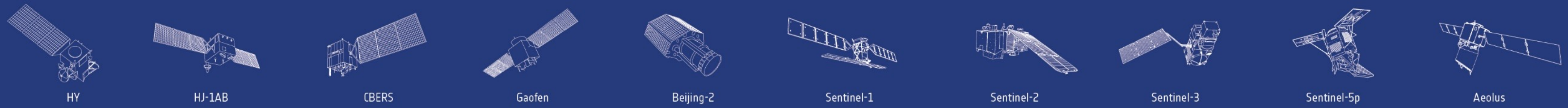


2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

PROJECT ID. 59199

CRYOSPHERE-HYDROSPHERE INTERACTIONS OF THE ASIAN WATER TOWERS: USING REMOTE SENSING TO DRIVE HYPER-RESOLUTION ECOHYDROLOGICAL MODELLING

WEDNESDAY, SEPT. 13TH 2023

ID. 59199

PROJECT TITLE: CRYOSPHERE-HYDROSPHERE INTERACTIONS OF THE ASIAN WATER TOWERS: USING REMOTE SENSING TO DRIVE HYPER-RESOLUTION ECOHYDROLOGICAL MODELLING

TITLE OF CONTRIBUTION: UNDERSTANDING THE WATER YIELD OF HIGH ELEVATION, GLACIERIZED CATCHMENTS IN HIGH MOUNTAIN ASIA BY ANALYZING GLACIER DYNAMICS

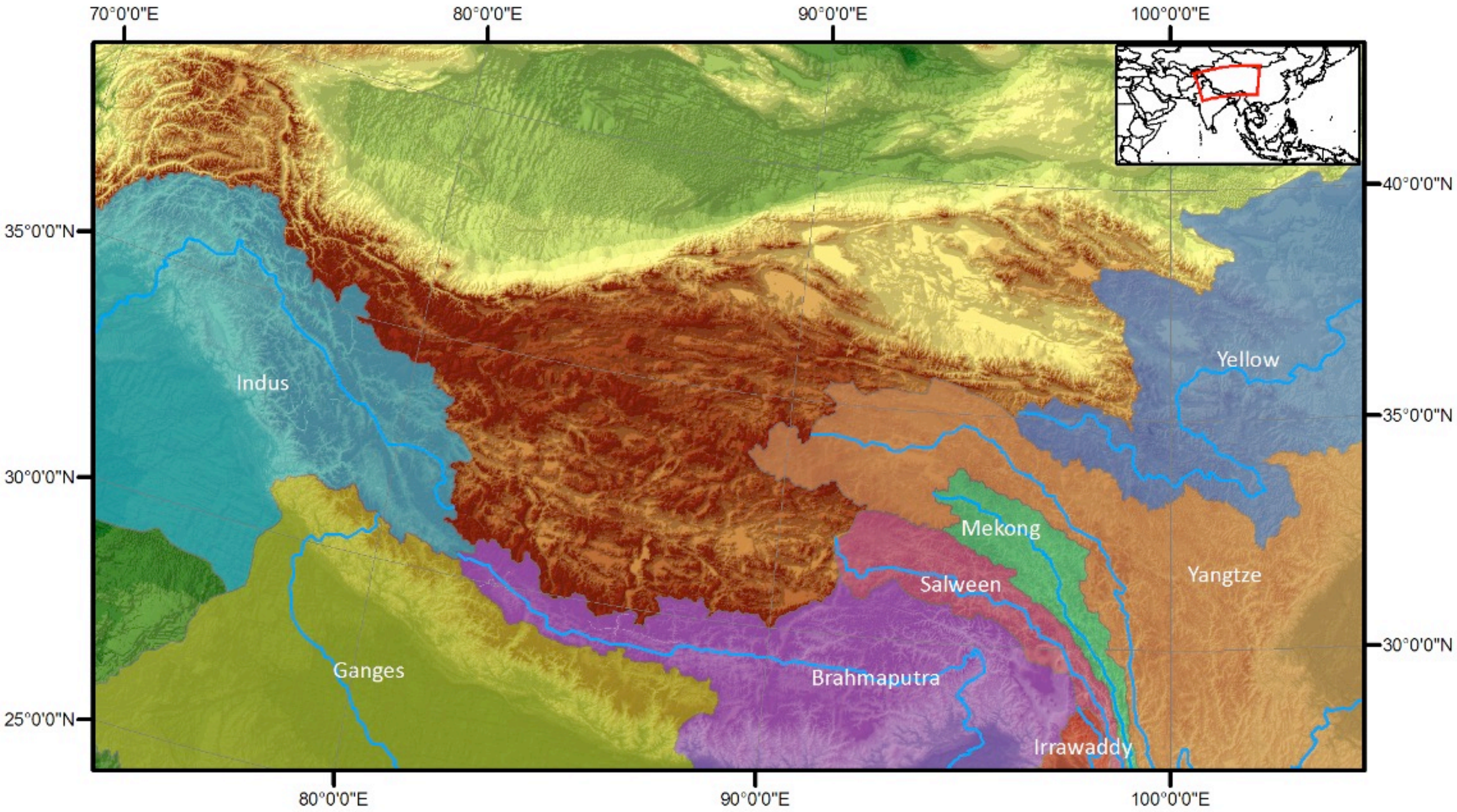
PRINCIPAL INVESTIGATORS: PROF.DR FRANCESCA PELLICCIOTTI, PROF.DR. MASSIMO MENENTI

CO-AUTHORS: PASCAL BURI, ACHILLE JOURBERTON, STEFAN FUGGER, EVAN MILES, THOMAS SHAW, MIKE MCCARTHY, YUBAO QIU, JUNRU JIA , SHAOTING REN, CONG SHEN, JING ZHANG AND LI JIA

PRESENTED BY: MASSIMO MENENTI, ZHENGXIN JIAN AND ACHILLE JOUBERTON

Objective

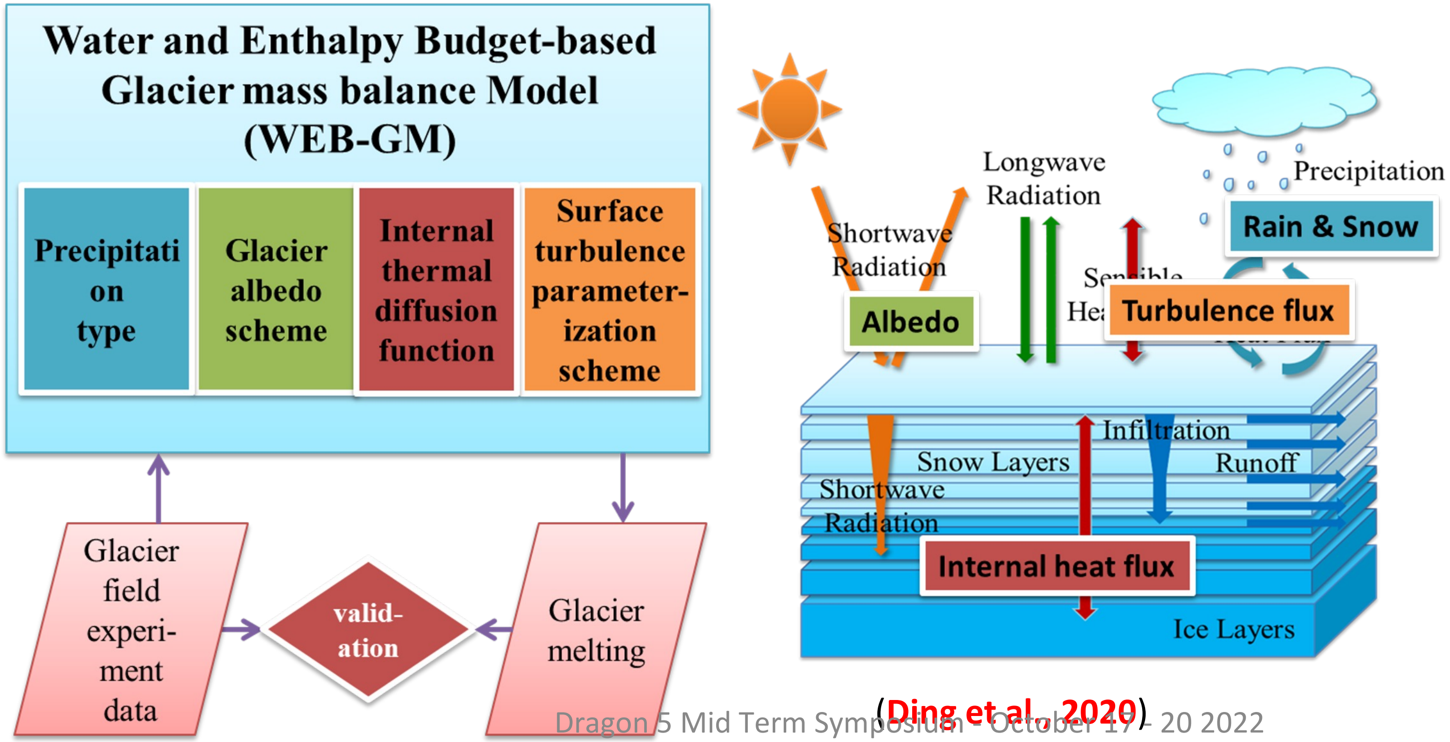
Observe, model and understand the overall dynamics of the high mountain water cycle, and the interactions of snow and ice dynamics with those of vegetation to shape HMA catchments response to weather and climate and their water yield.



Objectives

Document and understand the drivers of blue and green water flows at high elevation:

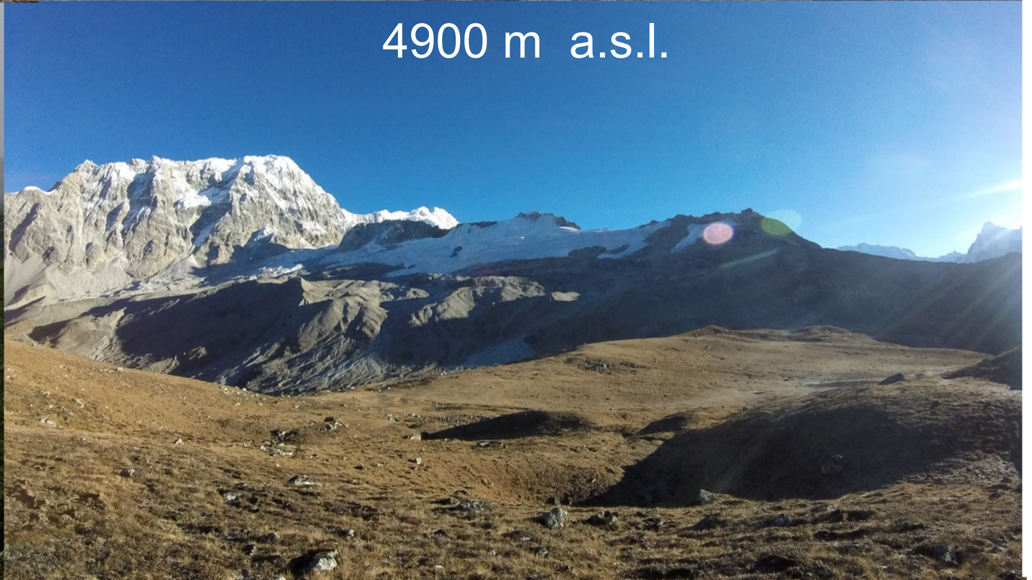
- **Understand cryospheric, vegetation and land surface changes**
- **Model land-surface interactions across the cryosphere, hydrosphere and biosphere**

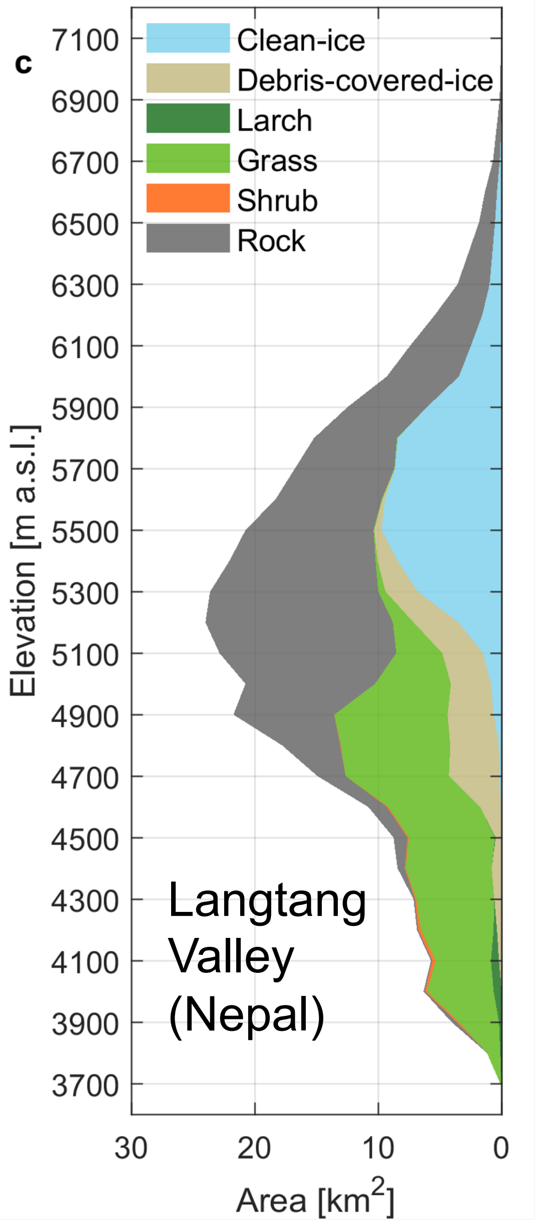


(Ding et al., 2020)

Motivation

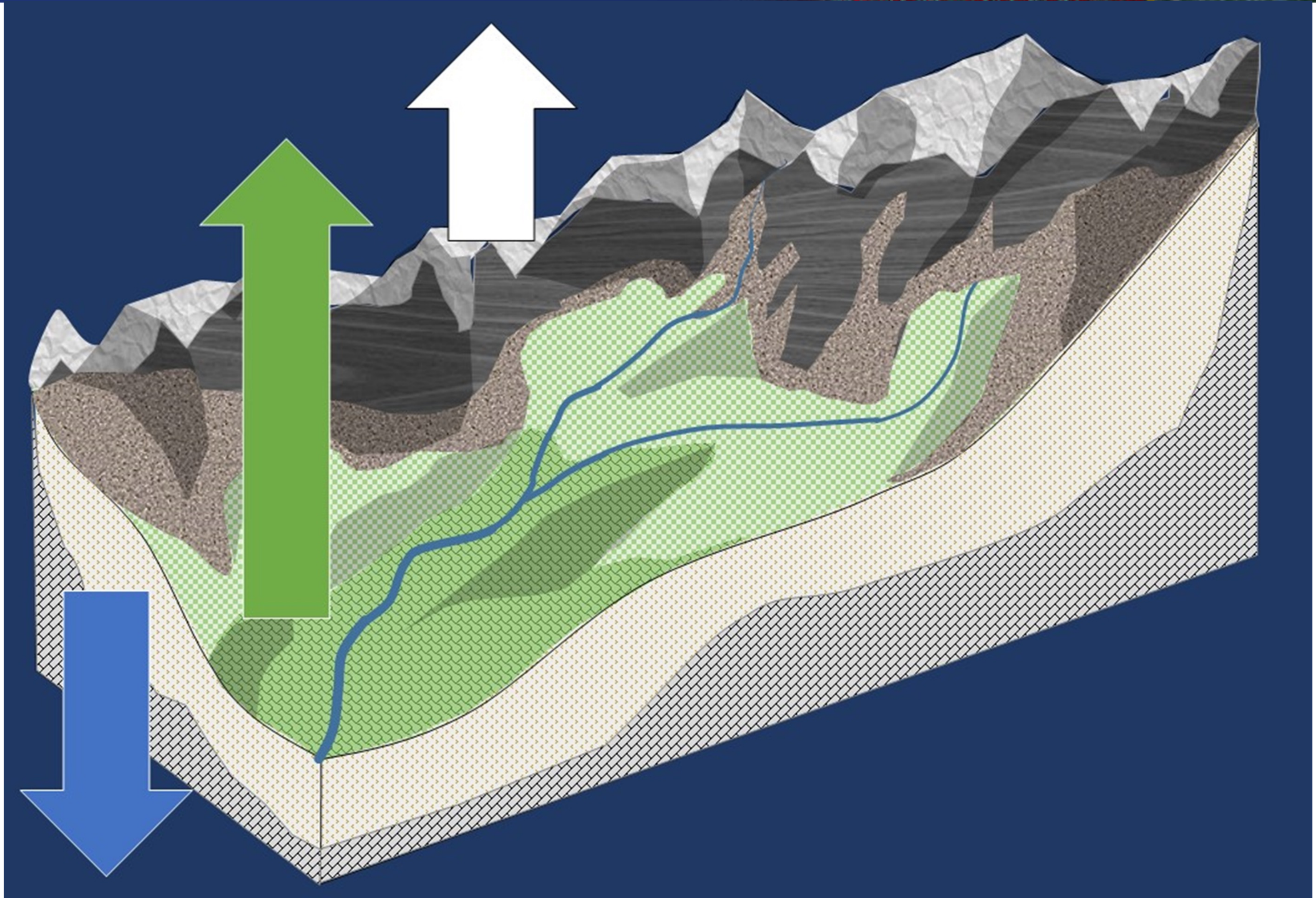
Glacierized catchment





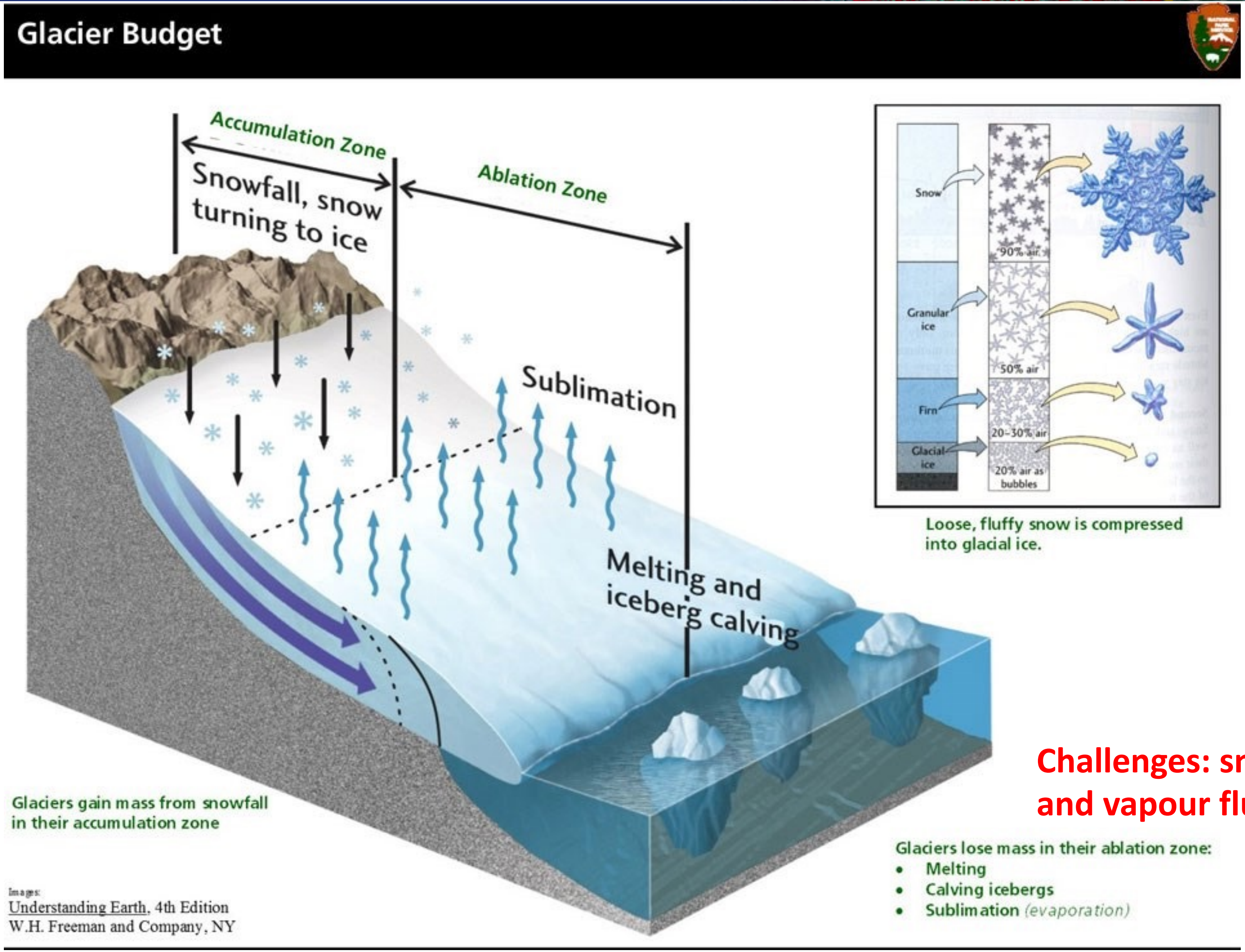
Motivation

Blue-green-white water fluxes



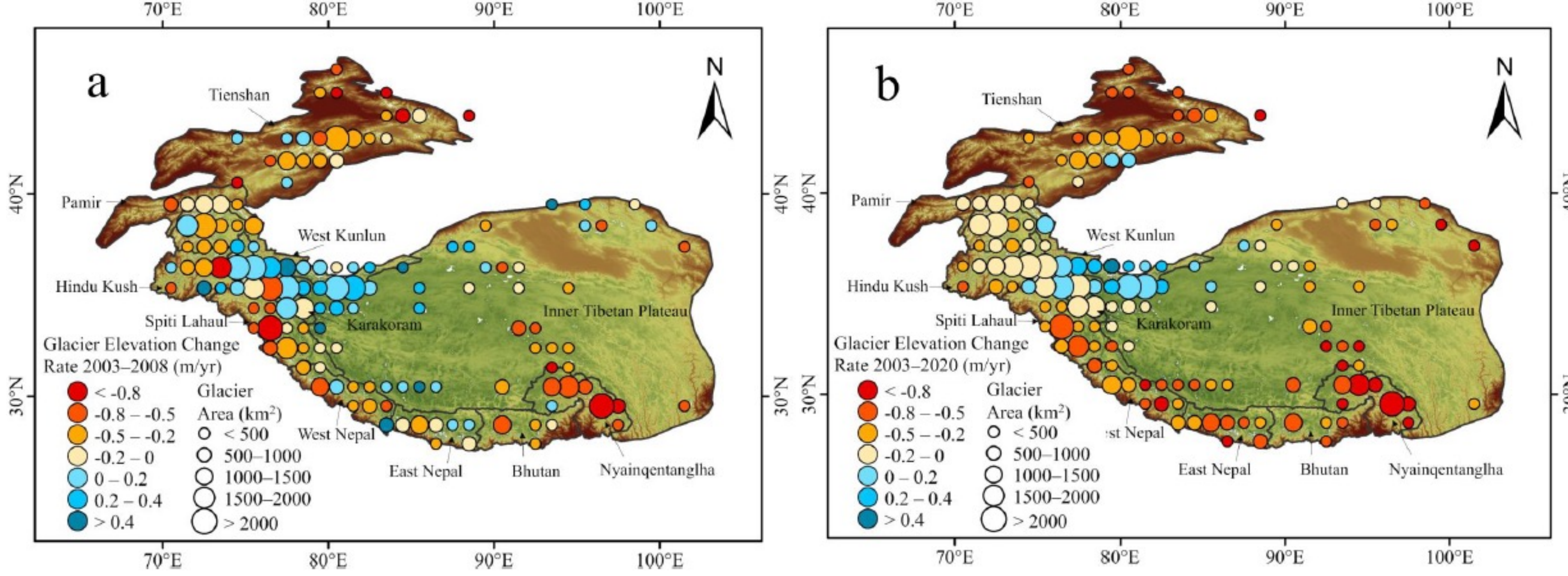
Motivation

Glacier mass balance and hydrology



Challenges: snowfall (accumulation) and vapour fluxes (ablation)

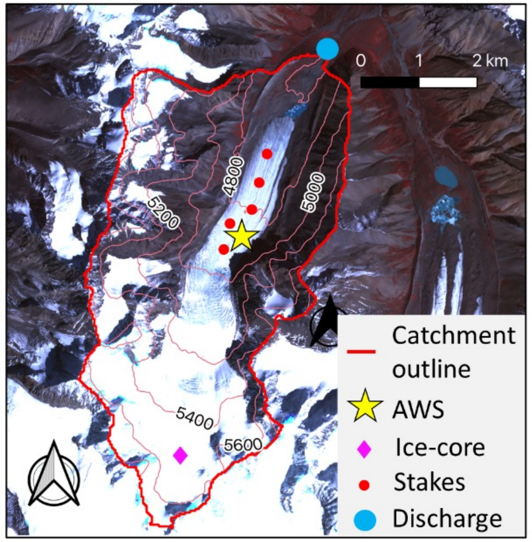
Results



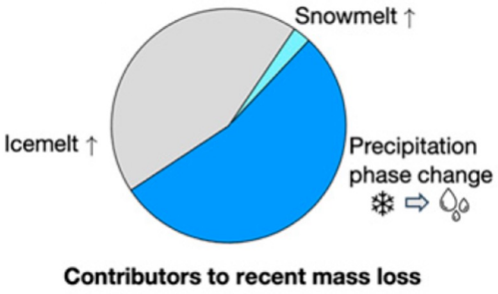
Glacier elevation change rate in the HMA in 2003–2008 (**a**) and in 2003–2020 (**b**) (Statistics in 1° × 1° grids).

