Changing Snow Cover Seasonality Can Affect Land Surface Phenology & Land Use

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SCERIN-6 CBW
Zagreb, HR 11-14 June 2018

Research supported in part by NASA project NNX15AP81G and the GSCE. Thanks!

Outline of Talk

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II. Data & Methods

III. Results: Changing Snow Seasonality Affecting Pastures in Kyrgyzstan

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I. Snow Cover and Snow Seasonality

Snow cover affects surface climate, including vegetation growth.

Changes in the timing of snow arrival and snowmelt and the duration of the snow season may also impact land use and land management.

Snow cover extent has been observed to be changing for more than three decades using both in-situ and remote sensing products.

Much of the change analysis has focused on broad scales—from hemispheric to subcontinental—at coarse spatial resolution, with a particular focus on the hydrological implications of reduced snow pack.

Here we focus on recent changes in snow seasonality at spatial resolutions from 500 m to 0.05° in two areas: Kyrgyzstan and most of SCERIN.

II. Data & Methods

We used the MODIS V006 snow cover products MOD10A2 and MOD10C2 that provide 8-day composites of snow cover at 500 m and 0.05°, respectively.

Our focal period for determining the snow season runs from (roughly) the summer solstice to the following summer solstice: DOY169 of Year to DOY 161 of Year+1.

We calculated five metrics from these data to characterize snow seasonality:

1) First Date of Snow (**FDoS**)
2) Last Date of Snow (**LDoS**)
3) Snow Covered Dates (**SCD**) 🡐 number of dates from FDoS to LDoS with snow
4) Duration of Snow Season (**DoSS**)
5) Ratio of SCD and DoSS (**SCD/DoSS**)

II. Data & Methods, continued

To evaluate significant changes in these snow season metrics, we used non-parametric techniques: Mann-Kendall trend test and Theil-Sen slope.

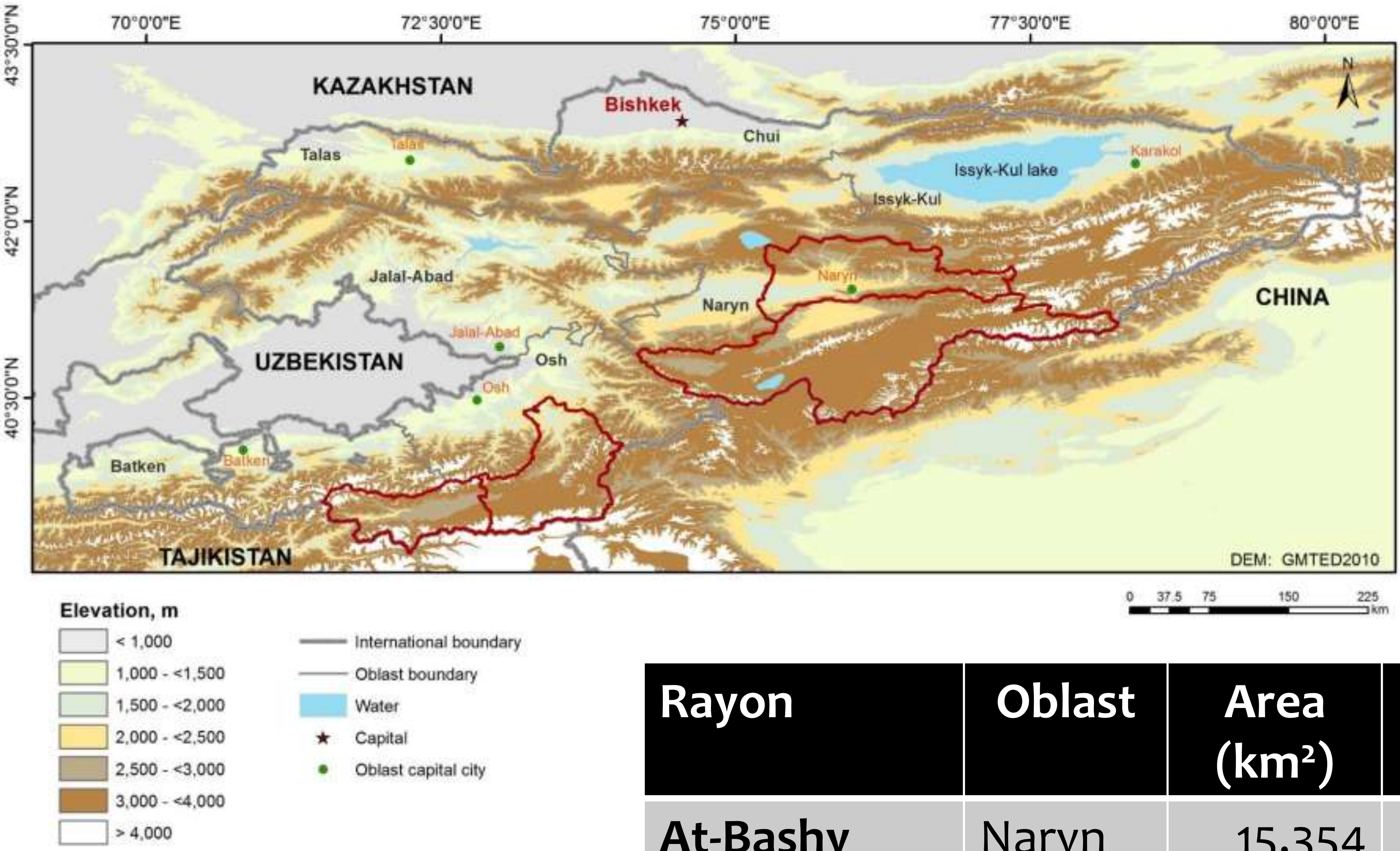
Our nominal threshold for significant change is $p<0.05$, but we add a further protection against Type I error (rejecting the null hypothesis when it is true) since we are necessarily making tests on many pixels.

To identify the ***areas of predominant change***, we report only significant trends at a study level (e.g., nation, subnational region, elevational range) when the area of the positive (or negative) significant trends was at least twice as large as the area of negative (or positive) significant trends.

