

K.Ya. Kondratyev and N.N. Filatov

---

# Limnology and Remote Sensing

A Contemporary Approach



Springer

Published in association with  
**Praxis Publishing**  
Chichester, UK



# Contents

Preface .....	v
<b>1 Contemporary limnological problems: local, regional and global aspects . .</b>	<b>1</b>
1.1 Direct anthropogenic impacts leading to lake eutrophication and toxic contamination .....	1
1.2 Indirect anthropogenic impacts stemming from regional climatic change driven by regional/global changes .....	8
1.3 Direct and feedback mechanisms of interactions of lakes with ambient environments (Lakes Ladoga and onega as examples) . .	15
1.4 A comparative analysis of the American Great Lakes and Lakes Ladoga and Onega ecological status. ....	22
1.4.1 Lake Onega .....	22
1.4.2 Lake Ladoga .....	24
1.4.3 North American Great Lakes .....	28
1.5 Feasibility, merits and limitations of using a large, deep lake as a physical model of the ocean .....	36
References .....	45
<b>2 Fundamental limnological processes and relevant indicators used in contemporary lake studies. ....</b>	<b>53</b>
2.1 Heat flux, storage and budget of a lake water-sediments system. . .	53
2.1.1 Thermal characteristics of lakes. Global inventories, database and GIS. ....	53
2.1.2 Equations for heat storage and budget .....	56
2.1.3 Heat flux components. Evaluation and simplification .....	58
2.1.4 Heat flux and budget of a lake surface .....	65
2.2 Temporal-spatial variability of lake surface temperature. Global approach and classification .....	76
2.2.1 Thermal classification of lakes .....	77
2.2.2 Global model for lake-surface temperature .....	78

2.2.3	Modelling of altitude effects and thermal classification of lakes . . . . .	79
2.3	Thermal bar in a moderate lake . . . . .	82
2.3.1	Discovery and study . . . . .	82
2.3.2	General description of the phenomenon . . . . .	83
2.3.3	Theoretical models and descriptions . . . . .	85
2.4	Langmuir circulation . . . . .	90
2.5	Ice formation and its temporal/spatial evolution, ice dynamics relation to the lake thermal regime and weather conditions . . . . .	98
2.5.1	Study of freeze-up phase change on large temperate-zone inland water bodies using microwave observation . . . . .	98
2.5.2	Basic laws of the process of ice-cover formation on large inland water bodies . . . . .	99
2.5.3	Radar signatures of the ice cover of large inland water bodies ( $\lambda = 5.7$ cm) . . . . .	105
2.5.4	Freeze-up phase classification and perspectives of SAR thematic decoding development . . . . .	112
2.6	Lake hydrodynamics and hydrology: weather and climate . . . . .	113
2.6.1	Spatial and temporal scales of water motions in lakes . . . . .	113
2.6.2	Hydrodynamics of the largest lakes in Europe: Ladoga and Onega . . . . .	115
2.6.3	Hydrodynamics of Lake Ladoga. Large-scale circulation: model results . . . . .	118
2.6.4	Hydrodynamics of Lake Onega . . . . .	120
2.6.5	Water circulation connected with topographic effects . . . . .	121
2.6.6	Currents and dynamics of wind-induced upwelling . . . . .	123
2.6.7	Technology of lake observations by remote sensing and assimilation of these data in a models . . . . .	126
2.6.8	Lake hydrodynamics, water ecosystem and climate changes . . . . .	127
2.7	Characteristics of water motion at various spatial/temporal scales . . . . .	128
2.7.1	Macroscale phenomena . . . . .	128
2.7.2	Microscale phenomena . . . . .	142
2.8	Lake hydrochemistry and hydrobiota (Lake Ladoga as an example) . . . . .	148
2.8.1	Seasonal and spatial distributions in the lake hydrochemical and hydrobiotic constituents. Consequences of anthropogenic influences . . . . .	148
	References . . . . .	157
<b>3</b>	<b>Modern passive and active optical and microwave remote sensing: advanced feasibility for applications in contemporary limnological studies . . . . .</b>	<b>169</b>
3.1	Optical remote sensing . . . . .	169
3.1.1	Passive remote sensing . . . . .	169
3.1.2	Active (lidar) remote sensing . . . . .	242
3.1.3	Atmospheric correction of satellite images . . . . .	256

3.2	Passive and active microwave remote sensing . . . . .	268
3.2.1	The physical basis for microwave diagnostics of lakes, reservoirs and watershed parameters . . . . .	268
3.2.2	Active microwave remote sensing of lakes . . . . .	286
	References . . . . .	291
<b>4</b>	<b>Combined <i>in situ</i> and remote sensing of inland water bodies of the moderate climatic zone . . . . .</b>	<b>306</b>
4.1	Hydrodynamics of large deep lakes: results of the complex studies . . . . .	306
4.1.1	Remote studies of major thermohydrodynamic processes and events in lakes, estuaries and coastal zones . . . . .	306
4.1.2	Surface roughness inhomogeneity as indicator of water mass dynamics: spatial variations in areas with subdued roughness driven by water density . . . . .	311
4.2	Thermal regime of lakes: results of complex studies . . . . .	316
4.2.1	Thermal structures of the lakes: transformation in the annual cycle, specific to regional features. . . . .	316
4.2.2	Retrieving lake temperatures: numerical modeling and results of sub-satellite experiments . . . . .	327
4.2.3	Ice formation and its temporal/spatial evolution: combined <i>in situ</i> and remote-sensing studies . . . . .	334
4.3	Hydrobiological studies. . . . .	352
4.3.1	Spatial and temporal variations in lake phytoplankton and dissolved organics distribution and macrophyte stands . . . . .	352
4.3.2	Remote assessment of primary production and advective carbon fluxes in aquatic environments . . . . .	363
	References . . . . .	368
<b>5</b>	<b>Geographical Information Systems in limnology . . . . .</b>	<b>374</b>
5.1	Geographical Information Systems: definitions, types, components . . . . .	374
5.2	GIS functions . . . . .	380
5.2.1	Visualization . . . . .	380
5.2.2	Query and analysis . . . . .	380
5.2.3	Classification . . . . .	382
5.2.4	Time-series analysis . . . . .	383
5.3	Data . . . . .	383
5.4	Internet and GIS . . . . .	386
5.4.1	Internet Map Servers . . . . .	386
5.4.2	GIS on-line for the Great Lakes . . . . .	387
5.5	Conclusion . . . . .	392
	References . . . . .	393
	<b>Afterword . . . . .</b>	<b>395</b>