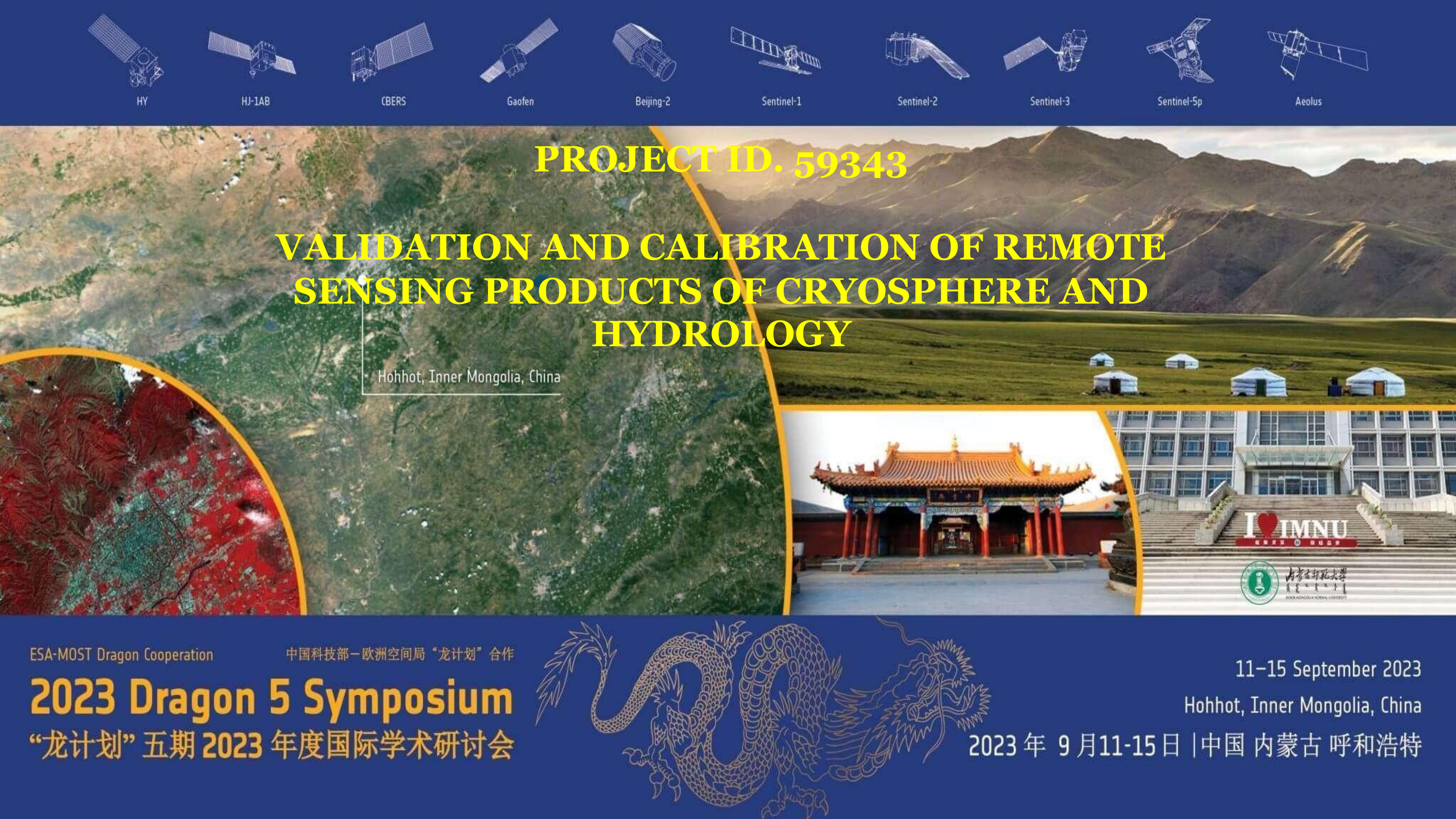
PROJECT ID. 59343

VALIDATION AND CALIBRATION OF REMOTE SENSING PRODUCTS OF CRYOSPHERE AND HYDROLOGY



CONTENTS

- ☐ Validation or assessment of snow cover data
- ☐ Validation or assessment of snow depth data
- ☐ Validation or assessment of soil moisture data

CONTENTS

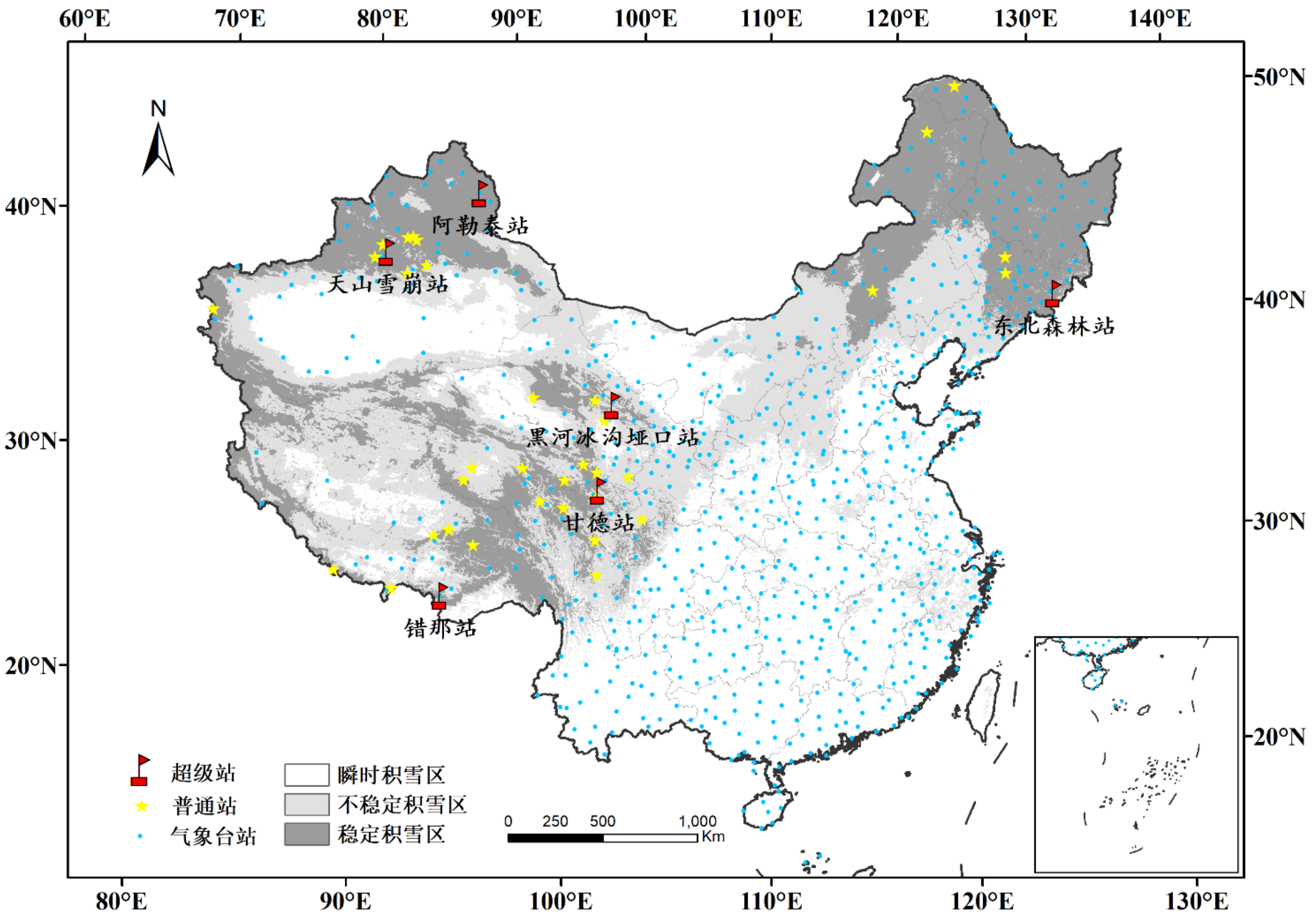
SNOW COVER PRODUCTS

Product	Temporal range	Temporal resolution	Spatial resolution	producer
AVHRR	1980-	Daily	5km	JAXA
MODIS	2000-	Daily	500m	NASA

Date sets properties of five cloud removal snow cover products over QTP

Data product	Data source	Method	Spatial resolution	Code
IMS	AVHRR, GOES, SSMI, USAF Snow/Ice Analysis, AMSU, AMSR-E, NCEP models,	Blending	4 km	Sea/lake=1,Land=2, Sea/lake ice=3,Snow=4 Outside=0.
MOD-SSM/I	MOD10A1,MYD10A1, Modified SSM/I	Terra/Aqua combination, Temporal combination, Blending	500 m	Snow=200, Land=25, Water=37, Snow or lake ice=200,Other or outside=255
MOD-B	MOD10A1,MYD10A1, DEM	Terra/Aqua combination, Temporal combination, Perennial snow/ice, Spatial interpolation , snowline	500 m	Snow=200, Land=25, Water=37, Snow or lake ice=200,Other or outside=255
TAI	MOD10A1,MYD10A1, IMS	Terra/Aqua combination, Blending	500 m	Snow=200, Land=25, Water=37, Snow or lake ice=200,Other or outside=255
I-TAI	MOD10A1,MYD10A1, IMS	Terra/Aqua combination, Temporal combination, Blending	500 m	Snow=200, Land=25, Water=37, Snow or lake ice=200,Other or outside=255

IN SITU OBSERVATION



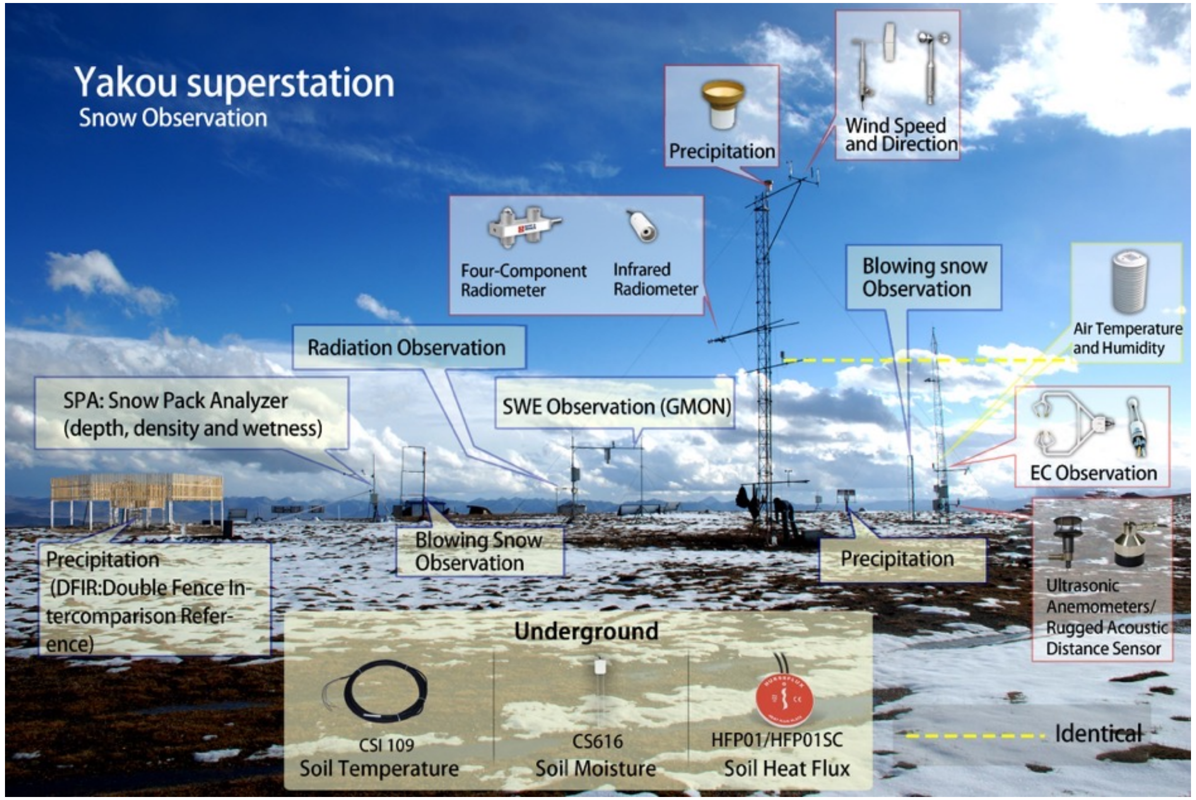
Meteorological station: 830, manual daily snow depth and SWE

Yellow stars (automatic station): 35, automatic snow depth, snow temperature

Red banners (supper station): 6, automatic snow depth, manual snow pit (layering thickness, density, grain size, SWE)

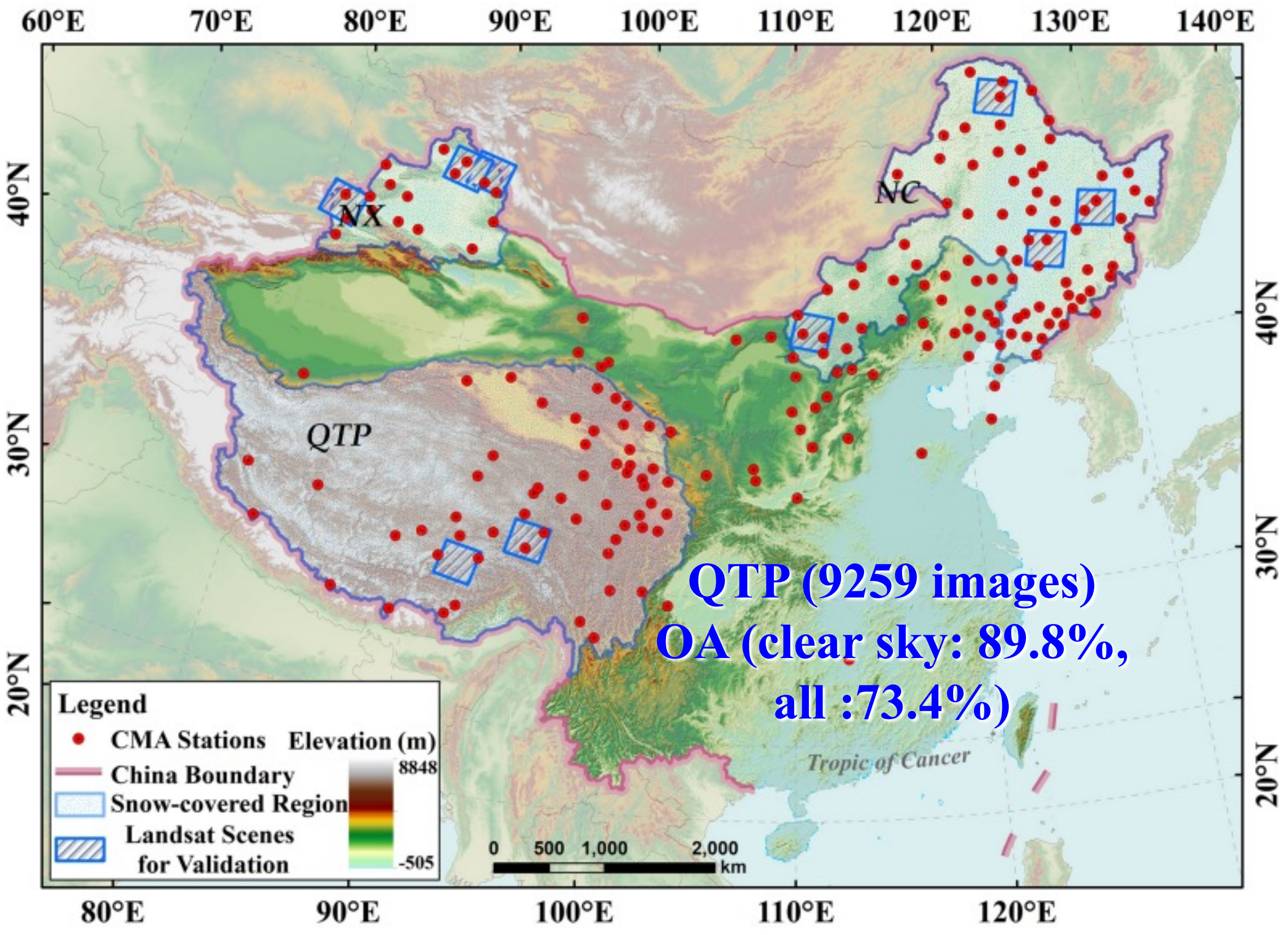
Meteoroglocial sation

Station for snow observation



Accuracy of MODIS product against landsat images

North Xinjiang (2687images)
Overall accuracy : clear sky: 95.5%, all :76.0%)



QTP (9259 images)
OA (clear sky: 89.8%, all :73.4%)

Inner Mongolia-Northeast (6250images)
OA (clear sky: 93.7%, all :70.8%)

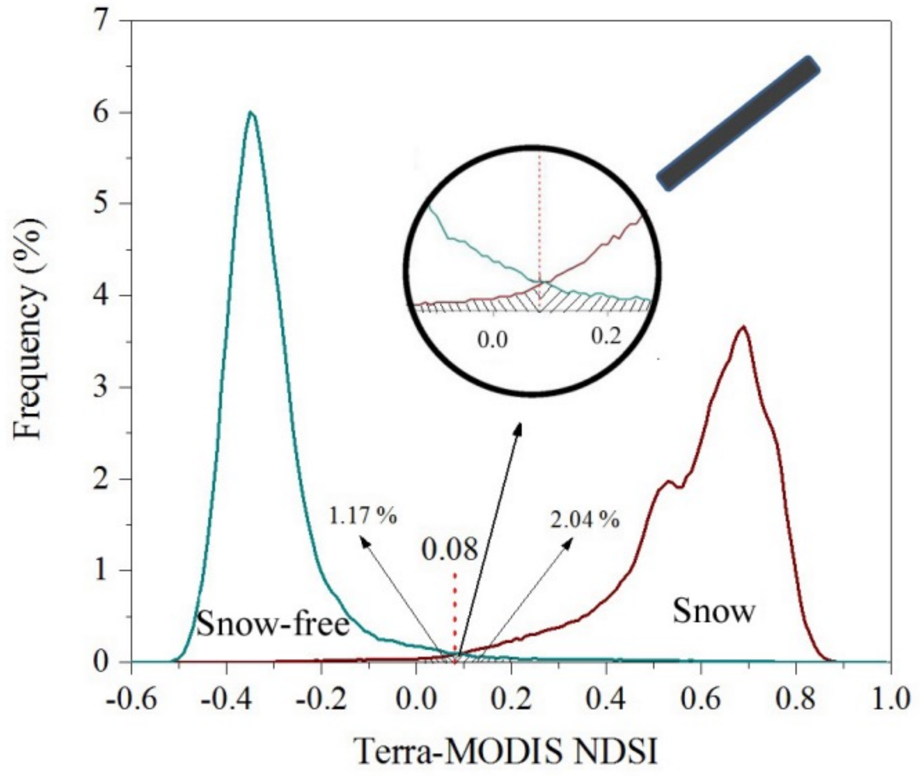
Accuracy is high in clear sky

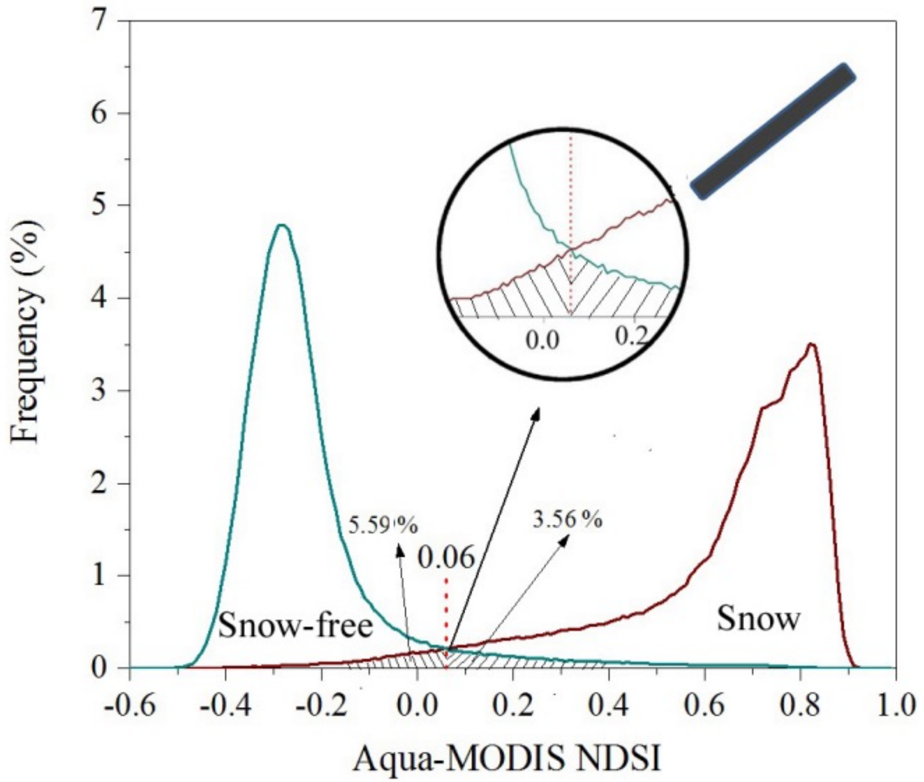
Accuracy of five cloud-gap-filled products against station data over the QTP

