Land Cover Change Protocol Developed For A Park Ecological Integrity Observing System (Park-EIOS)

R.H. Fraser, I. Olthof, and D. Pouliot
(in alphabetical order)

Canada Centre for Remote Sensing
Earth Sciences Sector, Natural Resources Canada

Also on CCRS GRIP Team: S. Wang, C. Prevost, W. Chen
Former CCRS Contractors: J. Orazietti, A. Clouston, G. Girouard, Y. Zhang
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Outline

1) Introduction to Park-EIOS

2) Challenges in using RS based change detection for EI monitoring

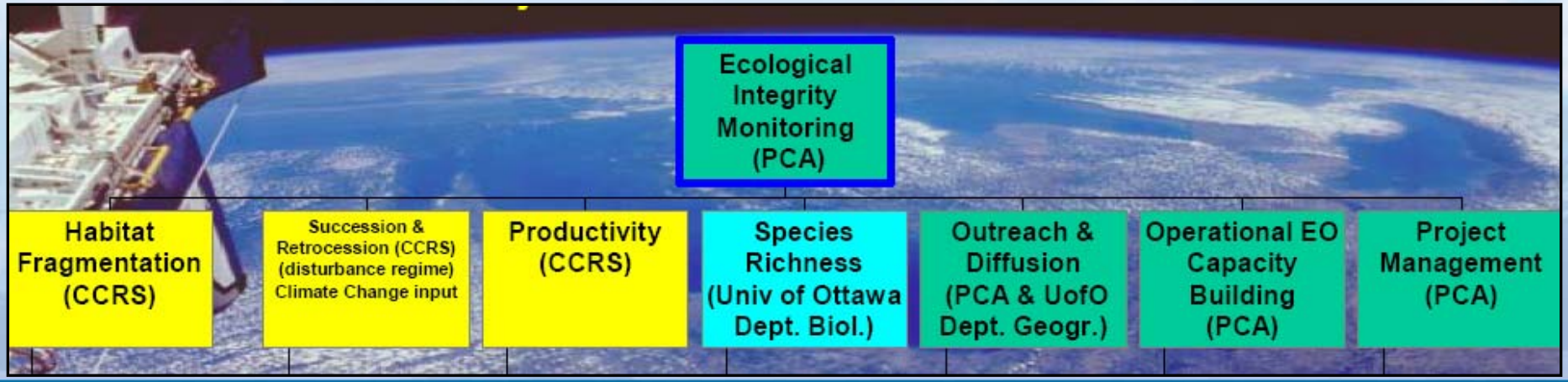
3) Change detection protocol developed for Park-EIOS and examples

4) Conclusions and future prospects

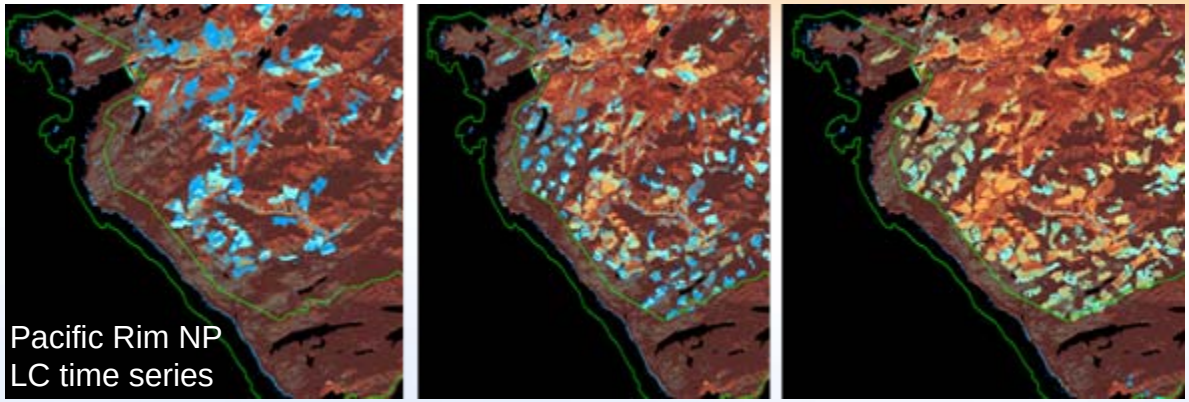
1. Park Ecological Integrity Observing System (Park-EIOS)

- PCA began partnership with ESS in 2004 to develop operational EO based Park Ecological Integrity Observing System (Park-EIOS) as component of an EI Monitoring Program beginning in 2008
- Demonstration products include Landsat time series analysis (1985-2005) of EI indicators over seven pilot parks
- The GRIP team will focus on two parks for this meeting: La Mauricie and St. Lawrence Islands

Project Framework Showing Work Packages

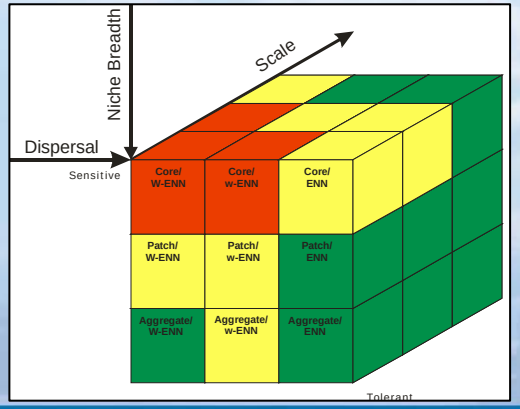


RS Land Cover Change Products Provide Foundation for Park-EIOS Indicators



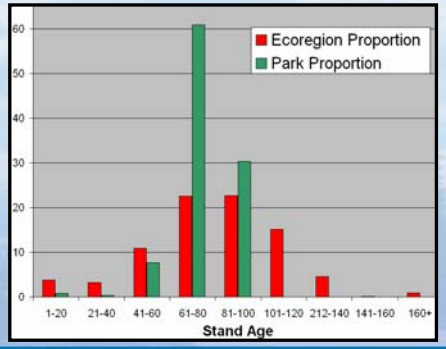
Habitat Fragmentation Indicators

PCA FragCube Method



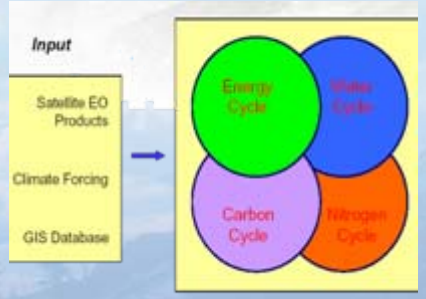
Succession / Retrogression Indicators

(e.g. stand age distribution)



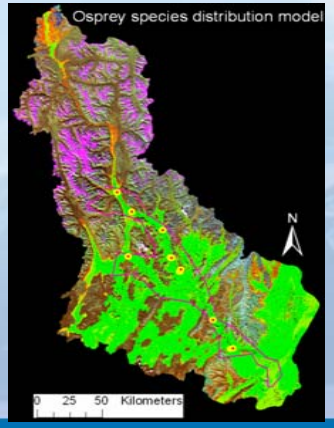
Productivity Indicator

EALCO Model



Biodiversity Indicators

Focal Species Modeling



2. Challenges for RS based change detection in Park EI monitoring

- Repeatability and automation
- Land cover *conversion* is usually a rare event → creates a RS signal/noise problem.
- Accurate radiometric normalization and spatial registration
- Land cover *modifications* (i.e. subtle changes within land cover class) are also important but more difficult to separate than LC change
- Need methods that can detect change events <u>and</u> label those changes

3. End-to-End Change Detection Protocol for Park-EIOS

Automated Multi-temporal Updating by Signature Extension (AMUSE)

