ESTIMATION OF MEAN DEPTH FOR BOREAL LAKES

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

- Lakes occupy about 1,8% of the land surface, and are distributed very unevenly.
- In the atmospheric modeling for parameterization of lakes the external parameters of lakes are needed – depth.
- Accuracy, reliability of depth data – not critical, global coverage – essential for the atmospheric modeling applications (no direct measurements → rough estimates).

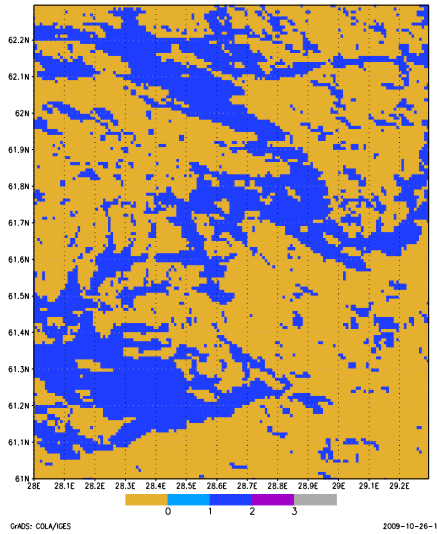
GLDB v.1

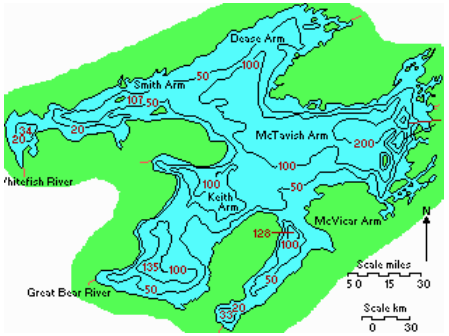
is already used

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	Ohrid	Albania
41	21	9999	9999	313.6	Big_Prespa	Albania
40.8	21.05	9999	9999	47.4	Small_Prespa	Albania
47.434	11.717	67.7	133	7.1	Achensee	Austria
47.765	13.959	2.5	5	0.9	Almsee	Austria
47.641	13.786	34.3	52.8	2.1	Altausseer_See	Austria
48.25	16.41	2.2	6.8	1.6	Alte_Donau	Austria
47.89	13.55	85.3	170.6	46.2	Attersee	Austria
47.611	9.679	89.8	254	539	Bodensee	Austria
48.592	15.4	14	40	1.5	Dobrastausee	Austria
47.542	16.058	24	38	0.5	Erlaufsee	Austria
46.578	13.924	14.9	29.5	2.2	Faaker_See	Austria
47.806	13.268	36	66.3	2.7	Fuschlsee	Austria
48.601	15.142	1.4	3.2	0.6	Gebhartsteich	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	Grundlsee	Austria
47.493	10.573	11	22	0.8	Haldensee	Austria
47.553	13.665	65.1	125.2	8.6	Hallstaetter_See	Austria
48.82	15.136	1.4	2.5	0.6	Haslauer_Teich	Austria
47.456	10.772	40.4	60	1.4	Heiterwanger_See	Austria
47.75	13.247	9.3	22	0.7	Hintersee	Austria
47.542	12.215	12.8	35	0.6	Hinterstoiner_See	Austria
47.924	13.305	14.9	32	3.5	Irrsee	Austria
46.588	14.182	10.4	15.6	1.4	Keutschacher_See	Austria

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.

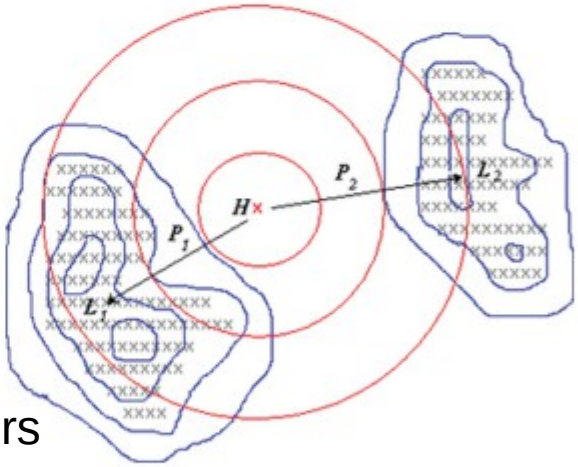


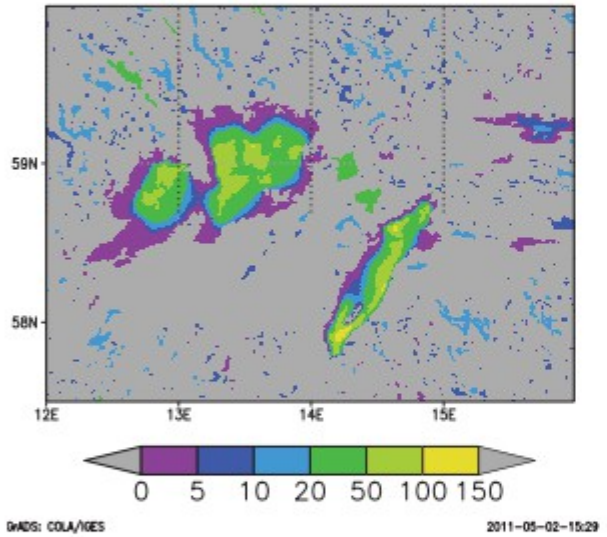


Mapping method

- 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
  8 000 000 lakes in the world
- The depths of many small lakes were never measured.
- It may be estimated **indirectly** from their geological origin.

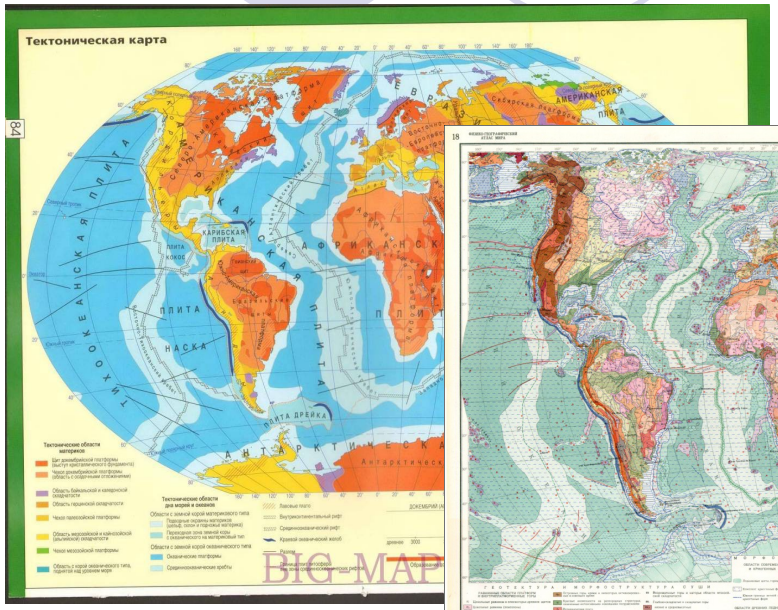
Main objective of the project:

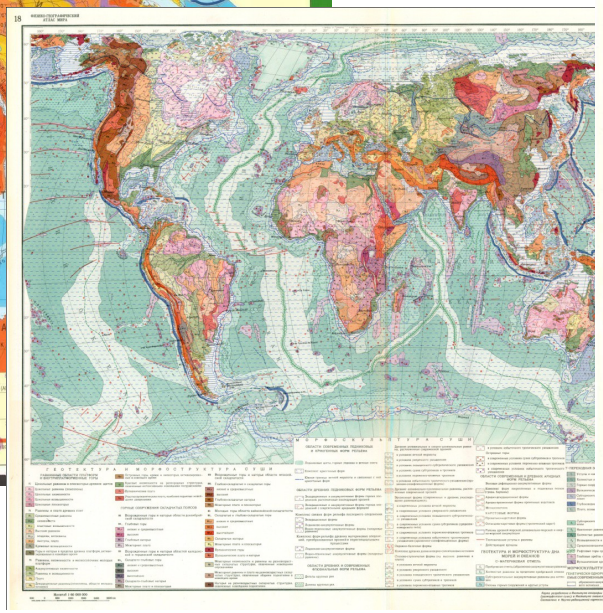
To upgrade the GLDB by indirect estimates of the mean depth from the geological origin of lakes for boreal zone.

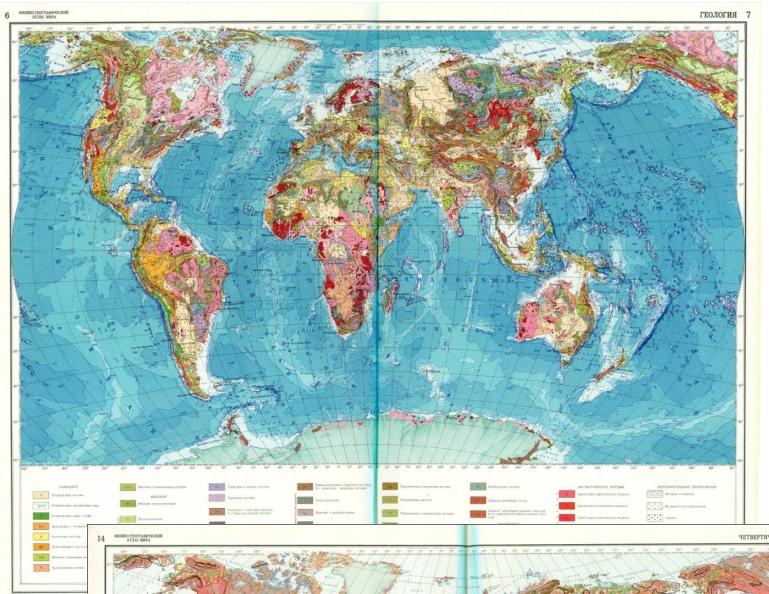
Methodology:

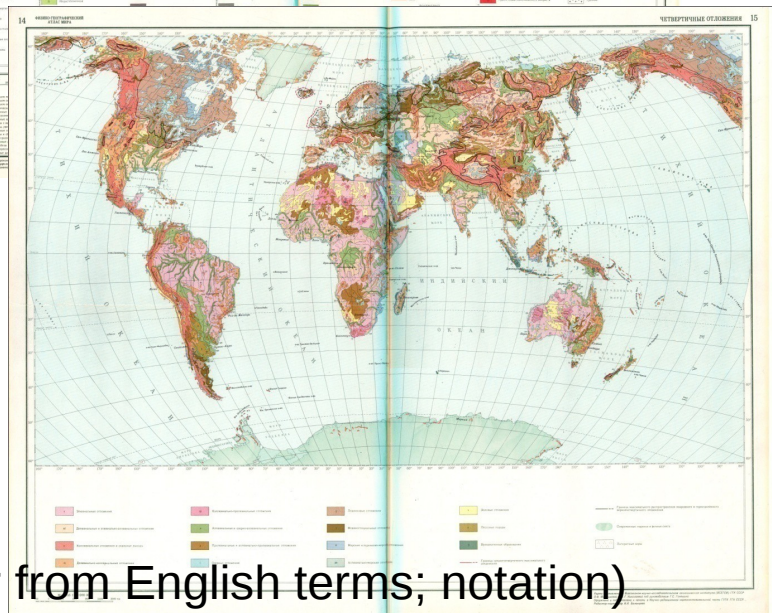
- to outline boundaries of regions with the homogeneous origin of lakes;
- to propose a typical lake depth for these regions;
- to develop the new version of GLDB, which includes the typical mean depths estimations from the geological origin of lakes for the boreal zone;
- to study the sensitivity of modeling results to GLDB modifications.

