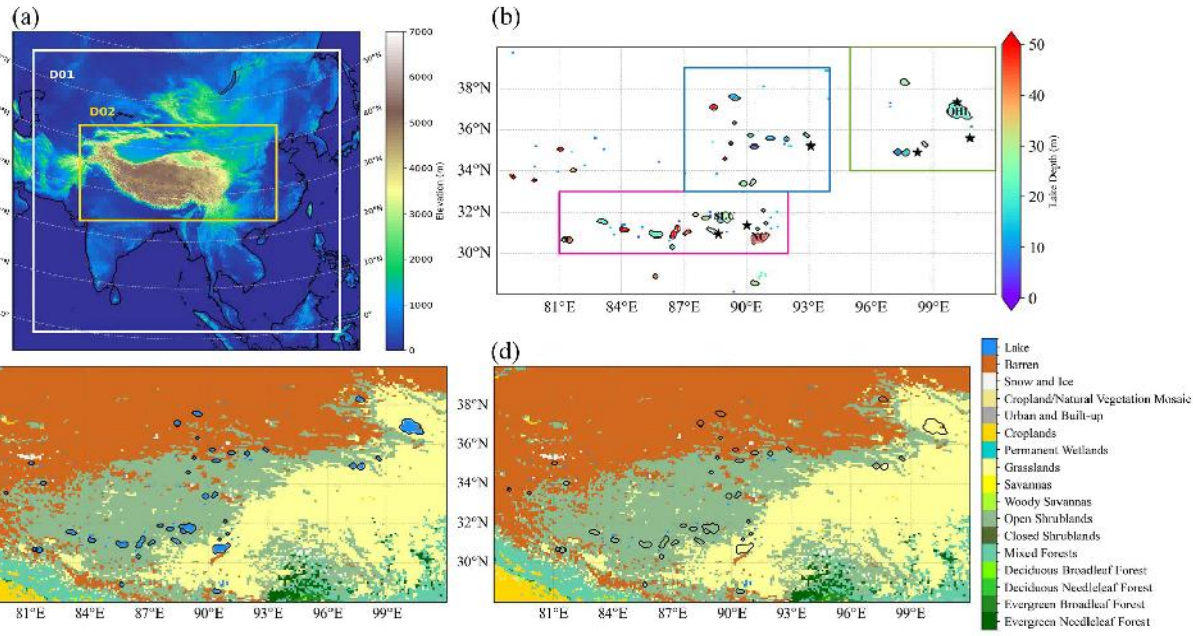


(h) 2022.11.11

