AN INCREASED POTENTIAL FOR THE LANDSAT DATA CONTINUITY MISSION TO CONTRIBUTE TO WATER QUALITY STUDIES FOR INLAND, CASE 2 WATERS

Aaron Gerace
John R. Schott

Sponsored by
United States Geological Survey
The Landsat Data Continuity Mission

True Color Composite

Thermal Channel
Water is Unique!

Air/Water Transition

Atmosphere to Sensor

In Water

Water/Air Transition
LDCM Features: Response

![LDCM Response Graph](graph1)

![ETM+ Response Graph](graph2)

![LDCM Response Graph](graph3)
LDCM Features: Quantization

ETM+

LDCM
LDCM Features: Signal to Noise
What do we gain from the addition of …

- an Aerosol Blue band
- 12 bit quantization
- Improved signal-to-noise ratios

• Can LDCM be effective in the constituent retrieval process? (perfect atm. comp.)
• Can we compensate for the atmosphere?
• Can we compensate for the lack of a thermal band?
Modeling the Process

![Image of satellite view and graph]

- Integrated Sensor Response
- Wavelength
- CHL=3, SM=4, CDOM=7

Digital Imaging and Remote Sensing Laboratory
Modeling the Process

Air/Water Transition

Atmosphere to Sensor

Water/Air Transition

In Water
Modeling the Process: Hydrolight
Modeling the Process: The Sensor

1. Spectrally Sample Signal
2. Add Sensor Noise
3. Quantize Signal
Modeling the Process: The Scene
LUT Development

<table>
<thead>
<tr>
<th>C</th>
<th>SM</th>
<th>CDOM</th>
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<tbody>
<tr>
<td>0</td>
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<td>7</td>
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<td>46</td>
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<td>12</td>
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<tr>
<td>68</td>
<td>24</td>
<td>14</td>
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Hydrolight

LUT

[C]

[CDOM]

[SM]
**Amoeba Process**

LUT

\[ \text{min} [(S_T - S_P)^2] \]

TRUE

FALSE

\[ S_Q \] Error

\[ \text{SP predicted} \]

[CHL] [SM] [CDOM]
Amoeba Process

The process involves calculating the light attenuation coefficient, $\alpha$, which is defined as $\cos \theta \frac{dL(z, \theta, \phi, \lambda)}{dz} = ...$. This coefficient helps in understanding the scattering and absorption properties of the medium.

The LUT (Look-Up Table) uses inputs such as CHL (Chlorophyll), SM (Sediment), and CDOM (Colloidal Dissolved Organic Matter) to predict $S_p$ (the scalar radiance at the surface). TheSQ Error is then calculated to determine if the predicted $S_p$ matches the observed $S_T$.

If the $S_Q$ Error is within a certain threshold, the prediction is considered TRUE; otherwise, it is FALSE.
Process Summary

Resample  Add Noise  Quantize  Amoeba

AVIRIS  [LUT]  [SM]  [CDOM]

ETM+  [LUT]  [SM]  [CDOM]

LDCM  [LUT]  [SM]  [CDOM]

Digital Imaging and Remote Sensing Laboratory  August 5, 2008
## RMS of Residual Errors

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**10% Goal**
Conclusions

• Blue band contributes to retrieval of suspended materials.

• 12 bit quantizer and improved SNR of LDCM significantly improves our ability to perform constituent retrieval.

• LDCM exhibits the potential to be a valuable tool in the constituent retrieval process.
Future Work

- How important is blue band for atmosphere correction?
- Role of thermal band in predicting hydrodynamics of receiving water.
Hydrolight-generated water pixels as seen through a 40km visibility atmosphere.

- (Left) TOA Radiance, (Right) Resampled to five LDCM bands.
- Atmospheric compensation algorithm developed to take advantage of deep blue band.
  - Notice low variability at 443nm and increased variability at 482nm.
  - Correction algorithm takes ratio of 443 band and 865 band based on the assumption that variability in these bands is due solely to atmosphere.
  - This assumption breaks down for 482 band as variability due to water signal increases.
International Archive Question

80% Solution vs. Cost of new Mission(s)
Using Remotely Sensed Data for Model Calibration

ALGE Hydrodynamic Model
- Meteorological Inputs
  - Wind Speed
  - Temperature
  - Pressure
  - Humidity
- River Inputs
  - Water Temperature
  - Flow Rate
  - Bathymetry
  - Turbidity
- Suspended Particle Data
  - Particle Diameter
  - Particle Density
  - Concentration

Model Side

Image Side

Meteorological Inputs
- Wind Speed
- Temperature
- Pressure
- Humidity

River Inputs
- Water Temperature
- Flow Rate
- Bathymetry
- Turbidity

Suspended Particle Data
- Particle Diameter
- Particle Density
- Concentration

Nudge Inputs

Using Remotely Sensed Data for Model Calibration
Performed constituent retrieval on real data (Genesee Plume) to test algorithm

- Ran algorithm with 482nm and 865nm bands of ETM+.
- Ran algorithm with 442nm and 865nm bands of LDCM.
- Compared in situ measurements to algorithm retrieved data to find RMSE of concentrations.

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<td>2.1%</td>
<td>10.0%</td>
<td>19.3%</td>
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LDCM Ratios Update

Review of Correction Algorithm &
Results of Test on Simulated Data
LDCM Approach

\[
\rho_i(\lambda) = \rho_r(\lambda) + \rho_a(\lambda) + \rho_{ar}(\lambda) + \rho_g(\lambda) + t(\lambda)\rho_w(\lambda)
\]

- We remove glint to obtain...

\[
\rho_c = \rho_r(\lambda) + \rho_a(\lambda) + \rho_{ar}(\lambda) + t(\lambda)\rho_w(\lambda)
\]

- Because we are working over case 2 waters, we can’t assume a zero water reflectance for NIR band.

- We do, however, have a spatially homogeneous body of water whose reflectance is fairly well known.
LDCM Procedure

- **Step 1**: Remove glint from image

- **Step 2**: Create LUT of atmospheres that implements “spatially ambient reflectance”

- **Step 3**: Choose “ambient” ROI and find

\[ \varepsilon = \frac{\rho_1}{\rho_5} \]

\[ \rho_c \]

to determine appropriate atmosphere.
The Simulation

• Used Hydrolight to create water samples that are representative of the Rochester embayment.
  – i.e. Lake Ontario (CHL=0.75, SM=0.50, CDOM=0.50) x 500
    • Cranberry Pond (5, 3, 5) x 500
    • Longpond (63, 22, 6) x 500
    • Genesee Plume (5, 8, 3) x 500
    • Braddocks Bay (6, 10, 9) x 500
• Propagated water-leaving signals to TOA using an arbitrary atmosphere…Marine aerosol, 30km visibility, standard water vapor, etc.
• Introduced noise and quantization to the 2500 sensor-reaching signals based on LDCM specifications.
• Attempted to recover constituent concentrations based on “imaged” water pixels using LDCM ratio technique and LUT inversion method.
## Results

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<td>Perfect Atmospheric Compensation</td>
<td>2.2</td>
<td>3.2%</td>
<td>0.6</td>
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<tr>
<td>LDCM Ratio Technique use to compensate for atmosphere.</td>
<td>5.54</td>
<td>8.1%</td>
<td>2.56</td>
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</table>

- **For real data**
  - Adjacency effects
  - Rms. vs. ratio comparison