2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

[PROJECT ID. 58516].

Monitoring and Modelling Climate Change in Water, Energy and Carbon Cycles in the Pan-Third Pole Environment (CLIMATE-Pan-TPE)

THURSDAY, 14/SEPT/2023, S.1.6: CLIMATE CHANGE

DRAGON 5 ID. 58516

MONITORING AND MODELLING CLIMATE CHANGE IN WATER, ENERGY AND CARBON CYCLES IN THE PAN-THIRD POLE ENVIRONMENT

PROJECT SUMMARY PRESENTED BY BOB SU

PI Europe Prof. Bob Su
University of Twente, Enschede
NETHERLANDS

PI China Prof. Ma Yaoming
Institute of Tibetan Plateau Research,
Chinese Academy of Sciences
CHINA

PROJECT PARTNERS AND ROLES

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Xuelong Chen (ITP), water vapor transport to the Tibetan Plateau, Land-atmosphere interactions
Binbin Wang (ITP), lake dynamics
Donghai Zheng (ITP), land surface processes
Cunbo Han (ITP), atmospheric boundary layer
Han Zheng (CAU), remote sensing
Jan G. Hofste (UT), scatterometry
Mengna Li (UT), integrated modelling of water cycle
Lianyu Yu (NWAF), freeze/thaw processes and soil moisture - groundwater interactions
Pei Zhang (UT), soil moisture and climate change trends
Hong Zhao (UT), community land active and passive microwave simulation
Yunfei Wang (UT), integrated energy, water and carbon transfers between land and the atmosphere
Ting Duan (UT), Retrieval of soil moisture and leaf area index
Qianqian Han (UT), ML based global soil moisture and fluxes retrievals

+6 poster presentations

Objectives of CLIMATE-Pan-TPE:

- Improve process understanding of the interactions between the Asian monsoon, plateau surface and atmosphere (in terms of water, energy and carbon budgets);
- Assess and monitor changes in cryosphere and hydrosphere;
- Model and predict climate change impacts on water resources and ecosystems in the Pan-Third Pole Environment.

- **ESA, Chinese and TPM data**

ESA EO data (ERS, ENVISAT, **Earth Explorer, and Sentinel**)

Chinese EO data (FY SERIES)

ESA TPM data (ALOS for validation sites, **MODIS, SMAP**)

Other Data

- Nationwide meteorological data (historical and real time data) (CNMC)
- Experimental database for all experimental sites (site PIs)
- Reanalysis data (ERA5, corrected NCEP reanalysis data and MERRA data)
- DEM and soil maps over China (ITC)
- Vegetation cover maps over China and the TPE (available at ITC)
- In-situ observation data from climate stations operated by ITP and NIEER

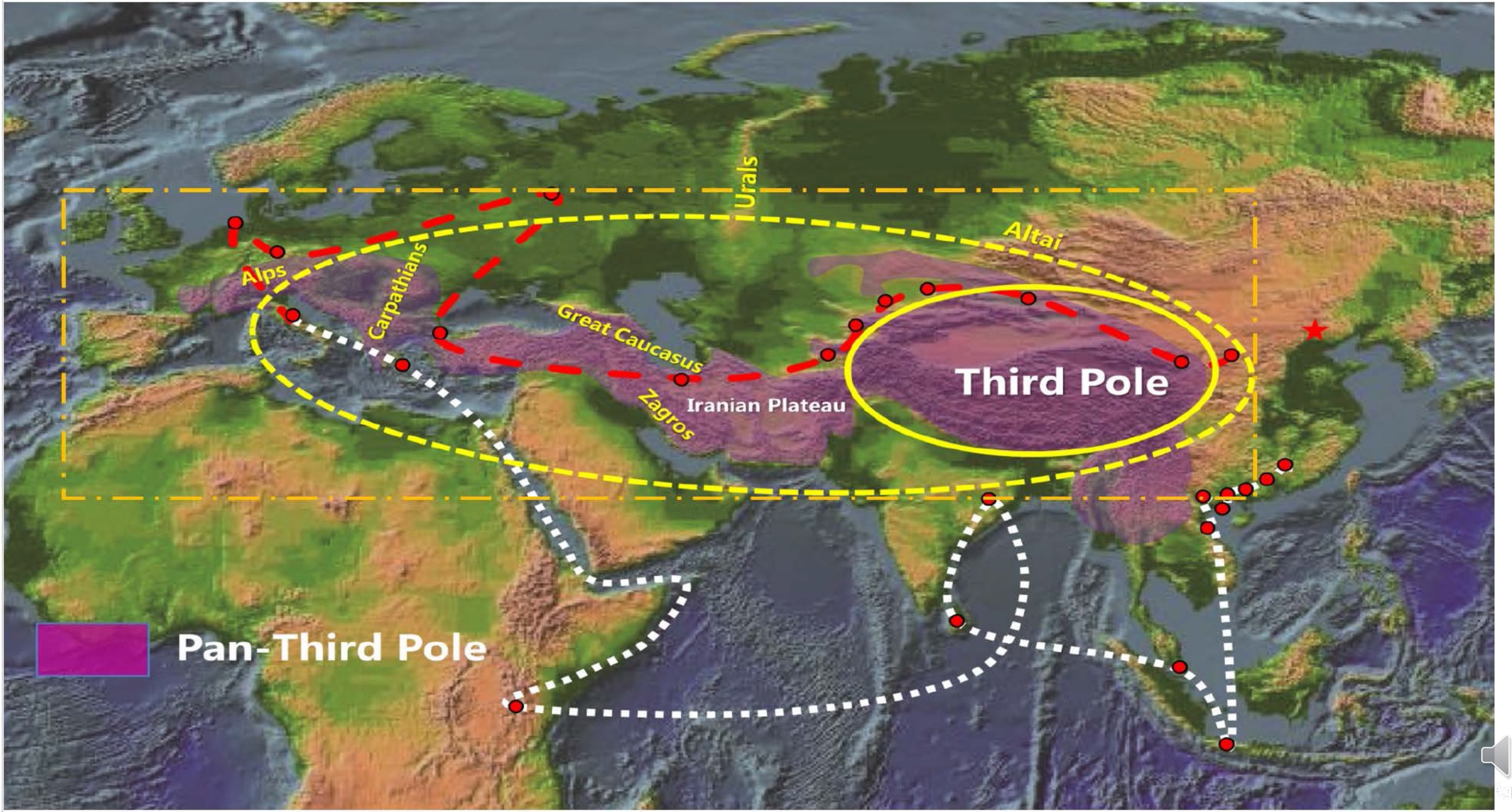
CLIMATE-Pan-TPE Work Plan

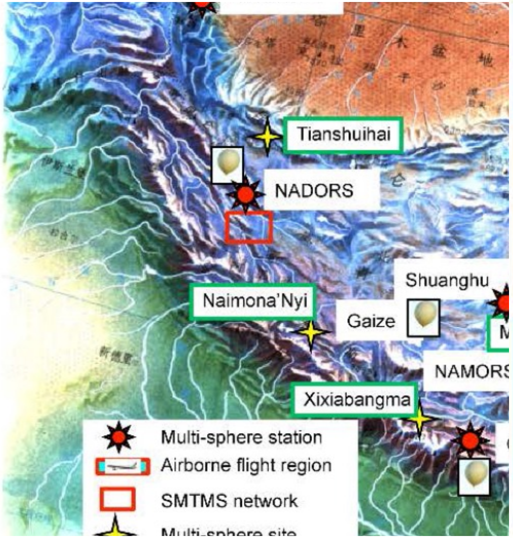
WP1: Observation and modelling of microwave scattering and emission under complex terrains with permafrost and freeze – thawing conditions.

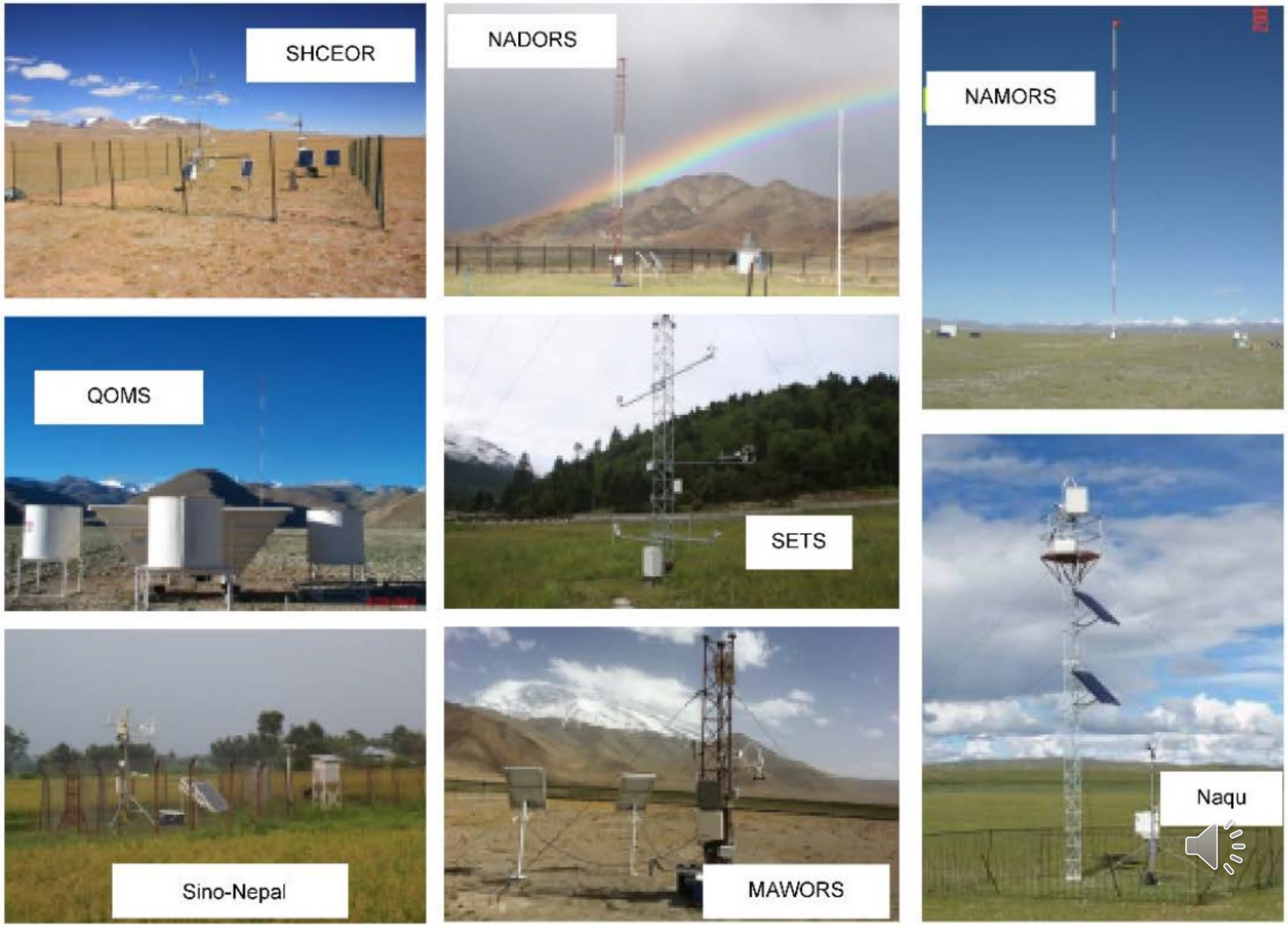
WP2: Advancement of physical understanding and quantification of changes of water and energy budgets in Pan-TPE.

