# Simulation of potential impacts of lakes on glacier behavior over the Tibetan Plateau in summer

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# CONTENTS

# 1. Background

## Asian Water Tower

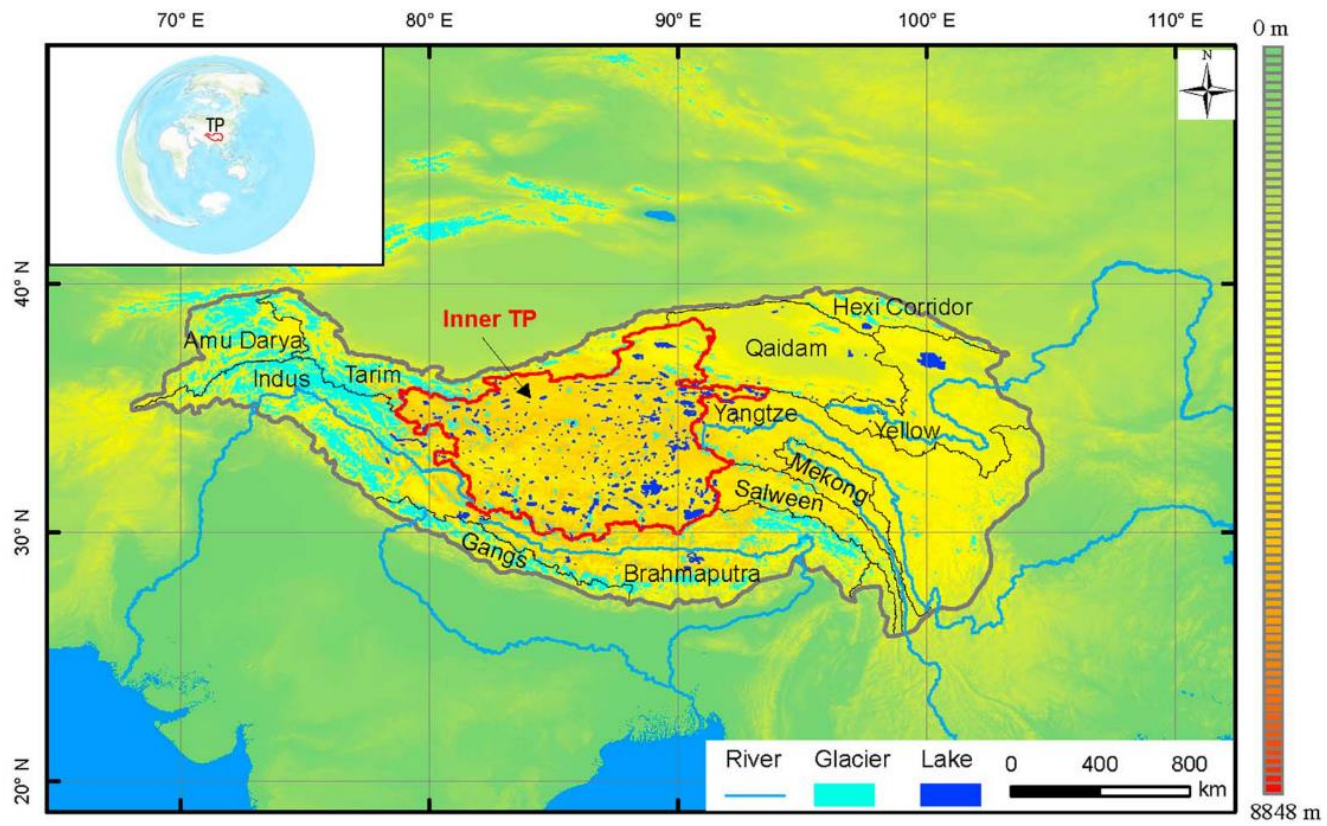



**Figure 1.** Distribution of lakes, glaciers, and rivers in the Tibetan Plateau (TP). The TP is divided into 12 river basins. The lakes are predominately located in the Inner TP, an endorheic basin (the red polygon). Inset shows the location of TP in the world.

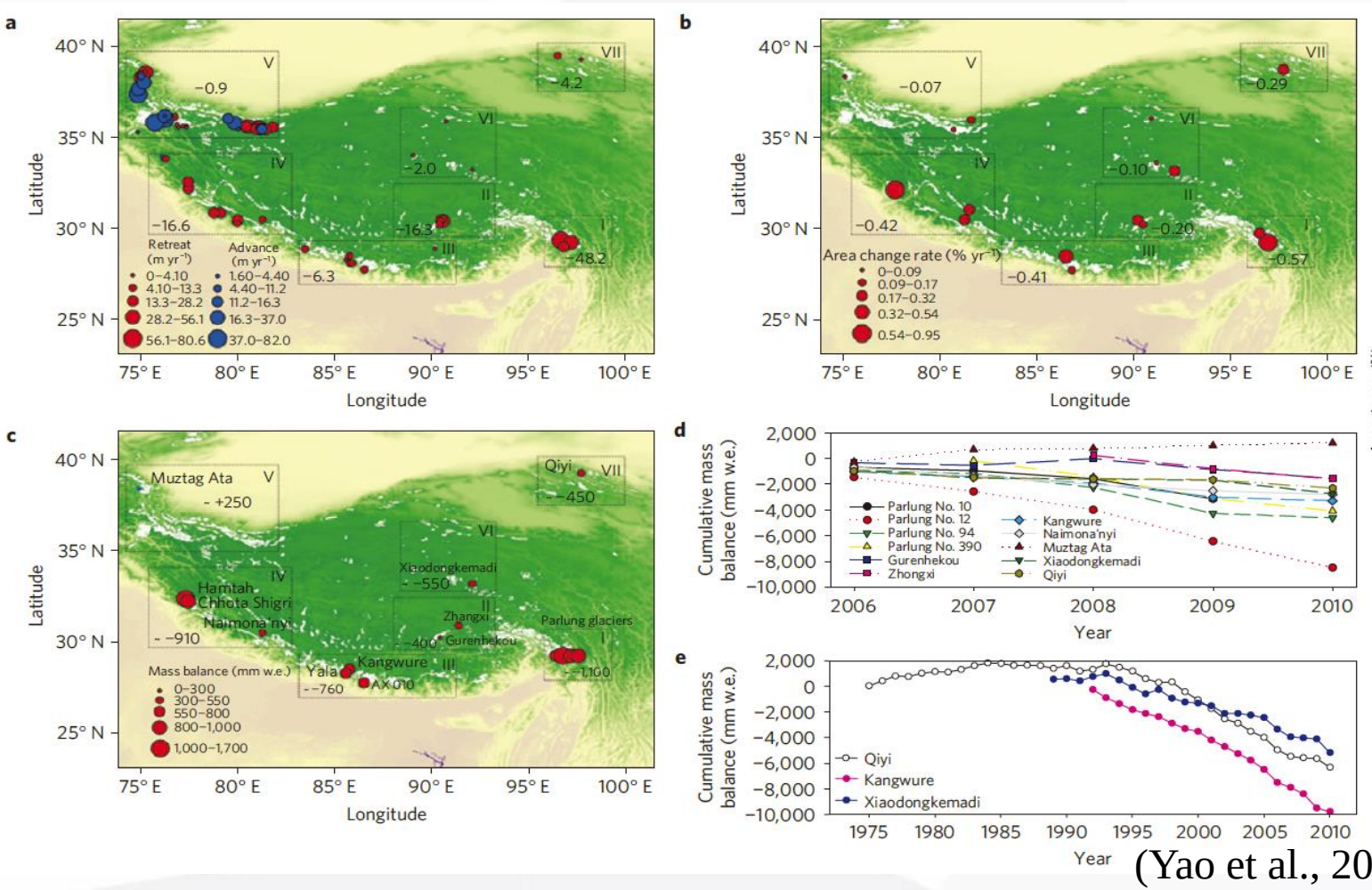
(Zhang et al.,2017)

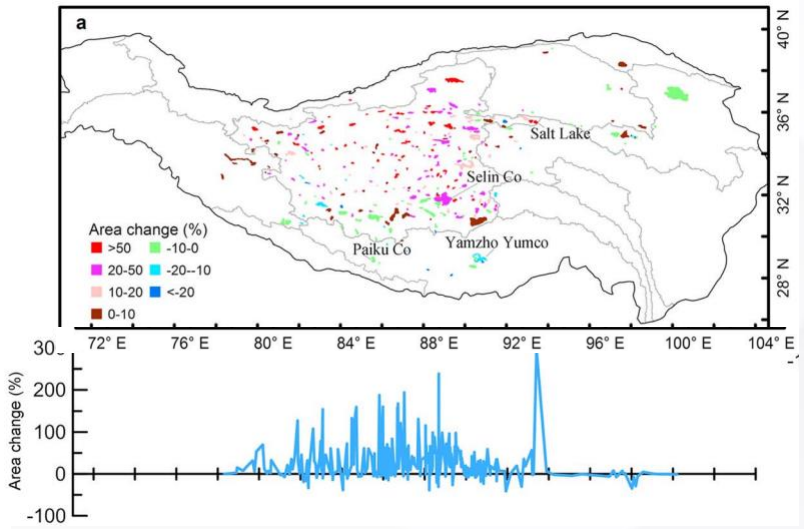
- ✓ Known as the "Asian Water Tower," the Tibet Plateau(TP) has more than half of China's total lake area.
- ✓ The TP and its surrounding area have abundant glaciers (about $9.8\times10^4$ $km^2$). It is the largest glacier-covered region apart from the polar regions.
- ✓ Melting glaciers serve as a crucial water source for TP lakes and major rivers in Asia , and play a significant role in alleviating water resource pressure in the region.