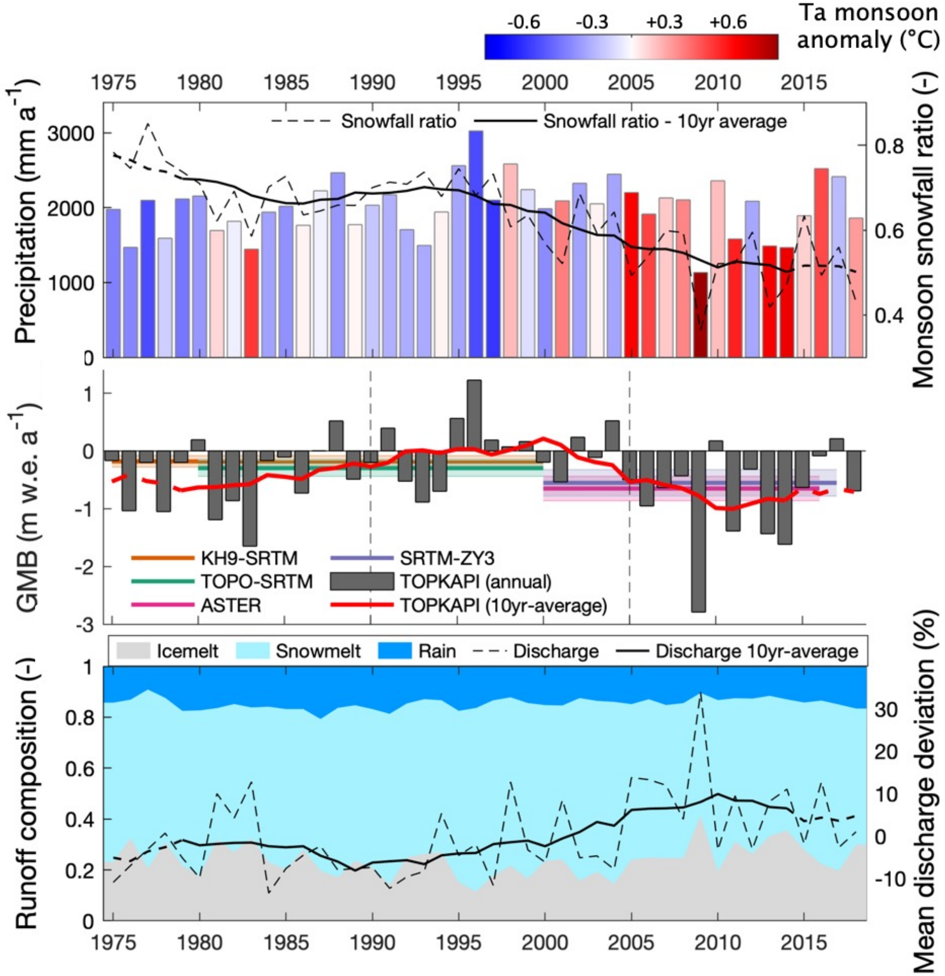
Understanding the causes of high glacier mass losses in the Tibetan Plateau

- Long term simulations of glacier mass balance and runoff, Parlung catchment, Southeastern Tibetan Plateau.
- Temperature increase (mean of 0.39 ◦C · dec^{-1} since 1990) has accelerated mass loss rates by altering both the ablation and accumulation regimes, in particular reducing monsoon snowfall.
- Ice melt and catchment discharge have unsustainably intensified since the start of the 21st century.
- Warming-induced monsoon precipitation phase change intensifies glacier mass loss in the southeastern Tibetan Plateau.



Parlung No.4 glacier



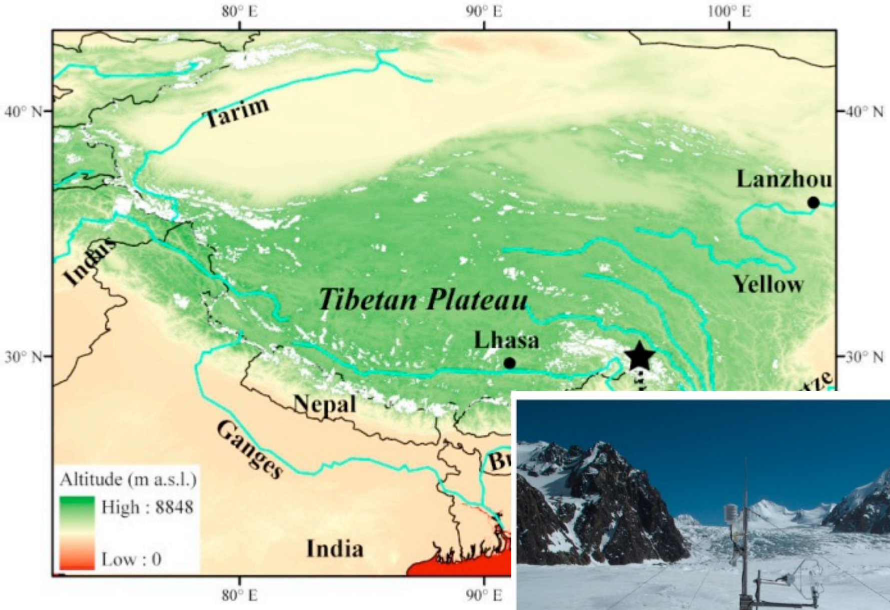


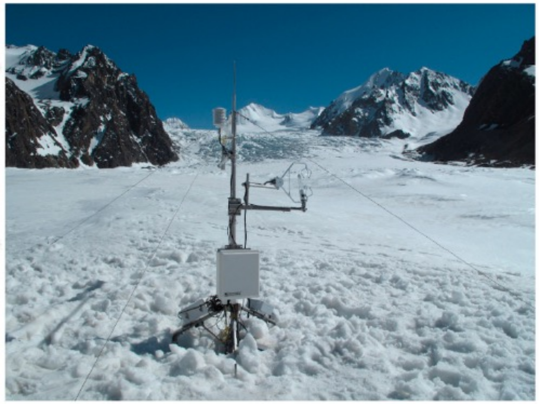
(**Jouberton et al., 2022, PNAS**)

Glacier surface heat flux

Glacier surface heat flux is important component of the glacier mass & heat balance, but the spatial and temporal variability of this process is not well understood.

Latent heat flux in the glacier surface can be either positive (LE>0, sublimation or evaporation) or negative (LE<0, condensation or deposition). To separate the sublimation & evaporation and condensation & deposition, methods based on different criteria are assessed.

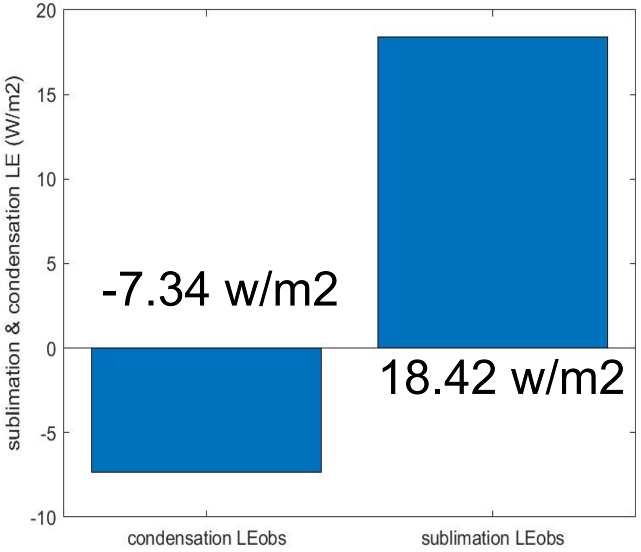




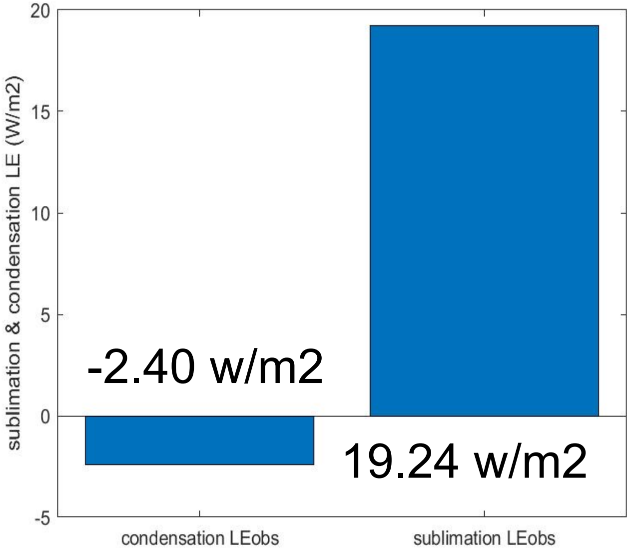
Parlung No. 4 Glacier on the southeast TP 2009.5 ~ 2009.09.

Adapted from Yang et al. (2011)

different methods to separate sublimation & condensation



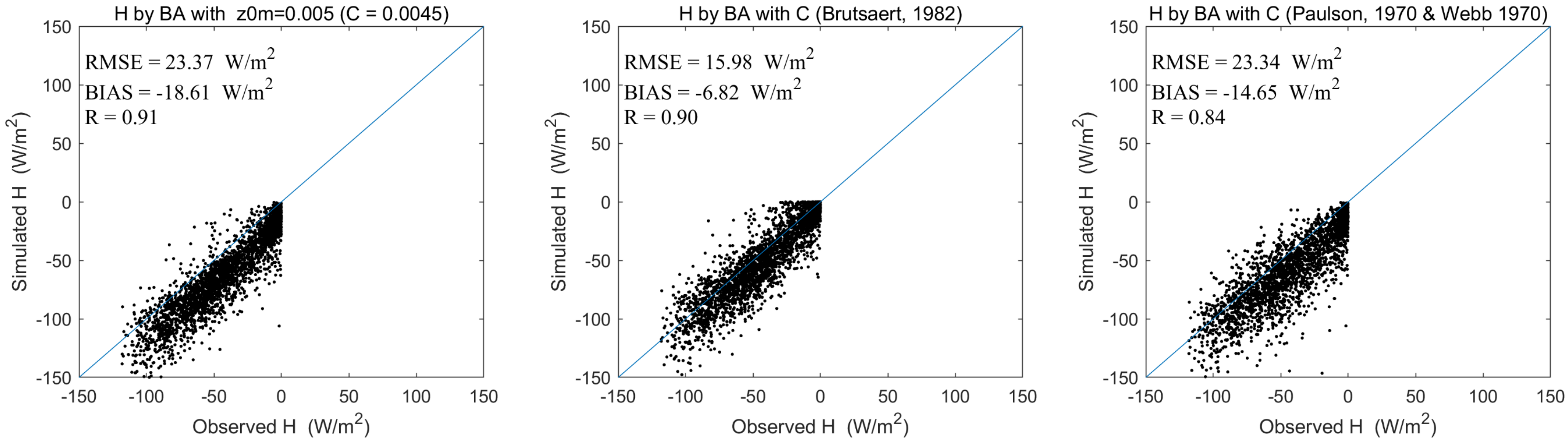
Sublimation&evaporation : LE>0
Condensation&deposition: LE<0



Sublimation&evaporation : e < e_sat(ice)
Condensation&deposition: e > e_sat(ice)

Glacier surface heat flux – Sensible heat flux estimation

The stability correction can also improve the accuracy of estimated H compared with the BA without stability correction, and the method by Brutsaert (1982) perform better.

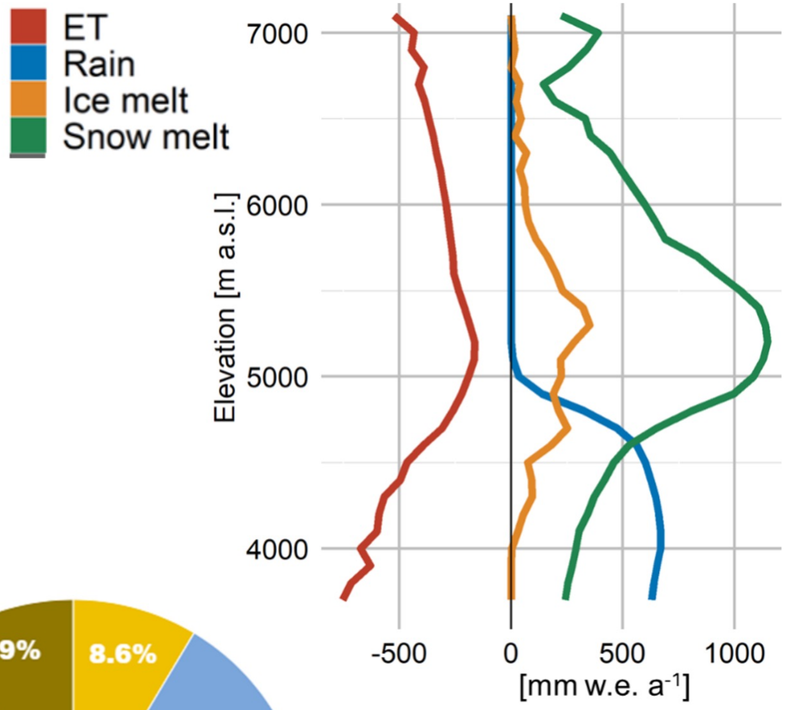


Glacier-specific altitudinal surface mass balance

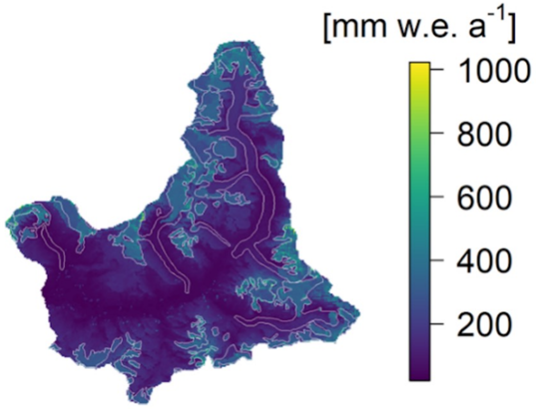
Importance of latent heat fluxes for the water balance of a high elevation catchment

- Land surface modeling reveals high altitudinal/subseasonal variability in water balance partitioning in a glacierized Himalayan catchment
- Water loss through snow sublimation, evaporation and transpiration exceeds water production from glacier melt by 54% at the catchment scale
- LE fluxes are particularly important for the catchment water balance above 6500 m (snow sublimation) and below 4500 m (transpiration)

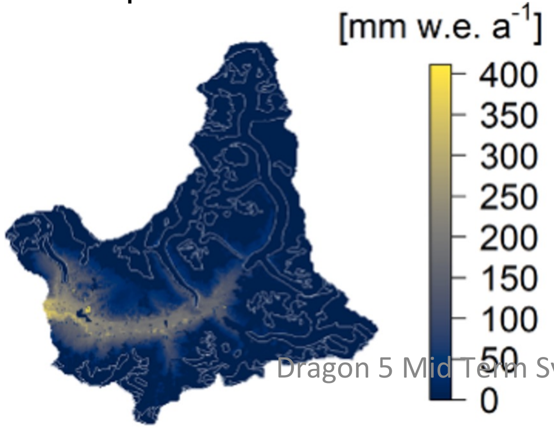
Modelled water balance partition



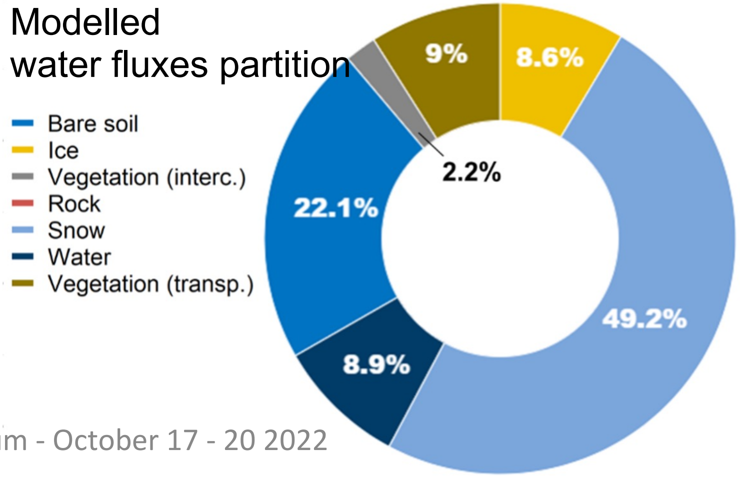
Modelled
sublimation from snow



Modelled
transpiration



Modelled
water fluxes partition

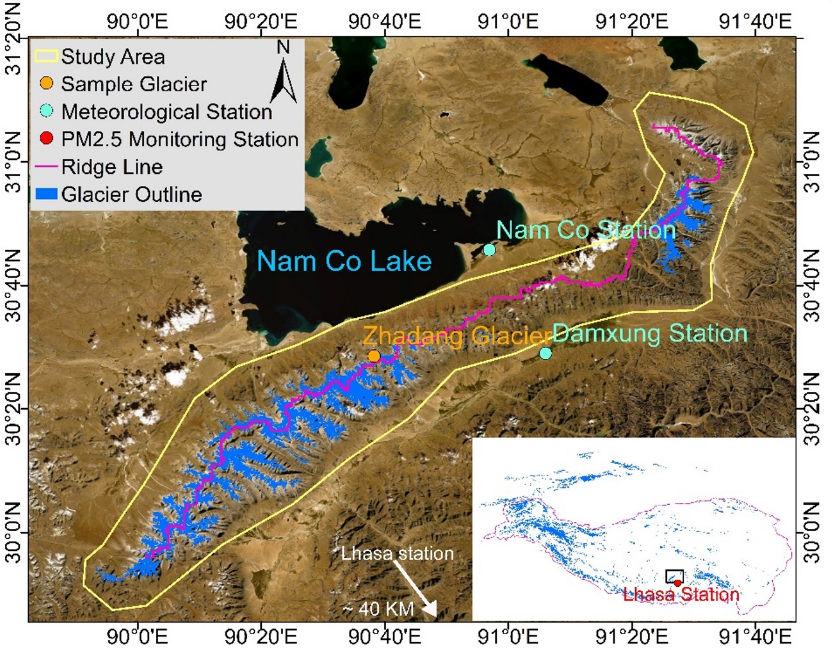


(**Buri et al., under review**)

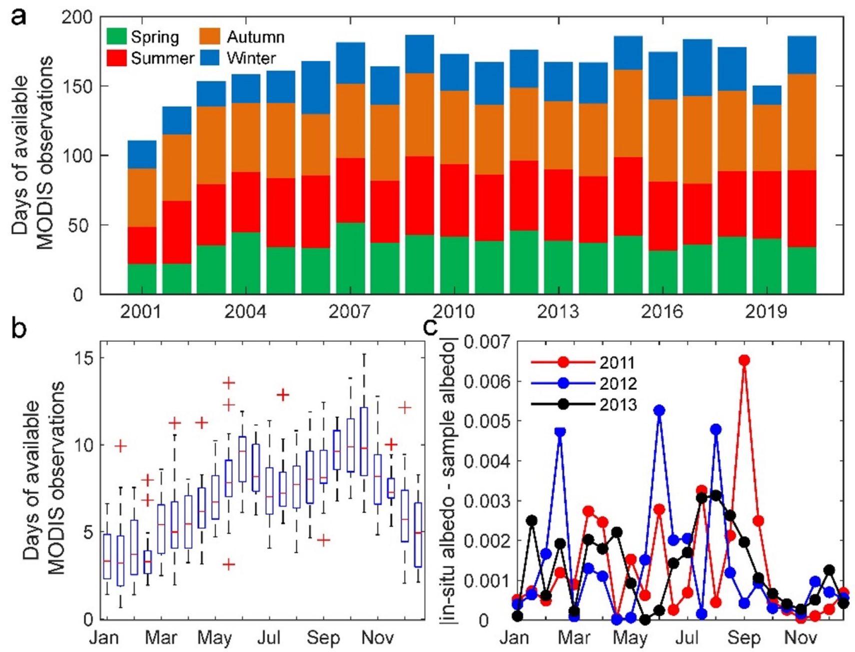
Cryospheric, vegetation and land surface changes

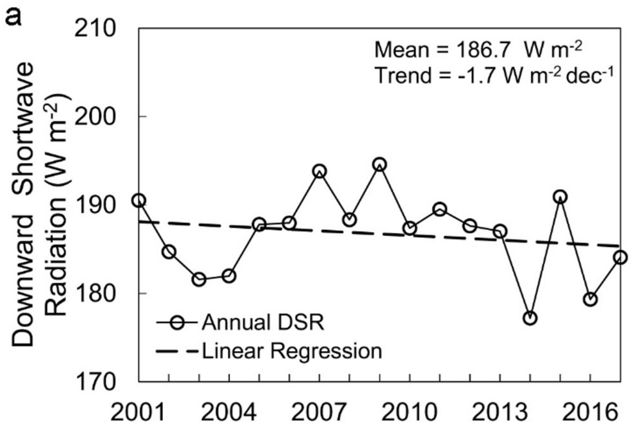
Albedo and mass loss in the Western Nyainqentanglha

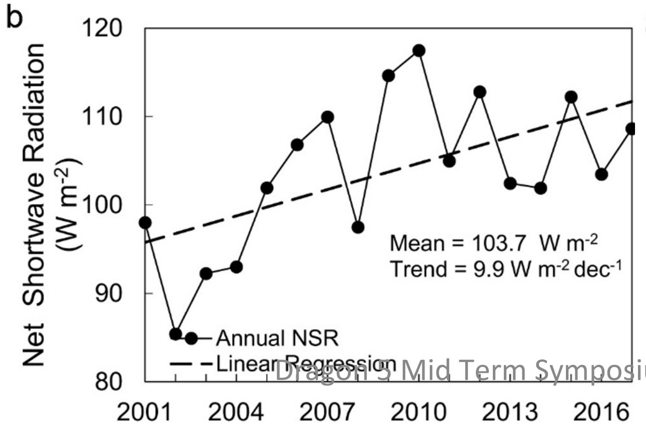
(Ren et al., 2021)

