

40 Years Global Snow Cover Fraction Based on AVHRR Data - First Analysis and Results within ESA CCI+ Snow Project



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- ESA CCI+ snow UniBern project aim:
 - Generating a consistent time series of snow cover fraction (viewable and on ground) of the last 40 years based on AVHRR data
- Phase 1: V2.0 (1981 – 2018)
- Phase 2: V3.0
 - Based on CLARA A3 (beta release); CMSAF; AVHRR GAC data incl. probability cloud mask
 - 1981 – 2023
 - Adapted transmissivity (temporal and spatial). **Implementing**



AVHRR Snow Cover Fraction (Global)

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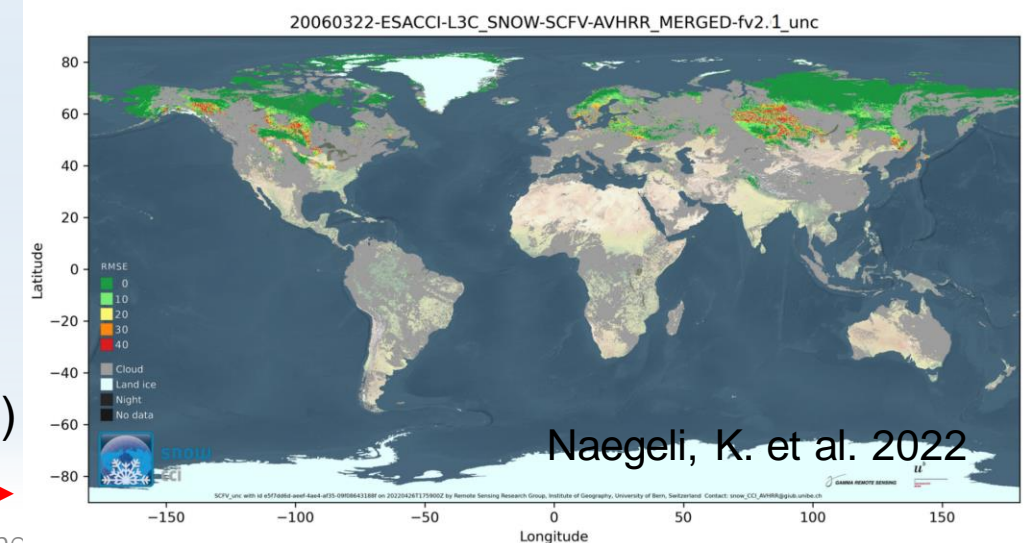
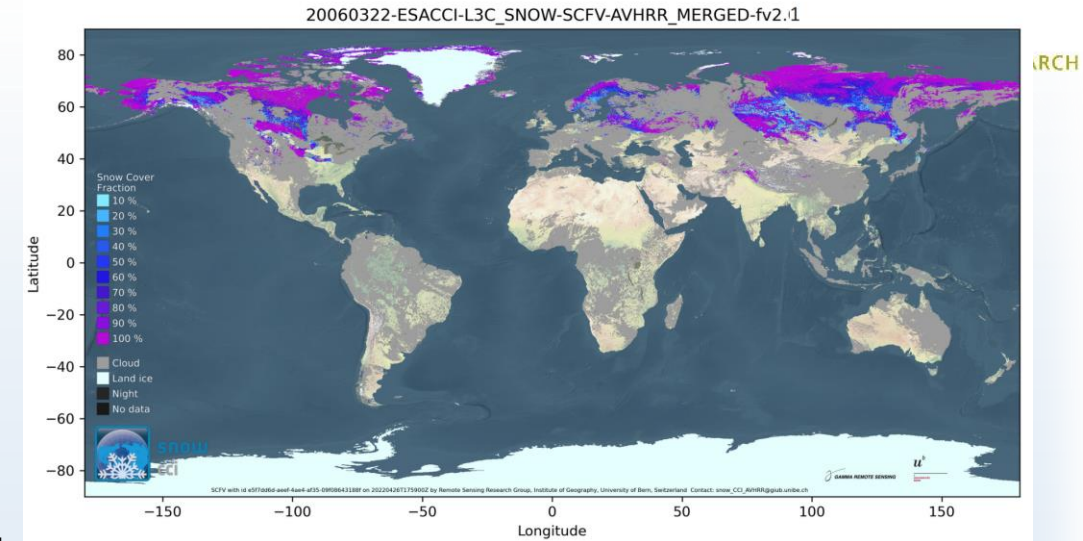
■ Procedure:

- Testing V2.0 processor with new calibrated AVHRR data set and new cloud data → **Internally V2.1 data set**
- Comparing V2.0 with V2.1 and adapt processor accordingly
- Validation of snow cover products by EURAC Team

■ Seven test regions (+ Arctic > 66° N) for comparison and first analysis:

- Selection of single periods and satellites
- Cloud cover
- Snow cover fraction
- 40 years monthly snow cover area anomaly (1980-2020)