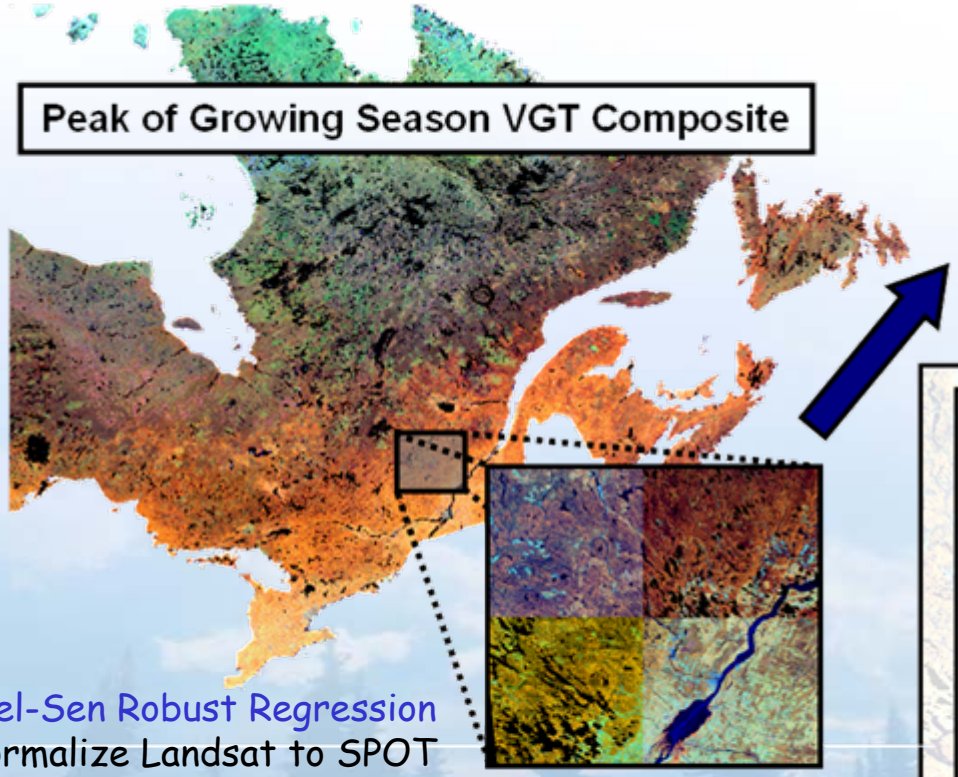
- Detects changes from baseline land cover then updates LC of changed areas by signature extension

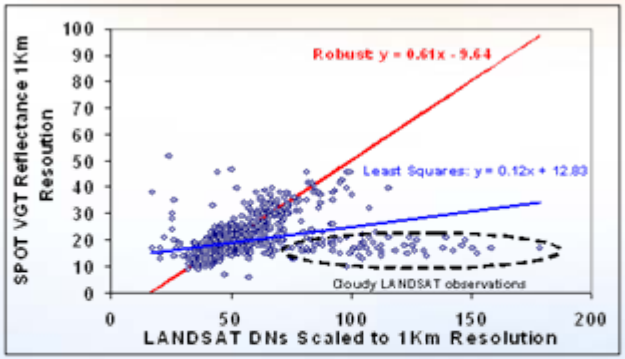
Goal: Automate change detection as much as possible, while still employing expert analyst guidance and quality control

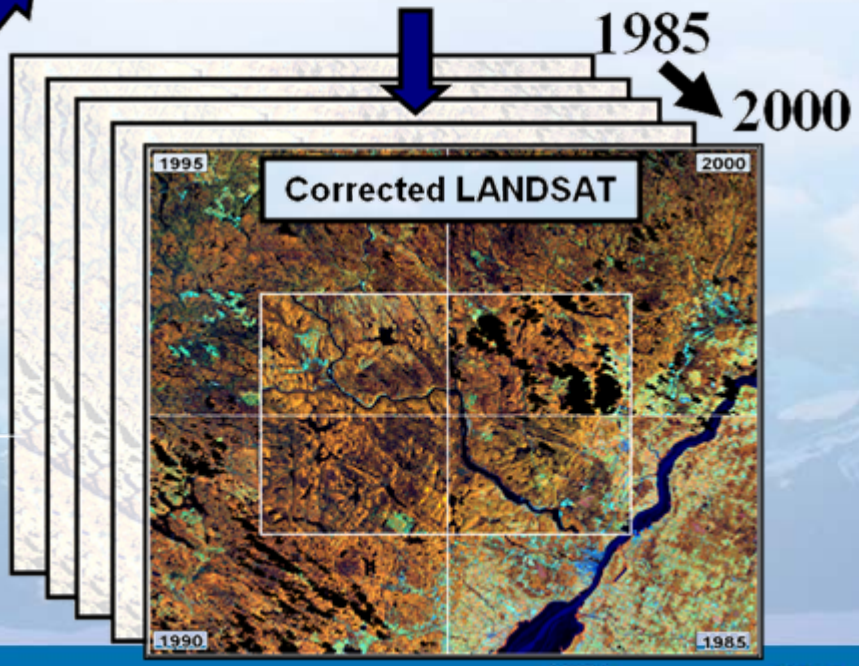
1. Radiometrically normalize baseline (Master) Landsat scenes to 1km imagery
2. Produce Master baseline land cover classification using unsupervised approach
3. Register raw Landsat imagery for other dates using automatic GCP collection (x # dates)
4. Apply Haze Optimized Transform (HOT) to remove spatially variable aerosol effects (x # dates)
5. Radiometrically normalize other dates to Master using robust regression and mosaic (x # dates)
6. Identify changed pixels in other dates using Change Vector Analysis (CVA) and thresholding (x # dates)
7. Update land cover for changed pixels in other dates using constrained signature extension (x # dates)
8. Validate baseline land cover and changes

Automated Multi-temporal Updating by Signature Extension (AMUSE)

1. Radiometrically normalize 30m baseline (Master) Landsat scenes to 1km imagery



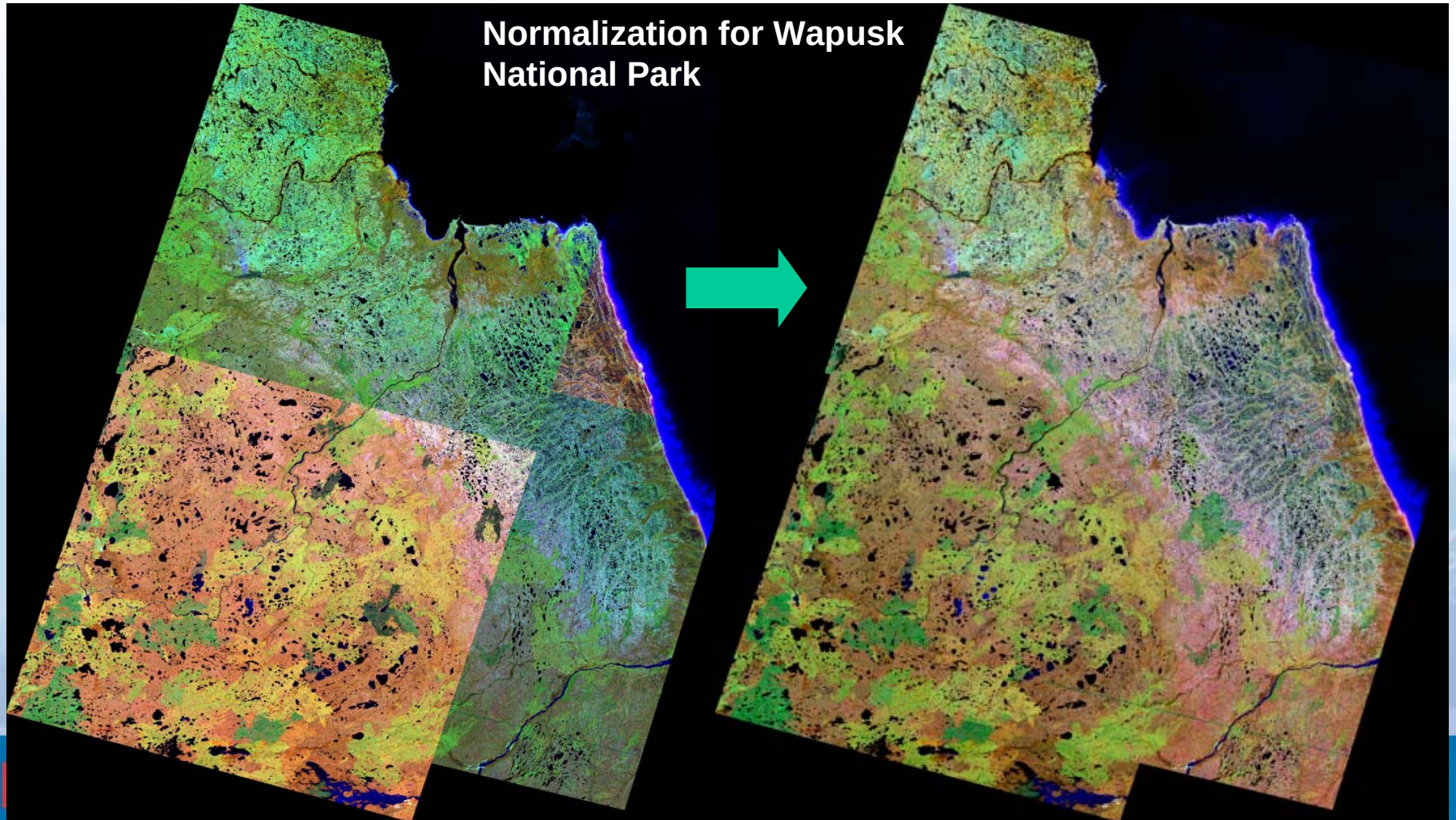




Thiel-Sen Robust Regression
- normalize Landsat to SPOT VGT reflectance product
(Fernandes and Leblanc, 2005; Olthof et al., 2005)

