PROGRESS REPORT

Satellite observation of boreal land cover (SILC): methods, data sets and applications

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1. BACKGROUND

This research project addresses the methods and applications of satellite data at various spatial resolutions for the determination of land cover characteristics over large areas in the boreal zone. The main interest is in effective use of satellite data for determining land cover type, primarily through an intermediate, model-based characterization of vegetation canopy; and in the quantification of land cover composition of Canada and its changes between 1993 and 2001. The use of the derived information for studying biosphere dynamics across Canada is pursued through collaboration with other programs and studies. From the methodology perspective, new methods for extracting land cover information over large areas, reliably and consistently, are the main focus. The characterization of wetlands is also of interest. In addition to robust and efficient methodologies, Canada-wide data sets will be produced for use in parallel and subsequent studies of the carbon and hydrological cycles.

2. KEYWORDS

1) Research Fields: biodiversity, and cover classification, carbon sequestration, change detection, ecosystem modeling
2) Geographic Area/biome: CANADA
3) Remote Sensing: AVHRR, LANDSAT, SAR, MODIS
4) Methods/Scales: mixture modeling, regional scale

1. GOALS and PROGRESS

Objective 1. Development of an operational method for producing land cover type information at the regional level

1.1 'Fine' resolution data-based land cover classification

- Carry out initial tests of the feasibility of combining unsupervised clustering and model-based labeling to classify Landsat TM images of forested areas

Accomplishments:

a) A new classification method has been constructed, using a combination of automated clustering (CPG) and model-based labeling (MFM-5 Scale). For forest canopies, the method gave results that compare favourably to forest inventory maps and field observations from BOREAS. The method can also be applied directly to satellite images (without prior clustering) and in principle it also yields stand biophysical parameters.– In addition, methods are being developed to minimize radiometric artifacts in fine resolution data (Landsat MSS, TM) with emphasis on (i) scene-to-scene and (ii) within scene (especially haze) effects (see Publications).

b) The previously developed classification procedures (Classification by Progressive Generalisation, CPG (Cihlar et al., 2000; Can J. Rem.Sen. 26: 446-454) and the Enhancement Classification Method, ECM (Beaubien et al., 1999; JGR 104 (D22): 27909-27920) have been further refined. A combined approach using the strengths of each method has been developed and used as the baseline in classifying TM images for the unmixing work (see Objective 5).

Gaps and issues: Among outstanding issues for MFM-5-Scale are applicability to non-forest cover types, robustness in performance over large areas, and the accuracy of biophysical parameters estimated in this manner. These are being pursued in follow-up research.

1.2 'Coarse' resolution land cover classification

- Prepare a consistent time series of AVHRR data for the 1993-2000 time period, using improved information on atmospheric and bi-directional properties of the AVHRR measurements

Accomplishments: 10-day composites of AVHRR data for growing seasons (April-October) between 1993-2000 were reprocessed to apply the most recent knowledge of (i) sensor calibration; (ii) new, pixel-specific information on atmospheric parameters (water vapour and ozone); and (iii) a new BRDF correction algorithm (Latifovic et al., 2001).

Gaps and issues: The suitability of the new (MFM-5-Scale, section 1.1 above) approach for mapping coarse resolution data has not been established; the existing algorithms will serve as a backup strategy.

Objective 2. To produce land cover maps over the 1993-2001 period using satellite data at 300-1000 m resolution.

- Select a legend for Canada-wide mapping and evaluate it suitability
- Assess the feasibility of detecting land cover changes with the coarse resolution data
- Apply existing land cover classification procedure to 1 km MODIS data

Accomplishments: The FGDC Vegetation Classification System was adopted by the project for mapping Canada's land cover. Its comparison with the previously employed scheme yielded favourable results, and was successfully employed to produce a land cover map of Canada for 1998 from SPOT4-VGT data. - Initial tests of change detection with this data set were carried out over the 1993-1998 period, using 5 different algorithms (including the MODIS algorithm) and a combined method. The results indicate that 'large' changes (e.g., fires) can be detected and mapped relatively readily, but there are also numerous other, regional changes with no easily evident cause. A paper describing the results is in preparation. – No progress was made with MODIS data due to data unavailability.
Gaps and issues: No decision has been made on how to obtain land cover maps for the 1993-2001-time period (obtain land cover maps at different years and identify changes, or obtain a map for the recent period that can be well validated and use change detection to arrive at land cover maps in previous years). Both are feasible at this point, and the work done on change detection suggests that a combination of approaches (including the use of separately derived burned forest area maps) may be desirable.

Objective 3. To prepare a database of wetland distribution for Canada using a combination of remotely sensed and other data types.

- Complete the assembly of existing regional wetlands data for Canada
- Carry out initial assessments of the feasibility of extracting wetland information from regional SAR mosaics

Accomplishments: A prototype digital database of Canada's wetlands was assembled through a separately funded project. This database contains estimated fractions of wetlands for sizeable land cover polygons. The initial plan to enhance the database through the use of SAR data has been delayed due to the unavailability of processed JERS SAR image mosaics. In the meantime, we have begun processing digital national topographic maps which contain more detailed wetland distribution, with the intent to use this information with other sources in the preparation of a 'best possible' wetland map.
Gaps and issues: The non-availability of SAR data. We can cope with some delay but should that data source (NASDA-NASA BFGM project) not materialize, the main improvement in wetland distribution will come from the topographic data. The wetland category from the classified TM images (Objective 5) will also be used.