Right: SCFV and uncertainty (20060322) based on AVHRR GAC



Naegeli, K. et al. 2022

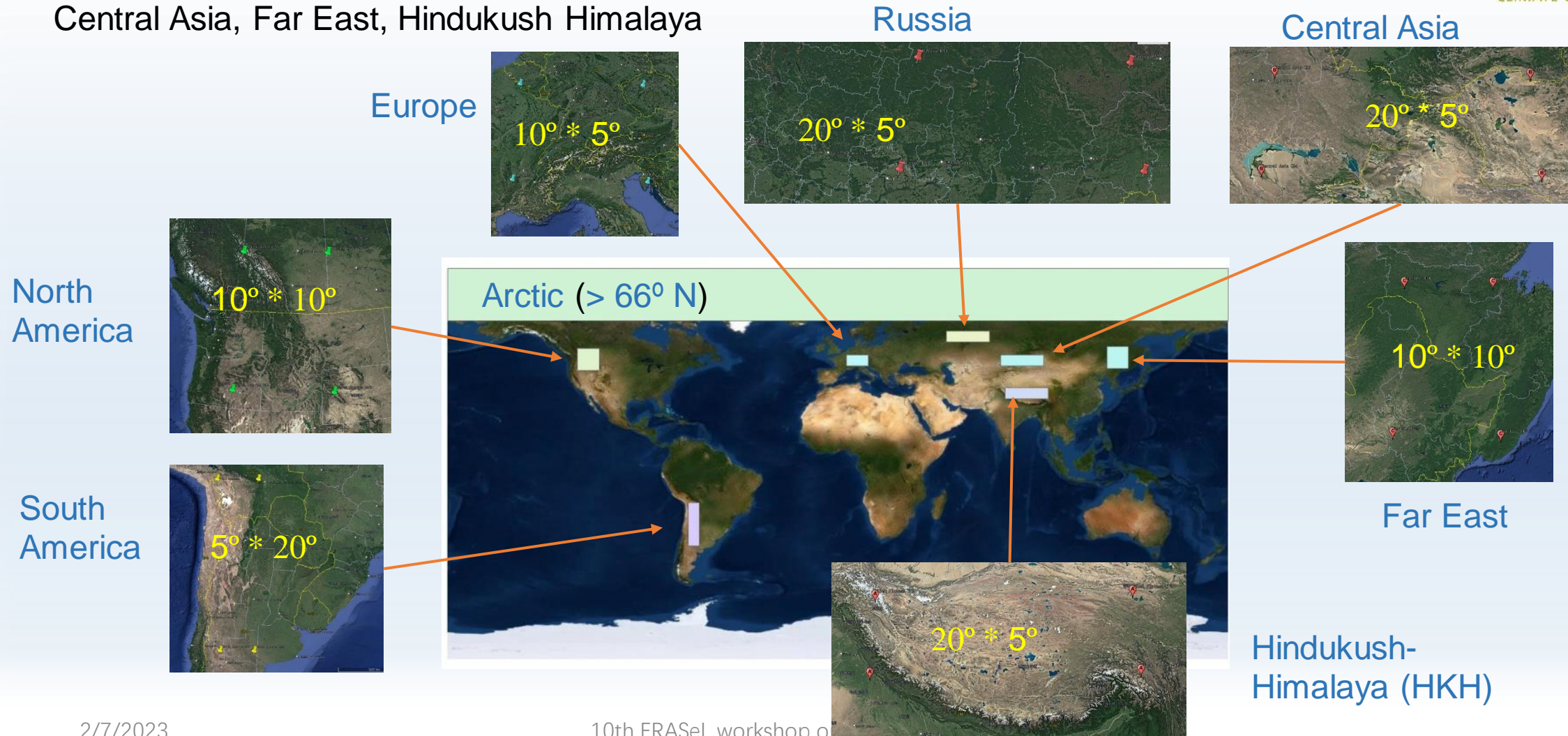
SCF products comparison preparation

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- 1. Selecting 8 study areas: Arctic ($> 66^\circ \text{N}$), North America, South America, Europe, Russia, Central Asia, Far East, Hindukush Himalaya

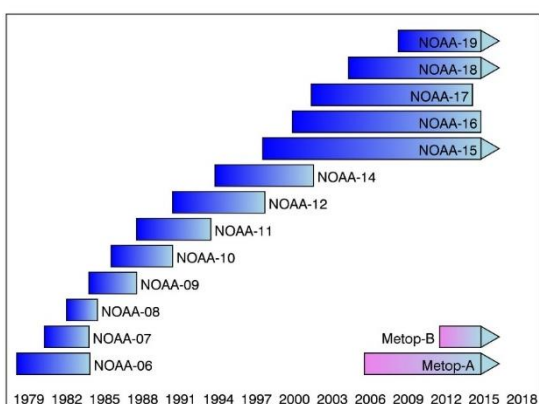


SCF products comparison preparation

- 2. 6 study periods & Sensors

Sensors	Periods
NOAA-07	1982.1 – 1984.12
NOAA-11	1991.1 – 1993.12
NOAA-14	1997.1 – 1999.12
NOAA-16	2002.1 – 2004.12
NOAA-18	2006.1 – 2008.12
NOAA-19	2015.1 – 2017.12

- 3. Comparison experiments

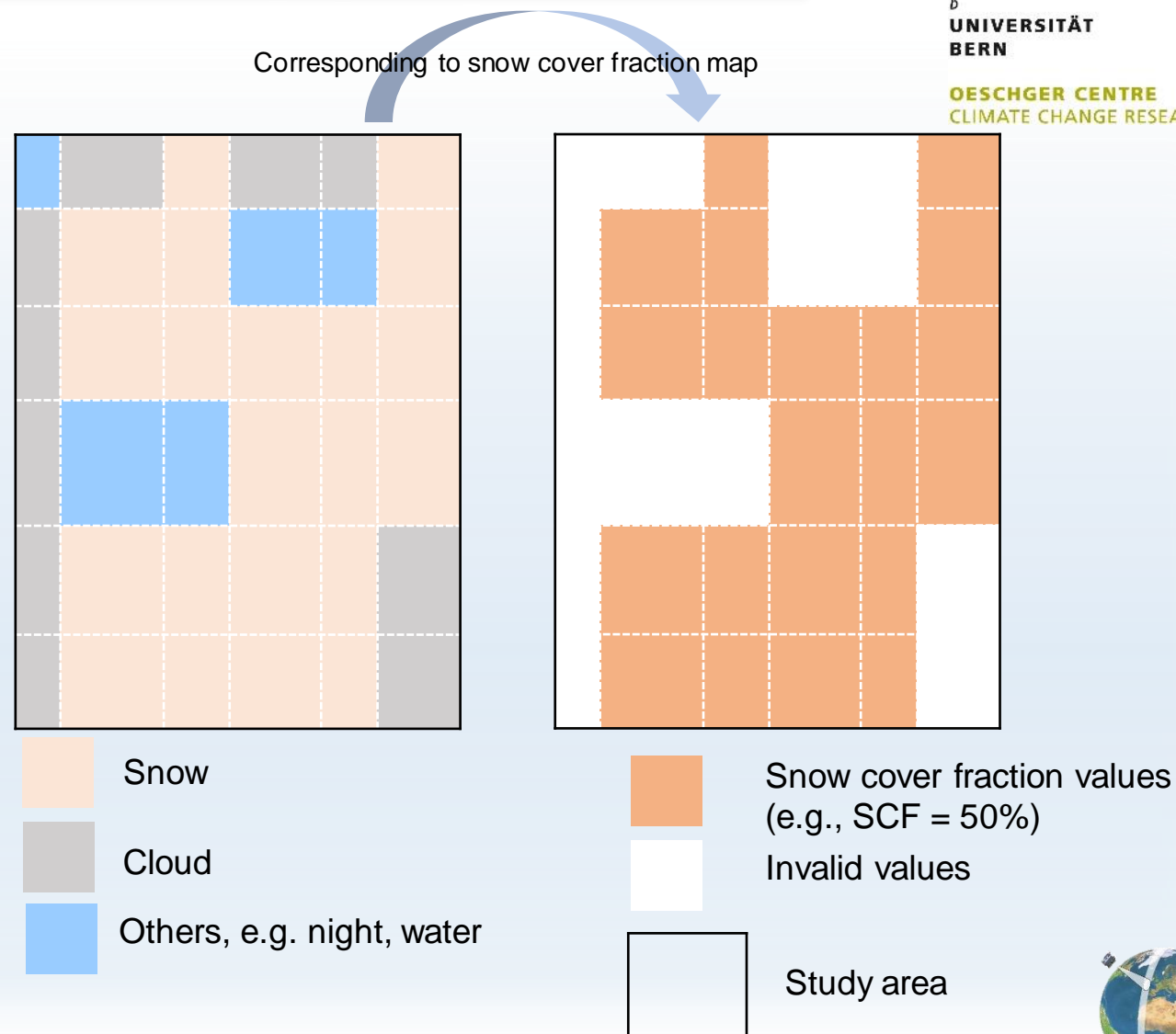
Comparision-1		Comparision-2 (Not shown here)	
V2.0	V2.1	V2.1-Single	V2.1-Merged
NOAA-07	NOAA-07	NOAA-07	
NOAA-11	NOAA-11	NOAA-11	
NOAA-14	NOAA-14	NOAA-14	
NOAA-16	NOAA-16	NOAA-16	
NOAA-18	NOAA-18	NOAA-18	
NOAA-19	NOAA-19	NOAA-19	
NOAA-19	NOAA-19	NOAA-19	

Note: snow cover area for V2.1-merged is an average of the snow cover fraction values derived from multiple sensors on a given day