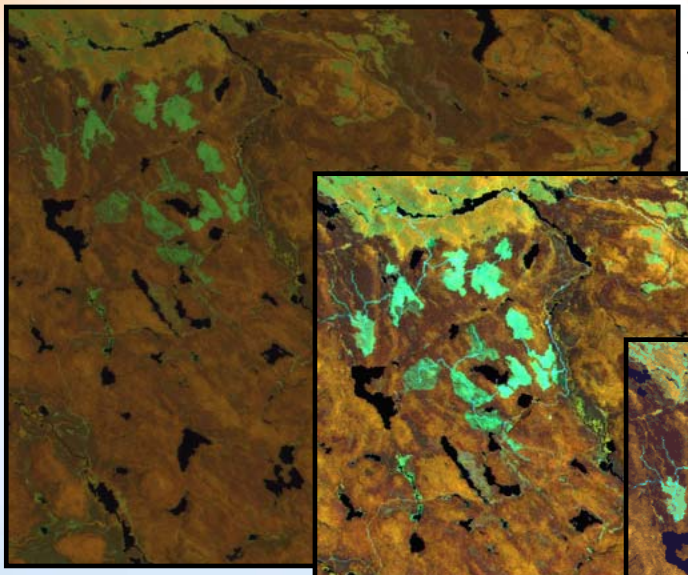
Automated Multi-temporal Updating by Signature Extension (AMUSE)

1. Radiometrically normalize baseline (Master) Landsat scenes to 1km imagery

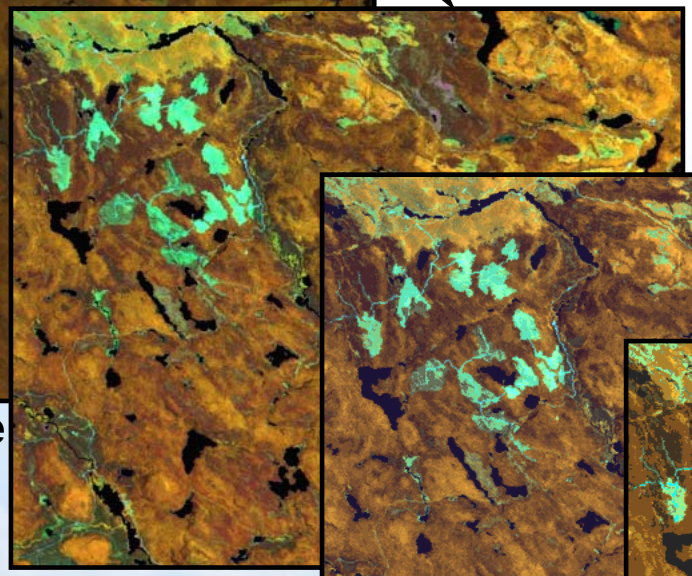


Automated Multi-temporal Updating by Signature Extension (AMUSE)

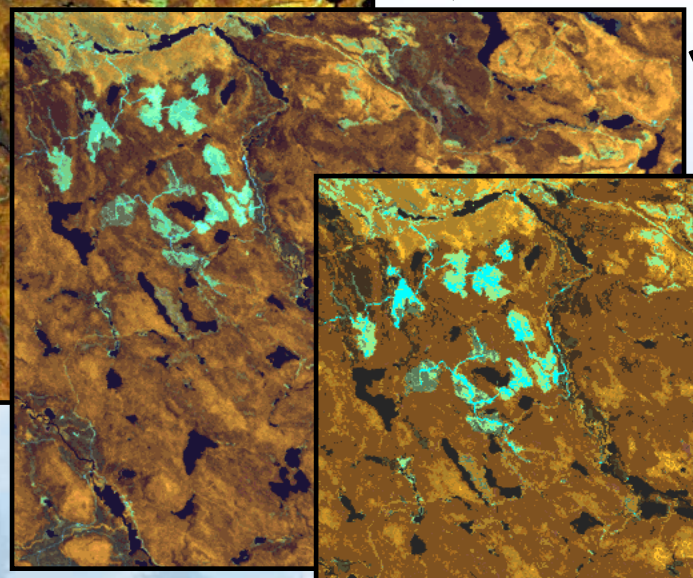
2. Produce Master baseline land cover classification using an unsupervised approach



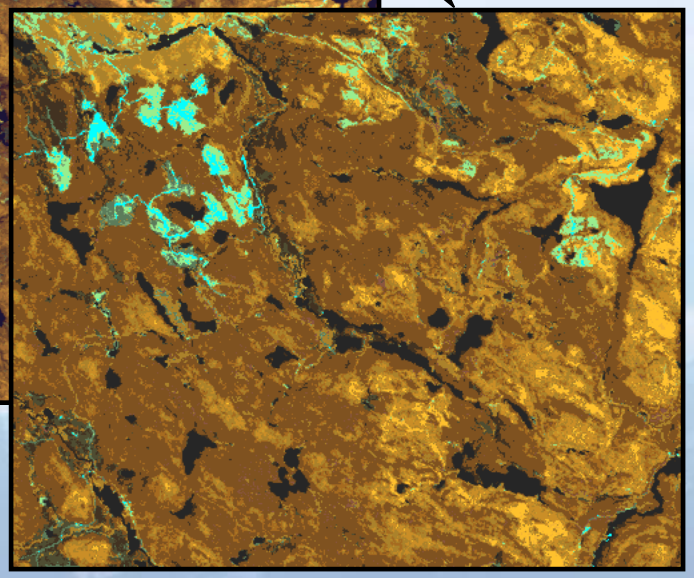
Original image



Enhanced image



150 cluster image



20 cluster land cover

- Evergreen forest (>75% cover)- old
- Evergreen forest (>75% cover)- young
- Deciduous forest (>75% cover)
- Mixed coniferous (50-75% coniferous)- old
- Mixed deciduous (25-50% coniferous)
- Evergreen open canopy (40-60% cover)- moss-shrub understory
- Evergreen open canopy (25-40% cover)- shrub-moss understory
- Deciduous open canopy (25-60% cover)
- Deciduous open canopy- low regenerating to young broadleaf
- Mixed evergreen-deciduous open canopy (25-60% cover)
- Mixed deciduous (25-50% coniferous trees; 25-60% cover)
- Low regenerating to young mixed cover
- Deciduous shrubland (>75% cover)
- Wetlands
- Sparse coniferous (density 10-25%), herb-shrub cover
- Annual row-crop forbs and grasses- high biomass
- Annual row-crop forbs and grasses- medium biomass
- Annual row-crop forbs and grasses- low biomass
- Mostly bare disturbed areas (e. g. cutovers)
- Water bodies

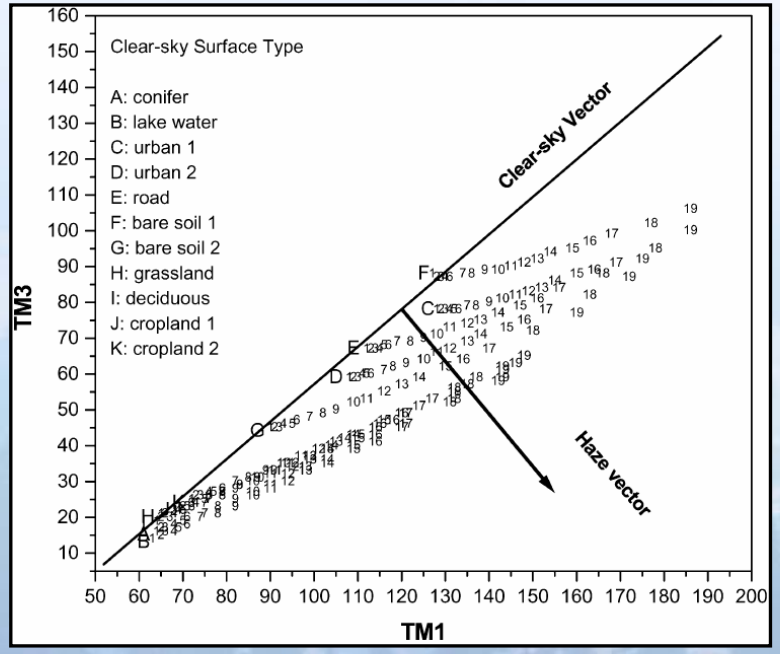
Combined Enhancement Classification Method (ECM) and Classification by Progressive Generalization (CPG)
(Beaubien, Cihlar, and Latifovic)

