Potential orobiome distribution over the South Siberian and North Mongolian Mountains associated with predicted climate change by the Mid-Century

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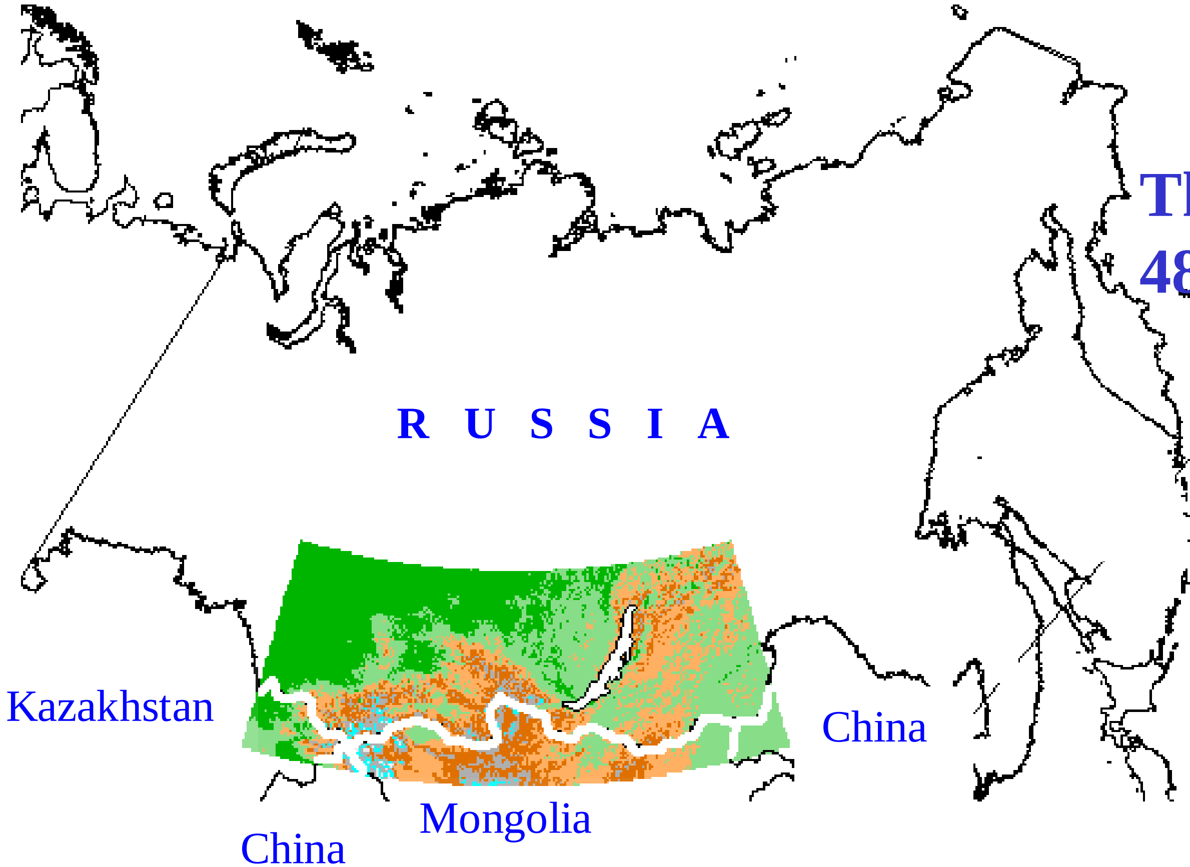
GOAL