SCF products comparison preparation

- 4. Definition of the analysis metrics
 - 1) **Cloud percent**: the cloud cover percentage in the given study region (=205)
 - 2) **Snow percent**: the snow cover percentage in the given study region ($20 \leq \text{SCF} \leq 100$)
 - 3) **Snow cover area**: It is equal to the sum of the pixel area multiplied by **the corresponding snow cover fraction**.
- E.g. Cloud percent = $10/36 \cdot 100\% = 27.8\%$
Snow percent = $21/36 \cdot 100\% = 58.3\%$



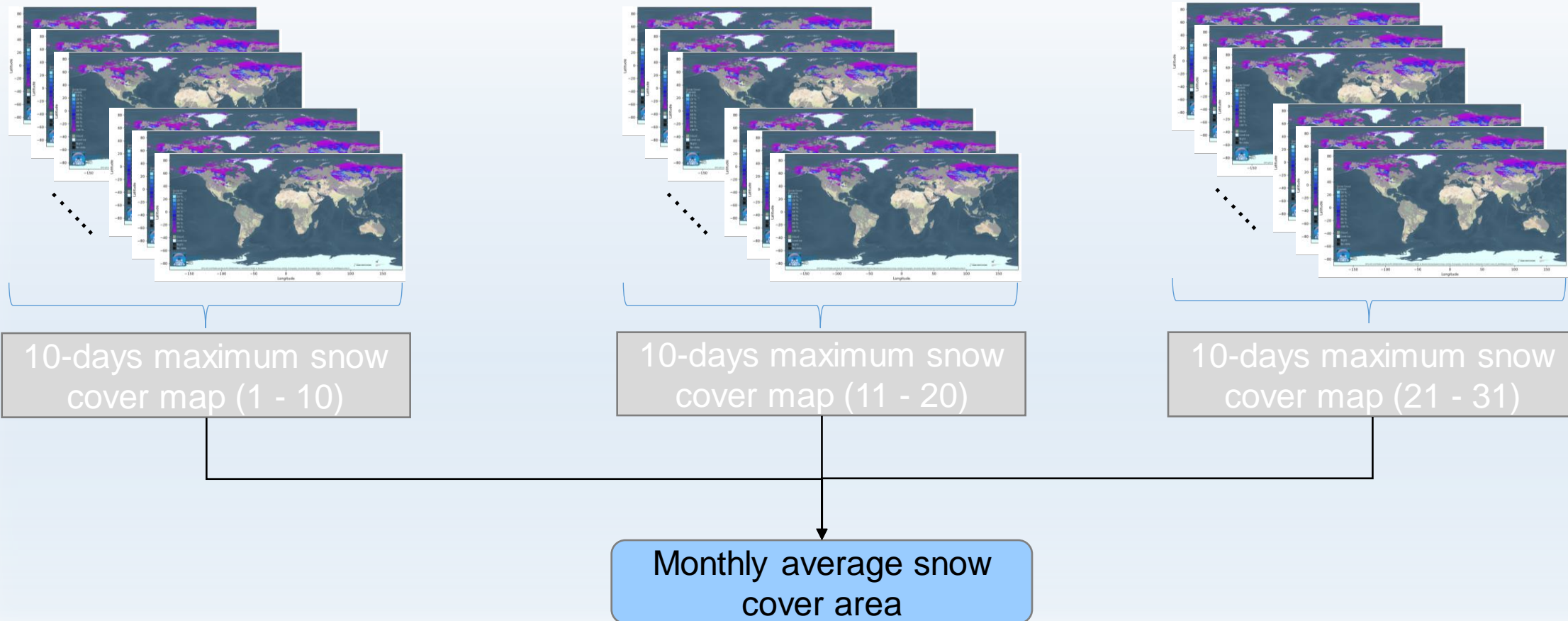
Monthly snow cover anomaly (1980 – 2020)

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- 5. To avoid the effects of polar night, only the period from Feb. to Oct. was used to analyze snow cover area anomaly during 1980 – 2020.



Comparison results SCFV (V2.0 vs. V2.1)

- 6. The statistic in this table is the annual average for 18-years. The area of one grid is about 25 km² (~5 * 5 km).

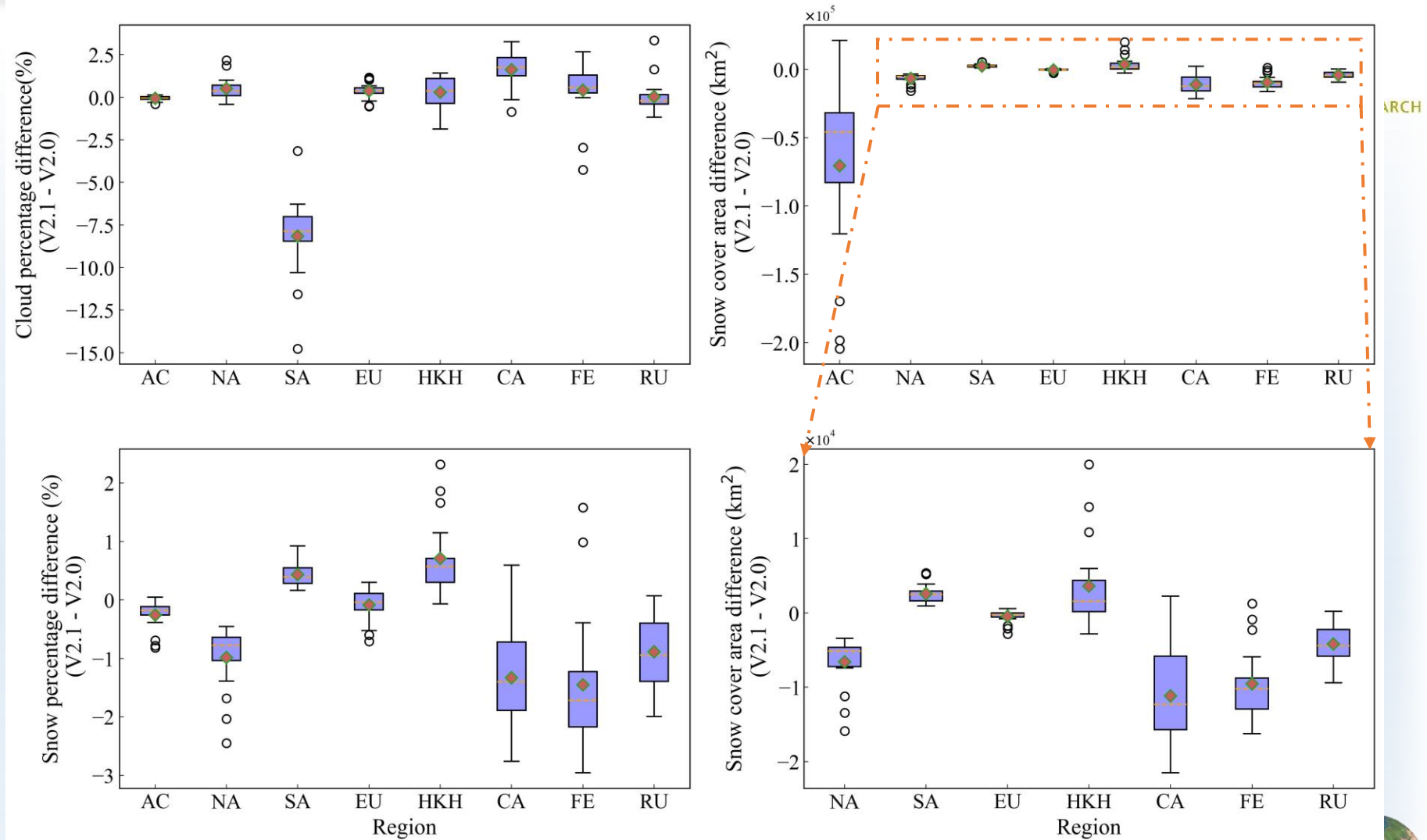
SCFV	Arctic	North America	South America	Europe	HKH	Central Asia	Far East	Russia
Cloud percent v2.0	8.5%	55.8%	42.8%	56.4%	56.7%	42.7%	44.9%	58.8%
Cloud percent v2.1	8.4% (-0.1%)	56.4% (+0.6%)	35.5% (-7.3%)	57.1% (+0.7%)	57.1% (+0.4%)	44.5% (+1.8%)	45.6% (+0.7%)	58.9% (+0.1%)
Snow percent v2.0 (SCF ≥ 20%)	5.3%	8.2%	0.2%	4.7%	4.9%	18.6%	21.0%	13.1%
Snow percent v2.1 (SCF ≥ 20%)	5.1% (-0.2%)	7.2% (-1.0%)	0.6% (+0.4%)	4.6% (-0.1%)	5.6% (+1.0%)	17.2% (-1.4%)	19.5% (-1.5%)	12.2% (0.9%)
Snow cover area v2.0 (km ²) (SCF ≥ 0)	1,568,119	42,912	748	10,377	38,307	111,641	86,840	45,642
Snow cover area v2.1 (km ²) (SCF ≥ 0)	1,497,442	36,747	2,240	9,972	41,964	102,150	78,350	41,581



