

ESTIMATION OF MEAN DEPTH FOR BOREAL LAKES

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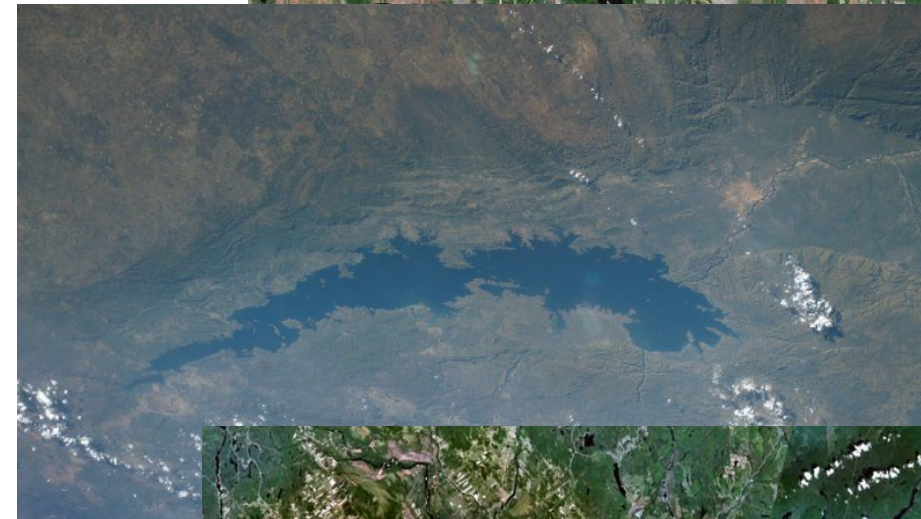
- Background
- GLDB and mapping method
- Objectives of the project
- Method of obtaining the typical mean lake depth
- Kitaev's and Doganovsky's methods
- Results
- Conclusion

Background

- Lakes occupy about 1,8% of the land surface, and are distributed very unevenly.

Lake – volume of water, which occupies a depression of the land, has no direct connection with a sea.

- Lakes influence local weather conditions and local climate.
- Lakes can influence global climate.
(carbon cycle, thermokarst lakes – one of the sources of methane)





Background

- In the atmospheric modeling – parameterization of lakes.
(important with increase of the model horizontal resolution)
- Computationally cheap lake model is needed – **FLake**.
- External parameters of lakes are needed – **depth**.
(accuracy, reliability of depth data – not critical, global coverage – essential)

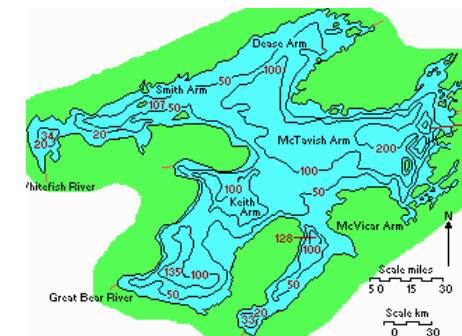
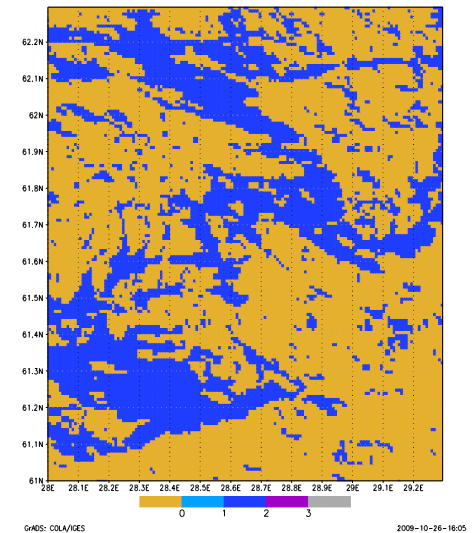
GLDB

- Global Lake Database (GLDB).

- Data sources:

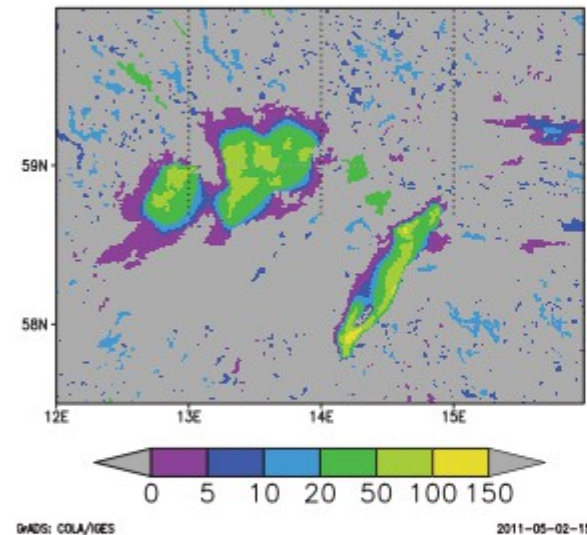
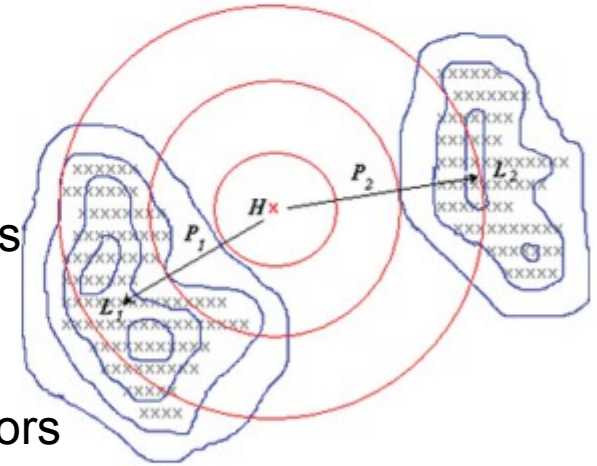
- the mean depth for individual lakes, from different regional databases (ca. 13 000 lakes);
- global map – ecosystem dataset ECOCLIMAP2;
- bathymetry data for 36 large lakes from ETOPO1 and digitized navigation and topographic maps.

Lat, deg	Lon, deg	mean Depth, m	max Depth, m	Surface area, km ²	International name	Country
42.2	19.3	5	8.3	372.3	Scutari_(Skadar)	Albania
41	20.8	143	286	340	Orind	Albania
41	21	9999	9999	313.6	Big_Prospe	Albania
40.8	21.05	9999	9999	47.4	Smel_Prespa	Albania
47.434	11.717	67.7	133	7.1	Achenisee	Austria
47.766	13.969	2.6	6	0.9	Almeos	Austria
47.641	13.766	34.3	62.8	2.1	Altaussee_Eco	Austria
48.25	16.41	2.2	6.8	1.6	Alle_Donau	Austria
47.89	13.55	85.3	170.6	46.2	Attersee	Austria
47.611	9.679	89.9	264	639	Bodensee	Austria
48.682	15.4	14	40	1.6	Dobratsensee	Austria
47.542	16.068	26	38	0.6	Erkaufsee	Austria
46.978	13.924	14.9	29.6	2.2	Fakker_See	Austria
47.806	13.268	36	66.3	2.7	Fuschlsee	Austria
48.601	15.142	1.4	3.2	0.6	Gebhartssee	Austria
46.932	10.739	53.8	112	2.6	Gepatsch Stausee	Austria
47.992	13.065	9.7	14	1.3	Grabensee	Austria
47.636	13.881	41.1	63.8	4.1	Grundsee	Austria
47.493	10.573	11	22	0.8	Haldensee	Austria
47.653	13.665	65.1	125.2	6.6	Hallstaedter_See	Austria
48.32	16.136	1.4	2.9	0.6	Halsbrunn_Toch	Austria
47.456	10.772	40.4	60	1.4	Heilerwanger_See	Austria
47.75	13.247	9.3	22	0.7	Hintersee	Austria
47.642	12.216	12.8	36	0.6	Hinterstoder_See	Austria
47.924	13.305	14.9	32	2.5	Insee	Austria
46.688	14.182	10.4	15.6	1.4	Keulschacher_See	Austria



Mapping method

- Automatic
for mapping the mean depth data for individual lakes
- Probabilistic
it is assumed that all data sources have random errors
- For lakes with no information, the **"default" depth of 10 m** is used.
- Result – global lake depth data set with the resolution of 30" (approximately 1 km).





But ...

- 13 000 lakes in the database
5 000 000 lakes in the world
- The depths of many small lakes were never measured.
- It may be estimated **indirectly** from their geological origin.



Main objective of the project:

To upgrade the GLDB by indirect estimates of the mean depth from the geological origin of lakes for boreal zone.

Methodology

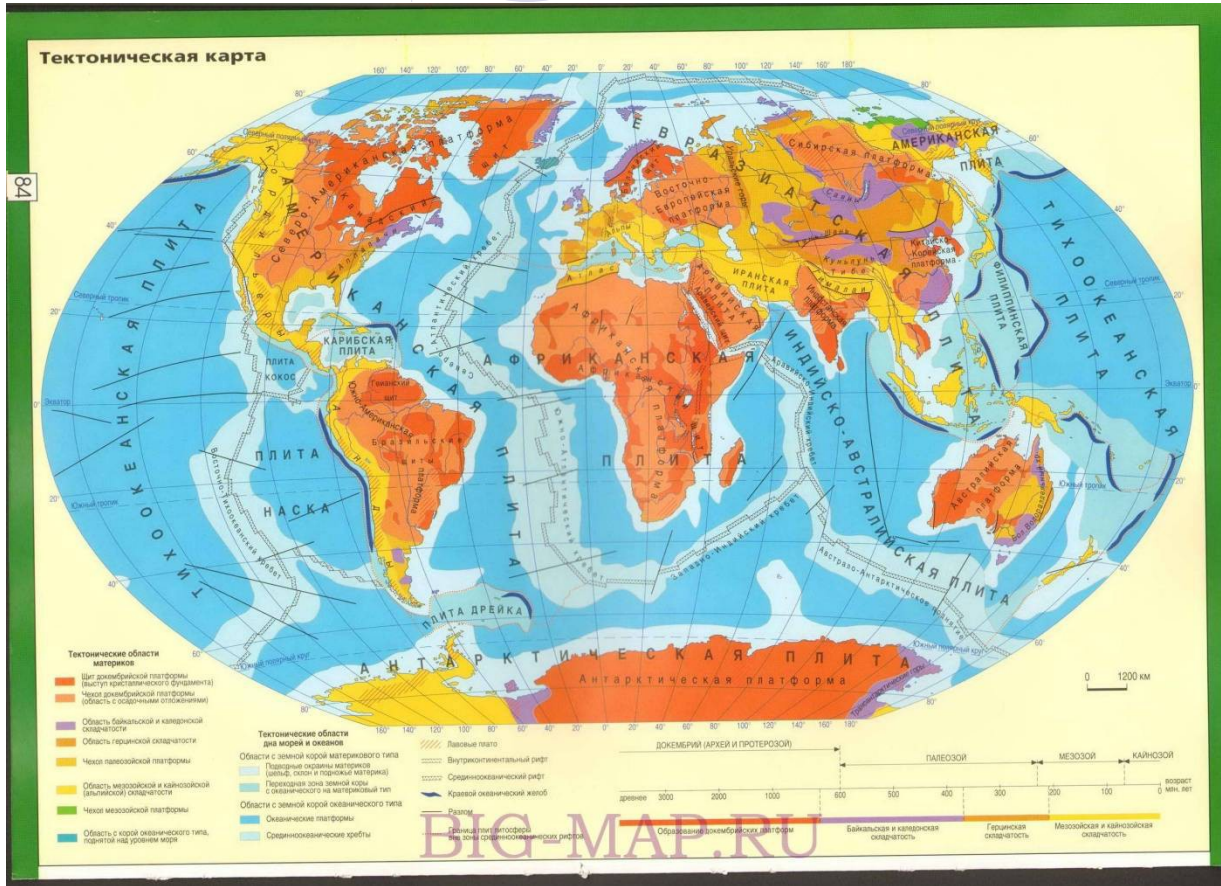


Regions with homogeneous geological origin of lakes were allocated. For this, the following materials were used:

- actual geological map of the world;
- tectonic map of the world;
- geo-morphological map of the world;
- world map of quaternary deposits.

Russian maps (geological terms, classifications differ from English terms)

Tectonic map of the world



Forms of bedding;

Time of the formation of structural elements of the earth's crust;

Conditions of the formation of structural elements of the earth's crust.

Tectonic map of the world

Lithospheric plates;

Platforms;

Orogens;

Volcanic plateaus;

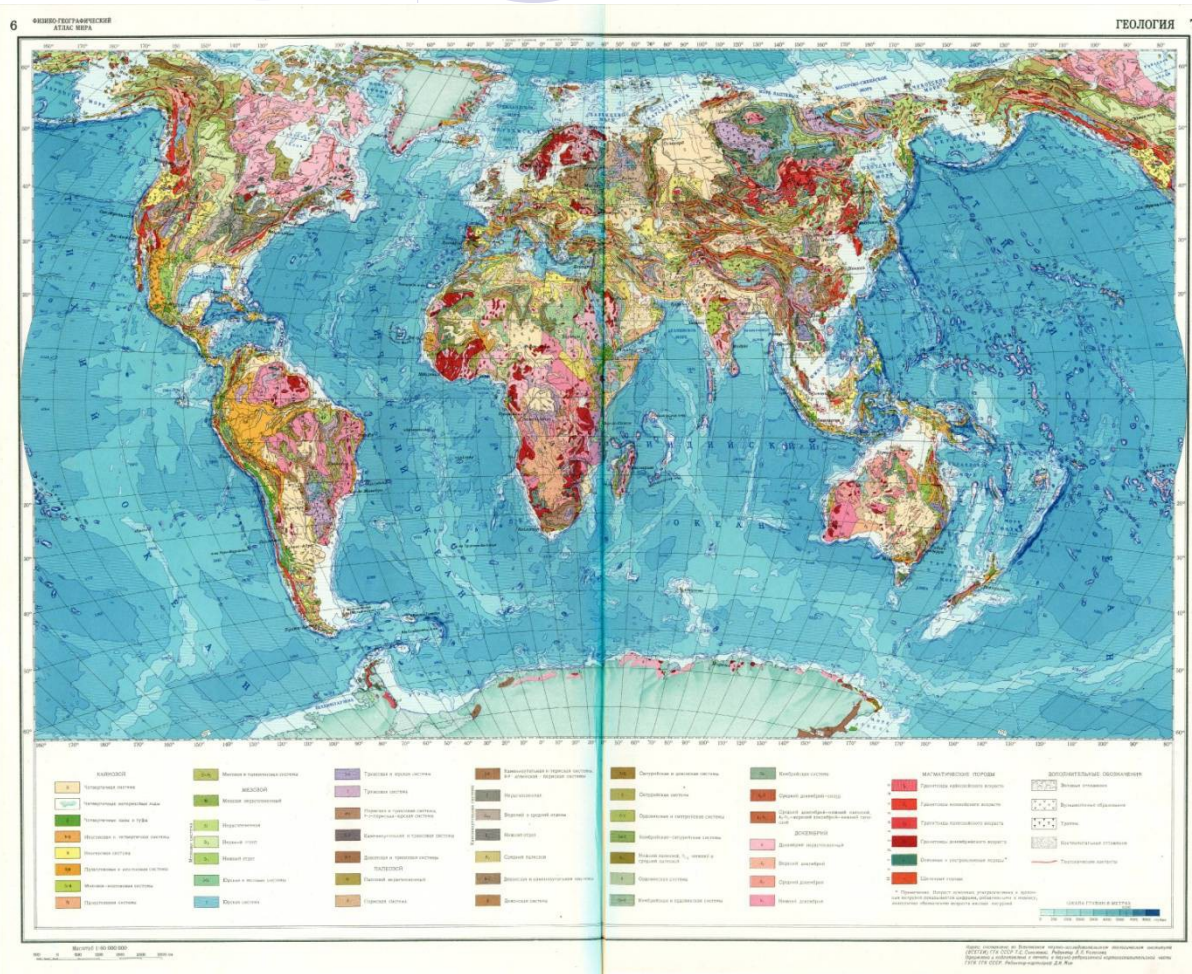
Intracontinental rifts;

Faults;

Part of the oceanic crust, uplifted above the sea level.