WP3: Advancement of quantifying changes in surface characteristics and monsoon interactions.

WP4: Modelling and predicting climate change impacts on water resources and ecosystems in the Pan-Third Pole Environment.


Urals
Altai
Alps
Carpathians
Great Caucasus
Zagros
Iranian Plateau
Third Pole
Pan-Third Pole



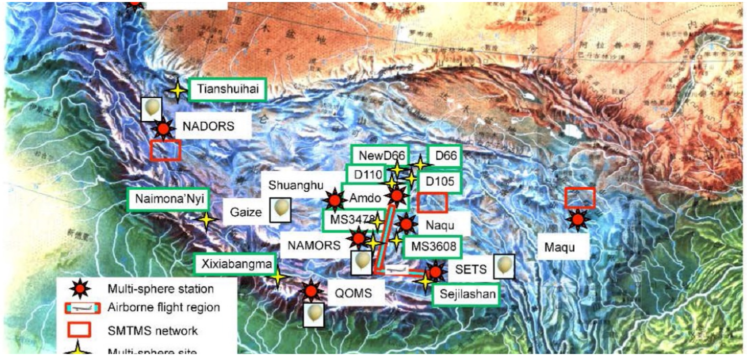


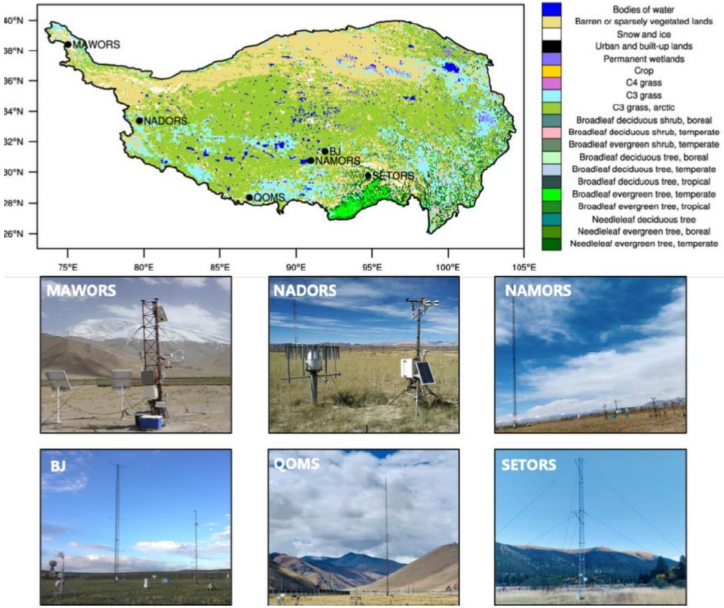
(a) Observation stations (sites) of hydrosphere-pedosphere-atmosphere-cryosphere-biosphere interactions over the TP (b) Observation instruments for different land surfaces).

Results:

1. a long-term (2005-2016) hourly dataset of the integrated land-atmosphere interaction observations from six field stations over the Tibetan Plateau;
2. monthly actual evapotranspiration and its spatial distribution on the TP (2001-2018) using the Surface Energy Balance System (SEBS) model with satellite products and meteorological reanalysis data as input;
3. hourly land surface heat fluxes and evapotranspiration estimated based on multisource remote sensing data;
4. a monthly 0.01° terrestrial evapotranspiration product for the TP (1982-2018) using the MOD16-STM equation;
5. estimation of the total annual evaporation amounts over the entire TP lakes as 51.7±2.1 km^3 $year^{-1}$, with a plausible hypothesis of near-zero heat storage during ice-free season and near-constant ice sublimation during winter; and
6. the water vapor channel of the Yarlung Zangbo Grand Canyon (YGC) in the southeastern TP was investigated by establishing a three-dimensional comprehensive observation system of mountain land-air interaction, water vapor transport, cloud cover, and rainfall activity.
7. methods for estimating surface soil moisture, monitoring and predicting freeze-thaw states and quantifying soil ice content with microwave remote sensing data;

Observation stations (sites) of hydrosphere-pedosphere-atmosphere-cryosphere-biosphere interactions over the Tibetan Plateau





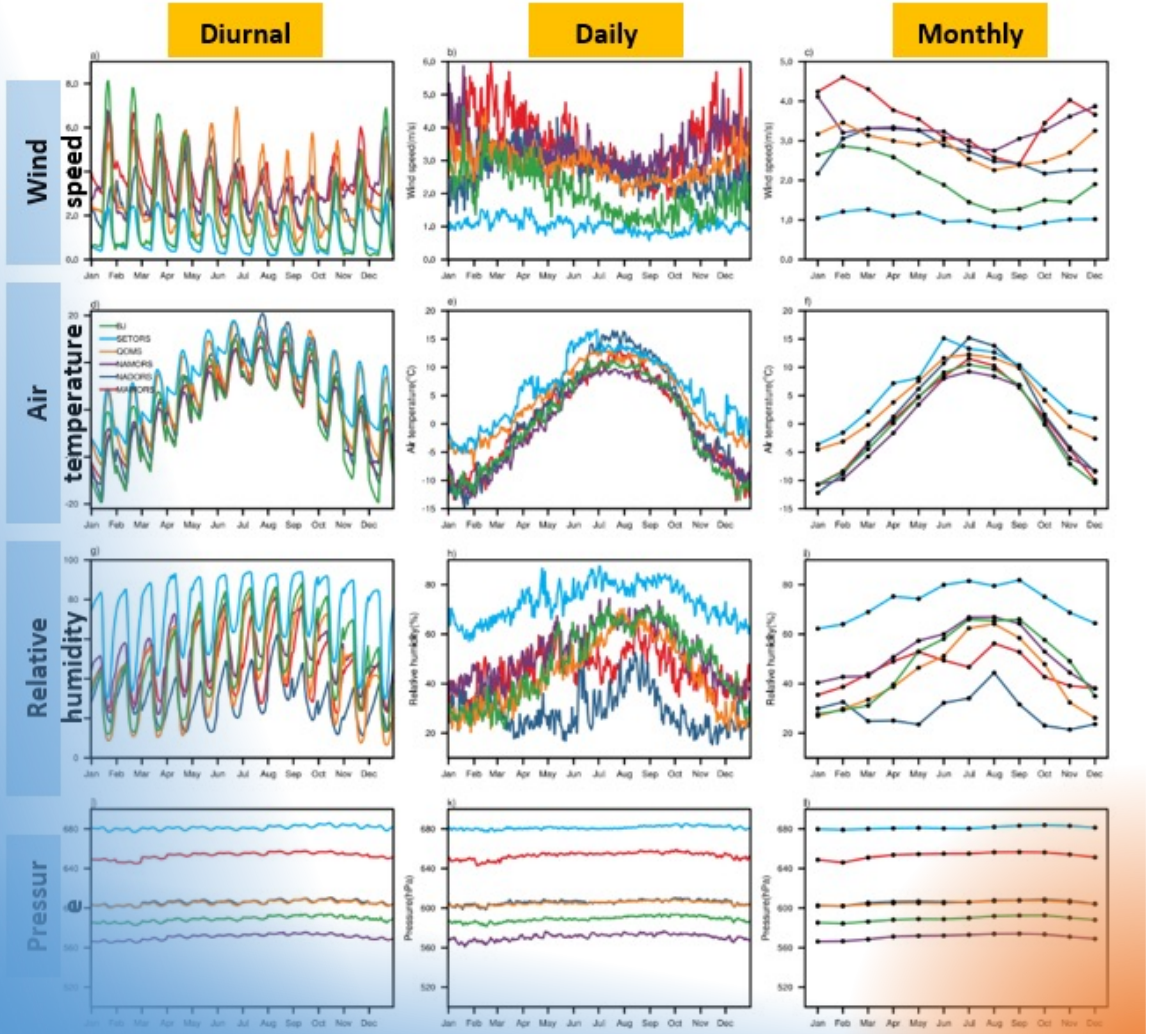
Earth Syst. Sci. Data, 12, 2937–2957, 2020
https://doi.org/10.5194/essd-12-2937-2020

Open Access
Earth System
Science
Data

A long-term (2005–2016) dataset of hourly integrated land–atmosphere interaction observations on the Tibetan Plateau

Yaoming Ma[1,2,3], Zeyong Hu[2,4], Zhipeng Xie[1], Weiqiang Ma[1,2], Binbin Wang[1], Xuelong Chen[1], Maoshan Li[5], Lei Zhong[6,7], Fanglin Sun[4], Lianglei Gu[4], Cunbo Han[1], Lang Zhang[1], Xin Liu[1], Zhangwei Ding[1], Genhou Sun[8], Shujin Wang[4], Yongjie Wang[1], and Zhongyan Wang[1]

