LEDAPS Overview and Status

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The central objective of the North American Carbon Program is to measure and understand the sources and sinks of Carbon Dioxide (CO2), Methane (CH4), and Carbon Monoxide (CO) in North America and in adjacent ocean regions.

Specific Program Goals
Develop quantitative scientific knowledge, robust observations, and models to determine the emissions and uptake of CO2, CH4, and CO, changes in carbon stocks, and the factors regulating these processes for North America and adjacent ocean basins.

Develop the scientific basis to implement full carbon accounting on regional and continental scales.

Support long-term quantitative measurements of fluxes, sources, and sinks of atmospheric CO2 and CH4, and develop forecasts for future trends.

http://www.nacarbon.org
• Forest disturbance (fire, harvest, insect damage) and recovery critical for carbon cycling
  - direct emissions
  - recovery ~ age distribution ~ NEE

• Patch size often small – requires Landsat-type data analysis

• NACP Science Plan calls for analysis of disturbance from satellite data
• Generate surface reflectance (SR) products for North America from Landsat GeoCover archive (1975-2000)
  • apply lessons from MODIS processing

• Generate **decadal, wall-to-wall** maps of forest disturbance, recovery, and conversion for **North America**
  • high-resolution (30m) scene-based products
  • coarse-resolution (0.05 deg) modeling products

• Develop automated approaches to Landsat processing that can be adapted for other applications
  • we do this for AVHRR, MODIS, VIIRS... why not Landsat?

• Work with representatives of USDA Forest Service to evaluate applications utility of SR and disturbance products for carbon management and forest monitoring.
LEDAPS Processing Overview

**Landsat TM, ETM+**
- Calibration
- Atmospheric Correction
- Cloud/Snow masking

**Landsat MSS**
- Radiometric Normalization

**Radiometrically Consistent Surface Reflectance Dataset (1975-2000)**

**Analysis**
- Disturbance Rate via Disturbance Index
- Biophysical change from canopy reflectance model

**Preprocessing**
- MODIS Products

**Disturbance/Recovery Products for Carbon Assessments**

**QA/Validation**
Atmospheric Correction

Based on MODIS/6S radiative transfer approach
- water vapor from NCEP re-analysis data
- ozone from TOMS, EP-TOMS
- topographic-dependent Rayleigh correction

Aerosol optical thickness estimated from imagery using the Kaufmann et al (1997) “Dense, dark vegetation” approach
- estimate blue reflectance based on TOA SWIR 2
- difference between $TOA_{blue}$ and $SR_{blue}$ gives AOT
- interpolate valid targets across image
Atmospheric Correction

1990’s Landsat-5 mosaic

TOA reflectance

Surface reflectance

BOREAS Study Region

100 km
Effect of Atmospheric Correction

(MOD9A surface reflectance) – (ETM+ reflectance), 8/3/00

$\Delta \rho (\%)$ (MOD9A surface reflectance) – (ETM+ reflectance), 8/3/00

Before AC (TOA reflectance)

After AC (surface reflectance)

8/3/2000 acquisitions

Band 1  Band 2  Band 3  Band 4  Band 5  Band 7
Reflectance Validation

Units:
Reflectance
(x 10000)
ETM+ Comparison with MODIS

Red spectral band

Near-infrared spectral band

Shortwave infrared spectral band (1.55-1.75 μm)
Initial Goal: stand-clearing disturbances (harvest, fire) and secular changes in forest cover

Two approaches to mapping disturbance:
1. **“Disturbance Index”**: semi-empirical spectral index developed by Sean Healey and Warren Cohen, USDA Forest Service.

2. Matching **spectral trajectories** from canopy reflectance models to retrieve physical canopy parameters (D. Peddle/F. Hall/F. Huemmrich)
Disturbance Index: \[ \text{Brightness}_{\text{rescaled}} - (\text{Greenness}_{\text{rescaled}} + \text{Wetness}_{\text{rescaled}}) \]

\[ \text{Brightness}_{\text{rescaled}} = (B - \mu_{\text{forest}}) / \sigma_{\text{forest}} \]
Disturbance Index Example

Olympic Peninsula

1988  2000  Disturbance Index Change  Map

5km
S.N. Goward, “North American Forest Disturbance and Regrowth since 1972“
Time Series Analysis

(a) Permanent forest

(b) Disturbance

(c) Thinning

(d) Aforestation

(e) Permanent non-forest
Landsat mapped forest change between 1987 and 2005 in western Oregon along the Clackamas County-Wasco County border (left)

Temporal variation of the percentage of change area (below)
LEDAPS SCIENCE MODULES

I. Image preprocessing
- Calibration, TOA reflectance
- Cloud/snow/shadow mask
- Precision registration and orthorectification
- 6S Atmospheric Correction to SR

II. Compositing/fusion
- Direct and BRDF/phenology adjusted compositing
- Synthetic “daily” Landsat SR
- Synthetic “daily” MODIS SR

III. Science analysis
- Disturbance index change
- Disturbance index change

Modules:
- Indcal
- Indcsr
- Indreg, ortho
- Indrr
- Indcom
- Indpacom
- Inndm

Data sources:
- NCEP Water Vapor
- TOMS Ozone 1km DEM
- MODIS SR
- MODIS VCF
• MODAPS architecture allows rapid processing of large data volumes
• Uses commodity PC’s – one scene per processor
• PGE (product generation executables) are C/C++ modules designed to work with standard library routines (HDF, geographic)

Processing a 30-year North American surface reflectance dataset should take < 4 days
-LEDAPS offers one way to move toward:
  - automated processing chains for Landsat data
  - higher level Landsat products (reflectance, biophysics, LC/ΔLC)
  - reflectance-based analyses of land cover condition
  - merging of multiple RS sources (Landsat, MODIS, IRS, etc)

•Current LEDAPS project funding 2003-2007

•Two pending proposals to continue LEDAPS capability at GSFC through 2010

•Vermote et al project funded through Landsat Science Team to continue development of atmospheric correction work
\[ X' = X + \Delta X_{\text{transl}} + \Delta X_{\text{topo}}(x,y) \{+ \text{ROT}\} \]

1. Automated GCP selection to calculate \( \Delta X_{\text{transl}} \)
   - Select candidate points along nadir
   - Subpixel cross-correlation within window

2. Apply \( \Delta X_{\text{transl}} \) to target image

3. Calculate topographic displacement using DEM and LOS calculation

4. Resample image (cubic convolution or nearest-neighbor)

5. Check RMS via GCP selection across whole scene

6. If RMS is high, go back to (1) and include rotation term

**NOTE:** Currently assumes UTM projection
S. Olympic Peninsula 2.6% disturbed / yr Turnover = 38 Yr

W. Montana 1.5% disturbed / yr Turnover = 69 Yr

W. Pennsylvania 0.2% disturbed / yr Turnover = 550 Yr

NW Colorado 0.7% disturbed / yr Turnover = 145 Yr

S. Virginia 2.2% disturbed / yr Turnover = 44 Yr

N. Louisiana 3.4% disturbed / yr Turnover = 29 Yr