Automated Multi-temporal Updating by Signature Extension (AMUSE)

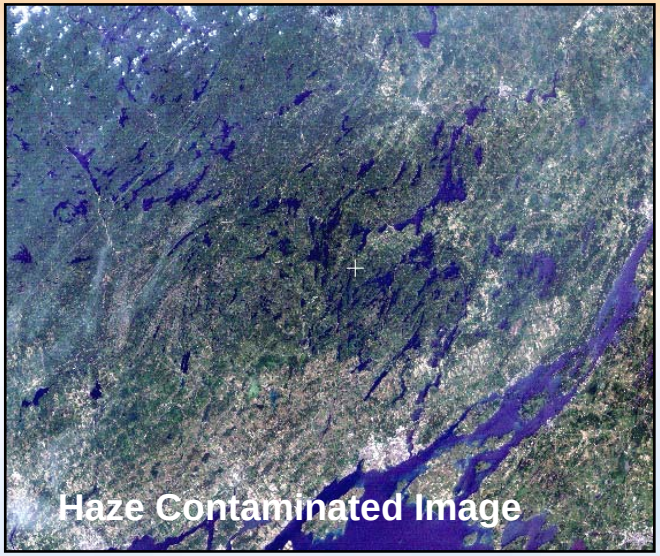
SLI NP

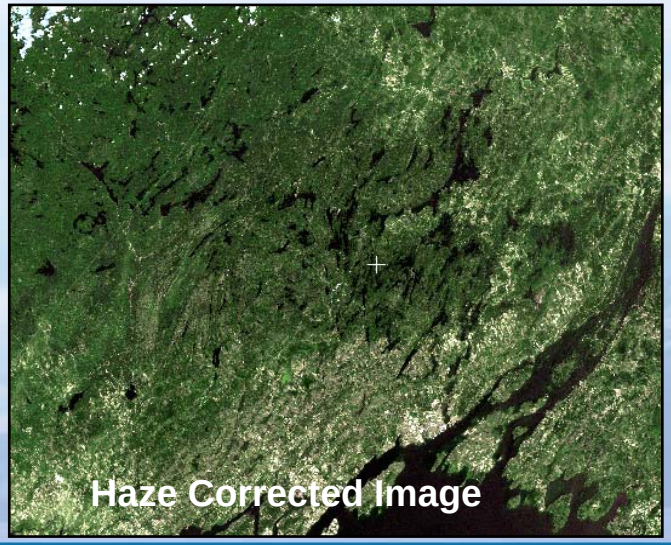
4. Apply Haze Optimized Transform (HOT) to remove spatially variable aerosol effects

Basis: Reflectance in visible channels is highly correlated, but response to haze is highly sensitive to wavelength and haze optical depth.



(Zhang, Guindon, and Cihlar, 2003, RSE)

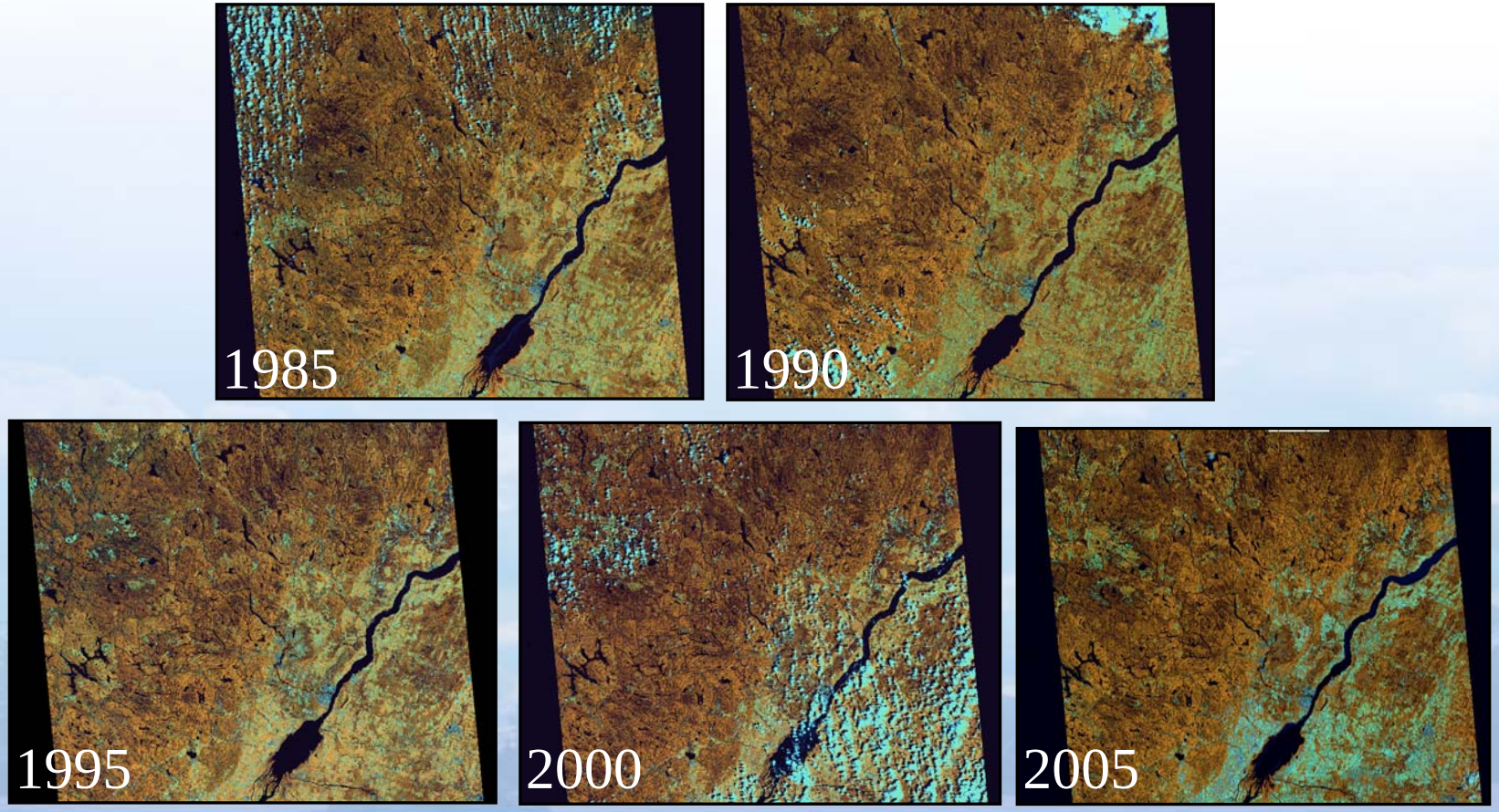




Automated Multi-temporal Updating by Signature Extension (AMUSE)

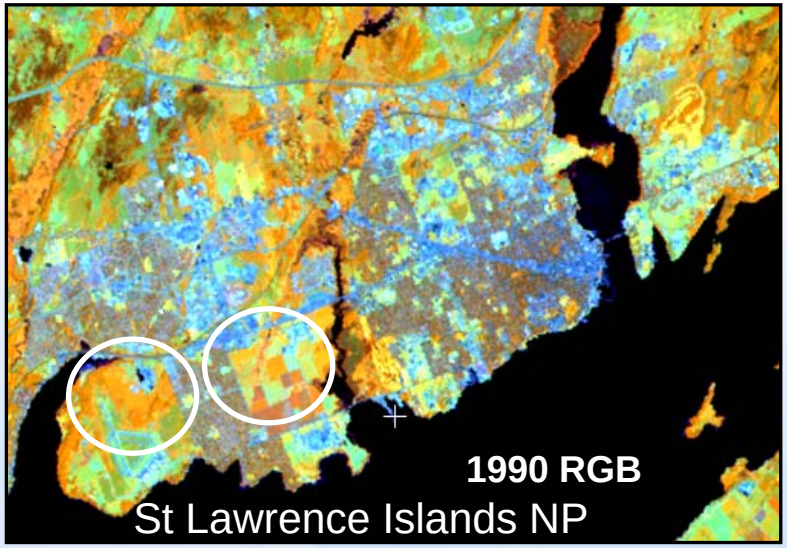
5. Radiometrically normalize other dates to Master using robust regression and mosaic

