Remote Sensing of Forest Cover in Western Russia and Fennoscandia Regional GOFC Workshop

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Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a coordinated international effort to ensure a continuous program of space-based and in situ forest and other land cover observations to better understand global change, to support international assessments and environmental treaties and to contribute to natural resources management.

GOFC-GOLD encourages countries to increase their ability to measure and track forest and land cover dynamics by promoting and supporting participation on implementation teams and in regional networks. Through these forums, data users and providers share information to improve understanding of user requirements and product quality.

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Report from the Regional GOFC Workshop

Remote Sensing of Forest Cover in Western Russia and Fennoscandia: *Integrating Satellite and in-situ Observations*

June 25-27, 2001
Center for International Environmental Cooperation
of the Russian Academy of Sciences (INENCO Center of RAS), St. Petersburg, Russia

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EXECUTIVE SUMMARY

The regional GOFC workshop on **Remote Sensing of Forest Cover in Western Russia and Fennoscandia** was held in St. Petersburg, Russia on June 25-27, 2001 at the Center for International Environmental Cooperation (INENCO) of the Russian Academy of Sciences. The general theme of the workshop was the integration of satellite and *in-situ* observations for monitoring forest and land cover. The workshop agenda included presentations on GOFC, LCLUC and several other international programs, summaries of research results from local studies, examples of operational use of satellite technology, and a series of discussion papers outlining future research needs in the region.

Boreal forests of Northern Europe have distinct characteristics that set them apart from other boreal forest regions. The western part of the Former Soviet Union and Fennoscandia have common land-use history and forest types, controlled fires, and active forest management for timber production and maintenance of multiple environmental functions of forest ecosystems. There is significant direct human impact throughout the region and very few remaining intact landscapes. The interest in conservation measures and in monitoring the remaining intact forests combined with active forest management for timber production and recreational use of forests creates a large group of current and potential operational users of remote sensing. The presence of large areas of aggrading forests in the region suggests that these forests may be currently a major carbon sink. The systems for collection of *in-situ* observations, in particular the forest inventory systems, are extensive and well maintained. This solid information base and local disciplinary expertise provide excellent opportunities for validating remotely sensed products and for addressing a wide array of LCLUC science questions. To develop effective methods for mapping and monitoring the entire boreal forest zone it is important to focus initially on information-rich regions such as Fennoscandia and Western Russia.

Past research efforts in the region generated extensive experience with integration of remotely sensed and *in-situ* observations. Landsat, Resurs, AVHRR, ERS, and SPOT imagery was integrated with *in-situ* data to map vegetation types, forest biomass, traces of disturbance, and biophysical properties of vegetation. GIS systems were developed for operational forest management and for monitoring the condition of protected forests. Several studies examined the impact of pollution, urban development, logging and other land-use on forest cover and carbon stores. *In-situ* data sets and models are being developed for projecting the future dynamics of forest biomass, water run-off, soil organic carbon, and peatland growth.

Based on presentations at the workshop the participants identified the long-term research priorities for the region. The workshop concluded that a **regional information network for Northern Europe (NERIN)** would address the regional need for coordination of research and application development; provide a forum for exchange of data and information, standardization of analysis methods, harmonization of data and products, advocacy concerning the needs of data users and providers; demonstrate to user communities the benefits of enhanced observational products. Covered by the network will be the forest zone of Western Russia – Baltic countries – Scandinavia, roughly North of 55º N. To provide a foundation for the new regional network it is important to foster international and interdisciplinary collaborations and explore opportunities for region-wide studies that use remote sensing to examine different aspects of LCLUC. Recommended follow-up activities include inventory of ongoing projects, formation of a coordinating committee, and the next workshop to be held in Finland in 2002.

1. Background

In recent decades, NASA has sought to encourage joint research programs with Russian scientists and is currently supporting several activities addressing a wide range of science issues in the Russian boreal forest region. Ongoing LCLUC projects, projects at NASA GSFC (Deering, LAI; Ranson, Forest Cover Mapping), and the Environmental Working Group (EWG) of the U.S.-Russian Joint Commission on Economic and Technological Cooperation (JCETC) have advanced understanding of Russian boreal forests, fostered collaborations between U.S. and Russian scientists, and developed local expertise in the use of remote sensing techniques in forest assessments. Forest fires in Siberia remain the major focus of research efforts. Examples include: "Contributions of Emissions from Boreal Forest Fires" (Kasischke, E.S., University of Maryland); "The Use of Satellite Fire Products and Models to Investigate the Effects of Fire on the Global C Cycle" (Randerson, J.T., California Institute of Technology); and "Estimating and Monitoring Effects of Area Burned and Fire Severity on Carbon Cycling, Emissions, and Forest Health and sustainability in Central Siberia" (Conard, S., U.S. Forest Service). Several new projects that examine LCLUC processes in Russia were recently funded including "Changes in Terrestrial Carbon Storage in Russia as a Result of Recent Disturbances and Land-Use Change" (PI(s): R.A. Houghton and O. Krankina); "Modeling Siberian Boreal Forest Land-Cover Change And Carbon Under Changing Economic Paradigms" (PI Kathleen M. Bergen)

To our knowledge, the only NASA-sponsored project focusing on LCLUC in Western Russia is "Modeling Carbon Dynamics and their Economic Implications in Two Forest Regions: Pacific Northwest USA and Northwestern Russia" (1996-2000, Mark Harmon, PI). The analyses of regional C dynamics will be synthesized into a book to be published in the Springer-Verlag Ecological Studies series. The new phase of this project ("Driving forces of change in regional carbon stocks: comparison of the Western Oregon, USA and St. Petersburg region, Russia" 2001-2004 Olga Krankina, PI) will examine how (and if) changes in the driving forces of land-use during the 1990's and in preceding decades manifest themselves in current and future regional carbon dynamics.

In August of 2000, the GOFC meeting on Boreal Forests was held in Novosibirsk (Russia) with the goal to further develop and coordinate satellite-based observations of the boreal forest region. The meeting identified the needs for ground validation of remotely sensed data products and emphasized the importance of educating and engaging the Russian user community. While it is clearly important to maintain the work in Siberia, there is a need to balance and complement this long-standing emphasis by studies of boreal forests in Western Russia. To address this need and to encourage regional collaborative interdisciplinary research, it was suggested that a regional workshop be held in Western Russia. The expertise in using remote sensing and related technologies for land cover monitoring, forest succession, C cycle research, and other applications is greater in Fennoscandia, while the physical environment is quite similar to that of Western Russia. This creates opportunities to make quick progress in developing Russian user community and advancing the region-wide studies of LCLUC. Such research efforts would advance ESE goals and would be highly relevant to the GOFC and NASA-LCLUC Program missions.

The regional workshop for Western Russia -Fennoscandia region was held in St. Petersburg, Russia June 25-27, 2001 at the Center for International Environmental Cooperation (INENCO) of the Russian Academy of Sciences. GOFC management (Drs. John Townshend, David Skole, and Chris Justice) attended the workshop and helped guide the workshop deliberations. Several other global, regional, national, and local programs are active in the region and were represented at the workshop (i.e., NASA, ESA, Russian Academy of Sciences, Forest inventory (Russia), EFI). The

workshop location enabled a large participation by the Russian scientific and forestry community (Appendix A. Participants).

2. Workshop Objectives

The general theme of the workshop was the **integration of satellite and *in-situ* observations** for monitoring forest and land cover. Within this general theme the workshop addressed three main objectives:

(i) review current uses of remote sensing in studies of forest cover in the region;

(ii) examine data requirements and information needs specific to the region;

(iii) identify mechanisms for improved coordination among scientists, in particular assess the need for a regional network that would address information needs unique to the region

The workshop was also intended to promote understanding of the capabilities of earth observing satellites to meet information requirements of the broad user community. The user community of remote sensing data in the region is expanding, yet in Russia technical, financial, and institutional barriers and constraints have hampered this process. The workshop provided a forum and a framework for engaging the local user community in dialogue on new technologies that may better serve their needs. To set up a stage for further discussions and planning, the workshop agenda included presentations on GOFC, LCLUC and several other international programs, summaries of research results from local studies, examples of operational use of satellite technology, and a series of discussion papers outlining future research needs in the region (Appendix B. Workshop Agenda).

3. Overview of Presentations.

The workshop agenda (Appendix B) included three types of presentations:

1. Presentations of national and international programs active in the region.
2. Presentations of recent and ongoing studies and projects
3. Discussion papers.

Several global, national and other large-scale programs are active in the region. Represented at the workshop were:

- GOFC (Drs. John Townshend, Dave Skole, and Chris Justice)
- NASA-LCLUC (Dr. G. Gutman)
- ESA (Dr. Olivier Arino)
- Forest Inventory system of the Russian Federal Forest Service (Mr. Rudolf Treyfeld)
- EFI (Dr. Oleg Chertov)
- Russian Academy of Sciences (Drs. Yurii Pykh and Gennadii Menzulin)

IGBP, LUCC, TACIS, CORINE, World Forest Watch, and other programs were also cited in discussions

Presentations and discussions demonstrated how these programs are working on integration of satellite and *in-situ* observations for monitoring forest and land cover. While these programs pursue somewhat different objectives and serve different users they all collect data and generate products useful for meeting the goals of GOFC. These and other programs active in the region

can clearly benefit from greater coordination, collaboration, and exchange of information and expertise.

Recent and current research projects that use remote sensing in studies of forest cover were presented and discussed during days one and two of the workshop. They address primarily two GOFC themes: "Forest Cover Characteristics and Change" and "Forest Biophysical Processes" (Appendices B and C). Dr. Korovin addressed the third theme, fires at an all-Russia scale in a presentation because forest fires are largely controlled in the Western Russia – Fennoscandia region. In all workshop participants reviewed 24 ongoing projects presented orally or on posters; abstracts are available at www.inenco.org and in Appendix C.

