

Global Lake Distributions and Decadal Lake Change Patterns

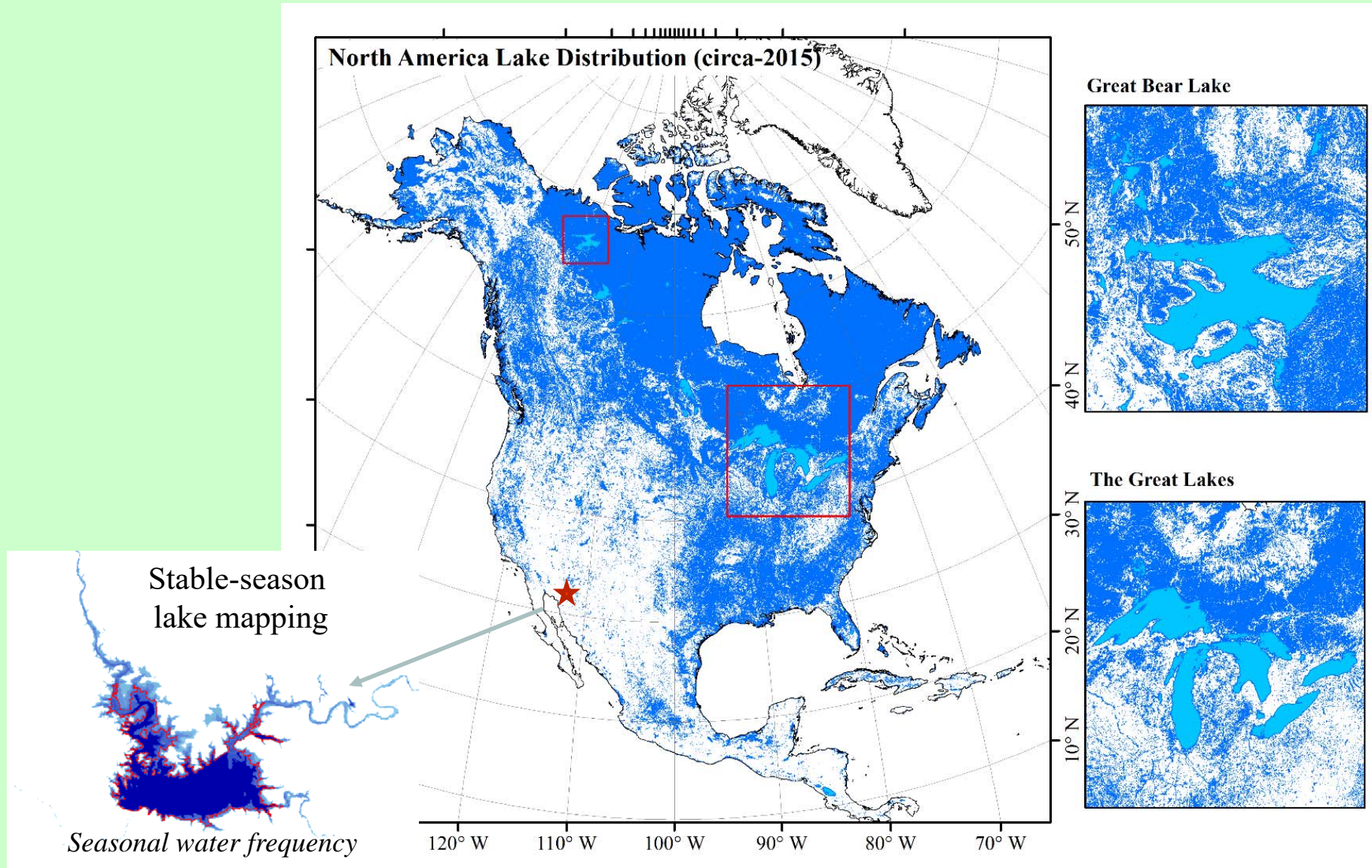
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Global Lake Mapping

- ☑ To produce decadal high-resolution systematic global lake products using:
 - Circa-2000 Landsat-7 ETM+ images;
 - Circa-2015 Landsat-8 OLI images.
- ☑ To assess lake dynamics at global scales;
- ☑ By using satellite big data:
 - ~80,000 Landsat scenes acquired at appropriate seasons to map millions of lakes (>0.5 ha) .
 - MODIS images;
 - ICESat data;
 - GRACE data.

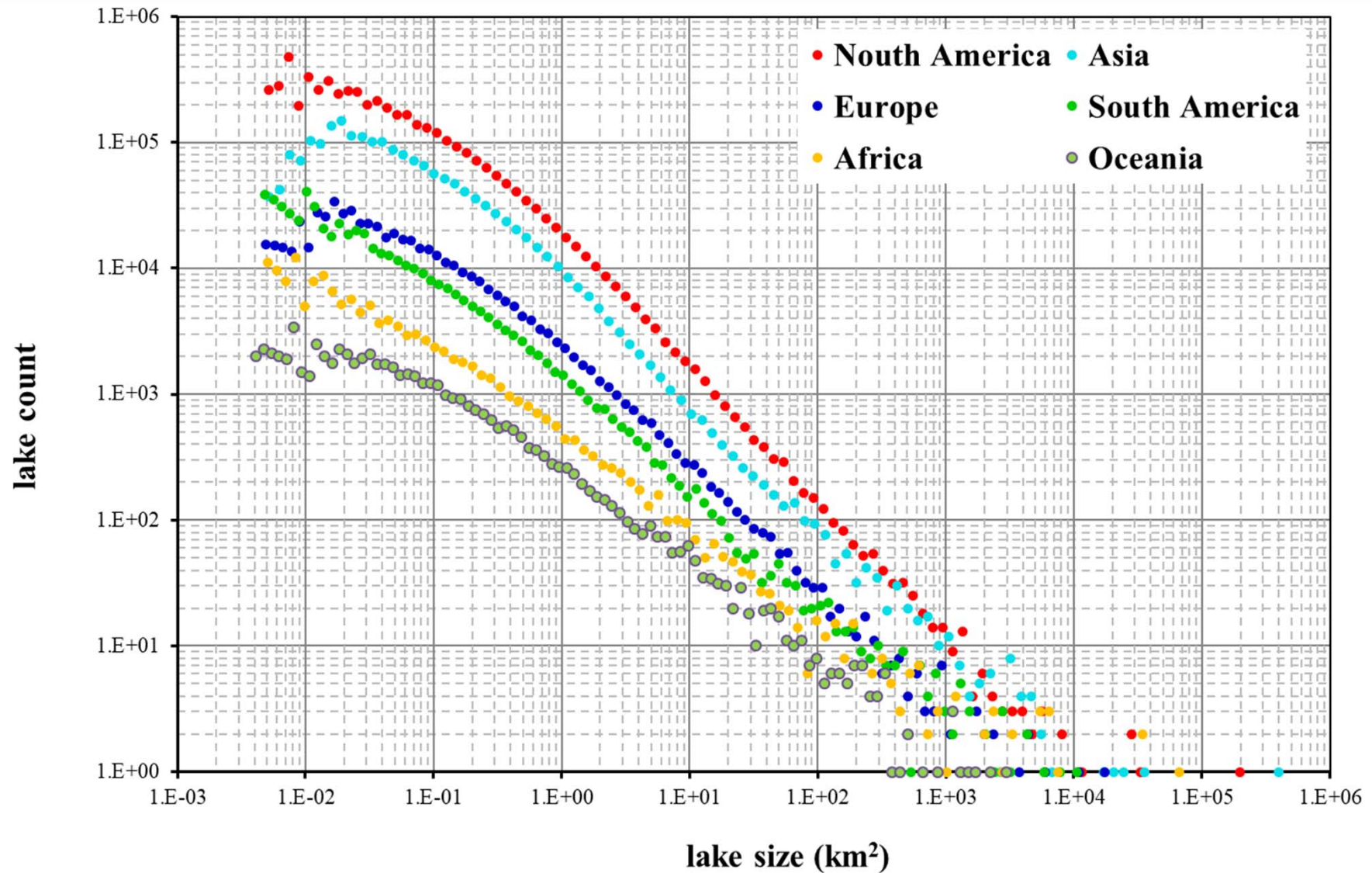
Lake Distribution as 2015 (North America)