Geological map of the world



Stratigraphic map of rocks:

Age of rocks;

Composition of rocks;

Origin of rocks;

Mode of bedding of rocks.

Geological map of the world

Igneous (crystalline)
rocks:

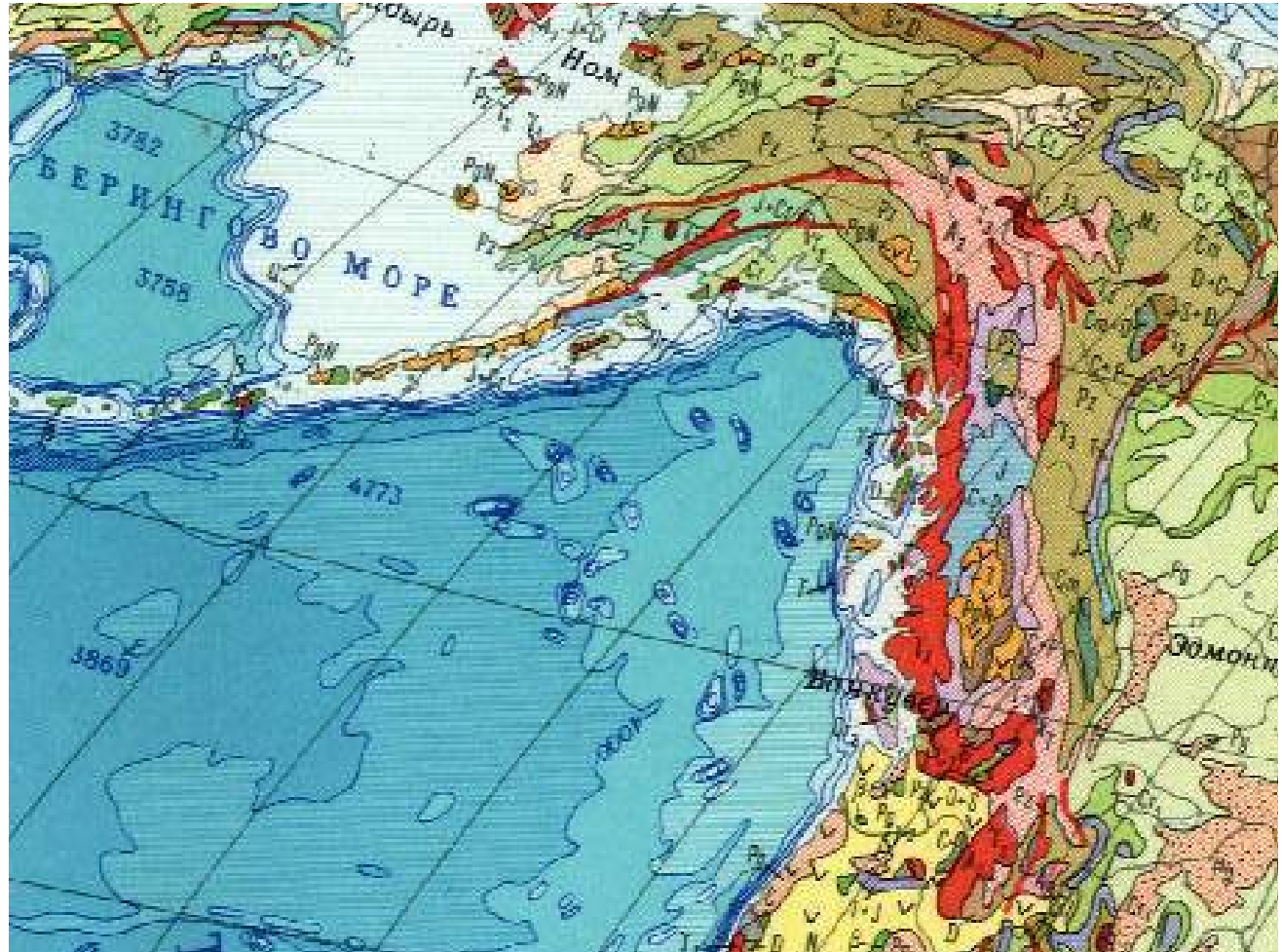
Granite;

Basalt;

Gypsum;

Tuffs;

etc.



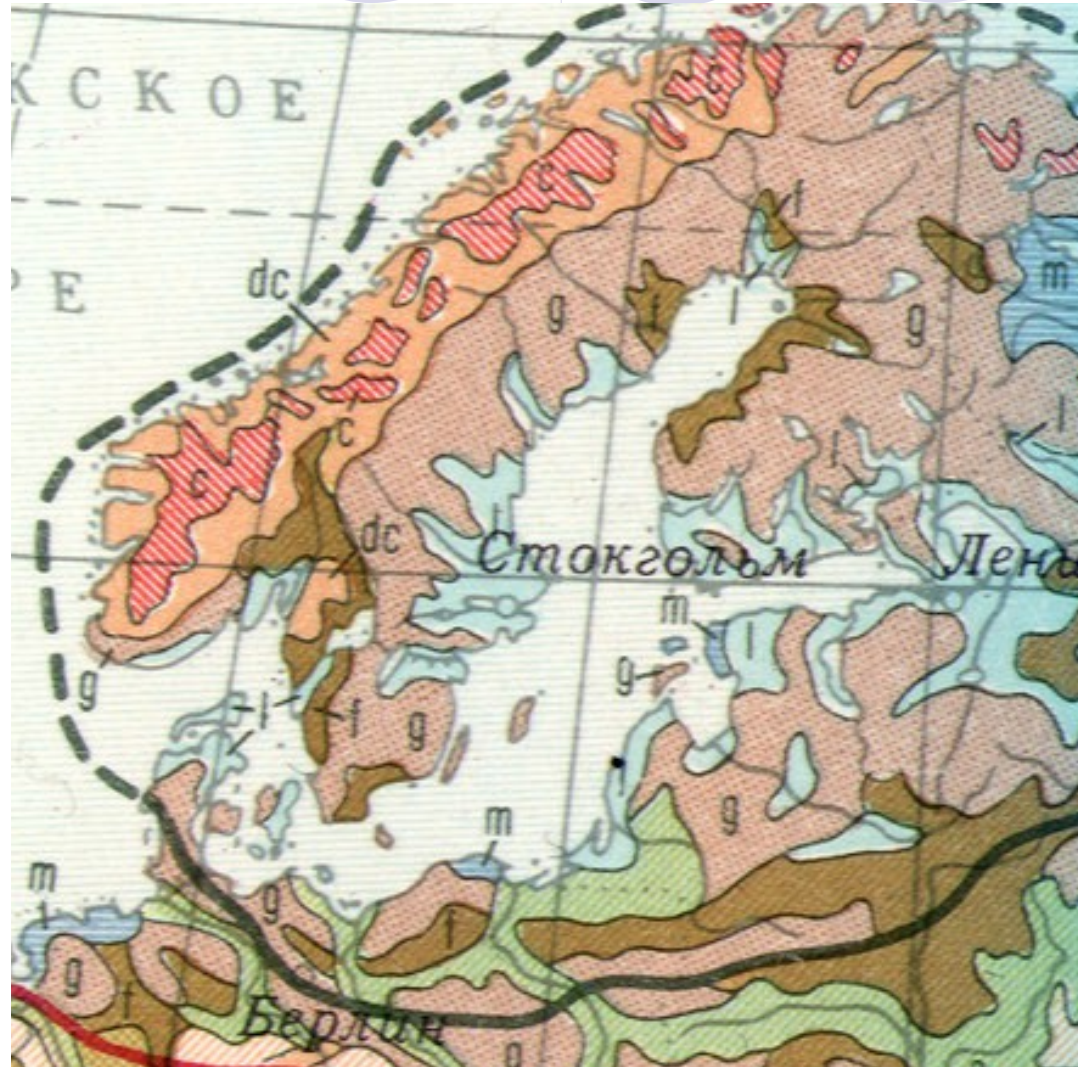
World map of quaternary deposits

Activities of the glaciers, their melting:

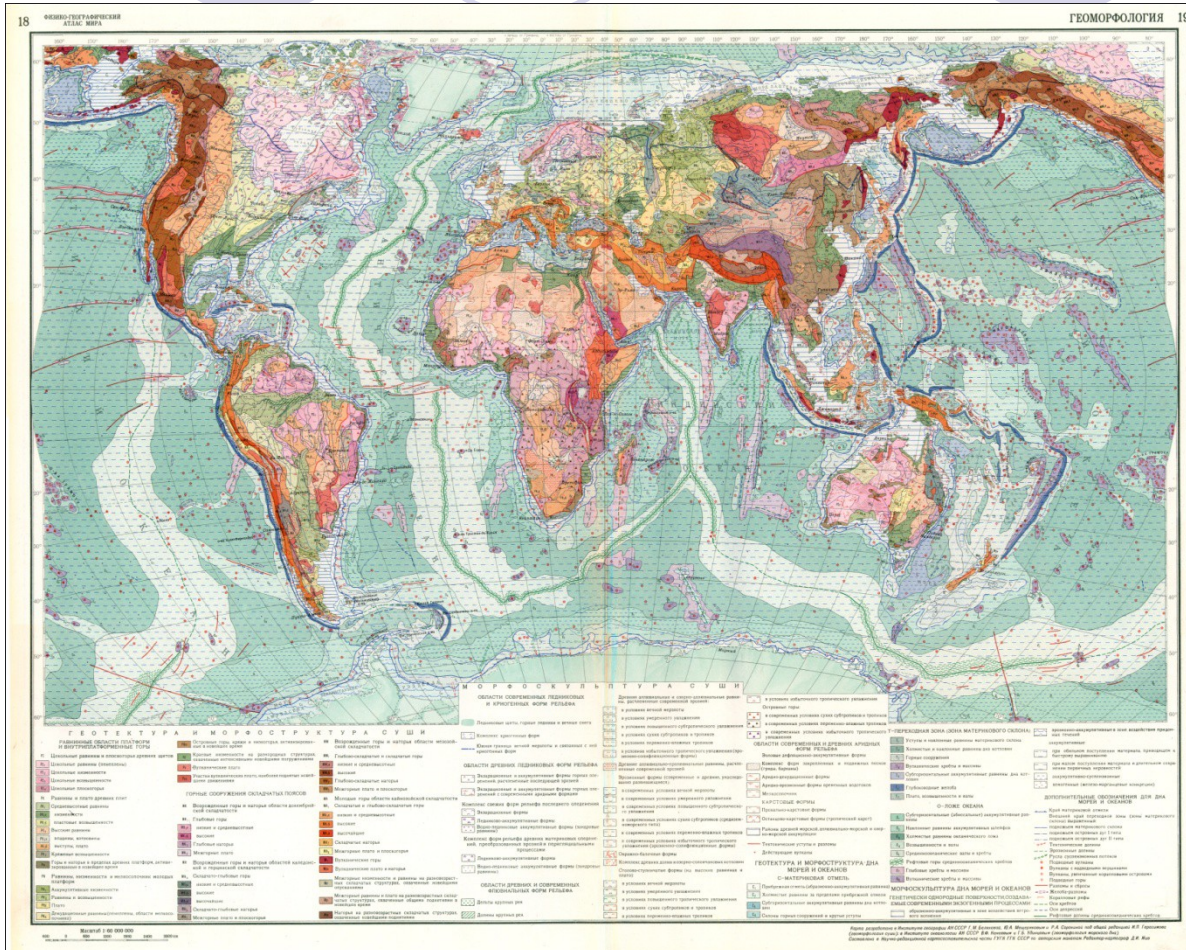
Glacial quaternary deposits;

Marine quaternary deposits;

Fluvioglacial quaternary deposits.



Geo-morphological map of the world



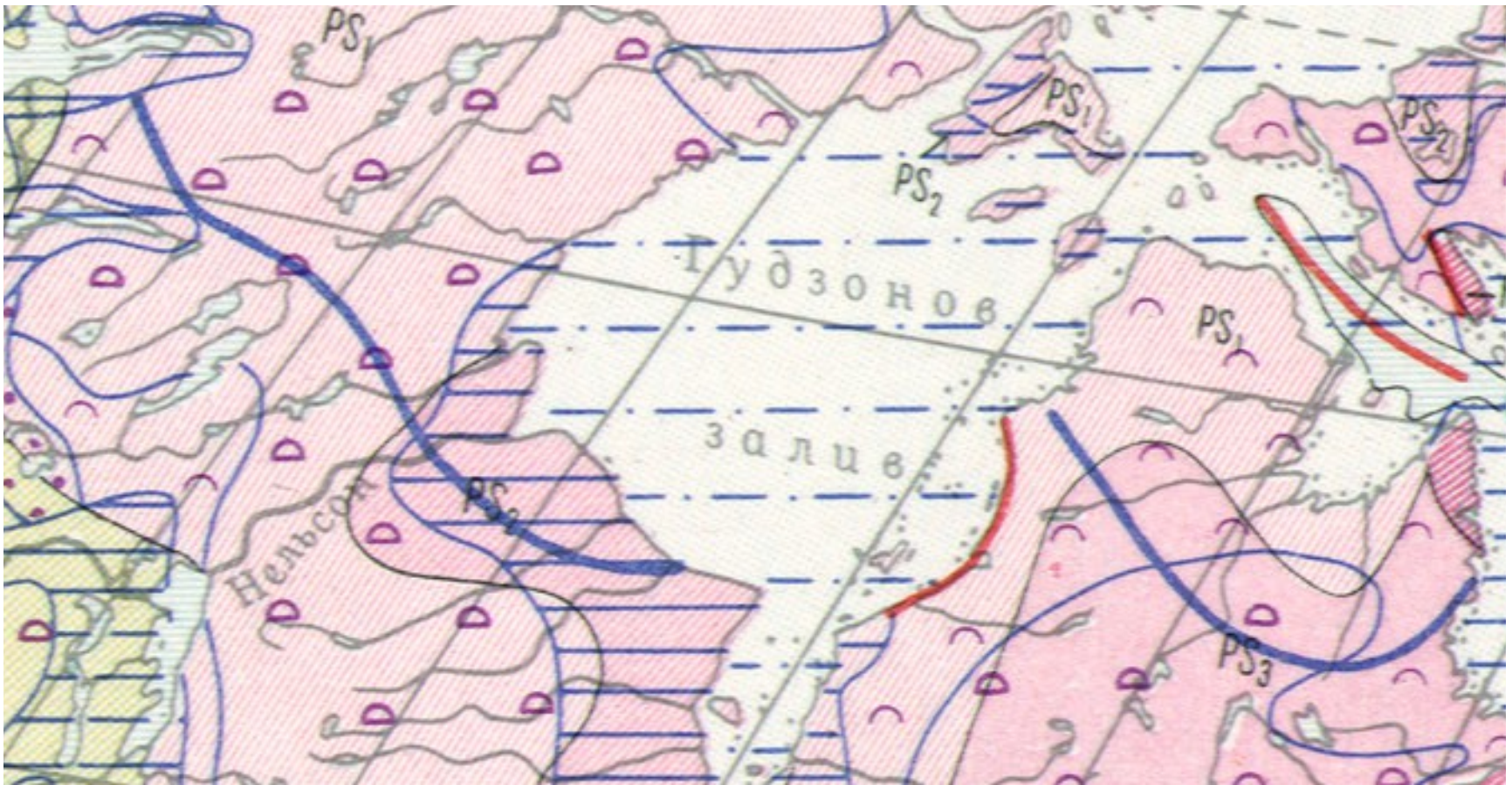
Main types of the relief;

Individual elements of the relief according to their origin;

Individual elements of the relief according to their age.