Studies presented under the theme of "Forest Cover Characteristics and Change" (Peterson, Yaroshenko, Chertov, Kogan, Rauste/Häme, Malysheva/Orlova, Semikobyla, Victorov) demonstrated a variety of methods and extensive experience with integration of remotely sensed and *in-situ* observations. In these projects Landsat, Resurs, AVHRR, ERS, and SPOT imagery was integrated with *in-situ* data to map vegetation types, forest biomass, and other variables. GIS systems were developed for operational forest management, monitoring the condition of protected forests and fires. Several studies examined the impact of pollution, urban development, logging and other land-use on forest cover and carbon stores.

Studies of "Forest Biophysical Processes" were presented by Vygodskaya/Varlagin, Malkina-Pykh, Kozoderov, and Sogachyev. In these studies biophysical properties of forest ecosystems were analyzed with a combination of flux tower measurements and modeling. Linking these studies with remotely sensed data provides a basis for large-scale assessments of the effect of LCLUC on light reflectance and interception, carbon and water exchange, and other biophysical processes.

The results of ongoing projects indicate that the boreal forests of Northern Europe have distinct characteristics that set them apart from other boreal forest regions. The distinctive features include:

~ ***significant direct human impact throughout the region***. There are very few remaining intact landscapes and natural disturbance regime has been replaced by logging for many decades. In many locations throughout the region forests are affected by industrial pollution. There is great interest in the region in conservation measures and in monitoring the remaining intact forests.

~ ***active forest management for timber production and recreational use of forests***. This creates a large group of current and potential operational users of remote sensing.

~ ***large areas of aggrading forests likely result in a major carbon sink***. The use of remote sensing for monitoring carbon accumulation is important for the global and regional studies of carbon exchange.

~ ***extensive knowledge base, research infrastructure, forest inventory and monitoring systems*** can provide a wealth of *in-situ* data for interpretation and validation of remotely sensed observations.

The review of data requirements and availability for the region of Western Russia and Fennoscandia included presentations by Hame and Treyfeld, both describing forest inventories and stressing the significance and value of these data. A related paper by Alexeev/Tarasov suggested additional opportunities for using forest inventory to refine existing methods for large-scale biomass estimation. Forest inventories and other well-maintained networks in the region (both research and operational) continuously collect ground data, which is potentially useful for

validation purposes. To facilitate the use of these data and their integration with satellite observations it is necessary to resolve the issues of data ownership and accessibility. It is also important to initiate efforts to evaluate existing ground data resources (especially *in situ* collections), compile information about them, and assess their utility for specific applications.

A set of brief discussion papers was intended to identify some of the future research priorities in the region and to stimulate discussions. The role of historic changes in land-use and availability of data for examination of changes over time was discussed in presentations by Alimov and Krankina. The history of land-use in Fennoscandia and Western Russia diverged significantly for a major part of the 20th century: for seventy years Fennoscandia had a market economy while Western Russia had a socialist economy. This provides a rare opportunity to quantify the long-term effects of different economic and social systems on LCLUC in similar physical environments. Cross-disciplinary research is needed to understand the complex interactions between the terrestrial ecosystems and the social systems and to develop capabilities to predict the changes that will take place in the future. The need for cross-disciplinary research has been emphasized in LCLUC and in other programs but full integration of socio-economic and environmental factors in the analysis of LCLUC remains a major challenge.

The need for interdisciplinary research was also expressed in presentations that discussed the research of hydrological systems (Georgiadi, Victorov, Kobak). While the hydrological processes and the processes of carbon cycling in terrestrial ecosystems are clearly linked, this link was largely overlooked by past research that used remote sensing to examine carbon pools and flux in boreal forests. Poor understanding of interaction between these two major biogeochemical cycles makes it difficult to project, for example, future changes in regional carbon stores in response to changes in precipitation or the impact of different forest management scenarios on water quality and river discharge. Peatlands are a major landscape feature in the region and represent an important interface between water and C cycles. A preliminary estimate indicates that peatlands in the St. Petersburg region contain about 75% of terrestrial organic C stores. *In-situ* data sets and models are being developed for projecting the future dynamics of water run-off and peatland growth.

4. Discussions and Recommendations

Based on presentations at the workshop the participants identified the following long-term research priorities for the region:

- further development of methodologies to address the following user needs:
    a. assess and map carbon stocks and annual deposition at regional and national levels based on integration of remotely sensed and forest inventory data.
    b. detect changes in vegetation cover with 10-100 m spatial resolution and annual – decadal temporal resolution
    c. detection methods for biomass change due to forest growth and non-clearcut timber harvest
    d. assess the capabilities of MODIS, MERIS, ASAR, AVHRR, and other instruments for improved mapping of major categories of forest lands, tree species and age composition of forests and the detection of forest decline. Appropriate algorithms will have to be developed.
- development of inter-disciplinary research
    a. increasing affiliation with social sciences for better understanding of driving forces and consequences of land-use change
    b. integrated studies to advance understanding of interaction between land use, hydrological processes, and carbon cycling

- harmonization of forest cover mapping between countries that make up the region
- develop, parameterize, and validate models of carbon and water exchange between the atmosphere and terrestrial ecosystems in the region
- address the need for continuous monitoring of forest cover with particular focus on natural/frontier and other protected forests

In addition to meeting the specific needs of the region, addressing these priorities will also advance the entire field of LCLUC research and forest cover monitoring with remotely sensed observations. The region of Fennoscandia and Western Russia is among the most intensively studied forest regions. The solid information base, local disciplinary expertise, and large ground data resources provide excellent opportunities for validating remotely-sensed products and for addressing a wide array of LCLUC science questions. To develop effective methods for mapping and monitoring the entire boreal forest zone it is important to focus initially on information-rich regions such as Fennoscandia and Western Russia.

The workshop participants also discussed options for improved coordination and information exchange among scientists and operational data users in the region. To frame this discussion the roles of GOFC and regional networks were reviewed by Dr. J. Townshend; the experience with SEARIN (South-East Asia Regional Information Network) and two African networks (Miombo Network (Southern African Woodlands) and OSFAC (Central African Network – Rainforest) was dicussed based on presentations by Drs. D. Skole and C. Justice (Appendix C). It was decided that a regional network for Northern Europe would address the following regional needs:

- coordination of research and application development
- provide forum for exchange of data and information, standardization of analysis methods
- harmonization of data and products
- advocacy concerning the needs of data users and providers
- demonstrate to user communities the benefits of enhanced observational products.

North-European Regional Information Network (NERIN) will cover the forest zone of Western Russia – Baltic countries – Scandinavia, roughly North of 55º N. Countries within this region share many common challenges in land and forest resource management. Because land-use and natural forest succession processes are significantly different in Eastern Eurasia, a separate Siberia-Far East network (to include the eastern part of Russia, Mongolia, China, Korea, and Japan) was suggested for consideration.

The following short-term tasks were proposed:

- **form a steering committee** of action-oriented regional representatives to review and refine the above research priorities for the region and to direct the network activities. In forming this committee it is important to maintain balanced representation of science, technology, operational forest management, government agencies, and NGOs. It is also critical to include representatives from all the countries in the region.
- **establish information network** with user-friendly data library, information on points of contact, news on availability of satellite data, ongoing research projects and their results, a bulletin board or a chat room.
- **identify short and medium-term objectives** to demonstrate the benefits and workability of the network, enhance its visibility and increase support at local, national, regional, and international levels. Candidate objectives include:
    a. developing links between remotely sensed and inventory data to enhance the quality of products

b. evaluation of different methods of spatial data extrapolation (statistical versus direct parameterization of remotely sensed signal)
c. expanding the scope of ongoing projects to include inter-disciplinary work (e.g., establish links with social and hydrological studies)
d. facilitate access to satellite data for research, operational forest management, conservation, various NGO activities, education and training
e. facilitate access to in-situ data for integration with remotely sensed observations and develop strategies for leveraging extant *in-situ* data resources for validation of GOFC-relevant products
f. promote the use of satellite imagery by operational users and form a group of "champion users". This may include evaluation of high-resolution data (SAR, ASAR) for use in forest inventories and monitoring.

5. Follow-up Activities

As the first step towards organization of the **North-European Regional Information Network (NERIN)** the following activities were recommended:

- Inventory of ongoing and planned projects in the region and associated datasets. The information will be collected from workshop participants and other interested professionals and posted at INENCO web site. Dr. Victorov of INENCO Center and Dr. Krankina of OSU will take the lead on compiling this information.
- Form a coordinating committee to plan the development of the regional network, identify research priorities and benefits for users, and define information and data distribution system. Drs. A. Isaev and T. Hame agreed to co-chair this committee, Dr. Krankina will coordinate its work with GOFC and NASA. Additional members will be invited to join this committee as needed.
- Convene a follow-up meeting in Finland in summer of 2002. This next meeting should include space agencies, forest inventory organizations, and other established networks (EFI, IUFRO, LUCC). It is also important to include representatives from all countries that make up the region. VTT (Dr. Hame) could host the next workshop with possible assistance from EFI (Dr. Paivinen) and JRC.

Since the conclusion of the workshop it was determined that September of 2002 appears a more convenient time for the next workshop and VTT (Dr. Hame) expressed interest in hosting it. The proposal by Dr. Hame to hold a workshop '***Remote sensing in inventory and monitoring of boreal forests***' received very positive evaluation from the Scientific Advisory Board and EFI. EFI Director Dr. Paivinen expressed interest in co-hosting the workshop.