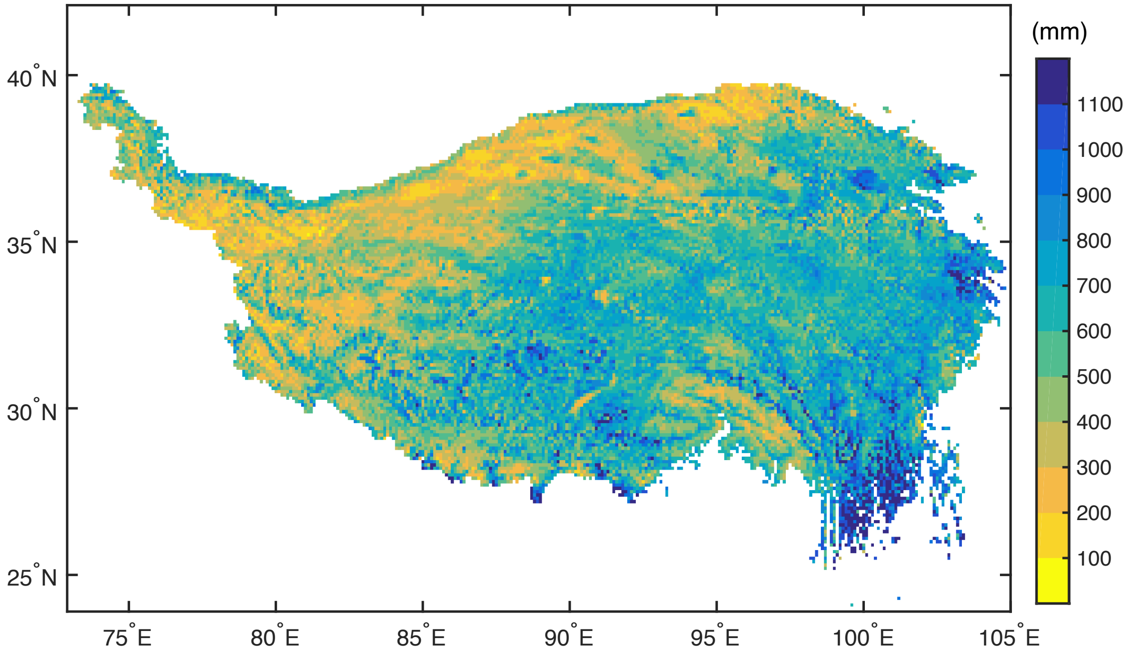
1. Hourly integrated land–atmosphere interaction observations on the Tibetan Plateau



- This dataset has been widely used in meteorology, hydrology, ecology, and remote sensing research

- **(AFM, 2022)**
- **(RSE, 2022)**
- **(One Earth, 2022)**
- **(STONE, 2022)**

2. Monthly Actual Evapotranspiration and Its Spatial Distribution on the Tibetan Plateau from 2001 to 2018

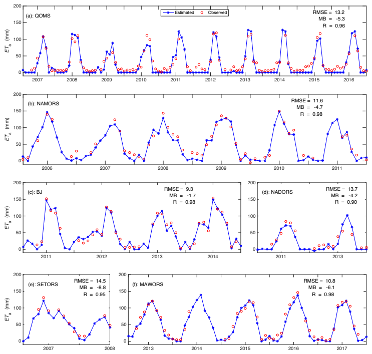


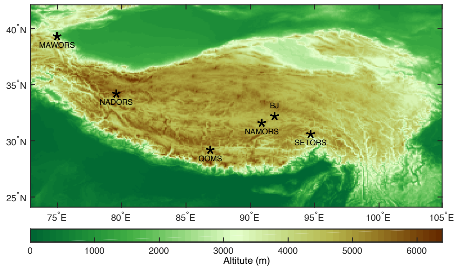
Validation at EC sites

- **R: ≥0.90**
- **RMSE: 9.3-14.5 mm/month**

Han, C., Ma, Y., Wang, B., Zhong, L., Ma, W., Chen, X., and Su, Z.: Monthly mean evapotranspiration data set of the Tibet Plateau (2001–2018), National Tibetan Plateau Data Center [data set], https://doi.org/10.11888/Hydro.tpdc.270995, 2020a

Han, C., Ma, Y., Wang, B., Zhong, L., Ma, W., Chen, X., Su, Z. (2021). Long-term variations in actual evapotranspiration over the Tibetan Plateau. Earth System Science Data, 13(7): 3513-3524.

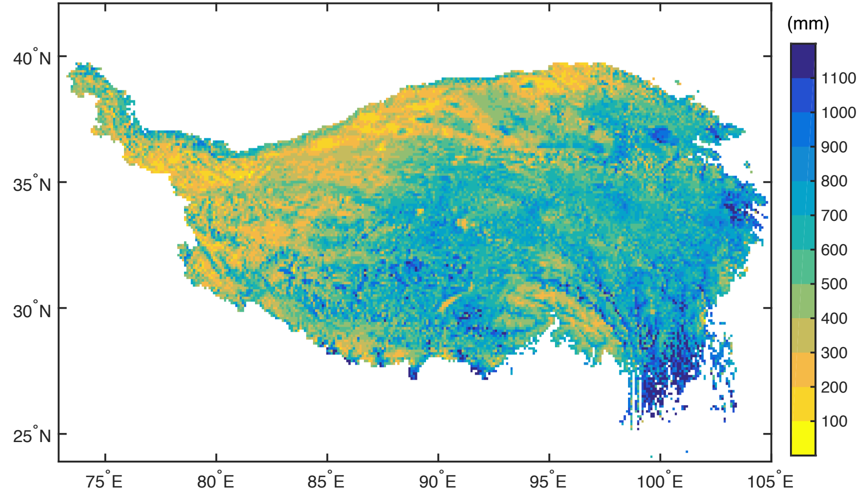




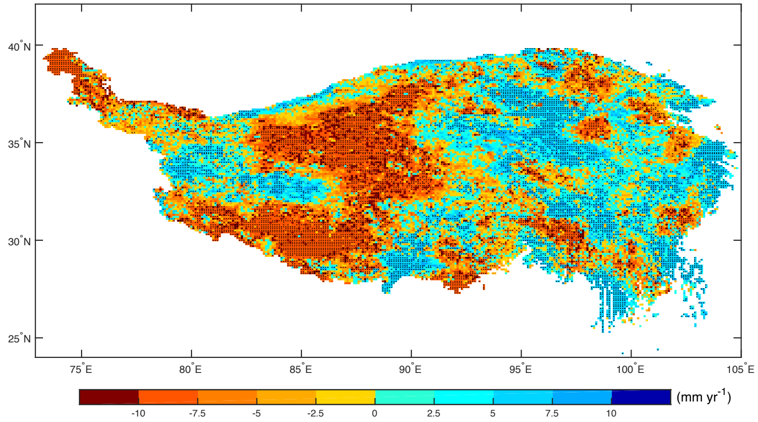
Station	Year	Annual ETa (mm)
QOMS	2007-2016	392.1
NAMORS	2006-2011	686.4
SETORS	2007	740.6
NADORS	2011, 2013	**268.8**
MAWORS	2013-2017	670.2
BJ	2011-2014	626.2

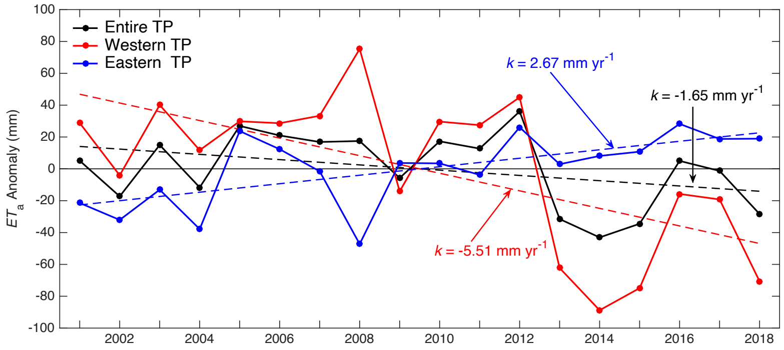
Evapotranspiration and its Changing Trend from 2001 to 2018

Averaged Spatial distribution of the Evapotranspiration



Spatial distribution of annual ETa linear trend

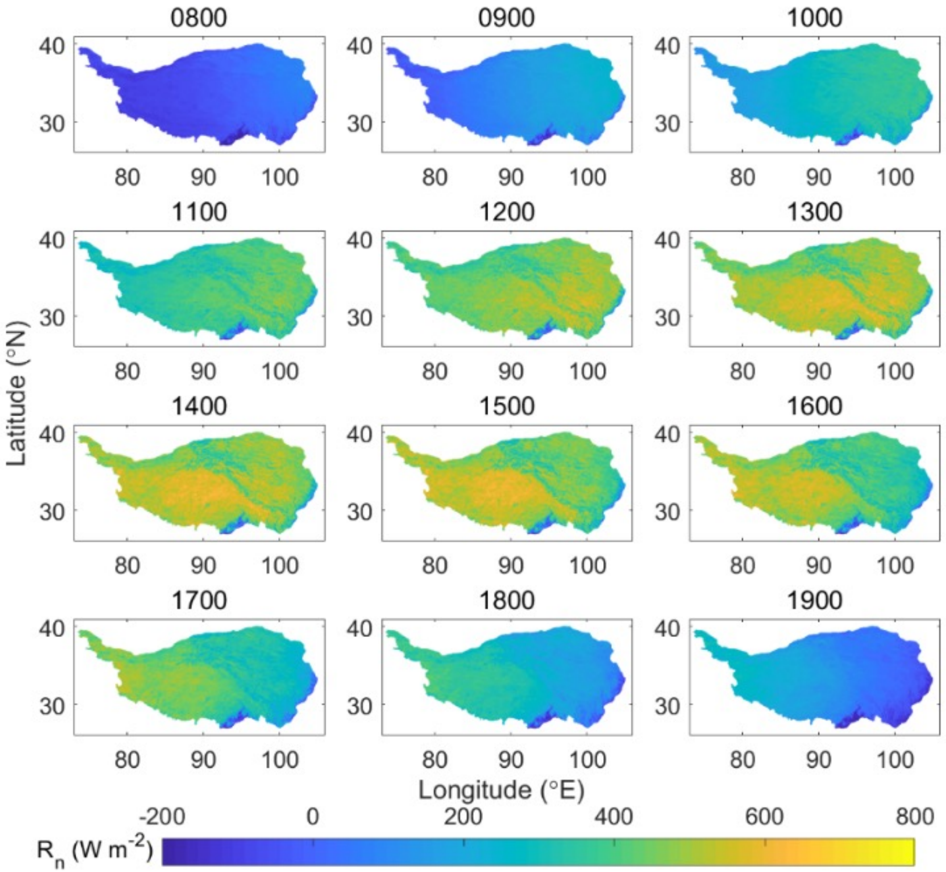




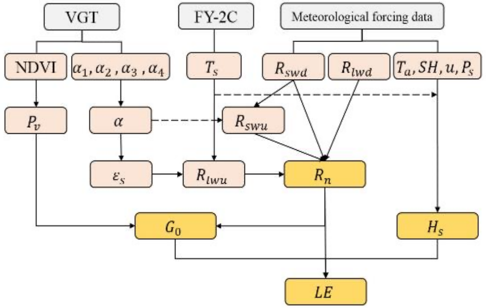
Anomalies of the domain-averaged annual ETa

- Domain- and multiyear-averaged annual ETa is 496 ± 23 mm
- Domain-averaged annual ETa on the TP decreased slightly
- The annual ETa increased significantly in the eastern part (lon > 90° E), while decreased in the western part of the TP (lon < 90° E)

