

# 青藏高原多圈层地气相互作用过程 及其天气气候效应研究

马耀明&地气作用与气候效应团队

1. 中国科学院青藏高原研究所
2. 中国科学院大学
3. 西藏珠穆朗玛特殊大气过程与环境变化国家野外科学观测研究站  
/中国科学院珠穆朗玛大气与环境综合观测研究站
4. 中国科学院加德满都科教中心
5. 中巴地球科学研究中心

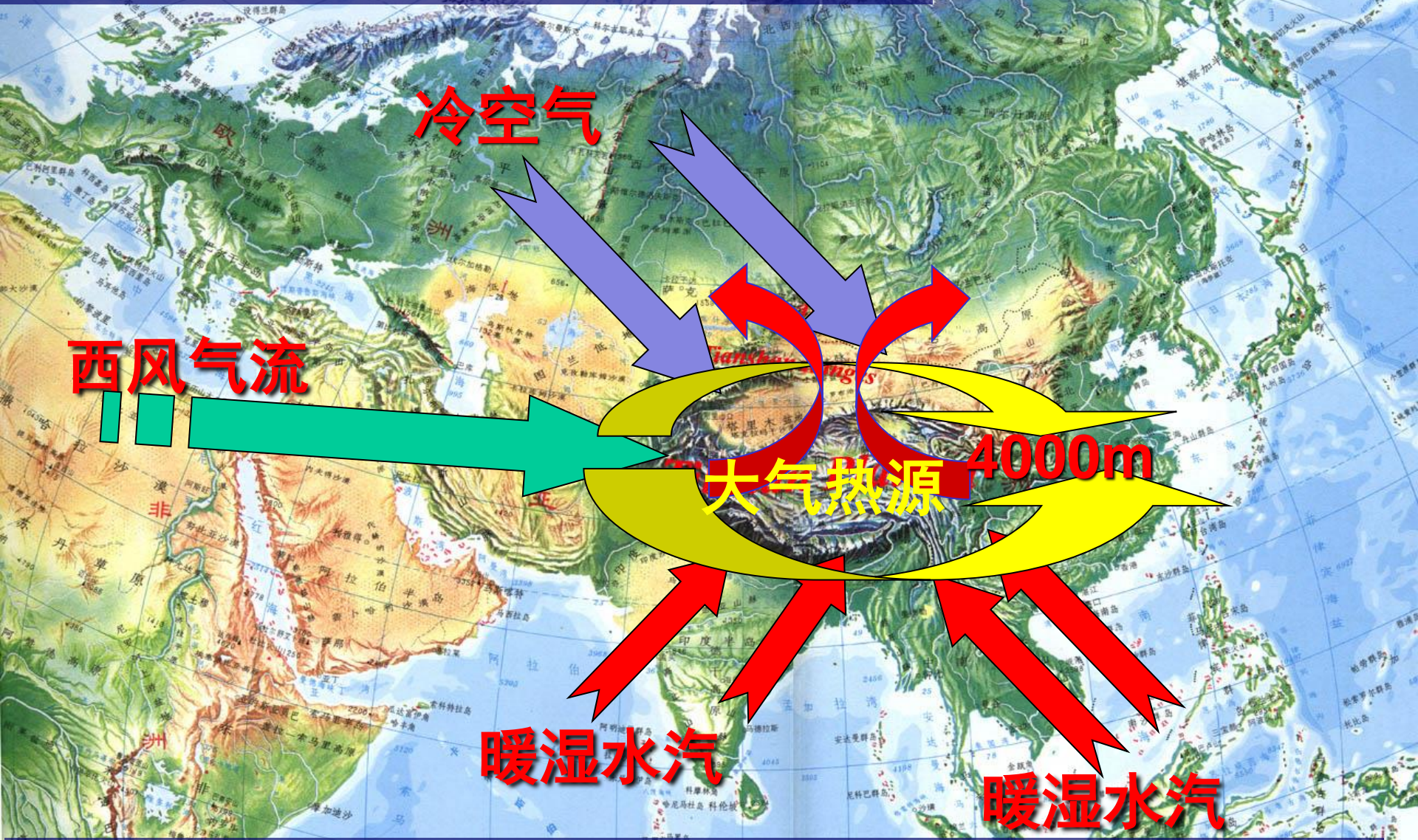
(2023年8月9-11日, 第五届全国中尺度气象学论坛, 中国 银川)

# 提纲

- 一. 为什么做（研究背景）？
- 二. 怎么去做（研究方案）？
- 三. 做了些什么（研究进展）？
- 四. 将要做什么（下一步研究计划）？



# 一、为什么做（研究背景）？

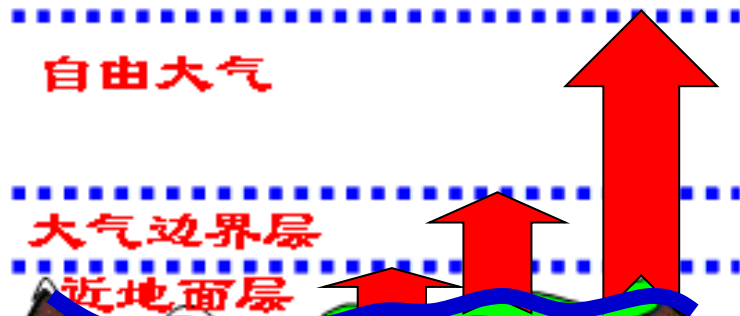


强大的动力和热力作用、影响东亚气候格局、亚洲季风进程和北半球大气环流



# 青藏高原

## 对大气的加热作用



多圈层地气间水热交换  
过程及其天气气候影响





## 二、怎么去做（总体思路及研究方案）？





复杂地表



大地形山地

如何正确认识青藏高原整个复杂地表区域上的水热交换过程及其天气气候效应规律

????????????



荒漠



冰川(雪山)



高原湖泊

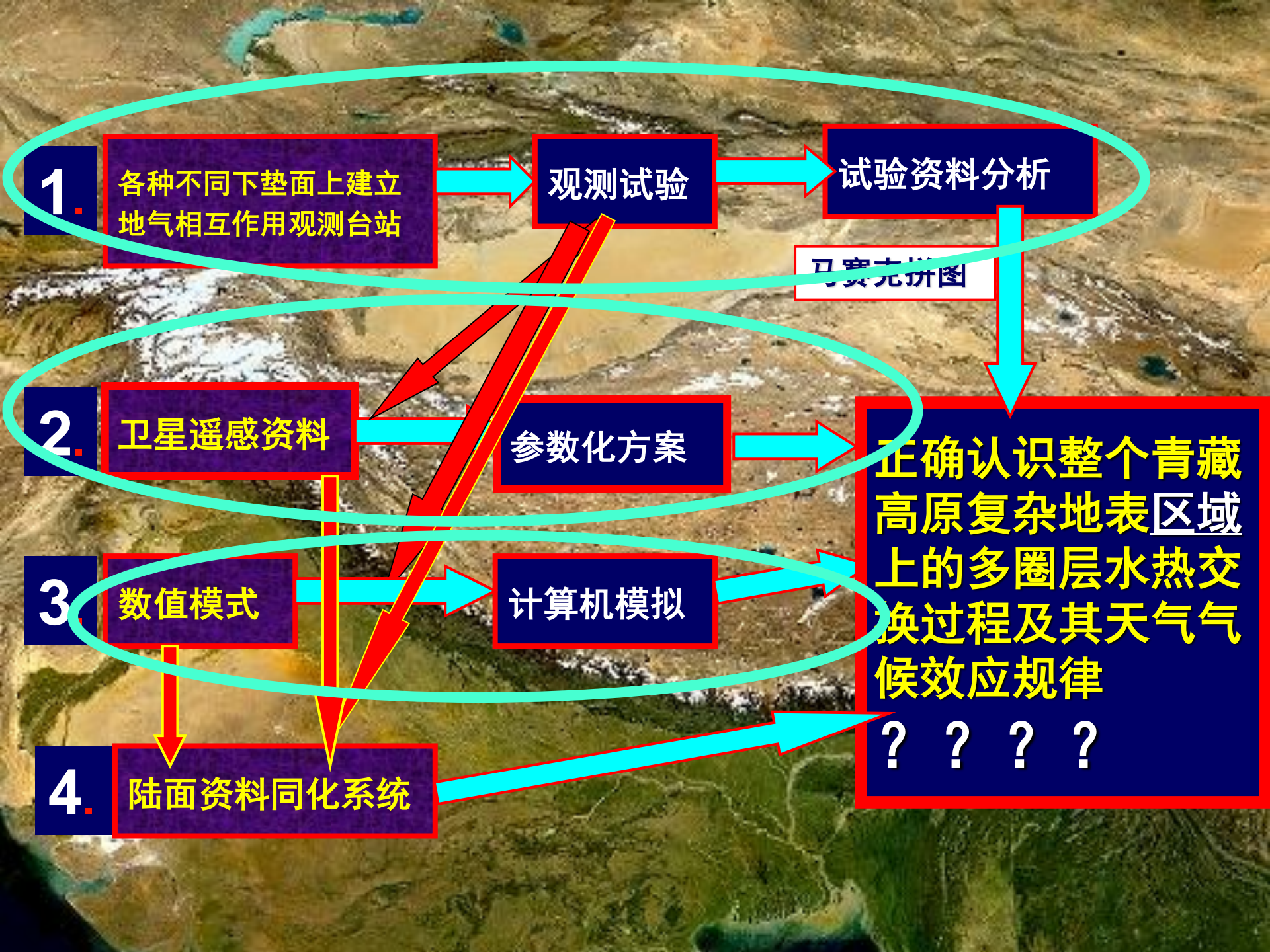


农田



湿地





1.

各种不同下垫面上建立地气相互作用观测台站

观测试验

试验资料分析

马赛克拼图

2.

卫星遥感资料

参数化方案

3.

数值模式

计算机模拟

4.

陆面资料同化系统

正确认识整个青藏高原复杂地表区域上的多圈层水热交换过程及其天气气候效应规律

????

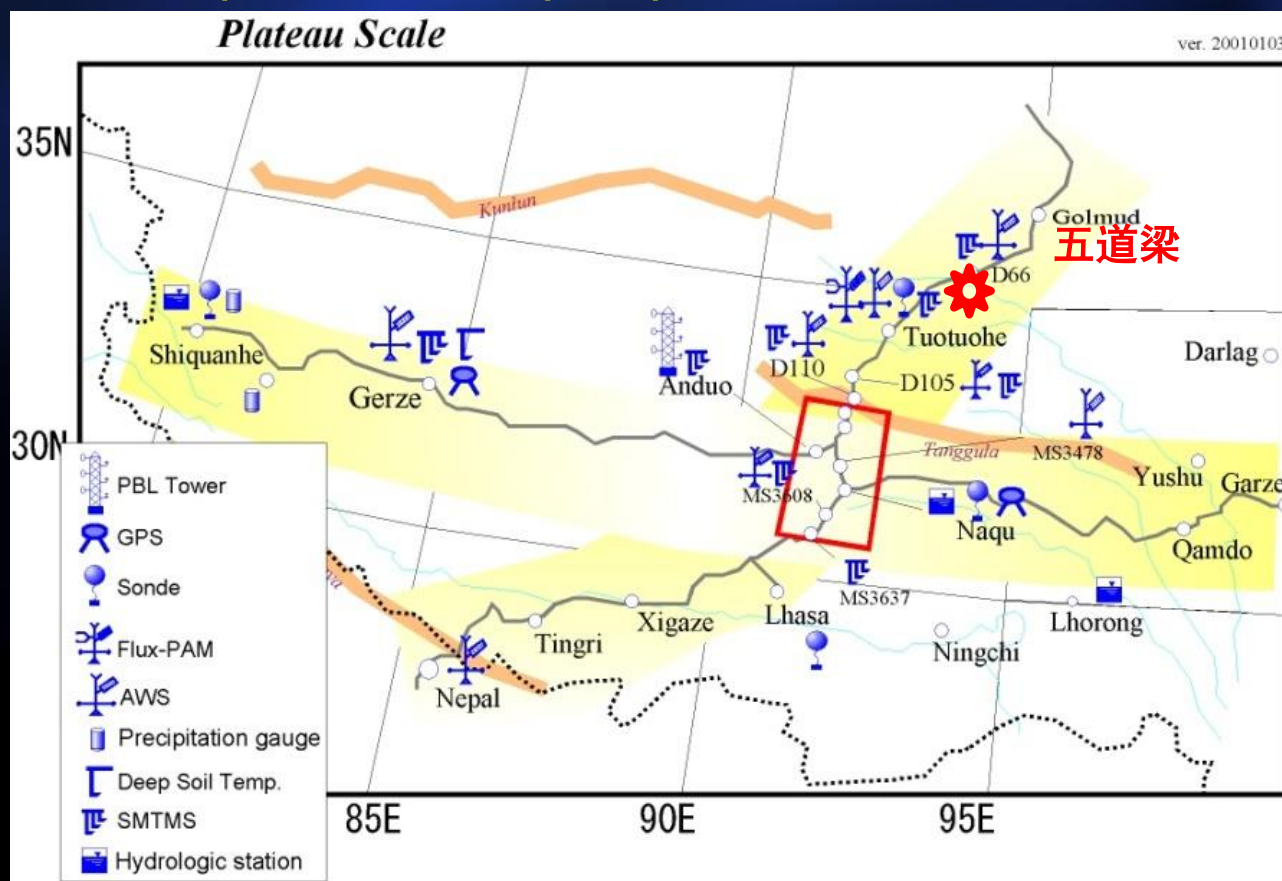


# 三、做了些什么？（研究进展）

(一) 经过三十余年的艰苦努力（1989年起…300余次带队3000余天的，克服高寒缺氧、环境恶劣等困难），创建了“青藏高原多圈层地气相互作用（水热交换）综合立体观测网络平台”（TPEITORP），建成了第三极地区多圈层地气相互作用过程数据库。（Ma, Y. et al., 2008; Ma, Y. et al., 2017; Ma, Y. et al., 2020, ESSD; Nieberding, F. et al., 2020, ESSD; 马耀明等, 2021 高原气象; Ma, Y. et al., 2022, AOSL; Ma, Y. et al., 2023, ESR; Ma, Y., et al., 2023 BAMS)



针对青藏高原地气相互作用过程综合观测研究站点的缺乏的短板，并充分考虑青藏高原不同地表类型和气候区地气交换规律的显著差异，从1989年开始，在青藏高原的不同下垫面（高寒草甸、荒漠草原、大地形山地、冰川（雪山）、高原湖泊、陡峭斜坡、高山森林、高原湿地等）的关键敏感区，“攀登计划”（孙鸿烈先生）五道梁综合观测站到GAME/Tibet（1996）到CAMP/Tibet(2001)



(Ma, Y. et al, 2003, *JMSJ*)





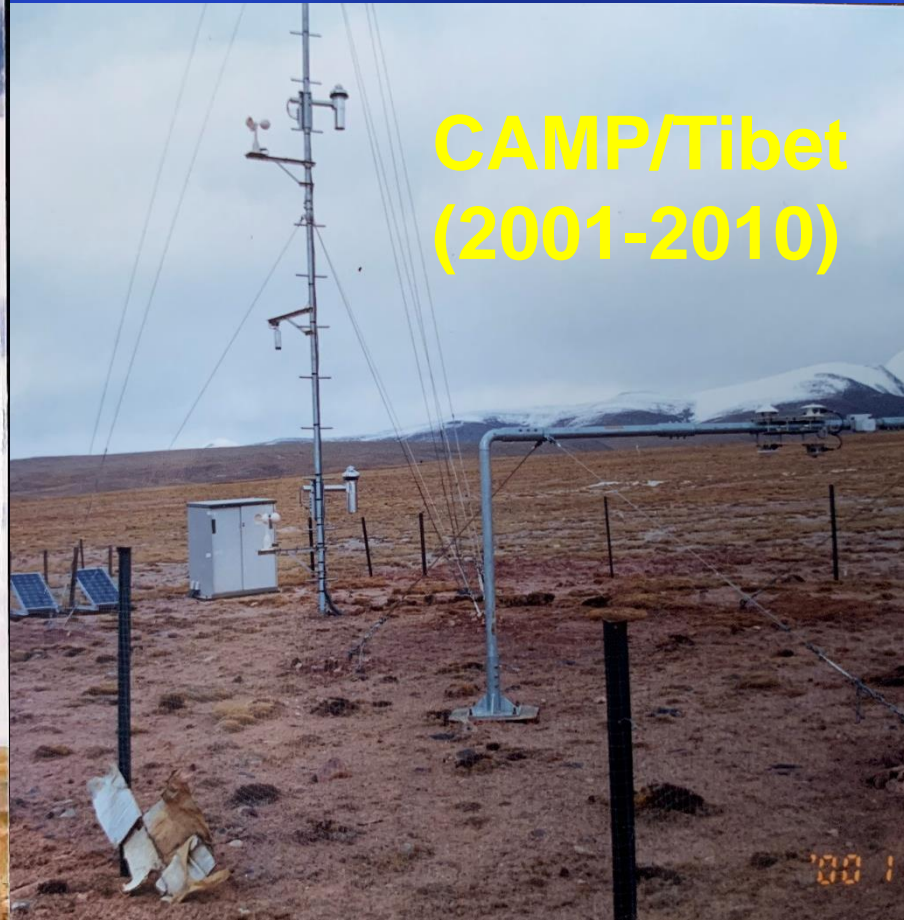


# GAME/Tibet(1996-2000)



02.06.2000

# CAMP/Tibet (2001-2010)



00 1



2003年ITP/CAS成立,开始设计并建立TORP

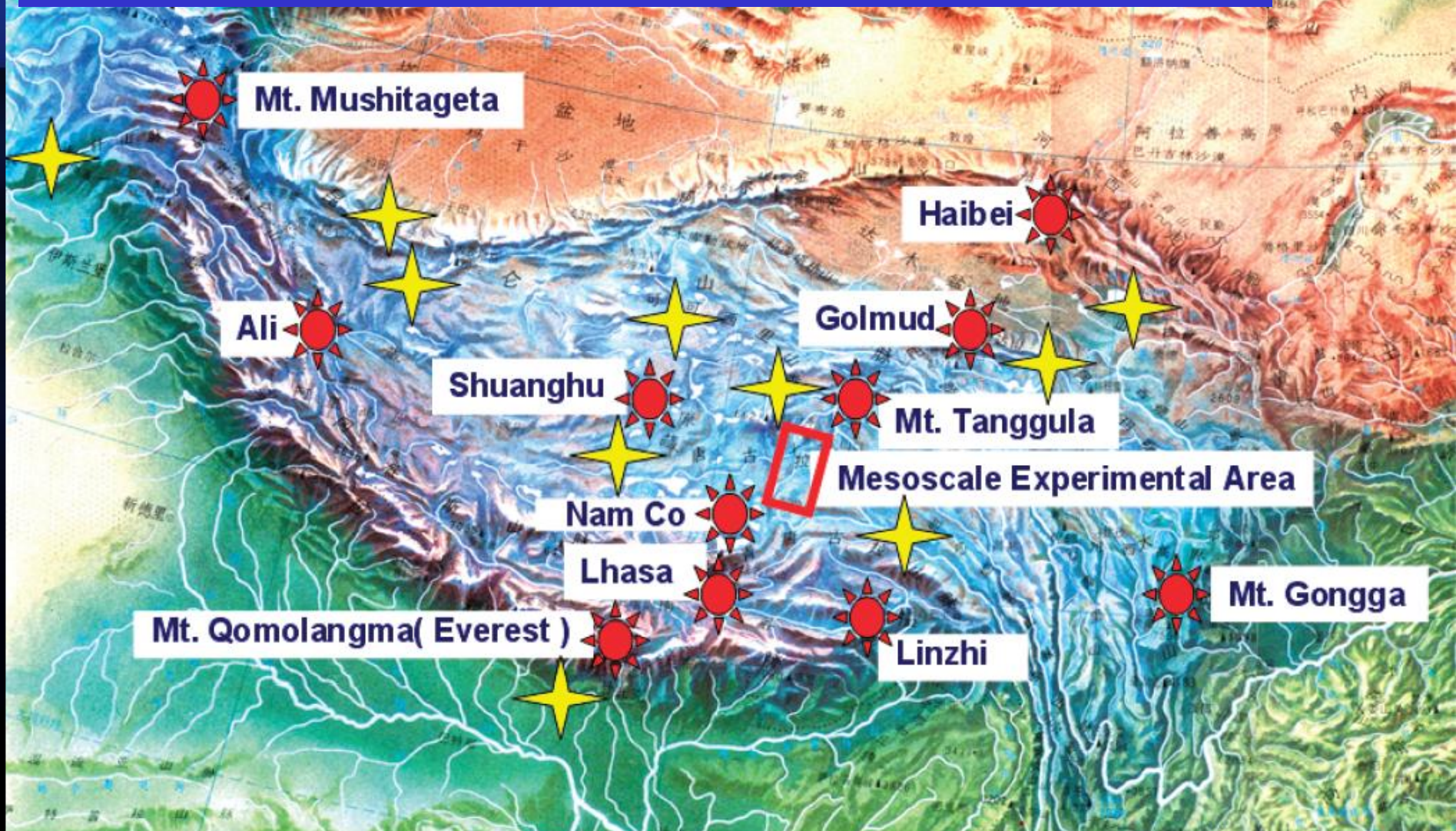
# Tibetan Observation and Research Platform

---TORP

(Ma, Y. et al, 2008, *BAMS*)



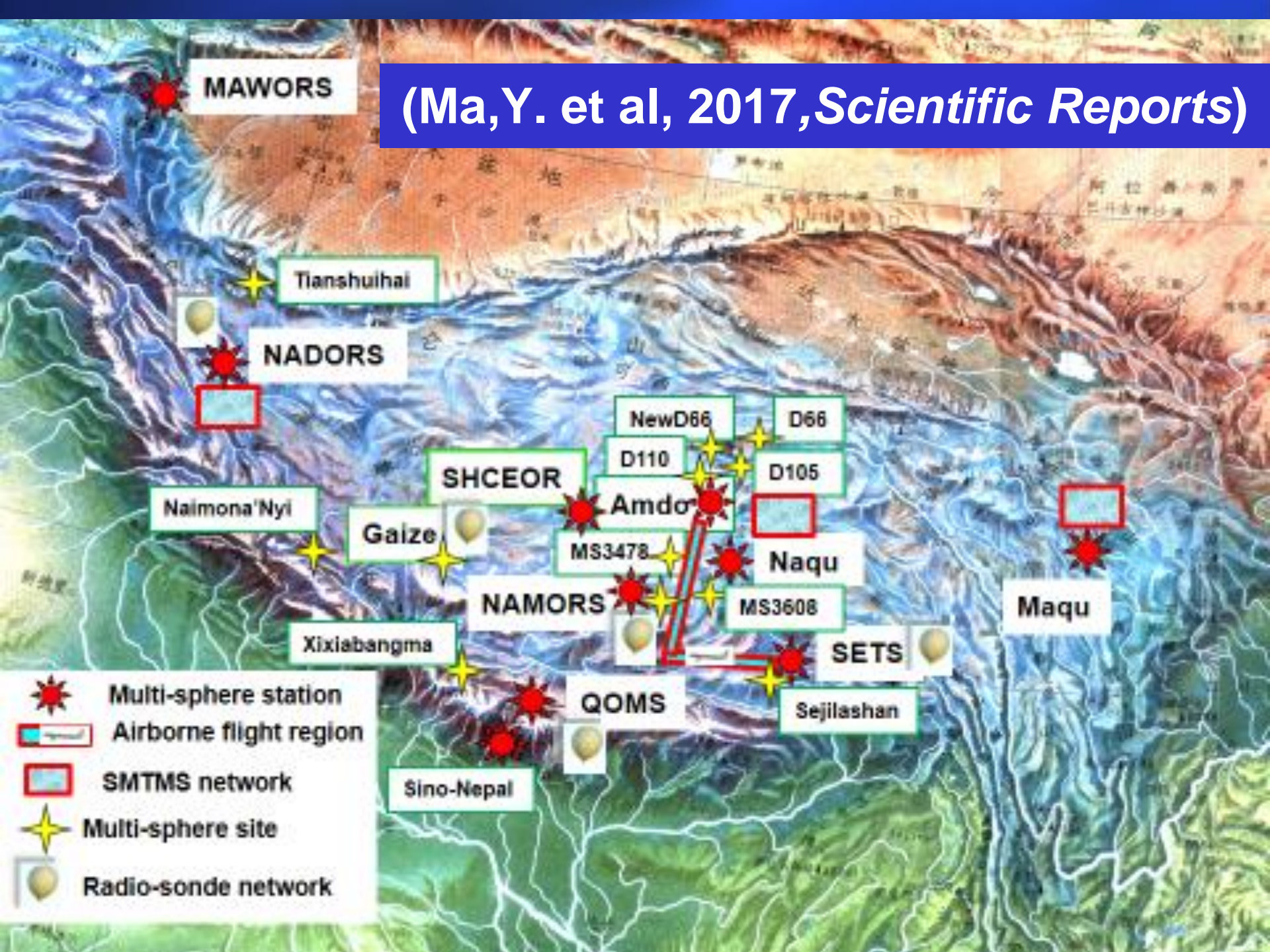
# 2003年ITP/CAS成立,开始设计并建立TORP



(Ma, Y. et al, 2008, *BAMS*)



(Ma, Y. et al, 2017, *Scientific Reports*)





**Ma, Y. et al., 2017, Scientific Report**

MAVORS

NADORS

Haibei

NewD66

Shuanghu

Amdo

D105

Selinco

MS3478

Naqu GL

Maqu

Naqu

NAMORS

Namco lake

Damxung WL

Damxung GL

QOMS

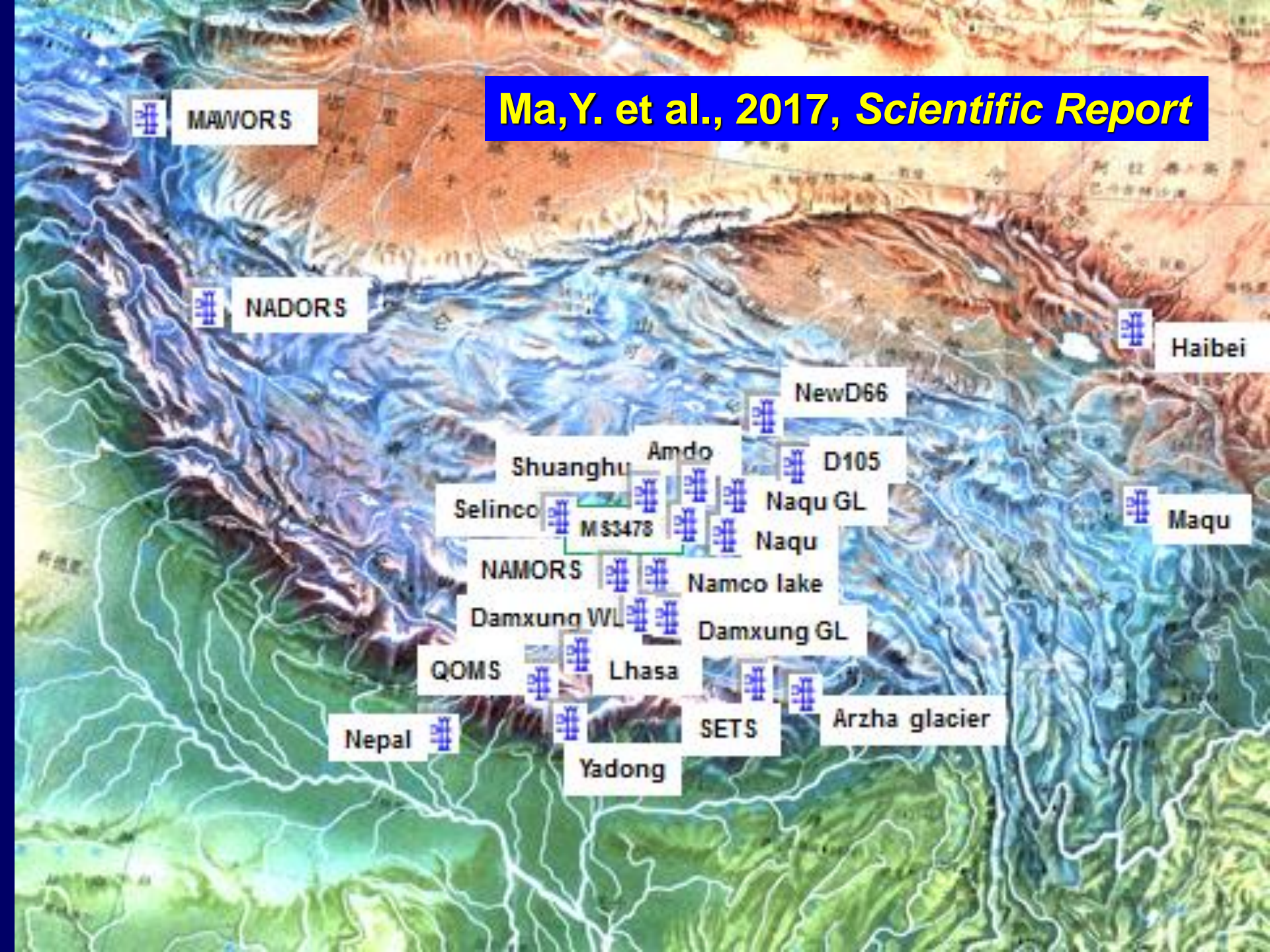
Lhasa

SETS

Arzha glacier

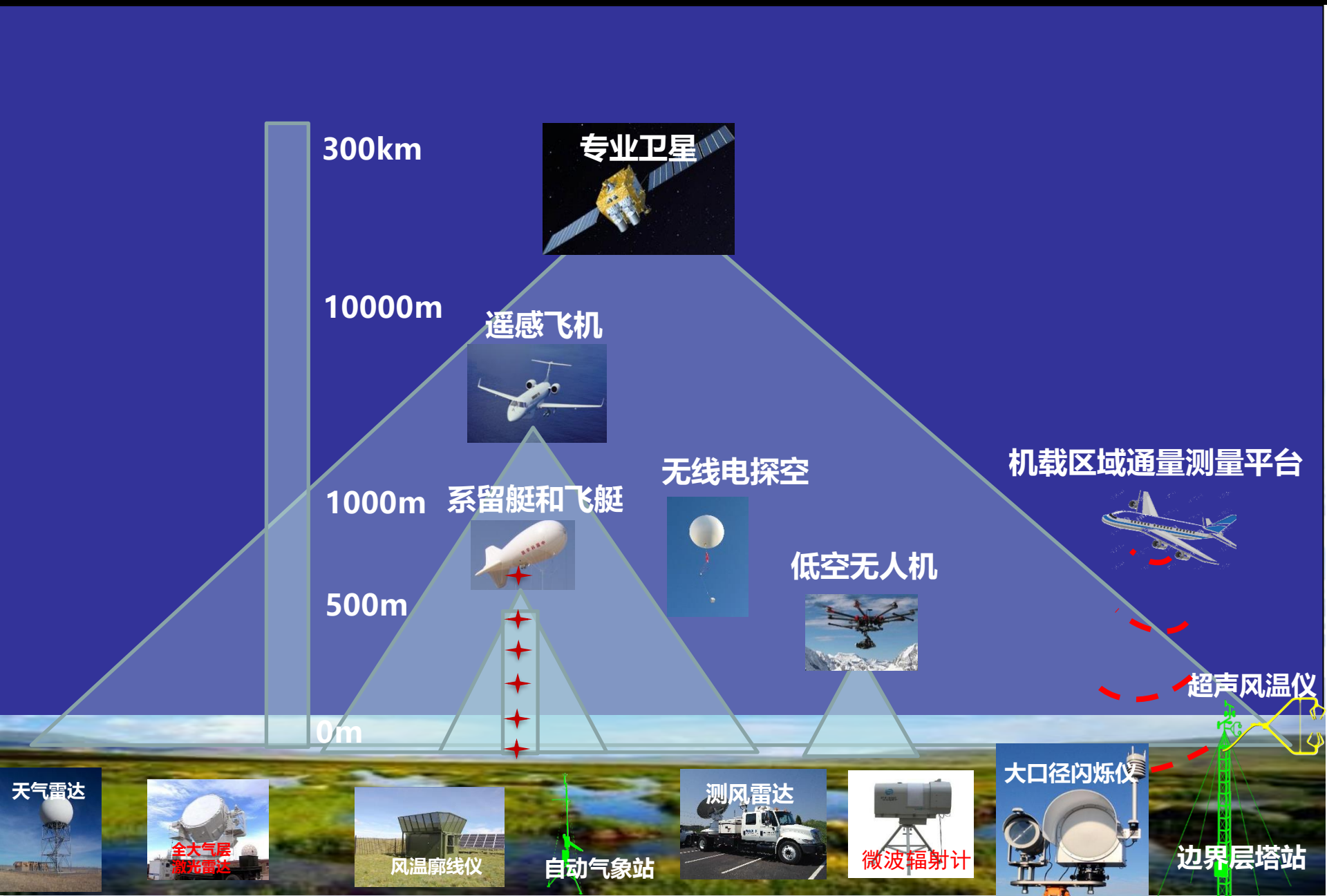
Nepal

Yadong





在二次青藏科考中，经过近三年的艰苦努力，新建青藏高原12个地气相互作用综合观测站，创建了“青藏高原多圈层地气相互作用综合立体观测网络平台 (TPEITORP)” (Ma, Y. et al., 2023, ESR; Ma, Y. et al., 2023, BAMS)



在二次青藏科考中，经过近三年的艰苦努力，新建青藏高原12个地气相互作用综合观测站，创建了“青藏高原多圈层地气相互作用综合立体观测网络平台（TPEITORP, 27个大气边界层塔群系统、37个涡动相关观测系统、10套微波辐射计组网、8套风温廓线、3个SMSTMS等）

“ (Ma, Y. et al., 2023, ESR; Ma, Y. et al., 2023, BAMS)



MAWORS

Gilgit

NADORS

Mangai

Dunhuang

SACOL

Shiquanhe

Qumalai

SHCEOR

Emei

Naimona'nyi

Gaize

Amdo

Naqu

Maqu

Qamdo

Burang

Coqen

Nyima

Baingoin

NAMORS

MS3608

Mangkam

Wenzhang

Xixiabangma

Gyirong

QOMS

Lhasa

Sejilashan

Medog

Sino-Nepal

Multi-sphere station

Airborne flight region

SMTMS network

Multi-sphere site

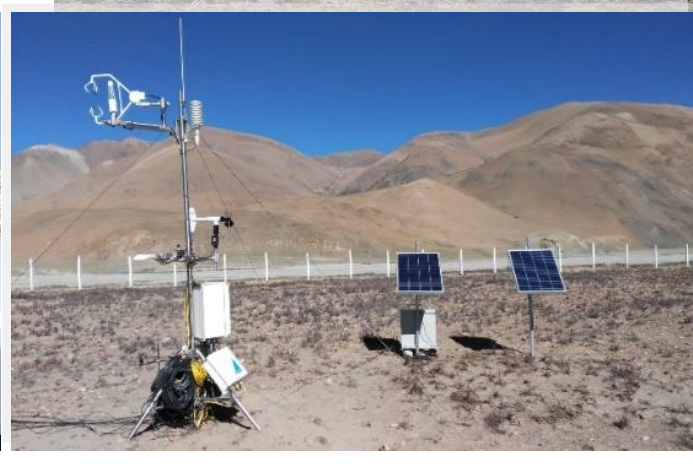
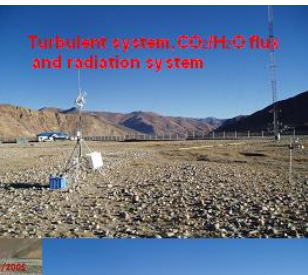
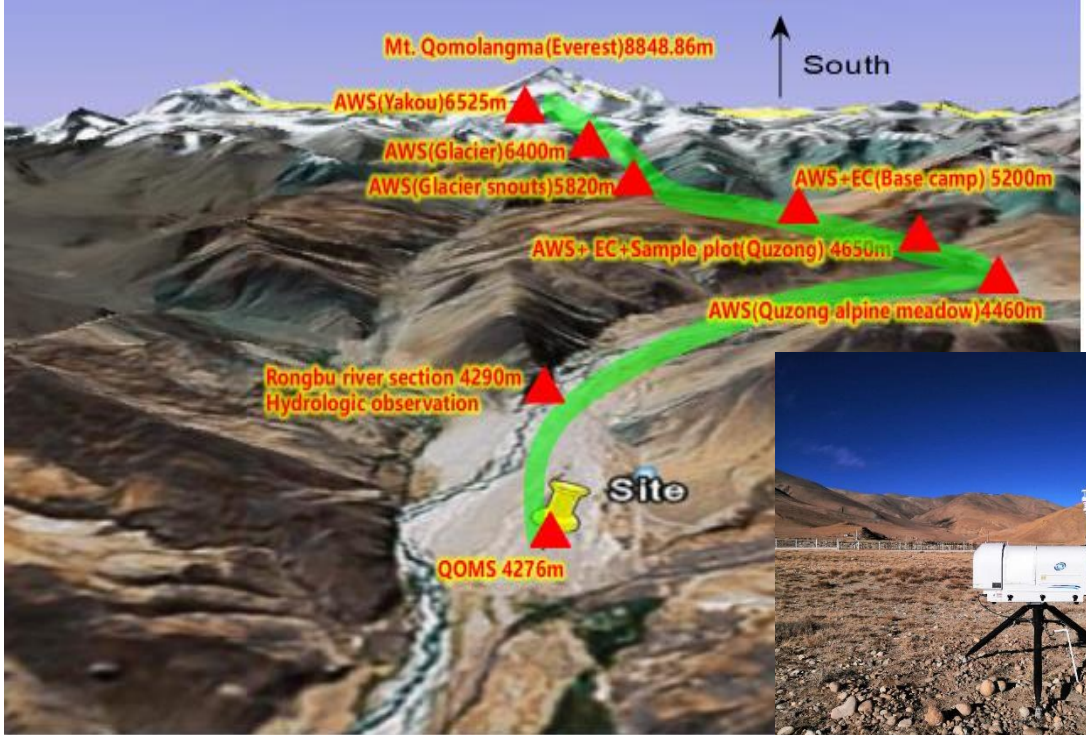
Radio-sonde network