Thus, we are seeking asymmetries in the distribution of significant trends as evidence that the apparent changes are not artifacts of random variation.

III. Results: Changing Snow Seasonality Affecting Pastures in Kyrgyzstan

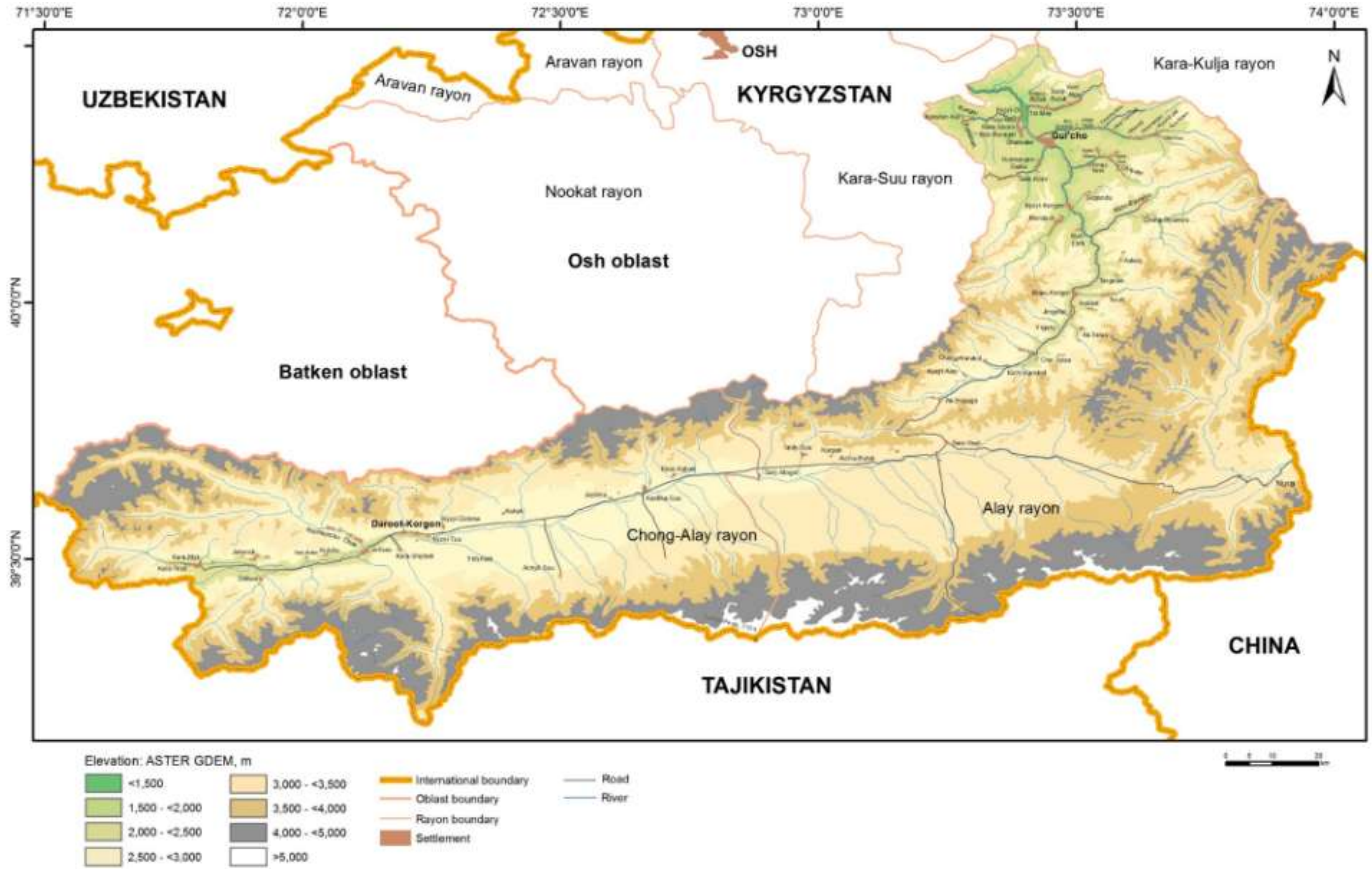
Changes in snow seasonality across Kyrgyzstan, in every oblast and in four focal rayons



Rayon	Oblast	Area (km²)	Population (n)	Density (n/km²)
At-Bashy	Naryn	15,354	~49,000	~3
Naryn	Naryn	4,055	~44,000	~4
Alay	Osh	6,821	~72,000	~11
Chong-Alay	Osh	4,857	~25,000	~5