Outline of the boundaries of regions with the homogeneous origin of lakes









Tectonic map of the world

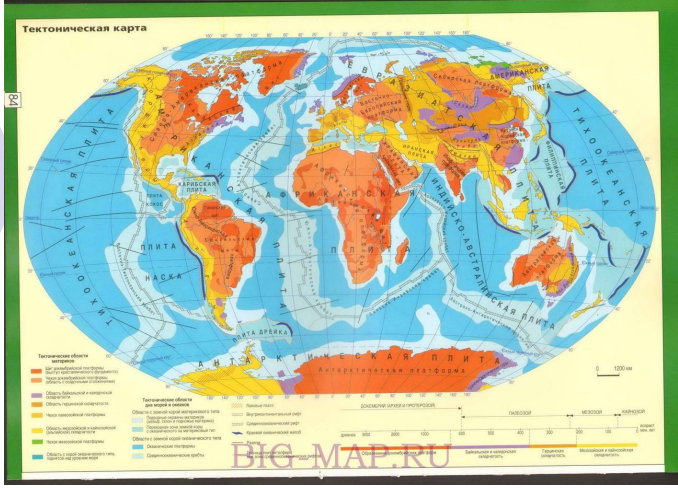
Geo-morphological map of the world

Actual geological map of the world

World map of quaternary deposits

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

Tectonic map of the world



Lithospheric plates;

Platforms;

Orogens;

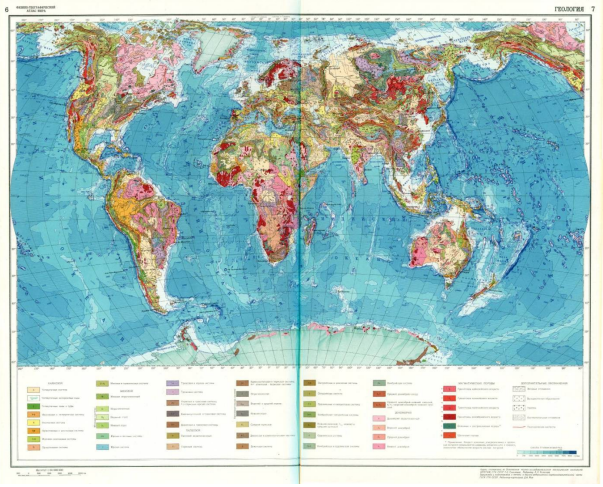
Volcanic plateaus;

Intercontinental rifts;

Faults;

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

Geological map of the world



Igneous (crystalline) rocks:

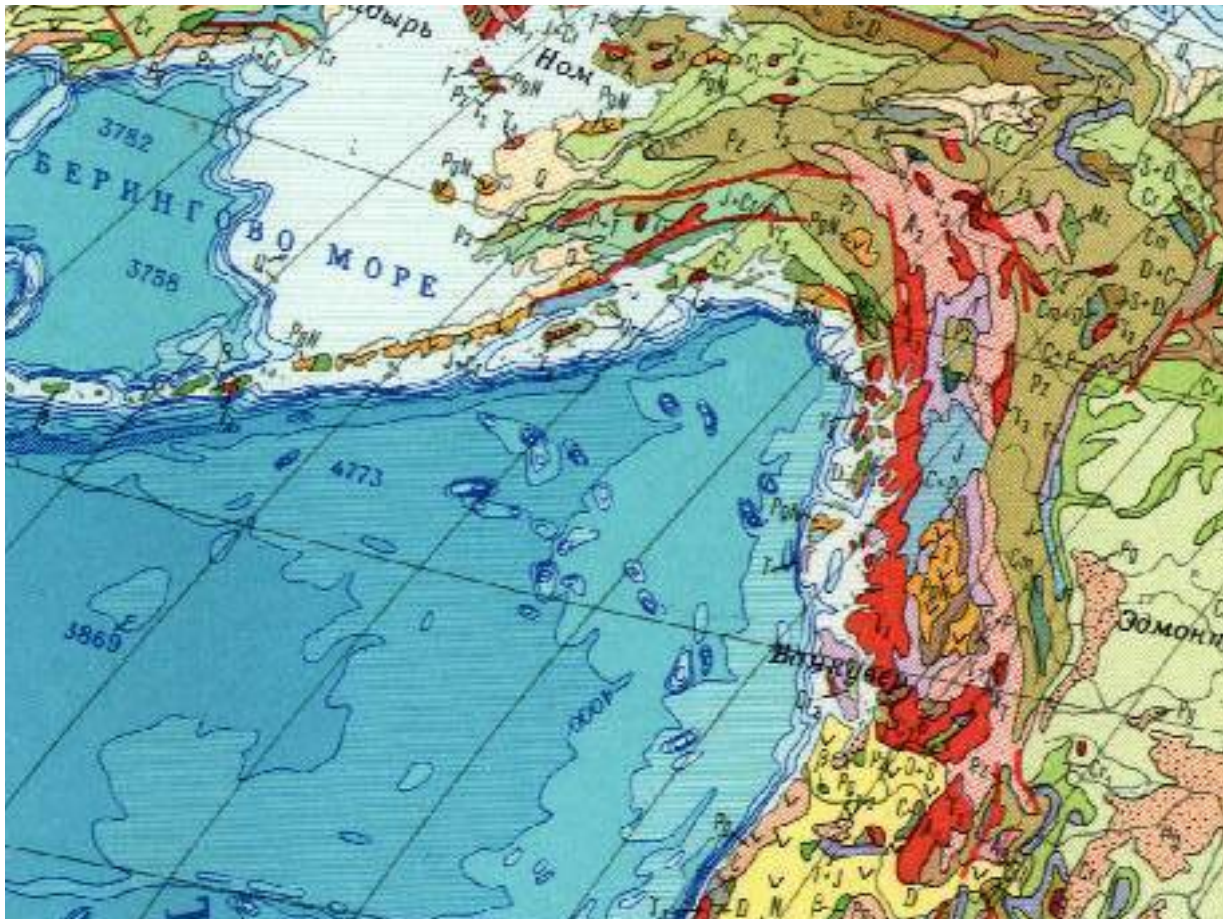
granite;

basalt;

gypsum;

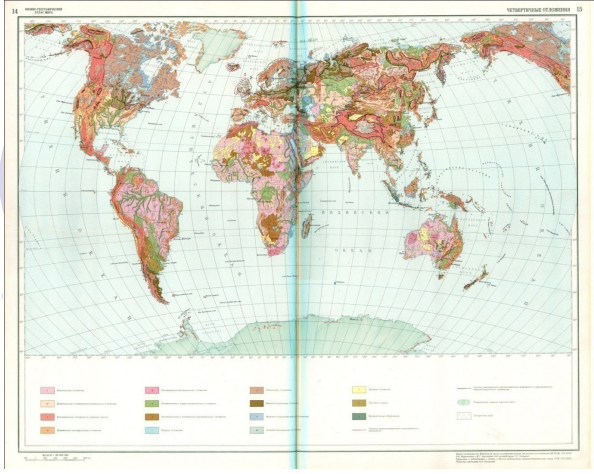
tuffs;

etc.



World map of quaternary deposits

Origin of deposits in the present geological period.

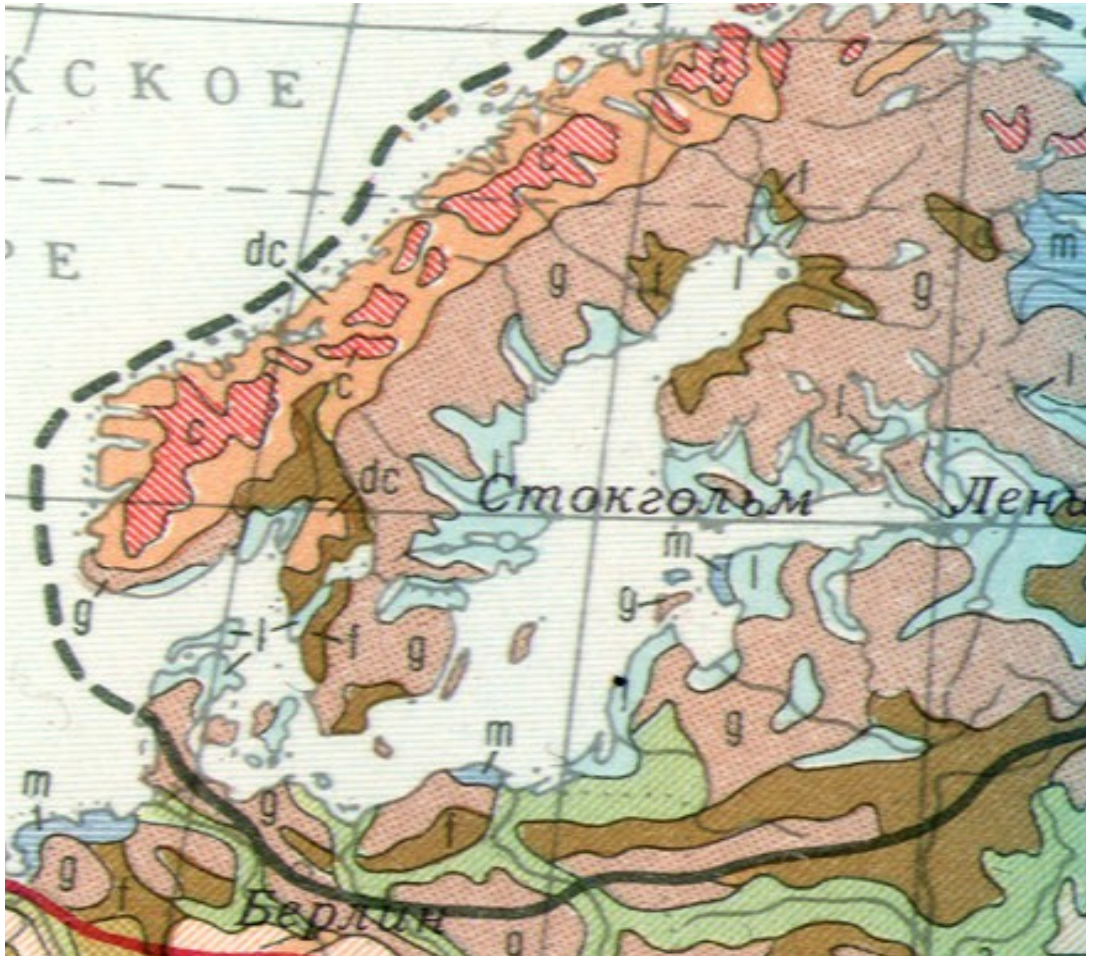


Activities of the glaciers, their melting:

glacial quaternary deposits;