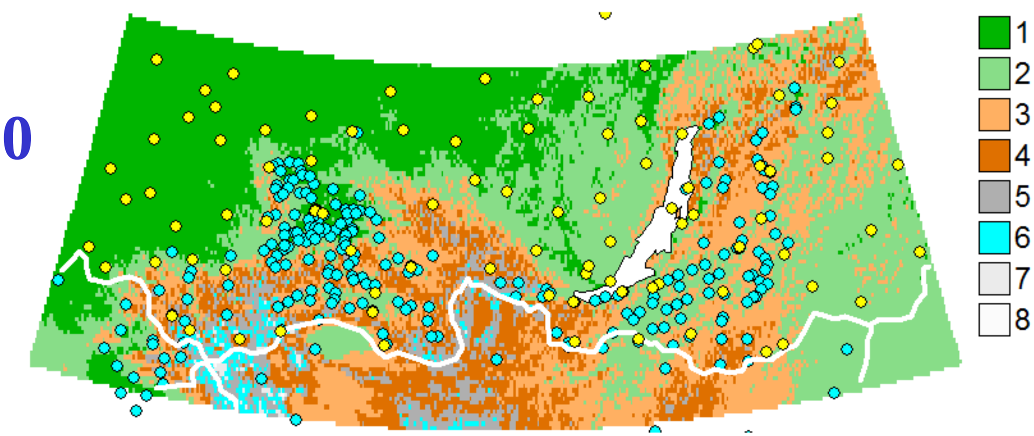
- To model Altitudinal Belt Complexes (ABC/orobiomes) of mountain vegetation across the South Siberian and North Mongolian Mountains using our static envelope model MontBioCliM (Tchebakova et al., 2009) in current and future climates under two climate change scenarios spp126 and ssp585 (IPCC, 2021) to understand potential vegetation change in a warming climate

South Siberian and North Mongolian Mts



The study window is 48-58N and 80-120E

Climate record from 250 weather stations across South Siberia and Mongolia were used



Database of the South Siberian Mts weather stations

	1 IMYA	2 HABS	3 LAT	4 LON	5 T5	6 RMM	7 T7	8 GDD5	9 AMI	10 dd0	11 t1	12 orobio_generaliz
109	MANGUT	807	49.7	112.7	2057	409	18.5	1298	3.2	-2592	-22.1	5
110	CHEMAL	410	51.4	86.0	2330	501	18.0	1512	3.0	-1310	-12.6	5
111	BELE	553	51.4	87.8	2180	584	16.9	1394	2.4	-960	-9.2	5
112	ONGUDAI	832	50.8	86.1	1920	379	16.2	1190	3.1	-2260	-22.1	5
113	UST_KOKS	978	50.3	85.6	1820	517	15.4	1112	2.1	-2580	-23.3	5
114	KATANDA	900	50.2	86.2	1800	472	15.2	1096	2.3	-2600	-23.6	5
115	KATON_KA	1068	49.1	85.6	2107	516	17.2	1337	2.6	-1672	-14.8	5
116	SARYG_SE	706	51.5	95.6	2066	367	17.6	1305	3.6	-4082	-34	5
117	PONOMARE	445	53.7	94.3	1908	837	17.4	1181	1.4	-2057	-16.1	6
118	V_KUZHEB	340	53.4	93.2	2098	889	18.1	1330	1.5	-2133	-18.2	6
119	BELOKURI	251	52.0	85.0	2480	776	19.2	1630	2.1	-1870	-16.8	6
120	TUROCHAK	320	52.2	87.7	2050	908	17.5	1292	1.4	-2200	-19.7	6
121	KYZYL_OZ	331	51.6	86.0	2210	795	18.0	1418	1.8	-1900	-15.9	6
122	YAILYU	441	51.8	87.6	2000	983	16.2	1253	1.3	-1040	-9.4	6
123	KOSH_AGA	1758	50.0	88.7	1410	127	13.8	790	6.2	-3890	-32.1	8
124	BURAN	410	48.0	85.2	2941	243	22.2	1991	8.2	-1925	-18.8	8
125	ABAKAN	246	53.8	91.4	2353	347	19.7	1530	4.4	-2322	-20.8	7
126	MINUSINS	251	53.7	91.7	2295	368	19.6	1484	4.0	-2255	-19.6	7
127	MINUS_OP	252	53.7	91.8	2295	362	19.6	1484	4.1	-2406	-21.2	7
128	BUDENNOV	276	54.5	91.1	2029	390	18.0	1276	3.3	-2451	-20	7
129	SHIRA_ZH	469	54.5	89.9	2015	360	17.6	1265	3.5	-2239	-18.8	7