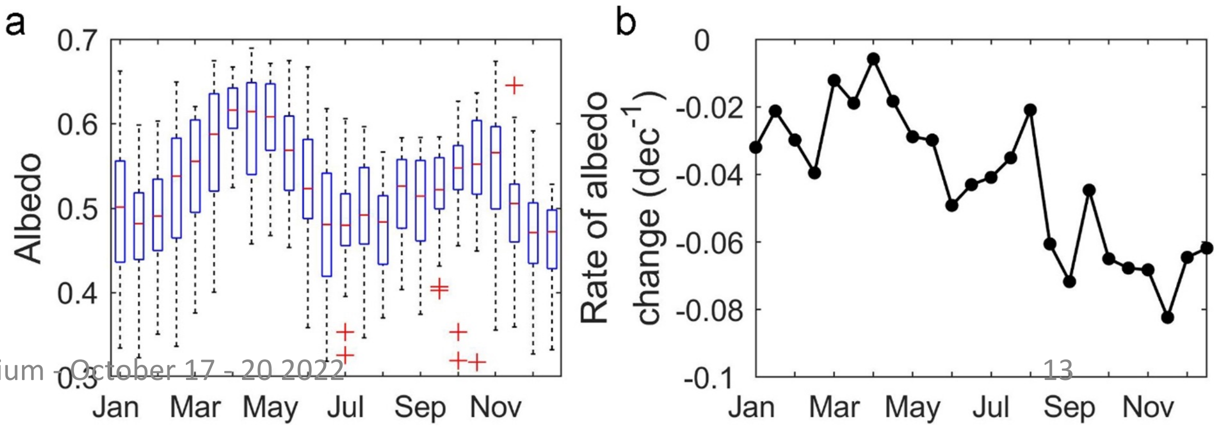


- New method to retrieve glacier daily albedo using MODIS data;
- Terrain slope and aspect; snow and ice BRDF anisotropy correction.
- Evaluation of response to rainfall, temperature and PM 2.5: trends,seasonality, spatial variability and elevation

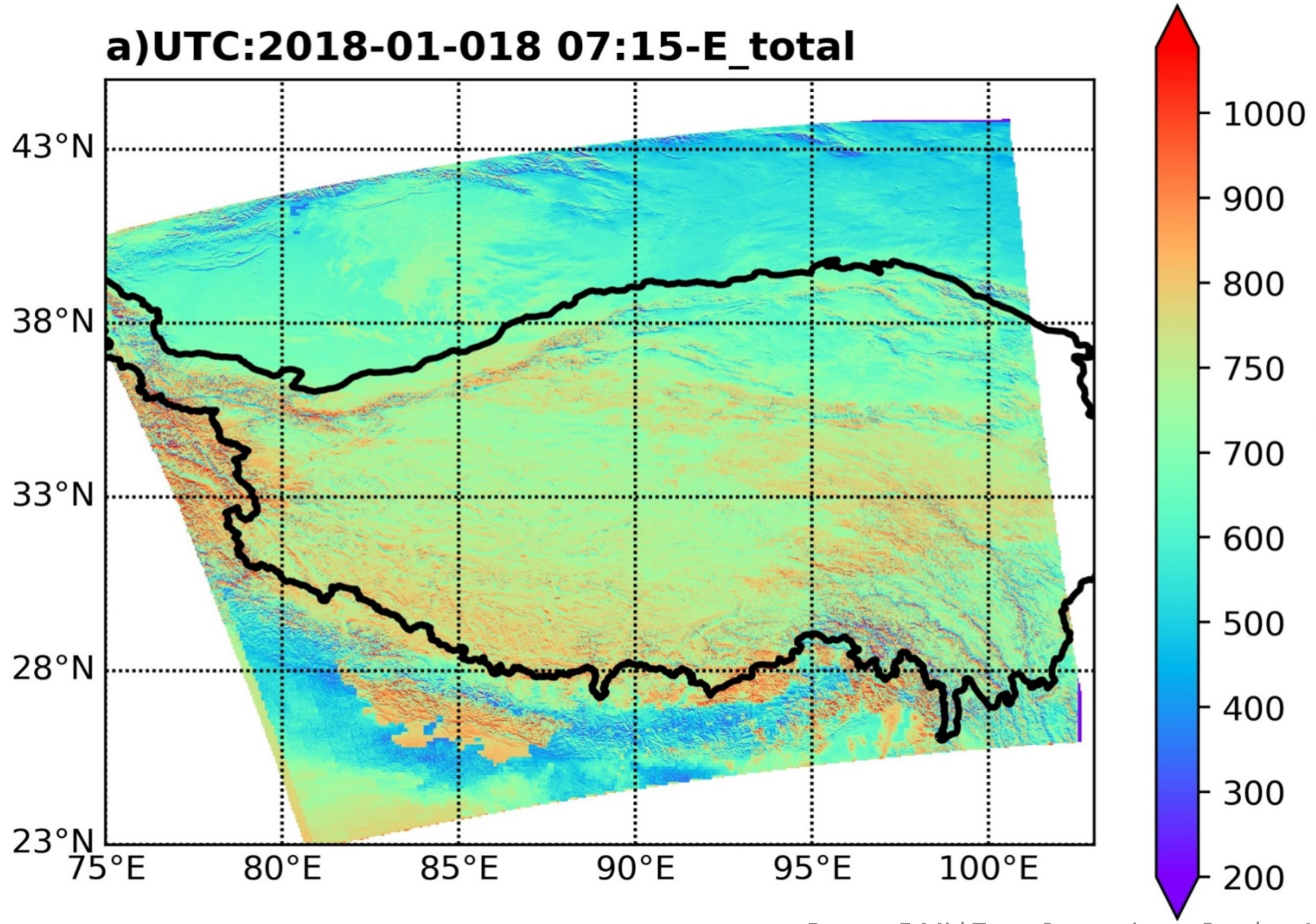




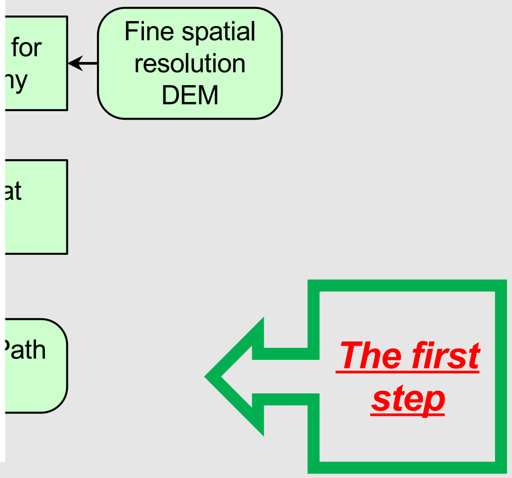




Simultaneous retrieval of AOD and surface BRDF: components of at-surface irradiance

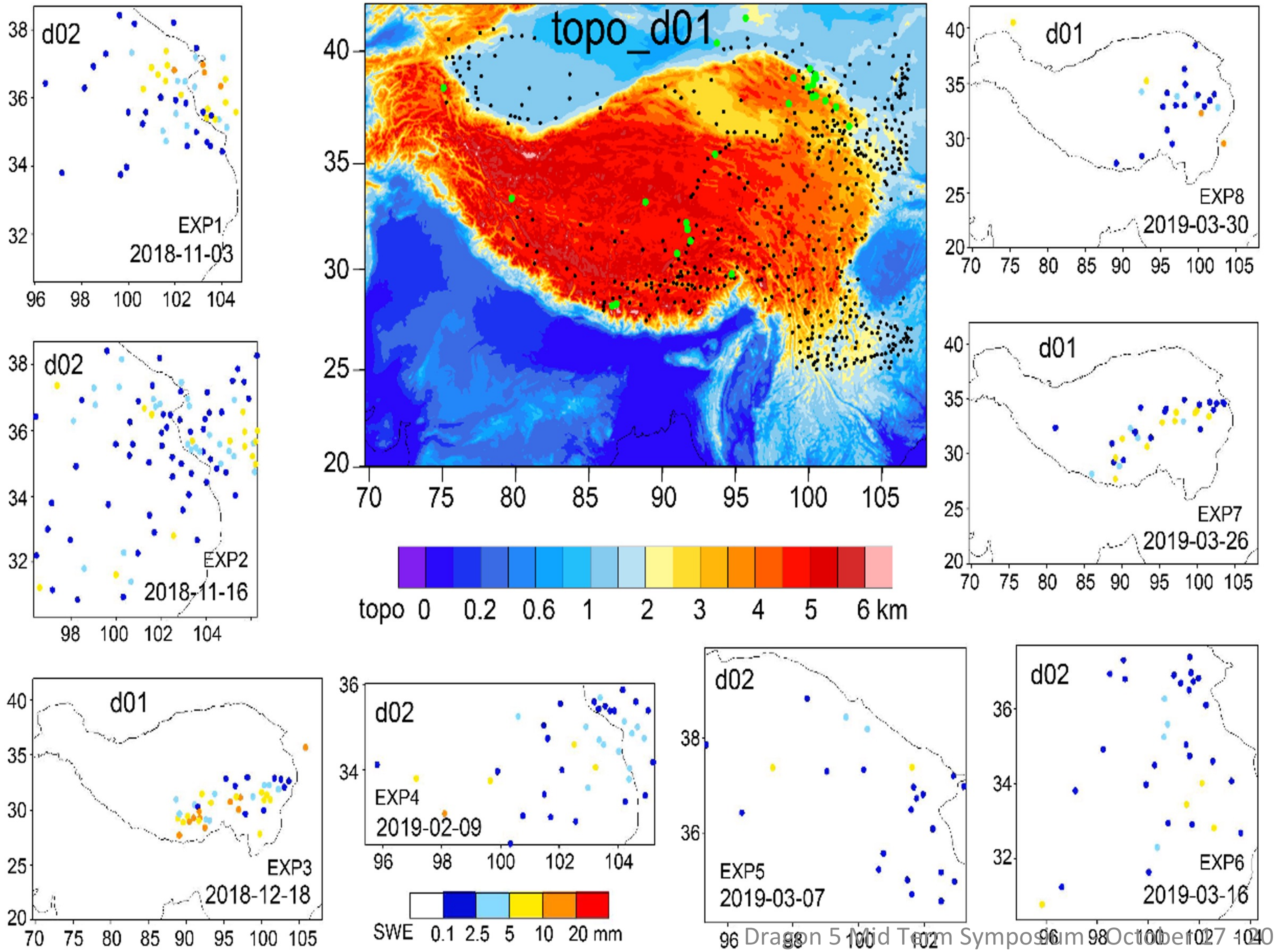


- Accurate knowledge of the magnitude and angular dependence of downwelling radiance necessary to retrieve both surface reflectance and AOD
- Increasing scattering increases path-radiance and modifies the angular dependence
- Terrain irradiance at a facet increases with increasing scattering



(Jia et al., 2021)

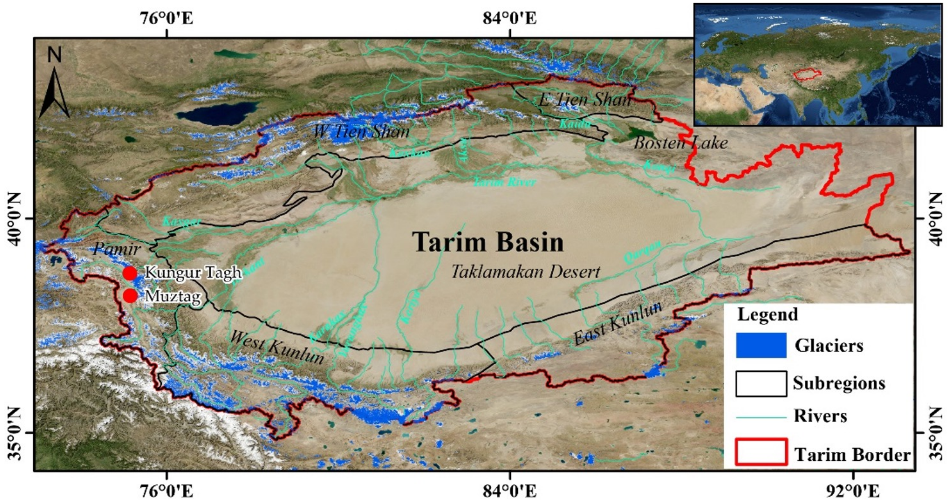
Land-surface interactions: cryosphere, hydrosphere and biosphere



Improved Noah Snow Albedo Scheme in the Simulation of Snow Processes

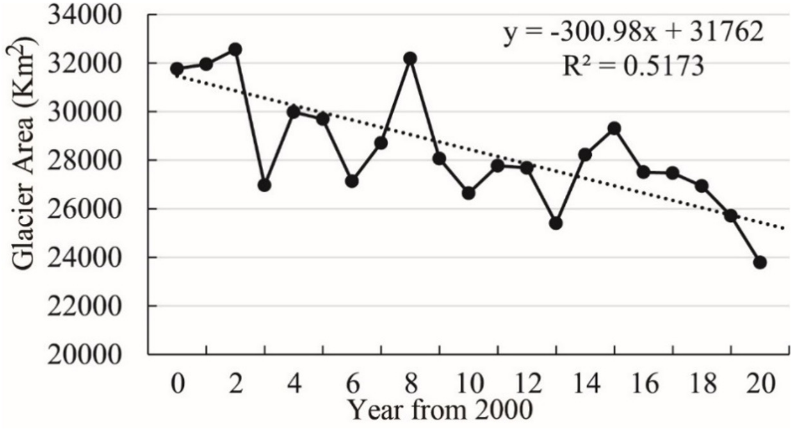
(**Liu et al., 2021**)

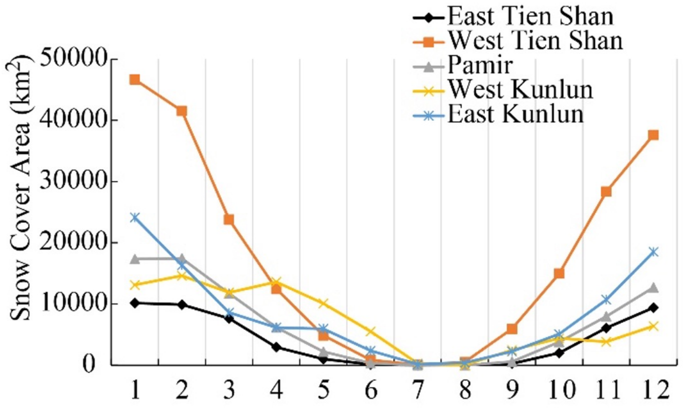
Glacier Area and Seasonal Snow Cover Changes in the Tarim basin - 2013 to 2020

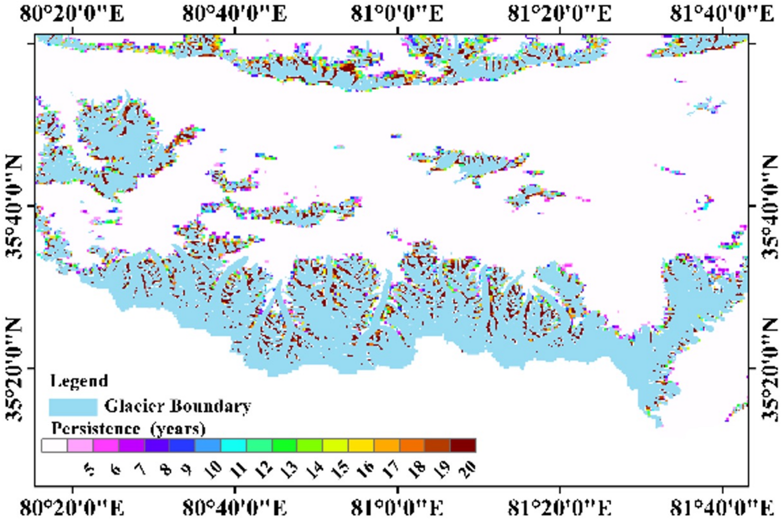


- Thresholding the NDSI to extract annual glacier area and snow cover
- MODIS Surface Reflectance 8-Day product (MOD09A1)
- Multiple snowfall and snowmelt events → intermittent snow cover → discriminate snow and glacier.
- Glacier outlines 2000, 2005, 2010, 2015 and 2020)
- Glacier area decreased 7975.71 km2 from 2001 to 2020; annual rate of change – 0.94 %

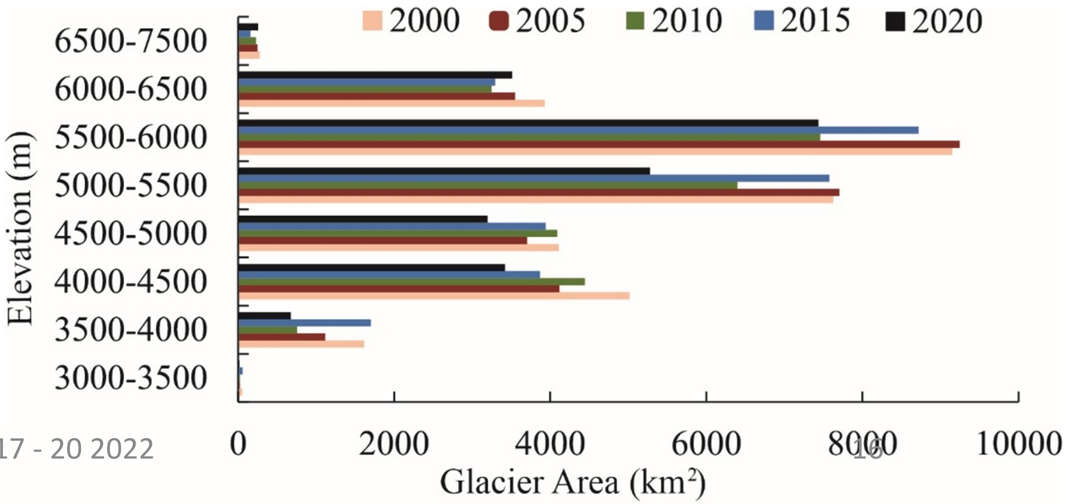
(Zhang et al., 2021 b)





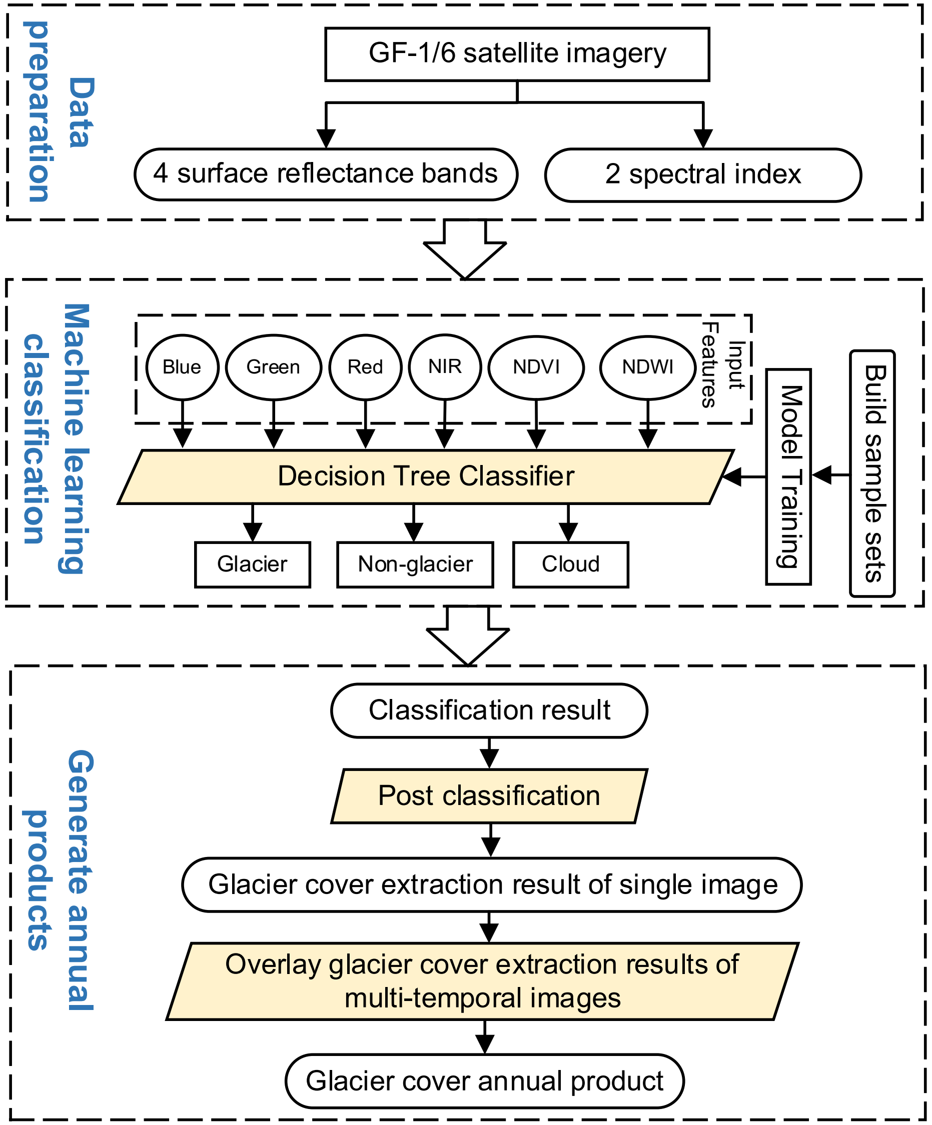


Long lasting snow



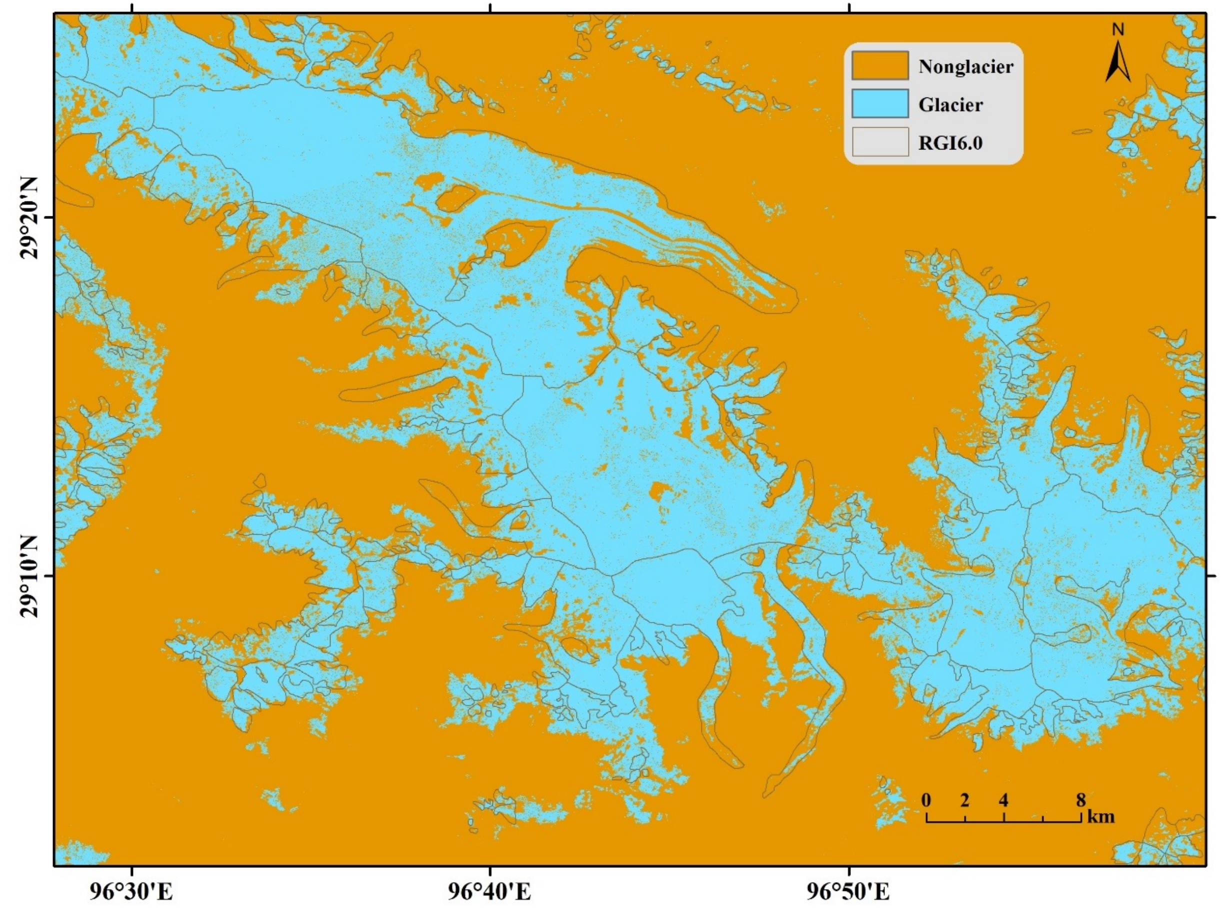
Glacier Cover Extraction

- Data: Gao Fen 1 and 6
- Image Classification (Decision Tree)
  - Input features
    - Surface reflectance: Blue/Green/Red/NIR
    - Spectral index: NDVI/NDWI
  - Class result: Glacier/Non-glacier/Cloud
- Post Classification
  - Remove noise and make images more continuous
- Overlay Classification Results of Multi-Temporal Images
  - Because seasonal snow and cloud cover could hamper the correct identification of glaciers.