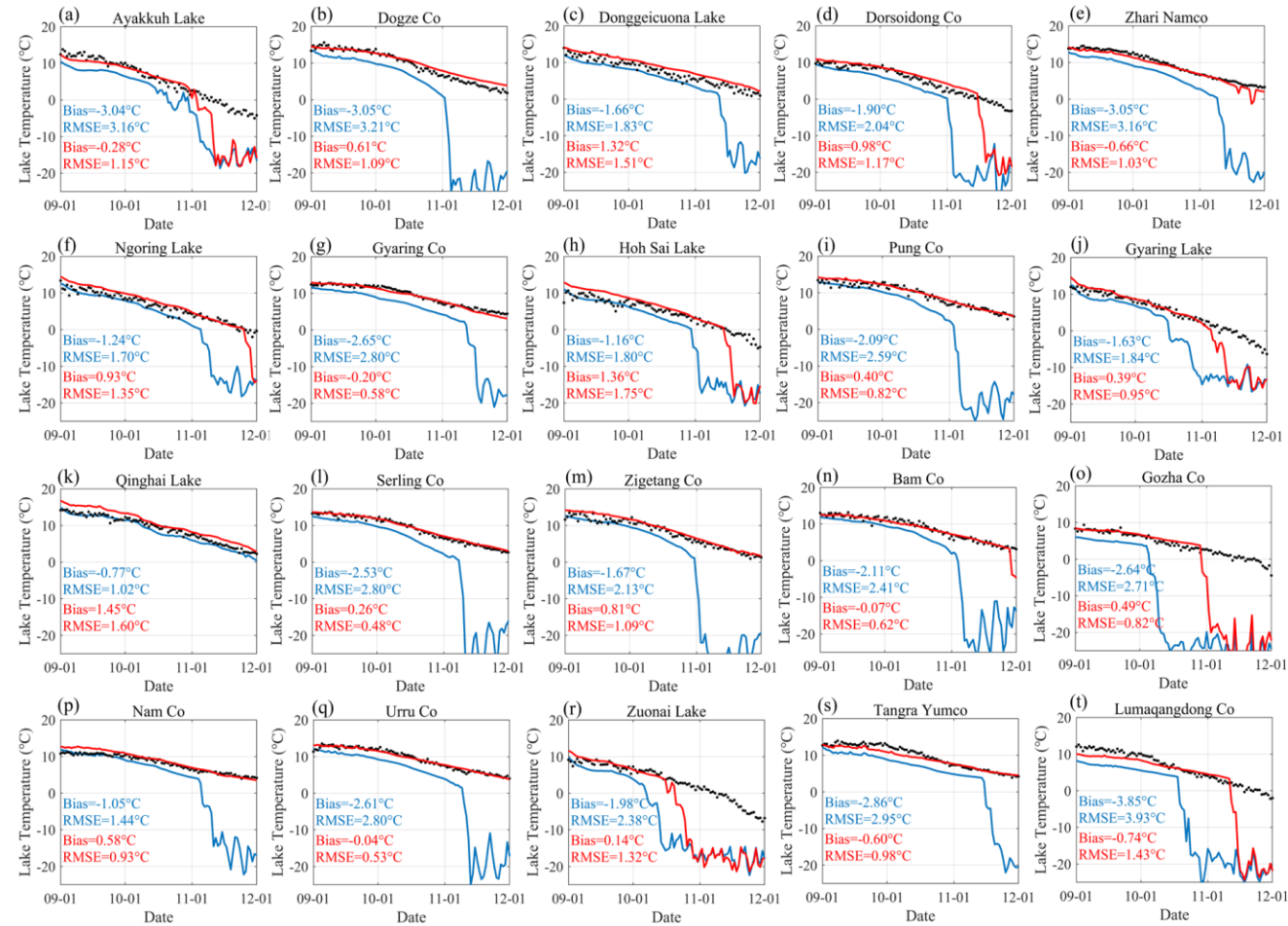


Fractional Snow Cover (%)