Naryn and At-Bashy rayons in Naryn oblast in central Kyrgyzstan

Alay and Chong-Alay rayons in Osh oblast in southern Kyrgyzstan




Most of the annual precipitation in the Kyrgyz highlands falls outside of the growing season.
Snow cover, snow amount, and timing of snow onset and snow melt all affect soil moisture availability that supports early growth in pastures.
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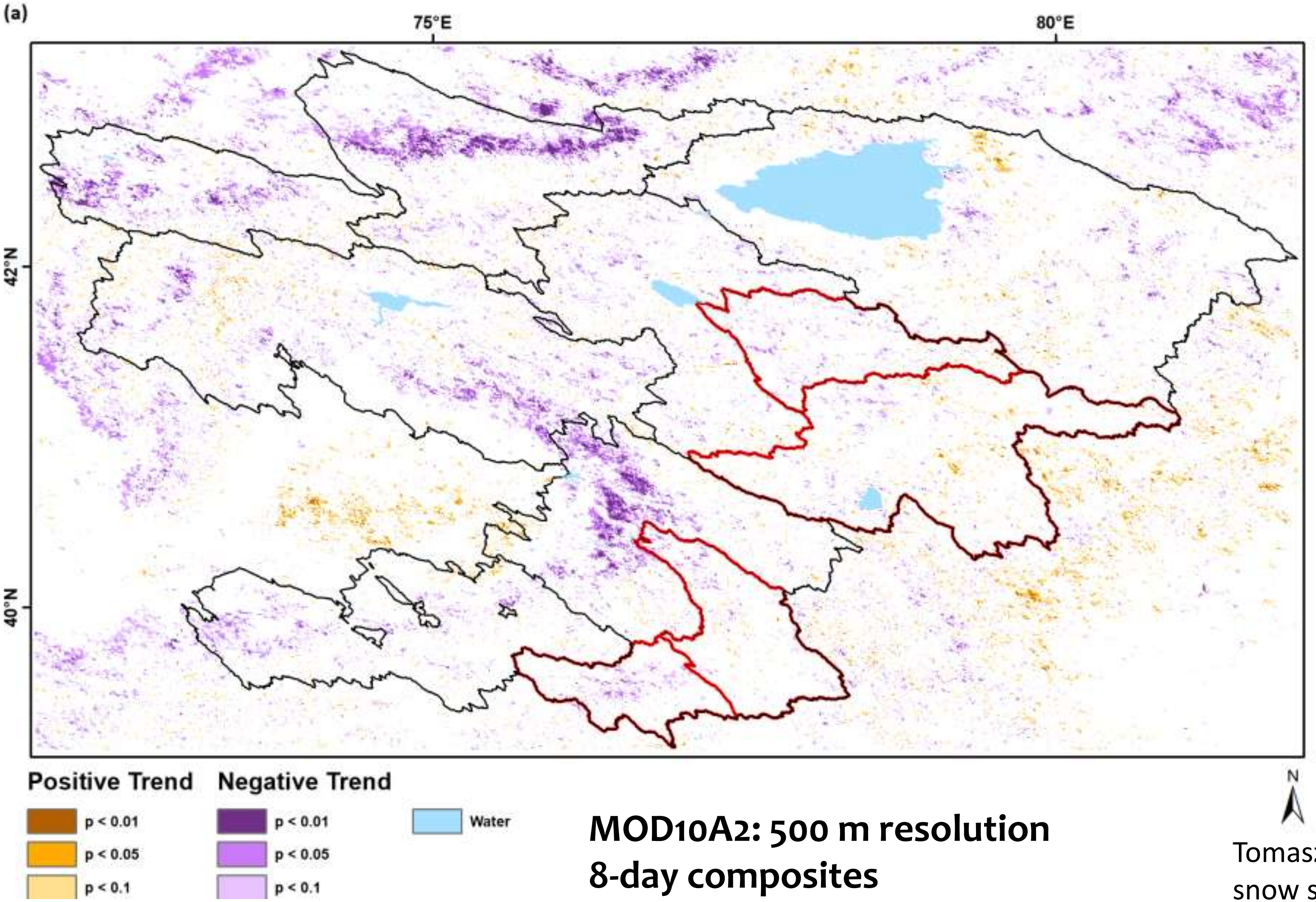
Significant Trends in the First Date of Snow across Kyrgyzstan



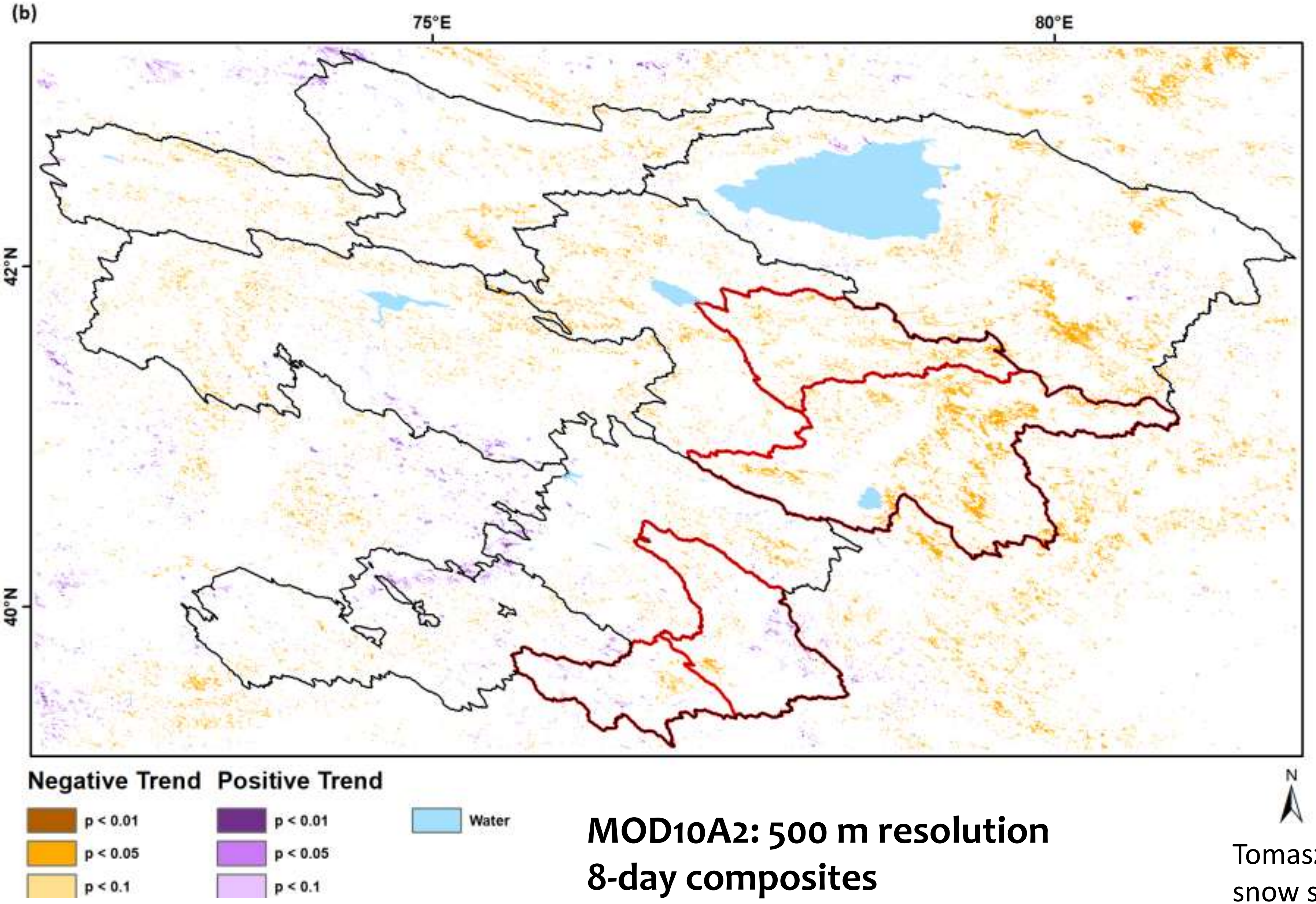
Significantly earlier snow onset, especially in Chuy and Osh oblasts