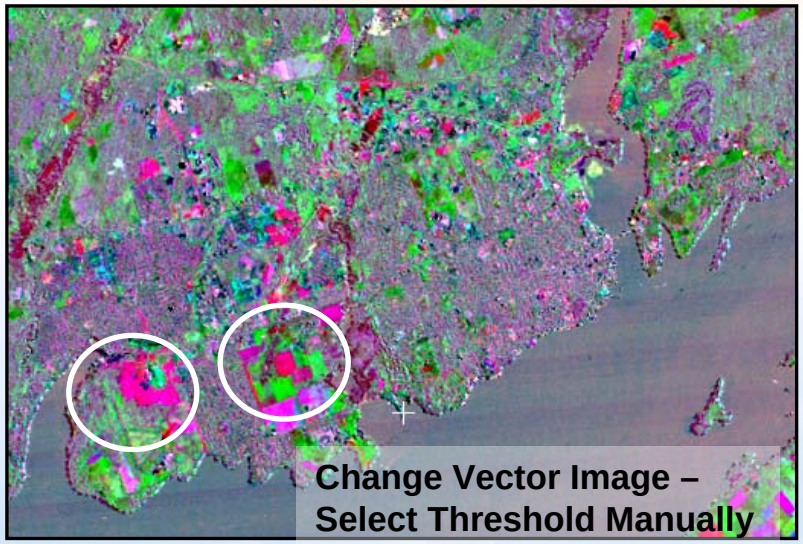
La Mauricie NP Normalized Reflectance Time Series

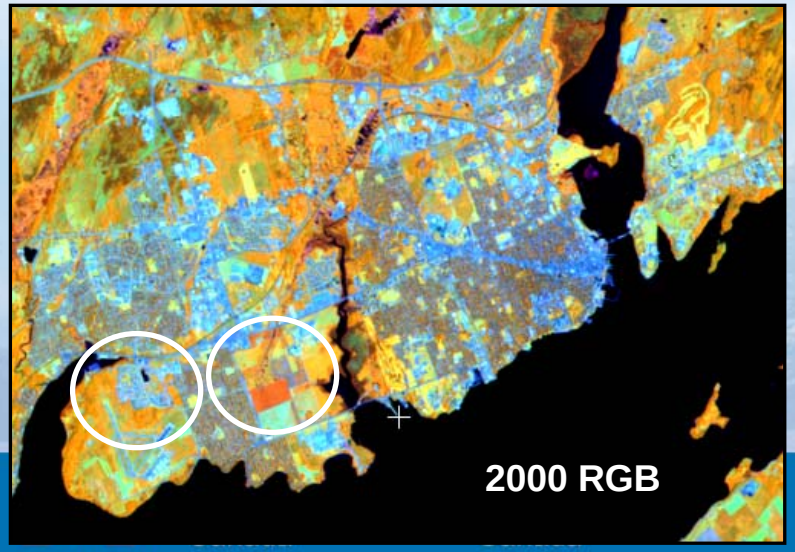


Automated Multi-temporal Updating by Signature Extension (AMUSE)

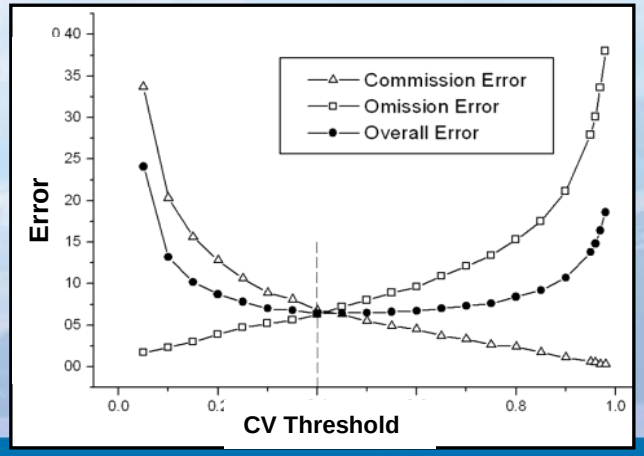
6. Identify changed pixels in other dates using Change Vector Analysis (CVA) and thresholding







Could use <u>accuracy assessment curves</u> to automatically generate optimal threshold

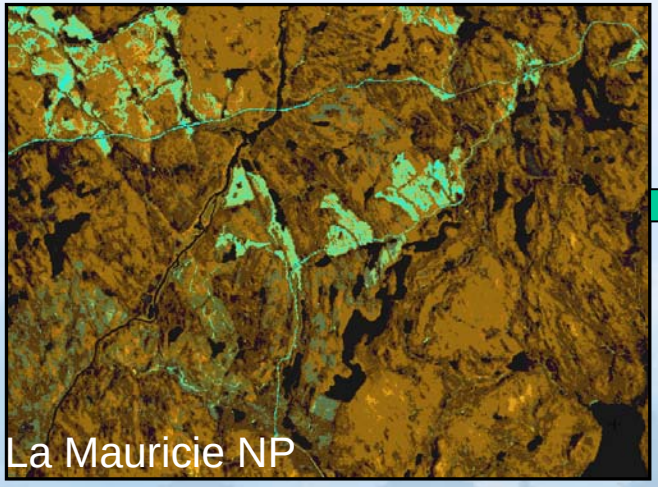


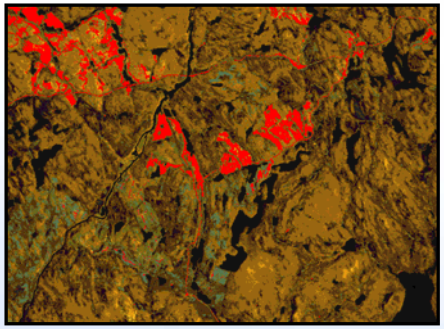
Canada

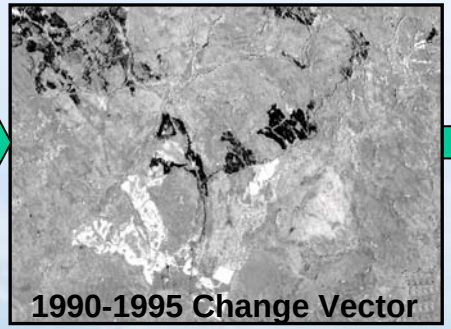
Automated Multi-temporal Updating by Signature Extension (AMUSE)

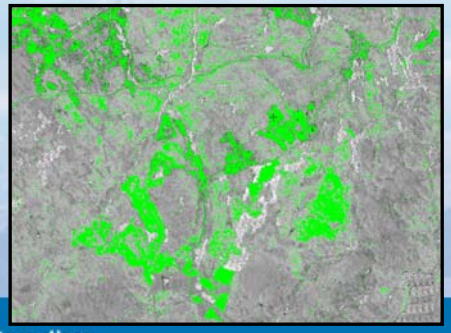
7. Update land cover for changed pixels in other dates using constrained signature extension

1990 land cover



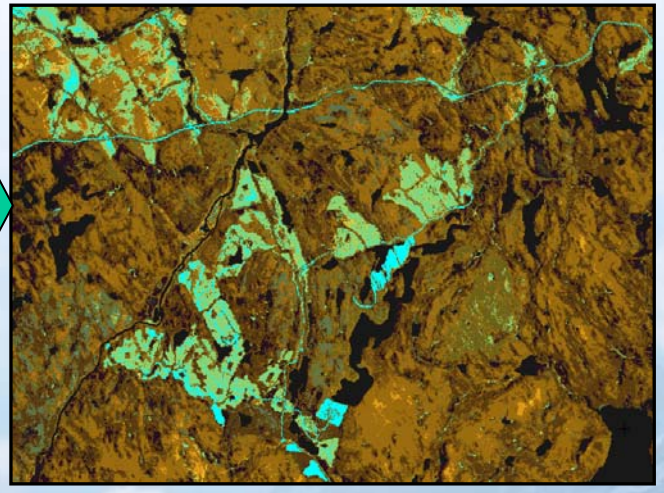






1985-1990 Previous Change
(1995 label constrained by knowledge of age and recovery trajectories)