6. Acknowledgements

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APPENDIX B. WORKSHOP AGENDA

Day 1. June 25, Monday

8:15 – 9:00 Registration

9:00 – 11.00 <u>Welcome, Workshop Overview, GOFC and Related International Programs.</u>

Welcome to St.Petersburg and INENCO Center
Mr. A.Galimzyanov - Department of Natural Resources of the Northwestern Federal District of the Russian Federation
Dr.Yuri Pykh - President of the INENCO Center.

A word from the sponsor – Garik Gutman
Workshop Logistics - Gennady Menzhulin, Local Organizing Committee
Workshop Overview - Olga Krankina

The Global Observation of Forest Cover Program (GOFC). John Townshend

LUCC. (David Skole)

Overview of ESA Products for Forest Monitoring in the region. (Olivier Arino).

Coffee Break

Plenary Session 1. <u>On-going projects and future research needs</u>

11:00 – 16:00 Forest Cover Characteristics and Change

Forest cover and its changes in Eastern Baltic region measured from multitemporal Landsat TM images (U. Peterson* and T. Nilson, Estonia)

Inventory of intact natural forest landscapes in northern European Russia (Potapov, P.V., S.A. Turubanova, A. Yu. Yaroshenko*).

Mapping soil carbon: stores and fluxes (O.G. Chertov* and A.S.Komarov)

Lunch

Changes in the northern European forests during 1985-2001 from AVHRR data. (Kogan, Felix)

The space monitoring of forest fires and the assessment of fire carbon emissions in the Russian Federation. (Korovin G.N.*, A.S. Isaev, D. V. Ershov)

Coffee Break and Poster Session (5 min. introductions of each poster)

16:00 – 18:00 Forest Biophysical Processes

Assessment of Seasonal and Year-to-Year Variability of Carbon Dioxide Fluxes in the European Russia Boreal Forests: Analysis of some Results of the Eurosiberian Carbon Flux Project. (Vygodskaya* N.N. and E.-D.Schulze)

Application of the Response Function Method for Prediction of Forest Dynamics Using Remote Sensing and Surface Measurement Data. (Y.A. Pykh and I.G. Malkina-Pykh)

Precision and accuracy of modeled attributes of boreal forests: integrating remotely sensed and in-situ data (V. Kozoderov).

Remote Sensing Information and Modeling of Nonstationary Energy and Matter Transport Processes in Inhomogeneous Forest Cover. (A.F. Sogachyev and G. V. Menzhulin)

Updates of Workshop Agenda and Logistics (Krankina, Menzhulin)

18:00 - Adjourn for the First Day - Reception.

Day 2. June 26, Tuesday

09:00 - 10:00 Discussion session 1 <u>How to proceed with better regional coordination and potential regional science network.</u> C. Justice, moderator.
GOFC regional networks and Miombo network - Chris Justice
SEARIN Network – Dave Skole
General Discussion

10:10 - 15:30 Plenary Session 2. <u>Data requirements and availability</u>.

Use of remote sensing in forest inventory and management planning – Tuomas Hame

Forest inventory in Russia: data needs and availability of in-situ measurements – Rudolf Treyfeld

Coffee Break

The role of land-use legacies in carbon exchange of forest ecosystems (Discussion paper, O. Krankina)

Socioeconomic Aspects of Forest Ecosystem Protection and Exploitation: Options for North-Western Russia (Alimov A.A.)

The importance of forest types for mapping carbon stores (Discussion paper, M. Tarasov)

Lunch

Studies of Hydrological Consequences of Social-Economic System Changes in Russia . A. Georgiadi

Remote Sensing Information on Present State of Water Objects and Forest Cover in the North-Western Russia and their Interpretation in Specialized Geoinformation Systems. Victorov S.V., .A.Bychkova and L.L.Sukhacheva.

Interaction between water and C cycle (Discussion paper, K. Kobak)

Coffee Break

15:30 – 17:30 Discussion session 2. <u>Planning renional GOFC network. John Townshend, moderator</u>.

Sightseeing Tour of St. Petersburg Organized by Host Committee

Day 3. June 27, Wednesday

9:00 – 10:30 Plenary Session 3. Networks and collaborative activities.

New information technologies of R&D Center ScanEx for GOFC. (V.E. Gershenzon)

US-Russia Research Networking for Data and Information Exchange: Leveraging MIRnet for Earth Science (Don Deering, NASA)

Coffee Break.

10:30 – 12 :45 Discussion Session 3. How to proceed with planning and development of a regional science network (General Discussion). Alexander Isaev and John Townshend, Co-Chairs

Lunch.

14:00 – 15:00 Wrap up: Where do we go from here?

Review of draft outline of Workshop summary, recommendations, and plans for follow-up activities – T. Hame
Concluding remarks of workshop participants

15:00 - 17:30 – Free time.

18 : 30 Banquet

List of Posters:

1. Forest type and biomass mapping using seasonal response in spaceborne L-band SAR data (Rauste and T. Häme*)
2. Integration of remote sensing and GIS for monitoring forest cover of National Parks in Northwestern Russia. N. Malysheva.
3. Semikobyla Ya.G. (INENCO Center of RAS), T.A.Popova (Aerospace Remote Sensing Research Institute, St.Petersburg) and O.B.Babenko (Giproshakht Institute, St.Petersburg). Aerospace Monitoring of Forest Cover in the Oil-Shales Mining Region of North-Western Russia.
4. Research and Education Case Study: The University of Michigan Joint Program in Natural Resources & Environment and Russian & East European Studies. Bergen*, Kathleen M.

APPENDIX C. ABSTRACTS AND OUTLINES OF PRESENTATIONS (alphabetic order)

THE IMPORTANCE OF FOREST TYPES FOR MAPPING CARBON STORES

Alexeyev V.[1], B. Ryabinin, M. Tarasov[2]

Many studies of carbon storage in Russian forests use the data of forest inventory. These estimates are usually based on different generalized information. When generalizing the differences in carbon stores of small forest units (forest types) are lost in favor of bigger units. In sense of Russian ecology term “forest type” considers set of forest species in connection with their habitat conditions. It is evidently that such site proprieties like soil type, water regime, etc. condition capacity and rate of carbon turnover of ecosystem components. When forest types are not considered, current carbon stores and influence of stress factors on carbon dynamics can be misunderstood.

In present study an approach to estimate carbon storage, based on information on forest type is developed. Phytomass carbon is estimated based on forest inventory data on growing volume, and converting factors, specific for groups of forest types. Estimates of litter carbon are based on 1) database of litter densities in different forest types, 2) information on climatic conditions in ecoregions, and 3) forest inventory data on distribution of forest areas by forest types and age groups. A simple model was developed for calculating storage of coarse woody debris (CWD). It is based on field data on wood decomposition rates and literature data on dynamics of mortality in forests. Storage of carbon in CWD and soil organic matter, related to groups of forest types, are studied now.

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SOCIOECONOMIC ASPECTS OF FOREST ECOSYSTEM PROTECTION AND EXPLOITATION: OPTIONS FOR NORTH-WESTERN RUSSIA.

Alimov A.A.[1], E.V. Stetsko[2], L.B. Vampilova[3]

Russian forests take more than 22 percent of the world forest covered territory. North-Western part of Russia includes 11 subjects of Federation and is often called the main gates to Europe. At the same time this region is very rich in boreal forests which are exploitated very intensively. The case is that the forests of the North-Western Russia started to be exploited since XYI and in some parts of the region they are highly anthropogenically depressed. It makes necessary to change the forest policy in North West part of Russia and to start to use forest not only in traditional way as a resource for industry, but to pay much more attention to other possible ways of forest management. Speaking about socioeconomic aspects of forest ecosystem protection and exploitation we bear in mind that all posible ways of forest management should be scientifically (ecologically) sounded, and economically oriented. It means that the forest policy has to be sustainable providing both usage and protection of forests. How can we put these two different aims together? At first we have to reevaluate forest and to find new options of its management, such as recreative, for scientific research purpuses, for environment tourism, aesthetic, etc. One of the main functions of forest is the biotical. According to the calculations made by russian specialist about 60 percent of the biota located at the territory of the Russian Federation is not significantly touched by our economic activities. The Nort-Western part of Russia is highly anthropogenically deppressed and the first task in our forest policy should be the protection of its biotical potential. At the same time organizing new specially protected territories for scientific research and educational activities we can run new scientific projects to find out the best ways of forest management. Environmentally oriented tourism should include on one hand tourism in environmentally (ecologically) clean areas and on the other - restoratin of those parts of nature which were damaged before. The last thing we have to mention about is the interest which is demonstrated by Northern countries to the forests of the North-Western part of Russia as a timber resource. As the timber market is not well developed in Russia our forest economy is suffering from cutting and selling timber so actively than in some regions the situation is close to critical. Socioeconomics aspects of forest management is an integrated and complex field of environmental state policy and it should be carefully worked out not only for the Russia's interests, but for the interests of other nations as boreal forests are of a great importance in supporting human life all round the world.

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RESEARCH AND EDUCATION CASE STUDY: THE UNIVERSITY OF MICHIGAN JOINT PROGRAM IN NATURAL RESOURCES & ENVIRONMENTAND RUSSIAN & EAST EUROPEAN STUDIES

Bergen K. M.[1]

For either research or education to be most productive they must be linked together. Research answers critical questions about our environment and provides the opportunity for students to work with experienced scientists on important projects such as those related to forest land-cover/land-use change and carbon supported by NASA and international partners. Formal education and training by scientists actively involved in research prepares students to meet the present and future challenges of such cutting edge work. This poster presents a case study. In response to changing political and economic circumstances in Russia and Eastern Europe, and to address environmental and natural resource needs in the region, the School of Natural Resources and Environment (SNRE) and the Center for Russian for East European studies (CREES) at the University of Michigan introduced a joint degree program. The first of its kind in the U.S., this joint M.A./M.S./M.L.A. or Ph.D. degree combines training in SNRE's forest science, natural resource management, and GIS-remote sensing-spatial analysis programs with CREES's focus on language proficiency, regional knowledge, and interdisciplinary expertise in the humanities and social sciences. Part I of this poster outlines the emphasis that the joint degree program places on both research and education. Part II highlights research projects underway by sample faculty and students working on land-cover/land-use change and carbon in Russia and Eastern Europe. Part III displays the expertise, educational curricula and facilities. This joint program also engages in continuing research and education through a formal program of visiting U.S. and international scholars and researchers.