The flowchart of the Glacier Cover Extraction

Result (Comparison with RGI6.0)



Glacier cover annual product(2020) of Parlung Zangbo

Aerospace Information Research Institute (AIR)
Chinese Academy of Sciences (CAS)

Snow remote sensing in High Mountain Asia

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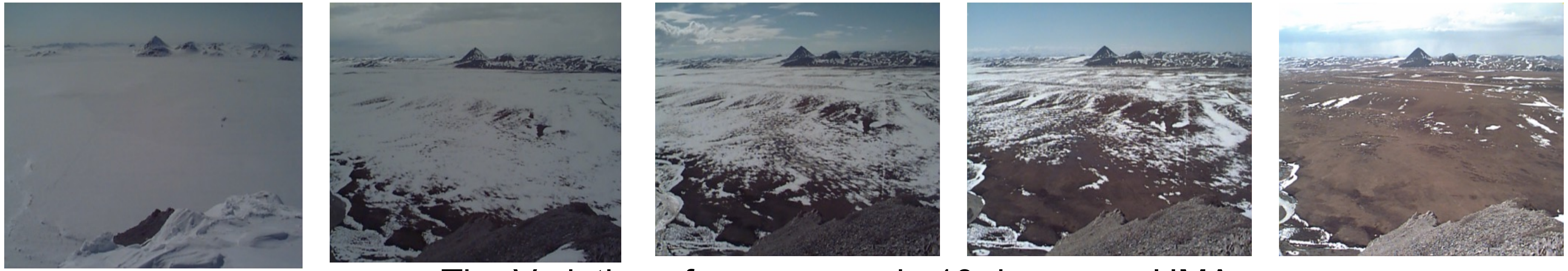
Aerospace Information Research Institute, CAS

2023-09-13

Background: Snow remote sensing in High Mountain Asia

A series of algorithms, data and systems for estimating snow parameters in High Mountain Asia were developed

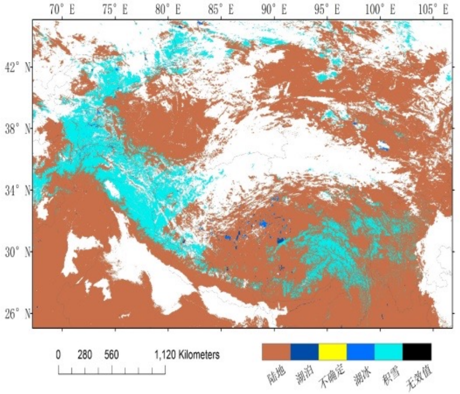


The Variation of snow cover in 10 days over HMA

Problems: (1) Poor (short) persistence of snow cover in Qinghai-Tibet Plateau; (2) MODIS 8-day snow products are insufficient; (3) Snow monitoring by passive microwave remote sensing is always overestimated;

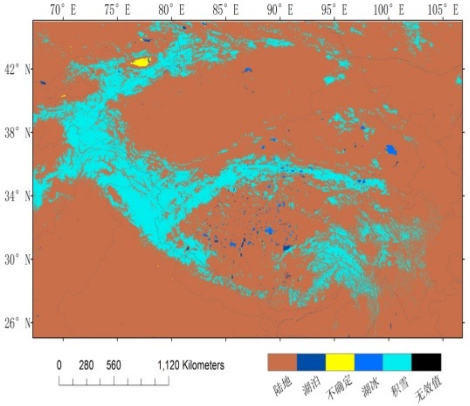
→ **Daily cloud-free snow cover and improved SWE products need to be developed**.

NDSI from MODIS/Terra & Aqua

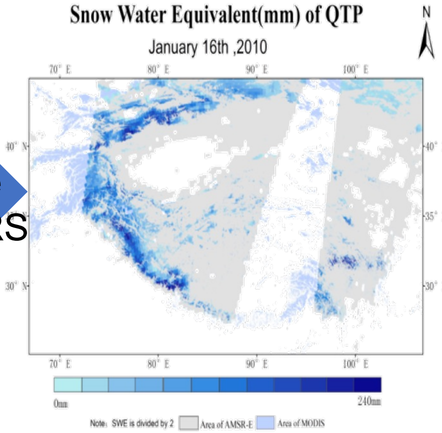


Through a series of algorithmic processes

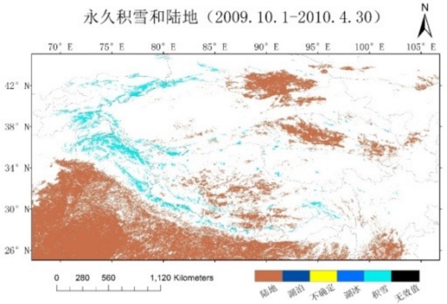
MODIS daily cloud-free snow cover products



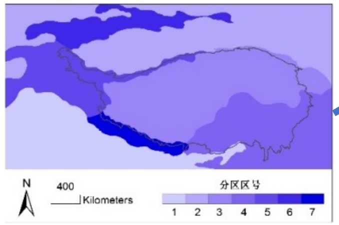
Integrated microwave and optics RS



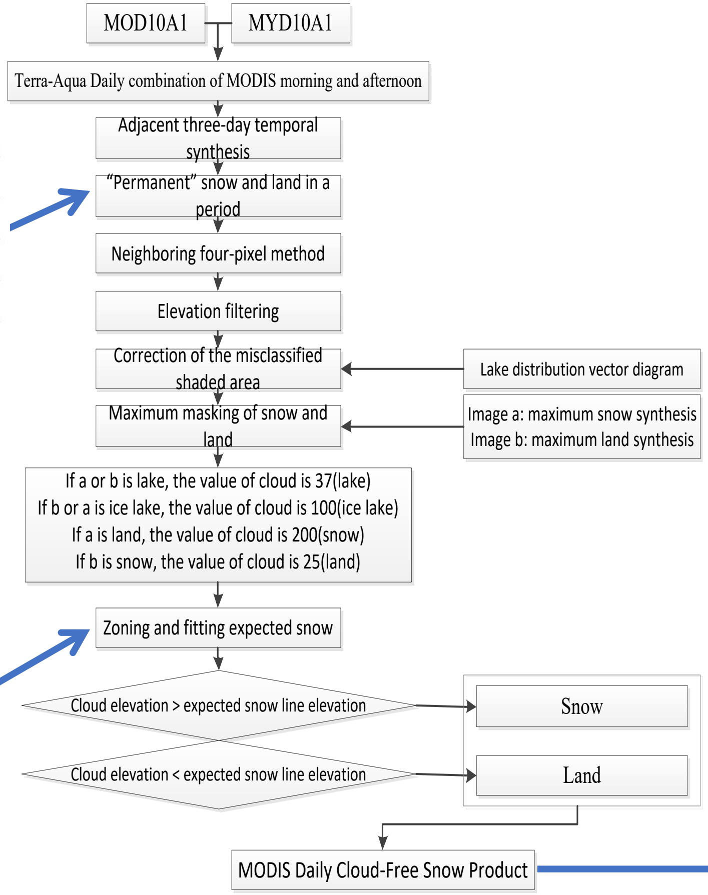
MODIS daily cloud-free snow cover area products



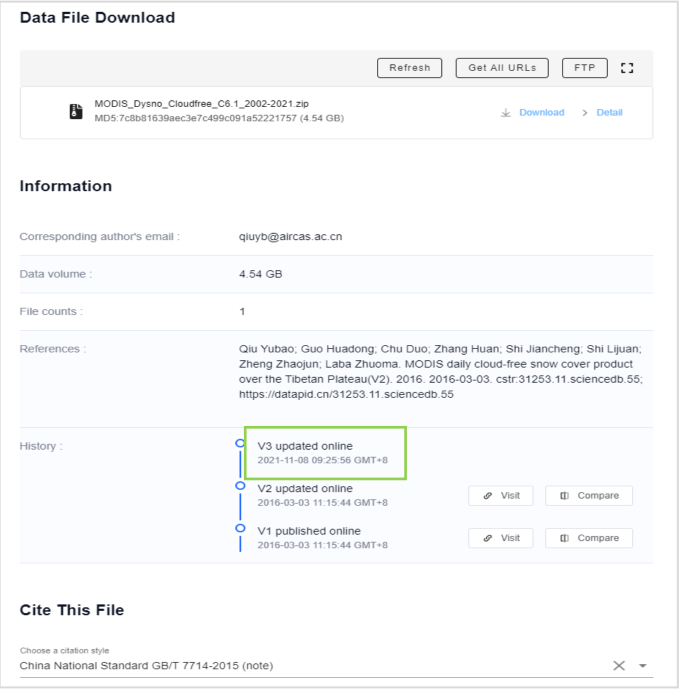
Everlasting snow
Everlasting land
Seasonal snow



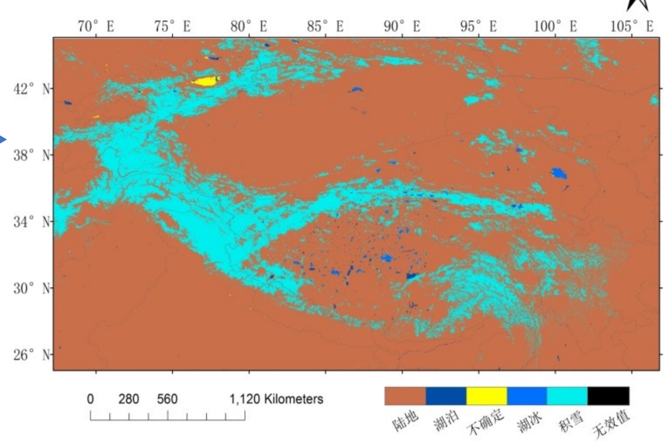
Zoning is determined based on factors of slope and altitude



Flow chart of algorithm for MODIS daily cloud-free snow products

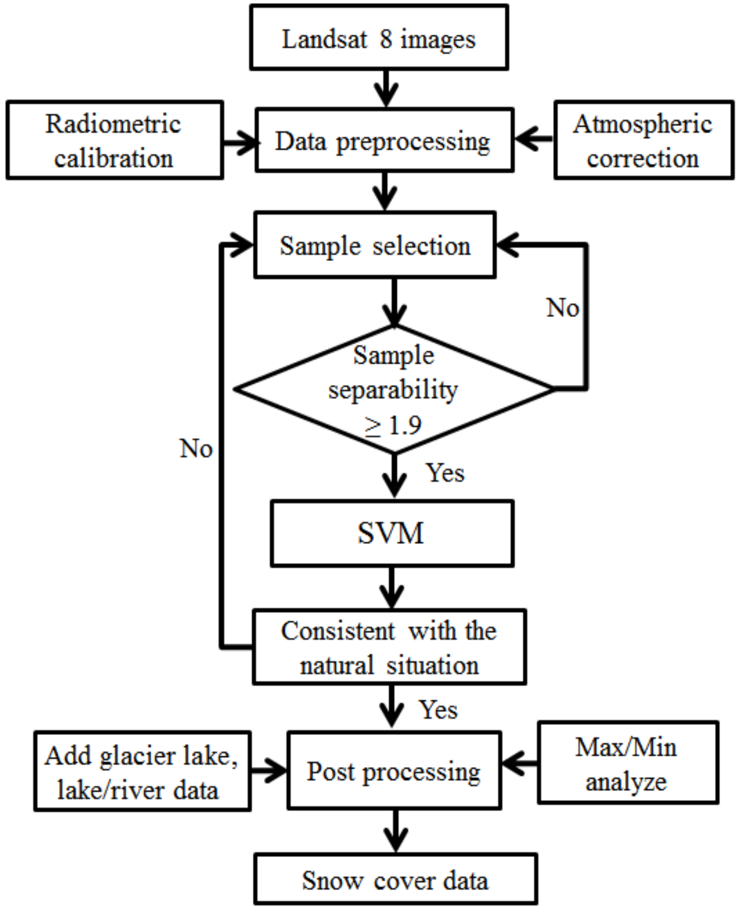


MODIS daily cloud-free snow cover products (2010.1.4)

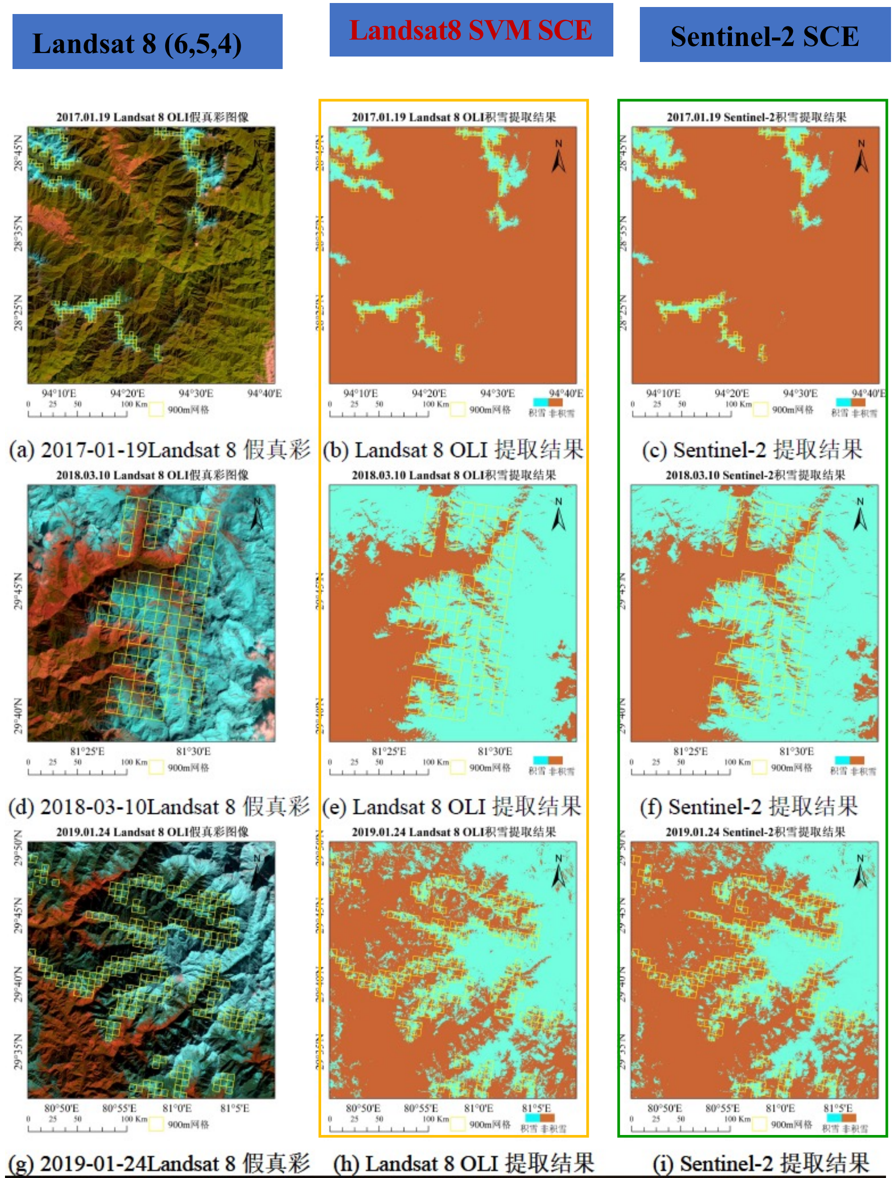


Snow cover monitoring in Himalayan based on support vector machine

Build high-resolution snow sample data (2002-2022), in order to drive snow prediction models and validate medium-resolution snow cover product



Landsat8 snow cover extraction process by using support vector machine



Validation:

The correlation coefficients are greater than 0.95 between Landsat 8 snow cover and Sentinel-2 snow cover, and the largest RMSE is 0.1.

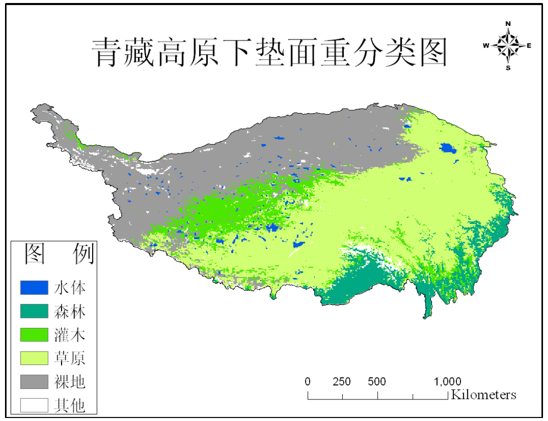
The consistency is high in 900 m grid cell, which also indicates the reliability of Landsat 8 snow cover dataset.

Date	Metric	
	Correlation coefficient	RMSE
2017.01.19	0.9683	0.0574
2019.01.24	0.9570	0.1080
2018.03.10	0.9867	0.0827
2019.05.09	0.9966	0.0399
2018.12.17	0.9556	0.0804
2020.12.31	0.9724	0.0702

Improving the AMSR-E SWE algorithm in Qinghai-Tibetan Plateau

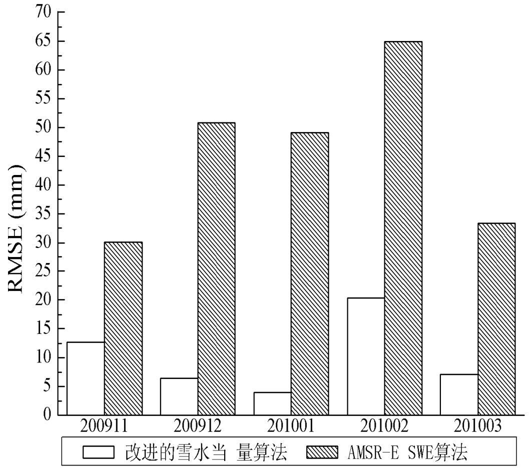
Data:

- AMSR-E: H&V pol, C, X, Ku, Ka band
- Ground weather station: in-situ snow depth
- Snow density
- Surface land cover data
- Other auxiliary data



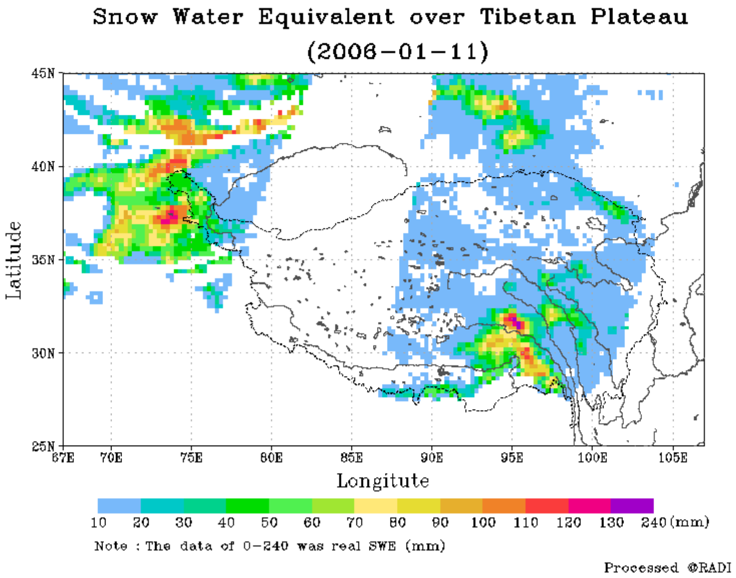
下垫面类型	雪水当量算法
Forest	$SWE_f = SD_f \times \rho_s \times 10$
Shrub	$SWE_s = SD_s \times \rho_s \times 10$
Grass	$SWE_g = SD_g \times \rho_s \times 10$
Bare soil	$SWE_b = SD_b \times \rho_s \times 10$

$$SWE = F_f \times SWE_f + F_s \times SWE_s + F_g \times SWE_g + F_b \times SWE_b$$

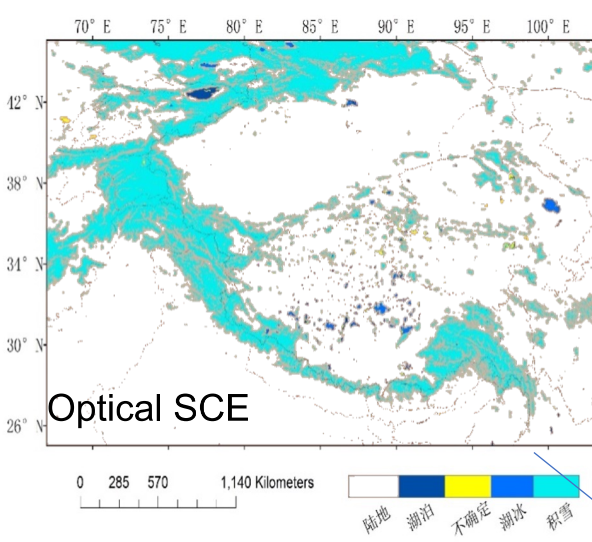


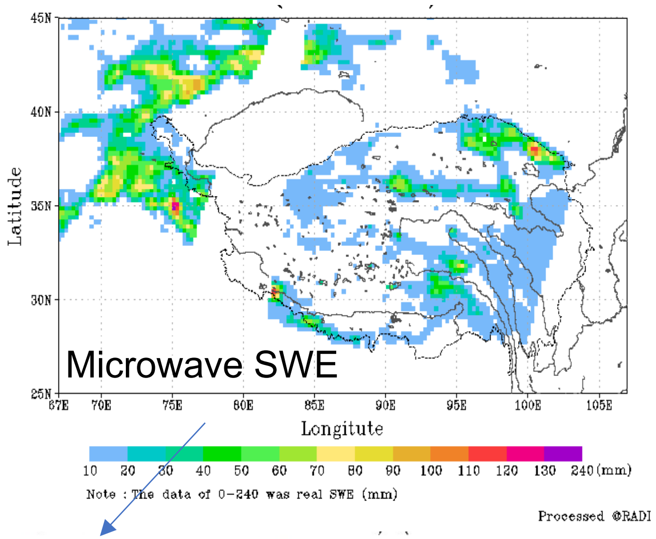
RMSE统计直方图

The results was compared with NASA AMSR-E SWE



Microwave and optical blended SWE products

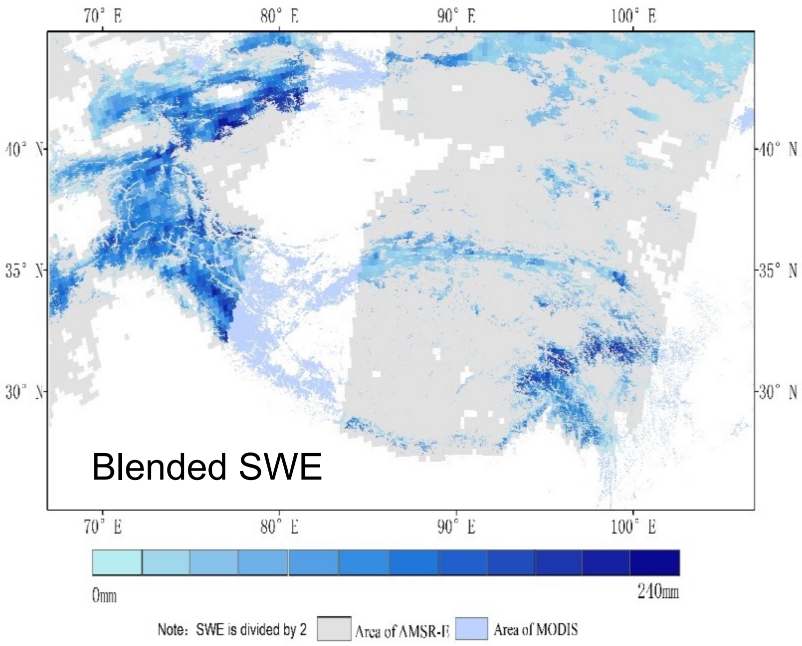


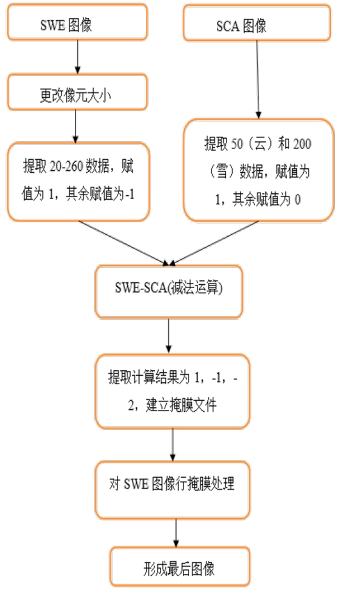


The Microwave and optical blended SWE products:

<u>Both accurate snow cover extent and snow water equivalent data are available</u>

	SWE	SCA
0	有 SWE 数据	有 SCA 数据
1	有 SWE 数据	没有 SCA 数据
-2	没有 SWE 数据	有 SCA 数据
-1	没有 SWE 数据	没有 SCA 数据





The applications of snow data products

Four high spatio-temporal resolution snow dataset over HMA were released

- **MODIS daily cloud-free snow cover products over Tibetan Plateau(V4). 2016. Science Data Bank. (2002-2021)**
- **Daily fractional snow cover dataset over High Asia. Science Data Bank, 2017. (2002-2018)**
- **Passive microwave remote sensing data of snow water equivalent in High Asia. Science Data Bank. 2018. (2002-2018)**
- **A dataset of Landsat 8 snow coverage in the central and eastern Himalayas from 2013 to 2020. Science Data Bank, 2022. (Now we have completed the whole Himalayas, time span：2002-2022）**

◆ Snow cover and fractional snow cover dataset in the whole "China Scientific Data" journal visits, downloads ranked 2nd and 5th;
◆ Won the inaugural ScienceDB Individual Achievement Award;
◆ In the convergence and sharing of big Earth data science, they won the Top1 annual download in 2019

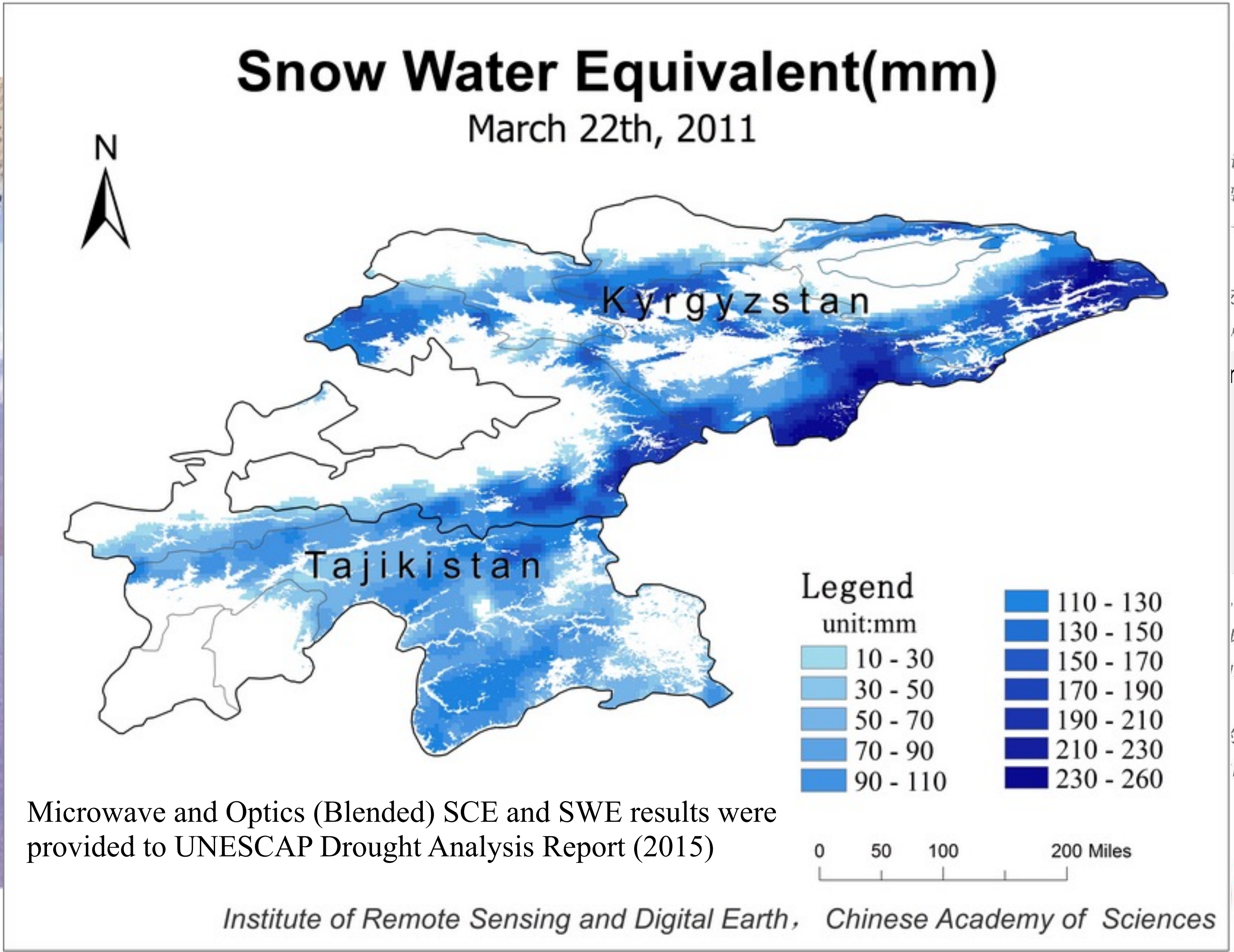
Technology and application acquired：
◆ The second class prize of Tibet Autonomous Region Advanced Science and Technology in 2019
◆ The first prize of science and technology progress of Xizang Meteorological Bureau in 2019

4 invention patents and 23 papers in snow parameters measurement and algorithm

Qinghai-tibet Plateau snow observation service network

（HiMAC Data Portal）

The applications of snow data products

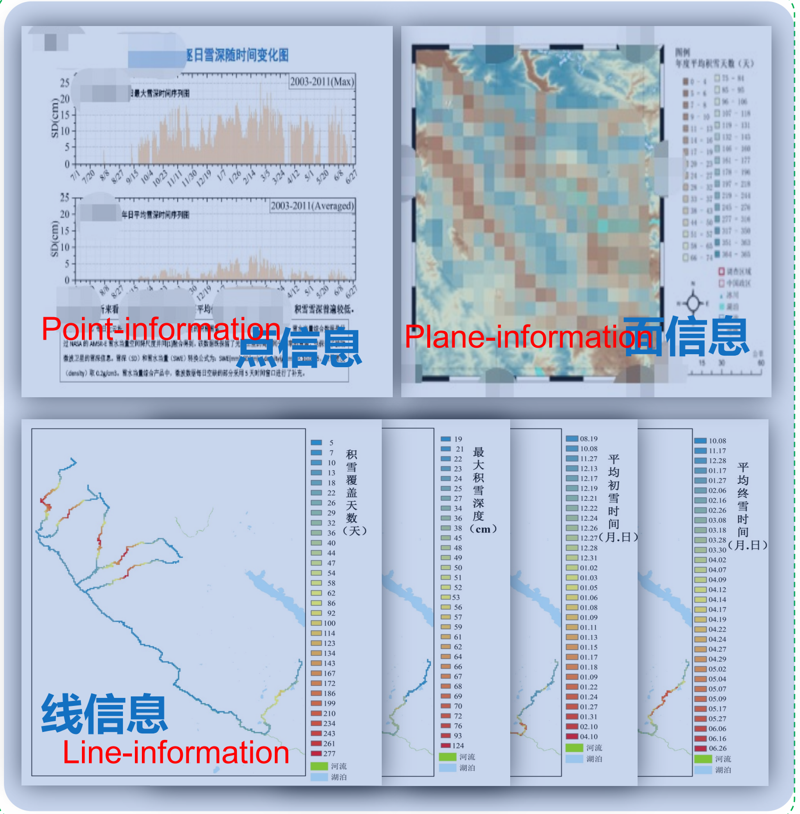


Microwave and Optics (Blended) SCE and SWE results were provided to UNESCAP Drought Analysis Report (2015)

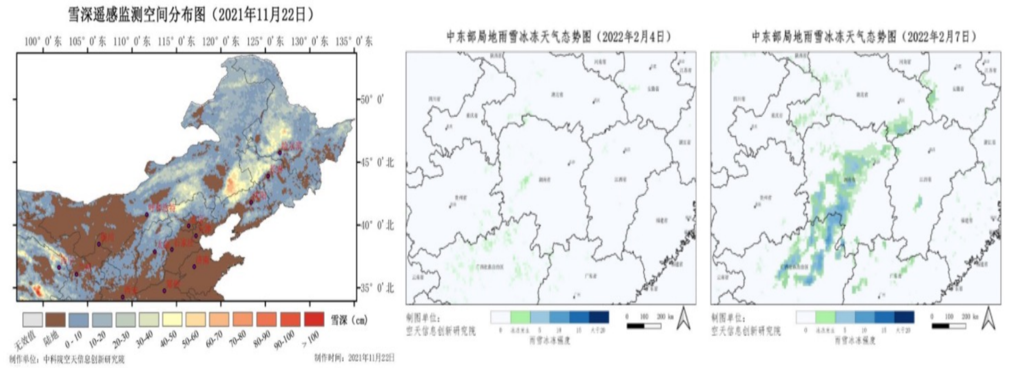
The applications of snow data products

Related data: Engineering application of daily snow cover and snow depth products

- It provides information on snow cover duration, snow depth and initial and final snow time in key areas, locations and routes, and provides key meteorological information for material transportation, snow environment, traffic and commuting support, as well as related strategic analysis. The mission was approved by the president of the Chinese Academy of Sciences (Bureau of Major R&D Programs Chinese Academy of Sciences).



- In the winter of 2021-2022, in view of the snow disaster in China and the freezing weather in the south of China, high-frequency microwave remote sensing combined with atmospheric correction technology have been used to monitor new and thin snow and ice, forming a rapid monitoring capability of snow cover and depth, and work with the National Disaster Reduction Center, Ministry of Emergency Management to support the snow and ice disaster information service.



The trend of frozen rain and snow climate in southern mountain area of China in Feb. 2022

* On the importance of vapour fluxes for the water balance of a high elevation Himalayan catchment

** Land surface modelling informed by earth observation data: Towards understanding blue-green-white water fluxes in High Mountain Asia

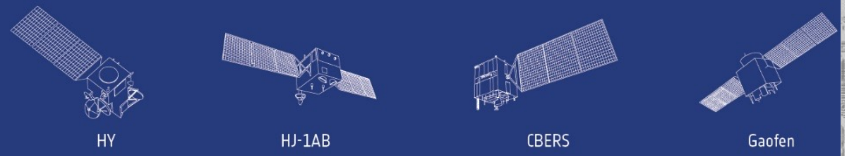
High Mountain Glaciers and Hydrology Group

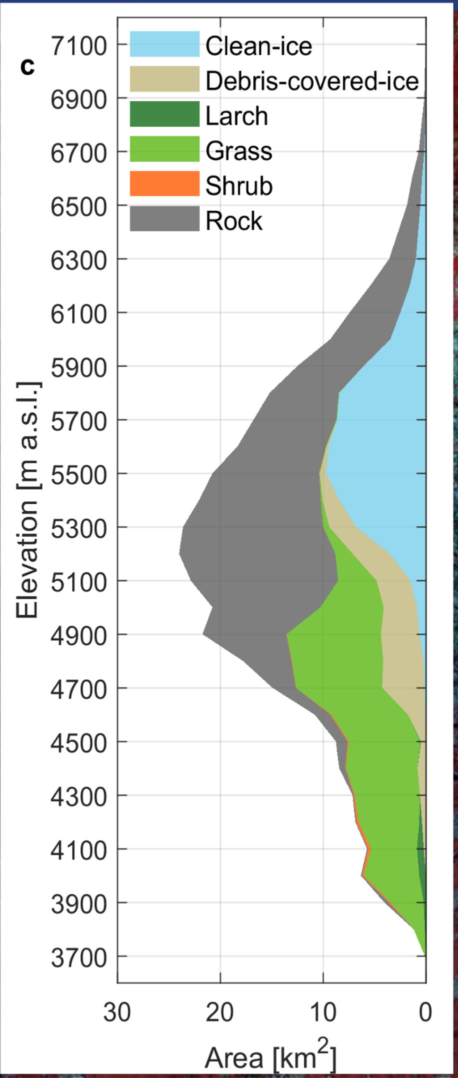
WSL

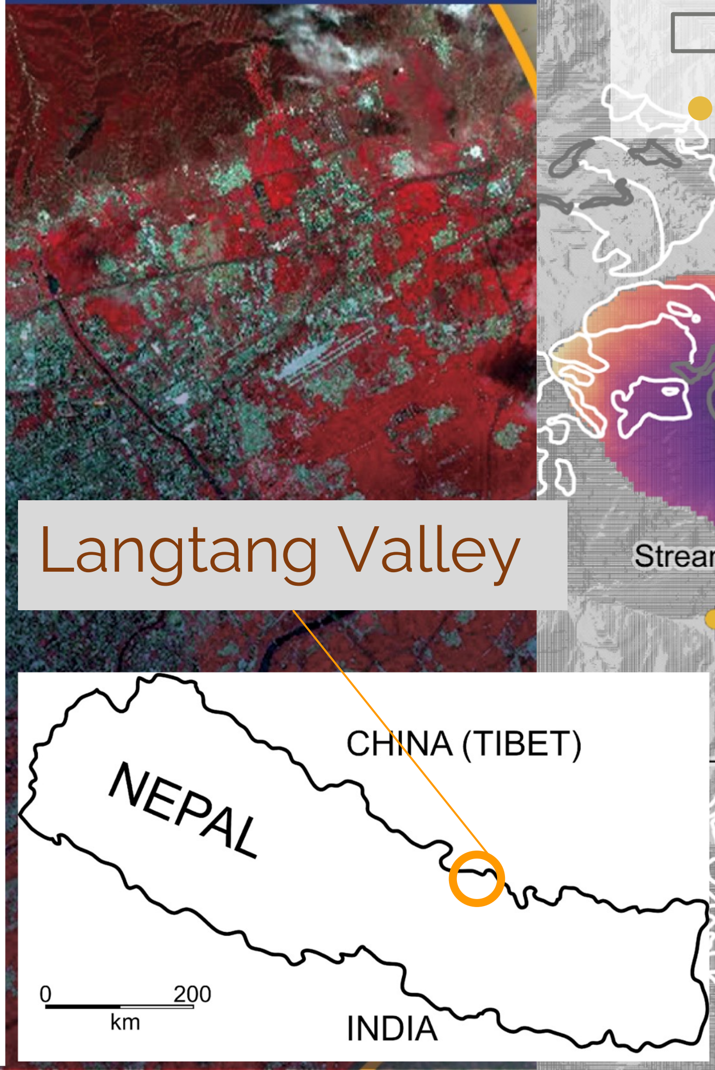
Swiss Federal Institute
for Forest, Snow and
Landscape Research WSL

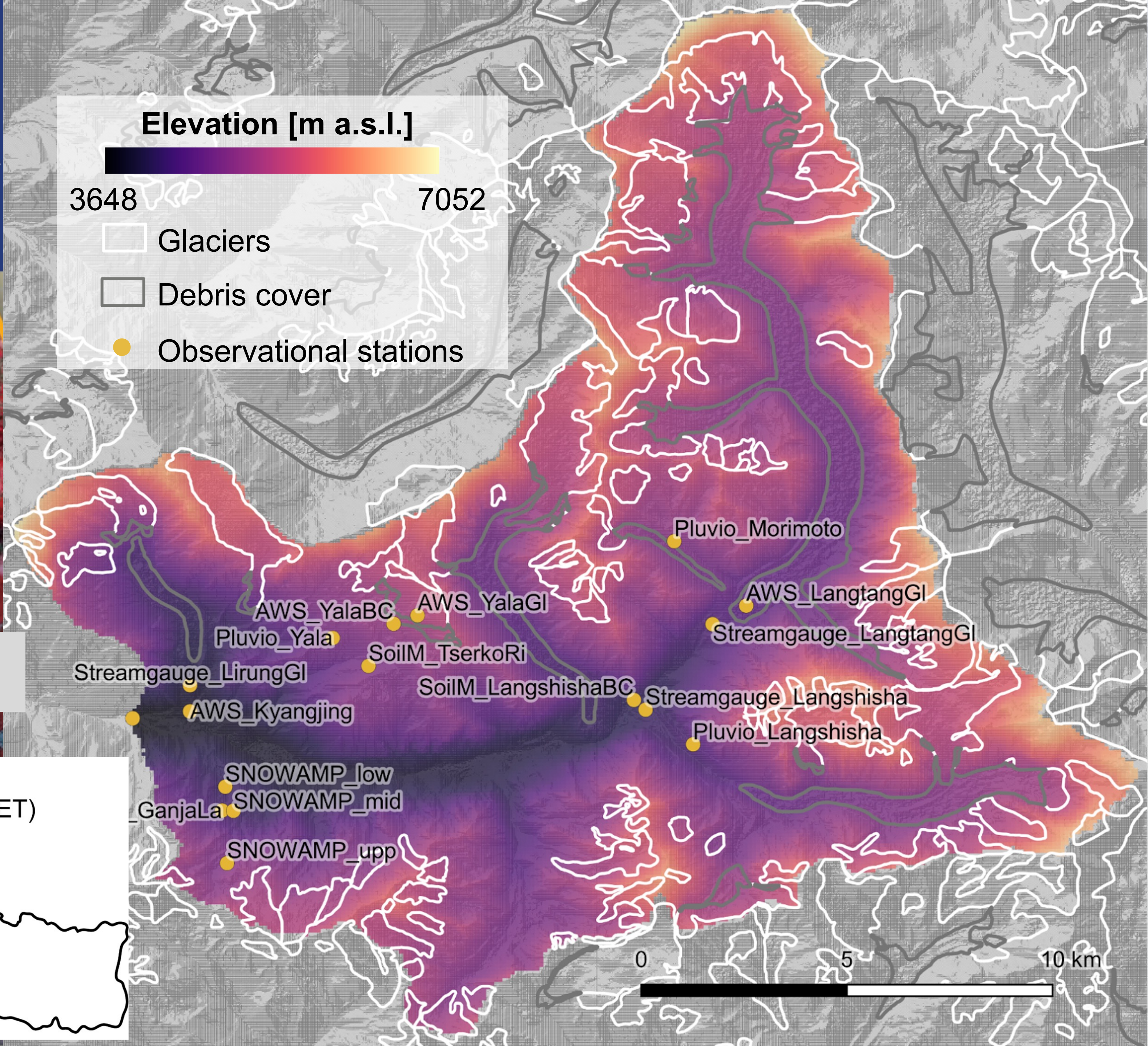
Under review in *Water Resources Research** and *Geo-spatial Information Science***

Study site

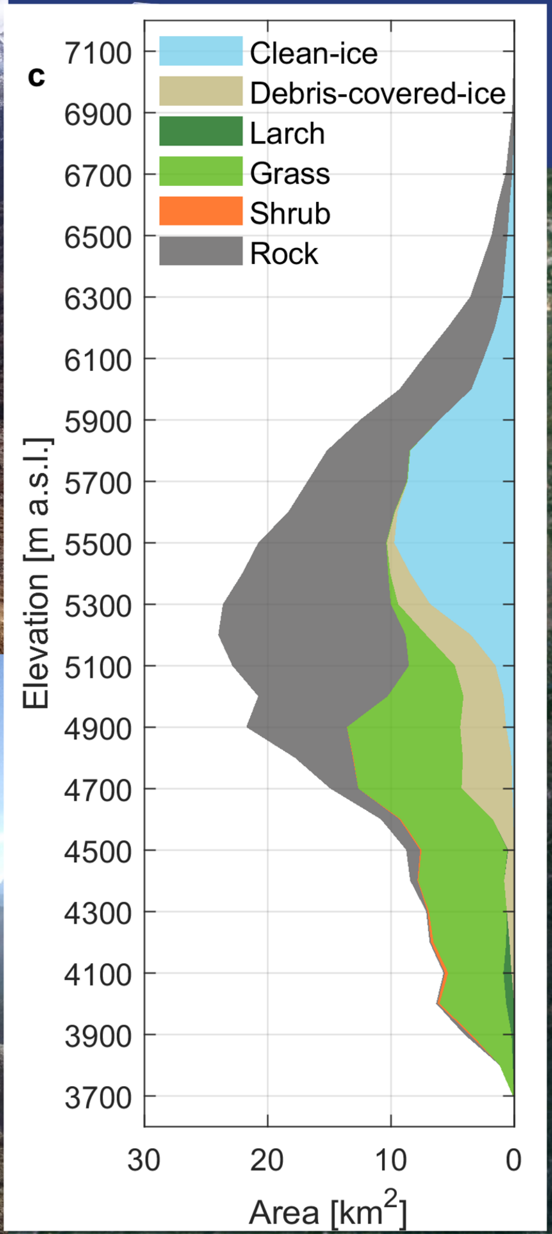

HY
HJ-1AB
CBERS
Gaofen


c
Clean-ice
Debris-covered-ice
Larch
Grass
Shrub
Rock
7100
6900
6700
6500
6300
6100
5900
5700
5500
5300
5100
4900
4700
4500
4300
4100
3900
3700
Elevation [m a.s.l.]
30
20
10
0
Area [km^2]


Langtang Valley
CHINA (TIBET)
NEPAL
INDIA
0
200
km


Elevation [m a.s.l.]
3648
7052
Glaciers
Debris cover
Observational stations
Pluvio_Morimoto
AWS_LangtangGl
Streamgauge_LangtangGl
AWS_YalaBC
AWS_YalaGl
Pluvio_Yala
SoilM_TserkoRi
Streamgauge_LirungGl
SoilM_LangshishaBC
Streamgauge_Langshisha
AWS_Kyangjing
Pluvio_Langshisha
SNOWAMP_low
SNOWAMP_mid
GanjaLa
SNOWAMP_upp
0
5
10 km