# 1. Background

Glaciers in TP rapidly retreat

Most TP Lakes are expanding




(Zhang et al.,2017)

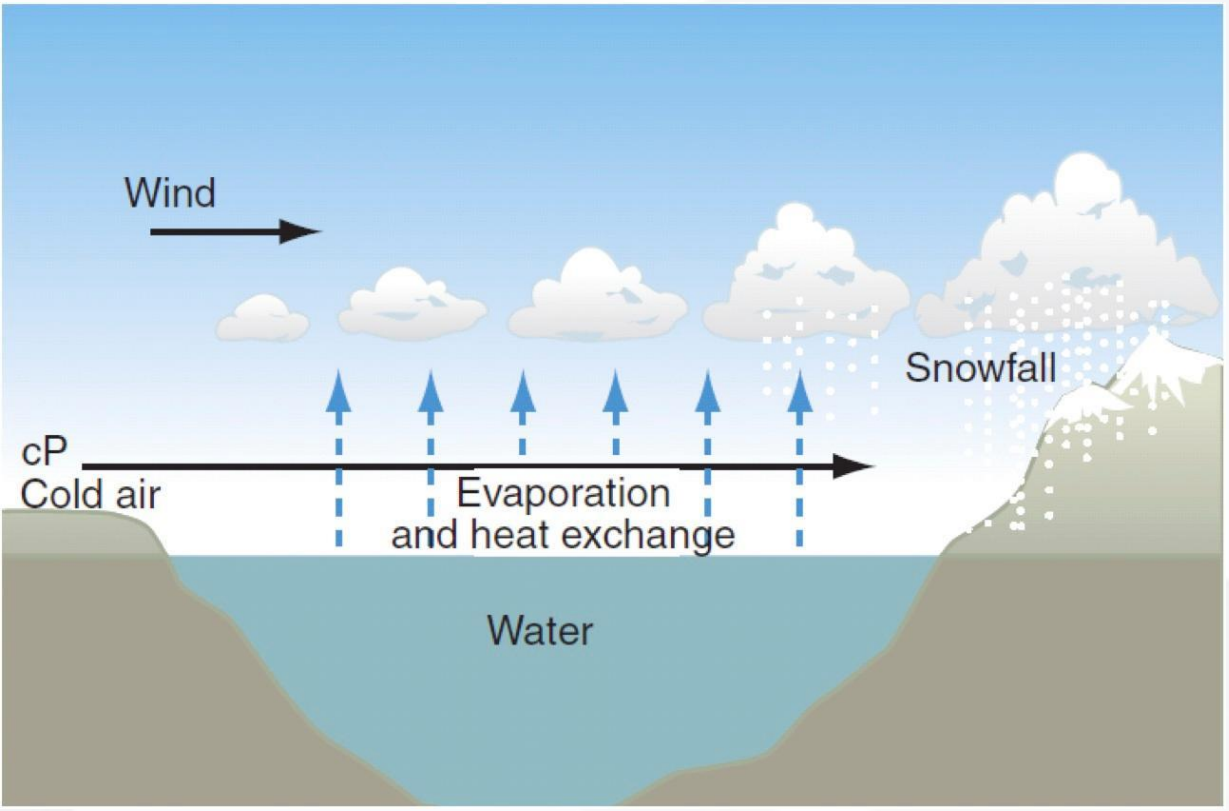
(Yao et al., 2012)

With the intensification of global warming, glaciers in TP are exhibiting rapid retreat.

With the increase of melting water and precipitation, most TP lakes are expanding.

# 1. Background

Lake effects

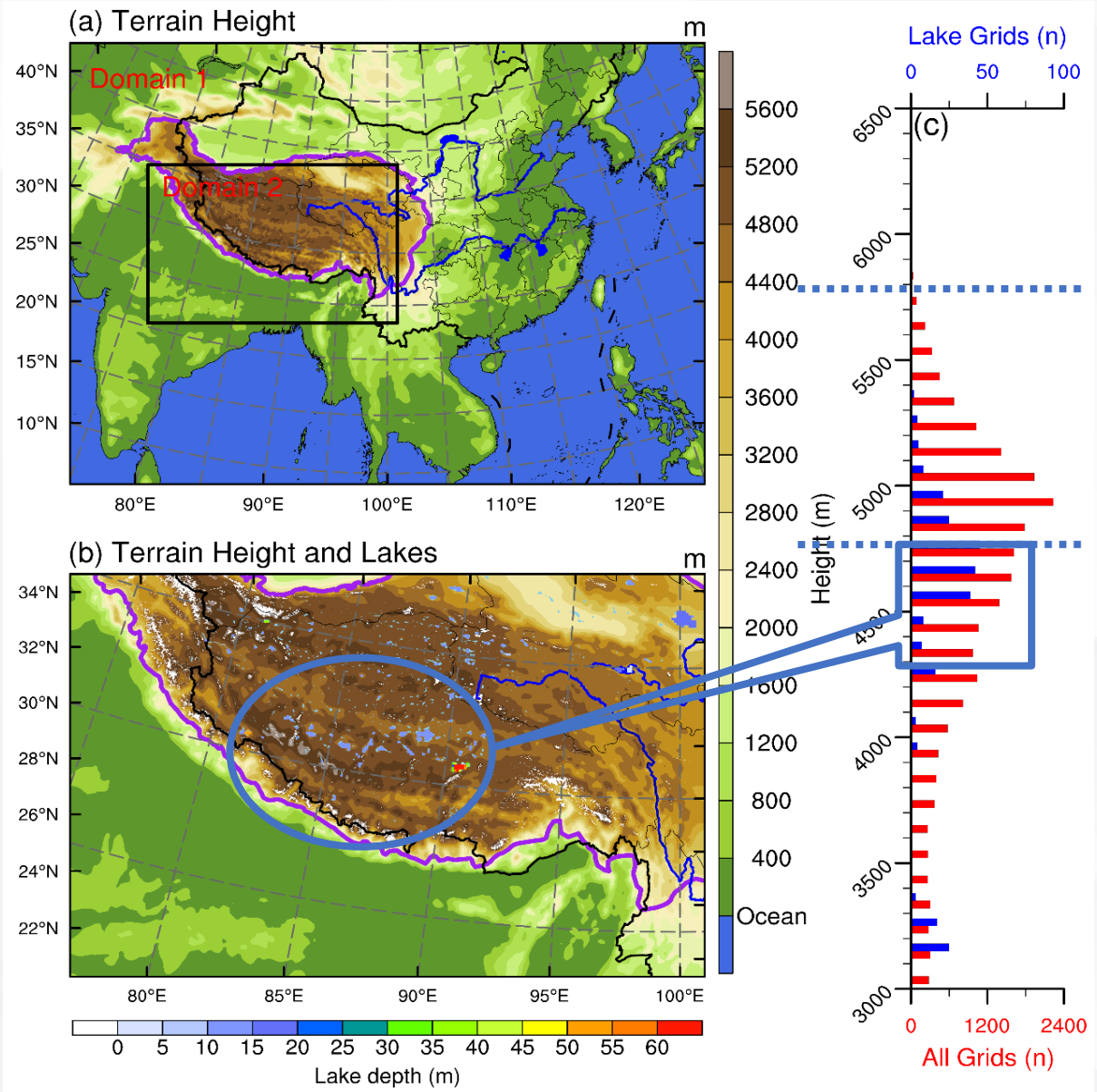



How do TP lakes affect glaciers?

Lakes have significant impacts on local climate due to their larger heat capacity, lower albedo, lower roughness, and water source.

# 2. Methodology

## Study area and model settings




| Model | WRF-Lake |
|---|---|
| Domains | 2 |
| Resolution | 30/10km |
| Forcing | NCEP-FNL |
| Period | 2013 Jun-Aug |
| Experiments | CRL/SEN |

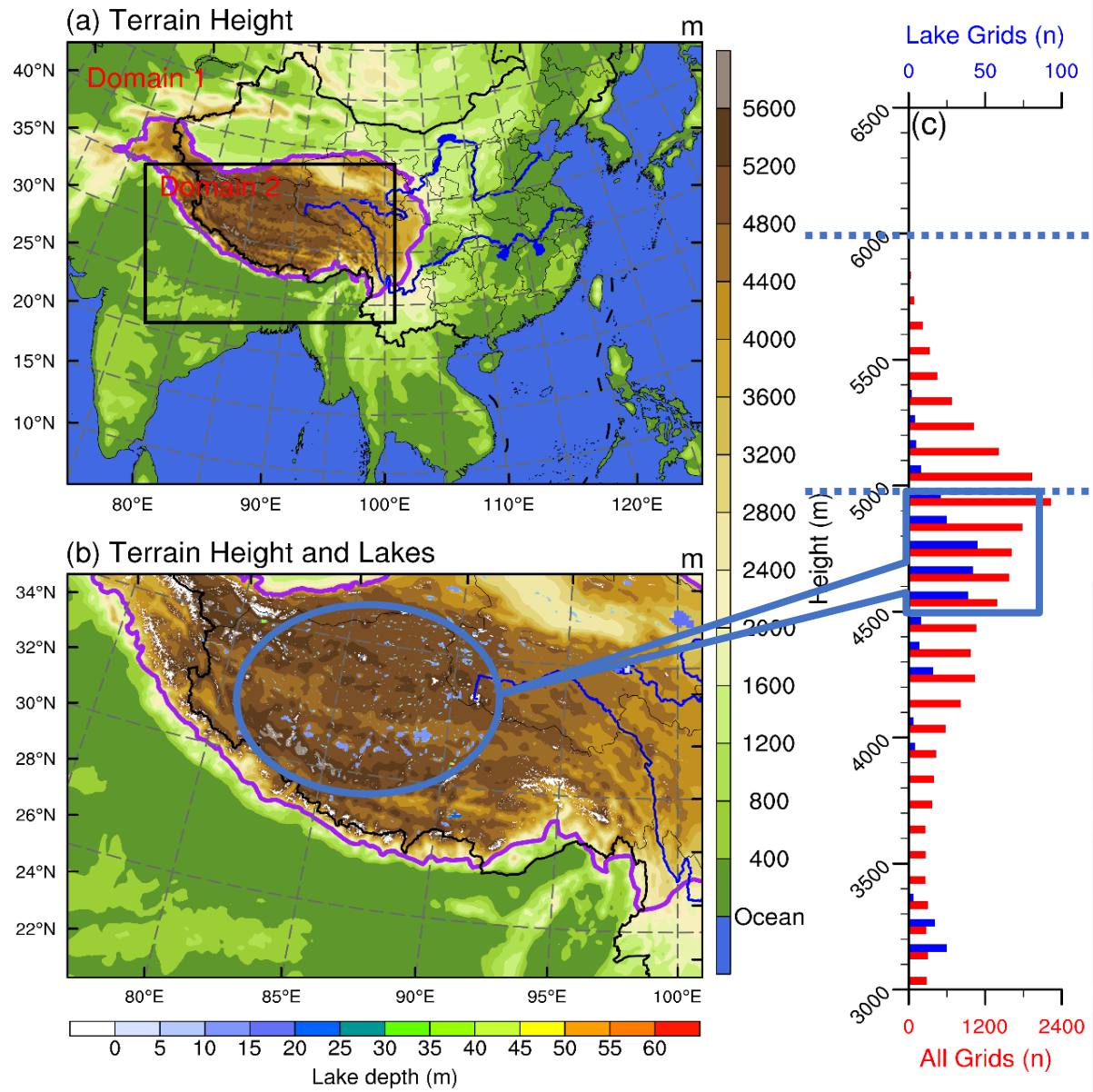
| Parameterizations |
|---|
| Single-Moment 6-class |
| RRTM |
| Dudhia |
| Noah |
| YSU |
| Grell-Devenyi ensemble |

The simulation includes two two-way nested domains of 30 km and 10 km horizontal grid spacing in Domain 1 and 2 with sub-grids for smaller lakes, respectively.

The outer domain encompasses most of the Asia continent, the northern Indian Ocean, and part of the northwestern Pacific Ocean.

The inner domain is centered over the south of the Inner TP and covers nearly the entire TP.