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Satellite Monitoring of Water Objects and Forests in Northwestern Russia

The state of the marine and terrestrial environments in the coastal zone of the eastern part of the Gulf of Finland and south-eastern part of Lake Ladoga is discussed. This region includes the Neva Bay and recreation zone in the Karelian isthmus where many small lakes are located. Using the available database of satellite imagery collected from KOSMOS-1939, RESURS-F, RESURS-O, NOAA, SPOT, ADEOS/AVNIR, our regional knowledge base and topographical maps for the period 1970s-1998 we managed to construct the map of anthropogenic load in this region. Size, shape and distribution of patches of different land-use/land cover types and regional test areas were used to compose this map. Analysis of the imagery is presented along with several samples of satellite imagery of this region taken in visible and thermal IR bands.

The possibility to make assessment of the state of the environment of the relatively small lakes and the forests in their coastal zones on the basis of high resolution satellite imagery is shown for the Royka-Lembolovskoe lake system. Analysis of the SPOT image from August 1996 revealed the intensive phytoplankton spreading in the northern part of the lake, where the number of children resort camps and the large area of gardening companies nearby the settlement of Vaskelovo and along the River Gruzinka are concentrated. The emphasis is given to the state of the forest ecosystems. The increase of an area affected by anthropogenic pollution up to 40% is considered as risk to human health and regional ecosystem.

MAPPING SOIL CARBON: STORES AND FLUXES

Chertov, O.G.[1] and A. S. Komarov[2]

Soil organic matter (SOM) is a large reservoir of forest ecosystem carbon changing under impact of natural processes (climate, forest site, ecosystem development and disturbance regime) and anthropogenic factors. Now there are successful attempts to determine soil carbon pools (SCP) for mapping using local and regional soil databases and other pedological information. A case study for forest soils of Leningrad administrative area described. A combination of regional soil carbon data with forest inventory units (forest types) has been realized. It allowed estimation of soil carbon concentration (t ha^{-1}) for main mapped units and total SCP of forest soils in the region. Afterward a simulation model of SOM dynamics (Chertov, Komarov, 1997) was applied to estimate carbon fluxes in forest ecosystems of the area. The simulation allowed assessing at first approximation soil carbon sources and sinks on regional level under stable climatic conditions and management regime. A feasibility of SCP evaluation in frame of forest inventory in Russia finally discussed. We propose: (a) to use generalized 'soil carbon table' (organic plus 100 cm layer with standard deviation) where SCP data are arranged by standard classification of forest sites, and (b) calculate litter input using 'tables of litter input' being now elaborating by the authors. This will allow SCP assess and mapping and, additionally, employ both simulation models of SOM dynamics and process/combined models of forest ecosystems for prediction SCP dynamics and carbon fluxes in the forests under changing climate and forest management.

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USES OF INVENTORY DATA, REMOTE SENSING, AND MODELS TO CHARACTERIZE CARBON STORES AND FLUXES

Cohen, W. B [1], O. N. Krankina[2], D. R. Oetter[3], and T. K. Maiersperger[4]

Three different approaches to linking inventory data with remote sensing and models to characterize carbon stores and fluxes are given. The first is a simple "measure and multiply" approach, where land cover classes are defined over a 5 x 5 km area in the St. Petersburg region using Landsat TM data, and inventory data are used to define the mean biomass amount for each class. These mean values are then multiplied by the area of each class, and the results summed to derive the total amount of biomass for the 5 x 5 km area. The second approach uses Landsat TM imagery and inventory data to map land cover and stand replacement disturbance over a 1.2 million ha area in western Oregon. The derived maps are linked to a series of carbon accounting models that rely on inventory data to map changes in carbon stores over a 20 year period ending in 1991. The third approach uses inventory data and Landsat ETM+ data to map land cover and leaf area index over a 7 x 7 km area in northern Manitoba. The derived maps are used with a biogeochemical cycling process model to estimate/map NPP for the year 1994 over the 7 x 7 km area.

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U.S. – RUSSIA NETWORK FOR SUPPORTING INTERNATIONAL RESEARCH COLLABORATION: LEVERAGING MIRNET FOR EARTH SCIENCE RESEARCH

Deering D.W.[1], M. Nadler[2]

The vast Siberian area of Northern Eurasia encompasses a wealth of Russian research resources and target research regions of particular interest to the Earth Science community. Unfortunately, outdated telecommunication networks throughout Siberia pose significant communication challenges in facilitating telephone and e-mail correspondence, as well as data and information exchange essential for current Russian science objectives, and potentially future domestic and international research collaborations. In an effort to help alleviate US-Russia communication deficiencies, and to encourage and support productive cooperation between US and Russian science communities, MIRnet, a NSF and Russian Ministry of Science and Technology sponsored project, was established in June 1999. MIRnet provides high performance Internet connectivity between US and Russian research organizations, enabling a variety of applications such as data visualization, remote instrumentation control, high quality multi-point audio/video conferencing, as well as data services potentially offered by the GOFC community.

Current MIRnet access points within Russia are limited to Moscow; however, plans include extending the network to locations such as St. Petersburg and Novisibirisk. Additionally, NASA will seek to help expedite further MIRnet expansion to key earth science institutes within Siberia with a short-term goal of facilitating research planning activities through teleconferencing and easy Internet Web Site access and long-term goal of facilitating international research collaborations including research data exchanges. Thus, through leveraging MIRnet capabilities, NASA hopes to obtain high volume data sharing and exchange services, as well as communication, information discovery and tracking tools needed for collaborative research and planning activities exemplified by large-scale international earth science field campaigns.

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STUDIES OF HYDROLOGICAL CONSEQUENCES OF SOCIAL-ECONOMIC SYSTEM CHANGES IN RUSSIA

Georgiadi A. G.[1]

The social-economic changes in Russia which has begun since 1985 and, especially, since 1990 years accompanied with fall of industrial and agricultural production (at least twice). These changes had nonadequate effect on water resources. On the one hand, the reduction of industrial and agricultural production has weakened anthropogenic "loading" on waters. Opposite results were caused by changes of structure of anthropogenic impacts on water resources whorse system of protection of nature. Rather complicate hydrologic and hydroecologic consequences of social-economic changes are extremely unsufficiently investigated. Overview of some recent results of mentioned topic will be presented.

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New information technologies of R&D Center ScanEx for GOFC

Gershenzon V.[1]

The rapid growth in Russia and CIS of ground receiving stations network for MODIS data reception in “direct broadcast” (DB) mode (these stations, produced by R&D Center ScanEx (www.scanex.ru) are named EOScan) and on-line Internet terminal, based on EOScan station permit to realize real-time monitoring of forest cover among different types of end users, not only governmental and science but NGOs and business.

The same approach in fine resolution satellite systems is in the process of realization on the base of other technology – UnisScan station for reception and processing of RS information transmitted by satellites IRS-1C/-1D, RADARSAT-1. For the same purposes launching of new fine resolution (about 50 m) satellite missions on the base of DB policy would be of great importance.

Another possibility is connected with the “coop” Landsat 7 library approach that is maintained by R&D Center ScanEx in frame of non-profit activity of “Transparent World” NGO (www.transparentworld.ru).

The utilization of obtained in R&D Center ScanEx Resurs-O1 satellites series data archive (1996-1999) and neuron network technology permits to fulfill in collaboration with World Resources Institute (www.wri.org) unique “Map of frontier forests of Russia” in scale 1:1 000 000.

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USE OF REMOTE SENSING IN FOREST INVENTORY AND MANAGEMENT PLANNING

Häme T.[1]

The traditional role of regional and national forest inventory is to produce information using unbiased procedures. The inventory is accomplished through field sampling and its main output is statistical estimates on forest characteristics and their confidence intervals. The statistical information is used to plan sustainable utilization of forest resources for the following decade and further. The information is also used to monitor past development of the resources. Multi-temporal field measurements have also been used to develop and define growth models.

Forest management planning needs information in form of maps. The most important use of inventory data is to plan cuttings and silvicultural measures at stand level. Minimization of bias is of secondary importance although the forest owner and the customer who buys the wood need to know rather reliably the amount of available timber and its economic value. The inventory for forest management planning has been done completely independently from the sampling inventory of the national forest inventory. The practice has been to estimate the resources conservatively so that the forest owner knows that his property is at least as valuable as the inventory indicates. During last decades, the scope of interest in forests has widened towards the environmental issues such as the carbon cycle, biodiversity, natural conservation, and the multiple use of forests. This further stresses the importance of map-format information. In several countries also the national forest inventory has been based and is based on forest mapping. In such a case the main objective of the inventory may not be to obtain unbiased estimates on forest resources but to perceive their distribution and plan their utilization using the maps.

The borders between the sampling inventory and mapping inventory are becoming less clear when the satellite imagery is used. For instance, in the national forest inventory of Finland the measurements from field sample plots are used to compute estimates for every pixel of a Landsat Thematic Mapper or Spot image. A statistical k nearest neighbor approach is applied in the estimation. Thus, not only the benefits of the sampling inventory are available but also maps can be output to plan the measures.

Forest management plans are today normally in a GIS system. The field inventory is not repeated anymore for the whole area of interest frequently every ten years or so but the measures are up-dated to the GIS system. The values of forest characteristics of stands without any measures are updated using growth models. Remote sensing is needed to confirm of the update and to find changes that are not caused by Man.