Land cover	IMS	MOD-SSM/I	MOD-B	TAI	I-TAI
Evergreen needleleaf forest	89.10%	77.50%	94.70%	86.10%	88.40%
Mixed forest	76.90%	50.20%	57.60%	66.70%	67.30%
Open shrublands	53.10%	97.60%	98.90%	98.70%	98.80%
Grasslands	53.10%	82.80%	84.50%	85.40%	86.90%
Urban and build-upland	64.50%	77.60%	77.70%	80.30%	80.20%
Barren or sparsely vegetated	72.60%	92.80%	93.00%	93.40%	93.50%

CALIBRATION OF MODIS PRODUCT IN CHINA

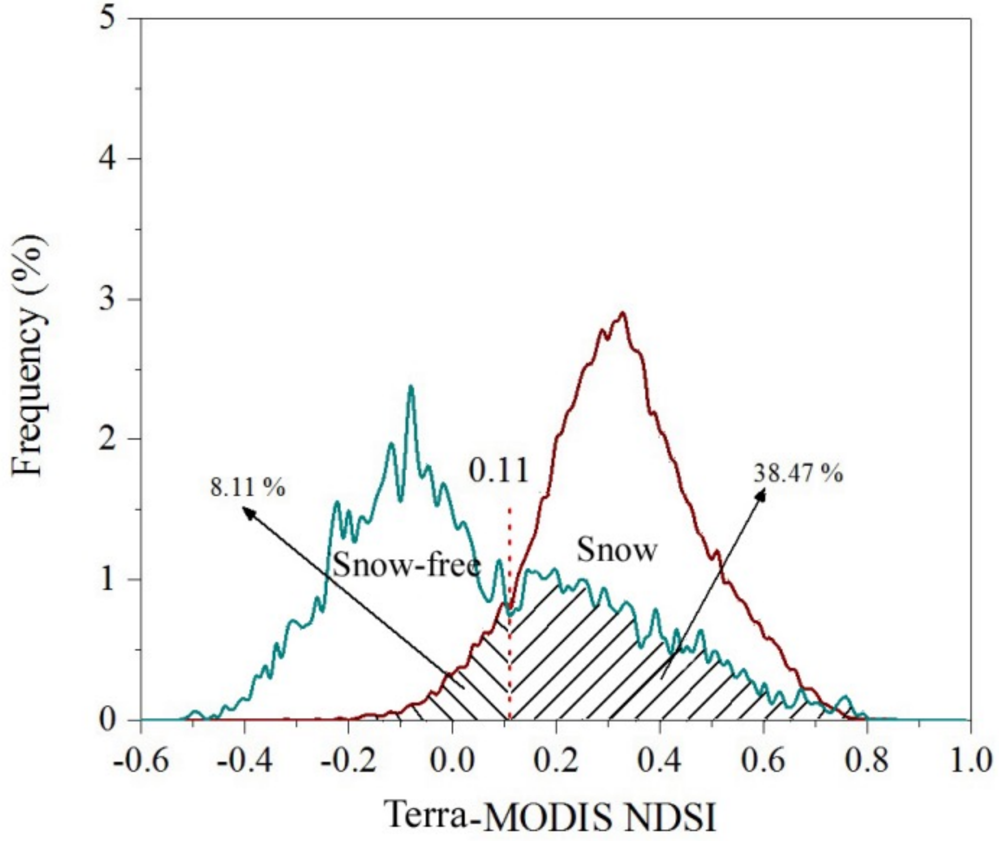
$$NDSI = (b4 - b6)/(b4 + b6)$$

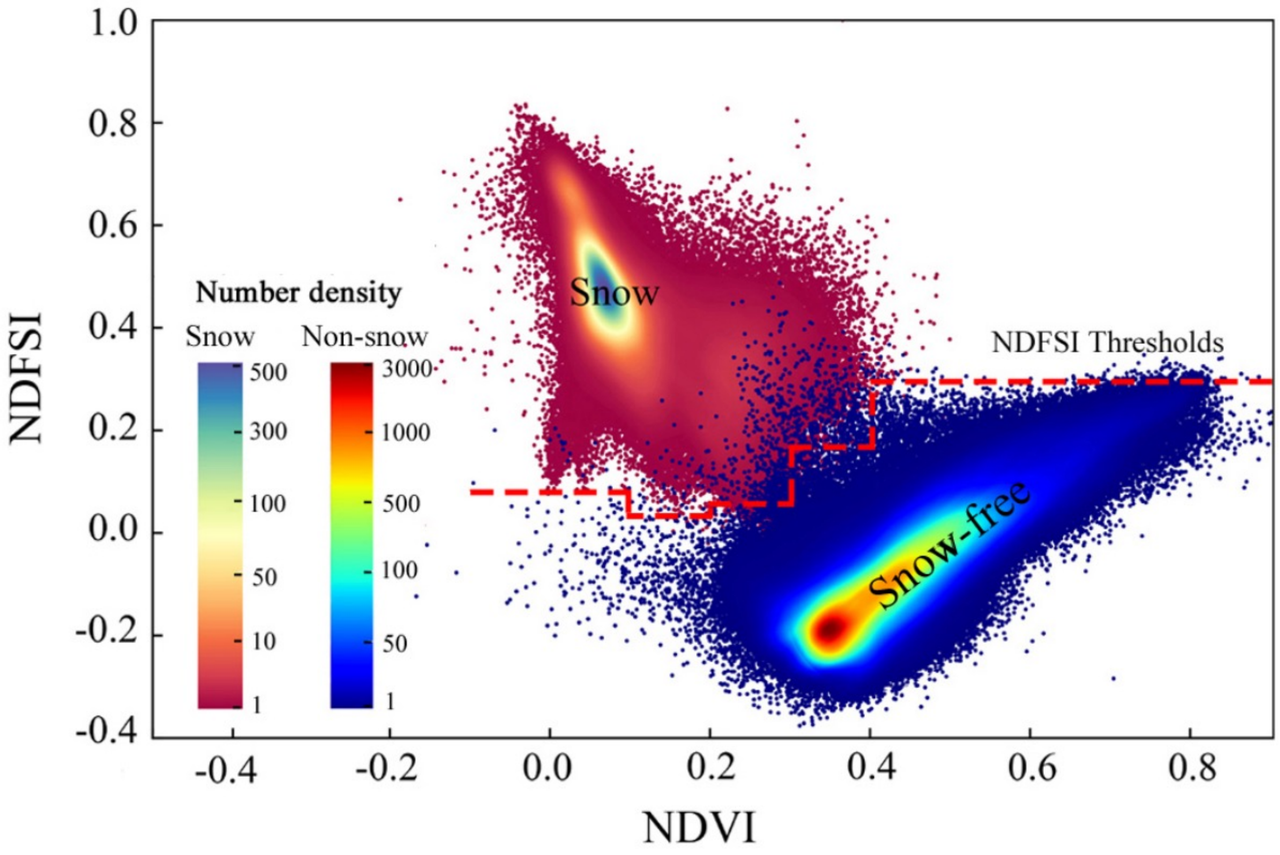




Barren or sparsely vegetated land cover

NDFSI = (b2 − b6)/(b2 + b6)

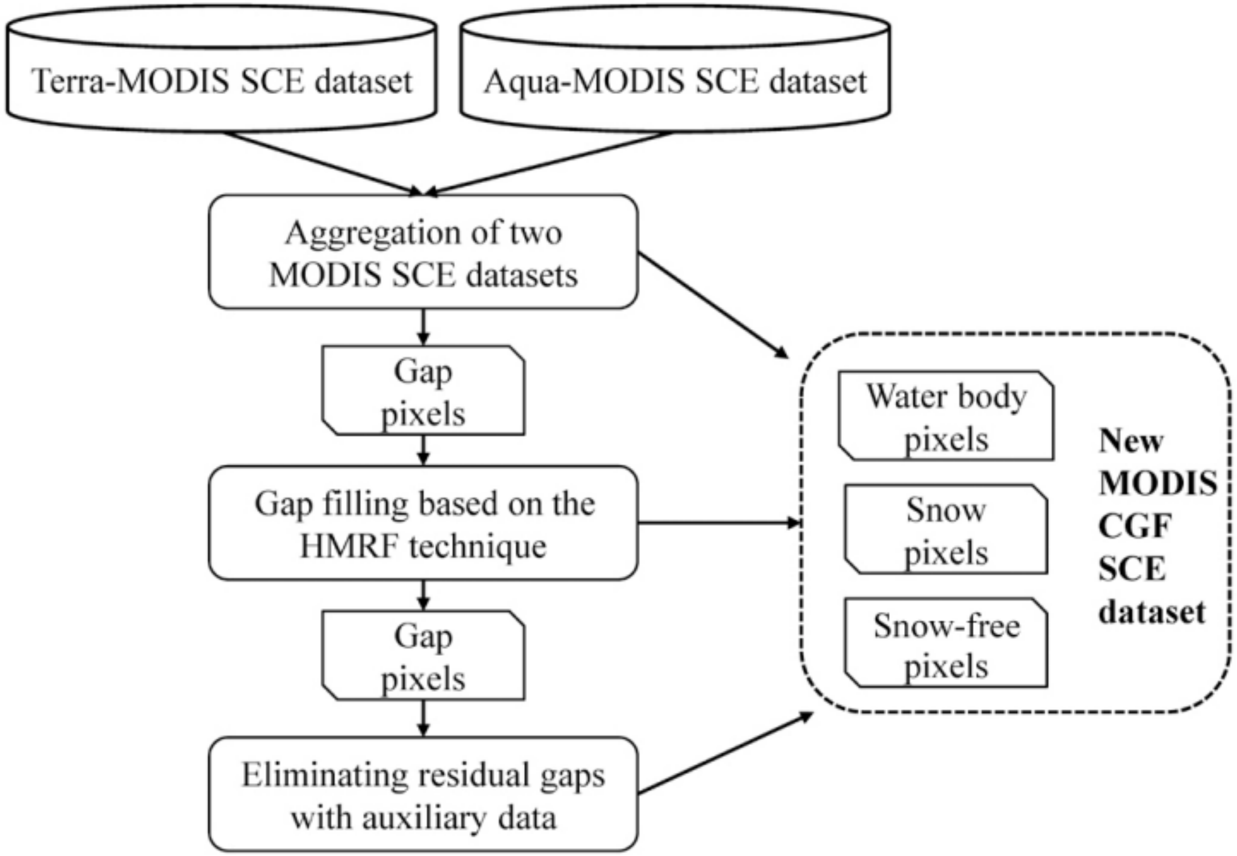




Deciduous broadleaf forest

Optimized Terra-MODIS NDVI-NDFSI decision rules for forest land-cover types (ENF: evergreen needleleaf forests; DNF: deciduous needleleaf forests; DBF: deciduous broadleaf forests; PWS: permanent wetland savannas).

Land-cover types (IGBP)	Terra-MODIS NDFSI thresholds							New OA[a] (%)	NDSI OA[b] (%)
	NDVI < 0.1	NDVI $[-0.1, 0)$	NDVI $[0.0, 0.1)$	NDVI $[0.1, 0.2)$	NDVI $[0.2, 0.3)$	NDVI $[0.3, 0.4)$	NDVI ≥ 0.4		
ENF	−0.18	0.12	0.05	0.06	0.16	0.24	0.31	99.80	75.92
DNF	0.08	0.08	−0.11	−0.03	0.02	0.14	0.22	99.91	54.65
DBF	0.08	0.08	0.08	0.03	0.05	0.17	0.30	99.91	88.77
Mixed forests	0.21	0.18	0.06	0.01	0.06	0.15	0.28	99.73	85.15
Woody savannas	0.37	0.11	0.04	0.02	0.03	0.15	0.30	99.86	87.98
Savannas	0.29	0.13	0.07	0.06	0.04	0.24	0.36	99.91	86.43
PWS	0.50	0.19	0.12	0.17	0.31	0.35	0.35	85.53	81.42



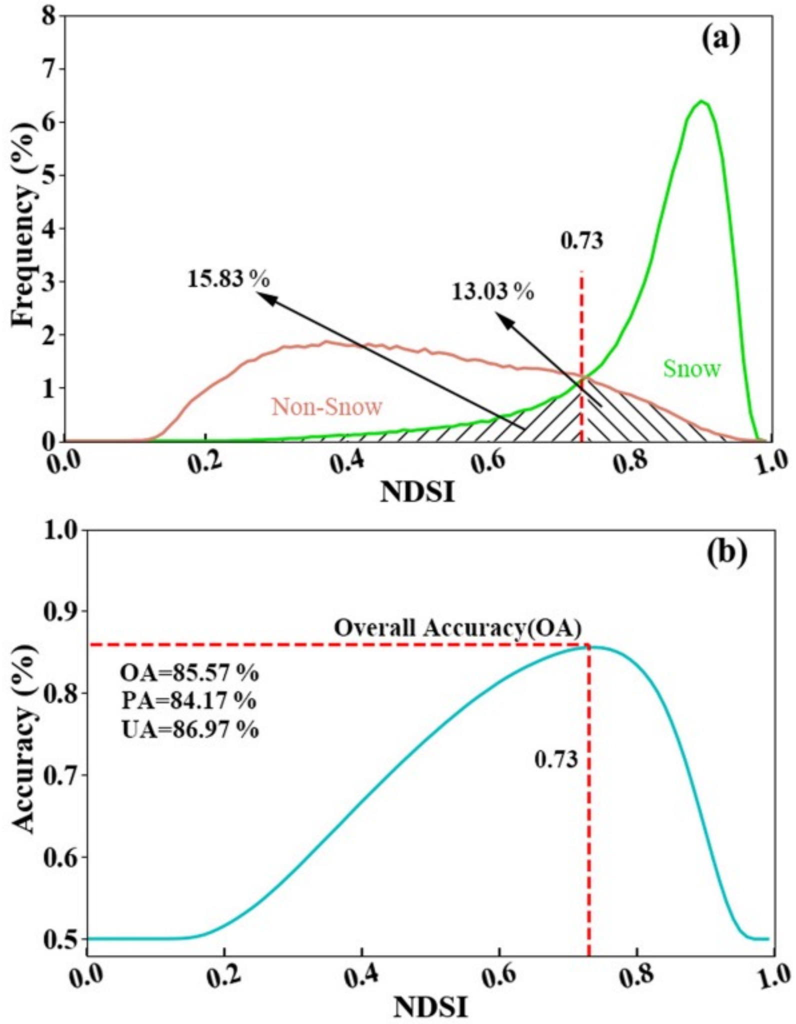
Flowchart of the new cloud-gap-removing algorithm

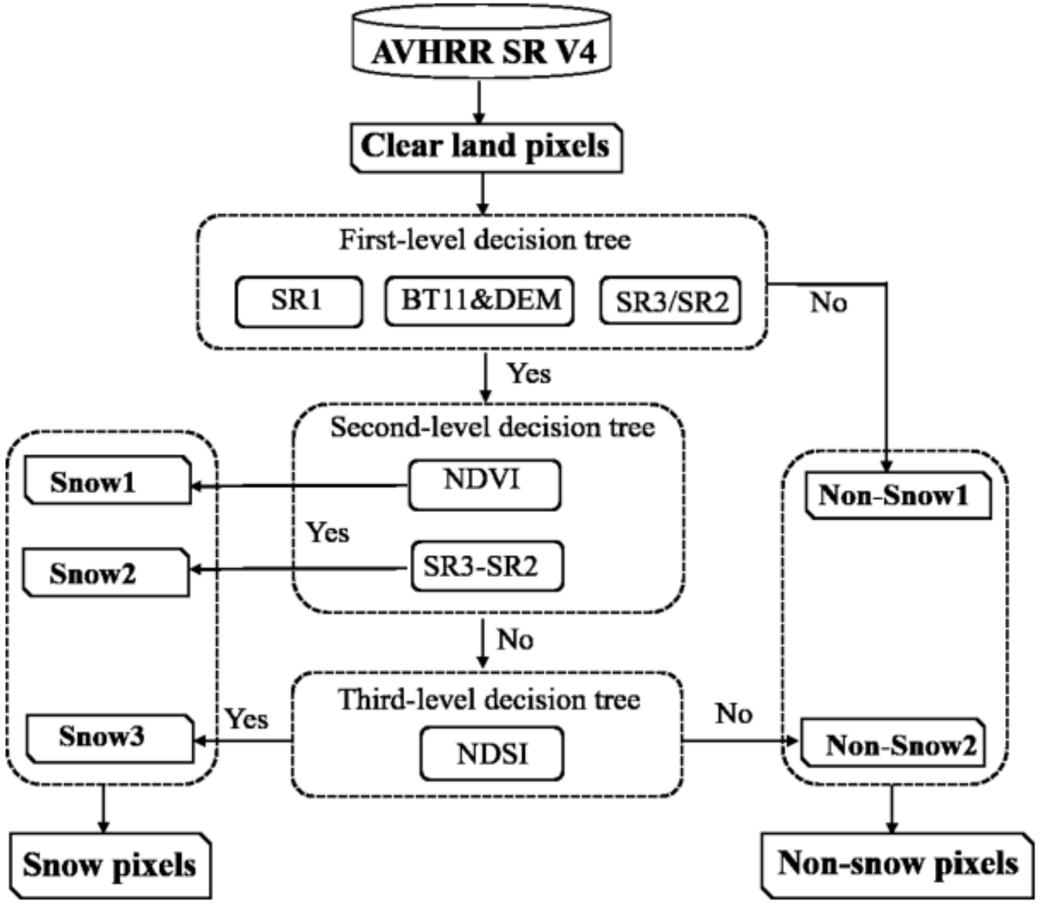
Validation and comparison four forest CMA stations

SCE products	OA (%)	PA (%)	UA (%)
Terra-MODIS SCE dataset	95.19	97.84	90.74
MOD10A1	92.48	96.62	86.01
Aqua-MODIS SCE dataset	94.18	97.77	90.38
MYD10A1	90.83	92.60	69.87
CGF-MODIS SCE dataset	91.23	93.39	92.12
MOD10A1F	81.79	85.95	84.10
MYD10A1F	82.78	89.53	83.12

Cloud-gap-filled products

CALIBRATION OF AVHRR PRODUCT IN CHINA





The flowchart of a three-level decision tree snow discrimination algorithm

The accuracy of NIEER AVHRR SCE maps versus Landsat-5 TM SCE maps. C1–C8 denotes the different Landsat-5 TM SCE.