Microwave radiometer



# (1) National Observation and Research Station for Qomolangma Special Atmospheric Processes and Environmental Changes, Tibet, China (QOMS, 2005-present)

## 珠峰站





# 世界上海拔最高的AWS!

央视新闻 · 正在直播

总台高山摄像实时回传



8800米! 全球海拔最高自动气象站正在架设



直播 CCTV.com

“巅峰使命”珠峰科考 珠峰气象保障与气候科考启动



西藏 “巅峰使命”珠峰科考 新闻直播间 气球携带监测仪器升空 实时传输气象



**2). Nam Co Station for Multisphere  
Observation and Research  
(NAMOR), Chinese Academy of Sciences**

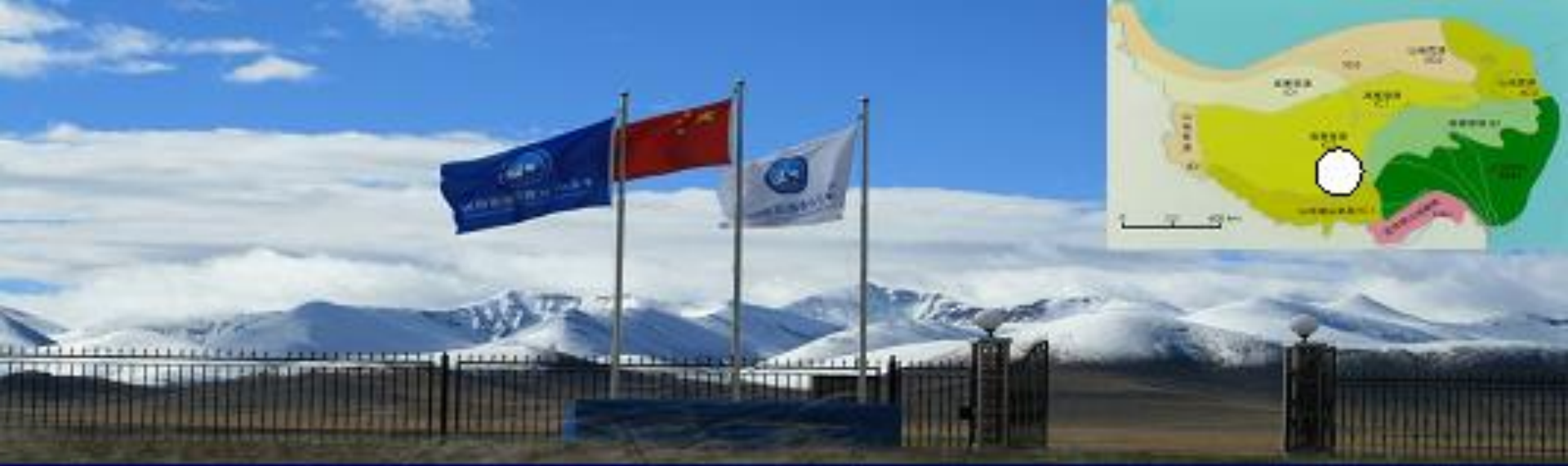
**Nam Co Station**

**Constructed date:**

**End of September, 2005**

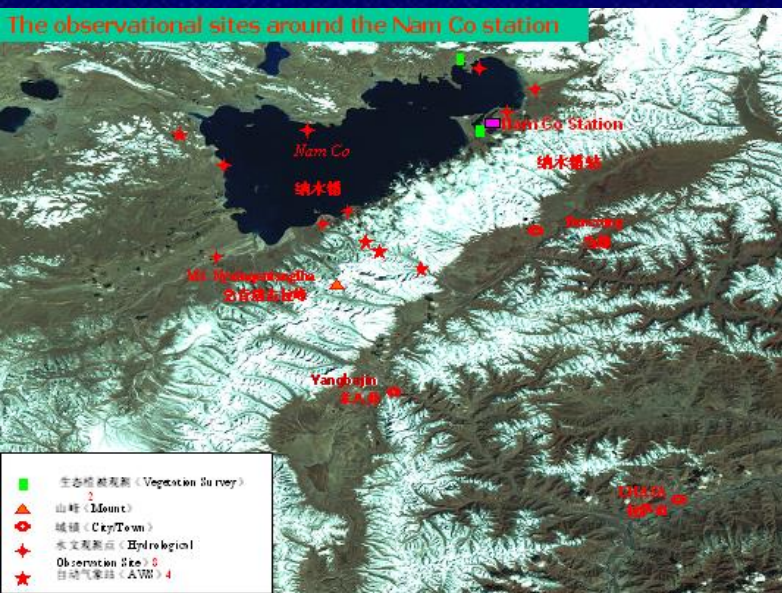




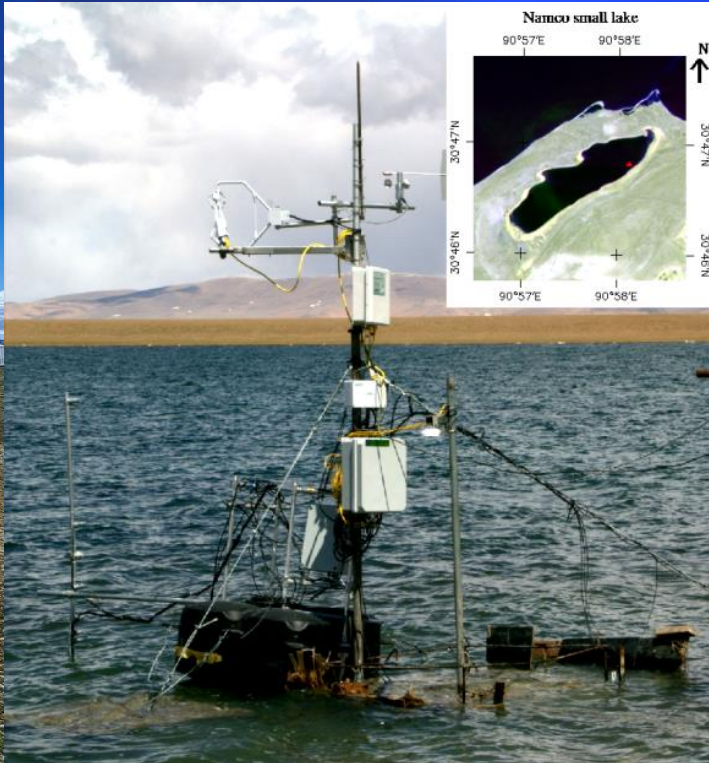


## Nam Co St.

The observational sites around the Nam Co station







4720m

2005 8 7

Turbulent system, CO<sub>2</sub>/H<sub>2</sub>O flux  
and radiation system

52m PBL tower  
( Radiation system  
and SMTMS)





### 3). Southeast Tibet Station for Alpine Environment Observation and Research (SETS), CAS (藏东南站 (林芝站))

**Constructed date: Beginning of November, 2006**







**20m PBL tower  
(SMTWS)**



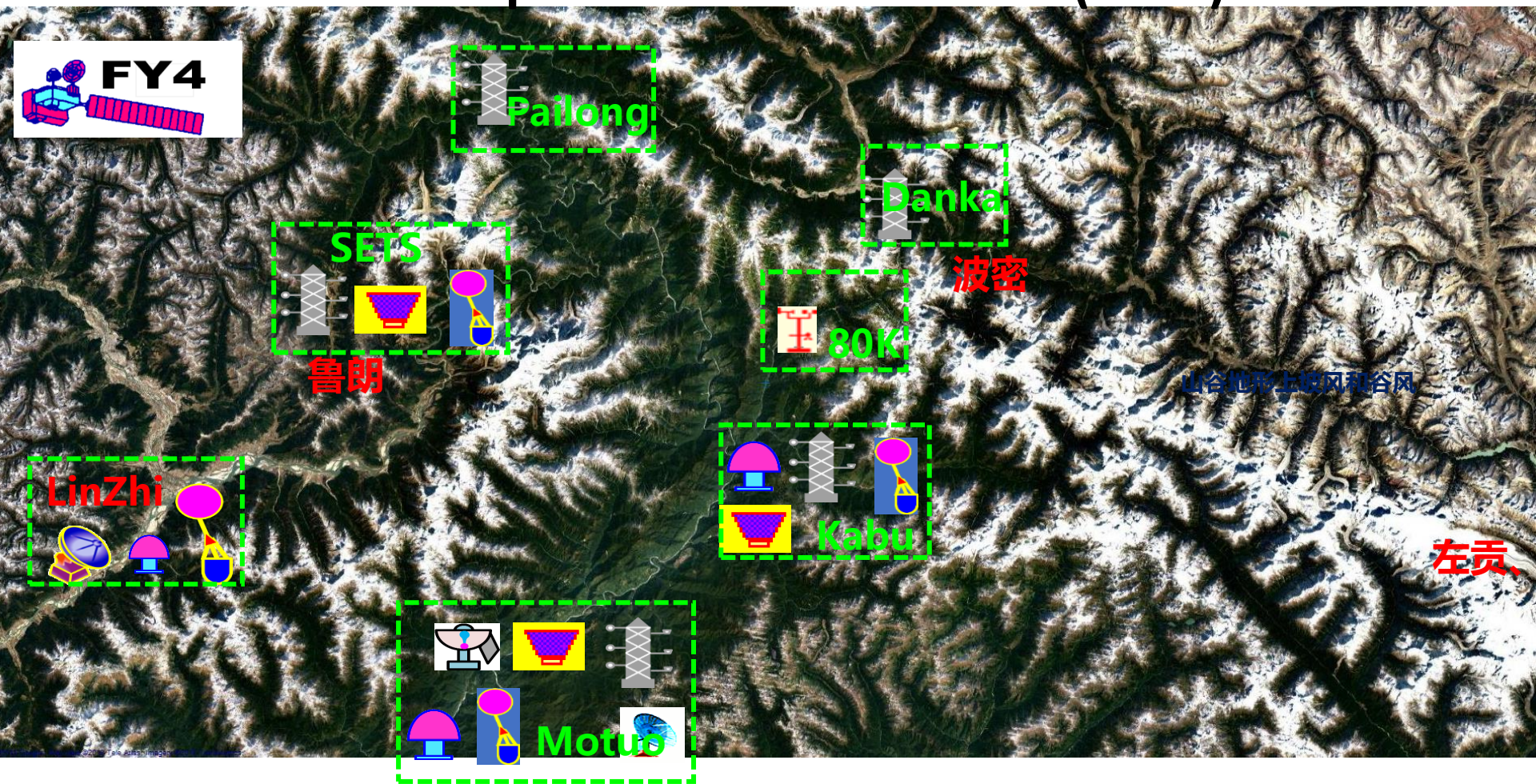
**Turbulent system & CO<sub>2</sub>/H<sub>2</sub>O flux**



**Radiation system**



# SETS intensifies observation efforts during Second Tibetan Plateau Scientific Expedition and Research (STEP)

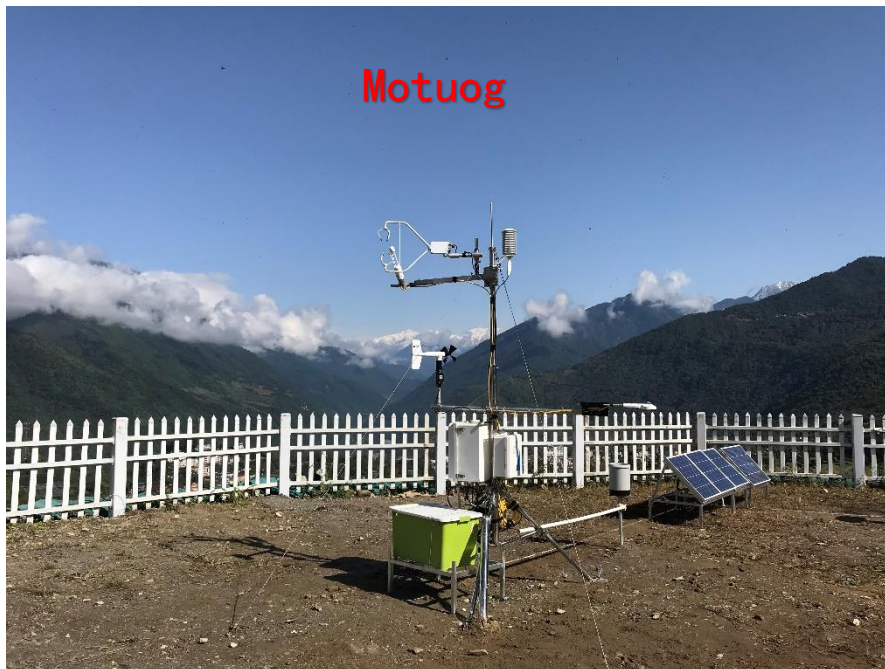


-  探空
-  微雨雷达
-  AWS
-  温湿廓线仪
-  云雷达
-  GPS水汽总量
-  近地层湍流

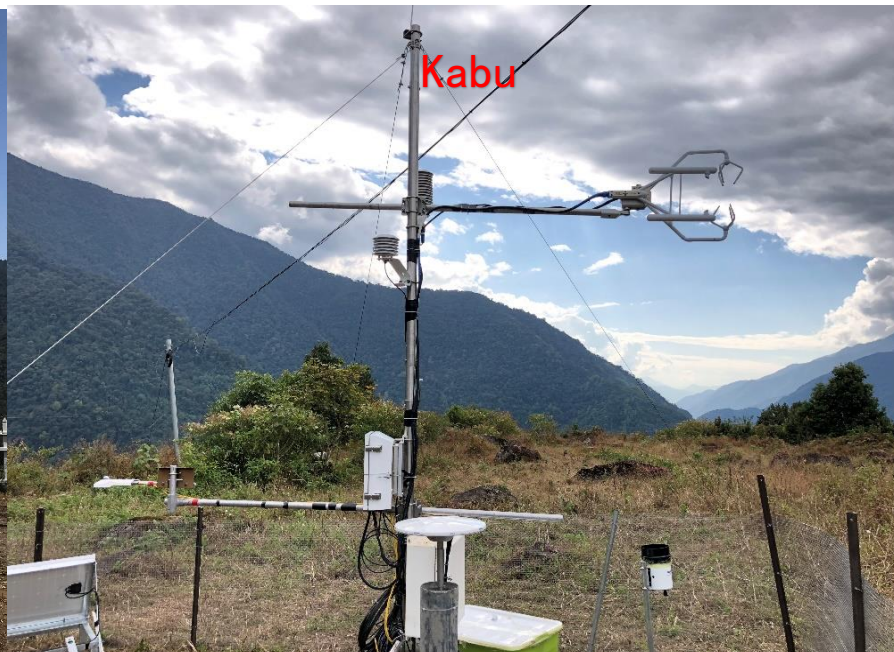


# 山地水热交换综合观测网

Motuog



Kabu



Pailong



Danka







Kabu



SETS



Motuog



GPS watervapor



# 4. Ngari Station for Desert Environment Observation and Research, Chinese Academy of Sciences (NASDE/CAS) 阿里站



AWS and radiation system



Turbulent system & CO<sub>2</sub>/H<sub>2</sub>O flux measurement



Aerosol Sampler



Evaporation Observation



Isotope





**5) Muztagh Ata Station for Westerly Environment Observation and Research, Chinese Academy of Sciences (MASWE/CAS) (慕士塔格站)**

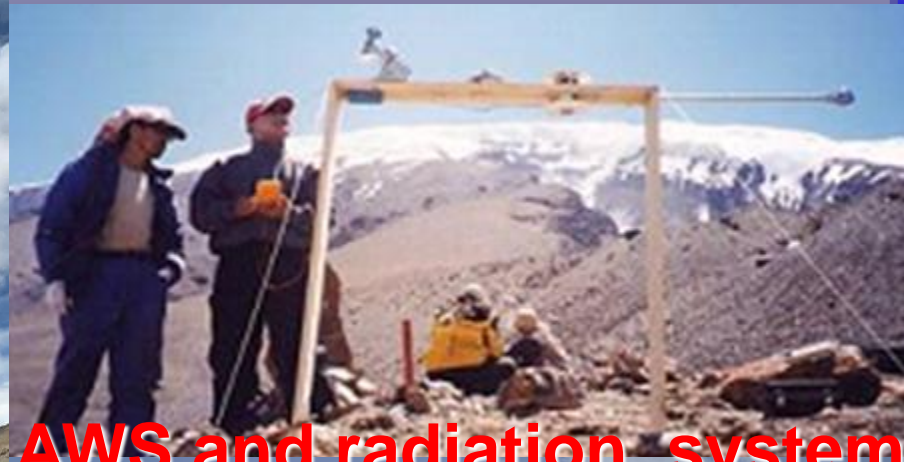




# Muztagh Ata Station for Westerly Environment Observation and Research, Chinese Academy of Sciences (MASWE/CAS)



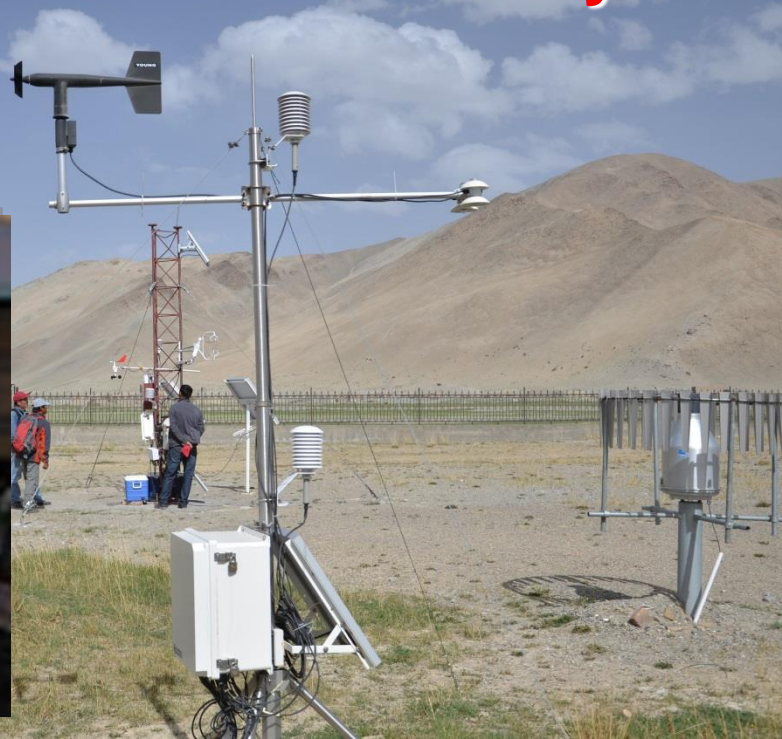
Turbulent system  
& CO<sub>2</sub>/H<sub>2</sub>O flux



AWS and radiation system



Aerosol  
Sampler





# 6). Shuanghu Station

双湖站（可可西里站）





# 7).Nagqu Station of Plateau Climate and Environment (NPCE) (那曲站)





## 8) Maqu Station (玛曲站)



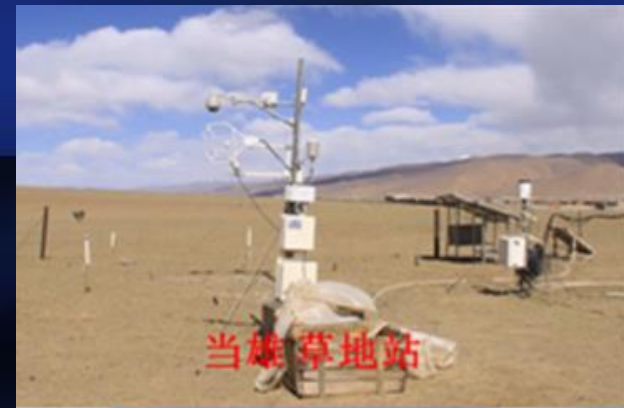




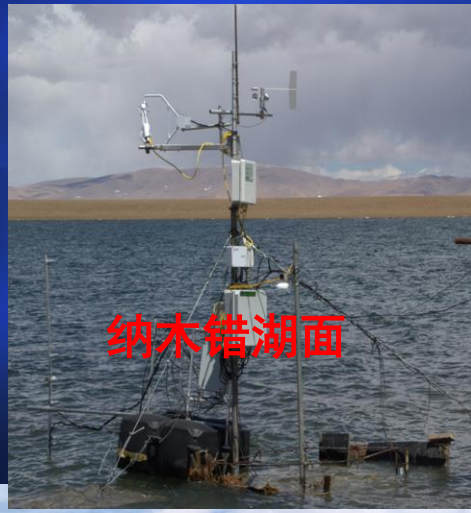
**9) Nepal Stations  
(尼泊尔站)**



# Flux stations over the different land surface



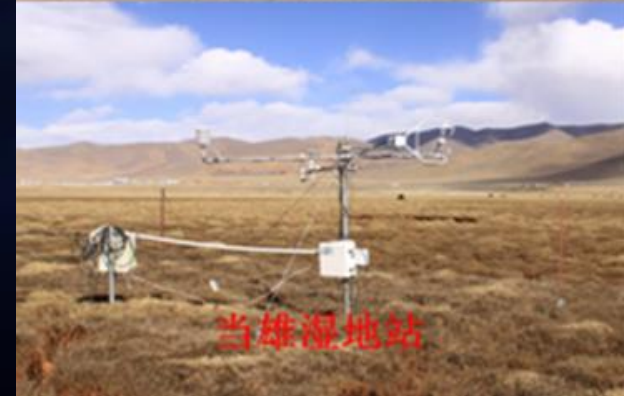
当雄草地站



纳木错湖面



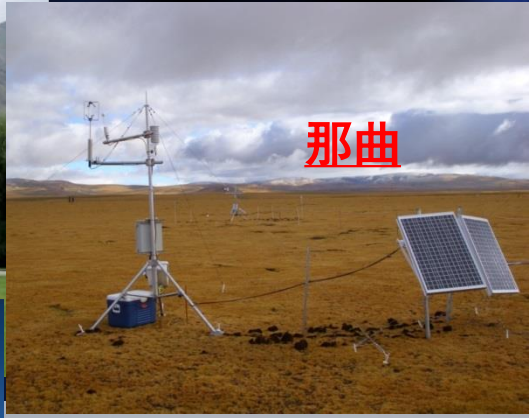
亚东



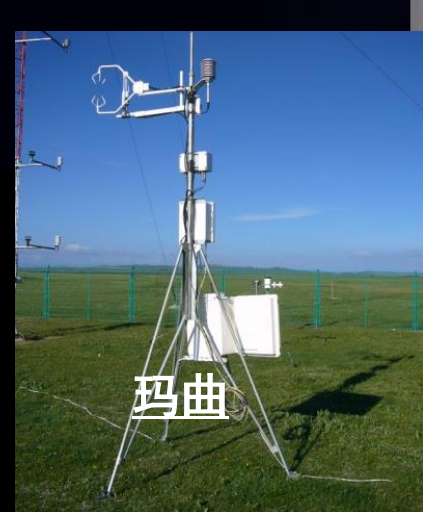
当雄湿地站



拉萨



那曲



玛曲



冰川



色林错湖

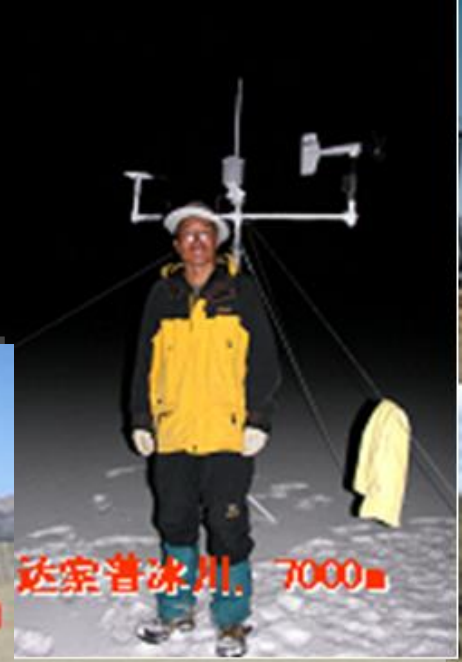


尼泊尔





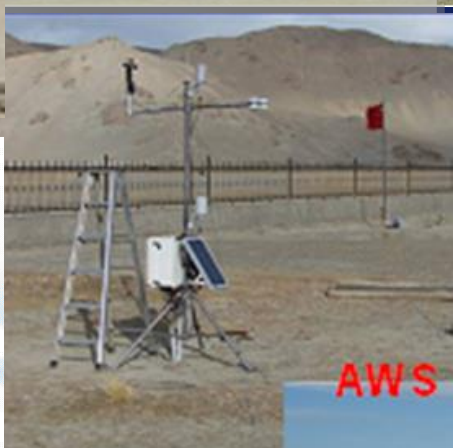
**AWS around the Nam co Station**



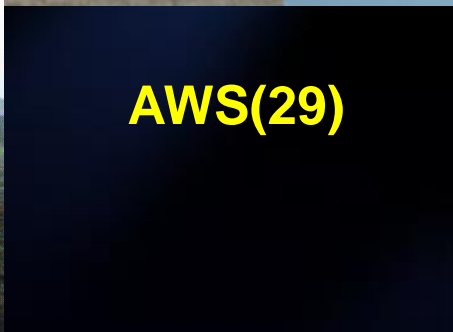
**达索普冰川, 7000m**



**AWS and radiation system**



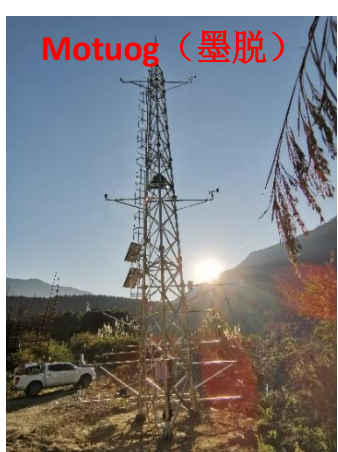
**AWS**



**AWS(29)**

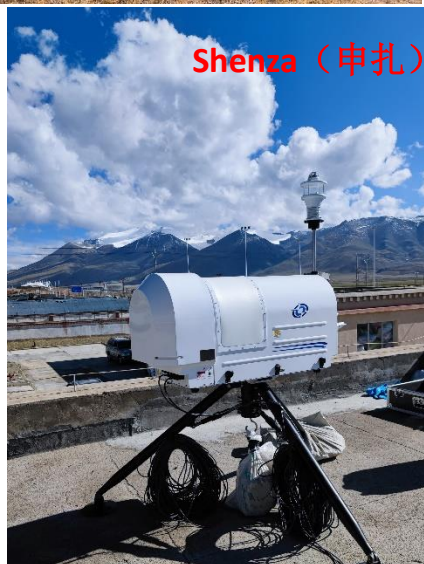
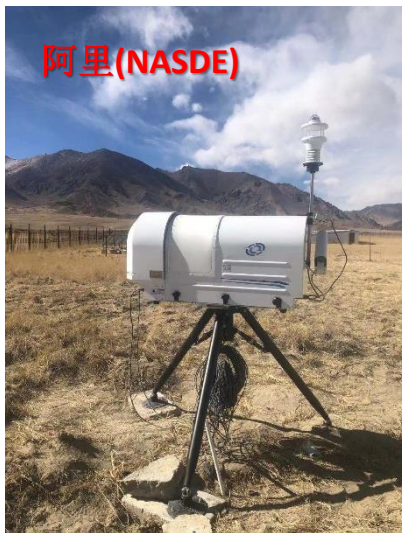


青藏  
高原  
新建  
的12  
个大气  
边界  
层塔  
站  
(含  
大气  
湍流  
观测  
系统  
和辐  
射观  
测系  
统)





# 首个青藏高原微波辐射计观测网络（10台联网）已建成，实现了联网观测









狮泉河



改则



申扎



那曲气象局



中科院那曲站



曲麻莱



沱沱河



昌都



中科院阿里站



林芝气象局



茫崖



藏东南站



峨眉山



加德满都





# 青藏高原地气相互作用（地气间水热交换）立体综合观测研究平台

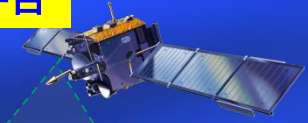
FY-3 (A/B/C)  
FY-2  
FY-1(02)  
MODIS-TERRA  
MODIS-AQUA  
NOAA-K  
GMS-5

卫星

## 飞机观测

温度，湿度，压强，  
水平风速风向，  
垂直风速；

新一代卫星遥感—探空、地面长期综合观测



高原与下游灾害  
天气适应性观测

云降水与大气水循  
环过程观测

T, q

$\bar{v}, T, q$   
云液态  
水含量  
云结构  
冰粒谱

探空

高原陆面—边界  
层综合观测

## 边界层

潜热、感热  
湍流分量

(边界层结构特征)  
 $\bar{v}, T, q, p$

$\sigma_4$   
 $\sigma_3$   
 $\sigma_2$   
 $\sigma_1$

(近地层结构特征)  
近地层

双偏振雷达  
微降水雷达



土壤温度  
水份观测

铁塔  
GPS/MET  
卫星同步试验区  
冻土区介电参  
数、 $q_s$ 、地表  
发射率等

微波辐射仪

# 青 藏 高 原

风廓线仪

业务雷达

毫米波  
云雷达

雨滴谱仪





台站网络建设和科考活动在央视新闻、新华网、人民资讯、凤凰网、光明网、中国气象网和北京电视台等媒体进行了广泛报道，引起了社会广泛关注。



# 第二次青藏科考专题科考队出征 聚焦区域气候变化

2021-07-16 15:02:49 浏览量: 101.1万  
来源: 新华社

科技 查看详情 >

新华社兰州7月16日电 (记者张文静) 15日,第二次青藏高原综合科学考察研究“地气相互作用及其气候效应”专题科考队从甘肃省兰州市启程,将开展为期1个月的科学考察。本次科考聚焦区域气候变化,完成多个任务,如建立地气相互作用和地理信息数据库,生成高原地气相互作用过程实景三维模型。

## Research on climate change kicks off on Qinghai-Tibet Plateau

Source: Xinhua | 2021-07-16 18:08:44 | Editor: huaxia



LANZHOU, July 16 (Xinhua) – A research group left northwest China's Gansu Province on Thursday for a scientific expedition on the Qinghai-Tibet Plateau.