Geo-morphological map of the world

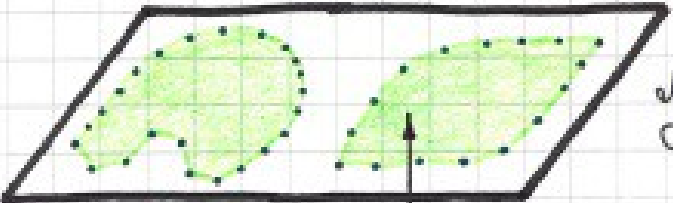
Southern boundary of the permafrost.



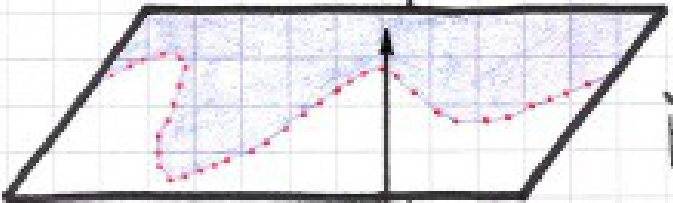


Methodology ...

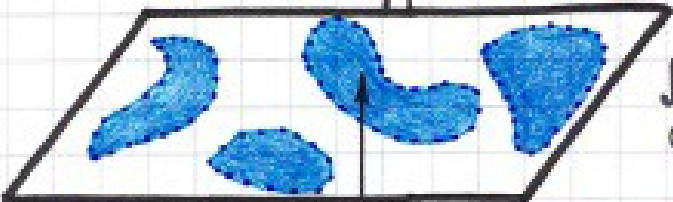
Automatically



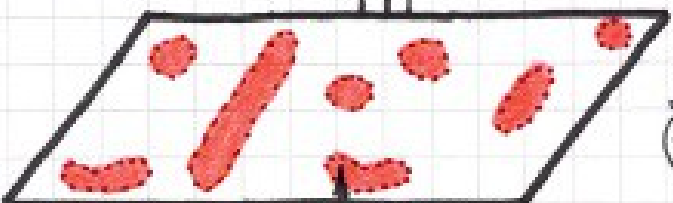
Map of plates and platforms



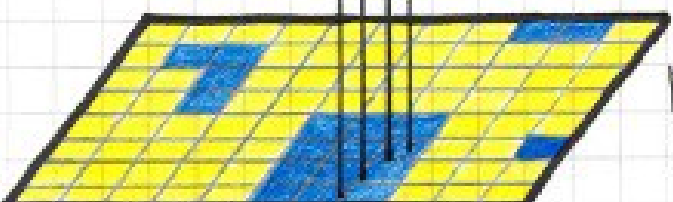
Map of permafrost



Map of quaternary deposits



Map of rocks (igneous, sedimentary)



Lakes on ECOCLIMAP

Arc GIS vector form

raster form

GLDB geo software (44 regions) with homogeneous geological origin of lakes

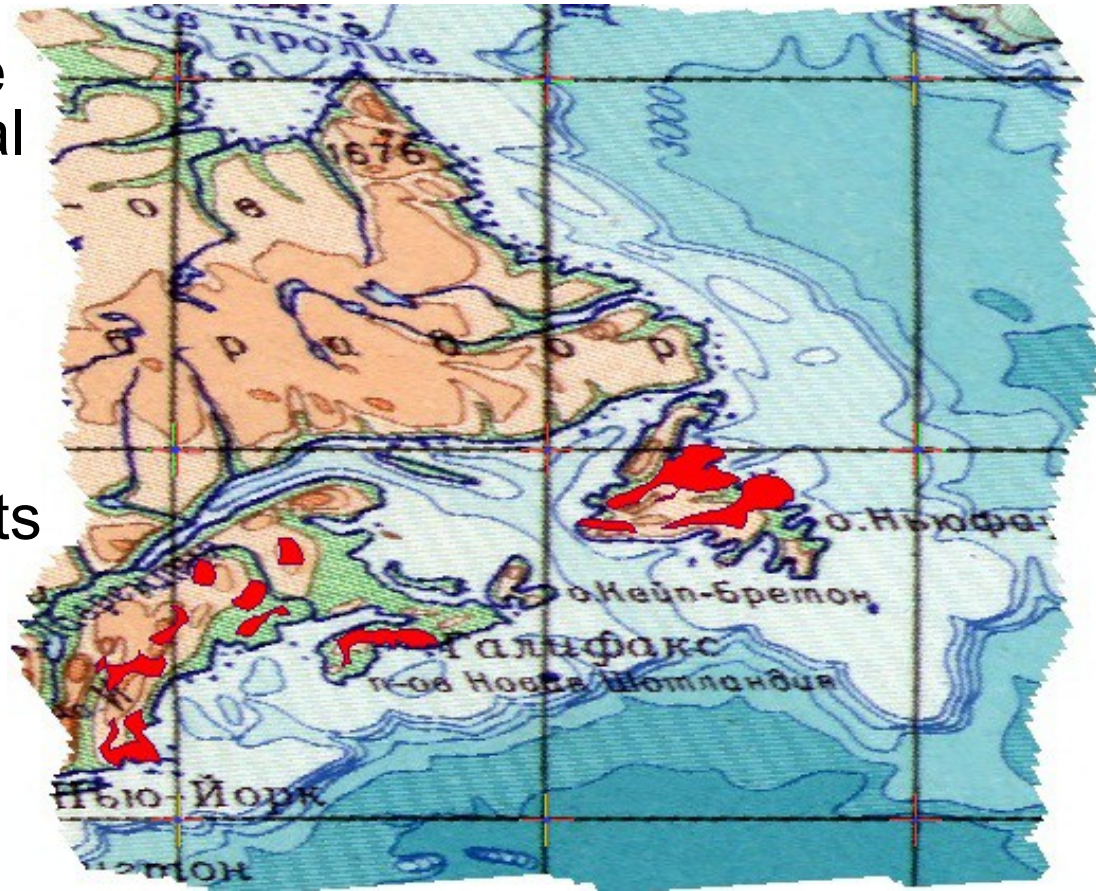
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	Numbers			Words		
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3	2	7	49	American	BaicalCaledonianFolding_1	Intersect_MagmMorsk
4	2	7	52	American	BaicalCaledonianFolding_1	Fluv
5	2	7	53	American	BaicalCaledonianFolding_1	Ledn
6	2	7	54	American	BaicalCaledonianFolding_1	Magm
7	2	7	56	American	BaicalCaledonianFolding_1	Morsk
8	2	7	57	American	BaicalCaledonianFolding_1	Osad
9	2	8	55	American	BaicalCaledonianFolding_2	Merzlota
10	2	9	53	American	Fault_1	Ledn
11	2	9	57	American	Fault_1	Osad
12	2	10	54	American	Fault_3	Magm
...
134	3	41	56	Euroasia n	PrecambrianPlatform_Shield_ 2	Morsk
135	3	41	57	Euroasia n	PrecambrianPlatform_Shield_ 2	Osad
136	4	0	42	LavaPlateau_Ocean		Intersect_FluvMerzlota
137	4	0	43	LavaPlateau_Ocean		Intersect_LednMerzlota
138	4	0	45	LavaPlateau_Ocean		Intersect_MagmFluvMerzlota
139	4	0	47	LavaPlateau_Ocean		Intersect_MagmLednMerzlot a
140	4	0	48	LavaPlateau_Ocean		Intersect_MagmMerzlota

Example of the allocated region

№	Adress					
	Numbers			Words		
	Plate	Platform	Layer	Plate	Platform	Layer
2	2	7	46	American	BaikalCaledonianFolding_1	Intersect_MagmLedn

- The region belongs to the American plate, the Baikal and Caledonian orogeny area.

- There are igneous (crystalline) rocks with glacial quaternary deposits and without permafrost.

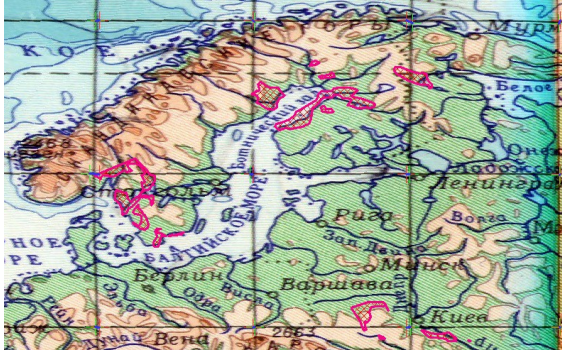




- For each allocated region, the lake depths statistics from GLDB was collected and analyzed .
- Lake depths histograms were drawn.
- The maximum of the histogram was considered as mostly probable (typical) lake depth.

According to this, an expert decision about typical lake depth was made.

Example of statistical analysis



3 – 41 – 52

Eurasian plate,
Precambrian platform
shield

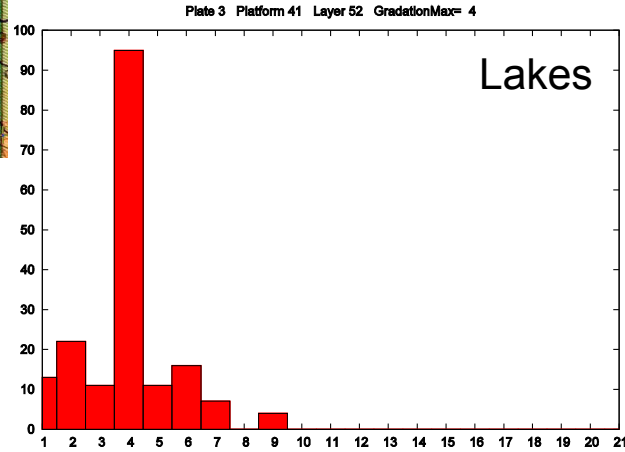
Fluvioglacial
quaternary deposits

Sedimentary rocks

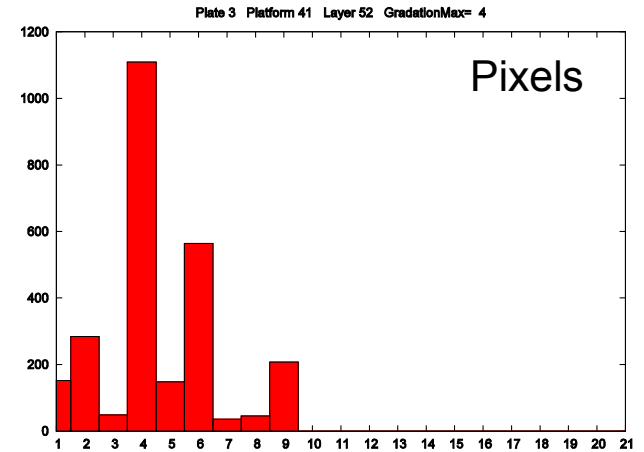
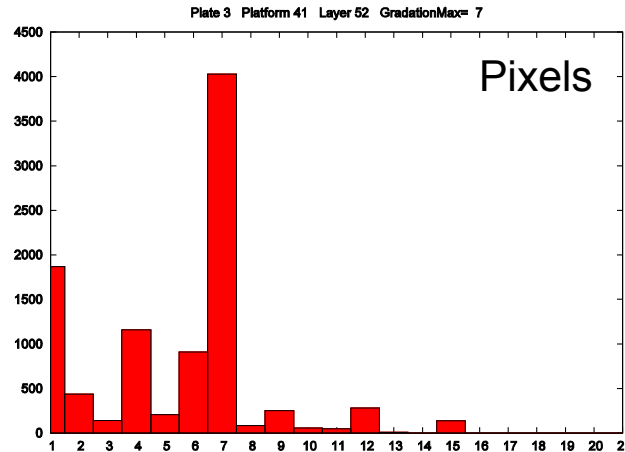
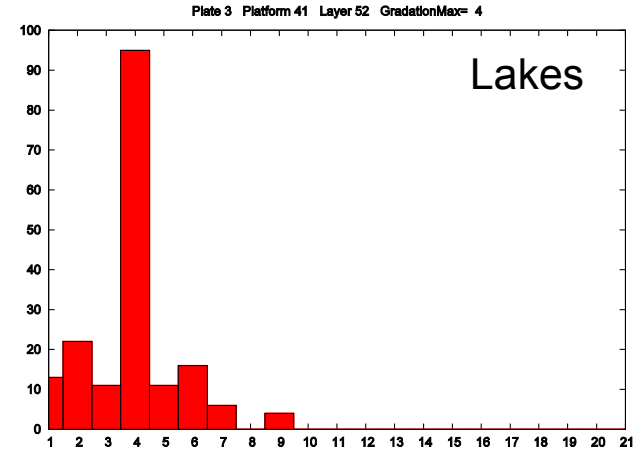
No permafrost

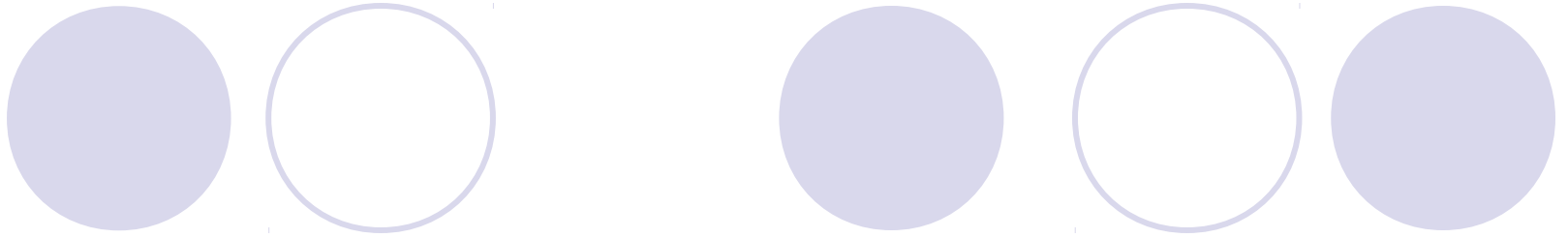
Lake pixels distribution
indirectly takes into
account lake areas.

All lakes



Lakes with an area of less than 200 km²





- If in some regions the statistics were not enough to make a decision about the typical lake depth. Method of analogies was used.
- Kitaev's and Doganovsky's methods were also involved.