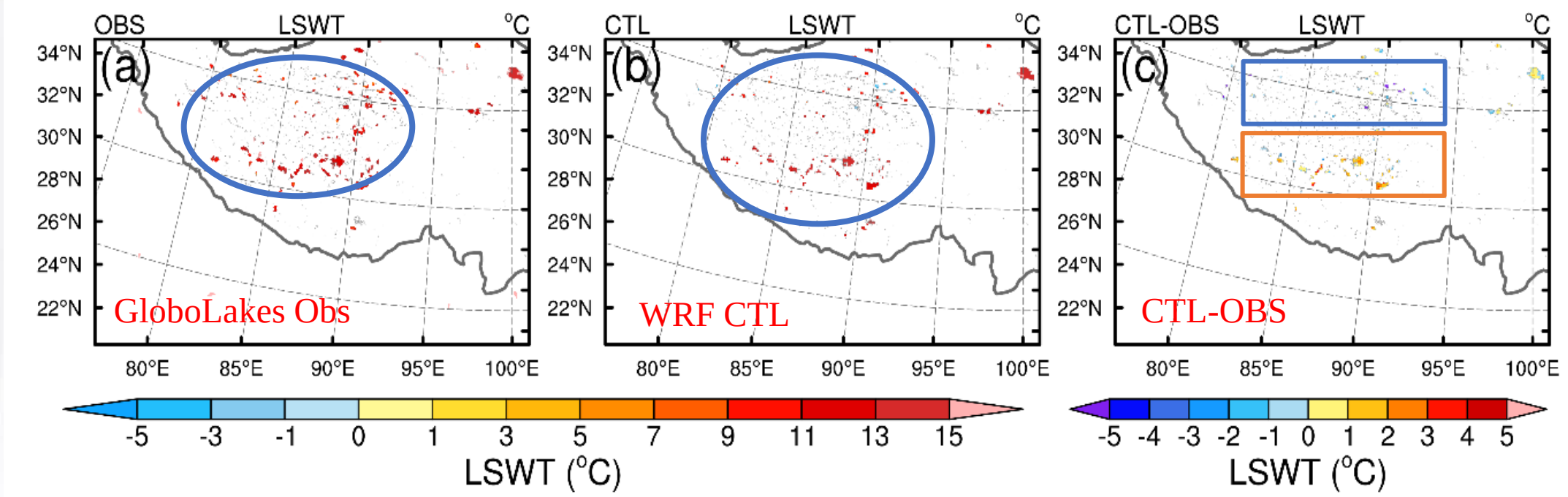
# 2. Methodology




- Most lakes in TP are concentrated in the interior region, within the altitude range of 4500-5000 m.
- The altitude range between 4500-6500 m is the area where glaciers are conc-entrated, accounting for more than 4/5 of the total glacier area in China.

# 3. Results

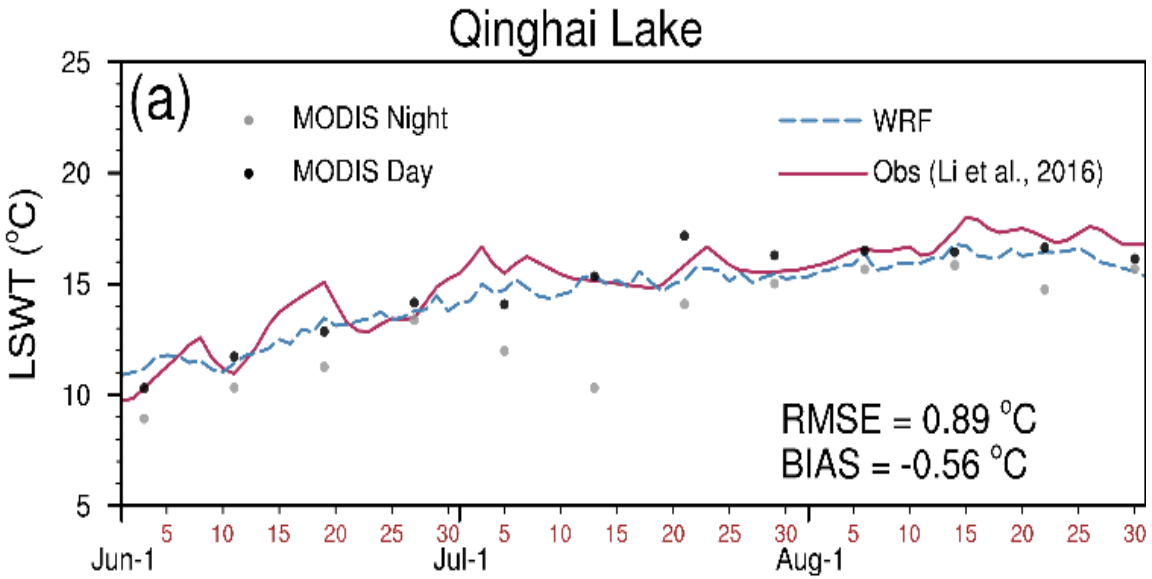
## Validation of lake surface water temperature of TP lake cluster

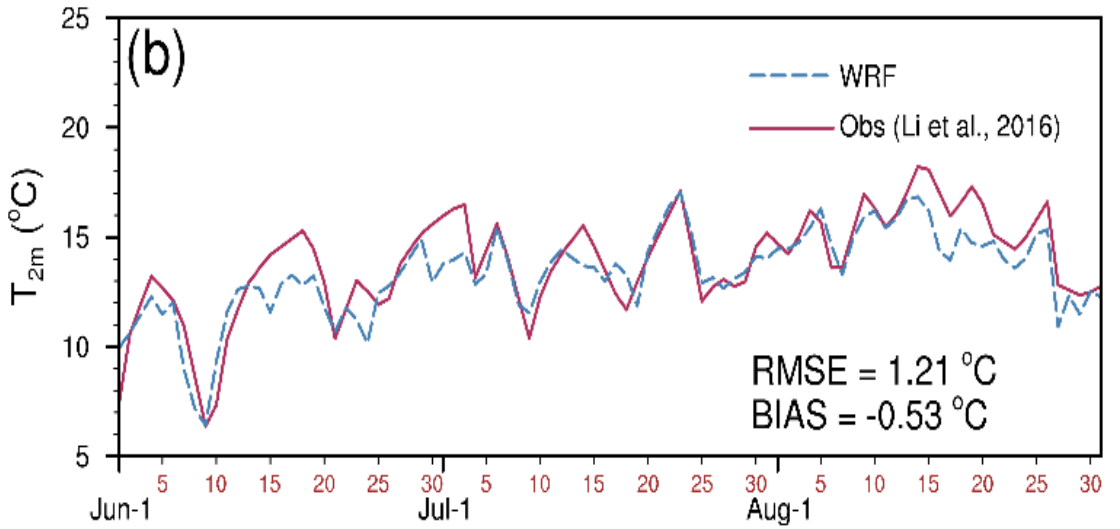



- Compared to satellite observations, WRF-Lake can simulate well lake surface water temperatures in TP with the bias -0.2 K.
- Lakes in the northern and northwestern regions are simulated to be slightly colder.
- Most lakes in the southern part of the plateau are simulated slightly warmer.

# 3. Results

## Validation of lake surface temperature and air temperature over the TP biggest lake




- Compared to field observations over the TP biggest lake-Qinghai Lake , WRF-Lake can accurately reproduce daily variations of lake surface temperature and air temperature.