There is a need to move from the purely statistical image interpretation procedures towards more physical approaches. This is because the pure statistical methods require availability of representative field sample data and recent enough data may not be available. Furthermore, estimates and maps on forest resources may be needed from areas of which ground data are not available. A spectral model that has been developed earlier can be applied to a calibrated image data over a new region. Extrapolation of the model certainly requires that in the new area the natural conditions are similar to the area where the spectral model was developed. Test results of the extrapolation of the semi-physical models indicate that this approach is successful.

The main challenge in the estimation of forest characteristics is saturation of the reflectance at high biomass forests. A partial solution to the saturation problem is development of instruments with high radiometric sensitivity at low reflectance levels. In an intensive forest inventory texture variables from very high resolution imagery can be used to separate the forests with highest biomass. In the microwave region, the P-band SAR has been proven to be effective in the estimation of tree biomass including the highest levels.

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GOFC REGIONAL NETWORKS

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•In each region there are individuals who have dedicated their lives to the study or management of forest resources – these individuals are in forest agencies, research institutes and universities

•The needs are often the same, the forests are largely the same, although policies and management may differ

•GOFC is endeavoring to develop strong networks of individuals to strengthen communication and share experiences – provide advocacy concerning their needs to the space agencies and operational agencies

•Projects come and go but the idea is that network remains

African Network Experience

Two African networks have been developed:

•Miombo Network (Southern African Woodlands)

•OSFAC (Central African Network – Rainforest)

OSFAC Network OBJECTIVES

Use satellite and ground-based techniques to acquire a better knowledge of the forests:

- extent
- rates of change
- structure, functioning,
- interaction with man,
- bio-diversity…

ASSUMPTION:

Progress in geospatial techniques (Remote sensing, lidar, video, radar, refined spatial resolution, revisit capability, GIS etc.) will help gather more reliable and timely data for forest monitoring and sustainable management.

PROBLEMS that GOFC can help with

Despite growing interest in remote sensing in the region, many obstacles still stand in the way:

- Lack of local expertise – need institution strengthening
- Lack of information or access to information - need improved metadata
- Lack of homogeneity in methodology, legend, classification – need standardization and harmonization workshop
- Weak communication network and links
- Difficult access to imagery and EO datasets - need improved access to data
- Lack of funding and infrastructures – need support to meet OSFAC goals

GOFC Regional Workshop Libreville

- In February 2000, a GOFC regional workshop was held in Gabon in order to develop the Central Africa GOFC network, OSFAC.
- The workshop was cosponsored by EEC-TREES, NASA-IGPB-START, and USAID-CARPE , with the technical support of ADIE in Gabon.
- National forest and mapping services, international organisations, donors, NGOs and private companies with an interest in forest monitoring attended the meeting.

Examples of current major projects

- OSFAC Website – information dissemination (U. Kinshasa –OSFAC network)
- Land-cover mapping of DRC at 1:250 000 (AFRICOVER/FAO)
- Fire monitoring for CAR as part of the World Fire Web (ADIE/OFB and JRC)
- TREES: Monitoring of sensitive areas: protected areas and deforestation hot spots (JRC)
- Forest classification derived from radar mosaics and coarse resolution optical data (JRC / NASA-JPL)
- Integration of in-situ data and aerial video with satellite images (NASA-WCS; JRC-ECOFAC)
- Forest stratification of Gabon using RADARSAT and ERS images (Tecsult)
- Regional Forest Cover Monitoring and Modelling (CARPE)
- Monitoring of regional trends in logging (WRI/ NASA/ WCS)
- Training workshop in Gabon (NASA – CARPE)
- Landcover mapping in the Bandudu Province in DRC (ERAFIT/UMD).
- Characterization of logging intensity (UMD/NASA/WCS/CARPE)
- Global Forest Watch (WRI)

Desired Future OSFAC Activities

Forest management and monitoring

–Continuous Training on remote sensing for forest management and monitoring

–Need of governmental rules for establishing forest management plans (request from the forest companies)

–Initially to be run by various external agencies with outside support but after 2-3 years would transition to be run by OSFAC groups in the region.

–Test with IKONOS images in CAR (CIRAD-Forêt)

–Necessity of a workshop to share the existing experience (end of 2001 ?)

Protected area monitoring

–Regional programs (ECOFAC) and NGO focus

–Provision of data and priority acquisition and capacity building to do the monitoring - tying in-situ and satellite data

–Development of tools for easily collecting the field data (hand-computer, aerial video)

–link to Millenium Ecosystem Assessment

Land Cover and Land Use Change

- Regional Land Cover (coarse and fine spatial resolution)
- Mapping and rate of change, biomass and carbon
- Linked to carbon theme / land cover and carbon
- Radar developments
- In-situ measurements are missing in the region
- Link with forest inventories

Recommendations to GOFC

Data coverage

–High priority for data acquisition by high resolution optical sensors

–For persistently cloud covered areas, provide microwave data and analysis tool

Data availability and cost

–Affordable prices during pilot phase

–Improve information on data availability

–Establish operational satellite system for forest management and monitoring

Information network

–Improve INTERNET facilities

Training

- Periodic basic training (RS for Forest Monitoring)
- Higher level training for specific expertise (new systems and specific forest applications)

Implementation

- Develop and support OSFAC Pilot Projects: data support, technical assistance, financial support

National GOFC Representatives for Miombo

Tanzania

Pius Yanda, Institute of Environ Studies, Univ of Dar es Salaam (pyanda@hotmail.com)

Malawi

Leo Zulu, SADC Forestry Sector Technical Coordination Unit (lzulu@hotmail.com)

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Mozambique

Manual Ferrao, CENACARTA (manuel@carvalho.uem.mz)

Zambia

Allan Mulondo, Zambia Met Services
George Kasali, Kafue MA Project

Miombo GOFC Overall Goals

.Build on the IGBP/START Miombo Network to improve access to observations and use of data for the study of Land Use/Land Cover and Operational Applications in Forestry

Current Objectives developed through a series of regional workshops include:
1) Mapping the miombo region using Landsat 5 and 7 data by working in conjunction with Southern African national mapping agencies;
2) Measurement of carbon densities in representative land cover/forest cover types of the region, building upon existing forest inventory and national biomass studies;
3) Development of a carbon accounting model that will quantify carbon pools in the miombo region for 1990 and the year 2000, and the major C fluxes due to land cover changes;
4) Development of a regional spatial database for site characterization;
5) Develop GOFC Fire Validation Network and Regional Fire Case Studies
6) Development of an information management system that will distribute satellite data for the Miombo region, and serve as a database archive for field data about the Miombo region, such as forest inventory records and site data for image classification.

Recent Miombo Activities

- Network has functioned through a series of thematic workshops
- Summary of GOFC results in a Journal of Forest Ecology and Management GOFC Miombo Special Issue
  - Papers in following categories
    - Reviews of Remote Sensing Applications (mostly Landsat and SPOT) and Methods for Southern Africa (woodlands/savannas)
    - Case studies of mapping and use of Landsat in Miombo
    - Carbon and Biomass assessments and modeling
    - Case studies of land use and change
- Compilation of Landsat data sets and easy access for network project use
- Harmonization of national land cover maps to develop a regional product (1990's epoch – derived from Landsat)
- GOFC Fire (burned area) Validation group – initial validation of MODIS
- Contribution to Southern Africa Millenium Assessment – mapping the Zambezi Catchment and applying a regional carbon model
- Development of a Land Use Integrated Assessment Model

Miombo GOFC Fire Validation SAFARI 2000
Near-term Planned Miombo Activities

- Miombo Forest Management Workshop in September, 2001 (organized by FAO-Forestry in Mozambique and Miombo Network)
- GOFC Workshop in 2002 (to review progress and analysis methods, models and coordination with Southern African MA project, etc)
- Fire Validation Activity Phase 2 (with NASA/MODIS – development of core sites; building upon Fire Workshop in Matopos, and fire field work in Zambia under Safari 2000)
- Land Cover/Land Use Benchmark sites (detailed mapping sites to highlight major forces of land use change and to contribute to local case studies under the Millennium Assessment projects for Southern Africa)
- Integrated Land Use Change Modeling as a contribution to the Millennium Assessment and southern African climate change programs
- Establish online data servers by country where Internet facilities suitable for online data archiving (GOFC-DIS)

Summary of Current Needs for the Network

(Based on recommendations from GOFC meeting in July 2000)

- Landsat 7 2000 coverage for the whole region (access to data sooner than later)
- Funding Support for Regional GOFC Coordination Workshop (planned for 2002)
- Validation data required including IKONOS and other high-res data
- Data samples from all satellite sensors over Miombo sites for evaluation and demonstration (IKONOS, Aster, etc)
- Data distribution through national nodes using CD-ROMs most effective means versus online data servers owing to very limited Internet availability in region
- Need a mechanism for easy preparation of hard-copy prints of satellite products (versus digital) for field use/local use
- Support for data rescue of forest biomass and other field data to support carbon budget studies and validation

THE SPACE MONITORING OF FOREST FIRES AND THE ASSESSMENT OF FIRE CARBON EMISSIONS IN THE RUSSIAN FEDERATION

Korovin G. N.[1], A. S. Isaev[2], D.V. Ershov[3]

The space monitoring of forest fires is analyzed being useful addition to ground and air techniques and methods of observations. Attended processing of remote sensing data, ground data and air observations is considered within the framework of the geoinformation system for forest fire monitoring (FFM GIS).

The observed images of cloud cover and its dynamics, space images for regions with high burning in FFM GIS are generated. Also there is the possibility of the detection of forest fires and control of its dynamics, mapping of acting fires and burned areas.