Study site: Langtang catchment

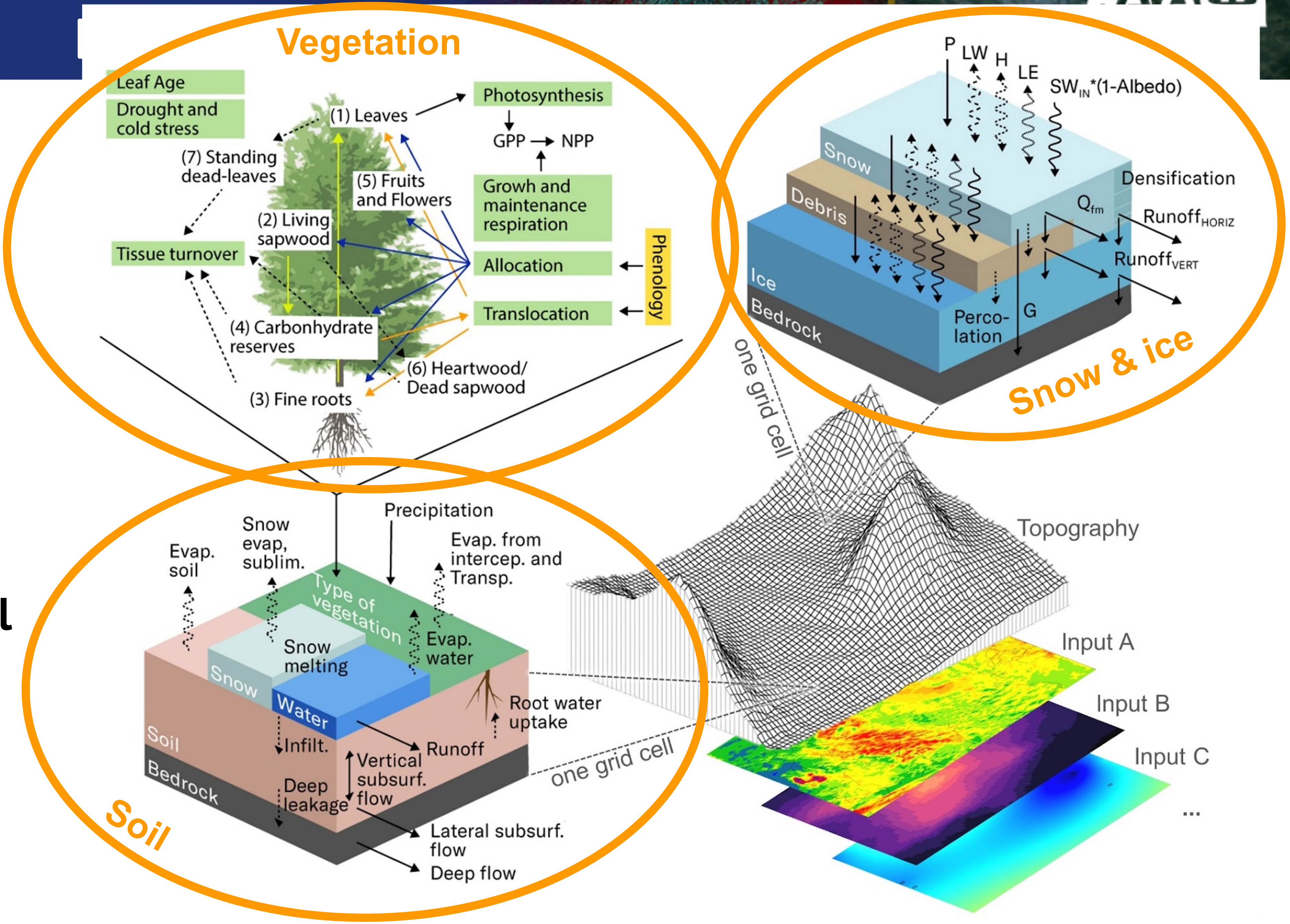


Model

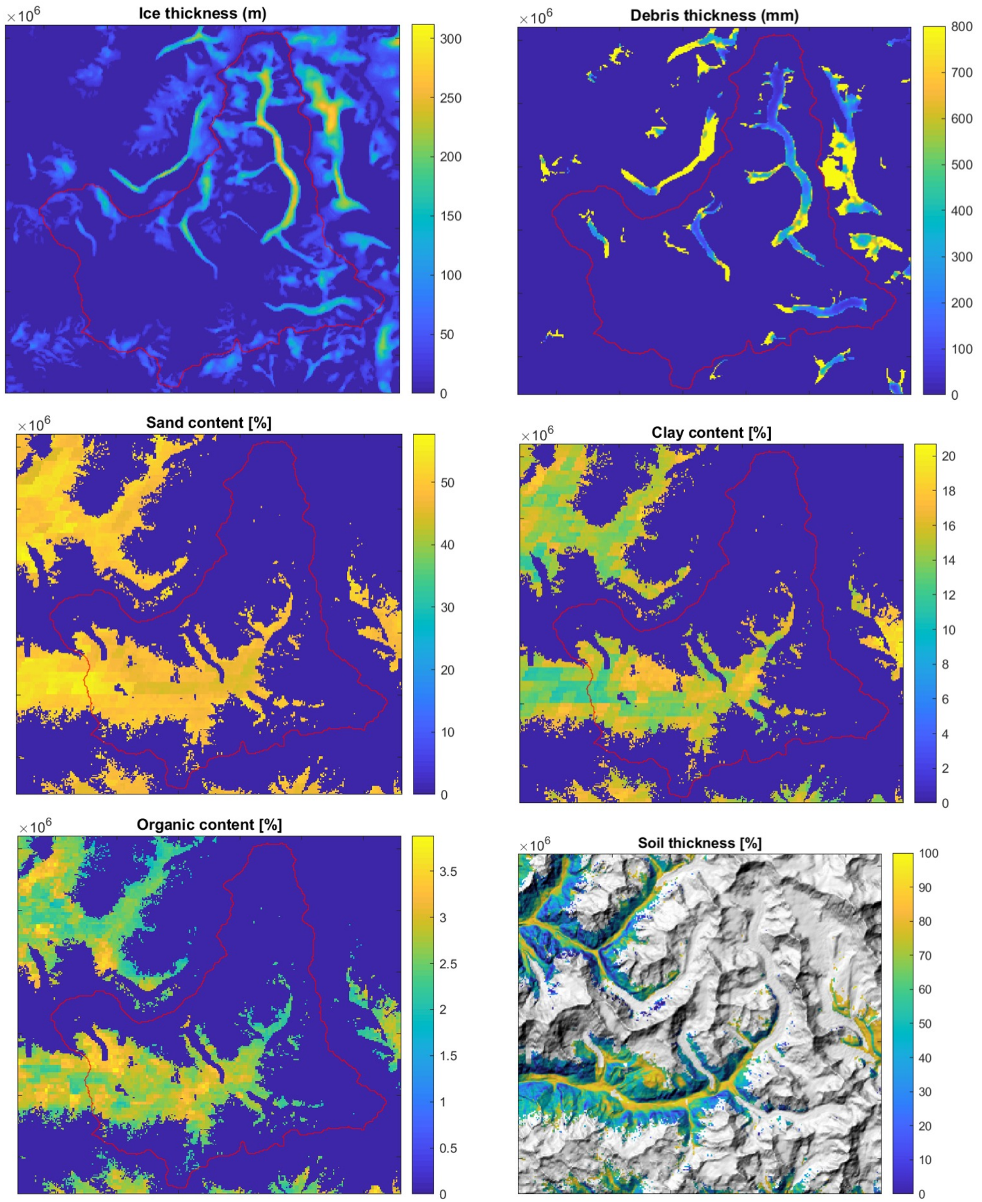
- Application of Land Surface Model of very high spatial, temporal and physical detail to simulate the glacierized Langtang catchment (Nepal)

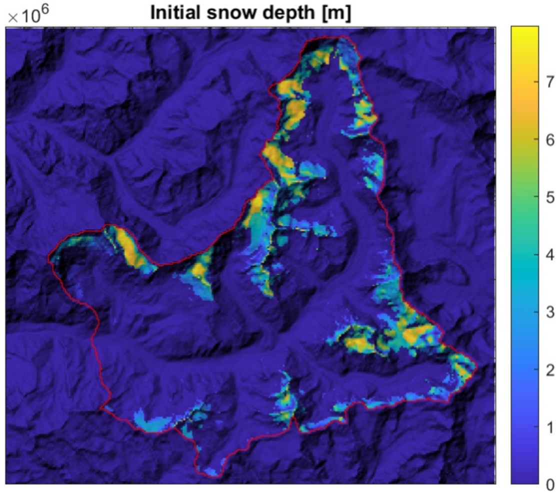
Tethys & Chloris
Land Surface Model

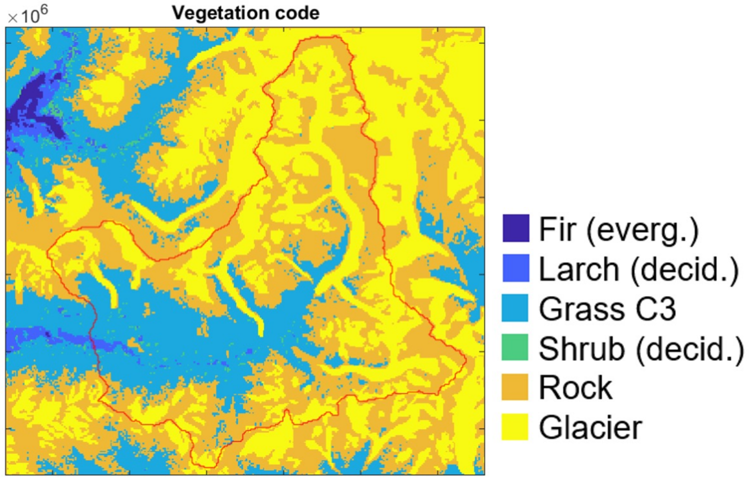
Fatichi et al. (2012)



Model set-up







Model set-up

Meteorological forcing (hourly):

- Air temperature
- Shortwave radiation
- Cloud cover fraction
- Wind speed
- Relative humidity
- Atmospheric pressure
- Precipitation

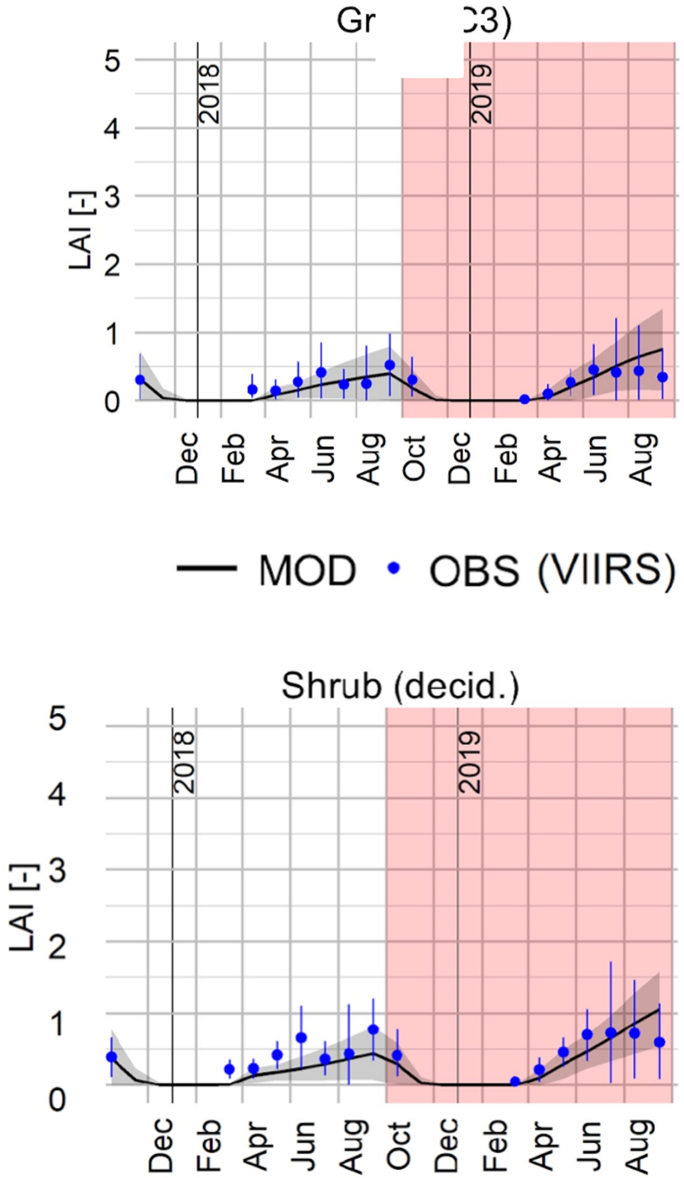
Spatial resolution: 100m

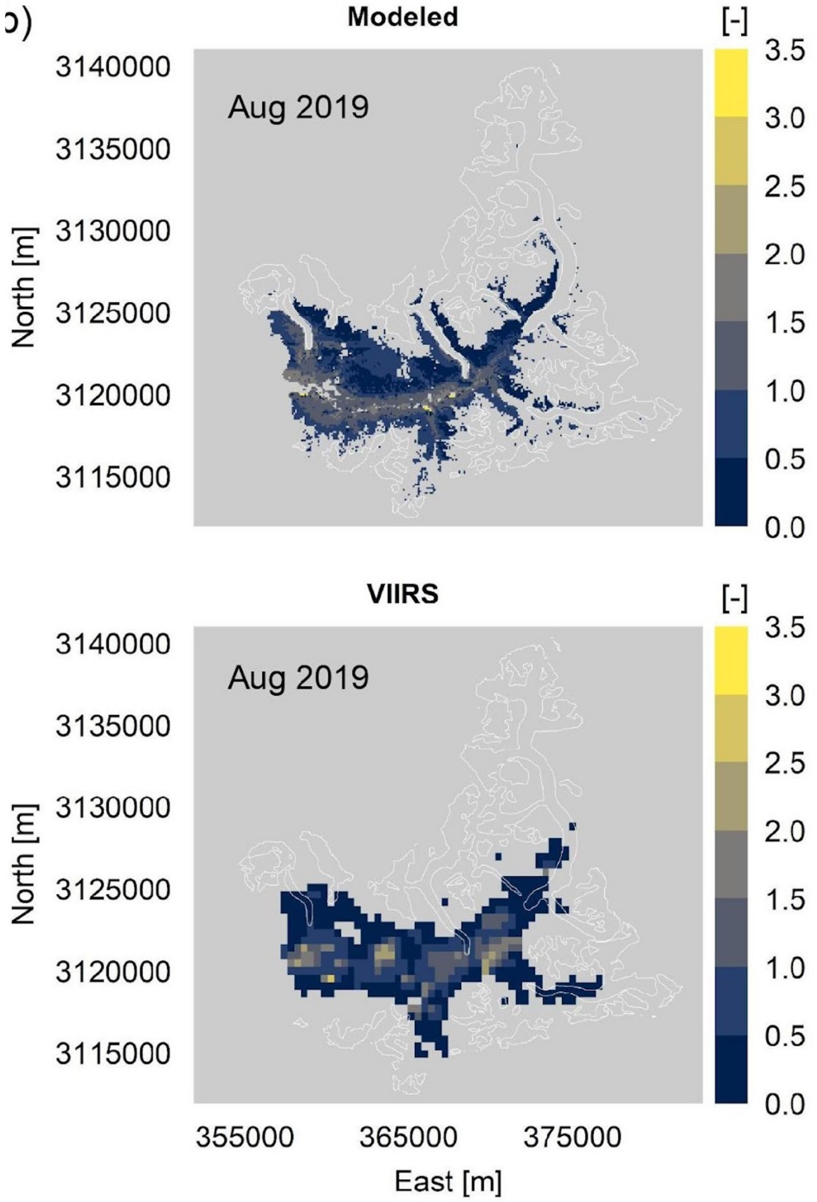
(**Buri et al., under review**)

Validation with Earth Observation data

Leaf area index

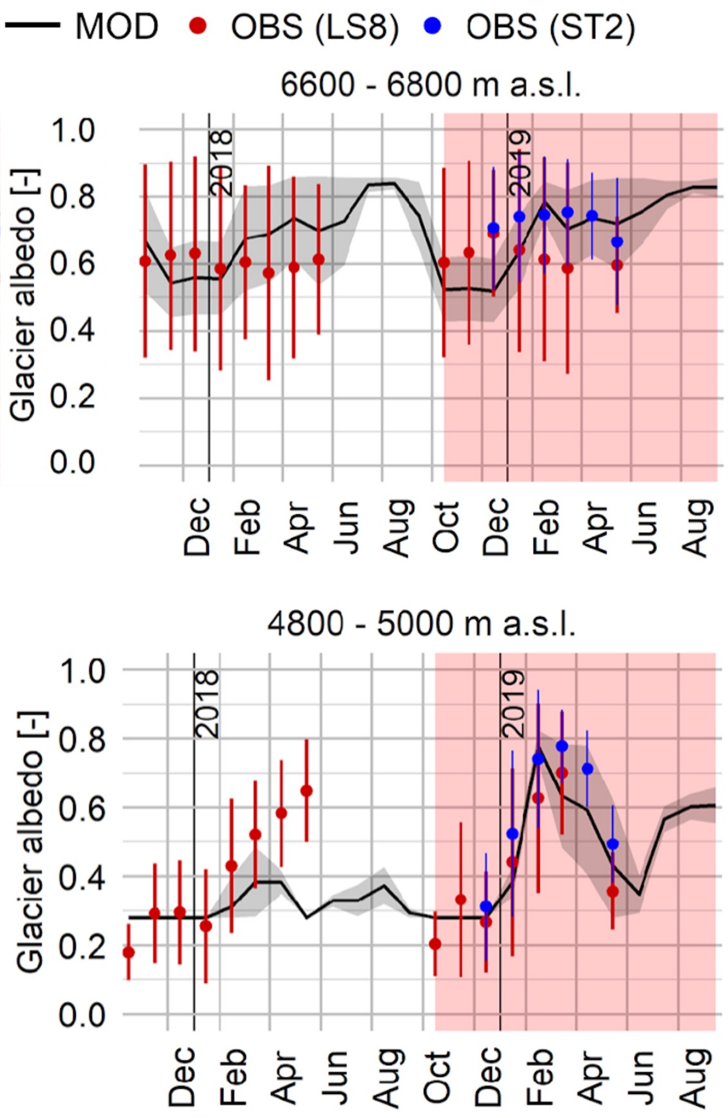
Model evaluation against various EO datasets:
- Snow covered area (MODIS)
- Leaf area index (VIIRS)
- Land surface temperature (ECOSTRESS)
- Glacier albedo (Sentinel2/Landsat8)
- Glacier mass balance (Pléiades)