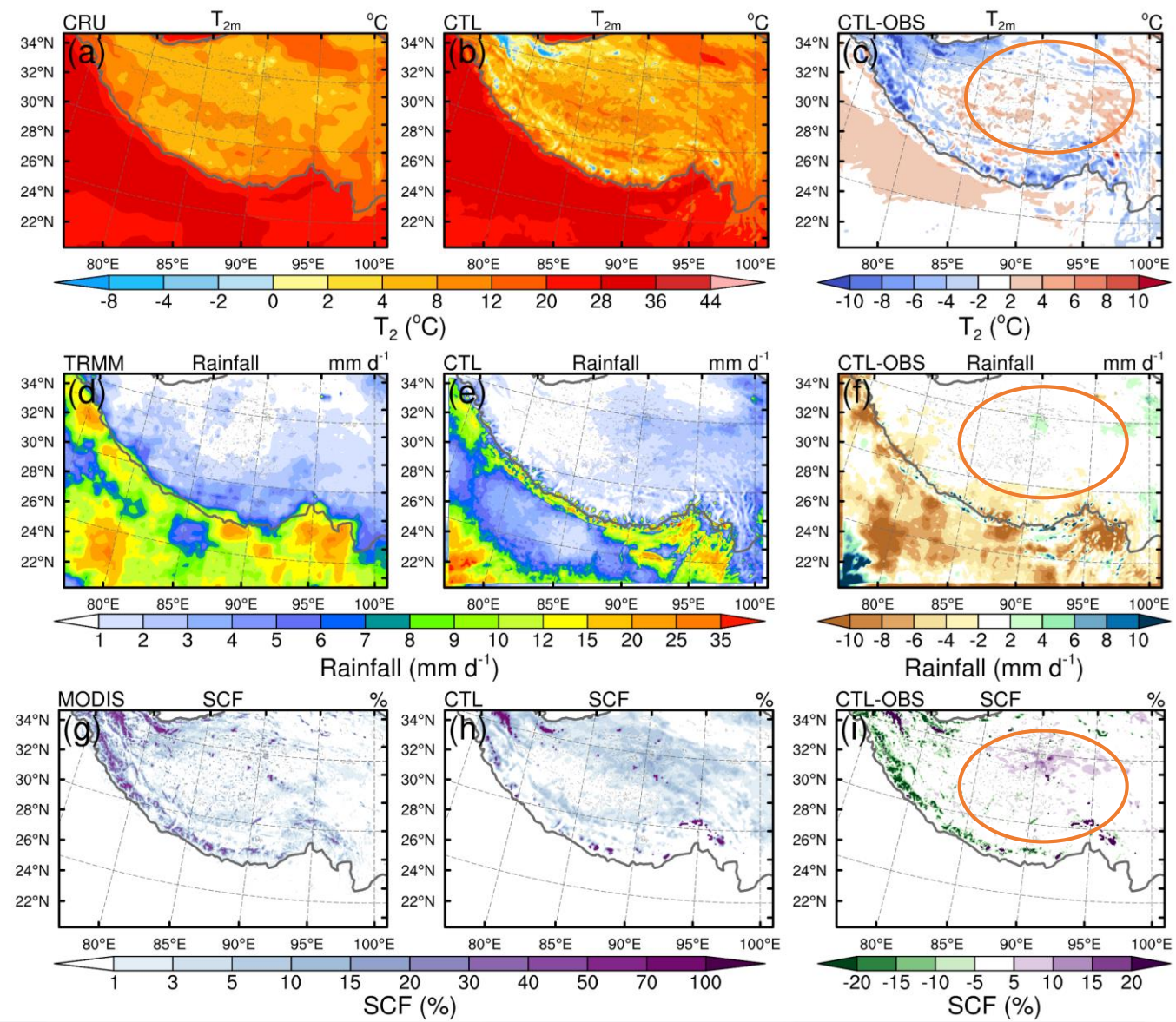
# 3. Results

## Validation of air temperature, precipitation, and snow cover over TP

T

P

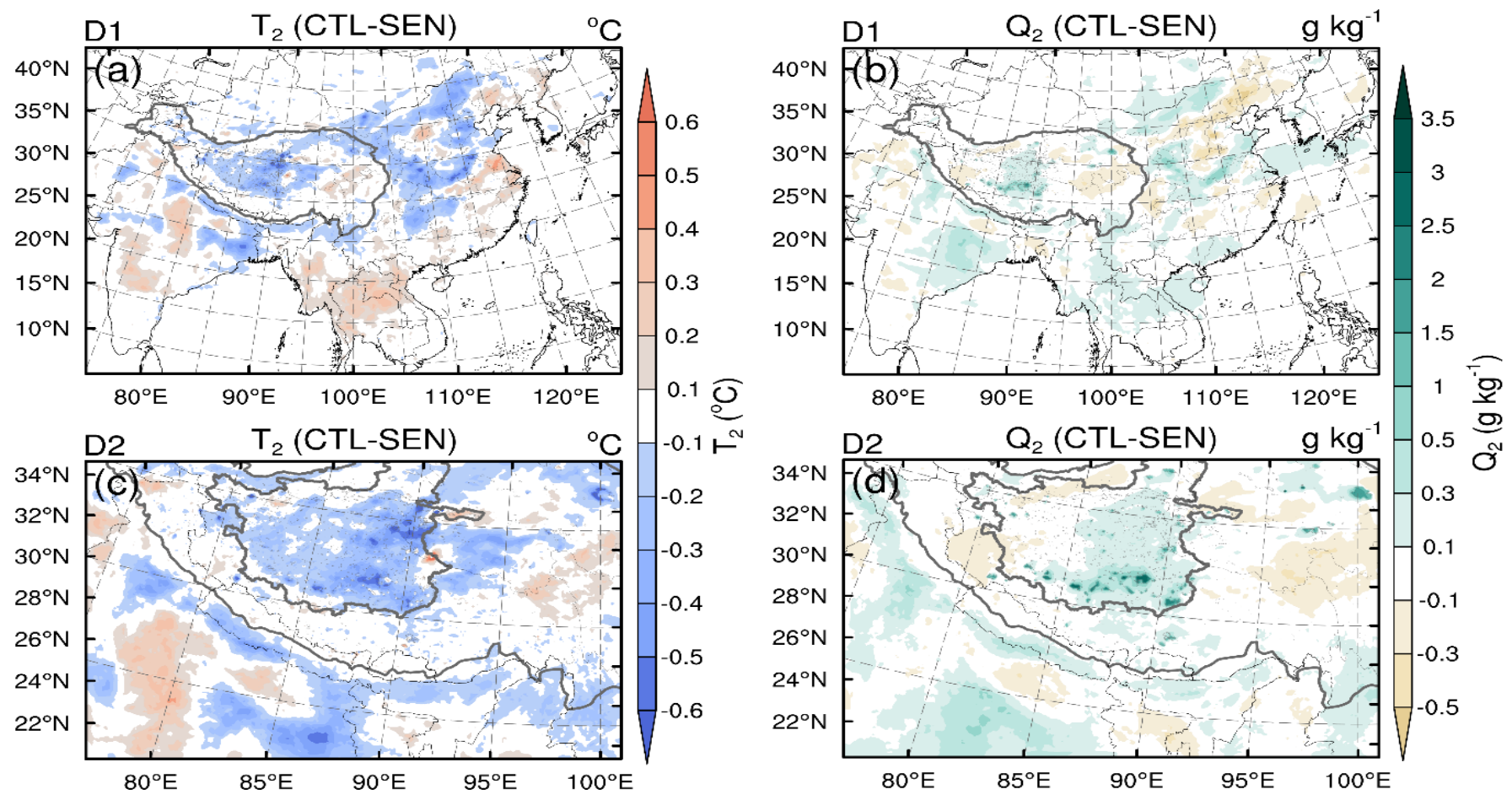
Snow




- ✓ The model can generally simulate the CRU temperature characteristics over TP (CC=0.97, bias=0.97K, RMSE= 2.84K).
- ✓ The spatial distribution and magnitude of simulated precipitation are generally close to TRMM satellite observations ( CC= 0.67 , bias=-2.21mm, RMSE= 4.91mm).
- ✓ The simulation of snow distribution is consistent with MODIS observations.

# 3. Results

## Lake effects on air temperature and humidity

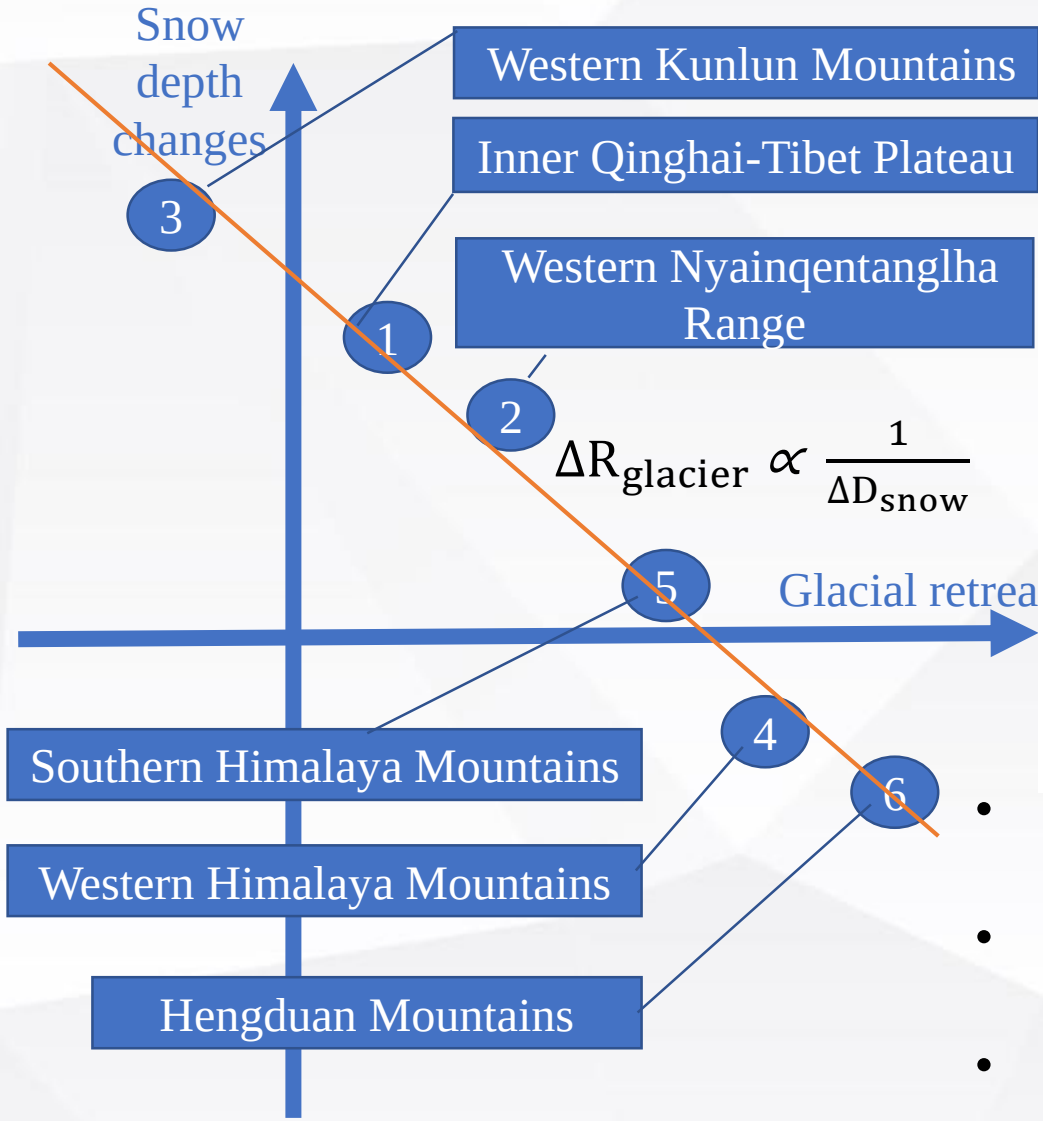


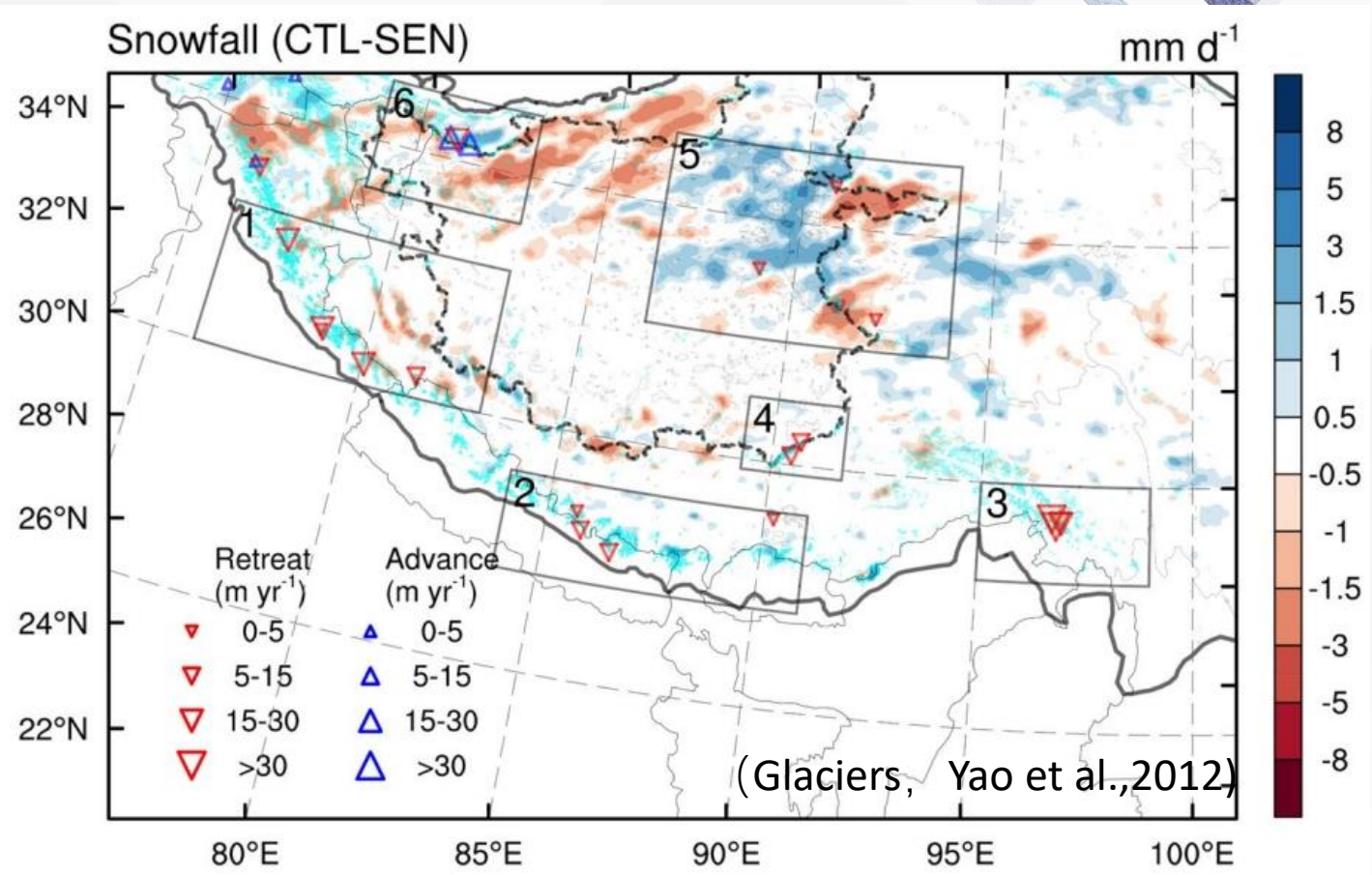

- Averaged over the entire Inner TP, lakes decrease $T_{2m}$ 0.17 °C (2.5%) and increase $Q_{2m}$ 0.15 g kg$^{-1}$ (3.4%).
- Over the lake surface, $T_{2m}$ was decreased 0.46 °C (4.6%), and $Q_{2m}$ was increased 1.84 g kg$^{-1}$ (34.1%).