Comparison results SCFV (V2.0 vs. V2.1)

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- The difference between V2.0 and V2.1 for cloud cover, snow cover, and snow cover area in 8 study regions.



Note (Right): Arctic: AC
Hindukush-Himalaya: HKH

North America: NA
Central Asia: CA

South America: SA
Far East: FE

Europe: EU
Russia: RU

Validation of SCF products (1980 – 2020)

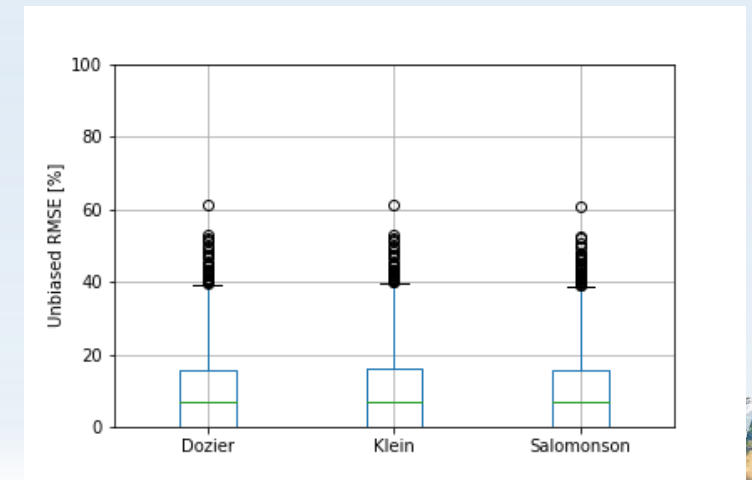
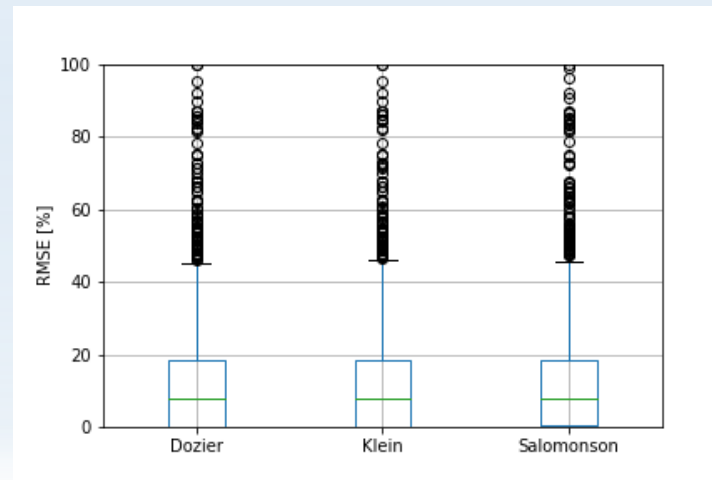
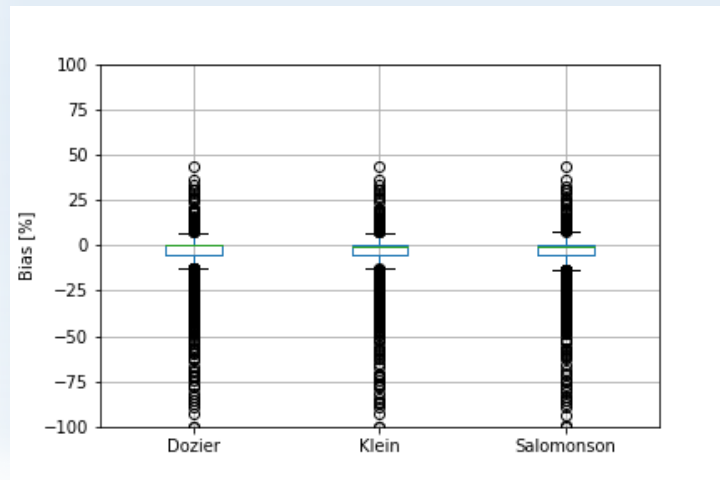
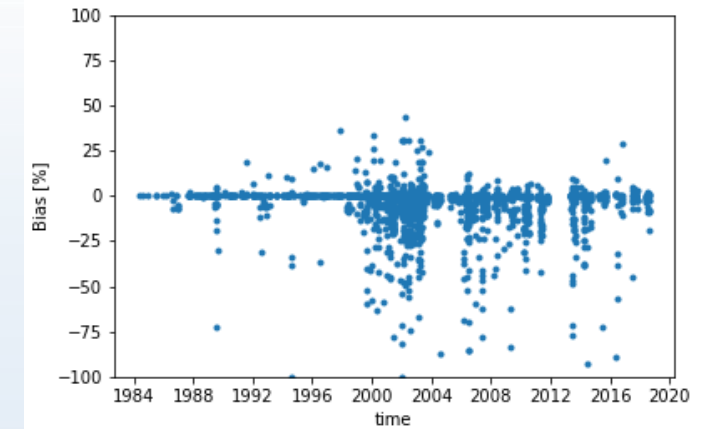
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- Landsat images were used as the reference observations; The validation was conducted in global area and the open areas (SCFG/SCFV).