Path/row	Serial number	Date	Cloud percentage	Snow percentage	OA	PA	UA	CK
116 028	C1	12 March 1997	2.0 %	77.2 %	87.9 %	88.3 %	95.9 %	0.678
121 024	C2	19 March 2016	1.8 %	96.4 %	98.1 %	100.0 %	98.1 %	1
135 038	C3	9 November 1996	1.0 %	66.5 %	79.5 %	81.0 %	87.9 %	0.552
137 039	C4	23 November 1996	2.0 %	50.7 %	78.2 %	65.7 %	88.5 %	0.566
142 027	C5	23 March 1987	0.0 %	96.1 %	97.2 %	100.0 %	97.2 %	0.036
143 027	C6	10 November 2005	2.0 %	48.6 %	93.1 %	86.7 %	99.8 %	0.863
147 029	C7	22 February 2016	1.1 %	89.0 %	90.6 %	91.4 %	98.0 %	0.587
147 029	C8	17 February 1997	2.0 %	88.3 %	89.8 %	90.9 %	97.7 %	0.560
Total					89.4 %	90.2 %	96.1 %	0.713

CALIBRATION OF AVHRR PRODUCT IN CHINA

Accuracy against station observation

		NIEER AVHRR SCE		JASMES SCE	
	Class	Snow	Non-snow	Snow	Non-snow
Ground snow-depth measurements	Snow	134 260	32 946	50 335	78 148
	Non-snow	36 367	295 890	23 594	209 149
OA		86.1 %		71.8 %	
PA		80.3 %		39.2 %	
UA		78.7 %		68.1 %	
CK		0.690		0.321	

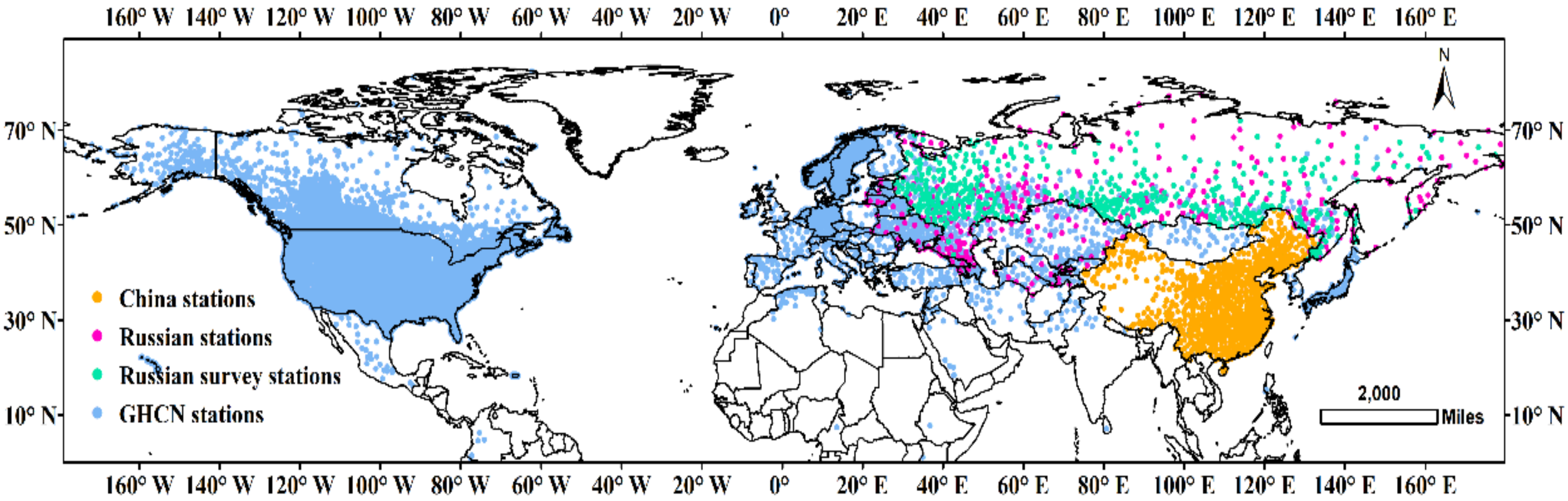
CONTENTS

ASSESSMENT ON SNOW DEPTH PRODUCTS

Global snow depth products

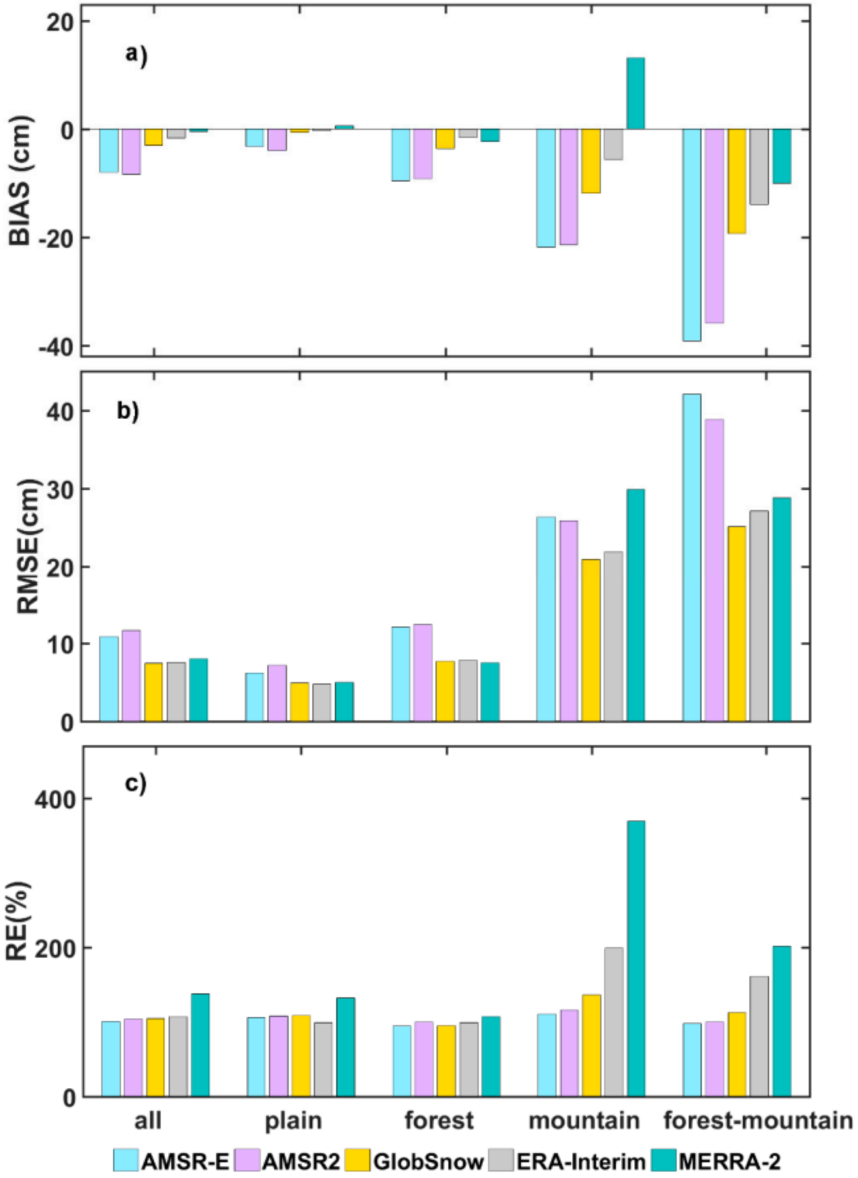
Dataset	AMSR-E	AMSR2	GlobSnow	ERA-Interim	MERRA-2
Organization	NASA/JAXA	NASA/JAXA	ESA	ECMWF	NASA
Spatial coverage	0°-90°N	0°-90°N	35°N-85°N	0°-90°N	0°-90°N
Spatial resolution	0.25°×0.25°	0.25°×0.25°	25km×25km°	0.25°×0.25°	0.5°×0.625°
Time duration	2003-2011	2013-2016	1980-2013	1980-2016	1981-2016
Projection/Datum	WGS-84	WGS-84	EASE-GRID	WGS-84	WGS-84
Temporal resolution	Daily	Daily	Daily	6 hours	Daily
Parameter transformation	SD	SD	SWE/ρ	SWE/ρ	SD^{*}×fsc
Algorithm/Model	Improved Chang algorithm	Improved Chang algorithm	HUT, model assimilation	TESSEL	NSIPP

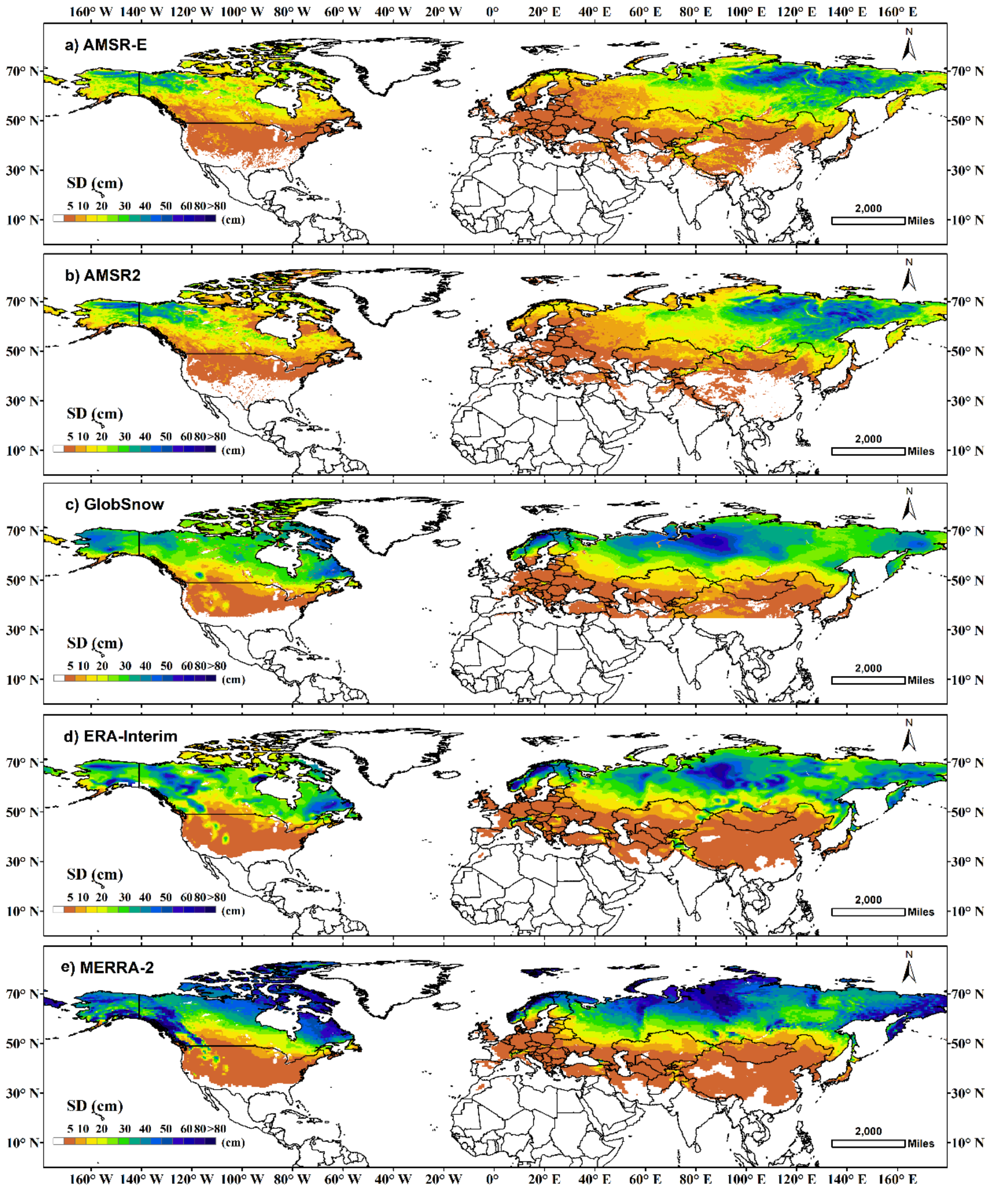
The ground observations from China, Russian meteorological stations, Russian snow survey and GHCN were represented by orange, purple, green and blue dots, respectively.



Large error in mountainous area

Different patterns, especially in Eurasia





ESA-MOST Dragon Cooperation 中国科技部—欧洲空间局"龙计划"合作

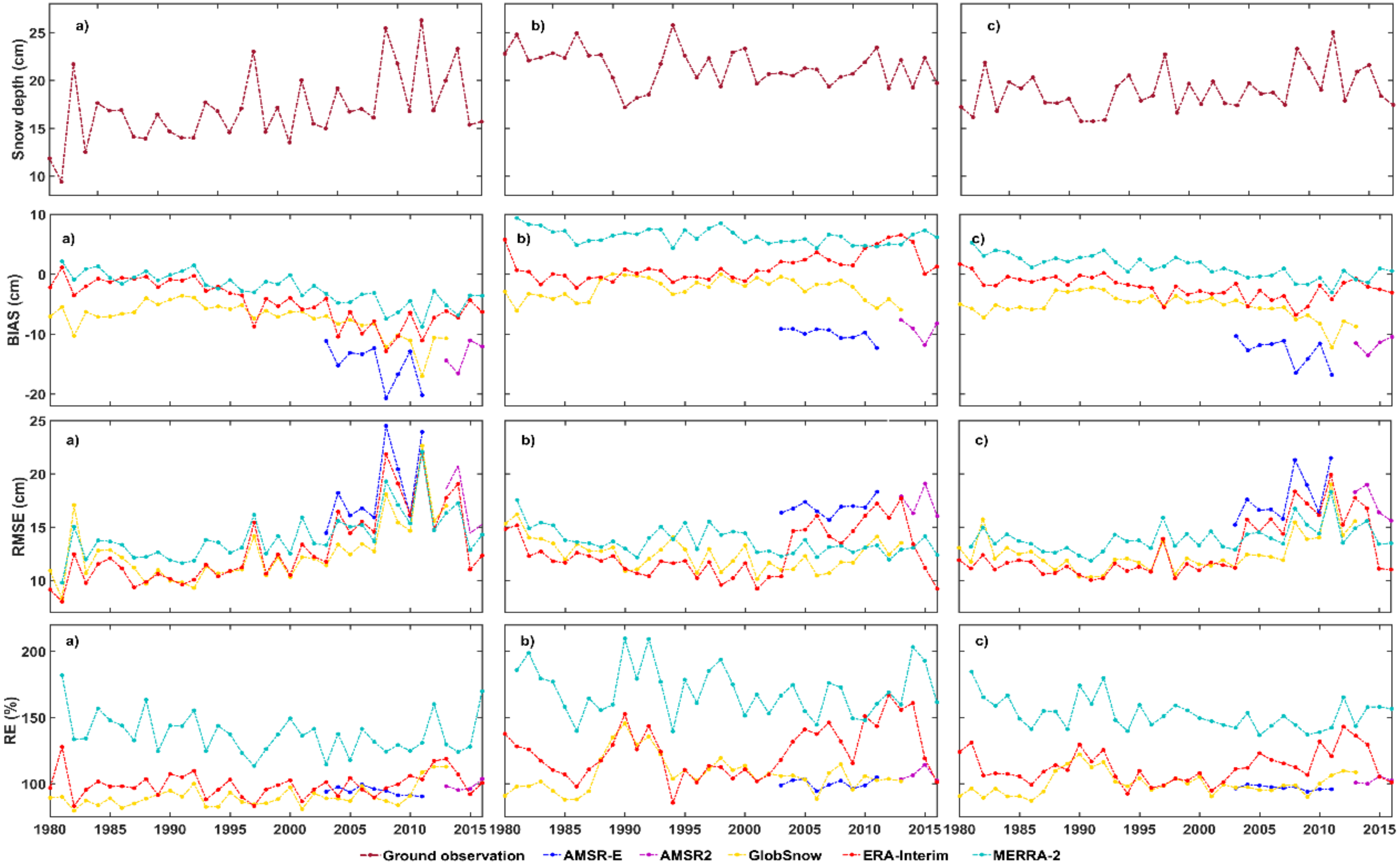
2023 Dragon 5 Symposium

"龙计划"五期 2023 年度国际学术研讨会

11–15 September 2023

Hohhot, Inner Mongolia, China

2023 年 9 月11-15 日 |中国 内蒙古 呼和浩特



a) North America
b) Eurasia
c) the Northern Hemisphere

ESA-MOST Dragon Cooperation 中国科技部—欧洲空间局“龙计划”合作

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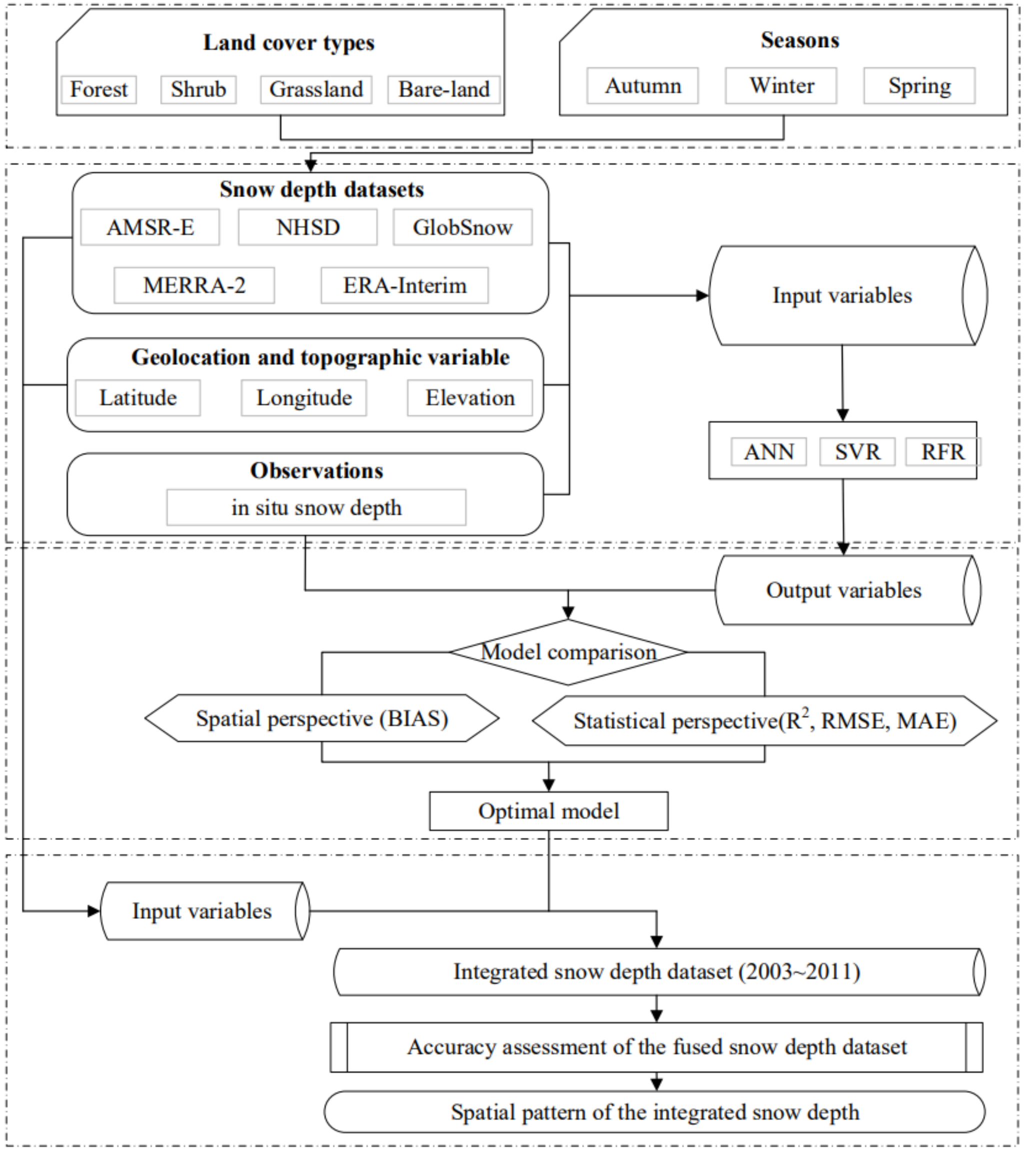
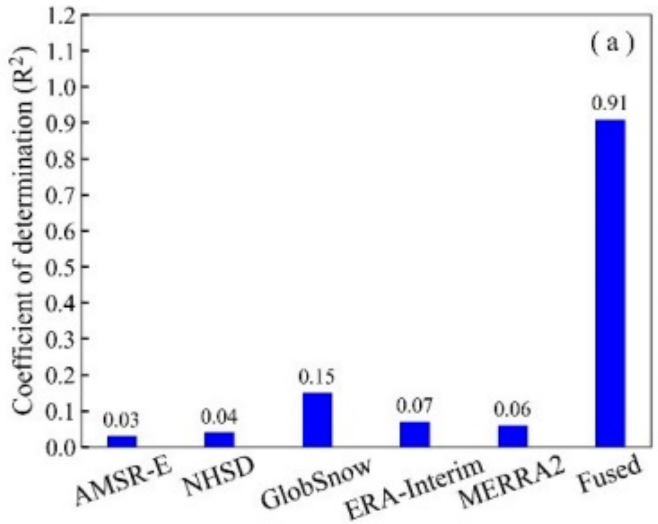
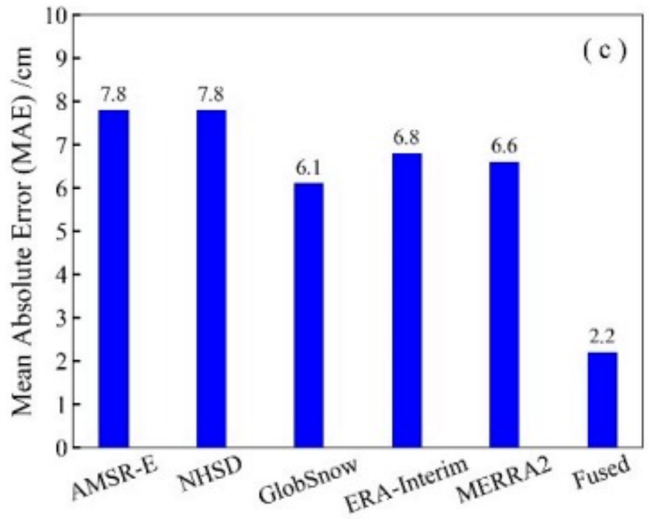
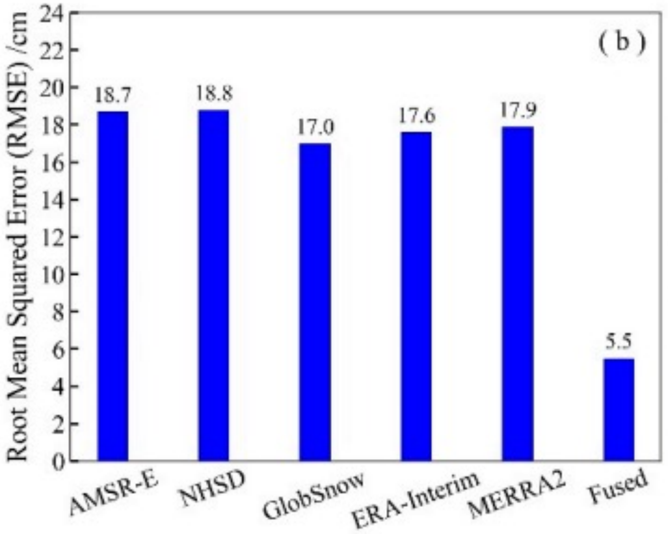
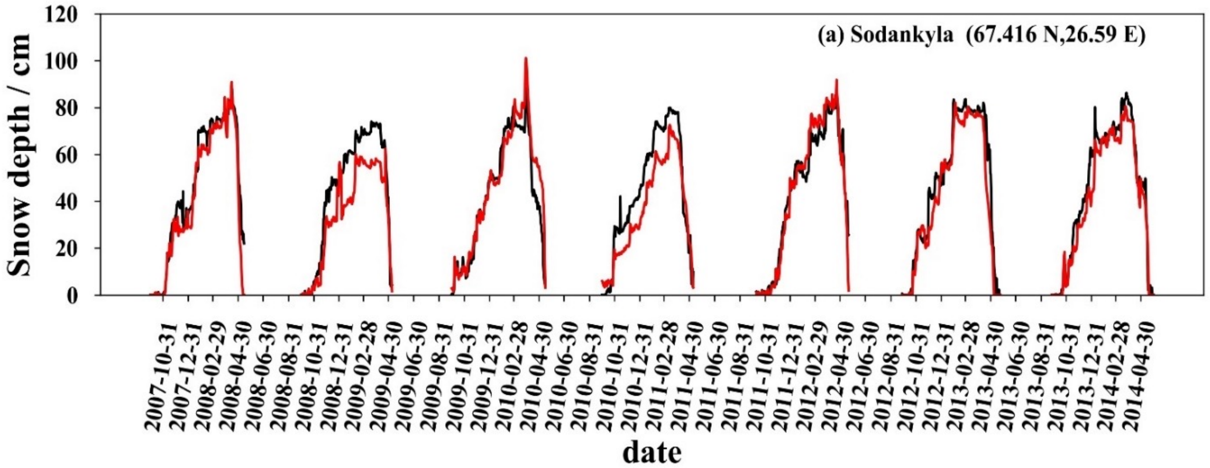