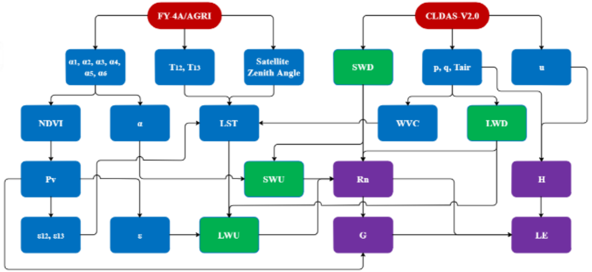
3. A long-term hourly dataset (2005-2016) of the integrated land-atmosphere interaction using Chinese geostationary satellites data



- Estimation of hourly land surface heat fluxes over the Tibetan Plateau using Chinese geostationary satellites data



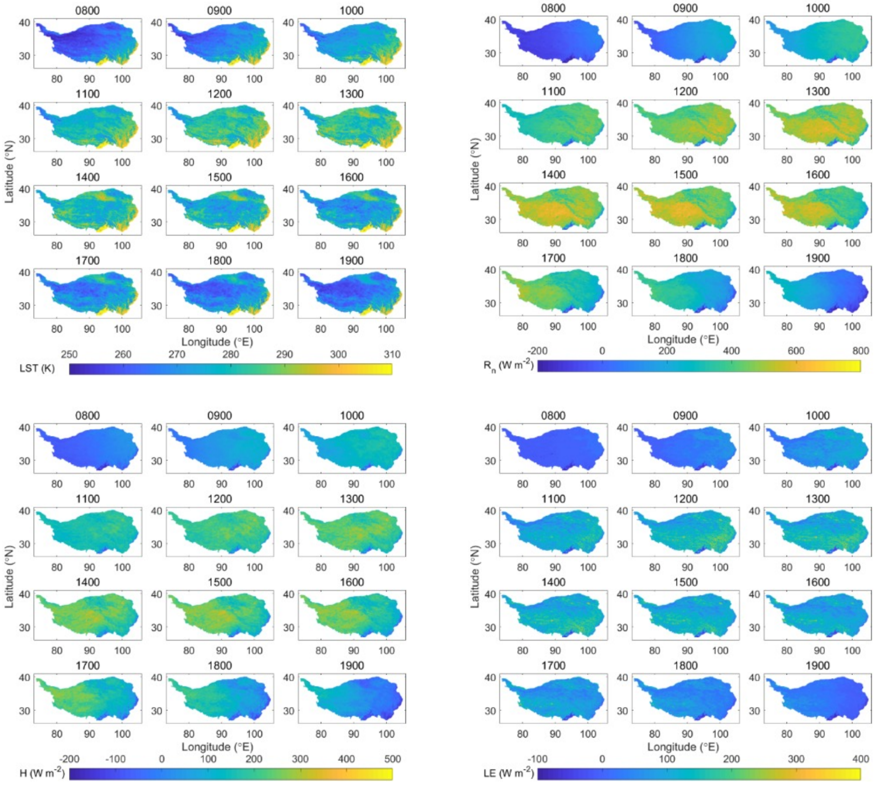
(Zhong et al., 2019@ACP)



(Ge et al., 2021@AAS)

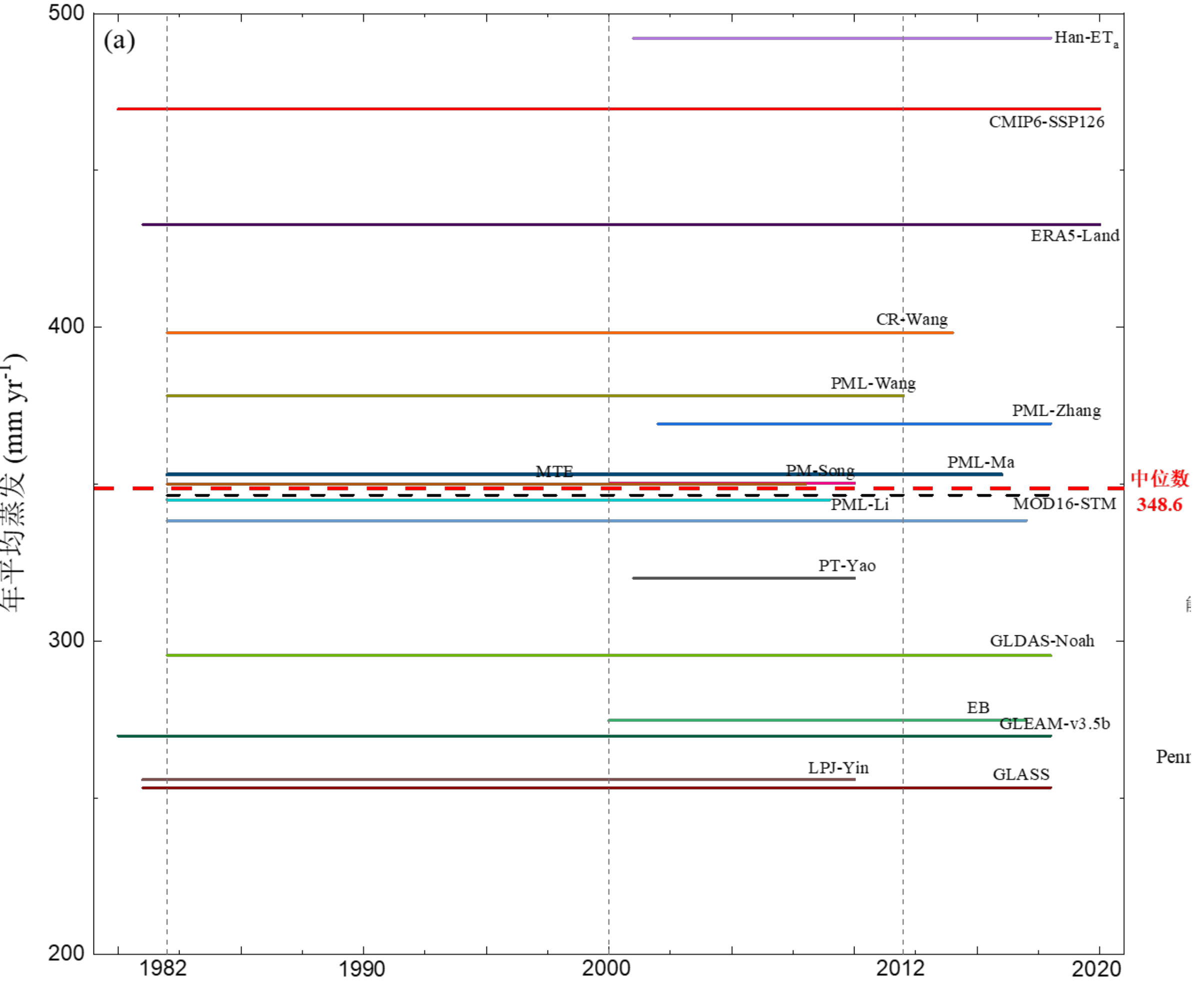
◆ Flowchart of the retrieval method for land surface characteristic parameters and heat fluxes over the TP by combining Fengyun geostationary satellite data and meteorological forcing data

Diurnal variations of the LST and energy balance components over the TP estimated by using FY-4A/AGRI (Average for April, 2018)



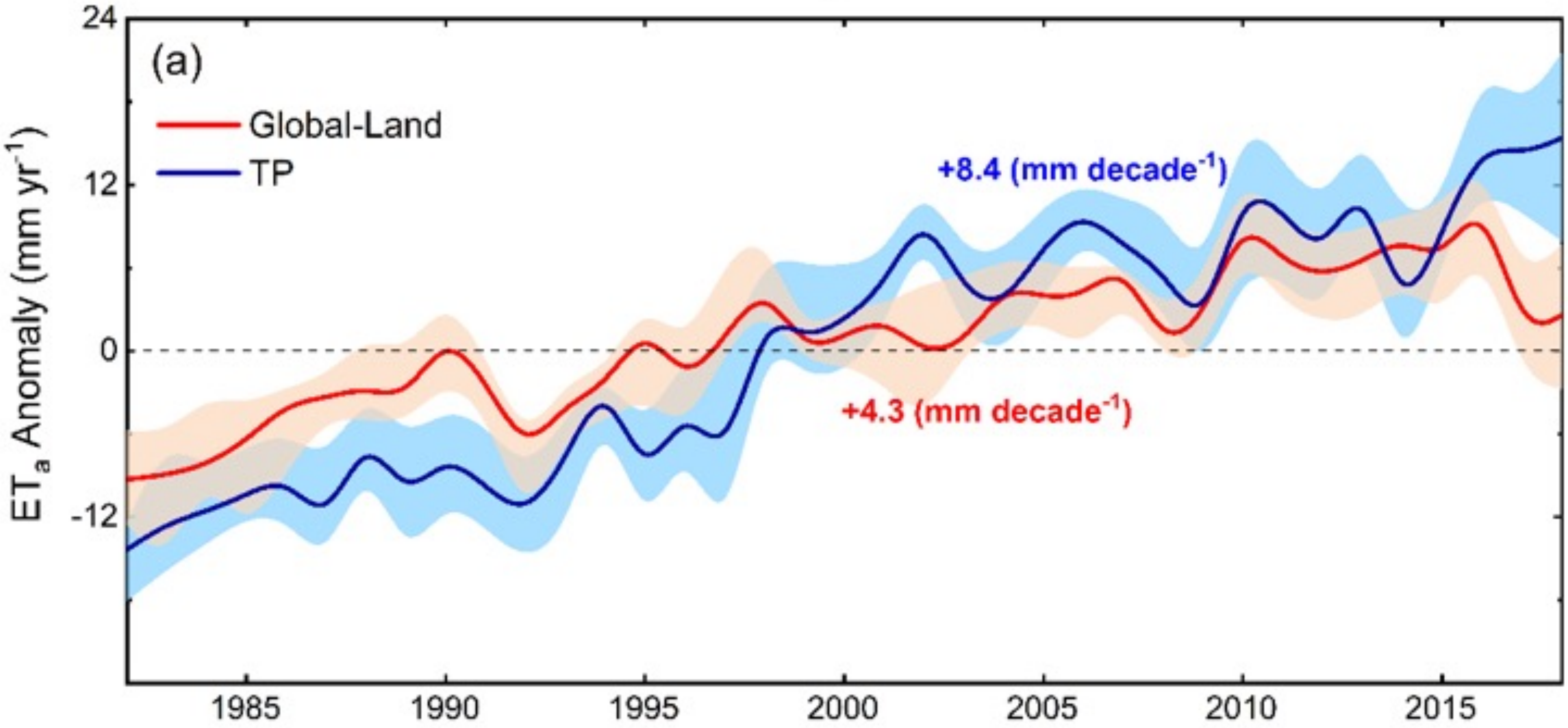
- ◆ Hourly variations of LST over the study area can exceed 10 K, which revealed the unique thermodynamic property of the TP.
- ◆ High-value zones of H were mainly situated in the central and western part of the TP, while those of LE mainly located in the southeastern part of the TP.
- ◆ The sensible heat flux dominates in the spring land surface heating field.