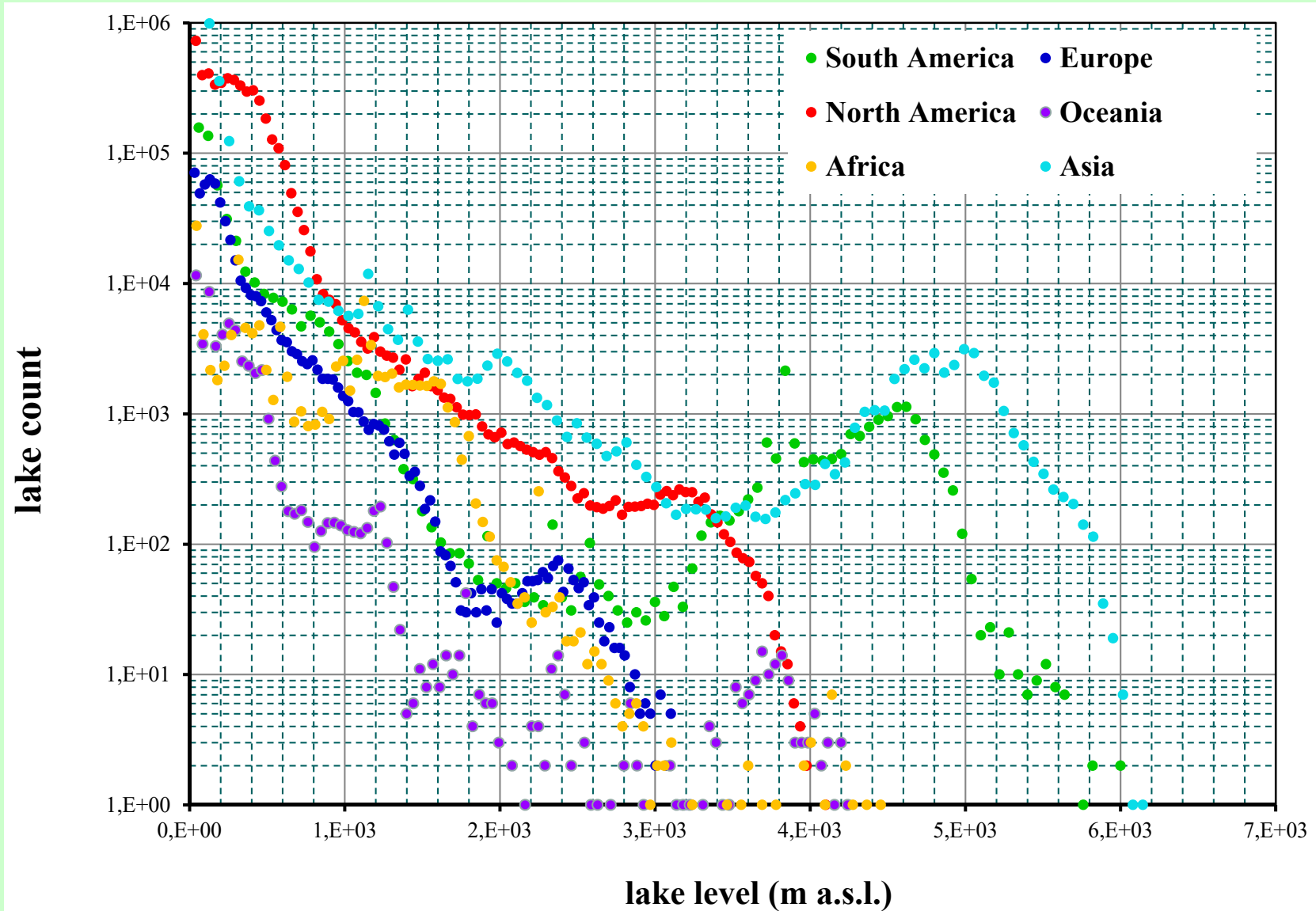
Lake Size Statistics

Size class (km ²)	Africa	Oceania	Europe	Asia	N America	S America	Global
< 10 ⁻²	47,935	25,948	232,747	971,910	1,660,702	189,449	3,128,691
10 ⁻² - 10 ⁻¹	60,710	35,848	368,523	1,267,110	2,682,153	192,267	4,606,611
10 ⁻¹ - 10 ⁰	14,238	10,965	102,461	329,141	731,764	52,336	1,240,905
10 ⁰ - 10 ¹	2,559	2,200	14,336	38,288	88,858	7,900	154,141
10 ¹ - 10 ²	451	451	1,520	3,132	7125	905	13,584
10 ² - 10 ³	96	73	147	368	628	144	1,456
10 ³ - 10 ⁴	21	11	16	45	57	24	174
> 10 ⁴	3	0	1	4	8	0	16
Total	126,013	75,496	719,751	2,609,998	5,171,295	443,025	9,145,578

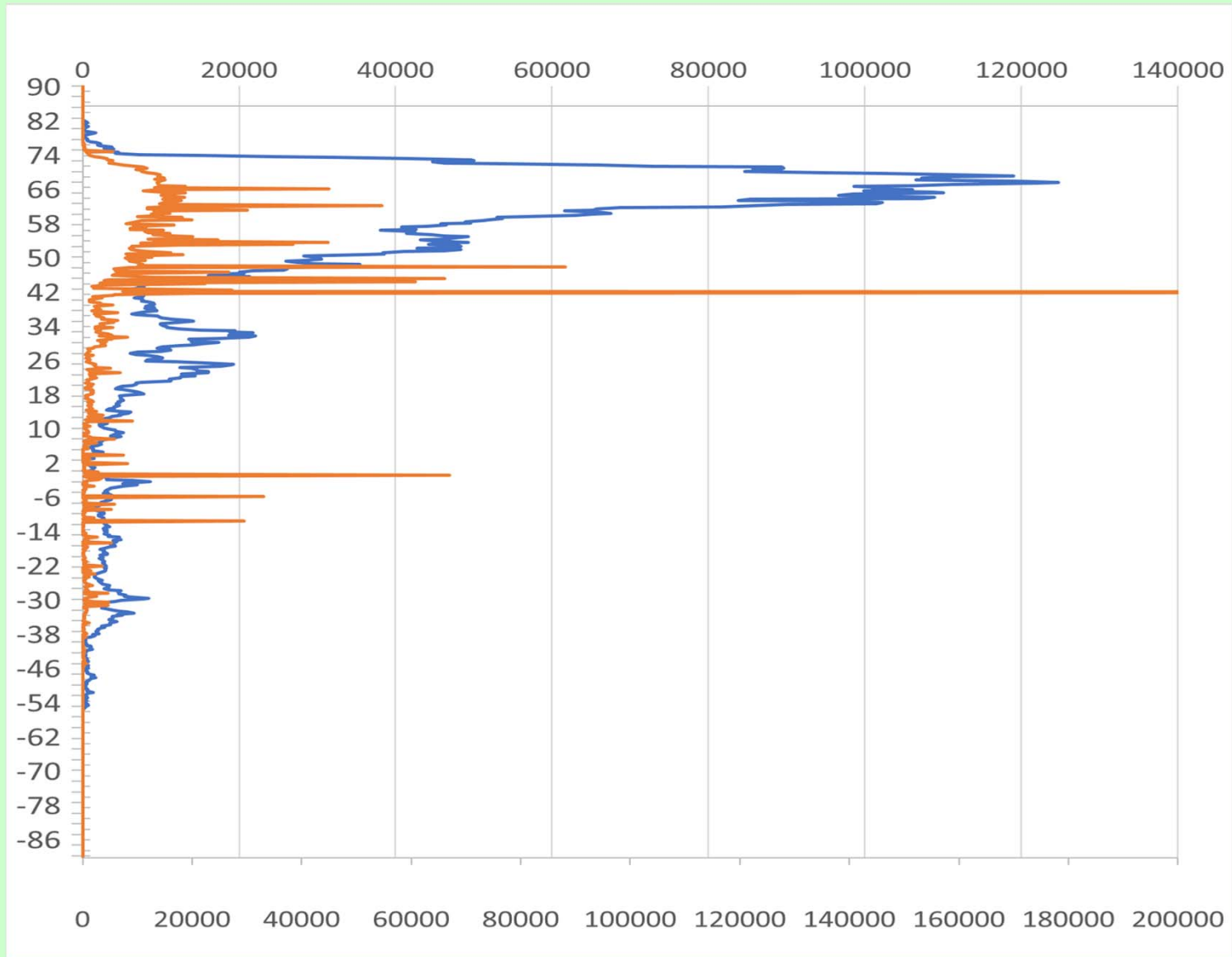
Lake Size Distribution of Each Continent



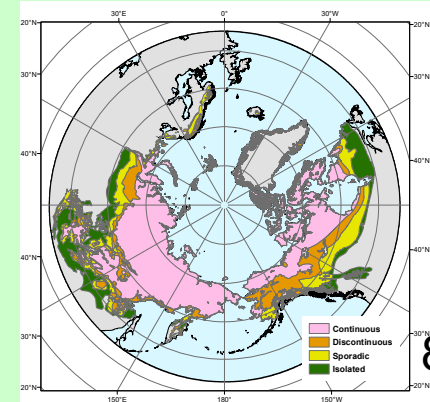
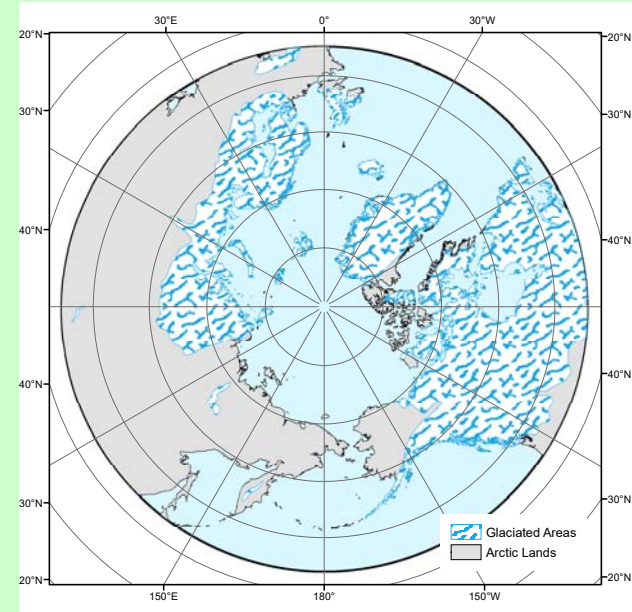
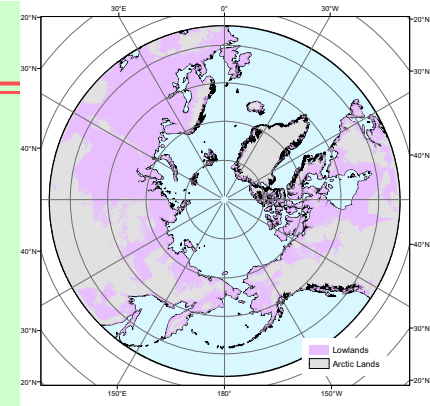
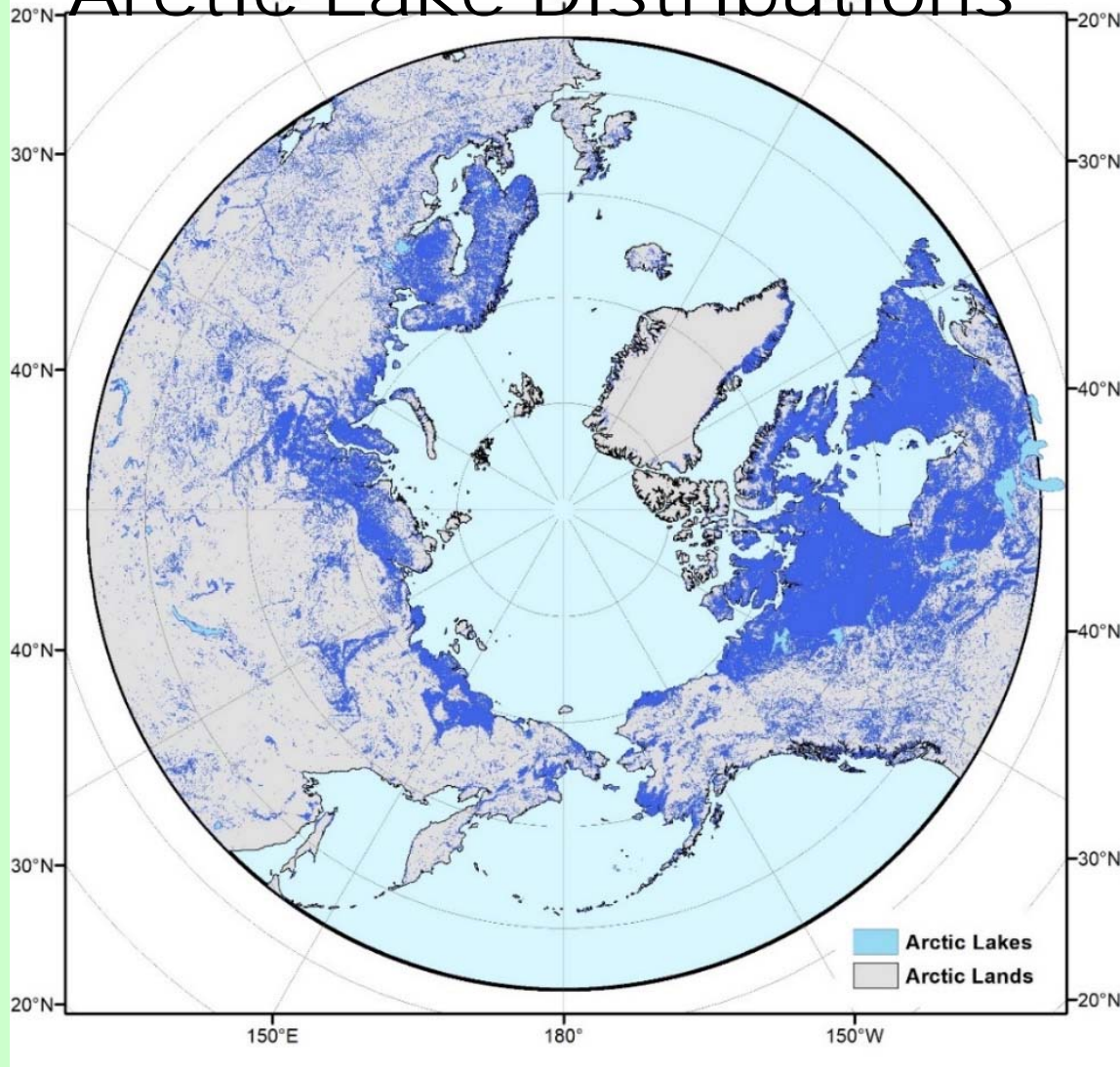
Lake count statistics on water level