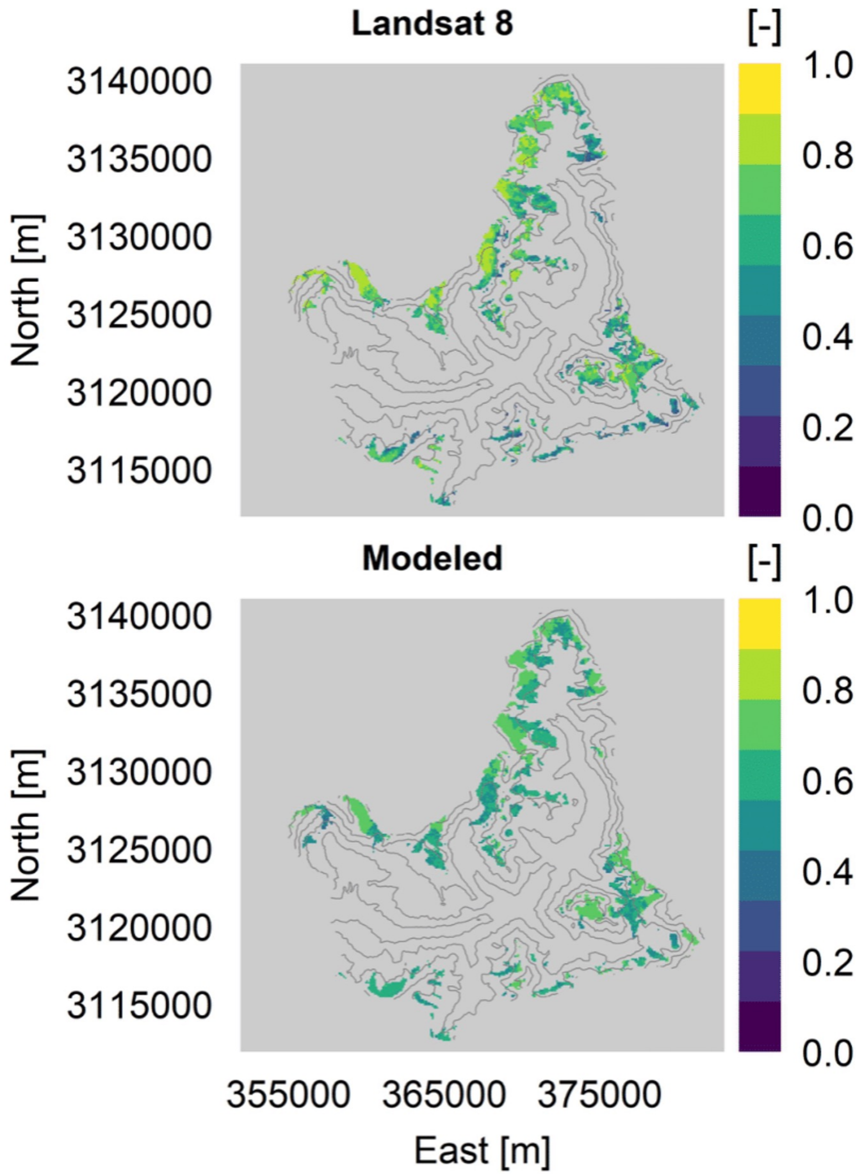




Validation with Earth Observation data

Glacier albedo

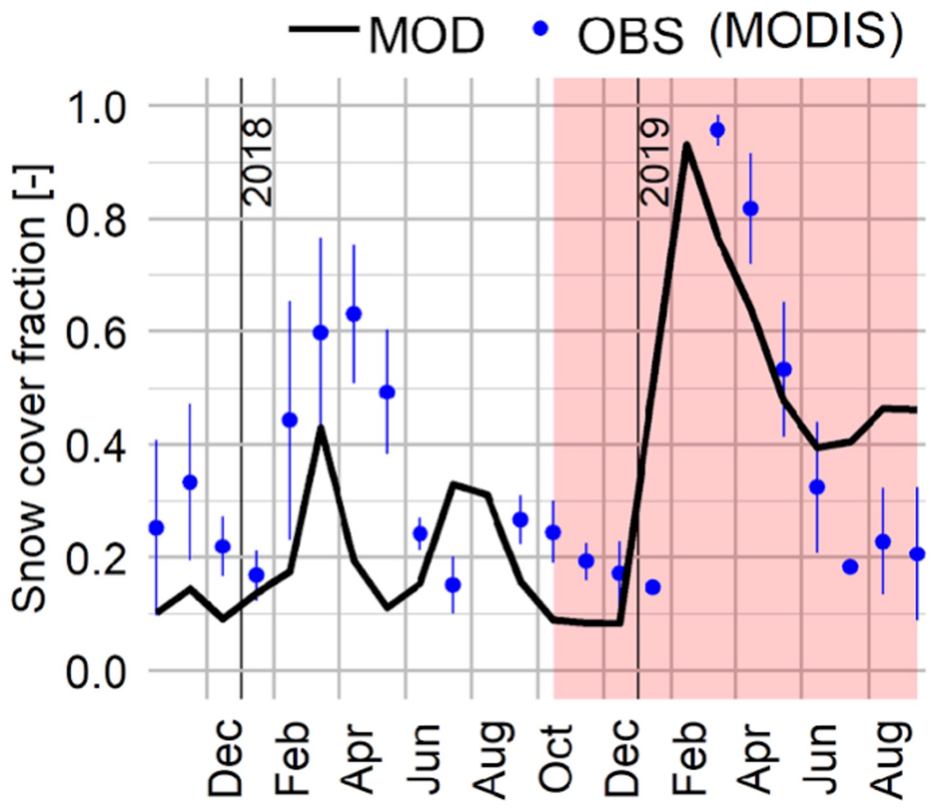


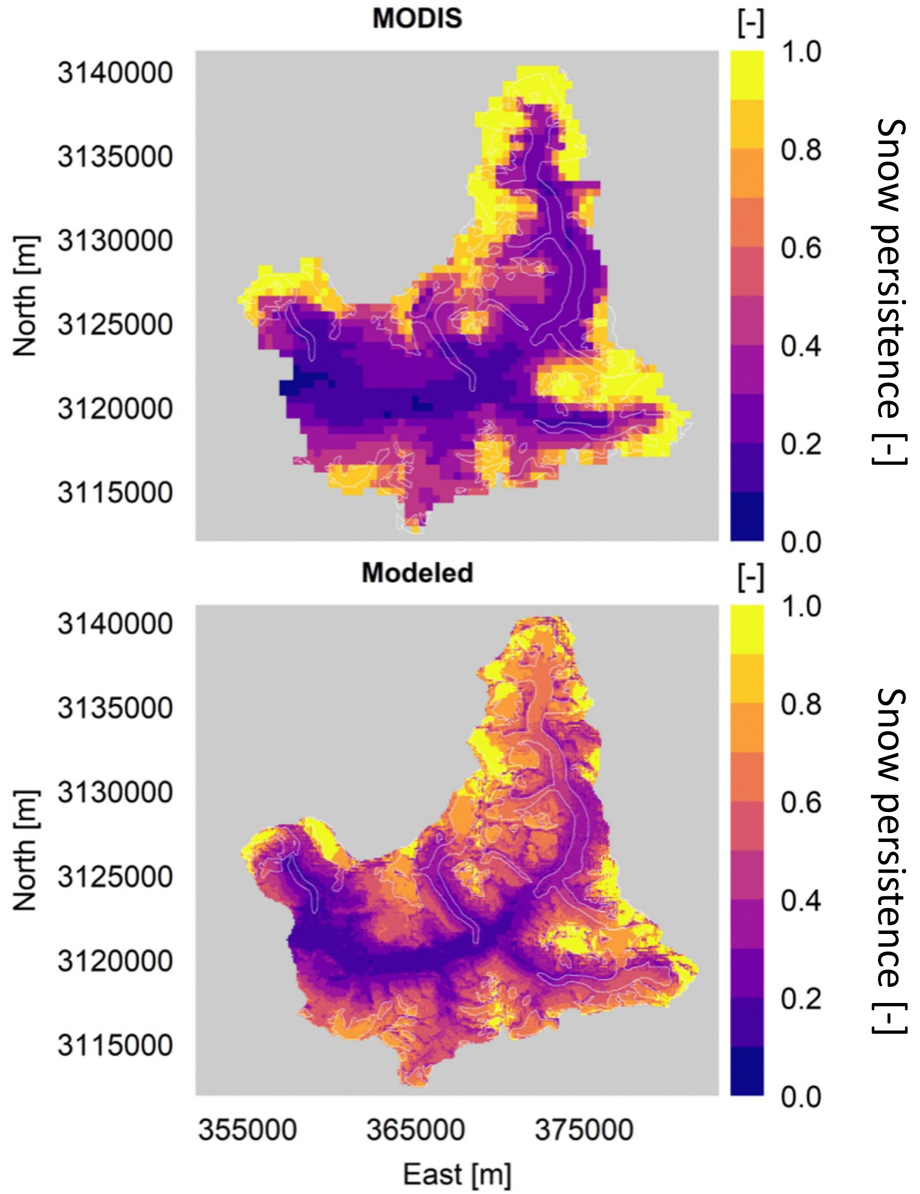


Validation with Earth Observation data

Snow cover fraction

Validation against MODIS snow cover

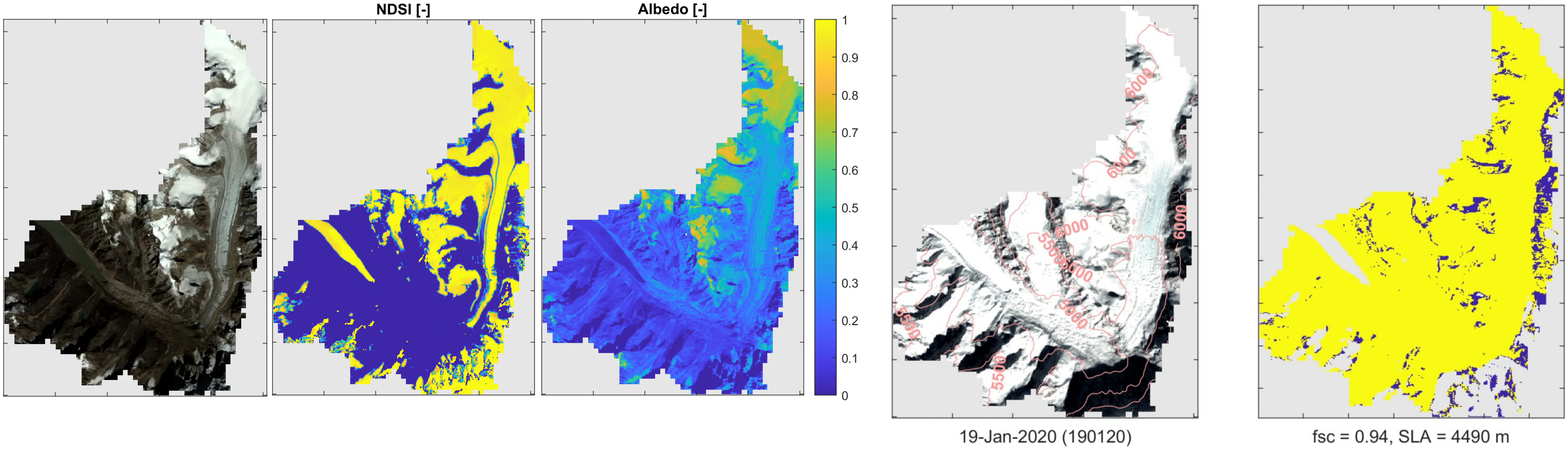




Validation with Earth Observation data

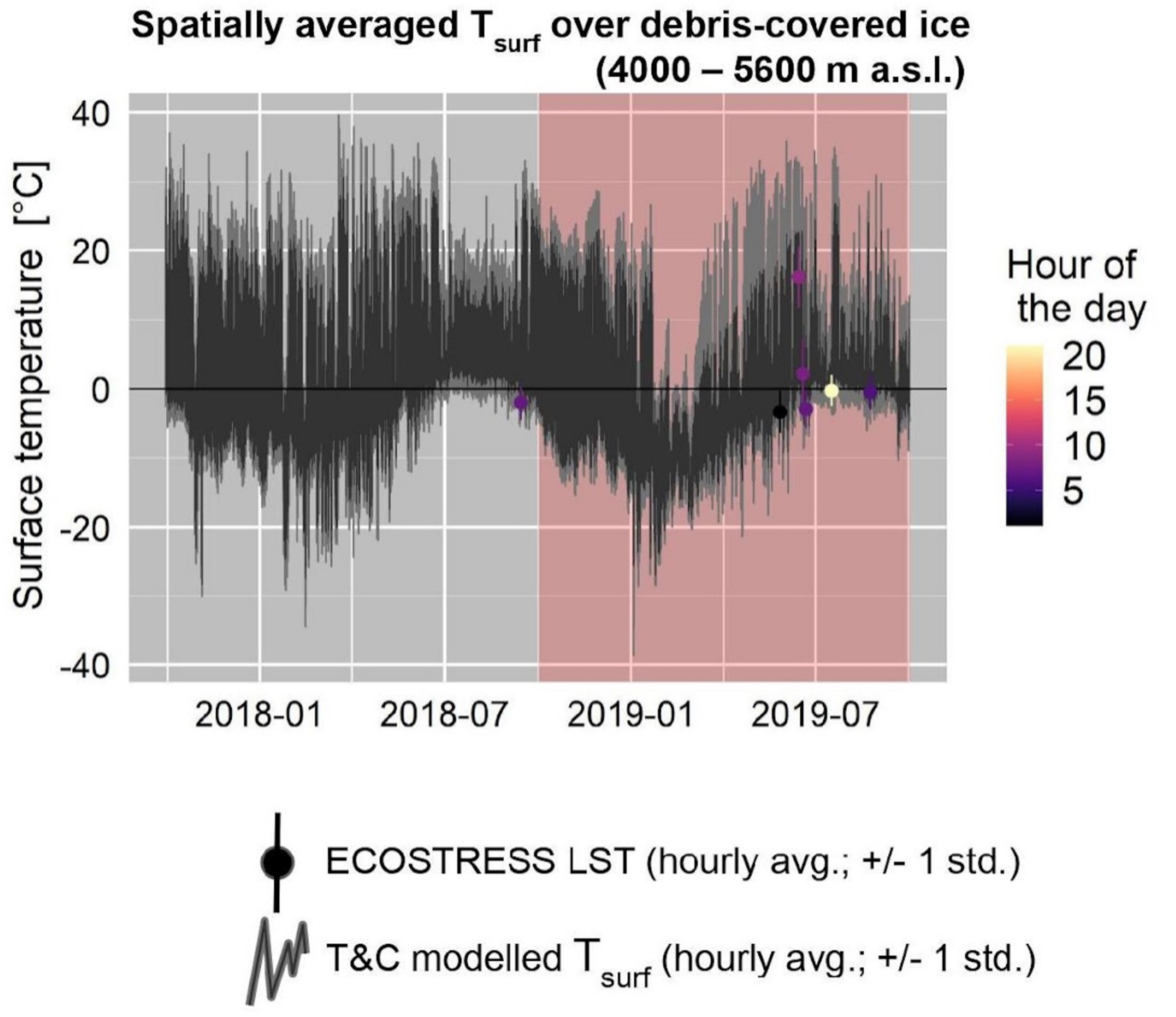
Snow cover fraction

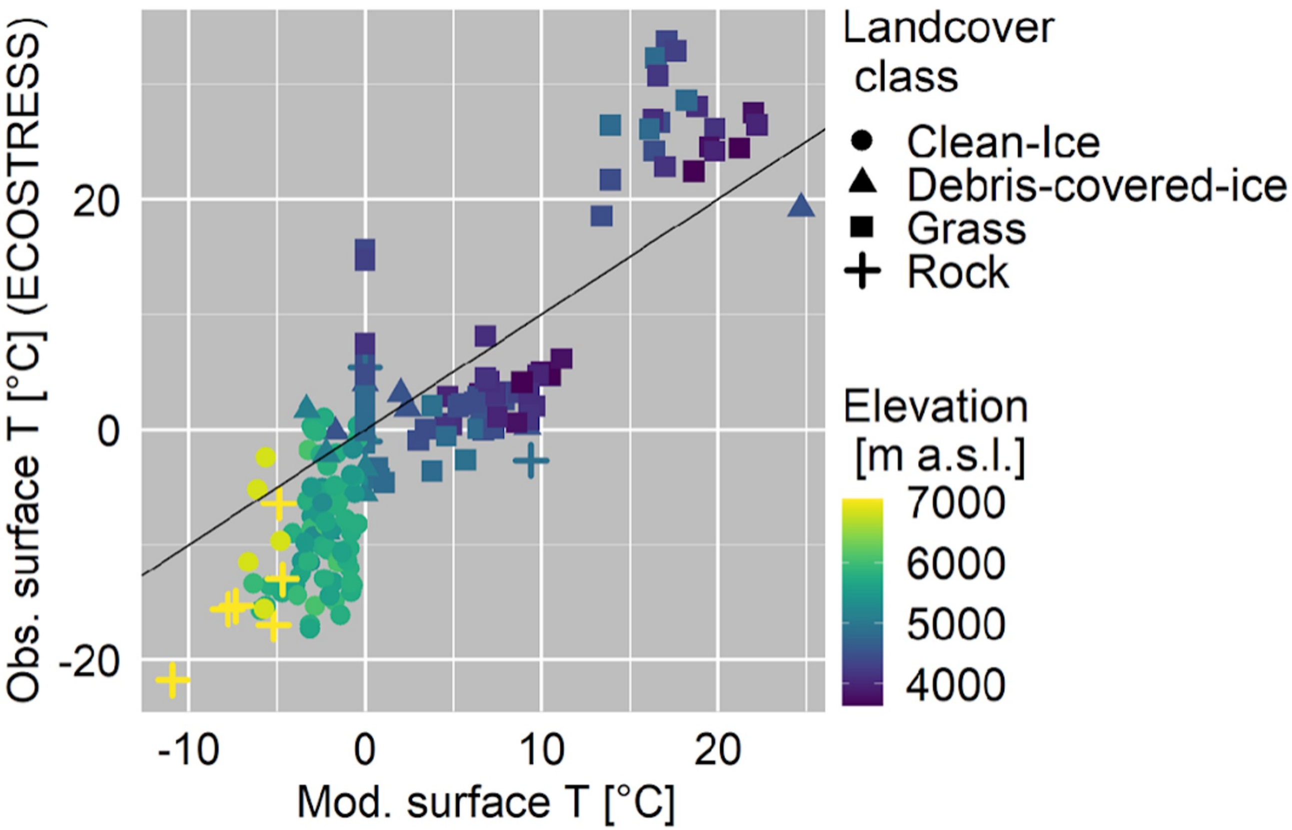
[To do] : Validation against high-resolution snow cover map (Sentinel2-Landsat8)



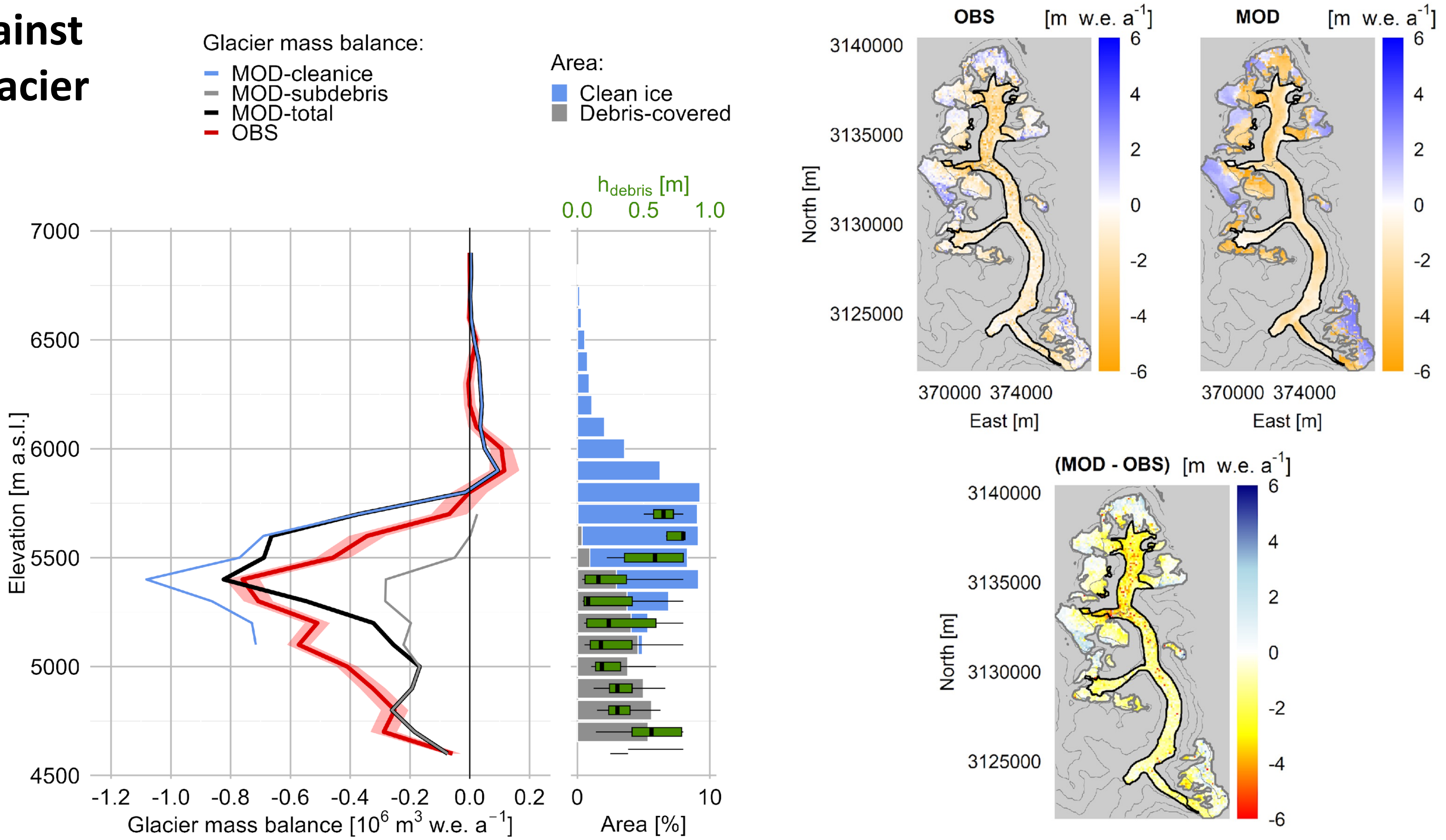
Validation with Earth Observation data

Surface temperature





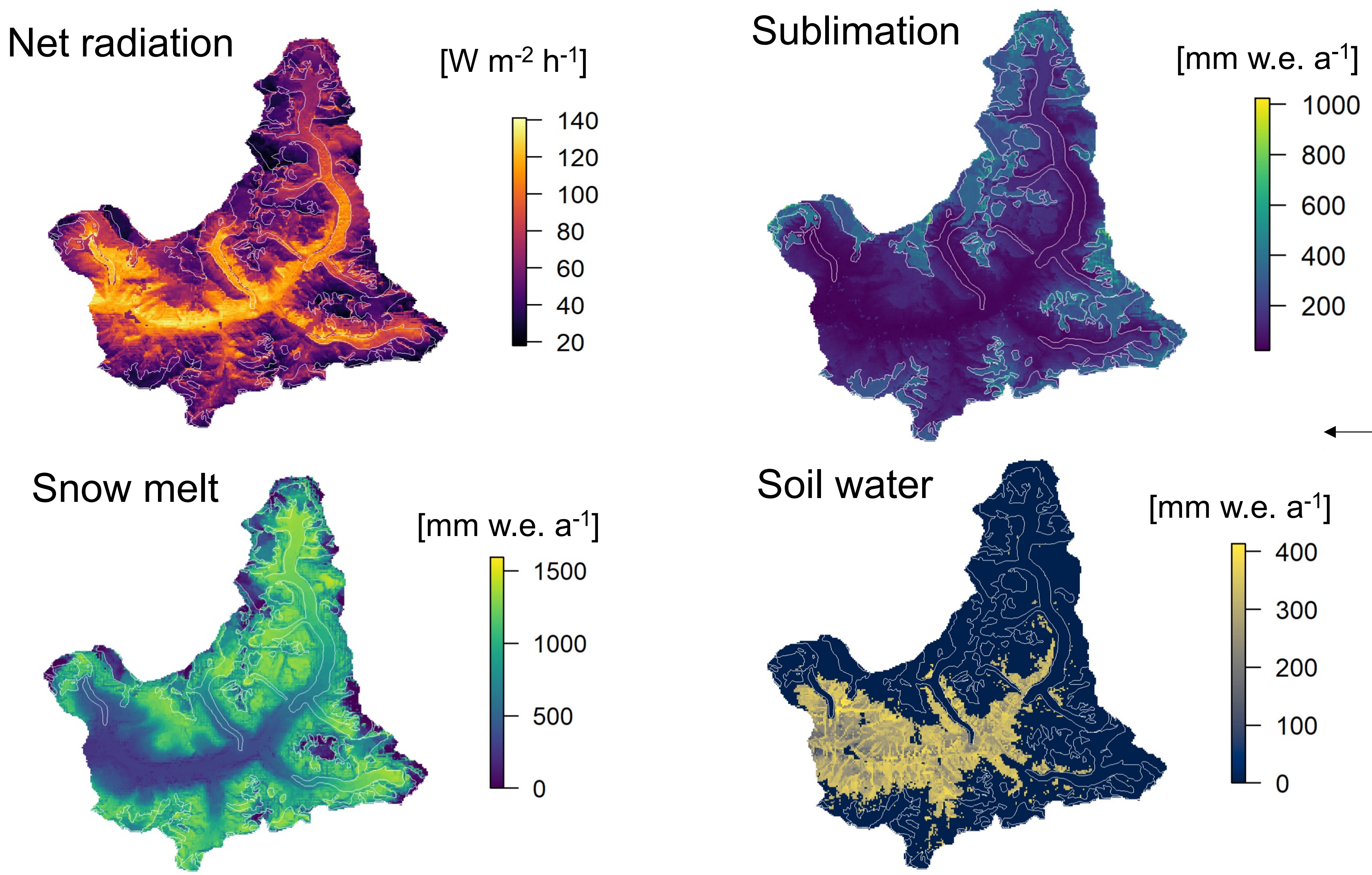
Validation against distributed glacier surface mass balance