# 青藏高原地气间水热交换立体综合观测研究平台启动

中国新闻网 2021-07-15 20:55:05



7月15日,第二次青藏科考地气作用与气候效应专题分队出征仪式在兰州举行。 丁思 摄

中新网兰州7月15日电 (记者 丁思)15日下午,中科院青藏高原研究所在兰州举办第二次青藏科考“西风-季风协同作用及其影响”任务“地气相互作用及其气候效应”专题分队出征暨青藏高原地气间水热

## 青藏高原地气间水热交换综合观测平台启动

2021-07-16 09:46  
(记者韩扬眉) 7月15日,中国科学院青藏高原研究所在兰州举办第二次青藏科考“西风-季风协同作用及其影响”任务“地气相互作用及其气候效应”专题分队出征暨青藏高原地气间水热交换立体综合观测平台启动仪式。  
该专题负责人、中国科学院青藏高原研究所研究员马耀明介绍,本专题已完成3次地气相互作用及其气候效应立体综合加强观测试验。在青藏高原上新建11座大气边界层廓线塔站观测系统、9套微波辐射计和10套风风速组网观测系统,加之高原上已有的大气边界层廓线塔站组网观测系统、涡动协方差通量组网观测系统以及土壤温、湿度组网监测系统,成功组建了青藏高原地气间水热交换立体综合观测平台。该平台可实现青藏高原近地层和对流层多要素、全天候的综合集成观测,为区域及其周边地区天气监测与预报、灾害性天气预警及气候环境预测等提供综合观测数据和决策依据。

# 领命出征! 第二次青藏科考“地气作用与气候效应”专题分队出征暨“青藏高原水热交换综合观测平台”启动

新甘肃 2021-07-15 23:02:11

新甘肃客户端兰州7月15日讯 (新甘肃·甘肃日报记者 李满福) 今天下午,中科院青藏高原研究所在兰州举办第二次青藏科考“西风-季风协同作用及其影响”任务“地气相互作用及其气候效应”专题分队出征暨“青藏高原地气间水热交换立体综合观测平台”启动仪式。



北京 6°C/5°C



### 第二次青藏科考开展大规模立体综合观测试验

发布时间: 2019年10月25日 来源: 中国气象报

中国气象报记者谷厚月报道 10月21日凌晨2时,第二次青藏科考地气相互作用及其气候效应团队在中国科学院青藏高原高山环境综合观测研究站(简称格尔布站)放飞此次立体综合加强观测试验的第一个探空气球。15名科研人员利用自动气象站、边界层廓线、探空气球、微波辐射计等获取了地表至30千米高空不同高度的气温、相对湿度、气压、风向、风速等观测数据,以“刻录”高原东南部大气的垂直信息档案。  
此次试验为第二次青藏科考在第三极地区开展立体综合观测的规模之最。试验采取数据为研究高原东南地区气候变化及其对周边地区气候的影响提供参考。同时也为揭开“亚洲水塔”的形成机理和变化提供关键科学依据。



## 青藏高原地气间水热交换立体综合观测研究平台启动

2021-07-16 09:55:05 来源: 中国新闻网 作者: 丁思

15日下午,中科院青藏高原研究所在兰州举办第二次青藏科考“西风-季风协同作用及其影响”任务“地气相互作用及其气候效应”专题分队出征暨青藏高原地气间水热交换立体综合观测平台启动仪式。

该平台综合大气边界层廓线、机载涡动流场观测平台、卫星遥感等,运用于此次青藏科考中,立体综合观测选区区域的地气相互作用特征,建立地气相互作用和地气耦合数据库,生成高原地气相互作用过程实景三维模型,为探明西风-季风变化背景下,地气相互作用在不同下垫面的长期变化趋势及对区域气候变化的影响提供数据支撑。

据该专题负责人、中科院青藏高原研究所研究员马耀明介绍,本专题已完成3次地气相互作用及其气候效应立体综合加强观测试验。在青藏高原上新建11座大气边界层廓线塔站观测系统、9套微波辐射计和10套风风速组网观测系统,加之高原上已有的大气边界层廓线塔站组网观测系统、涡动协方差通量组网观测系统以及土壤温、湿度组网监测系统,成功组建了青藏高原地气间水热交换立体综合观测平台。

马耀明说,该平台可实现青藏高原近地层和对流层多要素、全天候的综合集成观测,为区域及其周边地区天气监测与预报、灾害性天气预警及气候环境预测等提供综合观测数据和决策依据。

本次科学考察为一个月,由中科院青藏高原研究所牵头,科考队员来自中科院西极生态环境研究所、中科院天山生态研究所、中科院大气研究所、成都信息工程大学、四川气象中心、青海气象中心、西藏自治区气象局、中国科学院大学、南京大学、国家气候中心、兰州大学、南京信息工程大学、浙江大学、长安大学、华北电力大学、中山大学、暨南大学等18家科研院所和高校100余人。

科考队从兰州集结出发,途径敦煌,沿戈壁公路到格尔布,再沿青藏公路进入西藏,经可可西里及唐古拉山,沿新藏线一路西行阿里,再经中印边境三边接壤的普兰、中印边境普兰及塔县等县,最后经东南面的喜马拉雅山到达林芝、墨脱、拉萨。

本次科考区域涵盖受西风季风和季风影响的广大地区,也有青藏高原与欧亚大陆结合部的藏东南高山峡谷区,行程约6000公里。

此次科考将综合运用地面、机载和卫星等多种观测手段,获取高原地气相互作用和地气耦合数据库,生成高原地气相互作用过程实景三维模型,为探明西风-季风变化背景下,地气相互作用在不同下垫面的长期变化趋势及对区域气候变化的影响提供数据支撑。





# 建成了第三极地区多圈层地气相互作用数据库并在全球发布，引起国内外广泛关注

(Ma,Y. et al., 2020, *ESSD*; Nieberding, .....Ma\*,Y. et al., 2020, *ESSD*; Han,C. and Ma\*,Y. et al., 2021,*ESSD*; Ma,Y. et al., 2022,*AOSL*; Ma, Y.et al., 2023;*ESR*;Ma.Y. et al., 2023,*BAMS*)

数据类型	数据内容	时间段	空间分辨率
<b>卫星遥感产品</b> <a href="https://data.tpdc.ac.cn/allData?searchContent=%E8%A2%81%E4%BB%A4">https://data.tpdc.ac.cn/allData?searchContent=%E8%A2%81%E4%BB%A4</a>	地表温度、地表反照率、净辐射通量、土壤热通量、感热通量、潜热通量, 蒸散发量	2001年-2019年	1kmX1km <a href="https://data.tpdc.ac.cn/zh-hans/data/a80882c3-c764-495b-bea9-40e7b57d01f5">https://data.tpdc.ac.cn/zh-hans/data/a80882c3-c764-495b-bea9-40e7b57d01f5</a>
<b>地面观测</b> <a href="https://data.tpdc.ac.cn/zh-hans/data/b9ab35b2-81fb-4330-925f-4d9860ac47c3">https://data.tpdc.ac.cn/zh-hans/data/b9ab35b2-81fb-4330-925f-4d9860ac47c3</a>	气温、风速、地表温度、相对湿度、四分量辐射、感热通量、潜热通量、土壤热通量、CO2和水汽通量	2005年-2022年	纳木错站、珠峰站、藏东南站、那曲站（1997-2022）、阿里站、慕士塔格站、亚东站和双湖站（2012-2022）、尼泊尔4站（2012-2022） <a href="https://data.tpdc.ac.cn/zh-hans/data/6442c3ca-190f-4106-a1dc-63344cd4f8e5">https://data.tpdc.ac.cn/zh-hans/data/6442c3ca-190f-4106-a1dc-63344cd4f8e5</a>
<b>湖泊蒸发产品</b>	无冰期蒸发量	1980年-2017年	纳木错湖



# 地面观测详细数据 (Welcome!!)

观测系统及数据时段	观测内容
<b>大气边界层塔</b> (2005年1月1日 -2022年12月31日)	<ul style="list-style-type: none"> <li>● 5层(20m、10m、4m、2m、1m) 风速、风向、空气温度及相对湿度, 4分量辐射通量</li> <li>● 气压、地表温度及降雨量</li> <li>● 5层(-10 cm, -20 cm, -40 cm, -80 cm, -160 cm) 土壤温湿度</li> <li>● 2层(-10 cm, -20 cm)土壤热通量</li> </ul>
<b>大气湍流系统及辐射系统</b> (2005年1月1日 -2022年12月31日)	<ul style="list-style-type: none"> <li>● 风速、气温及湿度脉动量、感热及潜热通量; 风速、温度及湿度的特征量CO<sub>2</sub> 和水汽通量及稳定度参数</li> <li>● 4分量辐射通量</li> </ul>
<b>8个无线电探空系统</b>	<ul style="list-style-type: none"> <li>● 风速、风向、气温、气压和相对湿度廓线</li> </ul>
<b>3个风温廓线仪</b>	<ul style="list-style-type: none"> <li>● 风速、风向和气温廓线</li> </ul>
<b>7套自动气象站 (2005年1月1日-2022年12月31日)</b>	<ul style="list-style-type: none"> <li>● 2层(10m和1m) 风速、风向、空气温度及相对湿度, 4分量辐射、气压、地表温度及降雨量</li> <li>● 5层(-10 cm, -20 cm, -40 cm, -80 cm, -160 cm) 土壤温湿度</li> <li>● 2层(-10 cm, -20 cm)土壤热通量</li> </ul>
<b>尼泊尔4套大气湍流系统及辐射系统 (2016年3月1日-2022年12月31日)</b>	<ul style="list-style-type: none"> <li>● 风速、气温及湿度脉动量、感热及潜热通量; 风速、温度及湿度的特征量CO<sub>2</sub> 和水汽通量及稳定度参数</li> <li>● 4分量辐射通量</li> </ul>



## A long-term (land–atm

Earth Syst. Sci. Data, 13, 3513–3524, 2021  
https://doi.org/10.5194/essd-13-3513-2021  
© Author(s) 2021. This work is distributed under  
the Creative Commons Attribution 4.0 License.



## Long-term variations in the T

Cunbo Han<sup>1,2,3</sup>, Yaoming Ma<sup>1,2,4,5</sup>, Binbin

<sup>1</sup>Land–Atmosphere Interaction and its Climate System and Resources Environment Chinese Acad

<sup>2</sup>CAS Center for Excellence in Tibetan Plateau and its Environment  
<sup>3</sup>Institute for Meteorology and Climate Res

<sup>4</sup>College of Earth and Planetary Sciences, <sup>5</sup>Frontier Center for Eco-environment Lanzhou

<sup>6</sup>Laboratory for Atmospheric Observation in Sciences, University of Sc

<sup>7</sup>Faculty of Geo-Information Science and Earth

Correspondence:

Revised: 11 Oct

Received: 30 October  
Revised: 7 June 2021 – Ac

**Abstract.** The Tibetan Plateau thermal and dynamical mechanisms are characterized as an area sensitive to distributed over the TP, owing heterogeneous surfaces. Moreover, the local land–atmosphere coupling is quantified. This paper presents interaction observations from field stations on the TP. These measurements including gradient water content profiles. Meteorological boundary layer (PBL) observations vertical hydrothermal variations ultrasonic anemometer and an vertical exchanges of energy, layer. The release of these scientific data sharing across the surface processes. This dataset community by enabling the geophysical models for climate

**Abstract.** Actual terrestrial evapotranspiration processes and water cycle. However, the Tibetan Plateau (TP) remain very uncertain. Here we distribution on the TP by a combination of data from six eddy-covariance monitoring sites year month and correlation coefficients exceeding 0.5 (−1.45 mm yr<sup>−1</sup>,  $p < 0.05$ ) from 2001 to 2018 ( $p < 0.05$ ) in the eastern sector of the TP (as pronounced in the spring and summer seasons), seasons. The mean annual  $ET_{a,TP}$  during 2001–evapotranspiration from the terrestrial surface (presented in this study is useful for an improved dataset is freely available at the Science Data (Li et al., 2020b) and at the National Tibetan Plateau (Li et al., 2020a).

Earth Syst. Sci. Data, 12, 2705–2724, 2020  
https://doi.org/10.5194/essd-12-2705-2020  
© Author(s) 2020. This work is distributed under  
the Creative Commons Attribution 4.0 License.



## A long-term (2005–2019) and H<sub>2</sub>O fluxes from

Felix Nieberding<sup>1,2</sup>, Christian Wille<sup>2</sup>, Ger  
Yaoming M

<sup>1</sup>Institute of Geosystems and Bioindication, T  
<sup>2</sup>GFZ German Research Geoscience

<sup>3</sup>LI-COR Biosciences  
<sup>4</sup>Key Laboratory of Tibetan Environment Ch

<sup>5</sup>CAS Center for Excellence in  
<sup>6</sup>University of China

<sup>7</sup>Institute of Flight Guidance, Technis

Correspondence: Felix Nieberding

Received: 18 March

Revised: 2 September 2020 – Accepted

**Abstract.** The Tibetan alpine steppe ecosystem 3.3 % soil organic carbon in the uppermost 30 cm only (472.037 km<sup>2</sup>). With temperatures rising, the Tibetan Plateau (TP) make it clear exchange of carbon dioxide (CO<sub>2</sub>) and water CO<sub>2</sub> and H<sub>2</sub>O fluxes from the central Tibetan variance technique. The calculated fluxes were in concentration measurements. The gas analysis the standard correction procedure and new (2020). A wind field analysis was conducted to exclude the disturbed fluxes from subsurface gap filled using a standardized approach. The results highlight the special vulnerability of the Tibetan alpine warming. The data are freely available at https://doi.org/10.11888/Meteorol.pdc.270333 (Li et al., 2020b) and at the National Tibetan Plateau (Li et al., 2020a).

Earth Syst. Sci. Data, 13, 4727–4757, 2021  
https://doi.org/10.5194/essd-13-4727-2021  
© Author(s) 2021. This work is distributed under  
the Creative Commons Attribution 4.0 License.



## A first investigation of hydrogeology and hydrogeophysics of the Maqu catchment in the Yellow River source region

Mengna Li<sup>1,2</sup>, Yijian Zeng<sup>2</sup>, Maciek W. Lubczynski<sup>2</sup>, Jean Roy<sup>3</sup>, Liangyu Yu<sup>2</sup>, Hui Qian<sup>1</sup>, Zhenyu Li<sup>4</sup>, Jie Chen<sup>1</sup>, Lei Han<sup>5</sup>, Han Zheng<sup>1</sup>, Tom Veldkamp<sup>6</sup>, Jeroen M. Schoorl<sup>6</sup>, Harrie-Jan Hendricks Franssen<sup>7</sup>, Kai Hou<sup>3</sup>, Qiying Zhang<sup>1</sup>, Panpan Xu<sup>1</sup>, Fan Li<sup>4</sup>, Kai Lu<sup>4</sup>, Yulin Li<sup>4</sup>, and Zhongbo Su<sup>2</sup>

<sup>1</sup>School of Water and Environment, Chang'an University, Xi'an 710054, China

<sup>2</sup>Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, 7500 AB, the Netherlands

<sup>3</sup>IGP, Outremont, QC H2V 4T9, Canada

<sup>4</sup>Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan, 430074, China

<sup>5</sup>School of Land Engineering, Chang'an University, Xi'an 710054, China

<sup>6</sup>Soil Geography and Landscape Group, Wageningen University, P.O. Box 47, 6700 AA Wageningen, the Netherlands

<sup>7</sup>Forschungszentrum Jülich GmbH, Agrophere (IBG-3), Jülich, 52425, Germany  
Correspondence: Zhongbo Su (z.su@utwente.nl), Yijian Zeng (y.zeng@utwente.nl), and Hui Qian (qianhui@chi.edu.cn)

Received: 14 August 2020 – Discussion started: 22 December 2020

Revised: 1 September 2021 – Accepted: 10 September 2021 – Published: 15 October 2021

**Abstract.** The Tibetan Plateau is the source of most of Asia's major rivers and has been called the Asian Water Tower. Detailed knowledge of its hydrogeology is paramount to enable the understanding of groundwater dynamics, which plays a vital role in headwater areas like the Tibetan Plateau. Nevertheless, due to its remoteness and the harsh environment, there is a lack of field survey data to investigate its hydrogeology. In this study, borehole core lithology analysis, soil thickness measurement, an altitude survey, hydrogeological surveys, and hydrogeophysical surveys (e.g. magnetic resonance sounding – MRS, electrical resistivity tomography – ERT, and transient electromagnetic – TEM) were conducted in the Maqu catchment within the Yellow River source region (YRSR). The hydrogeological surveys reveal that groundwater flows from the west to the east, recharging the Yellow River. The hydraulic conductivity ranges from 0.2 to 12.4 m d<sup>−1</sup>. The MRS sounding results, i.e. water content and hydraulic conductivity, confirmed the presence of an unconfined aquifer in the flat eastern area. Based on TEM results, the depth of the Yellow River deposits was derived at several places in the flat eastern area, ranging from 50 to 208 m. The soil thickness measurements were done in the western mountainous area of the catchment, where hydrogeophysical and hydrogeological surveys were difficult to be carried out. The results indicate that most soil thicknesses, except on the valley floor, are within 1.2 m in the western mountainous area of the catchment, and the soil thickness decreases as the slope increases. These survey data and results can contribute to integrated hydrological modelling and water cycle analysis to improve a full-picture understanding of the water cycle at the Maqu catchment in the YRSR. The raw dataset is freely available at https://doi.org/10.17026/dans-z66-zpr07 (Li et al., 2020a), and the dataset containing the processed ERT, MRS, and TEM data is also available at the National Tibetan Plateau Data Center with the link https://doi.org/10.11888/Hydro.pdc.271221 (Li et al., 2020b).

Published by Copernicus Publications.

Published by Copernicus Publications.

Published by Copernicus Publications.



# 中国向全球发布首套青藏高原大气相互作用高时间分辨率数据集

中国新闻网  
2020-12-01 16:06:12



中科院珠穆朗玛大气与环境综合观测研究站气象站。中科院青藏高原所 供图

## Dataset launched for observing Qinghai-Tibet P atmosphere interaction

Source: Xinhua | 2020-12-07 01:16:40 | Editor: huaxia

BEIJING, Dec. 6 (Xinhua) -- A Chinese institute has launched a dataset for hourly observation interaction on the Qinghai-Tibet Plateau.

The Qinghai-Tibet Plateau is the largest high-elevation part of the cryosphere outside the polar mountain glaciers, permafrost and seasonally frozen ground, which are sensitive to global climate change.

The plateau plays a critical role in influencing regional and global climate, via both thermal and moisture exchanges with the surrounding regions.

Researchers from the Institute of Tibetan Plateau Research under the Chinese Academy of Sciences have launched a dataset for hourly observation interaction on the Qinghai-Tibet Plateau.

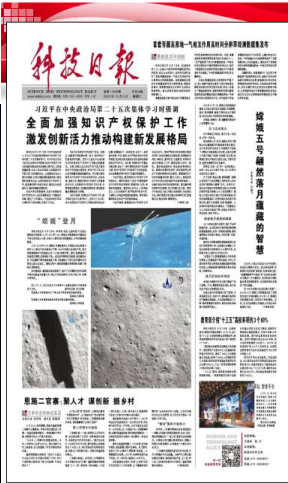
The researchers recorded multi-layer soil temperature and moisture to capture vertical hydrological processes, and captured the high-frequency vertical exchanges of energy, momentum and moisture within the atmospheric boundary layer.

The research presented a long-term (2005-2016) in situ observational dataset of hourly land-atmosphere observations from an integrated high-elevation and cold-region observation network, composed of multiple stations.

The dataset can be widely used in the analysis of meteorological features on the Qinghai-Tibet Plateau, remote sensing product evaluation and the development of remote sensing algorithms, as well as climate research and forecasting, said Ma Yaoming, a researcher with the CAS.

中国科学院网站新闻页面截图，标题为“青藏高原所发布青藏高原地-气相互作用高时间分辨率观测数据集”。

# 发表的数据2021年以来, 已在BAMS, ESSD, JGR, JH等杂志发表的文章中引用97次。



新闻网站截图，标题为“首套青藏高原地-气相互作用高时间分辨率观测数据集发布”。



- 首套青藏高原地-气相互作用高时间分辨率观测数据集发布
- 嫦娥五号翩然落月播撒的慧慧



## (二) 利用综合观测资料，综合分析发现了第三极地区多圈层地气间水热交换规律及其变化机制

### 1. 一些基本的地气相互作用过程特征量变化



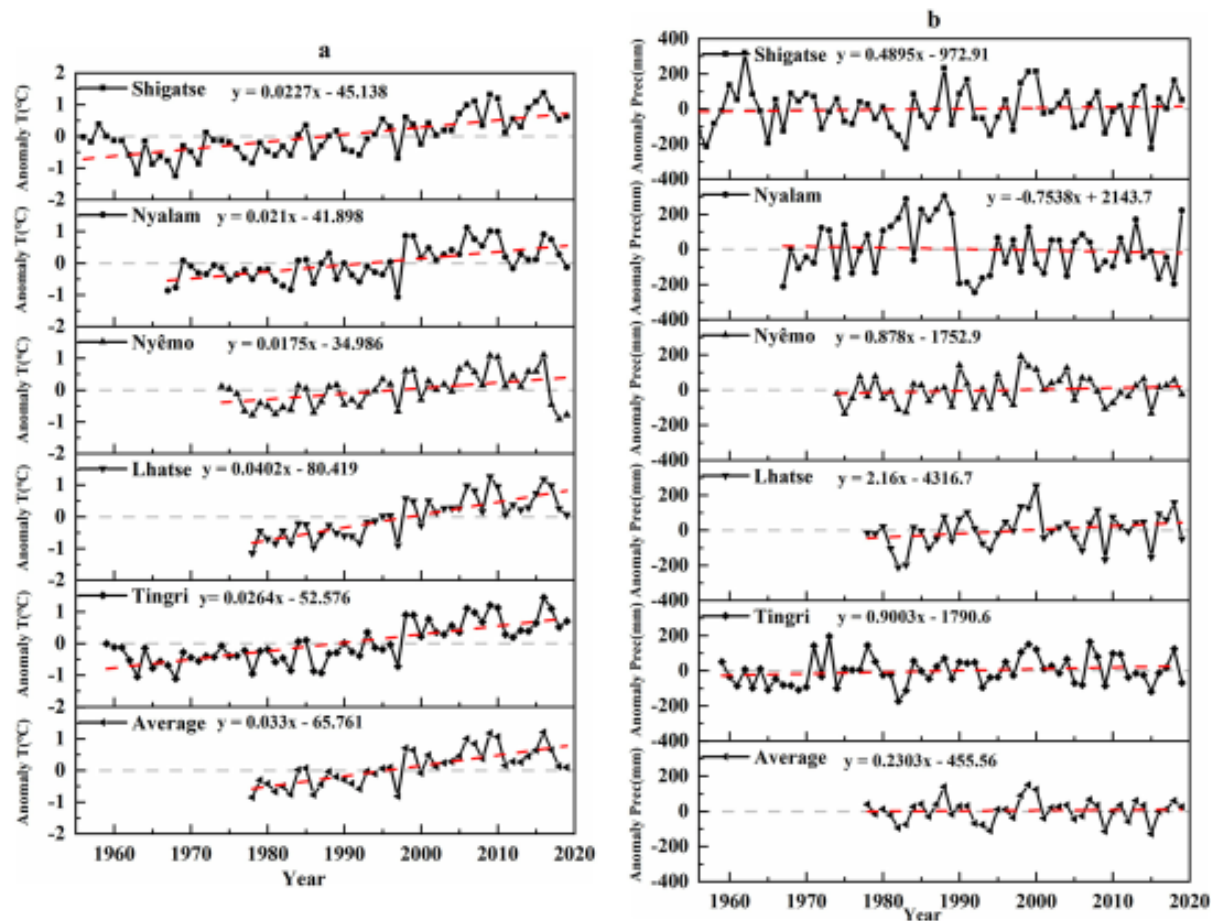
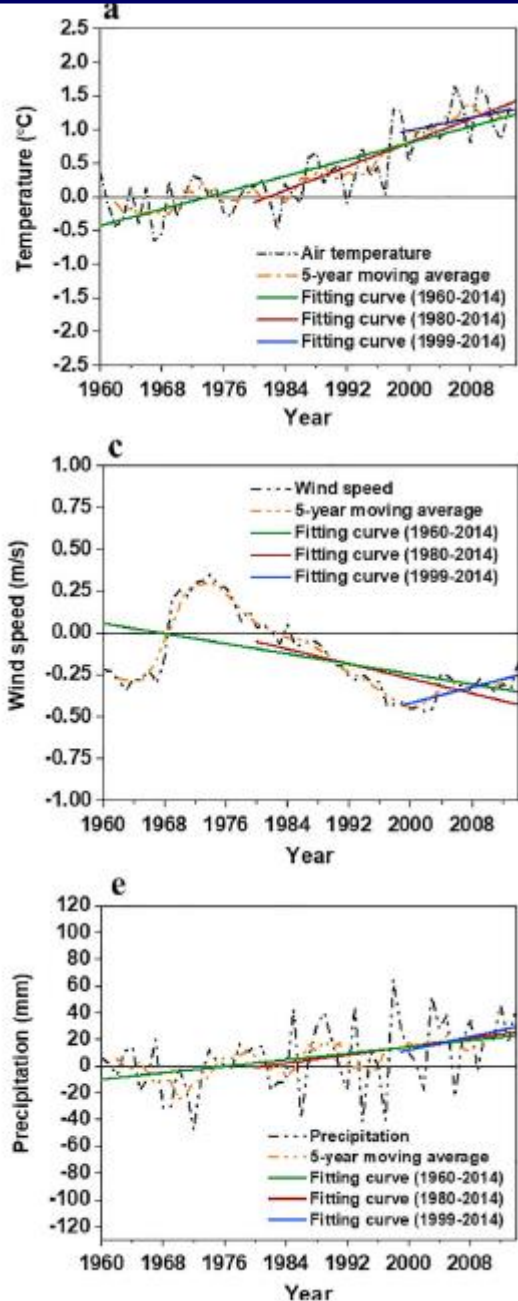
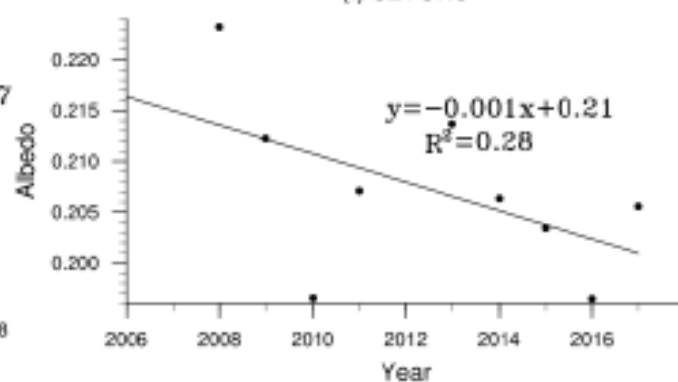
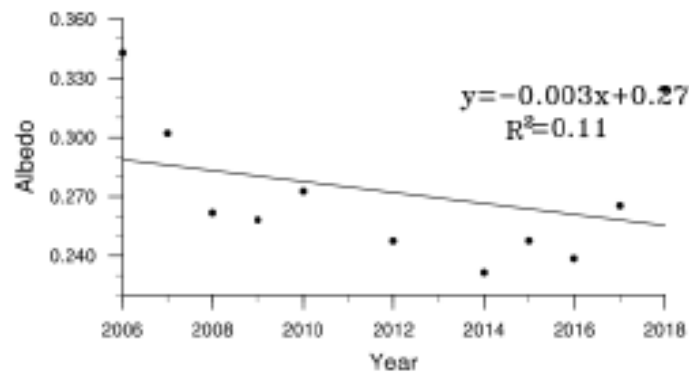
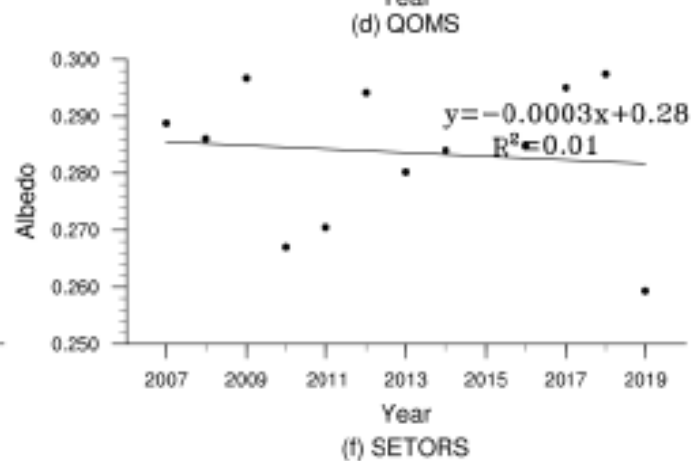
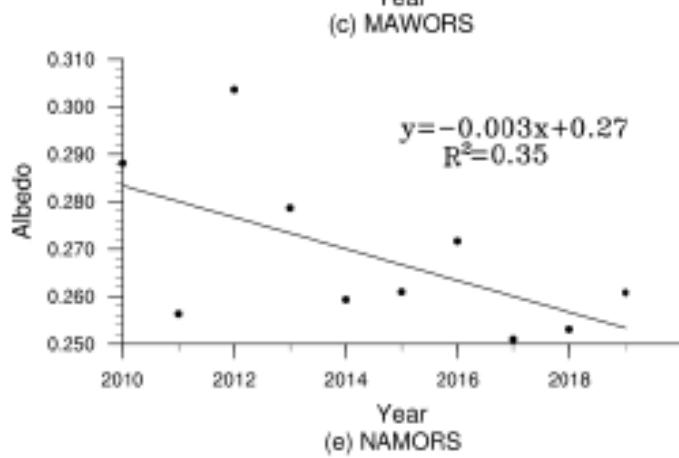
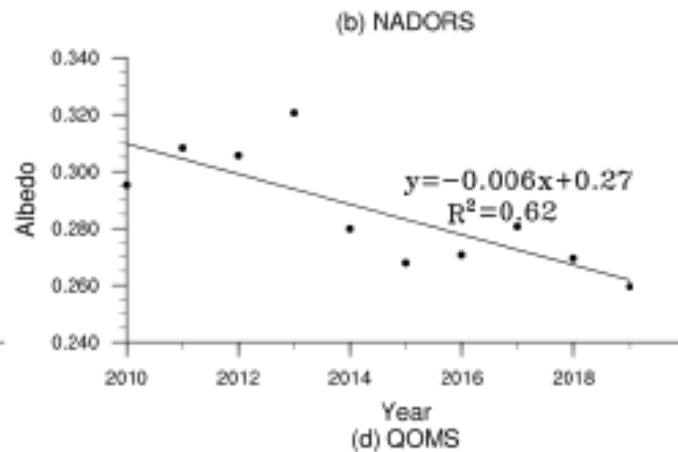
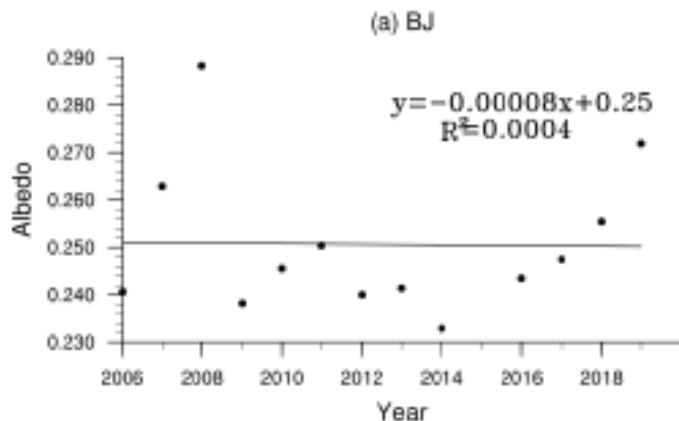


Fig. 2. Annual variations of observation data in 5 sites in the region north of Mount Qomolangma: temperature anomaly(a); precipitation anomaly(b). The red dotted line is the trend line, the gray solid line is at zero.

(Zhong, L. and Ma\*, Y. et al., 2019, *JGR-Atmospheres*)

(Han, Y. and Ma\*, Y. et al., 2021, AR)

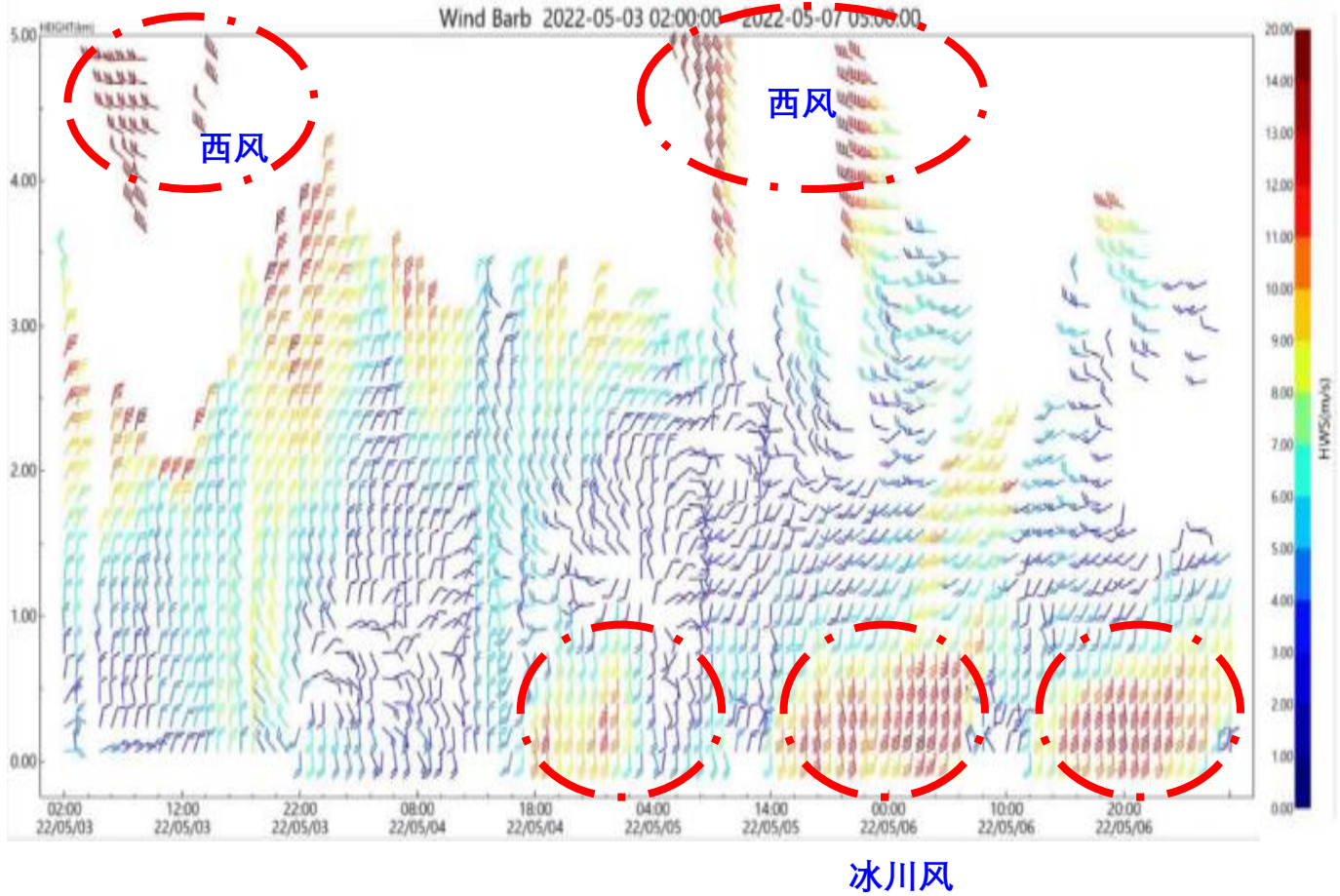






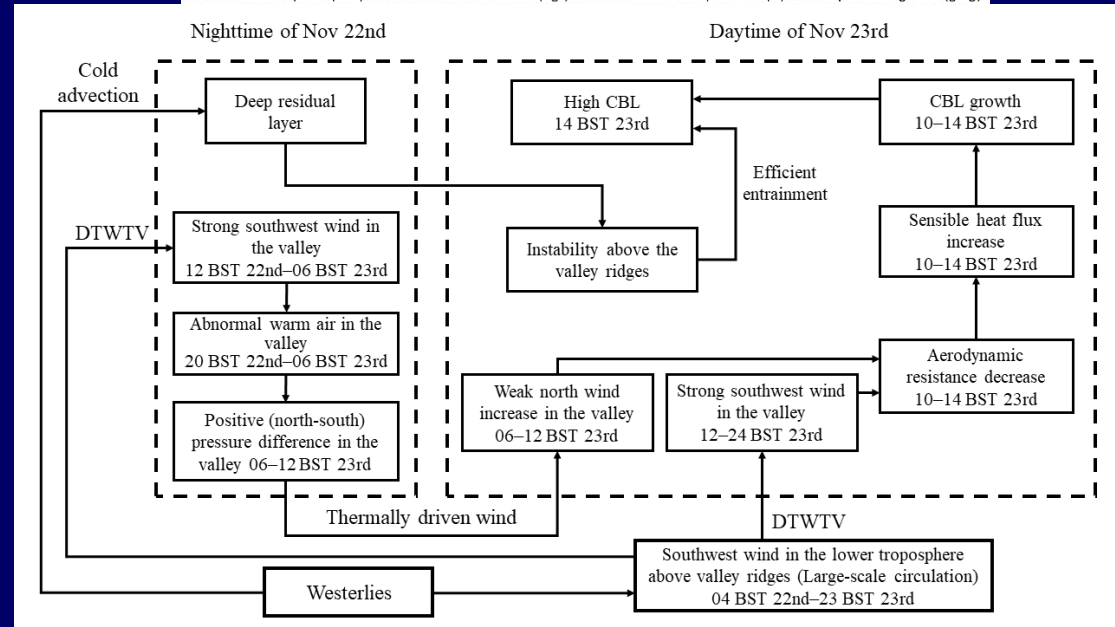
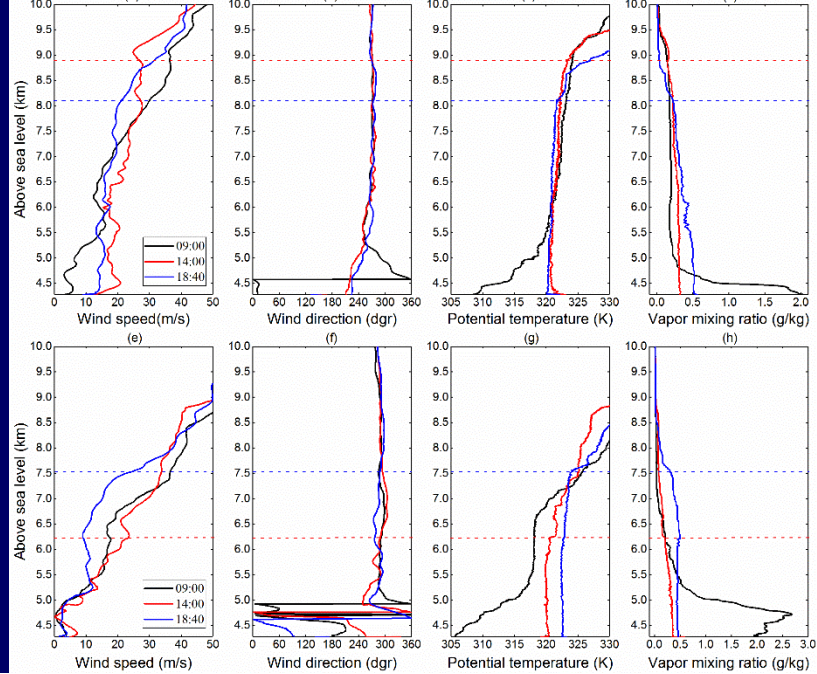


风雷达测得的  
珠峰大本营  
风速垂直分布



(Ma, Y. et al, 2023, AAS)