	Salomonson	Klein	Dozier
RMSE	14.262	14.315	14.241
Unbiased RMSE	14.053	14.101	14.034
BIAS	-2.436	-2.466	-2.420
Correlation Coefficient	0.943	0.944	0.944



Arctic snow cover area (1980 – 2020)

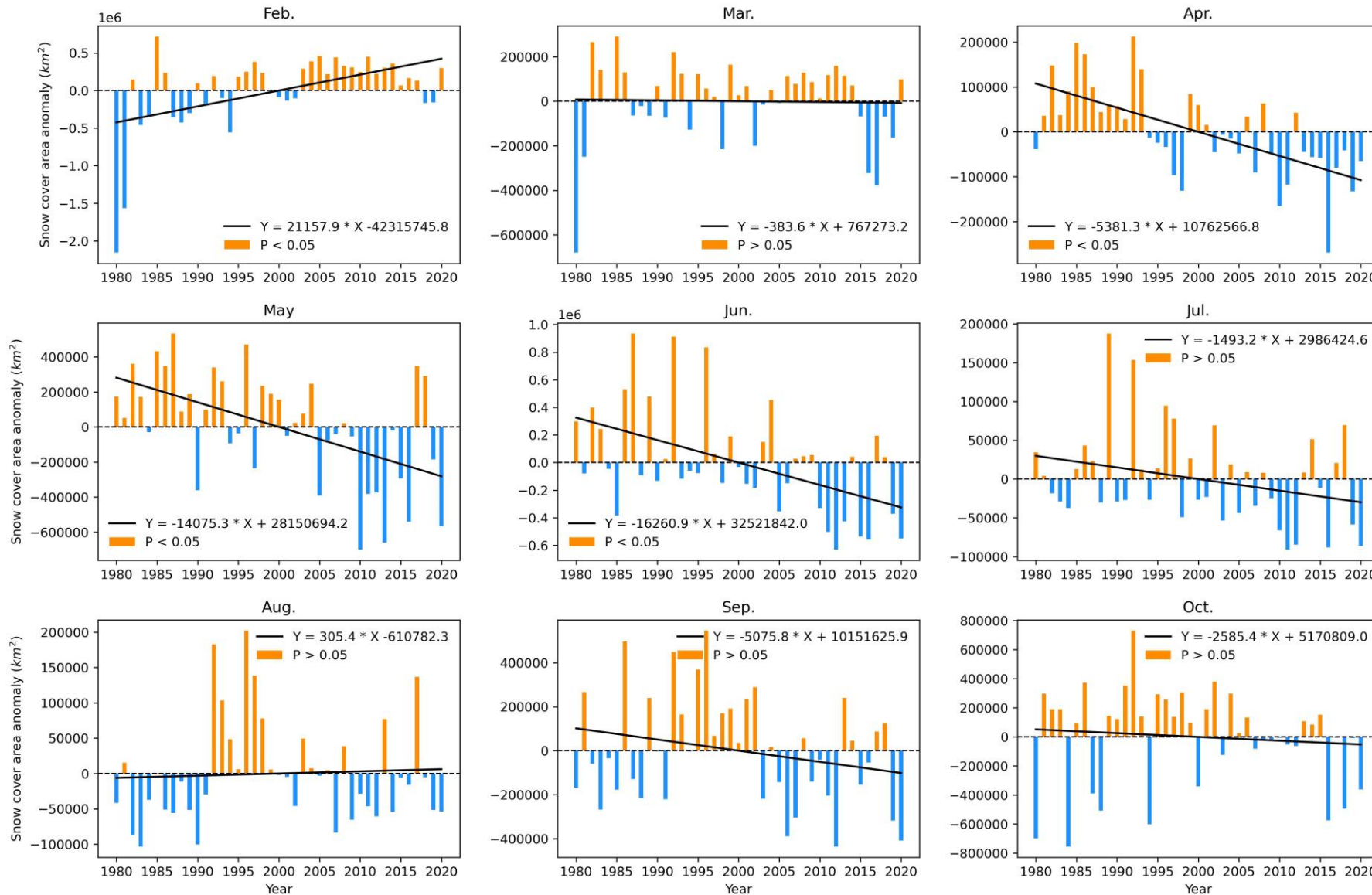
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- In February, snow cover area significantly increase at a rate of more than 21,000 km²/yr.
- For other months, there is the decrease trends in Arctic



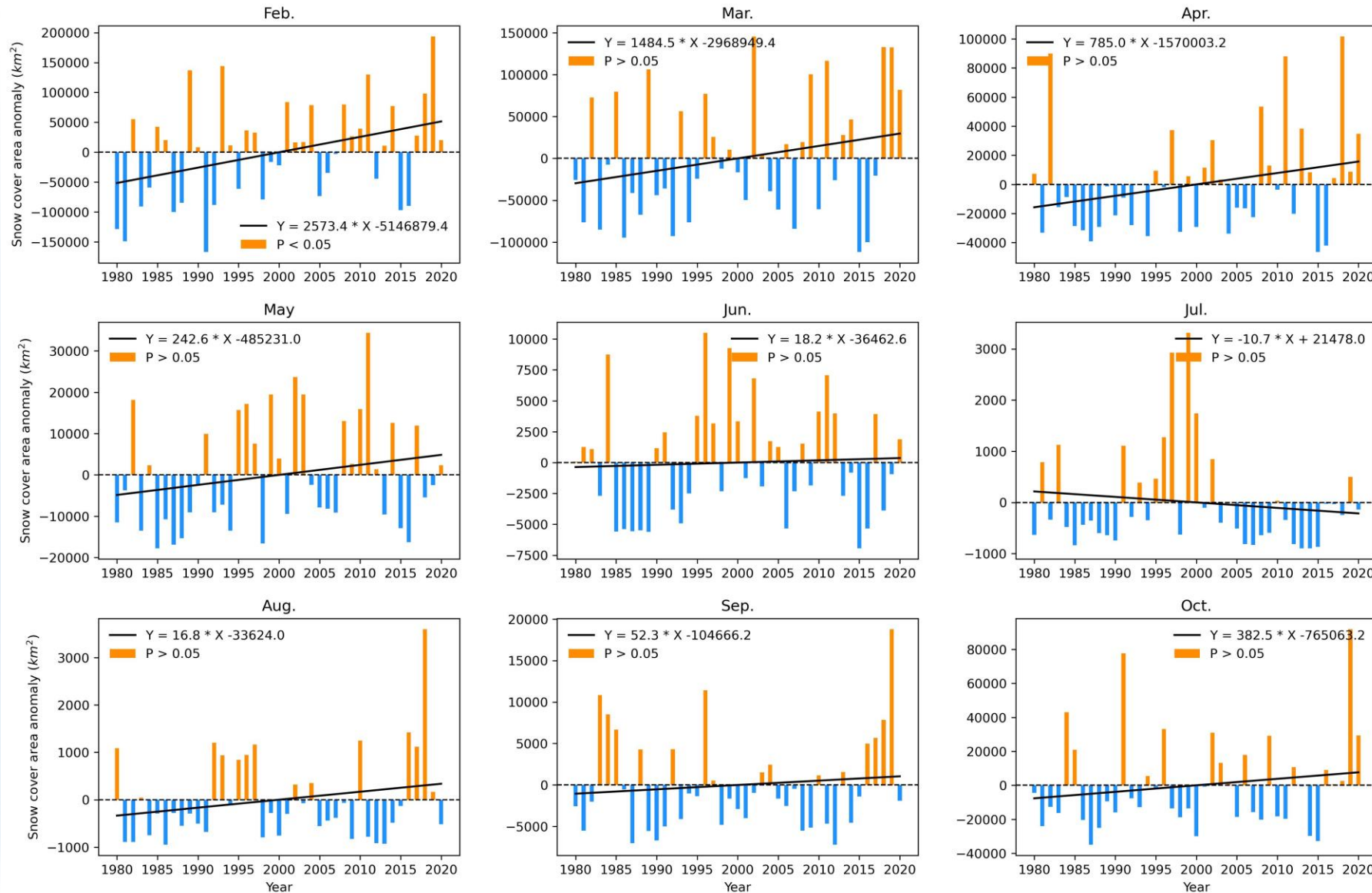
North America snow cover area (1980 – 2020) u^b