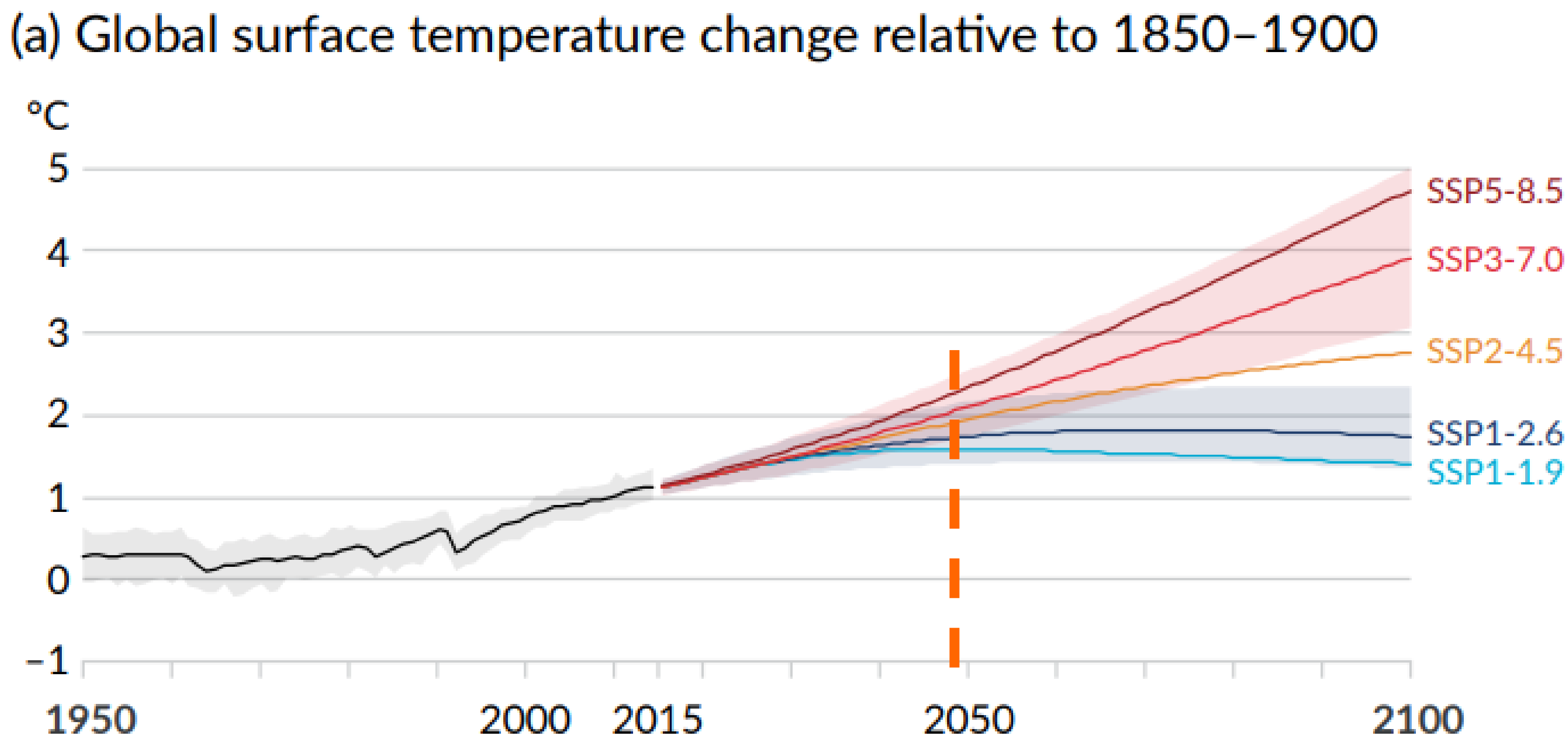
Climate variables bounded by blue rectangle;