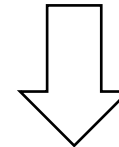
30  
20  
10  
0  
-10  
-20  
-30



# Improvement of lake process simulation

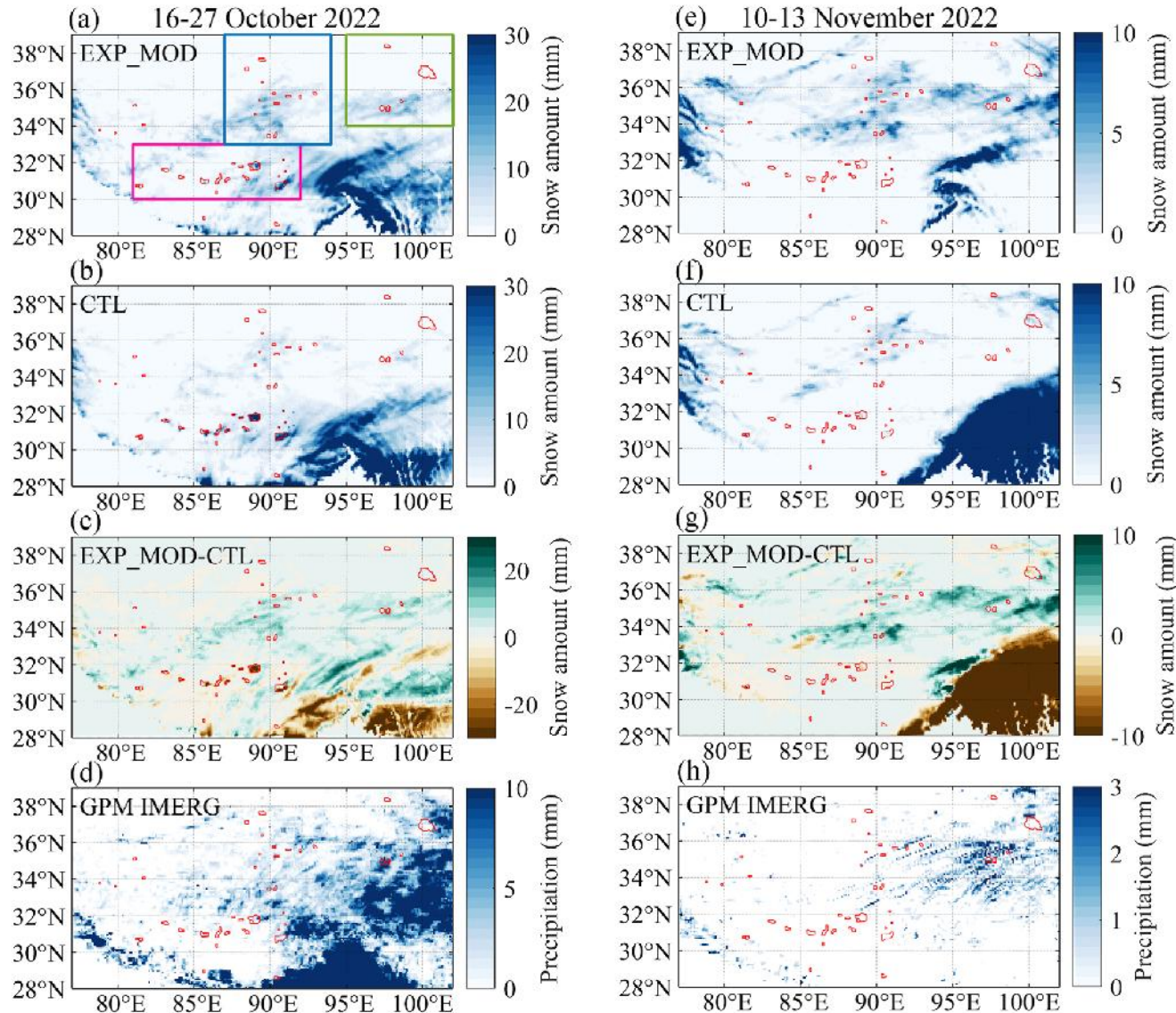


| Parameters                   | CTL                | EXP_MOD                                      |
|------------------------------|--------------------|----------------------------------------------|
| Initial temperature          | 4°C                | Observational and remote-sensing constraints |
| aerodynamic roughness length | Constant value     | Observation-based parameterization scheme    |
| extinction coefficient       | Empirical equation | Secchi disk-based calculation                |