oblast	FDoS earlier (km^2)
Batken	526
Chuy	2,079
Issyk-Kul	--
Jalal-Abad	1534
Naryn	839
Osh	2,021
Talas	972
total	7,971

MOD10A2: 500 m resolution
8-day composites

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Significant Trends in the Last Date of Snow across Kyrgyzstan



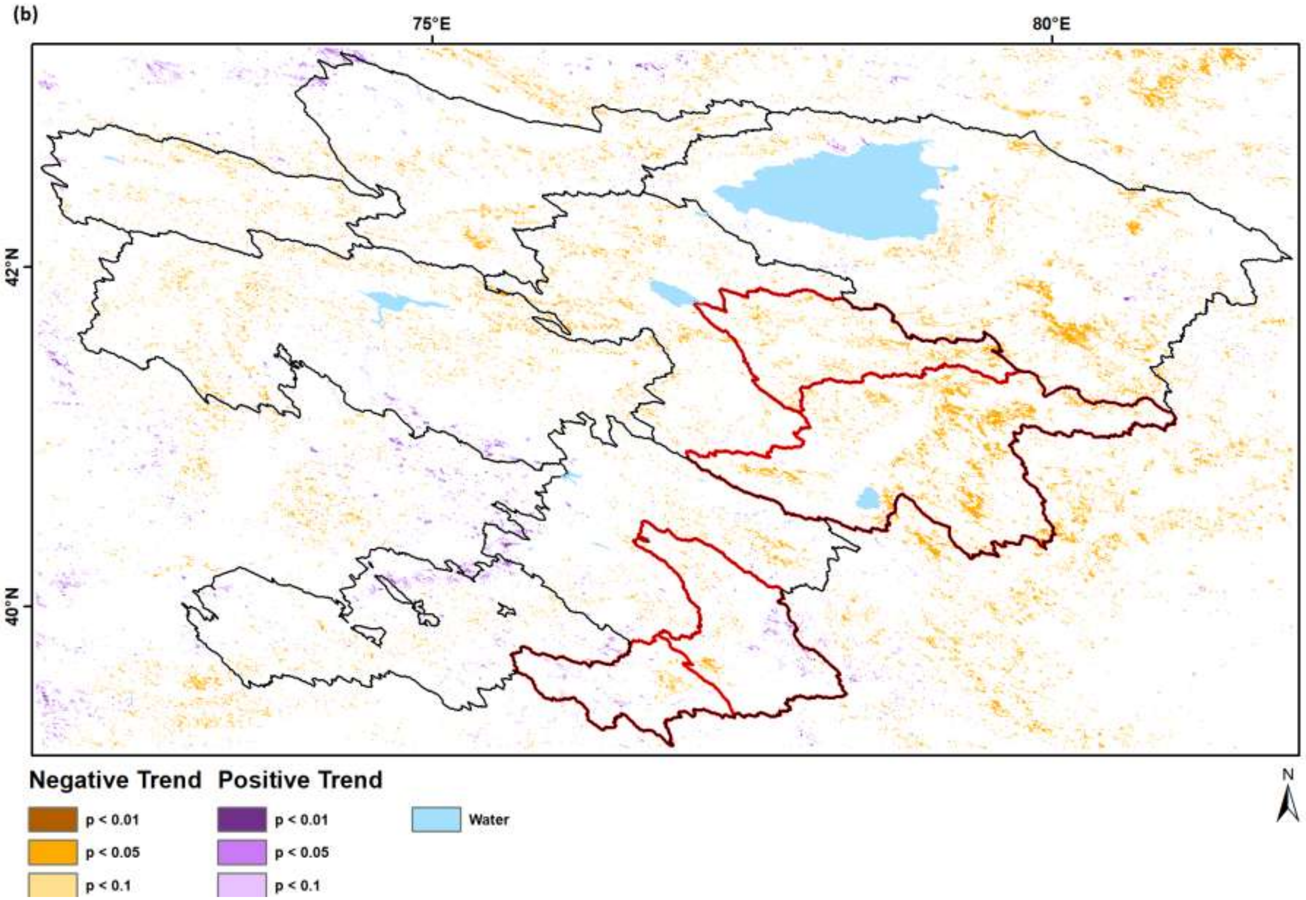
Significantly earlier snow melt, especially in Naryn and Issyk-Kul oblasts

oblast	LDoS earlier (km^2)
Batken	--
Chuy	401
Issyk-Kul	1,376
Jalal-Abad	759
Naryn	2,227
Osh	--
Talas	222
total	4,985

MOD10A2: 500 m resolution
8-day composites

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Significant Trends in the Last Date of Snow in Focal Rayons by Elevation



Significantly earlier snow melt, especially in Naryn, At-Bashy, Alay, and Chong-Alay rayons at most elevations.