TP lakes could decrease air temperature and increase humidity over TP, especially over the Inner TP, where the majority of lakes are concentrated, or over the lake surface.

# 3. Results

## Lake-induced snowfall over glaciers

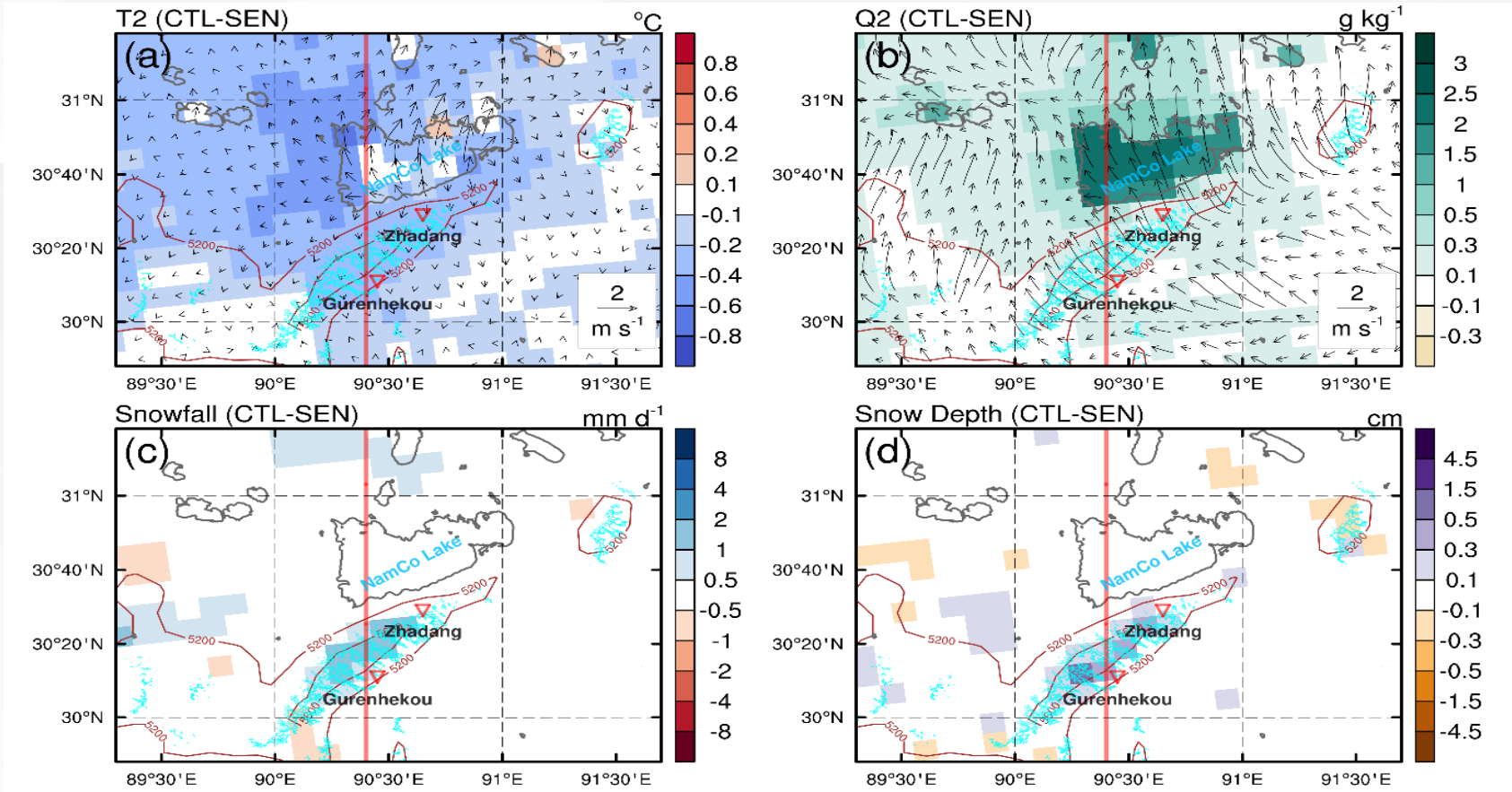



- Snowfall changes caused by TP lakes roughly coincide with the distribution and magnitude of glacier changes from observations.
- Subregions 1–3 are distributed along the Himalayas and are characterized by strong glacier retreat and low amount of lakes.
- The Inner TP with many lakes (Subregions 4-6) has generally lower rates of glacier retreat.

# Subregion 4 (Western Nyainqentanglha) : effects of a large lake moderating glacier retreat

Summer mean differences



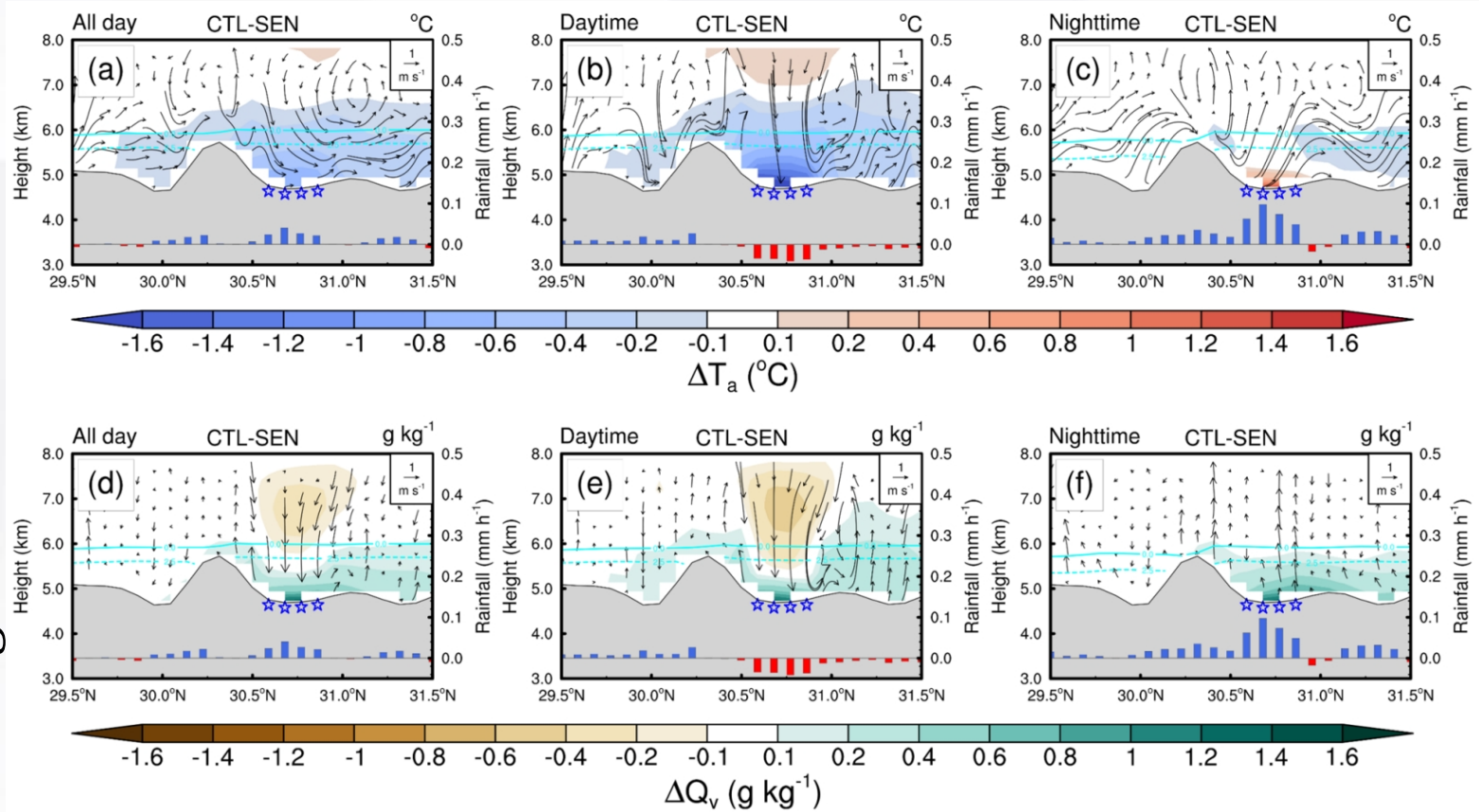

- Streamlines in Fig. a are 10 m wind difference between CTL and SEN.
- Streamlines in Fig. b are 10 m wind in CTL.
- The brown curve outlined the terrain height (only altitudes above 5200 m were shown).
- The red line represents the transaction used for the further vertical cross-section.

✓ The lake resulted in a substantial air temperature drop and humidity increase (Fig a and b).

✓ Snow over the Western Nyainqentanglha Range and the glaciers increased (Fig c and d). Lake Nam Co may facilitate glacier preservation.