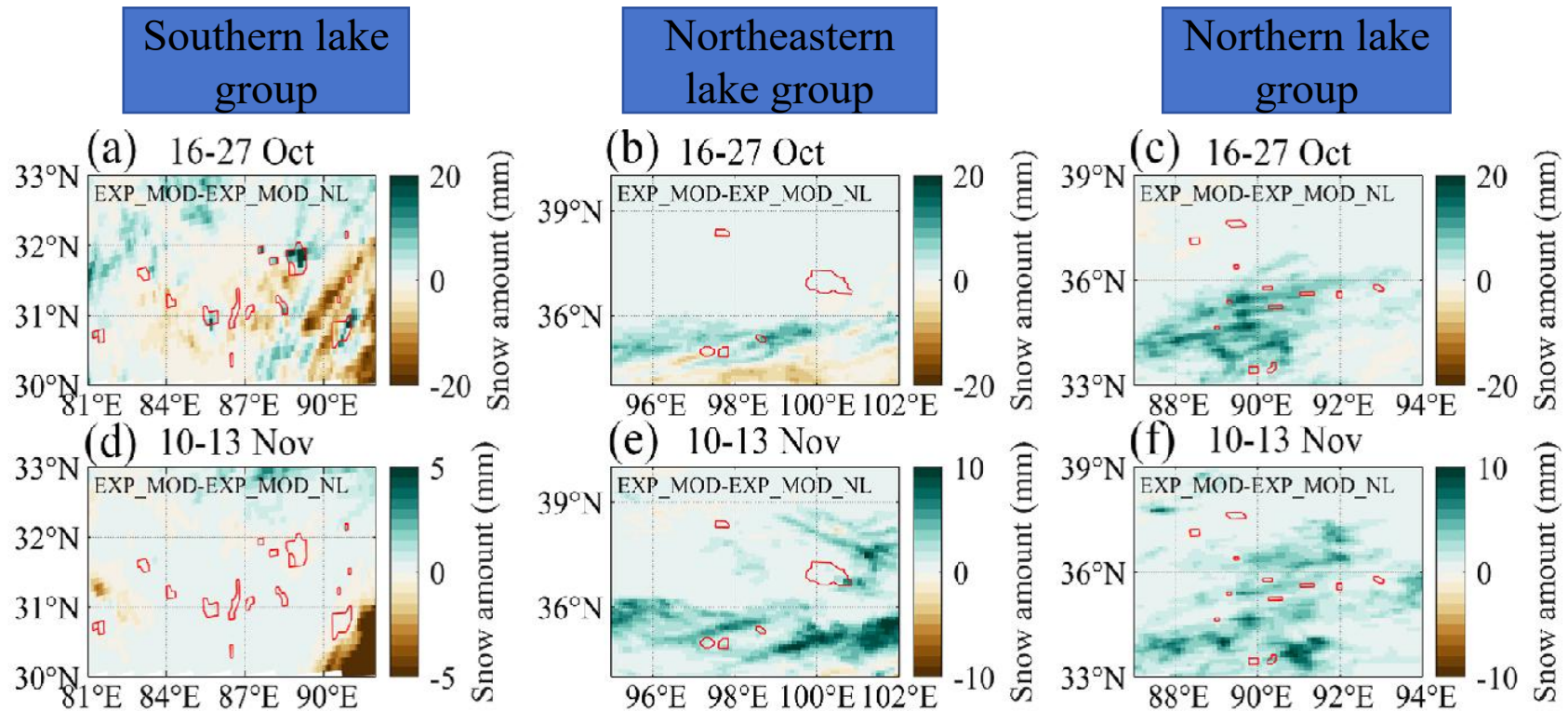
| 指标   | CTL             | EXP_MOD         |
|------|-----------------|-----------------|
| BIAS | -5.76 ~ -0.30°C | -2.52 ~ +2.65°C |
| RMSE | 0.99 ~ 5.84°C   | 0.48 ~ 3.32°C   |

# Improve on the lake effect snow



| Comparative object  | CTL                                                    | EXP_MOD                                                      |
|---------------------|--------------------------------------------------------|--------------------------------------------------------------|
| October             | Overestimation of snowfall over lakes (large wet bias) | Reduced bias and improved agreement with MODIS               |
| November            | The lake-effect snow signal over Qinghai Lake is weak. | Lake-effect snow over Qinghai Lake was successfully captured |
| Northern lake group | Underestimated snowfall extent                         | Better reproduction of MODIS-observed snow cover extent      |

# Improve on the lake effect snow



| Periods         | Southern lake group                         | Northeastern lake group<br>(Qinghai lake) | Northern lake group    |
|-----------------|---------------------------------------------|-------------------------------------------|------------------------|
| 16-27, October  | Significantly enhanced<br>(downwind region) |                                           | widespread enhancement |
| 10-13, November |                                             | markedly enhanced                         | sustained enhancement  |

# Concluding Remarks

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- We have established a three-dimensional observation network for land–atmosphere interactions across the Third Pole, and built a multi-sphere integrated database of land–atmosphere interaction observations for the region.
- We have revealed the spatiotemporal patterns of land–atmosphere water, heat, and carbon exchanges, including the lake-atmosphere interaction processes over the Tibetan Plateau.
- Incorporating in situ measurements into land-surface parameterization schemes leads to substantial improvements in simulating regional climate effects.