1995 land cover

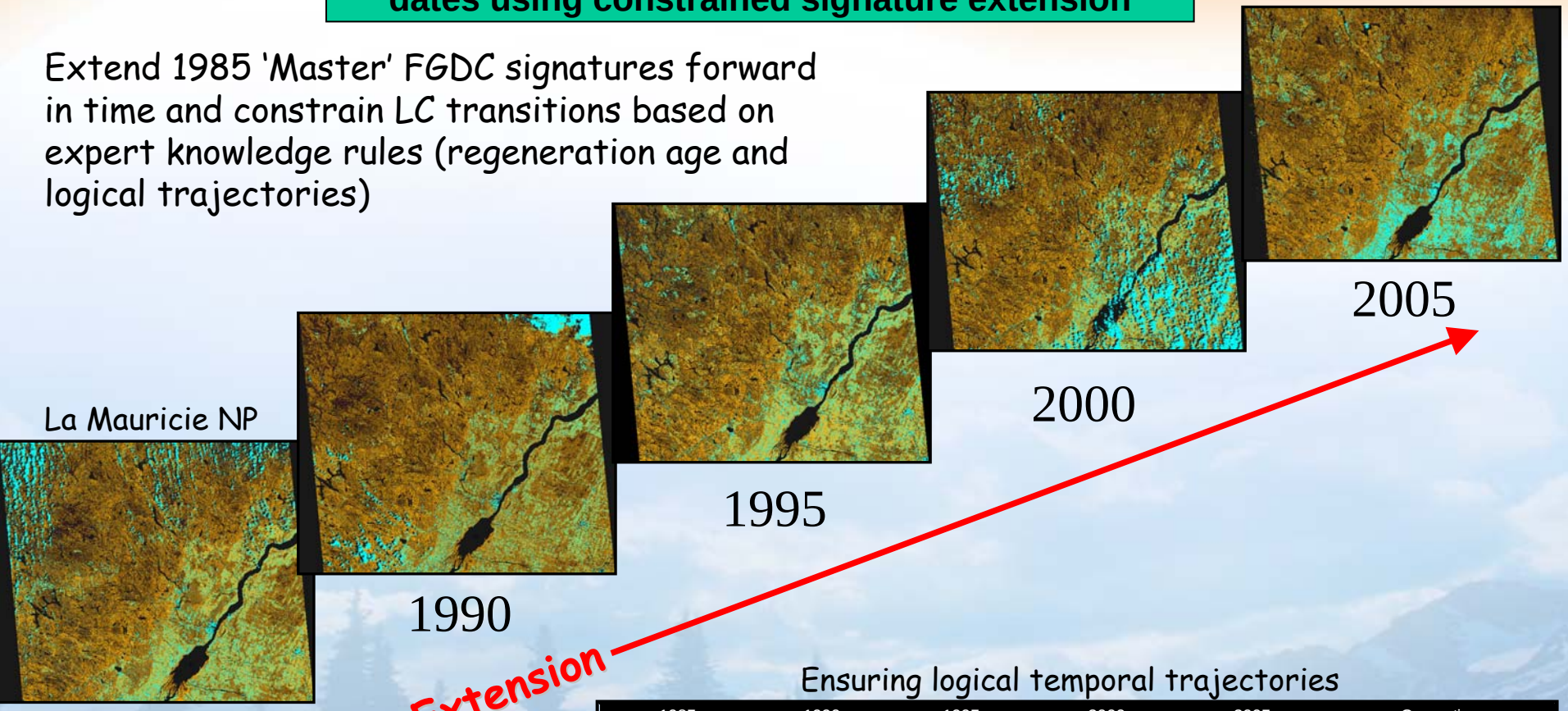


1990-1995 Change Mask - subject to sig. extension
(Everything else: LC carried over from 1985 Master classification)

Automated Multi-temporal Updating by Signature Extension (AMUSE)

7. Update land cover for changed pixels in other dates using constrained signature extension

Extend 1985 'Master' FGDC signatures forward in time and constrain LC transitions based on expert knowledge rules (regeneration age and logical trajectories)



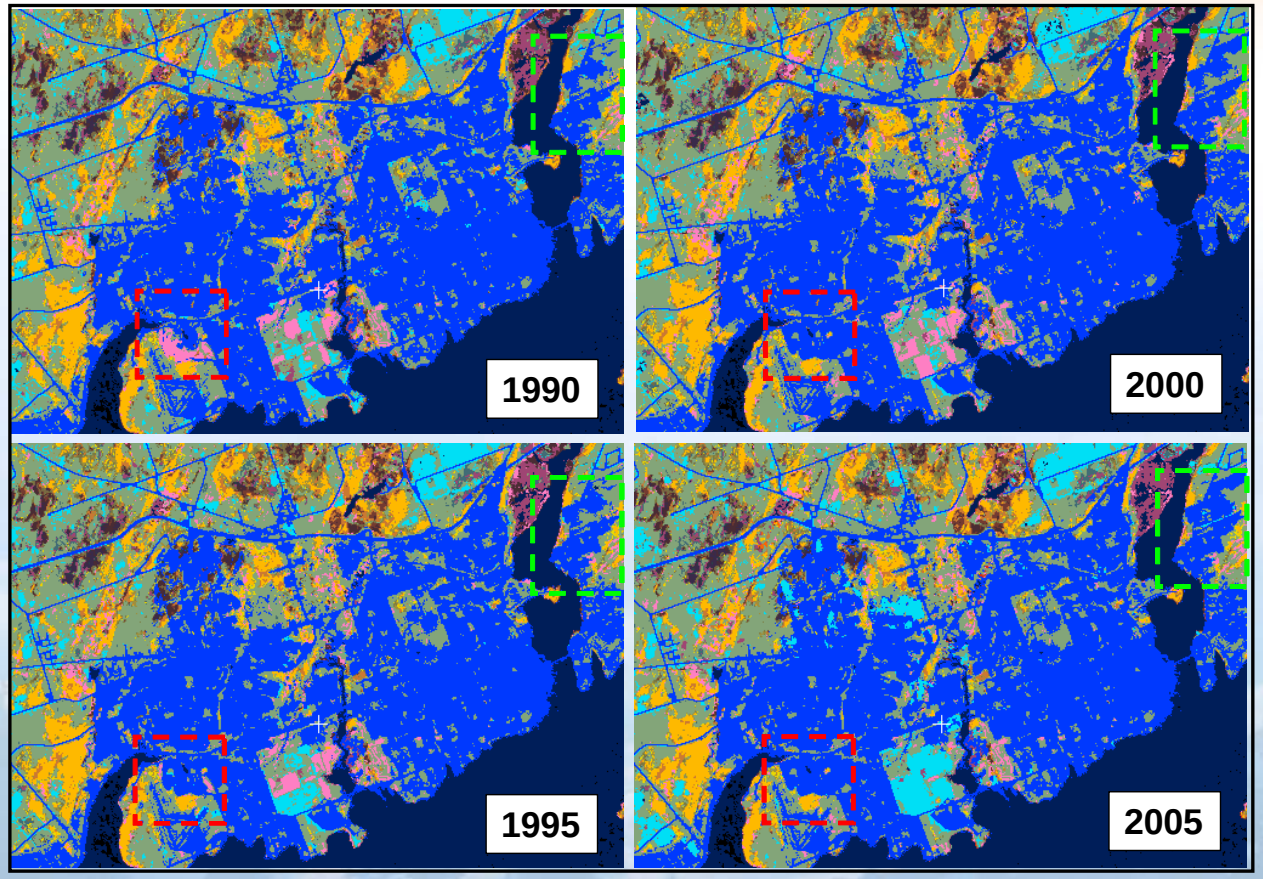
Ensuring logical temporal trajectories

1985	1990	1995	2000	2005	Correction
Wetland	Wetland	Water	Wetland	Water	All years = Wetland
Water	Water	Water	Wetland	Wetland	No Correction
Decidous Forest	Mixed Forest	Decidous Forest	Decidous Forest	Mixed Forest	All years = Decidous Forest
Mixed Forest	Mixed Forest	Decidous Forest	Decidous Forest	Decidous Forest	No Correction
Agriculture	Forest	Forest	Agriculture	Forest	All years = Forest
Forest	Agriculture	Agriculture	Agriculture	Agriculture	No Correction

Automated Multi-temporal Updating by Signature Extension (AMUSE)

7. Update land cover for changed pixels in other dates using constrained signature extension

Land Cover Times Series SLI NP (urban expansion)



Brown – conifer forest
Orange – deciduous forest
Grey – Low vegetation cover

Blue – urban
Light blue – barren
Purple - wetlands

Pink – crops
Dark Blue - water

Automated Multi-temporal Updating by Signature Extension (AMUSE)

8. Validate baseline land cover and changes

Site 16: Mixed deciduous closed canopy
73d17'57.9"W 46d57'54.29"N

(a) Field Validation

La Mauricie NP - Aug 29–Sept 1, 2005

- 43 sites surveyed using GPS, systematic photos, and vegetation description
- Very useful, especially for training, but time consuming