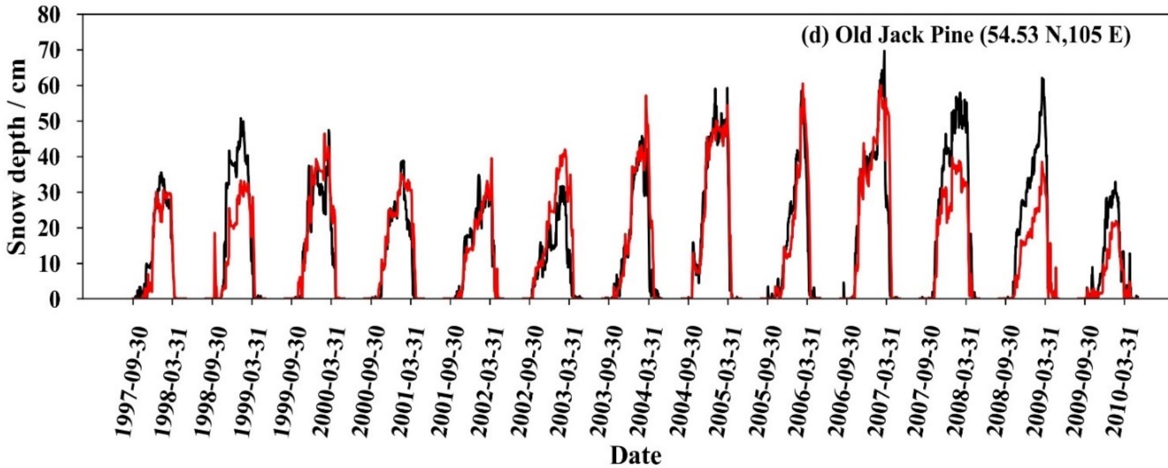


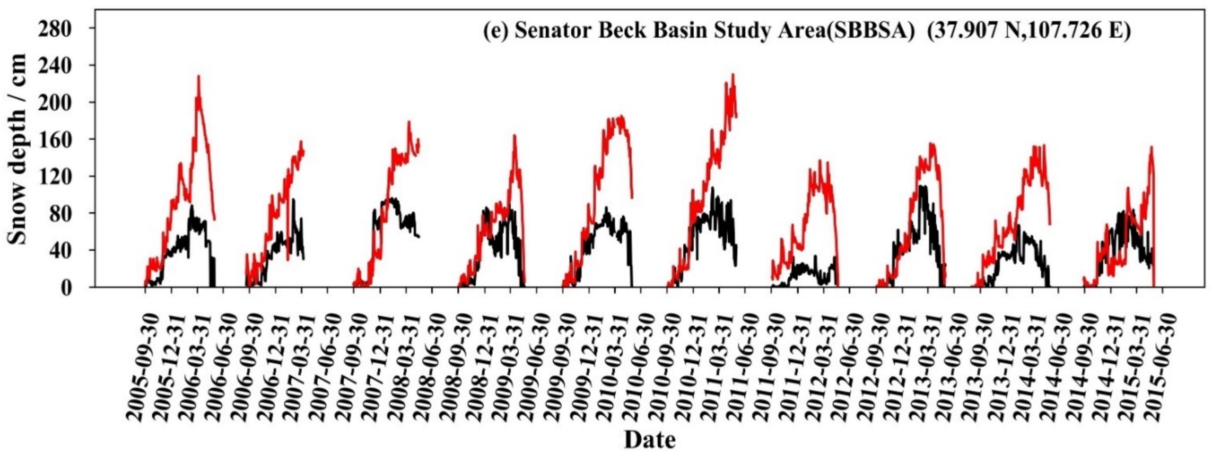


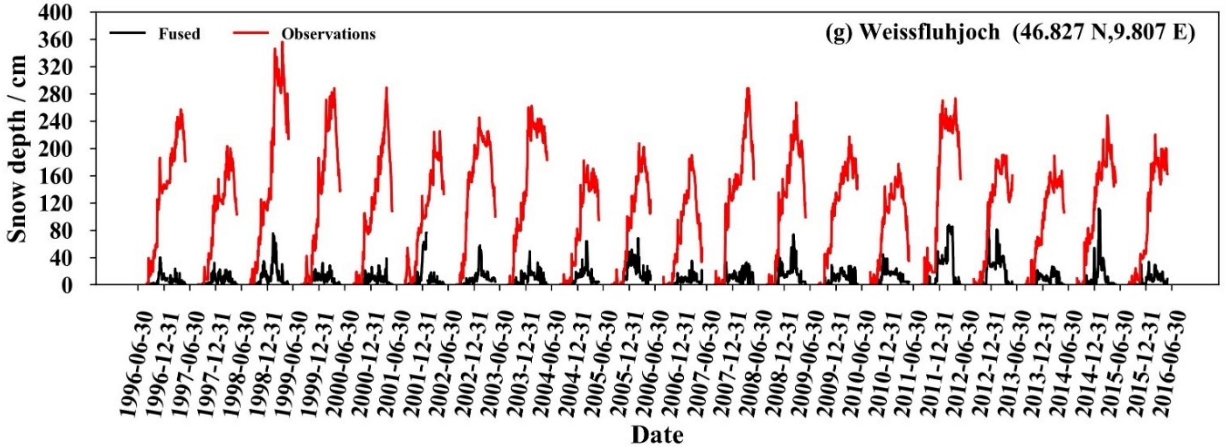


Fusing 5 snow depth products using machine learning method

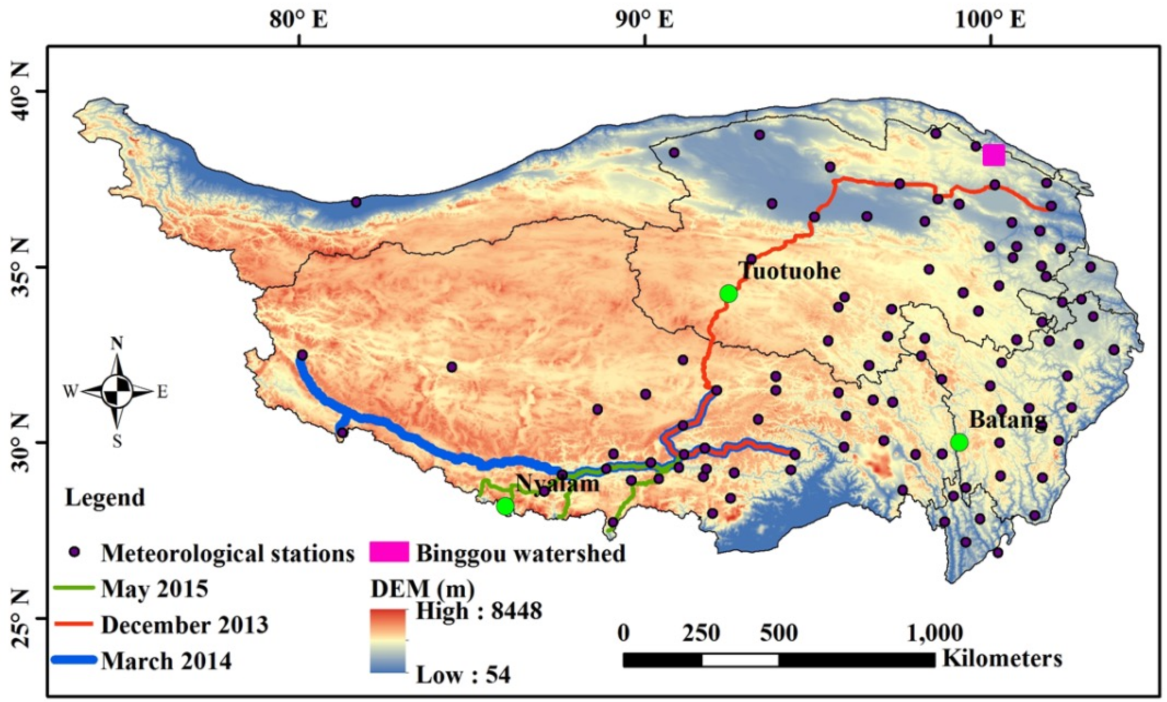

(a) Sodankyla (67.416 N,26.59 E)
Snow depth / cm
date

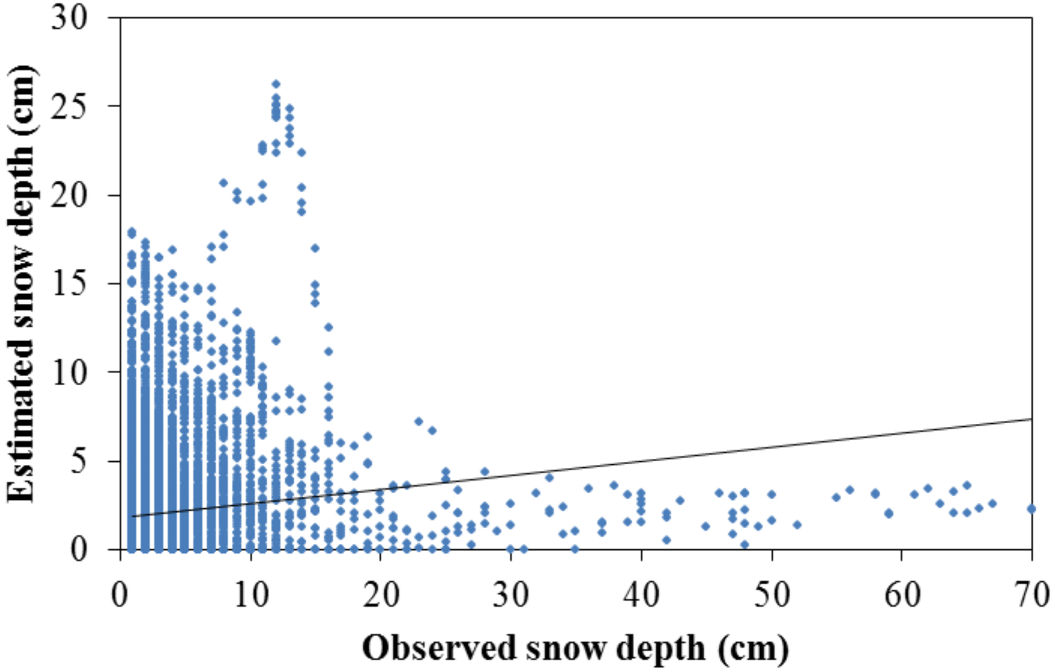

(d) Old Jack Pine (54.53 N,105 E)
Snow depth / cm
Date


(e) Senator Beck Basin Study Area(SBBSA) (37.907 N,107.726 E)
Snow depth / cm
Date


Fused
Observations
(g) Weissfluhjoch (46.827 N,9.807 E)
Snow depth / cm
Date

VALIDATION OF PM-BASED SNOW DEPTH IN THE QTP

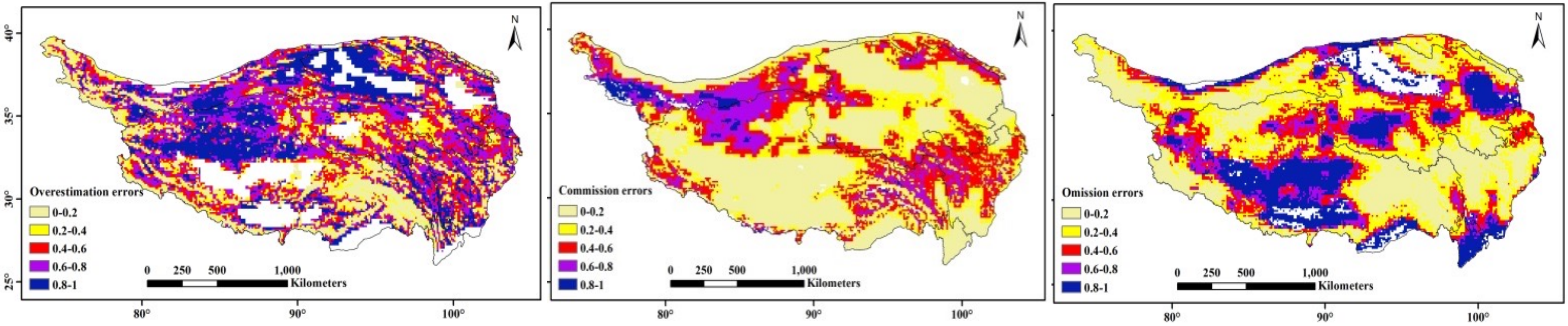




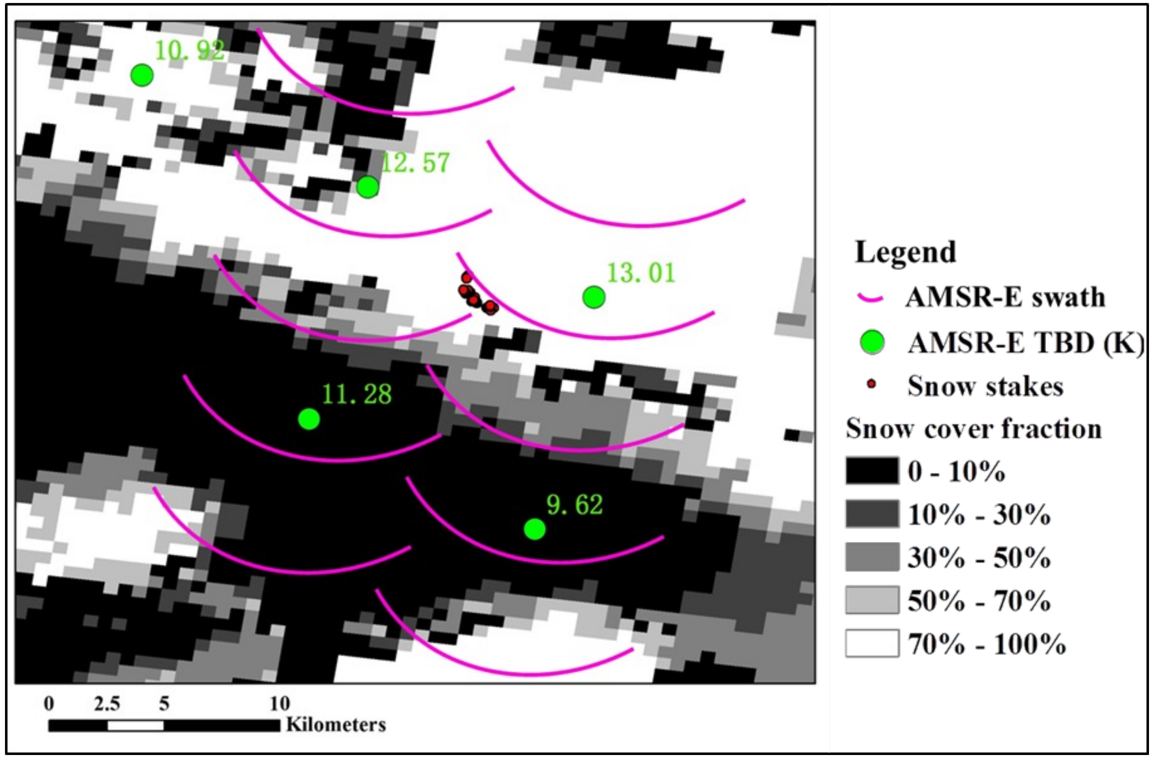
Compare with in situ snow depth
Compare with MODIS snow cover
Compare with pixel scale in situ snow depth (in situ snow depth multiply snow cover fraction)

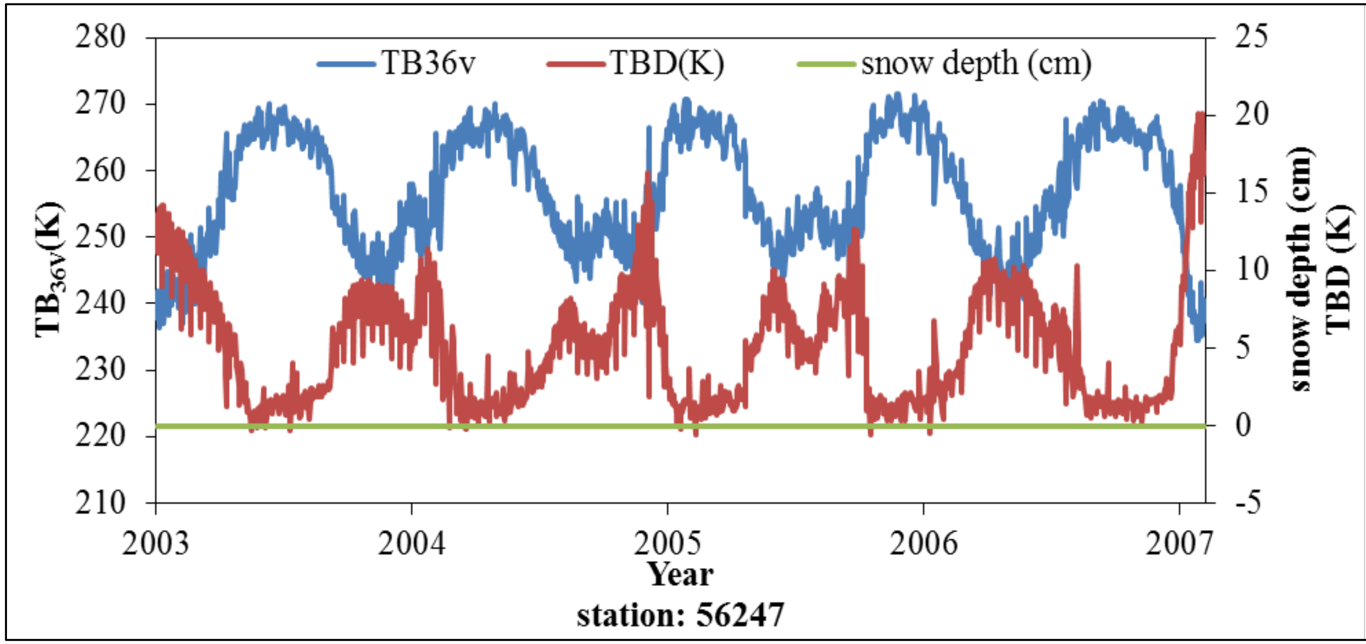
VALIDATION OF PM-BASED SNOW DEPTH IN THE QTP

Compare with MODIS snow cover



Generally, PM overestimated snow cover in the QTP
In the northwest region, frozen soil was misclassified as snow cover
Some shallow snow was misclassified as snow-free.