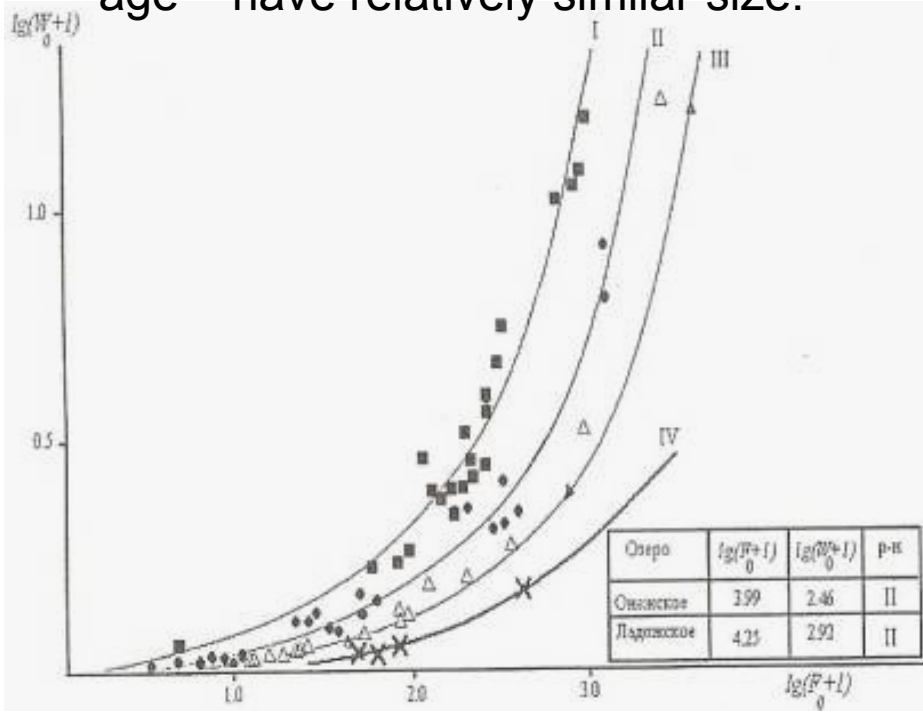
Method of analogies

Extrapolation of statistics using geological knowledge – sufficient statistics for a decision about the “default” depth of one region, not enough in another.

- Regions with glacial, marine and fluvioglacial quaternary deposits of one plate are regions-analogues and may be combined.
- Platform cases of one plate are regions-analogues and may be combined.
- Precambrian shields of different plates are regions-analogues and may be combined .
- Orogenies of one plate are regions-analogues and may be compared.

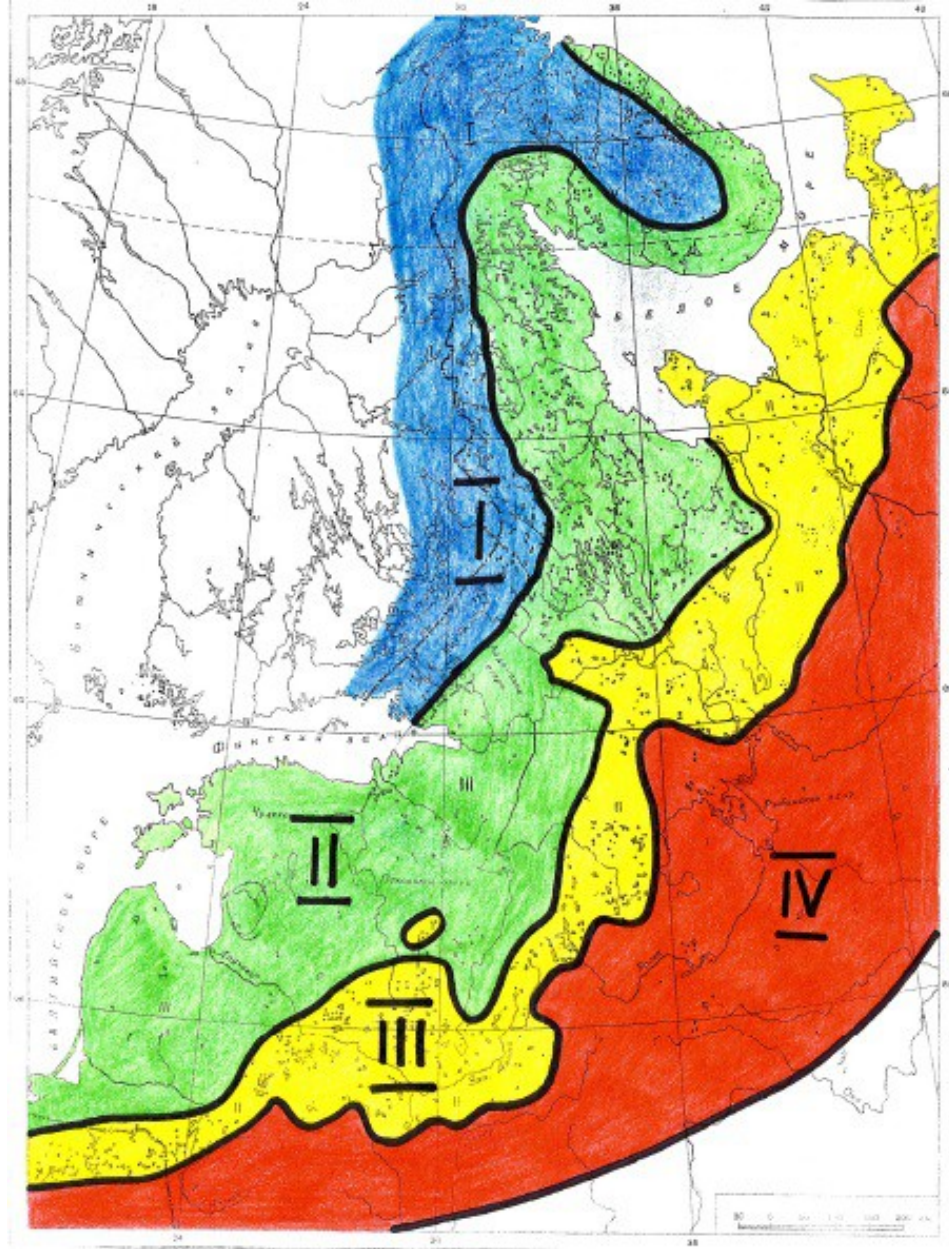
Doganovsky's method

Water basins of the same origin, same age – have relatively similar size.



Lake volume is logarithmically dependent of the lake area.

$$y = ax^m \cdot e^{x-1}$$



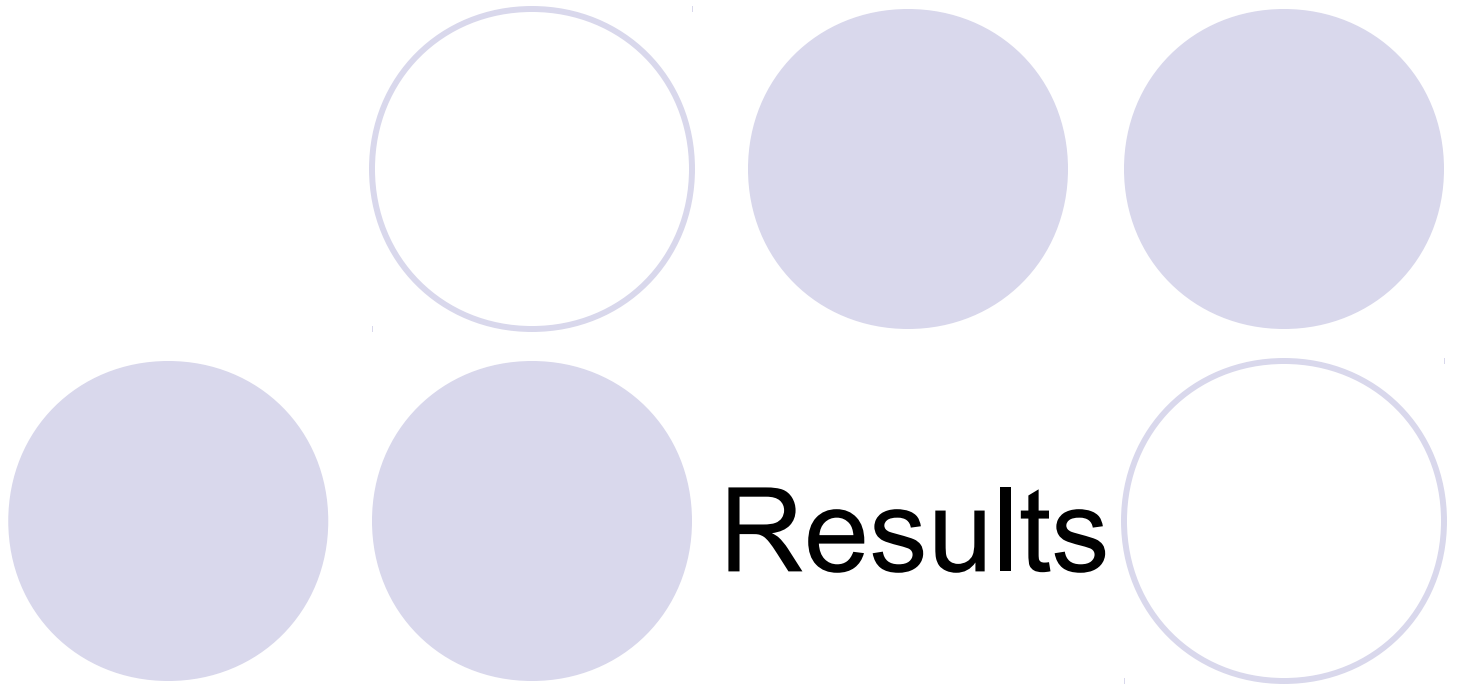
High reliability;
Developed only for some small areas (by now).

Kitaev's method

Geographical zones.

Lake area, km ²	Tundra	Northern taiga	Middle taiga	Mixed forest
< 1,0	1,93	4,67	3,90	5,49
1,0 - 5,0	3,14	4,83	4,02	5,67
5,0 - 10,0	4,96	4,05	5,48	5,92
10,0 - 50,0	6,23	5,19	6,37	5,40
> 50,0	3,50	10,35	6,21	6,37

Method has low accuracy and is applicable only for small lakes.

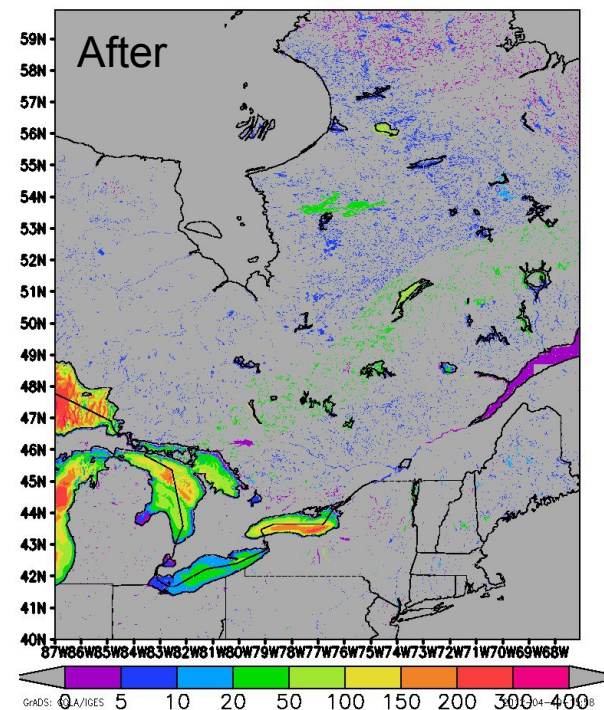
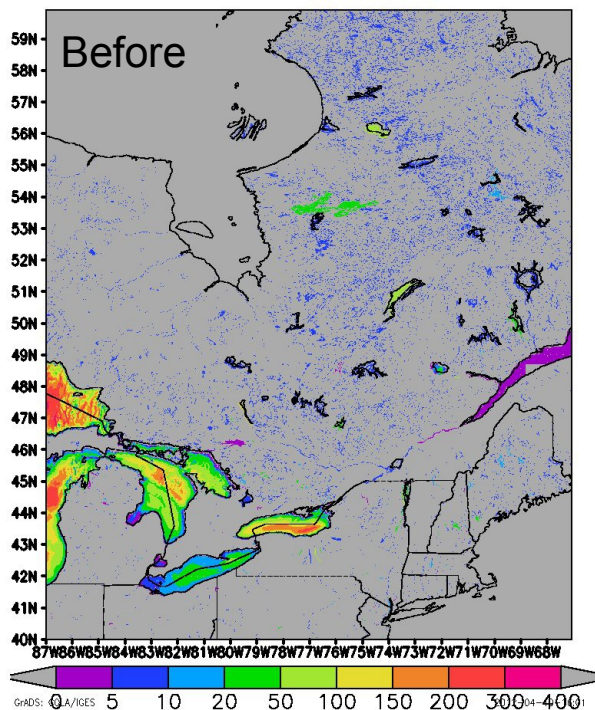
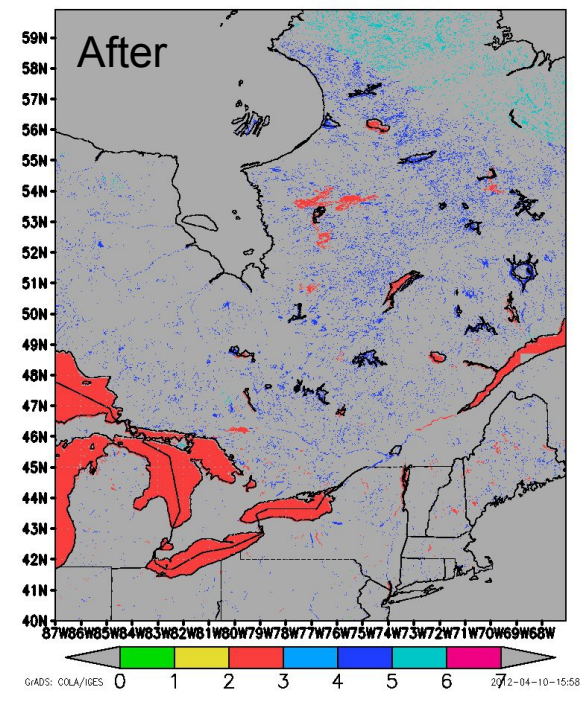
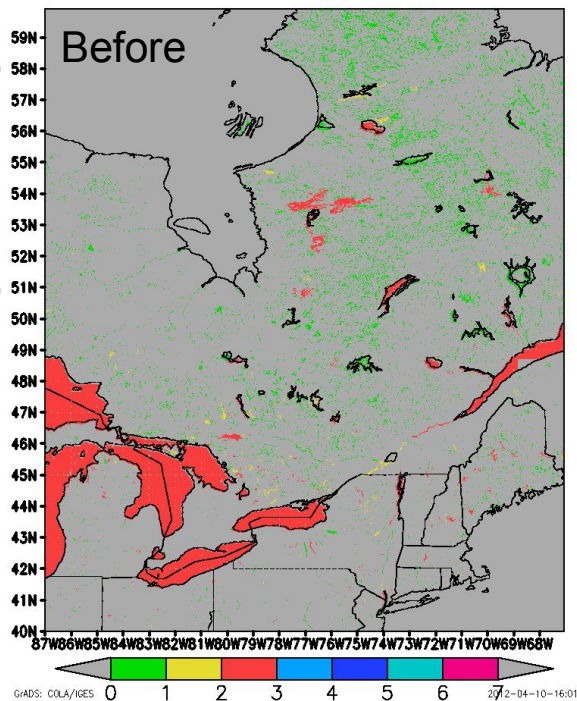