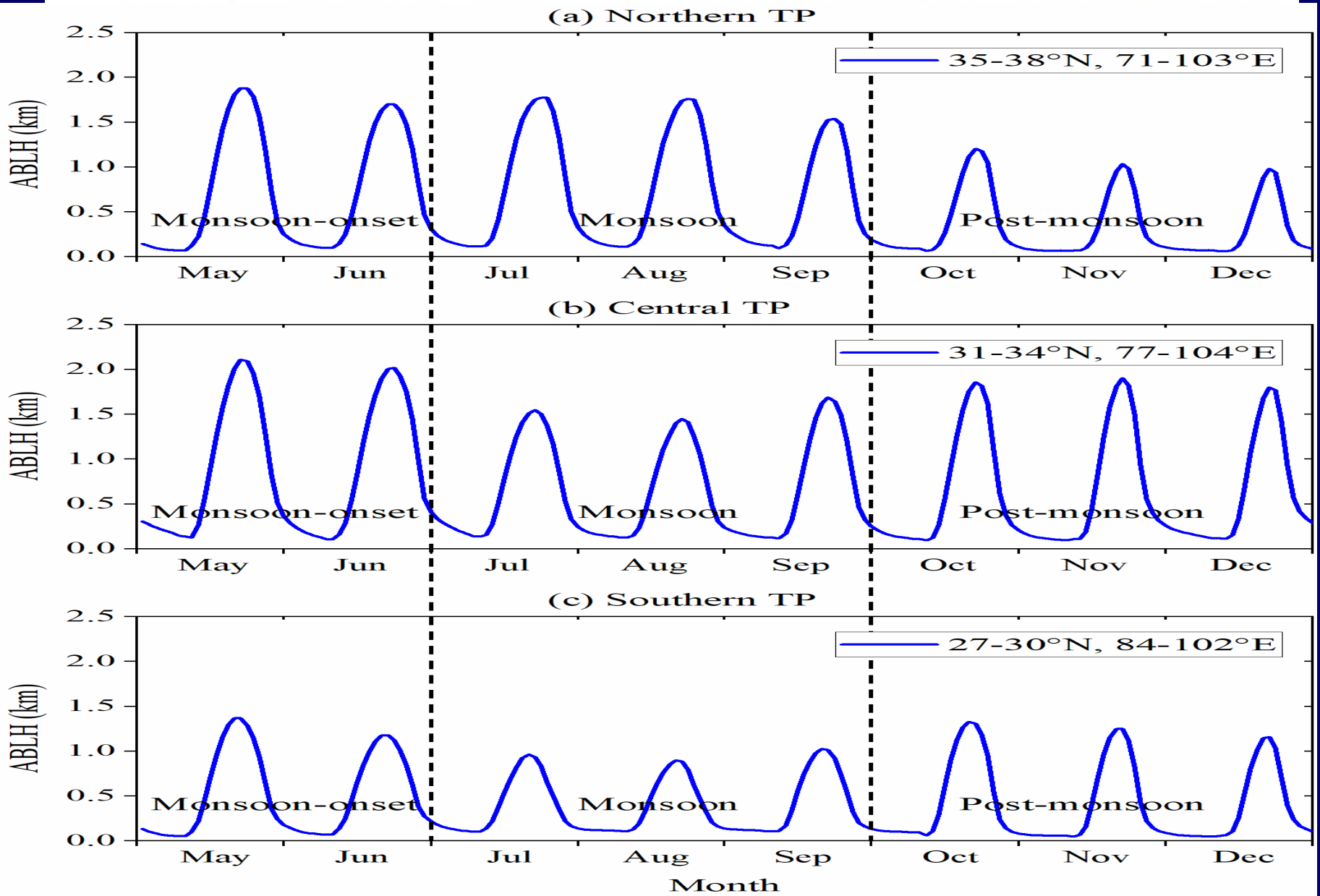




- 喜马拉雅上中段边界层高度：非季风期>季风期
- 冬季喜马拉雅山中段大气边界层的发展受到大尺度西风风向风速变化的强烈影响；
- 证明了高原山地地形与西风大尺度环流的相互作用对大气边界层的生长起着关键作用。

(Lai, Y., Chen\*, X. and Ma\*, Y. et al., 2021, *JGR-Atmospheres*)



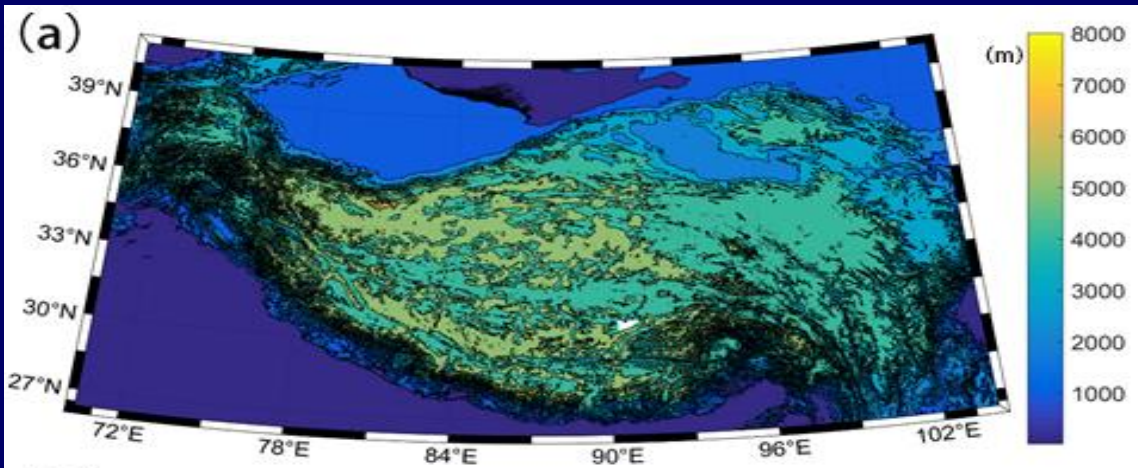


(Lai, Y., Chen\*, X. and Ma\*, Y. et al., 2023, *JGR-Atmospheres*)



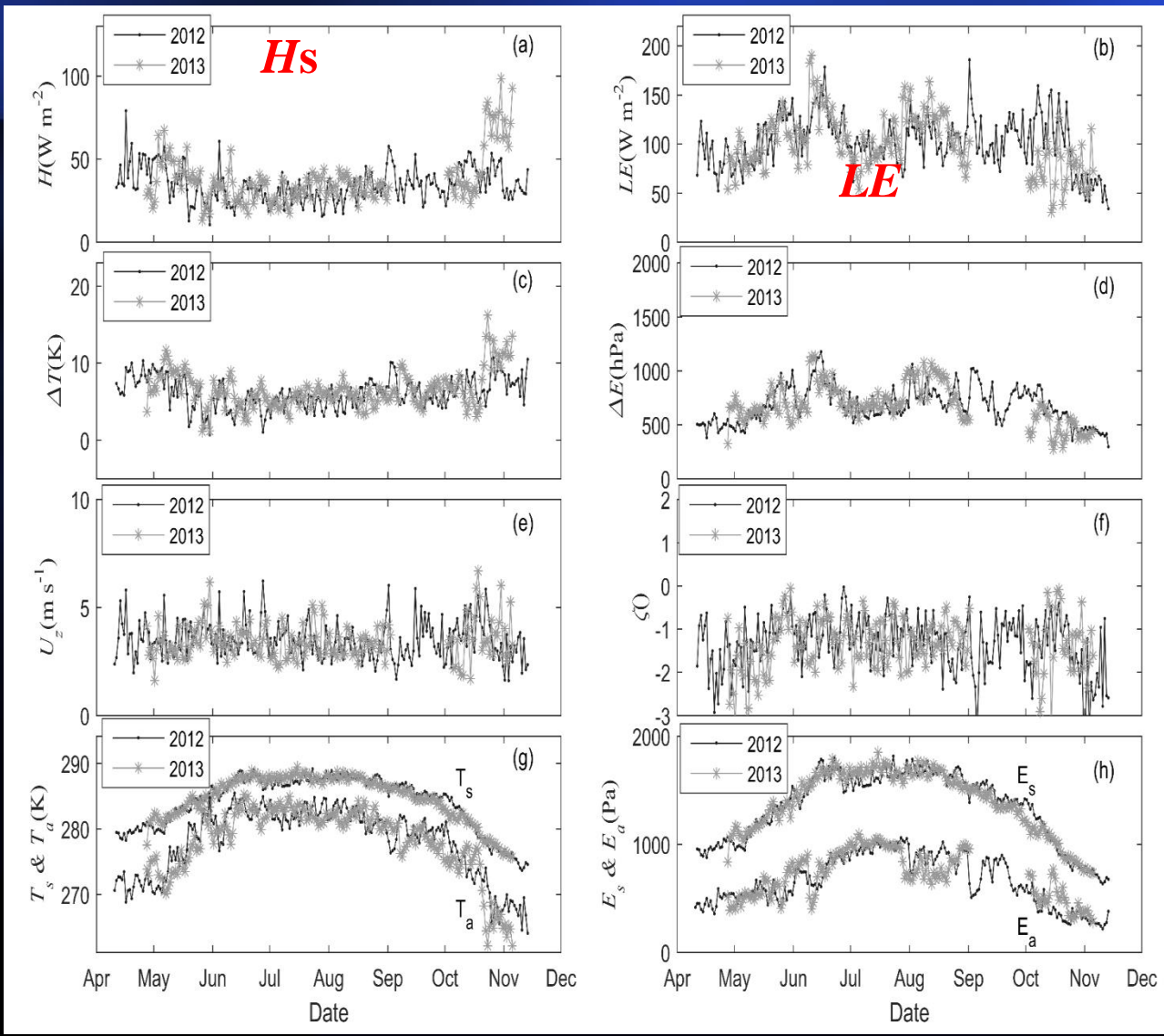
## 2.青藏高原湖气相互作用过程观测特征

青藏高原湖泊占全国的57.2%，达到近5万平方公里 (Zhang et al., 2019), 湖泊的蒸发对高原本身的水循环乃至下游的天气气候有着重要影响，但是...



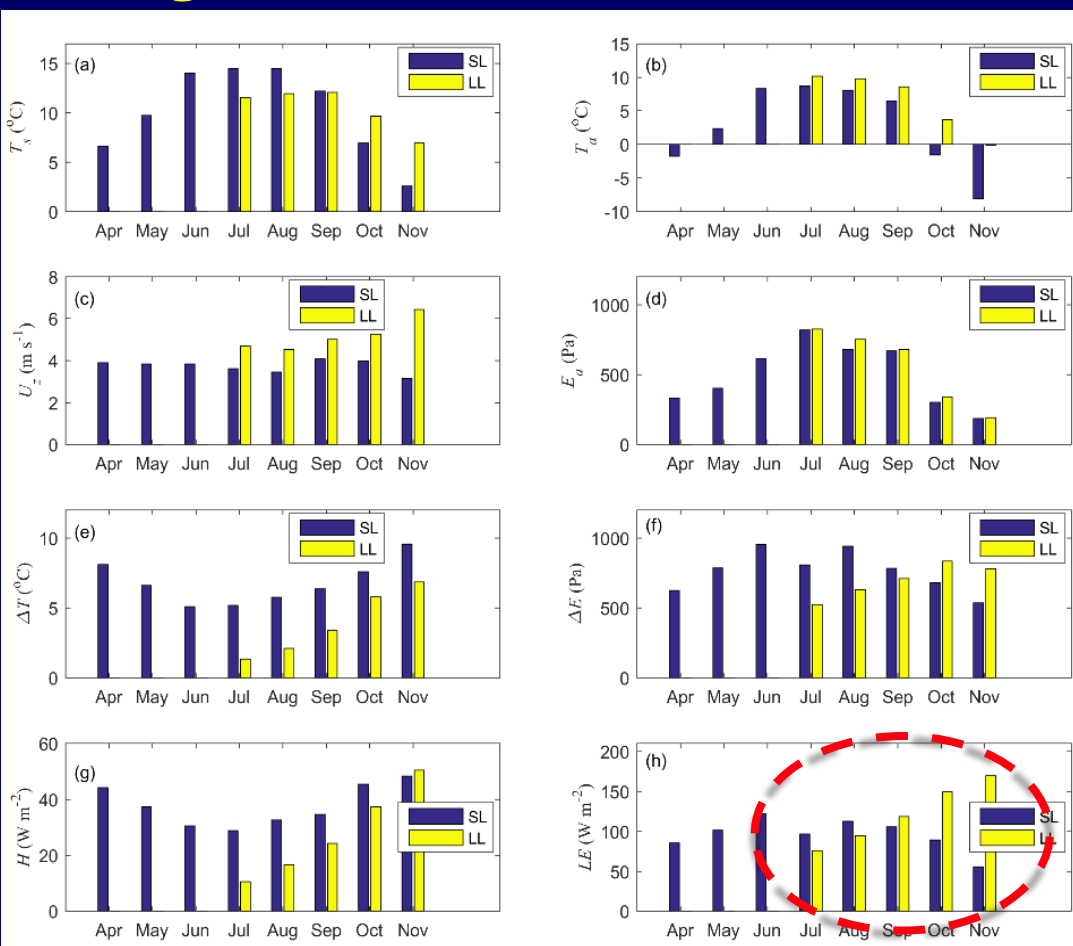
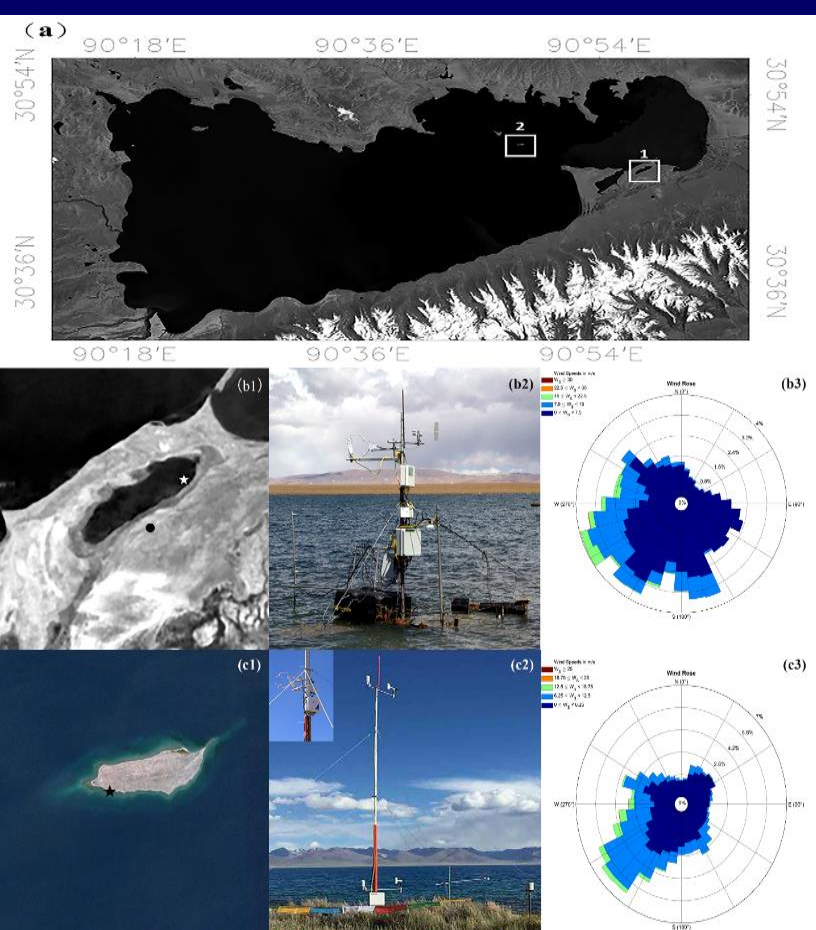


The observational results of lake-air interaction over the small lake of Namco during 2012 and 2013



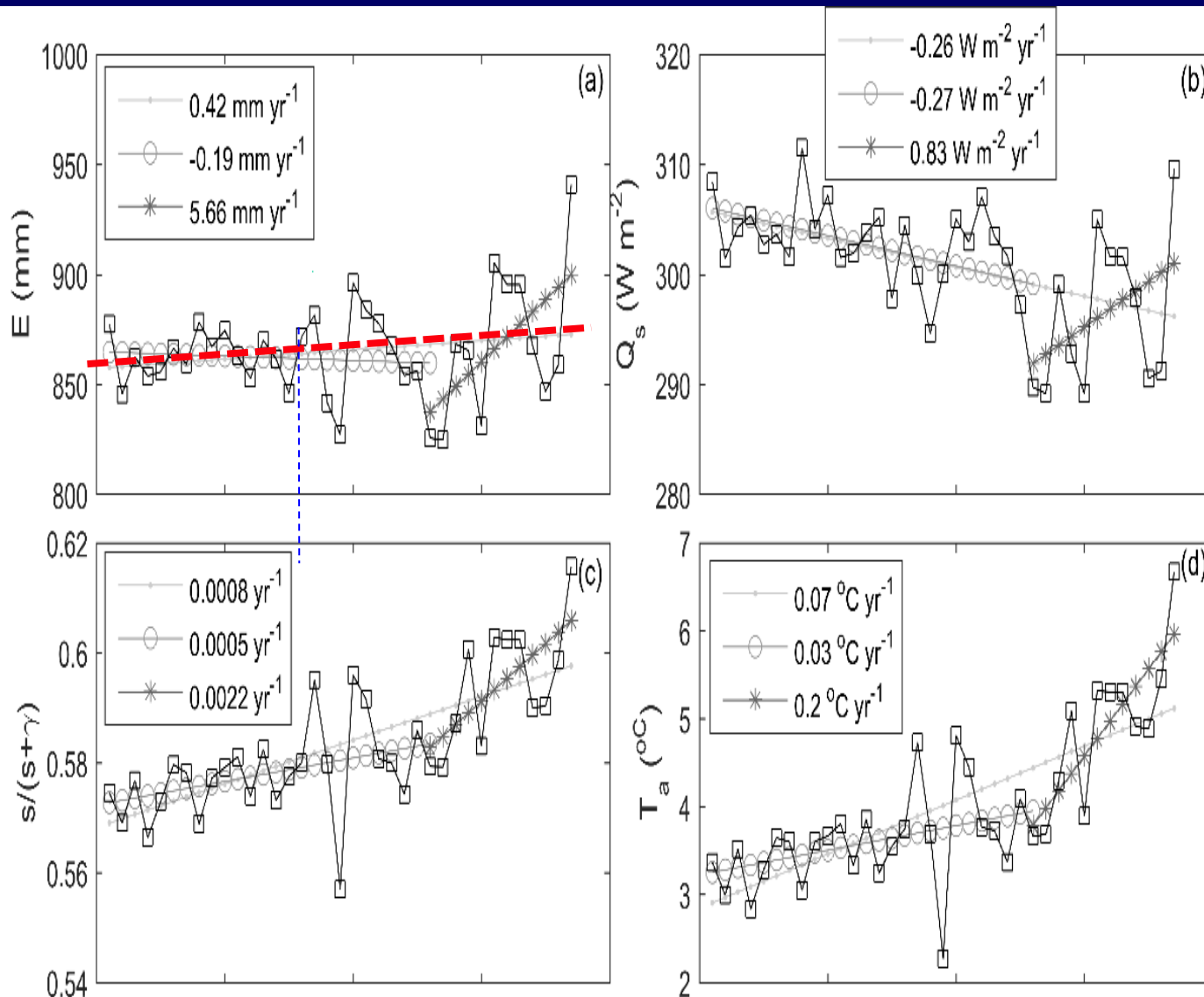
1. The daily average  $T_s$  and vapor pressure ( $E_s$ ) at the water surface are larger than the daily average  $T_a$  and vapor pressure ( $E_a$ ) in the air
2. The atmosphere is always in an unstable condition (Figure 5f) due to the large  $\Delta T$  and  $\Delta E$
3. The total evaporation in this small lake is about 812mm during their ice-free seasons, and it is larger than that from Nam Co
4. Energy stored during April to June and it is mainly released during September to November, and the energy budget over the entire ice-free period is generally closed, with an estimated EBC value of approximately 0.97

(Wang, B. and Ma, Y. et al., 2017, JGR-Atmosphere)



非结冰期大湖的总蒸发量  $981 \pm 18 \text{ mm}$  ， 大于同  
期小湖的  $812 \text{ mm}$





- ✓ 在缺乏湖泊温度观测的情况下，基于辐射和大气温度的Makkink方法可以获得较为可靠的湖面蒸发量估算结果；
- ✓ 基于Makkink方法得到纳木错湖1979-2015年的湖面蒸发整体呈现增大的趋势（1979-2004微弱减小，2005-2015快速增大，但整体呈现增大的趋势）

3. 发现了动力和热力传输的“不等效”和  
“非定常”（日变化）特征



•在青藏高原复杂地表区域感热通量的确定非常重要！

$$H(x, y) = \rho c_p k^2 u(x, y) \frac{T_{\text{sfc}}(x, y) - T_a(x, y)}{\left[ \ln \frac{z - d_0(x, y)}{z_{0m}(x, y)} + kB^{-1}(x, y) - \psi_h(x, y) \right] \cdot \left[ \ln \frac{z - d_0(x, y)}{z_{0m}(x, y)} - \psi_m(x, y) \right]} \quad (6.24)$$

如何准确确定？把每个变量准确确定出！

但是....

# 动力学和热力学粗糙度非等效

D08113

MA ET AL.: SURFACE HETEROGENEITY AND ITS IMPACT

D08113

Table 1. Aerodynamic Roughness Length  $z_{0m}$  Derived From Different Land Surfaces by Using the Independent Method

Land surface	Grass land	Grass land	Sand desert	Gobi	bean	wheat	corn
Observation	~5 cm	~15 cm	2.90	2.90	2.90	2.90	4.90
$z_{0m}$ , m	0.00436	0.0139	0.00267	0.0028	0.061	0.168	0.302

Table 2. Thermodynamic Roughness Length  $z_{0h}$  Derived From Different Land Surfaces

Land surface	Amdo	NPAM	HEIFE	HEIFE	HEIFE	HEIFE	AECMP'95
Height of observation, m	Grass land	Grass land	Sand desert	Gobi	bean	wheat	corn
$z_{0h}$ , m	0.00041	0.00114	0.000049	0.000011	0.000685	0.00132	0.00227

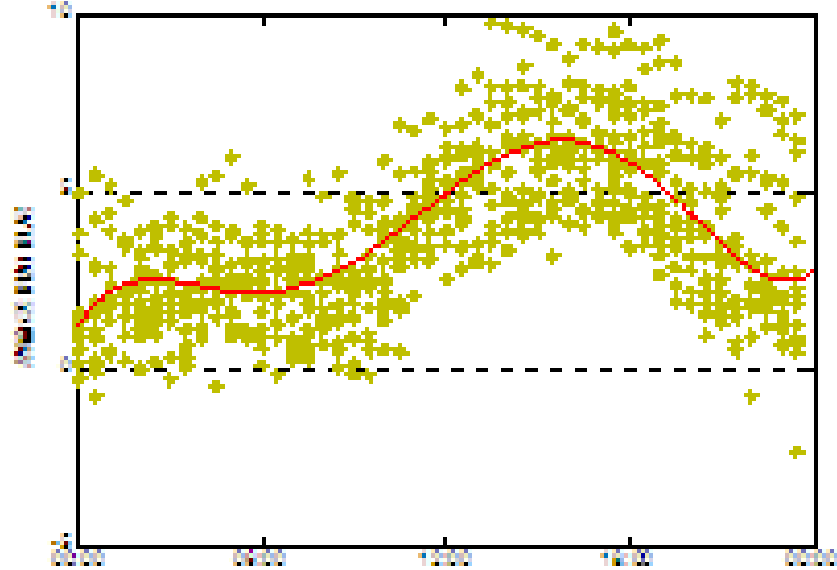
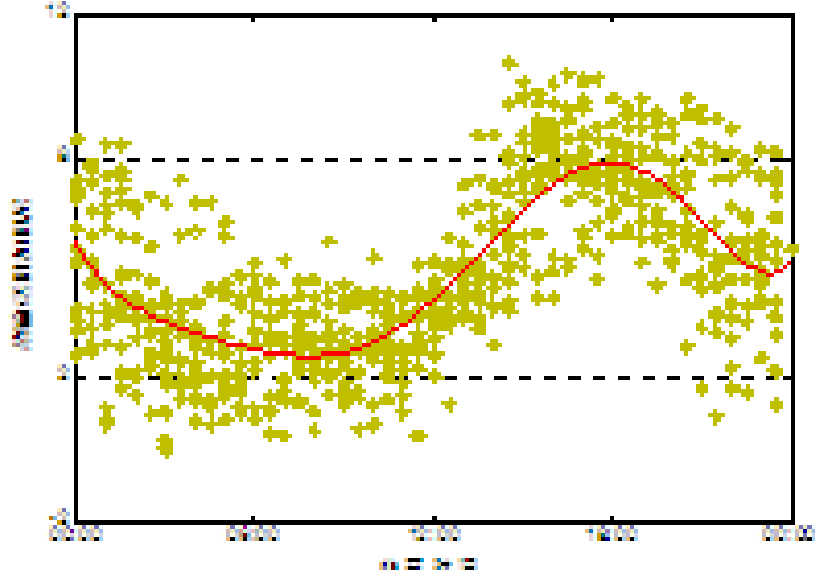
(Ma, Y. et al., JGR: Atmosphere)



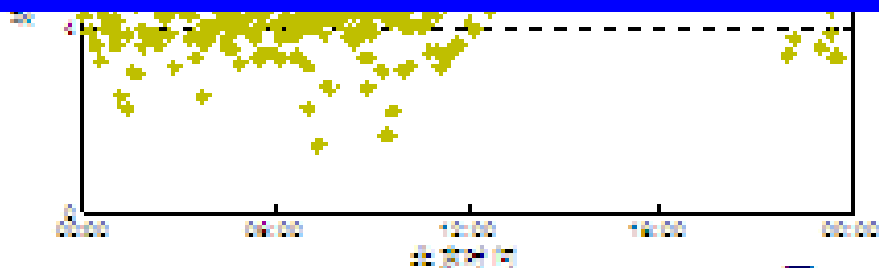
# 有效的动力学粗糙度和零平面位移

(Han and Ma, Y. et al., 2015, QJRMS; Ma, Y. et al., 2018, IJRS)

Station	$z_{0m}^{\text{eff}}$ (m)	$d_0$ (m)
QOMS(15)	$62.6 \pm 12.3$	$470.3 \pm 48.0$
NAMOS(8)	$1.7 \pm 1.1$	$19.4 \pm 11.9$
Linzhi(14)	$86.0 \pm 6.6$	$516.1 \pm 39.7$
Ali(11)	$1.9 \pm 1.1$	$8.1 \pm 5.5$
Shiquanhe(12)	$10.2 \pm 4.3$	$81.9 \pm 34.5$
Litang(9)	$6.0 \pm 1.1$	$60.7 \pm 11.6$



**热附加阻尼不是常数（非定常），明显的日变化，数值模拟和卫星遥感计算时必须考虑！**



Linzhi

Excess resistance to heat transfer ( $kB^{-1}$ )



Fig.2. Diurnal variations of the excess resistance to heat transfer  $kB^{-1}$  of Andao Station and NPAM Station.

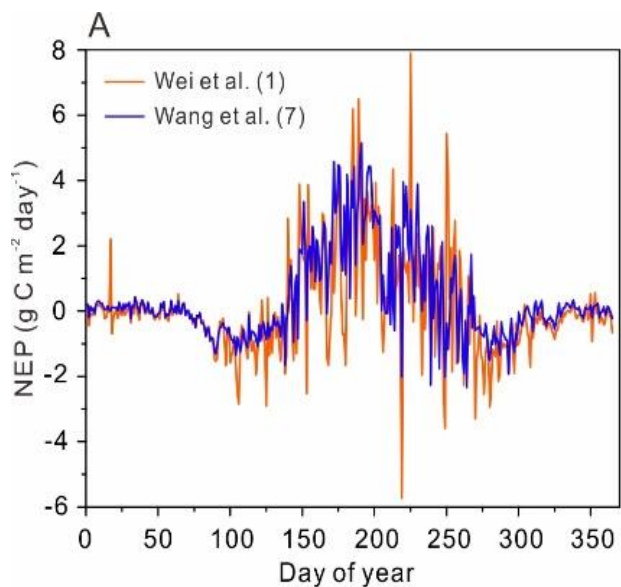
(Ma, Y. et al., 2002, PNS; Wang and Ma, Y., 2011, JHM)



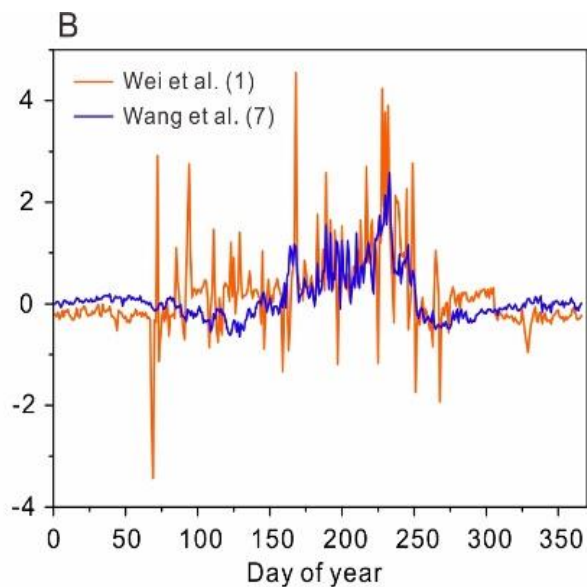
**4.给出了青藏高原复杂地表碳通量的分布和变化特征**

数据处理的不确定性可能会导致青藏高原碳汇能力的高估！

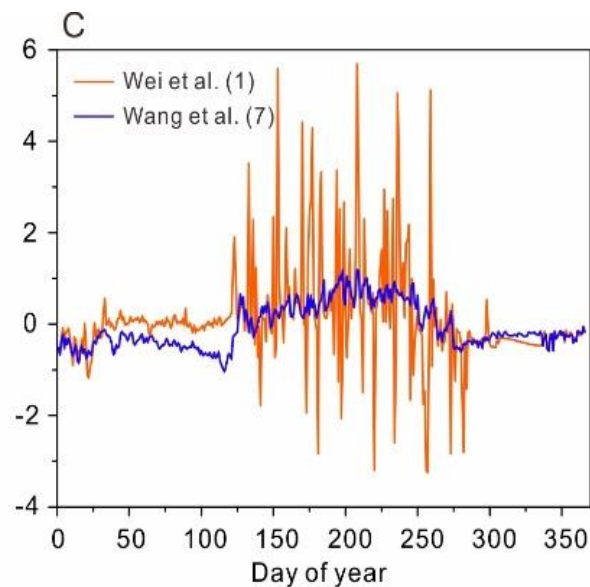
(Wang, Y., Ding,Z. and Ma\*,Y., 2022,PNAS)



**A: Arou in 2015**



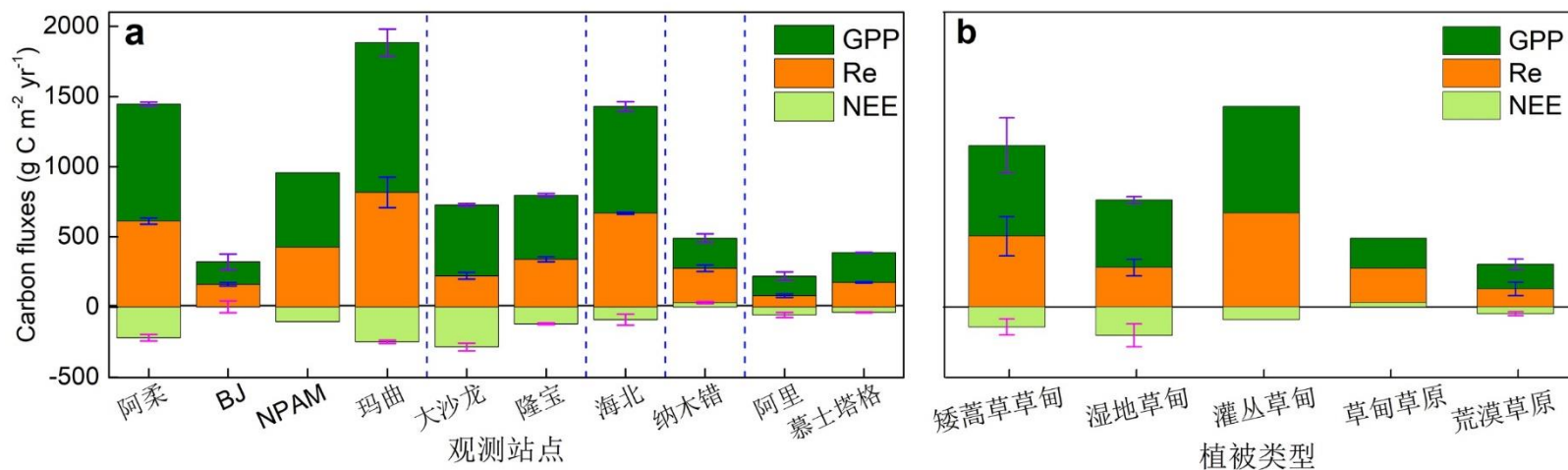
**B: Muztag in 2016**



**C: Nam Co in 2008.**



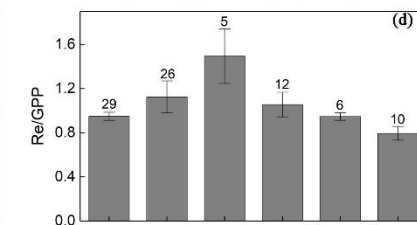
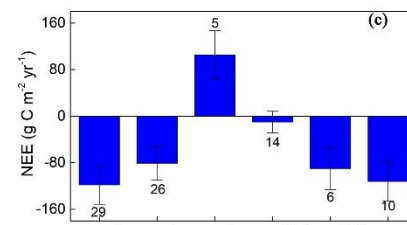
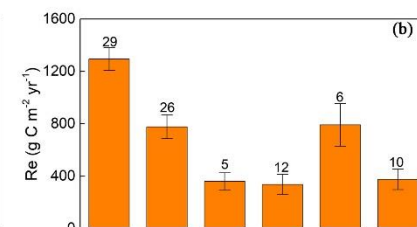
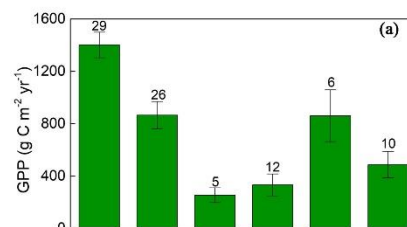
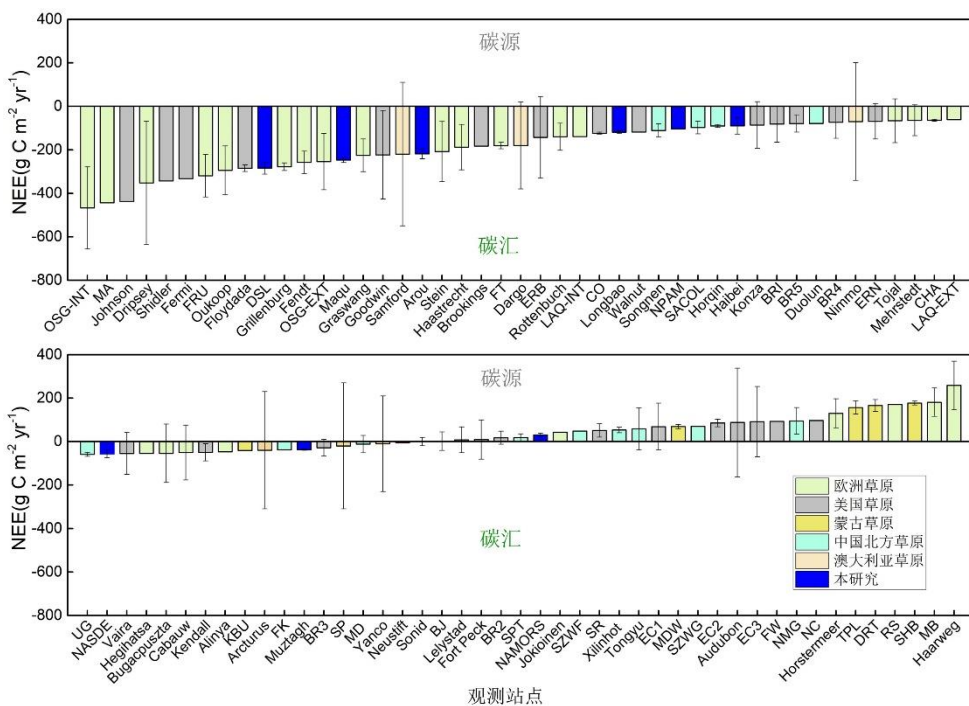
# 青藏高原不同高寒草地碳通量特征及控制因素分析