The assessment of seasonal carbon fire emissions is considered as one of the perspective objectives of national system of forest fire monitoring. In order to solve it three approaches are suggested different in requirements to composition and amount of used information and in precision of obtained results.

The first approach is based on the statistic reports on forest fires as well as experimental data on the specific outlays of forest fuel materials under different types of forest fires. It is appropriated for rough estimate of carbon fire emissions within actively protected territories of forest fund.

The second method is based on the mapping of acting fires and burned areas with usage of space images of low spatial resolution. This method requires available data on state forest account and it is recommended for rough estimate of seasonal carbon emissions within unprotected territories of forest fund.

The third method of fire carbon emissions is based on the mapping of acting fires and burned areas with usage of space images of low spatial resolution and consequent estimating of forest cover damage with usage of multi-temporal images of middle resolution. This method requires detail information about structure and state of forest vegetation before fire and this is recommended for most economically developed regions.

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PRECISION AND ACCURACY OF MODELED ATTRIBUTES OF BOREAL FORESTS: INTEGRATING REMOTELY SENSED AND IN-SITU DATA

Kozoderov V. V.[1] and V. S. Kosolapov[2]

A new approach of the functional description of the solar outgoing radiation is elaborated to identify relationships between remote sensing data and parameters of the forest tree stands on selected test sites of ground-based observations. The amount of the green phytomass of leaves/needles is one of such parameters calculated from the relevant techniques of the in-situ data assessment for boreal forests. This complex parameter is invariant to (not depending on) the solar zenith angle, the angular characteristics of the targets observed from space and the state of the atmosphere for a particular scene. The approach is an attempt to find an alternative to the common-used Leaf Area Index (LAI) concept derived from the radiative transfer theory for a turbid layer not applicable for random distributions of phytoelements with the absence of their regular structures. The asserted direct problem of the functional description enables to calculate sets of radiances for various spectral bands taking into account the shades on trees and other specific features of the forest cover. These sets are maintained to be represented in terms of the two-parametric coordinate space characterizing the density of the forest cover and “the tracery” of the related crowns of trees. The solution of the inverse problem of the major parameter retrieval for the statistical ensembles is resulted in looking for intersections between pairs of curves for selected spectral bands of multispectral remote sensing measurements using different sequences of the bands. Relatively high theoretical accuracy is gained by the proposed procedures of dividing the two-parametric space while finding the retrieval solutions. The measurement precision will inevitably lead to any biases from “the true solutions” given by the functional techniques. An information measure is ascertained of the precision and accuracy concurrence having in mind the random/systematic errors of remote sensing measurements and the partition of the gridded parameters of computation. To integrate data of measurements and calculations a modeled transect consistent with the similar lines of transects in the Tver region of Russia was created for different classes of deciduous, coniferous and mixed species. Exemplified by remote sensing data of high spatial resolution for the transect, the systematic errors are shown to be compensated while presenting the data under processing in terms of the invariant parameters instead of the intermediate products given by LAIs. This conclusions valid for the typically low level of the random errors of satellite radiometers open up prospects of the accuracy enhancement in remote sensing imagery processing as compared to the currently used applications.

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THE ROLE OF LAND-USE LEGACIES IN CARBON EXCHANGE OF FOREST ECOSYSTEMS: EXAMPLES FROM THE ST. PETERSBURG REGION, RUSSIA

Krankina O. N.[1], M. E. Harmon[2]

The history of land-use exerts a major control on present and future role of forests in carbon cycling. The response of forest ecosystems to changes in land-use can last for decades, centuries and even longer. The timing of response is controlled by natural successional patterns mediated by continued changes in the socio-economic system. The longer-term response can be opposite to the initial one as indirect effects and slowly changing components come into play. This creates a dynamic mosaic of carbon sources and sinks across forest landscapes and mapping them remains a challenge. To understand the driving forces that cause the transition of forest ecosystems from carbon sink to source and back, the effects of historic and social processes have to be considered. However, they are difficult to interpret at fine spatial scales thus the regional scale may be more appropriate for examination of land-use legacies. Historic land-use resulted in large C losses from terrestrial systems in many economically developed regions but it also created large areas of aggrading forests. Forest ecosystems in these regions differ significantly from their natural predecessors because many productive lands were converted from forest to agricultural use and urban development, primary old-growth/uneven-aged forests were replaced by even-aged managed stands, natural fire regime was virtually eliminated, and tree mortality was partially substituted with timber harvest. In the St. Petersburg region some of these impacts can be observed and measured using the available forest inventory data. For example, the current distribution of forests by age classes reflects the pulse of timber harvest and forest regeneration 50-70 years ago. This generation of forest stands was at the peak of productivity during the past 2-3 decades and contributed to the net C sink in the region estimated at 0.6 TgC/year. Because of the long history of timber harvest in the region the stores of coarse woody debris are low (3.1 MgC/ha) compared to less developed forest regions of Russia with similar levels of forest productivity (e.g. 5.8 MgC/ha in Irkutsk region). Further research is needed to understand how ecological and social processes interact in shaping the response of regional C stocks to changes in the social system.

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INTEGRATION OF REMOTE SENSING AND GIS FOR FOREST COVER MONITORING OF NATIONAL PARKS IN NORTHWESTERN RUSSIA

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The one of priority task turned over to national parks according to Russian Nature Protection Law is conducting the ecological monitoring to preserve the unique nature areas or restore the disturbed nature complexes. Forests as the main ecosystem component in Russian National Parks consider to be the indicator of unfavorable impacts. The forest monitoring strategy and a set of monitoring methods taken into consideration the problems and landscape features peculiar to Russian National Parks have developed.

The monitoring strategy is developed for every park separately. First of all, the strategy and methods of surveying are associated with observation areas. It is possible to design the monitoring system with three observation levels involved the space images, airborne survey and ground plots. The data collection for large parks in remote regions with virgin forests undisturbed by recreation and former management activity have made by space images for overall estimations of forest cover dynamics. The set of aggregate indices obtained for the estimation have to be adequate to criteria and indicators recognized by international community for sustainable management in nature protected areas.

The forest health assessment and nature preservation actions' control will be of great importance for small parks with disturbed forests under recreation stress. In this case, the monitoring system can be design with two observation levels including the airborne survey and selective ground plots. Different monitoring methods for evaluation of forest cover changes are tested. The practical experience includes the following:

- Processing the multitemporal Russian space images from “Kosmos”, “Resours- F”, “Resours-O” satellites and SPOT image for assessment of forest dynamics via aggregate indices;
- Producing the selective airborne TV survey and acquisition of the airborne data in different scales;
- Integrating the results of space images processing with results of airborne video mosaics’ processing for evaluation of the forest cover in detail;
- Interpretation and analysis of the space and airborne images in conjunction with forest ground observation data in GIS environment;
- Spatial analysis of forest cover and compilation of diverse maps.

The results of testing the different monitoring methods are demonstrated for National parks in Northwestern Russia. Experiments have conducted in parks located in different geographical subregions from the smallest one in the network of Russian National Parks (the Curonian Split) to one of the largest in Northwestern Russia (the Vodlozero Park). GIS advantages for spatial analysis and mapping in result of the monitoring are demonstrated in example of Vodlozero Park and Valday National Park. The information collected is important for long-term observations in a framework of international programs on global climate changes, biodiversity, global observation of forest cover also and for development of sustainability indices concerning the every kind of management activity.

LAND COVER AND FOREST BIOMASS IN ST. PETERSBURG REGION OF RUSSIA: INTEGRATING LANDSAT WITH FOREST INVENTORY DATA

Oetter D. R.[1], O. N. Krankina[2], W. B. Cohen[3], T. K. Maiersperger[4]

As part of an international effort to monitor and quantify carbon stores and fluxes within coniferous ecosystems, we constructed a land cover map and continuous forest biomass predictions for the 76,850 km^2 St. Petersburg Region of northwest Russia. Using ground reference data collected by the Northwest Regional Forest Inventory Enterprise in St. Petersburg, consisting of over 3400 stand-level inventory polygons, we analyzed 12 Landsat Thematic Mapper scenes to create a 13-class land cover map. For three forest classes (conifer, hardwood, and mixed conifer/hardwood), we used the forest inventory data to calibrate regression models to predict forest biomass. The spatial output of the remote sensing effort was used to estimate total regional forest cover and biomass, which were compared to ground-based estimates from forest inventories. The land cover map and continuous estimate of biomass were assessed for error. Extrapolation of our methodology allows for the estimation of carbon stores in coniferous forest ecosystems across a large geographical region such as the Russian boreal forest.

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FOREST COVER AND ITS CHANGES IN EASTERN BALTIC REGION MEASURED FROM MULTITEMPORAL LANDSAT TM IMAGES

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We have mapped forest cover in Eastern Baltic area, covering territories of Estonia, northern Latvia and western districts of Leningrad province and Pskov guberniya in Russia. Landsat Thematic Mapper (TM) images from a non-traditional season for forest mapping – early March with snow covered ground were used to compile a map in scale 1:100 000. Digital ortho photo quads were used to determine the threshold in classifying satellite images into forest and non-forest classes and later in error estimates. Landsat TM images from mid 1980s, mid 1990s and early 2000s were used to estimate the rate of land use conversion of abandoned agricultural land into forest during the past decade.

On the forests of southeast Estonia, we tested the Monteith (1977) hypothesis that the yearly CO_2 assimilation rate of a plant community could be proportional to the seasonal sum of the absorbed photosynthetically active radiation (APAR). The APAR of the forest stands was estimated through its relation with the NDVI index determined from atmospherically corrected Landsat TM and/or SPOT images. The yearly storage of carbon in wood was assumed to be proportional to the yearly stem volume increment while the latter was obtained from the forestry databases. A preliminary analysis showed that there existed an approximately linear trend in the relation between the yearly volume increment and seasonal NDVI, however, the dominating tree species had an important effect on this relation.

