Arctic Ecological Research from Microwave Satellite Observations

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PREFACE

Active (imaging radar) and passive (radiometer) microwave satellite systems are increasingly widely used in diverse fields of Arctic ecological research. Nevertheless, ecologists interested in remote sensing often have limited access to the full suite of physical and analytical techniques of microwave systems, data processing and ecological applications because a suitable reference book has not been produced.

This book provides a summary of main microwave satellite missions and applications for Arctic ecological research. It will be useful to undergraduate and postgraduate students, specialists with a background in microwave techniques and ecologists interested in applications of microwave active and passive remote sensing for tundra, boreal forest, and Arctic marine mammal studies.

Chapter 1 presents a brief introduction to Arctic ecological problems, the role of satellite remote sensing for systematic monitoring of Arctic ecosystems, elements of microwave remote sensing, data processing and applications.

Chapter 2 provides a summary of main characteristics and applications of Russian KOSMOS–OKEAN (real aperture radar, multispectral optical and passive microwave radiometer instruments) polar-orbiting satellite series and ALMAZ, RESURS–ARKTIKA (synthetic aperture radar) satellite series. To a lesser extent, we also treat the main national and international microwave and multispectral optical satellite systems that are of particular interest to the Arctic research community.

Chapter 3 represents some results of Arctic sea-ice habitat studies using remotely sensed and tracking satellite data. The sea-ice types, concentration and surface temperature are analyzed based on passive and active microwave OKEAN-01 satellite data.

Chapter 4 includes an example of Arctic sea-ice variability studies in the Barents–Kara Seas and adjacent parts of the Arctic Ocean using radar and passive microwave satellite measurements. Trends and sea-ice concentration are studied based on KOSMOS, OKEAN-01 and ALMAZ SAR satellite and historical data.

Chapter 5 gives the comparative analysis of multisensor satellite monitoring of Arctic sea-ice habitat using OKEAN-01, SSM/I and AVHRR satellite instruments. OKEAN-01 sea-ice type and concentration algorithms utilize radar and passive microwave information and *a priori* knowledge about the scattering and emission parameters of the basic sea-ice types.

Chapter 6 presents an example of boreal forest habitats studies using OKEAN-01 satellite data. Data processing and classification algorithms are based on the minimum loss criterion. These algorithms are used to classify satellite multispectral and microwave data into groups corresponding to different terrain cover of boreal forest habitat, and to evaluate information content of satellite data for discriminating boreal forest habitats.

Chapter 7 describes the evaluation of relative information content of ALMAZ-1, ERS-1 and JERS-1 SAR and Landsat-TM multispectral satellite data for identifying wet tundra habitats. Classification algorithms are based on minimum loss criteria to classify satellite data into groups corresponding to the different terrain covers of tundra habitats.

Chapter 8 summarises the results of investigating the influence of SAR data-focusing

parameters on the efficiency of tundra habitat classification. The special software is used for synthesizing images from the raw SAR data. The focusing algorithm allows control of a spatial resolution by means of the multi-look technique, and provides a set of window functions for flexible adjustment of the synthesized gain pattern.

Chapter 9 describes some aspects of polar bear regional ecology studies using simultaneous satellite telemetry and microwave remote sensing data collected by OKEAN-01 and SSM/I instruments. These aspects include regional and seasonal changes in habitat parameters; daily, seasonal and annual variability of movement rates; individual and group-specific direction and migration patterns, and a characteristic of using a particular type of habitat.

Chapter 10 presents some results of sensitive boreal forest type detection to monitor and assess potential impacts of climate change on the boreal forest structure. The primary objectives and analytical approaches employed by this study included a syntaxonomic classification of nature reserve forest community types, an evaluation of the biodiversity among the forest types and a comparative micro-climatic analysis to investigate bio-physical sensitivity.

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ERS-1 and JERS-1 imagery from the Alaska SAR Facility (ASF), Fairbanks received funds from the National Aeronautics and Space Administration. OKEAN-01 imagery from the Scientific Research Centers for Natural Resources Studies (NITS IPR), Moscow Region, Dolgoprudny and ALMAZ-1 SAR imagery from the NPO Mashinostroenia, Moscow was provided with funds from the Russian Ministry of Science and Technology. The National Snow and Ice Data Center, University of Colorado, provided the DMSP SSM/I Daily Polar Gridded Sea Ice Concentrations, the Global Hydrology Resource Center provided SSM/I brightness temperature data sets, and U.S. Geological Survey provided AVHRR data. Some studies included in this book were carried out with the support of The International Arctic Research Center, University of Alaska, Fairbanks; and USGS Alaska Science Center.

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Introduction to Arctic Ecological Research and Microwave Remote Sensing

1.1 ARCTIC ECOLOGICAL PROBLEMS AND REMOTE SENSING

The global ecological situation is characterized by a steady population growth and by an unprecedented threat to the biosphere by man's activities. Negative consequences of these processes are ozone depletion, acid precipitation, pollution of the ocean, contamination of the ground and subsoil waters, decreasing the fertility of the soil and rapid degradation of biodiversity and climatic change.

Arctic regions play an important role in the global ecology, having an influence on physical-chemical processes occurring in the atmosphere. Differences between conditions at the equator and at the poles are the main driver of the large-scale atmospheric and oceanic circulation systems that redistribute heat, water, gases and nutrients around the world and determine the global ecology and climate (Aagaard et al., 1985; Aagaard and Carmack, 1989). The effects of climate change are amplified in the Arctic. A particularly significant consequence of climate warming is an expected modification of the floristic composition of tundra and boreal forest and the transformation of Arctic ecosystem functions. Over longer periods, the effects of warming will feed back into the climate system through sustained changes in the extent of snow and sea ice, in the structure of Arctic ecosystems and in global ocean circulation (Gloersen and Campbell, 1988; Hall, 1988; Kondratyev, 1995). This offers an opportunity for early detection of changes by systematic monitoring of the amount of sea ice and snow, the duration of summer melting and Arctic ecosystems. The main goals of Arctic research are understanding the role of the Arctic Ocean and ice cover in the heat and moisture transfer between the ocean and the atmosphere, and heat redistribution from low to high latitudes. These goals include identifying and quantifying the responses of the Arctic Ocean, ice cover, permafrost and Arctic ecosystems in the context of climate change (Thomas, 1992).

In the framework of these problems, detection and investigation of sensitive tundra vegetation and boreal forest communities, as well as ecological studies of marine mammals in Arctic environments are important in an assessment of how they will be impacted by global change. Unfortunately, Arctic marine mammal status, natural habitat parameters,