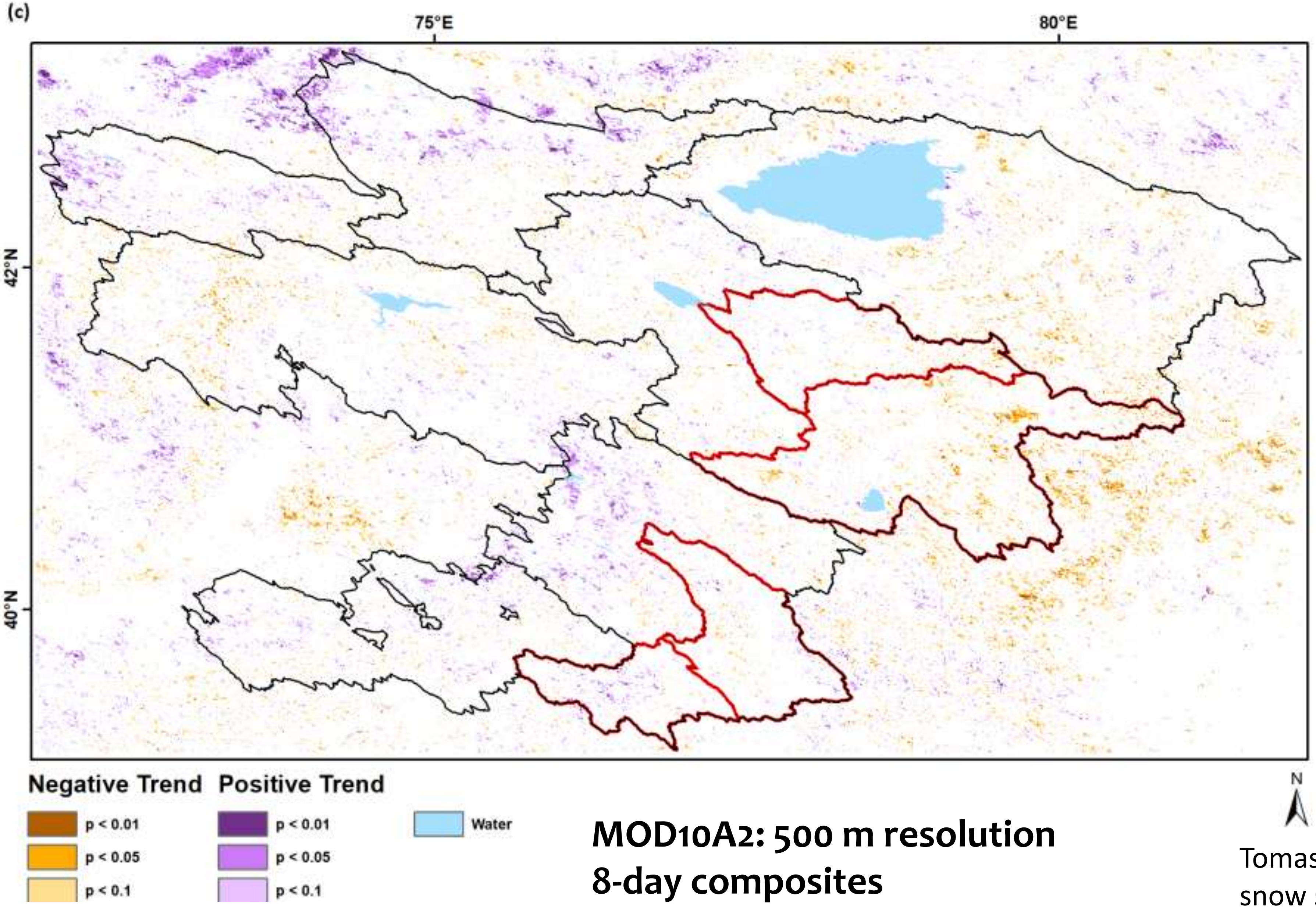
Significantly later snow melt in Alay and Chong Alay rayons above 3400 m.

elevation class	Naryn (km²)	At-Bashy (km²)	Alay (km²)	Chong-Alay (km²)
1,400-1,900 m	2.6	nd	2.1	nd
1,900-2,400 m	38.0	57.5	25.1	--
2,400-2,900 m	137.8	93.2	23.8	18.5
2,900-3,400 m	182.0	441.8	47.7	--
> 3,400 m	47.2	720.0	*49.2*	*18.7*
Total earlier	407.6	1,312.4	98.7	18.5
Total later	--	--	*49.2*	*18.7*

MOD10A2: 500 m resolution
8-day composites

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Significant Trends in the Duration of Snow Season across Kyrgyzstan



Shorter snow season to the east and longer snow season to the west.

oblast	DoSS shorter (km²)	DoSS longer (km²)
Batken	--	325
Chuy	--	701
Issyk-Kul	884	--
Jalal-Abad	--	--
Naryn	872	--
Osh	--	701
Talas	--	357
total	1,757	2,084

MOD10A2: 500 m resolution
8-day composites

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Two-stage trend analysis for FDoS and LDoS across Kyrgyzstan.

Bold entries indicate at least twice the area of the significant ($p<0.05$) pair

Trend of 1st metric: FDoS	Area in 1st metric (%)	Area in 1st metric (km^2)	Trend of 2nd metric: LDoS	Area in 2nd metric (%)	Area in 2nd metric (km^2)
FDoS earlier	**4.8**	**8,555**	**LDoS earlier**	**2.3**	**196**
			LDoS later	0.2	21
			LDoS ns	97.5	8,338
FDoS later	0.9	1,634	**LDoS earlier**	**3.2**	**54**
			LDoS later	1.0	15
			LDoS ns	95.8	1,565
FDoS ns	91.3	161,225	**LDoS earlier**	**3.3**	**5,264**
			LDoS later	0.5	742
			LDoS ns	96.2	155,219

Two-stage trend analysis for LDoS and DoSS across Kyrgyzstan.