Orobiomes bounded by red rectangle

Main climate variables: Growing Degree-Days, base 5°C, GDD5; Annual Moisture Index, AMI = GDD5/RMM; and NDD, negative degree-days, below 0°C

ABC categories/orobiomes: 1. Tundra; 2. Subalpine woodlands; 3. Darkleaf taiga; 4. Lightleaf taiga; 5. Subtaiga & Forest-steppe; 6. Black (Chern) taiga; 7. Steppe; 8. Semidesert/Desert; 9. Broadleaf forest; 10. Temperate Forest-steppe

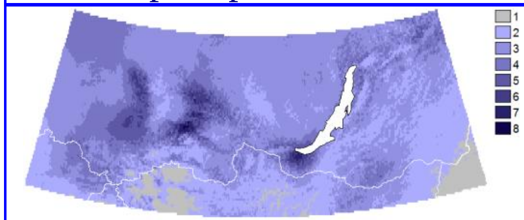
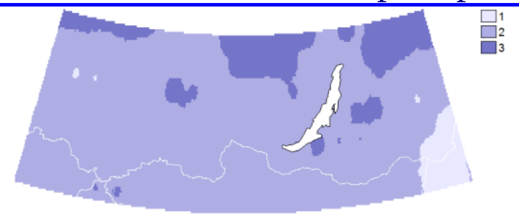
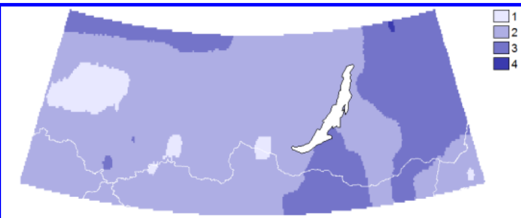
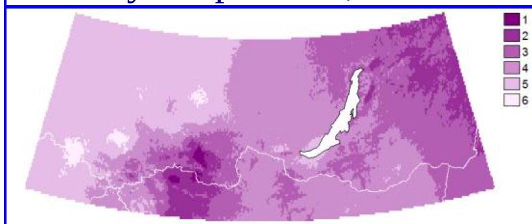
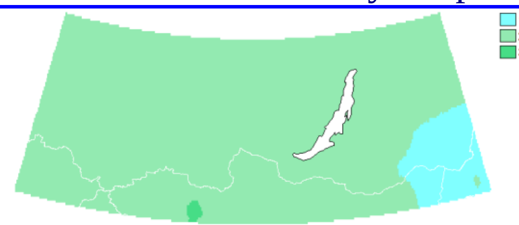
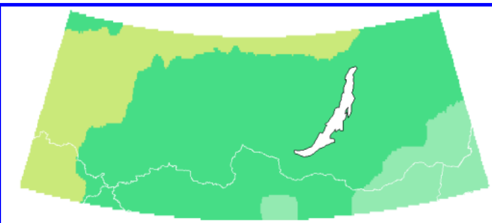
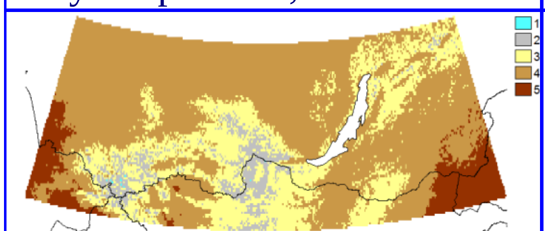
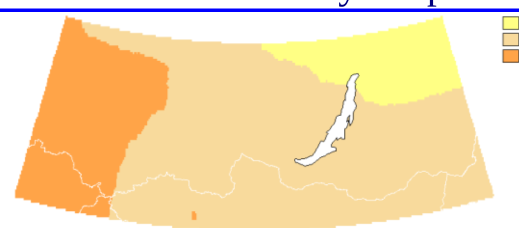
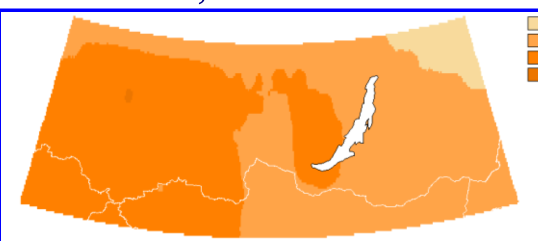
Climate change scenarios (IPCC, 2021)



IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001

Climate change by the 2050s predicted from the Climate Model INM_CM5_0

https://esgf-data.dkrz.de/search/cmip6-dkrz)

Base climate (1961-1990)	Climate 2050 (МОЦАО INM-CM5-0)	
	ssp126	ssp585
Annual precipitation, mm	Annual precipitation anomalies, mm	
		
1. < 200; 2. 200-400; 3. 400-600; 4. 600-800; 5. 800-1000; 6. 1000-1200; 7. 1200-1400; 8. >1400	1. -50-0; 2. 0-50; 3. 50-100; 4. 100-150	
January temperature, ^{o}C	January temperature anomalies, ^{o}C	
		
1. <-35; 2. -35 -30; 3. -30 -25; 4. -25 -20; 5. -20 -15; 6. -15 -10; 7. -10 -5	1. < 0; 2. 0-2; 3. 2-4; 4. 4-6	
July temperature, ^{o}C	July temperature anomalies, ^{o}C	
		
1. < 5; 2. 5-10; 3. 10-15; 4. 15-20; 5. 20-25	1. <1; 2. 1-2; 3. 2-3; 4. 3-4; 5. 4-5; 6. 5-6	

Across the South Siberian Mts, January temperatures are predicted to increase 1-4C, July temperatures – to 2-5C, and annual precipitation 50 to 120 mm by 2050 from the moderate and extreme scenarios, respectively

