Chapter 13
Water and Carbon Dynamics in Eastern Siberia: Concluding Remarks

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13.1 Introduction

Numerous interesting research topics are being explored in ongoing studies of the dynamics of water and carbon cycles in high-latitude regions of the Northern Hemisphere, particularly in eastern Siberia. These include one-dimensional observations and watershed-scale analyses of water, energy, and carbon fluxes under different permafrost conditions; analyses of satellite remote sensing data; and water and carbon flux modelling. Eastern Siberia is characterised as a "vegetation–permafrost symbiotic system" owing to the presence of permafrost and vegetation cover, which is dominated by larch (*Larix cajanderi*) forest ("light taiga") and tundra. Current climate warming in this region is causing large environmental variability and wetting–drying conditions. The eastern Siberian environment is also being affected by global climatic and abrupt socio-economic changes. Thus, the research findings and educational issues introduced in this book are of great importance.

13.2 Main Results in the Water and Carbon Dynamics in Eastern Siberia

Under global warming, atmospheric water vapour pressure trends to increase as air temperature increases, particularly in eastern Siberia, where the regional climate has been shaped by topography, distance from the ocean, vegetation types, and

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permafrost. These phenomena have been identified using upper- and lower-atmospheric analyses (Chap. 2) and modelling studies (Chap. 12). At smaller scales, one-dimensional fluxes of energy, water, and carbon have been estimated using land surface models, and these have been compared to data observed in situ in both wet and dry conditions in a larch forest stand (Chap. 12).

Due to current global warming, the water cycle has been enhancing through a reduction in Arctic sea ice extent. These changes to the water cycle have induced large amounts of rain and snow, surface runoff, and river discharge during the snowmelt season throughout the region. Accelerating soil water infiltration, evapotranspiration, and river discharge in summer have also been detected in the region. Rainfall and snowfall were higher in 2005–2008 than in the past century, with significant discharge events in the Lena River basin and other Eurasian pan-Arctic watersheds (Chap. 9). Soil water infiltrated from rain water and snowmelt water is transported from hillslopes to the Lena River. Permafrost plays a critical role in infiltration processes at high latitudes due to seasonal changes in air temperature. As amounts of rainfall and snowmelt water have increased, the active layers thickness of surface permafrost zones have gradually increased, and the effects of deepening these active layers have prolonged over the seasonal scales of water–carbon cycles (Chaps. 3, 4, and 8). The lengthening of the growing season affects ecological feedback not only in larch forests but also in grassland and bare lands (Chap. 8), and vegetation changes steadily (Chap. 7). Vertical and horizontal soil water content profiles have changed dramatically in larch forests, and soil water movement differs dramatically between wetting and drying periods. In the Spasskaya Pad experimental forest, differences in soil water uptake (extraction) by larch tree roots in wet and dry years were detected using stable water isotopes (Chap. 6). Studies of spatial variation in ecosystem CH_4 emissions with attention to landscape-scale variation are very important in tundra regions such as the Chokurdakh site (Chap. 5). At longer time scales, ecosystem H_2O, CO_2, and CH_4 emissions will change drastically as a result of different environmental factors, because precipitation, soil water content, permafrost conditions, and vegetation activities will change over time (Chap. 1).

Water and carbon cycles in eastern Siberia differ spatiotemporally, and there are vast regions of less-populated localities. The spatiotemporal variation in aboveground biomass and the growing season in eastern Siberia are monitored by several remote sensing techniques, which are useful for deciduous forests and other poorly accessible places not only in eastern Siberia but also throughout the Northern Hemisphere (Chap. 10). To determine terrestrial water storage, optical sensors are available primarily for detecting snow cover, whereas passive microwave sensors can detect surface water conditions. By contrast, active microwave sensors can detect surface soil moisture. Remote sensing sensors onboard several satellites can be used to detect terrestrial water, and their development is continuing to advance (Chap. 11). Although remote sensing techniques are extensively used (Chaps. 10 and 11), some types of data collection via remote sensing, such as data on leaf area and soil water content, still require development.

The effects of global warming have advanced greatly in eastern Siberia, where hydrological and meteorological measurements have demonstrated intensive wetting phenomena from 2005 to 2008; however, strong drought has not been detected within the past two decades. From 2001 to 2004, a weak drought period occurred in central Yakutia, with an annual minimum precipitation of 111 mm in 2001 (Chap. 3). Tree-ring analyses were used to detect this drought; however, dendrochronological measurements showed that vegetation has not been drastically altered (Chap. 7). These trends in meteorological conditions during drying events are not yet clearly understood from ecological, physiological, and hydrological perspectives.

13.3 Future Works in Eastern Siberia

The environmental factors related to wetting and drying conditions in eastern Siberia should be studied in hydrological and meteorological systems from the one-dimensional scale to the watershed scale. Continuous wetting years were detected during the two decades in which we observed hydro-meteorological variables, and the hydrological and meteorological data related to wetting phenomena in the region have helped to clarify regional water and carbon dynamics. In the near future, drying conditions and their hydrological ecosystem feedbacks should be studied intensively.

Such research projects have revealed much new information on ecological feedbacks to the global climate from a hydro-meteorological perspective, clarifying water and carbon cycles in forests and grasslands worldwide (Malhi et al. 1999; Ciais et al. 2005). In eastern Asia (including eastern Siberia), a large forest belt extends broadly from tropical forests to boreal forests (Yasunari 2007). Therefore, similar studies have been conducted or planned in boreal, temperate, and tropical regions from northern Eurasia to south-eastern Asia. These continuously vegetated areas, which include boreal, temperate, and tropical forests, are defined as a green belt; eastern Siberia is located at its northern edge. Future research in this region should regularly be conducted on topics including water, energy, and carbon dynamics and their feedback systems in conjunction with climate change.

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