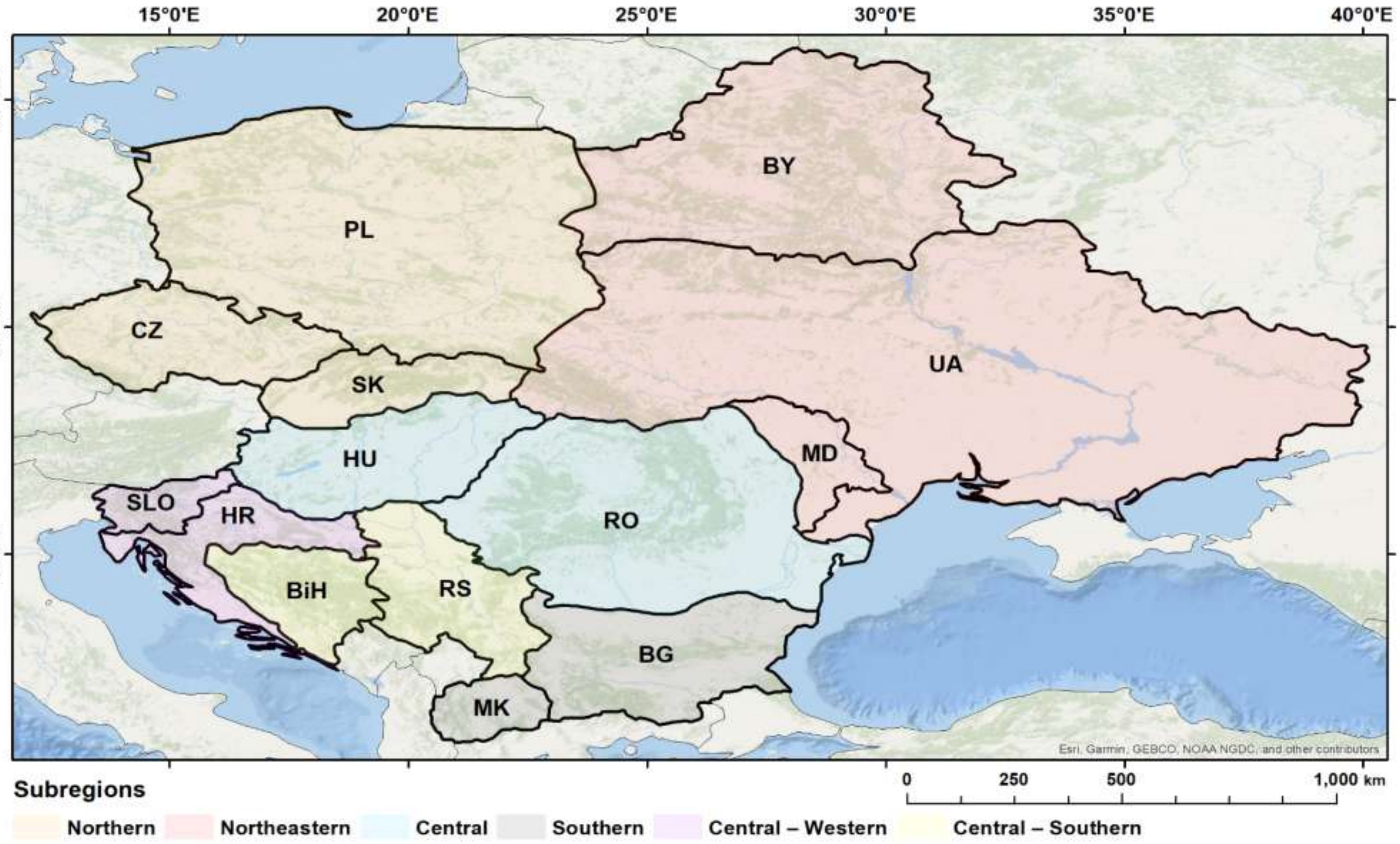
Bold entries indicate at least twice the area of the significant ($p<0.05$) pair

Trend of 1st metric: LDoS	Area in 1st metric (%)	Area in 1st metric (km^2)	Trend of 2nd metric: DoSS	Area in 2nd metric (%)	Area in 2nd metric (km^2)
LDoS earlier	**3.2**	**5,514**	**DoSS shorter**	**8.2**	**452**
			DoSS longer	0.1	8
			DoSS ns	91.7	5,054
LDoS later	0.4	778	DoSS shorter	<0.1	<1
			DoSS longer	**19.9**	**155**
			DoSS ns	80.1	623
LDoS ns	96.4	168,131	DoSS shorter	1.4	2,408
			DoSS longer	1.7	2,850
			DoSS ns	96.9	162,873

Potential impacts of changing snow seasonality in Kyrgyzstan include

- Disruption of ecological calendars & transhumance timing
- Earlier end to growing season in summer and spring/fall pastures, if moisture is not supplemented by rainfall
- Earlier end of access to fall pastures
- Increasing the difference in productivity between northern and southern aspect pastures
- Increasing the invasibility of pastures by non-palatable species that are active earlier in the growing season

IV. Initial Results: Changing Snow Seasonality Across SCERIN Region



MOD10C2:
0.05° resolution
8-day composites

Two-stage trend analysis for FDoS and LDoS across SCERIN.

Bold entries indicate at least twice the area of the significant ($p<0.05$) pair

Trend of 1^{st} metric: FDoS	Area in 1^{st} metric (%)	Area in 1^{st} metric (km^2)	Trend of 2^{nd} metric: LDoS	Area in 2^{nd} metric (%)	Area in 2^{nd} metric (km^2)
FDoS earlier	0.86	16,549	**LDoS earlier**	**0.07**	**1,127**
			LDoS later	0.00	0
			LDoS ns	0.93	15,422
FDoS later	1.59	30,484	**LDoS earlier**	**0.04**	**1,319**
			LDoS later	0.00	48
			LDoS ns	0.96	29,117
FDoS ns	97.55	1,870,257	**LDoS earlier**	**0.06**	**109,777**
			LDoS later	0.00	1,535
			LDoS ns	0.94	1,758,946

Two-stage trend analysis for FDoS and DoSS across SCERIN.