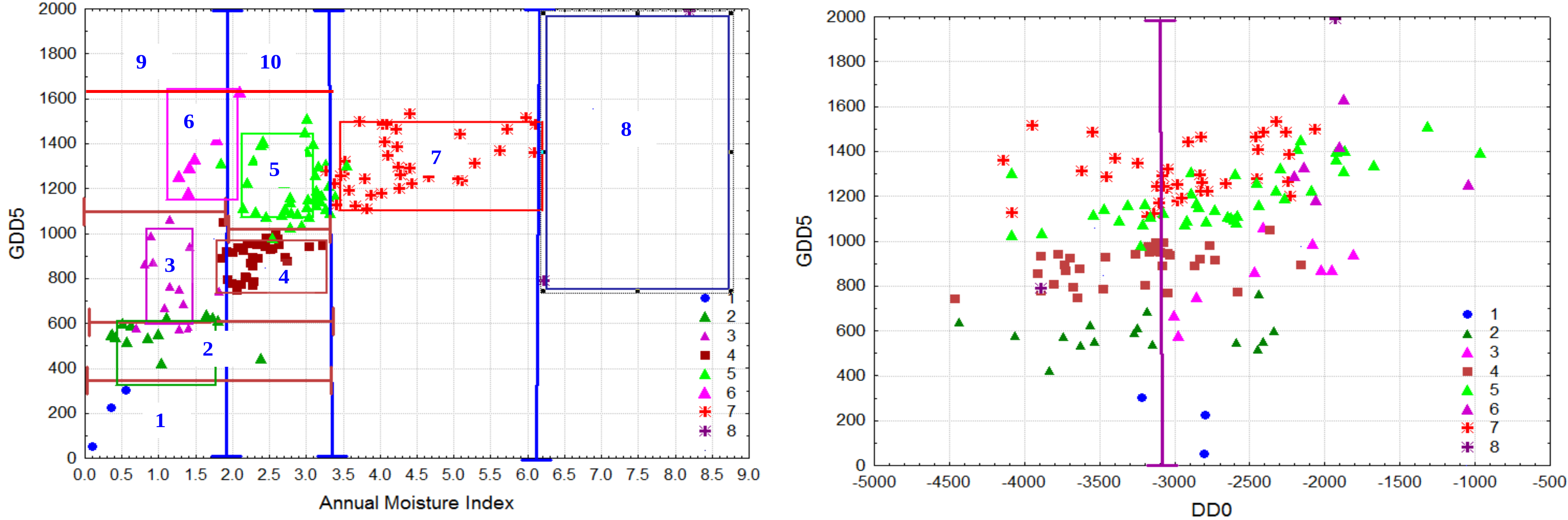
Climate change at the south of Siberia

- For the 1960-2010 period, summer temperatures increased 0.7-1.5°C and winter temperatures 1-2°C in the northern hollows of the South Siberian Mts; in the southern hollows temperatures increased 1.4-3.2°C and 2-4°C, respectively (Tchebakova et al., 2011).

- For the 1960-2010 period, change in precipitation is complex, however, trends are positive across the mountains from the Urals to Transbaikalia: (20-25 and negative (-10-20%) in intermountain basins;

- First signs of orobiome shifts are registered across the South Siberian Mts. in a warming climate such as steppe invasion into forest at the lower forest border and forest invasion onto tundra at the upper forest border (Kharuk et al., 2016 et seq.)

The envelope static bioclimatic model MontBioCliM of the South Siberian Mts based on the regional vegetation ordination

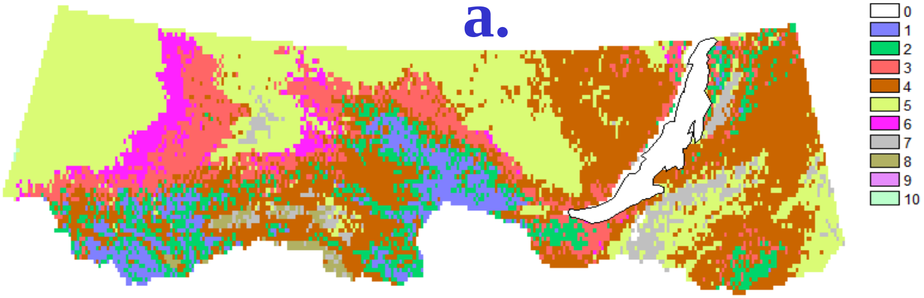


Ordination of orobiomes in climate space: (left) Growing Degree-Days, base 5°C, GDD5, and Annual Moisture Index, AMI; (right) GDD5 and NDD, negative degree-days, below 0°C

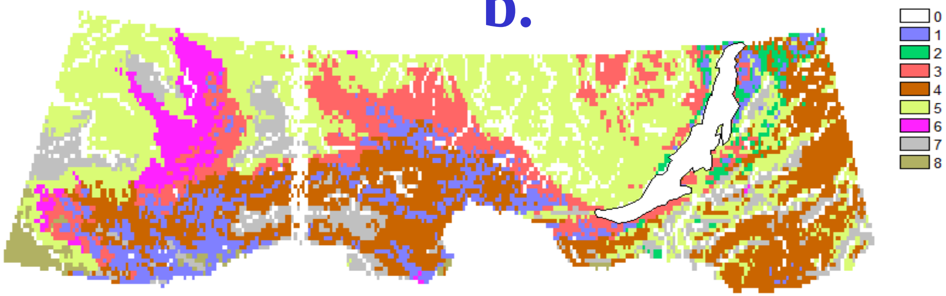
Orobiomes: 1. Tundra; 2. Subalpine woodlands; 3. Darkleaf taiga; 4. Lightleaf taiga; 5. Subtaiga & Forest-steppe; 6. Black (Chern) taiga; 7. Steppe; 8. Semidesert/Desert; 9. Broadleaf forest; 10. Temperate Forest-steppe

The MontBioCliM verification against actual vegetation in the South Siberian Mts

a.



b.