Latitudinal Lake Distributions



Arctic Lake Distributions



Zones	Land area (km ²)	Lake #	Lake area (km ²)	Lake density
Total	41,305,809	4,952,603	1,753,399	4.24%

Zonal Statistics of Controlling Factors

Zones	Land area (km ²)	Lake #	Lake abundance (#/1000km ²)	Lake area (km ²)	Lake density (%)
LGM Extents	18,371,069	3,916,754	213	1,304,322	7.10
Non LGM	22,934,740	1,035,849	45	449,077	1.96
Total	41,305,809	4,952,603	120	1,753,399	4.24

3.6:1

4.7:1

Zones	Land area (km ²)	Lake #	Lake abundance	Lake area (km ²)	Lake density (%)
Lowlands	18,371,069	3,259,054	177.40	1,037,668	5.65
Non Lowlands	22,934,740	1,693,549	73.84	715,731	3.12
Total	41,305,809	4,952,603	120	1,753,399	4.24

1.8:1

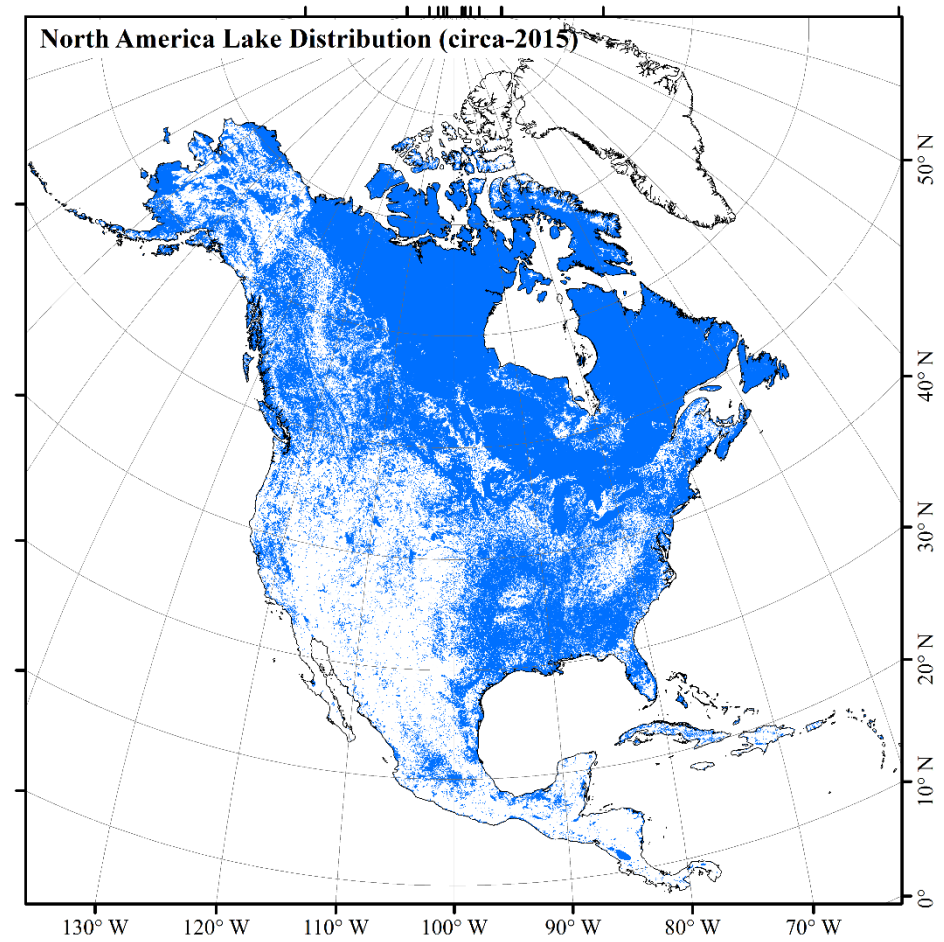
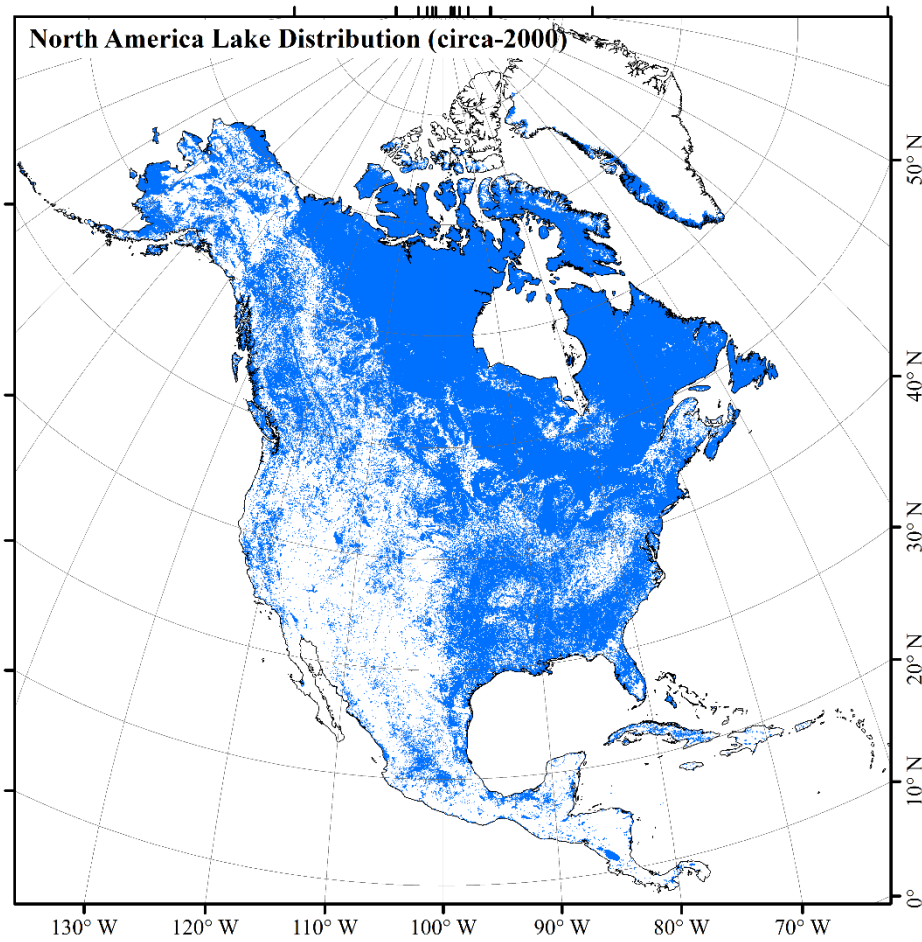
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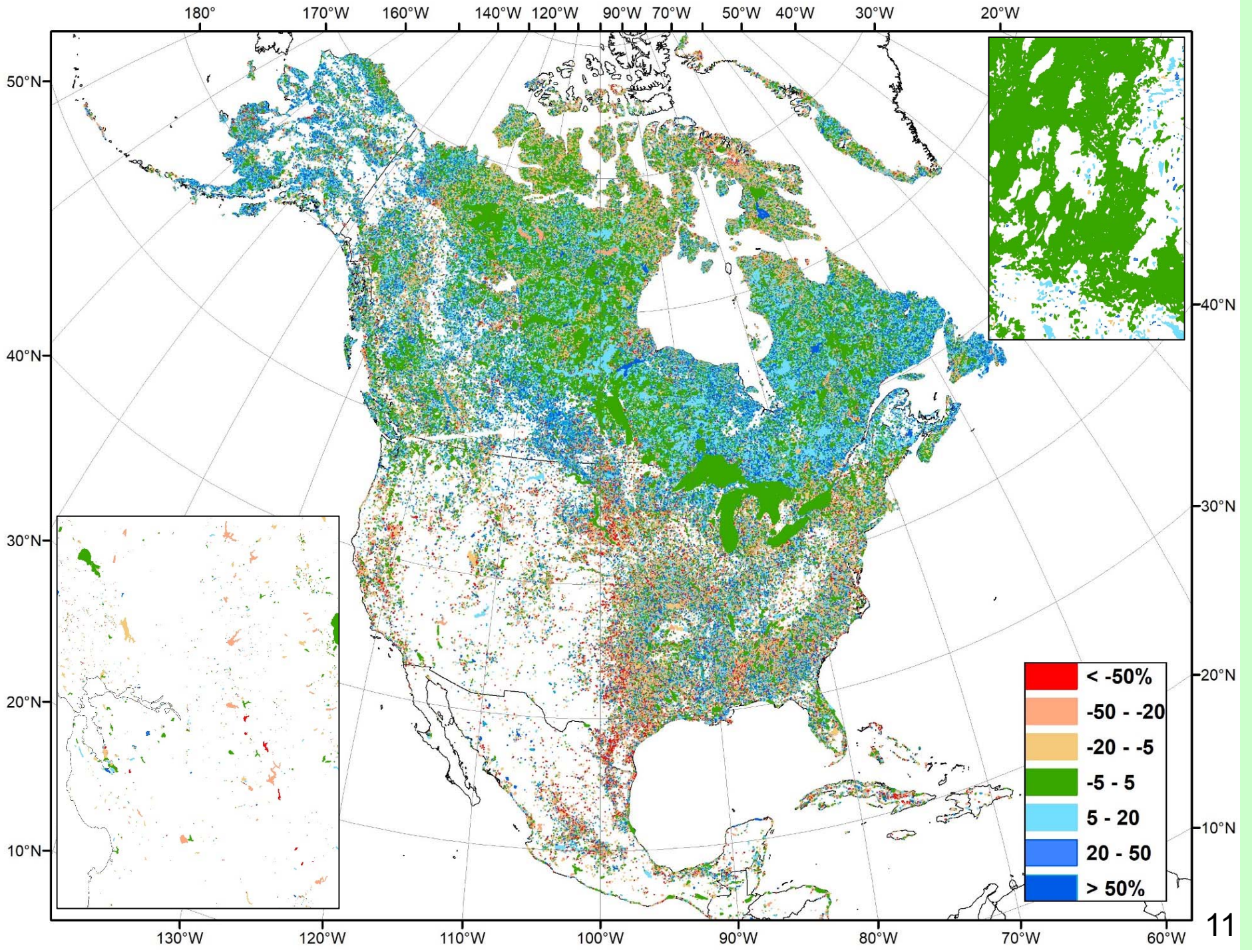
Zones	Land area (km ²)	Lake #	Lake abundance	Lake area (km ²)	Lake density (%)	
Permafrost	Continuous	10,974,152	2,553,809	233	475,453	4.33
	Discontinuous	3,199,002	453,268	142	129,222	4.04
	Sporadic	3,095,431	482,019	156	161,634	5.22
	Isolated	3,546,861	369,110	104	141,395	3.99
	Sum	20,815,446	3,858,206	185	907,704	4.36
Permafrost-free	20,490,363	1,094,397	53	845,695	4.13	
Total	41,305,809	4,952,603	120	1,753,399	4.24	