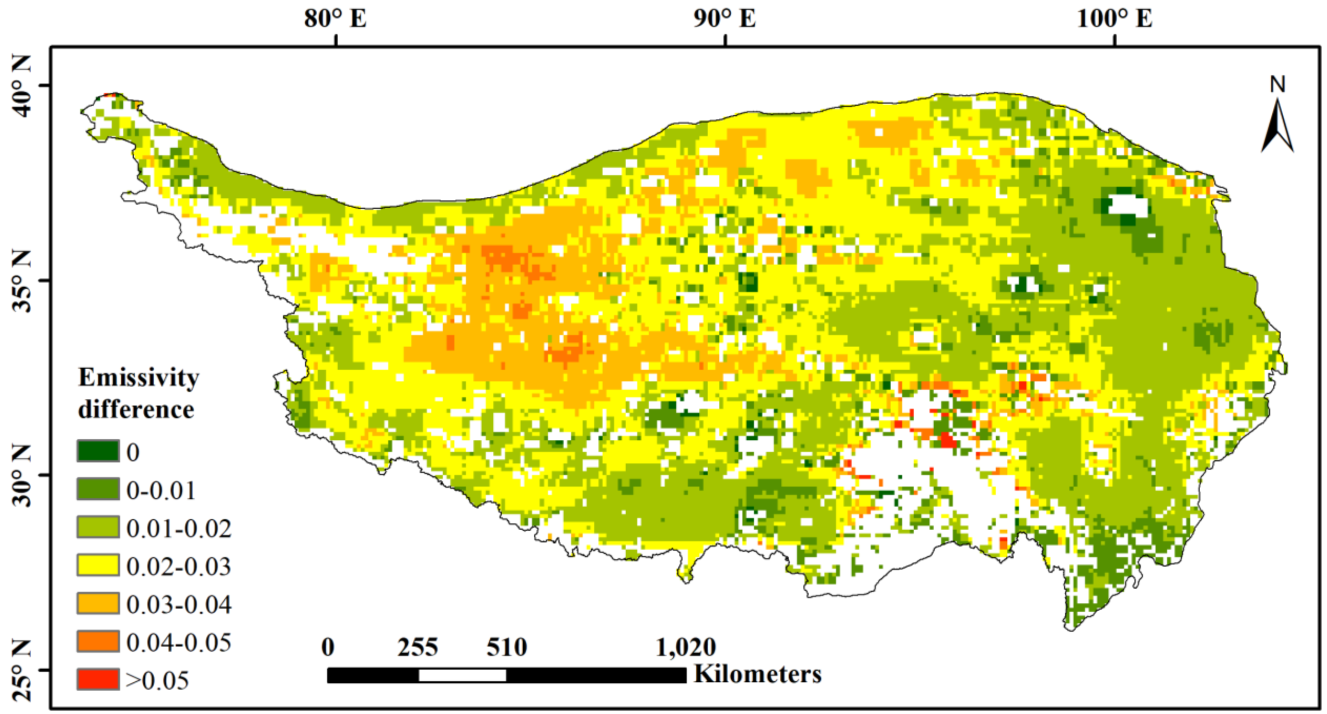




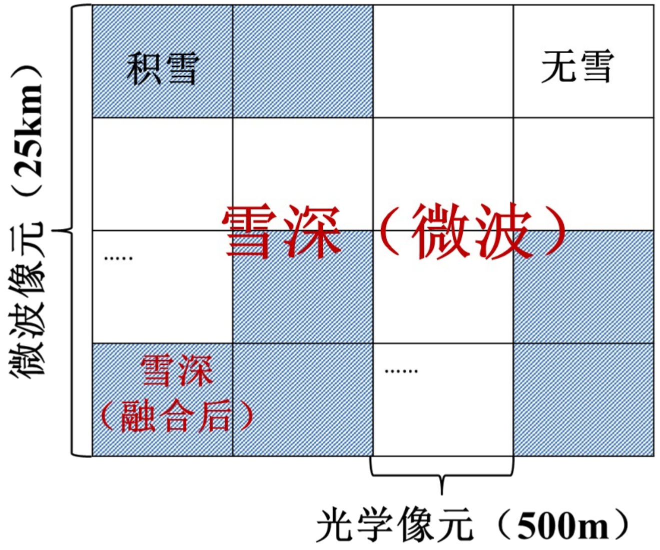
Low-temperature frozen soil cause large volume scatter

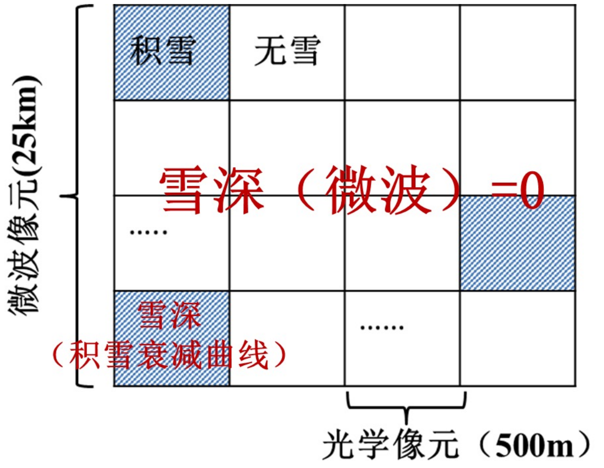
Brightness temperature difference at K and Ka band (TBD)

SNOW DEPTH ESTIMATION IN THE QTP

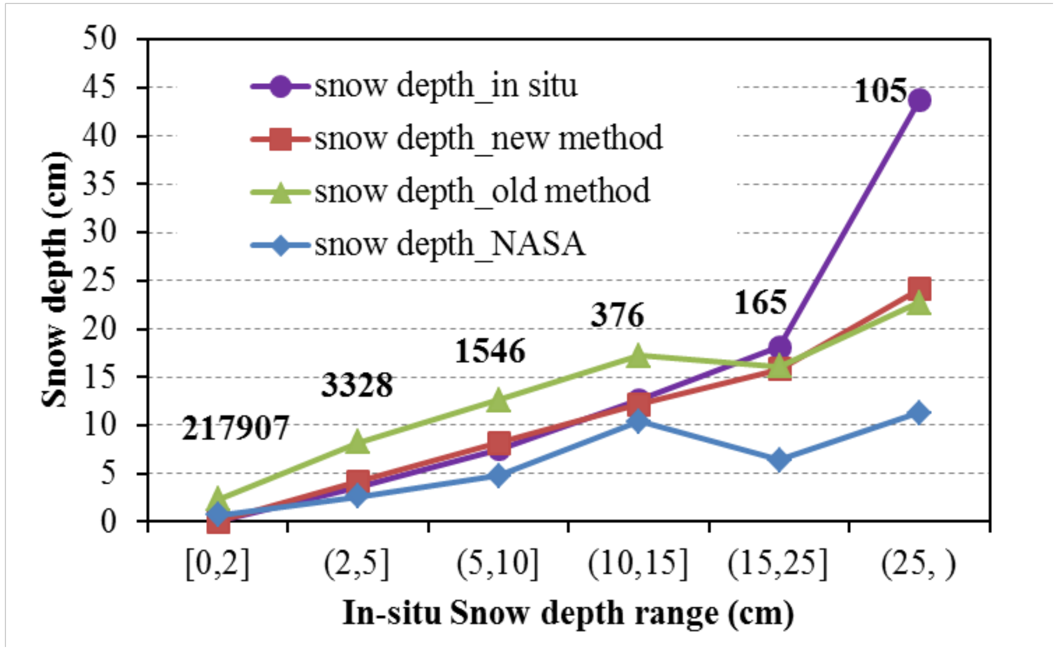


Spatial distribution of emissivity

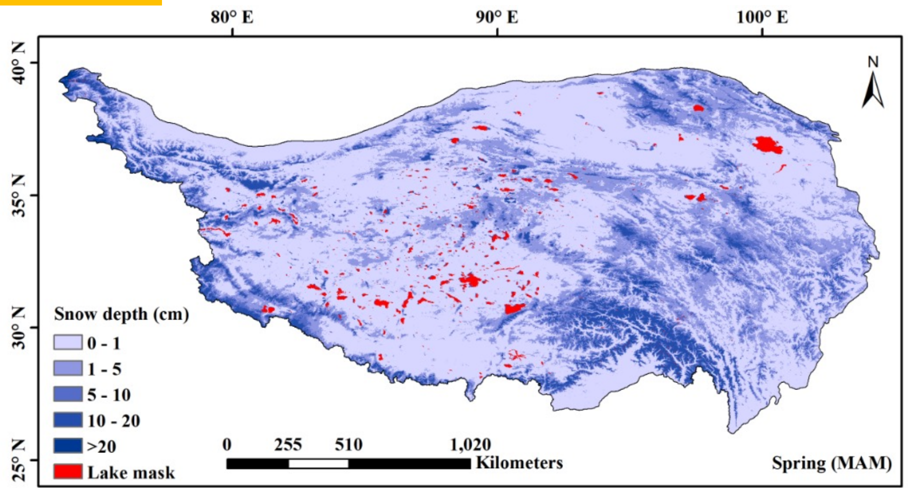


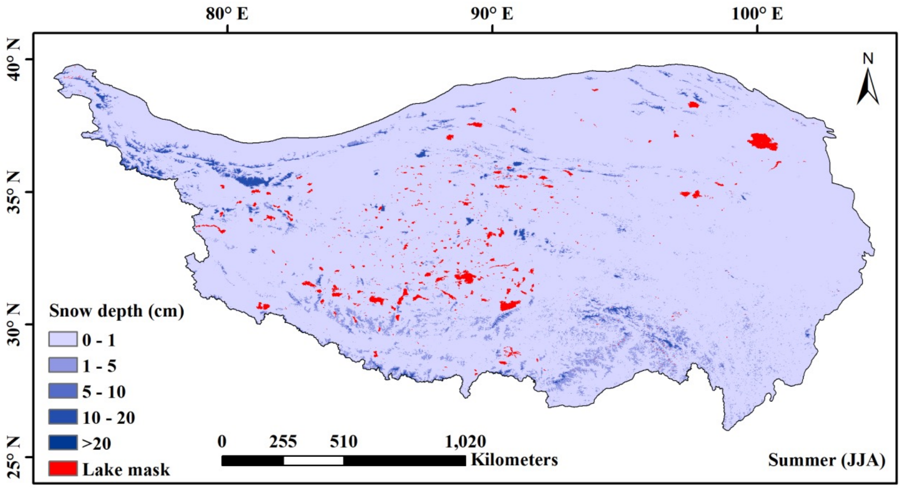


SNOW DEPTH ESTIMATION IN THE QTP



Accuracy of estimated snow depth against in situ data





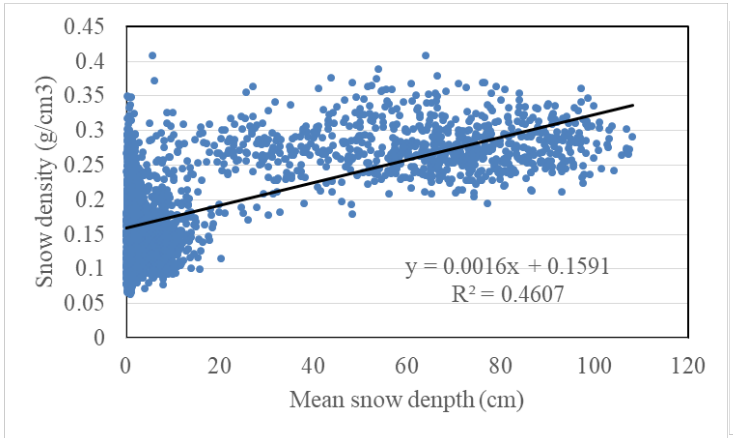
Snow density:

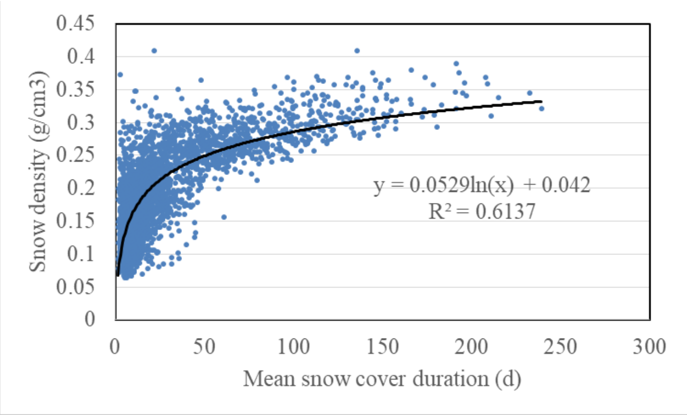
Global: 250-300kg/m^3

China: 180kg/m^3

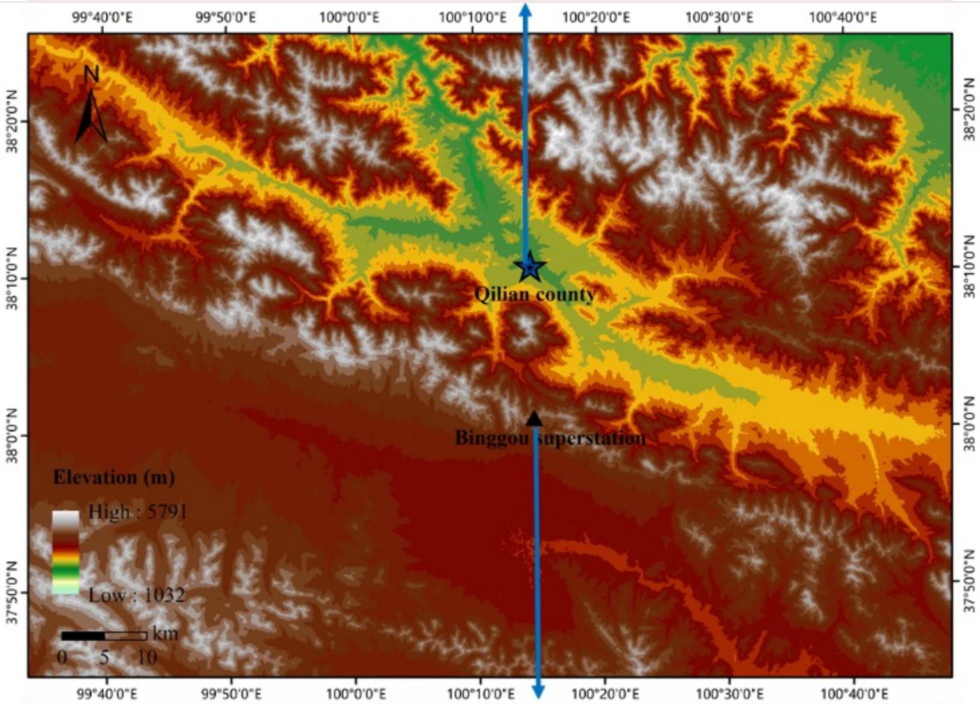
Tibetan Plateau (CMA station): 140kg/m^3

Tibetan Plateau (snow survey): 210kg/m^3





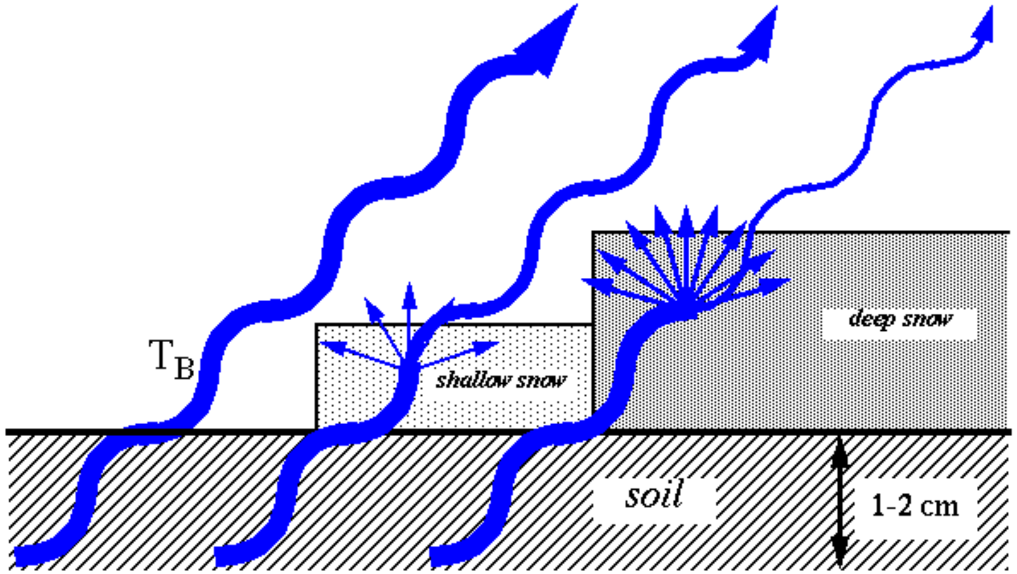
SCD=23 days; YLSD=0.1 cm; MSDn=0.108g/cm^3