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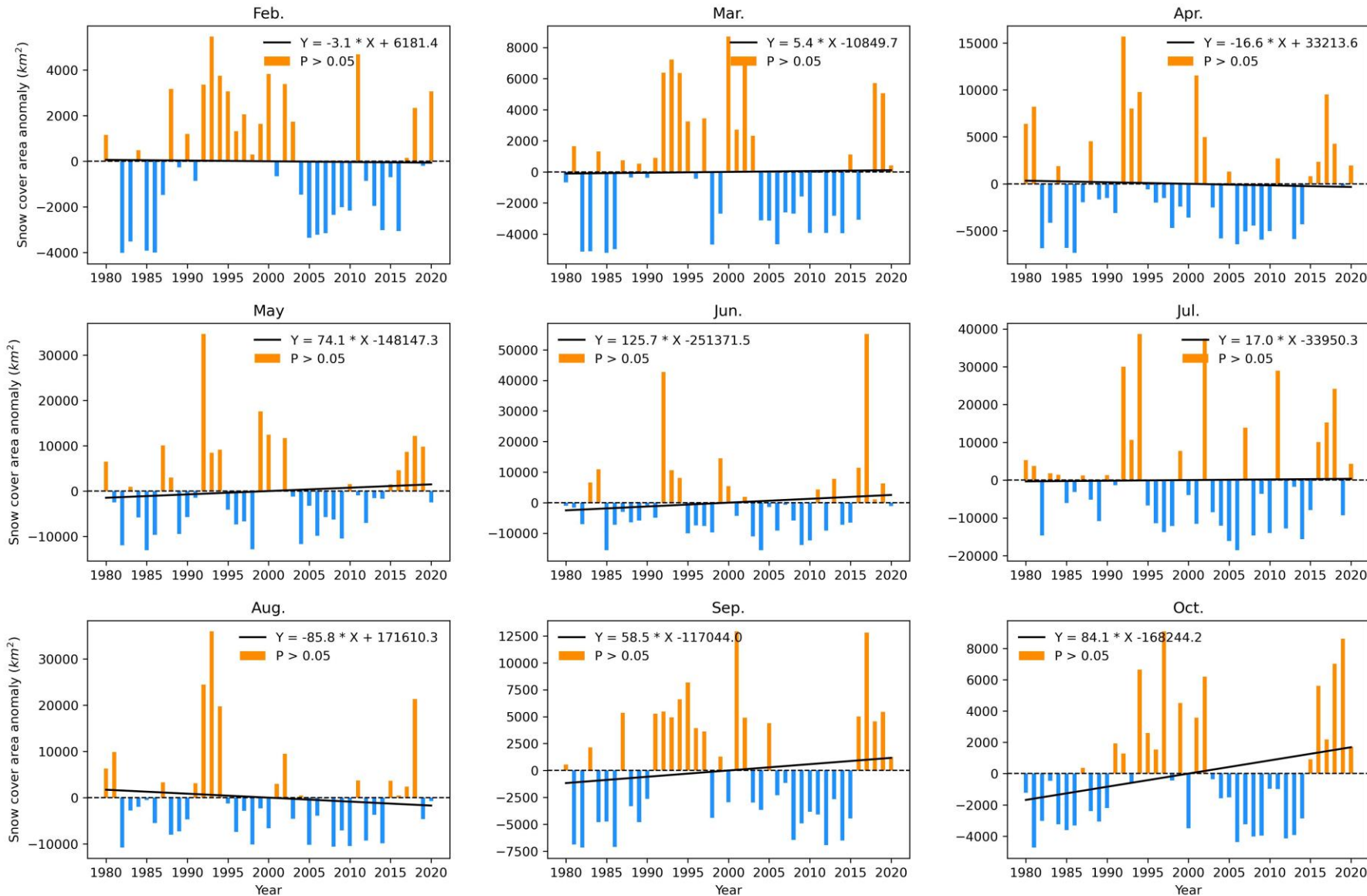
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- The monthly snow cover area shows the increase trends in most of months from Feb. to Oct.



South America snow cover area (1980 – 2020) u^b



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- In South America, the monthly snow cover area does not have significant variation trends.
- But six of nine months show the slight increase, including March, May, June, July, September, and October



Europe snow cover area (1980 – 2020)

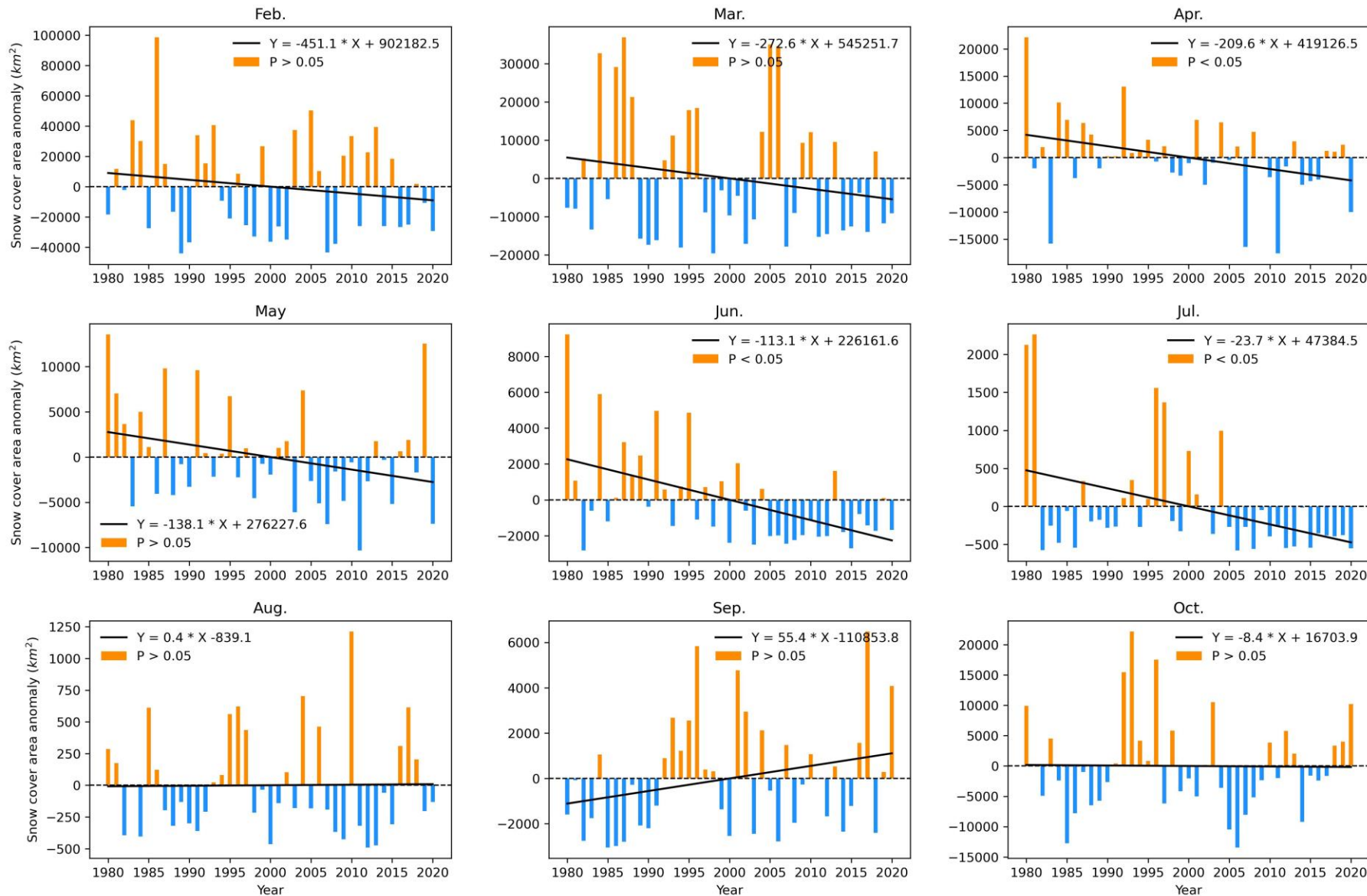
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- The snow cover area in Europe region shows the decrease trends in snow cover season (from Oct. to May)