(Ge et al., 2021@AAS)



4. ETa estimations on the TP have a very large uncertainty. ETa change on the TP can be quantified and explained based on an ensemble mean product from climate model simulations, reanalysis, as well as ground-based and satellite observations.

ETa on the TP experienced a significant increasing trend of ca. 8.4 ± 2.2 mm/10y during 1982–2018, app. twice the rate of the global land ETa (4.3 ± 2.1 mm/10 a). The dominant role of the increased temperature in ETa causes a continued acceleration of the water cycle in next 100 years.

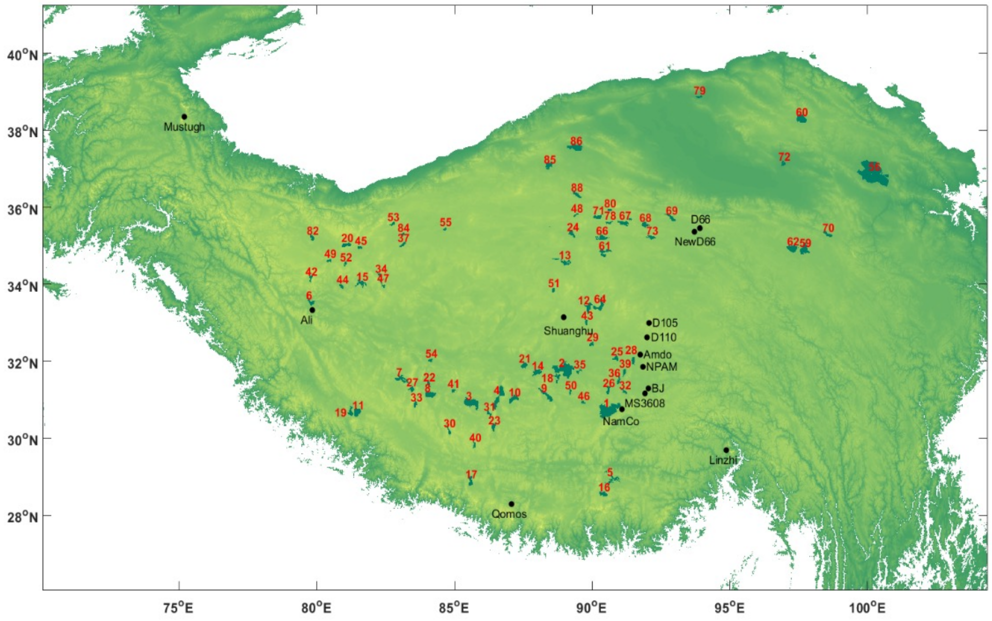


Chen, Yuan, Ma, ..Su et al. 2023 Science Bulletin (under review)

5. How Much Water is lost by Lake Evaporation on the Tibetan Plateau

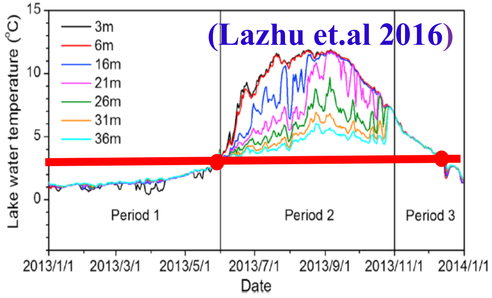
An innovative method for estimation of regional lake evaporation with satellite data

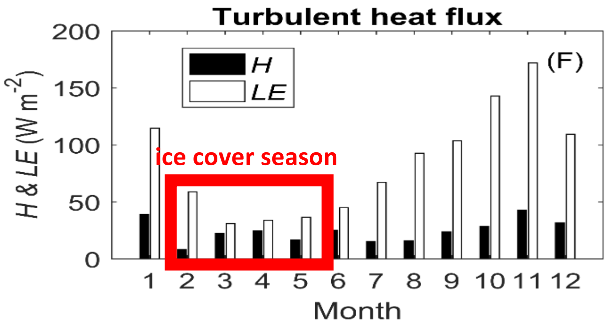
(Wang et al. 2020, Science Advances)



Research ideas

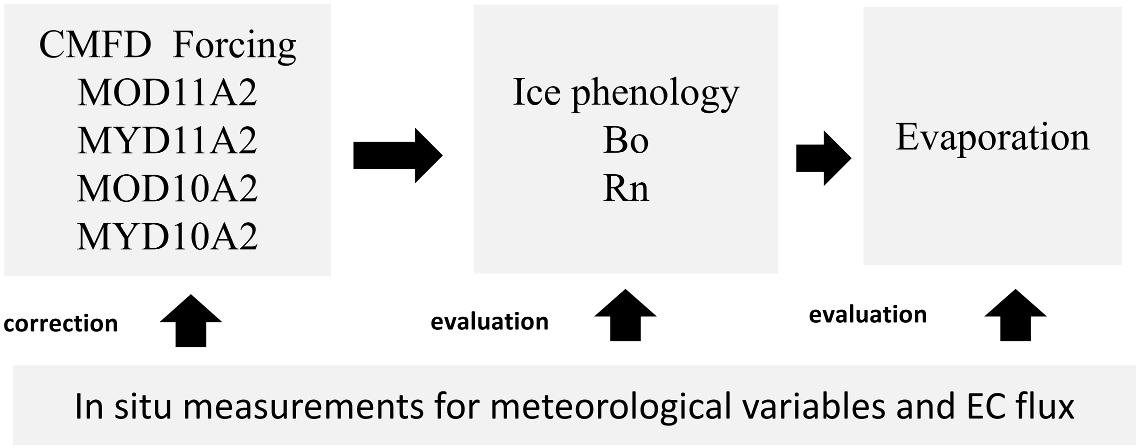
Assumption：
(1) the heat storage in the water during spring and summer can be all released during autumn and winter;
(2) winter ice sublimation can not be ignored and is assumed with a constant value.





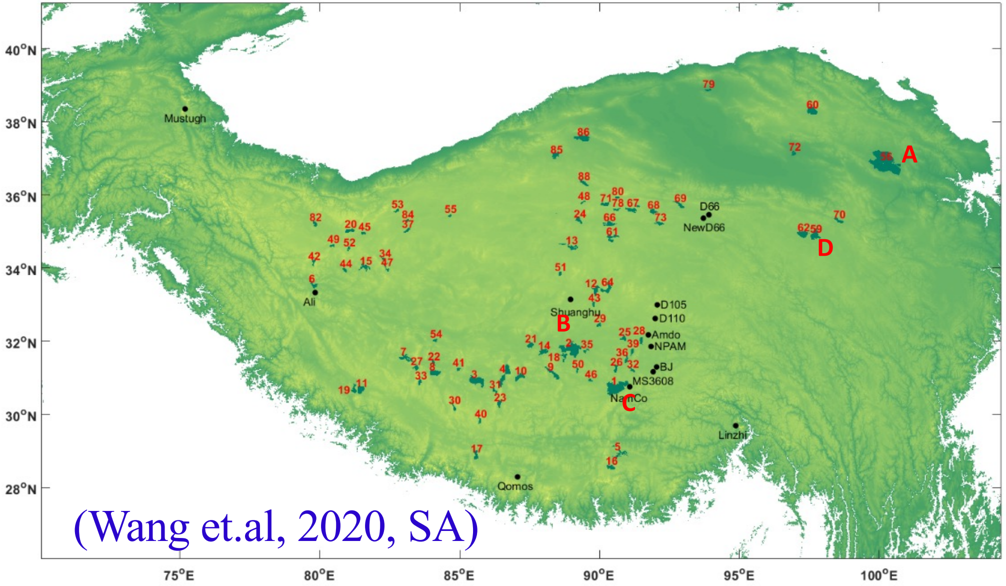
$$R_n = H + LE + G = (Bo + 1)LE$$

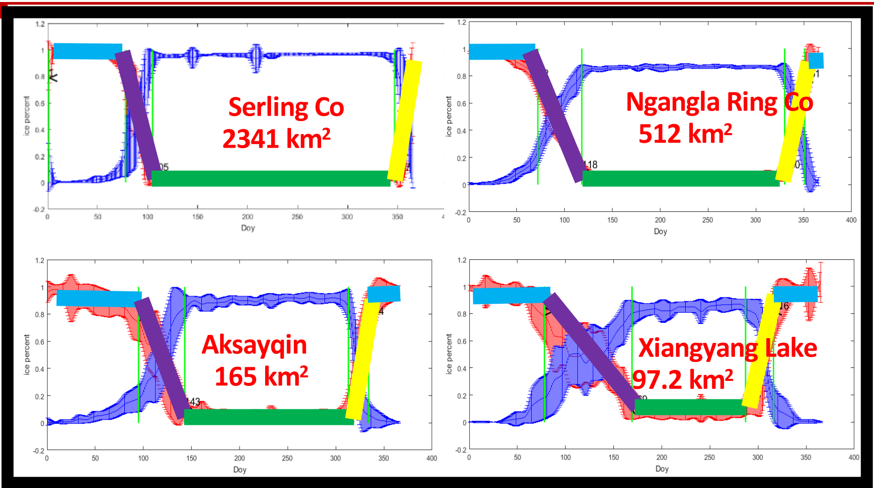
$$Bo = \gamma \frac{(T_s - T_a)}{(E_s - E_a)}$$