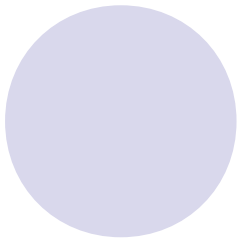
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3	2	7	49	American	BaicalCaledonianFolding_1	Intersect_MagmMorsk	7
4	2	7	52	American	BaicalCaledonianFolding_1	Fluv	10
5	2	7	53	American	BaicalCaledonianFolding_1	Ledn	10
6	2	7	54	American	BaicalCaledonianFolding_1	Magm	5
7	2	7	56	American	BaicalCaledonianFolding_1	Morsk	10
8	2	7	57	American	BaicalCaledonianFolding_1	Osad	10
9	2	8	55	American	BaicalCaledonianFolding_2	Merzlota	Kitaev
10	2	9	53	American	Fault_1	Ledn	22
11	2	9	57	American	Fault_1	Osad	22
12	2	10	54	American	Fault_3	Magm	10
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134	3	41	56	Euroasia n	PrecambrianPlatform_Shield_ 2	Morsk	7
135	3	41	57	Euroasia n	PrecambrianPlatform_Shield_ 2	Osad	7
136	4	0	42	LavaPlateau_Ocean		Intersect_FluvMerzlota	5
137	4	0	43	LavaPlateau_Ocean		Intersect_LednMerzlota	5
138	4	0	45	LavaPlateau_Ocean		Intersect_MagmFluvMerzlota	7
139	4	0	47	LavaPlateau_Ocean		Intersect_MagmLednMerzlot a	7
140	4	0	48	LavaPlateau_Ocean		Intersect_MagmMerzlota	3

Status:

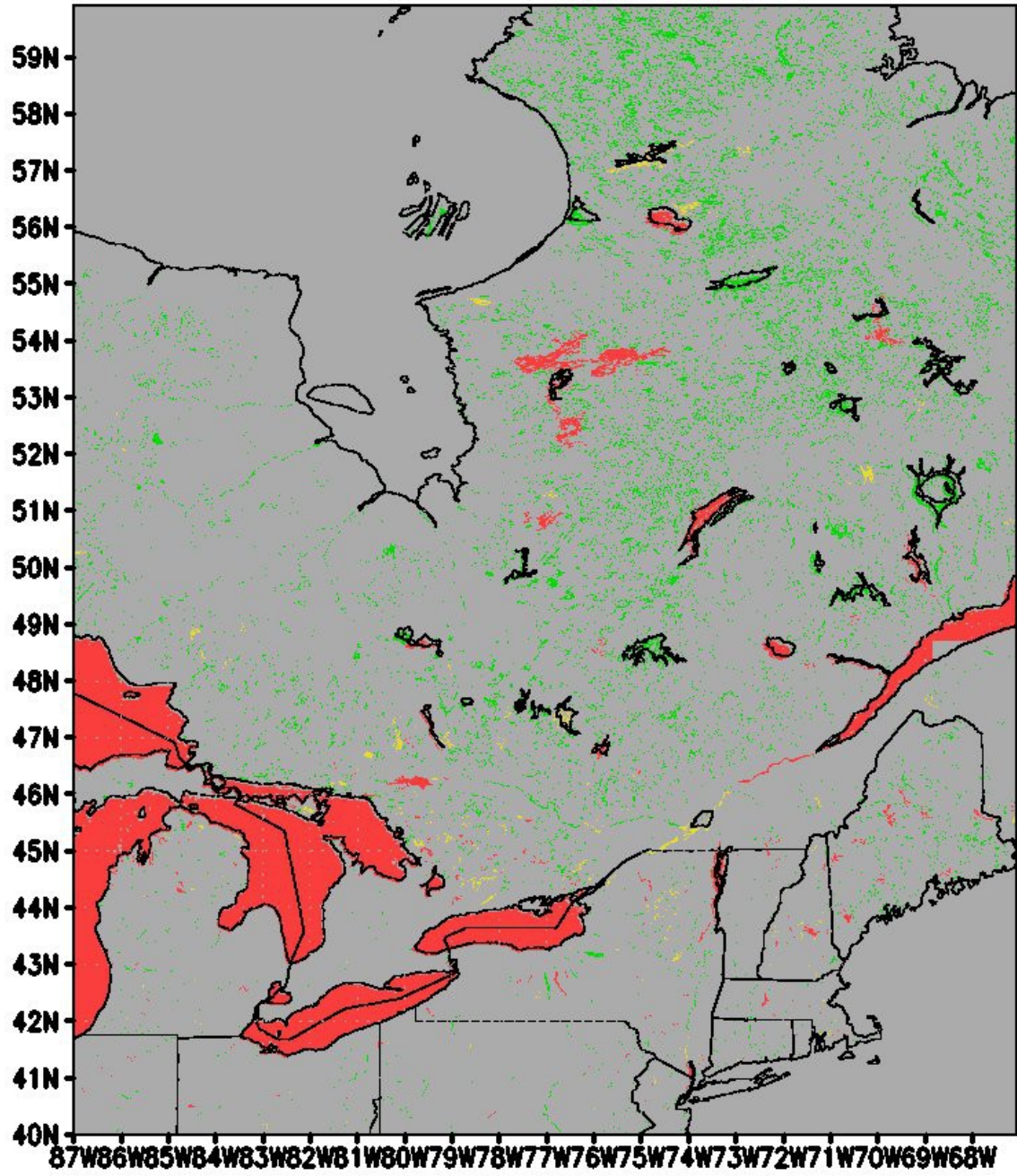
- 0 – no lake
- 1 – lake is present in ECOCLIMAP2, but is absent in the dataset for individual lakes
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- 4 – river
- 5 – mean depth is based on the expert evaluation
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- 7 – mean depth is based on the Doganovsky's method