Hindukush Himalaya (HKH) snow cover area

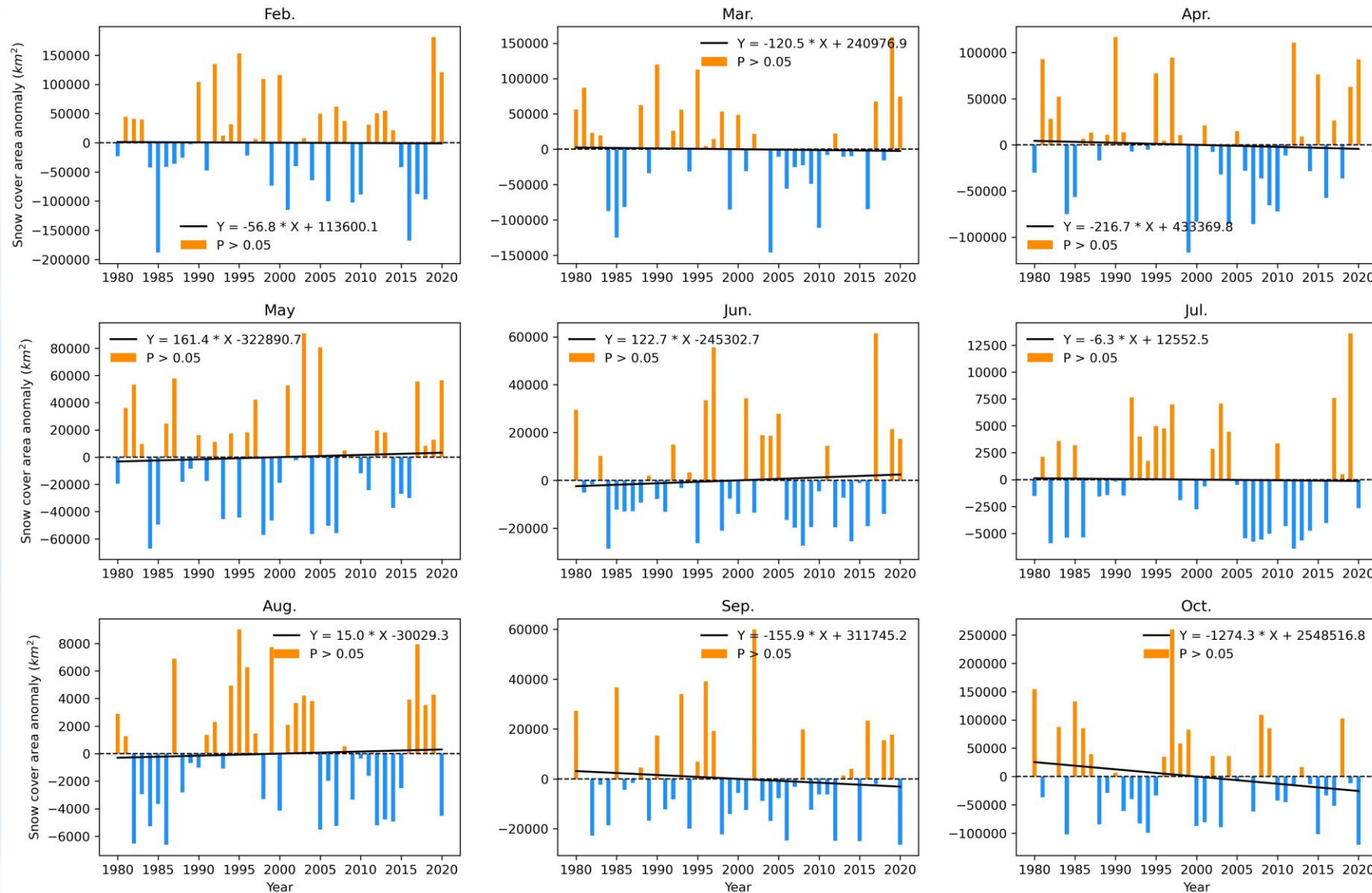
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- The snow cover area does not have very high decrease speed in HKH region.
- The variation trend is non-significant in all nine months.



Russia snow cover area (1980 – 2020)