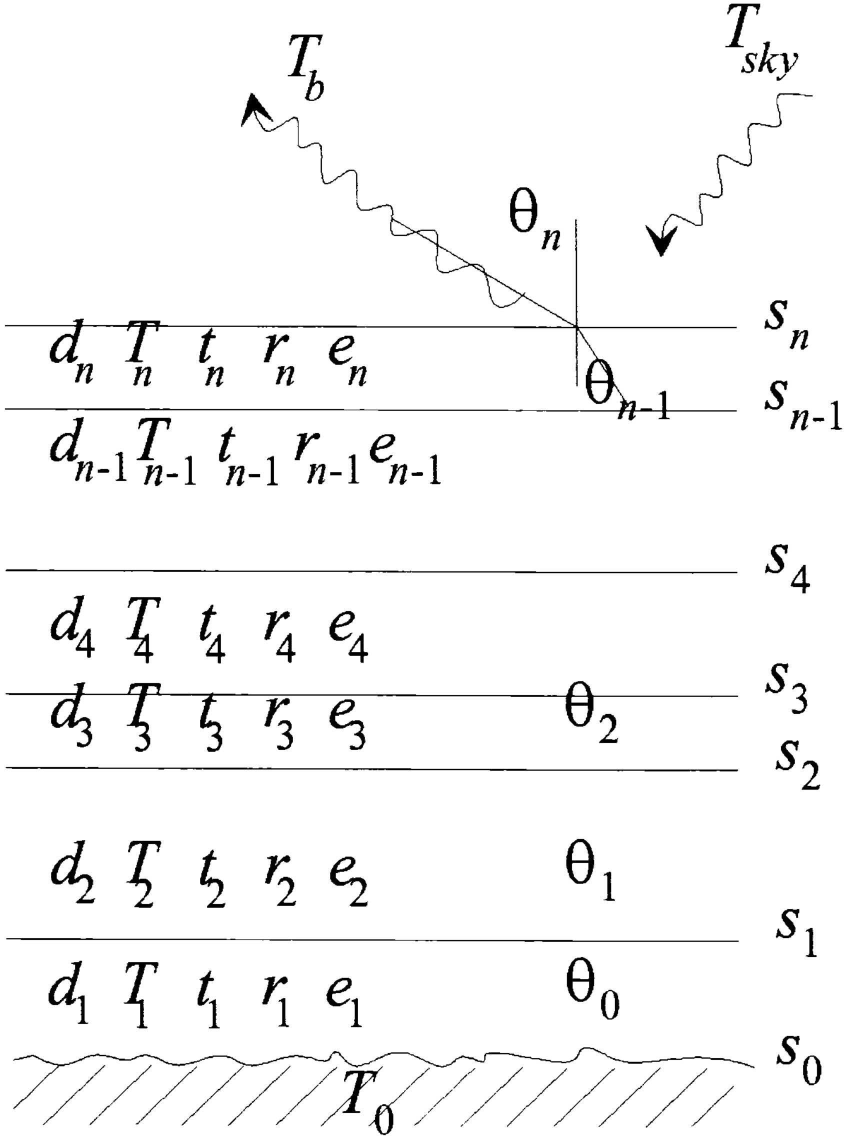


SCD=208 days; YMSD=15.8 cm; MSDn=0.230g/cm^3

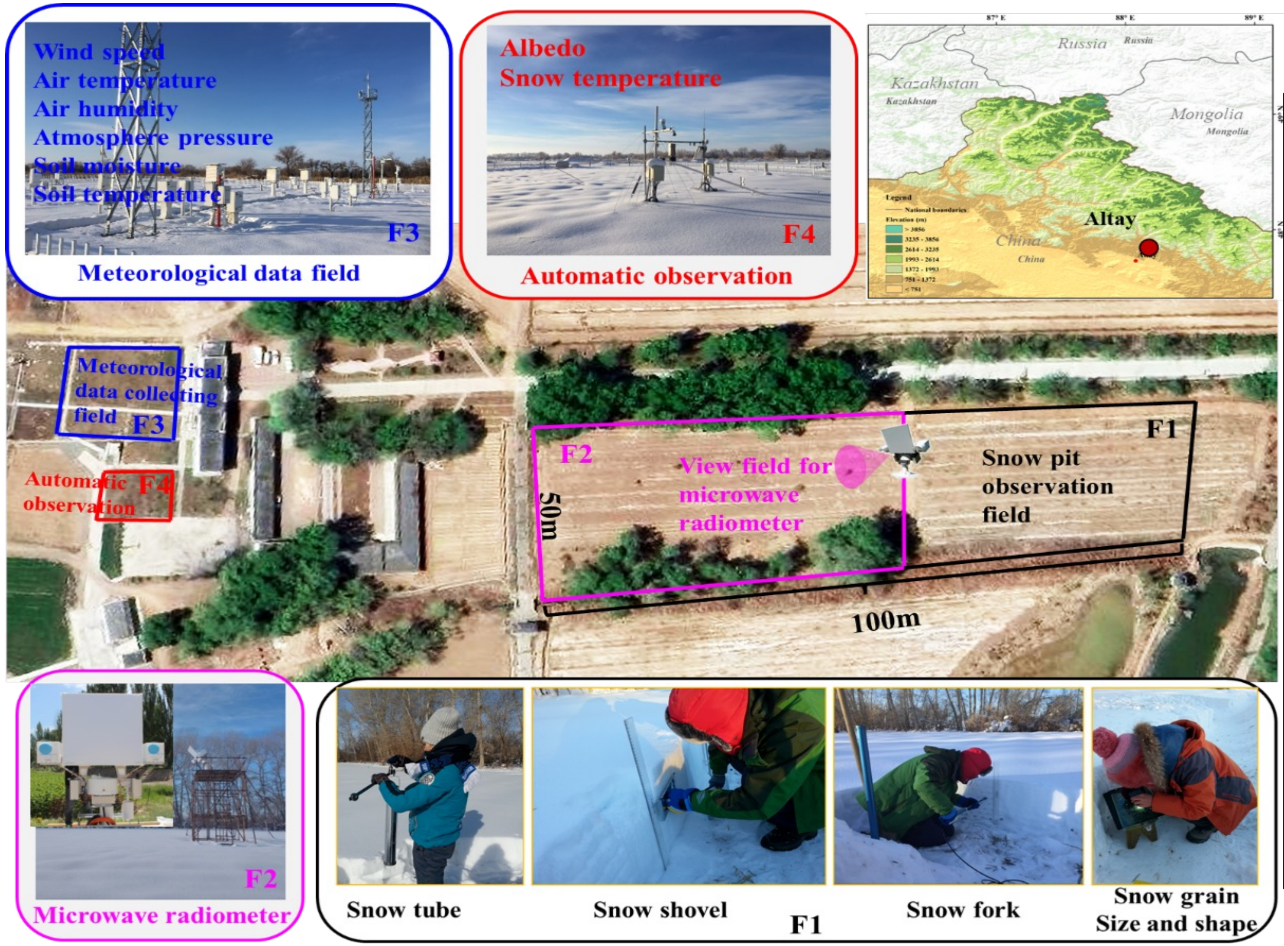
ASSESSMENT ON MEMLS

The microwave emission model of layered snowpacks (MEMLS) is the most used RTM in snow community.

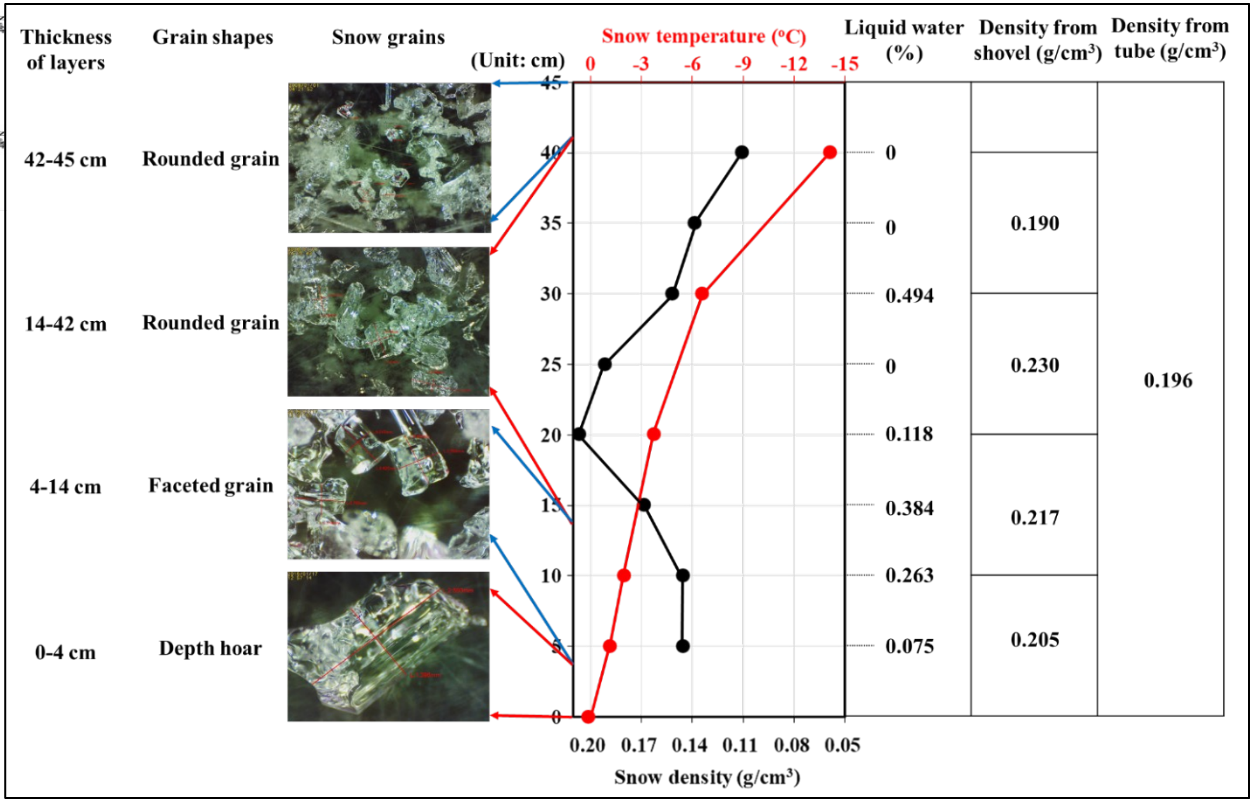




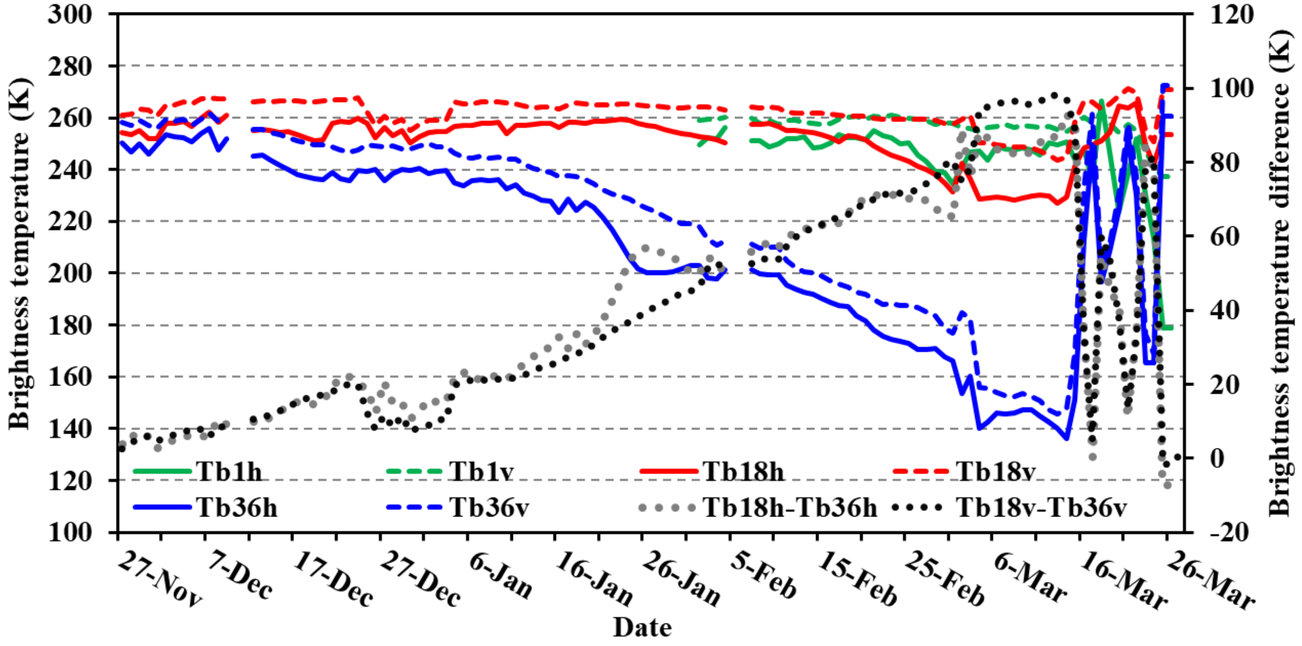
Wiesmann and Mätzler, 1999



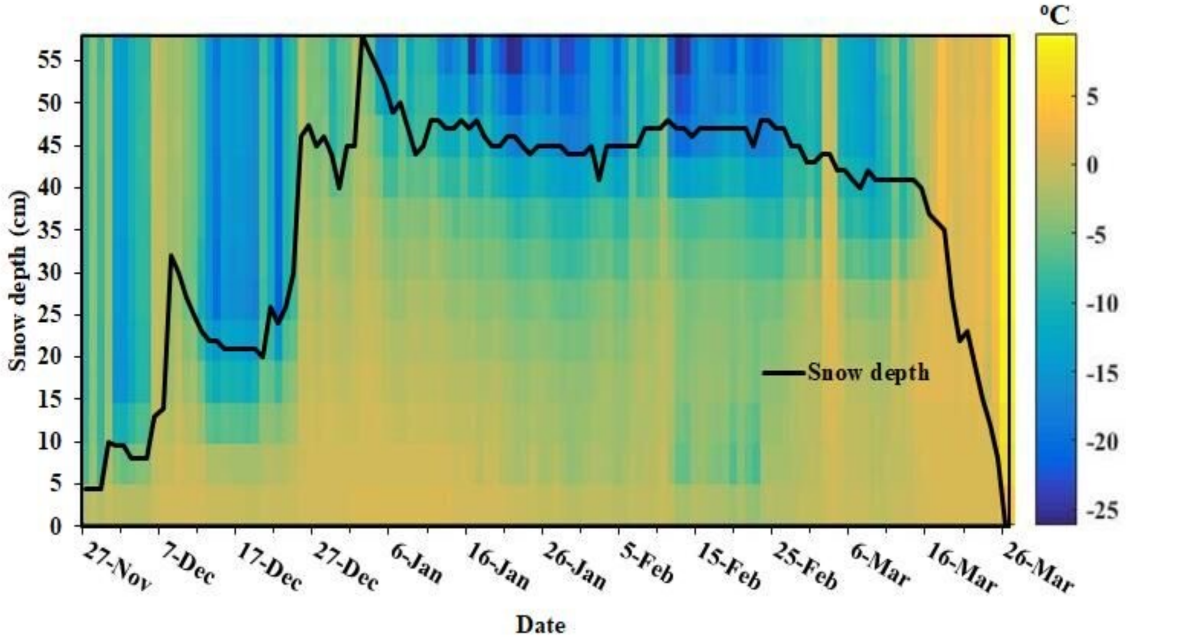
An example of snow pit observation



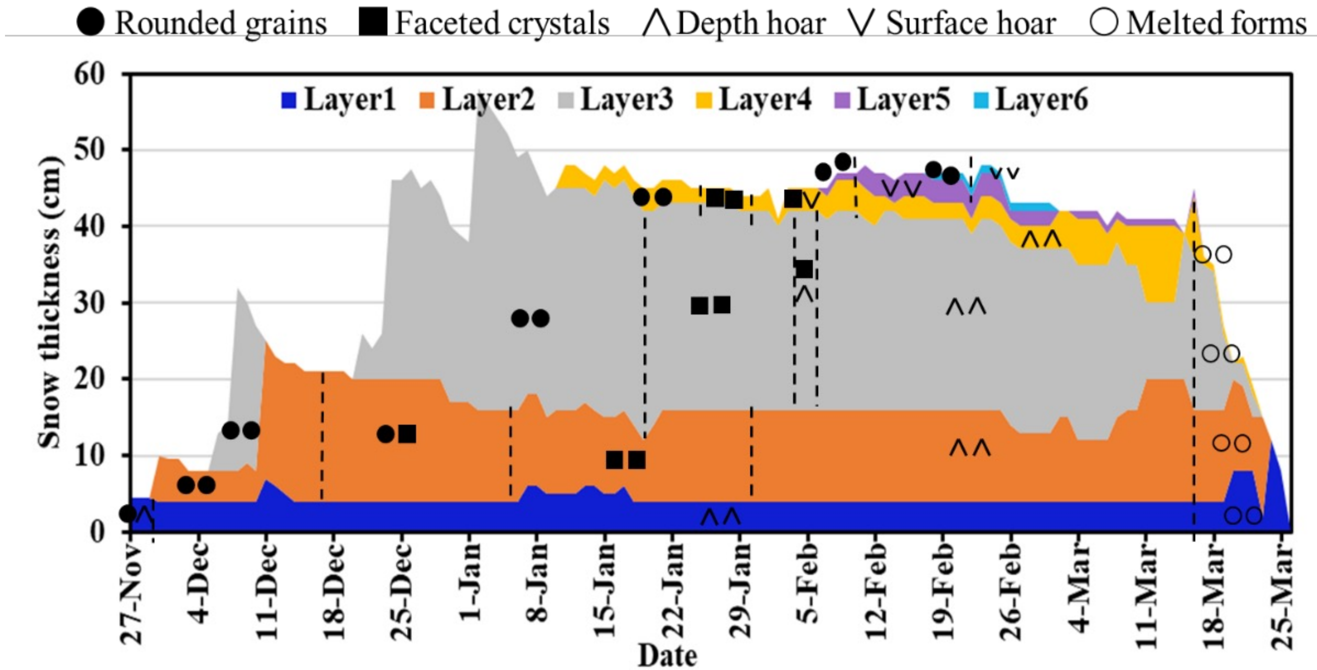
Location of the Altay National Reference Meteorological station (ANRMS) in Asia, along with the four test sites in the ANRMS



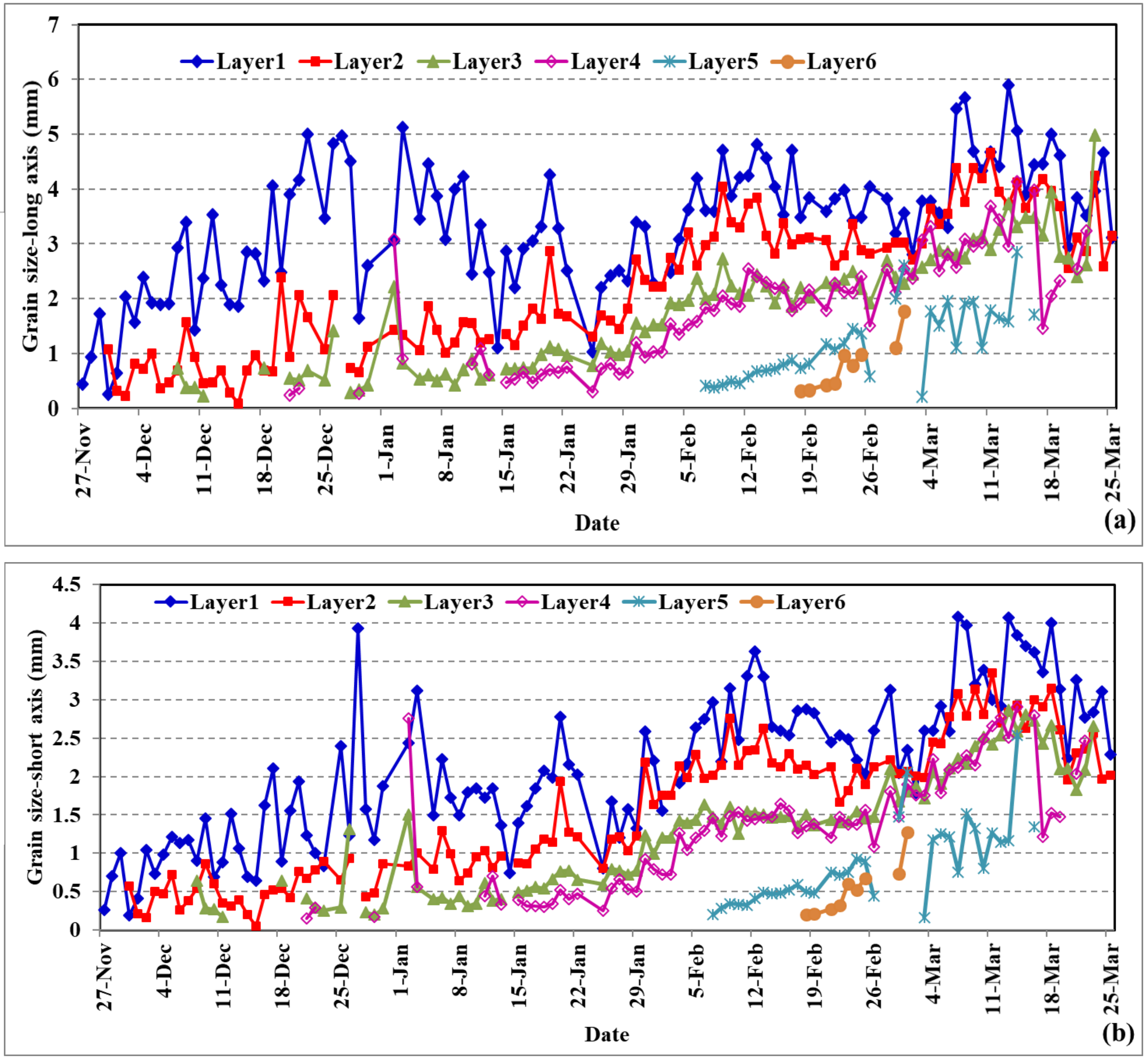
Daily variations in observed brightness temperatures at 1.4 GHz, 18 GHz and 36 GHz (L, K and Ka bands)