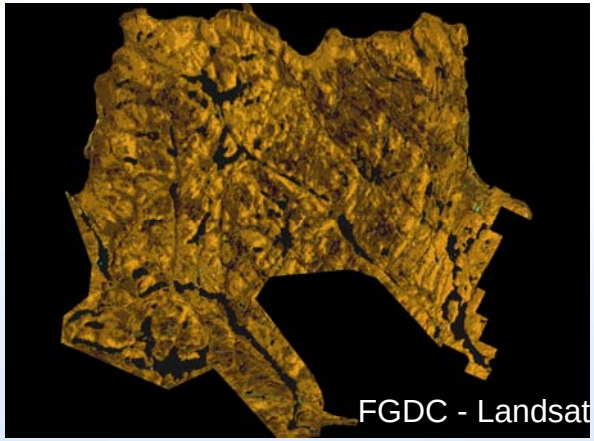
Error Matrix

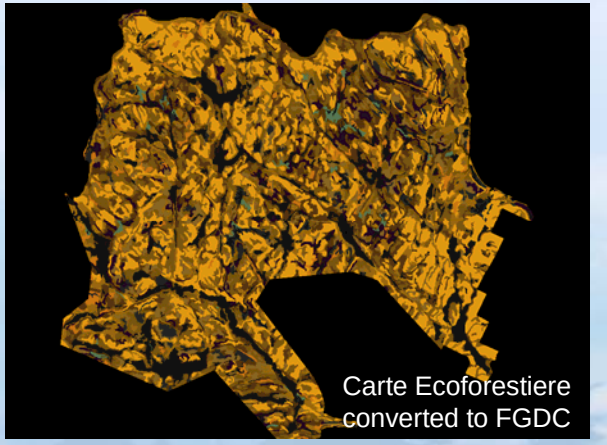
	2005 FGDC Land Cover												
Plot FGDC	2*	3	6	7	9	12*	13	14	15*	16*	18	40*	42
2*	5							1	1				
3		3											
6			1										
7				1			1						
9	1												
12*			1			6		1					
13			1				4						
14								2					
15*			1						4				
16*										4			
18	1												
40*												2	
42				1					1				

Overall accuracy (N = 43)	72.1%
*Change accurcy (N = 27)	77.8%
No change accuracy (N = 14)	71.4%

Automated Multi-temporal Updating by Signature Extension (AMUSE)

8. Validate baseline land cover and changes

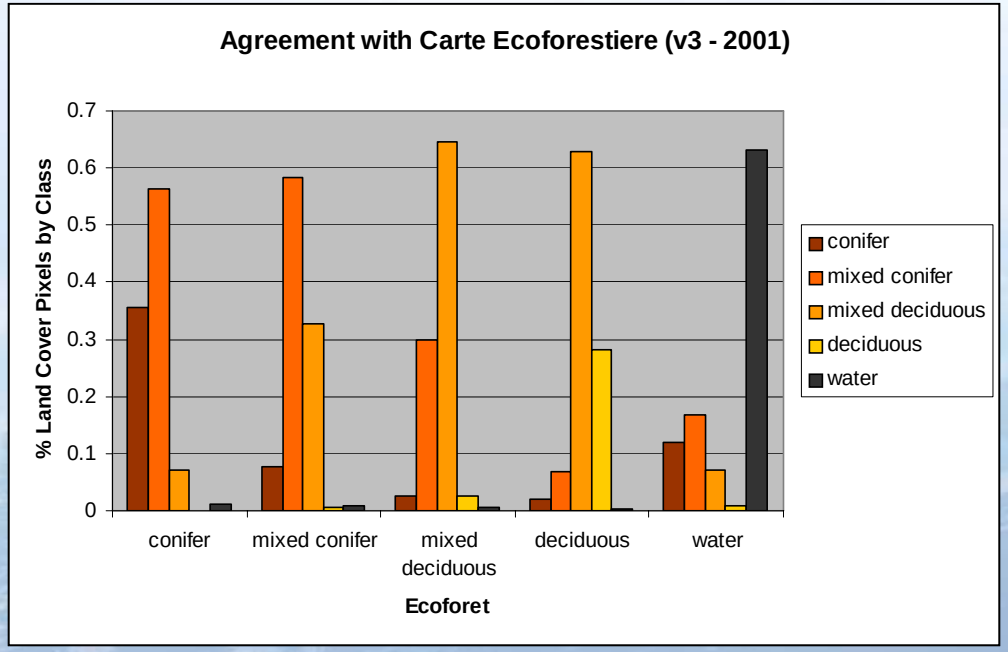




In one study 94% of conifer, 60% of mixed and 29% of deciduous stands from Ecoforestiere agreed with field observations (Dussault et al., CJFR, 2001).

(b) Validation by Comparing to Existing Map
(Carte Ecoforestiere of La Maurice, PQ)

- Cost effective, but scaling issues and reference map always contains errors

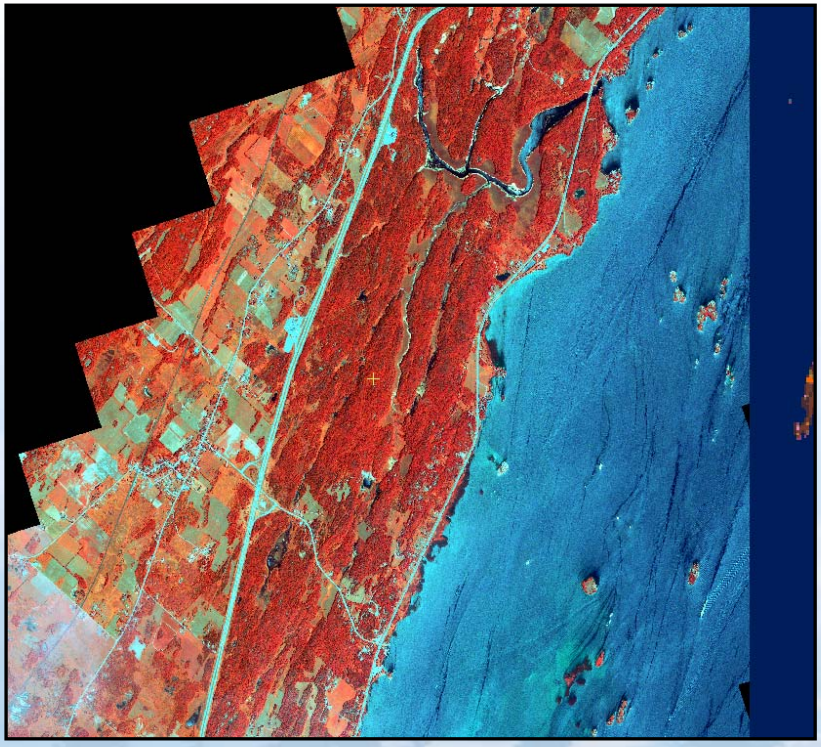


Per-pixel agreement: 33.17%

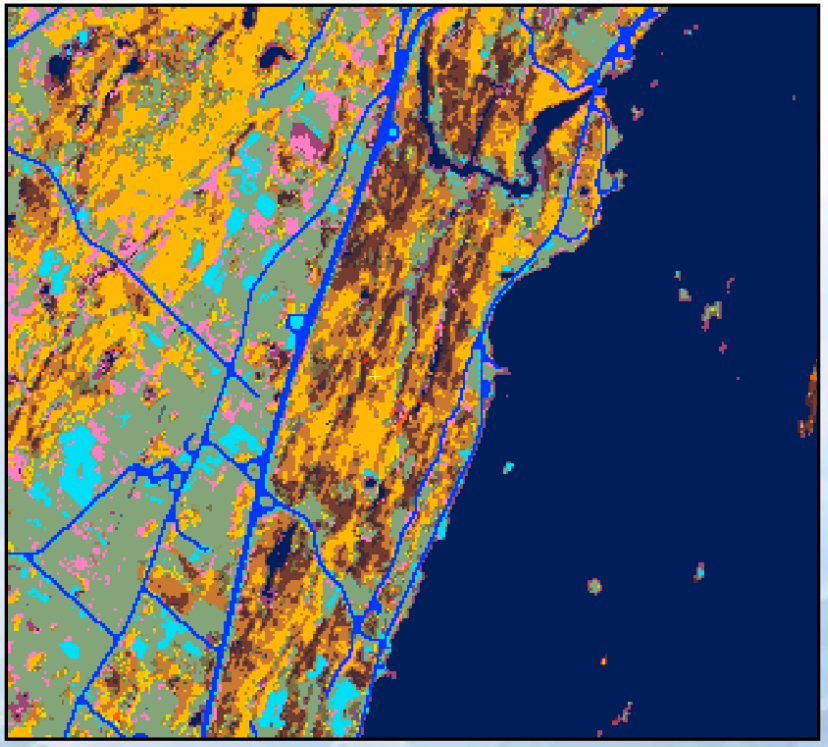
Automated Multi-temporal Updating by Signature Extension (AMUSE)