- 年平均NEE变化范围为-284 ~ 31g C m<sup>-2</sup> yr<sup>-1</sup>。
- 高寒湿地草甸和高寒矮蒿草草甸为强碳汇，高寒灌丛草甸次之，高寒荒漠草原为弱碳汇，高寒草甸草原为弱碳源。

(Wang, Y., Xiao, J., Ma\*, Y. et al., 2021, AFM)

# 青藏高原不同高寒草地碳通量特征及控制因素分析



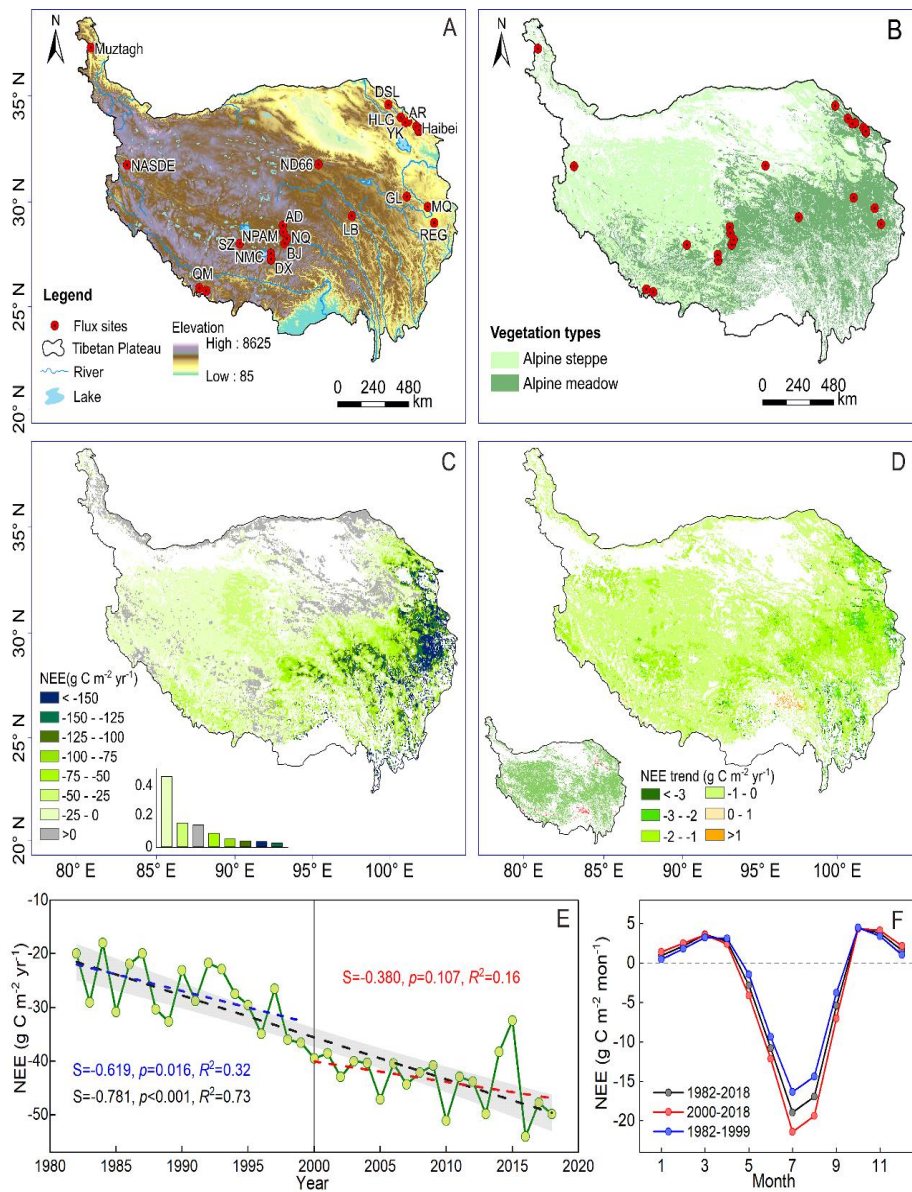
► 青藏高原东北部冷湿的气候有利于草地生态系统的光合作用，同时低温抑制生态系统呼吸作用，最终造就其较高的碳封存能力。

(Wang, Y., Xiao, J., Ma\*, Y. et al., 2021, AFM)



# 5. 发现了青藏高原高寒草地固碳能力持续增强特征

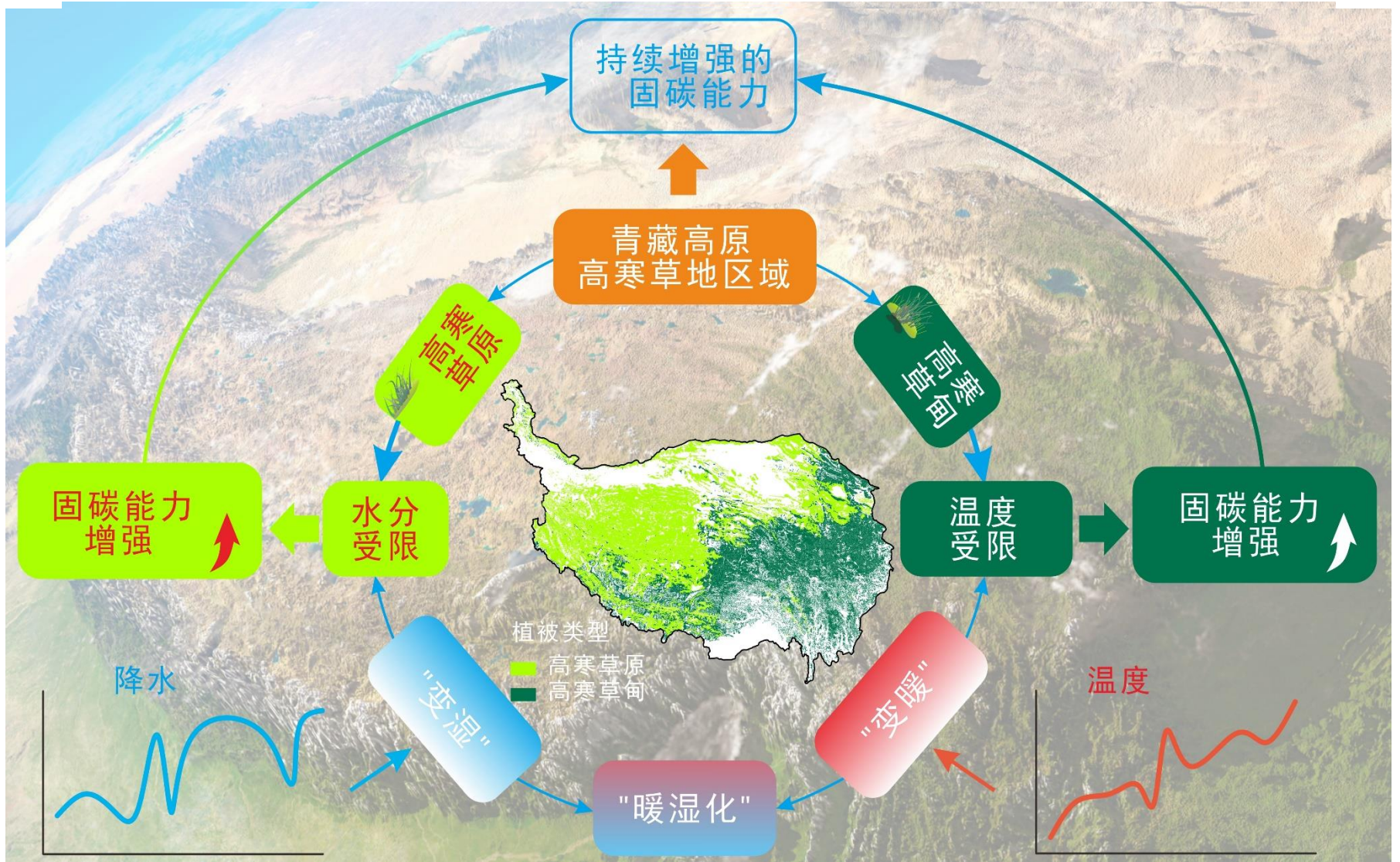
(Wang, Y., Xiao, J., Ma\*, Y. et al., 2023, *Science Advances*)



利用“青藏高原多圈层地气相互作用综合观测研究平台（TPEITORP）”长期综合观测和卫星遥感资料、再分析数据及机器学习方法我们发现：

- 在1982年至2018年期间，青藏高原高寒草地的碳封存量为每年2639到7919万吨，并以每年114万吨的增长速率增加；
- 高寒草原区域净生态系统碳交换量（NEE）的变化趋势倾向于由降水量主导，而高寒草甸区域则倾向于由温度调控。





(Wang, Y., Xiao, J., Ma\*, Y. et al., 2023, Science Advances )

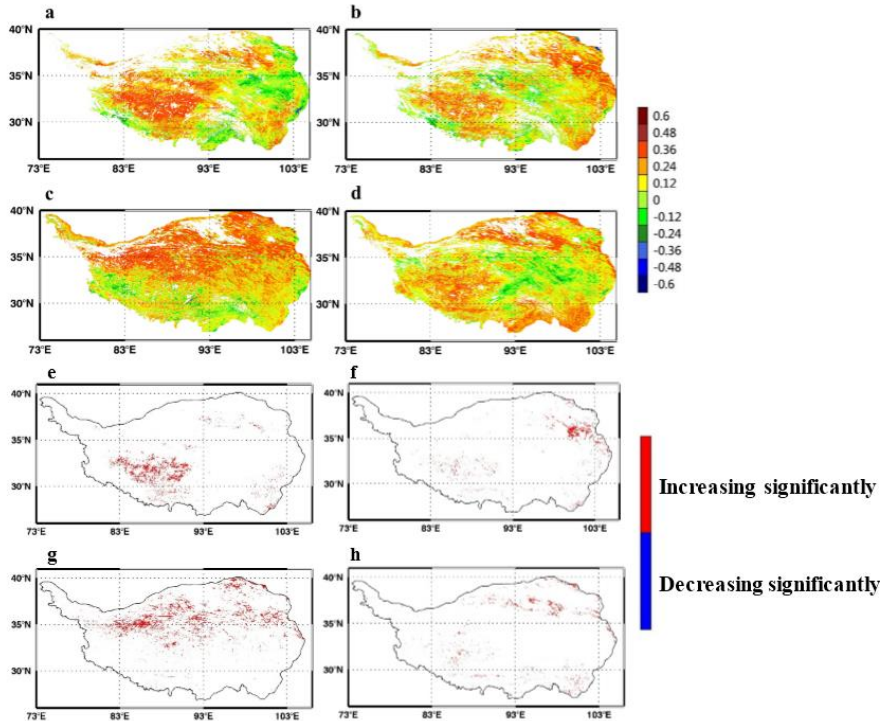


**(三) 针对整个高原区域热通量准确估算缺乏的短板，构建了非均匀下垫面多源卫星反演地表特征参数和水热通量参数化方案体系，揭示了青藏高原复杂地表区域上水热变化规律。**

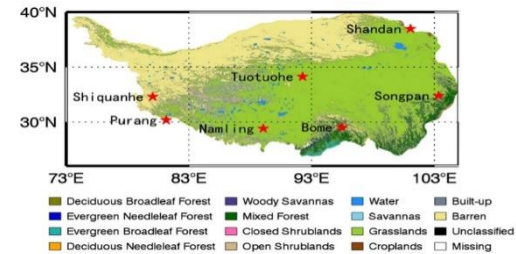




1. 建立了无云影响的光学植被指数数据集（15年：1999–2014）。在此基础上揭示了高原增温的同时，高原总体呈现植被指数增加的趋势，表明生态环境状况好转，而且显著增加区域面积约占高原总面积的7.63%，研究表明植被指数增加主要是由于自然气候因子的变化造成，人类活动的影响较小。



1999至2014年青藏高原植被指数线性变化趋势的空间分布 (a,e 冬; b,f春; c,g夏; d,h秋)



不同气候类型区7个代表性站点植被指数与气温和降水变化相关性

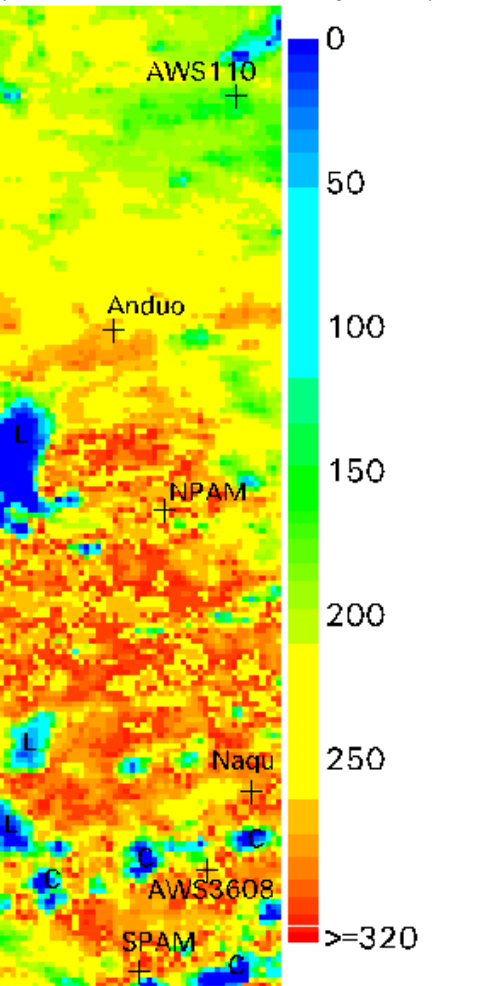
Station	Mean air temperature	Precipitation
Shiquanhe	0.687	0.511
Purang	0.832	0.338
Shandan	0.901	0.928
Tuotuohe	0.831	0.925
Namling	0.546	0.721
Songpan	0.707	0.555
Bome	0.675	0.117

**2. 首次较准确地给出了整个青藏高原地区热通量及蒸散发量的精细分布及日变化、月变化与年变化规律**

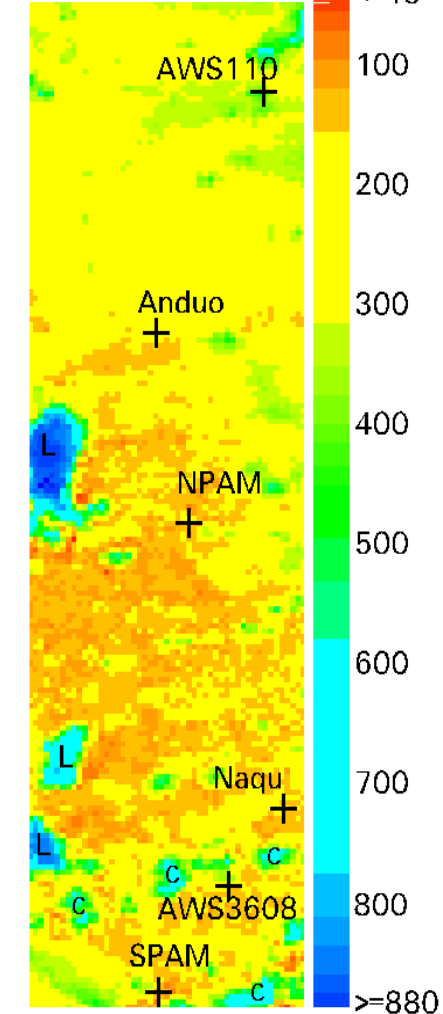


# 高空间分辨率的热通量分布

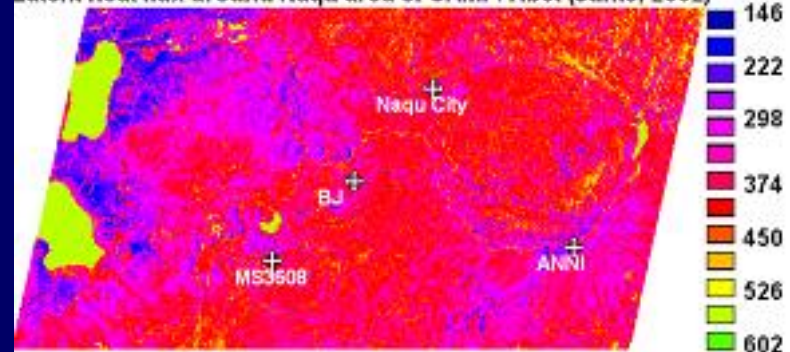
Sensible heat flux density ( $W/m^2$ )  
(12 June 1998, GAME/Tibet)



Latent heat flux density ( $W/m^2$ )  
(12 June 1998)

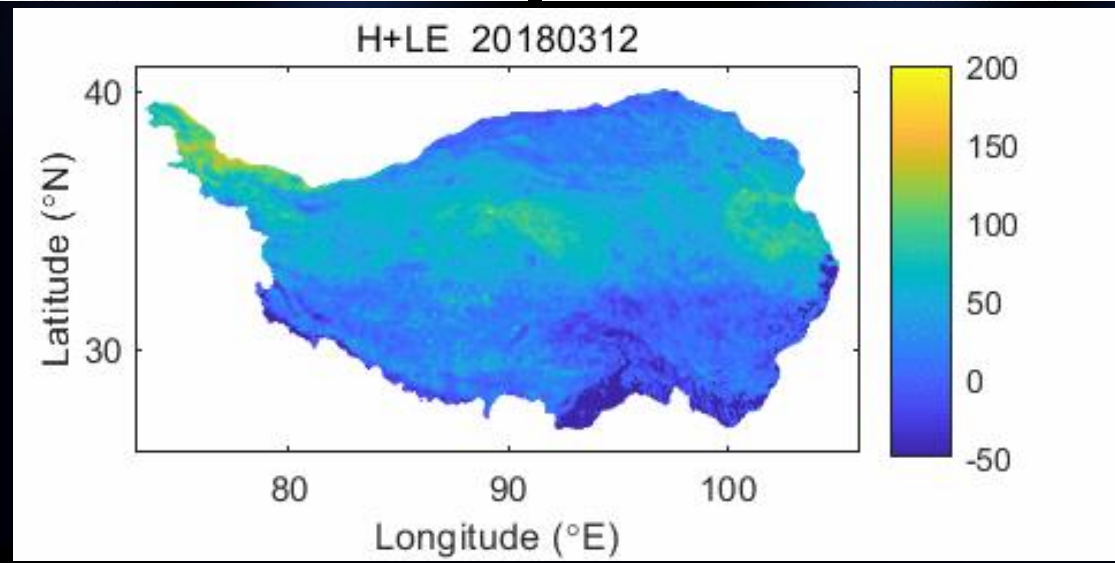
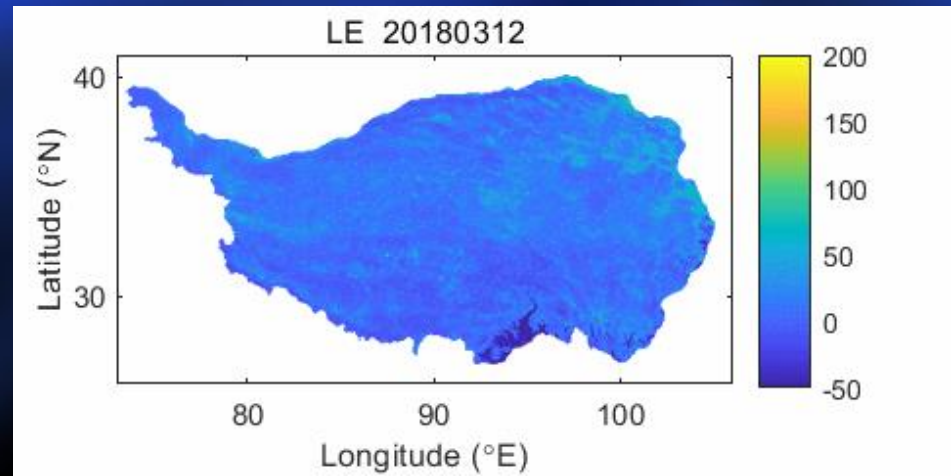
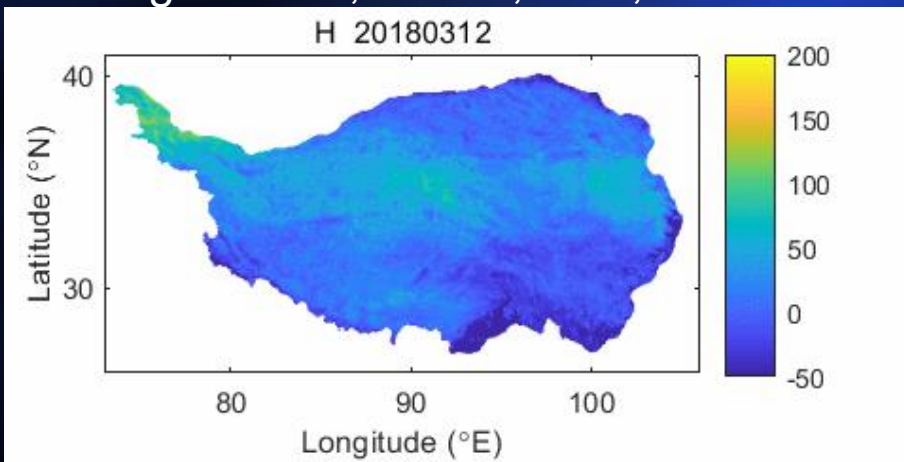


Latent heat flux around Naqu area of CAMP/Tibet (Jun.9, 2002)  $W/m^2$



(Ma, Y., et al., 2003, JMSJ)

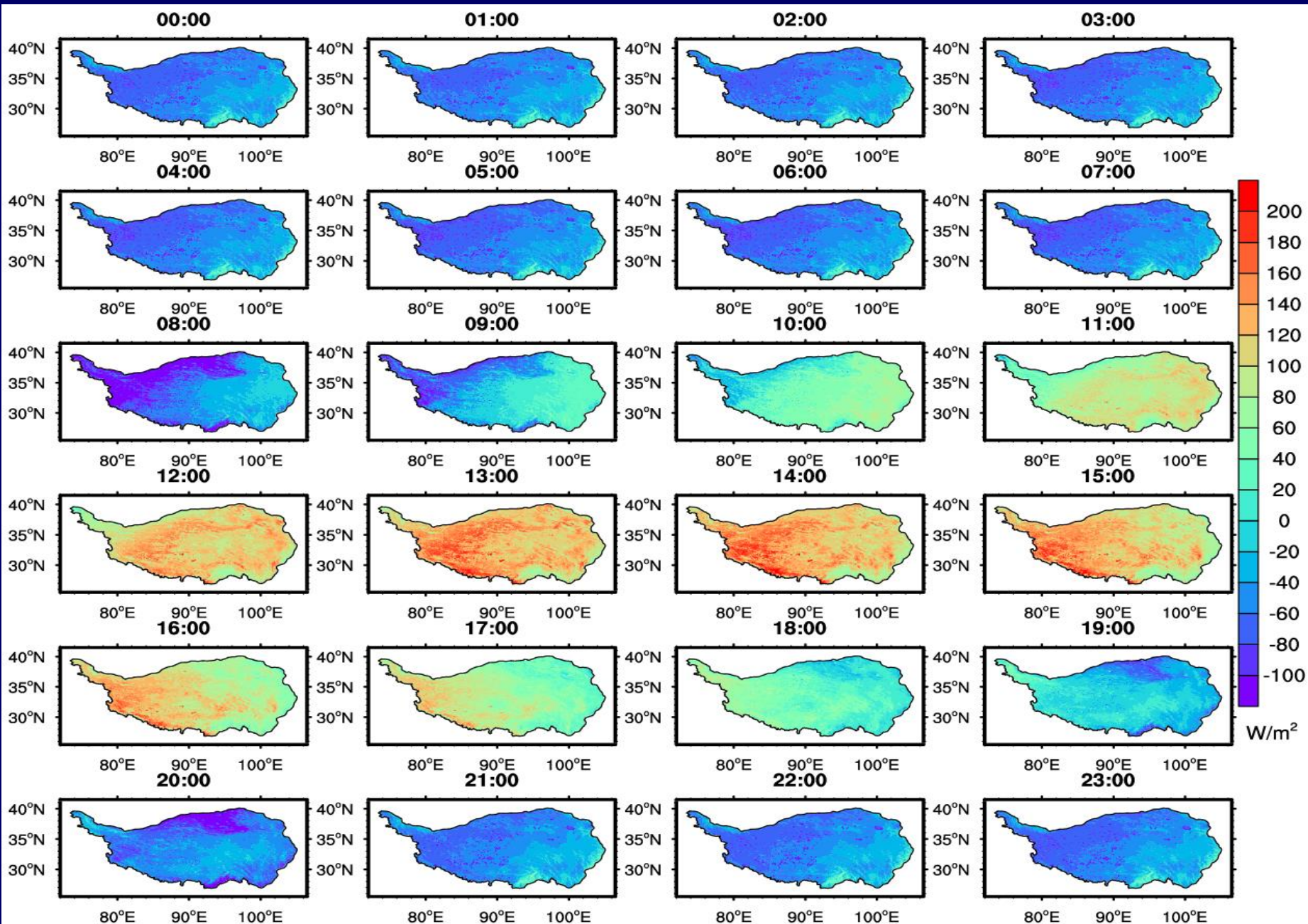
建立了一套针对国产FY-4A/AGRI的地表参数估算方法和小时分辨率地表参数资料，证实高原春季地面热源中感热占主导，潜热的空间分布差异和昼夜变化都小于感热（Ge,N., Zhong\*, L., and Ma,Y., et al., 2020, AAS),同时给出了热通量的日变化特征（Zhong and Ma,Y.et al.,2019,ACP）



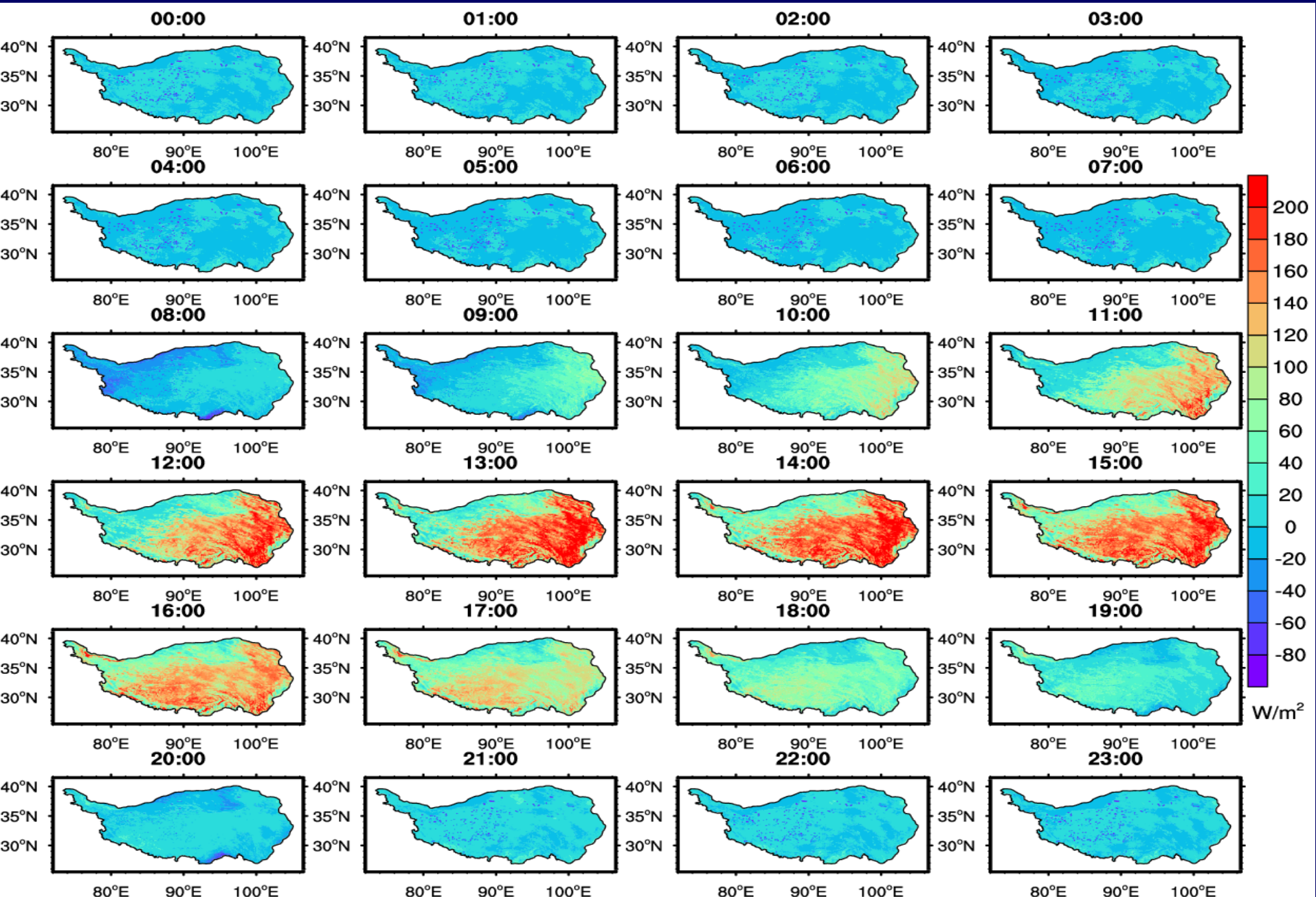
青藏高原春季地面热源的逐日变化



# 感热通量日变化 (Zhong and Ma, Y. et al., 2019, ACP)

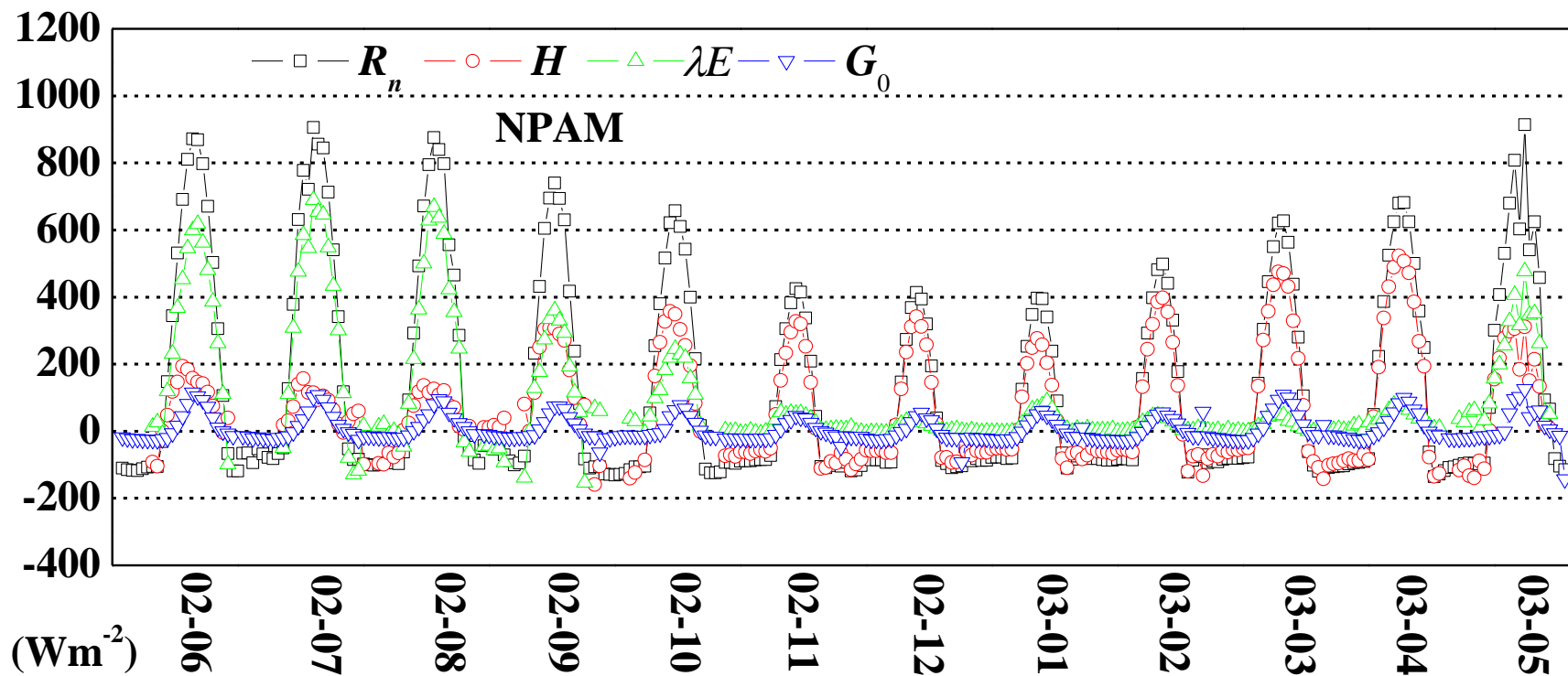


# 潜热通量日变化(Zhong and Ma, Y. et al., 2019, ACP)

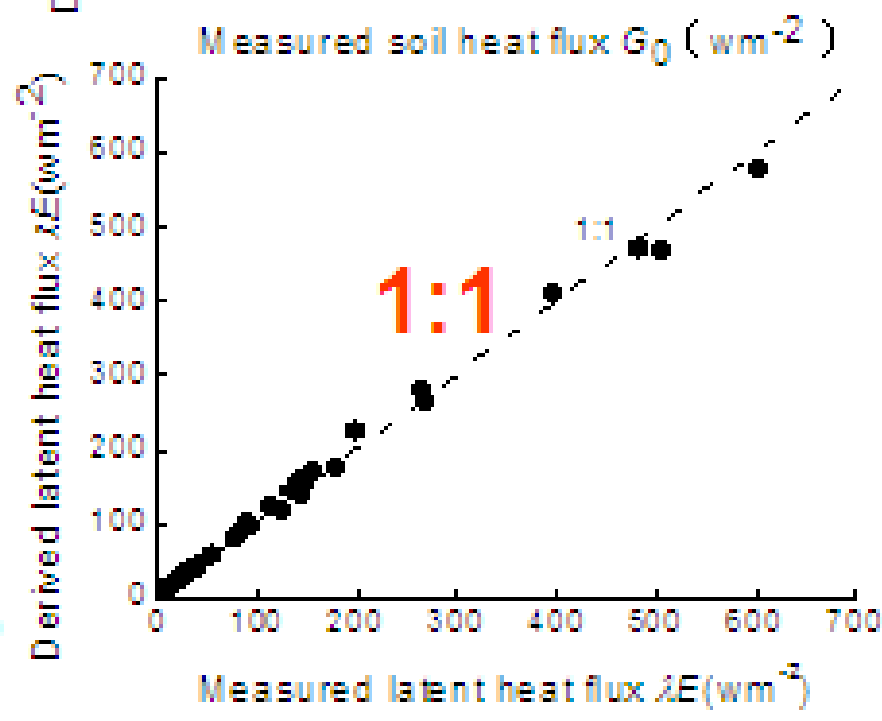
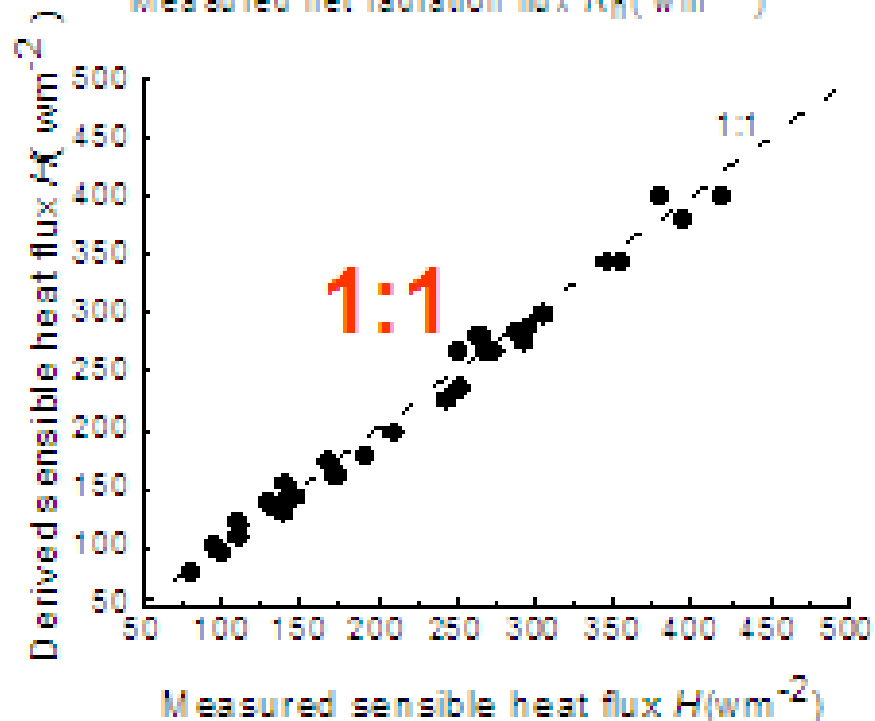
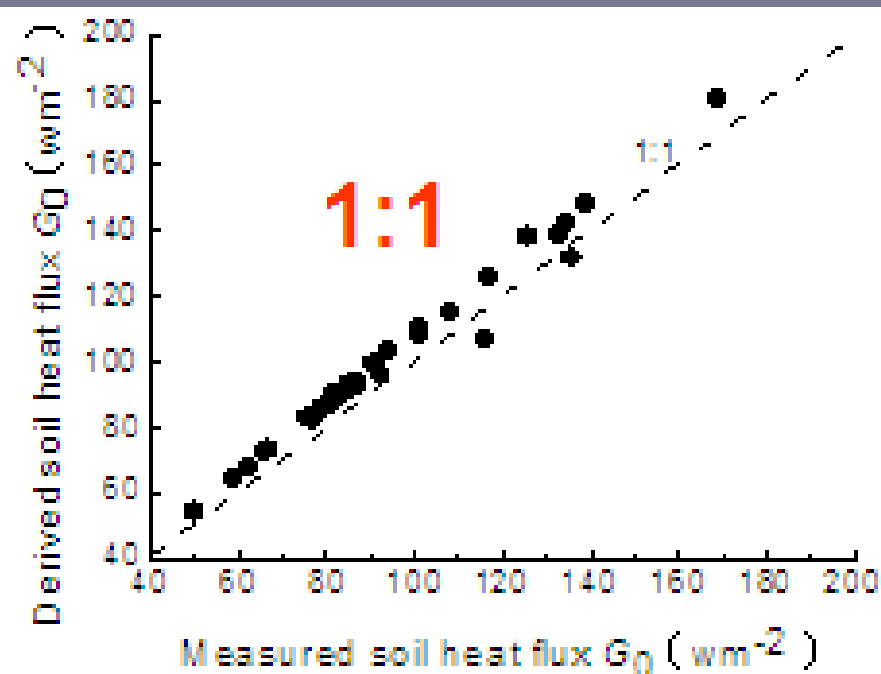
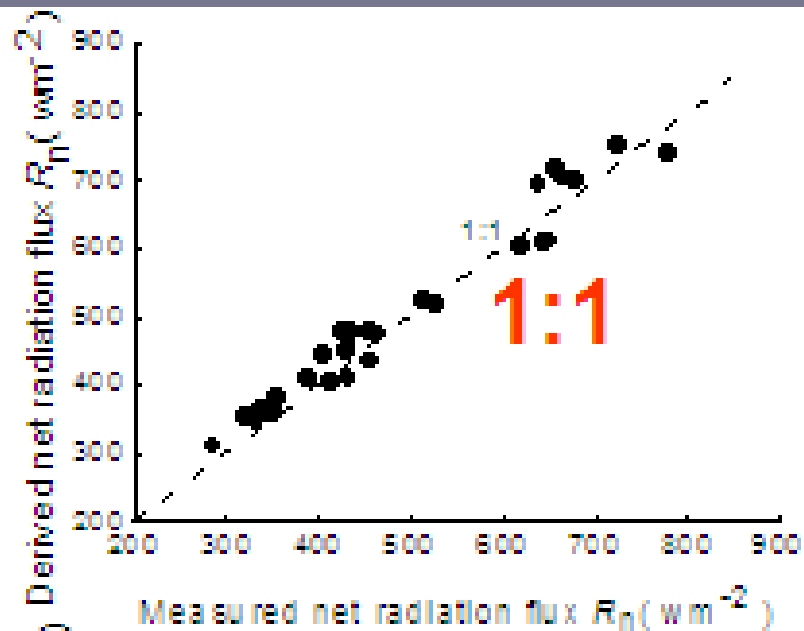