# Subregion 4 (Western Nyainqentanglha) : effects of a large lake moderating glacier retreat

Height-latitude cross-sections

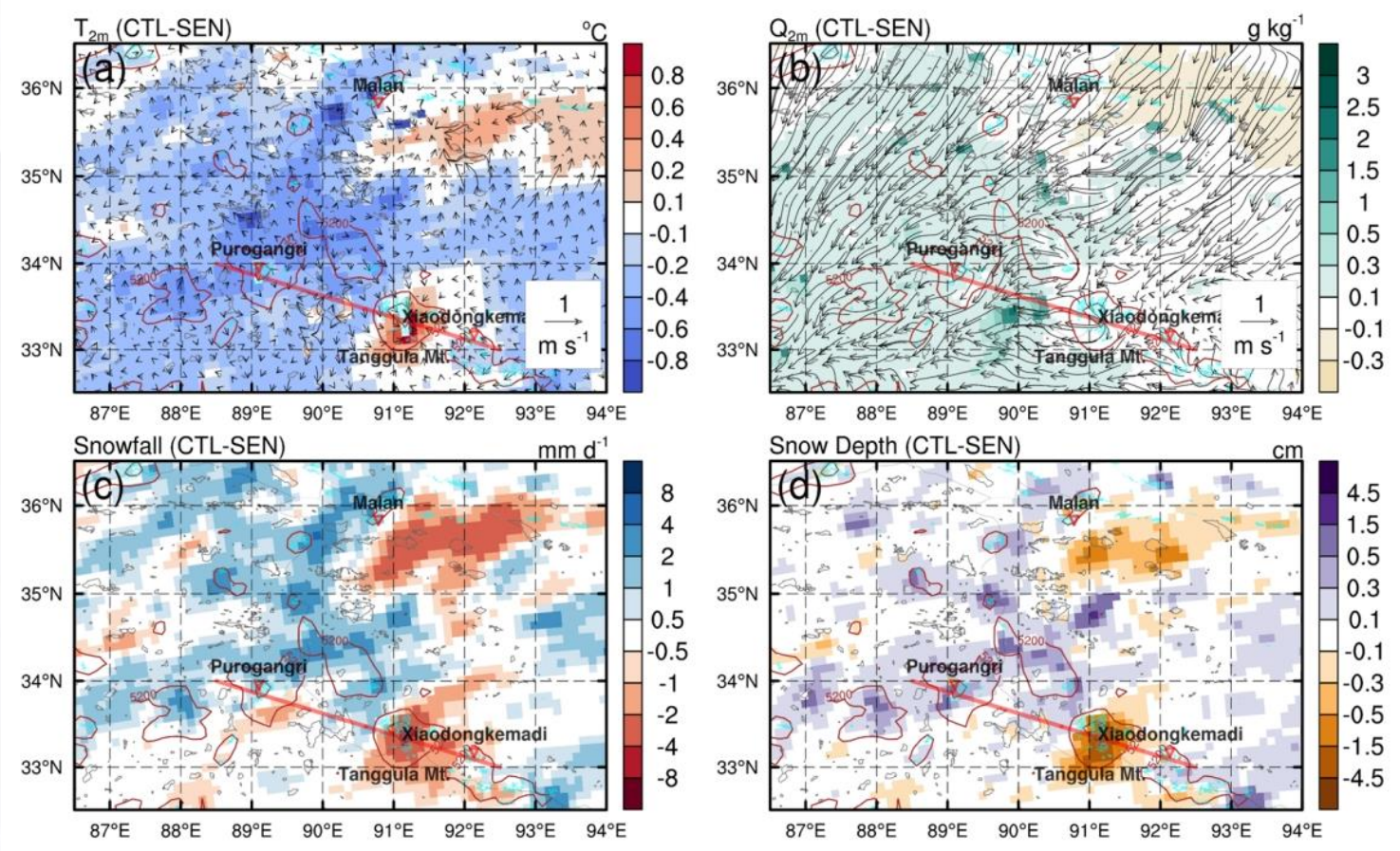



- Vertical circulation (vectors) in Fig. a–c was from CTL experiments, while others were differences between the two experiments (CTL-SEN); the vertical velocity was magnified by 100 times.
- The bar indicates precipitation differences (CTL-SEN).
- The blue stars represent grids of Nam Co Lake.
- The solid and dashed cyan lines represent 0° and 2.5° isotherms, respectively

During daytime, the subsidence with cooling Nam Co decreased precipitation over the lake and nearby area. The divergent surface flow of the lake breeze climbed the north slope of the Range and then to its other side, where it converged with Indian monsoon from south and further led to the precipitation increase on its southern slope.
During nighttime, updraft induced by warm Nam Co met with the Indian monsoon climbing over the mountain and lead to precipitation increase over both of the southern and norther slope.

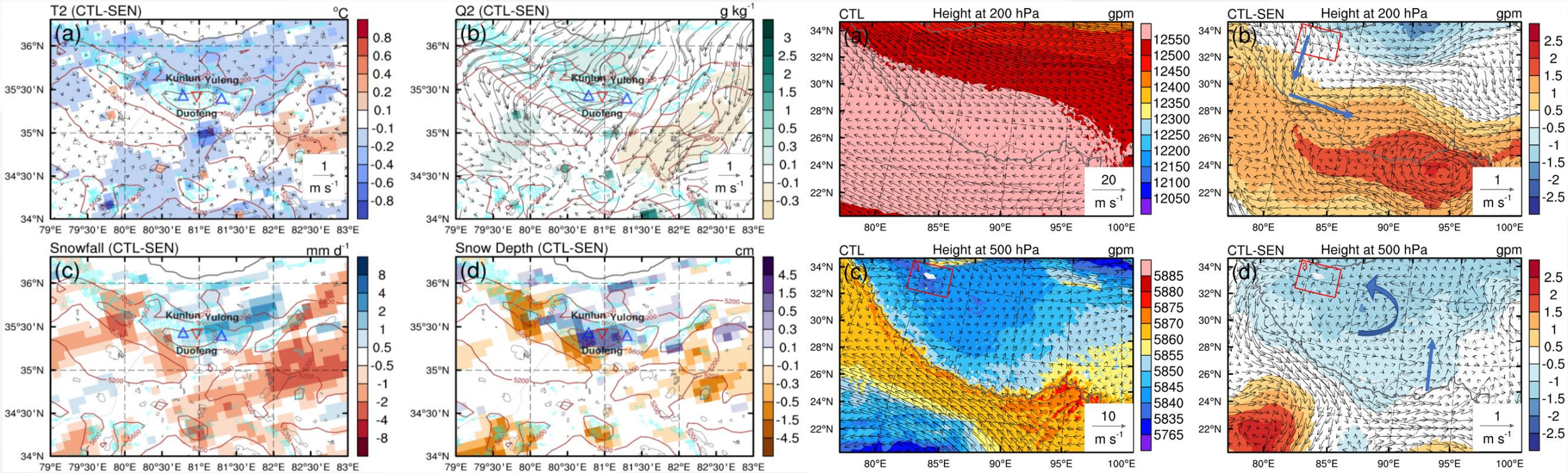
# Subregion 5 (Eastern Inner TP) : cumulative small lake effects slowing down glacier retreat

Summer mean differences




- ✓ The eastern Inner TP hosts numerous small lakes that also reduced temperature and increased moisture.
- ✓ But these effects were generated by many individual small lakes and a little weak, still triggered the second circulation, and extended them to influence each other.
- ✓ The cumulative effects of numerous small lakes increased snowfall in alpine areas.

# Subregion 6 (Western Kunlun Mountains) : large-scale lake effect, slowest glacier retreat



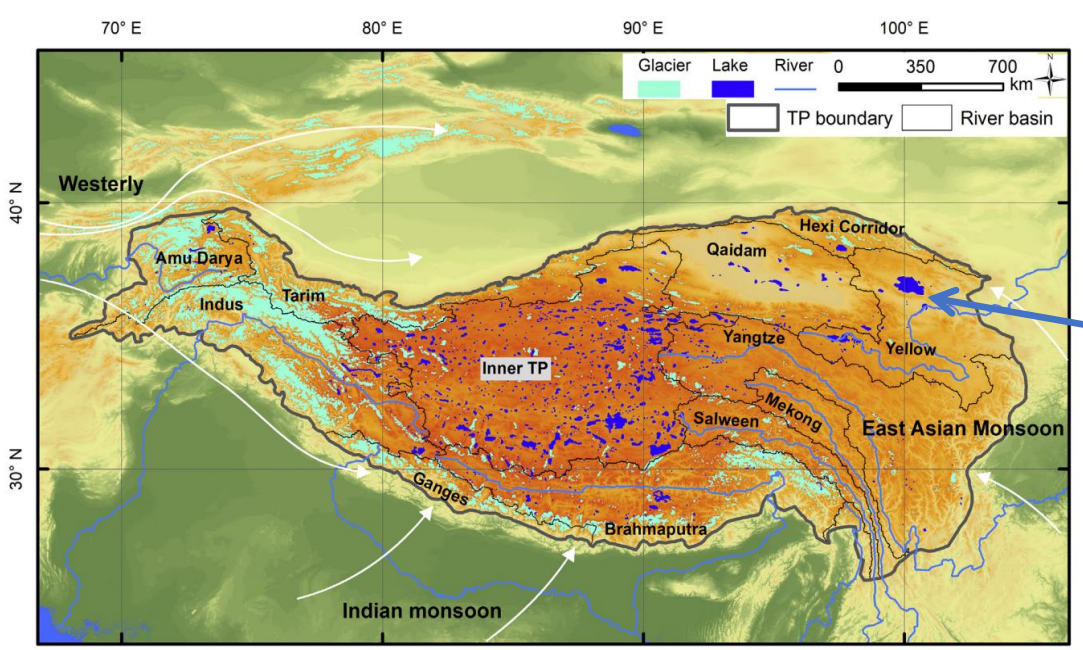

Lakes located in Western Kunlun Mountains are both less abundant and smaller in size, resulting in relatively weaker lake-induced local cooling and moistening. How do glacier retreat less, even advance?

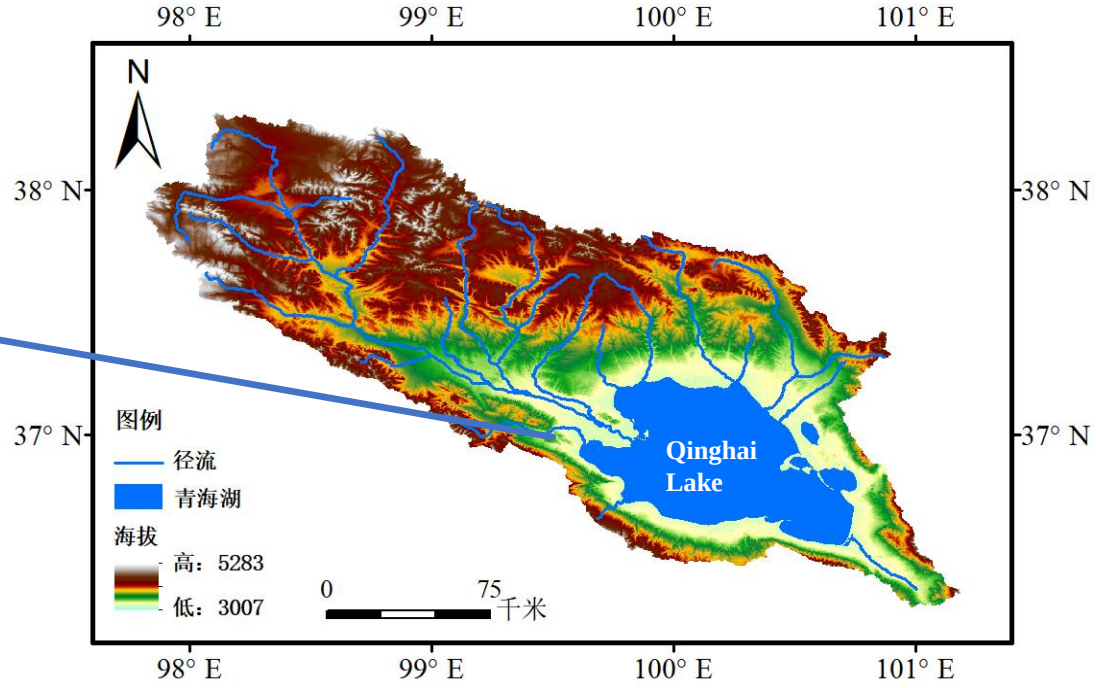
- The temperature in Western Kunlun is lower, most is below 0 °C.
- TP lake cluster reduced 200 hPa geopotential height over the north TP and increased it over the south TP, reinforcing South Asian high and southwardly strengthening westerlies above Western Kunlun .
- TP lakes reinforced a cyclonic circulation by lowering the 500 hPa geopotential height and providing the water vapor through evaporation, contributing to the snowfall increase in the Western Kunlun Mountains.