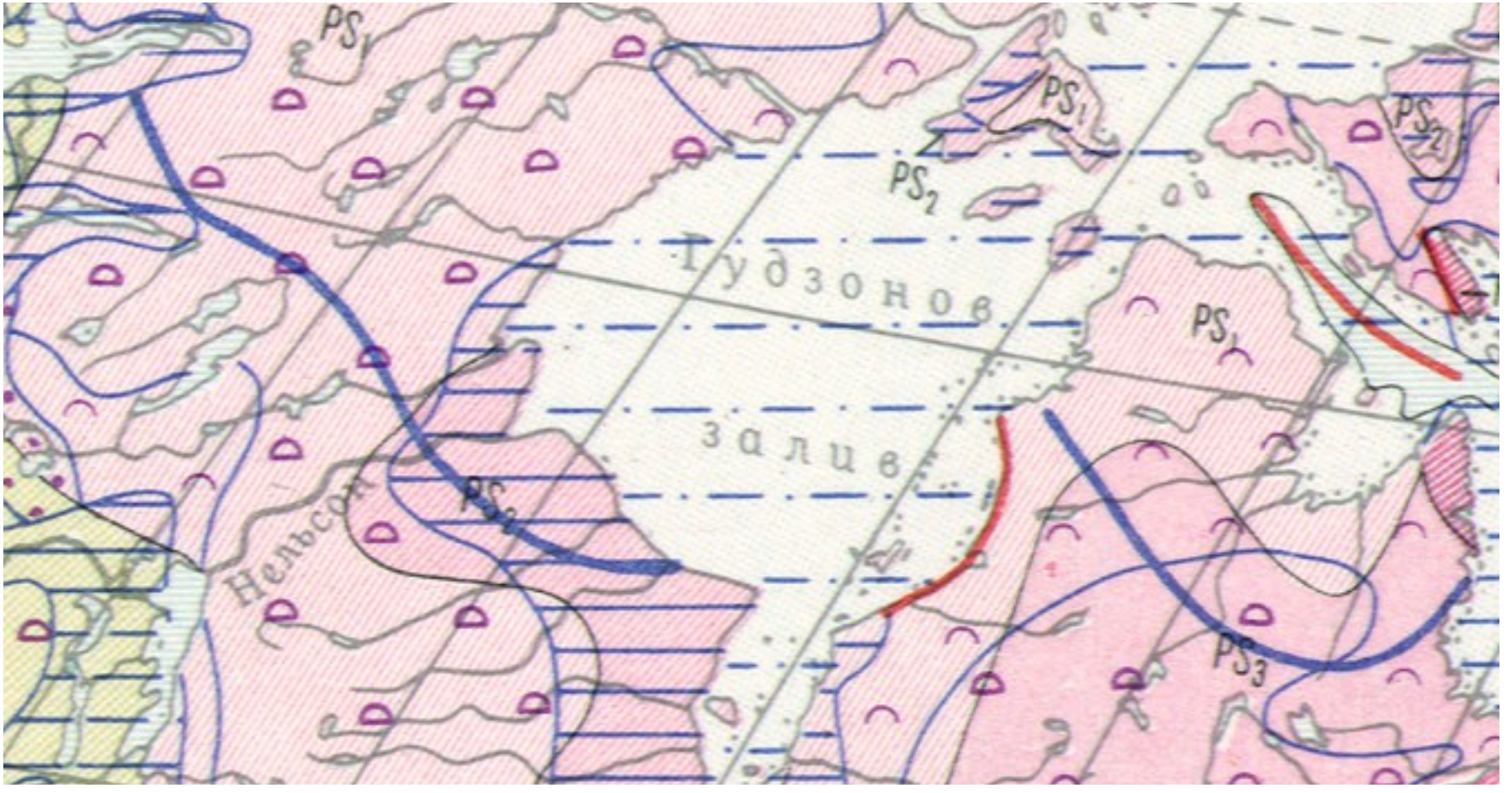
marine quaternary deposits;

fluvioglacial quaternary deposits.

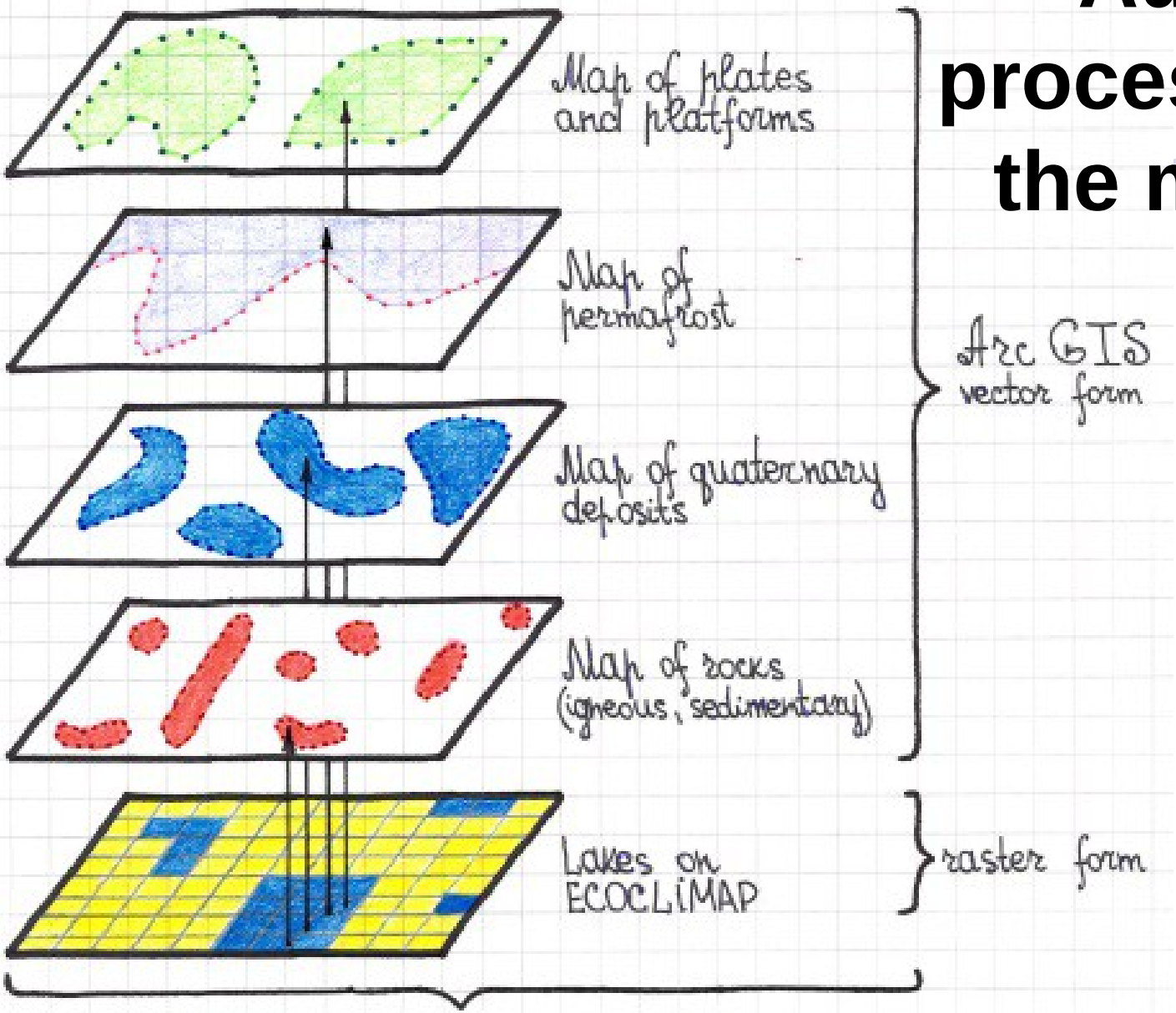


Geo-morphological map of the world

Southern boundary of the permafrost.



Automatic processing of the materials



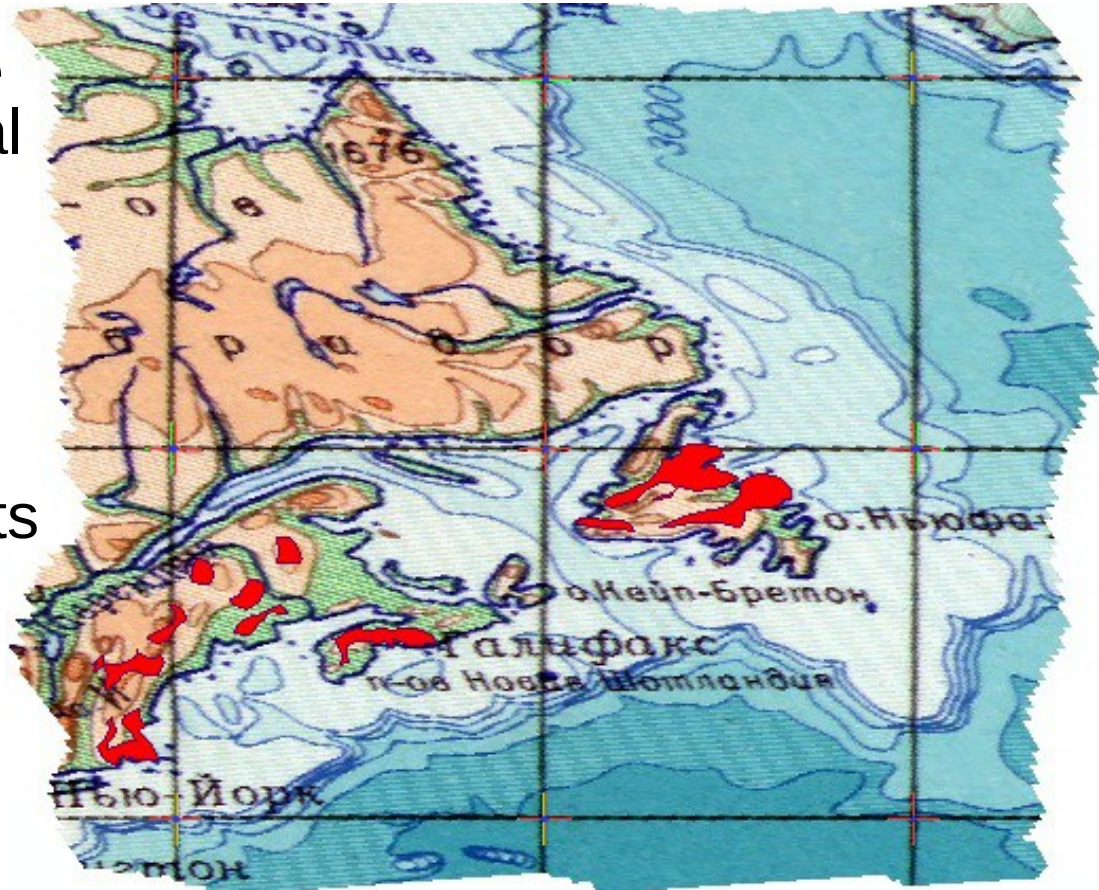
with homogeneous geological origin of lakes