# 潜热通量月变化



(Ma, Y. et al., 2011, ACP)



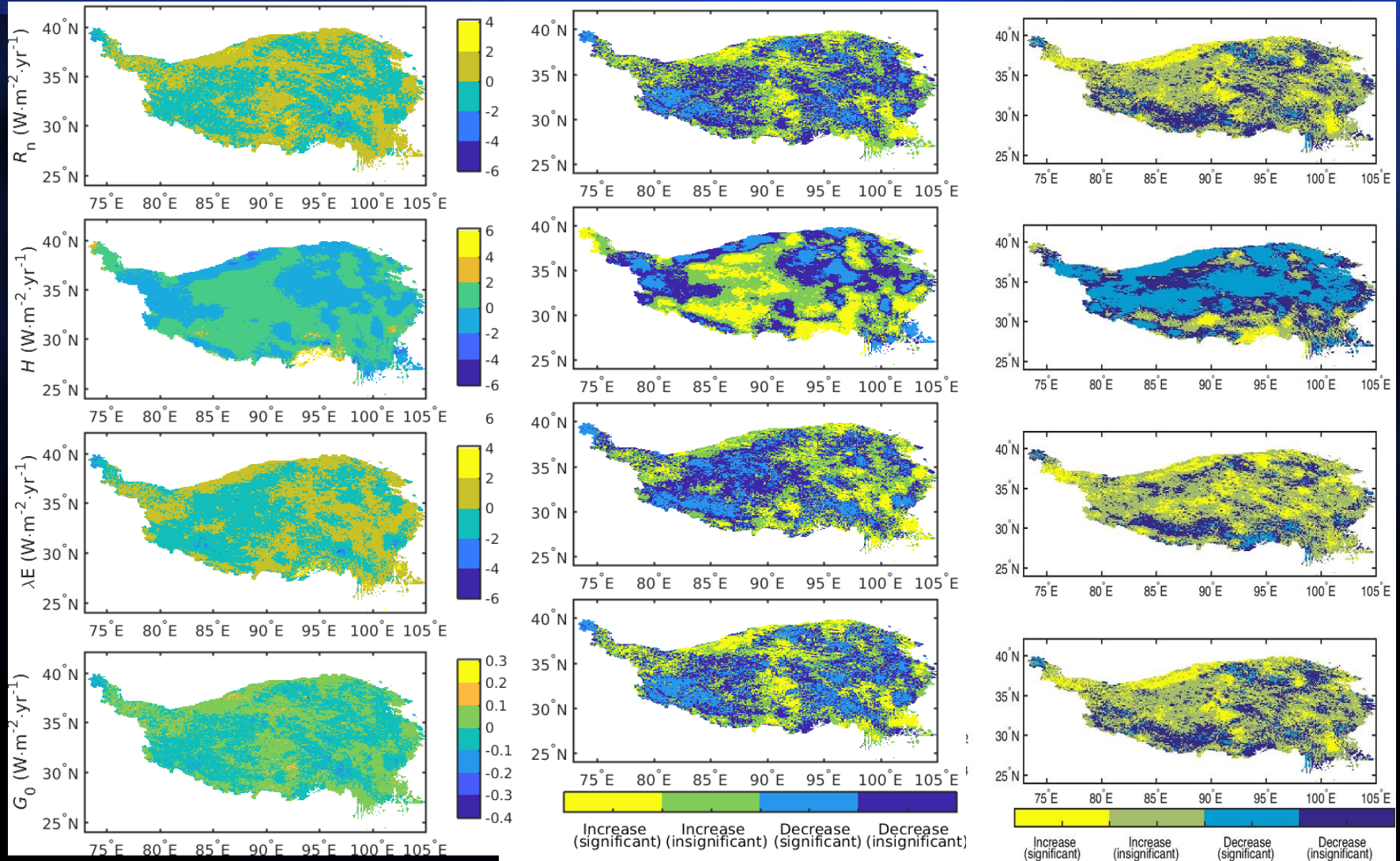
(Ma et al., 2011, ACP)



# 热通量年变化

(2001-2016)

(2001-2012)

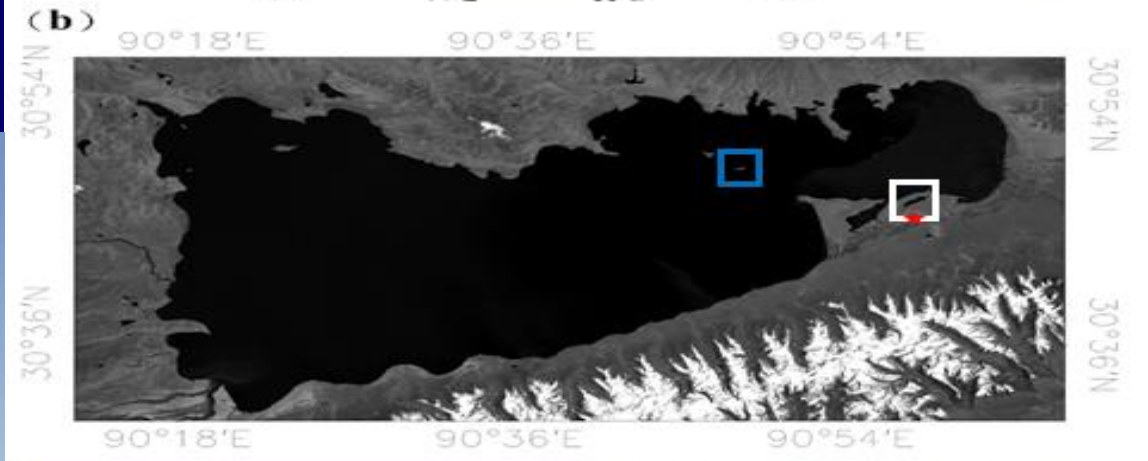
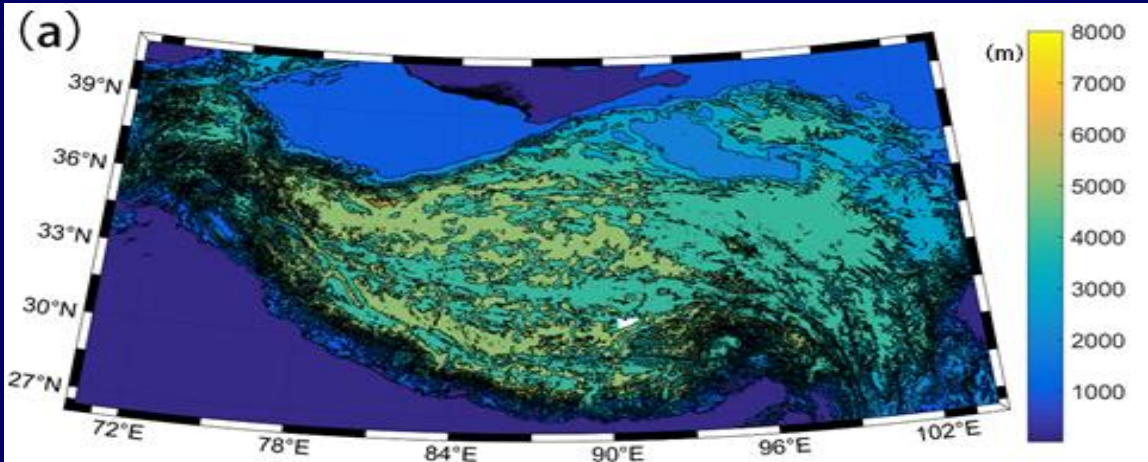


(Ma, Y. et al, 2018, IJRS)

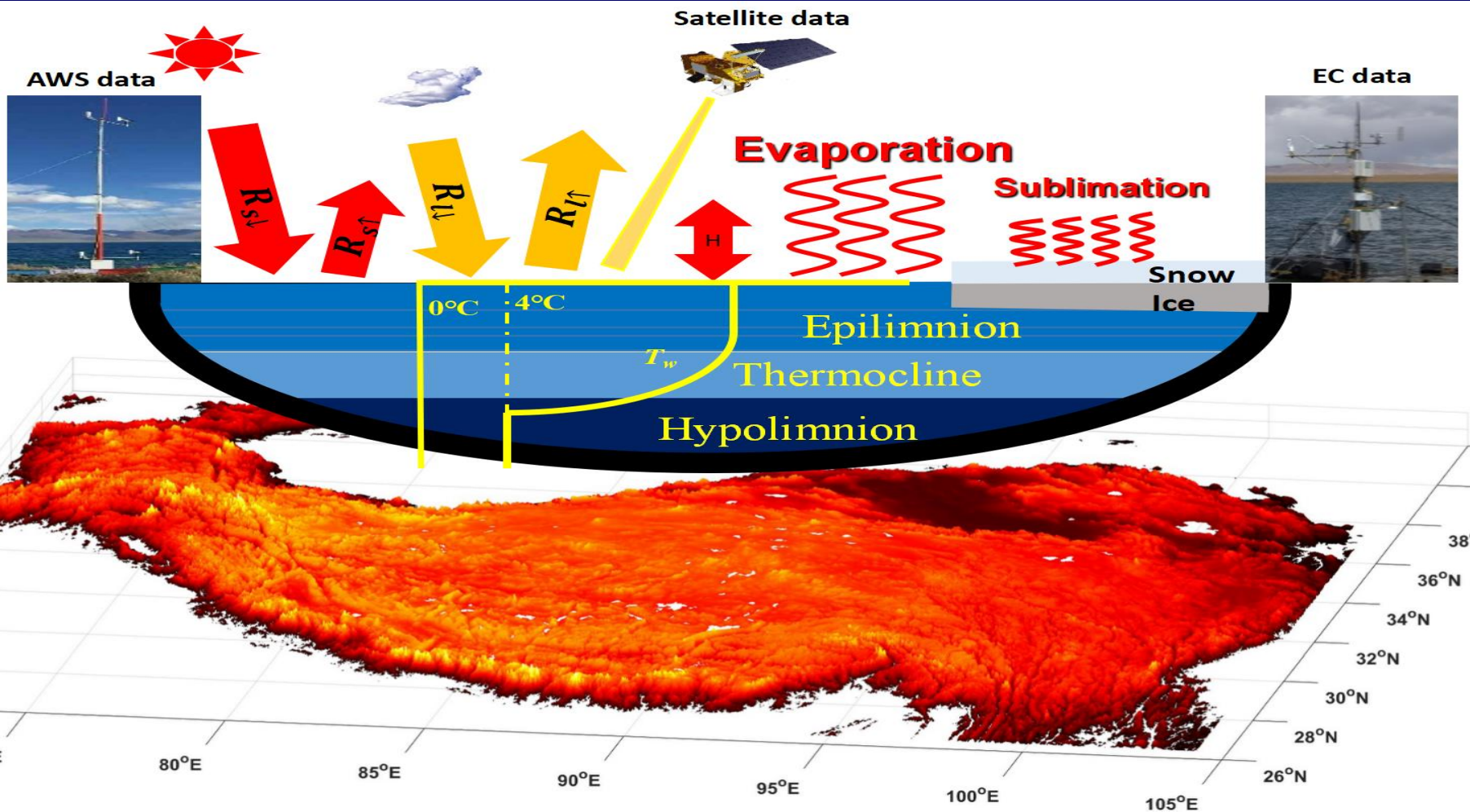
3. 首次较为准确地给出了整个青藏高原湖泊年蒸发总量 (Wang,B. and Ma\* ,Y., et al, 2020,*Science Advances*) 和青藏高原年总蒸散发量 (Han,C. and Ma\*,Y. et al., 2021,*ESSD*)



青藏高原湖泊占全国的57.2%，  
达到近5万平方公里（原来4万  
），大于1平方公里的湖泊1236  
个（原来1081个）（Zhang et  
al., 2019），**湖泊蒸发在青藏高  
原水循环中非常重要！**而原来  
高原湖泊每年蒸发掉的水量到底  
是多少，不清楚！  
基于...观测

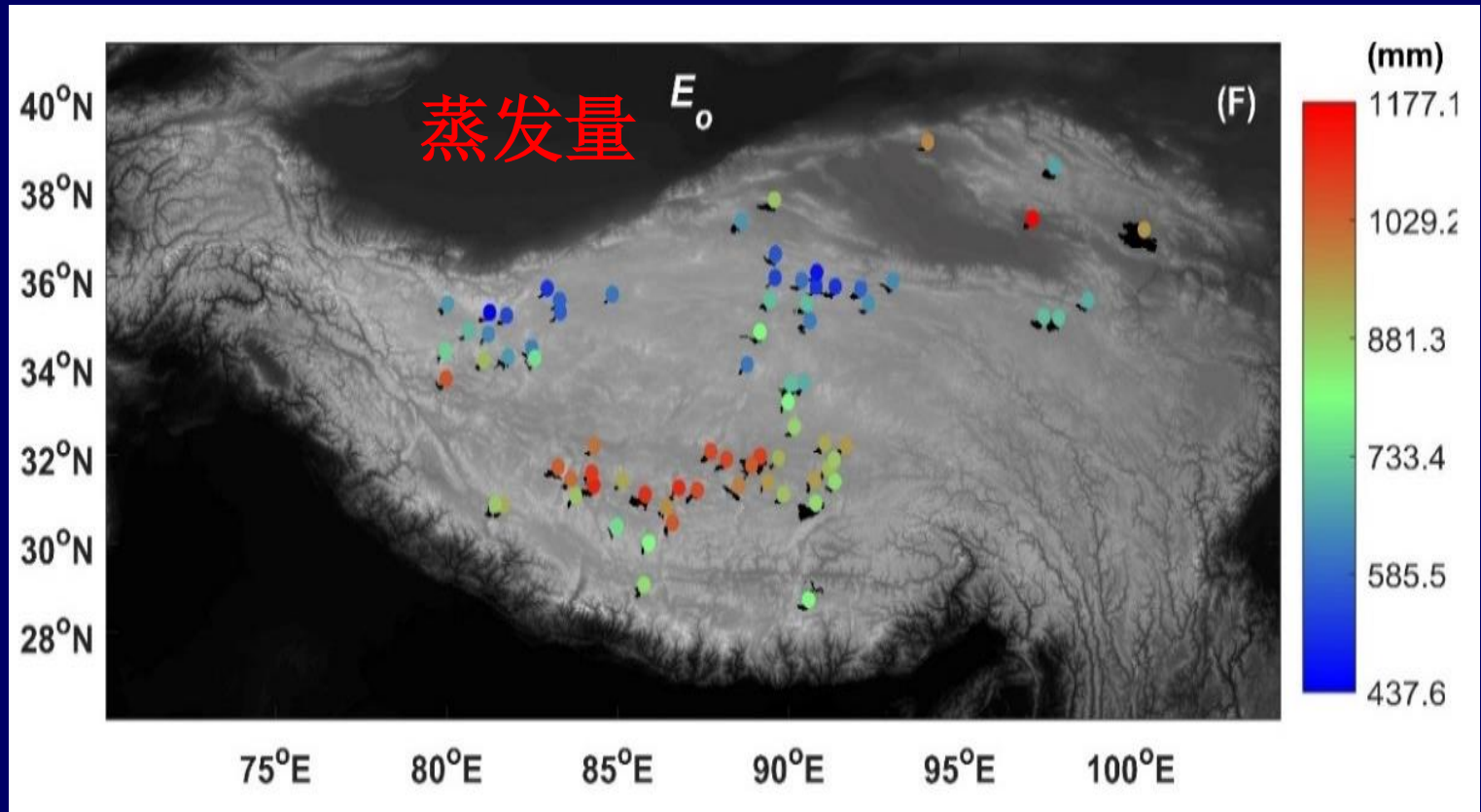


# 提出的影响湖泊蒸发的物理过程模型





(Wang ,B. and Ma\*,Y. et al., 2020,*Sciences Advances*)



基于青藏高原湖泊湖气相互作用的涡动相关观测和卫星遥感资料及我们提出的湖泊过程物理模型，首次发现青藏高原75个大湖总的年蒸发总量（来自2003年-2016年MODIS卫星资料） $294.0 \pm 1.2$  亿吨/年，整个高原湖泊年蒸发总量 $517.0 \pm 2.1$ 亿吨/年。

# 社会影响显著

8200多万浏览量



## 相当于3570个西湖！青藏高原湖泊每年蒸发517亿吨淡水

人民日报  
发布时间：06-28 20:31 人民日报社

中国科学院青藏高原研究所最新的一项研究显示，并据此估算青藏高原湖泊在蒸发总量为每年517亿吨，相当于3570个杭州西湖的水量，为准确估算“亚洲水塔”青藏高原中湖泊水资源储量提供数据参考。



### 作者最新文章

安徽鼓励高校毕业生通过志愿服务  
假期，带动就业

日本民间团体发布声明呼吁民众  
注意佩戴口罩

洞庭湖水质监测站，湖北实施不利  
因素监测

### 相关文章

人民日报关注 | 多措并举提升  
水能利用效率



## 科画 | 每年约517亿吨 科学家估算出青藏高原湖泊蒸发总量

新华社客户端  
发布时间：07-02 21:58 新华社客户端官方微博



### 作者最新文章

博索纳罗第四次接受新冠病毒检测

海报 | 2020，高考加油

高质量发展 | 如何全程监督 促脱贫攻坚实效

### 相关文章

“玉宝山新矿”话题升温热搜第5位，引发网友热议



## Qinghai-Tibet Plateau reports 51.7 bln tonnes of annual lake evaporation

Source: Xinhua | 2020-06-29 22:05:04 | Editor: huaxia  
Facebook, Twitter, LinkedIn, Weibo, WeChat

BEIJING, June 29 (Xinhua) -- Chinese researchers have estimated that the Qinghai-Tibet Plateau witnessed about 51.7 billion tonnes of lake water evaporation each year, according to the website of the Chinese Academy of Sciences.

Lake evaporation can influence basin-wide hydrological cycles and is a crucial factor in the loss of water resources of the Qinghai-Tibet Plateau.

Researchers from multiple institutes, including the Chinese Academy of Sciences, Lanzhou University and Tsinghua University, used a combination of meteorological and satellite data to explore the ice phenology and evaporation amounts in 75 large lakes across the Qinghai-Tibet Plateau.

They observed apparent variability of the evaporation amounts in their spatial distributions. Lakes with higher elevation, smaller areas, and higher latitudes are generally reported having lower evaporation.

The total evaporated water approximately amounted to 29.4 billion tonnes each year in the 75 studied lakes, while about 51.7 billion tonnes for all plateau lakes included, according to the research article published in the journal Science Advances.

微博搜索 #青藏高原湖泊每年蒸发517亿吨淡水#



综合 实时 热门 视频 图片

导语：6月28日消息，中国科学院青藏高原研究所最新的一项研究结果显示，并据此估算青藏高原湖泊蒸发总量为每年517亿吨，相当于3570个杭州西湖的水量，为准确估算“亚洲水塔”青藏高原中湖泊水资源储量提供数据参考。

置顶



每日经济新闻

【相当于3570个西湖！#青藏高原湖泊每年蒸发517亿吨淡水#】6月28日消息，中国科学院青藏高原研究所最新的一项研究结果显示，并据此估算青藏高原湖泊蒸发总量为每年517亿吨，相当于3570个杭州西湖的水量，为准确估算“亚洲水塔”青藏高原中湖泊水资源储量提供数据参考。青藏高原被称为“亚洲水塔”，其 展开全文



06月28日 21:42 来自 微博 weibo.com

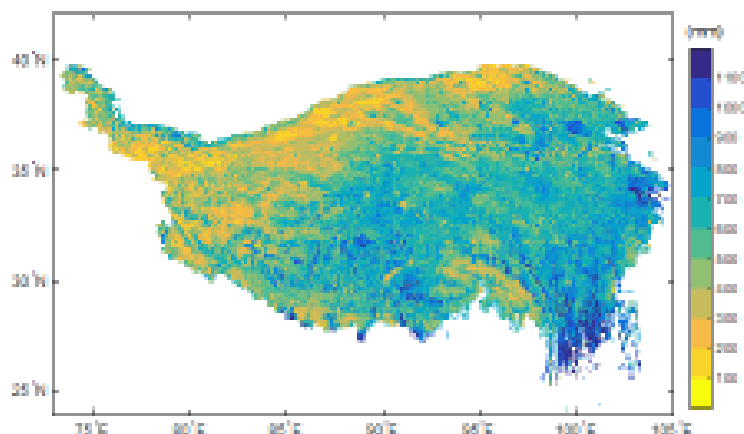
收藏 转发 606 评论 879 点赞 23015



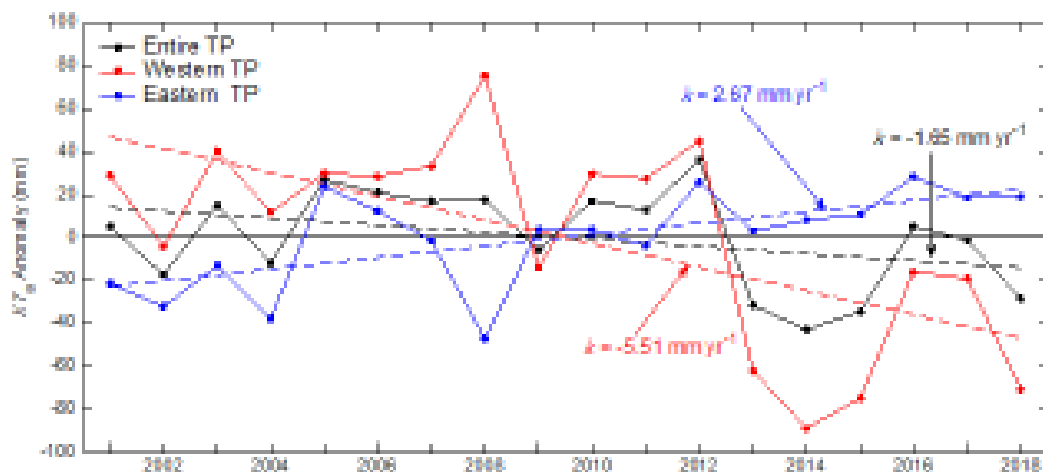
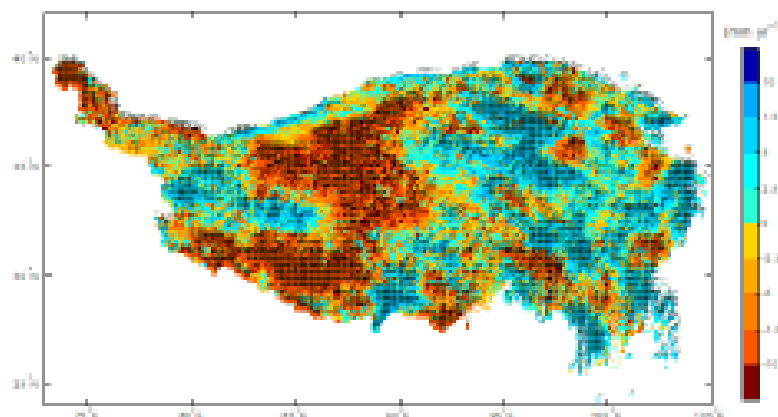


# (Han and Ma\* et al., 2021, *ESSD*)

多年平均年蒸散发总量(2001-2018)

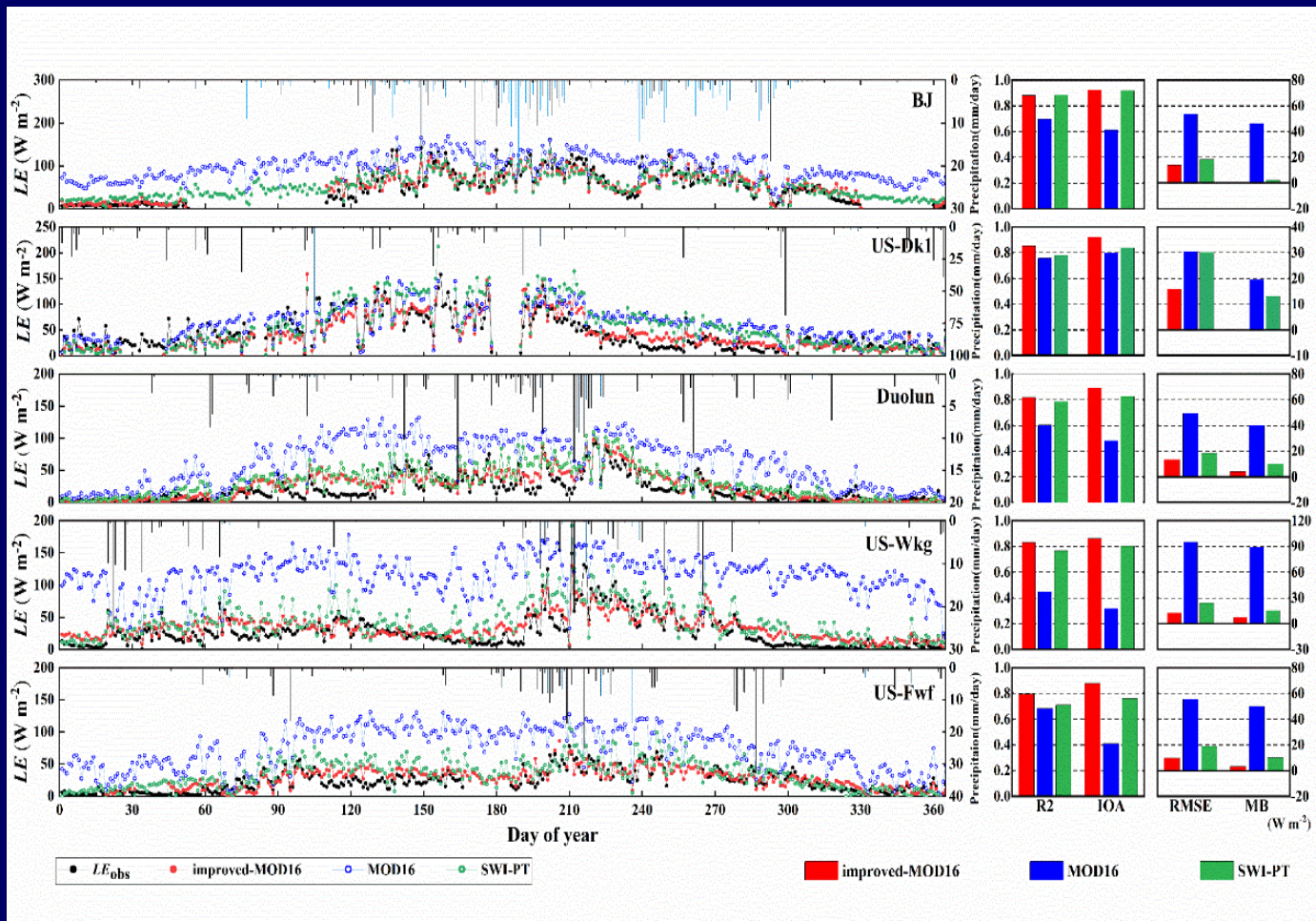


蒸散发变化趋势(2001-2018)



- TP多年平均年蒸散发总量为 $496.0 \pm 23.0$ mm, 整个高原年蒸散发的总水量为 $1.238 \pm 0.06$ 亿吨。
- 高原蒸散发量在其东部增加, 西部减少, 但整体呈减少趋势。

# 还在改进。。。。。



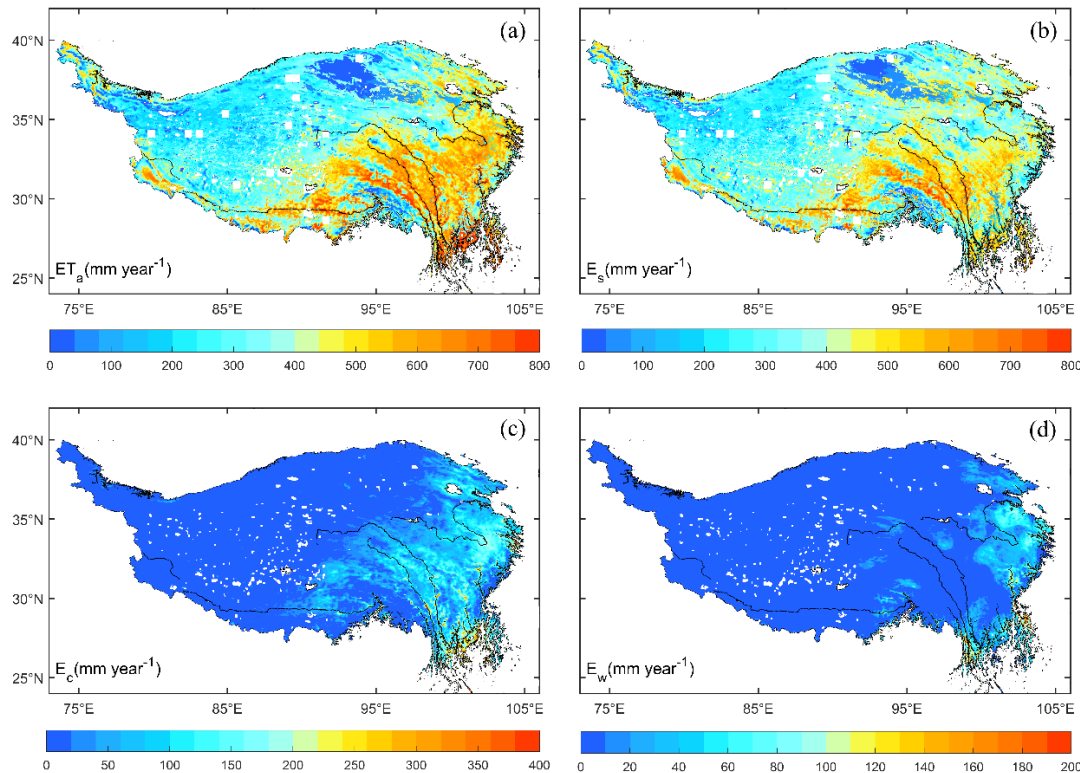
- 提出了基于浅层土壤含水量和土壤质地的改进MOD16蒸散发模型 (MOD16-STM)；
- 相比原始MOD16和基于土壤水分指数的Priestley-Taylor算法，MOD16-STM在独立站点能对蒸散发更准确的估计。

(Yuan, L. Ma\*, Y. and Chen\*, X. et al., 2021, *JGR-Atmospheres*)