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INVENTORY OF INTACT NATURAL FOREST LANDSCAPES IN THE NORTHERN EUROPEAN RUSSIA

Potapov, P.V., S.A. Turubanova and A. Yu. Yaroshenko[1]

Work on identification and mapping of intact forest landscapes in northern European Russia has been conducted at the GIS laboratory of Greenpeace Russia (together with other organizations within the framework of Global Forest Watch Russia). The objective was to identify remaining large areas with a minimum of human disturbance (for the purpose of developing regional conservation strategies). The smallest areas considered were at least 50,000 hectares and at least 10 kilometers wide. This size allows most of the natural structure and dynamics of the natural landscape to be preserved and reduces edge effects to a minimum.

The work utilized many different sources and types of information in order to make it as exact and credible as possible. The approach was a step by step elimination from the studied territory of different types of disturbed area:

- Basic infrastructure (cities and villages, main roads) – using general geographical maps.
- Tundra and severely disturbed areas – using satellite images from Resurs MSU-SK (resolution 150 m/pixel).
- Other disturbances, including small and low-intensity disturbances – using satellite images from Landsat ETM+ and for smaller area also Resurs MSU-E and SPOT HVR (15-35 m/pixel).

Some forms of disturbance (associated with ancient primitive forms of economic activity) were consided as insignificant (i.e. as ”background disturbance”).The map was verified using field data from 67 key inventory areas. The final boundaries were drawn on the basis of imagery from landsat ETM+ and other imagery of similar resolution.

Intact forest landscapes make up about 13 percent of the forest zone of European Russia. Most of this is in remote, inaccessible, low-productivity areas in the far north and near the tundra, mostly with a site productivity less than $1m^3$/ha and year and a stocking in mature stands of less than 100 m^3/ha. About 52 percent of the intact landscapes are in the transition zone between forest and tundra and officially excluded from industrial logging. The biggest threats to the intact forest landscapes are logging and mineral exploration. The most northern parts are typically situated beyond the reach of economic activity.

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Application of the Response Function Method for Prediction of Forest Dynamics Using Remote Sensing and Surface Measurement Data

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Regional and global environmental issues require that ecologists address the applicability of ecological models across diverse scales. If ecologists wish to develop models that use remote sensing data to validate our emerging conceptual views of Earth ecosystems, it will be necessary to create a new ecological paradigm consistent with the spectral data from satellite systems. An overall strategy to incorporate remotely sensed images into ecological models requires an examination of conceptual frameworks within ecology and the image processing tools used to relate remote sensing data to ecological processes. We discussed applications of remotely sensed images and links to variables needed for ecological models.

We propose the method of response functions (MRF) as a method of the construction of purposeful, credible integrated models from data and prior knowledge or information. The data are usually time series observations of system inputs and outputs, and sometimes of internal states. Prior knowledge available may include conservation laws, idealised physical equations, model parameter and noise values, the nature of the system response and hence possible parametrisations. The method of response functions implies credible models in the sense that they are identifiable, and, hopefully, explain system output behaviour satisfactorily.

The requirement for large amounts of data of kinds not now readily available is one major current problem of the MRF approach, although without these data the approach can be very useful when appropriate hypothetical structures are used for modelling and for stimulation of our mental processes. The MRF paradigm does, however, provide a useful framework as a guide in collection, organisation, and reporting of useful data. Data-intensive models can be used to assess the information content in data and consequently provide a guide as to the maximum level of detail that should be built into models of analogous processes, where data may not exist. Through case studies they can indicate the predictive uncertainties to be expected for decision makers, and where best to concentrate the collection of additional information, and indeed research, in order to reduce uncertainties. In short, data-intensive modelling studies are needed to provide advances in knowledge of environmental systems, and in an increasingly data-rich world such studies will continue to have more direct relevance.

The MRF approach may be used either to build relatively narrow purpose but often successful models, or, as part of a wider strategy, to develop regional model structures which may or may not ultimately be used to infer a more generic model.

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Forest Biomass Mapping Using Seasonal Response in JERS SAR Data

Rauste Y. A.[1], T. P. Häme[2]

In the GBFM project (Global Boreal Forest Mapping project, initiated and co-ordinated by the Japanese space agency NASDA), continent-wide mosaics are going to be produced for the whole Boreal-forest belt of the world. Objective of the study described in this poster is to study the potential of multi-temporal JERS SAR data for mapping forest biomass.

The study site is in Ruokolahti in south-eastern Finland (centre latitude 61 degrees, 31 minutes North, longitude 28 degrees, 46 minutes East). Ground data consists of forest inventory data for 2391 stands covering 3640 hectare (provided by the forest owner, Stora Enso Ltd). The JERS SAR data set consists of 6 scenes acquired (1993-1998) during the growing season (July, September, and October), in dry winter conditions (February and March), and in moist (wet snow) winter conditions (January).

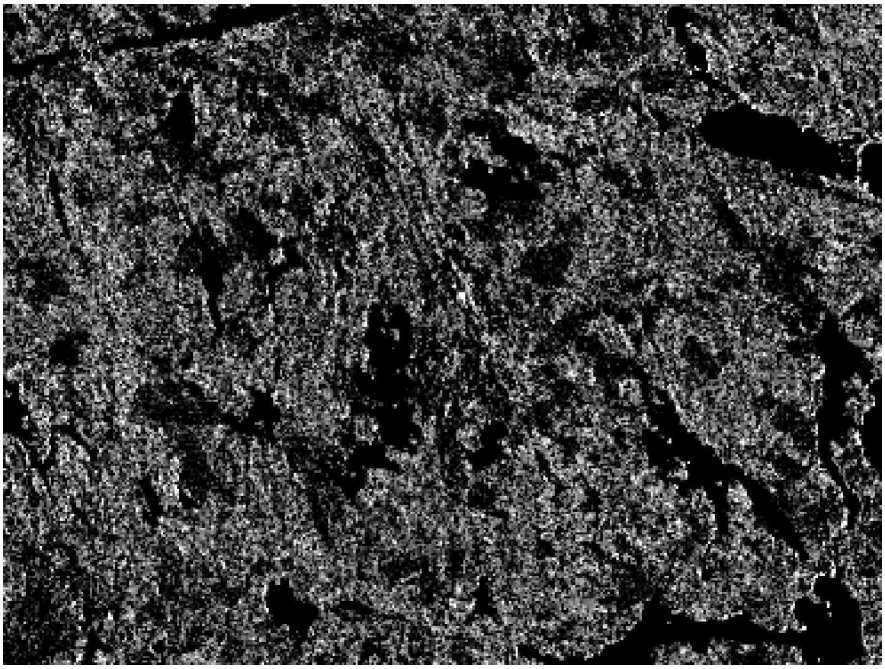
Pre-processing of the JERS SAR data included: 1) calibration to the same radiometric reference, 2) geo-coding using tie points and ground control points, and 3) ortho-rectification and radiometric correction using a digital elevation model.

The relationship between (stand-wise) average SAR backscatter (amplitude) and forest stem volume was studied using regression analysis. In summer scenes, correlation coefficients 0.63...0.78 were obtained for the whole data set (0.75...0.83 for stands with 130 m3/ha or less). The same level of correlation was found also in the winter scene with wet (new) snow cover. Correlation coefficients in the dry-condition (cold) winter scenes were lower (0.05...0.37).

The scene with wet snow shows potential for classification of clear-cut areas, which overlap with mature forest in all other scenes.

The high stability of the correlation between forest biomass and L-band SAR backscatter suggests that continental JERS SAR mosaics can be used for wide-area forest biomass mapping.

Forest-biomass map based on multi-temporal JERS SAR data:



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CORINE LAND COVER – OVERVIEW AND UPDATE

Roujean J.-L. C. H.[1]

The CORINE Programme (Co-ordination of Information on the Environment) was implemented in 1985 by the European Commission to investigate environment-related topics. The CORINE system concerns a maintained Information System describing the state of the European environment including a series of satellite databases with some background information. A systematic effort was made to concert activities with people involved in the production of environmental information at international level. Agreements were concluded which made possible to establish common nomenclatures and methodologies and optimise the data gathering. A major task undertaken in the framework of the CORINE Programme has been the establishment of a computerized inventory on quantitative, consistent and coherent land cover data base for the twelve EC countries (2,36' million Km2), at an original scale of 1:1000,000, using 44 classes which are grouped in main level categories for all countries: artificial surfaces (cities, etc.), agricultural areas, forests and semi-natural areas, wetland and water bodies. The nomenclature initiated by CORINE actually stands for reference in countries of Central and Eastern Europe, which are not covered by the project. For those countries, it was decided from 1991 to extend three main CORINE inventories (Biotopes, Corinair and Land Cover). The methodology consists of a computer-assisted photo-interpretation of Earth observation satellite imagery, merely from Landat and SPOT, along with ancillary data (maps, air photos, statistics, local knowledge) to help identify and confirm the contents of certain land units, which have been recognized on the images. An update of the CORINE land cover database is planned about every 10 years in either repeating regularly the interpretation process or by using an integrated satellite image processing and a geographical information system. This first thematic information was made available in 1993 and a new database is scheduled to be released in 2003.