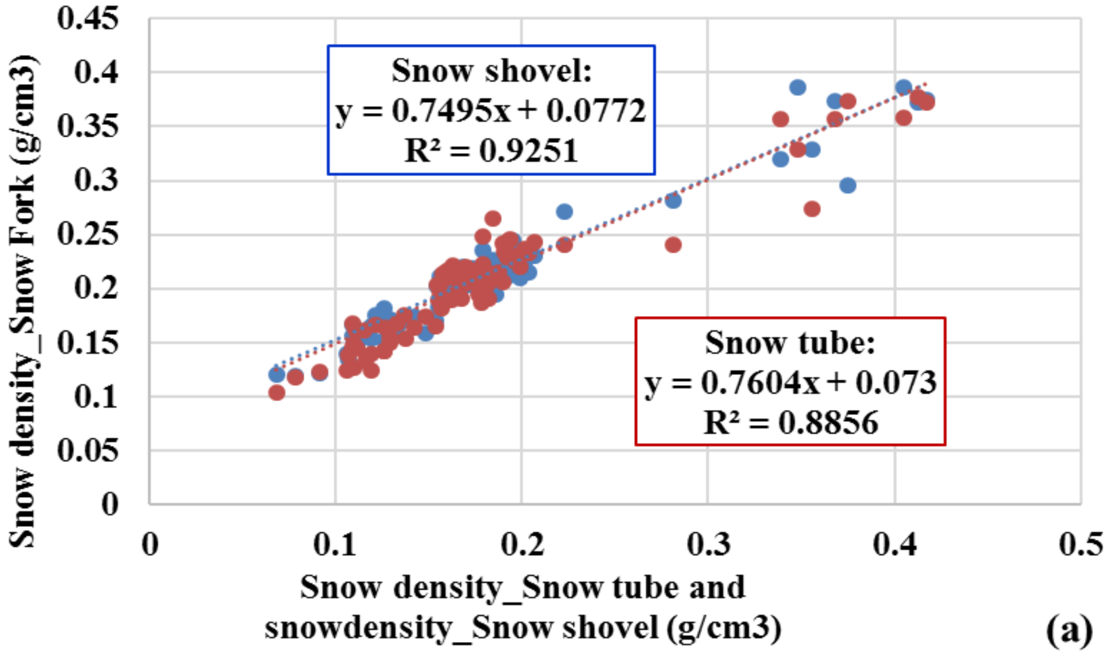
Variation in snow and air temperatures



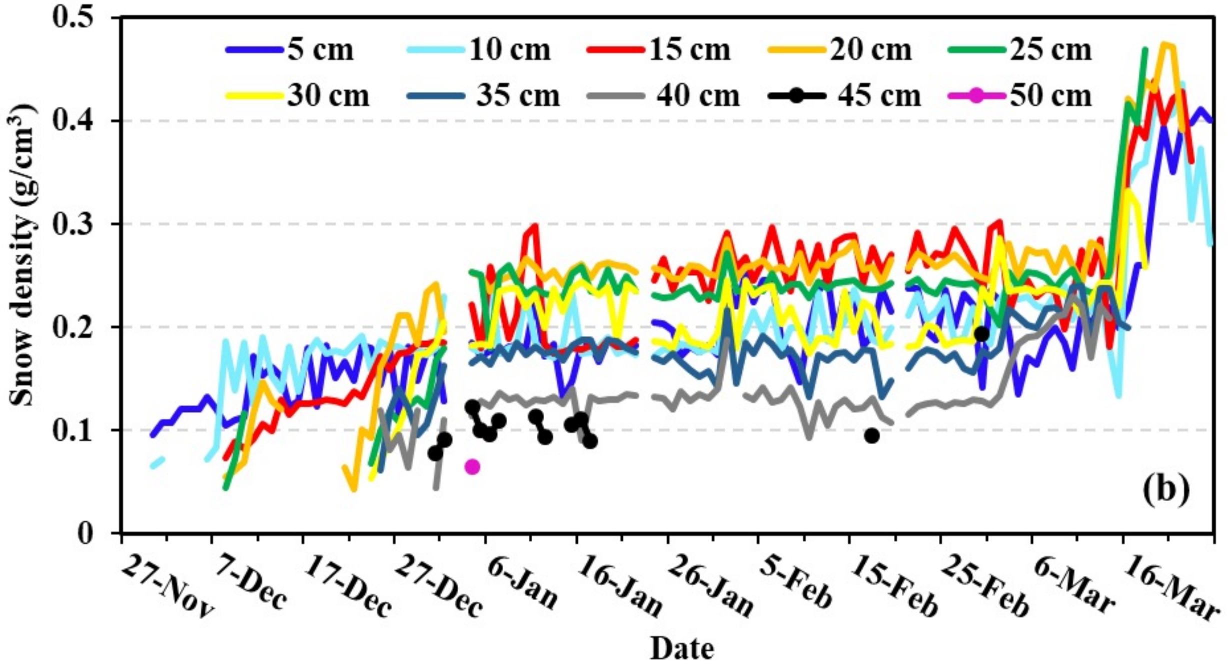
Daily variation in snow layers and grain shape in each layer in the whole of snow season



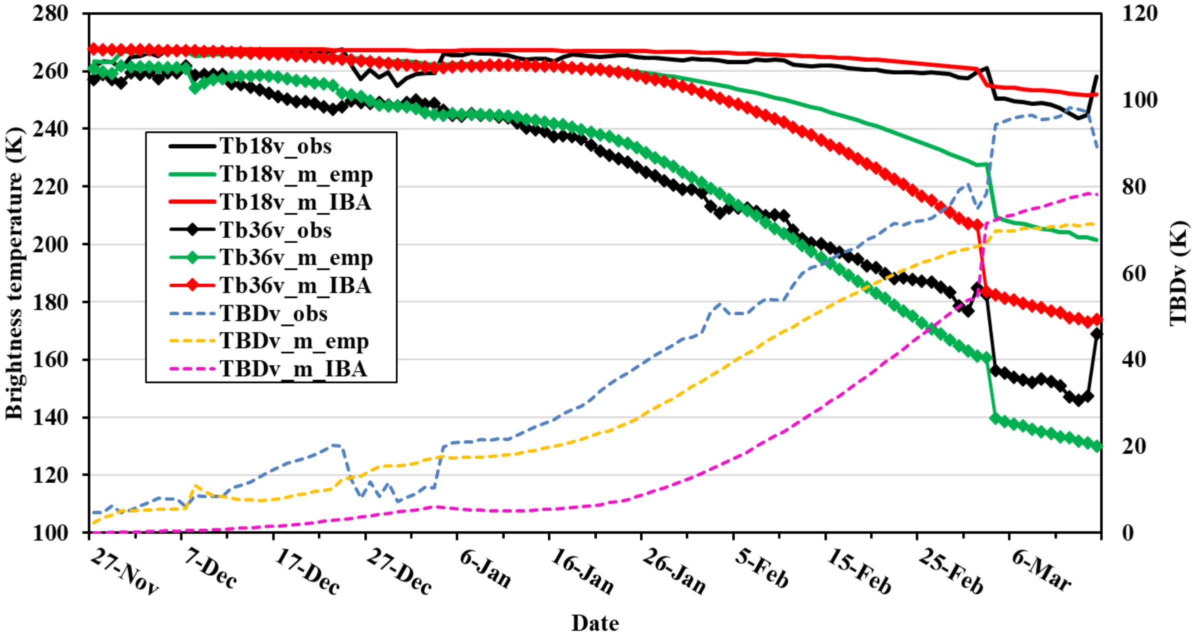
Daily variation in grain size within each layer



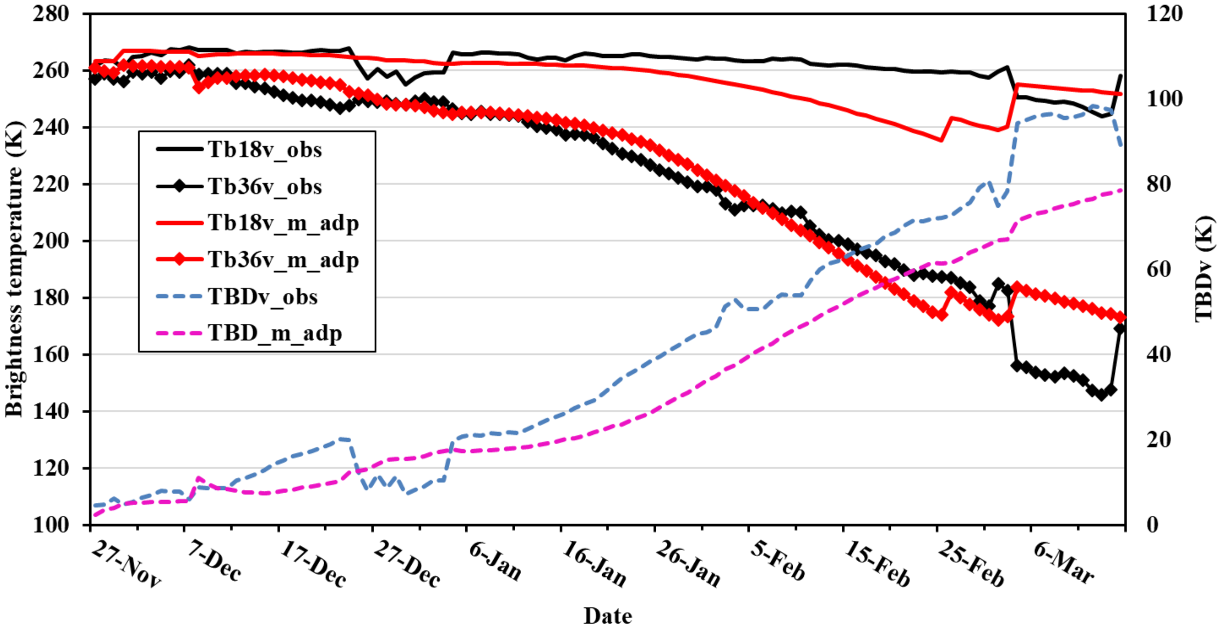
Comparison of snow densities measured using Snow Fork, snow shovel and snow tube.



Daily variation in snow density measured using Snow Fork



Brightness temperature from ground-based radiometer VS simulated brightness temperature using empirical and Improved Born Approximation (IBA) scatter models



Brightness temperature from ground-based radiometer VS simulated brightness temperature using adaptive scatter model

CONTENTS

- ☐ Validation or assessment of snow cover data
- ☐ Validation or assessment of snow depth data
- ☐ Validation or assessment of soil moisture data

EVALUATION OF SMAP, SMOS AND AMSR2 SOIL MOISTURE PRODUCTS BASED ON DISTRIBUTED GROUND OBSERVATION NETWORK IN COLD AND ARID REGIONS OF CHINA

- The performance of nine remotely sensed SM products from AMSR2, SMOS and SMAP missions, are evaluated based on observations collected from distributed observation networks in the Heihe River Basin (HRB) of China during 2013 to 2017.

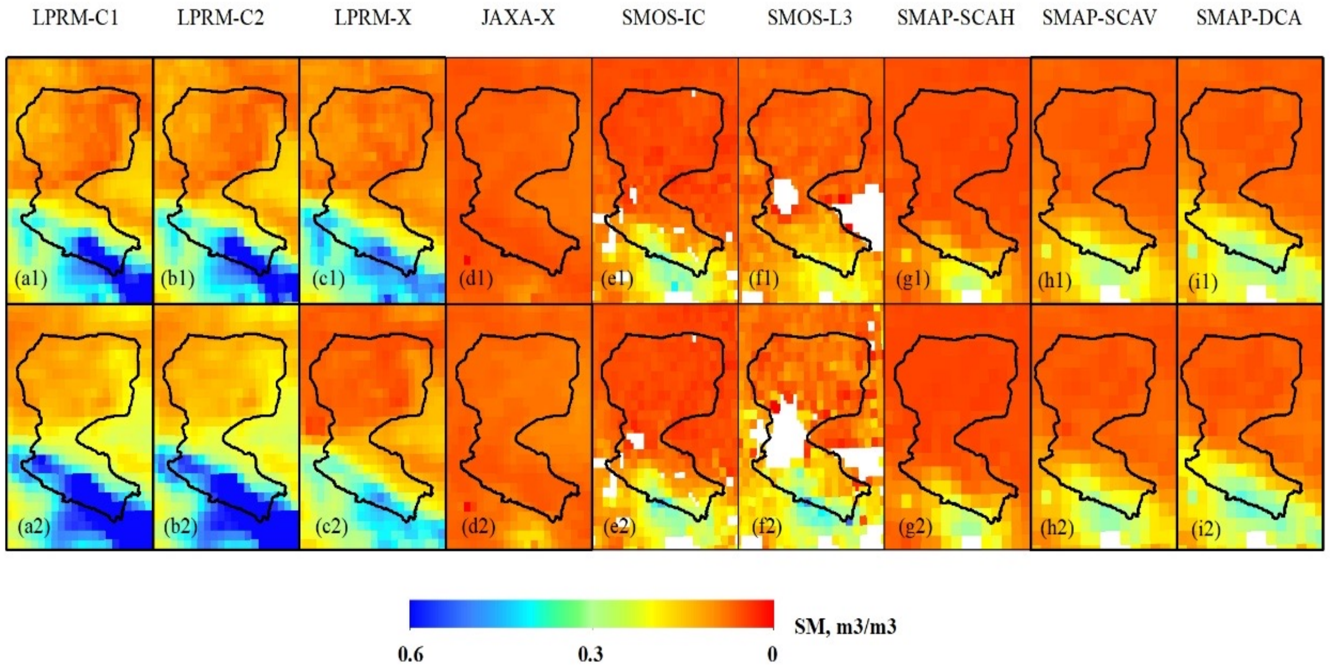
- Four widely used statistical indices are used to evaluate the accuracy of the time-series SM datasets, including the Pearson correlation coefficient (R), mean Bias (bias, m^3/m^3), root mean square error (RMSE, m3/m3) and the unbiased RMSE (ubRMSE, m3/m3). The definitions are given as follows:

$$R = \frac{E[(SM_{est} - E[SM_{est}]) \times (SM_{ref} - E[SM_{ref}])]}{\sigma_{est} \times \sigma_{ref}}$$

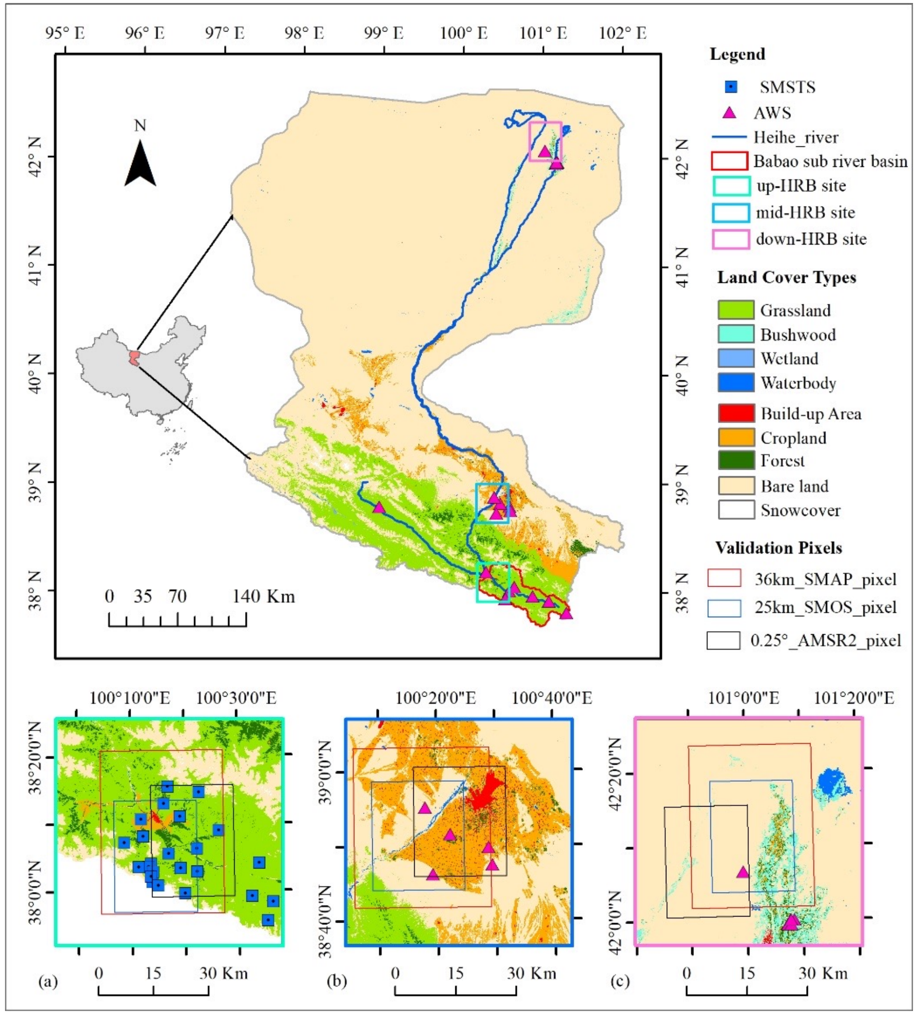
$$Bias = E[SM_{est}] - E[SM_{ref}]$$

$$RMSE = \sqrt{E[(SM_{est} - SM_{ref})^2]}$$

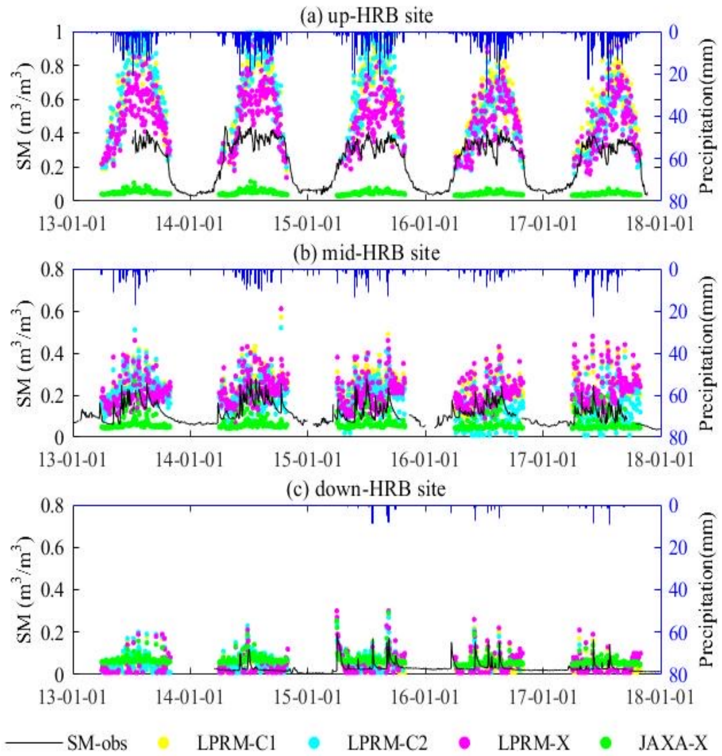
$$ubRMSE = \sqrt{\frac{\sum_{i=1}^{n} [(x_i - \bar{x}) - (y_i - \bar{y})]^2}{n}} = \sqrt{RMSE^2 - Bias^2}$$

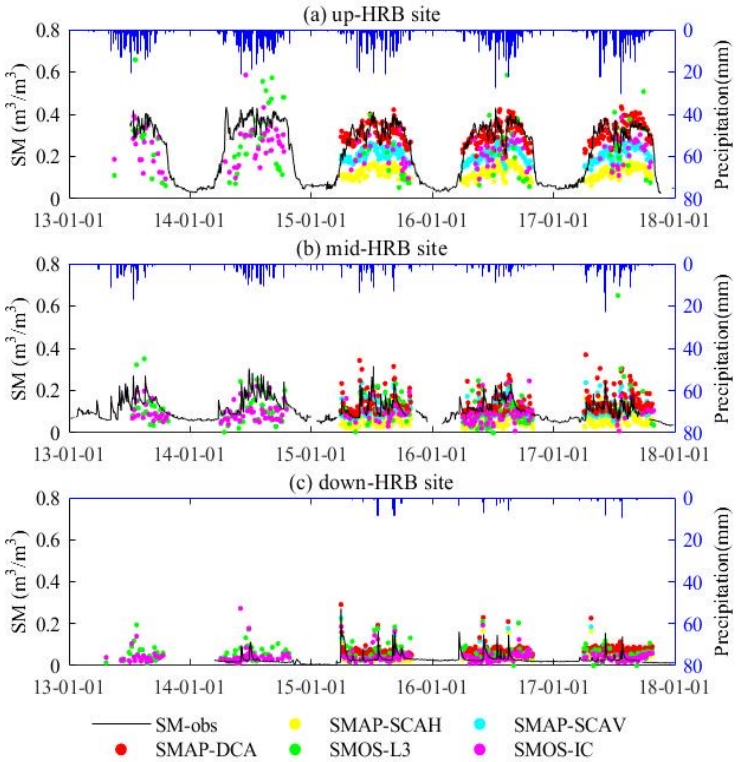


Spatial distributions of AMSR2, SMOS and SMAP soil moisture products (LPRM-C1, C2, X, JAXA-X, SMOS-IC, SMOS-L3 and SMAP-SCAH, SCAV, DCA) in both AM ((a1)-(i1)) and PM ((a2)-(i2)) orbits, averaged during the unfrozen seasons for 2015 in HRB.