# 4. Conclusions

- ✓ TP lakes reduce temperature, increase humidity and snowfall in the interior regions.
- ✓ In the Inner TP, the retreat of glaciers is partially offset by the lakes, but through different lake-related mechanisms:
  - The glaciers on the Western Nyainqentanglha Range are preserved mainly by the local cooling and snowfall-increase caused by the nearby large lake.
  - Numerous small lakes in the Eastern Inner TP exert a cumulative effect to preserve the glaciers through cooling and moistening the atmospheric boundary layer and thus increasing snowfall.
  - The glaciers in the western Kunlun Mountains benefit from the large-scale impacts of the TP lake cluster, which intensified westerlies and lead to snowfall increase.

# Qinghai Lake, the biggest  lake in China



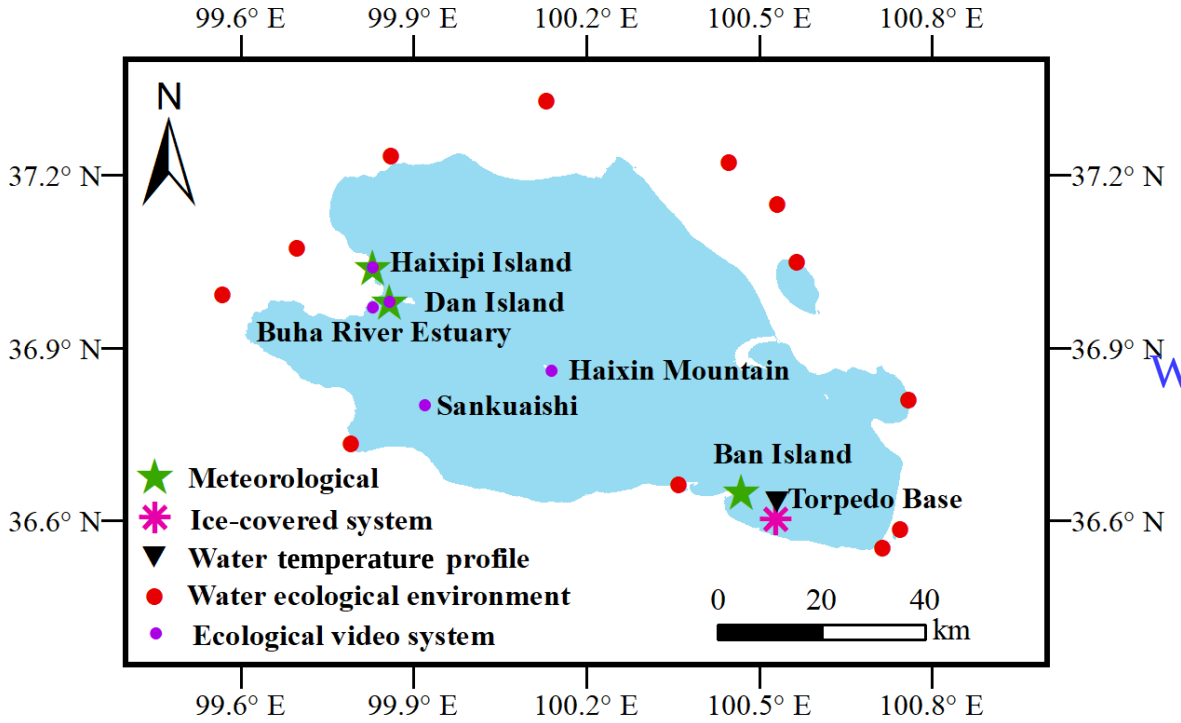
# Qinghai Lake Comprehensive Observation and Research Station, Chinese Academy of Sciences

## Meteorological

## Meteorological

## Ecological video system


## Distribution of field observation points

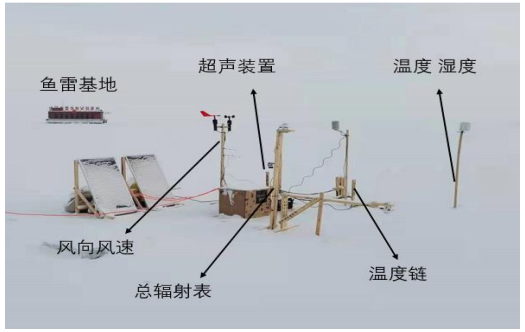



## Water environment monitoring

## Flux observation

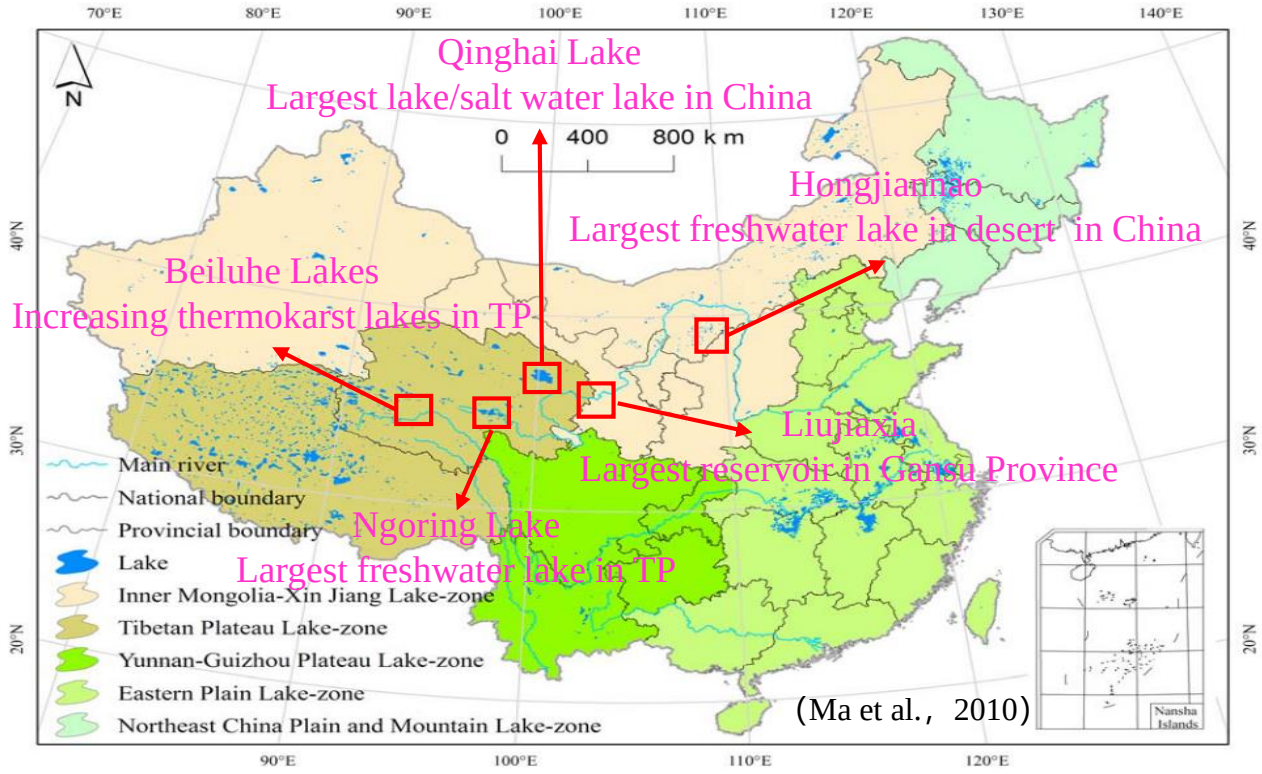
## Water temperature monitoring

## Ice-covered system

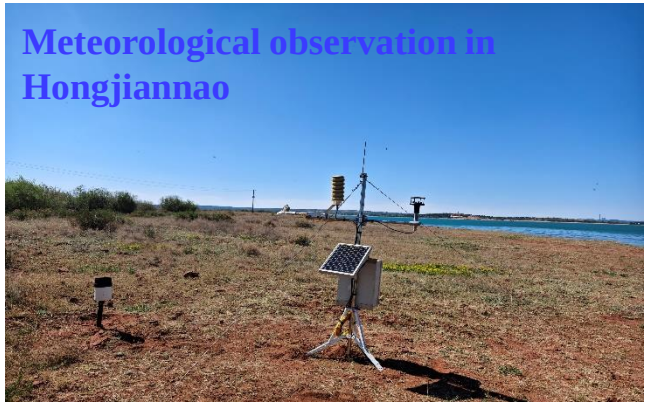


# Lake observations in other areas in China

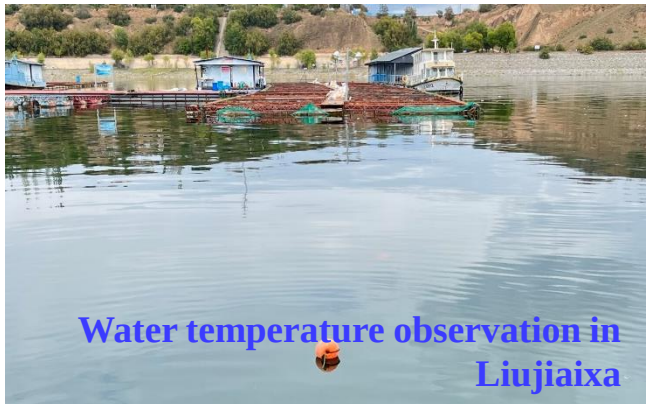
## Lake distribution in China

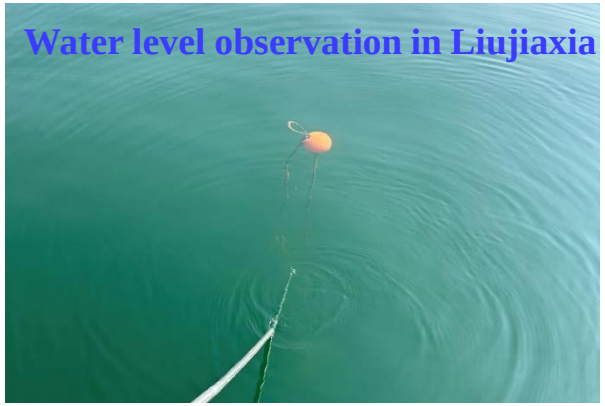



(Ma et al., 2010)



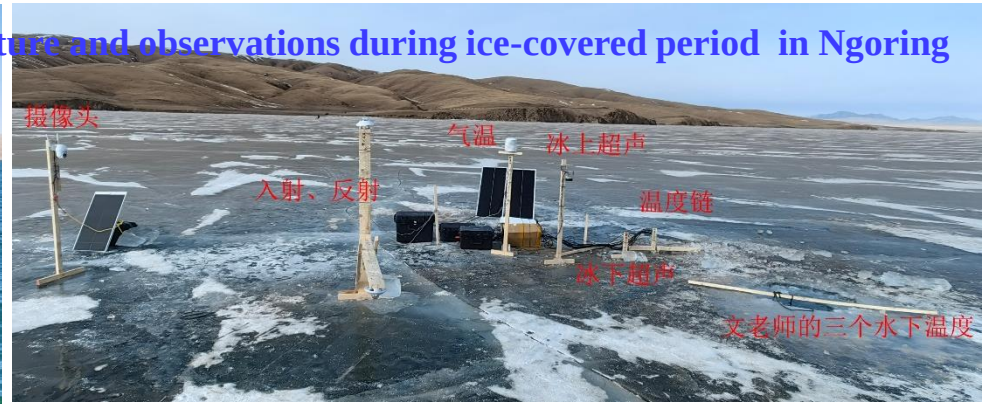










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|---|---|---|
| What will you do? | Conduct a lecture tour in at least two CAS branches (research institutes or universities) in **1-2 weeks** | Conduct academic visits or cooperative research at CAS for **2-9 months** |
| What do we **offer**? | **¥50,000 per week** (pre-tax) | **¥40,000 per month** (pre-tax) for foreign **professors** or those with equivalent qualifications |
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# CAS-PIFI Foreign Scientists