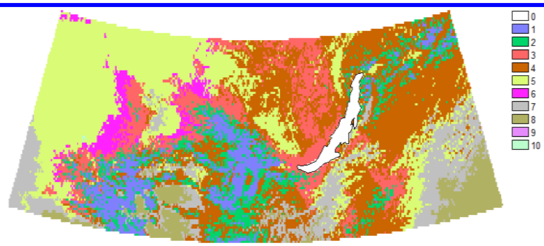
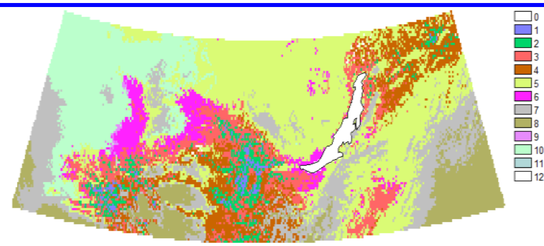
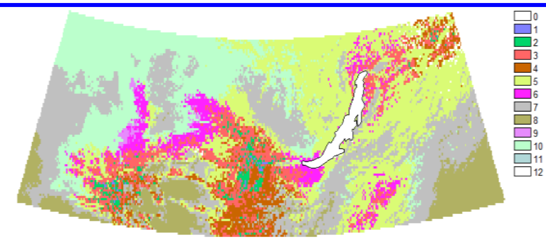


Based on kappa statistics we compared how the modeled orobiome map (a) matches with actual map (b) on the Landscape map of Isachenko (1988) over the South Siberian Mts.

Overall kappa match was fair (0.47); poor match was for ecotone upland open woods (0.06), steppe (0.11); darkleaf taiga (0.25) and tundra (0.36); fair for lightleaf taiga (0.55), good for lowland forest-steppe (0.56) and black taiga (0.59).

ABC categories/orobiomes: Tundra; 2. Subalpine woodlands; 3. Darkleaf taiga; 4. Lightleaf taiga; 5. Subtaiga & Forest-steppe; 6. Black (Chern) taiga; 7. Steppe;

Orobiome distribution across the South Siberian and North Mongolian Mts in the 2050 climate predicted from the GCM INM_CM5_0 – 2050

Base climate (1961-1990)	GCM INM-CM5-0/ 2050	
	ssp126	ssp585
orobiomes		
		

Altitudinal Belt Complex	Current Climate, %	Future climates, % ssp126	ssp585
Tundra	6.9	0.9	0.2
Subalpine woodland	9.0	3.6	1.4
Darkleaf taiga	11.7	9.7	8.7
Lightleaf taiga	26.9	9.9	4.7
Subtaiga & Forest-steppe	25.8	32.4	27.1
Black (Chern) taiga	3.0	4.5	4.9
Steppe	11.0	15.5	24.2
Semidesert/Desert	5.5	9.0	9.3
Broadleaf forest	0.0	0.2	0.6
Temperate Forest-steppe	0.0	14.3	18.8
TOTAL	100	100	100

Elevated temperatures not balanced by sufficient precipitation at the lower forest border would favor steppes to extend upslope into forests; elevated temperatures balanced with sufficient water at the upper forest border would favor forests to invade into tundra; Steppe would twice expand; Subalpine woodlands would substantially shrink and Tundra may disappear

Conclusions

- Our bioclimatic envelop model MontBioCliM was applied to current and future climates to predict vegetation distributions over the South Siberian and North Mongolian Mts by the Mid-Century;

-Current climate was derived from recorded data of 250 weather station; Future climates were derived from the Russian climate model INM-CM5-0 for two opposite climate change scenarios Spp126 (moderate) and Spp585 (extreme);

- the GCM was moderately sensitive to the double CO_2 concentration in the atmosphere (Volodin, 2022);

- Darkleaf forests together with black taiga would retain their area at the expense of subalpine woodlands; Lightleaf forests would reduce their area due to subtaiga and steppe invasion;

-Steppe would twice expand; Subalpine woodlands would substantially shrink and Tundra may disappear

Perspectives

To map orobiomes and zonobiomes distributions over Russia we plan to employ machine learning approach (like Maxent, Random Forest) that is widely used for plant an animal species distributions