Bold entries indicate at least twice the area of the significant ($p<0.05$) pair

Trend of 1st metric: FDoS	Area in 1st metric (%)	Area in 1st metric (km^2)	Trend of 2nd metric: DoSS	Area in 2nd metric (%)	Area in 2nd metric (km^2)
FDoS earlier	0.86	16,525	DoSS shorter	0.0	72
			DoSS longer	**0.03**	**552**
			DoSS ns	0.96	15,902
FDoS later	1.59	30,484	**DoSS shorter**	**0.33**	**10,121**
			DoSS longer	0.00	0
			DoSS ns	0.67	20,363
FDoS ns	97.55	1,870,281	**DoSS shorter**	**0.04**	**74,016**
			DoSS longer	0.00	1,439
			DoSS ns	0.96	1,794,826

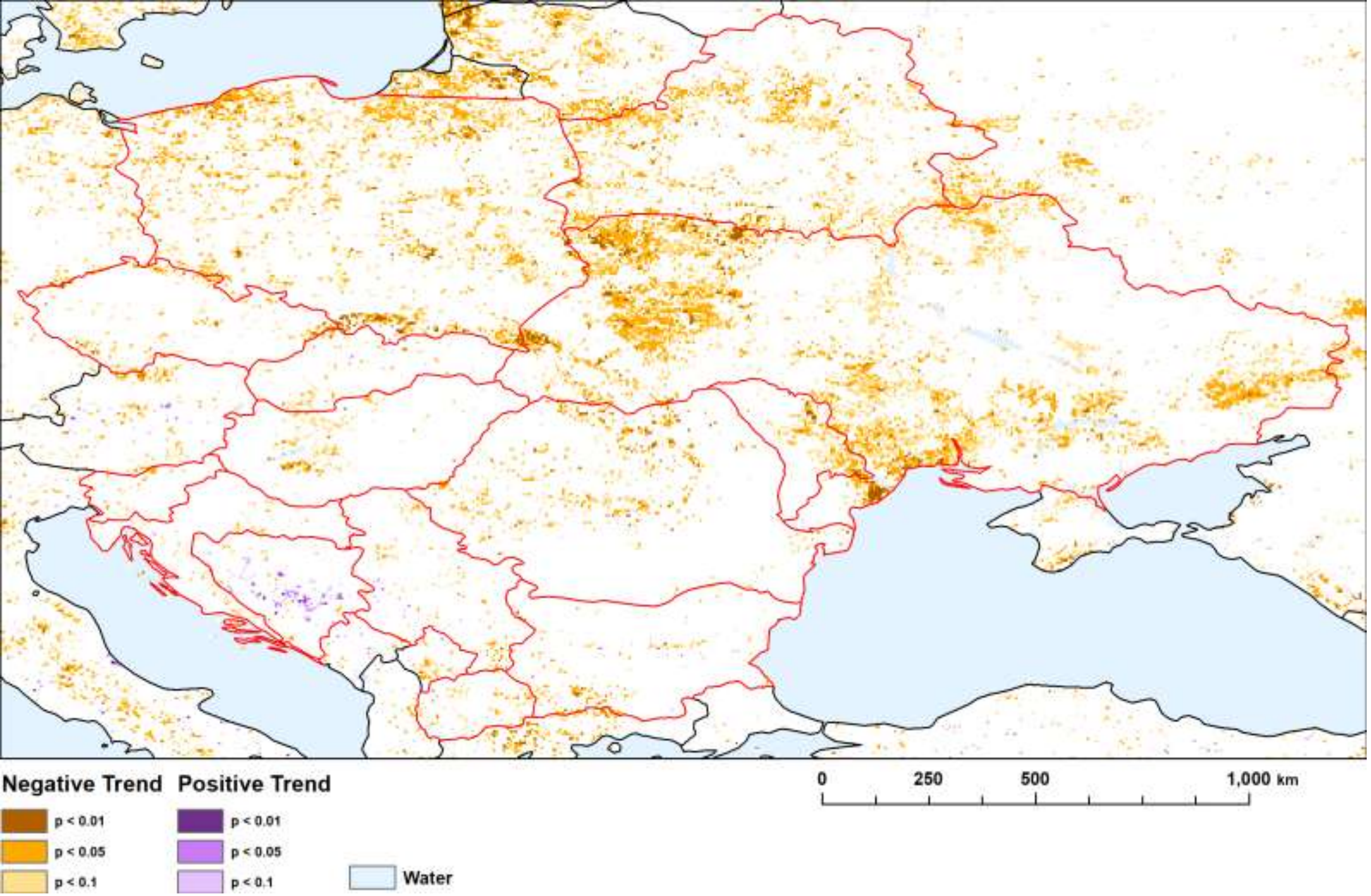
Two-stage trend analysis for LDoS and DoSS across SCERIN.

Bold entries indicate at least twice the area of the significant ($p<0.05$) pair

Trend of 1st metric: LDoS	Area in 1st metric (%)	Area in 1st metric (km^2)	Trend of 2nd metric: DoSS	Area in 2nd metric (%)	Area in 2nd metric (km^2)
LDoS earlier	**5.85**	**112,223**	**DoSS shorter**	**0.25**	**27,798**
			DoSS longer	0.00	0
			DoSS ns	0.75	84,425
LDoS later	0.08	1,607	DoSS shorter	0.00	0
			DoSS longer	**0.09**	**144**
			DoSS ns	0.91	1,463
LDoS ns	94.06	1,803,461	**DoSS shorter**	**0.03**	**56,411**
			DoSS longer	<0.01	1,871
			DoSS ns	0.97	1,745,179

This initial analysis including most of northern SCERIN suggests some changes but the results across 1.9M km^2 are weakly asymmetric, likely because the region spans considerable latitudinal and elevational gradients.