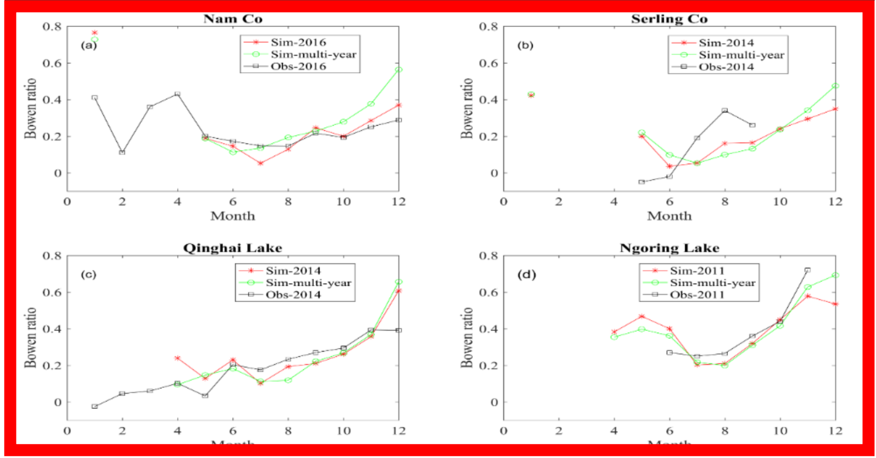


Schematic diagram of research ideas

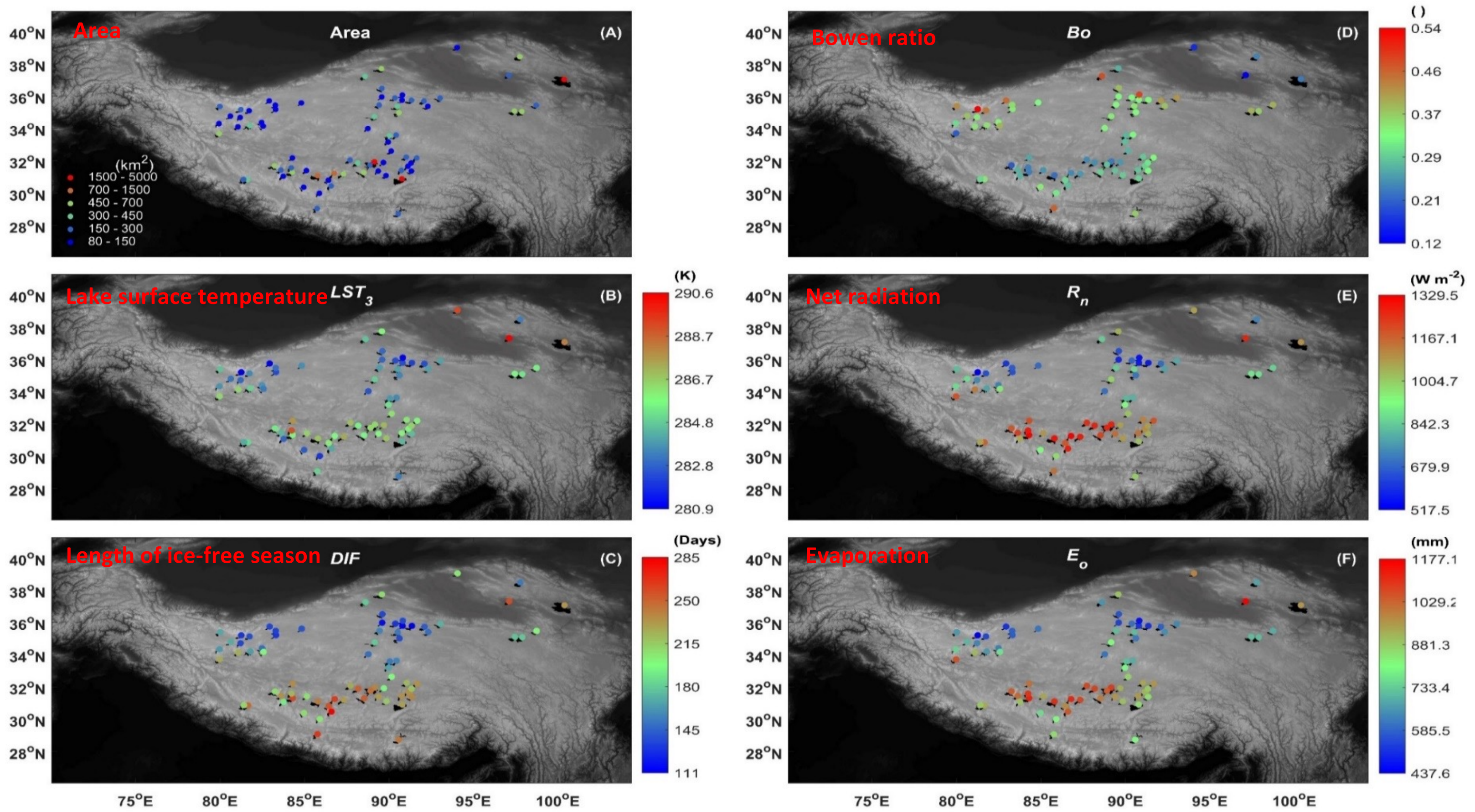
Validation sites and the evaluation of ice phenology and Bowen ratio





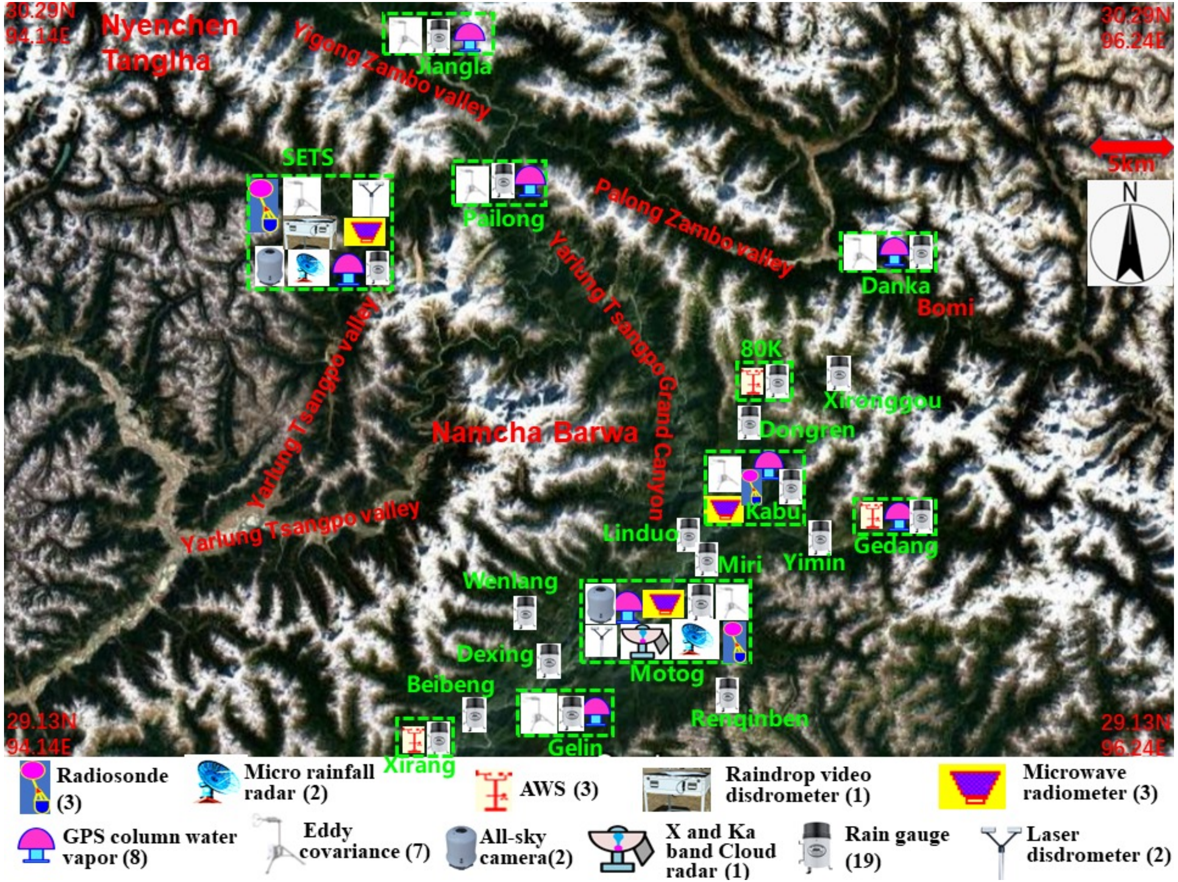


The spatial distribution of evaporation and related variables



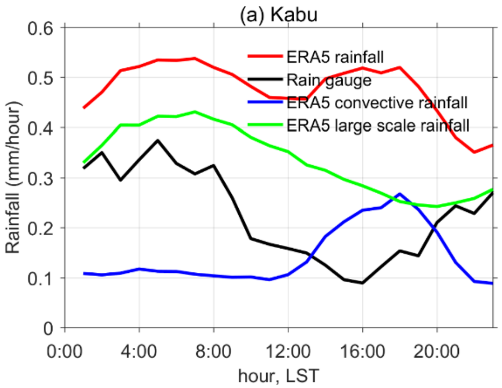
TP lakes evaporation 51.7±2.1 km^3 year^{-1}

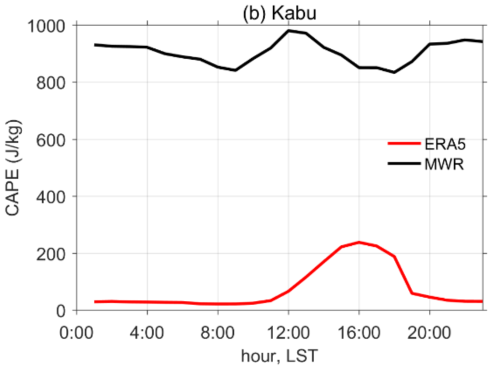
(Wang et.al, 2020, SA)



6. A 3-dimensional comprehensive observation system of mountainous land-air interaction in the water vapor channel of the Yarlung Zangbo Grand Canyon (YGC) in the southeastern TP was established (Chen et al., BAMS (in revision))

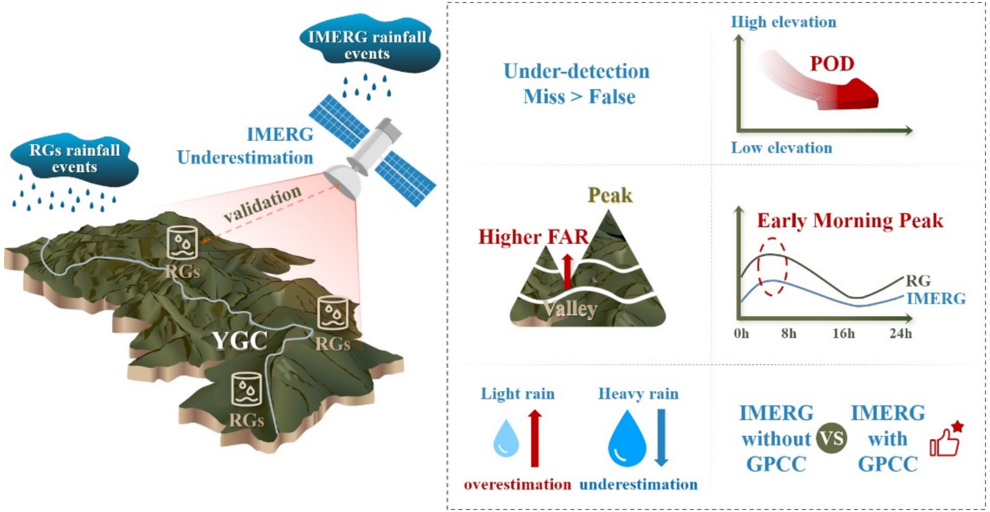
- **ERA5 cannot reproduce the diurnal variation of precipitation in the YGC.**
- ERA5 showed a wet bias for light rainfall and a dry bias for heavier (convective) precipitation.
- The erroneous diurnal variation of ERA5 was due to the CAPE based convective precipitation scheme.
- **The overestimation of ERA5 was due to the large-scale rainfall scheme in the IFS of ERA5.**