8. Validate baseline land cover and changes

(c) Validation by Comparing to Higher Resolution (4m) Imagery (SLI NP)



Ikonos 4m resolution



Land Cover 30m resolution

Brown – conifer forest
Dark Orange – mixed decidous
Orange – deciduous forest

Blue – urban
Light blue – barren
Purple - wetlands

Pink – crops
Dark Blue – water
Grey – Low vegetation cover

Automated Multi-temporal Updating by Signature Extension (AMUSE)

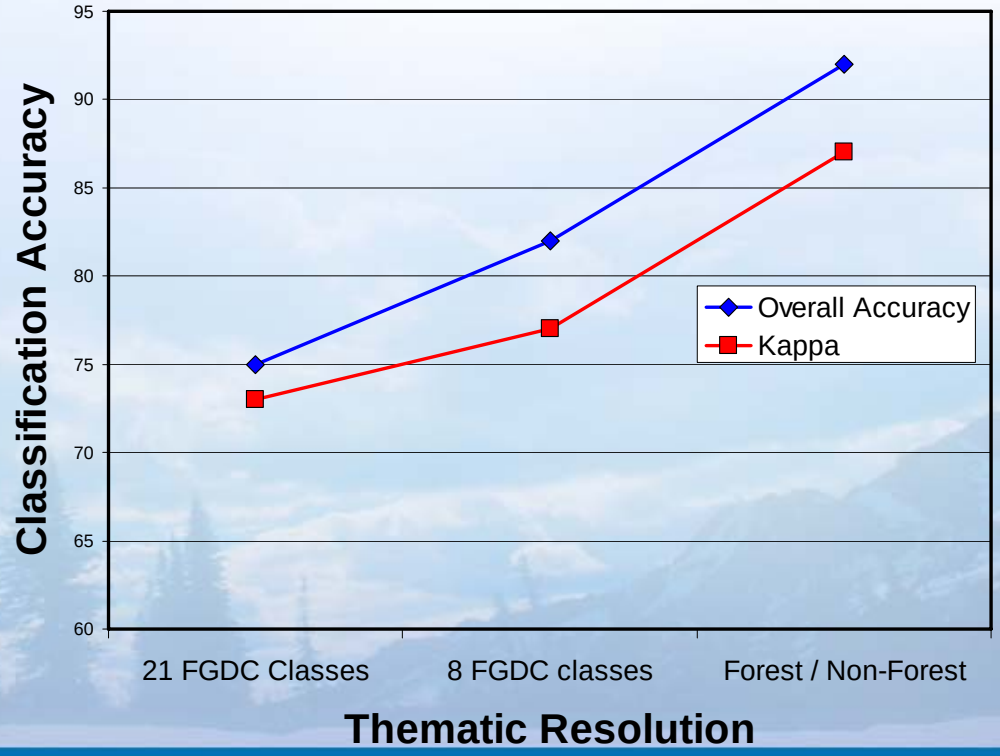
8. Validate baseline land cover and changes

Key Consideration: Thematic resolution is inversely proportional to accuracy

- Must determine where acceptable trade-off occurs

St. Lawrence Islands Accuracy Assessment

(200 points from field and Ikonos interpretation)

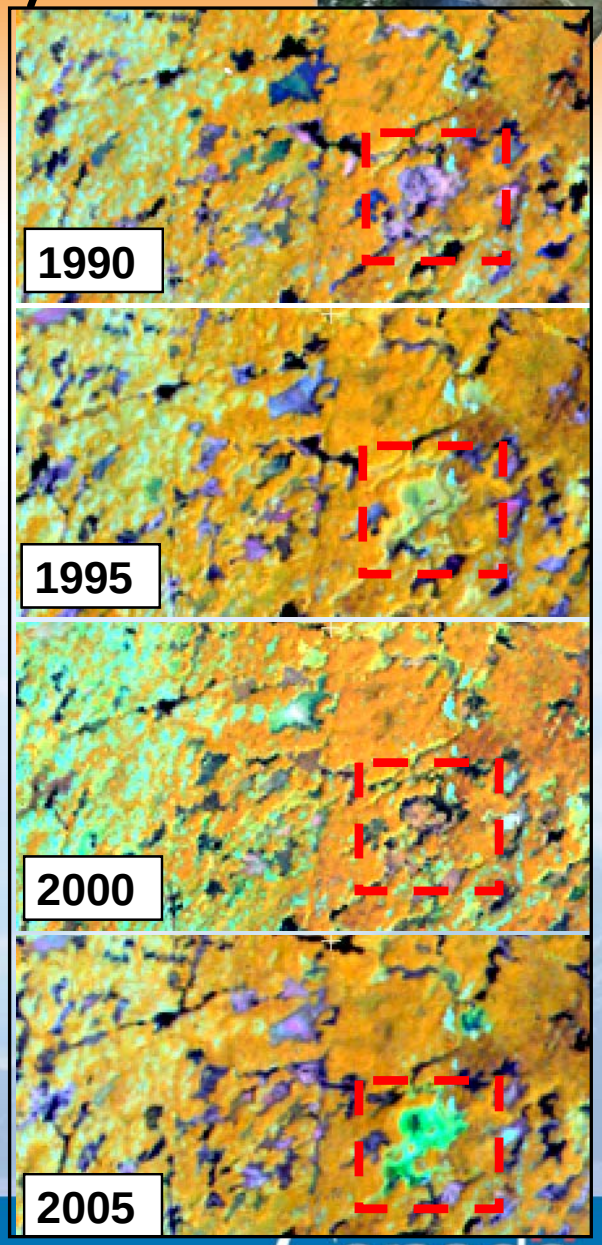


Automated Multi-temporal Updating by Signature Extension (AMUSE)

8. Validate baseline land cover and changes

Common Sources of Confusion\Error
(St. Lawrence Islands LC Time Series)

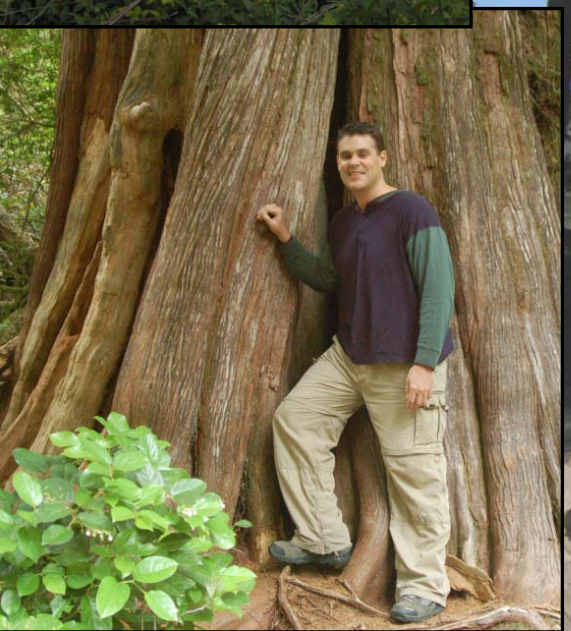
- Confusion between mixed forest and other forest classes
- Wetlands and lakes are confused, as aquatic vegetation in lakes can cause it to appear as wetlands
- Wetlands are also highly dynamic and change annually from wet to dry indicating different land cover types



4. Conclusions and Future Prospects

- Change methods can be semi-automated yet **experienced analyst** still required to produce accurate products
- Image **pre-processing steps** (especially normalization) are critical and many can be automated
- The change approach of **updating a baseline LC** is robust and becoming more common (e.g. Cross Correlation Analysis)
- Need to extend land cover change methods to **extract land use change** (the major threat to biodiversity !)
- EO-based monitoring should be done at **multiple temporal and spatial scales** (e.g. coarse res to detect inter-annual LC modifications)

Working Hard to Save Our Parks !
Questions?



Potential Synergy of Coarse and Medium Resolution Satellite Imagery for Monitoring Parks

- A coarse filter to target local analyses and field investigation
- Temporal information on the timing and evolution of changes
- Temporal information of the persistence of changes (e.g. forest conversion land use change or harvesting)

Coarse Resolution (annually)

Medium Resolution (~ 5 yrs)

- Validation of coarse-res products
- Calibration of scaling aggregation bias (e.g. burned area; Fraser et al., 2004, PE&RS)

Outputs

Coarse filter, national level indicators of change

Outputs

Quantitative Indicators of Park Ecological Integrity