1.1:1

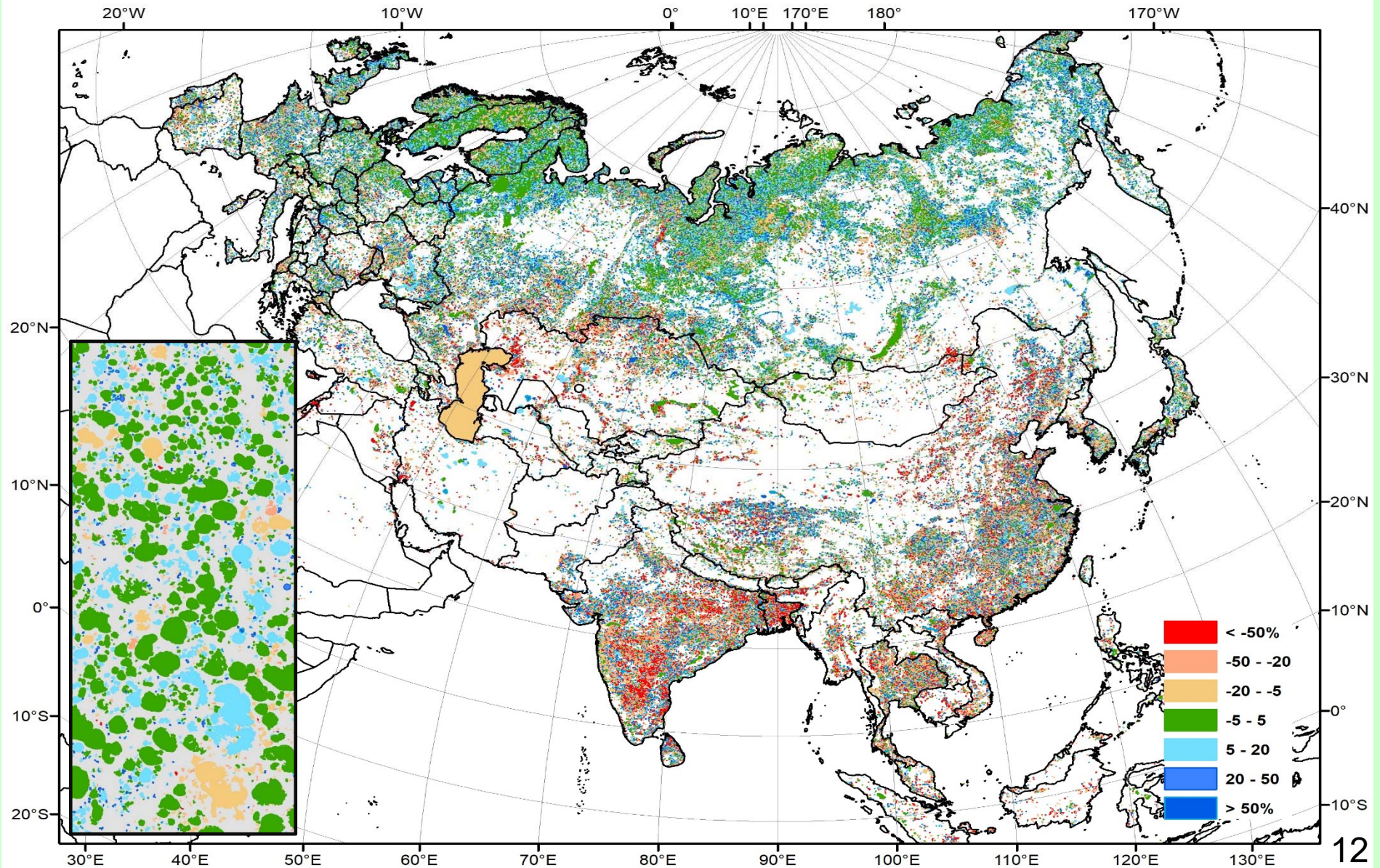
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Comparison of Circa-2000 and Circa-2015