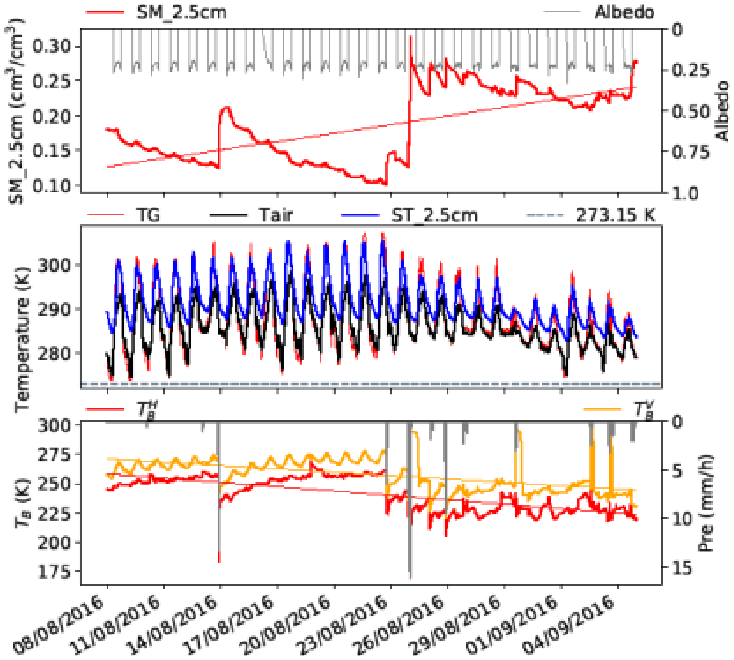
Chen et al. 2023, QJRMS

- GPM IMERG underestimates the total rainfall primarily due to under-detection of rainfall events, with misses being more prevalent than false alarms in the Yarlung Tsangbo Grand Canyon (YGC)



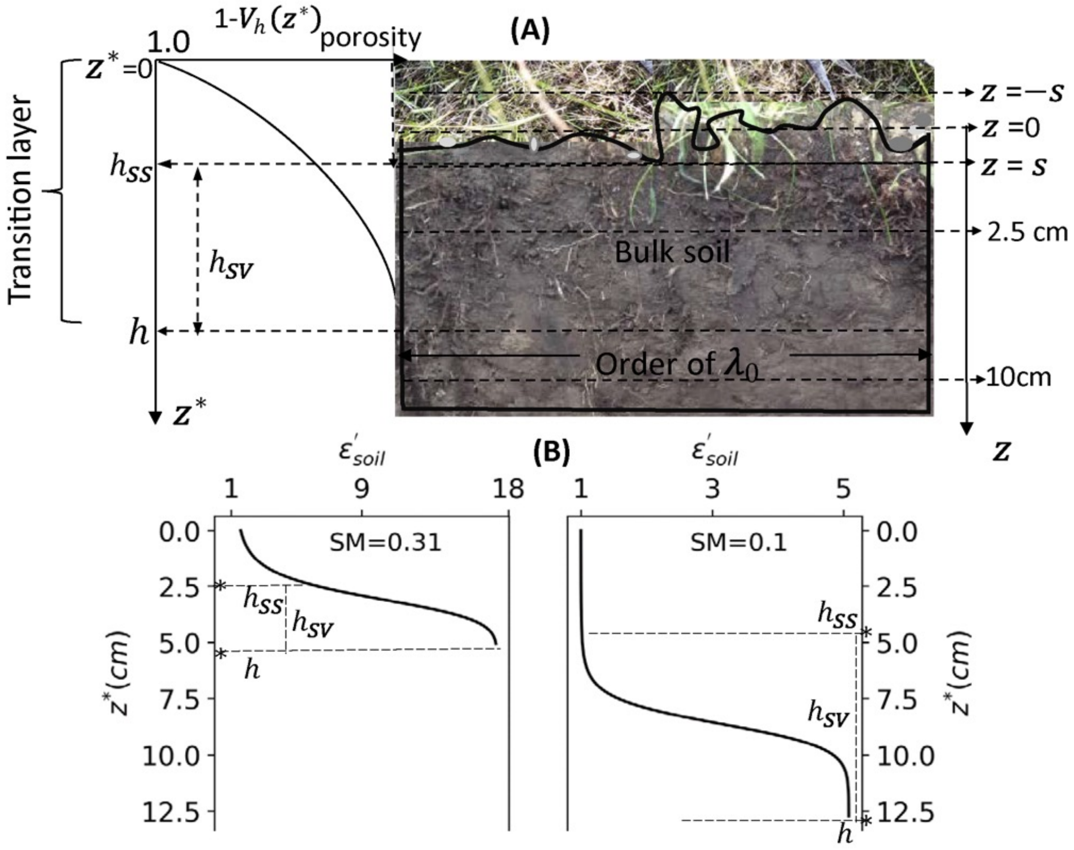
Li et al. 2023 RS;

7. Estimating surface soil moisture, monitoring and predicting freeze-thaw states and quantifying soil ice by interfacing Air-To-Soil dielectric transition



(Su et al., 2020, Sci Data)

CLAP - An Integrated Air-Plant-Soil Process Model for Modelling MW Scattering-Emission



CLAP (ATS-TVG-AIEM-CLM) links energy, water & carbon processes to EO MW P/A observables

Simulate/Retrieve State/Parameter/Flux with S-1, ROSE-L, CIMR, SMOS/SMAP +ASCAT

(Zheng et al., 2017, TGRS)
(Zhao et al., 2020, JRS)
(Hofste et al., 2023, TGRS)

Preprint

Preprints / Preprint hess-2022-333

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https://doi.org/10.5194/hess-2022-333