№	Adress Numbers			Words		
	Plate	Plateform	Layer	Plate	Plateform	Layer
1	2	7	44	American	BaicalCaledonianFolding_1	Intersect_MagmFluv
2	2	7	46	American	BaicalCaledonianFolding_1	Intersect_MagmLedn
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	Euroasian	PrecambrianPlatform_Shield_2	Morsk
135	3	41	57	Euroasian	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_MagmLednMerzlota
140	4	0	48	LavaPlateau_Ocean		Intersect_MagmMerzlota
141						

Example of the allocated region

	Adress					
№	Numbers			Words		
	Plate	Plateform	Layer	Plate	Plateform	Layer
2	**2**	**7**	**46**	American	BaicalCaledonianFolding_1	Intersect_MagmLedn

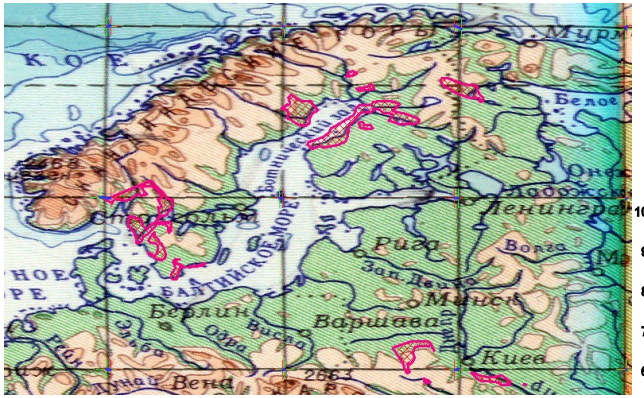
- The region belongs to the American plate, the Baikal and Caledonian orogeny area.
- There are igneous (crystalline) rocks with glacial quaternary deposits and without permafrost.



Estimation of typical lake depths for the allocated regions

- 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.
- Statistics was analyzed for individual lakes (list of 13 000 lakes) and for lake pixels from global map ECOCLIMAP2. Lake pixels distribution indirectly takes into account lake areas.
- Also special filter was used: additional histograms, with statistics only for lakes with lake area less than 200 km^2, were built.
- An expert decision about typical lake depth was made.

Example of statistical analysis



3 – 41 – 52

Eurasian plate

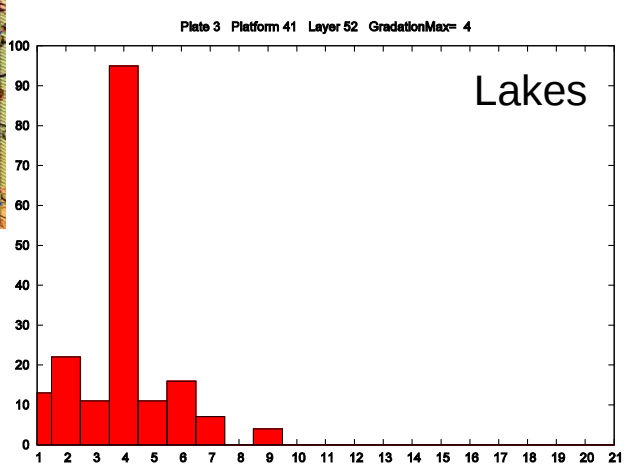
Precambrian platform shield

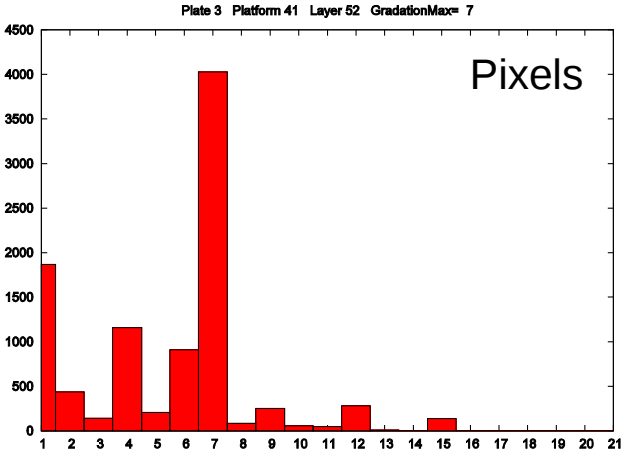
Fluvioglacial quaternary deposits

Sedimentary rocks

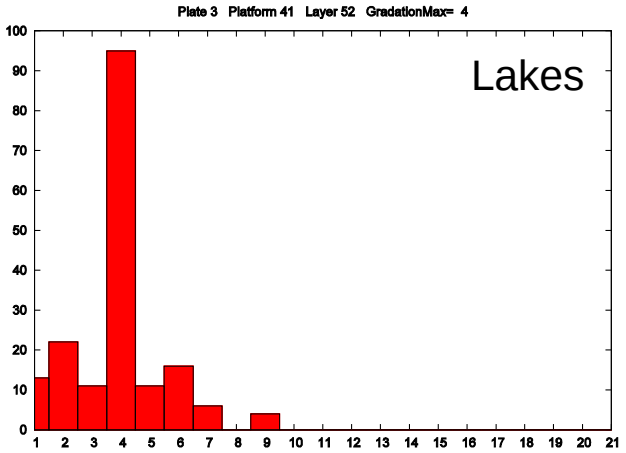
No permafrost

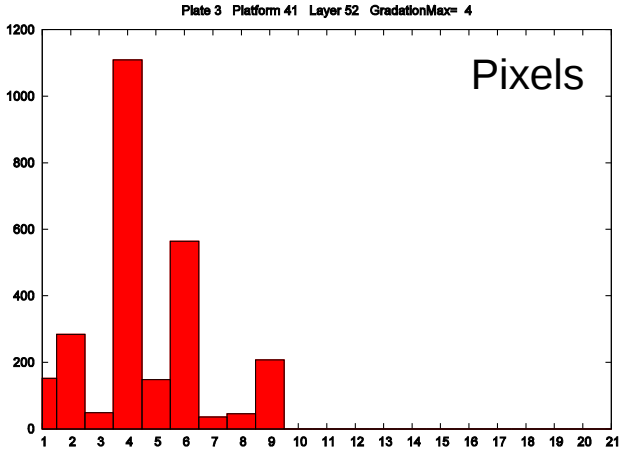
All lakes





Lakes with the area less than 200 km^2





- 564 lake depths histograms were build and analyzed.
- If in some regions, where 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.

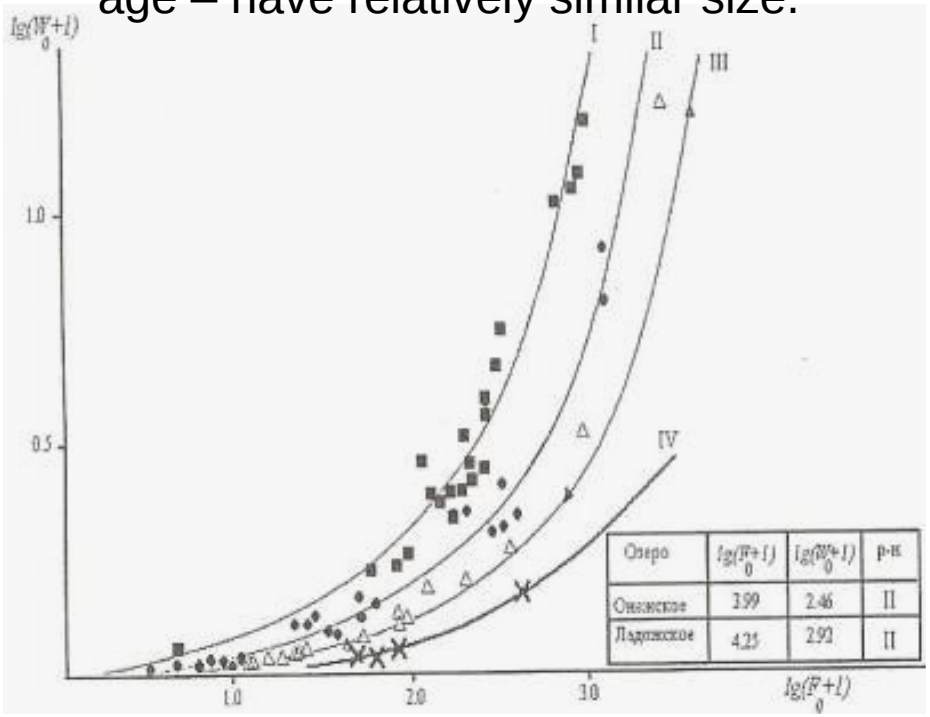
Method of analogies

Extrapolation of statistics using geological knowledge – sufficient statistics of one region extrapolate to the one with not enough statistics.

- 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

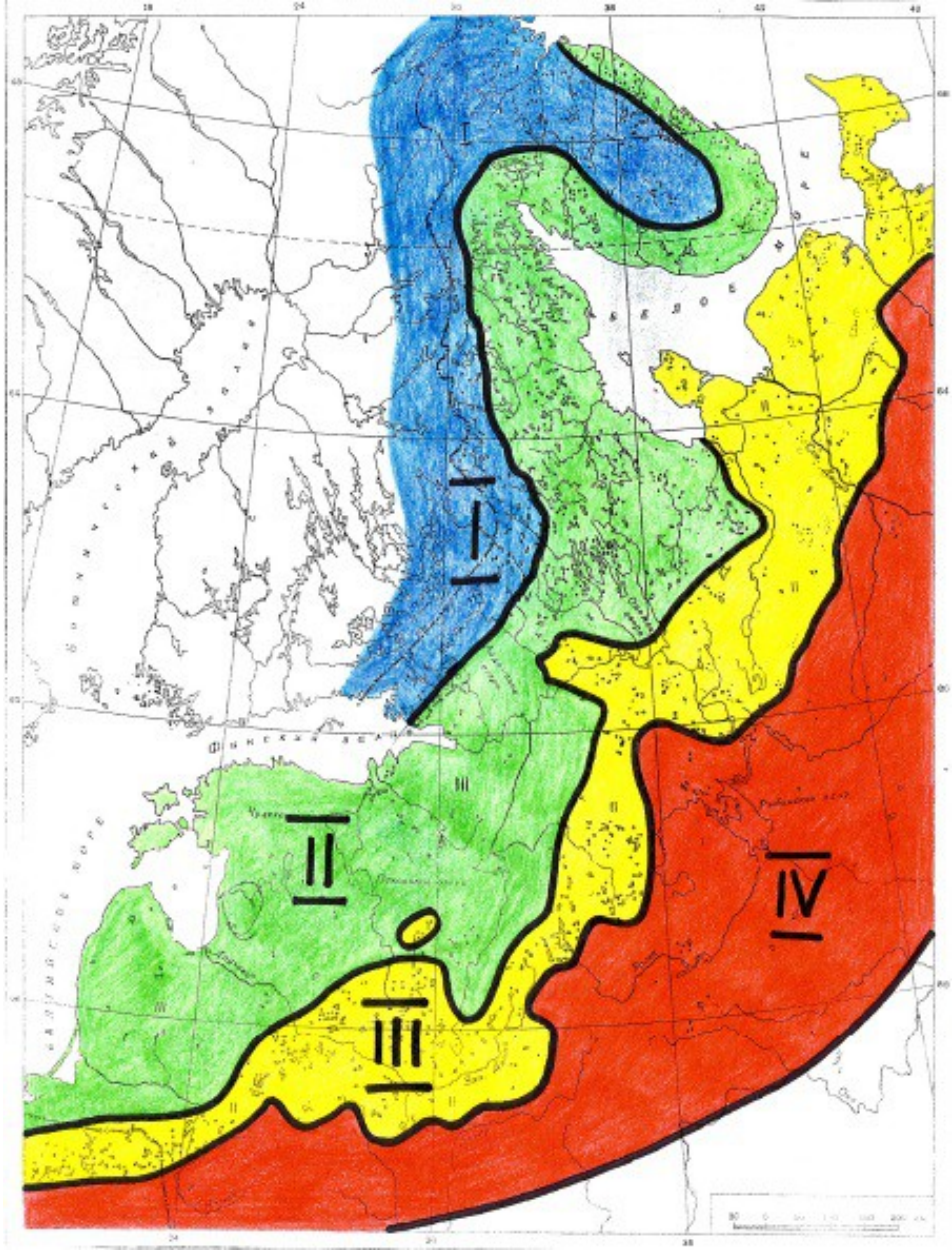
Water basins of the same origin, same age – have relatively similar size.



