

INTERNATIONAL GEOPHYSICS SERIES • VOLUME 12



EI 18

INSTITUT
FÜR METEOROLOGIE U. KLIMATOLOGIE
DER TECHN. UNIVERSITÄT 2/1296
HANNOVER · HERRENHAUSER STR. 2

EI 78

DK 557.521

RADIATION IN THE ATMOSPHERE

K. YA. KONDRATYEV

DEPARTMENT OF ATMOSPHERIC PHYSICS
LENINGRAD UNIVERSITY
LENINGRAD, U.S.S.R.



1969

ACADEMIC PRESS New York and London

CONTENTS

<i>Editor's Preface</i>	vii
<i>Preface</i>	ix
1. Radiant Energy. The Main Concepts and Definitions	1
1.1. The Sun as the Source of Radiation. The Concept of Stellar Temperatures	1
1.2. General Information on Radiant Fluxes in the Atmosphere	6
1.3. Main Quantitative Characteristics of a Radiation Field	9
1.4. Fundamental Laws of Thermal Radiation	22
1.5. Thermal Emission of Real Bodies	35
1.6. The Equation of Radiative Transfer for a Stationary Radiation Field	43
References	47
2. Methods of Actinometric Measurements	49
2.1. General Characteristic of the Methods for Measurement of Radiant Energy	49
2.2. Instruments for Measuring Direct Solar Radiation	52
2.3. Instruments for Measuring Global and Diffuse Radiation and Albedo	60
2.4. Instruments for Measuring Brightness and Illumination	65
2.5. Instruments for Measuring Radiation Balance and Effective Radiation	66
2.6. Main Types of Instruments for Spectral Measurements	72
2.7. Instruments for Measuring Atmospheric Thermal Emission	77
2.8. Instruments for Measuring Shortwave Radiation Fluxes	79
References	83

3. Radiation Absorption in the Atmosphere	85
3.1. General Principles of Selective Radiation Absorption	86
3.2. The Absorption Spectrum of Water and Water Vapor	107
3.3. The Absorption Spectrum of CO ₂	123
3.4. The Absorption Spectra of Ozone and Oxygen	132
3.5. General Characteristic of Minor Radiation-Absorbing Components of the Atmosphere	139
3.6. The Integral Transmission Function of the Atmosphere for Thermal Radiation	141
3.7. Absorption Spectroscopy of the Atmosphere as a Method for Investigation of the Atmospheric Composition	144
References	151
4. Scattering of Radiation in the Atmosphere	161
4.1. The Solar Ray Path in the Atmosphere	161
4.2. Scattering of Radiation (General Considerations)	169
4.3. Rayleigh Scattering	171
4.4. Scattering of Radiation on Large Particles	180
4.5. Computation of the Attenuation in the Atmosphere due to Scattering	194
4.6. Elementary Theory of Radiative Transfer, Including Multiple Scattering	200
4.7. Radiation Scattering and the Structure of Atmospheric Aerosol	209
References	212
5. Direct Solar Radiation	217
5.1. Distribution of Energy in the Solar Spectrum at the Earth's Surface Level	217
5.2. Spectral Atmospheric Transparency	234
5.3. Energy Distribution in the Solar Spectrum outside the Atmosphere	245
5.4. The Solar Constant	252
5.5. Total Attenuation of Solar Radiation in an Ideal Atmosphere	260
5.6. Quantitative Characteristics of the Real Atmospheric Transparency	263
5.7. Some Data of Observations on the Variation of the Atmospheric Transparency State	283
5.8. Attenuation of Solar Radiation by Clouds	300
5.9. Theoretical Calculations of Irradiation of the Earth's Surface by the Sun	304
5.10. Temporal and Spatial Variability of Fluxes and Totals of Solar Radiation	317
5.11. Income of Solar Radiation on Slant Surfaces	342
References	355

6. Diffuse Radiation of the Atmosphere	363
6.1. Energy Distribution in the Spectrum of Diffuse Radiation	363
6.2. Angular Distribution of Diffuse Radiation Intensity	368
6.3. Fluxes of Diffuse Radiation	376
6.4. The Main Observed Regularities of the Variability of Diffuse Radiation	
Totals	400
References	408
7. Albedo of the Underlying Surface and Clouds	411
7.1. Spectral Albedo of Natural Underlying Surfaces	411
7.2. Albedo of Various Continental Underlying Surfaces	422
7.3. Albedo of Water Basins	431
7.4. Albedo of Clouds	440
7.5. Geographical Distribution of Albedo	444
References	449
8. Global Radiation	453
8.1. Energy Distribution in the Spectrum of Global Radiation	453
8.2. Fluxes of Global Radiation	457
8.3. The Main Observed Regularities in the Variability of Global Radiation	
Totals	470
8.4. Incoming Shortwave Radiation on Oriented Slant Surfaces	485
8.5. Income of Global Radiation Under Vegetative Covers	502
8.6. Penetration of Radiant Energy into Water, Ice, and Snow	517
8.7. Illumination	531
References	532
9. Thermal Radiation of the Atmosphere	538
9.1. The Phenomenological Theory of the Transfer of Thermal Radiation in the Atmosphere	538
9.2. Approximate Transfer Equations and Their Use for Calculating Thermal Radiative Transfer in the Atmosphere	546
9.3. Radiation Charts	551
9.4. Radiative Heat Transfer in Clouds	558
9.5. Effective Radiation of the Underlying Surface and the Downward Atmospheric Radiation	559
9.6. Angular Distribution of Intensity of Effective Radiation and Atmospheric Emission over the Celestial Sphere	584

9.7. Some Practical Applications of Data on the Angular Distribution of the Intensities of Effective Radiation and Atmospheric Emission	599
9.8. Distribution of Energy in the Spectrum of Effective Radiation and Downward Atmospheric Radiation	617
9.9. Emission Spectroscopy as a Means of Investigating the Structure and Composition of the Atmosphere	624
References	646
10. Net Radiation	655
10.1. Observed Regularities in Variation of Net Radiation of the Underlying Surface	657
10.2. Results of Calculations of Net Radiation at the Underlying Surface	672
10.3. The Net Radiation of Slopes	680
10.4. Net Radiation and Its Components in a Free Atmosphere	686
10.5. Climatology of Net Radiation of the Earth	728
10.6. Investigations of the Earth's Net Radiation by Means of Satellites	750
10.7. Statistical Features of the Net Radiation of the Earth-Atmosphere System	765
References	782
11. Temperature Variation in the Atmosphere Due to Radiative Heat Exchange	791
11.1. Equation for the Heat Inflow	791
11.2. Methods for Calculating Radiative Heat Inflow	795
11.3. Results of Calculations of Radiative Flux Divergence	804
11.4. Radiation Factors in the Thermal Regime of the Stratosphere and Mesosphere	814
11.5. Relation between Radiative and Turbulent Heat Exchange in the Surface Layer of the Atmosphere	829
References	832
ADDITIONAL BIBLIOGRAPHY	837
APPENDIXES	860
<i>Author Index</i>	889
<i>Subject Index</i>	907