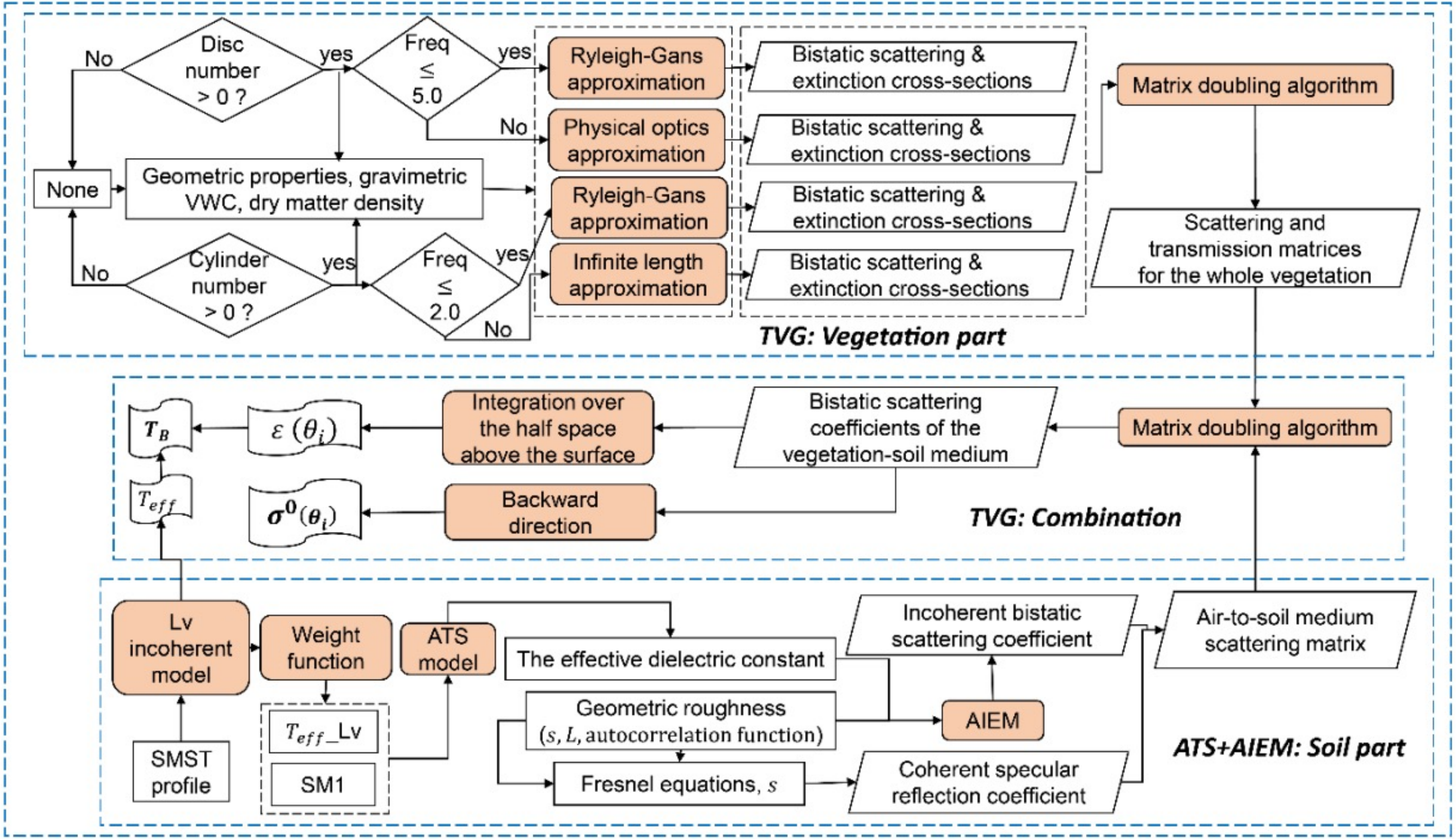
Abstract | Discussion | Metrics

21 Oct 2022

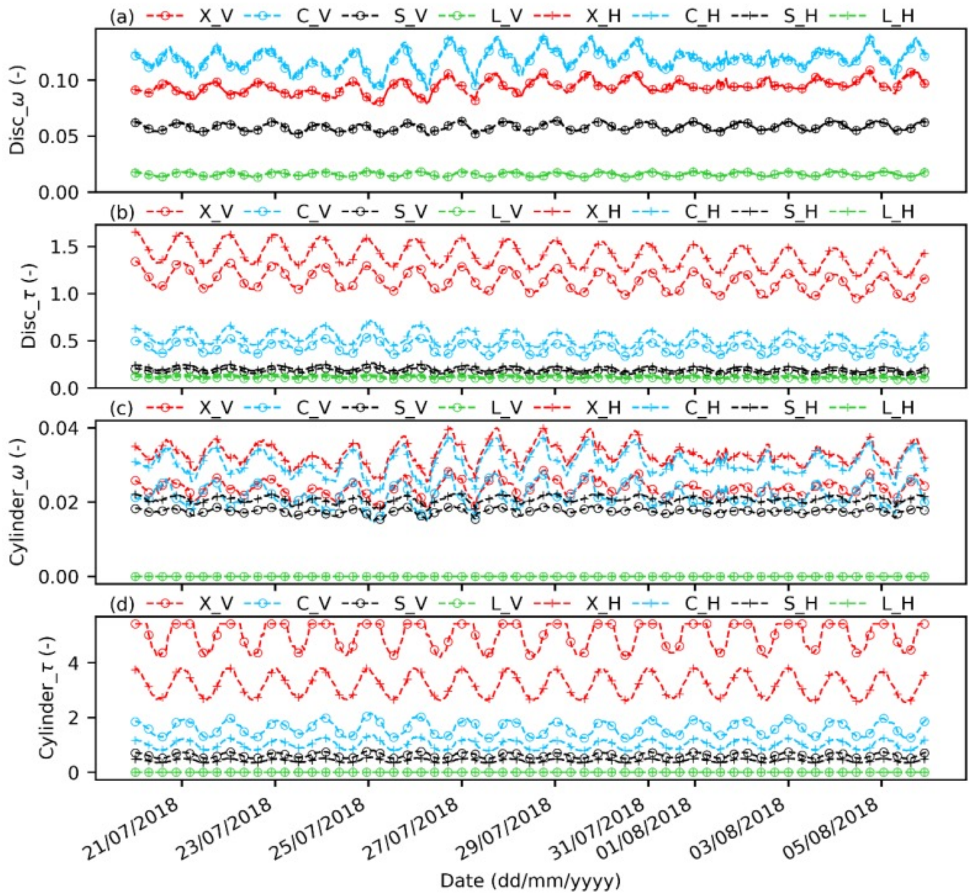
Status: a revised version of this preprint is currently under review for the journal HESS.

Modelling of Multi-Frequency Microwave Backscatter and Emission of Land Surface by a Community Land Active Passive Microwave Radiative Transfer Modelling Platform (CLAP)

Hong Zhao, Yijian Zeng, Jan G. Hofste, Ting Duan, Jun Wen, and Zhongbo Su



Disc number > 0 ?
No
yes
Freq ≤ 5.0
yes
No
Ryleigh-Gans approximation
Physical optics approximation
Ryleigh-Gans approximation
Infinite length approximation
Bistatic scattering & extinction cross-sections
Bistatic scattering & extinction cross-sections
Bistatic scattering & extinction cross-sections
Bistatic scattering & extinction cross-sections
Matrix doubling algorithm
None
Geometric properties, gravimetric VWC, dry matter density
Scattering and transmission matrices for the whole vegetation
Cylinder number > 0 ?
No
yes
Freq ≤ 2.0
yes
No
TVG: Vegetation part
T_B
$\varepsilon(\theta_i)$
Integration over the half space above the surface
Bistatic scattering coefficients of the vegetation-soil medium
Matrix doubling algorithm
T_{eff}
$\sigma^0(\theta_i)$
Backward direction
TVG: Combination
Lv incoherent model
Weight function
ATS model
The effective dielectric constant
Incoherent bistatic scattering coefficient
Air-to-soil medium scattering matrix
T_{eff}_Lv
SM1
Geometric roughness (s, L, autocorrelation function)
AIEM
SMST profile
Fresnel equations, s
Coherent specular reflection coefficient
ATS+AIEM: Soil part

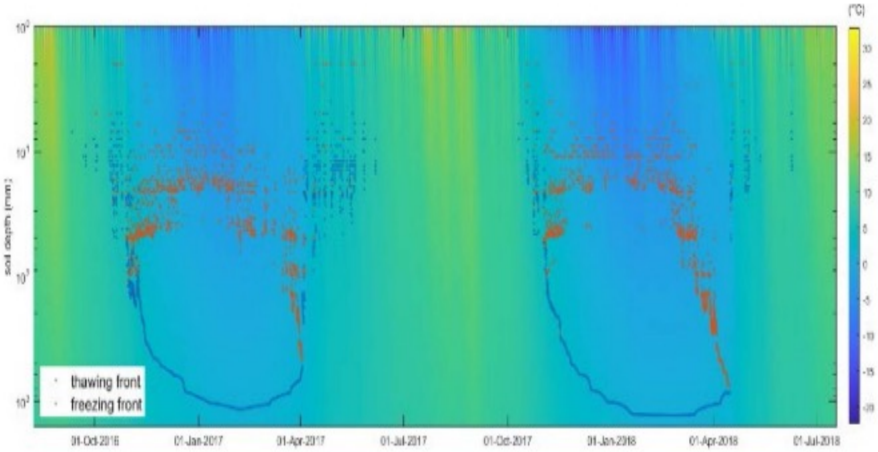


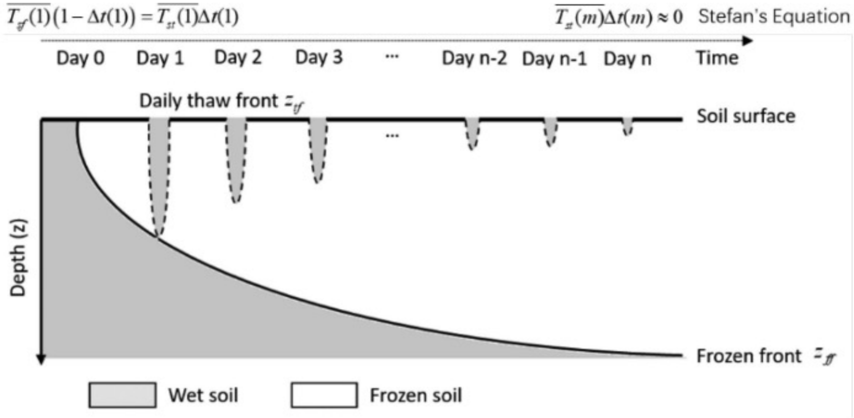
Comparison of estimated τ and ω at the multi-frequency during the summer period by the CLAP (ATS_AIEM_TVG model) using the disc and cylinder parameterizations respectively

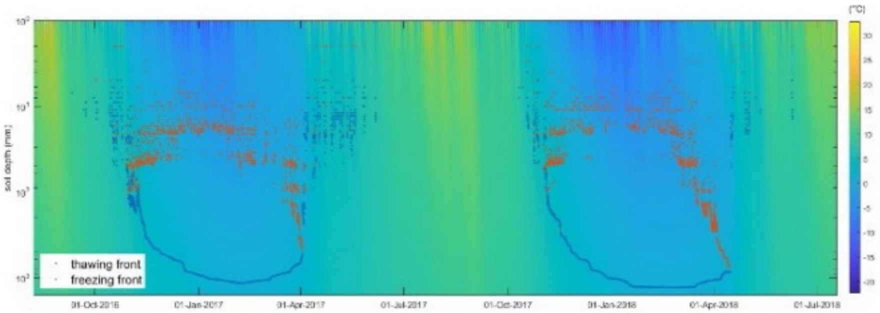
IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 16, 2023

Inference of Soil Freezing Front Depth During the Freezing Period From the *L*-Band Passive Microwave Brightness Temperature

Shaoning Lv, Lianyu Yu, Yijian Zeng, Jun Wen, Clemens Simmer, and Zhongbo Su







Soil temperature profile evolution simulated by STEMMUS-FT and the daily thawing front (thawed-up-frozen-down, red dots) and annual freezing front (frozen-up-thawed-down, blue dots) as inferred from soil temperatures.

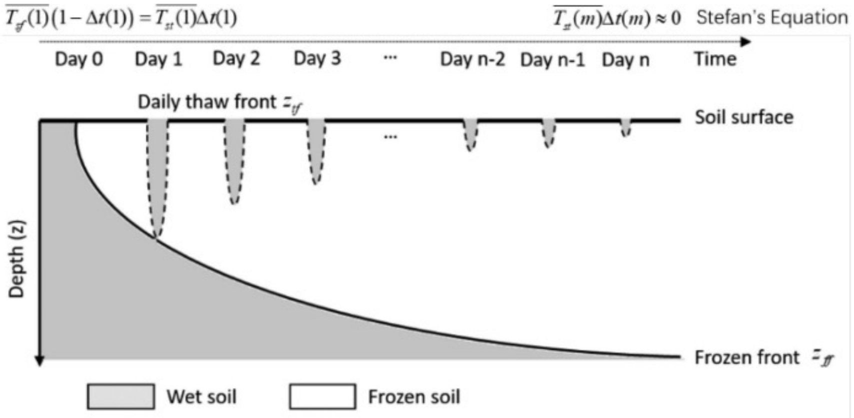


Illustration of the freezing process assumptions in the BT-FF model. zff is the freezing front, reflecting the annual FT state cycle, and ztf is the daily thawing front caused, e.g., by radiative heating during daytime. Symbol m is the total lasting days of the annual freezing process, i.e., the last day of period II

CONCLUSIONS

The CLIMATE-pan-TPE project has concentrated on processing and publishing data in 3rd year.

1. A long-term (2005-2016) hourly dataset of the integrated land-atmosphere interaction observations from six field stations over the Tibetan Plateau;
2. Monthly actual evapotranspiration on the TP (2001-2018);
3. Hourly land surface heat fluxes and evapotranspiration estimated based on multisource remote sensing data;
4. A monthly 0.01° terrestrial evapotranspiration product for the TP (1982-2018) using the MOD16-STM equation;
5. Total annual evaporation amounts over the entire TP lakes;

6. Investigate the water vapor channel of the Yarlung Zangbo Grand Canyon (YGC) in the southeastern TP by establishing a 3-dimensional comprehensive observation system of mountainous land-air interaction, water vapor transport, cloud cover, and rainfall activity;

7. methods for estimating surface soil moisture, monitoring and predicting freeze-thaw states and quantifying soil ice content with microwave remote sensing data;

8. Continue training to young European and Chinese scientists - joint supervision of young scientists started from Dragon 1/2/3/4 programme

- *Dr. **Harm-Jan Benninga**, 2022, Field Scale Soil moisture retrieval with Sentinel-1 (Consultant, Witteveen en Bos);*
- *Dr. **Lianyu Yu**, 2022, **Cum Laude**, Coupled water-heat-carbon exchange processes (Associate Professor, NW A&F University)*
- *Dr. **Hong Zhao**, 2021, **Cum Laude**, retrieval of soil properties, microwave remote sensing and data assimilation (Postdoc, Univ Twente);*