Озеро	$lg(F+1)_0$	$lg(W+1)_0$	р-н
Онежское	3.99	2.46	II
Ладожское	4.25	2.92	II

The lake volume is logarithmically dependent of the lake area.

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



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

Kitaev's method

Geographical zones.

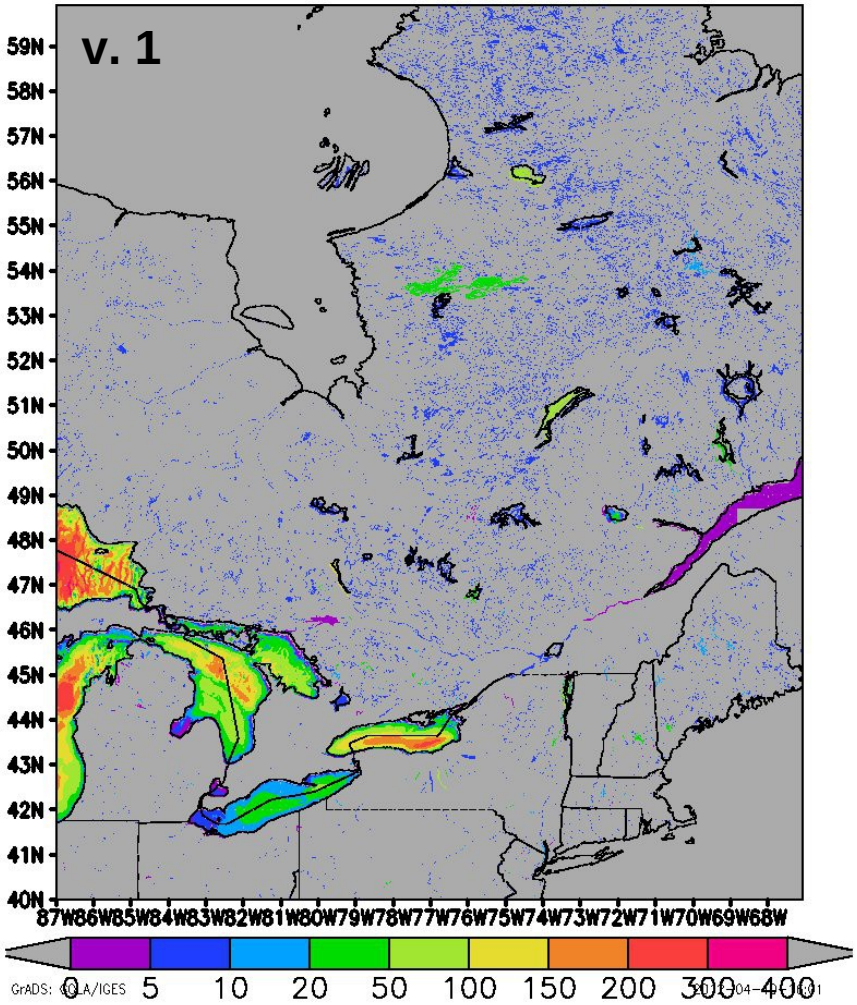
Lake area, km^2	Tundra	Northern taiga	Middle taiga	Mixed forest
< 1,0	1,93	4,67	3,90	5,49
1,0 - 5,0	3,14	4,83	4,02	5,67
5,0 - 10,0	4,96	4,05	5,48	5,92
10,0 - 50,0	6,23	5,19	6,37	5,40
> 50,0	3,50	10,35	6,21	6,37

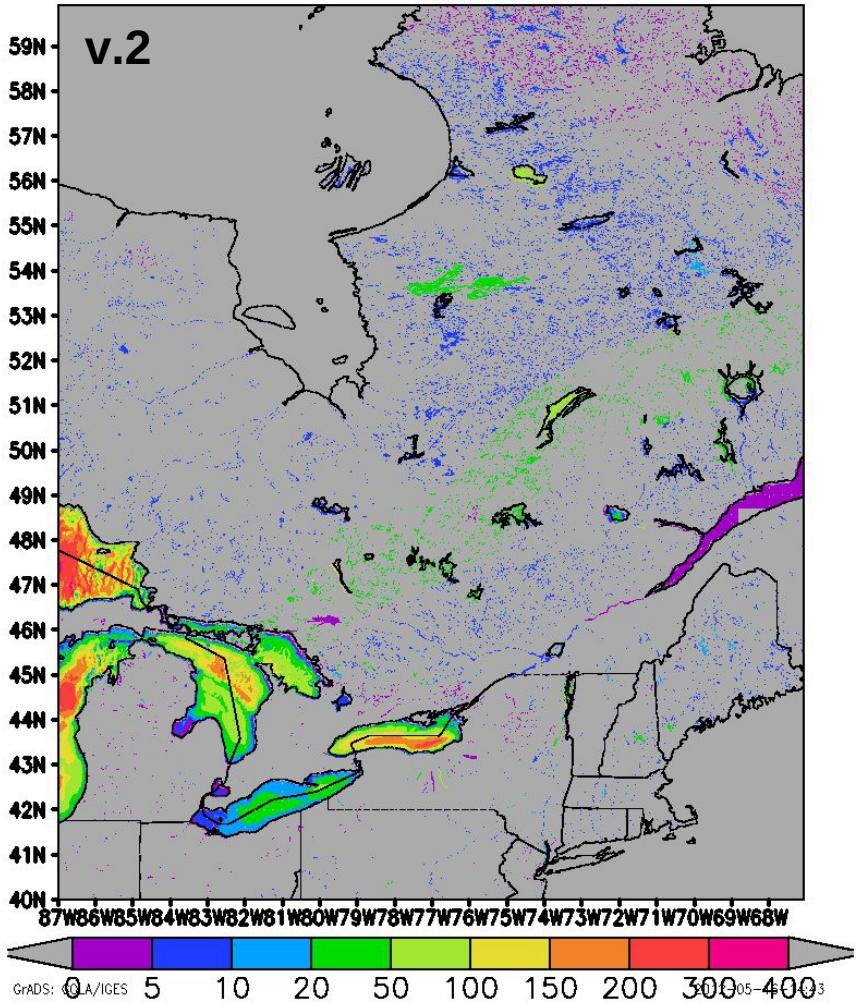
Method has low accuracy and is applicable only for small lakes.

№	Adress						
	Numbers			Words			Depth
	Plate	Plateform	Layer	Plate	Plateform	Layer	
1	2	7	44	American	BaicalCaledonianFolding_1	Intersect_MagmFluv	7
2	**2**	**7**	**46**	**American**	**BaicalCaledonianFolding_1**	**Intersect_MagmLedn**	**7**
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
...	...	...	...	...	...	...	...
134	3	41	56	Euroasian	PrecambrianPlatform_Shield_2	Morsk	7
135	3	41	57	Euroasian	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_MagmLednMerzlota	7
140	4	0	48	LavaPlateau_Ocean		Intersect_MagmMerzlota	3