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- More than 50 scientists working on a range of land cover and forestry-related problems in a regional network
- Focus also on policy relevant applications
- Multi-disciplinary, multi-sectoral, and multi-temporal

Southeast Asia network history

- Initiated through START activity on LUCC, with funding from GEF
  – Four core countries: Malaysia, Indonesia, Thailand, Philippines
  – Focused case studies
- External "Resource People" help secured additional funding from national and regional programs, expansion of network to include additional countries: Vietnam, Laos, Cambodia.
  – Leveraged funding from home institutions
- Formation of SEARIN with independently developed sources of funding

GOFC History

- GOFC Tropical Workshop, 1999 Washington DC
  – Builds on on-going LCLUC and START global change activities in the region
  – Organizes a GOFC framework for activities
- Regional workshop to establish work plan and coordination with national forestry agencies, 2000, Bogor Indonesia
- Regional workshop to define initial Forest Cover projects design and organizational/operational structure, 2000, Manilla, Philippnes
- Proposals to donors for initial funding, 2000-2001
- Regional workshop for site and regional methods, 2001, Chiang Mai, Thailand
- Data nodes implemented with joint support from NASA and CEOS, 2000-2001
- Regional workshop to establish fire products and operational structure, 2001, Tokyo, Japan
- Initiation of field campaigns, training, and product development, 2001

Focus of Activities

- Coordination of common methods for land cover and forest analysis using coordinated case studies.
- Regional cooperation on evaluation of global land cover products using case study sites
- Regional collaboration on harmonized forest inventory and mapping
- Development of a regional fire network to support applications and policy, e.g. transboundary haze problem
- Collaboration on technology transfer, human resource development, and training
- Regional scale production of forest cover assessments using current best practice and new methods as they come on-line

Program Areas

- Land use and cover change dynamics, including models (NASA, APN)
- Carbon cycle modeling and emissions estimates (APN)
- Forest Cover Change Monitoring, Mapping and Management (GOFC, NASA)
- Ecosystems and land cover change assessments (UN/Millennium Ecosystem Assessment)
- Climate and climate variability (NOAA-ECE)
- Training and Human Resouce Development (GEF, APN, START)

Network organization

- Secretariat function for each program area:
  - GOFC Forest Land Cover: Biotrop, Bogor Indonesia
  - GOFC Fire: UKM, Malaysia
  - LCLUC Research: UKM Malaysia
  - Training and technology transfer: GSTDA, Bangkok, Thailand
  - Outreach and network management: NAMRIA, Manilla, Pilippines
- Data centers (nodes within a GOFC-DISS)
  - Landsat acquisition and distribution: UKM, Bogor, Bangkok
  - Fire network: Bangkok, UKM
- Management
  - National “teams”
  - Executive committee Rotating network
  - Chair on annual basis
  - Annual Network meeting
  - Subprogram meetings for GOFC, APN, NASA LCLUC
  - Regular training workshops
  - Field campaigns

Lessons learned

- Development of the network needs support both internally and externally
- Long term commitment is needed; cannot happen in less than 2 years, although some significant activities can start right away.
- Resources are needed, but it is not a matter of finding a single source – needs a portfolio approach with a strategy for evolution of the portfolio
  - Intially from internatianl donars, followed by national agencies and regional donars
  - Expect and strive for significant home institution commitments
- Need to continuously advocate the needs of regional stakeholders to secure in-country and home institution support
- Network participation should be international, benfits to individual participating countries are best if they share mutual regional goals (e.g. common methods and products, access to and sharing of data, visibility)
- Linkage with the international programs to boot-strap the program can work (e.g. START) as it gives international credibility and recognition to participants and their home institions
- Need to have recognized leaders and champions --- a core leadership group is best
- Some form of organizational structure is necessary, but a federated approach – ie non governmental, non-official – is best

AEROSPACE MONITORING OF FOREST COVER IN THE OIL-SHALES MINING REGION OF THE NORTH-WESTERN RUSSIA

Semikobyla Ya. G.,[1] T.A.Popova and O.B.Babenko

One of the powerful anthropogenic factors impacting on the forests is the underground mining. It is connected to the mining rock disturbance which arises in the massif and leads to the trough deflection on the land cover. This problem has been investigated on the example of Slantsy mining district of Leningradskaya oblast, where 80% of territory was formerly covered by boreal forests. The investigations have been held using the aerospace monitoring methods. It was found out that all kinds of trees in troughs deflections except of black alder dies off very fast because of being drenched. The fields of large trough deflections distinguished on the space photographs on a scale 1:125000, 1:300000, 1:400000 which were took by the space devices "Salut", "Resurs-F". Especially good on the space photographs on a scale 1:125000 was seen the regularity of trough deflection rows disposition and vegetation on it over the waste mining outputs. On the space photographs died and dying off trees distinguishes essentially and differs by the light grainy tone. This allows to keep up the estimation of boreal forests disturbance by the space photographs on the field on the territory of old waste underground mining outputs by the condition of forest vegetation.

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REMOTE SENSING INFORMATION AND MODELING OF NONSTATIONARY ENERGY AND MATTER TRANSPORT PROCESSES IN INHOMOGENEOUS FOREST COVER

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When modeling of energy and matter exchange of the forest vegetation the problem of obtaining the initial information for the models developed concerning with the phytometry of forest covers as well as other characteristics responsible the environmental impacts on the forest ecosystems is very important. Very often these models use for solution of the problems characterizing with the large territorial and long temporal scales. Because of this it is difficult to look forward to obtain the data on the physical and physiological parameters of the forest ecosystems, as well as the orography information and especially the temporal changes of initial model parameters using only the information collected in-situ observations. According this the question about the necessary data securing using the remote sensing methods is one of the actual problem for the development of adequate models of the forest ecological processes and using these models for solution of practical questions.

In the paper presented one of the detail model of energy and matter exchange in forest cover is discussed. This model permit to calculate the temporal dynamics of solar radiation, turbulence and wind regime characteristics, as well as the heat, water vapor and carbon dioxide transport in horizontally inhomogeneous forest cover and in the atmospheric boundary layer over it in the condition of nonuniform orography. Some practical results of the numerical runs using this model is discussed. The conclusions on the obtaining of initial model parameters using the remothe sensing information are formulated.

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ROLES OF GOFC AND REGIONAL NETWORKS

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What GOFC can and cannot do

- GOFC focuses on international cooperation and coordination
  - – what happens within countries is determined within countries.
- It is not the business of GOFC to duplicate or replace other networking activities
- The priorities of a region have to be determined by members of the region.
- GOFC must engage the main players.
  - –Only partially successful at this meeting.

Working at the International Level

- GOFC provides the international coordination for the collection of systematic observations of forests and other covers.
- Like all international organizations its resources are relatively limited.
- It has to work through international organizations and mechanisms to ensure appropriate observations are collected and products made available largely through funding from national sources.

Types of GOFC activities

- Provides an overall conceptual framework for the international collection of observations through planning documents.
- Coordinates synthesizes and updates requirements for observations and products.
- Identifies requirements for observations and requirements which are not being or will not be met in the future.
- Works with space agencies to mitigate deficiencies through modifications to their programs
  - –Improving access to data
  - –Enhanced products
  - –Improved acquisition strategies
  - –Enhancement of new planned sensors
  - –Definition of new sensor requirements
- Works to improve collection of *in situ* data through
  - –coordination of networks.
  - –identifying key locations for additional observations
  - –assisting the transition of research networks to operational status
- Improve access to data - notably space data
- Initiate and/or enhance validation of GOFC-relevant products.
- Improve standards and harmonization for data collection and product creation through international consultation.
- Provide mechanisms to monitor the success of data collection activities.
- Provide a forum for standardization of analysis methods and reporting
- Demonstrate to user communities the benefits of enhanced observational products
- Define the information systems requirements.
- Seek commitments from national organizations able to take responsibility for GOFC-DISS and monitor their performance.

New approaches

- "*Competition and Cooperation*" and not "*Competition vs Cooperation*" ("Coopetition")
  - Agree on where there will be cooperation and where competition.
- 21st century approach - linking of different types of organizations
  - (National Agencies, NGOs, Universities, Research Laboratories)
- Distinctions between local, regional and global data sets and analyses are becoming blurred.
  - The best data may come from outside of a region.
  - Global analyses can provide *sometimes* better products than are available through national efforts.
- New modes of representation & analysis (CF and Assimilation)
- Hence key need to link the regional and the global.

A Regional Network

- Need a clear understanding and consensus of benefits of a new (or transformed) international network.
- What should be the Geographic scope?
  - Subsidiary question: one or two regions?
- Who should be the Participants?
- What are the Priorities for the Region?
- How will the Network be organized?

–governance
–physical location of Center(s)
–roles and responsibilities
–who are the champions, the leaders?

- One way to proceed
  - what are the priority needs for the region from GOFC
  - how can the network organize itself to meet those needs
  - early success in meeting those needs will demonstrate the benefits of the network and attract increased participation

Being more specific

- If we try and do everything for all users with every kind of observation the result likely will be nothing.
- A child when it starts walking takes small (baby) steps.
- What are the *baby steps* we need to take to start walking?
- Strategic question: Are there specific high profile contemporary forest and/or environmental problems that can be identified?
  - e.g problems of forest disturbance such as insect damage or pollution that are poorly characterized and understood.
  - Clearcut logging
  - Thinning instead of clear cutting.

Key issues to address

- Should there be a regional network?
- Should there be a single Eurasian network or two?

FOREST INVENTORY IN RUSSIA: DATA NEEDS AND AVAILABILITY OF IN-SITE MEASUREMENTS.

Treyfeld R. F.[1]

As directed by the Forest Code of the Russian Federation (1997) forest inventory is conducted on the entire territory of the Russian Federation using a standard system. The goal of forest inventory and management planning is to ensure the rational use of forest resources and to maintain their environmental, economic, and social functions. The inventory defines the species and age-class composition of forests and their health, as well as qualitative and quantitative characteristics of forest resources. Guidelines for forest inventory procedures were published in 1995 (vol. 1 – field methods, vol. 2 – data processing). Data is available at the level of individual stands, inventory blocks, ranger districts, forests, and administrative regions of the Russian Federation.

[1] Northwestern State Forest Inventory Enterprise, Ul. Koli Tomchaka 16, St. Petersburg, 196084, Russia