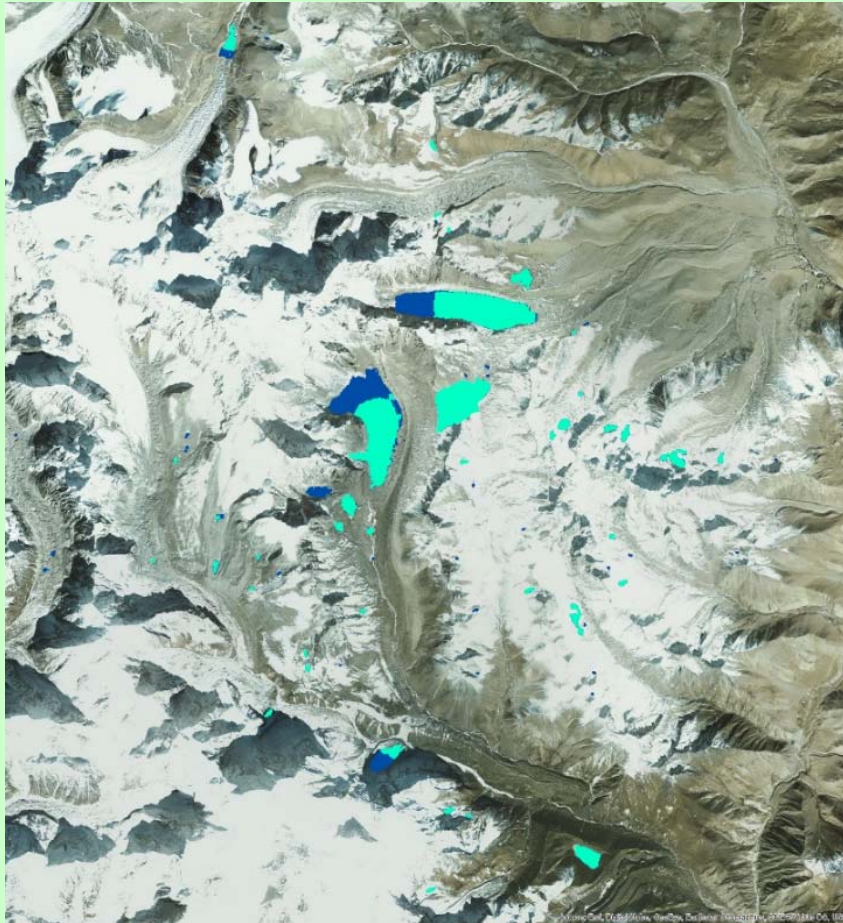




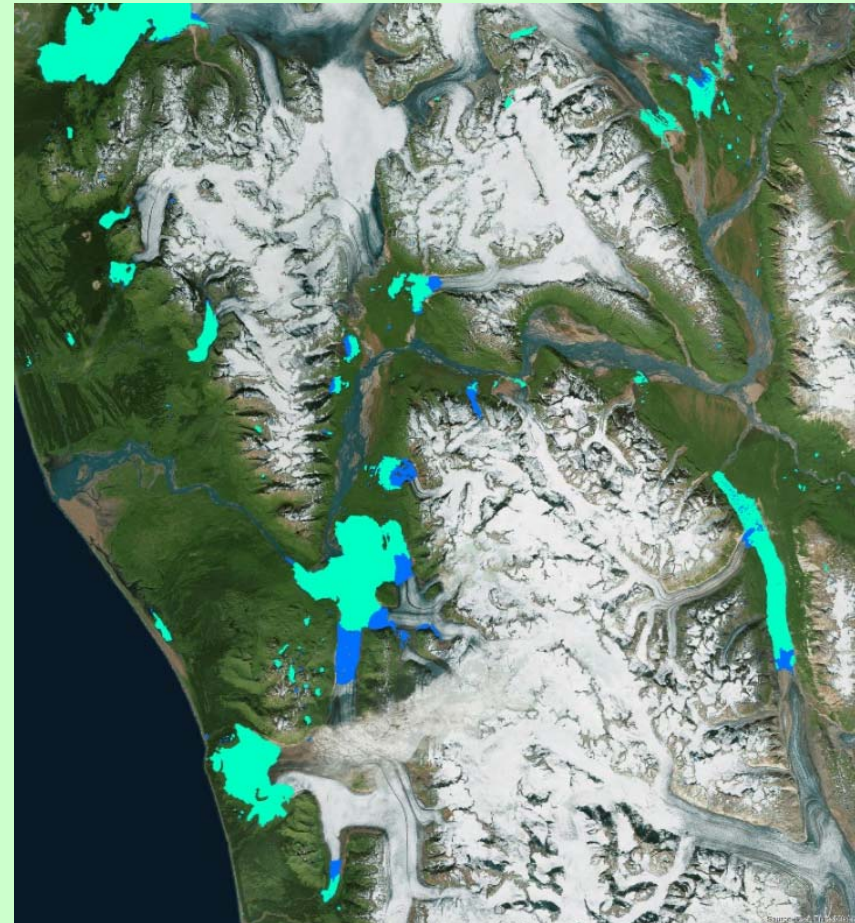
Eurasia Lake Changes (2000-2015)



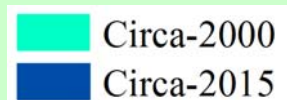
Newly emergent and expanding glacial lakes



The Himalayas

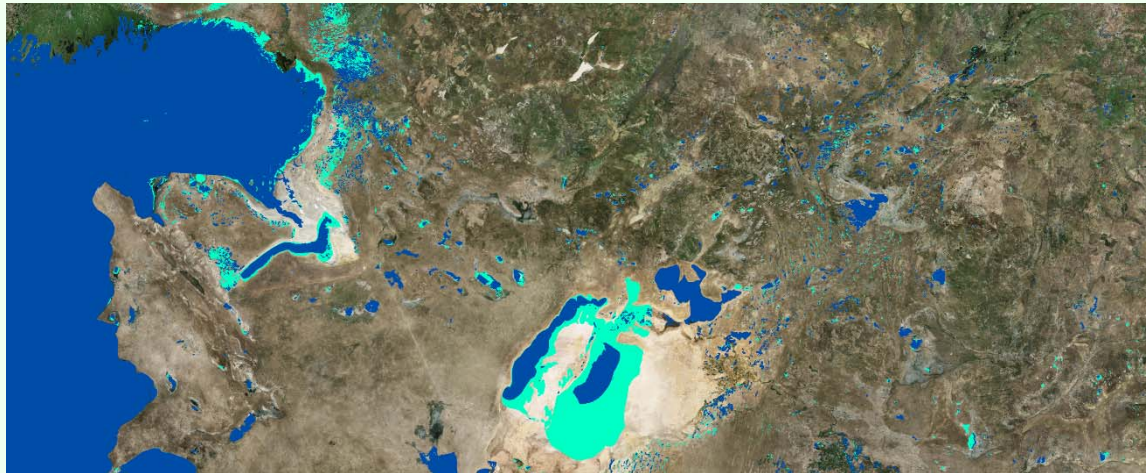


The Arctic



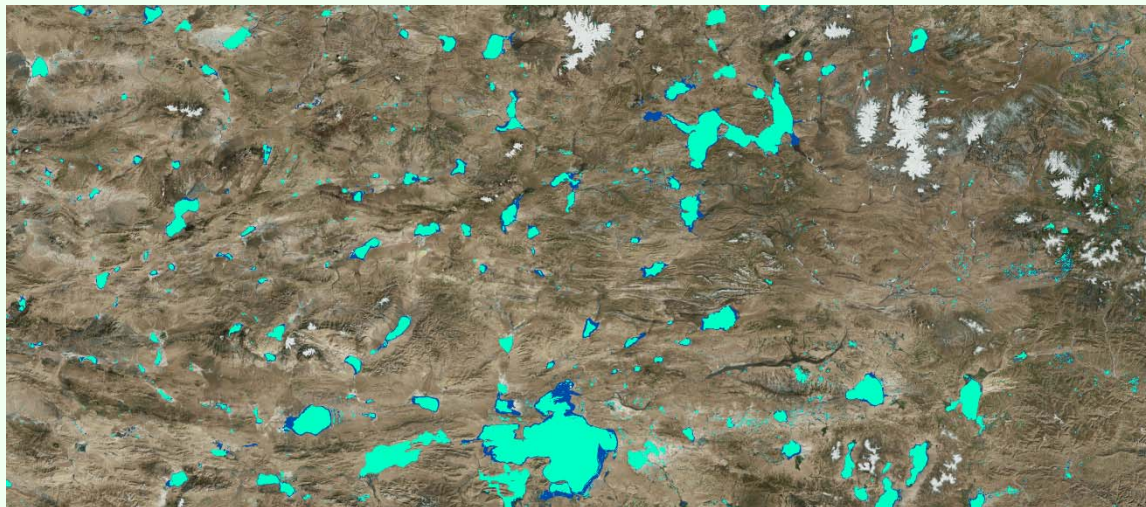
Lake change hotspots

Lake shrinking owing to drying climate and human intervention



■ Circa-2015
■ Circa-2000

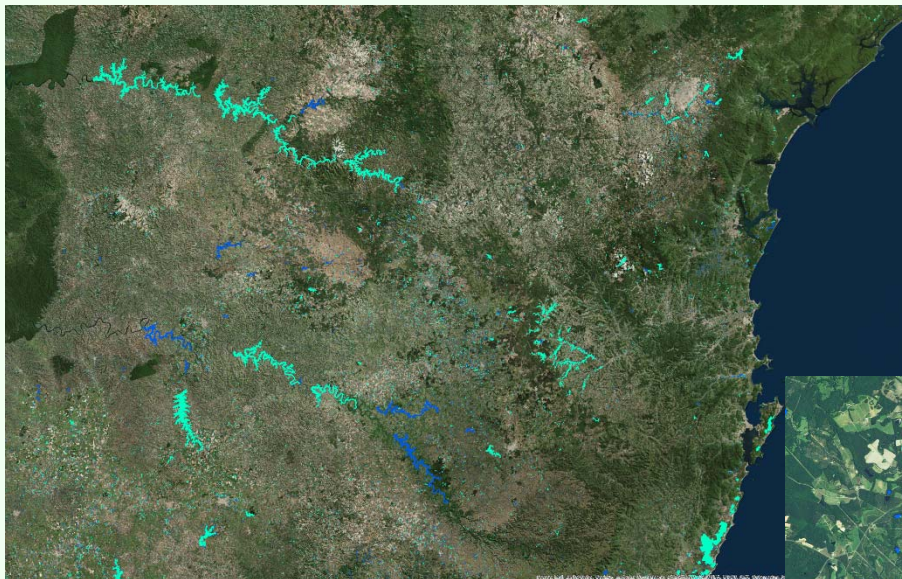
Lake expansion owing to wetting climate and glacier meltwater