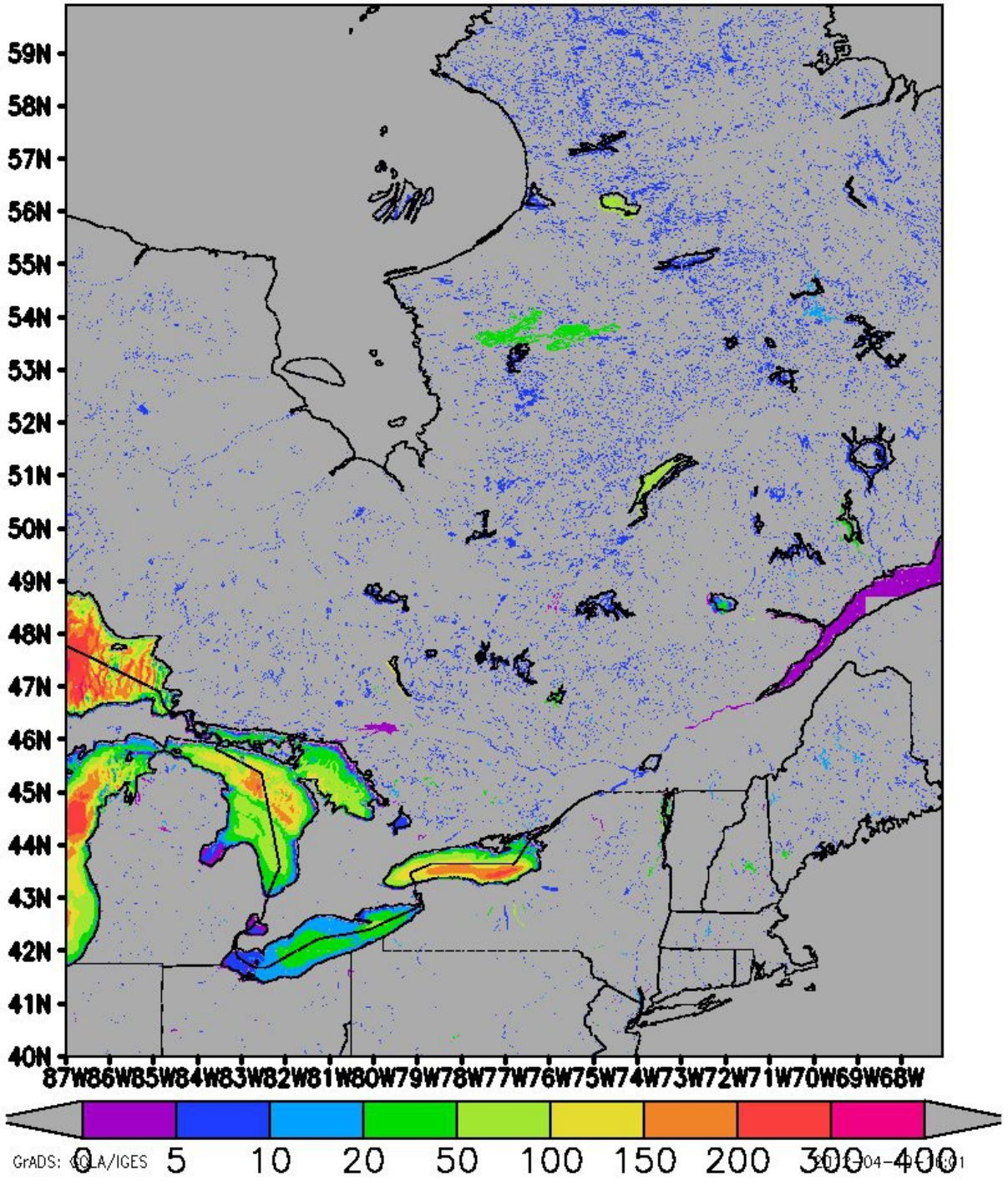
New version of GLDB

Lake depth, meters

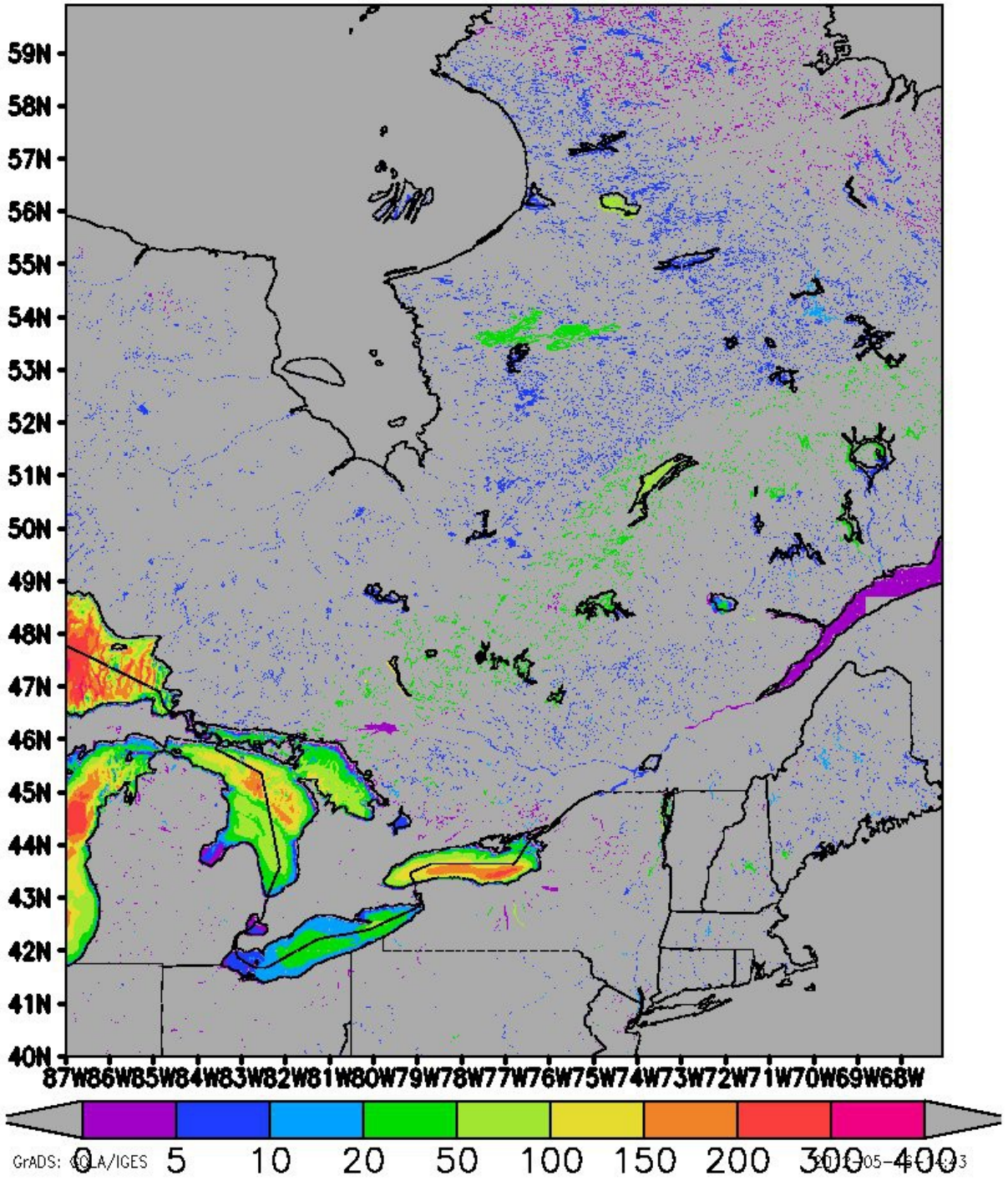




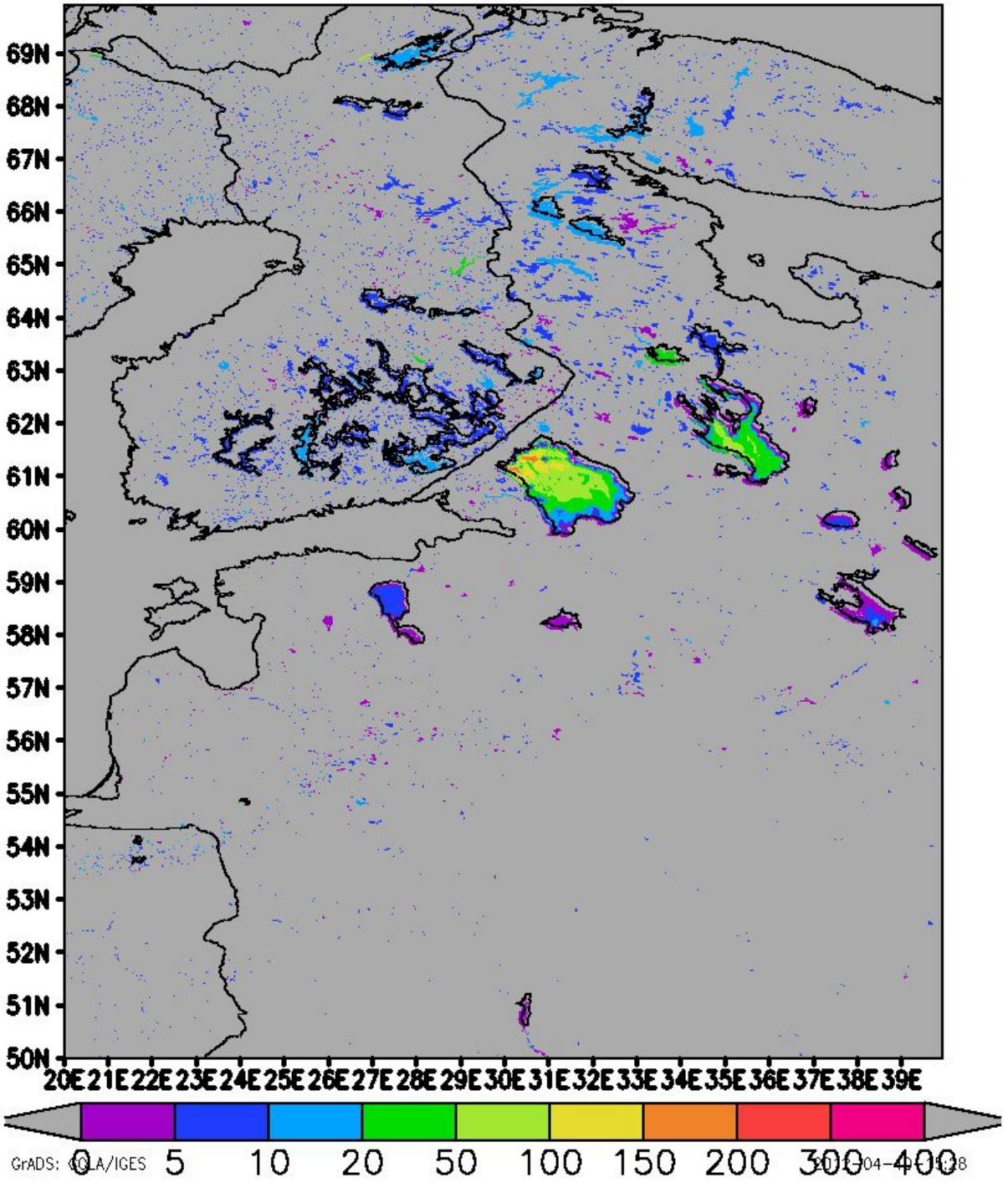
Lake depth, v.1



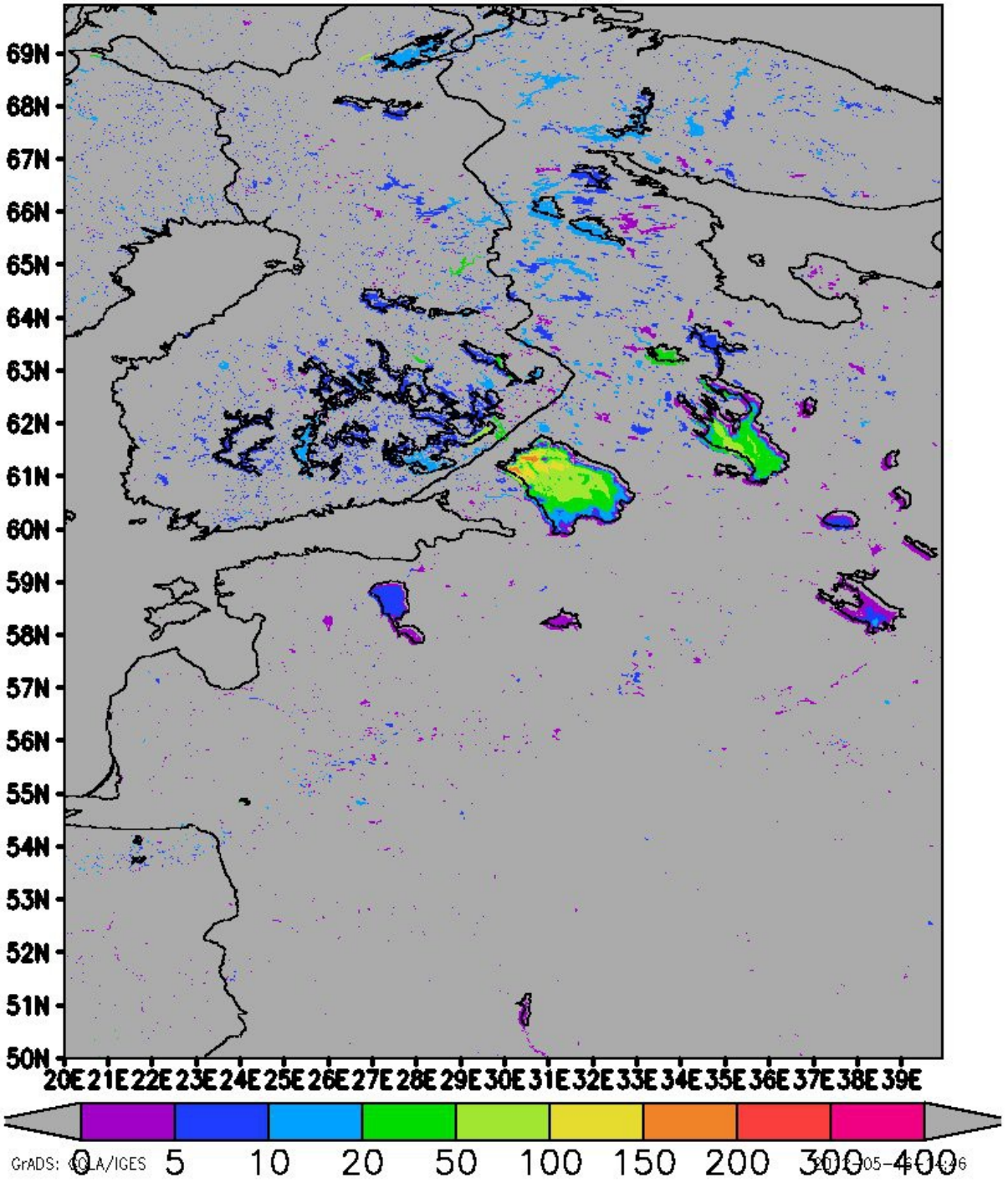
Lake depth, v.2



Lake depth, v.1



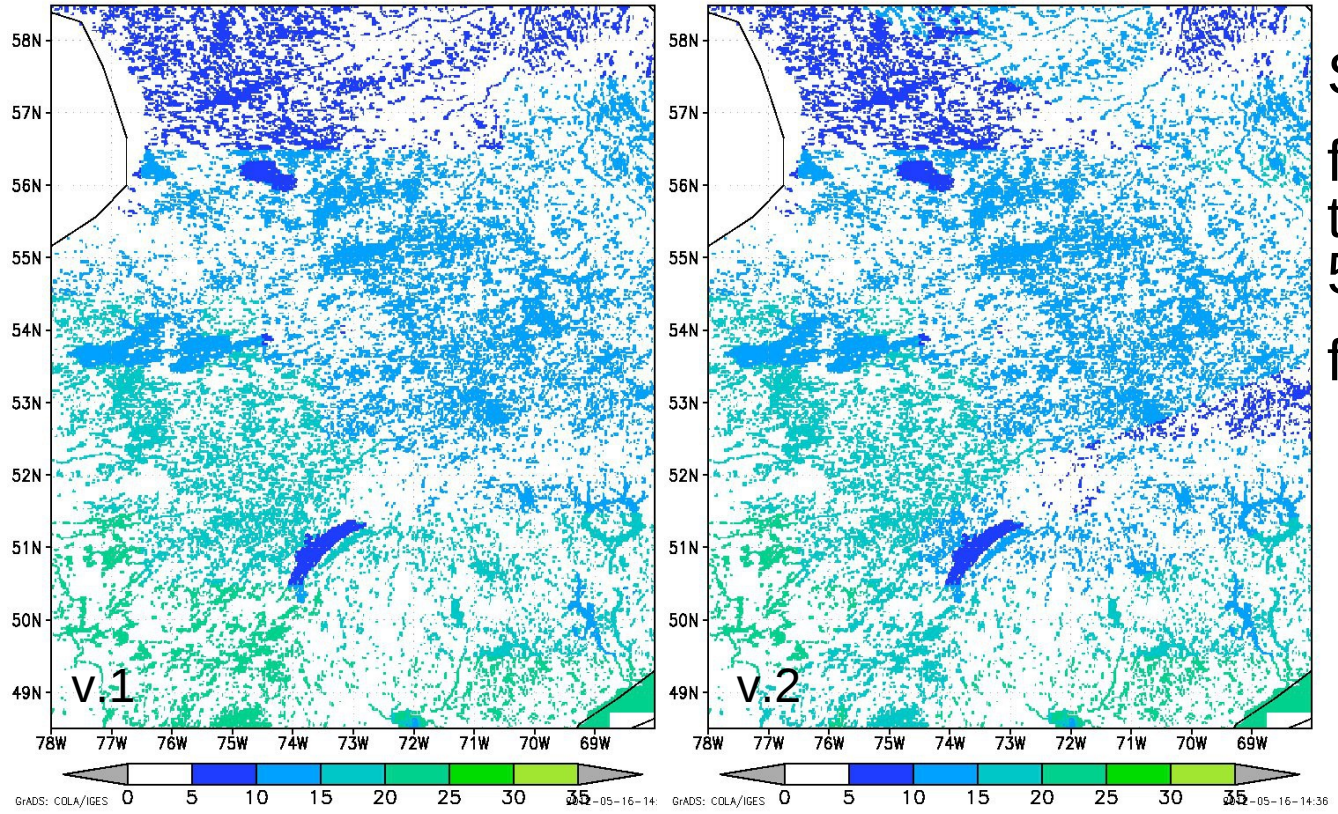