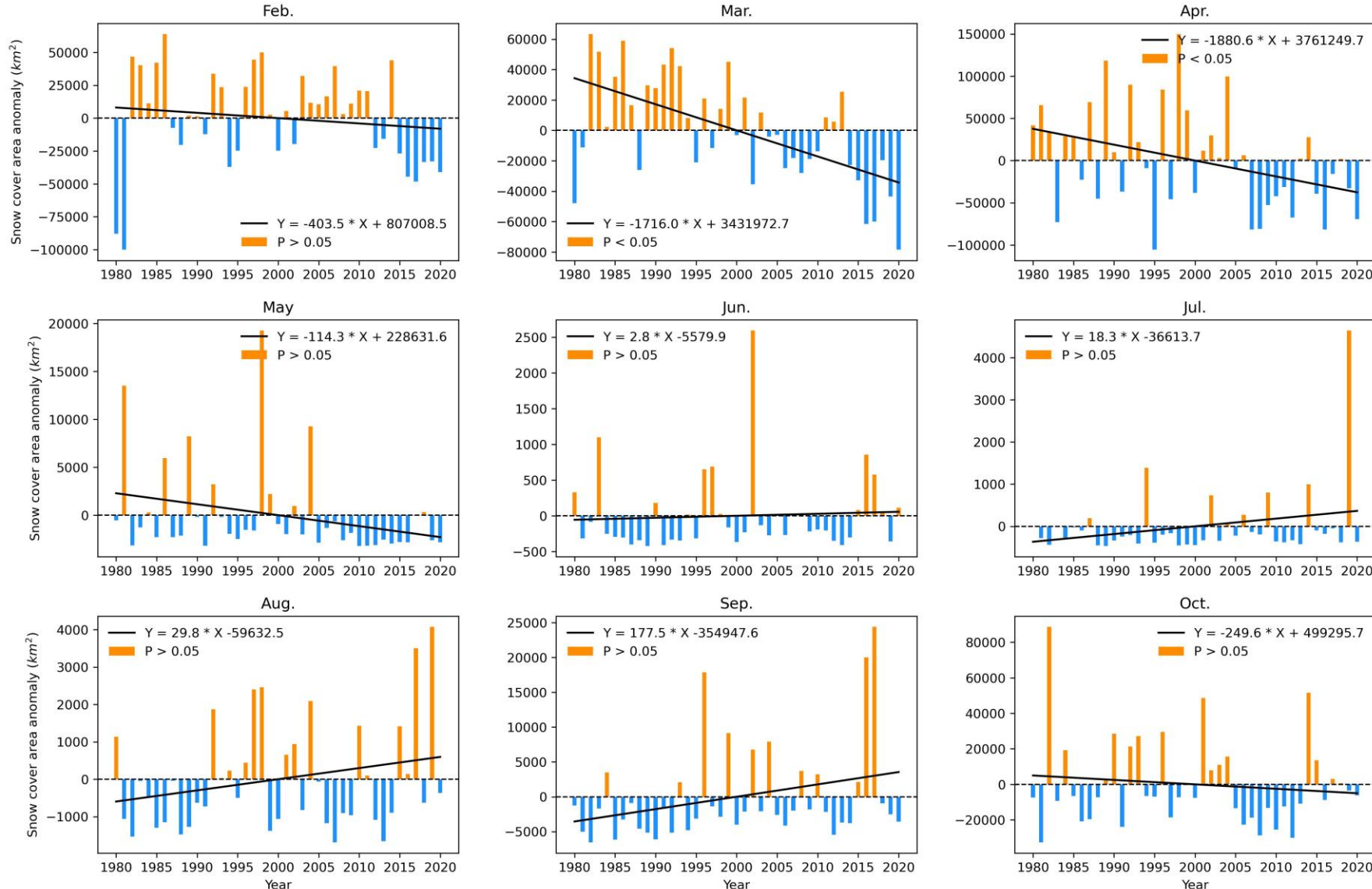
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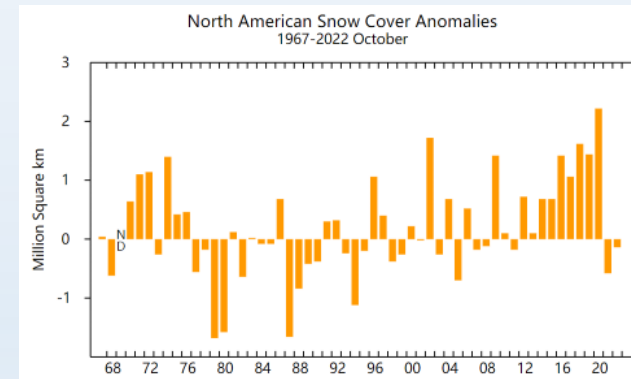
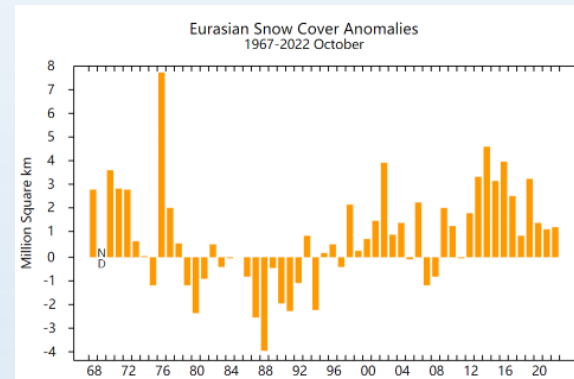
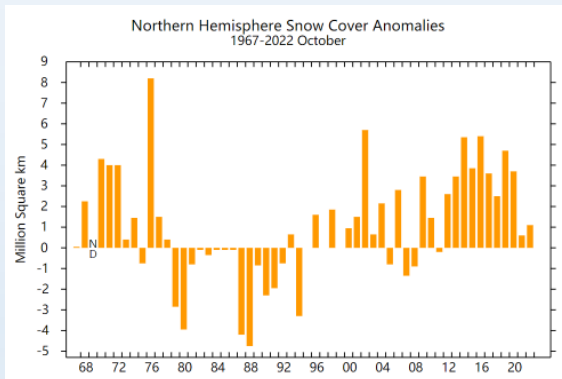
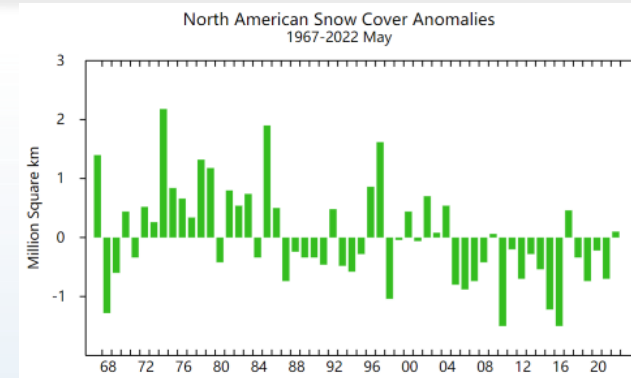
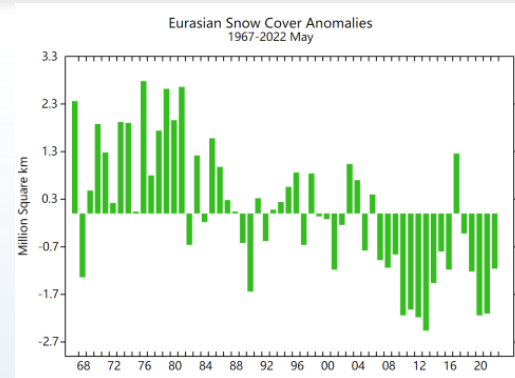
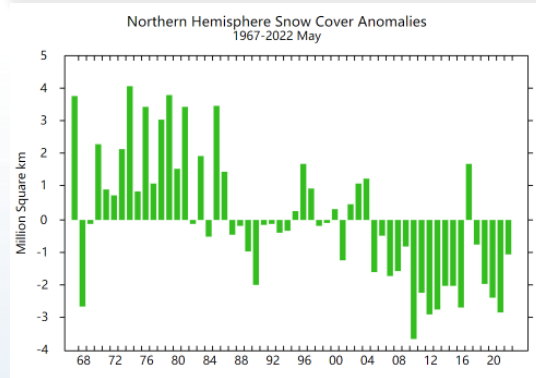
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- During the snow season (October, February, March, April and May), the snowpack area is decreasing at a relatively high rate ($> 100 \text{ km}^2/\text{yr.}$).



Discussion: Simple comparison with Rutgers snow cover products



Source from Rutgers University
(<https://climate.rutgers.edu/snowcover/>)

- For both snow cover data, the time of the significant changes all seem to start **around the year 2000**.
- Different variation trends for NH and the local regions:

May, the **decrease** for NH, EU, NA, but the **increase** was occurred in **North America, South America, Hindukush Himalaya**.

October, the **increase** for NH, EU, NA, but there are the **decrease** trends in **Russia, Hindukush Himalaya, Arctic, and Europe**.



Next plan for ESA CCI Snow products

- Validation with ground-based snow depth observations for ESA CCI+ Snow products
- Comparison with MODIS product from ESA CCI+ snow (ENVEO) to proof consistency
- Further comparison with global data sets (e.g. ERA5).
- Development of adaptive transmissivity based on surface vegetation cover.
- Producing V3.0 ESA CCI+ snow cover fraction products





Thanks for your listening!

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