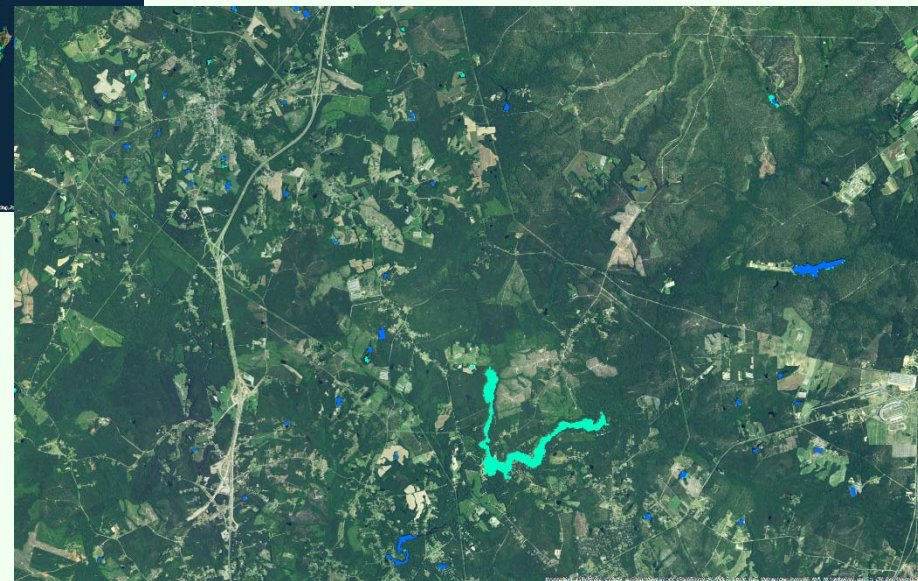
■ Circa-2000
■ Circa-2015

Lake change hotspots

Newly dammed reservoirs in South America



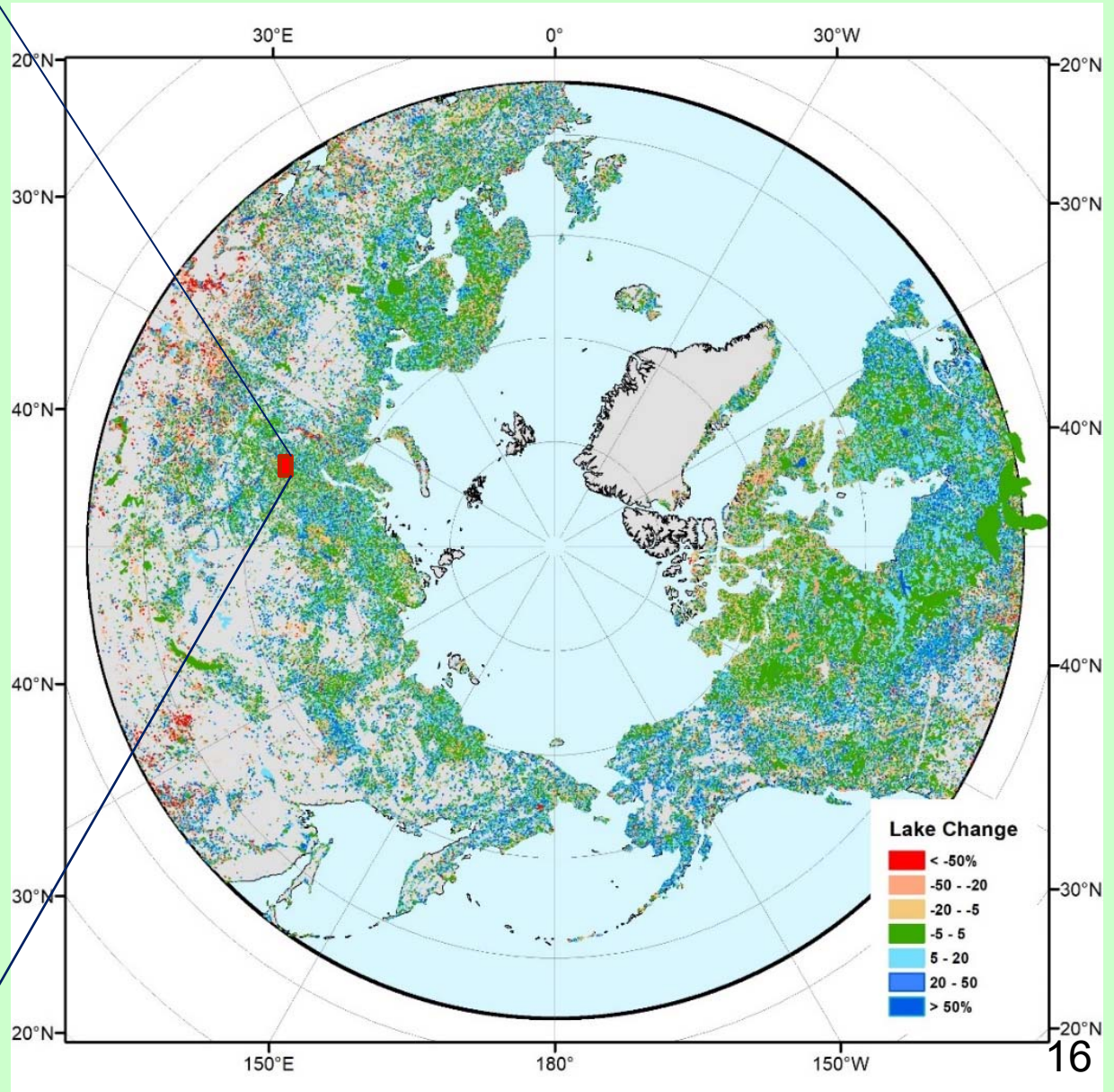
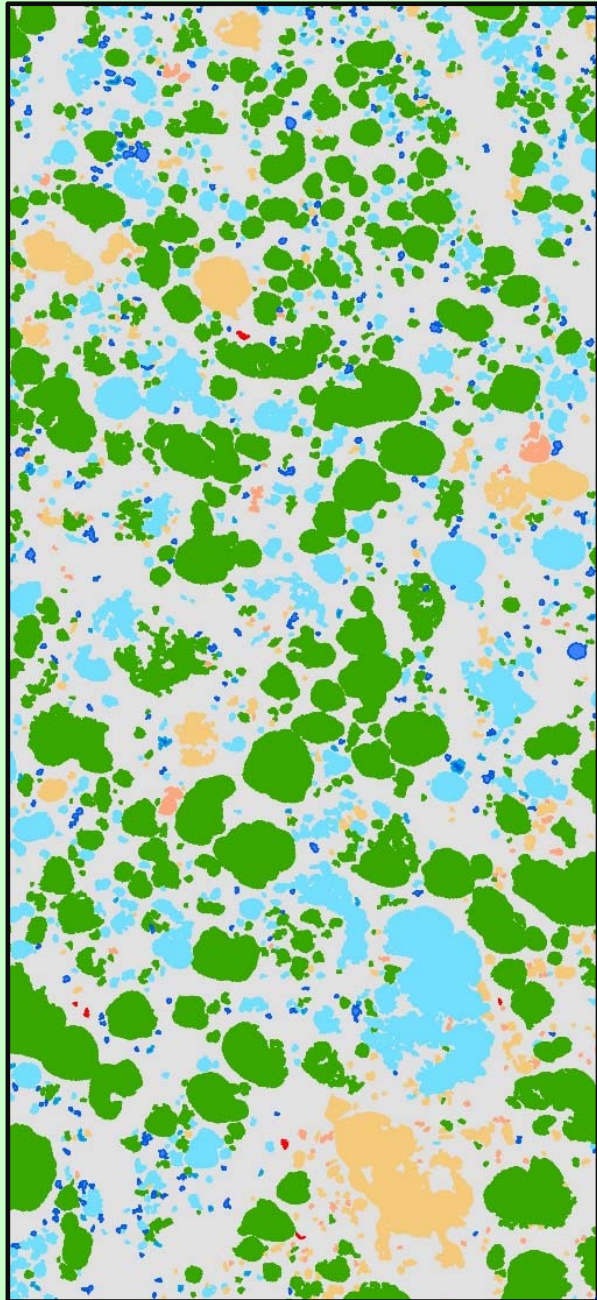
Circa-2000
Circa-2015



Circa-2015
Circa-2000

Missing reservoirs with
dam removal in USA

Pan-Arctic Lake Changes 2000--2015

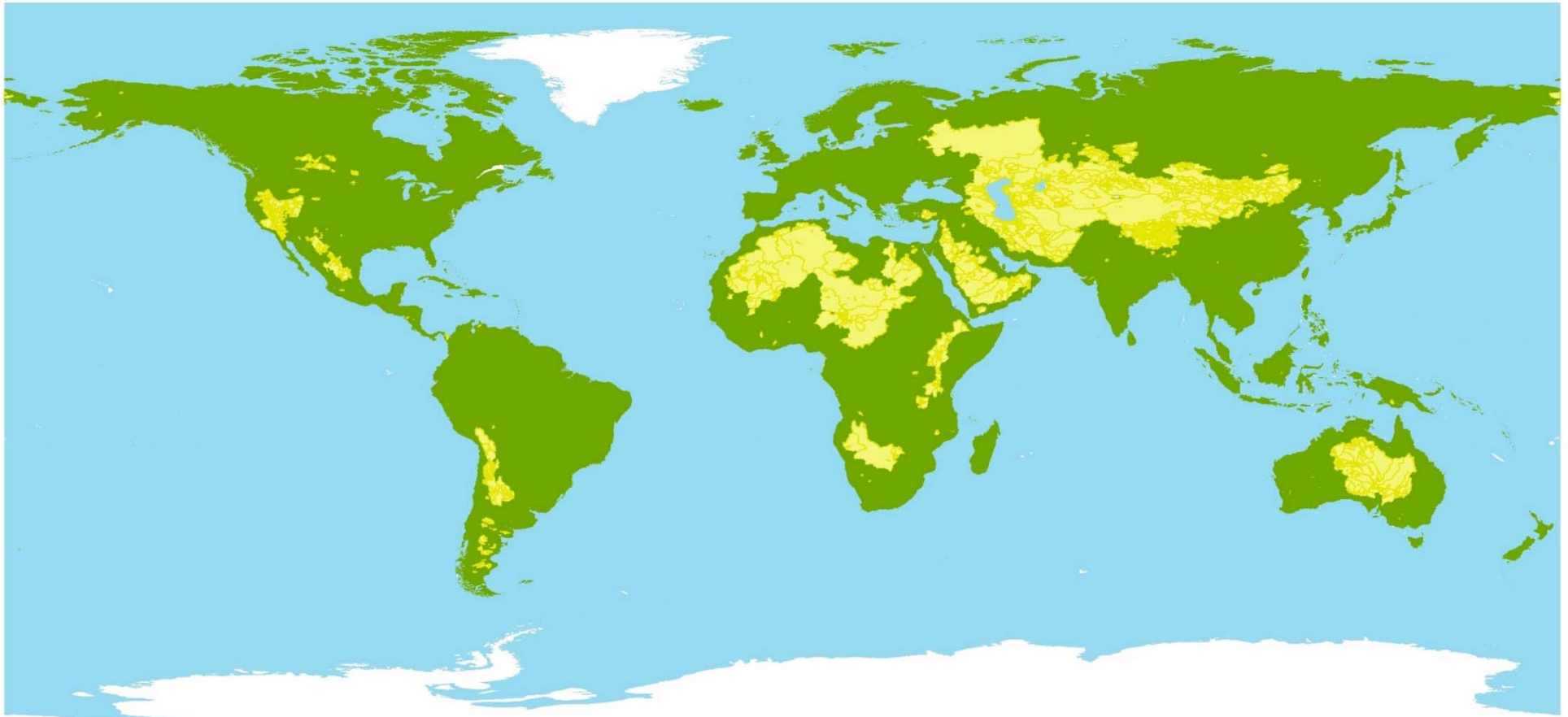


Arctic Lake Change Permafrost Zonal Statistics

Zones		Area (km ²)	Lake 2015	Lake 2000	Change Rate
Permafrost	Continuous	10,974,152	475,453	465,500	2.14
	Discontinuous	3,199,002	129,222	124,976	3.40
	Sporadic	3,095,431	161,634	155,416	4.00
	Isolated	3,546,861	141,395	134,867	4.84
	Sum	20,815,446	907,704	880,759	3.06
Permafrost-free		20,490,363	845,695	844,112	0.19
Total		41,305,809	1,753,399	1,724,871	1.65