Lake depth,
meters



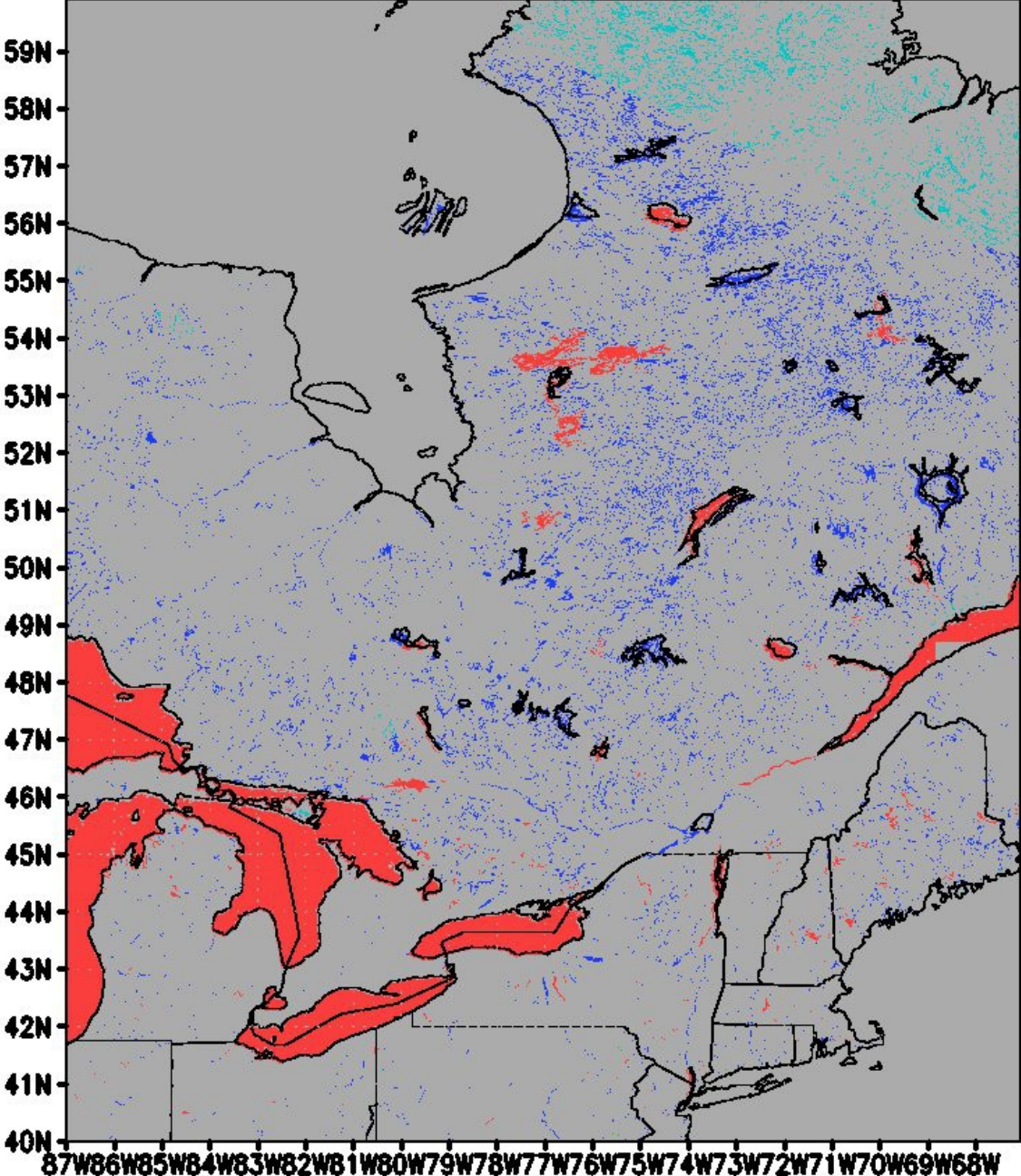


Status,
Before





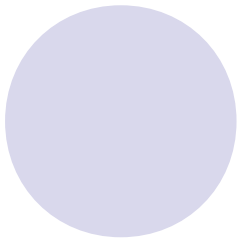
Status,
After



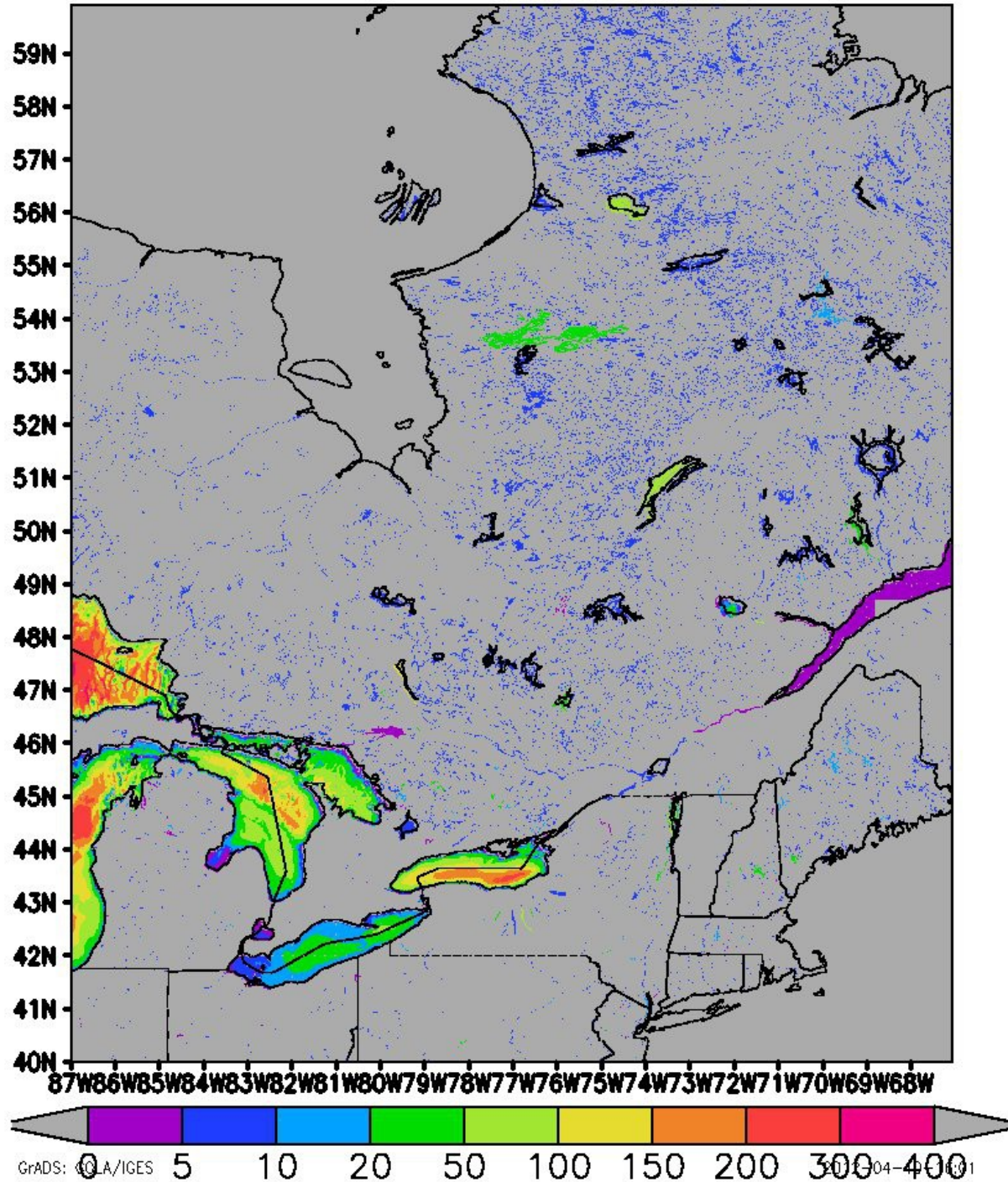
GRADS: COLA/IGES

0 1 2 3 4 5 6 7

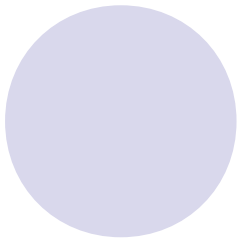
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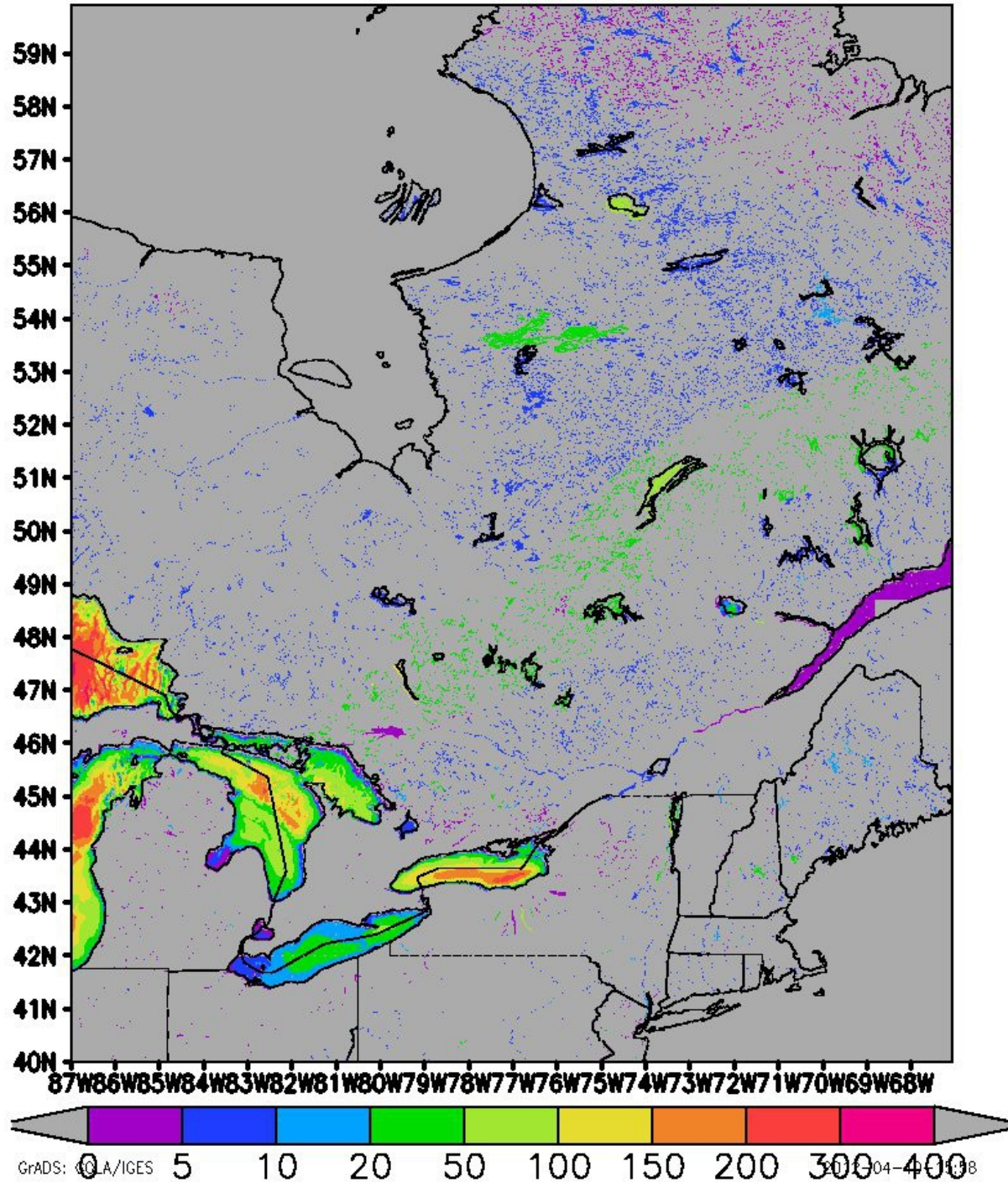
Lake depth,
Before



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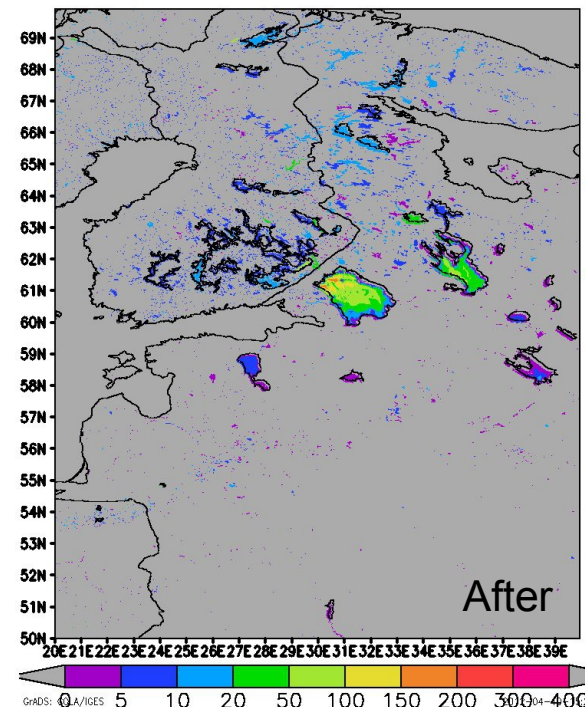
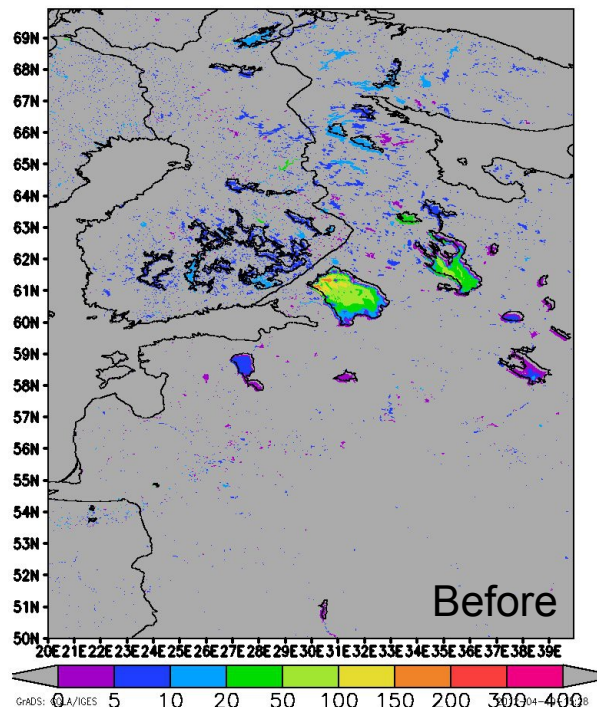
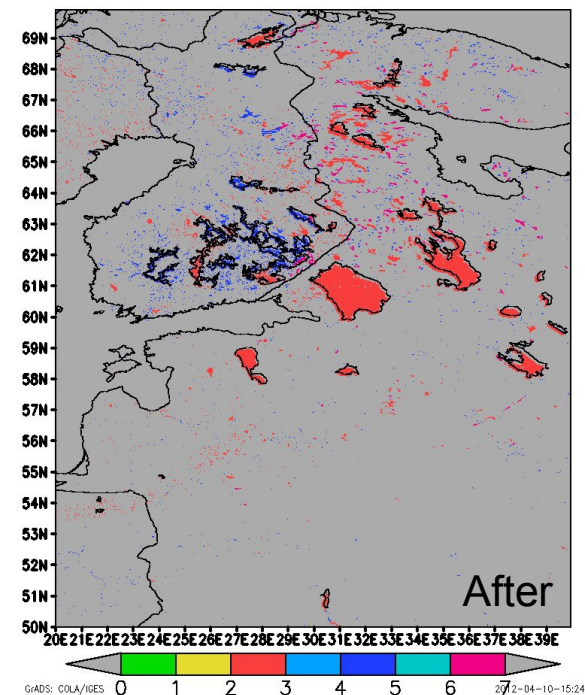
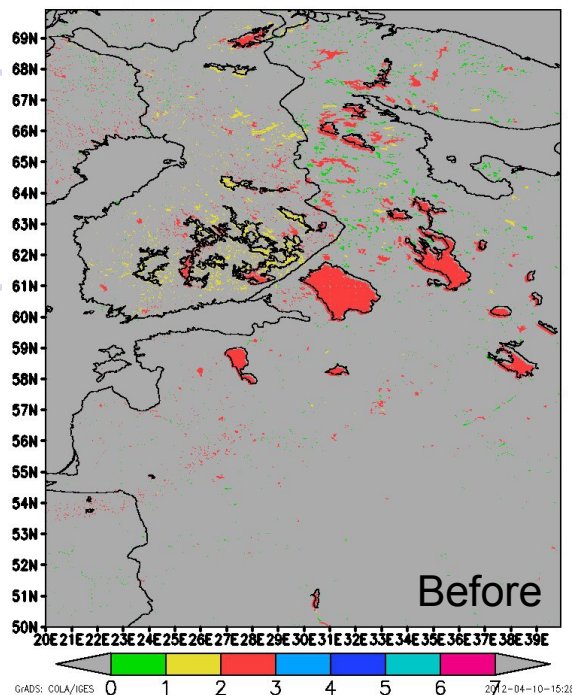
Lake depth,
After

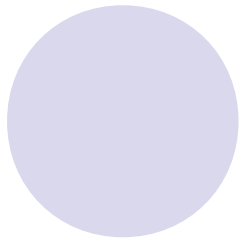


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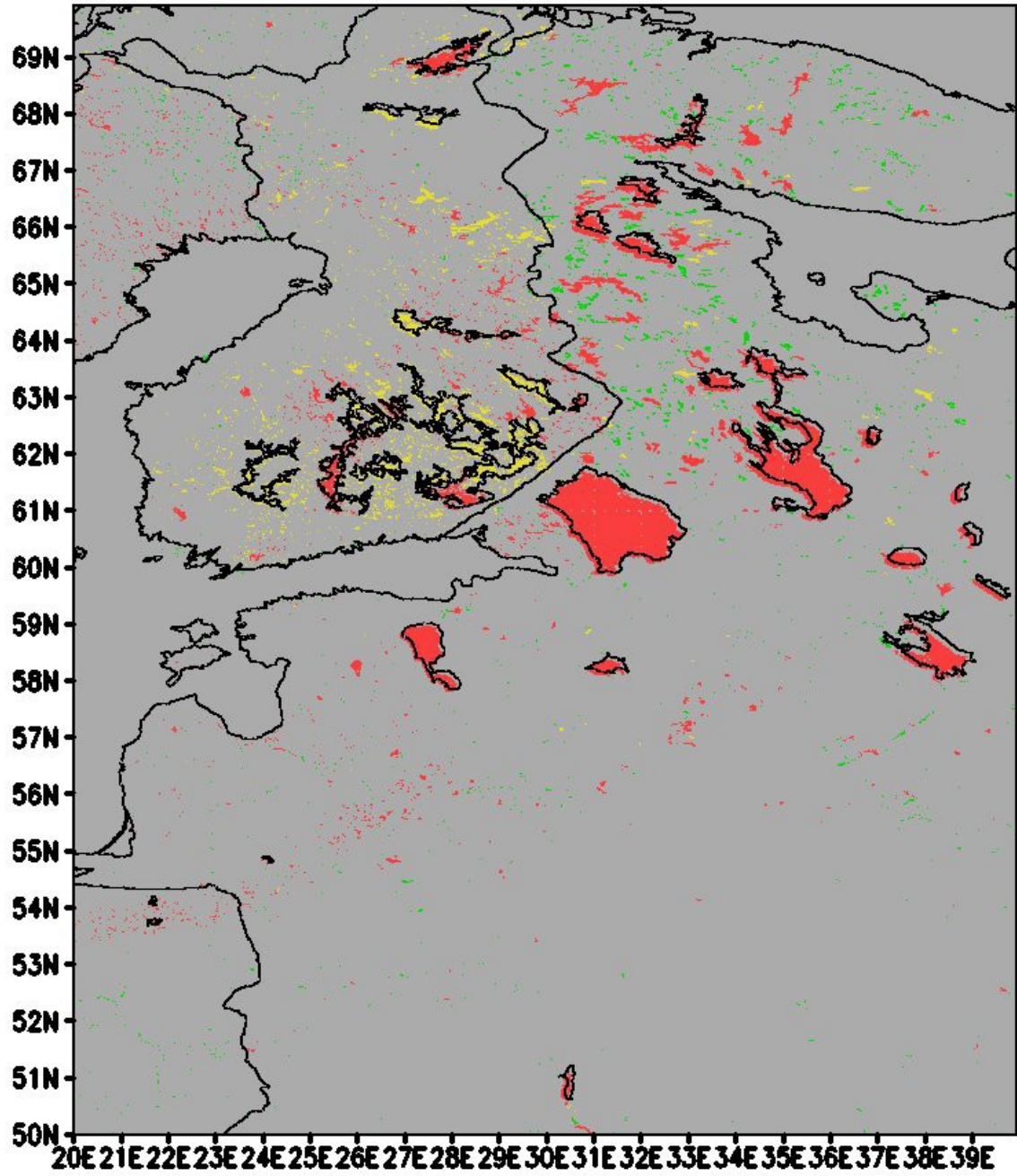
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Lake depth,
meters