Lake depth, v.2



Sensitivity of modeling results to GLDB modifications

Used model Lake Climatology dataset

Lake mean water temperature, °C on the grid of atmospheric model
August 20



Sensitivity:

for the mean water temperature – 5 °C;

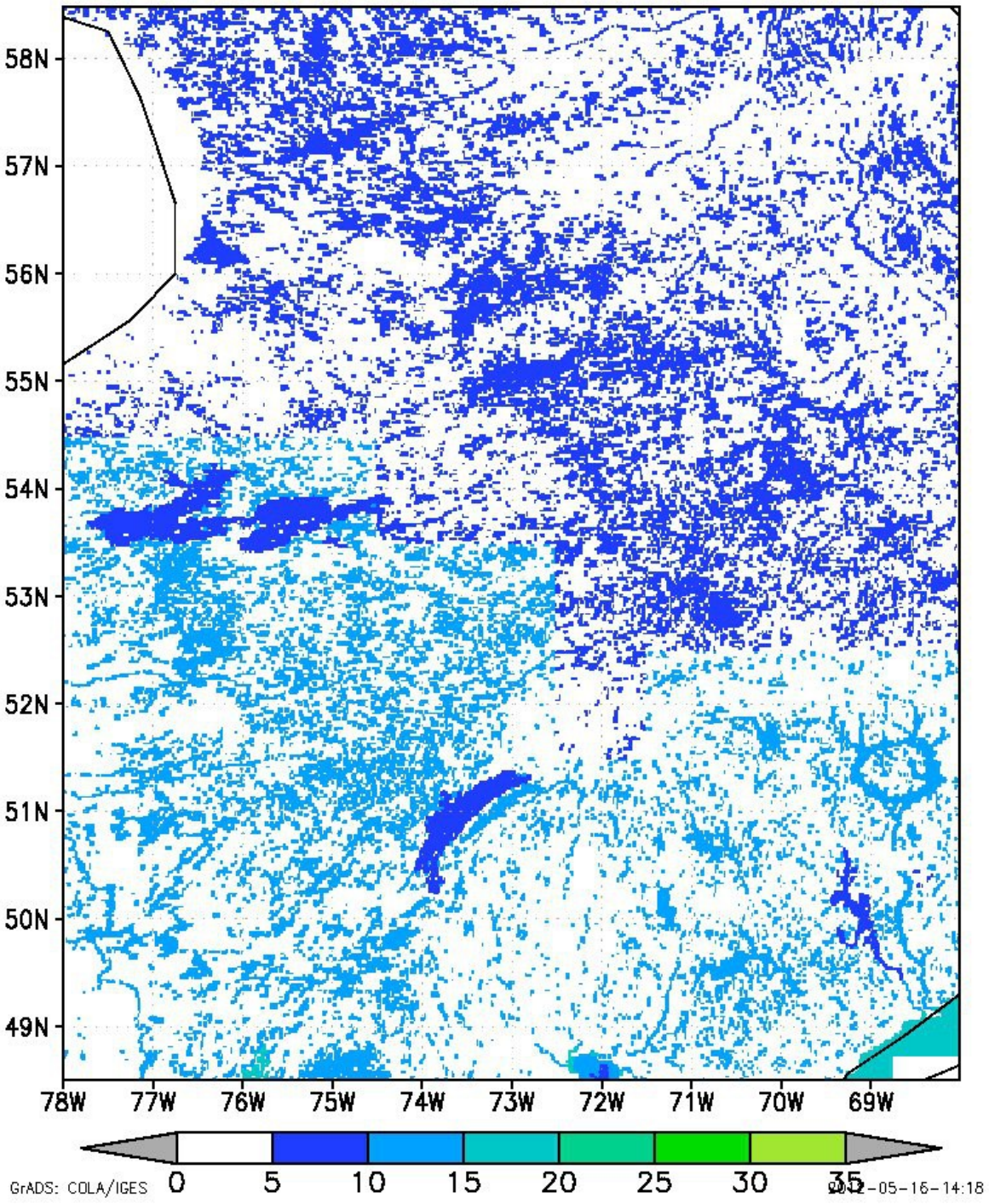
for the ice thickness - 0,5 m.