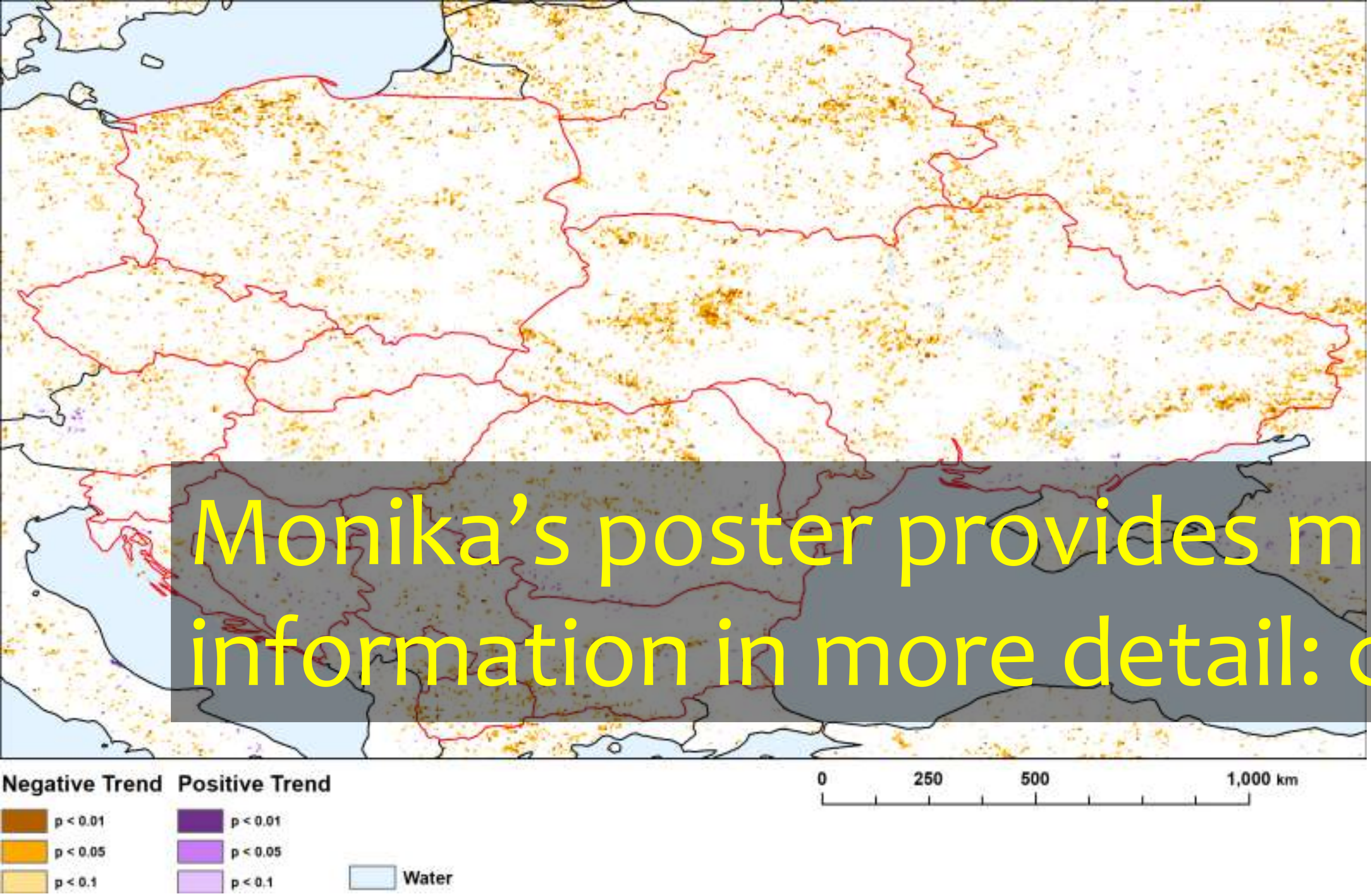
Let's look at the patterns by nation instead.



Significant negative
Significant positive

Country	LDoS [km²]	LDoS [%]
BY	**13,527**	**6.52**
UA	**53,269**	**9.31**
MD	**2,686**	**8.09**
PL	**25,118**	**8.00**
CZ	**2,590**	**3.29**
SK	**863**	**1.78**
RO	**7,363**	**3.12**
HU	**1,679**	**1.80**
BG	**1,967**	**1.75**
MK	**792**	**3.12**
SLO	**432**	**2.13**
HR	**576**	**1.06**
BIH	*1,343*	*2.95*
RS	**983**	**1.27**
	1,343	*0.07*
total	**111,840**	**5.81**

- Negative trends in LDoS 13 countries (5.81% of the total area)
- Positive trend only in BIH: 1,343 km² (2.95%)
- Area of the negative trend decreases from Northeastern through Northern to southern sub-regions



Monika's poster provides more information in more detail: check it out!

Significant negative
Significant positive

Country	DoSS [km²]	DoSS [%]
BY	**11,680**	**5.63**
UA	**32,859**	**5.74**
MD	**2,686**	**8.09**
PL	**16,813**	**5.36**
CZ	**2,590**	**3.29**
SK	**1,415**	**2.92**
RO	**7,363**	**3.12**
HU	**1,679**	**1.80**
BG	**3,526**	**3.13**
MK	**1,799**	**7.08**
SLO	**432**	**2.13**
HR	**508**	**0.92**
BIH	**627**	**1.20**
RS	**1,631**	**2.10**
	--	--
total	**84,209**	**4.37**

- Negative trends in DoSS cover 4.37% of the total area.
- No predominant positive trends in DoSS.
- Largest areas of change in UA (5.74%), PL (5.36%), and BY (5.63%).
- Smallest areas of change in SLO (2.13%) and HR (0.92%).

Potential impacts of changing snow seasonality in SCERIN region include

- Disruption of phenologies and ecological calendars
- Changes to tourism, e.g., shortening of the ski season
- Changes to cropland management, including timing of planting and harvest
- Extending the fire season
- Increasing the invasibility of pastures and other managed lands by weedy species that are active earlier in the growing season
- Hydrological implications (though snow cover is not snow depth)
- What else?

V. An Invitation to Collaborate

The national scale analyses suggest that snow seasonality has been changing within the SCERIN region in recent decades.

Caveat: Trend analyses reveal what has already happened, not what may happen in the future.

However, these are initial results at a coarser spatial resolution of 0.05° and the analyses should be run at the finer resolution 500 m data and cross-tabulated by elevation class.

Interpretation of the local ecological, cultural, and socio-economic significance of the results is beyond our expertise.

Thus, we invite you to collaborate on this project, bringing your expertise and data to address the challenge of interpretation.

If you are interested in joining this project, please contact us:

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Thanks for your attention!