GRACE-derived water decline in endorheic basins

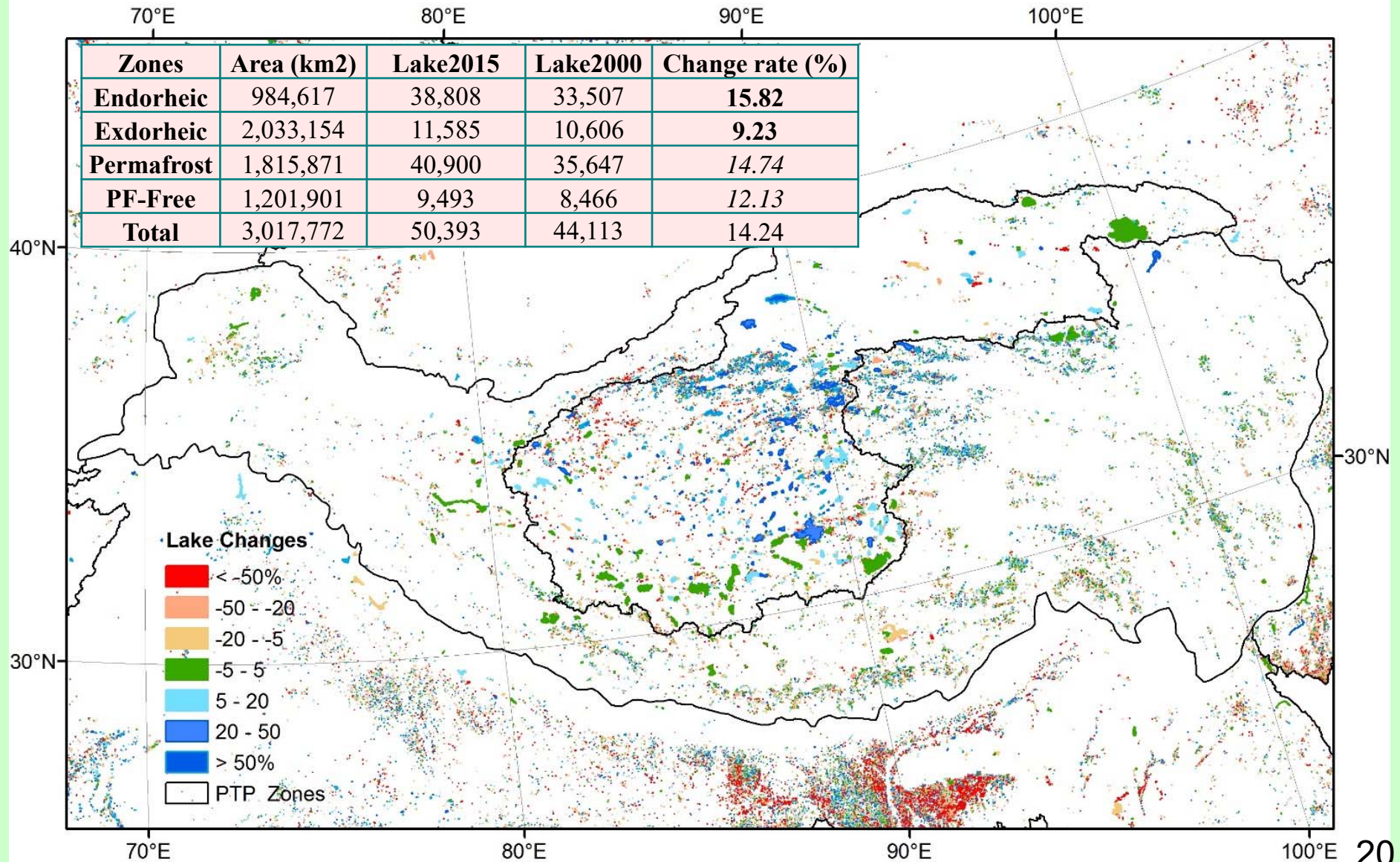
(Wang et al., 2018, Nature Geoscience)



Endorheic vs. Exorheic

Continents	Type	Lake 2015	Lake 2000	Change
Africa	Endorheic	29,366	32,747	-10.3%
	Exorheic	213,596	214,168	-0.3%
Asia	Endorheic	542,471	568,380	-4.6%
	Exorheic	425,372	411,319	3.4%
Oceania	Endorheic	19,463	22,564	-13.7%
	Exorheic	45,527	42,694	6.6%
Europe	Endorheic	25,462	24,614	3.4%
	Exorheic	200,133	194,270	3.0%
S. America	Endorheic	28,906	30,205	-4.3%
	Exorheic	143,285	140,038	2.3%
N. America	Endorheic	12067	11,816	2.1%
	Exorheic	1,313,322	1,274,576	3.0%
Global	Endorheic	657,735	690,326	-4.7%
	Exorheic	2,341,235	2,277,065	2.8%

TP Lake Changes 2000--2015



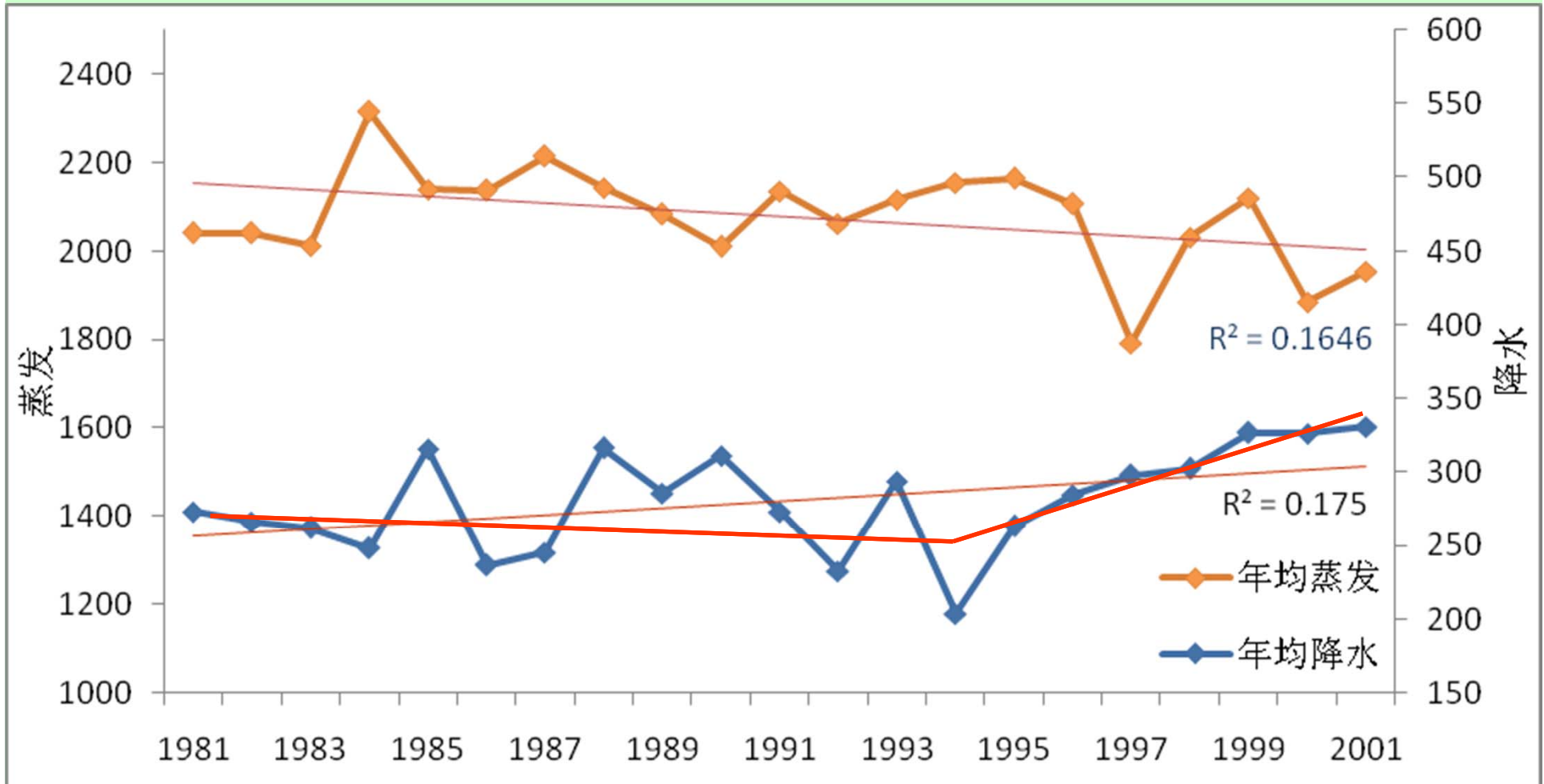
Decadal Tibetan Lake Changes

(*Sheng and Li, 2011*)