Horizontal resolution of the atmospheric model grid 0,02°;

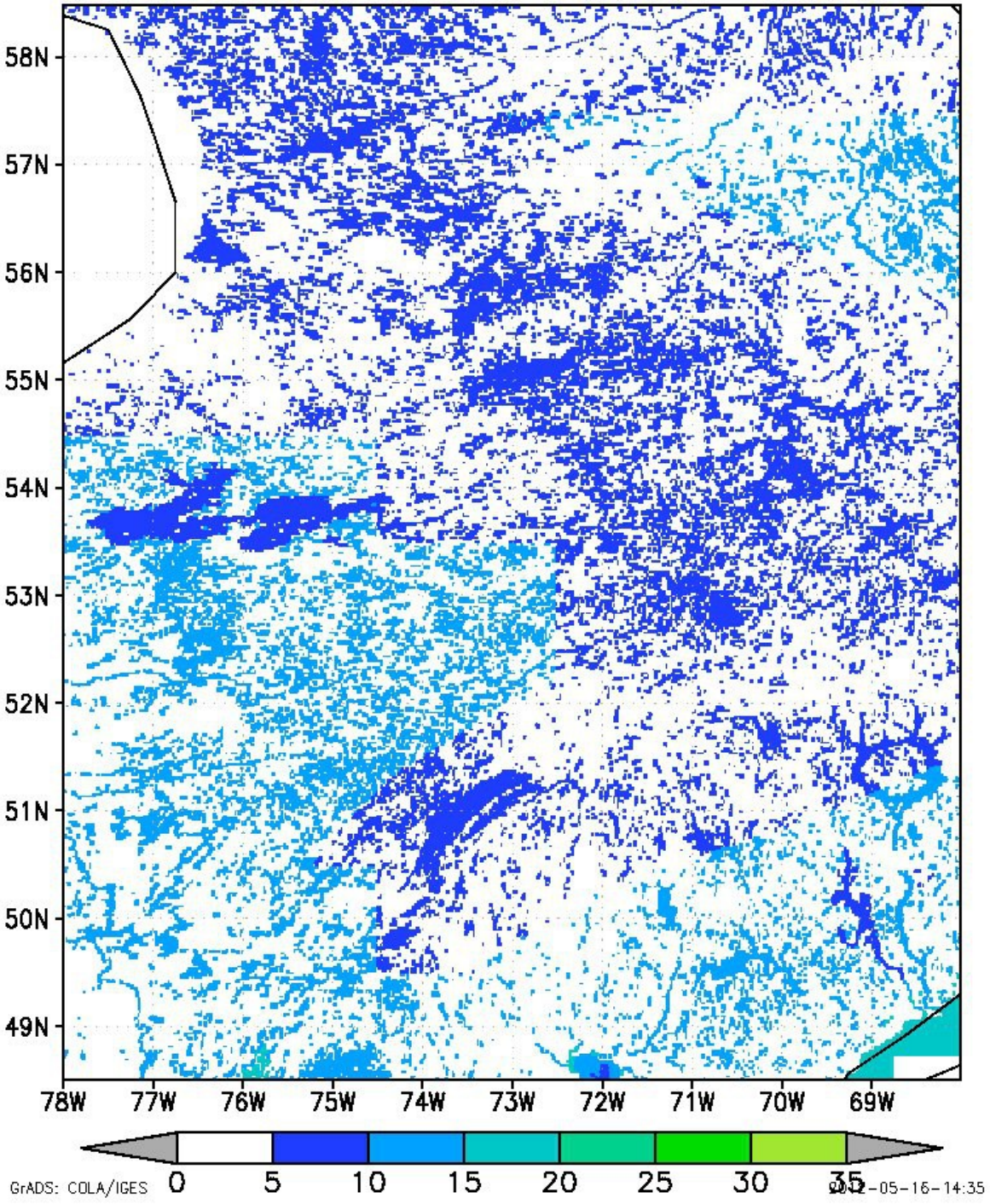
Geographical coordinates

Lake mean water temperature, °C on the atmospheric model grid, August 20,

v. 1

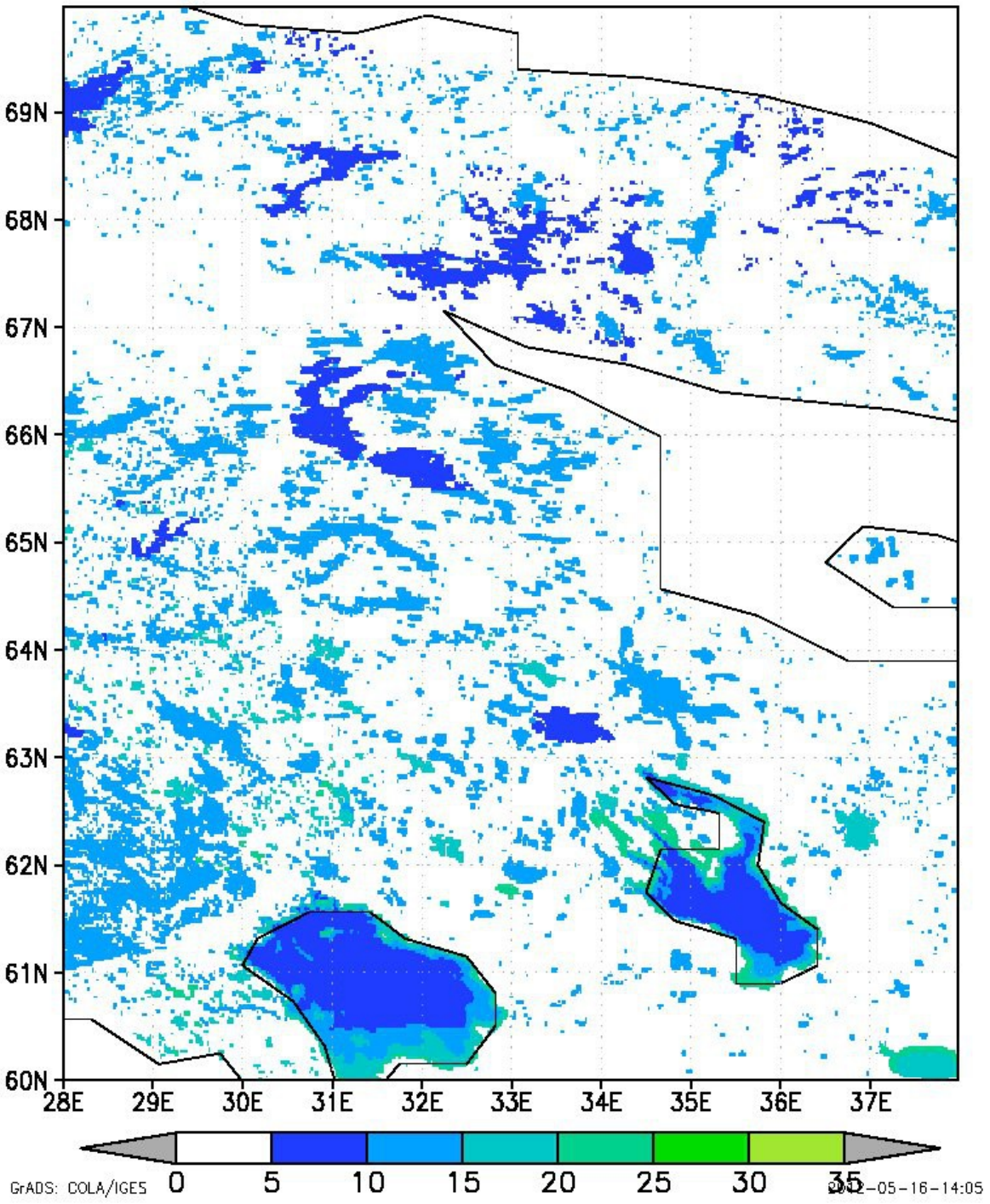


Lake mean water temperature, °C on the atmospheric model grid, August 20, v.2

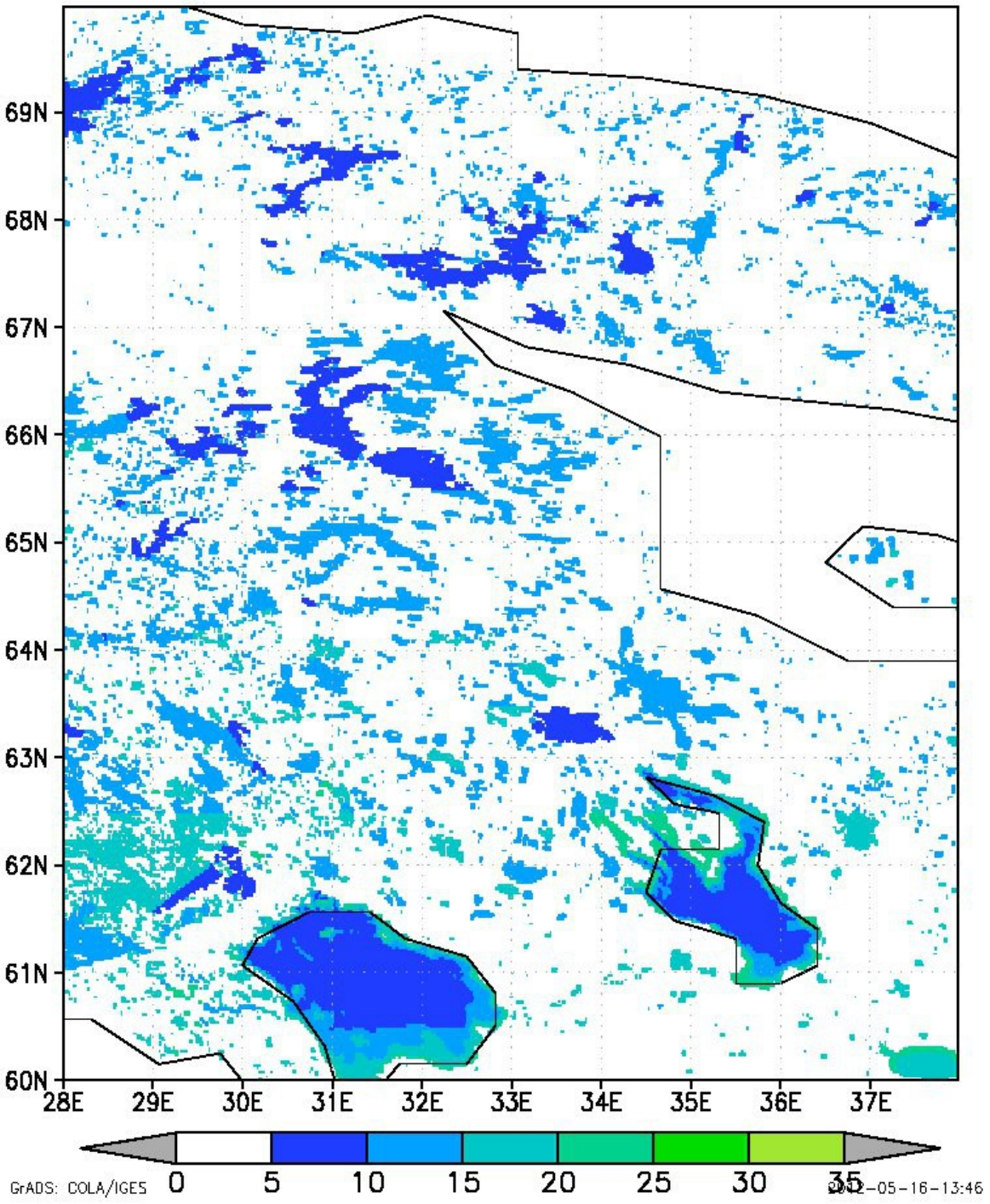


Lake mean water temperature, °C on the atmospheric model grid, August 20,

v. 1



Lake mean water temperature, °C on the atmospheric model grid, August 20, v. 2



Conclusion

- Boundaries of regions with the homogeneous origin of lakes were outlined.
- Typical lake depths for these regions were proposed.
- GLDB v.2 is developed. It includes the typical mean depths estimations from the geological origin of lakes for the boreal zone.
- Sensitivity of modeling results to GLDB modifications was studied.

Future plans

- Constant update of the GLDB with mean depth data for individual lakes.
- Receiving the typical mean depths estimations from the geological origin of lakes for other then boreal climate zones .
- Adding bathymetry data for large lakes .
- Improving spatial representation of data by using different global raster maps – different ecosystem datasets .

Thank you for attention!

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