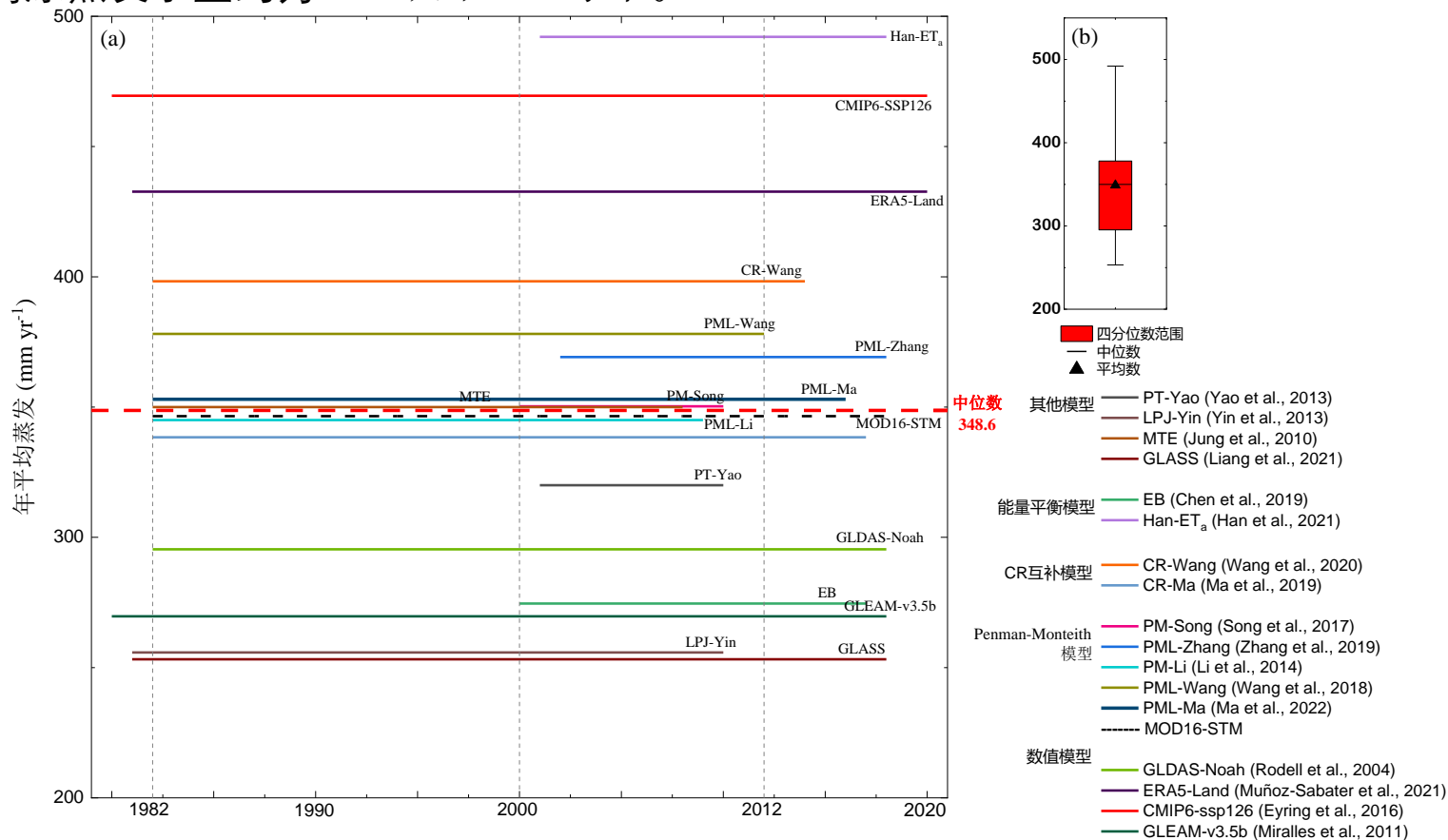
# 青藏高原陆表蒸散发的时空变化分析和蒸发水量 (Yuan, L. Chen\*, X. and Ma\*, Y. et al., 2023, ESSDD)

- 蒸散发空间分布格局由东南向西北递减，土壤蒸发占比超过 84%，青藏高原的年蒸发水量为 346.5 mm (约为  $0.93 \pm 0.037$  万亿吨)。



# 青藏高原陆表蒸散发的时空变化分析和蒸发水量 (Yuan,L. Chen\*,X. and Ma\*,Y. et al., 2022,ESSDD)

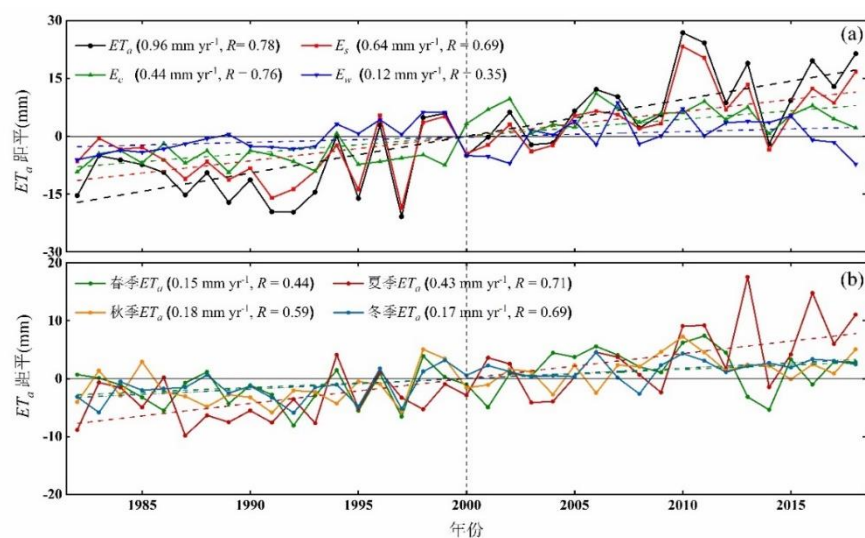
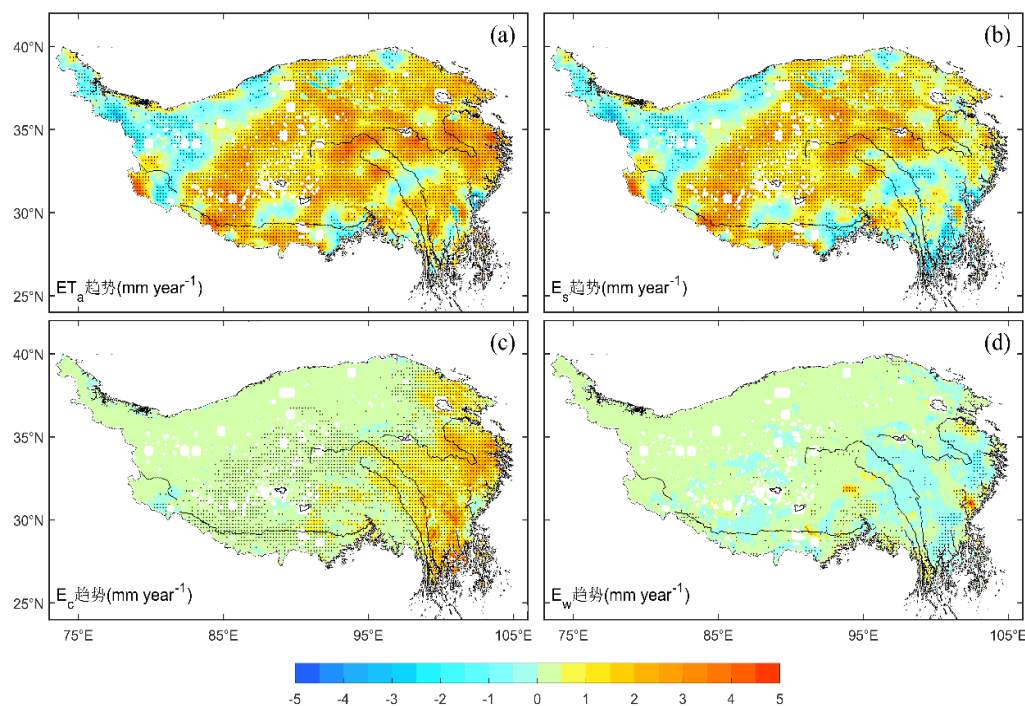
➤ 青藏高原蒸发水量约为0.94 万亿吨/每年。



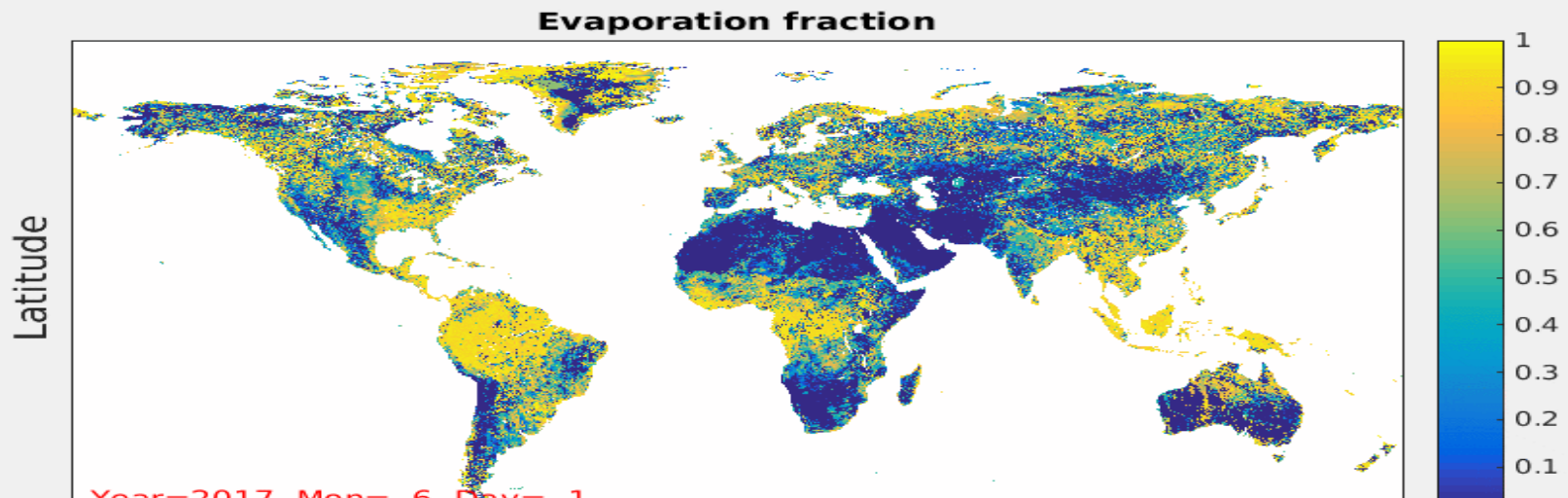
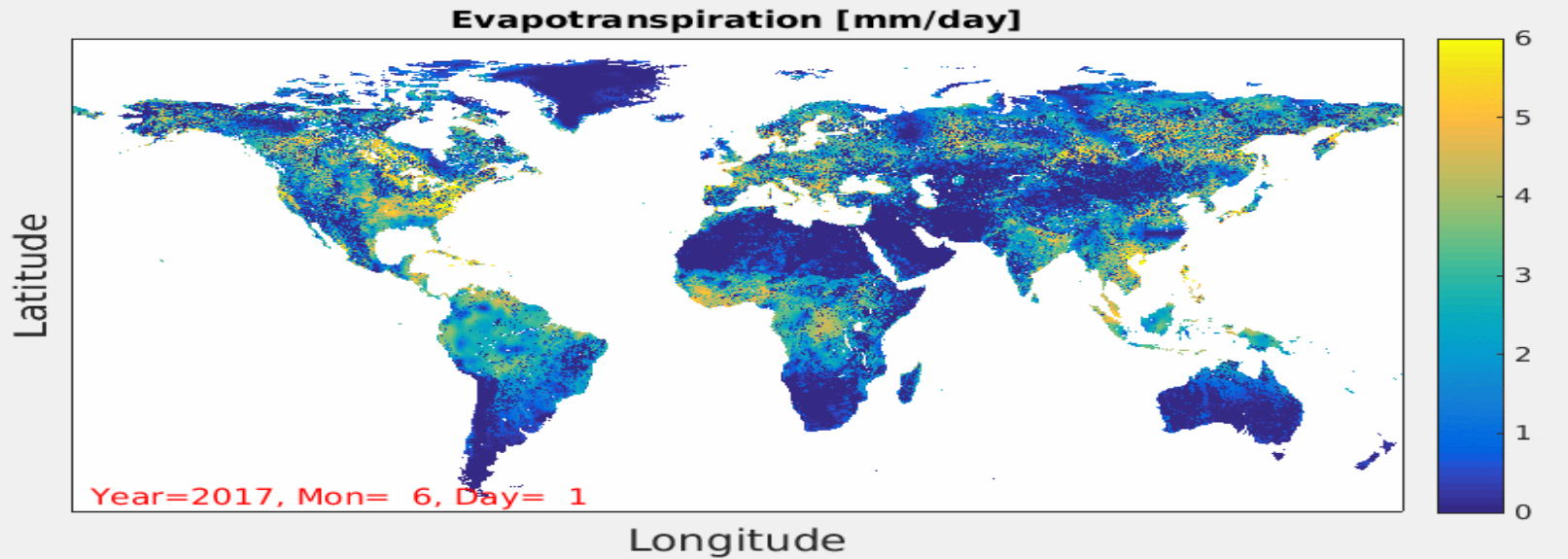


# 青藏高原陆表蒸散发的时空变化分析和蒸发水量 (Yuan,L. Chen\*,X. and Ma\*,Y. et al., 2022,ESDD)

➤ 青藏高原蒸散发在中东部区域呈显著增加趋势，区域年平均趋势为  $0.96 \text{ mm} \cdot \text{year}^{-1}$ 。



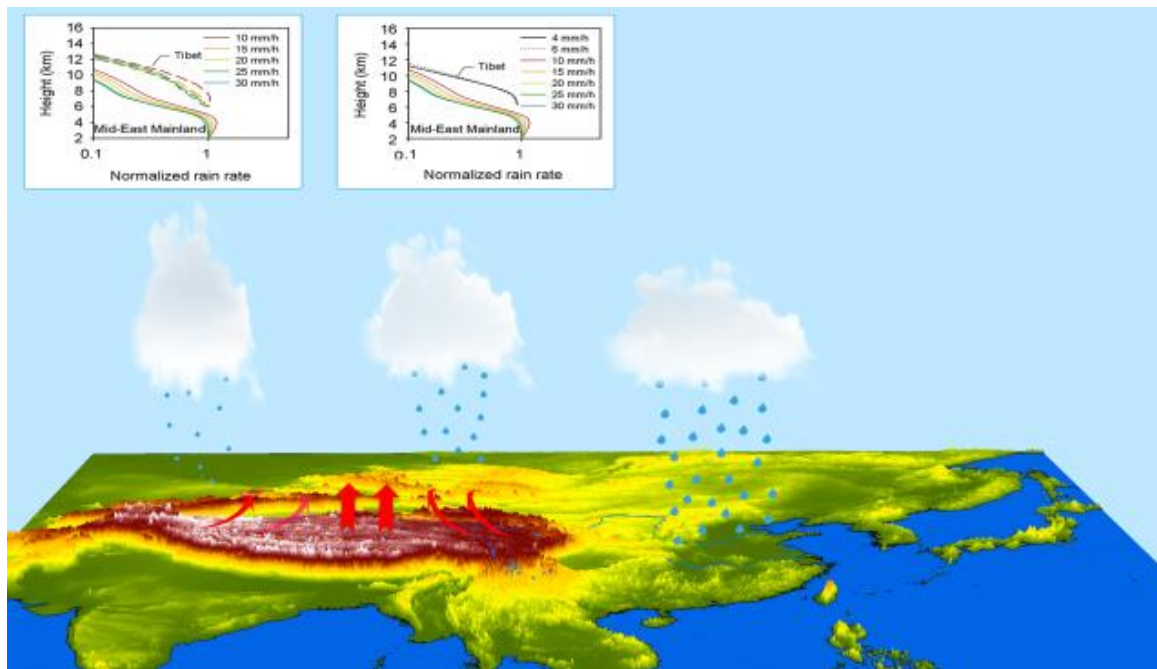
# 4.利用热红外卫星资料发展了全球每天的无空隙蒸发产品; (Chen,X. et al., 2021, JGR-Atmospheres)





**(四) 初步揭示了西风-季风协同作用下地  
气相互作用过程变化规律及其影响天  
气气候变化的机理**

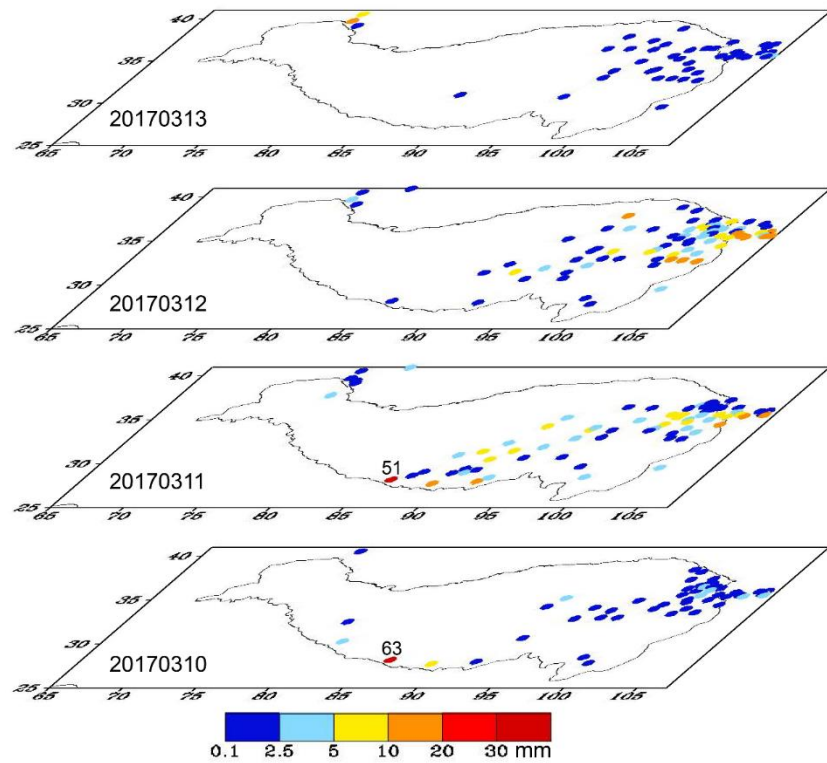
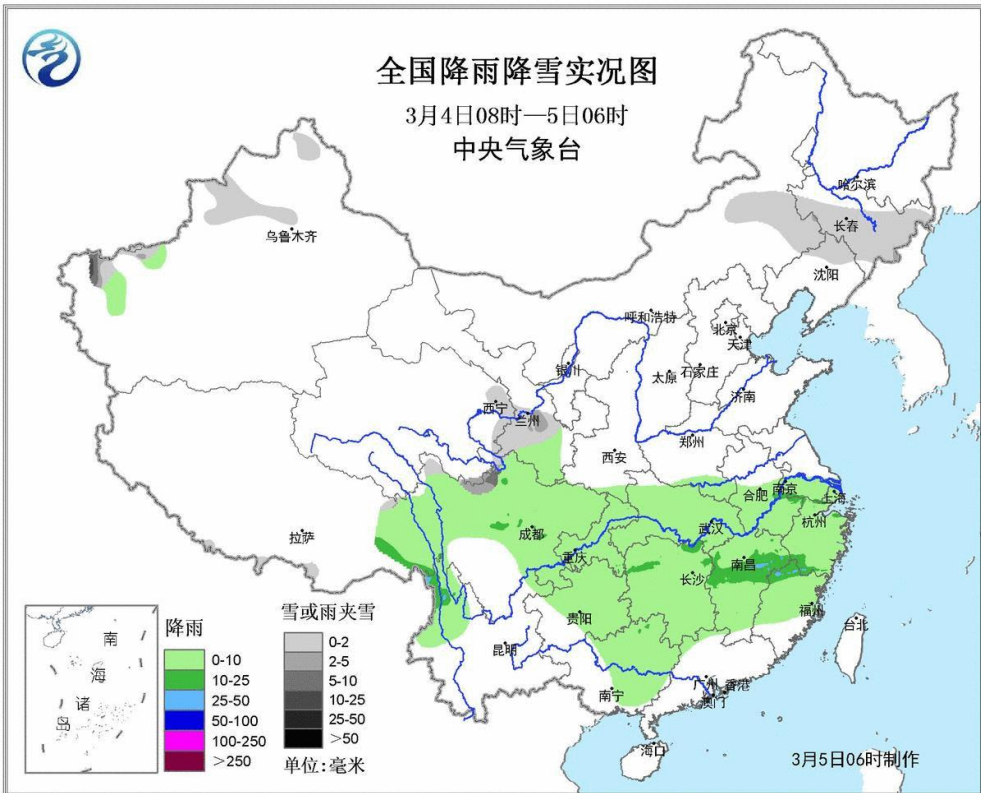
# 1.揭示青藏高原地气相互作用（水热交换）过程及其对下游天气影响规律 (Fu,Y. and Ma\*,Y. et al., 2020, *NSR*)

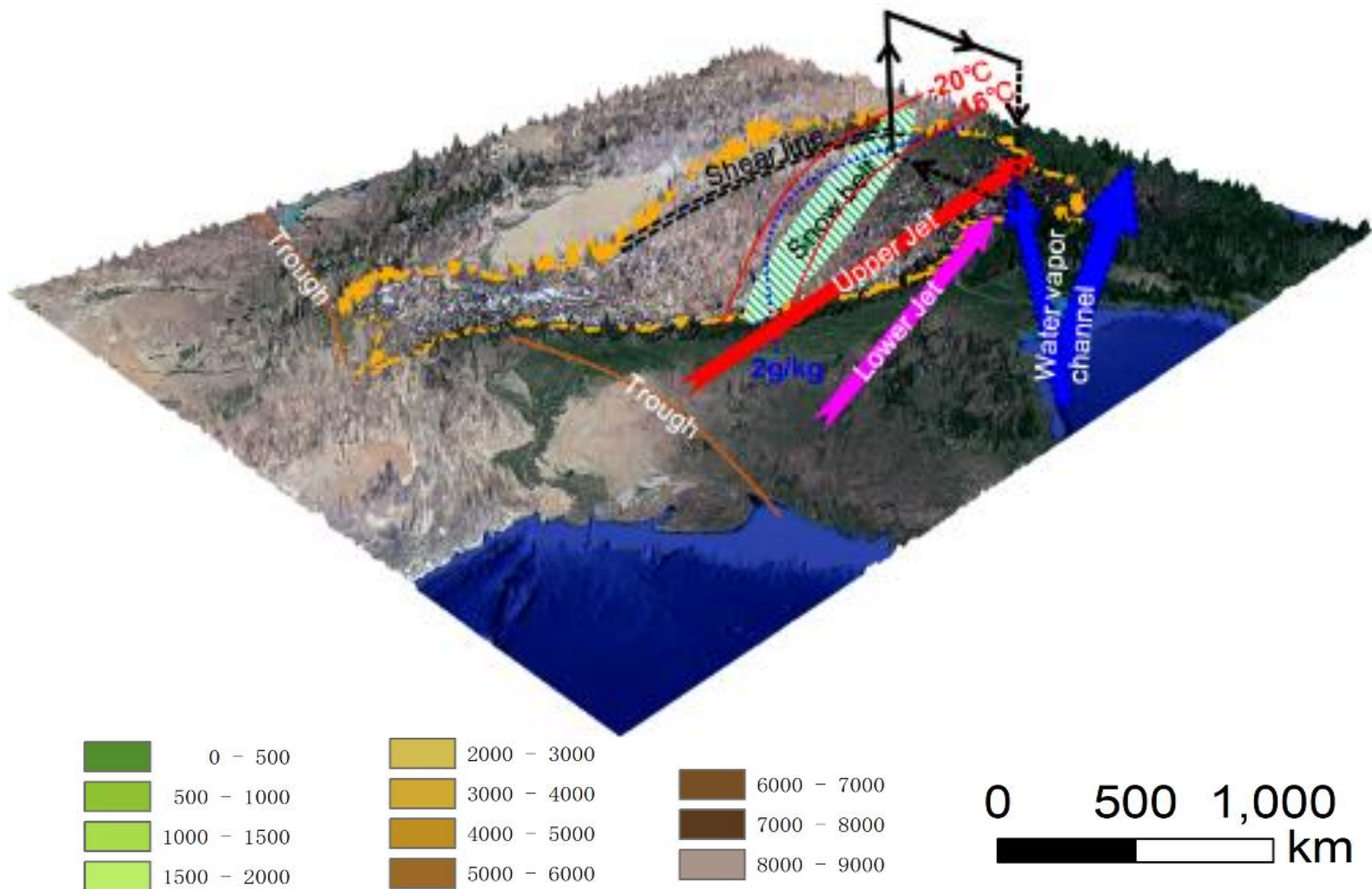


- 揭示了青藏高原地面和边界层热力作用引起的对流活动，与高空短波槽和低压气旋相伴，并东移引起高原东侧及下游地区强对流活动和强降水，且对流活动具有明显的日变化特征。



2. 揭示了青藏高原一次强降雪过程的机制与机理,同时发现我们改进的积雪反照率参数化方案在青藏高原降雪模拟中可以得到很好的应用。这不仅加深了青藏高原强降雪过程发展和演变机制的理解,并为准确预报青藏高原地区短期强降雪和发展可持续畜牧业提供了理论参考和科学依据,达到提高防灾减灾能力的目的。(Liu,L. and Ma\*,Y. et al., 2021, *CD*; Liu,L. and Ma\*,Y. et al., 2021, *HESS*; Liu ,L., Menenti,M. and Ma\*,Y. et al., 2022, *AAS* )

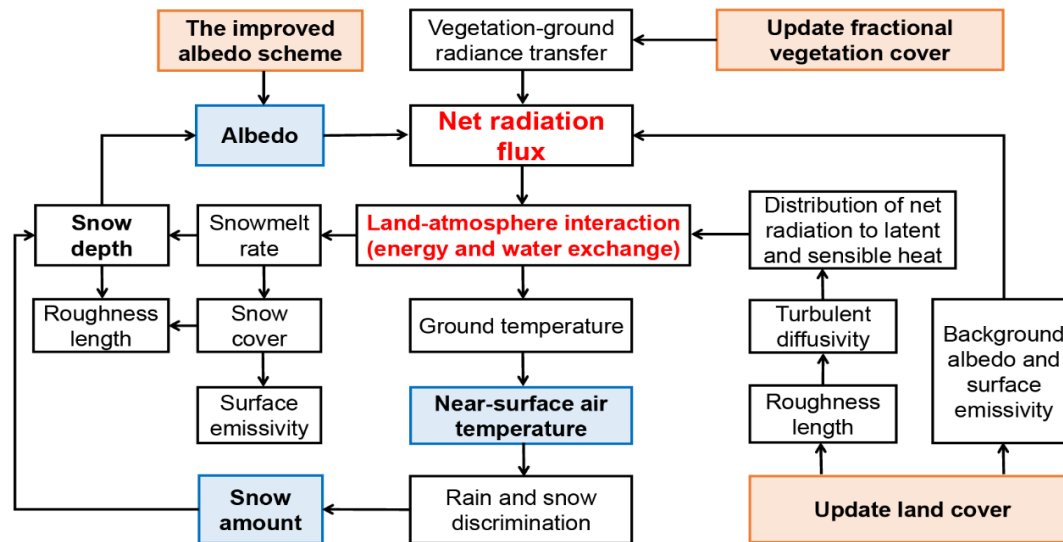




天气形势、要素配置与降雪落区综合图

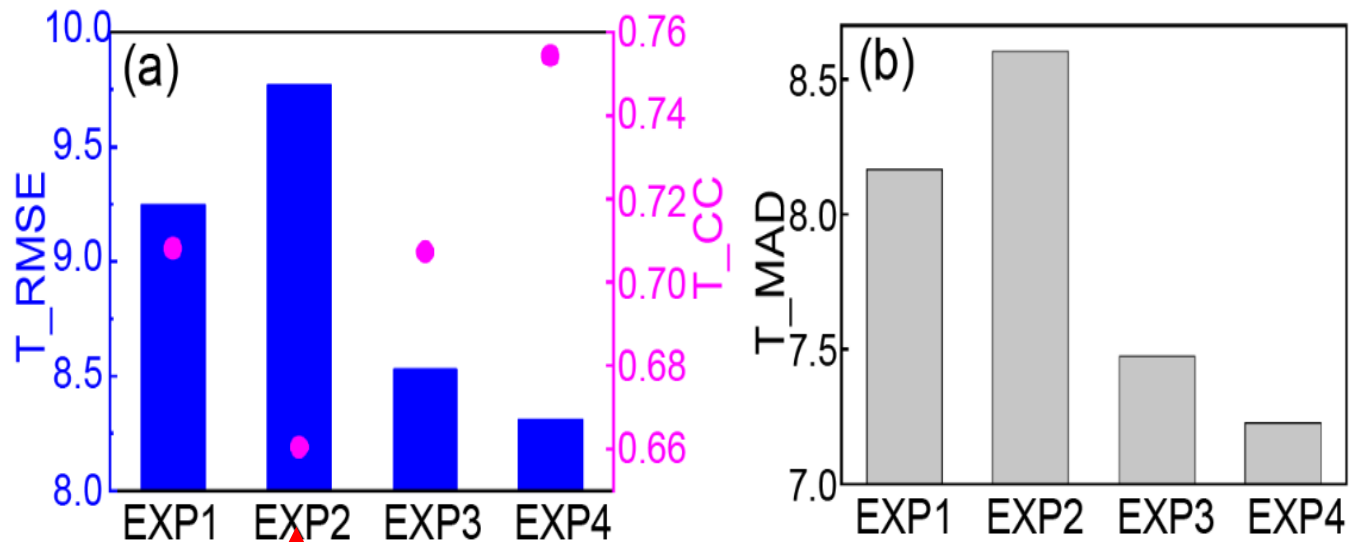
通过分析发现“北涡南槽型”是影响本次强降雪过程主要的天气尺度环流形势，水汽强辐合以及强动力抬升为降雪过程的发展、维持提供了重要条件。



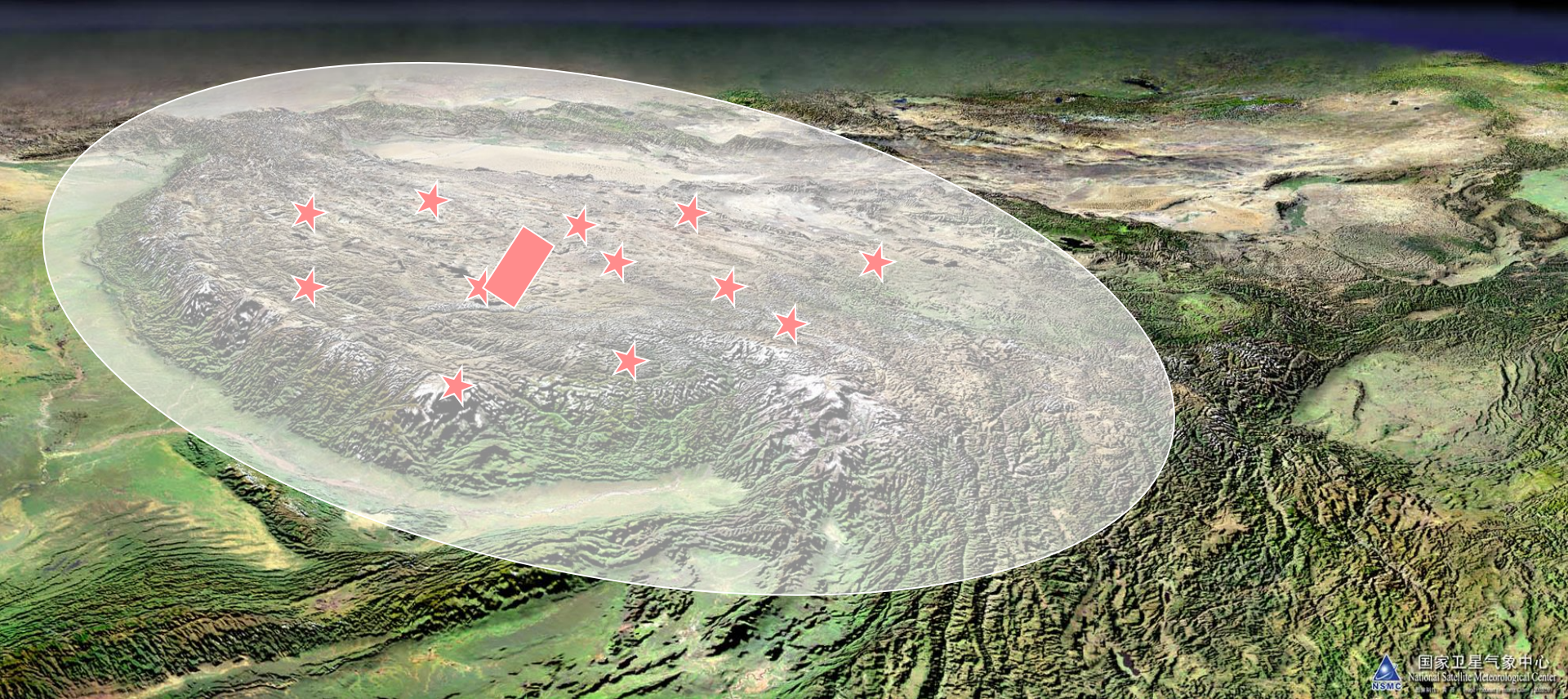


地表参数（地表反照率、地表类型和植被覆盖度）影响气温、反照率和降雪量的流程图

(Liu, L., Menenti, M. and Ma\*, Y. et al., 2022, AAS)



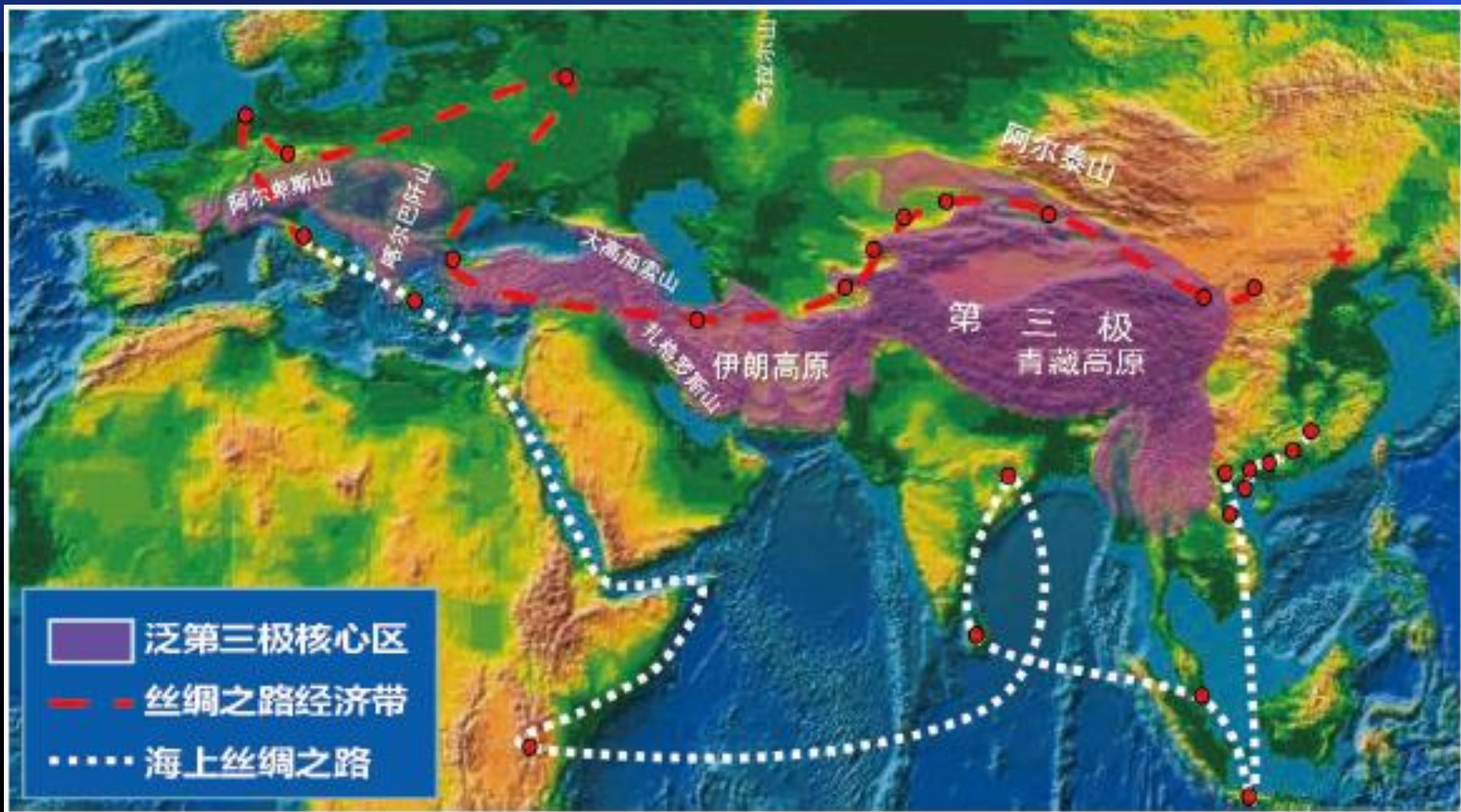
引入观测试验资料



## 四.将要做什么（下一步工作）：

如何到第三极、泛第三极到三极??