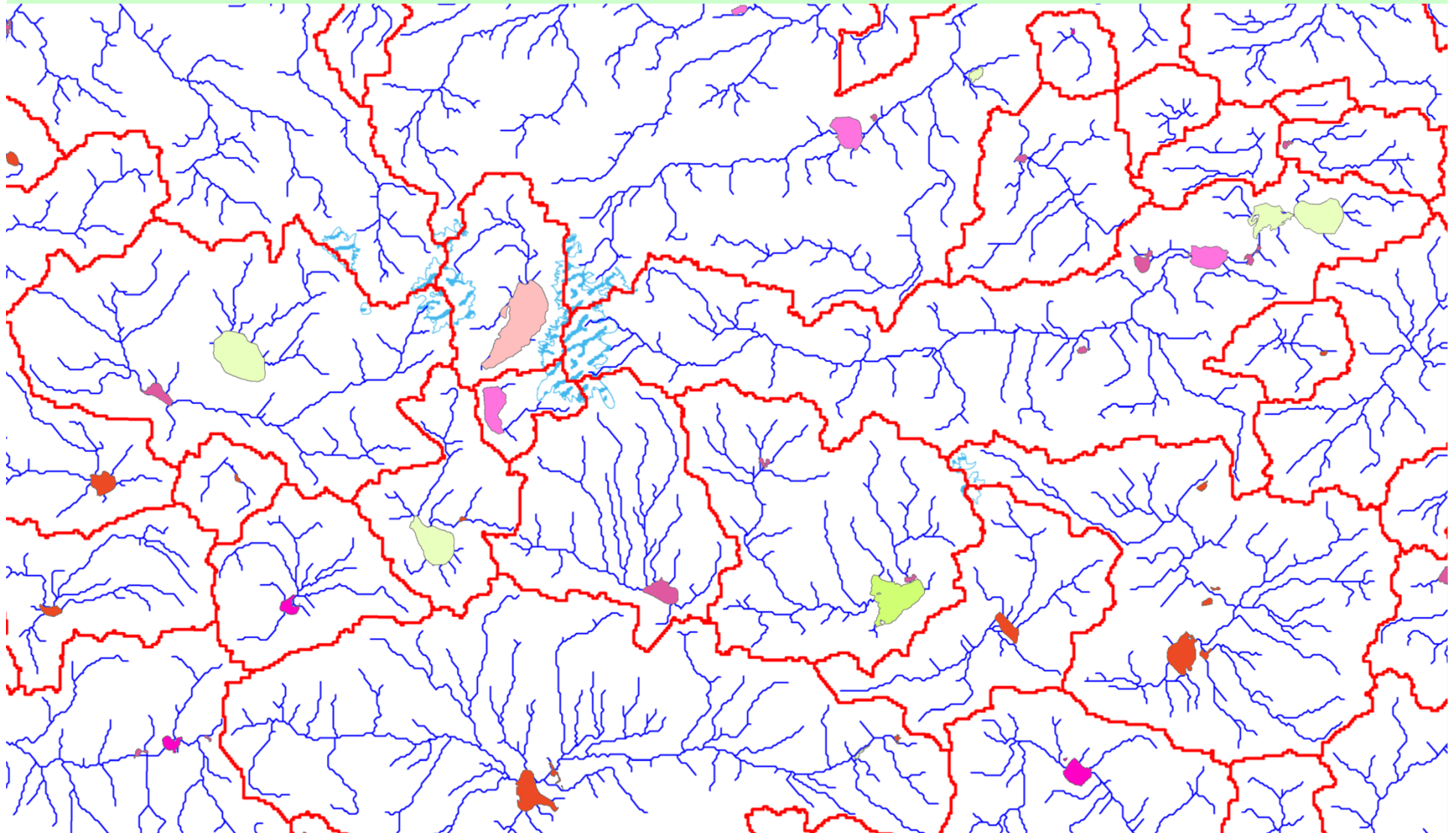
- ☑ The lake change over the past 4 decades is not constant over time.
- ☑ Annual change rate:
 - 1976-1990: -0.11%;
 - 1990-2000: 1.24%;
 - 2000-2009: 1.44%;
 - 2009-2015: 0.47%.



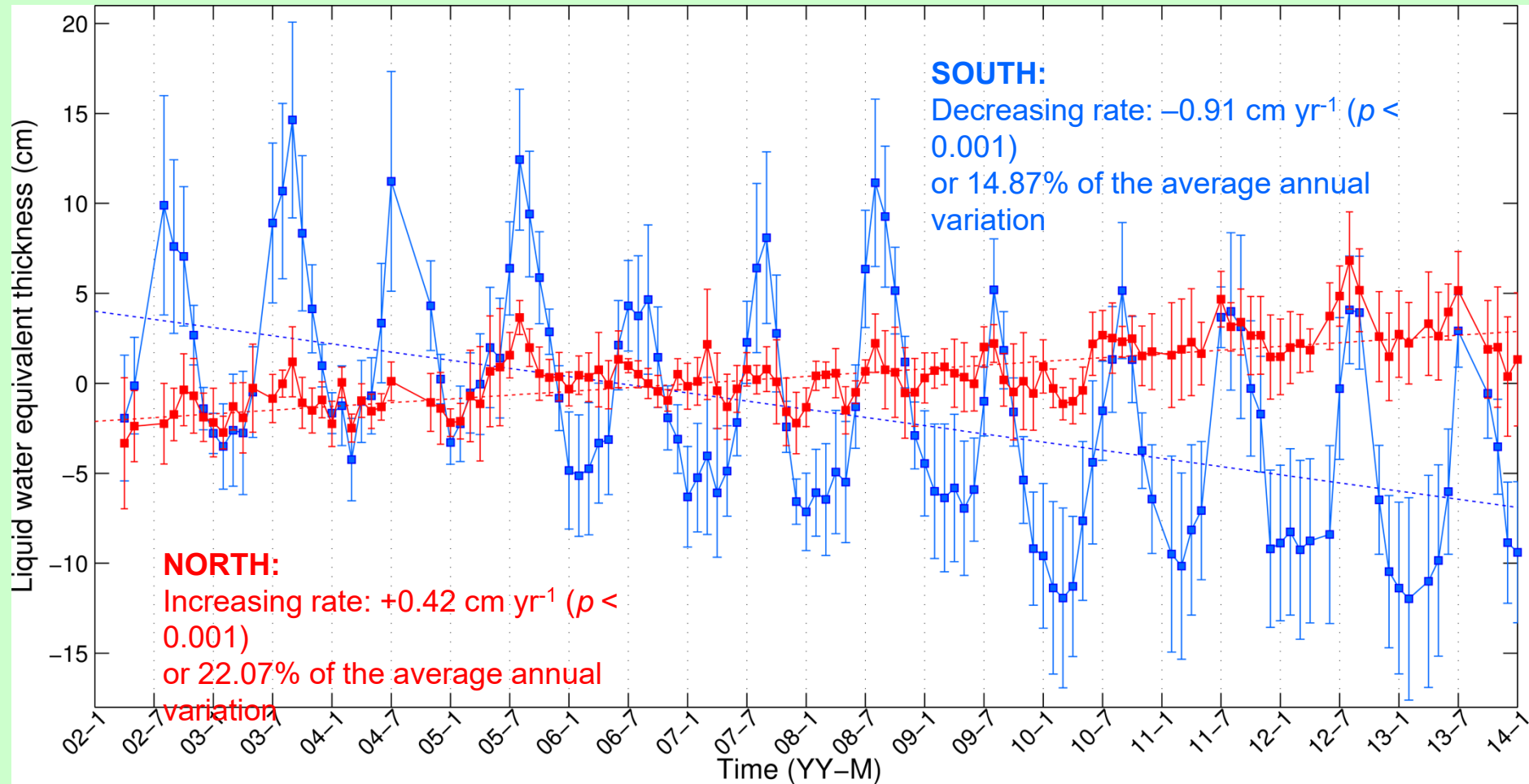
Lake Change in Response to Climate Change



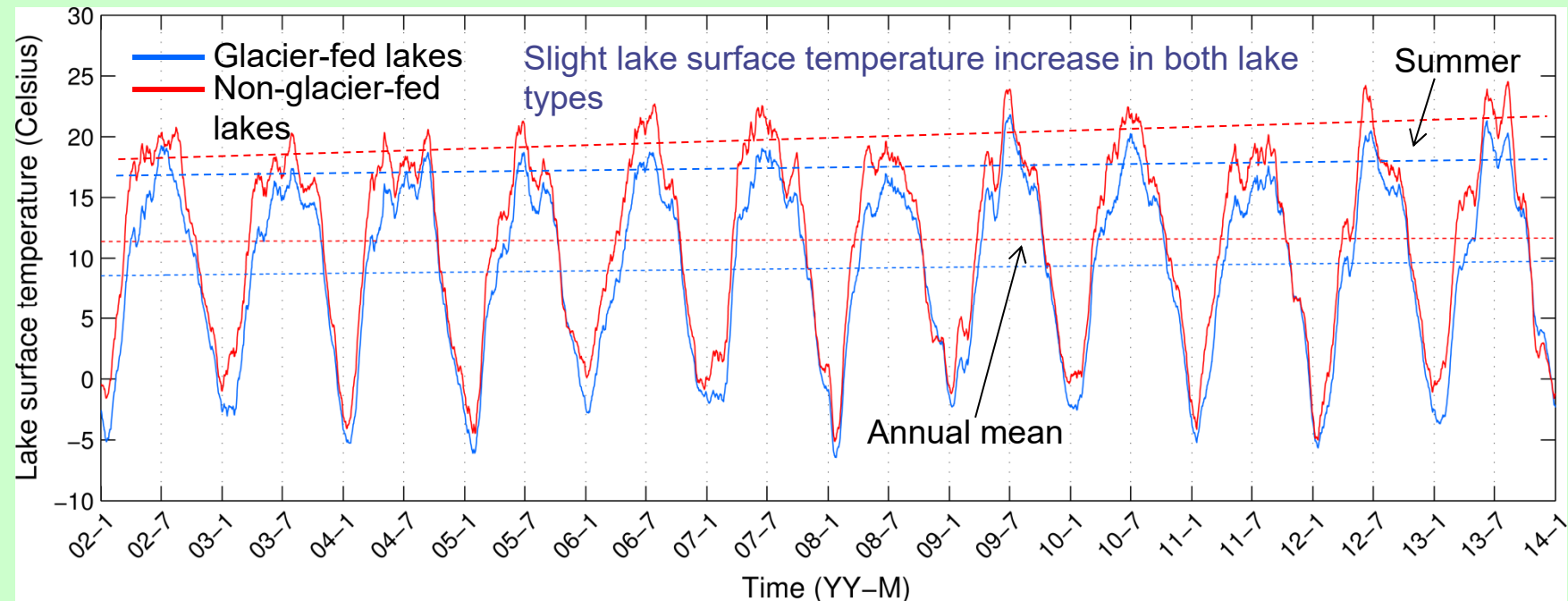
Contribution of Glacier Meltwater



GRACE-Derived glacier mass dynamics in the North and South Tibetan Plateau (2002–2013)



Dynamics of MODIS-derived lake surface temperature (2002–2013)



Summary of LST changes

Lake type	Spring	Summer	Fall	Winter	Year-round
Glacier	0.64 (19.52%) <i>p</i> = 0.211	0.60 (34.36%) <i>p</i> = 0.047	0.02 (0.45%) <i>p</i> = 0.500	0.22 (9.82%) <i>p</i> = 0.298	0.09 (1.24%) <i>p</i> = 0.266
Non-glacier	-0.02 (-0.68%) <i>p</i> = 0.484	0.76 (35.7%) <i>p</i> = 0.0497	-0.67 (-13.73%) <i>p</i> = 0.317	-0.01 (-0.31%) <i>p</i> = 0.483	0.02 (0.25%) <i>p</i> = 0.451