Objective 4. To develop methods for quantifying the content of medium resolution land cover maps using high resolution satellite data or other information sources

- Evaluate various techniques for sub-pixel composition estimation, for application to Canada's landmass

Accomplishments: A study has been conducted to evaluate various methods of estimating subpixel composition (neural network, clustering/look-up-table approach, multivariate regression, linear least squares inversion), and an optimum technique for boreal regions has been identified (see Publications).
Gaps and issues: None

Objective 5. To obtain statistics for land cover distribution at national, provincial and sub-provincial level using an optimum combination of medium and high resolution data

- Produce an initial data set allowing to estimate the fractional distribution of land cover

Accomplishments: Approximately 30 Landsat TM images were classified using approaches we developed previously. These scenes were selected to represent the diversity of Canada's land cover, using an objective selection algorithm previously published by the team (Cihlar et al., 2001, RSE 71: 26-42; 127-138). These scenes will be used in conjunction with the methods developed under Objective 4.
Gaps and issues: A major issue is the cost of rigorous accuracy assessment. We have considered various options and presently lean to a qualitative assessment, based on visual interpretation of enhanced TM images. However, this depends on highly experienced image analysts and has not been entirely resolved. The backup (undesirable) option is reducing the number of TM classes to a few basic types.

Objective 6. To use the land cover information for deriving higher-level products and to study surface-atmosphere interactions and the role of land cover in carbon and hydrological cycles.

- Complete a methodology for mapping NPP over large areas with land cover as input.

Accomplishments: A major paper was published on mapping NPP across Canada, including model testing and validation. The study provides the basis for estimating NPP and its spatial distribution on an annual basis.

2. APPROACHES

In general, so far we have followed the approaches described in the proposal. The use of topographic data represents a new addition.

3. SCIENTIFIC QUESTIONS

a) What are the changes in land cover? (with sub-questions on the most appropriate methodologies for extracting land cover and land cover change information from satellite data)

4. PROPORTION OF SOCIAL SCIENCE

10%. We are interested in the relation of land cover to land use, have developed a general methodological approach to obtaining LU from LC (see Publications), and are now developing a coarse resolution LU product at national scale by 'fusing' census data with land cover maps (paper in prep.).

4. THEMES

Land cover change, carbon cycle, water cycle

5. PROGRESS

In general, we have made significant progress in achieving the objectives stated in the proposal and are on track with respect to the original objectives. Re Objective 1a (fine resolution mapping), we expect to extend the tests to a regional scale, consider classification of non-forest cover types, and evaluate the accuracy of biophysical products derived in this manner. For coarse resolution mapping, we will likely rely on existing classification procedures and the new pixel unmixing work (Objectives 1b, 4). For Objective 3 (wetlands distribution), the integration topographic maps will be a significant improvement, but an addition of SAR-derived information will depend on the timing of the SAR processing for the boreal zone. Accomplishment of Objective 5 hinges on dealing successfully with the (affordable) accuracy assessment challenge. We have been negatively affected by the non-availability of MODIS data and SAR mosaics. A significant problem remains the cost of TM accuracy assessment, and we would like to learn of any cost-effective methods developed by other teams. We have a tentative approach based on assessing the accuracy of labeling clusters (as opposed to individual pixels) but this suffers from assumptions made.

6. SIGNIFICANT RESULTS

- The model-based labeling method for TM data (MFM-5-Scale) suggests promise for a more rapid, more objective and less expensive extraction of land cover information (type, biophysical properties) from satellite data (Peddle et al., 2001)
- A Canada-wide NPP map supported by substantive validation effort (Liu et al., 2001)
- A general model for efficiently using land cover product to obtain land use maps (Cihlar and Jansen, 2001)
- New products: Land cover map of Canada for 1998 (from SPOT4 VGT data, metadata now in preparation)
- A set of ~30 classified TM images, using a consistent methodology and a detailed classification legend; validation remains to be done).

7. CONCLUSIONS

Substantial progress has been made in the past year. Achievement of the planned objectives is hampered by delays in the availability of satellite data sets (MODIS and SAR). It is hoped these will be resolved to permit the use of these data in the project.

8. PUBLICATIONS (peer-reviewed only)

Cihlar, J., and Jansen, L. 2001. From land cover to land use: A methodology for efficient land use mapping over large areas. The Professional Geographer 53(2): 275-289.

Cihlar, J., Du, Y., and Latifovic, R. 2001. Land cover dependence in the detection of contaminated pixels in satellite optical data. IEEE Transactions for Geoscience and Remote Sensing 39(5): 1084-1094.

Cihlar, J., Latifovic, R., Chen, J., Trishchenko, A., Du, Y., Fedosejevs, G., and Guindon, B. 2001. Systematic corrections of AVHRR image composites for temporal studies. Remote Sensing of Environment (accepted).

Fernandes, R.A., R. Fraser, R. Latifovic, J. Cihlar, J. Beaubien and Du, Y. 2001. Mapping sub-pixel land cover in boreal landscapes. Remote Sensing of Environment (accepted).

Latifovic, R., Cihlar, J., and Chen, J. 2001. A comparison of BRDF models for the normalisation of satellite optical data to a standard sun-target-sensor geometry. IEEE Transactions on Geoscience and Remote Sensing (accepted).

Liu, J., J. M. Chen, J. Cihlar, and W. Chen, 2001. A Canada -wide map of net primary productivity at 1 km resolution. Global Ecology and Biogeography (in press).

Peddle, D. R., Johnson, R.L., Cihlar, J., Leblanc, S.G., and Chen, J.M. 2001. MFM-5-Scale: a physically-based inversion modeling approach for unsupervised cluster labeling and independent landcover classification and description. Canadian Journal of Remote Sensing (submitted).

Wulder, M., and Seemann, D. 2001. Spatially partitioning Canada with the Landsat Worldwide Referencing System. Canadian Journal of Remote Sensing 27(3): 225-231.