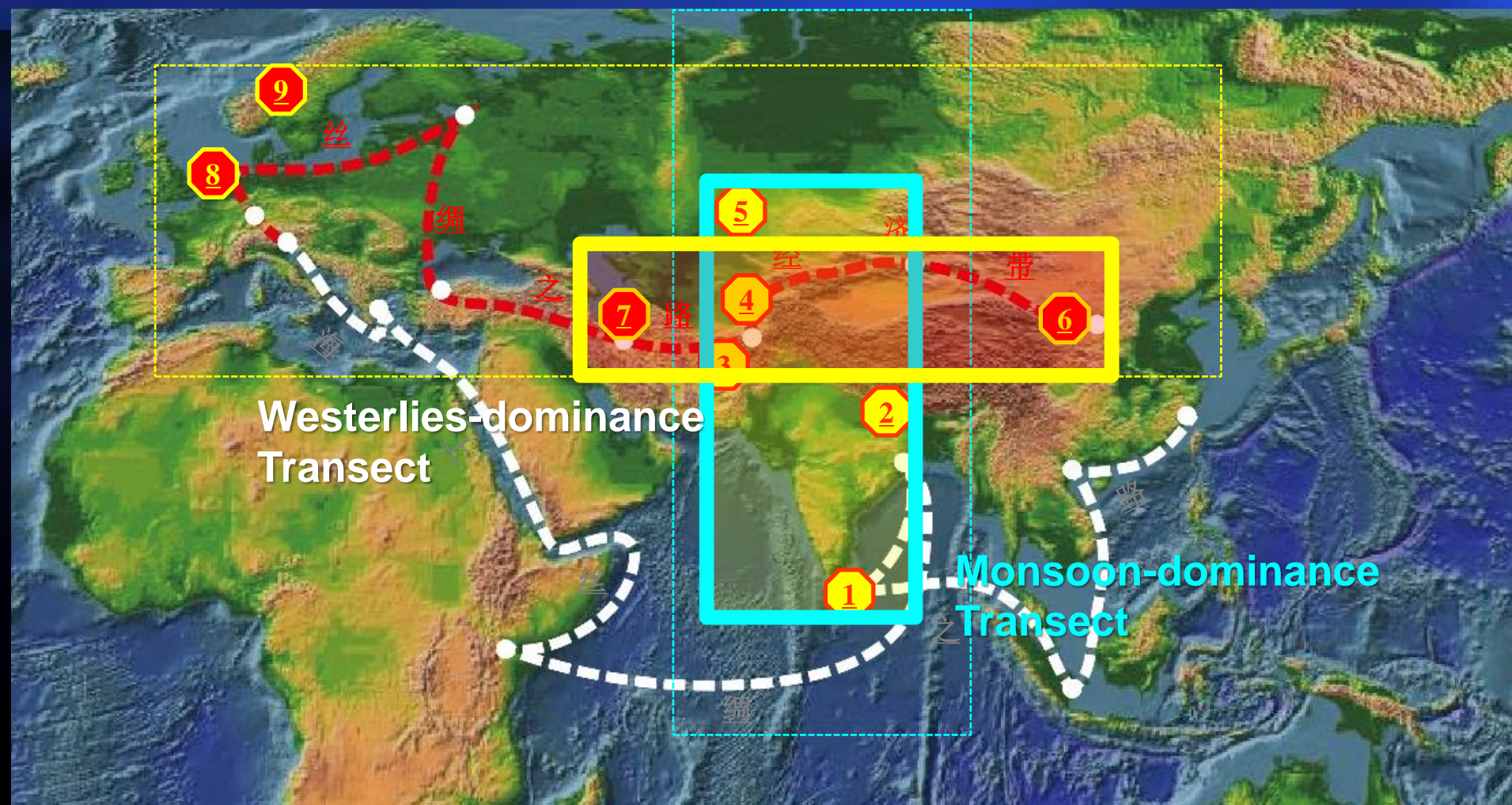




(姚檀栋等, 2017, 中国科学院院刊).

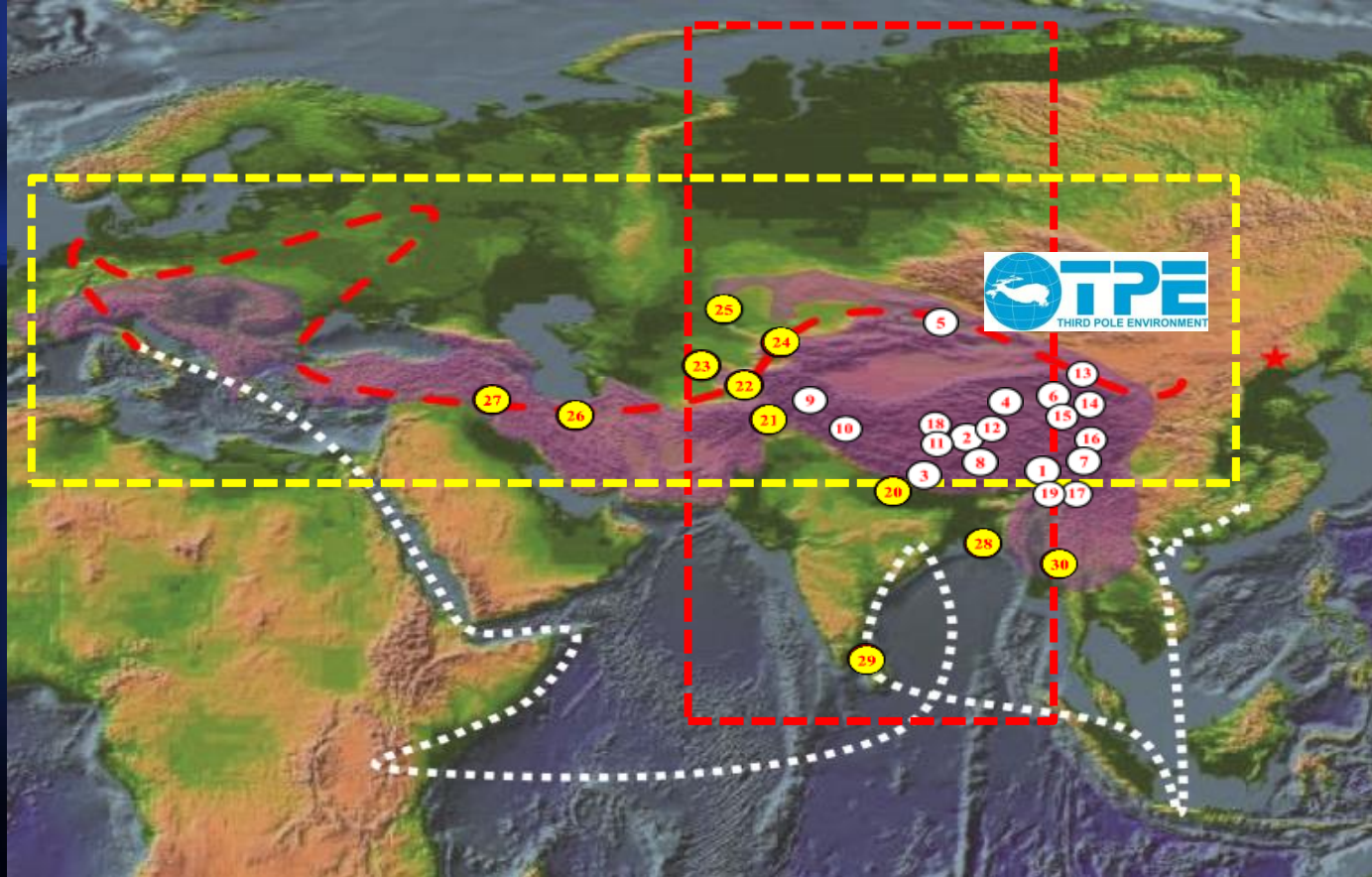


# Pan-TPE: Regional longitudinal and latitudinal transects



- |             |             |            |              |              |
|-------------|-------------|------------|--------------|--------------|
| ① Sri Lanka | ② Kathmandu | ③ Pakistan | ④ Tajikistan | ⑤ Kazakhstan |
| ⑥ Lanzhou   | ⑦ Iran      | ⑧ Germany  | ⑨ Sweden     |              |





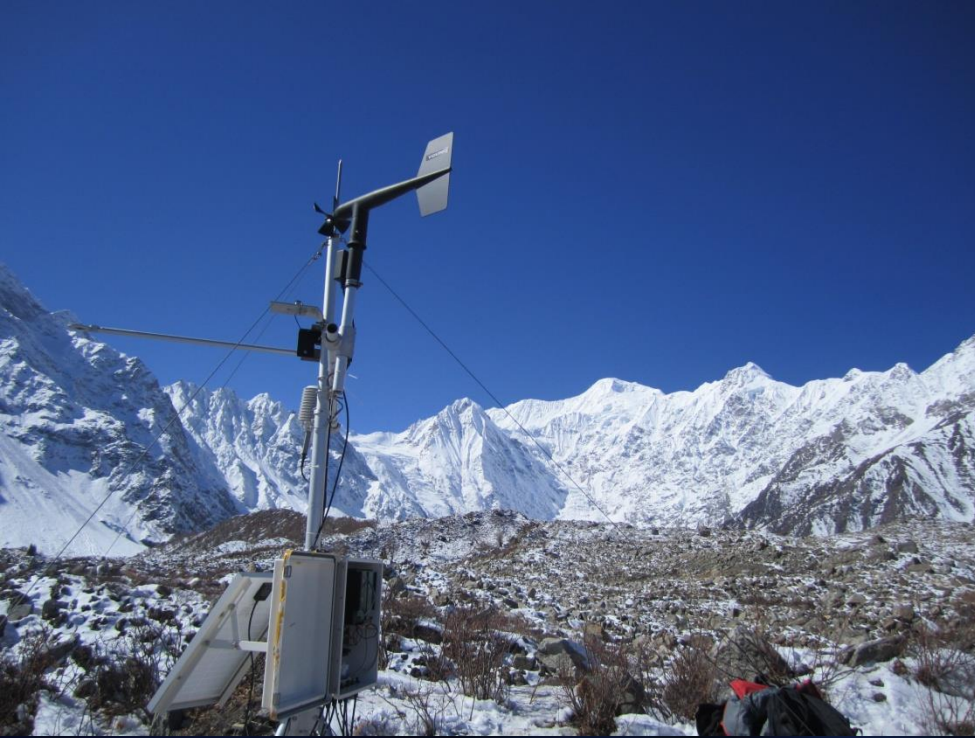
1. Southeastern TP station
2. Namco station
3. Qomolangma station
4. Golmud station
5. Tienshan station
6. Haibei station
7. Gongga station
8. Lahsa station
9. Muztagh Ata station
10. Ngari station
11. Shenzha station
12. Nagqu station
13. Qilianshan station
14. Qinghai lake station
15. Three rivers sources station

16. Norgay station
17. Mt. Yulong station
18. Shuanghu station
19. Motuo station
20. Katmandu (Nepal)
21. Gilgit (Pakistan)
22. Tajikistan (3)
23. Uzbekistan (3)
24. Kyrgyzstan (3)
25. Kazakhstan (6)
26. Iran-1
27. Iran-2
28. Dacca
29. Sri Lanka
30. Myanmar





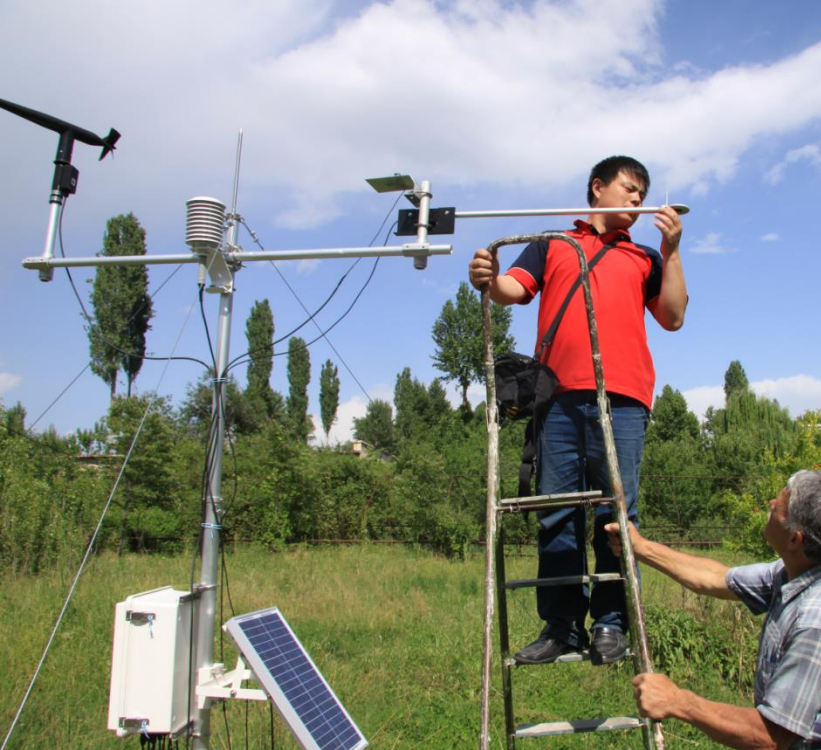




## Pakistan








## Tajikistan stations







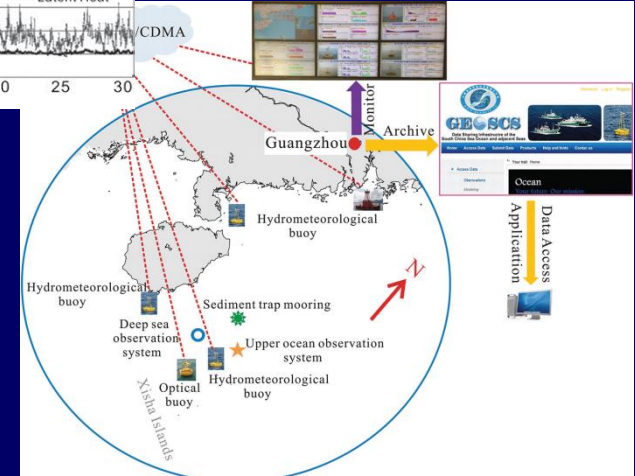
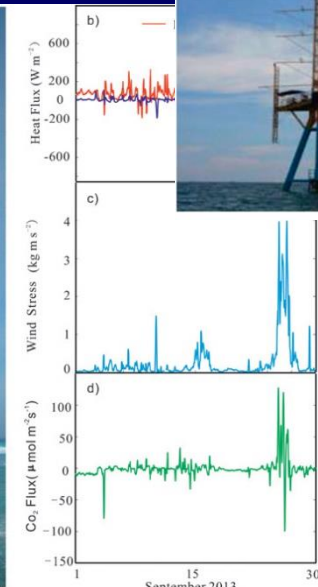
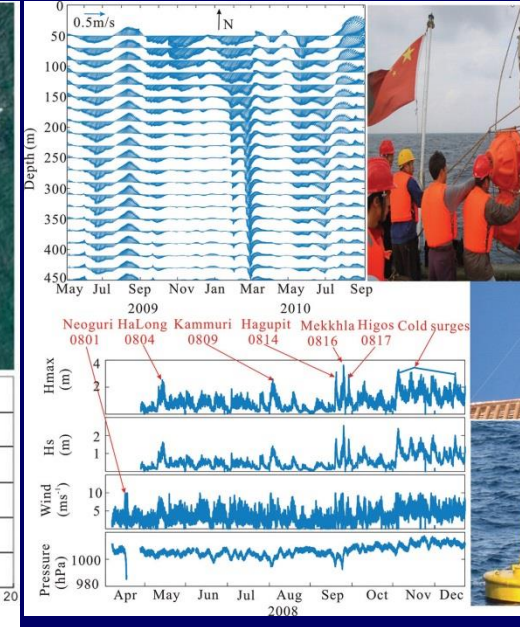
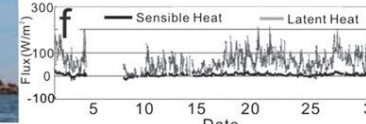
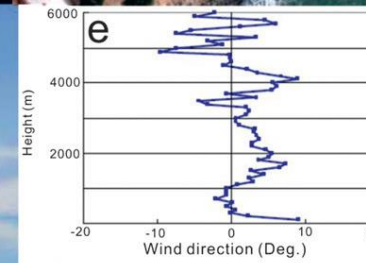
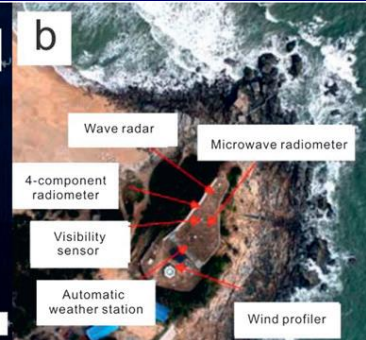
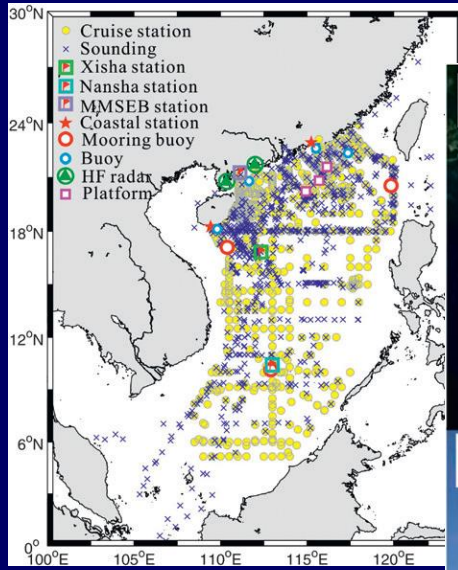
Station	Country	Lon(E)/Lat(N)	Elevation (m)	Ecosystem Type	Start year
Kalabalik	Kazakhstan	62° 06'07/53° 50'52	195	grassland	2012
Shchuchinsk	Kazakhstan	70° 13'10/52° 56'52	400	forest	2012
Atyrau	Kazakhstan	51° 56'52/47° 9'54	20	desert	2012
Kyzylorda	Kazakhstan	60° 59'7/46° 1'54	55	wetland	2012
Almaty	Kazakhstan	76° 13'6/44° 38'25	500	oasis	2012
Kyzyl-Suu	Kyrgyzstan	78° 12'00/42° 11'29	2540	mountain ecosystem	2012
Kondara	Kyrgyzstan	68° 49'51/38° 53'37 "	1411	mountain ecosystem	2013
Danghara	Tajikistan	69° 19'/38° 05'	600	cropland	2014
Zangiota	Uzbekistan	69° 07.74'/41° 10.6 1'	370	oasis cropland	2012



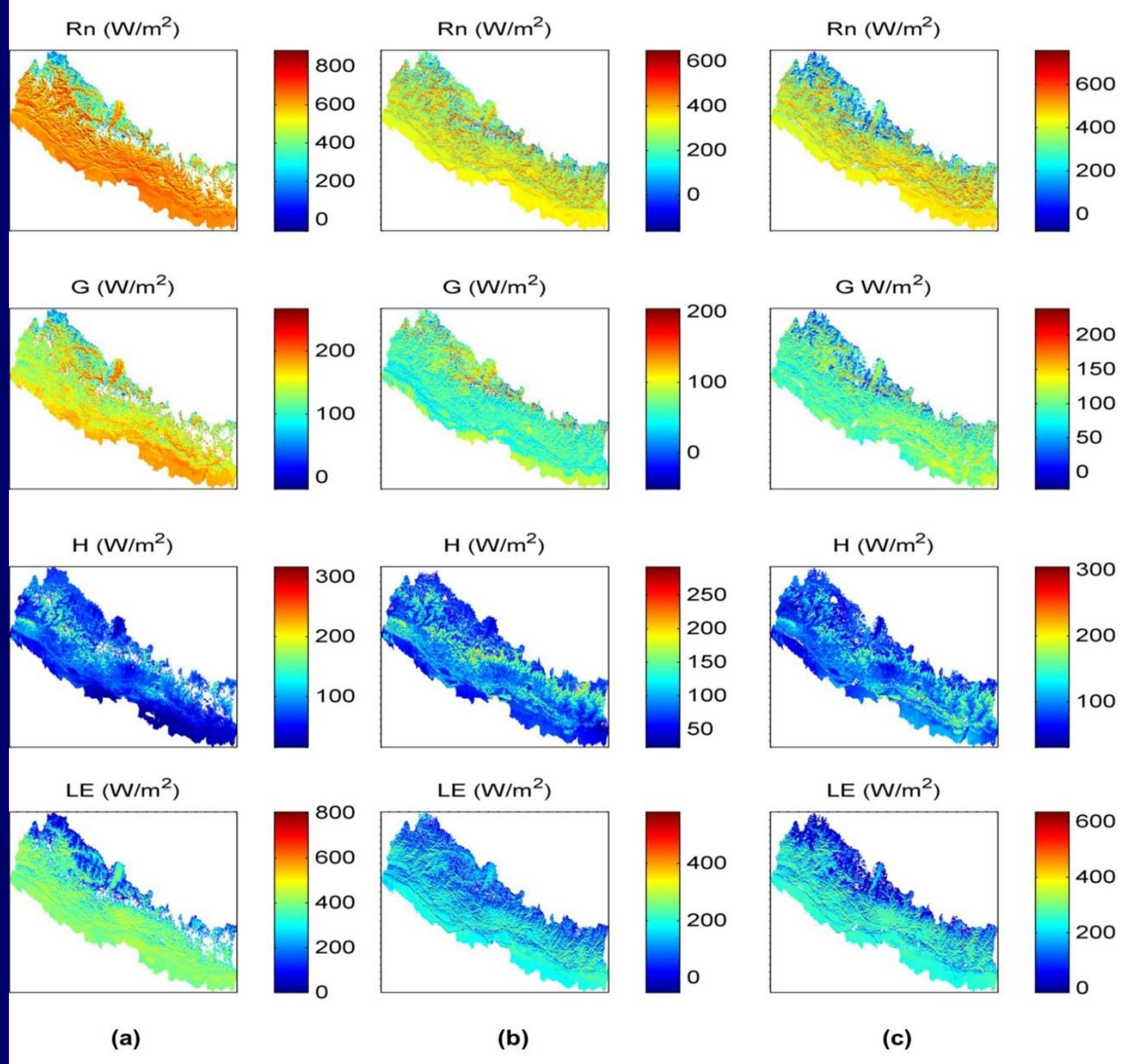




# A MESOSCALE HYDROLOGICAL AND MARINE METEOROLOGICAL OBSERVATION NETWORK IN THE SCS

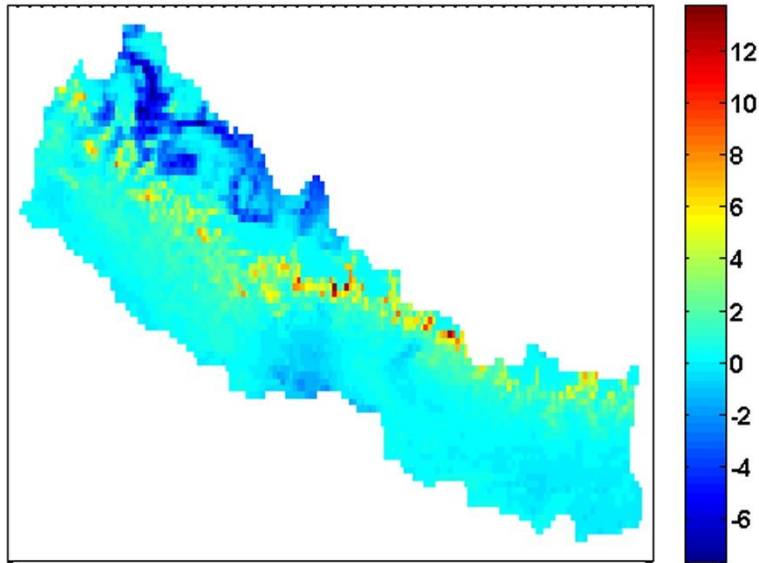


# 尼泊尔区域 能量分布 (Pukar and Ma, Y.et al., 2015,AR)

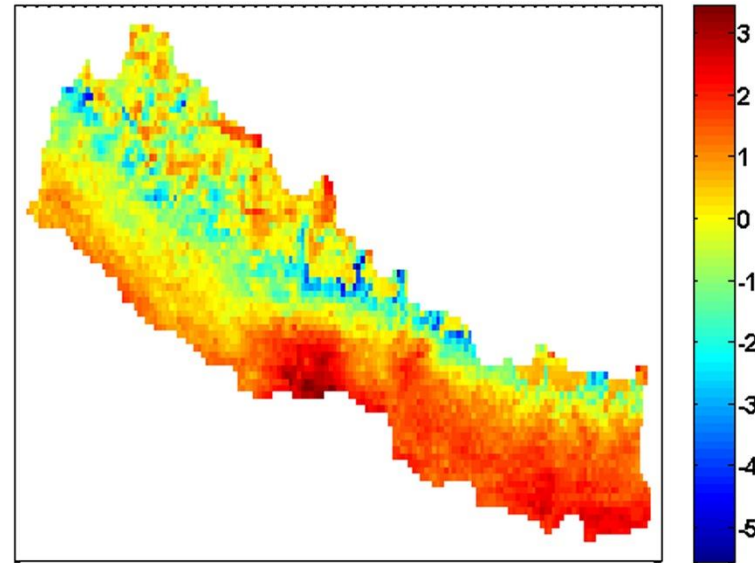




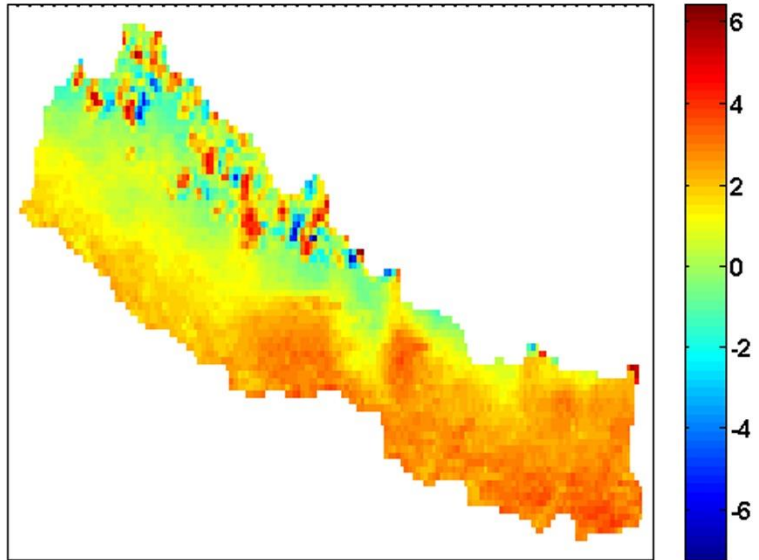
(a) Sensible heat flux ( $W/m^2$ , 2003-2013)



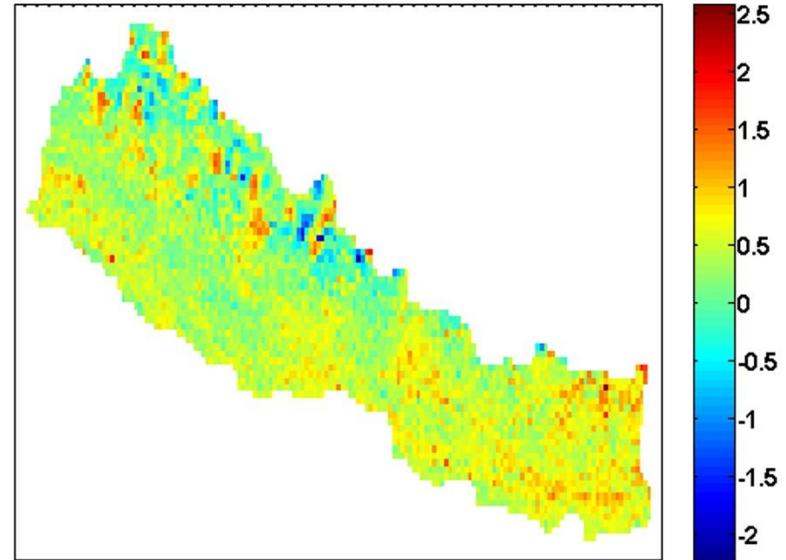
(b) Latent heat flux ( $W/m^2$ , 2003-2013)



(c) Net radiation ( $W/m^2$ , 2003-2013)



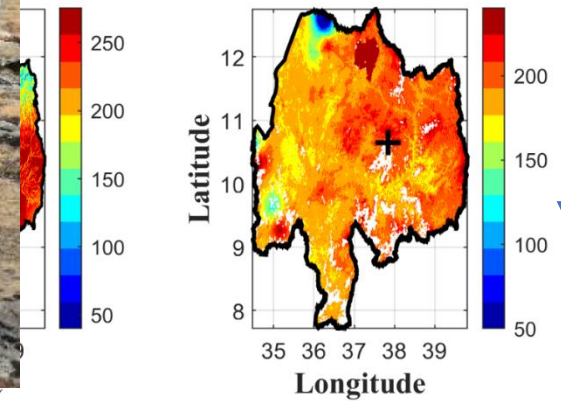
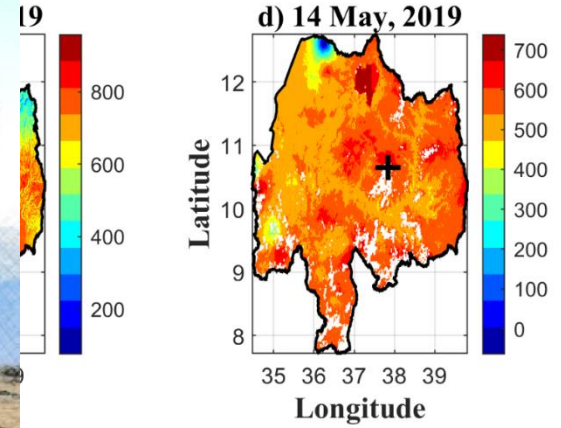
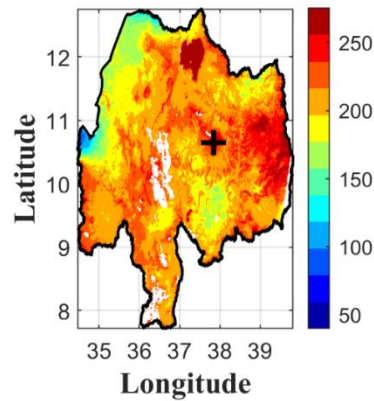
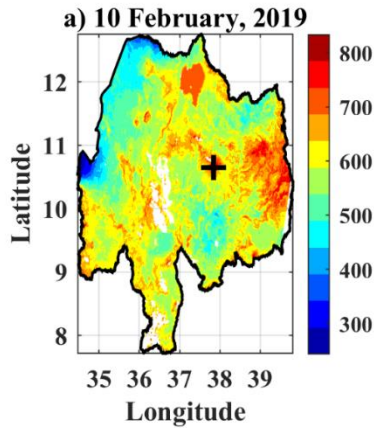
(d) Ground heat flux ( $W/m^2$ , 2003-2013)



**Spatial trends ( Pukar and Ma, Y. et al., 2015, JGR)**

Both  $R_n$  &  $G_0$  va

$R_n$



(Bayable, E. and Ma\*, Y. et al., 2021, TAAC)



# 泛第三极地区地气相互作用（水热交换） 过程及其天气气候变化的影响规律

TORP+TPEP+Pan-TPF

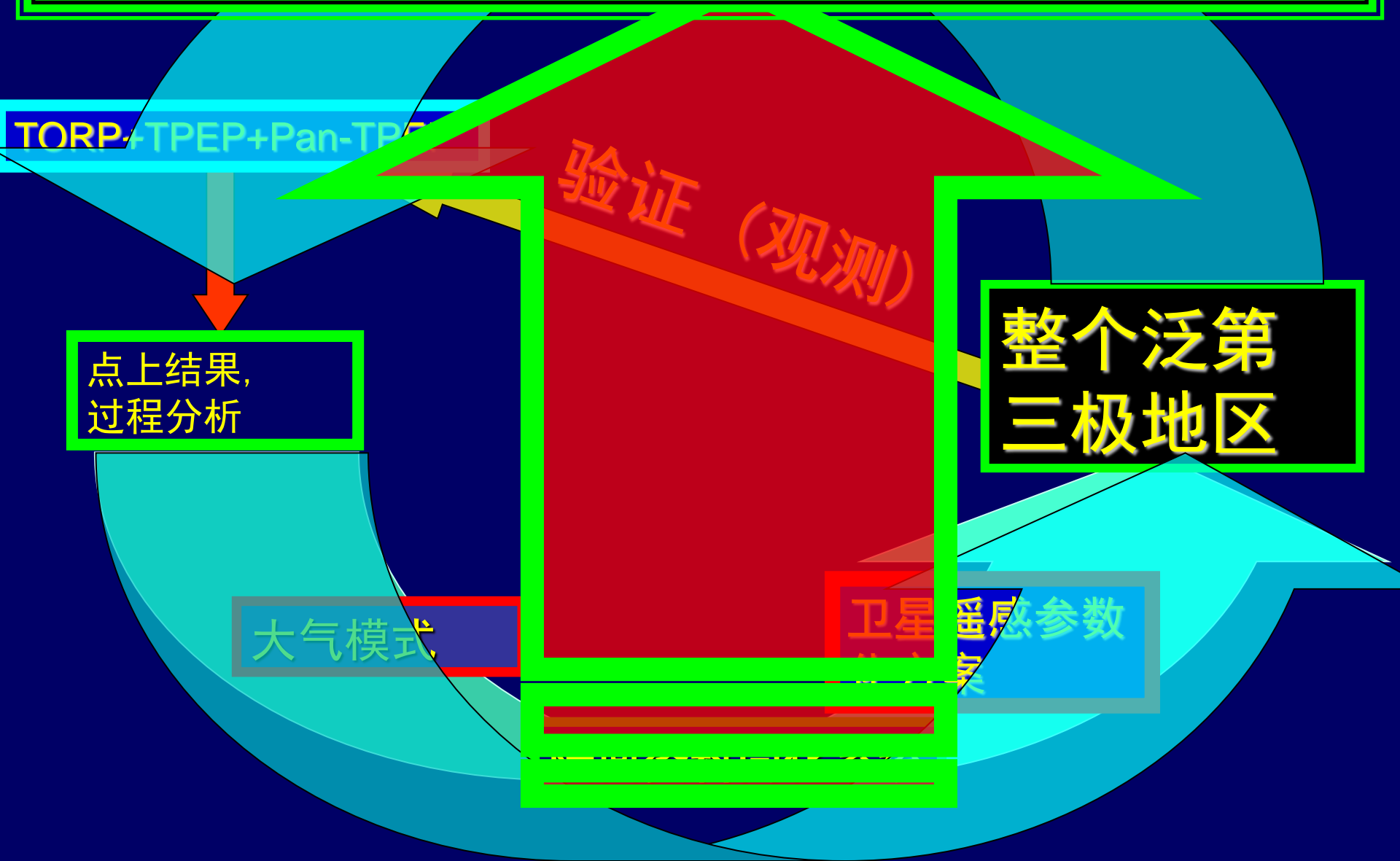
点上结果,  
过程分析

大气模式

验证 (观测)

整个泛第  
三极地区

卫星遥感参数



# 谢谢!

[ymma@itpcas.ac.cn](mailto:ymma@itpcas.ac.cn)

[http://sourcedb.itpcas.cas.cn/cn/expert/200907/t20090706\\_2001505.html](http://sourcedb.itpcas.cas.cn/cn/expert/200907/t20090706_2001505.html)