Observation:
Miles et al. 2021

Results

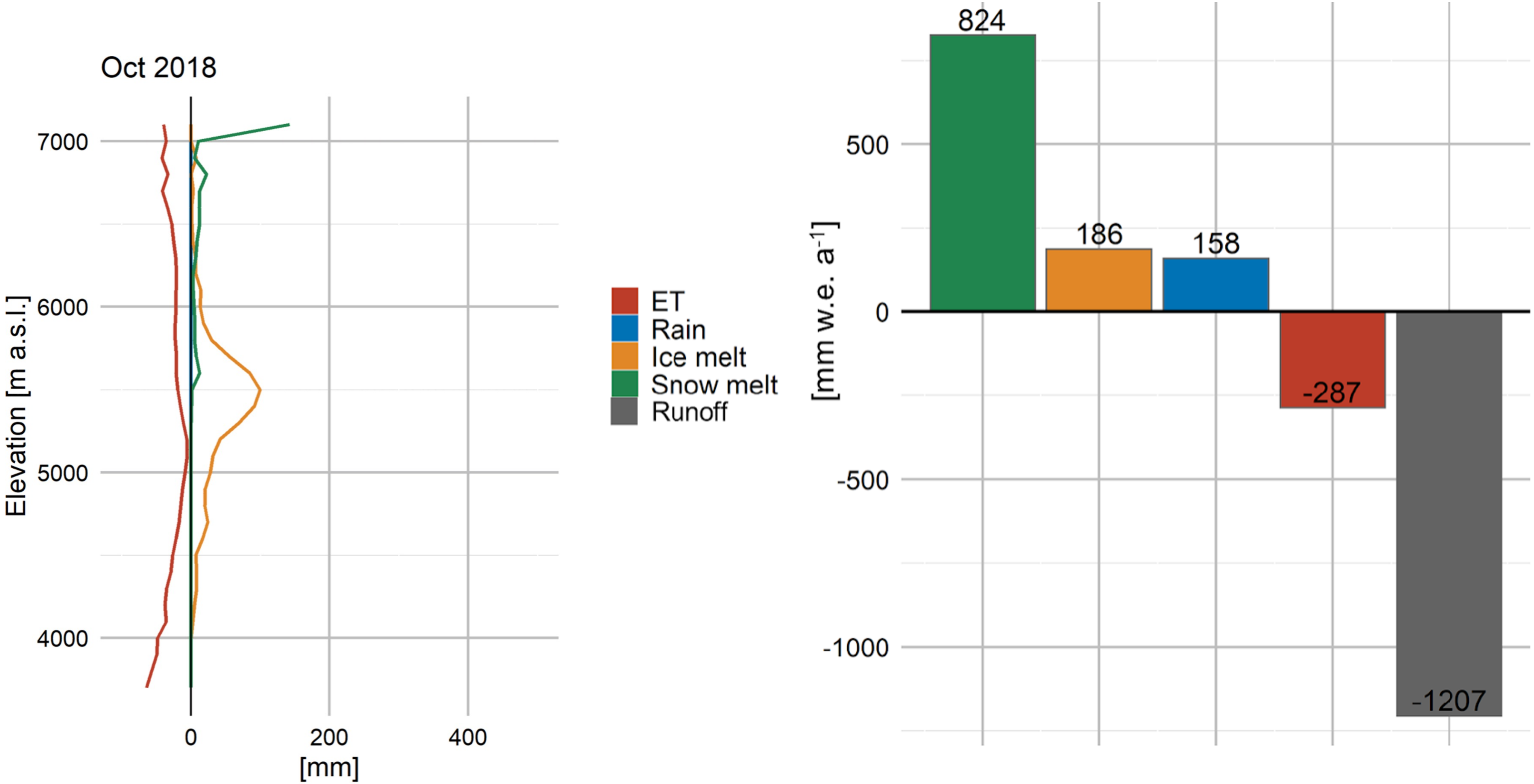
Spatial average output variables



2018-2019 average

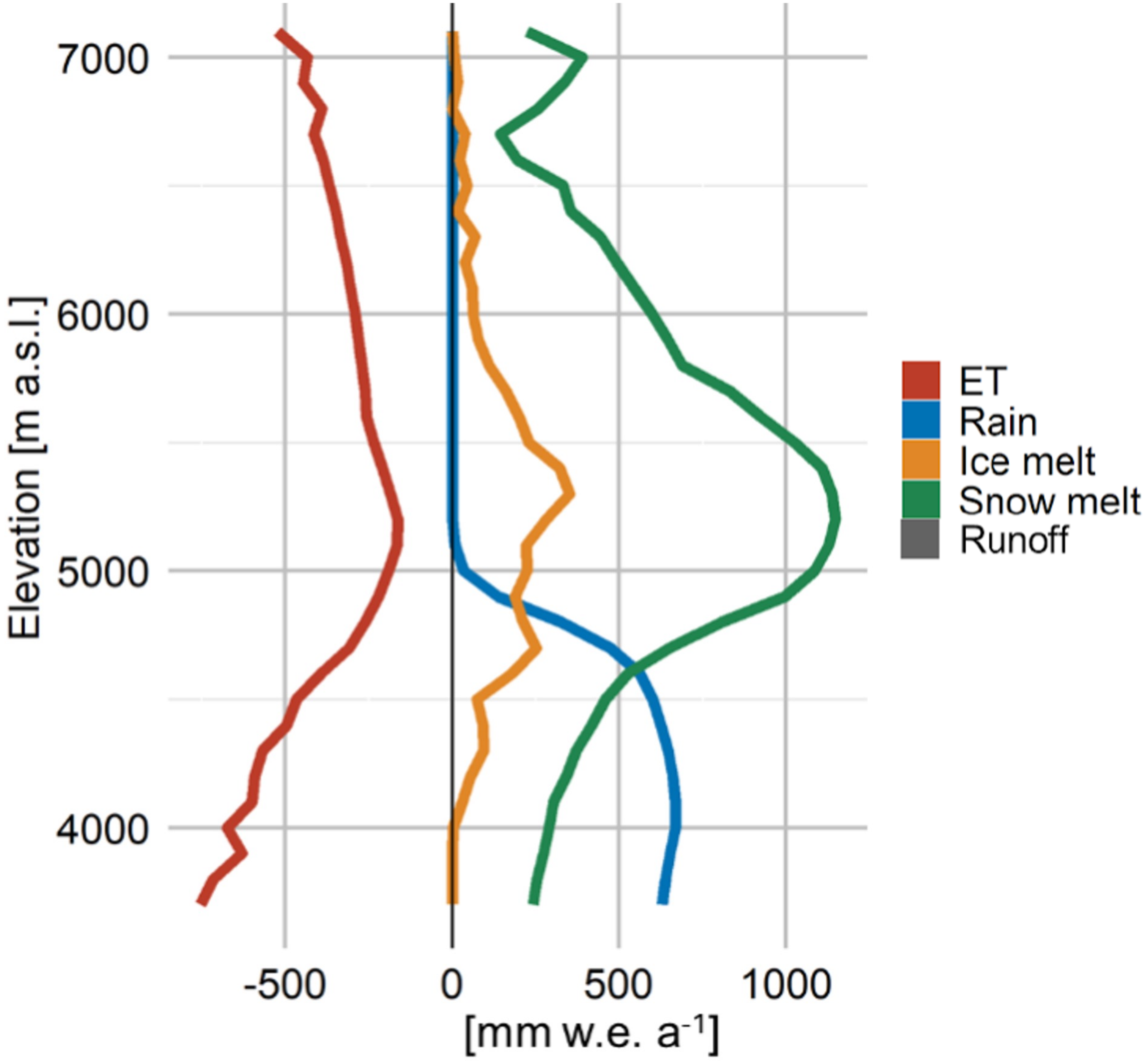
Results

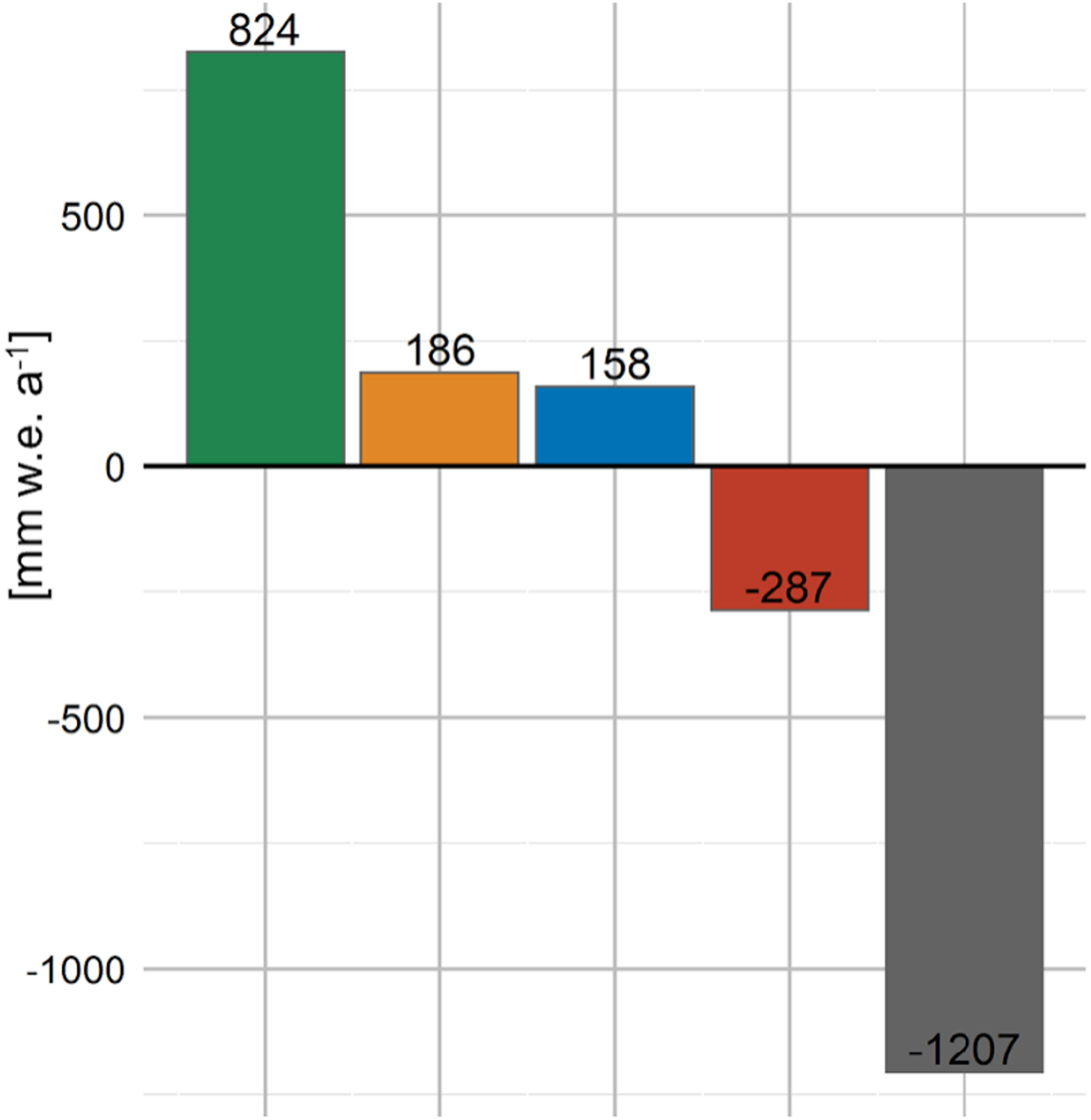
Water balance partition



Results

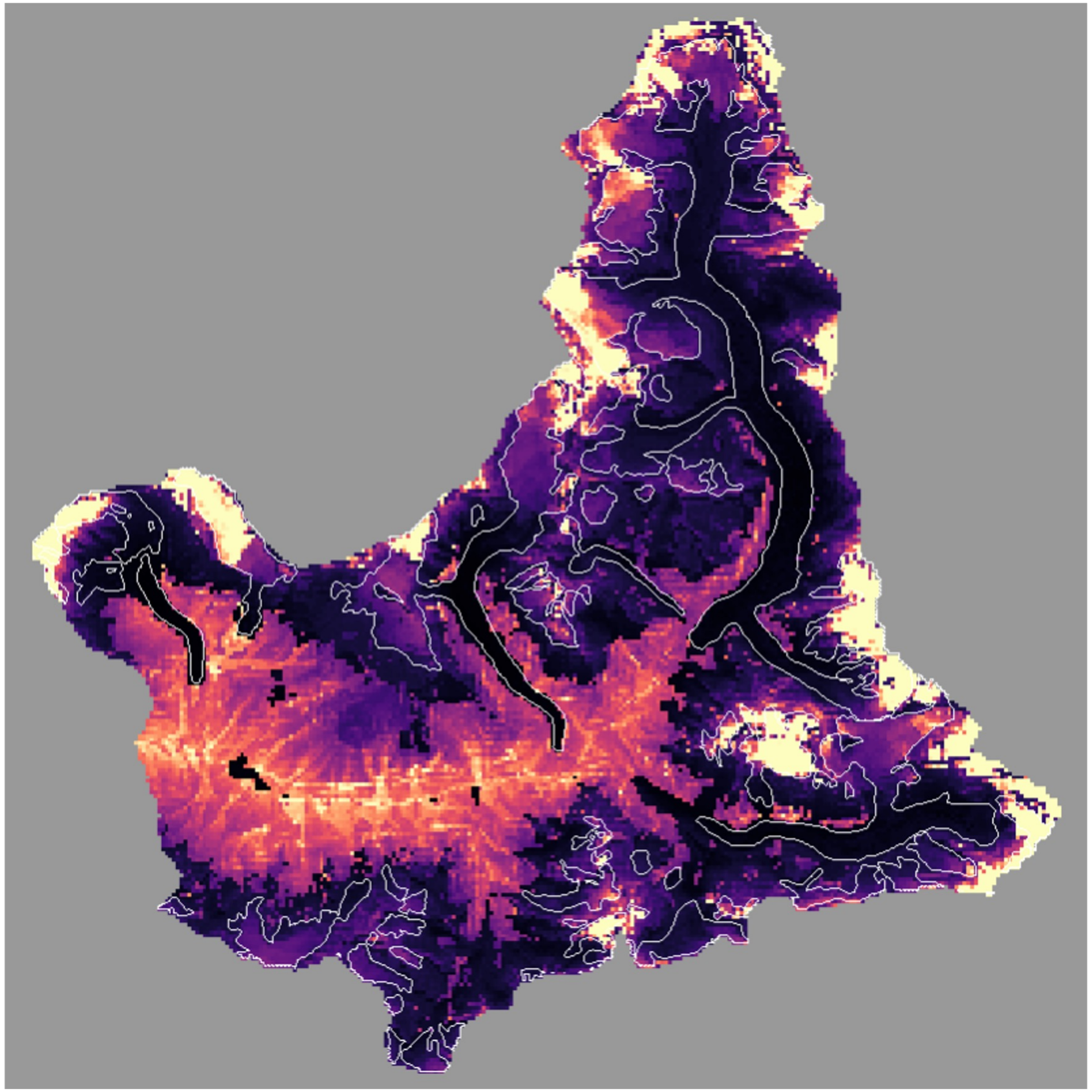
Water balance partition

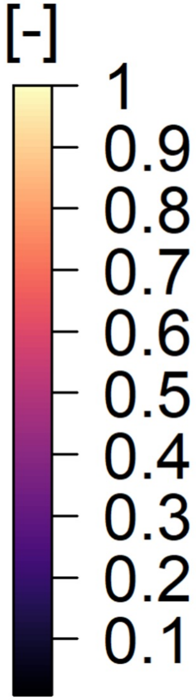




Results

Importance of evapotranspiration





$$\textbf{ET ratio} = \frac{\textbf{ET}}{\textbf{rain + snow melt + ice melt}}$$

Vapour fluxes, are especially important at very high and low altitudes in the Langtang watershed.

Conclusion & challenges

- Dynamics of the land surface, particularly of snow and ice can only be captured using space-borne observations
- Albedo and snowfall are two critical variables to capture the water balance of glacierized catchments
- Mechanistic land surface modelling (utilizing earth observation data) can produce distributed results, in which the relationships between water cycle components (with complex feedbacks between topography, elevation & land cover) is preserved
- Green & white water fluxes are of key importance in the high mountain water cycle, and vapour flux, dominated by snow sublimation, exceeds water production from glacier melt at the catchment scale
- Water depletion is dominated by snow melt (but at high elevations primarily dictated by sublimation)
- The direct quantification of water balance components (precipitation, runoff, groundwater, evapotranspiration) & belowground conditions (soil depth) from space remains challenging

EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA	No. Scenes
1. S-1	> 1000
2. S-2	> 1000
3. ESA CCI/ SM	500
4. PROBA-V	10
5. ASCAT	500
6. AMSR-E Enhanced data	ftp
7. AMSR-2 L1 data	ftp
8.	
9.	
10.	
11.	
Total:	
Issues:	

ESA Third Party Missions	No. Scenes
1. Pléiades	16
2. Pleiades stereo	3
3. SPOT	10
4. SPOT stereo	4
3. Deimos	2
4. L5,7,8	> 1000
5. PlanetScope	> 100
6. SMMR Enhanced data	ftp
7. MWRI L1 data	ftp
8. SSM/I Enhanced data	ftp
9. MODIS	4700
10. CALIOP	1507
11. ASTER GDEM	1
Issues:	

Chinese EO data	No. Scenes
1. FY3C	500
2. SDGSAT-1/TIS	4031
3. SDGSAT-1/GIU	897
4. SDGSAT-1/MII	510
5. GF-3	75161
6. GF-1/2/4/6	ftp
7. CBERS-01/03	ftp
8. ZY-3 TLA	14
9. ZY-3B	1439
10.	
11.	
12.	
Total:	
Issues:	

In-situ measurements and campaigns

Equipment	Institution	Measurements	Application	Period
Camera	AIR	Colour images	Glacier surface characteristics and flow	1/9/2019 – now
multiple	WSL, ETH	Debris thickness and glacier mass balance	Validation of models and data sets	2020 – 2021
Radiometers	ITP, AIR	Albedo , AOD	Validation of retrievals	2020 – 2022

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Pascal Buri	WSL	2022/ 230 Land Surface Modelling in the Himalayas: On the Importance of Evaporative Fluxes for the Water Balance of a High Elevation Catchment 2023/ 247 Land Surface Modeling Informed by Earth Observation Data: Towards Understanding Blue-Green Water Fluxes in High Mountain Asia	Numerical experiments on glacier response at high spatial resolution; 2020 - 2023
Achille Jouberton	WSL, ETH	2022/ 232 Combining High Resolution Atmospheric Simulations And Land-surface Modelling To Understand High Elevation Snow Processes In An Himalayan Catchment. 2023/ 248 Unraveling Snow Accumulation Dynamics at Climatically Distinct Glacierized Catchments in High Mountain Asia	Numerical experiments at high spatial resolution combined with EO data analyses; 2020 - 2023
Michael McCarthy	WSL	2022/ 233 A New Dataset of Supraglacial Debris Thickness for High-Mountain Asia	Integration of glacier flow modelling with satellite data to generate data set on debris thickness
Evan Stewart	WSL	2022/ 251 Applications of the Continuity Equation to Derive Targets for Glacier Models	Accurate mass balance of glaciers at high spatial resolution by integrating model and RS data

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Shaoting REN	AIR – CAS, ITP – CAS; WSL	2022/ 225 Decreasing albedo led to mass loss in the Western Nyainqentanglha Mountains during the past 20 years 2023/ 214 Spatiotemporal variability of glacier albedo over the Third Pole from 2001 to 2020	Explore the changes of glacier albedo and glacier mass balance; Development and implementation of algorithms; data analysis ; 2029 – 2021 Explore the spatiotemporal changes of glacier albedo over the Third Pole] 2020-2023
Junru JIA	AIR – CAS	2022 A method of joint retrieval of AOD and surface BRDF	Development, integration, testing of algorithm; data collected in the Tibetan Plateau
Lian LIU	ITP – CAS	2022 /136 Application of an Improved Noah Snow Albedo Scheme in the Simulation of Snow Processes over the Tibetan Plateau	Parameterization of the dependence of albedo on snow age and depth; implementation and experiments with Noah; 2020 - 2022
Jing ZHANG	AIR – CAS	2022/ 229 Annual Glacier Area and Seasonal Snow Cover Changes in the Range System Surrounding Tarim from 2000 to 2020 2022 Spatial-temporal Variability of Glacier Surface Velocity in the Parlung Zangbo Basin, Tibetan Plateau	Development, integration, testing of algorithm; data collected in the Tibetan Plateau; 2019 - 2022
Qiuxia XIE	AIR – CAS	2022/ 227 Global Soil Moisture Data Fusion by Triple Collocation Analysis from 2011 to 2018	Improvement of algorithm and application to generate a global data set; evaluation with ground measurements Tibetan Plateau; 2019 -2022
Yubao QIU	AIR / CBAS	Remote sensing of lake ice over cold regions of northern hemisphere	A total of 22 papers have been published in journals such as IEEE TGRS in past 3 years,see slide notes for more information; 2020 - 2023

Exchange visits 2023 - 2024

Name	Institution	Host	Topic
Dr. Qiuxia XIE	Shandong Jianzhu University	TU Delft	Retrieval of soil moisture in the Tibetan Plateau: spatial patterns and trends (2024)
Dr. Chaolei Zheng	AIR – CAS	TU Delft	Multi-source retrieval of vapour fluxes in high elevation, cold regions (2023 in progress)
Dr. Miin Jiang	AIR – CAS	TU Delft	Time series analysis on forcing – response in land surface processes (2023 – 2024)
Shaoting Ren	AIR , ITP – CAS	WSL	Multi-annual trend in albedo and evaluation of drivers (2020)

Publications 2020 - 2024

1. ZHANG J, JIA L, MENENTI M, et al. 2020. Interannual and Seasonal Variability of Glacier Surface Velocity in the Parlung Zangbo Basin, Tibetan Plateau. Remote Sensing [J], Vol. 13: 80 - https://doi.org/10.3390/rs13010080
2. ZHANG J, JIA L, MENENTI M, et al. 2021. Glacier Area and Snow Cover Changes in the Range System Surrounding Tarim from 2000 to 2020 Using Google Earth Engine. Remote Sensing [J], Vol.13: 5117. https://doi.org/10.3390/rs13245117
3. REN, S.T., M. MENENTI L. JIA, J. ZHANG, J. X. ZHANG and X. LI, 2020. Glacier Mass Balance in the Nyainqentanglha Mountains between 2000 and 2017 Retrieved from ZiYuan-3 Stereo Images and the SRTM DEM. Remote Sens. Vol.12(5): 864 – 898 DOI: 10.3390/rs12050864
4. REN, S., E.S. MILES, L. JIA, M.MENENTI, M. KNEIB, P. BURI, M.J. McCARTHY, T.E. SHAW, W. YANG and F.PELLICCIOTTI, 2021. Anisotropy Parameterization Development and Evaluation for Glacier Surface Albedo Retrieval from Satellite Observations. Remote Sens. Vol. 13: 1714- https://doi.org/10.3390/rs13091714
5. LU, J.Y. , Y. QIU , X.X.WANG , W. S. LIANG , P.F. XIE, L.J. SHI , M. MENENTI and D.S. ZHANG, 2020. Constructing dataset of classified drainage areas based on surface water-supply patterns in High Mountain Asia. Big Earth Data DOI: 10.1080/20964471.2020.1766180
6. LIU, L., Y. M. MA, M. MENENTI, R.SU, N. YAO and W.Q. MA , 2021. Improved parameterization of snow albedo in Noah coupled with Weather Research and Forecasting: applicability to snow estimates for the Tibetan Plateau. Hydrology and Earth System Sciences Vol. 25(9):4967-4981 DOI: 10.5194/hess-25-4967-2021
7. LIU, L., M. MENENTI and Y. MA, Y., 2022. Evaluation of Albedo Schemes in WRF Coupled with Noah-MP on the Parlung No. 4 Glacier. Remote Sens. Vol. 14: 3934. doi: 10.3390/rs14163934
8. XIE, Q.X., L. JIA, M. MENENTI and G.C. HU, 2022.Global soil moisture data fusion by Triple Collocation Analysis from 2011 to 2018. Scientific Data vol. 9: 687 https://doi.org/10.1038/s41597-022-01772-x
9. LIU,L. M.MENENTI, Y.M.MA AND W.Q.MA, 2022. Improved parameterization of snow albedo in WRF+Noah: Methodology based om a severe snow event on the Tibetan Plateau. Adv. Atmos. Sci. vol.39: 1079 – 1102
10. Fugger, S., Fyffe, C. L., Fatichi, S., Miles, E., McCarthy, M., Shaw, T. E., ... & Pellicciotti, F. (2022). Understanding monsoon controls on the energy and mass balance of glaciers in the Central and Eastern Himalaya. The Cryosphere, 16(5), 1631-1652.
11. Kneib, M., Miles, E. S., Jola, S., Buri, P., Herreid, S., Bhattacharya, A., ... & Pellicciotti, F. (2021). Mapping ice cliffs on debris-covered glaciers using multispectral satellite images. Remote Sensing of Environment, 253, 112201.
12. Miles, E. S., Steiner, J. F., Buri, P., Immerzeel, W. W., & Pellicciotti, F. (2022). Controls on the relative melt rates of debris-covered glacier surfaces. Environmental Research Letters, 17(6), 064004.
13. Kneib, M., Fyffe, C. L., Miles, E. S., Lindemann, S., Shaw, T. E., Buri, P., ... & Pellicciotti, F. (2023). Controls on Ice Cliff Distribution and Characteristics on Debris-Covered Glaciers. Geophysical Research Letters, 50(6), e2022GL102444.
14. McCarthy, M., Miles, E., Kneib, M., Buri, P., Fugger, S., & Pellicciotti, F. (2022). Supraglacial debris thickness and supply rate in High-Mountain Asia. Communications Earth & Environment, 3(1), 269.
15. Jouberton, A., Shaw, T. E., Miles, E., McCarthy, M., Fugger, S., Ren, S., ... & Pellicciotti, F. (2022). Warming-induced monsoon precipitation phase change intensifies glacier mass loss in the southeastern Tibetan Plateau. Proceedings of the National Academy of Sciences, 119(37), e2109796119.

Thank you！