Land cover types and the distributed soil moisture observation networks in three validation sites of up-HRB (a), mid-HRB (b) and down-HRB (c) in HRB.





- The SMAP Level 3 Dual Channel Algorithm (DCA) product gain superior performance than the SMAP-SCAH/SCAV with comparably high temporal correlations of ~0.7 and high accuracy within 0.04 m^3/m^3 in ubRMSE.

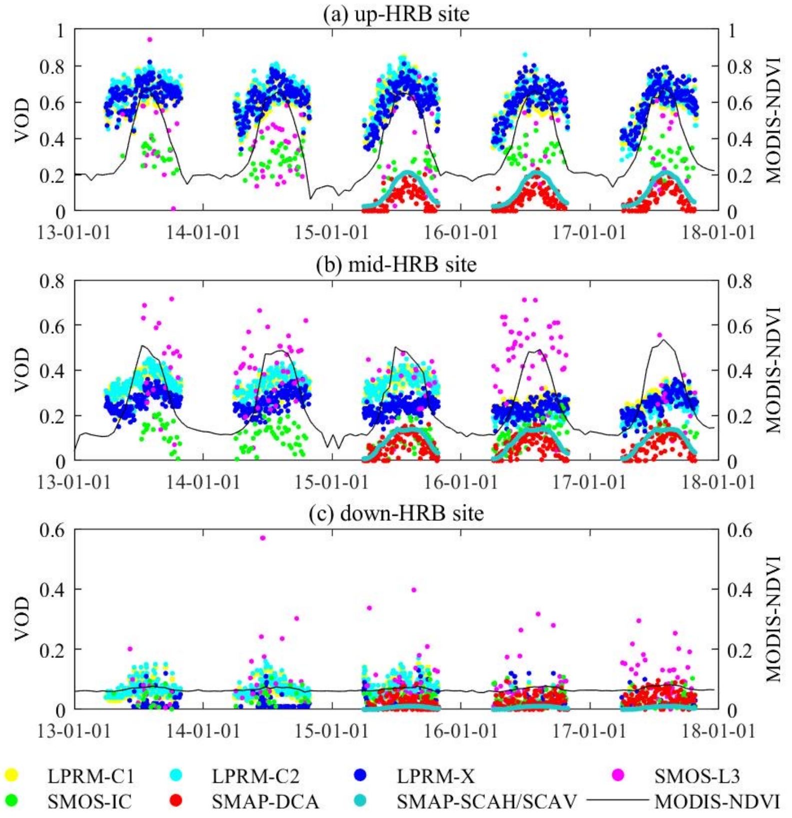
- AMSR2 Land Parameter Retrieval Algorithm (LPRM) SM products show **extremely large overestimation** over the vegetated regions in HRB, especially the C-band products.

EVALUATION OF SMAP, SMOS AND AMSR2 SOIL MOISTURE PRODUCTS BASED ON DISTRIBUTED GROUND OBSERVATION NETWORK IN COLD AND ARID REGIONS OF CHINA

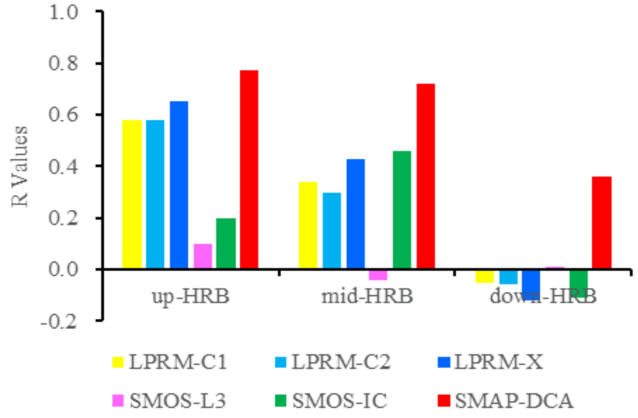
- **Parameter uncertainty analyses indicate that the different parameterization schemes of vegetation optical depth (VOD) inputs could be one of the main reasons resulting in the systematic overestimation / underestimation in the AMSR2/SMOS/SMAP SM retrievals.**

- The extremely high VOD retrievals in LPRM products over the dense vegetated regions in HRB could be one reason resulting in the large overestimation in the soil moisture retrievals.

- The obviously larger underestimation biases of VOD inputs in SMAP-SCAH/SCAV SM products indicate the possible error resources in their parameterization scheme.



Time series (2013-2017) of daily AM-orbit VOD retrievals in SMOS, SMAP and AMSR2 LPRM products with the MODIS NDVI observations for the three validation sites in HRB.



R values between the time series (2013-2017) of AM-orbit VOD retrievals and MODIS NDVI for the three validation sites in HRB.

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2023 Dragon 5 Symposium

"龙计划"五期 2023 年度国际学术研讨会

11–15 September 2023

Hohhot, Inner Mongolia, China

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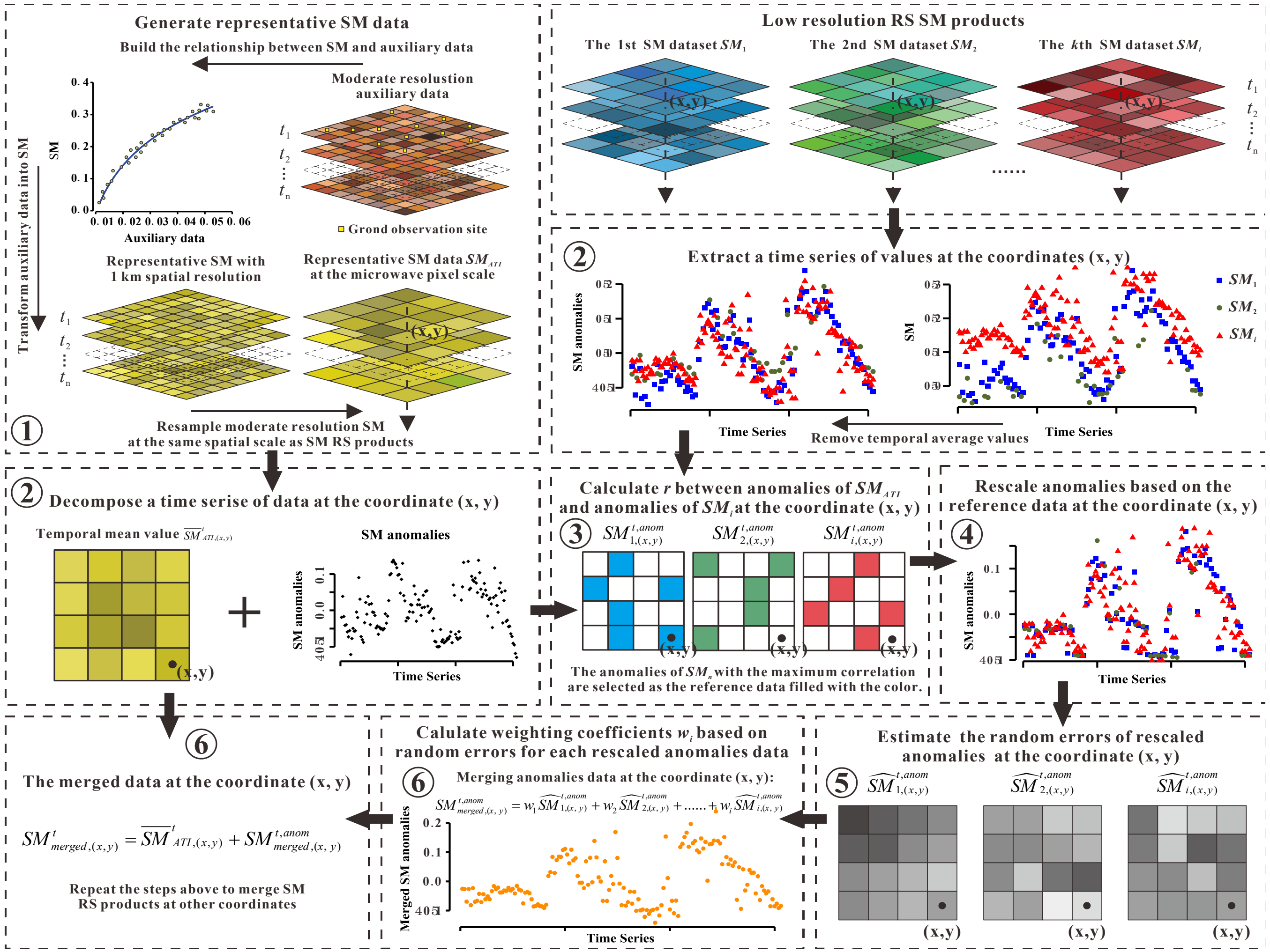
MERGING MULTI-SOURCE SOIL MOISTURE DATA BASED ON ERROR DECOMPOSITION

Steps

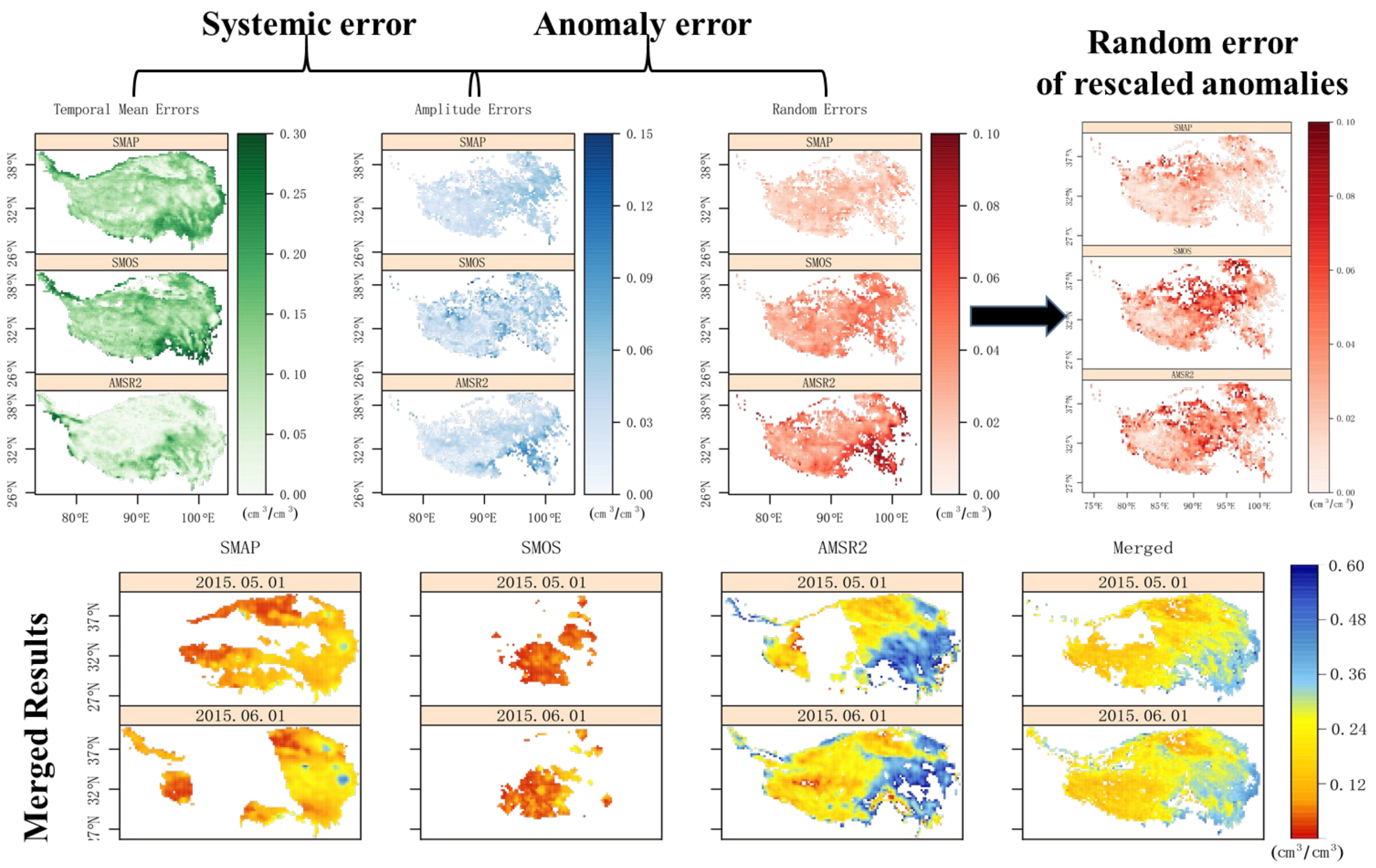
- Obtaining the reference data by transforming the apparent thermal inertia (ATI) into soil moisture (SM).
- Calibrating systemic error of the input data including the temporal mean bias and the amplitude bias
- Merging the rescaled anomalies based on random errors
- Add the merged anomaly on the temporal mean of the reference data to obtain final merging results

Procedure of merging Remotely Sensed SM products



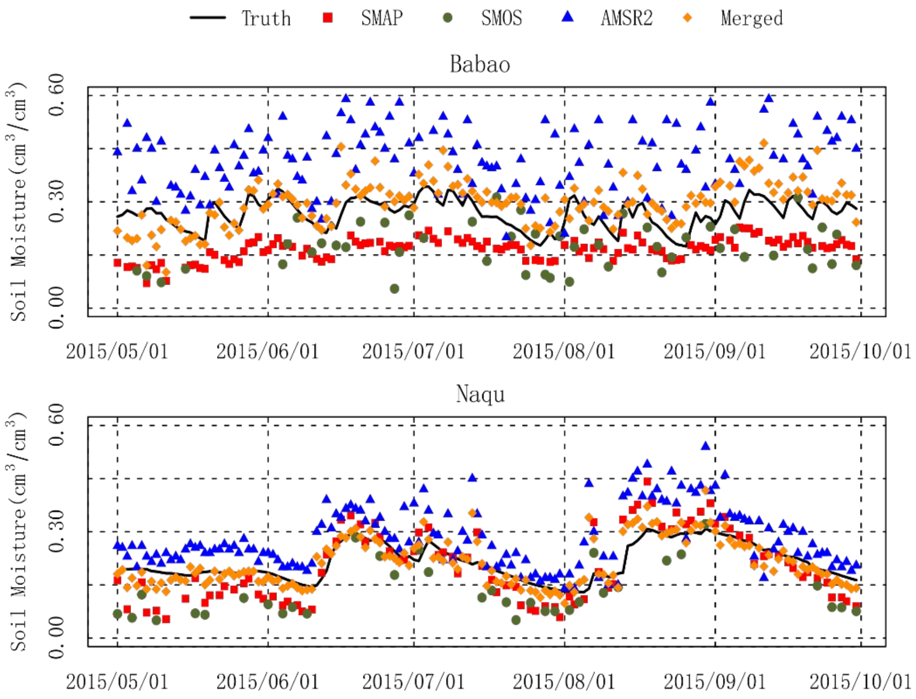
MERGING MULTI-SOURCE SOIL MOISTURE DATA BASED ON ERROR DECOMPOSITION

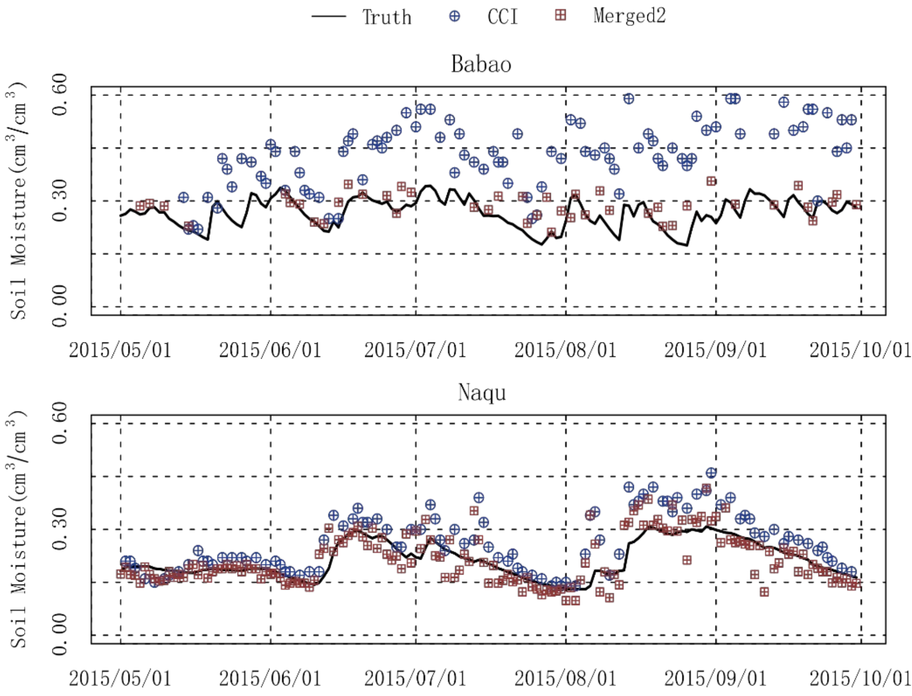
- None of the three products have consistently superior accuracy.
- The traditional arithmetic mean method is not the best due to unequal random errors.
- The random error vary when the amplitude is corrected.
- The composition dataset is the most complete relative to the input datasets



MERGING MULTI-SOURCE SOIL MOISTURE DATA BASED ON ERROR DECOMPOSITION

- The merged results have the highest temporal match with the validation data in the validation regions.
- The scheme for data fusion can maintain the optimal temporal accuracies of input datasets for the merged results.





Merged: merging SMAP, SMOS and AMSR2
Merged2: merging SMOS and AMSR2 for comparing with the CCI SM

MERGING MULTI-SOURCE SOIL MOISTURE DATA BASED ON ERROR DECOMPOSITION

- A great improvement in the total accuracy of the merged results, in which the RMSE values of the merged results are lower than those of any input dataset.

Region	Babao		Naqu	
Index	RMSE	R	RMSE	R
SMAP	0.106	0.616	0.059	0.881
SMOS	0.110	0.179	0.080	0.817
AMSR2	0.172	0.429	0.087	0.768
Merged	**0.052**	**0.604**	**0.029**	**0.885**
Merged2	**0.047**	**0.509**	**0.029**	**0.916**
ESA CCI	0.185	0.482	0.066	0.860

Merged: merging SMAP, SMOS and AMSR2
Merged2: merging SMOS and AMSR2 for comparing with the ESA CCI SM

Thanks &Discussion