## Matti Leppäranta


(Taken at Lanzhou, China on Nov 26, 2023)

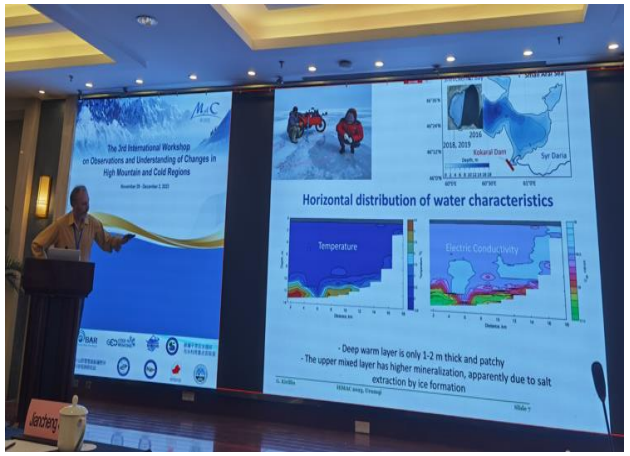
## Lauri Arvola


(Taken at Lanzhou, China on Dec 7, 2020)

| CAS-PIFI Foreign scientists | Title | Duration | Funder |
|---|---|---|---|
| **Matti Leppäranta** (University of Helsinki) | A study of the climatology of Eurasian lakes by modelling and remote sensing | 2022-2024 | CAS-PIFI Distinguished scientist |
| | Modelling the ice season of cold region lakes | 2016-2017 | CAS-PIFI Visiting scientist |
| | Modelling of ice season in Qinghai Lake | 2016-2017 | Key Laboratory of NIEER |
| **Lauri Arvola** (University of Helsinki) | Greenhouse gas (GHG) fluxes from a set of lakes situating in an elevation gradient on the Tibetian Plateau: the impact of melting permafrost on lake response | 2019-2020 | CAS-PIFI Visiting scientist |

# Corporation on projects

**Georgiy Kirillin**： Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany)




| Title | Duration | Funder |
|---|---|---|
| Heat and mass budget of Tibetan Plateau lakes | 2015-2016 | Key Laboratory of NIEER |
| Lakes as components of the Tibetan Plateau climate system (LaTiCS): Internal mixing processes and lake-atmosphere interaction | 2017-2020 | National Natural Science Foundation of China (NSFC) & Deutsche Forschungsgemeinschaft (DFG) |
| Evolution and mechanism of ice and snow physics and ice encrusted ecological environment in typical plateau lakes under the background of climate change | 2021-2023 | Ministry of Science and Technology of the People's Republic of China (MOST) & Bundesministerium fur Bildung und Forschung (BMBF) |

Dongsheng Su, Lijuan Wen, Anning Huang, et al. Simulation of the potential impacts of lakes on glacier behavior over the Tibetan Plateau in summer. Climate Dynamics, 2023, 60:3435–3454, https://doi.org/10.1007/s00382-022-06517-5.

# THANKS!

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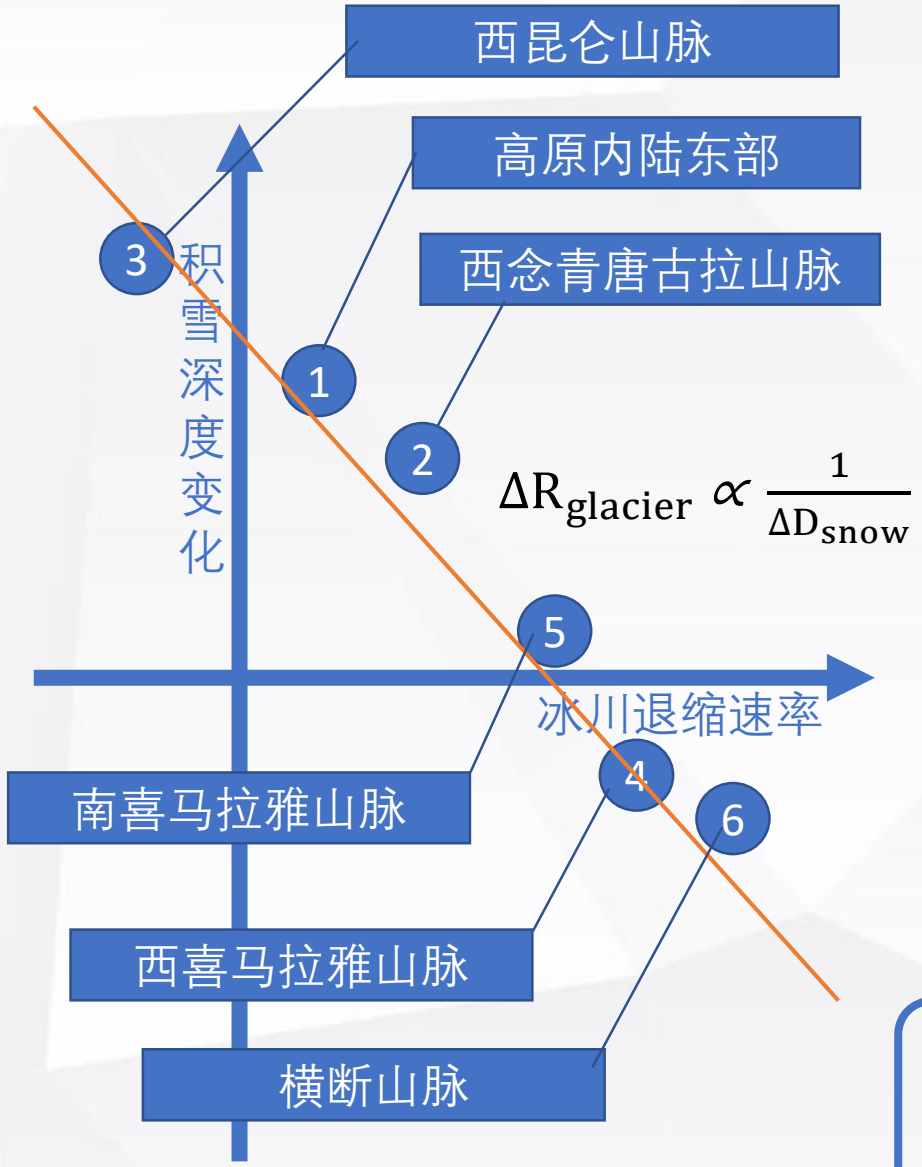
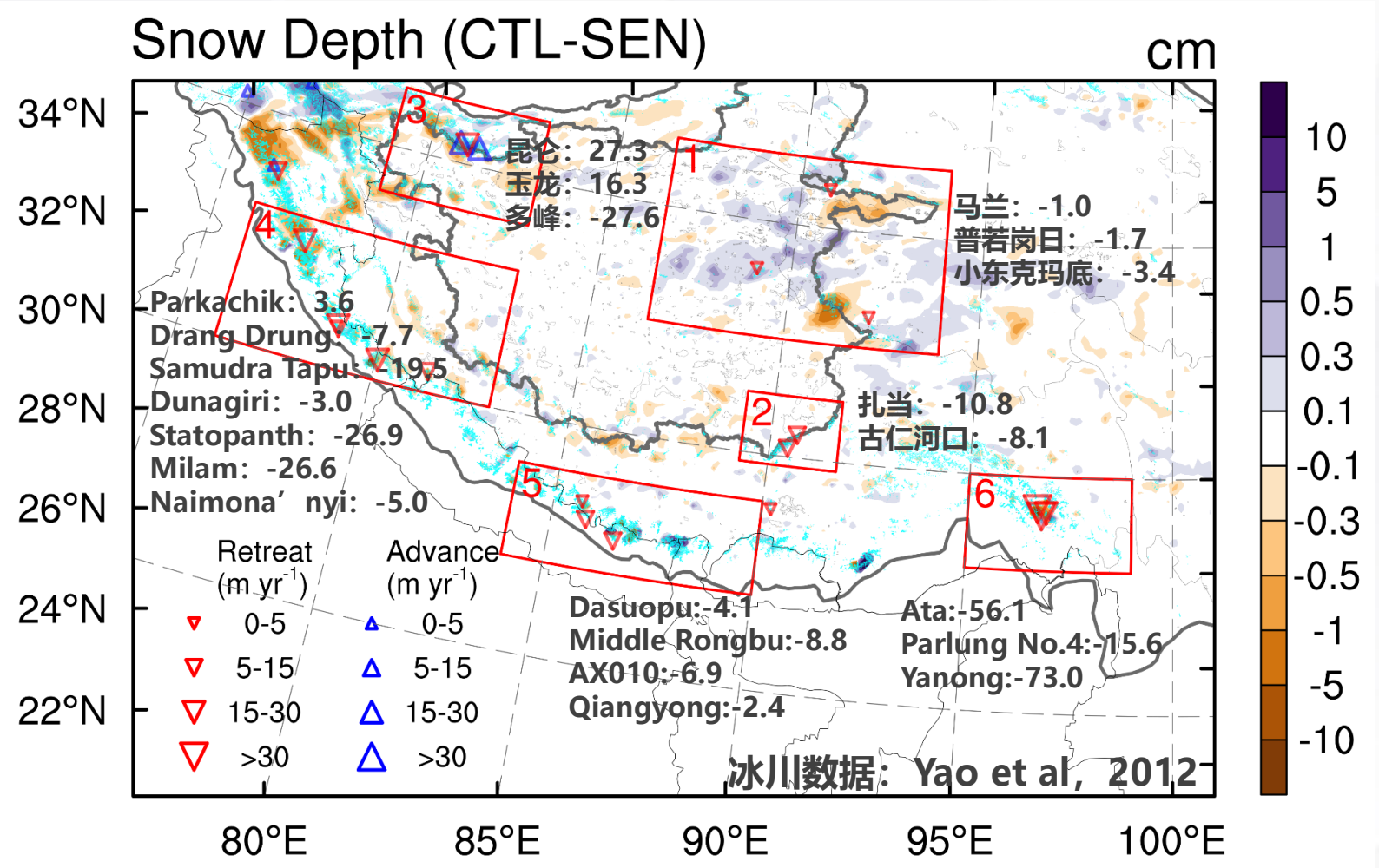
**Northwest Institute of Eco-Environment and Resources, Chinese Acedemy of Sciences**

# 6.2 湖泊引起冰川上的积雪变化






积雪反照率高、导热系数低，可减少太阳辐射吸收并将冰川融水以冷冻或液态形式储存起来，减少冰川表面的融化 (van Pelt et al., 2016)。