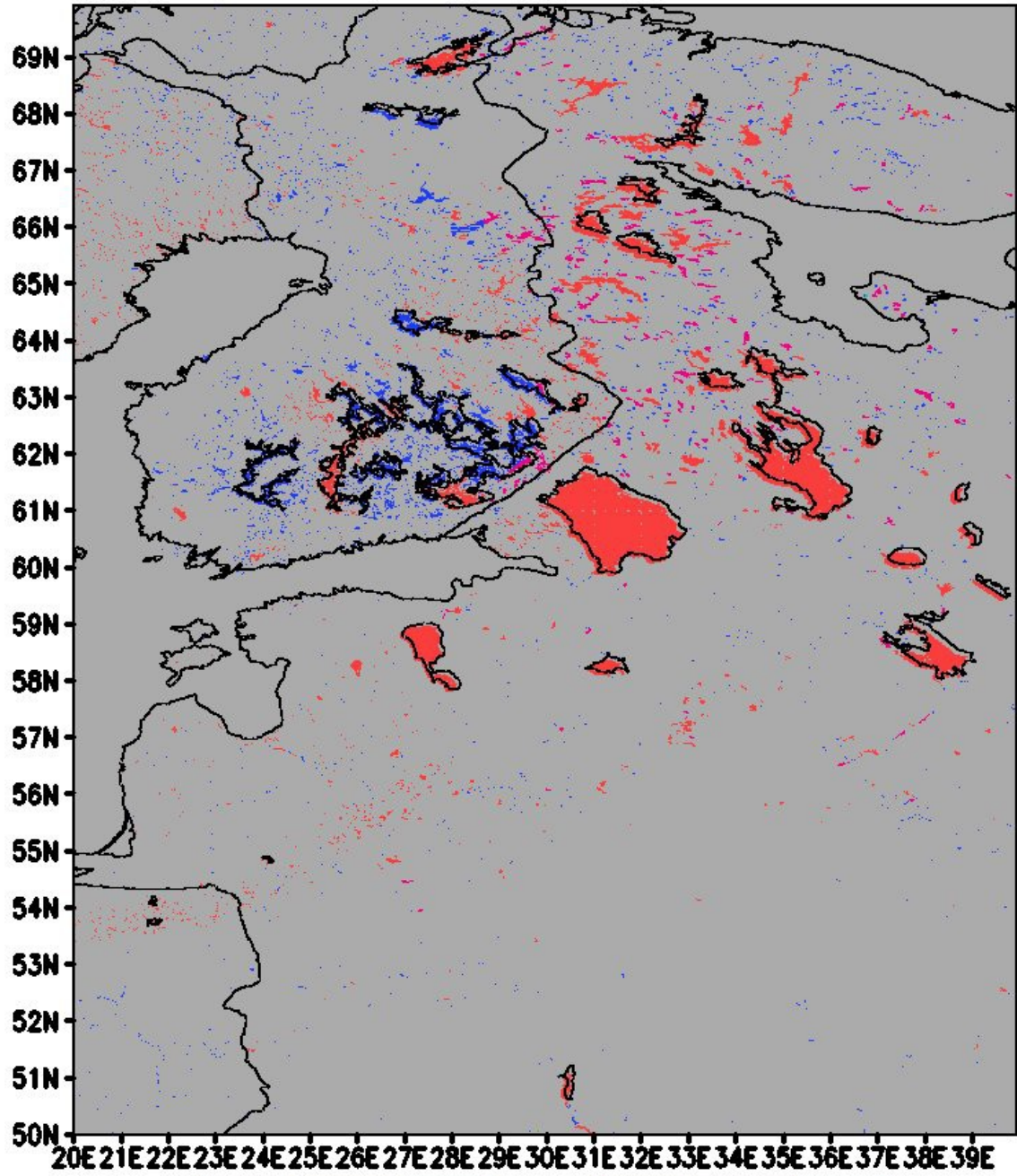


Status,
Before



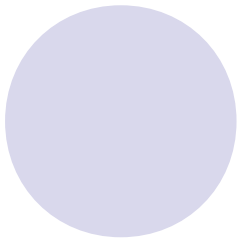


Status,
After

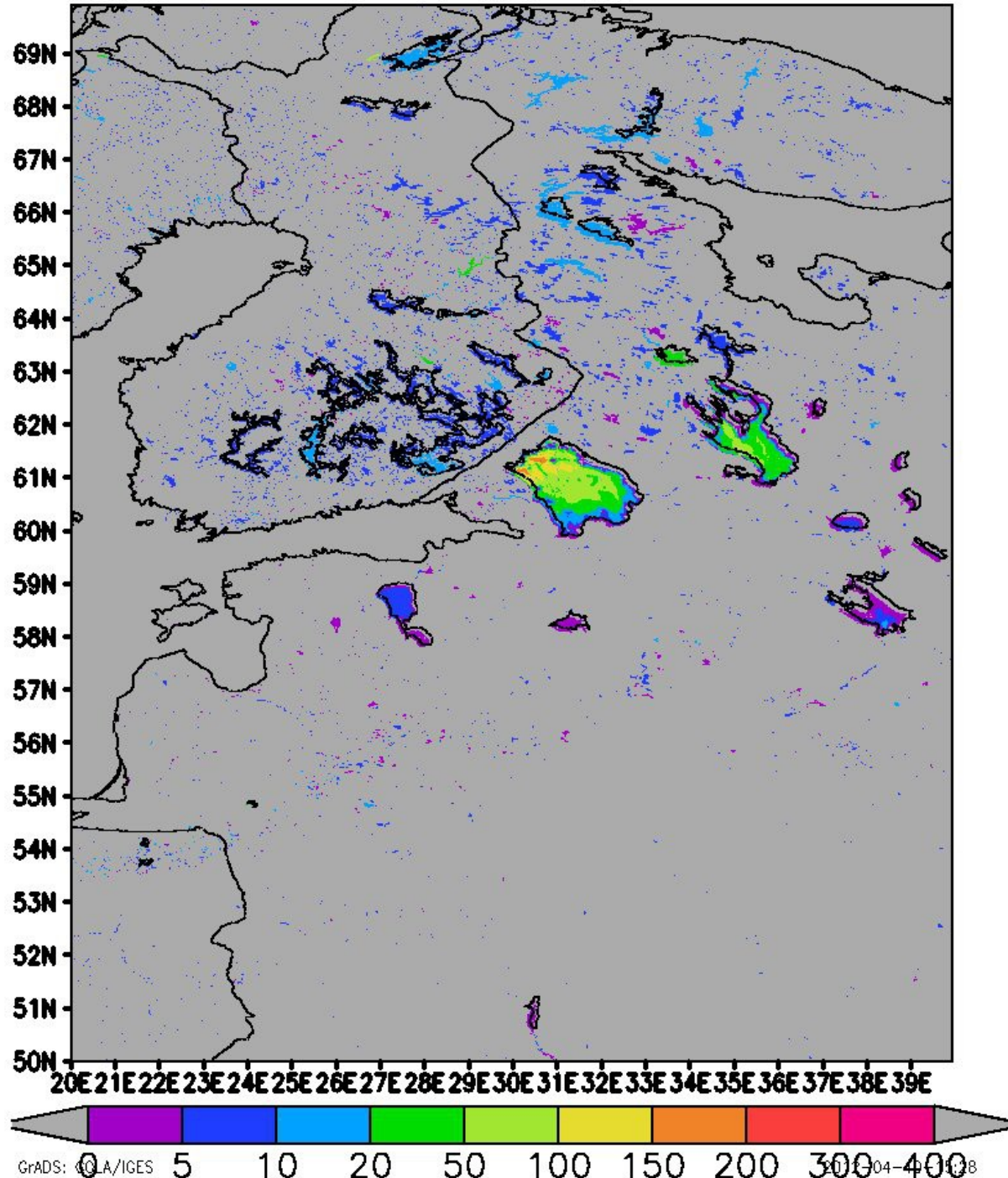


GrADS: COLA/IGES

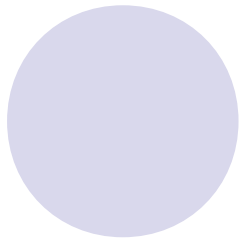
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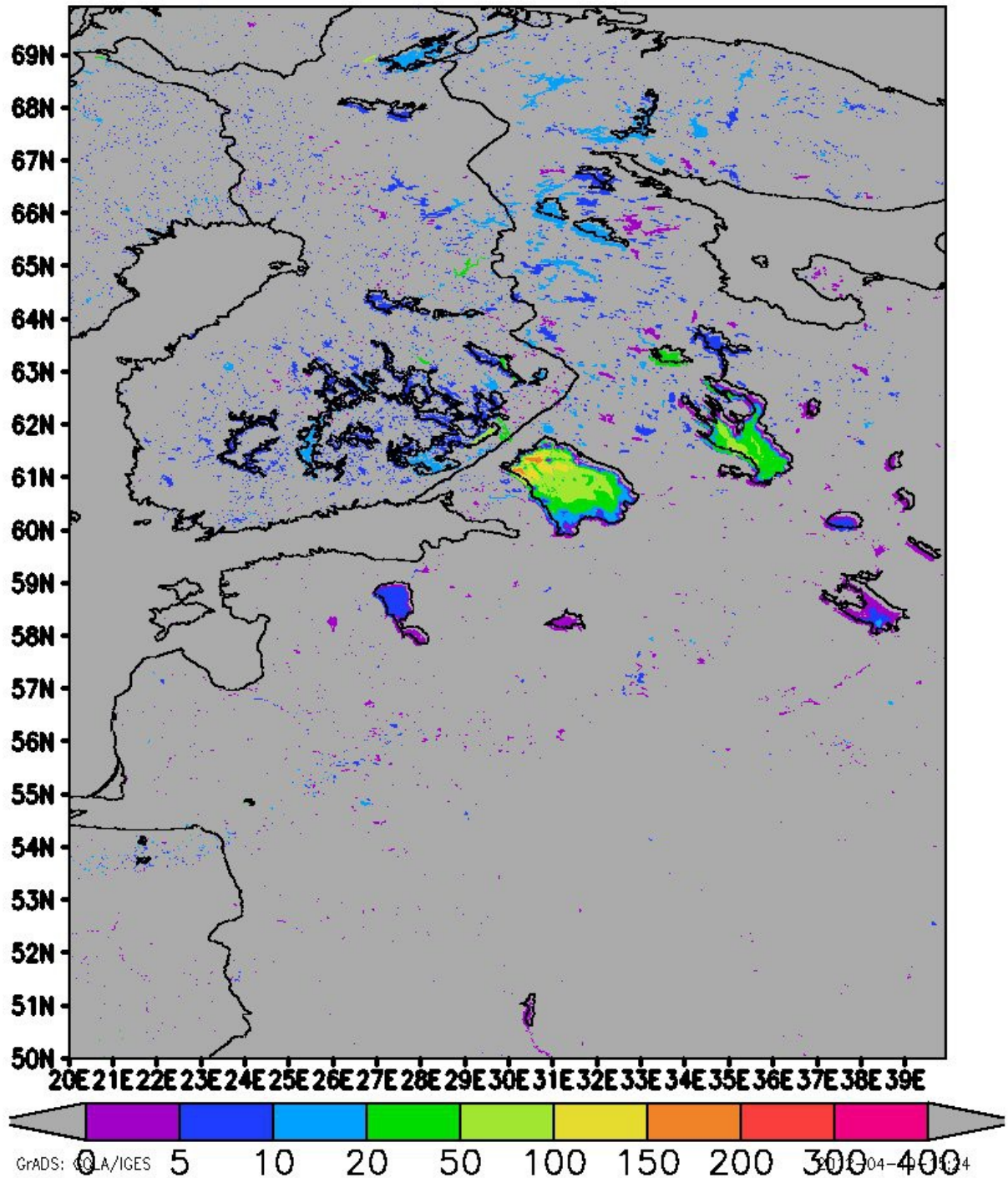
Lake depth,
Before



GRADS: 00LA/IGES 5 10 20 50 100 150 200 300 400



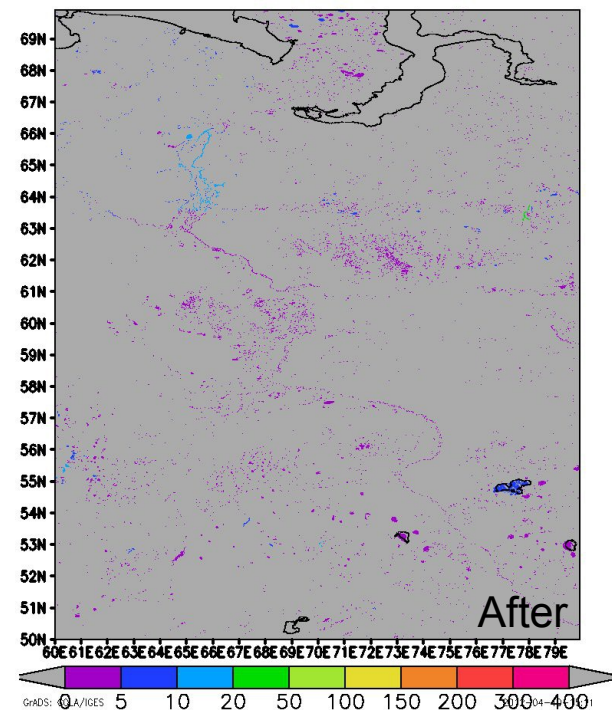
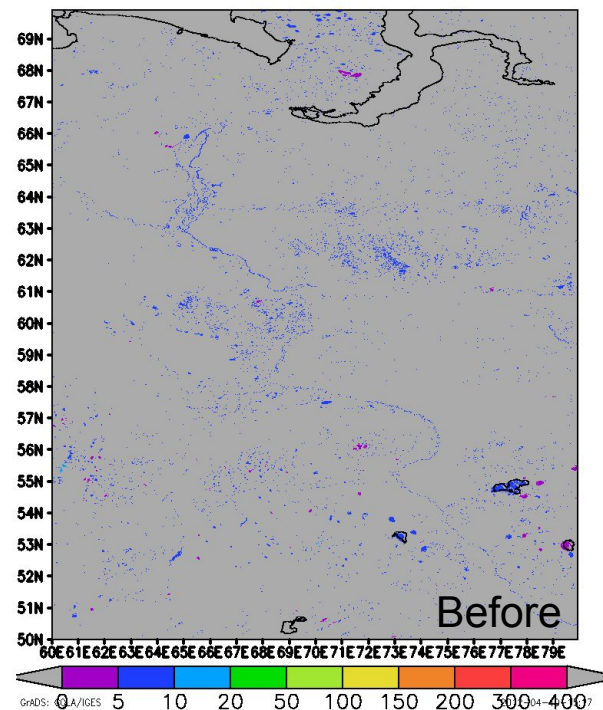
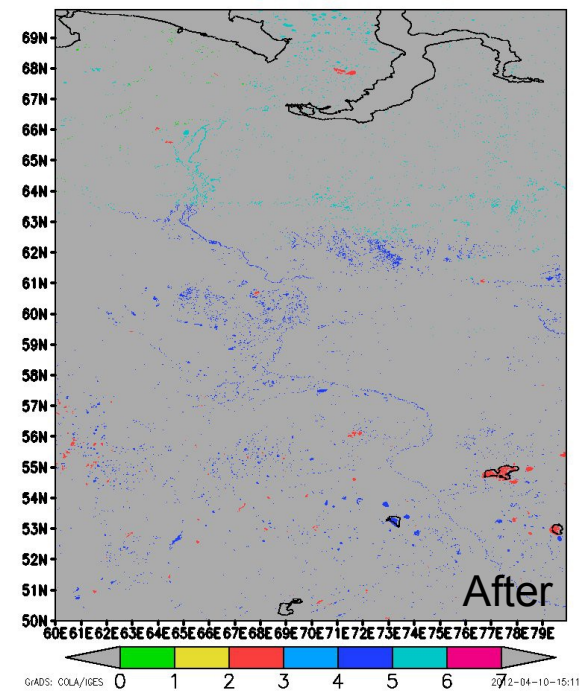
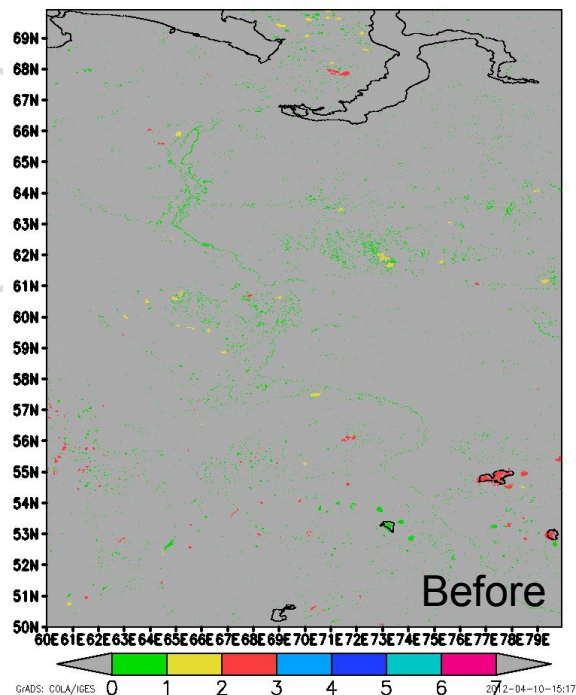
Lake depth,
After

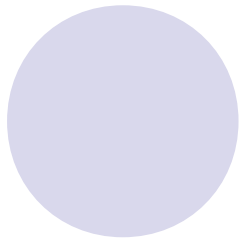


Status:

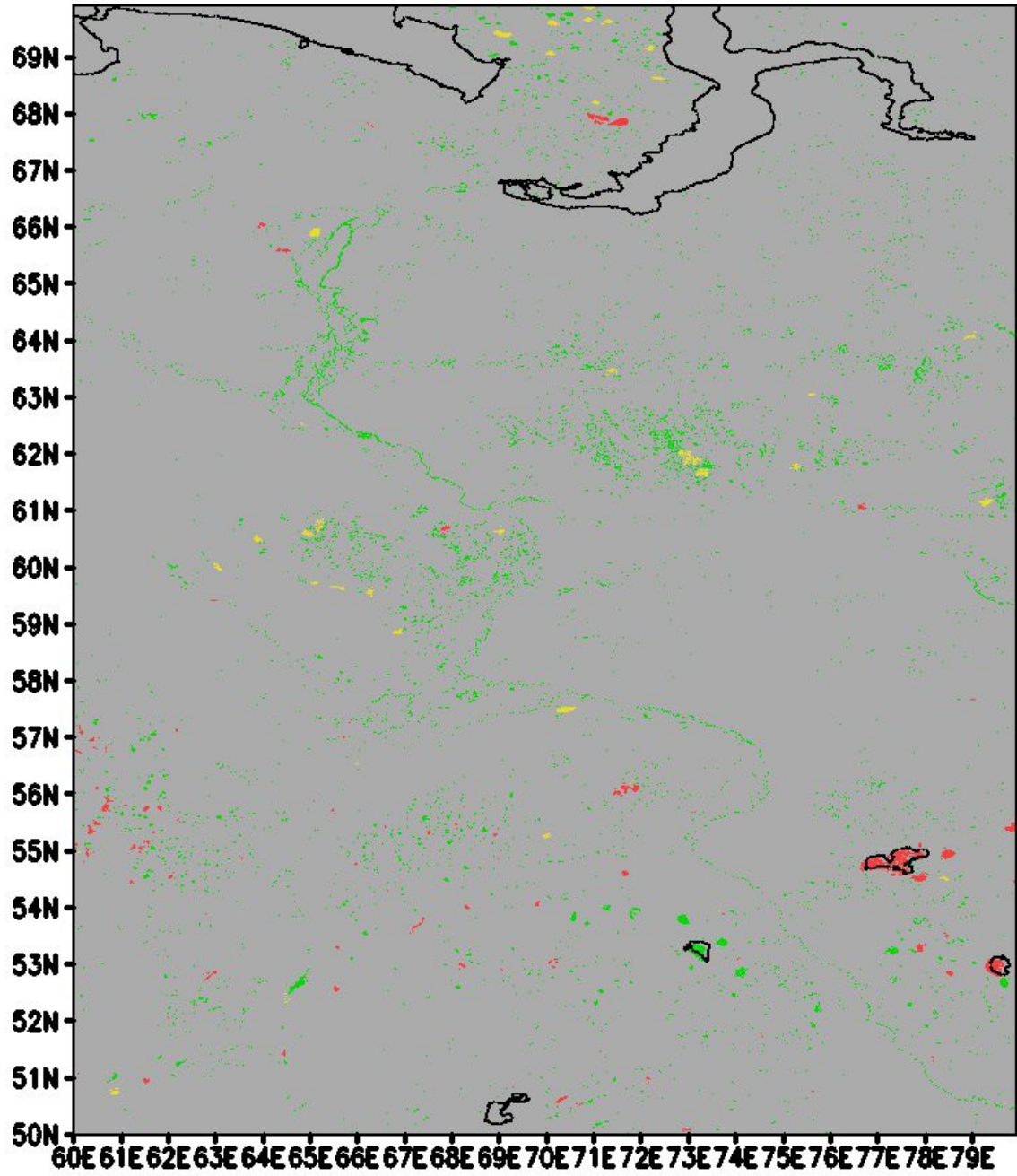
- 0 – no lake
- 1 – lake is present in ECOCLIMAP2, but is absent in the dataset for individual lakes
- 2 - lake is present in ECOCLIMAP2 and in the dataset for individual lakes, but with missing mean depth data
- 3 - lake is present in ECOCLIMAP2 and in the dataset for individual lakes with mean depth data
- 4 – river
- 5 – mean depth is based on the expert evaluation
- 6 – mean depth is based on the Kitaev's method
- 7 – mean depth is based on the Doganovsky's method

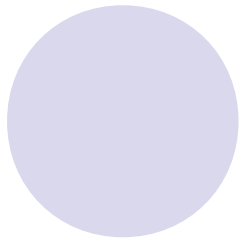
Lake depth,
meters



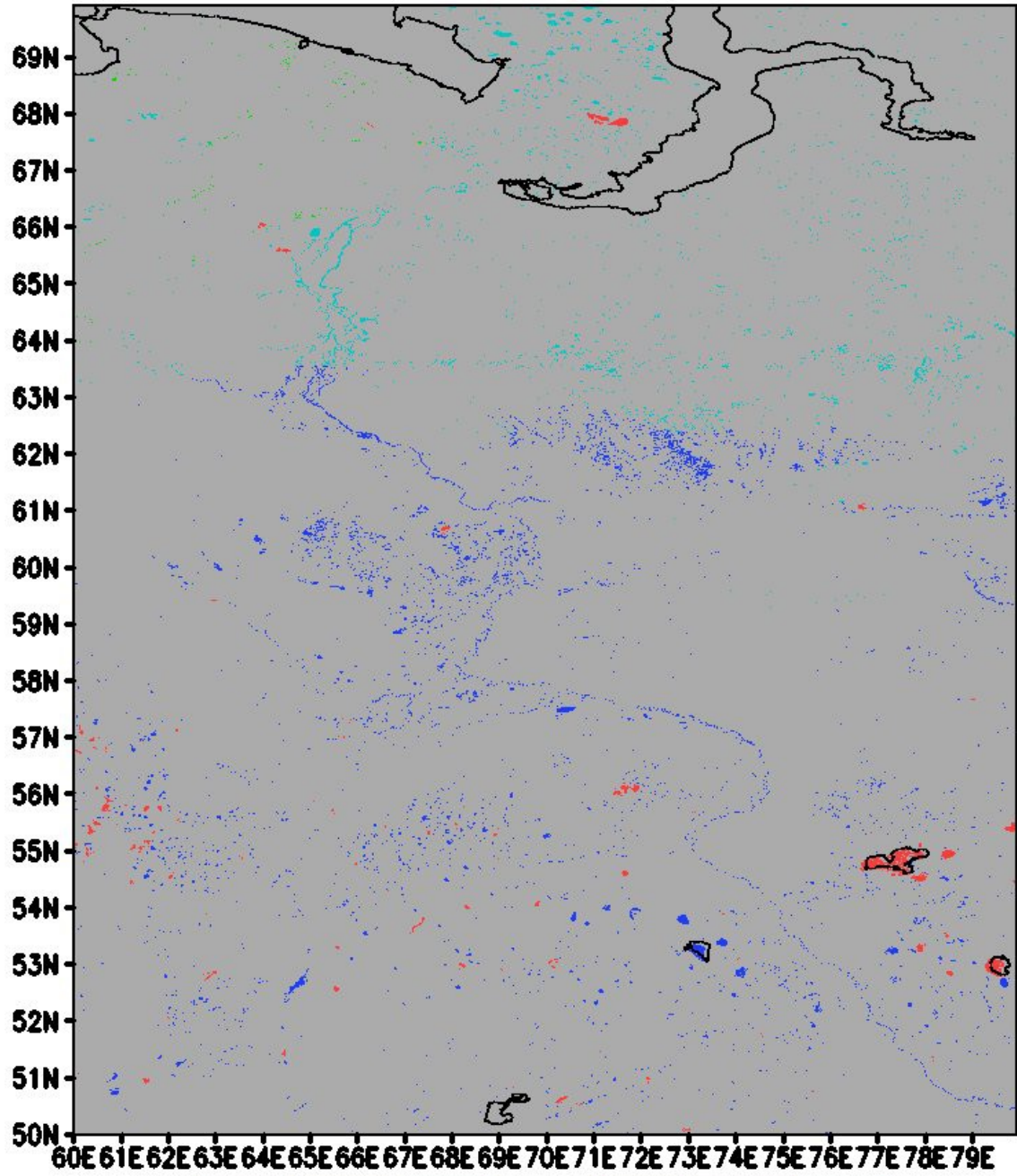


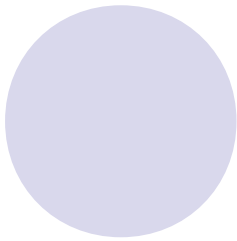
Status,
Before



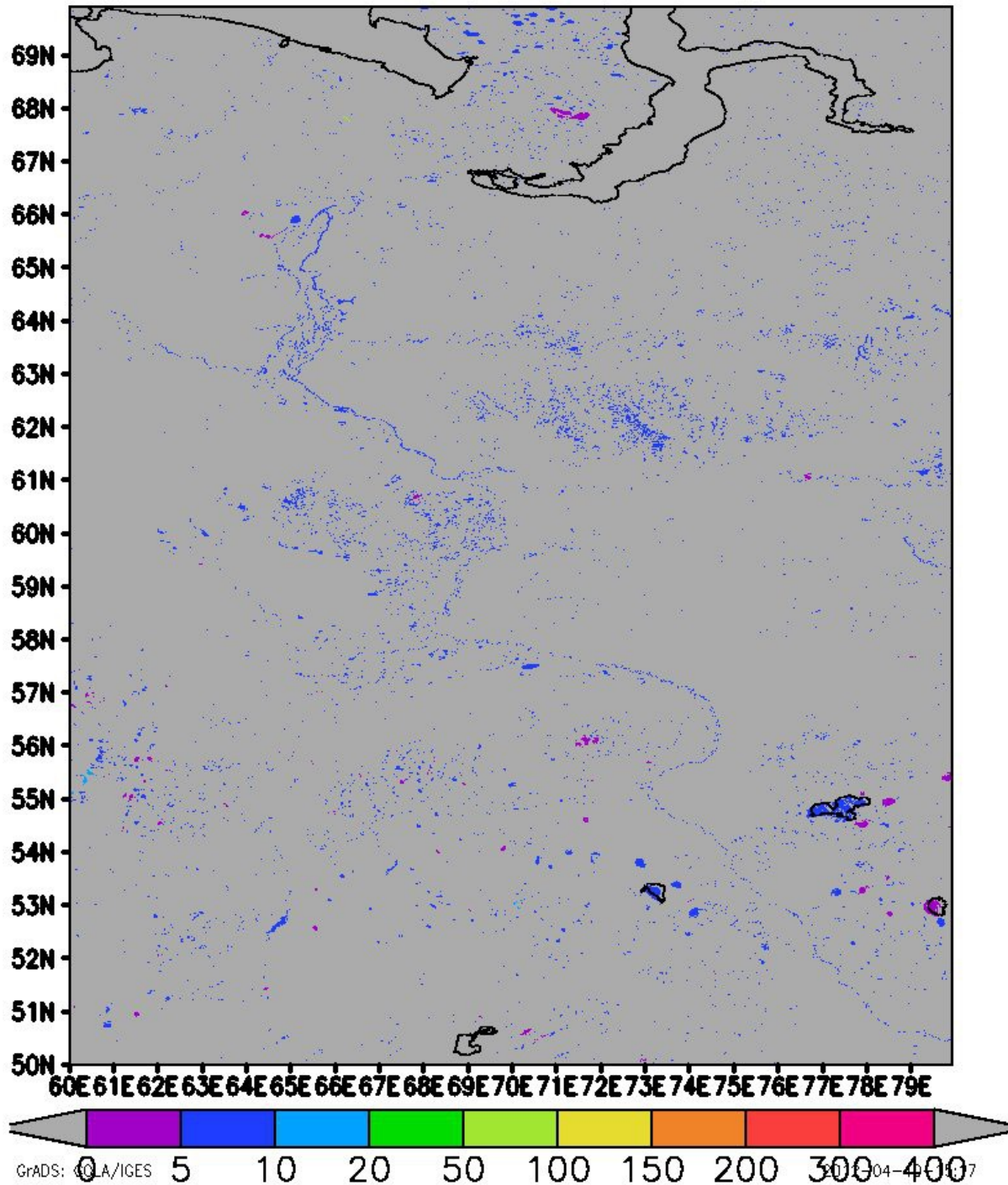


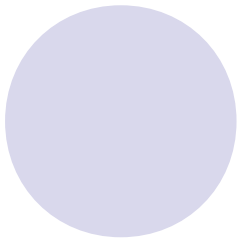
Status,
After



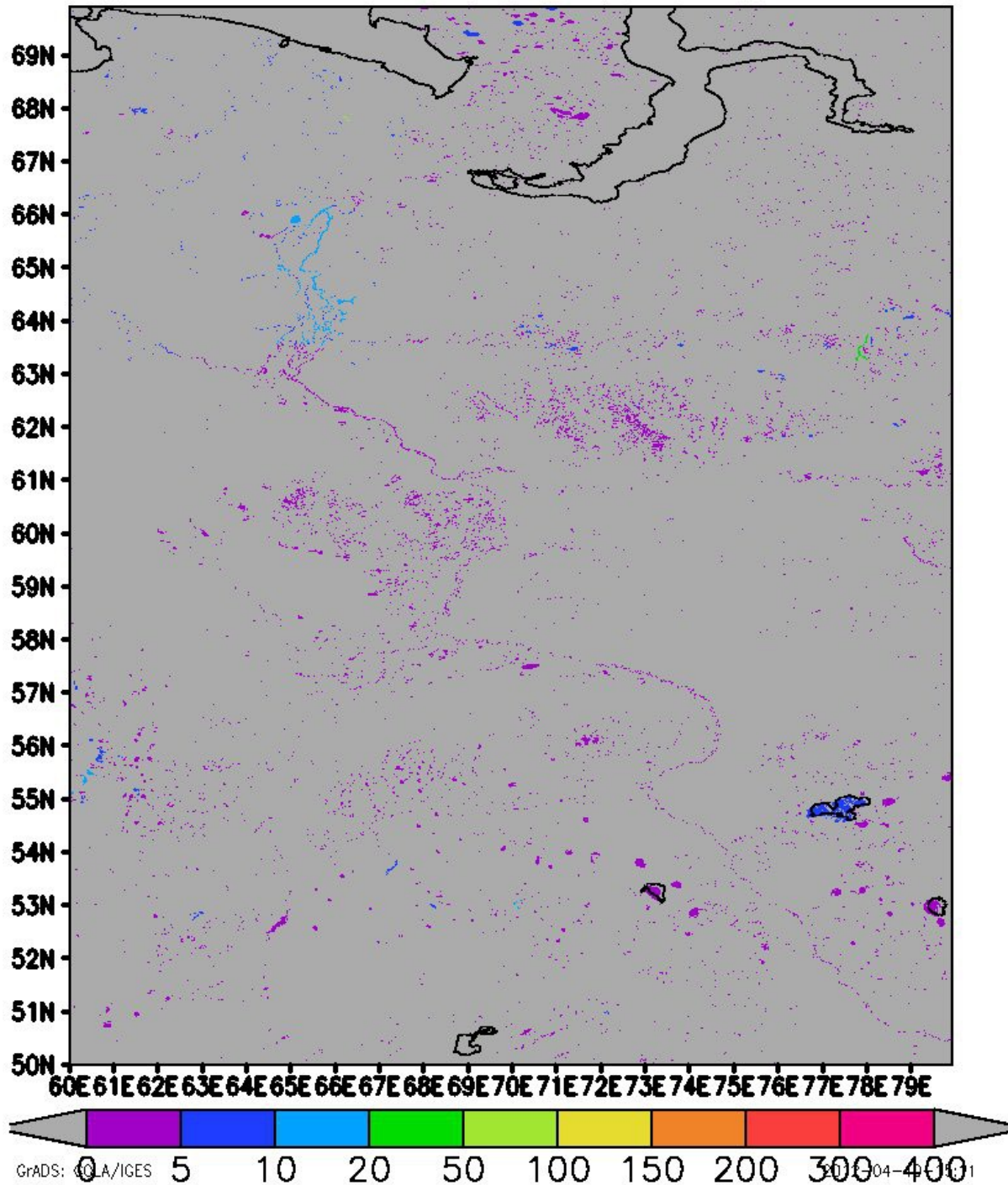


Lake depth,
Before





Lake depth,
After





Conclusion

- Boundaries of regions with the homogeneous origin of lakes were outlined.
- Typical lake depths for these regions were proposed.
- The new version of GLDB, which includes the typical mean depths estimations from the geological origin of lakes for the boreal zone is developed.

Plans for the GLDB development

- To continue with non-boreal lakes
- To add more bathymetry for large lakes
- To compare the coastline of ECOCLIMAP with the coastline from GLOBCOVER and GLC2000
- ...



**Thank you for
attention!**



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